Commissioning and first performance results of the new ALICE upgraded Inner Tracking System

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A Large Ion Collider Experiment

ALICE Inner Tracking System Upgrade for LHC Run 3

Run 3+ Run4 (>2022) Physics Objectives:

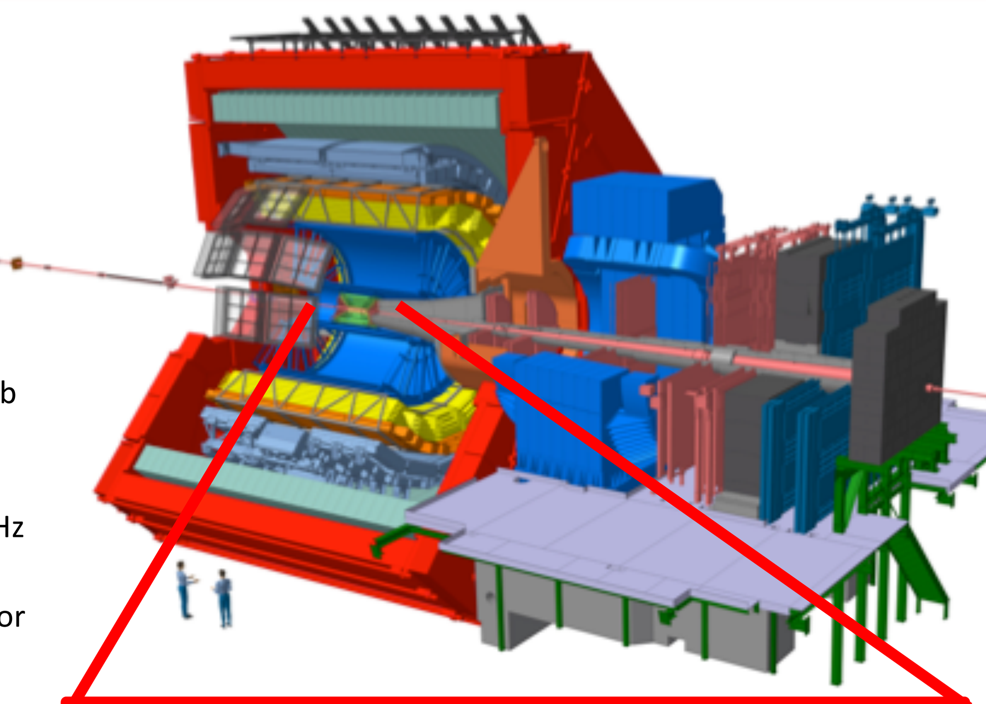
- Heavy-flavour mesons and baryons (down to very low p_T)
- Charmonium states
- Di-leptons from QGP radiation and low-mass vector mesons
- High-precision measurement of light and hyper-nuclei
- Largest possible data samples: Run 3+Run 4: 10^{11} events ~ 13 nb^{-1} in Pb-Pb (100x Run 2 statistics)

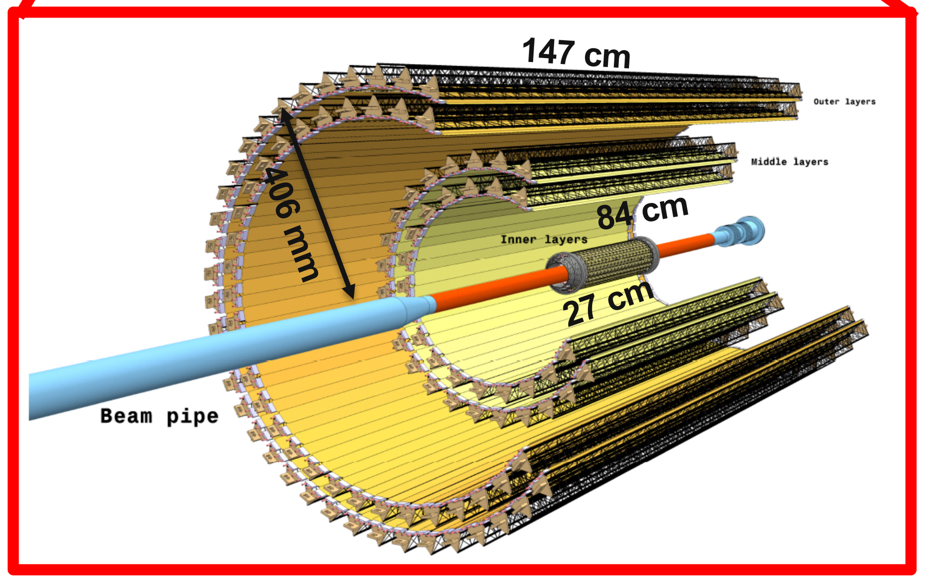
ITS Upgrade Design Goals:

