TPC sector alignment

Marian Ivanov

Outlook

- Requirements
- STAR TPC example
- Alignment algorithm using tracks – Inner outer sectors
  - Simulation
  - Results
- Laser system

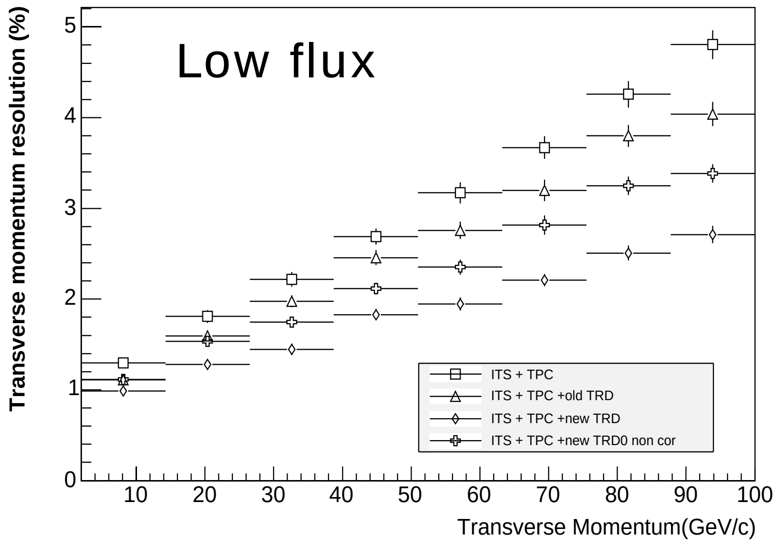
Requirements

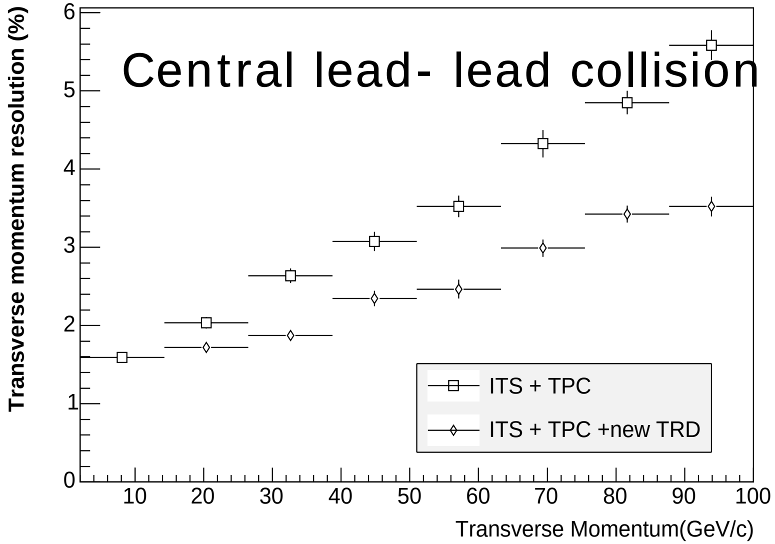
- The positioning of detector elements has to be known on the level better than precision of track parameters under ideal condition
  - Only stochastic processes, no systematic effects
  - Current AliRoot simulation
- High momenta tracks >20 GeV, inner volume of the TPC
  - Sigma y ~ 0.1 mm
  - Sigma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

Requirements

- Systematic effects
  - Uncertainty in positioning (alignment)
  - Drift velocity (as a vector)
    - Temperature and electric field dependent
    - E(x,y,z), T(x,y,z) – first approximation
      - E = Ez =const
      - T =const
  - ExB
  - Space charge
- Static – positioning, E field, B Field
- Non static (quasi static) - Temperature, space charge
- Expected distortion (according TPC TDR)
  - ~ 2 mm
  - ~ 1.5 mrad

Example - Sensitivity





- TRD calibration relative to the TPC - effective drift velocity, time 0, ExB
  - Corresponding shift of tracklet by ~300 mum
  - Improvement of pt resolution – factor ~30 %

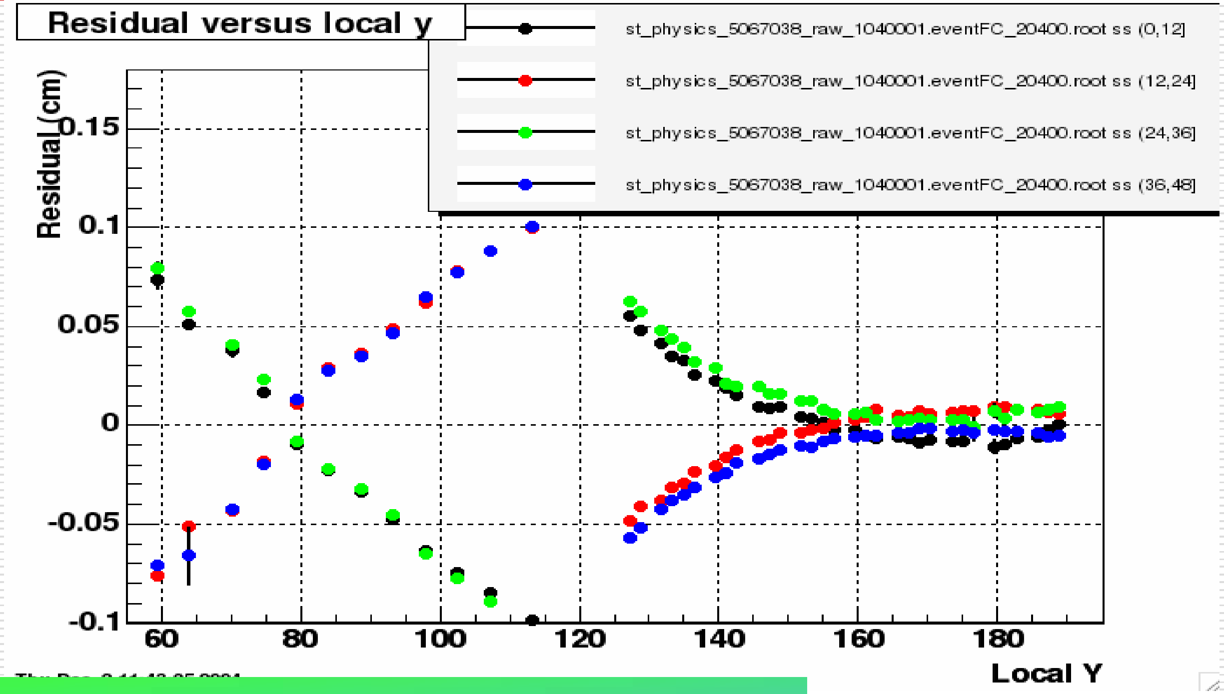
STAR - Tracking detectors

- TPC, SVT, SSD, FTPC, TOF, pVPD, CTB, RICH
  - Initial positions from survey (or previous year), later fine-tuned with tracking
  - Pedestals taken throughout run-year
  - Gains determined early in the run (and monitored) using pulsers
  - (Initial) drift velocities determined / monitored with lasers
  - Distortions studied in Fast Offline

