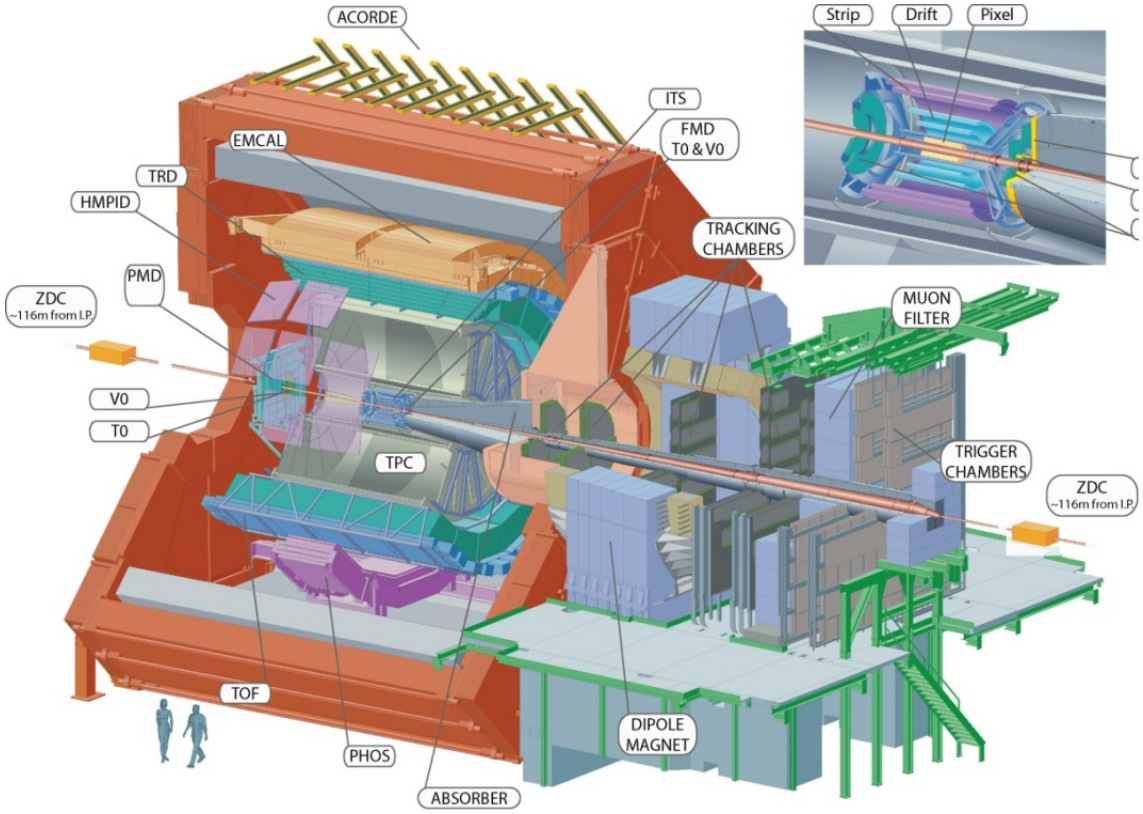
The ALICE data-flow: from calibration, to QA, through reconstruction

Marian Ivanov for the ALICE Collaboration

ALICE setup

ALICE Collaboration et al 2004 J. Phys. G: Nucl. Part. Phys. 30 1517



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

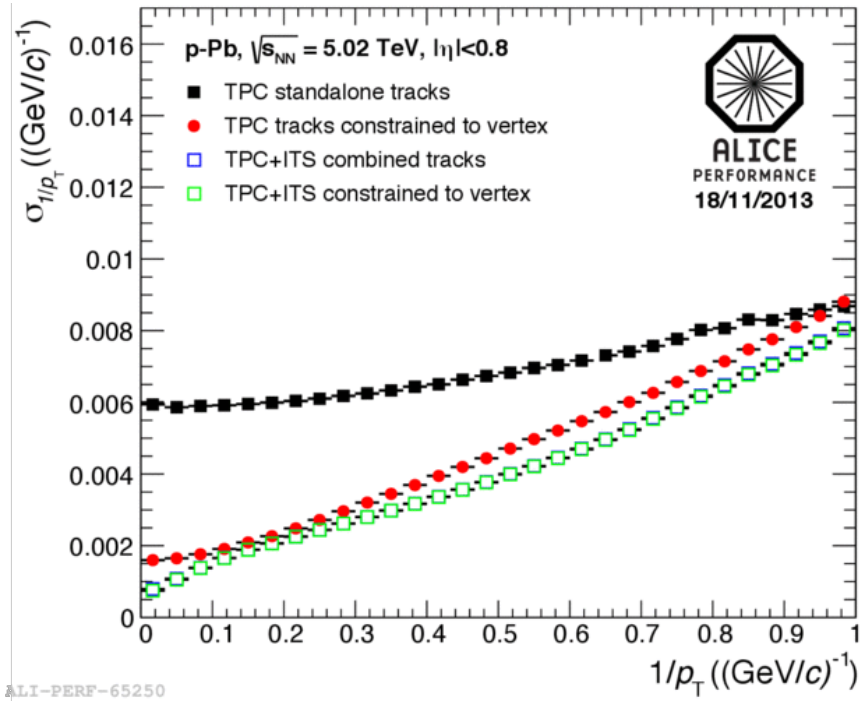
V0, T0, AD detectors

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 ($NeC0_2 \rightarrow ArCO_2$)

Run1: Tracking performance – p_T resolution

Combined tracking TPC-ITS **momentum resolution ~4% at 50 GeV/*c***



Small multiplicity dependence

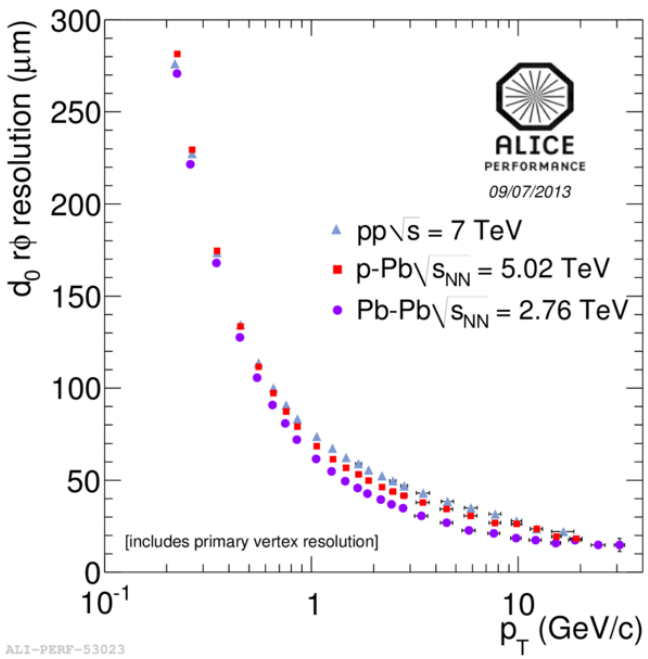
Additional uncertainty due to the mis-alignment and mis-calibration estimated from track matching residuals

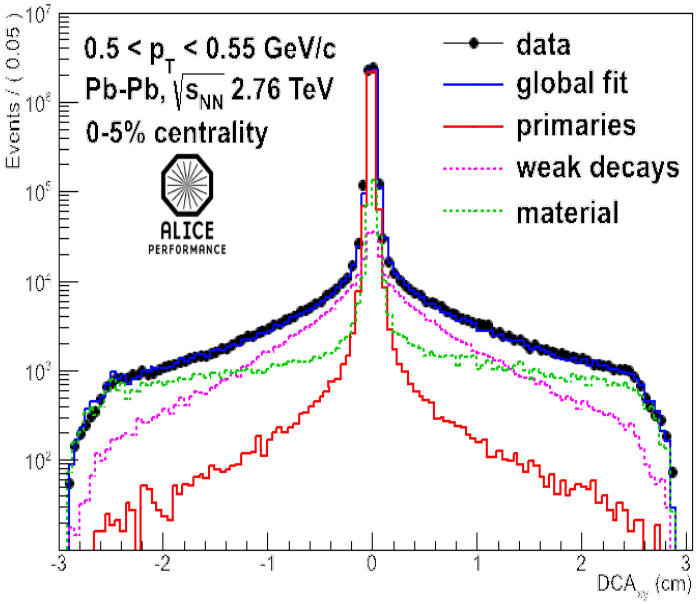
Verified using cosmic tracks and K_S^0 invariant mass distribution - systematic uncertainty: 20%

