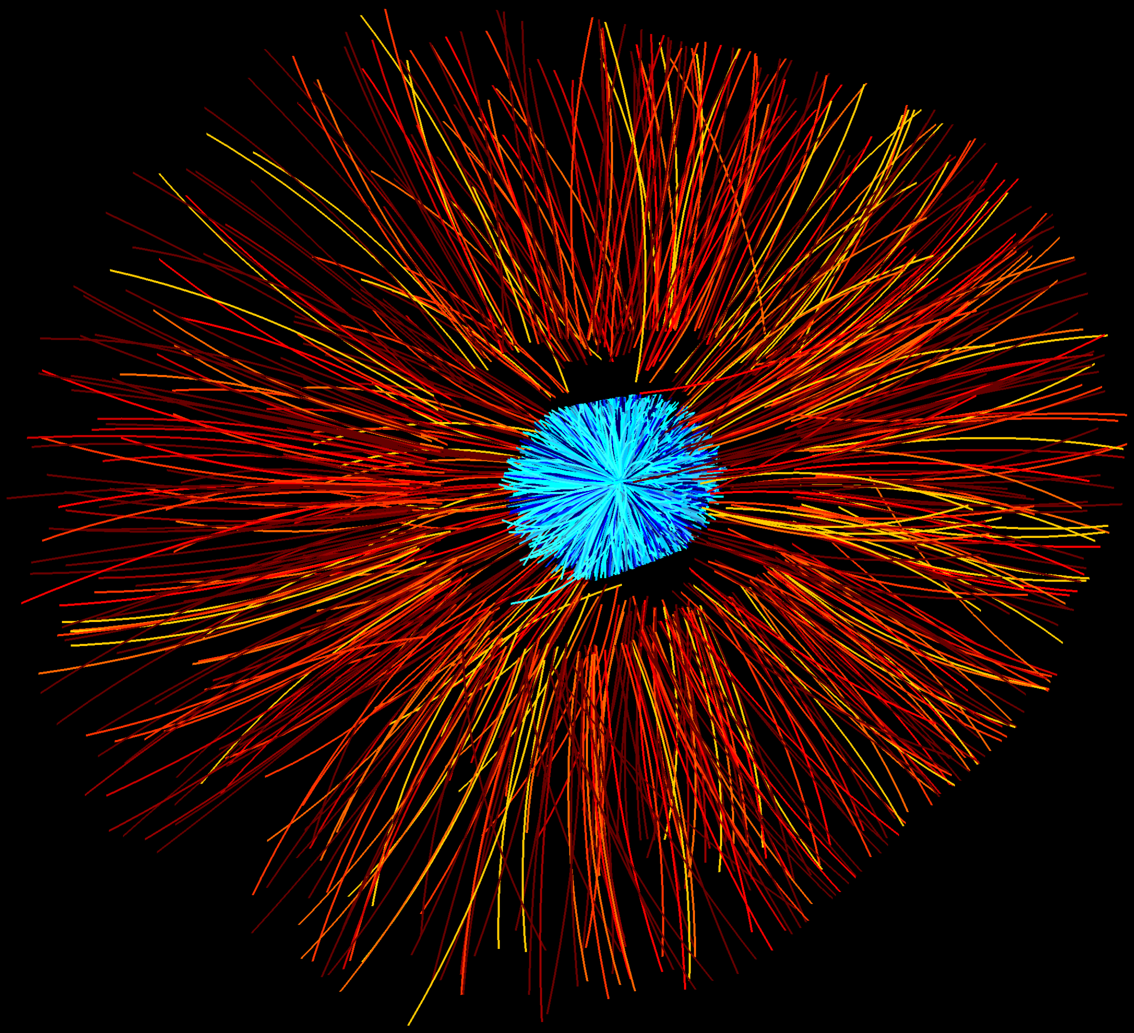
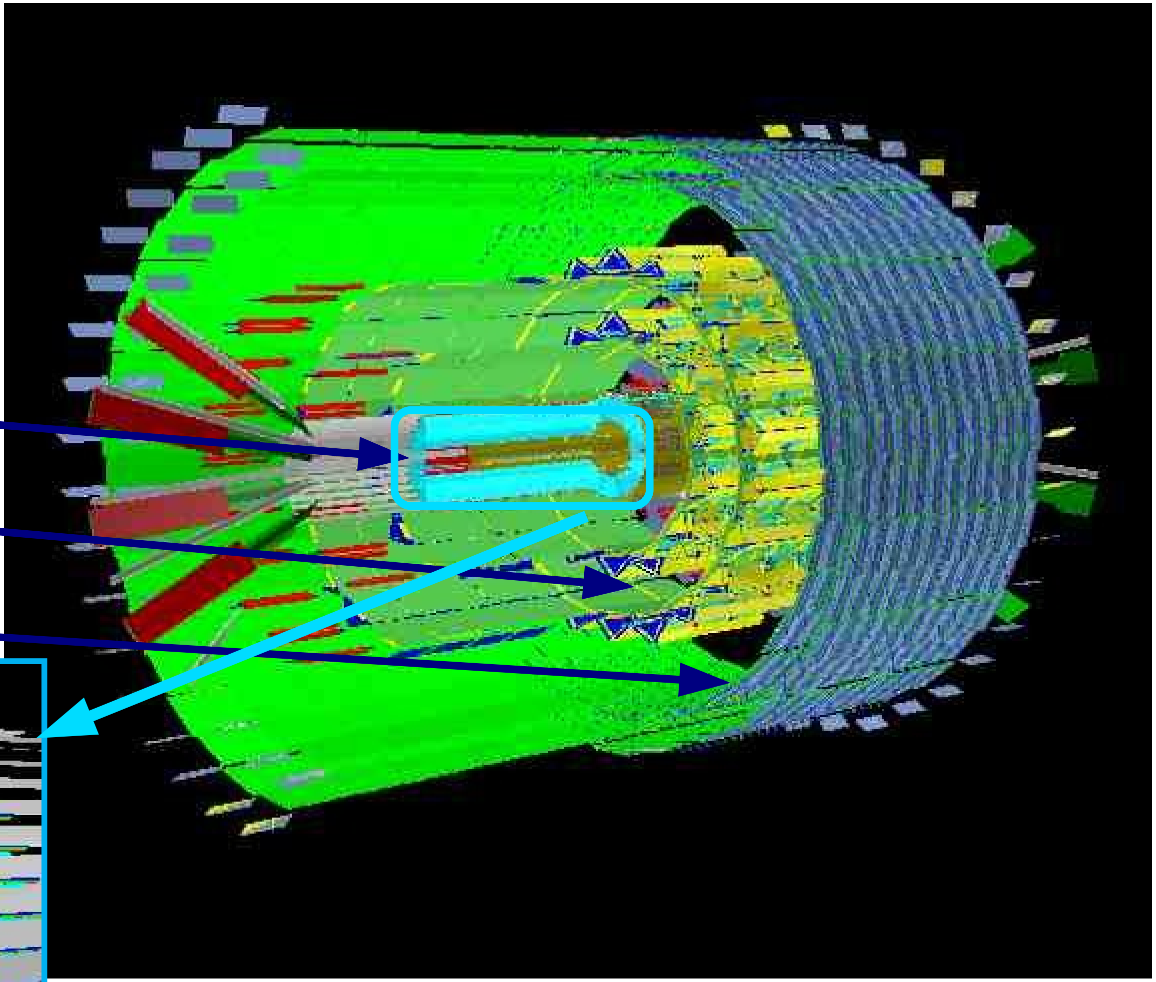
ALICE ~~SDD~~ ITS performance with pp and Pb-Pb beams

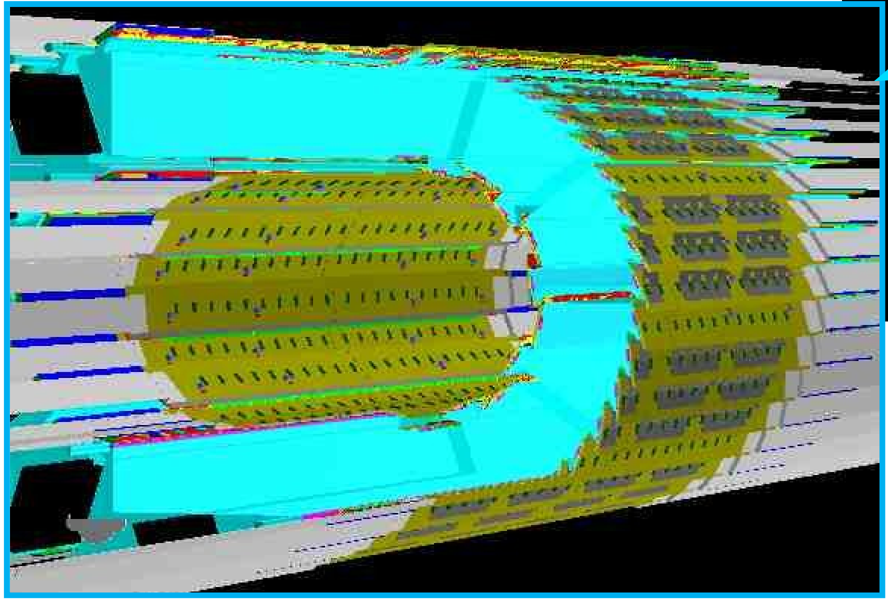


Stefania Beolè (*Università di Torino e INFN*)
for the ALICE Collaboration

Inner Tracking System (I)

- Six layers of silicon detectors
  - Coverage: |η|<0.9 full ITS
  - Coverage: |η|<1.4 SPD
- Three technologies
  - Pixels (SPD)
  - Drift (SDD)
  - Double-sided Strips (SSD)

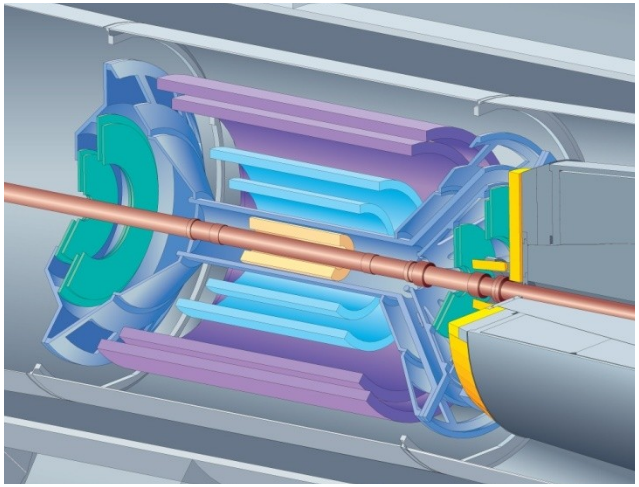




Inner Tracking System (II)

Design goals

- Optimal resolution for primary vertex and track impact parameter
  - Minimize distance of the innermost layer from beam axis (<r>≈ 3.9 cm) and material budget (~8 % X/X_0)
- Maximum occupancy (central PbPb) < few %
- 2D spatial information for all the layers
- dE/dx information in the 4 outermost layers for particle ID in $1/\beta^2$ region

