Tracking studies with cosmic rays using the ATLAS ITk end-cap system test.

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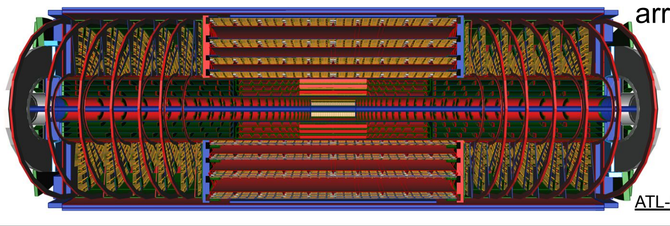
ATLAS ITk Strip End-Cap Detector.

» The ATLAS **Inner Tracker (ITk)** will replace the current tracking detector in the **HL-LHC** phase to cope with the challenging conditions

» Tracker is an **all-silicon** detector with **pixel** and **strip** detectors arranged in a central **barrel** region and two **end-caps** in the forward regions



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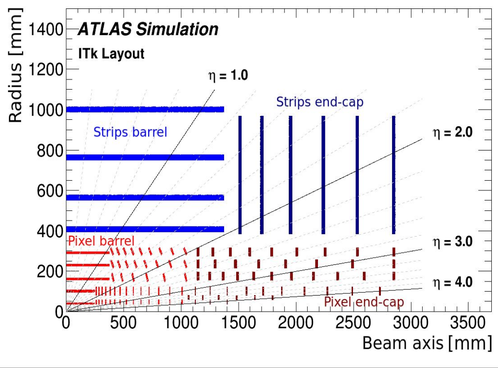
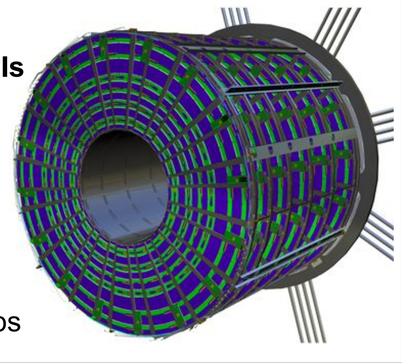


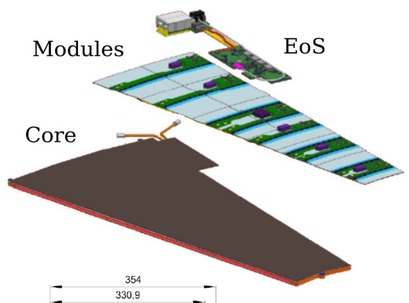
» The main building block of the **strips end-cap** detector are the so-called **petals**

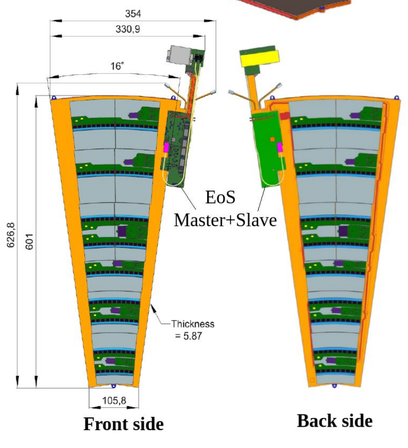
» Each end-cap consists of a **global support** structure providing mechanical support and connection to the services for six **disks**

» Each end-cap disk is populated with 32 petals, requiring in total the **production of 384 petals** for both ITk strips end-caps



Petal Design.



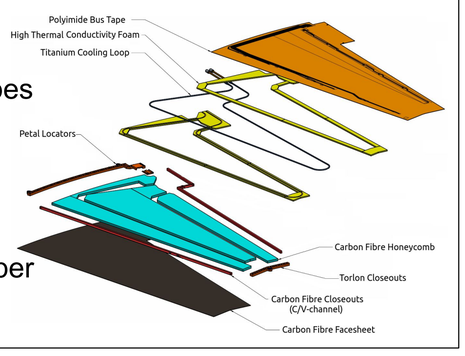


» The **petal** consists of the local support structure, the **core**, the directly glued on sensing elements, the silicon strip **modules**, and the also glued on off-detector interface board, the **end-of-substructure**

