TREDI2020: 15th ”Trento” Workshop on Advanced Silicon Radiation Detectors

Report of Contributions

https://indico.cern.ch/e/tredi2020

Contribution ID: **6** Type: **contributed talk**

Prolonged signal pulses from silicon strip sensors showing enhanced charge multiplication

Wednesday, 19 February 2020 16:00 (20 minutes)

P-type silicon strip sensors will be used as particle detectors in harsh radiation environment, as in the High Luminosity Large Hadron Collider with fluences up to $1 \cdot 10^{16}\ n_{\mathrm{eq}}/\mathrm{cm}^2$. They have been irradiated and annealed to predict their long term performance. Charge multiplication, which appears at high voltages after long annealing times, increases the n charge collection, but also leads to prolonged signals. The edge-transient current technique as well as beta-measurements were used to investigate the origin of these slow pulses. Sensors exhibiting those slow pulses showed a substantial low electric field even beyond the high field region close to the strip implants. Electrons created deep in the sensor are spreading while traveling slowly to the depletion region. All electrons reaching the high field close to the strips get multiplied and create a secondary, new broadend cloud of free holes. These holes move towards the backplane, but experience trapping and a self-screening effect and show a plasma-like behavior. Due to the low field region they introduce a slow and low signal.

The obtained results are supported by simulations and agree well with the observation of a ballistic deficit and an enlarged cluster size observed in charge collection measurement. The conclusion drawn by this study can also be extended to all semiconductor detector exploiting a severe charge multiplication while having low field regions.

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Presenter: DIEHL, Leena (Albert Ludwigs Universitaet Freiburg (DE))

Session Classification: Materials, Characterisation, Electronics

Track Classification: Planar sensors

Contribution ID: **7** Type: **contributed talk**

Performance of the HADES T0 and beam tracking system based on Ultra Fast Silicon Detectors

Tuesday, 18 February 2020 15:00 (20 minutes)

The recently developed sensors based on the Low Gain Avalanche Diodes (LGAD) sensors [1,2], aka Ultra Fast Silicon Detectors (UFSD), provide excellent position measurement capabilities and additionally provide fast signal response with a precision better than 100ps [3]. These unique properties combined with high radiation hardness [4] and low production costs are very attractive for tracking applications and place the UFSD technology ahead of diamond based scCVD sensors.
The HADES experiment [5] at GSI Darmstadt, Germany, in cooperation with INFN, Torino, Italy, prepared a demonstration system realized as a beam telescope consisting of two UFSD strip sensors. The sensors, manufactured by FBK [1], have a size of about 5mm x 5mm, 50 μm active thickness and the strip structure with a140 μm pitch. They are equipped with multi-stage analog amplifying circuits [6] connected to discriminators whose outputs were digitized by a TDC system based on the FPGA-TDC concept [7].
In a series of experiments carried out at the COSY Synchrotron at Jülich we have demonstrated a timing precision of 56 ps for protons of 1.92 GeV kinetic energy. To our knowledge, these are the best results obtained so far using this type of sensors integrated in a complete detection system.
In this presentation, the construction of the experimental setup, the data readout system and details of the analysis will be presented with particular emphasis on the final results obtained with the UFSD sensors.
[1] First FBK production of 50 μm ultra-fast silicon detectors - Sola, V. et al. Nucl. Instrum. Meth. A924 (2019)
[2] Design optimization of ultra-fast silicon detectors - Cartiglia, N. et al. Nucl. Instrum. Meth. A796 (2015) 141-148
[3] Beam test results of a 16 ps timing system based on UFSD - Cartiglia, N. et al. Nucl.Instrum.Meth. A850 (2017) 83-88
[4] Radiation Hardness of Thin Low Gain Avalanche Detectors - Kramberger, G. et al. Nucl.Instrum.Meth. A891 (2018) 68-77
[5] The High-Acceptance Dielectron Spectrometer HADES - G. Agakishiev et al. Eur. Phys. J. A41:243-277, 2009
[6] Diamonds as timing detectors ⋯, J. Pietraszko et al. Nucl. Instrum. Meth. A 618 (2010) 121-123
[7] A compact system for high precision time measurements (< 14 ps RMS) ⋯, M Traxler et al 2011 JINST 6 C12004

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Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **8** Type: **contributed talk**

Module development for the ATLAS ITk Pixel Detector

Monday, 17 February 2020 12:55 (20 minutes)

In HL-LHC operation the instantaneous luminosity will reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The current ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of ITk will consist of a state-of-the-art pixel detector.
Several different silicon sensor technologies will be employed in the five barrel and endcap layers. Based on first modules assembled using the RD53A prototype readout chip, numerous issues are being studied. These include production issues like bump bonding of large area, thin modules, as well as layout issues like optimization of the bandwidth and sharing of links between multiple chips and modules. The talk will present results of many of these studies, which directly impact the construction and assembly of modules with using the first production version of the readout chip ITKpixV1, which will become available shortly.

Presenter: LANGE, Joern (Georg August Universitaet Goettingen (DE))

Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **9** Type: **contributed talk**

Development and evaluation of prototypes for the ATLAS ITk pixel detector

Monday, 17 February 2020 12:35 (20 minutes)

The ATLAS tracking system will be replaced by an all-silicon detector for the HL-LHC upgrade around 2025. The innermost five layers of the detector system will be pixel detector layers which will be most challenging in terms of radiation hardness, data rate and readout speed. A serial power scheme will be used for the pixel layers to reduce the radiation length and power consumption in cables. New elements are required to operate and monitor a serially powered detector including a detector control system, constant current sources and front-end electronics with shunt regulators. Prototypes for all subsystems are built to verify the concept and operate multiple serial power chains as a system test. The evaluation of both the readout of multi-modules and mechanical integration are further aims of the prototyping campaign. In the contribution, results will be presented of this prototyping effort. Moreover, details and features of serial powering for full detector systems will be given.

Presenter: BUAT, Quentin (CERN)

Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **10** Type: **contributed talk**

Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

Monday, 17 February 2020 11:55 (20 minutes)

The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector, that has undergone significant hardware and readout upgrades to meet the challenges imposed by the higher collision energy, pileup and luminosity that are being delivered by the Large Hadron Collider (LHC), with record breaking instantaneous luminosities of 2 x 1034 cm-2 s-1 recently surpassed.
The key status and performance metrics of the ATLAS Pixel Detector are summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience.
By the end of the proton-proton collision runs in 2018, the innermost layer IBL, consisting of planar and 3D pixel sensors, had received an integrated fluence of approximately Φ = 9 × 1014 1 MeV neq/cm2.
The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector. A quantitative analysis of charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects with IBL and effects of annealing will be presented and discussed, as well as the operational issues and mitigation techniques adopted during the LHC Run2 and the ones foreseen for Run3.

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Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **11** Type: **contributed talk**

Radiation Hard Monolithic Pixel Sensors based on Small Collection Electrode: MALTA and miniMALTA.

Tuesday, 18 February 2020 09:40 (20 minutes)

The MALTA (Monolithic pixel sensor from ALICE To ATLAS) is a monolithic silicon pixel sensor that has been designed in the 180 nm CMOS imaging process of TowerJazz. It was designed to be compatible with conditions like in the outermost pixel layer of the ATLAS ITk High Luminosity upgrade, with a required radiation hardness up to a fluence of $1 \times 10^{15}\, n_{eq}/cm^2$ and a TID of $80\, Mrad$. The MALTA sensor is a $2\ \times\ 2\, cm^2$ large prototype, including a matrix of 512×512 squared pixel with a pitch of $36.4\, \mu m$. The pixel features a small collection electrode pixel, achieving a low input capacitance of about 2˜fF, and the matrix is red out using a novel asynchronous architecture. The low input capacitance, the front-end design and the implemented readout architecture yield a very low power consumption, $75\, mW/cm^2$ and $2.5\, mW/cm^2$ for analog and digital power, respectively, at the target data rate ($\sim 80\, MHz/cm^2$).
The promising results of the first chips (early 2018), before and after irradiation, triggered the development of two technology modifications to enhance the sensor radiation hardness. These fixes have been implemented first on a small scale prototypes, the MiniMALTA which was delivered in fall 2018, and then in a re-iteration of the MALTA chip, available in mid 2019. Both sensors have been tested in the laboratory and in a particle testbeam, demonstrating to achieve full efficiency after irradiation. The results of the tests will be presented. The MALTA chip has been used to develop a CMOS compatible in-silicon buried channel technology (BCT) for sensor cooling, and to produce preliminary studies about the design of a large area CMOS detector ($> 4\ \times\ 4\, cm^2$). The electrical test performed on a functional prototype after BCT processing and the large area detector studies will be presented as well.

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Presenter: CARDELLA, Roberto (University of Oslo (NO))

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **12** Type: **contributed talk**

LPNHE - FBK thin n-on-p pixels for HL-LHC upgrades and beyond

Monday, 17 February 2020 15:15 (20 minutes)

In view of the LHC upgrade phases towards the High Luminosity LHC (HL-LHC), the ATLAS experiment plans to upgrade the Inner Detector with an all-silicon system.
The n-on-p silicon technology is a promising candidate to achieve a large area instrumented with pixel sensors, since it is radiation hard and cost effective.
The paper reports on the performance of LPNHE thin n-on-p planar pixel sensors produced at FBK-CMM; the sensors were bump-bonded to the RD53A prototype chip, featuring a 50x50 umˆ2 pixel cell.
After discussing the sensor technology an overview of 2019 testbeam results of the produced devices will be given, before and after irradiation, including cluster
properties, hit efficiency and space resolution.
Results for new 50 um thick n-on-p pixel sensors, still produced by LPNHE at FBK-CMM and bump-bonded to the RD53A prototype chip, will be presented too.
These very thin modules are attractive for detectors at future high luminosity and high energy machines where the lowest possible material budget is required to achieve the best tracking and vertexing resolution.

