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Monitoring System of the ATLAS ITk Laboratory

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Abstract. The ATLAS ITk Upgrade project, culminating in the installation into the experiment in 2026, enters this year its production period. Cooperating laboratories dealing with the strip part of the project needs to meet various conditions in clean rooms and testing environments to ensure safety for production components during assembly and measurement procedures. One of the ITk laboratories, located in Prague, prepared for modules' production is presented as a model case. For this purpose, dedicated DAQ software called ITSDAQ is used together with the slow control monitoring system based on RS232/GPIB standards, MySQL database entry and Grafana visualization platform. Data are stored in the local database storage, a subset of them and the test results are also sent into the ITk Production Database. Such an integrated tool offers real-time plotting of crucial parameters and the possibility of receiving an immediate notification in case of exceeding any threshold.

1. Introduction

The general-purpose ATLAS detector placed at Point 1 of the Large Hadron Collider (LHC) at CERN is going to be upgraded in the framework of Phase-II upgrades on the road to the High-Luminosity LHC. The upgrade is scheduled for the 30-month period of the accelerator's Long Shutdown 3 (LS3) ending in mid-2027. The currently installed Inner Detector (ID) will be completely replaced by the all-silicon vertexing and tracking detection system called Inner Tracker (ITk), which is being developed at collaborating institutes.

2. ATLAS ITk Strip Modules

The ITk consists of the pixel detector placed closer to the beamline and the strip detector at the outer radii. Both systems use n^+-*in*-*p* silicon sensors of different solutions. A schematic layout of the tracker is shown in Figure 1.

The pixel detection system consists of 5 barrel layers and additional individual inclined modules covering space up to ± 4 units of pseudorapidity. The dimensions of pixel segments are planned to be 50x50 or 25x100 μm [1].

The strip detection system occupies an area of approximately 165 m^2 and covers ± 2.7 units of pseudorapidity. It is designed to accommodate modules into 4 barrel and 12 endcap layers of 8 different geometries. The strip length and pitch varies between 1.9 - 6 cm and 69.9 - 80.7 μm respectively, where the variations are mainly caused by the radial design of endcap modules [2].

The strip module consists of 300 μm thick silicon sensor, on which one or two low-mass PCBs called hybrids are glued. They are populated with several read-out ASICs, whose front-end (FE) channels, which are arranged in 4 rows, are wire-bonded to the sensor strip pads. The

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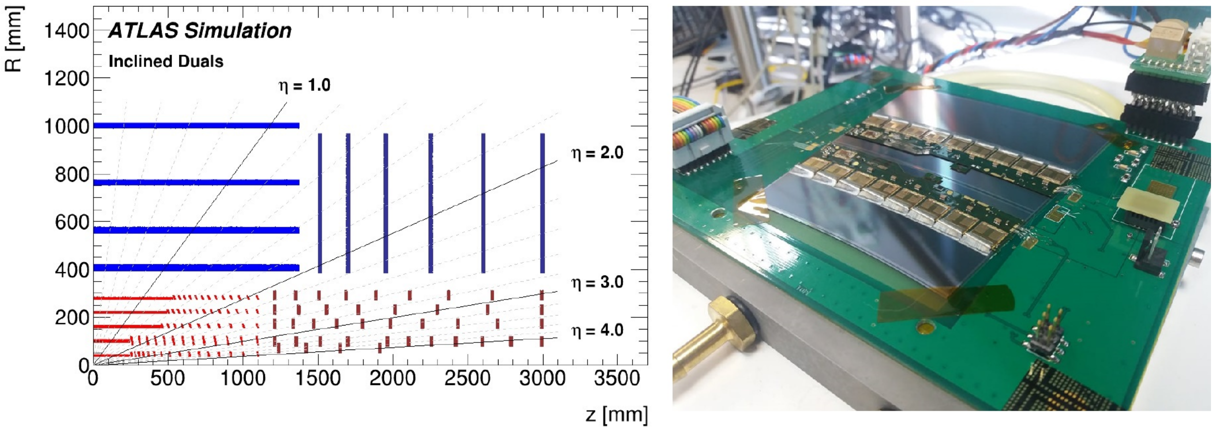

Figure 1. Left: The Schematic layer-by-layer layout of the ATLAS ITk detection system and its placement in the cylindrical coordinate system [1]. Right: Prototype of an strip endcap R0 module being tested at Charles University in Prague.

powering of module electronics is ensured by a power-board that distributes low voltage to the FE electronics of chips, high voltage to sensor bias ring for silicon bulk depletion and power to the system of environmental measurement and control. Assembled modules are mounted on larger structures called staves (barrel) and petals (endcap) providing local support.

