18th ”Trento” Workshop on Advanced Silicon Radiation Detectors

Report of Contributions

https://indico.cern.ch/e/1223972

Contribution ID: **1** Type: **Oral**

Performance and radiation hardness of Tower 180 nm MALTA monolithic pixel sensors

Wednesday, 1 March 2023 13:50 (20 minutes)

The MALTA monolithic active pixel sensor produced in TowerJazz 180 nm CMOS technology with pixels of size 36.4 x 36.4 um² and a 3 micro;m² electrode. As part of the MALTA family, the MALTA2 demonstrator features an asynchronous readout with cascoded front-end and demonstrates time resolution below 2 ns with radiation hardness up to 3e15 n/cm². As such, the MALTA family is a compelling candidate for tracking detectors for the HL-LHC and beyond. This contribution will show results from irradiated MALTA2 produced on both high-resistivity epitaxial silicon and on Czochralski substrates, obtained during the 2022 testbeam campaign at CERN SPS North Area. The timing performance of MALTA2 sensor irradiated to 3e15 n/cm² will be presented along with the detector efficiency. Future chip designs will also be discussed.

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Co-authors: SOLANS SANCHEZ, Carlos (CERN); Prof. BORTOLETTO, Daniela (University of Oxford (GB))

Presenter: GAZI, Martin (University of Oxford (GB))

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **2** Type: **Oral**

Spatial and timing resolution of RSD2 sensors measured at the DESY beam test facility

Wednesday, 1 March 2023 09:20 (20 minutes)

In this contribution, the performance of a Resistive Silicon Detector (RSD) measured with 4 GeV electrons at the DESY beam test facility is presented. The device-under-test comes from the second RSD production manufactured at FBK (RSD2). The RSD2 sensors feature a different design with respect to the previous production (RSD1), in order to improve the sharing of signals produced by ionizing particles and minimize the area covered by the read-out pads, which are both key elements to achieving excellent spatial and temporal resolution.

In this work, two RSD2 have been measured: a 2x2 array with 1.3 mm pitch and a 4x4 with 450 um pitch. The measurements have been performed at room temperature in the T24 line at DESY, using a EUDET pixel telescope to provide the reference hit position with less than 10um resolution; the reference timestamp, instead, is provided by an MCP with ˜15 ps resolution. The spatial and timing information have been obtained from the RSD2 sensor using both standard methods and machine learning techniques, and then compared with the reference ones, in order to assess the spatial and temporal resolution of the device. The sensor has been read out by a 16-channel fast analog board developed at FNAL, using a CAEN digitizer.

I will describe the sensor design and the DESY beam test facility, and I will present the spatial and timing results obtained at different bias voltages.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **3** Type: **Oral**

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

Thursday, 2 March 2023 12:10 (20 minutes)

The MONOLITH ERC Advanced project aims at producing a monolithic silicon pixel ASIC with 50μm pixel pitch and picosecond-level time stamping. The two main ingredients are low-noise, fast SiGe BiCMOS electronics and a novel sensor concept, the Picosecond Avalanche Detector (PicoAD). The PicoAD uses a patented multi-PN junction to engineer the electric field and produce a continuous gain layer deep in the sensor volume. The result is an ultra-fast current signal with low intrinsic jitter in a full fill factor and highly granular monolithic detector. Testbeam measurements show that the proof-of-concept prototype is fully efficient and achieves time resolutions of 17ps averaged on the pixel surface, with 13ps at the center of the pixel and 25ps at the pixel edge.
A second prototype without gain layer but with improved electronics provides 20ps time resolution.

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Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **4** Type: **Oral**

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

Thursday, 2 March 2023 15:00 (20 minutes)

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

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Presenter: ZAMBITO, Stefano (University of Geneva)

Session Classification: Applications

Track Classification: Applications

Contribution ID: **5** Type: **Oral**

Improvement of timing resolution and radiation torelance for finely segmented AC-LGAD sensors

Wednesday, 1 March 2023 09:40 (20 minutes)

Capacitive-coupled Low-Gain Avalanche Diode (AC-LGAD) is a semiconductor tracking detector with precise timing resolution and spatial resolution developed by KEK and Tsukuba group collaborating with Hamamatsu Photonics K.K. (HPK). A 100um x 100um pitch pixel type sensor and 80um pitch with 10mm length strip type sensor with 50um active thickness have been successfully developped with fully uniform gain across sensor active area while 50um x 50um pitch pixel type sensor must be working based on simulation although hard to test without readout ASIC. In this presentation we will discuss two things a) the timing resolution improvement by the thinner active thickness sensor (20um) b) improvement of radiation tolerance with the gain layer modification to minimize acceptor removal effect to operation voltage increase.

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Presenter: HARA, Kazuhiko (University of Tsukuba (JP))

Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **6** Type: **Oral**

Serial powering for the CMS inner tracker detector at High Luminosity LHC

Tuesday, 28 February 2023 10:05 (20 minutes)

The High Luminosity upgrade of the LHC machine aims at an increase of peak luminosity and to possibly reach an integrated luminosity of $3000 - 4500$ fb^{-1}. Consequently, the CMS experiment is called for an upgrade to keep up with the new challenges such as unprecedented radiation environment, requiring high resilience, and increased number of events per bunch crossing, requiring higher detector granularity. In this context, the CMS tracker needs to be upgraded in both its Outer and Inner part, fulfilling very stringent requirements. In particular, the Inner Tracker (IT) will make use of the serial powering scheme to provide the about 60 kW required by thousands of modular units. System tests performed on serial powering on the full final size CMS readout chip, C-ROC, will be presented.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **7** Type: **Oral**

Two Photon Absorption –Transient Current Technique: Recent results on segmented sensors and improved measurement methods

Thursday, 2 March 2023 16:50 (20 minutes)

The Two Photon Absorption –Transient Current Technique (TPA-TCT) exploits the quadratic absorption mechanism of light, to only excite charge carriers in a small volume around the focal point. Compared to conventional TCT methods that use light in the linear absorption regime, TPA-TCT enables true 3-dimensional resolution, while providing all the benefits of conventional TCT.
The TPA-TCT setup at CERN uses a 430 fs pulsed fiber laser, with a wavelength of 1550 nm and highly focusing optics, to only generate excess charge carriers in a volume of 1μm × 1μm × 20μm around the focal point. This talk presents the investigation of planar sensor, a HV-CMOS detector and a strip detector and highlights the power of the method. Furthermore, the weighted prompt current method and the mirror techniques are introduced that were especially developed for the investigation of segmented devices.

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Session Classification: TECHNOLOGIES

Track Classification: Technology

Contribution ID: **8** Type: **Oral**

Test Beam Results of 3D pixel sensors for the Phase-2 CMS Tracker with the RD53A and CROC readout chips

Wednesday, 1 March 2023 11:10 (20 minutes)

The High Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) will require new high-radiation tolerant silicon pixel sensors for the innermost layers of the CMS experiment tracking detectors, which should be capable of withstanding fluences up to 2.3E16 neq/cm2.
A comprehensive overview of the results obtained in beam test experiments with FBK and CNM 3D pixel sensors interconnected with the RD53A and CROC readout chips will be reported in this talk. RD53A is the first prototype chip issued from RD53 collaboration, while the CROC chip is the prototype full size version of the chip that will be mounted on the final detector.
The interconnected modules have been tested on beam at CERN and DESY, before and after irradiation up to an equivalent fluence of about 1.5E16 neq/cm2.
The 3D pixel sensors were made in the FBK and CNM foundries.
Analysis of collected data shows hit detection efficiencies around 98% measured after irradiation.
All results are obtained in the framework of the CMS experiment R&D activities.

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Session Classification: 3D Sensors

Track Classification: 3D Sensors

Contribution ID: **9** Type: **Oral**

100µPET: Ultra-high-resolution PET imaging with MAPS

Thursday, 2 March 2023 13:40 (20 minutes)

The 100µPET project, led by the University of Geneva, the University of Luzern, and the École Polytechnique Fédérale de Lausanne, aims at the development of a small-animal positron-emission tomography (PET) scanner with ultra-high-resolution molecular imaging capabilities. This is achieved through the use of a compact, modular stack of multiple thin layers of monolithic pixel detectors and flexible printed circuits (FPC), resulting in unprecedented scanner depth-of-interaction and volumetric granularity. Performance simulations have shown a point-spread-function of 0.2 mm, free of parallax effect, leading to a volumetric spatial resolution of about 0.015 mm3, one order of magnitude better than current PET scanners. Additionally, research and development on production methods have demonstrated the feasibility and reliability of the thin stack through cost-effective flip-chip bonding of the ASIC to the FPC using conductive adhesives. The recent developments in simulation and hardware prototyping will be presented in this contribution.

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Presenter: VICENTE BARRETO PINTO, Mateus (Universite de Geneve (CH))

Session Classification: Applications

Track Classification: Applications

Contribution ID: **10** Type: **Oral**

Test beam results of planar pixel quad modules and spatial resolution of 3D pixels for the phase-2 CMS tracker

Tuesday, 28 February 2023 15:05 (20 minutes)

The High Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) calls for an upgrade of the CMS tracker detector to cope with the increased radiation fluence, 2.3E16 neq/cm2 (1MeV equivalent neutrons) for the innermost layer while maintaining the excellent performance of the existing detector. An extensive R&D program aiming at 3D and thin planar pixel sensors, has been put in place by CMS. The new CMS pixel detector is built with sensor modules covering 2 or 4 (2x2) readout chips. In planar pixel modules, the inter-chip sensor region is made by special pixel cells having a non-standard, typically bigger, cell size in order to bridge the gap between the CMS Read Out Chip (CROC), avoiding dead regions. A non irradiated CMS quad CROC module, made in silicon planar technology by Hamamatsu, was tested with a particle beam and results on the performance of the inter-chip pixel cells are presented in this talk. Another topic presented in this talk is a first measurement of the spatial resolution as a function of the tilt angle for 3D pixel sensors , made by the FBK foundry in Trento, Italy, in collaboration with INFN, equipped with the CROC after irradiation up to an equivalent fluence of 1E16 neq/cm2.

