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Book of Abstracts

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Planar Devices / 94

Profiling 3D Doping Concentration for Silicon Sensors

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Doping concentration is a fundamental property in semiconductor manufacturing influencing the electrical properties and reliability of silicon sensors. Three-dimensional mapping of dopant distribution provides a deeper understanding of sensor characteristics, including depletion voltage, breakdown behavior, and charge collection properties. Uniform doping across large sensor areas and depths is critical for achieving high manufacturing yield and device reliability. However, conventional measurement techniques are limited when applied to modern low-doping, high-resistivity silicon sensors commonly used in high-energy physics and photon science. Secondary ion mass spectrometry provides high-resolution measurements but are insensitive to doping concentrations below 1×10ˆ12 cmˆ(-3), while capacitance-voltage profiling and spreading resistance profiling offer only coarse granularity.
We present a novel 3D doping imaging technique based on the backside-pulsing [1], which enables pixel-wise capacitance–voltage (C–V) measurements together with charge-integrating readout ASICs. Measurements were performed on a 1×1 cmˆ2 silicon sensor bump-bonded to the MÖNCH ASIC [2] with 25 µm pixels, and on a 4×8 cmˆ2 silicon sensor bump-bonded to JUNGFRAU ASICs [3] with 75 µm pixels. This method yields 3D doping concentration maps around 3×10ˆ11 cmˆ(-3) with a micrometer-scale resolution (down to 25 µm laterally and 10 µm in depth) and a relative uncertainty typically below 3%, revealing doping ring structures and anomalous regions. The approach holds promise for a broad range of detector characterization and sensor development applications.

Poster Session / 95

Design and Development of a Test Equipment for Silicon Drift Detector Front End Electronics

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We present the design and implementation of a custom Test Equipment (TE) developed for the experimental characterization of Front-End Electronics (FEE) ASICs for Silicon Drift Detectors (SDDs). The TE is tailored for NOVA and similar multi-channel, low-noise mixed-signal FEEs designed for X-ray and gamma-ray detection in space-borne high-energy astrophysics missions. Built around

a Xilinx Zynq-7000 FPGA platform, the system manages ASIC configuration and event acquisition through AXI (Advanced eXtensible Interface) interfaces. It enables testing of both stand-alone ASICs and complete detector assemblies under realistic operating conditions, allowing verification of functionality and performance against design requirements.
The TE provides a versatile and reliable framework for ASIC validation and detector characterization, and its applications in ongoing projects such as LEM-X (fast, all-sky transient detection from the lunar surface) and TASTE (X/γ-ray spectroscopy for planetary surface studies) will be discussed.

Poster Session / 96

The ALADDIN detector at LHC: pixel detectors

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ALADDIN (An LHC Apparatus for Direct Dipole moments INvestigation, https://aladdin.web.cern.ch/) is a proposed compact fixed-target experiment at the LHC, designed to enable precise measurements of charm baryon electromagnetic dipole moments. The experiment leverages an innovative storage-ring layout that redirects protons from the beam halo onto a solid target, coupled with a bent crystal. This setup produces forward-boosted charm baryons, which are then channeled through the crystal. By exploiting spin precession induced by the channelling effect in the bent crystal, ALADDIN aims to measure both the magnetic and electric dipole moments through an analysis of the polarization of decaying charm baryons. The experimental apparatus consists of a 4.4 m-long spectrometer and a 5.0 m-long RICH detector for particle identification. It is designed for installation in the LHC Insertion Region 3 during Long Shutdown 3, requiring no civil engineering and having minimal impact on LHC operations, with data-taking planned for Run 4. A proof-of-principle test at the LHC, TWOCRYST, is currently underway to demonstrate the feasibility of the concept, with results expected in 2025. The experiment's Letter of Intent has been submitted to the LHCC (https://cds.cern.ch/record/2905467). This contribution will focus mainly on the detector package, made of silicon pixel detectors and its developments. A prototype of the detector package has been installed and operated successfully at the LHC (TWOCRYST).

Planar Devices / 97

The impact of weighting field on timing response of planar pixel sensors measured using TDCpix modules and Timepix4 telescope

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The work presents a detailed study of the timing performance and its spatial variation within the pixel of planar sensors, using the high-resolution TimePix4 beam telescope for precise, track-referenced measurements. Sensors of 200, 100, and 50 um thickness were coupled to the trigger-less TDCpix

ASIC with 100 ps timestamping, originally developed for the NA62 GigaTracker at CERN. Tests were performed at the Super Proton Synchrotron H8 beamline, where the TimePix4 telescope provided hadron tracks with ˜2 um spatial resolution. Hardware-level synchronization between the telescope and TDCpix combined with large hybrid pixel pitch of 300 um enabled accurate pixel-level timing studies and made it easier to observe and characterise timing spatial non-uniformity.

Dependencies of the mean matrix time resolution on bias voltage and discriminator threshold were measured for each sensor thickness. Since TDCpix is optimised for charge deposition in a 200 um sensor, for thinner hybrids runs with rotated devices were conducted. The rotation increases hadron path length in material which improves charge deposition and enables reasonable comparison between sensors of different thicknesses. The results show better time resolution of thinner hybrids down to ˜90 ps. Combined testbeam results with laboratory TDCpix chip calibration allowed extraction of intrinsic sensor time resolution, reaching 50 ps for 200 um thick sensor and in a good agreement with theoretical expectations (see Figure 1 in attached file).

A key focus of the study was the spatial dependence of time resolution within a pixel. A dedicated space-time alignment algorithm was developed to integrate telescope tracks with TDCpix data, enabling intra-pixel maps of Time-of-Arrival and time resolution with sub-micron precision. These maps reveal non-uniform timing behaviour correlated with the analytical solution for the weighting field of the pixel electrode, showing variations in charge collection time of hundreds ps (see Figure 2 in attached file) and tens of ps differences in time resolution. The results highlight the significant influence of the weighting field on intra-pixel timing uniformity, particularly when the pixel pitch approaches the sensor thickness, underscoring the importance of optimized electrode design for future development of fast timing detectors.

LGAD 3 / 98

Serial readout of LGAD detectors for cosmic-ray space-borne instruments

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In the context of the Pentadimensional Tracking Space Detector project (PTSD), we are currently developing a demonstrator to increase the Technological Readiness Level of LGAD Si-microstrip tracking detectors for applications in space-borne instruments. Low Gain Avalanche Diodes (LGAD) is a consolidated technology developed for particle detectors at colliders which allows for simultaneous and accurate time (<100 ps) and position (˜ 10 µm) resolutions with segmented Si sensors. It is a candidate technology that could enable for the first time 5D tracking (position, charge, and time) in space using LGAD Si-microstrip tracking systems. The intrinsic gain of LGAD sensors may also allow to decrease the sensor thickness while achieving signal yields similar to those of Si-microstrips currently operated in Space.

In this contribution we discuss the activities for the design and development of a low-consumption LGAD Si-microstrip device. The development is based on the innovative approach of a "serial" read-out of several sensors. We also discuss possible applications and breakthrough opportunities in next generation large area cosmic-ray and sub-GeV gamma-ray detectors that could be enabled by LGAD Si-microstrip tracking detectors in Space.
The preliminary timing performance of the first laboratory prototypes will be presented and discussed

LGAD 1 / 99

Mortality of ultra-thin LGADs from high energy deposition

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Low Gain Avalanche Diodes (LGADs) are prime candidates for high-resolution timing applications in High Energy Physics, Nuclear science, and other fields. When used at hadron colliders, these sensors are required to withstand enormous amounts of radiation while maintaining acceptable performance. When particles interact with highly biased sensors in these high-radiation environments, this can produce irreversible damage to the sensors through a phenomenon known as Single Event Burnout (SEB).
SEB is one of the main limitations to the usage of silicon detectors in high-radiation environments, as it often results in the permanent destruction of the sensors. Recent studies conducted using minimum ionizing particles (MIPs) found that when LGADs are operated below a certain bias voltage threshold, the risk of SEB is greatly minimized. As LGADs would be exposed to a large energy range of radiation at hadron colliders, it is crucial to also understand this phenomenon, and the behavior of LGADs, at energy deposition levels greater than that of MIPs.
This was achieved by pre-irradiating 20, 30, and 50 µm LGADs and PiN diodes at the Rhode Island Nuclear Science Center up to 1.5×10^{15} neq/cm2, and then exposing them to high intensity beams of protons and several species of heavy ions (C, O, Fe, Au) produced at the BNL Tandem Van de Graaff accelerator. This talk describes the results of the irradiations, including a showcasing and categorization of the different observed mortality modes of the sensors for different energies and species of heavy ions. This study furthers our understanding of SEB and permanent radiation damage of LGADs in high-radiation environments, crucial towards developing techniques to mitigate this issue and safely operate LGADs at future detectors.

Poster Session / 100

Reliability assessment of CMS drift tube readout electronics for the HL-LHC upgrade

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The new readout electronics of the CMS Drift Tubes detector has been evaluated in terms of its reliability. Starting with a brief overview of the main board functionalities, operating requirements and critical elements, a first estimation of the hardware robustness with respect to expected faults in time is then presented. A global figure of merit is derived by means of a custom-developed software model accounting for the reliability data of each component and applying proper derating based on worst-case operating conditions. This is also going to be the occasion to highlight some peculiar design choices intended to limit the various stress sources related to the detector operating environment. Finally, the functional robustness of the board with respect to ionizing radiation is presented, discussing the setup, objectives, and results of two measurement campaigns that have been undertaken to this aim at the Trento Proton Therapy Centre. Most importantly, apart from analysing the type and condition of occurrence of every observed component failure, the resilience of the hardware/firmware combination is debated, projecting the expected need for intervention during the future measurement runs of High-Luminosity LHC.

Electronics and System / 101

CASSIA: A CMOS Active Pixel Sensor with Internal Gain and Implementation of In-Pixel Frontend and Readout

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Future high-energy physics experiments require tracking detectors with improved timing and spatial resolution, combined with a low material budget. The CASSIA (CMOS Active Sensor with Internal Amplification) project addresses these requirements by developing a monolithic pixel detector with internal amplification, achieved through the implementation of gain layers in an industrial 180 nm CMOS imaging process. The first prototype, CASSIA1, includes four 3 × 3 pixel matrices and 24 single-pixel structures with varying gain-layer geometries and electrode spacing, affecting gain, noise, and breakdown behavior.

CASSIA1 was characterized in a controlled environment using climate-chamber studies and both TCT and source measurements. The measurements confirm operation in both LGAD and SPAD regimes, soft-breakdown behavior allowing fine gain tuning, and low dark count rates suitable for high-SNR applications. The results obtained during this campaign were used to improve the design and make it compatible with in-pixel frontend electronics.

The next-generation CASSIA2 chip, also submitted in 180 nm, will feature larger matrices with a fully scaled frontend, combining mixed digital and analog readout. Its design will be presented, highlighting the challenges when integrating LGAD structures along CMOS circuitry. The different stages and design considerations, from in-pixel circuit placement to top-level digital readout architecture, will be discussed.

Poster Session / 102

A Readout ASIC for Microdosimeters

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Carbon-ion radiotherapy (CIRT) is a lifesaving technique for treating radioresistant cancer. Recent clinical evidence shows that besides the applied radiobiological effective (RBE) dose, the averaged values of the linear energy transfer (LET) in the irradiated volume are correlated to the tumor control. Probability density distributions of LET are currently based on simulations and show high inter-center variations. Good clinical
practice requires verification through measurements, and microdosimetric detectors are under investigation for this purpose.

We used Geant4/GATE simulations to obtain the energy deposition spectra from carbon ions deposited into a microdosimetric sensor consisting of a 12 µm-thick SiC PIN diode. The temporal structure of the carbon beam at MedAustron was measured with a time resolution of 0.3 ns. A scalable model for the particle arrival time (PAT) probability density function (PDF) was designed and validated against measurements. Together with the energy deposition spectra obtained from Geant4/GATE simulations, this PAT-PDF model enabled the generation of realistic time domain sensor signals as input for the front-end ASIC simulations. An array of charge-sensitive amplifiers (CSA) was designed and taped out in the IHP 130nm CMOS process.

The time-domain sensor signal was transformed into input stimuli for SPICE simulations of the CSA. Using ngspice, the CSA output transient and noise spectral densities were simulated for the generated input stimuli. Noise was generated based on the simulated output noise spectra of the CSA and added to the simulated transient output signal. The generated time-domain signal was post-processed in Python using a dual shaper approach. One shaper was used for pileup detection, the second was used for amplitude measurements. The applied peaking times for the shapers were 5 ns for pile-up rejection and 150 ns for amplitude measurement. Microdosimetric spectra were extracted for different locations along the Bragg peak for a microdosimetric sensor covering an area of 200 x 200 µm^2, taking into account the beam's time structure and the behavior of the CSA circuit, including added noise.

Poster Session / 103

Development of Position Sensitive Deep Transient Spectroscopy as a background mitigation tool for CCD-based dark matter searches

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The unparalleled sensitivity achieved with skipper CCDs, coupled with ultra-pure high-resistivity substrates (>22 kOhm×cm) and cryogenic operation, has rekindled interest in this technology for low-background experiments (DAMIC@SNOLAB, DAMIC-M, SENSEI, and OSCURA) Such devices offer sub-electron noise resolution, enabling the detection of extremely low-energy interactions critical for rare-event searches, including dark matter detection and neutrino studies. However, exposure to alpha particles and cosmic rays may induce lattice defects with extended annealing times, potentially degrading resolution and increasing background noise. We propose a novel method to mitigate

these effects by integrating Laplace Deep-Level Transient Spectroscopy (DLTS) with electrical state pumping through the bias line, combined with the sequential readout of CCDs. Utilizing a lock-in amplifier synchronized to the shift register clock, we achieve pixel-by-pixel readout following charge injection. This approach addresses the inherent loss of timing information in charge-accumulating devices through a frequency scan at the pumping signal level. The method can be applied across various temperature points and injection levels, with an operational range typically spanning 120 K to 200 K. By conducting measurements at multiple injection and thermal conditions, we aim to characterize and mitigate background effects caused by lattice defects.

Poster Session / 104

Deep learning for sub-pixel X-ray localization at high flux

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The MÖNCH detector [1], a charge integrating hybrid pixel detector with 25 um pixel pitch, has demonstrated micrometer-scale spatial resolution [2] via the η-interpolation method, enabling applications like energy-resolved X-ray imaging. However, this performance is restricted to low photon fluxes (˜105 ph/s/mm2), as η-interpolation relies on spatially isolated single-photon events, hindering its use at high-brightness fourth-generation synchrotrons.
To overcome this limitation, we have developed a deep learning (DL)–based approach for sub-pixel localization of both single and pile-up X-ray events. Our DL models are trained on high-fidelity simulations that accurately model key physical processes including charge drift, diffusion, and Coulomb repulsion [3]. For the single-photon events, the DL model outperforms η-interpolation in localization accuracy by enabling absorption-depth–dependent charge-sharing profiles, rather than using a single, depth-averaged η distribution. More importantly, the DL model uniquely enables the reconstruction of two-photon pile-up events with sub-pixel resolution, thereby extending the MÖNCH's usable flux range while preserving high spatial resolution.
We will present the detailed deep learning models and simulation-based training results quantitatively compared to the η-interpolation. We will also show experimental validation results, including an imaging phantom that directly compares the spatial resolution achieved with η-interpolation versus our DL-based method.

