PSD13: The 13th International Conference on Position Sensitive Detectors

Sunday, 3 September 2023 - Friday, 8 September 2023

Oxford

Book of Abstracts

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Test abstract

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Applications in security and environmental imaging / **2**

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 (1 Grad), high hit rate (3GHz/cm2) and high data rate readout (5 Gb/s).
The RD53 collaboration is a joint effort between the ATLAS and CMS experiments, established in 2013 and extended in 2018, to qualify the chosen 65nm CMOS technology and develop the readout chips for the HL-LHC pixel detectors of both experiments. Due to different mechanical constraints of the two trackers and specific requirements of each experiment, the chips have been designed in two flavours, having different dimensions and analog front-end.
After a half-scale demonstrator (RD53A) and full scale prototypes of the two ASICs (RD53B-ATLAS and RD53B-CMS), largely used by the two communities to characterize 3D and planar sensors, RD53 has developed the final chips: RD53C-ATLAS, submitted to foundry in March 2023 and RD53C-CMS, expected to be submitted in August 2023.
A general overview of the chip architecture and test results on the RD53B prototypes will be presented.

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Detectors at Neutron facilities / 3

The large area scintillator neutron detectors in Chinese Spallation Neutron Source (CSNS)

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Analyzing neutron scattering and diffraction is currently the best way to probe the microstructure and dynamic properties of materials. The China Spallation Neutron Source (CSNS) is a large scientific facility whose main aim is to support multidisciplinary research on material characterization using neutron scattering. It has been running steadily with four neutron instruments from March,2018. Twenty neutron instruments will be built as multidisciplinary platforms for scientific research by national institutions, universities, and industry. Several versions of large area scintillator neutron detector for the replacement of the 3He tubes have been developed to fulfill the requirements of different neutron Diffractometer. The first version detector which consists of 6LiF/ZnS (Ag) scintillators, crossed wavelength-shifting fiber (WLSF) arrays, and multi-anode photo multiplier tubes (MA-PMT) has been used in General Purpose Powder Diffractometer (GPPD) since 2018. It has 4×4 mm2 pixel size. The second version of the scintillator detector is designed with oblique ZnS(Ag):6LiF scintillators and Silicon Photomultipliers (SiPMs) readouts. It has applied in Engineering Materials Diffractometer (EMD) and Energy Resolution Neutron Imaging instrument (ERNI) with more than 6m2covera area. The pixel size is 3mm×50mm and 3mm×100mm respectively. And the neutron detect efficiency is improved from 38% to 62% for the 1.4 Å neutron. There are third version of the scintillator detector being developed for the high position resolution of 1mm. It will used in the single crystal neutron diffraction measurement.

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Poster Session I / 4

R&D of the Readout Electronics for X-ray Beam-position Feedback System Of SAPS

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For 4th generation synchrotron radiation (SR) light sources, the X-ray beam-position stability is one of the crucial factors in cutting-edge experiments. Instead of traditional passive vibration isolation techniques, active vibration isolation measures based on feedback control technology have begun to play an important role for stabilizing the beam-position. The readout electronics of the feedback

control system is presented in the paper. The proposed design is based on the integration of proportion integral differential (PID) controller and system on chip (SoC) module. By using the ARM for analyzing the convergence speed of PID controller with different parameters and configuring it, the readout electronics flexibly adapts to different vibration environments. The readout circuits based on this method is implemented for southern advanced photon source, and tests are carried out in the laboratory to evaluate the readout electronics. The results show that it can weaken the influence of vibration sources below 5Hz on the beam-position.

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Closing session / 5

Detector challenges of the strong-field QED experiment LUXE at the European XFEL

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The LUXE experiment aims at studying high-field QED in electron-laser and photon-laser interactions, with the 16.5 GeV electron beam of the European XFEL and a laser beam with power of up to 350 TW. The experiment will measure the spectra of electrons, positrons and photons in expected ranges of 10−3 to 109 per 1 Hz bunch crossing, depending on the laser power and focus. These measurements have to be performed in the presence of low-energy high radiation-background. To meet these challenges, for high-rate electron and photon fluxes, the experiment will use Cherenkov radiation detectors, scintillator screens, sapphire sensors, as well as lead-glass monitors for backscattering off the beam-dump. A four-layer silicon-pixel tracker and a compact electromagnetic tungsten calorimeter will be used to measure the positron spectra. The layout of the experiment and the expected performance under the harsh radiation conditions will be presented. The experiment has received stage 1 critical approval (CD1) from the DESY management and is in the process of preparing its technical design report (TDR). It is expected to start running in 2025/6.

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Poster Session I / 6

An 8-channel Low Power ASIC for Helium-3 Tube Position Sensitive Neutron Detectors

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The majority of neutron spectrometers designated for use in the China Spallation Neutron Source (CSNS) rely on position-sensitive detectors that utilize Helium-3 tube technology. To minimize the impact of air on neutron scattering experiments, these detectors must be located inside a vacuum chamber. For these types of spectrometers, it is also advisable to house the readout electronics within the vacuum chamber to limit the number of feed-through cables required and enhance the signal-to-noise ratio. This paper proposes an application-specific integrated circuit (ASIC) dedicated to position-sensitive Helium-3 tubes, including front-end amplification, shaping module and readout driving buffer. The 8-channel chip, named HEROCV1(HElium-3 ReadOut Circuits), achieve an input dynamic range from 10 fC to 1 pC, with a counting rate of up to 100 kHz. The equivalent noise charge (ENC) measurement result is 1297e-@15pF, and the power consumption is less than 9.9 mW per channel. The ASIC has replaced the traditional front-end circuit based on discrete components, fundamentally addressing the issue of front-end power consumption and enabling the entire detector system to operate in a vacuum environment.

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Applications in Astro-Particle Physics / 7

Electro-optical characterisation and radiation hardness of a CMOS image sensor optimised for soft X-ray astronomy

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CIS221-X is a prototype CMOS image sensor, optimised for soft X-ray astronomy and developed for the proposed ESA THESEUS mission. The sensor features 40 μm pixels built on a 35 μm thick, high-resistivity epitaxial silicon that is fully depleted by reverse substrate bias. A comprehensive electro-optical characterisation of CIS221-X has been completed. When cooled to -40 ℃, the image sensor reports a readout noise of 3.3 e- RMS and 12.4 $\pm$ 0.06 e-/pixel/s of dark current. Following per-pixel gain correction, an energy resolution of 126 $\pm$ 2 eV FWHM has been measured at 5.9 keV. In the 310 - 1900 eV energy range, the sensor achieves a quantum efficiency of above 80%. These results strongly support the consideration of CMOS technology for soft X-ray astronomy. To better understand how the CIS221-X would perform over the course of the THESEUS mission, it is necessary to test the radiation hardness of the image sensor. Using the ESTEC ^{60}Co facility, the CIS221-X sensitivity to total ionising dose (TID) has been measured. At increasing dose levels, readout noise, dark current and image lag were assessed. The results show the expected deterioration of CIS221-X performance due to TID over the course of the THESEUS mission.

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Poster Session III / 8

RD53A Quad Modules Production and QC for the ATLAS Inner Tracker Outer Barrel (OB) Demonstrator.

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Summary (Max 500 words)
ATLAS innermost detector layer will undergo a broad range of upgrades for the HL-LHC phase. To be able to cope with the new detector design and a large set of modules to be integrated on the ITk, a demonstrator-based project at SR1 facility in CERN is conducted, to test and integrate a large number of Pixel modules equipped with RD53a electronics.
To mimic the ITk detector, a demonstrator project for the outer barrel section is ongoing with 34 modules. RD53a modules will encounter several production operation stages to be loaded on the OB demonstrator and finally integrated with real on-detector services for a full system test of multiple modules. Additionally, to monitor the module's performance from the reception stage to the final system test on the demonstrator, electrical scans ranging from the front-end readout chip to the sensor level are carried out, with an additional X-ray scan to find any open bumps at each production step. Furthermore, the module performance is compared at different production stages to allow a better understanding of any undesired trend of performance degradation.
A comprehensive study will be presented; tracking the main module performance features and applying a newly developed tool to identify, categorize and locate different Pixel defects, to allow a better understanding of any degradation foreseen in the large production phase for the ITk modules and define a detailed quality control (QC) scheme.
Besides, the anticipation of the overall testing stages will quantify the production yield based on module performance. Using the module QC tool, a combined analysis of the electrical scans for the Pixel detector circuit, starting from the digital front-end part towards the sensor is carried out. Indeed, if at any incidence a Pixel defect is found, it will get recorded by the tool and counted for the individual module and later for the total number of Pixel channels in the OB demonstrator project. This approach is used to tackle the difficulties expected in modules and stave ratings once the ITk production starts. Hence, an envision of the most likely Pixel defects to occur is studied, based on classifying the origin of the Pixel defect failure with the QC tool. Moreover, to enable a deeper understanding of the expected difficulties, the 34 modules Pixel matrices are stacked to identify any specific geographical Pixel region containing any large number of Pixel defects.
In summary, this work is initiated to study in depth the Pixel quad module performance using RD53a front-end electronics, considering the implications of different testing stages during integration in the OB construction. The methodology applied here can be extended or adapted in the future, for the final module production to allow quick and systematic identification of defects in the module production and on-stave integration.

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Detectors at Neutron facilities / 9

Development of large area boron-coated GEM thermal neutron detector in CSNS

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As one of the ideal probes to detect the structure and dynamics behavior of matters, neutron scattering has been widely used in condensed matter physics, chemistry, life science, medicine, material science, aviation and national defense construction and many other fields. With the completion and operation of China Spallation Neutron Source (CSNS), a large number of neutron scattering spectrometers will be built on them, they have an urgent need for high-efficiency, large-area, and position-sensitive detectors. The boron-coated GEM neutron detector has high measurement accuracy, wide dynamic range, and excellent performance, which is one of the development directions of future gas detectors. With the goal of realizing the localization of key technologies and core devices, the ceramic nTHGEM (neutron Thick Gaseous Electron Multiplier) processing technology has been continuous optimized and improved. A ceramic nTHGEM with effective area of 100mm×100mm, 200mm×200mm, and the development of 300mm×300mm ceramic nTHGEM have been successfully realized, which fully meets the requirements of neutron detection. In order to achieve a larger area of boron coating, combined with the special requirements of the boron coating process, a high-performance large-area boron coating device based on magnetron sputtering mechanism was developed in cooperation with Tongji University for the research and production of boron coating process. The device has been functioning normally and successfully coated the boron carbide neutron conversion layer required by the GEM detector and realized neutron detection. At the same time, special ASIC chips are being developed independently, and the self-test is normal. In addition, a large-area high-efficiency multi-layer detector has been developed, and it is planned to be installed on the very-small-angle neutron scattering spectrometer under construction at CSNS as a central detector.

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Poster Session III / 10

Serial Powering Scheme and Performance Analysis for Innermost Layer (L0) for ATLAS ITk modules

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After ten years of massive success, the Large Hadron Collider (LHC) at CERN is going for an upgrade to the next phase, the High Luminosity Large Hadron Collider (HL-LHC) which is planned to start its operation in 2029. This is expected to have a fine boost to its performance, with an instantaneous luminosity of 5.0×1034 cm-2 s -1 (ultimate value 7.5×1034 cm-2 s -1) with 200 average interactions per bunch crossing which will increase the fluences up to more than 1016 neq/cm2, resulting in high radiation damage in ATLAS detector [1]. To withstand this situation, it was proposed to make the innermost layer [L0] of the new Inner Tracker (ITk) with 3D silicon sensor modules, which will have a radiation tolerance of more than 1×1016 neq/cm2 with a TID of 9.9 MGy [2].
Each 3D sensor is bump-bonded to a FrontEnd (FE) chip to form a bare module, and three bare modules are powered in parallel in a triplet module. The L0 layer will have 396 triplet modules. To reduce cable material and improve detector performance, 3 to 5 triplets (depending on the location in the detector) will be powered in series. The FE chip implements a number of features (like a shunt-low-dropout regulator and over-voltage and under-shunt protection) needed to guarantee stable operation of the detector with this powering scheme.
In this study, we powered in series 5 triplets based on the pre-production ATLAS FE chip for HL-LHC. We ensured that the chosen operational parameters are within our theoretical specs and result in stable operation of the modules within the serial power chain. Triplets were also powered in Low Power mode (LP), used to operate the module at a lower current, and their performance was tested without cooling requirements. The performance of the under-shunt and over-voltage protection were also analyzed.

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Poster Session I / 11

Simulating Performance of Microchannel Plate Photomultipliers in Magnetic Fields

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Photon counting detectors are utilised in applications in medical imaging, nuclear and particle physics where a strong magnetic field is present, requiring a detector that can operate in these circumstances. An extremely important characteristic of photon counting detectors is the method of electron multiplication used. In vacuum tubes such as photomultiplier tubes (PMTs) and microchannel plates (MCPs), secondary electron emission (SEE) provides electron multiplication through an accelerating field across the dynode. MCPs are high gain, fast timing electron multipliers and our research seeks to model their operation in magnetic fields.
We illustrate how a PMT can be simulated using a model generated using Computer Simulation Technology (CST) Studio Suite software. The model consists of a photocathode, a small seven-pore MCP structure including electrodes, resistive and secondary electron emitting dynode surfaces, and

a readout anode, with appropriate potentials applied to the components of the model. Magnetic fields can be applied to the model with different directions and amplitudes.
Using this simulation it is possible to produce the gain and timing characteristics of the PMT. We present simulation results from the modelled PMT, demonstrating electron multiplication performance and timing performance as a function of external magnetic field strength and direction. These results are compared to literature and previous results in a magnetic field. The simulation is repeated for single photons and multiple incident photons.

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Applications in Astrophysics / 13

X-ray performance of a large-format soft X-ray optimised charge-coupled device for astronomy

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For the upcoming European Space agency SMILE mission, launching in 2025, large-format soft X-ray optimised CCDs have been manufactured by Teledyne e2v, named the CCD370. The CCDs are approximately 8 cm x 8 cm, and are comprised of 4510 × 4510 18 µm pitch pixels, with a store shield covering approximately 6/7s of the active imaging area to facilitate frame-transfer operation mode. To optimise quantum efficiency within the soft X-ray energy band, the device is 16 µm thick, back illuminated, and has an additional back surface passivation process. The focal plane of the soft X-ray imager on the SMILE spacecraft will be comprised of 2 CCD370s, operating in a frame-transfer readout mode with 6x6 on-chip binning to mitigate against CTI-induced charge transfer losses and charge spreading throughout the 3-year mission lifetime.

As part of the pre-flight testing and calibration, a CCD370 was characterised at the PTB beamline at the BESSY 2 synchrotron in Berlin, and key metrics such as quantum efficiency and energy resolution in the 0.2 –1.9 keV energy band were assessed. The quantum efficiency measurements show expected performance, within specification for the instrument, and also match a transmission-layer QE model. The energy resolution shows near fano-limited performance, which is similar to the current generation of X-ray telescopes such as XMM-Newton, Chandra, and SWIFT XRT. Although competing technologies such as DEPFETs and sCMOS now have similar performance to CCDs, the performance shown here can still easily satisfy requirements for novel scientific instruments, and can still be useful in future astronomy missions given the rich heritage, high technology-readiness-level, and maturity of the technology.

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Applications in Particle Physics / 14

The LHCb VELO detector: design, operation and first results

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The LHCb experiment has been upgraded during the second long shutdown of the Large Hadron Collider at CERN, and the new detector is currently operating at the LHC. The Vertex Locator (VELO) is the detector surrounding the interaction region of the LHCb experiment, responsible of reconstructing the proton-proton collision (primary vertices) as well as the decay vertices of long-lived particles (secondary vertices).
The VELO is composed by 52 modules with hybrid pixel detector technology, operating at just 5.1 mm from the beams. The sensors consist of 200 μm thick n-on-p planar silicon sensors, read out via 3 VeloPix ASICs. The sensors are attached to a 500 μm thick silicon plate, which embeds 19 microchannels for the circulation of the CO_2 evaporative cooling. The VELO operates in an extreme environment, which poses significant challenges to its operation. During the lifetime of the detector, the sensors are foreseen to accumulate an integrated fluence of up to $8{\times}10^{15}$ 1MeV $n_{eq}cm^{-2}$, roughly equivalent to a dose of 400 MRad. Moreover, due to the geometry of the detector, the sensors will face a highly non-uniform irradiation, with fluences in the hottest regions expected to vary by a factor 400 within the same sensor. The highest occupancy ASICs foresee a maximum pixel hit rate of 900 Mhit/s and an output data rate exceeding 15 Gbit/s. The design, operation and early results obtained during the first year of commissioning will be presented.

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The LHCb VELO Upgrade II: design and development of the readout electronics

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In order to fully exploit the High-Luminosity LHC potential in flavour physics, the LHCb collaboration proposes a Phase-II Upgrade of the detector, to be installed during the LHC Long Shutdown 4 (2032-2034). Operating in the HL-LHC environment poses significant challenges to the design of the upgraded detector, and in particular to its tracking system. The primary and secondary vertices reconstruction will become more difficult due to the increase, by a factor 8, of the average number of interactions per bunch crossing (pile-up). Similarly, the track reconstruction will become more challenging, as well as time-consuming, because of the large increase in the track multiplicity. Finally, the much harsher radiation environment will make the design of the sub systems quite challenging, with the radiation damage expected to be more severe for most detectors. In particular, the performance of the VErtex LOcator (VELO), which is the tracking detector surrounding the interaction region, is essential to the success of this Phase-II Upgrade. Data rates are especially critical for the LHCb full software trigger, and with the expected higher particle flux, the VELO Upgrade-II detector will have to tolerate a dramatically increased data rate: assuming the same hybrid pixel design and detector geometry, the front-end electronics (ASICs) of the VELO Upgrade-II will have to cope with rates as high as 8 Ghits/s, with the hottest pixels reaching up to 500 khits/s. With this input rate, the data output from the VELO will exceed 30 Tbit/s, with potentially a further increase if more information is added to the read-out. The VELO collaboration is currently exploring new sensor technologies, and the benefits that would derive from adding a time stamp to the track reconstruction, such that interactions in the same bunch crossing can be more effectively disentangled. Recently, the implementation of precise (˜50 ps) time measurement in combination with excellent spatial resolution has become technologically possible. Moreover, the VELO case is extremely challenging, as the high granularity required for the spatial measurement severely limits the area in each pixel of the ASIC where the time-stamping circuitry can be implemented. Achieving a hit resolution of 50 ps per pixel is considered possible within the timescale of the Phase-II Upgrade. With such resolution, each VELO track would have multiple time measurements from the traversed pixels, which will lead to a precise estimation of the production time of charged particles. Moreover, at the hit level, a precise timing information will also help reducing the number of possible combinations to be considered for the track reconstruction, thus improving its quality. The most recent advances in this field, and the potential candidates that can meet the VELO Upgrade-II requirements, will be presented. In particular, the current state-of-the-art prototypes in the development of ASICs with TDC-per-pixel architecture, the PicoPix ASIC (which is an evolution of the Timepix4 design [3]) and the TIMESPOT ASIC [4], will be discussed. The most recent studies carried out on these two candidates will be presented, as well as the last results from simulations.

