42nd RD50 Workshop on Radiation Hard Semiconductor Devices for Very High Luminosity Colliders (Montenegro)

Tuesday, 20 June 2023 - Friday, 23 June 2023

Hotel Regent Porto Montenegro

Book of Abstracts

Contents

LGAD / 1

Gain degradation study after neutron and proton irradiations in Low Gain Avalanche Diodes

Author: Fasih Zareef[1]

Co-authors: Alessandro La Rosa [2]; Esteban Curras Rivera [3]; Michael Moll [2]

[1] *AGH University of Science and Technology (PL)*

[2] *CERN*

[3] *EPFL - Ecole Polytechnique Federale Lausanne (CH)*

Corresponding Authors: michael.moll@cern.ch, alessandro.larosa@cern.ch, fasih.zareef@cern.ch, esteban.curras.rivera@cern.ch

The high-luminosity upgrade of the ATLAS and CMS experiments includes dedicated sub-detectors to perform the time-stamping of minimum ionizing particles (MIPs). These detectors will be exposed up to fluences in the range of 1.5 − 2.5 × 10ˆ15 ⊠⊠⊠/⊠⊠2 at the end of their lifetime and, Low Gain Avalanche Diode (LGAD) has been chosen as their baseline detection technology. To better understand the performance of LGAD detectors in these environments, a gain layer degradation study after neutron and proton irradiations up to a fluence of 1.5 × 10ˆ15 ⊠⊠⊠/⊠⊠2 was performed. LGADs manufactured at Hamamatsu Photonics (HPK) and Centro Nacional de Microelectrónica (CNM-IMB) were chosen for this study and, a comparison in the gain degradation between neutrons at the Jožef Stefan Institute (JSI) in Ljubjana and 24 GeV/c protons at CERN-PS is presented here.

Facilities / 2

ELI ERIC: new capabilities for applications in molecular, bio-medical and material science

Author: Mateusz Rebarz[1]

[1] *ELI Beamlines Facility, The Extreme Light Infrastructure ERIC*

Corresponding Author: mateusz.rebarz@eli-beams.eu

Extreme Light Infrastructure (ELI) is a European Project forming a pan-European Laser facility to provide the most intense femtosecond lasers in the world for fundamental and applied research. The Extreme Light Infrastructure European Research Infrastructure Consortium (ELI ERIC) was established in 2021 to jointly manage operations of ELI Beamlines in the Czech Republic and ELI-ALPS in Hungary. ELI ERIC founding Members are the Czech Republic (Host), Hungary (Co-host), Italy, and Lithuania, with founding Observers Germany and Bulgaria. The scientific activities of ELI facilities are based on the utilization of ultrashort pulse lasers with a unique combination of pulse profile, repetition rate, and intensity. One of the important missions of ELI is to develop a new generation of laser-driven sources for ultrashort pulses covering the ultrabroad electromagnetic radiation range (from THz to γ-ray) based on plasma effects in gases, solids as well as relativistic electron acceleration.
Here we introduce the experimental research capabilities offered by ELI ERIC to researchers working in molecular, bio-medical and material science. In particular, we highlight unique infrastructure available at ELI Beamlines facility which is focused on developing the complementary capabilities in optical, VUV and X-ray science in one location, with advanced sample preparation abilities. The complex ultrafast phenomena in solids, liquids or gas phase can be studied utilizing pulsed lasers and laser-driven X-ray sources.
ELI is thought of as a user facility open to all scientists. Details of how to submit a proposal to carry on experiments using ELI ERIC infrastructure will be also provided.

Defects / 3

Photovoltaics for Space

Authors: Michael Moll[1]; Yana Gurimskaya[None]

Co-authors: Alex Fedoseev ; Mikhail Reginevich ; Stanislau Herasimenka

[1] *CERN*

Corresponding Authors: sh@solestial.com, yana.gurimskaya@cern.ch, michael.moll@cern.ch, mr@solestial.com, af@solestial.com

Converting light into electricity is one of the key strategies for space exploration. The ultimate solution should be low-cost, low-mass, flexible but rigid which possesses high conversion efficiency, remaining alike operating in harsh radiation environment as outer space easy to integrate with modern deployment systems and scilicet solar arrays.
Silicon solar cells have been the dominant technology for space applications due to their high efficiency, durability, and reliability. This presentation will focus on the use of this type of PV technology in space and the impact of the natural space environment, including the effects of radiation, temperature, and vacuum conditions. These factors cause degradation over time, leading to a decrease in solar cells power output. Strategies for mitigating these effects, such as radiation hardening and thermal management, will be discussed.
Finally, the presentation will explore new materials for solar cells in space, such as multi-junction solar cells and perovskite solar cells and directions in emerging technologies.

Defects / **4**

Defect spectroscopy on 23 GeV Proton-Irradiated CZ Pad Diodes

Author: Niels Sorgenfrei[1]

Co-authors: Anja Himmerlich ; Chuan Liao ; Eckhart Fretwurst [2]; Ioana Pintilie [3]; Joern Schwandt [2]; Michael Moll [4]; Moritz Wiehe [4]; Yana Gurimskaya

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

[2] *Hamburg University (DE)*

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

[4] *CERN*

Corresponding Authors: ioana@infim.ro, niels.sorgenfrei@cern.ch, eckhart.fretwurst@desy.de, chuan.liao@desy.de, yana.gurimskaya@cern.ch, joern.schwandt@cern.ch, michael.moll@cern.ch, m.wiehe@cern.ch, anja.himmerlich@gmx.de

This study focuses on investigating radiation-induced defects in CZ p-type silicon pad diodes by subjecting them to irradiation with 23 GeV protons at various fluences.
Two different diode thicknesses were used: 100 µm and 350 µm. The irradiation fluences applied were 1E+13, 7E+13, and 4E+14 p/cm^2.
The macroscopic (IV & CV) and microscopic (TSC) radiation-induced changes in the sensors were measured and analyzed.
The presented results include IV and CV measurements taken before and after irradiation, as well as the determination of defect concentrations and defect introduction rates through TSC measurements, utilizing electrical and optical filling techniques.
Additionally, the presence of a not yet understood negative peak spectrum observed in TSC measurements will be reported.

LGAD / **5**

Preparations for LGAD characterization with 30 MeV protons

Author: Filip Krizek[1]

Co-authors: Gordana Lastovicka Medin [2]; Gregor Kramberger [3]; Vasily Kushpil [4]

[1] *Czech Academy of Sciences (CZ)*

[2] *University of Montenegro (ME)*

[3] *Jozef Stefan Institute (SI)*

[4] *Nuclear Physics Institute of CAS*

Corresponding Authors: filip.krizek@cern.ch, gregor.kramberger@ijs.si, gordana.lastovicka.medin@cern.ch, kushpil@ujf.cas.cz

Development of a new generation of 4D, low-material-budget detectors based on LGADs allows for combining high temporal and spatial resolution in one technology. Thin LGAD sensors feature a strong dependence of a deposited energy on the incident angle. Therefore, it is important to study how the incident angle of ionizing particles influences the time resolution.

The talk will report on preparation of a test beam where we intend to use 30 MeV protons for characterization of LGADs sensors having 1.3 x 1.3 mm2 pad size and a thickness of 200 µm, with a 50 µm thick active layer. The talk will describe the U-120M cyclotron facility at the Nuclear Physics Institute of the Czech Academy of Sciences and the setup for the irradiation. In addition, we will also present results from lab tests where the LGADs were tested with 90Sr beta source in the auto-triggering and coincidence modes.