[1] M. Ramilli et al 2017 JINST 12 C01071
[2] S Cartier et al 2014 JINST 9 C05027
[3] X. Xie et al 2026 NIMA 1081 170894

LGAD 2 / 105

Optimizing LGAD Technology for Soft X-Ray Detection: The Deep-Junction LGAD

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Recent developments in X-ray technology have highlighted a significant gap between the advancements in X-ray facility capabilities and the corresponding limitations in detector technologies, especially in the soft X-ray energy range (200 eV to 2 keV). While hybrid pixel detectors are the standard for higher-energy X-ray applications (2–20 keV), their implementation in the soft X-ray regime remains underexplored despite their high frame rates, dynamic range, and excellent signal-to-noise ratios. Low Gain Avalanche Diodes (LGADs), characterized by moderate internal gains in the range of 5–10, have emerged as a promising solution for addressing the signal-to-noise ratio limitations inherent in soft X-ray detection. However, several challenges remain in optimizing LGAD technology for this lower energy range.
At Brookhaven National Laboratory, we are developing and optimizing the LGAD sensor technology for hybrid detectors targeting soft X-rays. This presentation will introduce the challenges and progress of our Deep Junction LGAD development. We will discuss optimization strategies and present results from recently developed sensors. Furthermore, we will report on the currently achievable performance and outline future improvements.

Wide Bandgap Devices / 106

Sub-Nanosecond Resolved Beam Structure Measurements Using a Fast Silicon Carbide Readout

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Detector characterization and instrumentation testing are routinely conducted at synchrotron and cyclotron facilities, many of which were originally designed for medical purposes. In experiments that rely on single-particle resolution—where pileup can severely impact data quality—detailed knowledge of the beam structure is essential for selecting appropriate readout parameters. However, this information is often not provided by the facility and can be difficult to obtain experimentally.

In this study, we present measurements of the spill structure at a medical accelerator facility using a high-frequency silicon carbide (SiC) based readout system. Owing to its high carrier saturation velocity and ability to withstand large bias voltages, SiC is particularly well suited for high-speed readout and precise timing measurements. Utilizing a novel 10 GHz readout setup and custom SiC diodes, we successfully characterized the beam structure on the sub-nanosecond scale, providing valuable insights into beam delivery to experimental setups. The arrival-time statistics exhibit a modulation at the accelerator's RF frequency, arising from the characteristics of the machine's extraction process —a factor not previously considered in pileup assessments.

The relevance of these measurements is demonstrated in the context of microdosimetric measurements, which demand single-particle spectroscopic precision at high dose rates and high amplitude

resolution. Our results highlight the importance of knowing the beam-structure for the design of specialized readout electronics and reaffirm the suitability of SiC as a detector material for ultra-fast timing applications.

Poster Session / 107

Study of Gain and Time-Resolution Dependence on Trench Geometry and Doping of Trench-Isolated LGADs

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This study investigates the gain behavior and time resolution of novel small pitch, 250 µm-thick, Trench-isolated Low Gain Avalanche Detectors (TI-LGADs) fabricated by
Micron Semiconductor Ltd. Sentaurus TCAD software was used to model charge distribution and fields within each of the designs before fabrication. Single Photon Absorption Transient Current Technique (SPA-TCT) characterization was performed on the devices at an in-house lab at University of Edinburgh to study the dependence of doping and trench geometry on gain and time resolution. Small-pitch silicon pixel detectors with precise timing information will be a key tool for future particle detectors, and offer opportunities in widespread applications beyond HEP. Low Gain Avalanche Detectors are a promising technology to reach this goal. Specifically, TI-LGADs are candidates for VELO device technology in Upgrade II for HL-LHC, however, TI-LGADs could in theory be used for any low-penetrating, high-isolation, particle detection whether that be in particle physics, medicine, or otherwise.

3D Detectors / 108

3D pixel sensors for the CMS Phase-2 Inner Tracker: a 10-years journey

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10 years ago the journey of 3D sensors in CMS began with a test beam at the Fermilab Test Beam Facility. The first FBK prototype sensors featuring pixel cells with 100 x 150 μm^2, same as the current CMS pixel detector, were bump bonded to the PSI46digv2 readout chip and measured on beam. Performance well beyond the best expectations were observed and paved the way to the development of small pitch sensors with 25 x 100 and 50 x 50 μm^2 pixel cells. Continuous test beam campaigns and irradiation campaigns were performed over the years following the developments of the phase-2 readout chip by the RD53 collaboration, for both ATLAS and CMS next generation pixel detectors. The first prototype, named RD53A, became available in 2018 and featured three different analogue front-ends. Following extensive test beam and laboratory measurements the CMS collaboration chose the linear front-end, that was implemented in the second prototype, named CROCv1, which became available in 2021. The sensors production process evolved in parallel, with the aim of mitigating the insurgence of noisy channels that was observed after irradiation and operation at high bias voltages. In 2022 CMS officially decided to employ 3D sensors with rectangular pixel cells in the innermost layer of the barrel section of the phase-2 pixel detector. This presentation will show highlights from this 10 years journey and will briefly describe the production status.

Poster Session / 109

Measurements and simulation of X-ray radiation damage effects on CNM n-type 4H-SiC MOS capacitors

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The 4H-SiC material offers high thermal conductivity, very low dark currents, high saturation velocity, high breakdown voltage, and possible advantages in radiation hardness. These intrinsic properties make it well-suited for high-radiation environments. Moreover, recent advances in SiC power electronic devices and substrate fabrication have enabled the production of high-quality, thick, low-doped epi wafers for SiC detectors. However, SiC radiation damage is only partially modelled in Technology CAD (TCAD), which is the standard design tool for semiconductor particle detectors. Although a bulk radiation model for 4H-SiC has been recently proposed [1], there is still no modelling scheme for surface radiation damage at the 4H-SiC-SiO2 interface.
This contribution presents the properties of the SiO2 layer and the 4H-SiC-SiO2 interface, studied using MOS capacitors fabricated by CNM (Barcelona, Spain) on high-resistivity n-type 4H-SiC. Measurements were performed both before and after X-ray irradiation at doses ranging from 50 krad to 10 Mrad. High-frequency (HF) and quasi-static (QS) C–V characteristics were analysed using the High-Low method [2] to extract the oxide charge density (NOX) and the interface trap density (DIT). These measured parameters, NOX and DIT, were implemented in TCAD to build a surface radiation-damage model for the 4H-SiC–SiO2 interface. The impact of annealing at 80℃ on oxide and interface trap charges was also investigated.

[1] P. Gaggl et al., "TCAD modeling of radiation-induced defects in 4H-SiC diodes", NIMA 1070 (2025) 170015. https://doi.org/10.1016/j.nima.2024.170015
[2] E. H. Nicollian and J. R. Brews, MOS (metal Oxide Semiconductor) Physics and technology, John Wiley and Sons, pp. 319-356, 1982

LGAD 2 / 110

Optimization of low gain avalanche detectors (LGAD) for sensing low energy electrons

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Low gain avalanche detectors (LGAD) are used to detect photons and particles with a medium internal gain of around 10. [1] In this contribution we report on the optimization of LGADs produced at CiS [2] for sensing particles with low penetration depth in silicon like low energy electrons. Such detectors could be used e.g. in SEMs for higher contrast images. The optimization strategy was to reduce the entrance window thickness and to develop a shallow gain layer region. As a result of the LGAD optimization work quantum efficiencies for electrons with an energy of 1keV of up to 450% could be realized.

[1] G. Paternoster et al., 'Developments and first measurements of Ultra-Fast Silicon Detectors produced at FBK', J. Instrum., vol. 12, no. 02, pp. C02077–C02077, Feb. 2017, doi: 10.1088/1748-0221/12/02/C02077.
[2] K. Lauer, K. Peh, S. Krischok, S. Reiß, E. Hiller, and T. Ortlepp, 'Development of Low-Gain Avalanche Detectors in the Frame of the Acceptor Removal Phenomenon', Phys. Status Solidi A, vol. 219, no. 17, p. 2200177, June 2022, doi: 10.1002/pssa.202200177.

Electronics and System / 111

Design and Current testing results of COFFEE3, a small monolithic active pixel sensor prototype for 55nm HVCMOS validation

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The HVCMOS technology is promising technology for tracking detectors at future experiments such as LHCb upgrade and Higgs factories, for its radiation hardness, fast charge collection and hence good spatial and timing resolution. Development of HVCMOS in smaller feature size will allow more functionalities in the same pixel area, and a reduced power consumption. We proposed a project to develop HVCMOS sensor prototypes using 55nm CMOS process based on initial validation of the process. A small Monolithic prototype sensor chip, COFFEE3, was submitted in January 2025 which features two pixel arrays with completely different readout architectures. Both are designed aiming at 10 micron spatial resolution and a few nanosecond timing resolution, with moderate power consumption. This talk will present the design and current test results of the COFFEE3 chips. Future development plan will also be briefly discussed.

Technology / 112

Development for the Belle II vertex detector upgrade with depleted monolithic active pixel sensors.

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The Belle II experiment at the asymmetric energy e- and e+ collider SuperKEKB provides rich flavor physics programs of beauty, charm, light quarks and tau-lepton at the luminosity frontier. Thanks to its nano-beam scheme, SuperKEKb holds the world’s highest instantaneous luminosity record of $5 \times 10^{34}\ cm^{-2}s^{-1}$, and aims to push up to $6 \times 10^{35}\ cm^{-2}s^{-1}$ after the upgrade of the interaction region, including the final focusing magnet, foreseen in 2032.
To cope with the harsh beam background conditions expected after the upgrade, a fully pixelated vertex detector (VTX) with monolithic CMOS sensor (OBELIX) is planned as one of the major upgrades of Belle II.

The OBELIX sensor, derived from TJ-Monopix2 originally developed for the ATLAS experiment, features a matrix of 896×464 pixels with $33 \times 33\ \mu m^2$ pitch. The chip is designed to cope with 30 kHz trigger rate at 120 MHz/cm^2 hit rate, and radiation tolerance up to 1 MGy and 5×10^{14} n_{eq}/cm^2.

The VTX consists of six cylindrical layers of OBELIX sensors surrounding the beam pipe at radii from 14 mm to 140 mm. The detection layer design is now being optimized considering the expected background hit rate and related power consumption at the target luminosity. A particularly challenging system aspect is to maintain the sensor at room temperature in order to preserve detection efficiency after irradiation, while minimising the material budget.
The ladders of the inner two layers (iVTX) are composed of self-supported four-consecutive OBELIX sensors inter-connected with a post-process redistributed metal layer. The last sensor is then connected to a readout flexible circuit board. The iVTX concept is exploring passive cooling using a thin layer of Thermal Pyrolytic Graphite (TPG) running below the sensors and thermally connected to end-mount blocks actively cooled.
The ladders of the outer four layers (oVTX) consist of aligned OBELIX chips connected to a flexible circuit board (flex for power and signals) and supported by a carbon fiber structure equipped with a cooling pipe and two end-mount blocks at both ends.

In this talk, we will present an overview of the project and its latest developments, especially focusing on passive cooling studies of iVTX with TPG and the development of low material budget flex using aluminum conductor.

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Silicon Quality Control Results from the Production Phase of the CMS HGCAL Silicon Sensors

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The CMS detector at the CERN Large Hadron Collider is undergoing major upgrades for the High-Luminosity LHC (HL-LHC), including the replacement of its endcap calorimeters with the High Granularity Calorimeter (HGCAL). The electromagnetic section (CE-E) and the high-radiation regions of the hadronic section (CE-H) will employ radiation-tolerant, fast-response silicon pad sensors, collectively covering a surface area of approximately 620 m². These sensors must maintain stable performance under the extreme particle fluences expected throughout the HL-LHC lifetime. Ensuring their reliability and consistency has required a comprehensive silicon quality control (SQC) program that monitors the electrical and mechanical robustness of the sensors across the entire production chain.

From early 2023 to mid-2025, the manufacturer Hamamatsu Photonics K.K. completed the production of nearly 25,000 8-inch p-type wafers with multiple sensor designs and thicknesses. This large-scale production included per-cell leakage current (IV) and capacitance (CV) measurements as well as mechanical inspections performed both at the vendor and during subsequent acceptance stages in multiple CMS institutes. The resulting dataset—both from Hamamatsu and by SQC efforts at CERN—enabled detailed monitoring of process stability, early identification of systematic effects, and quick feedback to the manufacturer.

In this talk, we present an overview of the QC workflow developed for HGCAL, including automated handling of vendor data, validation of electrical measurements, and cross-checking of wafer-level characteristics using CMS SQC results. We summarize key observations from the production campaign, such as thickness-dependent trends, recurring spatial patterns in leakage current, delivery-to-delivery variations, and correlations between mechanical features and electrical response. These findings provided essential input during the production phase and contributed to progressive improvements in sensor quality.

Beyond supporting HGCAL construction, the methodologies and insights gained from this large-volume testing campaign offer valuable guidance for future silicon detector projects facing similar challenges in scale, radiation hardness, and long-term reliability.

Poster Session / 114

CMS Pixel Detector Status, Challenges, and Performance in Run 3

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The CMS Silicon Pixel detector, the innermost component of the CMS silicon tracking system, plays a critical role in reconstructing charged-particle trajectories and identifying primary and secondary vertices in the high-luminosity environment of the LHC. Since the start of Run 3, the detector has been exposed to increasingly demanding conditions, including average pileup above 60 and particle fluences that now exceed the levels anticipated in its original design. Despite these challenges, the pixel system continues to deliver quality tracking information, supported by regular calibrations and monitoring of key performance indicators such as hit efficiency, charge collection, and cluster properties. Radiation-induced degradation of sensors and front-end electronics has become a dominant factor influencing detector behavior during Run 3. We present recent observations of these effects. These measurements are complemented by studies aimed at modeling the evolution of the detector response with increasing irradiation. This talk summarizes the current operational status of the CMS Pixel detector, the main challenges encountered during Run 3, and the insights gained for optimizing performance as the detector approaches the end of its lifetime.

LGAD 2 / 115

Defect Analysis Behind the Donor Removal in n-type Low Gain Avalanche Detectors (nLGADs)

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n-type LGAD detectors, with a p++/n+/n/n++ structure, are an emerging technology for the detection of shallow-penetrating radiation. However, experiments show that their gain layer is prone to radiation damage, exhibiting a more pronounced vulnerability compared to p-substrate LGADs. This effect was studied in our previous work and attributed to the donor removal mechanism, which remains under investigation. In this study, we perform a microscopic investigation of locally induced damage using shallow-penetrating broad-beam ion implantation, with the Bragg peak adjusted to deposit the damage into the n+ layer, avoiding Space Charge Sign Inversion. We track the evolution of donor removal through time-resolved charge collection efficiency (CCE) spectra obtained via microprobe irradiation and correlate this with the active doping profile evolution, evaluated using Spreading Resistance Profiling (SRP) and demonstrating the degradation of active donor concentration. We extract the donor removal constant from gain depletion voltages obtained through capacitance-voltage (CV) measurements after ion irradiation at different fluences. Thermally stimulated current (TSC) measurements on irradiated samples reveal electron trap levels with a peak that anneals after 45 minutes at 200 ℃, corresponding to the VP center in n-type silicon.

Technology / 116

Comparison of the performance of hydrogenated amorphous silicon sensors designed with different contacts configurations

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The INFN HASPIDE experiment is based on the development of innovative solid-state sensors made of hydrogenated amorphous silicon (a-Si:H). In these sensors, an extremely thin (2 – 10 [illegible]) a-Si:H layer is included between two electrodes, acting as a sensitive volume for detecting ionizing radiation. The a-Si:H layer is deposited on Kapton to obtain thin, flexible devices in particular for medical applications.
Different contacts configurations have been produced by the EPFL institute (Neuchâtel, Switzerland), which are the n-i-p junction (intrinsic a-Si:H layer between n- and p-doped layers of thickness 10 – 20 [illegible]), the charge-selective contact structure (the doped layers are replaced with metal oxides which selectively enhance the mobility of one charge-carrier, blocking the other) and finally the hybrid-type (in which the intrinsic a-Si:H layer is sandwiched between a n-doped layer and a metal oxide).
These different devices have been tested in laboratory, both in terms of dark current and X-ray sensitivity measurements. The results of these characterizations will be presented, together with a comparison about X-ray sensitivity at different biases.