$\Delta(1/p_T)$ shift monitored run-by-run

Run2:
the completion (13 → 18 modules) of the TRD installation in the central barrel
improvement of the resolution by 40 % in Monte Carlo

Tracking performance - Vertexing





DCA rϕ: Transverse distance-of-closest-approach

DCA resolution (~20 μm at 10 GeV/*c*)

Tool to control contamination from secondaries

Strict resolution-based DCA cut, small contamination

Residual contamination: MC + DCArϕ fits
Less than 1% for p_T > 4 GeV/*c*

Charged Particle IDentification (PID) in ALICE

Light charged hadrons ($\pi^{\pm}$, $K^{\pm}$, p, anti-p) and electrons in broad range:

~150 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

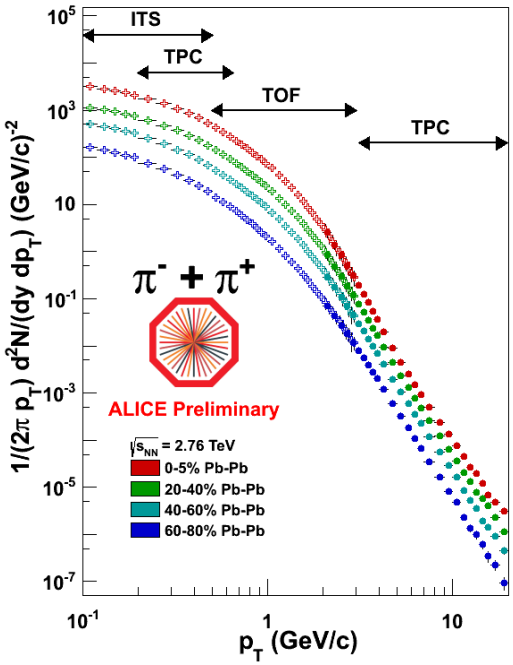
Transition Radiation Detector (TRD)

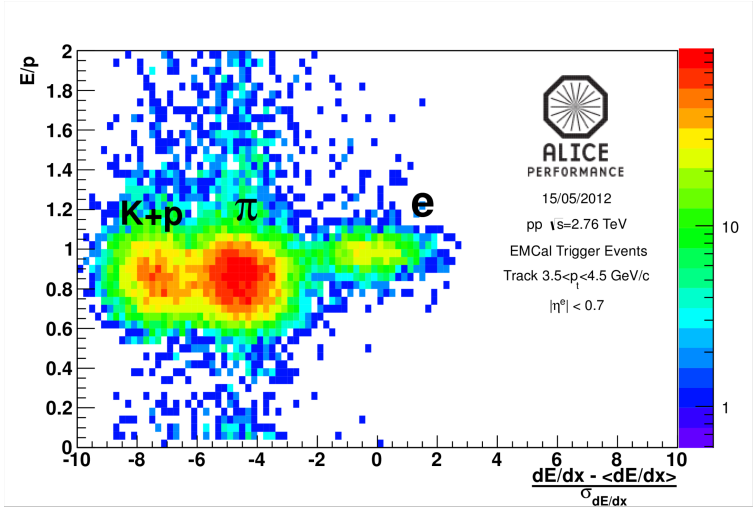
Electron identification via TR +

Hadron identification - energy loss in the gas

E/p from calorimeters

Electron identification



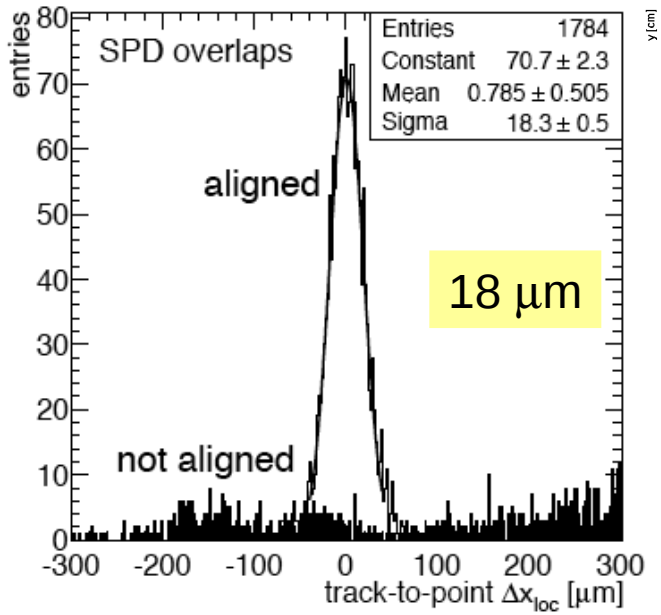


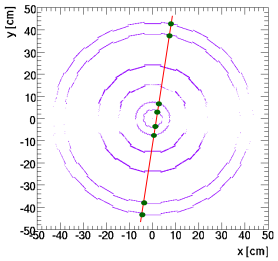
Space point distortion calibration and alignment

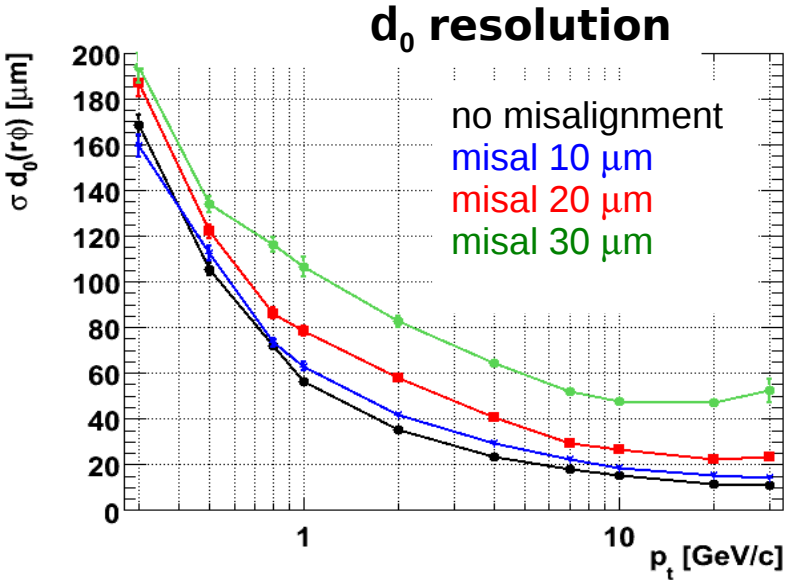
ITS Alignment

The ITS alignment task using MILLEPEDE:

- a total of 2198 modules for more than 16000 spatial DOF







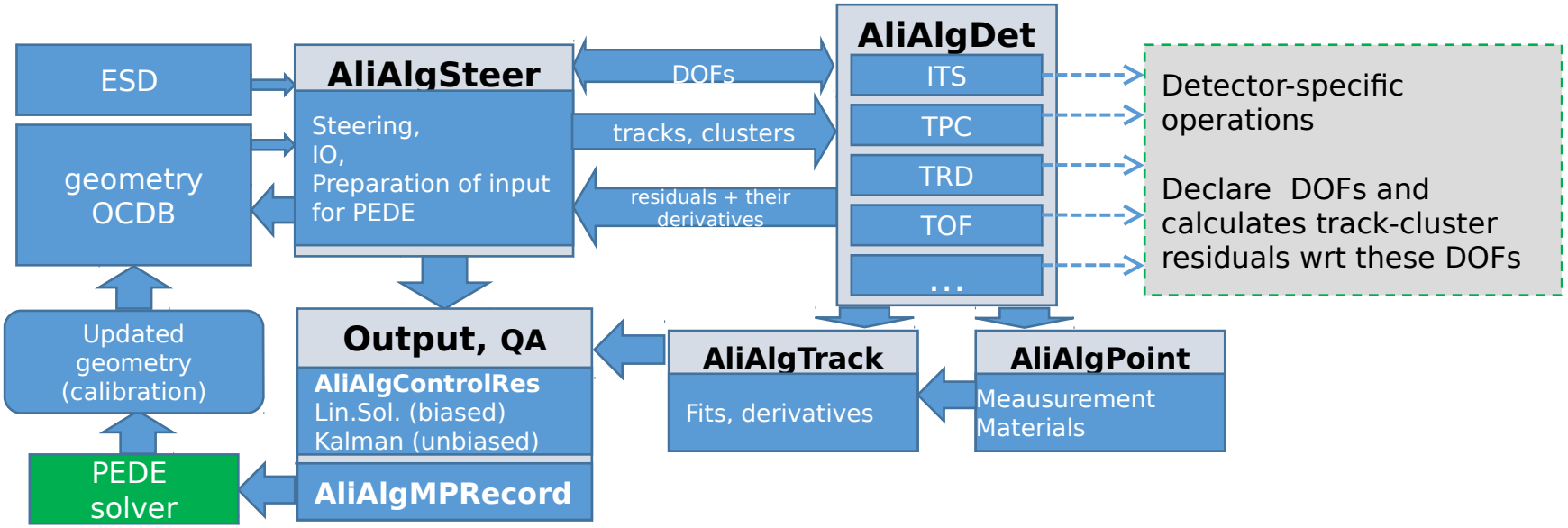
Track matching and point-to-track distance for extra clusters:

resolution $\sigma_{spat} \sim 13\ \mu m$

Estimated residual misalignment of $\sigma_{misal} \sim 7 \div 8\ \mu m$

Realignment program: resolution worsening shouldn't exceed 20%

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**

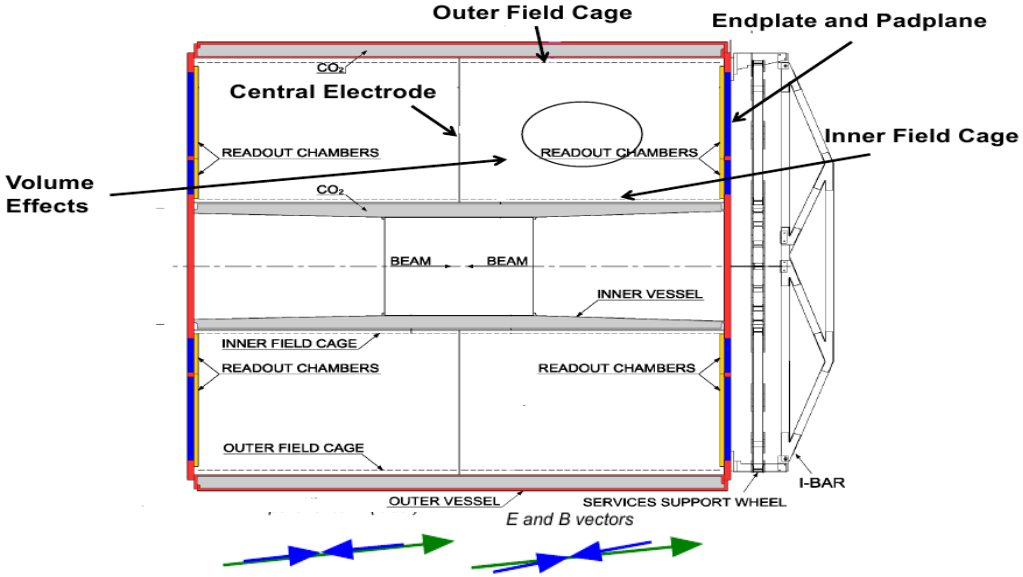
Run2 (2015-2018)→

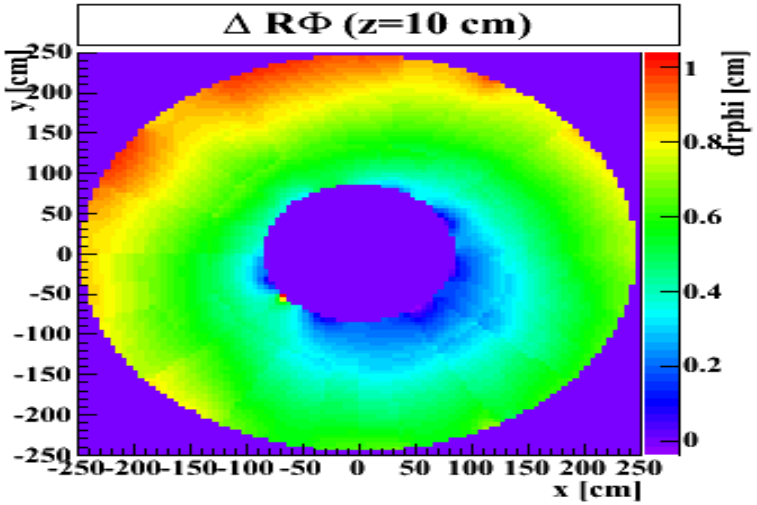
- Use **global alignment** with as many as possible detectors, accounting for their **calibration** DOFs if needed.
- Alice barrel ~ 27k DOF for alignment
  - 2015 data align ITS/TRD/TOF, skipping the TPC to avoid distortion effect
  - TPC distortion calibration using external reference tracks

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 σ~O(0.2 mm)





TPC internal mechanical alignment - σ~O(0.1 mm)

Distortion in the bending plane due to the ExB effect

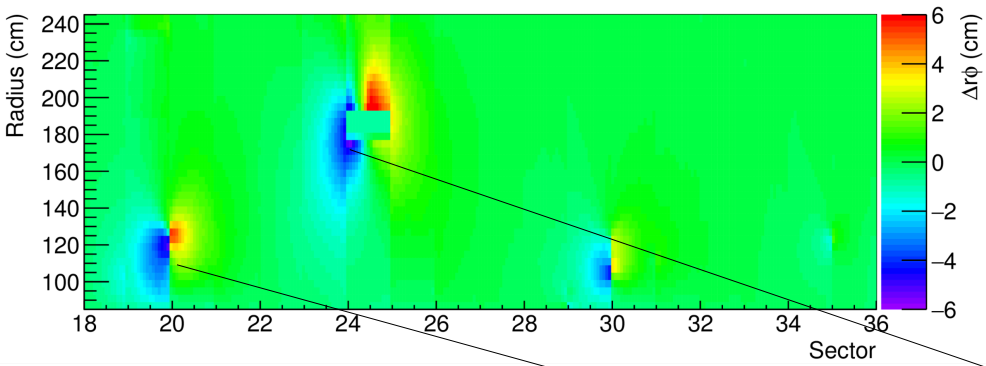
- B field inhomogeneity – Δ ~ O(8 mm)
- ExB nonlinearities due misalignments (~ 800 DOF) – Δ ~ O(6 mm)
- E || B misalignment – Δ ~ O(2 mm)
- ωτ – pressure, temperature, gas composition - Δ ~ O(0.2 mm)
- charging up of sensitive parts (rate dependent) - Δ ~ O(0.2 mm)
- rate dependent space charge - Run1- O(0.5 mm) - Run2 - O(5cm)

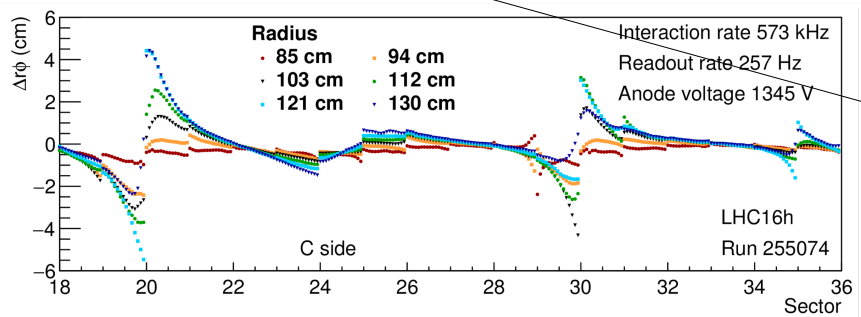
} Time dependence within fill

RUN2: TPC distortion calibration

Space point distortion due to space charge RUN1 O(1 mm) → RUN2 O(5 cm)

- exchange of gas mixture, increase of interaction rate
- target calibration precision σ~O(0.2 mm)





Distinct regions with large distortion

- unexpected O(5 cm)

Much smaller distortion in 'bulk' region

- scaling with IR as expected for ArCO2 O(1 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 $\sigma_{\rho\phi} \sim (0.2–0.3)\ \Delta_{\rho\phi}$

- IR O(1min), events/tracks within TPC - O(0.1 s), gating grid transparency fluctuation

