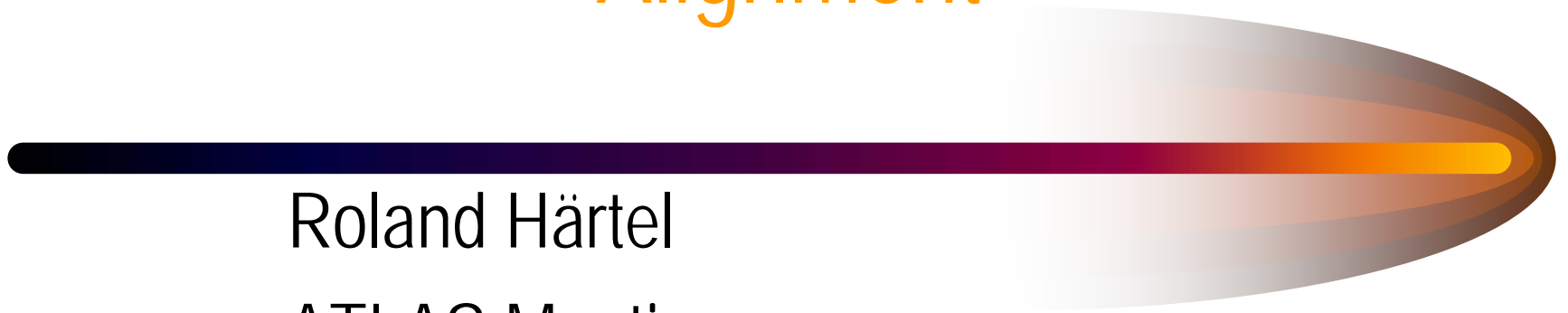




Current Status of the Pixel and SCT Alignment

Roland Härtel
ATLAS Meeting
May 8, 2006



Content

- Alignment concepts
- Results & Validation for full ATLAS
- Extensions of our approach
- Combined test beam alignment
- Cosmic setup alignment
- Conclusions



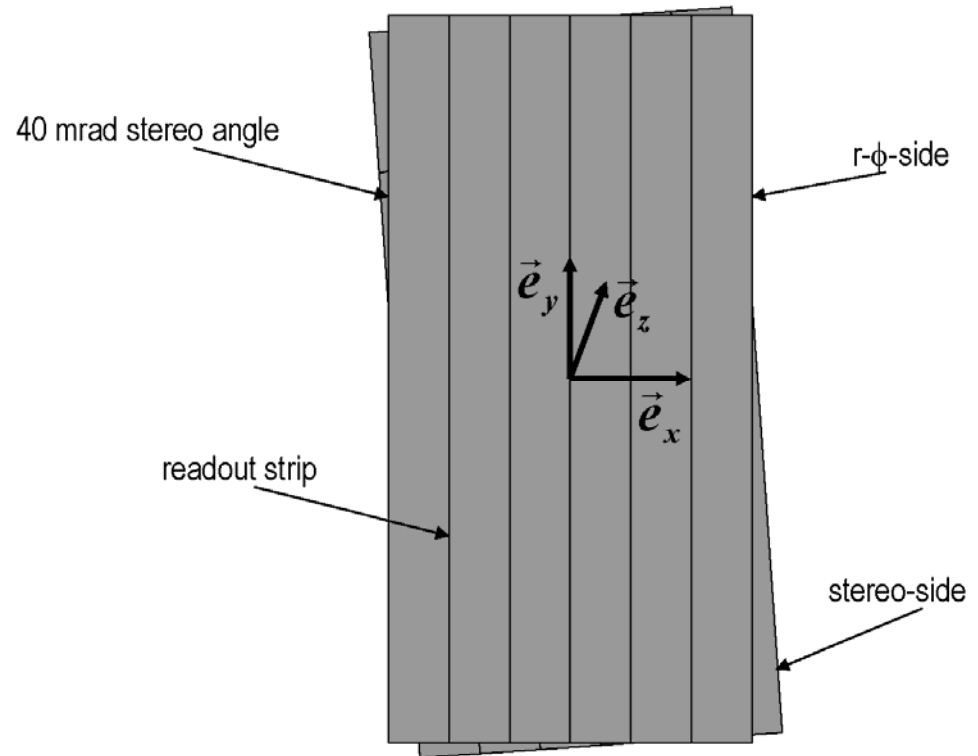
Alignment

- Process of deducing position of each Pixel and SCT module
- Misalignments can be corrected for in track reconstruction software
- Modules are not moved back into nominal position
- Alignment accuracy must match intrinsic spatial resolution to minimize systematic errors



