

# **The 39th RD50 Workshop (Valencia)**



## **Report of Contributions**

Contribution ID: 1

Type: **Talk**

## Topics in LGAD designs

*Thursday, 18 November 2021 09:10 (20 minutes)*

In this contribution, I will discuss two possible evolutions of the LGAD design.

- DC-RSD: up to now, resistive read-out in silicon detectors has been used only in AC-coupled detectors, the so-called AC-RSD or AC-LGAD. I will present here the first attempt to apply resistive read-out to a DC-coupled sensor.
- LGAD with bias ring: recent beam tests results showed that LGADs suffer destructive breakdown if the field in the bulk is above 11V/um. SiPMs manage to survive similar conditions given the presence of quenching resistors. I will present a possible LGAD design that introduces AC-coupled read-out and quenching resistors in each pad. This design should also provide increased stability with respect to floating pads or pads with high currents.

**Primary authors:** SIVIERO, Federico (INFN - National Institute for Nuclear Physics); CARTIGLIA, Nicolo (INFN Torino (IT)); BORGHI, Giacomo (Fondazione Bruno Kessler); DALLA BETTA, Gian-Franco (INFN and University of Trento); PATERNOSTER, Giovanni (Fondazione Bruno Kessler); MENZIO, Luca (Universita e INFN Torino (IT)); PANCHERI, Lucio (University of Trento and TIFPA-INFN); FERRERO, Marco (Universita e INFN Torino (IT)); MANDURRINO, Marco (INFN); TORNAGO, Marta (Universita e INFN Torino (IT)); CENTIS VIGNALLI, Matteo (FBK); BOSCARDIN, Maurizio (FBK Trento); ARCIDIACONO, Roberta (Universita e INFN Torino (IT)); SOLA, Valentina (Universita e INFN Torino (IT))

**Presenter:** CARTIGLIA, Nicolo (INFN Torino (IT))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 2

Type: **Talk**

## Evaluation of Landau contribution of a single cell 3D 50 $\mu$ m pixel under SPS 120 GeV pion beam

The proven potential of higher than  $10^{16}$   $n_{eq}/\text{cm}^2$  radiation tolerance that 3D geometries offer, in combination with a small cell approach, makes them an excellent choice for combined precision timing and tracking applications. In this study, timing resolution of a single 50 x 50  $\mu\text{m}$  3D pixel cell is presented in various temperatures through charged collection measurements in a laboratory setting. The series is complemented by an extensive test-beam campaign using 160 GeV SPS pions. A multi-plane timing telescope with integrated pixel tracker is used. Field uniformity, Landau contribution and collected charge are treated using varied incidence angles in the range of  $\pm 12^\circ$ . Relying on state-of-the-art numerical methods, the choice of instrumentation and subsequent bandwidth limitations are discussed as well as their effects on signal composition and biasing. With the introduction of 7  $\mu\text{m}$  resolution tracking, a detailed cartography of the cell is performed, and the field uniformity hypothesis is evaluated.

**Primary authors:** HALVORSEN, Marius Mahlum (University of Oslo (NO)); Dr GKOU GKOUSIS, Vagelis (CERN); COCO, Victor (CERN)

**Presenter:** Dr GKOU GKOUSIS, Vagelis (CERN)

**Session Classification:** New Structures - 3D

Contribution ID: 3

Type: **Talk**

## **Comparative doping profile evaluation of Carbonated LGADs**

Using Secondary Ion Mass Spectroscopy, the carbon and boron doping profile distributions of FBK and CNM LGADs are discussed. Obtained results are cross-referenced with previously reported performance of measured devices and conclusions are established with respect to the carbonated process implementation.

**Primary author:** Dr GKOU GKOUSIS, Vagelis (CERN)

**Presenter:** Dr GKOU GKOUSIS, Vagelis (CERN)

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 4

Type: **Talk**

## The Deep Junction LGAD: Concept and Progress [US - afternoon]

*Thursday, 18 November 2021 17:30 (20 minutes)*

Achieving granularity below the 1 mm scale (100 um or less) while maintaining high efficiency, precise timing, and good spatial resolution is a goal of continued R&D on silicon diode Low Gain Avalanche Detectors (LGADs). One approach, proposed by the SCIPP ultrafast sensor R&D group, is to make use of the diode junction to create avalanche-generating fields within the sensor, and then to bury the junction underneath several microns of n+ material to keep surface fields low, and allow for conventional pixelization techniques. In this talk, we will remind the audience of the principles of operation of the Deep Junction LGAD, and present updates relating to its design and fabrication.

**Primary authors:** SCHUMM, Bruce Andrew (University of California,Santa Cruz (US)); Dr MAZZA, Simone Michele (University of California,Santa Cruz (US)); GEE, Carolyn (University of California,Santa Cruz (US)); ZHAO, Yuzhan (University of California,Santa Cruz (US)); ZHAO, Yuzhan (University of California Santa Cruz)

**Presenter:** GEE, Carolyn (University of California,Santa Cruz (US))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 5

Type: **Talk**

## **Towards an All-Fiber Femtosecond Laser System as Excitation Source in the Two-Photon Absorption – Transient Current Technique**

*Wednesday, 17 November 2021 14:45 (20 minutes)*

Degradation of semiconductor detectors when exposed to high radiation rates leads to the necessity of development of tools and methods for characterization of these devices. One of these methods is the Two-Photon Absorption – Transient Current Technique (TPA-TCT) which provides spatially-resolved inspection of semiconductor detectors. This technique exploits the simultaneous absorption of two photons of same energy. Said energy being lower than the band-gap energy of the semiconductor material and higher than half the band-gap energy. The photons are delivered by a femtosecond laser and the absorption occurs only at the focal point of the laser beam focusing optics, allowing localized generation of transient current. In order to avoid single-photon absorption when performing TPA-TCT on silicon detectors, emission wavelengths longer than 1150 nm are required.

Mode-locked Ti:Sa solid state lasers are the current standard optical source of femtosecond pulses. Their natural emission wavelength is out of the 1550 nm region and complex and expensive conversion techniques are required to extend it. Instead, erbium doped fiber laser emission lies naturally in that region. This is why we recently developed a femtosecond fiber laser system of properties and functionalities particularly designed for the TPA-TCT. Said system was based in an all-fiber chirped pulsed amplification architecture seeded by a solitonic passively mode-locked erbium doped fiber oscillator, where the properties of the output pulses from said architecture were configured arbitrarily by free space optics accessories. These accessories allowed selection of pulse energy from  $< 10$  pJ to  $> 10$  nJ, pulse repetition rate from single shot to 8 MHz and pulse duration from 300 fs to 600 fs.

Our current work aims to achieve all these configurable properties through a fully all-fiber system to offer improved robustness and efficiency, while maintaining the required levels of average power and temporal coherence. We are doing this as follows: firstly, the stretching stage will be based in a chirped fiber Bragg grating of tunable dispersion, which will allow the variation of the pulse duration at the output of the source. Secondly, a fiber-pigtailed acousto-optic modulator will be designed and implemented in the system to perform, all-in-one device, the following functionalities: pulse energy selection, pulse repetition rate tunability and emission-to-detection synchronization.

**Primary authors:** Mrs ALMAGRO-RUIZ, Azahara (FYLA LASER); Dr MUÑOZ-MARCO, Héctor (FYLA LASER); Dr PÉREZ-MILLÁN, Pere (FYLA LASER)

**Presenter:** Mrs ALMAGRO-RUIZ, Azahara (FYLA LASER)

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 6

Type: **Talk**

## TI-LGAD characterization using TCT setup at UZH

*Thursday, 18 November 2021 13:00 (20 minutes)*

We present a characterization of the novel Trench-Isolated LGAD (TI-LGAD) technology using a scanning TCT setup. The studied devices belong to the first production of pixelated TI-LGADs at FBK done in the framework of the RD50 collaboration. The TI-LGAD is a variation of the Low-Gain Avalanche Detector (LGAD) in which the segmentation of the detector in pixels is done by etching physical trenches that isolate each pixel. TI-LGADs display the same outstanding performance of LGADs in terms of time resolution, while at the same time allow for a smaller inter-pixel distance, thereby increasing the fill factor, which is a requirement for pixelated LGADs that can provide both precision timing and position resolution (4D pixels). Several structures have been tested before irradiation using a TCT-setup at UZH. A comparison between the results from the different design patterns (number of trenches, depth of trenches, etc.) in this production will be discussed. The plan for an irradiation campaign will be presented.

**Primary author:** SENGER, Matias (Universitaet Zuerich (CH))

**Co-authors:** MACCHIOLO, Anna (Universitaet Zuerich (CH)); KILMINSTER, Ben (Universitaet Zuerich (CH))

**Presenter:** SENGER, Matias (Universitaet Zuerich (CH))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 7

Type: **not specified**

## Registration

*Wednesday, 17 November 2021 08:30 (30 minutes)*

**Session Classification:** organization issues

Contribution ID: **10**

Type: **not specified**

## **Friday 19 Introduction**

*Friday, 19 November 2021 09:00 (10 minutes)*

**Session Classification:** organization issues

Contribution ID: 11

Type: **Talk**

## Performance studies of CNM LGADs on Si-Si and epitaxial wafers irradiated to extreme fluences up to $1e16$ neq/cm<sup>2</sup>

*Thursday, 18 November 2021 12:20 (20 minutes)*

The fast rising signal of LGADs with high signal-to-noise ratio is key to achieve an excellent charge collection and time resolution for Minimum Ionizing Particles (MIPs). The LGAD technology will be used for the HL-LHC in the upgrade of both ATLAS and CMS timing detectors.

A full characterization of CNM LGADs on Si-Si and low resistivity epitaxial wafers irradiated up to  $1e16$  neq/cm<sup>2</sup> will be presented. LGADs are first electrically characterized on probe stations at room and at cold temperature. From the IV and CV characteristics parameters such as leakage current, full and gain layer depletion and breakdown voltages are studied. The rate of self pulses without an external source is measured to determine the maximum operational voltage. Measurements with a Sr-90 radioactive source are performed to study charge collection and timing from MIPs. Other parameters such as noise, jitter and rise time have been studied. The collected charge and time resolution performance is also studied at different bandwidths to understand how these parameters could be eventually affected by the readout.

