A Large Ion Collider Experiment

ALICE

ALICE ITS

Status Report 2024-2025

P. La Rocca

NB: Info and plots from ITS Plenary meetings, conference talks, …

ITS Project organization

INSTITUTE BOARD

Team Leaders, Project Leader, Deputy Project Leader, ITS3 sub-project leaders, Technical Coordinator

PROJECT LEADER

F. Reidt

DEPUTY PROJECT LEADER

Giacomo Contin

ITS3 SUB-PROJECT

Sub-project Leaders

A. Kluge, M. Mager

Work Packages Conveners

- **Physics and Performance:** F.Grosa, **A. Rossi**
- **Chip Design:** G. Aglieri, W. Snoeys
- **Chip Characterization**: M. Suljic, S. Senyukov, H.Hillemmans, M. Keil, **V. Sarritzu**
- **Thinning, Bending and Interconnection:** **G. Contin**, **D.Colella**
- **Mechanics and Cooling:** C. Gargiulo, M. Angeletti
- **Readout electronics, Power supply and Services:** O.Bourrion, **S. Siddhanta, P. Giubilato**

ITS2

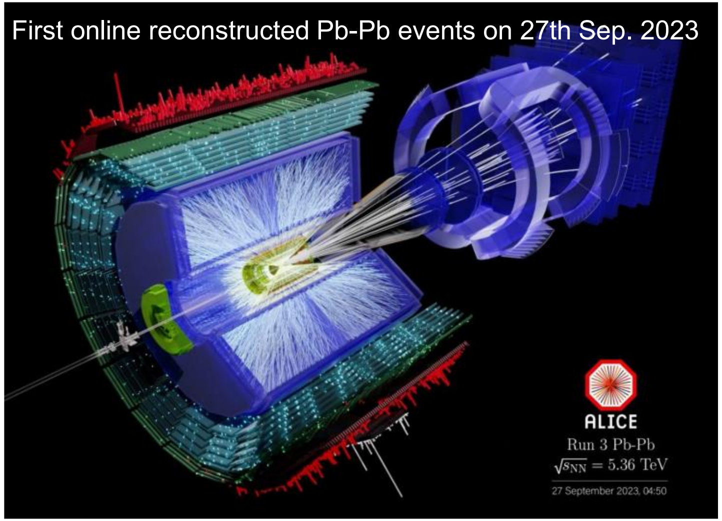
- **Technical Coordinator:** Markus Keil
- **System Run Coordinator (SRC):** Jiyoung Kim
- **Electronics Coordinator:** G. Aglieri
- **Software Coordinator:** **F. Prino**
- **Sub-system Coordinators:**
  - **DCS:** M. Keil
  - **ITS2S:** P. Martinengo
  - **Cooling:** S. Senyukov

A. Villani endorsed as SRC for first half of 2026

ITS2 data taking experience

ITS2: 3 years of experience with LHC beams, ~ 100% availability

- pp collisions: ~ 82 pb^{-1} (~3000x min. bias Run1+2)
- Pb-Pb collisions: ~ 3.3 nb^{-1} = ~ 25 billion hadronic collisions (~60x min. bias Run1+2)

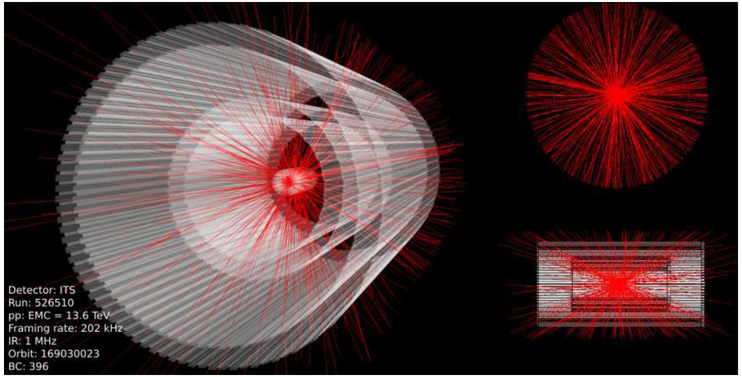


Operation highlights:

- Successful performance at interaction rates of up to 4 MHz of pp collisions
- 99.6% active pixels in the whole detector
  - 94 chips broken/excluded + 970 k dead pixels + 500 k noisy pixels (over 12.6 Gpix)
- Run with static pixel mask; update needed only once per year
- Stable charge threshold with good uniformity across the chips; it needs retuning ~ once per year
- In-run acceptance loss at the level of percent (pp) or below (Pb-Pb), automatically recovered by the Detector Control System (DCS)

ITS2 - Data-taking in 2024

- In 2024 ITS showed stable and optimal performance including Pb–Pb
- Recorded data:
    - pp ($\sqrt{s}$ = 13.76): 53.1 pb^{-1} (92.3 % efficiency)
    - pp reference ($\sqrt{s}$ = 5.36 TeV): 5.3 pb^{-1} (96 % efficiency)
      23 hours-long run was taken
    - Pb-Pb ($\sqrt{s_{NN}}$ = 5.36 TeV): 1.6 nb^{-1} (80 % efficiency)
      Reached the target lumi of 6400 b/s.
      Stable operation at 50 kHz IR
- Special runs
    - Van der Meer scan
    - Color runs
    - Beam background tests
- More than half of the expert on-call shifts were covered by INFN experts



