

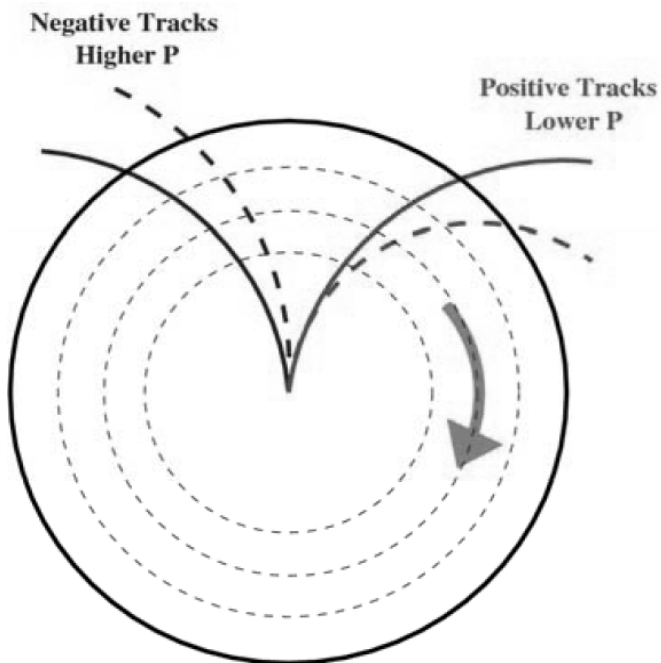


Clocking Effect in TRTAlignAlg

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Clocking Effect

- Basic idea – an incorrect residual minimum is found by systematically shifting modules around the beam axis leading to a biasing of the track Pt.



- Hard to detect in real data b/c
 - residuals are minimized
 - Effect tends to cancel in processes with opposite charged tracks (eg: $Z \rightarrow \mu\mu$)



- All studies done with:
 - Athena release 13.0.30
 - 5000 multimuon events
 - 9 iterations of the algorithm
 - no Si misalignments
 - Starting with TRT Globally aligned to Si
 - Ran L2 alignment using full tracks and local Chi2 minimization
 - 5 dof for ea. module (3 rotations, 2 translations)



Nominal Study

- Ran alignment algorithm starting with nominal CSC misalignments:

TRT modules level TRANSFORMS					
System	R (systematic)	R (random)	alpha	beta	gamma
Barrel modules lay0	+1.0	+/-0.2	0.0	0.0	0.0
Barrel modules lay1	-0.5	+/-0.1	0.0	0.0	0.0
Barrel modules lay2	+1.5	+/-0.3	0.0	0.0	0.0

- Ran with 9 disjoint event samples of 5000 events each.