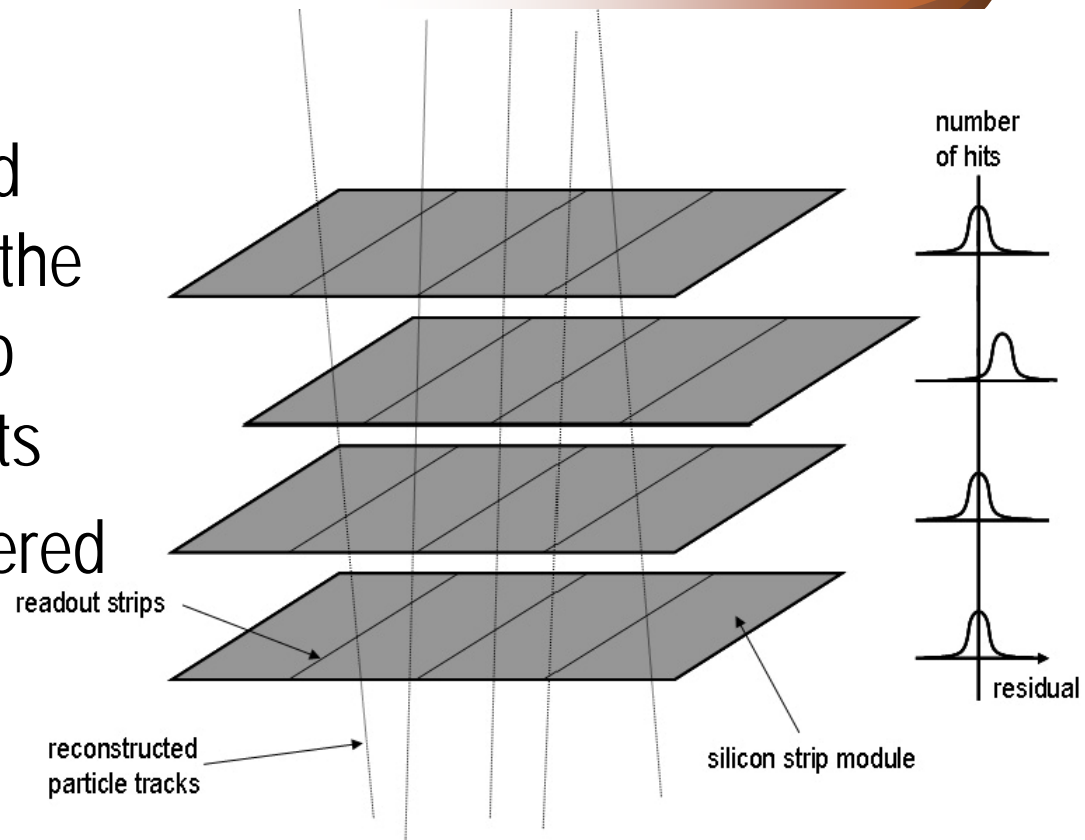
Coordinate system – degrees of freedom

- Coordinate system of Pixel / SCT module is a right-handed orthogonal three-dimensional frame
- Each module is assumed to be a rigid body with 6 degrees of freedom

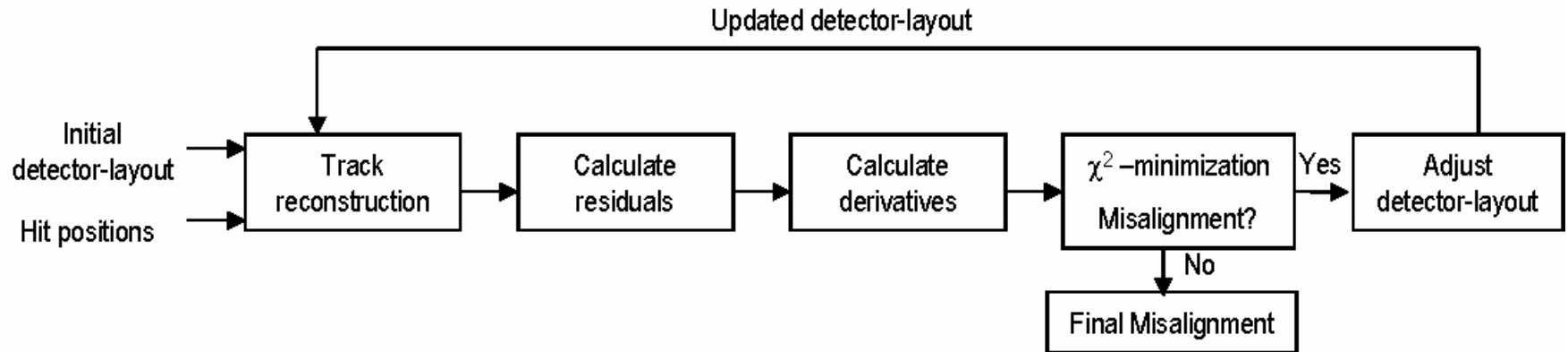


Track based alignment

- The residual, i.e. the distance between fitted particle trajectory and the readout strip is used to measure misalignments
- distorted and not centered residual distributions can be the effect of misalignments