LGAD / 6

Measurements of the RSD performance at a test beam (DESY)

Author: Nicolo Cartiglia[1]

Co-authors: Federico Siviero [2]; Leonardo Lanteri [3]; Luca Menzio [3]; Marco Ferrero [3]; Roberta Arcidiacono [3]; Roberto Mulargia [4]; Valentina Sola [3]

[1] *INFN Torino (IT)*

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

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

[4] *University & INFN Turin (IT)*

Corresponding Authors: marco.ferrero@cern.ch, valentina.sola@cern.ch, leonardo.lanteri@cern.ch, federico.siviero@to.infn.it, luca.menzio@edu.unito.it, roberto.mulargia@cern.ch, cartiglia@to.infn.it, roberta.arcidiacono@cern.ch

In the first part of this contribution, I will report the performance of RSD sensors measured at a test beam with 4-6 GeV electrons. The sensors under study are part of the RSD2 production from FBK.
In the second part, I will illustrate the studies carried on to validate the DC-RSD read-out scheme, i.e., the performance and noise levels of amplifiers connected to the same n+ electrode.

Monolithic devices / 7

Latest Testbeam Results of RD50-MPW3 and Design of RD50-MPW4

Author: Patrick Sieberer[1]

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

Corresponding Author: patrick.sieberer@cern.ch

This contribution reviews the testbeam results of the RD50-MPW3 chip presented at the last workshop. Detailed analysis results are presented and discussed.
The measured efficiency is far beyond expectations, thus; an extensive analog chip-simulation study has been carried out to find the reason. These simulations as well as their outcome are discussed.

In the end, changes in the design for the next prototype Chip, RD50-MPW4 are listed and an update about the submission status as well as future plans are given.

LGAD / 8

Correlation between leakage current and charge gain in irradiated LGADs

Authors: Alissa Shirley-Ann Howard[1]; Bojan Hiti[1]; Gregor Kramberger[1]; Igor Mandic[1]; Jernej Debevc[1]; Petja Skomina[None]

[1] *Jozef Stefan Institute (SI)*

Corresponding Authors: alissa.howard@ijs.si, jernej.debevc@cern.ch, petja.skomina@gmail.com, igor.mandic@ijs.si, bojan.hiti@cern.ch, gregor.kramberger@ijs.si

The gain of charge in LGADs (GQ) and the increase of the leakage current (GI) with respect to the generation current (Igen) are different, due to charge screening of the electric field in the gain layer, trapping-detrapping process and also possible other effects. A TCT was used to simultaneously measure GI and GQ in USFD-FBK4.0 prototypes. A special structure with PIN and LGADs very close together was used. The absolute charge measurements were assured with the use of beam-monitoring circuit. The difference between GI and GQ was found to become substantial at higher fluences and bias voltages.

LGAD / 9

Simulation of Landau fluctuations on timing performance of LGADs

Author: Jernej Debevc[1]

Co-authors: Alissa Shirley-Ann Howard [1]; Bojan Hiti [1]; Gregor Kramberger [1]; Igor Mandic [1]; Petja Skomina

[1] *Jozef Stefan Institute (SI)*

Corresponding Authors: petja.skomina@gmail.com, bojan.hiti@cern.ch, gregor.kramberger@ijs.si, jernej.debevc@cern.ch, igor.mandic@ijs.si, alissa.howard@ijs.si

Energy deposition of highly energetic particles was simulated in LGADs with GEANT4. The simulation step was adjusted to simulate deposits over the entire detector depth in <10 um steps. The signal formation was simulated with KDetSim using the parameters of HPK-P2 LGAD prototypes for ETL/HGTD and JSI model for impact ionization. The induced current pulses were convoluted with transfer function of typical electronics (ALTIROC ASIC). The impact of Landau fluctuations to time resolution (ToA variation) were simulated for different gains and thicknesses. Given the good agreement of results with measurements, simulations were used to estimate limits of LGAD and PIN detectors.

LGAD / 10

Deep-Junction LGAD and adaptive gain layer RD50 proposal

Authors: Bruce Andrew Schumm[1]; Carolyn Gee[1]; Simone Michele Mazza[1]; Yuzhan Zhao[2]

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

[2] *University of California Santa Cruz*

Corresponding Authors: carolyn.mei.gee@cern.ch, yuzhao@ucsc.edu, baschumm@ucsc.edu, simone.michele.mazza@cern.ch

Low Gain Avalanche Detectors (LGADs) are silicon detectors with modest internal gain (up to ˜50) and great time resolution (20 ps). In a broad array of fields, including particle physics (4-D tracking) and photon science (X-ray imaging), LGADs are a promising R&D path. However, due to structures required to provide electrostatic isolation between LGAD pixels, the granularity of production-level devices is limited to the 1x1 mmˆ2 scale. Applications in particle physics and photon science demand granularity scales of 100x100 umˆ2 or better. In this talk, we'll present a solution to the granularity issue, the deep junction LGAD (DJ-LGAD). The concept behind DJ LGAD and its potential to increase the granularity of LGADs will be explained. Furthermore the concept of 'adaptive gain layer'using DJ-LGAD technology will be presented, this type of gain layer might allow a significant increase of the radiation hardness reach of LGAD devices. Finally, a production of such a device in the scope of RD50 will be proposed.

Monolithic devices / 11

Timing performance of the RD50 HV-CMOS

Author: Uwe Kramer[1]

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

Corresponding Author: uwe.kramer@cern.ch

Monolithic Active Pixel Sensors (MAPS) provide excellent criteria in terms of pixel size and material budget and have become one of the most promising candidates for future tracking detectors. Beyond these aspects, timing is becoming an increasingly important aspect for tracking detectors, whether it is to reduce event complexity or provide particle identification via Time of Flight.
In this contribution I give an overview of the analog time resolution achieved through test pulse and bottom Transient Current Technique (TCT) measurements.
Measurements were performed both with the most recent RD50 HV-CMOS, the RD50-MPW3, and a comparison to results achieved with its predecessor, the RD50-MPW2, are presented.

SiC / 12

Investigation of neutron-irradiated 4H-SiC p-in-n Diodes in forward and reverse Bias

Authors: Andreas Gsponer[1]; Jürgen Maier[1]; Matthias Knopf[1]; Philipp Gaggl[1]; Richard Thalmeier[1]; Simon Emanuel Waid[1]; Thomas Bergauer[1]

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

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

Due to its low leakage currents and high radiation displacement energy, silicon carbide (SiC) is an attractive candidate for future radiation hard detectors.

We present electrical characterization (I-V and C-V) and charge collection efficiency (CCE) measurements in forward and reverse bias for neutron-irradiated samples (CNM run 13575) between 5×10^{14} n_{eq}/cm^2 and 1×10^{16} n_{eq}/cm^2 1 MeV neutron equivalent fluence.

After irradiation, no diode-like current is present in forward direction, and charge is still collected for UV-TCT or impinging particles. The CCE measurements were carried out using alpha particles, UV-TCT, and proton beams, which allows for a comparison of different charge deposition profiles. For the alpha measurements, the CCE in forward and reverse bias are comparable. However, using UV-TCT and proton beams, a signal enhancement was observed for irradiated samples in forward bias, with CCEs surpassing 100%. These observations are in agreement with recent TPA-TCT results and correlate with the measured I-V characteristics.

Based on these results, possible mechanisms are discussed, and the required further investigations are highlighted.

