TIPP 2021

International Conference
on Technology
and Instrumentation
in Particle Physics

BOOK OF ABSTRACTS

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Advanced Technologies for Detector Readout in Nuclear and Particle Physics

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Igniting Questions, Detecting Answers - Photon Resolving with Quantitative CMOS

Author: Brad Coyle[1]

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The evolution of imaging technology is directly linked to new scientific achievements. Scientific imaging has moved many experiments from relying on subjective recording into objectively documentable, repeatable, and quantifiable methods. Demanding and extremely valuable techniques such as single-molecule-based methods would not be possible without appropriate image sensors. The novel quantitative CMOS (qCMOS) technology finally reaches the physical limit: reliable quantification of photon numbers within each pixel, eliminating the influence of technology on the ‚Äútriangle of frustration‚Äù (resolution, sensitivity, speed). The ORCA-Quest quantitative CMOS (qCMOS) camera with Photon Number Resolving functionality is the leap in scientific camera evolution that transforms imaging into imagining. With ultra-quiet, highly-refined electronics, this camera is more than an image capture device; it is a precision instrument that unlocks the ability to investigate new photonic questions because it offers the quality and quantitative performance to detect meaningful data previously lost in the noise.

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Gamble Technologies

Author: Greg Gamble[1]

[1] *Gamble Technologies*

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A universal, low latency and open VME Data Acquisition Hardware and Software by MESYTEC

Authors: Andreas Ruben[1]; Garrett Stout[2]

[1] *W-IE-NE-R Plein & B*

[2] *W-IE-NE-R Plein & Baus Corp.*

Experiments: Calorimeters / 273

Crylin: crystal calorimeter with longitudinal information for a future muon collider

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Modern tracking systems are very precise, therefore, in particle flow-like reconstruction algorithms, the jet performance is usually limited by the calorimeter. The need to solve the fat jet substructure favors the design of finely segmented calorimeters. However, this contrasts with the need to have high temporal resolutions for signal events even at low energy deposits: for example due to the passage of high-energy muons. Our proposal is a semi-homogeneous calorimeter based on Lead Fluoride (PbF2) crystals with surface mounted UV extended Silicon Photomultipliers (SiPMs). This calorimeter can be segmented longitudinally as a function of the energy of the particles and the background level. A single module consists of longitudinal layers of crystal cells: each cell is composed of PbF2 crystals of 10x10x40 mm3 coupled with an array of 4 SiPMs of 4 mm2 areas, readout in series of 2. The realization and results on a small prototype of 2 layers with 3x3 crystals each, will be described.

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CALICE SiW ECAL - Beam test performance of a technical prototype of a highly granular silicon tungsten calorimeter

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A highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is the reference design of the ECAL for International Large Detector (ILD) concept, one of the two detector concepts for the detector(s) at the future International Linear Collider. Prototypes for this type of detector are developed within the CALICE Collaboration. The technological prototype addresses technical challenges such as integrated front-end electronics or compact layer and readout design.
During Autumn/Winter 2019/20 a stack of up to 22 layers with a dimension of ˜18√ó18√ó25cmˆ3 was compiled. A beam test at DESY is planned for May 2021. We will present preliminary results on the linearity w.r.t. to electromagnetic showers and the energy resolution as well as on shower shapes. An outline on the next steps will be given. One aspect that has to be addressed in the future is the proper technical implementation of power pulsing with local, i.e. next to the ASICs, power storage.

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CALICE SiW ECAL - Development and first beam test results of detection elements using Chip-on-Board Technology

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A highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is the reference design for the ECAL of the International Large Detector (ILD) concept, one of the two detector concepts for the detector(s) at the future International Linear Collider. Prototypes for this type of detector are developed within the CALICE Collaboration.
The contribution will report for the first time on the development of beam test results obtained with detection elements (combination of ASIC, PCB and Si Wafers) that are based on a PCB type, called Chip-on-Board (COB), that features wire-bonded ASICs. This latter design keeps the height of the PCB as thin as 1.2 mm compared to a height of about 3 mm for a variant using BGA packaging. The tight space constraints leave little room for extra components such as decoupling capacitances, accordingly, particular emphasis will be put on the performance in terms of noise sensitivity.

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Calorimetry for the Electron Ion Collider

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The Electron Ion Collider will be a new facility at Brookhaven National Lab that will study the structure of nuclear matter in the gluon dominated regime of QCD using Deep Inelastic Scattering with precision electromagnetic probes. It will utilize the existing RHIC collider to provide beams of polarized electrons from 2.5-18 GeV to collide with heavy ions from 10-100 GeV/A and protons up to 275 GeV/c. The EIC will require major new detector systems to measure the scattered electron and full calorimeter, tracking and particle id systems to reconstruct the overall event. The eRD1 Consortium has been investigating a number of calorimeter options for an EIC detector that include high resolution calorimeters to measure the scattered electron and new types of high density sampling calorimeters for full azimuthal and rapidity coverage. The latest results of R&D on these various types of calorimeters will be presented along with an overview of the EIC physics program and its detector systems.

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Calibration and Performance of the CMS Electromagnetic Calorimeter in LHC Run 2

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Many physics analyses using the Compact Muon Solenoid (CMS) detector at the LHC require accurate, high resolution electron and photon energy measurements. The CMS electromagnetic calorimeter (ECAL) is a fundamental instrument for these analyses and its energy resolution is crucial for the Higgs boson mass measurement. Recently the energy response of the calorimeter has been precisely calibrated exploiting the full Run2 data, aiming at a legacy reprocessing of the data. A dedicated calibration of each detector channel has been performed with physics events exploiting electrons from W and Z boson decays, photons from pi0/eta decays, and from the azimuthally symmetric energy distribution of minimum bias events. This talk presents the calibration strategies that have been implemented and the excellent performance achieved by the CMS ECAL with the ultimate calibration of Run II data, in terms of energy scale stability and energy resolution.

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Test beam performance of a digital pixel calorimeter

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A prototype of a digital pixel EM calorimeter, EPICAL-2, has been designed and constructed, following up on a previous prototype [1]. It consists of alternating W absorber and Si sensor layers, with a total thickness of ˜20 radiation lengths, an area of 30mm × 30mm, and ˜25 million pixels. The new EPICAL-2 detector employs the ALPIDE pixel sensors developed for the ALICE ITS upgrade. This R&D is performed in the context of the proposed Forward Calorimeter upgrade for the ALICE experiment, but it also serves the general understanding of the principle of a fully digital calorimeter.
We will report on first results regarding alignment and calibration from cosmics and on the calorimeter performance measured with the DESY electron beam. The prototype shows good energy resolution and linearity, comparable with those of a SiW calorimeter with analog readout. We will also show first results of shower-shape studies with unprecedented spatial precision.
[1] JINST13 (2018) P01014.

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Simulation of a SiW pixel calorimeter

Author: Tim Sebastian Rogoschinski[1]

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A prototype of a digital pixel electromagnetic calorimeter, EPICAL-2, has been designed and constructed. It consists of alternating W absorber and Si sensor layers, with a total thickness of ˜20 radiation lengths, an area of 30mm x 30mm, and ˜25 million pixels. The design is the next step in pixel calorimetry following up on a previous prototype using MIMOSA sensors [1]. The new EPICAL-2 detector employs the ALPIDE sensors developed for the ALICE ITS upgrade. This R&D is performed in the context of the proposed Forward Calorimeter upgrade for ALICE.
We have used the Allpix2 framework [2] to perform MC simulations of the detector response and shower evolution. Electron test beam results can be reproduced. Energy resolution and linearity for the total number of pixel hits and the total number of clusters were investigated, as well as more detailed microscopic features of the shower development and the propagation of particles.
[1] JINST13 (2018) P01014
[2] NIM A901 (2018) 164,Äì172

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Development of a highly granular scintillator-tungsten electromagnetic calorimeter prototype for the CEPC

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A highly granular electromagnetic calorimeter has been designed and optimised with particle flow algorithms within the CALICE collaboration for precision measurements of Higgs and electroweak physics at future lepton collider experiments, including the Circular Electron Positron Collider (CEPC). Scintillator strips and silicon photomultipliers (SiPMs) are instrumented as sensitive layers and tungsten-copper alloy plates as absorber. Scintillator strips are individually wrapped with ESR foil and directly coupled with SiPMs. A prototype with 32 sampling layers and over 6700 channels (around $600 \times 600 \times 400$ mm^3 in dimensions), has been constructed and commissioned in 2020. Long-term cosmic-ray tests were performed for quantitative studies on the key performance. This talk will cover key aspects in the prototype development, the latest status of commissioning, selected results of cosmic ray tests, as well as preparations for the future DESY beam tests.

Funding information:
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Calorimetry with Extremely Fine Spatial Segmentation

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Particle Flow Algorithms (PFAs) attempt to measure each particle in a hadronic jet individually, using the detector subsystem that provides the best energy/momentum resolution. Calorimeters that can exploit the power of PFAs emphasize spatial granularity over single particle energy resolution. In this context, the CALICE collaboration developed the Digital Hadron Calorimeter (DHCAL). The DHCAL uses Resistive Plate Chambers (RPCs) as active media and is read out with 1 x 1 cm2 pads and digital (1-bit) resolution. In order to obtain a unique dataset of electromagnetic and hadronic interactions with unprecedented spatial resolution, the DHCAL went through a broad test beam program. In addition to conventional calorimetry, the DHCAL offers detailed measurements of event shapes, rigorous tests of simulation models and various analytical tools to improve calorimetric performance. Here we report on the results from the analysis of DHCAL data and comparisons with the Monte Carlo simulations.

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Compact LumiCal prototype tests for future e+e- collider

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The FCAL collaboration is preparing large-scale prototypes of special calorimeters to be used in the very forward region at a future electron-positron collider for a precise and fast luminosity measurement and beam-tuning. The LumiCal is designed as a silicon-tungsten sandwich calorimeter with very thin sensor planes to keep the Moliere radius small, facilitating the measurement of electron showers in the presence of background. Dedicated FE electronics has been developed to match the timing and dynamic range requirements. In the recent beam tests, a multi-plane compact prototype equipped with thin detector planes fully assembled with readout electronics were installed in 1 mm gaps between tungsten plates of one radiation length thickness. High statistics data were used to perform sensor alignment, and to measure the longitudinal and transversal shower development in the sandwich. In addition, Geant4 MC simulations were done and compared to the data.

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The CALICE AHCAL - a highly granular SiPM-on-tile hadron calorimeter prototype

Authors: Frank Simon[1]; Antoine Laudrain[2]

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The Analogue Hadron Calorimeter (AHCAL) of the CALICE collaboration is a technological prototype for future linear collider detectors, addressing scalability, integration and engineering challenges imposed by the experimental environment. It is based on the SiPM-on-tile technology, where the active layers of the calorimeter are formed by 3x3 cm2 plastic scintillator tiles placed on top of SiPMs mounted on readout boards that also house SPIROC2E front-end ASICs. A large prototype with 22 000 channels has been constructed using techniques suitable for mass production and automatic assembly. The calorimeter took muon, electron and pion data at the CERN SPS, partially in conjunction with a silicon instrumented structure as prototype for the CMS endcap calorimeter upgrade, which uses a similar design as the AHCAL in its scintillator section. The presentation gives an overview of the construction, commissioning, calibration and first test beam results of the AHCAL technological prototype.

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Status and plans for the CMS High Granularity Calorimeter upgrade project

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The CMS Collaboration is preparing to build replacement endcap calorimeters for the HL-LHC era.
The new high-granularity calorimeter (HGCAL) is, as the name implies, a highly-granular sampling calorimeter with approximately six million silicon sensor channels (˜1.1cmˆ2 or 0.5cmˆ2 cells) and about four hundred thousand channels of scintillator tiles readout with on-tile silicon photomultipliers.
The calorimeter is designed to operate in the harsh radiation environment at the HL-LHC, where the average number of interactions per bunch crossing is expected to exceed 140.
Besides measuring energy and position of the energy deposits the electronics is also designed to measure the time of their arrival with a precision on the order of 50 ps.
In this talk, the reasoning and ideas behind the HGCAL, the current status of the project, the many lessons learnt so far, and the challenges ahead will be presented.

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The CMS High Granularity Calorimeter Scintillator/SiPM Tileboards

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The new CMS High Granularity Calorimeter (HGCAL), being built for HL-LHC, will have unprecedented transverse and longitudinal readout and trigger segmentation. In regions of low radiation, HGCAL will be equipped with small plastic scintillator tiles as active material coupled to on-tile silicon photomultipliers. With respect to earlier developments targeted at a future e+e- collider, additional challenges in terms of radiation hardness, data rates and mechanical integration including cooling need to be addressed. We will present the evolving design, results on the performance of irradiated SiPMs, the optimisation of scintillator tiles, the status of active element prototypes with integrated electronics, and the preparations for automated production.

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The HIBEAM/NNBAR Calorimeter Prototype

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The HIBEAM/NNBAR experiment is a free-neutron search for n,Üínbar and n,Üísterile n oscillations to be housed at the ESS in Lund, Sweden. The detector will be capable of identifying n-nbar annihilation events, which will produce on average ˜4 pions with a final state invariant mass of ˜1.9 GeV. The detector will feature a novel calorimeter design, which must provide good resolution of the point of impact of gammas from pi0 decay and sufficient energy resolution to reconstruct the sum of two nucleon masses. Calorimetry for these energies is challenging, as traditional sampling calorimeters used in HEP would suffer from degraded resolution from poor shower statistics. The calorimeter instead uses a hybrid approach of a range measurement in plastic scintillators implementing a binary readout, followed by total absorption in lead glass. This talk presents work towards a prototype calorimeter which is planned to be deployed in the ESS Test Beam Line for *in situ* background measurements.

Experiments: Calorimeters / 529

Towards the construction of the Mu2e electromagnetic calorimeter at Fermilab

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Mu2e will search for the CLFV conversion of a muon into an electron in the field of a nucleus. A clean discovery signature is provided by the mono-energetic conversion electron (Ee= 104.967 MeV). If no events are observed, Mu2e will set a limit of the ratio between the conversion and the capture rate below $6\sqrt{ó}10^{fl17}$ (@ 90% C.L.). The calorimeter requirements are to provide Eres < 10%, Tres < 500 ps for 100 MeV electrons while working in vacuum and in a strong radiation environment. It is made of two annular aluminum disks, each one filled with 674 pure CsI crystals read out by SiPMs. A sophisticated mechanics and cooling system have been developed to support the crystals and cool the sensors. Radiation hard analog and fast digital electronics have been developed. In this presentation the QC tests performed on the produced components and the construction status are reported, as well as the results obtained on the large size prototype with test beam data and a cosmic ray test stand.

Experiments: Dark Matter Detectors / 341

The PandaX-4T Dark Matter Experiment

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The PandaX-4T is a dark matter direct detection experiment with a dual-phase xenon detector. It is located at Jinping underground laboratory in Sichuan, China. In the 2.8-tonne fiducial mass and energy region of interest (1-10 keV), the total electron recoil and nuclear recoil backgrounds are supposed to be $(4.9¬\pm0.5)\sqrt{ó}10ˆ(-2)$ mDRU and $(2.8¬\pm0.5)\sqrt{ó}10ˆ(-4)$ mDRU. With an exposure of 5.6 ton-years, the expected sensitivity of PandaX-4T could reach a spin-independent dark matter-nucleon cross section of 6 $\sqrt{ó}$ 10ˆ(-48) cm2 at a dark matter mass of 40 GeV/c2. An overview of detector design, background control and current status will be presented in this talk.

Experiments: Dark Matter Detectors / 634

Diamond detectors for low-mass dark matter searches

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Co-authors: Ahmed Abdelhameed [1]; Antonio Bento [1]; Elia Bertoldo [1]; Anna Bertolini [1]; Dennys Erdtmann [1]; Nahuel Ferreiro [1]; Dominik Fuchs [1]; Abhijit Garai [1]; Michele Mancuso [1]; Athoy Nilima [1]; Federica Petricca [2]; Franz Proebst [1]; Francesca Pucci [1]; Johannes Rothe [1]

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Despite the multiple and convincing evidence of the existence of Dark Matter (DM) in our Universe, its detection is still one of the most pressing questions in particle physics. For this reason, in recent years a large fraction of the direct detection scientific community started to explore the possibility of detecting DM with mass in the sub-GeV range. Cryogenic diamond detectors have the potential to detect such light DM candidates thanks to their superior cryogenic properties. When operated as low-temperature calorimeters, diamonds could reach an energy threshold in the eV range and would allow for the exploration of novel parameters of the DM-nucleus cross section. In this contribution, the preliminary cryogenic performance of lab-grown single crystal diamonds operated with TES temperature sensors will be presented. The potential of such a detector in the current landscape of DM searches will be also illustrated.

Experiments: Dark Matter Detectors / 703

Low radioactivity Argon for the DarkSide-20k experiment

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A major worldwide effort is underway to procure the radiopure argon needed for DarkSide-20k (DS-20k), the first large scale detector of the new Global Argon Dark Matter Collaboration. The Urania project will extract and purify underground argon (UAr) from CO2 wells in the USA at a production rate of ˜300 kg/day. Additional chemical purification of the UAr will be required prior to its use in the DS-20k LAr-TPC.The Aria project will purify UAr using a cryogenic distillation column (Seruci-I), located in Sardinia (Italy).Assessing the UAr purity in terms of Ar-39 is crucial for the physics program of the DarkSide-20k experiment. DArT is a small (,à°1 litre) radiopure chamber that will measure the Ar-39 depletion factor in the UAr. The detector will be immersed in the active liquid Ar volume of ArDM (LSC, Spain), which will act as a veto for gammas from the detector materials and the surrounding rock.In this talk, I will review the status and prospects of the UAr projects for DarkSide-20k.

Experiments: Dark Matter Detectors / 718

Purity monitor and TPC design for Xenoscope

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Next-generation experiments for dark matter detection such as liquid xenon (LXe) time projection chambers (TPC) have the main goal of probing the experimentally accessible parameter space for weakly interacting massive particles (WIMPs) as a dark matter candidate. The realization of such large detectors requires the demonstration of a series of technologies. We, therefore, aimed to built a full-scale TPC demonstrator in the vertical dimension called Xenoscope. The main goal of Xenoscope is to demonstrate electron drift for the first time in an LXe TPC over a 2.6 m distance and benchmark several key requirements for the next-generation experiment DARWIN. To this end, we have designed a modular, scalable purity monitor as well with the upgrade to a dual-phase TPC. This talk will cover the challenges encountered in the design of long drift regions in LXe.

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Detection of low mass WIMPs with Spherical Proportional Counters

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NEWS-G is an experiment searching for dark matter using the Spherical Proportional Counter (SPC) technique. Such detectors can operate significant mass of target while keeping single ionization electron detection sensitivity. They can use light target gases such as hydrogen, helium, and neon. NEWS-G aspires to extend the sensitivity of direct dark matter searches to the mass range from 0.1 GeV to few GeV, opening a window to non-standard model physics.
The talk will cover principle of operations of the SPC and a description of the 140cm diameter detector and compact shielding, with projected WIMP detection sensitivity. Preliminary results obtained in 2019 with a temporary shield at the underground laboratory of Modane (LSM, France) with neon and methane as target gases will be presented. Very early results of the experiment final installation at SNOLAB (Canada) might be included in this talk.
Another contribution to this conference describes SPC characterisation.

Experiments: Dark Matter Detectors / 546

Design of keV-scale neutron sources using Fe and Sc

Author: Pratyush Patel[1]

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We will discuss recent progress in making sub-keV nuclear recoil calibrations practical in a university lab environment. First, we will describe a 124SbBe (gamma,n) neutron source in which a novel Fe shielding method suppresses the outgoing gamma flux while allowing the unmoderated escape of the 24keV neutrons. Second, we will describe a method to moderate and then filter neutrons from a pulsed Deuterium-Tritium (DT) generator, enabling a pulsed keV-scale neutron source. And lastly, we will describe work towards large area neutron capture-based backing detectors required for a neutron scattering calibration of dark matter experiment targets.

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Development of DarkSide-20k Dual-Phase Time Projection Chamber

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DarkSide-20k direct dark matter search experiment aims at cumulative exposure of 200 ton-year with zero instrumental backgrounds by utilizing several novel approaches such as extraction of argon from underground sources, purification of argon via destination column, readout via large array of silicon-based photosensors and two nested liquid argon-based detectors housed within a ProtoDUNE-style membrane cryostat. A short overview of the DarkSide-20k experiment is presented emphasizing the novel design and development of the inner detector, a sealed acrylic dual-phase time projection chamber.

Experiments: Dark Matter Detectors / 650

Improving sensitivity to low-mass dark matter in LUX using a novel electrode background mitigation technique

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For dual-phase xenon time projection chambers such as LUX, signatures of low-mass DM interactions would be ∼keV scatters that ionize only a few xenon atoms and seldom produce detectable scintillation signals. In this regime, extra precaution is required to reject a complex set of low-energy backgrounds that have long been observed in this class of detector. Noticing backgrounds from the electrodes were particularly prevalent, a machine learning technique based on ionisation pulse shape was developed to identify and reject these events. The technique was shown to improve Poisson limits by a factor of 2-7, and was applied to LUX events in an effective 5 tonne·day exposure to place strong limits on DM with masses $m_\chi \in 0.15\text{-}10$ GeV. The machine learning technique is expected to be useful for near-future experiments, such as LZ and XENONnT, which hope to perform low-mass DM searches with the stringent background control necessary to make a discovery.

Experiments: Dark Matter Detectors / 701

Low-energy Monoenergetic Neutron Production with a DD-Neutron Source for sub-keV Nuclear Recoil Calibrations in the LUX and LZ Experiments

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Nuclear recoil (NR) calibrations are vital for understanding detector responses to dark matter candidates and neutrino-nucleus signals in direct detection experiments. Low-mass (<5 GeV) dark matter candidates and ^{8}B neutrinos drive the need for high-statistics/low-systematic calibrations at sub-keV NR energies.

We report the results of NR calibrations in the LUX dark matter detector using 2.45 MeV neutrons from an Adelphi Technologies, Inc. DD neutron generator and describe the R&D done to increase the instantaneous intensity to 10^{10} n/s and reduce pulse width to 12 μs FWHM. Complete kinematic reconstruction has allowed the charge and light yields to be determined down to 0.27 keVnr and 0.45 keVnr, respectively.

We also describe techniques to reduce the incident neutron energy via controlled backscattering off deuterium- and hydrogen-based targets, achieving neutron energies of 350 keV and 10-100 keV, respectively, needed to probe even lower mass dark matter candidates.

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CrystaLiZe: A Solid Future for LZ

Author: Scott Kravitz[1]
Co-authors: Peter Sorensen ; Scott Haselschwardt ; Hao Chen ; Shilo Xia

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Radon and its daughter decays continue to limit the sensitivity of WIMP direct dark matter searches, despite extensive screening programs, careful material selection and specialized Rn-reduction systems. This problem is only expected to worsen as experiments grow in size. For liquid xenon TPCs, we propose to address this through crystallizing the xenon. Once solid, the xenon will no longer admit external Rn into the bulk, allowing existing Rn to decay away. These decays can also be efficiently vetoed using the time structure of the decay sequence and the fixed position of daughter isotopes. In this case, the limiting background for WIMP searches would be neutrinos from the sun and from cosmic ray muons. In this talk, I will argue that an instrumental radon tag in a crystalline xenon TPC, perhaps as an upgrade to LZ, may be the quickest path to reaching the neutrino floor and present preliminary results from a solid xenon test stand which indicate its viability as a detector medium.

Experiments: High energy physics / 315

ILD, a Detector for the International Linear Collider

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The International Large Detector (ILD) is a detector designed primarily for the International Linear Collider (ILC), a high-luminosity linear electron-positron collider with an initial center-of-mass energy of 250 GeV, extendable to 1 TeV. The ILD concept is based on particle flow for overall event reconstruction, which requests outstanding detector capabilities including superb tracking, very precise detection of secondary vertices and high-granularity calorimetry. In the past years the design has focused on building subdectector technological prototypes scalable to the full ILD size, studying their integration into a coherent detector, benchmarking the ILD performance and preparing for an optimization of the overall ILD size and costing. The current status has recently been made public in an ILD Interim Design Report (IDR) of interest for any future e+e- collider detector. The presentation will summarize the main IDR results and the plans to prepare a technical proposal for the ILC.

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BESIII detector performance and future plan

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BESIII experiment, which is the only tau-charm factory running in the world, has been working for more than 10 years, and published a lot of physics results about charmed hadron, exotic hadron states, tau lepton and light hadrons. In this talk, the current performance of the detector will be mentioned, including the tracking system, particle identification system, and calorimeter system. The experiment will run for another 10 years, and in this talk, the future plan of the experiment will be mentioned also.

Experiments: High energy physics / 543

Operation and Performance of Belle II Aerogel RICH Counter

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Belle II experiment at SuperKEKB is a B factory experiment aiming at collecting 50 times more data than Belle. One of the key components in the experiment is the particle identification (PID), especially the separation of kaons and pions. In the Belle II spectrometer, a proximity focusing ring imaging Cherenkov detector using aerogel as a radiator (ARICH) is equipped for the PID at the forward endcap. In this counter, a total of 420 of hybrid avalanche photo-detectors (HAPDs) with 144 channels are used as position-sensitive photon detectors that work inside the 1.5 T magnetic field. Belle II started the physics run with full detectors from 2019, and accumulated 90 fb^{-1} of collision data. We report on the operation of ARICH, including the fraction of dead channels, stability of HAPDs, and possible problems. We also report the PID performance of ARICH estimated with using $D^{*+} \to D^0 \pi^+_{\mathrm{slow}}$, $D^0 \to K^- \pi^+$ control sample with the initial data.

Experiments: High energy physics / 548

The Design and Study of RICH Detector for Super Tau-Charm Facility

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The Super tau-Charm facility (STCF) project, which is an electron-positron collider at the center-of-mass 2˜7 GeV, is under exploring and will play crucial role in the high density frontier of elementary particle physics. The PID detector in STCF serves an excellent PID capability for charged hadrons. The effective PID is required to reach a statistical separation power better than 3 sigma to fulfill the desired physics goals. In the conceptual design, RICH detector is one suitable candidate at STCF barrel. The RICH consist of 12 identical block modules. C6F14 is chosen as the radiator, followed with light propagation zone, photo-cathode, multiplier and anode. The threshold of the RICH is less than 1 GeV/c to connect to the PID power of tracking system and can reach to 2 GeV/c. Geant4 simulations are performed to study the expected performance. By applying the reconstruction algorithm, > 3 sigma separation capability can be reached. A beam test has also been performed on our prototype.

Experiments: High energy physics / 602

Precision Timing with the CMS MTD Barrel Timing Layer for HL-LHC

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase II upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of 30-40 ps for MIP signals at a rate of 2.5 Mhit/s per channel at the beginning of HL-LHC operation. The precision time information from this MIP Timing Detector (MTD) will reduce the effects of the high levels of pileup expected at the HL-LHC, bringing new capabilities to the CMS detector. The barrel timing layer (BTL) of the MTD will use sensors that based on LYSO:Ce scintillation crystals coupled to SiPMs with TOFHIR ASICs for the front-end readout. In this talk we will present motivations for precision timing at the HL-LHC and an overview of the MTD BTL design, including ongoing R&D studies targeting enhanced timing performance and radiation tolerance.

Experiments: High energy physics / 458

The ATLAS detector evolution towards the High Luminosity era

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After 9 years of successful operation in proton-proton collisions reaching up to $\sqrt{s}$ = 13 TeV, the ATLAS detector started in 2018 the preparations for an ambitious physics project, aiming the exploration of very rare processes and extreme phase spaces, an endeavor that will require a substantial increase in the integrated luminosity. To accomplish this purpose, a comprehensive upgrade of the detector and associated systems was devised and planned to be carried out in two phases. The Phase-I upgrade foresees new features for the muon detector, for the EM calorimeter trigger system and for all trigger and data acquisition chain. For the Phase-II upgrade, ATLAS will fully replace its inner tracker, install a new timing detector and the calorimeters and muon systems will operate on a free-running readout scheme. This presentation will summarize the expected performance of the aforementioned projects, as well as the new insights gained during the construction phase.

Experiments: High energy physics / 540

Fast Beam Condition Monitor of the CMS experiment at HL-LHC

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To achieve the challenging target of 1% precision on luminosity determination at the high-luminosity LHC (HL-LHC) with instantaneous luminosity up to 7.5 √ó 10^{34} cm^{,àí2} s^{,àí1}, the CMS experiment will employ multiple luminometers with orthogonal systematics. A key component of the proposed system is a stand-alone luminometer, the Fast Beam Condition Monitor (FBCM), which is fully independent from the central trigger and data acquisition services and able to operate during all times at 40 MHz providing bunch-by-bunch luminosity measurement with 1 s time granularity. FBCM is foreseen to be placed inside the cold volume of the Tracker as it utilizes silicon-pad sensors exploiting the zero-counting algorithm of hits for luminosity measurement. FBCM will also provide precise timing information with a few ns precision enabling the measurement of beam induced background. We report on the optimisation of the design and the expected performance of FBCM.

Experiments: High energy physics
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A High-Granularity Timing Detector for the Phase-II upgrade of ATLAS: detector concept, description and R&D and beam test results

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The increase of the particle flux (pile-up)at the HL-LHC with luminosities of L,âÉ 7.5√ó1034 cm,àí2s,àí1 will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer momentum resolution will be particularly affected. A High Granularity Timing Detector (HGTD) is proposed in front of the LAr endcap calorimeters for pile-up mitigation and for luminosity measurement. It will cover the pseudo-rapidity range from 2.4 to 4. Two Silicon sensors double sided layers will provide precision timing information for MIPs with a resolution better than 30ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3mm√ó1.3mm, leading to a highly granular detector with 3 M of channels.
Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed.

Experiments: High energy physics / 615

Initial performance of the GlueX DIRC detector.

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The GlueX experiment at Jefferson Laboratory aims to perform quantitative tests of non-perturbative QCD by studying the spectrum of light-quark mesons and baryons. A Detector of Internally Reflected Cherenkov light (DIRC) was installed to enhance the particle identification (PID) capability of the GlueX experiment by providing clean œÄ/K separation up to 3.7 GeV/c momentum in the forward region (Œ∏<11 deg), which will allow the study of hybrid mesons decaying into kaon final states with significantly higher efficiency and purity.
The new PID system is build using radiators from the decommissioned BaBar DIRC counter, combined with new compact photon cameras based on the SuperB FDIRC concept. The full system was successfully installed and commissioned with beam during 2019/2020.
We will discuss the status of the DIRC detector and its performance.

Experiments: High energy physics / 723

Test-beam performance of a TORCH prototype module

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The TORCH time-of-flight detector is designed to provide a 15 ps timing resolution for charged particles, resulting in pi/K particle identification up to 10 GeV/c momentum over a 10 m flight path. Cherenkov photons, produced in a quartz plate of 10 mm thickness, are focused onto an array of micro-channel plate photomultipliers (MCP-PMTs) which measure the photon arrival times and spatial positions. A half-scale (660 x 1250 x 10 mmˆ3) TORCH demonstrator module has been tested in a 5 GeV/c mixed proton-pion beam at the CERN PS. Customised MCP-PMTs of active area 5 cmˆ2 and granularity 64 x 64 pixels have been employed, which have been developed in collaboration with an industrial partner. The single-photon timing performance and photon yields have been measured as a function of beam position in the radiator, giving measurements which are consistent with expectations. The expected performance of TORCH for high luminosity running of the LHCb upgraded experiment has been simulated.

Experiments: Neutrino / 348

RPCs for the SND Muon System of the SHiP experiment

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SHiP (Search for Hidden Particles) is a proposed beam dump experiment at CERN SPS, with the aim of exploring the so-called Hidden Sector. Since a large neutrino flux is expected to be produced at the beam dump, the experiment could also allow for the study of neutrino physics with unprecedented statistics. A dedicated Scattering and Neutrino Detector (SND), equipped with a downstream Muon Identification System, is thus being designed. The SND muon detector consists of iron filters interleaved with tracking planes, based on RPC technology. Each muon plane has an active area of about (2 x 4) m2 and consists of three large gaps read out by two panels of perpendicular strips. The SHiP RPCs have to provide a uniform spatial response as well as high efficiency. The design of the SND muon system, based on RPCs, is presented and the performance of a prototype for SHiP RPCs is discussed.

Experiments: Neutrino / 530

Neutron Detection in MINERvA's Polystyrene Scintillator

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Accelerator-based neutrino experiments have historically discounted neutron detection as beyond the scope of their calorimeters and trackers. The MINERvA experiment has detected signals from 10-100 MeV neutrons from neutrino interactions in its polystyrene scintillator tracker. Energy deposit, timing, and distance from neutrino interaction point are explored for access to neutron kinematics. New neutron counting efforts in MINERvA's nuclear targets could help control systematic uncertainties in next-generation neutrino oscillation experiments that use detectors based on nuclei other than carbon.

Experiments: Neutrino / 542

Water Cherenkov Test Experiment

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Water Cherenkov detectors have a long history of being successfully used for neutrino oscillation and nucleon decay measurements. With the increase in collected data, the reduction of systematic uncertainties becomes essential.
Water Cherenkov Test Experiment (WCTE) is a proposed experiment at CERN that will study the response of a small water Cherenkov detector in a low momentum beam. The experiment will be used to test new photosensor technologies, apply calibration techniques with known particle fluxes to validate 1% level calibration at GeV scale, and measure physics processes such as Cherenkov light production, secondary neutron production and pion scattering. The experiment will also include a compact hadron spectrometer with a target to produce and characterize particle fluxes entering the water Cherenkov detector. We present the design of the small water Cherenkov detector and accompanying spectrometer along with the overview of the WCTE physics program.

Experiments: Neutrino / 604

An Intermediate Water Cherenkov Detector for Hyper-Kamiokande Using the NuPRISM Concept

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The Hyper-Kamiokande (HK) experiment will detect neutrinos produced at an upgraded 1.3 MW J-PARC 30 GeV accelerator with a new water Cherenkov detector that is 8 times larger than Super-Kamiokande. This will allow HK to accumulate neutrino events 20 times faster than the currently operating T2K experiment. To take advantage of the high statistics HK will collect, systematic uncertainties on neutrino production and interaction modelling must be reduced. The Intermediate Water Cherenkov Detector (IWCD) is A 1 kiloton scale water Cherenkov detector to be located ˜1 km from the neutrino source at J-PARC to study neutrino production and interactions. The IWCD has the unique feature that it can be moved to different positions relative the beam direction, enabling measurements that probe the relationship between neutrino energy and particles produced in neutrino interactions. I will describe the IWCD design, measurement program and the key technologies that will be deployed in the detector.

Experiments: Neutrino / 457

A Highly Granular Calorimeter System for the DUNE Near Detector

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DUNE requires a capable near detector system to achieve its ambitious physics goals. One subsystem is the ND-GAr detector, which will consist of a high pressure Ar TPC and an ECAL in a magnetic field. The calorimeter complements the capabilities of the TPC with photon and neutron reconstruction to enable a precise reconstruction of neutrino interactions. The ECAL will use highly granular active elements consisting of plastic scintillators and SiPMs, as well as scintillator strips, both with sub-ns timing capabilities. This enables directional reconstruction of electromagnetic showers for pi0 localization, high neutron sensitivity and energy measurement via time of flight. The fine granularity of the detector also provides powerful ¬μ/pi separation essential for a precise characterisation of the neutrino beam. The presentation gives an overview over the evolving design of the DUNE ND-GAr calorimeter and will discuss the expected performance and its relevance for the DUNE physics program.

Experiments: Neutrino / 304

The T2K Near Detector Upgrade

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The T2K collaboration is preparing for an increase of the exposure aimed at establishing leptonic CP violation at 3 σ level for a significant fraction of the possible δ_{CP} values. To reach this goal, an upgrade of the T2K near detector ND280 will be installed at J-PARC in 2022, with the aim of reducing the overall statistical and systematic uncertainties at the level of better than 4\%. We have developed an innovative concept for this neutrino detection system, comprising the totally active Super-Fine-Grained-Detector (SuperFGD), two High Angle TPC (HA-TPC) and six time of flight planes.
In this talk we will report on the status of the construction of these detectors, their performances obtained in test beams.

Experiments: Neutrino / 502

Dual Calorimetry at JUNO

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Dual Calorimetry is a technique designed for high precision control of detector calorimetry systematics. It is embodied at JUNO as two independent photosensors and readout systems with different photon occupancy regimes surrounding the 20 kton liquid scintillator. One is the ˜18,000 20-inch large PMTs (LPMTs) system, and the other is the ˜26,000 3-inch small PMTs (SPMTs) system. The LPMT system is designed for maximal light detection to achieve 3% energy resolution at 1MeV. The SPMT system, as the second calorimetry, is introduced to disentangle the degeneracy of calorimetry responses, isolate the charge non-linearity effects and provide a linear charge reference for LPMT. The Dual Calorimetry technique provides robust LPMT charge non-linearity calibration, thus helping the overall systematics control and physics measurement of JUNO. In this talk, the physics motivation, basic concept, novel calibration methodology and potential performance of Dual Calorimetry will be presented.

Experiments: Neutrino / 274

Latest results of the R2D2 project

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The search for neutrinoless double beta decay could cast light on one critical piece missing in our knowledge i.e. the nature of the neutrino mass. Its observation is indeed the most sensitive experimental way to prove that neutrino is a Majorana particle. The observation of such a potentially rare process demands a detector with an excellent energy resolution, an extremely low radioactivity and a large mass of emitter isotope. Nowadays many techniques are pursued but none of them meets all the requirements at the same time. The goal of R2D2 is to prove that a spherical high pressure TPC could meet all the requirements and provide an ideal detector for the 0ŒΩŒ≤Œ≤ decay search. The prototype has demonstrated an excellent resolution with Argon and the preliminary results with Xenon are already very promising. In the proposed talk the R2D2 results obtained with the first prototype will be discussed as well as the project roadmap and future developments.

Experiments: Neutrino / 433

Status of the NEXT experiment.

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NEXT is an experimental program aiming at the detection of ?≤ decay in ^{136}Xe using a high-pressure gaseous xenon electroluminescent TPC. The technique allows for superb energy resolution, 1% FWHM at QŒ≤Œ≤, and topological discrimination based on the unique signature that a double electron produces in a gaseous medium. With ˜0.5 m in each dimension, NEXT-White (NEW) is operating underground under low-background conditions at the Laboratorio Subterrneo de Canfranc, using xenon enriched to 90% ^{136}Xe. Its purpose is to validate all aspects of the technology on a large scale and demonstrate its performance on 2≤ decay events. x NEXT-100 will replace NEW and start operating during 2021. It will deploy 97 kg of enriched xenon and demonstrate sensitivity to 0ŒΩŒ≤Œ≤ decay half-lives on the scale of 10^{26} yr. An overview of the experiment will be presented in this talk with 2 main focus: 1) latest results of the NEW detector, 2) current status of the NEXT-100 detector.

Experiments: Neutrino / 682

CUPID: a next generation bolometric neutrinoless double beta decay experiment

Authors: CUPID collaboration[None]; CUPID-0 Collaboration[None]; Speaker to be assigned[None]; Dounia Helis[1]; Giovanni benato[None]

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CUPID is a next-generation tonne-scale bolometric neutrinoless double beta decay experiment to probe the Majorana nature of neutrinos and discover Lepton Number Violation if the effective neutrino mass is greater than 10 meV. CUPID will be built on experience, expertise and lessons learned in CUORE,CUPID-Mo and CUPID-0. The detector technology is based on scintillating bolometers of Li2MoO4 enriched in the isotope of interest 100Mo. CUPID will consist of about 1500 hybrid heat-light detectors for a total isotope mass of 250 kg. The CUPID scientific reach is supported by a detailed and safe background model that uses CUORE, CUPID-Mo and CUPID-0 results. The required performance in terms of energy resolution, alpha rejection factor and crystal purity have already been demonstrated and will be presented.

Experiments: Precision and Low Energy / 282

Laser spectroscopy of long-lived pionic helium at PSI

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The PiHe collaboration recently used the 590 MeV ring cyclotron facility of Paul Scherrer Institute to carry out laser spectroscopy of metastable pionic helium atoms [1,2]. This is a three-body atom consisting of a helium nucleus, a ground-state electron, and a negatively-charged pion occupying a Rydberg state of principal and orbital angular momentum quantum numbers of around n=17 and l=16. By using a sub-nanosecond infrared pulsed laser, the pion was resonantly deexcited from the state (17,16) to a short-lived state (17,15). In future experiments, we intend to increase the experimental precision and compare the results with three-body QED calculations. This would allow the negatively-charged pion mass to be determined with a higher precision than before.
[1] Nature 581, 37 (2020)
[2] Physical Review A 89, 042515 (2014)

Experiments: Precision and Low Energy / 285

KDK: Measuring the 40K Electron Capture Decay to the Ground State of 40Ar

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40K is one of very few isotopes that allow comparison of a third-forbidden unique decay with first-forbidden unique decay. It is also a source of uncertainty in certain dark matter searches, and in K-based geochronology dating techniques. In particular, one decay branch of 40K has never been experimentally measured: the electron capture directly to the ground state of 40Ar, expected to be of the order of fifty times smaller than the well-known decay to the excited state of 40Ar. In the KDK (potassium decay) experiment (https://arxiv.org/abs/2012.15232), this small decay branch has been investigated by integrating a low-threshold X-ray detector into the high-efficiency Modular Total Absorption Spectrometer (MTAS) at Oak Ridge National Laboratory. An alternative configuration using KSr2I5 scintillator has also been tested. We report details of the technique used to measure this small decay branch, the expected sensitivity, and the status of the analysis.

Experiments: Precision and Low Energy / 721

The PADME charged particle spectrometer

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The PADME experiment aims at searching signals of a dark photon A,Äô. This is done evaluating the final state missing mass of the process e+ e,àí ,Üí A'Œ≥ by knowing the beam energy and measuring the four-momentum of the ordinary recoil photon. The determination of this quantity, and the capability to reject the background, are the key points for the success of the experiment. Three charged particle detectors are employed to detect the positrons that have radiated a high energy photon in the target (PVeto), electrons from the beam interactions in the target or from particles which decay to final states with electrons (EVeto), and the positrons with a relatively low energy radiation in the target (HEPVeto). All three detectors are made of plastics scintillator bars placed inside the vacuum vessel of the PADME setup.
PADME Commissioning took place in 2018-2019 with the beam of the Linac of the local Beam Test Facility (BTF) and results and performance of the veto stations will be presented.

Experiments: Precision and Low Energy / 704

A High Efficiency Cosmic Ray Veto Detector for the Mu2e Experiment at Fermilab

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The Mu2e experiment is designed to search for the charged-lepton-flavor-violating process, μ^- to a e^-, with unprecedented sensitivity. The single 105-MeV electron that results from this process can be mimicked by electrons produced by cosmic-ray muons traversing the detector. An active veto detector surrounding the apparatus is used to detect incoming cosmic-ray muons. To reduce the backgrounds to the required level it must have an efficiency of about 99.99\% as well as excellent hermeticity. The detector consists of four layers of scintillator counters, each with two embedded wavelength-shifting fibers, whose light is detected by silicon photomultipliers. The design and expected performance of the cosmic ray veto detector will be described.

Funding information:
US Department of Energy

Experiments: Precision and Low Energy / 586

Modular J-PET applications in medical and particle physics

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J-PET is the first facility of its kind developed for applications in both medical and particle physics [1]. Recently, a new prototype based on modular construction (24 modules) is commissioned [2]. Each module is made of 13 plastic scintillators and can be used as a standalone, compact, and portable detection unit. In the framework of J-PET, the decays of positronium atoms in their ground state are being studied. Several odd-symmetric operators are constructed out of the momentum vectors of annihilation photons originating from the decays of metastable o-Ps atoms [1]. The spin of the o-Ps atom can also be accessed by reconstructing the 3D vertex positions of o-Ps annihilations. Few operators utilize the photon,Äôs polarization direction which is the unique feature of the J-PET detector. The specifics of Modular J-PET and its applications will be discussed.
[1] P. Moskal, PET Clin. 15 (2020) 439-452; P. Moskal et al, Acta Pys. Pol. B 47, 509 (2016)
[2] E. Czerwi≈Ñski,Cern courier 2018

Experiments: Space and Particle Astrophysics / 293

An Helium calorimeter for Anti-Deuteron identification in cosmic rays.

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Low energy anti-deuterons in cosmic rays are considered a golden channel for the search of Dark matter annihilations in the galaxy.
Anti Deuteron Helium Detector (ADHD) project is aiming to study the signatures offered by an high pressure He target for the identification of anti-deuterons in space.
In particular exotic atoms are produced by stopping anti-protons/anti-deuterons in the gas and the captured particle can orbit the He nucleus for microseconds before the annihilation.
This meta-stability is an unique feature for the He target and the characteristic delayed annihilation is a distinctive signature to identify the antimatter nature of the stopping particle.
A prototype of pressurized calorimeter, filled by 200 Bar He, has been characterized with muons and with 70-240 MeV proton beam in the INFN-TIFPA laboratory.
Sensitivity of a possible anti-deuteron space-detector based on pressurized He and the results of the measured response of the He calorimeter will be summarized.

Experiments: Space and Particle Astrophysics / 336

A dedicated SiPMs array for GRD of GECAM

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The discovery of gravitational waves and their gamma bursts has opened the era of multi messenger astronomy. China's Gravitational wave high energy Electromagnetic Counterpart All-sky Monitor (GECAM) uses two small satellites to monitor gamma-ray bursts in an all-sky field of view. It has a quasi-real-time gamma-ray burst broadcast capability and will play an important role in the location of gravitational wave sources and subsequent observations. Each GECAM small satellite is equipped with 25 3-inch diameter gamma ray detectors (GRD), which can cover 8 keV-2 MeV. GRD uses SiPMs instead of PMT to adapt to the size constraints of micro-satellite platforms, and uses high light yield lanthanum bromide crystals to lower the threshold to 8 keV. A unique 3-inch circular SiPMs array has been designed, using 64 6x6 mm chips, uniformly arranged in a circular shape. This presentation will introduce the status of GECAM and then focus on the SiPMs array, includes its design and performance.