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Advances in Pixel Detectors / 16

The MONOLITH project - picosecond time stamping capabilities in fully monolithic highly granular silicon pixel detectors

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The MONOLITH H2020 ERC Advanced project aims at producing a monolithic silicon pixel ASIC with 50μm pixel pitch and picosecond-level time stamping. The two main ingredients of the project are fast and low-noise SiGe BiCMOS electronics and a novel sensor concept, the Picosecond Avalanche Detector (PicoAD). The PicoAD uses a patented multi-PN junction to engineer the electric field and produce a continuous gain layer deep in the sensor volume. The result is an ultra-fast current signal with low intrinsic jitter in a full fill factor and highly granular monolithic detector.
Testbeam measurements of the proof-of-concept PicoAD prototype, based on a 2019 ASIC design, shows full efficiency and time resolutions of 13ps at the center of the pixel and 25ps at the pixel edge, for an average of 17ps over the pixel surface.
A new monolithic prototype with improved SiGe BiCMOS electronics was produced in 2022 on a 350Ωcm substrate. Although this ASIC does not have an internal gain layer, it provided 20ps time resolution in a testbeam with pions. A version of this new prototype that includes the PicoAD gain layer is under production. First results on radiation tolerance will be presented.

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Position Sensitive Fast Timing Detectors / **17**

Overview of the ATLAS High-Granularity Timing Detector: project status and results

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The increase of the particle flux (pile-up) at the HL-LHC with instantaneous luminosities up to L □ 7.5 × 1034 cm−2s−1 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) will be installed in front of the LAr end-cap calorimeters for pile-up mitigation and luminosity measurement.
The HGTD is a novel detector introduced to augment the new all-silicon Inner Tracker in the pseudo-rapidity range from 2.4 to 4.0, adding the capability to measure charged-particle trajectories in time as well as space. Two silicon-sensor double-sided layers will provide precision timing information for minimum-ionising particles with a resolution as good as 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm × 1.3 mm, leading to a highly granular detector with 3.7 million channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed.
The requirements and overall specifications of the HGTD will be presented as well as the technical design and the project status. The R&D effort carried out to study the sensors, the readout ASIC, and the other components, supported by laboratory and test beam results, will also be presented.

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Closing session / 18

A detailed study of Stitched Passive CMOS Strip Sensors

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Silicon tracking detectors are by now the standard for the inner tracking layers of most collider physics experiments. A promising technology for future silicon particle detectors is CMOS sensor. One issue with CMOS sensors is the limited size of the reticules around 4cm^2 used, which is adapted to the typical ASIC sizes in industrial applications but far too small for the 100cm^2 sensors used in e.g. ATLAS and CMS Phase-II tracker upgrades. One way to overcome the size limitation is to stitch many individual reticules together to a large sensor.
The CMOS project presented here is investigating stitched passive CMOS strip sensors fabricated by LFoundry in a 150 nm technology, with an additional backside processing from IZM Berlin. The sensors have a thickness of 150 µm, a resistivity of 3-5 kΩ cm and a strip pitch of 75.5 µm. By employing the stitching technique two different strip lengths have been realised, with the short format having three and the long having five stitches. A total of three different strip sensor designs have been investigated. They each vary in doping concentration and width of the n-well to study various depletion concepts and electric field configurations. Unirradiated as well as irradiated sensors sensors have been studied with several measurement techniques, including probestation characterisation, lab measurements with lasers and Sr90-sources and test beam campaigns. This presentation will provide an overview of simulation results, summarize the laboratory measurements and in particular present the test beam results for irradiated and unirradiated passive CMOS strip sensors. We will demonstrate that large area sensors with sufficient radiation hardness can be obtained by stitching in this CMOS process, and present our plans for the next CMOS submission in the framework of this project.

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Position Sensitive Fast Timing Detectors / 19

Low Gain Avalanche Detectors for the ATLAS High Granularity Timing Detector: laboratory and test beam campaigns

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The High Granularity Timing Detector (HGTD) is designed for the mitigation of pile-up effects in the ATLAS forward region and for bunch per bunch luminosity measurements. HGTD, based on Low Gain Avalanche Detector (LGAD) technology and covering the pseudorapidity region between 2.4 and 4.0, will provide high precision timing information to distinguish between collisions occurring close in space but well-separated in time. Apart from being radiation resistant, LGAD sensors should deliver 30 ps time resolution per track for a minimum-ionising particle (35 ps per hit) at the start of lifetime, increasing to 50 ps per track (70 ps per hit) at the end of HL-LHC operation. Each readout cell has a transverse size of 1.3×1.3 mm2 leading to a highly granular detector with about 3 millions of readout electronics channels. A dedicated ASIC for the HGTD detector, ALTIROC, is being developed in several phases producing prototype versions of 2×2, 5×5 and 15×15 channels. HGTD modules are hybrids of the LGAD and ALTIROC connected through flip-chip bump bonding process.
Several test beam campaigns have been conducted at DESY and CERN SPS in 2022. The performance of irradiated Carbon-enriched LGADs from different vendors has been studied. This talk covers the promising results in terms of collected charge, time resolution and hit efficiency. A time resolution of < 70 ps is observed for highly irradiated sensors (2.5e15 neq/cmˆ2), while integrating timing information to the EUDET system allows for a surface resolution of less than 50 µm. First module prototypes of 15×15 arrays for the HGTD project have been tested from different manufacturers. Their performance with charged-particle beams before irradiation is evaluated. The triggering architecture, picosecond synchronisation scheme and analysis logic will also be presented as well as application-specific electronics and components. A summary of the results from LGAD-only and hybrids will be presented.

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Poster Session III / 21

Mapping the effects of ionising and non-ionising radiation on the measurement of inter-strip isolation with ATLAS ITk strip sensors

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In order to meet the physics goals of the forthcoming high luminosity (HL) era of the CERN Large Hadron Collider (LHC), the inner detector of the ATLAS experiment will be replaced by a new all-

silicon tracking system, known as the inner tracker (ITk). The outer region of the ITk is instrumented with 22,000 n^+-in-p type silicon strip sensors manufactured by Hamamatsu Photonics (K.K.).

During HL-LHC operation, ITk strip sensors will be subjected to formidable doses of both ionising and non-ionising radiation. During the ongoing sensor production period, a comprehensive programme of Quality Assurance (QA) is taking place to ensure sensor batches delivered by the vendor operate as required after receiving the radiation doses expected after a lifetime of operation at the HL-LHC. The QA programme utilises a range of facilities to study the effects of proton, neutron and gamma-ray irradiation on the performance of sensor batches.

One parameter of critical importance to sensor performance is the inter-strip isolation, which can degrade substantially after significant radiation exposure, particularly due to the ionising radiation dose. Dedicated interdigitated test structures have been incorporated into the design of the ATLAS ITk strip QA test chip to facilitate the measurement of the inter-strip isolation after irradiation. The inter-strip resistance measured with the interdigitated test structures is expected to be affected by both ionising and non-ionising radiation damage effects, including the build-up of interface charge and changes in bulk resistance, respectively.

A dedicated investigation has been performed in which test chips are proton irradiated to several different fluence points, spanning the region from 1e14 n_eq cm^-2 to 2e15 n_eq cm^-2, at several distinct proton beam energies. The MC40 cyclotron at the University of Birmingham, CYRIC cyclotron at Tohoku University and the CERN IRRAD facility were utilised to irradiate samples with 23 MeV, 70 MeV and 24 GeV protons, respectively. The total ionising dose (TID) delivered per unit proton fluence at each facility differs due to the proton beam energies employed, leading to samples irradiated at each facility experiencing a different relative amount of ionisation and displacement (non-ionising) damage.

Studies of these irradiated samples allow the interplay between ionising and non-ionising radiation damage effects on the measurement of the interdigitated test structures to be mapped. These data are used to develop of a more complete understanding of the features observed in the inter-strip isolation measurements obtained after proton, neutron and gamma-ray irradiation at the facilities utilised by the ATLAS ITk strip QA programme.

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Poster Session III / 22

Characterization of Ultra-Fast Silicon Detectors for High Energy Physics Applications

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Ultra-fast silicon detectors (UFSD) are a specialized type of radiation detectors based on Low Gain Avalanche Detectors (LGADs) that are designed to have extremely fast response times, typically in the range of picoseconds or even femtoseconds. The exceptional temporal resolution of UFSD enables the precise determination of the particle arrival time and helps disentangle overlapping collision events in the context of High-Luminosity Large Hadron Collider (HL-LHC). This information is crucial for accurate reconstruction of particle trajectories and identification of rare or short-lived particles.
This work presents detailed results on the study of 50 µm thin-LGADs with different doping concentrations produced by Micron Semiconductors Ltd. A temperature dependent study of the leakage current and the breakdown voltages are examined using current-voltage (IV) characteristics. Additionally, frequency dependence of the Capacitance-Voltage (CV) measurements is also presented in this work. Laser characterization of these sensors is carried out using Transient Current Technique (TCT) to study the charge collection and gain characteristics, and the comparison is made on the basis of Laser wavelength (Red –658nm and IR –1064 nm) and the position of illumination (top and bottom). Temperature dependent measurements of gain as a function of voltage are also presented here. We observed the influence of different doping concentration and JTE width on the gain. The collection of TCT signals within 2 ns after the sensor is fully depleted refers to the fast signal processing that offers exceptional timing performance. A detailed study of timing resolution using source measurements will be carried out in the near future.

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Closing session / 23

The monolithic ASIC for the high precision preshower detector of the FASER experiment at the LHC

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The FASER experiment at the LHC will be instrumented with a high precision W-Si preshower to identify and reconstruct electromagnetic showers produced by two O(TeV) photons at distances down to 200µm. The new detector features a monolithic silicon ASIC with hexagonal pixels of 100 µm pitch, extended dynamic range for the charge measurement and capability to store the charge information for thousands of pixels per event. The ASIC integrates SiGe HBT-based fast front-end electronics with O(100) ps time resolution. Analog memories inside the pixel area are employed to allow for a frame-based event readout with minimum dead area. A description of the pre-shower and its expected performance will be presented together with the lab and testbeam results of the pre-production ASIC. While the final production chip submission was just launched, some information on its design will be given.

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Medical applications / 24

The 100µPET project: a small-animal PET scanner for ultra-high-resolution molecular imaging with monolithic silicon pixel sensors

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The 100µPET project, led by the University of Geneva, the University of Luzern, and the École Polytechnique Fédérale de Lausanne, aims at the development of a small-animal positron-emission tomography (PET) scanner with ultra-high-resolution molecular imaging capabilities. This is achieved through the use of a compact, modular stack of multiple thin layers of monolithic pixel detectors and flexible printed circuits (FPC), resulting in unprecedented depth-of-interaction and volumetric granularity. Performance simulations have shown a point-spread-function of 150 µm, free of parallax effect, leading to a volumetric spatial resolution of about 0.015 mm3, one order of magnitude better than the best current PET scanners. The recent developments in simulation and hardware prototyping will be presented.

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Applications in security and environmental imaging / 25

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

The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector. As the closest detector component to the interaction point, this detector is subjected to a significant amount of radiation over its lifetime. At the start of the LHC proton-proton collision RUN3 in 2022, the innermost layer IBL, consisting of planar and 3D pixel sensors, had received an integrated fluence of approximately Φ = 1 × 10**15
1 MeV neq/cm2.
The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector.
In this talk 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. A

quantitative analysis of charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects, effects of annealing will be presented and discussed, as well as the operational issues and mitigation techniques adopted for the LHC Run3.

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Applications in Particle Physics / 26

The Silicon Vertex Detector of the Belle II Experiment

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In June 2022 the data-taking of the Belle II experiment was stopped for the Long Shutdown 1, primarily required to install the new two-layer DEPFET detector (PXD) and upgrade components of the accelerator. In May 2023 the whole silicon tracker (VXD) was extracted from Belle II and the new VXD commissioning phase began to be ready to take data by the end of 2023. We describe the challenges and status of this upgrade.
We report on the performance of the SVD in terms of the high hit efficiency and the large signal-to-noise ratio. A novel procedure to group SVD hits event-by-event, based on their time, during reconstruction allows to significantly reduce the fake rate while preserving the tracking efficiency.
In the layer closest to the I.P., the SVD average occupancy has been less 0.5%, well below the estimated limit for acceptable tracking performance. Higher machine backgrounds are expected at increased luminosity and the excellent SVD hit-time information can be exploited for background rejection. We have developed a method that uses the SVD hit-time to estimate the collision time (event-T0) with similar precision to the estimate based on the drift chamber with an execution time three orders of magnitude faster. Furthermore, the front-end chip (APV25) is operated in "multi-peak"mode, reading six samples. To reduce background occupancy, trigger dead-time and data size, a 3/6-mixed acquisition mode, based on the timing precision of the trigger, has been successfully tested in physics runs.
Concerning the radiation damage, the SVD dose is estimated by the correlation of the SVD occupancy with the dose measured by the diamonds of the beam-abort system. Although the moderate increase shown by sensor current and the strip noise due to radiation, we expect that the detector performance will not be seriously degraded during the lifespan of the detector.

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Poster Session I / 27

Development of Simulation Software for Silicon Carbide Particle Detectors

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In the rapidly evolving field of semiconductor detector device design and performance prediction, computer-aided simulations play a crucial role. Various research institutions worldwide have developed simulation software and packages for semiconductor detectors, such as WeightField2, AllpixSquared, and TRACS, to address different software development requirements and computational performance demands. However, there is still a lack of dedicated software for simulating silicon carbide particle detectors.

This report introduces RASER, a Python-based fast semiconductor particle detector simulation software, jointly developed by the Institute of High Energy Physics and Jilin University, among others. The report presents the basic framework of RASER and highlights a comparative analysis between simulation results obtained from RASER and experimental measurements. Furthermore, the report discusses the guiding value of optimized device parameters derived from RASER simulations for the design of silicon carbide microstrip and pixel detectors.

By leveraging the capabilities of RASER, researchers and engineers can gain valuable insights into the design and optimization of silicon carbide particle detectors, contributing to the advancement of semiconductor detector technologies.

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Applications in Astro-Particle Physics / 28

Silicon Photomultipliers for the SST Camera of the Cherenkov Telescope Array

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The Cherenkov Telescope Array Observatory (CTAO) will be the major global observatory for gamma-ray astronomy over the next decade and beyond. It will consist of two arrays of telescopes of different sizes, one for each hemisphere, and will be sensitive to gamma rays in the energy range from a few tens of GeV to hundreds of TeV. The Small-Sized Telescopes (SSTs) are a crucial component of the southern array, as they will extend the sensitivity of the observatory to the highest energies. Their focal plane will be equipped with 2048 Silicon Photomultiplier (SiPM) pixels, each one read independently by a state-of-the-art full waveform sampling readout. These solid-state sensors offer advantages over the traditional photomultiplier tubes, such as lower operating voltage, higher photon detection efficiency, and tolerance to bright illumination. In particular, they are the best choice for a small and compact camera such as the SST one. After a detailed comparative study, LVR3-type SiPMs from Hamamatsu Photonics were selected, with an active area of 6x6 mmˆ2, a microcell of 50 µm and without a protective coating, for optimum performance. The sensors demonstrated to have a higher photon detection efficiency and a lower cross talk compared to the competitors, alongside a low dark count rate. In this contribution, we present the selection process and the latest measurements performed on the SiPMs mounted on the SST camera module.

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Applications in Particle Physics / 29

ATLAS ITk Pixel Detector Overview

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In the high-luminosity era of the Large Hadron Collider, the instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing. To cope with the resulting increase in occupancy, bandwidth and radiation damage, the ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of the ITk will consist of a pixel detector, with an active area of about 13 m2. To deal with the changing requirements in terms of radiation hardness, power dissipation and production yield, several silicon sensor technologies will be employed in the five barrel and endcap layers. Prototype modules assembled with RD53A readout chips have been built to evaluate their production rate. Irradiation campaigns were done to evaluate their thermal and electrical performance before and after irradiation. A new powering scheme –serial –will be employed in the ITk pixel detector, helping to reduce the material budget of the detector as well as power dissipation. This contribution presents the status of the ITk-pixel project focusing on the lessons learned and the biggest challenges towards production, from mechanics structures to sensors, and it will summarize the latest results on closest-to-real demonstrators built using module, electric and cooling services prototypes.

