The ATLAS ITk Strip Detector for the Phase-II LHC Upgrade

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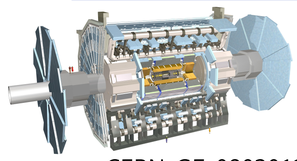
Large Hadron Collider (LHC) and ATLAS Detector

- LHC: particle accelerator at CERN, $\sqrt{s_{pp}} = 14\,\text{TeV}$
- High-Luminosity LHC upgrade: starting operation in 2029
  - Higher luminosity $\rightarrow$ increased statistics for physics studies
- ATLAS: general-purpose detector at LHC
  - Concentric subdetectors around interaction point
  - Innermost subdetector: particle tracking

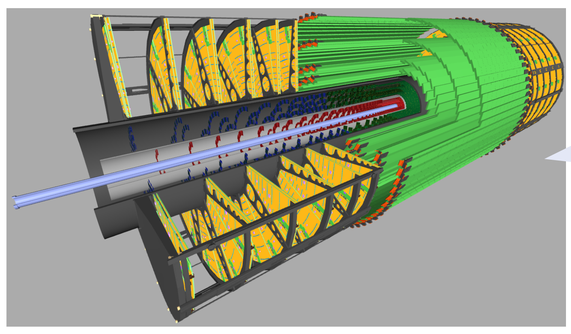
Virtual LHC tour



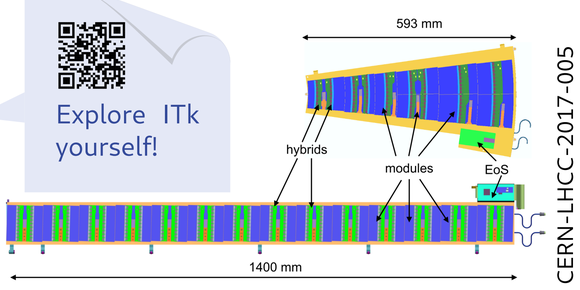
CERN-GE-0803012

ATLAS ITk Strip Detector

- New all-silicon tracking detector (ITk) for High-Luminosity LHC
- ITk pixel detector: closest to beam pipe with high granularity pixel modules
- ITk strip detector: strip modules located at radii $r \geq 384\,\text{mm}$
- Modules arranged in barrel and endcap layers to provide optimal coverage
  - ITk Strip barrel: *staves* with 14 detector modules per side
    - *Short-strip (SS)* modules with 24.1 mm long strips, 75 µm pitch
    - *Long-strip (LS)* modules with 48.2 mm long strips, 75 µm pitch
  - ITk Strip endcap: *petals* with six detector modules per side
    - Radially oriented strips in six module flavours *R0* to *R5*



Explore ITk yourself!



CERN-LHCC-2017-005

Silicon Sensor Production

- Full-scale production ongoing since 2021, $\approx 80\%$ of total amount received
- QC observed degradation of electrical properties due to static surface charges
- Mitigation strategies: de-ionisation with ion blowers and UV light exposure

Hybrid and Powerboard Production

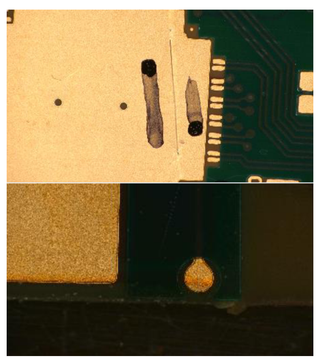
- PCB (*flex*) manufacturing and SMD population at industrial companies
- QC procedures before and after SMD population at responsible ITk institutes
- ASIC attachment, bonding and electrical testing

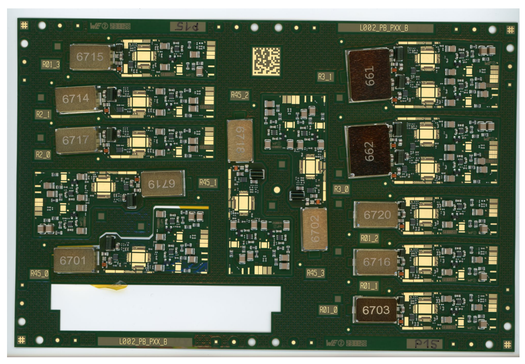
Barrel

- Flex production started
- After observation of *sensor cracking* ($\rightarrow$ see module loading status): production on hold to accomodate eventual mitigations

