ALICE upgrades and preparations for physics in Run 3

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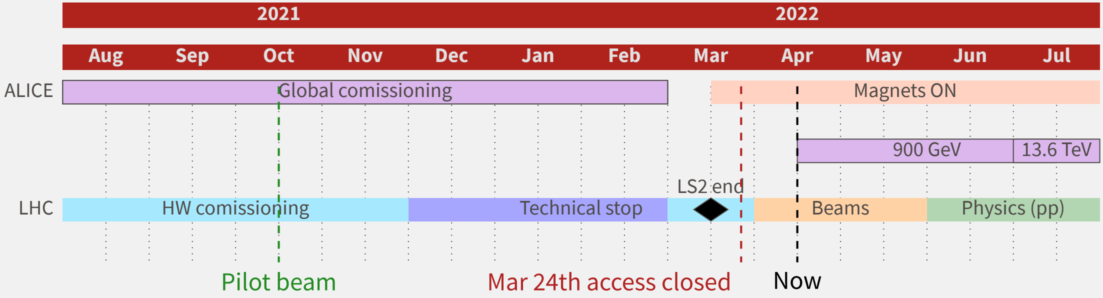
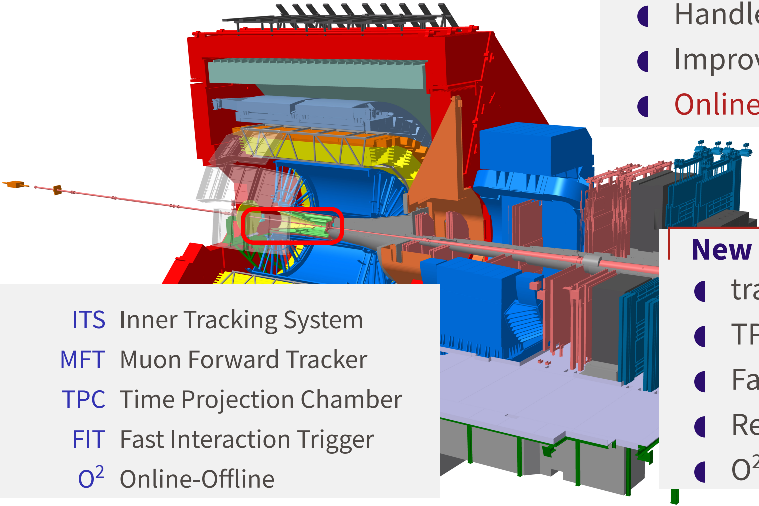
Run 3 challenges

- **A Large Ion Collider Experiment**:
  heavy ion physics, study of strong interaction and QGP properties: heavy flavour, thermal photons, low-mass dileptons → extremely high occupancy
- Continuous readout at 50 kHz interaction rate for Pb–Pb in Runs 3 and 4
- Improved tracking, vertexing, detection of low-momentum particles, PID
- Large target integrated luminosity of 13 nb^{-1}



ALICE 2

- Handle 50 kHz Pb–Pb collisions
- Improved tracking and vertexing
- Online reconstruction with GPUs[1]



ITS	Inner Tracking System
MFT	Muon Forward Tracker
TPC	Time Projection Chamber
FIT	Fast Interaction Trigger
O^2	Online-Offline

New systems

- tracking: ITS2[2], MFT[3]
- TPC with GEMs[4]
- Fast Interaction Trigger[5]
- Readout for all detectors
- O^2 software framework[6]

Inner Tracking System upgrade

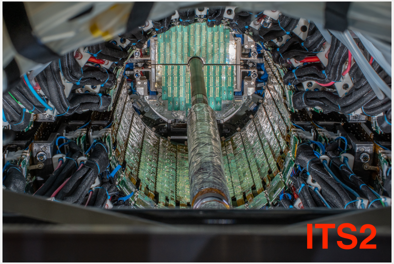
- Readout rate: up to 100 kHz from 1 kHz
- 3× better impact parameter resolution at low p_{T} in transverse direction
- Reduced material budget to 0.35% X_0 from 1.14% in inner barrel
- Fake hit rate of 1×10^{-10}/pixel/event with offline masking
- Muon Forward Tracker for forward rapidity $(-3.6 < \eta < -2.5)$