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Advances in Pixel Detectors / 30

The DMAPS Upgrade of the Belle II Vertex Detector

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The Super-KEKB collider will undergo a major upgrade to reach the target luminosity of 6 10ˆ35 cm-2 s-1. A long shutdown is foreseen around year 2027, which provides the opportunity to revisit significant parts of the Belle II experiment and adapt them to the expected change of the experimental conditions. In particular, a new pixelated vertex detector (VTX) is being designed to fit the upgraded interaction region. This new silicon tracker aims to be both more robust against the expected higher level of machine background and more performant in terms of precision and standalone track finding efficiency.
The VTX design presented here features an envelope close to the present one, spanning from radii of 14 mm to 135 mm. The baseline layout consists of two identical layers composing the inner part (iVTX) and three outer layers (oVTX), all arranged in a barrel-shaped geometry, with minimal material budget.
It is equipped with a dedicated depleted-MAPS CMOS sensor named OBELIX. The latter is an approximately 2 cm x 3 cm large die designed in the Tower 180 nm technology, which pixel matrix is derived from the TJ-Monopix-2 sensor originally developed for the ATLAS experiment. Featuring a 33 µm pitch, the pixel sensor will integrate hits over a 100 ns period while dissipating less than 200 mW/cm2 at an average hit rate of 60 MHz/cm2. The digital trigger logic is entirely revisited to match Belle II requirements of 30 kHz average trigger rate with 10 µs trigger delay and a maximum hit rate of 120 MHz/cm2. A first complete version of the sensor is being designed and is expected to be submitted to foundry by late 2023.
The two iVTX layers have a sensitive length of about 12 cm and are based on an "all-silicon ladder"concept aiming for a material budget below 0.2 % X0/layer, benefitting from air cooling. One ladder is made of a a 4-sensor wide module cut out from the processed wafer and submitted to post-processing operations in order to connect them at one end.
As for the oVTX, the target material budget is ranging from 0.3 % X0 for layer 3 up to 0.8 % X0 for the 70 cm-long ladders of the fifth and most external layer. An evolved design of the ladder concept used in the ALICE-ITS2 is adopted, with a light mechanical structure, supporting a liquid-cooled plate.
The talk will review all aspects of the project: the tests of the TJ-Monopix2 validating the pixel matrix performance, the OBELIX-1 features and design status, and finally prototype fabrication and tests for the iVTX and oVTX concepts.

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Applications in security and environmental imaging / 31

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

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ATLAS-ITK Strip Collaboration
(the speaker to be selected by the ITk Speakers Committee after the contribution acceptance)
The inner detector of the present ATLAS experiment has been designed and developed to function in the environment of the present Large Hadron Collider (LHC). At the ATLAS Phase-II Upgrade, the particle densities and radiation levels will exceed current levels by a factor of ten. The instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing. The new detectors must be faster and they need to be more highly segmented. The sensors used also need to be far more resistant to radiation, and they require much greater power delivery to the front-end systems. At the same time, they cannot introduce excess material which could undermine tracking performance. For those reasons, the inner tracker of the ATLAS detector was redesigned and will be rebuilt completely.

The ATLAS Upgrade Inner Tracker (ITk) consists of several layers of silicon particle detectors. The innermost layers will be composed of silicon pixel sensors, and the outer layers will consist of silicon microstrip sensors. This contribution focuses on the strip region of the ITk. The central part of the strip tracker (barrel) will be composed of rectangular short (˜ 2.5 cm) and long (˜5 cm) strip sensors. The forward regions of the strip tracker (end-caps) consist of six disks per side, with trapezoidal shaped sensors of various lengths and strip pitches. After the completion of final design reviews in key areas, such as Sensors, Modules, Front-End electronics, and ASICs, a large scale prototyping program has been completed in all areas successfully. We present an overview of the Strip System and highlight the final design choices of sensors, module designs and ASICs. We will summarise results achieved during prototyping and the current status of pre-production and production on various detector components, with an emphasis on QA and QC procedures.

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Poster Session I / 32

Research on Streaming Data Processing of Neutron Instrument

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As an advanced detection spectrometer with the most advanced design concept, neutron sources are an important platform for conducting cutting-edge disciplines and research on high-tech. In recent years, its performance and technology have made rapid development. With the evolution of upgrades, the traditional file-based data transmission framework is under great pressure in the face of high-bandwidth and high-concurrency data transmission and historical backtracking tasks, seriously affecting its overall performance indicators and operational efficiency. Therefore, neutron sources have proposed a new generation of neutron spectrometer data acquisition and transmission systems based on mature streaming transmission platforms. However, the distributed nature and optimized deployment requirements of the streaming transmission platform will bring new challenges to the processing of spectrometer experimental data. Therefore, the spectrometer needs to adapt a general data stream processing framework that links the streaming transmission platform and the spectrometer data processing tasks to standardize and simplify the data processing process and user application development. For neutron spectrometer experiments, the design and development of a general data stream processing framework is the basis for carrying advanced experimental methods and efficient operational efficiency.

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Advances in Pixel Detectors / 33

Study of MAPS silicon detector prototypes for the ALICE Inner Tracking System upgrade

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The ALICE experiment of the Large Hadron Collider (LHC) at CERN has planned an upgrade of the Inner Tracking System (ITS), called ITS3, for the LHC Long Shutdown 3, in 2025. The cornerstone of the upgrade is a new CMOS-65 nm pixel chip, built using Monolithic Active Pixel Sensor (MAPS) technology using the stitching technology to extend the chip length to 26 cm and bent around the beam pipe, replacing the three innermost layers of the existing detector with new ultra-light, truly cylindrical layers. ITS3 will show much higher tracking performances, especially at low transverse momentum, thanks to the better track impact-parameter resolution, improved by a factor two with respect to the current ITS2. In addition, the detector will be closer to the interaction point and will have a much lower material budget, of 0.02-0.04% X_0. The final configuration and structure of the ITS3 will be presented, as well as the challenges related to its design and construction and the results of the current R&D program on the sensor design and characterization. Finally, results of data collected at beam tests at CERN testing an analog pixel test chip (APTS Source Follower) will be reported. The performance in terms of their total efficiency and spatial resolution in different configurations will be presented and discussed.

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Poster Session I / 34

Characterization and simulation of radiation effects on active edges n-on-p planar pixel sensors

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Pixelated silicon sensors are the most precise detector for charged particle tracking currently in use at high-energy physics experiments. Located closely to the interaction point, they are required to function in a radiation harsh environment. It is hence necessary for such sensors to demonstrate an

increased radiation tolerance as well as to maintain a good performance in high beam luminosity conditions (l=1035cm−2s-1) and for fluences that could exceed 1016neq/cm2 1MeV equivalent neutrons at the inner layers. A major concern is to increase overall sensitive detection area while maintaining high charge collection efficiency in high radiation conditions. Several technologies exist to address these issues, mainly by combining a p-bulk process sensor with active edges and optimized bias rail geometries.
The main objective of this simulation work is to study a new detector structure implementing n-on-p active edges and analyze the electrical characteristics. ATLAS simulator of SilvacoTM Technology Computer Aided Design (TCAD) software is used for the simulation and for the study of the electrical field characteristics of the pixel device. For the simulator algorithm input, we used doping profile data extracted from the technique of Secondary Ion Mass Spectroscopy (SIMS). Breakdown voltage, leakage current, charge carrier distributions (holes, electrons), electric field distributions and charge collection efficiency (CCE) after irradiation are presented.

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Closing session / 35

Development of a baseline vertex detector prototype for the CEPC

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The proposed Circular Electron Positron Collider (CEPC) presents new challenges for the vertex detector in terms of material budget, spatial resolution, readout speed, and power consumption. To address these challenges, a Monolithic Active Pixel Sensor (MAPS) prototype called TaichuPix has been implemented, which is based on a column drain readout architecture. The TaichuPix sensor chip has been characterized at the DESY test beam facility, and the results indicate a spatial resolution better than 5 μm and a detection efficiency better than 98% under the set threshold.
The baseline vertex detector is proposed with a three-ladder architecture, which will be double-sided with TaichuPix sensors. The double-sided structure is adopted to reduce the multiple scattering of particles and improve the impact parameter. This means that the silicon pixel sensors and cables are installed on both sides of the support structure. A ladder is made of common support together with two layers of silicon detectors. For this prototype, one side of a ladder is proposed to assemble two TaichuPix sensors on a flexible printed circuit board. Two flexible boards are installed on the front and back sides of the lightweight carbon fiber support structure.
To verify the performance of the baseline vertex detector, six ladders were installed on the barrel,

and the beam test was conducted at the DESY II TB21 facility. The beamline runs straight through the prototype, producing precise reconstruction points by multi-layer TaichuPix sensors. This presentation proposes to show the architecture and beam test results of the baseline vertex detector prototype.

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Closing session / 36

Spatial resolution of IHEP AC-LGADs with different process and structure design

AC-coupled Low- Gain Avalanche Detectors (AC-LGAD) are designed as detectors with 100% fill factor for high precision 4D-tracking, which have been studied and researched by many institutes including BNL、FBK et al. Institute of High Energy Physics (IHEP) has also done many researches on AC-LGAD. First IHEP AC-LGAD sensors with a pitch of 2000 μm and AC pad of 1000 μ show time resolution better than 20ps, and spatial resolution better than 16um. Testing results show that as the N+ doping dose decreases from 10 P to 0.2 P, the spatial resolution is reduced from 33 μm to 15 μm. Details of the results will be discussed. Second version of IHEP AC-LGAD be fabricated, lower than 0.2P n+ layer dose be used for improve the spatial resolution and sensors with different pad-pitch structures also be fabricated. Testing results show that as decreasing the n+ layer dose from 0.2P to 0.02P, the spatial resolution of AC-LGAD can be lower than 8um. Strips with different pad-pitch structures be fabricated and studied, results show that pad-pitch structures will also affect the spatial resolution. Testing results of IHEP AC-LGAD v2 sensors tested by using laser system will also be shown.

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Poster Session III / 37

Results of system qualification and quality control strategies for the production of the ITk Pixel Outer Barrel of the ATLAS experiment

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The new Inner Tracker of the ATLAS experiment will be installed during LHC Long Shutdown 3 and will consist of a pixel and strip detector. The Outer Barrel, comprising three central outer pixel layers, will be constructed using a combination of flat sections called longerons and inclined half-rings. Silicon modules will be mounted on these structures with good thermal contact and powered in series, forming chains with multiple modules. The evaluation of not only the radiation-hard silicon detector modules but also the concept of powering and readout is underway, along with the preparation for production. Quality control and safe testing and operation are crucial for early system testing and subsequent efficient production.

The Outer Barrel will be composed of 4472 pixel modules. Quality control steps are planned at the module level and at three successive stages: upon loading the modules onto designated "cells," assembling them on longerons and half-rings, and finally integrating them into detector layers.

These quality control steps involve the operation of multiple modules within these substructures, necessitating a dedicated detector control system (DCS) and interlocking instrumentation to ensure their safe operation at all times. This presentation will focus on the results of system qualification for silicon modules in multi-module operation, with a particular emphasis on the DCS and interlocking infrastructure for quality control. The developed hardware, boards, their application, and the strategy employed during the integration stages of the cells and loaded local supports will also be discussed.

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Detectors for High radiation and extreme environment / **38**

3D single pixel time resolution and uniformity after proton and neutron irradiation of up to 1e17 neq/cm2 at 120 GeV SPS beams

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The proven radiation hardness of silicon 3D devices up to fluences of 1×10^{17} n_{eq}/cm^2 makes them an excellent choice for next generation trackers, providing < 10 μm position resolution at a high multiplicity environment. The anticipated pile-up increase at HL-LHC conditions and beyond, requires the addition of < 50 ps per hit timing information to successfully resolve displaced and primary vertices. In this study, the timing performance, uniformity, and efficiency of neutron and proton irradiated single pixel 3D devices is discussed. Fluences up to 1×10^{17} n_{eq}/cm^2 in three different geometrical implementations are evaluated using 120 GeV SPS pion beams. A MIMOSA26 type telescope is used to provide detailed tracking information with a ˜5 μm position resolution. Productions with single- and double-sided processes, yielding active thickness of 130 and 230 μm respectively, are examined with varied pixel sizes from 55×55 μm^2 to 25×100 μm^2 and a comparative study of field uniformity is presented with respect to electrode geometry. The question of electronics bandwidth is extensively addressed with respect to achievable time resolution, efficiency

and collected charge, forming a tri-dimensional phase space to which an appropriate operating point can be selected depending on the application requirements.

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Keynote: PSD Technologies for Particle Physics

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Keynote: applications in Astrophysics

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Gas Based Detectors / 41

Keynote: Gas Based Detectors

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Novel Photon Detectors / 42

Keynote: Novel photon Detectors

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Keynote: Quantum Detectors

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Keynote: Applications in Astro-particle Physics

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Position Sensitive Fast Timing Detectors / 45

Results and perspectives on sensors and electronics for high-resolution 4D-tracking

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Application in Nuclear physics / 46

Keynote: Applications to Nuclear Physics

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Keynote: Detectors at neutron facilities

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Detectors for FELS, Synchrotron and other advanced Light sources / 48

Keynote: Detectors for FELS, Synchrotron and other advanced Light sources

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Detectors for High radiation and extreme environment / 49

Keynote: Detectors for High radiation and extreme environment

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Application in life sciences and biology / 50

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Medical applications / 51

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Applications in security and environmental imaging / 52

Keynote: Applications in security and environmental imaging

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Poster Session II / 53

The time resolution and position resolution of IHEP LGAD strip

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Low Gain Avalanche Diode (LGAD) has high-precision time performance, and the time resolution can reach 30 ps. The LGAD with a size of 1.3 mm
× 1.3 mm was used for the upgrade of ATLAS and CMS time detectors to reduce the pile-up effect of High-Luminosity Large Hadron Collider (HL-LHC). Institute of High Energy Physics (IHEP, CAS) has designed a LGAD strip detector, which can be used as a time detector in electron colliders such as Circular Electron Positron Collider (CEPC) and Future Circular Collider (FCC-ee). The strip-shaped LGAD allows for a larger cell area, which reduces readout channel density, and provides position resolution with a double-ended readout method. This presentation will show the test results of IHEP LGAD strip, including beta source test, picosecond laser test, comparison of single-end or double-end readout, time resolution, position resolution, etc.

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Detectors at Neutron facilities / 54

Multi-Input Readout System for 3He/BF3 Position Sensitive Neutron Detectors

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Neutron sources are currently becoming standard tools to investigate the structures of various materials using elastic scattering techniques, which are applied across a wide spectrum of scientific disciplines such as physics, biology, materials science. Moreover, typical neutron physics experiments carried out at Neutron Spallation Sources and other laboratories make use of large arrays of 3He/BF3 position-sensitive tubes to detect neutrons. We present a 19"rack-mount solution for the readout of 3He/BF3 tubes for the above-mentioned applications, which could also be deployed as a solution for nuclear security scenarios thanks to its compactness. The solution is scalable and may acquire signals from few to hundreds of neutron detectors with the possibility of firmware real-time reconstruction for imaging and time-of-flight. It can be composed starting from three basic building blocks: high voltage board, charge sensitive preamplifier specifically designed for 3He/BF3 tubes and a 14-bit 125MS/s Digital Pulse Processor, with 32 independent analogue inputs. The described instruments can be controlled through a dedicated software which handles configuration and data analysis. It is possible to compute the collected charge, report the interaction time with a precision of 8 ns and perform a reconstruction of the interaction position. It provides simultaneous recording of all the required information, including the pulse waveform, in an oscilloscope mode. The DAQ chain includes a fast path for trigger generation and a slow path for charge evaluation and axial position calculation.

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Novel Photon Detectors / 55

Large area tiles of position-sensitive Silicon photomultipliers

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Silicon Photomultipliers (SiPMs) are solid-state single photon sensitive detectors that show excellent performance in a wide range of applications. In FBK (Trento, Italy), we developed a position sensitive SiPM technology, called "linearly-graded"(LG-SiPM), which is based on an avalanche-current weighted-partitioning approach. It shows position reconstruction resolution below 250 µm on an 8x8 mm² device area with four readout channels and minimal distortions. This technology was proven effective in the readout of segmented and monolithic LYSO crystals for PET application.

At FBK we recently developed a new version of LG-SiPM, with a larger chip active area (10x10 mm²) and based on NUV-HD technology, having a peak photon detection efficiency at 420 nm, as opposed to the previous ones centered at 550 nm. Such large area detector coupled with position sensitivity is very interesting in applications like MR-compatible PET, high-energy physics experiments, readout of time-projection chambers, readout of scintillating fibers for X ray spectroscopy, compact gamma and beta cameras with a reduced number of channels.

These SiPMs have been characterized in terms of noise, detection efficiency and position resolution. We also developed tiles of 2x2 and 3x3 elements with such SiPMs, reaching very large sensitive areas of 20x20 mm2 and 30x30 mm2. In such large area tiles, we implemented a smart channel connection configuration, being able to have just 6 output channels for the 2x2 elements and 8 channels for the 3x3 element tiles, with a position resolution below 0.5mm. We characterized the position resolution of such tiles, finding a small pincushion effect and some distortions, which will be studied and detailed. Still, these detectors and readout provide great advantages: a similar detector configuration with single elements would require hundreds of channels for the same spatial resolution. LG-SiPMs can be used to build larger arrays in a completely scalable approach.

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Advanced photon detectors X-rays and Gamma ray / 56

Characterisation of HEXITEC MHz –a 1 MHz continuous frame rate spectroscopic X-ray imaging detector system

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The HEXITEC$_{MHz}$ detector system is the latest generation of the STFC's HEXITEC spectroscopic X-ray imaging detector systems. When coupled to Cd(Zn)Te sensor material, the original HEXITEC system delivers high-resolution X-ray spectroscopy (50 electrons RMS) per 250 μm pitch pixel for hard X-rays with energies 2 - 200 keV. However, a 9.1 kHz frame rate and the need to identify charge-sharing events limits its application to photon fluxes of ˜10^4 ph s^{-1} mm^{-2}. With many photon light sources undergoing major upgrades to diffraction-limited storage rings, these expected increases in flux have motivated the development of the next generation of the HEXITEC technology. This demand has also been driven by spectroscopic X-ray imaging techniques such as Hyperspectral X-ray Tomography, which require operation under a high incident X-ray flux for time-resolved measurements.

The HEXITEC$_{MHz}$ system is targeted at delivering the same high-resolution spectroscopy as the original ASIC whilst targeting higher photon fluxes. Whilst the ASIC maintains the same 250 μm pixel pitch, the new integrating Front End architecture, in-pixel digitisation and high-speed serialisers deliver a 1 MHz frame rate. This enables operation at fluxes of >10^6 ph s^{-1} mm^{-2} for spectroscopic X-ray imaging applications.

