T 12: Pixel Detectors

Time: Monday 16:15–18:30 Location: T-H25

T 12.1 Mon 16:15 T-H25

ATLAS ITk Pixel Detector Quad Module Building and Testing for the HL-LHC Upgrade — Jörn Grosse-Knetter, Arnulf Quadt, •Yusong Tian, and Hua Ye — II. Physikalisches Institut, Georg-August-Universität Göttingen

In the ATLAS detector upgrade for the High-Luminosity LHC (HL-LHC), the current Inner Detector will be upgraded to an all-silicon Inner Tracker (ITk), to operate under higher occupancy and radiation damage resulting from the higher luminosity. The pixel detector is the inner-most layer of the ITk, shaped like a cylinder with about 0.4m radius and 6m long. It is assembled with barrels and end-cap rings made of single and quad-chip modules. Each module is assembled with a bare module and a printed circuit board (PCB). A quad bare module consists of one sensor bump-bonded to 4 front-end readout chips. RD53A is the name for the front-end readout chip prototype, the name for the final version is ITkPix. The modules are referred to with the name of the front-ends. This talk shows the module assembly and testing results.

T 12.2 Mon 16:30 T-H25

ITk-pixel outer barrel demonstrator — Jörn Grosse-Knetter[1], Susanne Kühn[2], •Silke Möbius[1], Arnulf Quadt[1], Benedikt Vormwald[2], and Hua Ye[1] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen — [2]CERN

For the upgrade of the LHC to the High-Luminosity-LHC, the ATLAS tracking detector will be replaced with a pure silicon detector, the Inner Tracker (ITk), as the higher luminosity requires radiation hard components that can deal with higher occupancies and radiation. Given the close proximity to the interaction point, the environment is especially challenging for the pixel detector which will comprise quad chip modules for outer barrel layers.

In order to characterize and test ITk-pixel prototype quad modules, up to 40 modules are built and tested for the outer barrel demonstrator. This so-called demonstrator is a larger structure which features some of the final mechanics to test the system functionalities. Systems like an interlock need to be implemented and tested and the modules behaviour before and after being powered in serial needs to be examined to allow for thorough tests.

After having done initial tests with a preliminary version of the demonstrator with older modules, the preparation of the set-up and commissioning of the new demonstrator is currently ongoing.

This talk will give an overview over the current state of the demonstrator, explain the set-up and summarize the potential tests to be performed on the demonstrator.

T 12.3 Mon 16:45 T-H25

Testing of loaded local supports of the ATLAS Inner Tracker — •Wael Alkakhi, Joern Grosse-knetter, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

During the third long shut down (LS3) of the Large Hadron Collider (LHC), a high luminosity upgrade takes place in which the instantaneous luminosity reaches $7.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in Run 4. The current inner detector of the ATLAS experiment is going to be replaced by inner tracker (ITk). ITk is composed of a pixel detector surrounded by a strip detector. The pixel detector consists of 5 layers where the first 2 layers represent the inner pixel detector and the last 3 layers represent the outer barrel and the endcap. The outer barrel consists of 4474 modules. These modules are mounted on loaded local supports of which there are two types : loaded longeron and loaded inclined half ring. Due to the large number of elements used during the assembly and production of the ITk, the ITk production database is used to store and track the information of the ITk components. Moreover a graphical user interface (GUI) is used to ease working with the ITk production database during the production of the ITk outer barrel.

This talk introduces the integration procedure of modules to local supports. Moreover it demonstrates my contribution to the implementation of the loaded local supports in the ITk production database and the GUI developments.

T 12.4 Mon 17:00 T-H25

ATLAS ITKPix Waferprobing — •Mark Standke, Yannick Dieter, Tomasz Hemperek, Florian Hinterkeuser, Fabian Hügging, Hans Krüger, David-Leon Pohl, Marco Vogt, and Jochen Dingfelder — Forschungs- und Technologie-Zentrum Detektorphysik - Kreuzbergweg 26, 53115 Bonn

Wafer-probing is a process, in which each individual chip is tested for its key function parameters on wafer level. For this purpose, Bonn has developed a fast and versatile testing and analysis environment, making large-scale testing for ATLAS-ITkPix possible. ITkPix is the first full-scale 65 nm ATLAS - hybrid pixel-detector readout chip, developed by the RD53 collaboration. ITkPix consists of more than one billion transistors with high triplication ratio in order to cope with high particle and therefore radiation densities at the heart of ATLAS. The chips will be located as close as possible to the interaction point to optimize impact parameter resolution. ITkPix features a single low power, low noise analog front-end to ensure high readout speeds and low detection thresholds. A failure of such chips at the heart of ATLAS is assumed to be hard to correct. Therefore, thorough testing is necessary. This talk will give an overview over the testing environment, while summarizing the latest results and performance of ATLAS's future inner tracker performance driver, ITkPix.

T 12.5 Mon 17:15 T-H25

Bump bond stress tests with ITk-Pixel-style daisy-chain modules through thermal cycling — Jörn Grosse-Knetter, •Steffen Korn, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

For the upgrade of the LHC to the HL-LHC, the Inner Detector will be replaced by the fully silicon-based Inner Tracker Detector (ITk). The pixel detector of the ITk uses hybrid modules where sensor and readout chips are connected by bump bonds. Early ITk module prototypes highlighted these bump bond connections as a possible point of failure in future ITk Pixel modules when exposed to thermally induced stress. In order to investigate this issue, daisy chain modules with realistic bump bond pitch were tested before and during exposure to thermal stress through cycling in a thermal shock chamber using a dedicated in-situ method in Goettingen. The results of these tests using different modules with different assembly options are presented in this talk.