Other devices / **13**

Radiation tolerance study using test-structure diodes from 8-inch silicon sensors for CMS HGCAL

Author: Leena Diehl[1]

Co-authors: Eva Sicking [1]; Jan Kieseler [1]; Marie Christin Muehlnikel [1]; Matteo Defranchis [1]; Oliwia Agnieszka Kaluzinska [2]

[1] *CERN*

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

Corresponding Authors: jan.kieseler@cern.ch, leena.diehl@cern.ch, oliwia.agnieszka.kaluzinska@cern.ch, matteo.defranchis@cern.ch, eva.sicking@cern.ch, marie.christin.muhlnikel@cern.ch

The High-Luminosity LHC will challenge the detectors with a 10-fold increase in integrated luminosity compared to the previous LHC runs combined, thus the CMS detector will be upgraded to face the higher levels of radiation and the larger amounts of data collected. The High-Granularity Calorimeter (HGCAL) will replace the current endcap calorimeters of the CMS detector. It will facilitate the use of particle-flow calorimetry with its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels. The electromagnetic section as well as the high-radiation regions of the hadronic section of the HGCAL (fluences above $10^{14}n_{eq}/cm^2$) will be equipped with silicon pad sensors, covering a total area of $620m^2$). Fluences up to 10^{16} 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. Each sensor contains several hundred individually read out cells of two sizes (around 0.5 or 1.1 cm^2). 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 $6.5 \cdot 10^{14}$ and $1.4 \cdot 10^{16} n_{eq}/cm^2$. In this talk, the electrical characterisation and charge collection measurements of the irradiated silicon diodes will be presented. This includes the isothermal annealing behaviour of the bulk material, the frequency dependence present in capacitance measurements in irradiated sensors and the comparison of measurements conducted in two different experimental setups. The observed behaviour of the electrical properties and charge collection efficiency is in agreement with the HGCAL specifications. The results can be used to optimise the HGCAL layout and to establish an operating and annealing scenario for HGCAL.

LGAD / 14

Radiation-Induced Bulk Defects and their Impact on the Charge Multiplication in Inter-Pad region in TI-LGADs: A Comparative Study between Irradiated and Non-Irradiated LGAD Samples with Two Trenches i

Authors: Gordana Lastovicka Medin[1]; Ivona Bozovic[2]; Jovana Doknic[2]; Vanja Backovic[2]; Mateusz Rebarz[3]

Co-authors: Dejan Karadzic [2]; Gregor Kramberger [4]

[1] *University of Montenegro (ME)*

[2] *University of Montenegro*

[3] *ELI Beamlines, ELI ERIC*

[4] *Jozef Stefan Institute*

Corresponding Authors: backovicvanja12@gmail.com, bozovic.ivona2710@gmail.com, gregor.kramberger@ijs.si, karadzicdejan1988@gmail.com, doknicjovana3@gmail.com, mateusz.rebarz@eli-beams.eu, gordana.medin@gmail.com

In this presentation, we report our findings on the impact of radiation-induced bulk defects on the previously reported phenomenon of strong charge multiplication in the inter-pad (IP) region of non-irradiated Trenched Low-Gain Avalanche Detectors (LGADs) that utilize two trenches as isolation structures. A comparative analysis is conducted between the results obtained from the study of irradiated samples and those from non-irradiated samples. Specifically, we focus on the LGADs with two trenches derived from wafer 11 (with the least shallow trenches) and examine the behavior of the sensors under various bias and laser power intensities. Notably, under identical operational conditions applied to both sets of sensors, we observe a significant reduction in the occurrence of strong spikes in the irradiated samples.

LGAD / 15

Investigating the effect of processing and isolation layout design parameters of IP region with 2 p-stops and bias ring on charge collection and hole amplification in IP region: Case studies on Type 10 from Ti-LGAD batch (W11) and UFSD 4.0 (W18)

Authors: Gordana Lastovicka Medin[1]; Ivona Bozovic[2]; Jovana Doknic[2]; Mateusz Rebarz[3]

Co-authors: Dejan Karadzic [2]; Gregor Krambereger [4]; Vanja Backovic [2]

[1] *University of Montenegro (ME)*

[2] *University of Montenegro*

[3] *ELI Beamlines, ELI ERIC*

[4] *Jozef Stefan Institute*

Corresponding Authors: karadzicdejan1988@gmail.com, mateusz.rebarz@eli-beams.eu, doknicjovana3@gmail.com, gordana.lastovicka.medin@cern.ch, backovicvanja12@gmail.com, gregor.kramberger@ijs.si, bozovic.ivona2710@gmail.com

In this presentation, we show the results from the comparative analysis of the charge distribution along the x-axes, measured in two segmented UFSD prototypes after their interpad regions were illuminated by fs-laser of different intensities. The segmented UFSDs are originating from two different batch productions. The two spikes recorded at the edge of p-stops in IP region, in Type 10 UFSD from the TI-LGAD batch, are compared to the charge distribution measured in the IP region of the UFSD 4.0 prototype. The UFSD 4.0 represents the latest and final CMS and ATLAS LGAD production. The interpad distance (IPD) in the reference Type 10 sensor from the TI-LGAD batch, as reported by vendor FBK, is 49 microns, while the nominal IPD in UFSD 4.0 Type 10 sensor is 61 microns. Those tested samples differ also in the length of the distance between the p-stop and the JTE;

they also differ in the width of the p-stops, width of JTE, and in the distance between the p-stops. Additionally, those two samples differ in other processing parameters, some of which are publicly known, while others have not been yet disclosed publicly by the FBK. Notably, both samples exhibit a similar X-profile with a well-defined position of the bias ring. However, while the spikes observed in the proximity of p-stops are significantly amplified in the case of the Type 10 LGAD sensors from the TI-LGAD batch, in the UFSD 4.0 Type 10 sensors the spikes are absent, except when enhanced laser power is used.

The results show the strong dependence of the electric field strength, in the IP region, on the geometry of the p-stops and their position in regard to the position of JTE. Also, the results show the strong correlation between the reduction of interpad distance and the increase in the el field strength at the edge of the p-stops, enabling the impact ionization and charge multiplication even in IP with no-gain layer, when critical value for strength of el field is achieved.

TCT / **16**

The impact of single and multiple trenches on interpad resistance and hole multiplication in interpad region: The Transient Signal Waveforms and X- Profile Analyses

Authors: Gordana Lastovicka Medin[1]; Jovana Doknic[2]; Vanja Backovic[2]; Mateusz Rebarz[3]

Co-authors: Dejan Karadzic [2]; Ivona Bozovic [2]; Gregor Krambereger [4]

[1] *University of Montenegro (ME)*

[2] *University of Montenegro*

[3] *ELI Beamlines, ELI ERIC*

[4] *Jozef Stefan Institute*

Corresponding Authors: karadzicdejan1988@gmail.com, backovicvanja12@gmail.com, doknicjovana3@gmail.com, gregor.kramberger@ijs.si, bozovic.ivona2710@gmail.com, mateusz.rebarz@eli-beams.eu, gordana.lastovicka.medin@cern.ch

In this presentation, we report the findings on the impact of single and multiple trenches employed as isolation structures in TI-LGADs (Trench Low-Gain Avalanche Detectors). Our study focuses on the collection of charge induced by fs-laser at various shooting points along the X-axis, with subsequent recording of waveform data. Subsequently, we compare the deduced X-profiles derived from these waveforms. The results indicate a significant increase in charge collection within the isolation region when employing two trenches as isolation structures. However, this enhancement was not observed in the isolation region where only one trench was utilized, although the inter-pixel distance (IPD) for the configuration with two trenches is slightly wider compared to the IP distance when only a single trench is employed to isolate pixels. This discrepancy can be attributed to the very short distance between the two trenches, as well as the closer proximity of one of the trenches to the neighboring pixel. Also, the fabrication/etching of trenches may produce additional surface defects that are causing non-uniformity of el field and larger gradient in el. field from one to another point along the X-axes of IP region leading to the fast changing in strength of el field in the case of IP region with 2 trenches.