An ever-improving detector

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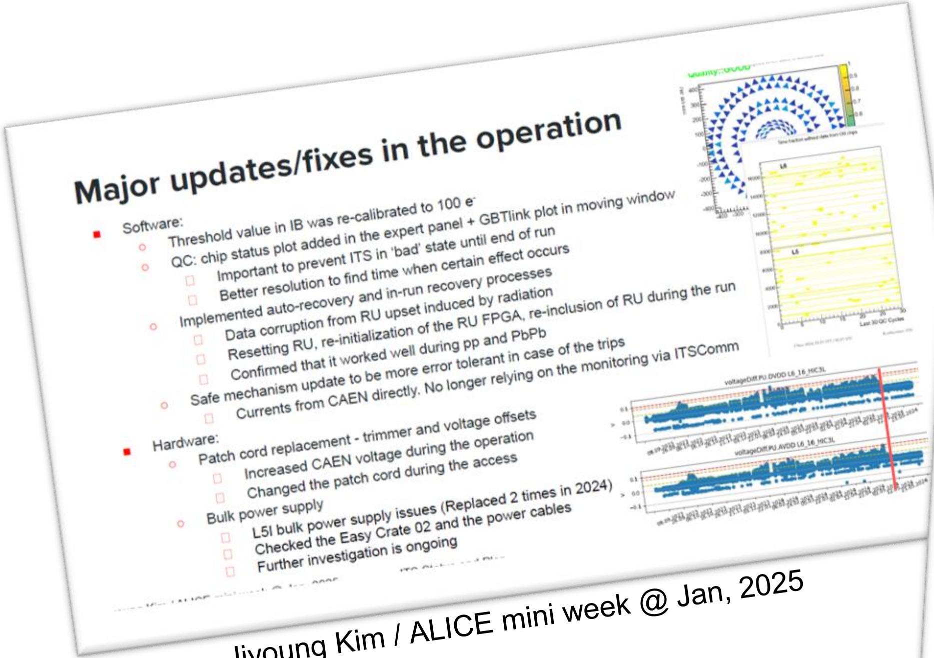
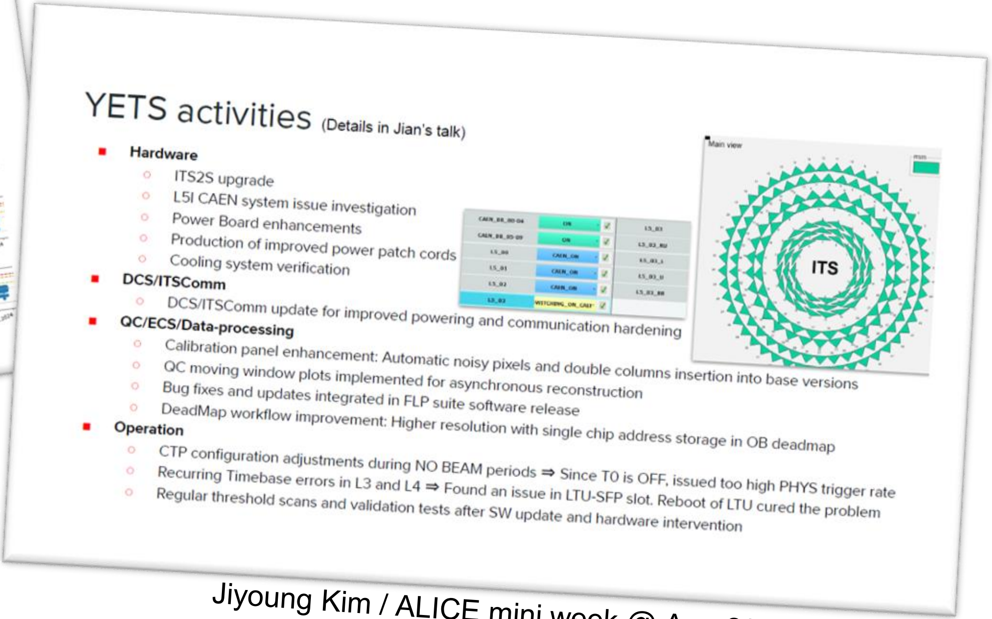
Many activities carried out during operation and the YETS!



Jiyoung Kim / ALICE mini week @ Jan, 2025



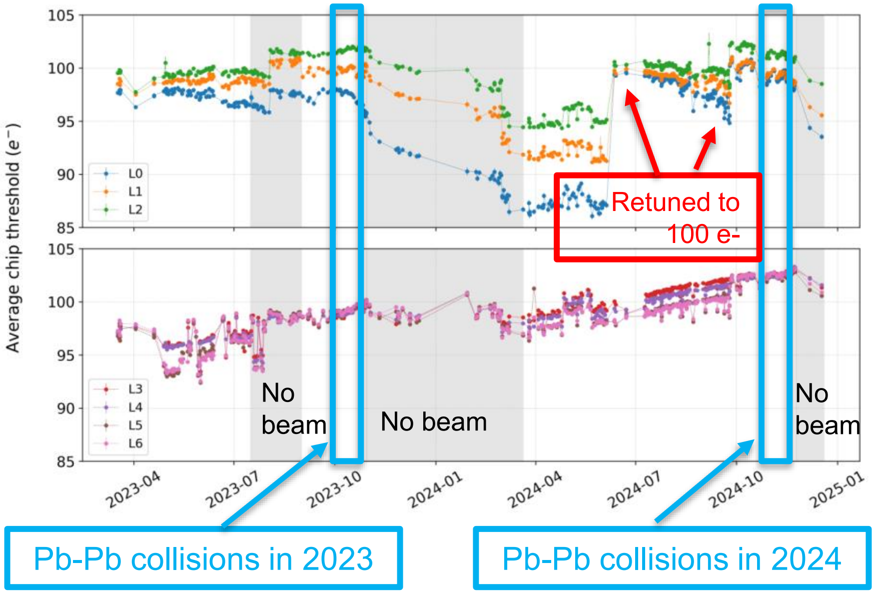
Jiyoung Kim / ALICE mini week @ Apr, 2025

