T 82: Pixel detectors IV

Time: Thursday 16:30–18:45 Location: L-2.004

T 82.1 Thu 16:30 L-2.004

Simulation Studies on the Robustness of the ATLAS Pixel Detector for the HL-LHC — •Timo Dreyer, Stan Lai, and Kira Abeling — Georg-August-Universität Göttingen

Around 2026, the LHC will start its high luminosity phase (HL-LHC), during which more than 3000 fb^{-1} of *pp* collision data is expected to be delivered. In addition to the physics benefits of the increased amount of data, new technical challenges will arise. These include an increased amount of pileup in the events and exposure of the detector components to larger radiation doses.

To face these challenges, the ATLAS experiment will undergo a major upgrade during the long shutdown 3 that will precede the HL-LHC phase. The current inner detector will be completely replaced by a new silicon based inner tracker (ITk) consisting of an inner pixel detector and an outer silicon strip detector.

This talk presents studies performed to evaluate the robustness of the planned ITk pixel detector under defects of sub-components. The methodology for masking pixel modules and front-ends is introduced and comparisons between the expected performance under different failure modes are presented.

T 82.2 Thu 16:45 L-2.004

Guard Ring investigation of Silicon Sensors with Modified Pixel Implant shapes in the context of the ATLAS experiment — •Serena Di Pede[1], Andreas Gisen[2], Valerie Hohm[2], Kevin Kröninger[2], Jonas Lönker[2], Maximiliano Sioli[1], Mareike Wagner[2], Jens Weingarten[2], and Felix Wizemann[2] — [1]Physics Department Bologna University, Italy — [2]TU Dortmund, Experimentelle Physik IV

Based on the standard design of the planar $n^+ - in - n$ silicon pixel sensors of the innermost part of the tracking detector of the ATLAS experiment, six modified pixel designs were developed in Dortmund in order to increase the average electric field and thus the radiation hardness. The REINER pixel sensors contain these six modified pixel implantation shapes beside structures with the standard pixel design. It is well-known that the high-voltage capability of detector diodes fabricated in the planar process is limited by the electric field generated at the edge of the junction. An approach to reduce the electric field at the junction edges is to use floating guard rings. Each pixel structure of the REINER sensor is provided by 13 guard rings and can be biased and investigated separately. This study investigates the guard ring structure of each of the eight pixel designs as well as the influence among the guard ring structure of the different pixel designs, in order to investigate the strength of the electric field at the edge and the phenomenon of the leakage current creation in the bulk and the surface of each pixel implant.

T 82.3 Thu 17:00 L-2.004

Radiation Damage Measurements of the Hybrid Pixel Readout Chip RD53A — Jochen Dingfelder, Florian Hinterkeuser, Tomasz Hemperek, Fabian Hügging, Hans Krüger, Konstantinos Moustakas, Piotr Rymaszewski, •Marco Vogt, and Norbert Wermes — Physikalisches Institut der Universität Bonn

After the phase-2 upgrade of the LHC at CERN, the instantaneous luminosity will be increased substantially. New detector systems are required which are able to deliver hit information at drastically increased data rates and cope with unprecedented radiation levels. The RD53 collaboration will provide the pixel readout chips for the innermost tracking detector layers of both ATLAS and CMS. The first large-scale prototype chip RD53A was manufactured in a 65 nm CMOS process and is available since 2017.

Accelerated irradiation campaigns indicate that the radiation damage of RD53A is significantly dose rate dependent. It is therefore necessary to improve the radiation models to make better predictions about the detector performance during its lifetime, prior to the submission of the next prototype chip.

In this contribution, the ongoing low-dose-rate irradiation campaigns and their results will be presented.

T 82.4 Thu 17:15 L-2.004

Radiation hardness 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. In addition, the use of monolithic chips in commercial CMOS processes would reduce the current production complexity and costs of large module areas.