These findings shed light on the effects of different isolation structures on charge collection and resistivity in TI-LGADs and provide valuable insights for further optimization of device design and performance, in particular when sensors are exposed to high intensity injection (case of non MIP particles).

SiC / **17**

Improving TCAD simulation of 4H silicon carbide particle detectors

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

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

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

Silicon Carbide (SiC) has several advantageous properties, making it an appealing detector material: the high charge carrier saturation velocity and breakdown voltage allow for a very fine intrinsic time resolution. The larger bandgap suppresses dark current, even for highly irradiated material, which omits the need for cooling and reduces power consumption.
TCAD simulations of SiC devices face several challenges. Several potential polytypes, its anisotropic nature, and ongoing improvements in manufacturing high-quality wafers have led to various contradicting material and model parameters. In addition, low charge carrier concentrations, a result of the wide bandgap, worsen convergence and increase computation times, necessitating adapted solver settings and error criteria as well as a thoughtful meshing procedure.

This talk presents our progress in designing and producing high-precision 4H-SiC particle detectors supported by TCAD simulations. It will review the available parameter sets and necessary physics models and discusses meshing strategies and convergence issues. Simulation results, such as I-V, C-V, and induced signals, are verified against measurements on prototype 4H-SiC p-in-n diodes.
We present a comprehensive study for a HV-optimized guard structure implemented in diodes and strip sensors of a wafer run currently being processed at CNM.
While Synopsis Sentaurus is well known and established in the HEP community, a recently initiated collaboration with the startup company Global TCAD Solutions (GTS) allows for further cross-checking and a more customized approach to build a sufficient simulation framework for 4H-SiC.

Monolithic devices / **18**

Status of the characterization and radiation-hardness of the LF-Monopix2 DMAPS prototype

Author: Ivan Dario Caicedo Sierra[1]

Co-authors: Alexandre Habib [2]; Alexandre Rozanov [3]; Christian Bespin [1]; Fabian Huegging [1]; Fabrice Guilloux [4]; Hans Krueger [5]; Jochen Christian Dingfelder [1]; Lars Philip Schall [5]; Marlon B. Barbero [3]; Norbert Wermes [1]; Patrick Breugnon [2]; Patrick Pangaud [6]; Philippe Schwemling [7]; Pierre Barrillon [8]; Piotr Rymaszewski [1]; Sinuo Zhang [1]; Tianyang Wang ; Toko Hirono [1]; Tomasz Hemperek [1]; Yavuz Degerli [9]

[1] *University of Bonn (DE)*

[2] *Centre National de la Recherche Scientifique (FR)*

[3] *CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)*

[4] *Université Paris-Saclay (FR)*

[5] *University of Bonn*

[6] *CPPM, Aix Marseille Université, CNRS/IN2P3, Marseille, France*

[7] *CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR)*

[8] *Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France*

[9] *CEA Saclay*

Corresponding Authors: alexandre.rozanov@cern.ch, degerli@cea.fr, hemperek@uni-bonn.de, christian.bespin@cern.ch, patrick.pangaud@cern.ch, barrillon@cppm.in2p3.fr, amr.habib@cern.ch, rymaszewski@physik.uni-bonn.de, id.caicedo@cern.ch, breugnon@cppm.in2p3.fr, lars.schall@uni-bonn.de, hans.krueger@cern.ch, sinuo.zhang@cern.ch, marlon.barbero@cern.ch, fabrice.guilloux@cern.ch, wermes@uni-bonn.de, philippe.schwemling@cern.ch, tianyang.wang@cern.ch, jochen.christian.dingfelder@cern.ch, fabian.huegging@cern.ch, toko.hirono@cern.ch

Depleted monolithic active pixel sensors ("DMAPS") use multi-well commercial CMOS processes to integrate sensor, front-end and read-out electronics in a single piece of silicon. These devices

aim to meet the hit-rate and radiation-hardness requirements of tracker systems in particle collider experiments. In order to do so, they require a careful implementation of a fast readout and the use of large voltages in highly resistive substrates to collect charge mainly by drift.

LF-Monopix2 is the second prototype with dimensions at a reticle-size scale ($2\,\mathrm{cm}^2$) in a series of DMAPS fabricated in a $150\,\mathrm{nm}$ CMOS process. The device implements a fully functional column-drain readout architecture, while full front-end and readout circuitries are placed and isolated inside a charge collection node of a size comparable to the pixel area. It inherited and improved radiation-hard designs tested in its direct predecessor, while also reducing its pixel size by 40% and increasing its active column length to $1.7\,\mathrm{centimeters}$.

The sensor and front-end performance of the chip were characterized before and after proton irradiation up to a NIEL fluence of $2 \times 10^{15}\ \mathrm{n_{eq}/cm^2}$. This contribution presents an overview of key results from measurements of leakage current, depletion, noise, threshold tuning capabilities, timing and detection efficiencies in test beam campaigns. The overall performance of the device benefited from an improvement of its guard-ring layout, a reduction of the pixel capacitance and modifications to front-end parameters.

SiC / 19

Development of 4H-SiC Low-Gain Avalanche Detector

Authors: Wang Congcong[1]; Xin Shi[1]

Co-authors: Keqi Wang [2]; Xiyuan Zhang [1]; Ye He [3]

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

[2] *Liaoning university*

[3] *Nanjing University*

Corresponding Authors: shixin@ihep.ac.cn, wangcc@ihep.ac.cn, zhangxiyuan@ihep.ac.cn, wangkq2326@163.com, heye@ihep.ac.cn

Silicon carbide (SiC) has wider bandgap, higher atomic displacement energy, saturated electron drift velocity and thermal conductivity. It has the potential to become a high time resolution detector resistant to radiation and high temperature. A 4H-SiC Low-Gain Avalanche Detector (LGAD) epitaxial structure has been designed and epitaxial growth. The epitaxial structure of 4H-SiC LGAD was P++/N+ gain/N–bulk/N buffer/N++ substrate. In this work, the 4H-SiC LGAD fast time detector (Detector name: SICAR1) was successfully fabricated through the process of photolithography, etching, magnetron sputtering and annealing. The electronic properties of operating voltage, barrier height, effective doping and dark current were analyzed.

