2nd DRD3 week on Solid State Detectors R&D

Monday 2 December 2024 - Friday 6 December 2024

CERN

Book of Abstracts

Contents

WG2 - Hybrid silicon technologies / 1

On the properties of signal formation in LGAD sensors

Authors: Anna Rita Altamura[1]; Federico Siviero[2]; Leonardo Lanteri[1]; Luca Menzio[1]; Marco Ferrero[1]; Nicolo Cartiglia[3]; Robert Stephen White[1]; Roberta Arcidiacono[1]; Valentina Sola[1]

[1] *Universita e INFN Torino (IT)*

[2] *INFN - National Institute for Nuclear Physics*

[3] *INFN Torino (IT)*

Corresponding Authors: cartiglia@to.infn.it, marco.ferrero@cern.ch, valentina.sola@cern.ch, federico.siviero@to.infn.it, anna.rita.altamura@cern.ch, roberta.arcidiacono@cern.ch, leonardo.lanteri@cern.ch, robert.stephen.white@cern.ch, luca.menzio@edu.unito.it

In this contribution, I will review the mechanisms that govern signal formation in LGAD.
In particular, the contribution investigates how the interplay among the initial energy deposition, space charge effects, and gain saturation determine several LGAD properties, such as the shape of the Landau distribution as a function of gain and the temporal resolution.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 2

Characterization of Low Gain Avalanche Detector Gain by Means of the Transient Current Technique

Authors: Alessandro Tricoli[1]; Enrico Rossi[2]; Gabriele D'Amen[1]; Gabriele Giacomini[1]; Mohamed Hijas Mohamed Farook[3]; Sally Seidel[3]

[1] *Brookhaven National Laboratory (US)*

[2] *Brookhaven National Laboratory*

[3] *University of New Mexico (US)*

Corresponding Authors: hijas.farook@cern.ch, erossi@bnl.gov, sally.seidel@cern.ch, giacomini@bnl.gov, gabriele.d'amen@cern.ch, alessandro.tricoli@cern.ch

Low Gain Avalanche Detectors (LGADs) are silicon-based devices that can achieve good timing resolution due to their unique internal gain. LGADs are proposed for a wide range of fast-timing applications in high energy physics, nuclear physics, and other precision measurements of rare processes. The p-doped gain layer in an LGAD allows generation of a controlled avalanche of charge carriers, with a multiplication factor in the range 10-100. The gain is strongly dependent on the bias voltage, particularly for values close to breakdown voltage. In this study, the gain of LGADs is studied as a function of the bias voltage and as a function of the injected charge. Tests were performed with an infrared laser and a beta source to characterize the gain. Techniques developed in this study expand the characterization of LGAD performance from the case of minimum ionizing particles to the case of highly ionizing particles.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 3

First Irradiation Studies of the novel nLGAD Concept

Authors: Margarita Biveinyte[1]; Veronika Kraus[2]

Co-authors: Jairo Antonio Villegas Dominguez ; Marcos Fernandez Garcia [3]; Michael Moll [4]; Moritz Wiehe [4]; Salvador Hidalgo [5]

[1] *Vilnius University (LT)*

[2] *Vienna University of Technology (AT)*

[3] *Universidad de Cantabria and CSIC (ES)*

[4] *CERN*

[5] *Instituto de Microelectronica de Barcelona (IMB-CNM-CSIC)*

Corresponding Authors: hidalgo.salvador@cern.ch, m.wiehe@cern.ch, michael.moll@cern.ch, veronika.kraus@cern.ch, jairo.antonio.villegas.dominguez@cern.ch, marcos.fernandez@cern.ch, margarita.biveinyte@cern.ch

Low Gain Avalanche Detectors (LGADs) show excellent precision timing performance for high-energy physics (HEP) particle detection and will therefore be employed in detector upgrades for the High-Luminosity LHC ATLAS and CMS. However, traditional p-type LGADs face limitations in detecting low-penetrating particles, such as soft X-rays and low-energy protons. To address this, n-type LGADs (nLGADs) have been developed by IMB-CNM. This study shall give an overview of the efforts to characterize nLGADs, focusing on their performance after 23 GeV proton irradiation at PS-IRRAD (CERN). Step-by-step irradiation with low fluences and high-fluence exposures were conducted to explore the impact on the device performance. Investigations cover the electrical characterization of the devices before and after irradiation. Further techniques like the 3D resolving Two Photon Absorption - Transient Current Technique (TPA-TCT) and red as well as UV TCT were used to study electric field distributions and the reduction of gain after irradiation. Compared to the well-studied acceptor removal effects in p-type LGADs, the obtained results show that it is more complex to investigate the irradiation induced degradation of the nLGAD gain layer, since the characteristics are strongly influenced by complicated field structures after type-inversion. Combined with the research on acceptor removal in standard pLGADs, this work can offer input not only for advancing the LGAD technology in general, but also the evelopment of future HEP detector concepts, such as the compensated LGAD.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG7 - Interconnect / 4

DRD7.6b - Status and Plans

Authors: Hoang Vu Nguyen[1]; Laci Andricek[2]; Michele Caselle[3]

[1] *U*

[2] *MPG HLL*

[3] *KIT - Karlsruhe Institute of Technology (DE)*

Corresponding Authors: michele.caselle@kit.edu, lca@hll.mpg.de

We will present the Workpackage DRD7.6b - common access to 3D and advanced integration. Besides the installation and qualification of advanced integration technologies, one of the key being objectives is the establishment of a distributed laboratory to provide the service to the detector community.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

III. other (please specify)

WG7 - Interconnect / 5

SMALLGAD: Capacitively-coupled AC-LGAD pixel detector for particle detection

Author: Mathieu Benoit[1]

[1] *Oak Ridge National Laboratory (ORNL)*

Corresponding Author: mathieu.benoit@cern.ch

In this R&D proposal, we aim at demonstrating a novel kind of low-cost, large-area, small-pixel silicon pixel detector based on AC-couple low-gain avalanche diode (AC-LGAD) technology. This new technology, the SMall pixel Adhesively coupled Large area LGAD (SMALLGAD), would combine the excellent timing resolution known of LGAD detectors with the small pixel readout of current state-of-the-art hybrid pixel detectors used in High Energy and Nuclear Physics (HEP&NP). Using precise flip-chip capabilities for bonding of silicon detectors, we plan to develop a new low-cost sensor-ASIC capacitive bonding technique for AC-LGAD based on adhesive that can achieve unprecedented combined spatial and timing resolution over a larger area than the current generation of pixel silicon detectors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG2 - Hybrid silicon technologies / 6

NEUROPIX: A neuromorphic computing framework for pixelated detector data processing

Author: Mathieu Benoit[1]

[1] *Oak Ridge National Laboratory (ORNL)*

Corresponding Author: mathieu.benoit@cern.ch

We propose the NEUROmorphic computing framework for PIXelated detector data processing (NEUROPIX) framework, which will create a path for hardware development, enabling the development of integrated circuit (IC)-based neuromorphic platforms that can perform powerful classification, interpolation, and anomaly-detection tasks with low latency and power. We base this framework on spiking neural networks (SNNs), a type of network closely related to biological examples of neural networks, which can perform complex tasks with fewer parameters and connections—and, therefore, lower power—than other types of networks. Our goal is to provide the software infrastructure for the simulation, training, and deployment to field-programmable gate arrays (FPGAs) and advanced systems on integrated circuits (ASICs) of SNN algorithms for edge processing of pixel detector data and extraction with low latency of complex quantities, such as beam luminosity and position, that are relevant for experiments at particle colliders. Our work will demonstrate the need for this type of solution in modern detector systems; justify investment in a large-scale, neuromorphic hardware platform with increased polyvalence and processing capabilities; and motivate the integration of such systems in future HEP detectors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG3 - Radiation Damage / **7**

Simulation of Irradiation Damage and Defect Evolution Induced by Neutrons in LGAD

Authors: Chaohui He[1]; Wei Li[1]; Yunyun Fan[2]

Co-authors: Haoxuan Guo [1]; Yuan Feng [2]

[1] *Xi'an Jiaotong University*

[2] *Chinese Academy of Sciences (CN)*

Corresponding Authors: skyair@stu.xjtu.edu.cn, wli@ihep.ac.cn, hechaohui@xjtu.edu.cn, y.feng@cern.ch, fanyy@ihep.ac.cn

The introduction of carbon doping in Low Gain Avalanche Detectors (LGADs) has been shown to effectively mitigate neutron-irradiation-induced acceptor removal effects. However, the microscopic mechanism behind this phenomenon remains unclear. In this study, Monte Carlo (MC) simulations model the effects of 1 MeV neutrons in critical regions in LGAD, providing data on the energy and spectrum of primary knock-on atoms (PKAs). Following this, molecular dynamics (MD) simulations are conducted with silicon lattice systems containing carbon, oxygen, and boron impurities, subject to cascades from the most probable PKAs. This allows us to trace defect formation, recombination processes, and evolution during cascade collisions, and to compile statistics on defect types and probabilities associated with each impurity after thermal equilibrium. These simulation results will compare with parameters L, K, and M from the experiment data (SIMS and CV test), providing an atomic-level explanation of how carbon doping mitigates acceptor removal. It is found that carbon impurities inhibit boron acceptor removal by competitively capturing neutron-induced Frenkel defects.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / 8

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

Authors: Leena Diehl[1]; Oliwia Agnieszka Kaluzinska[2]

Co-authors: Eva Sicking [1]; Natalya Gerassyova

[1] *CERN*

[2] *KIT - Karlsruhe Institute of Technology (DE)*

Corresponding Authors: natalya.gerassyova@cern.ch, oliwia.agnieszka.kaluzinska@cern.ch, leena.diehl@cern.ch, eva.sicking@cern.ch

To face the higher levels of radiation due to the 10-fold increase in integrated luminosity during the High-Luminosity LHC phase, the CMS collaboration will replace the current calorimeter endcaps with the new High-Granularity Calorimeter (HGCAL) concept. 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 $10^{14} n_{eq}/cm^2$) will be equipped with silicon pad sensors, covering a total area of $620m^2$). Fluences up to $10^{16} n_{eq}/cm^2$ and doses up to 1.5MGy are expected.

The sensors are processed on novel 8-inch p-type wafers with an active thickness of 300μm, 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 $2 \cdot 10^{15} n_{eq}/cm^2$ and $1.5 \cdot 10^{16} n_{eq}/cm^2$. In this talk, the electrical characterisation and charge collection measurements of the irradiated silicon diodes will be presented. The study focuses on the isothermal annealing behaviour of the bulk material at temperatures of 6.5℃, 20℃, 30℃, 40℃ and 60℃. The results are used to parametrise the temperature dependence of the annealing behaviour of p-type sensors using the Hamburg model, as input to define a suitable operation scenario (e.g. temperature during shutdowns) for the HGCAL.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 9

Performance of AC-LGADs in radiation hard environment and non-standard charge depositio

Authors: Abraham Seiden[1]; Adam Molnar[None]; Bruce Andrew Schumm[1]; Hartmut Sadrozinski[2]; Hartmut Sadrozinski[1]; Jennifer Ott[1]; Simone Michele Mazza[1]; Yuzhan Zhao[3]; Yuzhan Zhao[4]

[1] *University of California,Santa Cruz (US)*

[2] *SCIPP, UC santa Cruz*

[3] *Carleton University (CA)*

[4] *University of California Santa Cruz*

Corresponding Authors: abraham.seiden@cern.ch, yuzhan.zhao@cern.ch, simone.michele.mazza@cern.ch, hartmut@scipp.ucsc.edu, jeott@ucsc.edu, baschumm@ucsc.edu, hartmut@ucsc.edu, yuzhao@ucsc.edu, azmolnar@ucsc.edu

Low Gain Avalanche Detectors (LGADs) are characterized by a fast rise time (~500ps) and extremely good time resolution (down to 17ps). For the application of this technology to near future experiments, the intrinsic low granularity of LGADs and the large power consumption of readout chips for precise timing is problematic. AC-coupled LGADs, where the readout metal is AC-coupled through an insulating oxide layer, could solve both issues at the same time thanks to the 100% fill factor and charge-sharing capabilities.
Extensive characterization of AC-LGAD devices with both laser TCT and probe station (IV/CV) will be shown in this contribution, comparing the effect of various parameters among the readout electrode dimensions (strip/pad metal contact length and width, pitch) and sensor production details (manufacturer, N+ layer resistivity, dielectric capacitance, bulk thickness, doping of the gain layer). We will present the first results on AC-LGADs irradiated with 1 MeV reactor neutrons at JSI/Ljubljana to fluences on the order of 1e13 to 1e15 n/cm2. Using a rotational stage in our laser TCT system, we will show our initial investigation of charge sharing in AC-LGADs for hits incident on the sensor at an angle to evaluate the effect of the tilted installation which is typical for silicon pixel and strip sensor modules in tracking detectors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 10

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

Author: Simone Michele Mazza[1]

[1] *University of California,Santa Cruz (US)*

Corresponding Author: simone.michele.mazza@cern.ch

Status report on RD50 Common Fund Project - RD50-2023-03: Deep Junction LGAD

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG3 - Radiation Damage / 11

Updates on Thins Silicon Sensors for the eXtreme Fluences

Authors: Alessandro Fondacci[1]; Anna Rita Altamura[2]; Arianna Morozzi[3]; Ashish Bisht[None]; Daniele Passeri[4]; Federico Siviero[5]; Francesco Moscatelli[6]; Giovanni Paternoster[7]; Leonardo Lanteri[2]; Luca Menzio[2]; Marco Costa[2]; Marco Ferrero[2]; Maria Margherita Obertino[2]; Matteo Centis Vignali[8]; Matteo Durando[2]; Maurizio Boscardin[9]; Nadia Pastrone[2]; Nicolo Cartiglia[10]; Robert Stephen White[2]; Roberta Arcidiacono[2]; Simona Giordanengo[11]; Simone Galletto[12]; Tommaso Croci[None]; Valentina Sola[2]