» The petal concept follows a **modular approach** for the assembly of components and minimizes the **material budget** of the detector (e.g. direct gluing, wire-bonding)

» The wedge-shaped **petal core** is a light-weight sandwich structure and provides:

- **Mechanical support** for the modules
- Dual-phase CO_2 **cooling** via the embedded Ti pipes
- **Electrical connectivity** for power and data transmission via a polyamide-copper based bus tape

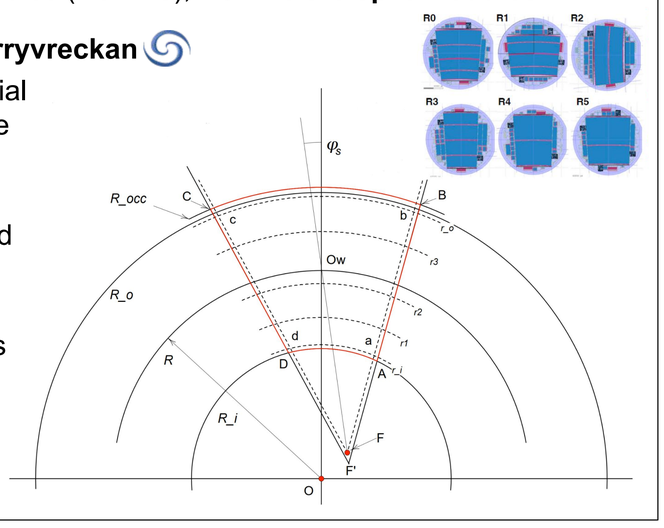


Module Coordinate System.

» Silicon strip modules for the ITk end-cap detector come in special radial strip geometry:
- The **radial** coordinate is the distance between the beam axis and the strips
- A **stereo angle** is introduced by rotating around the module centre
- The **polar coordinate** is calculated from **focal point** resulting from stereo angle

» There are six flavours of endcap modules (R0 - R5), R3 - R5 are **split modules**

» Implementation of radial strips in **Corryvreckan**
- **Clustering** is performed in radial coordinates; cluster centres are calculated by weighing by the contributing row resolution
- Cluster centres are transformed to local **cartesian** coordinates
- The **strip resolution** in local coordinates is found during this transformation using gaussian error propagation
- Tracking is then performed using the **Tracking4D** module



End-cap System Test.

Purpose of system tests

» Construction of system tests for the **barrel** (at CERN) and **end-cap** (at DESY) sub-detector of the ITk strips detector

» Demonstration of **full-system performance** from pre-production objects using the complete service chain (electrical power, data readout, cooling)

» Development of various tools for detector **integration and operation** (DAQ and DCS)

Setup of end-cap system test

» Realistic end-cap structure (51deg of full EC) as **global support** made out of carbon-fiber parts

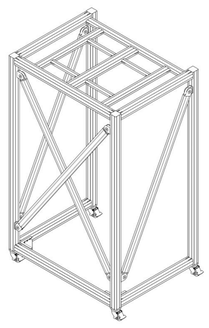
» Offering locking points at 16 positions for up to **12 petals** including service connections from full detector powering chain

» Enclosed by a custom made **thermal box** with dry air flushing and environmental monitoring

» Cooling with **CO2 dual-phase cooling** [+17°C, -35°C] using LUCASZ cooling plant

» Readout with two **DAQ** system variants available: Genesys-II/ITSDAQ and FELIX/YARR

» Milestone: population with first **fully-loaded PPB petal** using production insertion tooling



End-cap system test as cosmics telescope

» Vertical orientation of petal layers allow data taking with **cosmics**

» Implementation of **scintillator system** for external triggering

» Operation of petals in **testbeam-mode** using Trigger Logic Unit for handshaking → first pedestal scans with autotrigger recorded

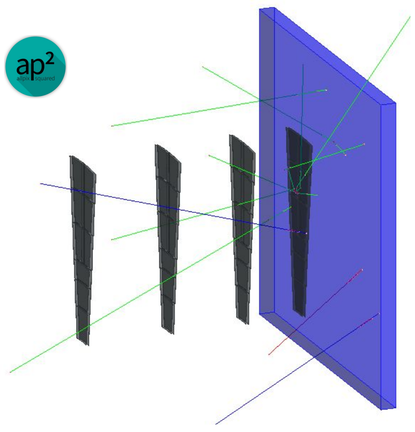
Simulation of Cosmic Muon Events.