Monolithic devices / 20

Design strategies towards a small pixel size in a large DMAPS prototype in a 150 nm CMOS process

Author: Tianyang Wang[None]

Co-authors: Alexandre Habib [1]; Alexandre Rozanov [2]; Christian Bespin [3]; Fabian Huegging [3]; Fabrice Guilloux [4]; Hans Krueger [5]; Ivan Dario Caicedo Sierra [3]; Jochen Christian Dingfelder [3]; Lars Philip Schall [5]; Marlon B. Barbero [2]; Norbert Wermes [3]; Patrick Breugnon [1]; Patrick Pangaud [6]; Philippe Schwemling [7]; Pierre Barrillon [8]; Piotr Rymaszewski [3]; Sinuo Zhang [3]; Toko Hirono [3]; Tomasz Hemperek [3]; Yavuz Degerli [9]

[1] *Centre National de la Recherche Scientifique (FR)*

[2] *CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)*

[3] *University of Bonn (DE)*

[4] *Université Paris-Saclay (FR)*

[5] *University of Bonn*

[6] *CPPM, Aix Marseille Université, CNRS/IN2P3, Marseille, France*

[7] *CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR)*

[8] *Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France*

[9] *CEA Saclay*

Corresponding Authors: marlon.barbero@cern.ch, toko.hirono@cern.ch, alexandre.rozanov@cern.ch, sinuo.zhang@cern.ch, christian.bespin@cern.ch, lars.schall@uni-bonn.de, tianyang.wang@cern.ch, fabrice.guilloux@cern.ch, fabian.huegging@cern.ch, patrick.pangaud@cern.ch, hans.krueger@cern.ch, philippe.schwemling@cern.ch, id.caicedo@cern.ch, barrillon@cppm.in2p3.fr, breugnon@cppm.in2p3.fr, rymaszewski@physik.uni-bonn.de, amr.habib@cern.ch, degerli@cea.fr, wermes@uni-bonn.de, hemperek@uni-bonn.de, jochen.christian.dingfelder@cern.ch

LF-Monopix2 is the latest prototype in a decade-long R&D effort to develop a large DMAPS device in a 150 nm CMOS process. All pixels in this chip contain both digital and analog electronics within their collection node and they are read-out through a fast column-based synchronous architecture. The design follows the so-called ''large electrode" approach, where a careful layout of each pixel's wells and circuitry is necessary in order to avoid low breakdown voltage or spurious signals coupled to the collection node due to digital activity.

This contribution will outline the design strategy of the LF-Monopix chip series, with an emphasis on the pixel layout design for small pixel size and cross-talk mitigation. In addition, it will present an outlook of the challenges and possible approaches to reduce it even further in a future device.

Defects / **21**

Irradiation effect on trapping time of silicon carbide detector

Author: Suyu Xiao[1]

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

Corresponding Author: suyu.xiao@cern.ch

Top-TCT is carried out on non-irradiated and irradiated SiC detectors to study the charge collection, from which the trapping time can be estimated. Electrical characteristic with irradiation up to 7.8e14neq/cm2 has been studied and predicted. Thus, simulation of carriers in RASER has been optimized based on the contribution from trapping time. The electric read-out in RASER is proceed by NGSpice, resulting in good agreement.

TCT / **22**

SOLID STATE SENSOR CHARACTERISATION USING TWO-PHOTON ABSORPTION TECHNIQUE

Authors: Alexander Oh[1]; Andreas Mastronikolis[1]; Enoch Ejopu[2]; Francisca Munoz Sanchez[1]; Graham Miller[1]; Ilyas Benaoumeur[1]; Marco Gersabeck[1]; Michael Perry[1]; Oscar Augusto de Aguiar Francisco[1]

[1] *University of Manchester*

[2] *University of Manchester (GB)*

Corresponding Authors: ilyas.benaoumeur@student.manchester.ac.uk, alexander.oh@cern.ch, michael.perry@manchester.ac.uk, graham.miller@manchester.ac.uk, enoch.ejopu@cern.ch, marco.gersabeck@cern.ch, andreas.mastronikolis@student.manchester.ac.uk, francisca.munozsanchez@manchester.ac.uk, oscar.augusto@cern.ch

Two-photon absorption is a very powerful technique for the characterization of solid-state detectors. A dedicated set-up was developed at PSI (Manchester) which allow the possibility of tuning the laser wavelength (330 nm to 16,000 nm) with order of 150 femtoseconds laser pulses. This opens the possibility to test sensors based on different materials like silicon and diamond sensors with the same laser source. In addition, the same set-up can also be used for 3D characterization and time resolution studies. A description of the setup as well as the results of first measurements with silicon and diamond sensors shall be presented, including energy, voltage, depth and knife-edge scans, and time resolution measurements, followed by plans for improvements.

LGAD / **23**

Electrical characterization and attenuation factor determination of AC-LGAD run at CNM

Authors: Giulio Pellegrini[1]; Ivan Lopez Paz[2]; Jairo Antonio Villegas Dominguez[3]; Milos Manojlovic[3]; Neil Moffat[3]; Salvador Hidalgo[4]

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

[2] *The Barcelona Institute of Science and Technology (BIST) (ES)*

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

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

Corresponding Authors: ivan.lopez.paz@cern.ch, hidalgo.salvador@cern.ch, neil.moffat@cern.ch, milos.manojlovic@cern.ch, jairo.antonio.villegas.dominguez@cern.ch, giulio.pellegrini@csic.es

This presentation aims to provide an update on the recently completed AC-LGAD run at CNM. We begin by showing the electrical characterization of the produced wafers by IV and CV measurements. Several devices with different pad configurations and sizes were subjected to extensive TCT measurements. The TCT measurements reveal that the signal weakens as the laser is moved further away from the AC pad. We demonstrate the linear attenuation behavior of the signal loss between adjacent pads.

SiC / **24**

SILICON CARBIDE DIODES FOR ULTRA-HIGH DOSE RATE DOSIMETRY

Author: Giulio Pellegrini[1]

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

Corresponding Author: giulio.pellegrini@csic.es

The recent development of FLASH radiotherapy has led to the challenge of developing aequate sensors for active dosimetry in Ultra-High Dose Rate (UHDR) beam delivery. Especially in the case of FLASH electron beams the dose delivery can reach up to several Gy even in a single pulse with a few microsecond duration. The accurate dosimetry of this new UHDR radiotherapy modalities represents a key issue for its clinical translation.
In this talk I will present the last results on Silicon carbide p-n diode dosimeters designed for the stringent requirements of FLASH radiotherapy that have been fabricated and characterized in an ultra-high dose
rate electron beam.

Facilities / 25

Advanced Additive Manufacturing of Foams for High-Power Laser Interactions at ELI Beamlines

Author: Tomas Lastovicka[1]

[1] *Czech Academy of Sciences (CZ)*

Corresponding Author: tomas.lastovicka@cern.ch

Additive manufacturing (AM) foam targets have gained significant attention in the realm of high-power laser–matter interaction. These two-photon polymerization 3D printed targets offer a controlled environment for laser interactions, enabling exceptional versatility in terms of average density, spatial structure, and material composition. Such attributes hold immense potential for diverse applications, ranging from inertial confinement fusion to the generation of intense X-rays and gamma rays. In this contribution, we present an approach for the design and fabrication of AM foams tailored specifically for laser–plasma interaction experiments. Key aspects covered include the selection of optimal cellular structures, the utilization of finite element analysis to enhance mechanical properties, and the successful printing of foams onto dielectric and conducting substrates. Additionally, we explore the integration of high repetition rate targetry systems for synchronizing with high repetition rate lasers. The future prospects of AM foams in advancing laser-driven applications are also discussed, highlighting the transformative impact they hold for cutting-edge research and technological innovation.

LGAD / 26

Study of avalanche multiplication models in Low Gain Avalanche Diodes

Author: Marco Ferrero[1]

Co-authors: Federico Siviero [1]; Leonardo Lanteri [1]; Luca Menzio [1]; Nicolo Cartiglia [2]; Roberta Arcidiacono [1]; Roberto Mulargia [3]; Valentina Sola [1]

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

[2] *INFN Torino (IT)*

[3] *University & INFN Turin (IT)*

Corresponding Authors: luca.menzio@edu.unito.it, federico.siviero@edu.unito.it, roberta.arcidiacono@cern.ch, cartiglia@to.infn.it, marco.ferrero@cern.ch, leonardo.lanteri@cern.ch, valentina.sola@cern.ch, roberto.mulargia@cern.ch

To better understand the performances of LGADs in terms of collected charge, it is important to know with high accuracy the models that predict the avalanche mechanism of charge carriers. Several literature models are not able to predict with very high precision the evolution of the avalanche multiplication in LGAD sensors, showing discrepancies with experimental data. This truth is driving the extraction of more accurate impact ionization parameters to better fit the models with empirical data.