STAR TPC

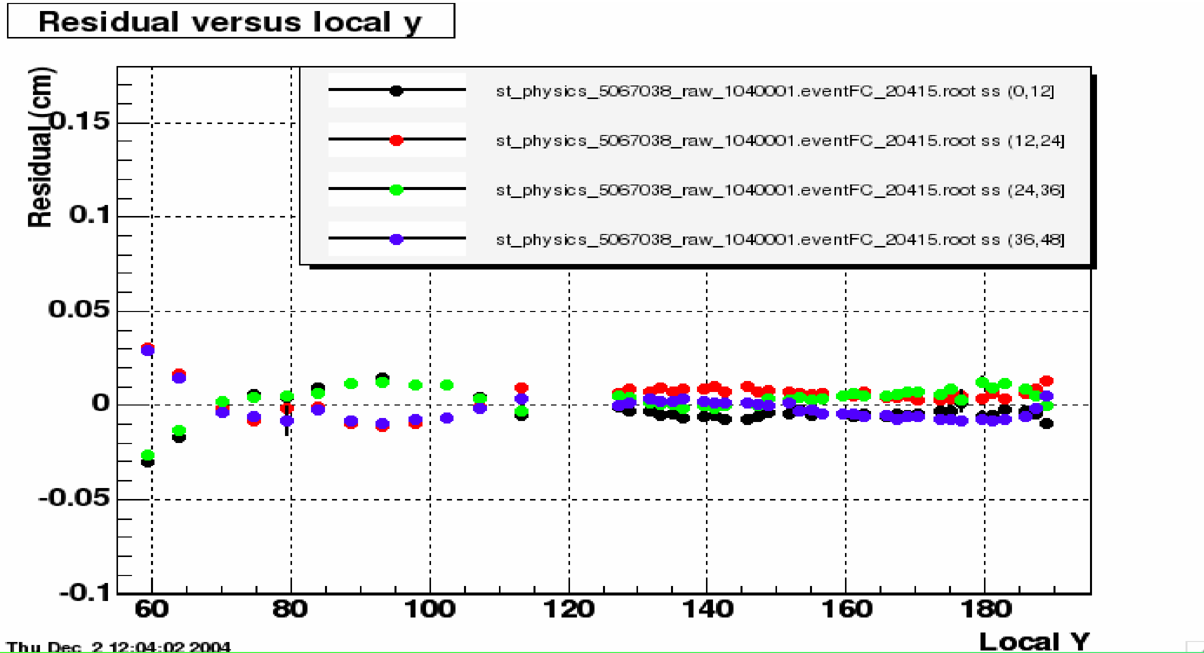
- Gains needed early in run-year to use online cluster-finder
  - Updated every few months, or when pads/RDOs die
- Automated updating of drift velocities (and initial T0) from laser runs
  - Checked / fine-tuned via matching primary vertex Z position using east and west half tracks separately
  - Ideally determined from track-matching to SVT (perpendicular drift), but requires all other calibs to be done already! (principle has been tested)

TPC GridLeak distortion



- Dependence on field, track charge, location, luminosity consistent with ion leakage at gated grid gap

STAR - TPC GridLeak distortion (space charge effect)



- Correcting for the gap leaves some residual even smaller effects (still under study - a testament to the TPC that we can see them!)

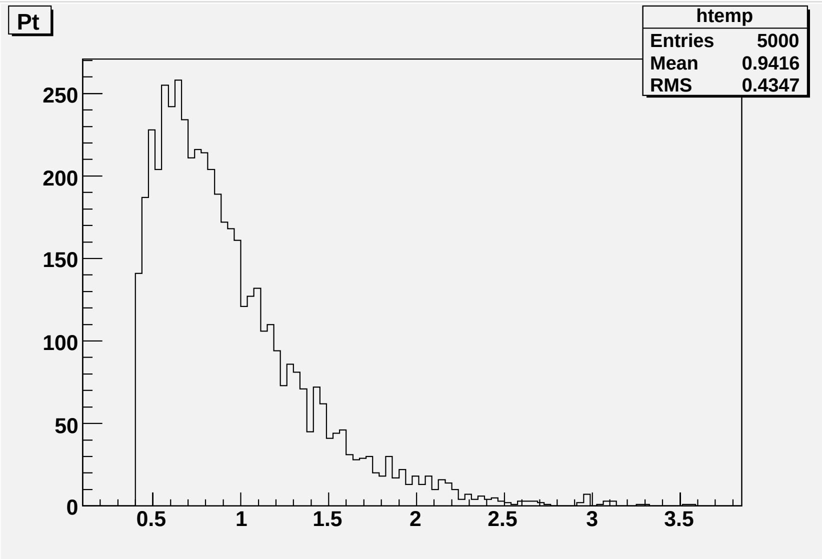
Simulation

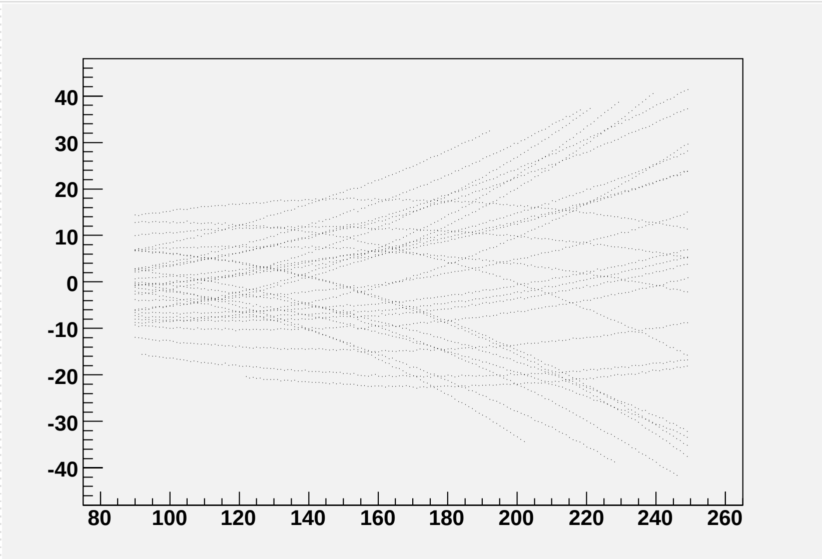
- Stand alone simulator
- Ideal helix
- Pt range >0.4 GeV
  - Exp(-x/0.4) distribution
- Magnetic field 0.5 T
- Tracks inside of one sector, inner and outer
  - Pads and pad-rows and time bins inside chamber perfectly aligned
- Outer sector misaligned
  - Characterize by TGeoHMatrix

Motivation

- Why to use tracks in the magnetic field for the alignment?
  - Rotation and translation of the chambers can be affected by the presence of the magnetic field

