



Contribution ID: 26

Type: Oral

## Module and System Test Development for the Phase-2 ATLAS ITk Pixel Upgrade

*Tuesday 3 September 2019 16:30 (25 minutes)*

The ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk) and its innermost part will consist of a pixel detector. Different silicon sensor technologies will be employed in its five barrel and endcap layers. Components for structures with multiple modules based on FE-14 front-end chips were produced and are in assembly and evaluation. With the arrival of the first readout chip prototype, the RD53A chip, the development of hybrid detector modules is starting to address numerous production issues, understanding of which will be crucial for the layout and production of the final ITk pixel detector modules

### Summary

For the high luminosity era of the Large Hadron Collider (HL-LHC) it is foreseen to replace the current inner tracker of the ATLAS experiment with a new, all-silicon detector to cope with the occurring increase in occupancy, bandwidth and radiation damage. It will consist of an inner pixel and outer strip detector aiming to provide tracking coverage up to  $|\eta|=4$ . The layout of the pixel detector is foreseen to have five layers of pixel silicon sensor modules in the central region and several ring-shaped layers in the forward region. This results in up to 14 m. of silicon depending on the selected layout. Detector requirements in terms of radiation hardness and occupancy, as well as thermal performance depend strongly on the distance from the interaction region. Therefore, the innermost layer will feature 3D silicon sensors, due to their inherent radiation hardness and low power consumption, while the remaining layers will employ planar silicon sensors with thickness ranging from  $100\mu\text{m}$  to  $150\mu\text{m}$ . All hybrid detector modules will be read out by novel ASICs, implemented in 65nm CMOS technology and thinned to  $150\mu\text{m}$ , which will be connected to the silicon sensors using bump bonding. With about 4 104 pixels per cm. the bump bond density is a much higher than in previous hybrid detectors. With the recent availability of the first prototype readout chip, the RD53A, module development for the ITk Pixel Detector is entering a new phase. Numerous modules will be assembled to test the performance of bump bonding of objects of realistic area, very small thickness and high bump bond density, as well as to finalize studies of the module performance with pixel pitches of  $50\times 50\mu\text{m}$ . and  $25\times 100\mu\text{m}$ . on the sensors. Flex circuits are glued on top of the modules for connection and routing of services which have to be qualified too. Moreover, tests of the new serial powering scheme for low voltage supply of the modules will be done as part of the prototyping program. The quality assurance criteria for the production of the final detector modules are verified, including mechanical properties like module flatness as well as electrical tests of the functionality of the modules and the bump bond quality. In addition, a large prototyping programme on system test level is ongoing within the ITk pixel detector community. Components for larger structures with multiple modules based on

the FE-I4 front-end chips were produced and are in assembly and evaluation. By this the system integration and design is prototyped and validated.

The paper will present the latest results from the assembly and characterization of the prototype modules. Important qualification steps of the module design will be discussed. Moreover, latest evaluation and results of thermo-mechanical prototypes and fully electrical prototypes are presented and the system-relevant aspects highlighted.

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**Session Classification:** Systems, Planning, Installation, Commissioning and Running Experience

**Track Classification:** Systems, Planning, Installation, Commissioning and Running Experience