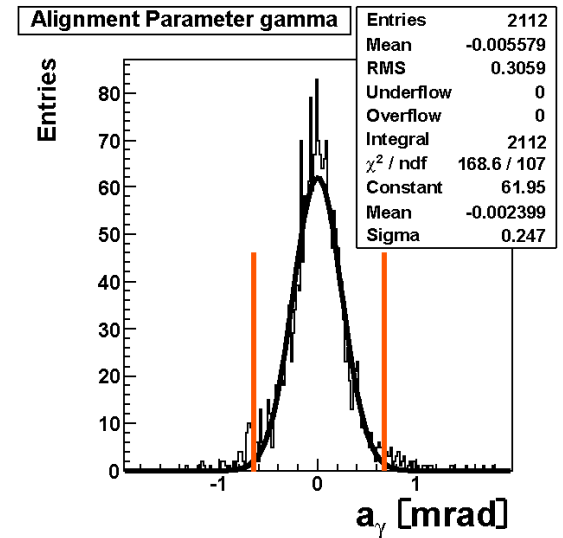
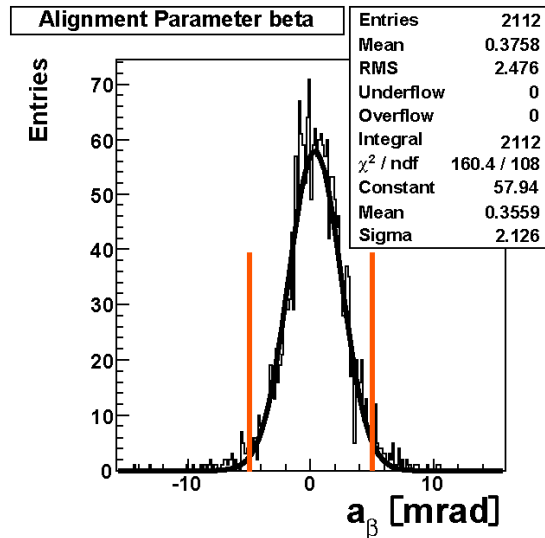
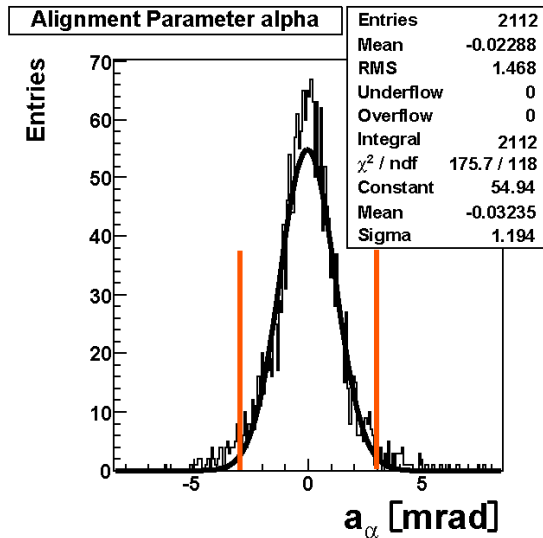
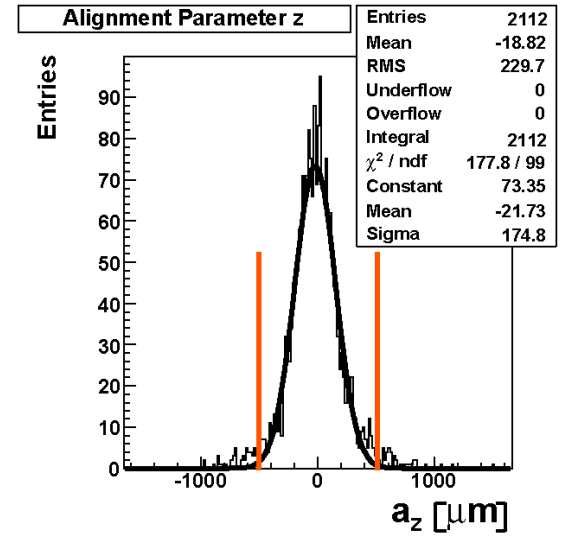
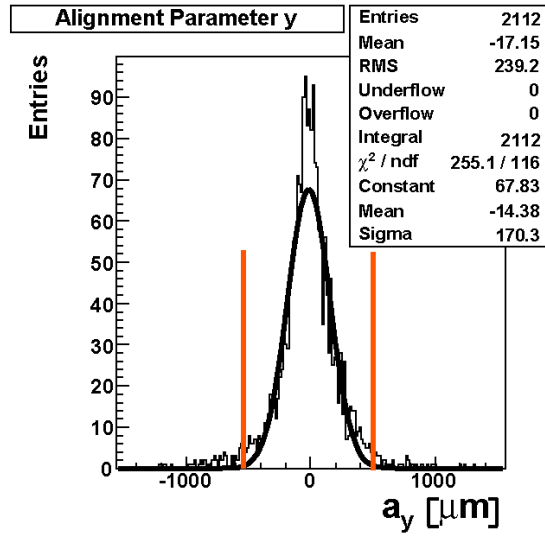
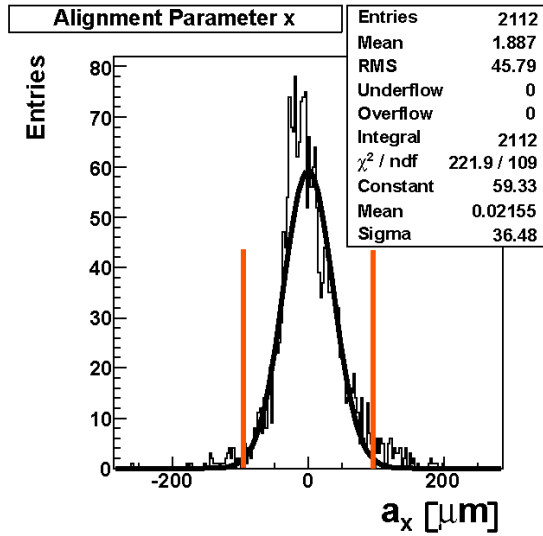
Iterative approach



