Alignment of CLAS-6 DCs using tracks with constrained vertex

E1-6 run period, years 2001-2002

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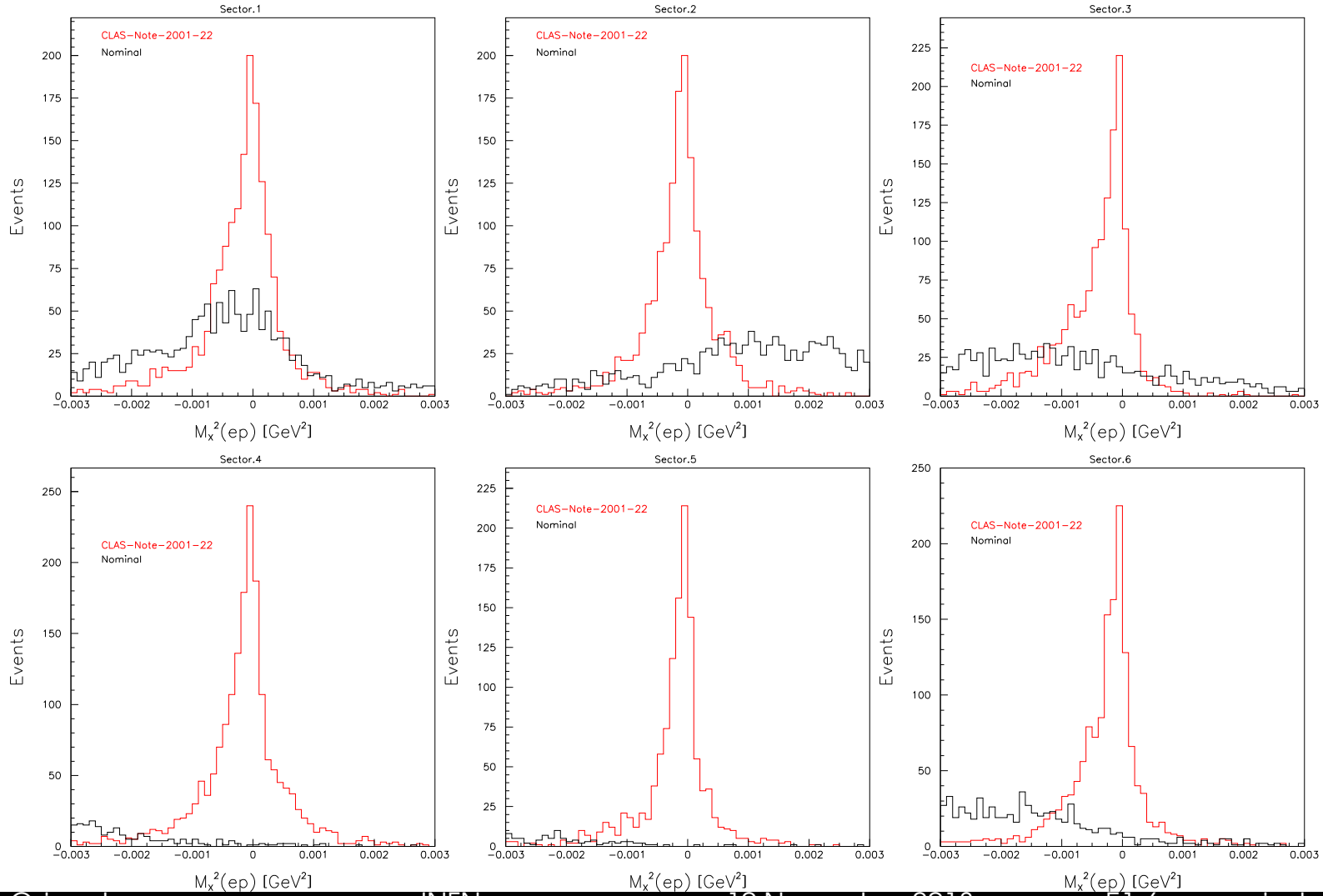
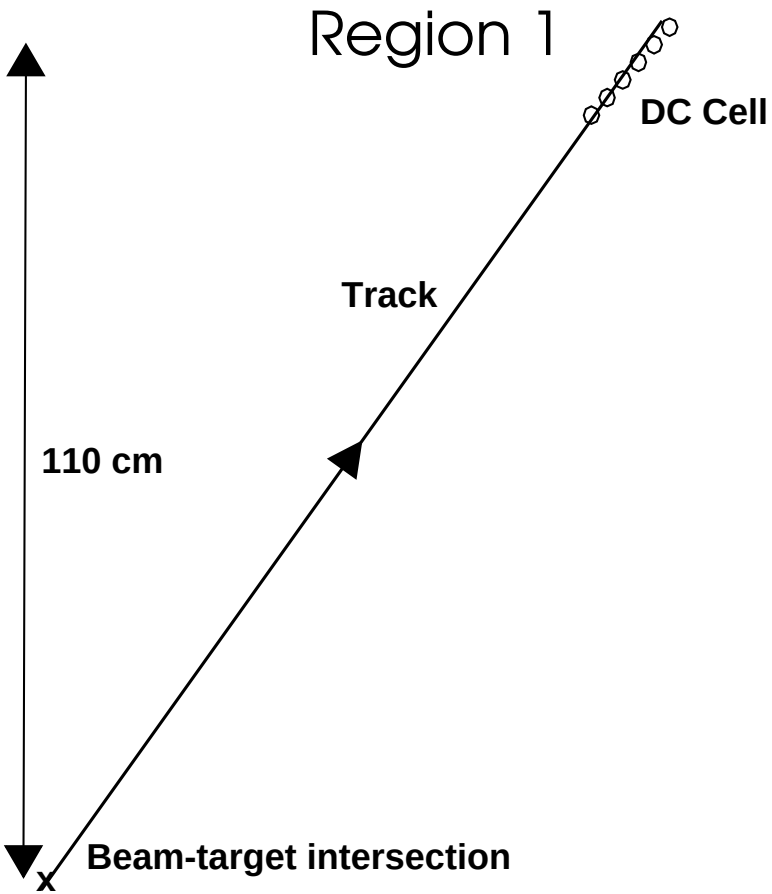
Nominal DC position

1. DCs installation tolerances <0.5 mm,
2. but CLAS-Note-2001-22 offsets >10 mm.



Alignment Procedure

1. straight tracks (zero mag. field),
2. two reference points (precise surveys < 0.15 mm),
3. distance between points defines resolution.



- Region 1 stereo+axial wires define two lines,
- intersection of the two lines gives one point,
- beam-target intersection provides second point,
- expected resolution: $\sigma_\theta < 0.1$, $\sigma_\phi < 1$ mrad.

Beam-Target Intersection

Target position (courtesy of Kelly Tremblay):

Survey date	X_{trg} (mm)	Y_{trg} (mm)	Z_{trg} (mm)
October 2nd 2001	0±0.1	0±0.2	-0.8
April 29th 2002	0±0.1	0.5±0.2	NA

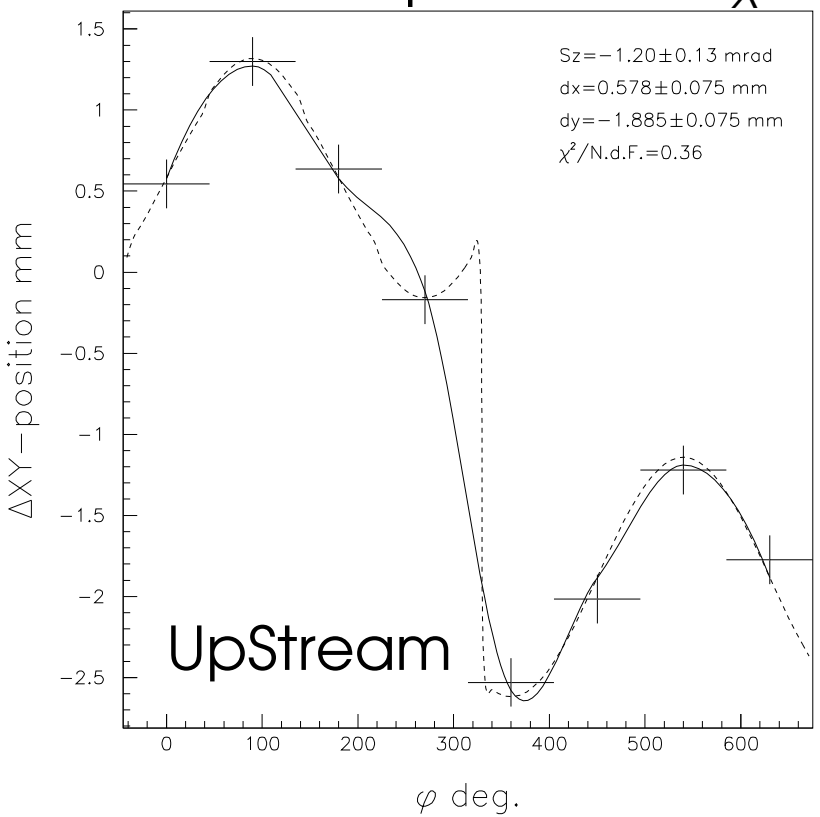
Beam-Target correlation (Logbook):

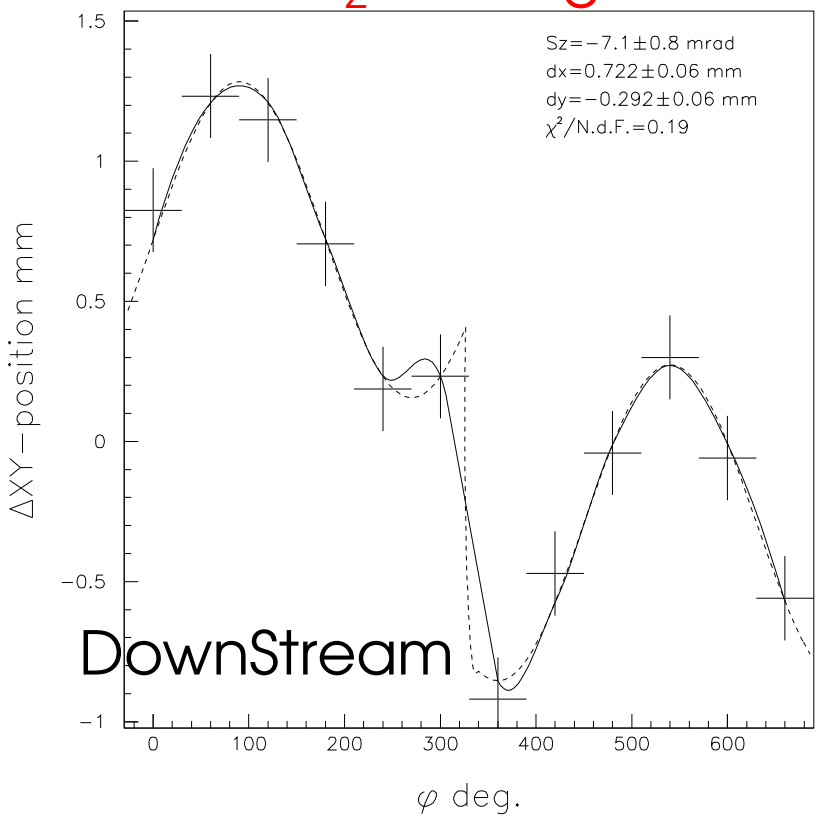
Scan Run	X_{2C21A} (mm)	X_{2C24A} (mm)	X_{2H01} (mm)	Y_{2C21A} (mm)	Y_{2C24A} (mm)	Y_{2H01} (mm)
30448	0.025	-0.193	0.3	-0.156	-0.465	-1.9
31274	-0.095	0.153	0.226	-0.244	-0.701	-2.323
31488/512	0.078	-0.010	0.773	0.143	0.043	-1.565
31949	0.027	0.008	0.7	0.050	0.057	-1.9

$$X_{beam} = X_{trg} - (X_{2H01} - X_{scan} + \Delta X),\ Y_{beam} = Y_{trg} + Y_{2H01} - X_{scan} + \Delta Y$$

DC Region 1 Survey: X,Y

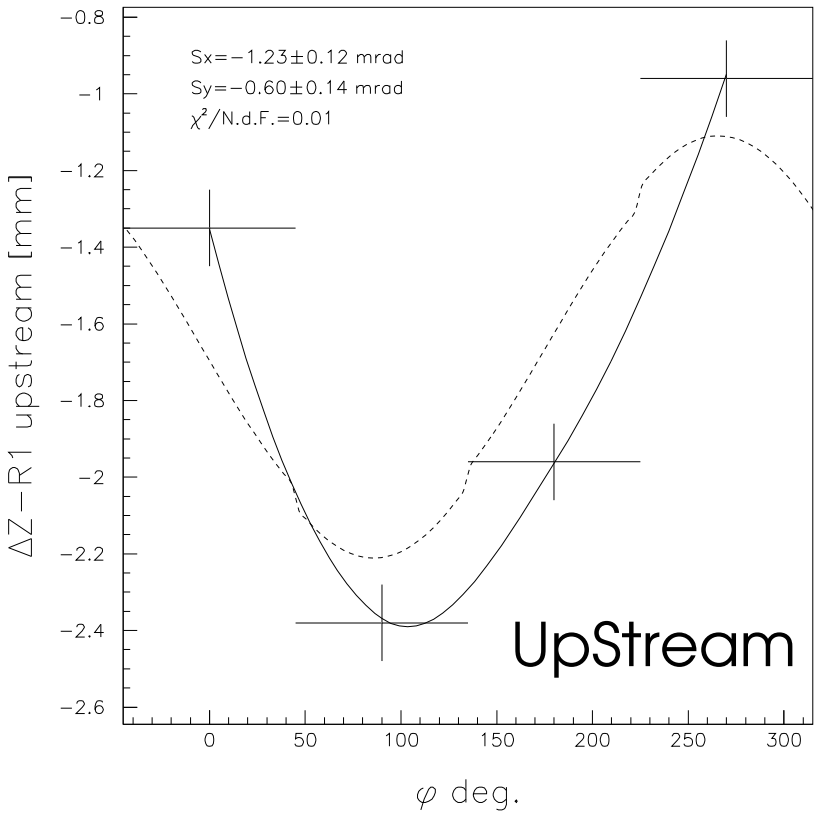
- DC Region 1 was surveyed in CLAS-Note-98-001,
- wrong indexing of X, Y-rotations in Geometry Table (used by all experiments): $S2 \leftrightarrow S6$, $S3 \leftrightarrow S5$,
- large ($> 15\sigma$) differences in Y and S_Z between upstream and downstream ends of R1,
- ΔY interpreted as S_X=−0.82 mrad, S_Z averaged.