A 300 μm thick p-type Si HEXITEC$_{MHz}$ detector was characterised on the B16 Test Beamline at the Diamond Light Source and are the first measurements taken at a 1 MHz frame rate. At 10 keV and 15 keV the device displayed average FWHM of 656 eV and 682 eV respectively, with minimal changes in spectroscopic performance over ˜8 h. Analysis of charge-sharing events show low charge loss and a linear energy-signal response. Higher-flux measurements illustrated the capability of HEXITEC$_{MHz}$ to operate as a photon-counting device, capable of measuring 30 × 10 keV photons in a single frame. Results from a high-flux CdZnTe device will also be shown.

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Poster Session I / 57

Towards an integrated, high-density Silicon strip measurement system

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Silicon strip detectors play a central role in applied nuclear physics thanks to the high channel density and almost 100% detection efficiency. In particular, double-sided silicon strip detector (DSSSD) enable very accurate 2D position sensing. Their principle of operation is straightforward, but the full exploitation of their potential requires many independent readout channels

In this work we explore the possibility to achieve a comprehensive and reliable multi-channel position sensing system using off-the-shelf Micron Semiconductor Ltd. Si detectors and CAEN readout electronics. This effort is to be intended as a proof of concept aiming at studying extremely integrated solutions that could be used in a variety of fields, including High-Energy Physics as well as Nuclear Security applications.

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Applications in Particle Physics / 58

Noise and performance tests results of the PS modules for the phase-2 CMS outer tracker

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The CMS Outer Tracker phase-2 upgrade is conditioned by the planned high-luminosity LHC (HL-LHC) project. The high radiation levels and the large pileup require a high granularity and low mass detector and the capability to handle high data rates. The OT modules will provide hit information to the Level 1 Trigger to form track segments, which allows to keep the trigger rates at a sustainable level. The CMS OT uses silicon pixel-strip sensors (PS) modules, which contain a silicon strip sensor and a silicon macro-pixel sensor with an area of $(5 \times 10) cm^2$. The silicon strip and macro-pixel sensors are wire-bonded to two front-end hybrids (FEHs), interconnected with a power hybrid (POH) on one side and with an optical readout hybrid (ROH) on the opposite side. The rejection of low momentum tracks for the L1 track trigger is also performed in the FE electronics by locally correlating the signals (hits) from a pair of pixel-strip sensor (stubs). The performance tests for noise investigation of the PS modules are presented.

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Applications in Astro-Particle Physics / 59

The High Energy Particle Detector (HEPD-02) onboard the CSES-02 Satellite.

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The High Energy Particle Detector (HEPD-02) is one of the scientific payloads onboard the second China Seismo-Electromagnetic Satellite (CSES-02), one of a serie of Chinese-Italian space missions dedicated to monitoring of the near-Earth environment and to study the lithosphere-atmosphere-ionosphere coupling mechanisms.
The launch of CSES-02 is foreseen in the first half of 2024.
HEPD-02 is designed to measure particle flux and precipitation from the inner radiation belts induced by solar, terrestrial or anthropic phenomena in a wide range of energies, from 3 to 100 MeV for electrons and from 30 to 200 MeV/n for protons and light nuclei. It is composed of a high precision tracking system made of monolithic active pixel sensors (MAPS), two layers of crossed plastic scintillator bars as a trigger system and a calorimeter combining a tower of plastic scintillators and two layers of LYSO crystals. The whole is surrounded by a containment detector consisting of five plastic scintillator panels.
We present here the main characteristics of HEPD-02, with particular regard to its calorimeter, highlighting its performance to reach the expected energy range and resolution as well as its capability in electron and proton angular reconstruction.

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Poster Session I / 60

Development of a phoswich imaging detector to simultaneously acquire neutron and gamma photon images

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We developed a phoswich imaging detector that can simultaneously but independently acquire images of neutrons and gamma photons. The developed neutron imaging system consists of a lithium-containing silver doped zinc sulfide (Li-ZnS(Ag)) plate stacked on a cerium doped yttrium aluminum perovskite (YAP(Ce)) plate to form a phoswich detector, which is optically coupled to a position sensitive photomultiplier tube (PSPMT). Neutrons are detected by the Li-ZnS(Ag) plate while gamma photons are detected by the YAP(Ce) plate. The scintillation light from the Li-ZnS(Ag) and YAP(Ce) plates is detected by the PSPMT, and the position of interaction is calculated. Pulse shape discrimination is used to separate the images of neutrons and gamma photons.The developed phoswich imaging detector can simultaneously and independently acquire the images of neutrons and gamma

photons, and thus it will impact the relevant research and applications of neutron detectors and imaging.

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Applications in Astrophysics / 61

Expected performance of the High Energy Particle Detector (HEPD-02) tracking system on board of the second China Seismo-Electromagnetic Satellite

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The China Seismo-Electromagnetic Satellite (CSES) is a scientific space program that aims to deepen the comprehension of the time correlation between the main earthquake shocks and an increase in the electron flux in the inner Van Allen belt. For this purpose, the suite of payloads on board the second CSES satellite (CSES-02) consists of several detectors to measure: the particle flux and the energy spectrum, the total intensity of the magnetic and electric fields with their components, the disturbance of plasma in the ionosphere and the density of electrons.
The launch of CSES-02 is foreseen in the first half of 2024.
The present work will be focused on the second generation High-Energy Particle Detector (HEPD-02), developed by LIMADOU Italian collaboration, and in particular on its tracking system (Direction Detector - DD) to reconstruct the incident particle angle. The DD is made of five standalone tracking modules, consisting, as first and unique case, of monolithic silicon pixel sensors, namely ALTAI. This technology is based on the ALPIDE (ALice PIxel DEtector) developed for the ALICE (A Large Ion Collider Experiment) ITS upgrade at CERN.
The results on the DD performance will be discussed based on the demanding requirements of space applications. Mechanical requirements on tracker stiffness, needed to withstand the vibrational stress, and its thermal properties for heat dissipation in vacuum will be presented as well as sensor performance as a function of the temperature.
Moreover, event selection strategies will be discussed.

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Poster Session II / 62

High resolution imaging and timing using capacitive division

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The capacitive division image readout (C-DIR) is a mechanically and electronically simple charge centroiding readout for single photon imaging detectors such as microchannel plate (MCP) detectors. It is purely capacitive in nature, and this endows it with a) very high signal bandwidth allowing MCP-limited time resolution, and b) low capacitance measurement nodes, allowing improved signal to noise charge measurement and correspondingly finer spatial resolution at high throughput.

We describe an implementation of an MCP detector with C-DIR, optimised to provide combined high spatial and temporal resolution in single photon counting operation. The C-DIR is instrumented with high-speed front-end electronics utilising a fast waveform digitizer with a sample rate in excess of 1Gsample/s.

We present results of the spatial and temporal resolution, and throughput of the detector system, and discuss the possible design variations which trade off performance parameters against each other.

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Applications in Astrophysics / 63

Imaging Earth's magnetosphere with the Soft X-ray Imager (SXI) on the SMILE mission

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The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) is an Earth orbiting satellite being developed as a joint European Space Agency (ESA) and Chinese Academy of Sciences (CAS) planetary science mission. The spacecraft is scheduled for launch in 2025 and equipped with complementing imaging instruments which will provide wide-field images with the goal of providing a more complete understanding of the full Sun-Earth connection. Two further instruments will capture in-situ measurements of particle flux and magnetic field as the spacecraft follows a highly inclined and highly elliptical orbit to study the flow of charged, solar wind (SW), particles.

The Soft X-ray Imager (SXI) instrument, a compact X-ray telescope developed and led by the University of Leicester, will detect photons in the soft X-ray band that are produced by a process called Solar Wind Charge eXchange (SWCX). This process results from the interaction of heavy ions in the SW with neutrals in the Earth's exosphere and provides a mechanism for imaging the SW flow

around the Earth. With a large field-of-view of 26.5 x 15.5 degrees, SXI captures images through a combination of a micropore optic array and two large area X-ray sensitive back-illuminated Charge Coupled Devices (CCDs).

We introduce the motivation for investigating the Sun-Earth interaction and link with the SMILE mission science objectives. We describe the SXI instrument architecture, including the X-ray focusing technique using micropore optics, and detail the detector subsystems along with radiation protection mechanisms, plus flight operational planning, designed to prolong the performance of the CCDs. We summarise the space readiness testing covering thermal, vibration and electromagnetic compliance and present the timeline to launch through commissioning. Finally, we discuss recent orbit simulations which highlight the opportunity for serendipity science observations and potential links with other operational space telescopes.

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Applications in Astrophysics / 64

Investigation of an irradiated CCD device: building and testing a Charge Transfer Inefficiency correction pipeline using the Pyxel framework

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Pyxel is a powerful end-to-end detector simulations framework with the aim of being reusable, reliable and help facilitate knowledge transfer between a wide range of related fields. To show how beneficial Pyxel can be, we present an investigation into the effect of Charge Transfer Inefficiency (CTI) on an irradiated CCD-273 device produced by Teledyne-e2v, the type of detector used for the Euclid VIS instrument. This requires production of two pipelines. Firstly, a calibration pipeline to search the parameter space and obtain best fitting trap parameters based upon the CTI within the detector. Secondly, a pipeline correcting the CTI-induced data using these trap parameters, trying to obtain a nominal correction efficiency better than the required 99.5%. The following presents work conducting in building, testing and validating the correction pipeline using Pyxel and the CTI model ArCTIC. This involves data from the un-irradiated portion of a CCD-273 device using the scene projection system at the labs at the European Space Agency (ESA). The images are computationally altered by varying parameters such as background levels and readout noise, and by synthetically producing CTI trails from known trap parameters. The resulting images are corrected and analysed to understand how noise affects the correction efficiency at varying image background levels.

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Poster Session I / 65

A new detector to muon tomography for glaciers melting monitoring

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We present a design project for a muon tomography detector aiming to the monitoring of glacier thickness. The glacier melting process is not completely understood and is considered a hot topic in view of the global warming.
Muon Tomography is a widely used technique, employed to perform imaging of the inner structure of large objects, as volcanoes, container, and pyramids. This technique takes advantages of the muon flux reaching Earth surface ($\sim 70\ \mathrm{m}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}$). In case of glaciers, thanks to the different density of ice and rock, a directional flux measurement provides information on the bedrock-ice interface depth.

The goal of our project is the development of a detector able to measure the glacier thickness with short exposure time, and with a real time data taking and processing, in order to perform studies of the seasonal behavior, and the glacier melting trend through the years. The detector will also be operable in open-sky and be replicable. The foreseen design of the detector is based on scintillation fibers disposed organized in layers, and read by SiPMs driven by FERS boards (A5202), developed by CAEN s.p.a., that both supply and read the detectors.

In this contribution, we will show the results of a set of simulations aimed to optimize the detector design, and the foreseen performances of the designed detector. The angular resolution of the reconstructed muon tracks will be shown considering different configuration of the detector, together with a study of the dependence of the angular resolution with respect to the direction of the incoming particle. We will present also the result of the tests on the read-out chain, that are performed in collaboration with CAEN s.p.a.. Finally, we will present also the results of a full simulation that includes the detector and the profile of a real mountain.

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Detectors for High radiation and extreme environment / 66

Latest Results on the Radiation Tolerance of Diamond 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 constant 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/cmˆ2 with both pad and pixel readout electronics. Our beam test results indicate a 2% upper limit to the pulse height dependence of unirradiated and neutron irradiated pCVD diamond detectors leading to the conclusion that the pulse height in pCVD diamond detectors is, at most, minimally dependent on the particle flux.

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Gas Based Detectors / 68

In-beam performance of a Resistive Plate Chamber operated with an eco-friendly gas mixture

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ALICE (A Large Ion Collider Experiment) studies the quark-gluon plasma (QGP), a deconfined state of nuclear matter which can be obtained in ultra-relativistic heavy-ion collisions. One of the key probes for QGP characterization is the study of quarkonia and open heavy flavour production, of which ALICE exploits the muonic decay. In particular, a set of Resistive Plate Chambers (RPCs), placed in the forward rapidity region of the ALICE detector, is used for muon identification purposes.

The correct operation of these detectors is ensured by the choice of the proper gas mixture. Currently they are operated with a mixture of $C_2H_2F_4$, i-C_4H_{10} and SF_6 but, starting from 2017, new European Union regulations have enforced a progressive phase-out of $C_2H_2F_4$, because of its large Global Warming Potential (GWP), making it difficult and costly to purchase. Moreover, CERN asked LHC experiments to reduce greenhouse gases emissions, to which RPC operation contributes for about 80% of the total.

A possible low-GWP alternative for $C_2H_2F_4$ is the $C_3H_2F_4$ (diluted with other gases, such as CO_2), which has been extensively tested using cosmic muons; few promising gas mixtures have been devised and next crucial steps are their detailed in-beam characterization as well as the study of their performance under increasing background irradiation.

This contribution will describe the methodology and results of a series of beam tests carried out at the CERN Gamma Irradiation Facility (equipped with a high activity 137Cs source and muon beam) with an ALICE-like RPC prototype, operated with several mixtures with varying proportions of CO_2, $C_3H_2F_4$, i-C_4H_{10} and SF_6, in the framework of the RPC EcoGas@GIF++ Collaboration. Results on absorbed currents, efficiencies, prompt charges, cluster sizes, time resolutions and rate capabilities will be presented, both from digitized (for shape and charge analysis) and discriminated (using the same front-end electronics employed in ALICE) signals.

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Poster Session III / 69

A study on the feasibility of CSNS becoming an ATLAS ITk sensor QA irradiation site

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The current ATLAS Inner Detector will undergo a complete upgrade in order to meet the requirements of the High Luminosity Large Hadron Collider (HL-LHC). The new Inner Tracker (ITk) will be made completely of silicon sensors fabricated by Hamamatsu Photonics K.K. (HPK). Quality Assurance (QA) is focused on providing confidence that quality requirements will be fulfilled in production such as irradiation tolerance and testing specification for the mini sensors. The Associated Proton beam Experiment Platform (APEP) beam line at the China Spallation Neutron Source (CSNS) commissioned in 2022. This study focused on verifying the feasibility of CSNS as an ITk sensor QA irradiation site. A low-temperature peltier cold box has been developed to keep the irradiation sensor samples at -15℃. Several fluence points have been studied from 5.1×10^{14} to 1.6×10^{15} neq/cm^2, measured by the aluminum sheet. The post-irradiation measurements (IV, CV, and CCE) are done after annealing for 80 minutes at 60℃ under the cold temperature (-8℃). Test results show CSNS could be a suitable proton irradiation site for the ATLAS ITk sensor project.

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Advanced photon detectors X-rays and Gamma ray / 70

Low Gain Avalanche Diodes for Photon Science Applications

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Low Gain Avalanche Diodes (LGADs) are silicon sensors with an internal gain in the order of 10 obtained via the impact ionization process.
The initial technological implementation of the sensors constrains their minimum channel size to be larger than 1 mm^2 in order to reduce inefficiencies due to the segmentation of the gain structure. In photon science, the gain provided by LGAD sensors can boost the signal-to-noise ratio of the detector system, effectively reducing the x-ray energy threshold of photon counting detectors and the minimum x-ray energy where single photon resolution is achieved in charge integrating detectors. This can improve the hybrid pixel and strip detectors for soft and tender x-rays by only changing the sensor element of the detector system. Photon science applications in the soft and tender energy range require improvements over the LGADs developed for other applications, in particular the presence of a thin entrance window to provide a satisfactory quantum efficiency and channel size with a pitch of less than 100 μm. In this review, the fundamental aspects of the LGAD technology are presented, discussing also the ongoing and future developments that are of interest for photon science applications. In particular, novel structures were recently proposed to improve the sensor segmentation while keeping the regions where no gain structure is present to a minimum: double sided (inverted) LGADs, trench-isolated LGADs, and AC-coupled LGADs are examples of the structures discussed in this talk. The measured and expected properties of available and proposed LGAD structures are discussed for several aspects relevant to photon science applications such as the impact of the placement of the gain structure on quantum efficiency, the sensor's signal characteristics and its compatibility with available readout chips.

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Gas Based Detectors / 71

Upgrade, commissioning and first performance of the ALICE Muon Spectrometer

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ALICE (A Large Ion Collider Experiment) at the CERN Large Hadron Collider (LHC) is designed to study proton-proton and heavy-ion collisions at ultra-relativistic energies. The main goal is to assess the properties of quark gluon plasma (QGP), a state of matter where quarks and gluons are

deconfined, reached in extreme conditions of temperature and energy density.
One of the main observables used to probe the QGP is the production of heavy quarkonia in Pb-Pb collisions. ALICE is equipped with a forward Muon Spectrometer (MS) to detect quarkonia via their dimuon decays.
In view of the LHC Run 3 (2022), ALICE had a major upgrade of its apparatus to enable a new programme of high-precision measurements and to cope with an increased collision rate, up to 50 kHz in Pb-Pb collisions (was 10 kHz in Run 2).
For the MS, ALICE implemented new hardware and software solutions. A new vertex tracker based on Monolithic Active Pixel Sensor technology, the Muon Forward Tracker (MFT), was installed in the acceptance of the MS. It allows one to separate, for the first time in ALICE at forward-rapidity, prompt and non-prompt contributions to the cross sections of charmonia. Moreover, the new MS vertexing capabilities greatly improve the invariant mass resolution, allowing for a better separation between J/ψ and ψ(2S) states, down to zero transverse momentum.
As a further upgrade of the MS, the front-end and readout electronics of the Muon Tracking System (Cathode Pad Chambers) and of the Muon Identification System (Resistive Plate Chambers) have been upgraded to optimize the detector performance and lifetime in the new running conditions.
A description of the MS upgrades and commissioning, together with the performance achieved with the first Run 3 data, will be presented.