This contribution compares a comprehensive set of experimental data with those obtained in simulation. The experimental data have been acquired on LGADs with different designs of the multiplication region, new and irradiated up to fluences of the order of 1015 neq/cm2. The simulation campaign has been performed with the tool Weightfield2, and the avalanche models investigated are Massey and Van Overstraeten optimized models.

LGAD / 27

Characterisation of the EXFLU1 batch from FBK

Author: Valentina Sola[1]

Co-authors: Alessandro Fondacci [2]; Arianna Morozzi [3]; Daniele Passeri [4]; Francesco Moscatelli [5]; Giacomo Borghi [6]; Giovanni Paternoster [7]; Leonardo Lanteri [1]; Luca Menzio [1]; Marco Ferrero [1]; Matteo Centis Vignali [8]; Maurizio Boscardin [9]; Nadia Pastrone [1]; Nicolo Cartiglia [10]; Roberta Arcidiacono [1]; Roberto Mulargia [11]; Simona Giordanengo [12]; Tommaso Croci ; marco costa [13]

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

[2] *INFN Perugia (IT)*

[3] *INFN, Perugia (IT)*

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

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

[6] *Fondazione Bruno Kessler*

[7] *Fondazione Bruno KEssler*

[8] *FBK*

[9] *FBK Trento*

[10] *INFN Torino (IT)*

[11] *University & INFN Turin (IT)*

[12] *INFN Torino*

[13] *University of Torino*

Corresponding Authors: tommaso.croci@pg.infn.it, daniele.passeri@unipg.it, cartiglia@to.infn.it, marco.ferrero@cern.ch, nadia.pastrone@cern.ch, francesco.moscatelli@cern.ch, leonardo.lanteri@cern.ch, boscardi@fbk.eu, paternoster@fbk.eu, gborghi@fbk.eu, roberto.mulargia@cern.ch, luca.menzio@edu.unito.it, matteo.centis.vignali@cern.ch, valentina.sola@cern.ch, arianna.morozzi@pg.infn.it, simona.giordanengo@to.infn.it, roberta.arcidiacono@cern.ch, alessandro.fondacci@pg.infn.it, mcosta@to.infn.it

The EXLU1 batch exited FBK clean rooms at the end of 2022, made of LGAD sensors on substrates with thicknesses ranging from 15 to 45 μm.

Different optimisation studies are addressed in the batch, namely the periphery design for thin substrates, the increase of the radiation tolerance of the gain implant through a carbon shield, and the first production of compensated LGAD, where the gain implant is obtained via the compensation of p^+ and n^+ dopants.

The characterisation of the sensors prior to irradiation is in progress. The latest results will be presented and discussed.

Monolithic devices / 28

Performance of unirradiated TJ-Monopix2

Author: Christian Bespin[1]

Co-authors: Hans Krueger [2]; Heinz Pernegger [3]; Ivan Dario Caicedo Sierra [1]; Jochen Christian Dingfelder [1]; Konstantinos Moustakas ; Lars Philip Schall [2]; Norbert Wermes [1]; Toko Hirono [1]; Tomasz Hemperek [1]; Walter Snoeys [3]

[1] *University of Bonn (DE)*

[2] *University of Bonn*

[3] *CERN*

Corresponding Authors: toko.hirono@cern.ch, id.caicedo@cern.ch, heinz.pernegger@cern.ch, lars.schall@uni-bonn.de, wermes@uni-bonn.de, hemperek@uni-bonn.de, christian.bespin@cern.ch, konstantinos.moustakas@cern.ch, walter.snoeys@cern.ch, hans.krueger@cern.ch, jochen.christian.dingfelder@cern.ch

TJ-Monopix is series of monolithic pixel detectors with column-drain readout architecture and small collection electrode facilitating low-power designs aiming for high-energy collider experiments.

The latest iteration TJ-Monopix2 is designed in a 180 nm TowerJazz CMOS process and features a pixel size of 33 um x 33 um. Results from laboratory measurements and test beam campaigns demonstrating threshold and noise performance as well as hit efficiency measurements will be presented to discuss the suitability of TJ-Monopix2 for use in high-radiation environments. Additionally, first results of timing measurements will be presented.

Defects / **29**

Carrier lifetime variations in proton irradiated LGAD structures

Author: Tomas Ceponis[1]

Co-authors: Esteban Curras Rivera [2]; Eugenijus Gaubas [3]; Federico Ravotti [4]; Jevgenij Pavlov ; Laimonas Deveikis [5]; Michael Moll [4]; Moritz Wiehe [4]; Roberta Arcidiacono [6]; Vytautas Rumbauskas [5]

[1] *Vilnius University*

[2] *EPFL - Ecole Polytechnique Federale Lausanne (CH)*

[3] *Vilnius university*

[4] *CERN*

[5] *Vilnius University (LT)*

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

Corresponding Authors: michael.moll@cern.ch, esteban.curras.rivera@cern.ch, laimonas.deveikis@cern.ch, federico.ravotti@cern.ch, m.wiehe@cern.ch, vytautas.rumbauskas@cern.ch, jevgenij.pavlov@tmi.vu.lt, eugenijus.gaubas@ff.vu.lt, tomas.ceponis@cern.ch, roberta.arcidiacono@cern.ch

Carrier lifetime, being sensitive to defects present within the material, is an important parameter governing the operational characteristics of particle sensors. Therefore, the control of carrier lifetime in particle sensor structures is beneficial for predicting the variations of sensors operational characteristics. Microwave probed photoconductivity transients (MW-PC) technique can be employed for measuring of carrier lifetime. In this work, carrier lifetime variations obtained in LGAD structures, irradiated by penetrative protons of energy 24GeV/c in the fluence range of 1012-1016 cm-2, are considered.

LGAD / **30**

RD50 Project proposal: Partial Activation of Boron to enhance the radiation tolerance of the gain implant –PAB

Author: Valentina Sola[1]

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

Corresponding Author: valentina.sola@cern.ch

The partial activation of the boron atoms implanted in the gain layer region will be investigated to mitigate the effect of radiation on the gain implant in LGAD sensors. Atoms of boron in the gain layer volume left as interstitials can interact with other impurities present in the silicon lattice, preventing the removal of boron atoms from substitutional positions.
The goal of the project is to investigate the effect of partial activation of boron (PAB) to mitigate the boron removal due to irradiation and to extend by more than a factor of 2 the radiation tolerance of the LGAD sensors.

Different concentrations of implanted boron need to be explored, together with different times and temperatures of activation, to define a standard procedure for the PAB. Different combinations of active/total concentrations of boron will be investigated, such as 1/4, 1/2, 2/3, and more.
The project foresees the process simulation and design of the boron implant with different activation strategies, together with the device simulation and the design of the structures that will be included in the batch. Irradiation of sensors with different types of radiation, such as neutrons and protons, is foreseen. Characterisation of the devices before and after irradiation will test the resilience to irradiation of the PAB design.