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Experiments: Space and Particle Astrophysics / 660

Massive argon space telescope (MAST): concept and physical program

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Modern rocket launchers such as Falcon Heavy are able to lift up to 30,Äì40 t payloads to medium (approximately 500 km) circular Earth orbits. Therefore, it is timely to consider a concept of a very massive space gamma-ray telescope that could in future serve as a successor to the Fermi-LAT instrument. We propose a new gamma-ray telescope called MAST (an abbreviation from ,ÄúMassive Argon Space Telescope,Äù) for the energy range of 100 MeV ,Äì 1 TeV based on the liquid Argon time projection chamber technique [Dzhatdoev & Podlesnyi, Astropart. Phys., 112, 1 (2019)]. We show that MAST could have the angular resolution 3-10 times better than the Fermi-LAT one and the differential sensitivity 10-30 times better than the Fermi-LAT one. Finally, we demonstrate the potential of the proposed instrument in several long-standing astrophysical problems [Dzhatdoev et al., Phys. Rev. D, 102, 123017 (2020); Khalikov & Dzhatdoev, arXiv:1912.10570].

Experiments: Space and Particle Astrophysics / 696

The Scintillating Fiber Tracker of the HERD facility

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The High Energy cosmic-Radiation Detection facility (HERD) will be one of the future astronomy missions on board the Chinese Space Station (CSS).
The installation of HERD on the CSS is planned for 2025, for an operation of at least 10 years. HERD is composed of an almost cubic calorimeter, a tracking system, plastic scintillator detectors, silicon charge detectors, and a transition radiation detector.
The tracker, made of scintillating fibres connected to SiPM arrays, will provide a full coverage of the 5 sensitive sides of the calorimeter, allowing for a sub-degree angular resolution and multiple independent measurements of the charge of the nuclei. We will present the tracker design, the DAQ electronics as well as the SiPM arrays. The prototype fibre module tests in particle beams at CERN will be presented. The space qualification tests (vibration and thermal vacuum tests) of two x-y tracking planes of ˜1m2 partially equipped with fully functioning modules will be presented.

Experiments: Space and Particle Astrophysics / 617

First space application of Monolithic Active Pixel Sensors for particle tracking: the High Energy Particle Detector onboard the CSES-02

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We report on the tracker of the High Energy Particle Detector, to be launched on board the second China Seismo Electromagnetic Satellite in mid 2022. The tracking module will be made of ALPIDE Monolithic Active Pixel Sensors, a 3.0x1.5 cm^2 ASIC, fabricated with a 180 nm CMOS process. The use of Monolithic Active Pixel Sensors is unprecedented in space applications and demands for specific solutions to limit the power consumption and ensure robustness against the mechanical and thermal stresses that the module has to withstand during the launch and in operation.
We describe the process of qualification that we have carried out in the last two years, detailing the tracker layout, the operation mode, the control and the readout. Results from tests at space qualification facilities and from beam tests are provided, demonstrating the effectiveness of Monolithic Active Pixel Sensors for space applications and the performance of ALPIDE for the HEPD scientific case.

Experiments: Space and Particle Astrophysics / 376

Status of the Telescope Array detectors

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Telescope Array (TA) is the largest ultrahigh energy cosmic-ray (UHECR) observatory in the Northern Hemisphere. It explores the origin of UHECRs by measuring their energy spectrum, arrival-direction distribution, and mass composition using a surface detector (SD) array covering approximately 700 km^2 and fluorescence detector (FD) stations. TA has found evidence for a cluster of cosmic rays with energies greater than 57 EeV. In order to confirm this evidence with more data, it is necessary to increase the data collection rate. We have begun building an expansion of TA that we call TAx4. In this presentation, we explain the motivation, design, technical features, and performance of the TA and TAx4 detectors. We also present resent results of the experiment.

Experiments: Space and Particle Astrophysics / 408

The AugerPrime Radio Detector

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The Pierre Auger Observatory measures the spectrum of cosmic rays at energies well beyond 10^{19}eV with unprecedented accuracy. Currently, it is being upgraded to increase its mass-composition sensitivity. The upgrade includes the installation of a radio antenna on top of each of the 1661 autonomously operating water-Cherenkov detector stations, covering an area of 3000km^2. The radio antennas are fully integrated within the existing detector stations. This allows sharing the (particle-) trigger and wireless data acquisition system.
An introduction to the AugerPrime Radio Detector, its design and technical implementation, will be given. The first data taken with a prototype array are presented and ongoing calibration efforts discussed. Furthermore, first results of the expected performance, investigated with an end-to-end simulation study, are shown. Based on this, the scientific potential of coincident detection with the Auger radio and particle detectors is highlighted.

Experiments: Space and Particle Astrophysics / 601

Fast imaging of single photons for astronomical applications

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Fast imaging of optical photons may play important role not only in particle physics experiments but also in astronomical observations. It has been recently suggested that optical interferometers would not require a phase-stable optical link between the stations if instead sources of quantum-mechanically entangled pairs could be provided to them, enabling extra-long baselines and, therefore, much improved astrometrical precision. To efficiently interfere the photons must be close enough in time and frequency or, formulating it differently, to be indistinguishable within the Heisenberg uncertainty principle. This sets stringent requirements on temporal measurements needed to determinate the two-photon correlators. Here we discuss requirements on the instrument for those observations, in particular, on its temporal and spectral resolution. We will also discuss possible technologies for the instrument implementation and first proof-of-principle experiments.

Experiments: Space and Particle Astrophysics / 565

The hybrid detector stations of the IceCube surface array enhancement

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The IceCube Collaboration plans to upgrade IceTop, the surface array located on the South Pole glacier, with scintillation detectors augmented by radio antennas. The enhancements will help measure and mitigate the effects of snow accumulation on the IceTop tanks, as well as improve the measurements of high-energy cosmic rays. The enhancements also provide R&D experience for the next generation (IceCube-Gen2) detectors.
A full prototype station was installed near the center of the IceTop array during season 2019/20. The station features custom-designed DAQ electronics and consists of three radio antennas and eight scintillation detectors, each read out by a silicon photomultiplier (SiPM).
This talk will focus on the DAQ and detector R&D, calibration methods, and the results from operation of the prototype station. Future plans for instrumenting the entire IceTop array with hybrid stations will be presented.

Experiments: Space and Particle Astrophysics / 642

KM3NeT: a next-generation undersea neutrino telescope

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KM3NeT is a distributed undersea research infrastructure in the Mediterranean Sea that will host two next-generation neutrino telescopes, ORCA and ARCA. Both consist of a regular 3D array of Digital Optical Modules (DOMs) equally spaced along flexible lines anchored on the seabed.
Built upon the expertise acquired with the currently operating ANTARES telescope, KM3NeT integrates significant technological improvements, among which a novel DOM design with 31 small (3") photomultipliers, leading to improved directional information and a smarter exploitation of the good optical properties of seawater. Data are sent to shore via an optical network supporting rates up to O(100) Gbps, then filtered by a flexible on-line software trigger system, also able to generate and receive external triggers in the context of multimessenger astronomy.
This contribution presents the design and status of the infrastructure, including the results obtained with the first detection units.

Experiments: Trackers / 569

A 4D fast tracking detector for the high-luminosity LHC

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We present recent results of the R&D for a novel 4D fast tracking system based on rad-hard pixel detectors and front-end electronics capable of reconstructing 4-dimensional particle trajectories in real time. The detector features excellent timing resolution of 30 ps, recently measured on a beam test, and 55 micron pitch for the 3D silicon pixel sensor. A stub-based fast tracking algorithm has been implemented and tested in commercial FPGA using a pipelined architecture and allows reconstruction at 40 MHz event rate. Tracking performance for a 4D pixel detector for a future upgrade of the LHCb experiment will be also discussed.

Experiments: Trackers / 533

Investigation of radiation damage effects in the CMS pixel detector

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The CMS pixel subdetector was upgraded at the beginning of 2017. CMS has seen a delivered integrated luminosity of 120 fb^{-1}, resulting in a fluence of $1 \times 10^{15} n_{eq}/cm^2$ received by the innermost layer of the Phase-1 pixel detector, after two years of operation in 2017-2018. Studies of radiation damage effects are essential to understand their implications on the detector operation as well as on its performance. The evolution of the detector properties, such as leakage current and depletion voltage, was studied during the data taking period. In this presentation we discuss the simulation of leakage current and depletion voltage in 2017-2018 for Phase-1 CMS pixel detector and compare it with the direct measurements of these parameters.

Experiments: Trackers / 480

The¬† New Small Wheel Project for the ATLAS muon Spectrometer

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The ATLAS collaboration at LHC has chosen the Large size multi-gap resistive strips Micromegas technology along with the small-strip Thin Gap Chambers (sTGC) for the high luminosity upgrade of the first muon station in the high-rapidity region, the so called New Small Wheel (NSW) project.
The NSW system is currently under construction and will be installed in the ATLAS underground cavern during the LHC long shutdown 2 to enter in operation for Run3.¬† ¬†
The construction of Micromegas and sTGC series detectors is now close to completion at the construction sites distributed all around the world.¬†
At CERN, the final validation and integration of the modules in sectors composing the wheel is well advanced.¬†
In this presentation the motivation of the NSW upgrade and the current status of the project will be reviewed, with particular focus on the main challenges, the adopted solutions and measured performance of the system.

Experiments: Trackers / 279

The novel, truly cylindrical, ultra-thin silicon detector for the ALICE Inner Tracker System

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ALICE is planning to replace its innermost tracking layers during LHC Long Shutdown 3 with a novel detector that will be as close as 18 mm to the interaction point and as thin as <0.05% X0 per layer. To achieve these figures, a wafer-scale Monolithic Active Pixel Sensor in 65 nm technology is being developed. This sensor, fabricated on 300 mm wafers, will reach dimensions of up to 280 by 94 mm. They are subsequently thinned down to values between 20-40 Œºm, where they become flexible and are bent into truly cylindrical half-barrels.
Following the publication of a Letter of Intent by ALICE in 2019, a very active R&D programme on bent silicon detectors has started.
This contribution will review the detector concept, the physics motivations, and lays out the R&D path. Mechanical integration tests with ultra-thin silicon wafers as well as electrical test of bent MAPS, including beam test results, will be shown and demonstrate the feasibility of this new class of tracking detectors.

Experiments: Trackers / 688

A novel TPC concept for a fast tracker for MAGIX

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MAGIX is a new precision experiment, currently being developed at the Johannes Gutenberg University in Mainz, that will explore fundamental nuclear and particle physics at energies up to 100 MeV at the MESA high intensity electron beam.
To achieve its goals, MAGIX requires two short-drift, low material budget TPCs. Those detectors will feature a novel open field-cage concept to reduce the material budget and will be among the first major users of the new SRS+VMM3 readout system which will allow them to achieve readout rates above 100 kHz.
To test the new technologies and ideas employed in the detector design, we built a small GEM-based prototype which was tested in the PRISMA Detector Laboratory, as well as in the test-beam line of the MAMI accelerator.
In this work, we will illustrate the most innovative aspects of this project and present the results of the measurement campaigns.

Experiments: Trackers / 695

Study of the performances of the DAMPE silicon-tungsten tracker after five years of mission

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DAMPE (Dark Matter Particle Explorer) is a satellite-based experiment launched in December 2015 and smoothly taking data after five years of mission. The Silicon-Tungsten Tracker (STK) is characterized by 6 double layers of silicon microstrip detectors, ensuring a total detection area of $\sim 7\ m^2$ and three tungsten plates of 1 mm tick placed in the mechanical support structure aimed to the photon conversion in $e^+ + e-$ pairs. The STK has a double role: precise reconstruction of the track of both charged particles and photons with a resolution better than 70 μm, identification of the charge of the incoming cosmic rays. The STK permits to improve the particle identificaction together with the increase of the background rejection power in case of single-species studies. The STK performances are excellent after five years of continuous operation in space: in this contribution the STK in-orbit calibration and performances during the whole DAMPE mission will be presented.

Experiments: Trackers / 378

CMS Phase-2 Inner Tracker Upgrade

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The HL-LHC conditions of instantaneous peak luminosity up to 7.5x10ˆ34 cm-2 s-1 and an integrated luminosity of the order of 300 fbˆ-1/year would result in 1 MeV neutron equivalent fluence of 2.3 x 10ˆ16 neq/cm2 and a total ionizing dose (TID) of 12MGy (1.2 Grad) at the center of CMS, where its innermost component, the Phase-2 Pixel Detector will be installed. The detector should survive the above radiation dose, handle hit rates of 3GHz/cmˆ2 at lowest radius, be able to separate and identify particles in extremely dense collision debris, deal with a pileup of 140-200 collisions per bunch crossing and have high impact parameter resolution. This translates into a highly granular detector design with thinner sensors and smaller pixels, and a faster and radiation hard electronics compared to the Phase-1 counterpart. This presentation focuses reviews the Phase-2 upgrade of the CMS silicon pixel detector focusing on the features of the detector layout and on developments of pixel devices.

Funding information:

Experiments: Trackers / 398

The LHCb VELO Upgrade

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The Vertex Locator (VELO), surrounding the interaction region of the LHCb experiment, reconstructs the collision points (primary vertices) and decay vertices of long-lived particles (secondary vertices). The upgraded VELO will be composed of 52 modules placed along the beam axis divided into two retractable halves. The modules will each be equipped with 4 silicon hybrid pixel tiles, each read out with by 3 VeloPix ASICs, glued onto a thin silicon plate with embedded micro-channels that allow the circulation of liquid CO_2. The silicon sensors must withstand an integrated fluence of up to 8×10^{15} 1 MeV n_{eq}/cm^2, a roughly equivalent dose of 400 MRad. The highest occupancy ASICs will have pixel hit rates of 900 Mhit/s and produce an output data rate of over 15 Gbit/s.
The design of the VELO upgrade will be presented with the results from the latest R\&D and detector construction.

Funding information:

Experiments: Trackers / 359

ATLAS ITk Pixel Detector Overview

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For the HL-LHC upgrade the current ATLAS Inner Detector is replaced by an all-silicon system. The Pixel Detector will consist of 5 barrel layers and a number of rings, resulting in about 14 m2 of instrumented area. Due to the huge non-ionizing fluence (1e16 neq/cm2) and ionizing dose (5 MGy), the two innermost layers, instrumented with 3D pixel sensors (L0) and 100Œºm thin planar sensors (L1) will be replaced after about 5 years of operation. All hybrid detector modules will be read out by novel ASICs, implemented in 65nm CMOS technology, with a bandwidth of up to 5 Gb/s. Data will be transmitted optically to the off-detector readout system. To save material in the servicing cables, serial powering is employed for low voltage.
Large scale prototyping programs are being carried out by all sub-systems.
The talk will give an overview of the layout and current status of the development of the ITk Pixel Detector.

Experiments: Trackers / 562

A new Triple-GEM Tracking Detector for COMPASS++/AMBER

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The COmmon Muon Proton Apparatus for Structure and Spectroscopy (COMPASS) operates since 2001 and is one of the longest running experiments at CERN. Its phase II is scheduled to be completed in 2022 with a measurement of transverse-momentum dependent PDFs in deep inelastic scattering of muons on a deuterium target.
A new proposal for a future QCD facility at the M2 beamline has been accepted recently. Running under the name COMPASS++/AMBER, the plans include, i.a., a measurement of the proton radius in elastic muon-proton scattering and studies of the pion PDFs using the Drell-Yan process.
The physics program requires an upgrade of the existing GEM tracking system. Currently an improved version of medium-size GEM detectors is being constructed to replace some of the existing detectors.
Future plans include a central pixel readout and front-end electronics which can operate in a self-triggered way. The presentation will show the design and the current status of these detectors.

Funding information:
Supported by BMBF.

Experiments: Trackers / 559

Irradiation studies at the Bern Cyclotron for the ATLAS ITk Upgrade

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At the high-luminosity LHC, the radiation levels for participating experiments will increase by over one order of magnitude in TID compared to current levels. Therefore, components and materials installed closest to the interaction points, such as the new ATLAS Inner Tracker (ITk), have to be tested for their durability in high-radiation environments. The variety and multitude of materials and components requires a large number of irradiation campaigns. For this purpose, the irradiation facility at the Bern medical cyclotron, an 18 MeV proton accelerator, can be utilised. The laboratory setup allows for studies of radiation hardness of different samples, such as cables, connectors, electronics and shielding materials.This talk gives an overview of various irradiation campaigns of components and materials for the ITk readout system, which were recently performed at the Bern cyclotron.

Experiments: Trackers / 334

Development of a System for Beam Abort and Luminosity Determination at the HL-LHC based on polycrystalline CVD diamond

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The High Luminosity upgrade of Large Hadron Collider (HL-LHC) will increase the LHC Luminosity by an order of magnitude increasing with it the density of particles on the detector by an order of magnitude. For protecting the inner detectors of experiments and for monitoring the delivered luminosity, a radiation hard beam monitor is being developed. We are developing a set of detectors based on poly-crystalline Chemical Vapor Deposition (pCVD) diamonds and a dedicated rad-hard ASIC. Due to the large range of particle flux through the detector, flexibility is very important. To satisfy the constraints imposed by the HL-LHC, our solution is based on segmenting each single diamond sensor into multiple devices of varying size and reading them out with a new multichannel readout chip. In this talk we describe the proposed system design including detectors, electronics, mechanics and services and present preliminary results from the first detectors fabricated using our prototype ASIC.

Experiments: Trackers / 319

The ALICE Muon Forward Tracker project: status and expected performances

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The ALICE Muon Spectrometer (MS) has produced, during the LHC Run 1 and Run 2, a wealth of precise and remarkable results on single muon and dimuon observables, despite the absence of a dedicated vertex detector in the rapidity region of interest. To overcome this limitation, a completely new all-pixel Si detector, the Muon Forward Tracker (MFT), has recently been installed at forward rapidity, close to the interaction point. The MFT is part of the ALICE detector upgrade for the LHC Long Shutdown 2 in view of the LHC Run 3 and Run 4. Composed of 936 CMOS pixel sensors, the MFT shares the same technology employed for the new ALICE Inner Tracking System. Covering almost the full acceptance of the MS, these sensors are arranged around the beam pipe in 5 vertically positioned disks made of light carbon composite materials. The technical aspects of the MFT project will be discussed, together with the main highlights from the present commissioning and expected physics performance.

Experiments: Trackers / 460

The ATLAS Strip Detector System for the Phase-II LHC Upgrade

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ATLAS is preparing for the HL-LHC upgrade, where integrated and instantaneous luminosity will reach unprecedented values. For this, an all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector. The strip system consists of 4 barrel layers and 6 endcap disks. After completion of FDRs in key areas, such as Sensors, Modules, Front-End electronics and ASICs, prototyping has been completed successfully. Pre-production is about to start. We present an overview of the Strip System, and highlight the final design choices of sensors, module designs and ASICs. We will summarise R&D results achieved during prototyping, including irradiated modules demonstrating the radiation hardness achieved. In addition, we will outline the current status of pre-production on various detector components, with an emphasis on QA and QC procedures. We will also discuss the plans for the pre-production and production phase distributed over many institutes.

Experiments: Trackers / 346

Preliminary results from the cosmic data taking of the BESIII cylindrical GEM detectors

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The leptonic collider BEPCII (Beijing Electron Positron Collider II) at IHEP in Beijing hosts the BESIII (Beijing Spectrometer III) experiment. The data taking is running since 2009 and 10 more year extension has been approved. Upgrades of the machine and the detector are on going to improve the measurement precision and to extend its physics program. In this presentation a description of the upgrade of the IT (inner tracker) with a cylindrical GEM (Gas Electron Multiplier) will be shown. The CGEM-IT is composed of three triple-GEM detectors cylindrically shaped. An analogue readout through the TIGER ASIC assures the time and charge measurement and it guarantee excellent performance on the wide range of incident angles at 1 Tesla magnetic field. Actually, two of the three layers have been assembled together and a complete test with the final configuration of readout chain and HV distribution is ongoing.

Plenary / 726

Welcome

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No abstract provided.

Plenary / 728

CEPC

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To be expended

Plenary / 729

Low Energy e+e- Colliders

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A brief overview of the development of the idea of colliding electron-positron beams is given. It led to the appearance of many modern installations-factories with extremely high productivity-luminosity. This development progressed as complexity increased from simple single ring machines with a single bunch in the beam to two ring machines with hundreds or even thousands of circulating bunches in each of the storage rings, such as PEP-II, KEKB, DAFNE, BEPCII/BESIII, and SuperKEKB.
A revolutionary solution in the technology of colliding beams was P.Raimondi's proposal to meet flat beams not head-on, but at a significant angle in the horizontal plane. At the same time one should compensate for the geometric loss of luminosity by additional compression of their transverse dimensions and reducing the value of the vertical beta function at the point of meeting the beams to a level significantly smaller than the length of the bunches.
The parasitic modulation of the moment of meeting of the particle with the centerline of the oncoming beam by the horizontal coordinate of the particle, which occurs in this scheme, leading to the vertical blow up, is proposed to be suppressed by a pair of sextupole lenses located before and after the meeting point. They work in such a way that always shift the vertical waist of the incoming beam to the centerline of the oncoming beam, cancelling effectively y-x coupling.
This approach, dubbed Crab Waist, is now widely accepted and is at the heart of almost all future electron-positron collider projects, including Tau-Charm in Novosibirsk, FCC-ee at CERN, and CEPC in China. Other concepts of cyclic colliders, such as round colliding beams and mu-mu-tron, are also discussed.

Plenary / 730

Status and perspectives of the ILC and CLIC studies

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A Higgs factory is considered the highest-priority next collider in the EPPSU 2020 strategy update. Two linear colliders projects, the International Linear Collider (ILC) and the Compact Linear Collider (CLIC), currently under study are among the candidates being considered. Although the linacs accelerating the particles use different RF technologies they share similar challenges, for example related to nanobeams, injectors and positron production, and provide a similar environment to detectors. The talk will summarize recent developments and the current status of the two projects, including their baselines parameters, on-going technology and performance studies, near future plans and international planning.

Plenary / 731

New technology and breakthroughs in axion dark matter search

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The axion dark matter search, even up a few years ago, looked nearly impossible to reach theoretically interesting sensitivities due to very feeble coupling strengths with ordinary matter and with itself. Recently, ADMX has reached DFSZ level sensitivities for frequencies below 1 GHz. Above 1 GHz, the situation becomes again very difficult very rapidly, but our recent breakthrough innovations and technological achievements make it possible to reach DFSZ level sensitivities for the 1-20 GHz frequency range eventually even for 10% of axion fraction in the local dark matter density.

Plenary / 727

Introduction to poster sessions

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No abstract provided.

Plenary / 732

The Electron-Ion Collider: A collider to unravel the mysteries of visible matter - Its Experimental Equipment

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Understanding the properties of nuclear matter and its emergence through the underlying partonic structure and dynamics of quarks and gluons requires a new experimental facility in hadronic physics known as the Electron-Ion Collider (EIC). The EIC will address some of the most profound questions concerning the emergence of nuclear properties by precisely imaging gluons and quarks inside protons and nuclei such as their distributions in space and momentum, their role in building the nucleon spin and the properties of gluons in nuclei at high energies. In January 2020 the EIC received CD-0 and Brookhaven National Laboratory was selected as site. This presentation will highlight the experimental equipment and its integration into the accelerator and give the status of the EIC project.

Plenary / 733

Detector challenges from HL-LHC to FCC

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The HL-LHC poses some serious challenges to particle detectors, with a luminosity of 5x10ˆ34 cmˆ-2s-1, a pileup of up to 200 pp collisions per bunch-crossing and hadron fluence of up to 2x10ˆ16 cmˆ-2 in the most exposed silicon sensors. The LHC community is at this moment preparing the detector upgrades for this project to be installed in the middle of this decade. The FCC-hh is a 100TeV next generation hadron collider, which will again increase the detector challenge by 1-2 orders of magnitude in terms of particle rates and radiation load. This talk will review the detector challenges at such a future facility.

Plenary / 734

The physics and engineering of total-body PET

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Total-body imaging with positron emission tomography (PET) was recently developed through a large, international collaboration (EXPLORER), that has so far resulted in the construction of several prototype and preclinical total-body PET systems for research purposes, along with the FDA-approved uEXPLORER total-body PET/CT system. Here, total-body PET imaging is achieved by extending the cylindrical scanner length to 194 cm compared to the ˜20-30 cm axial lengths of all other clinical PET systems. A longer scanner allows for the detection of 511 keV photons generated from positron-electron annihilation across the entire body simultaneously, along with detecting a greater number of coincident 511 keV photon pairs due to the increased solid angle of detection. While this general principle of total-body PET is relatively straightforward, the physics and engineering involved in total-body PET are not. I will describe the physics considerations of total-body PET from the detectors to data corrections, elaborate on the engineering challenges associated and encountered with the development of the first 2-meter long uEXPLORER PET/CT system at UC Davis, and give my outlook for the opportunities and current innovations in instrumentation for total-body imaging.

Plenary / 745

Technologies for manipulating and measuring antihydrogen for fundamental physics

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Precision comparisons of properties of well-studied hydrogen with its antimatter counterpart, antihydrogen, provide opportunities for testing foundational principles of modern physics ,Äì such as CPT invariance and Weak Equivalence Principle. Since the beginning of the Antiproton Declarator facility at CERN in 1999, significant progress has been made in developing techniques for synthesizing, trapping, manipulating, and measuring atoms made of antimatter. As a result, the precision of antihydrogen measurements [e.g. Nature 557, 71 (2018)] is now approaching that of hydrogen. Most recently, laser cooling of antihydrogen atoms has been demonstrated [Nature 592, 35 (2021)], a technique which has revolutionized the field of atomic physics in the past four decades, but has not been applied to antimatter atoms ,Äî until now . In this talk, I will discuss some of the key technologies which enabled the recent progress, with the emphasis on those developed by the ALPHA (Antihydrogen Laser PHysics Apparatus) collaboration. They range from superconducting magnetic traps, VUV lasers, and a radial-drift time projection chamber. I will also touch on a new project HAICU (Hydrogen-Antihydrogen Infrastructure at Canadian Universities) to develop future technologies in antimatter physics, including anti-atomic fountains, antimatter-wave interferometers, and the synthesis of anti-molecules.

Plenary / 735

Rare process searches

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No abstract provided.

Plenary / 736

Highlights of Dark matter detector technologies

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The nature of dark matter in the Universe is the Holy Grail for most particle physicists. It is a crucial element that is still missing in our understanding of the Universe and would provide a chance to discover physics beyond the standard model. Currently many experiments around the world are searching for dark matter and utilize detectors with large mass in extremely low background environments. Over the last decades, dark matter detection technologies have reached sensitivities at unprecedented levels to such an extent that new sources of backgrounds previously unseen have to be added. After giving an overview of the different detection techniques around the world to detect directly dark matter, I will present how developing new cutting-edge technologies and dedicated calibrations will help to address the different common challenges of dark matter detection that we are currently facing.

Plenary / 737

Neutrino technologies

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This talk will survey technology needs (detector and source) for next-generation neutrino experiments, and prospects for their development

Plenary / 485

Launch and first results of Mini-EUSO telescope, observing UV emissions of cosmic and terrestrial origin from the International Space Station

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Mini-EUSO is a detector observing the Earth in the ultraviolet band from the International Space Station, launched in 2019.
The main camera has an optical system with two Fresnel lenses and a focal surface with 2k channels and field of view of 44o, range (290-430 nm), pixel size of 6.3 km, sampling of 2.5mus, through a nadir-facing UV-transparent window in the Russian Zvezda module. It also has 2 cameras in the near infrared and visible ranges and Silicon Photomultipliers. Mini-EUSO is capable of observing Extensive Air Showers generated by Cosmic Rays with energy above 1e21eV and detect artificial showers. Other objectives are the search for nuclearites and Strange Quark Matter, the study of atmospheric phenomena, meteors and meteoroids, the observation of artificial satellites and man-made space debris.
We will discuss the instruments in the detector, its performance prior and during flight and the perspectives for future usage of this technology in future space missions.

Plenary / 570

Performance and Running Experience of the Belle II Silicon Vertex Detector

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The Belle II experiment is collecting data at the SuperKEKB collider (KEK, Japan), which aims to provide 50 ab-1 integrated luminosity with the unprecedented peak-luminosity of 6 √ó 10^35 cm-2s-1.
The challenge for the Belle II detector is the harsh beam background due to the high luminosity beams. The silicon vertex detector (SVD) is one of the vertex detectors in Belle II, consisting of four-layer double-sided silicon strip sensors. The SVD is operating reliably since 2019, showing high stability of the noise levels and calibration parameters. The measured performance includes excellent signal-to-noise ratio and hit efficiency, as well as hit-time and spatial resolution. Radiation effects on strip noise, sensor currents and depletion voltage are also measured, which reasonably match expectations based on the preliminary radiation dose evaluated by diamond sensors.
In this talk the performance of the SVD, as well as the operational experience and radiation effects, will be presented.

Plenary / 687

Hybrid pixel detectors with on-chip event selection

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Hybrid pixel detectors offer unrivalled performance in very high rate particle tracking. Moreover, as the sensor material can be freely chosen or replaced by a gas detector or a Micro Channel Plate the same readout ASIC may find uses in multiple applications. The Timepix4 chip tags particle arrival times to within 200ps and is capable of digesting ~700 Mhits/cm2/sec. This, however, comes at the expense of a very high readout bandwidth. As we approach the next ASIC generation we must ask ourselves how can we benefit from the added speed and power while limiting the readout bandwidth. In this contribution we propose adding computational power to the periphery of the readout chip enabling data selection and compression prior to off-chip readout. For example, in a sensor material with a high thickness to pixel pitch ratio it is possible to reconstruct particle trajectories sending off-chip only hit information of the particles of interest e.g. high Pt tracks, single photons, electrons, etc

Plenary / 428

The GRANDProto300 antenna and acquisition board

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GRAND is a newly envisioned Giant Radio Array for Neutrino Detection with a sensitivity large enough to be able to measure cosmic neutrinos in all reasonable scenarios. In its final configuration, it will consist of 200,000 radio antennas distributed over ˜20 sub-arrays worldwide with a total area of 200,000 km2. GRANDProto300 is created to further develop the hardware, software and trigger strategies for the full array. In our current stage of development we have reduced costs with respect to previous radio arrays while increasing functionality and monitoring. In this contribution, I will highlight the design of the readout system with a special emphasis on the 500MSPS ADC interface implemented in the FPGA part of a System on Chip (SoC). Next to this, the various peripherals on the board are discussed with their integration in the Linux kernel running on the processor part of the SoC. In addition, the first measurements on the performance of the whole readout chain will be presented.

Plenary / 415

HGCROC: the front-end readout ASIC for the CMS High Granularity Calorimeter

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The CMS High-Granularity Calorimeter (HGCAL) imposes extremely challenging specifications for the front-end electronics: high dynamic range, low noise, high-precision time information and low power consumption, as well as the need to select and transmit trigger information with a high transverse and longitudinal granularity. HGCROC-V2 has 72 channels of the full analog chain: low noise and high gain preamplifier and shapers, and a 10-bit 40 MHz SAR-ADC, which provides the charge measurement over the linear range of the preamplifier. In the saturation range of the preamplifier, a discriminator and TDC provide the charge information from TOT (200 ns dynamic range and 50 ps binning). A fast discriminator and TDC provide timing information to 25 ps accuracy. We will report on the performance in terms of noise, charge and timing, the DAQ and Trigger paths, as well as results from radiation qualification with total ionizing dose (TID) and heavy ions for single-event effects (SEE).

Plenary / 738

Highly Granular Calorimeters for Particle Flow

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Particle Flow algorithms promise to reach unprecedented jet energy resolution as needed for precision measurements at a future Higgs Factory. This is accomplished by combining the information from detector components in an optimal way. A key ingredient for this approach are highly granular calorimeters that provide a clear separation of nearby showers as well as a good energy measurement. The CALICE collaboration is devoted to developing such calorimeter concepts optimised for Particle Flow reconstruction.
The presentation will discuss recent developments of CALICE calorimeter prototypes and results from beam tests. It will also highlight further applications of highly granular calorimeters, like the upgrade of the CMS calorimeter endcap for HL-LHC (HGCAL) and possible use in future detectors.

Plenary / 739

State-of-the-art of Micro-Pattern Gaseous Detectors (RD51)

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No abstract provided.

Plenary / 740

Tracking Triggers for the HL-LHC

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he High Luminosity LHC (HL-LHC) upgrade will significantly increase the instantaneous luminosity of LHC collisions. The resulting proton-proton datasets will allow precise measurements of Higgs boson properties,Äã,Äã, searches for,Äã ,Äãrare processes, and much more. However, the associated experimental environment poses significant challenges for the LHC detectors and their triggering systems, which must therefore be upgraded.
This presentation will discuss the inclusion of hardware-based track reconstruction in the CMS and ATLAS triggering systems for the HL-LHC, with particular focus on the track trigger capability of the upgraded CMS experiment. The presentation will describe the challenges and opportunities of this novel capability, review the alternative implementations that were considered, and discuss its expected performance.

Plenary / 741

Fast timing silicon tracking detectors

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The last few years has seen the emergence of fast timing silicon detectors, first pioneered for the HL-LHC at CERN, as an option for deployment in large tracking arrays. These silicon detectors are based on the Low Gain Avalanche Detector (LGAD) concept, and are being made by a large number of vendors and labs. In addition a significant amount of R&D worldwide is happening to try and improve on the initial devices for many other applications. The device now most tested is the AC-LGAD with a goal of providing 4-dim tracking, that is position resolution <15 microns and timing measurement <15 picoseconds for each individual measurement. I will present the status of the LGAD family of devices and in the backup slides a number of interesting physics applications proposed.

Plenary / 462

Update on Photon Detection Module for Precise Timing Systems and Large-Scale Noble Liquid Experiments

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This contribution presents an update on the Photon Detection Module (PDM) R&D for large-scale noble liquid experiments and precise timing systems. Based on a multilayered silicon interposer, for radio purity and coefficient of thermal expansion matching between its components, the PDM has built-in modularity for system scaling. It is based on an array of Photon-to-Digital Converters (PDCs, a.k.a. digital SiPMs), which have advantages over analog SiPMs by using the boolean nature of Single Photon Avalanche Diodes (SPADs). The PDM also includes a tile controller for digital signal processing, timestamping and to manage the various components. Then a power management integrated circuit is required to bias the SPADs and the PDM components. Finally, a laser-less silicon photonics-based communication module is integrated to interface with the data acquisition system. The implementation status, challenges and benefits of each component will be discussed.

Plenary / 744

Skipper-CCDs and the SENSEI search for sub-GeV dark matter

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SENSEI (Sub-Electron Noise Skipper Experimental Instrument) is a leading experiment in the search for sub-GeV dark matter. Using the high granularity of CCDs and the sub-electron charge resolution of the Skipper readout, Skipper-CCDs can count individual electron-hole pairs in each of millions of pixels.

The SENSEI Skipper-CCDs have measured the lowest rates in silicon detectors of events containing one, two, three, or four electrons.

This results in world-leading sensitivity for a large range of dark matter masses, and significant improvement is expected with the full-scale SENSEI experiment at SNOLAB.

I will present the SENSEI experiment, and discuss the status and future directions for the Skipper-CCD technology.

Plenary / 743

Quantum enhanced methods for ultralight dark matter searches

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No abstract provided.

Plenary / 746

Farewell - TIPP and roadmaps

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No abstract provided.

Posters: Calorimeters / 720

The PADME Calorimeter

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To search a dark photon A‚Äô in the process e+ e‚àí ‚Üí A‚Äô‚Ü≥, the PADME apparatus has been built at the Frascati National Laboratory of INFN. The core of PADME detector is an e.m. calorimeter to detect the signal and background photons produced in the positron annihilations on the electrons of a thin target.
The PADME calorimeter consists of two components: ECAL and SAC. ECAL is a homogeneous BGO-crystal calorimeter with a cylindrical shape with a central hole to allow the passage of large rate of Bremsstrahlung events, which are sharply peaked at small angles. To mitigate such backgrounds, the fast Small-Angle Calorimeter is placed behind the main ECAL. The in-time correlation of photon events in the SAC and ECAL allows the tagging of 2- and 3- gamma events and hence the efficient vetoing of backgrounds.
PADME Commissioning took place in 2018 and 2019 at the INFN Frascati National Laboratories with the beam of the Linac of the local Beam Test Facility (BTF) and results will be presented.

Posters: Calorimeters / 643

Building Machine Learning Applications for Temporally Segmented High Granular Multi-readout Fiber Calorimeters

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New technologies have enabled the development of granular calorimeters with millions of channels. The signal of the ultra-sampled shower produced by these devices is thought to provide greater discriminating power to event reconstruction. Combining sub-nanosecond digitization with small area photosensors in a fiber calorimeter, we propose an enhancement to the traditional dual readout design that provides benefits of both high-granularity and multi-readout. We show that by applying machine learning techniques, namely Convolutional Neural Networks, Graph Neural Networks, and Recurrent Neural Networks to both a highly granular and proposed fiber calorimeters. We see, for instance, in the simple high granularity setup, the CNN improves reconstructed energy resolution from ˜40 to ˜33 %/sqrt(E). These results indicate the spatial distribution of energy deposition within the sensitive elements is both identifiable (able to be learned) and representative of underlying physical processes.

Posters: Calorimeters / 287

Development, production, quality control, and assembly procedures of the Mu2e electromagnetic calorimeter mechanical structures

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The Mu2e calorimeter employs 1348 CsI crystals readout by SiPM and fast FE and DAQ electronics assembled in two annular disks positioned downstream the aluminum target along the beamline.
The operational conditions (radiation levels, 1 tesla magnetic field and 10ˆ-4 Torr vacuum) have posed tight design constraints. The support structure of the two 674 crystals matrices employs two aluminum hollow rings and structural carbon fiber parts. The SiPM and FE electronics associated to each crystal are assembled in a unit inserted in a copper holder and Faraday cage. The 674 units are supported by a machined plastic plate. The plate integrates the cooling system made of a network of copper lines flowing a rad-hard fluid to maintain the SiPM temperature at 0 C. The DAQ electronics is hosted in aluminum crates positioned on the external surfaces of the two disks. The crates also integrate a cooling system. We will review the design and construction progress of the detector mechanical parts.

Posters: Calorimeters / 309

High-precision energy measurement of medium-light ions with the FOOT calorimeter

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FOOT is a portable setup to measure fragmentation cross sections in beam-tissue nuclear interactions typical for hadron therapy, with fragment energies reaching 400 MeV/A. The energy will be measured by a homogeneous calorimeter using 320 BGO scintillating crystals as active material and SiPM for light-detection. A series of tests using energetic proton and Carbon beams at the CNAO facility in Pavia, Italy, were performed to find the optimal configuration of every detector component and have demonstrated a linear response with resolution better than 2% over the wide dynamic range from tens of MeV to a few GeV. This contribution will present the main technical consideration of the calorimeter design, including the SiPM, reflective layer, readout electronics and mechanics, as well as results of the latest performance tests of a 3x3 crystal module. Important challenges including the temperature dependence, non-linear light absorption and scintillation quenching will be also discussed.

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WITHDRAWN - Picosecond Timing Layers for Future Calorimeters: Updates from the Askaryan Calorimeter Experiment (ACE)

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We report on results from the Askaryan Calorimeter Experiment (ACE) which uses the coherent microwave Cherenkov emission from high energy particle showers in dielectric-loaded waveguides as calorimetric timing layers. Above ACE's energy threshold, a single 5 cm thick (1.4 X_0) layer of ACE waveguides would provide ˜1 ps timing, 3D spatial constraints on the scale of ˜300 μm to 5 mm, and an additional energy measurement, making ACE a true 5D detector. When embedded inside another calorimeter technology, ACE layers could provide a powerful measurement for particle-flow algorithms as well as unique vertexing capabilities to significantly reduce pileup. Due to thermal noise limits, ACE elements have a relatively high energy threshold so they are currently limited to future high CoM colliders like the FCC-hh. We report on new simulations from deploying ACE layers in the barrel and forward calorimeters at future colliders and discuss ongoing research to further develop the ACE concept.

Posters: Calorimeters / 352

Status of ADRIANO2 R&D in T1604 Collaboration

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A novel high-granularity, dual-readout calorimetric technique (ADRIANO2) is under development as part of the research program of the T1604 Collaboration[1]. The building block of such a calorimeter comprises a pair of optically isolated, small tiles made of scintillating plastic and lead glass. The prompt Cerenkov light from the glass can be exploited to perform high resolution time measurements while the high granularity provides good resolution of the spatial components of the shower. Dual-readout compensation and particle flow techniques applied to the plastic and lead glass sections should provide excellent energy resolution as well as PID particle identification, making ADRIANO2 a 6D detector suited for High Energy as well as High Intensity experiments.
A report on the ADRIANO2 project, current and future R&D plans by T1604 Collaboration, and the construction status of a new prototype will be presented.

Posters: Calorimeters / 386

Upgrade of Projectile Spectator Detector at NA61/SHINE experiment

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Projectile Spectator Detector (PSD) is a modular sampling hadron calorimeter used in the NA61/SHINE experiment to measure collision centrality and event plane reconstruction independently from tracking detectors. Each PSD module has longitudinal segmentation with read out by ten Hamamatsu MPPCs. A fast-analog signal from PSD modules allows selecting events with required centrality on-line at the trigger level. Performance of the PSD will be shown for the measurements at the momentum range 13 - 150 AGeV/c.
The new physics program of NA61/SHINE experiments requires beam rate to be increased by order of magnitude. This requires PSD upgrade to survive in new high radiation conditions. It is proposed to use two forward calorimeters: a modified current PSD with a beam hole in the center, and the second new calorimeter with small transverse sizes placed downstream. Details of the PSD upgrade and results of the performance studies for the new calorimeter system will be presented.

Posters: Calorimeters / 390

Design and implementation of the double read-out system for the calorimeter of the HERD experiment

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The High Energy cosmic-Radiation Detection (HERD) facility will be installed aboard the China's Space Station around 2025. Thanks to its innovative design, based on a large, homogeneous and isotropic calorimeter, HERD will extend the direct measurement of cosmic rays by one order of magnitude in energy. In this talk, we will describe the solution that will be used for the read-out of the about 8000 LYSO crystals of the calorimeter. This is the main challenge of the hardware design, since a large dynamic range of 10^7 is needed and absolute energy scale calibration is crucial for space instruments. We will present the double read-out scheme, made of wave-length shifting fibers coupled with an intensified scientific CMOS and photodiodes connected to a specifically designed front-end electronics. Finally, we will discuss the advantages of this solution: independent systems for hardware trigger and energy measurement, improved cross-calibration capability, and increased redundancy.

Posters: Calorimeters / 488

Design and Study of Electromagnetic Calorimeter for Super Tau-Charm Facility

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Modern e^+e^- colliders will reach an exceedingly high level of luminosity, like SuperKEKB, Super Charm-Tau Factory (SCTF) proposed by Russia, and Super Tau-Charm Facility (STCF) proposed by China. Under such a high event rate and additional beam background, the electromagnetic calorimeter should be capable of maintaining good energy and position resolution while dealing with pile-up pulses and fake signals. A calorimeter system based on fast pure CsI crystal, read out by avalanche photodiodes, highlighting good time resolution and high granularity is designed for STCF. This talk will expand from three aspects: Tests of the scintillation counter; Geometry optimization and simulated performance of calorimeter system; Severe performance deterioration caused by beam background with possible solutions.

Funding information:
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Posters: Calorimeters / 509

Commissioning of new FHCal at BM@N experiment

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The BM@N (Baryonic Matter at Nuclotron) is the fixed target experiment at NICA-Nuclotron (JINR, Dubna, Russia) accelerator complex. The main goal of the experiment is studying the properties of dense nuclear matter produced in ion-ion collisions. New Forward Hadron Calorimeter (FHCal) with modular structure and a beam hole in the center has been developed and constructed to measure the collision centrality after the BM@N upgrade. The transverse and longitudinal segmentation of the FHCal allows to perform calibration of the calorimeter with cosmic muons.
FHCal modules have lead/scintillator sampling structure with longitudinal segmentation. Light signals from the sections are collected with MPPCs, amplified and read-out by ADC boards. Fast analog signals are collected for trigger system.
The status of development and construction of the new FHCal calorimeter for the BM@N experiment will be presented. Performance of FHCal front-end and readout systems will be discussed.

Posters: Calorimeters / 577

The development of a highly granular scintillator-steel hadron calorimeter for the CEPC

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Based on the particle-flow algorithm, a highly granular sampling hadron calorimeter (HCAL) with scintillator tiles as active layers and stainless steel as absorber is proposed to achieve an unprecedented jet energy resolution to address major challenges of precision measurements at future lepton colliders, including the Circular Electron Positron Collider (CEPC). A wide range of R&D efforts are being carried on with a major aim to construct a scalable HCAL prototype for the CEPC. This talk will present the latest progress of the prototype development, with highlights from optimization studies of the HCAL design based on the evolving CEPC Particle Flow Algorithm “Arbor”, characterisations of silicon photomulpiliers (SiPMs) from different vendors, testing of a new promising SiPM-readout chip developed within the CALICE collaboration, mass production of scintillator tiles, automated foil wrapping, as well as dedicated test stands for the quality control of scintillator tiles and SiPMs.

Funding information:
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Posters: Calorimeters / 680

The CMS Electromagnetic Calorimeter Clustering and Energy reconstruction for LHC Run3

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The CMS electromagnetic calorimeter (ECAL) is a high resolution, high granularity scintillating crystal calorimeter. Improvements to the CMS ECAL energy reconstruction algorithms are required to maintain the ECAL performance in the more challenging environment of the upcoming LHC Run 3 (2021-2024). We propose to mitigate the increase in the noise, due to the ECAL barrel front-end readout components ageing and to the crystal transparency loss, by revisiting the clustering algorithm. We will show the results obtained for the simulated reconstruction efficiency of the photons/electrons superclusters, their reconstructed energy, and the resolution obtained for the latter when refining the interplay between the different noise thresholds in the reconstruction of clusters and exploring less conventional methods for the collection of signals contributing to the electromagnetic shower, such as machine learning.