Planar Devices / 117

Silicon quality control results from the production phase and annealing of radiation defects of the CMS HGCAL Silicon Sensors

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The CMS detector at the CERN Large Hadron Collider is undergoing major upgrades for the High-Luminosity LHC (HL-LHC), including the replacement of its endcap calorimeters with the High Granularity Calorimeter (HGCAL). The electromagnetic section (CE-E) and the high-radiation regions of the hadronic section (CE-H) will employ radiation-tolerant, fast-response silicon pad sensors, collectively covering a surface area of approximately 620 m^2. The system is designed to endure particle fluences up to 1.5e16 neq/cm² and radiation doses reaching 1.5 MGy.

The manufacturer Hamamatsu Photonics K.K. completed the production of nearly 25,000 8-inch p-type silicon wafers with active thicknesses of 300 µm, 200 µm (both float zone), and 120 µm (epitaxial). This large-scale production included per-cell leakage current (IV) and capacitance (CV) measurements as well as mechanical inspections performed both at the vendor and during subsequent acceptance stages in multiple CMS institutes. The resulting dataset –both from Hamamatsu and by SQC efforts at CERN–enabled detailed monitoring of process stability, early identification of systematic effects, and quick feedback to the manufacturer.

In this talk, we summarize SQC results of the all types of sensors before irradiation and focuses on the first detailed annealing campaign with wafer-scale HGCAL 120 µm (epitaxial) sensor exposed to 2E15 neq/cm2. For the non-irradiated sensors we present an overview of the QC workflow developed for HGCAL, including automated handling of vendor data, validation of electrical measurements, and cross-checking of wafer-level characteristics using CMS SQC results. We summarize key observations from the production campaign, such as thickness-dependent trends, recurring spatial patterns in leakage current, delivery-to-delivery variations, and correlations between mechanical features and electrical response.

To study radiation-induced bulk damage as well as inter-cell effects on the wafer-scale sensors, full sensors –from prototypes to production rounds–were irradiated with neutrons at the Rhode Island Nuclear Science Center (RINSC) up to fluence levels of 1.4E16 neq/cm^2. The study investigates for the first time the isothermal annealing behaviour at 60℃ after annealing durations ranging from 10 to 5000 minutes. Hamburg model parameters for alpha damage constant and effective doping concentration changes with annealing time extracted from the full-sensor data will be presented. The post-irradiation behaviour of sensors with hot regions in the pre-irradiation IV measurements as well as epitaxial sensors with stacking faults in individual cells are investigated.

3D Detectors / 118

The 3D pixel tracker of the CMS Precision Proton Spectrometer in Run 3

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The CMS Precision Proton Spectrometer (PPS) was designed for measuring protons that escape along the LHC beam line after the interaction in CMS. It successfully took data during the LHC Run 2, collecting more than 110 fb-1 of integrated luminosity, and since 2022 is taking data in Run 3, having already collected more than 230 fb-1. The PPS tracker was substantially upgraded in preparation for Run 3, with new single-sided 150 um-thick silicon 3D pixel sensors (same design but different pitch as for the inner pixel layers under construction for the ATLAS and CMS trackers for the HL-LHC), read out with the PROC600 chip used in the layer 1 of the CMS pixel tracker after the Phase 1 upgrade. Concerning the mechanics, an innovative solution allowing for vertical movements was adopted to mitigate the radiation effects caused by the non-uniform irradiation of the readout chip, which were the main limiting factors in the Run 2 performance. To adapt the detector to the new

2025-2026 LHC optics with vertical beam crossing in the CMS interaction point, Roman Pots were successfully rotated modifying the acceptance of the detectors. In this contribution we will present the apparatus for Run 3 and the preliminary performance results obtained by analysing the Run 3 data collected up to now.

CMOS / 119

Testbeam results of the MiniCactus V2 timing demonstrator

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MiniCactus V2 is a demonstrator intended to study the timing performance that can be obtained from non amplified large electrode CMOS sensors developed with the 150 nm LFoundry HV CMOS LF15A technology.

MiniCactus V2 is the most recent iteration of a line of timing oriented sensors, with improved performance over its predecessors. It features pixels of different sizes, from 1mm x 1mm to 0.5 mm x 0.5mm. The pixels are equipped with different types of analog individual front-end and discriminators, with bias parameters and thresholds programmable via an integrated slow control.

MiniCactus V2 has been tested on three testbeam periods during the last two years. The first and second period using high energy muons, in parasitic mode during DRD1 testbeam campaigns. The third period was at the beginning of October 2025, as part of a DRD3 testbeam campaign. The beamline was equipped on the three periods with timing detectors allowing a precise and reliable measurement of the time resolution of the individual pixels of the MiniCactus V2 chip. For the DRD3 beam period, the beamline was also equipped with a silicon tracker allowing precise extrapolation of the tracks to the sensor.

This talk will focus on the most recent results from the third period. The data analysis shows that a time resolution of about 50 ps can be obtained on 0.5 x 0.5 mm pixels with a tracking efficiency close to 99%.

Electronics and System / 120

Current Status of the Phase-2 ATLAS ITK Pixel Detector

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The upgrade of the LHC to the high luminosity LHC (HL-LHC) by the end of this decade will impose significant challenges on the detectors of the LHC experiments. Increased luminosity of up to 7.5 10ˆ34cmˆ−2sˆ−1 with up to 200 simultaneous p-p interactions per bunch crossing and foreseen run-times equivalent to up to 4000 fb-1 make it necessary to develop new detectors that can cope with the corresponding radiation damage, occupancy, and bandwidth needs. Among other detector upgrades, ATLAS will replace its entire inner tracking system with a new, all-silicon inner tracker (ITk) with a 5-layer hybrid pixel detector at its heart. This new pixel detector will feature a sensitive surface of about 13 mˆ2 and deploy several silicon sensor technologies as well as innovative concepts like serial detector powering and evaporative CO2 cooling to unprecedented scales.
The ITk pixel project has finished its design and prototyping period and the different detector components are either in the pre-production or production phase. This contribution will give a comprehensive overview of the detector design, the overall project status and the biggest challenges towards production. It will include lessons learned from module pre-production, experience with the RD53 front-end chip, as well as first results on module loading on mechanical support structures. Recent results of close-to-real system-level tests as well as the remaining project timelines will also be discussed.

Simulations / **121**

A TCAD Simulation Framework for DLTS-based Defect Characterisation in Solid-State Particle Detectors

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The increasing radiation levels expected in future high-luminosity collider experiments demand robust predictive models for the design and optimisation of semiconductor particle detectors operating under extreme fluences (above $1 \cdot 10^{16}\,1\,\mathrm{MeV}\,n_{eq}/\mathrm{cm}^2$). Although TCAD-based modelling of radiation damage has evolved over the past two decades, a general-purpose model capable of reliably simulating the macroscopic effects of deep-level defects –particularly those induced at extreme fluences –is still lacking.

This work presents a TCAD simulation framework designed to reproduce Deep Level Transient Spectroscopy (DLTS) spectra and Arrhenius plots, enabling the refinement of trap characteristics – namely concentration, thermal activation energy, and electron and hole capture cross-section –to be implemented into numerical radiation damage models. In particular, the activities carried out so far include the reproduction of DLTS spectra of C_iO_i (carbon-interstitial-oxygen-interstitial), B_iO_i (boron-interstitial-oxygen-interstitial), I_2O (di-self-interstitial-oxygen-interstitial), and $V_2(0/+)$ (single-positive charge state of the di-vacancy) defects, based on current (I-DLTS) and capacitance (C-DLTS)

transient measurements in p-type silicon p-i-n diodes with different bulk resistivities (250 and 50 Ωcm) at irradiation doses of 0.1, 1, 2, and 5 MGy, using the developed TCAD framework. In addition, numerical strategies (e.g. tuning of mathematical parameters) and specific workarounds –such as artificially increasing the charge-carrier generation rate –have been implemented to ensure convergence of the TCAD simulations of DLTS measurements down to cryogenic temperatures. To evaluate the reliability of the proposed framework, a benchmark procedure is defined, using both I- and C-DLTS measurements as reference data to validate the simulated defect response. This approach allows for a systematic assessment of the "effectiveness"of each trap in reproducing key device-level observables, such as leakage current, depletion voltage, and charge collection efficiency.

By bridging the gap between microscopic defect spectroscopy and macroscopic device simulation, the framework establishes the foundation for general-purpose TCAD models across semiconductor materials and fluence regimes, enhancing predictive power and guiding the design of radiation-hard detectors for future collider environments.

LGAD 4 / 122

Radiation-Tolerance Improvement Studies of the LGAD Gain Layer in HPK Sensors

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Low-Gain Avalanche Diodes (LGADs) provide excellent timing resolution on the order of 20 ps and are strong candidates for several collider experiments, both as 4D tracking detectors and as timing layers for particle identification. LGADs with capacitively coupled electrodes (AC-LGADs) achieve highly uniform gain and electric fields, enabling fine pixelation without dead regions. These features make AC-LGADs promising devices for future 4D tracking systems. For hadron-collider environments in particular, radiation tolerance remains a key challenge. Higher operating voltages are required to compensate for the removal of active acceptor doping, and single-event burnout (SEB) has been observed when the electric field exceeds roughly 12 V/µm. Improving the radiation tolerance therefore requires reducing the acceptor-removal rate (coefficient CA) in the gain layer. HPK has implemented several mitigation approaches in recent test samples, including carbon co-implantation, compensated acceptor profiles, and reduced oxygen concentration. In this presentation, I will report on the latest results from newly fabricated samples irradiated up to 5×10ˆ15 neq/cm2, together with SEB studies performed using a 70 MeV proton beam.

Wide Bandgap Devices / 123

Characterization of Planar 4H-SiC Diodes and DC Resistive Devices from the Second RD50 SiC-LGAD Project Production Run

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4H silicon carbide (4H-SiC) is emerging as a promising candidate for radiation sensors in high-energy physics, medicine, and high-temperature environments. It offers intrinsically low leakage currents, even after irradiation, together with fast charge-carrier transport and excellent thermal stability. Historically, studies of 4H-SiC detectors were constrained by the limited access to advanced fabrication processes. Recent industrial and research interest, however, has enabled large-volume production and a broader range of device types, allowing the first systematic evaluation of spatially resolving 4H-SiC detectors and statistically robust irradiation studies.

We present results from the second fabrication run of planar 4H-SiC detectors within the RD50 SiC-LGAD project, comprising two wafers with epitaxial layer thicknesses of 50 μm and 100 μm produced at CNM. The production includes a large number of pn-diodes, strip sensors, and also the first 4H-SiC–based DC resistive devices with 2D spatial resolution. We performed electrical characterization at both wafer and device level, revealing <200fA leakage current levels. The resistive sensors were scanned via UV-laser injection to assess their 2D position resolution. We further discuss passivation-related production issues that rendered some structures, such as Van der Pauw test structures, non-functional.

A substantial fraction of the characterized pn-diodes has been deployed to ongoing proton and neutron irradiation campaigns spanning low to high fluences. These studies aim to inform improvements of simulation models, quantify radiation-induced defects in 4H-SiC, and evaluate the material's suitability for next-generation, radiation-hard detector technologies.

Poster Session / 124

Up-to-date test beam results of ATLAS ITk Pixel sensors and modules

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The ATLAS inner detector will be completely replaced with a new all-silicon tracking system (ITk) during the 2027–2029 shutdown, in order to operate under the demanding conditions of the High-Luminosity LHC. The innermost component of the ITk will be the pixel detector. Its Layer 0 will employ 3D sensor technology, designed to withstand fluences up to 1.7×10^{16} neq/cm^2, while the outer layers (L2–L4) and the first layer (L1) will use n-in-p planar hybrid modules, with sensor thicknesses of 150 μm and 100 μm, respectively. Test-beam studies of sensors and full modules are an essential tool for assessing performance and operational behavior, both before and after irradiation to the expected HL-LHC levels. Over the past few years, sensors from multiple vendors and of various geometries have gradually become available for beam tests. In the most recent 2025 test-beam campaigns, several new module configurations—quad and triplet modules—equipped with the final version of the readout chip (ITkPixV2) were evaluated. For the first time, triplet modules (three hybrids connected via flexible PCB) employing 3D sensors of both geometries (50×50 μm^2 and 25×100 μm^2) were tested in beam conditions, both before and after irradiation. Measurements were performed at multiple incident angles to study charge-collection efficiency under conditions representative of actual detector operation. The 2025 test-beam dataset therefore contains several important new elements, enabling further progress toward the full qualification of ITk pixel sensors and modules. A portion of these new data is currently under analysis. This talk will present an overview of the ITk pixel sensor and module qualification program using test beams, including the latest results from the 2025 campaigns.

Poster Session / 125

Overview on the Assembly and Testing of the Vertex Detector of the Mu3e Experiment

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The Mu3e Experiment aims to observe charged lepton flavor violation via the e+e-e+ channel with a Phase-I goal of single event sensitivity down to 2 10ˆ-15 on the branching ratio. The experimental detector is being actively constructed and commissioned at the Paul Scherrer Institute (PSI), where it will be subjected to 10ˆ8 muon stops per second at the piE5 beam-line. In order to sift through the background events and reduce multiple scattering, an ultra-thin detector with excellent vertex reconstruction performance and momentum resolution is required. Using HV-MAPS based MuPix 11 sensors at thicknesses down to 50 μm, the so-called Vertex Detector is made up of two layers of "ladders"with six chips each, concentric on the target. High Density Interconnects (HDIs) made up of aluminum traces and Kapton layers provide the electrical connections while keeping the radiation length to a minimum. A manual assembly procedure and dedicated air-cooled quality control (QC) setups have been developed for the production of the Vertex ladders. This poster will provide an overview on the assembly process and QC testing for the second iteration of the detector for a planned upcoming run in 2026.

Poster Session / 126

Studies of radiation damage in the silicon oxide layer with CMS HGCAL test structures

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For the High-Luminosity LHC, the CMS detector will undergo a significant upgrade that includes the installation of the High Granularity Calorimeter (HGCAL), which will employ 8-inch n-on-p silicon sensors. To ensure their reliable operation under the extreme radiation environment of HL-LHC, dedicated studies of surface radiation damage in the SiO_2 passivation layer are being carried out. These studies aim both to evaluate the radiation tolerance of the SiO_2 selected for the HGCAL sensors and to compare the quality and behaviour of different oxide variants for future high-energy physics experiments. The surface radiation damage is studied by means of X-ray irradiation with a fully automated measurement setup, enabling systematic characterisation of dedicated test structures. This talk will present results from the X-ray irradiation studies across multiple test structures and will compare the experimental findings with TCAD simulations.

LGAD 4 / 127

TI-LGAD Timing performance with Timepix4: From Laser-Based Calibration to Test Beam

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The realization of 4D tracking with simultaneous micrometer spatial and picosecond temporal resolution relies not only on sensor technology but also on a precise understanding and calibration of the readout electronics. While Trench-Isolated Low-Gain Avalanche Detectors (TI-LGADs) offer the necessary segmentation and intrinsic gain, this high level of segmentation necessitates a dedicated readout ASIC which adds additional complexity to the system and needs to be understood to a high level in order to achieve the best possible performance.

To show the limit of the achievable timing resolution, we will present results gathered via a femtosecond Two Photon Absorption (TPA) laser and testbeam measurements with the Timepix4 beam telescope. The results are obtained with two generations of FBK TI-LGADs on Timepix4. The Timepix4 ASIC has a pitch of 55 micron, and measures both the time of arrival (ToA) and the charge in the form of the time over threshold (ToT). The TDC bins are 195 ps which gives a temporal resolution of 56 ps. The combination of laser and testbeam measurements give us the tools to fully characterize both sensor and ASIC and to determine the best way to correct for effects such as timewalk and clock corrections to achieve our optimal temporal resolution.
The results show that we can achieve an excellent timing performance. We will focus on identifying the factors limiting the temporal resolution and discuss the potential for further improvement.

