A Compact BabyMOSS Telescope

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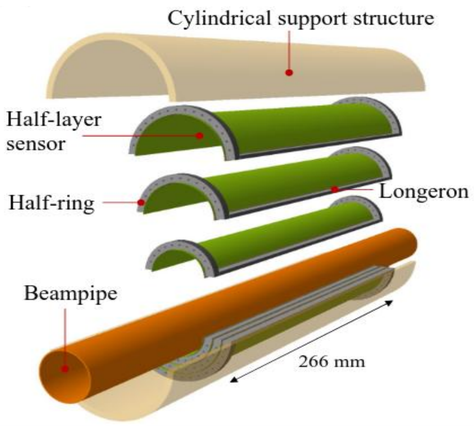
On behalf of the ALICE Collaboration

Inner Tracking System (ITS3) upgrade in ALICE during LS3:

- → 3 innermost layers of the ITS2 will be replaced by ultra-light wafer-scale stitched MAPS bent to cylinder shape
- → Innermost layer radius 24 mm → 19 mm – closer to the interaction point
- → Material budget reduction 0.35% X_0 → 0.09% X_0 per layer
- → Improved impact parameter resolution for low-p_T particles

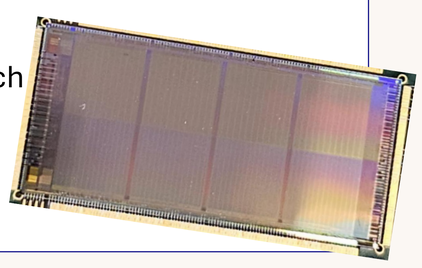
Sensor R&D:

- → Pixel design in 65 nm CMOS technology
- → Stitching to get wafer-scale sensors



BabyMOSS Prototype sensors:

- → Monolithic Stitched Sensors (MOSS) - 10 repeating sensor units (RSU)
- → BabyMOSS (14 mm x 25.9 mm) – single-RSU sensor, divided into 2 Half Units (HU) and 4 regions
- → Top HU: 256 x 256 pixels, 22.5 µm pitch
- → Bottom HU: 320 x 320 pixels, 18 µm pitch
- → Independent powering, readout and control for each HU
- → Binary readout with tuneable strobe duration



Why cosmic muons?

Naturally available & penetrating probe:

- → continuous source of ionizing particles without the need for a beam
- → allows for year-round data acquisition and sensor characterization

LHC Long Shutdown starts mid 2026 → no test beam at PS

- → build a compact muon telescope at Lund Physics Institute
- → study detection efficiency, dead areas, and pixel response uniformity of the babyMOSS sensors

Lund Telescope

- → 5 babyMOSS tracking planes
- → No scintillators for triggering!
- → Based on DAQ-Raiser test system:
  - 1xFPGA board + 1x Raiser interface board
  - full-chip active area & readout
- → Compact assembly of planes with 3 cm spacing
  - achievable tracking resolution better than 3 µm
- → EUDAQ2-based acquisition system with custom Producer

Trigger and Data Taking

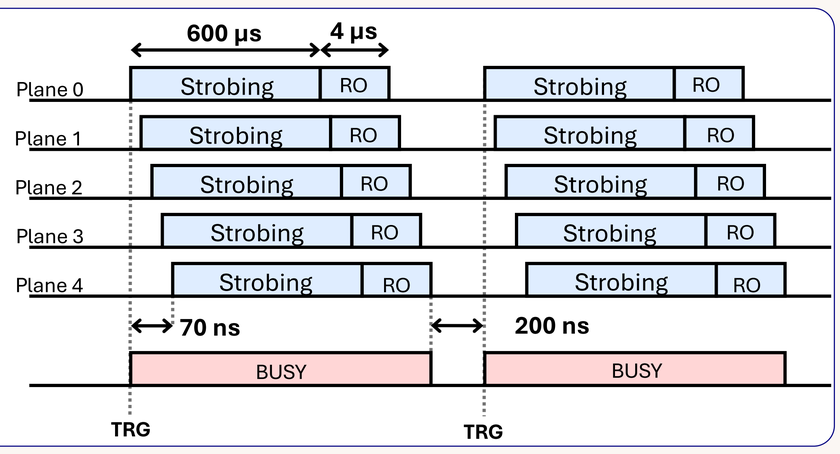
- → Trigger signal is generated by the trigger board with manually set trigger logic:

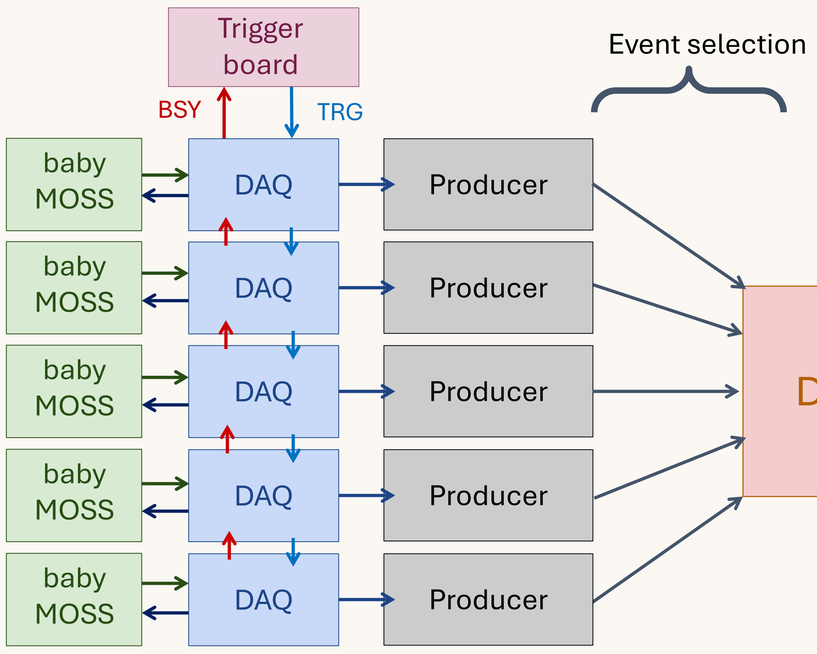
  trg_dead_time > 600 µs & !BUSY

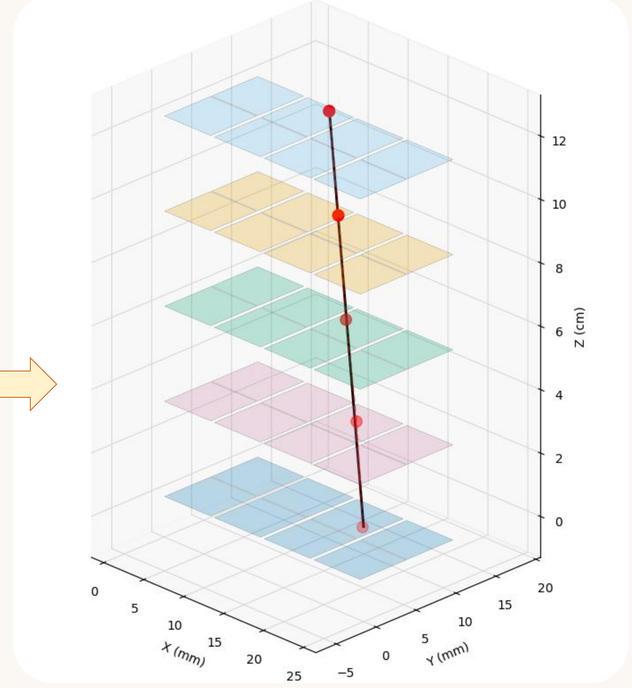
- → This starts a readout cycle:

  strobe cmd → strobing → readout cmd → sending data

- → Continuous data acquisition mode:
  - strobe window is 600 µs and read out time about 4 µs
  - 99% duty cycle → virtually no dead time
- → Threshold tuning and online event selection are implemented