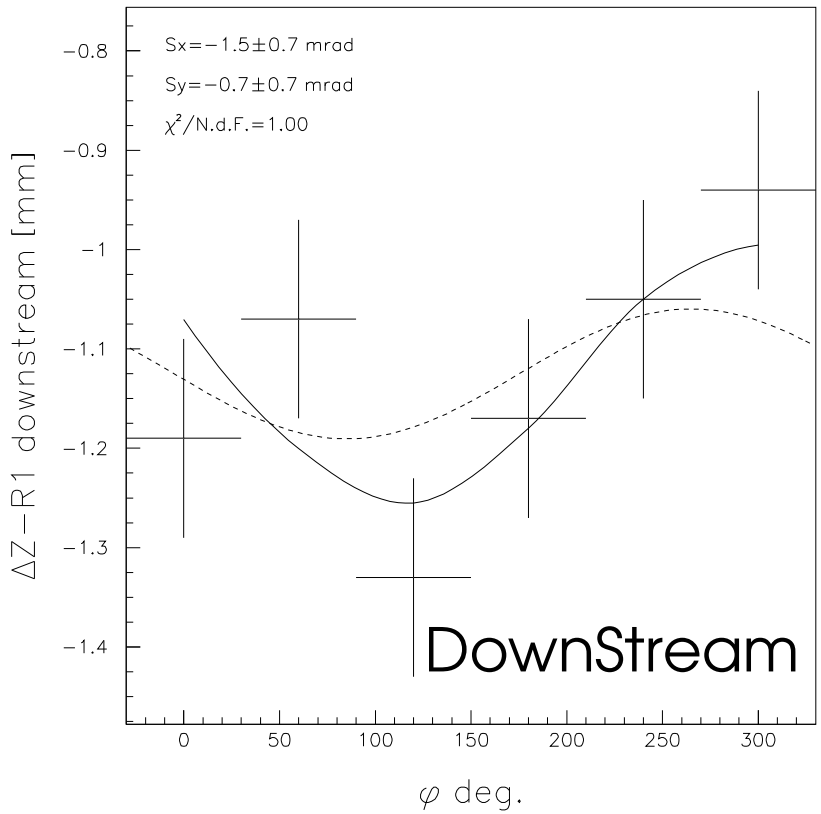




DC Region 1 Survey: Z

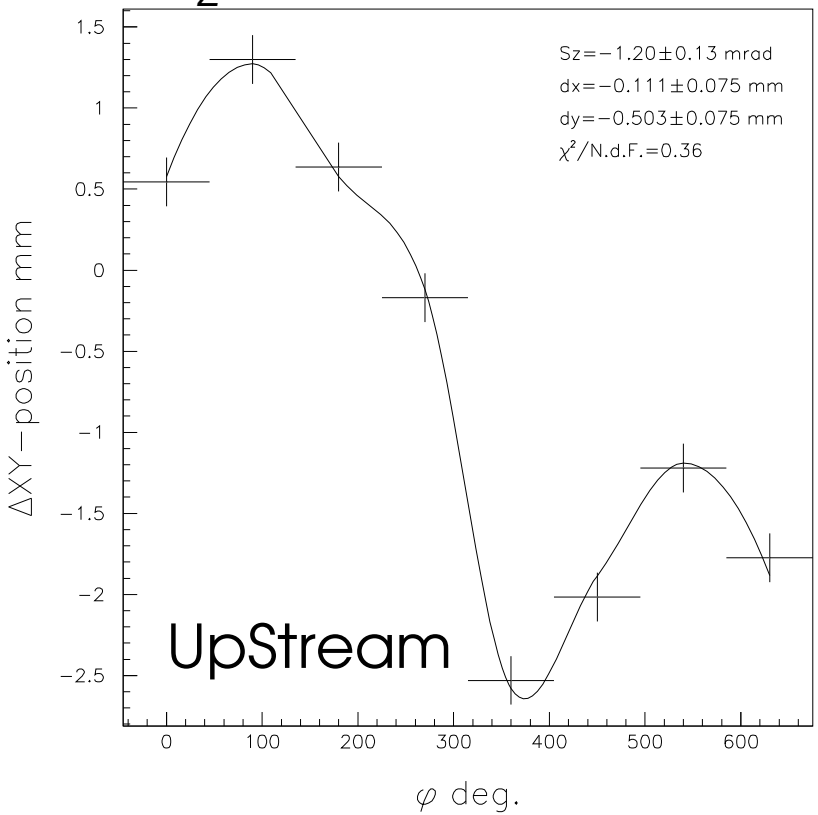
- $Z_{ups.} = -1.66 \pm 0.08$, $Z_{downs.} = -1.125 \pm 0.08$ mm, 5σ-difference suggests S_Y=1.1 mrad. (all Sectors),
- difference between X, Y upstream end downstream ends gives S_X=-0.82 ± 0.05 and S_Y=0.07 ± 0.05 mrad,
- fitting variations of Z gives S_X, S_Y different by $> 3\sigma$.

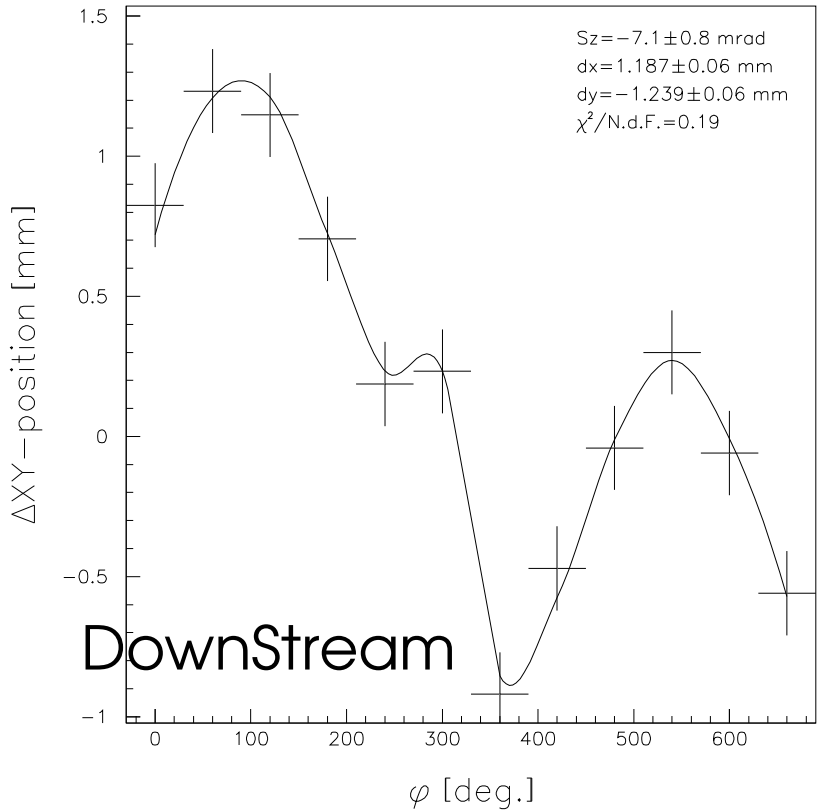




DC Region 1 Survey: X,Y - Refitted with S_X, S_Y

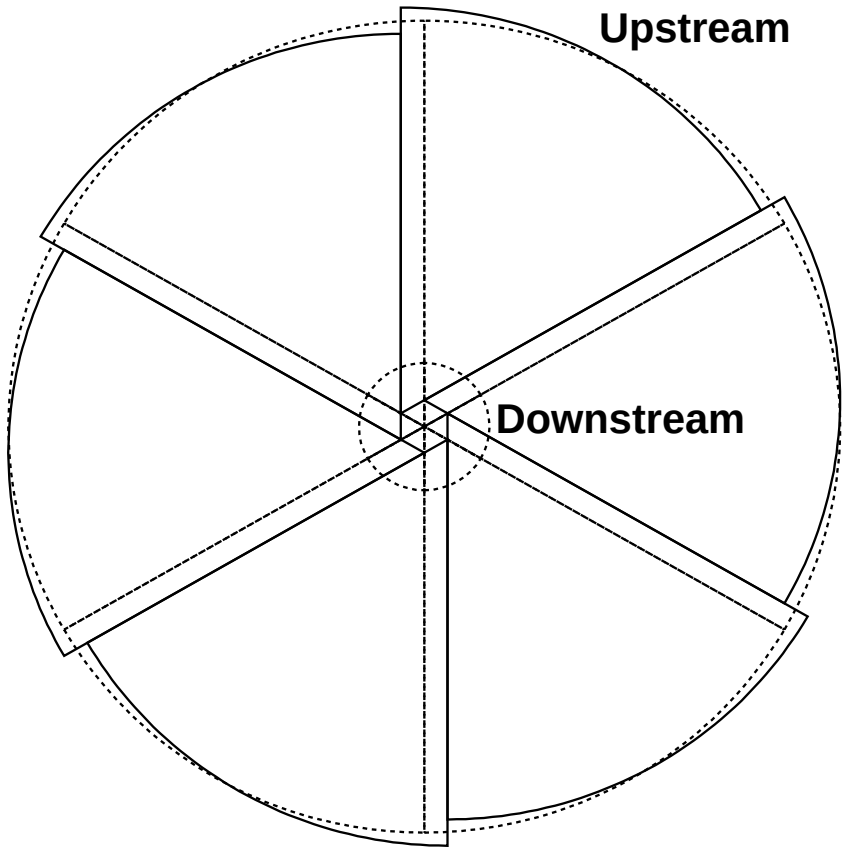
- using S_X, S_Y we can extrapolate independently upstream and downstream surveys to CLAS center,
- two extrapolations disagree by about 1.3 mm,
- upstream extrapolation agrees with inverse of target survey (0.01,0.5) mm,
- S_Z values are invariant.





DC Region 1 Survey: Z - Rotation Puzzle

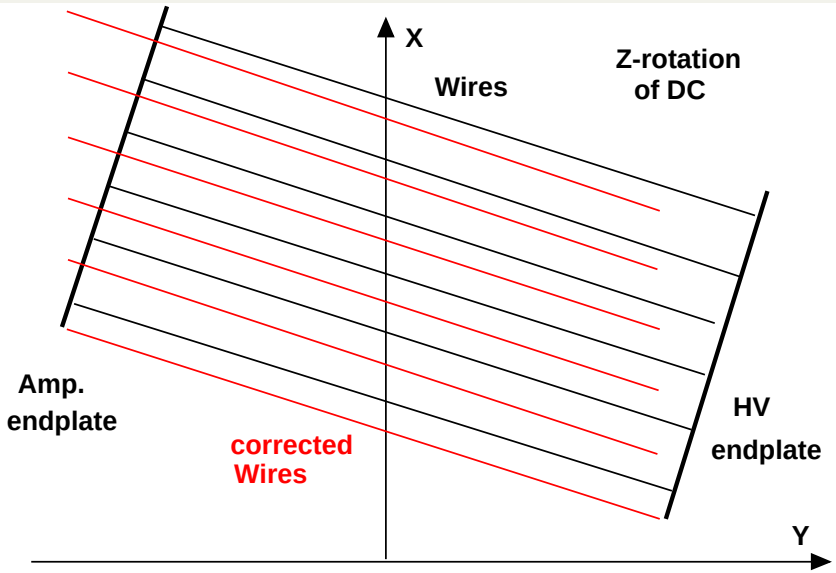
- while S_Z-values are inconsistent, $\Delta Y = S_Z R$ is the same for UpStream and DownStream ends:
  $$\Delta Y_{up} = -1.2 \pm 0.13 \times 10^{-3} * 510 = -0.61 \pm 0.07 mm,$$
  $$\Delta Y_{down} = -7.1 \pm 0.8 \times 10^{-3} * 79.4 = -0.56 \pm 0.06 mm,$$
- sectors are not rotated, but shifted in Y_{sector}.



Bugs in DC(dc_geom.c line.330)

```
/* actually, these (above) are the points on the wire in
 * the center of the chamber. To get the points in the
 * Sector midplane, we have to move along the wire to
 * where y=0 (definition of the Sector midplane).
 * Adjust the wire lengths as well.
 */
dist = -dcgw(wire).y_mid/dcgw(wire).y_dir;/*sign.dist.to move */
dcgw(wire).x_mid += dist*dcgw(wire).x_dir;/* slide along wire */
dcgw(wire).y_mid += dist*dcgw(wire).y_dir;/* should end up 0 */
dcgw(wire).z_mid += dist*dcgw(wire).z_dir;

wlp -= dist;/* the wire 1/2 lengths on 2 sides also changes */
wln += dist;
```

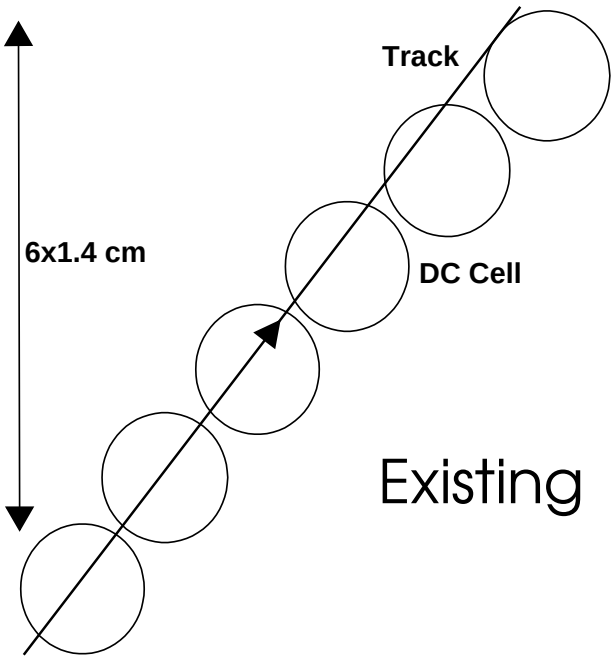


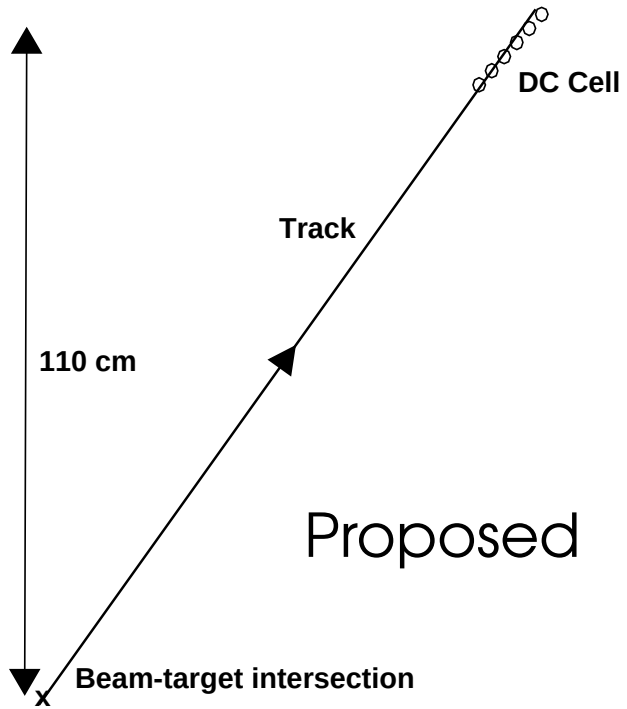
Alignment Data

Run Number	Run Period	Beam Energy (GeV)	Beam Current (nA)	Mini-Torus Current (A)	EC_{lo} Thresh. (mV)	Number of Events
8935	E1b	1.645	2.4*	6000	200	1138856
30909	E1-6	5.770	35*	6000	597	250573
30910	E1-6	5.770	35*	2000	597	1029523
31486	E1-6	5.770	35*	2000	600	358410
33006	E2b	4.470	1	2000	200	1566364
33683	E2b	0.984	1	2000	200	5733284
36654	E1e	5.015	1.5	2000	100	5032463
40905	Eg2a	4.023	20	0	172	360150
41709	Eg2a	5.015	2	2000	172	1011892
47447	DVCS	5.776	10	S 0 ?	168	14669929
50226	Bonus	5.268	21	S200	260	1114847
58609	DVCS2	5.911	16	S150	148	5426033
58612	DVCS2	5.911	30	S40	148	3215225
60110	EG1DVCS	5.979	5*	S40%	148	2009289
60111	EG1DVCS	5.979	5*	S80%	148	1270141
60649	EG1DVCS	5.777	5*	S?%	148	5059546

Existing Alignment (CLAS-Note-2001-22)