**Primary authors:** GRIECO, Chiara (Institut de Física d'Altes Energies (IFAE) - Barcelona (ES)); CASTILLO GARCIA, Lucia (IFAE - Barcelona (ES)); GRINSTEIN, Sebastian (IFAE - Barcelona (ES))

**Presenter:** CASTILLO GARCIA, Lucia (IFAE - Barcelona (ES))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 12

Type: **Talk**

## Performance of irradiated RD53A pixel modules with passive CMOS sensors

*Friday, 19 November 2021 10:30 (20 minutes)*

Passive CMOS pixel sensors are investigated in the context of the CMS Phase2 Tracker Upgrade. A prototype production of RD53A compatible pixel sensors was recently completed at LFoundry in 150nm CMOS process. This presentation will focus on the characterization of irradiated and non-irradiated pixel modules, composed by a CMOS passive sensor interconnected to a RD53A chip. The sensors are designed with a pixel cell of 25  $\mu\text{m}$   $\times$  100  $\mu\text{m}$  in case of DC coupled devices and 50  $\mu\text{m}$   $\times$  50  $\mu\text{m}$  for the AC coupled ones. Their performance in terms of charge collection, position resolution, and hit efficiency was studied with measurements performed in the laboratory and with beam tests. The RD53A modules with LFoundry silicon sensors were irradiated to fluences up to  $2 \times 10^{16}$  neq/cm<sup>2</sup>.

**Primary authors:** MACCHIOLO, Anna (Universitaet Zuerich (CH)); JOFREHEI, Arash (Universitaet Zuerich (CH)); RISTIC, Branislav (IPA - ETH Zürich); GLESSGEN, Franz (ETH Zurich (CH)); BACKHAUS, Malte (ETH Zurich (CH)); JIN, Weijie (Universitaet Zuerich (CH))

**Presenter:** MACCHIOLO, Anna (Universitaet Zuerich (CH))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 13

Type: **Talk**

## Gain suppression mechanism in LGADs and SEE studies in a RD53B chip measured with the TPA-TCT method

*Wednesday, 17 November 2021 15:05 (20 minutes)*

The Two Photon Absorption –Transient Current Technique (TPA-TCT) uses fs-pulsed infrared lasers, with photon energies below the silicon band gap. Excess charge carriers are generated mainly in a small volume (approximately  $1\mu\text{m} \times 1\mu\text{m} \times 20\mu\text{m}$ ) around the focal point of the laser beam, enabling resolution in all three spatial directions. Following the initial success of the method, a compact TPA-TCT setup was developed at CERN. The current setup status, first measurements on LGAD sensors with focus on the gain suppression mechanism, measurements on non-irradiated PIN diodes, and Single Event Effect (SEE) studies in a RD53B chip will be presented.

**Primary author:** PAPE, Sebastian (Technische Universitaet Dortmund (DE))

**Co-authors:** CURRAS RIVERA, Esteban (CERN); PALOMO PINTO, Francisco Rogelio (Universidad de Sevilla (ES)); VILA ALVAREZ, Ivan (Instituto de Física de Cantabria (CSIC-UC)); FERNANDEZ GARCIA, Marcos (Universidad de Cantabria and CSIC (ES)); MOLL, Michael (CERN); WIEHE, Moritz Oliver (Austrian Academy of Sciences (AT)); MONTERO SANTOS, Raúl (Universidad del Pais Vasco)

**Presenter:** PAPE, Sebastian (Technische Universitaet Dortmund (DE))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 14

Type: **Talk**

## Present and future development of thin silicon sensors for extreme fluences

Thursday, 18 November 2021 15:40 (20 minutes)

In this contribution, we present a new development of radiation-resistant silicon sensors. This innovative sensor design exploits the recently observed saturation of radiation damage effects on silicon, together with the usage of thin substrates, intrinsically less affected by radiation. The internal multiplication of the charge carriers will be used to overcome the small signals coming from thin substrates.

At the end of 2020, the Fondazione Bruno Kessler (Italy) delivered Low-Gain Avalanche Diodes (LGAD) produced on 25 and 35  $\mu\text{m}$  thick p-type epitaxial substrates, namely the EXFLU0 production: I-V and C-V characterisation of the sensors has been performed before and after irradiation up to  $1\text{E}17 \text{ n}_{\text{eq}}/\text{cm}^2$ , together with signal analysis from an infrared laser stimulus.

The outcome of the laboratory tests and the device-level simulations will be implemented in the EXFLU1 production, in which optimisation of the sensor peripheries and the gain layer responsible for internal multiplication will be pursued. The goal is to pave the way for a new design of silicon sensors that can efficiently operate above fluences of  $\text{n}_{\text{eq}}/\text{cm}^2$ .

**Primary authors:** SOLA, Valentina (Universita e INFN Torino (IT)); ARCIDIACONO, Roberta (Universita e INFN Torino (IT)); ASENOV, Patrick (Universita e INFN, Perugia (IT)); BORGHI, Giacomo (Fondazione Bruno Kessler); BOSCARDIN, Maurizio (FBK Trento); CARTIGLIA, Nicolo (INFN Torino (IT)); CENTIS VIGNALI, Matteo (FBK); CROCI, Tommaso (INFN - National Institute for Nuclear Physics); FERRERO, Marco (Universita e INFN Torino (IT)); GIOACHIN, Giulia (University of Turin); GIORDANENGO, Simona (Istituto Nazionale di Fisica Nucleare); MANDURRINO, Marco (INFN); MENZIO, Luca (Universita e INFN Torino (IT)); MOROZZI, Arianna (INFN, Perugia (IT)); MOSCATELLI, Francesco (IOM-CNR and INFN, Perugia (IT)); PASSERI, Daniele (University & INFN, Perugia (IT)); PATERNOSTER, Giovanni (Fondazione Bruno Kessler); SIVIERO, Federico (Universita e INFN Torino (IT)); TORNAGO, Marta (Universita e INFN Torino (IT))

**Presenter:** SOLA, Valentina (Universita e INFN Torino (IT))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 15

Type: **Talk**

## **Guard-ring optimisation for sensors in LFoundry 150nm CMOS technology for the RD50-MPW3 submission**

*Friday, 19 November 2021 10:10 (20 minutes)*

In high energy physics, the silicon pixel sensors manufactured in commercial CMOS chip fabrication lines have been proven to have a good radiation hardness and spatial resolution. Along with the mature manufacturing techniques and the potential of large throughput provided by the foundries, the so called “passive CMOS” sensor has become an interesting alternative to standard planer sensors.

High and predictable breakdown behaviour is a major design goal for sensors and the guard-ring structure is one factor to optimise. This is especially important for the applications that require higher voltages.

We present a concept of the guard-ring design which can be realised in the LFoundry 150nm CMOS technology. Indicated by TCAD simulations, such design can lead to a higher breakdown voltage by modifying the potential and electric field distribution in the guard-ring area. A number of test-structures have been designed for the RD50-MPW3 submission for verifications and further studies.

**Primary authors:** DINGFELDER, Jochen Christian (University of Bonn (DE)); HEMPEREK, Tomasz (University of Bonn (DE)); ZHANG, Sinuo (University of Bonn (DE))

**Presenter:** ZHANG, Sinuo (University of Bonn (DE))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 16

Type: **Talk**

## Response of Low Gain Avalanche Detector Prototypes to Gamma Radiation

*Thursday, 18 November 2021 10:30 (20 minutes)*

Motivated by the need for fast timing detectors to withstand up to 2 MGy of ionizing dose at the High Luminosity Large Hadron Collider, prototype low gain avalanche detectors (LGADs) have been fabricated in single pad configuration, 2x2 arrays, and related PIN diodes, and exposed to Co-60 sources for study. Devices were fabricated with a range of dopant layer concentrations and, for the arrays, a variety of inter-pad distances and distances from the active area to the edge. Measurements of capacitance versus voltage and leakage current versus voltage have been made to compare pre- and post-irradiation characteristics in gain layer depletion voltage, full bulk depletion voltage, and breakdown voltage. Conclusions are drawn regarding the effects of the gammas both on surface and interface states and on their contribution to acceptor removal through non-ionizing energy loss from Compton electrons or photoelectrons. Comparison of the performances of members of the set of devices can be used to optimize gain layer parameters.

**Primary authors:** HOEFERKAMP, Martin (Department of Physics and Astronomy); HOWARD, Alissa Shirley-Ann (Jozef Stefan Institute (SI)); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); SEIDEL, Sally (University of New Mexico / ATLAS); SORENSON, Josef Daniel (University of New Mexico (US)); YANEZ, Adam (University of New Mexico)

**Presenter:** SORENSON, Josef Daniel (University of New Mexico (US))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 17

Type: **not specified**

## Before and after irradiation test results of the low gain avalanche diodes developed by IHEP in China

*Thursday, 18 November 2021 09:30 (20 minutes)*

The High Granularity Timing Detector (HGTD) project of ATLAS will reduce the pile-up effect in HL-LHC by providing precise time measurement of tracks. The Low-Gain Avalanche Detector (LGAD) with time resolution better than 35(70) ps before(after) irradiation is the key technology which has been studied by many institutes. The Institute of High Energy Physics Chinese Academy of Science (IHEP) has been developing LGAD sensors IHEP-IME with the Institute of Microelectronics of the Chinese Academy of Sciences (IME). So far two versions of IHEP-IME LGAD sensors has been produced, IHEP-IMEv1 and IHEP-IMEv2. IHEP-IMEv1 sensors showed good potential in achieving the HGTD requirements with time resolution better than 60 ps and 4 fC charge collection around 700 V after irradiation. IHEP-IMEv2 sensors have modified doping profile compared with last version, especially focusing on the carbon implantation effect. Sensors with diverse producing process and carbon dose were fabricated and have showed improved performance. This talk will present the test results of IHEP-IMEv2 sensors irradiated with fluences of  $0.8 \times 10^{15}$  neq/cm<sup>2</sup>,  $1.5 \times 10^{15}$  neq/cm<sup>2</sup> and  $2.5 \times 10^{15}$  neq/cm<sup>2</sup> and compare them with results before irradiation. After irradiation, sensors with different carbon dose showed different performance. The effect of carbon implantation will be shown. Low temperature beta test results showed that, after  $2.5 \times 10^{15}$  neq/cm<sup>2</sup> irradiation sensors collect 4 fC at less than 400 V with time resolution better than 50 ps, by far satisfying the requirements.