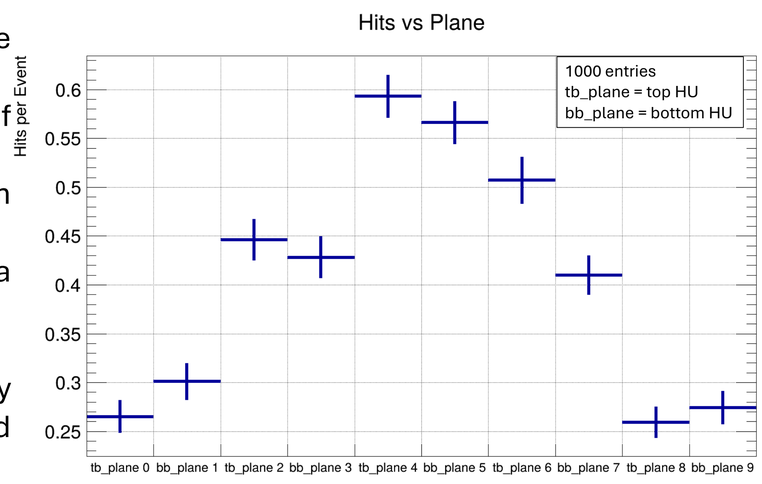




Event selection

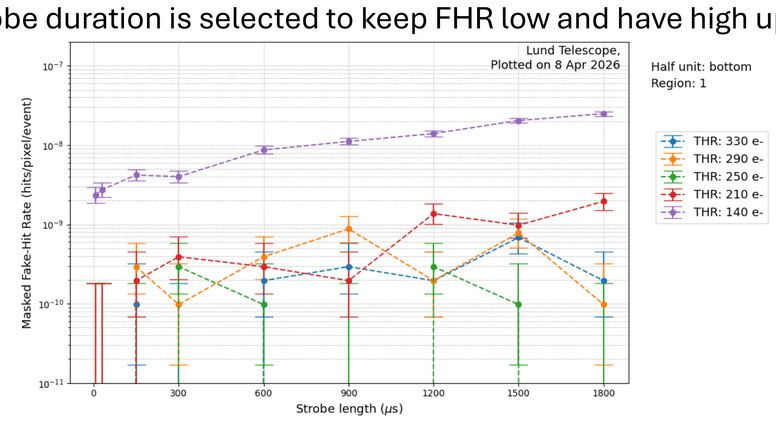
To make continuous data taking mode work, the following is implemented:

- → threshold tuning and on-chip masking of noisy pixels
- → Data packets are checked for hits in each Producer
- → Event is built if at least 3 planes have a hit with matching ID
- → Empty events are rejected
- → This allows for selecting and saving only events containing real muon hits and minimizing the size of the raw data file

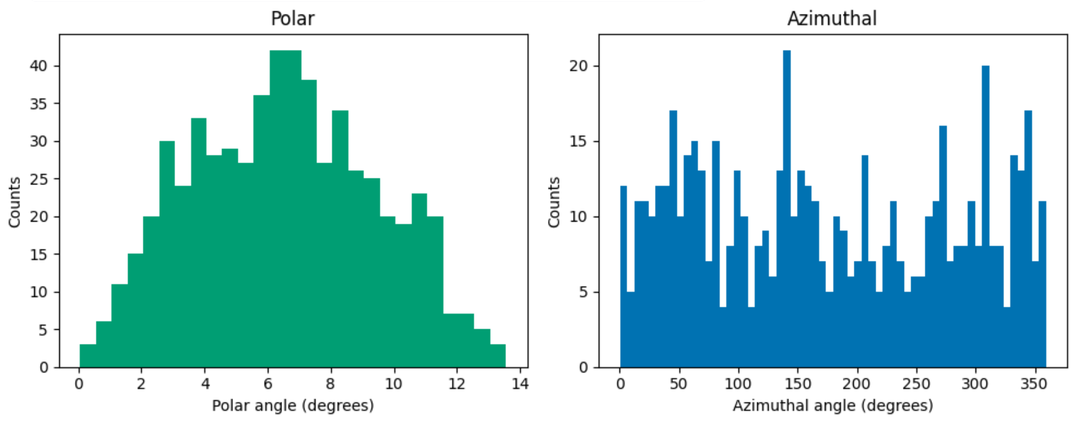


Fake-hit rate

- → Threshold tuning is performed to achieve fake-hit rate (FHR) below 10^{-8} hits/pixel/event
- → Strobe duration is selected to keep FHR low and have high up-time



Commissioning and first observations



- → Completed first commission run, collecting 1000 muons in 92 hours:
  - 1 event that passes the selection criteria every ~6 min
  - stable performance with robust muon track selection
- → Polar angle distributions show that muon tracks are close to perpendicular, most probable angle being ~7˚
- → Azimuthal angle shows uniform distribution
- → Long-term data acquisition run is in progress (~ 1 month)
- → Once sufficient statistics acquired, alignment will be performed by computing residuals for each plane.

References:

ALICE Collaboration, Technical Design Report for the ALICE Inner Tracking System 3 – ITS3; A Bent Wafer-Scale Monolithic Pixel Detector, CERN-LHCC-2024-003 [2024]

O. Abdelrahmn et al. Characterization of the First Wafer-Scale Prototype for the ALICE ITS3 Upgrade: The Monolithic Stitched Sensor (MOSS), NIM A 1086 (2026) 171297 [2025]