Simulations / 128

Van der Pauw test structures as a probe for doping removal in LGAD sensors

Authors: Alessandro Fondacci[1]; Tommaso Croci[2]; Anna Rita Altamura[3]; Roberta Arcidiacono[3]; Maurizio Boscardin[4]; Nicolo Cartiglia[5]; Matteo Centis Vignali[6]; Marco Ferrero[3]; Arianna Morozzi[7]; Daniele Passeri[8]; Giovanni Paternoster[9]; Brendan Regnery[10]; Valentina Sola[3]; Robert Stephen White[3]; Francesco Moscatelli[11]; Simone Galletto[12]; Ludovico Massaccesi[None]

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Doping removal—whether acceptor or donor—is a well-known effect of radiation damage in silicon detectors, and has been extensively characterized at the low doping levels typical of conventional silicon substrates. The development of Low Gain Avalanche Diode (LGAD) technology has pushed detailed studies of acceptor removal at high initial concentrations ($> 10^{16}$ at/cm^3). With the emergence of advanced LGAD designs such as NLGAD, resistive LGADs, and compensated LGADs, a systematic investigation of donor removal at similar concentrations is now essential for further device optimization.

In this contribution, we present a novel methodology for quantifying doping removal by analyzing irradiation-induced variations in sheet resistance measured with van der Pauw test structures. This method is applied to both shallow and deep doping profiles—acceptor and donor types—from NL-GAD, resistive, and compensated LGAD batches manufactured by Fondazione Bruno Kessler (FBK). Validation is performed through TCAD simulations calibrated with Secondary Ion Mass Spectrometry (SIMS), demonstrating a nearly two-fold faster removal of donors compared to acceptors.

Invited 4 / 129

Performance and design review of the FBK DC-RSD1 production.

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The DC-RSD is a thin LGAD sensor with a resistive DC-coupled read-out, that uses internal gain and intrinsic charge sharing to achieve excellent 4D-tracking capability with low electrodes density.
The DC-RSD1 production comprises matrices with both small and large pixels, and strips, with technological variations of electrode layout and resistive layer levels to investigate charge sharing and effective gain.
This contribution presents a summary of results obtained with the FBK DC-RSD1 production, including space and time resolutions, uniformity of response and detection efficiency for different sensor designs.
The measurements were carried out in three DESY test beam campaigns and complemented by dedicated laboratory studies. Updates on reconstruction methods, optimal sensor design parameters, and sensor occupancy limitation will also be discussed.

3D Detectors / 130

Small cell 3D detectors with intrinsic gain

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Small pixel 3D sensors were produced by IME-CAS on 8-inch p-type wafers of 700 Ωcm. The 30 µm thick silicon detectors have trench walls (ohmic p+) and very narrow n-column columns with a diameter of only 0.5 µm. A 5 × 5 matrix of 35 ×35 µm2 was measured with Two Photon Absorption Transient Current Technique as well as with minimum ionizing electrons from 90Sr source. At higher voltages the devices show stable operation with high gain originating from impact ionization close to the n+ junction column in a similar way in gas proportional chambers without
any specially dedicated gain layer doping. The devices were fully characterized in terms of charge collection uniformity and time resolution performance across the cell at different bias voltages. The gain and time resolution measured with electrons confirmed the conclusions from TPA-TCT measurements.

Poster Session / 131

Charge pump in 180 nm SOI technology for biasing silicon drift detectors with different regulation schemes

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X-ray fluorescence with silicon drift detectors (SDDs) is an effective method for raw material extraction and recycling. These systems require a large number of detectors to be fitted in a very small space. Therefore, miniaturizing the current external power supply by means of an integrated, space-saving charge pump circuit is very advantageous
This work presents an application-specific integrated circuit (ASIC) manufactured using 180 nm silicon-on-insulator (SOI) technology, which can generate all negative high voltages required for SDD operation, ranging from -20 V to -200 V.
The central element of the ASIC is a CMOS DC/DC converter based on a Pelliconi charge pump.
The Pelliconi-type charge pump topology uses low-voltage transistors and a simple two-phase clock scheme. This enables higher frequency operation, as well as higher current output and efficiency, while simultaneously reducing the size of the chip.
An appropriate control concept has been implemented to adjust the output voltage of the charge pumps required for the SDD.
The presented prototype compares the performance of an SDD supplied by charge pumps using two different control concepts:
One concept is based on a common two-point control system, whereby the pumping process is regulated by a comparator. As an alternative, the concept of controlling the supply voltage of the clock circuit to generate the desired output voltage is being investigated.
The result is a comparison of both control concepts with an external power supply in terms of stability, noise, and spectral performance of the detector.

Poster Session / 132

Novel Strip-like Readout Geometries in Resistive AC-coupled Silicon Detectors (RSD/ AC-LGAD)

Authors: Alexander Dierlamm[1]; Brendan Regnery[1]; Ling Leander Grimm[1]; Lorena Hahn[1]; Luca Menzio[2]; Markus Klute[3]; Nicolo Cartiglia[4]; Roberta Arcidiacono[2]

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Resistive Silicon Detectors (RSD/ AC-LGAD) are novel silicon detectors capable of both precise spatial and temporal resolution. Such sensors will be essential for the next generation of particle colliders (EIC, FCC-ee, CEPC, FCC-hh) and would enable the possibility of a 4D tracker. RSD sensors are typically fabricated with a pixel-like geometry that provides excellent spatial resolution in the x and y directions. However, in regions further from the interaction point, high spatial resolution

in one direction (strip-like geometry) is often preferred to reduce the number of readout channels. For example, strip AC-LGADs are now the default option for the US electron ion collider (EIC). The second production of RSD sensors by Fondazione Bruno Kessler includes sensors with unconventional read-out pad shapes that act as hybrid between strip-like and pixel-like readout. This work presents the first characterization of these new pad designs using the Transient Current Technique (TCT). The measurements demonstrate exceptional one-dimensional spatial resolution, confirming the potential of novel strip-like RSDs for future tracking systems.

Poster Session / 133

TCAD Studies of radiation effects on CMOS Strip sensors

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In the CMOS Strips Project, passive silicon strip sensors were designed by a collaboration of German institutes and fabricated in LFoundry. The sensors serve as a proof of principle to show that the CMOS technology brings a suitable solution for the fabrication of silicon strip sensors in the strip lengths required for high energy physics experiments. In this study, the TCAD simulations incorporating advanced radiation damage models, the Perugia bulk and surface model and the CERN model, are used to investigate properties of CMOS strip sensors. The leakage current and bulk capacitance are simulated using Sentaurus TCAD and the simulations are compared to measured characteristics of the sensors irradiated up to $1{\cdot}10^{16}$ n_{eq}/cm^2. A comparative overview of the charge collection simulations and laboratory measurement results of the CMOS strip sensors is also presented. The simulation shows a good agreement with the measurement data while providing an insight into the microscopic electrical characteristics of studied sensors.

LGAD 1 / 134

Performance of irradiated TI-LGADs at 120 GeV SPS pion beams

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Trench-Isolated Low-Gain Avalanche Detectors (TI-LGADs), implement pixel segmentation through physical trenches etched into the silicon substrate and filled with a dielectric material. In this work, we present results from several 120 GeV pion test beam campaign at the CERN SPS, focusing on carbon-infused single-trench TI-LGAD prototypes with varying trench widths. The devices, irradiated with neutrons up to a fluence of 2.5×10^{15} neq/cm², were characterized under minimum ionizing particle conditions. The experimental setup combines precise tracking from a MIMOSA26-based beam telescope, achieving sub-10 µm spatial resolution, with timing measurements from a reference LGAD and a multi-channel waveform digitization system.

We report on the spatially resolved time resolution, detection efficiency, and inter-pixel performance of the tested devices, highlighting the impact of trench geometry and radiation damage. Preliminary results from the April 2025 test beam campaigns will be presented and discussed.

LGAD 4 / 135

Performance of the renewed IMB-CNM LGAD technology before and after irradiation

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IMB-CNM has been a main actor in the development of Low Gain Avalanche Detectors since the initial device conception, more than a decade ago. One of the challenges for LGAD is the deterioration

of the gain and timing resolution after radiation damage due to the acceptor removal mechanism. A well-established solution to increase radiation tolerance is carbon co-doping in the gain layer.

The IMB-CNM's Radiation Detectors Group has revisited its strategy regarding the technological design with a redefinition of the doping profiles, looking for higher uniformity on the gain layers and better production yield.

This contribution aims at compiling the characterization of the latest IMB-CNM production, with a particular focus on the sensing performance (e.g. charge collection) and timing properties. The study includes neutron irradiations at the TRIGA reactor facility in JSI up to fluences of 8e14 neq/cm2, 1.5e15 neq/cm2 and 2.5e15 neq/cm2. Comparison of the irradiated and non-irradiated samples will be included in the contribution.

Poster Session / 136

GPU-Accelerated Simulation of 3D Diamond Sensors Using the TeRABIT Infrastructure

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Diamond detectors with electrodes orthogonal to the surface, engraved via laser-induced graphitization, are full-carbon sensors of interest for a wide range of applications, spanning from High Energy Physics to Nuclear Medicine and dosimetry.
In recent years, significant progress has been made in graphitization techniques, enabling the fabrication of lower-resistance electrodes. This has resulted in faster sensors, achieving time resolutions better than 100 ps.
However, simulating signal formation in these devices remains a challenge. The effects of fluctuations in energy deposition, carrier transport, signal propagation, and readout electronics intertwine in a way that is non-trivial to disentangle.
We have developed an innovative simulation approach based on an extension of the Ramo–Shockley theorem, modeling propagation effects in a theoretically sound manner by introducing time-dependent weighting potentials. These are obtained by solving a third-order partial differential equation derived as a quasi-static approximation of Maxwell's laws. The numerical solution of this equation emerged as the main challenge of the new approach.
In this contribution, we discuss an innovative solver that uses fundamental solutions to impose boundary conditions and spectral methods to extend the solution to the bulk of the diamond detector. We report on how the solver has recently been ported to GPUs and distributed across multiple computing sites, leveraging the TeRABIT HPC Bubbles and the InterLink protocol. This drastically reduces time-to-insight and effectively enables what-if studies on sensor geometry.

Wide Bandgap Devices / 137

Barrier Inhomogeneity and Temperature Dependence of Electrical Parameters in GaN Homoepitaxial Schottky Diodes –An Evaluation Towards Functional Radiation Detectors

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Wide band-gap (WBG) materials such as GaN and SiC are playing an increasingly important role in modern high-frequency and high-power electronic technologies. As advances in bulk growth continue to lower defect densities and improve crystalline quality, these semiconductors are also emerging as strong contenders for next-generation radiation detectors. Nevertheless, extensive optimisation and detailed characterisation are still needed before they can realistically compete with silicon in demanding radiation-intensive applications.
GaN, in particular, benefits from its large band gap (3.4 eV) and robust Ga–N bonding, which together indicate strong thermal stability and excellent resistance to radiation damage. Although GaN-based detector structures have been demonstrated, most rely on epitaxial GaN layers deposited on foreign substrates such as Si, SiC or sapphire. As a result, the behaviour and reliability of fully GaN-on-GaN devices in extreme environments are not yet comprehensively understood. Achieving wider use of these devices in harsh-radiation scenarios will require continued development and systematic characterisation.
In this work, Schottky diodes of varying geometries were fabricated on an n-type GaN bulk wafer with an n^- epilayer. Following metal rapid thermal annealing (500℃ for 2 minutes), the devices were characterized via current–voltage (I–V) and capacitance–voltage (C–V) measurements, exhibiting typical Schottky behaviour with design-dependent variations. Despite exhibiting typical rectification, the devices show high leakage current, high series resistance and evident barrier inhomogeneity.
A comprehensive temperature-dependent (233K to 573K) analysis of the forward-bias characteristics was performed to assess and improve their suitability as radiation detectors. This has allowed deeper insight into the underlying physical mechanisms driving the observed trends. In this work, barrier inhomogeneity was identified via Gaussian distributions, resistance corrections, and identification of typical inhomogeneous barrier trends. Its dependence on device perimeter and area was subsequently investigated. In addition, the prevalent current transport mechanisms have been studied, suggesting thermionic field emission (TFE) seen at low temperatures and bias voltages and thermionic emission (TE) as the dominant mechanism. Ultimately, elucidating the next steps in fabrication towards functional radiation detectors.

3D Detectors / 138

Control of the 3D FBK sensors leakage currents during pixel detector construction

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For the High Luminosity upgrade of the Large Hadron Collider, the current ATLAS Inner Detector will be replaced by an all-silicon Inner Tracker (ITk). The installation is foreseen during the next LHC Long Shut Down 3 (2026-2030). The new tracker has been designed to face the challenging environment associated with the high number of collisions per bunch crossing and the expected large integrated luminosity. Therefore, ITk design has been optimized to maintain the current tracking performance but in such much more hostile environment. The ITk consists of a Pixel detector in the innermost part and a Strip detector in the outermost part. Both detectors are arranged in a central

barrel section and two endcaps, to guarantee tracking hermeticity up to the very forward region of pseudorapidity 4.

Regarding the Pixel Detector, two different technologies have been chosen for the sensors: 3D and planar. Due to their intrinsic radiation hardness, 3D pixel sensor have been chosen to instrument the innermost layer of the Pixel detector while the other layers will use planar sensors. Two pixel cells have been chosen according to the detector location: a 25x100 um2 rectangular cell for the barrel, and a 50x50 um2 squared cell for the end-cap, to optimize the ATLAS detector performance. The 3D sensors are produced by two vendors: Fondazione Bruno Kessler (FBK, Italy) and Stiftelsen for industriell og teknisk forskning (SINTEF, Norway). Each 3D sensor is hybridized to a readout chip to form the so-called single bare module, and three bare modules are then assembled by a flex circuit in a triplet module.

Quality of the 3D sensors, namely their leakage current, is checked at any possible stage, i.e. at wafer level, after hybridization at single bare module level and finally once the sensors are assembled in the triplet module. Despite the yield at wafer level is pretty large, and only good tiles are used for the next steps, during the preproduction, it was realized that a significant part of the FBK sensors may generate an anomalous large current during the different stages. This evidence has called for an investigation to understand the occurrences of these large currents, their possible origin, and their evolution with time and radiation. Scope was to reduce the number of occurrences in production and to understand if this current is compatible with future detector operation in case the defect develops at a too late stage of integration or it is necessary to install them if better parts are missing.

This contribution will report on the yield of the anomalously high currents in 3D FBK preproduction and start of production sensors, and the results of the investigations done on the devices, including a few detectors irradiated to end-of-lifetime fluences.

Technology / 139

Microlens arrays for advanced silicon photon & radiation detectors

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Microlens arrays (MLAs) are widely employed for beam homogenisation and shaping, either as standalone optics or integrated with active components such as wafer-level optics (WLO). In image sensors, each microlens—commonly called an on-chip lens (OCL)—directs incoming light toward the active area of the pixel, improving photo detection efficiency (PDE) by boosting the effective fill factor. This is especially advantageous for front-illuminated sensors with inherently low fill factors.

We present recent progress in optimizing and integrating MLAs on high-performance single-photon avalanche diodes (SPADs) and silicon photomultipliers (SiPMs). In particular, the development of the latter is conducted in the context of CERN's next-generation Large Hadron Collider beauty (LHCb) scintillating fiber tracker (SciFi Tracker) located in a high radiation environment. Improvements of the PDE, external crosstalk and single photon time resolution are reported thanks to the MLA.

