T 37: Silicon trackers 2

Time: Tuesday 16:00–18:00 Location: Geb. 30.22: kl. HS B

T 37.1 Tue 16:00 Geb. 30.22: kl. HS B

Assembly and testing of ATLAS ITk pixel detector modules during the production phase — Patrick Ahlburg, Yannick Dieter, Fabian Hügging, Florian Hinterkeuser, Hans Krüger, Maximilian Mucha, •Matthias Schüssler, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

With the upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC), the instantaneous luminosity will increase by a factor of 5 from 2029 onward. This results in unprecedented hit rates and radiation levels which require major upgrades of the detectors located at the HL-LHC in order to meet these challenging requirements.

For the upgrade of the ATLAS detector, a new all-silicon inner tracking detector (ITk detector) consisting of silicon strip and pixel modules will be installed and replaces the currently operated Inner Detector. In total, approximately 10.000 new pixel detector modules have to be built and carefully tested to ensure that only functional detector modules are installed. At the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn, approximately 1000 pixel detector modules will be built and characterized during the production of the ATLAS ITk pixel detector. For testing the electrical functionality of the detector modules an intensive quality control (QC) with dedicated testing setups is necessary.

This talk gives an overview of the module assembly at Bonn and the electrical QC for ATLAS ITk pixel detector modules.

T 37.2 Tue 16:15 Geb. 30.22: kl. HS B

ITk Pixel DCS: Pixel System Monitoring Readout — •Anne Gaa and Stan Lai — II. Physikalisches Institut, Georg-August-Universität Göttingen

The ATLAS experiment is developing the new Inner Tracker (ITk) in preparation for the High-Luminosity LHC Upgrade. The ITk pixel Outer Barrel demonstrator, as a system prototype, recently passed its final design review phase in preparation of the construction of the finished detector. The Detector Control System (DCS) is responsible for monitoring and controlling the detector and its sub-systems.

Part of the DCS is the readout chain of the Monitoring of Pixel System (MOPS), which provides an independent monitoring of the temperature and voltage of the front-end pixel modules. The MOPShub is the bidirectional interface between the local DCS station and the MOPS chips. Testing sites for the Outer Barrel local supports, as well as the OB demonstrator currently use MOPShub4beginners, a preliminary readout chain based on a RaspberryPi. The MOPS chips are connected via CAN buses to the RaspberryPi, which sends the monitored data over an OPC UA server to the local DCS control station. OPC UA is an cross-platform, open-source standard for data exchange. This talk presents new developments of the MOPShub.

T 37.3 Tue 16:30 Geb. 30.22: kl. HS B

Bump connectivity and efficiency studies on ATLAS ITkPix using a high intensity X-Ray beam — Yannick Dieter, Fabian Hügging, Hans Krüger, •Andreas Ulm, Marco Vogt, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

With the upgrade of the Large Hadron Collider (LHC), which will increase the instantaneous luminosity by a factor of approximately 5 to the current luminosity, the ATLAS detector will also be upgraded. In particular, a new all-silicon tracking detector (ATLAS ITk) is installed consisting of strip and hybrid pixel detectors.

Hybrid pixel detectors consist of a passive sensor element and an active readout chip which are connected via small solder bumps. As this interconnection is a quite complex process the bump connectivity of each pixel has to be tested. To test the bumps, a setup inside of an X-Ray machine has been installed. A X-ray machine is used to archive the high statistics needed to identify connected bumps in a short amount of time. In addition to that, the high intensity X-ray beam can also be used to investigate the rate capability of the ATLAS ITk pixel detector readout chip.

In this talk, a setup for the investigation of the bump-connectivity is presented and efficiency studies using a high intensity x-ray beam are shown.

T 37.4 Tue 16:45 Geb. 30.22: kl. HS B

Performance of CMS Inner Tracker pixel assemblies for the Phase-2 Upgrade — •Bianca Raciti, Massimiliano Antonello, Erika Garutti, Chin-Chia Kuo, Jörn Schwandt, and Georg Steinbrück — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

During Long Shutdown 3, the entire CMS Tracking System will be replaced to operate during the High Luminosity LHC running phase with considerably increased luminosity. The pixel sensor modules for the CMS Inner Tracker will have to fulfill stringent requirements to operate in an extremely harsh radiation environment and to cope with the high data readout rate.

An extensive campaign has taken place to characterize the first half-size pixel chip demonstrator (RD53A), which led to the submission and production of the first full-size prototype chip (RD53B_CMS).

Sensor-readout chip assemblies have been extensively tested both in the laboratory and at the CERN and DESY testbeam facilities.

This study presents results on the analysis of testbeam data acquired with RD53B_CMS assemblies irradiated to fluences up to $\Phi_{\mathrm{eq}} = 1.0 \times 10^{16}\,\mathrm{N_{eq}\,cm^{-2}}$. For all investigated fluences, the requirement of reaching a hit efficiency $\epsilon_{\mathrm{hit}} > 99\%$ has been met, while keeping the percentage of pixels masked as noisy below 1%. Additionally, measurements of crosstalk levels observed in RD53B_CMS assemblies equipped with final design pixel sensors will be presented.