[1] *INFN Perugia (IT)*

[2] *Universita e INFN Torino (IT)*

[3] *INFN, Perugia (IT)*

[4] *University & INFN, Perugia (IT)*

[5] *INFN - National Institute for Nuclear Physics*

[6] *IOM-CNR and INFN, Perugia (IT)*

[7] *Fondazione Bruno KEssler*

[8] *FBK*

[9] *FBK Trento*

[10] *INFN Torino (IT)*

[11] *INFN Torino*

[12] *Torino University and INFN*

Corresponding Authors: robert.stephen.white@cern.ch, tommaso.croci@pg.infn.it, valentina.sola@cern.ch, luca.menzio@edu.unito.it, alessandro.fondacci@pg.infn.it, francesco.moscatelli@cern.ch, matteo.durando@cern.ch, simona.giordanengo@to.infn.it, simone.galletto@edu.unito.it, daniele.passeri@cern.ch, matteo.centis.vignali@cern.ch, anna.rita.altamura@cern.ch, marco.ferrero@cern.ch, nadia.pastrone@cern.ch, federico.siviero@to.infn.it, marco.costa@cern.ch, leonardo.lanteri@cern.ch, abisht@fbk.eu, arianna.morozzi@pg.infn.it, boscardi@fbk.eu, paternoster@fbk.eu, cartiglia@to.infn.it, roberta.arcidiacono@cern.ch, margherita.obertino@cern.ch

An update on the recent progress from the investigation on thin silicon sensors for extreme fluences will be given.
Results from thin sensors with and without gain will be presented and an overview of future developments will be discussed.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / 12

Updates on the PAB Project

Authors: Giovanni Paternoster[1]; Pablo Fernandez-Martinez[2]; Valentina Sola[3]

[1] *Fondazione Bruno KEssler*

[2] *IMB-CNM, CSIC*

[3] *Universita e INFN Torino (IT)*

Corresponding Authors: valentina.sola@cern.ch, paternoster@fbk.eu, pablo.fernandez.martinez@cern.ch

Updates on the ongoing activities of the Partial Activation of Boron (PAB) common project will be given.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

III. other (please specify)

WG1 - CMOS technologies / 13

TPA Laser Experiment on the MPW4 HVCMOS MAPS chip

Authors: Bernhard Pilsl[1]; Francisco Rogelio Palomo Pinto[2]; Jorge Jimenez Sanchez[3]; Jory Sonneveld[4]; Michael Moll[5]; Moritz Wiehe[5]

[1] *Austrian Academy of Sciences (AT)*

[2] *Universidad de Sevilla (ES)*

[3] *Universidad de Sevilla*

[4] *Nikhef National institute for subatomic physics (NL)*

[5] *CERN*

Corresponding Authors: bernhard.pilsl@cern.ch, jory.sonneveld@cern.ch, michael.moll@cern.ch, m.wiehe@cern.ch, jorge.jimenez.sanchez@cern.ch, francisco.rogelio.palomo.pinto@cern.ch

The experiment purpose is to get signals from the MPW4 monolithic active pixel sensor (MAPS) under femtosecond TPA laser excitation at different depths (z-scan mode) and positions (xy-scan mode) on the chip (backside illumination). At 1550 nm, the silicon is transparent below a light intensity threshold so the photoionization (light absorption) happens only around the focus point (voxel volume). A z-scan means to precisely position the voxel volumen along different die depths, also moving the beam along the pixel area. That way any particular detector volume can be excited to generate a signal in the collecting electrodes. We map the depletion volume and the charge sharing effect between neighbouring pixels by correlation the signal with the position of the voxel.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 14

Fluence profiling at JSI TRIGA reactor irradiation facility

Authors: Gregor Kramberger[1]; Igor Mandic[1]; Klemen Ambrožič[1]; Luka Snoj[2]; Marco Ferrero[3]; Valentina Sola[3]

[1] *Jozef Stefan Institute (SI)*

[2] *University of Ljubljana and Jozef Stefan Institute (SI)*

[3] *Universita e INFN Torino (IT)*

Corresponding Authors: klemen.ambrozic@ijs.si, igor.mandic@ijs.si, gregor.kramberger@ijs.si, luka.snoj@ijs.si, valentina.sola@cern.ch, marco.ferrero@cern.ch

We present the updated analysis of the fluence profile at the JSI TRIGA neutron reactor facility in Ljubljana. For the study, multi-pad Low-Gain Avalanche Diodes (LGADs) are used. The deactivation

of acceptor doping in the gain layer implant due to the irradiation, typical of LGAD devices, is exploited to map the fluence profile inside the irradiation channels. The amount of active doping of the LGAD gain layer is extracted via capacitance-voltage measurements for each pad before and after irradiation to a fluence of 1.5×10^{15} n_{eq}/cm^2, providing a precise and prompt measurement of the fluence distribution over the LGAD sensor. Experimental results are compared to neutron fluence expectations calculated with Monte Carlo techniques.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 15

Effect of proton irradiation on the performance of 4H-SiC LGAD devices

Authors: Sen Zhao[1]; Xiyuan Zhang[2]

Co-authors: Congcong Wang [2]; Xin Shi [2]

[1] *IHEP, CAS*

[2] *Chinese Academy of Sciences (CN)*

Corresponding Authors: xin.shi@cern.ch, zhaosen@ihep.ac.cn, xiyuan.zhang@cern.ch

4H-SiC detectors have potential to operate in high radiation and room-temperature environments due to the broader band gap, elevated atomic displacement threshold energy and high thermal conductivity. In order to verify the irradiation resistance of 4H-SiC LGAD devices, we successfully prepared LGAD devices with a gain factor of 3 and proceeded to irradiate the device with protons at 80 MeV (2×10^{11}neq/cm2 ~ 1×10^{14} neq/cm2). Based on the defects identified in the 4H-SiC LGAD, the current-voltage, capacitance-voltage and gain factor of the devices were characterized and simulated before and after irradiation. In terms of the performance of leakage current and charge collection after radiation, 4H-SiC exhibits good radiation resistance, and the physical explanation can be given by simulation.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 16

The RD50-MPW4 CMOS Pixel Sensor: Performance Post-Irradiation

Author: Bernhard Pilsl[1]

[1] *Austrian Academy of Sciences (AT)*

Corresponding Author: bernhard.pilsl@cern.ch

The RD50-MPW4, the latest HV-CMOS pixel sensor of the former CERN-RD50-CMOS group, enhances radiation tolerance, granularity, and timing resolution for future experiments like the HL-LHC and FCC. Fabricated by LFoundry in December 2023 using a 150nm CMOS process, it features a 64 x 64 pixel matrix with a $62 \times 62 \mu m^2$ pitch and employs a column-drain readout architecture. The previous model, RD50-MPW3, faced noise coupling issues between the digital periphery and pixels, limiting threshold settings to
$gtrsim5ke^-$ and restricting operation to the matrix's top half.

The RD50-MPW4 addresses these issues by separating power domains for the digital and analog components, allowing more sensitive threshold settings and enabling full matrix operation. A new backside biasing scheme and improved guard ring structure further support bias voltages up to 500V, enhancing radiation hardness.

Tests with unirradiated samples showed >99.9% efficiency, ˜16 μm spatial resolution, and ˜$10 ns$ timing resolution. Several samples were irradiated at JSI to fluences from 10^{14} to $10^{16} n_{eq}/cm^2$. This presentation covers IV measurements and injection scans at varying temperatures before and after annealing, along with results from the latest test beam campaign at DESY, comparing irradiated and non-irradiated samples and demonstrating the sensor's suitability for high-radiation environments.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 17

Status and plan of testbeam line at KEK

Author: Yuji Enari[1]

Co-author: Yuta Okazaki

[1] *KEK High Energy Accelerator Research Organization (JP)*

Corresponding Authors: yuji.enari@cern.ch, yuta.okazaki@kek.jp

At KEK an electron test beam facility with beam momentum up to 5 GeV has been established since 2022. 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.
We have a plan to improve the focusing the electron test beam line by modifying the beam transfer magnet configuration. We will discuss the plan and recent updates on the test beam line tracking system.
Also we have started to discuss a hadron test beam line at KEK Tokai campus (J-PARC). A test measurement is scheduled to verify there is enough amount of charged pion for a hadron test beam line. We will discuss these plan and prospect of the hadron test beam line.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 18

Prototype of SiC-LGAD Detector

Authors: Xin Shi[1]; Xiyuan Zhang[2]

Co-authors: Congcong Wang [2]; Keqi Wang [1]; Sen Zhao ; Zaiyi Li

[1] *Institute of High Energy, CAS*

[2] *Chinese Academy of Sciences (CN)*

Corresponding Authors: xin.shi@cern.ch, xiyuan.zhang@cern.ch, wangkq2326@163.com, lizaiyi@ihep.ac.cn, wangcc@ihep.ac.cn

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. In order to improve the tracking and timing capability of SiC-LGAD devices, the development of DC-coupled and AC-coupled LGAD devices paves the way for the application of wide band-gap semiconductor detectors in high energy fields. At present, there are still many difficulties in the research and development of SiC LGAD in the preparation process, gain model, simulation model, readout electronics and irradiation resistance. The work on device development, simulation models and defect models is ongoing. The gain factor of the first version of the DC-LGAD is about 2˜3 and is undergoing optimization. Radiation models and defects are also being studied gradually.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG5 - Characterization / 19

EURO-LABS Oportunities for DRD3

Author: Marko Mikuz[1]

[1] *Jozef Stefan Institute (SI)*

Corresponding Author: marko.mikuz@cern.ch

EURO-LABS is an EU project covering nuclear and particle physics (accelerator and detector) research infrastructures (RI). For HEP detector R&D, Transnational Access (TA) at 11 RIs is offered free of charge to the users.
I will review the usage at the RIs in the first two years of the project and point to opportunities for DRD3 projects to access the resources in the final two years, especially in the RIs that experienced less demand as foreseen.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

III. other (please specify)

WG1 - CMOS technologies / 20

H2M –Characterization of a MAPS in a 65 nm CMOS Imaging Process

Author: Finn Feindt[1]

Co-authors: Adriana Simancas [1]; Ana Dorda [2]; Anastasiia Velyka [1]; Christian Reckleben [1]; Dominik Dannheim [3]; Eric Buschmann [4]; Gianpiero Vignola [1]; Håkan Wennlöf [5]; Ingrid-Maria Gregor [6]; Iraklis Kremastiotis [3]; Judith Christina Schlaadt [1]; Karsten Hansen [7]; Larissa Helena Mendes [1]; Lennart Huth [1]; Manuel Alejandro Del Rio Viera [1]; Michael Campbell [3]; Philipp Gadow [3]; Rafael Ballabriga Sune [3]; Raimon Casanova Mohr [8]; Sara Ruiz Daza [1]; Sebastien Rettie [3]; Simon Spannagel [1]; Stefano Maffessanti ; Tomas Vanat [1]; Walter Snoeys [3]; Yajun He [9]; Younes Otarid [3]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *KIT - Karlsruhe Institute of Technology (DE)*

[3] *CERN*

[4] *Brookhaven National Laboratory (US)*

[5] *Nikhef National institute for subatomic physics (NL)*

[6] *DESY & Bonn University*

[7] *DESY*

[8] *IFAE - Barcelona (ES)*

[9] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Authors: yajun.he@cern.ch, stefano.maffessanti@cern.ch, h.wennlof@cern.ch, dominik.dannheim@cern.ch, rafael.ballabriga@cern.ch, sebastien.rettie@cern.ch, simon.spannagel@cern.ch, raimon.casanova.mohr@cern.ch, finn.feindt@desy.de, ana.dorda.martin@cern.ch, sara.ruiz.daza@desy.de, iraklis.kremastiotis@cern.ch, adriana.simancas@cern.ch, ingrid.gregor@desy.de, walter.snoeys@cern.ch, younes.otarid@cern.ch, judith.schlaadt@desy.de, gianpiero.vignola@cern.ch, anastasiia.velyka@cern.ch, eric.buschmann@cern.ch, tomas.vanat@cern.ch, christian.reckleben@desy.de, manuel.alejandro.del.rio.vie paul.philipp.gadow@cern.ch, larissa.mendes@cern.ch, karsten.hansen@desy.de, lennart.huth@cern.ch, michael.campbell@cern.ch

Monolithic Active Pixel Sensor (MAPS) are among the most promising options for vertex detectors in future lepton colliders. Manufactured in a TPSCo 65 nm CMOS imaging process, the Hybrid-to-Monolithic (H2M) prototype advances this sensor type in the context of high-energy physics applications. The design process employed a digital-on-top design flow, and studied the portability of hybrid pixel detector architecture into a monolithic chip.

The prototype has a sensitive area of 2.24×0.56 mm², and contains 64×16 square pixels with a pitch of 35 µm. The layout of the sensitive area makes use of process modifications to maximize the charge collection by means of a low dose n-type implant with a gap at the pixel boundaries. Each pixel features analog and digital front-end electronics with a Krummenacher-type charge sensitive amplifier, threshold trimming, and 4 readout modes to facilitate time-of-arrival, or time-over-threshold measurements, hit counting, or triggered readout.

Laboratory and test-beam characterization of the prototype shows full functionality of the chip within expectations from simulation, a hit-detection efficiency better than 99 %, and a spatial resolution on the order of 11 µm, all unperturbed by thinning down to 21 µm. A measured non-uniformity of the in-pixel response related to the size and location of the n-wells in the analog circuitry is qualitatively confirmed by simulation.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / 21

Impact of a magnetic field on integrated low-temperature photoluminescence of quenched silicon

Author: Kevin Lauer[1]

[1] *CIS Institut fuer Mikrosensorik GmbH (DE)*

Corresponding Author: kevin.lauer@cern.ch

Kevin Lauer,[1,2] Katharina Peh,[2] Dirk Schulze,[2] Stefan Krischok,[2] Mario Bähr,[1] Richard Grabs,[1] Frank Long,[1,3] Martin Kaleta,[1] Andreas Frank[1] and Thomas Ortlepp[1]

[1]CiS Forschungsinstitut für Mikrosensorik GmbH, Konrad-Zuse-Str. 14, 99099 Erfurt, Germany
[2]Technische Universität Ilmenau, Institut für Physik, Weimarer Str. 32, 98693 Ilmenau, Germany
[3]Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

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. Recently, acceptor-interstitial silicon (A_{Si}-Si$_i$)-defects [1] were proposed to be responsible for the gain loss in LGADs. This defect category seems to be relevant for silicon solar cell and silicon-based quantum technology, as well. [2] To further investigate possible defect mechanisms responsible for the ARP we report on first experiments related to changes of the integrated low-temperature photoluminescence (PL) due to application of magnetic fields. Silicon samples with and without indium doping were treated by a temperature quenching step to generate A_{Si}-Si$_i$-defects. The A_{Si}-Si$_i$-defect generation was done using a local laser quenching method as well as a Bunsen burner with subsequent water quenching. The integrated PL intensity increased after this generation process as expected. The application of magnetic fields to the samples changes the integrated PL intensity significantly. Differences between samples with and without indium doping will be discussed.