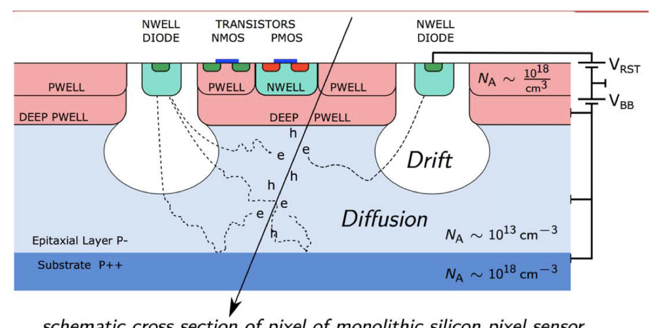
- Minimum-bias (no trigger) readout at 100 kHz for Pb-Pb interactions (1kHz during RUN1 and RUN2)
- Improvement of impact parameter resolution by a factor 3 in particular for very low p_T
- Improvement of standalone tracking efficiency and p_T resolution

New ITS Layout

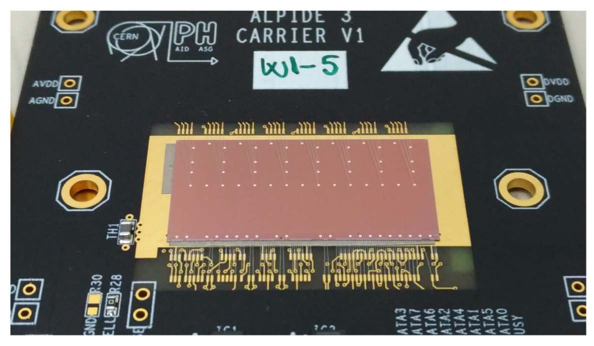
- 6 → 7 layers (3 inner, 4 outer layers)
- Distance to IP of innermost layer reduced from 39 mm → 22 mm, radial coverage 22 – 406 mm
- Higher tracking granularity through reduced pixel size (50×425 µm² → 27×29 µm²), based on Monolithic Active Pixel Sensors (MAPS)
- In total 24120 Chips, 12.5 Giga Pixels with 10 m² Active Surface
- Operation at room temperature
- Reduced material budget (1.14%-> 0.3% X_0 for the innermost layers)
- Nominal radiation load: 270 krad Total Ionising Dose (TID), 1.7 10^{12} 1 MeV n_{eq}/cm^2 Non Ionising Energy Loss (NIEL), max 1 MHz/cm² High Energy Hadron (HEH) flux (>20 MeV)
- Fast removal and insertion of the IB