Posters: Calorimeters / 686

Forward hadron calorimeter (FHCal) at MPD NICA

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The purpose of the MPD experiment at NICA is to study dense baryonic matter, and the facility is now under construction. The operating energy range at the MPD is 4,Äì11 AGeV. One of the MPD detectors is the forward hadron calorimeter (FHCal), which is designed to study the collisions geometry, primarily, the orientation of the reaction plane and the centrality of heavy ion collisions. The detector will measure energies of spectators (non-interacting nucleons).
The MPD experiment implements two calorimeters with holes in the center for the beam pipe. Each calorimeter consists of 44 individual modules, which are symmetrically located concerning a collision point. Each of the 44 modules consists of 42 lead/scintillator layers, each sized 15$\sqrt{}$615 cm2. The light from the scintillators is collected by wavelength shifting fibres (WLS) and then detected by silicon photomultipliers (SiPM) placed in the rear side of the module. The design, parameters and the energy calibration will be discussed.

Posters: Calorimeters / 691

Development of cosmic muon calibration methods for the segmented sampling lead/scintillator hadron calorimeters at the NA61/SHINE, CBM, BM@N and MPD experiments

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The NA61/SHINE, CBM, BM@N and MPD experiments are devoted to the study of the hot dense quark-gluon matter, which is formed in collisions of heavy nuclei. In all the mentioned experiments, forward hadron calorimeters will be used to determine the collision geometry. Due to the absence of a muon beam in the overwhelming majority of mentioned experiments, it is not possible to calibrate the detector with muon beams. Therefore, a new method was developed for the energy calibration of sections of hadron calorimeters with cosmic muons using longitudinal and transverse segmentation of the detector. The calibration procedure for hadron calorimeters with three-dimensional space reconstruction of cosmic muons tracks will be discussed.

Posters: Calorimeters / 697

Performance of CMS high granularity calorimeter prototypes in testbeam experiments

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The present electromagnetic and hadronic calorimeters of the CMS experiment will be upgraded to cope up with the harsh radiation environment and pileup conditions posed by the high luminosity operations of LHC (HL-LHC) expected to start in 2027. CMS has opted for a sampling calorimeter, based on silicon and scintillator technologies, with unprecedented transverse and longitudinal segmentation to facilitate particle identification, particle-flow reconstruction and pileup rejection. As part of the ongoing development and testing phase of the HGCAL, prototypes of both the silicon and scintillator based calorimeter sections have been tested in 2018 in beams at CERN. We report on the performance of the prototype detectors in terms of stability of noise and pedestals, MIP calibration, longitudinal/lateral shower shapes, as well as energy linearity and resolution for electrons and pions. We compare the measurements with a detailed GEANT4-based simulation.

Posters: Calorimeters / 698

Background suppression with SND electromagnetic calorimeter time channel

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The SND is a non-magnetic detector deployed at the VEPP-2000 e+e,àí collider (BINP, Novosibirsk) for hadronic cross-section measurements in the center of mass energy range below 2 GeV. The important part of the detector is a hodoscopic electromagnetic calorimeter (EMC) with three layers of NaI(Tl) counters. EMC signal shaping and digitizing electronics based on FADC allow us to obtain both the energy deposition and the signal arrival time. We demonstrate how EMC time is applied to detect background pileup and cosmic events.

Posters: Dark Matter Detectors / 353

Progress of kinetic inductance detectors on CaF2 for astroparticle physics

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Kinetic Inductance Detector (KID) is an exciting device that promises high sensitivity, large format, and submillimeter waves for X-ray imaging arrangements for astrophysics. The KID consists of a superconductor thin film microwave resonator combined with a transmission line. When energy accumulates, Cooper's pair in superconductor films break,„ÄÄproducing a quasi-particle. This change increases the kinetic induction in the resonant circuits and can be monitored by the transmission line. Lumped element KID (LEKID) is applied to CaF2 crystals as a substrate in our experiment. 48Ca is one of the double-beta decay nuclei, and 19F is sensitive to spin-dependent elastic scattering with dark matter. The LEKID on CaF2 can be cooled to 10mK. At this stage, the quality factors of the LEKID are about 400 √ó 10^3 and measurement for particle detection using 241Am particle irradiation also demonstrated at this low temperature.

Posters: Dark Matter Detectors / 403

CYGNO: Optically Readout TPC for Directional Study of Rare Events

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CYGNO is a project realising a cubic meter demonstrator to study the scalability of the optical readout concept for a large-volume, GEM-equipped gaseous TPC to be operated at atmospheric pressure that represents an ideal candidate to be employed as directional detectors for rare events studies.
The combined use of high-granularity sCMOS and fast sensors for reading out the light produced in GEM channels during the multiplication processes was shown to allow reconstructing 3D direction of the tracks, offering accurate energy measurements and sensitivity to the source directionality. This type of detector has demonstrated a high particle identification capability, very useful to distinguish nuclear from electron recoils.
Performance of the large prototype (50 litres sensitive volume, 50 cm drift gap, 1000 cm^2 readout plane) will be shown and discussed.

Funding information:
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Posters: Front-end electronics / 724

A possible design of the readout electronics for large area SiPM detectors of the TAO experiment

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The TAO (Taishan Antineutrino Observatory) is a ton-level Gadolinium doped liquid scintillator (GdLS) detector located ˜30 m far from one of the Taishan reactor cores in China serving the JUNO (Jiangmen Underground Neutrino Observatory) neutrino experiment. The goal of TAO is the measurement of the reactor antineutrino spectrum with very high energy resolution (˜ 1.5% at 1 MeV). In order to maximize the photon TAO will be equipped with ˜10 m2 of SiPMs working at -50 C. In this work we present a proposal for the full readout electronic chain specifically designed to meet the TAO purposes. It consists on an analog readout board directly coupled to the SiPMs and a digital FPGA-based board that manages the digitization and pre-processing of the signals. The boards are currently under development. The first prototypes have shown excellent single photoelectron resolution and timing properties and their performance will be discussed at this conference.

Posters: Front-end electronics / 580

Development of an integrated readout electronics system for a highly granular scintillator-tungsten calorimeter prototype for the CEPC

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An electromagnetic calorimeter (ECAL) based on scintillator and SiPMs is one of the high-granularity calorimetry options developed within the CALICE collaboration for future lepton colliders, e.g. the Circular Electron Positron Collider (CEPC). A dedicated SiPM-readout electronics system was developed for an ECAL prototype with 6720 scintillator strips individually read out by SiPMs. The complete front-end electronics system with a feature of low power consumption (about 8mW per channel) was successfully integrated into the prototype. Two calibration systems were implemented in the prototype to calibrate the front-end electronics and SiPMs respectively. Besides, a temperature monitoring system with the bias-voltage feedback strategy has been integrated to compensate the SiPM gain variations due to the environment. The talk will cover the design and performance evaluation of the electronics system, as well as highlights of the ECAL prototype long-term commissioning with cosmic muons.

Funding information:
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Posters: Front-end electronics / 587

An SCA ASIC-based multi-channel readout system for the Prototype MTPC at CSNS Back-n White Neutron Source

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The back-streaming white neutrons (Back-n) at China Spallation Neutron Source (CSNS), which has excellent energy spectrum and good time resolution, provides superior conditions for neutron induced light charged particle tracking experiment. To track light charged particles, CSNS is working on a project named Multi-purpose Time Projection Chambers (MTPC) and completed a 1519-channel prototype. A multi-channel readout system composed of switched capacitor arrays (SCA) waveform sampling electronics based on ASIC was designed to meet the requirements of the prototype MTPC. This paper presents the structure of this SCA ASIC-based multi-channel readout system and the results of the beam test with MTPC at CSNS. Time of Flight spectrum of neutron beam and 3D-track of neutron induced light charged particles were successfully reconstructed. These test results prove the feasibility of large-scale MTPC, and propose an improvement direction for the next generation of electronic system.

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Posters: Front-end electronics / 593

A direct-sampling RF receiver for MOLLER beam charge measurement

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We demonstrate an RF receiver that achieves 25 ppm uncertainty in measuring the amplitude of a 1497 MHz sinosoidal signal in a 0.5 ms integration window. The receiver employs a direct digital sampling architecture. The signal comes from beam intensity monitoring cavities on the beamline of the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab. The signal strength, frequency, and integration window demonstrated are consistent with the requirements of the upcoming MOLLER experiment. It provides a new instrumentation that improves on the beam charge uncertainty in each helicity state by a large factor for the experiment.

Posters: Front-end electronics / 608

CBM Projectile Spectator Detector Readout Chain

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The Projectile Spectator Detector (PSD) is a sampling lead/scintillator forward hadron calorimeter with transverse and longitudinal segmentation, which will be used to measure collision centrality and orientation of the reaction plane in the nucleus-nucleus collisions at the Compressed Baryonic Matter (CBM) experiment at FAIR. The PSD consists out of 44 modules with 10 longitudinal sections in each. PSD,Äôs readout chain consists out of radiation-hard Front-End Electronics (FEE), Readout Modules with 14-bit 125 Msps ADCs and a Service Module with bias and calibration apparatus.
This article covers design and features of the FEE and readout electronics, as well as the results of the readout chain tests done with cosmic radiation signals and during the heavy ion beam runs at mCBM.

Posters: Front-end electronics / 677

CMS ECAL upgrade for precision timing and energy measurements at the High-Luminosity LHC

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The High Luminosity upgrade of the LHC (HL-LHC) at CERN will provide unprecedented instantaneous luminosity of ˜5 x 10^{34}cm $^{-2}$s^{-1}, leading to an average of 150-200 simultaneous collisions. This high instantaneous luminosity scenario presents a significant challenge for the detectors. The barrel region of the CMS electromagnetic calorimeter (ECAL) will be preserved but will be operated at a lower temperature and with a completely new readout and trigger electronics. A dual gain trans-impedance amplifier and an ASIC providing two 160 MHz ADC channels, gain selection, and data compression will be used in the new readout electronics. The trigger decision will be moved off-detector and performed by powerful and flexible FPGA processors, allowing for more sophisticated trigger algorithms to be applied. The upgraded ECAL will be capable of high-precision energy measurements throughout HL-LHC and will greatly improve the time resolution for photons and electrons above 10 GeV.

Posters: Front-end electronics / 684

Innovative Safety Monitoring System based on Fiber Optic Sensors Technology Compatible with 4-20mA Standard

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In this contribution we propose an innovative, full analog, fiber optic sensors (FOS) interrogator which, being fully compatible with the 4-20 mA standard of the Programmable Logic Controller (PLC), enable the integration of the FOS technology in safety framework, such as the Detector Safety System (DSS) of the LHC Experiments. It is composed by a full analog electrical circuitry, capable to directly transduce the signal coming from the arrayed waveguide grating (AWG), into a monotonic electrical current in the range of 4- 20mA. In a first experimental analysis, a temperature of 50°C was detected, exhibiting an output trend which can be fitted with a 3rd order polynomial equation over the whole range. Furthermore, in a reduced range of 20°C, the trend behaves linearly. The proposed system has the potential to be fully integrated in the DSS of the LHC experiments. Indeed, a validation on field is on going in the framework of the DSS of the Compact Muon Solenoid (CMS) experiment.

Posters: Front-end electronics / 705

A Novel High Rate Readout System for a High Efficiency Cosmic Ray Veto for the Mu2e Experiment

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The Mu2e Cosmic Ray Veto must veto cosmic-ray muons over a large area with an efficiency of 99.99\% in the presence of high background rates. It consists of 5,376 scintillator extrusions with embedded 1.4\,mm wavelength-shifting fibers coupled to 2×2\,mm^2 silicon photomultipliers. A custom readout system consists of: (1) small circuit board, the Counter Mother Board, which provides the bias, a temperature sensor, flasher LEDs, and passive SiPM pulse shaping; (2) a Front End Board which digitizes, zero-suppresses, and stores in on-board memory signals from up to 64 Counter Mother Boards, provides bias to the SiPMs, pulses to the LEDs, and a measurement of the SiPM currents; and (3) a Readout Controller which collects data from the Front End Boards via Cat6 cables, which also deliver 48V power to the Front End Boards using PoE.

Funding information:
US Department of Energy

Posters: Front-end electronics / 717

Measurement results for the AARDVARC: A High Performance Waveform Digitizer System-on-Chip

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Data acquisition systems for state of the art imaging based particle identification detectors are expected to handle large numbers of channels, high accuracy timing, and operate under limited spatial and power constraints. In many applications, full waveform digitization is considered necessary to guarantee the required timing resolution and avoiding the undesirable degradation due to time walk, pile-up and other sources of noise. Such acquisition systems are even more problematic in that the data volume and the computational requirements push the power, cost and space limits even further.
Based on such requirements a new multi-channel Waveform digitizer the AARDVARC has been designed and fabricated. This 4 channel front-end chip operates at 13GSa/s and has 32k of sampling depth per channel. In this summary, measurements of analog and digital performance of the asic will be reported. The device has been fabricated in130 nm process.

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Posters: Front-end electronics / 310

Sub-nanosecond Cherenkov photon detection for the LHCb RICH system in high-occupancy conditions

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The LHCb upgrade programme, with increased luminosity, will cause a rise in particle multiplicity and hit occupancy in the LHCb detectors. To mitigate this effect for the Ring-Imaging Cherenkov (RICH) detectors, it is proposed to use photon detector hit time information. The new front-end readout includes a programmable time gate in the FPGA and the expected background reduction using a 6.25 ns gate and improvement in particle ID are demonstrated. The R&D proposal to consolidate the readout electronics with sub-ns timing around 2026 is presented. This is an important step in preparation for an order-of-magnitude rise in luminosity in 2031, where the opto-electronic chain will be upgraded to achieve fast single-photon timing. The intrinsic resolution of the RICH detectors of less than 10 ps and the potential to reconstruct primary vertex times are studied in simulation. Considering only improvements in timing, a 50 ps single hit resolution can achieve today,Äôs performance in the HL-LHC.

Posters: Front-end electronics / 326

A 4.5GHz to 5.6GHz PLL in 55 nm CMOS for High-Energy Physics Experiments

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This paper presents the design and test results of a radiation tolerant PLL ASIC as part of the optical link ASICs in the Nuclotron-based Ion Collider Facility (NICA) front-end readout electronics. To obtain low DC leakage current and reduce dynamic mismatch, the charge pump uses two unity-gain feedback operational amplifiers to keep the output common mode voltage constant. The LCVCO employs a novel capacitor array structure to improve the Q degradation due to the source/ drain leakage current from the binary controlled MOS transistor. All adjustable bits can be controlled by the SPI module, which is also strengthened with the Triple Modular Redundancy (TMR) structure. The PLL covers a wide-frequency range from 4.5GHz to 5.6GHz, consuming a total power of 25 mW from the post layout simulation. At 5.12GHz, the phase noise is -115 dBc/Hz @ 1MHz offset. The chip has been taped out and the tests are planned to be conducted in this March. The test results will be reported in the meeting.

Funding information:
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Posters: Front-end electronics / 327

A radiation tolerant 16 Gbps 1:16 Deserializer for High-Energy Physics Experiments

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The paper would present the design and test results of a 16Gbps 1:16 deserializer chip fabricated in 55 nm CMOS technology,which is a part of the optical link ASICs in the Nuclotron-based Ion Collider fA—Åility (NICA) front-end readout electronics.The input equalizer stage is used to compensate for the high frequency loss caused by the transmission line on PCB and the bonding wire.The strength of equalizer can be configured via SPI module with TMR structure.In order to improve the bandwidth of the high-speed 1:2 DEMUX and high-frequency divider,and save voltage margin,their latches adopt a CML structure without tail current source.We designed duty cycle correction circuit and clock alignment circuit to recover duty cycle and align clock edges. The whole chip consumes 305mW with 1.2V supply when working at 16Gbps.The total jitter of post-layout simulation is 28.2ps.This chip has been taped out and the test results will be reported in the meeting.

Funding information:
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Posters: Front-end electronics / 397

Development of the Readout Electronics System for CEPC ScECAL

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To acquire the feature of Higgs particle, construction of Circular Electron Positron Collider (CEPC) was proposed in recent years. Electromagnetic calorimeter based on scintillator and SiPM (ScECAL) is one of the options of the electromagnetic calorimeter system of CEPC. The ScECAL Electronic prototype was constructed. Special readout electronic system was developed to meet the demands of ScECAL prototype. The ScECAL prototype contains 32 layers of basic units which hold 6720 scintillators coupled with SiPM in total. The readout electronic system was highly embedded in the prototype. The readout system also comes with a low power consumption which is about 8mW per channel. There are 2 calibration systems integrated in the prototype: electronic calibration system and light calibration system. Besides, a temperature monitor and high voltage feedback strategy is adopted in the prototype. This talk will cover the details of the readout electronic system and its latest status.

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Prototyping Serial Powering with RD53A

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The high luminosity upgrade for the Large Hadron Collider at CERN requires a complete overhaul of the current inner detectors of ATLAS and CMS. These new detectors will consist of all-silicon tracking detectors. A serial powering scheme has been chosen in order to cope with the various constraints of the new detectors. In order to verify this new powering scheme, efforts are ongoing to set up a first larger prototype for serial powering using modules based on the RD53A chip, a half-size prototype in 65nm CMOS technology for the new pixel front-end chip, developed by the RD53 collaboration. In particular, a serial powering stave consisting of up to 8 RD53A quad chip modules has been set up in Bonn. First results from the ongoing activities, with an emphasis on the electrical characterization of an RD53A serial powering chain, using representative services and power supplies, are presented.

Posters: Front-end electronics / 490

Electronics for GEM Detectors - Recent Developments

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Multi-GEM detectors are widely used for the tracking of charged particles with good spatial resolution at high luminosity, while using only a very low material budget. For the COMPASS experiment at CERN, the third generation of these detectors is currently being constructed, while and the fourth generation is under development.
This talk presents the most recent improvements on the readout and auxiliary electronics for these detectors. A new stabilized high-voltage divider offers both a more stable operation under varying detector currents and an improved protection in case of short circuits in GEM foils. A new revision of APV frontend cards is currently being produced. The new revision includes specialized ESD protection diodes which have a lower parasitic capacitance while offering a better protection against discharges. The protection circuit was tested with a custom-built discharge simulator which is able to deliver surges with well reproducible characteristics.

Posters: Front-end electronics / 506

Design and Implementation of TCSA-based Readout System for STCF ECAL

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In this talk, a system based on Time and Charge Sensitive Amplifier (TCSA) reading out the signal of pure CsI crystal adopted in Super Tau-Charm Facility (STCF) Electromagnetic Calorimeter (ECAL) is reported. To realize high-resolution gamma detection and electron-hadron discrimination, the readout system needs to meet the demands of low noise and high-precision time resolution. By noise analysis and on-board testing, parameters of the electronic system are optimized. Thus a noise level of about 3200 electrons with four S8664-1010 avalanche photodiodes (APDs) is realized. Meanwhile, the fast rising edge of the unshaped signal enables the leading edge timing accuracy to reach 150 picoseconds. Furthermore, online Field-Programmable Gate Array (FPGA) waveform fits, which can provide time and amplitude results simultaneously, can achieve a timing performance similar to leading edge timing. The noise and timing performances indicate the readout system meets the design requirements.

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Posters: Front-end electronics / 507

SMART: SiPM Multichannel ASIC for high Resolution Cherenkov Telescopes

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We present the architecture of a new Application-Specific Integrated Circuit (ASIC) intended to read-out arrays of Silicon Photomultipliers (SiPMs) for low-level light detection down to the single photoelectron. The analog channel is composed of a high speed path with programmable gain and pole-zero filter designed for photon counting. An external fast digitizer can be used for the photon-counting analysis. A slow path allows the measurement of the mean SiPM current, sampled by an internal 10-bit ADC. A first 16-channel ASIC prototype, called SMART, has been designed for the Schwarzschild-Couder Telescope (SCT) camera of the CTA experiment. We present the characterization results obtained when coupling the SMART to a 16 SiPM matrix produced by Fondazione Bruno Kessler. A fast digitizer, called TARGET-C, has been used to read out and sample at 1GS/s the analog data coming from the SMART chip. Results in terms of charge spectrum, signal-to-noise ratio and dynamic range will be presented.

Posters: Front-end electronics / 511

A Low Noise Readout System for Diamond Microstrip Detectors

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Diamond detectors are suitable for accelerator beam monitor owing to the better radiation hardness compared to silicon detectors. But the smaller deposited energy and larger band gap cause the decrease of signals, which brings difficulties to readout system. In this paper, a low noise electronics based on charge sensitive amplifier (CSA) reading out the signal of diamond microstrip detectors is reported. Up to 40 channels are implemented in the system, each contains a CSA, a CR-RC^2shaper, an analog to digital convertor (ADC) and a discriminator for trigger generation. Uploaded data and downloaded commands are transmitted via Ethernet. After calibration and test with a prototype with a size of 300um x 4mm x 4mm, a noise level of less than 845 electrons and a channel linear inconsistency less than 5% are realized in all 40 channels. Furthermore, experimental results with a ^{90}Sr source and a laser indicate that the readout system meets the demands of diamond microstrip detectors.

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The QPix pixelated readout concept for future large liquid argon time projection chambers: status and prospects

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Pixelated readout for multi-kiloton Liquid Argon (LAr) Time Projection Chambers (TPCs), such as that being deployed for the Deep Underground Neutrino Experiment (DUNE), would enable full 3D-reconstruction of events, in contrast to wire/strip anode readout that is challenged by track disambiguation in 2D track reconstruction. The Q-Pix Consortium, established in 2019, is developing a low-power pixelated readout technique for LAr TPCs based on charge-integrate/reset (CIR) circuits. The CIR blocks generate a sequence of reset pulses with time intervals corresponding to fixed charge integrals, allowing signal reconstruction without continuous digitization. The Q-Pix ASIC, intended for reading out pixel arrays, comprises CIR blocks along with digital components responsible for communication and reconfigurable data routing. This talk will give an overview of the Q-Pix project, its status, and prospects, with emphasis on the development and prototyping of the Q-Pix readout ASICs.

Posters: Front-end electronics / 575

Characterization and verification of the Shunt-LDO regulator and its protection circuits for serial powering of the ATLAS and CMS pixel detectors

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The Shunt-LDO regulator has been integrated in the ATLAS and the CMS pixel detector front-end chip to implement the serial powering scheme which both experiments have chosen as the baseline option for the HL-LHC upgrade. The performance of the integrated regulators has been characterized and specific design challenges have been identified which are related to layout parasitics and shallow trench isolation (STI) stress effects. In addition the functionality of circuits which address crucial system level aspects like the protection against overvoltage/load and the regulator startup has been verified.

Posters: High Energy Physics Experiments / 710

DUPLICATE OF #449 in GASEOUS DETECTORS - Radiation background estimation for the GE1/1 Triple-GEM detector in the CMS endcap

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The Compact Muon Solenoid (CMS) is a general-purpose particle detector at the Large Hadron Collider (LHC) designed to study a wide range of particles produced in high energy collisions. These particles interact with the beam pipe, shielding and detector supporting materials to produce neutrons, gammas, electrons and positrons, forming a common background radiation field for CMS. A Monte-Carlo simulation is used to predict the change in the background due to the evolution of the CMS detector geometry expected for the Phase-2 upgrade. In the forward region, the upgrade includes Gas Electron Multiplier (GEM) detectors called GE1/1. In this study, an estimate of the GE1/1 detector response to the background radiation is presented. The flux of background radiation is predicted using the FLUKA framework and the response of the detector is predicted using the GEANT4 framework. A comparison of the prediction and GEM Slice Test data is done for validation of the technique.

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Design and Study of DIRC-like forward time of flight detector for STCF end-cap PID system

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The Super Tau-Charm Facility (STCF) in China is a future electron-positron collider, which has a very broad important physics programs and provides a unique platform to study the τ and charm physics. Excellent particle identification (PID) ability is one of the most important parts for the high energy particles experiment in the physics research of STCF. The effective PID over the full kinetic space is required within the detector acceptance for charged hadrons ($\pi^{\neg\pm}$, $K^{\neg\pm}$, and $p/\bar{p}$), with a statistical separation power better than 3σ up to 2 GeV/c. A DIRC-like forward time-of-flight (FTOF) detector is proposed to realize the PID aim at the endcap. In this talk, the conceptual design of FTOF is presented. Its geometry optimization and performance is studied by a Geant4 simulation, and a π/K separation power of FTOF of ,à°4σ or better at the momentum of 2 GeV/c is achieved over the full FTOF sensitive area.

Posters: High Energy Physics Experiments / 412

Forward scintillator and quartz hodoscopes for BM@N experiment

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The scintillator and quartz hodoscopes for BM@N experiment at Dubna (Russia) are discussed. They will detect the nuclear fragments produced in ion-ion collisions near the beam axis. The scintillator or quartz types will be used depending on the atomic number of beam ions and on the radiation conditions near the beam axis. The hodoscope consists of 16 scintillator or quartz strips with the length of 16 cm and 1 cm width each. The light from both ends of the scintillator/quartz strip is readout by the silicon photomultipliers (SiPMs). The values of light yield and its longitudinal non-uniformity are measured in the tests at the electron beam. The obtained performance of the hodoscopes will be reported.

Posters: High Energy Physics Experiments / 429

The PANDA EDD prototype in Giessen Cosmic Station

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The PANDA detector at the future Facility for Antiproton and Ion Research (FAIR) is currently being constructed in Darmstadt, Germany. It contains a fixed proton target and an antiproton beam with a momentum range between 1.5 GeV/c to 15 GeV/c. Two Cherenkov detectors are used to identify charged hadrons. The Disc DIRC (EDD) covers polar angles between 5° to 22° in the endcap region. In order to test the performance of the EDD prototype, the experimental setup driven by cosmic muons was built at the JLU in Giessen. It is called the Giessen Cosmic Station (GCS) and contains four tracking boxes for tracking muons, two trigger plates, and a lead absorber. The prototype of the EDD detector is integrated to the GCS setup to reconstruct the Cherenkov angle of each muon tracked by the GCS hodoscope.
This talk covers the technical design of the GCS and the performance tests of the EDD prototype in the GCS.

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The Bern medical cyclotron as an irradiation facility for HEP

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The Bern medical cyclotron is a robust proton accelerator facility used for isotope production, research and HEP radiation hardness studies. A beam-transfer line is used to extract the beam from the cyclotron into a second bunker, where the device under test is located. This unique setup provides tuneable beam parameters with a maximal energy of 18 MeV in vacuum (16 MeV in air) and an adjustable beam-spot size from a few mm^2 to 3x3 cm^2. The facility delivers irradiation dose rates from as low as 0.1 Mrad/hr, to 100 Mrad/hr. A set of detectors are used for the characterisation and online monitoring of the beam, and the calculation of the dose delivered. Specific equipment was designed and constructed to irradiate either in air or in vacuum. This talk will introduce the Bern medical cyclotron as a facility for HEP irradiations and provides an overview of its capabilities. Irradiation campaigns will be reviewed together with ongoing developments to further nurture its capabilities.

Posters: High Energy Physics Experiments / 441

Status of Spin Physics Detector at NICA

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The Spin Physics Detector (SPD) is one of the two large setups at the NICA collider under construction at JINR (Dubna). The ultimate goal of the studies at SPD is measurement of different spin observables in polarized proton-proton, deuteron-deuteron and proton-deuteron collisions sensitive to the polarized gluonic structure of the nucleon at the luminosity up to 10^{32} $cm^{-2} * s^{-1}$ and $\sqrt{s}$ up to 27 GeV.
SPD will consist of the superconducting magnetic system, silicon tracker based on the DSSD and MAPS technologies, straw mini-drift tubes tracker, time-of-flight system, electromagnetic ´shashlyk[a]-type calorimeter, muon (range) and local-polarimetry systems. The high performance free-streaming DAQ system will be able to operate at the collision rate up to 4 MHz.

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Precision Luminosity Measurement with the CMS detector at HL-LHC

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The high-luminosity upgrade of the LHC (HL-LHC) is foreseen to reach an instantaneous luminosity a factor of five to seven times the nominal LHC design value. The resulting, unprecedented requirements for background monitoring and luminosity measurement create the need for new high-precision instrumentation at CMS, using radiation-hard detector technologies. This contribution presents the strategy for bunch-by-bunch online luminosity measurement based on various detector technologies. A main component of the system is the Tracker Endcap Pixel Detector with dedicated triggers for online measurement of luminosity and beam-induced background using pixel cluster counting on an FPGA. The potential of the exploitation of the outer tracker, the hadron forward calorimeter and muon trigger objects is also discussed, as well as the concept of a standalone luminosity and beam-induced background monitor using Si-pad sensors.

Posters: High Energy Physics Experiments / 583

Material budget imaging with multi-GeV electrons - calibration and applications for 2D material scanning

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The technique of material budget imaging (MBI) uses multi-GeV electrons to directly measure the material budget $\mu = X/X_0$ of a material with thickness X and its radiation length X_0. The beam particles are deflected by multiple Coulomb scattering and the deflection angle distribution is centered at zero with a width depending on the traversed material.
Hence, a reconstruction of kink angles using individual electron trajectories measured in high resolution beam telescopes allows to estimate the material budget by applying appropiate models of multiple scattering theory, such as the Highland formula.
Measurements at the DESY II testbeam are performed with various materials in terms of thickness and type for a calibration of the MBI technique.
The material budget is an important quantity for the design of high-energy particle detectors. Therefore, the material budget of unknown materials can be experimentally measured as well as complex material distributions can be imaged in 2D.

Funding information:
The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).

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LHCb RMS-R3, new radiation hard system for on-line monitoring of beam and background conditions in Run 3

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During Run 3, the LHCb experiment will collect data at a higher luminosity with respect to the previous decade of data taking. The Radiation Monitoring System (RMS-R3) will display the interaction rate of the LHC,Äôs beams along with its background in LHCb. The RMS-R3 comprises four detector modules based on the Metal-Foil Detectors radiation hard technology that can withstand fluences up to 10^{20} MIPs/cm^2 or radiation doses of up to a GGy, during its entire lifespan. The modules are placed symmetrically around the beam pipe very close to the Interaction Point at LHCb at a distance of about 2.2 m, while covering a backward acceptance of 7,Äì14 degrees. The readout electronics provide a continuous relative luminosity measurement for LHCb and observations of background evolutions during the various stages of the beam preparation towards collisions. The RMS-R3 detector's performance has shown good response reproducibility of about 1% and excellent linearity.

Funding information:
National Research Foundation of Ukraine

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The SuperFGD prototype PID beam tests results

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The near detector ND280 of the T2K experiment will be upgraded in 2022 with the aim of measuring precisely CP violation in neutrinos. The ND280 upgrade consists of the installation of 3 new sub-detector types including SuperFGD, a novel neutrino active target concept.
SuperFGD (Super-Fine-Grained-Detector) will have 2million 1x1x1cm^3 plastic scintillator cubes forming a cube array of 184x56x192cm^3. Each of the cubes will be intersected by 3 orthogonal WLS fibers with an MPPC on one end. Thanks to its super-fine segmentation, high light yield, and excellent time resolution, great particle identification (PID) capabilities are expected. Since 2018, a set of prototypes have been exposed to particle beams (charged tracks and neutrons) to test this concept. Here, the SuperFGD prototype PID beam tests results are presented, including its measured time and dE/dx resolution, light yield for different particles and preliminary neutron detection capabilities.

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Status of the NP06/ENUBET neutrino beam

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The ENUBET experiment is developing a new narrow-band neutrino beam in which the flux and the flavor composition are known at 1% level, and the energy with $\mathcal{O}(10\%)$ precision. Such a goal is accomplished monitoring the associated charged leptons produced in the decay region of the ENUBET facility: e^+ and μ^+ from kaons are measured by a segmented calorimeter instrumenting the walls of the decay tunnel, while muon stations after the hadron dump can monitor ν from pions.
We report an improved design of the proton target and of the meson transfer line, that ensures a large neutrino flux while preserving an high purity in the lepton monitoring. The final design of the ENUBET demonstrator for the instrumented decay tunnel, that is due by end 2021 to prove the scalability and performance of the detector technology, will be discussed. Progress on the full simulation of the ENUBET facility, towards the full assessment of neutrino flux systematics, will be also reported.

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Towards the integration of the NUMEN experiment

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The most promising probe to establish the Majorana or Dirac nature of the neutrino is the neutrinoless double beta decay and the effective neutrino mass would be evaluated by the knowledge of the corresponding nuclear matrix elements.
Also measurements of the DCE interactions of heavy ion beams can get information on them.
The NUMEN experiment based on the pre-existing large acceptance MAGNEX spectrometer and integrated with new components aims at measuring DCE cross sections using ion beams of unprecedented intensity (10^{13} pps) on specific isotopes at INFN-LNS in Catania.
Expected rate on the sensitive area of about 0.15 m^2 reaches up to about 5 Mpps, demanding for adequate detectors in measuring position, direction, energy, mass and charge of the ions produced by interactions. Gamma detectors surround a scattering chamber containing a target.
The presentation is focused on the technological aspects of the design and the integration of the experiment.

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Cosmic Muon Veto for the INO's mini-ICAL detector

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A 51-kt magnetised Iron Calorimeter (ICAL), using Resistive Plate Chambers, is the flagship experiment at the India based Neutrino Observatory (INO). A prototype - 1/600 of the weight of ICAL, called mini-ICAL was installed in the INO transit campus at Madurai. A cosmic muon veto around the mini-ICAL is now being planned. The veto walls will be built using three staggered layers of extruded scintillator strips. WLS fibres of 1.4mm in dia are inserted into two extruded holes along the length of the strip to collect the light signal. Hamamatsu SiPM,Äôs of 2mm$\surd$62mm active area collect the light on both ends of the fibres. On veto trigger, the DAQ system will gather the charge, arrival time and position of muon tracks in the scintillator strips. But the data collected is transferred to the backend only if the trigger from mini-ICAL is also received in time. Details of the design and construction of the detector including the electronics, trigger and DAQ systems planned will be presented.

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ANNIE: The First Physics Experiment to Deploy LAPPDs

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The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton gadolinium-doped water Cherenkov detector located on-axis of Fermilab's Booster Neutrino Beam. ANNIE,Äôs main physics goal is to measure the final state neutron multiplicity of neutrino-nucleus interactions as a function of momentum transfer. This measurement will improve our understanding of these complex interactions and help reduce the associated systematic uncertainties, thus benefiting the next generation of long-baseline neutrino experiments. ANNIE will achieve its physics goals with the use of a new type of photodetector, the Large Area Picosecond Photodetector (LAPPD). The experiment is the first physics experiment to deploy an array of LAPPDs. Much progress has been made towards the full characterization and development of a LAPPD system. In this talk, the results of this development testing will be discussed, demonstrating the picosecond timing and centimeter-level spatial capabilities of the LAPPD.

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Vertex and Energy Reconstruction in JUNO with Machine Learning Methods

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Determination of neutrino mass ordering and precise measurement of oscillation parameters $\sin^2\theta_{12}$, Δm^2_{21} and Δm^2_{31} are the main goals of JUNO experiment. A rich physics program such as solar neutrinos, supernova neutrinos, geo-neutrinos, and atmosphere neutrinos is foreseen. The ability to accurately reconstruct events in JUNO is critical to the success of the experiment. In this talk, four machine learning methods applied to the vertex and the energy reconstruction will be presented, including Boosted Decision Trees (BDT), Deep Neural Networks (DNN), Convolution Neural Networks (CNN), and Graph Neural Network (GNN). We demonstrated that machine learning methods can provide the necessary level of accuracy required to achieve JUNO's physical goals: $\sigma_E = 3\%$ and $\sigma_{x,y,z} = 10$ cm at 1 MeV for energy and vertex, respectively.

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Antineutrino sensitivity at Theia

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Theia is a proposed large-scale novel neutrino detector designed with the ability to discriminate between Cherenkov and scintillation signals. The baseline design consists of a cylindrical tank viewed by inward-looking PMTs and filled with water-based liquid scintillator (WbLS), a novel target which would combine reconstruction of particle direction from the Cherenkov signal, with the energy resolution and low threshold of a scintillator detector. Theia would have a broad physics program ranging from low-E solar to high-E accelerator neutrinos.
In this presentation, we focus on the low-E antineutrinos detected via inverse beta decay interactions on protons. Using WbLS as target material for a 25 kT detector located at SURF, we present results for the sensitivity of Theia to both geo- and reactor antineutrinos. Moreover, separation between Cherenkov and scintillation signals offers particle identification capabilities for an additional discrimination between signal and background.

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Low-energy performance and physics reach of hybrid neutrino detectors

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Optical neutrino detectors have long provided landmark physics results. With the advent of hybrid detector technologies deployable at large scales, the future remains bright. Recent advancements in novel scintillating targets, fast photo-sensors, and chromatic sorting are among the techniques under study for the proposed Theia hybrid detector. By utilizing both Cherenkov radiation and scintillation light, hybrid technology can simultaneously achieve high light yields, direction reconstruction and robust particle identification in a single detector. We present results from Monte Carlo studies for the performance of large hybrid detectors and consider the implications for physics analyses, with a focus on the impact on the detection of CNO solar neutrinos.

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Mechanical design of the Water Cherenkov Test Experiment (WCTE) at CERN

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The Water Cherenkov Test Experiment (WCTE) is a test experiment proposed at CERN to measure the response of a Water Cherenkov Detector for charged particles such as œÄ¬±, p+, e¬±, etc The data obtained from WCTE will be used in future neutrino experiments.
WCTE consists of a sealed cylindrical tank filled with ultrapure water. 128 multi-PhotoMultiplier Tubes (mPMTs) are mounted on a cylindrical support structure facing inwards to map out the Cherenkov radiation with high granularity.
This work presents the mechanical design and analysis of the support structure for WCTE. It is designed to sustain the load of 128 mPMTs, arrangement of Photogrammetry system Cameras & lights and Calibration arm without significant change in the position / geometry of the structure. SS304 is identified as a suitable material to ensure the compatibility with the ultrapure water and Gd-treated water. The structure is robust against stresses during handling and subsequent transport with and without water.

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The high resolution PAN detector for deep space cosmic rays particles measurements

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The Penetrating particle ANalyzer, an instrument designed to operate in space, will provide precise measurements and monitoring of the flux, composition, and direction of highly penetrating particles with energy ranging from 100MeV/n to 20 GeV/n. The concept of the detector is based on a modular magnetic spectrometer of small size, reduced power consumption and low weight to make the instrument suitable for deep space and interplanetary missions. The magnetic spectrometer module consists in high-field permanent magnet sectors, high resolution silicon micro-strip detectors, Time Of Flight counters readout by SiPMs, and active Pixel detectors to maintain the detection capabilities in high rate conditions occurring during solar energetic particle events and traversing radiation belts around planets. Here we report on the concept of the PAN instrument and the construction status of the MiniPAN demonstrator for the in-orbit validation of the key functionalities of the instrument.

Posters: Particle Astrophysics and Space / 342

Opportunities of Si-microstrip LGAD for next-generation Space detectors

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Low Gain Avalanche Diodes (LGAD) is a consolidated technology developed for particle detectors at colliders which allows for simultaneous and accurate time (<100 ps) and position (< 10 ¬μm) resolutions with segmented Si-pixel sensors. It is a candidate technology that could enable for the first time 4D tracking (position and time) in space using LGAD Si-microstrip tracking systems. The intrinsic gain of LGAD sensors may also allow to decrease the sensor thickness while achieving signal yields similar to those of Si-microstrips currently operated in Space.
In this contribution we discuss the possible applications and breakthrough opportunities in next generation large area cosmic ray detectors and sub-GeV gamma-ray detectors that could be enabled by LGAD Si-microstrip tracking detectors in Space. We propose the design of a cost-effective instrument demonstrator on a CubeSat platform to enable and qualify the operation of LGAD Si-microstrip detectors in Space.

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Mass production of large-area lithium-drifted silicon detectors for the GAPS silicon tracker

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Unprecedented mass-production of large-area lithium-drifted silicon (Si(Li)) detectors has been performed for the General Antiparticle Spectrometer (GAPS). GAPS is the first experiment optimized for low-energy cosmic antinuclei. The first long-duration Antarctic balloon flight is scheduled for late 2022. A large-volume silicon tracker plays an essential role in the novel GAPS detection technique, which is based on exotic atom physics. The Si(Li) detectors developed for GAPS feature a large (10 cm) diameter, 2.5 mm thickness with $>$90% sensitive layer, and excellent energy resolution ($<$4 keV for 60 keV X-rays) at relatively high operating temperature (~ -40C). We established a fabrication method and produced $>$1000 detectors with a yield rate of $\sim$90%. Analysis of the fabrication and performance data provide valuable insights into the production methods for such large-area Si(Li) detectors. We report on the results of the mass production of GAPS Si(Li) detectors.

Posters: Particle Astrophysics and Space / 426

Status of the AugerPrime upgrade of the Pierre Auger Observatory

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The Pierre Auger Observatory consists of a detector system to study ultra-high-energy cosmic rays. These cosmic rays can be detected only through the observation of extensive air showers, i.e. cascades of secondary particles induced in the atmosphere. The hybrid detection of air showers at the Observatory is based on the Surface Detector (SD) - an array of about 1660 water-Cherenkov detectors, and the Fluorescence Detector with 27 telescopes, overlooking SD. Recently, an upgrade of the Observatory was initiated, called AugerPrime. The main purpose of the upgrade is to improve the mass composition sensitivity of SD through precise measurements of the muonic and electromagnetic components of extensive air showers. For this purpose, additional scintillator and radio detectors are being installed on top of SD stations. The upgrade also includes updated SD electronics, and underground muon detectors. In this talk the motivation for the upgrade and the current status will be reviewed.

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Mini-EUSO telescope on board the ISS: in-flight operations and performances

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Mini-EUSO is a high sensitivity imaging telescope that observes the Earth from the ISS in the ultraviolet band (290$\sqrt{\sum}$430 nm), through the UV-transparent window in the Russian Zvezda module. The instrument, launched in 2019 as part of the Italian Beyond mission, has a field of view of 44,ó¶, a spatial resolution on the Earth surface of 6.3 km and a temporal resolution of 2.5 microseconds. The telescope detects UV emissions of cosmic, atmospheric and terrestrial origin on different time scales, from a few microseconds upwards. Mini-EUSO main detector optics is composed of two Fresnel lenses focusing light onto an array of 36 Hamamatsu multi-anode photomultiplier tubes, for a total of 2304 pixels. The telescope also contains: two ancillary cameras to complement measurements in the near infrared and visible ranges, an array of Silicon-PhotoMultipliers and UV sensors to manage night-day transitions. In this work we will describe in-flight operations and performances of the various instruments.

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Assembly and test of prototype scintillator tiles for the plastic scintillator detector of the High Energy Cosmic Radiation Detection (HERD) facility

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Satellite experiments for gamma-ray and cosmic ray detection employ plastic scintillators to discriminate charged from neutral particles for gamma-ray identification. The future High Energy Cosmic Radiation Detection (HERD) facility will be able to detect cosmic rays and gamma rays up to TeV energies. The plastic scintillator detector (PSD) will consist of scintillator tiles or bars coupled to Silicon Photomultipliers (SiPMs). Besides the gamma-ray identification, the PSD will measure the ion charge up to iron nuclei, requiring a wide dynamic range from few tens up to thousands of photoelectrons. We have equipped a plastic scintillator tile with Hamamatsu and AdvanSiD SiPMs, coupled to the CAEN DT5550W board based on the CITIROC ASIC. This ASIC allows both a fast trigger formation with configurable threshold and the SiPM charge measurement along two paths with different gain settings. We will present the performance of our prototype system in terms of gain and signal-to-noise ratio.

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Simulation tool for MRPC telescopes of EEE experiment

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The Extreme Energy Events (EEE) experiment consists in a network of cosmic muon trackers, each made of three MRPC, able to precisely measure the absolute muon crossing time and the muon integrated angular flux at the ground level. To study the Multi-gap Resistive Plate Chambers (MRPC) telescope response and assess the detector performance, a simulation tool implementing the Multi-gap Resistive Plate Chambers (MRPC) telescope response was developed in a GEANT4-based framework (GEMC). The framework has been validated by comparing simulations to EEE telescope data. A detailed description of telescope response is not only crucial to carry on the physics program of the EEE project, but it may open other research avenues, such as using the telescope in combination with other detectors, to perform a (muon) tomography of material surrounding the telescope.
In this contribution, the EEE simulation framework will be presented, reporting results and discussing further applications.

Posters: Particle Astrophysics and Space / 521

SiPM-based camera for gamma-ray imaging air Cherenkov telescope

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The current status of the equipment development for the new wide-angle gamma-ray imaging air Cherenkov telescope for TAIGA hybrid installation is presented. A front-end electronic and data acquisition system board based on the Zynq family Xilinx FPGA chips specially designed for this project have been produced and are being tested. A detailed description of the internal structure of the four main subsystems of the board: four 8-channel 100 MHz ADCs, boards control system, internal clock and synchronization system and the power supply. Additionally, the current status of a small scale prototype telescope SIT consisting of 49 SiPM is presented. The telescope includes a digital camera for observing the stars and weather condition. The SIT-HiSCORE synchronization systems and the telemetry information collection had been tested.

Posters: Particle Astrophysics and Space / 523

Status of the SPHERE project for the high energy cosmic ray study by registering reflected Cherenkov light with a drone-borne detector

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Here we present the current status of the SPHERE project,Äôs new detector technical design. The SPHERE project is aimed at the primary cosmic ray studies in 1-1000 PeV energy range using the reflected Cherenkov light method. The concept is discussed of a drone mounted detector with a photosensitive camera based on silicon photomultipliers. The design details of a small scale prototype of such a detector is presented.

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A complete MC optical photons tracking simulation of Plastic Scintillator Detectors for the next generation of satellite experiments.

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Plastic scintillators are widely used for anti-coincidence systems and nuclei identification in satellite experiments. For this reason, a plastic scintillator detector (PSD) must have a high detection efficiency for charged cosmic rays and a very good capability in measuring nuclei charge. We implemented a full and customizable simulation tool to investigate the performance of a PSD coupled to Silicon Photomultipliers. The overall performance of the detector is studied by tracking optical photons produced inside the scintillator. The simulation will be used for the design of a PSD for future space experiments, such as HERD, AMEGO, e-Astrogam. In this work we investigated in detail the effect of Birks,Äô saturation effect in the discirimination of charged ions up to iron nuclei. We compare the simulations to measurements conducted on prototype scintillator tiles.