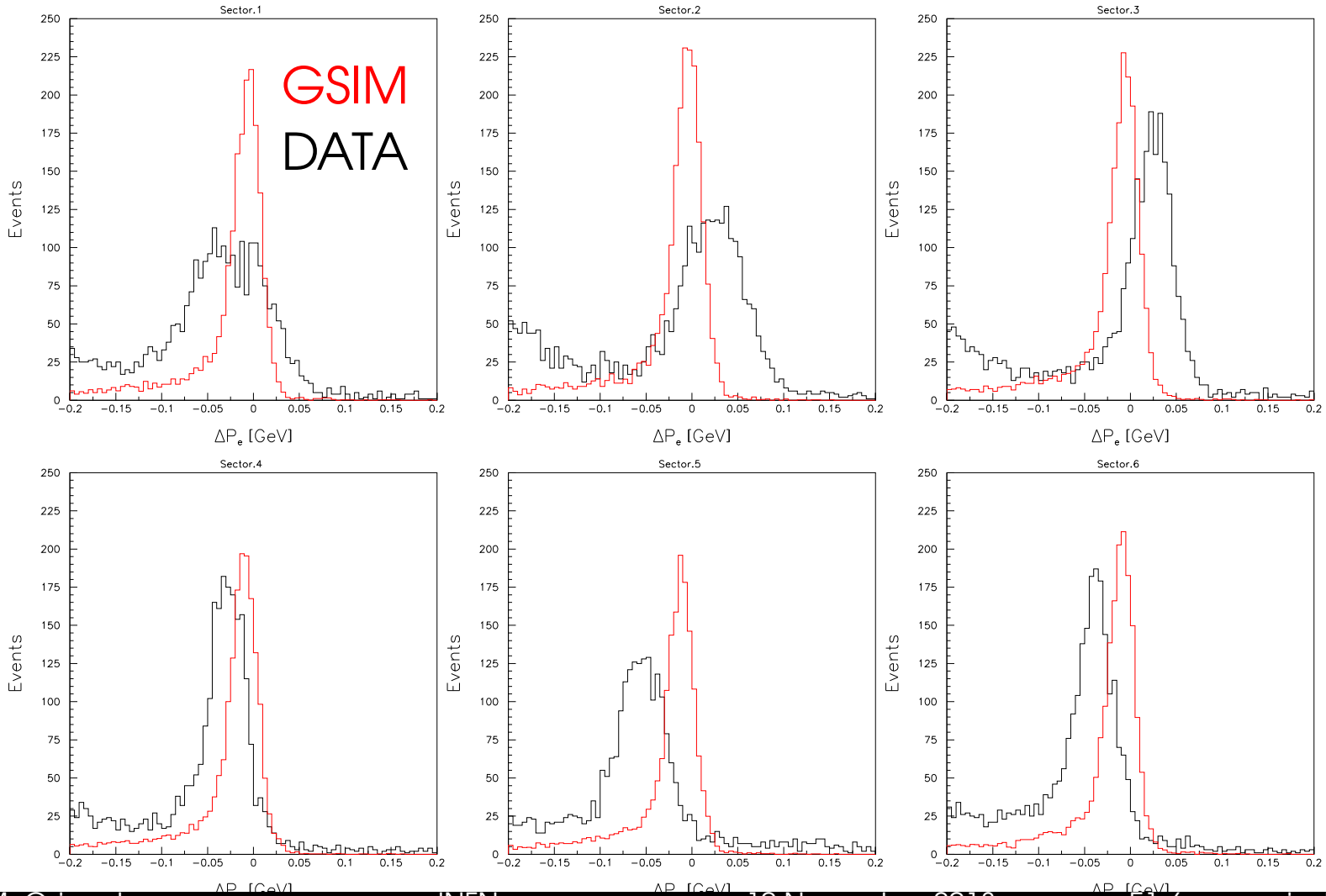
- define tracks by HBT (all three Regions) + TBT Region 1,
- results depend on input positions of Regions 2 and 3,
- no reference common to all sectors,
- $\delta\theta \sim 0.03/(1.4 \times \sqrt{6-2}) \sim 10.7$ mrad.,
- $\delta\phi \sim \delta\theta/tan6^\circ \sim 107$ mrad.,
- $\delta X, Z = 1$ cm in Region 2, and 2 cm in Region 3.





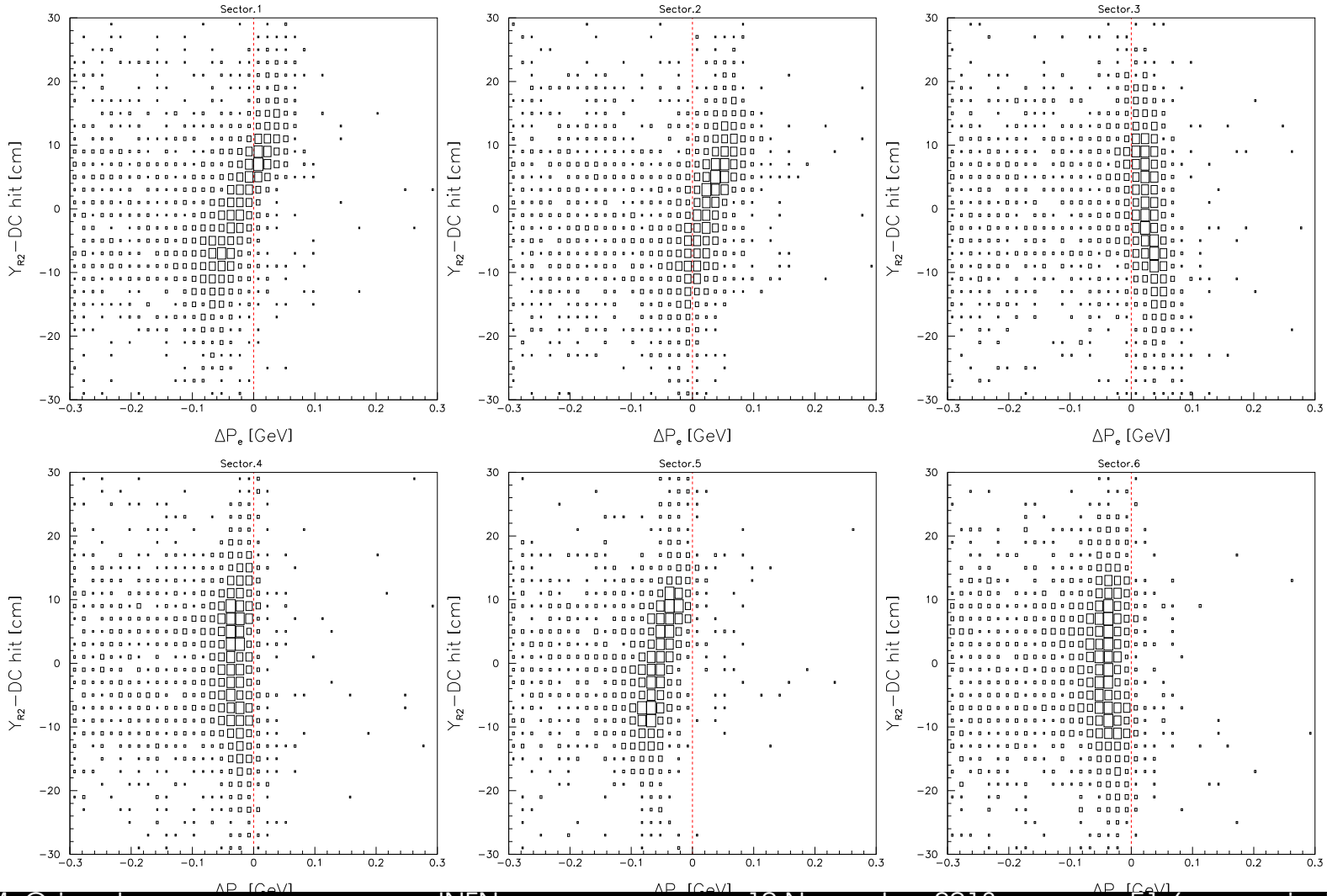
Existing Alignment Results: elastic e'

1. elastic peaks are shifted,
2. peak widths are larger.



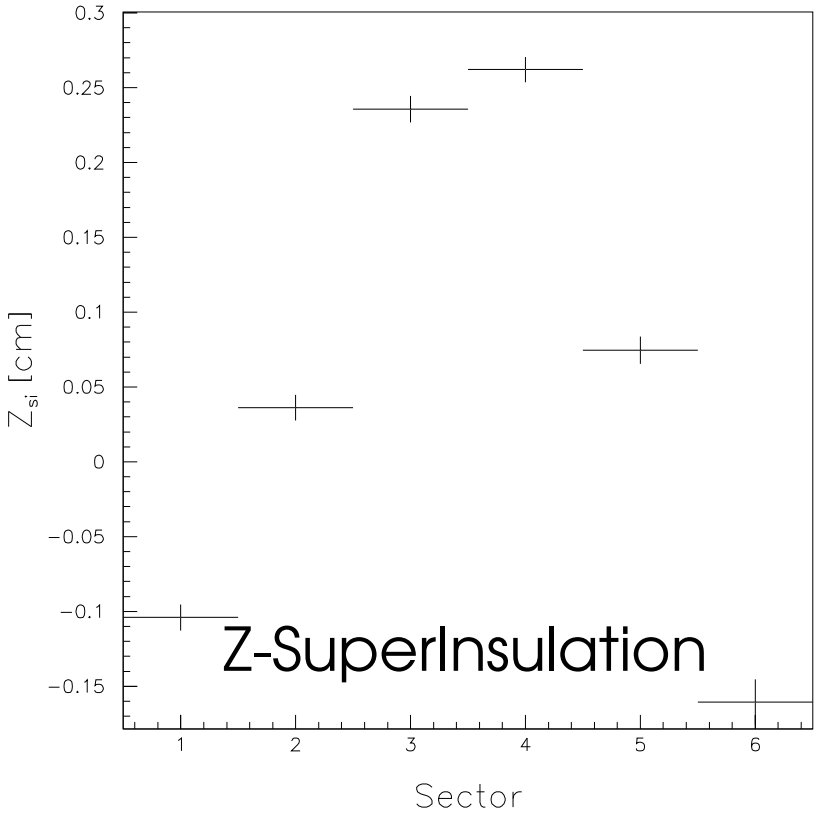
Existing Alignment Results: elastic e'

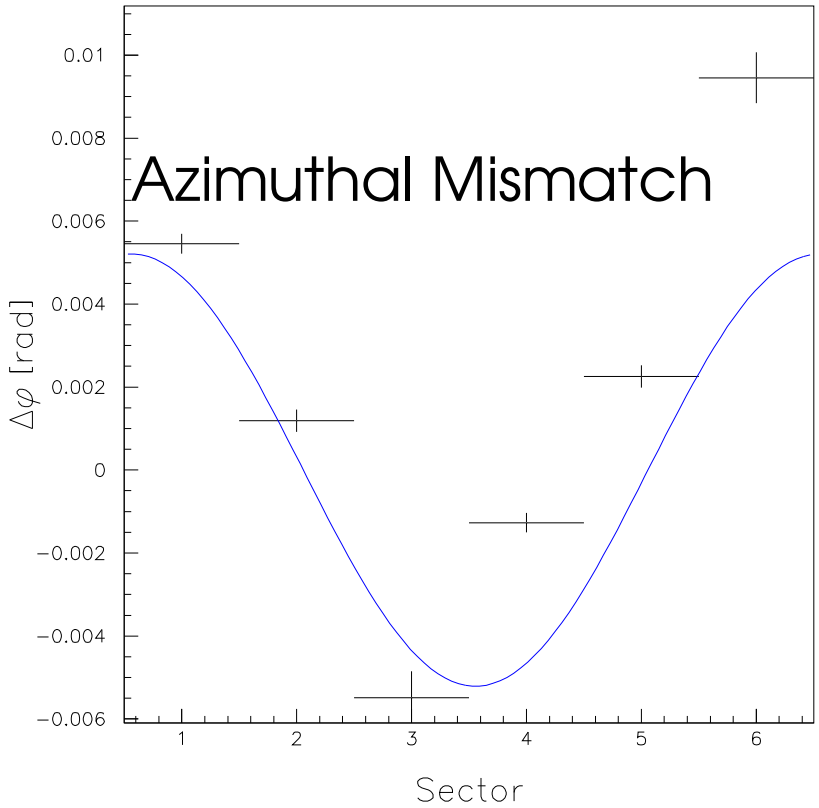
1. ϕ-dependence of the offset misalignment,
2. magnetic field is symmetric in ϕ (wrt mid. Sector).



Existing Alignment Results: elastic $e'p$

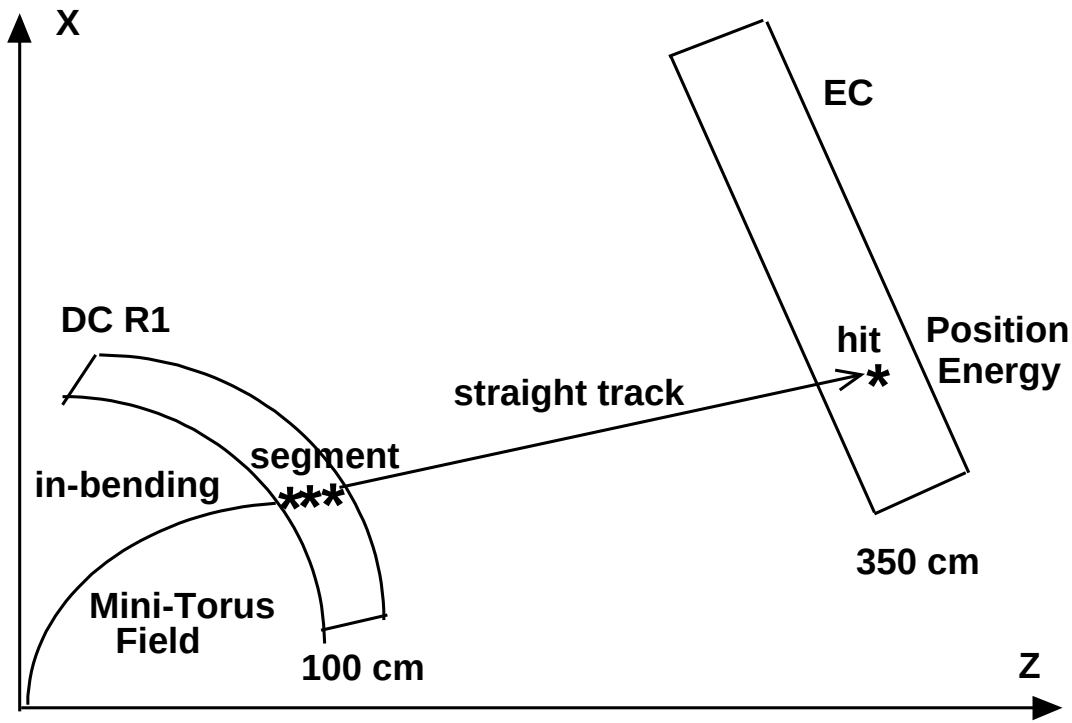
- vertex reconstruction is Sector-dependent,
- mitigated by phenomenological beam-position corrections,
- Sectors correlated in ϕ at ± 10 mrad.,
- not observed due to dc_geom.c bug from slide 9.