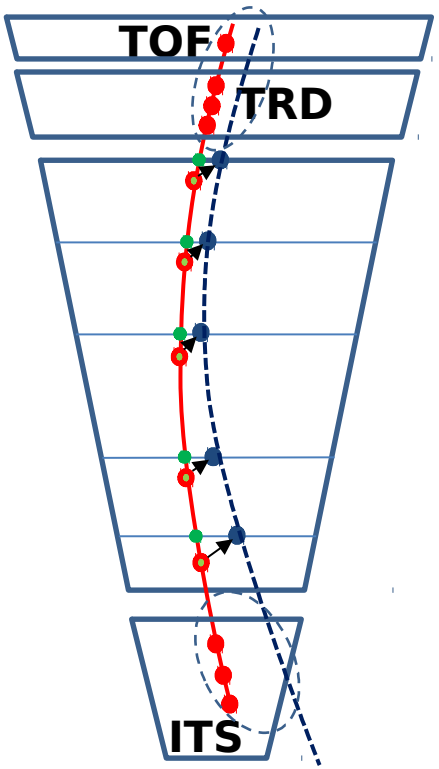
Procedure planned for Run3 SCD corrections

- 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 mm) → RUN2 O(5 cm)

- exchange of gas mixture, increase of interaction rate
- target calibration precision σ~O(0.2 mm)



1. TPC reconstruction with large road-widths to not loose 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 (~20-40 min, restriction by statistics)

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

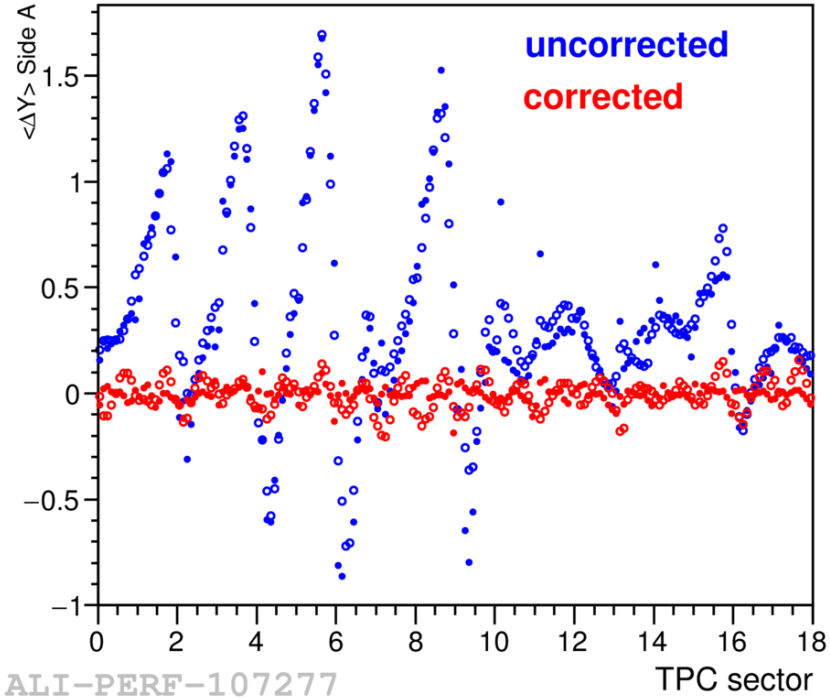
Procedure planned for Run3 SCD corrections

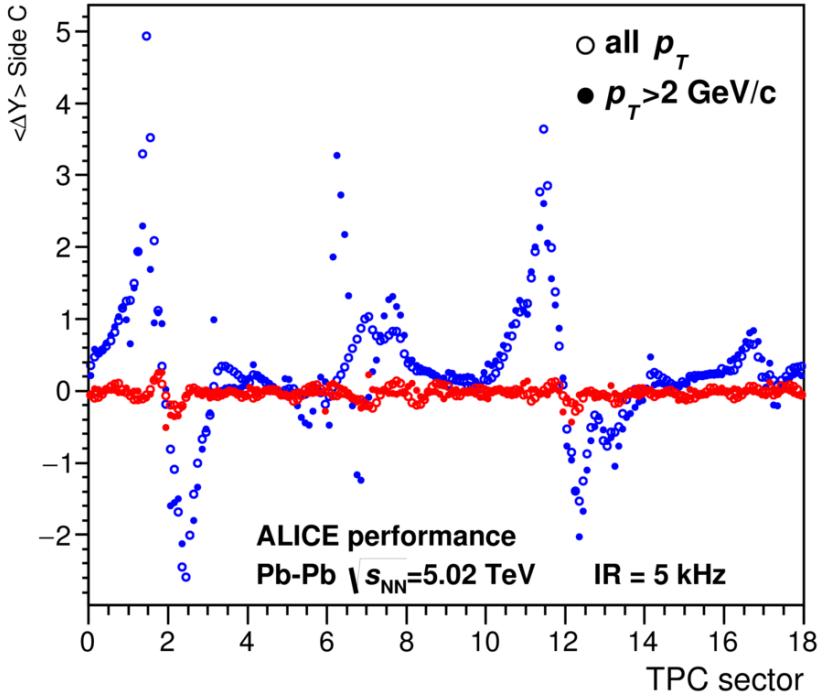
- 3x3D distortion map 429300 voxels. Effective DOF smaller (local kernel regression)

RUN2: TPC distortion calibration results

Space point distortion due to space charge RUN1 O(1 mm) → RUN2 O(5 cm)

- exchange of gas mixture, increase of interaction rate
- target calibration precision σ~O(0.2 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

Run1 dE/dx on relativistic rise

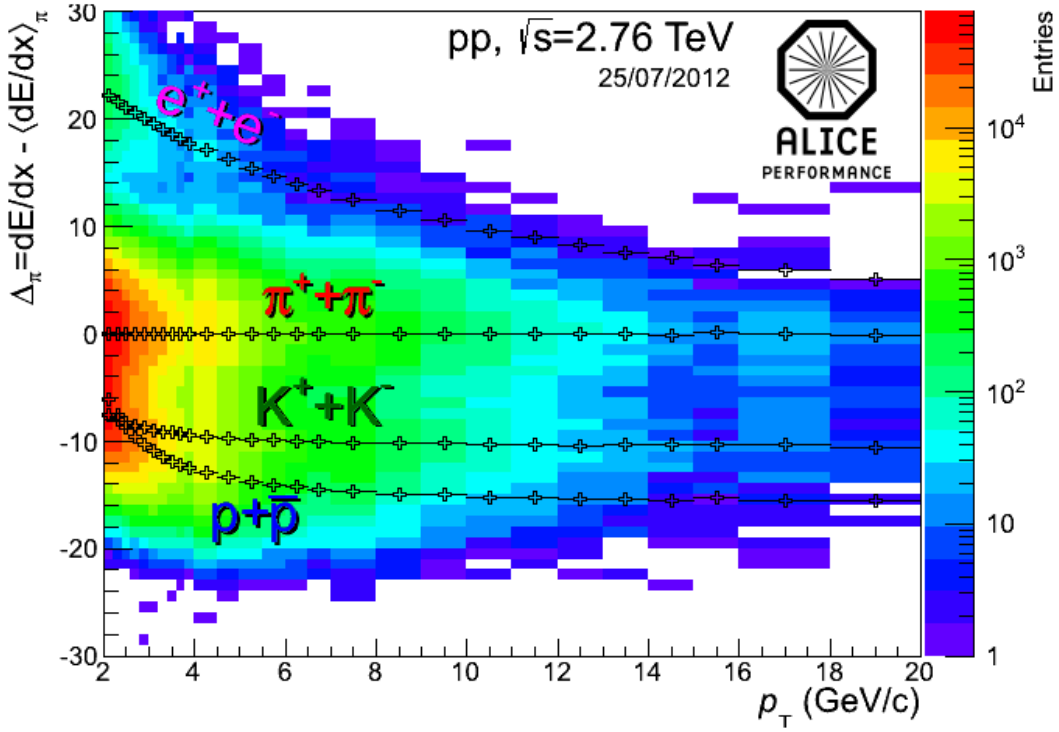
Unfolding statistical approach to measure particle spectra:

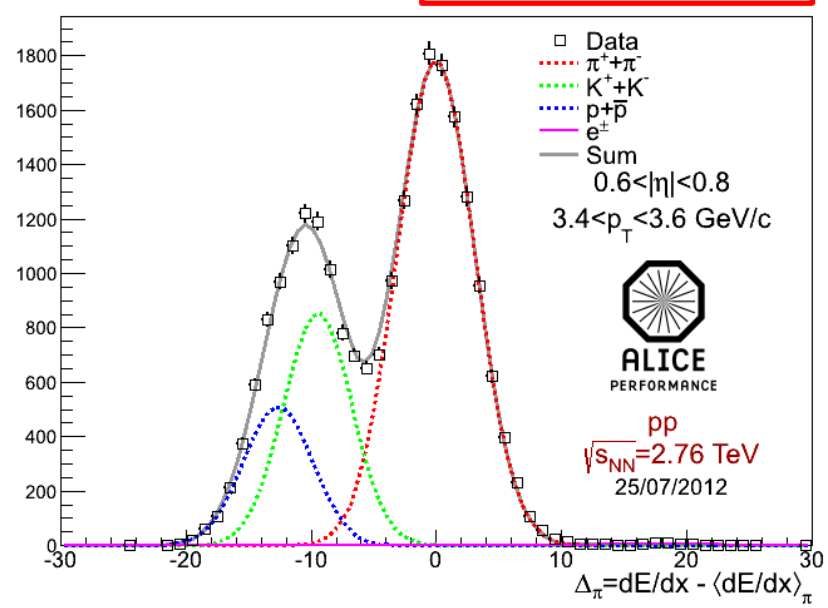
- Δ_π used to extract the particle fractions
- **target calibration precision** of the dE/dx measurement **0.2-0.5 %**
  - (0.04-0.1) $\langle dEdx \rangle_K - \langle dEdx \rangle_p$

TPC dEdx calibration

- ion tail correction (per gas mixture)
- Kr calibration- pad by pad gain equalization (year)
- **dEdx(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)

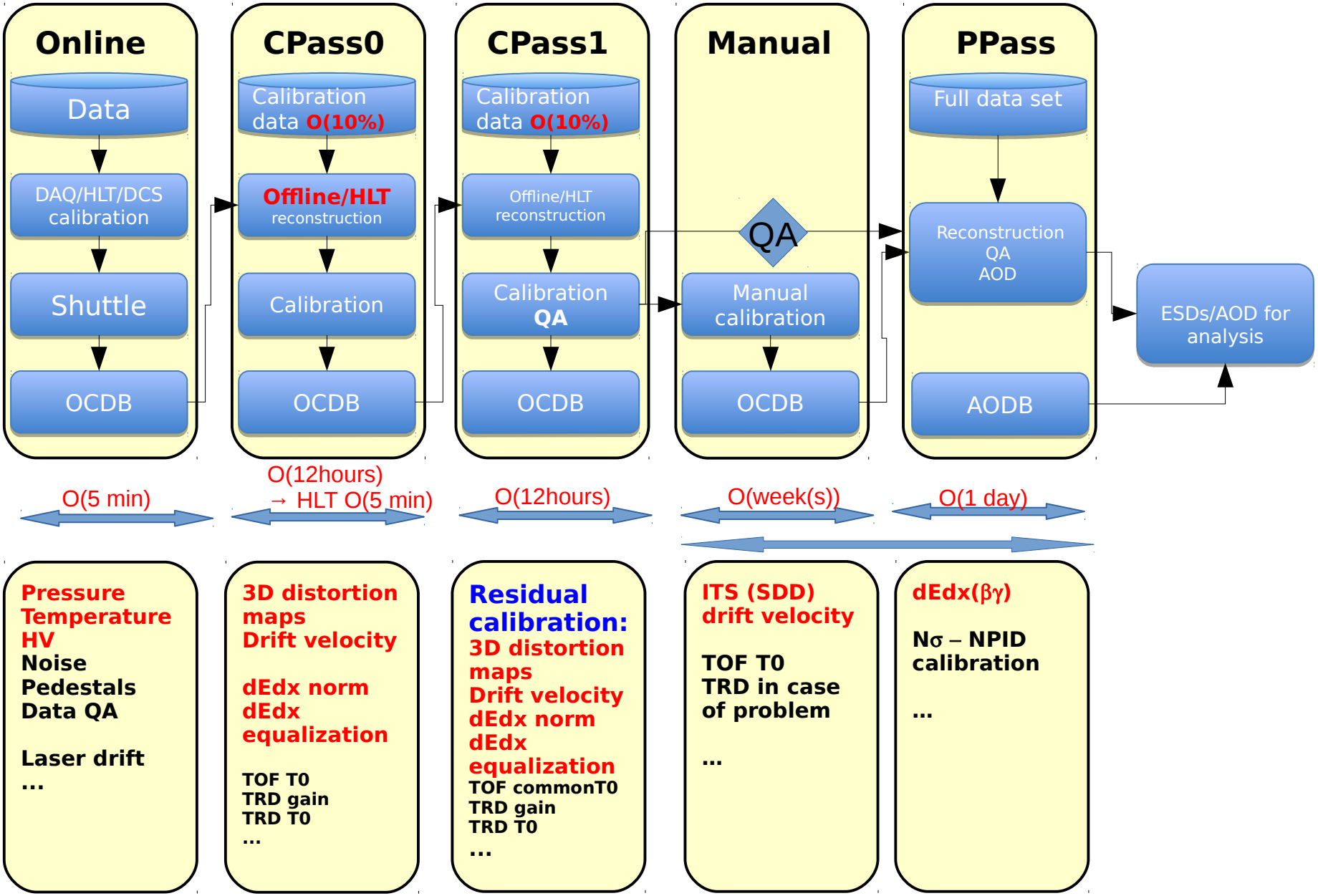
$$\Delta_\pi = \frac{dE}{dx} - \left\langle \frac{dE}{dx} \right\rangle_\pi$$





Alice data flow

Alice calibration/QA/reconstruction flow



QA and release validation

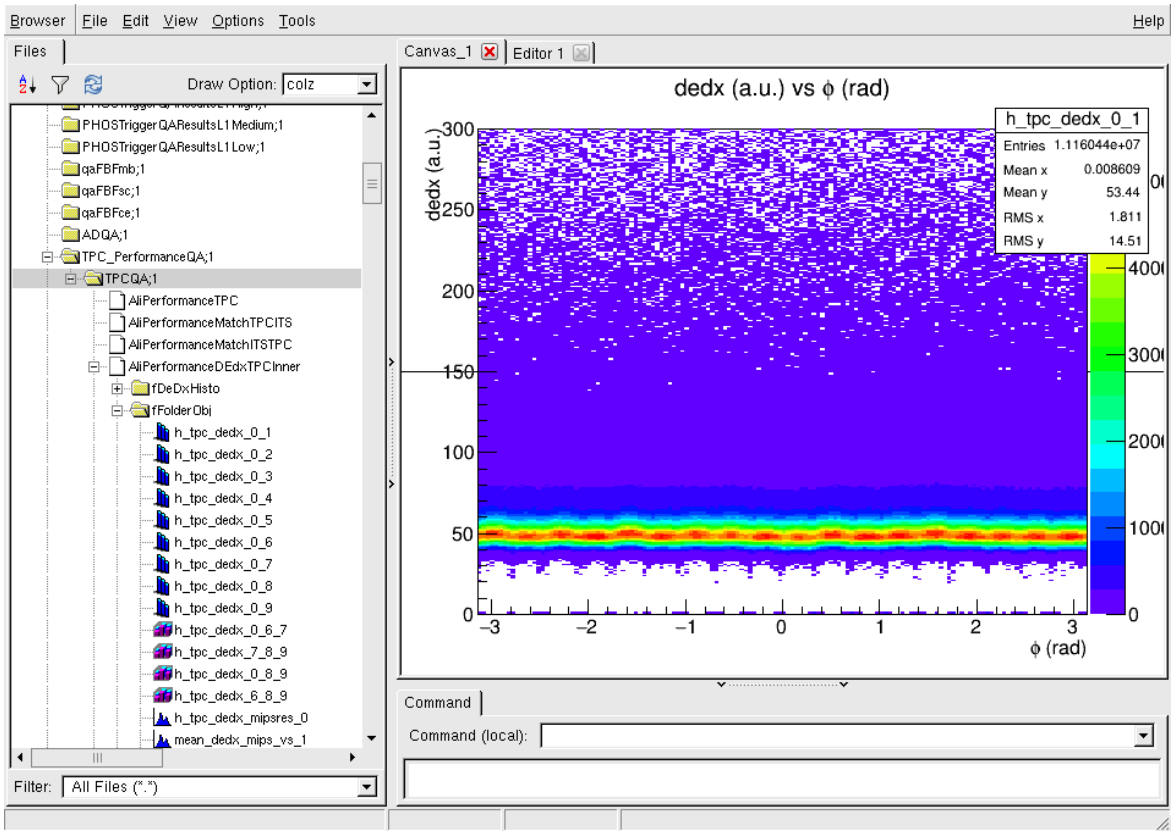
QA histogram

QA histograms and QA summary information stored in folder structure.
Same naming convention and folder structure as **AliEn file catalog.**
No external DB.