- For each module residuals and derivatives are determined, the complete geometry information is encoded there
- With a linear least squares method the most probable values for the alignment parameters are determined
- Updated alignment parameters are then used in the next iteration cycle to calculate new residuals and derivatives.



Alignment parameters – SCT barrel



Alignment accuracy SCT

Alignment accuracy limits

alignment parameter	SCT barrel module			SCT end-cap module		
	95%CL	2σ gauss fit	$2\sigma_{stat}$	95%CL	2σ gauss fit	$2\sigma_{stat}$
a_x	96 μm	73 μm	57 μm	38 μm	28 μm	9.8 μm
a_y	505 μm	341 μm	337 μm	290 μm	179 μm	113 μm
a_z	490 μm	350 μm	298 μm	2205 μm	1587 μm	600 μm
a_α	3.0 mrad	2.4 mrad	2.4 mrad	41 mrad	20 mrad	17 mrad
a_β	5.1 mrad	4.3 mrad	3.5 mrad	25 mrad	20 mrad	10 mrad
a_γ	0.66 mrad	0.49 mrad	0.49 mrad	0.75 mrad	0.51 mrad	0.25 mrad

- Achievable alignment accuracy after 10 iterations with 150k tracks from a single pion sample.
- Only SCT detector is aligned. Pixel detector frozen.



Alignment accuracy Pixel

Alignment accuracy limits

alignment parameter	Pixel barrel module			Pixel end-cap module		
	95%CL	$2\sigma_{gauss}$	$2\sigma_{stat}$	95%CL	$2\sigma_{gauss}$	$2\sigma_{stat}$
a_x	25 μm	19.8 μm	19.4 μm	4 μm	3.31 μm	1.43 μm
a_y	195 μm	124 μm	111 μm	55 μm	47.7 μm	32.4 μm
a_z	75 μm	59.7 μm	56.0 μm	260 μm	421 μm	153 μm
a_α	0.9 mrad	0.82 mrad	0.63 mrad	4.4 mrad	3.8 mrad	3.2 mrad
a_β	1.7 mrad	1.6 mrad	1.4 mrad	12.2 mrad	17 mrad	10 mrad
a_γ	0.32 mrad	0.28 mrad	0.25 mrad	0.18 mrad	0.12 mrad	0.085 mrad

- Achievable alignment accuracy after 10 iterations with 235k tracks from multi muon sample.
- Only Pixel detector is aligned. SCT detector frozen.