Our work tackles major challenges such as substrate variability (bare dies, packaged chips, full wafers up to 200mm), wide optical transmission (NUV to NIR), lens geometries spanning micrometers to millimeters, as well as radiation tolerance of the MLAs and operation at cryogenic temperatures.

Furthermore, our approach supports multi-project wafers (MPW), allowing multiple designs to be prototyped on a single wafer. This strategy significantly lowers development costs and accelerates time-to-market for research and industry partners.

These capabilities are offered through CSEM's MLA foundry services, providing end-to-end support from optical design and simulation to mastering, tooling, and UV replication. Our thermal reflow and UV-curing techniques guarantee ultra-smooth surfaces and precise alignment, even for complex detector architectures.

This scalable and flexible integration approach boosts next-generation photon detector performance for applications ranging from life sciences to advanced detectors for the CERN Large Hadron Collider.

LGAD 4 / 140

Characterization of ALTIROC-A modules for the ATLAS High-Granularity Timing Detector

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The High-Luminosity phase of the LHC (HL-LHC) will bring an increase in the instantaneous luminosity of the present accelerator by a factor of 7.5, leading up to 200 interactions per bunch crossing. This extreme pile-up environment will be a challenge for the track reconstruction performance of ATLAS, particularly in the forward region. To address this, the High-Granularity Timing Detector (HGTD) will be installed between the new Inner Tracker (ITk) and the calorimeters, covering a pseudorapidity range of $2.4 < |\eta| < 4.0$. It will provide precise timing measurements, with a resolution of 30 ps per track at the beginning of operation and up to 50 ps at the maximum HL-LHC fluence. This allows HGTD to recover the tracking performance in the forward region when combined with the ITk spatial resolution.

HGTD consists of 8032 modules, each composed of two hybrids, and a total of about 3.6M channels. A hybrid integrates a Low-Gain Avalanche Detector (LGAD) sensor bump-bonded to a dedicated front-end ASIC, called the ALTIROC. The readout cells have a size of 1.3 mm x 1.3 mm.

This talk will present recent performance studies of ALTIROC-A modules, the final version of the ASIC, ahead of the (pre-)production phase. The testbench characterization procedure will be described, including threshold tuning and connectivity tests. Results from testbeam campaigns will also be shown, highlighting the measurements of the hit efficiency and the timing performance of the modules.

Poster Session / 141

The LGAD-based Beam Monitoring detector for ATLAS (BMA)

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Accurate luminosity measurements are essential for stable machine operation and precision physics at the High-Luminosity LHC (HL-LHC), where pileup levels exceeding 140 interactions per bunch

crossing impose stringent requirements on fast and radiation-tolerant instrumentation. The Beam Monitoring detector for ATLAS (BMA) is a newly developed luminosity system designed to deliver robust, bunch-by-bunch measurements throughout HL-LHC operations. Its design is based on Low-Gain Avalanche Diodes (LGADs), which provide intrinsically fast signal rise times, high signal-to-noise ratio (SNR), and strong radiation tolerance - key features for resolving individual 25 ns bunch crossings in the HL-LHC environment.
This contribution presents the BMA detector architecture, including the LGAD sensor layout and the readout chain, all designed to operate under the high particle fluences expected at the installation position. The amplification of the detectors signal occurs far from the detector, allowing to reduce the radiation damage to the electronics, but still maintaining a high SNR. We report results from laboratory characterisation as well as the performance of prototype BMA detectors installed in ATLAS during the 2022–2025 data-taking periods. The LGADs performance - such as efficiency, gain stability, and gain degradation after irradiation - are analysed.
The results provide an assessment of the LGAD technology as a beam-monitor and luminosity detector in the LHC environment, indicating that the gain and the particle detection efficiency, relevant for bunch-by-bunch luminosity measurements, can be retained under HL-LHC conditions.

Poster Session / 142

Parylene Aluminium Filters (ParAlF) for Silicon based X-ray Detection Systems

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Next generation of high energy astrophysics missions require state-of-art Silicon based X-ray detectors to operate with maximum sensitivity, broad energy passband and microsecond timing resolution. Such high requirements demand minimal optical light contamination from outer space. While off-chip filter assemblies currently meet these operational requirements, they can degrade low energy X-ray response due to introduction of dead layers and entry of optical background radiations through detector-filter gaps. Supported by the INAF Fundamental Research Program 2023, with the ParAlF (Parylene Aluminium Filters) project we started to investigate the performance of glass slides and Si PiN detectors with on-surface Parylene and Aluminium thin film deposition. ParAlF is essentially driven by the performance requirements of Silicon Drift Detectors (SDDs) for the X and Gamma Imaging Spectrometer (XGIS) instrument proposed for the Transient High Energy Sky and Early Universe Surveyor (THESEUS) mission, however the outcomes of the project are suitable for any Silicon based X-ray detection systems beyond future space missions. This work reports the procedures utilized for glass and Si PiN sample characterizations, on-surface Parylene and Aluminium deposition processes and outlines the planned next steps derived from performance results.

LGAD 1 / 143

Processing and compression of signal shared AC-LGADs

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Resistive Silicon Devices (RSDs), particularly AC-coupled Low Gain Avalanche Diodes (AC-LGADs), open the path of pico-second level space and time (4D) tracking in high-energy physics (HEP) experiments such as those at the Large Hadron Collider (LHC), Electron-Ion Collider (EIC), and future (lepton) colliders facilities. These sensors combine the fine spatial resolution of segmented detectors with the excellent timing performance of LGADs, achieving nearly 100% fill factor. Unlike conventional detectors, typically structured as linear strip arrays (1D) or pixel matrices (2D), RSDs offer a highly flexible geometry for readout pads, allowing for optimization based on experimental demands.

When ionizing radiation interacts with these sensors, the generated charge spreads beyond adjacent pixels. This broad charge sharing, while beneficial for interpolation-based resolution enhancement, is complicated by reduced signal amplitudes and Landau fluctuations on pixels farther from the true hit location. To address these challenges, we study pixelated AC-LGADs fabricated at Brookhaven National Laboratory with different pad geometries, including square and triangular configurations with a 500 μm × 500 μm pitch, and analyze their impact on spatial resolution.

In contrast to previous studies, we leverage full-waveform information from each readout channel and utilize Recurrent Neural Networks (RNNs) to infer the full waveforms of the readout pads, given the hit's position and AC-LGAD structure, thereby reconstructing the hit position. The higher precision achieved by the classical charge-imbalance and geometry-based matrix inversion methods is leveraged by the amount of information processed by the networks, such as identifying optimal trade-offs between spatial granularity and data volume. Initial studies on Transient Current Techniques are used as inputs to further refine the algorithms with particle beams, where Landau fluctuations challenge the readout.

To support real-time applications and reduce computational load, we evaluate waveform rasterization techniques for compressing temporal signal data while preserving critical spatial information. These techniques are essential for future implementation on Field Programmable Gate Arrays (FPGAs) and other low-latency hardware platforms. Additionally, we conduct comparative studies of alternative geometric pad arrangements, assessing how shape and connectivity influence charge collection and algorithmic performance. These combined studies demonstrate the feasibility and scalability of using RSDs with flexible geometries, optimized readout configurations, and machine learning-enhanced reconstruction to meet the stringent resolution and speed requirements of next-generation high-energy physics detectors.

CMOS / 145

The Mu3e Vertex Detector

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Mu3e is an experiment designed to search for the charged lepton flavour violating decay $\mu^+ \to e^+e^-e^+$ and it will operate in two phases. Phase I, currently under construction, will take place at the πE5 beamline at PSI, using its intense DC surface muon beam of 10^8 μ^+/s to reach a sensitivity of 2×10^{-15}. Phase II will be built in the future High-Intensity Muon Beam (HIMB), to push the sensitivity to the 10^{-16} level. The nature of this decay imposes strict requirements on the detector system, especially concerning design compactness, material budget, efficiency and time resolution. This is reflected in the choice of Mupix11 as the silicon pixel sensor for the tracking system. Mupix11 is based on the HV-MAPS technology, which can deliver thin monolithic detectors while providing high performances. A first version of the Vertex detector, the innermost layers of the tracking system, has been produced and commissioned in 2025 at the PSI πE5 beamline. This campaign successfully validated several key features and proved the integration of the Vertex detector, along with other subsystems, with the high-intensity muon beamline under a 1 T magnetic field. These results represent a major

milestone towards readiness for Phase I measurements. This contribution will cover the experimental design, the sensor qualification and the first results from the recent commissioning run campaign at PSI.

LGAD 3 / 146

Comparing AC-coupled and DC-coupled resistive LGADs: strengths and weaknesses from TCT and test-beam studies

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Over the last decade, Low-Gain Avalanche Diode sensors (LGADs) and Resistive Silicon Detectors (RSDs) have significantly advanced silicon detector capabilities. LGAD sensors provide much improved time resolution thanks to the fast and large signals with optimized signal-to-noise ratio, achieving resolutions of 30 ps with 50 um-thick sensors. The addition of a resistive read-out to LGADs, as in the RSD sensors, enables precise concurrent measurement of the particle position, with spatial resolutions below 5% of the sensor pitch. These capabilities make RSDs a very promising candidate for silicon-based 4D tracking detectors of the future High Energy Physics experiments. RSDs are now available in two implementations, each defined by a different coupling between the read-out electrodes and the resistive layer. In this work, we present a preliminary comparison of AC-coupled (RSDs) and DC-coupled (DC-RSDs) resistive LGADs, fabricated at Fondazione Bruno Kessler (FBK). The performance of the two designs, in terms of spatial and temporal resolution, reconstruction efficiency and occupancy limit, is presented. The sensors have been studied using infrared TCT, TCT-TPA and 120 GeV-pion test-beam measurements. These results provide useful guidance for further optimization of the design.

Poster Session / 147

Design and implementation of a pulsed LED low light level source for measuring SiPM parameters

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The Silicon Photomultiplier (SiPM) technology has become widely embedded within the photodetection chain of detectors for high energy physics (HEP) experiments. Measuring the radiation hardness of commercial SiPMs involves careful characterisation before and after exposure to neutron or proton beams. Usually, laser beams are used in the measurements to extract the key parameters of SiPMs. Current study reports a novel circuitry for driving a LED with short pulses for emitting a low number of photons. The system is embedding a microcontroller for controlling two delay lines connected to a combinational logic circuit, with discrete-component logic, needed to generate a time variable trigger signal applied to a driver integrated circuit, further switching a gallium nitride transistor with the LED in high side configuration. The LTSpice simulations were found to be in agreement with experimental measurements, and a LED driving signal with a pulse width of 4 ns was obtained. This low cost implementation is suitable for SiPMs aging tests as well as for photodetection efficiency measurements at different wavelengths.

Invited 2 / 148

The Gain Layer Project –A study of radiation damage to gain layers

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Radiation damage is a concern for employing LGADs in the precision timing detectors at the HL-LHC and for other LGAD applications in strong radiation fields. The origin of the radiation induced loss of gain is found in a reduction of electric field strength in the highly doped gain layer, caused by an apparent de-activation of the acceptor doping and the formation of other defects impacting on the space charge, the so-called Acceptor Removal Effect (ARE). Successful mitigation techniques have been found in carbon co-doping of boron-based gain layers, while the exact defect kinetics behind the gain layer degradation remains still to be fully understood.
The study of radiation induced defects created inside the gain-layer of LGADs by standard defect characterization tools such as DLTS and TSC is very challenging and has so far not delivered stratifying results when studying LGADs. To overcome this challenge, we have produced an extensive set of silicon pin diodes on low resistive p-type FZ substrates mimicking the gain-layer doping. Across 25 wafers with about 19000 diodes and other test structures, various "flavours"of GLPDs (Gain-Layer Project Diodes) were fabricated to study the impact of different carbon doses, phosphorus co-doping, oxygenation and bulk resistivity. The GLPDs have been specifically designed for defect spectroscopy and will serve as the primary tool for defect studies in the coming years.
In this contribution we review the current understanding of radiation damage to gain layers and motivate the project. We then introduce the produced test structures including a detailed description of devices and the performed doping and processing steps for all material flavours. IV, CV, SIMS, DLTS, TSC and HALL measurements on the non-irradiated devices will be shown and discussed. Finally, results on a subset of devices exposed to 24 GeV/c protons are presented, including both isothermal and ongoing isochronal annealing studies of irradiated diodes. At present, neutron irradiations are being performed on a larger subset and we expect to present first results on these devices as well.
A discussion on the most probable mechanism of the Acceptor Removal Effects in p-type sensors and p-type gain layer LGADs will be given along with an outlook on further work in the project.

Poster Session / 149

Fast Timing and TCT Measurement Results of CNM double-sided 3D sensors

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Sensors with fast timing capabilities (on the order of tens of picoseconds) are a critical component of future tracking detectors. Such sensors provide the ability to disentangle high multiplicity events and to conduct time of flight measurements for particle ID. Silicon 3D sensors are capable of delivering this temporal resolution and additionally display an excellent radiation hardness, suitable for the harsh environments expected in future hadron colliders (e.g. FCC-hh). In contrast to regular, planar, detector technologies, they utilize columns etched orthogonal to the sensor substrate as their readout electrodes

In the course of the collaborative project "3D detectors optimized for timing applications", double-sided 3D sensors with two different column layouts, hexagonal and orthogonal, and different column

counts were designed and produced by CNM.

In this work, the results of fast timing measurements with a source setup as well as Top-TCT measurements will be presented. Furthermore, first data of proton-irradiated sensors will be shown.

Poster Session / 150

Application of exhaustive simulation flow for advanced performance prediction of monolithic active pixel sensors

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Monolithic active pixel sensor (MAPS) developments have pushed the detection performance in various directions, especially relative to timing where nanosecond-level precision is now considered. This evolution calls for a simultaneous upgrade of the simulation tools. We have developed a simulation flow that covers steps from signal creation in the sensitive volume to the output of the pixel digital logic that performs the time-of-arrival and time-over-threshold (ToA/ToT) measurements.

This approach adds several new features to the traditional use the of the TCAD - Allpix Squared duo:

- Precise location of the n-well and deep p-well implants, imported into TCAD from the pixel layout, allows to fully understand and highlight crucial aspects of the pixel behavior *ie.* evolution of the leakage current and potential punch-through current depending on sensor biasing and irradiation levels.
- Doping profile map with the damages introduced by the irradiation, obtained in the TCAD and exported to Allpix Squared, allows to reduce significantly the simulation time without loss in precision.
- Precise timing description of the current induced at the collection node, guarantee an embedded simulation of the front-end electronics with realistic signal events. Moreover coupling Monte-Carlo simulation (Allpix Squared) with high precision electrical simulations (SPICE), allow to benefit from the accuracy of both tools in a single iteration.

We applied this methodology to the MAPS developed in the context of the Belle II vertex detector upgrade [1]. The SuperKEK-B collider, located in Tsukuba, Japan, and hosting the Belle II experiment, will be upgraded in 2032 to reach a luminosity of 6.0 $cm^{-2}.s^{-1}$. To deal with the higher hit rate generated at this luminosity a new fully pixelated vertex detector is being developed –the VTX. All the VTX detection layers will be equipped with the same MAPS: OBELIX (Optimized BELLE II pIXel sensor). OBELIX is required to operate at room temperature after a NIEL fluence of $5{\times}10^{14}$ 1 MeV $n_{eq}.cm^{-2}$ and to provide time-stamping at 50 ns as baseline or 3 ns with increased power dissipation.

The OBELIX sensor chip is derived from the TJ-Monopix2 prototype (initially developed for ATLAS ITK outer layers [2]). Detailed in-beam characterization of TJ-Monopix2 has been performed to validate key performance [1, 2, 3].