Primary author: MANONI, Martina (Universita & INFN, Milano-Bicocca (IT))

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Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **11** Type: **Oral**

Radiation tolerance study using 8-inch full-wafer silicon sensors for CMS HGCAL

Tuesday, 28 February 2023 13:45 (20 minutes)

The CMS detector will be upgraded to face a 10-fold increase in integrated luminosity for the High-Luminosity LHC era compared to that of the current LHC Runs 1-3 combined. Its endcap calorimeters will be replaced by the high-granularity calorimeter (HGCAL). With its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels, HGCAL will facilitate the use of particle-flow calorimetry. Silicon pad sensors will be used for the electromagnetic section as well as for the high-radiation regions of the hadronic section of HGCAL (with fluences above 10^{14} neq/cm^2), covering a total area of 620 m^2. In the highest radiation regions, fluences up to 10^{16} neq/cm^2 and doses up to 1.5 MGy are expected. The silicon sensors are processed on 8-inch p-type wafers with three different thicknesses (300 μm, 200 μm, 120 μm), and cut into hexagonal shape for tiling and for optimal use of the wafer area. Each sensor is segmented into several hundred cells of hexagonal shape of 0.5 to 1.1 cm^2 in size, each of which is read out individually. The talk will focus on bulk radiation-tolerance studies performed in 2020-2022 with full and partial 8-inch sensors irradiated to fluences up to 1.4 x 10^{16} neq/cm^2 at the novel neutron irradiation facility at Rhode Island Nuclear Science Center (RINSC, US). Using the ARRAY system (a customised probe and switch card system), their electrical properties in terms of pad leakage currents and capacitances have been measured for the first time, after neutron irradiation both without and with additional beneficial isothermal annealing. We present the results of those measurements, hereby qualifying the RINSC neutron irradiation facility and showing that the measured electrical properties of the full-sized HGCAL silicon sensors after neutron irradiation meet expectations and are acceptable for the HGCAL.

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Presenter: KRAWCZYK, Marta Adamina (CERN)

Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **12** Type: **Oral**

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

Tuesday, 28 February 2023 14:05 (20 minutes)

The CMS detector will be upgraded to face a nearly 10-fold increase in integrated luminosity for the High-Luminosity LHC era compared to that of the current LHC Runs 1-3 combined. It will be adapted to the higher levels of radiation and larger amounts of data collected. The endcap calorimeters of the CMS detector will be replaced by the High-Granularity Calorimeter (HGCAL). The HGCAL will facilitate the use of particle-flow calorimetry with its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels. Silicon pad sensors will be used for the electromagnetic section as well as for the high-radiation regions of the hadronic section of the HGCAL (with fluences above $10^{14}n_{eq}/cm^2$), covering a total area of 620 m^2. In the highest radiation regions, fluences up to $10^{16}n_{eq}/cm^2$ and doses up to 1.5 MGy are expected. The silicon sensors are processed on novel 8-inch p-type wafers with three different thicknesses (300 μm, 200 μm, 120 μm), cut into hexagonal shape for tiling and for optimal use of the wafer area. Each sensor is segmented into several hundred cells of hexagonal shape of 0.5 to 1.1 cm^2 in size, each of which is read out individually. In addition to the main sensors, the full wafer hosts small sized test structures used for quality assurance and radiation-hardness tests. In order to study the radiation-induced bulk damage, the test structures were irradiated with neutrons at two institutes: JSI (Jožef Stefan Institute, Ljubljana), with a well-known neutron spectrum and fluence calibration and RINSC (Rhode Island Nuclear Science Center), a novel neutron irradiation facility that can host full 8-inch wafers. We present the results of a radiation-tolerance testing program of the bulk material of HGCAL prototype silicon sensors performed with irradiated test structure diodes. The talk will focus on the electrical characterisation and charge collection measurements, isothermal annealing behaviour of the bulk material and the comparison of the results between diodes irradiated at the different irradiation facilities. The measured results are compatible with previous studies and in line with expectations. We observe expected behaviour of the electrical properties and the charge collection efficiency is in agreement with the HGCAL specifications. The results can also be used in simulation studies for establishing an operating and annealing scenario for HGCAL.

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Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **13** Type: **Oral**

First test beam results of HPK planar pixel sensors with the CROC readout chip for the CMS Phase 2 Upgrade

Tuesday, 28 February 2023 14:25 (20 minutes)

The current tracking system of the CMS experiment will be fully replaced for the High-Luminosity running phase of the LHC with a planned integrated luminosity of more than 3000 fb^{-1} delivered to the experiments. The innermost layers of the CMS Inner Tracker (IT) will be subject to particle fluences up to about 2×10^{16} cm^{-2} (1 MeV neutron equivalent).

In an extensive R&D program with several vendors, various pixel sensor options have been evaluated, including different pixel pitches and sensor cell designs, and only recently the final decision has been made. All layers (except the innermost layer of the barrel section of the IT) will be equipped with planar n^{+}-p sensors with an active thickness of 150 μm and pixel pitches of 25 $\times$ 100 μm^2. In the previous phase of the sensor qualification campaign, sensors were coupled to demonstrator chips (RD53A) and the modules were irradiated to fluences up to Φ_{eq} = 2 $\times$ 10^{16} cm^{-2} and extensively tested in both CERN and DESY test beam facilities. During the last year, single chip assemblies and the first full modules with the final, full-size prototype readout chip (CROC) became available.

This talk will present an overview of the first very preliminary test beam results obtained at DESY for CROC assemblies. Studies of the hit efficiency, spatial resolution and noise for both non-irradiated samples and assemblies irradiated up to Φ_{eq} = 1 $\times$ 10^{16} cm^{-2} will be presented. The preliminary results obtained are compatible with previous results obtained with RD53A assemblies. The results described in this contribution are important input for the designers of the final CROC_v2 readout chip and will allow CMS to start the pre-production phase for pixel sensors for the IT soon.

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Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **14** Type: **Oral**

ATLAS ITk Pixel Sensor Characterization for the HL-LHC upgrade

Tuesday, 28 February 2023 12:15 (20 minutes)

To cope with the much increased pile-up, data rates and radiation damage from the upgrade of High Luminosity LHC, the current ATLAS Inner Detector will be replaced by an all-silicon Inner Tracker (ITk). The inner most part of ITk will be the pixel detector which covers an area of about 13m^2 and comprises the modules made of silicon planar or 3D sensors bump bonded to readout FE ASICs. Data taking is planned to start in 2029 and last for 10 years. Currently, the ITk pixel project is in pre-production. To assure the sensors meet the specification of being used in the detector, a fraction of full size pixel sensors and test structures, were tested in lab. The characterization results of ITk pixel sensors will be presented.

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Session Classification: Systems issues

Track Classification: System Issues

Contribution ID: **15** Type: **Oral**

Silicon sensors for beam monitoring: first characterization with Ultra-High Dose-Rate electron beams

Thursday, 2 March 2023 14:00 (20 minutes)

Introduction:
A normal tissue sparing effect (FLASH effect) has been observed in Ultra-High Dose-Rate electron and proton irradiation (UHDR). In this extreme regime, conventional transmission chambers show non-linear effects due to very high flux of particles. Therefore, the real time beam monitoring in UHDR requires the adaptation of detector technologies and the investigation of new approaches, to be capable of measuring the integrated flux of each FLASH pulse. In this contribution, thin silicon planar sensors studied by the University and INFN Turin within the INFN FRIDA project will be described. The first tests on pulsed electron FLASH beams at the SIT ElectronFLASH Linac (EF) installed at the Centro Pisano for Flash RadioTherapy (CPRF, through a special funding from the Fondazione Pisa) will be reported.

Materials and methods:
Silicon p-i-n sensors of 45 μm active thickness, segmented into 2 mm² strips and inversely polarized, were irradiated with 9MeV FLASH electron beams. Two different systems were used to readout the signal generated in the silicon and compared with each other: one sensor strip was connected to an oscilloscope (with a sampling frequency of 10 GS/s) and a second strip was connected to a TERA08 chip, a 64-channel current-frequency converter (20 MHz/channel maximum output frequency, 200 fC charge quantum). The clinical dose per pulse (DPP) was varied up to a value of 4 Gy in each pulse of 4μs duration.

Results:
It was observed that TERA08 saturates under EF irradiation. To overcome this issue, an RC circuit (R=2kOhm, C=1μF) was placed between the sensor and the chip to reduce the instantaneous charge input to the chip, keeping the integrated charge constant. In this way, the charge measured by a silicon strip (polarized at 200V) in each EF pulse is linear (R value > 0.99) up to ˜ 4 Gy/pulse for both readout systems (oscilloscope and TERA08). In condition of full depletion of the active thickness and lower bias voltage applied (i.e. 50 V), the collected charge vs dose per pulse deviates from linearity. This is due to the creation of an electric field opposite to the applied one (caused by the high charge density released in the silicon), inhibiting charge collection. Simulations with the TCAD Sentaurus software are being performed to reproduce the experimental results and to characterize this effect.

