Characterization of Pre-Production Staves in the System Test Structure for the ATLAS ITk Strip Detector Upgrade

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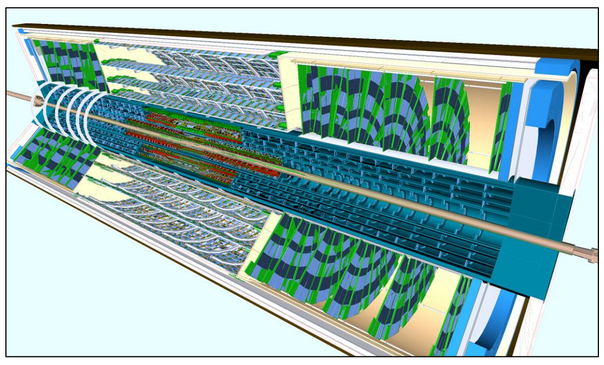
ABSTACT

The ATLAS experiment is currently preparing for an upgrade of the inner tracking detector for High-Luminosity LHC operation, scheduled to start in 2029. The new detector, known as the Inner Tracker or ITk, employs an all-silicon design with five inner Pixel layers and four outer Strip layers. The staves are the building blocks of the ITk Strip barrel layers. Each stave consists of a low-mass support structure that hosts the common electrical, optical and cooling services as well as 28 or 56 silicon modules. Staves are shipped from production sites to CERN where they undergo through reception tests after which they are mounted into the barrel support structure to be tested with full powering and cooling chain. The poster will give an outlook of the results from the front-end characterization scans and the noise performance at different stages of this process.

INTRODUCTION

- The new all Silicon, ATLAS Inner Tracker (ITk) will replace the current ATLAS inner Detector for the High Luminosity LHC.
- HL-LHC : nominal luminosity $\mathcal{L}_{peak}$ ~ 7*10^{34} s^{-1} cm^{-2}, $\mathcal{L}_{Integrated}$ ~ 3000(4000) fb^{-1} and Pileup of ~200 per 25 ns.
- The ITk is made up of barrels and endcaps centered around the interaction point, covering the pseudo rapidity range from -4 to +4



ITk Pixel Detector

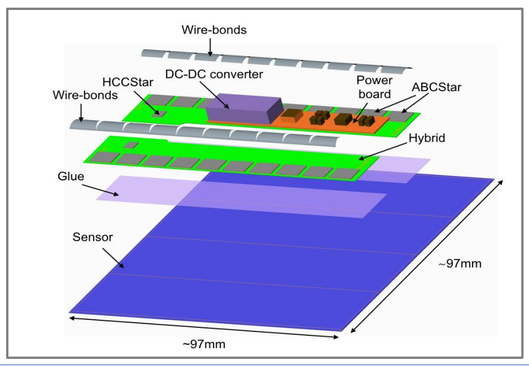
- 5-barrel layers including a section with inclined sensors
- End-Cap(EC) system containing individually located rings

ITk Strip Detector

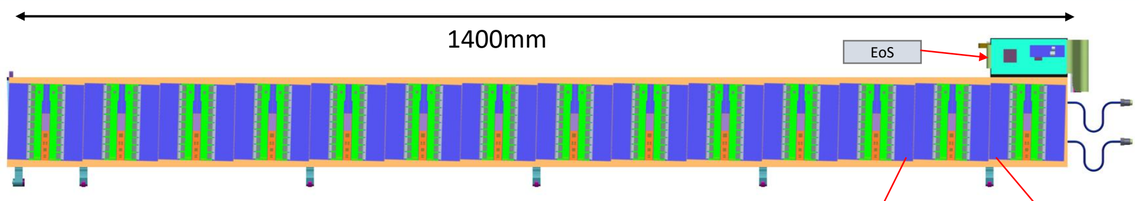
- 4-barrel layers
- End-Cap(EC) system with 6 rings on both sides

SILICON STRIP MODULES[Barrel]

- A barrel Silicon microstrip sensor module comes in two flavors, Short Strip(SS) with strip length 24.1mm and Long Strip(LS) with strip length 48.3mm.
- PCBs called Hybrid host readout ABCStar and the controller chip called HCCStar.
- The Power board is responsible for delivering Low Voltage power through the DC-DC buck Converter and hosts the monitoring and controller chip AMAC.