Posters: Particle Astrophysics and Space / 532

Mini-EUSO space qualification and integration for high atmosphere phenomena and cosmic UV emissions stuy on board the International Space Station

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Mini-EUSO is a telescope launched on August 2019 with the Soyuz MS-14, hosted on board the Russian Zvezda module of the International Space Station, facing a UV-transparent window in Nadir mode. It belongs to a novel set of missions committed to evaluate, for the first time, the capability of observing Ultra High Energy Cosmic Rays from a space-based point of view but also to search for Strange Quark Matter and to observe Transient Luminous Event. Mini-EUSO consists of a main optical system sensitive to UV spectrum (300,Äì400nm) and several ancillary sensors comprising a visible (400,Äì780nm) and NIR (1500,Äì1600nm) cameras and a 64 channels SiPM array which will increase the Technology Readiness Level of this ultrafast imaging sensor. The main detector has a field of view (44¬∞) which allows to map a ground area of 263 x 263 km2 thanks to the optics which comprises two Fresnel lenses focusing the radiation onto a 36 Multi- Anode PMT, each of 64 with a time resolution of 2.5 Œºs.

Posters: Particle Astrophysics and Space / 534

Trinity: An Air-Shower Imaging Observatory for UHE-Neutrino Detection

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The Trinity Observatory is a proposed UHE-neutrino detector with a core-energy range of 10^6 GeV-10^{10} GeV, bridging the observational gap between IceCube and UHE radio detectors. Trinity is a system of novel, 5x60-degree wide field-of-view air-shower imaging telescopes that detect Earth-skimming tau neutrinos from mountain tops. Trinity,Äôs primary science objectives are the extension of the IceCube measured neutrino flux to ultrahigh energies and the detection of cosmogenic neutrinos. Trinity will provide critical measurements to study flavor physics and neutrino cross-sections at energies that are out of reach for accelerators. In this contribution, we present the present design of Trinity and discuss its performance.

Posters: Particle Astrophysics and Space / 610

Thermo/mechanical design for embedding ALPIDE pixel sensor chip in a High-Energy Particle Detector space module

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The High-Energy Particle Detector (HEPD) module is designed to measure the pitch angle and energy of electrons and protons fluxes trapped in the Earth Magnetosphere with energies 3-100 MeV and 30-300 MeV respectively. In view of the launch of CSES-02 satellite, an interesting option for improving the HEPD is to endow the tracking module with ALPIDE monolithic active pixel, specifically developed for the ITS upgrade of ALICE experiment at CERN.
In this work we present the project of a modular and compact particle tracker made of 5 turrets, making use of 150 pixel sensors equipped with Hybrid Integrated Circuit (HIC) and supported by Carbon Fiber Reinforced Plastics (CFRPs) staves housed in an aluminium case.
All envisaged solutions have been validated with an intense campaign of qualification tests, concerning vibrations and thermal stresses. The HEPD-02 tracker project foreruns the massive usage of CFRPs for space initiatives both of scientific and exploratory nature.

Posters: Particle Astrophysics and Space / 633

A low-power sparsified readout for the MAPS-based High Energy Particle Detector space tracker

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The transfer to satellite-based applications of the silicon monolithic pixel technology can enable a higher particle detector granularity without increasing the number of bonding interconnections. However, power consumption and heat dissipation are issues to be dealt with for enabling such developments. This contribution will present a low-power sparsified readout architecture for the MAPS-based tracker which will be integrated in the High-Energy Particle Detector onboard the CSES-02 satellite. The whole tracker includes 150 ALPIDE sensors organised in three planes and is managed by a custom parallel readout architecture implemented on a single low-power FPGA chip. The adopted solution allows to address both the required performance and the stringent constraints on the power budget. Additionally, this architecture is scalable to larger and more complex detectors, thus representing an option for future space missions.

Posters: Particle Astrophysics and Space / 663

Development of scintillation detectors with light collection on wavelength shifting light guides for TAIGA experiment

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The TAIGA gamma observatory is continuing its deployment at Tunka valley, close to Baikal lake. The new, original detectors, able to work in severe conditions of Siberia were developed to increase the TAIGA power for the study of gamma-quanta at energies about 1 PeV and above. The distinguishing feature of the detectors is the use of the wavelength shifting light guides for scintillation light collection on a photodetector. Several designs of the counters have been successfully tested: equipped with PMT or SiPM photo-detectors, acrylic or polystyrene based scintillators with thickness from 1 to 5 cm and detecting area from 0.75 to 1.0 m^2. The data on the amplitude of the signal from cosmic muons measured in different points within the counter are presented. The first 48 counters were produced deployed in 2019 at the TAIGA experiment. They form 3 stations each with 8 surface detectors and 8 underground detectors buried at the depth of 1.7 m. After two winters, all counters are working.

Posters: Particle Astrophysics and Space / 674

Characterization of the Crystal Eye pathfinder

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Crystal Eye is a new generation all sky monitor for the observation of 10keV-30MeV cosmic photons exploiting a new detection technique, which foresees enhanced localization capability with respect to current instruments. This is now possible thanks to the use of new materials and sensors.
The proposed detection module is designed to be easily installed either on free flyer satellites or onboard space stations. Science goals include Gamma Ray Bursts, electromagnetic counterpart of Gravitational Wave emissions, Active Galactic Nuclei and line emission from supernova explosions observations
A Crystal Eye pathfinder, made by 4 pixels, has been set up to fly aboard of the Space RIDER, an uncrewed reusable orbital spaceplane aiming to provide the European Space Agency (ESA) with affordable and routine access to space.
The mission will follow a LEO orbit (similar to ISS orbit) for two months when it will come back at the base. We here present the first characterization of the pathfinder.

Funding information:
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Posters: Particle Astrophysics and Space / 690

The High Energy cosmic-Radiation Detection facility: an innovative apparatus design for cosmic-ray measurement

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The High Energy cosmic-Radiation Detection (HERD) facility will be installed aboard the China's Space Station (CSS) around 2025, and it will extend the direct measurements on cosmic rays by one order of magnitude in energy. This will be possible thanks to an innovative design that was carefully optimized to overcome the limitations that affect the experiments currently operating in space. In this talk, the HERD instrument will be presented: it is based on a large, homogeneous and isotropic calorimeter made of LYSO crystals, optimized in order to have good energy resolution and large geometric factor. The calorimeter is surrounded by a subdetector system, fiber tracker, plastic scintillator and silicon microstrip from inside out with fine segmentation, to allow for good angular resolution, multiple charge measurements of incoming particles. The detector is complemented by a transition radiation detector used to calibrate the high-energy hadronic calorimeter response in a data-driven way

Posters: Precision and Low Energy / 445

Control system for ion Penning traps at the AEgIS experiment at CERN

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The AEgIS experiment located at the Antiproton Decelerator at CERN aims to measure the gravitational fall of a cold antihydrogen pulsed beam. The precise observation of the antiatoms in the Earth gravitational field requires a controlled production and manipulation of antihydrogen. The neutral antimatter is obtained via a charge exchange reaction between a cold plasma of antiprotons from ELENA decelerator and a pulse of Rydberg positronium atoms. The current custom electronics designed to operate the 5 and 1 T Penning traps are going to be replaced by a control system based on the SINARA/ARTIQ open hardware and software ecosystem. This solution is present in many atomic, molecular and optical physics experiments and devices such as quantum computers. Our group is directly involved in the design and implementation of the ecosystem. We are going to report the status of the implementation as well as the main features of the new control system.

Funding information:
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Posters: Precision and Low Energy / 501

Development of a detector for a gravity measurement on positronium at the AEgIS experiment at CERN

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The primary goal of the AEgIS experiment at CERN is to measure the gravitational acceleration on neutral antimatter. Positronium (Ps), the metastable bound state of an electron and a positron, is a suitable candidate for a force-sensitive inertial measurement by means of deflectometry/interferometry. In order to conduct such an experiment, the impact position and time of arrival at the detector of Ps atoms must be detected simultaneously with a spatial resolution of better than 10 ¬μm and a time-resolution in the order of 100 ns. The detection of a low-velocity Ps beam with a spatial resolution of (88 ¬± 5) ¬μm was demonstrated [1]. Based on the methodology employed in [1], a hybrid imaging/timing detector with increased spatial resolution was developed. The performance of a prototype was tested with a positron beam. The concept of the detector is presented in detail and the results of the tests are shown.
[1] C. Amsler et al. NIM in Ph. Research B 457 (2019) 44-48

Posters: Precision and Low Energy / 364

Setup to study the Compton scattering of entangled annihilation photons

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In this contribution, the Compton scattering of entangled annihilation photons is discussed. The pairs of gammas with energy 511 keV are born in electron-positron annihilation and have the entangled polarization states. Since the Compton scattering depends on the polarization of the initial photon, one can expect to observe the peculiar properties of the Compton scattering of entangled gammas. The scattering kinematics of entangled and decoherent photons with different polarization states might be quite different.

To test the difference in the kinematics of Compton scattering of photons in entangled and decoherent states the dedicated experimental setup is now under construction at INR RAS. This setup has two arms, each containing plastic scatterer and 16 NaI(Tl) scintillator counters with PMT readout that arrarnge 16 dichromatic Compton polarimeters. An additional small scatterer of GAGG scintillator with SiPM readout is placed in one arm to produce the pairs of decoherent photons.

Posters: Precision and Low Energy / 628

ELITPC - an active target TPC for studying nuclear reactions at astrophysical energies

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Determining the ratio of carbon-to-oxygen produced at the end of the helium burning in stars is a paramount importance problem for nuclear astrophysics. In recent years, the advent of high-intensity γ-ray beams opened a new opportunity to study the $^{12}C(\alpha,\gamma)^{16}O$ reaction regulating the ration by investigating the time-reversal photodisintegration reaction.
To take advantage of this approach an active-target Time Projection Chamber with electronic readout is being developed at the University of Warsaw, Poland. The $^{16}O(\alpha,\gamma)^{12}C$ reaction will be studied in an experiment with the gamma-ray beam provided by the High Intensity Gamma-Ray Source (HIγS), USA, and in Day-1 experiments at the Extreme Light Infrastructure Nuclear Physics (ELI-NP), Romania.
During the presentation, I will discuss the challenges we have faced and the solutions we adopted for detector design. I will also outline the present problems and plans for future.

Funding information:
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Posters: Trackers / 685

SciFi - A large Scintillating Fibre Tracker for LHCb

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The LHCb detector is currently being upgraded to cope with higher instantaneous luminosities and to read out data at 40 MHz using a trigger-less read-out system. The new main tracker consists of 250$\neg\mu$m thick scintillating fibres (SciFi) and covers an area of 340 m^2. The tracker provides a spatial resolution for charged particles better than 80 $\neg\mu$m. The scintillation light is recorded with arrays of multi-channel silicon photomultipliers (SiPMs). A custom ASIC is used to digitize the SiPM signals and subsequent digital electronics performs clustering and data-compression. Single detector modules are mounted on so-called C-frames (3m $\times$ 6m) which will provide the mechanical support and the necessary services. The serial assembly of the 12 large frames, each comprising 50,000 SiPM channels, is progressing and the first detector elements have been commissioned. This presentation will cover the development, construction and the commissioning results of the detector.

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Noise performance of the ALPIDE-based ALICE Inner Tracking System

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The new ALICE Inner Tracking System is the first large-scale MAPS-based tracking system. It is covering an active surface of 10 m¬≤, with a total of 12.5 billion pixels. Several optimisations of the pixel chip lead to a quasi-noise-free operation, with measured fake-hit rates of below 1 hit per pixel and billion events (system level numbers), numbers compatible with the order of magnitude expected from cosmic and natural background radiation.
This contribution covers a detailed study of fake hits as recorded in the inner-most detector barrels, made of the highest quality chips. It reveals a localised noise pattern that could be traced down to originate from decoupling capacitors present on the detector module. It can most likely be explained by the radiative decay of Pb-210, which is present in trace amounts in the solder that was used to mount decoupling capacitors on the detector modules. This hypothesis is substantiated with a dedicated simulation study and laboratory measurements.

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ALICE ITS upgrade for LHC Run 3: commissioning in the laboratory

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ALICE is the CERN LHC experiment optimised for the study of the strongly interacting matter produced in heavy-ion collisions and devoted to the characterisation of the quark-gluon plasma. To achieve the physics program for LHC Run 3, a major upgrade of the experimental apparatus is ongoing. A key element of the upgrade is the substitution of the Inner Tracking System (ITS) with a completely new silicon-based detector whose features will allow the reconstruction of rare physics channels, not accessible with the previous layout. The enabling technology for such a performance boost is the adoption of custom-designed CMOS MAPS as detecting elements.
In this talk, an overview of the adopted technologies and results from commissioning in laboratory as well as the status of the ongoing installation in the ALICE cavern and global commissioning will be given.

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Evaluation a multi-module demonstrator for the ITk Pixel Outer Barrel for the ATLAS Phase-II upgrade

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The ATLAS tracking system will be replaced by an all-silicon detector for the HL-LHC upgrade around 2025. The innermost five layers of the detector system will be pixel detector layers which will be most challenging in terms of radiation hardness, data rate and readout speed. A serial power scheme will be used for the pixel layers to reduce the radiation length and power consumption in cables. New elements are required to operate and monitor a serially powered detector including a detector control system, constant current sources and front-end electronics with shunt regulators. A demonstrator prototype was built using about 40 FE-I4 modules powered in six serial chains, that employs realistic mechanics and services, interlock and cooling infrastructure, power supplies and readout system. In the presentation, the latest results and full evaluation of the electrical prototype are presented. Important qualification steps of the system design and its operation are discussed.

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Track and vertex reconstruction using moving emulsion blocks and a silicon pixel tracker for particles induced by 400 GeV/c protons on a thick target

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The SHiP-charm experiment is designed to measure the charm production cross section, including cascade production, of 400 GeV/c protons hitting a thick, SHiP-like target. For the detection of production and decay of heavy charmed particles, emulsion films are employed in a multilayered moving target, forming an emulsion cloud chamber. While the emulsion films provide excellent spatial resolution they do not provide timing information, integrate all events, and quickly get saturated. For the charm measurement the emulsion target is thus moving at a constant speed during data-taking. A first optimization run at the CERN SPS has been performed in 2018, with the purpose to develop the required analysis tools and to fine-tune the detector layout. We report on the experiment design, track reconstruction in the pixel tracker and the track matching with the moving emulsion detector.

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Module development for the ATLAS ITk Pixel Detector

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In HL-LHC operation the instantaneous luminosity will reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The current ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of ITk will consist of a state-of-the-art pixel detector. Several different silicon sensor technologies will be employed in the five barrel and endcap layers. Based on first modules assembled using the RD53A prototype readout chip, numerous issues are being studied. These include production issues like bump bonding of large area, thin modules, as well as layout issues like optimization of the bandwidth and sharing of links between multiple chips and modules. The talk will present results of many of these studies, which directly impact the construction and assembly of modules with using the first production version of the readout chip ITKpixV1, which will become available shortly.

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The performance and operational experience of ATLAS SemiConductor Tracker in Run-2 at LHC

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The performance of ATLAS SemiConductor Tracker (SCT) in Run-2 at Large Hadron Collider (LHC) has been reviewed during the current long shutdown. The LHC successfully completed its Run-2 operation (2015-2018) with a total integrated delivered luminosity of 156 fb,àí1 at the centre-of-mass pp collision energy of 13 TeV. The LHC high performance provide us a good opportunity for physics analysis. It came with high instantaneous luminosity and pileup conditions that were far in excess of what the SCT was originally designed to meet. The first significant effects of radiation damage in the SCT were also observed during Run-2. This talk will summarise the operational experience and performance of the SCT during Run-2, with a focus on the impact and mitigation of radiation damage effects.

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Developments and R&D plan for a future Vertex Locator using time measurements

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LHCb has recently submitted a physics case to upgrade the detector to be able to run at instantaneous luminosities of $1.5\times10^{34}cm^{-2}s^{-1}$, an order of magnitude above Upgrade I, and accumulate a sample of more than 300 fb^{-1}. At this intensity, the mean number of interactions per crossing would be 42, producing around 2000 charged particles within the LHCb acceptance. The LHCb physics programme relies on an efficient and precise vertex detector (VELO) to correctly identify the origin point of the b/c decays. To meet this challenge it is necessary to use temporal precision on each hit at the pixel detector region. To achieve this goal a new 4D hybrid pixel detector with enhanced rate and timing capabilities in the ASIC and sensor will be developed. Improvements in the mechanical design will be needed to allow periodic module replacement and lower detector material.
The early stages of R\&D a conceptual design of a 4D VELO and simulation studies will be presented

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Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

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The tracking performance of the ATLAS detector al LHC relies critically on its 4-layer Pixel Detector.The key status and performance metrics of the ATLAS Pixel Detector are summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience.
By the end of the proton-proton collision runs in 2018, the innermost layer IBL,
consisting of planar and 3D pixel sensors, had received an integrated Ô¨Çuence of approximately Œ¶ = 9 √ó 1014 1 MeV neq/cm2. The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector. A quantitative analysis of charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects with IBL, effects of annealing will be presented and discussed, as well as the operational issues and mitigation techniques adopted during the LHC Run2 and the ones foreseen for Run3.

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Quality inspection aspects of hybrid prototypes for the CMS Outer Tracker upgrade at HL-LHC

Authors: Alessandro La Rosa[1]; Imtiaz Ahmed[2]; Georges Blanchot[1]; Stephane Brunet Cooperstein[3]; Alan Honma[4]; Mark Istvan Kovacs[1]; Irene Mateos Dominguez[1]; Angelos Zografos[1]

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In the HL-LHC scenario, the CMS experiment will need to operate at up to 200 interactions per 25 ns beam crossing time and with up to 3000 fb^{-1} of integrated luminosity. To achieve the physics goals the experiment needs to improve the tracking resolution and the ability to selectively trigger on specific physics events. The CMS Tracker upgrade requires designing a new detector to cope with HL-LHC scenario. The new Outer Tracker is based on two silicon modules (strip-strip & pixel-strip). Each module type has a few types of high-density interconnect hybrid circuits which house the front-end and auxiliary electronics. Two sides of the sensors are wire-bonded to the front-end hybrids. For both module types, folded flexible circuits are used to enable wire-bonded connection from the sensor assemblies with various spacing.
The talk will introduce the technological choices for modules and hybrids and it will present the quality control aspects of the first hybrid prototypes.

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Testbeam studies of ATLAS ITk strip modules at DESY-II testbeam facility

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In order to cope with the occupancy and radiation doses expected at the HL-LHC, the ATLAS experiment will replace its Inner Detector with an all-silicon Inner Tracker (ITk). The ITk strip subsystem will be built from modules, consisting of one n+-in-p silicon sensor, one or two PCB hybrids with the front-end electronics, and one powerboard. To validate the detector performance, a series of testbeams has been performed at the DESY-II facility with modules before and after irradiation. Tracking was provided by EUDET telescopes, consisting of six Mimosa26 pixel planes, with an additional plane used to improve the timing resolution. This contribution summarizes the main results, including tracking performance, charge collection, efficiency, and noise occupancy. Detailed studies of sensor features are also performed. Finally, the measurements are compared to simulations made with Allpix2. The results give confidence that the ITk strip detector will meet the requirements of the HL-LHC.

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Precision survey of the readout elements of small-strip Thin GapChambers using collimated X-rays for the muonspectrometer upgrade of the ATLAS experiment

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The muon end-cap inner station of the ATLAS detector is being replaced by New Small Wheels (NSWs). The NSWs will effectively improve the online muon identification and maintain the current muon transverse momentum resolution despite the increased detector hit rates. The NSWs combine the Micromegas and small-strip Thin Gap Chambers(sTGC) technologies. The sTGC detector modules are arranged inw edges of 4 detector layers each counting up to 1000 readout strips used for precise muon trajectory measurements. The positioning of individual readout strips must be known to within 100 microns to satisfy the performance targets of this ATLAS upgrade. Non-conformities of the sTGC strip pattern are therefore measured on finished wedges using an X-ray gun precisely positioned at fixed reference points.The working principles and experimental procedure of this technique will be shown as well as validation studies based on measurement scarried out on the early production of sTGC wedges.

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Integration and commissioning of the ATLAS small-strip Thin Gap Chambers

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ATLAS endcap inner station muon detector is being replaced with a New Small Wheel (NSW) detector to handle the increase in data rates and radiation expected at HL-LHC. The NSW will feature two new detector technologies, Resistive Micromegas (MM) and small-strip Thin Gap Chambers (sTGC). Both detector technologies will provide trigger and tracking primitives. The sTGC detector is composed of 192 four-layer chambers and pad, strip and wire signals will all be read out. Its frontend electronic system has 11,776 ASICs on 1,536 frontend boards and ˜354,000 readout channels. Tasks such as time, trigger and control signal distribution and readout are performed by an Front End Link Interface eXchange (FELIX) system. Integration and commissioning of frontend and backend electronics on these chambers is ongoing at CERN. I will discuss the overall detector and electronic system and present integration and commissioning results.

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The ATLAS New Small Wheel Simulation and Reconstruction Software and Detector Performance Studies

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The New Small Wheels (NSW) are replacing the innermost stations of the two endcap sides of the ATLAS Muon Spectrometer. NSW are equipped with 2 new detector technologies: small strips Thin Gap Chambers (sTGC) and Micromegas (MM). The assembly of the first wheel, composed by 64 Micromegas and 64 sTGC modules, is almost completed. The software for simulation and reconstruction is also well advanced to be ready for data taking in 2022. The detectors response is simulated and compared with real data from cosmic rays and test-beam. Nominal geometries and misalignments and deformations are implemented, together with other deviations from nominal operating conditions resulted from the detectors validation studies. Trigger and reconstruction performance studies are carried out in different configurations.
After an overview of the software implementation and the adopted strategies, a summary of the studies carried out will be presented.

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Cosmic results with the final Micromegas sectors for the ATLAS Muon upgrade

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The innermost end-cap muon station of the ATLAS detector is being upgraded with the New Small Wheel (NSW) using new technology for precision tracking and triggering: Micromegas (MM) and small-strip Thin Gas Chamber (sTGC). Each of the two NSWs will consist 8 large and 8 small sectors. A sector is a combination of the sTGC wedges on either side of a double Micromegas wedge. Four Micromegas quadruplets are integrated to build a double wedge. After the electronic integration is completed, the double wedges are tested with cosmic muons at the cosmic stand¬†at CERN. Here, we make sure of the final high voltage configuration, measure the efficiency, cluster size, strip multiplicity per readout layers of the double wedge and qualify the Micromegas sector for the final integration with the sTGC wedges before mounting them on the New Small Wheel. The procedure and the test results of the final validation of Micromegas double wedges will be presented.

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Commissioning and installation of a new generation of Resistive Plate Chambers for the phase-1 BIS78 upgrade of the ATLAS muon spectrometer

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I,Ä®n preparation for the coming years of LHC running at higher luminosity, two upgrade projects of the ATLAS Muon spectrometer have been developed: the New Small Wheel project, improving the trigger in the end-cap regions, and the BIS78 project, dedicated to the transition region between barrel and the endcaps (1<|eta|<1.3).
The BIS78 project will add 32 RPC triplets along z on the edges of the inner barrel sectors where the ATLAS toroid is present. These new generation of RPCs are characterized by thinner gas gaps (1mm vs 2mm of the legacy RPCs) as well as thinner resistive electrodes, together with a new high gain front-end electronics with a lower operating voltage.
16 BIS78 stations have been already installed in the ATLAS Muon spectrometer between 2020 and 2021 and are being commissioned during this year. The state of art of the project, the status of the commissioning as well as the overall performances of the installed RPCs will be presented.

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Commissioning and studies of TPC prototype using 266nm UV laser beams

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To achieve the physical goals in the future circular collider, Time Projection Chamber(TPC) is one of the main concept proposal of the central tracker detector, it has an excellent performance on the moment, dE/dx and the spation resolution.
the TPC prototype with a MPGD detector module integrated the laser calibration system has been developed in Institute of High Energy Physics (IHEP). This prototype has an active readout area of 200mm$\times$200mm and the drift length of 500mm, the narrow laser beams can imitate straight ionization tracks at predefined position(<2μm). it is placed on an anti-vibration pneumatic optical platform and any vibration down to amplitudes of less than 2μm, 1280 channels readout system and the high voltage of 20,000V for the light field cage have been done, and the signal tests are very good for TPC prototype integrated 42 UV laser beams. In this talk, some performance results of dE/dx and the position resolution will be presented„ÄÇ

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Luminosity and beam-induced background measurement with the CMS tracker endcap pixel detector at HL-LHC

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The High Luminosity upgrade of the LHC (HL-LHC) places unprecedented requirements for background monitoring and luminosity measurements. The CMS Tracker Endcap Pixel Detector (TEPX) will be adapted to provide high-precision online measurements of bunch-by-bunch luminosity and beam-induced background. The implementation of dedicated triggering and readout systems, the real-time clustering algorithm on an FPGA and the expected performance are discussed. The innermost ring of the last layer (D4R1) will be operated independently from the rest of TEPX enabling beam monitoring during the LHC ramp and during unqualified beam conditions. The system optimisation and the dedicated timing and trigger infrastructure for D4R1 are also presented.

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Performance tests of dual-phase CO_2 cooling for particle detectors

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Evaporative CO_2 cooling is a promising solution for the cooling of high-energy particle detectors, such as the new ATLAS Inner Tracker (ITk) for the high-luminosity upgrade of the LHC.
CO_2 offers a high latent heat transfer at reasonable flow parameters and is an environment friendly alternative to many other currently used coolants.
At the same time, the operation in the dual-phase regime comes with several parameters influencing the cooling performance compared to a monophase coolant.
Some of these are experimentally studied using prototypes from the ITk strip detector end-cap. Here, the local support structure called petal core should allow a good heat transfer between the silicon strip modules glued on the surface and the embedded titanium cooling pipe.
Systematic investigations on the thermal performance using infrared thermography are used to study the influence of dual-phase CO_2 cooling parameters, such as heat load or mass flow rate, and are compared to simulation.

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New Beam Position Detectors for NA61/SHINE experiment

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The NA61/SHINE experiment at the CERN SPS is undergoing a major upgrade during the LHC Long Shutdown 2 period (2019-2021). The upgrade is essential to fulfill the requirements of the new open charm and neutrino programs. In these programs the NA61/SHINE will operate with the data acquisition rate increased by a factor of 10, which requires an upgrade of current Beam Position Detectors (BPDs). New BPDs should monitor beam particle positions with a frequency up to 10ˆ5 Hz.
The design and development of the new BPDs based on Si strip detectors as well as BPD‚Äôs readout electronics, integration with DAQ and electronics verification results will be discussed.

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A Muon Detector Design for STCF Based on Mixed Structure of RPC and Plastic Scintillator

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Abstract: The STCF is designed as one of the viable successor of the BEPC II, with 100 times higher luminosity promotion. The increased luminosity benefits the œÑ-Charm physical research, however asking for an advanced high-performance detector system. To get an optimal performance, a new MUC design with 3 layers of bakelite-RPC and 7 layers of scintillator detector is proposed. This design makes a compromise between particle detection, background tolerance and cost. The Geant4 simulations indicate that, under the background interference predicted for STCF, the muon detection efficiency can be higher than 95%@pion fake rate=0.03 with momentum above 0.8 GeV/c, and the detection efficiency for the neutron that cannot be detected by ECAL could be above 95%@fake rate=0.03. These results illustrate that this new MUC design can meet the demand of STCF, achieving a proper performance in the high luminosity electron-positron collider detector systems.

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Improved charged particle timing measurements with Timepix3 ASIC

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A possible solution to cope with the increased pile-up achieved at the HL-LHC and beyond is the 4D tracking, using time measurements in addition to space. New sensor technologies are being explored to achieve the time resolution required for this new approach.
In this presentation we show the most recent results obtained with devices under test studied with tracks reconstructed by the LHCb VELO Timepix3 Telescope. The telescope has fine time stamping thanks to the combination of several Timepix3 planes and scintillators, enabling resolution studies of the order of 100 ps. Our initial analysis points to best results around 590 ps resolution, where a 450 ps contribution is expected from the Timepix3 1560 TDC bin size. The newest results obtained with the particle beam at the SPS will be presented comparing a few different sensor prototypes including a typical planar geometry and 3D sensors.

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mPSD data monitoring at mCBM experiment

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The CBM experiment at the FAIR accelerator complex is aimed at studying hot compressed baryonic matter. A mini CBM (mCBM) facility was developed at the SIS18 accelerator at GSI, Darmstadt, Germany to test prototypes of detector subsystems for the CBM experiment, front-end and readout electronics at high intensities of the heavy ion beam. The mCBM project includes a prototype of the forward hadron calorimeter PSD, the so-called ‚Äúmini-PSD‚Äù (mPSD). Within the preparation to the mCBM experimental test runs, software modules for mPSD were developed. These software modules were introduced into the general data readout system, and are responsible for reading and storing the information of the mPSD detector. The mPSD online monitoring software module with quality control of the data will be discussed.

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ATLAS LAr Calorimeter Commissioning for LHC Run-3

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Liquid argon (LAr) sampling calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region |Œ∑| < 3.2, and for hadronic and forward calorimetry in the region from |Œ∑| = 1.5 to |Œ∑| = 4.9. After detector consolidation during a long shutdown, Run-2 started in 2015 and about 150fb-1 of data at a center-of-mass energy of 13 TeV was recorded. Phase-I detector upgrades began after the end of Run-2. New trigger readout electronics of the ATLAS Liquid-Argon Calorimeter have been developed. Installation began at the start of the LHC shut down in 2019 and is expected to be completed in 2021. A commissioning campaign is underway in order to realise the capabilities of the new, higher granularity and higher precision level-1 trigger hardware in Run-3 data taking. This contribution will give an overview of the new trigger readout commissioning, as well as the preparations for Run-3 detector operation.

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Development of new high speed data acquisition system prototype for SOI pixel detector using 10 Gb Ethernet SiTCP

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The SOI (Silicon-On-Insulator) pixel detector is the monolithic imaging device developed by the SOIPIX group led by KEK. This detector is being tested for practical use such as X-ray imaging, but the readout FPGA (Field-Programmable Gate Array) board SEABAS2 (Soi EvAluation BoArd with Sitcp 2), which is mainly used for the readout of this detector is becoming obsolete. This has led to problems such as insufficient readout speed, restrictions on the implementation of advanced processing due to the insufficient circuit scale of the FPGA. Therefore, in order to improve the performance and usability, we are developing the new readout board with newer generation FPGA and 10 GbE SiTCP (10 Gigabit ethernet network processor library logic circuit running on FPGA). Prior to the development of new board, we constructed a prototype system using the FPGA evaluation board KC705 to evaluate the 10 GbE SiTCP. We will report this prototype system's evaluation.

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Machine Learning for Real-Time Processing of ATLAS Liquid Argon Calorimeter Signals with FPGAs

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Within the Phase-II upgrade of the LHC, the readout electronics of the ATLAS LAr Calorimeters is prepared for high luminosity operation expecting a pile-up of up to 200 simultaneous pp interactions. Moreover, the calorimeter signals of up to 25 subsequent collisions are overlapping, which increases the difficulty of energy reconstruction. Real-time processing of digitized pulses sampled at 40 MHz is thus performed using FPGAs.

To cope with the signal pile-up, new machine learning approaches are explored: convolutional and recurrent neural networks outperform the optimal signal filter currently used, both in assignment of the reconstructed energy to the correct bunch crossing and in energy resolution.

Very good agreement between neural network implementations in FPGA and software based calculations is observed. The FPGA resource usage, the latency and the operation frequency are analysed. Latest performance results and experience with prototype implementations will be reported.

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FELIX: commissioning the new detector interface for the ATLAS trigger and DAQ system

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After the current LHC shutdown (2019-2022) the ATLAS experiment will operate in an increasingly harsh collision environment, motivating a series of upgrades. In order to improve the capacity and flexibility of the detector readout system, the Front-End Link eXchange (FELIX) system has been developed. FELIX acts as the interface between the data acquisition; detector control and TTC (Timing, Trigger and Control) systems; and new or updated trigger and detector front-end electronics. The system functions as a router between custom serial links from front end ASICs and FPGAs to data collection and processing components via a commodity switched network. FELIX also forwards TTC signals to front-end electronics. FELIX uses commodity server technology running a software routing platform in combination with FPGA-based PCIe I/O cards. Installation of FELIX took place in 2020. We will present the results of commissioning activities for the full system taking place throughout spring 2021.

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Design of a resilient, high-throughput, persistent storage system for the ATLAS Phase-II DAQ system

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The ATLAS experiment will undergo a major upgrade to adapt to the HL-LHC. The Trigger and Data Acquisition system (TDAQ) will record data at unprecedented rates: detectors will be read out at 1 MHz generating around 5 TB/s of data. Within TDAQ the Dataflow system (DF) introduces a novel design: readout data are buffered on persistent storage while the event filtering system selects 10 kHz of events for a total throughput of around 60 GB/s. New challenges arise for DF to design and implement a distributed, reliable, persistent storage system supporting several TB/s of aggregated throughput while providing tens of PB of capacity. In this paper after describing some of these challenges we present the ongoing R&D to address each of them: data safety, indexing at high rates in a distributed system, and high-performance management of storage capacity. Finally the performance achieved with a working prototype is shown.

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Upgrade of the ATLAS Level-1 Endcap Muon Trigger System for LHC Run-3

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LHC is expected to increase its instantaneous luminosity to 2x10ˆ34 cmˆ-2sˆ-1 in Run3. In order to cope with the high luminosity, upgrade of the trigger system is ongoing. The level-1 Endcap Muon trigger system reconstructs muons with high transverse momentum by combining data from Thin Gap Chambers (TGCs) and inner station detectors. In the upgrade, a new detector called New Small Wheel (NSW) is being installed in the inner station region. Finer track information from NSW is used as a part of the muon trigger logic to improve the trigger performance. A new trigger board, Sector Logic (SL), has been developed to handle data from TGC and NSW. SL has a modern FPGA to make use of Multi-Gigabit transceiver technology, used to receive data from NSW. Status of the commissioning of the ATLAS Level-1 Endcap Muon trigger system is presented, as well as implementation of the trigger logic as a firmware and its performance.

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Upgrade of the ATLAS Level-0 Endcap Muon Trigger for HL-LHC

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Status of the development of the Level-0 endcap muon trigger system for the ATLAS experiment at the HL-LHC is presented. The upgraded system reconstructs muon candidates with an improved pT resolution by combining data from various sub-detectors. This is realized by exploiting evolution of data transmission technologies, to send all hit data from Thin Gap Chambers (TGCs) and other sub-detectors to the counting room.
Performance of this new trigger system is also shown. Trigger efficiency is estimated with a software based algorithm and using simulation, to be higher than 90% for the threshold of pT>20 GeV in the endcap region. Trigger rate is also estimated with a software algorithm and using pp collision data, overlaid to simulate the high pileup condition at the HL-LHC. to be lower than 25 kHz for the threshold of pT>20 GeV.
Implementations of the new trigger algorithms with firmware for an FPGA, along with development of a new trigger prototype board are also shown.

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Performance and Integration results of a high resolution Time to Digital Converter designed for INO ICAL Experiment

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INO ICAL Experiment emphasis on studying various properties of Atmospheric Neutrinos. A 50 kton Iron Calorimeter and Resistive plate Chamber (RPC) in stacked geometry will be used to track neutrinos. Position and directional information are to be used to identify particle energies. RPC detector signal of rise time less than 1ns is amplified-discriminated and given to Digital Front End (RPC-DAQ). To time these fast pulses we designed a low power, compact multi-channel delay-chain-based time-to-digital converter (TDC) in a 0.13¬μm ASIC which will be integrated in the RPC-DAQ module. This TDC is capable of handling multiple hits per channel with a single-shot precision better than 65.34ps. A 4 line or 11 line serial peripheral interface (SPI) is used for readout and configuration. This paper presents the performance and integration results of this TDC.

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Firmware development for trigger-less mPSD readout at mCBM experiment at GSI

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The Compressed Baryonic Matter (CBM) experiment at FAIR needs a detector to measure the nucleus-nucleus collision centrality and orientation of the reaction plane. This will be obtained with the Projectile Spectator Detector (PSD), which is a sampling lead/scintillator forward hadron calorimeter.
The PSD readout system is based on ADC FPGA board (14-bit resolution and 125MHz digitization) which was originally designed for ECAL@PANDA. In order to integrate the PSD ADC board to the common CBM DAQ, a FPGA-GBT component was included into the FPGA design with a clock switching procedure to run the ADC board with the recovered GBT receive clock in order to synchronize the hardware to the common CBM DAQ time.
The development of components for digitizing waveforms reaching 1MHz readout rate per channel tested in mCBM test runs and the trigger-less readout will be discussed as well as the inclusion of the readout into the next-generation mCBM readout scheme.

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The Event Timing Finder for the Central Drift Chamber Level-1 Trigger at the Belle II experiment

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The Level-1 trigger system of the Belle II experiment is designed to select physics events of interest with almost 100% efficiency. In terms of event timing decision, the level-1 trigger is required to have an accuracy of less than 10 ns. The Central Drift Chamber (CDC) level-1 trigger provides the event timing information as one of the level-1 timing sources. We developed the new algorithm to measure the event timing with an accuracy of about 10 ns based on the CDC hit timing. Two-dimensional charged track reconstruction by Hough transformation was utilized to reduce high background hits. We used a new-developed general-purpose FPGA board (Universal Trigger board 4) for this module for the first time. We will report the performance of the new algorithm using e+e- collision data collected in 2020.

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The ATLAS Level-1 Topological Processor: experience and upgrade plans

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During Run-2 the Large Hadron Collider has provided, at the World's energy frontier, proton-proton collisions to the ATLAS experiment with instantaneous luminosity of up to 2.1x10ˆ34 cm-2s-1, placing stringent operational requirements on the ATLAS trigger system in order to reduce the 40MHz collision rate to a manageable event storage rate of 1kHz.
The ATLAS Level-1 trigger is the first rate-reducing step. Since 2017, an important role has been played by the Level 1 Topological Processor (L1Topo). Up to 128 topological algorithms can be implemented to select interesting events by applying kinematic and angular requirements on electromagnetic clusters, hadronic jets, muons and total energy. This resulted in a significantly improved background event rejection and acceptance of physics signal events.
We give an overview of the L1Topo architecture and performance results during Run-2 alongside with upgrade plans for the L1Topo system to be installed for the future data taking in 2022.

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The Particle Flow Algorithm in the Phase II Upgrade of the CMS Level-1 Trigger.

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The Phase II upgrade of the CMS detector for the High Luminosity upgrade of the LHC (HL-LHC) includes the introduction of tracking at the Level-1 (L1) trigger, thus offering the possibility of developing a simplified Particle Flow (PF) algorithm. We present the logic of the algorithm, along with its inputs and its firmware implementation. We show that this implementation is capable of operating under the limited timing and processing resources available at the trigger level. The expected performance and physics implications of such an algorithm are shown using Monte Carlo samples with hŒπgh pile-up, simulating the harsh conditions of the HL-LHC. Additionally, advanced pile-up techniques are needed to preserve the physics performance in the HL-LHC environment. We present a method that combines all information to perform Pile-Up Per Particle Identification (PUPPI) capable of running at trigger level. Demonstration of the algorithm on dedicated hardware (ATCA platform) is presented.

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Level 1 muon triggers algorithms for the CMS upgrade at the HL-LHC

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In view of the HL-LHC, the Phase-2 CMS upgrade will replace the trigger and data acquisition system. The detector readout electronics will be upgraded to allow a maximum L1 rate of 750 kHz and 12.5 $\neg\mu$s latency. The upgraded system will be entirely running on FPGAs and should greatly extend the capabilities of the current system to maintain trigger thresholds despite the harsh environment. The function of the muon trigger is to identify muon tracks and measure their momenta and other parameters for use in the global trigger menu. In addition to the muon detector upgrades that include improved electronics and new sub-detectors, the presence of a L1 track finder in CMS will bring some of the offline reconstruction capability to the L1 trigger, delivering unprecedented reconstruction and identification performance. We review the current status of the algorithm developments for a highly efficient L1 muon trigger and the measured performance on emulators and firmware demonstrators.

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CMS Hadron Calorimeter Pulse Filter for Pileup Mitigation at the Level-1 Trigger

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We explore the possibility of mitigating the effects of out-of-time pileup by developing an alternative scheme for signal amplitude reconstruction that is done online for the CMS Hadron Calorimeter (HCAL). This new scheme makes use of information from bunch crossings preceding the one that would generate an accept decision for the Level-1 Trigger (L1T). The scheme employs basic pulse shape filtering techniques that are optimized specifically to minimize the effects of out-of-time pileup at the Level-1 trigger. We find that the overall L1T performance gets improved in terms of energy scale and resolution for L1 Trigger quantities and the new scheme will be used during Run3 operation of the L

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Application and further improvement of the RD51 general Scalable Readout System with the VMM chip

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Within the last years, RD51 collaboration,Äôs general readout system, the Scalable Readout System (SRS), has been updated by integrating a recent front-end ASIC: The VMM, originally designed for the ATLAS New Small Wheel. Applying the SRS design strategy, a new front-end board and adapter card, as well as FPGA firmware and software was developed, while keeping general SRS hardware. With completion of the first production, the development phase was terminated. The users list contains a rich spectrum of future projects employing mainly gaseous detectors.
The presentation throws a glance on past developments. Our contributions as one of the RD51 teams are highlighted, e.g. readout rate improvements in firmware, noise evaluation and automated quality testing. An overview of applications of the system, focussing on our own, the upgrade of GEM detectors for the future COMPASS++/AMBER experiment and technology transfer from particle physics to neutron science, is given.

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ATLAS toward the High Luminosity era: challenges on electronic systems

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To maximize the physics reach, the LHC plans to increase its instantaneous luminosity to 7.5×10^{34} cm^{-2} s^{-1}, delivering from 3 to 4 ab^{-1} of data at $\sqrt{s}$ =14 TeV. In order to cope with this operation condition, the ATLAS detector will require new sets of both front-end and back-end electronics. A new trigger and DAQ system will also be implemented with a single-level hardware trigger featuring a maximum rate of 1 MHz and 10 Œºs latency. Enhanced software algorithms will further process and select events, storing them at a rate of 10 kHz for offline analysis. The large number of detector channels, huge volumes of input and output data, short time available to process and transmit data, harsh radiation environment and the need of low power consumption all impose great challenges on the design and operation of electronic systems. This talk will focus on these challenges, the proposed solutions and the latest results obtained from the prototypes.

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System-level performance study and commissioning of TGC frontend electronics for Phase-2 upgrade of LHC-ATLAS

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The Thin Gap Chambers (TGCs) of the LHC-ATLAS are responsible for triggering muons in the endcap region at the hardware trigger stage. The frontend system of TGC will be upgraded for HL-LHC to send binary hit-map at every bunch crossing (BC) to the backend system. Such an operation requires lots of unique challenges: high-performance hit BC Identification, fine-tuned clock distribution, robustness for SEU, and the capability of timing calibration. Accommodating these requirements, the primary processor board (PS-Board) is in charge of data processing and reception of control signals distributed by the backend. An independent control module (JATHub) will take responsibility for FPGA configuration and clock phase monitoring of the PS-Boards with an SoC-based design. Prototyping and initial system-level demonstration with the prototypes have been successfully performed. Exploiting the experience, we are developing the final design and the in-depth strategy for the commissioning.

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The upgraded electronics of the Pierre Auger surface detector

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The Pierre Auger Observatory's array of surface detectors is being upgraded by adding new detectors and replacing electronics. The upgrade project, called "AugerPrime," includes the addition of a small PMT to increase the dynamic range for particle counting, a plastic scintillator above each WCD to improve the discrimination between the electromagnetic and muonic shower components, a radio detector to measure radio emission from inclined air showers and a set of underground muon counters to provide additional information on muon content in atmospheric showers.
The new electronics, dubbed Upgraded unified Board or UUB, is designed to acquire all of these additional detectors and includes improved GPS receivers, higher sampling rates, increased dynamic range, greater processing capacity, and improved calibration and monitoring systems. In this talk I will present the UUB design and discuss its performance as observed in the first data from the upgraded array.

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Electronics Performance of the ATLAS New Small Wheel Micromegas wedges at CERN

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The present ATLAS small wheel muon detector is being replaced with a New Small Wheel (NSW) detector. One crucial part is the installation, testing and validation of the on-detector electronics & readout chain for a very large system with a more than 2.1 M electronic channels. These include ˜4K MM Front-End Boards (MMFE8), custom printed circuit boards each one housing eight 64-channel VMM Application Specific Integrated Circuits (ASICs) that interface with ATLAS TDAQ system through ˜1K data-driver Cards (ADDC & L1DDC, respectively). The readout chain is based on optical link technology (GigaBit Transceiver links) connecting the backend to the front-end electronics via the Front-End LInk eXchange (FELIX), a newly developed system that will serve as the next generation read out driver for ATLAS. Experience and performance results from the first large-scale electronics integration tests performed at CERN on final MM wedges, including system validation with cosmic-rays, will be presented.

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A muon tracking algorithm for the Level 1 trigger in the CMS barrel muon chambers during HL-LHC

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This contribution presents results on the Analytical Method (AM) algorithm for trigger primitive (TP) generation in the CMS Drift Tube (DT) chambers during the High Luminosity LHC operation (HL-LHC or LHC Phase 2). The algorithm has been developed and validated both in software with an emulation approach, and through hardware implementation tests. The obtained performance on Phase 2 simulated data shows timing and position resolutions close to the ultimate performance of the DT chambers, with resilience to potential ageing situations. The firmware version has been implemented in the so-called AB7 (TwinMux), spare uTCA boards from the present DT system which host Xilinx Virtex 7 FPGAs, and included in a prototype chain of the HL-LHC electronics operated with real DT chambers during cosmic data taking. Agreement between the software emulation and the firmware implementation has been verified using different data samples, including a sample of real muons collected during 2016 data taking.

