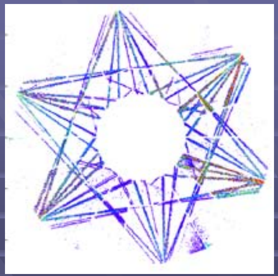


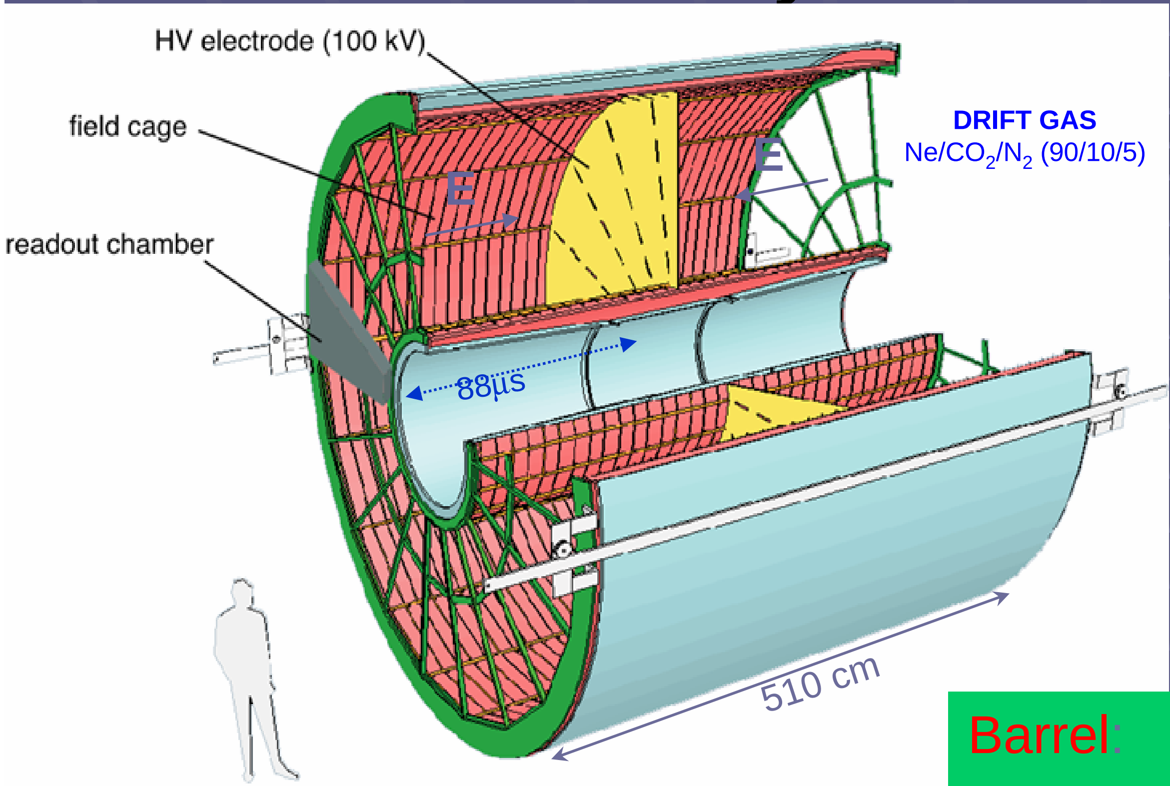
ALICE outer barrel alignment

Contents:

- TPC Alignment strategy
- Data samples
- Alignment algorithm
- Results

Marian Ivanov

Time Projection Chamber



Readout plane segmentation
18 trapezoidal sectors
each covering 20 degrees in azimuth

TPC (the largest ever build):
88 m^3 , 510 cm length, 250 cm radius
Ne (90%) + CO_2 (10%)
88 µs drift time
159 pad rows
570312 pads - channels
main tracking device, dE/dx

Barrel: 18 + 18 inner sectors
18 + 18 outer sectors
72 volumes to be aligned
Channel size: 4mm x 7.5 mm (inner)
6mm x 10.0 (15.0) (outer)
Single hit resolution: ~ 1mm
Hits per track: ~ 63 inner sector
~ 96 outer sector

TPC alignment - Requirements

- The positioning of detector elements should be known on the level better than precision of track parameters under ideal condition (only stochastic processes, no systematic effects).
- High momenta tracks >20 GeV, inner volume of the TPC
  - Sigma y ~ 0.1 mm
  - Sigma z ~ 0.1 mm
  - Sigma theta ~ 0.2 mrad
  - Sigma phi ~ 0.2 mrad

Fast simulation study (no multiple scattering, energy loss, homogenous magnetic field) - given precision obtained using sample of ~ 2000 tracks per sector
Current TPC commissioning data with 2 sectors connected at once – indication relative alignment ~ 100 microns
TPC data with all sectors connected will be available in March 2007

