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A big step towards ATLAS ITk: Performance Characterization of the first Loaded Local Supports

The ATLAS Inner Detector is undergoing a significant upgrade in preparation for the demands of the High-Luminosity LHC (HL-LHC) era. The expected increase in proton-proton interactions per bunch crossing from 30 to nearly 200 is demanding a replacement of the current Inner Detector (ID) with the new all-silicon Inner Tracker (ITk), which features higher granularity, extended pseudo-rapidity coverage (|η| up to 4), and a significantly reduced material budget.

The new ITk will comprise a Pixel region as well as a Strips region. Within the Pixel region, the key-detector component is the Loaded-Local-Support (LLS). A lightweight carbon-fiber structure, integrating the detector modules. Those LLS are the smallest functional detector unit, and in order to withstand the unprecedented radiation values, a completely novel concept of detector design and operation had to be developed, including a new readout chip (ITkPix) as well as the introduction of the concept of serial-powering, to fulfill the technical requirements that are demanded from the new ITk.
One LLS hosts up to 36 hybrid silicon detector modules, with each of these modules being connected via titanium pipes to boiling CO_2, enabling cooling to up to -35℃.

Characterizing those LLS is an essential task, to validate the mechanical integration, electrical functionality and thermal performance before large-scale deployment and integration. Key tests include evaluation of the sensor performance, bump-bond integrity, stability of the serial powering, data transmission efficiency as well as ensuring detector robustness through thermal cycling from -40℃ to 50℃.

The environment of these characterization tests needs to be as close as possible to the real detector, which required the build of a complex setup, which mimics the whole readout-chain. This includes high speed readout (10.28 Gb/s) with electrical to optical conversion, a fully-functional small scale Detector Control System (DCS) as well as an Interlock Crate.

This contribution presents the commissioning of the test setup as well as the challenges that had to be overcome and the potential instabilities which can be seen in such a complex setup. Another big focus will be on the results from the very first pre-production LLS, where a set of extensive tests was performed under realistic operating conditions. The results will provide insight into readout performance, system noise, sensor integrity across different loading steps as well as potential risks such as sensor delamination.
These findings contribute to the validation of the ITk LLS design and its readiness for full-scale detector assembly at the HL-LHC, which highlights the importance of these results and the associated performed tests.

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