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Detectors for High radiation and extreme environment / **72**

Study of radiation tolerance of Cu(In,Ga)Se2 detectors

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The European Organization for Nuclear Research (CERN) is planing a major update of the accelerator to HL-LHC and future hadron collider. These major upgrades give higher radiation doses to detectors, and degradation of semiconductor properties will be more serious problem. $\mathrm{Cu(In_x, Ga_{1-x})Se_2}$ (CIGS) is attracting attention a new semiconductor material that can be used for long-term operation in high-radiation environments.
A CIGS which is an alloy semiconductors of $\mathrm{CuInSe_2}$ and $\mathrm{CuGaSe_2}$, has been widely developed as a solar cell. It is known to have a recovery mechanism for radiation damage by a thermal annealing, and we have been developing a particle detector using the CIGS with high radiation tolerance.
The purpose of this study is to clarify the recovery mechanism of the radiation damage in the CIGS through irradiation experiments at Heavy Ion Medical Accelerator in Chiba (HIMAC) and Cyclotron and Radioisotope Center (CYRIC).
In the HIMAC experiment, we irradiated heavy ion beams ($^{132}\mathrm{Xe}^{54+}$) with the energy of 400 $\mathrm{MeV/u}$ to the CIGS detector with 2 $\mu\mathrm{m}$ thickness, and the amount of collected charge from $^{132}\mathrm{Xe}^{54+}$ signals and the leakage current were measured during the beam irradiation. After irradiation of 0.6

MGy, the amount of collected charge from xenon signals was decreased to 50% before irradiation. Afterwards, as a result of the thermal annealing for two hours at 130°C, the amount of collected charge was recovered to 97% before irradiation. Moreover, after $^{132}\mathrm{Xe}^{54+}$ beam irradiation again, we observed a second recovery of collected charge from 80% to 94% by the thermal annealing for another 50 minutes at 130°C. It indicates the possibility of the long-term operation in high radiation environments with periodic thermal treatments.
In the CYRIC experiment, proton beams with dose of $7 \times 10^{15}\ \mathrm{MeV} \cdot \mathrm{n_{eq}}/\mathrm{cm}^2$ irradiated to the CIGS solar cells with 2 μm thickness, and investigated to trend of thermal time and temperature in the recovery of semiconductor properties.

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Poster Session II / 73

Investigation of use of Wavelength Shifting Materials in Water Cherenkov Detectors for Gamma Ray Astronomy

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Water Cherenkov detectors for wide-field gamma-ray astronomy, such as HAWC and LHASSO and the upcoming Southern Wide-Field Gamma-Ray Observatory (SWGO) utilize a large number of water tanks at high altitudes to directly detect the gamma-ray-produced charged particle shower via the Cherenkov radiation generated within each tank. SWGO will be the first such wide-field survey instrument to explore the southern hemisphere, allowing access to areas that cannot currently be observed such as the Galactic Centre, and complementing the higher angular resolution but smaller field of view of the Cherenkov Telescope Array (CTA).
Water Cherenkov detectors typically utilize a large number of water tanks (6000-8000 for SWGO) instrumented with several PMTs per tank, meaning that costs are a major driver if large PMTs are required.
We discuss a technique that uses wavelength shifting (WLS) material to capture Cherenkov light over a larger area and couple it into a PMT, allowing the use of a smaller PMT at a lower cost. This solution is only useful for the lower muon tagging tank, which does not require as high a time resolution
We discuss simulations using Geant4 of a modified design where a smaller PMT is embedded in a WLS plate, which collects incoming Cherenkov photons over a larger area and downshifts their wavelength to more effectively match the quantum efficiency of the PMT.
We present simulation results showing the effect of the WLS on the time resolution and sensitivity of Cherenkov photon detection and discuss performance and cost trade-offs compared to a conventional design using a large PMT with no additional WLS material.

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ATLAS New Small Wheel Performance Studies After First Year of Operation

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After successfully completing Phase I upgrades during LHC Long Shutdown 2, the ATLAS detector is back in operation with several upgrades implemented. The most important and challenging upgrade is in the Muon Spectrometer, where the two inner forward muon stations have been replaced with the New Small Wheels (NSW) system featuring two entirely new detector technologies: small strip Thin Gap Chambers (sTGC) and the resistive Micromegas (MM).
After massive construction, testing and installation work in ATLAS, the two NSW endcaps have now been in operation for about a year in the experiment, in the experiment, participating in the muon spectrometer tracking system and muon trigger system. At the same time completing the phase of commissioning of this completely new system. A huge effort has gone into the operation of the new data acquisition system, as well as the implementation of a new processing chain within the muon software framework.
The new detectors are fully integrated into the software. Tracking is performed with full consideration of the absolute alignment of each individual detector module by the ATLAS Muon Spectrometer optical alignment system. All the deviations from the nominal geometry of all the constituent elements of each sTGC and MM module are accounted for through the modeling of the real chamber geometry reconstructed from the information of the construction databases.
After an overview of the strategies adopted for the simulations and reconstruction, the studies on the performance of the NSW system in its first year of operation with LHC Run3 data will be reported.

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Advanced photon detectors X-rays and Gamma ray / 76

Development of trigger-mode fine-pitch silicon hybrid detectors for electron tracking Compton camera

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Compton imaging is an important gamma-ray imaging method with wide-band energy measurement and large field-of-view in medical, astrophysics and environmental applications. One of the drawbacks of Compton imaging is its low signal to noise ratio (SNR) and electron tracking of Compton recoil electrons may help to improve SNR to limit the Compton cones to Compton arc. We have designed and fabricated a fine-pitch (18 μm) pixel hybrid silicon detectors by combining 18 μm pixel silicon sensor (450 μm thickness) and pixel ASIC (5 mm x 5 mm) fabricated with TSMC 250 nm CMOS technology using micro-bumps. ASIC includes the function to generate trigger for readout of the electron track and synchronize with the absorbers in Compton camera. Basic performance of the detector will be reported in the conference.

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Poster Session II / 78

Latest experimental results using large area picosecond photodetectors

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For the planned future upgrades of several high energy physics experiments, highly performing position sensitive photodetectors are needed. In ring imaging Cherenkov counters, planned for the upgrades of LHCb and Belle II experiments, detection of single photons with position resolutions a good as 1 mm will be required, with timing resolution on the order of 100 ps and surface coverage of m^2. In addition, the photodetector has to operate in high magnetic field and neutron radiation background, and no current photodetector can fulfill all of the requirements. One promising development is the large area picosecond photodetector (LAPPD), which features a large area of 200 mm x 200 mm and achieves excellent performance by using microchannel plates (MCP). In this contribution, experimental results obtained with the generation I LAPPD produced by INCOM company are presented. Using custom designed PCBs, capacitive couplings to the anode with different segmentation, and therefore, spatial resolution capabilities, were explored. As the photodetector readout, PETsys TOFPET 2, as well as FastIC ASICs were used. Reported results include characterization of spatial response, using precision scanning of focused laser light, and temporal response to picosecond illumination at single photon level.

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Poster Session III / 79

Assembly and Testing of 2S Module Prototypes for CMS Outer Tracker Phase-2 Upgrade

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The High Luminosity LHC (HL-LHC) requires the CMS detector to undergo a major Phase-2 upgrade, which involves the complete replacement of current tracker. The new tracker will be divided into two main parts: inner tracker and outer tracker. The Phase-2 outer tracker will employ two types of silicon modules, 2S and PS, based on a novel pT discrimination concept. These modules aim to reduce local data in the front-end electronics by utilizing the strong magnetic field of the CMS detector, effectively rejecting low transverse momentum (pT) particles.
This talk provides a comprehensive overview of the prototyping process for 2S modules, focusing on the precise assembly techniques and testing procedures employed during the development phase. These procedures play a crucial role in ensuring the performance, functionality, and quality of the 2S modules before their implementation in the outer tracker.
In addition, several test beam performance studies have been conducted on 2S module prototypes, utilizing the electron beam with energies up to 6 GeV at DESY. A comparison between the EUTelescope and Corryvreckan offline data reconstruction frameworks will be presented for the performance study of the 2S module, using the test beam data.

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Poster Session III / 80

Development of the BCM' system for beam abort and luminosity monitoring in ATLAS based on a segmented polycrystalline CVD diamond system and dedicated front-end ASIC

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The High Luminosity upgrade of Large Hadron Collider (HL-LHC) will increase the LHC Luminosity and with it the density of particles on the detector by an order of magnitude. For protecting the inner silicon detectors of the ATLAS experiment and for monitoring the delivered luminosity, a radiation hard beam monitor has been developed. We developed a set of detectors based on polycrystalline Chemical Vapor Deposition (pCVD) diamonds and a new dedicated rad-hard front-end ASIC. Due to the large range of particle flux through the detector, flexibility is very important. To satisfy the requirements imposed by the HL-LHC, our solution is based on segmenting diamond sensors into devices of varying size and reading them out with new multichannel readout ASICs divided into two independent parts - each of them serving one of the tasks of the system. In this talk we describe the system design including detectors, electronics, mechanics and services and present preliminary results from the most recent detectors fabricated using our prototype ASIC with data from beam tests at CERN.

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Poster Session I / 81

Spectroscopic-based simultaneous monitoring for neutron-gamma H*(10) using an organic scintillation detector

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A dose monitoring system is crucial for protecting workers from overexposure to neutrons and gamma rays in the neutron utilization facilities and decommissioning of nuclear power plants. Traditional passive dosimeters have been widely used to measure both radiation types simultaneously. However, these dosimeters are incapable of real-time dose estimation and detecting hotspot locations. A combination of GM counters and He-3 proportional counters also have been employed for area monitoring. Although it is possible to monitor dose in real-time, this is relatively bulky and requires additional equipment for identifying radionuclides.
This study proposes a methodology for spectroscopic-based neutron-gamma simultaneous dose (ambient dose equivalent, H*(10)) estimation using an organic scintillation detector. Firstly, we performed time-of-flight measurements with two detectors to obtain a neutron response matrix. A detection system,*

our interest, comprised a stilbene scintillator and a photomultiplier tube (PMT). The other consisted of PMT and an EJ-200 scintillator to detect gamma-triggering signals. A Cf-252 source was placed between two detectors at 50 cm from each detector. The 256 channels were calibrated to a range of 60 to 1850 keV. The neutron response matrix was validated for consistency with the Watt fission spectrum.
To convert $H(10)$ from the neutron spectrum, we calculated the G (E) function using the ADAM method, and it had the smallest mean square error at Kmax = 16. The performance of the G(E) function was evaluated with the H*(10) estimation accuracy and linearity depending on the dose rate. The test dataset was obtained with a pulse shape discrimination (PSD) method. The results demonstrated linearity within an error of approximately 18% ranging from 0.1 to 5 μSv/hr. The study on the* $H(10)$ estimation in environments with gamma sources only and simultaneous neutron and gamma sources is ongoing. The findings will be discussed at the conference presentation.

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Poster Session III / 82

Module development with the MALTA monolithic pixel chip

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The MALTA silicon pixel detector combines a depleted monolithic active pixel sensor (DMAPS) with a fully asynchronous front-end and readout. It features a high granularity pixel matrix with a 36.4 μm symmetric pixel pitch, low power consumption of <1 μW/pixel and low material budget with detector thicknesses as little as 50 μm. It achieves a radiation hardness to 100MRad TID and more than 1×10E15 1 MeV n_eq/cm^2 with a time resolution of < 2 ns [1].

In order to cover large sensitive areas efficiently with a minimum of power and data connections the development of modules, comprising of up to 4 MALTA detectors, is studied.
This contribution presents the beam test performance of parallel and serial powered MALTA 4-chip modules in an effort to characterize the sensor's chip-to-chip data and power transmission and prepare the production of a first prototype of an ultra-light weight 4-chip module on a flexible circuit with next generation MALTA2 sensors.

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Novel Photon Detectors / 83

Development of a single photon emission microscope with ~200μm spatial resolution

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With a low energy pinhole gamma camera, spatial resolution is mainly determined by the intrinsic spatial resolution of the imaging detector, pinhole diameter and magnification ratio of the collimator. However the pinhole diameter was so far limited to around 1 mm due to the manufacturing difficulty of tungsten. To overcome the limitation of the spatial resolution of the pinhole gamma camera, we manufactured a 0.1 mm diameter pinhole and combined with a YAP(Ce) imaging detector to form a ultrahigh resolution pinhole gamma camera. The imaging detector used a 40 mm x 40 mm x 1mm thick YAP(Ce) plate optically coupled to a 2-inch square flat panel photomultiplier tube (FPPMT) with a 1mm thick light guide. The intrinsic spatial resolution of the YAP(Ce) imaging detector was ~1.4 mm FWHM for 60 keV gamma photons. YAP(Ce) imaging detector was encased in a tungsten shield and 1 0.1 mm diameter pinhole collimator was set 100 mm from the imaging detector surface. At 10mm from the pinhole center with the magnification ratio of 10, the spatial resolution of ~200 μm was obtained with the developed pinhole camera. The system sensitivity was ~0.001%. The developed ultrahigh-resolution pinhole gamma camera was named "single photon emission microscope" . The developed single photon emission microscope will be useful for single photon imaging where ultrahigh resolution is required.

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Detectors for FELS, Synchrotron and other advanced Light sources / 84

Synchrotron light source X-ray detection with Low-Gain Avalanche Diodes

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Low Gain Avalanche Diodes (LGADs) represent the state-of-the-art in timing measurements, and will instrument the future Timing Detectors of ATLAS and CMS for the High-Luminosity LHC. While initially conceived as a sensor for charged particles, the intrinsic gain of LGADs makes it possible to detect low energy X-rays with good energy resolution and excellent timing (tens of picoseconds). Using the Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC, several LGADs designs were characterized with energies from 10 to 70 keV. The SSRL provides 10 ps pulsed X-ray bunches separated by 2 ns intervals, and with an energy dispersion ΔE/E of 10^{-4}. LGADs from Hamamatsu Photonics (HPK) and Brookhaven National Laboratory (BNL) with different thicknesses ranging from 20 µm to 50 µm and different gain layer designs were read out using fast amplification boards and digitized with a high bandwidth and high sampling rate oscilloscope. PiN devices from HPK and AC-LGADs from BNL were characterized as well. A systematic and detailed characterization of the devices' energy linearity, resolution and timing resolution as a function of X-ray energy was performed for different biasing voltages at room temperature and will be reported in this presentation. The charge collection and multiplication mechanism were simulated using GEANT4 and TCAD Sentaurus, providing an important handle for interpreting the data.

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Poster Session III / 85

Towards the construction of the ATLAS ITk Strip Endcap detector for the HL-LHC phase

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To sustain the five-fold increase in instantaneous luminosity of the High-Luminosity phase of the LHC, the ATLAS experiment will replace its current Inner Detector with a new all-silicon tracker

detector. The Inner Tracker (ITk) will consist of an inner silicon pixel detector, surrounded by layers of silicon microstrip sensors. The production phase of the ITk is starting during the year 2023.
This contribution gives an overview of the steps to build the forward regions of the ITk Strip detector (the so-called endcaps), focusing on the loading of the silicon microstrip sensors on the support structures (petals), and on the preparation for the integration of each petal on the final endcap frame.

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Advanced photon detectors X-rays and Gamma ray / 86

Demonstration of particle tracking with scintillating fibres read out by SPAD array sensor

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In this contribution, we present a proof-of-concept, fine-granularity particle detector constructed from plastic scintillating fibres (SFs) readout with a Single-Photon Avalanche Diode (SPAD) array sensor, intended for the next generation of neutrino experiments. These experiments will be limited by systematic uncertainties, of which many can be constrained by having a precise knowledge of the vertex activity and measuring the neutrino-nucleus cross-section. This includes tracking pions, low-momentum protons, rejecting photon conversion events, and a precise energy reconstruction. All the mentioned requirements are strongly aided by having a fine granularity detector, with sub-mm spatial resolution.

SFs are a natural choice for fine-granularity, plastic scintillation detectors as they can be manufactured with diameters down to 200 µm. Typically, SFs are coupled to Silicon PhotoMultipliers (SiPMs) however, for neutrino active targets a very large detector mass is required which would lead to a very large number of readout channels. Therefore, a new type of readout is necessary. SPAD array sensors fabricated using commercial CMOS Image Sensor (CIS) technologies would significantly reduce the required number of readout channels whilst maintaining the granularity of the detector as multiple SFs can be independently imaged by a single sensor.

In this study, a proof-of-concept detector has been constructed making use of sixteen 1 mm diameter SFs bundled together in a 4 × 4 array and coupled to the SwissSPAD2 sensor. Low-energy electrons from a Sr-90 source were directed through the SF bundle and particle tracks have been imaged from the generated scintillation photons, demonstrating the potential of this technology for the future neutrino experiment requirements.

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Position Sensitive Fast Timing Detectors / 87

Environmental conditions stress tests on Low Gain Avalanche Diodes

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Devices with internal gain, such as Low Gain Avalanche Diodes (LGADs) demonstrate O(30) ps timing resolution, and they play a crucial role in High Energy Physics (HEP) experiment. Similarly, resistive silicon devices, such as AC-coupled LGADs (AC-LGADs) sensors achieve a fine spatial resolution while maintaining the LGAD's timing resolution. Devices of both types, with varying gain-layer width and doping characteristics, are produced at Brookhaven National Laboratory (BNL) [1]. However, their performance is strongly affected by environmental factors such as temperature, humidity, rapid changes in bias voltage settings, and storage conditions. For example, phonon scattering, which is strongly affected by temperature, plays a central role in avalanche multiplication at higher temperatures, where phonon scattering becomes prominent due to the temperature dependence of the phonon population [2]. In particular, at high temperatures, carriers tend to lose their energy as they travel through the multiplication region, requiring longer paths, resulting in a weaker multiplication. Therefore, the operating conditions, such as noise, gain and breakdown voltage, depend on these variables. In view of applications beyond the controlled environment of HEP-experiments, these devices are stressed-tested against varying environmental conditions. For example, the challenging operating conditions in outer space impose constraints on the operation performance, against temperature fluctuations, for example. Sensors fabricated at BNL are characterized at the Silicon Lab at BNL and at the RD50 facility at CERN. We study how different devices with different depletion layers and implantation characteristics respond to these changing climatic conditions. In particular, we create a systematic evaluation of the response of LGAD sensors as a function of these environmental parameters. This allows us to map the device performance back to the sensors characteristics. In turn, this will allow the tailored fabrication of devices resilient to the hasheses conditions at no cost to the operational performance in controlled environments.

