T 70: Silicon Detectors VI (MAPS, Mighty Tracker)

Time: Thursday 16:15–18:30 Location: VG 0.111

T 70.1 Thu 16:15 VG 0.111

Characterization of H2M: a MAPS produced in a 65 nm CMOS imaging process — •Sara Ruiz Daza[1,3], Rafael Ballabriga[2], Eric Buschmann[2], Michael Campbell[2], Raimon Casanova Moh[2], Dominik Dannheim[2], Ana Dorda[2], Finn King[2], Philipp Gadow[2], Ingrid-Maria Gregor[1,3], Karsten Hansen[1], Yajun He[1], Lennart Huth[1], Iraklis Kremastiotis[2], Corentin Lemoine[2], Stefano Maffessanti[1], Larissa Mendes[1,3], Younes Otarid[1], Christian Reckleben[1], Sebastien Rettie[2], Manuel Alejandro del Rio Viera[1,3], Judith Schlaadt[1], Adriana Simancas[1,3], Walter Snoeys[2], Simon Spannagel[1], Tomas Vanat[1], Anastasiia Velyka[1], Gianpiero Vignola[1,3], Håkan Wennlöf[1], and Ono Feyens[1] — [1]DESY, Hamburg, Germany — [2]CERN, Geneva, Switzerland — [3]University of Bonn, Bonn, Germany

The high energy physics community recently gained access to a 65 nm CMOS imaging process, which enables a higher density of in-pixel logic in MAPS. To explore this novel technology, the H2M (Hybrid-to-Monolithic) test chip has been designed and manufactured. The design followed a digital-on-top design workflow and ports a hybrid pixel-detector architecture into a monolithic chip.

This contribution will introduce the H2M chip and cover its characterization in the lab and test beam. A hit-detection efficiency above 99% has been measured, unaffected by thinning samples down to 21 um. Additionally, a measured non-uniformity of the in-pixel response related to the size and location of the n-wells in the analog circuitry will be discussed, as well as its impact on time resolution.

T 70.2 Thu 16:30 VG 0.111

Time and position resolved charge collection studies on a monolithic active pixel sensor — •Jona Dilg[1,3], Ono Feyens[1,4], Ingrid-Maria Gregor[1,3], Karsten Hansen[1], Yajun He[1], Lennart Huth[1], Finn King[1], Stefano Maffessanti[1], Larissa Mendes[1,3], Christian Reckleben[1], Sara Ruiz Daza[1,3], Manuel Alejandro del Rio Viera[1,3], Judith Schlaadt[1,3], Adriana Simancas[1,3], Simon Spannagel[1], Tomas Vanat[1], Anastasiia Velyka[1], Gianpiero Vignola[1,3], and Haakan Wennlöf[2] — [1]Deutsches Elektronen-Synchrotron DESY, Germany — [2]National Institute for Subatomic Physics Nikhef, Netherlands — [3]Universität Bonn, Germany — [4]Vrije Universiteit Brussel, Belgium

Monolithic Active Pixel Sensors (MAPS) are used in vertex detectors for high-energy particle colliders. They integrate sensors and readout electronics on a single chip, reducing material use compared to hybrid pixel detectors. The recent adoption of a 65 nm Complementary Metal-Oxide-Semiconductor (CMOS) imaging process enables a smaller pixel pitch with enhanced in-pixel electronics.

The DESY ER1 test chip consists of a single pixel and a 2×2 matrix with $35 \times 25\,\mu$m pitch, with in-pixel amplification and digitization. In contrast to complementary test structures with fully digital readouts, it allows direct measurement of amplifier output, aiding in understanding effects obscured in purely digital schemes.

This contribution presents the chip's design and the insights gained through its characterization and pulse shape analysis of laboratory and test beam measurements.

T 70.3 Thu 16:45 VG 0.111

Simulation of Hexagonal Pixels in Monolithic Active Pixel Sensors — •Larissa Mendes — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Monolithic active pixel sensors (MAPS) produced using 65 nm CMOS imaging technology are being investigated for particle physics applications, particularly in tracking detectors to meet the demands of future lepton colliders. The complex silicon doping and non-linear electric fields require precise simulations for sensor performance optimization. This study utilizes a combination of electrostatic field simulations and Monte Carlo techniques to predict the performance of different sensor designs.