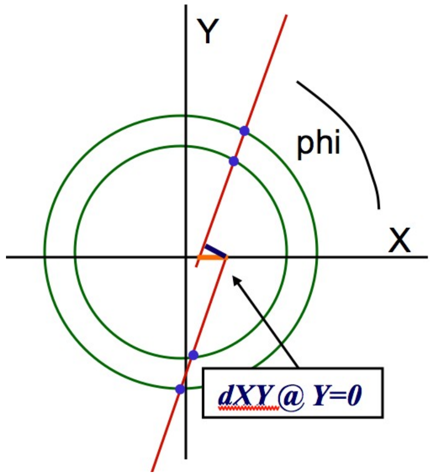


Layer	Det. Type	Radius (cm)	Length (cm)	Resolution (μm)		PbPb dN/dy=6000	
				rϕ	Z	Part./cm²	Occupancy (%)
1	SPD	3.9	28.2	12	100	35	2.1
2	SPD	7.6	28.2	12	100	12	0.6
3	SDD	15.0	44.4	35	25	3	2.5
4	SDD	23.9	59.4	35	25	1.5	1.0
5	SSD	38.0	86.2	20	830	0.6	4.0
6	SSD	43.0	97.8	20	830	0.45	3.3

Calibration and alignment

ITS alignment with cosmic rays 2009: SPD and SSD

Target: minimize the residual misalignment to reduce the resolution worsening



$\Delta xy \rightarrow$ distance between 2 half tracks in the xy plane at y=0

$$s^2_{dXY|_{Y=0}} = 2s^2_{d_0}$$

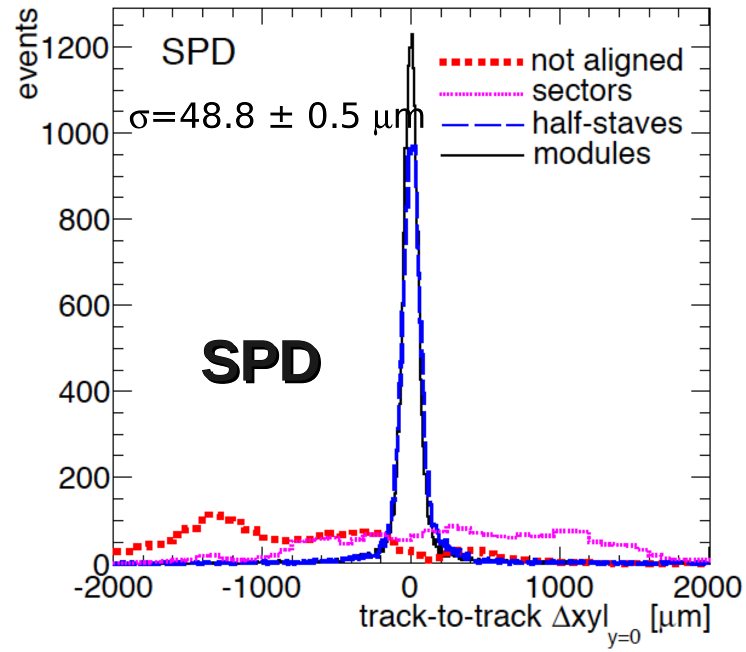
information on d_0 resolution

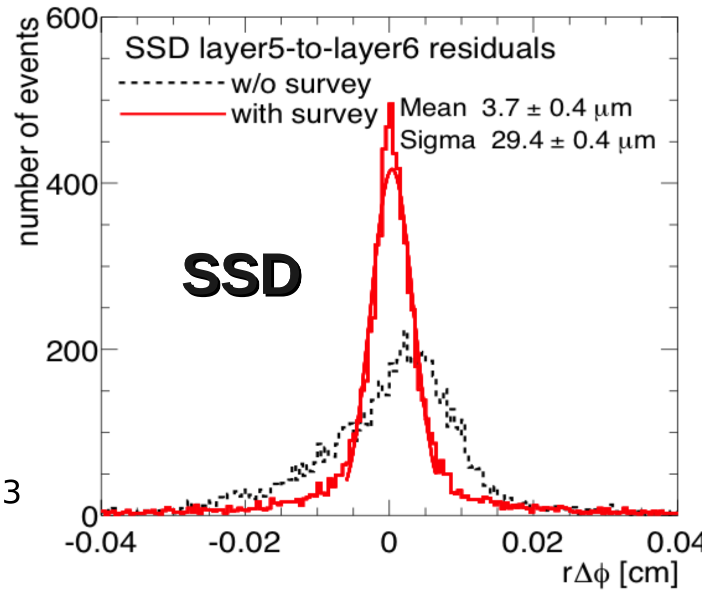
Alignment of the ALICE inner tracking system with cosmic-ray tracks
ALICE collaboration 2010 JINST 5 P03003

Two different algorithms for the minimization of the track-to-point residuals are used: Millepede (II) and an iterative module-by-module approach

SPD $\rightarrow$ hierarchical approach

- Spatial resolution =14 μm
- Residual misalignment = 7 μm





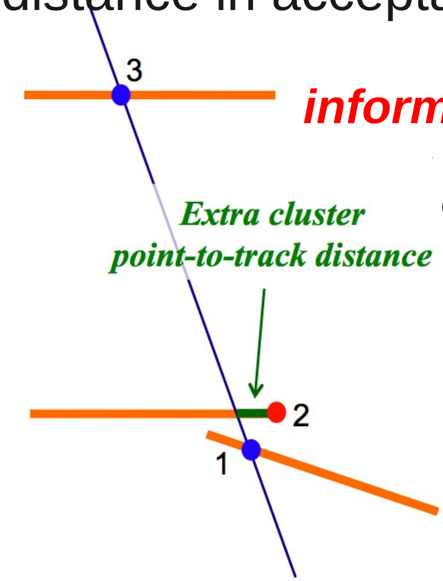
Good alignment with survey for SSD

- spatial resolution = 21 μm
- Residual misalignment for modules on ladders = 5 μm (negligible)

Millepede with cosmics used mostly to align the whole SPD barrel w.r.t. SSD

ITS alignment with collisions 2010: SPD and SSD

“extra” clusters distance = point-to-track distance in acceptance overlaps



information on spatial resolution

$$\sigma^2_{\Delta X_{loc}} \sim 2s^2_{spatial}$$

SPD

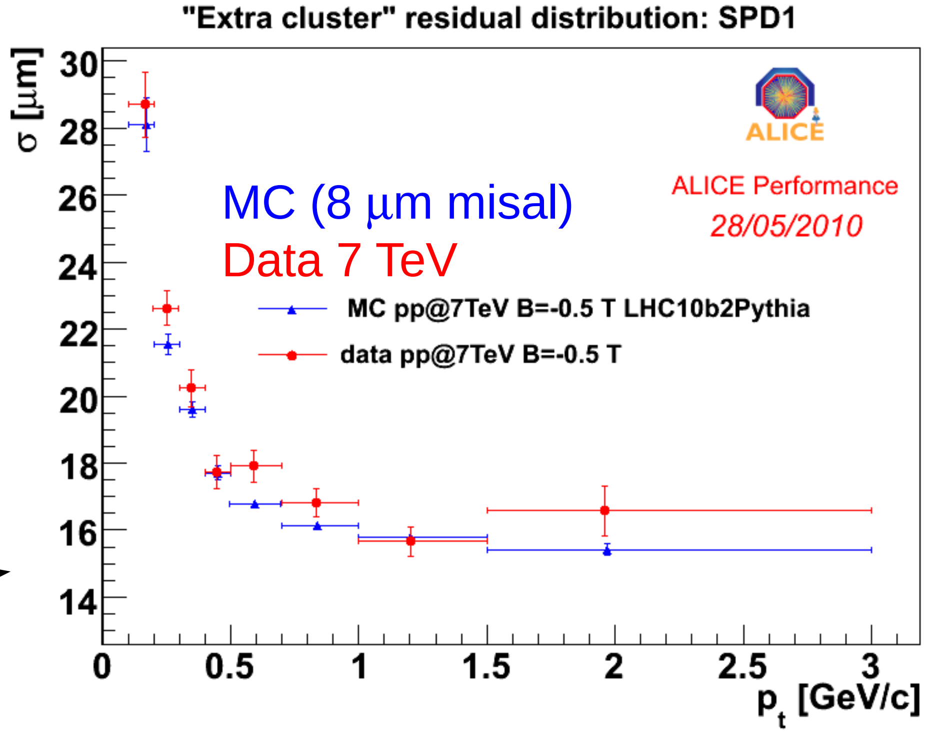
Alignment with mixed B>0, B<0 and B=0 collision data + B<0 cosmic data, using the curvature measured by the TPC and keeping the SSD points fixed

Extra cluster distance still compatible with a residual misalignment of about

$\sigma_{misal} \sim 8\ \mu m$

SSD

- **re-validation of survey** with “extra” clusters in pp collisions (full SSD barrel)
- estimated residual misalignment confirmed to be compatible with the survey precision on the whole detector (~5 μm)

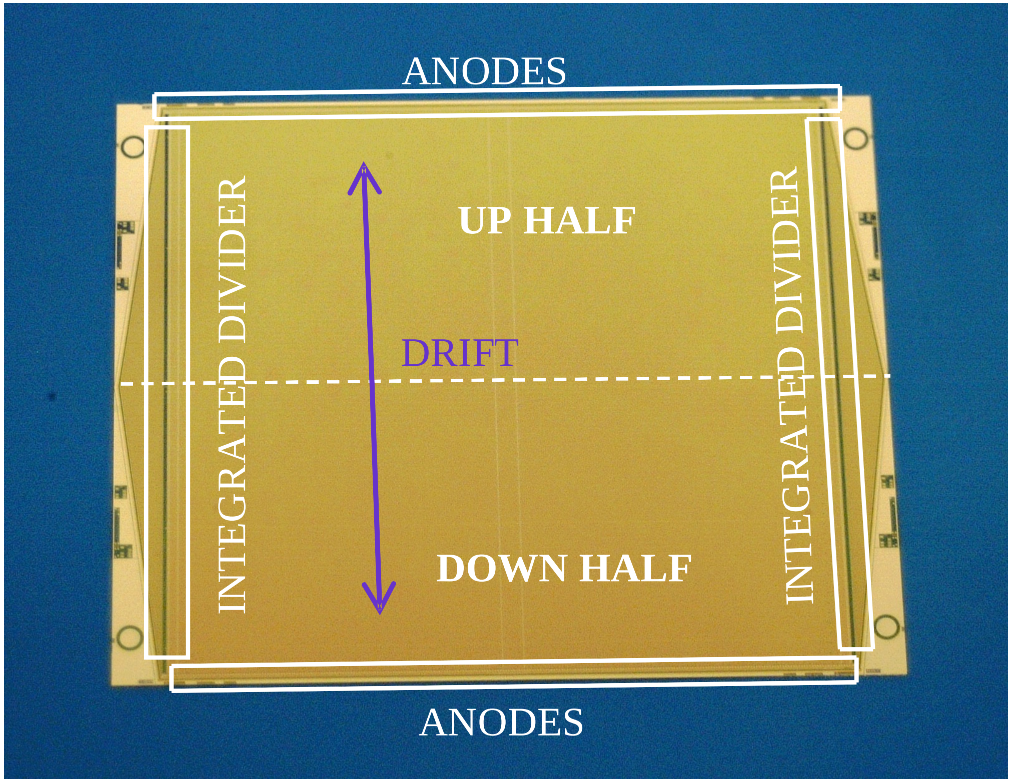


SDD calibration and alignment (1)

- In SDD, local x determined from drift time:

  $x_{loc} = (t - t_0) \times v_{drift}$

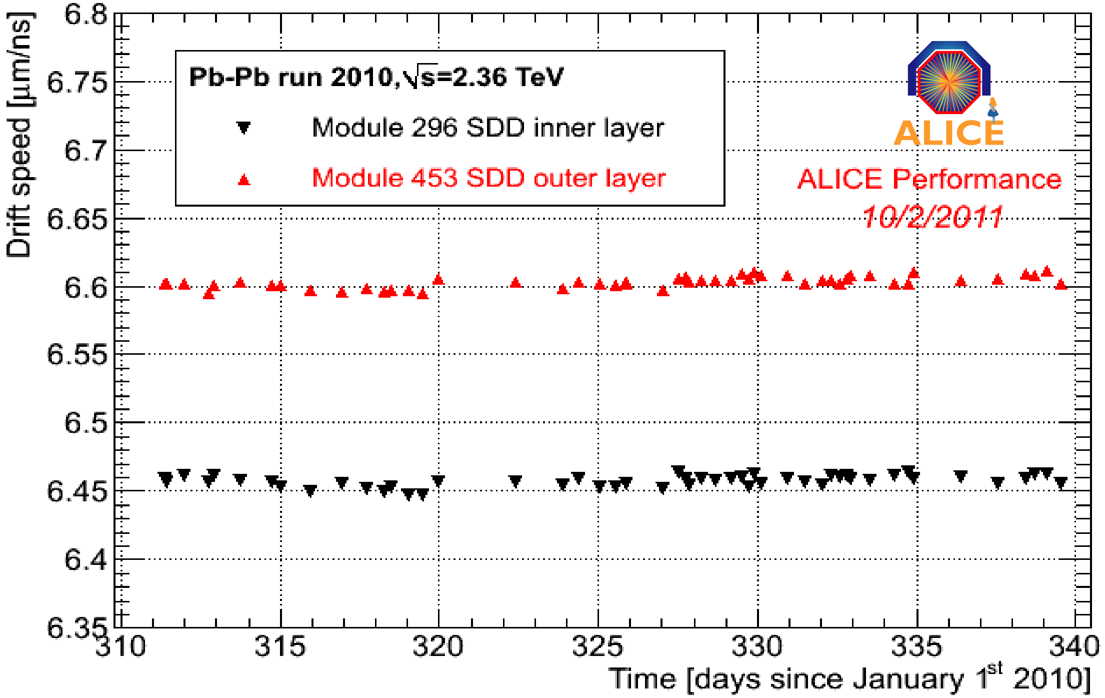
- Drift region divided into 2 halves
- Drift field generated by a voltage divider implanted on the surface
- Auxiliary external divider connected every ~20 cathodes



- two calibration parameters: t_0 and v_{drift}
  - t_0 initial values estimated either from the minimum drift time or from track to point residuals in the two drift regions
  - V_{drift} obtained by means of MOS charge injectors integrated on the detector surface. Stability within 1‰ mandatory to guarantee desired resolution of ~ 30 μm

SDD calibration and alignment (2)

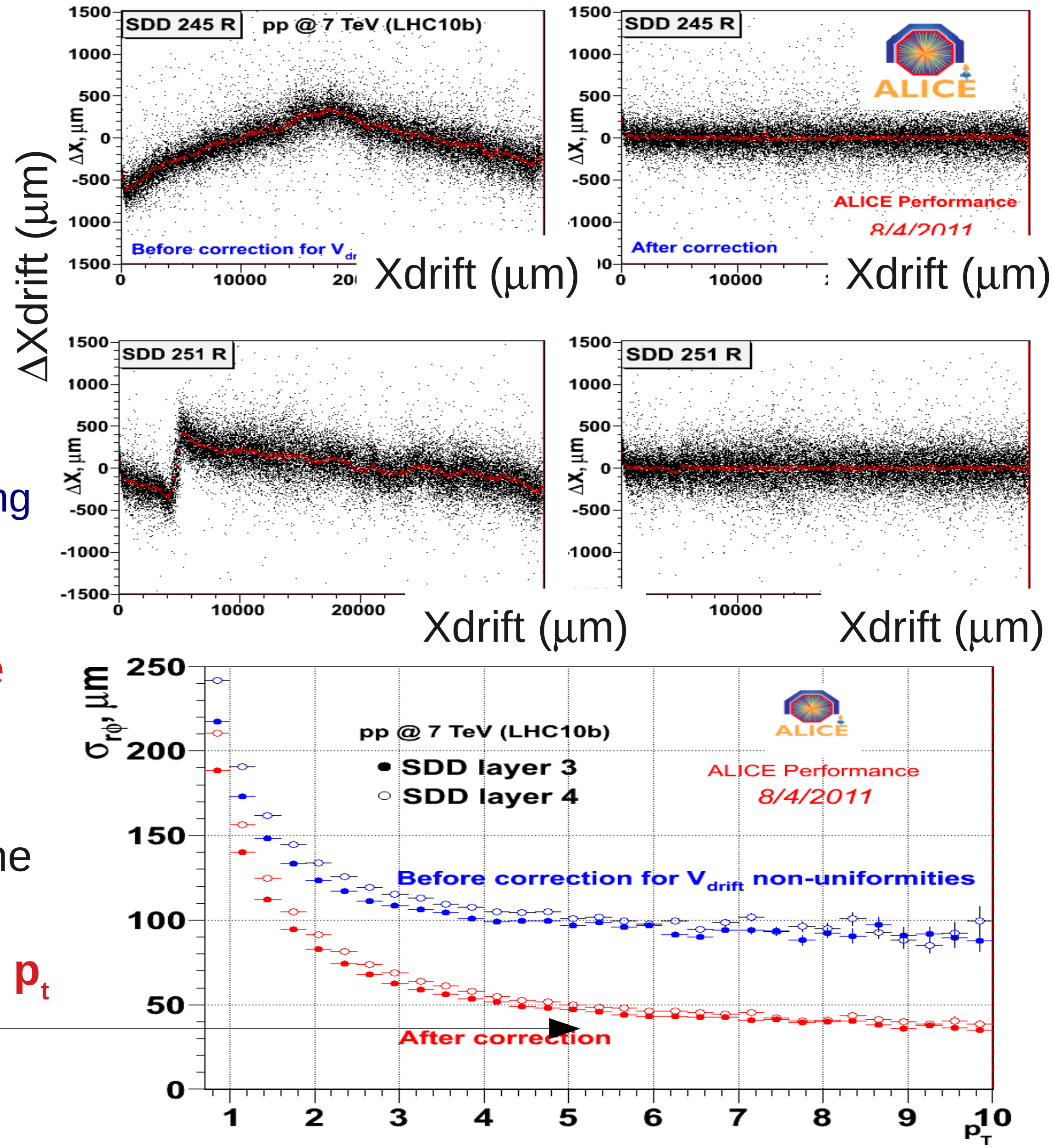
- V_{drift} monitored at every LHC fill with dedicated calibration runs triggering charge injectors
  - Stability ~ 1‰ to get nominal resolution ~ 30 μm
- Corrections on v_{drift} needed for:
  - Modules with malfunction injectors (≈ 30%)
  - Systematic effects in the estimation of the drift speed with injector



For detailed description of the charge injectors behavior see the poster presented by Svetlana Kushpil

SDD calibration and alignment (3)

- Defects in the voltage divider → bad resolution along x (drift direction)
  - Track to point residuals: clear "anomalous" profile for defective modules (20-30)
  - Corrections extracted from
    - Laser maps (measured in laboratory during construction phase)
    - "Particle" maps (extracted from p-p data)
  - t_0 and v_{drift} are free parameters in the Millepede alignment procedure



After correction for non-uniformities and fine tuning of t_0 and v_{drift} :

track to point residuals ~ 30 μm at high p_t

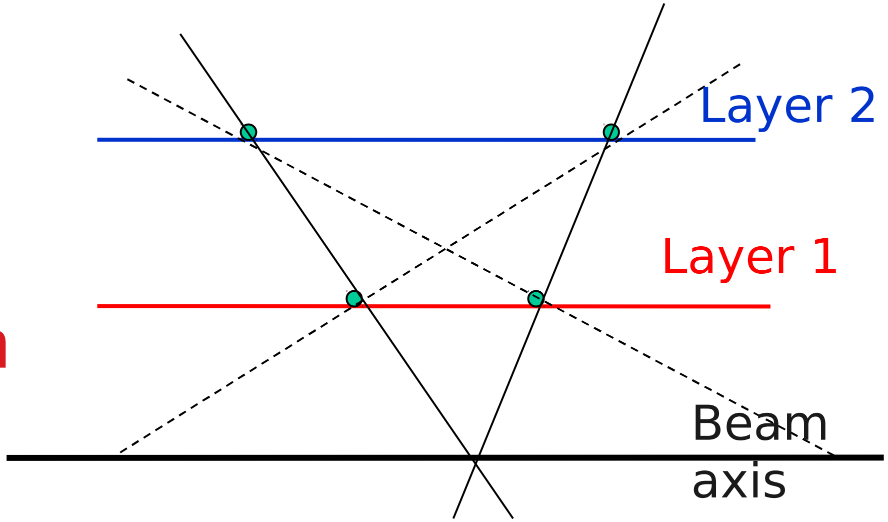
→ nominal resolution for SDD

Vertex determination

Vertexing with SPD tracklets: "*vertex SPD*"

Build "tracklets" from SPD Clusters

- associate each Cluster on layer1 to all the Clusters on layer2 within a window Δφ <0.5 (0.025) rad



Combine tracklet pairs and select them according to:

- small Distance of Closest Approach (<1 mm) between the two tracklets
- build all combination of traclet pair and select those with intersection in the diamond region (Δr<0.5 Δz<40 cm)

Compute the "*vertex SPD*" using the selected tracklets

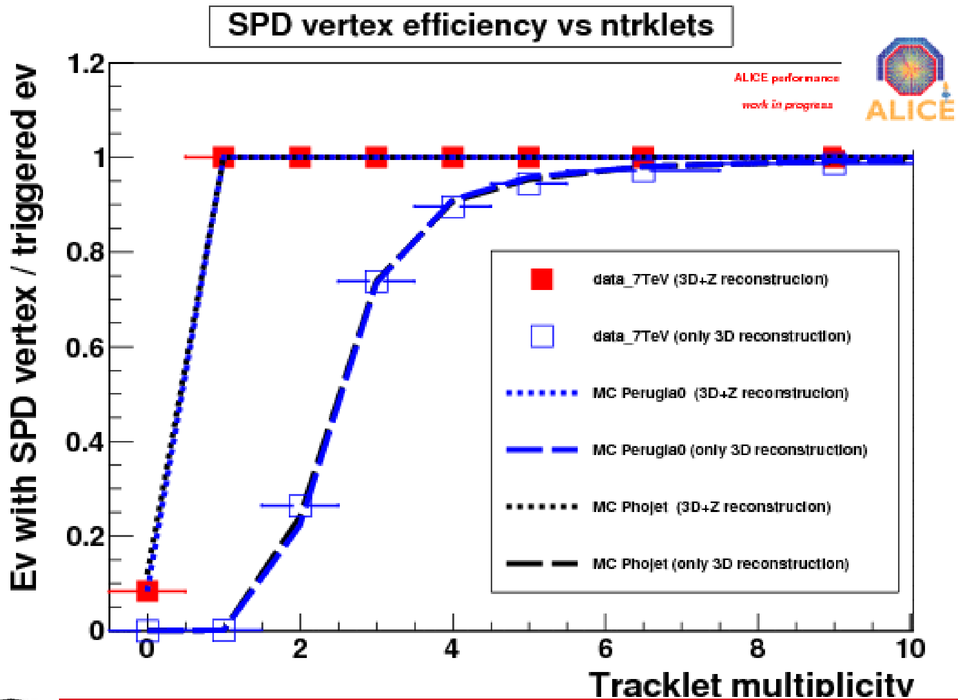
Vertex "*SPD*" and "*tracks*" performance