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Session Classification: Planar Pixel R&D

Track Classification: Planar sensors

Contribution ID: **13** Type: **contributed talk**

Deep Junction LGAD: a new approach to high granularity LGAD

Tuesday, 18 February 2020 13:40 (20 minutes)

Low Gain Avalanche Detectors (LGADs) are silicon detectors with modest internal gain (up to ˜50) that allows the sensor to be very thin (20-50 um). LGADs are characterized by an extremely good time resolution (down to 17ps), a fast rise time (˜500ps) and a very high repetition rate (˜1ns full charge collection). In a broad array of fields, including particle physics (4-D tracking) and photon science (X-ray imaging), LGADs are a promising R&D path. However, due to structures required to provide electrostatic isolation between LGAD pixels, the granularity of production-level devices is limited to the 1x1 mmˆ2 scale. However applications in particle physics and photon science demand granularity scales of 100x100 umˆ2 or better. Several promising approaches to improve this current limitation of LGADs are currently in R&D status. In this talk, we'll present a completely new idea involving a buried gain layer to overcome the current granularity limit: the DJ-LGAD.

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Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **14** Type: **contributed talk**

R&D on LGAD Radiation Tolerance for HL-LHC

Tuesday, 18 February 2020 17:40 (20 minutes)

Low Gain Avalanche Detectors (LGADs) are silicon detectors with modest internal gain (up to ~50) that allows the sensor to be very thin (20-50 um). LGADs are characterized by an extremely good time resolution (down to 17ps), a fast rise time (~500ps) and a very high repetition rate (~1ns full charge collection). These devices are relatively new but will be perfect candidates in a number of application in the future thanks to their proprieties. The first application will be with the ATLAS and CMS timing layers at the LHC where they will be utilized to mitigate the high pileup environment of High Luminosity LHC (HL-LHC) thanks to the extraordinary time resolution.
A current challenge is to produce LGADs with sufficient radiation hardness to withstand fluences up to 3E15 Neq/cm2 which is the level required for the HL-LHC environment. We'll report on the results of a radiation campaign with neutrons and protons up to a fluence of 3E15 Neq/cm2 of LGAD sensors produced by HPK and FBK.

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Session Classification: Radiation and High Fluence

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **15** Type: **contributed talk**

Interstrip Isolation of p-type Silicon Strip Sensors

Monday, 17 February 2020 16:55 (20 minutes)

Nowadays silicon strip sensors in high luminosity experiments usually consist of a p-doped bulk with n-type strip implants.
General consensus is that such a design requires an additional interstrip isolation structure like a p-stop implant.
If no additional implant is implemented between the strips, it is expected that the interstrip resistance will be insufficient before and especially after irradiation.
Before irradiation, impurities in the material lead to positive oxide charge inside the silicon dioxide surface which attracts electrons from the bulk.
Those electrons accumulate just beneath the silicon dioxide surface and between the strip implants which decreases the interstrip resistance significantly.
Ionising radiation introduces fixed charge inside the silicon dioxide which again decreases the interstrip resistance.

If the interstrip resistance decreases too much, the spatial resolution of the detector will eventually be lost.
Contrary to that expectation, a high interstrip resistance was observed after heavy proton irradiation with a fluence of $1 \times 10^{15} n_{eq}/cm^2$.

This talk presents the investigation of the interstrip isolation of n^+p strip sensors and how it is affected by radiation.
Therefore, sensors with no specific interstrip isolation implant were irradiated with x-rays, neutrons and protons.
A major focus is set on the dependence of the interstrip resistance.
The results are compared with simulations and discussed.

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Session Classification: Planar Strip R&D

Track Classification: Planar sensors

Contribution ID: **16** Type: **contributed talk**

Performance of 3D-trench silicon sensors designed for high time resolution

Wednesday, 19 February 2020 11:20 (20 minutes)

Developments on future tracking detectors go in the direction of a full 4D approach, in the sense of having both space and time measuring capabilities at the single pixel level. This is strongly motivated by the extremely high interaction intensities foreseen in the collider experiments of the next couple of decades and possibly beyond. Presently, no satisfactory technical solutions are available and important development programs are on the way. Minimal system requirements are the capability to sustain fluences greater than some 10ˆ16 1 MeV n_eq/cmˆ2 and radiation doses of some Grad, space resolutions around 10 μm and time resolutions below 50 ps.
It is well known that 3D silicon sensors have very high radiation hardness and intrinsic structural and operational characteristics which can be exploited for fast response. During 2019, tests have been made by the TIMESPOT collaboration on developed 55-μm-pitch 3D-trench sensor prototypes, produced by FBK, Trento, obtaining extraordinarily good results in terms of timing. The tests have been performed both in laboratory, under a 1030 nm pulsed laser beam, and under minimum ionizing particle beam at the PSI laboratories (Paul Scherrer Institute, Villigen, Switzerland). Dedicated fast discrete-component electronics has been used for signal read-out. The tests yield values of time resolution of the order and below 30 ps (sigma). Such results indicate that, as of today, these devices are possibly the only ones capable to satisfy the complete set of system requirements for a future vertex detector and can be considered a very interesting solution to be further developed and finalized. An optimized new batch of sensors is presently under development and will be submitted soon.
This paper will describe the characteristics of the developed sensors, the kind of measurements performed and will discuss the results obtained. The ongoing activity about further 3D sensor and fast front-end electronics developments will be also briefly illustrated.

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Presenter: OBERTINO, Maria Margherita (Universita e INFN Torino (IT))

Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **17** Type: **contributed talk**

Compact IV/CV measurement instrument for silicon sensors

Wednesday, 19 February 2020 15:20 (20 minutes)

IV and CV curves of are crucial measurements required to characterise silicon sensors. They have to be performed at reception and at several steps of particle detector modules assembly procedure to spot potential damages, at least in the prototyping phase.
High voltage (1kV) biasing of those sensors and accurate, low current measurements (50µA max) are mandatory for this. Typical instruments to perform those measurements are high voltage electrometers and LCR meters with proper decoupling. Those instruments are rather expensive (10k euros range) and commonly have over-specifications for this precise task. We developed a system tailored to perform both IV and CV measurements of sensors in one compact, lower cost instrument. It is based on a PCB that implements a low ripple (100mV) 1kV high voltage power supply, high-side AC/DC current measurement with 15nA granularity. Coupled with an external signal generator and a computer that extracts electrical parameters and IV/CV curves, a Programmable System-On-Chip (PSOC) handles sources control in addition to current, voltage and voltage/current phase measurements. On top of that, temperature, relative humidity are monitored and low voltage DC regulators can supply readout electronics of a fully assembled module to provide a standalone test station usable in sensor/module characterisation or in thermal cycling.

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Session Classification: Materials, Characterisation, Electronics

Track Classification: Characterization (TCT and others)

Contribution ID: **18** Type: **contributed talk**

Passive CMOS sensors for the future ATLAS hybrid pixel detector

Tuesday, 18 February 2020 10:00 (20 minutes)

With the upgrade of the inner tracking detector of the ATLAS experiment in 2026, the surface covered by hybrid pixel detectors increases from less than 2 m² at present to approximately 13 m². This makes sensor designs that utilize cost-effective, high-throughput CMOS processing lines with large and high-resistive wafers an attractive option. In addition, CMOS process features can be used to enhance the sensor design, for example by the implementation of bias resistors or AC coupling capacitors in every pixel.
Multiple sensors in the LFoundry 150 nm process technology were produced and characterized with the ATLAS FE-I4 and RD53A readout chips. Important properties like hit detection-efficiency, breakdown behavior, and input capacitance are presented for various pixels designs. A method for cluster-charge measurement using the RD53A is depicted and the recent full-size sensor production, covering up to four RD53Bs, is introduced.

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Presenter: POHL, David-Leon (University of Bonn (DE))

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **19** Type: **contributed talk**

Simulation of signal creation in MAPS to speed up the characterization and development of sensors

Tuesday, 18 February 2020 12:00 (20 minutes)

Monolithic Active Pixel Sensors (MAPS) are used in many high energy physics experiments, also in ALICE at CERN. To find the most suitable geometry for the current ALICE inner tracking system (ITS2), several slight modifications had to be processed and lots of manual characterisation was done. This added high costs and time to the project. Using modern TCAD device simulation software combined with the signal calculation capabilities of CERN's Garfield++ software one can simulate the sensor's signal creation down to the electron/hole pair level. Electric and weighting fields for the slight geometry modifications only have to be extracted once from TCAD. Signal generation is then done in Garfield++ by deposit of photons or MIPS and tracking the electron/hole pair movement through the sensor. The signal of single hit events can be extracted, stored and reused as input for electrical simulation software (SPICE, CADENCE) to design the read out electronics. The results are promising, seed pixel signal and cluster multiplicity of ITS2 radiation measurements could be recreated and timing capabilities for new geometries in view of upgrades during long shut-down 3 and 4 are investigated. With the recent development the signal behaviour of radiation detectors after different radiation levels to track degradation effects like trapping can be simulated as well. This paves the way for a full beginning to end simulation of MAPS detectors with all effects included.

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Presenter: HASENBICHLER, Jan (CERN, Vienna University of Technology (AT))

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **20** Type: **contributed talk**

Progress on a UV Sensitive SiPM for Readout of the Fast Component of BaF_2 Scintillation Light

Wednesday, 19 February 2020 13:40 (20 minutes)

A UV-sensitive SiPM incorporating an internal ALD filter is under development by a Caltech/FBK/*emphasized text*JPL group. The filter provides efficient detection of the 220 nm fast scintillation component of BaF_2 scintillation light together with strong discrimination of the larger 300 nm slow scintillation component. Measurements on a 6 mm $\times$ 6 mm device will be presented, including I/V curves, QE *vs.* wavelength and gamma ray spectra.

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Presenter: Prof. HITLIN, David (Caltech)

Session Classification: Silicon Photomultiplier

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **21** Type: **contributed talk**

Signal formation and designed optimization of Resistive AC-LGAD (RSD)

Tuesday, 18 February 2020 14:00 (20 minutes)

Resistive AC-LGAD (RSD) are sensors based on an evolution of the traditional LGAD designed aimed at eliminating the no-gain area between pads.
The principle of operation of RSD is based on the combination of 3 elements: the gain layer, a resistive n-doped junction contact, and the AC coupling. The design of RSD exploits the signal sharing among neighboring pads to achieve extremely good position and timing precision.

In this talk, we will illustrate the principle of signal formation in RSD, and show results of the first FBK RSD production.