In this contribution, we detail the key features of the exhaustive simulation, presents the outcome of the comparison with the TJ-Monopix2 measurements and discuss the interest of the methodology for the development of modern MAPS.

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[2] C.Bespin et al, "Development and characterization of a DMAPS chip in TowerJazz technology for high radiation environments"NIM A 1040 (2022) 167189, DOI: 10.1016/j.nima.2022.167189.

[3] D.Auguste et al, "Upgrade of the Belle II Vertex Detector with Depleted Monolithic Active Pixel Sensors ", JINST 20 (2025) 10, C10013, DOI : 10.1088/1748-0221/20/10/C10013.

Poster Session / 151

Results from an HV-MAPS-Based Detector Prototype for Position-Resolved μSR Measurements

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Muon Spin Rotation (μSR) is a well-established technique in material science for probing magnetic properties at the atomic scale. However, conventional μSR spectrometers based on plastic scintillators are fundamentally limited by coarse granularity and strict pile-up constraints, which restrict the usable muon rate and prevent spatially resolved measurements.
To overcome these limitations, we developed a pixel-based μSR detector using four ultra-thin HV-MAPS tracking layers based on MuPix11 sensor modules, which record incoming muons and decay positrons with high spatial precision. This enables accurate track reconstruction and a sub-millimeter determination of the decay vertex inside the sample. The approach further supports measurements of multiple samples and composite materials, while the resulting spatial information allows three-dimensional sample reconstruction and provides access to local magnetic fields by correlating vertex positions with the position-dependent precession signal.
The detector was operated multiple times at the πE3 beamline at PSI, demonstrating stable performance at beam intensities up to two orders of magnitude beyond the limits of scintillator-based systems. Its combination of high-rate capability and precise vertexing marks a significant step toward next-generation μSR spectrometers with full spatial sensitivity.

Poster Session / 153

How to operate a compensated LGAD

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This study presents parametric and MC analyses of the radiation resistance of compensated LGAD. Starting from measured values of the acceptor and donor removal coefficients, this presentation will illustrate the optimal initial concentrations of donors and acceptors to maximize the extent of LGAD's radiation tolerance. The presentation will provide quantitative predictions of the radiation resistance under various initial conditions and will illustrate the findings using results obtained with the Weightfield2 fast simulator and TCAD MC studies.

CMOS / 154

Simulation and characterisation of sensors with intrinsic gain in LFoundry 150 nm process

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With the development of high-luminosity colliders, need for 4D particle tracking has arisen. For this to be possible, tracking detectors have a requirement not only for high granularity, but also to have timing resolution of sub 60 ps .
To achieve this, the MiniCactusV2 chip has been designed to study the timing capabilities of non-amplified High Voltage-CMOS sensors, developed in the LFoundry 150 nm process (LF15A). The chip consists of pixels ranging in sizes from 1 mm x 1 mm to 0.5 mm x 0.5 mm. Data from two test beam periods in July 2025 and October 2025 show timing performance of 50 ps can be observed.
Although this achieves the time resolution requirement for 4D particle tracking, the pixel size limits the sensors spatial resolution. In this work, we present the performance of the Cactus Gain Layer (Cactus-GL) chip, a monolithic LGAD (Low-Gain Avalanche Diode) developed in the LFoundry 150 nm process. This device incorporates a novel buried gain layer within a traditional HV-CMOS sensor. The gain layer is implanted deep inside the silicon substrate, removing the need for segmentation and allowing the high fill factor characteristic of HV-CMOS technologies to be preserved. As a result, the goal of this study is to achieve sub-60 ps timing resolution while retaining high spatial resolution , making monolithic LGADs strong candidates for future high-granularity timing detectors.
The Cactus-GL contains six structures: one reference structure without gain, and five variants with differing inter-diode isolation designs. The chip has been fabricated with two gain-layer concentrations on both high-resistivity silicon wafers and epitaxial wafers. Initial results show breakdown voltages up to 260 V for devices on high-resistivity wafers, and up to 140 V for those on epitaxial wafers. Gain has been observed using Strontium-90 beta sources and IR laser measurements. The high-resistivity, high-gain-layer-concentration wafer exhibits the highest gain, enabled by its ability to sustain higher operating voltages.
We will also present measurements of inter-diode channel currents to demonstrate that segmentation of the gain layer is not required to suppress pixel-to-pixel crosstalk. Finally, we discuss planned future work, including a proton-irradiation campaign and the design of the next Cactus-GL iteration . Here, Technology Computer Aided Design (TCAD) simulations have been carried out to first understand the current iterations behaviour. Once this had been characterised within the simulations, further simulations had been carried out to optimise the chip design, with a focus on optimising breakdown voltage and sensor gain.

Poster Session / 156

Temperature dependence of the annealing behavior of silicon produced on 8-inch wafers for CMS HGCAL

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To face the higher levels of radiation due to the 10-fold increase in integrated luminosity during the High Luminosity LHC the CMS detector will replace the current endcap calorimeters with the new High Granularity Calorimeter (HGCAL). The electromagnetic section as well as the high-radiation regions of the hadronic section of the HGCAL (fluences above $10^{14} n_{eq}/cm^2$) will be equipped with silicon pad sensors, covering a total area of $620 m^2$). Fluences up to $10^{16} n_{eq}/cm^2$ and doses up to 1.5 MGy are expected.

The sensors are processed on novel 8-inch p-type wafers with active thicknesses of $300\,\mu$m, $200\,\mu$m and $120\,\mu$m and with each main sensor several small sized test structures are hosted on the wafers, used for quality assurance and radiation hardness tests. In order to investigate the radiation-induced bulk damage, the diode test structures of these sensors have been irradiated with neutrons at JSI (Jožef Stefan Institute, Ljubljana) to fluences up to $1.5 \cdot 10^{16} n_{eq}/cm^2$.

In this talk, the electrical characterisation and charge collection measurements of the irradiated silicon diodes will be presented. The study focuses on the isothermal annealing behaviour of the bulk material at temperatures of 5.5℃, 20℃, 30℃, 40℃ and 60℃ in order to extract the temperature dependent annealing time constants that allow scaling to temperatures such as the 0℃ foreseen as the shutdown temperature of the CE. Additionally, first results of a campaign investigating the effects of successive irradiation and annealing will be presented. This campaign mimics CMS' operating scenario at the HL-LHC, with a fraction of the end-of-life fluence accumulated in Run 4, annealing in the Long Shutdown 4, and remaining fluence accumulated in the final Run 5, by doing a two-step irradiation with in-between annealing.

Poster Session / 158

Development of an open-source FEM simulation tool for aluminum PCBs based on PALACE-FEM

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Aluminum PCBs are widely used in particle physics experiments because they offer a significantly lower material-budget than traditional copper-based solutions ($\mathrm{X_0} : \mathrm{Al} \approx 8.89\ \mathrm{cm}, \mathrm{Cu} \approx 1.43\ \mathrm{cm}$). This approach has already been adopted in several major experiments, such as ALICE ITS1/ITS2 and STAR. The integration of low-material-budget Kapton-aluminum PCBs with MAPS sensors is now being considered for next-generation detector systems, including IDEA (FCC-ee), ALICE3, and ePIC. Motivated by the growing interest within the community, Fondazione Bruno Kessler (FBK) started developing an innovative approach to Kapton-aluminum PCBs manufacturing. This effort

has produced the first results of a novel manufacturing process based on a Kapton and aluminum PCB, demonstrating its feasibility through the successful interconnection of an ALPIDE chip. The resulting PCB achieves an overall material budget of approximately 0.05%, comparable to the sensor X_0. To validate the electrical properties of these flexible PCBs, a dedicated simulation environment is required. Standard commercial software does not allow the modification of PCB parameters when non-standard materials, such as specific aluminum, polyimide or adhesive layers, are utilized. For this reason, the goal of this work is to develop a comprehensive simulation tool capable of incorporating realistic PCB properties derived from material-characterization techniques such as resistivity analysis or precise cross-section measurements with Plasma Focused Ion Beam (PFIB). The presentation focuses on Finite Element Method (FEM) simulations performed using the open-source PALACE framework to model the flexible PCB structures with high precision. In the initial phase, different meshing strategies and refinement parameters were varied to identify the optimal trade-off between computational cost and solution accuracy, with simulation results validated against IPC-2251 standards.
Then, S-matrix calculations were carried out for coplanar-waveguide (CPW) transmission lines and compared with vector network analyzer (VNA) measurements. The influence of different boundary conditions settings on the simulation accuracy is discussed, and preliminary results from the software validation against VNA data are reported.

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Comparison of Silvaco and Synopsys TCAD Predictions Including the Perugia Radiation Damage Model in Silicon Pixel Detectors for the HL-LHC

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At the High Luminosity Large Hadron Collider (HL-LHC), silicon pixel detectors will be exposed to radiation fluences about 5 to 10 times larger than those experienced by the current innermost pixel layers up to today.
Signal loss will be the main limitation to tracking and vertexing performance due to radiation damage in hybrid pixel detectors, with the increase in leakage current and depletion voltage posing severe constraints on operating conditions.
It is important to have reliable predictions for all observables - such as charge collection performance, leakage current level and breakdown voltage - after irradiation, in order to estimate operational voltage values and to test the robustness of tracking algorithms.
In this contribution, the predictions of Silvaco and Synopsys TCAD device simulations are compared when the surface and bulk defects and traps of the “Perugia radiation damage model” are included.
The results are quite promising regarding leakage current, electric field and trap statistics, at two distinct reference temperatures.

Poster Session / 160

Silicon Tracking for Particle Therapy and Space Radioprotection: recent results from the FOOT experiment

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The main goal of FOOT is to measure double differential fragmentation cross sections of light elements ($Z \leq 10$) in the energy range of 100–1000 MeV/nucleon, of interest both in medical and space-related fields. Particle Therapy is a medical treatment that uses charged particles with a tuned Bragg Peak to maximize the dose to tumors while minimizing damage to healthy tissue. Nevertheless, ion fragmentation along the beam path can alter dose distribution, making precise cross section measurements essential for accurate treatment planning. In space, cosmic rays interact with spacecraft materials, producing secondary radiation that can affect astronauts and electronics. Thus, accurate cross section measurements are crucial also for improving shielding strategies in Space Radioprotection.\\

At the core of the FOOT electronic setup is a magnetic spectrometer, which combines permanent magnets with a suite of silicon detectors. These include the Vertex Detector (VTX) and Inner Tracker (IT), both employing MIMOSA-28 CMOS MAPS sensors. The VTX provides $\sim 5\ \mu$m spatial precision for interaction point reconstruction, while the IT extends the lever arm for accurate momentum measurement. Together, they enable robust fragment tracking, even under challenging conditions such as significant pile-up, where multiple primary particles are reconstructed within the same event.\\

In this contribution, results from the 2025 CNAO data-taking campaigns about ^{12}C 200 MeV/n beam impinging on C and C_2H_4 targets will be shown. They regard the performance of the VTX and IT during full physics running, highlighting their stable operation and confirming the reliability of the silicon tracking system under realistic beam conditions.
In addition, the first tests performed on a prototype of the new Vertex Detector based on MIMOSIS technology will be presented, illustrating its potential to operate with a faster readout and to sustain higher particle rates in future data-taking campaigns.

LGAD 2 / 161

Characterisation of the first 55 µm thick nLGAD sensors from FBK

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We present the results from a new batch of silicon sensors with internal gain produced by the Fondazione Bruno Kessler (FBK, Italy). The sensors are p-in-n Low-Gain Avalanche Diodes, in which the high-concentration implant responsible for signal multiplication is formed by an n-type dopant (nLGAD). The nLGADs are made on thin epitaxial-type substrates, with an active thickness of 55 μm. A brand-new design of the p^{++} ohmic contact and the n^{+} gain implant has been implemented to account for the activation and diffusion of the dopant elements used in the batch. Fourteen different wafers are produced, with different diffusion and depths for the two implants, and two different dopants, namely Phosphorus and Arsenic. Moreover, an extensive R&D on the peripheral structures optimised for n-type thin substrates has been included in the batch. The nLGAD sensors will provide unique information on the donor removal mechanism at a concentration of about 10^{16} atoms/cm^2. This study will provide crucial knowledge for the design of the p^+-n^+ compensated LADs in the path to the extreme fluences. Moreover, nLGAD sensors are a valuable tool for detecting low-energy photons. Preliminary results on the sensors characterisation before and after irradiation will be presented and discussed.

LGAD 3 / 162

Transforming Single-Sided LGADs into Double-Sided Detectors, Concept and Proof-of-Principle Prototype Performance.

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The essential performance criteria for novel 4D tracking sensors are high-precision timing, fine spatial resolution, high-rate capability, and low material budget.

Low Gain Avalanche Diode (LGAD) sensors provide this combination of capabilities, which makes them valuable in high-energy physics, nuclear experiments, beam monitoring, and medical applications such as ionCT.
While widely used single-sided LGAD strip sensors offer excellent rate and timing capability, they require two layers to provide both X and Y position coordinates. Integrating both coordinates into a single sensor would significantly simplify experimental systems and reduce the active area's material budget.
Within a broader collaboration between several institutes, coordinated and led by the GSI, we have developed a concept to transform single-sided LGADs into double-sided detectors.
For this project, single-sided conventional strip LGAD sensors with a total thickness of 200 µm and an active thickness of 85 µm, produced in 2020 at FBK for HADES experiment, were used.
Importantly, this design enables dual-sided functionality without increasing the total sensor thickness, and the procedure can be applied to sensors with any active thickness.
This contribution details the concept and the processing steps required to fabricate these devices. We present results obtained using a 90Sr source and proton beam tests, which demonstrate the stable operation and expected performance of the prototype double-sided LGAD strip sensors. To our knowledge, this represents the first successfully operating prototype of a thin double-sided strip LGAD sensor.

Poster Session / 163

Simulation of 3D 4H-SiC pixel sensors

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Owing to their unique characteristics, 3D Silicon pixel sensors are the most radiation hard solution for particle tracking in HEP experiments. Both ATLAS and CMS chose to equip the innermost layers of their upgraded trackers at HL-LHC with 3D pixels, and productions are currently under way. Moreover, 3D pixels are also inherently very fast, allowing for remarkable timing performance both before and after irradiation at very large fluences. LHC-b intends to exploit these properties for the second upgrade of its Vertex Detector (VELO2).

In view of future experiments, like FCC-hh, we have started to investigate the possibility to use 4H-SiC for the fabrication of 3D sensors. In fact, Silicon Carbide would allow operation at room temperature with low leakage currents even after extremely large radiation fluences, so that no complex cooling system would be required. Moreover, the very high critical electric field of SiC would also allow to sizably increase the breakdown voltage, which currently represents one of the main problems in 3D Si pixels after irradiation.
As a first step in this activity, we have established a simulation platform, based on the combination of TCAD (Synopsys Sentaurus) and Monte Carlo (AllPix2) simulations, adapting to SiC the approach that we had previously developed for 3D Si pixels. TCAD models for SiC have been validated against experimental results available in the literature for planar sensors. Simulations of 3D pixels have first been implemented with a simplified two-dimensional domain (horizontal slice), before being extended to a more realistic three-dimensional structure.
In this contribution, we will present the initial results from this activity. In particular, two-dimensional distributions of the electrical and weighting potential and field, charge collection efficiency and signal time of arrival will be reported as a function of the active layer resistivity and bias voltage, for different pixel geometries, before irradiation. We are also starting to investigate the post-irradiation performance, based on existing radiation damage model available in the literature, featuring trap levels characteristics of radiation induced defects. Preliminary results will be reported.