[1] K. Lauer, K. Peh, D. Schulze, T. Ortlepp, E. Runge, and S. Krischok, 'The A_{Si}-Si$_i$ 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.
[2] K. Lauer et al., 'Examining the properties of the A_{Si}-Si$_i$-defects for their potential as qubits', presented at the GADEST, Bad Schandau: ResearchGate, May 2024. doi: 10.13140/RG.2.2.18793.51048.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 22

Planar SiC diodes for material and radiation hardness studies

Author: Thomas Bergauer[1]

[1] *Austrian Academy of Sciences (AT)*

Corresponding Author: thomas.bergauer@cern.ch

4H-SiC is becoming a leading candidate for next-generation semiconductor detectors due to the increased availability in industry. These new sensors show promising properties like its stable performance across a wide temperature range, making cooling of irradiated devices not necessary.
This project aims to study radiation hardness, annealing, traps, and the applicability of the NIEL hypothesis to planar junction- and Schottky 4H-SiC diodes in detail. For this it uses state-of-the-art characterization techniques like IV/CV, UV-TCT, TPA-TCT, TSC, DLTS and other methods to determine trap levels, eventually leading to a TCAD irradiation model.
Irradiations over a wide range of fluences with neutrons, protons up to $10^{17} n_{eq}\ cm^{-2}$, heavy ions, and X-rays up to 1Grad, will be performed.
For all these studies, many samples of identical quality are necessary. These samples will be purchased commercially from the industry or produced by collaborating research institutes.
Eventually, all results will contribute to developing SiC-LGADs and other SiC-based detectors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG3 - Radiation Damage / **23**

Timing and CCE Performance of the LGAD from Teledyne e2v

Author: Dengfeng Zhang[1]

Co-authors: Daniel Hynds [2]; Daniela Bortoletto [2]; Douglas Jordan ; Giulio Villani [3]; Martin Gazi ; Steve Mcmahon [3]; Trevor Vickey [1]

[1] *University of Sheffield (GB)*

[2] *University of Oxford (GB)*

[3] *Science and Technology Facilities Council STFC (GB)*

Corresponding Authors: giulio.villani@stfc.ac.uk, daniela.bortoletto@cern.ch, daniel.hynds@cern.ch, douglas.jordan@teledyne.com, stephen.mcmahon@cern.ch, trevor.vickey@cern.ch, martin.gazi@magd.ox.ac.uk, dengfeng.zhang@cern.ch

Owing to their timing capabilities, of the order of 50 ps or better for MIP, Low Gain Avalanche Detector (LGAD) have been chosen for next-generation timing detectors at the HL-LHC and other high-energy physics experiments. Both ATLAS and CMS collaborations have adopted them as baseline sensors for the High Granularity Timing Detector (HGTD) and MIP Timing Detector (MTD) in their upgrades.
During their lifetime, the detectors will be exposed to high level of radiation, both ionising and non-ionising, hence their radiation hardness is one of the key parameters to be assessed.
In this talk, we will present the results of charge collection and timing of neutron-irradiated 1x1 mmˆ2 LGAD sensors produced by Teledyne e2v (Te2v) and jointly developed by the University of Oxford, the University of Birmingham, the Rutherford Appleton Laboratory, and the Open University.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 24

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

Authors: Dominik Dannheim[1]; Eric Buschmann[2]; Hucheng Chen[2]; Mathieu Benoit[3]; Ryan St-Jean[4]; Shaochun Tang[2]; Simon Spannagel[5]; Thomas Koffas[4]; Tomas Vanat[5]; Younes Otarid[1]

[1] *CERN*

[2] *Brookhaven National Laboratory (US)*

[3] *Oak Ridge National Laboratory (ORNL)*

[4] *Carleton University (CA)*

[5] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: younes.otarid@cern.ch, tomas.vanat@cern.ch, simon.spannagel@cern.ch, thomas.koffas@cern.ch, dominik.dannheim@cern.ch, shaochun.tang@cern.ch, hucheng.chen@cern.ch, mathieu.benoit@cern.ch, eric.buschmann@cern.ch, ryanstjean@cmail.carleton.ca

Caribou is a versatile data acquisition system used in multiple collaborative frameworks (CERN EP R&D, DRD3, AIDAinnova, Tangerine) for laboratory and test-beam qualification of novel silicon pixel detector prototypes. The system is built around a common hardware, firmware and software stack shared accross different projects, thereby drastically reducing the development effort and cost. It consists of a custom Control and Readout (CaR) board and a commercial Xilinx Zynq System-on-Chip (SoC) platform. The SoC platform runs a full Petalinux distribution integrating the custom software framework (Peary) and a device-specific build of the common FPGA firmware (Boreal) or any other custom firmware. The CaR board provides a hardware environment featuring various services such as powering, slow-control, and high-speed data links for the target detector prototype. Boreal and Peary, in turn, offer firmware and software architectures that enable seamless integration of control and readout for new devices. While the first version of the system used a SoC platform based on the ZC706 evaluation board, migration to a Zynq UltraScale+ architecture is progressing towards the support of the ZCU102 board and the ultimate objective of integrating the SoC functionality directly into the CaR board, eliminating the need for separate evaluation boards. This talk describes the Caribou system, focusing on the latest project developments and showcasing progress across its hardware, firmware, and software components.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG4 - Simulation / 25

TCAD Parameters for 4H-SiC: A Review

Authors: Andreas Gsponer[1]; Jürgen Burin[1]; Philipp Gaggl[1]; Simon Emanuel Waid[1]; Thomas Bergauer[1]

[1] *Austrian Academy of Sciences (AT)*

Corresponding Authors: juergen.maier@oeaw.ac.at, andreas.gsponer@cern.ch, thomas.bergauer@cern.ch, simon.waid@oeaw.ac.at, philipp.gaggl@cern.ch

A very promising candidate for a more power efficient (e.g., in power electronics) replacement of Silicon is the wide band gap material 4H-SiC. To describe its physical properties in Technology Computer-Aided Design (TCAD) simulations many models with accompanying parameters have been proposed. Often these contradict each other which makes it challenging to identify a suitable

initial set of parameters. In addition, the origin of popular values, e.g., which of the many SiC polytypes was used during characterization, is often unclear, because authors cite only the latest research but not the, sometimes decades old, original publication. This makes it hard to evaluate the suitability of a model for the problem at hand.

To tackle these issues we conducted an extensive literature review on TCAD parameters for 4H-SiC. With this research we aim to decrease the entrance barrier to 4H-SiC simulations and to identify shortcomings in the state-of-the-art, highlighting areas respectively parameters that would benefit from in-depth investigations.

In this presentation we report on the current status of this literature review. After a description of the methods we utilized in our analyses we summarize the major insights we gained for the topics permittivity, density-of-states mass, impact ionization, incomplete ionization and band gap. We also present the recently finished evaluation of charge carrier recombination and, finally, conclude with shortcomings we were able to identify that demand further research.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 26

Characterisation of Diamond and SiC sensors with TPA and modelling of response

Authors: Huazhen Li[1]; Alexander Oh[1]

Co-authors: Marco Gersabeck [2]; Oscar Augusto De Aguiar Francisco [1]; Patrick Parkinson [3]; Olivier Allegre [3]; Patrick Salter [4]; Charles Smith [3]; Nawal Al-Amairi [3]

[1] *The University of Manchester (GB)*

[2] *Albert Ludwigs Universitaet Freiburg (DE)*

[3] *The University of Manchester*

[4] *University of Oxford*

Corresponding Authors: olivier.allegre@manchester.ac.uk, huazhen.li@cern.ch, patrick.parkinson@manchester.ac.uk, oscar.augusto.de.aguiar.francisco@cern.ch, charles.smith@manchester.ac.uk, alexander.oh@cern.ch, patrick.salter@eng.ox.ac.uk, marco.gersabeck@cern.ch, nawal.alamairi@postgrad.manchester.ac.uk

Two Photon Absorption (TPA) effect is a second order non-linear optical effect in semiconductor material, which refers to the phenomenon that when a femto-second laser is focused inside the device, electrons in valance band could absorb two photons simultaneously and create a point-like activation region around laser focus. Electron-hole pairs generated in the activation region can be used to test the field inside the device. This technique features precisely controllable testing position and high temporal resolution. In this work, we applied TPA testing on a planar diamond sample and a 4H-SiC sample (cooperating with HEPHY), and the performance of the detectors are examined. With Sentaurus TCAD, electric fields in the samples are simulated, the drifting and diffusion of carriers generated by TPA effect and signal response are then modelled with Monte Carlo method using Garfield++, which is compared with the experimental TPA results.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 27

Establishment of a Silicon Carbide Source Test Setup and Initial Results

Author: Roman Mueller[1]

Co-authors: Faiza Rizwan [2]; Michael Moll [1]; Moritz Wiehe [1]; Susanne Kuehn [1]

[1] *CERN*

[2] *Cern*

Corresponding Authors: roman.mueller@cern.ch, susanne.kuehn@cern.ch

Silicon Carbide (SiC) is a promising material for particle detection and beam diagnostics due to its supposedly high radiation resilience. We established a new probe station setup and an experimental setup to evaluate SiC performance using radioactive sources. This effort involved integrating SiC pad sensors from the Common RD50 project into a small, shielded tabletop setup, enabling precise measurement of pulse characteristics such as the charge and timing resolution with several Am241 sources.
Initial results highlight the development of the measurement setup, IV characteristics will be presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 28

Impact of high deposited energy on Single Event Burnout in LGAD sensors

Author: Gabriele D'Amen[1]

Co-authors: Abraham Tishelman-Charny [1]; Alessandro Tricoli [1]; Alexander Buzzi ; Dylan Ponman [2]; Enrico Rossi [3]; Gabriele Giacomini [1]; Jennifer Roloff [2]; Matthew Glenn Kurth [1]; Stefania Antonia Stucci [1]

[1] *Brookhaven National Laboratory (US)*

[2] *Brown University (US)*

[3] *Brookhaven National Laboratory*

Corresponding Authors: jroloff2@gmail.com, alessandro.tricoli@cern.ch, abraham.tishelman.charny@cern.ch, alexander_buzzi@brown.edu, stefania.stucci@cern.ch, giacomini@bnl.gov, dylan_ponman@brown.edu, erossi@bnl.gov, matthew.glenn.kurth@cern.ch, gabriele.d'amen@cern.ch

Silicon sensors with gain such as LGADs (Low Gain Avalanche Diodes) are prime candidates for high resolution timing applications in High Energy Physics, Nuclear science, and other fields. Over the course of their lifetime, these sensors are required to withstand enormous amounts of radiation ($> 10^{15} n_{eq}/cm^2$) while maintaining acceptable performances at hadron colliders. Particles interacting with highly biased sensors can produce irreversible damages known as Single Event Burnouts (SEBs).

Recent studies conducted using high energy protons or pions, i.e. minimum ionizing particles (MIPs), have shown that the probability of mortality caused by SEB for these sensors is proportional to the strength of the electric field generated locally by the particle interaction. Thus, the current expectation is that SEB events are more likely when a particle deposits a high amount of energy in the interaction with silicon. Protons and ions in the O(10 - 100) MeV energy range deposit a high amount of energy in silicon in their interaction, increasing the probability of SEBs with respect to a MIP produced at higher energy accelerators.

We exposed a variety of LGADs, pre-irradiated at the Rhode Island Nuclear Science Center up to 1.5 x $10^{15} n_{eq}/cm^2$, to a high intensity beam of both non-MIP protons and ions produced at the BNL Tandem Van de Graaff accelerator. Results from this study allow us to strengthen our understanding of SEB and permanent radiation damages and parametrize SEB probability in interactions with high deposited energy.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / **29**

Preliminary results on 3D silicon sensors using femtosecond TCT-SPA and TPA-TCT techniques at ELI: Work in Progress

Authors: Gordana Lastovicka Medin[1]; Danijela Mrkic[2]; Vuk Baletic[2]; Gregor Kramberger[3]; Mateusz Rebarz[4]

[1] *University of Montenegro (ME)*

[2] *University of Montenegro*

[3] *Jozef Stefan Institute*

[4] *ELI Beamlines, ELI ERIC*

Corresponding Authors: mateusz.rebarz@eli-beams.eu, gordana.medin@g, vuk097210@gmail.com, danijela.mrkic4@gmail.com, gregor.kramberger@ijs.si

In this presentation we show the preliminary results from our study on 3D columnar pixel sensor technology using femtosecond laser based TCT (both SPA and TPA modes). We investigated 3D columnar silicon technology fabricated within RD50 Common project and fabricated at CNM-IBM. This analysis is work under progress. The aim is to develop advanced tool with high precision for studying the 3D sensors in future.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / **30**

Ghosty Ti-LGAD

Authors: Gordana Lastovicka-Medin[1]; Danijela Mrkic[2]; Vuk Baletic[2]; Gregor Kramberger[3]; Jiri Kroll[None]; Mateusz Rebarz[4]

[1] *University of Montenegro (ME)*

[2] *University of Montenegro*

[3] *Jozef Stefan Institute*

[4] *ELI Beamlines, ELI ERIC*

Corresponding Authors: jiri.kroll@cern.ch, vuk097210@gmail.com, danijela.mrkic4@gmail.com, mateusz.rebarz@eli-beams.eu, gordana.medin@gmail.com, gregor.kramberger@ijs.si

In this contribution we will first give a short introduction on the results from our previously reported study on ghosts in Ti-LGADs with double trenches in the inter-pixel region. The focus will be given on the most recent results from our study on irradiated samples. Both, irradiated 2Tr PINs and irradiated 2Tr LGADs are investigated from AIDAinova and RD50 production. Also, irradiated 1Tr PIN and 1Tr LGADs are investigated. Comparing a large pool of data measured on a large set of samples, both irradiated and unirradiated, with single and double trenches from two vendors, enabled us to deepen our knowledge on understanding the origin and mechanism behind the observed ghosts.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 31