Conclusions:
Initial tests with delivered EF beams have demonstrated the potential of thin planar silicon sensors to monitor UHDR electron beams up to a few Gy/pulse. A lower charge collection was observed with sensor polarization <200V and is being studied through simulations. New sensor geometries will be tested on both electron and proton beams.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **16** Type: **Oral**

Ionizing and non-ionizing radiation damage on Silicon Photomultipliers

Thursday, 2 March 2023 15:50 (20 minutes)

Silicon Photomultipliers are single-photon sensitive detectors that continue to attract increasing interest in several industrial and scientific applications that require fast detection speed, high sensitivity, compactness, insensitivity to magnetic fields and low bias voltages. SiPMs have been employed in a growing number of applications thanks to these properties and the good optical dynamic range. They are currently the detector of choice in scientific experiments and industrial applications, like in Positron Emission Tomography, with Time-of-flight information (ToF-PET), Cherenkov light readout, in the readout of liquid noble gases scintillators at cryogenic temperatures (e.g. LAr, LXe), and in industrial and automotive Light Detection and Ranging (LiDAR) systems. SiPMs are also quickly replacing photomultiplier tubes (PMTs), hybrid photodiodes (HPDs), or other detector technologies in high-energy physics (HEP) experiments (like CMS, LHCb, etc.), and for the readout of scintillators in gamma-ray detectors for space experiments. In such applications the SiPMs receive a significant dose of particles (e.g. protons and neutrons) as well as X and gamma rays, in the order of 10^{12} up to 10^{14} particles/cm^2 in HEP and of 10^{11} particles/cm^2 for space applications (considering for example satellites working in LEO or Polar orbit, for few years operations and with typical detector shielding).
While the effect of radiation in silicon detectors has been well studied, the literature is not as much concerning Avalanche photodiodes (APDs) and photon-counting detector, working in Geiger-mode (like SPADs and SiPMs). At FBK (Trento, Italy) we have been developing different technologies during last years for SiPMs and SPADs, optimized for different applications, e.g. with sensitivity peaked in the near-ultraviolet or in the near-infrared region. Such technologies are based on different silicon-starting-materials (with different doping species), and made with different internal layouts and micro-cell structures. It is interesting to directly compare their performance when irradiated with the same particles and fluences, also highlighting possible different behaviors in their performance with irradiation. To study the effect of radiation damage on SiPMs we performed several irradiation campaigns, using protons and X-rays, to study the effects of Ionizing Energy Loss (IEL) and Non-Ionizing Energy Loss (NIEL) on their electrical properties, on their noise characteristics and on their detection efficiency. We highlighted the main effects and differences between the SiPM technologies, and we interpreted the results with the help of TCAD simulations of the electric fields inside the SiPM micro-cells.

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Presenter: ACERBI, Fabio

Session Classification: TECHNOLOGIES

Track Classification: Technology

Contribution ID: **17** Type: **Oral**

Pixel cell local efficiency of FBK 3D pre-production pixel sensors after irradiation up to 1.9·10^{16} n_{eq}/cm^2

Wednesday, 1 March 2023 11:30 (20 minutes)

The High Luminosity program of the Large Hadron Collider (HL-LHC) will improve the performance of the accelerator by increasing the instantaneous luminosity $\mathcal{L}$ up to 7.5· 10^{34} cm^{-2} s^{-1}, with an average of 200 proton-proton collisions per beam-crossing. An upgrade of the ATLAS detector is needed to cope with the harsher radiation levels and with a much higher number of tracks. The Inner Tracker (ITk) will be the new all-silicon tracker. The ITk innermost layer will be exposed to a fluence of 1.3·10^{16} n_{eq}/cm^2 at the half at the HL-LHC program when it is scheduled to be replaced. Considering a 1.5 safety factor the sensors placed in this layer need to be qualified up to a fluence of 2·10^{16} n_{eq}/cm^2. Due to their radiation hardness, 3D pixel sensors have been chosen to instrument the innermost layer of the detector. 3D sensors with a pixel cell 25x100 μm^2 have been chosen for the central region of the detector (Barrel) while the 50x50 μm^2 ones will instrument the two side regions (End-Caps). The latter have been characterized in laboratory and in beam tests after irradiation up to a fluence of 1.9·10^{16} n_{eq}/cm^2 during 2022. A summary of their performance before and after irradiation will be presented, with a particular focus on the pixel cell local efficiency.

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Session Classification: 3D Sensors

Track Classification: 3D Sensors

Contribution ID: **18** Type: **Oral**

A CMOS pixels upgrade for the Belle II Vertex Detector

Wednesday, 1 March 2023 15:30 (20 minutes)

The success of the Belle II experiment at KEK (Tsukuba, Japan) relies on the very high instantaneous luminosity expected from the SuperKEKB collider in the coming years, close to $6 \times 10^{35}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. The beam conditions required to reach such luminosity cause a large rate of background particles to reach the innermost layers of the Belle II detector, which exceeds by far the rate of particles from signal events: this sets stringent constraints on the vertex detector, which must provide robust and efficient track and vertex finding for physics analyses.

In the 2026-2027 time frame accelerator upgrade works are planned, with a possible redesign of the interaction region being considered. In addition, while the current Belle II vertex detector has been showing excellent performance since the data-taking started in 2019, prospects show that, at full luminosity, its occupancy rates will fall close to the current technology's limits, with large uncertainties. For these reasons, the Belle II collaboration is considering the possibility to replace the current pixels-and-strips vertex detector with a fully-pixelated CMOS system, and R&D activities are ongoing.

The new system would employ a fully-depleted monolithic active CMOS pixel sensor, dubbed OBELIX, based on the TJ-Monopix-2 prototype, which benefits from the significant developments made in recent years for other particle physics experiments. This upgraded vertex detector will allow to reduce the material budget and improve the spatial resolution with respect to the current detector. Moreover, thanks to its fast readout architecture and timestamp resolution under $100\ \mathrm{ns}$, it will provide a satisfactory safety factor with respect to the background rate expected at full luminosity.

This talk will briefly introduce the proposed upgrade for the Belle II vertex detector and provide an overview of the technological proposals. Then it will focus on the current status of the sensor and detection module developments, especially the in-laboratory tests of the TJ-Monopix2 sensor, relevant for the ongoing design of the OBELIX chip.

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Presenter: MASSACCESI, Ludovico

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **19** Type: **Oral**

Calculation of geometrical parameters of 3D sensors for timing application

Wednesday, 1 March 2023 17:20 (20 minutes)

One of the requirements for the next generation of tracking sensors is a good time resolution, down to tens of picosecond.
For hybrid pixel sensors, one of the limiting factor for the temporal resolution comes from the readout electronics.
Simulations of typical charge sensitive amplifier electronic front end has been performed and the results shows that the timing jitter
is dominated by the relationship between input charge and capacitance (j.nima.2013.04.060).

On the sensor side, 3D sensors have shown good potential for timing applications. In this talk, the capacitance (c_{det}) and input charge (Q_{in}) of 3D sensors have been calculated as a function of the column size (w) and aspect ratio (R). By combing this calculation and results of the front-end electronic simulation, a region in the $w - R$ space which satisfies the requirements for timing resolution of 30 ps is found. In addition the issue of the fill factors of 3D sensors for perpendicular and inclined tracks is discussed.

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Presenter: HAJHEIDARI, Mohammadtaghi (CERN)

Session Classification: Simulations

Track Classification: Simulations

Contribution ID: **20** Type: **Oral**

Latest results on RSD2 performances, a lab update

Wednesday, 1 March 2023 09:00 (20 minutes)

In this work, we present a comprehensive analysis of the spatial and temporal resolutions of RSD sensors belonging to the second FBK RSD production (RSD2). The RSD2 production results from the optimization process performed on the FBK RSD1 sensor production. Specifically, RSD2 sensors have innovative read-out electrode layouts geared toward reaching a uniform response over the whole surface. The performances of the detectors were measured with a Transient Current Technique setup equipped with a picosecond laser with a narrow (~10 µm) beam. In this presentation, we will outline the results of such measurements, which yield excellent spatial and timing resolutions: down to about 5 µm and 20 ps time jitter. We will present detailed studies on the effect of varying the n++ electrode doping, the difference between read-out pad geometries, and the best achievable temporal and spatial resolution in each case.

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Presenter: MENZIO, Luca (Universita e INFN Torino (IT))

Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **21** Type: **Oral**

First results on monolithic pixel sensors test structures in the 65 nm technology

Wednesday, 1 March 2023 14:10 (20 minutes)

The ALICE ITS3 (Inner Tracking System 3) upgrade project together with the CERN EP R&D on monolithic sensors are exploring the Tower Partner Semiconductor Co. (TPSCo) 65 nm ISC process.
The ITS3 project aims to build the first fully cylindrical tracker by using wafer scale, ultra thin (20 - 40 μm) bent MAPS.
Four different pixel test structures, Circuit Exploratoire 65 (CE65), Digital Pixel Test Structure (DPTS), Analogue Pixel Test Structure - Source Follower (APTS-SF), Analogue Pixel Test Structure - Operational Amplifier (APTS-OPAMP), were designed to validate the sensor technology through an extensive characterization both with laboratory and in-beam measurements.
A particular focus will be given to the APTS-OPAMP which is equipped with a fast in-pixel OPAMP-based buffering to explore the sensor timing performance.
This work will show the sensor design, an overview on the different pixel test structures, and results obtained with a Fe-55 source and at test beam facilities.

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Presenter: PERCIBALLI, Stefania (Universita e INFN Torino (IT))

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **22** Type: **Oral**

Radiation tolerance study of LGADs for the CMS Encap TIming Layer detector

Tuesday, 28 February 2023 16:55 (20 minutes)

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase 2 upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). The addition of the MIP timing detector (MTD) to CMS will be critical to mitigate the impact of high pileup collisions anticipated during the HL-LHC. The MTD will provide timing information at an unprecedented precision level. The endcap part of MTD, Endcap Timing Layer (ETL), will depend on a new Silicon based technology, Low Gain Avalanche Diodes (LGADs), as well as a specially design ASIC to readout and digitize the LGAD signal. As part of the LGAD sensor market survey for the CMS ETL detector, a radiation tolerance study of LGADs irradiated with neutrons manufactured by FBK and IMB-CNM up to a fluence of 1.5e15 n_eq/cmˆ2 is performed. The dependence of the collected charge, jitter and timing resolution on fluence is determined using a radioactive source and a TCT setup. The dependence of the capacitive cross-talk with the fluence at electrodes adjacent to the collector electrode is also shown.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **23** Type: **Oral**

Assembly and characterization of 3D pixel modules for the ATLAS ITk detector

Tuesday, 28 February 2023 11:55 (20 minutes)

The Large Hadron Collider (LHC) next upgrade is the High-Luminosity LHC (HL-LHC) planned to start operation in 2029. One of the most critical and demanding sub-detector systems of the ATLAS HL-LHC upgrade is the Pixel Detector of the Inner Tracker (ITk), which is a key component to achieve excellent track impact parameter resolution.

