T 14: Pixel detectors I

Time: Monday 16:00–18:15 Location: Tn

T 14.1 Mon 16:00 Tn

Development of MAPS in 65nm CMOS Imaging Technology — •Adriana Simancas, Simon Spannagel, Anastasiia Velyka, and Lennart Huth — Deutsches Elektronen-Synchrotron, Hamburg, Deutschland

Monolithic CMOS sensors have found their way through imaging technologies into High Energy Physics thanks to its multiple advantages in particle detection. Their main characteristic is the integration of the sensor and the readout in a single chip, which provides a reduction in production effort, costs and material. As part of the next generation of silicon pixel sensors that are usually employed as tracker and vertex detectors, a 65 nm CMOS sensor is being investigated at DESY. Device simulations (TCAD) are needed to develop the understanding of this technology and to obtain inputs for Monte Carlo simulations (Allpix^2). The outcomes of these simulations can give an important insight into performance parameters of the sensor, which will be tested in experiments later on. This contribution will present the latest developments and simulation results of a 65 nm CMOS sensor.

T 14.2 Mon 16:15 Tn

Development of a Monolithic Pixel Sensor with sub-nanosecond Time Resolution in BiCMOS — Heiko Augustin[1], Ivan Peric[2], André Schöning[1], and •Benjamin Weinläder[1] — [1]Physikalisches Institut, Universität Heidelberg — [2]IPE, Karlsruher Institut für Technologie

In the field of particle physics, High Voltage Monolithic Active Pixel Sensors (HV-MAPS) are promising candidates to fulfil the high demands on spatial and time resolution of modern detectors. The Mu3e experiment with its development of the MuPix sensor has strongly driven this technology in recent years. By using a 180 nm HV-CMOS technology, a typical time resolution in the order of 5 ns was achieved. To improve this further, the combination of HV-MAPS with a BiCMOS process opens up further possibilities, which was proven in the scope of the TT-PET project at the university of Geneva (Y. Bandi *et al.* 2018 **JINST** 13 C01007).

Following this concept and based on the experience with developing the MuPix a subsequent R&D project was started, with the ambition to achieve a time resolution in the sub-nanosecond regime. For this purpose the BiCMOS technology SG13S from IHP is used, which offers great advantages for high-frequency circuits. Using Cadence Virtuoso® a small pixel layout with a size of $25 \times 25\,\mu\text{m}^2$ was designed. Simulations with a signal corresponding to a MIP showed high performance with a ToA Jitter of $\sigma_{ToA} = 86\,\text{ps}$ and an $ENC = 205\,\text{e}^-$.

T 14.3 Mon 16:30 Tn

Study of current, capacity and thermal runaway of hadron-irradiated silicon sensors — Ingo Bloch[1], Heiko Lacker[2], •Felix Riemer[2], and Christian Scharf[2] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Humboldt-Universität zu Berlin

Silicon sensors are widely used in HEP experiments for particle tracking and calorimetry. One of the problems silicon detectors are facing is the increase of leakage current due to radiation damage. Leakage currents generate considerable heat for large detectors. At the same time, the leakage current increases with increasing sensor temperature. Therefore, catastrophic thermal runaway can occur with accumulated radiation damage during service if the cooling performance falls short of the demands. In order to estimate the effects, capacitance and current of irradiated silicon diodes have been measured as a function of particle fluence, temperature, bias voltage, cooling power, and for different pad areas. The diodes were irradiated with 70 MeV/c protons and 1 MeV/c neutrons to equivalent fluences between 1E13 cm^{-2} and 5E16 cm^{-2}. A parametrization to describe the reverse current of highly irradiated silicon sensors and an analytical model for thermal runaway were used to estimate the critical parameters. A setup was built to confront the model with measurements within its validity range. Runaway was achieved and the existing analytical model was tuned using experimental data. The results can be applied to estimate the change of the heating power of silicon sensors in harsh radiation environments and the cooling infrastructure which is necessary to prevent thermal runaway in future ATLAS operation and other future detectors.