**Primary author:** JIA, Xuewei (Chinese Academy of Sciences (CN))

**Co-authors:** YAN, Gangping; Mr XU, Gaobo; KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); BARREIRO GUIMARAES DA COSTA, Joao (Chinese Academy of Sciences (CN)); WU, Kewei (Chinese Academy of Sciences (CN)); ZHAO, Mei (Chinese Academy of Sciences (CN)); LI, Mengzhao (Chinese Academy of Sciences (CN)); YANG, Tao (Chinese Academy of Sciences (CN)); LIANG, Zhijun (Chinese Academy of Sciences (CN))

**Presenter:** JIA, Xuewei (Chinese Academy of Sciences (CN))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 19

Type: **Talk**

## Signal-sharing in AC-LGAD (RSD)

*Thursday, 18 November 2021 17:10 (20 minutes)*

We analyzed beam test data from a beam test at FNAL with 120 GeV protons to show the effect of signal sharing in AC-LGAD fabricated by BNL and FBK. The main thrust is the understanding of the signals underneath the metal pads/strips which can't be investigated with laser light which is usually used.

The two topics discussed are the position resolution and the long-range pulse sharing.

**Primary authors:** SEIDEN, Abraham (University of California,Santa Cruz (US)); SADROZIN-SKI, Hartmut (University of California,Santa Cruz (US)); MOLNAR, Adam; TRICOLI, Alessandro (Brookhaven National Laboratory (US)); APRESYAN, Artur (Fermi National Accelerator Lab. (US)); SCHUMM, Bruce Andrew (University of California,Santa Cruz (US)); MADRID, Christopher (Fermi National Accelerator Lab. (US)); PEÑA, Cristián (Fermi National Accelerator Lab. (US)); RYAN, Eric (SCIPP-UC Santa Cruz); D'AMEN, Gabriele (Brookhaven National Laboratory (US)); GIACOMINI, Gabriele (BNL); GOYA, Ikumi (High Energy Accelerator Research Organization (JP)); OTT, Jennifer (University of California,Santa Cruz (US)); HARA, Kazuhiko (University of Tsukuba (JP)); NAKAMURA, Koji (High Energy Accelerator Research Organization (JP)); WONG, Marcus; NIZAM, Mohammad (University of California Santa Cruz); HELLER, Ryan (Fermi National Accelerator Lab. (US)); XIE, S. (FNAL); KITA, Sayuka (University of Tsukuba); LOS, Sergey (FNAL); MAZZA, Simone Michele (University of California,Santa Cruz (US)); UEDA, Tatsuki (University of Tsukuba (JP)); ZHAO, Yuzhan (University of California Santa Cruz)

**Presenter:** WONG, Marcus

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 20

Type: **Talk**

## Capacitance-voltage measurements on AC-LGADs

*Thursday, 18 November 2021 15:00 (20 minutes)*

AC-coupled LGADs, also referred to as resistive silicon detectors (RSDs), rely on a design in which the multiplication layer and  $n^+$  contact are continuous, and only the metal layer is patterned. In AC-LGADs, the signal is capacitively coupled from the continuous, resistive  $n^+$  layer over a dielectric to the metal electrodes. The spatial resolution is not only influenced by the electrode pitch, but also the relative size of the metal electrodes. Knowledge of the capacitances of various sensor regions is crucial for understanding charge sharing in the detector, and for providing input for the design of suitable readout electronics.

We have studied the capacitances of the DC and AC contacts, interpad capacitances, and capacitance of the dielectric between the resistive  $n^+$  layer and top contacts, using AC-LGADs both in small pad array and strip geometries. The impact of measurement parameters, such as serial or parallel mode, grounding of neighboring pads, and frequency will be discussed, while the role of metal electrode size and pitch, as well as  $n^+$  layer doping, on the detector characteristics is investigated.

**Primary author:** Dr OTT, Jennifer (University of California,Santa Cruz (US))

**Co-authors:** SEIDEN, Abraham (University of California,Santa Cruz (US)); SUMMERELL, Andrew (University of California, Santa Cruz); DAS, Ayan (University of California, Santa Cruz); SCHUMM, Bruce Andrew (University of California,Santa Cruz (US)); POTTER, Emma (University of California, Santa Cruz); GONZALEZ, Eric (University of California, Santa Cruz); SADROZINSKI, Hartmut (University of California,Santa Cruz (US)); WONG, Marcus; WILDER, Max (University of California,Santa Cruz (US)); TOURNEBISE, Nikita (University of California, Santa Cruz); MAZZA, Simone Michele (University of California,Santa Cruz (US))

**Presenter:** Dr OTT, Jennifer (University of California,Santa Cruz (US))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 21

Type: **Talk**

## Test results of the first 4H-SiC LGAD from NJU China

*Wednesday, 17 November 2021 09:40 (20 minutes)*

SiC as a typical wide bandgap semiconductor material has the potential to be used in the high energy field thanks to its good performance under radiation environment as well as running without cooling compared with traditional Si devices. Followed by the previous study of the timing performance of the 4H-SiC PIN device, a first 4H-SiC LGAD has been fabricated by Nanjing University (NJU) China. The device has 20 $\mu$ m active layer and 0.15 $\mu$ m gain layer. The preliminary test results of the electrical properties and response from alpha particle will be presented.

**Primary authors:** Dr YANG, Tao (Chinese Academy of Sciences (CN)); Dr LIU, Qing (Nanjing University); LU, Hai (Nanjing University); SHI, Xin (Chinese Academy of Sciences (CN))

**Presenters:** Dr YANG, Tao (Chinese Academy of Sciences (CN)); Dr LIU, Qing (Nanjing University)

**Session Classification:** Defect and Material Characterization

Contribution ID: 22

Type: **not specified**

## Solid state electron multiplier

*Friday, 19 November 2021 12:30 (20 minutes)*

The next generation of inner tracking detectors will require spatial resolution down to 10 $\mu$ m, radiation hardness above 10e16Neq/cm<sup>2</sup> together with a temporal resolution in the order to tens of pico seconds.

To face these challenges and overcome limitations of today's technologies, an alternative approach to internal gain through the use of a radiation sensitive doping layer is investigated and simulated. An enhanced radiation hardness is foreseen by implementing additional metallic structures in the sensor substrate. These can be biased in such a way that localized high electric field are created. In this talk, TCAD and Garfield++ simulations of this proposed structure will be presented along with plans of fabrication. Gain in excess of a factor 10 can be achieved and the temporal response is similar to those of LGADs.

**Primary authors:** HALVORSEN, Marius Mahlum (University of Oslo (NO)); GKOU GKOUSIS, Vagelis (CERN); COCO, Victor (CERN)

**Presenter:** HALVORSEN, Marius Mahlum (University of Oslo (NO))

**Session Classification:** New Structures - 3D

Contribution ID: 23

Type: Talk

## Performance studies of Low Gain Avalanche Detectors (LGAD) coupled to the Timepix3 ASIC

Friday, 19 November 2021 09:30 (20 minutes)

In this work the properties of  $200\ \mu\text{m}$  thick highly pixelated LGAD sensors bonded to a Timepix3 readout ASIC were characterised for the first time. Recent advances in the control of the LGAD fabrication process by Micron Semiconductor Ltd has allowed the manufacture of highly segmented devices where each pixel has an internal gain. Devices with  $55\ \mu\text{m}$  pixel with  $5\ \mu\text{m}$  Junction Termination Element (JTE),  $110\ \mu\text{m}$  pixel with  $10\ \mu\text{m}$  JTE and  $110\ \mu\text{m}$  pixel with  $20\ \mu\text{m}$  JTE were bump bonded to a Timepix3 readout ASIC and characterised with a micro-focus monochromatic  $15\ \text{keV}$  X-ray beam.

Figure 1 shows the response profile from the  $110\ \mu\text{m}$  pixel device from the X-ray beam as the pixel array was moved relative to the beam for the pixel of interest (PoI), and its neighboring pixels (left-hand side and right-hand side pixels). The quantity plotted is the integrated time-over-threshold (ToT) for the pixel from an illumination of 5 seconds per illumination position. This corresponds to the total collected charge at the pixel electrode. The PoI boundaries can be seen between motor positions  $-17.55$  and  $17.44\ \text{mm}$ . A region of gain in the middle of each pixel can clearly be observed. The gain of factor approximately three can be extracted directly from the pixel profile. Figure 2 shows a 2D map obtained by a raster scan of the pixel array recording the integrated ToT from the PoI. The regions of gain and no gain are clearly visualized. Results obtained suggest a good degree of understanding of the fabrication processes involved but demonstrated the limitations of the standard LGAD process with a JTE for small pixel. This work will report on the characterisation of fabricated devices and suggest mechanisms for mitigating the effects of limited gain regions for small sized pixel.

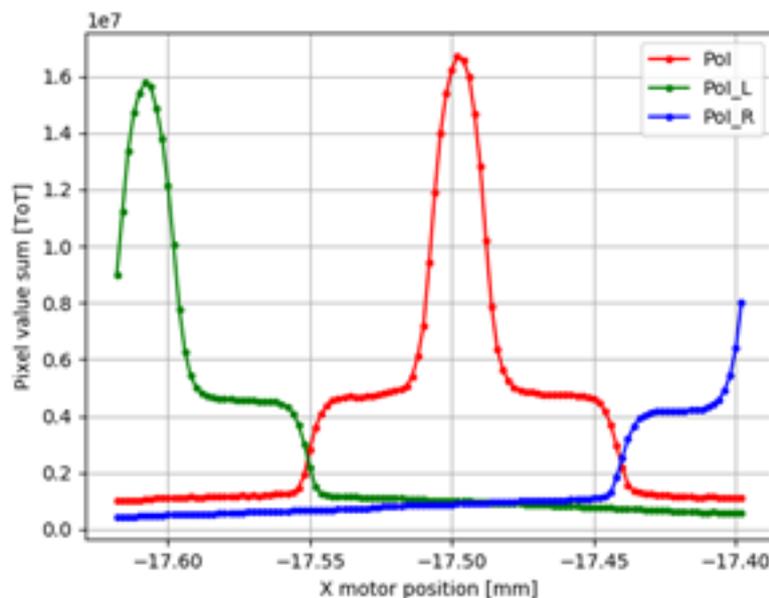


Figure 1: Figure 1. Pixel response as a function of incident x-ray beam for a  $110\ \mu\text{m}$  pixel pitch,  $10\ \mu\text{m}$  JTE Timepix3 LGAD device.