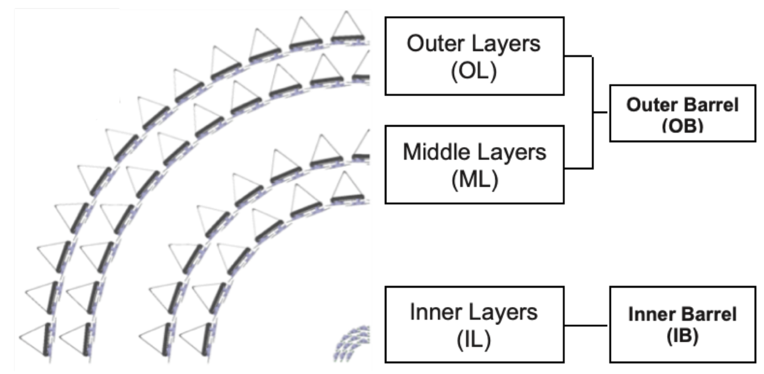


schematic cross section of pixel of monolithic silicon pixel sensor



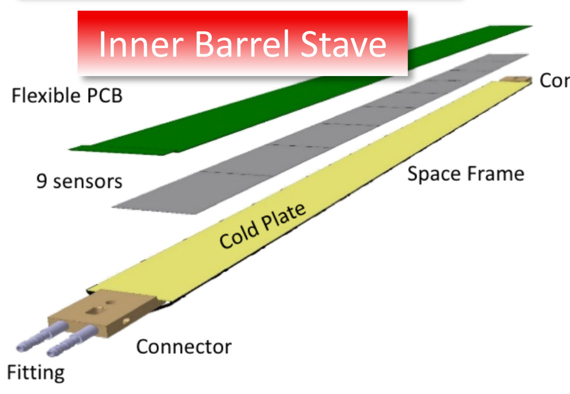
Key characteristics of MAPS manufactured in TowerJazz 180 nm CMOS Technology:

- Quadruple well technology using deep p-well shielding: full CMOS circuits in the active sensor area
- High Resistivity epitaxial layer thickness of 25 µm (not fully depleted):
  - Increased depletion volume around the collection diode by applying reverse substrate bias VBB
  - Charge collection through drift (white) and diffusion (light blue) within 1ns and 100ns, respectively
- Small n-well diode (2 µm – 3 µm, significantly smaller than pixel), thus lower input capacitance resulting in an increased input voltage and thus an increased S/N
- Reduced sensitivity to TID due to thin (3 nm) gate oxides

