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The ATLAS Inner Tracker Strip Detector system tests - development of DAQ and DCS

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The new ATLAS Inner Tracker (ITk), consisting of pixel and microstrip detectors, will replace the current tracking system of the ATLAS detector to cope with the challenging conditions of the high luminosity LHC. System tests of the strip sub-detector are being developed which serve as a testbed for testing and evaluating the performance of several close-to-final detector components before production. System tests for the barrel and end-cap region are being developed and operated using pre-production staves and petals, as the building blocks of the detector. This contribution shows the developments of a FELIX-based DAQ system as the foreseen system for Phase-II to work with staves and petals of the ITk strip detector. As a benchmark, the FELIX results are compared to the ones gained with the collaboration internal DAQ systems used by the assembly sites. Moreover, several DCS tools for control and monitoring of the detector developed and validated at the system tests will be presented.

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1. ATLAS Inner Tracker for the HL-LHC

In preparation for the High Luminosity upgrade of the LHC, the ATLAS experiment is replacing its current tracking detector with a new all-silicon Inner Tracker (ITk), including a pixel sub-detector surrounded by a strip sub-detector [1]. The ITk strip detector consists of a central barrel region with four cylindrical layers made of "staves", and two identical end-cap regions each with six disks made of "petals". Each stave or petal consists of modules and end-of-substructure (EoS) cards glued to both sides of a local support structure. The modules are made of custom readout and power control ASICs glued directly to silicon strip sensors. The EoS card hosts optical transceivers and functions as the data and power interface between staves or petals and the off-detector electronics. Staves of the inner two barrel layers host modules with ~2.5 cm "short strip" (SS) silicon sensors, and staves of the outer two barrel layers host modules with ~5.0 cm "long strip" (LS) silicon sensors, All end-cap petals are identical, each hosting six ring modules (R0 - R5) at different radii.

2. ITk strip system tests

The goal of the ITk strip system test [2] is to demonstrate full-system performance from close-to-final components using the complete service chain including data, power, and cooling. It also provides a testbed for developing and validating the data acquisition (DAQ) system and the detector control and safety (DCS) system for detector integration. Two separate test stands have been set up at CERN and DESY, respectively, for the barrel and end-cap sub-detectors. The barrel system test at CERN consists of a custom-made support structure designed to host up to five LS staves and three SS staves. The end-cap system test setup at DESY replicates one sector of the realistic end-cap global structure, which can host up to twelve petals. Both setups are enclosed in thermal boxes that provide dry air and environmental monitoring. Dual-phase CO_2 cooling systems are used to reduce temperatures to -25 °C at CERN and -35 °C at DESY.

2.1 DAQ development

The data readout chain for both the barrel and end-cap system tests, as shown in figure 1, is based on the FELIX [3] system targeting the final readout architecture. Calibration scans are

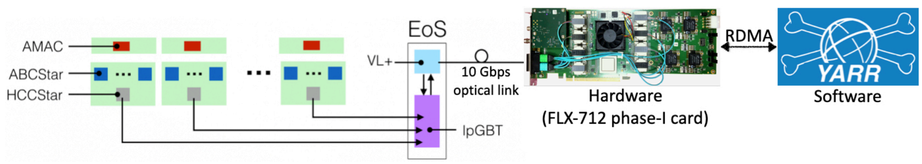


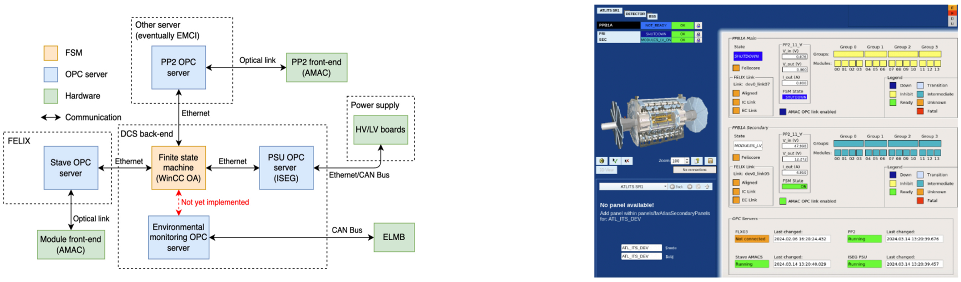
Figure 1: The data acquisition chain for the ITk strip system test. FELIX cards communicate with the EoS boards hosted on staves or petals via 10 Gbps optical links. The communication between FELIX and the DAQ software utilizes Remote Direct Memory Access (RDMA) via dedicated network interfaces.

performed with this readout chain. The scan results are validated against the ones obtained from a different readout system used during production and are found to be compatible. Small residual differences are due to statistical fluctuations or minor variations in the analysis algorithms.

In preparation for taking collision data, tests have been run using 1 MHz triggers generated from the FELIX firmware to read data packets from a stave with low occupancy. Thresholds on the front-end readout chips are adjusted to ensure an average of 1% occupancy from noise. After sending triggers for a fixed period of time, all expected data packets were successfully received and processed. A similar test has been done using an external trigger source from the ATLAS Timing Trigger and Control (TTC) system. It is verified that triggers are correctly forwarded by FELIX to the front-end electronics with the correct trigger tags.

2.2 DCS development

The DCS system ensures stable and safe operations of the detector. Several Open Platform Communication (OPC) servers are in charge of communications among various power and monitoring units., as illustrated in figure 2a. A WinCC project has been set up for the barrel system



(a) **(b)**

Figure 2: (a): A diagram showing various detector power and monitoring units connecting via OPC servers. (b): An example of the DCS FSM graphic user interface.

test and will be extended to include the end-caps. It is responsible for controlling and monitoring power delivered to the front ends, monitoring environmental conditions, and performing controlled shutdown in case of faulty conditions. A Finite State Machine (FSM) graphic interface has been developed for detector operation. In addition to reflecting the current states of detector components, the DCS FSM also enforces a safe control path via defined state transitions. Efforts have been ongoing to further automate the state transitions for starting or shutting down the system.

3. Summary

The ITk strip system tests have been operational at CERN for the barrel system and at DESY for the end-caps. The setups are also used as platforms for the DAQ and DCS development.

References

[1] ATLAS collaboration, *Technical Design Report for the ATLAS Inner Tracker Strip Detector*, Tech. Rep. CERN-LHCC-2017-005, ATLAS-TDR-025, CERN, Geneva (2017).

[2] J.-H. Arling, *Development of the system tests for the ATLAS Inner Tracker strip detector*, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **1064** (2024) 169427.

[3] ATLAS TDAQ collaboration, *FELIX: the Detector Interface for the ATLAS Experiment at CERN*, *EPJ Web Conf.* **251** (2021) 04006.