Cosmic Muon Flux

» Extensive Air Shower muons are simulated in **Allpix²** using DepositionCosmics (CRY implementation)

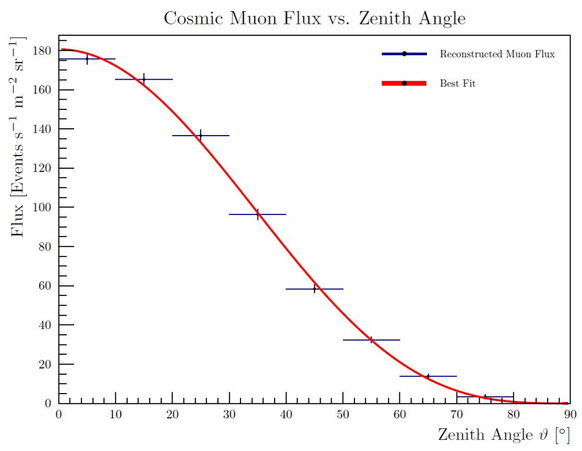
» A vertical setup with **four petals** was chosen to demonstrate the capability of tracking of cosmics with the system test

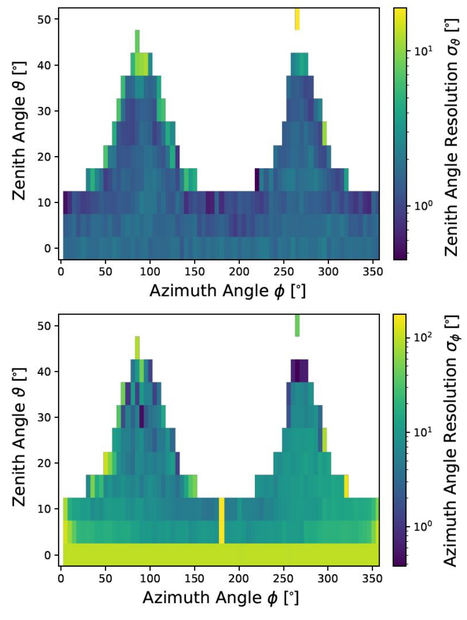
» Cosmic muon **flux** was reconstructed from the simulated data



Setup Resolution

» The **resolution** of the setup in zenith and azimuth angle was calculated using Monte-Carlo methods
- A particle beam was directed at the centre-of-mass; the reconstructed track angle was compared to the beam direction for different **angles of incidence**
- The **zenith** angle was reconstructed with a resolution < 2° for the majority of the detectors sensitive region
- The **azimuthal** resolutions were observed to be < 20° except for θ ≤ 3°





Conclusion.

» Coordinate system for **radial strips** of ITk end-cap modules now implemented and functional in Allpix² and Corryvreckan

» Preparation of the **experimental setup** of the system test for cosmics ongoing

» Simulation showed ability of system test to measure the **cosmic muon flux**

» Determined the expected **angular resolution** of the 4-petal setup

Outlook.

» Insertion of further petals to **populate** the end-cap system test at DESY

» Exploration of DAQ chain with external triggering (ITSDAQ and FELIX)

» **Measurement** of cosmic muon flux with the equipped system test

» Using muons to take **SNR curves** → compare with analysed test beam data

» Build and commission the full end-cap at DESY → **detector integration**

References

- ATLAS Collaboration, Technical Design Report for the ATLAS Inner Tracker Strip Detector, ATLAS-TDR-025 (2017)
- Corryvreckan - The Maelstrom for Your Test Beam Data, https://gitlab.cern.ch/corryvreckan MR!644
- Allpix Squared - Generic Pixel Detector Simulation Framework, https://gitlab.cern.ch/allpix-squared MR!555
- Maximilian Caspar, PhD thesis, DESY Hamburg, 2024 (in preparation)

12th Beam Telescopes and Test Beams Workshop