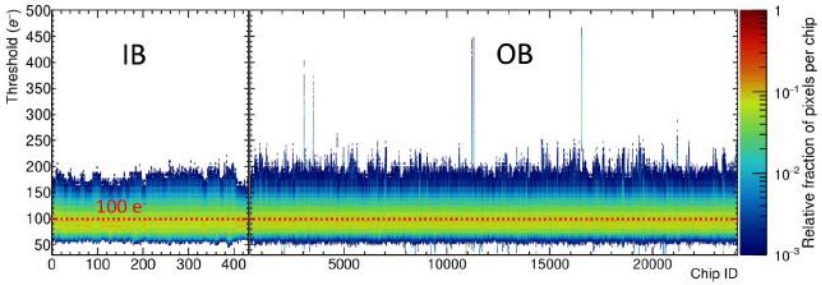
Most relevant items discussed in the next slides

Threshold calibration in 2024

Threshold monitoring:

- Full threshold scan run ~1/year
- Fast threshold scan (~1% pixels) run at each beam dump

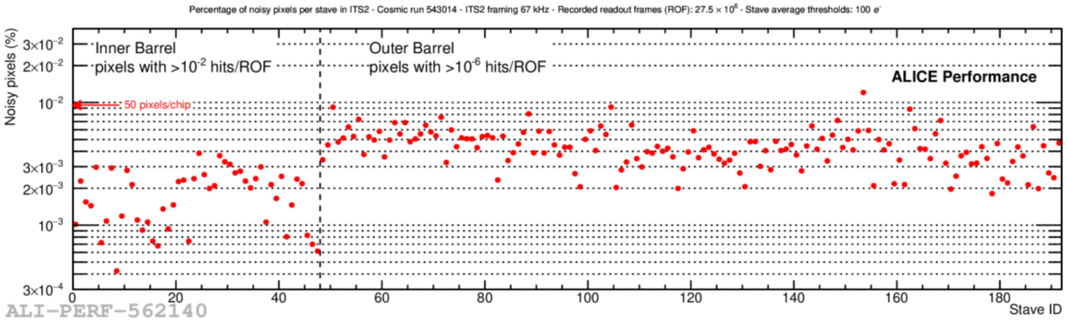


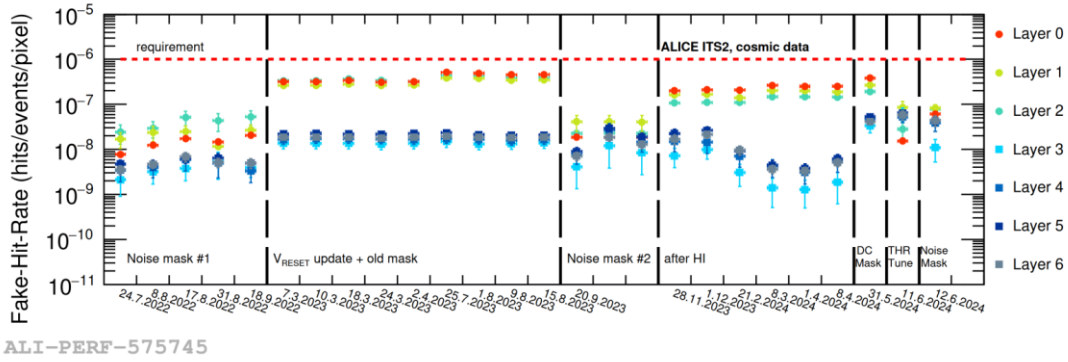


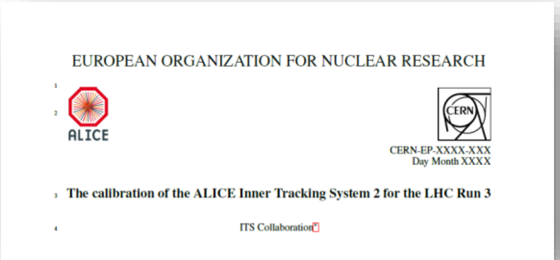
- Uniform response across the detector achieved (100 e^- target)
- Noise ~5 e^- (compatible with production QA measurements)
- Threshold stability has been consistently maintained across 24 k chips → minor fluctuations due to supply voltage optimizations
- Radiation effect observed in IB after Pb-Pb runs in 2023 → decrease in the average THR
- THR(L0) < THR(L1) < THR(L2)
- → effect compensated with new tunings in 2024

Fake hit rate (FHR)

- Possibility to run with static masks already proven during surface commissioning
- Masking criteria:
  10^{-6} hits/event/pixel in Outer Barrel
  10^{-2} hits/event/pixel in Inner Barrel
  → prioritization of efficiency over data rate reduction in IB, almost no masking
- Fraction of masked pixels: 0.004%
- Stable noisy pixel map → occasionally noise calibration is sufficient
- Extremely quiet detector!
- Paper on calibration: draft nearly complete



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CERN-EP-XXXX-XXX
Day Month XXXX

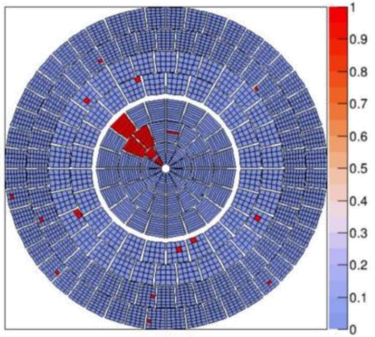
The calibration of the ALICE Inner Tracking System 2 for the LHC Run 3

