Data Quality Control of the ALICE Inner Tracking System (ITS2) in the LHC Run 3

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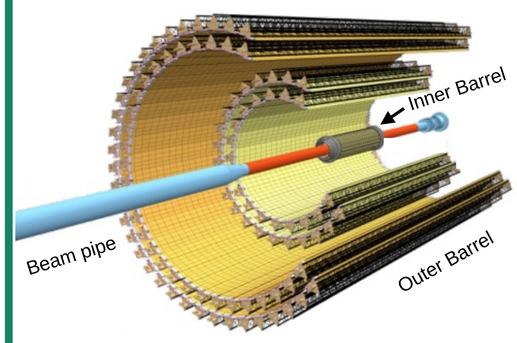
ALICE in Run 3 & Run 4

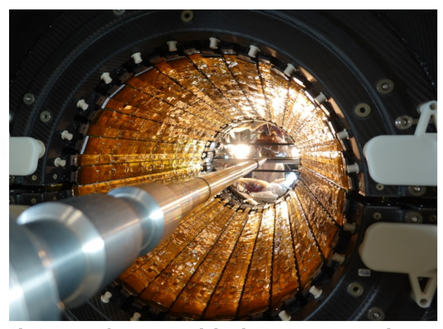
- **High precision** measurements of **rare probes** such as heavy-flavour mesons and baryons down to **very low p_T**.
- Such events are difficult to trigger ⇒ ALICE runs in a **continuous readout** mode to collect a **large minimum bias data sample**.
- ITS was upgraded before Run3 with ITS2 fully replacing the previous ITS1. ITS2 significantly improves the **pointing resolution** and **tracking efficiency** at **low p_T**.

ITS2 detector layout

- 7 layers of ALPIDE sensors
  Inner Barrel (IB) 3 layers (48 staves, length 27 cm)
  Outer Barrel (OB) 4 layers (144 staves, length 84-150 cm)
- Low material budget: IB 0.36% X_0/layer, OB 1.10% X_0/layer
- Layer radii spanning 22 mm to 400 mm
- 10 m^2 active silicon area, 12.5 × 10^9 pixels

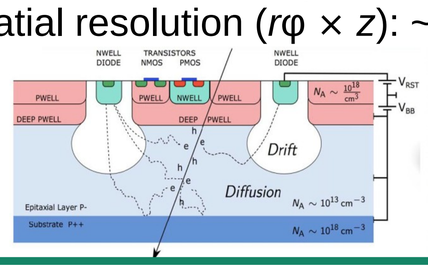


ITS2


Picture of assembled Outer Barrel

ALPIDE sensor

- Monolithic Active Pixel Sensor (MAPS)
  TowerJazz 180 nm CMOS Imaging Sensor process
- In-pixel amplification, shaping, discrimination and hit buffers
- In-matrix zero suppression
- Low power density < 47.5 mW/cm^2
- Detection efficiency > 99%
- Fake-hit rate ≪ 10^{-6}/pixel/event
- 512 × 1024 pixels
- Pixel size ~ 27 × 29 μm^2
- Spatial resolution ($r\varphi$ × z): ~ 5 × 5 μm^2