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Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **22** Type: **contributed talk**

The LS3 upgrade of the ALICE Inner Tracking System based on ultra-thin, wafer-scale, bent Monolithic Active Pixel Sensors

Tuesday, 18 February 2020 11:20 (20 minutes)

During LHC LS3, ALICE plans to replace its innermost tracking layers with a new detector that is based on wafer-scale Monolithic Active Pixel Sensors, fabricated in 65 nm on 300 mm wafers. These sensors will be thinned down to 20-40 µm, a thickness such that they become flexible enough to be shaped into half cylinders. This will allow to place them very close to the beam pipe, at a distance of only 18 mm away from the interaction point. In addition, no supporting material –neither for powering, nor for cooling and data transmission –will be necessary due to a fully monolithic integration of the full stave-length into a single chip. The resulting arrangement features an unprecedented material-budget value of below 0.05% X0 per layer and will directly and substantially enhance the physics programme of ALICE.

This contribution will review the detector concept, the physics motivations, and lays out the R&D path. The R&D phase of the project has recently been endorsed by the Large Hadron Collider Committee, and was launched in December 2019.

Primary author: MAGER, Magnus (CERN)

Presenter: MAGER, Magnus (CERN)

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **23** Type: **contributed talk**

pLGAD: A new sensor concept for low-penetrating particles

Tuesday, 18 February 2020 17:00 (20 minutes)

In contrast to High Energy Physics, where particles easily traverse the whole thickness of a silicon sensor, low-energy particles may be completely stopped in the sensor material. We propose a new pixelated silicon sensor with signal amplification for particles which deposit their entire energy in the range of hundreds of nanometers or less in silicon. The proposed sensor utilizes the iLGAD (inverted Low Gain Avalanche Detector) principle to amplify signals near the surface of the detector, but without amplifying the leakage current and its corresponding noise. As the sensor is designed for detection of low penetrating particles with high detection efficiency, special care has to be taken for the entrance window. Apart from the window being 10 - 15 nanometers thin, it also has to be homogeneous to ensure the same response to particles regardless of their position of incidence. The main motivation for the sensor is to use it for the detection of protons from neutron beta decay in the NoMoS measurement concept, where the protons have an energy well below 30 keV after post acceleration. Hence the name pLGAD (proton Low Gain Avalanche Detector). However, other potential applications of the detector include usage in neutron detection, low energy X-ray detection, medical physics and space experiments.

Primary authors: KHALID, Waleed (OEAW); VALENTAN, Manfred (HEPHY Vienna)

Co-authors: DOBLAS MORENO, Albert; Dr HIDALGO VILLENA, Salvador (Instituto de Microelectronica de Barcelona (IMB-CNM-CSIC)); Ms JIGLAU, Raluca (Austrian Academy of Sciences); MOSER, Daniel (Technische Universität Wien); Dr PELLEGRINI, Giulio (Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)); Dr SOLDNER, Torsten (Institut Laue Langevin); ZMESKAL, Johann (Austrian Academy of Sciences (AT)); Dr KONRAD, Gertrud (SMI & TU Wien)

Presenter: KHALID, Waleed (OEAW)

Session Classification: LGAD and Timing

Track Classification: non-HEP applications

Contribution ID: **24** Type: **invited talk**

Welcome & Opening

Monday, 17 February 2020 10:00 (10 minutes)

Presenter: SCHIECK, Jochen (Austrian Academy of Sciences (AT))

Contribution ID: **25** Type: **contributed talk**

Timing resolution on a 3D silicon pixel detector

Wednesday, 19 February 2020 11:40 (20 minutes)

We report the measurements of time resolution for double-sided 3D pixel sensors with a single cell of 50 {\mu}m x 50 {\mu}m fabricated at IMB-CNM. Measurements were conducted using a radioactive source at -20 and 20 degrees C in a bias voltage range of 50-200 V. The reference time was provided from an LGAD detector produced by Hamamatsu. Results are compared to previous measurements on identical type sensors.

Primary authors: BETANCOURT, Christopher (Universitaet Zuerich (CH)); DE SIMONE, Dario (Universitaet Zuerich (CH)); PELLEGRINI, Giulio (Universidad de Valencia (ES)); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); MANNA, Maria (Centro National de Microelectronica - CNM-IMB-CSIC); SERRA, Nicola (Universitaet Zuerich (CH))

Presenter: DE SIMONE, Dario (Universitaet Zuerich (CH))

Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **26** Type: **contributed talk**

Process quality control strategy for the Phase-2 upgrade of the CMS outer tracker and calorimeter endcap

Monday, 17 February 2020 17:55 (20 minutes)

The CERN Large Hadron Collider (LHC) will undergo a major upgrade between 2025 and 2027, to increase the collision rate by a factor of about 5 compared to the present. Some existing components of the CMS detector - most notably the Tracker and Endcap Calorimeter - will have to be replaced to cope with the conditions of the high luminosity (HL-LHC) era: instantaneous peak luminosity up to $7.5 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and integrated luminosity up to $3000\,\mathrm{fb}^{-1}$ by 2037. Over $50,000$ new silicon sensors covering a total area of about $800\,\mathrm{m}^2$ will constitute the CMS tracker and parts of the CMS calorimeter endcaps. The quality of the sensors and the production process must be monitored constantly during production time to facilitate stable operation under HL-LHC conditions. This presentation introduces the process quality control strategy for the sensor series production. Each manufacturing wafer contains at least two instances of a set of test structures designed to provide easy access to critical process parameters. These include parameters not directly accessible on the sensors (e.g. oxide charge concentration and interface trap density) and parameters requiring potentially destructive measurements (e.g. dielectric strength). The set is divided into test structures for initial evaluation of the most relevant process parameters and structures for in-depth analysis. All structures can be contacted using a 20-needle probe card and an automated positioning stage. With this system, the initial analysis of one wafer is possible in under 30 minutes. We present the finalized layout of the set that will be implemented in the production runs for the CMS outer tracker and calorimeter endcap and report on measurements illustrating the functionality of the included test structures.

Primary authors: HINGER, Viktoria (Austrian Academy of Sciences (AT)); ON BEHALF OF THE CMS COLLABORATION; COLLABORATION, CMS

Presenters: HINGER, Viktoria (Austrian Academy of Sciences (AT)); COLLABORATION, CMS

Session Classification: Planar Strip R&D

Track Classification: Characterization (TCT and others)

Contribution ID: **27** Type: **contributed talk**

Measurements with Si detectors irradiated to extreme fluences

Tuesday, 18 February 2020 17:20 (20 minutes)

Results of measurements with thin pad silicon detectors irradiated with reactor neutrons to 1e17 n/cm2 will be presented. Measurements were made with CNM LGAD pad detectors made on 75 um thick epitaxial layer on low resistivity support silicon. LGADs were chosen because this was the available set of thin pad detectors that could withstand high bias voltages. Edge-TCT, charge collection with Sr-90 and detector current were measured under reverse and forward bias. Annealing at 60 C was studied.

Primary author: MANDIC, Igor (Jozef Stefan Institute (SI))

Co-authors: GORISEK, Andrej (Jozef Stefan Institute (SI)); HITI, Bojan (Jozef Stefan Institute (SI)); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); Prof. MIKUZ, Marko (Jozef Stefan Institute (SI)); ZAVRTANIK, Marko (Jozef Stefan Institute (SI)); CINDRO, Vladimir (Jozef Stefan Institute (SI))

Presenter: MANDIC, Igor (Jozef Stefan Institute (SI))

Session Classification: Radiation and High Fluence

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **28** Type: **contributed talk**

Comparative TCAD study of neutron irradiated p-stops for the CMS HGCAL

Monday, 17 February 2020 17:15 (20 minutes)

The segmented n-on-p sensors require isolation implants to prevent the electrodes from electrically shorting and two isolation configurations are being considered for the high granularity end-cap calorimeter (HGCAL) of CMS at the high luminosity LHC: common and individual (atoll) p-stops. Performance of the two p-stop options after irradiation is the focus of this study. We present a parametrization of Si/SiO_2 interface charge density with 1-MeV equivalent neutron fluence $N_f(\Phi_{eq},N_{f0})$, where N_{f0} is the initial N_f before irradiation, for silicon MOS-capacitors irradiated at reactors up to 1×10^{16} n_{eq}/cm^2, expected at the inner radius of HGCAL. $N_f(\Phi_{eq},N_{f0})$ is used to develop a preliminary non-uniform 3-level defect model (3L-model) for neutron bulk and surface damage at a fluence of 1×10^{15} n_{eq}/cm^2. Finally, $N_f(\Phi_{eq},N_{f0})$ and 3L-model are utilized for the first comparative simulation study of the surface properties of neutron irradiated common and atoll p-stops. Atoll p-stop was found to be more susceptible to the degradation of surface properties and increased electric fields with increasing N_f due to electron trapping between p-stops.

Primary authors: Dr PELTOLA, Timo Hannu Tapani (Texas Tech University (US)); COLLABORATION, CMS

Presenters: Dr PELTOLA, Timo Hannu Tapani (Texas Tech University (US)); COLLABORATION, CMS

Session Classification: Planar Strip R&D

Track Classification: Planar sensors

Contribution ID: **29** Type: **contributed talk**

Beam test measurements of hit efficiency and resolution of DEPFET pixel sensor modules for the Belle II experiment

Wednesday, 19 February 2020 12:00 (20 minutes)

The Belle II experiment at the super-B-factory SuperKEKB in Tsukuba, Japan started data taking in 2019. Its purpose is the measurement of electroweak phenomena and rare decays with unprecedented high precision. A up to 40-fold increase in instantaneous luminosity compared to the predecessor experiment Belle is targeted and will allow for recording a large dataset at the $\Upsilon(4S)$ center-of-mass energy. Besides the e^+e^--collider itself, the individual detector components are upgraded to higher precision and to resist the higher radiation flux. One of the significant improvements in Belle II is the silicon pixel detector surrounding the beam pipe. Two layers of DEPFET pixel based sensor modules are arranged at radii of 14 mm and 22 mm around the interaction point. Utilizing the DEPFET technology, very thin sensors (75 μm thickness of the fiducial volume) with a high signal-to-noise ratio (about 40) were constructed, featuring pixel pitches of $50 \times 55\,\mu\mathrm{m}^2$ to $50 \times 85\,\mu\mathrm{m}^2$. The sensor modules are all-silicon, self-supporting structures with three types of application-specific integrated circuits (ASICs) steering the read-out.
Pixel sensor modules of the final design were characterized and their operation parameters optimized in laboratory measurements. Two measurement campaigns at the DESY electron beam test facility ($2-6$ GeV electrons) were conducted to measure the sensor modules' hit efficiencies and intrinsic hit resolutions at different incidence angles and operation parameters. The results confirm satisfactory hit efficiency numbers and hit resolutions that benefit from charge sharing among pixels. Furthermore, a sensor module has been irradiated with a continuous spectrum of up to $40\,$keV x-rays to a TID of about $260\,$kGy. The measurements show that, to this irradiation dose, the shift of the MOSFETs gate threshold can be compensated for and that the sensor module can still be operated at an unchanged hit efficiency.