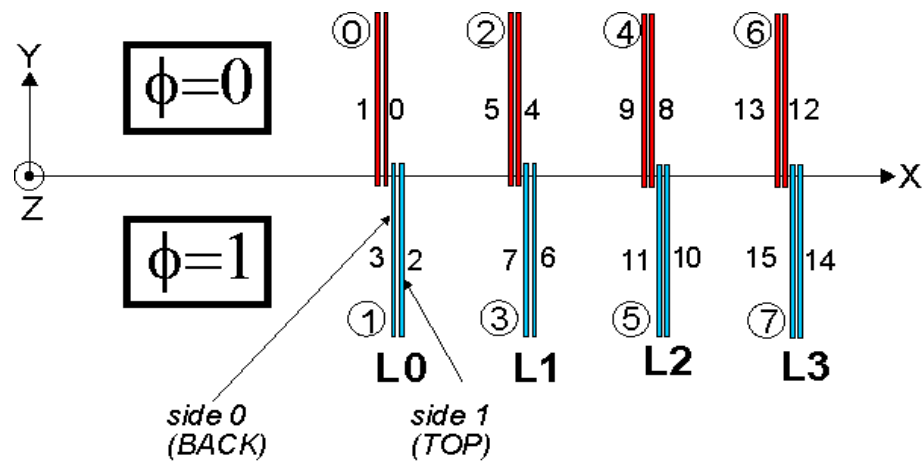
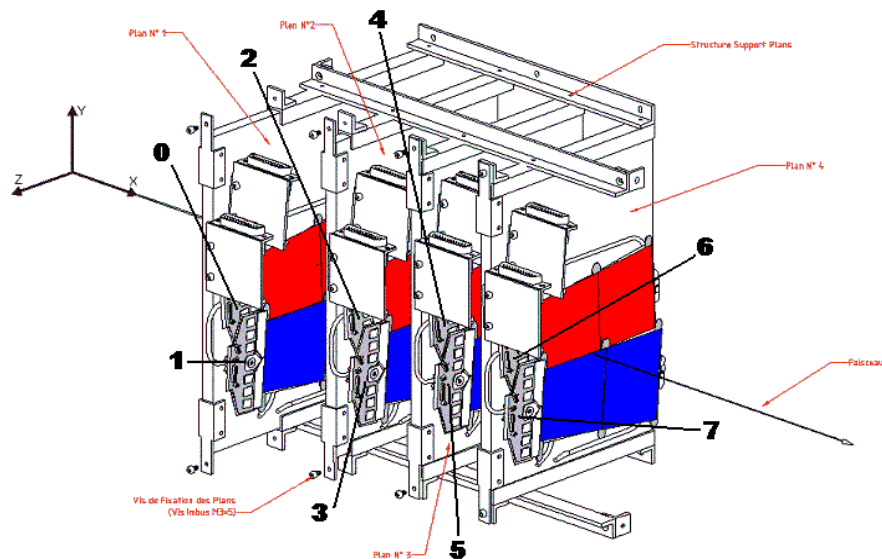
Extensions

- Alignment with survey constraints (Tobias Golling, LBL)
 - Use survey measurements of local module positions as additional alignment information
- Alignment of superstructures (collaborative effort between Tobias Golling and MPI)
 - Misalignments of Barrel/EndCaps – layers/disks – single modules have different orders of magnitude ($O(\text{mm})$ – $O(100 \mu\text{m})$ – $O(\mu\text{m})$)
 - This misalignments decouple from each other (makes no sense to correct displacements of e.g. whole barrel on local module level)
 - Possible to extend our approach and align larger structures as rigid bodies with 6 degrees of freedom



