2nd LHC Detector Alignment Workshop

ALICE
First Alignment Plans

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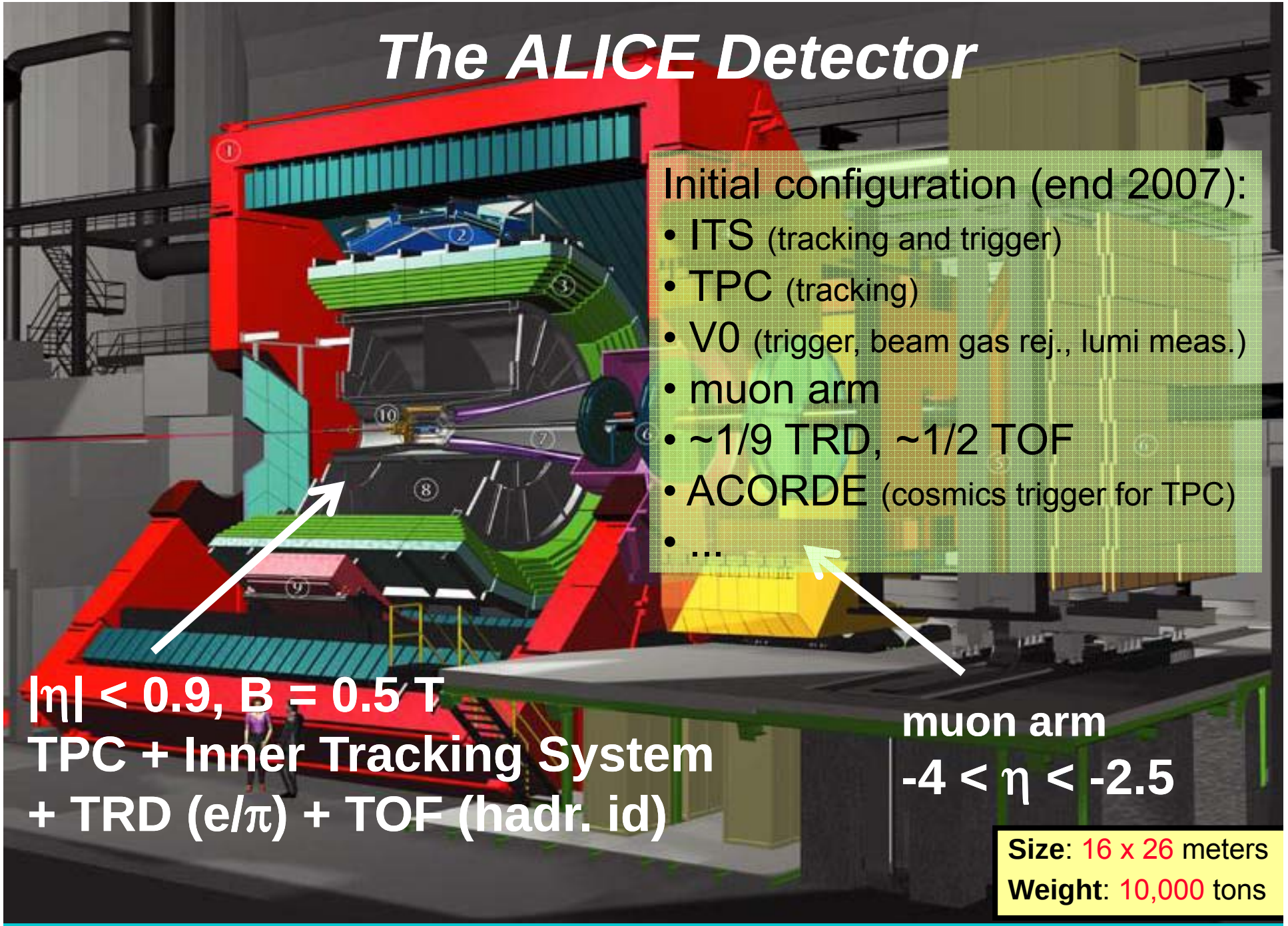
for the ALICE Collaboration

Contents

- ALICE detector layout for first data (end 07)
- Plans for first alignment (cosmics and first pp)
  - Inner Tracking System (ITS)
  - Outer barrel detectors (TPC)
  - Relative alignment of ITS and TPC
  - Muon spectrometer
- Summary

The ALICE Detector



Initial configuration (end 2007):

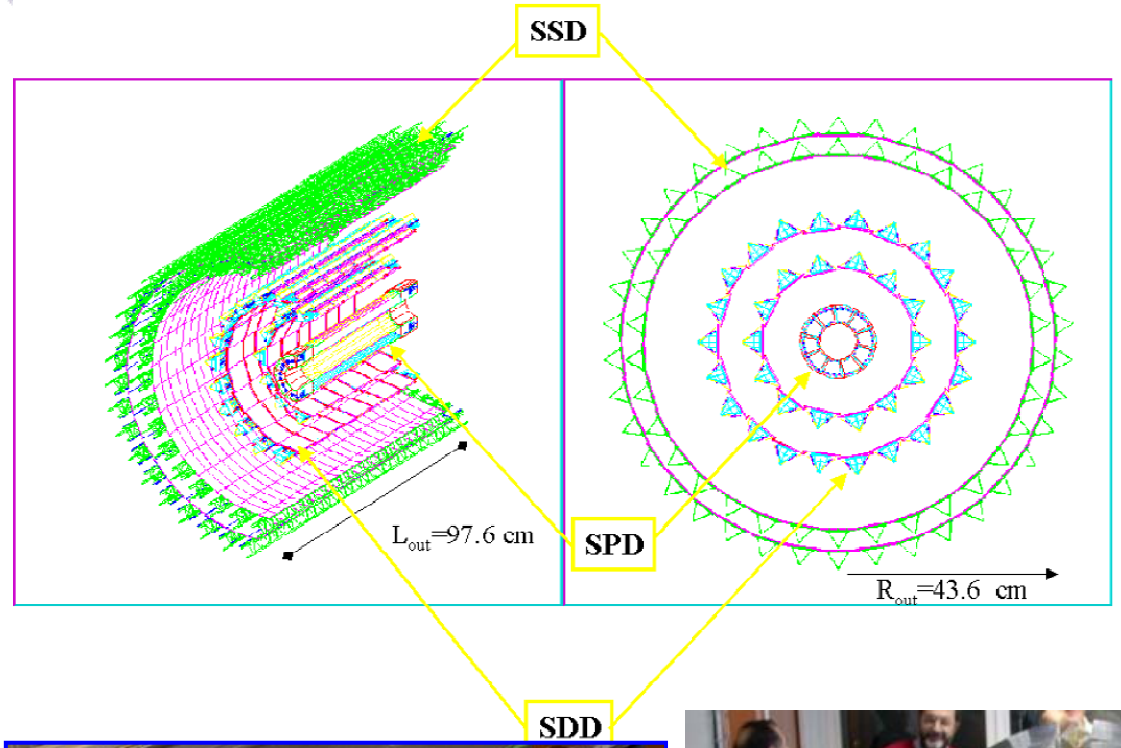
- ITS (tracking and trigger)
- TPC (tracking)
- V0 (trigger, beam gas rej., lumi meas.)
- muon arm
- ~1/9 TRD, ~1/2 TOF
- ACORDE (cosmics trigger for TPC)
- ...