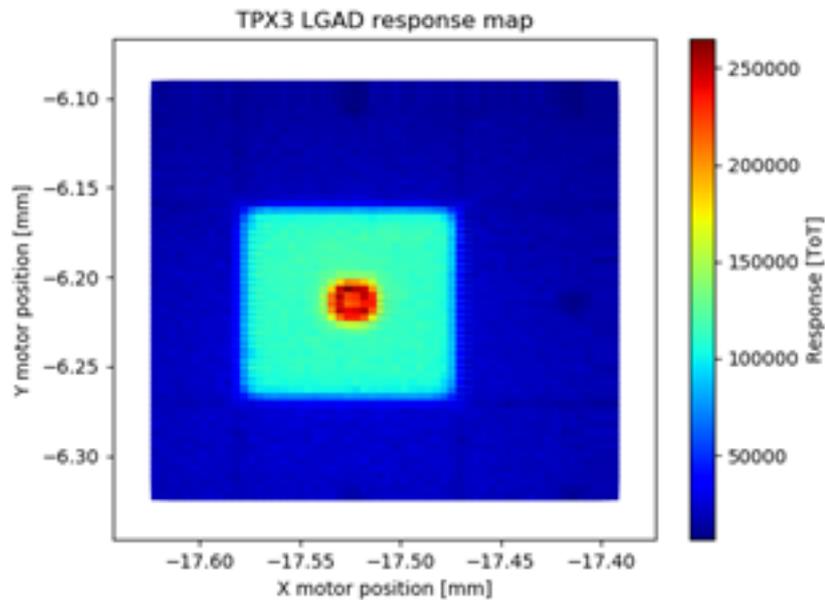


Figure 2: Figure 2. 2D pixel response map for a 110  $\mu\text{m}$  pixel pitch, 10  $\mu\text{m}$  JTE Timepix3 LGAD device

**Primary authors:** Dr MANEUSKI, Dima (University of Glasgow (GB)); EKLUND, Lars (Uppsala University (SE)); LOMBIGIT, Lojius (University of Glasgow); Dr BULLOUGH, Mark (Micron Semiconductor Ltd); MOFFAT, Neil (Consejo Superior de Investigaciones Cientificas (CSIC) (ES)); TARTONI, Nicola; Dr BATES, Richard (University of Glasgow (GB))

**Presenter:** Dr MANEUSKI, Dima (University of Glasgow (GB))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 24

Type: **Talk**

## Development of 2D GaN and 3D SiC detectors

*Wednesday, 17 November 2021 09:20 (20 minutes)*

Wide band gap semiconductors, such as GaN and SiC, have exhibited notable advantages, when they are applied as a nuclear radiation detector in a harsh environment of high temperature or strong radiation field. Recently a GaN alpha-particle detector of p-i-n structure was fabricated on a sapphire substrate in this article. The intrinsic layer of the detector was isoelectronic Al-doped GaN with the thickness of 10  $\mu\text{m}$ . The leakage current of the detector remained below 10 pA when the reverse voltage increased from 0 to 40 V, which proved that it had a better crystal quality than the detector based on undoped i-GaN layer, of which the dark current was 10 nA at -40 V. The i-GaN layer would be fully depleted at -48 V. With the remarkable improvement of electrical properties, the charge collection efficiency (CCE) of the full depleted detector in this article was as high as 99%, while the energy resolution was about 4%. Further, in order to obtain better time resolution characteristics, the 3D SiC detector was developed using a laser drilling method. The SiC single crystal was about 350 microns, and the diameter of the holes are 50 microns and 100 microns, respectively. Then Indium was filled into the holes. The basic electrical characteristics have been mastered by I-V and C-V tests.

**Primary authors:** Dr WANG, Congcong (Institute of High Energy Physics Chinese Academy of Sciences); Prof. LIANG, Hongwei (Dalian University of Technology); Dr ZHAO, Mei (Institute of High Energy Physics Chinese Academy of Sciences); Dr XU, Ruiliang; Dr SHI, XIn (Institute of High Energy Physics Chinese Academy of Sciences); Dr XIA, Xiaochuan (Dalian University of Technology); Dr TAN, Yuhang (Institute of High Energy Physics Chinese Academy of Sciences); Dr ZHANG, Zhengzhong (Dalian University of Technology)

**Presenters:** Prof. LIANG, Hongwei (Dalian University of Technology); Dr SHI, XIn (Institute of High Energy Physics Chinese Academy of Sciences); Dr XIA, Xiaochuan (Dalian University of Technology); Dr ZHANG, Zhengzhong (Dalian University of Technology)

**Session Classification:** Defect and Material Characterization

Contribution ID: 25

Type: **Talk**

## **Non-Ionizing Energy Loss: Geant4 simulations towards more advanced NIEL concept for radiation damage modelling and prediction**

*Wednesday, 17 November 2021 10:00 (20 minutes)*

The Non Ionizing Energy Loss (NIEL) concept is used to compare and scale the damage impacted on semiconductor devices in different radiation fields. A particular weakness of the present NIEL concept consists in the inability to predict the different formation rates of cluster and point defects in the silicon (Si) crystal for different particles and particle energies. NIEL gives only the total energy imparted in displacements and does not separate between energy going in point defect formation and energy going into cluster formation. To be more specific, differences between radiation damage produced by neutrons and protons of the same displacement energies (i.e. damage parameters normalized to the NIEL) has been observed experimentally. In this work, we present the results of Geant4 and FLUKA simulations in order to investigate proton/neutron differences from first principles. The interactions of neutrons and protons of different energies in a 100 um thick Si target were studied and the kinematics of the Primary Knock-on Atoms (PKA) has been characterized. The dependence on NIEL on the target recoil energy is explored along with its dependence on secondary particle production from inelastic collisions.

**Primary authors:** HIMMERLICH, Anja (CERN); SUBERT, Vendula (Hamburg University (DE)); DAWSON, Ian (University of London (GB)); MOLL, Michael (CERN); GURIMSKAYA, Yana (Universite de Geneve (CH))

**Presenter:** SUBERT, Vendula (Hamburg University (DE))

**Session Classification:** Defect and Material Characterization

Contribution ID: 26

Type: **Talk**

## Defect characterization studies on highly irradiated Low Gain Avalanche Detectors

*Wednesday, 17 November 2021 11:30 (20 minutes)*

The operation of Low Gain Avalanche Detectors (LGADs) in the harsh radiation environment of the CERN-LHC is limited by the disappearance of the gain at particle fluences higher than  $2E+15$  cm<sup>-2</sup> due to the so-called Acceptor Removal Effect (ARE). Thereby radiation induced defects inside the highly doped LGAD multiplication layer are created, like the boron-interstitial oxygen-interstitial (BiOi), that deactivate the active boron dopant and reduce the capability for charge multiplication. However, based on fundamental defect models, BiOi formation alone does not explain the observed ARE in the highly B-doped LGAD layer. Here we present defects characterization studies on LGADs using Deep-Level-Transient-Spectroscopy (DLTS) as well as Thermally Stimulated Current technique (TSC). Besides an overview about defects that were created, we will also discuss limitations of the characterization techniques applied to LGADs caused by e.g. charge multiplication effects, device geometries as well as internal defect induced electric fields.

**Primary authors:** HIMMERLICH, Anja (CERN); LIAO, Chuan (Hamburg University (DE)); FRETWURST, Eckhart (Hamburg University (DE)); PINTILIE, Ioana (NIMP Bucharest-Magurele, Romania); SCHWANDT, Joern (Hamburg University (DE)); MAKARENKO, Leonid (Belarusian state University); MOLL, Michael (CERN); CASTELLO-MOR, Nuria (Universidad de Cantabria, CSIC, Instituto de Fisica de Cantabria IFCA, (ES)); SUBERT, Vendula (Hamburg University (DE)); GURIMSKAYA, Yana (Universite de Geneve (CH)); CURRAS RIVERA, Esteban (CERN)

**Presenter:** HIMMERLICH, Anja (CERN)

**Session Classification:** Defect and Material Characterization

Contribution ID: 27

Type: **Talk**

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

*Friday, 19 November 2021 14:50 (20 minutes)*

The CMS detector will be upgraded to face a 10-fold increase in integrated luminosity for the High-Luminosity LHC era. Its endcap calorimeters will be replaced by the high-granularity calorimeter (HGICAL). With its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels, HGICAL will facilitate the use of particle-flow calorimetry. Silicon pad sensors will be used for high radiation regions, covering a total area of 620 m<sup>2</sup>, where it is expected to reach integrated neutron fluences of 10<sup>16</sup> neq/cm<sup>2</sup> and doses of 1.5 MGy. The silicon sensors are processed on 8-inch wafers with three different thicknesses (300, 200, 120 μm), and cut into hexagonal shape for tiling and for optimal use of the wafer area. Each sensor is segmented into several hundred cells of hexagonal shape of 0.5 to 1.1 cm<sup>2</sup> in size, each of which is read out individually. In addition to the main sensors, the full wafer hosts small sized test structures used for quality assurance and radiation-tolerance tests. The talk will focus on radiation-tolerance studies performed with the hexagonal 8-inch sensors irradiated to fluences up to 10<sup>16</sup> neq/cm<sup>2</sup> at the novel neutron irradiation facility at Rhode Island Nuclear Science Center (RINSC, US). Using the ARRAY system (a customised probe and switch card system), their electrical properties in terms of pad leakage currents and capacitances have been measured for the first time, after neutron irradiation both without and with additional beneficial annealing. We present the results of those measurements, hereby qualifying the RINSC neutron irradiation facility and showing that the measured electrical properties of the HGICAL silicon sensors after irradiation meet expectations.

**Primary authors:** SICKING, Eva (CERN); HALUSZCZAK, Oliwia Agnieszka (Wroclaw University of Science and Technology (PL)); QUAST, Thorben (CERN)

**Presenter:** HALUSZCZAK, Oliwia Agnieszka (Wroclaw University of Science and Technology (PL))

**Session Classification:** New Structures - 3D

Contribution ID: 28

Type: **Talk**

## AC-coupled LGAD development by IHEP for future lepton collider

*Thursday, 18 November 2021 14:40 (20 minutes)*

The Flavor physics program is one of the important topics for future lepton collider projects. In order to explore the full potential of the flavor physics program, a time-of-flight detector is needed to perform particle identification at an energy range from 1GeV to 5GeV.

We propose a time-of-flight detector based on AC-coupled LGAD technology, which has high timing resolution and spatial resolution. It can serve as a time-of-flight detector and outer layer of the tracking detector.

The Institute of High Energy Physics Chinese Academy of Science (IHEP) developed a prototype of AC-coupled LGAD detector. According to the laser test results, it can reach 5-10 microns spatial resolution using 2\*2 AC pads array design with a millimeter level pitch. The spatial resolution and charge sharing effect have been studied with different n+ doping.