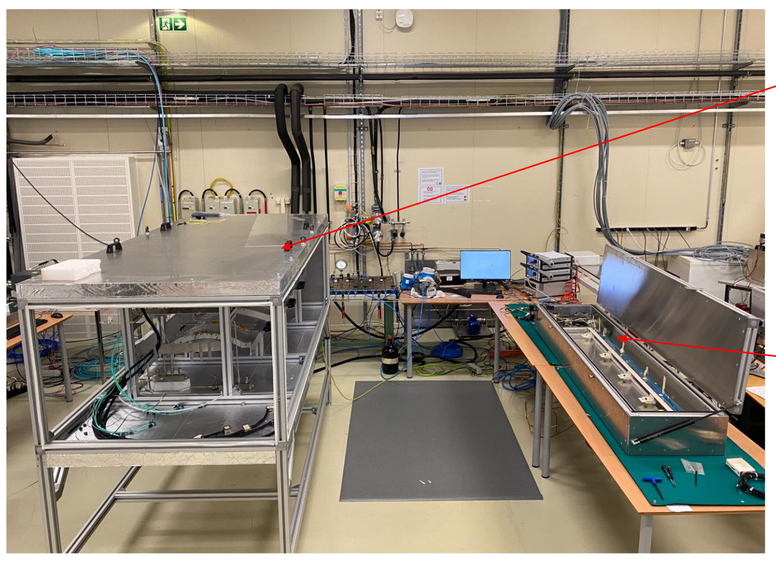


ITk BARREL STAVES



- **Staves** are the Barrel support structure for the modules.
- It hosts the common electrical, optical connections and cooling services.
- 28 Barrel modules on each LS stave (14 modules per side)
- Made up of a low-mass composite carbon fiber support structure
- End of Substructure (EoS) at one end of the Stave

TEST SETUP AT CERN (SR1)



Above: Test Setup in SR1 at CERN. Staves will first be tested In the reception box and then mounted in the support structure

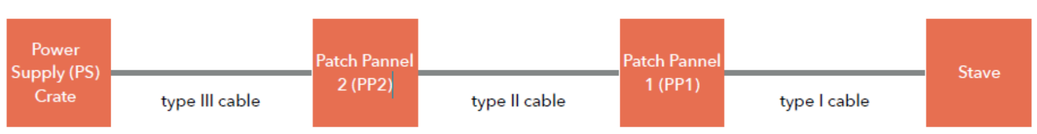
Barrel Support Structure

- 3SS+1LS staves (14lpGBTs) are supposed to be tested in the structure for the Systems test

Stave Reception Test box

- Test box to do the reception test (mainly with ITSDAQ) on the stave within the transport frame.

Above: Cooling Chain for the testing the staves in the Support Structure.



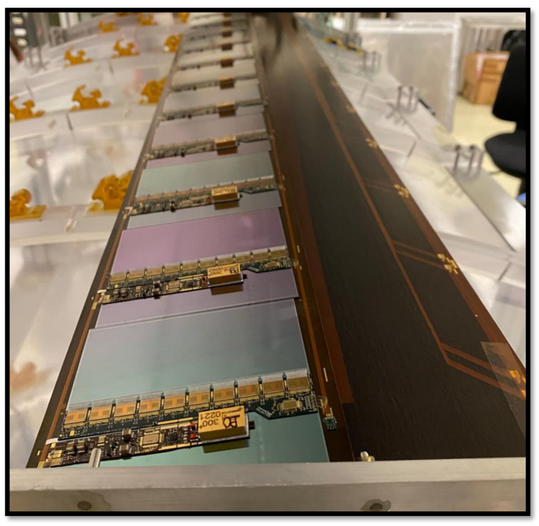
Above: Powering Chain for the testing the staves in the Support Structure.

TEST SETUP AT CERN (SR1)

There are two staves mounted in the support structure

- Prototype Stave from Rutherford(RAL,UK)
  - Short Strip stave with only the Side L fully loaded with 14 modules.
- Pre-Production Stave from Brookhaven(BNL,US)
  - Long strip stave with Side J fully loaded with 14 modules and side L loaded with only 4 modules.

Staves are tested at the production sites and the Shipped to CERN enclosed in ESD Bags with Relative Humidity controlled.



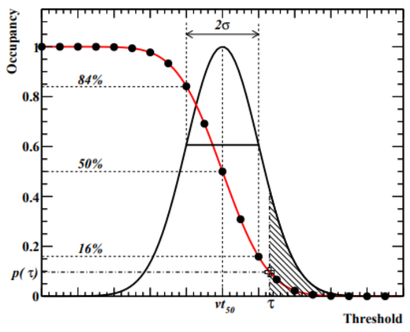
Right: 2 staves mounted in the support structure. BNL PPA stave on left and the RAL stave 25 on the right.