The basic unit of the ITk Pixel Detector is the pixel module, an assembly of one or more pixel sensors with their respective readout chips (the so-called bare modules or hybrids), mounted on a single flexible PCB (the flex) which allows for biasing and communication. The linear triplet modules, which will be used in the innermost layer (L0) of the barrel, are composed by a set of three pixel sensors, flip-chipped to their respective readout chips, and glued and wire-bonded to the flex.

Given the space constraint inside the Pixel Detector, each pixel module must meet demanding geometrical and alignment specifications. Consequently, a thorough study of the assembly and electrical validation methods was conducted, in order to develop appropriate strategies and well-structured procedures to ensure fine accuracy and high repeatability.

The sensors used for the linear triplet modules are 3D pixel silicon sensors which have been chosen because of their high-radiation tolerance. Novel 3D pixel sensors were manufactured using a single-side technology on Silicon on Insulator (SOI) wafers with an active thickness of 150 μm. Two kinds of pixel sensor cells will be used in the forward rings and in the barrel part of innermost layer, respectively: 50 x 50 μm^2 and 25 × 100 μm^2 both with one collecting electrode.

In this presentation I am going to briefly describe the assembly methodology to finally focus on the electrical tests and performance of first prototypes of linear triplets assembled at IFAE. Moreover, I am going to show the electrical characterization of the 3D pre-production sensors irradiated in a proton beam up to the final neutron equivalent particle fluence required for the innermost layer of ITk (1.7E16 neq/cm^2). These measurements are part of the Quality Assurance (QA) procedures for the ITk pixel sensor production.

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Session Classification: Systems issues

Track Classification: System Issues

Contribution ID: **24** Type: **Oral**

MightyPix: An HV-CMOS Pixel Chip for LHCb's Mighty Tracker

Wednesday, 1 March 2023 14:30 (20 minutes)

In the coming years the Large Hadron Collider (LHC) at CERN is being upgraded to work at higher luminosities, leading to the High-Luminosity LHC. The HL-LHC will reach luminosities up to 5 × 10^{34} cm^{-2} s^{-1} collecting at least 3000 fb^{-1} of data in its lifetime. To handle the increased luminosity and data rate, the experiments at the LHC will be upgraded as well. One of the proposed changes is the installation of the Mighty Tracker, a new hybrid tracking system for the LHCb detector. It would consist of scintillating fibres in the outer regions and silicon sensors in the inner regions, where the hit density is the highest. The proposed baseline technology for the silicon sensors are High-Voltage CMOS detectors, which meet the requirements for radiation hardness and granularity. These pixel chips combine sensing element and readout logic in a single device and prototypes for the ATLAS and Mu3e experiments have already proven successful.

The HV-CMOS pixel chip currently being developed for the Mighty Tracker is called MightyPix. A first test chip has already been designed, fabricated, and studied at a test beam at DESY. The first LHCb compatible prototype has been submitted for fabrication in June and received back in December. It has a full column height of 2 cm and is 0.5 cm wide, one fourth of the final width. It can already handle the Timing and Fast Control signals coming from LHCb and has an I2C interface, needed for the lpGBT readout chips used by LHCb. Additionally, the chip's efficiency within the LHCb environment was simulated extensively to ensure its optimal performance within the Mighty Tracker. The first full-sized prototype with a reticle size of 2 cm x 2 cm will follow this year. Eventually, over 46000 MightyPix sensors would be installed in the Mighty Tracker to cover an area of 18 m^2.

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Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **25** Type: **Oral**

AstroPix: A novel HV-CMOS pixel sensor for space-based experiments

Thursday, 2 March 2023 10:50 (20 minutes)

A new application for monolithic pixel detectors is NASA's AMEGO-X project, which is a low-orbit gamma ray observatory for multimessenger astrophysics, proposed as a 3 to 5 year mission. For the 40-layer gamma-ray telescope, which will consist of over 64000 sensors with a total area of more than 25 m², a new low power and high dynamic range monolithic active pixel sensor named AstroPix is currently being developed.
The first two versions, AstroPix v1 a 5 x 5 mm² test chip with 200 x 200 µm² pixels and AstroPix v2 a 1 x 1 cm² test chip with 250 x 250 µm² pixels have already been designed and fabricated. The energy resolution and the SEU and latchup performances required for the usage in space are currently studied in test beams. The newest version AstroPix v3, has been submitted for fabrication in July 2022 and received back in January 2023.
This prototype is the first full reticle chip with 500 x 500 µm² large pixels. It features a new guard ring design which is expected to withstand a depletion voltage of over 300 V, which is needed to fully deplete the substrate of 500 µm. Being able to deplete thick sensors would also enable new applications of HV-CMOS sensors for detection of high energy photons and direct energy measurement of charged particles.

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Presenter: STRIEBIG, Nicolas (KIT - Karlsruhe Institute of Technology (DE))

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **26** Type: **Oral**

Investigation of soft X-ray detection using iLGAD sensors

Wednesday, 1 March 2023 16:40 (20 minutes)

Inverse Low Gain Avalanche Diodes (iLGAD) can improve the signal-to-noise ratio for X-ray detection in photon science applications. PSI collaborates with FBK for the development of iLGAD sensors with a thin entrance window (TEW) targeting soft X-rays. For this development a first batch of wafers, consisting of diodes and pixelated sensors, was fabricated and is currently under test.
In this talk, we will present measurements performed in the photon energy range from 200 eV to 1000 eV at the Surface/Interface Microscopy (SIM) beamline at the Swiss Light Source (SLS).
Quantum efficiency measurements were exploited to determine the thickness of the passivation layers and to estimate the charge collection efficiency. From the measurements of the average gain of the iLGAD diodes, the multiplication factor was also modeled as a function of the photon absorption depth.
In addition, soft X-ray detection with iLGAD sensors bump-bonded to the Mönch readout chip has been investigated. The spectral response shows double peaks due to the dependence of the multiplication factor on the position where the photon is absorbed. Namely, if the absorption occurs before the gain layer, the avalanche is initiated by holes that drift to the readout side, resulting in a lower multiplication factor. If the photon is absorbed after the gain layer, the avalanche is induced by electrons drifting to the backplane, leading to a higher multiplication factor.
The origin of the observed spectrum has been confirmed with Monte Carlo simulations. The simulations consider photon absorption, drift and diffusion of carriers, as well as charge multiplication. In particular, the model used for the multiplication factor as a function of the absorption depth has been extracted from the iLGAD diodes. The results have been compared to the measurements, providing not only a qualitative, but also a quantitative interpretation of the spectrum.

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Presenter: LIGUORI, Antonio

Session Classification: Simulations

Track Classification: Simulations

Contribution ID: **27** Type: **Oral**

Characterisation of a digital SiPM in 150 nm CMOS Imaging Technology

Thursday, 2 March 2023 11:30 (20 minutes)

Silicon Photomultipliers (SiPMs) are well known as excellent light detectors in the ultraviolet to visible energy range with sub-nanosecond time resolution. Due to their unique characteristics, these detectors are widely used in high-energy physics and medical imaging systems. In conventional SiPMs, an array of Single Photon Avalanche Diodes (SPADs) is connected in parallel. In these devices the time resolution is intrinsically limited by the total output capacitance and the spatial resolution on the order of the physical size of the array.
In recent years, SPADs have been integrated into standard high-volume CMOS processes. This not only allows the production of large volumes of SiPMs at a relatively low cost but also offers the possibility of combining the excellent light detection efficiency and time resolution of SPADs with the flexibility and possibilities offered by CMOS imaging technology.
A prototype of a digital SiPM was designed at DESY in 150 nm LFoundry CMOS technology using 25 x 25 μm^2 SPADs. The main array consists of 32 x 32 pixels, containing 4 SPADs, quenching and readout circuitry. The readout is frame-based, operating with a 3 MHz clock. The data from the chip contains the hit map with the coordinates of the firing pixels and timestamps given by four shared 12-bit TDCs. The dSiPM has been characterized using the versatile Caribou DAQ system. Detailed Current/Voltage (IV) and Dark Count Rate (DCR) studies were performed in a temperature-controlled environment, Minimum Ionizing Particle (MIP) detection efficiency and spatial resolution measurements were carried out at the DESY-II Test Beam Facility using an electron beam, and a characterisation of the temporal performance was conducted using a laser setup.
In this contribution, the main features of the dSiPM are reported along with the results of the performed characterizations. Plans for future studies and developments are also presented.

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Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **28** Type: **Oral**

Design and performance of UKRI-MPW0: an HV-CMOS prototype with a novel sensor cross-section

Wednesday, 1 March 2023 15:10 (20 minutes)

The High Voltage CMOS (HV-CMOS) technology is a promising candidate for future particle physics experiments. To meet the needs of future experiments, especially in terms of single point resolution ($50 \times 50\mu\mathrm{m}^2$), time resolution (0.2 ns) and radiation tolerance ($10^{16}\mathrm{n_{eq}}/\mathrm{cm}^2$), the HV-CMOS pixel sensor performance needs to be further improved. The Liverpool HV-CMOS group has developed a prototype HV-CMOS chip, named UKRI-MPW0, which aims at addressing some of these challenges.
This chip is developed using the 150 nm HV-CMOS process from LFoundry. It implements a novel sensor cross-section optimised for backside biasing at unprecedented high voltages. Preliminary measurements have shown the chip is able to sustain high bias voltages (> 600 V) much beyond the state of the art, thus promising a large improvement in radiation tolerance. Pixel matrices with 20 rows and 29 columns (pixel size of $60 \times 60\mu\mathrm{m}^2$) and several test structures are included in the chip.
This contribution will present the design details and evaluation of UKRI-MPW0, with focus on the performance characterisation of its pixel matrix. Initial characterisation results show pixels have Equivalent Noise Charge (ENC) $< 100\mathrm{e}^-$ and gain $> 100\mathrm{mV/ke}^-$.

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Presenter: ZHANG, Chenfan (University of Liverpool (GB))

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **29** Type: **Oral**

Large-area passive CMOS sensors for radiation tolerant hybrid pixel detectors

Tuesday, 28 February 2023 15:25 (20 minutes)

CMOS process lines are an attractive option for the fabrication of hybrid pixel sensors for large-scale detectors like ATLAS and CMS. Besides the cost-effectiveness and high throughput of commercial CMOS lines, multiple features like poly-silicon layers, metal-insulator-metal capacitors and several metal layers are available to enhance the sensor design.