|η| < 0.9, B = 0.5 T
TPC + Inner Tracking System
+ TRD (e/π) + TOF (hadr. id)

muon arm
-4 < η < -2.5

Size: 16 x 26 meters
Weight: 10,000 tons

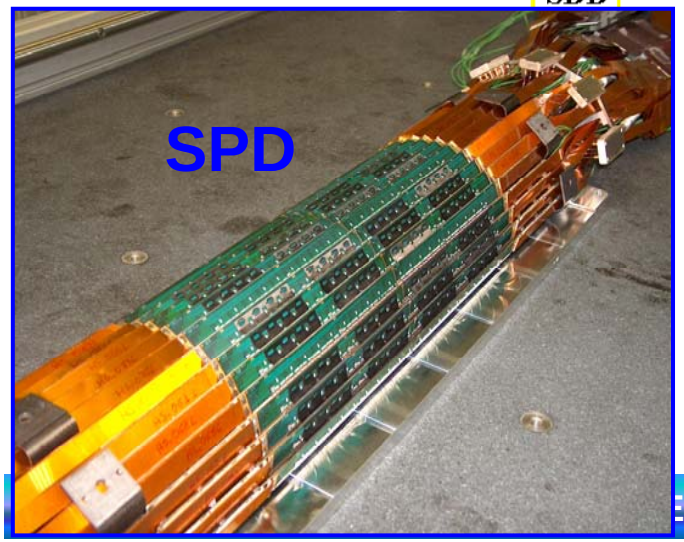
Inner Tracking System (ITS)

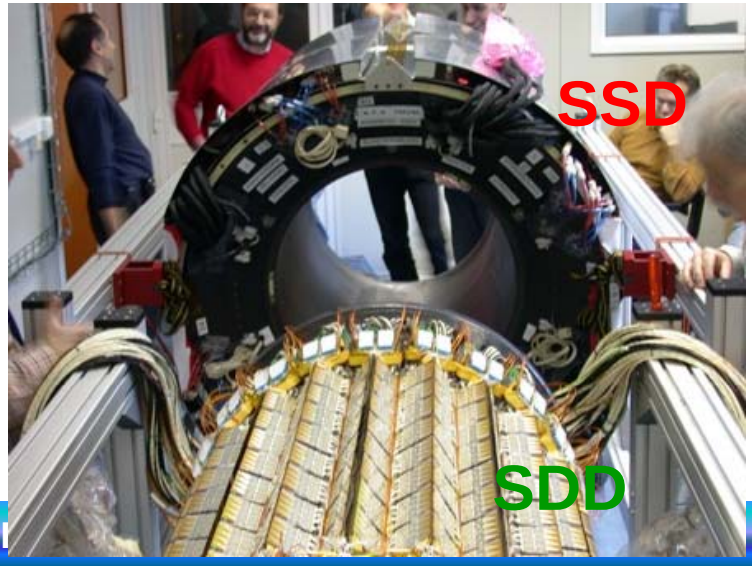


Silicon Pixel Detector (SPD):
- ~10M channels
- 240 alignable vol. (60 ladders)

Silicon Drift Detector (SDD):
- ~133k channels
- 260 alignable vol. (36 ladders)

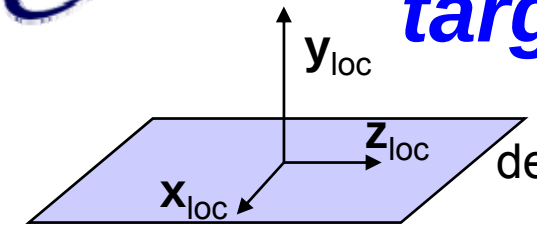
Silicon Strip Detector (SSD):
- ~2.6M channels
- 1698 alignable vol. (72 ladders)





ITS total:
2198 alignable sensitive volumes
→ 13188 d.o.f.

ITS detector resolutions & target alignment precisions



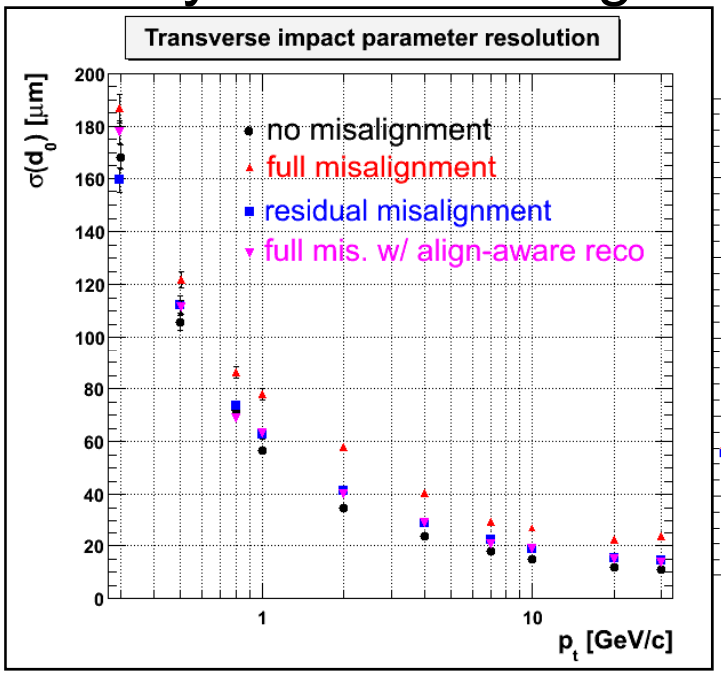
detector local c.s.: $x_{loc} \sim r\phi_{glob}$, $y_{loc} \sim r_{glob}$, $z_{loc} = z_{glob}$

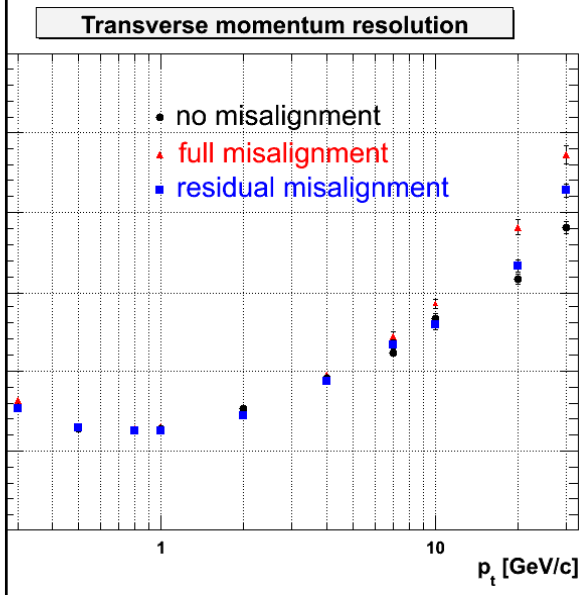
	SPD (r = 4 & 7 cm)	SDD (r = 14 & 24 cm)	SSD (r = 39 & 44 cm)
nom. resolutions $x_{loc} \times z_{loc}$ **[μm²]**	**12 × 120**	**38 × 20**	**20 × 830**
full mis. (shifts) $x_{loc} \times y_{loc} \times z_{loc}$ [μm³]	20 × 20 × 20	45 × 45 × 45	30 × 30 × 100
residual mis. (shifts) $x_{loc} \times y_{loc} \times z_{loc}$ **[μm³]**	**10 × 10 × 20**	**20 × 20 × 20**	**15 × 15 × 100**
rotations (mrad) around $x_{loc}, y_{loc}, z_{loc}$	0.3	0.3	0.3

