

Tracker alignment with MILLEPEDE

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25/11/2015

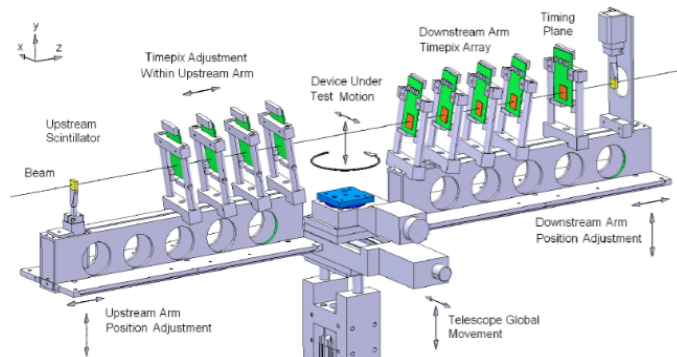
Multiple Scattering with Field Off



- Particles follow straight tracks through the spectrometers, scattering off absorber material in AFC
- Use TOFs to measure momentum, KL, EMR & CKOVs for PID
- Measure multiple scattering as a function of momentum

Tracker Alignment

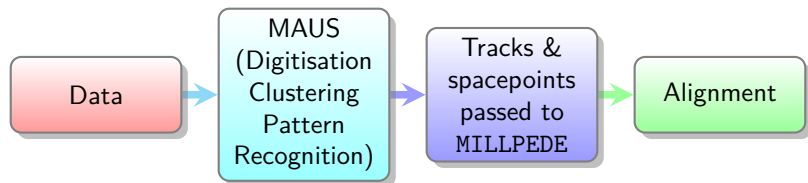
- Bach - common software-tool to align telescope-like detectors.
Employs the MILLEPEDE alignment algorithm
- MILLEPEDE - solves a linear least squares problem with a simultaneous fit of all global and local parameters



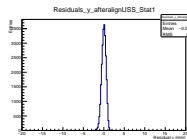
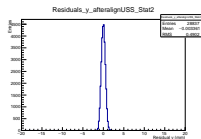
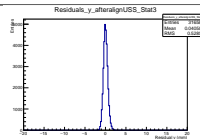
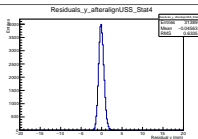
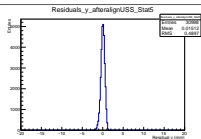
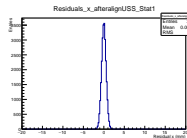
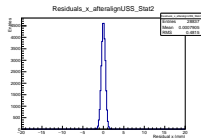
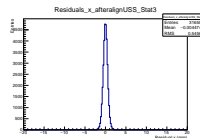
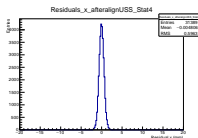
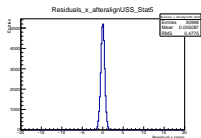
<https://svnsrv.desy.de/viewvc/aidasoft/AIDAAlign/>

Tracker Internal Alignment

- Tracker frames were surveyed at Imperial - position of stations known accurately
- First test: Can MILLEPEDE return the correct internal alignment of the tracker stations?
- Alignment done with (3,240) MC beam



Alignment Residuals Upstream MC



Alignment Offsets Upstream MC

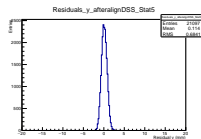
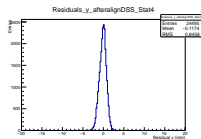
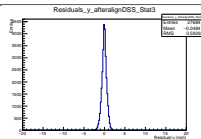
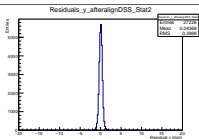
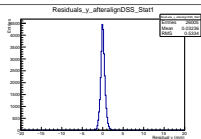
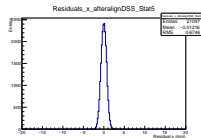
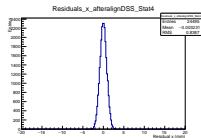
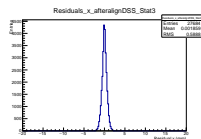
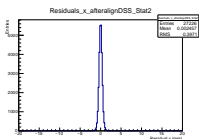
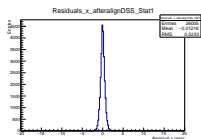
Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
5	0	0	0	0.0368	-0.7912	0.0209
4	-0.5694	-0.604	0	-0.5634	0.4838	0
3	-1.2021	-0.1657	0	-1.2021	-0.1657	0
2	-0.5709	-0.7375	0	-0.5529	0.025	0
1	0	0	0	0.05559	-0.8914	-0.0105