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Development of FPGA based 128-Channel TDC for Time Projection Chambers

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Time Projection Chamber (TPC) is a gaseous detector used for tracking charged particles. These detectors comprise of sensitive gas volumes applied with high electric field between the endplates. When a charged particle traverses the TPC volume, it ionizes the gas atoms along its trajectory. The free electrons produced move towards anode with a speed depending on the gas mixture and the applied field. Arrival times and hit channel information are used to track the particle. In order to measure accurately, the arrival times of these slow-moving electrons at the anode, an FPGA-based Start-Stop type TDC is designed. The TDC Starts on Trigger and Stops on the arrival of electrons at each anode channel. Dynamic range of 160us and least count of 2.5 ns are obtained, which cover the entire particle trajectory. Also, another useful feature of this TDC is its multi-hit capability up to 4 hits. Design features and preliminary test results of the TDC will be presented.

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The HL-LHC Upgrade of the ATLAS Tile Hadronic Calorimeter

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The High-Luminosity phase of LHC, delivering five times the LHC nominal instantaneous luminosity, is scheduled to begin in late 2027. The ATLAS Tile Hadronic Calorimeter (TileCal) will need new electronics to meet the requirements of a 1 MHz trigger, higher radiation dose, and to ensure sound performance under high pile-up conditions. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2025-2027. PMT signals from every TileCal cell will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms. The TileCal upgrade program has undergone extensive R&D and beam tests. A miniature “demonstrator” module has been tested in actual detector conditions. We will present the results of these studies.

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A new data transfer scheme for HL-LHC upgrade of the ATLAS Tile Hadronic Calorimeter

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The upcoming High-Luminosity LHC (HL-LHC) upgrade of the ATLAS Tile Hadronic Calorimeter (TileCal) includes a complete replacement of all on- and off-detector electronics with a new read-out architecture. Detector signal digitized by the on-detector electronics will be transferred to Pre-processors (PPr) located off-detector that will interface with the ATLAS trigger and data acquisition systems. The ATLAS common hardware platform FELIX is designed to act as a data router. A software data handler Read-Out Driver (SWROD) will perform detector-specific data-processing, which includes configuration, calibration, control, and monitoring, without buffering the data. We will present the ATLAS TileCal read-out strategy for the HL-LHC, a detailed description of the PPr interface with FELIX, results of tests performed with the PPr and FELIX prototypes, and in a "demonstrator" module already installed in the ATLAS cavern.

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The DAQ and control system for Jadepix3

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The silicon pixel detector is the core component of the vertex detector in the CEPC experiment. The Jadepix3 is one of the chips designed to study the performance and design of pixel sensor chips. The chip is a design of the full-function large-size chip based on CMOS technology. To test all the functions and the performance of this chip, we designed a test system based on the IPbus framework and the EPICS framework. The data acquisition system is developed by using the IPbus framework. The data of the chip will be read out into an FPGA first and then transferred to PC via a 1 Gigabit ethernet. Besides the devices on the test PCB, some important parameters of the readout system are also controlled and monitored by using the EPICS framework. The robustness, scalability, and portability of this system have been verified in the laboratory tests.

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The Monitoring of Pixel System (MOPS) chip for the Detector Control System of the ATLAS ITk Pixel Detector

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The ATLAS experiment will get a new inner tracker (ITk) during the phase II upgrade. The innermost part is called the Pixel Detector. A new Detector Control System (DCS) is being developed to provide control and monitoring of the ITk pixel detector. The Monitoring of Pixel System (MOPS) chip is an Application Specific Integrated Circuit (ASIC) foreseen in the DCS to independently monitor the voltage and the temperature across the modules which constitute the front end electronics responsible for tracking and data readout. The modules which need to be monitored are powered serially in a chain. The MOPS chip has a 12-bit ADC which can read up to 34 channels. Controller Area Network (CAN) and CANopen protocols are used for communication.
The final chip is required to be radiation hard up to an ionizing dose of 500 Mrad. In this talk, the functionality of the chip will be discussed, and also results from the first version of the chip will be presented.

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The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC

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The future High Luminosity era of the Large Hadron Collider, with its unprecedented instantaneous luminosity, will impose new challenges on the LHC experiments. ATLAS will replace its inner detector with a new all-silicon Inner Tracker (ITk), whose innermost layers will be based on pixel technology and are expected to produce a data output of about 11 Tb/s. A high-speed transmission chain with many parallel lines running at 1.28 Gb/s will transmit data from the detector to an opto-electrical conversion system. This Optosystem features custom-designed radiation-hard electronics devoted to signal equalisation, aggregation (to 10.24 Gb/s) and optical-electrical conversion.
In this talk, the ITk Pixel data transmission chain will be discussed, emphasising how the Optosystem fulfils the stringent design requirements and describing the ongoing and future tests to qualify the system.

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Development of the Level-1 trigger system in Bellell experiment

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The Level-1 trigger system for the Bellell experiment is designed to select various physics targets under high background environment at the SuperKEKB, energy-asymmetric electron-positron collider. We have developed the FPGA based system to provide the trigger within 4.5Œºs with the central drift chamber, electromagnetic calorimeter, time-of-propagation detector, muon detectors and their coincidence. The system has been operated for the physics data taking since 2018 and continuously updated to improve the signal efficiency and background rejection. We present the latest status of the level-1 trigger system and its performance during the physics operation.

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Monitoring System of the ATLAS ITk Laboratory

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The ATLAS ITk Upgrade project, culminating in the installation into the experiment in 2026, enters this year its production period. Cooperating laboratories dealing with the strip part of the project needs to meet various conditions in clean rooms and testing environments to ensure safety for production components during assembly and measurement procedures. Prague strip ITk laboratory prepared for modules' production is presented as a model case. For this purpose, dedicated DAQ software called ITSDAQ is used together with the slow control monitoring system based on RS232/GPIB standards, MySQL database entry and Grafana visualization platform. Data are stored in the local database storage, a subset of them and the test results are also sent into the ITk Production Database. Such an integrated tool offers real-time plotting of crucial parameters and the possibility of receiving an immediate notification in case of exceeding any threshold.

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CALICE SiW ECAL Development and performance of a highly compact digital readout system

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A highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is the reference design for the ECAL of the ILD concept, one concept for detectors at the future International Linear Collider. Prototypes for a SiW ECAL are developed within the CALICE Collaboration.
A highly compact digital readout card (SL-Board), is now available. The SL-Board combines data acquisition, power regulation and signal buffering for up to 10000 readout channels on a surface as small as 18√ó64cmˆ2. The system complies with space constraints in modern particle physics detectors such as ILD. The SL-Board can be read out by a regular USB interface or via a dedicated module (CORE Module). The CORE Module also delivers clock and fast commands and synchronises the SL-Boards. It acts as a data concentrator receiving input from up to 15 layers. The entire system is designed for a data throughput of up to 80 MBit/s.
In the next beam test in May 2021, we will read out up to 22 layers with the new system.

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CMS RPC Link System upgrade

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The LHC will be upgraded in several phases that will allow significant expansion of its physics program. The luminosity of the accelerator is expected to exceed 5√ó1034cm,àí2s,àí1. In order to sustain the harsher conditions and to help maintain good trigger efficiency and performance the Resistive Plate Chambers (RPC) system of the CMS experiment, its Link System will be upgraded. The present RPC Link System has been servicing as one of the CMS subsystems since installation in 2008. The use of new generation of electronics components, specially new FPGAs, will improve the timing resolutions of the RPC system to 1.5 ns. Also, the communication rate with the readout electronics will be increased to 10.24 Gbps. Those will allow the RPC to cope with requirements to operate in the HL-LHC conditions. A more robust control interface will be implemented, as well as a new online software. Possible performance improvements of the CMS L1 muon trigger system will also be presented.

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PMT Base with Integrated Waveform Capture for IceCube-Gen2

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A PMT base with integrated waveform recording has been designed for next-generation multi-PMT modules in the IceCube Neutrino Observatory at the South Pole. The base has a single ribbon cable connection for low voltage power supply, timing synchronization and communication signals. A Cockcroft-Walton multiplier provides high voltage for a 10-stage PMT, following the design of current IceCube multi-PMT modules. The new design includes a 2-channel ADC, FPGA and ARM microcontroller, together providing full readout of PMT waveforms with extended dynamic range. The FPGA captures ADC data and a high-resolution discriminator-based time stamp for each hit. The microcontroller performs basic data processing and buffering, and also operates and regulates high voltage generation. The design uses off-the-shelf components chosen for low power consumption and cost. It will be included in new version multi-PMT prototype modules that will be installed in the near-term IceCube Upgrade project.

Posters: Trigger and DAQ / 678

ECAL trigger performance in Run 2 and improvements for Run 3

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The CMS electromagnetic calorimeter (ECAL) is a high resolution crystal calorimeter operating at the CERN LHC. It is read out at 40 MHz (the proton-proton collision rate) in order to provide information to the hardware-level (Level-1) trigger system, which decides whether the full CMS detector must be read out for each collision. The ECAL trigger performance achieved during LHC Run 2 (2015-2018) will be presented. The increased luminosity with respect to the LHC Run 1 has required frequent calibrations during LHC operation to account for radiation-induced changes in crystal and photodetector response. Further improvements in the energy and time reconstruction of the CMS ECAL trigger primitives are being explored for LHC Run 3 (2021-23), using additional features implemented in the on-detector readout. In this presentation, we will review the ECAL trigger performance during LHC Run 2 and present improvements to the ECAL trigger system for LHC Run 3.

Readout: Front-end electronics / 325

Analog performance of ITkPix-V1 pixel readout chip

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The ITkPix-V1 readout front-end (FE) chip, based on 65 nm CMOS technology, is designed by the RD53 collaboration as the pre-production chip for the upgraded ATLAS Inner Tracker Pixel detector operating with extreme rates and radiation at the High-Luminosity LHC. The ITkPix-V1 chip uses a novel differential analog FE design featuring low noise and small time-walk. ITkPix-V1 was submitted in March 2020. In this talk, we will summarize the most recent measurements on the analog FE of this chip.

Readout: Front-end electronics / 380

Development of Low Temperature Analog Readout (LTARS 2018) for LAr-TPC

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We currently developed a new front-end electronics for a liquid argon time projection chamber (LAr-TPC) detector, which has been developed for neutrino oscillation and nuclear decay search experiments.
We developed the electronics (LTARS 2018) to have a wide dynamic range for input charge up to 1600 fC and a function to output a signal with an appropriate time constant for signals having various peaking times. These unique properties may make the LTARS 2018 multi-purpose, for example, not only for LAr-TPC but also a negative-ion gas TPC for dark matter search.
In this paper we will report the evaluation test on the noise and charge signal conversion performance of LTARS2018 at room temperature and cryogenic temperatures and the results of cosmic ray measurement tests using the LTARS2018. In addition, we will discuss the design concept and characteristics of a new electronics(LTARS2020) that has been modified to improve performance in cryogenic environments.

Readout: Front-end electronics / 644

Cold Readout Electronics for Liquid Argon TPCs in the DUNE experiment

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As the leading-edge international experiment for neutrino science and proton decay studies, Deep Underground Neutrino Experiment (DUNE) is based on the LArTPC technology. The first 10-kton DUNE far detector module will employ wired-based anode planes with cold readout electronics (CE) installed inside the cryostat. The CE developed for cryogenic temperatures (77K-89K) operation is an optimal solution that achieves excellent noise performance and decouples the electrode and cryostat design from the readout design. This presentation will review the experience of ProtoDUNE single-phase detector located at the CERN neutrino platform and give an overview of the progress of the CE development activities, including recent results from system integration activities involving the characterization of new versions of the cryogenic ASICs and front-end motherboards mounted on small scale anode planes immersed in cryogenic liquids.

Readout: Front-end electronics / 313

RD53 pixel chips for the ATLAS and CMS Phase-2 upgrades at HL-LHC

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The Phase-2 upgrades of ATLAS and CMS will require a new tracker with readout electronics operating in extremely harsh radiation environment and high data rate readout.
The RD53 collaboration, a joint effort between the ATLAS and CMS experiments, developed in 2017 a large size demonstrator, called RD53A, to qualify the chosen 65nm CMOS technology and compare different analog front-ends and digital architectures for the development of the final production ASICs.
The final chips for the two experiments are being designed based on these results, having as a reference a common virtual baseline chip, called RD53B, which is adapted to the needs of each experiment. The RD53B-ATLAS version was submitted in March 2020 and it has been extensively tested, providing valuable results for the implementation of the RD53B-CMS version, which is planned to be submitted in March 2021.
A general overview of the chip architecture will be presented, as well as the first preliminary test results.

Readout: Front-end electronics / 284

Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

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To meet new TDAQ buffering requirements and withstand the high expected radiation doses at the high-luminosity LHC, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded. Developments of low-power preamplifiers and shapers to meet low noise and excellent linearity requirements are ongoing in 130nm CMOS technology. In order to digitize the analogue signals on two gains after shaping, a radiation-hard, low-power 40 MHz 14-bit ADCs is developed in 65 nm CMOS. The signals will be sent at 40 MHz to the off-detector electronics, where FPGAs connected through high-speed links will perform energy and time reconstruction through the application of corrections and digital filtering. The data-processing, control and timing functions will be realized by dedicated boards connected through ATCA crates. Results of tests of prototypes of front-end components will be presented, along with design studies on the performance of the off-detector readout system.

Readout: Front-end electronics / 305

Pixel detector hybridization and integration with Anisotropic Conductive Films

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An alternative pixel-detector hybridization technology based on Anisotropic Conductive Films (ACF) is under development to replace the conventional fine-pitch flip-chip bump bonding. The new process takes advantage of the recent progress in industrial applications of ACF and is suitable for time- and cost-effective in-house processing of single devices. This new bonding technique developed can also be used for the integration of hybrid or monolithic detectors in modules, replacing wire bonding or solder bumping techniques. This contribution introduces the new ACF hybridization and integration technique, and shows the first test results from Timepix3 hybrid pixel assemblies and from the integration of ALPIDE monolithic pixel sensors to flex circuits.

Readout: Front-end electronics / 281

Performance of the "IRSX" multi-GSa/s, Switched Capacitor Array Waveform Sampling Frontend ASIC

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The “Ice Ray Sampler X” (IRSX) is a low-power 8-channel waveform sampling frontend ASIC designed for HEP applications, fabricated by TSMC in a 250nm CMOS process. Each input channel samples into a switched capacitor array (SCA) of 32,768 samples depth at an adjustable rate of 2-4GSa/s, for an effective sample buffer depth of 8-16Œºs. Stored samples can be digitised with 12bit resolution using the integrated Wilkinson ADC, without incurring any dead time on the sampling. The sample storage array is designed for random access for both sampling and digitisation, allowing for flexible acquisition schemes depending on the application.
The IRSX ASIC is currently being used in the 8192 channel front end electronics of the Belle II TOP detector. This talk will present performance figures and characterisation measurements of the IRSX ASIC obtained from test bench campaigns and during the operation in the installed TOP system.

Readout: Front-end electronics / 331

Low Background Readout Electronics for Large Area Silicon Photomultipiers

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In this work we present a low noise high speed readout electronics for large area Silicon Photomultipiers (SiPMs) to be used in a cryogenic environment. The board is able to manage the signals coming from a ˜ 25 cm^2 SiPM tile, showing <10% SPE resolution and wide dynamic. The sub-nanosecond timing properties make them suitable to work with the typical mixtures of Liquid Scintillators currently being used in particle and astroparticle physics experiments. The boards have been tested with several types of SiPMs from room temperature down to -70 C showing excellent single photo-electron resolution in all the enviroment. The board,Äôs PCBs have been developed with ultra low background material in order to be used in rare event searches.

Readout: Front-end electronics / 699

Development of a timing chip prototype in 110 nm CMOS technology

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We present a readout chip prototype for future pixel detectors with timing capabilities. The prototype is intended for characterizing 4D pixel arrays with a pixel size of 100x100 ¬μm¬$\leq$, where the sensors are LGADs. The long term focus is towards a possible replacement of disks in the extended forward pixel system (TEPX) of the CMS experiment during the HL-LHC. The requirements for this ASIC are the incorporation of a TDC (Time to Digital Converter) in the small pixel area, low power consumption and radiation tolerance up to 5E15 neq/cm¬$\leq$ to withstand the radiation levels in the innermost detector modules during HL-LHC. A prototype has been designed and produced in 110 nm CMOS technology at LFoundry and UMC with different versions of TDC structures, together with a front end circuitry to interface with the sensors. The design of the TDC will be discussed, with the test set-up for the measurements, and the first results comparing the performance of the different structures.

Readout: Front-end electronics / 629

Readout of Large Capacitance SiPMs in Noble Liquid TPCs

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Silicon Photomultipliers (SiPMs), used for light detection in Noble Liquid Time Projection Chambers (TPCs), can be ganged as good spatial resolution is not needed in the light detection. Thus, the detector capacitance seen at the input of the SiPM readout electronics is larger than any previous detector arrangement: from 5 to 12.5 nF. We propose an integrated readout system suitable for reading out large capacitance SiPM arrays in Noble Liquid TPCs, using two cryogenic ASICs developed at BNL. The two-ASIC readout separates high sensitivity analog functionality from mixed and digital circuits, optimizes allocation of functionalities with fewer risks, and makes paths of development more independent. The analog ASIC is a modified LArASIC chip developed for the readout of charge signals in liquid Argon TPCs. The signal and data processing ASIC provides the ADC, digital filtering, data processing, receives the configuration data, commands and synchronization, and drives data to the DAQ.

Readout: Front-end electronics / 635

Single Event Effects Testing of the RD53B chip

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The RD53 collaboration has been working since 2014 on the development of pixel chips for CMS and ATLAS phase 2 upgrades. This work has recently led to the development of the RD53B full-scale readout chip which is using the 65nm CMOS process and containing 153600 pixels of 50√ó650 Œºm2.
The RD53B chip is designed to be robust against the Single Event Upset (SEU), allowing such a complex chip to operate reliably in the hostile environment of the HL-LHC. Different SEU mitigation techniques based on the Triple Modular Redundancy (TMR) have been adopted for the critical information in the RD53B chip. Furthermore, the efficiency of this mitigation scheme has been evaluated for the RD53B chip with heavy-ion beams in the CYCLONE facility and with a 480 MeV proton beam in the TRIUMF facility.
The purpose of this talk is to describe and explain all the SEU mitigation strategies used in the RD53B chip, to report and analyze the SEU test results and to estimate the expected SEU rates at the HL-LHC.

Readout: Front-end electronics / 512

Low-radioactivity large-scale silicon interposer technology for particle physics experiments

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The nEXO experiment requires a low-radioactivity and cryogenically compliant interconnect medium for its photodetection tile modules. The pursued tile size is 100 cm^2 which is larger than what is available with commercial interposers. We made a partnership with the IZM Fraunhofer institute to develop a custom technology. In Fall 2019, an 8" full scale wafer has been designed at Sherbrooke. The fabrication of 25 wafers was started at IZM in 2020. Wafers are extracted from fabrication at different steps for preliminary analysis. Measurements on the partial architecture show a high RDL interconnect yield and high intra/inter-layer isolation. The test vehicle contains RF transmission lines, via daisy chains, BGA/flip chip footprints, power distribution networks, and more.
The presentation at the TIPP2021 will detail the custom technology alongside the technology potential for the nEXO experiment according to the initial characterization.

Readout: Front-end electronics / 358

pSLIDER32: a 32 channels mixed-signal processor for the GAPS Si(Li) Tracker

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This work describes the first experimental results from the characterization of a 32 channels mixed-signal processor developed for the readout of lithium-drifted silicon, Si(Li), detectors of the General AntiParticle Spectrometer (GAPS) experiment to search for dark matter. The instrument is designed for the identification of antideuteron particles from cosmic rays during an Antarctic balloon mission scheduled for late 2022.
A full custom integrated circuit, named pSLIDER32 (32 channels Si-LI DEtector Readout ASIC prototype), has been produced in a commercial 180 nm CMOS technology. The ASIC is comprised of 32 low-noise analog readout channels featuring a dynamic signal compression to comply with the wide input range, an 11-bit SAR ADC and a digital back-end section which is responsible for channel setting and to send digital information to the data acquisition system (DAQ). The circuit design criteria and the experimental results will be presented at the conference.

Readout: Front-end electronics / 471

Upgrade of the ATLAS Monitored Drift Tube Frontend Electronics for the HL-LHC

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The monitored drift tube (MDT) chambers are the main component of the precision tracking system in the ATLAS muon spectrometer, capable of measuring the sagitta of muon tracks to an accuracy of 60 Œºm, which corresponds to a momentum accuracy of about 10% at pT=1 TeV. To cope with large amount of data and high event rate at HL-LHC, the present MDT readout electronics will be replaced and the MDT detector will be used at the first-level trigger with an output event rate of 1 MHz and a latency of ˜6 us. Prototypes for two frontend ASICs, a frontend mezzanine card and a data transmission board have been realized and tested. The design of a mobile mini-Data Acquisition system is ongoing and will be crucial for testing newly-built small-diameter MDT chambers with new frontend electronics prototypes and for future integration and commissioning. I will present the overall design of MDT frontend electronic system, results from ASIC and board prototypes and tests using the miniDAQ system.

Readout: Front-end electronics / 592

Electronics and Triggering Challenges for the CMS High-Granularity Calorimeter

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The High Granularity Calorimeter (HGCAL) will replace the CMS endcap calorimeters for the High Luminosity phase of LHC and will feature 6 million channels. The requirements of the front-end electronics are extremely challenging: high dynamic range (0-10 pC), low noise (˜2000e- to allow MIP calibration through to end-of-life), pileup mitigation through 25 ps binning timestamping within a power budget of ˜15mW/channel, as well as the need to select and transmit trigger information with a high granularity to off-detector boards. We describe the present iterations of the front-end and back-end electronics, including the hardware and studies of the algorithms to be implemented.

Readout: Trigger and DAQ / 385

Concept of KamLAND2 DAQ system

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KamLAND is a 1 kton liquid scintillator detector implementing 1879 of PMTs and the experiment have been exploring various neutrino physics. Based on the requirements from observations, we are designing a new DAQ system for KamLAND2, the next phase of KamLAND, to overcome the limitations on high event rate and successive data acquisition. For example, the impact of spallation backgrounds are critical in neutrinoless double-beta decay search, while we would get strong discrimination power if we could detect all of neutrons induced by spallation. For nearby supernova observation, expected event rate is about 1MHz for 1 s, that data rate corresponds to 25 Gbps. To realize fast processing, RFSoC and large DDR4 memory will be installed in the front-end electronics, 10GB Ethernet and ZeroMQ for the network. The primary trigger circuit will be replaced by a computer so that the level 2 software trigger could be issued more effectively. The overview of KamLAND2 DAQ system will be reported.

Readout: Trigger and DAQ / 288

Trigger-DAQ and slow control systems in the Mu2e experiment

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The muon campus program at Fermilab includes the Mu2e experiment that will search for a charged-lepton flavor violating processes where a negative muon converts into an electron in the field of an aluminum nucleus, improving by four orders of magnitude the search sensitivity reached so far. Mu2e, Trigger and Data Acquisition System (TDAQ) uses *otsdaq* as its solution. Developed at Fermilab, *otsdaq* uses the *artdaq* DAQ framework and *art* analysis framework, under-the-hood, for event transfer, filtering, and processing. *otsdaq* is an online DAQ software suite with a focus on flexibility and scalability, while providing a multi-user, web-based, interface accessible through a web browser. A Detector Control System (DCS) for monitoring, controlling, alarming, and archiving has been developed using the Experimental Physics and Industrial Control System (EPICS) open source Platform. The DCS System has also been integrated into *otsdaq*.

Readout: Trigger and DAQ / 483

Real-Time Signal Processing for Large-Volume Cyclotron Radiation Emission Spectroscopy

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The Project 8 collaboration seeks to measure the absolute neutrino mass using tritium beta decays and a new spectroscopy technique, Cyclotron Radiation Emission Spectroscopy (CRES). The initial phases of Project 8 demonstrated that CRES could be used to detect single-electron cyclotron radiation, and could be applied to measure the tritium beta-decay spectrum. The current phase of Project 8 will use a cylindrical array of up to 75 radio-frequency antennas to detect the cyclotron radiation from electrons in a $\sim$10 cm^3 fiducial volume. The data-acquisition and signal-processing (DAQ) system will assemble the signals from the antenna array using digital beamforming, and perform real-time triggering and reconstruction of the electron events. The digital-beamforming aspect presents a compelling challenge in designing a real-time DAQ system. We will present the DAQ architecture that is under development, and how we plan to address the DAQ requirements of the upcoming experiment.

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Readout: Trigger and DAQ / 616

Electronics for Multi-PMTs for the IWCD at Hyper-Kamiokande

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The Intermediate Water Cherenkov Detector (IWCD) will be a new near detector for the approved Hyper-Kamiodande experiment. It will use approx. 500 multi-PMT modules (mPMTs) as its photosensors. Each mPMT will house nineteen 3” PMTs enclosed in a water-tight pressure vessel, along with the associated electronics. In this talk, we will briefly describe the overall architecture of the electronics system, followed by a description of analog front-end electronics, digitization system utilizing flash-ADC converters, digital signal processing algorithms planned for data compression and extraction of pulse features (i.e. estimation of time of arrival and charge), and finally high voltage and slow-control systems.

Readout: Trigger and DAQ / 681

Development of a dedicated DAQ system for Crystal Eye pathfinder

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Crystal Eye is an innovative detector that aims to provide more information about the electromagnetic counterpart of gravitational waves by detecting X and Œ≥-rays events, improving the event localization of concurrent detectors. The detector consists of LYSO scintillation crystals, each one read by an array of Silicon Photomultipliers (SiPMs) and it has been positively evaluated to fly onboard the Space RIDER, an uncrewed reusable orbital spaceplane of the European Space Agency (ESA).
For the proposed detection module we developed a dedicated DAQ system consisting in a ZYNQ-based board which manage the HV provided to each SiPM, control the ASIC (CITIROC-1A) linked with the photomultipliers, the collection and storage of the data.
The board also implent two different levels of trigger, to better discriminate between the LYSO's self-activity and the detection of an event we are interested in, avoiding excessive consumption of redundant SSDs space.

Funding information:
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Readout: Trigger and DAQ / 432

System Design and Prototyping for the CMS Level-1 Trigger at the High-Luminosity LHC

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For the High-Luminosity Large Hadron Collider era, the trigger and data acquisition system of the Compact Muon Solenoid experiment will be entirely replaced. Novel design choices have been explored, including ATCA prototyping platforms with SoC controllers and newly available intercon- nect technologies with serial optical links with data rates up to 28 Gb/s. Trigger data analysis will be performed through sophisticated algorithms, including widespread use of Machine Learning, in large FPGAs, such as the Xilinx Ultrascale family. The system will process over 50 Tb/s of detector data with an event rate of 750 kHz. The system design and prototyping are described and examples of trigger algorithms reviewed

Readout: Trigger and DAQ / 345

The LHCb Upstream Tracker data flow architecture

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The current LHCb Tracker Turicensis is being upgraded to gain spatial resolution, accommodate higher occupancy and use a trigger-less data flow. The enhanced detector is called the Upstream Tracker (UT). A core part of the UT electronics is the SALT ASIC: a device tailored to the task with several transmission modes to optimize the number of differential pairs. This optimizes copper traces inside the detector acceptance. The different data transmission modes, together with the different granularity and expected data rates, will produce a variety of situations that the data flow architecture has to cope with. This contribution focuses on the UT,Äôs unique electronics and data processing architecture, how the readout adapts to the multiple scenarios that such tracking system imposes. It discusses the tradeoffs that had to be made so that the output data format is as homogeneous as possible across the different areas and how it tries to maintain a reasonable VHDL hardware implementation.

Readout: Trigger and DAQ / 365

Performance of the readout system of the ALICE ZDC calorimeters in LHC Run 3

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The ALICE ZDCs provide information about event geometry in heavy ion hadronic collisions through the detection of spectator nucleons and allow to estimate the delivered luminosity. They are also very useful in p-A collisions, allowing an unbiased estimation of collision centrality.

The Run 3 operating conditions will involve a tenfold increase in instantaneous luminosity in heavy-ion collisions, with event rates that, taking into account the different processes, could reach 5 MHz in the ZDCs. The challenges posed by this demanding environment lead to a redesign of the readout system and to the transition to a continuous acquisition. The new system is based on 12 bit, 1 Gsps FMC digitizers that will continuously sample the 26 ZDC channels. Triggering, pedestal estimation and luminosity measurement will be performed on FPGA directly connected to the frontend.

In this contribution the new readout system will be presented and the performances foreseen in Run 3 will be discussed.

Readout: Trigger and DAQ / 320

Triggering on charged particles in collider experiments

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We propose an algorithm, deployable on a highly-parallelized graph computing architecture, to perform rapid triggering on high-momentum charged particles at the Large Hadron Collider and future colliders. We use software emulation to show that the algorithm can achieve an efficiency in excess of 99.95% for reconstruction with good accuracy. The algorithm can be implemented on silicon-based integrated circuits using FPGA technology. Our approach can enable a fast trigger for massive charged particles that decay invisibly in the tracking volume, as in some new-physics scenarios. If production of dark matter or other new neutral particles is mediated by metastable charged particles and is not associated with other triggerable energy deposition in the detectors, our method is useful for triggering on the charged mediators using the small-radius silicon detectors. The estimated spurious trigger rate is below 40 kHz for the HL-LHC with 200 collisions per 25 ns beam crossing.

Readout: Trigger and DAQ / 554

Recent experience with Streaming Readout for CLAS12-Forward Tagger

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CLAS12 detector is installed at JLab and the purpose of its huge science program is to provide substantial progress in understanding the QCD. Such a detector requires a sophisticated trigger and current experiments use an on-line FPGA-based system that relies upon custom firmware and electronics both of which are difficult reconfigure from one experiment to the next. To overcome these challenges an effort is underway to develop streaming readout (SRO) data acquisition system. The latter would allow a more flexible, easier to debug, software trigger to be developed. A SRO prototype system was developed based on four main components: front-end electronics based on JLAB-FADC250 and VTP modules, TriDAS and CODA data acquisition systems and the JANA2 reconstruction framework. In this contribution I will present the results of successful on-beam test performed in the the winter and summer of 2020 to read in streaming mode, with the cited triggerless chain, the CLAS12 Forward Tagger.

Readout: Trigger and DAQ / 360

INO, RPC-DAQ module: Performance review and upgrade plans

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The India-based Neutrino Observatory (INO) has proposed to build a magnetised Iron-CALorimeter (ICAL) to study atmospheric neutrinos. The ICAL detector will use 28,800 Resistive Plate Chambers (RPCs) of 2 m x 2 m area as active detector elements. The particle interaction signals in the RPCs are amplified and converted into logic signals using discriminators. These logic signals are processed by the RPC-DAQ module which is mounted with every RPC. RPC-DAQ is built around Intel,Äôs Cyclone IV FPGA, HPTDC and Ethernet controller W5300. Pre-trigger signals generated in each RPC-DAQ, participate in forming a global event trigger (GT). On receiving the GT, the RPC-DAQ records mainly the event time, RPC strip-hit pattern along with relative time stamps of the hits. The strip rates, are recorded periodically in order to monitor the health of the RPCs. The RPC-DAQ then packages these data and sends them over Ethernet to the back-end servers. RPC-DAQ performance and upgrade plans will be presented.

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Hog (HDL on git): a collaborative HDL management tool

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Coordinating firmware development among many international collaborators is becoming a very widespread problem in high-energy physics. Guaranteeing firmware synthesis reproducibility and assuring traceability of binary files is paramount.
We devised Hog (HDL on git), a set of Tcl scripts (no external tool or library is needed) that tackles these issues and is deeply integrated with HDL IDEs (Xilinx Vivado Design Suite/ISE PlanAhead, Intel Quartus Prime).
Hog assures absolute control of HDL source files, constraint files, Vivado/Quartus settings and guarantees traceability by automatically embedding the git commit SHA and a numeric version into the binary file, also automatically renamed.
Hog allows the IDE GUI to be used normally, so developers can get quickly up to speed: clone repository, run Hog script, work on your IDE.
Hog works on Windows and Linux, supports IPbus, Sigasi and provides pre-made yml files to set up a working CI on Gitlab with no additional effort.

Readout: Trigger and DAQ / 640

Design of a Robust Fiber Optic Communications System for Future Giga-scale Neutrino Detectors

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In this work we discuss ongoing development of a hybrid fiber optic data and timing infrastructure for the future IceCube Gen2 detector. The IceCube Neutrino Observatory is a kilometer scale detector operating with 86 strings of modules. These modules communicate utilizing a custom protocol to mitigate the signaling challenges of long distance copper cables. Moving past the limitations of a copper-based backbone will allow larger future IceCube detectors with extremely precise timing and a large margin of excess throughput to accommodate innovative future modules. To this end, the upcoming IceCube Upgrade offers an opportunity to deploy a pathfinder for the new fiber optic infrastructure, called the Fiber Test System. This design draws on experience from AMANDA and IceCube and incorporates recently matured technologies such as ruggedized fibers and White Rabbit timing to deliver robust and high performance data and timing transfer.

Readout: Trigger and DAQ / 493

Muon trigger with fast Neural Networks on FPGA, a demonstrator

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As the LHC experiments are undergoing significant upgrades to prepare for the High Luminosity LHC run expected for 2027, trigger algorithms need to be redesigned to cope with the higher expected detector occupancy and the increased readout capabilities. Recent developments on the implementation of Neural Networks (NNs) on FPGA have opened the stage to low-latency inference, enabling highly specialized tasks to be carried out at trigger level. A muon tracking trigger algorithm is presented, combining NNs and analytic processing of time digitized signals generated on FPGA from drift tubes muon detectors. NNs are implemented on-line to univocally select signals compatible with genuine muons, thus removing the otherwise large amount of combinatorial. A fully integrated demonstrator based on CMS phase-2 upgrade front-end electronics is used as a testbed, where the trigger algorithm is fully implemented on a Xilinx Kintex Ultrascale. The algorithm and its performance will be described.

Readout: Trigger and DAQ / 328

Readout system and testbeam results of the RD50 MPW2 HV-CMOS pixel chip

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The RD50-CMOS group aims to design and study High Voltage CMOS (HV-CMOS) chips for use in a high radiation environment. Currently, measurements are performed on RD50-MPW2 chip, the second prototype developed by this group.
The active matrix of the prototype consists of 8x8 pixels with analog frontend. Details of the analog frontend and simulations have been already published earlier. Standard tests on passive test-structures have been performed as well and will be briefly mentioned.
This talk focusses on the Caribou based readout system of the active matrix. Each pixel of the active matrix can be readout one after the other. Details on slow-control, configuration settings and a setup for use in testbeams are given. Relevant aspects of hardware, firmware and software are introduced, always focusing on the operation of the chip in combination with a tracking telescope to measure efficiency and residuals.

Sensor Posters: Gaseous Detectors / 372

Neutron spectroscopy with a nitrogen-filled large-volume spherical proportional counter at high pressure

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In direct searches for dark matter, a dedicated, precise, and in-situ measurement of the neutron flux in underground laboratories is of paramount importance, as neutron induced backgrounds can mimic the standard dark matter signal.
We investigate the development of novel neutron spectroscopy technique, using spherical proportional counters (SPC) operated with N_2-based gas mixtures. This exploits the $^{14}N(n,Œ±)^{11}B$ and $^{14}N(n,p)^{14}C$ reactions for the detection of fast and thermal neutrons, respectively. Recent advancements in SPC instrumentation, including the multi-anode resistive sensor, improve the field homogeneity in the volume of the detector, provide efficient charge collection with high gain, and allow increased target masses through operation at high pressures. We present measurements of fast and thermal neutrons from an Am-Be source with SPCs installed at the University of Birmingham and the Boulby underground laboratory, operated in pressures up to 2 bar.

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Sensor Posters: Gaseous Detectors / 389

Hybrid high pressure TPC developments in measurements and simulations

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A hybrid readout Time Projection Chamber (TPC) is a TPC which is simultaneously read out by means of optical readout and charge readout. Optical readout of the device provides 2D images of particle tracks in the active volume, while the charge readout provides additional information on the particle position perpendicular to the image plane. Such a hybrid TPC working at high pressure is an attractive device for physics cases where a high target density is required as *e.g.* measuring a neutrino beam at the source of long baseline neutrino oscillation experiment. In this talk we will present two different lines of work towards the goal of developing hybrid TPC technology: a) Studies with gas electron multipliers employing optical and charge readout. b) An analytical parametrisation of the gas gain for a multi wire proportional chamber based on garfield++ simulations and validated with measurements, which allows to skip these simulations in the future altogether.

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Recent results on low-pressure Time Projection Chamber for Accelerator Mass Spectrometry

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Recent results on a new ion identification technique for Accelerator Mass Spectrometry (AMS), based on measuring the ion track ranges in low-pressure TPC, are presented. As a proof of principle, a low-pressure TPC with THGEM-based charge readout has been recently developed. In this work we developed a new, larger version of the TPC, with a dedicated thin silicon nitride window for efficient passage of ions. The THGEM gain was measured and the improved resolution for measuring the track ranges of alpha particles was obtained at the nominal TPC pressure (50 Torr). Using these results and SRIM code simulations, it is shown that isobaric boron and beryllium ions can be effectively separated at AMS. This technique will be applied in the AMS facility in Novosibirsk for dating geological objects, namely for geochronology of Cenozoic era.

Sensor Posters: Gaseous Detectors / 411

GEM detectors for the upgrade of the CMS Muon Spectrometer

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The Large Hadron Collider (LHC) will restart in 2022 (Run-3), colliding protons with an instantaneous luminosity of 2 ,àí 3 √ó 10^{34} cm^{,àí2} s^{,àí1}. A subsequent upgrade in 2025-27 (Long Shutdown 3 - LS3) will increase the luminosity up to 5 √ó 10^{34} cm^{,àí2} s^{,àí1}. The CMS muon system must enable a physics program that maintains sensitivity for electroweak measurements and for Beyond the Standard Model searches. To cope with the corresponding increase in trigger rates and to provide additional coordinate measurements in the high background environment, a first set of Gas Electron Multiplier (GEM) detectors have been installed and are currently being commissioned (GE11), while two more sets of GEM detectors (GE21, ME0), are finalizing R&D and preparing for construction. We present an overview of the muon spectrometer upgrade using the GEM technology, the performance of the GE11 chambers during Quality Control tests and in cosmic ray tests, and the design of the GE21 and ME0 chambers.

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Neutrino-hydrogen interactions with a high-pressure time projection chamber

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Long-baseline neutrino oscillation experiments are currently limited by systematic error due to nuclear effects of neutrino interactions. Obtaining new input data, especially of nuclear-free neutrino interactions at MeV tracking threshold for protons, could help to reduce these uncertainties.
A suitable detector that could provide a large number of neutrino-hydrogen interactions is the high-pressure gaseous time projection chamber, which is foreseen for DUNE's near-detector suite.
With the projected neutrino exposure,
$calO(10^4)$ neutrino-hydrogen events per year could be achieved with a filling of 50% Ar+alkanes, using the transverse-kinematic-imbalance method.
For design and operation of such a pressurized TPC, it is essential to study microscopic tracking parameters, e.g. drift velocity, to ensure performance at large detector scales. A systematic study of hydrogen-rich argon-alkane mixtures is presented and assessed in terms of expected operational abilities and challenges.

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Studies on impurities and F-radicals production in gaseous detectors operated with Freon based gas mixtures at LHC Experiments

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At the CERN LHC experiments several gaseous detectors are operated with Freon based gas mixtures. CF4 is used for wire chambers and Gas Electron Multiplier (GEM) detectors while C2H2F4 and SF6 for Resistive Plate Chambers (RPCs). Under the effects of electric field and radiation, these gases undergo radiolytic dissociation producing new molecules and radicals, which could be detrimental to detector long term operation.
During LHC Run 2 several gas analyses were performed on the gas mixtures of RPCs and GEMs operated in ALICE, CMS and LHCb experiments. It was observed that several impurities and F- radicals are created inside the detectors and their concentration depends on several factors. Systematic studies on F- production in RPC and GEM detectors have been performed at CERN GIF++ with high background radiation. Correlations between impurities, gas flow, integrated charge, rate and detector currents were established.A comprehensive overview of the results obtained will be presented

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High rate capability studies of triple-GEM detectors for the ME0 upgrade of the CMS Muon spectrometer

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In the CMS Muon System gaseous detectors, the increase in luminosity will produce a particle background ten times higher than at the LHC. To cope with the high rate environment and maintain the actual performance, the triple-Gas Electron Multiplier technology is a promising candidate as high-rate capable detectors for the CMS-ME0 project. An intense R&D and prototype phase is currently ongoing to prove that technology meets the stringent performance requirements of highly efficient-particle detection in the harsh background environment expected in the ME0 region. The authors will describe the recent rate capability studies on triple-GEM detectors by using a high intensity X-ray generator. We will present the novel foils design based on double-sided segmented GEM-foils, high voltage distribution powering and filtering, which the collaboration adopted for realization of the latter projects, and their impact on the performance of the detector in the light of new rate capability studies.

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Radiation Background estimation for the GE1/1 Triple-GEM detector in the CMS endcap

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The Compact Muon Solenoid (CMS) is a general-purpose particle detector at the Large Hadron Collider (LHC) designed to study a wide range of particles produced in high energy collisions. These particles interact with the beam pipe, shielding and detector supporting materials to produce neutrons, gammas, electrons and positrons, forming a common background radiation field for CMS. A Monte-Carlo simulation is used to predict the change in the background due to the evolution of the CMS detector geometry expected for the Phase-2 upgrade. In the forward region, the upgrade includes Gas Electron Multiplier (GEM) detectors called GE1/1. In this study, an estimate of the GE1/1 detector response to the background radiation is presented. The flux of background radiation is predicted using the FLUKA framework and the response of the detector is predicted using the GEANT4 framework. A comparison of the prediction and GEM Slice Test data is done for validation of the technique.

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CMS RPC upgrade program

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The LHC will be upgraded in several phases that will allow significant expansion of its physics program. The luminosity of the accelerator is expected to exceed 5$\sqrt{}$ó1034cm,àí2s,àí1. In order to sustain the harsher conditions and to help maintaining good trigger efficiency and performance the Resistive Plate Chambers (RPC) system of the CMS experiment will be upgraded.
The present RPC system would continue to operate, and it would be upgraded with new Link Boards system. In addition, the coverage of the RPC system would be increased up to pseudo rapidity of 2.4 by installing a new generation of improved RPCs (iRPCs). Their design and configuration are optimized to sustain higher rates and hence to survive the harsh background condition during HL-LHC operation. The iRPC are equipped with newly developed electronics designed to read out the detectors from both sides, allowing in this way a good spatial resolution along the strips O(cm). The status of the upgrade project will be presented.

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Hydrodynamic simulation studies on avalanche and streamer formation in GEM detector

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The dynamics of electrons and ions in gaseous ionization detectors have been studied reasonably well with particle simulation models developed using the Garfield++ numerical simulation framework. This is an important area of study since it allows prediction of the detector response in a given experimental situation. In this work, a fluid simulation model has been developed in the COMSOL Multiphysics simulation framework to simulate the avalanche and streamer formation in GEM-based detectors. Possible detector geometries in 2D, 2D axisymmetric and 3D coordinate systems have been explored to find the optimum numerical configuration. Transport of charged fluids has been simulated in the optimized model for various operating voltage ranges suitable for single, double and triple GEM detectors using Ar + CO2 (70:30) as the gas mixture. Simulated gain variations have been compared with experimental observations. Effect of space charge and its relation to streamer formation have been studied.

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Micromegas with high-granularity readout: stability and performance at high particle rates

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Micromegas (MM) are being used as tracking detectors in HEP experiment upgrades. For applications at future accelerator experiments, we are developing the MM technology to increase its rate capability and reach a stable and efficient operation up to particle fluxes of 10 MHz/cm2.
In resistive MM, the anode plane hosts the readout elements overlayed by an insulator and a resistive plane to reduce the spark intensity. We tested several MM prototypes with a high-granularity readout plane, with 1x3 mm2 size pads, and different resistive protection schemas exploiting a pad-patterned layer or two uniform DLC layers.
To cope with the high number of readout channels and allow for the size scalability of the detector avoiding dead areas, we are implementing the integration of the readout electronics in the back of the detector.
We will present measurements to assess the optimal resistive schema and preliminary results on the embedded electronics prototype currently under test

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Studies of charging up in THGEMs

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The time-dependent variation of detector response in MPGDs, especially THGEMs, is a challenging problem that has been attributed to the “charging up” and “charging down” processes of insulating materials present in these detector. Experimental studies of stabilization of gain with time due to these phenomena under various experimental conditions have been given in the presentation. Effects of sources with varying irradiation rates on the gain saturation process have been studied. Low-rate source shows two-step gain stabilization phenomena, one short-term saturated gain, another long-term saturated gain, whereas high-rate source shows just one-step gain saturation. While this two-step stabilization has been attributed to the charging up of the rim by earlier studies, its effect seems to be subdued for high-rate irradiation according to the observations presented here. The final results provide an insight into the transients of gain saturation in THGEMs.

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Development of Micromegas detectors with high radio-purity and energy-resolution using a thermal bonding method for the PandaX-III experiment

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High pressure gaseous Time Projection Chamber (TPC) with Micromegas, which is considered to be a very attractive solution for the next generation of ton scale 0vŒ≤Œ≤ experiment, features the high granularity, high energy resolution, and low radioactive background. The PandaX-III experiment adopted the TPC scheme and will search for 0vŒ≤Œ≤ of Xe-136 at China Jinping Underground Laboratory. In this work, we present R&D of Micromegas with thermal bonding method at USTC. Thermal bonding Micromegas offers spark-resistant and dead-channel-free readout modules for readout. We first report the specific design and manufacturing process for this radio-pure and high energy resolution Micromegas detector with active area of 200mm$\sqrt{}$ó200mm. The prototypes were characterized under 10 bar pressure and the performance such as gas gain, energy resolution, and long-term stability etc, were studied in detail, and the results are presented and show a promising solution for PandaX-III experiment.

