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On behalf of the **ATLAS ITk Collaboration**

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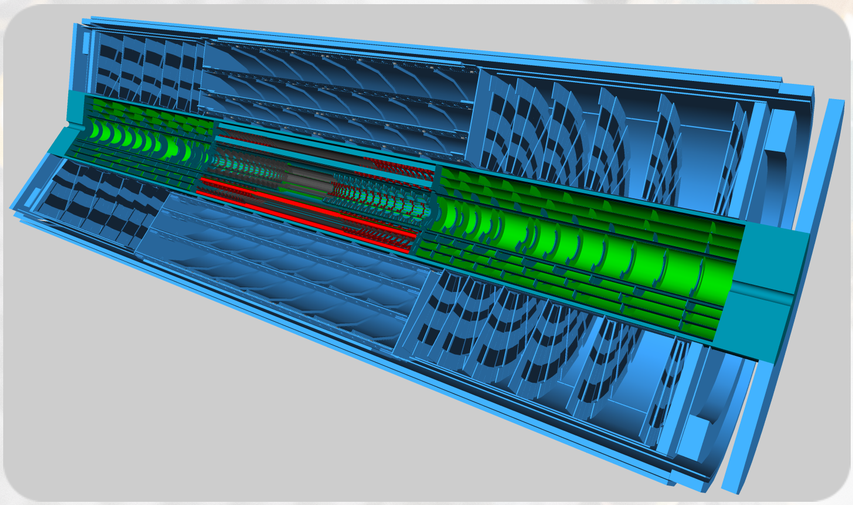
Italian-cluster technical solutions for the Quality Control tests to the modules of the ITk detector

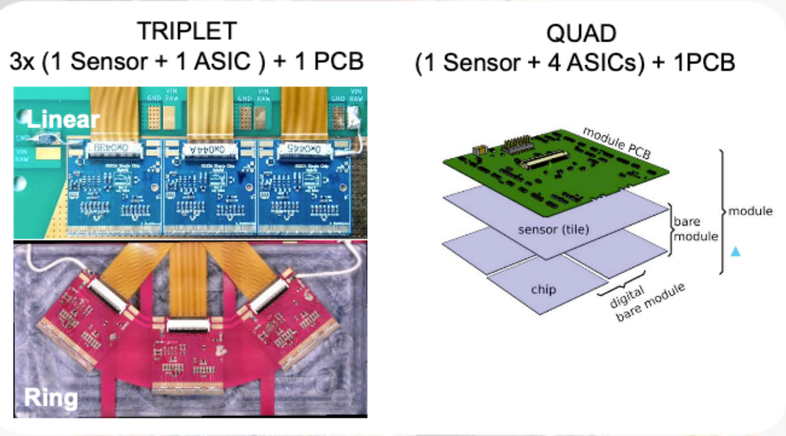
Introduction

The instantaneous luminosity of the High-Luminosity LHC will achieve unprecedented levels, leading to the occurrence of up to 200 proton-proton interactions per bunch crossing. To face these challenging conditions, the ATLAS experiment will upgrade its tracking detector during the Phase-II LHC shutdown. The following data-taking period is expected to start by 2029. The new all-silicon system is known as the Inner Tracker (ITk). It will include a pixel detector, featuring an active area spanning approximately 13 m^2, and a strip detector. Concentric layers will be accommodated so as to build a Barrel (5 pixel + 4 strip layers) and two Endcaps (several rings each) with extended angular coverage.



Sensor Technology

- Pixel: 3D for the innermost layer, planar elsewhere
  - pitch size 50 x 50 μm^2 except 25 x 100 μm
  - 50 x 50 μm for barrel most inner layer
- Strip: 165 m^2, planar n-in-p