Pt spectra and tracks



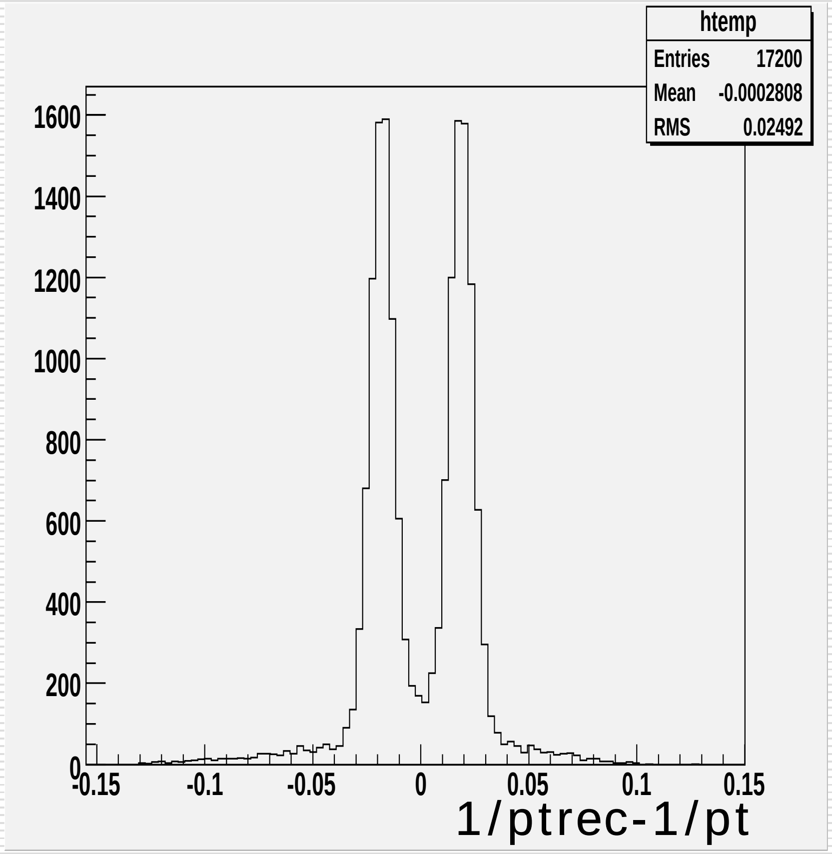


Simulation

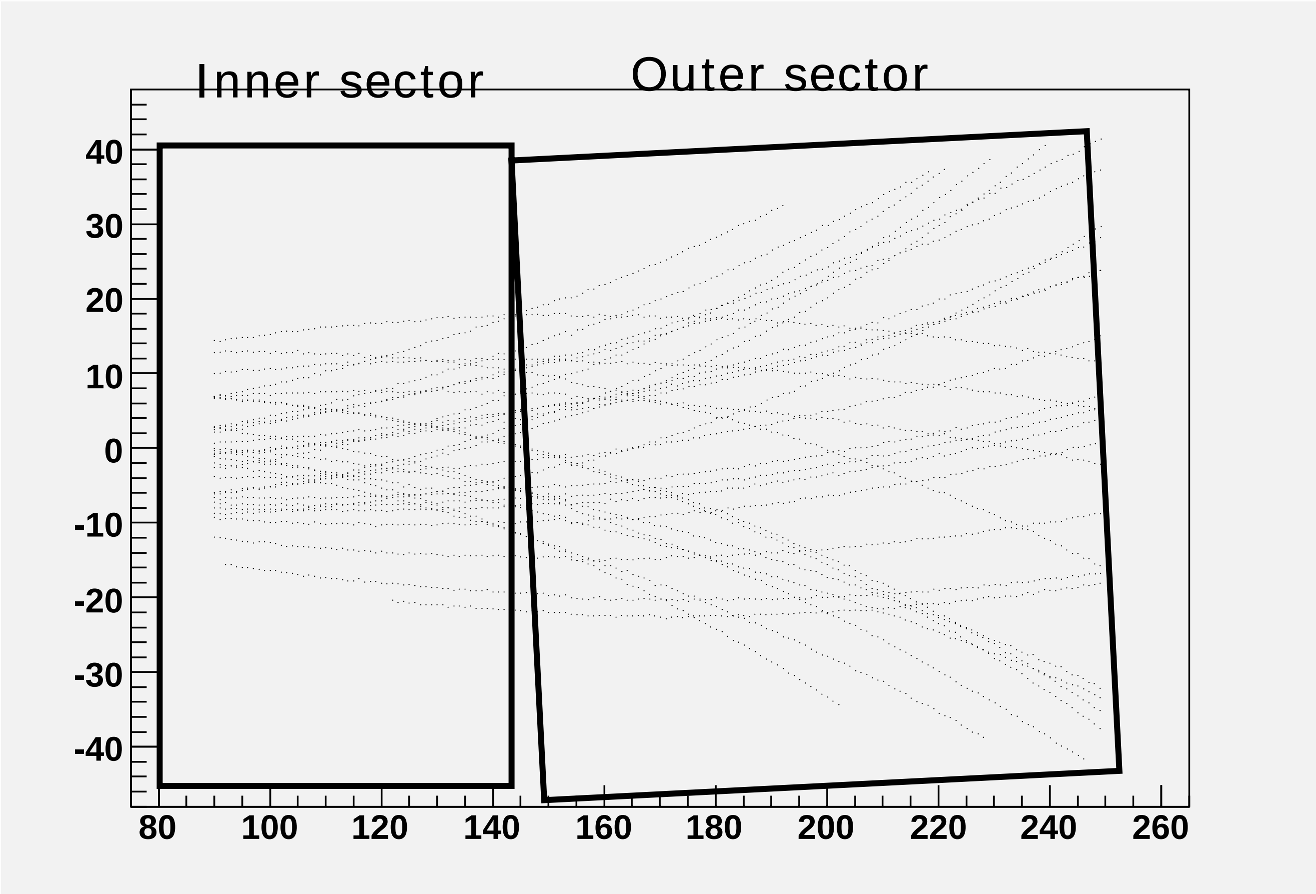
- Example results:
  - Misalignment matrix:
  - .999999 -0.000873 0.000698 Tx = -0.2
  - 0.000873 1.000000 -0.000174 Ty = 0.2
  - -0.000698 0.000175 1.000000 Tz = 0.2
  - Space charge effect and ExB switched off

Track fitting

- AliRieman (new standalone class) used for track fitting
  - Less than 1 s for track fitting (20000 tracks)
- Picture:
  - Pt resolution for non aligned sectors



Alignment (0)



Inner sector
Outer sector
40
30
20
10
0
-10
-20
-30
-40
80
100
120
140
160
180
200
220
240
260

Alignment (1)

- Separate track –fitting in inner and outer sector
- Parabolic track approximation at the middle reference plane in both chambers
- Minimization of the chi2 distance between space point in reference plane of upper chamber and corresponding extrapolation of the inner track
  - TMinuit used

Alignment (2)

- FCN=1257.14 FROM MIGRAD STATUS=CONVERGED 132 CALLS 133 TOTAL
  EDM=2.42528e-12 STRATEGY= 1 ERROR MATRIX UNCERTAINTY 0.0 per cent

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	rx	1.07144e-02	8.90503e-04	1.58139e-05	-2.35997e-01
2	ry	3.95478e-02	1.99467e-03	6.68023e-06	-2.30862e+01
3	rz	4.82396e-02	5.75040e-03	9.11108e-06	1.29964e-01
4	sx	-1.96256e-01	4.94420e-03	4.00290e-05	-3.84583e+00
5	sy	2.05511e-01	1.60506e-02	2.49723e-05	7.85195e-02
6	sz	1.99985e-01	5.07757e-03	2.49634e-05	5.15010e+00

Alignment – Covariance matrix

- PARAMETER CORRELATION COEFFICIENTS

NO.	GLOBAL	1	2	3	4	5	6
1	0.86752	1.000	0.018	-0.192	-0.025	0.266	0.014
2	0.99573	0.018	1.000	0.023	-0.921	-0.021	0.971
3	0.99896	-0.192	0.023	1.000	-0.005	-0.996	0.027
4	0.97508	-0.025	-0.921	-0.005	1.000	0.002	-0.819
5	0.99900	0.266	-0.021	-0.996	0.002	1.000	-0.025
6	0.99065	0.014	0.971	0.027	-0.819	-0.025	1.000

Results (5000 tracks)