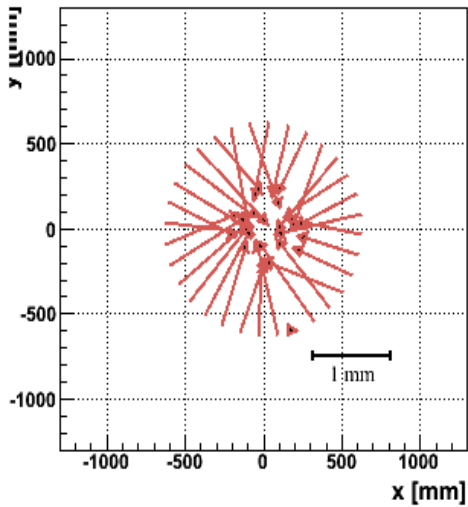


Nominal Study

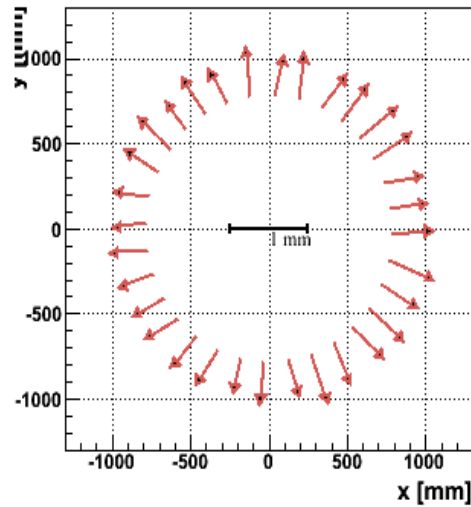
Initial misalignments

typical residual misalignments

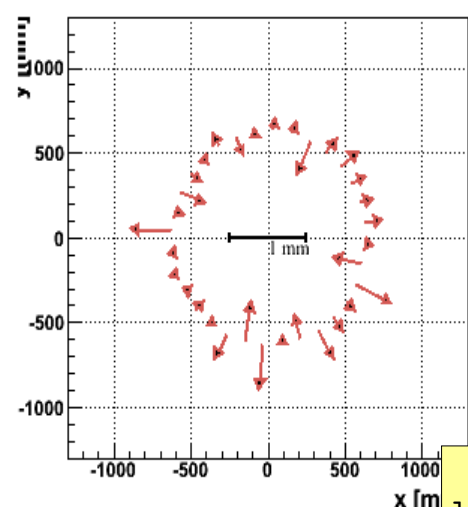
translation x 500 - Layer 0



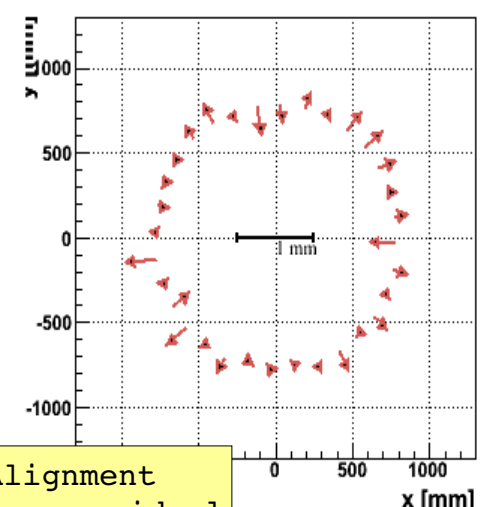
translation x500- Layer 1



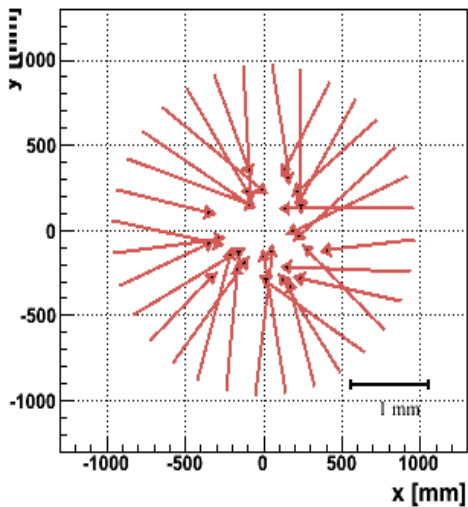
translation x 500 - Layer 0



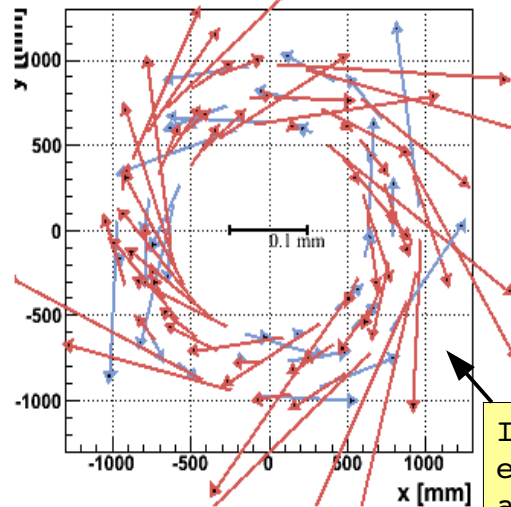
translation x500- Layer 1



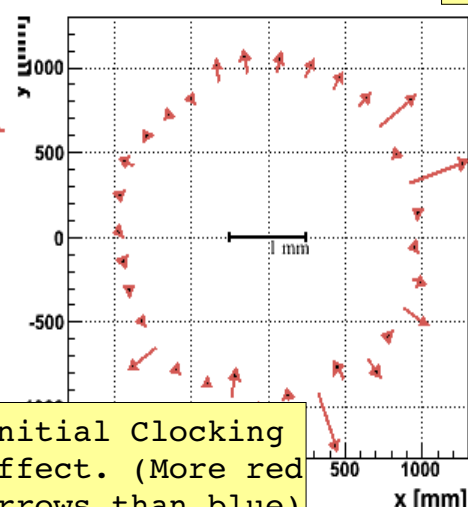
translation x500 - Layer 2



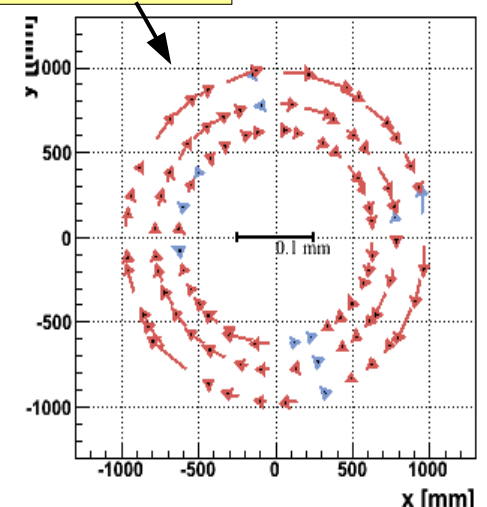
Projection of the translation along #5 x 5000



translation x500 - Layer 2



translation along #5 x 5000

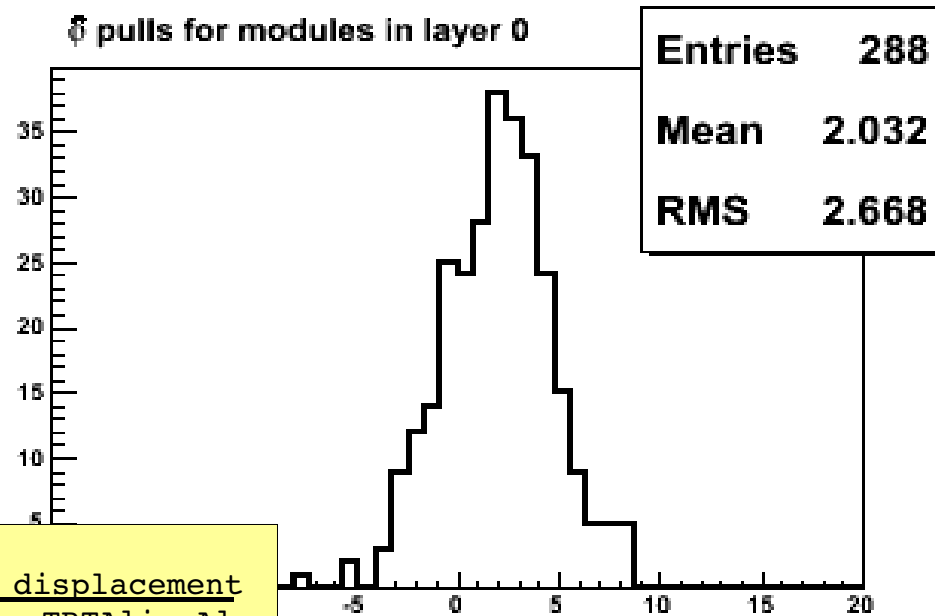
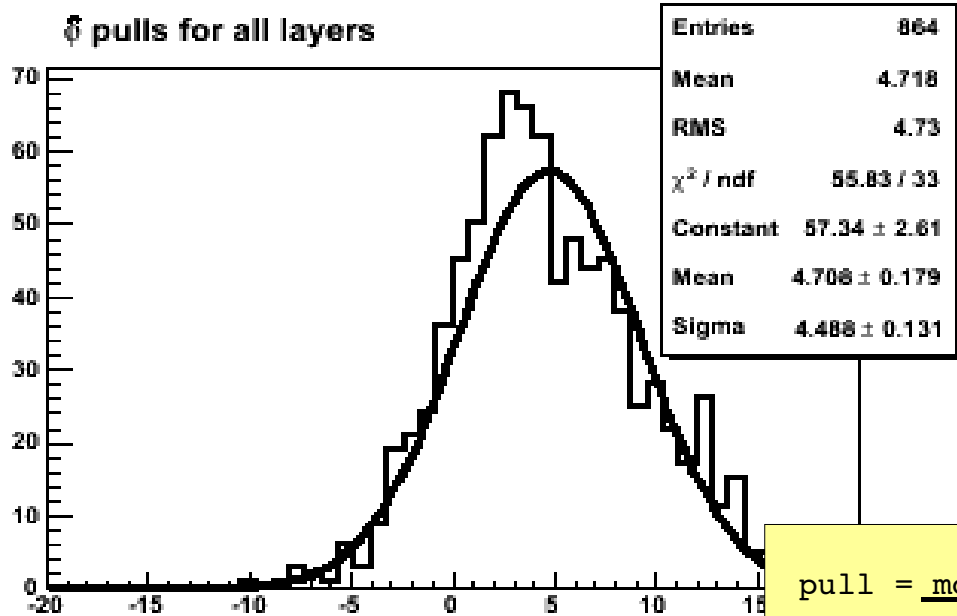