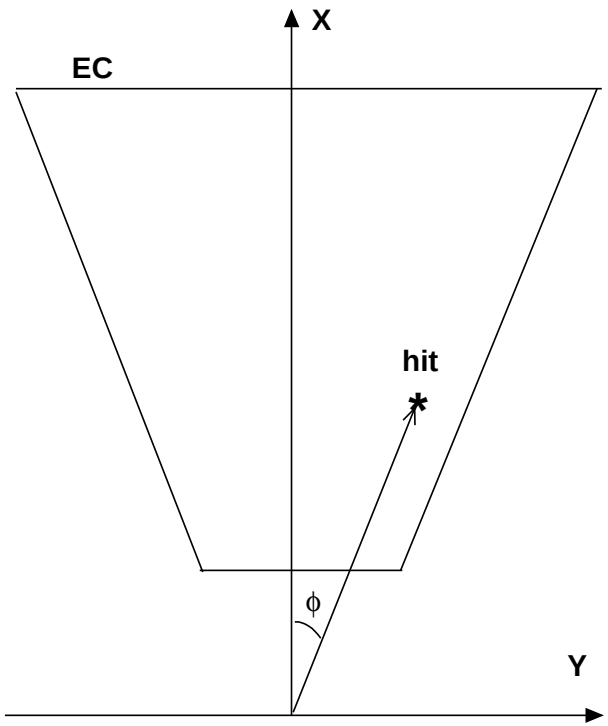




New Alignment

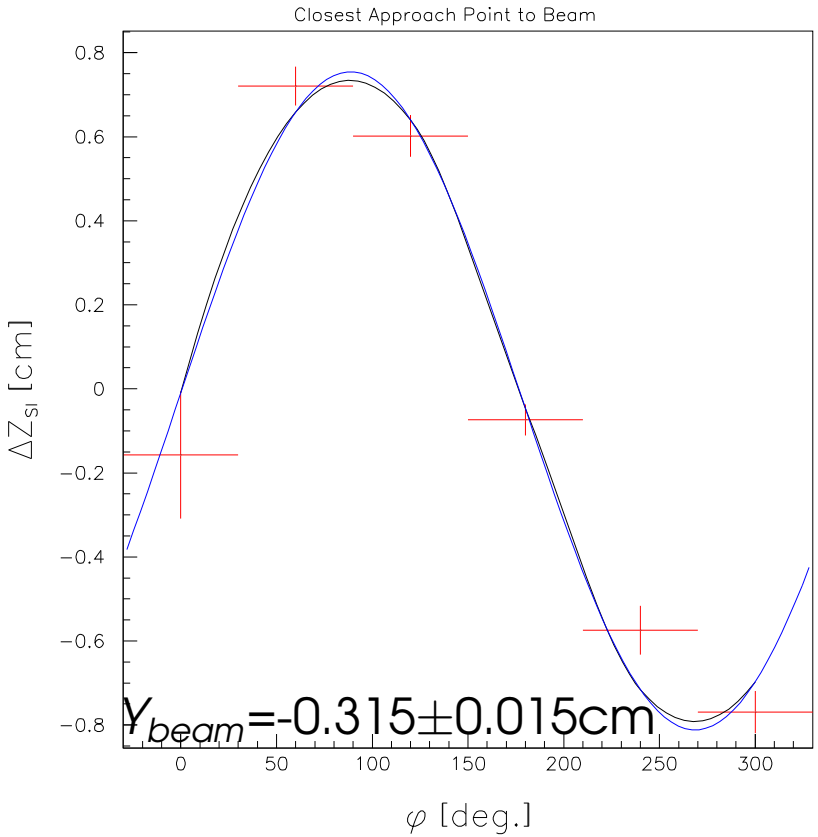
- select electrons only by $E_{EC}^{rec} > 1.7$ GeV cut,
- use reconstructed E_{EC}^{rec} to swim in Mini-Torus field,
- track back to the vertex to check beam/target rec.,
- use ϕ_{EC} and vertex to fit θ-only in SL2 (check SL1).

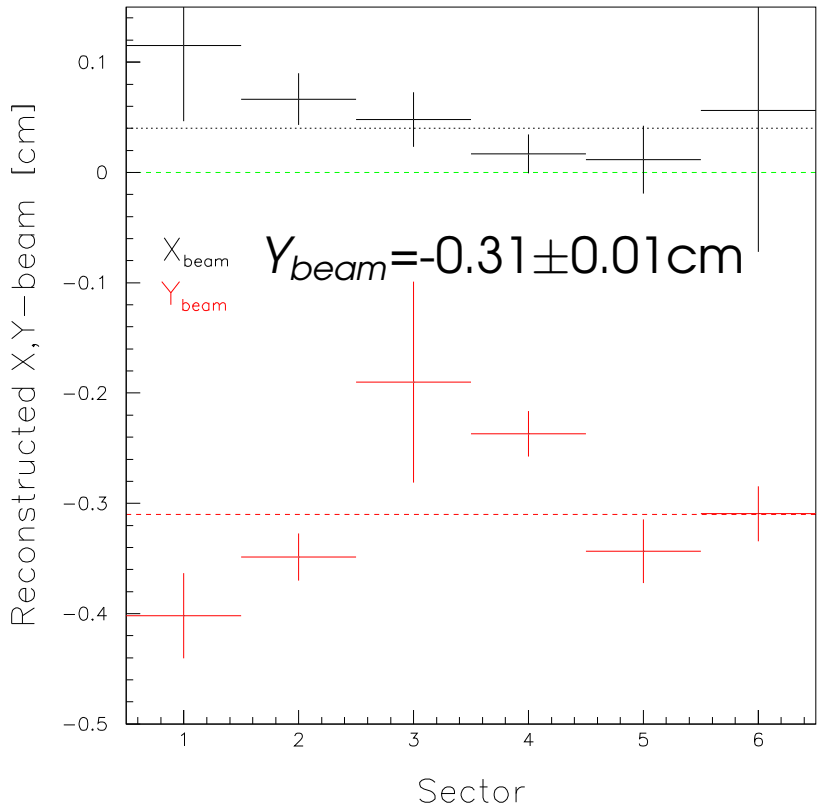




Vertex Reconstruction (θ_{EC}, ϕ_{EC})

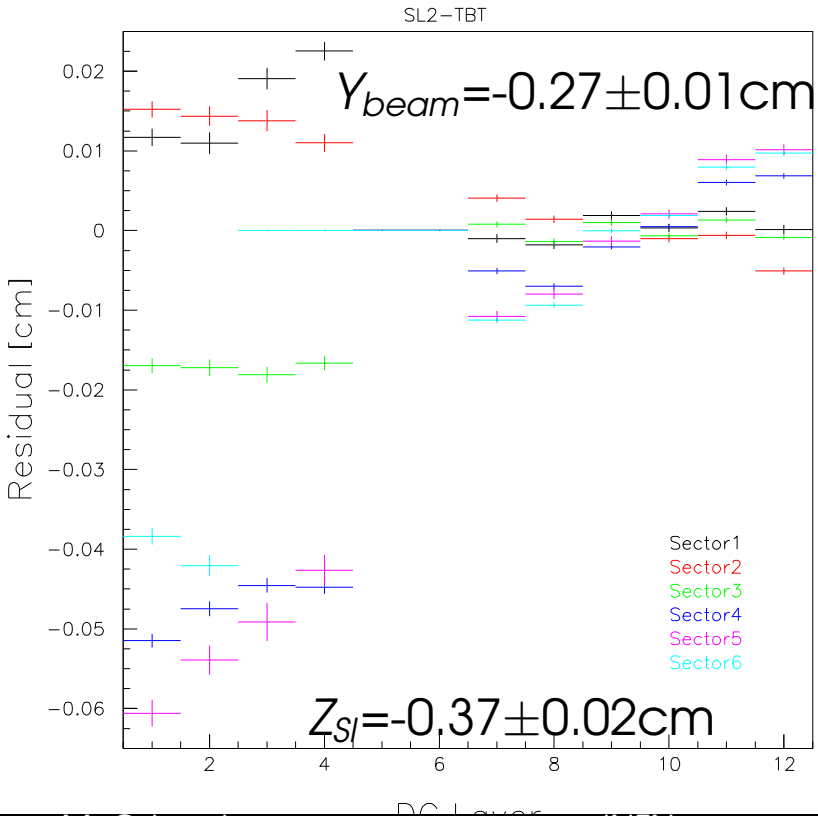
- reconstructed Z-vertex is Sector-dependent,
- fit of Sector-dependence gives $Y_{vtx} = -0.315$ cm,
- $X, Y(Z_{SI} = 0.42)$ cm gives $Y_{vtx} = -0.31$ cm,
- Beam offset by -0.31 or DC R1 by +0.31 cm in Y.

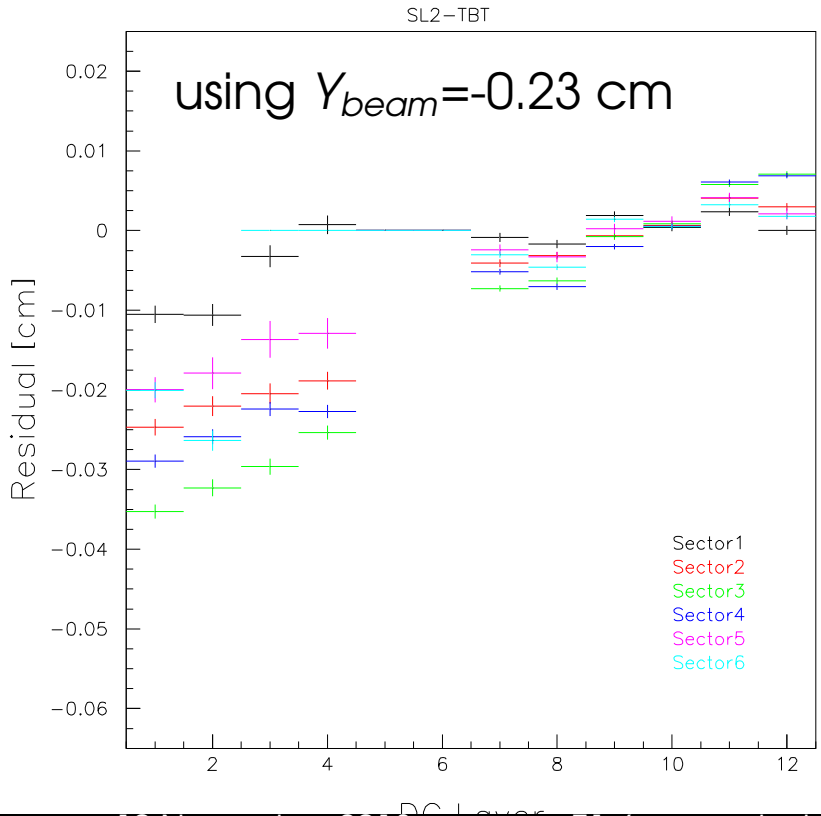




SL1 Residuals (ϕ_{EC})

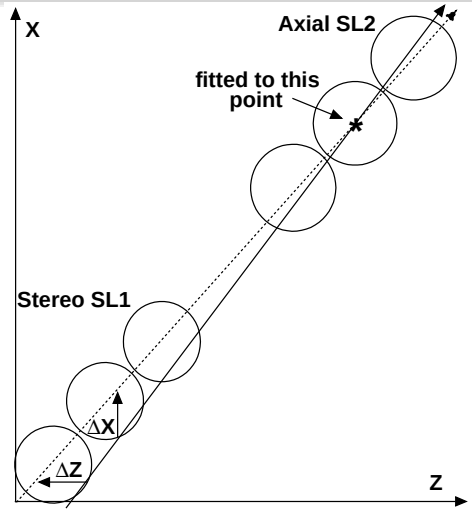
- fixed vertex and ϕ_{EC}, fitted θ using SL2-only,
- deviations in SL1 indicates $Y_{vtx} = -0.27$ cm,
- SL1 is offset by -200 μm, SL1-SL2 distance is 8.582 cm, $\Delta Z_{SI} = 0.02/8.6 * 95/\sin\theta = 0.75$ cm or $\Delta X_{wires} = 0.02/8.6 * 95/\cos\theta = 0.23$ cm,
- either ΔZ_{SI}=-0.75 cm or ΔX_{wires}=-0.23 cm.

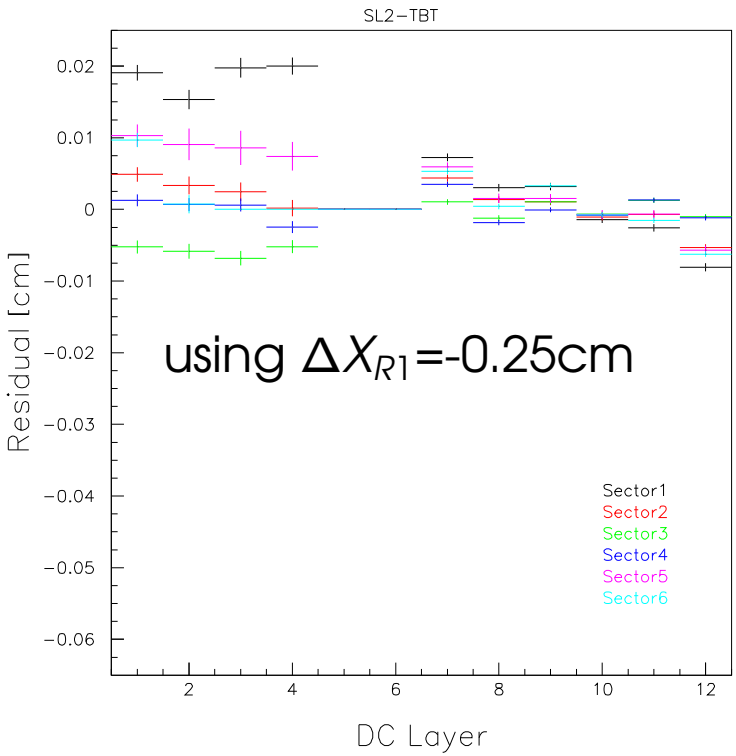


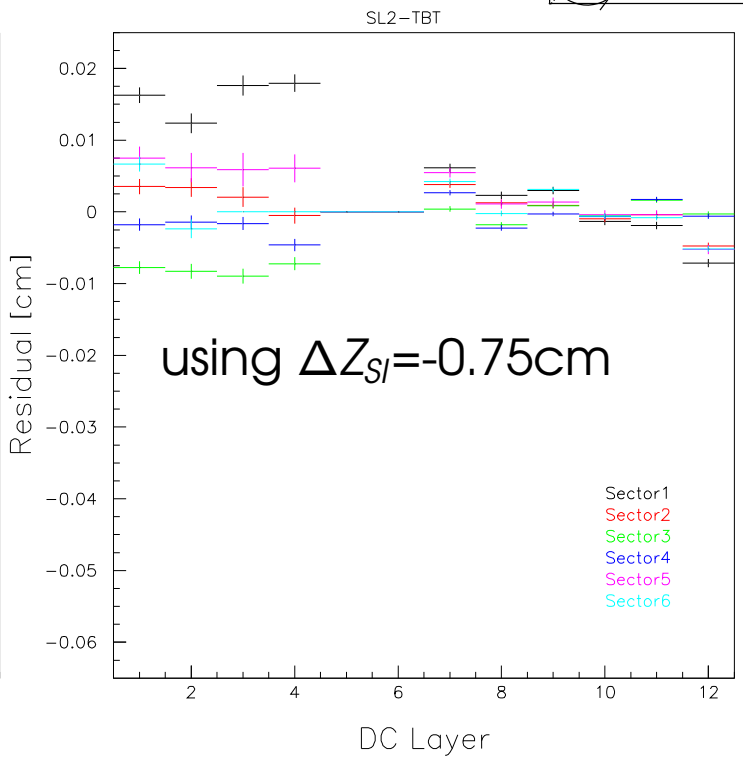


SL1 Residuals (ϕ_{EC}) Solutions

- ΔX_{wires}=-0.25 cm means constructive defect in R1,
- ΔZ_{SI}=-0.75 cm means target or DC R1 (survey) Z-offset,
- Indistinguishable in alignment data (Mini-Torus field >0).