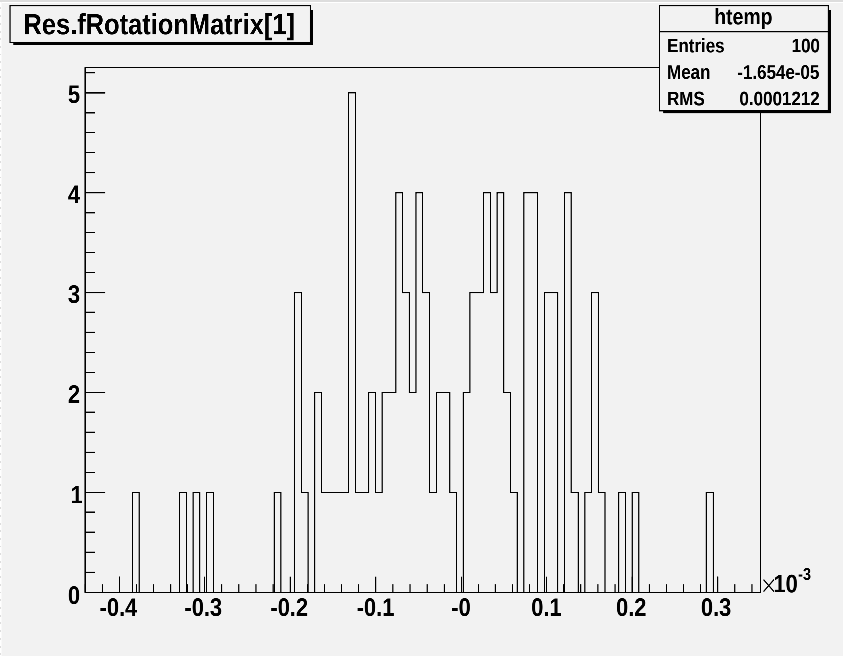
- Original misalignment matrix - Amis
  - matrix - tr=1 rot=1 refl=0

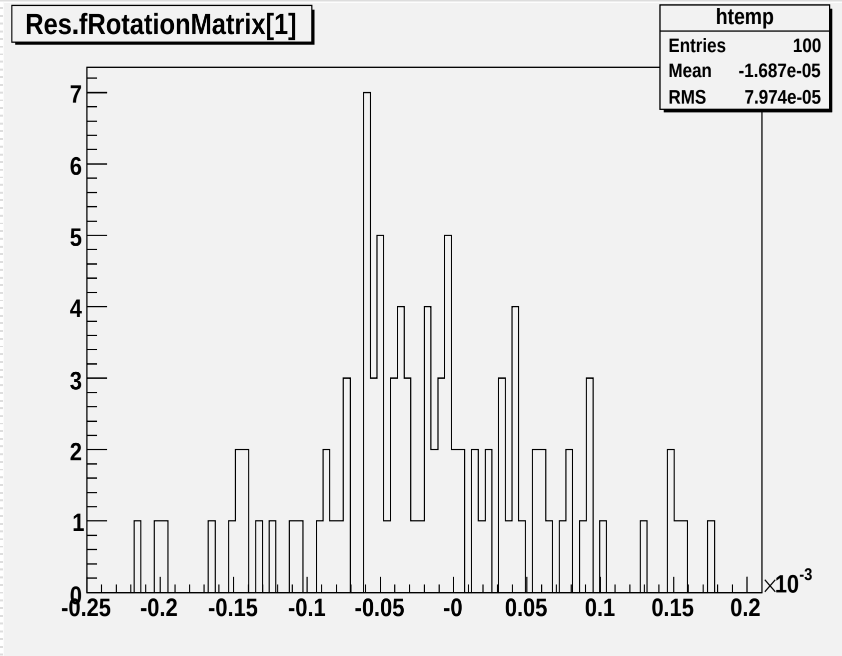
0.999999	-0.000873	0.000698	Tx = -0.2
0.000873	1.000000	-0.000174	Ty = 0.2
-0.000698	0.000175	1.000000	Tz = 0.2

- Residual matrix – Afit.Inverse()*Amis
  - matrix - tr=1 rot=1 refl=0

1.000000	-0.000020	0.000085	Tx = -0.0121112
0.000020	1.000000	0.000016	Ty = -0.00518356
-0.000085	-0.000016	1.000000	Tz = 0.0116462