Primary author: WIEDUWILT, Philipp (Georg-August University Göttingen)

Presenter: WIEDUWILT, Philipp (Georg-August University Göttingen)

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **30** Type: **contributed talk**

Results on 3D Pixel Sensors for the CMS Inner Tracker Upgrade at the High Luminosity LHC

Wednesday, 19 February 2020 09:20 (20 minutes)

The High Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) will require new high-radiation tolerant silicon pixel sensors, capable of withstanding, in the innermost tracker layer, fluences up to $2.3 \times 10^{16} n_{eq}/cm^2$ (1MeV equivalent neutrons). An extensive R&D program aiming at 3D pixel sensors, built with a top-side only process, has been put in place in CMS. A few sensors were interconnected with the RD53A readout chip, the first prototype in 65nm technology of the pixel readout chip which will be used in the HL-LHC inner trackers. In this presentation results obtained in laboratory measurements and beam tests before and after irradiations will be reported. Irradiation of single chip interconnected modules were performed at CERN IRRAD facility up to a maximum equivalent fluence of $1 \times 10^{16} n_{eq}/cm^2$, which corresponds to about half of the full fluence foreseen at HL-LHC. Preliminary analysis of collected data shows excellent performance and hit detection efficiencies close 99% measured after the above mentioned irradiation fluence. Latest results on spatial resolution of 3D pixel sensors with pitch $50\mu m \times 50\mu m$ and $25\mu m \times 100\mu m$ will be also shown.

Primary author: COLLABORATIO, CMS

Presenter: CASSESE, Antonio (INFN, Firenze (IT))

Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **31** Type: **contributed talk**

Serial powering at CMS silicon tracker detector for High Luminosity Upgrade

Wednesday, 19 February 2020 15:40 (20 minutes)

The LHC machine will be upgraded targeting a peak luminosity of $5 - 7.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and aiming to collect an integrated luminosity of $3000 - 4500$ fb^{-1} in 10 years. The Compact Muon Solenoid (CMS) silicon tracker (Inner Tracker, IT) will be replaced at the High Luminosity Large Hadron Collider (HL-LHC) upgrade by a new radiation-hard detector capable of handling higher pileup, higher data rates, and longer trigger latency. RD53A prototype chip in a 65 nm feature size CMOS technology has been developed by RD53 Collaboration to meet these requirements. Meeting the performance specifications requires higher granularity which leads to a higher power consumption. In addition, the smaller feature size leads to lower operating voltage, thus further increasing the current. This cannot be satisfied with the current parallel powering scheme, without significantly increasing the cable mass. Therefore a serial powering scheme will be used. Chains of up to 12 modules will be powered by a constant current generator while the necessary internal rails will be provided by the special on-chip voltage regulators called Shunt Low Drop-Out (SLDO) regulators. The SLDO regulator also ensures that the chip sinks a constant input current independent of the internal circuit consumption. In addition, this scheme is less susceptible to voltage transients and noise, while improving the powering efficiency. Two or four chips on each module are powered in parallel to prevent a single failure from compromising the chain. Powering specification review is ongoing: many tests have been performed and will be presented.

Primary author: COLLABORATION, CMS

Presenter: SEIDITA, Roberto (Universita e INFN, Firenze (IT))

Session Classification: Materials, Characterisation, Electronics

Track Classification: HEP Systems

Contribution ID: **32** Type: **contributed talk**

The CMS Pixel Detector for the High Luminosity LHC

Monday, 17 February 2020 13:15 (20 minutes)

The High Luminosity Large Hadron Collider (HL-LHC) at CERN is expected to collide protons at a centre-of-mass energy of 14 TeV and to reach the unprecedented peak instantaneous luminosity of $5-7.5\times10^{34}cm^{-2}s^{-1}$ with an average number of pileup events of 140-200. This will allow the ATLAS and CMS experiments to collect integrated luminosities up to 3000-4000 fb^{-1} during the project lifetime. To cope with this extreme scenario the CMS detector will be substantially upgraded before starting the HL-LHC, a plan known as CMS Phase-2 upgrade. The entire CMS silicon pixel detector will be replaced and the new detector will feature increased radiation hardness, higher granularity and capability to handle higher data rate and longer trigger latency. In this talk the Phase-2 upgrade of the CMS silicon pixel detector will be reviewed, focusing on the features of the detector layout and on developments of new pixel devices.

Primary author: COLLABORATION, CMS

Presenter: SONNEVELD, Jory (Hamburg University (DE))

Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **33** Type: **contributed talk**

The CMS Outer Tracker Upgrade for the High Luminosity LHC

Monday, 17 February 2020 14:35 (20 minutes)

The High Luminosity Large Hadron Collider (HL-LHC) at CERN is expected to collide protons at a centre-of-mass energy of 14 TeV and to reach the unprecedented peak instantaneous luminosity of $5 - 7.5 \times 10^{34} cm^{-2} s^{-1}$ with an average number of pileup events of 140-200. This will allow the ATLAS and CMS experiments to collect integrated luminosities up to 3000-4000 fb^{-1} during the project lifetime. To cope with this extreme scenario the CMS detector will be substantially upgraded before starting the HL-LHC, a plan known as CMS Phase-2 upgrade. CMS Tracker detector will have to be replaced in order to fully exploit the delivered luminosity and cope with the demanding operating conditions. The new detector will provide robust tracking as well as input for the first level trigger. This report is focusing on the replacement of the CMS Outer Tracker system, describing new layout and technological choices together with some highlights of research and development activities.

Primary author: COLLABORATION, CMS

Presenter: MARIANI, Valentina (Universita e INFN, Perugia (IT))

Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **34** Type: **contributed talk**

Performance and prospects of the PPS tracking system.

Wednesday, 19 February 2020 09:00 (20 minutes)

The CMS-TOTEM Precision Proton Spectrometer (PPS) consists of tracking and timing detectors installed along the LHC beam line between 210 and 220 m from the interaction point on both sides of the CMS experiment. The aim of the apparatus is to measure the position, direction and time-of-flight of protons which emerge intact from the pp collision. Fully integrated in the CMS data acquisition system, PPS has taken data in standard high luminosity conditions during the LHC-Run2 (2016-2018), with different detector configurations. 3D pixel sensors, produced by CNM in double-sided technology, bump bonded to the PSI46dig ROC, were used in 2 of the 4 tracking stations in 2017 and in all of them in 2018. In this contribution the performance of the PPS tracking system during the LHC-Run2 will be discussed, with special focus on the effects produced on 3D pixel detectors by the operation at a few millimetres from the beam, in highly non-uniform irradiation environment. PPS will take data in the LHC-Run3 with all tracking stations equipped with 3D pixel detectors. The new sensors produced by FBK in single-sided technology will be presented.

Primary author: CMS-TOTEM, CMS-TOTEM

Presenter: BELLORA, Andrea (Universita e INFN Torino (IT))

Session Classification: 3D Sensors

Track Classification: HEP Systems

Contribution ID: **35** Type: **contributed talk**

Study of 3D pixel sensors after non-uniform proton irradiation

Wednesday, 19 February 2020 10:00 (20 minutes)

The Phase-II upgrade of the inner tracker of the CMS experiment is considering to use 3D pixel sensors for the innermost layers, given their intrinsic properties, well suited to resist the extreme radiation fluences expected at the High Luminosity Large Hadron Collider (HL-LHC). In this talk we present data collected from beam tests of 3D sensors bump-bonded to the RD53A prototype readout ASIC, irradiated with protons at CERN IRRAD facility, to an target equivalent fluence of about $1 \times 10^{16} n_{eq}/cm^2$ (1 MeV equivalent neutrons). We will present the methodology used to precisely estimate the actual fluence reached at the sensor, showing that different fluences are present in the same module because of the irradiation beam spot size. We use the different estimated fluence regions to study in the same module the sensor response with respect to the irradiated fluence, obtaining a potential indication of charge multiplication when increasing the fluence.

Primary author: COLLABORATION, CMS

Presenter: Dr DUARTE CAMPDERROS, Jordi (Universidad de Cantabria and CSIC (ES))

Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **36** Type: **contributed talk**

Radiation effects in the CMS phase 1 pixel detector

Monday, 17 February 2020 12:15 (20 minutes)

An upgraded silicon pixel detector has been installed in 2017 in the Compact Muon Solenoid (CMS) to cope with the harsh environment of the even increased luminosity of the proton-proton collisions at the Large Hadron Collider (LHC) and maintain high tracking performance at instantaneous luminosities of $2 \times 10^{34} cm^{-2} s^{-1}$, and fluences up to $1 \times 10^{15} n_{eq}/cm^2$. The phase 1 CMS pixel detector has 4 barrel layers and 3 endcap disks, with the innermost layer placed at just 2.9 cm from the beam line. The detector uses modules with n+ in n sensors of $100 \times 150 \mu m^2$ with an active layer of $285 \mu m$. The sensors are connected to PSI46dig readout chips, except for the innermost barrel layer where sensors are connected to PROC600 chips that have been designed especially to handle the high rates of the innermost layer. In this presentation we discuss radiation-induced changes in pixel sensor and chip properties including depletion voltage and leakage current. We also present variations of radiation-induced changes with temperature, fluence, and time. A model of these radiation-damaged induced pixel sensor properties is compared to data for both the central and the two endcap regions.

Primary author: COLLABORATION, CMS

Presenter: BRZHECHKO, Danyyl (Universitaet Zuerich (CH))

Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **40** Type: **contributed talk**

Performance of highly irradiated pixel sensors for the CMS HL-LHC upgrade

Monday, 17 February 2020 15:55 (20 minutes)

The CMS pixel detector upgrade for the HL-LHC must withstand unprecedented radiation fluence, up to 2×10^{16} neutron-equivalent per cm^2 over the lifetime of the detector. Sensors and the RD53A prototype readout chip have been developed to deliver the needed performance, but their radiation hardness at the full expected fluence still needs to be demonstrated. We have extensively tested and operated two planar HPK pixel sensors irradiated to approximately 1.3 n_{eq}/cm^2 at the LANSCE facility. Beam tests are performed at the Fermilab Test Beam Facility (FTBF), using the 120 GeV proton beam and a "telescope" consisting of silicon strip and pixel planes. This talk presents results on the efficiency, resolution, charge response, and I-V curves of one of these sensors. With a threshold of 1400 electrons and considering active pixels only, we achieve an efficiency of over 88% at a temperature of -30C and a bias voltage of -800V.

