1st DRD3 week on Solid State Detectors R&D

Monday 17 June 2024 - Friday 21 June 2024

CERN

Book of Abstracts

Contents

WG4 - Simulations / 1

A lightweight algorithm to model radiation damage effects in Monte Carlo events for High-Luminosity LHC experiments

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Radiation damage significantly impacts the performance of silicon tracking detectors in Large Hadron Collider (LHC) experiments such as ATLAS and CMS, with signal reduction being the most critical effect. While adjusting sensor bias voltage and detection thresholds can help mitigating these effects, generating simulated data that accurately mirrors the performance evolution with the accumulation of luminosity, hence fluence, is crucial.
The ATLAS and CMS collaborations have developed and implemented algorithms to correct simulated Monte Carlo (MC) events for radiation damage effects, achieving impressive agreement between collision data and simulated events.
In preparation for the high-luminosity phase (HL-LHC), the demand for a faster ATLAS MC production algorithm becomes imperative due to escalating collision, events, tracks, and particle hit rates, imposing stringent constraints on available computing resources. This article outlines the philosophy behind the new algorithm, its implementation strategy, and the essential components involved. The results from closure tests will be presented; some preliminary
results on computing performance will be commented too.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG7/WP4 - Interconnect technologies / 3

Highly Integrated All-Silicon Detector Modules - Belle II PXD and beyond

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We will present and discuss the lessons learned during the R&D and production phase of the all-silicon detector modules for Belle II PXD. The focus will be on technology and quality control in the production phase. The same technology is also being utilised for direct electron detectors and is now being extended to incorporate active cooling with integrated micro-channels.
Finally we will discuss the future plans and the extension of the interconnection technology at the MPG HLL including low temperature direct and hybrid bond techniques for heterogeneous integration.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 4

Characterization of the RD50-MPW4 HV-CMOS pixel sensor

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The RD50-MPW4, the latest iteration in the HV-CMOS pixel sensor series developed collaboratively by the CERN-RD50-CMOS working group, marks a significant advancement in the RD50-MPW series. Rooted in generic research and development, the RD50-MPW program aims to address challenges posed by future physics experiments, such as HL-LHC and FCC, focusing on radiation tolerance, granularity, and timing resolution. Fabricated by LFoundry using their 150nm High Voltage CMOS process and delivered in December 2023, this sensor incorporates an active matrix of 64 x 64 pixels with a pitch of 62 x 62μm^2. The chip uses a column-drain readout architecture in the FEI3 double-column style.

While the predecessor, the RD50-MPW3, is an advanced prototype in our R&D program (mid-sized pixel matrix, with advanced digital periphery), problems due to noise coupling effects between the digital periphery and the pixels, caused limitations on threshold settings to
$gtrsim 5ke^-$ while also restricting matrix operation to the top half.

The improved architecture of RD50-MPW4 effectively mitigates crosstalk through carefully separated power domains between digital and analog components, enabling more sensitive threshold settings while simultaneously operating the entire matrix. A new post-processing step facilitating backside-biasing, as well as the implementation of an improved guard ring structure allowing the RD50-MPW4 to accommodate bias voltages >500V further boost the radiation hardness of the revised design.

This presentation will summarize preliminary measurements and compare the results with the predecessor chip, highlighting the improvements in our latest design. Laboratory assessments, including I-V measurements, an in-depth exploration of the trimDAC capabilities in harmonizing pixel responses, and an examination of the impact of threshold settings on pixel response, will be presented. Additionally, insights from a test beam conducted at DESY in Apr. 2024 will contribute valuable information on the sensor's spatial resolution, cluster-size distribution, and total as well as in-pixel efficiency.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 5

First Results from the Planar Run of the RD50-SiC-LGAD Common Project

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The RD50-SiC-LGAD common project initiated by HEPHY aims to investigate, design, and manufacture 4H silicon carbide (4H-SiC) LGADs.
SiC LGADs are a key development required to overcome the main drawbacks of SiC: high ionization energy and limited epi thicknesses, which limit the charge signal in SiC detectors, especially for MIPs. Furthermore, due to the high charge carrier mobilities and the multiplication of holes (instead of electrons in Si), SiC-LGADs could enable unprecedented timing performance.

As a part of the RD50-SiC-LGAD project, a first run of planar detectors designed by HEPHY was carried out before manufacturing 4H-SiC LGADs. The planar run aims to better characterize and understand the material properties of 4H-SiC, validate the detector design, and, in the future, assess the radiation hardness of 4H-SiC with large statistics.

We present the first results from SiC detectors manufactured by IMB-CNM on 6' wafers with 50 and 100 um high-quality epi layers. We first report on the yield characterization and electrical properties measured at the wafer level during spring 2024. Finally, we present preliminary results of the particle detection performance using alpha particles, UV-SPA-TCT, and the proton beam at the MedAustron synchrotron.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG4 - Simulations / **7**

Allpix Squared - Semiconductor Detector MC Simulations for Particle Physics and Beyond

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Allpix Squared is a versatile, open-source simulation framework for semiconductor detectors. It enables detailed numerical simulations for both single sensors and more complex setups with multiple detectors. While originally developed for silicon pixel detectors in high-energy physics, it is capable of simulating a wide range of detector types, semiconductor materials, and geometries for a variety of different application scenarios. It has a wide user base, good documentation, and an active community participating actively in the forum and the yearly workshops.

The framework is based on an extensible system of modules that implement the individual simulation steps. The modules include an interface to Geant4 for describing the interaction of particles with matter, various algorithms for charge transport in the sensor, and for digitizing the signals in the front-end electronics. Detailed field, potential, and doping maps imported from TCAD simulations can be used to accurately model the motion and recombination behavior of charge carriers. The framework comes with a variety of mobility, recombination and trapping models as well as impact ionization for low-gain applications.

This presentation gives an overview of the framework and its components, and highlights recent developments. It also points out the various possibilities to contribute to the project, along with the relevant developer documentation.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 8

Defects Induced by 1 MeV Electron and Co-60 Gamma Irradiation in Boron-Doped Silicon

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This study investigates radiation damage in CZ p-type silicon pad diodes irradiated with 1 MeV electrons and Co-60 gamma rays, using Capacitance Deep-Level Transient Spectroscopy (C-DLTS), Current Deep-Level Transient Spectroscopy (I-DLTS) and Thermally Stimulated Current (TSC) techniques. The results are compared to those of Co-60 gamma-irradiated epitaxial (EPI) silicon material. In CZ material, a unique compensation capacitance behavior was observed, possibly linked to a defect not detected in irradiated EPI bulk. Additionally, the introduction rate of the BiOi defect, a candidate for so-called acceptor removal, was found to be lower in CZ material, likely due to its higher oxygen content. These findings suggest pronounced differences in radiation-induced defect formation and behaviour between CZ and EPI silicon materials.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 9

DMAPS development at PSI

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PSI is developing DMAPS prototype chips with time of arrival measurements for potential use in small scale physics experiments at PSI and also for detectors used outside the field of particle physics. After the production of a first basic prototype in the TSI 180nm process node we have recently

switched to LF 150 and just submitted a design in a MPW run. We will present the design of this first LF15 DMAPS chip and included test structures.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

other

WG7/WP4 - Interconnect technologies / 10

Interconnections and multi-chip flex developments

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A significant effort is underway to develop large area and lightweight modules using monolithic sensor demonstrators. These studies are performed within CERN's R&D programme on technologies for future experiments (EP R&D). A novel flex PCB has been designed to reduce the material budget as much as possible while ensuring dense packaging maximising the active area in the detector. Scalable interconnection technologies enable production targeting large detector surfaces. These technologies include ACF/ACP (Anisotropic Conductive Film/Anisotropic Conductive Paste), epoxy-supported gold studs, and nano-structured pads (nano-wires). Nano-wires have been deposited with a diameter of 0.4 - 0.6 µm and a length of 3-5 µm onto sensor pads of a monolithic sensor chip (MALTA2). The optimized process has demonstrated a near 100% pad yield, enabling usage on large chip quantities at wafer level. It further allows for the reliable bonding of sensors housing a large number of bond pads. We show how nano-wires can be used in different bonding methods such as cold welding, copper sintering, and glue-assisted bonding enabling the bonding of a wide variety of pad geometries. The current smallest inter-pad distances on MALTA2 are 32 µm while the process has the potential to interconnect pitches down to 8 µm. The presented interconnection technologies are essential to overcome the minimal distance requirements of the wire bonding process while reducing parasitics, and enabling denser packaging over a wide signal frequency range. To demonstrate the capabilities of the flip-chip bonding technology for minimal material module integration, a flexible PCB with a thickness of ˜30 µm and track widths down to 17 µm has been produced. This allows for design flexibility in the support structure, including features such as flaps providing backside biasing onto the rear of the chips it houses. This structure can provide a homogeneous electrical field in the sensor which contributes significantly to its stable performance. Besides the sensor integration on the flex using multiple technologies, the reliable integration of passive components as well as a 140-pin connector on a 5 µm copper layer via reflow solder is shown. This talk will summarize the test results of demonstrator modules as well as of the interconnection studies. An outlook for a compact silicon pixel module concept as well as the necessary interconnection technologies for future experiments, with a high active area, minimal material, and potential for scalability will be presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 11

R&D of MAPS for the Super Tau-Charm Facility(STCF)

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A MAPS based inner tracker is proposed for the Super Tau-Charm Facility, a next-generation high-luminosity electron-positron collider operating in the tau-charm energy regime. In order to satisfy the challenge of high luminosity, high event rate, and the high tracking performance of benchmark physics programs, the inner tracker has to be of low power consumption, low material budget and provide precise measurements of the hit position and arrival time, with a resolution of better than 30um and 50ns, respectively. Prototypes of the STCF MAPS chips have been designed with three different processes, 180nm, 130nm and 90nm CIS technologies. The latest R&D status of the STCF MAPS will be presented in this report.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 12

Research and development of 3D detector and LGAD based on 8-inch CMOS Process

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At IMECAS, we have pioneered the development of various silicon detectors based on 8-inch CMOS process, encompassing 3D detectors, Low-Gain Avalanche Detectors (LGAD), pixel detectors, and silicon drift detectors (SDD). Our research focuses on investigating innovative 3D detectors, such as double-sided 3D trench electrode detectors (DS-3DTED), back-incidence 3D Composite Electrode Silicon Detectors (3DCESD), hypothetical sphere-electrode detectors, and so on. In addition, we explore the fabrication process of 3D detectors utilizing the 8-inch CMOS process. This has led to the successful creation of a 311 μm deep trench, achieving an impressive depth-to-width ratio close to 105:1. Furthermore, we have developed LGAD in IMECAS, which has found its application in the ATLAS High Granularity Timing Detector (HGTD) program with mass production in our institute.

Currently, we are looking to expand our international collaboration efforts and aspire to join international organizations, aiming to contribute to the advancement of high-energy particle/photon detection technologies.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 13

Test beam and irradiation facilities in Japan

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We will discuss test facilities in Japan which can be used for DRD3 developments.
At KEK an electron test beam facility with beam momentum upto 5 GeV has been established available since 2022. This facility will be available for the down time of major test beam facilities in Europe. Usually the beam is available for sensor testing for three periods (May-June, Oct-Dec and Feb-Mar) in each year in total about 5.5 months. The beam rate at 3 GeV is more than 2 kHz with beam spot size of 2 cm (1 cm) in horizontal (vertical) direction in RMS.
In Japan irradiation facilities are available in Kobe University and Tohoku University. These facilities are often used for ATLAS Phase-2 upgrade projects to certify radiation tolerance of silicon sensors and components for on-detector electronics.
In presentation, we will introduce these test facilities with their characteristics and discuss potential difficulties for users from abroad.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 14

Investigating LGAD Degradation with Proton Irradiation and the Novel nLGAD Technology

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Low Gain Avalanche Detectors (LGADs), implemented as ⊠++−⊠+−⊠, show outstanding precision timing performance when detecting high-energy charged particles and will be used in the timing detectors for the upcoming High Luminosity LHC ATLAS and CMS detector upgrades. Therefore, studying the LGAD technology and their degradation with irradiation will be an important task for the newly formed DRD3 collaboration. The efforts to gain a more profound understanding of the LGAD degradation with irradiation as well as complementing studies of novel LGAD technologies will be presented in this talk.

The first part of the talk will summarize the plans and first results of an extensive LGAD irradiation study to compare the effect of different proton energies on the gain layer of the devices. The investigation of radiation-induced degradation produced by low energy protons is of special interest since it demonstrates the limits of the Non-Ionizing Energy Loss (NIEL) scaling. Over 100 LGAD samples produced by Hamamatsu Photonics (HPK) as well as devices with differently carbonated gain layers produced by Centro Nacional de Microelectrónica (CNM)-IMB are included in the study. Electrical characterization, radiation-induced acceptor removal and gain reduction of a selected subset of samples will be presented.