**Primary authors:** ZHAO, Mei (Institute of High Energy Physics Chinese Academy of Sciences); LIANG, Zhijun (Chinese Academy of Sciences (CN)); LI, Mengzhao (Chinese Academy of Sciences (CN)); ZHANG, Xiaoxu (Nanjing University (CN)); FAN, Yunyun (Chinese Academy of Sciences (CN))

**Presenters:** LIANG, Zhijun (Chinese Academy of Sciences (CN)); LI, Mengzhao (Chinese Academy of Sciences (CN))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 29

Type: **Talk**

## Time Resolution Studies of Low Gain Avalanche Detectors Fabricated at Micron Semiconductor Ltd.

*Thursday, 18 November 2021 11:40 (20 minutes)*

Low Gain Avalanche Detectors (LGADs) are a promising technology for high energy physics experiments, since they can potentially offer spatial resolution down to sub 100  $\mu m$  and temporal resolution below 100  $ps$  simultaneously. Thanks to these properties, these devices are considered for the upgrades of the ATLAS, CMS, and LHCb experiment at CERN.

This work will focus on timing resolution studies of recent devices produced by the University of Glasgow and Micron Semiconductor Ltd. These devices will be compared to those produced at CNM Barcelona. Specifically, details of the produced devices will be introduced and the Sr-90 experimental setup to measure the timing resolution will be described. Time resolution for Micron-Glasgow devices in the region of 55  $ps$  was achieved. Specifically, the measurement results for both CNM and Micron-Glasgow devices show temperature and bias voltage dependence of timing resolution and the details will be discussed. Finally, the outlook for future developments and studies will be presented.

**Primary authors:** MORIYA, Ryuji; MOFFAT, Neil (Consejo Superior de Investigaciones Cientificas (CSIC) (ES)); BATES, Richard (University of Glasgow (GB)); MANEUSKI, Dima (University of Glasgow (GB)); BULLOUGH, Mark (Micron Semiconductor Ltd); WILLIAMS, Mark Richard James (The University of Edinburgh (GB))

**Presenter:** MORIYA, Ryuji

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 30

Type: **Talk**

## Time resolution of an irradiated 3D silicon pixel detector

*Friday, 19 November 2021 12:10 (20 minutes)*

We report on the measurements of time resolution for double-sided 3D pixel sensors with a single cell of  $50\ \mu\text{m} \times 50\ \mu\text{m}$  and thickness of  $285\ \mu\text{m}$ , fabricated at IMB-CNM and irradiated with reactor neutrons from  $8 \times 10^{14}\ \text{MeV}\ n_{\text{eq}}/\text{cm}^2$  to  $1.0 \times 10^{16}\ \text{MeV}\ n_{\text{eq}}/\text{cm}^2$ .

Measurements were conducted using a radioactive source at a temperature of  $-20$  and  $20\ \text{°C}$  in a bias voltage range of 50-250 V. The reference time was provided by an LGAD detector produced by Hamamatsu. The results obtained are compared to measurements conducted prior to irradiation.

**Primary author:** DE SIMONE, Dario (Universitaet Zuerich (CH))

**Co-authors:** PELLEGRINI, Giulio (Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)); MANNA, Maria (Centro Nacional de Microelectronica - CNM-IMB-CSIC); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); BETANCOURT, Christopher (Universitaet Zuerich (CH))

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

**Session Classification:** New Structures - 3D

Contribution ID: 31

Type: **Talk**

## Investigation of the BiOi defect in EPI and Cz silicon diodes using Thermally Stimulated current (TSC) and Thermally Stimulated Capacitance (TS-Cap)

*Wednesday, 17 November 2021 11:50 (20 minutes)*

In this work the Thermally Stimulated Techniques including TS-Current (TSC) and TS-Capacitance (TS-Cap) has been used to study the properties of the radiation induced BiOi defect complex by 6 MeV electrons. Two different types of diodes manufactured on p-types epitaxial-(EPI) and czochralski-CZ silicon with a resistivity of about 10 Wcm were irradiated with fluence values in the range between  $1 \times 10^{15} \text{ cm}^{-2}$  and  $6 \times 10^{15} \text{ cm}^{-2}$ . In order to evaluate the parameter of BiOi defect (activation energy, capture cross section, concentration) from the TSC and TS-Cap measurements the well known electric field enhance emission effect (Poole Frenkel effect) in 3D version had to be considered and was included in the simulation software. The changes of the position dependent electric field strength, the effective doping profile as well as the occupation of the defect during the BiOi emission were simulated as function of temperature in the relevant range. In addition, the macroscopic properties (dark current and effective doping concentration) were extracted from current-voltage (I-V) and capacitance-voltage (C-V) measurements at 20°C for the EPI- and Cz-diodes. Furthermore, isothermal annealing studies at 80°C for annealing times between 0 min and 120 min had been performed. The results will be presented and discussed.

**Primary authors:** HIMMERLICH, Anja (CERN); Mr LIAO, Chuan (Hamburg University (DE)); FRETWURST, Eckhart (Hamburg University (DE)); GARUTTI, Erika (Hamburg University (DE)); PINTILIE, Ioana (NIMP Bucharest-Magurele, Romania); SCHWANDT, Joern (Hamburg University (DE)); MAKARENKO, Leonid (Belarusian state University); MOLL, Michael (CERN); CASTELLO-MOR, Nuria (Universidad de Cantabria, CSIC, Instituto de Fisica de Cantabria IFCA, (ES)); GURIMSKAYA, Yana (CERN)

**Presenter:** Mr LIAO, Chuan (Hamburg University (DE))

**Session Classification:** Defect and Material Characterization

Contribution ID: 32

Type: **Talk**

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

*Friday, 19 November 2021 15:10 (20 minutes)*

The CMS detector will be upgraded to face a 10-fold increase in integrated luminosity for the High-Luminosity LHC era. Its endcap calorimeters will be replaced by the high-granularity calorimeter (HGICAL). With its unprecedented transverse and longitudinal readout/trigger segmentation, with more than 6M readout channels, HGICAL will facilitate the use of particle-flow calorimetry. Silicon pad sensors will be used for high radiation regions, covering a total area of 620 m<sup>2</sup>, where it is expected to reach integrated neutron fluences of  $10^{16}$  neq/cm<sup>2</sup> and doses of 1.5 MGy. The silicon sensors are processed on 8-inch wafers with three different thicknesses (300, 200, 120  $\mu$ m), cut into hexagonal shape for tiling and for optimal use of the wafer area. Each sensor is segmented into several hundred cells of hexagonal shape of 0.5 to 1.1 cm<sup>2</sup> in size, each of which is read out individually. In addition to the main sensors, the full wafer hosts small sized test structures used for quality assurance and radiation-hardness tests. We present the results of an ongoing radiation-tolerance testing program of the bulk material of HGICAL prototype silicon sensors that has been carried out with test structure diodes irradiated up to  $10^{16}$  neq/cm<sup>2</sup> in the JSI Ljubljana reactor. This talk will focus on the annealing behaviour of the bulk material. Results on the electrical characterisation in terms of capacitance and leakage current measurements will be presented as well as measurements of the charge collection efficiency using infrared TCT as a function of annealing time.

**Primary author:** KIESELER, Jan (CERN)**Presenter:** KIESELER, Jan (CERN)**Session Classification:** New Structures - 3D

Contribution ID: 34

Type: **Talk**

## Bulk damage study in gamma irradiated n-in-p silicon diodes

*Friday, 19 November 2021 12:50 (20 minutes)*

In this presentation the relation between the leakage current and full depletion voltage to TID will be shown. From the measured I-V and C-V characteristics it is obvious that the dependence of the leakage current with respect to the TID is increasing linearly. On the other hand, the full depletion voltage and thus also the effective doping concentration shows a decreasing trend with higher TID. This gradual decrease of the effective doping concentration could be interpreted as acceptor removal or donor introduction.

For the purpose of this study 14 diodes fabricated together with the main ATLAS pre-production sensors on n-in-p standard float zone silicon wafers with the initial resistivity of about  $3 \text{ k} \cdot \text{cm}$  were irradiated by  $^{60}\text{Co}$  gamma rays up to a total dose of 366 MRad in approximate charge particle equilibrium. The samples consist of several test structures including  $8 \times 8 \text{ mm}^2$  diodes which enables the study of leakage current and bulk capacitance. The advantage of using these diodes is the presence of contact pads on the guard ring which allows it to be grounded during I-V and C-V measurements and thus makes it possible to separate the bulk and surface current. The samples were measured before irradiation and after gamma irradiation both before and after annealing.

**Primary authors:** LATONOVA, Vera (Czech Academy of Sciences (CZ)); MIKESTIKOVA, Marcela (Czech Academy of Sciences (CZ)); ZATOCILOVA, Iveta (Charles University (CZ))

**Co-authors:** KROLL, Jiri (Czech Academy of Sciences (CZ)); KVASNICKA, Jiri (Czech Academy of Sciences (CZ)); FEDERICOVA, Pavla (Czech Academy of Sciences (CZ)); DUDAS, Denis (Czech Technical University (CZ)); PRIVARA, Radek (Palacky University (CZ))

**Presenter:** LATONOVA, Vera (Czech Academy of Sciences (CZ))

**Session Classification:** New Structures - 3D

Contribution ID: 35

Type: **Talk**

## Soft X-Ray Low Gain Avalanche Detectors with 55um pitch for Imaging Applications using Timepix4 ASIC

*Friday, 19 November 2021 09:10 (20 minutes)*

The AC-LGAD technology has been shown to be a very promising technology within HEP due to its extremely good time resolution and 100% fill factor. This technology is proposed to be used with the Timepix4 ASIC for imaging applications using soft X-rays. The fabrication of these devices is underway. Simulation studies have been performed to optimize the technology for a 55um pixel pitch and a radiation damage study has been performed in order to understand the performance of these devices within HEP experiments and to study the surface damage effects for soft-x-ray detection.