Primary author: COLLABORATION, CMS

Presenter: MILLS, Corrinne (University of Illinois at Chicago (US))

Session Classification: Planar Pixel R&D

Track Classification: Planar sensors

Contribution ID: **41** Type: **contributed talk**

Hybrid LGAD-based detector design for microdosimetry applications

Tuesday, 18 February 2020 16:40 (20 minutes)

Radiotherapy with ions has become a diffuse tool for curing cancer. Despite scientific and technological advances to improve the treatment efficacy, several critical issues have yet to be addressed. In order to fully understand the biological effect of ions, a complete characterization of the radiation field is needed.
Microdosimetry has been identified as a powerful tool to tackle this challenge, providing single-event energy spectra that relate the absorption of ionizing radiation in matter to the microscopic size of biological targets.
Among the existing microdosimeters, the tissue equivalent proportional counter (TEPC) is the only one that can directly provide the energy deposition in tissue at the micron scale. Currently, to assess the lineal energy y (the microdosimetric equivalent of the LET), the energy deposited by each particle is divided by the mean track length, which represents the most probable path traversed and thus depends on the detector geometry.
In order to have a more accurate spectrum, we propose an innovative design for a two-stage hybrid microdosimeter, consisting on a TEPC followed by four thin low-gain avalanche detectors (LGAD). This setup provides both the energy deposited in tissue-equivalent and the exact track length event-by-event. The y values can thus be corrected by the actual path length travelled by the particles inside the TEPC instead of using an average value.
Furthermore, the possibility of using the energy deposition in the LGAD for particle identification is also being investigated.
We will present a full description of the detector geometry and of the performances assessed with GEANT4 Monte Carlo toolkit.

Primary authors: Mrs MISSIAGGIA, Marta (University of Trento); Mr CASTELLUZZO, Michele (University of Trento); Mr PIEROBON, Enrico (University of Trento); Dr CENTIS VIGNALI , Matteo (FBK); Dr SCIFONI, Emanuele (TIFPA); Dr TOMMASINO, Francesco (University of Trento); Prof. RICCI, Leonardo (University of Trento); Prof. MONACO, Vincenzo (University of Turin); Mr BOSCARDIN, Maurizio (FBK); Prof. LA TESSA, Chiara (University of Trento)

Presenter: Mrs MISSIAGGIA, Marta (University of Trento)

Session Classification: LGAD and Timing

Track Classification: non-HEP applications

Contribution ID: **42** Type: **contributed talk**

Dark Matter in CCDs at Modane (DAMIC-M): a silicon detector apparatus searching for low-energy physics processes

Monday, 17 February 2020 10:55 (20 minutes)

Dark Matter In CCDs (DAMIC) is a silicon detector apparatus used primarily for searching for low-mass dark matter using the silicon bulk of Charge-Coupled Devices (CCDs) as targets. The silicon target within each CCD is 675 μm thick and its top surface is divided into over 16 million 15 μm x 15 μm pixels. The DAMIC collaboration has installed and operated seven of these CCDs at SNOLAB, achieving a pixel readout noise of 1.6 e and a leakage current as low as 2E-22A/cmˆ2.
The low instrumental noise of the devices allowed DAMIC at SNOLAB to perform highly sensitive searches for the scattering and absorption of light dark matter particles. A new DAMIC apparatus will be installed at Laboratoire Souterrain de Modane in a few years. The DAMIC at Modane (DAMIC-M) collaboration will be using an improved version of CCDs designed by Lawrence Berkeley National Laboratory with skipper amplifiers that use non-destructive readout with multiple-sampling, enabling the CCDs to achieve a readout noise of 0.068 e. The low readout noise, in conjunction with low leakage current of these skipper CCDs, will allow DAMIC-M to observe physics processes with collisions energies less than 10 eV. The DAMIC-M experiment will consist of an array of 50 large-area skipper CCDs with more than 36 million pixels in each CCD. The following talk will introduce the DAMIC apparatus at SNOLAB and its results as well as the capabilities and the status of the new DAMIC-M experiment.

Primary author: LEE, Steven Juhyung (University of Zurich (CH))

Presenter: LEE, Steven Juhyung (University of Zurich (CH))

Track Classification: HEP Systems

Contribution ID: **43** Type: **contributed talk**

Technology Development of LGADs at FBK

Tuesday, 18 February 2020 13:20 (20 minutes)

Low Gain Avalanche Detectors (LGADs) are silicon sensors with internal charge gain. The gain feature is used to improve the signal to noise ratio of the detector. These sensors are finding different applications including timing for high energy physics, beam monitoring for hadron therapy, and soft x-ray detection. This talk details the optimization of LGADs for different applications, with an emphasis on the radiation hardness and soft x-ray detection aspects. A feature of LGADs is the presence of a termination structure between regions with gain. This results in regions without gain between the readout channels reducing the fill factor of the devices. Different strategies to improve the fill factor of LGADs are being developed, such as double-sided LGADs, resistive AC-coupled LGADs, and trench isolated LGADs. The development and results obtained with these technologies are shown and discussed in the talk.

Primary authors: BORGHI, Giacomo (Fondazione Bruno Kessler); BOSCARDIN, Maurizio (FBK Trento); CENTIS VIGNALI, Matteo (FBK); Dr CENTIS VIGNALI , Matteo (FBK); FICORELLA, Francesco (Fondazione Bruno Kessler, via Sommarive 18, 38123, Povo (TN), Italy); HAMMAD ALI, Omar (INFN - National Institute for Nuclear Physics); PATERNOSTER, Giovanni (Fondazione Bruno KEssler); DALLA BETTA, Gian-Franco (INFN and University of Trento); PANCHERI, Lucio (University of Trento); ARCIDIACONO, Roberta (Universita e INFN Torino (IT)); CARTIGLIA, Nicolo (INFN Torino (IT)); MANDURRINO, Marco (INFN); MONACO, Vincenzo (Universita e INFN Torino (IT)); FERRERO, Marco (Universita e INFN Torino (IT)); GIORDANENGO, Simona (Istituto Nazionale di Fisica Nucleare); SIVIERO, Federico (INFN - National Institute for Nuclear Physics); SOLA, Valentina (Universita e INFN Torino (IT)); TORNAGO, Marta (Universita e INFN Torino (IT)); VIGNATI, Anna (INFN - National Institute for Nuclear Physics); ANDRÄ, Marie (PSI - Paul Scherrer Institut); BERGAMASCHI, Anna (PSI); SCHMITT, Bernd (Paul Scherrer Institut); ZHANG, Jiaguo (Paul Scherrer Institut)

Presenters: CENTIS VIGNALI, Matteo (FBK); Dr CENTIS VIGNALI , Matteo (FBK)

Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **44** Type: **contributed talk**

Test Beam Characterization of Planar Pixel Sensors for the CMS Phase 2 Upgrade

Monday, 17 February 2020 15:35 (20 minutes)

The CMS Inner Tracker for the High Luminosity upgrade of the Large Hadron Collider (HL-LHC) has to allow for tracking in a high track multiplicity environment caused by an instantaneous luminosity of up to 7.5×10^{34} cm^{-2} s^{-1}. In addition, the tracker has to tolerate 1 MeV neutron equivalent fluences ϕ_{eq} of up to 2×10^{16} cm^{-2} accumulating in the data taking period at 2.8 cm distance from the beam.

New n^{+}p-planar pixel sensors with pixel sizes of 50×50 μm^2 and 100×25 μm^2, 150 μm active thickness, with different implantation and metallization layout as well as different pixel isolation technologies have been produced by Hamamatsu Photonics (HPK). The sensors were bump bonded to a ROC4SENS or RD53A readout chip, where the former is dedicated to sensor studies and the latter is a common ATLAS and CMS prototype for the HL-LHC. Afterwards the sensor assemblies have been irradiated with protons at the PS-IRRAD Proton Facility at CERN and at the Irradiation Center Karlsruhe or neutrons in the TRIGA Mark II reactor in Ljubljana to fluences ϕ_{eq} above 5×10^{15} cm^{-2}. Finally, the sensors were characterized in an electron beam at the DESY II test beam facility.

The presented results show that these planar sensors reach efficiencies above 99 % at bias voltages well below 800 V even after proton or neutron irradiation to the given fluences. Thereby, planar sensors fulfill a key requirement for the second layer of the CMS Inner Tracker for the HL-LHC. Furthermore the comparison of different sensor designs provides input for the final sensor.

Future measurements on sensors proton irradiated to ϕ_{eq} of 1×10^{16} cm^{-2} and beyond will show if planar sensors are an option for the innermost layer of the CMS Inner Tracker in case of a replacement after half the operation period.

Primary authors: FEINDT, Finn (Hamburg University (DE)); COLLABORATION, CMS

Presenters: FEINDT, Finn (Hamburg University (DE)); COLLABORATION, CMS

Session Classification: Planar Pixel R&D

Track Classification: Planar sensors

Contribution ID: **46** Type: **contributed talk**

Sub-nanosecond charged particle detector with fast scintillator and hybrid photodetector

Wednesday, 19 February 2020 14:00 (20 minutes)

We present here the concept and results of a charged particle detector based on a novel inorganic scintillator coupled to a hybrid photodetector (HPD). The newly developed inorganic scintillator has a decay time ≤ 0.5 ns, high photon yield and long-lifetime. Together with the HPD, the detector exhibits a single electron pulse width of ≤ 0.7 ns, while allowing for quantitative detection over a dynamic range of several orders of magnitude. Custom-designed electronics produce an output pulse without distortion or ringing. Overall gain of ˜10ˆ6 makes single particle detection possible without the need for an additional amplifier. Unlike traditional MCP-based detectors or electron multipliers, the optical decoupling between particle detection and gain enables the use of low-voltage electronics. Additionally, an ion-to-electron convertor can be coupled to the detector, thus enabling the detection of both positive and negative particles. A more compact version of this detector with Si-PM or PMT is also available, having the same advantages described above, with pulse width of a few ns. The use of long-lifetime scintillator and photo-sensor dramatically improves detector stability and lifetime, up to a total detector output charge of several tens of coulombs. Several implementations of this detector as a time-of-flight (TOF) detector for mass spectrometry have already demonstrated its outstanding combination of properties: time resolution, dynamic range, stability and lifetime. This concept can be applied in future exciting new applications in other fields, such as e-beam tools in semiconductor industry, medical instruments and particle physics.