The second part of the talk will cover studies on the novel nLGAD technology. Due to the difference in multiplication mechanisms for holes and electrons, the detection performance of LGADs is significantly reduced for low penetrating particles. A novel concept of an LGAD detector, the nLGAD (⊠++−⊠+−⊠), was designed and fabricated at CNM and tested at the SSD laboratory at CERN. Studies were conducted to understand the performance of nLGAD detectors, using techniques such as TPA-TCT. Investigations also cover impact ionization and its temperature dependence, as well as gain reduction mechanisms. Gain response measurements were conducted using laser light of different wavelengths. Prospects should be given for radiation studies to answer fundamental questions, for example whether donor removal occurres in the gain layer equivalent to acceptor removal in high-energy physics LGADs.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG8 - Dissemination & outreach / 15

The DRD3 speakers committee

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WG/WP2 - Hybrid silicon technologies / 16

Technology Transfer of LGAD Technology for Large-Volume Productions

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LGAD sensors have recently captured the attention of the HEP detector community due to several advantages such as high temporal resolution and excellent radiation hardness. One of the objectives of the new DRD3 collaboration is to demonstrate the production capabilities of LGAD sensors on a larger scale for upcoming Tracking/Time-of-Flight applications. The ability to manufacture a full-scale detector based on LGADs is contingent upon both the microelectronics industry's availability to support medium-volume productions and the reliability of the manufacturing technology, which must meet stringent requirements in terms of reproducibility and uniformity of key sensor characteristics.
In this context, FBK has recently initiated a technology transfer of the FBK-LGAD technology to an external CMOS foundry capable of handling larger productions at reduced costs. The production of the first learning batch, aimed at demonstrating the feasibility of running the FBK process in an external CMOS foundry, was completed in May 2024. The design for evaluating the technology transfer corresponds to the one envisaged for the CMS-ETL detector (16x16 pixels with a total area of approximately 2x2 cm^2). The batch included some process splits of the Gain Layer dose, while carbon co-implantation was included on all wafers. Subsequent to production, the wafers have been characterized at the automatic probe stations at FBK under dark conditions and IR illumination.
The first characterization outcomes revealed highly promising results in terms of electrical properties of the sensor: Breakdown Voltage, Depletion Voltage, and Gain align with expectations and the results obtained at the FBK internal facility. Additionally, critical aspects such as uniformity and reproducibility of Gain and Breakdown Voltage were assessed. The positive results, along with the exceptional production yield, are very promising for the future of large-scale LGAD production.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 17

Applying DMAPS technology to the Upgrade of the Belle II Vertex Detector

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The Belle II experiment currently records data at the SuperKEKB e+e- collider, which holds the world luminosity record of $4.7x10^{34}cm^{-2}s^{-1}$ and plans to reach $6x10^{35}cm^{-2}s^{-1}$ at the end of the decade. In such luminosity range for e+e- collisions, the inner detection layers should both cope with a hit rate dominated by beam-induced parasitic particles and provide minute tracking precision. An R&D program has been established to develop a new pixelated vertex detector (VTX), based on the most recent pixel detection technologies. The proposed VTX will be more robust against the expected higher level of machine background and more performant in terms of standalone track finding efficiency.

The VTX design is comprised of five layers in a barrel-shaped configuration, targeting minimal material budget from 0.2 to 0.5% X_0 with increasing radius.

All the ladders feature the OBELIX depleted-MAPS CMOS sensor, with an active area of approximately 1.5 cm × 3 cm, designed in the Tower 180 nm technology. The pixel-matrix is derived from the TJ-Monopix2

sensor developed to match the requirements for a fast (< 100 ns) and radiation tolerant (10^{15} 1MeV n_eq/cm2 or below) pixels, needed for the outer layers of the ATLAS-ITk of the ATLAS experiment and close to the Belle II specifications. However the digital logic handling the information issued by the pixel matrix is entirely new, in order to match the Belle II needs. Featuring a 33 µm pitch, OBELIX integrates hits over 50 or 100 ns while dissipating less than 200 mW/cm^2 at an average hit rate of 60 MHz/cm^2. The digital trigger logic matches the required 30 kHz average Belle II trigger rate with 10 µs trigger latency and a maximum hit rate of 120 MHz/cm^2. Hit rate pikes of up to 800 MHz/cm^2 can also be sustained for sub-microsecond periods without loss of data. Additional features are intended for the outer layers with expected hit rates below 10 MHz/cm^2. They allow additional time stamping of the hits with 3 ns precision and providing fast hit information for track-triggering with a substantially reduced spatial resolution.

The presentation will outline some VTX relevant tests of the TJ-Monopix2 to validate pixel-matrix performance, then focus on the OBELIX features development and performance estimates calibrated with those measurements of TJ-Monopix2. Finally the submission in 2024 and tests of the first version OBELIX-1 will be discussed.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 18

The Development of Silicon Carbide Low Gain Avalanche Detector

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High-energy and high-luminosity collision experiments on the future collider demand higher radiation resistance and time resolution detectors due to events pile-up. Silicon Low-gain avalanche detectors (LGADs) with excellent time resolution have been identified for use in collider experiments, such as ATLAS and CMS experiments. However, due to the inherent properties of silicon material, the operating voltage and temperature requirements for irradiated Si LGADs are even more demanding. Especially in environments with irradiation fluences exceeding 10ˆ16 neq/cmˆ2 and under general detector operating conditions, there is a need to explore new solutions. In comparison to silicon, silicon carbide (SiC) offers lower intrinsic carrier concentration, faster carrier saturation drift velocity, higher breakdown electric field, and greater theoretical radiation resistance. This makes it a promising candidate for applications in collider experiments. In recent years, with the increasing demand for commercial silicon carbide power devices, related silicon carbide processing technologies have rapidly advanced. This has made it possible to fabricate multi-layer epitaxial structures of silicon carbide devices, such as SiC LGAD. However, the fabrication of SiC LGAD also imposes additional requirements on the processing technology, such as ultra-low-doped silicon carbide epitaxial layers, precise control of epitaxial layer doping concentration and thickness, and termination etching.
Our collaboration, consisting of the Lawrence Berkeley National Laboratory Physics Division and the North Carolina State University Department of Electrical and Computer Engineering, has designed and fabricated prototype 4H-SiC LGAD and PIN structures and these are under test. We propose a set of criteria necessary to demonstrate a working 4H-SiC LGAD device. We will report

on recent measurements of charge gain and charged particle response as part of this program aimed at demonstrating the behavior of a 4H-SiC LGAD structure.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 19

Radiation Hardness and Leakage Current Homogeneity of CMS HGCAL 8-Inch Silicon Sensors irradiated at RINSC

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The High-Luminosity LHC will challenge the detectors with a nearly 10-fold increase in integrated luminosity compared to the previous LHC runs combined, thus the CMS detector will be upgraded to face the higher levels of radiation and the larger amounts of data collected. The High-Granularity Calorimeter (HGCAL) will replace the current endcap calorimeters of the CMS detector. It will facilitate the use of particle-flow calorimetry with its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels. The electromagnetic section as well as the high-radiation regions of the hadronic section of the HGCAL (fluences above 10¹⁴ n_{eq}/cm²) will be equipped with silicon pad sensors, covering a total area of 620 m². Fluences up to 10¹⁶ n_{eq}/cm² and doses up to 1.5 MGy are expected. The sensors are processed on novel 8-inch p-type wafers with an active thickness of 300 µm, 200 µm and 120 µm and cut into hexagonal shapes for optimal use of the wafer area and tiling. Each sensor contains several hundred individually read out cells of two sizes (around 0.5 cm² or 1.2 cm²). In order to investigate the radiation-induced bulk damage, the sensors have been irradiated with neutrons at RINSC (Rhode Island Nuclear Science Centre, US) to fluences between 6.5·10¹⁴ n_{eq}/cm² and 1.5·10¹⁶ n_{eq}/cm². We present electrical characterisation (IV) results from partial sensors cut from multi-geometry wafers with internal dicing lines on the HV potential within the active sensor area as well as from full sensors. The leakage current data is corrected for the pad volume to become sensitive to fluence and annealing inhomogeneities across the 8-inch sensor area. We investigate means to limit the annealing time of the sensors during irradiation, analyzing the influence of the irradiation container material and the impact of splitting high-fluence irradiations. Finally, we provide recommendations for future irradiation campaigns in the RINSC irradiation facility.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 20

Investigation of defect meta-stabilities in silicon doped with thallium by low temperature photoluminescence spectroscopy

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An acceptor removal phenomenon (ARP) appears in irradiated low-gain avalanche detectors (LGAD) and reduces their functionality for higher irradiation fluences. The underlying defect mechanisms are still not fully understood. To further investigate possible defect mechanisms responsible for the ARP we report on experiments related to defect meta-stabilities for the acceptor thallium in silicon.[1] Low-temperature photoluminescence measurements are done during carrier injection and annealing treatments at moderate temperatures. Irreversible and reversible changes of defect luminescence are found, which correspond to similar findings for the case of the acceptor indium. For the acceptor boron the applied treatments lead to detectable PL signals, as well. However, the changes of defect luminescence in that case are different to the indium and thallium cases. The experimental results are discussed in frame of the idea of acceptor-interstitial silicon (ASi-Sii)-defects.[2]

[1] K. Lauer et al., 'Investigation of Tl-doped silicon by low temperature photoluminescence during LID treatments', accepted, Phys. Status Solidi A, 2024.
[2] K. Lauer, K. Peh, D. Schulze, T. Ortlepp, E. Runge, and S. Krischok, 'The ASi–Sii Defect Model of Light-Induced Degradation (LID) in Silicon: A Discussion and Review', Phys. Status Solidi A, vol. 219, no. 19, p. 2200099, 2022, doi: 10.1002/pssa.202200099.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 21

Large electrode sensors with intrinsic amplification for ultimate timing performance

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Large size electrode monolithic sensor designs have been explored successfully in the past, mainly for tracking applications. Notable examples of this concept are LF-CPIX, followed by the large size

(1 cm2) LF-MONOPIX1, LF-MONOPIX2 and TJ-MONOPIX demonstrators, intended for ATLAS ITK outer layers. LF-CPIX, LF-MONOPIX1 and LF-MONOPIX2 were designed in LF-15A technology, and TJ-MONOPIX is in TJ-180 technology.
One important feature of the large electrode designs is that the geometry of the charge collecting region is very close to a parallel plate capacitor. This is very favorable to obtain good timing performance for MIPs, since the dependence between the signal shape and the impact point position on the sensor is minimal.
This is why we have started investigating the performance of large-electrode sensor designs in LF-15A technology. The most recent designs in this research line are MiniCactus v1 and MiniCactus v2. These sensors are designed in LF15A process and built upon the tracking-oriented demonstrators LF-CPIX and LF-MONOPIX. The MiniCactus chips share many structures that were originally designed and optimized for LF-CPIX and MONOPIX (guard rings, slow control DACs, configuration register, global front-end architecture).

The long-term goal of MiniCactus developments is to provide a timing sensor with performances compatible with LHC timing detector upgrades, to be considered post LHC phase 2. Typically, an evolution of MiniCactus could be a candidate for the replacement of the ATLAS HGTD inner disks.

The foundry process LF15A used has been shown in the past to be intrinsically radiation hard. In addition, since MiniCactus uses a standard foundry process, ASICs based on this principle should be cheap to produce in high volume, as needed for large detectors.

MiniCactus v1 has been developed in 2020-2021. It features several pixel sizes, the biggest being 1 mm by 1 mm, the smallest 50 µm by 50 µm, and several pixels architectures. The best time resolution (65 ps) has been obtained in test beam with a 0.5 mm by 1 mm pixel, with integrated AC coupling capacitor, with a 200 µm thick sensor biased at 450 V. The read out electronics is in the form of an end of column block, to avoid running large metal rails over pixel surfaces to power in pixel electronics. This kind of design has proven in the past (Cactus design, done in 2017-2018) to bring large parasitic capacitance.

MiniCactus v2 builds upon the experience gained with MiniCactus v1. This chip implements mostly the pixel identified as having the best performance with MiniCactus v1. The original charge amplifier front-end has been reoptimized, the discriminator has been improved and digital/analog separation has been reinforced, to minimize couplings observed on MiniCactus v1. In addition, Minicactus v2 features several new front-end architectures, inspired from the Altiroc analog front-ends. These new front-end should according to simulation give performance somewhat better than the original charge amplifier, and the output signal duration is below 25 ns, making them tailored for integration in an LHC experiment.

The time resolution depends not only on the jitter but also the landau fluctuations of the sensor. These are of tens of ps, the same order of magnitude as the jitter. Therefore, in order to obtain smaller time resolutions, it is not only mandatory to improve the electronics but also the sensor. Landau fluctuations can be reduced by thinning the sensor, but less charge is collected and the signal to noise ratio is degraded. To overcome this limitation, we propose to explore the implementation of a buried PN junction, acting as a charge multiplication layer below the active electronics of a CMOS monolithic sensor. This will improve the signal over noise ratio, allowing to simultaneously improve time resolution, reduce the front-end power consumption, and exploit smaller pixel sizes. It should be noted that implementing a gain layer in the framework of a commercial CMOS process opens up the long term possibility of an intrinsically amplified, fully integrated sensor, with analog front-end and digital blocks on the same substrate, making it a potentially cheap solution suited for large detectors.
TCAD simulations have been completed and show that a gain of the order of 10 is achievable using the existing available layers and available implant energies for the LF-150 technology. Test structures have been submitted in May 2024 and will be characterized in the coming months.
In addition to the LF-150 technology, we intend to study the same concept with the more advanced technologies TPSCO 65

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG4 - Simulations / 22

TCAD Models/Parameters and Tool Fusion

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Technology computer-aided design (TCAD) simulation are crucial in modern electronic developments, as the behavior of a component can be explored before the first costly prototypes have been produced. Accurate and thus trustworthy predictions are, however, only achievable when the models and parameters provided by the user to the tools are state-of-the-art and include the most recent improvements.

For Silicon carbide (SiC), a very promising candidate for a more power efficient (e.g., in power electronics) and radiation hard (e.g., as particle detector with good timing performance) replacement of Silicon, the available models and parameters can be separated in two categories. On the one hand many different descriptions and values have been published in literature over the last century, which makes a proper selection very challenging. On the other hand, specific properties like radiation damage, have hardly been investigated yet, demanding basic level research and model building.

In this presentation we summarize our latest efforts regarding the simulation of 4H Silicon Carbide. At first we present preliminary results from our extensive literature review on TCAD model parameters. This work aims to provide an easy access for newcomers and to trigger a critical evaluation of the available values within the scientific community. We also include our latest achievements towards a 4H-SiC radiation damage model. The simulations in two distinct frameworks fit the measurements qualitatively well. The latter already showed that with increasing dose the utilized diode behaves almost identical in forward and backward direction, although the fundamental physical processes inside the device differ.

We conclude our talk with the latest information about the upcoming integration of GEANT4 simulations into the TCAD framework of Global TCAD Solutions (GTS), a company located in Vienna. We show that this update will allow a much tighter interleaving of statistical particle energy deposition and the evaluation of the signal introduced by these electron hole pairs in a time dependent electric field.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 23

Investigation of ionizing radiation damage in the SiO2 layer in of silicon sensors for the CMS Endcap Calorimeter upgrade

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The High-Luminosity Large Hadron Collider (HL-LHC) will present an approximately 10-fold increase in integrated luminosity relative to the aggregate of all previous LHC operational phases. Consequently, the CMS detector needs to be upgraded to withstand the increased radiation levels. The current endcap calorimeters will be replaced by the High-Granularity Calorimeter (HGCAL) which, additionally, is designed to significantly increase transverse and longitudinal segmentation compared to current calorimeters. The HGCAL sensors are fabricated on 8-inch p-type silicon wafers, featuring active layers of 300 µm, 200 µm, and 120 µm thicknesses and main cell sizes of 0.5 and 1cm2. The sensors have hexagonal layout to optimize wafer surface utilization and facilitate efficient tiling.