Track based alignment for ALICE TPC

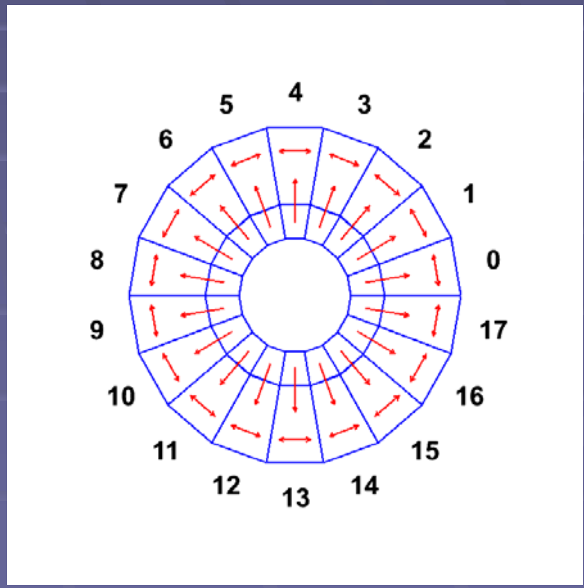
- Strategy:
  1. Relative alignment of pairs of sectors – minimization of the chi2 distance between track extrapolation from sector k to space point at sector i (Kik)
  2. Find the set of correction constants Ci for each sector

$$K_{ik}\, I_i X_{li} - I_k X_{lk} = 0$$

$$K_{ik} = C_k^{-1} C_i$$

$$X_g = C_i\, I_i X_{li}$$

$$C_i\, I_i X_{li} - C_k\, I_k X_{lk} = 0$$



•K and C transformation

•Currently - 6 alignment parameters

•3 translations δx δy δz

•3 (small) rotations αx αy αz

Residuals minimization

- Fast **linear minimization**:
  - Assume small mis-alignment rotation angles:
    $\Rightarrow$ linear transformation
  - Sufficient precision assuming angles ~mrad
- What we minimize:

$$\chi^2 = \sum \left(\vec{r}_{te} - \vec{r}_{sp} - T(\vec{r}_{sp})\,\vec{p}\right)^T \left(V_{te} + V_{sp}\right)^{-1} \left(\vec{r}_{te} - \vec{r}_{sp} - T(\vec{r}_{sp})\,\vec{p}\right)$$

where:

'te' – track extrapolation point;

'sp' – space-point at point;

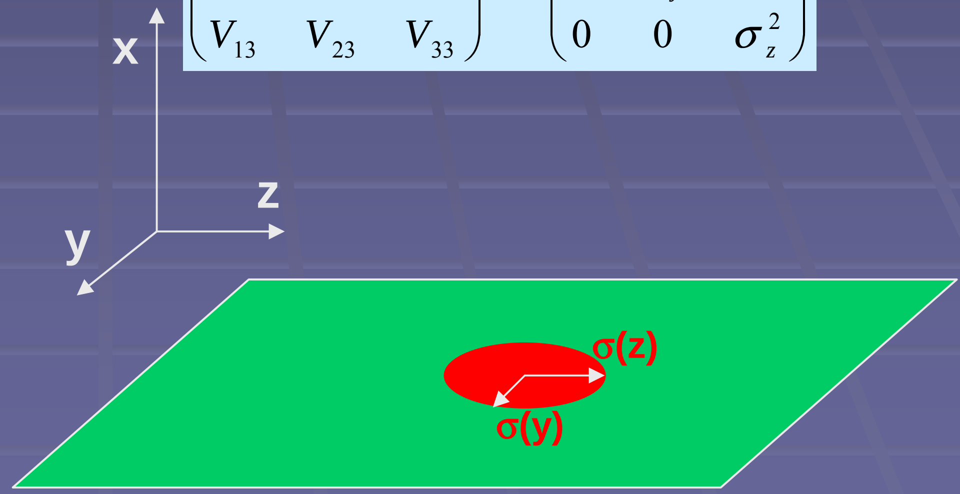
'p' - vector of transformation parameters

(3 translation, 3 rotation)

Space-points

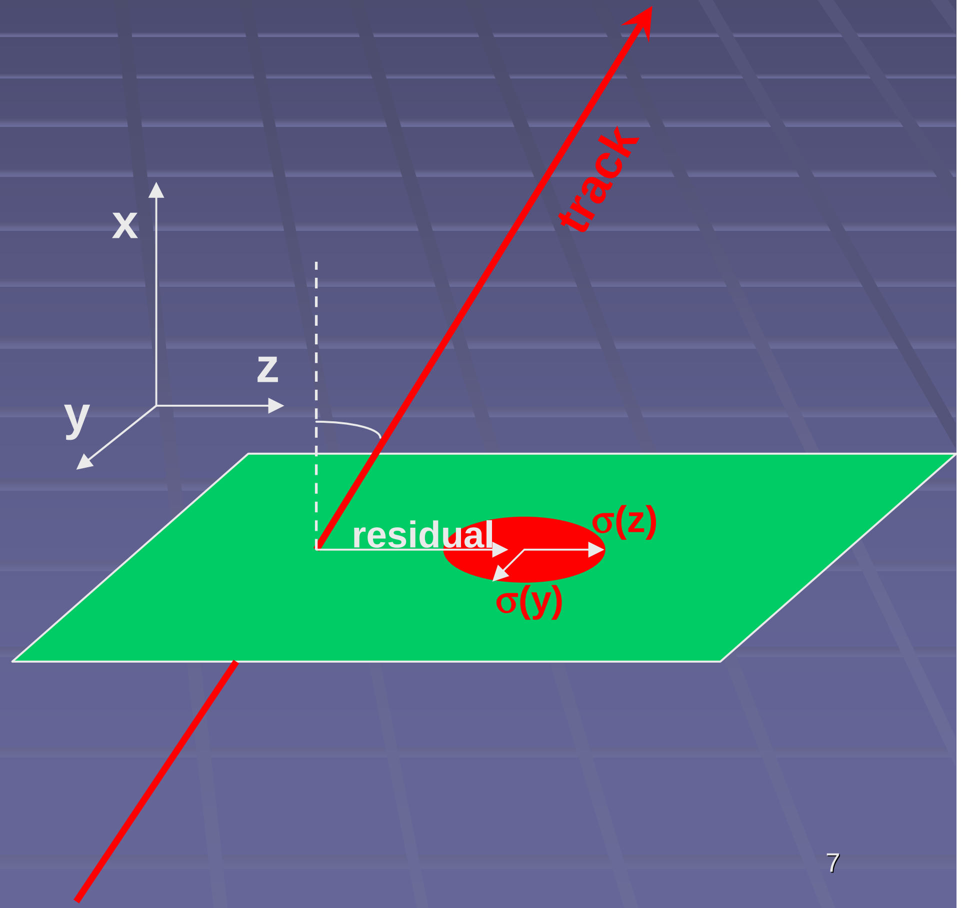
- Space points
  - X,Y,Z – in the global coordinate system
  - Full covariance matrix