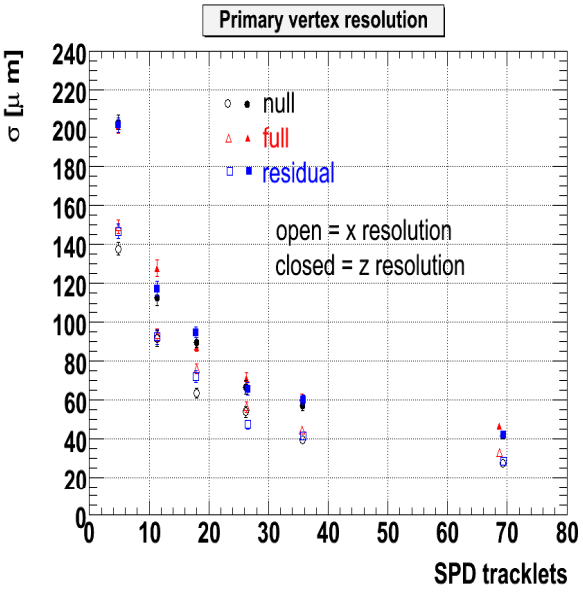
- Full: initial misalignments as expected from the mechanical imprecision after installation, actually set to 20-45 μm at the sensor level, probably higher at the ladder or layer level (~100 μm)
- **Residual:** expected misalignment left after applying the realignment machinery, taken ~0.7×resol. → ~20% degradation of the resolution

Impact of ITS misalignment on tracking performance

- Track impact parameter (d_0) resolution is crucial for the rich heavy flavour program of ALICE (in pp and Pb-Pb)
- Effect of misalignment on d_0, p_t, vertex resolutions studied by reconstructing misaligned events with ideal geometry







Alignment awareness of the reconstruction tested by reconstructing misaligned events with the input misaligned geometry

ITS: first alignment with tracks

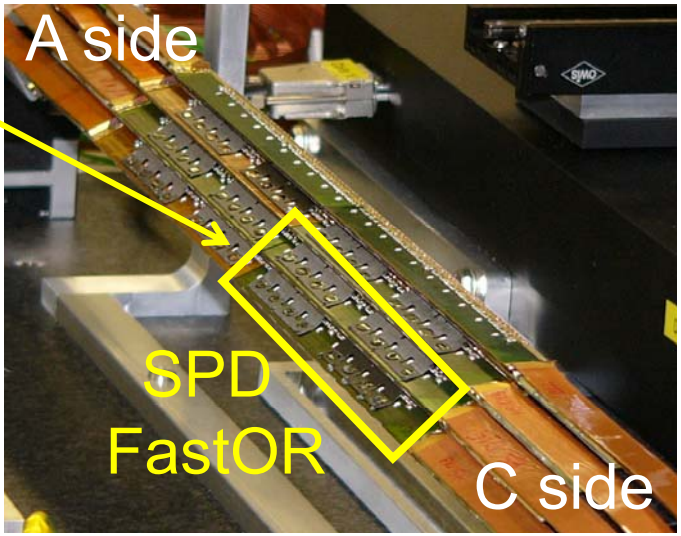
- Data sets: cosmics + first pp collisions (and beam gas)
  - use cocktail of tracks from cosmics and pp to cover full detector surface and to maximize correlations among volumes
- Start with B off, then switch on B (0.5 T for barrel → possibility to select high-momentum tracks for alignment)
- **General strategy** (not yet finalized)**:**

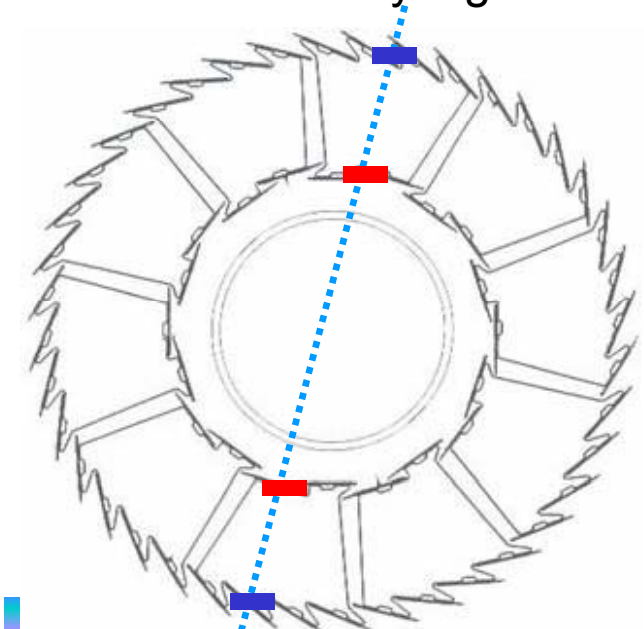
  1) start with layers easier to calibrate: pixels and strips
     - good resol. in rϕ (12-20μm), worse in z (120-830μm)
     - ITS z resol. provided by drifts anode coord. (20μm) → easily calibrated → can be included from the beginning in alignment chain
  2) global ITS alignment relative to TPC (already internally aligned)
  3) finally, inclusion of silicon drifts (drift coord: rϕ), which probably need longer calibration (interplay between alignment and calibration)

- **Track-based alignment methods** (work in progress)**:**
  - local: iterative method based on residuals minimization
  - global: Millepede 1 (already ported to ALICE for muon arm alignment)

Preparation for cosmics data (1)

- Expected muon rate through ITS inner layer (~200cm^2, ~40m underground): ~0.02 Hz (→ ~10^4 μ/week)
- Trigger on cosmics (for ITS alignment) with SPD layers:
  - FastOR (FO) of the 20 chips on 2 half-staves
  - For each half-barrel (A side, C side):
    - 20 FOs outer layer, 10 FOs inner layer
    - Any logic combination of these 30 FOs





- Option being considered for cosmics:

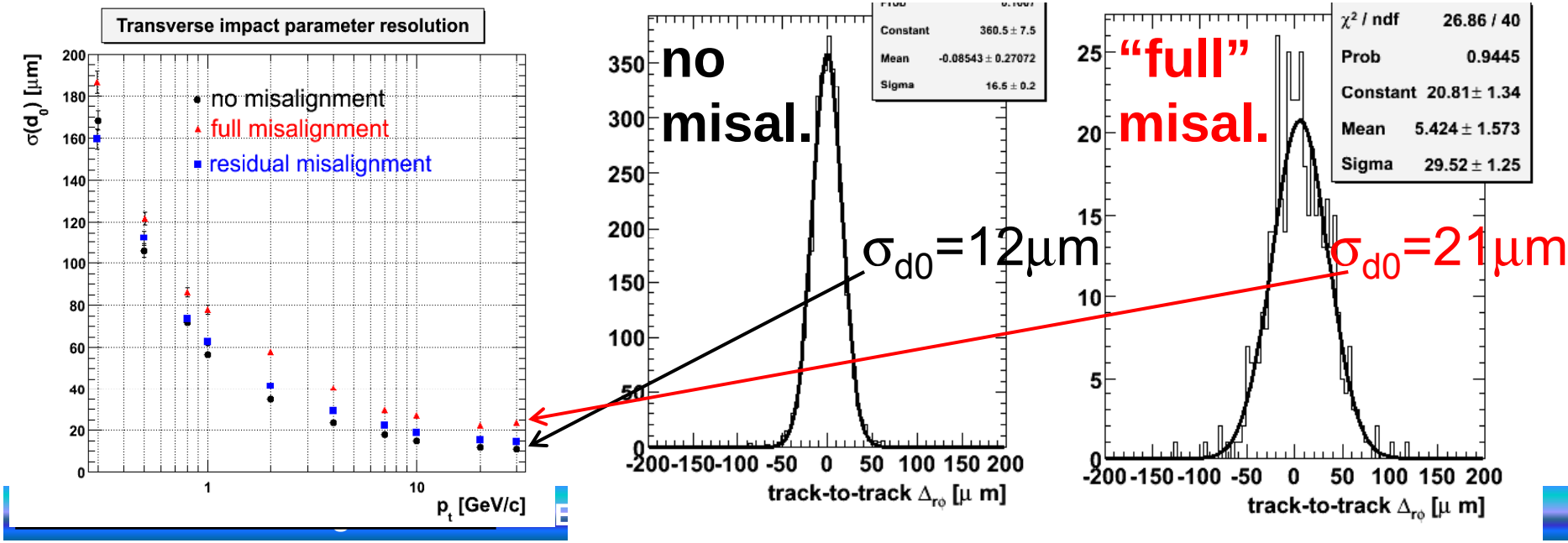
Double Layer coincidence (≥2FOs inn layer & ≥2FOs out layer)

purity (fraction with 1 μ with 4 SPD hits): ~97%,

inefficiency (fraction of lost μ with 4 SPD hits): ~19%

Preparation for cosmics data (2)