The objective of this study is to investigate the radiation-induced damage to the SiO2 layer of the HGCAL silicon sensors up to the doses expected at the end of the HL-LHC program. Different aspects of the radiation damage are investigated using dedicated test structures made from surplus segments of the silicon wafers hosting the HGCAL sensor. These structures include Metal Oxide Semiconductor (MOS) sensors, Gate Controlled Diodes (GCD) and microstrip sensors. Different oxide variants and sensor thicknesses are considered. The test structures have been exposed to X-ray irradiation up to doses of 1MGy, which is of the same order of magnitude of the expected dose at the end of the HL-LHC program. The electrical characterization of the test structures was conducted in situ, in order to minimize the effect of thermal annealing. Both irradiation and measurements are performed at a controlled temperature of -20C. After the irradiation, the thermal annealing of the radiation damage was studied at room temperature. These results have been a crucial input to the choice of silicon oxide variant currently used in the production of the HGCAL sensors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 24

Development of radiation-hard GaN devices for MIP detection - Phase I

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Gallium nitride (GaN) semiconductors are now commonly found in optoelectronic and high-power devices, e.g., light-emitting diodes (LEDs), lasers and high electron mobility transistors (HEMTs). GaN can also be used for detecting ionizing radiation under extreme radiation conditions due to its properties such as a wide bandgap (3.39 eV), large displacement energy (theoretical values averaging 109 eV for N and 45 eV for Ga), and high thermal stability (melting point: 2500C). Compared to narrower band-gap semiconductors such as silicon, GaN can operate at higher temperatures; while a comparison with other wide band-gap semiconductors, such as SiC, demonstrates GaN's higher electron mobility and potential for better carrier transport properties. In the proposal below, we provide the outline of a project that aims to exploit recent developments in GaN fabrication processes aiming at robust performances at harsh environments, e.g. high temperatures, and assess the potential of GaN as a meterial for the fabrication of radiation hard devices for MIP detection.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

DRD3 CB Meeting / 25

CB Meeting (restricted)

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

26

First characterisation of Trench Isolated LGADs fabricated at Micron Semiconductor Ltd

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We are excited to present the first results from our Trench Isolated Low Gain Avalanche Detectors (TI-LGAD), developed in collaboration with Micron Semiconductor Ltd and the Scottish Microelectronics Centre. The TI-LGAD represents an innovative approach to low gain avalanche diodes (LGAD), featuring fine segmentation and narrow trenches (1 µm) that effectively isolate adjacent pixels. This design significantly narrows the no-gain inter-pad region to under 2 µm, a notable improvement from the 20-80 µm range seen in conventional LGAD technology. Such enhancement enables sensors with a finer pixel pitch and greater fill-factor, crucial for advancements in particle physics and imaging applications.
Prototypes of this cutting-edge technology, produced by Micron Semiconductor on 250 µm thick wafers, have undergone characterization using the transient current technique (TCT). The results demonstrate that trench-isolation effectively isolates the pixels, ensuring a low dark current and maintaining the sensor's gain, all while achieving a near 100% fill factor. Additionally, IV measurements indicate no premature breakdown at the trenches, with breakdown voltages reaching up to 1000V.

These findings align closely with our process simulation studies, which were instrumental in optimizing the trench width and depth to maximize the fill factor.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 27

Non-Ionizing Energy Loss in Silicon: Geant4 and TRIM simulations and defect cluster studies towards more advanced NIEL concept for radiation damage modelling and prediction

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The concept of Non-Ionizing Energy Loss (NIEL) is used to compare and quantify the damage caused to semiconductor devices in various radiation environments. However, the current NIEL concept has a limitation in predicting the formation rates of cluster and point defects in silicon (Si) crystals for different particles and particle energies. Experimental observations have revealed differences in radiation damage produced by neutrons and protons with the same displacement energies (i.e., damage parameters normalized to NIEL).

In this study, we introduce a wide theoretical framework that aims to distinguish between clusters and defects from first principles. In the first step Geant4 simulations (using standard electromagnetic physics lists) of high-energy particles (neutrons, protons, electrons and gammas) produce Primary Knocked-on atoms (PKA) spectra. In the second step PKA of various energies and Z=1 to Z=15 are used as a SRIM/TRIM input and subsequent Silicon cascades are produced, stored and analyzed in terms of Non-Ionizing-Energy-Loss. From Step 1 and 2 the classical Damage equivalent curve as defined by RD-48 collaboration is reproduced. Third step, crucial for the novel distinction between clusters and isolated defects consists of two possible approaches. The first approach uses OPTICS (Ordering points to identify the clustering structure) algorithm as a tool to differentiate between isolated and clustered fractions of each event, while the alternative approach is a random-walk simulation encompassing molecular dynamics constants relevant for the actual physical defects creation. The results are compared to the collection of Deep-Level-Transient-Spectroscopy measurements. This revised approach allows for a more accurate prediction of damage and estimation of clustered and isolated defects for different incident particle energies.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 28

Fine-pitch CMOS pixel sensors with precision timing for vertex detectors at future Lepton-Collider experiments

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This project concerns the simulation, development and evaluation of monolithic fine-pitch pixel sensors implemented in the TPSCo65 process, targeting the vertex-detector requirements of future Lepton Colliders as outlined in the ECFA detector roadmap. Key final development goals include 3 µm single-point resolution, down to 5 ns time resolution as required for the high-energy Linear-Collider proposals, thinning to 50 µm, an average power consumption below 50 mW/cm2, a minimal inactive periphery area, and a sensor architecture scalable to a large-area detector system. The development of new high-resolution sensors for beam telescopes at DESY and CERN is foreseen as an intermediate target, with relaxed power-consumption (<500 mW/cm2) and timing requirements (100 ns). This staged approach allows for a further refinement of the performance targets, following the conclusions of the next update of the European Strategy for Particle Physics.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG4 - Simulations / 29

Simulating monolithic active pixel sensors: A technology-independent approach using generic doping profiles

Authors: Adriana Simancas[1]; Anastasiia Velyka[1]; Daniil Rastorguev[None]; Dominik Dannheim[2]; Doris Eckstein[1]; Finn Feindt[1]; Gianpiero Vignola[1]; Håkan Wennlöf[1]; Ingrid-Maria Gregor[3]; Katharina Dort[4]; Larissa Helena Mendes[1]; Lennart Huth[1]; Manuel Alejandro Del Rio Viera[1]; Marcel Stanitzki[1]; Paul Schütze[1]; Sara Ruiz Daza[1]; Simon Spannagel[1]; Stephan Lachnit[1]; Walter Snoeys[2]

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The optimisation of the charge collection behaviour in the sensitive region of CMOS sensors with nonlinear electric fields requires precise simulations, and this can be achieved by a combination of finite-element electrostatic field simulations and Monte Carlo methods.
This talk aims to demonstrate that by making basic assumptions and performing simulations based on the fundamental principles of silicon detectors and using generic doping profiles, performance parameters of MAPS can be inferred and compared for different sensor geometries. A procedure for this will be described in detail, along with example results. The described procedure utilises Sentaurus TCAD together with Allpix Squared, and serves as a toolbox for performing sensor response simulations without detailed knowledge of the sensor doping concentrations and manufacturing process.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 30

Results and perspectives of the Monopix2 depleted monolithic active pixel sensors

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The increasing availability of high-resistivity substrates and high-voltage capabilities in commercial CMOS processes facilitate the application of depleted monolithic active pixel sensors (DMAPS) in modern particle physics experiments. TJ-Monopix2 and LF-Monopix2 chips are the most recent large-scale prototype DMAPS in their respective development line originally designed for compliance with the ATLAS Inner Tracker outer layer requirements.

LF-Monopix2 is a 1x2 cm² chip with a 50 x 150 um² pixel pitch designed in 150 nm LFoundry technology. All in-pixel electronics are embedded in a large charge collection electrode relative to the pixel size, rendering a homogeneous electric field and short drift distances across a pixel. The resulting sensor capacitance of O(250fF) originating from the collection node compromises the noise performance requiring more analog power for optimal operation.

Designed in 180 nm Tower Semiconductor technology, TJ-Monopix2 features a 33x33 um² pixel pitch on a 2x2 cm² chip. The small charge collection electrode relative to the pixel size requires the separation of the in-pixel electronics into p-wells. The resulting small detector capacitance of O(3fF) facilitates large signal-to-noise ratio with low power consumption. Additionally, process modifications are implemented to minimize regions with low electric field and improve the charge collection efficiency impaired by the long drift distances.

This contribution provides an overview of laboratory characterizations and beam test results of both DMAPS. Furthermore, potential future applications of these sensors in particle physics experiments are discussed.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / **31**

Research on CMOS MAPS at GSI/FAIR –Status and Next Step

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Since 2003, IPHC Strasbourg, Goethe University Frankfurt, and GSI have been performing R&D to develop sensors for the Micro Vertex Detector of CBM at FAIR. Complemented by R&D targeting the ALICE-ITS3, this research activity now focuses on developing the MIMOSIS sensor. In response to the particular needs of fixed-target heavy ion physics experiments, MIMOSIS features a spatial/time resolution of 5 µm / 5 µs, tolerance to >1E14 neq/cm², an 80 MHz/cm² peak rate, and proven tolerance to direct heavy ion impacts. We discuss the status of MIMOSIS, the specific requirements of FAIR and FAIR upgrade experiments, possible solutions, and synergies with other communities.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 32

New particle detector wih the CIGS semiconductor

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A Cu(In,Ga)Se2 (CIGS) semiconductor is expected to have high radiation tolerance with the recovery feature by the compensation of defects by ions. The CIGS has been developed for solar cells, and its radiation tolerance was initially investigated for space applications.
We developed new CIGS semiconductor detector and evaluated by Xe ion (400 MeV/u, 132 Xe54+) at the Heavy Ion Medical Accelerator in Chiba (HIMAC) . Single Xe ion is successfully detected, and we confimed the recovery with the heat annealing.
In this talk, results of Xe ion irradiation to the CIGS detector, and also temperature and time dependence with heat annealing will be presented.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 33

Defect Characterisation on 4H Silicon Carbide Devices

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Future collider experiments will reach fluences too high for current silicon-based detectors to handle. Research into making silicon more radiation hard is required, but new materials could also yield the desired properties. Silicon carbide is one of the materials currently considered due to it's large bandgap, leading to low leakage currents even after high fluences of irradiation and allowing for non-cooled operation.
This talk aims to give an overview and update on the status of the defect characterisation measurements on this novel material performed in the SSD group at CERN.
Two kinds of n-type 4H-SiC pad diodes produced by CNM are being investigated with I-DLTS, C-DLTS and TSC measurements. Some samples have been irradiated with 23 GeV protons to fluences of up to 1E+15 p/cm^2. Their performance before and after irradiation will be discussed as well as the defects present in the as is material.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 34

TCAD modeling of radiation induced defects in 4H-SiC diodes and LGADs

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Silicon Carbide (SiC) has several advantageous properties compared to Silicon (Si) that make it an appealing detector material, such as a larger charge carrier saturation velocity, bandgap, and thermal conductivity.

While the current understanding of simulation parameters suffices to simulate unirradiated 4H-SiC devices, TCAD models to accurately predict performance degradation after irradiation due to induced defects, acting as traps and recombination centers, do not exist. Despite increasing efforts to characterize the introduction and nature of such defects in 4H-SiC, published results are often contradictory. Parameter values vary by multiple orders of magnitude, extraction of hole cross sections is scarce, and even the origin and charge state of known lifetime killers are still under discussion.