Research on graphene-optimized silicon carbide detector

Author: Wang Congcong[1]

Co-authors: Jiang Zhenyu [1]; Keqi Wang [2]; Suyu Xiao [3]; Xin Shi [2]; Xiyuan Zhang [4]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences*

[2] *Institute of High Energy, CAS*

[3] *Shandong Institute of Advanced Technology, Jinan, China*

[4] *Chinese Academy of Sciences (CN)*

Corresponding Author: wangcc@ihep.ac.cn

Silicon carbide as wide band-gap semiconductor, has physical characteristics of wide bandgap, excellent carrier mobility, higher breakdown electric field, higher thermal conductivity and higher saturated drift velocity compared with silicon. However, the existing 4H-SiC radiation detectors all use metal electrodes, which are easy to produce structural defects after metal electrode irradiation, thus seriously reducing the mechanical and physical properties of the material. Therefore, the application of silicon carbide detector in the field of nuclear detection and heavy ion detector is limited. Graphene has the advantages of zero band-gap, high carrier mobility, high conductivity and anti-irradiation, which provides a new idea for demetallization of particle detector electrodes. A graphene-optimized silicon carbide detector was developed and its electrical properties and charge collection properties were studied. The experimental results predict that the graphene-optimized silicon carbide detector can improve the charge collection speed and time resolution of the detector.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG3 - Radiation Damage / **32**

Measurement on Prototype of Double-Sided 3D Sensors Produced by CNM

Authors: Christopher Betancourt[1]; Daniela Bortoletto[2]; Manabu Togawa[1]; chuan liao[3]

[1] *KEK High Energy Accelerator Research Organization (JP)*

[2] *University of Oxford (GB)*

[3] *The High Energy Accelerator Research Organization*

Corresponding Authors: liao@post.kek.jp, christopher.betancourt@cern.ch, manabu.togawa@cern.ch, daniela.bortoletto@cern.ch

To meet the high radiation hardness and timing resolution requirements of high-energy physics experiments, we present an initial investigation into double-sided 3D sensors with various geometrical structures developed by CNM. We evaluated their electrical performance through I-V and C-V measurements and compared the results with TCAD Silvaco simulations and theoretical estimations. Initial testing with a beta source was conducted using AC-LGADs. The readout board developed by the Energy Frontier Group in Japan was used for the testing.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG4 - Simulation / **33**

TCAD Simulation of Electrical Characteristics and Irradiation Modeling for ATLAS ITk-Strip Sensors

Author: Yuzhan Zhao[1]

Co-authors: Callan Jessiman [1]; Christoph Thomas Klein [1]; Ezekiel Staats [1]; Jeff Dandoy [1]; John Stakely Keller [1]; Thomas Koffas [1]

[1] *Carleton University (CA)*

Corresponding Authors: yuzhan.zhao@cern.ch, e.staats@cern.ch, christoph.klein@cern.ch, callanjessiman@cmail.carleton.ca, jeff.dandoy@cern.ch, thomas.koffas@cern.ch, john.stakely.keller@cern.ch

The ATLAS ITk strip sensors are n-on-p sensors with thousands of strips, designed for the ATLAS tracker upgrade for the High-Luminosity LHC and built to withstand extreme radiation levels, up to a 1 MeV neutron equivalent fluence of 1.6×1016/cm2. Developing precise models to understand sensor performance at the device level throughout their operational lifespan is essential for optimizing electronics operation settings and ensuring accurate particle tracking and physics performance.
To achieve this, TCAD simulations are used to model the sensors' electrical properties and behavior both before and after irradiation. Given the computational challenges of simulating the entire sensor geometry, we leverage the symmetry and periodic structure of the strip sensors to create an efficient 2D TCAD simulation pipeline. This approach simulates individual strip elements and edge

structures separately, then scales and combines them to replicate the full sensor. The simulation results are validated using data from testing main sensor wafers and MD test diodes. Additionally, irradiation effects are assessed by implementing the Perugia radiation damage model and comparing it with recent DLTS-based models, with simulated charge collection directly compared to data from irradiated MD test diodes.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG4 - Simulation / 34

TCAD + AllPix2 pipeline for the ATLAS ITk-Strip Digitization Model

Authors: Callan Jessiman[1]; Christoph Thomas Klein[1]; Ezekiel Staats[1]; Jeff Dandoy[1]; John Stakely Keller[1]; Thomas Koffas[1]; Yuzhan Zhao[1]

[1] *Carleton University (CA)*

Corresponding Authors: christoph.klein@cern.ch, thomas.koffas@cern.ch, jeff.dandoy@cern.ch, callanjessiman@cmail.carleton.ca, e.staats@cern.ch, yuzhan.zhao@cern.ch, john.stakely.keller@cern.ch

The ATLAS ITk-Strip detector is a planned tracker upgrade for the High-Luminosity LHC which utilizes n+-in-p silicon sensors fabricated by Hamamatsu Photonics with 300 µm signal-generation thickness and approximately 75 µm strip pitch. The sensors must withstand severe irradiation over their operational lifetimes, corresponding to fluences of up to 1.6×10^{16} 1-MeV neq/cm^2, with consequences on the charge collection efficiency. To achieve a precise understanding of the expected performance and Monte Carlo simulations with realistic tracking performance, TCAD models of irradiation effects on internal electric fields are developed and coupled with AllPix2 simulations of ionization-charge propagation through the sensors. A software pipeline has been created that automatically configures & connects simulations for several intermediary fluence estimates, translates per-fluence models to detector-wide per-luminosity models using GEANT4 predictions, and parameterizes the dependence of the charged collection efficiency on charge deposition depth for faster simulations in the ATLAS Athena reconstruction framework.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 35

The Study of SiC DC-LGAD and SiC AC-LGAD by Ultra-Violet Transient Current Technique (UV-TCT)

Authors: Tao Yang[1]; Ben Sekely[2]; Yashas Satapathy[2]; Greg Allion[2]; Gil Atar[2]; Philip Barletta[2]; Carl Haber[1]; Steve Holland[1]; John Muth[1]; Spyridon Pavlidis[2]; Stefania Stucci[3]; Abraham Tishelman[3]

[1] *Lawrence Berkeley National Laboratory*

[2] *North Carolina State University*

[3] *Brookhaven National Laboratory*

Corresponding Authors: seholland@lbl.gov, chhaber@lbl.gov, grallion@ncsu.edu, abraham.tishelman.charny@cern.ch, gatar@ncsu.edu, stucci@bnl.gov, spavlidis@ncsu.edu, pbarlet@ncsu.edu, ysatapa@ncsu.edu, bjsekely@ncsu.edu, tao.yang@lbl.gov, muth@ncsu.edu

As a wide bandgap semiconductor material, silicon carbide (SiC) has been widely used in power devices due to its inherent advantages. In recent years, the use of SiC as a replacement for silicon in charged particle detectors for collider experiments has gained increasing attention. However, due to various limitations in SiC processing (such as ultra-low doping epitaxy and high energy ion implantation), fabricating devices with specific structures to meet the demands of charged particle detection remains highly challenging. The capability of future collider detectors to perform 4D tracking (time + position) has become a well-established requirement. Over the past decade, the silicon Low Gain Avalanche Detector (Si LGAD) has been extensively studied for its excellent timing performance and has demonstrated outstanding results in 4D tracking (delete this part). Owing to the unique properties of SiC, a SiC LGAD offers better theoretical timing performance and operability at room temperature after irradiation compared to the Si LGAD, making it a promising alternative.

In this report, we will present the characterization results both of 4H-SiC DC-LGAD and 4H-SiC AC-LGAD using the ultra-violet transient current technique (UV-TCT), including gain uniformity, timing resolution, and position resolution. These results preliminarily validate the 4D tracking capability of 4H-SiC LGADs.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / 36

Carrier recombination characteristics in neutron irradiated Si at extreme fluences

Author: Tomas Ceponis[1]

Co-authors: Eugenijus Gaubas [2]; Igor Mandic [3]; Jevgenij Pavlov [1]; Kazimieras Nomeika [1]; Kestutis Zilinskas [1]; Laimonas Deveikis [2]; Margarita Biveinyte [2]; Vytautas Rumbauskas [2]

[1] *Vilnius University*

[2] *Vilnius University (LT)*

[3] *Jozef Stefan Institute (SI)*

Corresponding Authors: eugenijus.gaubas@cern.ch, tomas.ceponis@cern.ch, kazimieras.nomeika@ff.vu.lt, laimonas.deveikis@cern.ch, margarita.biveinyte@cern.ch, igor.mandic@ijs.si, vytautas.rumbauskas@cern.ch, jevgenij.pavlov@cern.ch, kestutis.zilinskas@cern.ch

The carrier recombination properties of semiconductors are critically influenced by defect species introduced by irradiations. In particle detectors, a reduction in carrier lifetime correlates with the degradation of charge collection efficiency and with an increase of leakage current. 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, carrier recombination characteristics in Si, irradiated by reactor neutrons up to extreme fluences (1018 cm-2), will be considered. The results were obtained by the contactless microwave

probed photoconductivity transients technique and the pump-probe setup by employing femtosecond laser pulses.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / **37**

Update on the RD50-SiC-LGAD Project

Authors: Andreas Gsponer[1]; Jürgen Burin[1]; Philipp Gaggl[1]; Simon Emanuel Waid[1]; Thomas Bergauer[1]

[1] *Austrian Academy of Sciences (AT)*

Corresponding Authors: simon.waid@oeaw.ac.at, andreas.gsponer@cern.ch, thomas.bergauer@cern.ch, philipp.gaggl@cern.ch, juergen.maier@oeaw.ac.at

Silicon carbide (SiC) detectors have recently undergone a resurgence of research interest due to significant industry improvements in production and processing. The material's favorable characteristics, including extremely small leakage currents, a high breakdown voltage, and high charge carrier velocities, make it a promising candidate for replacing silicon detectors in the future. One disadvantage of SiC, however, are still the limitations of commercially obtainable material quality. The production of thick 4H-SiC epi-layers ($>$100 μm) is particularly challenging and costly, and the required depletion voltages can be considerable. Together with the fact that the ionization energy of 4H-SiC is higher than that of silicon, this results in very small signals for MIPs.

One potential solution to address this issue is the use of low-gain avalanche diodes (LGADs), which can significantly enhance the signal-to-noise ratio through charge carrier multiplication. For an adequate signal-to-noise ratio (SNR), thin SiC-LGADs ($\leq$ 50 μm) would enable an excellent timing performance, potentially even surpassing that of Si-LGADs.

This talk offers an update to the status of the RD-50-SiC-LGAD project, which aims to develop a demonstrator SiC-LGAD and evaluate its performance in terms of gain, timing, and radiation hardness. The design of the mask has recently been completed and will be presented, with a particular focus on the gain layer termination structures. In addition to the status of the LGAD design, updates will also be provided on the laboratory characterization infrastructure for electrical characterization of future SiC-LGADs. Finally, the radiation hardness of SiC-LGADs (e.g., the donor removal in the gain layer) will be discussed based on simulations applying the radiation damage model devloped for planar 4H-SiC detectors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / **38**

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

Authors: Alexandre Hennessy[1]; Iskra Velkovska[2]; Ivan Vila Alvarez[3]; Jordi Duarte Campderros[4]; Marcos Fernandez Garcia[5]; Parisa Rezaei Mianroodi[None]; Vagelis Gkougkousis[6]

Co-authors: Anna Macchiolo [1]; Claudia Gemme [7]; Gregor Kramberger [2]

[1] *University of Zurich (CH)*

[2] *Jozef Stefan Institute (SI)*

[3] *Instituto de Física de Cantabria (CSIC-UC)*

[4] *IFCA*

[5] *Universidad de Cantabria and CSIC (ES)*

[6] *University of Zurich*

[7] *INFN Genova (IT)*

Corresponding Authors: gregor.kramberger@ijs.si, claudia.gemme@cern.ch, marcos.fernandez@cern.ch, iskra.velkovska@ijs.si, egkougko@cern.ch, duarte@ifca.unican.es, alexandrekilianderek.hennessy@uzh.ch, ivan.vila@csic.es, parisa.rezaeimianroodi@uzh.ch, anna.macchiolo@cern.ch

Trench-isolated (TI) LGADs, developed at FBK, are pixelated LGAD implementations where pads are separated by physical trenches etched within the silicon substrate and filled with a dielectric. Developed as an alternative approach to implant-based inter-pad separation (JTEs), this technology promises a dramatic reduction to dead regions, mitigating fill factor issues inherent to small-pitch pixelated LGAD matrices. Through a dedicated 120 GeV SPS pion test beam campaign, the time resolution, efficiency and inter-pad distance of Carbon Infused irradiated TI-LGADs is presented in MIP conditions. Fluences up to 2.5×10^{15} n_{eq}/cm^2 are evaluated, for single trench implementations with varied trench width. The combined timing and tracking readout used in this study, integrating ROI triggering, sub-μm multi-object alignment, multi-channel waveform digitization and achieving a 5-7 μm spatial resolution through a MIMOSA26 telescope, is also reviewed. Preliminary results are discussed for temperatures of -25^{o}C.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / **39**

Assessment of electronic structure and metastabilities of complex defects in boron doped silicon samples following irradiation at high fluences

Authors: Nicolae Filipoiu[1]; Mihaela Cosinschi[1]; Calin-Andrei Pantis-Simut[1]; Amanda Teodora Preda[1]; Ioana Pintilie[2]; George Alexandru Nemnes[1]

[1] *Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering*

[2] *National Inst. of Materials Physics (RO)*

Corresponding Authors: mihaela.cosinschi@nipne.ro, alexandru.nemnes@nipne.ro, ioana@infim.ro, nicolae.filipoiu@nipne.ro, calin.pantis@nipne.ro, amanda.preda@nipne.ro

We present the research activities within the DRD3 project proposal "*Radiation damage in Boron-doped Silicon diodes and LGAD sensors*", relevant to understanding radiation damage in silicon. One of the main objectives is the defect characterization at microscopic level in boron doped silicon subject to extreme irradiation fluences (2x10^{16} n_{eq}/cm^2) and establish the role of B, C, O and P impurities in the formation of electrically active defects. The theoretical investigations shall be focused on establishing the likely defect configuration, potential metastabilities and electronic structure. To this

end, we employ molecular dynamics simulations using LAMMPS software to obtain the vacancy and extrinsic impurity dynamics and to describe the metastability of defect configurations. Furthermore, selected defect configurations (e.g. silicon di-, trivacancy + extrinsic impurities) shall be investigated by *ab initio* density functional theory (DFT) calculations, which will provide the impact in the density of states, p- and n-type character and formation energies of the considered complex defects. These theoretical results come in support of experimental studies focused on DLTS and TSC/TSCap on irradiated silicon samples, and contribute to the research goals WG3-RG3.2, concerning the development of radiation damage models of point and cluster defects and WG4-RG3.2, by supplying information for TCAD and MC simulations.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG2 - Hybrid silicon technologies / **40**

study of deep carbonated LGAD at IHEP

Authors: Mei Zhao[1]; Yuan Feng[1]; Yunyun Fan[1]; Zhijun Liang[1]

[1] *Chinese Academy of Sciences (CN)*

Corresponding Authors: mei.zhao@cern.ch, y.feng@cern.ch, fanyy@ihep.ac.cn, zhijun.liang@cern.ch

Low Gain Avalanche Detectors (LGADs) are crucial for high-energy physics applications, especially in the harsh radiation environments of future colliders. This abstract 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 and longevity.