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Characterization of iLGAD Sensors Coupled to the JUNGFRAU ASIC for High-Performance Soft X-ray Detection

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Inverse Low-Gain Avalanche Diode (iLGAD) sensors with a thin entrance window (TEW) have emerged as a promising technology for extending the applications of hybrid pixel detectors into the soft X-ray regime. The latest iteration of our TEW technology achieves a quantum efficiency exceeding 85% at 250 eV, comparable to state-of-the-art soft X-ray detectors, and the internal charge amplification of the iLGAD enables reliable discrimination of low-energy photon signals, reaching a signal-to-noise-ratio (SNR) greater than 5 down to 400 eV. In this contribution, we present the recent characterization results from iLGAD sensors bonded to the charge-integrating JUNGFRAU ASIC, with a focus on performance parameters relevant for both synchrotron and free-electron laser applications.

We report systematic measurements of sensor leakage current, gain stability, and equivalent noise charge for different pixel and gain layer designs at various temperatures and sensor bias voltages. Spatial-resolution studies are presented for detectors employing rectangular pixels, which exploit charge sharing to achieve sub-micrometer interpolation accuracy in one dimension, ultimately aiming to provide a high-performance detector option for Resonant Inelastic X-ray Scattering (RIXS). Furthermore, we discuss the spectral response of the current iLGAD generation, including challenges of the inverse LGAD configuration, such as the depth-dependent multiplication factor and reduced quantum efficiency at grazing incidence. Based on these characterization results, we conclude with an outlook on the new iLGAD R&D batch currently in fabrication and expected by mid-2026, which is designed to provide substantially improved quantum efficiency and higher intrinsic gain.

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Development and Simulation of 3D Silicon Pixel Sensors for the LHCb VELO Upgrade 2

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The High-Luminosity LHC will expose vertex detectors to unprecedented radiation levels, requiring sensors capable of withstanding high fluences in the $10^{16} - 10^{17}$ n_{eq}/cm^2 range while maintaining excellent spatial and temporal resolution. This work presents the development of 3D silicon pixel sensors for the second upgrade of the LHCb Vertex Locator (VELO), leveraging their intrinsically short charge-collection distances to achieve enhanced radiation tolerance and fast timing.

To identify optimal 3D sensor geometries, a simulation pipeline is being developed to explore a large parameter space. Design parameters under study include column diameter and spacing, sensor thickness, isolation structures (p-stop vs.\ p-spray), and electrode configurations for both single- and double-sided devices, with current efforts primarily focused on single-sided sensors due to an ongoing production run. Initial device-simulation studies have focused on breakdown voltage, capacitance, and electric-field behaviour, particularly in view of timing performance when coupled to the PicoPix fast-timing ASIC.

Following the device-simulation studies, the next step in the pipeline is a Monte Carlo track generator, which is now operational and provides charge-deposition patterns for arbitrary track angles, enabling a first systematic study of signal-formation dependence on the incidence angle, enabling comparisons between test-beam data and simulation results.The simulation pipeline is currently midway through integration, linking sensor-geometry optimisation, charge-transport modelling, and readout-electronics response. Experimental validation is being carried out through laboratory measurements and test-beam campaigns at the CERN SPS using a discrete electronic setup integrated with the Timepix4 telescope.

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N-type LGADs for Particle and Photon Detection

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Low-Gain Avalanche Diodes (LGADs) are typically fabricated on p-type substrates, following an n–p^+–p junction configuration, where a boron-doped layer forms the gain region.
This architecture is considered optimal for timing and particle-tracking applications since the primary charge carriers initiating the avalanche process are electrons, which feature higher drift velocity and ionization coefficient compared to holes. However, for the detection of low-penetrating particles, such as soft X-rays, the conventional p-on-n configuration becomes less efficient. In these cases, most carriers are generated close to the front junction (n-type region) or within the high-field gain layer, resulting in reduced gain and possibly lower signal-to-noise ratio (SNR).
To overcome these limitations and improve the detection efficiency of low-energy photons and particles, LGADs on n-type substrates (N-LGADs) have been recently proposed. This inverted doping configuration, compared to standard LGADs, is expected to deliver higher gain and SNR for low-penetrating radiation, particularly for X-rays below 1 keV.

The fabricated N-LGADs employ 55 µm-thick n-type epitaxial substrates, with the front junction formed by boron ion implantation. Several junction depths and doping profiles have been implemented to investigate QE and Gain vs interaction depth as a function of junction design. Electrical characterization (I-V, C-V, and gain measurements) will be presented for the different splits, along with optical characterization in the 380–950 nm wavelength range. The latter enables the determination of Gain and QE as a function of the charge generation depth, providing a comprehensive comparison among the various device configurations.

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Developments of glass-less TSV interconnections for SiPM at FBK

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FBK has been developing in the past few years a glass-less bulk-TSV (Through-Silicon Via) technology for 2.5D and 3D interconnections of photodetectors, in particular applied to silicon photomultipliers (SiPM). Such development is essential for applications where there is a need for space management, segmentation, or minimization of external optical crosstalk by removing the top wire-bonding protective resin. In this talk, the parametric characterization of the first full production batch of SiPM sensors implementing the TSV via-last approach will be presented. This batch was produced for the CTA+ project on FBK's NUV-HD-MT technology where the minimization of optical crosstalk, including external crosstalk, is of utmost importance. Preliminary yield characteristics and comparisons between the I-V characteristics measured with and without the TSV will be shown.

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Updates on 3D Silicon Detectors activities at FBK

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Thanks to their radiation hardness, demonstrated up to a fluence of $3{\times}10^{16}$ 1 MeV n_{eq}/cm^2, and their fast response times, 3D sensors are among the most promising technologies for meeting the stringent requirements of current and next-generation vertex detectors at the Large Hadron Collider (LHC). FBK has been actively engaged in 3D detector development for many years, introducing numerous process innovations and supplying sensors for CERN experiments, including CMS (CROC) and ATLAS (ITKPix), with these productions now nearing completion. We are currently fabricating a batch of Si-3D devices based on square pixels with 1E and 2E electrode configurations, with a minimum pitch of 45 µm, aiming to achieve a time resolution of approximately 30 ps even at extreme fluences up to 10^{17} n_{eq}/cm^2. Furthermore, we are carrying out technological tests aimed at achieving an aspect ratio of approximately 30:1, to enable the fabrication of fully through-going columns on thick substrates.

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Development of Segmented 4H-SiC LGADs

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This talk reviews the development of 4H-SiC Low Gain Avalanche Detectors as a next step in wide bandgap sensor technology. It will outline the material advantages of 4H-SiC including radiation hardness, thermal stability, and high breakdown strength, and then focus on the ongoing LGAD program led by the Czech collaboration with onsemi together with partners within DRD3 WG6.

A central part of the contribution is the development and evaluation of the first segmented LGAD structures produced in 4H-SiC. The presentation will highlight progress on segmentation design, charge-sharing behaviour, and early timing studies, supported by initial TCT and testbeam campaigns. In parallel, the stability and uniformity of the implanted gain layer are being investigated across wafers and compared with TCAD predictions to understand the achievable control of internal multiplication in SiC. These results frame the current status of SiC LGAD development and define the next steps toward robust, radiation-tolerant timing detectors for future high energy physics applications.

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The CMS pixel tracker upgrade for High-Luminosity LHC: from sensors to the full detector

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The Phase-2 upgrade of the CMS pixel tracker for High-Luminosity LHC is entering a crucial stage, with several Inner Tracker components already in production or transitioning from prototyping to full-scale manufacturing. System tests are ongoing to validate the performance of the upgraded detector, and integration is scheduled to begin in 2026 for all Inner Tracker subsystems.

The procurement and qualification of nearly 47,000 CROCv2 pixel readout ASICs, developed within the RD53 Collaboration, has been completed in 2024-2025. Pixel sensor production is also well advanced, with more than 90% of planar sensors and over 50% of 3D sensors delivered thus far. These readout chip and sensor batches have enabled the assembly of pre-production detector modules, including flip-chip hybrids from all vendors and covering all sensor technologies. Inner Tracker services, such as low-mass electrical links and flex PCBs for power and high-voltage bias distribution, are likewise progressing, with most components in production or nearing completion.

System test activities are intensifying across all pixel tracker subsystems, making use of an increasing fraction of final components. Current test setups support detailed thermal and electrical characterisation, validation of serial powering operation, and studies of optical readout performance.

This contribution will present an overview of the current status of the CMS pixel tracker Phase-2 upgrade, with a focus on the latest results from component production, module pre-production, and system-level testing.

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Current Status and Progress of the SiPM Camera Upgrade in the Prototype SCT

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The field of very-high-energy gamma-ray astrophysics is poised for a significant leap in sensitivity with the advent of the Cherenkov Telescope Array Observatory (CTAO), which will operate from two locations to achieve full-sky coverage. Among the proposed instruments for the medium-sized telescope (MST) class at the CTAO-South site is the Schwarzschild-Couder Telescope (SCT). This telescope adopts an innovative dual-mirror optical configuration and employs a high-resolution camera based on silicon photomultipliers (SiPMs). A prototype version of the telescope, the pSCT, was deployed at the Fred Lawrence Whipple Observatory in Arizona, USA. Even with a partially populated camera featuring a 2.7° field of view, the instrument succeeded in detecting the Crab Nebula in 2020 with a statistical significance of 8.6σ.

An extensive upgrade of the focal plane is now underway to equip the camera with 11,382 enhanced SiPMs, expanding the field of view from 2.7° to 8°. This improvement is expected to deliver excellent angular resolution (≈0.07°) and superior background rejection. In parallel, newly developed low-noise front-end electronics will lower the trigger threshold and refine event reconstruction capabilities. This work summarizes the pSCT project, highlights recent results, and outlines the progress and expected performance of the upgraded camera.

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Preliminary Results on the Timing Response of CMOS LGADs for the ALICE 3 Experiment

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ALICE 3 is an innovative experiment that will be installed at the LHC during Long Shutdown 4, replacing the current ALICE detector, and will operate in Run 5 (2036-2041). The new apparatus will be equipped with compact silicon-based timing detector to provide an excellent electron identification capability up to 500 MeV/c and π/K separation up to 2 GeV/c over a wide rapidity range. The Time-Of-Flight system will be composed by two barrel layers, the inner and the outer, and a forward one, based on state-of-the-art sensors with a required time resolution below 20 ps. The sensors will also need to withstand the expected irradiation levels, up to $10^{13}\ \mathrm{MeVn_{eq}/cm^2}$ in the forward TOF.

In this context lies the development of Low Gain Avalanche Diodes (LGADs) prototype in CMOS technology, featuring an internal gain layer beneath the collection electrode. This sensors are characterized by a 48 μm active volume and a particularly fast integrated front-end amplifier. Recent studies conducted within our RD program on standard LGAD prototypes have demonstrated that the time resolutions required by the ALICE 3 experiment can indeed be achieved by reducing the sensor thickness. However, the development of CMOS-LGAD sensors allows the integration of both the sensor and the electronics within a single substrate. This approach not only simplifies the system but also significantly reduces production costs, while maintaining the desired performance.

The first CMOS-LGAD prototypes with moderate gain were devoleped from an RD program carried out by ALICE and INFN ARCADIA introducing a gain layer in the CMOS Monolithic Active Pixel Sensors produced by LFoundry in the 110nm technology. The characterization was performed both in the laboratory, using a pulsed 1054 nm laser to estimate the electronic jitter contribution, and in several test-beam campaigns at the CERN Proton Synchrotron with 10 GeV/c proton and pion beams to evaluate the overall time resolution. The measured jitter was found to be about 30-35 ps, while the time resolution of the devices with the highest gain is about 75 ps at room temperature. An overview of the current state of the RD and future plans aimed at achieving the time resolutions required by the ALICE 3 experiment will be presented. In particular, this contribution will discuss the performance in terms of time resolution as a function of the sensor temperature, as well as the in-pixel efficiency.

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Effects of Microwave Annealing on Surface and Bulk Defects in Silicon Devices

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Bulk and surface defects in semiconductor devices are known to cause negative effects, including increased leakage current and increased charge trapping. Radiation from both high energy photons and particles (typically neutrons or protons) increases these negative effects, and will eventually render the device unusable. Previous studies have been performed demonstrating microwave annealing as an effective technique for low-temperature activation of dopants and reduction of interface defects in some limited applications, but have not considered using microwave annealing to enhance

silicon radiation sensors, or microwave annealing of radiation induced defects.
In this study, we investigate the impact of microwave annealing on defects in devices fabricated with sensor-grade float-zone silicon, evaluating their behavior both before and after irradiation. A set of MOS capacitors, gate-controlled diodes, and PIN diodes were irradiated at the Gamma Irradiation Facility (GIF), and a set of silicon photomultiplier sensors (SiPMs) and PIN diodes were irradiated at the McClellan Nuclear Research Center. Several parameters pertaining to surface and bulk defects are measured for these devices, such as the surface current density, oxide charge density, carrier lifetime, and dark count rate in the SiPMs. Following microwave annealing, improvement in some of these parameters are observed both for unirradiated and irradiated devices.

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Characterization of X-ray Radiation Effects on Ferroelectric Materials for Improved Electronic Devices

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Future High Energy Physics (HEP) experiments demand particle detectors with unprecedented performance, particularly in terms of radiation hardness, low power consumption, and enhanced signal detection in increasingly harsh environments. This work explores the significant potential of ferroelectric MOSFETs (FeFETs), leveraging their unique negative capacitance (NC) properties, as a promising solution for these challenges. We discuss their radiation hardness, critical for long-term stability under high radiation fluences. Their electrical characteristics before and after X-ray irradiation up to 100 Mrad(SiO2) is presented.

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SiPM Characterization in a Wide Temperature Range and for High Irradiation Level for the LHCb RICH Upgrade II Detector

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The LHCb experiment at CERN plans to have a major upgrade, the so called LHCb Upgrade II, in order to increase the instantaneous luminosity at the LHCb interaction point to ˜1.5 x 10ˆ34 cmˆ-2sˆ-1 starting from 2035. Increasing the luminosity by a factor of ˜7 compared to the current experiment requires major upgrades to the LHCb detectors. Part of the LHCb Upgrade II project is the replacement of the present RICH photon detectors (MAPMTs) with sensors which can guarantee optimal particle identification performance at the High-Lumi conditions. This is a challenging task since the photo-sensors must have single photon detection capability and good spatial and time resolution in a very high radiation environment.

SiPM is a candidate technology, given the small dimensions, fast response, high detection efficiency and relatively low cost. Their main drawback is the dark count rate which increases rapidly with radiation but can be mitigated by lowering their working temperature. Extensive studies are ongoing to understand how their performance degrade with radiation and how they recover with annealing at higher temperature.
In this work we will present the full characterization of 45 commercial SiPMs (MPPCs) from Hamamatsu Photonics, model 13360-13xxPE, of three different micro-cell sizes: xx=25, 50 and 75um and with an active area of 1.3 x 1.3 mmˆ2. For each device, results will be presented for the direct and reverse I-V curves, the gain, the DCR and the time resolution, measured at five temperature steps, from room temperature down to the liquid Nitrogen temperature. After the initial characterization, the SiPMs were irradiated at the TRIGA II reactor in Ljubljana at five neutron fluences steps, from 3 x 10ˆ11 up to 6 x 10ˆ13 1MeV-neq. After the irradiation the SiPM were characterized again, to quantify the degradation of the parameters as a function of the fluence and of the temperature. Results will be presented, together with first measurements after a subsequent annealing campaign.

