# Electrical characterisation of stave prototypes for the ATLAS ITk Strip Detector Upgrade

Francesca Capocasa*, on behalf of the ATLAS Collaboration

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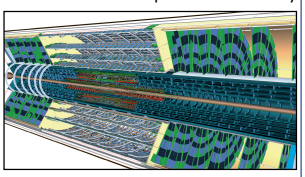
## Abstract

The ATLAS experiment is currently preparing for an upgrade of the inner tracking detector for High-Luminosity LHC operation, scheduled to start in 2027. 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 which hosts the common electrical, optical and cooling services as well as 28 silicon modules, 14 on each side. A prototype electrical long-strip stave was assembled at BNL in December 2019. To characterize the stave, a set of electrical and functional measurements have been performed both at room and at cold temperature. In this poster, I will present the methods used to characterize this stave with particular focus on noise studies.


## The ITk project

- Instantaneous luminosity reaching $\mathcal{L}$= 7.5 x $10^{34}$ $cm^{-2}s^{-1}$ for next phase of discovery at LHC beginning in 2027 (HL-LHC) [1]
- Expecting up to <$\mu$> = 200 p-p collisions per bunch crossing
- Current ATLAS Inner Detector (ID) being replaced by Inner Tracker (ITk) during Phase-II Upgrades

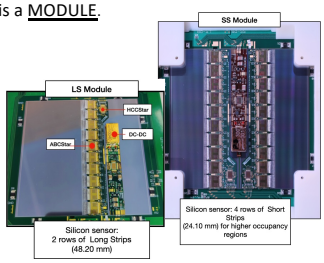


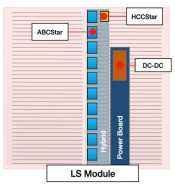
- ITK Pixel Detector
  - 5 barrel layers
  - End-Cap (EC) system containing individually located ring
- ITK Strip Detector
  - 4 barrel layers
  - 6 EC rings on both forward regions

## Silicon Microstrip Module

The smallest functional unit of a stave is a MODULE.

- Two module variants with same architecture but different strip length : Long Strip (LS) and Short Strip (SS)
- Consists of one silicon microstrip sensor and one or two low mass PCBs, called hybrids, and one power board (PB)

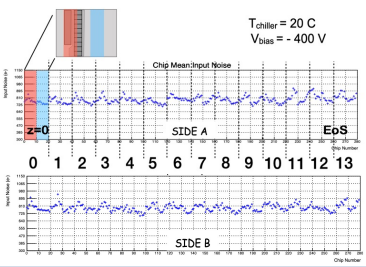



The hybrid hosts 10 front-end readout ASICS and a controller chip (HCCstar), while the PB is responsible to deliver LV power by using a DC-DC buck converter

## Room Temperature Results

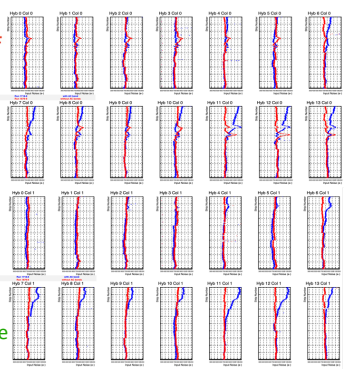
The stave has been initially tested at Room Temperature




- Input noise profile for all 28 modules on the stave
- Each point represents the mean of the input noise of 128 strips channels

## Solution

$T_{chiller}$ = -50 C
Stave Signal Ground Bonds ON,OFF
$V_{bias}$ = - 400 V



- By removing the Stave Signal Ground Bonds on the hybrid, the noise increase in the upper half of the hybrid disappears
- These Stave Signal Ground Bonds provide a path for noise current to flow in the upper half of the hybrid

- Good stave performance achieved by removing the Stave Signal Ground Bonds !!!

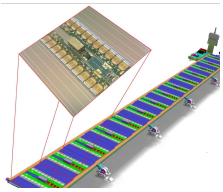
## Reference

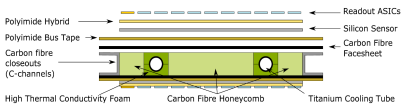

[1] The ATLAS Collaboration, "Technical Design Report for the ATLAS Inner Tracker Strip Detector", Tech. Rep. CERN-LHCC-2017-005, ATLAS-TDR-025, CERN, 2017.


## ITk Barrel Staves

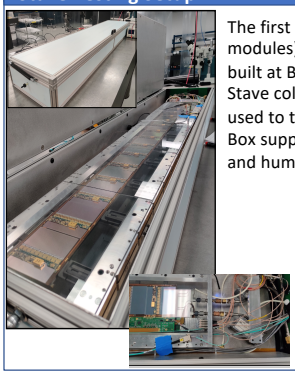
The basic unit of the ITK Barrel Strip Detector is the STAVE.


A stave consists:
- a low-mass composite carbon fiber support structure
- 14 silicon modules on each side of the stave
- End of Substructure Card (EoS) at one end of the stave

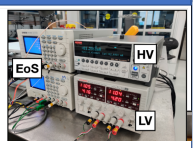





## Stave Testing Setup



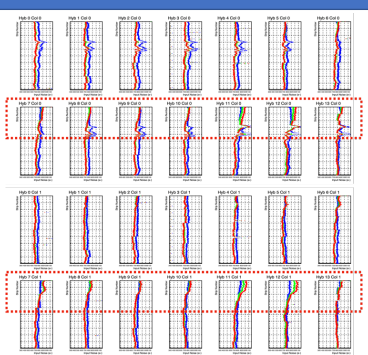
The first double sided (28 modules) electrical stave was built at BNL at the end of 2019. Stave cold box and SPS chiller used to thermal cycle the stave. Box supplied with temperature and humidity control.




DAQ:
- EoS hosts radiation hard lpGBT ASIC and VTRx+ fibre optics which serialize the data and drives the optical connection
- FPGA (Genesys 2 board)


## Cold Temperature Results

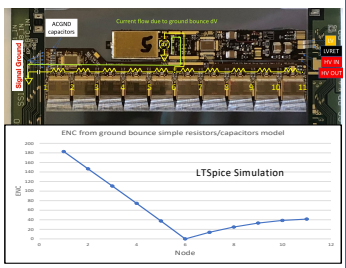
$T_{chiller}$ = 20 C, -40 C, -50 C
$V_{bias}$ = - 400 V



- Input response for the 14 modules on one side of the stave
- Contrary to expectations, noise increases as temperature decreases in the upper half of the hybrid
- Noise increases towards the EoS
- Same behavior for both stave sides

## A Possible Model

- Power board introduces a ground bounce (dV) at every power board clock cycle
- Ground bounce causes current flows through Signal Ground Bonds connecting hybrid ground to Fast Signal Ground.
- Position dependent voltage difference causes noise pattern as seen in simulation and data




Removing Stave Signal Ground Bonds has been approved as solution for the next generation of staves

* Brandeis University – fcapocasa@brandeis.edu