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Application in life sciences and biology / 88

Development of an ultrahigh resolution 1mm Si-PM array based GGAG alpha camera with gamma rejection capability

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For precise distribution measurements of alpha particles such as those required in alpha radionuclide therapy research, a high-resolution alpha particle camera is desired. Although combining a thin scintillator with a photodetector such as position sensitive photomultiplier (PSPMT) or silicon photomultiplier (Si-PM) array is a possible method to develop an event-by-event based alpha camera, the spatial resolution is so far limited around 1.0 mm FWHM. To overcome the limitation, we employed a 1 mm channel size Si-PM array combined with a thin GGAG plate to form an alpha particle imaging detector and evaluated the performance. For the developed alpha particle imaging detector, a Si-PM array with 1 mm x 1 mm channel size arranged 8 x 8 was optically coupled to a 1mm thick GGAG plate with a 1-mm-thick light guide between them. Since the decay times of GGAG are different between alpha particles and gamma photons, we could separately measure alpha particle and gamma photon images using pulse shape discrimination. The spatial resolution of the developed alpha was 0.2 mm FWHM and the energy resolution was 11 % FWHM for 5.5 MeV alpha particles. We could separately measure the alpha particle and gamma photon images using pulse shape discrimination. The developed camera is promising for distribution measurements of alpha particles as well as gamma photons where high resolution is required.

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Closing session / 89

Characterization of monolithic CMOS pixel matrices with various pitch fabricated in a 65 nm process.

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The performance of monolithic CMOS pixel sensors depends on their fabrication process and especially the feature size which directly drives the pixel size. A consortium led by the CERN EP R&D program, the ALICE experiment and various European projects (AIDAinnova, EURIZON) is investigating the benefits of a 65 nm CMOS imager process to design a new generation of pixel sensors. These developments target a first application for an upgraded version of the inner layers (ITS3) of the ALICE experiments and foster further studies for detector including those for future e+e- colliders that are still currently unmatched by any technology.

Two fabrications of a variety of prototype sensors already took place, in 2020 and 2022. This contribution reports on the characterization of the first version of some of them, the CE-65 sensors. They include analogue output matrices featuring 2048 (or 1536) pixels with either 15 or 25 µm pixels. Three versions of the sensing node were fabricated in order to modify the charge sharing between pixels. Sensors were irradiated to non-ionizing fluences between 10^{13} and 10^{16} n_{eq}/cm^2 as well to 100 and 500 Mrad ionizing radiations.
Illumination with ^{55}Fe source allowed to estimate the equivalent collection node capacitance and its pixel-to-pixel fluctuation, as well as the leakage current before and after irradiation. Non-irradiated sensors were tested in a 10 GeV electron beam to study in detail the charge sharing among pixels and extract the sensor detection efficiencies as well as their position resolutions. The evolution of the latter with digitization strategies, simulated from the data, was also investigated in order to explore the potential of pixels with binary or few bits output, designed in this 65 nm process.

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Gas Based Detectors / 90

High granularity resistive Micromegas for future detectors

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The resistive Micromegas technology can stably operate up to O(10 MHz/cm^2) particle rate thanks to novel resistive spark-protection structures suitable for readout pads of a few mm^2 area. These

structures are made by Diamond-Like-Carbon (DLC) in a double-layer configuration in most of the investigated detectors with active surfaces of $\sim 25\,\mathrm{cm}^2$ and in the new one with an active area of $\sim 400\,\mathrm{cm}^2$. Specifically, the DLC foils have a surface resistivity of $\sim 30\,\mathrm{M}\Omega/$
$square$ in the last prototype. The results of the performance in terms of gain, rate capability, robustness, dependence on the irradiated area, and space-time dedicated studies will be presented. With the proven high performance of the medium size detector and the already-started construction of a high granularity resistive Micromegas with an even larger area, our R&D is reaching the goal of establishing the technology for future large-scale and high-rate employment in Particle Physics and other fields.

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Application in Nuclear physics / 91

Recent results from the MIMOSIS-1 CMOS MAPS

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The CMOS Sensor MIMOSIS is being designed to equip the Micro Vertex Detector (MVD) of the CBM experiment at FAIR in Darmstadt, Germany. It will feature 1024 × 504 pixels with 27 x 30µm pitch and combine a time resolution of 5 µs with a spatial resolution of ~ 5 µm. Moreover, it will have to handle a peak rate of 80 MHz/cm² and radiation doses of 5 MRad and up to $10^{14}\ \mathrm{n_{eq}/cm^2}$ per year. It is being developed within a joint R&D program of IPHC Strasbourg, Goethe University Frankfurt and GSI/FAIR.

The first full size sensor prototype MIMOSIS-1 was developed and tested intensely. It hosts conventional DC-coupled pixels and innovative AC-coupled pixels suited to fully deplete the sensing element with voltages of up to 20V. The detection performances of the device, its immunity to the above-mentioned radiation doses and heavy ion impacts was studied in the laboratory and in a series of beam tests at DESY, CERN, and GSI. In addition, the capability of the device to identify nuclear fragments by dE/dx was evaluated with a deuterium beam at COSY. The contribution will summarize the design considerations of MIMOSIS, discuss the results obtained and introduce our plans for the test of the consecutive MIMOSIS-2 prototype.

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Application in life sciences and biology / 92

Planar silicon sensors for real-time monitoring of electron (and protons) FLASH beams

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Background. FLASH Radiotherapy (RT) delivers an average dose-rate > 40 Gy/s in less than 200 ms with extremely high instantaneous dose-rates, and preclinical studies demonstrated a tumoricidal effect comparable to conventional RT with an increased sparing effect on healthy tissues (FLASH effect). Real-time monitoring of FLASH beams is challenging, but crucial for studying the delivery parameters triggering the FLASH effect. Within the INFN-FRIDA project, we are exploring thin silicon sensors as beam monitors for electron and proton FLASH beams.

Materials and methods. Planar silicon sensors of 30/655 and 45/570 μm active/total thicknesses and 0.25, 1 and 2 mm^2 active areas were tested on 9 MeV electron beams from the Pisa CPFR Electron-Flash accelerator (EF, funded by the Pisa Foundation). Measurements were performed with a 5 GS/s oscilloscope and a 64-channel TERA08 chip, a current-pulse-frequency converter with a maximum conversion frequency of 20 MHz and a maximum current of 4 μA per channel. Silicon sensors were placed at the output of the 30-mm-diameter EF applicator after a solid water slab. Measurements performed with the PTW FlashDiamond were taken as reference.

Results. The temporal structure of the beam and the charge collected in each 4μs pulse by silicon sensors were measured at the Pisa EF by varying the delivered dose-per-pulse, reaching a response linearity up to the maximum value reached ($\sim$10 Gy/pulse).

Conclusions. The preliminary results confirmed that silicon sensors can be employed to measure the fluence and shape of electron FLASH beams. A 3x3 cm^2 silicon sensor segmented in strips and an upgraded version of the TERA08 chip are being properly connected to monitor an area of few cm^2 on both electron and proton FLASH beams.

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Advanced photon detectors X-rays and Gamma ray / 93

Evaluation of Compton recoil electron tracking capability of fine-pitch pixel silicon detector with a Monte Carlo simulation

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Compton imaging can visualize a radioactive source visualization without any mechanical collimators based on the Compton scattering kinematics. The conventional imaging method confines the source location only on a conical surface with a calculated scattered angle from the energy depositions and interaction positions in a scatterer and an absorber. However, Compton cones causes an artifact in a reconstructed image and decreases the signal-to-background ratio (SBR). The measurement of recoil electron tracks is a promising technique to overcome this limitation because the source position can be estimated from on a conical surface to an arc surface.
We have developed fine-pitch pixel silicon detectors for electron tracking Compton imaging, which generate triggers to readout only radiation hit pixels. One is a silicon-on-insulator (SOI) pixel detector with pixel size of 36 μm × 36 μm, and the other is a hybrid detector of pixel silicon sensor and pixel application specific integrated circuit (ASIC) with pixel size of 18 μm × 18 μm. In this study, we have evaluated the capability of recoil electron tracking measurement of these detectors with a Monte Carlo simulation using GEANT4 toolkits. We will report on the simulated performance of electron tracking Compton imaging with 18 μm or 36 μm pitch pixel silicon detectors, such as detection efficiency, SBR, accuracy of incident direction measurement, and so on.

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Detectors at Neutron facilities / 94

A new oscillating detector for monitoring the velocity spectrum of ultracold neutrons and its time evolution

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The velocity spectrum of ultracold neutrons (UCN) is an important factor in characterizing a UCN source and in determining the systematic effects in precision measurements utilizing UCNs, most prominently the search for an electric dipole moment of the neutron [1]. The oscillating ultra-cold neutron spectrometer (OTUS) [2] is a new tool designed for monitoring the velocity distribution and its time evolution in different places of the transport system connecting a UCN source with experiments. We will present the applied detection and analysis methods with the current status of the project, including measurements using the oscillating spectrometer installed at different UCN beamports of the UCN source at the Paul Scherrer Institute (PSI). The obtained results will be compared to the available TOF method results [3] and a detailed Monte Carlo simulation [4]. Especially, the results from the spectrum measurements performed in a large storage tank filled by the PSI UCN source and the spectrum time evolution for different UCN storage times will be demonstrated.
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Poster Session II / 95

MPGD-based Hadronic Calorimeter for Muon Collider Experiments

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The future development of High Energy Particle physics in the post High Luminosity LHC era could greatly benefit from a Multi-TeV muon collider, which stands as one of the most promising options. This machine would enable leptonic collisions at high center-of-mass energy, creating opportunities for a wide range of unexplored physics studies. However, designing an appropriate detection system poses a significant technological hurdle due to the inherent instability of muons. The interaction between muon decay products and the components of the machine can generate a substantial background particle flux, which may negatively impact the performance of the detector. In this presentation, we will showcase the latest simulation studies that have been conducted to optimize the design of the detector, along with an overview of the potential detector technologies that could meet the demanding requirements of a Muon Collider. Special attention will be given to the ongoing research and development efforts in this field.

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Poster Session I / 96

Evaluation and simulation of High Voltage-CMOS chips for high radiation environments

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High Voltage-CMOS (HV-CMOS) sensors are gaining steam as a capable, radiation tolerant, and cost effective solution for silicon based detectors in current and future experiments. These devices can be biased to high voltage, for radiation tolerance, and due to their monolithic nature they can also meet a low material budget. Additionally, they do not require external processing, such as bump-bonding, which can be expensive and limit pixel granularity. Although an attractive option further development is still needed to meet anticipated targets for experiments such as the High Luminosity LHC (HL-LHC) upgrades.

The UKRI-MPW1 is the next iteration in a series of proof-of-concept chips designed to increase radiation tolerance through high biasing voltages. Designed in the LFoundry 150 nm HV-CMOS technology, the chip has a dedicated cross-section consisting of a 3.0 kΩ cm high resistivity backside biased p-type substrate with a Voltage Terminating Scheme (VTS) ring structure, and a new low dose p-type current blocking layer jointly developed with LFoundry. This builds upon the previous UKRI-MPW0 which had a measured breakdown voltage of 600 V, and a 50 µm depletion depth after a fluence of 1×10^{16} 1 MeV n_{eq} cm^{-2}; however, the design suffered from a high leakage current of 4 mA. The new design seeks to reduce the leakage current by way of the VTS, and the new p-layer placed around each pixel, to prevent current flow between pixels.

This contribution presents experimental measurements of the UKRI-MPW0 and varying TCAD evaluations used to develop the new chip cross-section for the UKRI-MPW1. These include Current Voltage (IV) breakdown and inter-pixel current measurements and simulations. As well as, 2D cross-section simulations of current flow, electric field, and breakdown of the new UKRI-MPW1 chip design.

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Medical applications / 97

Monitoring of carbon ion therapeutic beams with thin silicon sensors: status and perspectives

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Background. Single ion counting in particle therapy may lead to new beam monitoring systems much faster and accurate than those currently used in clinics, thus opening the way to innovative delivery strategies. Thin silicon PIN sensors (60 µm active thickness) segmented in strips, manufactured at FBK with different geometries, were optimized for tracking of clinical carbon ions. The results using the CNAO carbon ion clinical beam will be reported.

Materials and methods. Signals of 8 strips of small size sensors were readout using a custom amplifier board and sampled with a 5 GS/s digitizer. Coincidence signals of two sensors were also acquired. The signal peaks were analyzed in terms of, amplitude, peak duration and time resolution at different sensor bias voltages.

A second system, using a larger area (2.6 × 2.6 cmˆ2) strip sensor covering the entire beam cross section, was tested to evaluate the counting efficiency. The strip signals were read out by a 144-channels front-end board equipped with custom ASICs for signal discrimination, followed by 3 Kintex7 FPGA boards for the counting operations.
All the measurements were performed at different beam energies covering the clinical energy range (115 - 399 MeV/u).

Results:
The peak amplitude distributions show a very good separation between signal and noise, scaling as expected with the beam energy, and the signal duration decreases incrementing the bias voltage up to ˜ 2 ns, reaching a single hit time resolution of ˜ 25 ps. Charge sharing and signal cross talk indicate an overall negligible effect and a counting efficiency of ˜ 90% is achieved.

Conclusions:
Initial tests of silicon sensors with carbon ion beams show very promising results, preparing the groundwork for future devices and applications for particle therapy based on the single ion tracking capability.

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Poster Session II / 98

Can machine learning reduce the number of anode readouts for reconstruction coincident single photon in CDIR resistive sea photon detectors?

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This study focuses on exploring the potential of Charge Division Imaging Readout (CDIR) for MCP based resistive sea photon detectors. CDIR spreads the MCP charge footprint capacitively between readout nodes forming anode segments. Charge measurements at each node are then used to reconstruct incident photon's position and time.
A primary objective is to investigate the minimum number of anode segmentations necessary, to allow successful reconstruction of multiple photons within a given time interval where pile up would be an issue for traditional approaches. Allowing for optimisation of the anode structure, segmentation and readout scheme for improved distortion, timing, or rate capability.
Algorithmic and machine learning techniques will be compared and utilised to reconstruct spatial positions of multiple photons, while considering computational efficiency. The comparison will aim to determine whether machine learning reduces the required number of readout nodes for successful reconstruction, in comparison to traditional algorithmic methods, and will investigate if machine learning techniques can be utilised to correct for algorithmic systematic errors to provide a more robust system.
This investigation holds promise for improving the computational efficiency and overall performance of single photon detectors particularly for coincident single photon detection, opening new possibilities for advancements in fields such as quantum physics, particle physics, and biomedical imaging.

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Poster Session II / 99

Exploring Timepix4: A Promising X-ray Detector for EuXFEL Applications

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We present our findings on the characterization and performance evaluation of the Timepix3 X-ray detector in conjunction with a microchannel plate (MCP) and phosphor screen at the European X-ray Free Electron Laser (EuXFEL) facility. The tests conducted on the Timepix3 detector, with a pixel size of 55 µm, have yielded promising results, demonstrating its suitability for EuXFEL applications. The encouraging outcomes obtained from the Timepix3 tests have paved the way for the utilization of Timepix4, which features a similar pixel size but an extended area on all four sides and higher time resolution. In this poster, we showcase the characteristics of the Timepix detector and present the results of the performed tests, including the readout frequency compatibility with the EuXFEL pulsing rate and a spatial resolution of better than 50 µm. The impressive performance of Timepix3 and the anticipated advantages offered by Timepix4 present exciting prospects for enhancing X-ray imaging and spectroscopy at EuXFEL. The integration of Timepix4 in future experiments holds great potential for pushing the boundaries of scientific research at this state-of-the-art facility.

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Poster Session I / 100

Position Resolution for the Segmented Inverted-Coaxial Germanium detector, SIGMA

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The position resolution of the novel p-type Segmented Inverted-Coaxial Germanium (SIGMA) detector was investigated using the Pulse Shape Analysis (PSA) technique. The design of this large volume HPGe detector is based on a coaxial geometry and combines the small point contact technology along with the segmentation of the outer contact. The location of the γ-ray interaction points is determined by extracting the digitized signals of the 18 outer segments and of the small point contact electrode, which are characteristic for each point of interaction in the detector.
In order to evaluate the position resolution of the SIGMA detector, PSA methods using a figure of merit minimization grid search algorithm are applied, which require a pulse shape database of all possible positions of γ-ray interactions with the detector volume as input. Thus, to determine the γ-ray interaction points, the experimentally measured pulse shapes are compared to the reference signal database. For this reason, the detector response has been simulated using Signal Generation

simulation (SigGen) to generate a database of calculated pulse shapes for the SIGMA detector. The simulated pulses were validated against their corresponding average experimental pulses produced on known positions using the University of Liverpool scanning system.
The preliminary result of the position resolution shows that the FWHM obtained is between 2.5 mm and 4.6 mm for the radial positions and is around 7 degrees for the azimuthal positions.

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Applications in Astro-Particle Physics / 101

An Improved Laser Speckle Modulation Transfer Function Measurement Method

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The Modulation Transfer Function (MTF) is an important performance metric for all position sensitive pixelated imaging detectors. Many methods of determining MTF experimentally in the optical wavelength region have been presented in the literature over the years, and generally involve projection of a known test pattern of some kind. Laser speckle MTF measurements are of interest for small pixels because they do not require refractive optics in the projection, and are therefore not restricted by the implied optical information limit.

The laser speckle MTF method works by preparing a light field consisting of the speckle pattern resulting from random reflections of a laser from a rough surface. This light field is then band limited (by means of an aperture) and linearly polarised. The resulting intensity distribution at the sensor some distance away has known second order statistics and a known power spectrum, and thus the MTF can be obtained by a Fourier Transform.

The method has been well known and used for many years. However, conventional measurements using this technique cannot recover information above the Nyquist Frequency of the sensor. We present a modification of the laser speckle technique which allows recovery of the MTF beyond Nyquist in small pixel CMOS APS detectors. We contrast our suggested improvement with two previous approaches to recover super-Nyquist information in laser speckle measurements, compared to which it is simpler and cheaper though with some tradeoffs.

We present results from the measurement of MTF on two commercial CMOS APS devices of different pixel sizes at two wavelengths, and compare the result on the larger pixel size with a conventional optically projected MTF test pattern measurement.

We remark that this technique will be used, alongside others, in the characterisation of the MTF of the science cameras for the MAGIS-100 atom interferometer.