Combined TestBeam

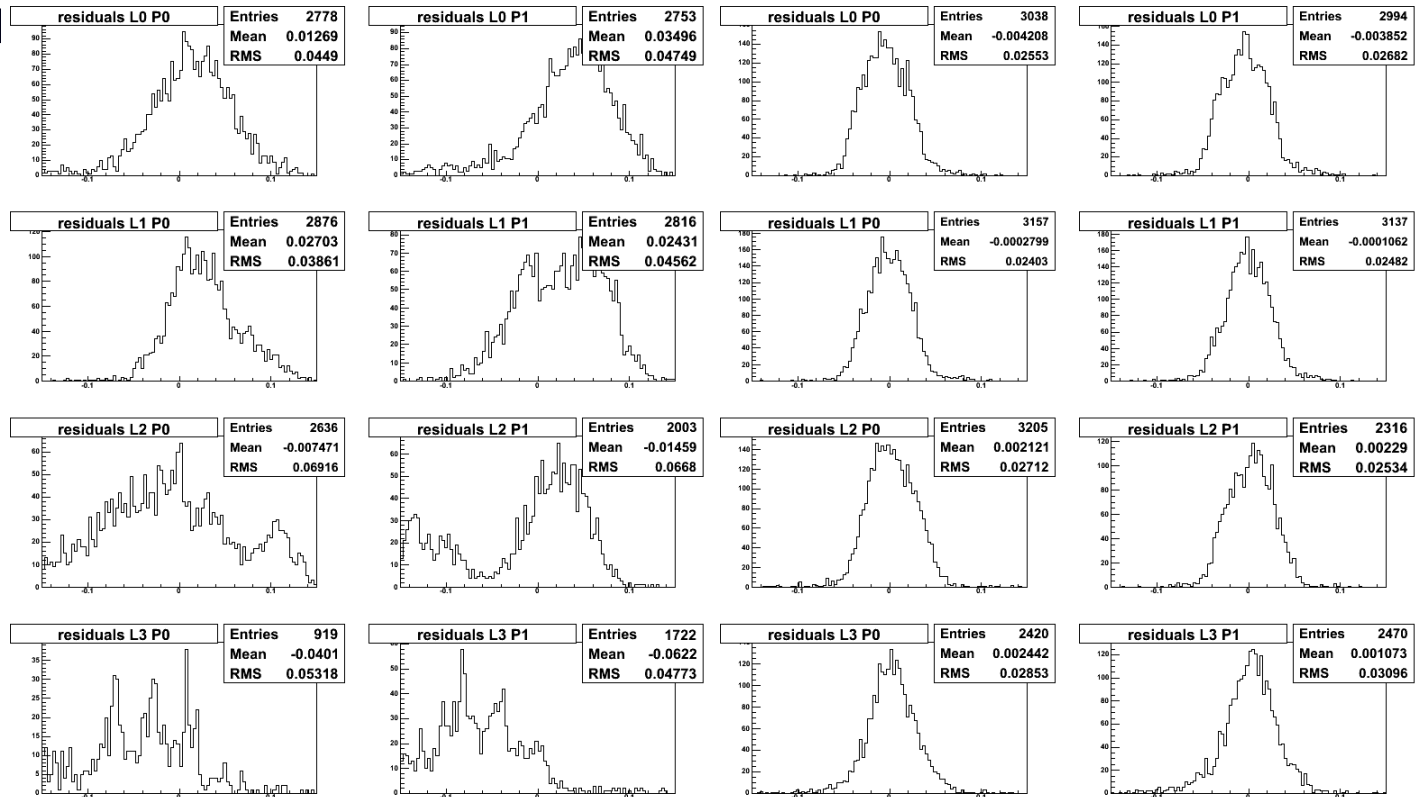
- Combined test beam in 2004 with all ATLAS subdetectors
- Setup was like a slice from the ATLAS barrel
- Magnetic field and tracking detectors themselves provide a reference frame