This talk presents our first steps towards a radiation-induced trap model for 4H-SiC. Initial trap definitions based on literature were optimized to fit I-V, C-V, and CCE measurements performed on neutron-irradiated 4H-SiC PiN samples in the fluence range of $5 \cdot 10^{14}$ –$1 \cdot 10^{16}$ n_{eq}/cm^2. Results, though qualitative, are in reasonable agreement with experimental data and strongly suggest the $EH_{6,7}$ defect be of Donor-type, as well as the relevance of a second Acceptor-type defect (EH_4) besides the well-known $Z_{1,2}$ center.
Applying the derived radiation model, predictions on the performance alteration of 4H-SiC-LGADs on the example of a design recently commissioned within the scope of the RD50-SiC-LGAD common project will be shown.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 35

Radiation hard read-out architectures

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An asynchronous read-out architecture was developed for the MALTA family of Pixel detectors in Tower 180 nm as an alternative to well established column-drain architecture by means of a self-generating reference pulse in groups of 8x2 pixels without the distribution of a clock over the matrix, a power consumption smaller than 80 uW/cm2 and a hit rate capability larger than 1 GSps. The aim of this proposal is to develop this architecture further to reach hit rates above 100 MHit/cm2, radiation hardness better than 3e15 n/cm2, and on-chip time tagging below 1 ns. Hit rate capability and radiation hardness have been evaluated with the MALTA and MALTA2 prototypes. Sub-nanosecond timing resolution is being evaluated with the latest prototype, Mini-MALTA3, that includes an upgraded synchronization memory that runs at a clock speed of 1.28 GHz generated by an on-chip PLL. This proposal considers to explore the limit of Tower 180 nm imaging process on which the designs are available to design a prototype with a matrix larger than 2x2 cm2 with output data protocol compatible with the state of the art optical transveivers. This proposal has an potential application for beam tests across the DRD3 community.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP2 - Hybrid silicon technologies / 36

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

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Low Gain Avalanche Diodes (LGADs) represent the state-of-the-art in timing measurements and will instrument the future timing detectors of ATLAS and CMS for the High-Luminosity LHC. While initially conceived as a sensor for charged particles, the intrinsic gain of LGADs makes it possible to detect low-energy X-rays with good energy resolution and excellent timing (tens of picoseconds). Using the Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC and the Sirius Lightsource at Laboratorio Nacional de Luz Sincrotron (LNLS), several LGADs and AC-LGADs designs were characterized with energies ranging from 5 to 70keV and beam spots from nanometric to micrometric sizes. Both facilities provide 10ps pulsed X-ray bunches separated by 2ns intervals with very low energy dispersion ($\delta E/E < 10^{-4}$). The tested LGADs are prototypes from several manufacturers – fabricated with different thickness and gain layer designs – and were read out using fast amplification boards and high bandwidth, high sampling rate oscilloscopes. The charge collection and multiplication mechanism were simulated using Geant4 and TCAD Sentaurus, providing an important handle for interpreting the data. In this contribution, the results of the data analysis and simulation will be presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 37

Caribou: A versatile data acquisition system for silicon pixel detector prototyping

Authors: Dominik Dannheim[1]; Eric Buschmann[2]; Hucheng Chen[2]; Mathieu Benoit[3]; Shaochun Tang[2]; Simon Spannagel[4]; Tomas Vanat[4]; Younes Otarid[1]

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Caribou is a versatile data acquisition system used in multiple collaborative frameworks (CERN EP R&D, DRD3, AIDAinnova) for both bench-top and test-beam qualification of novel silicon pixel detector prototypes. The system is built around a common hardware, firmware and software base shared accross different projects, thereby drastically reducing the development effort and cost. The current version consists of a custom Control and Readout (CaR) board and a commercial Xilinx Zynq 7000 series Sytem-on-Chip (SoC) platform. The CaR board provides a hardware environment featuring various services such as powering, slow-control and high-speed data links that can be used by the target detector prototype. The SoC platform is based on a ZC706 evaluation board running a fully featured Yocto-based Linux distribution (Poky) and a custom data acquisition software (Peary). Migration to a Zynq UltraScale+ architecture is ongoing with the additional objective of merging the SoC and the CaR board into a single hardware platform. This talk describes the current Caribou system architecture, its capabilities, examples of projects where it is used, and the foreseen system upgrade.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 38

Radiation tolerance and annealing studies using test-structure diodes from 8-inch silicon sensors for CMS HGCAL

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To face the higher levels of radiation due to the10-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). It will facilitate the use of particle-flow calorimetry with its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels. The electromagnetic section as well as the high-radiation regions of the hadronic section of the HGCAL (fluences above $1e14n_{eq}/cm^2$) will be equipped with silicon pad sensors, covering a total area of 620m^2). Fluences up to $1e16n_{eq}/cm^2$ and doses up to 1.5MGy are expected. The whole HGCAL will normally operate at -35℃ in order to mitigate the effects of radiation damage.

The sensors are processed on novel 8-inch p-type wafers with an active thickness of $300\mu m$, 200μm and 120μm and cut into hexagonal shapes for optimal use of the wafer area and tiling. 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, these sensors have been irradiated with neutrons at JSI (Jožef Stefan Institute, Ljubljana) to fluences between 2e15 and $1.5e16n_{eq}/cm^2$.

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 6.5℃, 20℃ and 60℃. The results have been used to optimize the layout of the silicon modules in HGCAL and are being used to evaluate the annealing possibilities for HGCAL during year-end technical stops and long HL-LHC shutdowns at around 0℃.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG7/WP4 - Interconnect technologies / 39

Ultra-thin hybrid pixel detectors using Wafer-to-Wafer bonding

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Wafer to wafer bonding offers an economic approach to interconnect all readout electronic chips with the solid-state sensor chips on the wafer by only one bonding step. This is a promising technology for the fabrication of 3D integrated ultra-thin hybrid modules for particle detection and timing layers in future particle detectors. The technology described in this paper combines the metal-metal interconnection of pixels by Cu-Sn pillar bumps and the wafer level bonding by a photo-patterned polymer layer. In comparison to the metal-oxide-hybrid bonding process established in the industry for high volume production the metal-polymer hybrid wafer to wafer bonding process is applicable for wafers with higher surface topography tolerances. In this project TimePix3 wafers are used together with a passive sensor wafer built with LFoundry 150 nm technology to proof the concept. The project will be introduced and recent results from the process development and sensor design and fabrication are presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG7/WP4 - Interconnect technologies / 40

Development of adhesive-based pixel-detector hybridisation concepts

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A reliable and cost-effective interconnect technology is required for the development of hybrid pixel detectors. The interconnect technology needs to be adapted for the pitch and die sizes of the respective applications. This contribution presents recent results of an in-house single-die interconnection process based on Anisotropic Conductive Adhesives (ACA), which is under development within the CERN EP R&D programme and the AIDAinnova collaboration. The ACA interconnect technology replaces solder bumps with conductive micro-particles embedded in an epoxy layer applied as either film or paste. The electro-mechanical connection between the sensor and ASIC is achieved via thermo-compression of the ACA using a flip-chip device bonder. The ACA technology can also be used for ASIC-PCB/FPC integration, replacing wire bonding or large-pitch solder bumping techniques. This contribution introduces the developed interconnect processes and showcases different hybrid assemblies produced and tested.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 41

Optimization of the femto laser facility at UPV-EHU for TPA-TCT in SiC

Authors: Cristian Quintana San Emeterio[1]; Marcos Fernandez Garcia[1]; Michael Moll[2]; Moritz Wiehe[2]; Raul Montero[None]; Ivan Vila Alvarez[3]; Jordi Duarte Campderros[4]; Diego Rosich Velarde[1]

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We will report on the activities conducted at the femto laser facility at the University of the Basque Country in Bilbao. The study focuses on the effects of various laser systematic issues, such as spherical aberration and spatial mode instabilities, and the implementation of several mitigation measures to address these challenges.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 42

On-going studies on diminishing the acceptor removal effect by tuning the charge state of Boron containing defects in p-type irradiated PAD samples

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The Boron containing radiation induced donor BCD (attributed in the literature to BiOi) is a bistable defect located at approximately Ec-0.25V and is the cause for the acceptor removal in p-type samples. The bistable nature of the defect has been previously evidenced in high resistivity samples (12 kΩcm), via the fluctuations observed in depletion voltage after a stimulus of excess charge carriers at ambient temperatures. In its ground state (A) the BCD is in a positive charge state and in its metastable state (B) has a neutral charge state. The magnitude of the acceptor removal process determined in C-V measurements depends on the charge state of BCD, being significant larger when the defect is in donor charge state A than when it is in the neutral charge state B. Accordingly, if succeeding to switch and froze-in the defect configuration in its neutral charge state, the detrimental acceptor removal effect will be reduced to a half. We will present our on-going studies (C-V/TSC) on this matter on PAD samples of different resistivity irradiated with 10ˆ14 MeV neutrons/cmˆ2. Our experiments show that the change of the BCD configuration into its less detrimental B state, is more efficient as the resistivity increases, a behavior qualitatively explained by the flow of holes and electrons through the diodes. In addition, we noticed that a bistable behavior is also manifested by the H152K clusters, hole traps with acceptor energy levels.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 43

Integration of high temporal resolution planes into AIDA-type telescopes for Sensor Characterization

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AIDA telescopes are systematically employed for sensor characterization, particularly in high-energy particle physics. With their exceptionally high spatial resolution, on the order of a few microns, they serve as suitable instruments for characterizing pixelated sensors in high-energy experiments, involving the extraction of detection efficiencies, spatial resolution, and more. However, these telescopes lack any plane capable of temporal resolution. Introducing the ETROC2 chip, a 16x16 pixel matrix ASIC capable of resolving temporal distances on the order of tens of picoseconds, offers a solution. The final version of this ASIC, currently in R&D, aims to be incorporated into the future MIP Timing Detector of the CMS upgrade for the HL-LHC. We have utilized the ETROC2 mounted on LGAD sensors to construct a detection plane integrated into the AIDA telescope, enabling the characterization of sensors not only with high spatial resolution but also with high temporal resolution. In this contribution, we will explain the integration process of this spatial plane into the infrastructure of AIDA telescopes and describe the main features of this chip.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG6/WP3 - Non-silicon-based detectors / 44

SiC AC-LGAD Timing Pixel Detector

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Pixelated SiC LGAD device with both timing and position capabilities has the potential to address the 4D tracking in extreme fluence of future collider experiment. To improve the tracking and timing capabilities of SiC-LGAD device, this project proposes to fabricate the AC-coupled LGAD SiC device with pixelated structures. These devices will be characterized by spacial and temporal resolution

before and after proton/neutron irradiation up to fluences of 1e17 neq. The SiC properties after high fluence irradiation will be investigated with correlation of the detector performance.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

WG6/WP3 - Non-silicon-based detectors / 45

Design of innovative diamond detectors for beam monitoring in highly radiative environment for applications in nuclear and medical physics

Author: Jayde Livingstone[1]

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New accelerators are being developed, either for medical applications (X-ray radiotherapy, hadrontherapy, radiotherapy by synchrotron radiation and "flash" therapies), or for nuclear physics. These developments create the need for very precise beam monitoring with fast counting in a highly radiative environment. An important issue is the adaptation to the temporal beam structures, which vary greatly depending on the type of accelerators (cyclotrons, synchro-cyclotrons or synchrotrons), in terms of duty cycle or peak intensity. A recent tendency to increase the intensity of the beams, for example in a clinical setting, for flash therapy, poses new challenges for the detection of secondary radiation (adapting the counting capacity of the detectors, electronics and data acquisition). The intrinsic qualities of diamond (fast timing, low leakage current, excellent signal-to-noise ratio, radiation hardness, equivalence to human tissue) make this semiconductor a perfect candidate to meet the monitoring requirements of such accelerators and the detection of particles.
The objectives of our multidisciplinary projects are the development of innovative diamond detectors for beam monitoring based either on single or poly-crystalline Chemical Vapor Deposition (CVD) and dedicated front-end electronics readout designed in-house. Diamonds are used as solid-state ionization chambers. Their charge collection properties were investigated with various ionizing particles to evaluate the capability of diamond to be a position sensitive detector. Detectors were exposed to 68 MeV proton (ARRONAX) and 95 MeV/u carbon ion beams (GANIL), short-bunched 8.5 keV photons from the European Synchrotron Radiation Facility (ESRF) and 30 keV electron beams at Institut Néel to perform 2D charge collection mapping. Our ultimate scientific objective is to demonstrate that diamond can become a "standard detector"for particle detection, particle counting, time stamps through the design of beam monitors operating with temporal resolutions of 100 ps or less and a high-count rate (from a single particle up to bunches of thousand particles) over a wide dynamic range of beam intensities (fraction of pA up to µA).

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 46

The H2M project: Porting the functionality of a hybrid readout chip into a monolithic 65 nm CMOS imaging process

Authors: Adriana Simancas[1]; Ana Dorda[2]; Anastasiia Velyka[1]; Christian Reckleben[1]; Corentin Lemoine[3]; Dominik Dannheim[4]; Eric Buschmann[5]; Finn Feindt[1]; Gianpiero Vignola[1]; Håkan Wennlöf[1]; Ingrid-Maria Gregor[6]; Iraklis Kremastiotis[4]; Judith Christina Schlaadt[1]; Karsten Hansen[1]; Larissa Helena Mendes[1]; Lennart Huth[1]; Manuel Alejandro Del Rio Viera[1]; Michael Campbell[4]; Peter Svihra[4]; Philipp Gadow[4]; Rafael Ballabriga Sune[4]; Raimon Casanova Mohr[7]; Sara Ruiz Daza[1]; Sebastien Rettie[4]; Simon Spannagel[1]; Stefano Maffessanti[None]; Tomas Vanat[1]; Yajun He[8]; Younes Otarid[4]

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Monolithic active pixel sensors (MAPS) are attractive candidates for the next generation of vertex and tracking detectors for future lepton colliders. Especially an only recently accessible 65 nm CMOS imaging technology, that allows for higher logic density at lower power consumption compared to currently used imaging processes, is of high interest. To investigate this technology, explore the design challenges of porting a hybrid pixel detector architecture into a monolithic chip and to exercise the digital-on-top design methodology, the H2M (Hybrid-to-Monolithic) test chip has been developed and manufactured. It features a 64x16 pixel matrix with a pitch of 35 × 35 µm², resulting in a total active area of approximately 1.25 mm². The sensitive pixel matrix is designed in the so called n-gap layout to optimise charge collection and to minimise charge sharing between pixels to boost the detection efficiency.

This contribution first introduces the H2M chip and gives an overview of the readout that is based on the Caribou DAQ system. Laboratory optimisation of the settings and calibration results will be presented, as well as performance results from test-beam measurements with electrons at the DESY-II test beam and pions at the CERN SPS test beam.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 47

TPA-Based Characterisation of Solid State Sensors Using a Tunable Femtosecond Pulsed Laser

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The Two-Photon Absorption (TPA) process provides an excellent method for the characterization of solid-state sensors due to its intrinsic 3D resolution for the excitation of electron-hole pairs when compared to the single-photon process. A Light Conversion ORPHEUS optical parametric amplifier with tuneable output wavelength across 310-16000 nm is used as the excitation source for order of 150 femtoseconds laser pulses. This broad range offers a unique opportunity to characterize devices with TPA for a wide range of solid-state devices including silicon and diamond. In addition, this set-up "developed at The Photon Science Institute (Manchester)"is also used for timing measurements. The results of the timing measurements, and energy, voltage, depth and knife-edge scans, followed by plans for improvements will be presented. First results from simulations (KDetSim) compared with experimental data will also be presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 48

From analog readout to ML-processed Silicon Device signal-sharing: a path to complex charge collection methods.