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Poster Session I / 102

High-Speed Data Transmission and Serial Powering IP's in 65nm CMOS Image Sensor Process at the Electron Ion Collider

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High-Speed Data Transmission and Serial Powering IP's in 65nm CMOS Image Sensor Process at the Electron Ion Collider

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ABSTRACT:
Next generation particle physics experiments like Electron Ion Collider demand high-speed data communication and lower mass designs for its detectors. Thanks to the availability of smaller technologies and innovative designs techniques, novel scientific detectors will be based on high speed and energy efficient sensor systems. This paper therefore presents circuits designed to meet the EIC powering and high-speed data requirements. These include a shunt LDO to support serial powering in EIC vertex tracker, a dual-frequency PLL that supports two frequency modes of operation, a 5GHz PRBS Generator for system testing, an I2C block and a high speed CML receiver.
Shunt LDO is a novel design technique that is used for the implementation of highly efficient, low mass, current based serial powering scheme. In this paper, we describe our initial work on a Shunt LDO architecture for the implementation of serial powering in the EIC. Shunt LDO employs several protection-features like over voltage protection and under shunt protection.
Phase locked loops which generate on-chip clock/carrier are an essential part of every communication system. In this paper we are proposing a flexible PLL design that supports existing data read out systems (where the supporting infrastructure imposes a speed limit) and future systems (where the infrastructure can be designed to support higher rates). Special schemes and design techniques

are employed to make the design radiation tolerant and area efficient.
As a part of ITS3 upgrade, high speed I/O ‘s were designed and fabricated. They are i) High speed CML Receiver, which can operate up to 8GHz. ii) I2C IP, which supports serial communication iii) PRBS Generator, which can produce a random sequence up to 10Gbps to enable system testing.
The supporting LVDS receiver and CML line driver were already fabricated as part of the CERN Experimental Physics R&D Programme (EP R&D WP1.2) and have been shown to be functional on silicon up to 2Gbps .

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Application in Nuclear physics / 103

Results of the new MAPS-based ALICE inner tracker operation in the LHC Run 3

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As part of a major upgrade of the ALICE experiment at the Large Hadron Collider (LHC) during Long Shutdown 2, several new detectors have been installed together with new online and offline computing systems and the modification of detectors readout. A key detector of such upgrade is the new, ultra-light, high-resolution Inner Tracking System (ITS2) that significantly enhances the resolution on the determination of the distance of closest approach to the primary vertex, the tracking efficiency at low transverse momenta, and the read-out rate capabilities with respect to what was achieved in the LHC Run 2.
The new tracker consists of seven layers, azimuthally segmented into Staves, equipped with silicon Monolithic Active Pixel Sensors with a pixel size of 27×29 μm^2 and flexible printed circuits with unprecedented specifications in terms of material thickness and spatial resolution: 50 μm sensors for the three innermost layers, and 100 μm ones
for the outer layers with an in-chip spatial resolution of about 5 μm. A first layer with a radius of 23 mm, makes this detector the closest to the interaction point in a barrel configuration. In addition, with a total sensitive area of about 10 m^2 it represents the largest scale application of the MAPS technology in a HEP experiment and the first ever built at the LHC.
The LHC Run 3 started in July 2022 with proton-proton collisions at a centre-of-mass energy of 13.6 TeV, and more than 250 billion events have been collected at an interaction rate of 500 kHz, which is five times larger than Run 2. During standard operations, the detector is characterized by a stable spurious hit rate of about 10^{-8} hits/event/pixel and an impact parameter resolution of about 40 μm at a transverse momentum of 500 MeV/c, in agreement with Monte Carlo simulations.
This contribution will show the long effort which allowed the construction, characterization, installation and commissioning of the new tracking system with the focus on the detector performance results coming from proton-proton collisions of the LHC Run 3.

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Application in life sciences and biology / 104

Characterisation of a Novel Wafer-Scale CMOS Detector Optimised for 100keV CryoEM

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Advancements in electron detection have significantly improved the quality of biological structures resolved by cryogenic electron microscopy (cryoEM). Using direct electron detectors (DEDs) with high detective quantum efficiency (DQE), researchers can solve structures quicker and easier than in the past. The majority of structures deposited in the Electron Microscopy Data Bank were resolved from datasets captured by microscope systems with a resolution below 3Å using 300keV electrons[1,2]. However, Transmission Electron Microscopes (TEMs) operating at 300keV are expensive to purchase and maintain, presenting a financial obstacle for many institutes and a barrier to discovery[3]. There is a deficit of suitable DEDs optimised for 100keV operation, although it is recognised that 100keV TEMs could improve the affordability of such structure determination as well as increase the ratio of information gained to sample radiation damage caused[3,4].

The C100 DED is a novel CMOS detector optimised for 100keV electrons developed to fill this gap. C100 is a wafer-scale stitched sensor with 54µm pitch pixels forming a large active area of 2048x2048 pixels. The continuous rolling shutter sensor operates with 12-bit effective pixel resolution at a rate of 2000 fps. The frame rate is achieved by sampling and converting multiple rows at a time from two sides, before being serialised at 4.3 Gb/s via the Xilinx Aurora 64b/66b protocol. The sensor's 34 Aurora transceivers transmit over 110 Gbit/s of data, off-chip via Common Mode Logic (CML) lines and via Samtec FireFly optical links to remote camera system hardware outside the vacuum housing.

Here, we present the architectural breakdown of C100 alongside initial results from our characterisation of the sensor's in-pixel source follower, PGA, ADC, PLL and Aurora transceivers. We will finally supplement our characterisation of C100 by presenting the Landau distribution, MTF and DQE for 100keV electrons incident on our small-scale test structure.

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Detectors for FELS, Synchrotron and other advanced Light sources / 105

A look at single photon counting detectors for SLS2.0

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Starting this autumn, the Swiss Light Source is undergoing an upgrade to a diffraction limited light source and with this the coherent flux will increase with up to two orders of magnitude. This poses a huge challenge for single photon counting detectors which despite being incredibly successful still suffers from pulse pile-up at high rates. In this talk we present our strategy for single photon counting at SLS2.0 which includes: the Matterhorn ASIC, a 100Gbit/s readout system and iLGAD sensors for single photon counting with soft X-rays.

The Matterhorn (v0.1) prototype, designed in UMC110, features four 16 bit counters per pixel which can be used for pile-up tracking, energy windowing or gating with four independent gates. The prototype has a pixel matrix of 64x64 square pixels at a 75um pitch. For the final detector we target 256x256 ASICS from which we build 4x8cm2 modules by bump bonding 8 ASICS to a single silicon sensor. Matterhorn is compatible with both electron and hole collection and can be combined with high Z sensors for operation above 20 keV. We present first results with the prototype and the road to full detector.

Another challange for single photon counters is the sensitivity to low energy photons. Due to the noise the lowest possible threshold is usually somewhere in the 2-3 keV range. To solve this, we have worked closely together with FBK to develop silicon sensors with internal amplification (LGADs) with the aim of bringing single photon counting down to 250 eV. Here we show that with a 512x512 pixel sensor bump bonded to EIGER it is possible to do phytography at 700 eV.

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Advanced photon detectors X-rays and Gamma ray / 107

Progress towards seamless large area X-ray and gamma-ray detectors

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Advances in Pixel Detectors / 108

Keynote Advances in Pixel Detectors

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Detectors for High radiation and extreme environment / 109

Including radiation damage effects in ATLAS MonteCarlo simulations: status and perspectives

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Signal reduction is the most important radiation damage effect on performance of silicon tracking detectors in ATLAS. Adjusting sensor bias voltage and detection threshold can help in mitigating the effects but it is important to have simulated data that reproduce the evolution of performance with the accumulation of luminosity, hence fluence.
ATLAS collaboration developed and implemented an algorithm that reproduces signal loss and changes in Lorentz angle due to radiation damage. This algorithm is now the default for Run3 simulated events. In this talk the algorithm will be briefly presented and results compared to first Run3 collision data.
For the high-luminosity phase of LHC (HL-LHC) a faster algorithm is necessary since the increase of collision, event, track and hit rate imposes stringent constraints on the computing resources that can be allocated for this purpose.
The philosophy of the new algorithm will be presented and the strategy on how to implement it and the needed ingredients will be discussed.

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Poster Session II / 110

Performance of Eco-friendly Gas Mixtures in CMS Improved Resistive Plate Chambers in the HL-LHC Environment

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Resistive plate chamber (RPC) detectors in the Compact Muon Solenoid (CMS) operate with a gas mixture made of 95.2% $C_2H_2F_4$ (providing a high number of ion-electron pairs), 4.5% iC_4H_{10} (ensuring the suppression of photon-feedback effects), and 0.3% SF_6 (used as an electron quencher to further operate the detector in streamer-free mode). $C_2H_2F_4$ is known to be a greenhouse gas with a global warming potential (GWP) of 1430. Several eco-friendly alternatives to $C_2H_2F_4$ have been studied in the last few years with good performance for HFO based mixtures. Degradation studies for the chambers are now ongoing. Also in this context, one short- to medium-term approach for the coming years of LHC operation could be to focus on reducing the GWP of the RPC gas mixture by only adding CO_2 instead of $C_2H_2F_4$. Studies were performed at the CERN Gamma Irradiation Facility (GIF++) in the North Area of the LHC where a 13.6TBq radiation source and a muon beam from SPS mimic HL-LHC conditions. In this work we present the performance and future perspectives of a 1.4 mm gap RPC chamber with HFO and CO_2 based mixtures with a high gamma background.

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Poster Session II / 111

Development and Characterisation of the HEXITEC 2X6 Detector System for NXCT

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The HEXITEC 2×6 Instrument was developed for the National X-ray CT (NXCT) Centre's Colour X-ray bay at the University of Manchester. A single HEXITEC ASIC is typically bonded to a 2×2cm

CdZnTe, CdTe or other High-Z material and readout by the HEXITEC GigE system. However, with an increasing demand for large area high energy detectors we have employed the use of tiled arrays of 2×6 ASICs. The HEXITEC 2×6 is made of twelve 2mm thick High Flux CdZnTe sensors supplied by Redlen Technologies Inc. mounted in a 2×6 array resulting in 76.8k fully spectroscopic pixels, operating from 3-180keV with 1keV FWHM energy resolution and a 48cm2 active area. Each individual sensor consists of 80×80 pixels on a 250um pixel pitch.

The HEXITEC 2×6 has been designed as a compact system allowing it to be used flexibly for a large range of experimental setups in the dark or bright field, with the entire system measuring 1750×2400×950mm. HEXITEC runs at 9kHz with readout performed row by row in four parallel blocks of 20×80 pixels per ASIC. Modular readout boards digitise ASIC outputs into 16-bit values which are received by an FPGA board. Incoming data streams are converted into 160×480 pixel frames and 10G ethernet packets. Two 10G lanes on a QSFP connector send odd and even frames to the control PC with a total raw data rate of 15Gbps. The control and data receiving and processing is conducted using ODIN, which can be integrated with the EPICS software used at many large science facilities.

In this paper we will present the technical design and operation of the camera followed by a characterisation of the overall performance. Additionally, we will discuss results from the CdZnTe with a focus on spectral performance and spatial uniformity.

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Poster Session II / 112

Energy Absorption Interferometry: a theoretical and experimental method for probing the behaviour of multimode detectors, sensors and energy-harvesting structures

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Sensors and structures of many different kinds can absorb energy through a number of spatial degrees of freedom simultaneously. For example, the ultra-low-noise detectors being developed for far-infrared space telescopes can absorb energy through typically 1-20 optical modes. An important question is how to match the amplitude and phase patterns of the incoming partially coherent field to those of the detector. Modes that are not coupled efficiently become sources of noise. Measuring the modes to which quantum sensors and complete instruments are sensitive is an important task in optical, far-infrared, elastic and acoustic applications. A new technique, Energy Absorption Interferometry is able to determine the spatial forms of the individual degrees of freedom through which structures can absorb energy. The technique can be applied experimentally, but also makes a powerful numerical tool for studying behaviour: for example, plasmonic surfaces. The method illuminates the device under test with two coherent sources, and then modulates time delay between the excitations. The detected signal displays a fringe, which gives a complex visibility. The experiment is

repeated as the two sources are moved, and the measured visibilities assembled into a matrix, which is diagonalized. The eigenvectors are the spatial forms of the individual degrees of freedom through which the structure can absorb energy. One is actually measuring the dynamics of the individual solid state processes responsible for absorption. Remarkably, the two sources do not have to be of the same type, exposing the forms of processes that can be driven by the two kinds of excitation: electromagnetic and elastic, etc. The method is essentially a generalized form of holography, and measures the spatial state of coherence of the reception pattern. It is closely related to aperture synthesis interferometry, used extensively in astronomy. In the talk we describe the principles of EAI, and overview applications.

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Poster Session II / 113

A 5.12-Gbps serializer circuit for front-end fast readout electronics of silicon pixel detectors

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The advanced synchrotron radiation sources are major facilities to analyze the formation and evolution of material structure for multidisciplinary researches, in terms of its high luminosity, low emittance, wide energy bandwidth and so on. Several advanced synchrotron radiation sources are under construction in China, involving the HEPS (High Energy Photon Source) and SHINE (Shanghai high repetition rate X-ray Free Electron Laser and extreme light facility). They will be major multidisciplinary-researches platforms in China. To meet the requirements of pixel detectors in these facility, dedicated pixel readout chips are being developed, such as HEPS-BPIX and HYLITE. In this paper, we present a high-speed serializer circuit developed in a commercial 130-nm CMOS technology for the full-scale (128×128) pixel readout chip of HYLITE, which requires a data rate of 4 Gbps. The serializer adopts a 16-to-1 binary-tree multiplexer, a ring-oscillating based phase-locked loop (PLL) and a current mode logic driving stage with a multi-stage pre-amplifier. The test results show that it functions as expected with a wide operating range from 0.52 Gbps to 5.5 Gbps and satisfies the data-rate requirement. The measured jitter values at 5.12 Gbps are about 2 ps and 20 ps for the random and deterministic jitter, and 47 ps for the total jitter, and the horizontal and vertical eye openings are 0.84 UI and 72%. At the maximal 5.504 Gbps, the eye is still open and clear with the total jitter of about 52.2 ps. Several modules (the previous version of the PLL) has already been verified working normally after taking 130 Mrad (Si) X-ray irradiation. The full-scale HYLITE chip integrated the serializer has been fabricated in an engineering run. More detailed designs and tests will be reported.

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Poster Session II / 114

Evaluation of X-ray Imaging Technologies for use at the Extreme Photonics Applications Centre

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The Extreme Photonics Applications Centre (EPAC) at the STFC-Rutherford Appleton Laboratory will be a new facility utilising high intensity laser plasma interactions (LPI) for the generation of ultra-short pulses of ionising radiation. LPI drive sub-picosecond sources of radiation, emitting from an interaction point in the range of 100 nm –100 μm, allowing for high resolution X-ray imaging. With EPAC the laser plasma interaction can deliver 10Hz repetition rate X-ray pulses in the energy range of ˜10-100 keV for betatron interactions, narrowband 1-50 MeV x-ray via inverse Compton scattering, and broadband bremsstrahlung emission up to GeV energies
To fully utilise the properties of LPI sources the imaging detectors will use scintillators lens coupled to high performance CMOS sensors and will be tuned to match the properties of each type of interaction, either betatron or bremsstrahlung/inverse Compton scattering. A high spatial resolution system using ≤100 μm thick YAG:Ce will exploit the high resolution betatron source. A ≥1 mm thick YAG:Ce array will be used for the bremsstrahlung/inverse Compton scattering for high energy >100 keV imaging. We will present the optical test results of large aperture commercially off the shelf lenses, evaluating their performance for imaging these scintillator arrays. The uniformity, resolution, collection efficiency, and veiling glare –a measure the amount of light scatter in the lens, will be presented.
We will also present the results from the characterisation of three scientific grade camera systems for use in these imagers along with X-ray testing of different scintillator materials for resolution, signal level and afterglow.

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Application in life sciences and biology / 115

Flexible X-Ray Imaging Detectors Using Scintillating Fibers

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Some medical and industrial X-ray imaging applications need to reconstruct an image on a flexible surface, so they use photographic film rather than electronic detectors. Current flat-panel X-ray imaging detectors are difficult to adapt to these applications. We will present the FleX-RAY project, which aims to create an electronic X-ray detector with the flexibility of photographic film, suitable for a variety of applications.

FleX-RAY uses a sheet of flexible scintillating fibers to detect X-rays and guide the scintillation light to arrays of silicon photomultipliers. The detector also self-reports its curved shape using optical waveguides with Bragg gratings in a flexible glass substrate, which act as curvature sensors. Multiple reconstruction algorithms have been developed, suitable for different X-ray energies.

In this contribution, we present the advances in scintillating fibers, self-shape-reporting sensors, and image reconstruction algorithms made by the FleX-RAY collaboration. We will also present simulations of the expected detector performance and results of the initial tests on the FleX-RAY prototype.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement No. 899634.

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Detectors for FELS, Synchrotron and other advanced Light sources / 116

Dynamix: A charge cancellation ASIC for high dynamic range measurements of hard X-rays

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The advent of diffraction limited storage ring synchrotron facilities is pushing the requirements of X-ray detectors into a new regime. The Diamond II synchrotron will deliver X-ray fluxes ˜10^{12} ph/mm^2/s at the detector for some experiments. At such high fluxes the photons arrive at such a rate that conventional photon counting detectors are unable to make accurate measurements. Additionally, the energy of the X-rays will increase to above 20keV on many of the beamlines and the traditional Si detector technology becomes transparent. STFC have developed the DynamiX ASIC to readout CdZnTe detector material to offer a solution to the requirements of 4th generation synchrotrons.

A test structure has been manufactured in a 65nm CMOS process with 16x16 pixels on a 110μm pitch. The concept is designed to be scaled up to 192 x 192 pixels in future versions. The ASIC achieves a high dynamic range by operating at a frame rate of 533kHz, to match one orbit of Diamond, and an integrating amplifier with two stages of charge cancellation and digitisation in each pixel. The first "coarse stage"is optimised to cancel 25 photons at 25 keV at a cancellation rate of 166MHz and an 8-bit counter that records each cancellation. The remaining signal charge at the end of a frame is passed to the "fine stage"that conducts a constant rate charge removal that is timed by an 83MHz clock. A charge equivalent to 0.2 of 25keV photon is removed for each clock count and a 7bit counter records the magnitude of the charge. An out-of-range bit is used to identify coarse stage transfers greater than 25 photons. Each 4-column wide block of pixels is readout as 64b66b Aurora encoding data using a 14.1Gbps CML serialiser. The test structure and plans to scale up the technology will be presented.