$PATH=$prefix/$datatype/$year/$period/$recopass/$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")
```

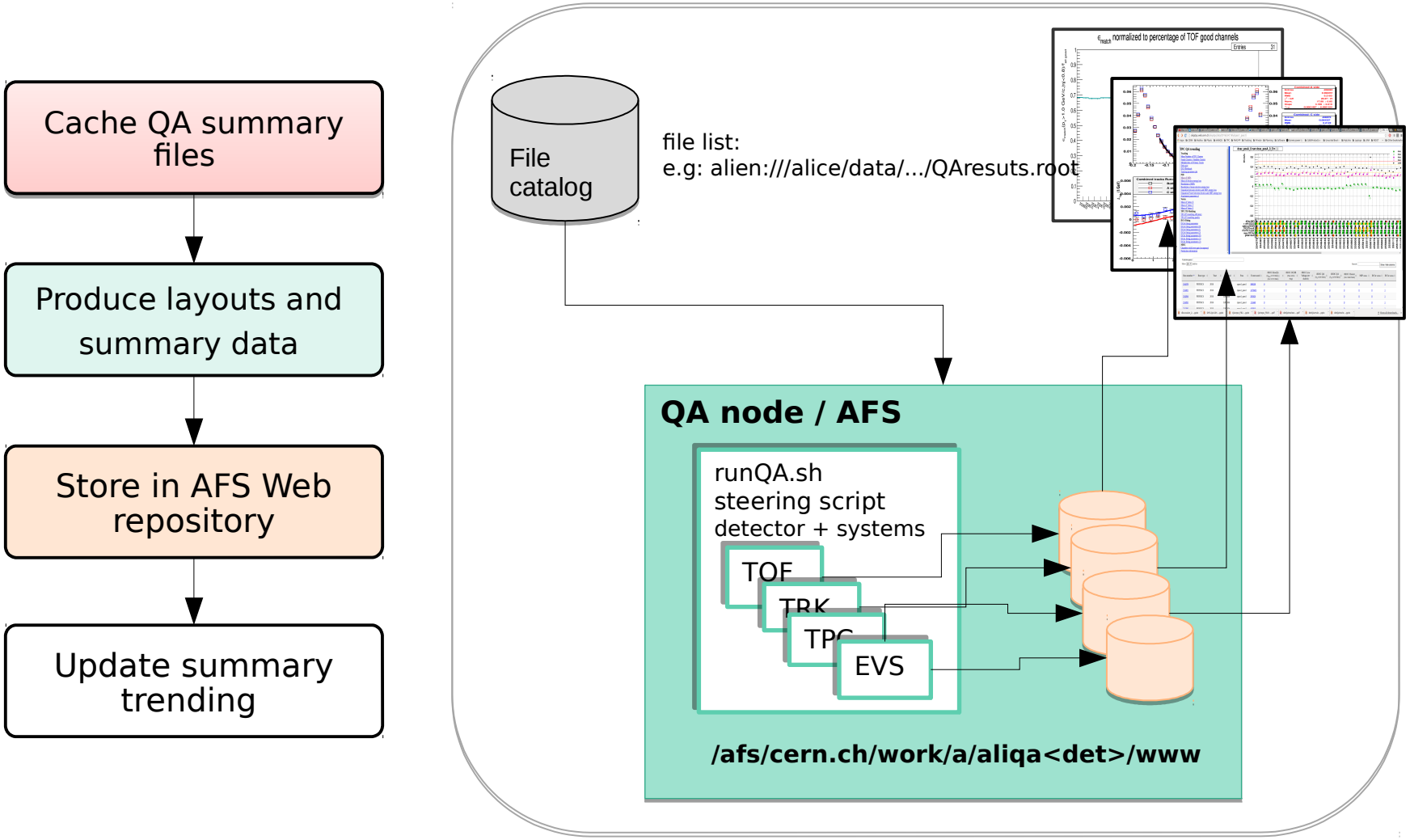


Example:
TPC dEdx vs ϕ(sector)

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



CPass1 - Run QA properties example

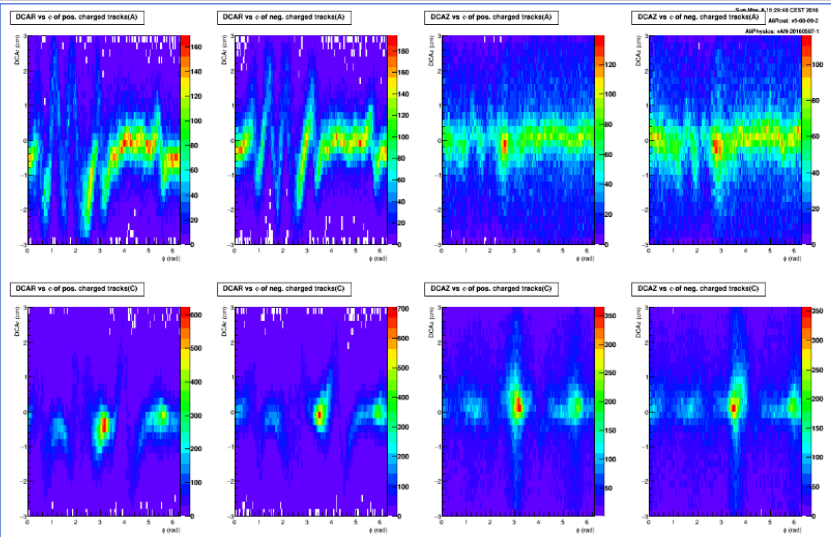
Outliers browsing example:

- 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, nσ bands, &&,||)

aliqatpc.web.cern.ch/aliqatpc/data/2016/LHC16e/cpass1_pass1/

TPC QA trending

- **Tracking**
  - Mean Number of TPC Clusters
  - Found Clusters / Findable Clusters
  - Multiplicities of Primary Tracks
  - Delta q/pt
  - DCA Residuals
  - Tracking parameter phi
- **PID**
  - Mean of MIPs
  - Mean of electron energy loss
  - Resolution of MIPs
  - Resolution of mean electron energy loss
  - Separation between electron and MIPs energy loss
  - Separation Power between electron and MIPs energy loss
  - Attachment parameter p1
- **Vertex**
  - Mean of Vertex X
  - Mean of Vertex Y
  - Mean of Vertex Z
- **TPC ITS Matching**
  - TPC-ITS matching efficiency
  - TPC-ITS matching quality
- **DCA Fitting**
  - DCAr fitting parameters
  - DCAr fitting parameters (0)
  - DCAr fitting parameters (1)
  - DCAr fitting parameters (2)
  - DCAz fitting parameters (0)
  - DCAz fitting parameters (1)
  - DCAz fitting parameters (2)
- **MISC**
  - Chambers with lower gain (occupancy)
  - Production information



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

Runs selected by DCA status 11

Strong DCA bias because of space charge

Custom query: data[5]>100000

Show 50 entries

Search: Show / hide columns

Run number	Run type	Year	Period	Pass	Events used	#ROC RawQA (Q_{max}<0.75×Med.) || (Occ<0.75×Med.)	#ROC OCDB (Non Active Map)	#ROC Low Voltage (HV disabled)	#ROC QA (N_{cl}<0.70×Med.)	#ROC QA (N_{tr}<0.70×Med.)	#ROC Cluster (Occ<0.60×Med.)	MIP status	DCAr status	DCAz status
253461	PHYSICS	2016	LHC16e	cpass1_pass1	157300	0	0	0	0	6	0	110	11	0
252856	PHYSICS	2016	LHC16e	cpass1_pass1	322479	0	0	0	0	12	1	100	11	0
253512	PHYSICS	2016	LHC16e	cpass1_pass1	101920	0	0	0	1	17	0	100	11	11