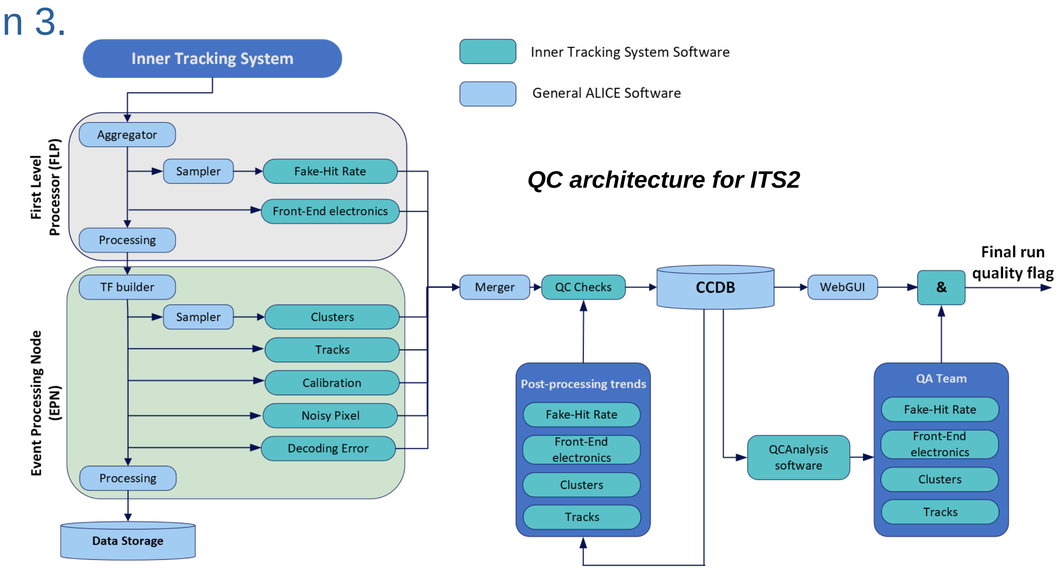


ALPIDE schematic cross section

Data Quality Control (QC) of ITS2 in Run 3

The ITS QC development started during the on-surface commissioning prior to Run 3.
It is used to validate the detector performance and guarantee efficient data taking.

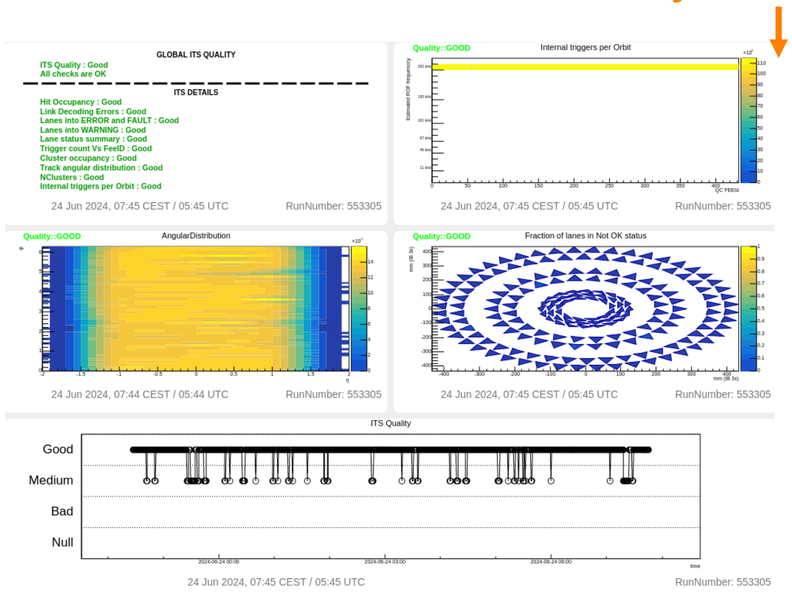
- 7 QC online tasks (online monitoring on data subsets)
  - **Front-end electronics**: data integrity check with payload decoding of all events
  - **Occupancy**: monitoring of detector occupancy
  - **Clusters**: monitoring cluster size, topology etc.
  - **Tracks**: monitoring of track multiplicity, angular distribution, clusters etc.
  - **Noisy pixel**: extraction of noisy pixels for offline noise masks
  - **Threshold**: monitoring during calibration scans (threshold, ENC, dead pixels)
  - **Chip status**: availability of a chip or high-speed transmission line in the data stream, also as input for MC simulations
- Post-processing tasks
  - Offline post-processing framework provides trends of the online information