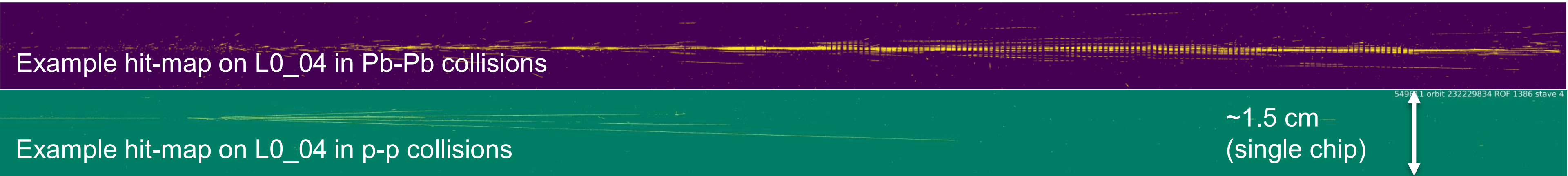
ITS Collaboration

Beam background tests

- Early discovery in the first minutes of stable Pb-Pb beams in 2023
- Source promptly identified and largely mitigated → Orbit bump on beam 1
- RU firmware was enhanced to manage these events more effectively
- Large clusters also observed in pp collisions at similar positions but with different properties
- Task force with RC, experts from ITS, ZDC, MFT, MCH, FIT, MID & Simulation
  - Magnet polarity
  - With/without collisions
  - (TCT) collimators position
  - Tuning of beam disp knob (orbit bump)
  - Effect of bump applied at IP1 (ATLAS)
  - Single circulating beam

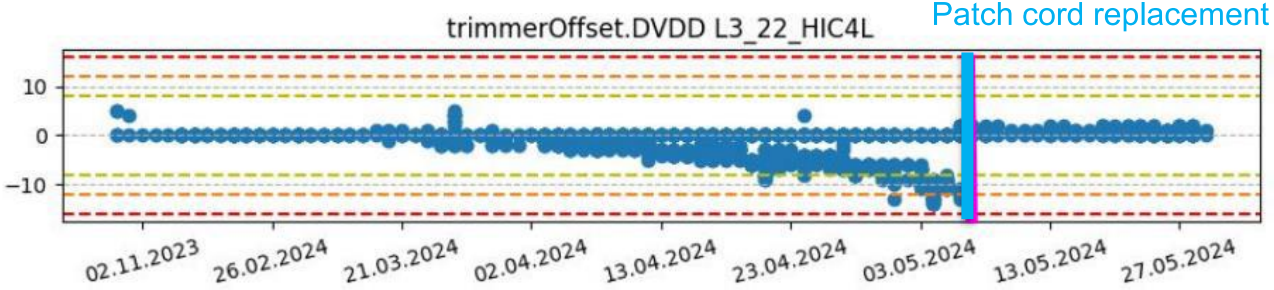
    → Most likely hypothesis: three different background sources pp -- ^{207}Pb on TCT -- residual PbPb
- Work ongoing to understand the origin of the remaining background





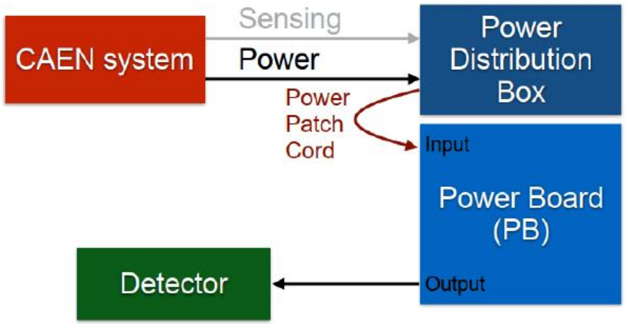
Power Board (PB) voltage stability and mitigation

- Symptom: PB shows drifting output voltage that can be cured by replacing the input power patch cords
  - Attributed to voltage drop variations on the patch cord
  - Increasing voltage is an issue for the detector safety
  - Major fraction of alerts and interventions caused by this issue
  - Significant complication of our DCS system due to workarounds
- Due to space constraints voltage sensing is terminated before the last patch cord connecting the PB
- Understanding based on recent laboratory tests, but exact failure mechanism of the patch cords not reproduced in the laboratory so far
- Extending the sensing to the PB should stabilize and facilitate the operation significantly



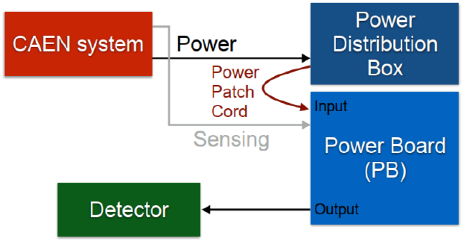
Power Baord (PB) voltage stability and mitigation

- Two alternative solutions under investigation:

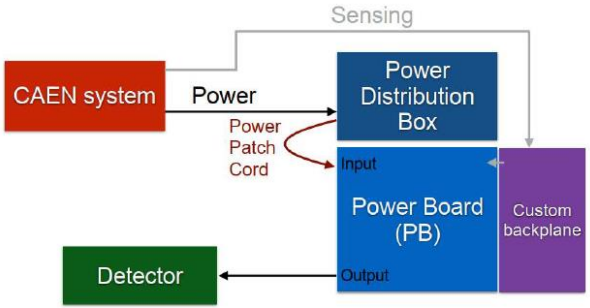


Current power system diagram: the voltage sensing is terminated before the last patch cord connecting the PB

Select a solution towards end of June → production in the second half of the year → installation in the next YETS



1. Front Panel sensing: power connector replaced by add-on board



2. Custom backplane: Replacements of the VME J1 backplane by a custom one

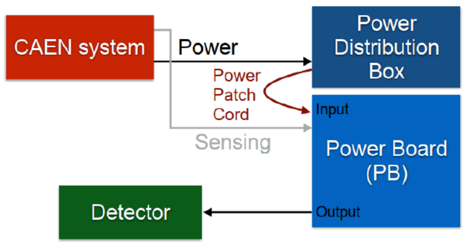
Power Baord (PB) voltage stability and mitigation