Endcap

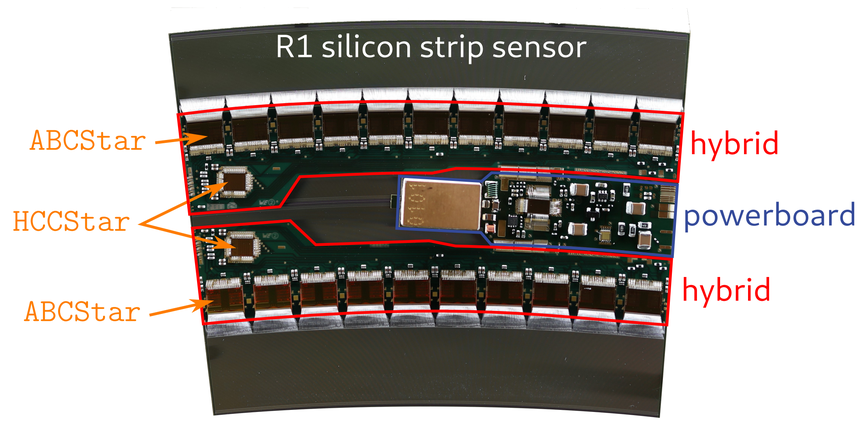
- Varying PCB quality observed at start of production $\rightarrow$ intense QC effort
  - Change of hybrid SMD population company was necessary
  - Mixed-type PCB production to reduce risk for shortages of single types
- Powerboard design change necessary in 2023 due to high noise observations
- Electrical powerboard QC setup and procedures developed at Freiburg





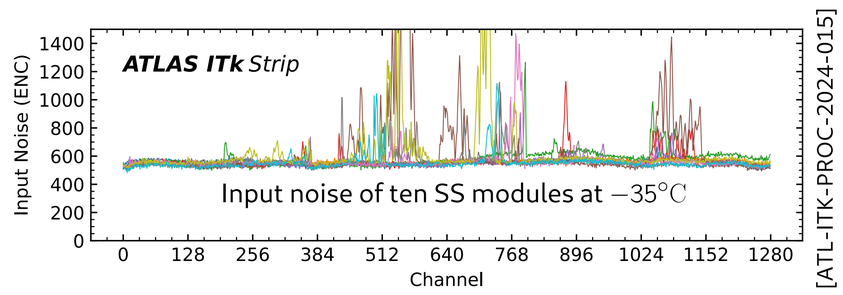
ITk Strip Module Design

- Silicon sensors:
  - 320 μm thick, n^+-in-p doped, radiation tolerant to $\Phi_{\text{eq}} = 1.2 \times 10^{15}\,\text{cm}^{-2}$
  - 8 different geometries (2 in barrel, 6 in endcap)
- Hybrids: glued onto silicon sensor
  - Polyimide flexible PCBs housing readout ASICs (`ABCStar`) and aggregation ASIC (`HCCStar`)
  - 15 different geometries (2 in barrel, 13 in endcap)
- Powerboard: glued onto silicon sensor
  - Polyimide flexible PCBs housing voltage sources (`bPOL`, `linPOL`)
  - Control and monitoring ASIC for voltages and temperatures (`AMAC`)
  - High voltage filter circuitry and transistor (`HV-MUX`)
  - 7 different geometries (1 in barrel, 6 in endcap)



Status of Module Assembly

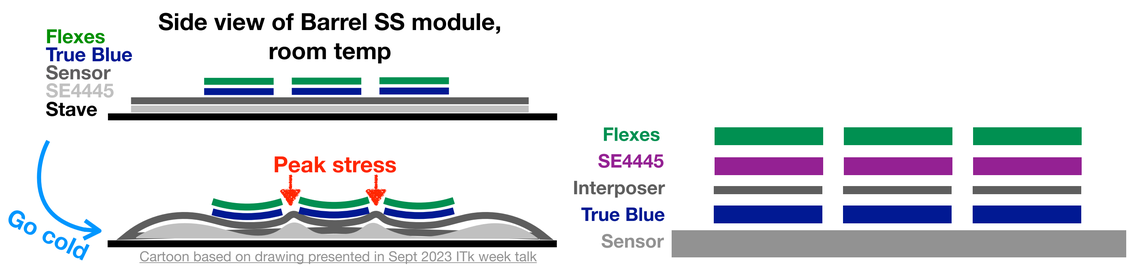
- Module assembly workload shared between > 30 institutes all over the world
- Institute "site qualification" procedure in place to get approved for production
  - $\approx 94\%$ of steps approved
- Start of production delayed by technical issues spotted during pre-production: *Cold noise*: clusters of noisy channels appearing at temperatures below $0°\text{C}$
  - Induced by vibrating capacitor on powerboard
  - Mitigation by changing glue applied between sensor and flexes



Sensor cracking: $\rightarrow$ see module loading status

Module Loading Status

- First staves and petals assembled and thoroughly tested
- After loading: few modules on pre-production staves showed HV breakdown after cycling to cold temperatures, similar for petals
- Intense investigation with simulation and measurements ongoing
- Origin: CTE mismatch between sensor and flexes creates mechanical stress $\rightarrow$ sensor breaks at gaps between hybrids and powerboard
- Investigated mitigation strategies:
  - Stiffer glue in module loading to reduce stress in sensor
  - Introduction of *interposer* layer between flexes and sensor using soft glue to absorb stress



A. Fortmann, *Interposers for Modules*, ITk Week, March 2024

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