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Poster Session I / 117

HASPIDE: a project aiming at the development of hydrogenated amorphous silicon radiation detectors on a flexible substrate

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Hydrogenated amorphous silicon (a-Si:H) is a material with an excellent radiation hardness and with the possibility of deposition on flexible substrates like Polyimide (PI). Exploiting these properties, the HASPIDE (Hydrogenated Amorphous Silicon PIxels DEtectors) project has the goal of developing a-Si:H detectors on flexible substrates for beam dosimetry and profile monitoring, neutron detection and space experiments. The detectors for this experiment will be developed in two different structures: the p-i-n diode structure, that has been used up to now for the construction of the

planar a-Si:H detectors, and the recently developed charge selective contact structure. In the latter the doped layers (p or n) are replaced with charge selective materials namely electron-selective conductive metal-oxides (TiO_2 or Al:ZnO) and hole-selective conductive metal oxides (MoO_x). In this presentation the aim and the structure of the project will be described and some preliminary data on the capabilities of these detectors to measure x-ray, electron and proton fluxes will be presented. In particular, the linearity, the sensitivity, the stability and dark current in various conditions will be discussed. Also, some results about radiation testing will be presented.

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Poster Session II / 118

Experimental investigation of the imaging capabilities of a DEPFET ladder of the DSSC X-ray camera at the European XFEL

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The European XFEL is a state-of-the-art research facility capable of producing both soft and hard X-rays with an unprecedented brightness, pulse duration and coherence. It delivers up to 2700 X-ray pulses with 220 ns interspacing, enabling operation at a maximum frame rate of 4.5 MHz. These unique temporal characteristics of XFEL empower scientists to conduct time-resolved experiments in research fields like chemistry, physics, and biology faster than ever before, thus providing access to previously unexplored areas. However, to take full advantage of the XFEL's capabilities, advanced X-ray detectors are essential.

Several X-ray detectors based on cutting-edge technology with MHz frame rate readout capabilities are available for users at the European XFEL. Additionally, a new X-ray imaging detector prototype, a module of the DSSC detector based on DEPFET sensor technology, is currently undergoing commissioning. DSSC stands for DEPFET Sensor with Signal Compression; the detector can record up to 800 images at a maximum frame rate of 4.5 MHz. It has been specifically developed by an international consortium to fulfill the exceptional characteristics of the European XFEL facility, the repetition rate in particular. The final detector is in the assembly phase and will feature an active area of 1 Mpixels.

The preliminary findings recently obtained from the data collected with one DEPFET ladder of the DSSC camera at SQS (Small Quantum Systems), one of the XFEL instruments, demonstrates the impressive imaging performance of the DSSC ladder in various aspects, including the sensor non-linear response to the input signal, precise detection of single photons with a signal-to-noise ratio exceeding 50, and a high dynamic range of approximately 3100 Aluminum ka photons of 1.48 keV,

while keeping noise at about 8 ENC (Equivalent Noise Charge). The DSSC copes well with the rigorous requirements specified by the facility, namely high repletion rate and high dynamic range with very low noise, thereby opening up new imaging possibilities relevant for investigating samples with nanosecond time-scale resolution.

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Poster Session II / 119

Halide Perovskite X-ray Detector with a Low Dark Current via Interfacial Engineering

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Recently X-ray photon counting detectors (PCDs) with energy discrimination capabilities based on pulse height analysis have been developed for medical X-ray imaging with substantially improving signal-to-noise and overall performance when compared to the conventional energy integrating detectors (EIDs) that comprising the majority of CT scanners. PCDs for medical X-ray CT require extremely expensive high-purity Cadmium Telluride (CdTe) or Cadmium Zinc Telluride (CZT) semiconductors that suffer from detrimental material defects that act as recombination centres and limit performance. Therefore substantial challenges in the fabrication and deployment of the active layer material have limited their widespread deployment.

Halide perovskite (PVK) materials have emerged as promising materials for X-ray detection, already demonstrating excellent mobility-lifetime products (μτ) comparable to CZT and CdTe, detector-grade bulk resistivity, and high stopping power at high-energy X-rays. To date, high sensitivity up to 10ˆ6 μC Gyair cm−2 and a very impressive lowest detectable dose rate (LoD) of <10 nGy s−1 have been achieved. However, the dark current is still large >1 nA cm−2 which is one of the main obstacles to utilising PVK materials for PCDs. One of the origins of the large dark current is related to the interface defects at the PVK material and charge transport layers in the device stack.
In this talk, we present a high-performing, direct X-ray detector with a device structure based on an alloyed perovskite single crystals synthesized via a state-of-the-art inverse temperature crystallisation (ITC) method. We obtained an impressive low dark current of ˜10 pA cm−2 with high sensitivity ˜10ˆ3 μC Gyair cm−2. This study will open a new direction for PVK X-ray detectors with extremely low dark current towards integration with application-specific integrated circuit (ASIC) chips/backplanes for multi-pixel detection PCDs.

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Poster Session III / 120

A 4-Gbps serializer circuit in a 180 nm technology for monolithic pixel sensor prototypes developed for the CEPC vertex detector

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Monolithic CMOS Pixel Sensor (CPS) is one of the promising candidates for the Circular Electron Positron Collider (CEPC) Vertex detector, due to its good performance and trade-off of granularity, readout speed, material budgets and power consumption. A full-scale TaichuPix chip, including a matrix of 512 × 1024 pixels with a size of 25 × 25 μm2 is developed to provide a spatial resolution better than 5 μm. It requires a raw data rate up to 3.84 Gbps and power consumption less than 25mW/Gbps for the serializer circuit. Based on one of the small-scale prototypes, the highest serial data rate is tested to be 3.36 Gbps with a peak-to-peak jitter of about 150 ps and large current consumption. Moreover, the 32-bit parallel data width of the serializer isn't suitable for the 8B10B encoder. Therefore, two 4-Gbps serializers (20:1 and 40:1) have been designed and optimized to meet these requirements based on the same process node of 180 nm as the TaichuPix, considering the funding and time costs. The serializer consists of a phase locked loop (PLL), 5:1 sub-multiplexers based on a shift-register chain, a 4:1 or 8:1 sub-multiplexer based on the binary-tree structure, a clock distributor and a high-speed driver. A ring-oscillating PLL with a simulated frequency tuning range (TR) of 0.34~3.12 GHz and a 1-MHz -offset phase noise (PN-1M) of -103dBc/Hz is integrated in the 20:1 serializer. We also tried an LC-tank PLL with a narrower TR (1.8~2.3 GHz) and a better PN-1M (-118 dBc/Hz) in the 40:1 serializer. The total current is 71 and 82 mA for the 20:1 and 40:1 serializer operating at 4 Gbps, respectively. The simulation results indicate that both circuits meet the data rate and the power consumption requirements. The serializers will be characterized and reported in the presentation.

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Poster Session III / 121

High Rate Camera Systems - our approach for control and data

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A new era of high rate pixel sensors has now arrived, across the imaging community there are a number of new devices utilising multigigabit serializers to tackle the requirements for greater frame rates and pixel counts. At STFC two such systems are currently under development with ICs delivered and camera systems under development alongside chip characterisation. Hexitec-MHz for photon science and C100 in the field of electron microscopy. Both systems have data rates in excess of 80Gbps per die. But they are also just the start, precursors for another generation of systems using even faster serializers. With that in mind we have tried to develop a control and readout system that is scalable in both size and speed.
We will present the overall architecture for control and data flow in these new system, the hardware used, some discussion of the applications so far and how this will be developed further. We have also started to tackle issues further down steam of frame assembly and have developed examples of real time data processing and high performance disk writing.
Challenges and issues will be discuss along with the successes to date.

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Medical applications / **122**

An application-specific small field of view gamma camera for intraoperative dual-isotope parathyroid scintigraphy

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The gold standard technique for preoperative parathyroid localisation is 99mTc-Sestamibi/123I dual-isotope parathyroid imaging. This technique subtracts 123I uptake in normal tissue from 99mTc-Sestamibi imaging to reveal parathyroid glands which would otherwise be obscured by the thyroid. Due to the difficulty of interpreting preoperative images within the surgical environment, the translation of preoperative findings into surgical success is highly demanding on the surgeon. The current generation of intraoperative gamma cameras cannot perform dual-isotope parathyroid scintigraphy due to the high energy resolution requirements of this technique. A new device capable of performing intraoperative dual-isotope parathyroid imaging would allow surgeons to directly visualise tracer uptake precisely when needed to aid their surgical decision making; offering the potential to improve parathyroidectomy outcomes.

Intraoperative 99mTc/123I scintigraphy is a challenging application, requiring excellent energy resolution to distinguish between the 99mTc (140keV) and 123I (159keV) photopeaks without down-scatter compromising image quality. Additionally, the small size of parathyroid glands (˜1 mm) and limited activity of radiopharmaceuticals used during surgery demand good detector spatial resolution and sensitivity. Devices for dual-isotope scintigraphy must therefore be optimised to achieve the correct balance of detector properties required to produce images of diagnostic quality. This requires knowledge of the expected source geometry and the detector system response.

This study examines the suitability of the HEXITEC detector system for 99mTc-Sestamibi/123I dual-isotope parathyroid scintigraphy. This small-pixel geometry system uses compound semiconductor materials, such as CdTe/ CdZnTe, and the HEXITEC ASIC to achieve excellent energy resolution, sensitivity and spatial resolution. The expected imaging performance of this system has been simulated using anthropomorphic phantom volumes derived from CT data and Monte Carlo simulation. This study also explores the broader implications of using clinical-like source geometries to design application-specific detector systems for intraoperative imaging.

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Detectors for FELS, Synchrotron and other advanced Light sources / 123

Characterisation of the Performance of High-Flux CdZnTe at MHz XFEL Pulse Repetition Rates

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Xray Free Electron Lasers (XFELs) produce extremely high intensity pulses of photons with ultra-short duration. Planned upgrades to these facilities will increase photon energies above 20keV as well as increasing pulse repetition rates to greater than 1MHz. At these energies silicon has poor quantum efficiency and is susceptible to radiation damage, so new detector materials must be used. CdZnTe is the most promising alternative for XFEL applications but its performance under these challenging conditions is not yet fully understood.

Three 1.5mm thick HF-CdZnTe sensors were bonded to the Large Pixel Detector (LPD) ASIC, each sensor consists of a 16×32 array of 400µm×250µm pitch pixels. Two 500µm thick Hamamatsu silicon LPD sensors, each with 128×64 pixels on a pitch of 500µm, were mounted alongside the HF-CdZnTe to provide a reference.

Measurements were taken at the European XFEL on the FXE instrument. The pulse repetition rate was set to 1.1MHz with 44 pulses per train and an X-ray energy of 9.3keV. The sensors were placed at 90° to a copper target generating a flat field of 8.0keV fluorescence photons. The detectors were read out at 2.25MHz, twice the pulse repetition rate, using the LPD DAQ system. The intensity of the

X-ray pulses was varied using beam line attenuator foils, exposing the pixels to flux levels ranging from 10^0 to 10^4 photons per pulse.

In this paper results will be presented for the linearity of HF-CdZnTe as a function of flux, its response time compared to the silicon sensors and the effect of the sensor bias voltage.

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Position Sensitive Fast Timing Detectors / 124

Investigating the Impact of Isolation Structure Configurations on the Charge Carrier Excess in the Inter-Pad Region within Low and High-Injection Carrier Dynamics: Comparative study of LGADs with 2 p-stops and Bias ring in IP Region vs. Configuration with Two Trenches

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We present an in-depth investigation of the inter-pad (IP) gap region in the Ultra Fast Silicon Detector (UFSD) Type 10, utilizing a femtosecond laser beam and the transient current technique (TCT) as probing instruments. The sensor, fabricated in the TI-LGAD RD50 production batch at FBK Foundry, enables a direct comparison between TI-LGAD and standard UFSD structures. This research aims to elucidate the isolation structure in the IP region and measure the IP distance between pads, comparing it to the nominal value provided by the vendor. Our findings also reveal unexpectedly strong signal induced near p-stops. This effect is amplified with increasing laser power, suggesting significant avalanche multiplication, and is also observed at a moderate laser intensity and high HV bias. The high-injection carrier dynamics induce large space-charge effects that disturb the local electric field, thereby affecting the peak, shape and the duration of a transient waveform. Furthermore, the study on LGADs with 2 p-stops and bias ring in IP region was extended to the Trenched LGADs with two trenches. Much stronger charge carrier excess, measured in the inter-pad region of 2Tr Ti-LGADs, may be attributed to the proximity of the two trenches and the closer proximity of one trench to the neighboring pixel (its gain layer) that increases significantly the electric field in the IP region. Additionally, the defects due to trench etching may modify the electric field in IP region leading to the significant variation in the charge collection. This investigation contributes valuable insights into the IP region's isolation structure and electric field effects on charge collection, providing critical data for the development of advanced sensor technology for the CMS and ATLAS experiments and other high-precision (with high density charge) applications.

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Poster Session I / 125

Impact of Single and Multiple Trenches as Isolation Structures in TI-LGADs: A Study on Charge Collection and Resistivity of IP region as seen by the fs-laser based TCT

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We presents the findings of a study investigating the impact of single and multiple trenches employed as isolation structures in Trench Low-Gain Avalanche Detectors (TI-LGADs). The focus of this study is to analyze the collection of charge induced by fs-laser at various shooting points along the X-axis and compare the deduced X-profiles derived from the recorded waveform data.

The results reveal a significant increase in charge collection within the isolation region when employing two trenches as isolation structures. However, this enhancement was not observed in the isolation region where only one trench was utilized to isolate the pixels. This discrepancy can be attributed to the proximity of the two trenches and the closer proximity of one trench to the neighboring pixel.

Furthermore, the fabrication and etching processes involved in creating the trenches may introduce additional surface defects, leading to non-uniformity of the electric field and a larger gradient in electric field along the X-axis of the inter-pixel region, particularly in the case of the region with two trenches. For conclusive statement larger pool of prototypes is required.

These findings provide valuable insights into the effects of different isolation structures on charge collection and resistivity in TI-LGADs. They contribute to the optimization of device design and performance, particularly when the sensors are exposed to high-intensity injection of non-Minimum Ionizing Particles.

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Poster Session III / 126

Implementation of the annihilation gamma-ray polarizations in Positron Emission Tomography

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Positron emission tomography (PET), is a profound imaging technique that exploits features of positron annihilation, where two back-to-back gamma photons emitted with 511 keV energies are detected in coincidence. In the current PET systems, only the photoelectric interaction of the gamma photons is considered, and their Compton scattering is assumed to have a parasitic effect. Since the annihilation photons have orthogonal polarizations, simulations have shown its potential use to improve image quality by suppressing the random background which lacks this correlation. In this way, one could discern true coincidences from false ones and improve the signal-to-noise ratio of the reconstructed image. To test this hypothesis, we developed and commissioned a PET device that utilizes single-layer Compton polarimeters which can reconstruct azimuthal correlations of the annihilation quanta. The single-layer Compton polarimeter detector modules contain scintillator matrices that are read out by silicon photomultipliers. Four such detector modules are mounted on an aluminum ring, capable of rotation around the source. Each detector module consists of four 8x8 crystal (GAGG:Ce and/or LYSO:Ce) matrices with either 2.2 mm or 3.2 mm pitch. Through rotation, they establish 16 trans-axial rings with a total of 1024 pixels. This PET device has been tested with clinically relevant sources at the University Hospital Centre Zagreb. We will report on the device' s polarimetric performance and characteristics with various clinical sources and reconstructed images. We shall also discuss the potential use of the Maximum Likelihood analysis method to improve the polarimetric sensitivity of the detectors.

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Application in Nuclear physics / 127

Development of self-calibration techniques for γ-ray energy-tracking arrays

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The development of γ-ray energy-tracking arrays using highly segmented High Purity Germanium (HPGe) detectors is currently the technological frontier of high-resolution gamma-ray spectroscopy for modern nuclear physics investigations[1]. The tracking capability of such arrays strongly depends on the performance of the Pulse Shape Analysis (PSA), which uses the position-dependent response of the detector signals to determine the γ-ray interaction positions within the detector volume. The PSA algorithm is performed by comparing the measured signal pulse shape to expected pulse shapes associated with different interaction positions from the signal basis. Therefore, producing a reliable signal basis is one of the key points for PSA.
A novel method to generate a reliable signal basis in a notably simple experimental way was proposed in reference[2]. In this method, a γ-ray source illuminates the full array and the Compton scattering data is obtained. Starting with the assumption of a segment-sized position resolution for every interaction point and using an iterative minimization procedure based on the tracking of Compton scattering events, it is possible to converge to the real positions after several iterations, which is so-called self-calibration. The self-calibration method was demonstrated in reference[2] with the simulation of a simplified geometry for the array and without considering electronic pulses.
This report presents the development of the self-calibration technique with a realistic geometry for the AGATA array with pulse shape signals. To demonstrate the performance of this technique, it is first applied to a simulation data obtained using the interaction points produced by the AGATA Geant4 simulation package combined with a pulse shape signal basis generated by the AGATA Detector Library (ADL)[3]. The signal basis produced by self-calibration method is compared with the initial ADL basis to show the validity of the method. This method is then applied to signals from a real gamma source calibration data to generate an experimental signal basis. The experimental signal basis is compared with the currently used ADL basis. PSA with both signal bases are attempted and observe reasonable results. Further development of the self-calibration technique is discussed. A more reliable experimental basis generated by the self-calibration technique is foreseen in the near future.

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Novel Photon Detectors / **129**

NNUV-MT –A new generation of blue sensitive SiPMs: Performance, Products and Roadmap

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Applications in security and environmental imaging / **130**

First results from the RD53 ATLAS pixel production readout ASIC (ITkPixV2) for HL-LHC

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Welcome / **131**

Welcome

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