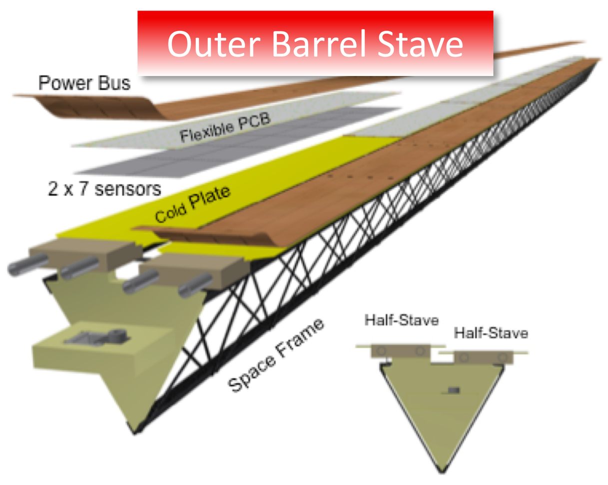


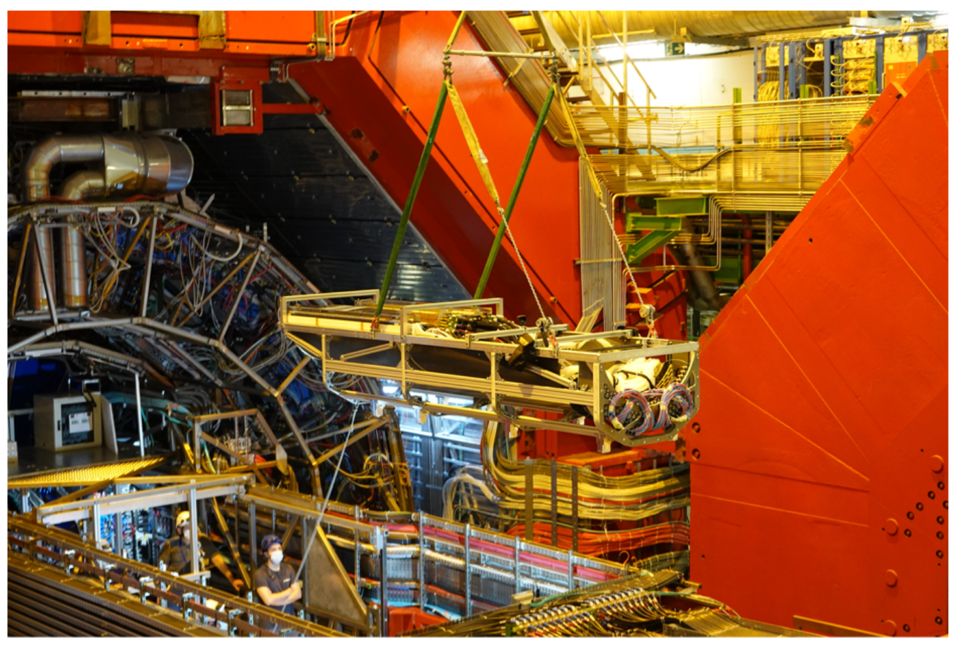
Installation

Inner Barrel Stave

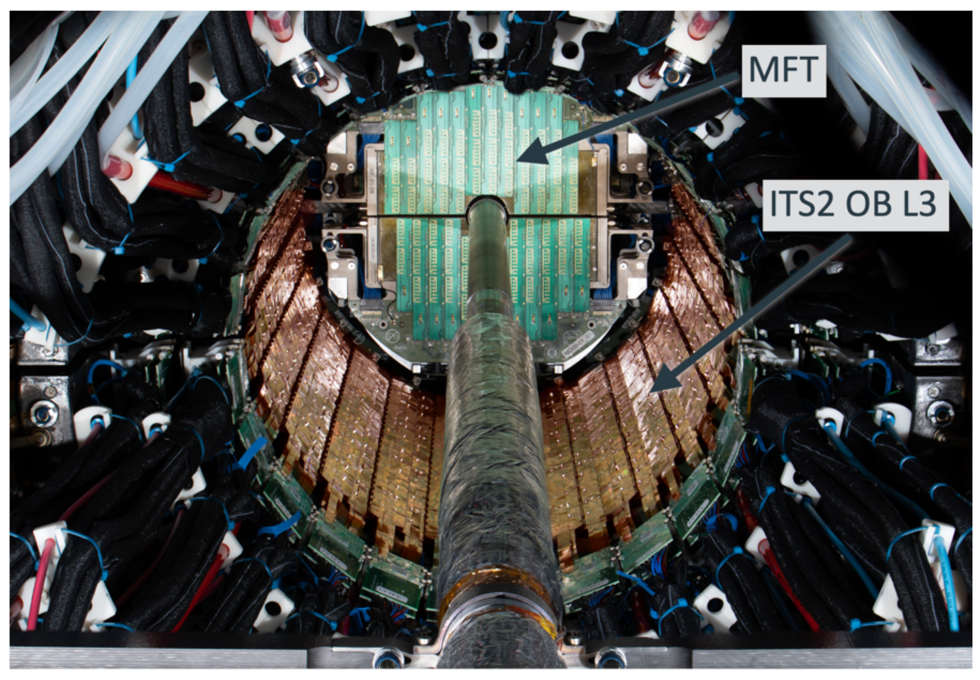


Outer Barrel Stave



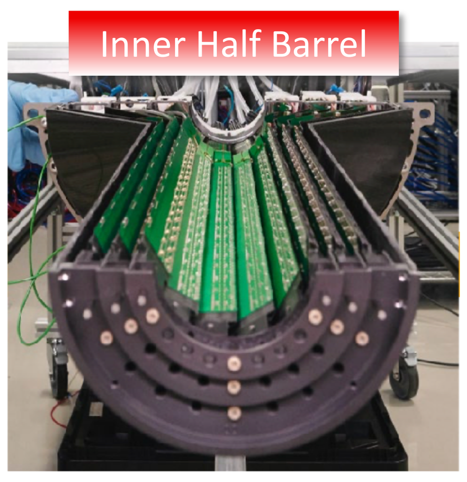


Outer Barrel Bottom lifted to the Mini-Frame by crane