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Session Classification: Silicon Photomultiplier

Track Classification: non-HEP applications

Contribution ID: **47** Type: **contributed talk**

Simulation and Technology Study of Shallow Doping Profiles

Wednesday, 19 February 2020 15:00 (20 minutes)

In silicon detectors, a fraction of the highly-doped region represents a dead layer, where the generated charge carriers are lost. By minimising the dead layer, this charge loss is minimised as well. This is important when the determination of the exact generated charge is crucial: e. g. in case of isotope identification with the ΔE-E method or energy resolution measurements of alpha-particles emitted by decaying nuclei. It is especially important when the penetration depth is very small: for example for low energy x-rays, UV-radiation and low energy electrons.

For an upgrade of the T-Rex detector at the Miniball experiment at ISOLDE, the demanding processing of a large, double-sided AC-strip sensor is under way. Besides a sensor thickness of 70 μm, a dead layer of less than 100 nm within the silicon is requested; therefore a very shallow and homogeneous doping profile of the boron implantation is needed.

Several test runs have been produced to explore how shallow the boron profiles can get, especially when an isolating oxide is favoured. Plenty parameter variations of the Plasma Immersion Ion Implantation (PIII) and the Rapid Thermal Annealing (RTA) have been tested. The samples are analysed by SIMS and resistivity measurements. The results are compared to TCAD simulations. A further innovative, promising technology which is under development is the co-implantation with solid phase epitaxial growth (SPER).

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Session Classification: Materials, Characterisation, Electronics

Track Classification: Planar sensors

Contribution ID: **48** Type: **contributed talk**

TCT characterization and scanning of fine pitch of n+-in-p pixel detectors

Wednesday, 19 February 2020 16:20 (20 minutes)

Previously, fabrication of n+-in-p AC-coupled pixel detectors on p-type magnetic Czochralski silicon substrates at Micronova Nanofab facilities in Espoo, Finland has been reported. In our pixel detectors, we employ a layer of aluminum oxide (Al2O3) grown by atomic layer deposition (ALD) as dielectric and field insulator, instead of the commonly used SiO2. The high dielectric constant and dielectric strength of Al2O3 facilitates the implementation capacitive coupling, which separates the signal from the significantly increased leakage currents caused by radiation damage in the silicon detector. In addition, Al2O3 exhibits high negative oxide charges and thus serves as a substitute for p-stop/p-spray insulation implants between pixels. The charge and interface properties of the Al2O3 film can be by the ALD process, most importantly by the choice of oxygen precursor.

Our detectors have two geometries. First, 80 × 52 pixels in 26 double columns, compatible for flip-chip bonding with the currently used CMS PSI46dig readout chip (ROC). The size of the pixel in this layout is 120µm × 70µm. The size of the detector chip is 1 cm2 and the pixel are capacitively coupled (AC). The second geometry we have implemented on 150mm wafers is a larger 2cm × 1cm size detector. This follows the design of RD53 ROC to be foreseen in the future. The size of the pixel is 40µm × 40µm and layout forms a symmetric 400 × 192 matrix with 50µm pitch. The "RD53"sensor is DC coupled. In both designs the pixels are resistively connected by integrated metal nitride thin film bias resistors.

Here, we report Transient Current Technique (TCT) characterization of above-mentioned detectors. TCT measurements have been carried out by 660nm (RED) and 1064nm (IR) lasers for different bias voltages. Our TCT setup provided by Particulars d.o.o, allows scanning measurements in xyz –directions and the data is read out by a 4GHz Oscilloscope. With focused laser beam, TCT area scans reveal microstructure of those detectors. A emphasize has been put on analyzing the data to determent the homogeneity over the active pixel area. Analytic methods like the Discrete Fourier Transform (DFT) were performed to disentangle mechanical and stage controller issues.

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Session Classification: Materials, Characterisation, Electronics

Track Classification: Characterization (TCT and others)

Contribution ID: **49** Type: **contributed talk**

Preliminary results from the latest production of 3D pixel detectors at SINTEF MiNaLab

Wednesday, 19 February 2020 10:20 (20 minutes)

SINTEF MiNaLab recently completed its fifth fabrication run of full 3D pixel detectors with active-edges. The sensors were designed by the University of Oslo in collaboration with SINTEF within the Norwegian 3D detector collaboration. Sensors were fabricated on 6", Si-Si bonded wafers, with a device layer thickness of 150µm, using a single-sided processing approach. The production run included two different wafer layouts featuring multiple pixel geometries, 50x50 (1E), 25x100 (1E) and 25x100 (2E). Sensor compatible with both RD53A and RD53B readouts were included, as well as FE-I4 compatible sensors as reference with past productions. The temporary metal layer was deposited in December 2019 and measurements started in January 2020. In this presentation we will focus on the promising preliminary measurement results from standard planar test structures, 3D diodes and 3D pixel detectors of all flavors. The fabrication process and its challenges will be discussed, together with the plans for functional testing, irradiation, and for the next production run of RD53B compatible 3D sensors at SINTEF MiNaLab in the near future.

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Presenter: Dr POVOLI, Marco (SINTEF MiNaLab)

Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **50** Type: **contributed talk**

The Inner Tracking System upgrade for ALICE

Tuesday, 18 February 2020 11:00 (20 minutes)

Major upgrades of the ALICE experiment are underway and will be completed during the LHC Long Shutdown 2 to enhance the physics capacities of ALICE for LHC Run3 and Run4. One key part of this upgrade is the new Inner Tracking System (ITS2), a CMOS monolithic active pixel sensor based pixel detector. The upgraded Inner Tracking System consists of three innermost layers (50 μm thick sensors) and four outermost layers (100 μm thick sensors) covering 10 m^2 and containing 12.5 billion pixels with a pixel pitch of 27 μm x 29 μm. The smaller pixel size, the thinner sensor in combination with a lightweight support structure and the increased number of layers of the ITS2 compared with the former inner tracker, as well as smaller radius and thinner wall beam pipe configuration, will result in a significant improvement of impact parameter resolution and tracking efficiency.

The assembly of the full detector and services were completed in December 2019. A comprehensive commissioning phase in laboratory is currently ongoing. In this talk, the motivation and concept of this upgrade will be summarized. The assembly verification and detector commissioning status and plans, as well as the detector performance during the commissioning, will be discussed in detail.

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Session Classification: CMOS

Track Classification: HEP Systems

Contribution ID: **51** Type: **contributed talk**

Sensor development and characterisation for Velo Upgrade

Monday, 17 February 2020 14:15 (20 minutes)

The upgrade of the LHCb experiment, planned for 2020, will transform the experiment to a triggerless system reading out the full detector at the LHC collision rate and up to $2 \times 10^{33} cm^{-2} s^{-1}$ instantaneous luminosity.

As part of the LHCb Upgrade, hybrid pixel prototypes have been studied in detail at SPS testbeams using the Timepix3 Telescope. A range of prototype planar sensors, with varying thickness, type, implant size and guard rings were provided by two manufacturers. These sensor have been characterised using two different readout ASICs, the Timepix3 (analogue) and VeloPix (binary).

The evaluation programme of the prototypes also includes studies to show the effects of radiation damage. The sensors were irradiated at several facilities, including reactor neutrons at JSI in Ljubliana, mid energy (27 MeV) protons at KIT in Karlsruhe and high energy (24 GeV) protons from IRRAD at CERN

Complementary measurements without the telescope tracking have been done using only the hit information within a sensor. The grazing angle method consists of placing the device under test (DUT) almost parallel to the beam, such that tracks cross multiple adjacent pixels, where each pixel then represents a certain depth in the sensor. This is one of the few methods to perform depletion depth measurements and investigate the evolution of the charge collection profile at different depths. The high timing resolution of the Timepix3 chip also made it possible to study the charge collection time as a function of depth.

The impact of radiation damage on the charge collection and time-to-threshold is investigated at different fluences by studying non-uniformly irradiated assemblies. The spatial resolution and collected charge were studied as a function of track angle, bias voltage and threshold both before and after irradiation. In this presentation an overview of the test beam results will be shown comparing the performance against all the different parameters implemented in the prototypes.

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Session Classification: HEP Systems

Track Classification: HEP Systems

Contribution ID: **52** Type: **contributed talk**

Characterization of FBK 3D pixel sensor modules based on RD53A readout chip for the ATLAS ITk

Wednesday, 19 February 2020 09:40 (20 minutes)

3D pixel sensors are the technology of choice for the innermost layer (L0) of the ATLAS ITk detector at High Luminosity LHC. The considered sensors have pixel size of either 25 um x 100 um or 50 um x 50 um, with one read-out electrode at the center of a pixel and four bias electrodes at the corners. The former geometry has been chosen for the central part of L0 (barrel), the latter for the lateral rings (endcap). A new generation of 3D pixels featuring these small-pitch dimensions and reduced active thickness (˜150 um) has been developed to this purpose within a collaboration of INFN and FBK since 2014. The most recent R&D batches have been oriented to sensors compatible with the RD53A chip. Several sensors of different geometries were bump bonded to RD53A read-out chips at Leonardo (Rome, Italy) and tested in laboratory and at beam lines.
In this talk, we report on the module characterization results, including threshold tuning and noise measurements, and results from a beam test performed at DESY facility on a 25 um x 100 um sensor irradiated with 27 MeV protons up to a fluence of 5×1015 1 MeV neq cm-2.

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Session Classification: 3D Sensors

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **53** Type: **contributed talk**

Performance variation of FBK Silicon Photomultipliers with proton radiation up to 10^13 neq/cm2

Wednesday, 19 February 2020 13:20 (20 minutes)

Silicon Photomultipliers (SiPMs) are very sensitive light detectors made by arrays of many Single-photon avalanche diodes (SPADs) connected in parallel. They are becoming more and more important in an increasing number of applications, such as high-energy physics experiments (e.g. photodetectors in the future upgrade of the CMS calorimeter) or more recently for reading out liquid noble-gasses scintillators, operating at cryogenic temperatures. When used in high-energy physics experiments, they are often exposed to high radiation doses during their operating lifetime, due to the interaction of hadrons, electrons, gamma- and X-rays.

