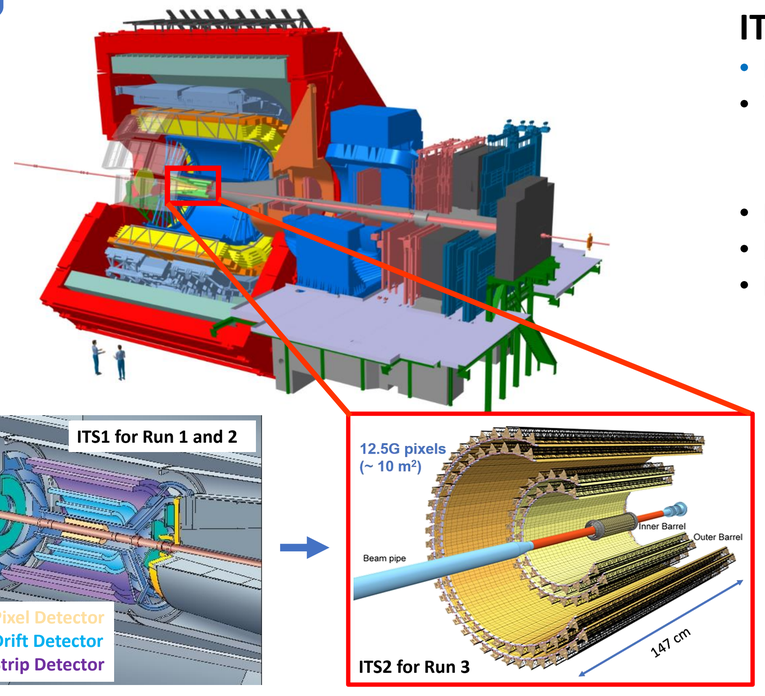
Performance of the ALICE upgraded Inner Tracking System

Jian Liu on behalf of the ALICE collaboration
J.l.liu@liverpool.ac.uk, University of Liverpool, UK

ALICE Inner Tracking System upgrade for LHC Run 3

ALICE Upgrade for Run 3

- Major upgrades are underway for ALICE during LHC long shutdown 2 (LS2)
- Physics goals → high-precision measurements of QGP properties
  - Heavy-flavor hadrons and quarkonia at very low p_T
  - Vector mesons and low-mass dileptons
  - High-precision measurements of light nuclei and hypernuclei
- Main detector requirements for the new Inner Tracking System (**ITS2**)
  - High tracking efficiency and resolution at low p_T
    - Improved spatial resolution, reduced material budget
  - High statistics
    - Increased readout rate, online data reduction



ITS2

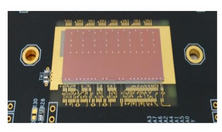
- Entirely Monolithic Active Pixel Sensor (MAPS) based
- 7 cylinders covering ~ 10 m² area
  - Inner barrel: 3 inner layers
  - Outer barrel: 2 Middle Layers (MLs) + 2 Outer Layers (OLs)
- Fake-hit rate requirement: < 10^{-6} /event/pixel
- Detection efficiency requirement: > 99%
- Fast removal/insertion of inner barrel for yearly maintenance

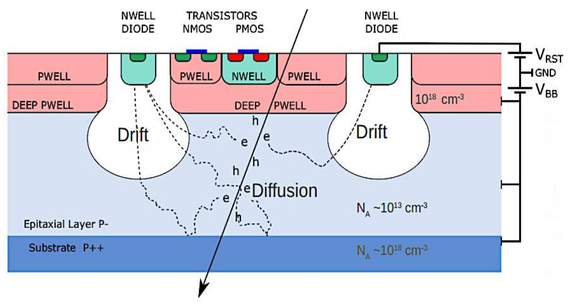
	ITS1	ITS2
Technology	Hybrid, drift, strip	MAPS
Layers	6	7
Spatial resolution	12 µm x 100 µm	5 µm x 5 µm
Radius	39 – 430 mm	22 mm – 400 mm
Pseudorapidity	-1 ≤ η ≤ 1	-1.4 ≤ η ≤ 1.4
Material budget	~ 1.14% X_0	~ 0.3% X_0 (inner barrel), ~ 1% X_0 (outer barrel)
Readout capability	1 kHz	>100 kHz (Pb-Pb), >1 MHz (pp)