**Primary authors:** PELLEGRINI, Giulio (Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)); VILLEGAS DOMINGUEZ, Jairo Antonio (Consejo Superior de Investigaciones Cientificas (CSIC) (ES)); MOFFAT, Neil (Consejo Superior de Investigaciones Cientificas (CSIC) (ES))

**Presenter:** MOFFAT, Neil (Consejo Superior de Investigaciones Cientificas (CSIC) (ES))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 36

Type: **Talk**

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

*Wednesday, 17 November 2021 10:20 (20 minutes)*

We report on results of the irradiation bulk damage study in gamma irradiated standard float zone p-type silicon diodes. The study includes three types of diodes with different resistivities by CNM, HPK and IFX manufactures. The diodes were irradiated by Cobalt-60 gamma source up to 3.66 MGy in approximate charged particle equilibrium and then annealed for 80 minutes at 60°C. Electrical properties of diodes are characterized by measuring IV and CV curves of each diode before and after irradiation and annealing. During all the measurements we were able to separate surface and bulk currents by contacting the guard ring of each diode. The measurements of n-in-p type diodes show increasing linear-looking dependence of leakage current and decreasing linear-looking dependence of full depletion voltage and effective doping concentration on TID.

**Primary authors:** ZATOCILOVA, Iveta (Charles University (CZ)); MIKESTIKOVA, Marcela (Czech Academy of Sciences (CZ)); LATONOVA, Vera (Czech Academy of Sciences (CZ))

**Co-authors:** KROLL, Jiri (Czech Academy of Sciences (CZ)); PRIVARA, Radek (Palacky University (CZ)); DUDAS, Denis (UJP Praha); KVASNICKA, Jiri (Czech Academy of Sciences (CZ)); FEDERICOVA, Pavla (Czech Academy of Sciences (CZ))

**Presenter:** ZATOCILOVA, Iveta (Charles University (CZ))

**Session Classification:** Defect and Material Characterization

Contribution ID: 37

Type: **Talk**

## Update on radiation damage investigation of epitaxial p-type silicon using Schottky and pn-junction diodes

*Wednesday, 17 November 2021 10:40 (20 minutes)*

This project focuses on the investigation of trap energy levels introduced by radiation damage in epitaxial p-type silicon. Using 6-inch wafers of various boron doping concentrations ( $1e13$ ,  $1e14$ ,  $1e15$ ,  $1e16$ , and  $1e17$  cm<sup>-3</sup>) with a 50 $\mu$ m epitaxial layer, multiple iterations of test structures consisting of Schottky and pn-junction diodes of different sizes and flavours are being fabricated at RAL and Carleton University.

In this talk, details on the latest iterations of diode fabrication on high and low-resistivity wafers and electrical measurements of the structures will be given. IV and CV scans of fabricated test structures have been performed and cross-checked between institutes, the results of which will be presented. Emphasis will be placed on approaches to reduce the surface component of the leakage current that could potentially be applicable to the foreseen irradiated sample measurements. Furthermore, process and electrical simulations of the diodes fabricated from the high resistivity wafer will be shown.

Finally, the on-going activities for charge collection measurements, the next round of wafer processing, and proposed plans for irradiation in the coming months, will be reviewed.

**Primary author:** VILLANI, Enrico Giulio (Science and Technology Facilities Council STFC (GB))

**Co-authors:** KLEIN, Christoph Thomas (Carleton University (CA)); KOFFAS, Thomas (Carleton University (CA)); MCCORMICK, Angela (Carleton University (CA)); TARR, Garry (Carleton University (CA)); VANDUSEN, Robert (Carleton University (CA)); WILSON, Fergus (Science and Technology Facilities Council STFC (GB)); ALLPORT, Philip Patrick (University of Birmingham (UK)); GONELLA, Laura (University of Birmingham (UK)); KOPSALIS, Ioannis (University of Birmingham (GB)); MANDIC, Igor (Jozef Stefan Institute (SI)); CHEN, Yebo (IHEP (CN)); LIU, Peilian (IHEP (CN))

**Presenter:** KLEIN, Christoph Thomas (Carleton University (CA))

**Session Classification:** Defect and Material Characterization

Contribution ID: 38

Type: **Talk**

## Collected charge, gain and jitter measurement of unirradiated LGADs from Teledyne e2v

*Thursday, 18 November 2021 09:50 (20 minutes)*

To suppress the pile-up expected at High-Luminosity LHC, timing information can be assigned to particle tracks. In order to implement this technique, track timing resolution of the order of tens of picoseconds is required over the lifetime of the detector. Low Gain Avalanche Detectors (LGADs) were selected as the basis for the timing detectors at the HL-LHC, offering suitable timing resolution. While the development and testing of sensors is undertaken by the University of Oxford, the University of Birmingham, the Rutherford Appleton Laboratory, and the Open University, production of LGAD sensors is done by Teledyne e2v. This collaboration focuses on developing ultra-fast silicon detectors with characteristics suitable for the implementation in the HL-LHC High Granularity Timing Detector, with the potential to be used in other high-energy experiments as well. In this talk we will present results from one of the LGAD wafers produced by Teledyne e2v, focusing on the measurements of charge collected and gain, including jitter measurements, using a system based on a ps laser source and SPICE characterization of the RF amplifiers used. Details and plans for future tests will also be discussed.

**Primary author:** GAZI, Martin

**Co-authors:** ALLPORT, Philip Patrick (University of Birmingham (UK)); BORTOLETTO, Daniela (University of Oxford (GB)); HYNDS, Daniel (University of Oxford (GB)); GONELLA, Laura (University of Birmingham (UK)); JORDAN, Douglas; MCMAHON, Stephen (Science and Technology Facilities Council STFC (GB)); KOPSALIS, Ioannis (University of Birmingham (GB)); MULVEY, Jonathan (University of Birmingham); PLACKETT, Richard (University of Oxford (GB)); STEFANOV, Konstantin (University of Oxford (GB)); VILLANI, Enrico Giulio (Science and Technology Facilities Council STFC (GB))

**Presenter:** GAZI, Martin

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 39

Type: **Talk**

## Upgraded Proton Irradiation Site at Bonn University

*Friday, 19 November 2021 13:10 (20 minutes)*

The proton irradiation site at Bonn University has been introduced at previous RD50 workshops. Recently, the setup has been upgraded to minimize fluence fluctuations on the DUT and enable flexible irradiation procedures. The Bonn Isochronous Cyclotron delivers 14 MeV (~12.5 MeV on-device) protons with typical beam currents of 1 nA and beam diameters of a few millimeters to the setup. Enhanced beam diagnostics as well as R/O electronics allow for online monitoring across several orders of magnitude of beam currents with a relative uncertainty of approx. 1%.

Devices are irradiated by being scanned through the beam in a row-wise pattern while housed in a thermally-insulated cooling box at approx. -20 °C to minimize annealing. Online monitoring of the beam current at extraction allows to measure the fluence per scanned row, ensuring homogeneous irradiation, with an accuracy of a few %. The setup allows to power and readout DUTs during irradiation as well as pause irradiations for in-between measurements. Latest irradiations of thin LFoundry test structures yield a proton hardness factor with reduced uncertainty, compatible with previous measurements and simulation, enabling to irradiate up to  $10^{16}$  n<sub>eq</sub>/cm<sup>2</sup> within a few hours. The setup, its reworked components, the irradiation procedure as well as the latest proton hardness factor measurements are presented in this talk.

**Primary authors:** DINGFELDER, Jochen Christian (University of Bonn (DE)); POHL, David-Leon (University of Bonn (DE)); Dr SAUERLAND, Dennis (University of Bonn); WERMES, Norbert (University of Bonn (DE)); WOLF, Pascal (University of Bonn (DE))

**Presenter:** WOLF, Pascal (University of Bonn (DE))

**Session Classification:** New Structures - 3D

Contribution ID: 40

Type: **Talk**

## Evaluation of MOS and Gated Diode Devices of the ATLAS ITk Test Chip

*Friday, 19 November 2021 11:20 (20 minutes)*

The new ATLAS Inner Tracker (ITk) sub-detector is necessitated by the impending High Luminosity Large Hadron Collider (HL-LHC) upgrade. This replacement is part of the phase-II upgrade programme for the HL-LHC which will see a sevenfold increase in peak instantaneous luminosity with a total ionizing dose of 53 MRad. The fully solid state ITk will employ silicon n+-in-p microstrip sensors in the outer layers of the tracking detector. The main sensors are manufactured on 6" diameter silicon wafers. Periphery wafer area (halfmoons) to which the main sensor does not extend serves as convenient venues for the implementation of test devices. The primary utility of the test devices is Quality Assurance (QA), that is, the monitoring of the consistency and reliability of the manufacturing process. A Metal-Oxide-Semiconductor (MOS) and Gate-Controlled Diode (GCD) are two such test devices aimed at characterizing the surface oxide and silicon-oxide interface. Measurement procedures and parameters for QA are established for these devices and the viability of these tests for gamma irradiated samples is evaluated. The suitability of these devices to further monitor the strip sensor fabrication process is also investigated.

**Primary author:** Mr STAATS, Ezekiel (Carleton University (CA))

**Co-authors:** JESSIMAN, Callan (Carleton University (CA)); ALLPORT, Philip Patrick (University of Birmingham (UK)); FADEYEV, Vitaliy (University of California,Santa Cruz (US)); FLETA, Celeste (Instituto de Microelectrónica de Barcelona, Centro Nacional de Microelectrónica (ES)); KLEIN, Christoph Thomas (Carleton University (CA)); KOFFAS, Thomas (Carleton University (CA)); KOPSALIS, Ioannis (University of Birmingham (GB)); KROLL, Jiri (Czech Academy of Sciences (CZ)); SCHARF, Christian (Humboldt University of Berlin (DE)); MIKESTIKOVA, Marcela (Czech Academy of Sciences (CZ)); ULLAN, Miguel (CNM-Barcelona (ES)); UNNO, Yoshinobu (High Energy Accelerator Research Organization (JP))

**Presenter:** Mr STAATS, Ezekiel (Carleton University (CA))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 41

Type: **Talk**

## RSD2, the new production of AC-LGADs at FBK

*Thursday, 18 November 2021 15:20 (20 minutes)*

In this contribution we present RSD2, the second production of Resistive AC-Coupled Silicon Detectors (RSD), a new frontier in 4D particle tracking through Silicon detectors with internal gain and 100% fill-factor. RSD are *n-in-p* LGAD-based detectors characterized by three key-elements: (i) a continuous multiplication implant, without any segmentation, (ii) a resistive *n*-cathode and (iii) a dielectric coupling layer deposited on top. Thanks to the internal gain and the capacitive readout, RSD allow to reach almost the same timing performances of traditional LGADs, with high performances in space reconstruction. Starting from the very good results of the previous run, RSD1, we will introduce some important details about the new technological and physical parameters implemented in RSD2, designed at INFN Torino and manufactured in 2021 by Fondazione Bruno Kessler (FBK) in Trento. To this aim, TCAD simulations, layout design and a full electrical characterizations will be provided.