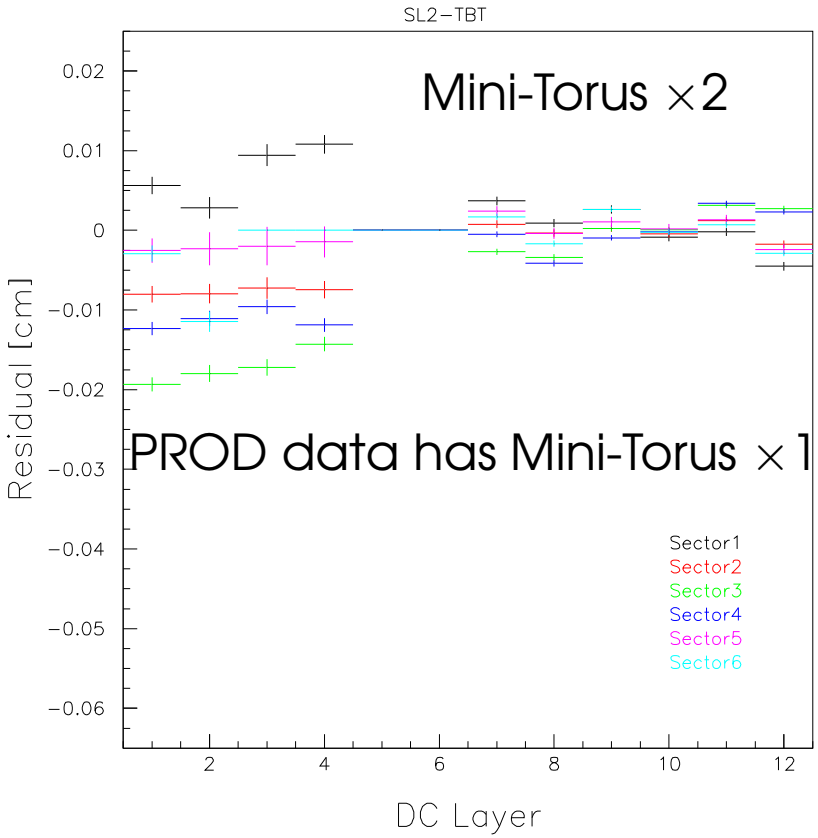


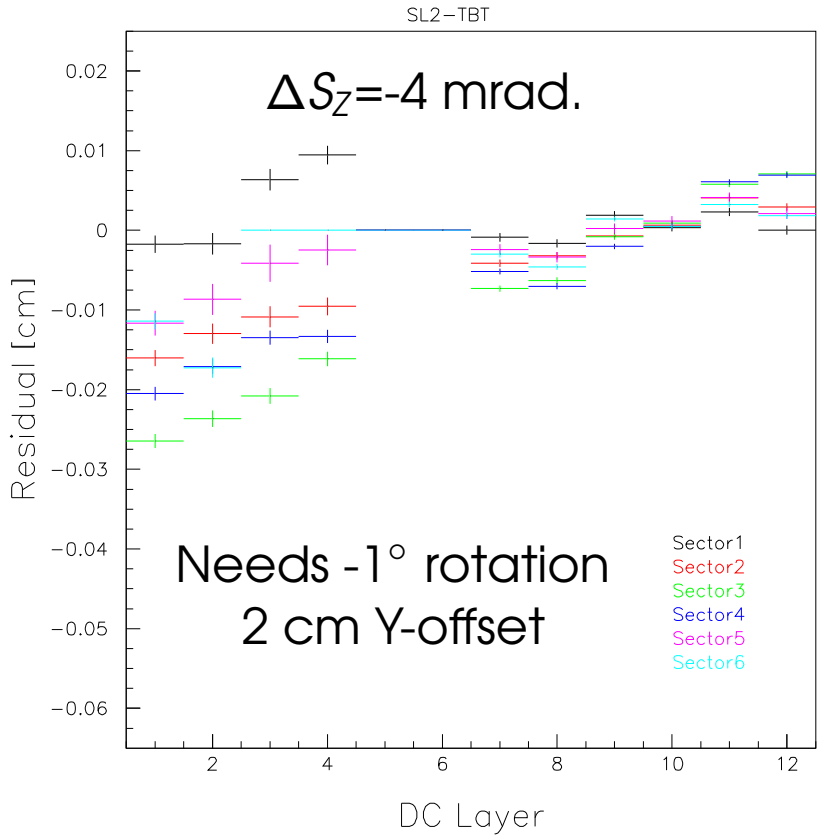




SL1 Residuals (ϕ_{EC}) Alternative Solutions

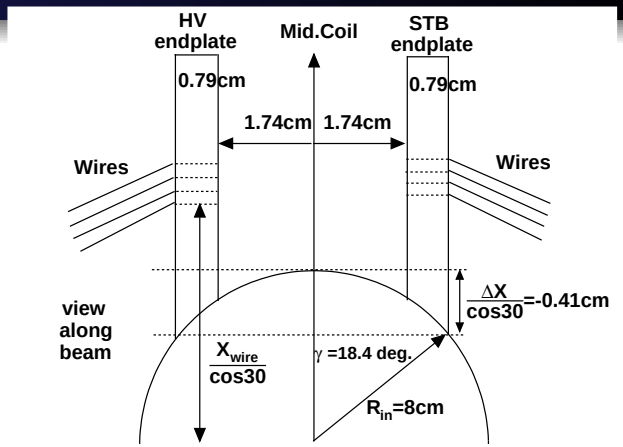
- EC has 10% energy resolution, increase of P_e by 1σ corresponds to change of -10μm in SL1 residual,
- increase of Mini-Torus field $\times 2$ gives -50 μm,
- R1 Z-rotation by 4 mrad gives -150 μm,
- T_0-calibration offsets in R1.

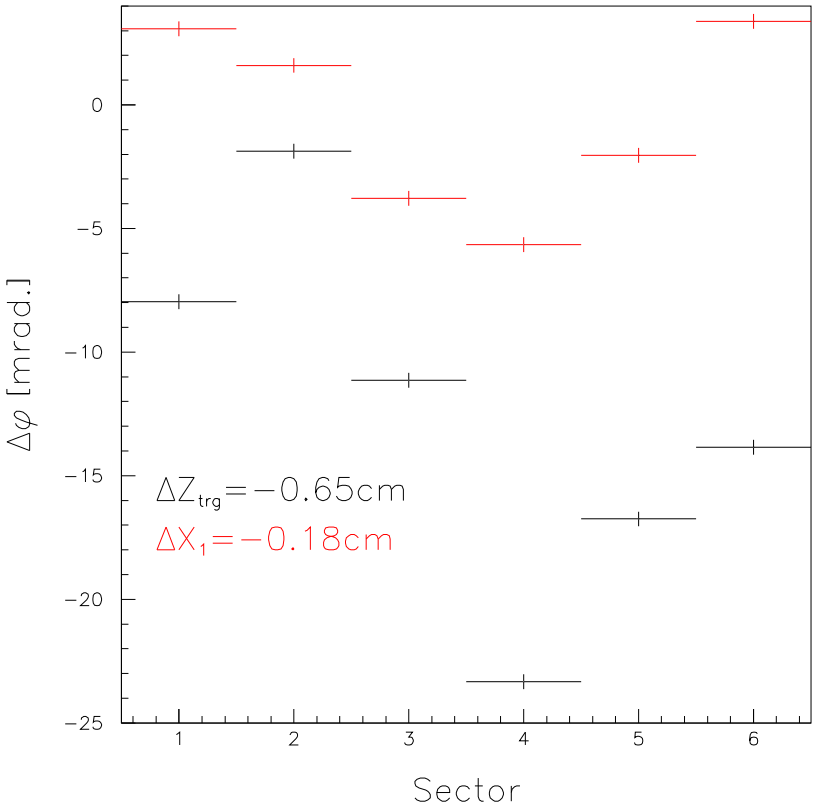


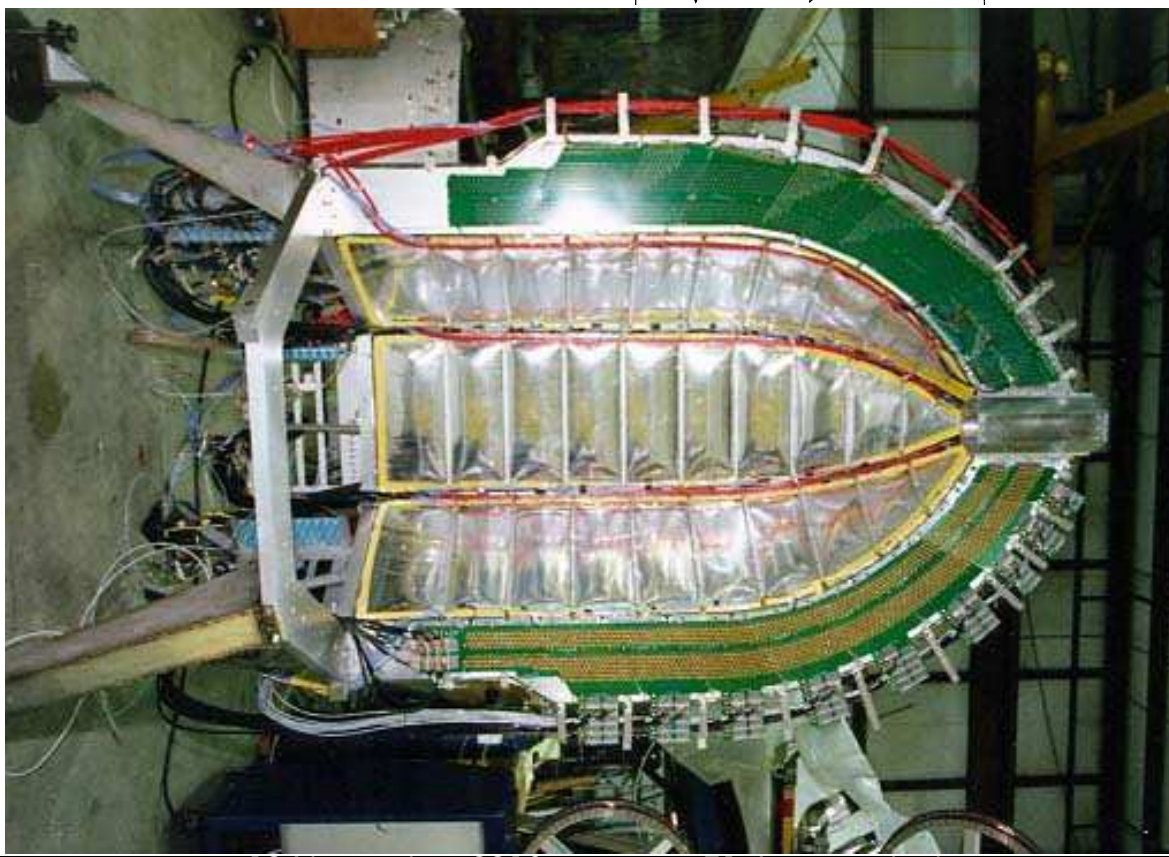


Best Solution

- ΔZ_{trg}-correction gives large $\Delta\phi_{ep}$ for elastic $e'p$-events (>20 mrad.~1 deg.) in PROD,
- ΔX_1-correction consistent with sys. precision,



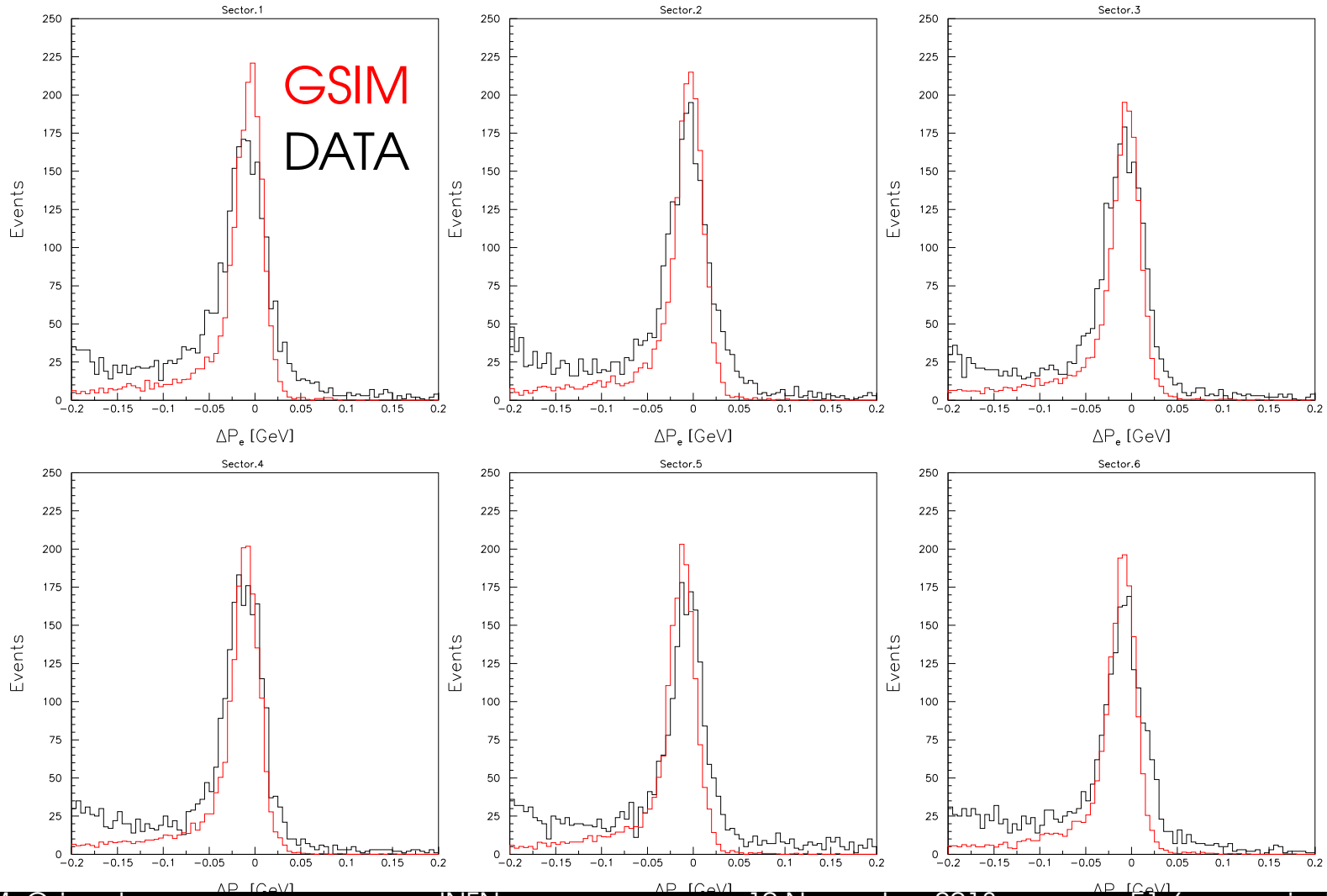




The following come from old version of alignment!