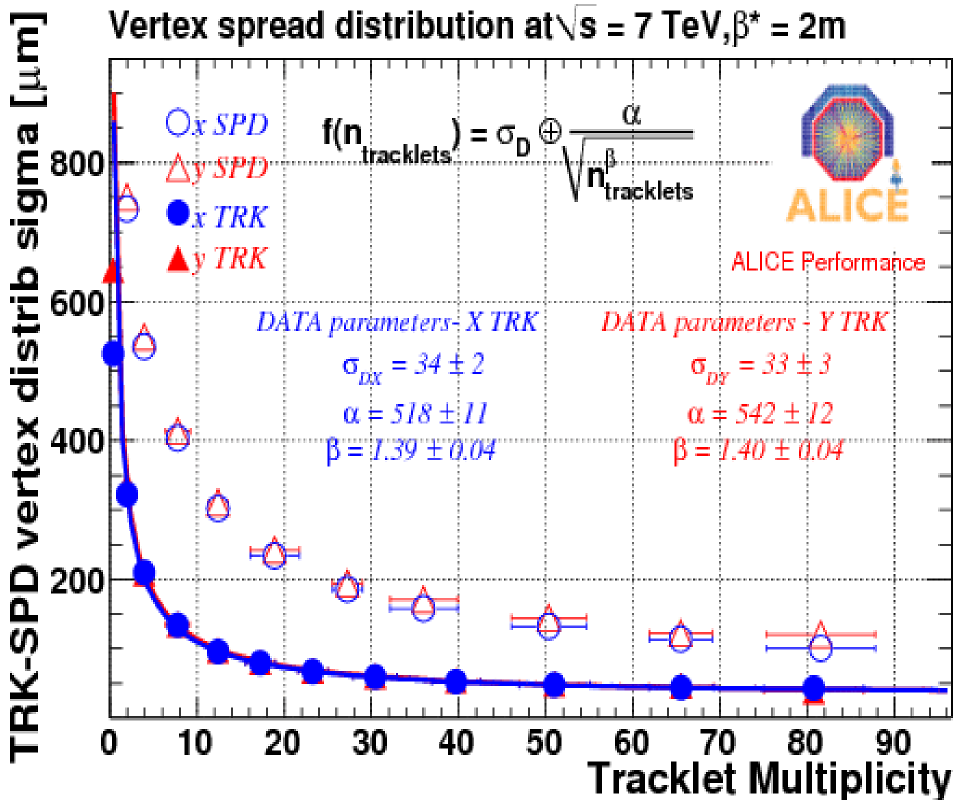
SPD Vertex needed to:

- Monitor the interaction diamond position quasi-online
- Initiate barrel and muon arm tracking
- Measure charged particle multiplicity

More accurate second reconstruction of interaction vertex from tracks in the barrel "vertex tracks"

- Needed for secondary vertices reconstruction





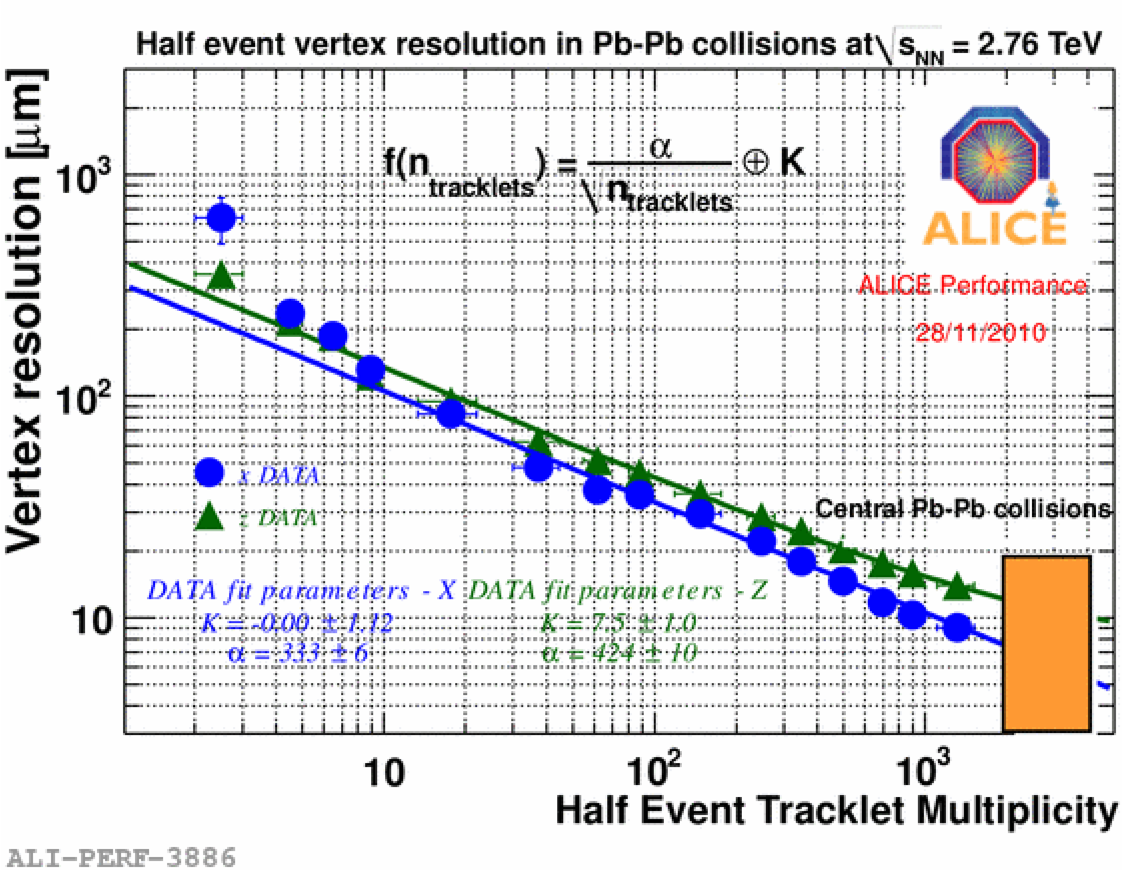
The asymptotic limit estimates the size of the luminous region, seen for the vertices reconstructed with tracks (filled markers).

Vertex "*tracks*" in Pb-Pb

Primary vertex reconstructed with tracks in Pb-Pb data at 2.76 TeV per nucleon pair

Method to evaluate resolution on the vertex position:

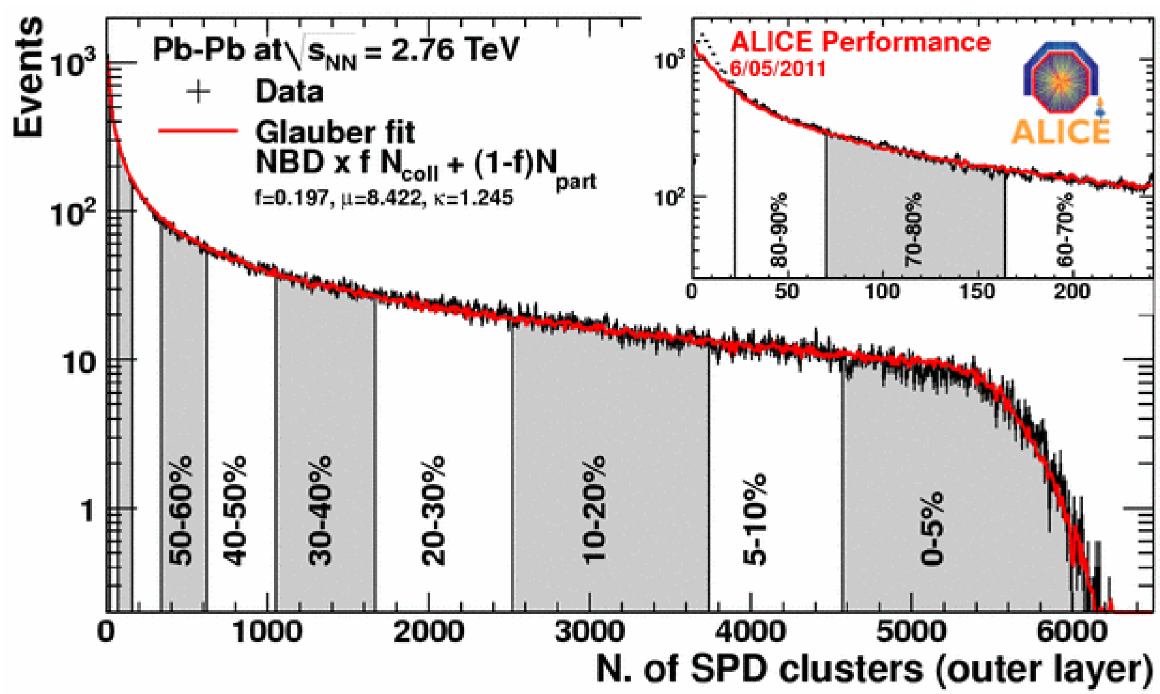
- The tracks sample is randomly divided into two.
- A primary vertex is reconstructed for each of the sub-sample.
- The resolution is extracted from the σ of the distribution of the residual between the two vertices.
- The resolution is extrapolated for most central (5%) Pb-Pb collisions (orange box).

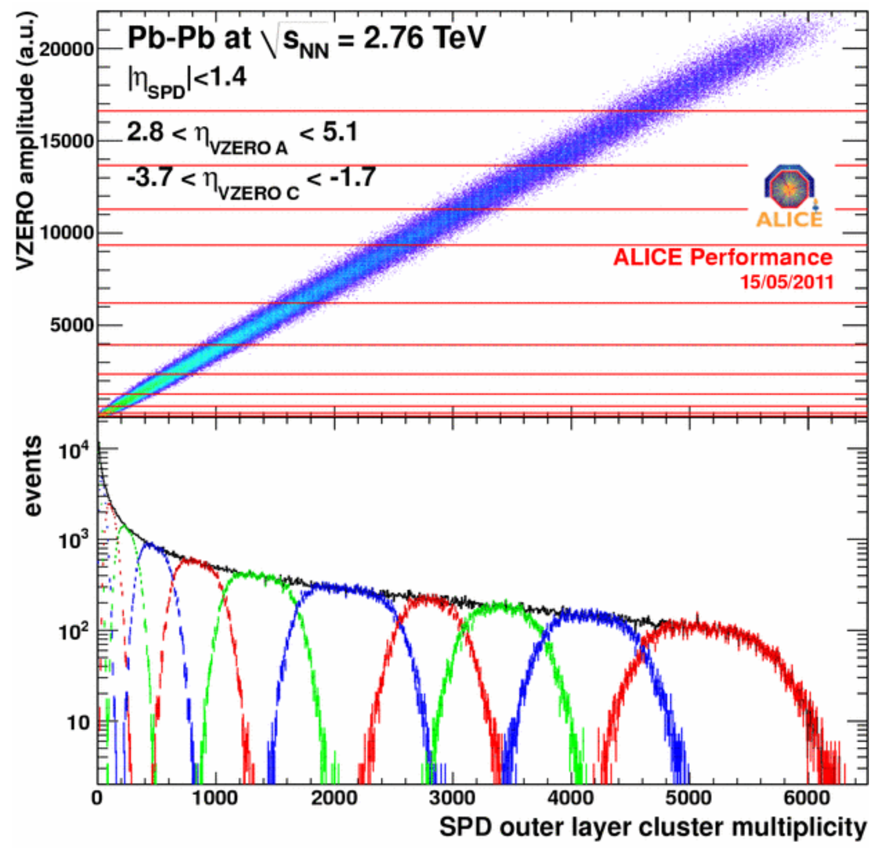


σ = 10 μm for central events

Measuring $dN_{charged}/d\eta$

- New tracklets are built using the vertex and the SPD points
  - Tracklet: pair of clusters (inner/outer layer) aligned with the reconstructed primary vertex within fiducial windows in θ and ϕ
- measure charged $dN/d\eta$ in p-p and Pb-Pb collisions
- define centrality in Pb-Pb collisions