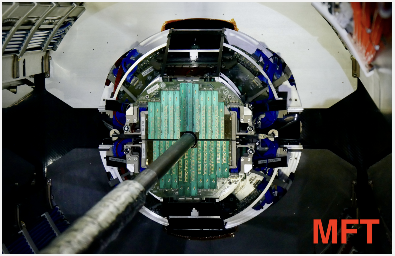
Link: Performance Evaluation of Forward Muon Track Matching

Link: First results with Muon Forward Tracker in pilot pp collisions

ALPIDE[7]

- Custom Monolithic Active Pixel Sensor chip
- Used in ITS2 (all 7 layers) and MFT

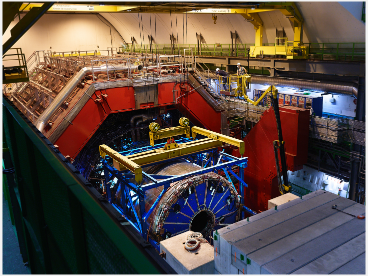


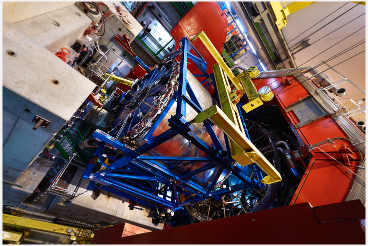


Time Projection Chamber Upgrade

- MWPC[a] → GEM[b] stack
  - Removes rate restriction
  - Reduces ion backflow to under 1%
  - Space-charge distortions are minimized preserving PID capabilities
- Pb–Pb collisions at 50 kHz correspond to 5 collisions in a readout time → continuous readout
- Outgoing data rate of more than 3 TB/s can only be handled by specialized readout hardware and dedicated GPU-based data reduction

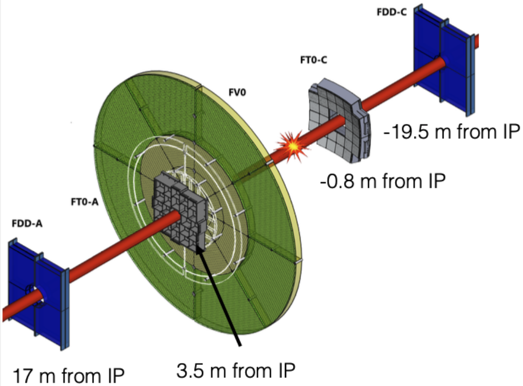
Link: Space-charge distortion calibration for the ALICE TPC