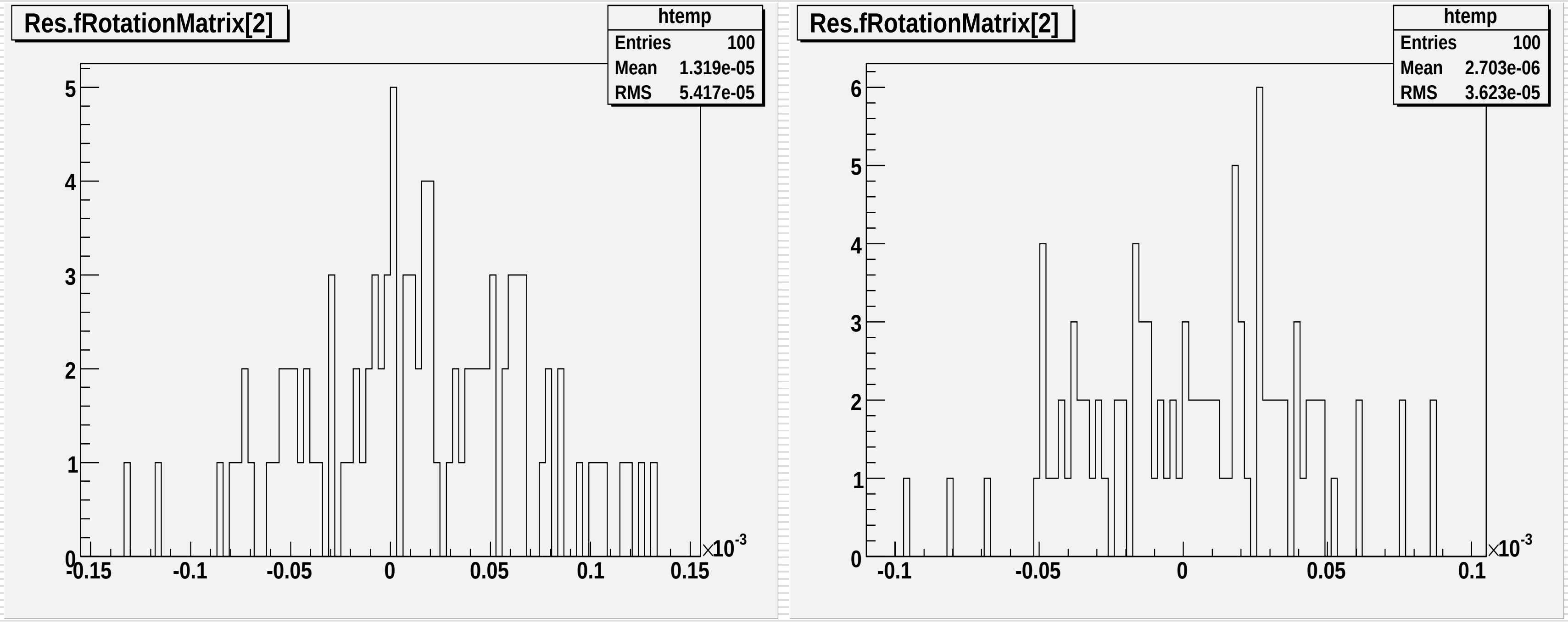
Results –Rotation Z





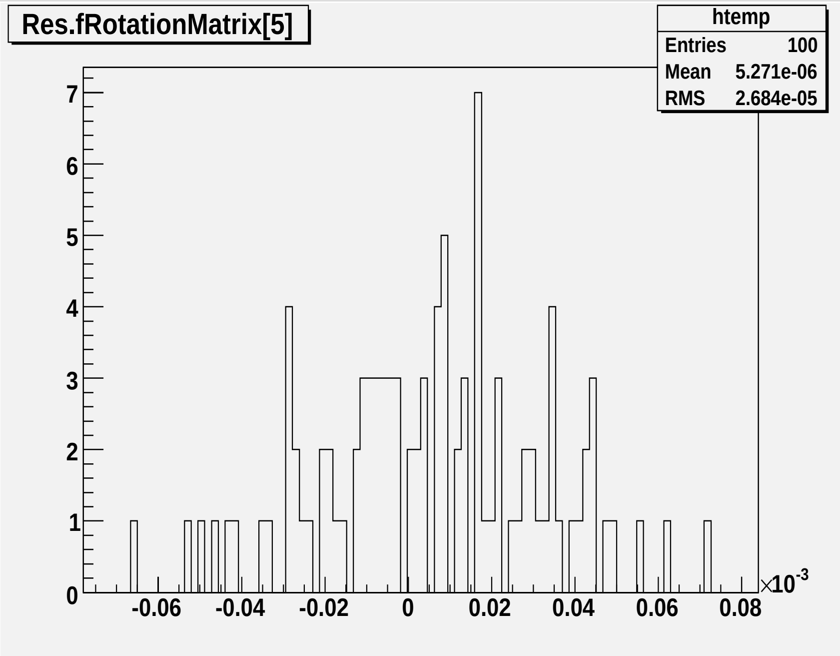
- Left side – 2000 track samples
- Right side – 5000 track samples