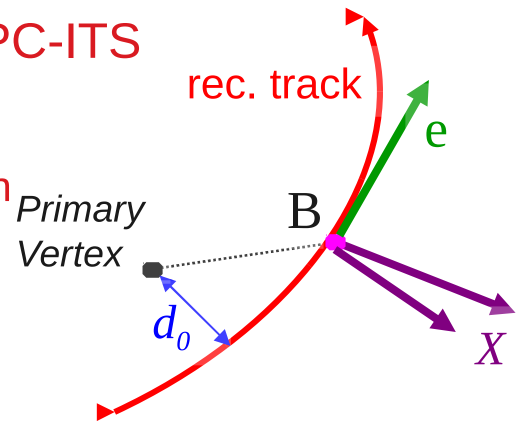


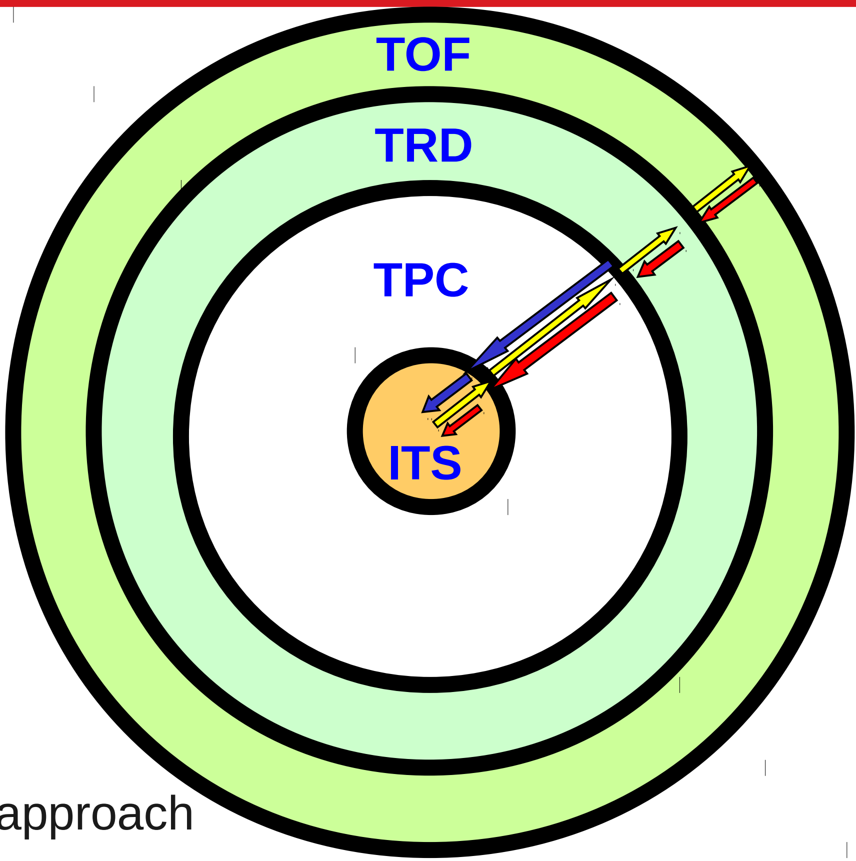
ITS tracking

ITS tracking

- Global Tracking in the barrel
  - Track finding + fitting based on Kalman filter
  - Initial seeding in the external TPC pad-rows (low track density). Tracks are followed inwards
  - Back propagation ITS-TPC-TRD-TOF
  - Refit inward TOF-TRD-TPC-ITS
- ITS improves
  - momentum and angle resolution
  - track impact parameter

  (crucial for heavy flavours)

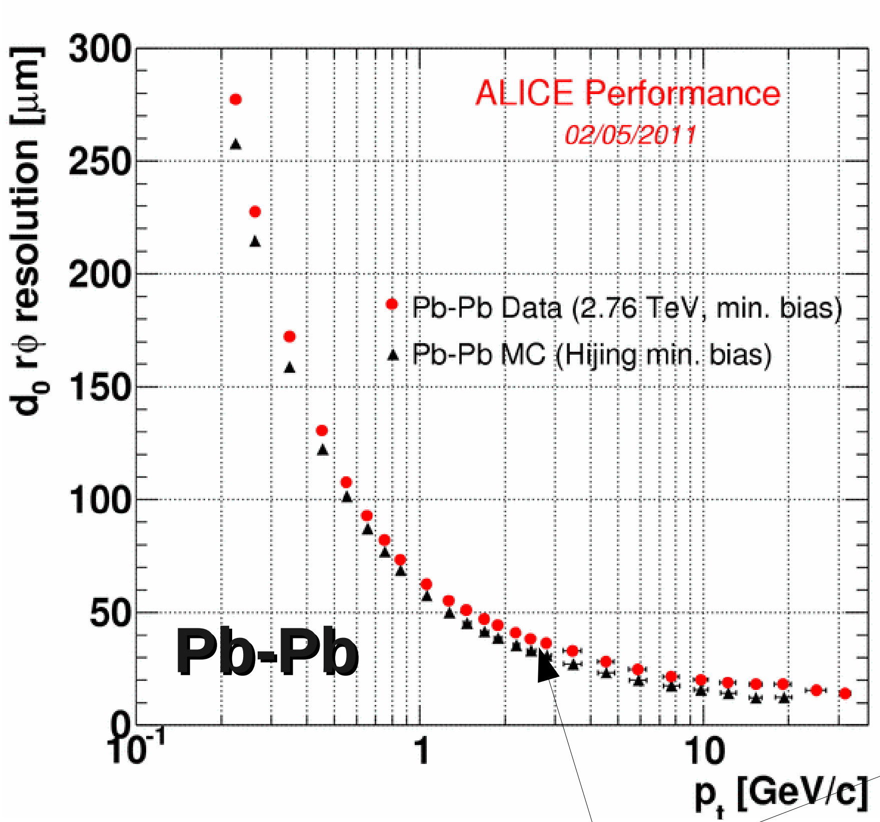


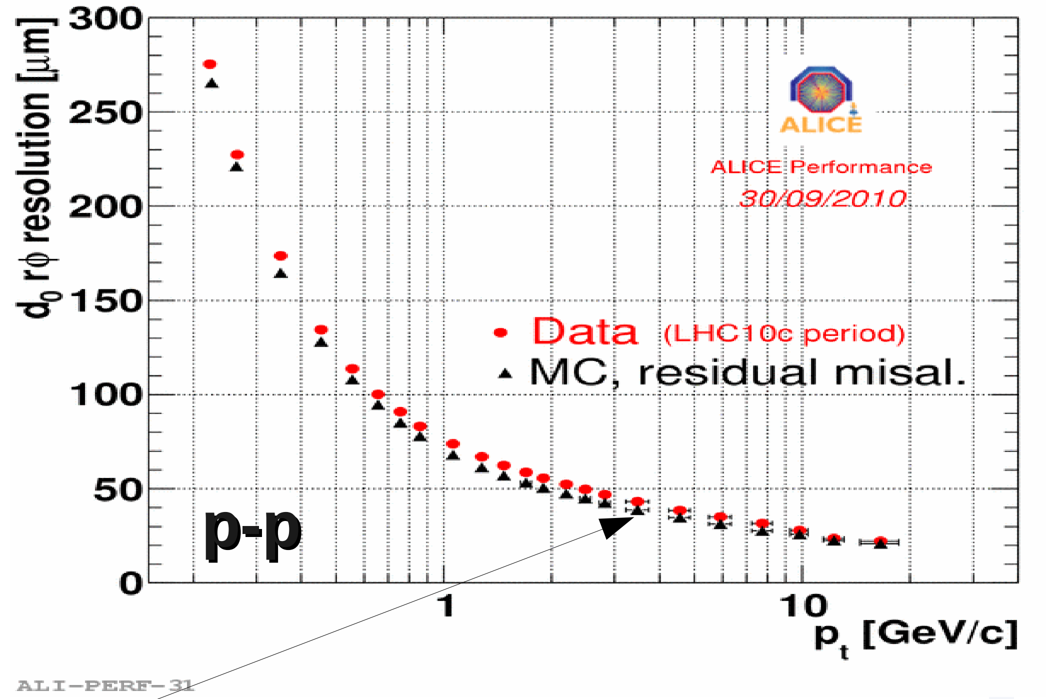


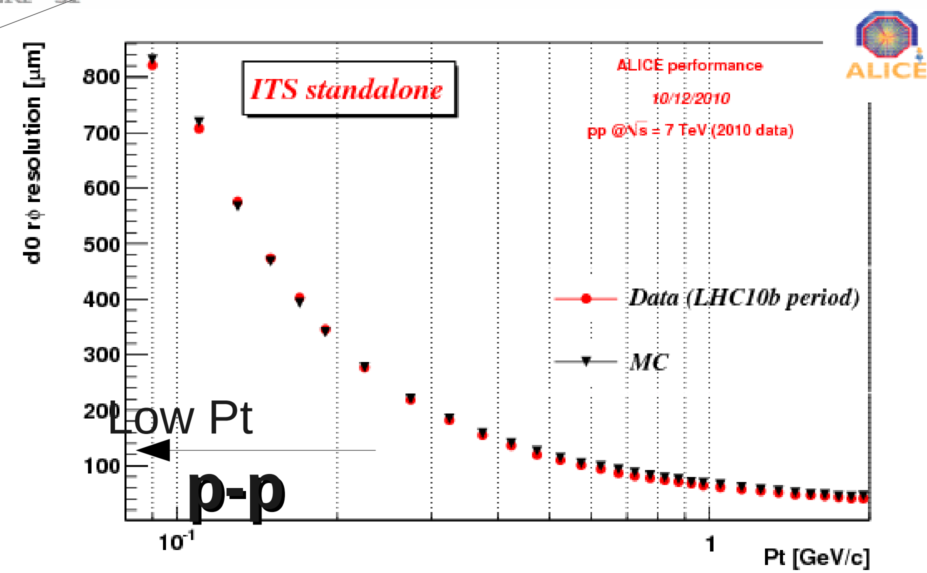
Track impact parameter d0: distance of closest approach DCA track → vertex

- Standalone ITS tracking
  - Tracks and identifies particles missed by TPC due to dead zones between sectors, decays and p_T cut-off
  - p_T resolution <≈6% for a pion in p_T range 200-800 MeV

