T 66: Semiconductor Detectors: Radiation Hardness, new Materials and Concepts 2

Time: Wednesday 16:15–18:30 Location: T-H25

T 66.1 Wed 16:15 T-H25

Study of the self-heating in SiPMs — •Carmen Victoria Villalba Petro, Erika Garutti, Robert Klanner, Stephan Martens, and Jörn Schwandt — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland.

A dramatic increase of the dark current is the main effect of radiation damage in SiPMs. The power dissipated, if not properly cooled, heats the SiPM, whose performance parameters depend on temperature. Therefore, the knowledge of the SiPM temperature is necessary to understand the changes of its parameters with irradiation.

The self-heating studies were performed with a KETEK SiPM, 15x15 mm^2 pixel size, mounted on an Al_2O_3 substrate 0.6 mm thick, which was either directly connected to the temperature controlled chuck of a probe station, or through layers of material with well-known thermal resistance. The SiPM was illuminated by a LED operated in DC-mode. SiPM current was measured at different voltages, LED currents, chuck temperatures, and thermal resistivities for a number of measurement cycles. The data are used to determine the steady-state temperature as a function of dissipated power and thermal resistance, as well as the time dependencies for heating and cooling. This information could be used to correct the parameters determined for radiation-damaged SiPM for the effects of self-heating.

The presentation describes the experimental layout, the data taking, the analysis methods, the results obtained and a comparison to thermal simulations. The application of the method for the study of radiation damaged SiPMs and its use in actual experiments is discussed.

T 66.2 Wed 16:30 T-H25

PeakOTron: A Python Module for Fitting Charge Spectra of Silicon Photomultipliers — •Jack Rolph, Erika Garutti, and Joern Schwandt — Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

An automated software method is developed to characterise the pulse-height spectra of SiPM obtained in the dark or response to low-intensity light illumination. The method is based on a fit utilising a published SiPM response model. It aims to provide SiPM performance parameters for single measurements, mass production characterisation, or high granular detector calibration. The fit considers dark count rate, the average number of detected photons, crosstalk and after-pulsing, electronics noise and gain fluctuations. Due to the sensitivity of the fit to the initial values assigned to these parameters, the software must perform careful estimation before fitting the model to data, which has been designed to be fast, accurate and robust to fluctuations. First, the model*s accuracy is validated against simulation and then tested to experimental data from various SiPMs.

T 66.3 Wed 16:45 T-H25

Silicon Photomultiplier characterization for a space-borne optical instrument in Low Earth Orbit — •Lucas Finazzi[1,2,4], Federico Golmar[2,4], Andreas Haungs[1], Thomas Huber[1], and Federico Izraelevitch[2,3,4] — [1]Institut für Astroteilchenphysik (IAP), Karlsruher Institut für Technologie (KIT), Germany — [2]Universidad de San Martín (UNSAM), Argentina — [3]Comisión Nacional de Energía Atómica (CNEA), Argentina — [4]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

The S4 (Space-borne SiPM-based Single-photon Sensor) is an instrument designed for single-photon detection in Low Earth Orbit (LEO) using Silicon Photomultiplier (SiPM) technology. The instrument, currently under developed by the LabOSat group (UNSAM), is expected to launch on Q2 2023 as a secondary payload of a commercial Earth-observation satellite. Beside the increase of the Technology Readiness Level (TRL) of SiPM sensors for space applications, the S4 instrument will be a pathfinder for Ground-LEO single-photon communications and fundamental Physics experiments that require single-photon detection.

In this talk we will describe the S4 instrument, focusing on the Analog-Front End (AFE) and SiPMs subsystem. Particularly, we will present the characterization performed at the SPOCK (Single PhOton Calibration stand at KIT) laboratory at the Institute of Astroparticle Physics (KIT), including studies on the performance of the AFE board and sensors at different temperatures, SiPM overvoltages and illumination conditions.