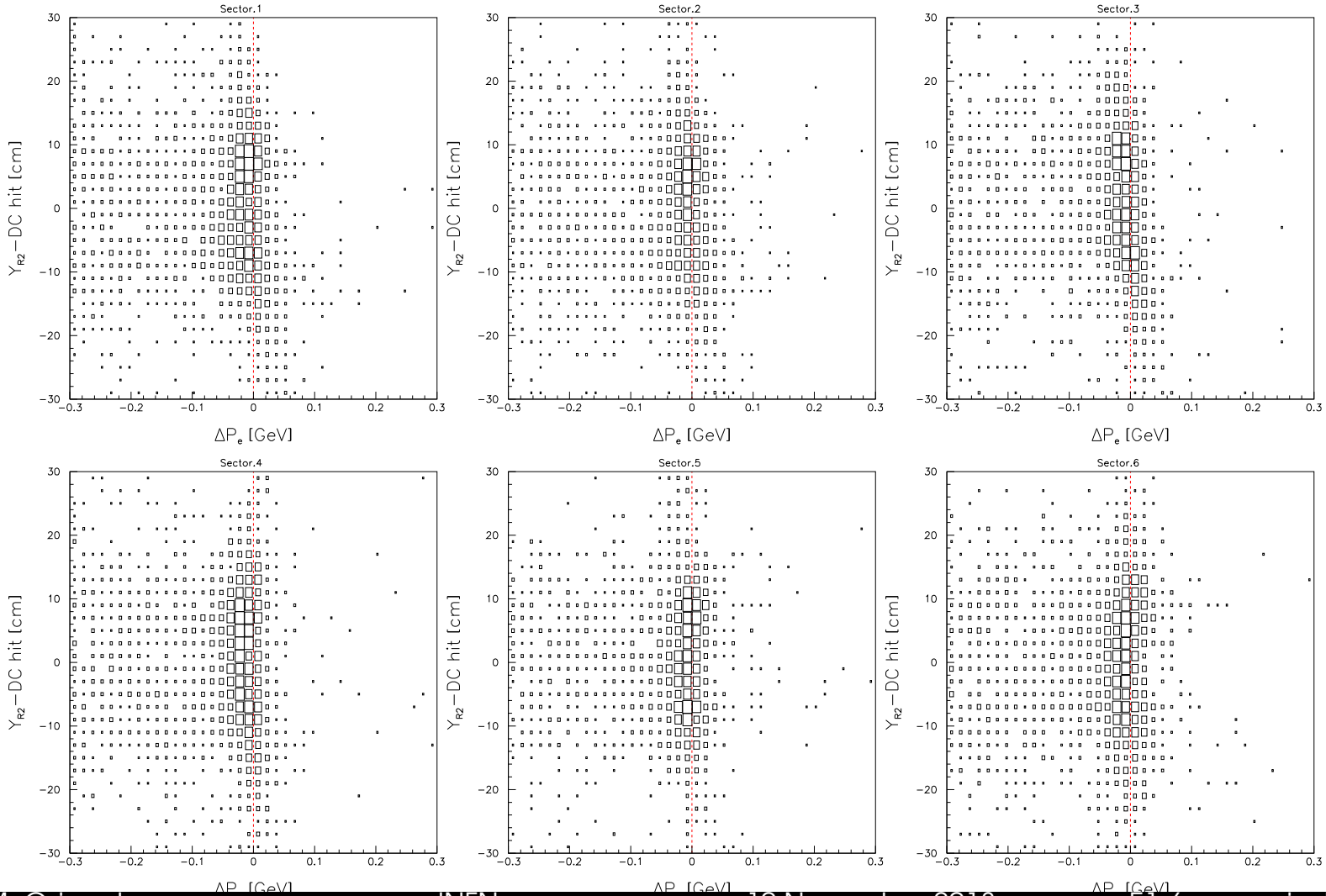
elastic e′

1. elastic peaks are all aligned,
2. peak widths are in agreement with GSIM.



elastic $e'(\phi)$

1. ϕ-dependence of the offset is almost flat,
2. small shape differences.



elastic p'

1. elastic peaks are all aligned,
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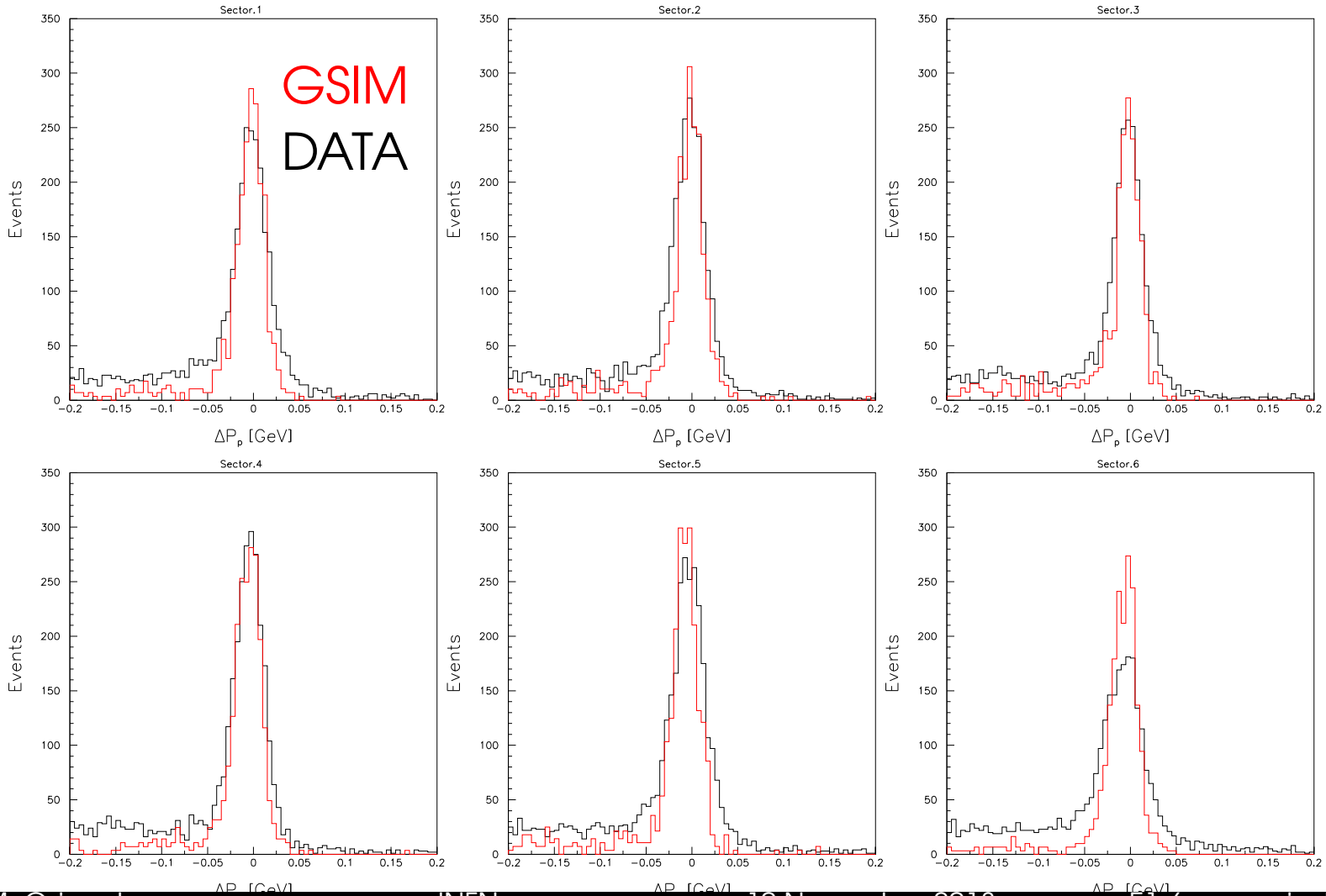
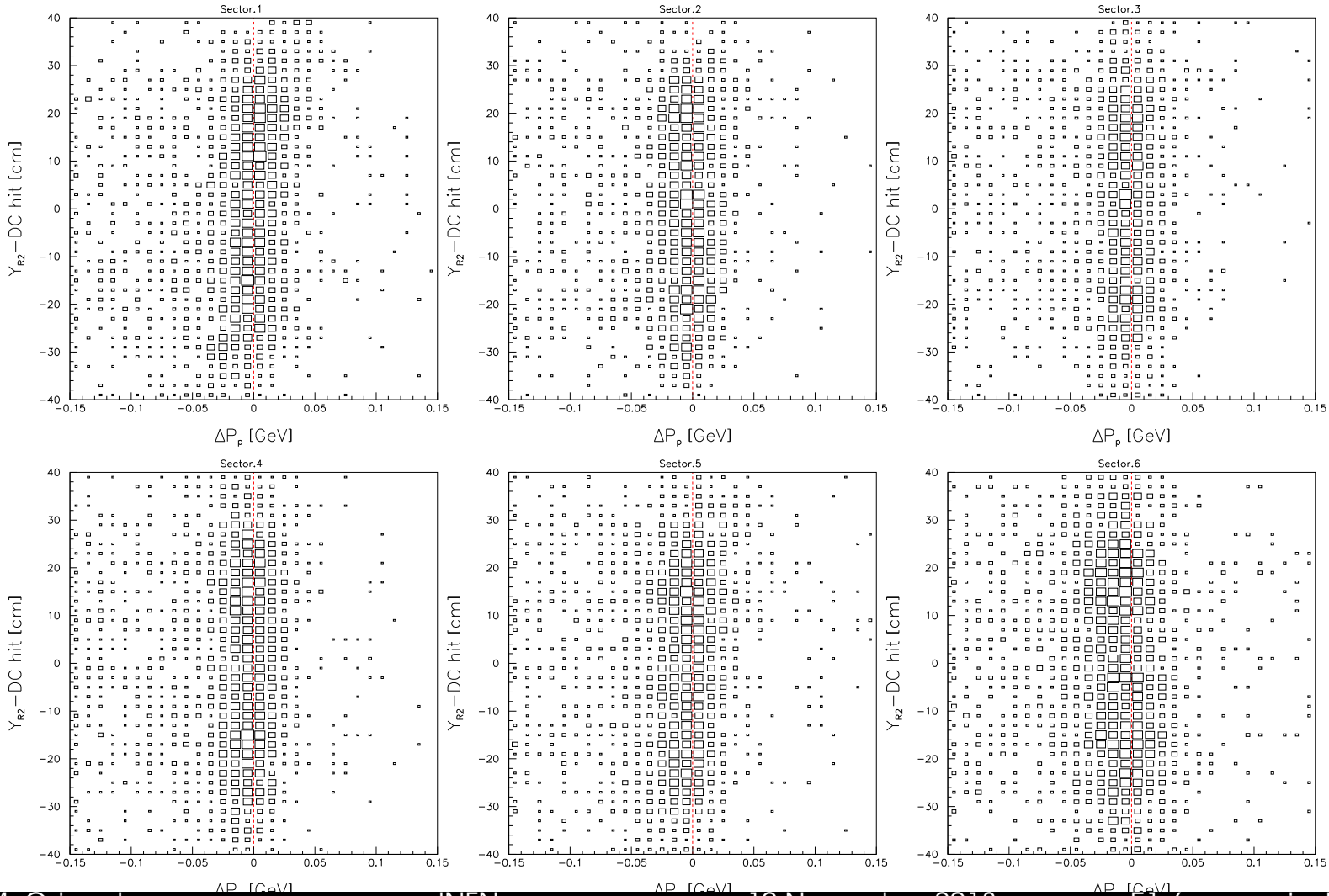


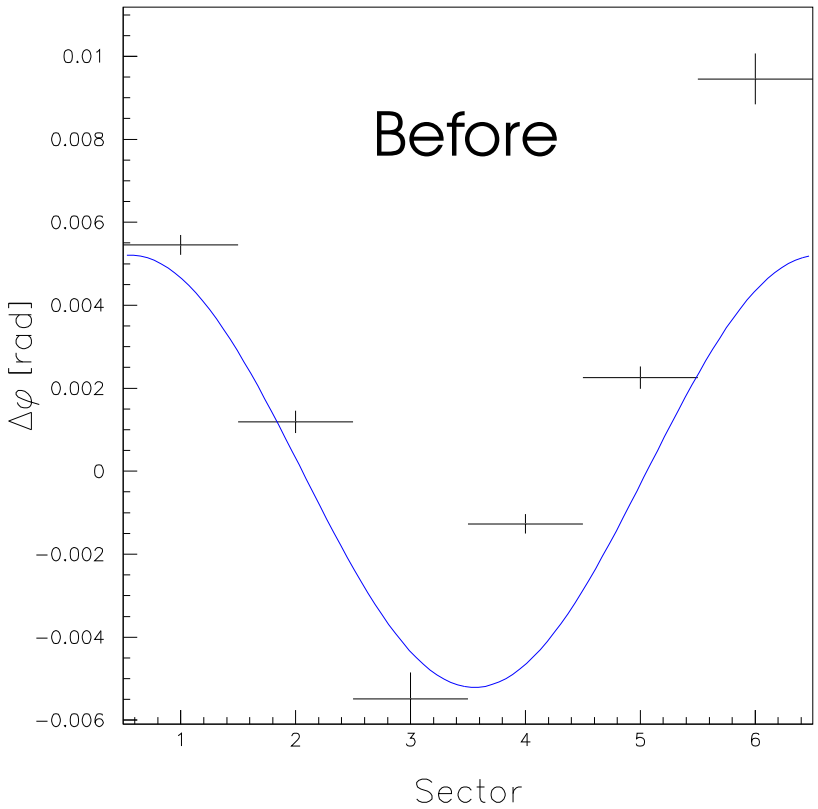
elastic $p'(\phi)$

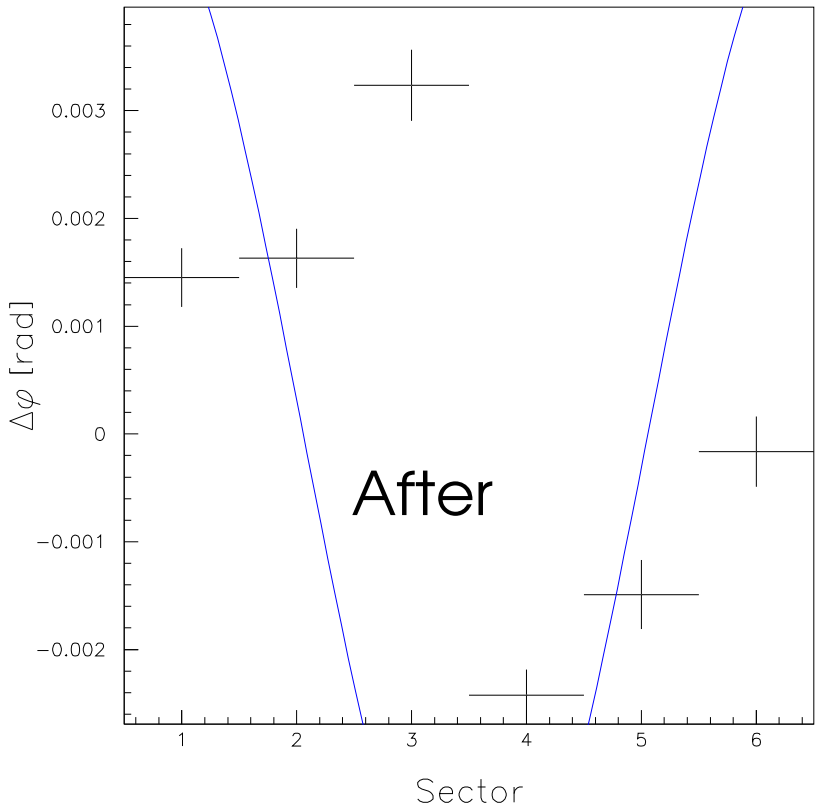
1. ϕ-dependence of the offset is almost flat,
2. only Sector 6 (2 stereo layers) has different width.