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Resistive Silicon Devices (RSDs), such as AC-coupled Low Gain Avalanche Diodes, achieve a fine spatial resolution while maintaining the LGAD's timing resolution with near to 100% fill factor, achieving time and space (4D) tracking measurements for collider experiments in High Energy Physics (HEP) at the Large Hadron Collider (LHC), Electron-Ion Collider (EIC), and Lepton Collider experiments. Technological limitations in segmented detection technologies impose a geometrical disposition as an array of linear strips with 1D spatial resolution or a matrix of pixels with 2D spatial resolution. In contrast, for RSDs, the shape and disposition of the readout pads along the detector surface can be easily tuned and modified. When ionizing radiation hits these devices, the collected charge spreads well beyond the two adjacent pixels. The limitations due to the lower amplitudes and Landau fluctuations on the pixels further apart from the true particle's hit limit the full potential of the readout. Using pixelated AC-LGADs fabricated at Brookhaven National Laboratory, with different geometric pad arrangements, we study and characterize the possible improvements on the position resolution through multi-channel collection complex machine learning-based algorithms, such as Recurrent Neural Networks. The sensors are built with a pixel density of 500 micrometers x 500 micrometers in a square and triangular arrangement.. In contrast to traditional methods, we use full wave-form information to infer the particle's hit position, improving the resolution capabilities of these sensors and opening the path to arbitrary geometrical pixel arrangements. We compare their performance to that of traditional charge-imbalance algorithms as well as geometry-based matrix inversion methods. We perform these studies with infrared lasers using the TCT technique and at test beams. Further, we study how to compress the resulting information through wave-form rasterization techniques while maintaining the improved spatial resolution, opening the path to implementing such algorithms on Field Programmable Gate Arrays for fast signal processing.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 49

MARTHA - Monolithic Array of Reach THrough Avalanche photo diodes

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We proposed a novel APD array with very high detection efficiency also in inter pixel gap regions to achieve nearly 100% fill factor. The APDs operate in proportional mode at low or moderate gain. By applying a fully depleted reach-through structure light entrance side and electronics side are kept separated. In contrast to common APD arrays where the gain drops to 1 or less within inter pixel gaps the avalanche process is sustained in the gap regions as well.
A non structured boron doped multiplication region (MR) extends over the entire array . Parasitic early breakdown at the n+ pixel edges caused by electric field peaks near to convex doping shapes is in our approach suppressed by a n-doped layer, called field drop region (FDR), located directly beneath the n+ pixels. The positive space charge of this fully depleted layer causes a reduction of the electric field to a non critical level when it reaches the n+ edges. The FDR gets depleted by the negative MR space charge preventing pixel shortage.
We have completed a first prototyping on 450µm thick p-type float zone wafers to demonstrate the feasibility of the concept. The prototype design contains small pixel and strip arrays for eta-plot measurements. We will present a description of the operating principles and comparison of the first measurements with simulations. By modifications of implantation parameters and reduction of wafer thickness the concept can by adapted for fast timing applications. For the next production a multi project wafer run is planned where

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 50

Development of TI-LGAD technology towards 4D Tracking

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Institutes interested to join: FBK, LPNHE, JSI, UHH, UZH
The project is open to other interested groups.

Two consecutive productions of TI-LGAD at FBK (Trento, Italy), in the framework of RD50 and AIDAinnova WP6, have proven the potential of this technology for the implementation of 4D tracking. Trench-isolated LGADs (TI-LGADs) are a strong candidate for solving the fill-factor problem, as the p-stop termination structure is replaced by isolated trenches etched in the silicon itself. Different design combinations related to the trenches have been studied to determine their inter-pixel distance.
In this project, a systematic testing campaign is proposed, to determine the radiation hardness of a new run of devices after Carbon co-implantation, possibly optimizing the implantation parameters

with respect to the past productions. Since one of the possible applications of these devices could be the Phase-3 upgrade of ATLAS and CMS outer pixel layers, the radiation hardness requirement is in the range of 1-5x10**15 neq/cm2.
The sensors will be characterized both at test-structure level, by connecting them by wire bonding to pre-amplifiers and by bump-bonding them to prototype timing chips that are being developed at the moment.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 51

A versatile pixel matrix in TPSCo 65 nm for future trackers

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This project addresses the development in the TPSCo 65 nm CMOS process of prototype monolithic active pixel sensors matching the needs of the next generation of trackers in high energy physics.

The guiding principle is to establish a versatile pixel matrix design suited for various trackers with possibly diverse hit-rate (1 to 100 MHz/cm2), time resolution (1 to 100 ns), radiation tolerance (1011 to 10^15 1 MeV n_eq/cm2) and power constraints (20 to 100 mW/cm2) but similar pixel pitch (below 50 µm) requirement and read-out architecture. The adaptation to a given set of constraints is expected to be reached without any redesign but using the following possibilities: modifying the process (which requires splitting wafers during fabrication), tuning pixel front-end parameters, changing clock frequency of some specific functionalities and switching on/off some digital features.

Though the project does not plan to produce a reticule-size sensor dedicated to a specific experiment, the sensors developed in this project should offer sufficient sensitive area and testability to validate the concept. The prototype sensor periphery should contain the functional blocks allowing to test the matrix performances under all required conditions. The digital logic at matrix periphery for a given application should then either be re-designed quickly from these initial blocks or, in the ideal case, simply be reprogrammed.

The ambition of this project is such that a relatively large consortium of groups is needed to complete all design and test activities within a limited number of years (typically 2024 to 2027). The versatile aspect of the pixel matrix is thought to trigger interest in various scientific communities, listed here in alphabetical order: ALICE3, BelleII, EIC, FCCee, LHCb.
In addition, synergies can be identified with a project targeting excellent position resolution (3µm or below) for future vertex detectors and planning to use the same TPSCo 65 nm technology.

The presentation will expose the motivations, concepts and a preliminary work programme for the project.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

52

Gain measurements and spectral response of the latest IMB-CNM fabricated nLGAD

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In the last few years, Low Gain Avalanche Detectors (LGAD) have demonstrated their outstanding performance when detecting high-energy charged particles. However, the very nature of electrons and holes under avalanche multiplication highlights that this good performance is diminished when they are to detect low penetrating particles (e.g. low-energy protons or soft x-rays). A novel design of an LGAD detector, the nLGAD, was designed and fabricated at CNM in order to try to overcome this drawback. A qualitative description of the nLGAD concept is presented in this work, along with gain response measurements under UV light of 369 nm, visible light of 404 nm and IR light of 1064 nm; all of them carried out on test devices of the last IMB-CNM nLGAD fabrication batch. The results demonstrate the potential of the nLGAD for experiments that imply the detection of low penetrating particles.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 53

LGAD development at the IMB-CNM

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Since the pioneering proposal of the Low Gain Avalanche Detector (LGAD) concept, IMB-CNM has played along the years a fundamental role in the development of this technology. LGADs have demonstrated an outstanding performance when detecting high-energy charged particles thanks to their proportional response, their good efficiency and spectral range, and their better sensibility, and signal to noise ratio, both enhanced by the gain. As a consequence, LGAD is going to populate the timing layers of both the ATLAS and CMS timing layers at the HL-LHC. This presentation looks at how the LGAD concept can be adapted to overcome the future challenges on particle detection. Specifically, we will show IMB-CNM advances on the inverse and trench-isolated inverse LGAD designs, conceived to overcome the small pixel problem; the engineering of the multiplication layer profiles, to enhance the LGAD response under high fluence irradiation, as well as the new designs oriented to the detection on the soft x-ray or deep UV domain.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

other

WG6/WP3 - Non-silicon-based detectors / 54

3D diamond

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The radiation hardness of diamond has been tested mostly in the planar configuration and only limited data is available on the radiation hardness on 3d devices down to 55mum cell size up to 10ˆ16 neq. The project proposes to investigate the radiation hardness of 25mum cell size devices up to fluences of 10ˆ17 neq, characterise devices in terms of charge collection properties and defect studies on the bulk material as well as on the graphitic electrodes. The results will show if 3D diamond detectors can in principle deliver a reliable detection signal up to fluences expected for the FCC-hh and will provide more insights into the radiation damage process in 3D diamond detector devices.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG7/WP4 - Interconnect technologies / 55

Development of an in-house Ni/Au plating process for pixel-detector hybridisation and module integration

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Within the CERN EP R&D programme and the AIDAinnova collaboration, innovative and scalable hybridization and module-integration concepts are pursued for pixel-detector applications in future colliders. Most interconnect processes require specific surface properties and topologies of the bonding pads. An in-house Electroless Nickel Gold (ENIG) plating process is therefore under development, which is performed on single-die level and can be adapted to a large range of pad geometries and bonding techniques. This contribution introduces the ENIG process and its optimisation and shows example plating results for dedicated test structures and functional ASICs and sensors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 56

Low Gain Avalanche Detectors with deep Carbon implantation

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Low Gain Avalanche Detectors (LGADs) are crucial for high-energy physics applications, especially in the harsh radiation environments of future colliders. This talk introduces LGADs enhanced with deep carbon implantation, emphasizing their superior radiation tolerance.

LGADs achieve high temporal resolution and precise spatial measurements through an internal gain mechanism and fine structure. The deep implantation of a carbon layer significantly enhances performance by protecting the boron gain layer from deactivation caused by irradiation. This protection is critical for maintaining detector efficiency (charge collection, timing performance) and longevity.

Our proton irradiation campaign demonstrates that deep carbon implanted sensors exhibit outstanding performance, with smaller gain deterioration after 80 MeV proton radiation exposure up to $2.5 \times 10^{16} n_{eq}/cm^2$ compared with shallow Carbon implanted devices. These improvements ensure consistent and reliable operation in high-radiation environments, making LGADs with deep carbon implantation a pivotal advancement.

This presentation will delve into LGAD operation principles, merits and drawbacks of deep carbon implantation, and experimental results showcasing enhanced performance in radiation tolerance.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 57

All-silicon ladder concept for CMOS monolithic pixel detectors

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CMOS sensor technology leverages the production of fully monolithic pixel detectors with smaller pixel size and without costly interconnections between sensors and readout electronics. This results in cost reduction and lower material budget in the detector volume.

An additional opportunity for further improvement is the module assembly method. By integrating power- and data lines directly on the CMOS wafer, all-silicon ladders are created, eliminating the need for hybrid PCBs and reducing material. Wafer-scale post-processing methods can be used to deposit alternating layers of metal and polymer on the surface, creating electrical redistribution layers (RDL).
Each ladder, consisting of multiple neighboring sensors on the wafer, is diced in one large self-supporting piece, allowing for direct assembly in the detector. Within power constraints, direct air cooling can be applied.

Initial technology demonstrators are constructed and evaluated to validate the feasibility of this approach for low material budget applications like the upgrade of the Belle II vertex detector.

This presentation will outline the all-silicon ladder concept, the RDL processing steps and the design of first demonstrators.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 58

First measurements on the CASSIA Sensor (CMOS Active SenSor with Internal Amplification)

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The CASSIA Project (CMOS Active SenSor with Internal Amplification) aims to develop monolithic MAPS with internal signal gain and low noise in a widely used CMOS imaging process towards a broad range of applications. Monolithic CMOS sensors with internal gain can provide several advantages for future monolithic CMOS detector systems: Due to internal amplification these sensors produce higher input signal amplitude enabling simplification of in-pixel electronics, which can be exploited for low-power amplification circuits (e.g. for ultra-light detector systems operating at low power dissipation) . Internal signal amplification also promise superior timing resolution in fine-pitch MAPS for future 4D tracking applications or time-tagging application. Furthermore improved signal-to-noise can enable extended operation in high radiation environment after suitable engineering of the gain layer.

The current developments are based on the Tower Semiconductor CIS 180nm in view of later portability towards other process including smaller node size process (e.g. 65nm). A first prototype CASSIA sensors has been manufactured in 2023 in an MPW in the TJ 180nm process. The presentation will introduce the specifics of the CASSIA sensor and present the first results in static IC tests, photo-gain measurements as well as first signal measurements in response to a 1064nm pulsed laser.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG4 - Simulations / **59**

Development of Simulation Software - RASER

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RAdiation SEmi-conductoR(RASER) is an open-source software to simulate semi-conductor detector developed by Institute of High Energy Physics(Beijing), Jilin University(Jilin) and Shandong Institute of Advanced Technology(Jinan). Simulation researches have been finished and published including IV/CV curve, timing resolution, and edge-TCT scan. Charateristics of silicon and silicon carbide both can be achieved before and after irradiation. Based on the previous work, AC-coupled SiC LGAD is proposed to be added in RASER with main focus on timing and spatial resolution while developing bulk and surface model for fluences up to 1e17 neq.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 60

DMAPS for measuring energy depositions and tracks of Galactic Cosmic Ray and Solar Energetic Particles

Authors: Alexandros Papangelis[1]; Elena Papadomanolaki[1]; Gerasimos Theodoratos[1]; Haris Lambropoulos[1]

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Coarsely segmented Si diode detectors are widely used in space applications for measuring the mixed radiation fields. Starting in 2012, when 5 Timepix chips were installed at the International Space Station hybrid pixel detectors have entered space radiation dosimetry and monitoring. The problems to be solved for measuring GCR and SEP events are the dynamic range of the charge signal which exceeds 80 dB, the event rates starting from 2 to 4 per cm2·s-1 and reaching 55·107 per cm2·s-1 (for a 4π sr field of view), and, most importantly, the fact that limited power is available from solar or other sources while the heat generated requires material (i.e., extra weight) to manage.We developed two kinds of pixel architecture: The low gain pixel can process high energy (charge) depositions up to 8 pC and the high gain can process low energy depositions by fast charged particles down to 0.5 fC.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

61

Development of precision timing silicon detectors for future high energy collider experiments

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This research program, which is submitted to the US-Japan Cooperation Program in HEP, aims to advance the development of silicon detectors, focusing on the technology that achieves O(10) picoseconds time resolution for minimum ionizing particles (MIP) together with a spatial resolution of the order of O(10) microns. It includes as a goal the implementation of a versatile testing system for prototype characterization and design of readout electronics that can match the sensor layout and performance. In this research program we will develop a prototype of a highly granular silicon precision timing detector, i.e. a 4D detector, for future colliders, using Capacitor-Coupled Low gain Avalanche Diode (AC-LGAD) technology. The radiation tolerance of such detectors will be investigated and techniques to improve radiation-hardness will be studied. KEK, University of Tsukuba with Hamamatsu Photonics K.K. (HPK) and BNL are developing novel designs of AC-LGAD sensors

and a versatile benchmarking system will be developed and implemented at the Fermilab Test Beam Facility that will be used for precise characterization of sensors
developed in this program together with colleagues at UCSC and LBNL. Dedicated readout electronics will be studied and prototyped, building upon existing fast-time ASIC designs. The project includes the ambitious scope opportunity to develop a monolithic LGAD for low-mass detector applications, if funds allow.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP2 - Hybrid silicon technologies / 62

