The ALICE data-flow: from calibration, to QA, through reconstruction

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ALICE setup


Central Detectors:
- Inner Tracking System
- Time Projection Chamber
- Time-of-Flight
- Transition Radiation Detector
- High Momentum PID (RICH)

Forward detectors:
- Photon Multiplicity
- Forward Multiplicity
- Muon Spectrometer

Calorimeters:
- EM Calorimeter
- Photon Spectrometer (PHOS)
- Zero Degree Calorimeter
- V0, T0, AD detectors

Run2:
The completion (13 → 18 modules) of the TRD installation in the central barrel
Completion of EMCAL with DCAL. One additional PHOS module.
Exchange of the TPC gas (NeC\textsubscript{0}\textsubscript{2} \rightarrow ArC\textsubscript{0}\textsubscript{2})
Run1: Tracking performance – $p_T$ resolution

Combined tracking TPC-ITS **momentum resolution** $\sim 4\%$ at 50 GeV/c

- Small multiplicity dependence
- Additional uncertainty due to the mis-alignment and mis-calibration estimated from track matching residuals
  - Verified using cosmic tracks and $K_S^0$ invariant mass distribution - systematic uncertainty: 20%
  - $\Delta(1/p_T)$ shift monitored run-by-run

Run2:
-the completion (13 $\rightarrow$ 18 modules) of the **TRD installation** in the central barrel
-improvement of the resolution by 40 % in Monte Carlo
DCA $\phi$: Transverse distance-of-closest-approach

DCA resolution ($\sim 20 \, \mu m$ at 10 GeV/c)
Tool to control contamination from secondaries

Strict resolution-based DCA cut, small contamination
Residual contamination: MC + DCA $\phi$ fits
Less than 1% for $p_T > 4$ GeV/c
Light charged hadrons ($\pi^\pm$, $K^\pm$, $p$, anti-$p$) and electrons in broad range:
\(~150\text{ MeV}/c < p_T < 20\) (potentially 50 GeV/c)

**Inner Tracking System (ITS)**
standalone tracker, extends low-$p_T$ reach
PID - energy loss in the silicon

**Time Projection Chamber (TPC)**
main tracking system
PID - energy loss in the gas

**Time of Flight (TOF)**
tracks extrapolated from ITS-TPC
resolution ~80 ps (PbPb)

**Cherenkov detector HMPID**
Cherenkov angle measurement

**Transition Radiation Detector (TRD)**
Electron identification via TR +
Hadron identification - energy loss in the gas

**E/p from calorimeters**
Electron identification
Space point distortion calibration and alignment
The ITS alignment task using MILLEPEDE:
- a total of 2198 modules for more than 16000 spatial DOF

Realignment program: resolution worsening shouldn't exceed 20%

Track matching and point-to-track distance for extra clusters:
- resolution $\sigma_{\text{spat}} \sim 13 \mu m$
- Estimated residual misalignment of $\sigma_{\text{misal}} \sim 7\div8 \mu m$
Run2: Alice Millepede global alignment

Run1 (2009-2013) →

• TRD: internal alignment between chambers, sectors aligned wrt TPC
• TOF sectors aligned wrt extrapolation from TPC/TRD

Run2 (2015-2018) →

• Use global alignment with as many as possible detectors, accounting for their calibration DOFs if needed.
• Alice barrel ~ 27k DOF for alignment
  • 2015 data align ITS/TRD/TOF, skipping the TPC to avoid distortion effect
  • TPC distortion calibration using external reference tracks
TPC calibration and alignment

Custom ALICE calibration/alignment code using physical models - O(800) DOF
- using cosmic tracks, V0, matching with external detectors (B+,B-, B=0)
- target precision $\sigma \sim O(0.2 \text{ mm})$

TPC internal mechanical alignment - $\sigma \sim O(0.1 \text{ mm})$

Distortion in the bending plane due to the ExB effect
- B field inhomogeneity - $\Delta \sim O(8 \text{ mm})$
- ExB nonlinearities due misalignments ($\sim 800$ DOF) - $\Delta \sim O(6 \text{ mm})$
- $E \parallel B$ misalignment - $\Delta \sim O(2 \text{ mm})$
- $\omega \tau$ – pressure, temperature, gas composition - $\Delta \sim O(0.2 \text{ mm})$
- charging up of sensitive parts (rate dependent) - $\Delta \sim O(0.2 \text{ mm})$
- rate dependent space charge - Run1- O(0.5 mm) - Run2 - O(5cm)