ITS impact parameter resolution





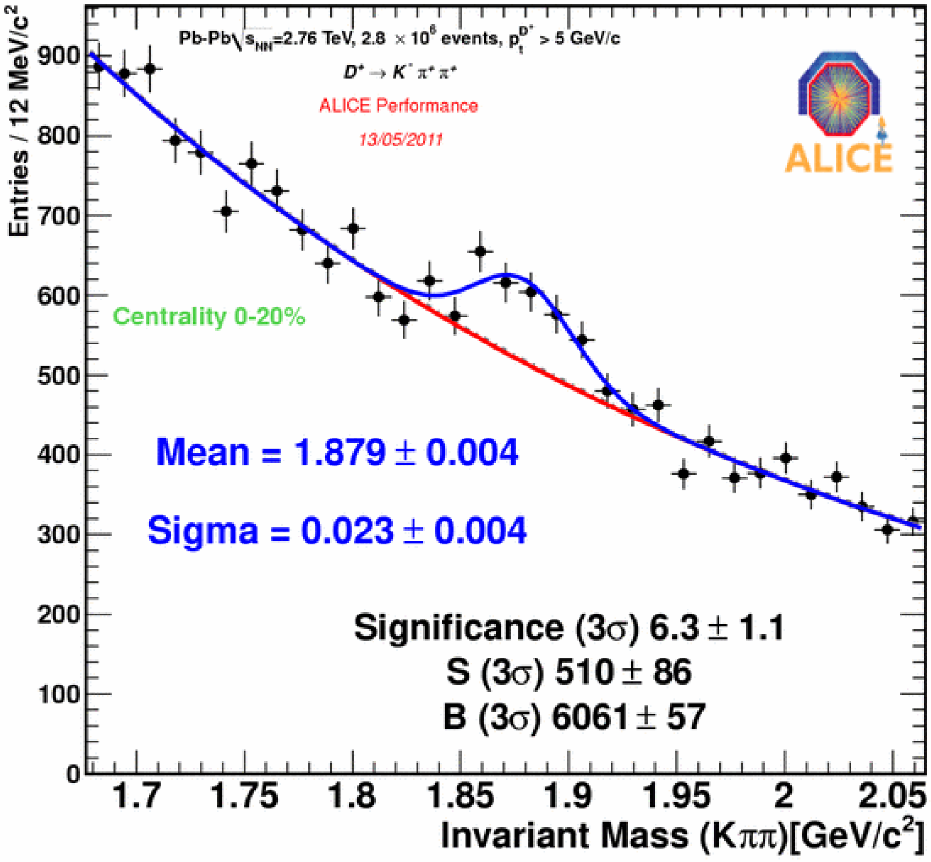


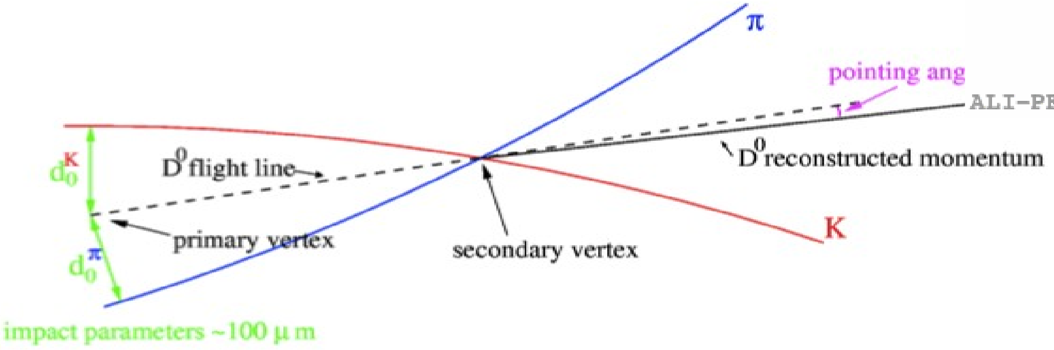
- Resolution below 30 μm for p_t > 1 GeV/c
- ITS standalone enables the tracking for very low momentum particles (low p_t reach=80-100 MeV/c pions)
- Good agreement data-MC (~10%)

Secondary vertex reconstruction

- Very good impact parameter resolution allows reconstruction of secondary vertices
  - detect open-charm mesons (D+,D_0, D*, D_s)

First results presented at QM2011





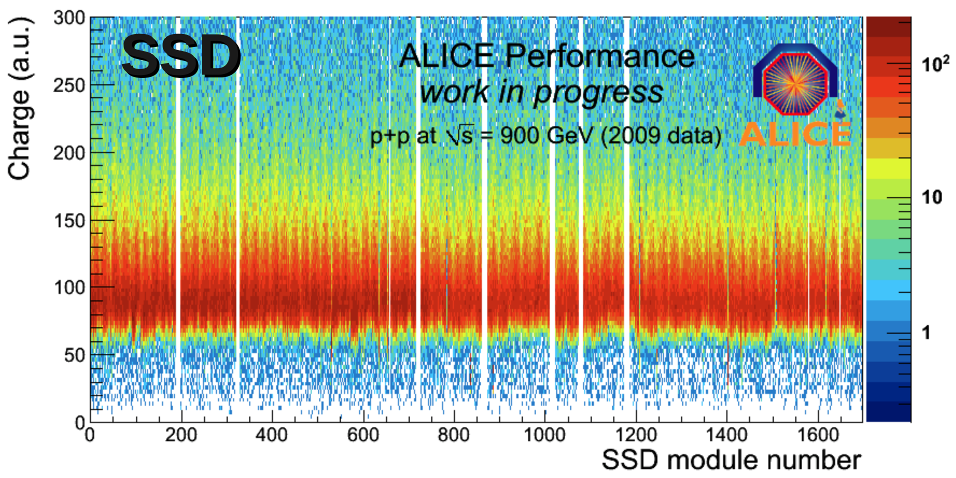
Particle identification with ITS

ITS Particle Identification (I)

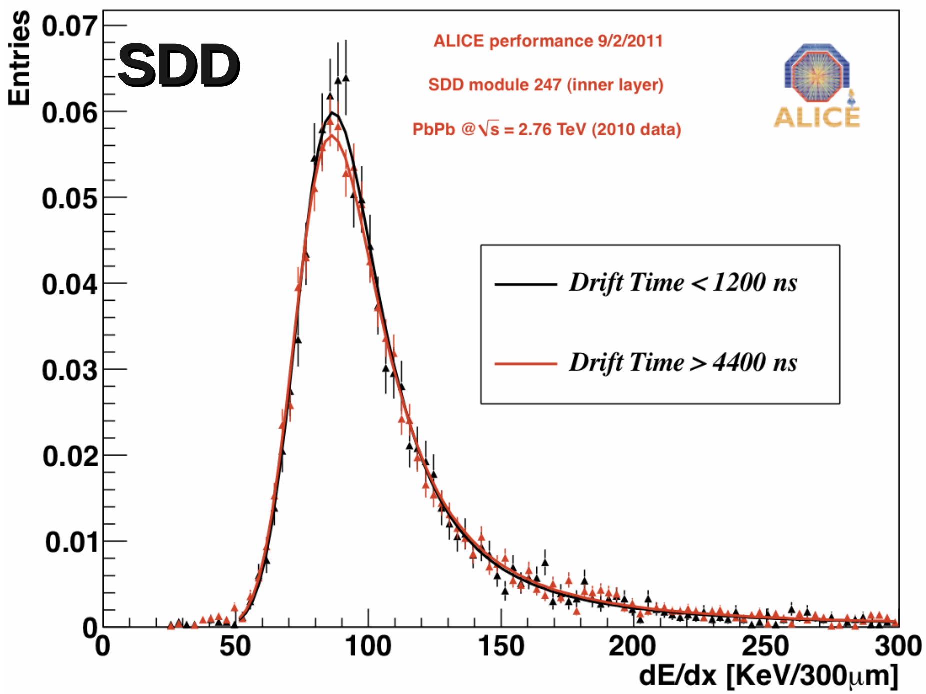
SDD and SSD analogue readout has a dynamic range large enough to provide the dE/dx measurement for low momentum, highly ionizing particles, down to the lowest momentum at which tracks can still be reconstructed. The ITS is a stand-alone low-p_t particle spectrometer.

- uniformity of the charge collection among all the modules and among different layers
- stability of the charge collection vs drift time in the SDD
- stability of the performance during the data taking

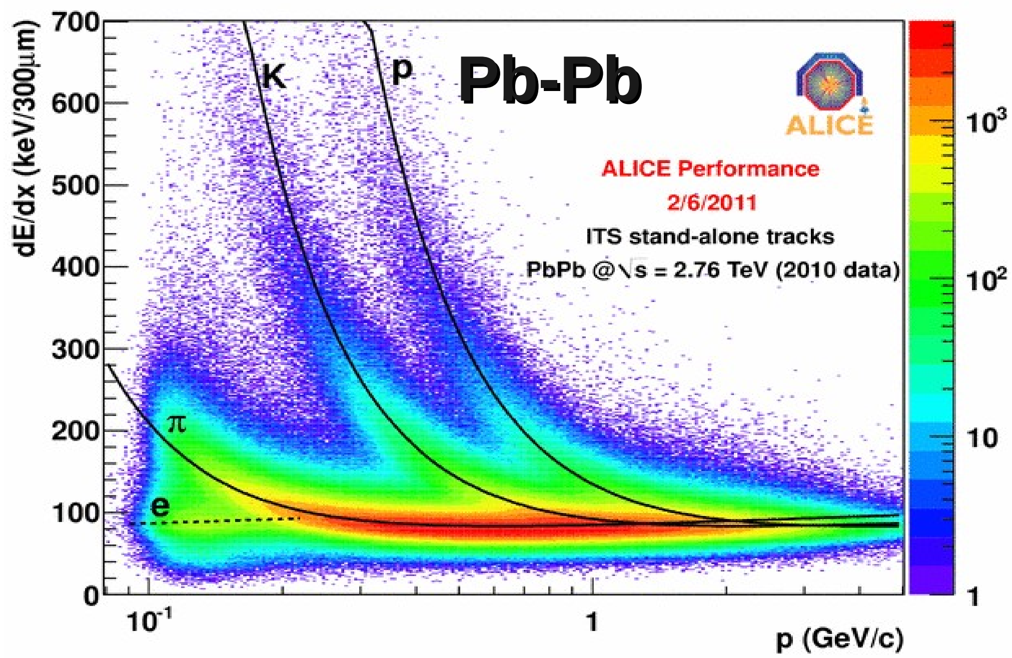
Dedicated Quality Assurance analysis tasks



dE/dx for the 1698 SSD modules in pp collisions at 900 GeV. Each bin is fitted with a Landau-Gaussian convolution distribution.