Our proton irradiation campaign demonstrates that deep carbon implanted sensors exhibit outstanding performance, with better charge collection efficiency and 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 (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / **41**

Research of AC-LGAD strip detector for 4D tracking

Authors: Mei Zhao[1]; Mengzhao Li[1]; Tianyuan Zhang[1]; Weiyi Sun[1]; Yuan Feng[1]; Yunyun Fan[1]; Zhijun Liang[1]

[1] *Chinese Academy of Sciences (CN)*

Corresponding Authors: weiyi.sun@cern.ch, y.feng@cern.ch, mei.zhao@cern.ch, tyzhang@ihep.ac.cn, zhijun.liang@cern.ch, mzli@ihep.ac.cn, fanyy@ihep.ac.cn

With the development of collider experiments, the demand for detectors with high time and spatial resolution has become increasingly stringent. AC-LGAD has sparked wide research due to its exceptional time and spatial resolution and can achieve lower readout electronics density under a fixed effective area and enable position resolution with directional sensitivity. The project aims to develop an AC-LGAD strip for future colliders such as CEPC, FCC-ee, ILC, CLIC, etc.
IHEP associated with IME has developed an AC-LGAD strip sensor prototype with 150-250μm pitch and 5.6 mm length and achieved time resolution up to 30 ps scale and spatial resolution to 10 μm scale. AC-LGAD strip will contribute to the technical design reports for future lepton collider projects, and even other experiments demanding 4D tracking ability beyond collider experiments.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 42

Integrating Track Lab with Constellation for distributed DAQ of Timepix3 and Timepix4 detector networks.

Author: Petr Manek[1]

Co-authors: Benedikt Ludwig Bergmann [2]; Peter Svihra [3]; Simon Spannagel [4]; Stephan Lachnit [4]

[1] *Czech Technical University*

[2] *Czech Technical University in Prague (CZ)*

[3] *Czech Academy of Sciences (CZ), Czech Technical University in Prague (CZ)*

[4] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: benedikt.bergmann@cern.ch, stephan.lachnit@cern.ch, petr.manek@cern.ch, peter.svihra@cern.ch, simon.spannagel@cern.ch

We propose to combine two existing DAQ programs: Track Lab and Constellation. Track Lab is a graphical application focusing on pixel detectors of the Timepix family, compatible with a diverse range of readout hardware such as Katherine and MiniPIX. Thanks to its modular architecture, Track Lab allows users to construct complex data processing workflows by interconnecting simple building blocks, and execute them efficiently in parallel within a scope of a single process. Constellation is a hardware-agnostic DAQ fabric that implements robust finite state machine over a (physically) distributed network of *satellites*, which use IP-backed communication to exchange data and receive commands from a single *controller.* With focus on high performance, Constellation represents a promising solution for interoperability of large detector networks. In this contribution, we will investigate potential benefits of harmonizing both programs to leverage their desirable properties. For instance, reinterpreting Track Lab's modules as satellites would allow them to be deployed beyond the scope of a single process, single platform or a single machine. This would enable data workflows to be effortlessly scaled up over many CPUs in high-flux environments, analysis to be partially offloaded directly to detector hardware, or distant detectors to be operated in concert as a single setup. Conversely, Track Lab could potentially assume the role of Constellation's controller, supplying a

tested graphical interface that includes monitoring of the state machine, data flow accounting, back-pressure tracking and real-time data visualization. A combination of Track Lab with Constellation could therefore give rise to a computationally powerful, yet lightweight and versatile family of DAQ tools, which would be particularly attractive for use with networks of data-intensive detectors such as Timepix4.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG6 - WBG sensors / 43

Characterization by IBIC of neutron irradiated SiC detectors at CNA

Authors: Carmen JIMENEZ RAMOS[None]; Carmen Torres Muñoz[None]; Javier Garcia Lopez[None]; Mauricio Rodriguez Ramos[1]

Co-authors: Cristian Quintana San Emeterio [2]; Gemma Rius [3]; Giulio Pellegrini [4]; Ivan Lopez Paz [5]; Ivan Vila Alvarez [6]; Joan Marc Rafí [7]; Philippe Godignon [8]

[1] *Centro Nacional de Aceleradores (CNA). University of Seville.*

[2] *Universidad de Cantabria and CSIC (ES)*

[3] *Institute of Microelectronics of Barcelona IMB-CNM-CSIC*

[4] *Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)*

[5] *Microelectronics Institute of Barcelona (IMB-CNM-CSIC)*

[6] *Instituto de Física de Cantabria (CSIC-UC)*

[7] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

[8] *CNM-IMB*

Corresponding Authors: ivan.lopez.paz@cern.ch, cristian.quintana.san.emeterio@cern.ch, giulio.pellegrini@csic.es, gemma.rius@imb-cnm.csic.es, ctorres1@us.es, mcyjr@us.es, ivan.vila@csic.es, jm.rafi@csic.es, mrodriguez67@us.es, fjgl@us.es, philippe.godignon@imb-cnm.csic.es

SiC is among the most promising materials for use in detectors operating under extreme radiation and temperature conditions. For these applications, the replacement of the front electrode with a graphene layer could represent a significant improvement due to the thermal and electronic properties of this novel material. As a first approach, the Barcelona Institute of Microelectronics has developed 50 microns thick SiC PN diodes where the front metal electrode has been deposited only on the periphery of the detector.In this study, both pristine and neutron-irradiated SiC detectors, have been characterized at the National Accelerator Center (CNA, Seville) using a triple alpha source and the Angular-Resolved Ion Beam Induced Charge (AR-IBIC) technique with a 2.7 MeV focused proton beam.

One of the most significant features of the detector irradiated to the fluence of $1x10^{15} n_{eq}/cm^2$ is that it operates in both reverse and forward voltage. The measurements of the Charge Collection Efficiency (CCE) obtained with the triple alpha source, whose ranges in SiC are between 16 and 20 microns, indicate an important decrease in the CCE compared to the pristine detector for both polarities. On the contrary, the AR-IBIC experiments carried out with 2.7 MeV protons, whose range is similar to the nominal thickness of the diode, reveal a significant enhancement in the signal under forward bias for low incident angles, with CCE values exceeding 100%. This behavior suggests the presence of gain mechanisms, likely induced by irradiation-induced defects, which enhance carrier multiplication. These findings are consistent with recent measurements obtained using the Two Photon Absorption-Transient Current Technique (TPA-TCT) conducted at IFCA.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 44

Simulations and characterisation of the first monolithic CMOS LGAD implemented in 110nm

Author: Umberto Follo[1]

Co-authors: Stefania Bufalino [2]; Stefano Durando [3]; Marco Mandurrino [4]; Chiara Ferrero [5]; Giulia Gioachin [2]; Lucio Pancheri [6]; Angelo Rivetti [3]; Manuel Rolo [4]

[1] *Politecnico e INFN Torino (IT)*

[2] *Politecnico di Torino (IT)*

[3] *INFN - National Institute for Nuclear Physics*

[4] *Universita e INFN Torino (IT)*

[5] *Politecnico di Torino*

[6] *University of Trento and TIFPA-INFN*

Corresponding Authors: marco.mandurrino@cern.ch, stefania.bufalino@cern.ch, giulia.gioachin@cern.ch, manuel.rolo@cern.ch, lucio.pancheri@unitn.it, stefano.durando@to.infn.it, chiara.ferrero@polito.it, angelo.rivetti@to.infn.it, umberto.follo@polito.it

Monolithic CMOS silicon sensors represent an important innovation for high-energy physics experiments due to their cheaper production and assembly cost compared to hybrid ones. Indeed, in hybrid devices, the electronics and the sensor are produced on different silicon substrates, which must be later connected using bonding techniques. However, as far as the time resolution is concerned, the most mature and high-performance technology today is represented by the Low Gain Avalanche Diode (LGAD), where a silicon sensor with an internal gain is connected to a custom electronics in a hybrid way.

The last ARCADIA submission exploited the integration of the LGAD concept in CMOS Monolithic Active Pixel Sensors (MAPS) to obtain the benefits provided by both technologies. The multiplication of the signals in MAPS has a major impact on the signalto-noise ratio; hence, the power consumption of the in-pixel front-end can be lowered to achieve the same performances. In addition, this feature increases the attractiveness of these devices for space applications where low power absorption is desired. Nevertheless, the union of the two technologies still lies in its early stages, and vigorous R&D is necessary.

This presentation will focus on the structures with internal gain fabricated in a standard 110 nm CMOS technology within the ARCADIA project. An overview of the recently produced passive structures will be provided together with the first prototype with integrated electronics. Measurements obtained using an infrared laser and in a test beam will be presented and compared with the simulations. The expected gain between 5 and 14 was confirmed by the measurements, and a time resolution below 100 ps was achieved. Finally, the future perspectives of the next steps and an insight into the ongoing R&D will be given.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 45

Observation of signal multiplication in neutron irradiated SiC detectors characterized using TPA-TCT

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

Co-authors: Carmen JIMENEZ RAMOS ; Carmen Torres Muñoz ; Gemma Rius [4]; Giulio Pellegrini [5]; Ivan Lopez Paz [6]; Javier Garcia Lopez ; Joan Marc Rafí [7]; Mauricio Rodriguez Ramos [8]; Philippe Godignon [9]

[1] *Universidad de Cantabria and CSIC (ES)*

[2] *Instituto de Física de Cantabria (CSIC-UC)*

[3] *IFCA*

[4] *Institute of Microelectronics of Barcelona IMB-CNM-CSIC*

[5] *Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)*

[6] *Microelectronics Institute of Barcelona (IMB-CNM-CSIC)*

[7] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

[8] *Centro Nacional de Aceleradores (CNA). University of Seville.*

[9] *CNM-IMB*

Corresponding Authors: giulio.pellegrini@csic.es, philippe.godignon@imb-cnm.csic.es, ivan.vila@csic.es, marcos.fernandez@cern.ch, ctorres1@us.es, mcyjr@us.es, gemma.rius@imb-cnm.csic.es, rosich@ifca.unican.es, cristian.quintana.san.emeterio@cern.ch, fjgl@us.es, raul.montero@ehu.es, ivan.lopez.paz@cern.ch, mrodriguez67@us.es, jm.rafi@csic.es, duarte@ifca.unican.es

Pristine and neutron-irradiated silicon carbide (SiC) detectors have been systematically characterized using the Two-Photon Absorption Transient Current Technique (TPA-TCT) at the laser facility of the University of the Basque Country (UPV/EHU). The SiC detectors under investigation are p-in-n diodes fabricated at IMB-CNM, with an active thickness of 50 microns.

Our study reveals a radiation-induced signal multiplication effect, which suggests enhanced charge carrier generation under irradiation. This multiplication process has been further corroborated through Ion Beam Induced Charge (IBIC) characterization. These findings provide insights into the radiation hardness and performance of SiC detectors, making them promising candidates for applications in high-radiation environments.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 46

First Demonstration of the Three-Photon Absorption Transient Current Technique (3PA-TCT) in SiC p-in-n Diodes

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

[1] *Universidad de Cantabria and CSIC (ES)*

[2] *Instituto de Física de Cantabria (CSIC-UC)*

[3] *IFCA (UC-CSIC)*

Corresponding Authors: marcos.fernandez@cern.ch, raul.montero@ehu.es, jorge.duarte.campderros@cern.ch, rosich@ifca.unican.es, ivan.vila@csic.es, cristian.quintana.san.emeterio@cern.ch

We demonstrate the application of the Three-Photon Absorption Transient Current Technique (3PA-TCT) for the characterization of silicon carbide (SiC) p-in-n diodes with an active thickness of 50 µm, manufactured at IMB-CNM. The characterization was performed at the laser facility of the University of the Basque Country (UPV-EHU), utilizing advanced nonlinear optical techniques to achieve localized charge generation with high spatial resolution. This advancement highlights the potential of 3PA-TCT as a powerful tool for the precise characterization of wide-band semiconductor radiation detectors and other semiconductor devices.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / **47**

Defect investigation in irradiated ATLAS18 ITk Strip Sensors using transient spectroscopy techniques

Author: Christoph Thomas Klein[1]

Co-authors: Jeff Dandoy [1]; Callan Jessiman [1]; John Stakely Keller [1]; Thomas Koffas [1]; Ezekiel Staats [1]; Yuzhan Zhao [1]

[1] *Carleton University (CA)*

Corresponding Authors: christoph.klein@cern.ch, thomas.koffas@cern.ch, john.stakely.keller@cern.ch, jeff.dandoy@cern.ch, yuzhan.zhao@cern.ch, e.staats@cern.ch, callanjessiman@cmail.carleton.ca