3D silicon sensors as timing detectors

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Novel collider experiments demand an increased performance of the silicon detectors used, such as withstanding $10^{17} n_{eq}/cm^2$ in unprecedented pile-up conditions, and providing time resolution around 10ps. Currently, Low Gain Avalanche Diodes (LGADs) are the standard, achieving resolutions below 30ps. However, their limited radiation hardness is an area of ongoing research. As an alternative to LGADs, 3D sensors are interesting due to their proven radiation hardness. In 3D sensors, where the columns are etched into the sensor from the top (junction columns) and the back (ohmic columns), the drift distances can be very short, the depletion voltage is low and the electric field can be high, resulting in fast and short signals.
In this study, the time resolution of different 3D pixel and strip sensors was investigated with signals generated by electrons or an IR laser. Results show that 3D pixel sensors can achieve time resolutions of less than 30ps. TCT timing measurements allow studying the position dependence of the time resolution, which is interesting for 3D sensors due to their complex electric field structure. Examples of position-timing maps will be shown, proving the direct correlation between time resolution and electric field. The time resolution of 3D sensors before and after irradiation will be demonstrated, showing that 3D sensors can reach the time resolution of standard LGADs. In addition, the results demonstrate that the radiation-induced performance degradation in 3Ds can be less severe than in LGADs. At last, we will present initial results from a production run of dedicated fast 3D sensors which have recently been produced at CNM as a common RD50 project. We envisage to continue in this research line with a future DRD3-Project on fast 3D sensors. Details will be depending on the forthcoming results from the fast 3Ds from the current RD50 run.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 63

Monolithic sensors for tracking and precision timing for the ALICE experiment in Run 4 and beyond

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In view of the Long Shutdown 3 the ALICE experiment is foreseeing an upgrade of the inner barrel of its Inner Tracking System (ITS3), based on Monolithic Active Pixel Sensors produced in a commercial 65 nm CMOS technology. This technology represents the baseline for the development of tracking systems for future experiments at colliders (NA60+, EPIC@EIC, ALICE 3, FCC⋯).
ALICE 3 experiment has been proposed as a next generation heavy-ion experiment for the HL era of the LHC. The tracking system will be based on a vertex detector, integrated in a retractable structure inside the beam pipe to achieve the best possible pointing resolution, and a very-large-area outer tracker, surrounding the vertex detector. Furthermore, a Time Of Flight (TOF) system, equipped with silicon sensors with a timing resolution of 20 ps, will be of crucial importance to identify charged particles.
The "MAPS"group of INFN Torino is deeply involved in the R&D of monolithic sensors, with and without timing capabilities, for the projects mentioned above.
In this contribution the present status of the R&D will be presented, highlighting the detector requirements, sensor specifications together with the results from the latest test beam.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

64

AC-LGAD based Timing tracker development for future lepton collider

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The project aims to develop AC-LGAD based strip silicon sensors and detector modules for the outer tracker in future lepton colliders (CEPC, FCC-ee, ILC, CLIC, etc.). This development is crucial for enhancing the flavor physics and Higgs physics potential of these future lepton colliders.

The primary objective is to develop AC-LGAD sensors with a long strip structure. Additionally, we plan to create AC-LGAD strip sensors for the endcap region, where the strips will be oriented along the azimuthal direction. The developed sensor prototypes, along with ASICs featuring high-precision TDCs, will be used to construct detector module prototypes. These modules are expected to achieve a spatial resolution better than 10 μm (R-phi direction) and a timing resolution in the range of 30-50 ps. We anticipate that this development will significantly contribute to the technical design reports for future lepton collider projects.
Collaborative work with WG5-TB is foreseen, with potential synergies in the timing tracker development for the EIC.
The proposal document can be found in this link: https://cernbox.cern.ch/s/eEFSdjE04icgfc1

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

WG3/WP3 - Extreme fluence and radiation damage characterization / 65

Study of irradiation characteristics of carbon enriched LGAD for high radiation fluence application

Author: Mei Zhao[1]

Co-authors: Mengzhao Li [1]; Weiyi Sun [1]; Yuan Feng [1]; Zhijun Liang [1]

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Carbon enriched LGAD sensors will be used for ATLAS HGTD project, since LGAD with carbon implantation be demonstrated to have good radiation hardness as compared to the one without carbon. Researches of radiation damage to the LGAD and how to improve the carbon process also been studied preliminarily by IHEP. In this project, we plan to do more studies of irradiated carbon enriched sensors by using DLTS and so on, in order to identify the damage caused by radiation and how carbon can improve it. Based on the study, we will also try to improve the radiation performance of LGAD by optimizing the carbon enrichment process and gain layer implantation, such as high energy boron and carbon implantation, and aim to increase the radiation fluence to 7e15neq/cm2. The LGAD with better than 7e15 neq/cm2 radiation performance can be used to HGTD LGAD replacement and high timing detectors for future collider.
link to the document (DRD3 Work Package Project proposal) : https://cernbox.cern.ch/s/IudHhJcJxLD4KLf

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

WG6/WP3 - Non-silicon-based detectors / 66

Pixelated Gain Devices on Epitaxial SiC

Author: Kazuyoshi Carvalho Akiba[1]

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Silicon Carbide (4H) is a promising semiconductor for radiation tolerant particle tracking. The high bandgap offers the additional advantage of room temperature operation which in turn requires less material due to cooling. The main goal of this project is to achieve high fill factor pixelated devices with a built-in gain junction. The devices will be fabricated at IISB Fraunhofer based on epitaxial sensing volumes grown on 4H-SiC wafers. Performance will be evaluated in the Lab with radioactive sources and laser and at beam facilities such as PartRec (Groningen) and SPS (CERN);

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 67

Innovations in CMOS Pixel Sensor Technology at IPHC: Projects and Future Prospects

Author: Frederic Morel[1]

Co-authors: Ajit Kumar [2]; Andrei Dorokhov [3]; Antonin Maire [4]; Auguste Guillaume Besson [1]; Christine Guo Hu [1]; Christophe Wabnitz [1]; Claude Pierre Colledani [1]; Fadoua GUEZZI MESSAOUD [5]; Franck Agnese [1]; Gilles Lucien Claus [1]; Grégory Bertolone ; Isabelle Valin ; Jean Soudier [1]; Jerome Baudot [6]; Kimmo Kalevi JAASKELAINEN ; Mathieu Goffe [1]; Matthieu SPECHT [7]; Olivier Alain Clausse [1]; Serhiy Senyukov [1]; Thanh Hung PHAM [8]; Xiaochao Fang [1]; Ziad El Bitar [1]; abdelkader HIMMI [5]

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The IPHC Strasbourg has been developing CMOS pixel sensors for over two decades. The laboratory leverages the unique expertise of its C4PI microelectronic platform, encompassing everything from design to testing, in close collaboration with scientific groups. IPHC participates in numerous vertex and tracking detector projects, including CBM-MVD, ALICE ITS-3, the Belle-2 upgrade, and future e+e colliders. Additionally, they are engaged in generic R&D efforts, such as new readout architectures and TPSCo 65 nm R&D. This presentation will cover the main achievements of these projects and the current R&D program. The IPHC strategy aims to maximize synergies among various R&D initiatives, particularly benefiting from the DRD3 framework.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 68

TCAD Radiation Model for 4H-SiC

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4H-SiC is considered a promising candidate to increase the radiation hardness of particle detectors. Nevertheless, there is not yet a commonly accepted radiation model for TCAD simulations. On the contrary: the values presented in literature, i.e., the trap levels, types and cross sections, deviate significantly.

This project proposes the development of a model that is able to describe radiation damage of 4H-SiC in TCAD tools. Various device types (e.g. diodes, MOS capacitances and transistors) will be irradiated with multiple particle types (neutron, proton, gamma). Results from I-V, C-V and CCE (charge collection efficiency) measurements will then be used to fit a radiation model.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

project proposal for future work

WG4 - Simulations / 69

A simulator for Timepix-like pixel front-ends

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This work presents the development of a front-end simulation code for the Timepix3 readout chip, intended as digitizer stage in full detector simulation. The front-end electronics is modelled using an integrator stage and 3 parallel feedback loops with individually configurable time constants. The main feedback discharging the integrator consists of 3 low-pass filtered feedback loops. The leakage current compensation is approximated by an additional independent low-pass filtered feed-back loop. The system noise is modelled using independent bandwidth limited noise channels for pre-amplifier, feedback and threshold noise. The Timepix3 time of arrival (ToA) and time over threshold (ToT) measurement is implemented by a discriminator model with independent rise and fall times and 2 independent clock frequencies for ToA and ToT. The measured dependence of the ToT on the pre-amplifier input charge using test-pulses of a Timepix3 assembly is correctly reproduced for a wide range of discriminator settings.

The work has been presented at the IWORID 2023, see https://iopscience.iop.org/article/10.1088/1748-0221/19/03/C03022

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 70

Thin monolithic High Voltage CMOS sensors with excellent radiation tolerance

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State-of-the-art silicon tracking detectors, used in the current generation of physics experiments such as the Large Hadron Collider (LHC) at CERN, are not able to meet in a single sensing device the challenging specifications anticipated by future experiments. These specifications include high radiation tolerance and low-mass, along with fast timing, high spatial resolution and low-power consumption. This contribution will present a new project proposal to tackle the strategic research goal of thin monolithic detectors with excellent radiation tolerance (200 μm, >10^{16} $\mathrm{n_{eq}/cm^2}$) for tracking charged particles in future physics experiments, such as the High Luminosity LHC major upgrades and beyond Phase II replacements initially. It will build on existing expertise in High Voltage CMOS sensor technology, the most promising route for achieving this goal.

The proposal will use the RD50-MPW prototypes, which are High Voltage CMOS pixel chips in the 150 nm technology from LFoundry S.r.l., as a starting point. RD50-MPW4, the latest prototype within this programme, implements significant improvements for a high breakdown voltage, and therefore an excellent radiation tolerance, through a multiple ring structure around the chip edge and substrate backside-biasing to high voltage. The chip was fabricated on a p-type substrate with a nominal 3 kΩ·cm high resistivity, thinned to 280 μm and backside processed. It is composed of a 64 rows × 64 columns matrix of 62 μm x 62 μm pixels with large collection electrode, and a digital periphery for slow control configuration and hit data transmission. The DAQ of the chip is based on the Caribou readout system. Non-irradiated RD50-MPW4 samples have been successfully evaluated in the laboratory and at a recent test beam at DESY. Samples have been irradiated with neutrons up to 3 x 10^{16} $\mathrm{n_{eq}/cm^2}$ and the evaluation of these irradiated samples is currently ongoing. Preliminary current-to-voltage measurements show a >400 V breakdown voltage before irradiation, and a close to 800 V breakdown voltage after irradiation. However, the multiple ring structure around the chip edge occupies a significant non-sensitive area. The timing resolution of the pixel matrix is too slow, the size of the digital periphery too large and the power consumption of both the pixel matrix and digital periphery too high. This proposal will boost the pixel chip parameters, especially tackling the challenges of fast timing resolution (2 ns goal), low-power consumption (a few $100\ \mathrm{mW/cm^2}$ goal) and increased fill-factor (>90% goal), while maintaining if not improving the radiation tolerance of this technology (>$10^{16}\ \mathrm{n_{eq}/cm^2}$ goal). The proposal comprises chip design and simulation, chip submission, development of the specific DAQ, and evaluation of the fabricated prototypes in the laboratory and at test beams before and after irradiation to high fluence and ionising dose. We are open to new collaborators who are interested in participating in this project.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 71

Adaptation and Modularization of MPW4 Firmware for Integration into the Caribou Boreal Architecture: A Pilot Project

Authors: Jorge Jimenez Sanchez[1]; Francisco Rogelio Palomo Pinto[2]; Younes Otarid[3]; Dominik Dannheim[3]; Helmut Steininger[4]; Bernhard Pilsl[4]; Jose Maria Hinojo Montero[2]; Fernando Munoz Chavero[2]

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The pilot project aims to modularise, adapt and integrate the original MPW4 firmware developed at HEPHY into Caribou's new Boreal architecture. This initiative marks the introduction of the first chip within Caribou's new modular firmware. Leveraging the original MPW4 firmware developed at HEPHY, the project focuses on modularisation, adaptation and integration into the user core of the Boreal firmware architecture. Other objectives include automation, simulation and verification, culminating in full system testing. The phased implementation ensures systematic progress, with the current focus on phase 1: modularisation and integration of the MPW4 chip's slow control into Boreal. This phase follows the initial study and analysis of the HEPHY code of the MPW4 firmware.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 72

CMOS Active SenSor with Internal Amplification –CASSIA

Authors: Heinz Pernegger[1]; Tomislav Suligoj[2]

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The CASSIA Project (CMOS Active SenSor with Internal Amplification) aims to develop monolithic MAPS with internal signal gain and low noise in a widely used CMOS imaging process towards a broad range of applications. The current developments are based on the Tower Semiconductor CIS 180nm technology in view of later portability towards other processes including smaller node size process (e.g. 65nm).

Sensors with internal gain can provide several advantages for future monolithic CMOS sensors:
• Considerably higher input signal amplitude enabling simplification of in-pixel electronics (e.g. for low-power electronics),
• Superior timing resolution in fine-pitch MAPS for future 4D tracking applications or time-tagging applications,
• Improved signal-to-noise ratio for operation in high radiation environment.