$$\begin{pmatrix} V_{11} & V_{12} & V_{13} \\ V_{12} & V_{22} & V_{23} \\ V_{13} & V_{23} & V_{33} \end{pmatrix} \Rightarrow \begin{pmatrix} 0 & 0 & 0 \\ 0 & \sigma_y^2 & 0 \\ 0 & 0 & \sigma_z^2 \end{pmatrix}$$

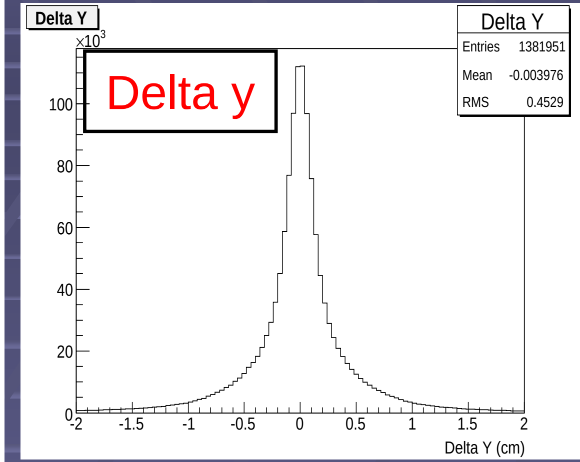


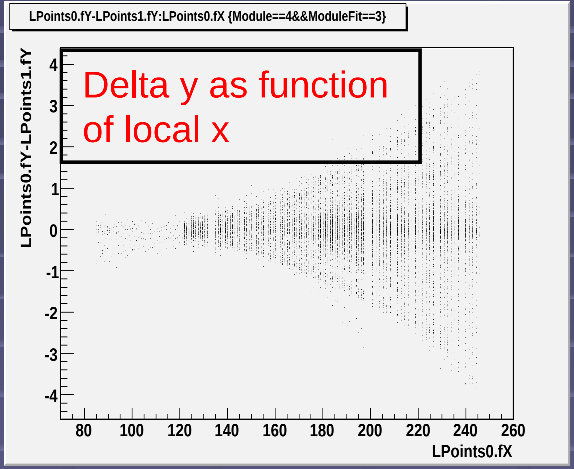
Track extrapolation point

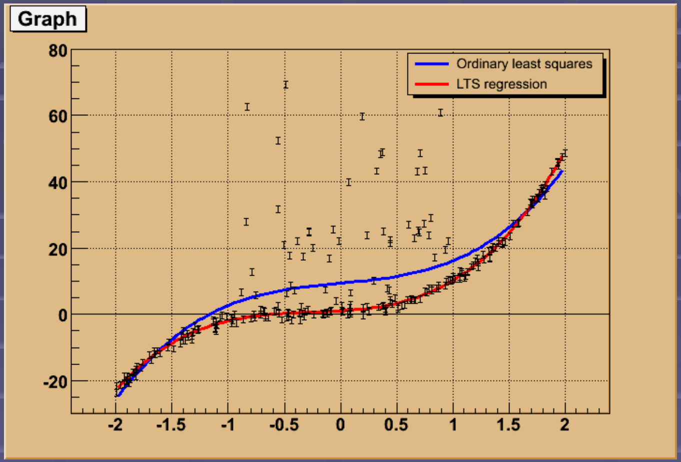
- After the track is fitted, it is extrapolated to each space-point of the sector to be aligned:
  - Calculate the crossing point on the reference plane
  - Assume straight line in the vicinity of the space-point
  - Calculate the track inclination angles and construct the cov.matrix:
    - Track extrapolation point is allowed to move only along the track trajectory