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Time and band-resolved scintillation studies in high pressure xenon

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We have conducted systematic measurements for different particle types, pressures, and electric fields, resolving the second and third continuum components of the scintillation in high pressure xenon. We observe that the third continuum emission, despite being a subdominant contribution to the overall scintillation in the 150-500nm range, represents an important contribution to its fast component. Third continuum is both fast and immune to electric-field field effects, contrary to the recombination component of the second continuum, that is slow in gas phase and strongly field-dependent. In particular, and as noted recently for the case of argon (arXiv:2012.08262), these observations enable particle-identification schemes based on the different spectral components of the scintillation.
We will present a comprehensive description of the experimental results in light of the microscopic simulation toolkit for scintillation in gases, recently developed by our group, and future prospects.

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New studies on the rate capability of resistive gaseous detectors

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The introduction of resistive elements in gaseous detectors has been a real breakthrough, since it provided them with auto-triggering capabilities, spark protection and long term stability. Though, it adds a limitation on the maximum flux of particles that can be measured without efficiency loss, and this is of major relevance both for the operation of the experiments at the High Luminosity LHC, and for the design of the detection systems at the next generation of accelerators. Therefore understanding how to optimize rate capability without losing other benefits will be of paramount importance. Here the latest results about rate capability of various kinds of gaseous detectors will be presented, and compared to a mathematical model able to describe the complex processes taking place in gaseous detectors operating at high rate. Also the implications of the insights gained during this study on the design of the future generation experiments featuring gaseous detectors will be discussed.

Sensor Posters: Gaseous Detectors / 621

Improved Resistive Plate Chambers for the upgrade of the CMS muon detector

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Several upgrades of the CMS Resistive Plate Chamber (RPC) system are currently being implemented to ensure a highly performing muon system during the upcoming High Luminosity phase of the Large Hadron Collider (HL-LHC) which will have an increased integrated luminosity of 3000 fb^{-1}. An improved version of the existing RPCs (iRPCs) will be installed in the forward region of the 3rd and 4th endcap disks. These iRPCs offer a better spatial resolution of the order of a few cm along the strip direction and the new front-end electronics is designed to fully exploit the intrinsic time resolution of the iRPCs. The performance of the proposed iRPCs has been studied at the CERN Gamma Irradiation Facility (GIF++). A longevity study is ongoing, and main detectors parameters (currents, rate, resistivity) are regularly monitored as a function of the integrated charge. The present overall status of the CMS iRPC project, including also results of the ongoing studies at GIF++ will be presented.

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GEM foil characterization in cost-effective, and efficient way and attempt made to use it as an imaging detector

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Increasing demand for security scanners and medical imaging techniques has risen with the advancement of technology based on silicon sensors. However, these technologies are much expensive and require critical handling. The Gas Electron Multiplier (GEM) foil based detector has been attempted to use as an imaging detector. GEM foil is generally constructed using 50 μm highly insulating film coated with 5 μm copper on both sides and a network of highly dense double conical holes of size 50-70 μm in it. Due to the microscopic structure of holes and the dependence of the electric field inside them, it becomes essential to study the defects and uniformity of holes along with the electrical property of foils in various conditions. In our work, we have tested GEM foils both optically and electrically and saw the response of the triple-layered GEM detector in various gas mixture ratio to study the best operating point along with stability and uniformity.

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Absolute primary scintillation yield in Xe for electrons and alpha particles

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Xenon scintillation has been widely used in recent particle physics experiments. However, information on primary scintillation yield in the absence of recombination is still scarce and dispersed. The mean energy required to produce a VUV scintillation photon (Wsc) in gaseous Xe has been measured in the range of 30-120 eV. Lower Wsc-values are often reported for alpha particles compared to electrons produced by gamma or x-rays, being this difference still not fully understood.
We carried out a systematic study of the absolute primary scintillation yield in Xe at 1.2 bar, using a Gas Proportional Scintillation Counter. The simulation model of the detector's geometric efficiency was benchmarked through the primary and secondary scintillation produced at different distances from the photosensor. Wsc-values were obtained for gamma and x-rays with energies in the range 5.9-60 keV, and for 2-MeV alpha particles. No significant differences were found between alpha particles and electrons.

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A Wire Tension Analyzing Instrument for Particle Physics Detectors

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We present a hardware tool that is capable of measuring wire tensions in particle physics detectors in a rapid and automatic way, greatly improving on the time required to perform quality control measurements compared to the traditional method of physically stimulating the wires. The instrument measures a wire tension by applying a combination of AC and DC current on the neighboring wires, which causes the central wire to oscillate and a current to be induced by the changing capacitance of the system. It then sweeps through a range of AC frequencies, and a resonance is observed at the natural frequency of the wire, which identifies the tension. The instrument can also measure multiple wire tensions simultaneously, and can measure hundreds of wire tensions in a single automated process.

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Development of a fast simulator for GEM-based neutron detectors

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Gas Electron Multiplier (GEM)-based detectors using a layer of ^{10}B as a neutron converter is becoming popular for thermal neutron detection. A common strategy to simulate this kind of detector is based on two frameworks: Geant4 and Garfield++. The first one provides the simulation of the nuclear interaction between neutrons and the ^{10}B layer, while the last allows the simulation of the interaction of the reaction products with the detector gas leading to the ionization and excitation of the gas molecules. Given the high ionizing power of this nuclear reaction products, a full simulation is very time consuming and must be optimized to become viable. In this work, we present a strategy to develop a fast simulator based on these two frameworks that will allow to generate enough data for a proper evaluation of the expected performance and optimization of this kind of detector. We will show the first results obtained with this tool concentrating on its validation and performance.

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Characterization and Calibration of a Triple-GEM Detector for Medical Dosimetry

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We characterized and calibrated a triple Gas Electron Multiplier (triple-GEM) detector, and studied its possible applications in medical dosimetry. The response to various sources of radiation was analyzed, and its efficiency, gain, energy resolution, and time resolution were calculated. Then, radiation doses from an Iron-55 source and a medical portable X-ray machine were measured, obtaining the calibration factor for the GEM detector by comparison with reference values.
We found an energy resolution of 19.5%, a time resolution of 40ns, and a maximum gain of 5×10^6. The detector's response to dose measurements was linear, with a calibration coefficient of 1.13×10^4 for different sources of radiation. It was concluded that GEM detectors can be reliably used as dosimeters in nuclear medicine and radiology.

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Development of THGEM-based detectors for Nuclear Fission Studies

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To optimize the exploration of Super Heavy Elements (SHE), the key challenge is to understand the dynamics of fusion-fission reactions through the measurement of mass and angular distributions of the fission fragments. For the detection of the fission fragments, position-sensitive Multi-Wire Proportional Counters are usually used due to their high gain, good temporal and position resolutions. However, these detectors use fragile anode wires having a diameter of only 10 microns and therefore are not portable. In the present work, a detector based on robust THick Gaseous Electron Multiplier (THGEM), has been proposed. In the presentation, a numerical demonstration of THGEM-MultiWire hybrid detector technology as a possible candidate for new generation low energy fission studies and their evaluation as a function of different possible geometric and electric configurations in low-pressure Isobutane gas will be discussed.

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Sensor Posters: Gaseous Detectors / 300

Options for gain elements and gas mixtures in a high rate EIC Time Projection Chamber

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ÔÄ† ÔÄ† In order to investigate options for a future high rate TPC we have tested various gas gain structures and gas mixtures. Our goal was to focus on crucial TPC parameters: ion back flow, energy resolution (dE/dx), electron and ion drift speed, electron diffusion (in E- and B-fields), and stability. We concentrated on two options for the gain structure: 4 GEMs and MMG+2GEMs. We investigated a potential instability (MMGs) that occurs primarily from a high voltage (HV) power supply (PS) voltage drop in reaction to a discharge. It was demonstrated that a resistive protection layer on a readout structure reduces the HV PS voltage drop after a spark to practically negligible levels. The hybrid micro-pattern gas amplification stage allows for a TPC design that can operate in a continuous mode, serves as an option to limit space charge distortions in high-rate TPCs, and guarantees that dE/dx, space reconstruction resolution, drift parameters and detector stability will not be compromised.

Sensor Posters: Gaseous Detectors / 302

Construction of an RPC using additive manufacturing technology

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In this work, we report the progress in the design and construction of an RPC detector fully built using additive manufacturing technology, an emerging/interdisciplinary engineering domain only partially utilized in HEP.
Our novel design of the 3D detector stack can be automatically and fully constructed in short time, ensuring repeatability and accuracy, while minimizing construction mistakes. 3D printing, applied to instrumentation for physics enhances detector performance and capabilities, cutting construction costs and improving standardization over large scale productions. The delivered detector constitutes a new generation of RPC detectors, electrically equivalent to the existing ones but mechanically better and standardized according to the prescribed specifications.
We aim at proving the feasibility studies of a 3D printed detector that features state-of-art performance, at a fraction of the cost and potentially constructed without the need of external industrial partners.

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Numerical Evaluation of Electric Field and Dark Current of Resistive Plate Chamber

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It is important to understand the calculation of electric field and current in RPC in order to envisage the working of the device. This is useful in optimizing its design and operation for specific applications. A method of calculating the 3D electric field using the law of full current conservation showed that the voltage drop across the gas gap is same as that applied across the resistive electrodes and reproduced the ohmic region of the I-V characteristics. The electrical equivalent circuit of RPC modeled in other works simulated the non-ohmic region, but did not calculate field configuration in the gas gap. We have performed a calculation of the electric field and current of RPC from the first principle using finite element method. The results have been compared to the analytic approach to establish the model. It has been then used to study the effect of the electrode and spacer materials on field configuration and dark current and produce the non-ohmic character of the I-V graph.

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Performance of the Multigap Resistive Plate Chambers of the Extreme Energy Events Project

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The muon telescopes of the Extreme Energy Events (EEE) Project are made up of 3 Multigap Resistive Plate Chambers (MRPC). The whole array is composed of 61 telescopes installed in Italian High Schools, constructed and operated by students and teachers, constantly supervised by CREF and INFN researchers.

The unconventional working sites are a unique test field for checking the robustness and the low-ageing features of the MRPC technology for particle tracking and timing purposes. The MRPCs are fluxed with a standard mixture (98% C2H2F4 - 2% SF6), of greenhouse gases (GHG) phasing out of production.

The EEE Collaboration aims to find an environmentally and economically sustainable gas mixture in order to reduce GHG emissions, without affecting MRPC excellent performance.

Performance in terms of time and spatial resolution, efficiency, tracking capability and stability will be described, together with a comparison with expectations and with the results obtained using new gas mixtures.

Sensor Posters: Light-based Detectors / 659

Fast and Radiation Hard Inorganic Scintillators for Future HEP Experiments

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Future HEP experiments at the energy and intensity frontiers require fast and ultrafast inorganic scintillators with excellent radiation hardness to face the challenges of unprecedented event rate and severe radiation environment. We report recent progress in fast and ultrafast inorganic scintillators for future HEP experiments. Examples are LYSO crystals and LuAG ceramics for an ultra-compact shashlik sampling calorimeter for the HL-LHC and the proposed FCC-hh, and yttrium doped BaF2 crystals for the proposed Mu2e-II experiment. Applications for Gigahertz hard X-ray imaging will also be discussed.

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Sensor Posters: Light-based Detectors / 311

Detection of low-energy X-rays with 1/2 and 1 inch LaBr3:Ce crystals read by SiPM arrays

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LaBr3:Ce crystals are used for radiation imaging in medical physics, with PMT or SiPM readout. A R&D was pursued with 1/2 and 1" crystals to realize compact large area detectors (up to some cm^2 area) with SiPM array readout, aiming at high light yields, good energy resolution/linearity and fast time response for low-energy X-rays. The study was triggered by the FAMU experiment at RIKEN-RAL μ facility. The goal is the detection of characteristic X-rays around 130 KeV. Other applications may be foreseen in medical physics, such as PET and gamma-ray astronomy. A direct readout, employing CAEN V1730 FADCs, better suited for applications, was used. The temperature gain drift of SiPM was controlled by custom NIM modules, based on CAEN A7585D power supply chips. Laboratory test results will be reported. As an example, at the Cs^{137} peak, an energy resolution up to ˜3 % was obtained, with Hamamatsu S14161 array SIPM. This compares well with best results obtained with PMT readout.

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The upgrade of the LHCb RICH detector

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The two LHCb RICH detectors have provided excellent particle ID until the end of Run2 in 2018 operating at the luminosity of $\sim 4 \times 10^{32}$ $cm^{-2}s^{-1}$. From the beginning of Run3 in 2022, the Level 0 hardware trigger of the experiment will be removed to allow data readout at the full LHC collision rate of 40 MHz and the luminosity will be increased to $\sim 2 \times 10^{33}$ $cm^{-2}s^{-1}$. In order to adapt the RICH system to the new rate, the current HPD detectors with embedded electronics limited to readout event rate of 1 MHz have been replaced by MaPMTs with external readout electronics. Moreover, in order to reduce the occupancy of the photon detectors due to the higher luminosity, a reoptimization of the optics is required. In this talk the upgraded opto-electronics chain and the performance expected for Run3 will be presented together with the automated quality control procedures to qualify the RICH photon detectors and support electronics.

Sensor Posters: Light-based Detectors / 347

Strong light yield enhancement in oriented crystalline media for homogeneous calorimetry

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Scintillating homogeneous detectors represent the state of the art in electromagnetic calorimetry. Moreover, the currently neglected crystalline nature of the most common inorganic scintillators can be exploited to achieve an outstanding performance boost in terms of compactness and energy resolution. In fact, it was recently demostrated by the AXIAL/ELIOT experiments that a strong reduction in the radiation length inside $PbWO_4$, and a subsequent enhancement in the scintillation light emitted per unit thickness, are attained when the incident particle trajectory is aligned with a crystal axis within $\sim 0.1^\circ$. This remarkable effect has been directly observed at CERN with a 120 GeV/c electron beam and a custom, SiPM-based light readout system. The same concept can be applied to full-scale detectors that would feature a design significantly more compact than currently achievable and unparalleled resolution in the range of interest for present and future experiments.

Sensor Posters: Light-based Detectors / 400

Development of the in-situ Calibration System using LEDs and Light Guide Plates for the SuperFGD

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T2K is a long-baseline neutrino experiment that aims to investigate the CP violation in the neutrino sector. An upgrade of the ND280, which is one of the T2K near detectors, is in progress. The active target detector of the upgraded ND280 is a segmented highly granular plastic scintillation detector (SuperFGD) consisting of about two million cubes. About sixty thousand silicon photo-multipliers (SiPMs) coupled with wavelength shifting fibers are used for light readout. The fibers go through the scintillator cubes along the orthogonal three directions. We developed a new system based on LEDs and notched light guide plates for in-situ calibration of SuperFGD. The developed system can distribute LED light for SiPMs simultaneously with high uniformity and be used for gain calibration and stability monitor of the signal readout. In addition, it can fit in the confined space of the SuperFGD due to its thin structure. We will present the design and the performance of the calibration system.

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Electroluminescence yield in pure krypton

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The krypton electroluminescence yield was studied, at room temperature, as a function of electric field in the gas scintillation gap. A large area avalanche photodiode has been used to allow the simultaneous detection of the electroluminescence pulses as well as the direct interaction of x-rays, the latter being used as a reference for the calculation of the number of charge carriers produced by the electroluminescence pulses and, thus, the determination of the number of photons impinging the photodiode. An amplification parameter of 113 photons per kV per drifting electron, a scintillation threshold of 2.7 Td and an ionisation threshold of 13.5 Td was obtained. The krypton amplification parameter is about 80% and 140% of those measured for xenon and argon, respectively. The electroluminescence yield in krypton is of great importance for modeling krypton-based double-phase or high-pressure gas detectors, which may be used in future rare event detection experiments.

Sensor Posters: Light-based Detectors / 526

PANDA Barrel DIRC: From Design to Component Production

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Excellent particle identification (PID) will be essential for the PANDA experiment at FAIR. The Barrel DIRC will separate kaons and pions with at least 3 s.d. for momenta up to 3.5 GeV/c and polar angles between 22 and 140 deg.
After successful validation of the final design in the CERN PS/T9 beam line, the tendering process for the two most time- and cost-intensive items, radiator bars and MCP-PMTs, started in 2018. In Sep. 2019 Nikon was selected to build the fused silica bars and successfully completed the series production of 112 bar in Feb. 2021. Measurements of the mechanical quality of the bars were performed by Nikon and the optical quality was evaluated at GSI. In Dec. 2020, the contract for the fabrication of the MCP-PMTs was awarded to PHOTONIS and the delivery of the first-of-series MCP-PMTs is expected in June 2021.
We present the design of the PANDA Barrel DIRC as well as the status of the component series production and the result of the quality assurance measurements.

Sensor Posters: Light-based Detectors / 557

The LYSO scintillation light measurement with an ultra-fast MCP-PMT

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The scintillator can be seen as a wavelength shifter which converts the incident particle into a number of photons. The decay time of scintillators is measured by coupling the scintillation with the photosensitive device. Through the scintillation light waveform sampling and the decay time exponential fitting, we can obtain the decay time of the scintillation. Traditionally the photosensitive device used to measure the scintillation light have a rise time on the order of ns. In our experiment, an ultra-fast MCP-PMT with a rise time of 100 ps and a transit time spread of 46 ps at single-photon mode was used to be coupled with the Lu1.8Y2SiO5:Ce (LYSO) scintillator and obtain the scintillation light waveforms. The waveform obtained is not a complete scintillation pulse, the photons in one scintillation event are distinguished and becomes discrete pulses. The results will show the intrinsic decay time of the LYSO and may be an experimental prove of some scintillator luminescence theory.

Sensor Posters: Light-based Detectors / 573

Systematic Study of LED Stimulated Recovery of Radiation Damage in Optical Materials

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The radiation damage in optical materials, mostly manifest as the loss of optical transmission, recovers to some extent in the presence of natural light, and at a faster rate in the presence of stimulating light. On the other hand, the systematic study of the dynamics of the recovery as a function of the stimulating light parameters such as its wavelength, intensity and exposure duration and method has not been performed in detail.

We established an LED recovery station which provides pulsed and continuous light at various wavelengths at custom geometries. The study starts with the irradiation of optical samples at various gamma doses at a rate of 87.5 Gy/min. The optical transmittance of the samples are then measured in 200 nm - 2000 nm range for an extended period of time.

Here we report on the details of the irradiation and recovery setups, and the results of recovery from radiation damage under different light exposure mechanisms.

Sensor Posters: Light-based Detectors / 581

High-quality aerogel Cherenkov radiators recently developed in Japan

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Japan,Äôs KEK laboratory started developing silica aerogels as a Cherenkov radiator around 1980. The high-energy physics group at Chiba University began aerogel R&D ˜15 years ago, collaborating with KEK. Improving aerogel transparency enables the design of state-of-the-art ring-imaging Cherenkov (RICH) detectors. This study was first motivated by the radiator R&D for the Belle II Aerogel RICH (ARICH) detector. The technology was later transferred to the HELIX RICH and EMPHATIC ARICH detectors. In parallel, ultrahigh- and ultralow-refractive-index aerogels were developed for filling the gap in available indices for the identifications of low- and high-momentum particles, respectively. These were and will be employed in the ongoing and future hadron experiments in Japan and for the EMPHATIC beam identification counters at Fermilab and the NASA HELIX balloon payload in Antarctica. We report the latest results from the aerogel R&D and ongoing applications to threshold-type and RICH counters.

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Radiation Damage and Recovery Mechanisms in Scintillating Fibers

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Optical scintillating Ô¨Åbers lose their transparencies when exposed to radiation. Nearly all studies of radiation damage to optical Ô¨Åbers so far only characterize this darkening with a single period of irradiation. Following the irradiation, Ô¨Åbers undergo room temperature annealing, and regain some of their transparencies. We tested the irradiation-recovery characteristics of scintillating fibers in four consecutive cycles.

In addition, three optical scintillating Ô¨Åbers were irradiated at 22 Gy per minute for over 15 hours, and their transmittance were measured each minute by pulsing a light source through the Ô¨Åbers. Here, we report on the in-situ characterization of the transmittance vs radiation exposure, allowing future applications to better predict the lifetime of the scintillating Ô¨Åbers.

Sensor Posters: Light-based Detectors / 600

Measurement of Light Yield, Timing and Radiation Damage and Recovery of Common Plastic Scintillators

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PEN and PET (polyethylene naphthalate and teraphthalate) are common plastics used for drink bottles and plastic food containers. They are also good scintillators. Their ubiquity has made them of interest for high energy physics applications, as generally plastic scintillators can be very expensive. However, detailed studies on the performance of the scintillators has not yet been performed.
At various tests, we measured the light yield and timing properties of PEN and PET with Fermilab and CERN test beams. We also irradiated several samples to varying gamma doses and investigated their recovery mechanisms. Here we report on the measurements performed over the past few years in order to characterize the scintillation properties of PEN and PET and discuss possible future implementations.

Sensor Posters: Light-based Detectors / 606

Development of an Argon Light Source as a Calibration and Quality Control Device for Liquid Argon Light Detectors

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The majority of future large-scale neutrino and dark matter experiments are based on liquid argon detectors. Since liquid argon is also a very effective scintillator, these experiments also have light detection systems. The fact that none of the existing photodetectors alone is sensitive to the liquid argon scintillation wavelength of 127 nm leads to the development of specialized light detectors, mostly based on wavelength shifters. The effective calibration and quality control of these newly developed detectors is still a persisting problem.
In order to respond to this need, we developed an argon light source which is based on plasma generation and light transfer across a MgF2 window. The light source is designed as a small, portable and easy to operate device to enable the acquisition of performance characteristics of several square meters of light detectors. Here we will report on the development of the light source and its performance characteristics.

Sensor Posters: Light-based Detectors / 641

Upgrade of Belle II ARICH detector

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Aerogel RICH currently identifies charged particles in the Belle II spectrometer. Cherenkov photons, emitted in the aerogel radiator are detected by single-photon Hybrid Avalanche Photon sensors working in a 1.5 T magnetic field and occupying an area of 4.5 m^2. By 2030 the Belle II will reach its design goal of 50 ab^{-1} and the HAPD performance will degrade. The upgrade of the spectrometer to extend its operation will thus require replacement of the ARICH photo-sensors. Silicon photomultipliers are one of the candidates. Due to its sizeable dark count rates and their sensitivity to neutrons ,Äì we expect fluences of up to 5×10^{12} n/cm^2 - such a device requires to read out the signals in a narrow time window of several ns, requiring optimized SiPM design and high integration with the read-out electronics. In the presentation, we will present a SiPM module design, a study of single-photon detection capabilities of irradiated SiPMs and read-out FastIC chip.

Sensor Posters: Light-based Detectors / 648

Developing the high-performance DIRC detector for the future Electron-Ion Collider

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The Electron-Ion Collider (EIC) will be the next frontier project of nuclear physics in the United States. Excellent particle identification (PID) is one of the key requirements for the EIC central detector. A radially compact PID system using the Detection of Internally Reflected Cherenkov light (DIRC) principle is a very attractive solution to meet these requirements.
The R&D program performed by the EIC PID collaboration (eRD14) is focused on developing the innovative high-performance DIRC (hpDIRC) that would extend the DIRC pion/kaon separation power well beyond the state-of-the-art to 3 standard deviations or more up to at least 6 GeV/c. Key components of the hpDIRC are a 3-layer compound lens and small pixel-size photo-sensors. This contribution presents major developments in the hpDIRC R&D program, with a focus on developing and validating the radiation-hard focusing optics, and the preparation of the hpDIRC prototype program with a Cosmic Ray Telescope and particle beams.

Sensor Posters: Noble Liquids / 612

WITHDRAWN - Spectroscopic-based particle discrimination in Ar gas

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We performed a time-resolved spectroscopic study of the VUV/UV scintillation in argon gas as a function of pressure and electric field, with a wavelength sensitive detector operated with different radioactive sources. Distinctive features of the argon light are evidenced, which are in contrast with the general assumption that the scintillation is mainly monochromatic at 128 nm.
Our work opens new paths toward novel particle identification techniques based on the spectral information of the scintillation light. This technique is complementary to the ones currently used in dual phase TPCs and offers new ways to reduce significantly the background leakage. The results of our R&D on this novel particle discrimination technique will be presented in this talk along with future plans for large-scale detector applications.

Sensor Posters: Noble Liquids / 517

A new high voltage cable feedthrough concept for future dark matter and neutrino experiments

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Physics experiments featuring liquid noble gas time projection chambers are becoming larger in scale. Consequently, their high voltage (HV) requirements have increased as well, making conventional design HV feedthrough (FT) impracticable. A new concept for a HV cable FT usable in cryogenic environment is presented. It features a co-extruded multi-layered coaxial cable fabricated with a single material and relies on the ability to develop a plastic material with tunable resistivity.

Sensor Posters: Noble Liquids / 322

Wavelength-Shifting Performance of Polyethylene Naphthalate Films in a Liquid Argon Environment

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Liquid argon is commonly used as a detector medium for neutrino physics and dark matter experiments in part due to its copious scintillation light production in response to its excitation and ionization by charged particle interactions. As argon scintillation appears in the vacuum ultraviolet (VUV) regime and is difficult to detect, wavelength-shifting materials are typically used to convert VUV light to visible wavelengths more easily detectable by conventional means. Here we present the results of recent investigations into the wavelength-shifting and optical properties of polyethylene naphthalate (PEN), a proposed alternative to tetraphenyl butadiene (TPB), the most widely-used wavelength-shifter in argon-based experiments.

Sensor Posters: Photodetectors / 725

Optical Model for Large Area Photomultipliers of JUNO and Other

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Photomultipliers (PMTs) are widely used in scintillation and Cherenkov detectors for their great performances on photon detection. For example, the Jiangmen Underground Neutrino Observatory (JUNO) will use ˜18,000 20-inch PMTs in its central detector to achieve an unprecedented energy resolution of 3%/,àö(E(MeV)). A key parameter of PMT is its detection efficiency (DE), which will be strongly influenced by the optical processes in PMT including: (1) Reflection between external medium and PMT bulb. (2) Reflection, absorption and transmission on its anti-reflective coating and photocathode, in which interference effect happens. (3) Multiple reflection inside PMT. Based on multilayer thin film theory, experimental tests and Geant4 simulations, a PMT optical model has been established for the 20-inch PMTs used in JUNO, including the NNVT MCP-PMT and the Hamamatsu dynode PMT. In this talk, the PMT optical model and its related experimental tests will be introduced.

Sensor Posters: Photodetectors / 362

Characterisation of Hamamatsu SiPM for cosmic muon veto detector at IICHEP

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A miniature version of ICAL experiment at the India-based Neutrino Observatory, mini-ICAL is running at Madurai, India. A Cosmic Muon Veto detector on top of mini-ICAL is going to be made with extruded plastic scintillators with embedded WLS fibers to propagate light and SiPM as photon transducers. A test setup is built to characterise the SiPM along with the muon detection efficiency of the scintillator detector. The SiPM will be calibrated using LED source, but also alternate calibration procedure using radio-active source as well as noise data is also tested as alternate procedures. The SiPM is operated at various overvoltage (Vov) to choose the operational Vov by optimising the muon detection efficiency and noise rate. The muon position along the length is measured using timing information on both sides of the fibre. These results along with specific characteristics of SiPM, e.g. after pulse, cross-talk, recovery time etc will be presented in this talk.

Sensor Posters: Photodetectors / 368

Silicon Geiger Hybrid Tube (SiGHT) for future rare event search experiments

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The Silicon Geiger Hybrid Tube (SiGHT) is a novel photosensor designed for future generations of rare event search experiments using noble liquids. The idea is to replace conventional multi-dynode photomultiplier tubes (PMTs) with a hybrid technology, consisting of a low temperature sensitive bi-alkali photocathode for conversion of photons into photoelectrons and a low dark count Silicon Photomultiplier (SiPM) for photoelectron signal amplification. SiGHT can achieve ultra low internal radioactivity, high quantum efficiency and stable performance at low temperatures, which are required features for direct dark matter search and neutrinoless double beta decay experiments. The R&D work of SiGHT, as well as the fabrication and test of the first prototype, will be presented.

Sensor Posters: Photodetectors / 414

Simulation of Charge Sharing Effects in 70 ¬μm Pixelated CdTe Sensor

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Pixel detectors are an integral part of medical imaging, particle physics, and many other research areas. Sensors are made from various types of materials such as GaAs, Si, CdTe. Current research tends to use CdTe as X-ray sensors due to its high absorption coefficient in the X-ray spectrum. With decreasing size of pixels, charge diffusion causes charge sharing between neighboring pixels. That decreases the spatial and spectral resolution.
This study simulated the effects of charge diffusion in a 2 mm thick 70 ¬μm pixelated CdTe. We created a sensor model with an array of 5 x 5 pixels, and we simulated the propagation of e-h pairs generated upon absorption of a gamma photon. Based on the simulation outcome, we calculated the total charge distribution between neighboring pixels, and we estimated the dynamic range in electrons of the analog front-end amplifier. Finally, we created a Verilog-A sensor model, which is to be used for analog front-end design.

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Sensor Posters: Photodetectors / 422

Study on the properties of a multi-anode MCP-PMT and cross-talk suppression

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We studied the performance of a MCP-PMT with 2×2 matrix anode pixels fabricated by Xi'an Institute of optics and precision mechanics of CAS. The test result shows that the gain of the MCP-PMT remains stable up to 1×10^7. And the time resolution of single photoelectron (SPE) is better than 60ps (σ). The Cross-talk phenomenon among adjacent pixels which deteriorates the high time performance was also studied. We have developed an electronic model to explain its generation mechanism and suppress the crosstalk-over-signal amplitude ratio from 20% to lower than 5%. Furthermore, this mechanism has a universality that can also be applied in other multi-anode MCP-PMT Hamamatsu R10754.

Sensor Posters: Photodetectors / 465

Mechanical Design of Multi-PMTs for IWCD

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We will be using approximately 500 multi-PMTs (mPMTs) as the photosensors for the Intermediate Water Cherenkov Detector (IWCD), a new near detector for the approved Hyper-Kamiodande experiment that will be built by 2025. The IWCD mPMT design has nineteen 3" PMTs enclosed in a water-tight pressure vessel, along with the associated electronics. The 3" PMTs provide excellent spatial imaging of the neutrino-induced Cherenkov light ring. This talk will focus on the mechanical design of the mPMT. In particular, we will describe the design of the UV transparent acrylic domes and how we use gel to optically couple the dome to the PMTs. We will also summarize results from several mPMT prototypes, as well as the IWCD plans for mass production of mPMTs.

Sensor Posters: Photodetectors / 482

Status of 20-inch PMT Instrumentation for the JUNO experiment

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment. The primary physics goal of JUNO is determination of the neutrino mass ordering by detecting the reactor antineutrinos. There will be 20000 20-inch PMTs equipped for JUNO, including 15000 MCP PMTs from NNVT company and 5000 dynode PMTs from Hamamatsu company. To achieve the designed energy resolution of 3%@1MeV, the PMTs need to have high detection efficiency, high optical coverage, and low failure rate during the operation of JUNO. How to instrument these PMTs, including performance test, waterproof potting, implosion protection and installation, was extensively studied in the past several years. By now, the design of the instrumentation methods has been finalized, and mass production has started. Moreover, some parts of the instrumentation work have been finished or close to be finished now. In this talk, the current status of the JUNO 20-inch PMT instrumentation will be introduced.

Sensor Posters: Photodetectors / 551

The MCP based Large Area PMTs for Neutrino Detector

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The large scalar neutrino detectors (JUNO, HyperK), need the 20 inch area PMTs as the photo-detection device for their large photocathode coverage and less electronic channels. In 2009, the researchers at IHEP have conceived a new concept of large area PMTs, of which the small MCP units replace the bulky Dynode chain. After several years R&D, the 20 inch MCP-PMT was successfully produced. This type of PMT has large sensitive area, high QE, and large P/V for good single photon detection. The JUNO ordered 15000 pic 20 inch MCP-PMTs in Dec.2015. Then, from 2017 to 2020, all the 20-inch PMTs will be produced and tested one by one in the company for JUNO. This presentation will talk about the R&D, the mass production and batch test result of the 15K pieces of MCP-PMT prototypes for JUNO. Further more, another Flower-liked MCP-PMT will also be introduced. This new type of 20 inch MCP-PMT designed with the TTS less than 5ns, has already be used in the LHAASO project in China.

Sensor Posters: Photodetectors / 555

Coincidence time resolution of ultrafast photomultiplier tube coupled with LYSO crystal

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This manuscript aims to use two ultra-fast photomultiplier tubes (FPMT) coupled with Lu1.8Y2SiO5:Ce (LYSO) crystals to perform a coincidence time resolution (CTR) test applied to Time of Flight- Positron Emission Tomography (TOF-PET). The FPMT used in this work refers to a Micro Channel Plate-PMT(MCP-PMT) with rise time of 100ps, TTS of 46ps in a single photon mode. The scintillation light waveform of the LYSO crystal appears “separated” when it is detected by the FPMT. At the same time, it is found that the setting of the timing threshold has a greater impact on the results of the time resolution. The waveform processing algorithm is optimized by interpolation, and the acquired waveform is processed by the method of aspect ratio timing. The whole test is carried out under the radiation background of 22Na, the sigma of CTR measured by LYSO crystal coupled with FPMT is 40ps. This result is not regarded as the final test result, follow-up work will continue to optimize this result.

Sensor Posters: Photodetectors / 556

Test and Simulation of FPMT with single chip MCP

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Abstract: Micro-channel plate photomultiplier tube (MCP-PMT) is a kind of photosensitive device with single photon detection capability and great time resolution, which is also called Fast-PMT (FPMT). The MCP is the electron multiplier structure and in order to achieve single photon detection, two layers of MCPs are always used together. Due to the new-generation particle accelerators with high energy and luminosity, the time resolution of the detector is more important than single-photon detection. The single-MCP-FPMT is expected to have a greater time resolution. Based on the CST STUDIO SUITE, the single-chip-FPMT model was built and relative structure parameters are changed to see the performance change of the model including the gain, transit time, transit time spread and rise time. At the same time, two single-chip FPMTs samples produced by North Night Vision Tech. Co. in China are tested thoroughly in our laboratory and the performance evaluation results are given.

Sensor Posters: Photodetectors / 646

Super-Kamiokande PMT characterizations using artificial magnetic field and robotic laser-equipped arms

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Super-Kamiokande (Super-K) is a neutrino detector located in Japan. Its research program includes search for proton decay and measurement of neutrino oscillations among others. It contains ˜11,000 20 inches photomultiplier tubes (PMTs) surrounding a massive tank filled with 50 ktonne of ultra-pure water. A detailed understanding of the PMTs and their response to environmental effects, is necessary for a precise understanding the detector and consequent reduction of systematic uncertainties. This is also a very important contribution towards the future Hyper-Kamiokande detector which will be instrumented of ˜40,000 PMTs, helping realize the best design and monitoring needed to achieve maximum sensitivity of the experiment.
I will present the measured non-uniformity of the PMT used in Super-K as well as the effects of the magnetic field on the PMT parameters. I will also describe the recent facility upgrades implemented to improve the accuracy and reproducibility of the measurements.

Sensor Posters: Photodetectors / 658

Photomultipliers as High Rate Radiation-Resistant In-Situ Sensors in Future Experiments

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New compact PMT have rate capability >300MHz, able to survive ˜GigaRad radiation doses, and time resolution <50 ps. This study investigates high gain quartz window metal envelope compact multi-anode photomultipliers as direct in-situ light and particle sensors. In addition to the Cerenkov light generated in the quartz window (or as coupled to Cerenkov or scintillator tiles), the photomultiplier dynodes in-situ in hadron or e-m showers generate signals from ionizing particles traversing the PMT dynodes. The dynodes have smaller sensitivity to mips(minimum ionizing particles), but low momentum, low energy particles penetrating the PMT cause secondary emission electrons (SEe) at higher efficiency than mips, due to higher dE/dx in the dynodes, forming a dual-readout correction to an energy signal as combined with Cerenkov signal. PMT with metal envelopes and quartz windows have been shown to survive GigaRads. Shielded to <1T, PMT are in-situ calorimeter sensors and beam taggers.

Sensor Posters: Photodetectors / 670

Characterization of Photon readouts and Scintillators for Direct Dark Matter Search

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As a precursor to setting up a Dark Matter (DM) direct search experiment involving scintillators at low temperatures, we have investigated the change in characteristic properties of the photon readout channel. Silicon Photomultiplier (SiPM), known for its high gain, miniature size, and low mass was studied. Leakage current of SiPM was found to have sensitive dependence on the temperature and also a shift in the operating bias was observed. Photon response to a temperature-stabilized light-emitting diode (LED) pulsar was used to study the SiPM bias compensation as a function of temperature, from ambient to about 30 K. We find that the voltage compensation, though reported to be linear within a small temperature range, is fairly nonlinear when operated over such a wide temperature range. Using the voltage compensation data, we have studied the temperature dependence of the light output of some doped and un-doped scintillators which can serve as potential detectors for direct DM search.

Funding information:
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Sensor Posters: Photodetectors / 716

HIPeR: High channel Integration Picosecond Readout - An integrated read-out solution for Large Area Picosecond Photo Detectors

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The transit time spread timing performance reported for Large Area Picosecond Photo Detector (LAPPD,Ñ¢) is often limited by the speed of cost-effective readout electronics, rather than the actual timing of the detector device itself. In this paper, an electronic board is presented that integrates a high-speed low-cost waveform sampling ASIC directly onto readout boards that can be located at the detector, or, in the case of LAPPD, coupled directly to the bottom of the detector, able to acquire time synchronized waveform data locally and promptly export a reduced data set, including charge, position and accurate timing information. The readout AARDVARC waveform digitizing chip with a sample rate of up to 14 GSa/s and a timing resolution below 5 ps is used as a scalable building block.
We describe the HIPeR board and the first measurements while coupled with a LAPPD,Ñ¢, its performance, as well as the advantages in terms of flexibility of acquisition modes (triggered, streaming).

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Sensor Posters: SS Cryo / 306

A thermal model for low-temperature TeO_2 calorimeters read out by NTD thermistors

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Reaching a complete understanding of thermal signal pulse formation in low-temperature calorimeters can contribute to the improvement of their performance, both in the identification of low energy events and in the optimized choice of geometry and materials for future experiments.
We performed dedicated measurements with TeO_2 crystals read-out by Ge-NTDs hosted in copper and PMMA holders. Analyzing the data at different temperatures (from 10 to 30 mK), we identified the main physical parameters which determine the thermalization processes. The different materials of the two holders strongly affect how the calorimeters are linked to the thermal bath, playing a crucial role in the resulting shape and characteristic times of the thermal pulses, which are different for the two frames. We are developing a model able to describe and predict the pulse shapes in terms of the thermal capacities and conductances of the different systems. Current results are encouraging.

Funding information:
GSSI (Gran Sasso Science Institute), INFN (Istituto Nazionale di Fisica Nucleare)

Sensor Posters: SS Position / 675

Latest developments and characterisation results of DMAPS in TowerJazz 180nm for High Luminosity LHC

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The last couple of years have seen the development of Depleted Monolithic Active Pixel Sensors (DMAPS) fabricated in TowerJazz 180nm with a process modification to increase the radiation tolerance. While many of MAPS developments focus on low radiation environment, we have taken the development to high radiation environment like pp-experiments at High Luminosity LHC. DMAPS are a cost effective and lightweight alternative to state-of-the-art hybrid detectors if they can fulfil the given requirements for radiation hardness, signal response time and hit rate capability. The MALTA and Mini-MALTA sensors have shown excellent detection efficiency after irradiation to the life time dose expected at the outer layers of the ITK. Our development focuses on providing large pixel matrixes with excellent time resolution (<2ns) and tracking. This talk will discuss characterisation results of the DMAPS devices with special focus on the new MALTA2 sensor and will show the path of future developments.

Sensor Posters: SS Position / 652

New Photon Trap Design proposed for next-generation neutrino telescopes

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We propose a photon trap designed for improved photon detection efficiency in a cost-efficient way. A Wavelength Shifting plastic sheets (WLS) are deployed at the bottom of a PMT, surrounded by dichroic film by which photons are efficiently trapped and guided to the PMT. We measured wave-length dependent transmittance of a commercially available dichroic film in water, a key variable determining photon trapping efficiency. We ran a Geant4 based simulation with the property of the commercially available dichroic film as a realistic case. We also studied an ideal case with a hypothetical dichroic film whose bandpass is optimized to absorption and reemission spectra of the WLS and the quantum efficiency of the PMT. The preliminary results of the photon collection and detection efficiency enhancements are computed, as well as timing distribution of the photons. We discuss how this new conceptual design can be applied to next-generation neutrino telescopes.

Sensor Posters: SS Position / 308

New beam test results of 3D pixel detectors constructed with poly-crystalline CVD diamond

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Detectors based on Chemical Vapor Deposition (CVD) diamond have been used successfully in beam conditions monitors in the highest radiation areas of the LHC. Future experiments at CERN will to accumulate an order of magnitude larger fluence. As a result, an enormous effort is underway to identify detector materials that will operate after fluences of >10ˆ{16}/cmˆ2. Diamond is one candidate due to its large displacement energy that enhances its radiation tolerance. Over the last 2 years the RD42 collaboration has constructed 3D CVD diamond pixel detectors that use laser fabricated electrodes to enhance radiation tolerance. We will present beam test results of these devices. The cells in these detectors had a size of 50¬μm x 50¬μm with columns 2.6¬μm in diameter ganged in 1 x 5 and 3 x 2 patterns to match the ATLAS and CMS pixel read-out electronics. In beam tests, a tracking efficiency of 99.3% was achieved. The efficiency of both devices plateaus at a bias voltage of 30V.

Sensor Posters: SS Position / 312

Performance Studies of the ATLASpix HV-MAPS Prototype for Different Substrate Resistivities

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The ATLASpix_Simple is a high-voltage monolithic active pixel sensor (HV-MAPS), which was initially designed as a candidate for the ATLAS ITk Upgrade and the CLIC tracking detector. In this contribution new results from test-beam campaigns with inclined tracks are presented, in which the performance is compared for different substrate resistivities and the active charge collection depth is determined. These findings are complemented by laboratory energy calibrations using fluorescent x-rays.

Sensor Posters: SS Position / 324

Development of AC-LGADs for large-scale high-precision time and position measurements

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We present measurements on AC-LGADs (aka Resistive Silicon Detectors RSD), a version of LGAD which has shown to provide spatial resolution on the few 10,Äòs of micrometer scale. This is achieved by un-segmented (p-type) gain layer and (n-type) N-layer, and a di-electric layer separating the metal readout pads. The high spatial precision is achieved by using the information from multiple pads, exploiting the intrinsic charge sharing capabilities of the AC-LGAD provided by the common N-layer.
Using focused IR-Laser scans directed alternatively at the read-out side and the bias side, the following detector parameters have been investigated in RSD produced by FBK: sheet resistance and termination resistance of the n-layer, thickness of the di-electric, doping profile of the gain layer, and pitch and size of the readout pads.
The data are used to recommend a base-line sensor for near-future large-scale application with need for precision timing and position resolution (e.g. EIC)

Funding information:
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Sensor Posters: SS Position / 393

Measurement results of IHEP-IMEv1 low gain avalanche devices and IHEP-IMEv2 sensor design for ATLAS HGTD

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Low- Gain Avalanche Detector (LGAD) with time resolution better than 50ps has been choose as the sensors for HGTD project and have so far been developed by several institutes. This talk will show the measurement results about 50um thick IHEP-IMEv1 LGAD sensors designed by the Institute of High Energy Physics (IHEP) and fabricated by Institute of Micro Electronics (IME). Beta source measurement results show that the time resolution of IHEP-IMEv1 sensors are better than 40ps and the collected charges are larger than 20fC before irradiation. The properties of IHEP-IMEv1 sensors fulfill the required specifications of sensors before irradiation for ATLAS HGTD project. Performance of the sensors after irradiation will also be shown. Furthermore, this talk will show the second version of sensor design for 15$\sqrt{}$ó15 sensor arrays, especially simulation results of process parameters for gain layer implantation which will be optimized for the sensors to meet irradiation requirements of the project.

Sensor Posters: SS Position / 418

Modeling Radiation Damage to Pixel Sensors in the ATLAS Detector

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Silicon pixel detectors are at the core of the current and planned upgrade of the ATLAS detector at the Large Hadron Collider (LHC). As the closest detector component to the interaction point, these detectors will be subjected to a significant amount of radiation over their lifetime: prior to the High-Luminosity LHC (HL-LHC), the innermost layers will receive a fluence of 1-5 1015 1 MeV neq/cm2 and the HL-HLC detector upgrades must cope with an order of magnitude higher fluence integrated over their lifetimes. Simulating radiation damage is critical in order to make accurate predictions for current future detector performance. A model of pixel digitization is presented that includes radiation damage effects to the ATLAS pixel sensors for the first time. In addition to a thorough description of the setup, predictions are presented for basic pixel cluster properties alongside early studies with LHC Run 2 proton-proton collision data.

Sensor Posters: SS Position / 423

RD53 wafer testing for the ATLAS ITk pixel detector

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RD53 is the research and development group at CERN, responsible for developing and producing the next generation of readout chips for the ATLAS and CMS pixel detector upgrades at the HL-LHC. Its most recent development, ITkPix is the first full-scale 65 nm hybrid pixel-detector.
ITkPix consists of more than one billion transistors with a high triplication ratio in order to cope with the high particle and therefore radiation density at the heart of ATLAS. A failure of chips at the heart of ATLAS is problematic. Therefore, thorough testing before and during the production phase is necessary.
For this purpose, Bonn has developed bdaq, a fast and versatile simulation, testing and analysis environment, making small-and large-scale testing for ITkPix possible. This talk will give an overview over the testing environment, while focusing on large scale wafer testing results to evaluate ITkPix,Äôs fitness for its deployment at the HL-LHC.