Alignment leaves residual clocking

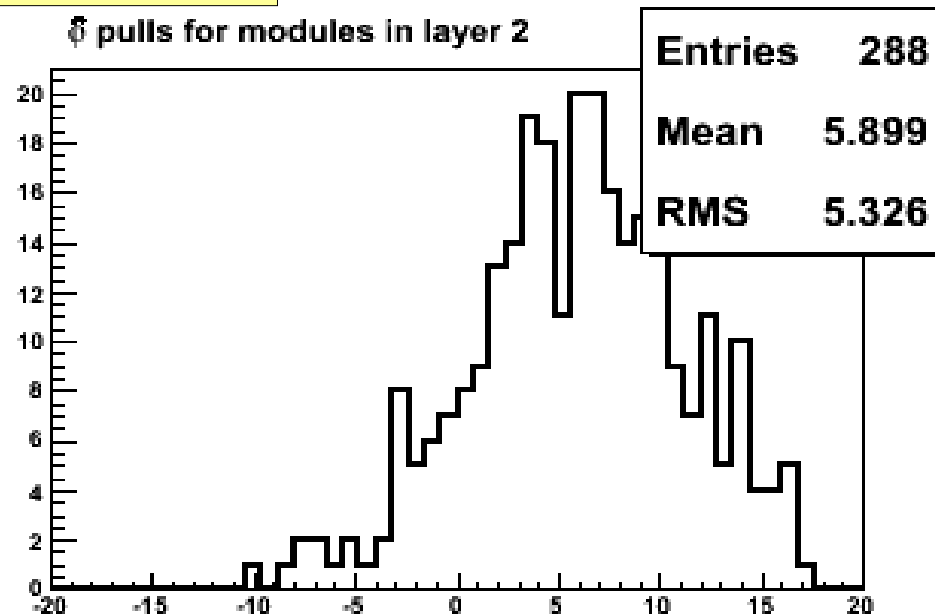
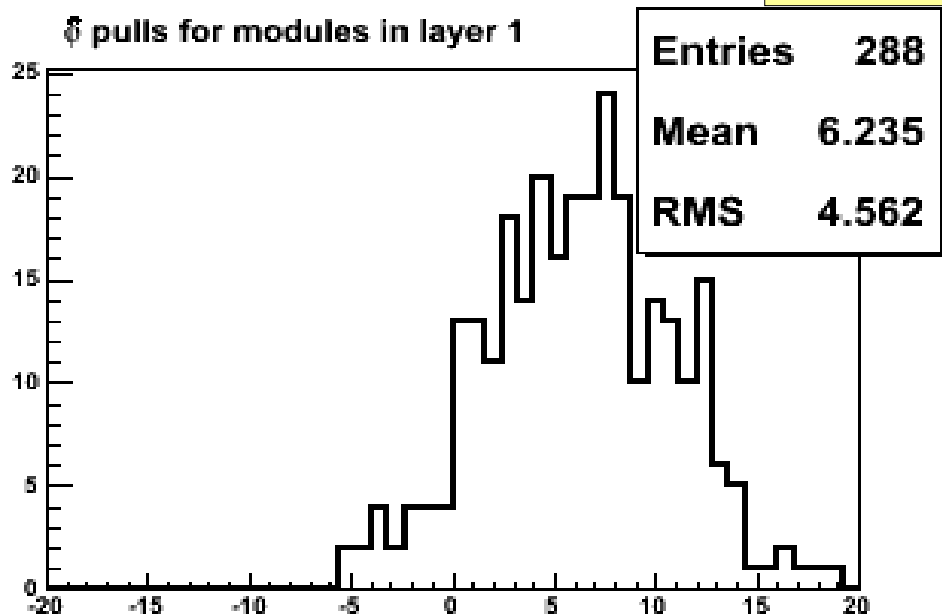
Initial Clocking effect. (More red arrows than blue)



module pulls along phi



pull = module displacement
error from TRTAlignAlg





the perfect study

- Ran alignment algorithm for 9 iterations
- Starting in the ideal position (ie: no initial misalignments)
- Using same event samples as in the nominal study.