Changes:
- Removal of current input connector
- Addition of a custom assembly adding a sense connector in addition to a smaller footprint power connector
- Sense cables connected directly to the PB

Advantages:
- Only power board needs to be modified

Disadvantages:
- Additional connections in the front of the PB
- Interventions on the PBs / Readout Units become more complicated

Implemented on 3 staves



1. Front Panel sensing: power connector replaced by add-on board

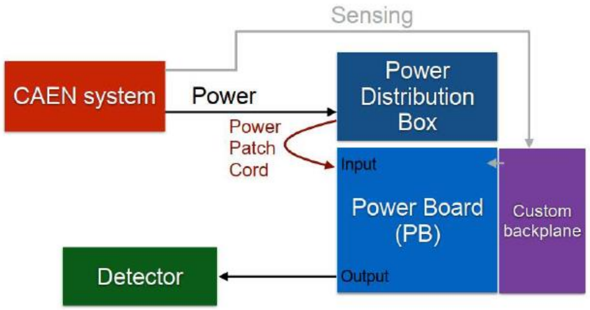
Power Baord (PB) voltage stability and mitigation

Changes:
- Replacements of the VME J1 backplane by a custom one
- Re-routing of the sense cables to the back-plane
- Connection of the sensing to the backplane connector using a custom wire harness

Advantages:
- Interventions on Readout Units / PBs remain the same complexity: “cleaner”
  - ➞ Preferred by experts

Disadvantages:
- Initial installation more complicated due to custom back plane: both RUs and PBs have to be removed from the subracks

Implemented on 11 staves



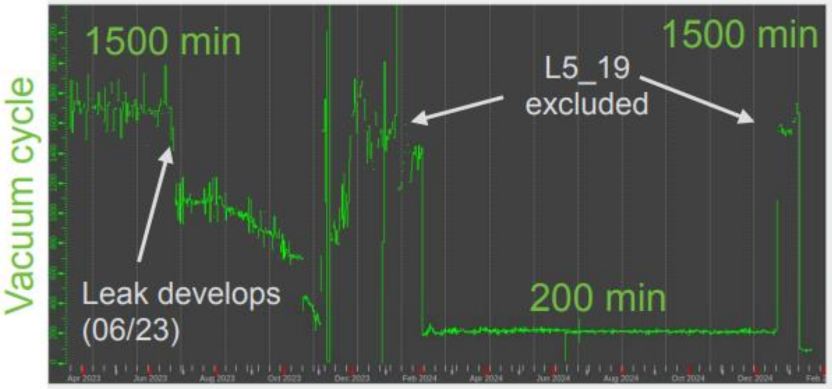
2. Custom backplane: Replacements of the VME J1 backplane by a custom one

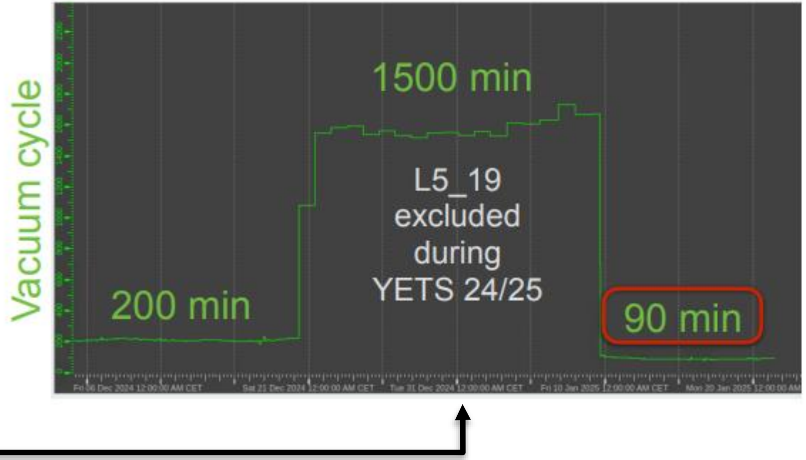
Power Board modification – next steps

- So far no issues related to the modifications (limited number of staves modified and operational experience)
- Sensing working, i.e. increase resistance due to patch cord degradation successfully compensated
- Both solutions working, detailed performance comparison to be done
- Production of chosen solution during July/August/September
- Preparation of material for installation at CERN in October
- Formation of a team in the coming weeks:
  - Production and follow-up
  - Extraction and re-installation of electronics
  - Reworking of Power Boards (soldering)
- Installation starting from December 8th until January 23rd (5 weeks, tentative planning)
- Short YETS, experiments closing on February 20th => little contingency

Cooling issue

- Dominant leak on the ITS cooling plant (Stave L5_19), developed in 2023
- Stave excluded during YETS to assess the tightness of the rest of the system
  - After recent exclusion and re-inclusion of the line, the leak rate approximately doubled
  - Operational margin on the corresponding cooling line drastically reduced (inlet pressure at 0.95 bar)
  - Stave L5_19 still running, but the operational margin on the cooling is very small
  - During LS3, we plan to intervene on the Half-Barrel