Detector construction

ALPIDE

- TowerJazz 180 nm CiS Process, full CMOS
- High resistivity epi-layer (>1 kΩ·cm)
- Reverse biasing available
- 1.5 x 3 cm, 512 x 1024 pixels
- In-pixel amplification, discrimination and buffering
- Spatial resolution ~5 µm
- Read out up to 1.2 Gbit/s



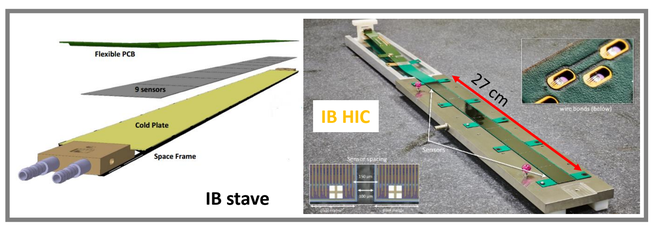


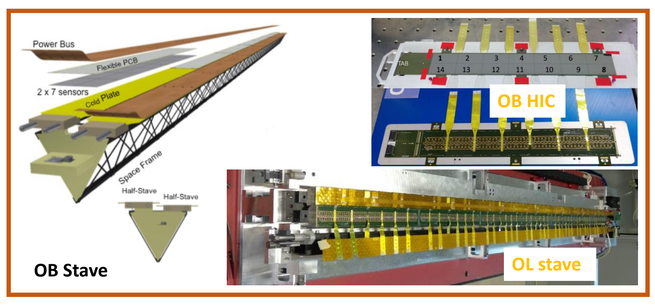
Inner Barrel

- 3 layers, 48 staves
- 9 chips per stave
- Chip thickness: 50 µm

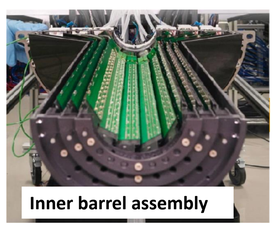
Outer Barrel

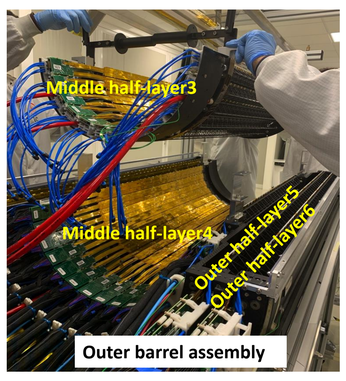
- 2 MLs (56 staves) + 2 OLs (90 staves)
- 112(196) chips per ML(OL) staves
- Chip thickness: 100 µm

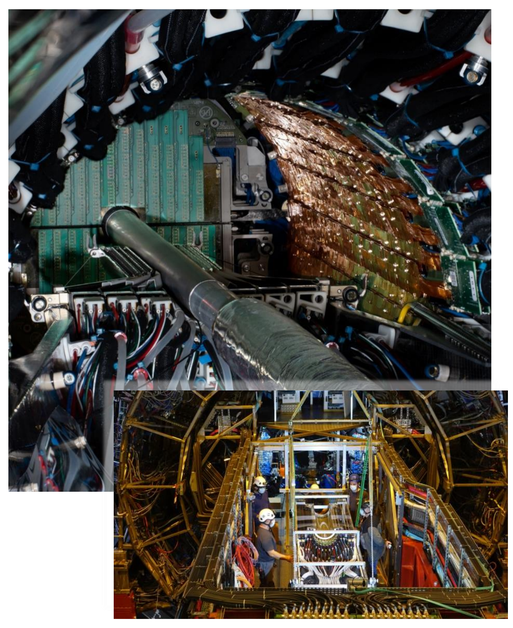


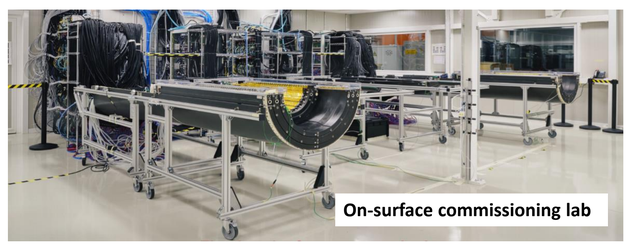


December 2019 → Fully assembled
May 2021 → Successfully installed in the ALICE experiment