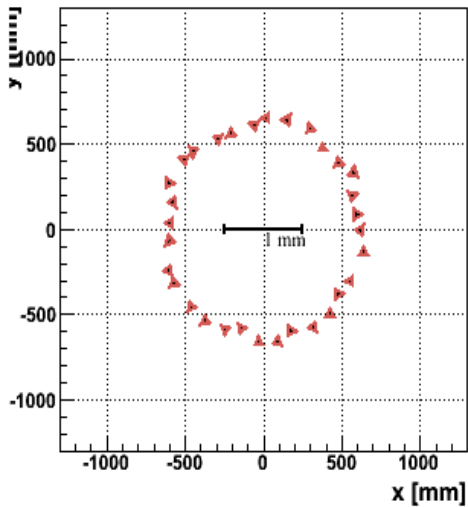


the perfect study

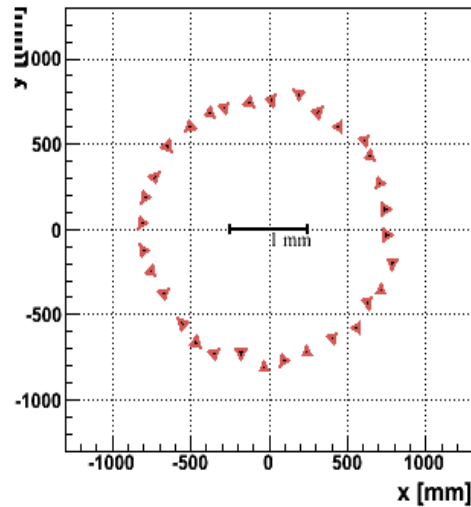
Initial misalignments

typical residual misalignments

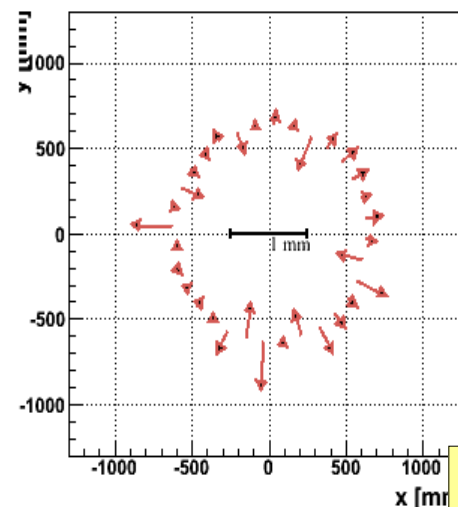
translation x 500 - Layer 0



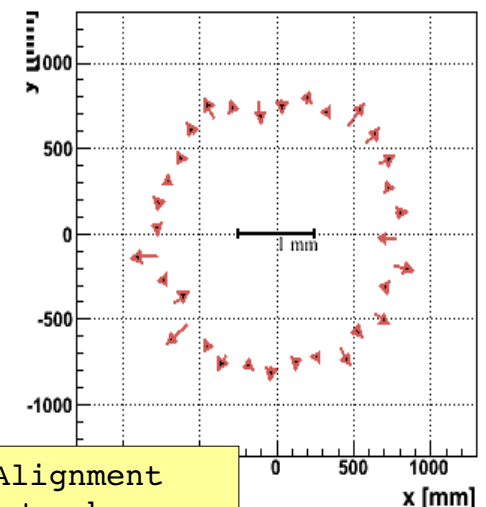
translation x500- Layer 1



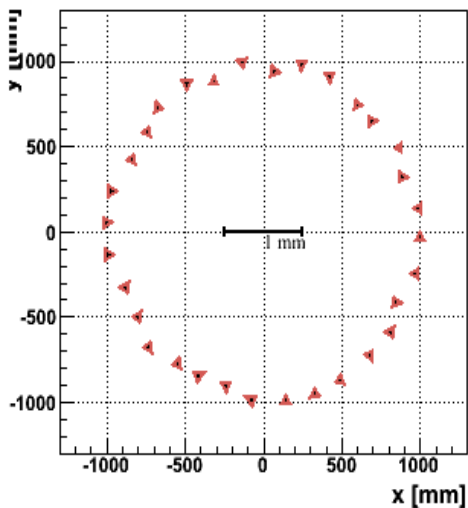
translation x 500 - Layer 0



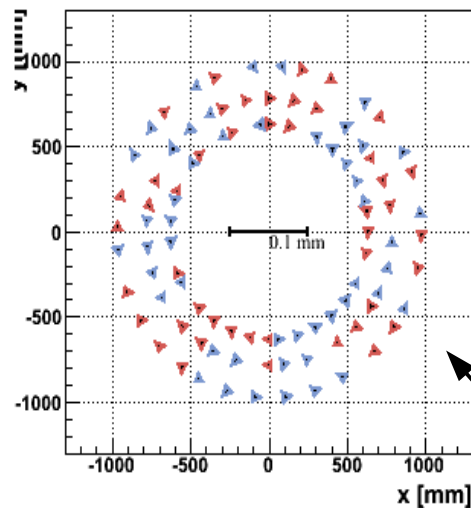
translation x500- Layer 1



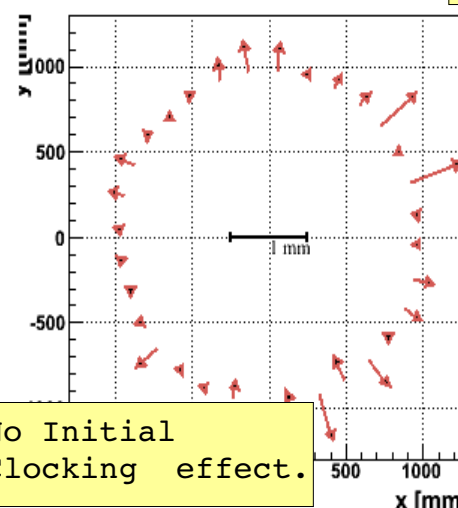
translation x500 - Layer 2



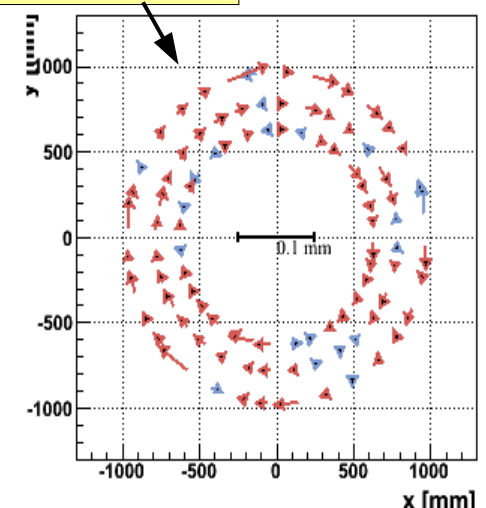
Projection of the translation along #5 x 5000