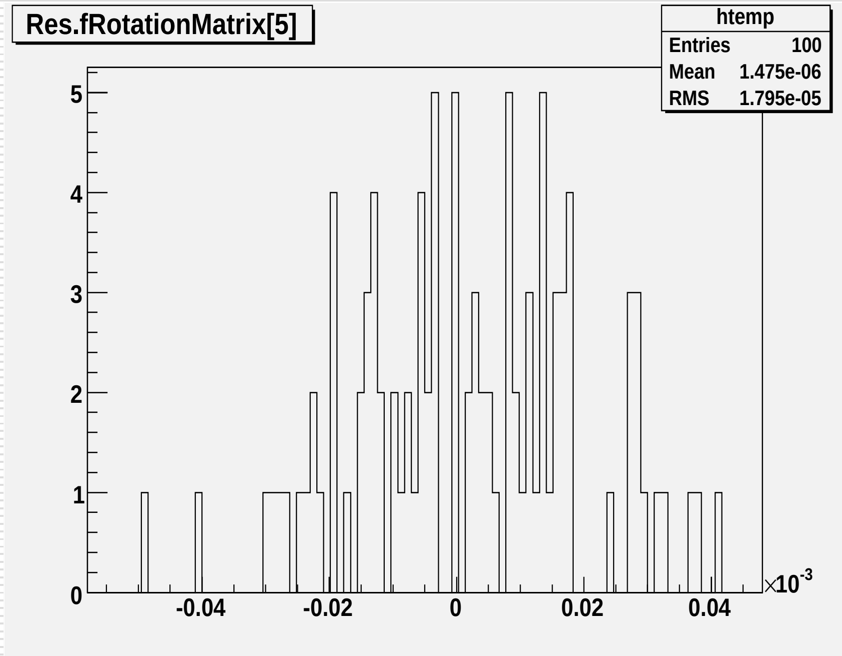
Results –Rotation Y



- Left side – 2000 track samples
- Right side – 5000 track samples

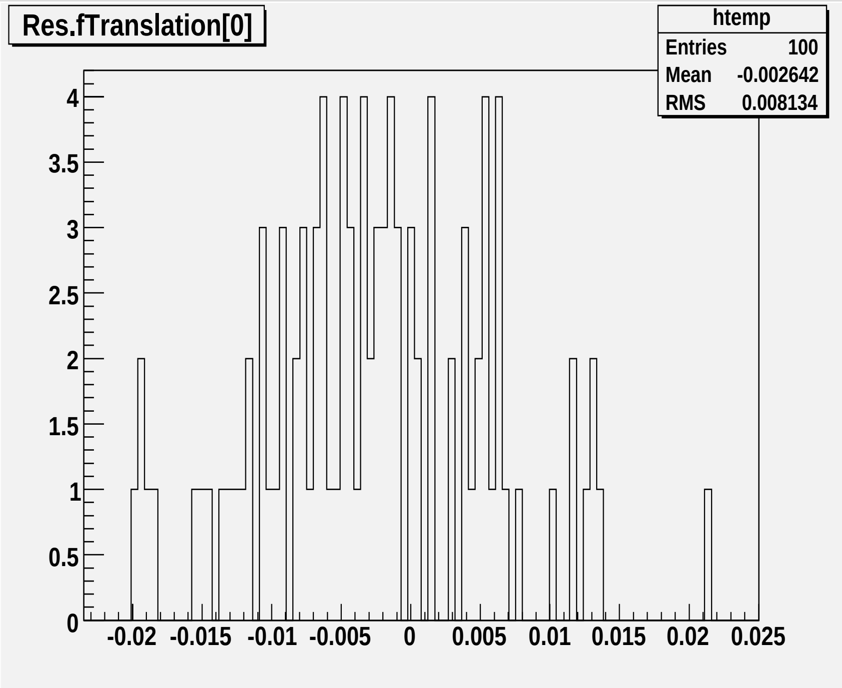
Results –Rotation X

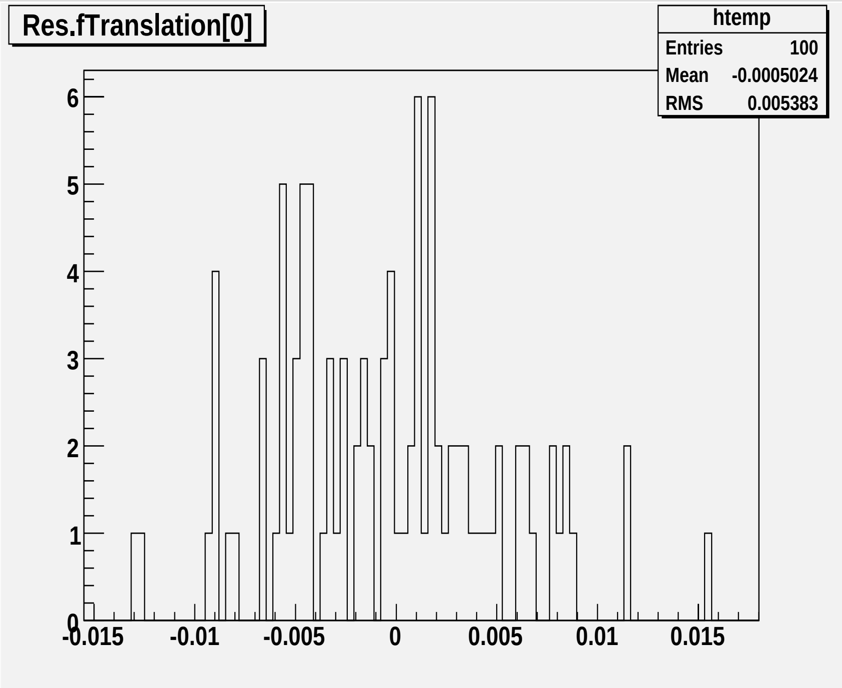




- Left side – 2000 track samples
- Right side – 5000 track samples

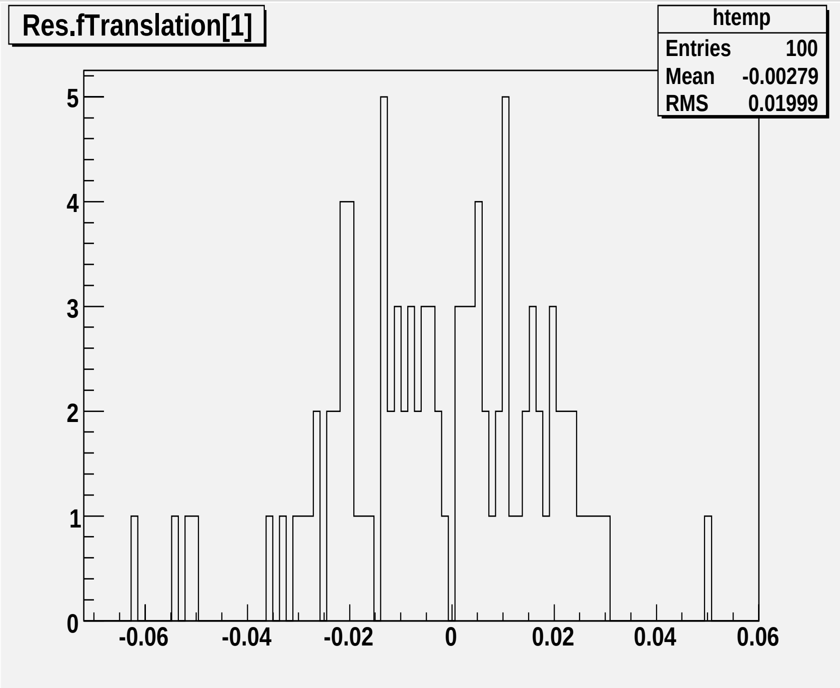
Translation X

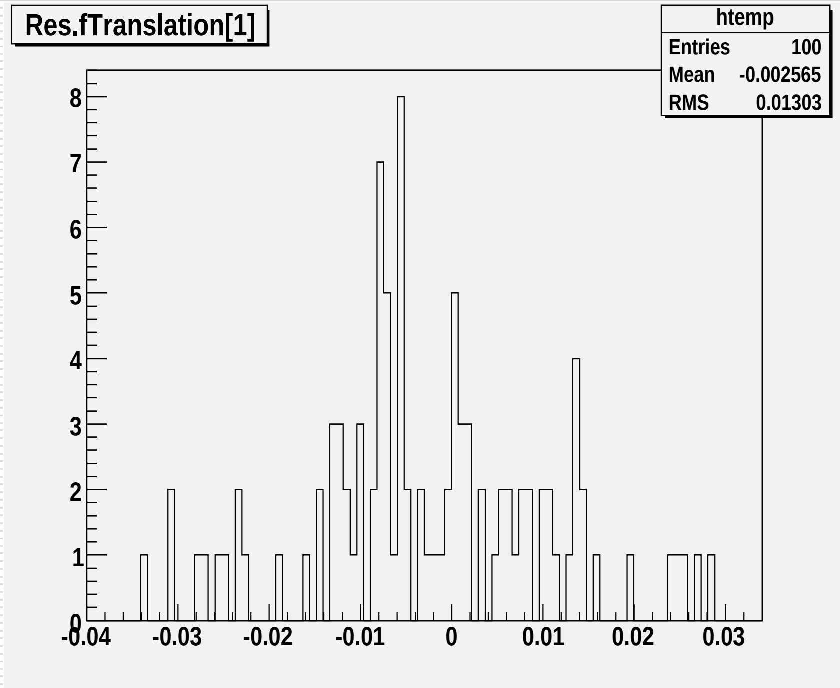