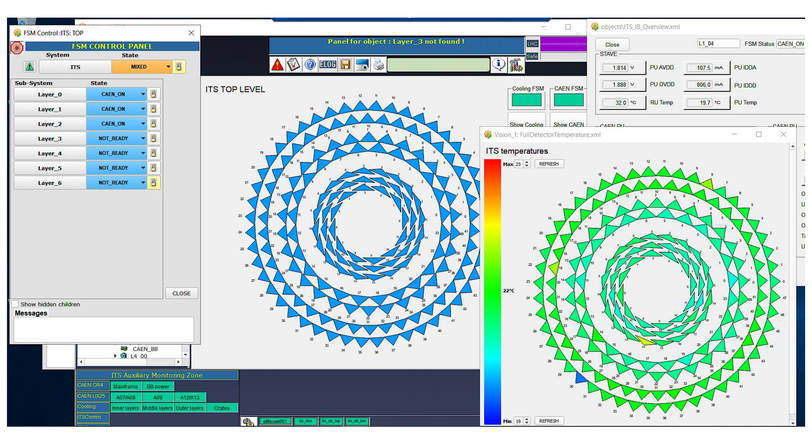




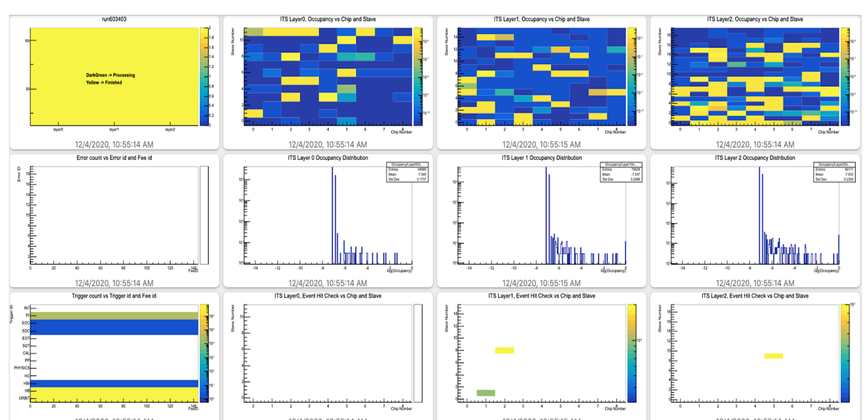
Detector commissioning and performance

- **On-surface commissioning**
  - Verification of detector performance and long stability of parameters
  - Commissioning with 24/7 shifts started in July 2019 and completed in December 2020
- ***In-situ* commissioning**
  - Standalone (April – June 2021)
    - Similar configuration as the on-surface commissioning
  - Global (July – December 2021)
    - Cosmic data taking, pilot beams, calibration, etc

Detector Control System



Data Quality Control

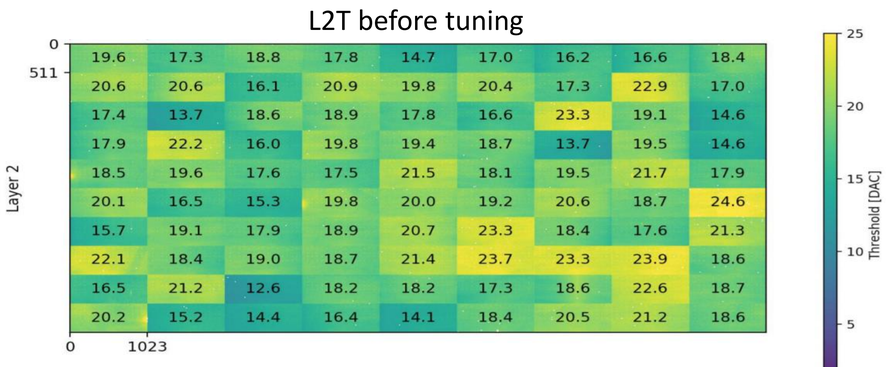


Inner Barrel

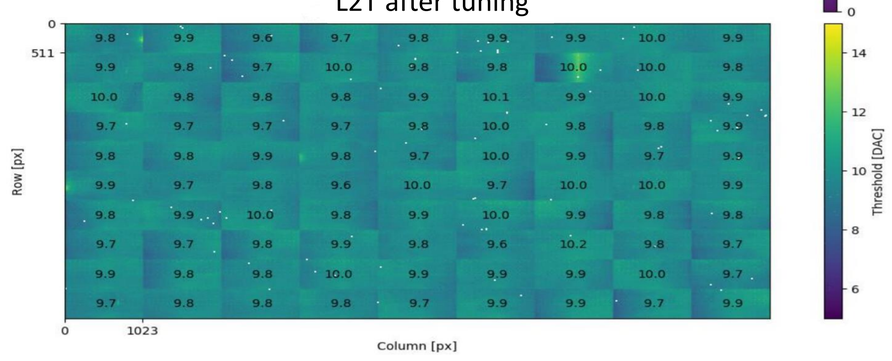
Threshold

- Adjustment of front-end parameters to optimize the thresholds
- Achieving uniform response across the detector
- Very satisfying threshold stability over time