After an extensive R&D programme with several prototype sensors in 150 nm LFoundry technology, passive CMOS pixel sensors have been manufactured for the first time as large-area sensors using the reticle stitching technique. The sensors are compatible with the RD53 readout chips designed for the ATLAS and CMS tracking detector upgrades.

The sensors have been extensively studied in the lab and using a minimum ionising particle beam. In this talk, the performance of large-area passive CMOS sensors before and after irradiation to fluences of 2×10^{15} neq/cm² and 5×10^{15} neq/cm² is shown.

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Presenter: DIETER, Yannick Manuel (University of Bonn (DE))

Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **30** Type: **Oral**

Silicon Strip Detectors in Physics: From Nuclear Physics to Space Applications

Thursday, 2 March 2023 14:20 (20 minutes)

Semiconductor detectors are a popular choice in many areas of physics because of their flexibility. One possible technology of semiconductor detectors is silicon strip detectors (SSDs): by means of segmenting readout electrodes in the form of thin, long strips, it is possible to measure several properties of charged particles, keeping under control the number of channels.

The ability to finely tune the parameters of the silicon construction, such as its area, thickness, and number/width of strips, in combination with the use of low noise, high dynamic range readout electronics, allows for easy adaptability to different situations. The resulting detectors can achieve very high spatial resolutions, ranging from tens of micrometers down to less than 5 micrometers, with good charge resolution.

In this work, we provide an overview of the results that can be achieved with strip segmented detectors in a wide range of applications. These include tracking low energy charged particles for nuclear fragmentation momentum reconstruction and tracking and particle identification for space applications. Both applications have in common the need to measure the Z charge of the impinging particle with great accuracy, with the addition of a strictly limited power consumption, especially for space applications. Results are based on test performed with different particles (p, ions) and different energies in the range from few tens of MeV up to hundreds GeV.

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Presenter: SILVESTRE, Gianluigi (Universita e INFN, Perugia (IT))

Session Classification: Applications

Track Classification: Applications

Contribution ID: **31** Type: **Oral**

Study of gamma irradiated p-type silicon diodes with different resistivities

Tuesday, 28 February 2023 14:45 (20 minutes)

This study focuses on radiation damage caused by gamma irradiation in standard float zone p-type silicon diodes. We were able to study bulk damage in detail thanks to the separation of bulk and surface currents. The study includes three types of diodes with different resistivities by CNM, HPK and IFX manufacturers. The diodes were irradiated by Cobalt-60 gamma source up to 8.28 MGy in approximate charged particle equilibrium and then annealed for 80 minutes at 60 ℃. Electrical properties of diodes were characterized by measuring IV and CV curves of each diode before and after irradiation and annealing. Surface and bulk currents were separated by contacting the guard ring of each diode during all measurements. The measurements of n-in-p type diodes show increasing linear dependence of leakage current and decreasing dependence of full depletion voltage and effective doping concentration on TID that starts to increase again at irradiation dose specific for each type of diode.

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Session Classification: Planar sensors

Track Classification: Planar sensors

Contribution ID: **32** Type: **Oral**

Radiation Tolerance Study of neutron-irradiated SiC pn planar diodes

Thursday, 2 March 2023 16:10 (20 minutes)

We report on the study of the radiation tolerance of silicon carbide (SiC) pn planar diodes manufactured at IMB-CNM. Dedicated TPA-TCT and TRIBIC measurement campaigns, carried out at the UPV-EHU and CNA femto laser and ion microbeam facilities respectively, were used to characterise the response of the diodes. The studied devices were irradiated with neutrons up to a fluence of $1 \times 10^{15} n_{eq}/cm^2$. The charge collection efficiency and the depletion region were studied as a function of fluence. We observed evidence for a possible radiation-induced polarisation of the SiC substrate, with a strong recovery of charge collection efficiency and depletion width when the irradiated diodes are forward biased.

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Session Classification: TECHNOLOGIES

Track Classification: Technology

Contribution ID: **33** Type: **Oral**

Pixel detector hybridisation with anisotropic conductive adhesives

Thursday, 2 March 2023 16:30 (20 minutes)

Hybrid pixel detectors require a reliable and cost-effective interconnect technology adapted to the pitch and die sizes of the respective applications. During the ASIC and sensor R&D phase, and for some small-scale applications, such interconnect technologies need to be available for the assembly of single-dies. Within the CERN EP R&D program and the AIDAinnova collaboration, innovative pixel detector hybridisation technologies are studied, targeting vertex-detector applications at future colliders. In this framework, an in-house single-die flip-chip bonding process based on Anisotropic Conductive Adhesives (ACA) is in development. The ACA interconnect technology replaces the solder bumps with conductive particles embedded in an adhesive film or paste. The electro-mechanical connection between the sensor and the ASIC is achieved via thermo-compression of the ACA using a flip-chip device bonder. The required pixel-pad topology is achieved on single-dies with an in-house maskless Electroless Nickel Immersion Gold (ENIG) plating process that is also under development within the project. This contribution presents recent development and results of the ENIG and the flip-chip bonding process, qualified by Timepix3 ASICs and sensors with 55 µm pixel pitch and 12-14 µm pad diameter.

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Session Classification: TECHNOLOGIES

Track Classification: Technology

Contribution ID: **34** Type: **Oral**

New performance for MAPS readout using an asynchronous architecture based on priority arbiters

Thursday, 2 March 2023 09:00 (20 minutes)

Monolithic CMOS pixel sensors (or MAPS) offer a particularly advantageous balance between pixel granularity, hit rate and power dissipation, making them attractive devices for vertexing and tracking. Existing reticule-size sensors [1, 2, 3] display power ranging roughly from 35 to 100 mW/cm2 for corresponding hit rates in the range 10 to 100 MHz/cm2 and timestamping capabilities from 5 µs down to 25 ns. The readout performance of pixel matrices results obviously from a compromise between the bandwidth and power consumption. Future projects including MAPS require to reach new optimization approaching or exceeding maximal current bandwidth (100 MHz/cm2), nanosecond timestamping and power compatible with very light colling system (few tens of mw/cm2 at most).
To achieve this goal, new back-end architectures are proposed mainly based on clock-gating or asynchronous design [2]. This work presents an implementation for MAPS readout of the architecture proposed in [4]. This circuit is based on Fixed Priority Arbiters (FPA) and acts as an asynchronous multiplexer. The initial circuit designed for visible light detection is adapted to charged particle sensors, having in mind the requirements set above as well as compactness for minimal pixel pitch (around 20 µm).
The architecture performance depends strongly on the size of the basic elements that composed the reading tree of the matrix. While a two-to-one basic element is proposed in [4] for the arbiter size, we explore all sizes from two to one until ten-to-one. Merging basic elements leads to sharing memories at each level of the tree and first reduce the layout area. In addition, power consumption is also mitigated since fewer gates are used. However, the bandwidth is reduced since there are fewer temporary memory across the whole tree.
A representative double-column read-out circuit is developed for a matrix featuring 512 pixels per column, with variants corresponding to the different arbiter sizes. All results are extracted from a layout in a 65nm node, based on the method presented in [5] and compared to an existing synchronous priority encoder implemented in the MOSS circuit [3]. We conclude on the best suited approach depending on the MAPS requirements in terms of hit rate bandwidth, power dissipation and timestamping.

[1] G. Aglieri Rinella, 'The ALPIDE pixel sensor chip for the upgrade of the ALICE Inner Tracking System', Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 845, pp. 583–587, Feb. 2017, doi: 10.1016/j.nima.2016.05.016.

[2] R. Cardella et al., 'MALTA: an asynchronous readout CMOS monolithic pixel detector for the ATLAS High-Luminosity upgrade', J. Inst., vol. 14, no. 06, pp. C06019–C06019, Jun. 2019, doi: 10.1088/1748-0221/14/06/C06019.

[3] P. Vicente Leitao et al., « Development of a Stitched Monolithic Pixel Sensor prototype (MOSS chip) towards the ITS3 upgrade of the ALICE Inner Tracking system », J. Inst., vol. 18, no 01, p. C01044, janv. 2023, doi: 10.1088/1748-0221/18/01/C01044.
[4] E. Aguénounon et al., « Design and Characterization of an Asynchronous Fixed Priority Tree Arbiter for SPAD Array Readout », Sensors, vol. 21, juin 2021, doi: 10.3390/s21123949.

[5] G. Gimenez, A. Cherkaoui, G. Cogniard, et L. Fesquet, « Static Timing Analysis of Asynchronous Bundled-Data Circuits », in 2018 24th IEEE International Symposium on Asynchronous Circuits and Systems (ASYNC), mai 2018, p. 110 118. doi: 10.1109/ASYNC.2018.00036.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **35** Type: **Oral**

A low-power, 64-channel ASIC for space applications for Cherenkov radiation detection

Thursday, 2 March 2023 09:20 (20 minutes)

This work describes the development of a 64-channel ASIC implemented in a commercial 65 nm CMOS technology. The electronics is designed to readout a camera plane composed by a matrix of Silicon Photo-Multipliers (SiPMs) where a current signal is induced by Extensive Airshowers (EASs). Latters are generated by Ultra-High Energy Cosmic Rays (UHECRs) and Cosmic Neutrinos (CNs) through Cherenkov radiation processes. A single channel records the full waveform of the associated event by storing the information in 256 cells arranged in a daisy chain architecture. Each cell is equipped with an analog memory, a Wilkinson Analog-to-Digital Converter (ADC) with 12-bits resolution and latches to locally save the data. The circuitry runs at a sampling rate of 200 MS/s and provides a hitmap of the 64 channels that can be elaborated by an FPGA. If the mapping is validated, the data are converted and sent off-chip with a dedicated serializer working at 400 MHz in Double Data Rate (DDR). The ASIC is characterized by a high configurability which makes the chip suitable for several investigations besides the space one. Indeed the user can select the partition of the channels to operate with slices of 32, 64 or 256 cells. The resolution is programmable as well in the range of 8-12 bits to guarantee an appropriate granularity for many applications and both to save conversion time and power.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **36** Type: **Oral**