Station 3 is fixed in MILLEPEDE so the offset is 0

Positions are taken from CMM measurements done at Imperial

Alignment done with 210k tracks

Alignment Residuals Downstream MC



Alignment Offsets Downstream MC

Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
5	0	0	0	1.0220	-0.0912	0.0267
4	0.1722	-0.2912	0	0.6261	-0.6977	0
3	-0.6717	-0.1759	0	-0.6717	-0.1759	0
2	0.4698	0.0052	0	0.0888	0.3163	-0.0103
1	0	0	0	-0.6810	0.5416	-0.0170

Station 3 is fixed in MILLEPEDE so the offset is 0

Positions are taken from CMM measurements done at Imperial

Alignment done with 210k tracks

Tracker to Tracker Alignment

To-Do List

- ① Create single track for all spacepoints from both trackers - fitting done with Minuit as packaged in ROOT
- ② Use only two stations for tracker to tracker alignment. Plane that defines the centre of each tracker volume in z
 - ▶ Stations within tracker are considered 'fixed' with respect to each other
- ③ Perform tracker-to-tracker alignment

Alignment Offsets Tracker to Tracker MC

Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
USS (549.55)	0	0	0	0	0	0
DSS (5450.8922)	0	0	0	0.8822	6.8619	0
MICE Technical Drawings	0.72	6.6				

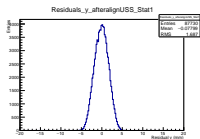
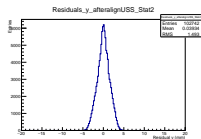
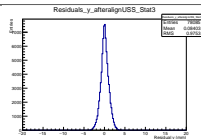
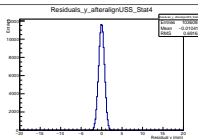
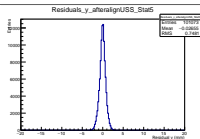
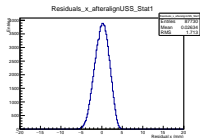
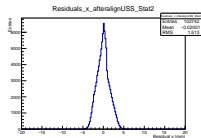
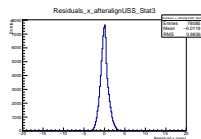
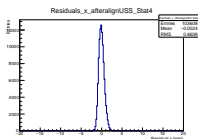
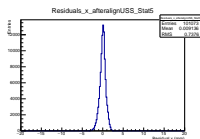
USS is fixed in MILLEPEDE so the offset is 0

Compare with technical drawings to confirm hypotheses

Alignment done with 27k tracks

Residual plots are 0 in two plane scenario

Alignment Residuals Upstream Data



Alignment Offsets Upstream Data

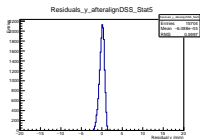
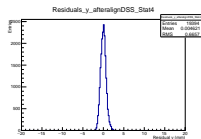
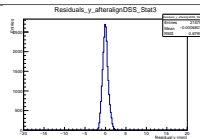
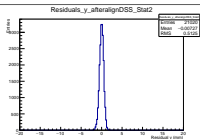
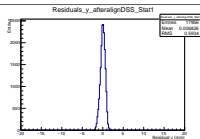
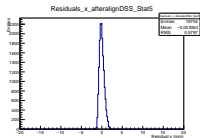
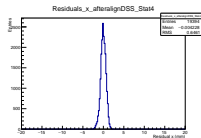
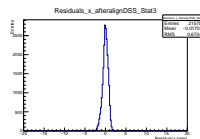
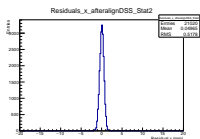
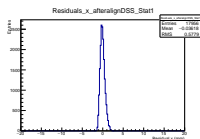
Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
5	0	0	0	-0.7991	0.2356	0
4	-0.5694	-0.604	0	-0.4596	-0.64	0
3	-1.2021	-0.1657	0	-1.2021	-0.1657	0
2	-0.5709	-0.7375	0	-1.0896	-0.988	0
1	0	0	0	-1.3638	-0.5536	-0.0552