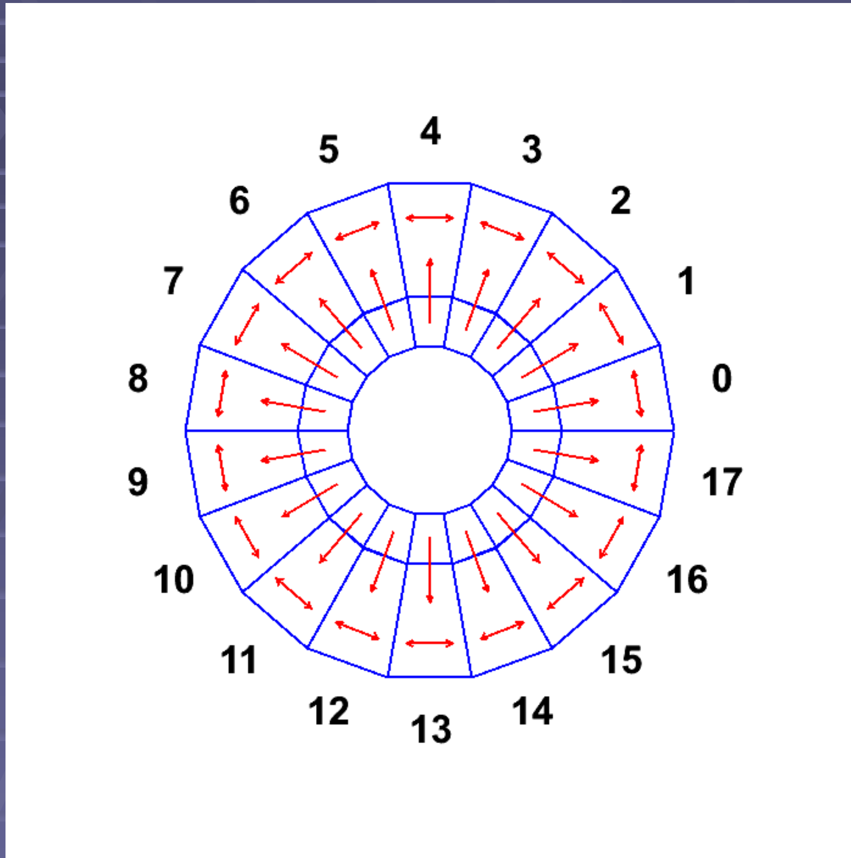
Robust fitter

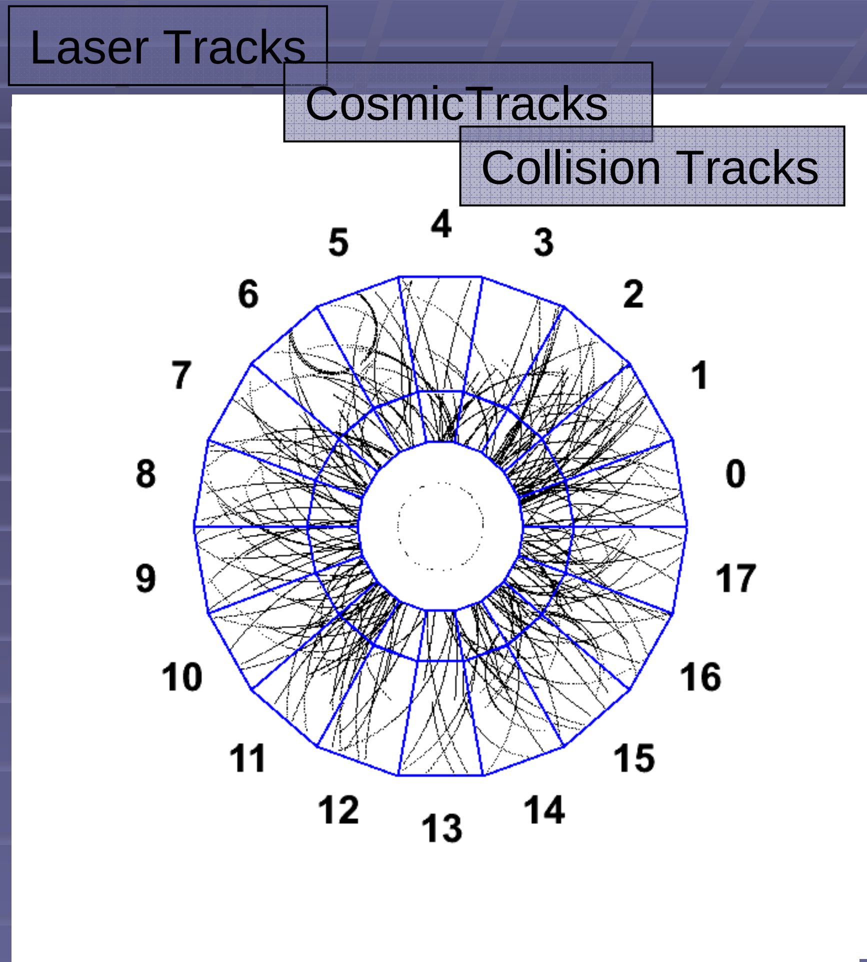






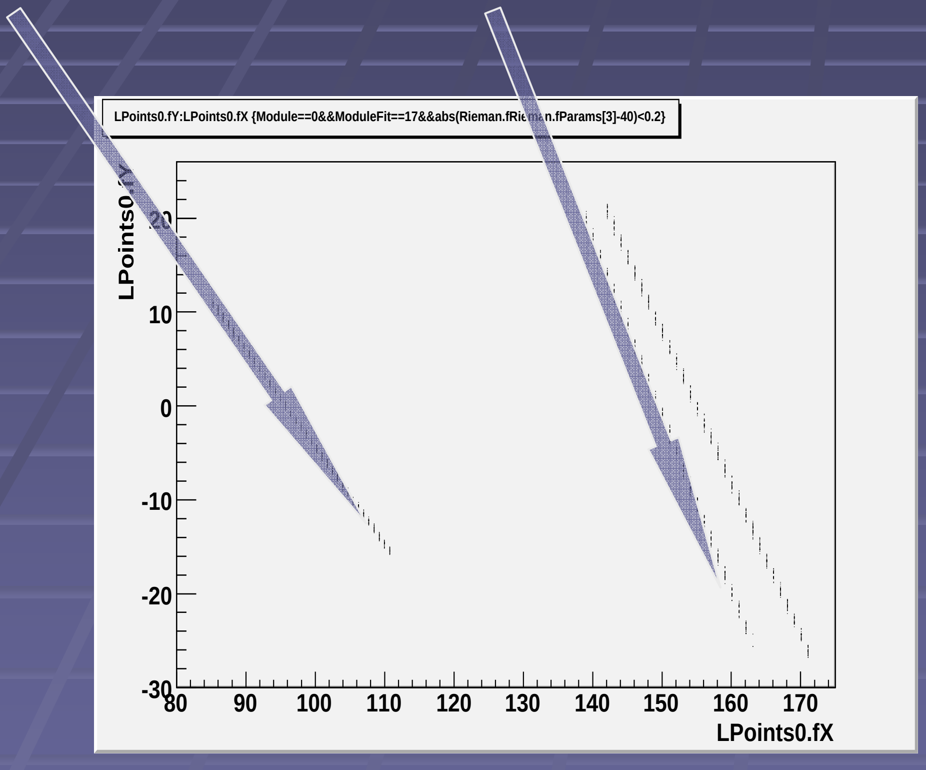
- Least Trimmed Squares regression (LTS)
  - The idea of the method is to find the fitting coefficients for a subset of h observations (out of n) with the smallest sum of squared residuals. The size of the subset h should lie between (npoints + nparameters +1)/2 and n, and represents the minimal number of good points in the dataset.