LF-Monopix1 is the first DMAPS with a fully functional column-drain read-out 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 presentation will give an overview of the chip performance and then focus on its radiation hardness. Measurements on irradiated samples showed a detection efficiency of $\sim$ 99% after a NIEL dose of $1 \times 10^{15} n_{eq}/cm^2$. Moreover, their gain did not degrade and their noise increased by 25% after a TID dose of 100 MRad from X-rays. In both cases, the chips remained operational and within reasonable values of leakage current and power consumption.

T 82.5 Thu 17:30 L-2.004

Effects of gamma irradiation on DEPFET pixel sensors for the Belle II experiment — Patrick Ahlburg[1], Ladislav Andricek[2], Jochen Dingfelder[1], Ariane Frey[3], Tomasz Hemperek[1], Hans Krüger[1], Carlos Marinas[4], •Botho Paschen[1], Rainer Richter[2], Harrison Schreeck[3], Benjamin Schwenker[3], Philipp Wieduwilt[3], and Norbert Wermes[1] — [1]University of Bonn, Germany — [2]HLL of Max-Planck-Society, Munich, Germany — [3]University of Göttingen, Germany — [4]University of Valencia, CSIC, Spain

For the Belle II experiment at KEK (Tsukuba, Japan) the KEKB accelerator was upgraded to deliver e^+e^- collisions at a center of mass energy of $E_{\mathrm{CM}} = 10.58$ GeV with an instantaneous luminosity of $8 \cdot 10^{35}$ cm^{-2}s^{-1}. As the innermost part of the Belle II detector, the PiXel Detector (PXD), based on DEpleted P-channel Field Effect Transistor (DEPFET) technology, is most exposed to radiation from the accelerator. A module from the final Belle II production batch was irradiated with X-rays to a total dose of 266 kGy corresponding to 7-10 years of Belle II operation. While individual components have been irradiated before, this campaign is the first full system irradiation. The performance of the DEPFET sensors and front-end electronics and efficiency studies of the module from beam tests performed before and after the irradiation will be presented.

T 82.6 Thu 17:45 L-2.004

Irradiation burst study of Belle II PXD module components — Florian Bernlochner[1], Jochen Dingfelder[1], Martin Hensel[3], Matthias Hoek[2], Florian Lütticke[1], Botho Paschen[1], and •Jannes Schmitz[1] for the Belle II-Collaboration — [1]University of Bonn, Germany — [2]University of Mainz, Germany — [3]HLL of Max-Planck-Society Munich, Germany

The Belle II detector started recording physics collision data in spring 2019 with its full tracking detectors installed. During this years campaign, unexpected irradiation burst events were observed, which exposed the inner detectors and especially the PXD (PiXel Detector) to unwanted levels of prompt irradiation. A dedicated measurement campaign with spare PXD modules was carried out at the Mainz Microtron or brief MAMI, which aimed to reproduce the observed effects of irradiation burst events on the PXD in Belle II. To this end, a focused high intensity (800 nA) pencil beam of 855 MeV electrons was used to irradiate a full system demonstrator in several spatially confined fiducial regions. In this talk, the results of this campaigns will be presented and compared to the observed impact on the PXD modules installed inside Belle II.

T 82.7 Thu 18:00 L-2.004

Testbeam measurements with passive CMOS pixel sensors in

150 nm LFoundry technology bump-bonded to the RD53A readout chip — •Yannick Dieter, Michael Daas, Tomasz Hemperek, Fabian Hügging, Jens Janssen, Hans Krüger, David-Leon Pohl, Mark Standke, Marco Vogt, Tianyang Wang, Norbert Wermes, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

The Large Hadron Collider at CERN will be upgraded to the High-Luminosity-LHC and will deliver an instantaneous luminosity increased by a factor of 5 - 8 from 2026 on compared to now. In order to cope with the increased radiation level and hit rate, detectors with better radiation tolerance and higher data rate capabilities are demanded. Therefore, the ATLAS experiment develops an all-new pixel detector which will consist of 5 barrel layers and an increased surface of approximately 15m^2.