3. Strip Data Acquisition System

A total of almost 60 million of channels from 18,000 single-sided modules are being processed by the on-detector electronics based on the ATLAS Binary Chip (ABCStar). The analogue signal coming from each strip is amplified, shaped and discriminated by the ABCStar FE electronics. The binary signal, whose value depends on the threshold set on the FE discriminators, is collected by the Hybrid Control Chip (HCCStar) and transmitted at the speed of 640 Mbit/s to the stave/petal End of Structure (EoS) via copper bus tape.

Strip modules undergo different QA/QC testing procedures before they can be approved as suitable for use. For these purposes the off-detector custom testing boards are being developed, which supplement commercial FPGA-based NEXYS read-out board. Data from tested modules is collected by the NEXYS board and analyzed in the dedicated ITk Strip Data Acqusition (ITSDAQ) software developed by the strip community.

4. Laboratory Monitoring System

Specific requirements and limits are defined to be met for ITk laboratory environment during QA/QC production testing. Similar approaches to the slow control monitoring system are being developed across the community and Prague is used as a model case here. Various communication interfaces such as RS232, GPIB or ethernet are integrated into the complex ROOT-based structure of scripts, which drive the readout process from many laboratory devices in one session. These include SHT75 relative humidity and temperature sensors controlled via Arduino boards, TTi low voltage and Keithley high voltage power supplies, power sockets, Julabo chillers, dry cabinets, Comet barometers or Lutron environmental sensors.

5. Data Repositories

Data from the slow control monitoring system of testing environment as well as data from the QA/QC testing of every single module should be recorded and stored so that they can be

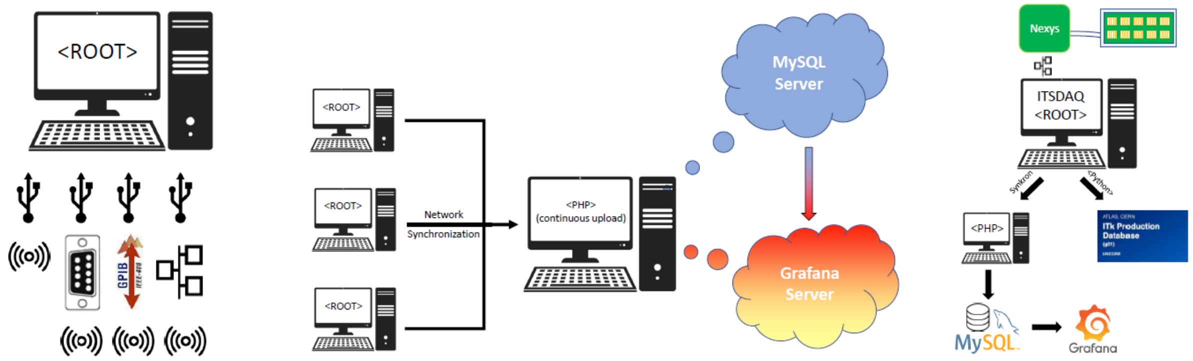

Figure 2. Left: First readout stage of Prague slow control monitoring system driven by the ROOT-based complex script. Middle: Second stage of the system, which ensures backup, database upload and visualization from all monitored rooms. Right: Module DAQ system summary scheme.

traceable in the later phase of the production and during HL-LHC operation. Therefore, a global ITk Production Database and a local Prague database were established for this purpose.

5.1. Global Database

The ITk Production Database (see Fig. 3) is being developed as a common tool for both the strip and the pixel project to record all business logic covering approximately 10^7 numbered items. This will include individual components, batches or assemblies. History of shipments and detailed results of every single QA/QC test should be stored as well. In Prague, ITSDAQ results from electrical module testing are processed by a custom ROOT-based script and directly uploaded into the global ITk database. More detailed channel-to-channel data is being uploaded through the local database system.