The ultimate goals of the project are to find the best combination of boron dose and activation parameters, enhance the gain implant resistance to radiation, and define a standard process with easy-to-use production parameters for LGAD sensors with PAB.

Defects / **31**

Exploring boron-induced defects in n-type 4H-SiC Schottky barrier diodes

Authors: Tihomir Knezevic[1]; Eva Jelavić[2]; Yuichi Yamazaki[3]; Takeshi Ohshima[3]; Takahiro Makino[3]; Ivana Capan[1]

[1] *Ruđer Bošković Institute*

[2] *Faculty of Science, University of Zagreb*

[3] *National Institutes for Quantum Science and Technology*

Corresponding Author: tihomir.knezevic@irb.hr

In this work, we study boron-induced defects in 4H-SiC Schottky barrier diodes (SBDs) by employing minority carrier transient spectroscopy (MCTS). Additional electrical characterization was performed using temperature-dependent current-voltage (I–V), capacitance-voltage (C–V), and deep-level transient spectroscopy (DLTS) measurements to determine the effects of unintentionally incorporated boron on the steady-state electrical performance of n-type 4H-SiC semitransparent Schottky barrier diodes. The SBDs were fabricated on lightly nitrogen-doped 4H-SiC epitaxial layers with a thickness of approximately 25 µm, while semi-transparent nickel films were evaporated with a thickness of 15 nm to form a Schottky barrier diode. The MCTS study identified that the introduction of boron resulted in at least two deep-level defects identified as shallow boron (B) and deep boron (D-center). The activation energies for hole emissions for B and D-center are estimated as EV + 0.21 and EV + 0.60 eV, respectively. The concentrations of these defects were determined to reach values up to 1×10ˆ15 cm−3. The boron concentration was found to be higher than the nitrogen-dominated net effective doping concentration of ˜3 × 10ˆ14 cm−3 determined from the room-temperature (RT) C-V measurements. Even though the boron concentration was extremely high, no discernable decline in the steady-state electrical properties of the n-type 4H-SiC SBDs was found.

Defects / **32**

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

Authors: Erika Garutti[1]; Ian Dawson[2]; Michael Moll[3]; Vendula Subert[1]

[1] *Hamburg University (DE)*

[2] *University of London (GB)*

[3] *CERN*

Corresponding Authors: ian.dawson@cern.ch, vendula.maulerova@cern.ch, michael.moll@cern.ch, erika.garutti@desy.de

The concept of Non-Ionizing Energy Loss (NIEL) is used to compare and quantify the damage caused to semiconductor devices in various radiation environments. However, the current NIEL concept has a limitation in predicting the formation rates of cluster and point defects in silicon crystals for different particles and particle energies. Experimental observations have revealed differences in radiation damage produced by neutrons and protons with the same displacement energies (i.e., damage parameters normalized to NIEL).
In previous contributions for the RD50 workshop Geant4 simulations of high-energy particles (neutrons, protons, and electrons) were reported and Primary Knocked-on atoms (PKA) were analyzed. Additionally, a specific Geant4 physics module ScreenedNuclearRecoil was employed to track the subsequent creation of silicon cascades. The OPTICS (Ordering points to identify the clustering structure) algorithm was utilized as a tool to differentiate between isolated and clustered defects.
In this study, the ScreenedNuclear module in Geant4 is replaced by the more widely accepted SRIM/TRIM(Stopping Range in Matter/ Transport Range in Matter) simulation framework. Furthermore, this work combines Geant4, SRIM/TRIM, and the OPTICS algorithm. Neutrons, protons, and electrons are defined as the initial beam in Geant4. The resulting Primary Knocked-on atoms (PKA) are compared with FLUKA simulations and saved for further analysis. Separate studies are conducted on low-energy recoils using the TRIM framework and the OPTICS algorithm, and the results are also saved. By combining the results obtained from Geant4 and TRIM+OPTICS, it becomes possible to estimate the NIEL specifically relevant to vacancy creation, rather than the total NIEL. This revised approach allows for a more accurate prediction of damage and estimation of clustered and isolated defects for different incident particle energies.

Other devices / 33

Characterization of Indium Phosphide sensors for future large-scale thin film detectors

Authors: Earl Russell Almazan[None]; Jason Nielsen[1]; Jennifer Ott[1]; Jessica Metcalfe[2]; Manoj Bhanudas Jadhav[2]; Mike Hance[3]; Sungjoon Kim[None]; Tony Affolder[1]; Vitaliy Fadeyev[1]

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

[2] *Argonne National Laboratory (US)*

[3] *UC Santa Cruz*

Corresponding Authors: jeott@ucsc.edu, majadhav@cern.ch, fadeyev@ucsc.edu, skim606@uic.edu, jessica.metcalfe@gmail.com, affolder@ucsc.edu, etalmaza@ucsc.edu, jnielsen@ucsc.edu, michael.hance@cern.ch

Charged particle tracking detectors with very precise spatial and temporal resolution are a vital component of future high-energy and nuclear physics experiments. Thin film technology, as used e.g. in LCD displays and photovoltaics, could enable the fabrication of large-area, low-mass detectors in a straightforward and cost-effective way. In addition, physical and chemical vapor deposition methods could be used to fabricate tracking devices made from many other semiconductors besides Silicon. Potential new material candidates for charged particle tracking and photon detection are identified by properties such as band gap, resistivity, charge carrier mobility and charge collection efficiency.
This presentation focuses on Indium Phosphide (InP), which stands out as having a significantly higher electron mobility (>4500 cm^2/Vs) than Si and has found use in optoelectronics and high-frequency electronics. Single-pad sensors and 5x5 pad arrays were fabricated at Argonne National Laboratory on commercially available 350-µm thick InP:Fe wafers. The devices were characterized with CV-IV measurements, as well as with red laser TCT and beta particles from a Sr-90 source. It is shown that these comparatively thick sensors, with no particular design optimization nor gain implant, can reach a timing resolution of ca. 35 ps on a fast 1-ch UCSC readout board. Spatial scans with the red laser on 5x5 arrays and pronounced opposite-polarity cross-talk between pads are demonstrated. Preliminary results from focused X-ray test beams will also be discussed.

LGAD / 34

Characterization of W7 Type 10 and W7 Type 4 and comparison to W11 Type 10 LGAD prototypes

Authors: Gordana Lastovicka-Medin[1]; Jovana Doknic[2]; Vanja Backovic[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, doknicjovana3@gmail.com, gregor.kramberger@ijs.si, backovicvanja12@gmail.com, gordana.lastovicka.medin@cern.ch

In this presentation we report our research on W7 UFSD Type10 (2 p-stops + bias ring) and W7 UFSD Type 4 (with only bias ring in interpad region) prototype samples. Those results will be compared to the results obtained on W11 UFSD Type 10. Those UFSD prototype samples are not standard UFSD, they are produced in TI-LGAD batch as reference samples.