Sensor Posters: SS Position / 443

Characterization of RD53A pixel modules with passive CMOS sensors

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Both the current upgrades to accelerator-based HEP detectors (e.g. ATLAS, CMS) and also future projects (e.g. CEPC, FCC) feature large-area silicon-based tracking detectors. We are investigating the feasibility of using CMOS foundries to fabricate silicon radiation detectors, both for pixels and for large-area strip sensors. The availability of multi-layer routing will provide the freedom to optimize the sensor geometry and the performance, with biasing structures in poly-silicon layers and MIM-capacitors allowing for AC coupling.
A prototyping production of strip test-structures and RD53A compatible pixel sensors was recently completed at LFoundry in 150nm CMOS process.
This presentation will focus on the characterization of pixel modules, studying the performance in terms of charge collection, position resolution, hit efficiency with measurements performed in the laboratory and with beam tests. We will report on the investigation of RD53A modules with 25x100mm2 cell geometry.

Sensor Posters: SS Position / 496

Passive CMOS Strip Sensors with Multiple Stitching

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Two current issues with Silicon particle sensors are the high cost, making them a cost driver, and the limited availability from only a few manufacturers. Most CMOS foundries are equipped for producing small chips only. To obtain larger sensors as required in strip trackers, reticles have to be connected by stitching. In our study, passive strip sensors were developed in p-CMOS 150 nm technology on a 150 [U+F8FF]ùúám thick wafer and produced by a European manufacturer. Stitching of up to 5 different reticles was used. Sensors were characterised on probe stations and then tested in the lab with Sr-90 sources and IR-lasers. We will present position-resolved signal measurements to evaluate the sensor performance. Results from 2 batches of sensors are shown in this study, with an improved backside processing on the 2nd batch of sensors to enhance the HV performance of the initial batch. We are able demonstrate that the sensors perform well and stitching does not show negative effects.

Sensor Posters: SS Position / 524

Performances of the latest FBK UFSD production

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Ultra-Fast Silicon Detectors (UFSD) are sensors based on the LGAD technology and designed to achieve concurrent precise timing and position measurements.
In the past 5 years, an intense R&D program has been carried out at FBK-Trento to optimize the design of UFSD, exploring specific features such as the gain layer design, radiation hardness, time resolution, production uniformity, and interpad distance.
In this contribution, we present results on the above points from the latest FBK production, UFSD3.2. UFSD3.2 consists of 19 wafers of different thicknesses, from 25 to 55 micron, with shallow and deep gain implants, co-implanted with different carbon doses to maximize radiation hardness.

Sensor Posters: SS Position / 576

ARCADIA: sensor development and chip design for low-power, large area FD-MAPS

Authors: Lucio Pancheri[1]; on behalf of the ARCADIA collaboration[None]

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The ARCADIA collaboration is developing Fully-Depleted Monolithic Active Pixel Sensors (FD-MAPS) with an innovative sensor design, providing efficient charge collection and fast timing over a wide range of operational and environmental conditions. The design targets very low power consumption, of the order of 20 mW cm^{-2} at 100 MHz cm^{-2} hit flux, to enable air-cooled operation. In November 2020, the collaboration finalized the first design of a prototype with 1.3×1.3 cm^2 active area, consisting of 512×512 pixels with 25 μm pitch. This prototype is currently being produced in a first engineering run together with additional test structures of pixel and strip arrays. In this contribution, we will present the current status of the project and the design of the first prototype. Additionally, we will discuss ongoing developments with a special focus on ultra-fast timing applications.

Funding information:
INFN

Sensor Posters: SS Position / 603

Test of a prototype Microstrip Silicon Detector for the FOOT experiment

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The FOOT (FragmentatiOn Of Target) experiment aims to measure the fragmentation cross-section of protons into H, C, O targets at beam energies of interest for hadrontherapy (50,Äì250 MeV for H and 50,Äì400 MeV/u for C ions).
Given the short range of the fragments, an inverse kinematic approach requiring precise tracking capabilities in a magnetic volume has been chosen.
A key subsystem of this experiment will be the Microstrip Silicon Detector, based on 150 um thick single side microstrip sensors. In this work, we present the results of characterization of the new version of a 64 channel low-noise/low power high dynamic range readout ASIC and subsequent tests of the first 150 um thick sensor prototype.
A series of tests were also performed to validate a novel “grazing angle” approach, where it is possible to change the track length below a given strip varying the incoming particle’s incident angle onto the sensor to test the electronics dynamic range without using high Z ions.

Sensor Posters: SS Position / 609

Test beam measurements of AC-LGAD sensors from HPK and BNL

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Tracking at future hadron colliders will require sensors that achieve precise spatial and temporal resolution simultaneously. AC-coupled Low Gain Avalanche Detectors (AC-LGADS) are a promising candidate technology, combining the precision timing achieved in LGADs with highly granular readout. We present results from a 2021 test beam campaign to characterize AC-LGAD prototypes produced by Hamamatsu and by Brookhaven National Laboratory using the 120 GeV proton beam at Fermilab. In particular we demonstrate the spatial and time resolutions provided by these sensors, and present a study of key design parameters that determine the signal properties.

Sensor Posters: SS Position / 622

New Approaches to Fine Granularity Timing Detectors

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A collaboration involving a US National Laboratory (Brookhaven National Laboratory), a private-sector technology company (Cactus Materials, Inc.) and a University institute (the Santa Cruz Institute for Particle Physics at the University of California, Santa Cruz) has been working on new approaches to the development of highly-granular timing layers for minimum-ionizing particle and X-Ray detection. Progress has been made in the design and prototyping of the Deep Junction LGAD, a novel approach to the implementation of impact-ionization gain in silicon diode detectors that allows for the reduction of the granularity scale to below 100 microns, while maintaining DC coupling to the readout electrodes. Work is also progressing on high-density interconnect ("3D Integration") technology geared towards the enabling of commensurate high-density readout of granular systems. Progress in both of these areas will be presented.

Sensor Posters: SS Position / 639

Quantum Dot Based Scintillators: A New Type of Sensor for Particle Physics

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Development of semiconductor technology has enabled engineering of ultrafast, high-yield, and radiation-tolerant quantum dot (QD) based scintillation materials with sub-nanosecond emission time and light yield > 2x10^5 photons/MeV. Such materials could be very attractive for various HEP applications, particularly for fast timing and low-mass tracking detectors. We present results on a scintillation detector based on self-assembled InAs QDs grown with molecular beam epitaxy and embedded into GaAs bulk. The detector consists of a 25 ¬μm thick scintillator with an InGaAs photodiode grown directly on the scintillator. Signals measured using 5 MeV Œ±-particles correspond to a light collection efficiency of ˜13% with a measured scintillation time of ˜500 ps, making this system the fastest high-yield scintillating material reported so far. Furthermore, strong carrier localization results in a radiation hardness that significantly exceeds that of bulk GaAs.

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Sensors: Emerging Technology / 475

CRAB: A Camera Readout and Barium Tagging System R&D for the NEXT collaboration

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The experimental effort to detect neutrinoless beta decay has shown numerous R&D advancements in the past several years. One of the R&D lines being explored in NEXT and presented in this talk is that of digitizing tracking information with a fast optical camera. This would enable a novel direction in the search for neutrinoless double beta decay within the NEXT collaboration: demonstrating a detector that includes tagging of the daughter Barium ion, from the decay of Xenon136, leveraging the latest breakthroughs in single molecule florescence. To achieve this, we need to house single-ion Barium detection (via single molecule florescence) as well as adapt the TPC to hold the electroluminescence (EL) region at high voltage. In this talk, we,Äôll describe the design, status, and early information from the CRAB (Camera Readout and Barium Tagging) system which is under construction at Argonne National Laboratory, focusing on the fast optical camera.

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Barium capture and identification through bi-color molecular sensors

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The next generation of neutrinoless double beta decay searches aims to reach sensitivities in the half-life of the process up to 10^{28} years. This will require tonne scale detectors with essentially no background in their region of interest. One of the most promising solutions, which may be implemented by gas or liquid xenon TPCs, is the possibility of tagging the daughter ion produced in the decay. The NEXT collaboration is currently involved in a intense R&D program based on molecular indicators able to capture the Ba^{++} cation, changing their response when chelated. In this talk I will present one of the NEXT R&D lines, called BOLD, which proposes the use of fluorescent bicolor indicators (FBI). I will show the latest results based on the spectral shift of the emission fluorescence of this molecule after Ba^{++} capture in dry media. The emission light is then detected by laser microscopy. I will also detail how this technique can be integrated into a xenon gas detector.

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HeRALD: Dark Matter Direct Detection with Superfluid 4He

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HeRALD, the Helium Roton Apparatus for Light Dark Matter, will use a superfluid 4He target to study the sub-GeV dark matter parameter space. The HeRALD design is sensitive to all signal channels produced by nuclear recoils in superfluid helium: singlet and triplet excimers, as well as phonon-like excitations of the superfluid medium. Excimers are detected via calorimetry in and around the superfluid helium. Phonon-like vibrational excitations eject helium atoms from the superfluid-vacuum surface which are detected by adsorption onto calorimetry above the surface. I will discuss the design, sensitivity projections, and ongoing R&D for the HeRALD experiment. In particular, I will present an initial light yield measurement of superfluid helium down to approximately 50 keV.

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R&D on Microwave Transparent Thermal Insulation for the Project 8 Neutrino Mass Experiment

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Project 8 aims to measure neutrino mass by detecting radiation from single electrons. The operating principle is to observe tritium beta decay in a uniform magnetic field, which causes the emitted electron undergo cyclotron motion and radiate. Measuring the radiation frequency yields the electron's energy spectrum, which in turn encodes the neutrino mass. For the current R&D phase, the detector design is a vessel of gaseous molecular tritium viewed by an antenna array in a 1 T medical MRI magnet. Detection is challenging because an electron emits $<$1 fW at $\sim$26 GHz in this field, motivating antenna operation at very low temperatures. However, the thermal requirements differ significantly for the tritium, introducing a tension between RF transparency and thermal shielding between the source and detector. This motivates the design of insulation that is transparent to the microwave signal. In this talk, I will discuss potential solutions and our progress towards their realization.

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Performance of semi-insulating metal-semiconductor-metal GaN prototype devices as ionizing radiation detector

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We describe the fabrication and characterization of semi-insulating GaN devices for the detection of ionizing radiation with applications in high radiation environment. We present the DC characterization and the signal response from Am-241 Œ±-source of such device. The detector prototypes show up to 80% charge collection efficiency with bias voltages as low as -40V. Wide band gap semiconductors like synthetic diamond, GaN, SiC have gained immense importance in the field of charged particle detection due to their low intrinsic noise and high radiation tolerance. We have made interdigitated metal-semiconductor-metal(MSM) device on a 3¬μm thick GaN layer epitaxially grown on sapphire substrate by MOCVD technique. We employed Ni/Pt/Au metal stack for Schottky contact with finger width of 4¬μm, spacing of 8¬μm and finger length of 120¬μm. Details of the experimental setup for fabrication and characterization will be presented.

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Strategies for reducing the use of greenhouse gases from particle detectors operation at the CERN LHC experiments

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A wide range of gas mixtures is used for the operation of the gaseous detectors at the CERN LHC experiments. Some gases, as C2H2F4, CF4, C4F10 and SF6, are greenhouse gases (GHG) with high global warming potential and therefore subject to a phase down policy.
The reduction of GHG emissions is of paramount importance for CERN, which has identified four different strategies.
The first strategy is based on the optimization of the gas mixture recirculation plants already in use. The second approach is the recuperation of used gas mixtures followed by separation of the GHG for its re-use. Several R&D are ongoing to evaluate this possibility and prepare the design of final systems. A third approach is making use of industrially available solutions for disposal of GHGs. Finally, the search of new eco-friendly gases is object of many R&D programs by the detector communities.
The four strategies will be compared by considering investment required, return benefit and technological readiness.

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TPC Development by the LCTPC Collaboration for the ILD Detector at ILC

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An extensive research and development program for a ILC TPC has been carried out within the framework of the LCTPC collaboration. A Large Prototype TPC in a 1 T magnetic field, which allows to accommodate up to seven identical Micropattern Gas Detector (MPGD) readout modules of the near-final proposed design for the ILD detector at ILC, has been built as a demonstrator at the 5 GeV electron beam at DESY. Three MPGD concepts are being developed for the TPC: Gas Electron Multiplier, Micromegas and GridPix. Successful test beam campaigns with different technologies have been carried out between 2014 and 2019. Fundamental parameters such as transverse and longitudinal spatial resolution and drift velocity have been measured. In parallel, a new gating device based on large-aperture GEMs have been produced and studied in the laboratory. In this talk, we will review the track reconstruction performance results and summarize the next steps towards the TPC construction for the ILD detector.

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Development of a GridPix X-ray polarimeter

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In gaseous detectors it is possible to determine the polarisation of an X-Ray beam by tracking photoelectrons which are created in photoelectric interactions of the photons with the gas molecules. In this interaction the emission angle of the photoelectrons is correlated with the polarisation plane of the beam.
Depending on the photon energy and on scattering of the photoelectrons on gas molecules the length of the relevant part of the track is only in the order of a few hundred microns. Thus, a high tracking resolution is needed. This is achieved with the GridPix - a combination of the highly granular Timepix3 pixel ASIC and a photolithographically postprocessed MicroMegas which holes are aligned with the pixels of the ASIC.
In this talk I will present the working principle of a GridPix X-ray polarimeter and how it depends on detector parameters as well as first measurement results. Furthermore, I will give an outlook on our future plans for the development of such a detector.,Äã

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Development of high rate capable and ultra-low mass Resistive Plate Chamber with Diamond-Like Carbon

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A novel background identification detector is under development for the MEG II experiment, aiming for further sensitivity improvement in the $\mu \to e\gamma$ search. This detector needs to detect MIP positrons in a high-intensity low-momentum muon beam up to 10^8 μ/s. Hence, ultra-low material budget and high rate capability are required.
The detector under development is a new type of Resistive Plate Chamber (RPC) with thin-film resistive electrodes based on Diamond-Like Carbon coating instead of glasses which are widely used in the conventional RPCs. A high efficiency (>90%) and a good timing resolution (˜250 ps) for MIP particles are shown to be achievable with a multi-layer configuration. The performance measured with prototypes including the high rate capability for low momentum muon beam will be presented.

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NoAmpTPC, a direct read-out of primary ionization electrons for high pressure gaseous TPC

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Time projection chambers read by gaseous detectors are widely used but the gaseous amplification has several drawbacks: constraints on the gas mixture, energy resolution degradation, ion backflow. The present project proposes to detect directly the primary ionization electrons without gaseous amplification, for several applications: hydrogen TPC as proton active target, search for neutrinoless double-beta decays in Xenon, very low ion backflow TPC, etc... Primary electrons will be read by very low-noise (around 100 electrons) IDeF-X read-out chips developed at CEA Saclay, connected to a read-out plane with an optimized electron collection.
Different electrode geometries were optimized with Garfield++ simulations. A small-scale prototype TPC as well as new front-end cards are presently tested with radioactive sources and different gas mixtures. The performance in terms of noise level, electron collection efficiency, signal to noise ratios, and energy resolutions will be presented.

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Development of Novel Designs of Resistive Plate Chambers

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A novel design of Resistive Plate Chambers (RPCs), using only a single resistive plate, was developed and tested. Based on this design, prototype chambers of size ranging from 10 cm x 10 cm to 32 cm x 48 cm were constructed and tested with cosmic rays and particle beams. The tests confirmed the viability of this new approach for calorimetric applications where the particle rates do not exceed 1 kHz/cm2, such as CALICE digital calorimeters. The chambers also have improved single-particle response, such as a pad multiplicity close to unity.
In addition to this development, we probed a new technique to mitigate limitations associated with common RPC gases compatible with the environment. The technique is based on electron multiplication in a thin layer of high secondary electron yield material coating on the anode plane.
Here we report on the construction of various different glass RPC designs, and their performance measurements in laboratory tests and with particle beams.

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Performance of a fast timing micro-pattern gaseous detector for future collider esperiments

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The instrumentation of large areas in experiments at future colliders will require an advancement in the present micro-pattern gaseous detector technologies, particularly focused for various applications (ranging from muon spectrometers to calorimeter readout) in sustaining higher expected pile-ups while maintaining good rate capability and space resolution. The development of the fast timing MPGD is focused at improving the time resolution of current state-of-the-art GEM-based detectors with a fully resistive structure and a multi-gap geometry. This contribution follows a timeline approach in presenting the design and performances of the first FTM prototypes realized, with details on the choice, production and coating of resistive materials, the latest results obtained with laser and cosmic tests and a perspective on the following R&D studies.

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A new readout scheme for RPC and other gaseous detectors

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A new readout scheme allowing the exploitation of Resistive Plate Chamber (RPC) spatial precision while using a limited number of electronic channels was designed. The new scheme that exploits the spread of the RPC induced charge on several adjacent inter-connected pads, allows the simultaneous detection of several particles without ambiguity. In this scheme, pads are connected in rows through buried vias in a genuine way so the charged induced by the passage of one particle is shared among pads belonging to different directions. The pads of one row are connected to one electronic channel. The position of the particle is determined by the intersection of the rows associated to the fired pads. PCBs with pads of lozenge shape were produced and equipped with HARDROC ASICs. They were then successfully tested on detectors in a cosmic bench. To equip large detectors, a modular electronic board using this scheme was conceived and successfully tested.

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CMS RPC data taking during the CMS Run-2 and activities during Long Shutdown 2

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The CMS experiment collected 162 fbˆ-1 of proton-proton collision data at sqrt(s)=13 TeV during the Run-2 data taking period of LHC. The CMS RPC system provided redundant information for robust muon triggering, reconstruction and identification. To ensure stable data taking, the CMS RPC collaboration has performed detector operation, calibration and performance studies. After the end of Run-2, it was started the second LHC long shutdown period (LS2), an important opportunity for maintenance and preparation for the next data taking period (Run-3) and future upgrades (Phase-II upgrade). The activities included, maintenance of power, gas and online systems. In preparation for Phase-II, gas pipes for future chambers have been installed, as well as kilometers of service cables (optical fibers, LV/HV cables). In this presentation, the overall performance of the CMS RPC system during Run-2 period is summarized as well as all the activities done in preparation for future data taking periods.

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A Compact TPC for the sPHENIX Experiment

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The sPHENIX detector to be installed at RHIC in 2022 is designed to precisely measure jets, jet correlations, and dilepton pairs in heavy-ion collisions. With these measurements in mind, sPHENIX will employ a compact TPC covering 20cm < r < 78 cm and |[U+F8FF]ùúÇ| < 1.1 as the central tracker. Utilizing an optimized Ne-CF4 gas mixture, zigzag readout pads, a 1.4T solenoid, and a modified SAMPA chip for streaming readout, the TPC will provide a position resolution sufficient for measuring target observables in a high event rate environment. The sPHENIX TPC, with some modifications, could be a mid-rapidity tracking component in a day-one Electron-Ion Collider (EIC) detector. The design of the TPC will be discussed, as well as test beam data and applicability to the EIC.

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An experimental study to understand the physics behind charging-up of Gas Electron Multiplier (GEM)

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Charging-up is a phenomenon observed while working with gaseous ionization detector having dielectric. It is comprised of two processes: the polarization of dielectric due to exposure to high electric field and collection of charges on dielectric surface. Both these charging-up processes affect the gain of the detector as they change the local field configuration around the dielectric. Here, we have studied these effects using experimental techniques for a single GEM detector. It is observed that due to polarization the gain increases following a curve similar to charging-up of a capacitor. However, the radiation charging-up reduces gain depending on radiation rate. The radiation rate was modified by a) collimators, b) strong and weak sources. As the rate increases the rate of collection of charges on GEM dielectric accelerates. Its effects are important for experiments where beam current changes significantly with time and in TPC application which requires gain to be stable over time.

Funding information:
Saha Institute of Nuclear Physics, Homi Bhabha National Institute

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Commissioning and installation of the new small-diameter Muon Drift Tube (sMDT) detectors for the phase-1 upgrade of the ATLAS muon spectrometer

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The Muon Drift Tube chambers provide very precise and reliable muon tracking and momentum measurement in the ATLAS spectrometer. They have to cope with very high background counting rates up to 500 Hz/cm2. At HL-LHC the background rates are expected to increase by almost a factor of 10. New small (15 mm)-diameter Muon Drift Tube detectors have been developed to provide higher rate capability and allow for the installation of additional new RPC trigger chambers. Several sMDT chambers have already been installed and operated in ATLAS. The detailed studies of the muon detection efficiency and track resolution have been carried out after the assembling of the sMDT detectors in MPI and repeated at CERN after the integration with the new RPC detectors. The author will describe the detector design, the quality assurance and certification path, as well as will present the status of sMDT detectors installation and commissioning in the ATLAS experiment.

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2D charge-sharing readout planes for GEM, uRWELL and other detector applications

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Charge sharing technique for various types of 1D (strip) gaseous detectors was applied several times in the past in an ad hoc fashion with varying results. If realized properly it allows one to reduce the number of instrumented channels, maintain a spatial resolution several times better than the canonical sigma ˜ pitch/,àö12 estimate, and eliminate the differential non-linearity in the detector response. In this talk, novel 2D readout plane designs with these properties will be presented. The spatial resolution for simultaneous 2D coordinate sampling by interleaved X- and Y-strip structures realized in the active area of the same kapton-based readout plane for the GEM and uRWELL detector prototypes will be presented. Results obtained with the similar readout planes for capacitively coupled LAPPDs will be shown. The prospects of replacing traditional pixel arrays by low channel count XY-strip readout planes with built-in redundancy in single-photon RICH applications will be discussed.

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Electroluminescence measurements in He, CF4 and iso-butane mixtures for directional dark matter searches with the CYGNO Time Projection Chamber

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CYGNO (a CYGNus TPC with Optical readout) fits into the wider CYGNUS proto-collaboration, developing a ton scale Galactic Nuclear Recoil Observatory with directional sensitivity for Dark Matter searches below the Neutrino Floor and Solar Neutrino Physics. Located at Gran Sasso National Laboratory (Italy), CYGNO will operate a TPC readout by a Micro Pattern Gaseous Detector ensuring charge multiplication and electroluminescence (EL) production. The visible component of the EL is collected by a sub-mm position resolution scientific camera, enabling particle identification and track reconstruction capability, crucial to measure nuclear recoils direction.

In this work the EL produced in a Gas Electron Multiplier is read by a Large Area Avalanche Photodiode. EL yield, charge gain and energy resolution in He, CF4 and iso-butane mixtures are measured with low energy X-rays. The inclusion of iso-butane, with its high H content, will allow to reduce the observable WIMP mass threshold.

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Measurement of gas properties in a Spherical Proportional Counter

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NEWS-G (New Experiments With Spheres-Gas) is an experiment searching for dark matter using the Spherical Proportional Counter (SPC) technique. SPCs are low capacitance detectors which allow the detection of gas ionisation with very low (single electron) thresholds. It consists in a grounded metal sphere with a small sensing anode at the center, creating a radial electric field.

Using a UV laser, we extract electrons from the sphere surface, which allows a fine calibration of gain, diffusion and drift time of electrons in the SPC. We also use gaseous ^{37}Ar as a uniformly distributed, low energy calibration source. These tools are used together with simulations to do a detailed characterisation of the detector. We will show in particular results obtained during a commissioning campaign at the Modane underground laboratory (LSM).

Another contribution to this conference describes the general aspects and goals of the NEWS-G detector.

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A study of self-vetoing balloon vessel for liquid-scintillator detectors

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KamLAND-Zen searches for neutrinoless double-beta decay with an ultra-pure liquid-scintillator (LS) filled with a custom-made clean nylon balloon. The primary backgrounds are radioactive impurities such as uranium and thorium series.

To reduce them, we developed a self-vetoing balloon vessel for a future upgrade program, "KamLAND2-Zen", instead of the current nylon-made balloon.

We selected a Polyethylene-Naphthalate (PEN) film that has a blue photon emission and performed the feasibility studies.

Due to its scintillation properties, we estimated that 99.7% of a ²¹⁴Bi background could be identified in the KamLAND.

Moreover, thanks to the different waveforms between the LS and the PEN, we recently established the pulse-shape-discrimination for ²¹²Bi background. We evaluated its background rejection efficiency as more than 90%.

Resulting from these studies, we proved to be able to use 100% of the fiducial volume.

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Charged particle identification performance of the TOP counters in Belle II

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The Time-Of-Propagation (TOP) counter is a novel ring-imaging Cherenkov detector that primarily consists of a quartz bar radiator, micro-channel plate photomultipliers and front-end readout electronics. These TOP counters are installed in the central region of the Belle II detector to provide the crucial information on charged
particle identification (PID). Here we present an overview of PID studies in Belle II, with a focus on the performance of the TOP detector. The results presented are from the most recent data recorded and show reasonable agreement with expectations based on simulation studies.

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"Plans for novel Cherenkov detectors at the Super Charm-Tau Factory at Novosibirsk"

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The future e^-e^+ Super Charm-Tau Factory (SCTF) to be built at Novosibirsk will cover an energy range of 2 – 6 GeV. The projected record luminosity of 10^{35} cm $^{-2}s^{-1}$ and the longitudinal polarization of the electrons will enable a wide range of standard model precision tests and options for the discovery of flavor violating decays beyond the standard model. A 4π detector with excellent particle identification (PID) required with challenging μ/π-separation in the range 0.2 – 1.2 GeV/c. This talk focuses on two new concepts and the first tests of novel Cherenkov detectors for SCTF, a focusing aerogel RICH (FARICH) and a focusing DIRC (FDIRC). Both require single-photon detection with good coordinate and timing resolution. The prototyping for both versions already started at BINP and Giessen. The tests include various photon detectors (MCP-PMT, SIPM, MPPC). The first results using cosmic muons at the Giessen Cosmic Station are presented.

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The Upgrade II of the LHCb Calorimeter

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The LHCb Upgrade 2 will run at a luminosity of $(1..2) \cdot 10^{34} cm^{-2} s^{-1}$ to collect ~300 fb^{-1} of data. This will require a major revision of the LHCb Calorimeter. The increased luminosity will result in very high particle densities and radiation doses in the central area. The ECAL has to provide high-quality energy and position measurement for electromagnetic showers. One option for the central part is a sampling scintillation ECAL comprising radiation-hard crystal scintillators with tungsten converter and organic scintillators with lead converter. Measuring the time of arrival of neutrals with an accuracy of few tens of picoseconds is crucial to mitigate pile-up. The preferred option is to use the intrinsic time resolution of the ECAL modules. An R&D campaign started to optimize the ECAL. It includes studies of fast and radiation hard scintillating materials, simulations, and beam tests. We present the R&D results and the current status of the LHCb Calorimeter upgrade.

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Study on the possibility of neutron gamma discrimination in GAGG crystal

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In this manuscript, we investigated the possibility of cerium-doped galuminum gallium garnet (GAGG: Ce) coupled to an ultrafast photomultiplier tube (FPMT) to achieve neutron gamma discrimination. The rise time of the FPMT used in this manuscript is 100ps, and the Transit Time Spread (TTS) in single-photon mode can reach 46ps, which can distinguish neutron signals from gamma signals. Using a high-sampling oscilloscope to sample the FPMT waveform, it was found that the waveform with a longer decay time was split into a single-photon waveform. And through the rise time, fall time, amplitude, pulse width and other information to select the waveform combined with pulse shape discrimination method to achieve neutron gamma identification based on GAGG crystal.

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Performance of Photosensors in High Rate Environment for Gas Cherenkov Detector

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The SoLID project at Jefferson Laboratory will use a light gas Cherenkov detector for electron identification as part of their trigger. Due to the very high luminosity of the proposed experiments, the expected single-photon background rate is exceptionally high. It is essential to validate the planned photosensors and readout electronics to determine the limits of these sensors and mitigate the risk of failure of the trigger. We report on a beam test results with a prototype telescopic Cherenkov device in a high-rate environment in Hall C at Jefferson Lab. Commercially available multi-anode photomultipliers (MaPMT) and low-cost large-area picosecond photodetectors (LAPPD) were tested with the JLab FADC250 modules for the data acquisition to assess their performance in such an environment. The beam test results demonstrate that MaPMT array and LAPPD performed successfully at an experimental rate up to 190 kHz/cm^2.

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Sensors: Light-based detectors / 637

Compact, Projective and Modular Ring Imaging Cherenkov Detector for Particle Identification in EIC Experiments

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The recent announcement of the construction of an Electron Ion Collider (EIC) at Brookhaven National Lab by the U.S. Department of Energy makes the reality of a long-sought experimental effort to explore the structure and properties of proton and nuclei. Particle identification (PID) of the final state hadrons is a key requirement for EIC. A compact, projective, and modular ring imaging Cherenkov (mRICH) detector has been developed for K/π separation from 3 up to 10 GeV/c and for e/π around 2 GeV/c. The mRICH detector consists of an aerogel radiator block, a Fresnel lens, a mirror-wall and a photosensor plane. The first prototype of this detector design was successfully tested at Fermilab in 2016 followed with the second beam test in 2018 with much improved optical designs. Two more beams tests are planned in 2021 for quantifying the mRICH PID performance and new photosensor technology. This talk presents the state of the art of the mRICH development and test results.

Funding information:
Office of Science, US Department of Energy

Sensors: Light-based detectors / 584

An imaging detector for Liquid Argon experiments

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Large volumes of liquid Argon constitute an excellent medium for the detection of neutrino interactions.
As an alternative or a complement to the established readout method based on charge collection, the scintillation light produced by Argon may allow to reconstruct charged particle tracks by means of an imaging detector. Constructing such a device presents several challenges: the performance of both photodetectors and conventional optical elements at 128nm is generally poor; a large, densely packed array of photodetectors and electronics must be operated at cryogenic temperatures; the optical system must provide deep and wide fields of vision while remaining compact in order to maximize the fiducial volume.
This contribution will present initial steps undertaken in order to reach a functional detector design, with a focus on the simulation of novel optical systems and the performance of small scale prototypes. The design of a larger system with O(1k) channels will be presented.

Funding information:
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Sensors: Light-based detectors / 623

Novel approach to Xenon optical TPCs: the presence of Neutral Bremsstrahlung

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We have measured, for the first time in pure Xe, non-excimer-based secondary scintillation, Neutral Bremsstrahlung (NBrS), in a dedicated setup based on a Gas Proportional Scintillation Counter.
The emission of NBrS by drifting electrons occurs even for electric field values below the gas excitation threshold. We have shown the presence of NBrS in the NEXT-White TPC, at present the largest optical HPXe-TPC in operation.
Moreover, for field values above 1 kV/cm/bar, as typically employed for electroluminescence (EL), there is consistent evidence that NBrS is present with an intensity about two orders of magnitude lower than conventional, excimer-based, EL.
Our data show excellent agreement with calculations of NBrS yield.
Despite fainter than EL, in pure xenon, this new source of emission has to be accounted for in Xe optical TPCs and may play an important role in future single-phase LXe TPCs.

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Sensors: Light-based detectors / 656

Proton light yield of water-based liquid scintillator

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Future neutrino detectors, whether answering questions of fundamental physics or exercising nuclear monitoring techniques, will require advanced technologies for optimal performance. One such candidate technology is water-based liquid scintillator (WbLS), a material for which Cherenkov and scintillation light may be discriminated and examined independently. We present a measurement of the relative proton light yields of WbLS and an LAB-based liquid scintillator, using a broad-spectrum neutron source at the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory. A double-time-of-flight technique was employed, which allows for kinematic reconstruction of the proton recoil energy over a range of 2 to 20 MeV. We also present a characterization of the nonlinearity in photomultiplier tube response over the full dynamic range of the electronics system.

Sensors: Light-based detectors / 425

Scintillator cubes for 3D neutrino detector SuperFGD

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A highly granular scintillator detector SuperFGD is under construction to reduce systematic uncertainties in the T2K experiment in order to improve the sensitivity to CP-violation in neutrino oscillations. SuperFGD will be comprised of about 2x10ˆ6 of optically isolated small (10x10x10 mmˆ3) polystyrene based plastic scintillator cubes with three orthogonal holes of 1.5 mm in diameter. The readout of scintillating light from each cube is provided by three wavelength shifting fibers inserted into three holes and coupled to micropixel photosensors MPPC,Äôs. Cubes are covered by a white chemical reflector for optical isolation. The technology of making these cubes and their mechanical properties will be reported. Obtained main characteristics with cosmic muons, temperature tests, and a method of the assembly a large segmented detector will be presented

Sensors: Light-based detectors / 631

Photogrammetry position calibration for water Cherenkov detectors

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The calibration of all parts of water Cherenkov detectors is essential to obtain the precision measurements being pursued in current and next generation neutrino experiments. The positioning of photosensors within the detector and of calibration sources used to calibrate the detector may slightly deviate from the design, and these deviations may cause biases in event reconstruction. Calibrating these positions through direct measurement can allow the related systematic errors to be constrained further than has been achieved previously. We present a method of position calibration through 3D photogrammetric reconstruction. An overview of the photogrammetry procedure will be discussed along with motivations, simulation studies and a proof-of-concept analysis for the detectors of the Super-Kamiokande and Hyper-Kamiokande experiments.

Sensors: Light-based detectors / 407

Preliminary tests of Plastic Scintillator Detector for the High Energy cosmic-Radiation Detection (HERD) experiment

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The High Energy Cosmic Radiation Detection (HERD) facility onboard the future China's Space Station (CSS) will provide high quality data on charged cosmic rays and gamma rays in the energy range from few GeV to PeV. HERD will be equipped with a fine granularity cubic crystals calorimeter and a microstrip Si tracker detector. The entire instrument will be surrounded by a Plastic Scintillator Detector (PSD) that will be used to discriminate charged from neutral particles in order to correctly identify gamma-rays and nuclei. One proposed configuration for the HERD PSD consists of tiles of plastic scintillator, optically coupled to SiPMs. In 2019-2020, two beam tests were performed at CNAO (Centro Nazionale di Adroterapia Oncologica) in Pavia (Italy), exposing some PSD tiles, equipped with SiPM, to low Œ≤ p and C ion beams in order to evaluate the detector response to heavy ions. Spatial and temporal resolution were also evaluated using a radioactive source. These results will be presented.

Sensors: Light-based detectors / 515

Simulation of a Compton-pair imaging calorimeter and tracking system for the next generation of MeV gamma-ray telescopes.

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The astrophysical community is currently focusing its efforts in the development of a new generation of gamma-ray telescopes to detect low-energy photons in the MeV-GeV energy range, operating both in the Compton and pair conversion regimes. The reconstruction of the incident photons energy and direction is not straightforward, as the range of secondary particles produced by photon interactions is usually short. We propose a detector consisting of a tracker system based on scintillating fibers and of a Compton-pair imaging calorimeter made of CsI(Na) crystals coupled to wavelength shifting (WLS) fibers read out by Silicon Photomultiplier (SiPM) arrays. We have developed a dedicated simulation code to study the performance of this detector. The simulation takes into account the optical photon production and propagation inside the fibers and is used to optimize the fiber geometrical and optical properties and the design of the readout system.

Sensors: Light-based detectors / 651

Advances in radiation detectors based on finely-segmented PSD plastic scintillator: from fast neutrons to reactor antineutrinos

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Pulse-shape discrimination between nuclear and electronic recoil is a powerful technique to improve background rejection in scintillation detectors.
Until recently, only the liquid form of PSD organic scintillators has been available. The invention of stable plastic PSD scintillators at LLNL made it possible to envision a new class of radiation detectors. The plastic form is advantageous over liquid as one can machine segments into any shape without the need for any non-scintillating containment material. We have been designing and testing a variety of thin segmented detectors, utilizing silicon photomultiplier (SiPM) arrays as an optical readout. If doped with Li-6, the scintillator becomes sensitive to thermal neutrons; thus, capable of detecting reactor antineutrinos via the inverse-beta-decay (IBD) reaction. This has been the primary focus of our research, to develop the Segmented AntiNeutrino Directional Detector (SANDD).

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Sensors: Noble liquid detectors / 436

Scintillation light detection in the long-drift ProtoDUNE-DP liquid argon TPC

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ProtoDUNE-DP is a 6x6x6 m3 liquid argon time-projection-chamber (LArTPC) operated at the Neutrino Platform at CERN in 2019-2020 as a prototype of the DUNE Far Detector. DUNE is a dual-site experiment for long-baseline neutrino oscillation studies, neutrino astrophysics and nucleon decay searches. The light signal in these detectors is crucial to provide precise timing capabilities. In ProtoDUNE-DP, scintillation and electroluminescence light produced by cosmic muons in the LArTPC is collected by the photosensors placed up to 7 m away from the point of interaction. The scintillation light production and propagation processes are analyzed and compared to simulations, improving the understanding of some liquid argon properties.

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Precise liquid argon drift electron lifetime measurement and calibration with purity monitors for ProtoDUNE-SP LArTPC

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DUNE is a next-generation long-baseline neutrino oscillation experiment based on liquid argon TPC (LArTPC) technology. A key component of calibration for LArTPC is the drift electron lifetime in LAr, which corrects the charge attenuation caused by drift electrons captured by impurities. A purity monitor is a miniature TPC that measures the drifting electron lifetime. I will discuss new techniques to significantly improve the charge and electron lifetime measurement of purity monitors at DUNE's prototype detector ProtoDUNE-SP at CERN. The improved charge measurement uncertainty reaches below 1%, which is promising to fulfill the requirement of calibration at DUNE. The purity monitor based electron lifetime measurement has unique importance for DUNE's deep-underground far detector calibration, where the cosmic-ray-based calibration is very challenging due to the low cosmic statistics.

Sensors: Noble liquid detectors / 468

Liquid Argon Time Projection Chamber Trigger Development with MicroBooNE

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The Micro Booster Neutrino Experiment (MicroBooNE) is a Liquid Argon Time Projection Chamber (LArTPC) neutrino detector at Fermilab that has been collecting data since 2015. It aims to perform ŒΩ-Ar cross-section measurements, explore the low-energy excess in the ŒΩe spectrum reported by the MiniBooNE experiment and perform a combined search for sterile neutrino oscillations as part of three LArTPCs that make up the Short Baseline Neutrino Program at Fermilab. Since MicroBooNE is currently in an R&D phase, it offers a unique opportunity for the implementation and testing of TPC-based triggers as an R&D towards Deep Underground Neutrino Experiment (DUNE). One of the technical challenges of DUNE that we aim to address with this study is that of efficient self-triggering of a LArTPC utilizing TPC signal information which will enable searches for rare processes in the DUNE. This talk will describe the MicroBooNE TPC readout system and ongoing R&D efforts to develop TPC-based triggering.

Sensors: Noble liquid detectors / 568

Study of Light Production With A Fifty Liter Liquid Argon TPC

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The Deep Underground Neutrino Experiment (DUNE) is the next largest-scale neutrino science and proton decay experiment. DUNE will consist of large-scale near and far detectors. The core elements of these detector systems are Time Projection Chambers (TPCs) and light readout systems. Two prototype far detectors were built and operated at CERN Neutrino Platform and extensive developments are underway for improved and upgrade detectors.

In order to evaluate various design alternatives and validate new concepts of light readout related to both prototype and full-scale DUNE detectors, we have performed several experiments with a fifty liter liquid argon TPC at CERN. Among the long list of configurations we probed, study of various wavelength shifters, operation in dual phase mode and Xe and N2 doping under different scenarios can be listed.

Here we report on the details of the various test campaigns and discuss our findings and their impact on the design and operational parameters.

Sensors: Noble liquid detectors / 528

Impact of xenon doping in the scintillation light in a large liquid-argon TPC

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The use of xenon-doped liquid argon is a promising alternative for large pure liquid-argon TPCs. Not only xenon-doped liquid argon enhances the light production, mitigating the possible suppression due to impurities, but also it increases the wavelength of the scintillation light, enlarging the effective Rayleigh scattering length and improving the detection uniformity. ProtoDUNE Dual-Phase is a 300-ton active volume LAr TPC, a prototype for the Deep Underground Neutrino Experiment (DUNE), a dual-site experiment for long-baseline neutrino oscillation studies, neutrino astrophysics and nucleon decay searches. ProtoDUNE Dual-Phase took cosmic muon data at CERN with pure liquid argon and with xenon-doped liquid argon for over a year. The impact of the presence of xenon in the scintillation light and its comparison with the pure liquid argon data will be presented. These results are of interest to any future large LAr TPCs.

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Sensors: Noble liquid detectors / 396

The Recoil Directionality (ReD) Experiment

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Directional sensitivity to nuclear recoils would provide a smoking gun for a possible discovery of dark matter in the form of WIMPs. Given this potential importance, a new dedicated experiment, ReD (Recoil Directionality), was designed in the framework of the DarkSide Collaboration. A small dual-phase liquid argon TPC is irradiated with neutrons produced by the p(Li7,Be7)n reaction at the INFN Laboratori Nazionali del Sud (LNS), Catania, Italy, such to produce Ar nuclear recoils in the range (20 ,Äì 100 keV). Energy and direction of nuclear recoils are inferred by the detection of the elastically-scattered neutron by a set of scintillation detectors. Furthermore, ReD can be operated to study the response of the TPC to very low-energy nuclear recoils (in the keV range). In this contribution the latest recents results on the characterization and the optimization of the ReD LAr TPC will be presented, together with an overview on the forthcoming measurements with a Cf252 neutron source.

Sensors: Noble liquid detectors / 491

Further studies of unusual slow components in electroluminescence signal of two-phase argon detector

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Proportional electroluminescence (EL) in noble gases is used in two-phase detectors for dark matter search to record ionization signals in the gas phase induced by particle scattering in the liquid phase (S2 signals). The fast component and two unusual slow components have been previously observed in the EL pulse shapes of a two-phase argon detector, with time constants of about 5 μs and 60 μs. The unusual characteristic property of slow components is that their contribution and time constants increase with electric field. In this work, the slow components have been further studied in a wide range of reduced electric field, varying from 3 to 9 Td, and for different EL gap thicknesses. The pulse shapes were also studied at different readout configurations and spectral ranges: using cryogenic PMTs and SiPMs, with and without a wavelength shifter (WLS), in the VUV and visible range. The results obtained can have practical applications in DarkSide dark matter search experiment.

Sensors: Noble liquid detectors / 655

Commissioning, operation, and early results from the light collection system of the ICARUS T600 detector at the Short Baseline Neutrino (SBN) Experiment

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The proposed Short-Baseline Neutrino experiment (SBN) at Fermilab (USA) uses three Liquid-Argon Time Projection chambers (LArTPCs) located along the Booster Neutrino Beamline (BNB) to search for anomalies in low energy electron neutrino appearance signals. The ICARUS T600 detector, with its active volume of 760t of liquid Argon, will act as a far detector for the experiment. During 2021, the detector will transition from commissioning into stable operation using neutrinos from the BNB. The light collection system of ICARUS deploys 360 Hamamatsu R5912-MOD PMTs, covering one-third of the total internal surface of the detector, and will have a major role in identifying the neutrino signals and rejecting the cosmic background. This talk describes the commissioning and calibration of the light collection system and presents the first results obtained from the commissioning and early operation stages.

Sensors: Noble liquid detectors / 545

Electronic and nuclear recoil discrimination in xenon TPCs with the PIXeY experiment

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Liquid noble detectors are a critical piece of the international particle physics landscape, and multiple community-led processes (including the 2020 U.S. BRN for HEP Detector R&D) have identified them as one of our most promising tools for discovering new physics. In particular, the two-phase liquid/gas xenon time projection chamber is a leading technology for dark matter direct detection. A crucial part of using this technology is being able to classify energy deposits as nuclear recoils (NR) or electronic recoils (ER). This allows upcoming experiments like XENONnT and LZ to mitigate ER backgrounds like Rn daughters and pp neutrinos. I will present an analysis of ER-NR discrimination, using data from the PIXeY (Particle Identification in Xenon at Yale) experiment. PIXeY was an R&D-scale xenon TPC that operated at drift fields between 50 and 2000 V/cm. The experiment's data allows us to study discrimination across this wide range of fields, as well as its dependence on recoil energy.

Sensors: Noble liquid detectors / 709

Light only Liquid Xenon with Silicon Photomultipliers

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The Light only Liquid Xenon experiment (LoLX) is a few cm scale octagon housing of 96 Hamamatsu VUV4 Silicon Photomultipliers (SiPMs) packaged by group of 4, with radioactive needles (Œ≤-source Sr-90 or Œ±-source Po-210) in the centre. The project aims to study light production and transport and the operating of SiPMs in liquid xenon. In the first phase, 22 out of the 24 SiPM groups are covered by 225nm longpass filters blocking the scintillation light, in order to detect the Cerenkov photons that are several orders of magnitude less abundant that scintillation photons. The current analysis focuses on comparison between measured external cross-talk (light emitted from SiPM avalanche triggering avalanche in another SiPM) and GEANT4 simulation, to allow characterizing cross-talk photon production, propagation in the chamber and detection. Future development includes upgrading the sampling electronics to reach sub nano-second timing resolution and repeating measurement with argon.

Sensors: Photo-detectors / 384

Mass production and characterization of 3-inch PMTs for the JUNO experiment

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26000 3-inch PMTs have been produced for Jiangmen Underground Neutrino Observatory (JUNO) by Hainan Zhanchuang Photonics Technology Co., Ltd (HZC) company in China and passed all acceptance tests with only 15 tubes rejected. The mass production began in 2018 and elapsed for about 2 years at a rate of ˜1,000 PMTs per month. The characterization of the PMTs was performed in the factory concurrently with production as a joint effort between HZC and JUNO. Fifteen performance parameters were tracked at different sampling ratios, and novel working strategies were implemented to improve quality assurance. This constitutes the largest sample of 3-inch PMTs ever produced and studied in detail to date. This talk will provide an overview of the mass production and characterization of the 3-inch PMTs of JUNO.

Sensors: Photo-detectors / 552

The R&D of the Ultra Fast MCP-PMTs for High Energy Physics

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The Micro-Channel Plate (MCP) is a specially crafted microporous plate with millions of independent channels, which have secondary electron emission capability. The MCP could be used as the electronic multiplier amplifier in the PMTs. There are two types of MCP Photomultiplier tube (MCP-PMT), large-area electrostatic focusing PMTs (LPMT) and small size proximity focusing PMTs (FPMT) respectively. The LPMT always used in the large scalar neutrino detector for it,Äôs large area efficiency photocathode. The small size FPMT is widely used in high energy physics for its fast time response, strong anti-interference ability. The MCP-PMT Collaboration Group in China has successfully research and developed the LPMT for JUNO in 2017, and plan to research a new type of FPMT with multi-anode readout (4X4, 8X8). We will introduce some design of the FPMTs for the time measurement, and the performance of the several different prototypes with different readout channels.