T 66.4 Wed 17:00 T-H25

Timing measurements of a tip avalanche photodiode (TAPD) - A near-infrared enhanced silicon photomultiplier based on spherical depletion — •Wolfgang Schmailzl[1,3], Jonathan Preitnacher[1], Erika Garutti[2], and Walter Hansch[1] — [1]Bundeswehr University Munich, Neubiberg, Germany — [2]University of Hamburg, Hamburg, Germany — [3]Broadcom Inc., Regensburg, Germany

The gain of attention in LiDAR technology also pushed the development of sensors for time of flight measurements. Such a measurement requires a fast and very sensitive receiver. Often a wavelength in the near-infrared (NIR) region is chosen if the emitter is part of the system while a high sensitivity over a broad range is an advantage for deviating applications. Silicon photomultiplier (SiPM) with enhanced sensitivity in the NIR region provide a good combination of performance and cost-efficiency. In our investigations we simulated and fabricated spherical junctions for the single-photon avalanche diodes and a photo-detection efficiency of 22% at 905nm was achieved. We present timing measurements of this new NIR SiPM to provide an overview and to put the performance into the context of possible applications with very low and high light intensities. Compared to their blue enhanced counterparts, the single photon time resolution of these devices is lower where some of this performance loss is related to the required depletion depth for longer wavelengths while the current design is still not at its limit. We want to outline some of these intrinsic limits and show where improvements can be made.

T 66.5 Wed 17:15 T-H25

Characterisation and Radiation Hardness of Tip-Avalanche PhotoDiodes — •Julius Römer[1], Erika Garutti[1], Wolfgang Schmailzl[2,3], Jörn Schwandt[1], and Stephan Martens[1] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland — [2]Bundeswehr Universität München, Neubiberg, Deutschland — [3]Broadcom Inc., Regensburg, Deutschland

Silicon Photomultipliers (SiPM) are the photon detectors of choice for many applications. Development of SiPMs with conventional single photon avalanche diode (SPAD) built around a planar pn-junction reaches a trade-off between photon detection efficiency (PDE) and dynamic range. A challenge in designing efficient red-sensitive SiPMs lies in the requirement for large depletion depths.

A novel design design featuring a quasi-spherical pn-junction called Tip Avalanche Photodiode (TAPD) tackles both problems. For a pixel pitch of 15 μm, the SiPM prototype reaches a PDE of 73 % at 600 nm and 22 % at 900 nm, a high dynamic range, as well as a recovery time below 4 ns. The aim of this study is to characterize this novel type of SiPM. In particular the question of radiation hardness of TAPD is addressed.

After irradiation with reactor neutrons with fluences up to $1 \cdot 10^{12}\,\mathrm{cm}^{-2}$ 1 MeV neutron equivalent, characterisation with $I-V$ and $C-V-f$ measurements show that despite the increased bulk volume, TAPD-SiPMs show similar loss of response and increase in dark count rate (DCR) with irradiation compared to planar SiPM devices, enhancing the usability in high energy particle experiments.

T 66.6 Wed 17:30 T-H25

Investigation of the Time Resolution of LGADs and 3D Sensors — •Leena Diehl, Monty King, Dennis Sperlich, Ulrich Parzefall, Marc Hauser, and Christina Schwemmbauer — Universität Freiburg

Future collider experiments as the high-luminosity LHC or the FCC will increase the demands of the detectors used for tracking. Sensors will not only face fluences of up to $1 \cdot 10^{17}\ n_{eq}/\mathrm{cm}^2$, but also high pile-up scenarios. Thus sensors are needed which have a high radiation tolerance, but also an excellent time resolution while still providing a good spatial resolution. Currently Low Gain Avalanche Diodes (LGADs) are the prime candidate when it comes to timing, reaching a resolution of below 30 ps. However, 3D sensors are promising candidates as well, as they have not only a good time resolution but also a superior radiation hardness. In order to investigate the time resolution of both LGADs and 3D sensors thoroughly, timing measurements were performed using either a beta-source or a laser with infrared wavelength. The timing-TCT measurements allow to measure the position-dependence of the time resolution, which is interesting especially for the 3D-sensors, where the time walk is an important component of the resolution. This talk will present some initial results of the measurements, including the calibration of the timing-TCT setup and first measurements with were 3D-sensors as well as LGADs.