T 12.6 Mon 17:30 T-H25

Pixel front-end masking and DQ monitoring — Marcello Bindi, Jörn Grosse-Knetter, •Andreas Kirchhoff, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany

During Run 2 of the LHC, the ATLAS tracking software masked non-working pixel modules for offline reconstruction. The masking itself is applied if a module does not receive hits. To improve track reconstruction the number of holes should be reduced. Holes are defined as intersections of reconstructed tracks with sensitive detector elements that did not result in a hit. They are estimated by comparing the hits-on-track with the intersected modules. Inactive modules are excluded from the hole definition. As a consequence, a masked module is treated in the track reconstruction as if it received always a hit.

The ATLAS tracking group for Run 3 will increase the granularity of the masking (moving from module to single front-ends) in order to reduce the number of pixel holes and increase the tracking efficiency. Hit maps collected at the end of each run are chosen as input for the front-end masking. Due to the detector geometry the masking for the different front ends needs to be optimised individually. This talk will present the corresponding studies.

The second topic of the talk will be data quality monitoring. While taking data it is extremely crucial to check whether the detector performs as expected to avoid loss in data. Therefore different monitoring software exists. This talk will present the updated software GNAM2 and its current status.

T 12.7 Mon 17:45 T-H25

Data quality monitoring for the ATLAS pixel detector using large radius tracks — Carmen Diez Pardos, Ivor Fleck, •Jan Joachim Hahn, and Iskander Ibragimov — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

The ATLAS detector is a general-purpose detector at the Large Hadron Collider (LHC) at CERN. Its Inner Detector (ID), used for reconstruction of tracks of charged particles, consists of four barrel layers and two end-caps of three discs each of the silicon pixel detector, surrounded by the silicon strip detector and the transition radiation tracker. During operation of ATLAS, a small fraction of recorded collision events is reconstructed in real time, providing prompt information on the quality of data being taken. For the upcoming LHC Run 3, the reconstruction of tracks in the ID will include the reconstruction of large radius tracks (LRT). These tracks are of interest for the search of long-lived particles beyond the Standard Model. With respect to the standard tracks, they are reconstructed with relaxed constraints on their starting position. The information from LRTs can be used to create additional histograms for monitoring detector performance during operation of ATLAS. This talk will discuss how this can improve data quality monitoring of the pixel detector.

T 12.8 Mon 18:00 T-H25

Measurement of position resolution of small pixel sensors — •Amala Augusthy[1], Daniel Pitzl[2], Erika Garutti[1], and Jörn Schwandt[1] — [1]Institute für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Deutschland

In order to cope with the high radiation environment in the phase 3 upgrade of CMS and ATLAS, pixel detectors with spatial resolution below $1\mu m$ will become necessary. The resolution of pixel sensors can be improved by reducing their pitch. However, the pitch of pixel sensors is limited by the read-out electronics.

To study the intrinsic resolution capabilities, non-irradiated pixels sensors with sizes of $17 \times 150\mu m^2$, $25 \times 100\mu m^2$ and $50 \times 50\mu m^2$ were tested with $5.2GeV$ electron beam at the DESY test beam facility. The $25 \times 100\mu m^2$ and $50 \times 50\mu m^2$ sensors have already been characterized and are being considered for the phase 2 upgrade of the CMS experiment. The aim of this study is to reduce the pitch even further to $17\mu m$ and investigate its performance.

These sensors have a thickness of $285\mu m$ and are bump bonded to a low noise read-out chip ROC4SENS. The spatial resolution as a function of angle of incidence of the particle is extracted from these measurements. In this talk, the results of these measurements will be presented.

T 12.9 Mon 18:15 T-H25

Characterisation of planar pixel sensor for the CMS phase-2 upgrade — •Mohammadtaghi Hajheidari[1], Massimiliano Antonello[1], Finn Feindt[2], Erika Garutti[1], Daniel Pitzl[2], Jörn Schwandt[1], Georg Steinbrück[1], Annika Vauth[1], and Irene Zoi[3] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Deutschland — [3]Fermilab, Batavia, IL, 60510, USA

For the High Luminosity phase of the Large Hadron Collider (HL-LHC), the CMS pixel detector is expected to collect up to 1-MeV neutron equivalent fluence, Φ_{eq}, of $2.3 \times 10^{16}\text{cm}^{-2}$ for integrated luminosity of $3000\,\text{fb}^{-1}$. The pixel detector will be upgraded to withstand this range of fluence.

Planar n-in-p pixel sensors with an active thickness of $150\,\mu$m and a pixel size of $25 \times 100\,\mu\text{m}^2$ have been produced by Hamamatsu Photonics (HPK) and FBK. The sensors were bumped bonded to the RD53A readout chip prototype. The sensor-chip modules were irradiated with 23 MeV protons to the equivalent fluence of up to $2.4 \times 10^{16}\,\text{cm}^{-2}$.

The modules were investigated in the DESY II beam test facility after irradiation. The hit efficiency and spatial resolution as a function of the incidence angle of pixel sensors were determined from these measurements. For non-irradiated modules, a single hit resolution of $2\,\mu$m was achieved at the optimal angle. For irradiated modules with highest fluence, the single hit efficiency still reached 98% at bias voltages below 800 V.