Performance studies of Low Gain Avalanche Detectors for the ATLAS High Granularity Timing Detector

Tuesday, 28 February 2023 16:35 (20 minutes)

The High Granularity Timing Detector (HGTD) is designed for the mitigation of pile-up effects in the ATLAS forward region and for bunch per bunch luminosity measurements. HGTD, based on Low Gain Avalanche Detector (LGAD) technology and covering the pseudorapidity region between 2.4 and 4.0, will provide high precision timing information to distinguish between collisions occurring close in space but well-separated in time. Apart from being radiation resistant, LGAD sensors should deliver 30 ps time resolution per track for a minimum-ionising particle at the start of lifetime, increasing to 75 ps at the end of HL-LHC operation. In this talk, we will present the performances of several unirradiated, as well as neutron irradiated, LGAD sensors from different vendors studied using charged-particle beams in 2022 at CERN SPS and DESY. This study covers the promising results in terms of collected charge, time resolution and hit efficiency of LGADs. A time resolution of < 75 ps is observed in most cases for highly irradiated sensors (2.5e15 neq/cmˆ2), while integrating timing information to the EUDET system allows for a surface resolution of less than 50 µm. The triggering architecture, picosecond synchronisation scheme and analysis logic will also be presented as well as application-specific electronics and components.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **37** Type: **Oral**

LGADs for Astroparticle Physics Experiments in Space

Wednesday, 1 March 2023 16:20 (20 minutes)

The astroparticle physics experiments operating in space for the measurement of charged cosmic rays include a tracker and a calorimeter to identify the incoming primary charged cosmic rays. These experiments face challenges in separating primary particles from the back-scattered particles entering the tracker from the calorimeter. The timing measurement of each hit can be used to distinguish between the primary and secondary particles. In recent years, Low Gain Avalanche Detectors (LGADs) have emerged as a technological solution for precise timing measurements in the tens of ps range for High Energy Physics and other applications. The typical channel size of a silicon sensor for strip geometry in space application is 50-60 cm in length with 100 μm pitch, resulting in a channel area of about 1 cm^2 whereas, the typical LGAD channel size is O $(1\ mm^2)$. This work evaluates the use of LGADs for timing in space and discusses the challenges in making large-area LGAD sensors. The TCAD simulations to achieve a gain of about 100 are presented, which is thought to improve the time resolution for larger channel sensors. Preliminary measurements of the pad sensors with dimensions $1\ cm \times 1\ cm$ (with and without gain) are presented.

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Session Classification: Simulations

Track Classification: Simulations

Contribution ID: **38** Type: **Oral**

SpacePix3: SOI MAPS Detector for Space Radiation Monitoring

Thursday, 2 March 2023 11:10 (20 minutes)

Radiation in space is a potential risk to human health and electronic systems. SpacePix3 is a high voltage monolithic active pixel sensor (HV-MAPS) ASIC capable of measuring flux and deposited energy in pixels, distinguishing between types of radiation, protons, electrons, and ions. SpacePix3, improved version of the SpacePix2, features 64 × 64 pixel matrix with a pixel pitch of 60 μm and a total sensitive area of 3.84 × 3.84 mm^2. New measured data of implemented SpacePix3 prototype are provided. Analog signals from pixels are digitized by 32 10-bit column ADCs with successive approximation register (SAR). The total power consumption is 43 mA from a 1.8 V power supply. Sensor diodes are biased at -150 V. Special SpacePix3 features are backside channel signal processing, SPI/LVDS readout modes, hit trigger output, debugging features, thermometer, radiation-hardened design, multichip operation, and analog pixel output. The chip is manufactured in a 180 nm SoI technology.

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Presenter: VANCURA, Pavel

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **39** Type: **Oral**

Performance of the RD50-MPW3 HV-CMOS Detector

Wednesday, 1 March 2023 14:50 (20 minutes)

The goal for tracking detectors is the combination of excellent spatial resolution, low material budget, high radiation tolerance and excellent timing resolution for the best achievable tracking performance.
Many different approaches are taken to reach this goal, with CMOS based silicon detectors providing one of the most promising angles of approach.

The CERN RD50 collaboration works on the development of radiation hard silicon detectors, with the CMOS working group focusing on monolithic detectors based on a $150\,\mathrm{nm}$ High Voltage CMOS process by LFoundry and investigates their viability for future particle physics experiments.

As part of the ongoing developments, the newest prototype, the RD50-MPW3, was delivered in July 2022 and has since been tested both in laboratories and at the CERN SPS test beam. The RD50-MPW3 consists of a 64×64 pixel matrix arranged in a 32 double-columns. The $62\,\mu\mathrm{m}$ pixels include both an analog front-end as well as a digital readout. Its predecessor, the RD50-MPW2, consisted of 8×8 pixels of $60\,\mu\mathrm{m}$ pixel pitch that only included the analog front-end.

In this talk I will present recent results on the performance of the newest RD50 HV-CMOS prototype such as the achieved time resolution, as measured in the laboratory, as well as first results about the achieved performance of the MPW3 gathered during the CERN test beam campaign conducted in October 2022.

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Presenter: KRAEMER, Uwe (Nikhef)

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **40** Type: **Oral**

Carbon ions tracking in particle therapy: first tests with thin silicon sensors

Thursday, 2 March 2023 14:40 (20 minutes)

Introduction:
The single particle tracking is a demanding task in clinical particle beams due to the high instantaneous fluence rate, up to 10^{10} protons/cm^2·s and 10^8 carbon ions/cm^2·s. The aim of a fast and accurate (< 1% uncertainty) single particle counter is to overcome the slow charge collection times (hundreds of microseconds) and low sensitivity (thousands of particles) of the gas detectors currently employed in clinics, which limit the development of new faster and more accurate dose delivery strategies.
Over the last years, the INFN MoVeIT Project demonstrated the potential of using thin Low Gain Avalanche Diodes (LGADs) for counting protons and for developing time-of-flight applications to measure the particle's beam energy. The design of sensors optimized for carbon ions are among the tasks of the new INFN-SIG project. To this goal, a subset of LGAD sensors segmented in strips and developed for protons were manufactured without implantation of the gain layer. The results of the first tests using a clinical carbon ion beam at CNAO (Pavia) will be reported.
Materials and methods:
The 8 central strips (4000 μm length and 591 μm pitch) of a PIN sensor of 60 μm active thickness were connected to a 8 channels custom frontend board providing a gain of about 2mV/fC. The output signals were sampled with a CAEN digitizer model DT5742, providing 5 GS/s with 12 bit resolution (1 ADC = 0.24 mV) in windows of 1024 samples.
The measurements were performed with 4 beam energies covering the clinical energy range (115, 166, 269 and 399 MeV/u), each run being characterized by consecutive spills with 8×10^7 ions delivered per spill at clinical beam intensities. Several runs were acquired at each beam energy varying the sensor bias voltages from 4 to 299 V and using two different beam incidence angles (0° and 40°). In each run, the peaks were selected in the waveforms and analyzed in terms of crossing time, amplitude and signal duration. Amplitude distributions were fitted using a convolution of a Landau with a Gaussian, the most probable value (MPV) being related to the average energy loss by the ions in silicon. Few runs with two detectors in coincidence were also preformed to measure the time resolution.
Results:
The peak amplitude distributions show a very good separation between signal and noise, with an MPV reaching the maximum at a sensor bias above 100 V and scaling with the beam energy, as expected by the Bethe-Bloch formula, and with the increase of the crossed thickness when the incidence angle is varied. Similarly, the signal duration decreases with the increase of the bias voltage up to 100 V, where it reaches a value of less than 2 ns. A single hit time resolution of about 25 ps is achieved at the two extreme energy values of 115 and 399 MeV/u. Studies of charge sharing and signal induction between adjacent strips indicate an overall negligible effect.
Conclusions:
Initial tests of thin silicon sensors segmented in strips irradiated with therapeutic carbon ion beams show very promising results, preparing the groundwork for future devices and applications for particle therapy based on the single ion tracking capability.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **41** Type: **Oral**

A low cost, high dynamic range readout system for SiC strip detectors

Thursday, 2 March 2023 09:40 (20 minutes)

The semiconductor industry is currently adopting SiC as a replacement for silicon in power devices. Compared to Si, SiC offers several advantages which make it an attractive detector material. Among them is the higher displacement energy as compared to silicon, which makes SiC potentially more radiation hard. The very low leakage currents do not increase even for highly irradiated samples. Both properties promise to make the material particularly suitable for use in high-radiation environments.

Apart from studying SiC as replacement for Si-based HEP detectors, we are also developing a beam monitoring system using SiC strip sensors. This beam monitor is intended to work at a ion cancer therapy center, where particle rates from the kHz to the GHz regime occur. While in the kHz regime, single particles are counted, in the GHz regime, counting is unfeasible, and the integrated detector current is measured.
The system is based on components off the shelve (COTS), omitting the long and expensive development of a front-end ASIC. Instead, we employed a commercial X-Ray TFT front-end chip for sensor readout, connected to an ADC and a subsequent FPGA for data processing.
The output data is transmitted via a TCP stream, which can also be used to control and configure the FE system.