The CASSIA sensor targets the optimization of different pixel designs to operate in low-gain amplification (linear mode), as well as strong amplification (Geiger mode) at low dark-count-rates. The pixel implantation design shall be optimized for charge collection, full efficiency, different gain-layer designs including gain termination structures. CASSIA sensor shall also include developments of required in-pixel electronics e.g. for low-power or timing-optimized signal amplification, biasing and quenching circuits depending on operation mode, first level digitization, etc.). Submissions are planned in dedicated MPWs or shared common engineering runs depending on availability.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 73

Radiation hardness and timing performance of MALTA monolithic Pixel sensors in Tower 180 nm

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The MALTA family of Monolithic Active Pixel Sensors produced in Tower 180 nm CMOS imaging technology on high-resistivity epitaxial silicon and on Czochralski substrates with a pixel size of 36.4 um2, and a 3 um2 electrode size, feature an asynchronous read-out architecture. Several process modifications, and front-end improvements have been implented on several prototypes that have resulted in reduced RTS noise, increased gain, radiation hardness of 3e15 n/cm2, time resolution below 2 ns, and a uniform charge collection efficiency across the pixel. Results form the beam tests of MALTA2 at the SPS at CERN will be presented, together with the results in laboratory conditions of Edge Transient Current Technique measurements. These measurements together with efficiency, cluster size and timing measurements before and after neutron irradiation show that MALTA2 is an interesting tracking sensor for HL-LHC and beyond collider experiments, providing both very good tracking capabilities and radiation hardness in harsh radiation environments. Preliminary results from the latest prototype, Mini-MALTA3, that includes an on-chip syncrhonization memory running at 1.28 GHz and on-board serialization will also be discussed.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG7/WP4 - Interconnect technologies / 74

100µPET MAPS stack: 3D pixels enabling ultra-high resolution PET imaging

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The 100µPET project is developing a pre-clinical medical scanner for positron-emission tomography (PET) with ultra-high-resolution molecular imaging capabilities. The scanner comprises multiple layers of monolithic active pixel sensors (MAPS) connected to flexible printed circuits (FPC). With pixels of 150 µm pitch and a thickness of 270 µm + 300 µm (MAPS + FPC), the scanner achieves an unprecedented volumetric spatial resolution of 0.02 mm^3, one order of magnitude better than the best current PET scanners and uniform over the scanner's field-of-view (parallax free). The scanner's detection layer is composed of 2x2 MAPS, with Au stud bumps on the IO bonding pads, flip-chipped to the read-out FPC, with ENIG plating. The bonding is done with an epoxy paste and low-temperature thermocompression. We will showcase the construction and quality control of the scanner and its multiple detection modules, prototyped with pre-production chips and FPCs, as well as the MAPS design features and the latest imaging reconstruction with simulated high-definition mouse phantoms.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / 75

The ATLASPIX3 CMOS pixel sensor and module performance

Authors: Attilio Andreazza[1]; Fuat Ustuner[2]; Harald Fox[3]; Ivan Peric[4]; Lingxin Meng[3]; Riccardo Zanzottera[1]; Ruoshi Dong[5]; Yanyan Gao[6]

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High voltage CMOS pixel sensors are proposed to be used in future particle physics experiment. The ATLASPIX3 chip consists of 49000 pixels of dimension 50µm x 150 µm, realized in in TSI 180nm HVCMOS technology. It was the first full reticle size monolithic HVCMOS sensor suitable for construction of multi-chip modules and supporting serial powering through shunt-LDO regulators. The readout architecture supports both triggered and triggerless readout with zero-suppression.
With the ability to be operated in a multi-chip setting, a 4-layer telescope made of ATLASPix 3.1 was developed, using the GECCO readout system as for the single chip setup. To demonstrate the multi-chip capability and for its characterisation, a beam test was conducted at DESY using 3−6 GeV positron beams with the chips operated in triggerless readout mode with zero-suppression. The detector performance have also been tested with hadron beams and operating both with and without the built-in power regulators.
Multichip modules have been operated and behaviour in a serial powering configuration has been tested.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

76

Riddle of Puzzling Ghosts in Double Trench Isolated LGAD

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In our presentation, we delve into the investigation of the intrepad (IP) region within double trench isolated LGADs (2Tr TI-LGADs), focusing on double-trenched PINs from both the RD50 and Aida Innova production runs. Our previous research revealed that exceptionally large signals, with prolonged duration, manifest in the IP region alongside the standard IP signals recorded in conventional LGADs with 2JET and 2 p-stops. We have identified a correlation between strong signals and ghost signals persisting in the IP region even when the laser is deactivated. Recently, we replicated a study using double-trenched PINs (without gain layer in pads) and observed no ghost signals. However, under specific laser power and bias threshold conditions, we recorded remarkably high signals in IP region between trenches, with prolonged duration, akin to observations in double-trenched LGADs where ghost signals were present. A new puzzle came after we found ghosts also in irradiated 2Tr LGAD (0.8x1015 neq/cm2) although we could stimulate a strong signal in the IP region with a laser. Observed ghosts in irradiated samples have some important differences in comparison to previously observed ghosts for non-irradiated 2TR LGAD. Those ghosts (seen in the irradiated sample) are much stronger than previous ghosts (amplitude of 3-4 V vs 0.2-0.3 V in non-irradiated W11 LGAD). The

frequency of occurrence is much lower (about 30 Hz vs tens of kHz previously). They appear at a very high bias which is close to the damage threshold (previous ghosts appear at quite a low bias, ˜50V, quite far from the damage limit). As emphasized above, this signal does not appear as laser synchronized "strong"signal. It could be that this type of ghost signal, contrary to previous cases from non-irradiated 2 Tr LGADs, does not come from the IP region but from the pad. Not being able to stimulate a strong signal we could not locate the region with the highest occurrence of ghosts in the irradiated sample. An additional charge, opposite to what is seen in PINs may be killing the ghost in the pad region due to the presence of the gain region. It is also possible that due to high hole excess current in the irradiated sample and bulk inversion, depletion starts from the back side and the laser wavelength (800 nm) is too short to interact with the bubble of charge; charge defuses from the non-depleted region between trenches not reaching the critical density needed for ghosts to be formed in IP. In future campaigns at ELI, to decipher the ghost riddle we will explore the ghosts with the fs-laser of different wavelengths and with the lower laser repetition rates.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP1 - CMOS technologies / **77**

Large area low-power Monolithic CMOS Tracking Detectors for future particle physics experiments

Authors: Attilio Andreazza[1]; Daniel Muenstermann[2]; Yanyan Gao[3]

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This abstract summarise a preliminary proposal focuses on low-power, high granularity tracking detectors R&D using MAPS technology that's suitable for large-area application in modest radiation environments for future particle physics experiments, in particular the future Higgs factory experiments where silicon layers of 50-100 m2 are foreseen..

This proposal follows two complementary approaches:

- The primary route explores new MAPS designs targeting low-power and high granularity, featuring smaller nodes (SMIC foundry 55nm), on-chip solutions allowing for efficient data aggregation (e.g. chip-to-chip communication) and Shunt LDO regulators allowing for serial powering, and multi-chip aggregation via hybrids or on wafer stitching.
- Building upon our on-going system integration prototyping work using ATLASPix3 chips, we plan to continue developing towards a large-scale system demonstrator, using state-of-the-art CMOS sensors, that has scalability for large area production as a core element of its design and includes a low-mass mechanical support and efficient cooling strategy. Ultra thin and curved designs will be investigated in the context of vertexing to minimize material budget.

The proposed area of research has a strong synergy with several on-going MAPS based R&D projects, such as the LHCb Upgrade II (MightyTracker) and Mu3e, but also benefits the ALICE3 SVT upgrade, Belle2 vertex detector upgrade, and the EIC tracking detector R&D. It has extended impact in areas such as medical physics and muon tomography.

Institutes involved:

Karlsruhe Institute of Technology (KIT), Hochschule RheinMain, INFN Milano, INFN Pisa, University of Edinburgh, Lancaster University, Queen Mary University of London, STFC RAL PPD, STFC Daresbury, IHEP

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG4 - Simulations / 79

Simulating Solid State Detectors Using Garfield++

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In-depth simulations of the response of modern particle detectors are crucial for understanding their underlying workings and optimizing their performance. Garfield++ is an open-source Monte Carlo toolkit designed for detailed simulations of detectors based on ionization measurements in gases and semiconductors.

This presentation will provide a comprehensive overview of how Garfield++ works and its application in simulating semiconductor devices, from the primary ionization pattern to signal induction on the readout electrodes. Examples will cover scenarios with and without internal multiplication (both at finite gain and in breakdown mode), highlighting key technologies such as Low-Gain Avalanche Detectors (LGADs), Silicon Photomultipliers (SiPMs), and 3D diamond sensors. Particular emphasis will be placed on signal formation in the presence of resistive elements, employing the time-dependent weighting potential within the framework of the extended form of the Ramo-Shockley theorem for conductive media.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG3/WP3 - Extreme fluence and radiation damage characterization / 80

Running projects

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG3/WP3 - Extreme fluence and radiation damage characterization / 81

Discussion on WG3/WP3

WG6/WP3 - Non-silicon-based detectors / 82

Hydrogenated Amorphous Silicon Pixel Detectors to Precisely Measure Ionizing Radiation

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Hydrogenated amorphous silicon (a-Si:H) particle detectors are highly regarded as alternatives to crystalline silicon detectors (c-Si) in high radiation environments, due to their exceptional radiation hardness. The INFN HASPIDE research program focuses on developing a-Si:H detectors designed for characterizing ionizing radiation beams. Integrating hydrogen into amorphous silicon plays a crucial role in reducing dangling bonds, thereby enhancing the charge collection efficiency of these devices. These detectors are made of thin layers of a-Si, just a few micrometers thick, deposited on various substrates, including flexible materials. The presentation will delve into the fabrication processes of a-Si devices, the characterization methods employed, and the preliminary results achieved in measuring ionizing radiation. The findings demonstrate high sensitivity levels and linearity in response to beam flux, comparable to those of diamond detectors, with very low variability observed across production batches.
References:
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→ Large M. J. et al: Characterization of a flexible a-Si:H detector for in vivo dosimetry in therapeutic x-ray beams. Medical Physics 51 4489-4503 (2024).

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG/WP2 - Hybrid silicon technologies / 83

Introduction to WG2

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WG7/WP4 - Interconnect technologies / 84

Discussion on Interconnect

WG7/WP4 - Interconnect technologies / 85

Interconnect Projects

WG4 - Simulations / 86

Updates on WG4

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Feedback from the session(s) and from surveys

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 87

Coffee break

WG/WP2 - Hybrid silicon technologies / 88

Riddle of puzzling ghosts in double trench isolated TI-LGADs

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WG/WP2 - Hybrid silicon technologies / 89

First characterisation of Trench Isolated LGADs fabricated at Micron Semiconductor Ltd

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WG/WP2 - Hybrid silicon technologies / 90

Gain measurements and spectral response of the latest IMB-CNM fabricated nLGAD

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WG/WP2 - Hybrid silicon technologies / 91

START OF PROJECT DISCUSSION - Summary of Expression of Interest for WG2

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WG/WP2 - Hybrid silicon technologies / 92

From analog readout to ML-processed Silicon Device signal-sharing and LGADs at BNL

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Resistive Silicon Devices (RSDs), such as AC-coupled Low Gain Avalanche Diodes, achieve a fine spatial res- olution while maintaining excellent timing resolution when they have internal gain, achieving time and space (4D) tracking measurements for collider experiments in High Energy Physics (HEP) at the Large Hadron Col- lider (LHC), Electron-Ion Collider (EIC), and Lepton Collider experiments. The typical pad arrangement imposed by readout electronics imposes geometrical disposition constraints of the pads in matrix arrays of equidistant pixels. For RSDs and, more specifically, AC-LGADs, the shape disposition of the readout pads can be modi- fied to arbitrary geometries. However, when ionizing radiation hits these devices, the collected charge spreads well beyond the two adjacent pixels. This complex charge collection challenges the devices readout due to the increased signal sharing and the noise in readout electronics. Current readout methods restrict themselves to either using only one high-level quantity or imposing (spatial) restrictions on the number of readout channels used due to the complexity. Given the complexity of correlated degrees of freedom involved in the charge collection, applying Machine Learning (ML) techniques becomes advantageous. Although previous studies performed in this direction showed little performance gains, they used the above-mentioned restrictions. By benefiting from all the correlations among all the readout quantities of the device, such as amplitude, rise time, pulse width, and amount of signal shared across electrodes, among others, the information loss will be minimized. Preliminary studies showed that on pixel sensors, ML techniques could potentially exploit the complexity of the signal-sharing in two dimensions due to AC-coupling of the signal across pixels. In a full system design, this information must be transmitted from the sensor to off-detector electronics, allowing ML algorithms to be exploited. Additionally, ML algorithms eliminate the need to solve the analytical laws governing complex geometry-induced behaviors. This motivates the optimization of these additional degrees of freedom, which can be fine-tuned when targeting a specific application. In turn, non-standard arrangements of readout pads, such as squares, triangles, hexagons, or different shapes, can be optimized for optimal spatial resolution. This project aims to pair compression algo- rithms in digitizing the analog signal of RSDs that exploit the correlated degrees of freedom for improved spatial resolution with the sensor design. This unique approach is expected to significantly reduce the data throughput while optimizing the sensor geometry with arbitrary pad arrangments to maximize the spatial resolution.

WG/WP2 - Hybrid silicon technologies / 93

US-Japan project proposal : Capacitive Coupled Low Gain Avalanche Diode (AC-LGAD) detectors.

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This research program, which is submitted to the US-Japan Cooperation Program in HEP, aims to advance the development of silicon detectors, focusing on the technology that achieves O(10) picoseconds time resolution for minimum ionizing particles (MIP) together with a spatial resolution of the order of O(10) microns. It includes as a goal the implementation of a versatile testing system for prototype characterization and design of readout electronics that can match the sensor layout and performance. In this research program we will develop a prototype of a highly granular silicon precision timing detector, i.e.
a 4D detector, for future colliders, using Capacitor-Coupled Low gain Avalanche Diode (AC-LGAD) technology. The radiation tolerance of such detectors will be investigated and techniques to improve radiation-hardness will be studied. KEK, University of Tsukuba with
Hamamatsu Photonics K.K. (HPK) and BNL are developing novel designs of AC-LGAD sensors and a versatile benchmarking system will be developed and implemented at the Fermilab Test Beam Facility that will be used for precise characterization of sensors developed in this program together with colleagues at UCSC and LBNL. Dedicated readout electronics will be studied and prototyped, building upon existing fast-time ASIC designs.
The project includes the ambitious scope opportunity to develop a monolithic LGAD for low-mass detector applications, if funds allow.