T 14.4 Mon 16:45 Tn

Evolution of currents in irradiated DEPFET sensors — •Marike Schwickardi[1], Ariane Frey[1], Benjamin Schwenker[1], Botho Paschen[2], Georgio Giakoustidis[2], and Harrison Schreeck[1] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Deutschland — [2]Physikalisches Institut Uni Bonn, Nußallee 12, 53115 Bonn

The Belle II experiment at the Japanese Super B-factory SuperKEKB has started data taking in early 2019, the peak luminosity will be ramped up to $8{\cdot}10^{35}\text{cm}^{-2}\text{s}^{-1}$, which is 40 times higher than the previous luminosity at the Belle experiment, which was therefore upgraded with a new DEpleted P-channel Field Effect Transistor (DEPFET) based silicon pixel detector (PXD) for vertex detection. The silicon bulk, on which the field-effect transistors form the individual pixels, is biased by different voltages enabling bulk depletion, charge collection and charge removal.

Due to the much harsher environment, the radiation hardness of the equipped sensors in the PXD has to be well understood and is investigated. Especially, since during operation in the Belle II environment with only small neutron fluences, an increase in the bulk depletion current could be observed. Therefore, x-ray irradiation studies were conducted to investigate the current behaviour of the sensors. This talk will present observations on the sensor performance during an irradiation campaign with doses of up to 18.5 Mrad in the silicon oxide.

T 14.5 Mon 17:00 Tn

Characterization of a depleted monolithic active pixel sensor in 180 nm TowerJazz technology — Ivan Berdalovic[2], •Christian Bespin[1], Ivan Caicedo Sierra[1], Tomasz Hemperek[1], Toko Hirono[1], Fabian Hügging[1], Hans Krüger[1], Thanusan Kugathasan[2], Cesar Augusto Marin Tobon[2], Konstantinos Moustakas[1], Heinz Pernegger[2], Walter Snoeys[2], Tianyang Wang[1], Norbert Wermes[1], and Jochen Dingfelder[1] — [1]Physikalisches Institut, Universität Bonn — [2]CERN, Genf

The high-luminosity upgrade of the LHC (HL-LHC) imposes new requirements on the detectors. With the availability of highly resistive silicon in commercial CMOS processes, there are ongoing efforts to build depleted monolithic active pixel sensors (DMAPS) for high energy particle detectors. TJ-MonoPix is a prototype of such a pixel sensor in 180 nm TowerJazz technology. It is designed for usage in high-radiation environments such as the HL-LHC. The pixels with a small collection electrode design and pixel pitch of 36 um * 40 um are read out using a column-drain readout architecture.

In this talk, results from measurements with radioactive sources and in test beams will be presented. Furthermore, an overview of the ongoing work towards a future chip in this CMOS technology will be shown.

T 14.6 Mon 17:15 Tn

Inter-pixel resistance measurements of passive CMOS sensors — •Sinuo Zhang, David-Leon Pohl, Tomasz Hemperek, and Jochen Dingfelder — Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany

Using commercial CMOS chip fabrication lines, the so-called "passive CMOS" pixel and strip sensors have become an interesting alternative to standard planer sensors. To achieve and maintain a high spatial resolution for operating in HEP experiment facilities with high radiation levels, it is important to understand how the resistance between electrodes changes after irradiation for various implant geometries. We present results on the measurements of the inter-pixel resistance of n-on-p passive CMOS sensor test-structures fabricated in the LFoundry 150nm CMOS technology. The inter-pixel resistance of two types of test-structures: 1) p-stop isolation and 2) field plate between pixel implants, were evaluated by fitting the current-voltage behavior between a single pixel and the surrounding pixels. Results from the samples after 14MeV proton irradiation reveal a drop of the inter-pixel resistance for both types of the structures, with respect to the un-irradiated samples. An improvement of the inter-pixel resistance has been observed after applying appropriate voltages on the inter-pixel field plate.