Combined TestBeam - SCT residuals

Iteration 1

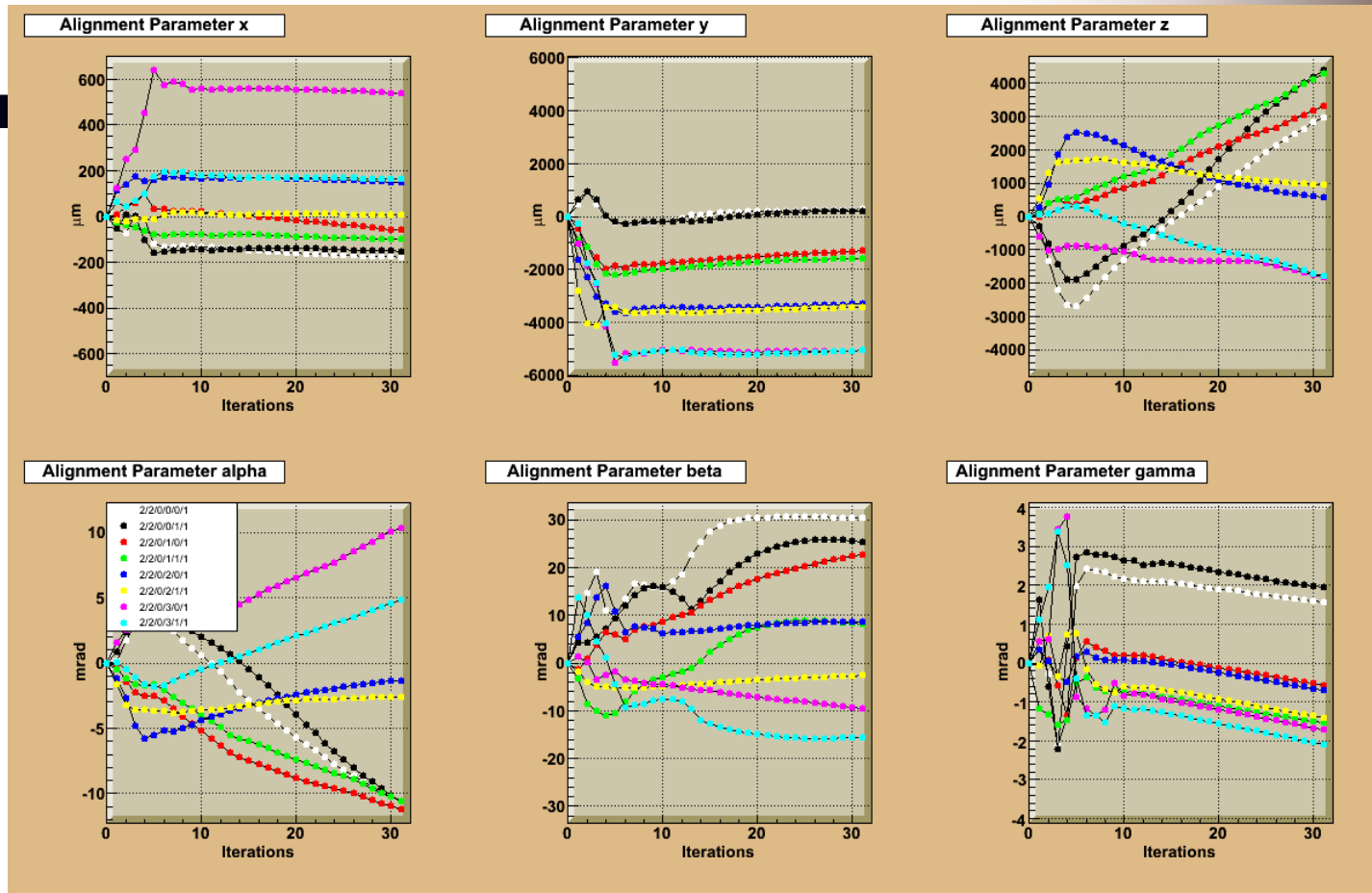
Iteration 30



- Residuals of the 8 SCT modules in CTB without alignment corrections and with alignment corrections after 30 iterations



Combined TestBeam – alignment parameters

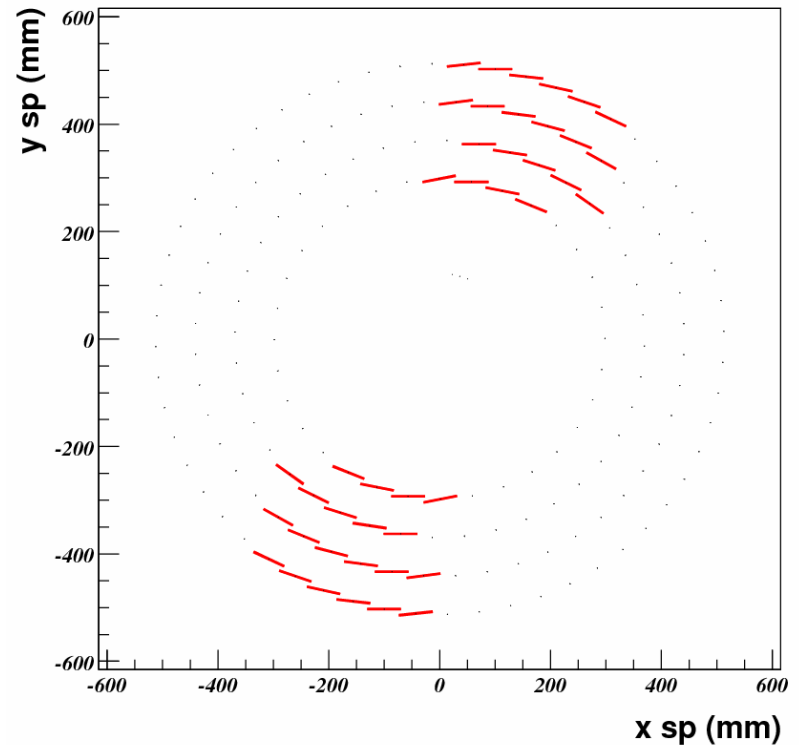


- After a few iterations the alignment parameters of most degrees of freedom converge on stable values