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 94

AC-LGAD based Timing tracker development for future lepton collider

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG6/WP3 - Non-silicon-based detectors / 95

Discussion

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG5 - Characterization techniques, facilities / 96

High-performance software package for Timepix3 data acquisition, online analysis and automation

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This contribution presents Track Lab, a multi-platform DAQ software for solid-state pixel detectors designed with versatility and high-performance applications in mind. Originally designed to service the Timepix3 ASIC [1] and the Katherine readout [2], Track Lab has outgrown its intended application and gained compatibility with a diverse range of research instruments. One of its pivotal features is the capability to perform online analysis by composing complex data workflows from simple building blocks, such as filters, transformations or aggregations. Inspired by large-scale systems like MapReduce and Hadoop [3], Track Lab allows for an arbitrary number of processing elements to be visually linked together in user interface to form directed acyclic graphs (DAG), which are typically terminated in persistent storage or real-time plots that conveniently generate immediate feedback for the user. For extensibility, logic of these elements is implemented in plug-in modules, which are included with the software. While the latest program version ships 14 such modules, their programming interface is publicly documented, so as to allow custom plug-ins and extensions to be developed easily.

Track Lab utilizes many conventional strategies to resolve a commonly encountered trade-off between high performance and extensibility. First of all, thanks to multi-threading, its data processing elements operate simultaneously in parallel, enabling them to fully utilize advantages of many-core CPUs. Secondly, data flow is handled by ZeroMQ [4], an industry-standard message-passing middleware, which significantly reduces memory footprint of the program by transparently multiplexing data between a single sender and multiple receivers. Broad adoption of ZeroMQ also permits nearly effortless interoperability with data sources and sinks provided by external programs. Finally, high throughput is achieved by employing asynchronous memory-mapped file access, and wide-bandwidth system buses.

While Track Lab's development is continuously ongoing, its stable versions have been thus far successfully deployed in Mini.PAN [5] beam campaigns at SPS, nuclear safety applications [6] and at the ATLAS-TPX3 [7] and MoEDAL-TPX3 [8] detector networks at LHC. Thanks to such a wide range of applications, its compatibility has been verified for all three major operating systems: Linux, Windows and macOS. Binaries of the software can be freely used by the public, and its sources are available upon request.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (scientific results or project proposal):

Presentation on scientific results

WG5 - Characterization techniques, facilities / 97

Showcase of Facilities

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WG/WP1 - CMOS technologies / 99

DRD7 - Technology Access

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The DRD7 collaboration intends to develop future electronic systems and technologies for particle physics detectors, and provide a platform to enhance the cooperative effort within the community necessary to address the increasing complexity of these systems and technologies. Within this effort the 7.6a work package concentrates on providing common access to advanced imaging technologies through the organization of common fabrication runs.
These are initially envisaged for the TowerJazz 180 nm, TPSCo 65 nm ISC, and the LFoundry 110 nm CMOS imaging technologies. These will be accessible for different clients in the community, among which the other DRDs like DRD3, experiments
and projects in HEP. Assembly of the reticle for the different runs is foreseen, as well as design support for the PDK, development of special design rules, TCAD support for sensor optimization and interfacing to the foundry.
IP development is also foreseen to accelerate and streamline the design effort. Continuation of this common access beyond the initial three years is expected. Synergy with the 7.6b 3D development will be explored possibly with already existing chips or chiplets.
Full 3D-stacked runs, offered in all three technologies, may possibly be pursued later.
Workpackage 7.6a concentrating on imaging technologies is very close to workpackage 7.7 which concentrates on tools, IP and technologies for regular circuits.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP1 - CMOS technologies / 100

Introduction to WG1/WP1 session

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WG/WP1 - CMOS technologies / 101

Discussion time about project preparation

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 102

ML-processed Silicon Device signal-sharing with BNL AC-LGAD sensors

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Resistive Silicon Devices (RSDs), such as AC-coupled Low Gain Avalanche Diodes, achieve a fine spatial resolution while maintaining the LGAD's timing resolution with near to 100% fill factor, achieving time and space (4D) tracking measurements for collider experiments in High Energy Physics (HEP) at the Large Hadron Collider (LHC), Electron-Ion Collider (EIC), and Lepton Collider experiments. Technological limitations in segmented detection technologies impose a geometrical disposition as an array of linear strips with 1D spatial resolution or a matrix of pixels with 2D spatial resolution. In contrast, for RSDs, the shape and disposition of the readout pads along the detector surface can be easily tuned and modified. When ionizing radiation hits these devices, the collected charge spreads well beyond the two adjacent pixels. The limitations due to the lower amplitudes and Landau fluctuations on the pixels further apart from the true particle's hit limit the full potential of the readout. Using pixelated AC-LGADs fabricated at Brookhaven National Laboratory, with different geometric pad arrangements, we study and characterize the possible improvements on the position resolution through multi-channel collection complex machine learning-based algorithms, such as Recurrent Neural Networks. The sensors are built with a pixel density of 500 micrometers x 500 micrometers in a square and triangular arrangement.. In contrast to traditional methods, we use full wave-form information to infer the particle's hit position, improving the resolution capabilities of these sensors and opening the path to arbitrary geometrical pixel arrangements. We compare their performance to that of traditional charge-imbalance algorithms as well as geometry-based matrix inversion methods. We perform these studies with infrared lasers using the TCT technique and at test beams. Further, we study how to compress the resulting information through wave-form rasterization techniques while maintaining the improved spatial resolution, opening the path to implementing such algorithms on Field Programmable Gate Arrays for fast signal processing.

WG/WP2 - Hybrid silicon technologies / 103

RD50 Common Fund Project - RD50-2023-09: State-of-the-art Radiation Resistant AC- coupled Resistive LGAD - RadHard AC-LGAD

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 104

RD50 Common Fund Project - RD50-2023-03: Deep Junction LGAD

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WG/WP2 - Hybrid silicon technologies / 105

LGAD development at Teledyne and Micron

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WG/WP2 - Hybrid silicon technologies / 106

Summary of Expression of Interest for WG2

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WG/WP2 - Hybrid silicon technologies / 107

Research and development of 3D detector and LGAD based on 8-inch CMOS Process

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At IMECAS, we have pioneered the development of various silicon detectors based on 8-inch CMOS process, encompassing 3D detectors, Low-Gain Avalanche Detectors (LGAD), pixel detectors, and silicon drift detectors (SDD). Our research focuses on investigating innovative 3D detectors, such as double-sided 3D trench electrode detectors (DS-3DTED), back-incidence 3D Composite Electrode Silicon Detectors (3DCESD), hypothetical sphere-electrode detectors, and so on. In addition, we explore the fabrication process of 3D detectors utilizing the 8-inch CMOS process. This has led to the successful creation of a 311 μm deep trench, achieving an impressive depth-to-width ratio close to 105:1. Furthermore, we have developed LGAD in IMECAS, which has found its application in the ATLAS High Granularity Timing Detector (HGTD) program with mass production in our institute. Currently, we are looking to expand our international collaboration efforts and aspire to join international organizations, aiming to contribute to the advancement of high-energy particle/photon detection technologies.

WG/WP2 - Hybrid silicon technologies / 108

Development of TI-LGAD technology towards 4D Tracking

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Institutes interested to join: CERN, FBK, IFIC, IJClab, LPNHE, JSI, UHH, UZH
The project is open to other interested groups.

Two consecutive productions of TI-LGAD at FBK (Trento, Italy), in the framework of RD50 and AIDAinnova WP6, have proven the potential of this technology for the implementation of 4D tracking. Trench-isolated LGADs (TI-LGADs) are a strong candidate for solving the fill-factor problem, as the p-stop termination structure is replaced by isolated trenches etched in the silicon itself. Different design combinations related to the trenches have been studied to determine their inter-pixel distance.

In this project, a systematic testing campaign is proposed, to determine the radiation hardness of a new run of devices after Carbon co-implantation, possibly optimizing the implantation parameters with respect to the past productions. Since one of the possible applications of these devices could be the Phase-3 upgrade of ATLAS and CMS outer pixel layers, the radiation hardness requirement is in the range of 1-5x10**15 neq/cm2.
The sensors will be characterized both at test-structure level, by connecting them by wire bonding to pre-amplifiers and by bump-bonding them to prototype timing chips that are being developed at the moment.

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 109

Discussion on WG2 Plans and Projects

WG4 - Simulations / 110

Discussion on Simulation

WG/WP1 - CMOS technologies / 111

Monolithic CMOS Strip Sensors for large area detectors

Authors: Fabian Huegging[None]; Ingrid-Maria Gregor[1]; Jens Weingarten[2]; Michael Karagounis[3]; Ulrich Parzefall[4]

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Within this project next generation strip sensors for large area applications will be developed. In recent years the consortium of the universities of Bonn, Dortmund, Freiburg and DESY developed stitched passive CMOS strip sensors fabricated by LFoundry in a 150 nm technology, with an additional backside processing from IZM Berlin. The sensors have a thickness of 150 µm, a resistivity of 3-5 kΩ cm and a strip pitch of 75.5 µm. By employing the stitching technique two different strip lengths have been realised, with the short format having three and the long having five stitches. A total of three different strip sensor designs have been investigated. They each vary in doping concentration and width of the n-well to study various depletion concepts and electric field configurations. Unirradiated as well as irradiated sensors have been studied with several measurement techniques, including probe station characterisation, lab measurements with lasers and Sr90-sources and, in particular, test beam campaigns of the different sensor designs in various stages of irradiation. We demonstrated that large area sensors with sufficient radiation hardness can be obtained by stitching in this CMOS process. Based on the positive results obtained it is planned to include a front-end stage into the strips to move towards a fully monolithic strips sensor.

The project targets the technology area DRDT 3.1 - Achieve full integration of sensing and microelectronics in monolithic CMOS strip sensors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG8 - Dissemination & outreach / 112

Organization of the work in WG8

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WG/WP1 - CMOS technologies / 113

Development of MAPS using 55nm HVCMOS process for future tracking detectors

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The High-Voltage CMOS technology is intrinsically radiation-hard and fast at charge collection, making it a promising technological option for tracking detectors at future experiments requiring large-area coverage, high spatial resolution and radiation tolerance. Such examples are LHCb Upstream Trackers in Upgrade II, or inner tracking detector at Circular Electron-Positron Collider (CEPC). Previous R&D on HVCMOS mainly uses 180nm technology. To integrate more functionality in the front-end without substantially increasing the power consumption, we have been exploring sensors in smaller node of 55nm HVCMOS process. Two MPW have been submitted for COFFEE - CMOS sensOr in Fifty-FivE nanometer ProcEss. Preliminary tests are performed to study their IV and CV characteristics, and response to laser signal is observed.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (scientific results or project proposal):

project proposal for future work

WG/WP2 - Hybrid silicon technologies / 114

Development of very small pitch, ultra rad-hard 3D sensors for tracking + timing applications at FBK

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Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 115

Development of Capacitve Coupled LGAD detector (AC-LGAD) in US and Japan

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Particle detectors at future lepton or hadron colliders will require covering a very large area with a tracker with fine spatial resolution of O(10)um. A timing capability of O(10)ps in addition should improve the tracking reconstruction, particle identification of charged particles and mass measurement of newly discovered particle. Capacitive-coupled Low-Gain Avalanche Diode (AC-LGAD) is a semiconductor tracking detector with precise timing resolution and spatial resolution developed by KEK and Tsukuba group collaborating with Hamamatsu Photonics K.K. (HPK). A 100um x 100um pitch pixel type sensor and 80um pitch with 10mm length strip type sensor with 20-50um active thickness have been successfully developed with fully uniform gain across sensor active area. In this presentation we will present about recent status of the development of AC-LGAD detector and possibility of improvement for timing resolution and radiation tolerance.

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP2 - Hybrid silicon technologies / 116

3D activities and plans for the VELO upgrade

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WG/WP1 - CMOS technologies / 117

An OpenPDKs/OpenSource approach to DRD3 CMOS sensors

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This is not a project proposal, but was meant as a WP1 discussion contribution: Experience has shown that the availability of proprietary processes that we invested a lot of money and manpower into is not guaranteed. One possible mitigation might be to evaluate "OpenSource" processes (ideally including OpenPDKs, OpenSource documentation of the process details like doping profiles and OpenSource design tools). I would like to share that we have started the evaluation of a 130 nm OpenPDK-process and would be interested to learn whether this could be done within the DRD3 framework, e.g. as a DRD3 common project or even as part of a WP1 project.

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG/WP1 - CMOS technologies / 118

Next steps in WG1 (September zoom meeting)

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WG8 - Dissemination & outreach / 119

DRD3 www page

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WG3/WP3 - Extreme fluence and radiation damage characterization / 120

Research of carrier recombination characteristics in Si and wide-band-gap materials

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Tomas Ceponis, Laimonas Deveikis, Eugenijus Gaubas, Jevgenij Pavlov, Vytautas Rumbauskas; Institute of Photonics and Nanotechnology, Vilnius University

Carrier recombination characteristics strongly depend on defect species present within the semiconductor material. The reduction of carrier lifetime correlates well with decrease of charge collection efficiency and with increase of the leakage current in particle detectors. In order to develop radiation hard particle sensors and to predict variations of sensor functional parameters with aging, the investigation of recombination processes in pristine and irradiated detector materials is of paramount importance. In this talk, contactless techniques based on measurements of microwave probed photoconductivity transients and different measurement regimes for extraction of surface and bulk recombination as well as trapping parameters will be discussed. The techniques, applied for investigation of ultra-short processes within carrier dynamics, by employing femtosecond laser pulses of variable wavelength and pump-probe setups, will be presented. The temporal resolution of the pump-probe technique is only limited by laser pulse duration (hundreds of femtoseconds), therefore this technique is appropriate for characterization of heavily irradiated structures, where ultra-fast processes in carrier dynamic appear. The application of the aforementioned techniques for characterisation of Si as well as wide-band-gap material based structures will be discussed.

Type of presentation (scientific results or project proposal):

Type of presentation (in-person/online):

WG5 - Characterization techniques, facilities / 121

Discussion on WG5