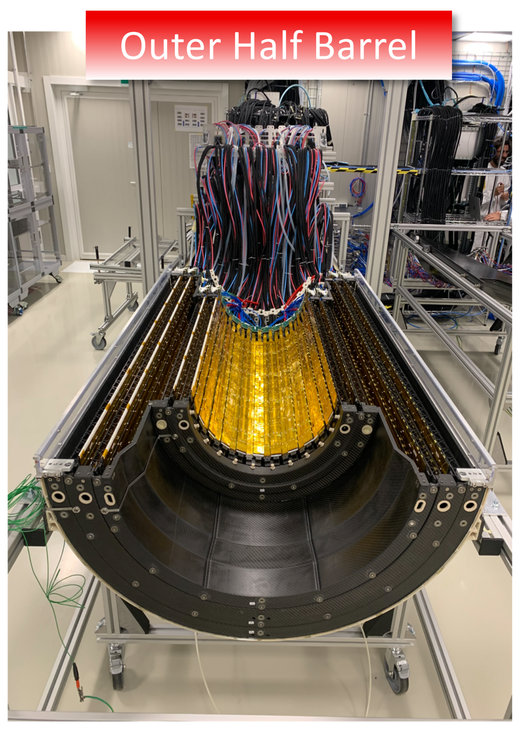


ITS Outer Barrel surrounding the beam pipe, MFT in the back

Inner Half Barrel

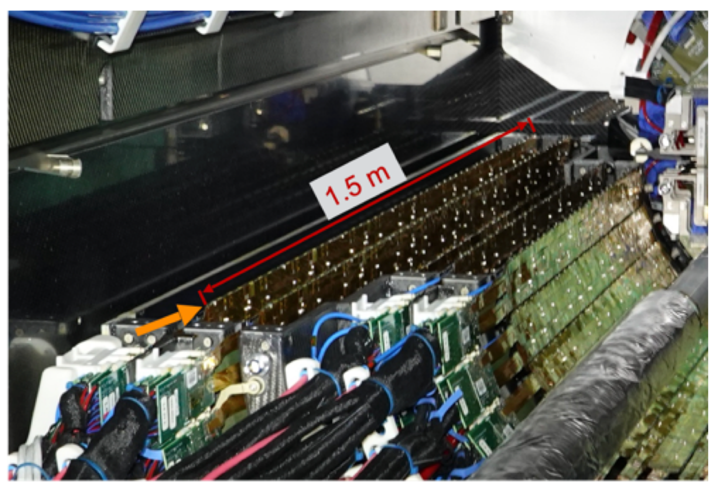


Outer Half Barrel

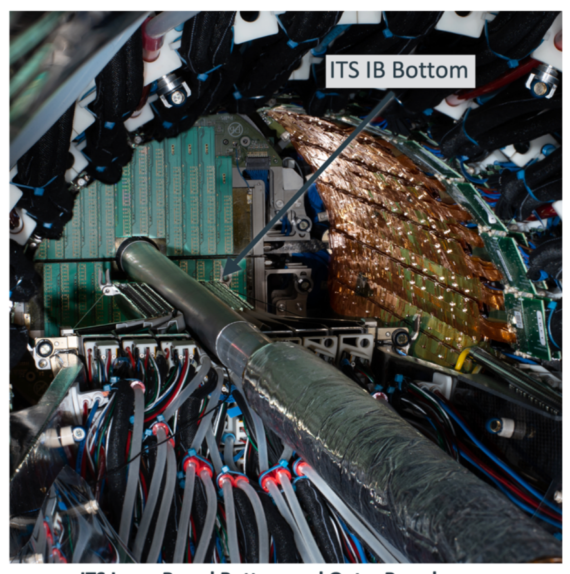