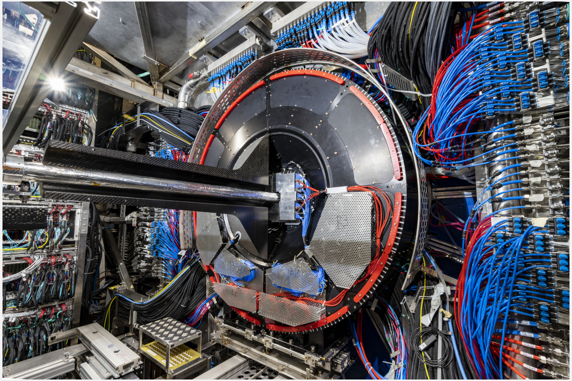




[a] Multi-Wire Proportional Chambers
[b] Gas Electron Multipliers

Fast Interaction Trigger

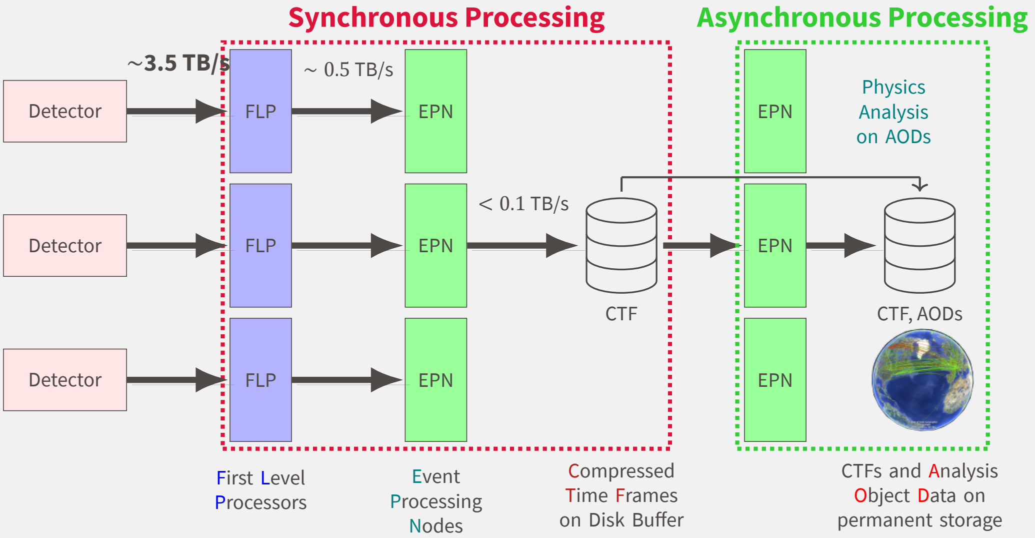




- Low-latency min. bias collision trigger (<425 ns)
- Timing signal for TOF with high resolution (13 ps FT0; 200 ps FV0)
- Provides centrality, luminosity and event plane determination

Link: The ALICE Fast Interaction Trigger Upgrade

O^2: data flow



Synchronous Processing
Asynchronous Processing
~3.5 TB/s
~ 0.5 TB/s
< 0.1 TB/s
Detector
Detector
Detector
FLP
FLP
FLP
EPN
EPN
EPN
EPN
EPN
EPN
Physics
Analysis
on AODs
CTF
CTF, AODs
First Level
Processors
Event
Processing
Nodes
Compressed
Time Frames
on Disk Buffer
CTFs and Analysis
Object Data on
permanent storage

O^2: data flow

First Level Processors (FLP) cluster

Composed of 200 nodes, addresses the challenge of reading more than 3 TB/s for Pb–Pb events at 50 kHz interaction rate

Event Processing Nodes (EPN) cluster

The EPN cluster is composed by 250 dual core AMD Rome nodes, for a total of 64 physical CPU cores. Each node will be equipped with 8 AMD MI 50 GPUs.

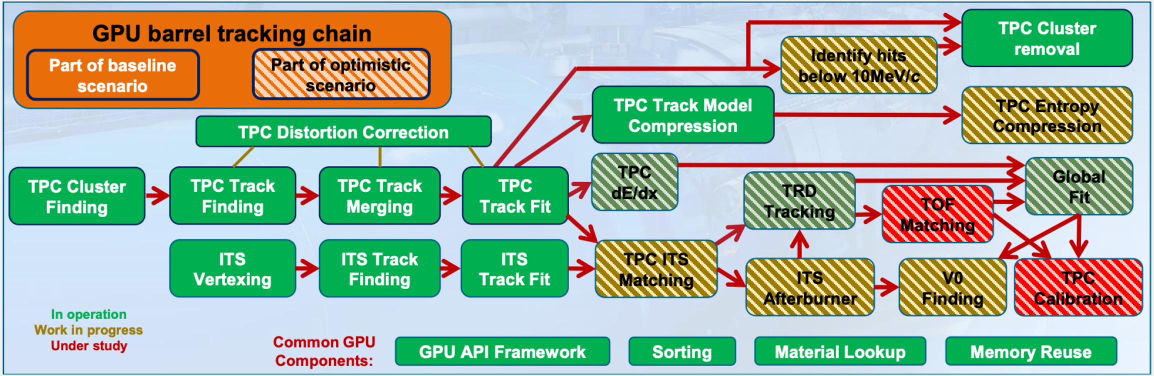
Synchronous

- Beams: Pb–Pb
- Rapid data reduction
- Full TPC reco
- Partial/full for other detectors needed for calibration