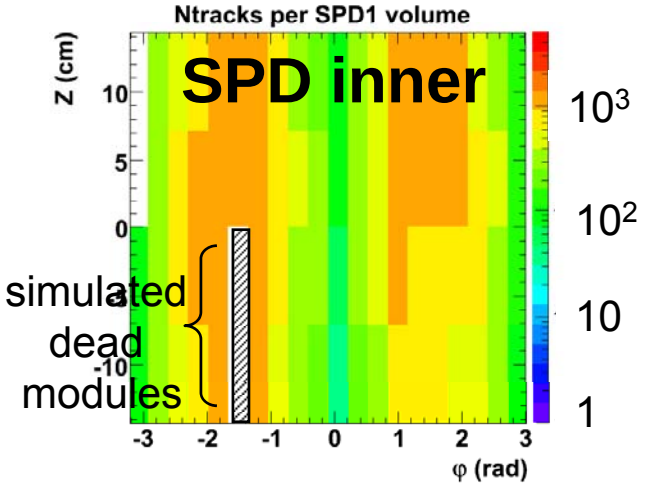
- Cosmics at ALICE: p > 10 GeV/c, <p>~20 GeV/c (Hebbeker, Timmermans, 2001)
- Cosmics tracking in ITS:
  - stand-alone ITS tracking (cluster-grouping algo), starting from
  - "fake" vertex built from the two tracklets in inner two layers
  - 98% efficiency (12 points, 6inward+6outward) for muons that leave 12 hits, with B=0 and B=0.5T
  - tracks prolongation from TPC to ITS being optimized for cosmics
- Preparing first d_0 resolution meas. by cosmics two-track matching

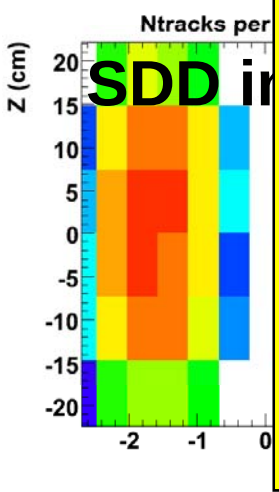


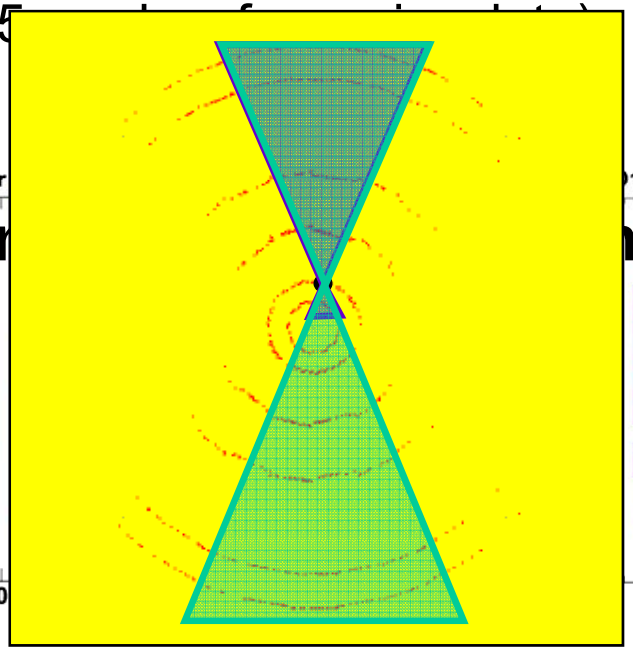
Cosmics in the ITS

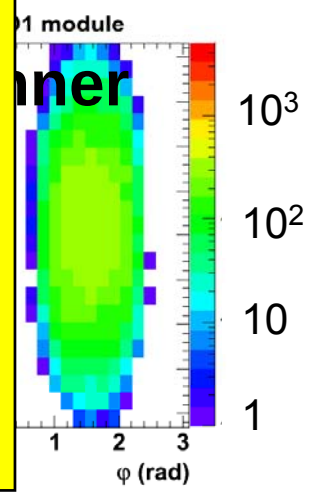
A.Rossi

- 50k μ's through inner ITS layer (~5
- Track multiplicity per module:



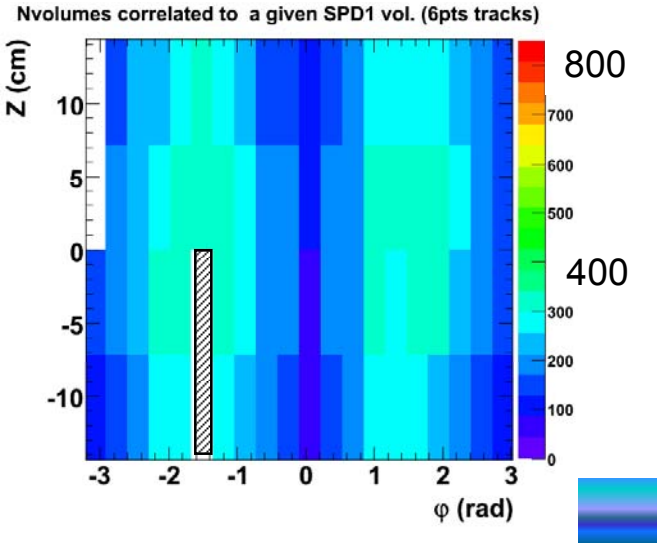




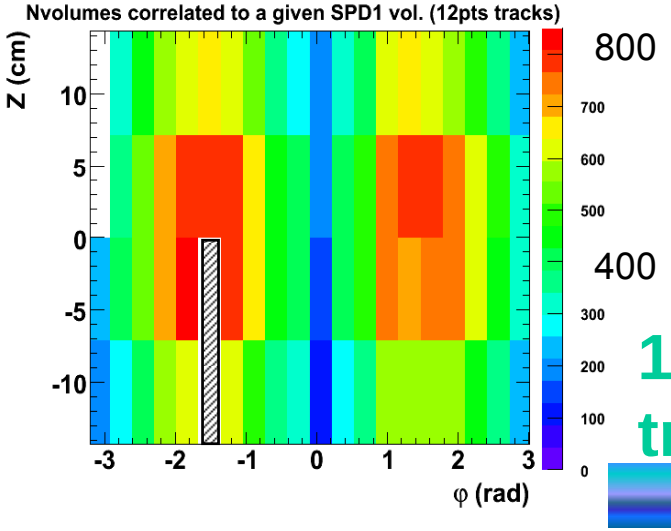


- Volume correlations. Number of modules correlated to a given module:

SPD inner



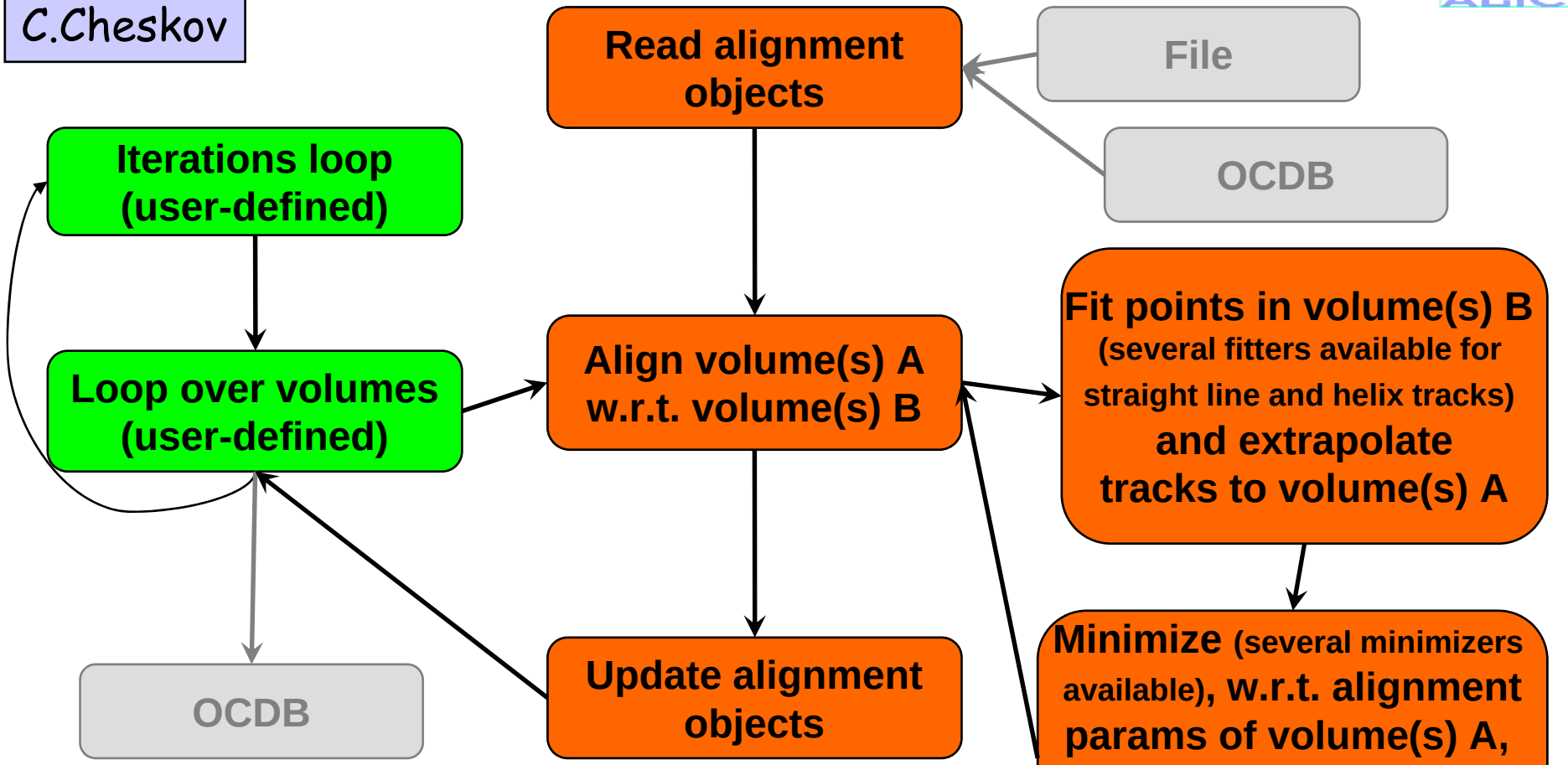
6 pts tracks



12 pts tracks

ITS alignment with tracks: local

C.Cheskov

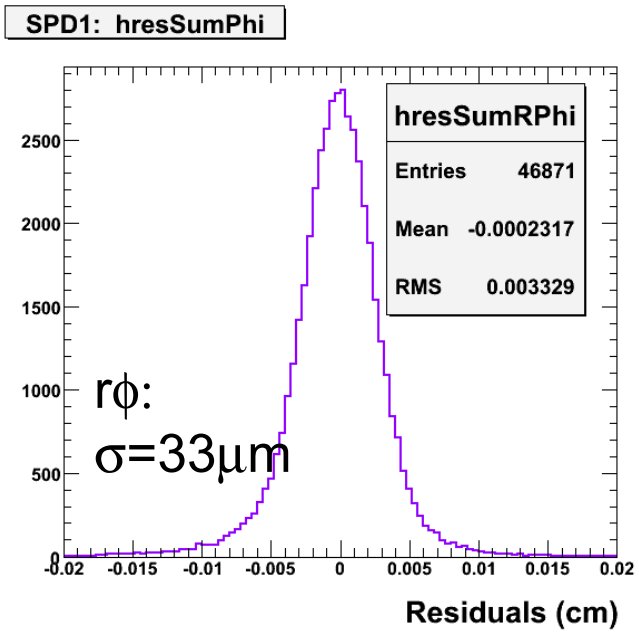


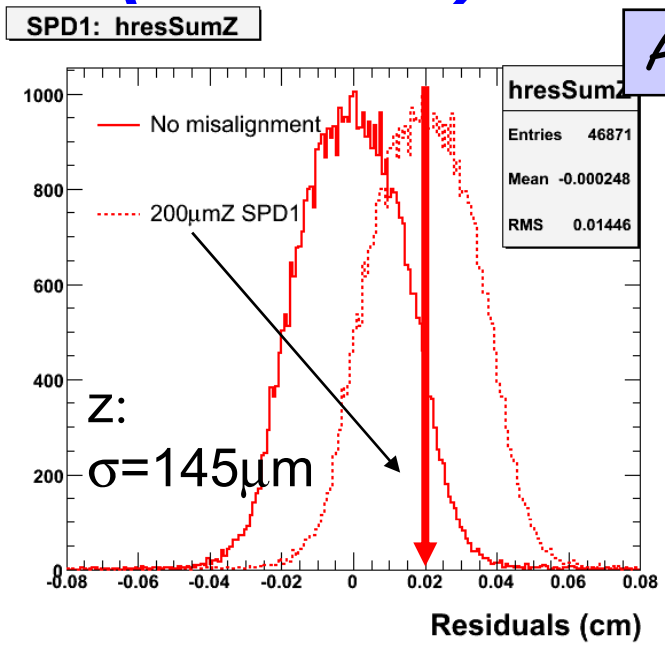
see talk by R.Grosso

ITS alignment with tracks: local
- First look at residuals (Cosmics) -

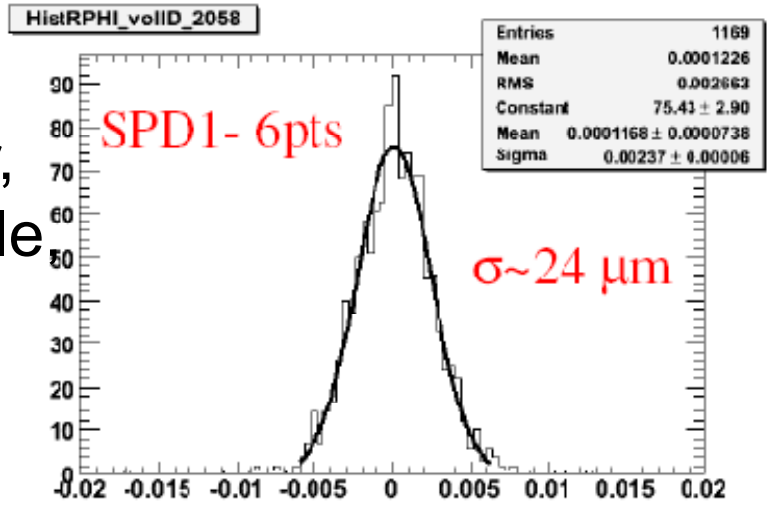
A.Rossi

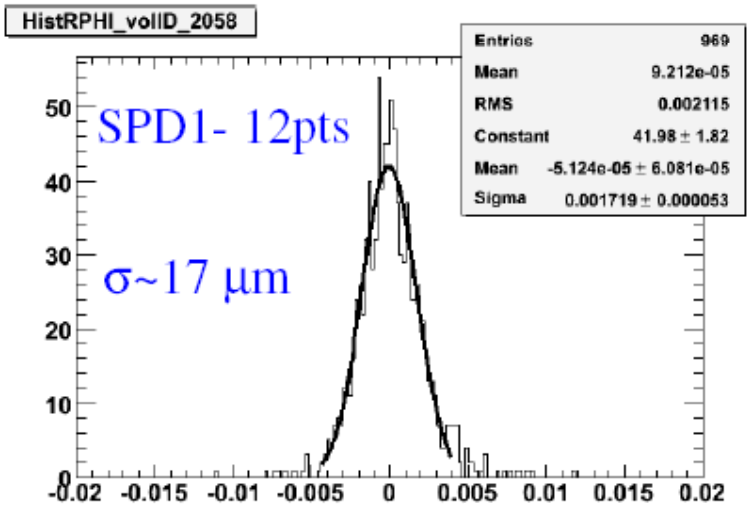
SPD inner, all modules





SPD inner, one module rϕ

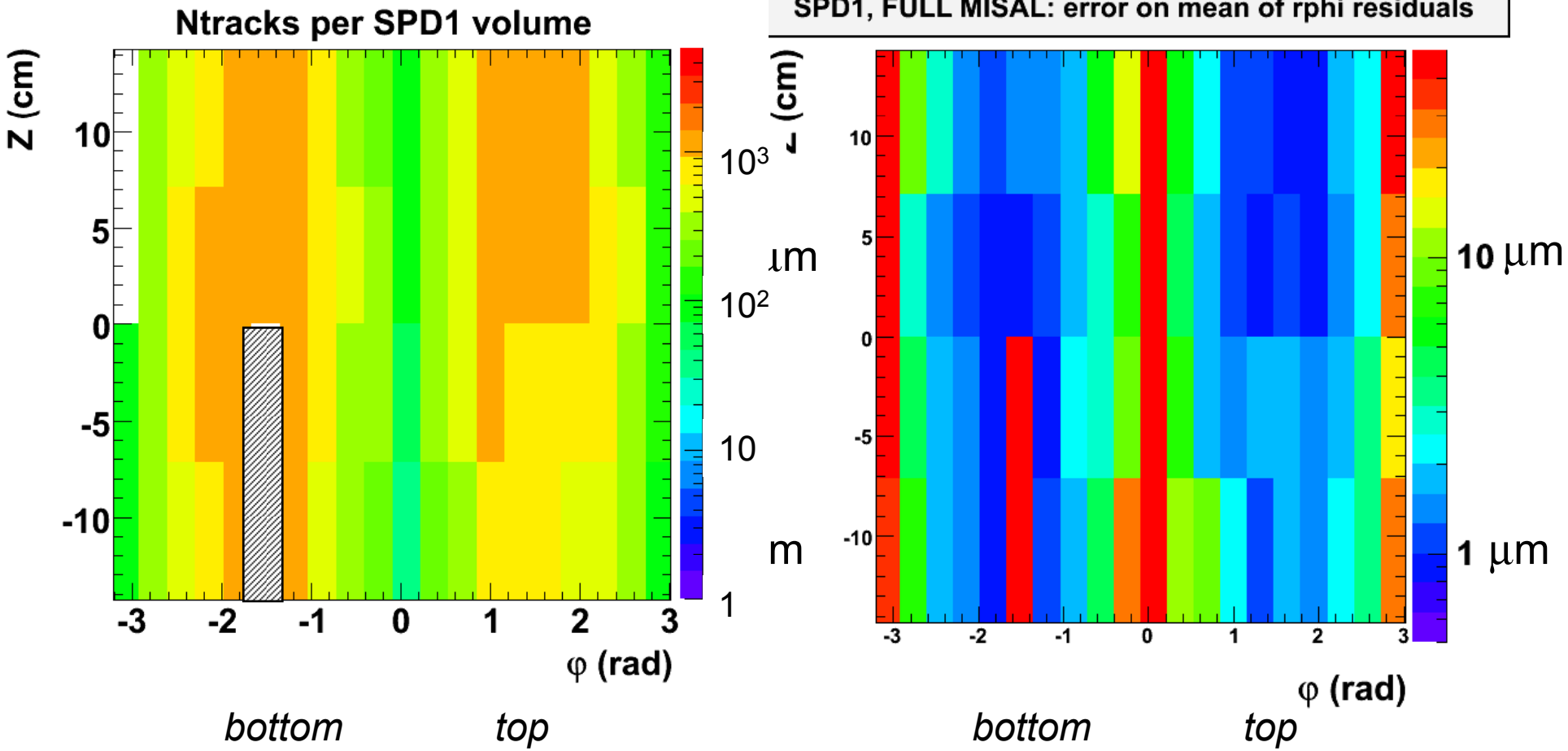




ITS alignment with tracks: local
- First look at residuals (Cosmics) -

A.Rossi

SPD inner layer: error on the centroid of rϕ residuals, about 5 weeks of cosmics



ITS alignment with tracks: Millepede

M.Lunardon, S.Moretto

- (Well-known) Millepede principle: the measured value (points coords) can be expressed as a linear (→small deviations) function of the global (d_i, align. params) and local (δ_i, track params) parameters

$$z = \underbrace{a_1 \cdot d_1 + a_2 \cdot d_2 + \ldots a_n \cdot d_n}_{\text{global parameters}} + \underbrace{\alpha_1 \cdot \delta_1 + \alpha_2 \cdot \delta_2 + \ldots \alpha_\nu \cdot \delta_\nu}_{\text{local parameters}} = \sum_{i=1}^{n} a_j \cdot d_j + \sum_{j=1}^{\nu} \alpha_j \cdot \delta_j$$