Installation in the cavern

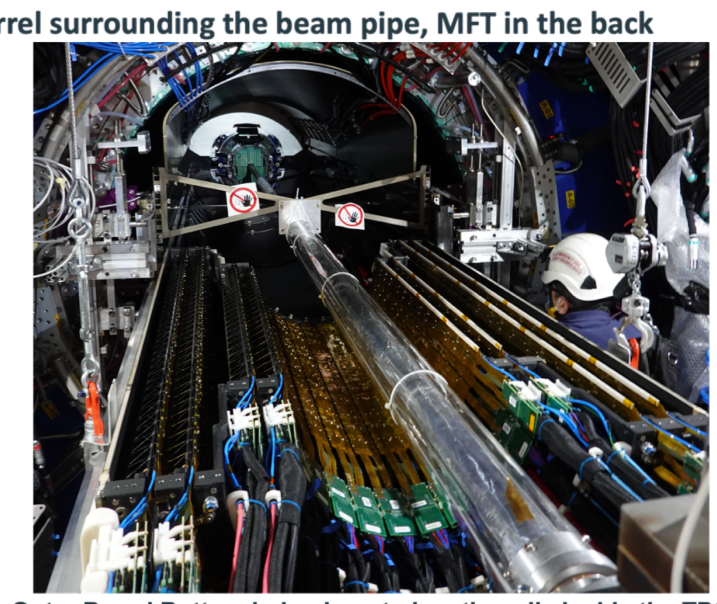
- precise positioning of half barrels in the TPC at the level of about 0.1 mm using six cameras to monitor the positions of the key detector components and compare them to 3D CAD models