L2T before tuning

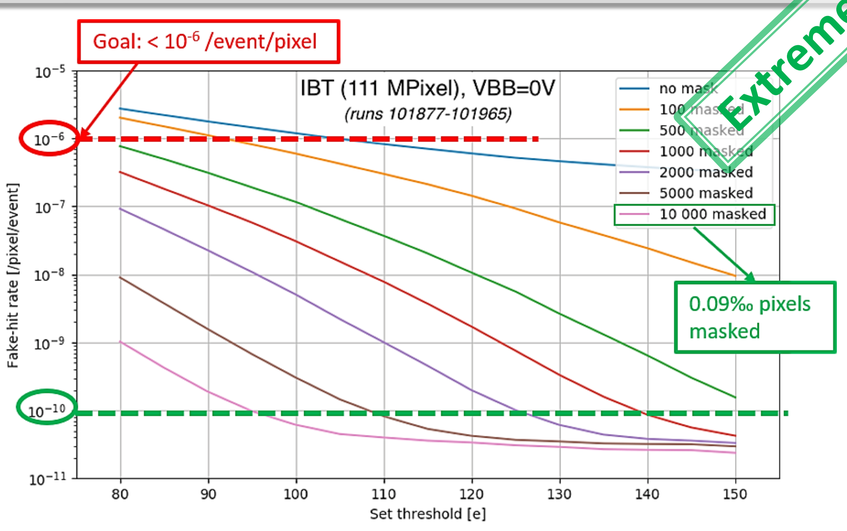


L2T after tuning



Fake-hit rate

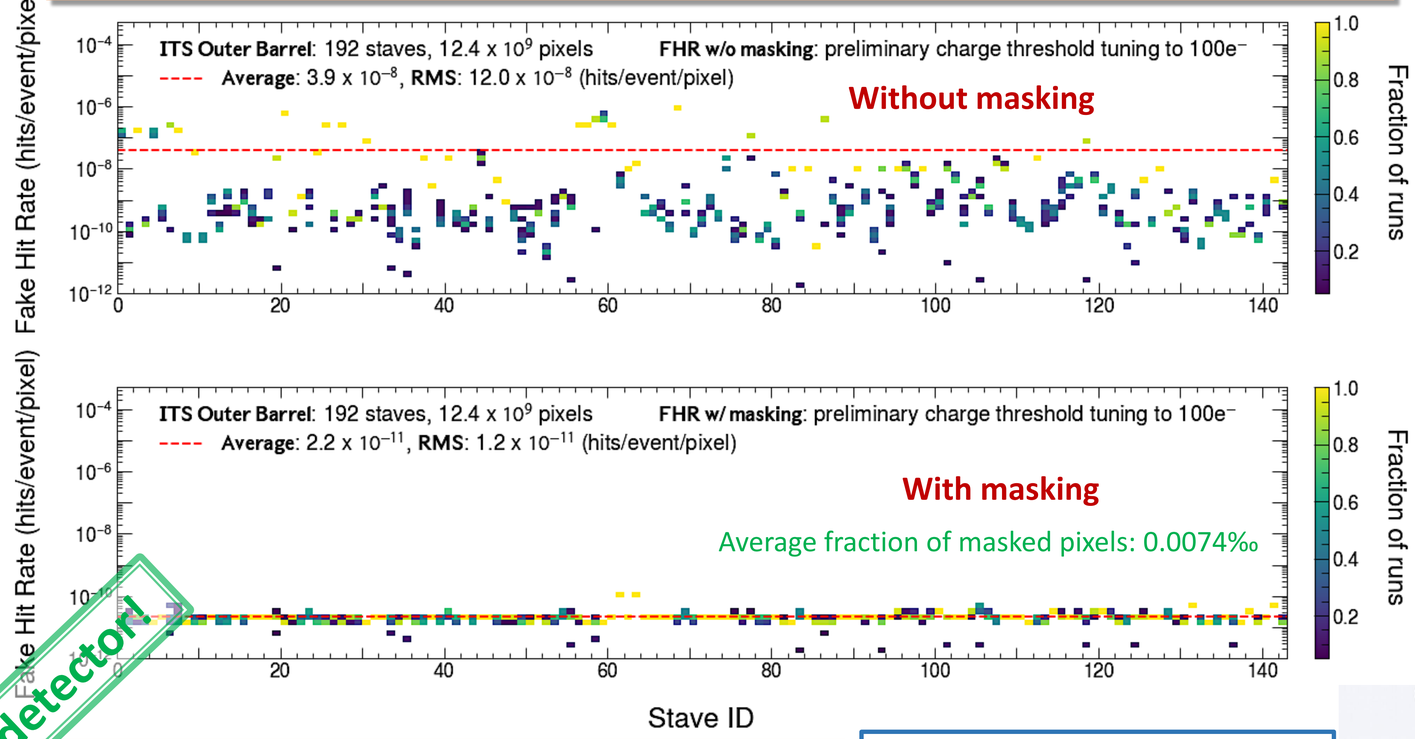
- Measurement performed on half IBs
- Running at a fake-hit rate below 10^{-10}/event/pixel seems feasible