Asynchronous

- Beams: OFF or pp
- Improved calibration

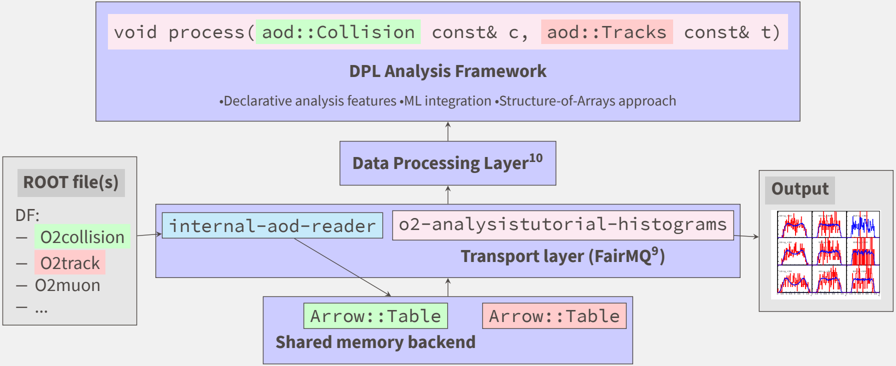
O^2: GPU tracking



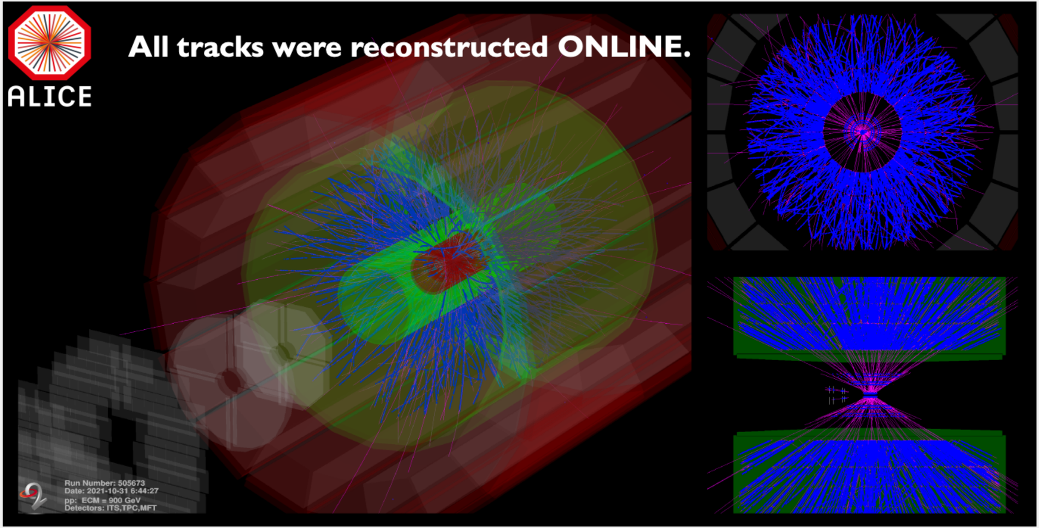
- The goal is to use GPUs for as many tasks as possible
- The framework is cross-platform and can run on both GPUs and CPUs
- Smooth operation during pilot beam and async reconstruction
- Further development ongoing

O^2: analysis framework

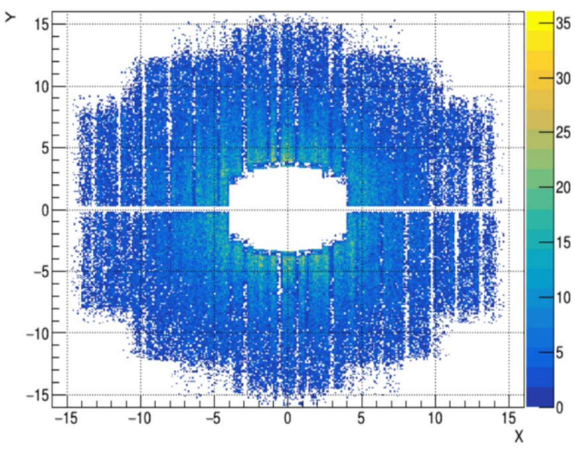
- Comprehensive framework built from ground-up using distributed message-passing model
- Used on all levels from FLPs to end-user analysis
- Designed to leverage hardware capabilities of CPUs (vectorization), GPUs and shared memory
- Hyperloop web-based analysis train system is used for organized analysis