For this reason in the last few years there has been a growing interest in studying the degradation of SiPMs performance after irradiation. Unfortunately, this kind of analysis is not straightforward since in SiPMs many aspects contribute to the overall performance, e.g. primary noise, correlated noise, quenching resistor value, recharge time-constant, etc. These should be studied separately in order to get insight into the damages and the physical modifications introduced by the radiation. Moreover, another drawback is that SiPMs generally lose their single-photon-resolution capabilities for radiation doses higher than ~ 10^9 –10^{10} neq/cm^2, thus preventing the possibility to use the most common measurements techniques for characterizing the photo-detection efficiency and the noise of SiPMs.

In this contribution we present the results of a systematic study of the effects induced in FBK SiPMs by proton irradiation, for different doses. In particular, we compare the effects induced in 1x1mm^2 SiPMs made with different cell pitch and with different technologies: RGB-HD, NUV-HD (HD stands for high-density) and RGB-UHD ("ultra-high-density"of cells). The bare SiPM dies have been irradiated at the LNS-INFN laboratories in Catania (Italy) with doses between 10^8 and 10^{13} neq/cm^2, and tested after about 1 month of room-temperature annealing. Results show that SiPMs are working up to an irradiation dose of 10^{13} neq/cm^2, but that there are saturation effects (due to the very high dark count rate) already at doses of 10^{12} neq/cm^2. The saturation effect is visibly dependent on the SiPM cell density. Noise of the SiPMs (i.e. dark count rate) shows an increment of about 1.5 orders of magnitude at irradiation doses of 10^8 neq/cm^2, of 2.5 orders of magnitude at irradiation doses of 10^{10} neq/cm^2 and of about 4 to 6 orders of magnitude at irradiation doses of 10^{13} neq/cm^2, reaching a DCR of ~10^{10} cps/mm^2. We verified that at irradiation doses higher than 10^{10} neq/cm^2 the SiPMs lose the single-photon resolution capabilities even when cooled down to -20°C. Further studies foresee to irradiate SiPMS with higher doses (e.g. 10^{14} neq/cm^2) and to measure irradiated samples at cryogenic temperatures.

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Session Classification: Silicon Photomultiplier

Track Classification: Characterization (TCT and others)

Contribution ID: **54** Type: **contributed talk**

Silicon Sensors for Extreme Fluences

Tuesday, 18 February 2020 18:00 (20 minutes)

Present silicon sensor technology allows to efficiently operate sensors up to 10^{16} n_{eq}/cm^2. However, several future applications, such as tracking detectors in high-luminosity and high-energy particle physics experiments, monitors for particle therapy and nuclear fusion reactors, envisage the use of silicon sensors in environments with fluences exceeding 10^{17} n_{eq}/cm^2.

To overcome the present limit, we propose a design of silicon sensors which extends the range of operation by more than one order of magnitude, up to fluences of $5{\cdot}10^{17}$ n_{eq}/cm^2. The idea behind this radiation tolerance exploits the saturation of radiation damage effects, observed above $5{\cdot}10^{15}$ n_{eq}/cm^2, in combination with two developments in sensor technology: (i) the use of thin sensors (20-30 μm), intrinsically less affected by radiation than thicker sensors, and (ii) the presence of internal signal multiplication (gain of 5-10), to compensate for the low signals generated in thin active volumes.

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Session Classification: Radiation and High Fluence

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **55** Type: **contributed talk**

SiPM development at FBK for the barrel timing layer of CMS

Wednesday, 19 February 2020 13:00 (20 minutes)

The peculiar features of SiPMs, such as their compact size, insensitivity to magnetic fields, low power consumption and mechanical robustness make them very promising as photosensors in calorimeters and precision timing detectors in the future generation of high energy physics experiments. In these contexts, a critical aspect is the radiation hardness of the silicon detector. Currently available technologies show performance deterioration at fluencies of about 1e10 neq/cm2, and compromised single photon counting capabilities at fluencies of about 1e13 neq/cm2.
At FBK, dedicated technological improvements of SiPMs are in progress for the barrel timing layer (BTL) of CMS experiment, in view of the high luminosity phase of LHC (HL-LHC). In the current design of the detector upgrade, SiPMs will be used for double-side readout of LYSO:Ce scintillating bars with a length of 50 mm and a base area of 3×3 mm2.
In recent studies, FBK NUV-HD Low Field SiPMs showed improved performance after irradiation compared to conventional NUV-HD technology. The dark current of NUV-HD Low Field SiPMs after irradiation at 5e13 neq/cm2 showed a temperature coefficient of 1.77/10℃ compared to 1.65/10℃ obtained with conventional NUV-HD technology . This fact is attributed to the reduction of field-enhanced generation in Low Field technology. NUV-HD Low Field technology was selected as the baseline for this development, allowing a significantly reduced dark noise level if SiPMs are operated at a temperature of -30℃ or lower.
The SiPM technology development for the upgrade of BTL detector combines a small cell size with a modified version of NUV-HD Low Field. The small cells provide a low microcell gain, of about 3e5 at an excess bias of 3 V, which results in a small direct crosstalk probability (<10%). Moreover, the small microcell capacitance allows to obtain a fast recharge time constant (10 ns), which reduces cell occupancy. The electric field engineering resulted in a faster rise of the triggering probability as a function of the excess bias compared to NUV-HD Low Field. The photon detection probability (PDE) of the technological version that has been selected in the R&D phase is of about 27% at 420 nm at an excess bias of 3 V and it saturates at about 45% at high excess bias (˜10 V).
FBK SiPMs optimized for BTL were tested after irradiation up to 1e13 neq/cm2, showing performance in line with the requirements of the experiment, when operated at -30℃ and at low excess bias (about 2 V). In the next months, FBK will run a preproduction of SiPMs for BTL, based on the results of the R&D phase. The preproduction will aim to demonstrate performance and reliability of the developed technology. Advanced packaging solutions will be tested to provide a radiation hard device, suitable for long term operation in the high luminosity phase of LHC.

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Session Classification: Silicon Photomultiplier

Track Classification: HEP Systems

Contribution ID: **56** Type: **contributed talk**

LGAD Performance at Low Energy Proton and Ion Beams for Medical Applications

Tuesday, 18 February 2020 16:00 (20 minutes)

Over the past decade, proton and ion-beam therapy has become an established form of cancer treatment. Currently, the achievable precision of this therapy is limited by uncertainties due to treatment planning based on conventional photon imaging. A significant effort is therefore invested into the development of proton or ion imaging modalities. A typical apparatus for such applications consists of a front and rear tracking detector, which surrounds the target, followed by a calorimeter.

Low Gain Avalanche Detectors (LGADs) are a rather new technology that would be particularly well suited as time-of-flight calorimeter for such applications. While for the detection of minimum ionising particles (MIPs) their resolution is typically limited to around 30 ps due to Landau fluctuations, it is expected that for higher energy deposits, such as from a few hundred MeV proton beam, this limitation is reduced. Additionally, they would allow to simplify the full detector concept by eliminating the rear tracking detector as the spatial resolution of existing LGAD designs is most likely already enough to improve the tracking accuracy below the multiple Coulomb scattering (MCS) limit.

At the MedAustron particle therapy centre, proton energies between 62 MeV and 800 MeV as well as carbon ions between 120 MeV/n and 400 MeV/n are available for treatment and research purposes. Beam test results on the timing performance of LGADs at those beam energies will be shown and their possible application to ion imaging will be discussed.

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Presenter: PITTERS, Florian Michael (HEPHY)

Session Classification: LGAD and Timing

Track Classification: non-HEP applications

Contribution ID: **57** Type: **contributed talk**

FAST: a front-end readout ASIC for picosecond time resolution applications with UFSD

Tuesday, 18 February 2020 14:20 (20 minutes)

Measurements of Time of Arrival of particles in detectors with picosecond time accuracy is becoming fundamental for several applications worldwide. The future upgrade of High Luminosity LHC (HL-LHC) is one example where these measurements will be exploited to mitigate the pile-up effects generated by the increase of luminosity. Thanks to this tool, events overlapped in space but separated in time will be distinguished increasing the overall detector efficiency. Dedicated timing layers for performing picosecond measurements are under construction. Examples are the MIP Timing Detector in the CMS experiment and the High Granularity Timing Detector in the case of the ATLAS experiment. In parallel, several R&D projects started worldwide to fabricate dedicated sensors and electronics to grow the technology required to build these new detectors. This level of accuracy requires specific sensors able to provide signals with large amplitudes and short duration. Ultra Fast Silicon Detectors are an example of optimized silicon devices suitable to reach 30 ps time resolution. Concerning the electronics coupled to sensors, very strict requirements (like power consumption) make it difficult reaching this kind of resolutions. Also having large sensors in the order of 6 pF or greater represents an additional complexity to deal with.

In this work we present FAST, a low power multichannel ASIC developed for high precision timing measurements with UFSD sensors. The target of FAST is reducing the jitter contribution to the time resolution below 30 ps with 6 pF sensor capacitance. The channel architecture consists of a Trans-Impedance Amplifier (TIA), a second amplification stage based on a common source amplifier, a two stages leading edge discriminator, a Pulse Width Regulator to tune the digital output duration and a LVDS driver. The most critical part is the trans-impedance amplifier. The power consumption of this block is 1.2 mW. Three flavors of FAST have been developed to explore more front-end architectures. According to the post-layout simulations, the flavors of FAST exhibit a time resolution below 30˜ps when coupled to sensors with capacitance up to 10 pF. First measurements with one flavor show a jitter of 25 ps of the typical signal generated by UFSD (8 fC). These preliminary data show a 14 ps jitter saturation starting from 30 fC injected charges.

The ASIC has been produced in September 2019 and several tests are ongoing. Simulation and characterization results showing the timing performance of the prototype will be presented at the conference.