translation x500 - Layer 2



Projection of the translation along #5 x 5000

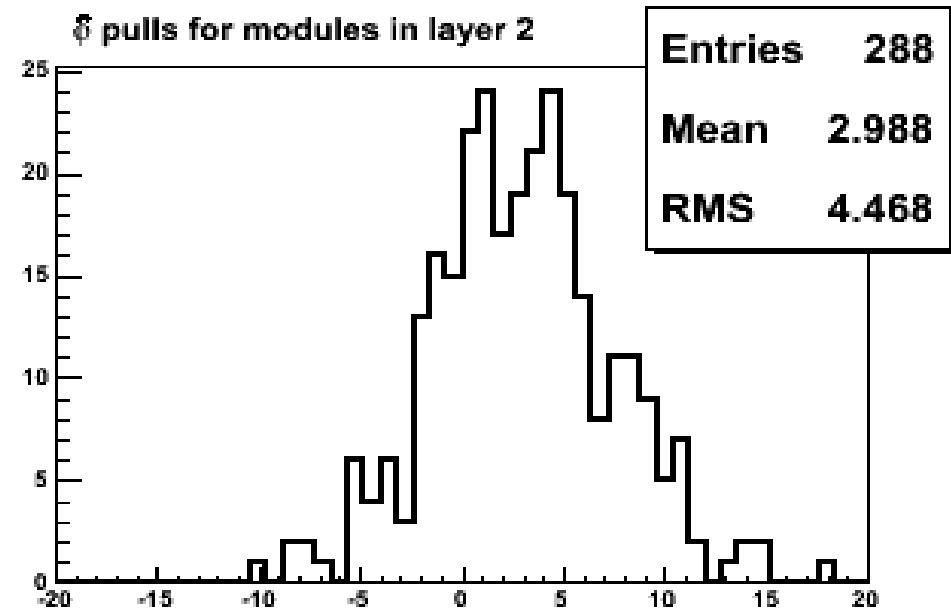
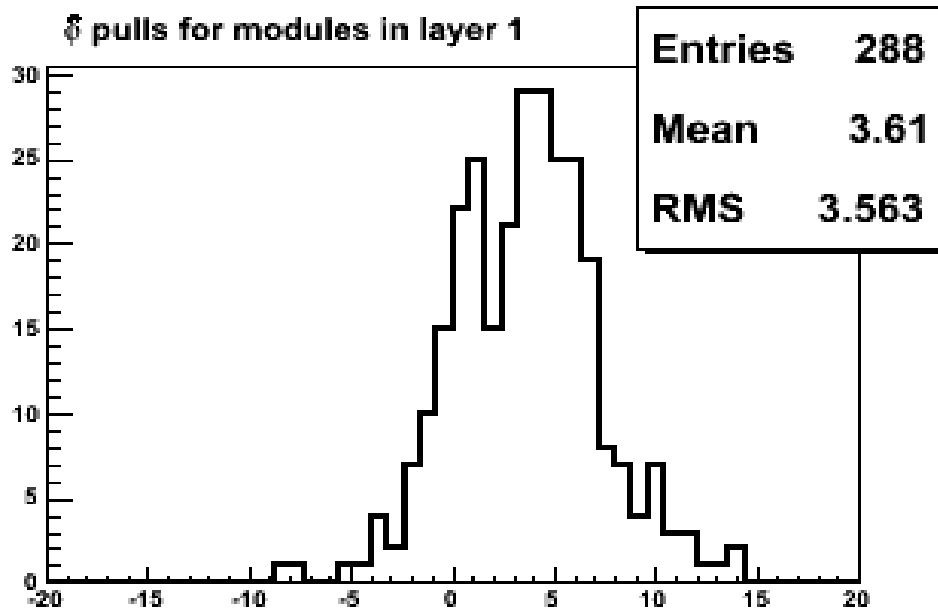
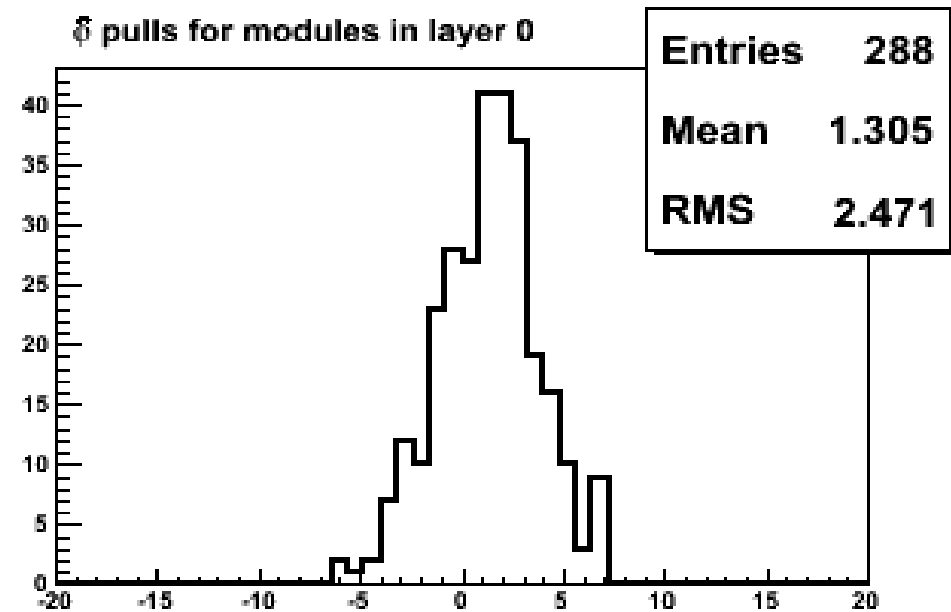
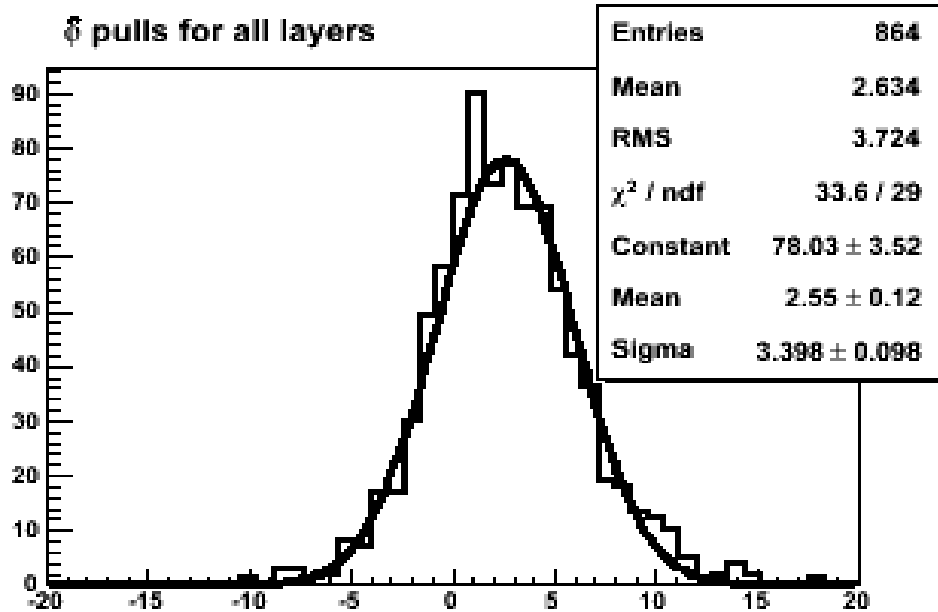


Alignment introduces clocking

No Initial Clocking effect.



module pulls along phi





impact on tracking

Pt Pulls (Ideal)

Entries 9245
Mean 0.04831
RMS 1.299

Pt Pulls (After Alignment From Perfect)