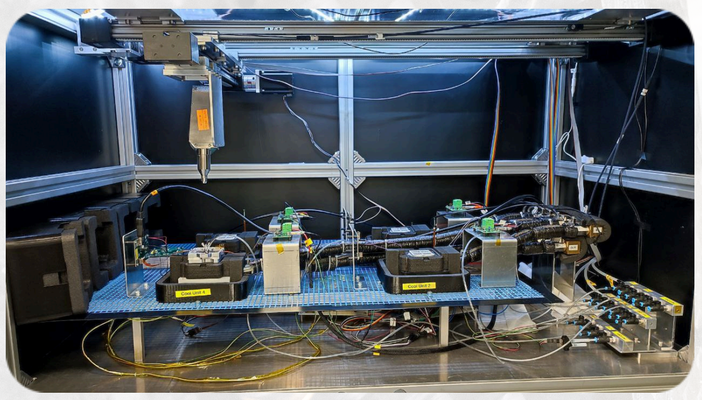
Italian Cluster Responsibility

The Italian Community, with the responsibility to build one of the Endcaps, has decided to share the different activities related to production, assembly, testing and integration in various Institutes:

- **Bologna**: (quads + triplets) thermal cycles and full quality assurance and control tests
- **Frascati** & **Lecce**: Integration and Loading
- **Genova**: Assembly (quads + triplets) and tests
- **Milano**: Assembly (quads + triplets), coating and test
- **Trento** & **Udine**: triplet (TN) and quad (UD) tests

Testing Setup

Modules need to be tested both at room ($\sim 20°C$) and operational temperatures (-15 $°C$ for quads and -25 $°C$ for triplets).

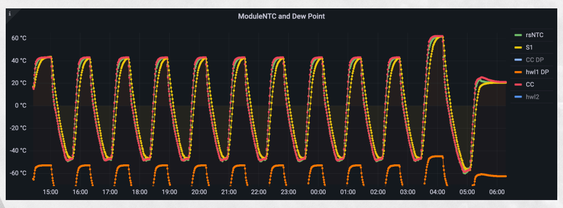


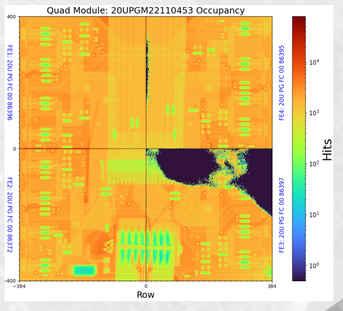
Three different kinds of tests are performed on each module:

- **Electrical Quality Control (QC)**: to verify that the readout chips meet the electrical specifications
- **Sensor Quality Control:** measurement of the leakage current as function of the bias voltage
- **Functional tests:** including pixel-threshold tuning and tests to check bump-bonding quality

Thermal Cycles

Due to the thermal inertia of the cooling system, power cuts during operation will cause the detector to reach very low temperatures. To ensure the bump bonding will survive such stress, each module will be **thermal-cycled (TC)** between -45 $°C$ and +40 $°C$. TCs are performed in a dedicated **climate chamber** and a custom **Detector Control System** (DCS) "python-based" has been developed to store online parameters on a database and take gentle safety actions in case of dangerous conditions.
Additional tests are performed after TCs, to check for possible **disconnected bumps** and display the functionality of unmasked pixels via a **source scan**.

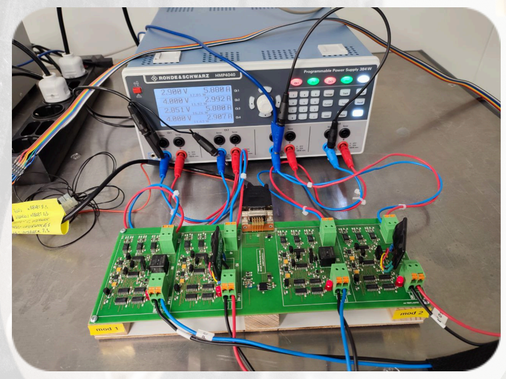




Software & Hardware Interlock

A **DCS** system based on WinCC OA and OPC Server is used by all the divisions of the Italian Cluster to monitor and control all the different devices.
Several levels of **interlocks** have been implemented to protect the module from harmful operating conditions and potential disruption:

- **Software:** handled by the DCS, takes action in a more gentle way
- **Hardware:** last resort safety measure.
  Implemented via a breaker board using standard and real relays driven by an ESP32 devkit fed with various temperature and humidity sensors.



References:
- ATLAS all silicon inner tracker, the ITk detector (2022): https://cds.cern.ch/record/2838231
- Technical Design Report for the ATLAS Inner Tracker Pixel Detector (2017): https://cds.cern.ch/record/2285585?ln=it