Time dependence within fill
Space point distortion due to space charge

- exchange of gas mixture, increase of interaction rate
- target calibration precision $\sigma \sim O(0.2 \text{ mm})$

Distinct regions with large distortion
- unexpected $O(5 \text{ cm})$

Much smaller distortion in 'bulk' region
- scaling with IR as expected for ArCO2 $O(1 \text{ mm})$

Two types of hot distortions
- floating wires in Outer Read-Out Chambers (OROC)
- leakage of electrons and ions through “gating grid” in boundary between some Inner Read-Out Chambers (IROC)

Distortion model - space charge density in the gas volume.
Distortion increases monotonously with luminosity
Density and distortion fluctuates in space and time $\sigma_{\rho} \sim (0.2–0.3) \Delta_{\rho}$
- IR $O(1\text{ min})$, events/tracks within TPC - $O(0.1 \text{ s})$, gating grid transparency fluctuation

Procedure planned for Run3 SCD corrections
- 3x3D distortion map 429300 voxels. Effective DOF smaller (local kernel regression)
RUN2: TPC distortion calibration procedure

Space point distortion due to space charge  RUN1 $O(1\, \text{mm}) \rightarrow$ RUN2 $O(5\, \text{cm})$
- exchange of gas mixture, increase of interaction rate
- target calibration precision $\sigma \sim O(0.2\, \text{mm})$

1. TPC reconstruction with large road-widths to not lose TPC clusters attachment
2. Match to ITS and TRD/TOF
3. Refit ITS-TRD-TOF part and interpolate to TPC as a reference of true track at every pad-row
4. Collect Y, Z differences between distorted clusters and reference points in sub-volumes (voxels) of TPC
5. Extract 3D vector of distortion in every voxel
6. Create smooth parameterization (DB object) to use for correction during following reconstruction
7. Distortions change with time (interaction rate): procedure in short time intervals ($\sim 20-40 \, \text{min}$, restriction by statistics)

Run2, Run3 procedure: TPC voxels aligned wrt interpolation from ITS/TRD/TOF

Procedure planned for Run3 SCD corrections
- 3x3D distortion map 429300 voxels. Effective DOF smaller (local kernel regression)
RUN2: TPC distortion calibration results

Space point distortion due to space charge \( \text{RUN1 O}(1 \text{ mm}) \rightarrow \text{RUN2 O}(5 \text{ cm}) \)
- exchange of gas mixture, increase of interaction rate
- target calibration precision \( \sigma \sim \text{O}(0.2 \text{ mm}) \)

Mean distortion suppressed below intrinsic resolution.
Impact of distortion fluctuation reduced increasing space point error estimates
- Activities to further decrease fluctuation following high frequency fluctuation

Procedure planned for Run3 SCD corrections
- 3x3D distortion map 429300 voxels. Effective DOF smaller (local kernel regression )
PID calibration selected topics
Unfolding statistical approach to measure particle spectra:
- $\Delta_\pi$ used to extract the particle fractions
- **target calibration precision** of the $dE/dx$ measurement 0.2-0.5%
- $(0.04-0.1) <dEdx>_K - <dEdx>_p$

TPC $dE/dx$ calibration
- ion tail correction (per gas mixture)
- Kr calibration- pad by pad gain equalization (year)
- $dE/dx(bg)$ calibration - (period)
- sector equalization (run)
- pad length equalization correction (run)
- drift length correction (attachment diffusion) (run)
- gas density correction (P/T) O(1min)
- gas composition correction O(20 min)
- high voltage O(1s)

$$\Delta_\pi = \frac{dE}{dx} - \langle \frac{dE}{dx} \rangle_\pi$$
Alice data flow
Alice calibration/QA/reconstruction flow

**Online**
- Data
  - DAQ/HLT/DCS calibration
  - Shuttle
- OCDB

**CPass0**
- Calibration data $O(10\%)$
  - Offline/HLT reconstruction
  - Calibration
  - OCDB

**CPass1**
- Calibration data $O(10\%)$
  - Offline/HLT reconstruction
  - Calibration QA
  - OCDB

**Manual**
- Manual calibration
  - OCDB

**PPass**
- Full data set
  - Reconstruction QA AOD
    - ESDs/AOD for analysis
  - AODB

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**Pressure**
- Temperature
- HV
- Noise
- Pedestals
- Data QA

**3D distortion maps**
- Drift velocity
- dEdx norm
- dEdx equalization
  - TOF T0
  - TRD gain
  - TRD T0

**Residual calibration:**
- 3D distortion maps
- Drift velocity
- dEdx norm
- dEdx equalization
  - TOF common T0
  - TRD gain
  - TRD T0