A hexagonal pixel grid is explored as an alternative to traditional square or rectangular layouts, and the performance is assessed for various pixel sizes. Hexagonal pixels are particularly interesting because they can reduce electric field edge effects seen in square designs, provide a more homogeneous response over the pixel cell, and allow for a shorter drift path while maintaining adequate area for circuitry in the p-well, as well as reducing the number of neighboring pixels. While results for a thin epitaxial layer of 10 um show limited improvements in quantities like efficiency, cluster size, and spatial resolution, further investigations address design limitations and potential advantages, such as enhanced timing performance.

T 70.4 Thu 17:00 VG 0.111

Development and simulation of the LHCb Upgrade 2 tracker — Johannes Albrecht, Dominik Mitzel, •Donata Osthues, and Dirk Wiedner — TU Dortmund University, Dortmund, Germany

During the High-Luminosity LHC period, the LHCb collaboration aims to operate its detector at significantly higher instantaneous luminosities than in Run 3 data taking.

To adapt to higher radiation levels and hit occupancies, the LHCb detector will undergo a second upgrade. This includes a replacement of the SciFi-Tracker by the Mighty-Tracker, a combination of silicon-fiber modules in the outer region and MightyPix modules in the space closest to the beam pipe. The MightyPix module development includes overall module design choices, serial powering and cooling solutions as well as the MightyPix chip development.

This talk presents quantities such as overall tracking efficiencies and material budget scans that are calculated to test and verify the hardware development by using a detailed detector geometry simulation as baseline. The results help to make justified decisions during the development process.

T 70.5 Thu 17:15 VG 0.111

Timing studies of an HV-MAPS for LHCb Mighty Tracker — •Benedict Maisano, Lucas Dittmann, Ruben Kolb, Ulrich Uwer, and Sebastian Bachmann — Physikalisches Institut, Heidelberg, Germany

For the LHC Run 5 the LHCb experiment plans to increase the instantaneous luminosity significantly. As a consequence an upgrade of the experiments detectors is pursuit. A part of this proposed LHCb Upgrade II is to replace the inner regions of the scintillating fibre tracking system with pixel detectors, tackling the increased occupancies and radiation. For this Mighty Tracker, the high-voltage monolithic active pixel sensor MightyPix is currently developed and characterised. The MightyPix utilizes an amplifier and a comparator inside every pixel.

As future MightyPix designs are likely to utilize an NMOS comparator instead of the currently used CMOS versions, it is necessary to ensure that performance is uneffected by this change. For this purpose the performance of a MightyPix predecessor with NMOS comparator, the Run2020v1, is studied. The presentation will feature results of the timing measurements performed in both the lab and testbeam setup and compare them to the timing requirement of the Mighty Tracker.

T 70.6 Thu 17:30 VG 0.111

Studies of the Depletion Region in irradiated HV-CMOS MAPS towards the LHCb Mighty-Tracker using TCT — •Niclas Sommerfeld, Klaas Padeken, Hannah Schmitz, and Sebastian Neubert — University of Bonn

With the high luminosity upgrade to the LHC during LS3 the instantaneous luminosity at the LHCb experiment will be eventually increased by more than a factor of 6 to $1.3 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for Run 5. As a part of Upgrade II the downsteam tracker (Mighty-Tracker) is foreseen to be instrumented with $13\mathrm{m}^2$ of HV-CMOS MAPS arround the beam pipe. This is intended to meet the increased requirements in terms of granularity and radiation tolerance imposed by the higher luminosity.

As a part of the ongoing efforts to develop the HV-CMOS MAPS foreseen for the Mighty-Tracker, the change of the depletion region in irradiated HV-CMOS MAPS is studied. The non trivial behavior – evolving from a large size monolithic senor – is investigated in several measurements with a focus on the transient-current-technique(TCT), using a TCT setup at CERN.