elastic e′p(ϕ)

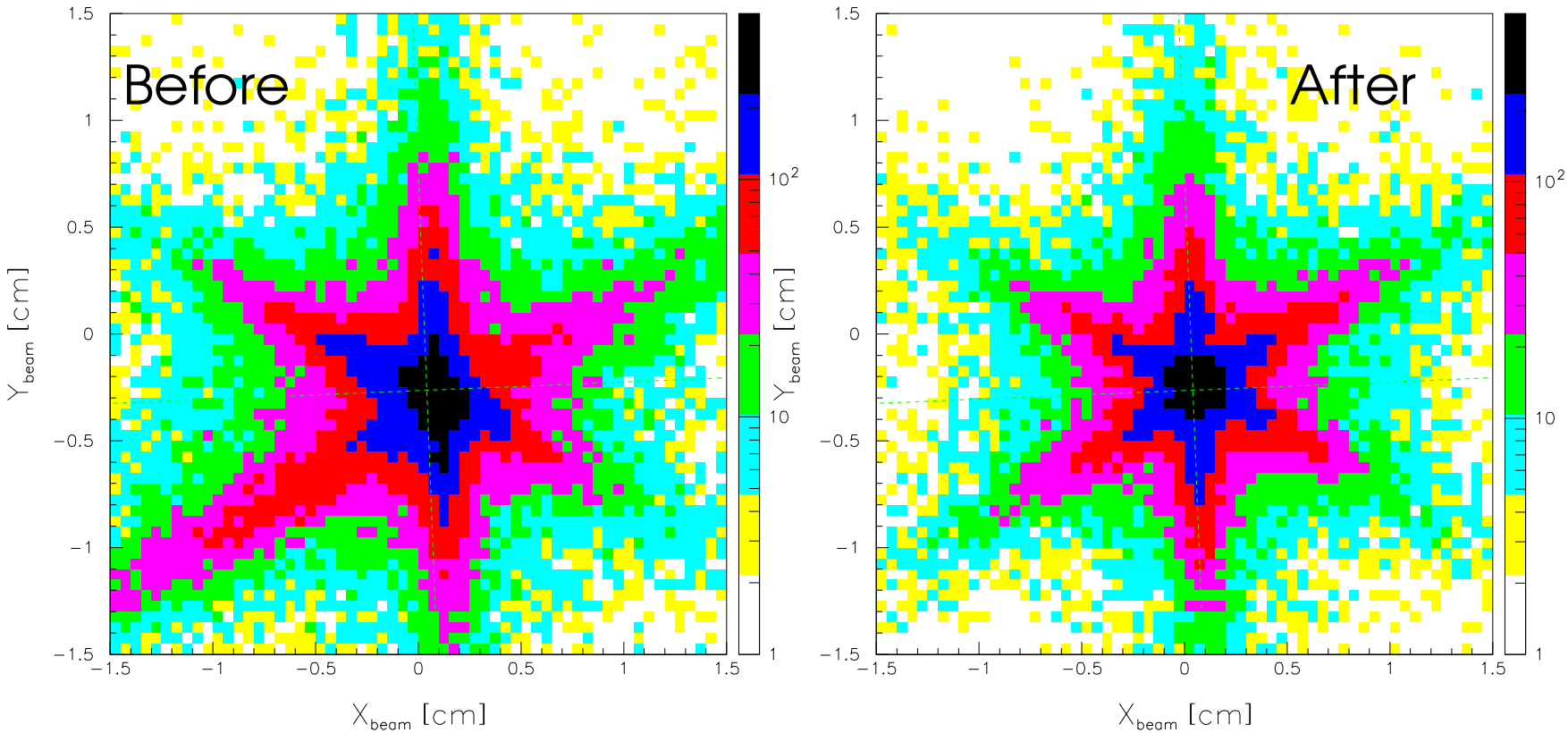
- $\Delta\phi$-spread reduced from 20 mrad. to few mrad.,
- sectors divided in two groups: top and bottom.





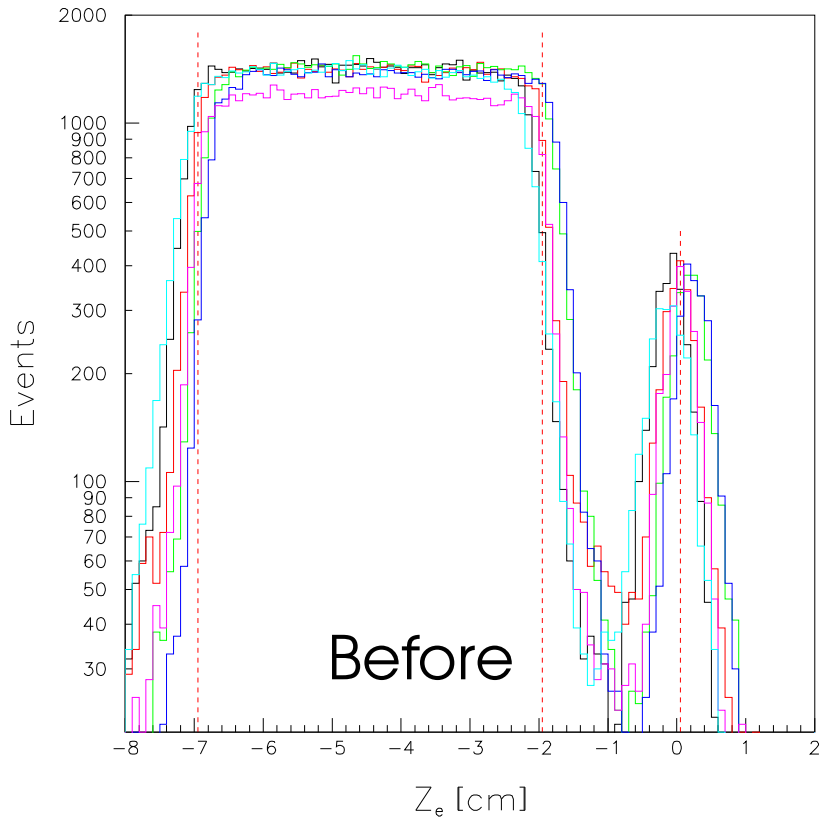
X,Y-vertex reconstruction

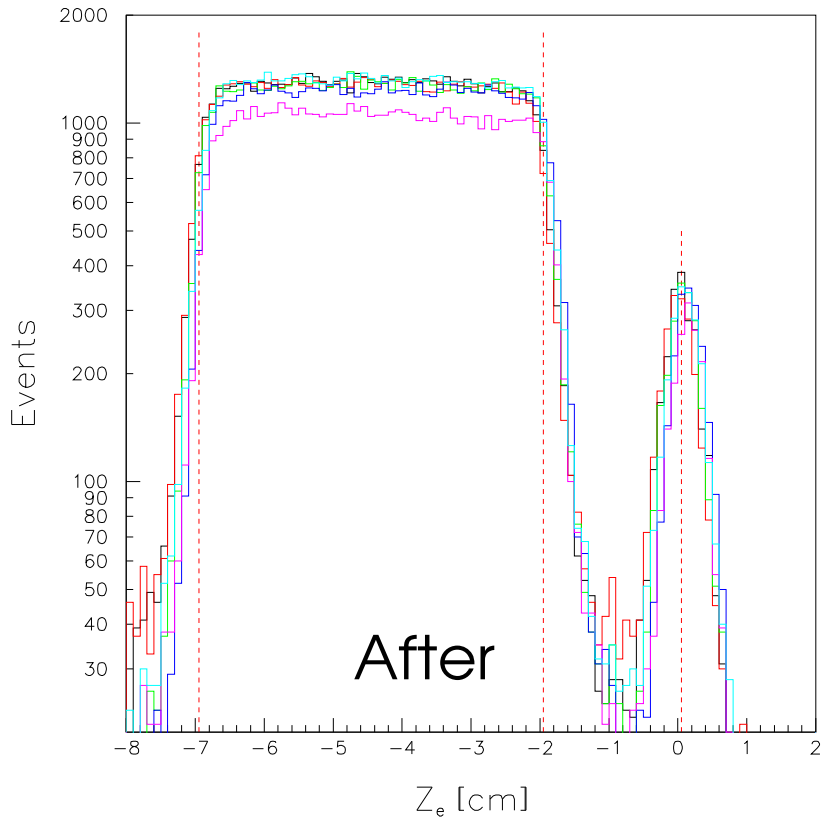
- more symmetric and narrower beam spot,
- reconstructed beam position is compatible with that used in alignment.



Z-vertex reconstruction

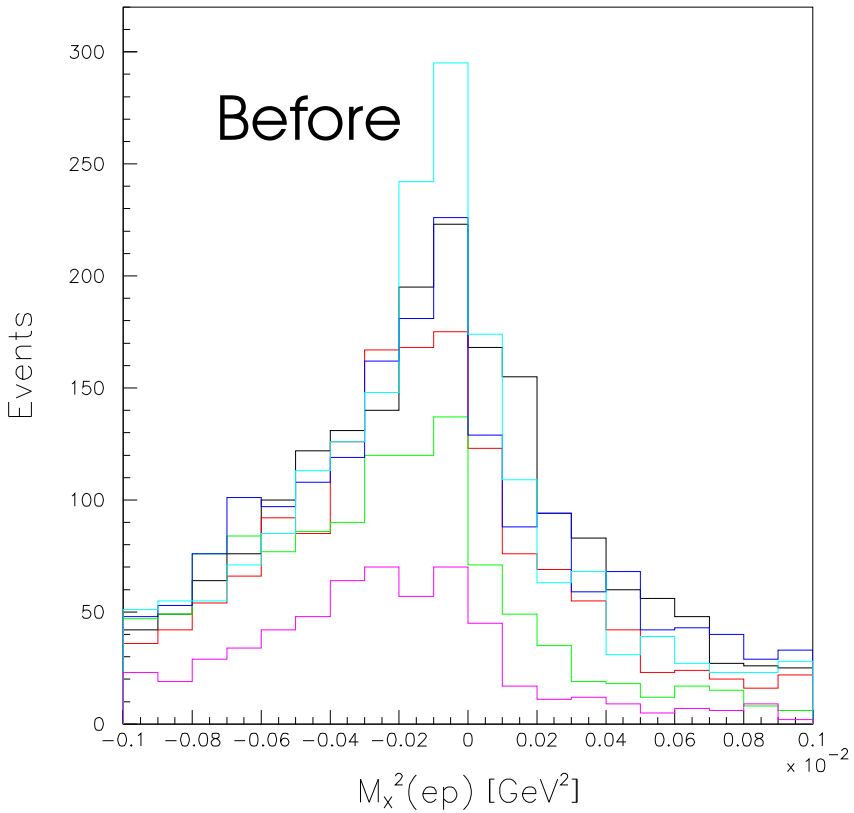
- vertex reconstruction is Sector-independent,
- reconstructed target position is almost compatible with that used in alignment (+1 mm).

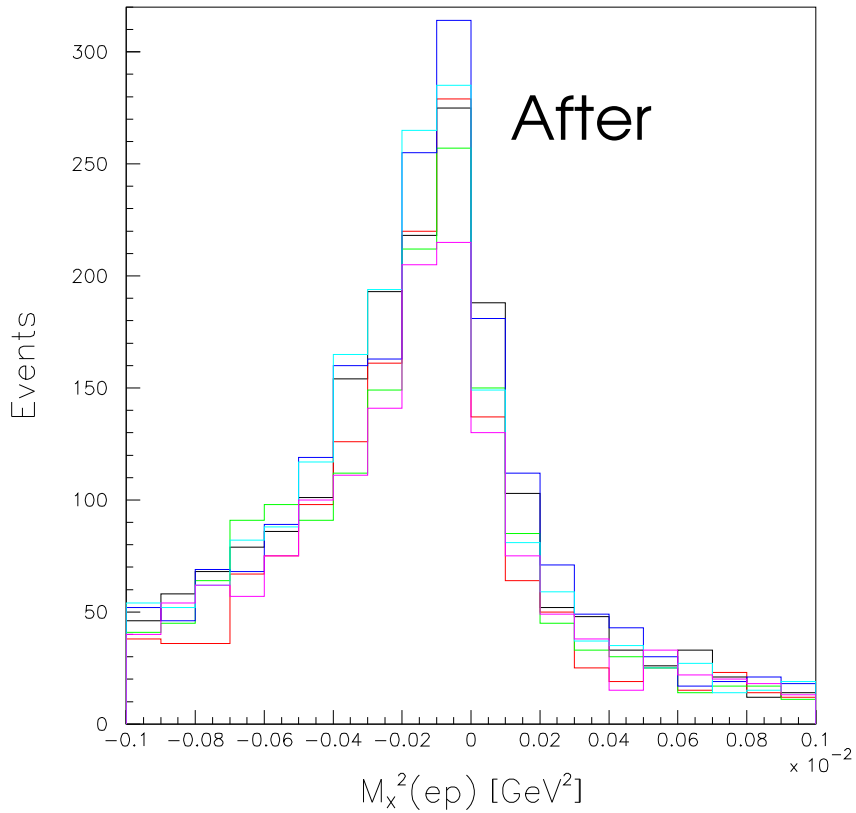




ep missing mass

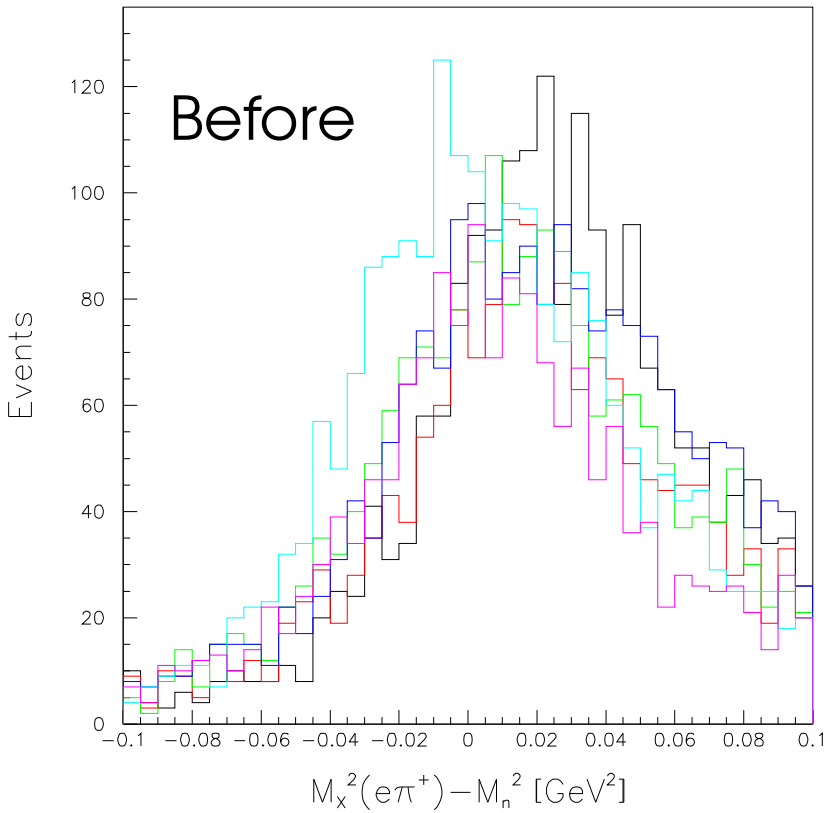
- Sector-dependence was removed,
- better resolution in many Sectors.