**ITS (SDD) drift velocity**
- TOF T0
- TRD in case of problem

**dEdx(\beta\gamma)**
- $N_\sigma$ – NPID calibration
- ...

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O(5 min) → HLT O(5 min) O(12hours) → HLT O(5 min) O(12hours) O(week(s)) O(1 day)
QA and release validation
QA histograms and QA summary information stored in folder structure. Same naming convention and folder structure as AliEn file catalog. No external DB.

\[ \text{PATH} = \text{prefix} / \text{datatype} / \text{year} / \text{period} / \text{recopass} / \text{suffix} \]

RAW QA histograms browsable from file catalog (e.g. alien file catalog for central production)
O(150MBy) per run

TFile::Open("alien://alice/data/2015/LHC15o/000244917/cpass1_pass2_lowIR/QAresults_barrel.root")

Example:
TPC dEdx vs $\phi$ (sector)
Automatic post processing QA data flow

Data layouts and high level summary data automatically processed - the same code used:

**central production QA release** (CPass0/CPass1/QA) **validation**

**user validation** (CPass0/CPass1/QA) - automatic QA checks and **residual calibration** check

Cache QA summary files

Produce layouts and summary data

Store in AFS Web repository

Update summary trending

QA node / AFS

runQA.sh steering script detector + systems

/afs/cern.ch/work/a/aliqa<det>/www

file list: e.g: alien:///alice/data/.../QAresults.root

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Outliers browsing example:
- Based on DataTables plug-in for the jQuery Javascript
- Histograms organized into layouts to bundle related information
- Status flag: defined by user defined logical expression (TTree query) using summary information (absolute bands, no bands, &&, ||)

**Example:**
Outlier runs $DCA_{r\phi}$ and $DCA_z$ vs $\phi$

Runs selected by DCA status 11

Strong DCA bias because of space charge
TPC run trending and alarms example

- Based on DataTables plug-in for the jQuery Javascript
  - Example: CPass1 calibration pass with failed \(dEdx\) calibration
Run and period trending of summary data

Period summary

Automatic trending of high level summary data

Example status bar (period with failed dEdx calibration):
- dEdx
- vdrift
- DCA (distortion)
- matching efficiency

Run summary
Conclusion

Alice overview of selected topics

• performance
  • Close to intrinsic resolution

• calibration
  • New algorithm to deal with the substantial space point distortion at RUN2 (2015-2018) implemented and integrated into data flow
  • OFFLINE CPass0 calibration partially implemented inside of HLT (more coming). Online version of the space point distortion calibration (Run2 like) under development

• data flow
  • First feedback using calibrated data within a day

• QA
  • Data organized in folder structure and published on the web for easy access. High level summary data automatically processed. Automatic alarms implemented for many detectors.
Backup
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ExB distortion time dependent

- $\omega \tau$ – pressure, temperature, gas composition - $\Delta \sim O(0.2 \text{ mm})$
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Distortion increases monotonously with luminosity
- function individual for each chamber
- not unique \( (\sigma \sim 0.14 \text{ cm}) \)
- onset at critical IR

Distortion B field dependent \((B+ , B-)\)
Distortion fluctuation:
- \( \sigma_{\rho\phi} \sim (0.2-0.3) \times \Delta_{\rho\phi} \) residuals itself
- behavior expected due fluctuation of space charge density
- Precision of correction limited

Procedure planned for Run3 SCD corrections
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QA - repository structure

\[ \text{PATH} = \$\text{prefix}/\$\text{datatype}/\$\text{year}/\$\text{period}/\$\text{recopass}/\$\text{sufffix} \]

alien:///alice/data/2015/LHC15o/000244917/cpass1_pass2_lowlR/QAresults_barrel.root

- \$prefix=http://cern.ch/aliqa<DET>
- \$datatype="data" / "sim"
- \$year=2013, 2012, 2011, 2010, ...
- \$period= e.g. LHC13b, ...
- \$recopass = cpass1, vpass1, ppass1, ppass2, ..., muon_calo, ...
- \$suffix can be one or more of the following

**Folder structure:**
same naming convention and folder structure as **AliEn file catalog**

**Production QA**
- post-processed output of the QA train during reco passes and/or central productions
- filled by every detector
- trending of QA variables
- controlled by the QA group + report to QA meetings

**Expert QA**
- additional information for the users or for internal purposes

**Calibration QA**
- mainly trending of calibration variables
- controlled by the Calibration group