With the upgrade of the LHC to the High-Luminosity LHC (HL-LHC), the Inner Detector will be replaced with the new all-silicon ATLAS Inner Tracker (ITk) to maintain tracking performance in a high-occupancy environment and to cope with the increase in the integrated radiation dose.
Comprising an active area of 165m^2, the outer four layers in the barrel and six disks in the end-cap region will host strip modules, built with single-sided micro-strip sensors and glued-on hybrids carrying the front-end electronics necessary for readout. Before being shipped out for module building, the ATLAS18 main sensors were tested at different institutes in the collaboration for mechanical and electrical compliance with technical specifications, the quality control (QC), while technological parameters were verified on test structures from the same wafers before and after irradiation, the quality assurance (QA).
As a part of ongoing studies in parallel to ITk Strip Sensor Production quality control (QC) and quality assurance (QA), diodes fabricated as test structures were measured using variants of Deep-Level Transient Spectroscopy (DLTS). Irradiated diode samples were investigated with Current-DLTS, using both electrical and photo-induced injection. Utilising DLTS spectra, trap energy levels, and cross-sections associated with defects in the devices were obtained. This was done to improve the precision of TCAD models as part of the simulation pipeline developed for the ITk Strip Digitization Model, as well as to compile a more complete model of radiation damage in ITk Strip Sensors. For those reasons, this talk will present a summary of the defect parameters observed in the samples and will compare results obtained for diode samples with radiation damage from different irradiation sources at various fluences.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 48

CMOS Strip Sensors –Characterisation, Simulation and Test Beam Results

Authors: Dennis Sperlich[1]; Fabian Huegging[2]; Fabian Simon Lex[3]; Ingrid-Maria Gregor[4]; Iveta Zatocilova[3]; Jan-Hendrik Arling[5]; Jens Weingarten[6]; Jochen Christian Dingfelder[2]; Karl Jakobs[3]; Kevin Alexander Kroeninger[6]; Leena Diehl[7]; Marc Hauser[3]; Marta Baselga[6]; Michael Karagounis[8]; Naomi Davis[5]; Niels Sorgenfrei[9]; Roland Koppenhöfer[3]; Simon Spannagel[5]; Ulrich Parzefall[3]

[1] *Albert Ludwigs Universitaet Freiburg (DE)*

[2] *University of Bonn (DE)*

[3] *University of Freiburg (DE)*

[4] *DESY & Bonn University*

[5] *Deutsches Elektronen-Synchrotron (DE)*

[6] *Technische Universitaet Dortmund (DE)*

[7] *CERN*

[8] *Fachhochschule Dortmund Univ. of Applied Sciences and Arts (DE)*

[9] *CERN / Albert Ludwigs Universitaet Freiburg (DE)*

Corresponding Authors: fabian.simon.lex@cern.ch, karl.jakobs@uni-freiburg.de, jens.weingarten@cern.ch, iveta.zatocilova@cern.ch, leena.diehl@cern.ch, jochen.christian.dingfelder@cern.ch, ulrich.parzefall@cern.ch, niels.sorgenfrei@cern.ch, michael.karagounis@cern.ch, fabian.huegging@cern.ch, jan-hendrik.arling@cern.ch, naomi.afiriyie.davis@cern.ch, kevin.alexander.kroeninger@cern.ch, dennis.sperlich@cern.ch, ingrid.gregor@desy.de, marc.hauser@cern.ch, roland.koppenhofer@cern.ch, simon.spannagel@cern.ch, marta.baselga@cern.ch

In the passive CMOS Strips Project, strip sensors were designed by a collaboration of German institutes and produced at LFoundry in 150 nm technology. Up to five individual reticules were connected by stitching at the foundry in order to obtain the typical strip lengths required for the LHC Phase-II upgrade of ATLAS or CMS trackers. The sensors were tested in a probe station and characterised with a Sr90-source as well as laser-based edge- and top-TCT systems. At last, detector modules were constructed from several sensors and thoroughly studied in a test beam campaign at DESY. All of these measurements were performed before and after irradiation. Sensors were also simulated using Sentaurus TCAD. We provide an overview of simulation results, summarize the laboratory measurements and present the test beam results for irradiated and unirradiated passive CMOS strip sensors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 49

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

Authors: Hongbo Zhu[1]; Jianchun Wang[2]; Mei Zhao[2]; Weiguo Lu[2]; Yang Zhou[3]; Yiming Li[4]; Zhiyu Xiang[2]; Zijun Xu[2]

[1] *ZJU - Zhejiang University (CN)*

[2] *Chinese Academy of Sciences (CN)*

[3] *Institute of High Energy Physics, CAS, Beijing, China*

[4] *Institute of High Energy Physics, Chinese Academy of Sciences (CN)*

Corresponding Authors: yiming.li@cern.ch, zijun.xu@cern.ch, zhouyang@ihep.ac.cn, weiguo.lu@cern.ch, hongbo.zhu@cern.ch, jwang@ihep.ac.cn, zhiyu.xiang@cern.ch, mei.zhao@cern.ch

For the future era of high luminosity operation in LHCb experiment, the Upstream Tracker (UT) is planned to be upgraded to a higher granularity and radiation hard tracker. CMOS technology is a promising solution. Compared to hybrid silicon pixel sensors, CMOS processes enable smaller sensor sizes while maintaining a lower material budget. CMOS technology is also a potential candidate for the tracker of future CEPC experiment. Unlike many CMOS processes that require modifications to achieve sufficient signal generation, commercially available high-resistance wafer-based High Voltage CMOS (HVCMOS) is intrinsically radiation-hard. we have designed and submitted a prototype chip named COFFEE2, fabricated using a 55nm HV-CMOS process. This chip features a pixel array of 32 rows by 20 columns, divided into three regions, each with distinct in-pixel amplifier and comparator structures. Additionally, the chip includes a bandgap reference, row/column switch, and digital-to-analog converters (DACs) integrated into the peripheral circuitry surrounding the pixel matrix. We will present detailed electronic designs, simulation results, and preliminary test results from COFFEE2 chip.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 50

OPTIMA, a board dedicated to Optimized Precision Timing for Multichannel Acquisition

Authors: Edgar Lemos Cid[1]; Federico De Benedetti[2]

Co-authors: Abraham Antonio Gallas Torreira [2]; Antonio Fernandez Prieto [3]; Efren Rodriguez Rodriguez [1]; Eliseo Perez Trigo [2]; Morag Williams [1]; Paula Collins [1]; Victor Coco [1]

[1] *CERN*

[2] *Universidade de Santiago de Compostela (ES)*

[3] *Instituto Galego de Física de Altas Enerxías (IGFAE/USC) (ES)*

Corresponding Authors: eliseo.perez.trigo@cern.ch, antonio.fernandez.prieto@cern.ch, abraham.gallas@cern.ch, edgar.lemos.cid@cern.ch, efren.rodriguez.rodriguez@cern.ch, morag.williams@cern.ch, federico.de.benedetti@cern.ch, paula.collins@cern.ch, victor.coco@cern.ch

We will present the development of an electronics board that will make the rapid characterization of multipixel silicon sensor arrays for fast timing possible. OPTIMA is optimized for multichannel readout, such that full information relative to the timing performance of shared charge between pixels is acquired. Each channel comprises a dual-stage amplifier design with a uniform response up to a frequency range of 8 GHz. A trans-impedance amplifier configuration using a SiGe transistor is used for both stages. The design features a passive daughterboard for versatile sensor replacement. Full characterization has been done in the lab achieving a total gain of more than 100. LGAD and 3D sensors have been tested in the test beam, and time resolutions of less than 50 ps have been obtained.

Moreover, the board has been synchronized with the Timepix4 telescope. These preliminary results will be presented.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 51

CEPC vertex detector R & D status and plan

Authors: Jinyu Fu[1]; Jun Hu[1]; Liang ZHANG[2]; Meng Wang[3]; Mingyi Dong[None]; Wei Wei[1]; Ying Zhang[1]; Zhijun Liang[1]

[1] *Chinese Academy of Sciences (CN)*

[2] *Shandong University*

[3] *Shandong University (CN)*

Corresponding Authors: zhijun.liang@cern.ch, meng.wang@cern.ch, dongmy@ihep.ac.cn, jun.hu@cern.ch, wei.wei@cern.ch, zhang.l@sdu.edu.cn, ying.zhang@cern.ch, jinyu.fu@cern.ch

The project aims to develop key technologies for the vertex detector in future lepton colliders, with a focus on CEPC. This development is crucial for enhancing the physics potential of future lepton colliders.

The current design of the CEPC vertex detector employs curved MAPS technology, inspired by the ALICE ITS3 upgrade. However, new challenges arise in adapting this curved MAPS technology for the CEPC vertex detector. First, the b-layer of the CEPC vertex detector is positioned closer to the beam pipe (with a radius of ˜11 mm). Second, the data rate in CEPC is exceptionally high, particularly during Z-pole operation, where the data rate per chip exceeds 1 Gbps, even during low-luminosity Z-pole runs.

To address these challenges, a wafer-scale monolithic sensor with stitching technology needs to be developed to enable fast readout speeds suitable for future lepton colliders. This chip must feature relatively low power consumption and strong radiation hardness to meet performance requirements.

We anticipate that these advancements will make significant contributions to the technical design reports for future lepton collider projects. Collaborative efforts with WG5-TB are planned, leveraging potential synergies in vertex detector development for ALICE, BELLE II, and FCC-ee. A proposal document will be prepared.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG5 - Characterization / 52

Constellation - a flexible DAQ and control system for lab setups & test beams

Authors: Simon Spannagel[1]; Stephan Lachnit[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: simon.spannagel@cern.ch, stephan.lachnit@cern.ch

The qualification of new detectors in laboratory or test beam environments presents a complex challenge, requiring the stable operation of multiple devices often supported by separate control and data acquisition systems. These setups frequently undergo modifications, such as the inclusion of different reference detectors depending on the facility, adding further complexity. Successfully managing such dynamic configurations demands a robust system capable of controlling data acquisition, monitoring experimental setups, enabling seamless reconfiguration, and integrating new devices with limited effort.

To address the limitations of existing frameworks, a collaborative effort between DESY, DVel, Lund University, and the University of Hamburg has resulted in the development of Constellation —a flexible and innovative framework tailored to laboratory and test beam environments. Constellation enables efficient setup integration through network discovery, enhances system stability through autonomous operation, and simplifies onboarding with user-friendly documentation and tools.

This talk will introduce the core features of Constellation, share insights from its first successful deployment in a test beam environment, and provide an outlook on future developments and applications.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 53

ASIC Development for Timing Measurements using LGAD Sensors

Author: Abderrahmane Ghimouz[1]

[1] *Paul Scherrer Institute (CH)*

Corresponding Author: abderrahmane.ghimouz@cern.ch

The CMS experiment will enhance its capabilities with precision timing detectors covering $|\eta| \leq 3$ to manage high rates and reduce pile-up in the HL-LHC era starting in 2030. Future upgrades may extend timing across the full tracker acceptance ($|\eta| \leq 4$), with LGADs as a potential option for pixel detector end-cap replacements. This project focuses on the development of an ASIC in 28 nm CMOS technology, optimized for TI-LGAD sensors, capable of achieving sub-30 ps timing resolution. Key features include a low-jitter preamplifier, a discriminator stage, and a Time-to-Digital Converter (TDC), with radiation tolerance up to 1-5 × 10^{15} neq/cm^2.

The ASIC design will balance performance, power efficiency, and integration while addressing HL-LHC challenges. Initial prototypes will feature a limited number of channels for systematic testing of timing resolution and radiation hardness. Successful designs will scale to full-channel ASICs compatible with various LGAD types, ensuring flexibility for future sensor developments.

Fabrication will occur via MPW/mini@sic runs, with testing in realistic radiation environments. Results will support the CMS Tracker upgrade, contribute to advancements in 4D tracking technologies, and enable future high-energy physics experiments.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG4 - Simulation / 54

Semiconductor Detector End-to-end Simulations with Allpix Squared: Latest Features, Ongoing Developments, and Application Examples

Authors: Håkan Wennlöf[1]; Paul Schütze[2]; Simon Spannagel[2]

[1] *Nikhef National institute for subatomic physics (NL)*

[2] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: paul.schuetze@desy.de, simon.spannagel@cern.ch, h.wennlof@cern.ch

Allpix Squared is a versatile open-source simulation framework for semiconductor detectors, and was presented at the last DRD3 week. The framework enables detailed end-to-end simulations of pixellated sensor setups for several detector types, semiconductor materials, and geometries for a variety of applications. It also takes advantage of multi-processor architectures for fully parallel event simulation.

The framework holds a curated interface to Geant4 for describing the interaction of particles with matter, various algorithms for charge transport in the sensor, and digitisation of the signals in the front-end electronics. A new interface to SPICE is being developed for more sophisticated front-end simulations, and detailed field, potential, and doping maps can be imported from TCAD simulations to accurately model the motion and recombination behaviour of charge carriers.
In addition, new physical models such as impact ionization and trapping have been integrated. Simulation of gain layers and 3D sensors are possible, and actively used in the community.

This contribution will highlight recent additions, ongoing developments, and application examples. A selection of simulations carried out with the framework will be shown to demonstrate its versatility and predictive power, and its ongoing usage in a DRD3 context.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

III. other (please specify)

WG2 - Hybrid silicon technologies / 55

LGAD and 3D technology at the IMB-CNM

Authors: Giulio Pellegrini[1]; Neil Moffat[2]; Pablo Fernandez-Martinez[3]; Salvador Hidalgo[4]

[1] *Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)*

[2] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

[3] *IMB-CNM, CSIC*

[4] *Instituto de Microelectronica de Barcelona (IMB-CNM-CSIC)*

Corresponding Authors: pablo.fernandez.martinez@cern.ch, giulio.pellegrini@csic.es, neil.moffat@cern.ch, hidalgo.salvador@cern.ch

We will present the overview of 4 projects of interest at the IMB-CNM. We aim to create a collaboration for each project.