OB stave edge



ITS Inner Barrel Bottom and Outer Barrel

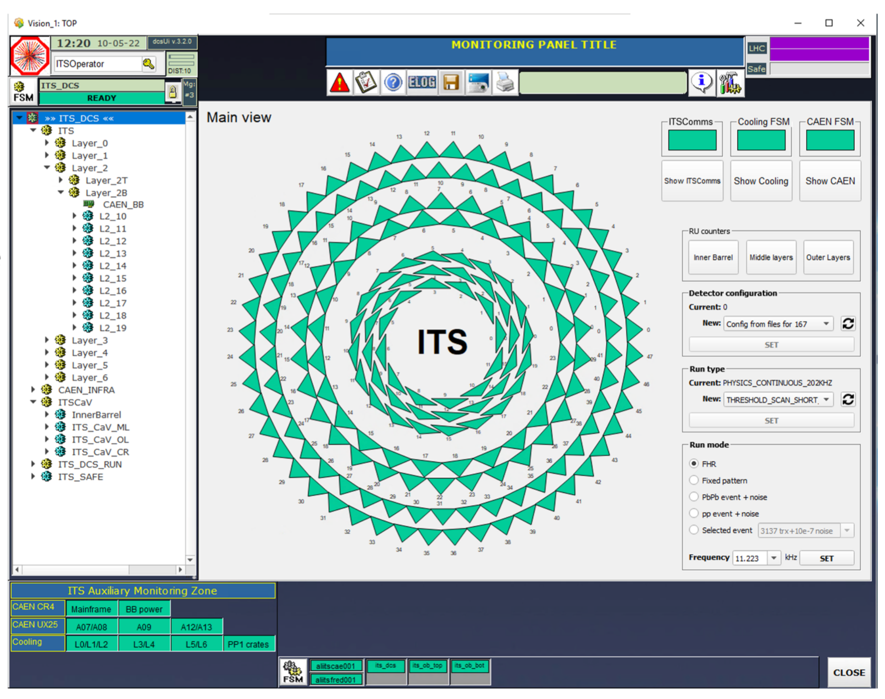


Outer Barrel Bottom being inserted on the rails inside the TPC

Commissioning and Operation

ITS2 Detector Control System fully operational and integrated in ALICE DCS

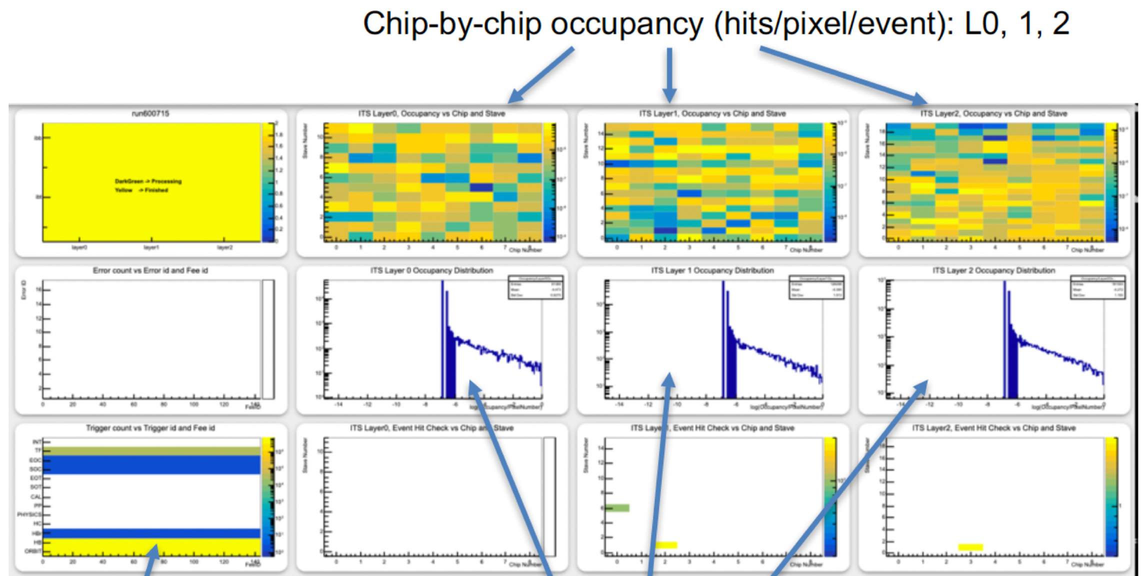
- Pixels, staves, readout electronics and infrastructure fully controlled and configured
- full detector functionality implemented as C++ library , can be run in standalone mode (testing) and with the ALICE FRED framework (operation)
- GUI, alarms, FSM implemented in WinCC
- the full system has been routinely used during commissioning



Comprehensive Data Quality Control for real time data checking and early problem detection

- FEE data integrity checks
- Occupancy
- Cluster size and topology monitoring
- Track monitoring (multiplicity, clusters, angular distribution)
- Noisy Pixel detection for offline masking
- Threshold monitoring during calibration scans