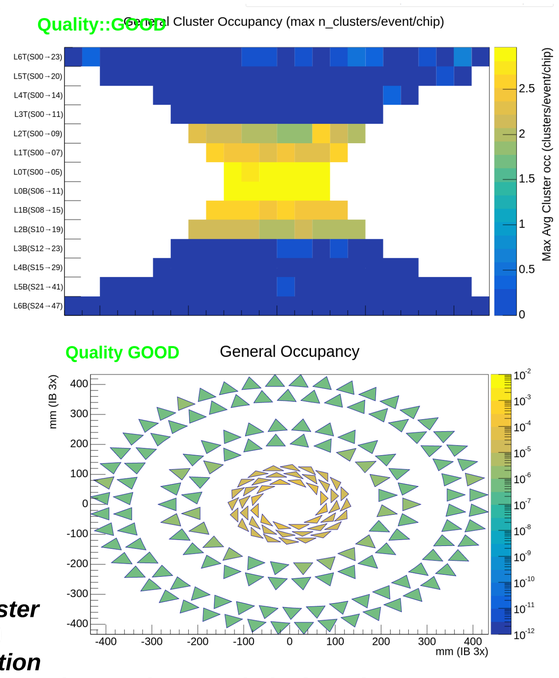


QC architecture for ITS2

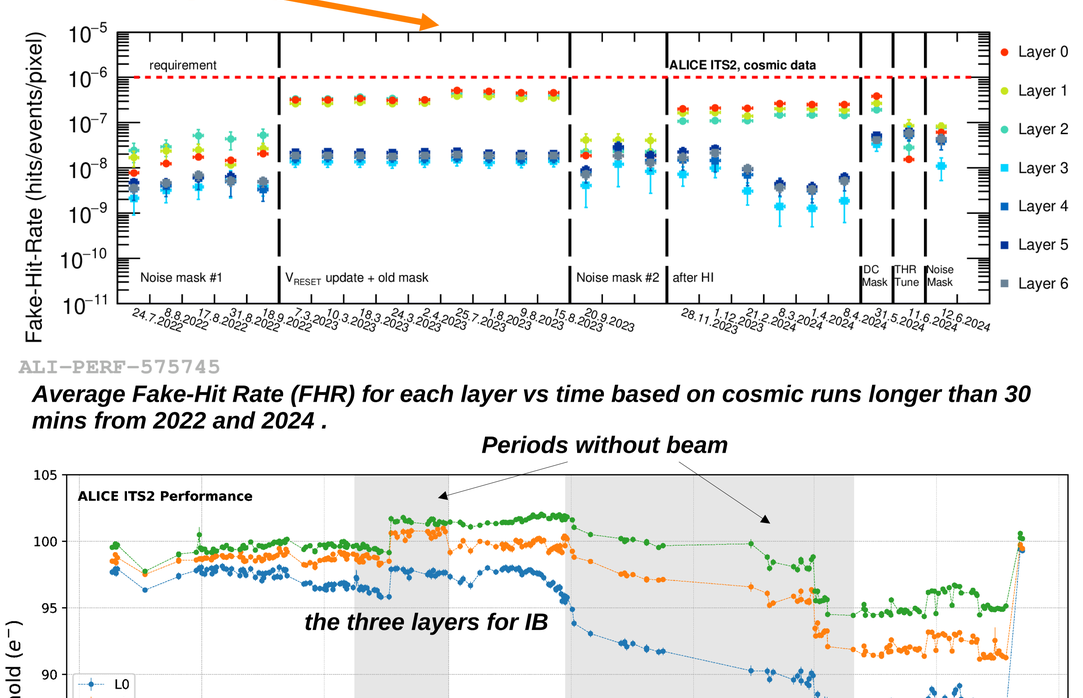
Comprehensive investigations to achieve the optimal detector performance

The detector data quality and performance are monitored in real time relying on the **synchronous** QC and studied in more detail in the **asynchronous** data reconstruction.