Entries 9245
Mean 0.03982
RMS 1.33

$$\text{Pt pull} = \frac{\text{Pt}(\text{true}) - \text{Pt}(\text{rec})}{\text{err Pt}(\text{rec})}$$

Entries 4639
Mean 0.03492
RMS 1.298

Entries 4606
Mean 0.0618
RMS 1.3

Entries 4639
Mean -0.09802
RMS 1.313

Entries 4606
Mean 0.1787
RMS 1.332

Pt Pulls (After Alignment From Nominal)

Entries 9245
Mean 0.04442
RMS 1.351

- Pt Pulls for:
 - all tracks - black
 - positive - blue
 - negative - red

Entries 4639
Mean -0.2008
RMS 1.324

Entries 4606
Mean 0.2916
RMS 1.333

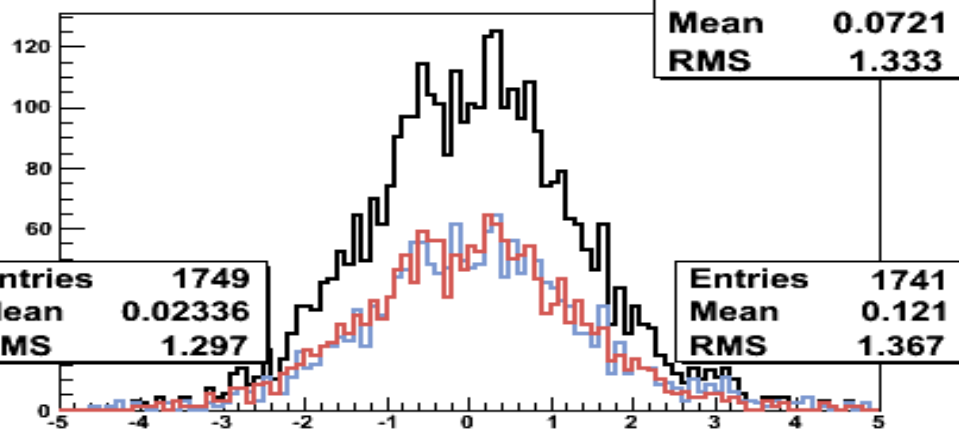
-typical event sample
w/5000 events



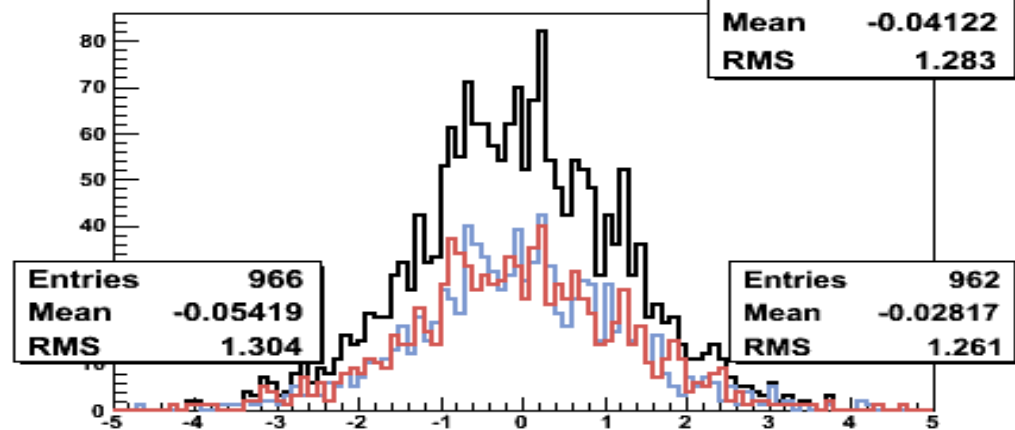
impact on tracking

- clocking effect also nasty b/c its expected to grow with Pt.
 - most "damage" done to high Pt tracks
- The CSC Multi muons events are simulated with a flat Pt distribution from 10-50 Gev
- In the slide that follows pulls are shown using low Pt (< 20 Gev) and high Pt (> 40 Gev) tracks with the same event sample as above

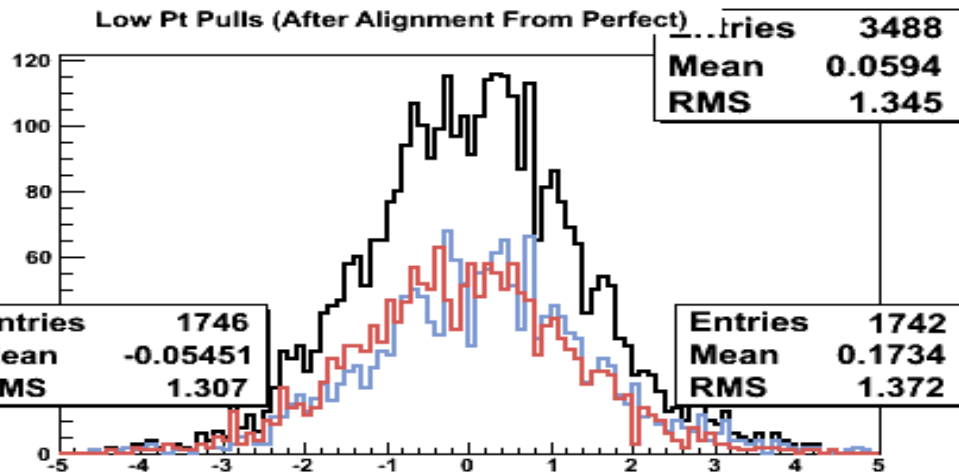
Low Pt Pulls (Ideal)