Chip-by-chip occupancy (hits/pixel/event): L0, 1, 2



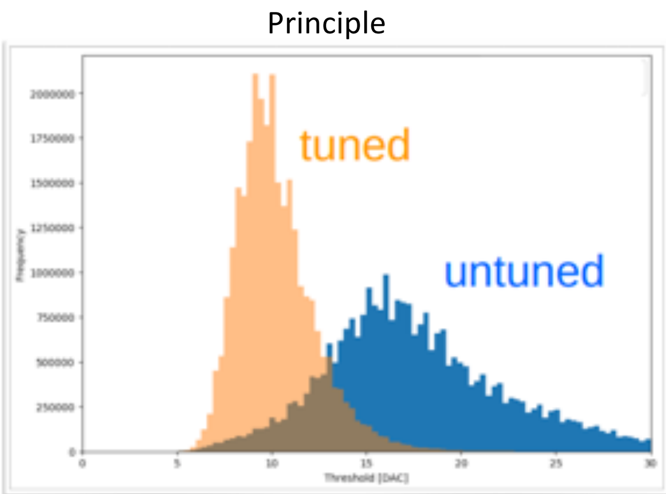
Trigger types

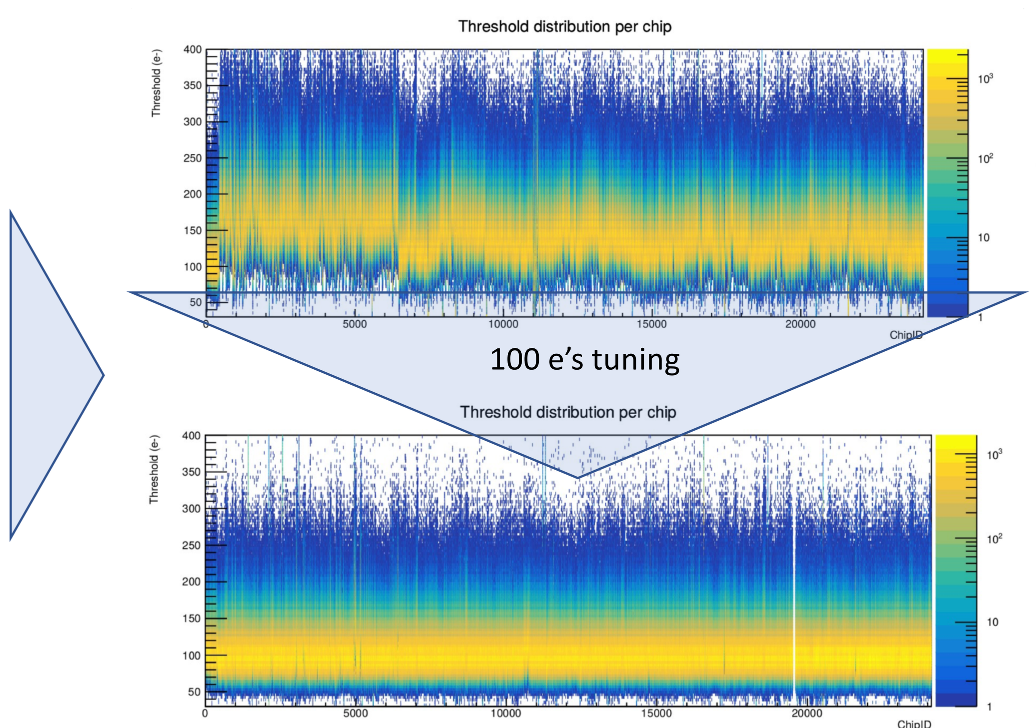
Pixel occupancy (hits/event)

Calibration

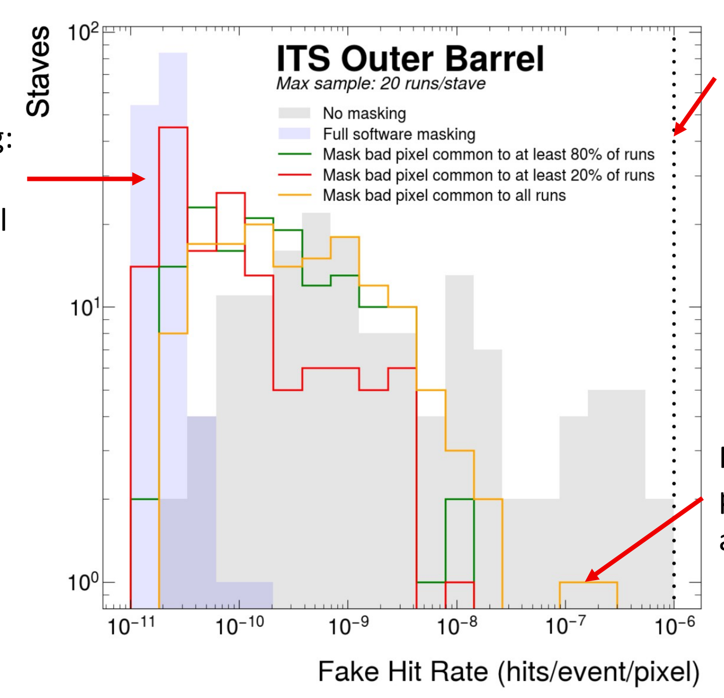
- Online Calibration of 12.5 billion pixels (> 50TB of data for the full detector)
- several scans running sequentially:
  - threshold tuning (adjustment)
  - threshold scan (actual thresholds)
- scans performed by DCS (configuring and triggering test injections)
- all tests of a stave in parallel
- distributed analysis on event processing nodes

Principle





Offline masking: 10^{-10} hits/event/pixel



Requirements: 10^{-6} hits/event/pixel

Masking noisy pixels common to all runs

LHC Pilot Beam

- first tracks of p-p collisions in pilot beam tests in October 2021
- data shown before alignment

Current activities and next steps

- comprehensive commissioning, detector tuning and error correction both in standalone mode and with ECS:
  - identify issues in hardware and software
  - maximizing operational experience