Station 3 is fixed in MILLEPEDE so the offset is 0

Positions are taken from CMM measurements done at Imperial

Alignment done with 134k tracks

Alignment Residuals Downstream Data



Alignment Offsets Downstream Data

Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
5	0	0	0	0.9104	-1.3421	-0.0196
4	0.1722	-0.2912	0	0.3086	-0.3909	-0.0132
3	-0.6717	-0.1759	0	-0.6717	-0.1759	0
2	0.4698	0.0052	0	0.5546	-0.2319	0.0128
1	0	0	0	0.6603	0.0248	0.0181

Station 3 is fixed in MILLEPEDE so the offset is 0

Positions are taken from CMM measurements done at Imperial

Alignment done with 134k tracks

Alignment Offsets Tracker to Tracker Data

Station	Position			Position After Alignment		
	x	y	θ_z	x	y	θ_z
USS (549.55)	0	0	0	0	0	0
DSS (5450.8922)	0	0	0	0	6.6168	0
MICE Technical Drawings	0.72	6.6				

USS is fixed in MILLEPEDE so the offset is 0

Compare with technical drawings to confirm hypotheses

Alignment done with 22k tracks

Residual plots are 0 in two plane scenario

Alignment Offsets Tracker to Tracker Data

Station	Position		Position After Alignment	
	θ_x	θ_y	θ_x	θ_y
USS (549.55)	0	0	0	0
DSS (5450.8922)	0	0	-0.0042	0.0054

After running MILLEPEDE output for x , y & θ_z put in tracker description

Now x , y & θ_z fixed and θ_x & θ_y floating

USS is fixed in MILLEPEDE so the offset is 0

Alignment done with 22k tracks

Residual plots are 0 in two plane scenario

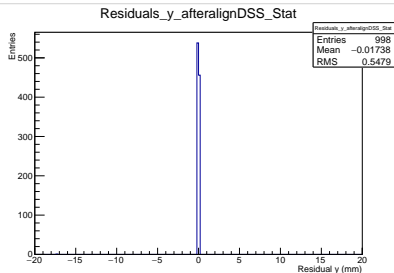
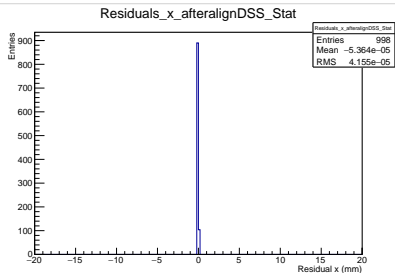
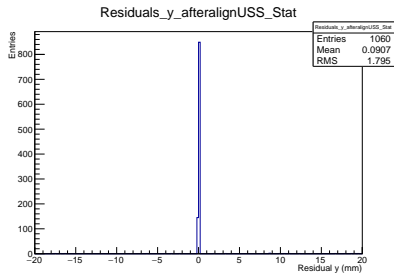
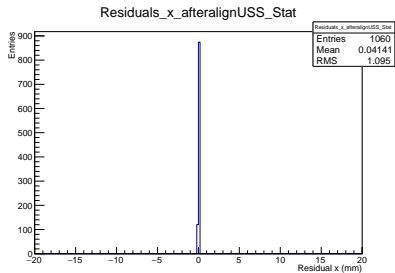
Status

- MILLEPEDE built & running with MAUS framework
- Internal alignment with MC/data complete
- T2T alignment with MC/data complete
- T2T alignment for θ_x & θ_y data complete

Conclusions

- Preliminary numbers for alignment
- MILEPEDE alignment study well under way but further refinement possible
- We have Step IV data - so organising the study as quickly as possible

Tracker to Tracker Residuals



Tracker Internal Alignment

range in which MILLEPEDE looks for Δ	
σ_x	0.1 mm
σ_y	0.1 mm
$\sigma_{x'}$	10 mrad
residual cut	40 mm
DOF	x, y, z'