Sensors: Photo-detectors / 706

Development of a hybrid single-photon imaging detector with embedded CMOS pixelated anode

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The development of a single-photon detector based on a vacuum tube, transmission photocathode, microchannel plate and CMOS pixelated read-out anode is presented. This imager will be capable of detecting up to 1 billion photons per second over an area of 7 cm^2, with simultaneous measurement of position and time with resolutions of about 5 microns and few tens of picosecond, respectively. The detector has embedded pulse-processing electronics with data-driven architecture, based on the Timepix4 ASIC, producing up to 160 Gb/s data that will be handled by a high-throughput FPGA-based external electronics and data acquisition system. These performances will enable significant advances in particle physics, life sciences, quantum optics or other emerging fields where the detection of single photons with excellent timing and position resolutions are simultaneously required.

Sensors: Photo-detectors / 406

Employment of nanodiamond photocathodes on MPGD-based HEP detector at the future EIC

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In high momenta range, the construction of a Ring Imaging CHerenkov (RICH) detector for the particle identification at the future Electron Ion Collider (EIC) is a complicated task. A compact collider setup imposes to construct a RICH with a short radiator length, hence limiting the number of photons. The number of photons can be increase by choosing a far UV region, imposes to initiate a R&D for a novel and robust photo-cathode (PC) material based on nanodiamond particles for a windowless RICH approach. To characterize The performance of nanodiamond PC coupled to THGEM-based photon detectors is the main objective of our ongoing R&D.
The first phase of these studies includes the characterization of THGEMs coated with nanodiamont PC, the comparison of the effective QE in vacuum and in gaseous atmospheres and the aging effects with ion bombardment.
The approach is described in detail as well as all the results obtained so far with these exploratory studies.

Sensors: Photo-detectors / 373

The COMPASS RICH-1 MPGD based photon detector performance

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In 2016 we have upgraded the COMPASS RICH by novel gaseous photon detectors based on MPGD technology. Four new photon detectors, covering a total active area of 1.5 square m, have been installed in order to cope with the challenging efficiency and stability requirements of the COMPASS physics programme. The new detector architecture consists in a hybrid MPGD combination: two layers of THGEMs, the first of which also acts as a reflective PC thanks to CsI coating, are coupled to a bulk Micromegas on a pad-segmented anode; the signals are read-out by analog F-E based on the APV-25 chip. These detectors are the first application in an experiment of MPGD-based single photon detectors.
Presently, we are further developing the MPGD-based PDs to make them adequate for a setups at the future EIC collider.All aspects of the COMPASS RICH-1 Photon Detectors upgrade are presented:R&D, engineering, mass production, QA and performance and the on-going development for collider application.

Sensors: Photo-detectors / 708

Introducing the Dichroicon, a Spectral Photon Sorter

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Many large scale particle detectors use photons as their primary event detection method, usually detecting numbers of photons and their arrival times. Photons also carry information about an event through their wavelength, polarization, and direction, but often little to none of this information is utilized. In this talk, we introduce the ‚Äúdichroicon‚Äù a Winston-style light cone comprised of dichroic filters which allows detectors to use the wavelength information encoded in photons. The dichroicon functions as a spectral photon sorter and has a broad range of applications including correction for photon dispersion in large scale detectors, the discrimination between Cherenkov and scintillation light, and new handles on particle ID. This talk will present results that quantify the dichroicon's ability to separate scintillation and Cherenkov light, as well as present simulation results illustrating the impact of dichroicons in next generation neutrino detectors, specifically THEIA.

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Sensors: Photo-detectors / 495

Latest Technological Advances with Microchannel-Plate PMTs

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Since the recent success in solving the long-standing aging issues of MCP-PMTs by applying an atomic layer deposition (ALD) technique to the MCP pores, these fast and B-field tolerant devices have become very attractive sensors for future experiments. Moreover, significant improvements in collection (CE) and quantum efficiency (QE) allow a DQE=QE*CE of ˜30%. The DIRC detectors of the PANDA experiment at FAIR will be read out by ALD-coated MCP-PMTs in 8x8 and 3x100 anode designs.
The talk will discuss the most recent advances with MCP-PMTs. The status in terms of lifetime, DQE, rate capability, time resolution, and their behavior in B-fields will be summarized. In a new setup up to 300 anode pixels can be read out simultaneously allowing a glance “inside the PMT”. Parameters like dark count rates and ion afterpulsing are measurable as a function of the incident photon position as well as the temporal and spacial spread of recoil electrons and electronic and charge-sharing crosstalk.

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Sensors: Photo-detectors / 624

Recent progress on development of MCP-PMT at Argonne National Laboratory

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Fast timing photosensors are critical for Nuclear Physics and High Energy Physics instruments. Microchannel plate photomultipliers (MCP-PMT) have compact electron amplification design, providing them with precision timing performance and excellent magnetic field immunity.
We report the development of MCP-PMTs with low-cost microchannel plates functionalized by the atomic layer deposition (ALD) technique at Argonne National Laboratory. Multiple photomultipliers were fabricated with different microchannel plate pore sizes and gap lengths. Their precision timing performance and magnetic field immunity were characterized and compared. To expedite the application of MCP-PMT for various programs, a $10 \times 10 cm^2$ MCP-PMT fabrication facility is under construction at Argonne to produce larger size, high-performance MCP-PMTs to fulfill R&D needs for various programs.

Sensors: Photo-detectors / 613

Surface passivation of single photon avalanche diodes for enhanced sensitivity in the vacuum ultraviolet range for liquid noble gas experiments

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The next Enriched Xenon Observatory (nEXO) is an experiment dedicated to the fundamental study of neutrinos. It searches for new physics beyond the Standard Model through the observation of the neutrinoless double-beta decay in xenon-136. The design of the nEXO time projection chamber includes Silicon Photmultipliers (SiPM) as key components to detect the scintillation light at 175nm, where a photon detection efficiency greater than 15 % is required.
This talk reviews the challenges of VUV direct detection in silicon-based detectors. It presents the prototype of Sherbrooke,Äôs single photon avalanche diodes on which a highly doped and very thin passivation layer is applied in order to prevent surface dark electron injection while improving the collection of VUV photogenerated carriers. It overviews the fabrication process challenges with suggestions for a second revision. The impact on the detector,Äôs dark noise and photon detection efficiency is also presented.

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Development of (V)UV-Sensitive GaN Geiger-Mode Photodiodes

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We present results from our ongoing development of Geiger-mode GaN-photodiodes. Motivated by the silicon photomultiplier's great success, our objective is to transfer the silicon-photomultiplier concept - a matrix of individually quenched single-photon avalanche diodes - to GaN and AlGaN. These are wide band-gap III-N semiconductors with much better intrinsic (V)UV sensitivity than silicon, making them interesting photon-detector materials, for example, to detect scintillation light from liquid Xe and Ar detectors.
The purity of III-N semiconductor substrates is now sufficiently high to envision single-photon sensitive photodiodes operating in Geiger mode. And indeed, we successfully fabricated GaN photodiodes and could demonstrate their Geiger-mode characteristics and single-photon sensitivity.
This presentation will discuss the electrical and optical characteristics of our GaN structures and their implications for developing a GaN solid-state photomultiplier.

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Sensors: Photo-detectors / 401

Fully Integrated CMOS SPAD Array Sensor for Optical Fibre Readout

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Various particle detectors use optical fibres for tracking or to bring light from scintillators to photo sensors. In order to detect the photons, the fibres are typically aligned to arrays of SiPMs and these are read out with dedicated ASICs. We propose a novel, fully integrated solution based on an array of Single Photon Sensitive Avalanche Diodes (SPADs) fabricated in a CMOS technology, i.e. combining photo sensors and electronics on the same chip. Our architecture allows assigning the SPADs to arbitrary groups so that no alignment of the fibres is required. The sensitive area of one group is confined to just the fibre, and bad SPADs can be masked, so that dark counts are minimised. The low power, data driven architecture delivers a hit multiplicity and time on a digital output per group. We will present the architecture and measurements obtained with a prototype chip. Our approach could greatly reduce mechanical complexity and cost of fibre readouts at improved performance.

Sensors: Photo-detectors / 625

External Cross-talk characterization from dark avalanches

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This talk presents a characterization of the light emission from dark noise in Silicon Photomultipliers (SiPMs). SiPMs are made of arrays of $\sim 10^4$ single photon avalanche diodes (SPADs) which are known to emit photons during the charge avalanche process. The spectral shape and emission rates of these photons are crucial data for understanding both external and internal cross-talk in these devices. This talk will present measurements of the dark noise emission spectra of the Fondazione Bruno Kessler (FBK) VUV-HD3 SiPM and the Hamamatsu Photonics K.K. (HPK) VUV4 SiPM, using a custom Light Emission and Injection Microscopy apparatus, for photon wavelengths between $400 - 1050\ nm$ and as a function of over-voltage. Additionally, we will propose a new theoretical model to infer the source of the dark noise in p-on-n SiPMs. This model shows as dark noise avalanches in p-on-n SiPMs are hole driven and they cannot be reduced to Shockley-Read-Hall thermal recombination.

Sensors: Photo-detectors / 343

Cryogenic detector system for background-free Muonium observation at temperatures below 200 mK

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We are developing a high brightness atomic Muonium (Mu = $\mu^+ e^-$) beam, amenable to the direct measurement of the gravitational interaction of μ^+. The characterization of this source and the prospective gravity experiment require background-free detection of atomic Mu emitted from the surface of T=200 mK superfluid helium (He-II). We developed the prototype of this detector based on the tracking of ∼50 MeV e^+ from μ^+ decay and the simultaneous measurement of the liberated few-eV atomic e^-. The e^+ trackers consist of 16 scintillator bars, coupled to silicon photomultipliers (SiPM). The few-eV e^- were first accelerated to ∼8 keV energies in an ion funnel, then left a few photon signal in a SiPM coupled to a scintillator pill. We present here the cryogenic development of SiPM detectors down to 170 mK for the first time, the temperature dependence of the single photon detection efficiency and the first test carried out using a surface muon beam at PSI.

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Performances of the SiPMs operated at low temperature for the JUNO - TAO detector

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The TAO (Taishan Antineutrino Observatory) near detector of the JUNO (Jiangmen Underground Neutrino Observatory) neutrino experiment is a ton-level high energy resolution liquid scintillator (LS) Gadolinium-based detector. It will be located at a distance of about 30 - 35 m from the 4.6 GW core of the Taishan Nuclear Power Plant (NPP), China. The main goal of TAO will be the measurement of the reactor neutrinos spectrum via the Inverse Beta Decay (IBD) to detect the anti- neutrinos generated in the core of the NPP. In order to achieve its goal, the TAO experiment will be equipped with about 10 m2 surface of SiPMs (˜ 95% coverage) working at -50¬∞ C to lower the dark noise. In this conditions the expected dark counts rate is about 100 Hz/mm2 with a Photo-Detection Efficiency (PDE) better than 50%. In this talk we will report on the performances of the SiPMs operated at low temperature for the JUNO - TAO detector, down to about -70¬∞ C. The test are running at INFN - Roma Tre, Italy

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Light detection with SiPMs for the nEXO experiment

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Silicon PhotoMultiplier(SiPM) technology represents an almost ideal solid-state photon detector. For this reason the nEXO experiment is migrating to a SiPM-based light detection system. nEXO aims to probe the boundaries of the standard model of particle physics by searching for $0\nu\beta\beta$ of 136Xe. Decays in the xenon produce both scintillation and ionization. The light flash is simultaneously detected by an array of SiPMs. In this talk we will present the latest results of the nEXO program for the detection of the 175¯nm scintillation light of liquid Xenon. In particular we will show results for the characterization of a new generation of VUV sensitive SiPMs (FBK VUV-HD-3) as a possible candidate for the nEXO experiment. Additionally, we will also show updates on the construction of new characterization setups for the testing of a large SiPM tile and stave and on the development of a SiPM tile charge readout. Finally, we will report on the status of the nEXO mini-prototype.

Sensors: Solid-state cryogenic detectors / 638

BULLKID: Low-threshold Kinetic Inductance Detectors for neutrino and dark matter searches

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Cryogenic sensors are used in experiments to detect low-energy nuclear recoils from dark matter or neutrino interactions through coherent neutrino scattering. Besides the record energy thresholds, the limit of current technologies resides mainly in the scale-up capabilities.
BULLKID is a R&D supported by INFN. It is developing a new detector concept to reach relatively high target masses with high granularity, by exploiting the multiplexing capability of Kinetic Inductance Detectors.
The detector unit we are designing consists in an array of,Äâ¯,Äâ100 silicon absorbers sensed by phonon-mediated, microwave-multiplexed kinetic inductance detectors, with energy threshold below 100 eV and total target mass around 30 g. The single detector unit will be engineered to ensure a straightforward scalability to a future kg-scale experiment. In this talk we will describe the challenge and the status of the project.

Sensors: Solid-state cryogenic detectors / 665

Transition-edge sensor based photon calorimeter for the CUPID experiment

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The CUORE Upgrade with Particle ID (CUPID) is a next-generation neutrinoless double-beta decay experiment that will require cryogenic light detectors to improve background suppression by reading out both the heat and light signals from the scintillating crystals. In this work, we describe a light detector based on a novel Ir/Pt bi-layer transition edge sensor for the first time. We have performed a systematic study of improving the electron-phonon coupling of the sensor and, thereby, its responsivity. Our very first devices easily meet CUPID's timing resolution criteria for rejecting pile-up events. The obtained energy resolution is close to CUPID's energy resolution requirement and is at present limited only by excess noise from the cryogenic apparatus. We will present the characterization and modeling of such detectors and the detector components' thermal properties. The study will inform the fabrication of future devices, culminating in the final detector designs.

Sensors: Solid-state cryogenic detectors / 661

Novel Low Workfunction Semiconductors for Dark Matter, Neutrino Phenomena, and Particle Physics

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Weakly bound semiconductor materials, Cs3Sb and Ag-O-Cs (photocathodes), have low electron-hole pair energies=Eg+Ea.These semiconductors in shapes and volumes could be used as detectors for: (1) low energy depositions, with thresholds as low as ˜50 eV depositions when cooled to ,â§4¬∞K(Ag-O-Cs), and (2) applications of Cs3Sb to calorimetry or tracking, with a pair energy 1.8-2 eV, but with far lower thermal noise than Si since Eg˜1.6 eV. Progress in Atomic Layer Deposition has been shown to deliver large area (˜m2) films and ˜few mm thicknesses. Applications of semiconductor detectors with low pair-energy thresholds range over detecting dark matter interactions, low energy (sub-MeV, coherent) neutrino interactions, neutrino-less double-beta decay, and neutrino interactions from the cosmos or sun. may result. Cs3Sb and Ag-O-Cs materials are radiation resistant for high resolution particle flow sampling calorimeters with more ion pairs and mobility larger than Si.

Sensors: Solid-state cryogenic detectors / 700

The Cryogenic Underground Test Facility at SNOLAB

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I describe the Cryogenic Underground TEst (CUTE) facility at SNOLAB. The facility includes an operating dilution refrigerator that can acheive stable operations at 12 mK base temperature. The CUTE facility also includes shielding from ionizing radiation, both from the SNOLAB ground and from the dilution unit of the refrigerator. There are also technologies to isolate the experimental stages from vibrations from the laboratory and from the cooling system. The facility is transitioning to a user facility, and I will discuss the current status and plans to start supporting experiments, as well as device and detector development in this cryostat that is isolated from the environment.

Sensors: Solid-state cryogenic detectors / 714

Novel Active Noise Cancellation Algorithms for CUORE

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The Cryogenic Underground Observatory for Rare Events (CUORE) experiment is an ongoing search for neutrinoless double beta decay located at the Gran Sasso National Laboratory (LNGS) in Italy. Recent work has found that the CUORE calorimeters are sensitive to acoustic and seismic events originating from outside the detector at LNGS. To measure the effect of these mechanical disturbances on the calorimeter signals, microphones and accelerometers were installed around the CUORE cryostat. Existing adaptive algorithms which use auxiliary devices (e.g. accelerometers) to remove microphonic noise from high-purity germanium detectors may be changed to remove excess noise from low-temperature calorimeters. Here I will present how said changes can be implemented for noise removal from calorimeters instrumented with neutron transmutation doped (NTD) germanium detectors or transition edge sensors (TES) and demonstrate how this new adaptive algorithm improves the energy resolution of these devices.

Funding information:
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Sensors: Solid-state sensors for tracking / 486

TCAD numerical simulation of irradiated Low-Gain Avalanche Diodes

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The project 4DInSiDe has the ambitious goal to implement several technological breakthroughs in the fabrication of the Low Gain Avalanche Diode (LGAD). In this work the results of device-level simulations, carried out with the state-of-the-art Synopsys Sentaurus Technology CAD (TCAD) tool, of non-irradiated and irradiated LGAD will be presented. In order to have a predictive insight into the electrical behaviour and the charge collection properties of the LGAD detectors, a radiation damage model has been fully implemented within the simulation environment. By coupling this numerical model with an empirical model that describes the mechanism of acceptor removal in the multiplication layer, it has been possible to reproduce experimental data with high accuracy, demonstrating the reliability of the simulation framework. Indeed the new developed model can be proÔ¨Åciently applied for predictive insight of the electrical behavior and for the optimization of the design of the detector.

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Sensors: Solid-state sensors for tracking / 627

Buried Layer Low Gain Avalanche Diodes

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We report on the design, simulation and test of Low Gain Avalanche Diodes (LGADs) which utilize a buried gain layer. The buried layer is formed by patterned implantation of a 50-micron thick float zone substrate wafer-bonded to a low resistivity carrier. This is then followed by epitaxial deposition of a ˜3 micron-thick high resistivity amplification region. The topside is then processed with junction edge termination and guard ring structures and incorporates an AC-coupled cathode implant. This design allows for independent adjustment of gain layer depth and density, increasing design flexibility. A higher gain layer dopant density can also be achieved by controlling the process thermal budget, improving radiation hardness. A first set of demonstration devices has been fabricated, including a variety of test structures. We report on TCAD design and simulation, fabrication process flow, and preliminary measurements of prototype devices.

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Performance of HPK Prototype LGAD sensors for the ATLAS High-Granularity Timing Detector HGTD

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We report on the layout and performance of Low-Gain Avalanche Detectors (LGAD) produced by HPK as prototypes for the HGTD in ATLAS. The HGTD is a multi-layer upgrade of the ATLAS detector of total area of 6.4m2 covering the pseudo-rapidity region between 2.4 and 4.0 with timing sensors with time resolution of 50 ps, representing the first large scale application of the LGAD.
Sensors with an active thickness of 50 ¬μm and 35 ¬μm were produced with common masks and different combinations of doping profile of the gain layer. The power dissipation and breakdown voltage are determined from I-V measurement, doping profile of the gain layer and the bulk from C-V data. The dynamic properties of the LGAD were determined by charge collection measurements using laser and charged particles. Samples of the sensors are irradiated with neutrons, protons and gammas to study the radiation-hardness. The dependence of the gain and of the time resolution on bias voltage and fluences will be presented.

Sensors: Solid-state sensors for tracking / 374

Radiation field characterization and particle tracking with Timepix3 in ATLAS and MoEDAL

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Timepix3 detectors are hybrid pixel detectors (256 x 256 pixels, pixel-pitch: 55 ¬μm) providing simultaneous ToT and ToA measurement in each pixel with negligible dead time (˜475 ns). Ionizing particle interactions in the sensor are seen as tracks with a rich set of features which can be exploited for particle identification and trajectory reconstruction (even with single layer setups). The presented contribution describes results achieved with Timepix3 installed in the ATLAS and MoEDAL experiments at CERN, where they perform real-time measurements of the radiation field composition, 3D particle trajectories and dE/dX spectroscopy. It is shown that, owing to the continuous operation and their large dynamic range of particle energies and count rate, Timepix3 detectors allow to study the induced radiation (radiation from radioisotope created during collision periods), changes in radiation levels during beam injection and particles emanating from the interaction points.

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Silicon Detectors for the LHC Phase-II Upgrade and Beyond ‚Äì RD50 Status Report

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A large R&D program has been underway to develop silicon sensors with sufficient radiation tolerance for LHC-Phase-II trackers and the next generation of collision experiments. Key areas of recent RD50 research include new technologies such as CMOS and Low Gain Avalanche Detectors (LGADs), where a dedicated multiplication layer to create a high field region is built into the sensor. We also seek for a deeper understanding of the connection between macroscopic sensor properties such as radiation-induced increase of leakage current, doping concentration and trapping, and the microscopic properties at the defect level. Another strong activity is the development of advanced sensor types like 3D silicon detectors. We will present the state of the art in silicon detectors at radiation levels corresponding to LHC-Phase-II fluencies and beyond. Based on our results, we will give an outlook towards the silicon detectors to be used for particle detectors at future experiments like the FCC.

Sensors: Solid-state sensors for tracking / 513

First results from thin silicon sensors irradiated to extreme fluence

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In this contribution, we present a new development of radiation-resistant silicon sensors produced by the Fondazione Bruno Kessler (FBK, Italy). The design of the sensors exploits the recently observed saturation of radiation damage effects on silicon, together with the usage of thin substrates, intrinsically less affected by radiation. To cope with the small-signal coming from thin sensors, internal multiplication of the charge carriers will be used. At FBK, Low-Gain Avalanche Diodes (LGADs) have been produced on 25 and 35 Œºm thick p-type epitaxial substrates: when new, the signal multiplication will occur due to the gain layer typical of the LGAD design; after irradiation, the loss of gain resulting by the deactivation of the gain layer atoms will be compensated by the increase of the operating bias. The goal is to prove that the new sensors can efficiently operate up to fluences of 1E17 1MeV neutron equivalent/cm2.

Funding information:
INFN

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The MIMOSIS pixel sensor

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MIMOSIS is a CMOS Pixel Sensor developed at IPHC, Goethe University Frankfurt and GSI for high granularity and large hit rate capability. These features meet the requirements of the Micro-Vertex Detector of the Compressed Baryonic Matter, a future experiments at FAIR: spatial resolution of ˜5 ¬μm, minimum radiation tolerance to 7$\sqrt{}$ó10ˆ13neq/cm¬$\leq$ and 5Mrad, operation in vacuum, and continuous read-out with 5 ¬μs integration time and 70 MHz/cm¬$\leq$ peak counting rate.
The architecture combines a pixel array derived from the ALPIDE sensor and a novel digital circuitry. The logic in the periphery regulates the data flow at the output of the pixel array, rating up to 20 Gbits/s, to 2.56 Gbits/s at the sensor outputs, by averaging the data flow over several integration windows. While allowing for high data rates, the power consumption stays below 50 mW/cm¬$\leq$.
This contribution will detail the sensor design and describe preliminary test results of the first full-scale (3.1x1.7 cm¬$\leq$) prototype MIMOSIS1.

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Latest Results on the Radiation Tolerance of Diamond Pixel and Pad Detectors

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As nuclear and particle physics facilities move to higher intensities, the detectors used there must be more radiation tolerant. Diamond is in use at many facilities due to its inherent radiation tolerance and ease of use. We will present radiation tolerance measurements of the highest quality poly-crystalline Chemical Vapor Deposition (pCVD) diamond material for irradiations from a range of proton energies, pions and neutrons up to a fluence of 2 x 10ˆ16 particles/cmˆ2. We have measured the damage constants as a function of energy and particle species and compare with theoretical models. We also present measurements of the rate dependence of pulse height for non-irradiated and irradiated pCVD diamond pad and pixel detectors, including detectors tested over a range of particle fluxes up to 20 MHz/cm2 with both pad and pixel readout electronics. Our results indicate the pulse height of unirradiated and neutron irradiated pCVD diamond detectors is not dependent on the particle flux.

Sensors: Solid-state sensors for tracking / 337

Optimization of gain layer doping, profile and carbon levels on HPK and FBK sensors

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Low Gain Avalanche Detectors (LGADs) are thin silicon detectors with moderate internal signal amplification. LGADs are capable of providing measurements of minimum-ionizing particles with time resolution as good as 17 pico-seconds. The first implementation of this technology will be with the high luminosity upgrade at the Large Hadron Collider (HL-LHC). Past publications have proven the vast improvement in term of radiation hardness of deep gain layer and carbon implantation in LGAD designs. In this contribution a study will be shown on the tuning of the doping concentration in the deep gain layer of HPK sensors to optimize the performance before and after radiation damage. Furthermore the effect of the combination of a deep gain layer and carbon implantation in FBK sensors will be shown alongside an optimization of the carbon concentration level. Results on electrical properties and charge collection will be shown on pre and post irradiation.

Funding information:
US department of energy

Sensors: Solid-state sensors for tracking / 503

Characterization of carbonated gain implants in Ultra Fast Silicon Detectors (UFSD) pre- and post-irradiation

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Ultra Fast Silicon Detector (UFSD) is an innovative thin silicon sensor, based on Low Gain Avalanche Diode technology, able to measure the time of a hit with a temporal precision of ˜30 ps. The application of this technology in HL-LHC experiments requires unaltered temporal performances at fluences of the order of 1E15 neq/cm2, making the radiation resistance a key point of this technology. Past UFSD productions, fabricated by Fondazione Bruno Kessler (FBK), demonstrated the improvement of radiation hardness when the gain implant is enriched with carbon. In past FBK productions, shallow and deep gain implants have been enriched with carbon doses from 0.4 to 10 a.u., with the aim of mapping the carbon effect as a function of carbon dose. This contribution will illustrate how the carbon dose that maximizes the radiation resistance of the gain implant has been identified, and that, in combination with a deep gain implant, allows to maintain unchanged performances up to 2.5E15 neq/cm2.

Funding information:
Universit√† del Piemonte Orientale

Sensors: Solid-state sensors for tracking / 314

Test-beam and simulation studies for the CLICTD technology demonstrator - a monolithic CMOS pixel sensor with a small collection diode

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The CLIC Tracker Detector (CLICTD) is a monolithic pixel sensor¬†featuring pixels of 30 um x 37.5 um and a small collection diode. The sensor is fabricated in a 180 nm CMOS imaging process, using two different pixel flavours: the first with a continuous n-type implant for full lateral depletion, and the second with a segmentation in the n-type implant for accelerated charge collection. Moreover, CLICTD features an innovative sub-pixel segmentation scheme that allows the digital footprint to be reduced while maintaining a small sub-pixel pitch. In this contribution, test-beam measurements for both pixel flavours are presented. Their performance is evaluated in terms of time and spatial resolution as well as efficiency. Furthermore, the test-beam data is compared to simulation studies using a combination of 3D TCAD and Monte Carlo simulation tools.

Sensors: Solid-state sensors for tracking / 439

Performance of radiation hard 3D pixel sensors for the upgrade of the ATLAS Inner Tracker

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The inner detector of the ATLAS experiment will be replaced by a completely new Inner Tracker (ITk) to exploit the performance of the High Luminosity upgrade of the LHC accelerator (HL-LHC). The new detector will have to operate in an unprecedented radiation environment. In particular, the hybrid pixel detectors of the innermost layer of the ITk will be exposed to a particle fluence of about 2e16 n_{eq}/cm^2 before being replaced.
A novel 3D pixel sensor technology featuring thin active substrates and small pixel cells has been selected to instrument the innermost barrel layer and rings of the ATLAS ITk.
Prototypes of these 3D pixel sensors produced at CNM in Barcelona, Spain have been irradiated with protons and neutrons up to the radiation doses expected at HL-LHC. Results obtained from the characterisation of 3D pixelated test structures as well as half-size sensors coupled to the RD53A ASICS prototype for HL-LHC will be presented.

Sensors: Solid-state sensors for tracking / 672

Exploiting the distributed signal in Resistive Silicon Detectors (RSD, AC-LGAD) to achieve micron-level spatial resolution

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Resistive Silicon Detectors (RSD, also known as AC-LGAD) are novel n-in-p silicon sensors, based on the LGAD technology, featuring an unsegmented gain layer that spreads over the whole sensor active area.
The innovative feature of the RSD design is that the signal produced by an ionizing particle is seen on several pixels, allowing the use of Machine Learning techniques that exploit the information of many read-out channels to predict the particle impact position with great accuracy. For instance, the spatial resolution of an RSD with 100 Œºm pixels is measured to be less than 2 Œºm.
I will discuss the key aspects of the RSD design and present results on the position resolution of sensors with different geometries, obtained with a precise laser setup. I will also describe the development and training of the Machine Learning algorithm used to reconstruct the impact positions. All tested sensors come from the first RSD production (RSD1) produced at Fondazione Bruno Kessler (FBK, Italy).

Sensors: Solid-state sensors for tracking / 673

Comprehensive technology study of radiation hard LGADs

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Towards radiation tolerant sensors for pico-second timing, several dopants are explored. Using a common mask, CNM produced LGADs with Boron, Boron+Carbon and Gallium implanted gain layers are studied under neutron and proton irradiation. With fluences ranging from 1e14 to 6e15 n_{eq}/cm^2 on both species, reported results focus on breakdown voltage-mode, acceptor removal and gain reduction via electrical characterization. Timing performance, charge collection, gain and relative efficiency are treated through charged particle measurements, including signal Fourier analysis and noise characterization. An accent is placed on stability, via dark rate and operating voltage studies while, radiation related gain reduction mechanisms are examined comparing gain estimations using different approaches. Finally, With data at -10C, -20C and -30C, temperature dependence is assessed while investigating sensor failure modes under different conditions, including macro- and microscopic inspection.

Funding information:
CERN

Sensors: Solid-state sensors for tracking / 715

Radiation damage investigation of epitaxial p-type silicon using Schottky and pn-junction diodes

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Focus of this RD50 project is the investigation of trap energy levels introduced by radiation damage in epitaxial p-type silicon. Using 6-inch wafers of various boron doping concentrations (1e13, 1e14, 1e15, 1e16, and 1e17 cm-3) with a 50 ¬μm epitaxial layer, multiple iterations of test structures consisting of Schottky and pn-junction diodes of different sizes and flavours are being fabricated at RAL and Carleton University.
Details on the initial fabrication phase of devices on high resistivity wafers will be given. IV and CV scans of test structures have been performed and cross-checked between institutes, the results of which will be presented.
Samples of both Schottky and pn-junction diodes have been further investigated using Deep-Level Transient Spectroscopy (DLTS) and Thermal Admittance Spectroscopy (TAS) to characterise trap energy levels in unirradiated devices.
The findings as well as plans for measurements of irradiated samples will be discussed.

Tech Transfer Posters / 713

TOPAS Simulations for Estimating 48V Yields of Natural Titanium Foil Irradiation

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Natural titanium foils can be used in the production of several medical isotopes, including Œ≤+ emitter vanadium-48. Due to its 16 day half-life, vanadium-48 has potential application in long-term monitoring and longitudinal studies. While foils are often irradiated via solid target system, medical cyclotrons lacking these systems often have components that can be manipulated for this purpose, such as placing thin foils in a beamstop. In this work, we simulate the irradiation of natural titanium foils via TOPAS, a Geant4-based Monte Carlo program, calculate the theoretical yield using cross section data from the literature, and compare the results to the experimental yield of 12 ¬μm foils bombarded in a beamstop with 18 MeV protons via compact medical cyclotron IBA 18/9 Cyclone. TOPAS results produced a 10% difference compared to experimental results and a 54% difference compared to theoretical calculations, indicating that factors such as foil angle may have lowered experimental yields.

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Tech Transfer Posters / 318

Gaseous Tracking Detectors at the Sakurajima Muography Observatory

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Muography is a novel imaging technology to reveal density structure of hill-sized objects. The cosmic muons predictably lose their energy and penetrate hundreds of meters into the ground, thus their differential local flux correlates with the crossed density-length.
The Sakurajima Muography Observatory in Kagoshima, Japan, is the largest muography experiment targeting an active volcano. A set of multilayered gaseous detectors are used to reconstruct the muon tracks, thus by measuring the flux, imaging of the inner part of the vulcano becomes possible.
The presentation will focus on the technical challenges of such a particle
tracking system, the designed multi-wire proportional chambers,
and the recent results from the measurements.

Tech Transfer Posters / 333

INSTRUMENTS AND METHODS FOR THERANOSTIC RADIOISOTOPE PRODUCTION AT THE BERN MEDICAL CYCLOTRON

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Radioisotopes for theranostics are essential for nuclear medicine developments. Their production using solid target stations is challenging and new instruments and methods derived from particle physics are needed. A research program is ongoing at the 18 MeV Bern medical cyclotron, equipped with a solid target station and a 6 m long Beam Transfer Line ending in a separate bunker. To bombard compressed powder pellets, novel target coins were conceived and realized together with methods to assess the beam energy and the production cross-sections. The EoB-activity is measured with a CdZnTe (CZT) detector. To accurately assess the properties of the beam, novel non-destructive one- and two-dimensional beam monitoring detectors were developed. An ultra-compact active irradiation system based on a novel magnetic lens and two-dimensional beam detectors is under development. Results on Er-165, Tb-155, Ga-68, Cu-61, Cu-64, Sc-43, Sc-44 and Sc-47 production are presented.

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Tech Transfer Posters / 367

Stand-alone Low Power Consumption FEE and DAQ for Particle Tracking in Outdoor Applications

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We developed a stand-alone DAQ and FEE for low power consumption and outdoor applications. The system can work autonomously thanks to dedicated algorithms implemented in a embedded system. The FEE, based on the EASIROC chip that gives the readout of Silicon photomultipliers (SiPMs), digitizes the amplitude of the signals and provides time information with time of flight capability. Different trigger logics can be programmed and physical and accidental coincidences rates can be measured. The SiPMs temperature is controlled by thermoelectric cells and, thanks to a network of temperature and humidity sensors, a real-time software is able to set the optimal operating point, adapting to external conditions and eventually stop and resume the data acquisition to avoid the damage of the electronics.The system has been tested in several muon radiography experiments.

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Investigation of deflection angle for muon energy classification in muon scattering tomography via GEANT4 simulations

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In muon scattering tomography, the investigated materials are discriminated according to the scattering angle that mainly depends on the atomic number, the density, and the thickness of the medium at a given energy value. The scattering angles at different initial energies also provide the opportunity to classify the incoming muons into a number of energy groups. In this study, by employing the GEANT4 code, we show that the deflection angle exponentially decays with respect to the energy increase, and the numerical values for the current configuration are below the detector accuracy except the initial energy bins owing to the low-Z, low density, and low thickness of the current plastic scintillators. This implies the necessity of additional components that provoke the muon scattering. Therefore, we introduce stainless steel surfaces into the top and bottom sections in order to amplify the deflection angle as well as to reduce the uncertainty, thereby improving the detector performance.

Tech Transfer Posters / 409

Low gas consumption in tracking detectors for outdoor applications

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The tracking detectors of particle physics are facing new demands in applied physics. Muography is in highlight, where tracking of cosmic muons could reveal the inner structures of geological or archaeological objects. The dedicated R&D shall focus on portability, robustness against outdoor conditions, low consumption, high tracking efficiency, and cost efficiency. A practical choice is gaseous detectors, offering excellent tracking efficiency, good position resolution, and low weight. Our group developed several multi-wire detectors for muography, where the classical MWPC concept was tuned to meet all the former criteria.
Robust and lightweight systems required open-end gas line, meaning continuous gas exhaustion. An application of a proper buffer tube allows reduced consumption, resulting a 0.12 l/h (3 l/day) gas flow in long term outdoor conditions.
The presentation will focus on the limitations of gas consumption, detailing the measurement series and the results.

Tech Transfer Posters / 452

Optical fiber array to monitor isotope production targets

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Low-energy cyclotrons are in use worldwide to produce medical isotopes for nuclear medicine. Beam monitoring during the irradiation of targets is difficult due to the high-power density of low-energy protons, space limitations and interference with the beam delivery. Doped silica fibers are sensitive to ionizing radiation, and produce radiation induced luminescence (RIL) when exposed. The fibers can be attached to the outside of the target in a low-profile fiber array, ensuring efficient and safe operation. We performed proof-of-principle experiments with different dopants and fiber diameter. Our results show that the RIL signature can be used to track the steering of a proton beam at a medical cyclotron, the beam intensity and the target material, and we are currently working on the design of a prototype.

Tech Transfer Posters / 479

The industrial production and validation of Micromegas boards for the ATLAS upgrade.

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The muon system of the ATLAS Experiment is currently undergoing a major upgrade with the replacement of the innermost detector wheel with new structures (New Small Wheel, NSW) based on resistive Micromegas (MM) and small-strip Thin Gap Chambers.¬†
MM covers an active area of about 1280 m2, being the largest system based on Micro¬†Pattern Gaseous Detector (MPGD) ever built so far.¬†The key element of the detectors are the anode boards which carry the readout strips, the resistive protection layer and the insulating pillars supporting the mesh. In total more about 3000 boards, of 16 different types with size up to 40x220 cm2, are produced by two industries in Europe, which opened the road to MPGD mass production.
The talk will review the technological transfer effort to make the Micromegas board production an industrial process. The main challenges encountered and the adopted solutions will be presented in detail, together with the results of the QA/QC performed at CERN.

Tech Transfer Posters / 582

Improvement in Material Discrimination Using Muon Momenta Information in Muon Scattering Tomography

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Muon Scattering Tomography is a major non-destructive technique to discriminate materials by finding deviation in muon tracks which depends on atomic number (Z) and density (,ç¥) of the target material. Based on scattering parameters obtained from Geant4 simulation, a Pattern Recognition Method has been devised which is able to distinguish high-Z and low-Z materials with more than 5[U+F8FF]ùúé accuracy [S. Tripathy et al., 2020 JINST 15 P06029]. The scattering angle also depends on the incoming muon momentum which is a key to distinguish multiple small deviations through large path-lengths of low-Z material from significant deviations through smaller path lengths of a high-Z target. In this work, an analytical function, derived by fitting the muon momentum distribution in selected ranges, has been used to determine the momentum of individual events. It has been used as weighting parameter to normalize the scattering angle of the respective event to improve the accuracy of material discrimination.

Technology Transfer / 286

A Proton Computed Tomography Demonstrator for Stopping Power Measurements

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Particle therapy is an established method to treat deep-seated tumours, using accelerator-produced ion beams. For treatment planning, the precise knowledge of the stopping power (SP) within the patient is vital. Conversion errors from x-ray CT measurements to SP introduce uncertainties in the applied dose distribution. Using a proton Computed Tomography (pCT) system to directly measure the SP could potentially increase the accuracy of treatment planning.
A pCT demonstrator, consisting of double-sided silicon strip detectors (DSSD) as tracker and plastic scintillator slabs coupled to silicon photomultipliers (SiPM) as a range telescope, was developed. After a major hardware upgrade of the range telescope, a 3D tomogram of an aluminium stair phantom was recorded at MedAustron.
Imaging results as well as current design studies for a new prototype, based on time-of-flight detectors, will be shown.

Technology Transfer / 295

Characterization of pixelated silicon detectors for the measurement of small radiation fields in proton therapy

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The advanced imaging and accelerator techniques in proton therapy allow conformal high dose irradiation of tumors with precision using pencil beam scanning or beam shaping apertures. These irradiation methods increasingly include small radiation fields with large dose gradients, which require the development of small field dosimetry systems with high spatial resolution for quality assurance. Based on their good spatial resolution and high rate compatibility, pixelated silicon detectors could meet the new requirements. To assess their applicability in proton therapy ATLAS pixelated silicon detectors are used to measure lateral beam profiles of different irradiation modes, as well as the dose gradient at the field edges with high resolution. Analysis strategies to determine the residual proton energy and the possibility to measure the proton flux are under study. The talk will present first results from measurements at the West German Proton Therapy Centre in Essen, Germany

Technology Transfer / 508

A compact gamma-ray imaging camera for radio-nuclides detection

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The detection of natural radio-nuclides is of interest in several applications, for example for natural environmental monitoring or for the identification and tracing of illegal radioactive materials. We designed and developed a camera for gamma-ray imaging based on the coded mask technique. The camera proposed is a compact instrument, ideal for real-time analysis, with a low power consumption. It consists of 16 CsI(Tl) scintillators arranged in a 4x4 matrix and coupled to photo-multiplier tubes (PMTs) with a digital readout. We used a 7$\sqrt{}$ó7 mask composed by transparent and opaque tiles to allow the position reconstruction of a radioactive gamma-ray point source. Measurements were conducted using radioactive sources placed at a fixed distance from the mask. We will present the performance of this prototype camera in terms of energy and spatial resolutions. Different reconstruction algorithms were used to decode the source images and their performance will be compared.

Technology Transfer / 525

Fragmentation Measurements in Particle Therapy: status and plans of the FOOT experiment

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Due to the advantageous characteristics of charged particles' energy deposition in matter, protons in the energy range of 70-230 MeV or ^{12}C beams with energy up to 400 MeV/u are used in hadrotherapy to treat deep-seated solid tumors. Using these beams, the maximum of the dose is released to the tumor tissues at the end of the beam range. In this process nevertheless, fragmentation of both projectile and target nuclei can occur in the nuclear interactions of the beam with the patient tissues and needs to be carefully taken into account.
The goal of the FOOT (FragmentatiOn Of Target) experiment is to estimate target and beam fragmentation cross sections in the energy range of interest for hadrotherapy, in order to provide new data for medical physicists, radio-biologists and to improve the new generation of Treatment Planning Systems.
In this talk the project, the status of the different sub-systems construction and the plans for the final experiment assembling will be presented.

Technology Transfer / 321

A Large Area GEMPix detector for treatment plan verification in hadron therapy

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We propose a novel detector for quality assurance in hadron therapy, for which an accurate dose calculation and verification with high spatial accuracy are required. For this purpose, a promising tool is the GEMPix detector, which combines a triple GEM (Gas Electron Multiplier) and a quad Timepix ASIC used as highly pixelated readout. The GEMPix (active area 28x28 mm2) is capable of providing 2D images of the beam with high spatial resolution, the Bragg curve and the 3D energy deposition. Although promising, a wider sensitive area is required to cover the typical radiation field size and to avoid losses due to beam spread out.
We present an original solution named LaGEMPix by replacing the ASIC by a matrix of organic photodiodes coated on an oxide thin film transistor backplane produced by Holst Centre/TNO. We combined the two technologies and developed this innovative detector to achieve a wider area (60x80 mm2) imaging detector and to fully exploit its optical readout capability.

Technology Transfer / 355

A novel cylindrical detector for borehole muon radiography

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Muography (or muon radiography) is a recent inspection methodology that uses cosmic muons to investigate the mass distribution in large objects, such as volcanoes or mines, or to detect the presence of cavities in the subsoil or within buildings such as the pyramids. In recent years detectors with different geometries, sizes and technologies have been developed. In particular detectors with reduced size, that can be inserted in a borehole, are of particular interest in geophysical applications. We have developed, and patented, an innovative detector for well applications consisting of plastic scintillators with arc shape and rectangular section bars. Good spatial resolution was achieved with a reasonable number of channels. Detailed simulations based on Monte Carlo methods have shown excellent performance in cavity detection. Preliminary results of a prototype show good performance in terms of the number of photoelectrons produced by cosmic muons and track reconstruction.

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Underground Muography with Portable Gaseous Detectors

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Muography is a novel imaging technology to reveal density structure of hill-sized objects. The cosmic muons lose slowly their energy and penetrate hundreds of meters into the ground, thus their differential local flux correlates with the density-lenght they traveled through.

Exploiting the high flux around the zenith the imaging of the internal structure of hills could be done underground. Various fields could benefit from this non-invasive imaging, eg. speleology, mining, and cultural heritage targets.

The main challenges are the portability, low power consumption, and robustness against the out-of-the-laboratory environment.

Portable gaseous tracking detector system has been designed and built, and successfully used in several underground locations.

The preseatation will focus on the designed portable tracking system, the main requirements, and measurement campaigns for calibration, natural caves, and cultural heritage.

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MURAVES muon telescope: a low power consuming muon tracker for muon radiography applications

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Muon Radiography is a technique based on the measurement of the absorption degree of cosmic ray muons as they pass through rocks to investigate the interior of large scale bodies, such as pyramids, volcanoes, little hills and others.
The MURAVES project aims to optimize the knowledge of the density distribution along the body of the Mt. Vesuvius, an active volcano near Naples in Italy, providing a useful information that can help, in addiction to the standard gravimetric measurements, to understand its past and future activity.
The MURAVES apparatus is a modular, robust and low power consumption muon hodoscope consisting in an array of three identical muon trackers each of one square meter sensitive area. Each tracker consists of four XY stations made of plastic scintillator bars optically coupled with SiPMs. The hodoscope has been installed on the flank of the volcano and up-to-now a four-months net statistics has been collected.

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The Curious Cryogenic Fish (CCF): Development of a diagnostic robot for large cryostats

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The Curious Cryogenic Fish (CCF) Project aims to develop a robotic device able to operate in large cryostats while filled. The goal is to perform visual inspections, environmental measurements and simple repair tasks, integrating the functionalities of a diagnostic station with the flexibility of an unmanned vehicle.
The idea originates from the particle physics domain, but it has many potential applications, particularly in the field of liquefied gas transport and storage, as well as in cryogenic plant monitoring.
The challenging realisation of the CCF requires not only the integration of a set of existing technologies into a single robotic device operating in a cryogenic environment, but also the extension of those technologies in order to work in that unusual environment.
This paper presents the state of the art of the technologies required for the endeavour, the results of the early feasibility studies carried out, and the necessary future steps to bring the project to maturity.

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URANIA-V (muRwell Advanced Neutron Identification Apparatus)

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A new challenge in particle physics is neutron detection. Innovative detection techniques are needed for the application in this field, e.g. radioactive waste monitor homeland security applications, scanner with neutron scattering. Gaseous detector together with a proper converter can be used for these purposes; a boron coated cathode converts the neutron and the products are detected with muRwell technology: single amplification stage gas detector with a resistive spark-protection. In this presentation an overview of the project is given: a thermal neutron detector has been designed, built and tested with a Am241-B neutron source. A detection efficiency of about 4% with thermal neutron has been achieved with a simple configuration of converter, detector and electronics. This design has been shared with the industry and the technological transfer has started. The R&D is focused on new design and a more sensitive electronics to count the single-particle.