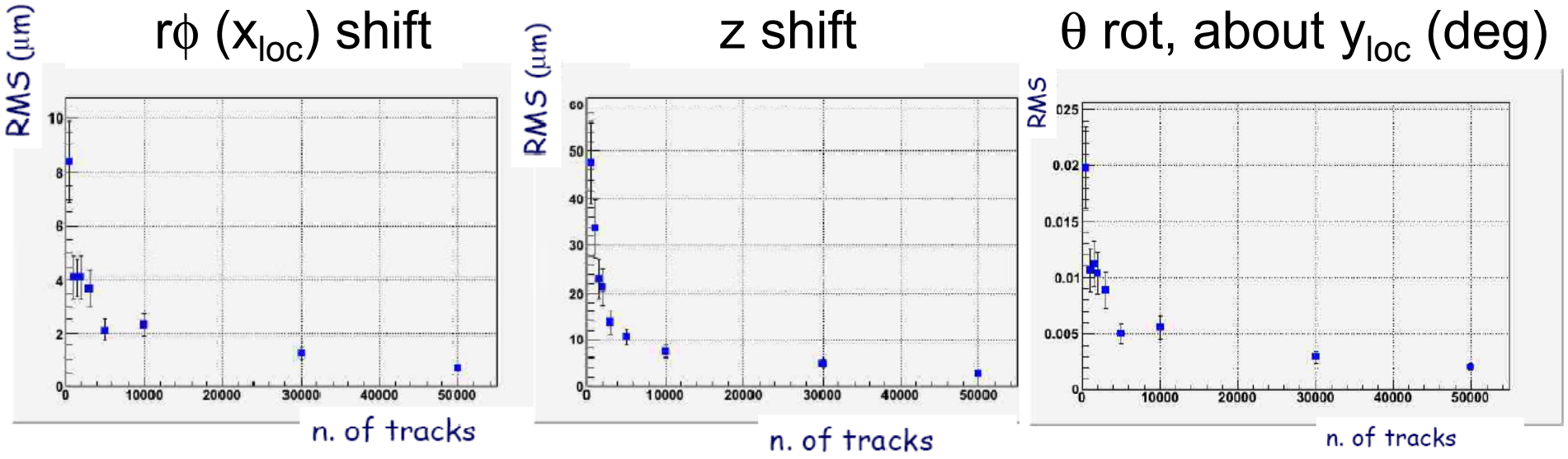
- ITS implementation:
  - use AliMillepede class (Millepede1 ported to ALICE for muon arm)
  - configuration (text file): list of modules to be aligned, constraints, initial geometry
  - tracks as lists of points (AliTrackPointArray)
  - setting equations:
    - reference track with simple linear fit (starting with B=0)
    - evaluation of residuals w.r.t. reference track
    - derivatives of residuals w.r.t. local and global params, numerically (ROOT TF1)

ITS alignment with tracks: Millepede
- First tests -

M.Lunardon, S.Moretto

- Set of cosmic-like tracks crossing a small number of modules (4 SPD modules, 8 SDD modules, 4 SSD modules), with 3 d.o.f. per module (2 shifts, 1 rotation): total of 16×3 d.o.f.

RMS of ($Par_{Millepede}$ – Par_{Input}) vs. # of used tracks



- Promising first results: reach the level of residual misalignment with <1k cosmics tracks (few weeks)

Time Projection Chamber: first alignment with laser, cosmics, pp

M.Ivanov

Readout chambers:

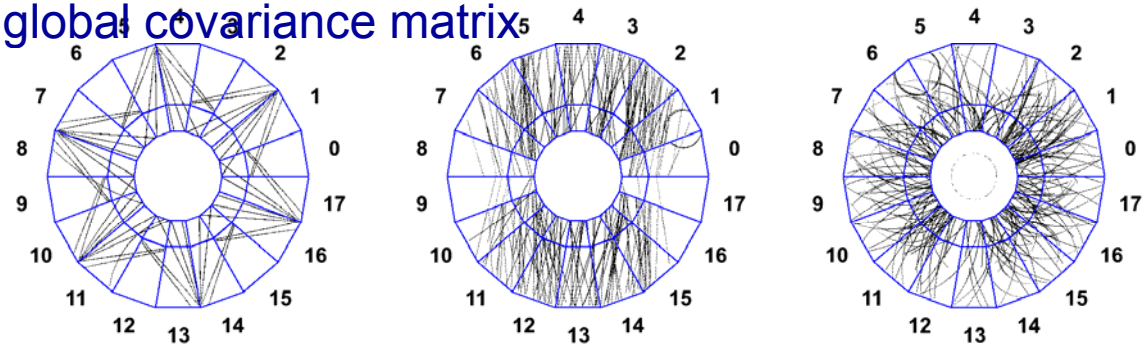
18 + 18 inner chambers

18 + 18 outer chambers

72 volumes to be aligned

- Alignment requirements: given by precision of track parameters (high-p_t tracks)
  - rϕ , z ~ 100 μm
  - ϕ, θ ~ 0.1 mrad
- Alignment strategy:
  1. Align all inner to outer chambers
  2. Align adjacent sectors

Laser, cosmics, collisions populate different parts of the global covariance matrix



Requirements achieved with:

~240k laser tracks

~200k cosmic tracks

(few hours at ~30 Hz)

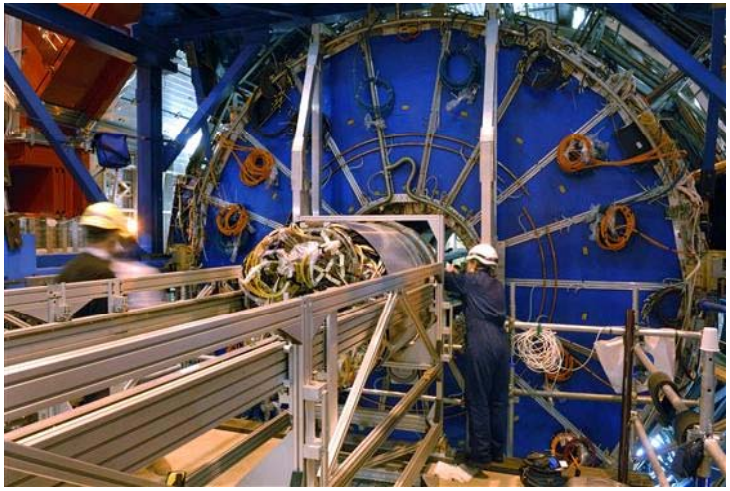
~15k pp events

But, *TPC calibration (E×B!) much more challenging...*

ITS-TPC relative alignment

M.Krzewicki

- Relative alignment of ITS and TPC (3 shifts + 3 angles) with straight tracks (including cosmics)
- Alignment requirements: given by TPC resolutions:
  - shifts: ~100 μm
  - angles: ~0.1 mrad
- Method (under development):
  - Assume that TPC and ITS are already internally aligned and calibrated
  - Use independently fitted tracks in the ITS and the TPC
  - **Alignment params are estimated by a Kalman filter algorithm**