Beam tests show that using a 50 µm thick SiC pad detector, our system can count single particles in a 62.4 MeV proton beam (particle energy equivalent to 5.03 minimum ionizing particles, MIP). Using a Si Strip detector, the setup was employed to reveal the time structure of the particle beam of the MedAustron facility. The system enables a sampling rate of 37 kHz and works at beam fluences up to 10^9 particles per second, with intensity peaks being an order of magnitude larger.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **42** Type: **Oral**

Winner-Leader-Follower - a novel charge summing and hit allocation algorithm

Thursday, 2 March 2023 10:00 (20 minutes)

X-ray color imaging is a promising method that provides extra information due to photon energy binning. Due to the high demand for high spatial resolution, the detectors tend to decrease the pixel pitch size. The decreasing pixel pitch size directly affects the spectral resolution due to the charge-sharing effect and fluorescent photons that travel elsewhere in the sensor material. Therefore, on-chip charge sharing and hit allocation algorithms are being developed to compensate for these effects. This work introduces a novel charge-sharing and hit allocation algorithm together with testing ASIC ColorPix-2, which was designed to test the algorithm.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **43** Type: **Oral**

Performance study of very thin Low Gain Avalanche Detectors (LGADs) and investigation of the new "double LGAD"concept

Wednesday, 1 March 2023 10:20 (20 minutes)

The present study focuses on the performance evaluation of the first very thin Low Gain Avalanche Detectors (LGADs) prototypes produced by the Fondazione Bruno Kessler (FBK), with a thickness of 25 and 35 μm, and the introduction of a new concept that consists of two similar LGADs connected to the same board.

Despite its already impressive timing performance, for which this technology is planned to be used in many detector upgrades, the ongoing R&D efforts aim to further improve time resolution to meet the challenging demands of future experiments. The results of the present study demonstrate the potential for improved time resolution with a thinner LGAD design. Several results on this new generation of LGADs with a thickness of 25 and 35 μm will be shown in the presentation, including many extracted characteristics, such as drift electric field, noise and charge distribution together with a comprehensive analysis of the timing performance.

In addition, the novel concept of "double LGAD", in which two similar sensors are connected to the same board, was tested for the first time in a beam test setup, considering couples of LGADs with a thickness of 25, 35 and 50 μm. Being them connected to the same amplifier, a higher signal is generated, allowing for less power-consuming electronics. A little benefit in the time resolution is also expected from the simulations. Many results for this innovative concept will be presented, followed by a comparison with single sensors.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **44** Type: **Oral**

Time resolution of single pixel irradiated 3D devices up to $1 \times 10^{17}\ n_{eq}/cm^2$ at 120 GeV SPS pion beams

Wednesday, 1 March 2023 11:50 (20 minutes)

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

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Session Classification: 3D Sensors

Track Classification: 3D Sensors

Contribution ID: **45** Type: **Oral**

New Results from Timepix4 at the SPS

Tuesday, 28 February 2023 11:15 (20 minutes)

A double arm beam telescope was built with Timepix4v2 ASICs to test the performance of the new ASIC's synchronous readout and track reconstruction capabilities, as well as its temporal performance. The new telescope is composed of eight planes with n-on-p silicon sensors. Four of these planes are instrumented with 300 µm thick sensors tilted with respect to the beam, to provide high quality spatial measurements, while the remaining four have 100 µm thick sensors to achieve a better timing response. In between the two arms a DUT can be placed. Each detector assembly (sensor plus Timepix4 ASIC) is readout with a SPIDR4 system developed by Nikhef and ASI. They are cooled by a 3D printed titanium blocks directly attached to the test PCB, through which a cooling fluid is circulated. The cooling block has a circular cut-out to minimise the amount of material traversed by incident particles. A PicoTDC in combination with a MCP is employed in order to provide a precise time reference for low rate applications, while three scintillators are employed to provide an initial time reference for high rate applications and to probe the temporal performance of the individual telescope planes. In this presentation, the initial results of the timing and spatial resolution of this telescope will be shown and the dependency on the operating conditions of the telescope such as the threshold level and bias voltage are discussed. Furthermore, the steps towards the next iteration of the telescope planned for this year will be shown.

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Session Classification: Systems issues

Track Classification: System Issues

Contribution ID: **46** Type: **Oral**

Test results of the Timespot1 ASIC on 3D-trench sensors

Tuesday, 28 February 2023 09:45 (20 minutes)

We present test results of the hybridized Timespot1 ASIC, developed for 4D-tracking in high luminosity LHC experiments. The ASIC reads a 32x32 pixel matrix bump-bonded on a 3D-type trenched electrode silicon sensor, which already demonstrated intrinsic timing performance and high radiation hardness at test beams, achieving temporal resolutions close to 10 ps. The ASIC is developed in CMOS 28-nm technology and features a fast front-end and high resolution TDC for each of its 1024 channels.
We present the ongoing test activity performed in the laboratory, using both a beta radioactive source and an infrared laser source. Tests are performed with multiple Timespot1 boards connected to a control and data acquisition system based on a commercial Xilinx KC705 FPGA board, and are aimed at a full characterization of the hybrids and at the preparation of test beams planned for the coming months, which will feature a small multi-station 4D-tracking demonstrator.

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Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **47** Type: **Oral**

Investigation on observed charge multiplication in no-gain multiped LGAD region within plasma formation and under low and high intensity injection using femtosecond laser at ELI

Tuesday, 28 February 2023 17:35 (20 minutes)

We report an experimental investigation on charge multiplication in a no-gain (inter-pad) region in a multi-pad Ultra Fast Silicon Detector (UFSD). The UFSD sample we measured is not a standard segmented UFSD that is now accepted as CMS LGAD. It is a sample that has been produced in the Ti-LGAD RD50 production batch. Furthermore, this UFSD is not a trench LGAD (Ti-LGAD). This tested UFSD has 49 microns of inter-pad distance, and as isolation structures, it uses a guard (bias) ring with 2 p-stops. The JTE is employed as a termination structure. The non-irradiated, investigated sample has been subjected to a femtosecond laser at the ELI ERIC, Eli Beamlines, in Prague. Charge multiplication is observed as strong enhancements in the charge collection distribution. Very strong dependence on bias and charge intensity injection (deposited energy) has been observed. It was found that the observed enhancements in charge collection in the inter-pad region where no gain layer is present, significantly increases with increased bias and with increased laser power. Those enhancements, are understood as a charge multiplication in inter-pad region and explained as the results of the impact of a strong electric field near the p-stops, that is further enhanced by the design of an isolation structure and consequently, by the processing parameters chosen in IP design: the distance between JTE and p-stop, and the distance between two p-stops where a grid (bias) ring is inserted.

Intensity of laser pulses and the rate of charge injection allow the plasma formation in inter-pad region, therefore, the observed charge multiplication must follow the additional underlining mechanism that differs from the one that usually leads to the reduced impact ionization (due to charge density induced electric field screening). Contrary to expectations, for the case we observed, the impact ionization is enhanced with increased plasma density.

An extensive and systematic study that will cover different UFSD prototypes is currently a work in progress, and through covering a large pool of measured samples, we will be able to give a more conclusive answer.

Beside the observed charge multiplication under plasma regime in no-gain region in non-irradiated LGAD (without defects inside that would facilitate the impact ionization), we also emphasize here the accuracy of our methodology and precision on measured inter-pad distance that is achieved with TCT set up developed at the ELI Beamlines, Extreme Light Infrastructure ERIC.

In general, this work contributes to R&D on segmented n-on-p sensors and the acquired knowledge is also transferable to future development of any picosecond avalanche detectors required for FCC.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **48** Type: **Oral**

Tests on radiation hardness of 3D-trench silicon sensors

Wednesday, 1 March 2023 12:10 (20 minutes)

We present performance tests on irradiated 3D-trench silicon sensors, developed within the TimeSPOT project. The tests were performed in different experimental conditions and at different fluences, both in the laboratory and in test-beam at SPS, CERN. The tests show excellent time resolution (around 10 ps) and nominal geometric efficiency (around 99%) of such sensors up to the maximum tested fluence of 2.5 10ˆ16 1-MeV-neutron equivalent per cmˆ2 and demonstrate that their limit in radiation resistance is still to be reached.

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Presenter: GARAU, Michela (Universita e INFN, Cagliari (IT))

Session Classification: 3D Sensors

Track Classification: 3D Sensors

Contribution ID: **49** Type: **Oral**

First radiation damage studies on the LHCb VELO upgrade.

Tuesday, 28 February 2023 11:35 (20 minutes)

The LHCb experiment has recently been upgraded in the second long shutdown of LHC. The new Vertex Locator (VELO) is composed of 52 modules with hybrid pixel detector technology. The new detectors have performed very well throughout the first year of Run 3 of the LHC, but face new operational challenges with increased radiation damage foreseen till the end of this run. The cumulative radiation damage poses challenges in reaching full depletion in the most irradiated zones of the detectors, which have highly non-uniform exposure, reaching fluences of $0.02 - 8 \times 10^{15}$ 1 MeV-n_{eq} cm^{-2} in the same sensor. The overall damage is monitored through regular measurements of the leakage current and charge collection efficiency (CCE) as function of the bias voltage. The results in evaluating the radiation damage and detector performance throughout the first year of operation in LHC run 3 will be presented.

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Presenter: ZUNICA, Gianluca (University of Manchester (GB))

Session Classification: Systems issues

Track Classification: System Issues

Contribution ID: **50** Type: **Oral**

Advances in LGAD Technology for High Radiation Environments

Tuesday, 28 February 2023 16:15 (20 minutes)

LGAD sensors have proven to be an excellent solution for 4D-tracking in HEP experiments thanks to the presence of internal gain that provides good time resolution also at high fluences (up to $\sim 2 \cdot 10^{15}$ neq/cm^2). However, approaching 10^{16} neq/cm^2, the internal gain is completely lost due to the acceptor removal effect, leading to a deterioration of the time performances.
In the framework of the exFlu project, different solutions to preserve internal gain above 10^{16} neq/cm^2, and possibly up to 10^{17} neq/cm^2, have been studied: i) usage of thin substrates (in the range $15-45$ μm); ii) defect engineering of the LGAD gain implant, such as a carbon shield to protect the gain layer, and iii) a p/n co-implantation to obtain a compensated gain layer profile. In the latter case, the concurrent acceptor/donor removal effects, acting on Boron/Phosphorous dopant, respectively, could be advantageous in reducing the loss of gain. The final goal is to pave the way for a new sensor design that can efficiently perform precise tracking and timing measurements up to 10^{17} neq/cm^2. All these technological solutions have been implemented in the most recent R&D batch produced at FBK. Preliminary results on the sensors'characterization will be presented and discussed.