T 66.7 Wed 17:45 T-H25

Time resolution comparison between LGADs and 3D silicon detectors — •Montague King, Christina Schwemmbauer, Leena Diehl, Dennis Sperlich, Marc Hauser, and Ulrich Parzefall — Albert-Ludwigs Universität, Freiburg, Germany

For the planned high luminosity upgrade of the LHC it is vital to develop detector systems with both excellent spatial and timing resolution in the inner tracking layers to be able to distinguish separate collisions in the same bunch crossing. This has to be achieved even after severe irradiation with expected fluences of up to 2.6 x 10^{16} n_{eq}/cm^2.

It has been shown that a timing resolution of 30 ps can be achieved with Low Gain Avalanche Diodes (LGADs). However, these devices have drawbacks, especially regarding spatial resolution, effective fill factor and radiation hardness. A second detector type, 3D-detectors with electrodes extending deeply into the silicon bulk, are expected to be able to achieve such a high timing resolution while having a superior spatial resolution and radiation hardness.

In this talk, the calibration of a setup developed specifically for fast timing measurements at the University of Freiburg will be presented. This setup utilises a ^{90}Sr electron source along with a reference sensor and scintillator to measure fluctuations in the time between signals from reference and tested sensor. Furthermore, first results measured for LGADs before and after irradiation as well as unirradiated 3D sensors will be discussed.

T 66.8 Wed 18:00 T-H25

Boron removal effect in silicon sensors induced by 6 MeV electrons — •Chuan Liao, Eckhart Fretwurst, Erika Garutti, and Joern schwandt — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland

In the frame of the CERN_RD50 collaboration, the acceptor removal effect is investigated in p-type material, used for example in pixel sensors or Low Gain Avalanche Detectors (LGADs). The suspected cause is the displacement of substitutional Boron (Bs), being negatively charged, by incident particles or other recoil atoms into an interstitial position (Bi). This is followed by Bi migration and being captured by Oxygen atoms and forming complex defects of interstitial Boron and interstitial Oxygen (BiOi) with a positive charge. This is the boron removal effect. For lower radiation fluence, this has one main consequence: The maximum electric field at a given reverse bias will decrease, causing e.g. a decrease of the LGAD gain. In this presentation, the Thermally Stimulated Techniques including TS-Current (TSC) and TS-Capacitance (TS-Cap) have 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 x 1015 cm-2 and 6 x 1015 cm-2. The results will be presented and compared with those gained from sensors exposed to 23 GeV protons.

T 66.9 Wed 18:15 T-H25

Physics case for a forward timing disc covering 3<η<4 of the CMS detector at HL-LHC — •Anna Albrecht[1], Anna Benecke[2], Andreas Hinzmann[1], Ben Kilminster[3], and Stefanos Leontsinis[3] — [1]Universität Hamburg — [2]UC Louvain — [3]University of Zurich

The LHC will be upgraded to a collider with 10 times higher luminosity, the high luminosity (HL)-LHC. One main challenge arising from the upcoming high luminosity, is the large amount of interactions that occur in one proton-proton bunch crossing, and therefore the separation of the interaction of interest from the additional ones (pileup). The insertion of a new timing layer in the upgraded CMS experiment is planned, to use timing as an additional discrimination variable between signal and pileup.

One interesting channel to probe at the HL-LHC is vector boson fusion (VBF) Higgs pair production that has two characteristic jets in the forward region of the detector. The separation of this signal from pileup is extremely challenging. In this physics case study, the performance of an extension of the timing layer from $\eta < 3$ to $\eta < 4$ is estimated by using the Delphes simulation software.