T 55: Silicon Detectors VI

Time: Wednesday 16:15–18:45 Location: KH 01.022

T 55.1 Wed 16:15 KH 01.022

Simulation and development of the Mighty-Tracker for LHCb Upgrade II — Johannes Albrecht, Dominik Mitzel, •Donata Osthues, Dirk Wiedner, and Lukas Witola — TU Dortmund University, Dortmund, Germany

During the High-Luminosity LHC period, the LHCb detector will be operated at a significantly higher instantaneous luminosity compared to Run 3.

To adapt to higher radiation levels and hit occupancies, the LHCb detector will undergo a second upgrade. The SciFi tracker will be replaced by the Mighty-Tracker, comprised of scintillating fibres in the outer region and silicon pixel sensors in the region closest to the beam pipe. The MightyPix modules are currently under development; the module design, serial powering and cooling solutions must be determined.

Simulation studies are a crucial input to these developments. This talk presents material budget scans, tracking efficiency calculations and momentum resolution results using a detailed detector geometry simulation based on the latest Mighty-Tracker design.

T 55.2 Wed 16:30 KH 01.022

Low-Mass Mechanics: Support structure investigations for the LHCb Mighty Tracker — •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, a potential support structure solution and progress towards its prototyping is discussed.

T 55.3 Wed 16:45 KH 01.022

Performance Characterisation of LF-MightyPix for the LHCb Mighty Tracker — •Celina Welschoff, Sebastian Bachmann, Lucas Dittmann, Ruben Kolb, David Kuhn, and Ulrich Uwer — Physikalisches Institut, Universität Heidelberg

For Run 5 of the LHC, LHCb will reach an instantaneous luminosity of up to $1.0 \cdot 10^{34}$ $cm^{-2}s^{-1}$. To cope with this challenging environment the current detector needs to be upgraded. One crucial part is the new main tracker, the Mighty Tracker. It will utilise scintillating fibres in the outer regions and silicon pixel sensors in the innermost region. For that inner region, prototype chips based on the High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) technology have been developed. To fulfil the detector's requirements and support LHCb's physics performance, the sensors have to achieve a detection efficiency of > 99 % within the 25 ns bunch crossing period. LF-MightyPix is the first prototype sensor for the Mighty Tracker using the LFoundry process. The previous first and upcoming third prototype are produced with different foundries. Evaluating the performance of LF-MightyPix allows to qualify the LFoundry 150nm HV-CMOS process as possible technology for the Mighty Tracker pixel sensor. LF-MightyPix is a small scale prototype and has a size of 3.5 $mm \times 4$ mm and a pixel size of 100 $\mu m \times 100$ μm. In addition, it features a LHCb compatible readout. In this presentation the key features of LF-MightyPix are outlined and the performance of LF-MightyPix is presented utilising both lab and testbeam results. These results show a detection efficiency of > 99 % within 25 ns, fulfilling the Mighty Tracker requirements.

T 55.4 Wed 17:00 KH 01.022

Investigation of X-ray-induced effects and resulting high backside currents in DePFET pixel sensors for the Belle II experiment — Florian Bernlochner, Jochen Dingfelder, and •Georgios Giakoustidis — University of Bonn, Bonn, Germany

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 $E_{CM} = 10.58$ GeV and it has reached a record-breaking instantaneous luminosity of $5.1 \cdot 10^{34}$ $cm^{-2}s^{-1}$ in December 2024. During the so-called Long Shutdown 1 (LS1) the innermost part of the Belle II detector, the initially descoped PiXel Detector (PXD1) with 20 modules, based on Depleted P-channel Field Effect Transistor (DePFET) technology, was replaced by a fully-populated, two-layer PXD with 40 modules. As the detector closest to the experiment's interaction region, the PXD is most exposed to radiation from the accelerator. Throughout the operation of the PXD1 a steady increase of backside current with irradiation was observed in several modules. Doping-profile measurements and electric field simulations show that this is a consequence of (partially) shorted guard rings at the backside leading to high electric fields and avalanche current multiplication. In this contribution, irradiation studies investigating both the X-ray-induced effects in DePFET sensors and the resulting high backside currents will be presented.