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Photon detection using 3D sensors with geometrical gain: The OPTIME 3D silicon sensor

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Within the INFN OPTIME project, we present the latest characterization results of a novel 3D silicon sensor developed as a core component of a multistage photo-detector system for fast timing with resolutions below the ps threshold. The presented device is based on FBK double-sided 3D silicon technology and is optimized for low-energy electrons and photon detection. Extensive electrical and functional tests have been performed to assess its performance, including studies of its charge collection and time response using Trans Current Technique (TCT).
The results from the characterisation campaign show an intrinsic time resolution below 1 ps, displayed during TCT scan as well as the presence of a stable intrinsic charge gain without the need for a dedicated gain layer up to a factor of 10 at 200 V bias volage, indicating the potential for radiation-tolerant silicon sensors with internal amplification. While its primary application is in fast-timing detectors, we also explore its suitability as a compact, high-resolution photosensor. Such versatility could enable its use in fields requiring precise timing, such as at pulsed fs X-ray facilities.
In this work we will present the overall characterisation of the device, its performances after TCT scan and show its future applications as a fast-timing sensor

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Current and low-field carrier mobility in silicon sensors irradiated to extreme fluences

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We present a study of the forward and reverse currents in silicon pad diodes irradiated to extreme neutron fluences of up to $1\times10^{18}\ n_{eq}/\mathrm{cm}^2$, slightly more than the expected fluences at the innermost radii of tracking detectors at a future circular hadron collider.

At such high fluences, the low-doped silicon bulk and the highly doped implant no longer behave like a typical pn diode. Excess free carriers are trapped at radiation-induced deep defects, compensating ionized shallow defects in the bulk. Consequently, the carrier concentrations in the bulk decrease and become similar to those in intrinsic silicon, increasing the resistivity of the bulk. The interaction between ionized defects and free carriers leads to increased Coulomb scattering, causing a decrease in the low-field carrier mobilities with fluence.

To quantify the mobility degradation caused by ionized impurity scattering as a function of fluence and to obtain a qualitative understanding of the diode's electrical performance, current-voltage characteristics were measured for fluences ranging from 9×10^{14} to $1 \times 10^{18}\ n_{eq}/\mathrm{cm}^2$ at various temperatures. These measurements are compared to TCAD simulations using different radiation-damage models to evaluate their ability in reproducing the observed currents at such extreme fluences, and to gain insight into the underlying physical processes driving these changes.

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Calibration and tuning studies of the Mu3e Vertex Detector

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The Mu3e experiment searches for the charged lepton flavour violating decay μ+⟶e+e−e+ with a target sensitivity of 10e-16.
This poster presents the beam-based calibration and tuning studies of the Mu3e Vertex Detector performed during the commissioning run in 2025 at PSI in πe5. The work includes LVDS signal transmission studies, Time-over-Threshold (ToT) adjustment, and per-pixel threshold tuning using TDACs, including pixel masking for noise suppression.
Through these calibration and tuning procedures, operating conditions for stable and efficient data taking could be established.

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Design of Monolithic Low Gain Avalanche Detectors (LGADs): A TCAD Simulation Study

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Monolithic chips that integrate sensors and electronics can significantly reduce the material budget and system complexity caused by interconnections. Low Gain Avalanche Detectors (LGADs), featuring picosecond-level time resolution, are widely used in particle physics experiments, and the Monolithic LGAD represents a crucial future development direction for this technology. The monolithic design integrates the LGAD sensor and front-end readout electronics onto the same substrate, thereby enhancing cost-effectiveness and expanding the application range of LGADs. This paper presents a novel monolithic LGAD structure that achieves sensor-electronics integration by depositing an epitaxial layer on top of the LGAD for the fabrication of electronic circuits.
Based on two-dimensional Technology Computer-Aided Design (TCAD) process and device simulations, this study analyzes the impact of key parameters on the performance of the monolithic LGAD sensor, including the doping concentration and thickness of the epitaxial layer, the doping concentration and depth of the isolation P-well for the electronic circuits, and the LGAD anode voltage. Simulation results demonstrate that an increase in the epitaxial layer thickness leads to a decrease in the LGAD breakdown voltage, while increasing the doping concentration of the isolation P-well can reduce the crosstalk between the LGAD and the electronic circuits. Furthermore, the signal response of the LGAD combined with the epitaxial electronic circuits under particle incidence is simulated. This structure provides new design insights and a theoretical basis for addressing the challenges of integrating sensors with electronics.

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The Performance study on LHCb UP Detector in Upgrade II

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The LHCb experiment is planning a second major upgrade (Upgrade II) in the 2030s, with the goal of increasing the instantaneous luminosity to 1.0x1034 cm−2s−1. This upgrade aims to enhance the study of heavy flavor physics and to search for potential signals of new physics in the beauty and charm quark sectors. To operate under the demanding conditions of Upgrade II—characterized by higher radiation levels and significantly increased data rates—the LHCb detector will undergo substantial upgrades. For instance, the current Upstream Tracker (UT), which is based on silicon strip sensors, will be replaced by a new pixel sensor detector, known as the Upstream Pixel Tracker (UP).

The primary function of the UP detector within the LHCb tracking system is to reduce the rate of ghost tracks and accelerate track reconstruction, particularly within the LHCb trigger system. It also enhances the reconstruction efficiency for long-lived particles such as KS0 and Λ0. Currently, the detector is in the research and development (R&D) phase, with the goal of delivering the Upgrade II Technical Design Report (TDR) by 2026.

The presentation begins with an overview of the UP detector design, including the detector layout and the pixel sensor chip options under consideration from different foundries. It then presents simulation studies of the new UP detector and discusses its expected performance under the LHCb Upgrade II conditions.

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Time of Arrival and Charge Collection Studies in 3D Double Column Double Type Silicon Detectors Using Multi-Photon TCT Techniques

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In this work, we present our studies on the time of arrival and charge collection in various 3D Silicon Double Column Double Type (3D-DCDT) structures. Both single-cell configurations (with the central cell biased and surrounding cells grounded) and multi-cell configurations (with all cells biased) are investigated, considering square and hexagonal arrangements of ohmic (p^+) cells. The devices were characterized using Single Photon (SPA) across multiple wavelengths and Two-Photon Absorption (TPA) Time-Resolved Charge Collection (TCT) techniques at 1550 nm. Preliminary results from Three-Photon Absorption TCT measurements are also reported. Devices were fabricated at CNM Barcelona within the 3D RD50 Common Project and irradiated at the Josef Stefan Institute with fluences of 10^{15} and 10^{17} neq/cm^2. Measurements were conducted both with and without the amplifier connected to the sensor readout, and the results are analyzed in relation to the charge density injected in the low- and high-electric-field regions of the devices.

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Development of hybrid perovskite on silicon X-ray detectors

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This contribution discusses the path towards the demonstration of hybrid X-ray detectors combining a high-stopping-power perovskite absorption layer and a CMOS silicon active layer with integrated readout electronics. Unlike typical hybrid detectors, the proposed concept features direct electron injection from the perovskite absorber into low-capacitance sensing sites, which is essential for low-noise readout. The perovskite's high stopping power enables high detection efficiency for X-rays in the 10s keV range, potentially improving Detective Quantum Efficiency (DQE) and spatial resolution over current mainstream detectors. The silicon integrated circuit is post-processed to allow for backside deposition of perovskite material, targeting a thickness of the order of 100 µm. A gradual approach is pursued towards the final goal, starting with the fabrication of passive pad detectors and later moving to an array of active pixel detectors. Perovskite single crystals are grown using bottom-up lithography techniques (microfluidics and dewetting) to produce self-assembling, detector-grade semiconductors. The growth conditions have been optimized to first obtain a sensitive area in the mm^2-range, capable of covering a small-size pixel array, and providing a path to assess the scalability

of the process. The first results, current challenges and future progress towards the demonstration of a hybrid perovskite-on-CMOS pixel array will be discussed at the workshop.

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Small Pixel IME-CAS 3D Silicon Sensors with Gain Characterized with Multi-Photon TCT

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Small-pixel 3D sensors were fabricated by IME-CAS on 8-inch p-type wafers (700 Ω·cm) with a thickness of 30 µm, featuring trench walls (ohmic p^+) and narrow n^+ columns (0.5 µm diameter). A 5×5 matrix of $35\times35\,\mu m^2$ pixels was characterized using Two-Photon Absorption Transient Current Technique (TPA-TCT); we varied the TPA depth, laser intensity, pulse duration, and bias. At higher bias voltages, the devices exhibit stable operation with intrinsic gain from impact ionization near the n^+ junction (without dedicated gain-layer doping). Cross check with SPA (800 nm) was additionally performed. Both irradiated and non-irradiated samples were measured to investigate charge collection, gain and timing after radiation exposure. The effect of the amplifier on signal shape and tail was also evaluated by connecting and disconnecting it during tests. Irradiated samples were studied using both 2PA and 3PA.

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Results and perspectives of the IGNITE project on the development of CMOS 28-nm technology ASICs

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The IGNITE project develops technical solutions for the next generation of trackers at colliders. It plans to implement an integrated module, comprising sensor, electronics, and fast readout, aimed at fast 4D-tracking. System pixels are required to have pitch around 50 µm and time resolution below 30 ps on the full chain (from sensor to time to digital conversion).
In the present paper we present recent measurement results concerning the performance of a prototype ASIC (Ignite64), which features a pixel matrix of 64x64 pixels, having 55 µm pitch.
The ASIC explores circuital solutions for Analog Front End and Time-to-Digital Converter circuits and is dedicated to the characterization of fast timing silicon sensors. Performed measurements show that the AFE and TDC have time resolution below 20 ps rms, with very small performance dispersion across the full pixel matrix and satisfying the given system requirements.
The structures integrated into the Ignite64 prototype have been validated for integration in a larger area ASIC, named the Ignite-ER, featuring a 320x256 pixel matrix, 45 µm pitch. We will also present design criteria and expected performance of the Ignite-ER ASIC, to be submitted in the coming months.

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Sensor R&D for VELO Upgrade 2

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LHCb plans an Upgrade II detector for 2034 to operate at luminosities of 1.0x10$^{34}cm^{-2}s^{-1}$, accumulating over 300 fb^{-1}. This will result in about 30 interactions per crossing, producing approximately 1500 charged particles within acceptance.

The higher luminosity requires a new VErtex LOcator (VELO) with enhanced capabilities to handle increased data rates, radiation levels, and occupancies. New techniques are needed to assign b hadrons to their primary vertices and perform real-time pattern recognition, involving a new 4D hybrid pixel detector with advanced rate and timing capabilities.

Prototype front-end ASICs are under design in 28 nm technology, including large processing power and rapid analog response, which requires fast rise times and high power consumption, yet limited by vacuum operation and cooling constraints. The ASIC must handle extreme hit rates and added timing information. The sensor must provide time measurements with 35 ps resolution and resist to 2.5x10^{16} 1 MeV n$_{eq}$ cm^{-2}, while keeping the and spatial resolution below 10 µm.

The mechanical design will minimize material and achieve an integrated module with thinned sensors and ASICs combined with lightweight cooling.

This presentation will highlight promising technologies for the LHCb upgrade, emphasizing timing precision for vertexing in next-generation detectors. Recent beam test results on time measurements and R\&D of new sensor technologie will be presented.

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New time-of-flight ion imaging system based on LGADs

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Time-of-flight ion computed tomography (TOF-iCT) is a promising imaging modality for improving dose conformity and range accuracy in ion beam therapy by enabling direct reconstruction of patient stopping power (SP) images using clinical ion beams.

The realisation of TOF-iCT critically depends on detector technologies that combine high spatial precision with ultra-fast timing to enable the reconstruction of individual ion tracks at clinically relevant beam intensities, a requirement that can be fulfilled by Low Gain Avalanche Diodes (LGADs).In this contribution, we present our new TOF-iCT demonstrator system, which consists of 12 single-sided LGAD strip detectors that can be simultaneously operated as a TOF-iCT system with a TOF-calorimeter and in the so-called Sandwich TOF-iCT mode.

In this contribution, we report on the development of a TOF-iCT demonstrator based on 12 single-sided LGAD strip detectors, operable with a TOF calorimeter or in the Sandwich TOF-iCT configuration. Imaging results from a sacrificed mouse are presented, along with ongoing efforts toward in vivo imaging of live mice. Key challenges related to fast 4D tracking of different ion species and the identification of nuclear fragments are discussed.

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Recent developments in Low Gain Avalanche Diodes

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The silicon sensors known as Low Gain Avalanche Diodes, or LGADs, are widely considered for fast-timing applications, especially in high energy and nuclear physics, thanks to an intrinsic gain that allows the production of a controlled avalanche of carriers, with multiplication on the order of 2-100. This technology can provide time resolution of about 20-30 ps, and some of its variants can

provide precision tracking too at the 10-micron level, for example AC-coupled LGADs (AC-LGADs). The LGAD technology will be used for timing detectors in several experiments, including the Electron Ion Collider (EIC) for 4D detectors, medical physics, among others.
A robust R&D is on-going to make LGAD faster, i.e. <20 ps time resolution per hit, more reliable under different experimental conditions, including high radiation and extreme temperatures and humidity environments, as well as to understand their performance in detecting highly ionizing particles. Innovative machine learning techniques have also being studied to improve the performance of such devices using the pulse shape characteristics. Read-out electronics are being developed to read LGADs with low jitter and precision spacial resolution for pixel and strip sensors. This presentation will review the status of such R&D on the LGAD technology carried out at Brookhaven National Laboratory (BNL), within the DRD3 Collaboration at CERN.

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Development of Germanium Drift Detectors for Hard X-Ray Spectroscopy

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The growing demand for semiconductor detectors capable of sensing high-energy photons with exceptional energy resolution has driven interest in high-Z materials. Among these, germanium is particularly attractive not only for its ability to exceed the 20 keV energy threshold of silicon-based devices, but also for offering superior energy resolution compared with other high-Z materials.
Nevertheless, fabrication challenges have so far confined germanium detectors to simple p–i–n diode architectures. Despite the widespread use of germanium detectors in these conventional geometries, more advanced architectures such as drift detectors have yet to be realized in this material system. In this work, we investigate the adaptation of the silicon drift detector (SDD) topology to germanium.
This contribution will present the sensor design, fabrication strategy, initial electrical characterization and spectroscopic performance.

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Investigating the behavior of amorphous-Silicon pixels under UHDR flash proton irradiation

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Particle and radiation therapy are leading tactics to combat chronic and malignant cancers. Ultra-high dose rate proton therapy promises higher radiobiological advantage and increased effectiveness in targeting tumor cells while sparing healthy cells, by providing the total dose in a short time at a rate higher than 40 Gy/s .
This work aims to characterize the charge acquisition of hydrogenated amorphous silicon (a-Si) pixels under proton flash irradiation. A-Si gains particular interest due to its capacity to produce large-scale and high-resolution flat panel detectors at an affordable cost with improved radiation hardness.
A test board of 2.4 x 2.4 mm aSi pixel array was acquired and bonded to test under flash proton

irradiation at MedAustron in Vienna. The test plan was to irradiate using a single spot at different spill lengths and spill numbers to test the behavior from conventional to flash regimes for dose rate dependence measurements. Additionally, a calibrated ionization chamber fitted for flash proton measurements (IBA PPC05) was placed at the isocenter for dose and spill length verification. The chamber was connected to the IBA DoseX electrometer equipped with an API measuring at a rate of 1 KHz. A Flat Panel was placed behind the pixels for beam spot positioning.
Analyzing dose rate dependence, measurements were normalized twice by the dose measured via the PPC05 and the average. The integration time was kept the same at 10s for all measurements. At higher dose rates, the normalized charge increases until it reaches a plateau, then saturates in the flash regime. This is expected since at higher current, charge traps get filled the higher the dose rate, until all the charge traps saturate.
To test for radiation hardness, dose sensitivity was measured before and after heavy irradiation of 5.56 × 10¹⁰ protons (in the active region) using a clinical map. The sensitivity was reduced by 10%.
The results show proper reproducibility and dose linearity. With calibration needed for dose rate dependence. Additional irradiation campaigns are planned soon to examine the Bragg peak quenching at different bias voltages.

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Welcome by the Directors of INFN-Perugia and the Department of Physics and Geology

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Logistic

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