ITS Particle Identification (II)



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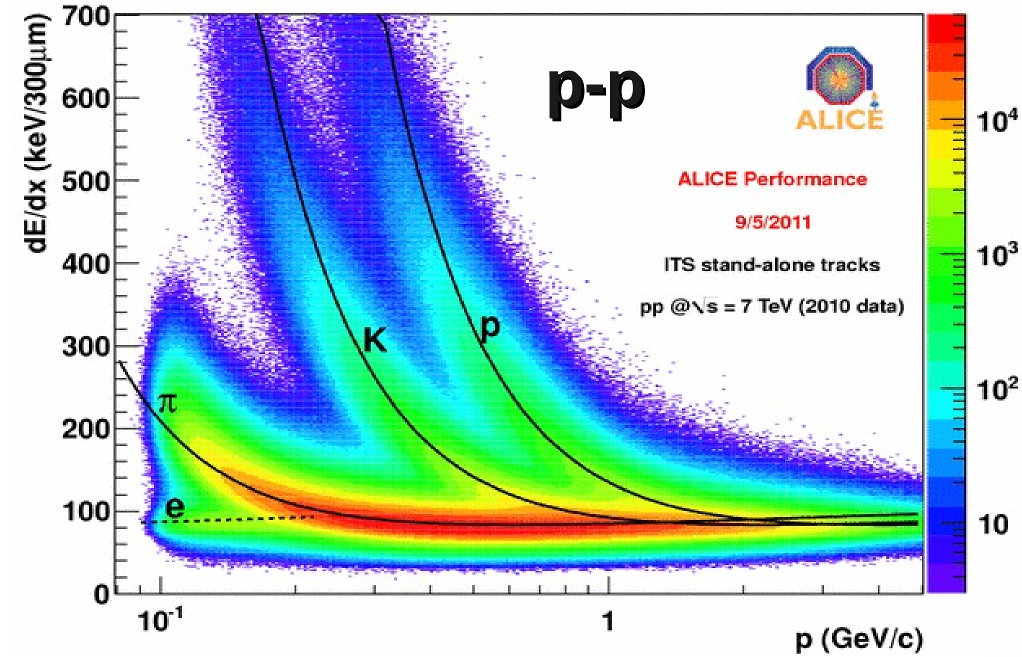
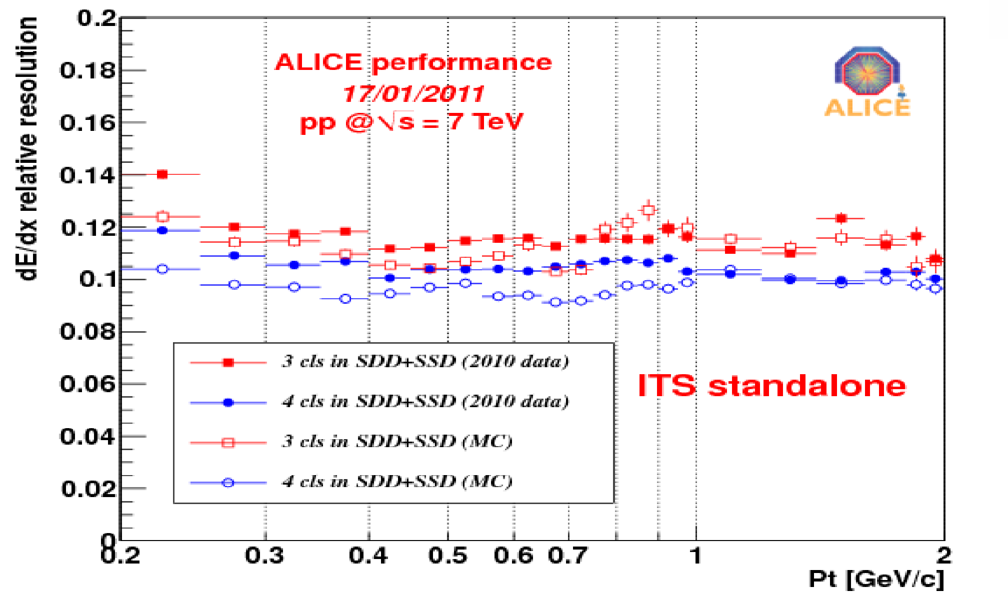


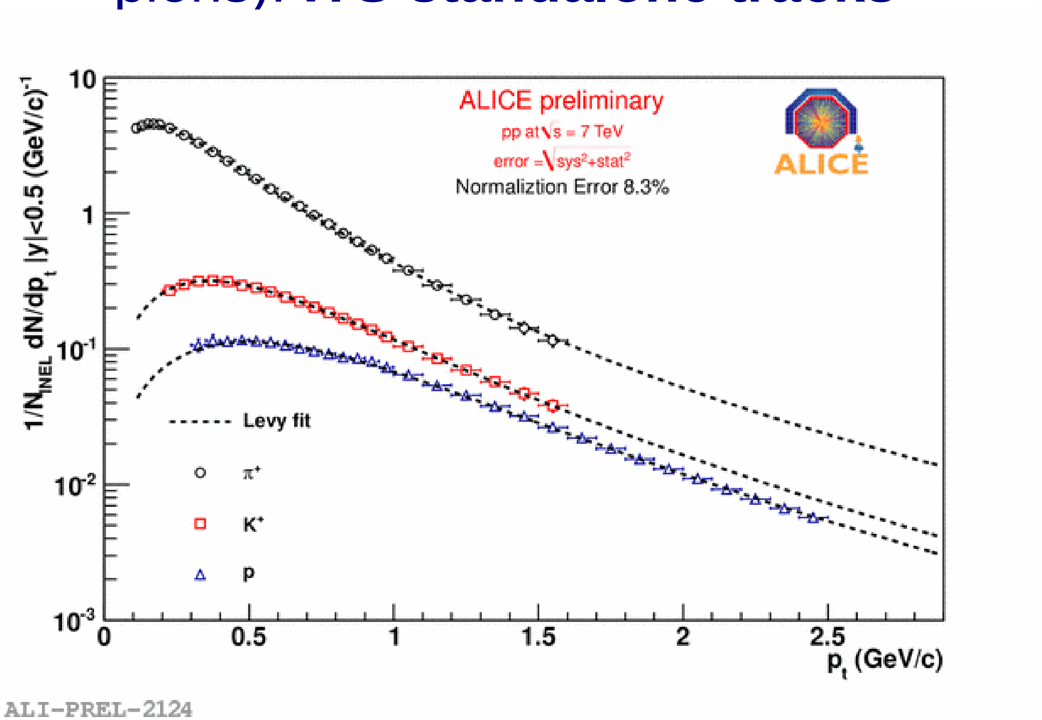
The resolution of the ITS dE/dx measurement is about 11%

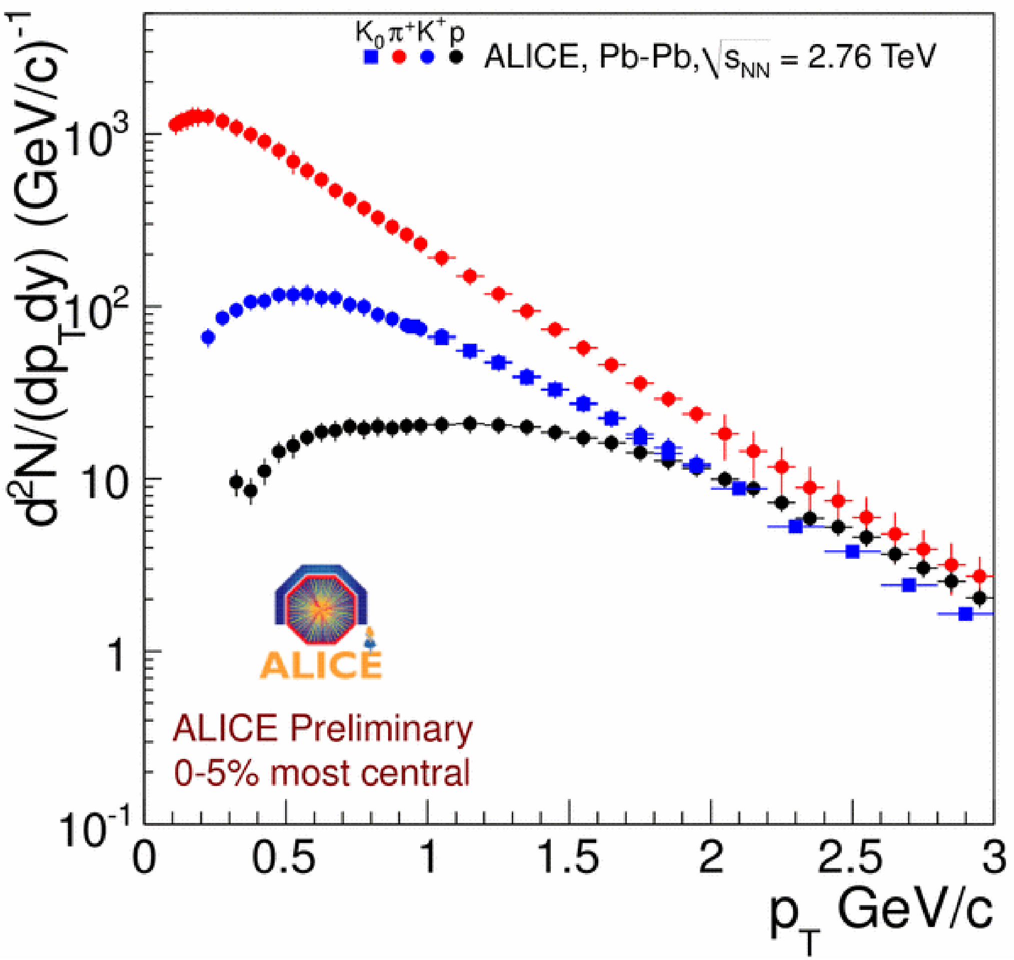
- good π/K separation up to 450 MeV/c
- good p/K separation up to about 1 GeV/c.



Identified particles spectra in Pb-Pb

- Combined results of different PID techniques
  - High p_T: TOF
  - Intermediate p_T: TPC
  - Low p_T (down to 100 MeV/c for pions): **ITS standalone tracks**





- Low p_T reach is very important for reducing the extrapolation of the yield down to p_T=0

  (extrapolation = 10% for π)

Conclusions

- ITS calibration and alignment
  - SPD SSD alignment along $r\phi$ ready since 2009
  - Alignment along z fixed in 2010 using SDD as a reference
  - SDD calibration/alignment parameters tuned with 2010 data: nominal resolution of ~30 μm along drift direction reached
  - Analyses with new SDD alignment parameters running now
- Vertexing and trackleting:
  - Good precision on vertex position (asymptotic limit $\rightarrow$ diamond size)
  - $dN_{ch}/d\eta$ and centrality measured using SPD tracklets
- Tracking and PID:
  - π, K, p identified in ITS down to very low momentum (p_t<100MeV for π)
  - Open charm mesons reconstructed in the hadronic decay channels down to low p_T bins