253513	PHYSICS	2016	LHC16e	cpass1_pass1	107659	0	0	0	1	13	0	100	11	0
Search	Search	Search	Search	Search	Search	0	Search	Search	Search	Search	Search	Search	11	Search

Showing 1 to 4 of 4 entries (filtered from 31 total entries)

Previous 1 Next

TPC run trending and alarms example

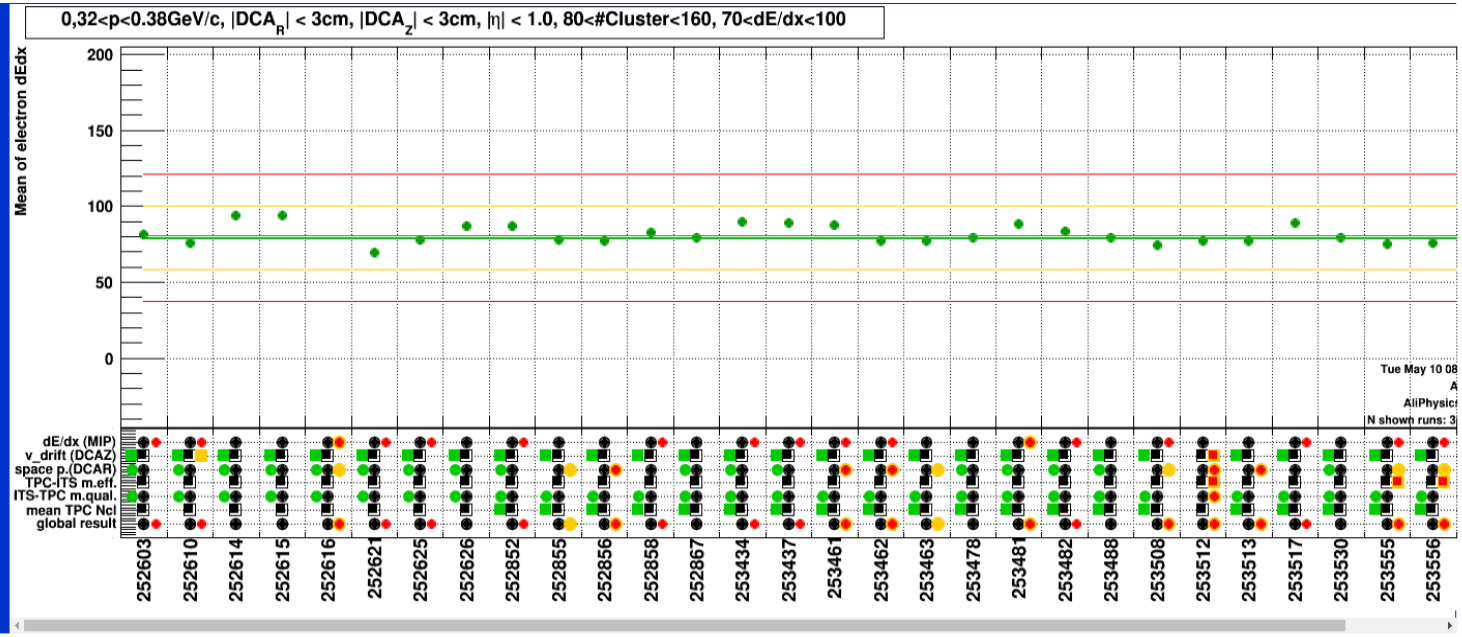
Run status browsing example:

- Based on DataTables plug-in for the jQuery Javascript
  - Example: CPass1 calibration pass with failed <dEdx> calibration

aliqatpc.web.cern.ch/aliqatpc/data/2016/LHC16e/cpass1_pass1/

TPC QA trending

Tracking
Mean Number of TPC Clusters
Found Clusters / Findable Clusters
Multiplicities of Primary Tracks
Delta q/pt
DCA Residuals
Tracking parameter phi
PID
Mean of MIPs
Mean of electron energy loss
Resolution of MIPs
Resolution of mean electron energy loss
Separation between electron and MIPs energy loss
Separation Power between electron and MIPs energy loss
Attachment parameter p1
Vertex
Mean of Vertex X
Mean of Vertex Y
Mean of Vertex Z
TPC ITS Matching
TPC-ITS matching efficiency
TPC-ITS matching quality
DCA Fitting
DCAr fitting parameters
DCAr fitting parameters (0)
DCAr fitting parameters (1)
DCAr fitting parameters (2)
DCAz fitting parameters (0)
DCAz fitting parameters (1)
DCAz fitting parameters (2)
MISC
Chambers with lower gain (occupancy)
Production information



Custom query: data[5]>100000

Show 50 entries

Search: Show / hide columns

Run number	Run type	Year	Period	Pass	Events used	#ROC RawQA (Q_{max}<0.75×Med.) || (Occ<0.75×Med.)	#ROC OCDB (Non Active Map)	#ROC Low Voltage (HV disabled)	#ROC QA (N_{cl}<0.70×Med.)	#ROC QA (N_{tr}<0.70×Med.)	#ROC Cluster (Occ<0.60×Med.)	MIP status	DCAr status	DCAz status
253461	PHYSICS	2016	LHC16e	cpass1_pass1	157300	0	0	0	0	6	0	110	11	0
252856	PHYSICS	2016	LHC16e	cpass1_pass1	322479	0	0	0	0	12	1	100	11	0
253512	PHYSICS	2016	LHC16e	cpass1_pass1	101920	0	0	0	1	17	0	100	11	11
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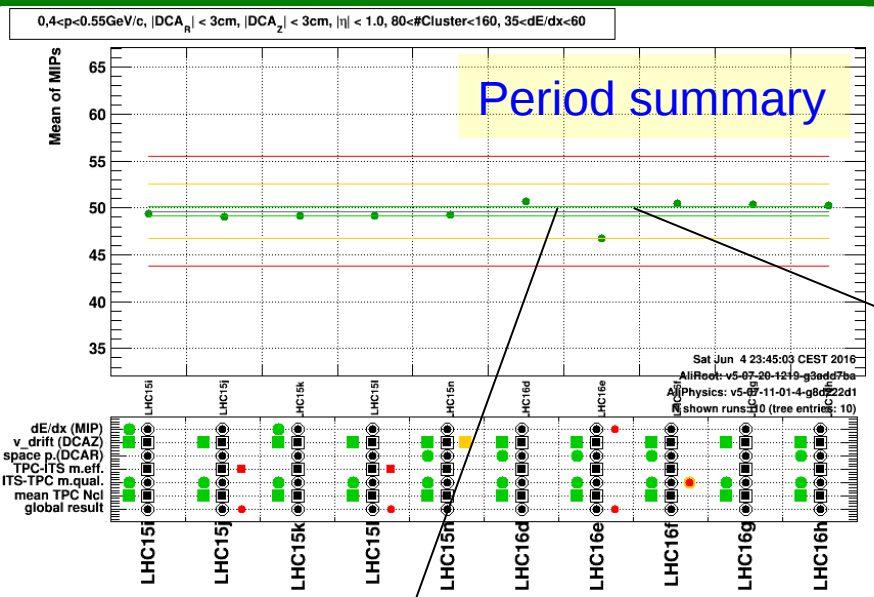
Search	Search	Search	Search	Search	Search	0	Search	Search	Search	Search	Search	Search	11	Search

Showing 1 to 4 of 4 entries (filtered from 31 total entries)