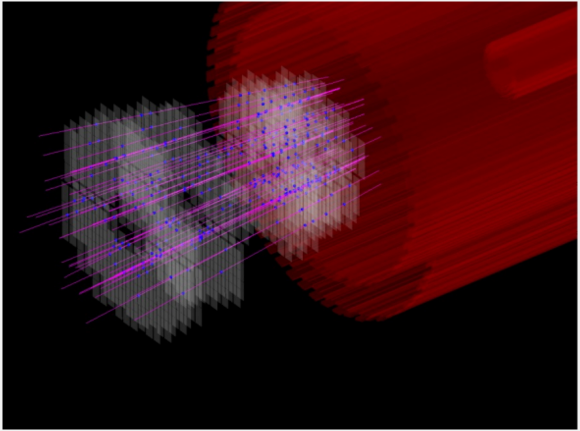


Comissioning: ITS and TPC

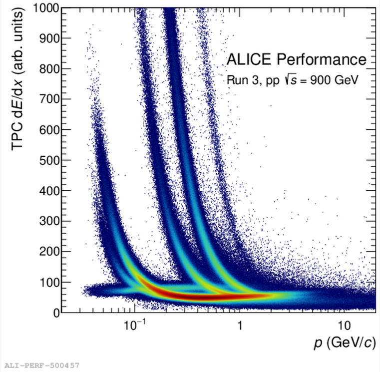


Comissioning: MFT

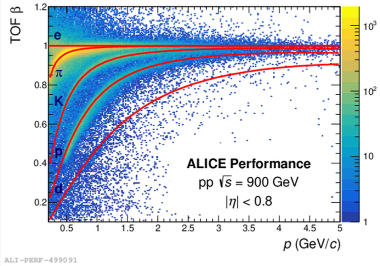


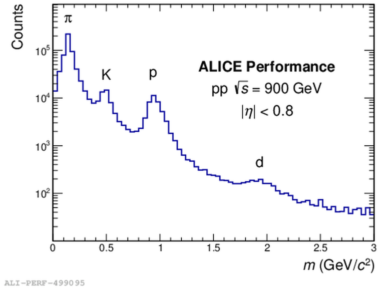


Physics performance



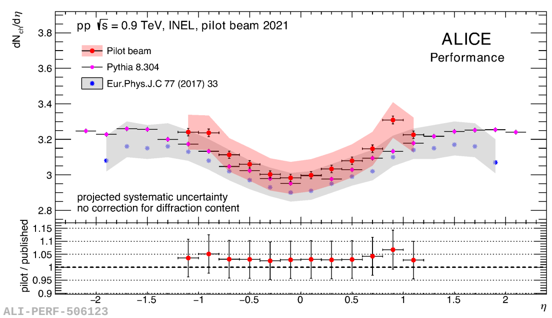
- Data taking, online reconstruction and calibration

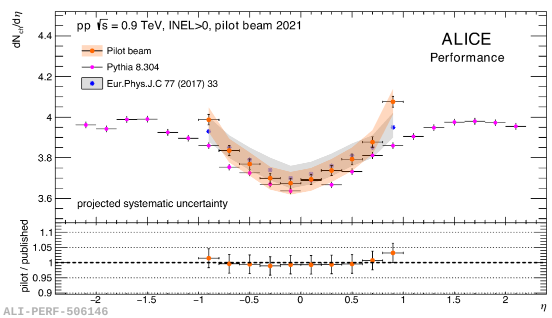




- Several benchmark physics analyses
- Continued improvement of the reconstruction and calibration workflows

Physics performance





- Up to ×10 improvement in analysis throughput in terms of processed events/s compared to old framework

Link: A novel algorithm of event mixing

- New analysis framework provides significant performance improvements
- Full-chain analyses with pilot beam data are being finalized

Conclusion

- ALICE 2 upgrade provides continuous readout capability and improved tracking performance, crucial for heavy-ion physics
- O^2 software framework and new computing infrastructure (FLPs/EPNs) as well as extensive use of GPUs allow for handling over 3 TB/s of detector readout
- New Analysis framework, based on O^2, leverages hardware capabilities, provides declarative analysis features and integrates ML features
- Hyperloop web-based analysis train system enables fast analysis cycle
- Pilot beam test of ALICE systems was successful: several physics analyses using pilot beam data are being finalized
- ALICE is ready for new data!

Link: Future ALICE upgrades for Run 4 and beyond

References

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