- Left side – 2000 track samples
- Right side – 5000 track samples

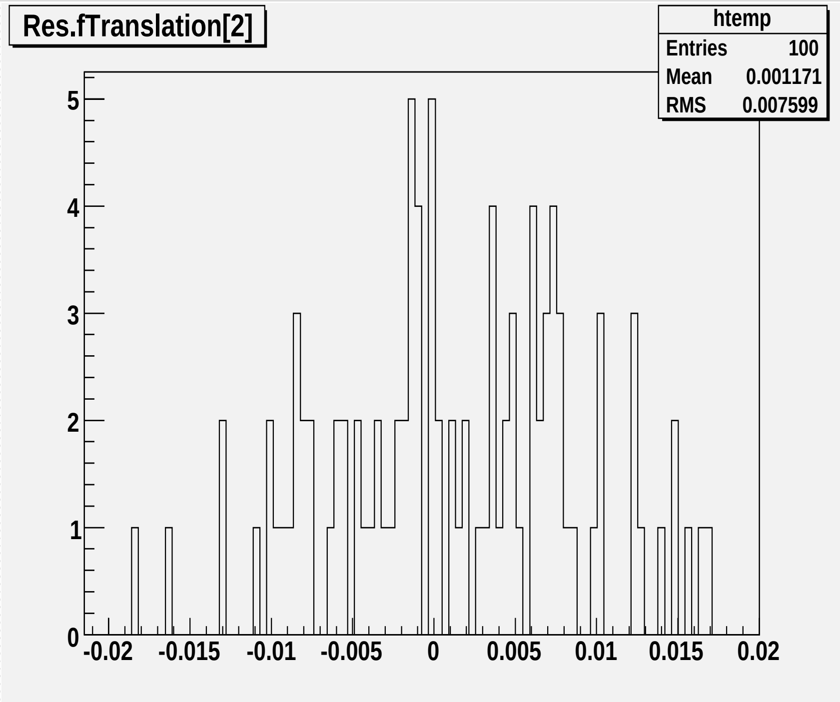
Translation Y

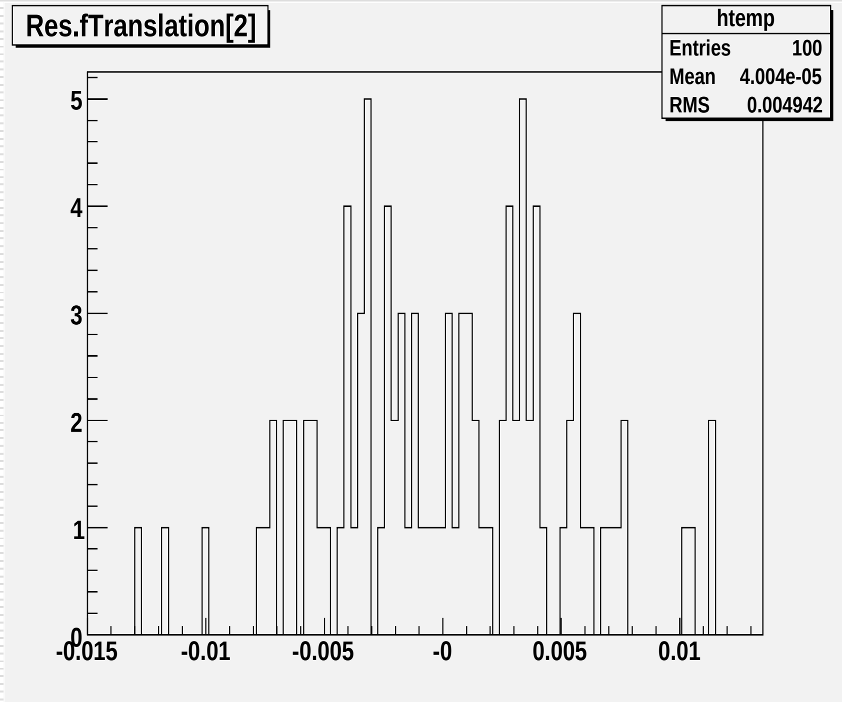




- Left side – 2000 track samples
- Right side – 5000 track samples

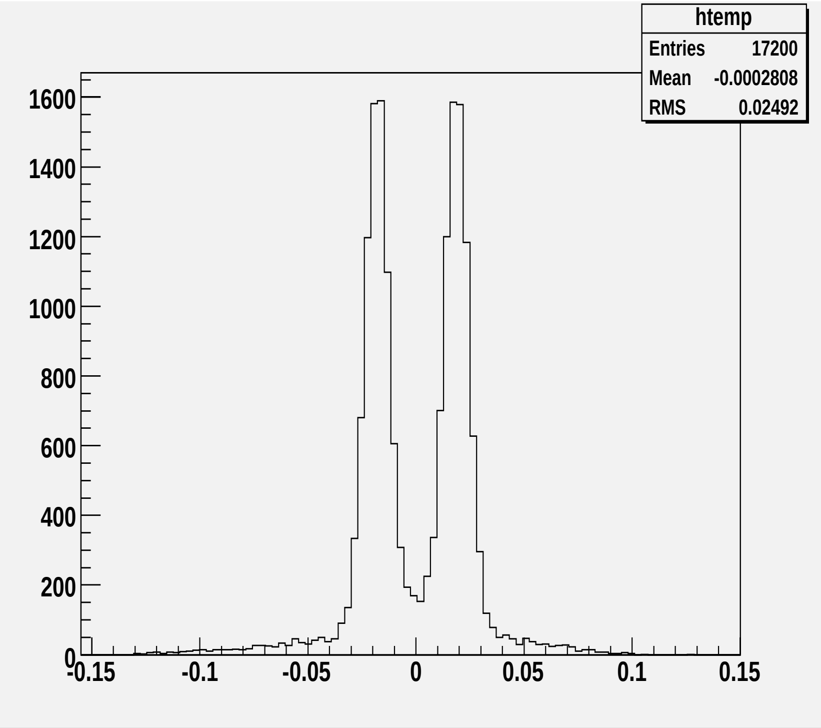
Translation Z

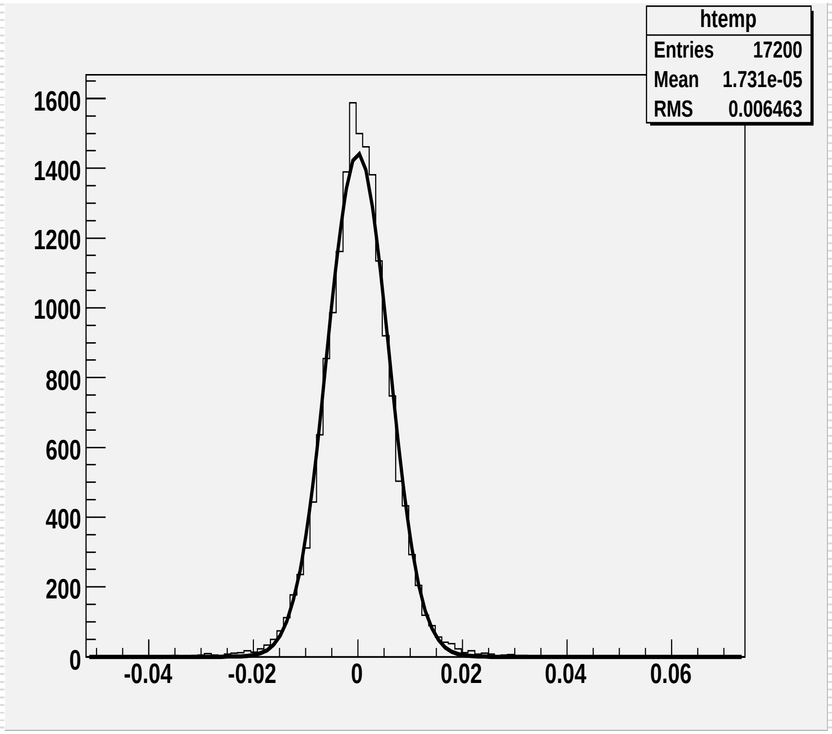




- Left side – 2000 track samples
- Right side – 5000 track samples

Result (Pt residuals)