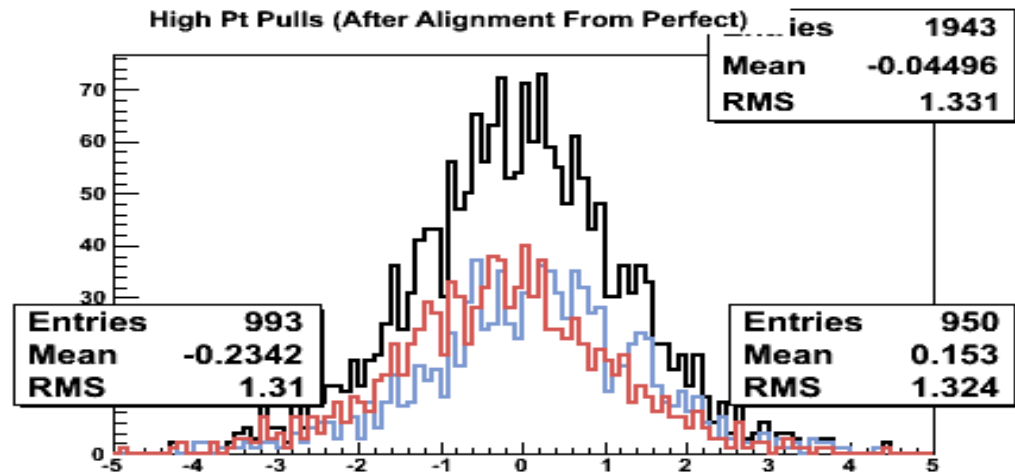
High Pt Pulls (Ideal)



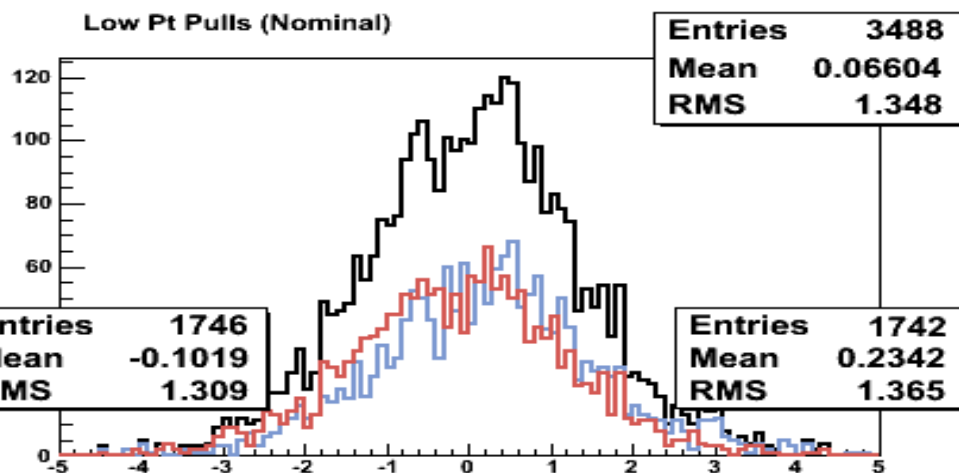
Low Pt Pulls (After Alignment From Perfect)



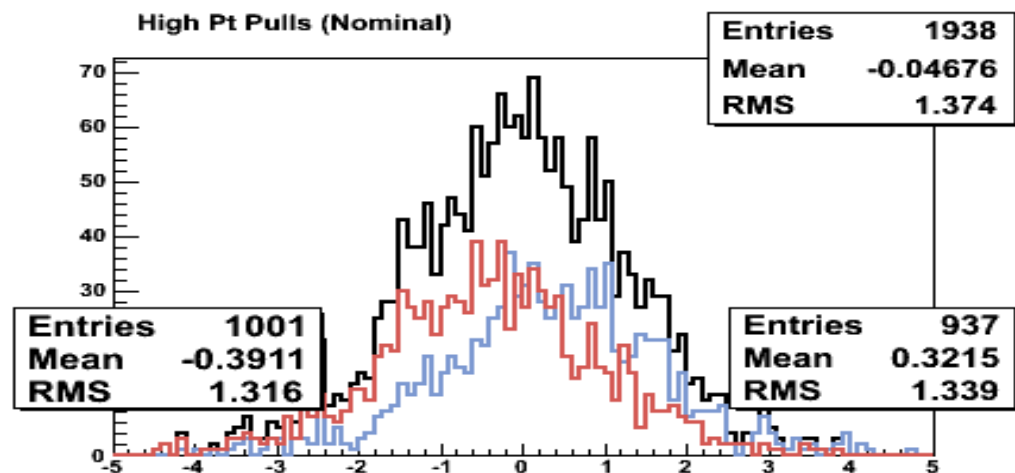
High Pt Pulls (After Alignment From Perfect)



Low Pt Pulls (Nominal)



High Pt Pulls (Nominal)



Consistent with L1 rotation?



- b/c Si is in the ideal position an overall global rotation of the TRT will also introduce a clocking effect.
- Is the L2 alignment introducing what amounts to (and could be fixed by) an overall L1 rotation?



Consistent with L1 rotation?

- Significant spreads in phi pulls for each layer tends to rule out L1 hypothesis
- Using average phi residuals can calculate the magnitude of the L1 rotation needed to explain the pulls.

- Nominal: θ
 - Lay0 => 14.51 +/- 1.13 muRad
 - Lay1 => 21.35 +/- 0.92 muRad
 - Lay2 => 23.57 +/- 1.27 muRad

- Perfect: θ
 - Lay0 => 9.31 +/- 1.04 muRad
 - Lay1 => 12.37 +/- 0.72 muRad
 - Lay2 => 11.62 +/- 1.03 muRad

clocking effect seems not to be a result of overall misalignment w.r.t. the Si, but internal to the TRT

- Angles inconsistent, further evidence against global rotation cause of clocking



Conclusions.

- Clocking effect in alignment is not under control (using CSC muons)
 - algorithm does not correct an initial clocking effect.
 - algorithm itself may introduce a clocking effect
- Noticeable impact of the effect on tracking, which grows with Pt
- Errors given by the TRTAlignAlg seem to be underestimated by factor ~ 3
- Evidence for need of cosmics?



to do . . .

- determine how errors given by TRTAlignAlg change from 13.0.30 -> updated tracking in the nightlies
- determine if, and how many cosmics are needed to get a handle on clocking effect.
- Is there a analogous internal mechanism in the endcaps which could give a momentum biasing?