Project 1: Trench Isolated iLGAD for fill factor optimization
Project 2: AC-LGAD for HEP and Synchrotron Applications.
Project 3: Deep Junction LGAD, stabilisation of the technology at the IMB-CNM.
Project 4: Doubled sided 3D detectors for ultra-radiation hard timing applications.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG4 - Simulation / **56**

TCAD simulations of Low Gain Avalanche Detectors incorporating improved impact ionization modelling

Author: Chakresh Jain[1]

Co-authors: Kalpna Tiwari [1]; Ashutosh Bhardwaj [1]; Kirti Ranjan [1]; Rahul Sharma [1]; Namrata Agrawal [2]

[1] *CDRST, Department of Physics and Astrophysics, University of Delhi*

[2] *Swami Shraddhanand College, University of Delhi, India*

Corresponding Authors: kranjan@physics.du.ac.in, chakreshjain.ehep@gmail.com, namrata@ss.du.ac.in, abhardwaj@physics.du.ac.in, kdott1296@gmail.com, rahulsharma280101@gmail.com

Low-Gain Avalanche Detector (LGAD) has become an attractive candidate for ultra-fast silicon detectors. TCAD simulations are playing an increasingly important role in optimizing the LGAD design configurations. A few TCAD studies have indicated a disagreement between the simulated and the measured charge collection, even in the non-irradiated LGADs. In simulations, the impact ionization models mainly control the internal charge multiplication of the LGADs and are sensitive to the electric fields developed within the LGADs. This highlights the importance of not only the accurate implementation of p-well doping profiles but also tailoring the parameters of the impact ionization models used in simulations. The present simulation study focuses on refining the impact ionization parameters in existing models for LGADs within the TCAD Silvaco framework for a better agreement with the measurements. The improved impact ionization modelling and the gain layer degradation, is then used alongside the already developed neutron damage model to understand the performance of LGADs.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG7 - Interconnect / 57

Development of a Novel Low-Mass Flip-Chip-Capable Module Flex PCB

Author: Julian Weick[1]

Co-authors: Abdelhak M. Zoubir [2]; Abhishek Sharma [1]; Carlos Solans Sanchez [1]; Dominik Dannheim [1]; Dominik Dobrijevic [1]; Dumitru-Vlad Berlea [3]; Florian Dachs [1]; Heinz Pernegger [1]; Ignacio Asensi Tortajada [4]; Leyre Flores Sanz De Acedo [1]; Lucian Fasselt [5]; Maria João Lourenço de Sousa [6]; Mateus Vicente Barreto Pinto [7]; Milou Van Rijnbach [1]; Petra Riedler [1]; Rui De Oliveira [1]; Valerio Dao [8]

[1] *CERN*

[2] *Darmstadt*

[3] *Deutsches Elektronen-Synchrotron (DE)*

[4] *Millennium Institute for Subatomic Physics at High Energy Frontier (CL)*

[5] *DESY*

[6] *Delft*

[7] *Universite de Geneve (CH)*

[8] *Stony Brook University*

Corresponding Authors: dominik.dobrijevic@cern.ch, abhishek.sharma@cern.ch, lucian.fasselt@desy.de, leyre.flores.sanz.de.acedo@cern.ch, dumitru-vlad.berlea@cern.ch, ignacio.asensi@cern.ch, milou.van.rijnbach@cern.ch, florian.dachs@cern.ch, dominik.dannheim@cern.ch, julian.weick@cern.ch, zoubir@spg.tu-darmstadt.de, valerio.dao@cern.ch, m.vicente@cern.ch, rui.de.oliveira@cern.ch, heinz.pernegger@cern.ch, carlos.solans@cern.ch, mjl.sousa03@gmail.com, petra.riedler@cern.ch

To reduce the material budget and maximize the active area of sensors for future experiments, a 30 μm thick lightweight flex has been developed. The fabrication technology, combined with novel interconnection techniques, enables compact packaging through the direct attachment of chip connection pads to the flex. In addition to interconnection methods such as Anisotropic Conductive Films and gold studs, the successful integration and bonding of nanowires is demonstrated using advanced principles like sintering and glue-assisted bonding. This contribution introduces the module concepts and presents the initial electrical and mechanical results from demonstrator modules. Furthermore, the principles and preliminary results are shown, demonstrating how the current fabrication technology can be extended to address ASIC yield and increase the packaging density of the assembly.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 58

Update on the DC-coupled Resistive Silicon Detector for 4D tracking

Authors: Roberta Arcidiacono[1]; et al.[None]

[1] *Universita e INFN Torino (IT)*

Corresponding Authors: roberta.arcidiacono@cern.ch, roberta.arcidiacono@gmail.com

This contribution presents the design strategy and the preliminary characterization of the first, proof-of-concept, production of DC-coupled Resistive Silicon Detector (DC-RSD). The DC-RSD is a resistive thin LGAD with a DC-coupled read-out. This design leads to signal containment within a predetermined number of electrodes using isolating trenches (TI technology).
Several test structures and application-oriented devices have been implemented in the wafer layout. The sensors, produced at FBK in the framework of the 4DSHARE project, have been characterized on wafer @FBK. A small subset of devices have been tested also with a laser TCT system, to study signal properties and signal sharing in the DC-RSD.
This preliminary studies will provide us with very useful feedback on the soundness of the DC-RSD concepts.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG1 - CMOS technologies / 59

Monolithic Active Strip Sensors for Applications in future Tracking detectors & medical Imaging

Authors: Dennis Sperlich[1]; Fabian Huegging[None]; Fabian Simon Lex[2]; Ingrid-Maria Gregor[3]; Iveta Zatocilova[2]; Jan-Hendrik Arling[4]; Jens Weingarten[5]; Jochen Christian Dingfelder[6]; Karl Jakobs[2]; Kevin Alexander Kroeninger[5]; Marc Hauser[2]; Marta Baselga[5]; Michael Karagounis[7]; Naomi Davis[8]; Niels Sorgenfrei[9]; Roland Koppenhöfer[2]; Simon Spannagel[10]; Ulrich Parzefall[2]

[1] *Albert Ludwigs Universitaet Freiburg (DE)*

[2] *University of Freiburg (DE)*

[3] *DESY & Bonn University*

[4] *Deutsches Elektronen-Synchrotron (DESY)*

[5] *Technische Universitaet Dortmund (DE)*

[6] *University of Bonn (DE)*

[7] *Fachhochschule Dortmund Univ. of Applied Sciences and Arts (DE)*

[8] *ATLAS*

[9] *CERN / Albert Ludwigs Universitaet Freiburg (DE)*

[10] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: naomi.davis@desy.de, jan-hendrik.arling@desy.de, marc.hauser@cern.ch, roland.koppenhofer@cern.ch, marta.baselga@cern.ch, iveta.zatocilova@cern.ch, dennis.sperlich@cern.ch, michael.karagounis@cern.ch, kevin.alexander.kroeninger niels.sorgenfrei@cern.ch, ulrich.parzefall@cern.ch, jochen.christian.dingfelder@cern.ch, jens.weingarten@cern.ch, simon.spannagel@cern.ch, karl.jakobs@uni-freiburg.de, huegging@physik.uni-bonn.de, fabian.simon.lex@cern.ch, ingrid.gregor@desy.de

We intend to develop monolithic active CMOS Strips sensors for particle tracking applications, using experience from a previous project with stitched passive CMOS sensors.

The project is open to further collaborators.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG7 - Interconnect / 60

Development of in-house plating and hybridisation technologies for pixel detectors

Authors: Ahmet Lale[None]; Alexander Volker[1]; Dominik Dannheim[2]; Giovanni Calderini[3]; Haripriya Bangaru[None]; Janis Viktor Schmidt[1]; Mateus Vicente Barreto Pinto[4]; Matteo Centis Vignali[5]; Peter Svihra[6]; Petra Riedler[2]; Rui De Oliveira[2]; Xiao Yang[2]; Yahya KHWAIRA[None]

[1] *KIT - Karlsruhe Institute of Technology (DE)*

[2] *CERN*

[3] *LPNHE-Paris, Centre National de la Recherche Scientifique (FR)*

[4] *Universite de Geneve (CH)*

[5] *FBK*

[6] *Czech Academy of Sciences (CZ), Czech Technical University in Prague (CZ)*

Corresponding Authors: matteo.centis.vignali@cern.ch, peter.svihra@cern.ch, ahmet.lale@cern.ch, giovanni.calderini@cern.ch, rui.de.oliveira@cern.ch, xiao.yang@cern.ch, dominik.dannheim@cern.ch, alexander.volker@cern.ch, janis.viktor.schmidt@cern.ch, haripriya.bangaru@cern.ch, yahya.khwaira@lpnhe.in2p3.fr, m.vicente@cern.ch, petra.riedler@cern.ch

Within the CERN EP R&D programme and the DRD3 collaboration, innovative and scalable hybridisation 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. The hybridisation processes under study include bonding with anisotropic conductive adhesives (ACA), as well as gold-stud bonding with epoxy underfill. This contribution introduces the developed plating and hybridisation processes, and presents recent results for dedicated test structures and functional ASICs and sensors.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG6 - WBG sensors / 61

RD50 GaN Schottky Diodes Fabrication at IMB-CNM - Preliminary Results

Authors: Joan Marc Rafí[1]; Jack Nickson[1]; Josep Montserrat[1]; Alex Walker[2]; Jean-Paul Noel[None]; Ryan Griffin[3]; Giullio villani[4]; Thomas Koffas[5]

[1] *Instituto de Microelectrónica de Barcelona, CNM-CSIC*

[2] *National Research Council of Canada*

[3] *National Research Council*

[4] *Rutherford Appleton Laboratory*

[5] *Carleton University (CA)*

Corresponding Authors: josep.montserrat@imb-cnm.csic.es, jack.nickson@imb-cnm.csic.es, thomas.koffas@cern.ch, jm.rafi@csic.es

Wide band-gap (WBG) semiconductors, specifically SiC and GaN, have shown increasing use in industry as transformative innovations for high-efficiency and high-power electronic devices. They stand as some of the most promising contenders for a new generation of semiconductors that could overtake Si in certain fields. Due to this greater commercial use, developments have been made in the growth of WBG substrates, displaying fewer defects. This opens up the door for wider commercial applications, one of the most encouraging being their use as radiation detectors. Specifically, for high energy physics and space applications. Some properties of WBG semiconductors like high radiation hardness, high thermal stability and high signal-to-noise ratios are fundamental to these applications [1]. Despite their advantages, considerable work remains in characterizing and optimizing these devices to enable them to replace silicon in certain domains, as in radiation detectors applications. GaN's main advantages extend from its high band gap (3.4 eV) and high Ga-N bond strength, suggesting both high temperature and radiation resilience. A few reports have assessed the usefulness of GaN as radiation detectors, specifically as α-particle, x-ray, neutron and electron detectors. Though many of these have been shown on a GaN eptaxial layer grown on Si, SiC or sapphire bulk. It is still not fully understood the extent of harsh environment robustness and radiation detection efficiency of GaN on GaN devices [2]. As a result, adoption of GaN technologies in high-radiation environments, such as the future FCC at CERN, requires a deeper understanding of radiation effects on GaN devices [3,4], so as to propose possible strategies to enhance their radiation hardness.
In this work, basic Schottky diode test structures intended for radiation detectors studies have been fabricated on non-intentionally doped n-type epitaxial GaN layers grown on 2-inch diameter bulk GaN substrates. The design of the Schottky structures include different layouts, with different sizes, geometries and guard rings. Preliminary electrical characterisation of the devices, including before and after first Schottky metal annealing step (required to stabilize the properties of the Schottky contact) is being carried out by means of current-voltage (I-V) and capacitance-voltage (C-V) techniques [5]. The obtained results and performed analysis will be given at the Workshop.

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[3] J. Wang, et al. Review of using gallium nitride for ionizing radiation detection. Appl. Phys. Rev. 2, 031102, 2015.
[4] A. Sandupatla, S. Arulkumaran, N.G. Ing, S. Nitta, J. Kennedy, H. Amano. Vertical GaN-on-GaN Schottky diodes as α-particle radiation sensors. Micromachines, 11(5), 519, 2020.
[5] A. Walker, et al. Development of radiation-hard GaN devices for MIP detection - Phase I, 1st DRD3 week on Solid State Detectors R&D, CERN, 17-21 June 2024, abstract no. 24.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 62

SPS test-beam infrastructure extension for low temperature, fast triggering applications

Author: Vagelis Gkougkousis[1]

Co-authors: Aboud Falou [2]; Andre Rummler [3]; Anne Dabrowski [3]; Dominik Dannheim [3]

[1] *University of Zurich*

[2] *Université Paris-Saclay (FR)*

[3] *CERN*

Corresponding Authors: dominik.dannheim@cern.ch, fallou@cern.ch, anne.evelyn.dabrowski@cern.ch, andre.rummler@cern.ch, egkougko@cern.ch

The recent rise of fast timing applications at high radiation fluences requires testing in low-temperature environments (< -40°C) to mitigate thermal runaway for multi-pixelated matrices bonded to readout ASICs and to regulate carrier mobility. To that end, we present an upgraded infrastructure for the EUDAQ-based AIDA telescope at the SPS North Area H6B beamline. The system integrates a 1.2 kW water-cooled, ethanol-based chiller, a low-mass, 0.035 W/mK thermal conductivity wall, cold box and a two-axis (Y-Z) mechanical stage with a 34.2 kN dynamic carrying load, 5 mm pitch, and 1 m travel range. The cold box, with internal usable dimensions of 37 × 30 × 31 cm, supports a removable DUT assembly designed for 30 nm positioning precision and plane-independent 3-axis movement (2 linear and 1 rotational). In addition, accompanying control hardware and software are under development to enable temperature and flow control, seamlessly integrating as a EUDAQ-level producer. To address the 130 nsec trigger decision latency of the AIDA TLU 2, we introduce a fast trigger decision board. The latter, targeting latencies below 10 nsec, while incorporating a synchronization subsystem with the accelerator clock, represents a critical improvement for timing applications.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG3 - Radiation Damage / 63

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

Author: Vagelis Gkougkousis[1]

[1] *University of Zurich*

Corresponding Author: egkougko@cern.ch

The unparalleled sensitivity achieved with skipper CCDs, coupled with ultra-pure high-resistivity substrates (>22 kOhm×cm) and cryogenic operation, has rekindled interest in this technology for low-background experiments (DAMIC@SNOLAB, DAMIC-M, SENSEI, and OSCURA) Such devices offer sub-electron noise resolution, enabling the detection of extremely low-energy interactions critical for rare-event searches, including dark matter detection and neutrino studies. However, exposure to alpha particles and cosmic rays may induce lattice defects with extended annealing times, potentially degrading resolution and increasing background noise. We propose a novel method to mitigate these effects by integrating Laplace Deep-Level Transient Spectroscopy (DLTS) with electrical state pumping through the bias line, combined with the sequential readout of CCDs. Utilizing a lock-in amplifier synchronized to the shift register clock, we achieve pixel-by-pixel readout following charge injection. This approach addresses the inherent loss of timing information in charge-accumulating devices through a frequency scan at the pumping signal level. The method can be applied across various temperature points and injection levels, with an operational range typically spanning 120 K to 200 K. By conducting measurements at multiple injection and thermal conditions, we aim to characterize and mitigate background effects caused by lattice defects.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG7 - Interconnect / 64