  - The method used here is based on the article and algorithm: "Computing LTS Regression for Large Data Sets" by P.J.Rousseeuw and Katrien Van Driessen
    - ROOT TLinearFitter implementation used

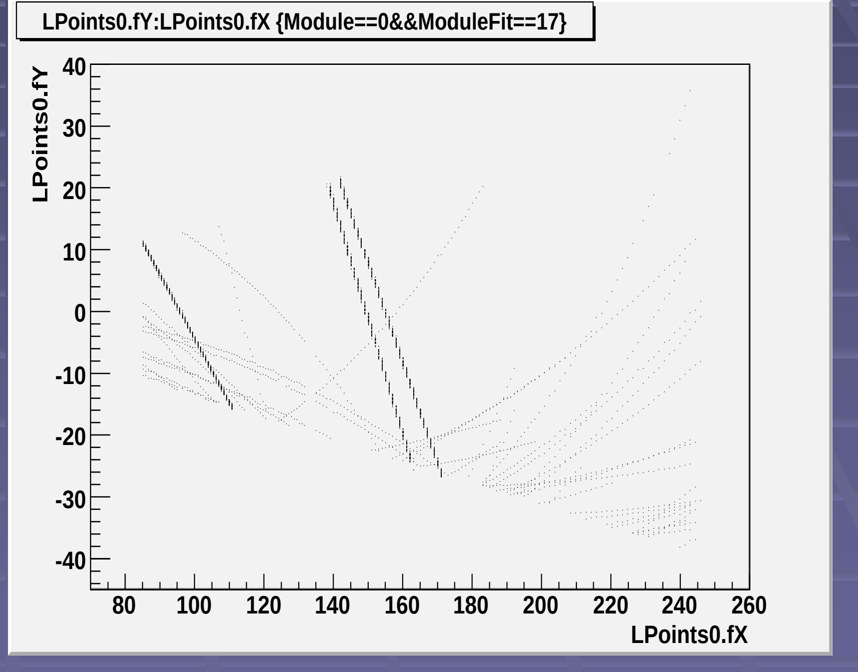




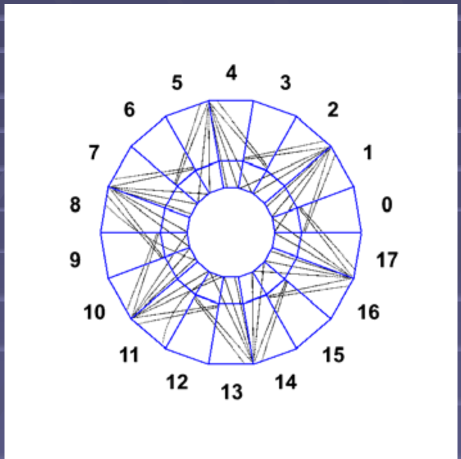
•Collision, cosmics and laser tracks populate different parts of global covariance matrix ! reduce correlations!