**Primary author:** MANDURRINO, Marco (INFN)

**Co-authors:** Prof. ARCIDIACONO, Roberta (INFN and UPO); Mr BISHT, Ashish (FBK and UniTn); Dr BORGHI, Giacomo (FBK and TIFPA); Dr BOSCARDIN, Maurizio (FBK and TIFPA); Dr CARTIGLIA, Nicolo (INFN); Dr CENTIS VIGNALI, Matteo (FBK and TIFPA); Prof. DALLA BETTA, Gian-Franco (UniTn and TIFPA); Dr FERRERO, Marco (UPO); Dr FICORELLA, Francesco (FBK and TIFPA); Dr HAMMAD ALI, Omar (FBK and TIFPA); Dr MARTINEZ ROJAS, Alejandro David (INFN); Mr MENZIO, Luca (INFN and UniTo); Prof. PANCHERI, Lucio (UniTn and TIFPA); Dr PATERNOSTER, Giovanni (FBK and TIFPA); Mr SIVIERO, Federico (INFN and UniTo); Dr SOLA, Valentina (INFN); Mrs TORNAGO, Marta (INFN and UniTo)

**Presenter:** MANDURRINO, Marco (INFN)

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 42

Type: **not specified**

## Characterization of AC-LGAD sensors using the ALTIROC readout ASIC [US-afternoon]

*Thursday, 18 November 2021 16:30 (20 minutes)*

The development of detectors that provide high resolution in four dimensions has attracted widespread interest in the scientific community for several applications in high-energy physics, nuclear physics, medical imaging, mass spectroscopy as well as quantum information. The Low-Gain Avalanche Diode (LGAD) silicon technology has already shown excellent timing performances, but since fine pixelization of LGADs is difficult to achieve, the AC-coupled LGAD (AC-LGAD) approach was introduced to provide high spatial resolution. In this type of device, the signal is capacitively induced on fine-pitched electrodes placed over an insulator and is shared among multiple electrodes. AC-LGADs are therefore considered as promising candidates for future detectors to provide 4-dimensional measurements with high resolution in both space and time dimensions. AC-LGAD sensors designed and fabricated at the Brookhaven National Laboratory have been assembled and read out with a fast-time ASIC prototype, the ATLAS LGAD Timing Integrated Read-Out Chip (ALTIROC) that was developed by Omega/IJCLab for the ATLAS timing detector at the HL-LHC. The response of an AC-LGAD strip sensor to beta particles and infra-red photons has been measured using an ALTIROC ASIC prototype. The presentation will include studies of signal sharing between electrodes, as well as spatial and time resolution.

**Primary authors:** TRICOLI, Alessandro (Brookhaven National Laboratory (US)); DE LA TAILLE, Christophe (OMEGA (FR)); D'AMEN, Gabriele (Brookhaven National Laboratory (US)); ROSSI, Enrico (Brookhaven National Laboratory); GIACOMINI, Gabriele (Brookhaven National Laboratory (US)); SERIN, Laurent (IJCLab-CNRS/IN2P3 Orsay(Fr)); MORENAS, Maxime (OMEGA (FR)); SEGUIN-MOREAU, Nathalie (OMEGA - Ecole Polytechnique - CNRS/IN2P3); CHEN, Wei (Brookhaven National Laboratory)

**Presenter:** D'AMEN, Gabriele (Brookhaven National Laboratory (US))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 43

Type: **Talk**

## Timing Results of LGADs from Teledyne e2v using an Sr-90 Beta Source

*Thursday, 18 November 2021 10:10 (20 minutes)*

The University of Birmingham, University of Oxford, the Rutherford Appleton Laboratory and the Open University are developing and testing new LGAD sensors. This project, aims at developing Ultra-Fast Silicon Detectors (UFSD) of characteristics and performance suitable for use at HL-LHC High Granularity Timing Detectors (HGTDs) in collaboration with a company having significant long-standing production capabilities for scientific imaging sensors, Teledyne e2v Ltd.

The first fabricated batch of 22 six-inch wafers, featuring 50  $\mu\text{m}$  thick high resistivity epi layer with different gain layer implants was completed successfully and I-V and C-V characteristics presented previously to RD50. Here we discuss the commissioning of the Strontium-90 source set-up and first measurements of timing resolution with these LGADs which are already in the 30ps range. We also discuss some improvements to our laser TCT setup with additional gain measurements. Lastly we present the plans for further improvements to the timing system and testing of devices after proton irradiation at the MC40 facility.

**Primary author:** MULVEY, Jonathan

**Co-authors:** VILLANI, Enrico Giulio (Science and Technology Facilities Council STFC (GB)); STEFANOV, Konstantin (University of Oxford (GB)); PLACKETT, Richard (University of Oxford (GB)); MCMAHON, Stephen (Science and Technology Facilities Council STFC (GB)); KOPSALIS, Ioannis (University of Birmingham (GB)); JORDAN, Douglas; GONELLA, Laura (University of Birmingham (UK)); GAZI, Martin; ALLPORT, Philip Patrick (University of Birmingham (UK)); BORTOLETTO, Daniela (University of Oxford (GB))

**Presenter:** MULVEY, Jonathan

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 44

Type: **Talk**

## Determining the Impact Ionisation Parameters for LGADs

*Wednesday, 17 November 2021 16:00 (20 minutes)*

Existing impact ionisation models and parameters for silicon do not accurately describe the behaviour seen in LGAD sensors, so new impact ionisation parameters specifically applicable to LGADs was determined using simulations and timing measurements of sensors from various producers. The resulting model and parameters will be presented.

**Primary authors:** HOWARD, Alissa Shirley-Ann (Jozef Stefan Institute (SI)); Dr KRAMBERGER, Gregor (Jozef Stefan Institute (SI))

**Presenter:** HOWARD, Alissa Shirley-Ann (Jozef Stefan Institute (SI))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 45

Type: **Talk**

## Status and first results of the "RD50 TI-LGAD" Project

*Thursday, 18 November 2021 12:40 (20 minutes)*

Trench-Isolated LGAD (TI-LGAD) is a novel LGAD design where the standard inter-pixel isolating structure has been replaced with a trench, physically etched in the silicon and filled with a dielectric material.

The "RD50 TI-LGAD" project aimed at exploiting this new technology for the production of pixelated detectors with pixel and strip pitches down to 50  $\mu\text{m}$ .

In the project framework, FBK produced a batch of TI-LGADs, where many different technological and layout splits have been tested. In this contribution, we will present the parametric and functional characterization of the produced samples and discuss the following characterization activities that will be carried out by the partner institutes.

**Primary authors:** PATERNOSTER, Giovanni (Fondazione Bruno Kessler); BORGHI, Giacomo (Fondazione Bruno Kessler); BISHT, Ashish; BOSCARDIN, Maurizio (FBK Trento); CENTIS VIGNALI, Matteo (FBK); FICORELLA, Francesco (FBK); HAMMAD ALI, Omar (FBK)

**Presenter:** PATERNOSTER, Giovanni (Fondazione Bruno Kessler)

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 46

Type: **Talk**

## HVCMOS pixel characterization with the RBI Microprobe

*Friday, 19 November 2021 09:50 (20 minutes)*

Where we present the characterization of the HVCMOS MPW2 chip pixel matrix using the ion microprobe station at the RBI 1 MV Tandetron accelerator with protons at 2 MeV. The proton beam spot (most probable area of impact) was around 30  $\mu\text{m}^2$ , small enough to scan pixel by pixel the whole pixel matrix and with energy low enough to avoid SEE effects.

**Primary author:** PALOMO PINTO, Francisco Rogelio (Universidad de Sevilla (ES))

**Co-authors:** Dr HINOJO MONTERO, Jose María (Escuela Técnica Superior de Ingenieros de Sevilla); JAKSIC, Milko; KARADZHINOVA-FERRER, Aneliya (Helsinki Institute of Physics (FI)); Mr VICENTIJEVIC, Milan (Ruder Boskovic Institute); VILELLA FIGUERAS, Eva (University of Liverpool (GB)); POWELL, Samuel (University of Liverpool); PROVATAS, Georgios (Ruder Boskovic Institute)

**Presenters:** PALOMO PINTO, Francisco Rogelio (Universidad de Sevilla (ES)); VILELLA FIGUERAS, Eva (University of Liverpool (GB)); POWELL, Samuel (University of Liverpool); PROVATAS, Georgios (Ruder Boskovic Institute)

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 47

Type: **Talk**

## Test Beam Measurements of BNL and HPK AC-LGADs

*Thursday, 18 November 2021 16:50 (20 minutes)*

We present measurements of AC-LGADs performed at Fermilab's test beam facility using 120 GeV protons. We studied the performance of various strip and pixel sensors that were produced by BNL and HPK. The measurements are performed with our upgraded test beam setup that utilizes a high precision telescope tracker, and a simultaneous readout of up to 6 channels per sensor, which allows detailed studies of charge sharing characteristics. These measurements allow us to assess the differences in designs between different manufacturers and optimize them, based on experimental performance in test-beams. We then study several reconstruction algorithms to optimize position and time resolutions that utilize the charge sharing properties of each sensor.

**Primary authors:** MOLNAR, Adam (Fermi National Accelerator Laboratory); MADRID, Christopher (Fermi National Accelerator Lab. (US)); TRICOLI, Alessandro (Brookhaven National Laboratory (US)); APRESYAN, Artur (Fermi National Accelerator Lab. (US)); SAN MARTÍN, Claudio (Universidad Técnica Federico Santa María); PEÑA, Cristián (Fermi National Accelerator Lab. (US)); D'AMEN, Gabriele (Brookhaven National Laboratory (US)); GIACOMINI, Gabriele (Brookhaven National Laboratory (US)); NAKAMURA, Koji (High Energy Accelerator Research Organization (JP)); HELLER, Ryan (Fermi National Accelerator Lab. (US)); XIE, S. (FNAL); KITA, Sayuka (University of Tsukuba); Prof. BROOKS, William (Universidad Técnica Federico Santa María)

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

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 48

Type: **Talk**

## Effects of charge screening in LGADs

*Wednesday, 17 November 2021 15:40 (20 minutes)*

TCT was used to study the effect of ionization density on gain in different non-irradiated LGADs. A simple model was used to explain the screening and was verified by measurements.