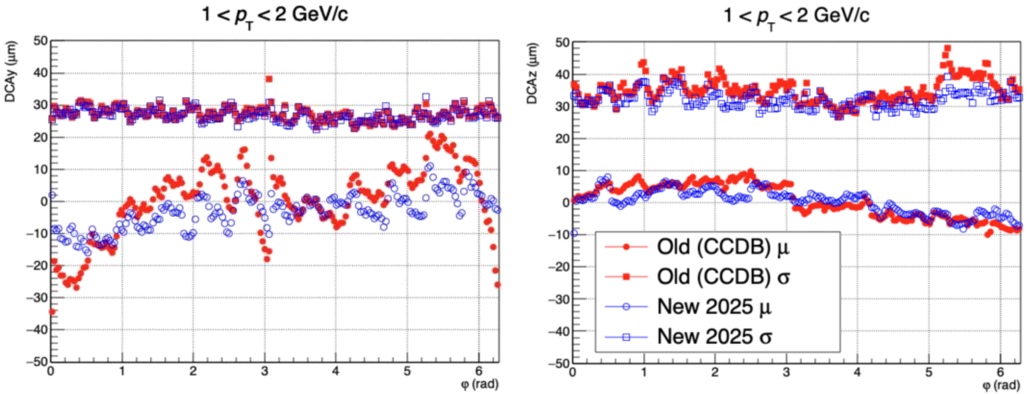


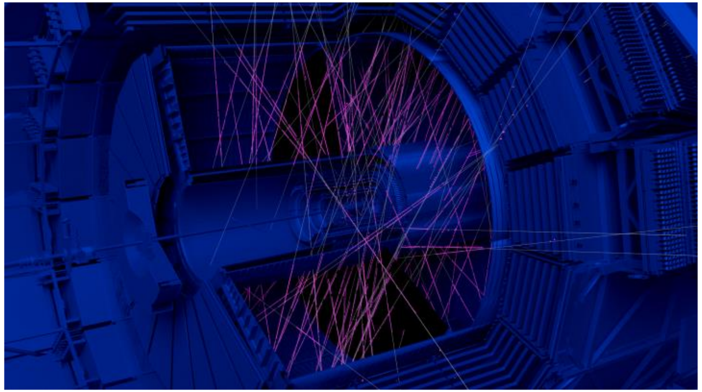
Reconstruction, simulation and data preparation

- Geometry: ITS Staves described to a high level of detail, but still some elements described in a rough way
- Reconstruction:
  - GPU developments
  - Treatment of tracks with shared clusters
  - Use information about sensor acceptance/inefficiency in the tracking
  - …
- Alignment: current alignment produces good physics results, but work in progress to improve σp_T and remove DCA biases
- Impact parameter: material features visible
- … many other studies
  - Detection efficiency from tracks
  - Studies on PID (color runs)
  - Efficiency vs. occupancy studies
  - Occupancy: Data/MC matching
  - QC: systematic checks of reconstructed data and MC samples
  - Parallel worlds for MC simulation
  - …

Alignment

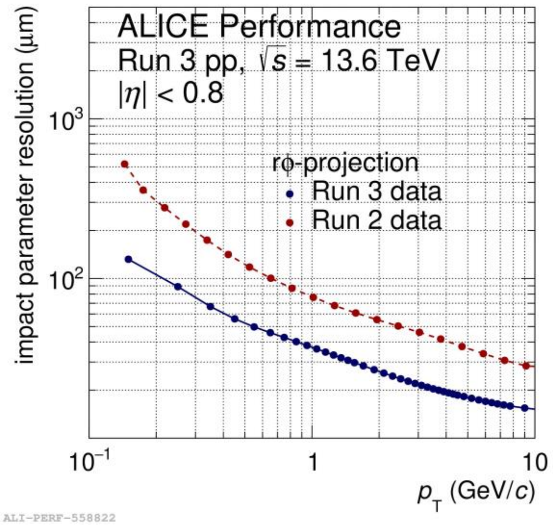
- 2025 where are we?
  - Use new cosmic data acquired this year (x3 statistics, >300 hours of data taking)
  - New 2025 alignment → overall improvements visible, some problematic regions remain
  - Tested in D^0 raw yield analysis → significance improved
  - **New alignment will be used from now on**

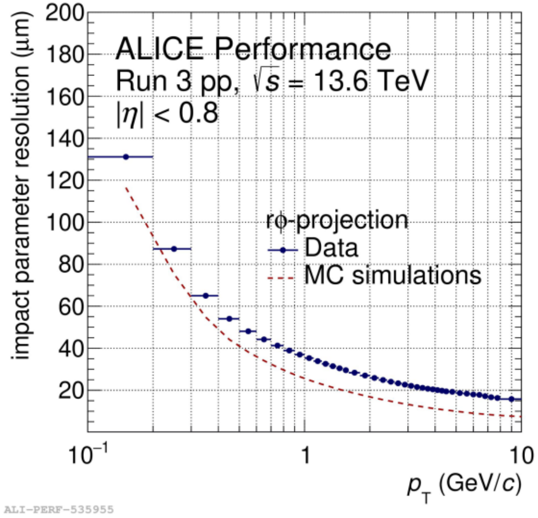




Impact parameter resolution

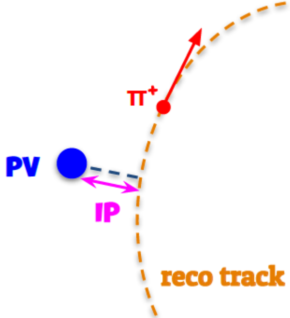
- 2025 where are we?
  - ITS2 TDR: factor 3 improvement over ITS1
  - Current status: factor 2 improvement over ITS1
  - Current simulations predict a factor 2.5 improvement over ITS1 (partially due to increase material budget)