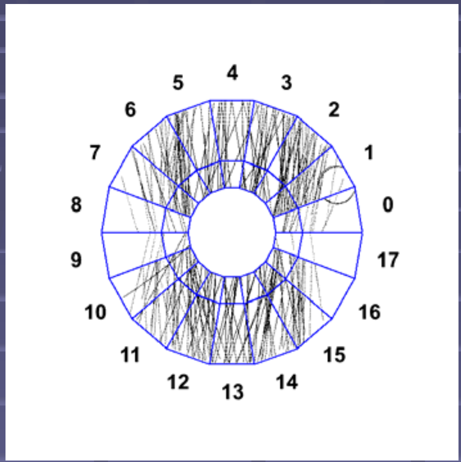
Left – right alignment (sector 0-17)

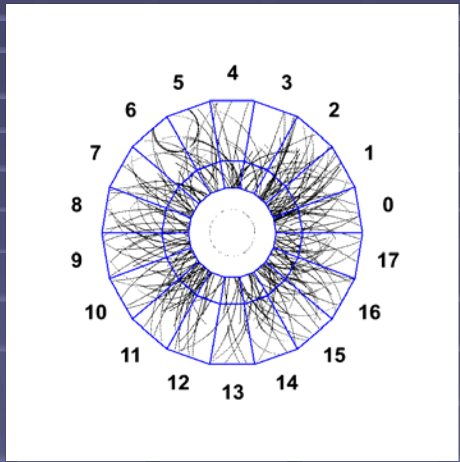




Data sample

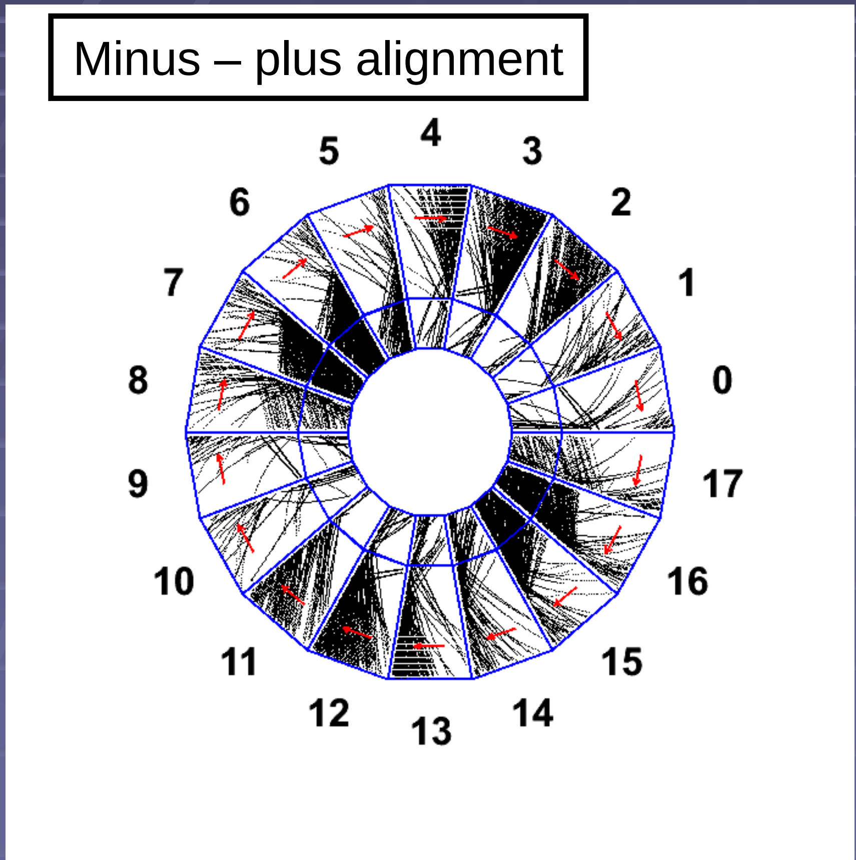


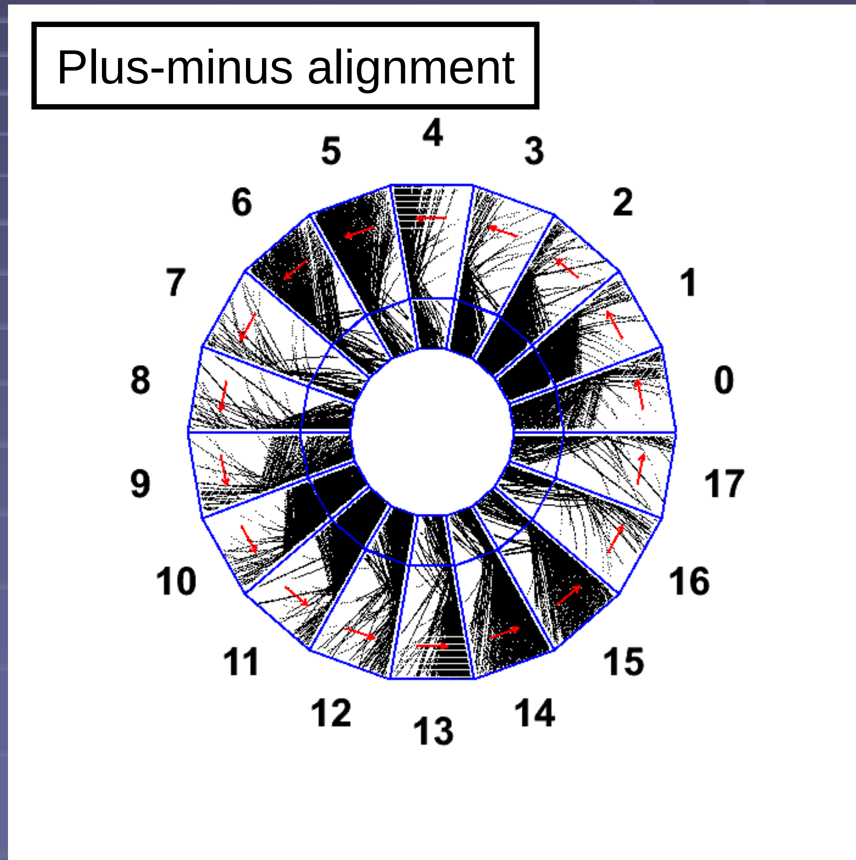




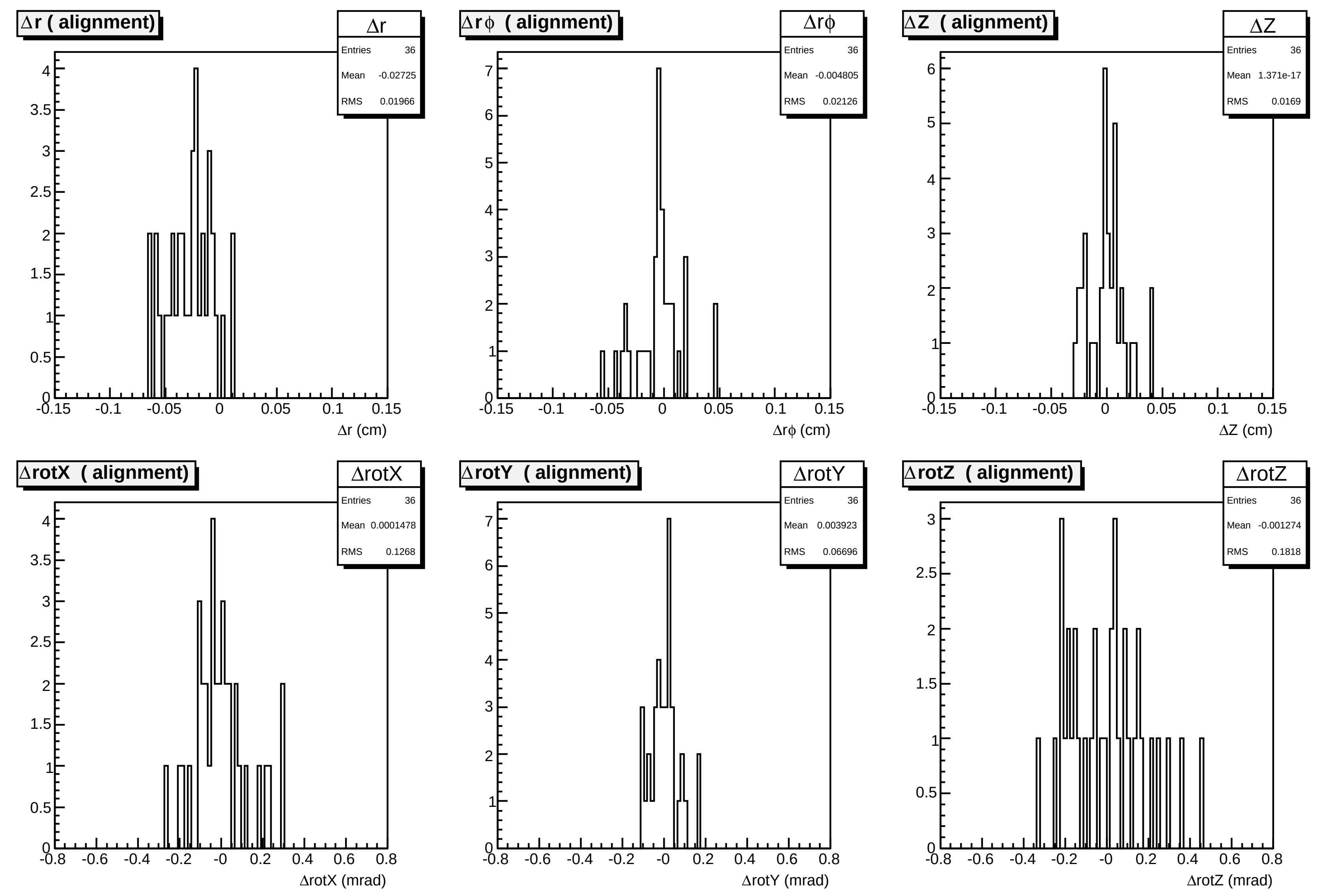
- Full Monte-Carlo simulation
- High momenta tracks
  - ~240.000 laser tracks
  - ~200.000 cosmic tracks
- Collision tracks ~15.000 pp events
- ➔
  - ~ 1000-6000 tracks for inner-outer alignment
  - ~ 500-6000 tracks for plus-minus alignment