**Primary authors:** KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); PETEK, Martin (Jozef Stefan Institute); RISTIC, Aleksandar (University of Nis, ELFAK); HOWARD, Alissa Shirley-Ann (Jozef Stefan Institute (SI)); CINDRO, Vladimir (Jozef Stefan Institute (SI)); MANDIC, Igor (Jozef Stefan Institute (SI)); MIKUZ, Marko (Jozef Stefan Institute (SI))

**Presenter:** KRAMBERGER, Gregor (Jozef Stefan Institute (SI))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 49

Type: **Talk**

## Radiation Hardness of Carbonated CNM-IMB LGAD samples

We revisit the radiation hardness of Carbonated CNM LGAD detectors (50 active thickness, run 10478) irradiated with PS protons up to  $10^{15} n_{eq}/cm^2$ . The study comprises electrical characterization of the gain layer doping removal, charge collection and timing with radioactive source.

**Primary authors:** NAVARRETE RAMOS, Efren (Universidad de Cantabria and CSIC (ES)); CURRAS RIVERA, Esteban (CERN); VILA ALVAREZ, Ivan (Instituto de Física de Cantabria (CSIC-UC)); FERNANDEZ GARCIA, Marcos (Universidad de Cantabria and CSIC (ES)); MOLL, Michael (CERN)

**Presenter:** FERNANDEZ GARCIA, Marcos (Universidad de Cantabria and CSIC (ES))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 50

Type: **Talk**

## **Compensation of TPA-TCT signal fluctuations using the 2nd harmonic**

*Wednesday, 17 November 2021 15:25 (15 minutes)*

We present the commissioning measurements of the new fiber femto-laser at IFCA equipped with a fully integrated optical bench for microfocusing, signal stability monitoring and focus imaging. Compensation of the TPA-TCT signal fluctuations using the second harmonic generated with a BBO crystal will be described

**Primary author:** VILA ALVAREZ, Ivan (Instituto de Física de Cantabria (CSIC-UC))

**Presenter:** VILA ALVAREZ, Ivan (Instituto de Física de Cantabria (CSIC-UC))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 51

Type: **Talk**

## Thickness dependence of the Single Event Burnout bias threshold in fs-laser based mortality study on LGADs from different producers

*Wednesday, 17 November 2021 13:00 (15 minutes)*

Gordana Lastovicka-Medin<sup>1</sup>, Mateusz Rebarz<sup>2</sup>, Gregor Kramberger<sup>3</sup>, Jakob Andreasson<sup>2</sup> Tomas Lastovicka<sup>4</sup>, Jiri Kroll<sup>4</sup>, Kamil Kropielnicki<sup>2</sup>

<sup>1</sup>University of Montenegro

<sup>2</sup>Extreme Light Infrastructure

<sup>3</sup>Jozef Stefan Institute

<sup>4</sup>Czech Academy of Sciences

Different active thickness of LGADs and probing the sensitive depth from front and backside are exploited, The sensors used in this study are as follows: BK UFSD3.2 W18 with C-enriched gain layer and with active thickness of 47 microns (2x2 array); HPK-P2 W36 (no C-enriched gain layer) with 50 microns of active thickness, 2x2 area); HPK-P1, Type 1.2 , 35 microns and CNM - sensor from Run9254 with active thickness of 70 microns. All types of sensors are irradiated at the fluence of  $1.5 \times 10^{15}$  and  $2.5 \times 10^{15}$  neq/cm<sup>2</sup>. Femtosecond laser based SPA mortality study was mainly focused on study of LGAD's stability because we tried to avoid fatal damage so that sensors can be subjected to the illuminated from the back side. Front illumination was performed on all considered sensors. TPA mortality study was performed from both sides: front and back. The results are discussed as well as future plans,

**Presenter:** LASTOVICKA MEDIN, Gordana (University of Montenegro (ME))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 52

Type: **Talk**

## Discussion: LGAD

*Thursday, 18 November 2021 17:50 (30 minutes)*

**Presenters:** PELLEGRINI, Giulio (Universidad de Valencia (ES)); PELLEGRINI, Giulio (Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); CARTIGLIA, Nicolo (INFN Torino (IT)); HIDALGO, Salvador (Instituto de Microelectronica de Barcelona (IMB-CNM-CSIC))

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: 53

Type: **not specified**

## **Discussion: Pixel, 3D and CMOS sensors**

*Friday, 19 November 2021 11:40 (30 minutes)*

**Presenter:** VILELLA FIGUERAS, Eva (University of Liverpool (GB))

**Session Classification:** Pixel Sensors and Monolithic Devices

Contribution ID: 54

Type: **not specified**

## **Discussion: New Structures and Standard Sensors**

*Friday, 19 November 2021 15:30 (30 minutes)*

**Presenter:** CASSE, Gianluigi (University of Liverpool (GB))

**Session Classification:** New Structures - 3D

Contribution ID: 55

Type: **Talk**

## **Discussion: TPA-TCT system and studies**

*Wednesday, 17 November 2021 16:20 (30 minutes)*

**Presenter:** VILA ALVAREZ, Ivan (Instituto de Física de Cantabria (CSIC-UC))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 56

Type: **not specified**

## **Discussion: Defect Studies & New Materials**

*Wednesday, 17 November 2021 12:10 (30 minutes)*

**Presenters:** PINTILIE, Ioana (NIMP Bucharest-Magurele, Romania); MOLL, Michael (CERN)

**Session Classification:** Defect and Material Characterization

Contribution ID: 57

Type: **not specified**

## Evidence of multistage charge collection in Si irradiated detectors operated as the monitors of intensive fragmented proton beams

*Wednesday, 17 November 2021 12:40 (20 minutes)*

Charge collection in Si p<sup>+</sup>-n-n<sup>+</sup> detectors was studied in the in situ irradiation test at 1.9 K with intense 23 GeV proton beam fragmented in 400 ms spills in view of detector application as beam loss monitors in the LHC at CERN. The current pulse responses demonstrated a two-stage process of charge collection, in which, in the first stage, the current was induced by holes, and in the second, by electrons arising due to avalanche multiplication produced by holes. The data treatment and the current response shapes simulation for detectors irradiated by  $5 \times 10^{13}$  p/cm<sup>2</sup> yielded a full set of carrier transport characteristics and a signal internal gain. The charge collected in the second phase exposed a threshold in voltage for the signal rise, which verifies evolution of avalanche multiplication as the origin of the second phase and total signal amplification. In Si detector irradiated to  $2.7 \times 10^{14}$  p/cm<sup>2</sup>, a new third stage of charge collection was observed and assigned to avalanche multiplication produced by electrons reaching the n<sup>+</sup> contact and to the following drift of generated holes back to the p<sup>+</sup> contact.

**Presenters:** SHEPELEV, Artem (Ioffe Institute (RU)); SHEPELEV, Artem (Ioffe Institute); VERBITSKAYA, Elena (Ioffe Physico-Technical Institute RAS); VERBITSKAYA, Elena (Ioffe Institute (RU)); EREMIN, Vladimir (Ioffe Institute (RU))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 58

Type: **not specified**

## Updated IBIC and Ion-TCT study on LGAD at RB: Work in Progress on Effects of Screening in LGADs

*Wednesday, 17 November 2021 13:15 (10 minutes)*

Gordana Lastovicka-Medin<sup>1</sup>, Milko Jaksic<sup>2</sup>, Gregor Kramberger<sup>3</sup>, Mauricio Rodriguez Ramos<sup>2</sup>,  
Andreo Crnjac<sup>2</sup>, Milos Manojlovic<sup>1</sup>

<sup>1</sup> University of Montenegro,

<sup>2</sup> Rudjer Boskovic Institute,

<sup>3</sup> Jozef Stefan Institute

This work in progress is three folded. Firstly, gain anomalous behavior was studied in a such way that ion beams (C, He, Li, H<sup>+</sup>) and their energies were chosen so that Bragg peaks correspond to the same depth in LGAD but significantly different charge was deposited. Secondly, protons of 4 MeV energy were used to irradiate LGAD from two sides: back and front. The aim was to systematically observe the contributions of impact ionization and multiplication of holes and electrons in more distinguishable way, knowing at the same time the most probable depth where induced charge should be mostly generated. However, since slowing down of ions in matter is accompanied by a spread of beam energy, this so called energy straggling effect has to be studied in depth. The difference in energy lost when 4 MeV H<sup>+</sup> ion is injected from front and back side is considered too. Thirdly, inter-pixel distance vs bias was mapped using probing H<sup>+</sup> ion beams: 0.75, 1.15 and 1.5 MeV.

**Presenter:** LASTOVICKA MEDIN, Gordana (University of Montenegro (ME))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: 59

Type: **Talk**

## Timing measurements on neutron-irradiated LGADs in epitaxial wafers

*Thursday, 18 November 2021 12:00 (20 minutes)*

In this contribution, we will present measurements on neutron-irradiated LGADs corresponding to our 6-inch, 50 $\mu$ m active layer thick, epitaxial wafers run (6LG3). Samples were fabricated using three boron implantation doses, and one energy, for the gain layer definition. Gain, collected charge, acceptor removal constant and timing measurements were carried out on these LGADs irradiated with neutrons at equivalent fluencies ranging from  $1e14$  to  $5e15$  atm/cm<sup>2</sup>. The presented results have served as a stepping stone to select the best technological parameters for the gain layer definition in the upcoming ATLAS-CMS common runs, based on 6-inch epitaxial and Si-Si wafers (6LG3 and 6LG2 technologies, respectively).

**Primary author:** ANTONIO VILLEGAS DOMINGUEZ, Jairo

**Presenter:** ANTONIO VILLEGAS DOMINGUEZ, Jairo

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: **60**

Type: **not specified**

## **Announcement: Trento Workshop in Freiburg**

*Wednesday, 17 November 2021 16:50 (5 minutes)*

**Presenter:** PARZEFALL, Ulrich (Albert Ludwigs Universitaet Freiburg (DE))

**Session Classification:** TPA-TCT (Two-Photon Absorption Transient Current Technique)

Contribution ID: **61**

Type: **not specified**

## **Nicolo Part II - LGAD design**

*Thursday, 18 November 2021 11:20 (10 minutes)*

**Session Classification:** LGAD - Low Gain Avalanche Diodes

Contribution ID: **62**

Type: **not specified**

## **Farewell**

*Friday, 19 November 2021 17:00 (5 minutes)*

**Session Classification:** organization issues