Data Acquisition

- The EoS hosts the **Low Power Giga Bit Transceiver** (lpGBT), a radiation tolerant ASIC that is used to implement multipurpose high speed bidirectional optical links between the DAQ (Genesys or FELIX) and the front-end ASICs.
- The data from the lpGBT is decoded at the DAQ, which is then passed on to the DAQ software(ITSDAQ or YARR) for analysis.

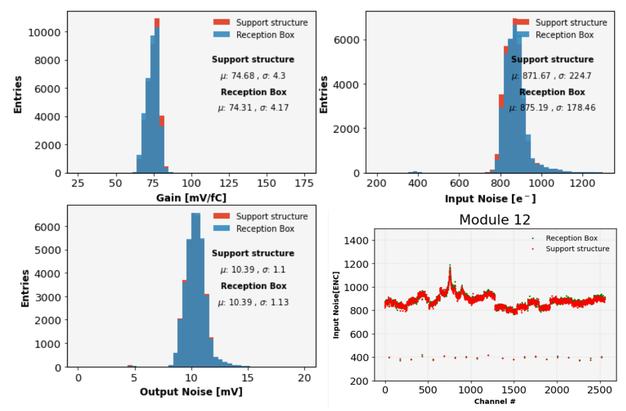
Front-End Characterization

- When a particle passes through the sensor, signal from the strips is transmitted to the front-end ASICs.
- **Strobe Delay** is used to scans over the possible delay values of charge injection with respect to the system clock.
- **Response Curve** is used to measure the response of the front end (in mV or DAC counts) to the injection of a calibration charge. Output of varying the trim-DAC threshold is an S-curve for a given charge. Threshold at which Occupancy is 50% is called **vt50**. Standard deviation of the erf-fit to the S-Curve is the **Output Noise**. **Input Noise** is calculated from the **Chip-Gain** (slope of vt50 vs charge plot) and output noise for each charge variation.



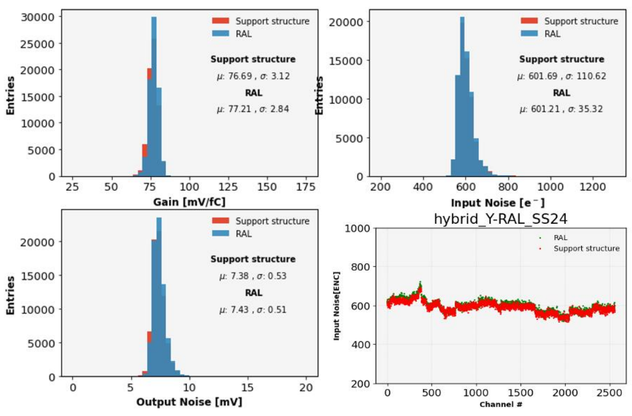
Above: Output at the trim-DAC for a given charge [2].

STAVE TESTING RESULTS



BNL Pre Production stave (Right)

- Tested in the reception box at 500V with table-top power supplies and with monophase cooling and compared when tested in the support structure with the powering and cooling chain.
- Gain ~75 mV/fC and Input Noise of ~870 electrons was observed in both cases.
- (Bottom Right) Input Noise comparison for all channels on the module 12 when tested in the two setups.



RAL Prototype stave (Right)

- Noise Performance of the stave when tested at RAL in stave testing box at 350V with table-top power supplies and compared when tested in the support structure with the powering and cooling chain.
- Gain ~75 mV/fC and Input Noise of ~600 electrons was observed in both cases.
- (Bottom Right) Input Noise comparison for all channels on one of the hybrids when tested in the two setups.

CONCLUSION

- Noise Performance of the staves at different stages has been compared.
- No additional noise was observed in the front-end scans when tested with the powering and cooling chain.

REFERENCE

[1] The ATLAS Collaboration, “Technical Design Report for the ATLAS Inner Tracker Strip Detector”, Tech. Rep. CERN-LHCC-2017-005, ATLAS-TDR-025, CERN, 2017.

[2] The ATLAS Collaboration, “Electrical results of double-sided silicon strip modules for the ATLAS Upgrade Strip Tracker”, ATL-UPGRADE-PUB-2012-002

[3] Y. Unno, et al., "Specifications and Pre-production of n+-in-p Large-format Strip Sensors fabricated in 6-inch Silicon Wafers, ATLAS18, for Inner Tracker of ATLAS Detector for High-Luminosity Large Hadron Collider", submitted for publication in J. Instrum.(Preprint no. JINST 002T 1022).

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