For the construction of such large scale detectors, commercial CMOS processes, which offer high yield and high throughput at comparatively low costs, are of interest not only for the readout chip but also for the sensor. In order to qualify the suitability of commercial CMOS pixel sensors for the ATLAS pixel detector upgrade, pixel sensors using a 150 nm CMOS technology offered by LFoundry have been designed and produced.

Measurements of the pixel sensor bump-bonded to the RD53A readout chip and test-beam results using a 2.5 GeV electron beam will be presented.

T 82.8 Thu 18:15 L-2.004

Teststrahl- and Laborergebnisse von ATLAS Sensoren mit modifizierten Pixelimplantationen — •Mareike Wagner, Andreas Gisen, Valerie Hohm, Kevin Kröninger, Jens Weingarten und Felix Wizemann — TU Dortmund, Experimentelle Physik IV

Während des ersten Long Shutdowns (LS1) des LHC am CERN wurde der Insertable B-Layer (IBL) in das bestehende ATLAS Experiment eingebaut um das Tracking zu verbessern. Er befindet sich zwischen der innersten Pixellage und einer neuen Strahlröhre. Aufgrund des geringen Abstands zum Interaktionspunkt, sind die planaren und 3D Sensoren des IBL einer hohen Strahlenbelastung ausgesetzt. Die planaren Pixelsensoren sollen einer Fluenz von $5 \cdot 10^{15}\ \text{n}_{\text{eq}}/\text{cm}^2$ standhalten. Die Pixel mit einer Größe von $250\,\mu\text{m} \times 50\,\mu\text{m}$ sind in einer Matrix aus 80 Spalten und 336 Reihen angeordnet und werden mit dem FE-I4B Auslesechip ausgelesen.

Diese IBL-Sensoren sind die Basis für neue Implantationsformen, die in Dortmund entwickelt wurden. Sie sollen zu Maxima des elektrischen Feldes führen um so die Ladungssammlung zu verbessern. Es könnten höhere Detektionseffizienzen bei niedrigerer Spannung erreicht werden, was besonders bei bestrahlten Modulen erstrebenswert ist.

In dieser Präsentation werden Ergebnisse von bestrahlten Sensoren mit modfizierten Implantationen aus verschiedenen Teststrahlmessungen präsentiert. Außerdem werden Resultate nach verschiedenen Annealing-Schritten gezeigt und mit Messungen der Ladungssammlung, die mit Hilfe eines Lasers im Labor generiert wurden, verglichen.

T 82.9 Thu 18:30 L-2.004

Testbeam results of ATLASPix3 — H. Augustin[1], F. Ehrler[2], D.M. Immig[1], •D. Kim[1], L. Mandok[1], L.O.S. Noehte[1], I. Perić[2], M. Prathapan[2], T.T. Rudzki[1], R. Schimassek[1], A. Schöning[1], A. Weber[1,2], and H. Zhangh[2] — [1]Physikalisches Institut, Uni Heidelberg — [2]Karlruher Institut für Technologie

For the high luminosity upgrade at the Large Hadron Collider (HL-LHC) ATLAS will replace its tracking system with the Inner Tracker fully made of silicon detectors. The instantaneous luminosity, that increases by 5-7 times with respect to the current LHC value, causes challenges in terms of radiation tolerance and readout speed. An alternative to the hybrid detectors of the outer pixel modules are High-Voltage Monolithic Active Pixel Sensors (HV-MAPS).

HV-MAPS combines the fast charge collection via drift of the active pixel matrix with a fully integrated readout structure in one entity. ATLASPix3 is an HV-MAPS prototype based on HV-CMOS 180nm technology and was produced with a substrate resistivity of the wafer of 200 Ωcm. In ATLASPix3, an NMOS comparator is embedded in the pixels. The pixel matrix consists of 132 columns and 372 rows with a pixel size of the ATLASPix3 is a pixel size of 150 x 50 μm^2.

This talks presents first testbeam results of ATLASPix3, including the efficiency and time resolution, as measured with MuPix telescope.