Development of ultra-thin hybrid pixel detectors using Wafer-to-Wafer bonding

Author: Fabian Huegging[1]

[1] *University of Bonn (DE)*

Corresponding Author: fabian.huegging@cern.ch

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 contribution 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 bonding process development with daisy chain wafers and sensor design and fabrication are presented.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG4 - Simulation / 65

Simulation of SiC detector

Author: Suyu Xiao[1]

[1] *Shandong Institute of Advanced Technology, China*

Corresponding Author: suyu.xiao@iat.cn

SiC detector can work stably for a long time in extreme environments with high temperature and strong irradiation because of its high electron saturation drift rate, high thermal conductivity, high breakdown voltage and strong irradiation tolerance. RAdiation SEmi-conductoR is now developing the full process simulation of various SiC detector like PIN, LGAD and strip detector. Not only the basic electrical properties like IV&CV curve, but also the electronic readout after the detector activated by beam or laser can be obtained with RASER, by which we can get the timing and spatial resolution. Irradiation defect damage model will be established covering at least the range from

1e11neq to 1e16neq based on realistic detector defect study, and this will advance the development of SiC detectors.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

II. Presentation on project proposal

WG3 - Radiation Damage / **66**

Status of defect investigations in Si and SiC

Author: Ioana Pintilie[1]

Co-authors: Andrei Nitescu [2]; Anja Himmerlich [3]; Cristina Besleaga [4]; Eckhart Fretwurst [5]; Joern Schwandt [6]; Michael Moll [3]; Moritz Wiehe [3]; Niels Sorgenfrei [7]; Valentina Sola [8]; Yana Gurimskaya [3]

[1] *National Inst. of Materials Physics (RO)*

[2] *National Institute of Material Physics -NIMP*

[3] *CERN*

[4] *National Institute of Materials Physics*

[5] *Hamburg University (DE)*

[6] *Hamburg University*

[7] *CERN / Albert Ludwigs Universitaet Freiburg (DE)*

[8] *INFN Torino*

Corresponding Authors: m.wiehe@cern.ch, anja.himmerlich@cern.ch, valentina.sola@cern.ch, cristina.besleaga@infim.ro, andrei.nitescu@infim.ro, joern.schwandt@cern.ch, yana.gurimskaya@cern.ch, ioana@infim.ro, michael.moll@cern.ch

We will present an overview of the on-going investigations of radiation induced defects in Si and SiC sensors performed within WG3 group.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / **67**

WG2 - Discussion

Corresponding Authors: anna.macchiolo@cern.ch, martin.van.beuzekom@cern.ch, alessandro.tricoli@cern.ch

WG7 - Interconnect / **68**

WG7 - Discussion on Interconnect Technologies

Corresponding Authors: huegging@physik.uni-bonn.de, fabian.huegging@cern.ch, giovanni.calderini@lpnhe.in2p3.fr, giovanni.calderini@cern.ch, dominik.dannheim@cern.ch

WG3 - Radiation Damage / 69

WG3 - Discussion on Radiation Damage

Corresponding Authors: ioana@infim.ro, joern.schwandt@cern.ch

Type of presentation (I. scientific results or II. project proposal):

Type of presentation (in-person/online):

WG6 - WBG sensors / 70

Discussion on WBG

Corresponding Authors: alexander.oh@cern.ch, xin.shi@cern.ch

Type of presentation (I. scientific results or II. project proposal):

Type of presentation (in-person/online):

WG4 - Simulation / 71

WG4 - Discussion

Authors: Marco Mandurrino[1]; Håkan Wennlöf[2]

[1] *Universita e INFN Torino (IT)*

[2] *Nikhef National institute for subatomic physics (NL)*

Corresponding Authors: h.wennlof@cern.ch, marco.mandurrino@cern.ch

Type of presentation (I. scientific results or II. project proposal):

Type of presentation (in-person/online):

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Coffee Break & Registration

Type of presentation (I. scientific results or II. project proposal):

Type of presentation (in-person/online):

WG5 - Characterization / 73

WG5 - Discussion

WG1 - CMOS technologies / 74

Discussion on CMOS projects

WG3 - Radiation Damage / 75

Evidence of Charge Multiplication in Thin $25\mu\mathrm{m} \times 25\mu\mathrm{m}$ Pitch 3D Silicon Sensors

Author: Andrew Donald Gentry[1]

Co-authors: Gian Franco Dalla Betta [2]; Jiahe Si [1]; Marco Povoli [3]; Martin Hoeferkamp [4]; Maurizio Boscardin [5]; Sally Seidel [6]

[1] *University of New Mexico (US)*

[2] *Universita degli Studi di Trento and INFN (IT)*

[3] *SINTEF MiNaLab*

[4] *Department of Physics and Astronomy*

[5] *FBK Trento*

[6] *University of New Mexico / ATLAS*

Corresponding Authors: jsi@unm.edu, boscardi@fbk.eu, hoeferka@unm.edu, seidel@phys.unm.edu, marco.povoli@sintef.no, gian.franco.dalla.betta@cern.ch, andrew.donald.gentry@cern.ch

Characterization measurements of 25 μm × 25 μm pitch 3D silicon sensors are performed, for devices with active thickness of 150 μm. Evidence of charge multiplication caused by impact ionization below the breakdown voltage is observed in sensors operated at -45 °C. Small-pitch 3D silicon sensors have potential as high precision 4D tracking detectors that are also able to withstand radiation fluences beyond 10^{16}~$\mathrm{n_{eq}}/\mathrm{cm}^2$. This is applicable for use at future facilities such as the High-Luminosity Large Hadron Collider and the Future Circular Collider. Characteristics of these devices are compared to those of similar sensors of pitch 50 μm × 50 μm, showing comparable charge collection at low voltage, and acceptable leakage current, depletion voltage, breakdown voltage, and capacitance despite the extremely small cell size. The unirradiated 25 μm × 25 μm sensors exhibit charge multiplication above about 90 V reverse bias, while, as predicted, no multiplication is observed in the 50 μm × 50 μm sensors below their breakdown voltage. The maximum gain observed below breakdown is 1.33.

Type of presentation (in-person/online):

online presentation (zoom)

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 76

Study of advanced detectors for future accelerator facilities with ion beam microscopy

Author: Georgios Provatas[1]

Co-authors: Milko Jaksic [1]; Donny Domagoj Cosic [2]; Karla Ivanković Nizić [3]; Zdravko Siketić [1]

[1] *Ruđer Bošković Institut*

[2] *Ruder Boskovic Institute*

[3] *Rudjer Boskovic Institute*

Corresponding Authors: zsiketic@irb.hr, jaksic@irb.hr, karla.ivankovic@irb.hr, georgios.provatas@irb.hr, dcosic@irb.hr

Semiconductor radiation detectors intended to be used in future accelerator facilities have often very specific requirements in terms of radiation hardness, spectroscopic quality, timing properties and spatial sensitivity. The ion microprobe technique IBIC (Ion Beam Induced Charge) is a well-established technique which provides information about most of these detector properties in a rather simple and fast way. The characterization of the detectors different properties is carried out using high spatial resolution microprobe systems coupled to a tandem accelerator. The latter can provide a variety of ion species, and a wide range of energies and beam currents. As such, using variations of the IBIC technique, i.e., the ion-beam transient current, lateral / angular resolved IBIC, the different detector properties can be probed.
The Laboratory for Ion Beam Interactions of the Ruđer Bošković Insitute has a long-term experience in the application and the development of IBIC the technique, equipped with two ion microprobes which have been further upgraded and subsequently used for characterization of a wide range of different detector systems, over the last years. In this presentation we focus on recent examples where IBIC provided unique information which cannot be obtained by other detector characterization techniques. Studies of scCVD, SiC detectors under extreme conditions will be presented as well as LGAD detectors, prototypes intended to be used in the next generation of CERN experiments, demonstrating the capability of IBIC to characterize detector response in three dimensions.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG2 - Hybrid silicon technologies / 77

Controlled charge multiplication in thin small-pitch 3D pixel sensors

Corresponding Author: andrew.donald.gentry@cern.ch

WG2 - Hybrid silicon technologies / 78

Introduction

Corresponding Authors: martin.van.beuzekom@cern.ch, anna.macchiolo@cern.ch, alessandro.tricoli@cern.ch

WG1 - CMOS technologies / 79

Performance studies of the CE-65v2 MAPS prototype structure

Author: Alessandra Lorenzetti[1]

Co-authors: Anna Macchiolo [1]; Armin Ilg [2]

[1] *University of Zurich (CH)*

[2] *University of Zurich*

Corresponding Authors: alessandra.lorenzetti@cern.ch, anna.macchiolo@cern.ch, armin.ilg@cern.ch

With the next upgrade of the ALICE inner tracking system (ITS3) as its primary focus, a set of small MAPS test chips have been developed in the 65 nm TPSCo CMOS process. The Circuit Exploratoire 65 nm (CE-65) focuses on the important characterisation of the analogue charge collection properties of this technology. The latest iteration of sensor design in this line of development is CE-65v2, which was produced in different processes (standard, with a low-dose n-type blanket, and blanket with gap between pixel) and pixel pitches (15, 18, 22.5μm). The comparatively large pixel array size of 48×24 pixels in CE-65v2 allows, among other benefits, to study the uniformity of the pixel response.
This year, the CE-65v2 chip was characterised in a test beam at the CERN SPS. A first analysis showed that hit efficiencies of $\geq 99\%$ and spatial resolution better than 5μm can be achieved for all pitches and process variants. For the standard process, with a pitch of 15μm, spatial resolutions below 3μm are achieved, thanks to larger charge sharing between the pixels, in line with the requirements of FCC-ee vertex detectors.
This contribution further investigates the data collected at the SPS test beam. The large amount of statistics collected, thanks to the large sensor size and efficient data taking, allow for detailed in-pixel studies to see the efficiency and spatial resolution as a function of the hit position within the pixels, again comparing different pitches and process variants.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

WG5 - Characterization / 80

Characterisation of fast sensors at the Timepix4 Telescope

Authors: Kazu Akiba[1]; Kevin Heijhoff[1]; Martin Van Beuzekom[1]

[1] *Nikhef National institute for subatomic physics (NL)*

Corresponding Authors: k.heijhoff@nikhef.nl, martin.van.beuzekom@cern.ch, kazu.akiba@cern.ch

A beam telescope based on the Timepix4 ASIC was built in order to perform tests of synchronous multiple-detector readout and track reconstruction with fast timing capability. The beam telescope is an excellent tool to study novel sensors with both high spatial and time resolution, and is capable of operating at high rates. The Timepix4 is a readout ASIC for hybrid pixel detectors that is designed to record both the time of arrival (ToA) and the time over threshold (ToT) of each discriminated signal. It has a 448 × 512 pixel matrix with square pixels at a 55 μm pitch. The ToA is digitized by a TDC with time bins of 195 ps, while the ToT is proportional to the charge collected by the silicon sensor, and is used to achieve sub-pixel spatial resolution. The ToT is also used to correct for time-walk and thereby improve the ToA resolution. The telescope consists of eight planes with n-on-p silicon sensors. Four of these planes are instrumented with 300 μm thick planar sensors, which are tilted and rotated by 9° with respect to the beam incidence to provide highly accurate spatial measurements. The other four

planes have 100 µm thick sensors to achieve a better time response. Each detector assembly (sensor + Timepix4 ASIC) is cooled by circulating chilled glycol through a 3D-printed titanium block that is directly attached to the carrier PCB. The assemblies are readout by SPIDR4 systems that send the data via 10 Gbit ethernet to the data acquisition (DAQ) computers. Three scintillators and two micro-channel plate (MCP) detectors provide precise time-reference signals that are recorded by a PicoTDC chip, which has time bins of 3 ps. The time references are used to characterise and calibrate the time measurements of the telescope and fast-sensor prototypes. Several fast sensor technologies are being studied such as iLGAD, TI-LGAD, and 3D silicon. The telescope will be presented together with an overview of the ongoing analyses of fast sensor prototypes that have been operated in the telescope as DUT.

Type of presentation (in-person/online):

in-person presentation

Type of presentation (I. scientific results or II. project proposal):

I. Presentation on scientific results

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Status of the DRD3 collaboration

Corresponding Author: gregor.kramberger@ijs.si

WG2 - Hybrid silicon technologies / 82

Summary of Proposed Projects in WG2

Corresponding Authors: martin.van.beuzekom@cern.ch, anna.macchiolo@cern.ch, alessandro.tricoli@cern.ch

WG5 - Characterization / 83

Development of next generation particle beam telescope using OBELIX chips

Corresponding Author: carlosmarinas@gmail.com

OBELIX will be the next chip in the succession line of the TJ-Monopix family. Implemented in Tower Semiconductor 180 nm technology, with its small pixel pitch (33 um2) and fast time precision (100 ns), OBELIX is designed targeting the vertex and tracker detectors for future e+e- collider experiments. In this contribution a first OBELIX-based telescope system will be proposed as possible infrastructure deliverable in DRD3 WG5.

WG5 - Characterization / 84

Introduction

Corresponding Authors: bojan.hiti@cern.ch, ivan.vila@csic.es

WG7 - Interconnect / 85

Extra flip-chip bonding results

Corresponding Author: m.vicente@cern.ch

WG3 - Radiation Damage / 86

Sensors Journal - Special Issue (2nd Edition)

Corresponding Authors: michael.moll@cern.ch, shixin@ihep.ac.cn

Type of presentation (I. scientific results or II. project proposal):

Type of presentation (in-person/online):

WG6 - WBG sensors / 87

Room for Thursday Morning = 4/3-006

Corresponding Author: michael.moll@cern.ch

WG1 - CMOS technologies / 88

Evaluation of Open PDKs and Open Source Design Tools for DMAPS

Corresponding Author: daniel.muenstermann@cern.ch