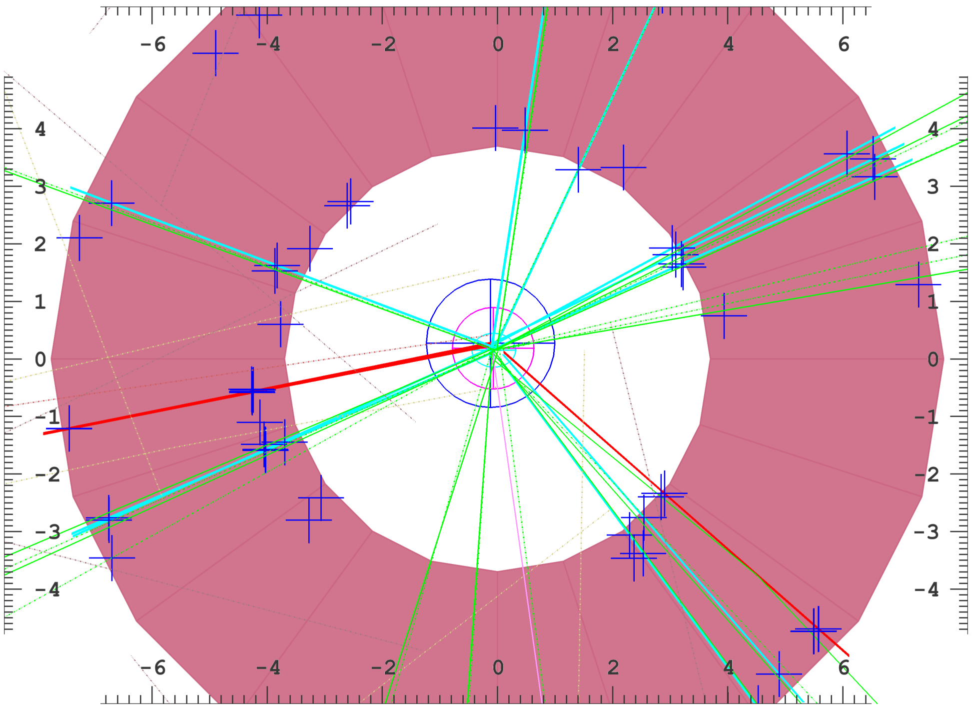
Back up

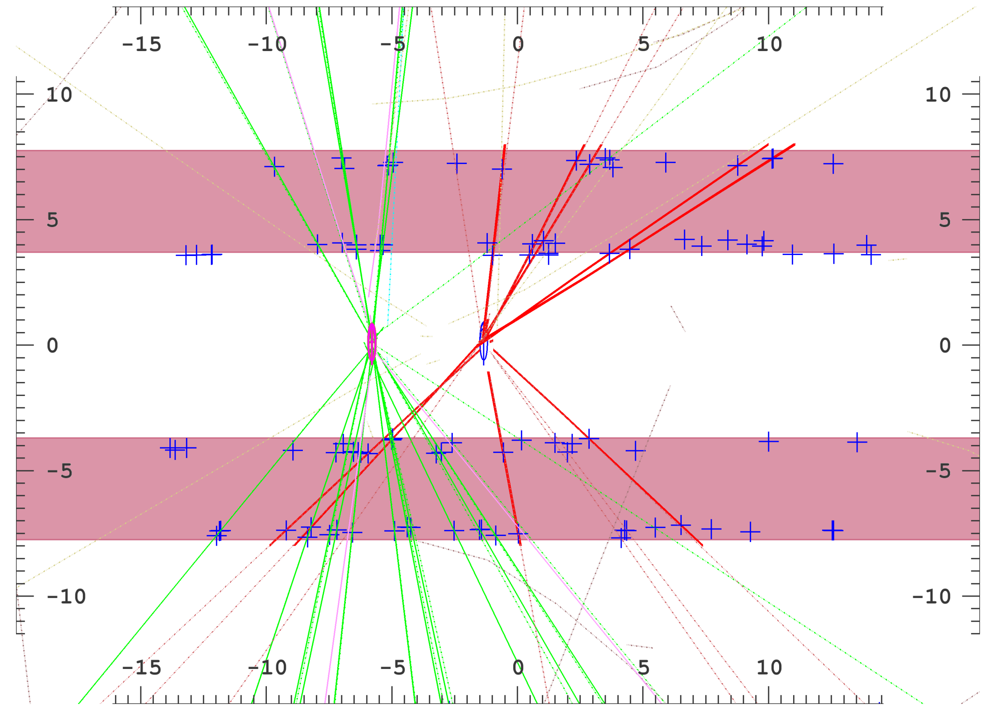
Pile-up tagging

Interactions occurring in a time window of 100 ns (4 bunch crossings) pile-up in the SPD

The SPD vertexer can be used to tag pile-up events

After finding the first vertex, the tracklets which are not pointing to this (“main”) vertex are used to check if there are other vertices originating particles

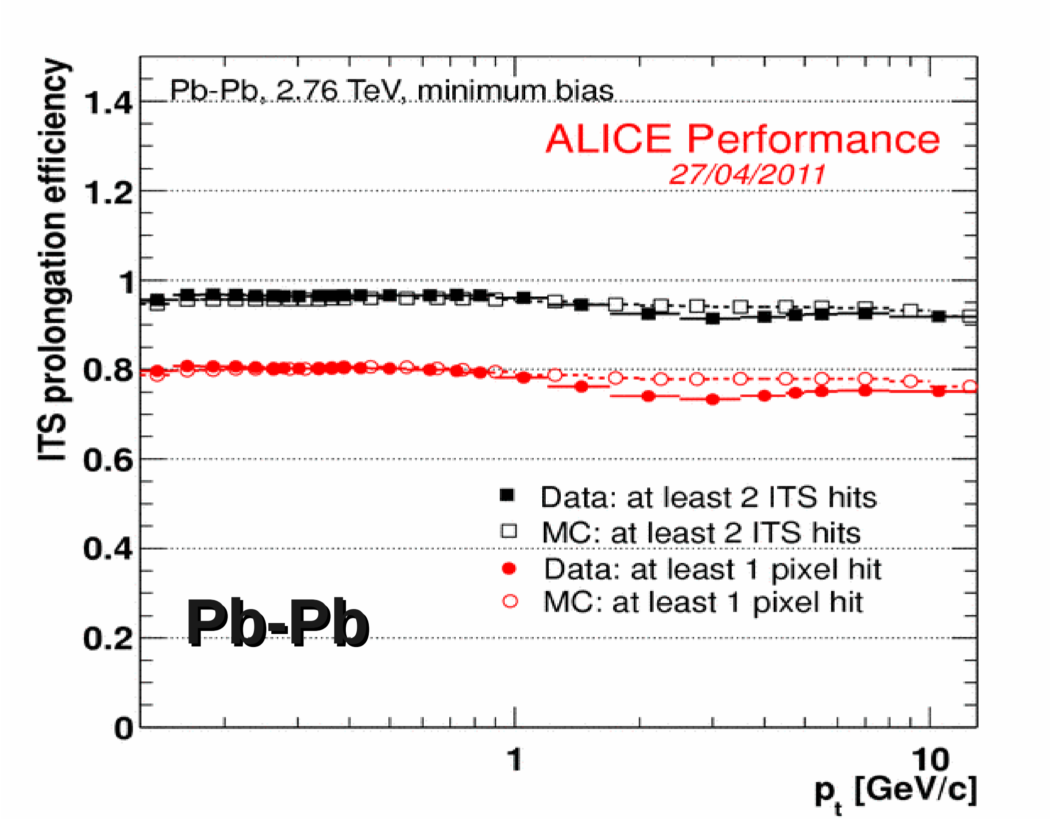


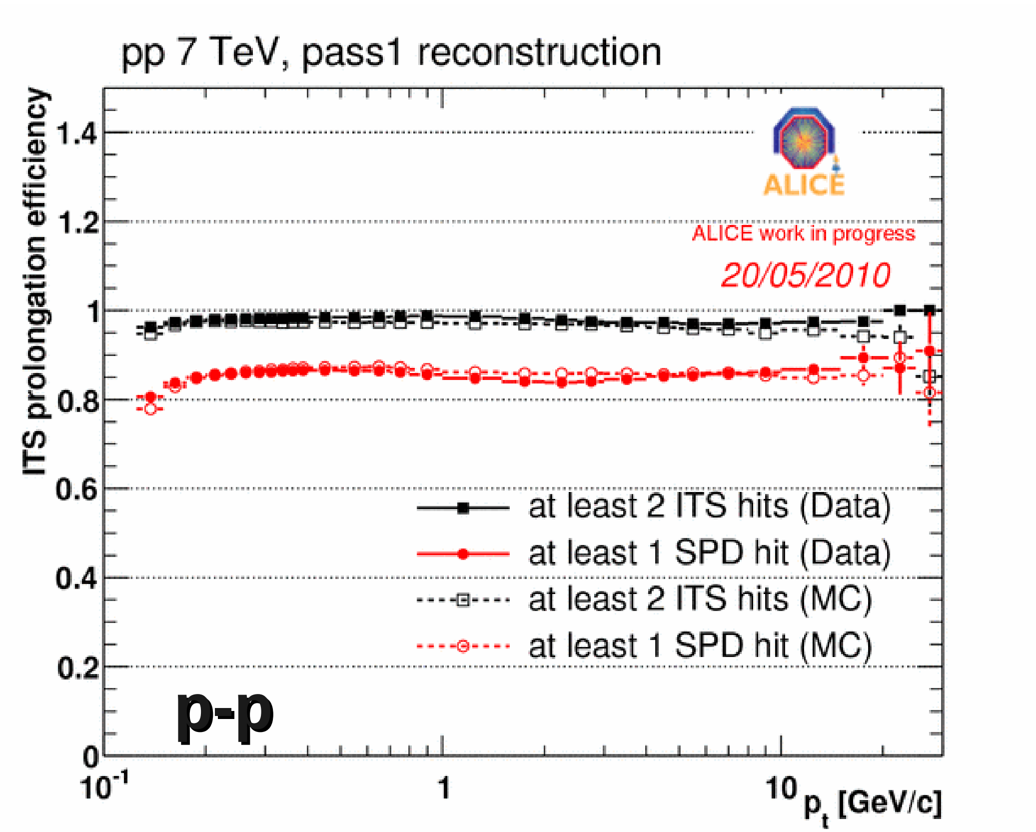


ITS tracks prolongation efficiency

Probability for the TPC track prolongation in ITS

- p-p and Pb-Pb data
- Different selection of clusters in the ITS → different efficiency 80-98%



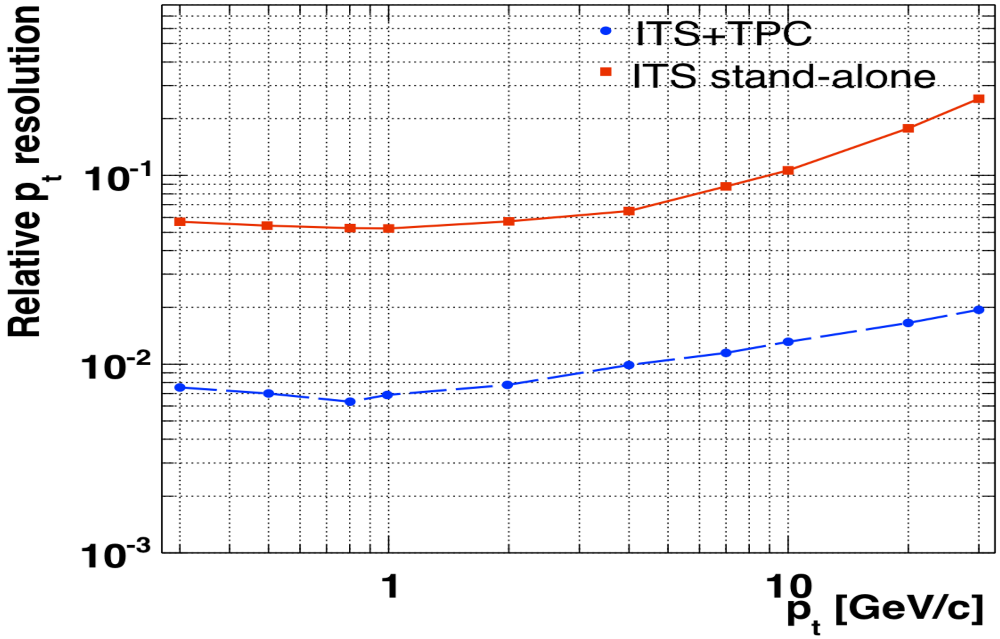


Lower efficiency if asking 1 point in SPD due to bad modules
Very good agreement between data and MC

Impact parameter and Momentum resolution

Transverse impact parameter resolution vs p_t for the ITS Standalone tracks reconstructed in pp collisions at 7 TeV and compared with the Monte Carlo results.

- ITS Standalone enables the tracking for very low momentum particles.



Comparison of the pt resolution for the standard ITS+TPC tracking and for the ITS stand-alone tracking as a function of p_t .

- ITS stand-alone resolution is worse by about an order of magnitude with respect to the TPC+ITS tracks.
- This is due both to the smaller lever-of-arm and to the limited number of points.

Outline

- ITS design goals
- Calibration and alignment: focus on SDD
- Vertexing with SPD
- Tracking in the barrel and with the ITS in standalone mode
- Particle identification
- Conclusions