T 55.5 Wed 17:15 KH 01.022

Fast Shutdown for the Belle II Pixel Detector — •Paula Scholz[1], Jannes Schmitz[1], Florian Bernlochner[1], Jochen Dingfelder[1], and Michael Ritzert[2] — [1]Universität Bonn — [2]Universität Heidelberg

During beam loss events at the SuperKEKB accelerator in Japan, large amounts of radiation can severely damage the innermost layers of the Belle II Pixel Detector (PXD). Due to these events, the PXD has remained shut down since May 2024. The PXD consists of silicon pixel matrices based on DEPFET technology. Application-Specific Integrated Circuits (ASICs), known as "switchers", control these matrices by changing voltage levels of 20 V within a few nanoseconds during each 50 kHz readout cycle. Since the detector is safe when the switchers are unpowered, a secure method for rapidly powering down modules during beam loss events is required.

To address this, a modification of the custom-made power supply enabling an immediate pull-down of the switcher channels has been developed. Tests in the laboratory were conducted to verify its reliability and to observe the voltage evolution during the shutdown. The effectiveness of the fast shutdown was further evaluated during a test beam campaign at the MAMI electron facility, where it was triggered before an electron beam reached the sensitive switchers to determine limits for minimum shutdown response times and tolerable beam currents. This upgrade is a key prerequisite for the safe reactivation of the PXD and therefore essential for restoring full vertexing capabilities in the next SuperKEKB run.

T 55.6 Wed 17:30 KH 01.022

Investigation of neutron-induced single-event effects in the Belle II PXD overvoltage protection logic — •Jannes Schmitz, Florian Bernlochner, Jochen Dingfelder, and Hans Krüger — University of Bonn

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, collects e^+e^- collision data reaching a record-breaking instantaneous luminosity of $5.1 \cdot 10^{34}$ $cm^{-2}s^{-1}$ in December 2024. The innermost Belle II sub-detector is the PiXel Detector (PXD), which is based on modules with Depleted P-channel Field Effect Transistor (DePFET) sensors. Each PXD module is powered by a custom-made power supply, providing 23 channels for the DePFETs operational voltages, linear post regulation and overvoltage protection circuitry. Although located on top of the Belle II detector and far away from the interaction region, the PXD power supplies triggered false overvoltage events induced by increased beam backgrounds during operation. Expecting a proportional increase up to the target instantaneous luminosity of $6 \cdot 10^{35}$ $cm^{-2}s^{-1}$, investigations started to find the cause of these effects and minimize the resulting downtime of the detector.

This talk will discuss the observed neutron-induced single-event effects, covering improvements of the firmware as well as dedicated studies of its effectiveness in neutron-rich accelerator environments.

T 55.7 Wed 17:45 KH 01.022

Wafer-level quality control procedure of silicon pixel sensors for the LHCb U2 Mighty-Tracker — Johannes Albrecht, •Jonas Rönsch, Dirk Wiedner, and Lukas Witola — TU Dortmund University, Dortmund, Germany

To exploit the full flavour physics potential of the HL-LHC after long

shutdown 4 (2034-2036), the LHCb detector will be operated at an instantaneous luminosity of $1.0 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Due to the higher particle density, an upgrade is necessary to increase the granularity of the tracking system. The main tracking stations will be replaced by the Mighty-Tracker. It combines roughly $285\,\mathrm{m}^2$ of scintillating fibres in the outer region and $8\,\mathrm{m}^2$ of high voltage monolithic active pixel sensors (HVMAPS) called MightyPix in the inner region.
The pixel detector will be instrumented with approximately 46000 sensors, which all need to be thoroughly tested before being assembled into modules. Due to the large quantity the tests will be performed on a semi-automatic probe station.
The wafer-level quality control procedure of the MightyPix will be presented in this talk.