Wafer W7 and W11 differ in gain and in leakage current. The wafer W11 has a higher gain and a lower leakage current, while W7 has lower gain and higher leakage current. Those distinctive features will be used as parameters to estimate the influence of gain and leakage current on already reported excess in charge collection in intrepid region (reported in UFSD W11 Type 10 from Ti-LGAD). Study on W7 Type 4 (also produced in TI-LGAD batch) where only bias ring is interfaced in interpad region, and comparison to W7 Type 10 (with 2 p-stops + bias ring in interpad region) will help us to distinguish the role of each of interfaced structures in IP region on anomalous excess in charge collection in IP region.-

TCT / 35

Investigation of neutron, proton, and gamma irradiated planar sensors using the Two Photon Absorption –Transient Current Technique

Author: Sebastian Pape[1]

Co-authors: Cristian Quintana San Emeterio [2]; Esteban Curras Rivera [3]; Francisco Rogelio Palomo Pinto [4]; Ivan Vila Alvarez [5]; Marcos Fernandez Garcia [2]; Michael Moll [6]; Moritz Wiehe [6]; Raul Montero

[1] *Technische Universitaet Dortmund (DE)*

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

[3] *EPFL - Ecole Polytechnique Federale Lausanne (CH)*

[4] *Universidad de Sevilla (ES)*

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

[6] *CERN*

Corresponding Authors: raul.montero@ehu.es, m.wiehe@cern.ch, francisco.rogelio.palomo.pinto@cern.ch, sebastian.pape@cern.ch, michael.moll@cern.ch, ivan.vila@cern.ch, esteban.curras.rivera@cern.ch, marcos.fernandez@cern.ch, cristian.quintana.san.emeterio@cern.ch

The Two Photon Absorption –Transient Current Technique (TPA-TCT) is a newly developed tool for the characterisation of particle detectors. Contrary to present state of the art TCT, it allows to perform characterisation with a three dimensional spatial resolution. The setup at CERN is used to pioneer the technique with a tabletop setup that is designed for the investigation of silicon based detectors. It uses a 430 fs pulse fiber laser with a wavelength of 1550 nm, which is well beyond the linear absorption regime of silicon. Excess charge carriers are only generated in a small volume (approximately 1 µm × 1 µm × 20 µm) around the focal point of the laser beam, which allows a resolution in all three spatial directions.

This talk presents the TPA-TCT setup at CERN SSD and shows recent investigation of radiation damage in 150 µm thick FZ planar sensors fabricated by CIS. The dependence of the parasitic single photon absorption background on the fluence is presented, as well as a summary of available correction techniques. Further, CCE measurements conducted with TPA-TCT are presented and compared to 90Sr measurements. Finally, a comparison between the influence on the TPA-TCT of neutron, proton, and gamma irradiation is presented.

Defects / **36**

Bistable Boron related defect associated with the acceptor removal process in irradiated p-type silicon –electronic properties of configurational transformations

Authors: Andrei Nitescu[1]; Cristina Besleaga Stan[2]; Ioana Pintilie[3]; Nemnes George Alexandru[4]

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

[2] *National Institute of Materials Physics, Romania*

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

[4] *University of Bucharest, Faculty of Physics & Horia Hulubei National Institute for Physics and Nuclear Engineering*

Corresponding Authors: andrei.nitescu@infim.ro, cristina.besleaga@infim.ro, alexnemnes@yahoo.com, ioana@infim.ro

According to the observed "Acceptor Removal"effect a radiation induced Boron Containing Donor (BCD) defect is formed in p-type silicon. This defect shows bistable properties that are observed in variations of the depletion voltage as determined from C-V/I-V characteristics in PAD and LGAD structures irradiated with 10ˆ14 1 MeV neutrons/cm2. The electronic properties of the BCD defect in its two different configurations (A and B) are presented alongside with the transformation kinetics in the 243 K- 308 K temperature range. We show that in the presence of carriers in excess, a transformation of defect structural configuration from A to B takes place. The reverse configurational transformation appears when the excess carriers are removed. Energy barriers of 0.36 eV and 0.94 eV are determined for the A⟶B and B⟶A configurational transformations of BCD defect, respectively. The determined transformation rates indicate that the defect structural transformations are accompanied by electron capture for the A⟶B conversion and by electron emission for the B⟶A transformation. A configuration coordinate diagram of the BCD defect transformations is proposed.

LGAD / **37**

First measurements of irradiated CNM LGADs with carbon enriched gain layer

Authors: Alissa Shirley-Ann Howard[1]; Bojan Hiti[1]; Giulio Pellegrini[2]; Gregor Kramberger[1]; Jairo Antonio Villegas Dominguez[3]; Jernej Debevc[1]; Petja Skomina[None]; Salvador Hidalgo[4]

[1] *Jozef Stefan Institute (SI)*

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

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

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

Corresponding Authors: jairo.antonio.villegas.dominguez@cern.ch, jernej.debevc@cern.ch, petja.skomina@gmail.com, gregor.kramberger@ijs.si, alissa.howard@ijs.si, hidalgo.salvador@cern.ch, bojan.hiti@cern.ch, giulio.pellegrini@csic.es

The latest CNM LGAD run (R15973) was dedicated to improvement of radiations hardness by introduction of carbon in gain layer. Several different carbon doses were used. The initial gain layer

doping was chosen to have operational voltage at -30C around 110-130V, thus offering good temporal resolution and good radiation hardness. The first tests after neutron irradiations up to the equivalent fluences of 2.5e15 cm-2 have shown improved radiation tolerance with respect to previous runs. The preliminary results of CV/IV analysis, charge collection and timing resolution will be shown.

38

Welcome

Corresponding Author: gordana.medin@gmail.com

Defects / 39

Discussion: Defect studies

Corresponding Author: ioana@infim.ro

SiC / 40

Discussion: SiC

Corresponding Authors: giulio.pellegrini@csic.es, thomas.bergauer@cern.ch

Social event / 41

Tour to Kotor

Tivat - Kotor: 1h 15 min (welcome drink and catering)

Social event / 42

Guided tour in Kotor

guided tour of Kotor, 45 min

Social event / 43

Free time in Kotor

free time Kotor 1h - 1h 15 min (total 2 hours in Kotor)

Social event / 44

Tour back to Tivat

Kotor - Tivat: 1h 15 min

Monolithic devices / 45

Discussion: Monolithic devices

Corresponding Author: vilella@hep.ph.liv.ac.uk

LGAD / 46

Discussion: LGAD 2

Corresponding Authors: giulio.pellegrini@csic.es, gregor.kramberger@ijs.si, cartiglia@to.infn.it

Social event / 47

Boarding Pine, Tivat

Social event / 48

Tivat to Mirista with fish lunch

Cruise from Tivat to Mirista with fish lunch

Social event / 49

Break at Miriste

Break at Miriste, where people can transfer to the boat that will take them to the blue cave (there, of course, they can bathe and swim). The boat service to the blue cave costs 5 euros per person.

Social event / 50

Gospa od Skrpjela

Cruise to the island of Gospa od Skrpjela

Social event / 51

Visit of island

visit to the island, church and museum

Social event / 52

Gala dinner

gala dinner in a restaurant in Perast, restaurant Conte (https://hotelconte.me/)

Social event / 53

Back to Tivat

Other devices / 54

Discussion: Other devices

55

Farewell

Facilities / 56

Discussion: Facilities

Corresponding Author: gordana.medin@gmail.com

LGAD / 57

Discussion: LGAD 1

Corresponding Authors: giulio.pellegrini@csic.es, gregor.kramberger@ijs.si

Social event / 58

Excursion to Budva

Meeting Point: https://maps.app.goo.gl/UdFqAHBdQQ557RQ67?g_st=ic

Tivat - Budva 2 hours (guided tour through the old town and free time) –Tivat

59

Montenegro and Boka Bay between West and East

60

Status of DRD3 proposal

Corresponding Author: cartiglia@to.infn.it

LGAD / 61

Fast QA tests for LGADs

Corresponding Author: gregor.kramberger@ijs.si

Other devices / 62

Project proposal: MPW4 DAQ

Corresponding Author: francisco.rogelio.palomo.pinto@cern.ch