T 37.5 Tue 17:00 Geb. 30.22: kl. HS B

Quality control for the production of multi-chip modules for CMS Inner Tracker — •Chin-Chia Kuo, Massimiliano Antonello, Erika Garutti, Bianca Raciti, Jörn Schwandt, and Georg Steinbrück — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

Quality control studies of Inner Tracker quad modules for the Phase-2 upgrade of the CMS Inner Tracker are presented. An Inner Tracker quad module is a hybrid detector consisting of a silicon pixel sensor and four (2×2) CMS Readout Chips (CROCs) coupled via fine pitch flip-chip bump bonding. In this design, the space between adjacent readout chips is bridged using large sensor pixels.

Several methods for measuring the yield of missing bumps are presented and compared, which will be part of quality control after mass production. Furthermore, the performance of large pixels is presented with quad modules tested at the DESY testbeam facility, using electrons with an energy of 5.2 GeV.

T 37.6 Tue 17:15 Geb. 30.22: kl. HS B

Test Beam Analysis of Irradiated, Passive CMOS Strip Sensors — •Fabian Lex for the CMOS Strips-Collaboration — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Nearly all envisioned future high-energy particle detectors will employ silicon sensors as their main tracking devices. Due to the increased demand in performance, large areas of the detectors will have to be covered with radiation hard silicon, facilitating the need for silicon sensors produced in large quantities, reliably and cost-efficiently.
A possible solution to these challenges has been found in the utilization of the CMOS process, which is an industrial standard, offering the advantage of a large choice of vendors and reduced production costs.
To create the larger sensor structures typical for silicon strip trackers, the stitching process has to be used.
Three variations of passive CMOS strip sensors have been designed by the University of Bonn and produced by LFoundry in a 150 nm process.
Sensor samples have been irradiated up to a fluence of $1 \cdot 10^{16} \mathrm{n_{eq}/cm^2}$ with reactor neutrons and up to $1 \cdot 10^{15} \mathrm{n_{eq}/cm^2}$ with 23 GeV protons.
In order to investigate the general performance of the designs and the influence of the stitching on resolution, hit detection efficiency and charge collection, unirradiated as well as irradiated samples have been tested in the DESY-II test beam facility. This talk will show that even after heavy irradiation signal collection by the different sensor designs is still possible and that the stitching does not impact sensor performance.

T 37.7 Tue 17:30 Geb. 30.22: kl. HS B

Characterisation and TCAD Simulation of Stitched, Passive CMOS Strip Sensors — •Iveta Zatocilova for the CMOS Strips-Collaboration — Albert-Ludwigs-Universität, Freiburg, Germany

Silicon sensors play a key role in the tracking detectors of high-energy physics experiments. Due to upcoming upgrades and future particle detectors, the requirements in radiation hardness and reliability of the sensors are constantly increasing. There is a need for alternative silicon sensor concepts that can realise a larger choice of manufactures while meeting the complex requirements.

A promising technology is found in passive CMOS sensors, based on CMOS imaging technology. As this technology is an industry-standard, it can offer a lowered sensor cost, as well as access to fast and large-scale production.

The passive CMOS project is investigating passive CMOS strips sensors fabricated by LFoundry in a 150 nm technology. A total of three different strip designs have been investigated.

Passive CMOS strip sensors were evaluated based on simulated electrical characteristics of the fabricated structures. For this purpose, Synopsys Centaurus TCAD was used. By simulating electric field we were able to look at differences between the designs. On the macroscopic level we have simulated electrical characteristics that are yielding a satisfactory agreement when compared to measured data.

This presentation will provide an insight into the sensor design and a comparison of simulated and measured sensor characteristics will also be presented.

T 37.8 Tue 17:45 Geb. 30.22: kl. HS B

Characterisation and Simulation of stitched CMOS Strip Sensors — •Naomi Davis for the CMOS Strips-Collaboration — Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg

In high-energy physics, upgrades for particle detectors and studies on future particle detectors are largely based on silicon sensors as tracking devices. Consequently, there is a need to investigate silicon sensor concepts that offer large-area coverage and cost-efficiency. Sensors based on the CMOS imaging technology present such an alternative silicon sensor concept for tracking detectors. As this technology is a standardised industry process it can provide a lower sensor production cost, as well as access to fast and large-scale production from a variety of vendors. The CMOS Strips project is investigating passive CMOS strip sensors fabricated by LFoundry in a 150 nm technology. By employing the technique of stitching, two different strip formats of the sensor have been realised. The strip design varies in doping concentration and width of the strip implant to study various depletion concepts and electric field configurations. Unirradiated and irradiated samples have been characterised in several test beam campaigns at the DESY II test beam facility. In addition, the detector response was simulated based on Monte Carlo methods and electric fields provided by TCAD device simulations. This contribution presents studies on the signal distribution, spatial resolution and the hit detection efficiency of the strip sensors. The simulated detector response is presented and compared to test beam data.