T 55.8 Wed 18:00 KH 01.022

Cluster Size Simulations in Allpix Squared for the LHCb Mighty Pixel Tracker — •Ruben Kolb, Sebastian Bachmann, Lucas Dittmann, David Kuhn, Ulrich Uwer, and Celina Welschoff — Physikalisches Institut Universität Heidelberg

During LHC's Run 5, the instantaneous luminosity of the LHCb experiment is expected to increase by at least a factor of five, imposing significantly more stringent requirements on the tracking detectors in terms of occupancy and radiation tolerance. To meet these challenges, the Upgrade II program foresees the replacement of the current scintillating fiber (SciFi) tracker with the so-called Mighty Tracker. This new tracking system combines scintillating fiber detectors in the outer regions with monolithic silicon pixel sensors (Mighty Pixel) in the innermost region.

One of the critical specifications to design the pixel detector is the expected hit rate. Here, the cluster size has a substantial impact, as the particles traverse the detector under an angle. This has implications on the expected data rate and the overall detector performance. Besides the incident angle, the cluster size depends on pixel geometry, depletion depth, sensor thickness and detection threshold. A data-validated simulation in Allpix Squared utilizing the angle distribution expected in the pixel region of the Mighty Tracker is presented in this talk. The results aid in the decision for critical sensor design choices and detector layout.

T 55.9 Wed 18:15 KH 01.022

Particle-Weighted Material Budget Studies for the Mighty Pixel Layer and Enclosure Box in LHCb Upgrade II — •Rehan Waheed Haroon Rashid Sayyed, Ksenia Solovieva, and Marco Gersabeck — Physikalisches Institut, Albert-Ludwigs-Universitat Freiburg, Freiburg, Germany

The LHCb Upgrade II requires a complete redesign of the downstream tracking system to withstand extreme particle flux at increased luminosity. The Mighty Tracker design, featuring interleaved Mighty Pixel and Mighty SciFi layers, must minimise both active and passive material to preserve tracking performance. The work centers on optimising the layout of material in Mighty Pixel layers, focusing on the thermal enclosure box and the strategic placement of associated electronics (HDI and DCDC converters). Particle-weighted material budget estimations are performed using simplified simulations of particle trajectories through these system components, including staves (comprising carbon foam, Nomex, titanium cooling tubes, and other materials), the readout-flex, the enclosure, and the electronics. The study specifically targets the geometric and material optimisation of these elements. A primary objective is to determine the optimal placement for high-density electronics, evaluating whether to integrate them within the enclosure volume, mount them on its exterior, or position them further away, based on their exposure to the particle flux. This work aims to design a Mighty Pixel layer system that minimises the degradation of track quality from material-particle interactions, thereby supporting the overall physics performance goals of the LHCb Upgrade II tracker.

T 55.10 Wed 18:30 KH 01.022

Development and Validation of a TID irradiation setup based on a strong ^{90}Sr β-source — •David Kuhn, Sebastian Bachmann, Lucas Dittmann, Ruben Kolb, Ulrich Uwer, and Celina Welschoff — Physikalisches Institut, Universität Heidelberg

During Long Shutdown 4 of LHC, the LHCb detector is planned to receive its Upgrade II to be able to cope with the significant increase in instantaneous luminosity to up to $1.0 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. As part of the upgrade the current scintillating fiber tracker will be replaced by the Mighty Tracker. This new main tracker will continue to use scintillating fibers in the outer region. In the inner region, however, the required granularity and radiation tolerance exceed the capabilities of this technology. There, a silicon-based pixel detector will be employed instead. The proposed technology for this is High Voltage Monolithic Active Pixel Sensor (HV-MAPS).

As the MightyTracker pixel detector will be subject to ionizing radiation damage up to dose of 40 Mrad during its lifetime, the associated influence on the operation of the pixel sensors needs to be studied precisely. For this, a setup utilizing a 3.7 GBq Strontium-90 β-source is developed and simulated using FLUKA. The simulated dose rate of up to 10 krad/h for silicon pixel detectors in the irradiation setup can be validated by using dose rate and hit rate measurements. In this talk the development and validation process of the irradiation setup will be presented.