T 14.7 Mon 17:30 Tn

Radiation hardness and development of a large electrode DMAPS design in a 150 nm CMOS process — •Ivan Caicedo,

Christian Bespin, Jochen Dingfelder, Tomasz Hemperek, Toko Hirono, Fabian Hügging, Hans Krüger, Piotr Rymaszewski, Tianyang Wang, and Norbert Wermes — Physikalisches Institut, Universität Bonn. Bonn, Germany.

Monolithic CMOS active pixel sensors in depleted substrates (DMAPS) are an attractive development for pixel tracker systems in high-rate collider experiments. The radiation tolerance of these devices is enhanced through technology add-ons and careful design, which allow them to be biased with large voltages and collect charge through drift in highly resistive silicon bulks.

LF-Monopix1 is the first DMAPS with a fully functional column-drain readout architecture. It was designed in a 150 nm CMOS process that made it possible to place and isolate each pixel's front-end circuitry within a charge collection electrode of a size comparable to the pixel area. This talk will summarize the chip performance and focus on its radiation hardness. Measurements on irradiated samples showed an in-time detection efficiency of $\sim 97\%$ after a NIEL dose of $1 \times 10^{15} n_{eq}/cm^2$. In addition, their gain did not degrade and their noise increased by 25% after a TID dose of 100 MRad from X-rays.

In the end, an overview and initial test results of the new prototype chip LF-Monopix2 with increased column length, reduced pixel pitch and design changes motivated by measurement results will be given.

T 14.8 Mon 17:45 Tn

CAD Simulation and Testbeam characterization studies of High-Voltage Monolithic Active Pixel Sensors — •Annie Meneses Gonzalez on behalf of the HV-MAPS consortium — Physikalisches Institut, Universität Heidelberg

Modern particle physics experiments set high requirements on the sensor technologies for their tracking detectors. High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) are ideal for tracking low momentum particles at very high rates. This technology has been chosen as the baseline for the Mu3e Pixel Tracker and is under study for application in future detectors for PANDA, P2, CLIC, and LHCb.

In this talk, an HV-MAPS engineering run developed within the HV-MAPS consortium will be presented. The results include sensors manufactured by TSI Semiconductors, implemented in a commercial 180-nm High-Voltage CMOS process, with different pixel sizes and in-pixel electronic. Technology Computer Aided Design (TCAD) simulations and testbeam campaigns at DESY are used to characterize the sensors, aiming for a comprehensive understanding of their characteristics

T 14.9 Mon 18:00 Tn

Radiation tolerant small-pixel passive CMOS sensors with RD53A readout — •Yannick Dieter, Michael Daas, Tomasz Hemperek, Fabian Hügging, Jens Janssen, Hans Krüger, David-Leon Pohl, Tianyang Wang, Norbert Wermes, Pascal Wolf, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

With the HL-LHC upgrade of the ATLAS detector, the surface of the ATLAS pixel detector will increase from 2 m^2 to approximately 13 m^2. Therefore, commercial CMOS processing lines offering high production throughput at comparatively low costs represent an attractive option for such large-area detectors. Further benefits originate from multiple metal layers, metal-insulator-metal capacitors, and polysilicon layers which offer enhanced sensor designs through additional routing options.

Thinned, small-pixel passive CMOS sensors in 150 nm technology offered by LFoundry were manufactured and assembled to hybrid pixel modules using the RD53A readout chip.

The sensors were characterized, before and after irradiation to fluences of $5{\times}10^{15}\mathrm{n_{eq}/cm^2}$ and $1{\times}10^{16}\mathrm{n_{eq}/cm^2}$, in the laboratory and also using a minimum ionising electron beam. Their performance in terms of noise and hit-detection efficiency equals that of conventional planar pixel sensors. Special emphasis will be put on the results after a fluence of $1{\times}10^{16}\mathrm{n_{eq}/cm^2}$ yielding a hit-detection efficiency of approximately 99 %.