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Session Classification: LGAD and Timing

Track Classification: HEP Systems

Contribution ID: **59** Type: **contributed talk**

The use of thermal cameras as a diagnostic tool in the qualification of LGAD designs

Tuesday, 18 February 2020 16:20 (20 minutes)

The Hamamatsu ORCA2 C11090-22B is a EM-CCD camera working with visible light, able to perform Ultra-Low Light Imaging. In this contribution, we will show how such a camera can be employed to study the breakdown of Silicon detectors by looking at their "hot spots", namely regions of a device that emit visible photons because of the high current densities flowing through them. We performed measurements on LGADs with different design strategies of the inter-pad region, aiming to reduce the size of the no-gain area between pads. The camera allows determining those parts of the structures where a high density of current concentrates, helping us understand the cause of sensor's premature breakdown. This visualization is a very good tool to pinpoint design choices that might lead to unwanted sensors' characteristics

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Presenter: SIVIERO, Federico (Universita e INFN Torino (IT))

Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **60** Type: **contributed talk**

AC-coupled pixel detectors with aluminium oxide field insulator on p-type MCz silicon

Wednesday, 19 February 2020 14:40 (20 minutes)

In previous work, we have reported on the fabrication of pixel detectors on p-type magnetic Czochralski silicon substrates, employing a layer of aluminium oxide (Al2O3) grown by atomic layer deposition (ALD) as dielectric and field insulator. The high dielectric constant of Al2O3 facilitates implementation of capacitive coupling, which separates the signal from the significantly increased leakage currents caused by radiation damage in the silicon detector. In addition, Al2O3 exhibits a negative oxide charge and thus serves as a substitute for p-stop/p-spray insulation implants between pixels. The charge and interface properties of the Al2O3 film can be to some extent tuned by the ALD process, most importantly by the choice of oxygen precursor.

Devices obtained by the abovementioned process are characterized by CV, IV, and TCT measurements. Results show the expected high negative charge of the Al2O3 dielectric, and acceptable leakage current densities.
Capacitively (AC) coupled n+-in-p pixel detectors, in a geometry of 80 x 52 pixels in 26 double columns, are flip-chip bonded to the current CMS PSI46dig readout ASIC for further testing. The functionality of these assemblies, including determination of suitable threshold settings in the readout ASIC, is studied with x-ray/gamma radiation sources.

A future development to improve AC-coupled pixel detectors features the use of hafnium oxide (HfO2), also deposited by ALD, as an additional high-k dielectric layer in the area of the pixel implant. HfO2 has very low oxide charge and thus does not interfere with the field-effect passivation provided by Al2O3. However, its chemical inertness makes HfO2 difficult to pattern by wet and fluorine-based dry etching. We are therefore currently investigating chemical-mechanical polishing (CMP) for patterning our HfO2 films.

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Presenter: OTT, Jennifer (Helsinki Institute of Physics (FI))

Session Classification: Materials, Characterisation, Electronics

Track Classification: Planar sensors

Contribution ID: **61** Type: **contributed talk**

Popcorn Noise and Timing Measurements on LGADs

Tuesday, 18 February 2020 14:40 (20 minutes)

Popcorn noise has been observed as a detrimental effect in LGADs operation under certain biasing conditions and is manifested as a random charge fluctuation in the detector output signal. We present a systematical analysis of popcorn noise studied in 35 and 50 µm thick CNM LGADs measured via TCT (Transient Current Technique) and a Sr-90 beta setup. The findings are used to define optimal bias voltage conditions to avoid popcorn noise as well as to identify the origin of the effect. Additionally, timing studies measurements from both the TCT and beta setup are presented.

Primary author: BOELL, Julian Alexander (Hamburg University (DE))

Co-authors: Dr MOLL, Michael (CERN); FERNANDEZ GARCIA, Marcos (Universidad de Cantabria and CSIC (ES))

Presenter: BOELL, Julian Alexander (Hamburg University (DE))

Session Classification: LGAD and Timing

Track Classification: hybrid sensors (3D, LGAD)

Contribution ID: **62** Type: **contributed talk**

First results with novel pixel detectors based on wafer-wafer bonding

Tuesday, 18 February 2020 12:20 (20 minutes)

Wafer-wafer bonding enables the fusion of two semiconductor wafers, without any additional material at the interface. In the context of pixel detectors, the method has the potential to enable limitless combinations of absorber materials with readout chips fabricated with CMOS technologies.

In this talk we present the status of our studies on the design, optimization and characterization of pixelated wafer-wafer bonded detectors.

In particular, we report on a CMOS readout chip bonded to silicon and gallium-arsenide. We will present the design of the detectors, their manufacturing principle, and compare their simulated performance to the measured characteristics such as leakage current, noise, and single photon collection efficiency in the X-ray domain. We will further highlight the current challenges of this novel technology and present our plans for future developments.

Primary authors: Mr WÜTHRICH, Johannes Martin (ETH Zurich (CH)); RUBBIA, André (ETH Zurich (CH))

Presenter: Mr WÜTHRICH, Johannes Martin (ETH Zurich (CH))

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **63** Type: **invited talk**

Detector requirements for future high-energy collider experiments

Monday, 17 February 2020 10:10 (45 minutes)

Particle detectors for operation at future high-energy collider
experiments are designed in view of both their facilities' physics
objectives and their experimental conditions, which differ substantially between lepton and hadron colliders as well as between linear and circular colliders. Example differences are background conditions and duty cycles, which for instance translate into very different requirements in terms of shielding, radiation-hardness requirements and cooling concepts. Furthermore the detector designs take into account
cost and engineering constraints as well as anticipate future technology developments. An overview of the physics cases and experimental environments of the currently proposed future high-energy colliders is given, including CEPC, CLIC, FCC-ee and ILC for e+e- colliders, FCC-hh,
HE-LHC and SppC for pp colliders as well as muon collider concepts. The corresponding detector design choices are discussed and challenges in the design are outlined.

Primary author: SICKING, Eva (CERN)

Presenter: SICKING, Eva (CERN)

Track Classification: HEP Systems

Contribution ID: **64** Type: **invited talk**

The Monopix detectors —CMOS pixel detectors with large and small electrodes

Tuesday, 18 February 2020 09:00 (40 minutes)

The development of radiation hard, depleted monolithic active pixel sensors (DMAPS) over many years has led to full size detector matrices, realised in LFoundry 150 nm and TowerJazz 180 nm technologies.
Large and small electrode designs have been investigated and characterised, with different readout schemes, in a collaboration between Bonn-CERN-CPPM-IRFU. The talk will present the results of these developments with respect to design features and performance with a focus on the chips with column-drain readout realised in the large chips LF-Monopix1 and 2 as well as TJ-Monopix1 and 2.

Primary author: WERMES, Norbert (University of Bonn (DE))

Presenter: WERMES, Norbert (University of Bonn (DE))

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **65** Type: **contributed talk**

The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade

Monday, 17 February 2020 17:35 (20 minutes)

The ATLAS experiment at the Large Hadron Collider is currently preparing for a major upgrade of the Inner Tracking for the Phase-II LHC operation (known as HL-LHC), scheduled to start in 2026. In order to achieve the integrated luminosity of 4000 fb-1, the instantaneous luminosity is expected to reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The radiation damage at the full integrated luminosity implies integrated hadron fluencies over 2x10ˆ16 neq/cm2 requiring a complete replacement of the existing Inner Detector. An all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector, aiming to provide increased tracking coverage up to |η|=4.

The ITk Strip Detector system consisting of four barrel layers in the centre and forward regions composed of six disks at each end, is described in the ATLAS Inner Tracker Strip Detector Technical Design Report (TDR). With the recent completion of Final Design Reviews (FDRs) in a number of key areas, such as Sensors, modules, ASICs and front-end electronics, the prototyping phase has been completed successfully. The pre-production phase is about to start at the institutes involved.

In this contribution we present an overview of the ITk Strip Detector System, including the final layout of the ITk Strip Detector System, and highlight the final module designs and ASICs. We will give an extended summary of the R&D results achieved in the prototyping phase. Some of
the modules were irradiated with a range of fluencies and reaching up to and in some cases exceeding
HL-LHC doses, demonstrating the excellent radiation hardness achieved. In addition, we will outline the current status of pre-production on various detector components, with an emphasis on QA and QC
procedures. We will also discuss the status of preparations and the plans for the forthcoming pre-production and production phase.

Primary author: VICKEY, Trevor (University of Sheffield (GB))

Presenter: SAWYER, Craig Anthony (Science and Technology Facilities Council STFC (GB))

Session Classification: Planar Strip R&D

Track Classification: HEP Systems

Contribution ID: **66** Type: **contributed talk**

The ATLAS ITk Strip Detector Sensors for the Phase-II LHC Upgrade

Monday, 17 February 2020 14:55 (20 minutes)

The ATLAS experiment at the Large Hadron Collider is currently preparing for a major upgrade of the Inner Tracking for the Phase-II LHC operation (known as HL-LHC), scheduled to start in 2026. In order to achieve the integrated luminosity of 4000 fb-1, the instantaneous luminosity is expected to reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The radiation damage at the full integrated luminosity implies integrated hadron fluencies over 2x10ˆ16 neq/cm2 requiring a complete replacement of the existing Inner Detector. An all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector, aiming to provide increased tracking coverage up to |η|=4.

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In this contribution we present a detailed overview of the ITk Strip Detector Sensors, highlight the final design choices and give an extended summary of the R&D results achieved in the prototyping phase.

Presenter: HOMMELS, Bart (University of Cambridge (GB))

Session Classification: HEP Systems

Track Classification: Planar sensors

Contribution ID: **67** Type: **not specified**

Closeout

Wednesday, 19 February 2020 16:40 (20 minutes)

Presenter: DALLA BETTA, Gian-Franco (INFN and University of Trento)

Contribution ID: **68** Type: **contributed talk**

The CLICTD monolithic CMOS sensor for the CLIC tracking detector

Tuesday, 18 February 2020 11:40 (20 minutes)

Challenging requirements are imposed on the detector for the proposed future Compact Linear Collider CLIC. For the large-area (140 sqm) main tracker, a temporal resolution of a few nanoseconds and a spatial resolution of 7 μm need to be achieved simultaneously with a material budget per layer of 1% of a radiation length. The CLICTD monolithic CMOS sensor has been developed targeting these requirements. It features a small collection-electrode design with a pixel size of 30 μm x 300 μm and sub-segmentation of each pixel into 8 analogue frontends. The chip is implemented in two variants of a modified 180 nm CMOS imaging process, optimised for fast signal collection and high spatial resolution. This contribution introduces the CLIC tracking-detector requirements and concept, and presents results of recent laboratory and test-beam data-taking campaigns with the CLICTD sensor.

Presenter: DANNHEIM, Dominik (CERN)

Session Classification: CMOS

Track Classification: Monolithic Sensors (CMOS)

Contribution ID: **69** Type: **not specified**

Travel to Dinner location

Tuesday, 18 February 2020 18:45 (45 minutes)