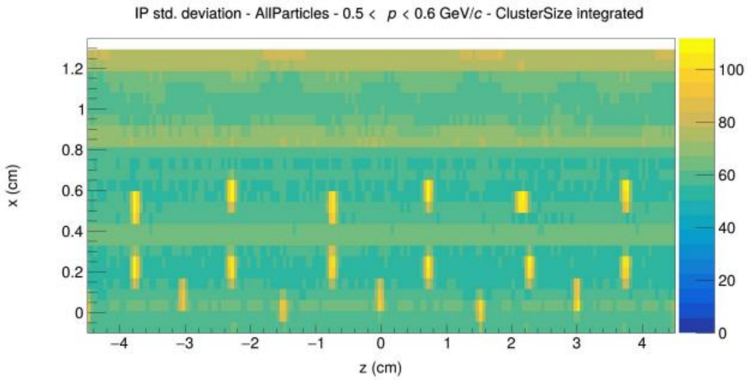


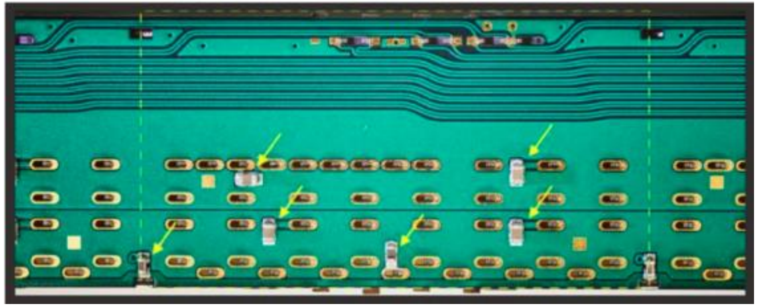


Impact parameter resolution

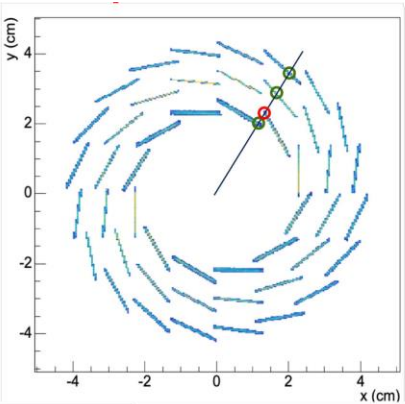
- Goal: understand the observed discrepancy between data and MC simulations
- Impact parameter resolution affected by the material budget due to:
  - multiple scattering for low pT particles
  - intrinsic point resolution of each tracking layer
- Understand the influence of the material budget inhomogeneity
  - Potential contributions arising from the decoupling capacitors on the stave
  - Every capacitor of size 1 mm x 0.5 mm → adding about 3-4% X0
  - The effect becomes less pronounced for increasing particle momentum
- Studies ongoing







Exploring the full potential of ITS2



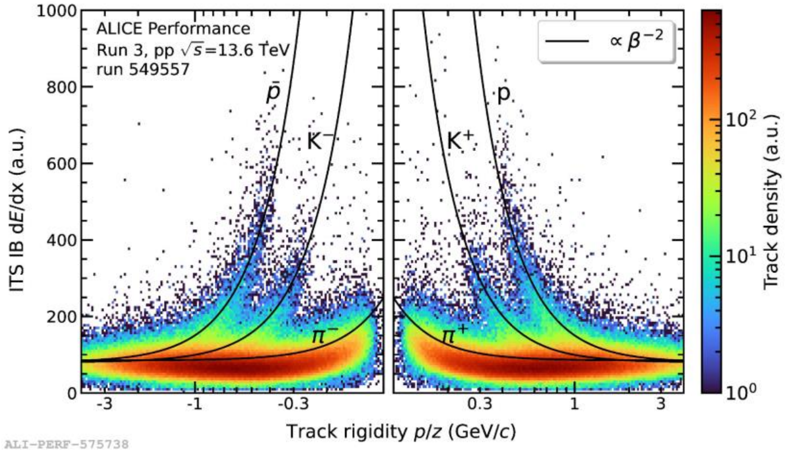
Detection efficiency from tracks

- Reconstructed tracks in ITS do not have missing hits in the central layers
- This prevents us from calculating the efficiency in the “classical way”
- Estimate the ITS detection efficiency by exploiting the staves overlaps

Studies on PID - Color run

Usage of Time over Threshold information to access the particle energy loss in ALPIDE sensitive layer

- Front-end tuned to achieve analogue pulse length proportional to deposited charge
- High readout rate (2.2 MHz) to oversample analogue front-end response
- Only feasible at < 1 kHz of pp collisions



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Milestones

2024

		Data prevista per il completamento	Descrizione	Completamento al 30.06.2024 (%)	Commenti al 30.06.2024	Completamento al 31.12.2024 (%)	Commenti al 31.12.2024
3	ITS	30/11/2024	Ottimizzazione software di ricostruzione tracce per interazioni pPb	100	Il software di ricostruzione è stato validato nella sua versione completa. Possibili ottimizzazioni per GPU sono possibili e permetteranno di ridurre il tempo di elaborazione dei dati	100	

2025

		Data prevista per il completamento	Descrizione	Completamento al 30.06.2025 (%)	Commenti al 30.06.2025	Completamento al 31.12.2025 (%)	Commenti al 31.12.2025
24	ITS	31/12/2025	Partecipazione con alta efficienza alla presa dati durante tutti i periodi di fascio	40%	L’ITS ha partecipato alla presa dati della prima metà 2025 in modo continuo, mostrando prestazioni stabili e ottimali		

Milestones

2026

		Data prevista per il completamento	Descrizione	Completamento al 30.06.2026 (%)	Commenti al 30.06.2026	Completamento al 31.12.2026 (%)	Commenti al 31.12.2026
	ITS	30/06/2026	Partecipazione con alta efficienza alla presa dati durante tutti i periodi di fascio				
	ITS	31/03/2026	Risoluzione problema Power Board, tale da garantire prestazioni stabili da qui alla fine del Run 3				