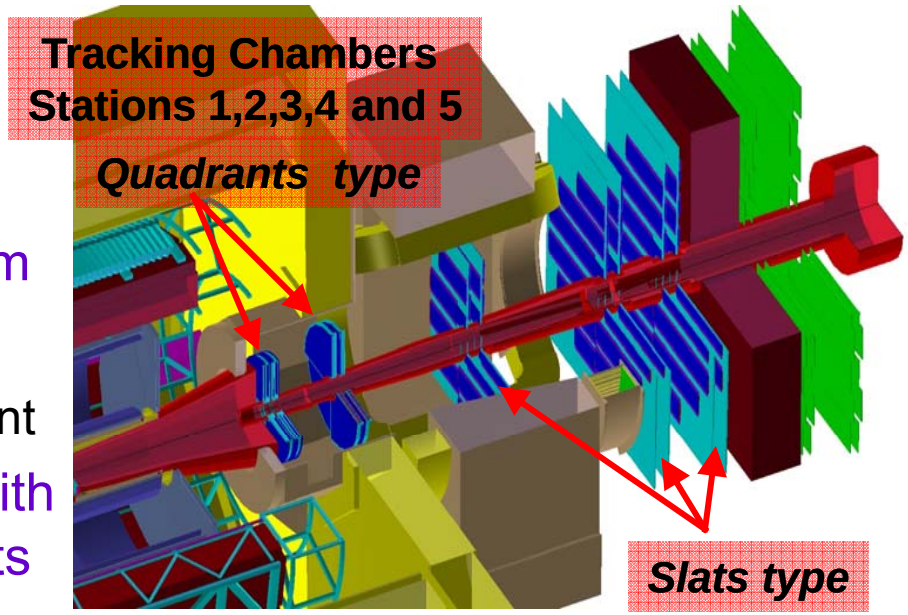


MUON spectrometer

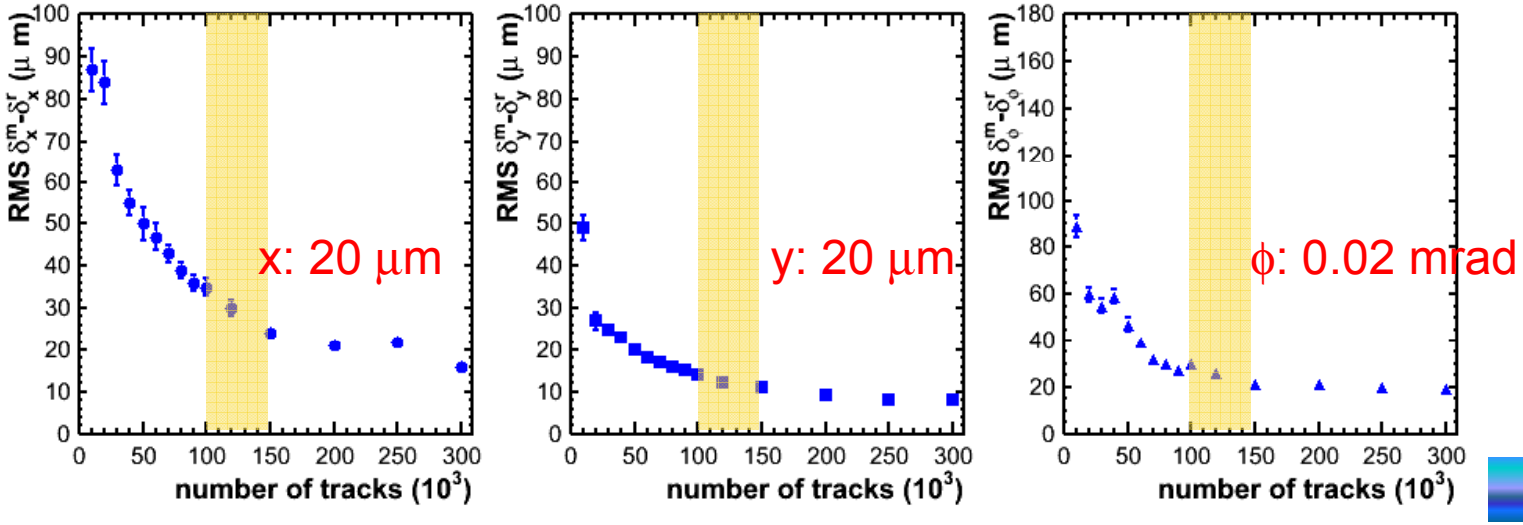
J.Castillo et al.

see also talk by R.Tieulent

- Expected mounting precision (survey+photogrammetry):
  - chambers x,y,z ~ 1 mm
  - detection elements x,y,z ~ 500 μm
- Alignment requirements: x, y < 50 μm
- Geometrical Monitoring System:
  - chambers x,y,z ~ 20 μm → R.Tieulent
- Track-based (need pp!) alignment with Millepede1 for the detection elements



B=0



Summary

- ALICE first alignment plans being defined
- Track-based alignment algorithms
  - ***common framework for barrel tracking detectors***
    - extract track points, fit tracks, handle & minimize residuals
  - ***local iterative approach*** expected to be ok for big detectors with limited number of volumes (***TPC, TRD***)
  - more challenging is ***ITS***: 3 Si-detector types, > 2000 volumes, high precision required
    - ***local iterative method***
    - ***Millepede1 (global)***
  - ***muon arm:*** well advanced (***Millepede1, need pp events***)
- Getting ready for cosmics run (end 07)
  - trigger strategies
  - adapting/optimizing tracking for cosmics events

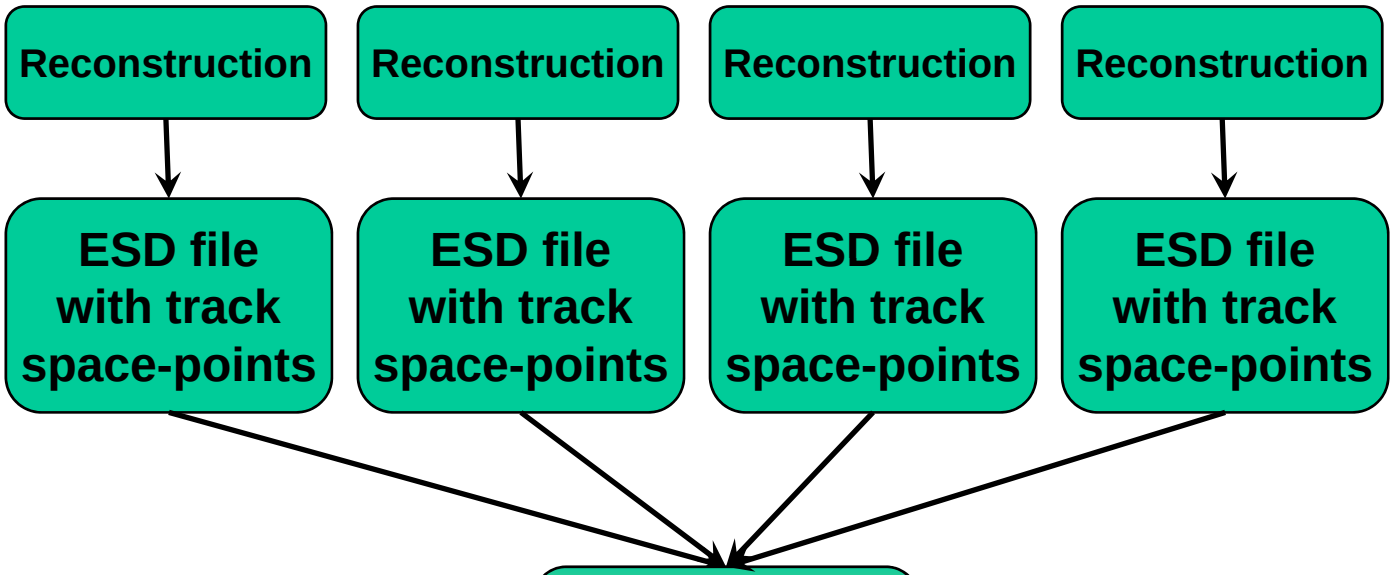
thanks to A.Jacholkowski, R.Grosso, R.Silva & all ali(ce)gners

EXTRA SLIDES

LHC running conditions (ALICE)

Pb-PB nominal run	pp nominal run
$\int L dt = 5.10^{26}\ cm^{-2}\ s^{-1} \times 10^{6}\ s$	$\int L dt\ dt = 3.10^{30}\ cm^{-2}\ s^{-1} \times 10^{7}\ s$
$5.10^{32}\ cm^{-2}$ PbPb run, 5.5 TeV	$5.10^{37}\ cm^{-2}$ for pp run, 14 TeV
$N_{PbPb\ collisions} = 2 .10^{9}$ collisions	$N_{pp\ collisions} = 2 .10^{12}$ collisions
Muon triggers: ~ 100% efficiency, ~ 1kHz	Muon triggers: ~ 100% efficiency, < 1kHz
Electron triggers: Bandwidth limitation	Electron triggers: ~ 50% efficiency of TRD L1
$N_{PbPb\ central} = 2 .10^{8}$ collisions	20 physics events per event
Hadron triggers:	Hadron triggers:
$N_{PbPb\ central} = 2 .10^{7}$ collisions	$N_{pp\ minb} = 2 .10^{9}$ collisions

Track-based alignment in the barrel
- Framework Overview -



C.Cheskov

see talk by R.Grosso

Distributed

Local

Entire process from
ESD → align.consts → OCDB controlled by AliAlignmentTracks steering class

Iterative residuals minimization
Millepede
...