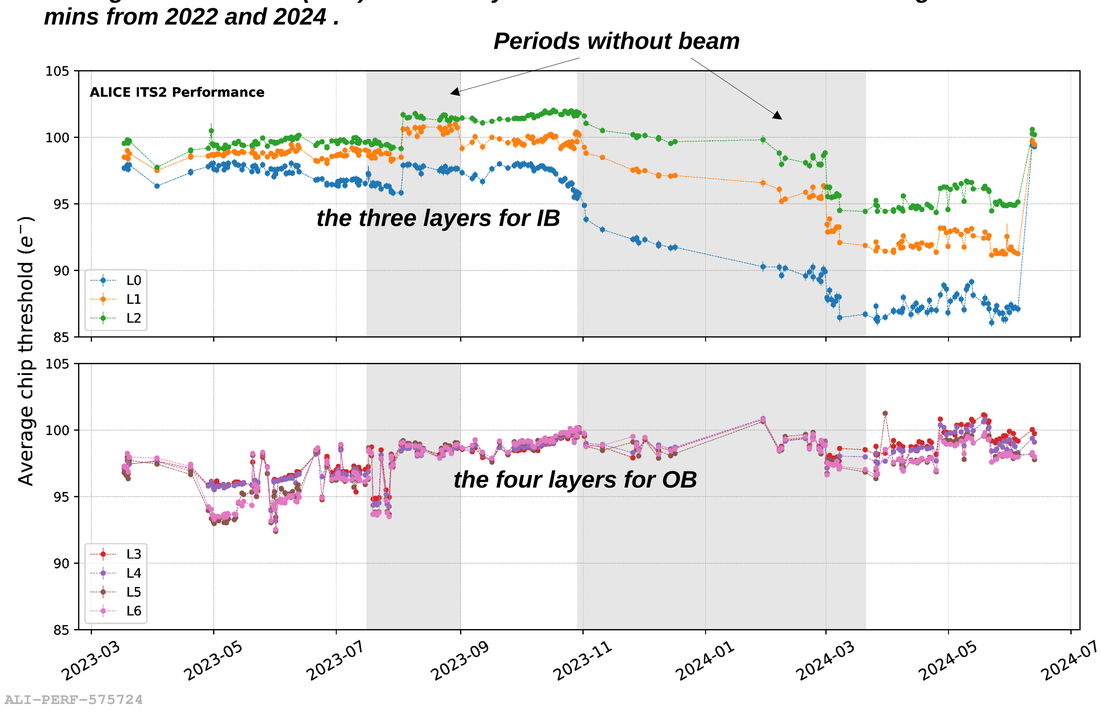


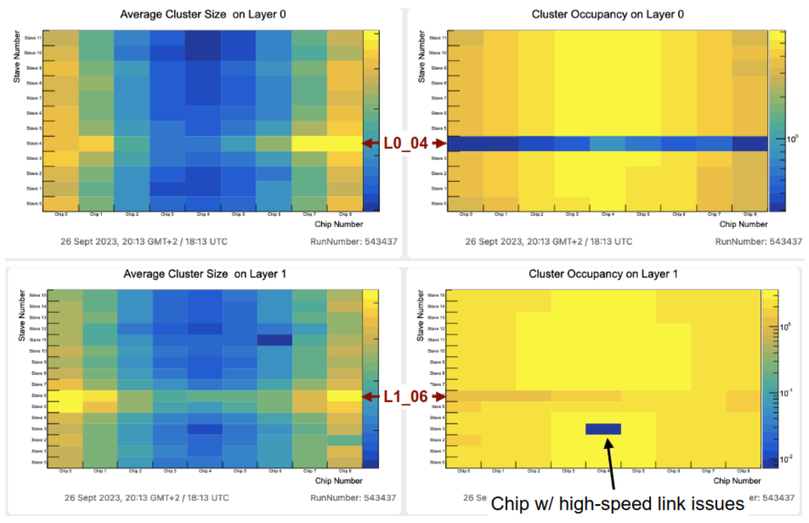


An example of the QC on-line monitoring for 27/4 shifts. The distributions (left) show the ITS2 status and quality. General Cluster Occupancy (right top) and General Cluster Occupancy (right bottom) are based on clusters or on tracks from the synchronous reconstruction correspondingly. The run was taken in pp collisions at √ = 13.6 TeV for an interaction rate (IR) of 500 kHz.



Average Fake-Hit Rate (FHR) for each layer vs time based on cosmic runs longer than 30 mins from 2022 and 2024 .





An example of Pb-Pb beam background:

QC monitoring during the first run in the stable beam in 2023. We can see the increase In Cluster size (left) and the decrease in Cluster Occupancy (right).

- ***Occupancy drastically reduced in affected staves***
- ***Cluster size significantly increase in the most-affected staves as well as their neighbors***

Threshold stability: evolution of the average in-pixel discriminating threshold per layer, from March 2023 to June 2024. Thresholds are tuned to 100 e^- the optimal working point in 12/2022 and 06/2024. The fluctuations are due to supply-voltage optimizations, which do not compromise the detector efficiency during standard data taking.

Summary

- The new MAPS-based ITS2 has been designed and constructed with the primary goal of enhancing the ALICE, tracking capabilities, in particular at low transverse momentum.
- Data Quality Control software is available to monitor the detector to synchronously check the quality of the data.
- The detector has been successfully operated in pp and Pb-Pb collisions with a very low noise level and stable pixel threshold.

Acknowledgment

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