Primary authors: PATERNOSTER, Giovanni (Fondazione Bruno KEssler); SOLA, Valentina (Universita e INFN Torino (IT))

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **51** Type: **Oral**

The observed effect of thermal expansion of plasma on dynamics of charge collection in LGAD

Tuesday, 28 February 2023 17:15 (20 minutes)

The Low Gain Avalanche Detector (LGAD) is developed with the aim to serve as a timing detector for two leading HEP experiments in CERN, CMS and ATLAS. This means that it is adjusted for work with Minimum Ionizing Particles (MIP). However, its excellent timing resolution and good spatial resolution, have made LGAD an attractive solution in experiments where much higher charge is generated than those generated by MIP as well. When Highly ionized Particles (HIP) cross the sensor, the plasma formation can not be avoided. Moreover, if HIP particles cross the LGAD at an angle that differs from the perpendicular one, it also means that charge is at the initial step, mainly induced in no-gain region. In the past a lot of attention has been given to the investigation of the pad region when HIP particles cross this region, while the no-gain region has been less investigated. All factors considered above indicate that it is also important to investigate the no-gain region under high intensity injections.

In this contribution, we report the results from an investigation on dynamics of charge transport when the charge density is such that conditions for plasma formation are met and plasma is created in bulk.

Two effects of plasma creation in LGAD on dynamics of charge transport and charge collection have been investigated: 1) the level of doping and 2) the density of plasma in both, the low and the highly doped bulk region. For this purpose the two selected regions of standard segmented LGAD are investigated: the inter-pad region with no gain layer beneath the n++ electrode, and the pad region with gain layer beneath the n++ electrode.

By increasing the laser power we varied the plasma density.

Contrary to the expectations, it was observed that the transient signal in LGAD becomes faster and shorter if plasma is denser. Moreover, the ratio between the amplitudes of signals from the pad and the inter-pad region has been increasing with the decreased plasma density.

The observed behavior can only be explained by additional underlying mechanism which is more dominant then it is plasma induced screening of local electric field; the charge screening of local field would slow down the charge velocity, and thus the probability for impact ionization would be reduced. Instead of observing the slower signal with the increased plasma density as it would be if only charge screening of local el field dominates the dynamics of charge collection, we observed the opposite effect: the faster signal. The wavelength of fs-laser is 800 nm, this corresponds to 20 microns of absorption depth in silicon that is far away from the bottom electrodes in LGAD. Also, only Single Photon Absorption of TCT technique was used. Therefore, the reflection of the laser beam from the bottom electrode can not be the reason.

We think that the thermal effect is responsible for faster plasma expansion in denser plasma, broadening the plasma charge cloud; as result the induced signal becomes faster in denser plasma. The repulsion effect of the same sign charge clouds may also contribute.

However, more data and larger pool of LGAD prototypes are needed for more conclusive statement. This will be researched during next LGAD campaign at ELI ERIC.

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Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **52** Type: **Oral**

MoTiC (Monolithic Timing Chip)

Thursday, 2 March 2023 11:50 (20 minutes)

MoTiC (Monolithic Timing Chip) is a prototype DMAPS Chip that builds on sensor technology developed in the ARCADIA project.
The 50 by 50μm^2 pixels contain a small charge collecting electrode with a very low capacitance surrounded by radiation-hard in-pixel electronics.
The chip contains a matrix of 5120 pixels on an area of 3.2 by 4 mm^2.
Each pixel features a trimmable and maskable comparator with a sample and hold circuit for the analog pulse height.
Groups of 4 pixels share a TDC situated also in the readout matrix.
This work presents the chip design and preliminary results measured in a first test beam campaign with 4-5 GeV/c electrons conducted at DESY.

Primary author: BURKHALTER, Stephan (ETH Zurich (CH))

Presenter: BURKHALTER, Stephan (ETH Zurich (CH))

Session Classification: CMOS

Track Classification: CMOS

Contribution ID: **53** Type: **Oral**

TCAD analysis of leakage current and breakdown voltage in small pitch 3D pixel sensors

Wednesday, 1 March 2023 17:00 (20 minutes)

Small-pitch 3D pixel sensors have been developed to equip the innermost layers of the ATLAS and CMS tracker upgrades at HL-LHC. They feature 50×50 and 25×100 μm^2 geometries, and are fabricated on p-type Si-Si Direct Wafer Bonded substrates of 150 μm active thickness with a single-sided process. Due to the short inter-electrode distance, charge trapping effects are strongly mitigated, making these sensors extremely radiation hard. Results from beam test measurements of 3D pixel modules irradiated at the large fluences of interest to HL-LHC ($\sim 10^{16} n_{eq} cm^{-2}$) indeed demonstrated high efficiency at maximum bias voltages of the order of 150 V. However, the downscaled sensor structure also lends itself to high electric fields as the bias voltage is increased, so that premature electrical breakdown due to impact ionization is a concern.
In this study, TCAD simulations incorporating advanced surface and bulk damage models are used to investigate the leakage current and breakdown behavior of these sensors. Simulations are compared with measured characteristics yielding a satisfactory agreement. The dependence of the breakdown voltage on geometrical parameters (e.g., the n$^+$ column radius and the gap between the $^+$ column tip and the highly doped p^{++} handle wafer) is also discussed.

Primary author: Mr YE, Jixing (University of Trento)

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Presenter: Mr YE, Jixing (University of Trento)

Session Classification: Simulations

Track Classification: Simulations

Contribution ID: **55** Type: **Oral**

Multichannel board for picosecond timing measurements of silicon sensors

Tuesday, 28 February 2023 10:25 (20 minutes)

A dedicated 16-channel board was designed for matrix test and inter-pixel proprieties. Each channel is composed of a dual stage amplifier design with an uniform response up to a frequency range of 8 GHz. A single SiGe transistor configuration is used for both stages, with the first acting as a transimpedance amplifier and the second as a voltage amplification stage. The design features a passive daughter board for versatile sensor replacement, triaxial HV input and coaxial outputs, implemented on a hermetically EM shielded HF-Rogers dielectric. Preliminary tests indicate a total gain of 70 with both stages combined and an SNR higher that 100 for a typical 50 μm planar pixel sensor signal. The inter-channel cross-talk with a 4x4 50 μm thick pixelated matrix has been evaluated. More test are on the way to evaluate 3D sensors.

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Presenter: LEMOS CID, Edgar (Universidade de Santiago de Compostela (ES))

Session Classification: Electronics

Track Classification: Electronics

Contribution ID: **56** Type: **Oral**

First survey of centimeter-scale AC-LGAD strip sensors with a 120 GeV proton beam

Wednesday, 1 March 2023 10:00 (20 minutes)

We will present the first beam test results with centimeter-scale AC-LGAD strip sensors, using the Fermilab Test Beam Facility, and a study of the performance of AC-LGAD sensors as a function of their thickness. Sensors of this type are envisioned for applications that require large-area precision 4D tracking coverage with economical channel counts, including timing layers for the Electron Ion Collider (EIC), and space-based particle experiments. Long strip sensors with sparse readout offer better cost and performance for applications where channel count or electrical power density is a constraint. Thanks to the excellent signal to noise ratio in AC-LGADs, sparse readout can be exploited without significant degradation of spatial or time resolution, which is demonstrated in our studies. A survey of sensor designs is presented, with the aim of optimizing the electrode geometry for spatial resolution and timing performance. We will present our studies of the sensor geometry optimization to maintain the desirable sensor performance characteristics with increasingly larger electrodes.

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Presenter: MADRID, Christopher (Fermi National Accelerator Lab. (US))

Session Classification: LGAD

Track Classification: LGAD

Contribution ID: **57** Type: **Oral**

ARCADIA fully-depleted monolithic active pixel sensors optimised for sub-nano second timing

Wednesday, 1 March 2023 17:40 (20 minutes)

Monolithic sensors are regarded nowadays as valid alternatives to hybrid detectors in the design of next generation high-performance silicon vertex, tracking and timing detectors for high-energy physics (HEP) experiments and other fields of research like medical imaging and space applications.
In this context, Fully Depleted Monolithic Active Pixel Sensors (FD-MAPS) are a state-of-the-art detector technology that can provide cost-effective devices for both particle tracking and timing applications. Indeed, they have the advantage of collecting charges by drift, enabling a fast and uniform response over the pixel matrix. In particular, the ARCADIA project is developing FD-MAPS with an innovative sensor design, which exploits backside bias voltage to fully deplete the sensor and to improve the charge collection efficiency and the timing performances.
A detailed simulation study of the timing resolution achievable by monolithic detectors designed in the ARCADIA process has been conducted using simulation domains with characteristics tuned on experimental data. The studies were carried out by combining TCAD and Allpix^2 frameworks, implementing high statistics Monte Carlo simulations with very precise electric field and weighting potential maps as starting points.
In this work, the timing performance of pad diodes with pixel pitches ranging from 50 µm to 200 µm and different thicknesses will be presented and discussed in view of the possible applications. Tools and analysis methods will be explored. Experimental measurements on the test structures are ongoing and results will be available in the next months.

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Presenter: FERRERO, Chiara (Politecnico di Torino e INFN Sez. di Torino (IT))

Session Classification: Simulations

Track Classification: Simulations

Contribution ID: **58** Type: **Oral**

Welcome

Tuesday, 28 February 2023 09:30 (15 minutes)

Presenter: Prof. HALL-WILTON, Richard (FBK)

Contribution ID: **59** Type: **not specified**

Registrations

Tuesday, 28 February 2023 09:00 (30 minutes)

Contribution ID: **60** Type: **not specified**

Conference Photograph

Wednesday, 1 March 2023 12:30 (10 minutes)

Contribution ID: **61** Type: **Oral**

Closing

Thursday, 2 March 2023 17:10 (5 minutes)

Presenter: Prof. DALLA BETTA, Gian Franco (Universita degli Studi di Trento and INFN (IT))

Contribution ID: **62** Type: **not specified**

FBK visit

Thursday, 2 March 2023 17:15 (3 hours)

Primary author: BOSCARDIN, Maurizio (Universita degli Studi di Trento and INFN (IT))

Presenter: BOSCARDIN, Maurizio (Universita degli Studi di Trento and INFN (IT))