Outer Barrel

Fake-hit rate (FHR)

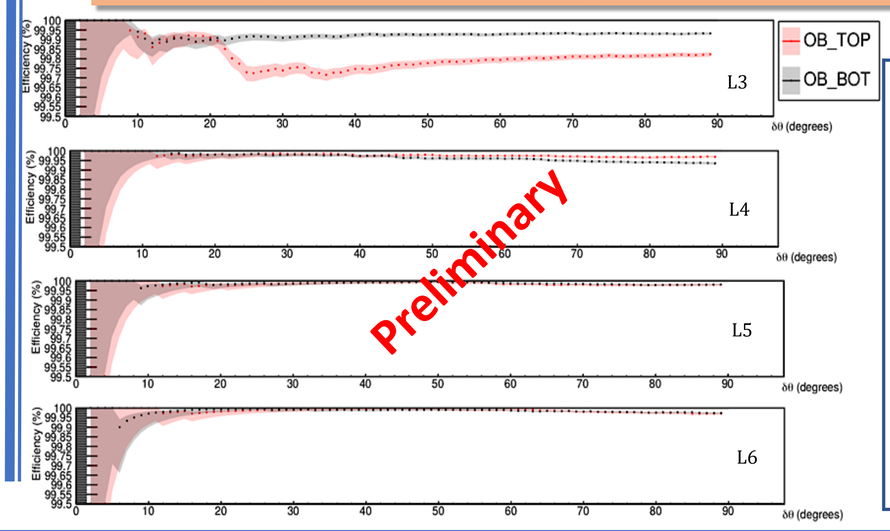
- Fake-hit rate runs using fixed settings (preliminary tuning for thresholds: ~100 e^-)
- Slight variations in the voltage applied to chips require 5-10 runs to detect all the hot pixels
- Masking hot pixels in each run, the average FHR reaches ~10^{-11}/event/pixel for all staves (→ 10^{-10} when masking pixels in common to at least 80% of runs)



Extremely quiet detector!

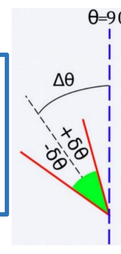
Detection efficiency

- Cosmic tracks during the on-surface commissioning
- Efficiency >99.5% (±0.3%) → requirement satisfied!

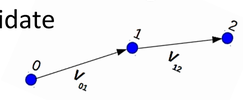


Conditions

- Decision value < 0.1
- Δθ = 90°, δθ = 10° (~vertical tracks)
- χ^2 < 1 for fit to clusters



- A track that hits at least three layers is extrapolated onto the fourth layer. If a cluster on the fourth layer lies within the search window around the expected cluster, the track is efficient
- The decision value is the vector product of the two vectors connecting the three clusters in the seed candidate



$\vec{P} = \vec{V_{01}} \times \vec{V_{12}}$

Decision value = $p_x + p_y + p_z$

- If the decision value < 0.1, the track is tagged as a potential cosmic event → a straight line is fit to the clusters → refitting the track by taking into account the clusters which lie < 0.2 cm away from the track