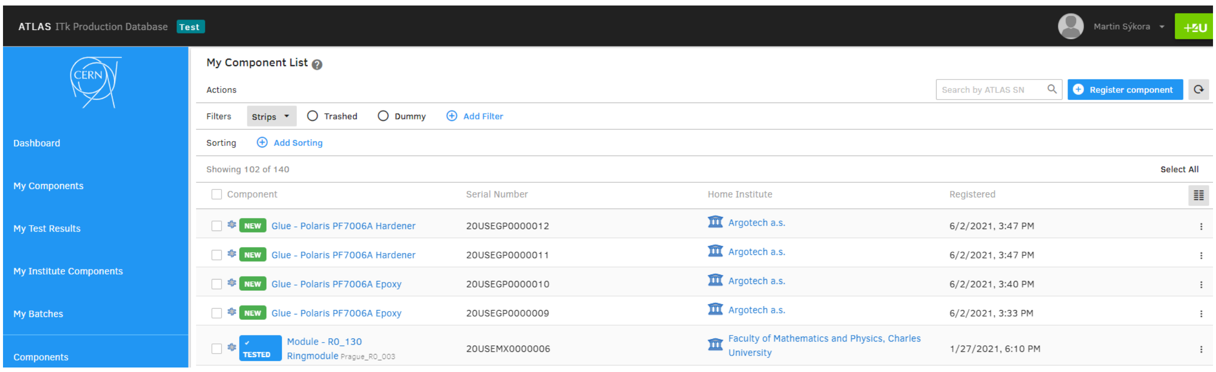

Figure 3. Illustration of component list in user interface of the ITk Production Database.

5.2. Local Database

The Prague repository system is based on central PC intended for data collecting and its subsequent uploading. The data is synchronized via network tool from monitoring computers all over Prague ITk laboratory rooms (see scheme in Fig. 2). In addition, the local MySQL repository is created to store more detailed data from the environmental slow control monitoring system and the specially adapted module DAQ system. Data is being uploaded into the database continuously over time using php script, which allows user to control measured parameters in real time using chosen visualisation tool and react to the situation.

6. Automation and Visualisation

The data flow between the environmental monitoring interface, detector DAQ system and local MySQL database is fully automated in all laboratory areas. Automatic uploading interval depends on a specific device, but data could be also recorded into the database as a batch at any time later. The user is asked to control proper operation of all systems in the chain.

For visualisation purposes the central slow control computer is equipped by the Grafana server accessible from anywhere. Grafana dashboards are designed using SQL queries and panel settings to clearly display state of individual sensors in custom time range (see Fig. 4). The Grafana server could be set to automatically send alarm notifications to a chosen communication platform in case the monitored value exceeds a specific threshold.

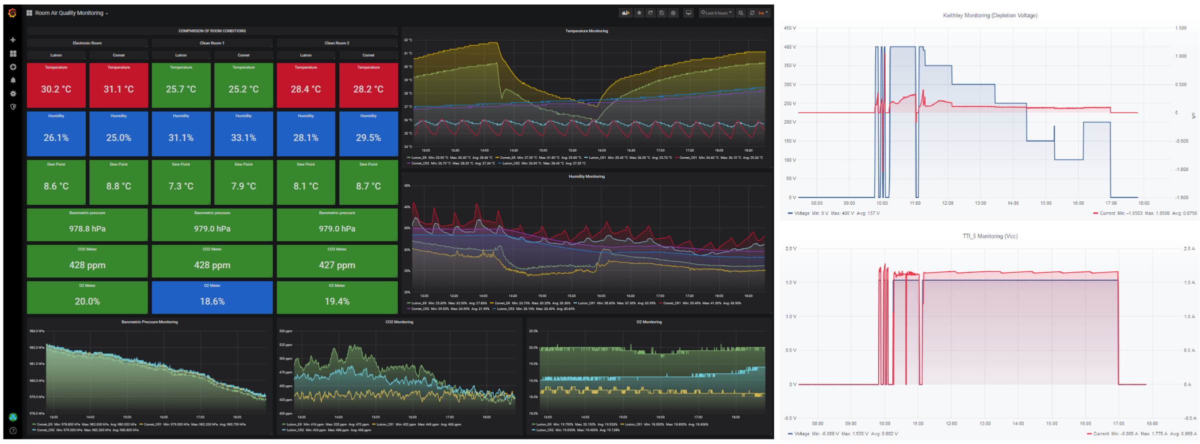

Figure 4. Left: Illustration of Prague Grafana summary dashboard filled by data from environmental monitoring sensors of individual rooms. Right: Voltage (blue) and current (red) data from HV and LV power supplies during module bias scan.

7. Conclusions

Going towards to the production period of the ITk project the data repositories and the related traceability of causes of arising issues are becoming more important. Therefore a suitable monitoring tool for the laboratory environment and DAQ system was introduced. This comprehensive control system is run automatically at startup and has a potential to become GUI in the future.

8. Acknowledgments

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