Financial requests 2026

M&OB

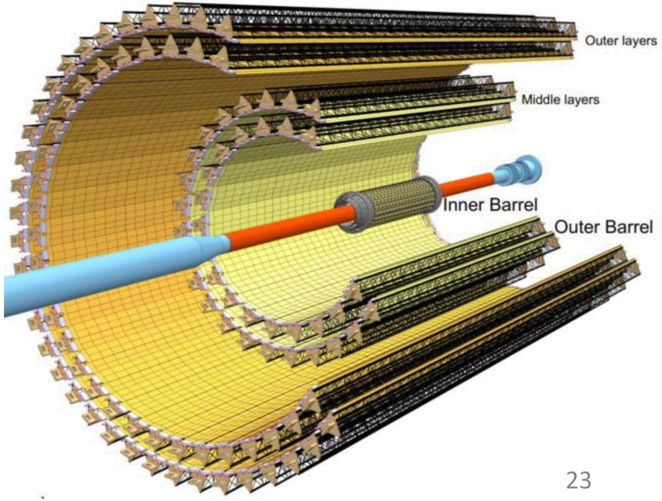
78 kEUR (CERN RRB Apr. 2025)

Backup slides

Inner Tracking System (ITS2)

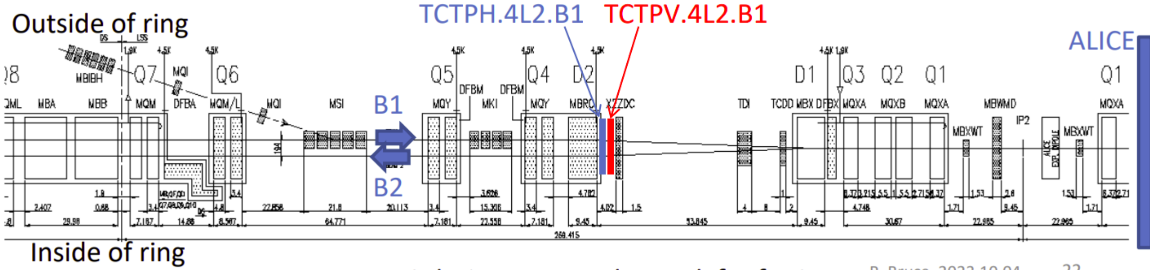
- The first Monolithic Active Pixel Sensor (MAPS) based detector at LHC
- ITS2 design objectives:
  - Higher granularity:
    - 7 pixel layers - ITS1: 6 layers
  - Improved impact parameter resolution:
    - Closer to the interaction vertex 22 mm - ITS1: 39 mm
    - Reduced material budget ~ 0.36% X_0/inner layer - ITS1: ~1.14% X_0
    - Reduced pixel size ~ 30 x 30 μm^2 - ITS1: ~ 50 x 425 μm^2
  - Fast readout, continuous mode, at higher interaction rates:
    - Pb-Pb up to 50 kHz (previously 1 kHz)
    - pp up to 1 MHz
- Timeline:
  - 2013 TDR
  - 2019 Start of on-surface commissioning
  - 2021, spring Installation in the ALICE cavern
  - 2022, July Start of LHC run 3
  - Next: Inner Barrel replacement during Long Shutdown 3 → ITS3

12.6 billion pixels



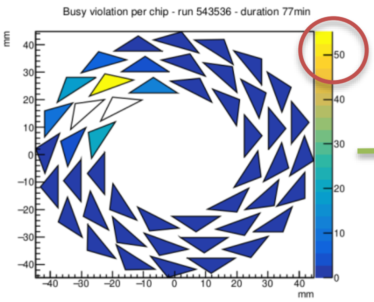
2023 Pb background

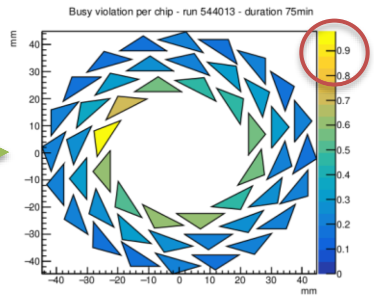
- Pb208 electromagnetic dissociation into crystal collimators in IP7
- Pb207 isotopes hitting bottom jaw of TCT, 117m away from IP2
- Keeping TCT in parking position solves background but not affordable for the LHC due to radiation load
- Orbit bump on beam 1, shifting Pb207 trajectories in the z direction → nuclei missing the TCT (Oct 05th)

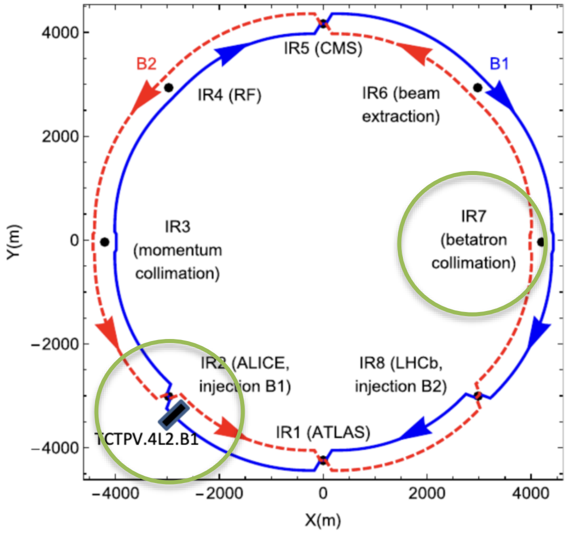


LHC design report – layout left of IP2

R. Bruce, 2023.10.04 22







Detection efficiency from tracks

- New studies on B=0 data in different years
- Excluded chips adjacent to switched-off chips, to avoid biases
- Correlation with applied threshold
  - Higher efficiency for higher thresholds
  - Under investigation