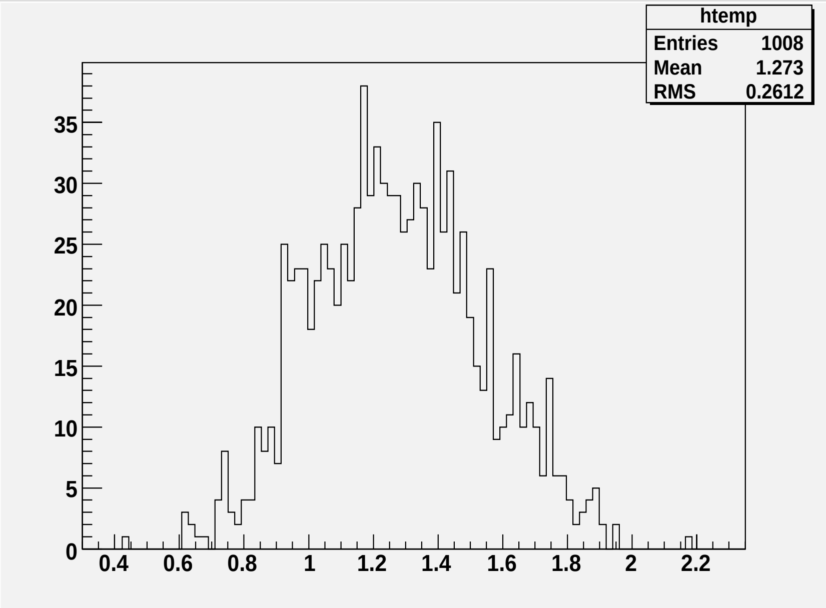


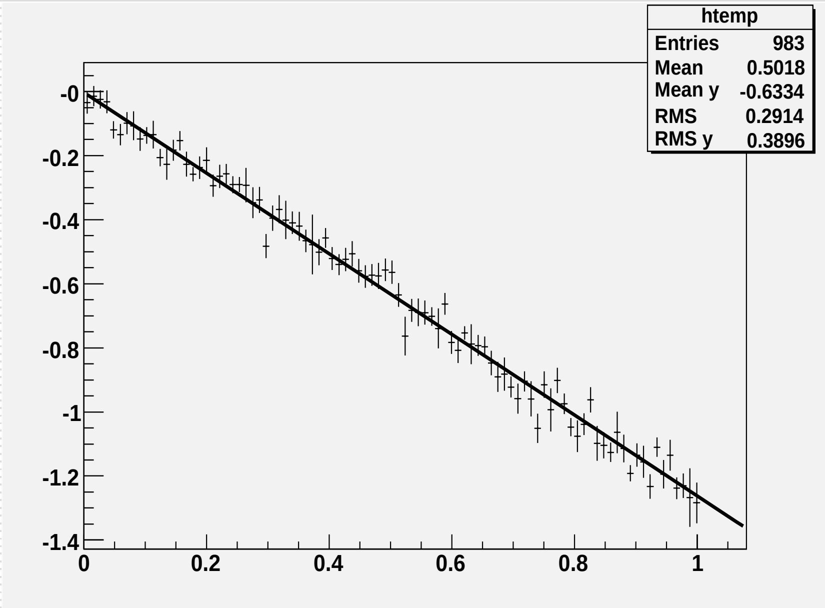


Alignment - ExB

- ExB effect – simulated
  - Xshift = kx*(z-250) – kx=0.005
  - Yshift = ky*(z-250) - ky=0.005
  - The same in both sectors
- Alignment with tracks (2000 track samples)
  - Systematic shifts in translation estimates
    - X – 0.02 mm, Y – 0.08 mm, Z – 0.003 mm
  - Systematic shift in rotation estimates
    - Rz – 0.05 mrad, Ry – 0.006 mrad, Rx – 0.006 mrad

ExB effect





- Left - Systematic shift of DCA in r-phi
- Right side – Systematic shift of DCA in Z as function of theta

Alignment - Conclusion

- Huge statistic needed to develop and validate alignment procedure
  - First estimation made
- How to proceed?
  - Use and develop stand alone simulator for calibration study?
    - 5000 tracks *100 samples =500000 tracks
  - Or use AliRoot framework to generate space points
    - Apply different systematic shift on the level of space points
      - Rotation, translation, ExB, space charge (parameterization needed)

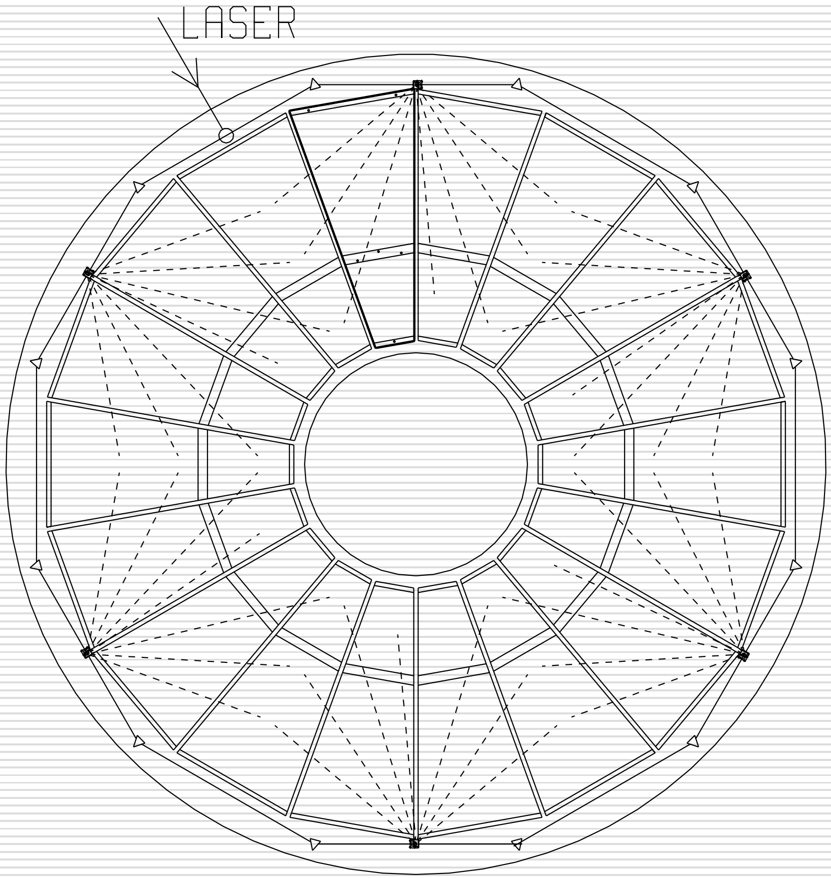
Laser system (0)

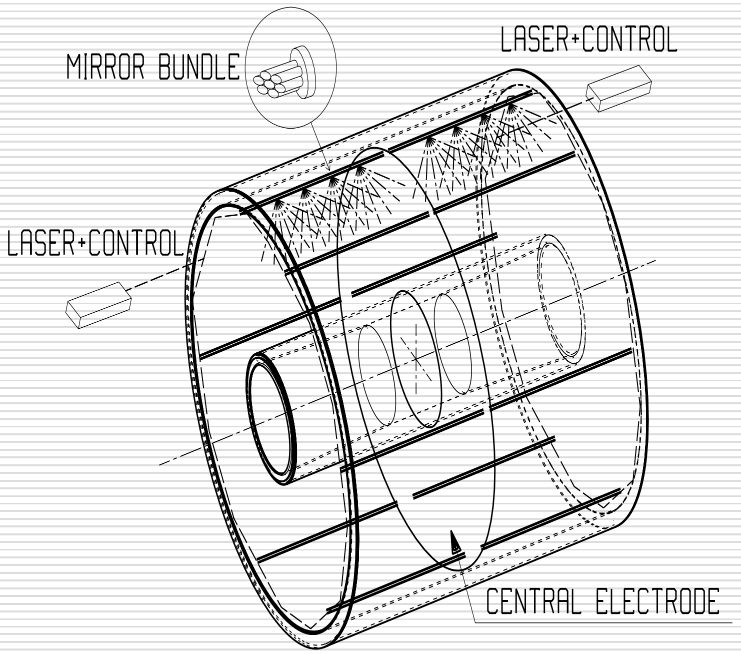
- Narrow and short-duration UV laser beams can be used to simulate particle
  tracks in the TPC.
- Nd:YAG lasers (1064~nm) with two frequency doublers,
  generating a beam with 266~nm wavelength,
  have been successfully applied for this purpose in NA49 and
  in CERES/NA45 at the SPS
- The ionization occurs via two-photon absorption and thus the transverse
  distribution of the ionization density is in every direction sqrt(2) times narrower than the light-intensity distribution

Laser system (1)

- The aim of the laser calibration system
  - Measure the response of the TPC to straight tracks at known position.
- In particular, the laser system should allow the TPC readout electronics and software to be tested, distortions caused by misalignment of the sectors to be measured
- Temporal and spatial changes of the drift velocity down to 10^-4 to be monitored (0.25 mm?)
- Apparent track distortions due to ExB and space-charge effects to be measured, and the transition region between the drift volume and wire chambers to be understood.

Laser system (2)





Laser system (3)

- 168 beams in each of the TPC halves
  - 6x7x4
- absolute position
  - up to 2 mm
    at the entrance of the track into the TPC
  - up to 2 cm at its end-point
- Relative position
  - up to 0.2 mm entrance
  - and 2 mm at the end-point
- Size
  - Directly after the mirror the beam has a box profile, with a size equal to that of the mirror (1 mm)
  - About 60--80~cm later the beam acquires a perfect Gaussian shape with diameter ~0.6 mm (4 sigma)
  - Subsequently, the beam stays Gaussian and its diameter increases to d~=1.6mm at 300 cm, which corresponds to a divergence of 0.5~mr