- Data volume:
  - 1.7 GBy file
  - ~500000 tracks
  - 67 million points

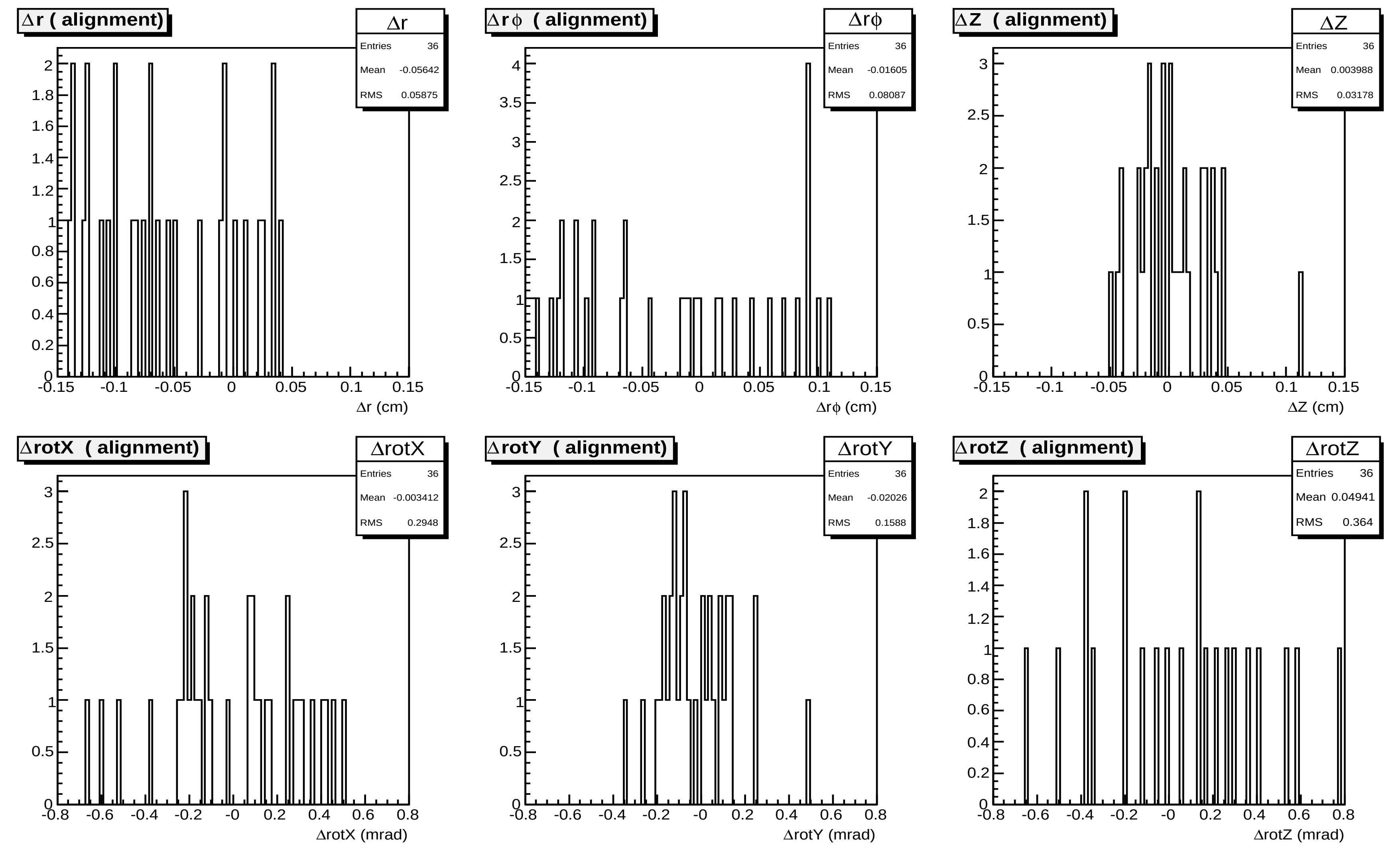

Minus – plus alignment
4
3
2
1
0
17
16
15
14
13
12
11
10
9
8
7
6
5


Plus-minus alignment
4
3
2
1
0
17
16
15
14
13
12
11
10
9
8
7
6
5

Results: Robust minimization



Results: Standard minimization



Results.

Translation

	dr(mm)		drϕ(mm)		dz(mm)	
	μ	σ	μ	σ	μ	σ
Robust	0.27	0.21	-0.04	0.21	0	0.16
Linear	0.56	0.59	-0.16	0.81	0.04	0.32

Rotation

	drotx(mrad)		droty(mrad)		drotz(mrad)	
	μ	σ	μ	σ	μ	σ
Robust	0.0001	0.126	0.0039	0.067	-0.0013	0.188
Linear	-0.003	0.295	-0.02	0.159	0.049	0.364

Observed systematic shift in radial (270 microns) direction due low momenta tracks used for left-right alignment. The magnitude of systematic shifts scale momentum cut. To some extend the effect can be cured using robust fitting.

Further test with Kalman filter instead of the Rieman sphere fitting

Future Plans

- Presented results using tracks generated with full MC chain
  - The imperfection of wdrift, time 0 determination and ExB effect neglected
  - Will be included in the next development stage
  - Cross check results using different algorithms with different approaches
- Next step - use test TPC data (available in March 2007)