Previous 1 Next

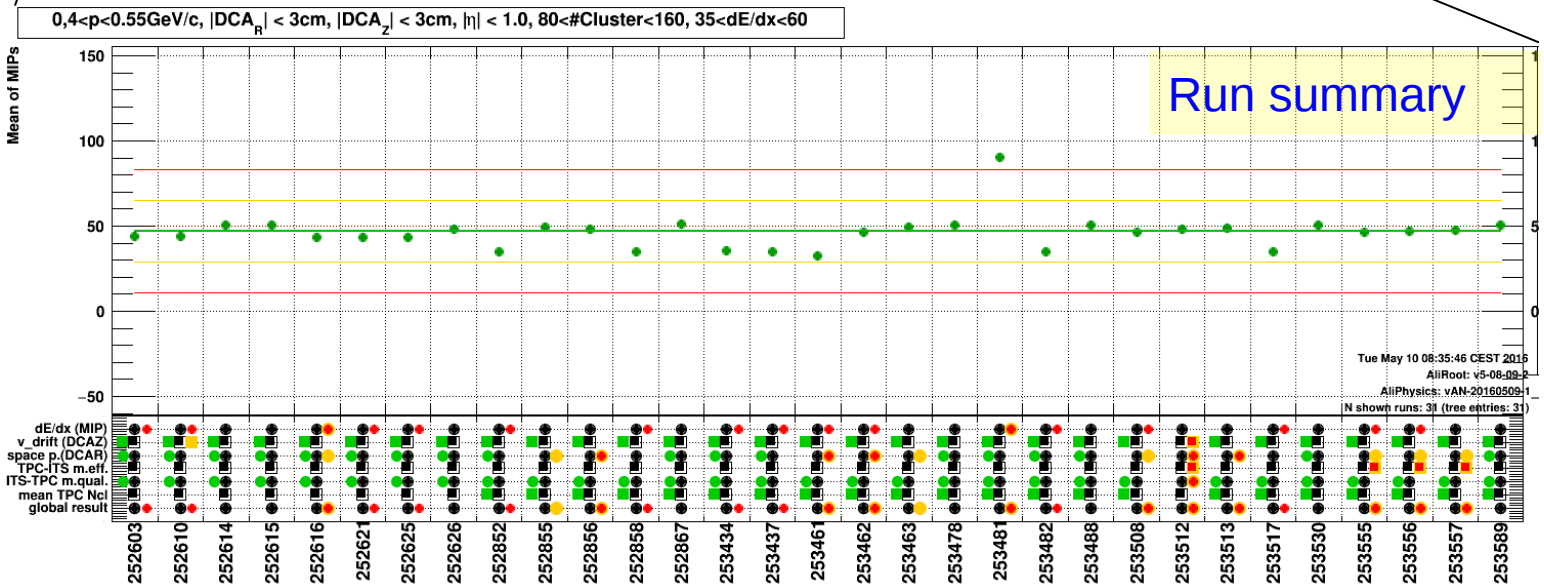
Run and period trending of summary data



Automatic trending of high level summary data

Example status bar (period with failed dEdx calibration):

- dEdx
- vdrift
- DCA (distortion)
- matching efficiency



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

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 σ~O(0.2 mm)

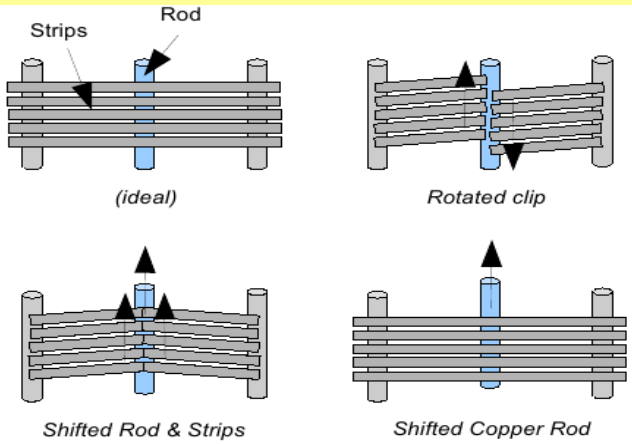
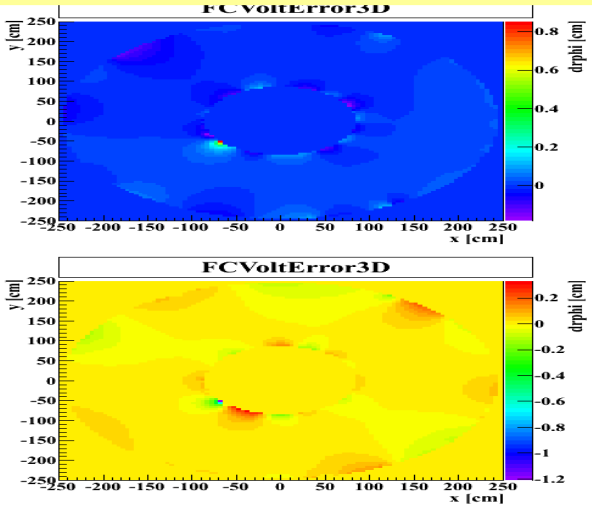


Figure 7: Misalignment scenarios of the FC components at each rod



TPC internal mechanical alignment - σ~O(0.1 mm)

Distortion in the bending plane due to the ExB effect

- B field inhomogeneity – Δ ~ O(8 mm)
- ExB nonlinearities due misalignments (~ 800 DOF) – Δ ~ O(6 mm)
- E || B misalignment – Δ ~ O(2 mm)

ExB distortion time dependent

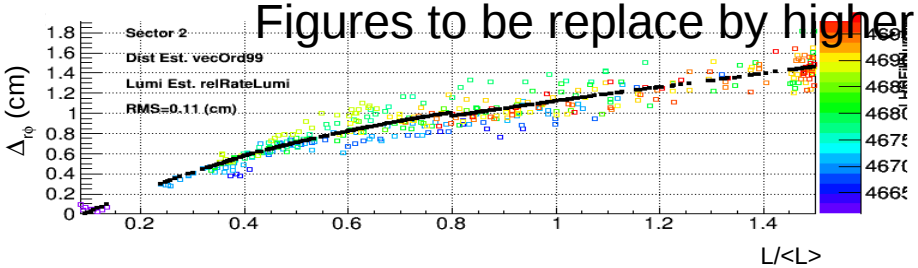
- ωτ – pressure, temperature, gas composition - Δ ~ O(0.2 mm)
- charging up of sensitive parts (rate dependent) - Δ ~ O(0.2 mm)
- rate dependent space charge - Run1- O(0.5 mm) - Run2 - O(5cm)

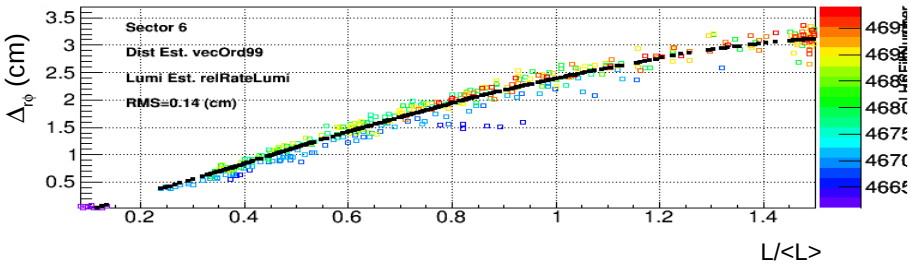
RUN2: TPC distortion calibration

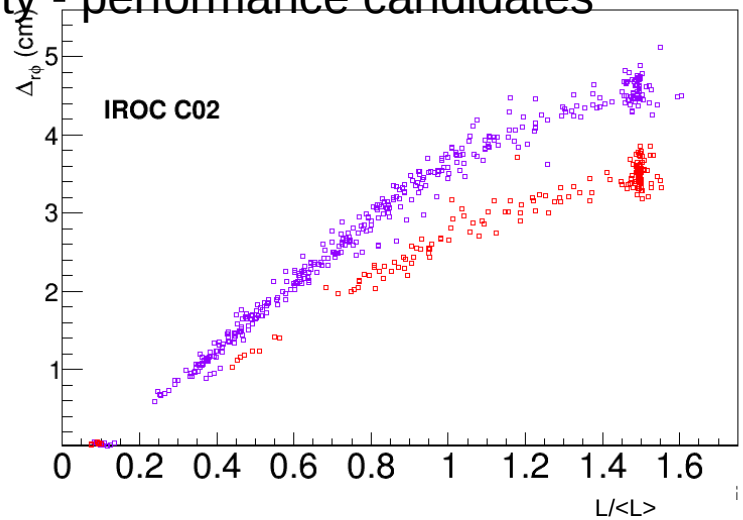
Space point distortion due to space charge RUN1 O(1 mm) → RUN2 O(5 cm)

- exchange of gas mixture, increase of interaction rate
- target calibration precision σ~O(0.2 mm)

Figures to be replace by higher quality - performance candidates







Distortion increases monotonously with luminosity

- function individual for each chamber
- not unique (σ ~ 0.14 cm)
- onset at critical IR

Distortion B field dependent (B+, B-)

Distortion fluctuation:

- $\sigma_{\rho\phi}$ ~ (0.2–0.3) x $\Delta_{\rho\phi}$ residuals itself
- behavior expected due fluctuation of space charge density
- Precision of correction limited

Procedure planned for Run3 SCD corrections

- 3x3D distortion map 429300 voxels. Effective DOF smaller (local kernel regression)

QA - repository structure

$PATH=$prefix/$datatype/$year/$period/$recopass/$suffix

alien:///alice/data/2015/LHC15o/000244917/cpass1_pass2_lowIR/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