T 70.7 Thu 17:45 VG 0.111

Studies on the Radiation Tolerance of HV-CMOS MAPS for the LHCb Mighty-Tracker — •Hannah Schmitz, Klaas Padeken, Niclas Sommerfeld, and Sebastian Neubert — University of Bonn

By the start of Run 5 of the LHC the instantaneous luminosity at LHCb will increase from $2 \cdot 10^{33}\text{cm}^{-2}\text{s}^{-1}$ to $1.3 \cdot 10^{34}\text{cm}^{-2}\text{s}^{-1}$. Therefore, the overall tracking system has to be upgraded. The upgraded downstream tracker (Mighty-Tracker) is foreseen as a hybrid detector consisting of six layers of HV-CMOS MAPS with a total size of 13m^2, covering the central part of the acceptance close to the beampipe, and scintillating fibers in the outer part.

HV-CMOS MAPS are chosen to fulfill the upcoming requirements: High granularity, power consumption $\leq 150\text{mWcm}^{-2}$, time resolution $\leq$ 3ns - required to operate the trigger-less 40MHz DAQ - and a high radiation level of $3 \cdot 10^{14}$1-$\text{MeVn}_{\text{eq}}\text{cm}^{-2}$ (NIEL) and 25MRad (TID).

Performance studies of 180nm processed HV-CMOS MAPS with focus on the radiation tolerance, have been performed. Using a 14MeV proton beam at the Bonn cyclotron as well as an irradiation with x-rays, the impact of different types of radiation damages on the sensor have been investigated.

Both campaigns and the consequences induced by the radiation damage on the sensor operation with emphasis on the performance goals will be covered by this presentation.

T 70.8 Thu 18:00 VG 0.111

Support Structure Investigations for the LHCb Mighty Tracker in Upgrade II — •Ksenia Solovieva, Todor Todorov, and Marco Gersabeck — Albert-Ludwigs-University,Freiburg

In preparation for the challenging environment of the High Luminosity LHC, the LHCb detector will undergo major improvements. The Upgrade II is scheduled to be installed during Long Shutdown 4 and includes a replacement of the downstream tracker. The current scintillating fibre tracker detector will be replaced with a hybrid system, the Mighty Tracker, comprising layers of improved scintillating fibres and 6 layers of silicon pixel detectors. The latter requires optimisation in the detector design, service routing and support structures to adhere to a strict material budget of below 1% X/X0 per layer. In this presentation, early considerations and studies of potential support structure solutions are discussed.

T 70.9 Thu 18:15 VG 0.111

Irradiation Studies related to the Bias Behaviour of the MightyPix — Johannes Albrecht[1], •Jonas Rönsch[1], Sebastian Rüssmann[1], Klaas Padeken[2], Hannah Schmitz[2], Niclas Sommerfeld[2], Dirk Wiedner[1], and Lukas Witola[1] — [1]TU Dortmund University, Dortmund, Germany — [2]Helmholtz Institute for Radiation and Nuclear Physics, Bonn, Germany

To exploit the full flavour physics potential of the HL-LHC, the LHCb detector will be operated at an unprecedented instantaneous luminosity after long shutdown 4. Due to the new conditions, an upgrade of the tracking system is unavoidable. The Mighty Tracker will be the downstream LHCb Upgrade 2 tracking system. It combines scintillating fibres and high voltage monolithic active pixel sensors (HVMAPS) called MightyPix.

The MightyPix will be placed in the inner part of the detector. Therefore, they encounter irradiation levels up to 3×10^{14}1-$\text{MeVn}_{\text{eq}}\text{cm}^{-2}$.

As part of the radiation tolerance studies, several MightyPix were irradiated at the Isochronous Cyclotron of the Helmholtz Institute for Radiation and Nuclear Physics in Bonn up to a fluence of 3×10^{15}1-$\text{MeVn}_{\text{eq}}\text{cm}^{-2}$. The effect of the irradiation on the complex system of the monolithic sensor will be presented.