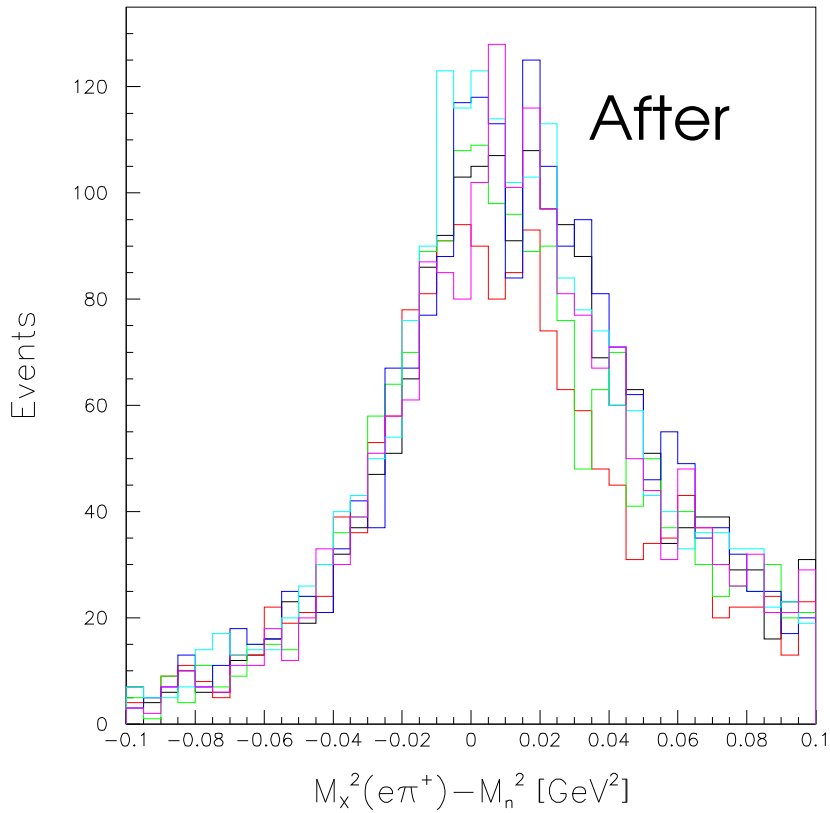




$e\pi^+$ missing mass

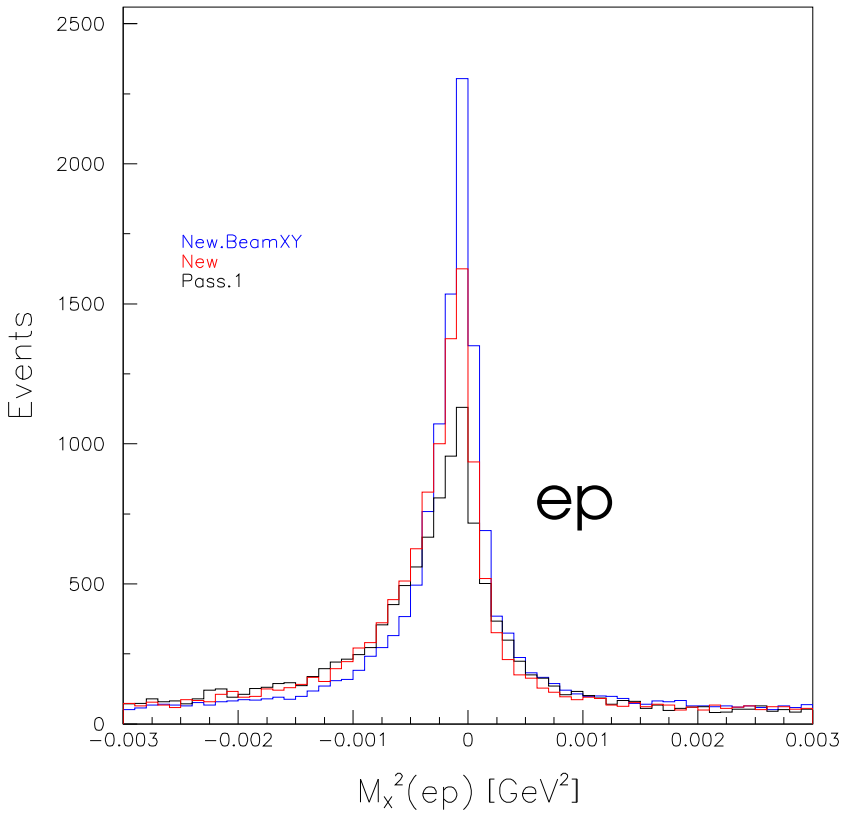
- Sector-dependence was removed,
- better resolution in many Sectors.

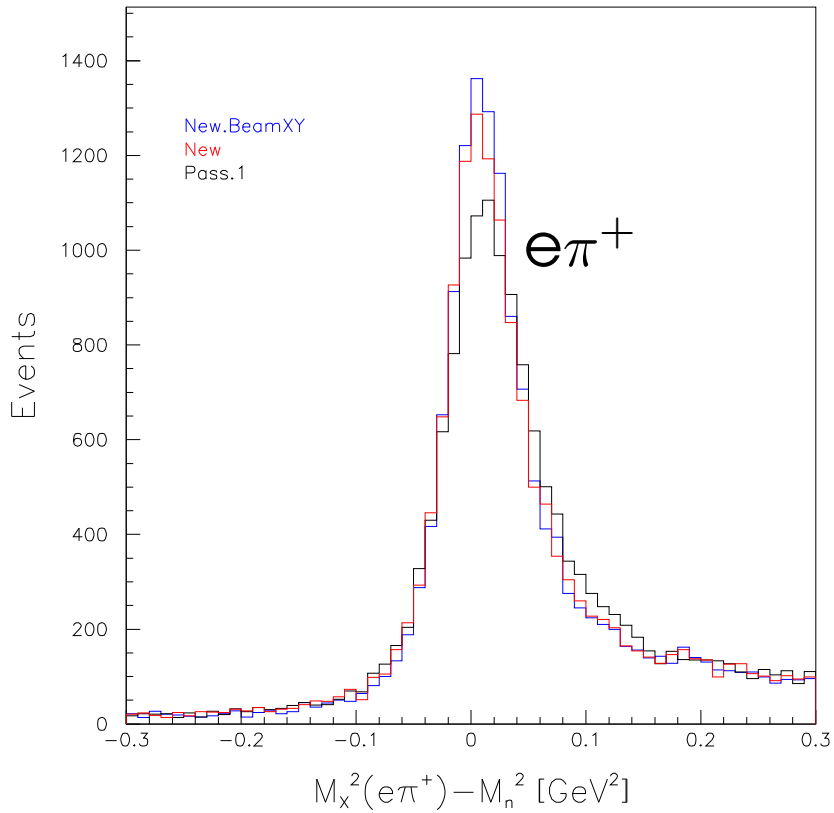




Beam Spot Constraint

- increased reconstruction efficiency,
- ep-efficiency +15%, $e\pi^+$-efficiency +1.5%,
- surplus events are outside e-fiducial cuts,
- but resolution is improved.



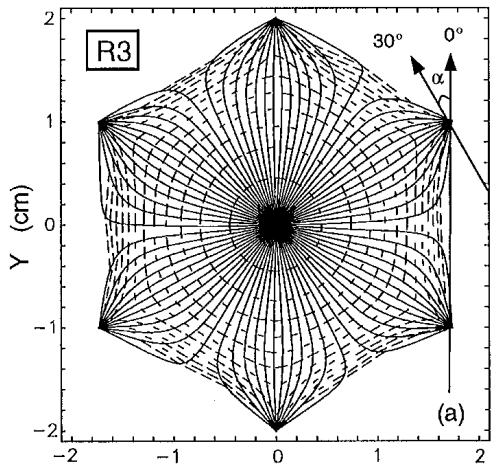


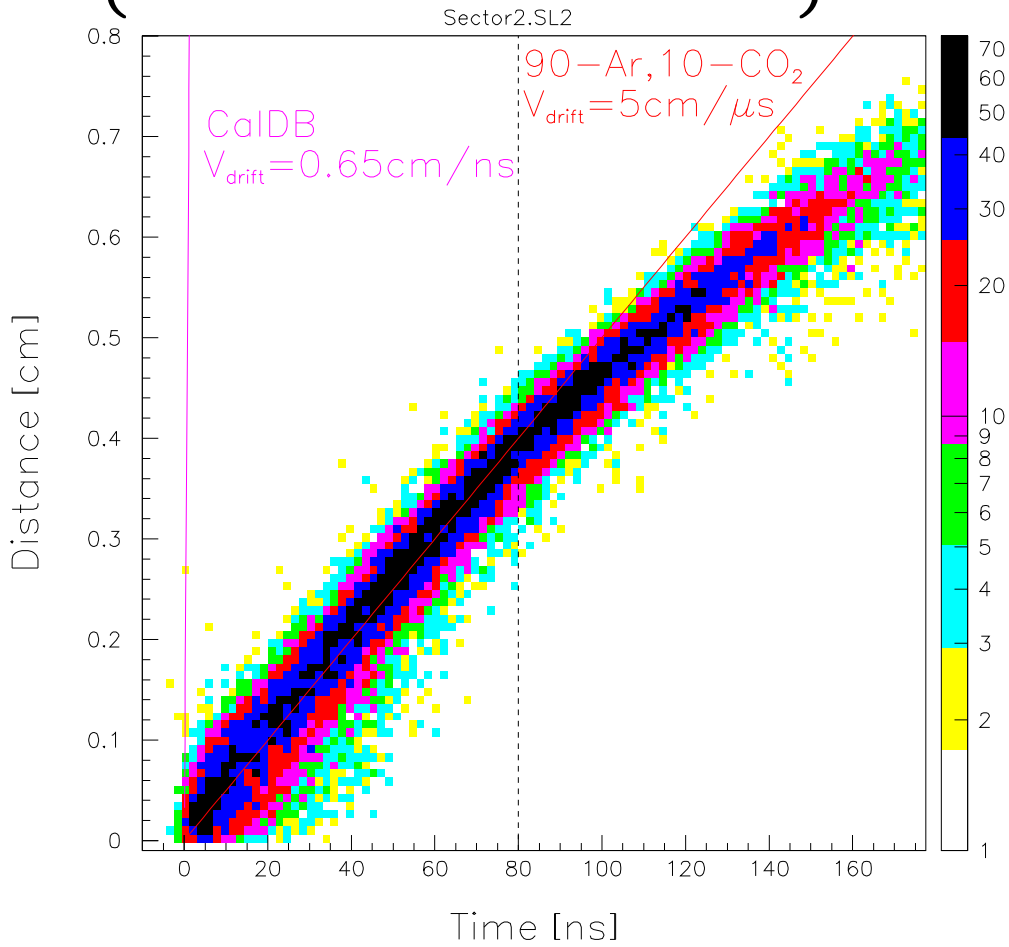
D vs. T Calibrations

The parametrization of time-to-distance function used in the calibrations has the following form:

$$d = p_1 t + \frac{d_{max} - p_1 t_{max}}{1 - p_2} \left\{ \left(\frac{t}{t_{max}} \right)^{p_3} - p_2 \left(\frac{t}{t_{max}} \right)^{p_4} \right\},$$

1. p_1 is drift velocity,
2. 90% Ar+10% CO_2 has 5 cm/μs,
3. $p_{2,3,4}$ are correction for curved field lines.



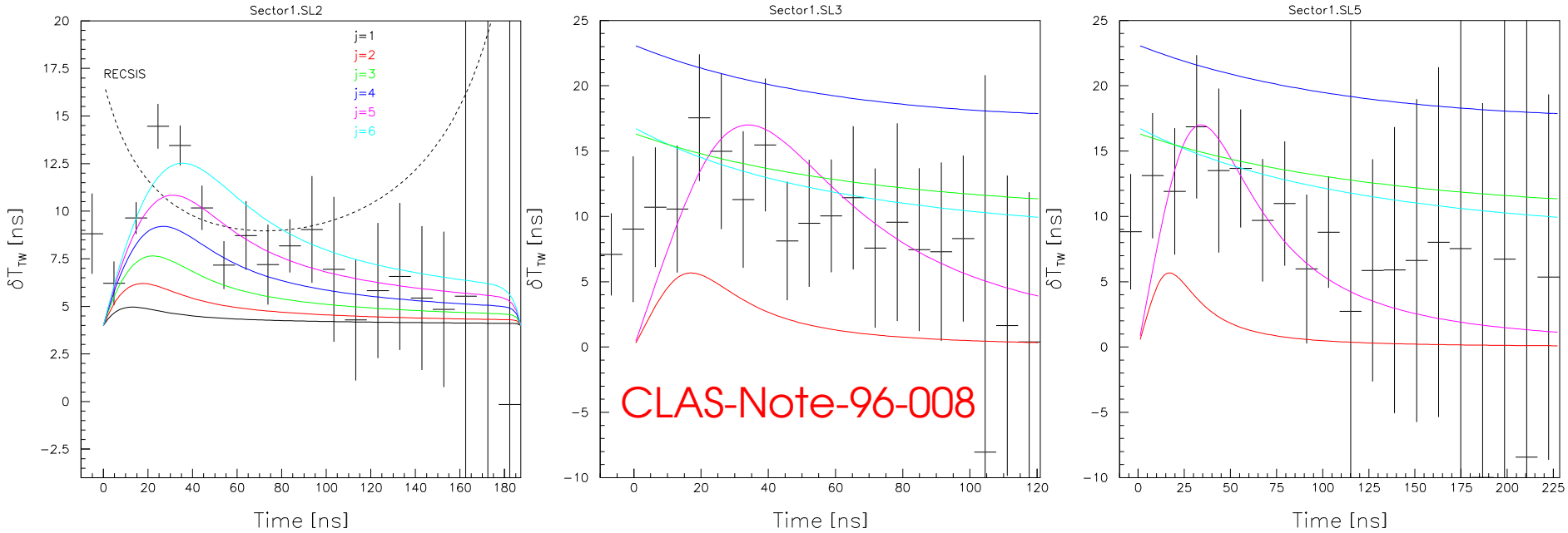


Time-Walk in DC

- Time-Walk was studied in CLAS-Note-96-008,
- but results were not used in RECSIS:

$$\Delta T_{RECSIS} = s\beta\left[\frac{a}{(t - s\beta)/t_{max} + b} + \frac{c}{d - (t - s\beta)/t_{max}}\right],$$

- β-slope s=16 ns (R1,R2) or 24 ns (R3),
- actually $dE/dx \sim 1/\beta^2$ and $\Delta T \sim t_{rise} E_{th}/|dE|$,
- T_0-calib. correction: $\Delta T \sim (\beta^2 - \beta^2_{cal.})t_{rise}$.



Summary

- Region 1 survey was reanalyzed correcting rotation matrix, resolving Z-rotation puzzle;
- new DC alignment procedure was developed;
- many errors and approximations were removed;
- obtained resolution of elastic electron and proton peaks is compatible with GSIM Monte Carlo almost everywhere;
- efficiency increase was observed when using beam position constraint.

References

1. M. D. Mestayer *et al.*, "The CLAS drift chamber system", *Nucl. Instr. and Meth.* **A449**, 81 (2000).
2. R. Magahiz, "Documentation for the Region I wire position program" 1992.
3. R. Schumacher, "Region one drift chamber analysis of survey data", CLAS-Note-98-001, 1998.
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5. S.A. Morrow and M.D. Mestayer, "Drift Chamber Alignment", CLAS-Note-2002-10, 2002.