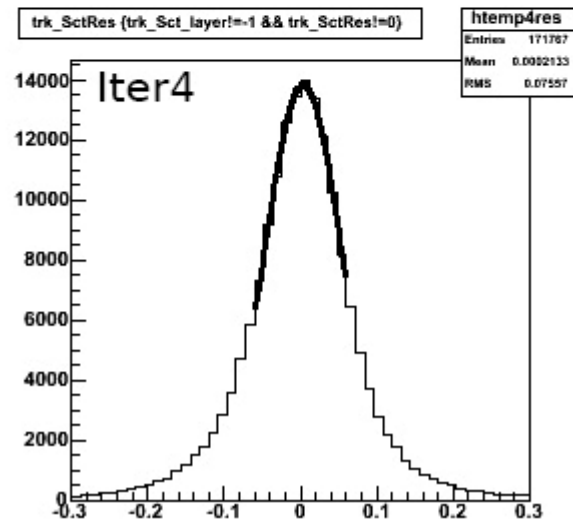
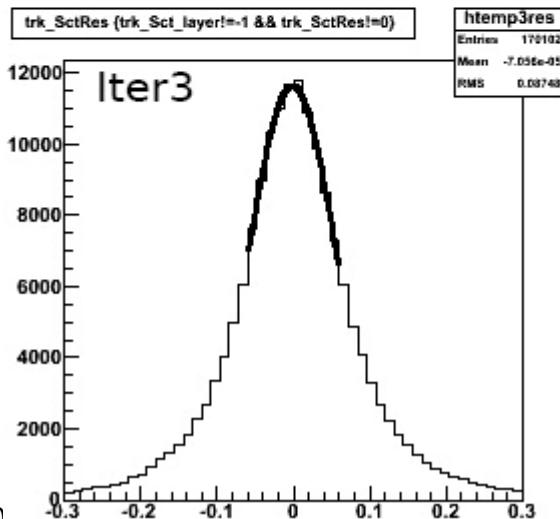
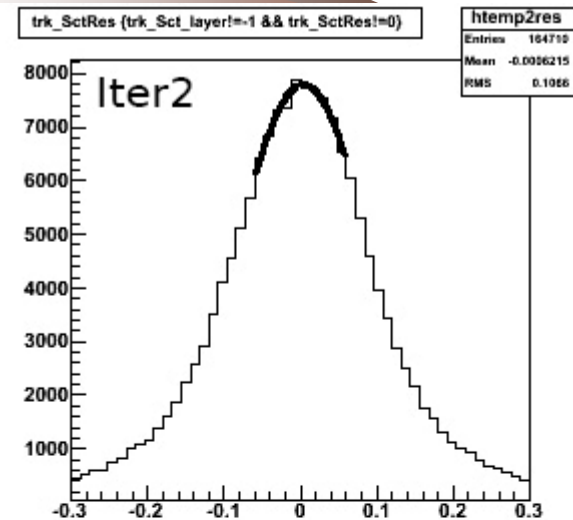
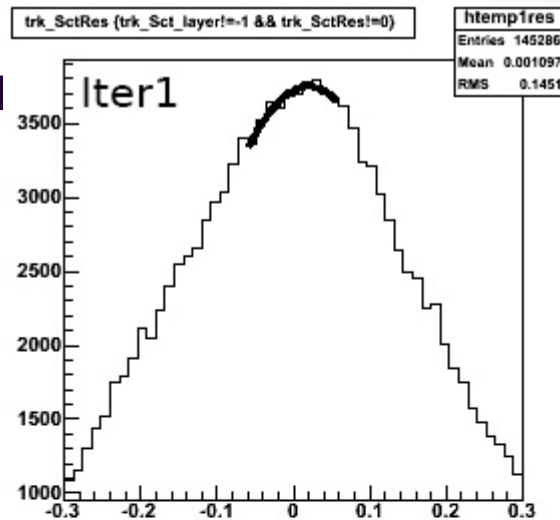
Cosmic test setup

- Cosmic test stand of integrated TRT and SCT barrel in SR1
- 2 TRT sectors are read out
- 504 SCT modules cover same solid angle and are read out



Cosmic test setup – SCT residuals

- Ola Kristoffer Øye uses our approach on simulated cosmic data (0.2 – 200 GeV)
- For randomly misaligned modules after 4 iterations:
 $\sigma = 50 \mu\text{m}$



Conclusions - Outlook

- Alignment algorithm for Pixel / SCT is in place
- Validation and testing of algorithm with simulated data for full ATLAS setup
- Used for alignment of CTB and cosmic setup
- Improvement / extension of approach is ongoing