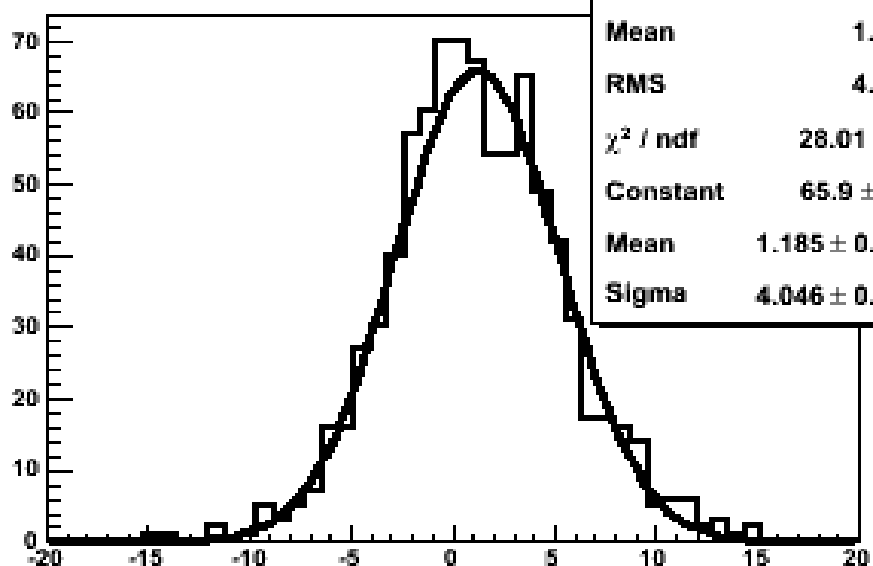


Backup Slides



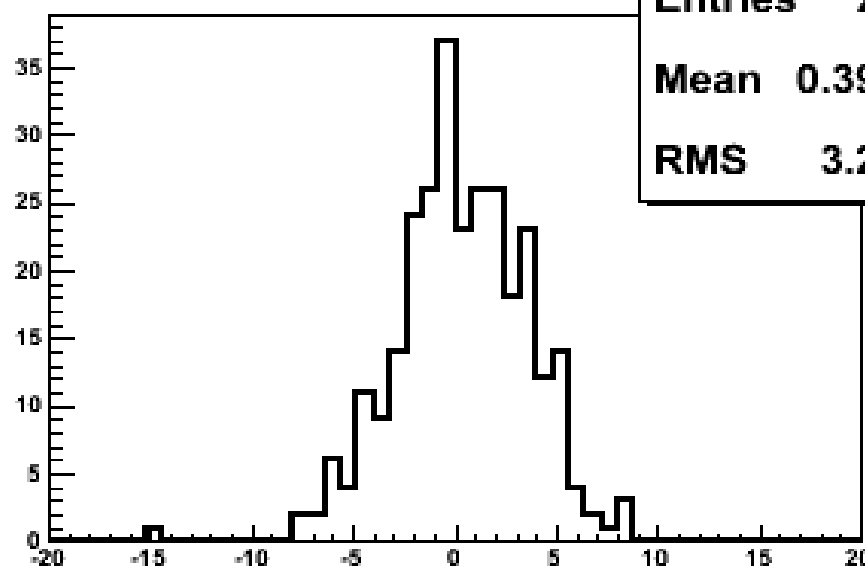
pulls along r (nominal)

\bar{r} pulls for all layers



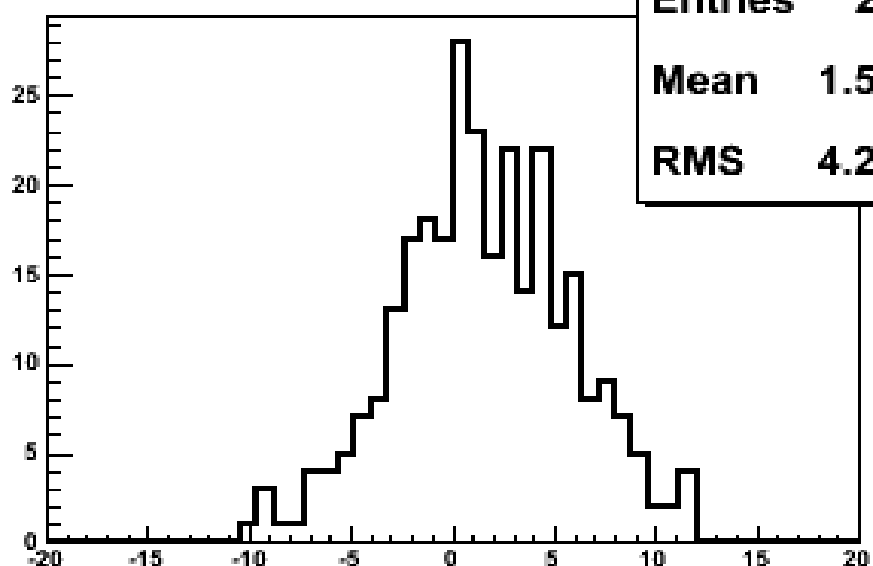
Entries	864
Mean	1.248
RMS	4.253
χ^2 / ndf	28.01 / 32
Constant	65.9 \pm 3.0
Mean	1.185 \pm 0.143
Sigma	4.046 \pm 0.117

\bar{r} pulls for modules in layer 0



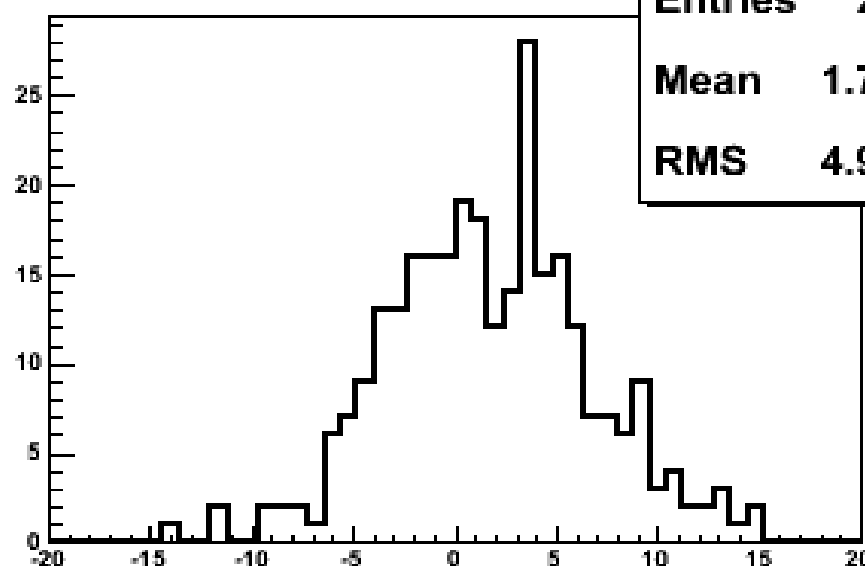
Entries	288
Mean	0.3978
RMS	3.207

\bar{r} pulls for modules in layer 1



Entries	288
Mean	1.573
RMS	4.237

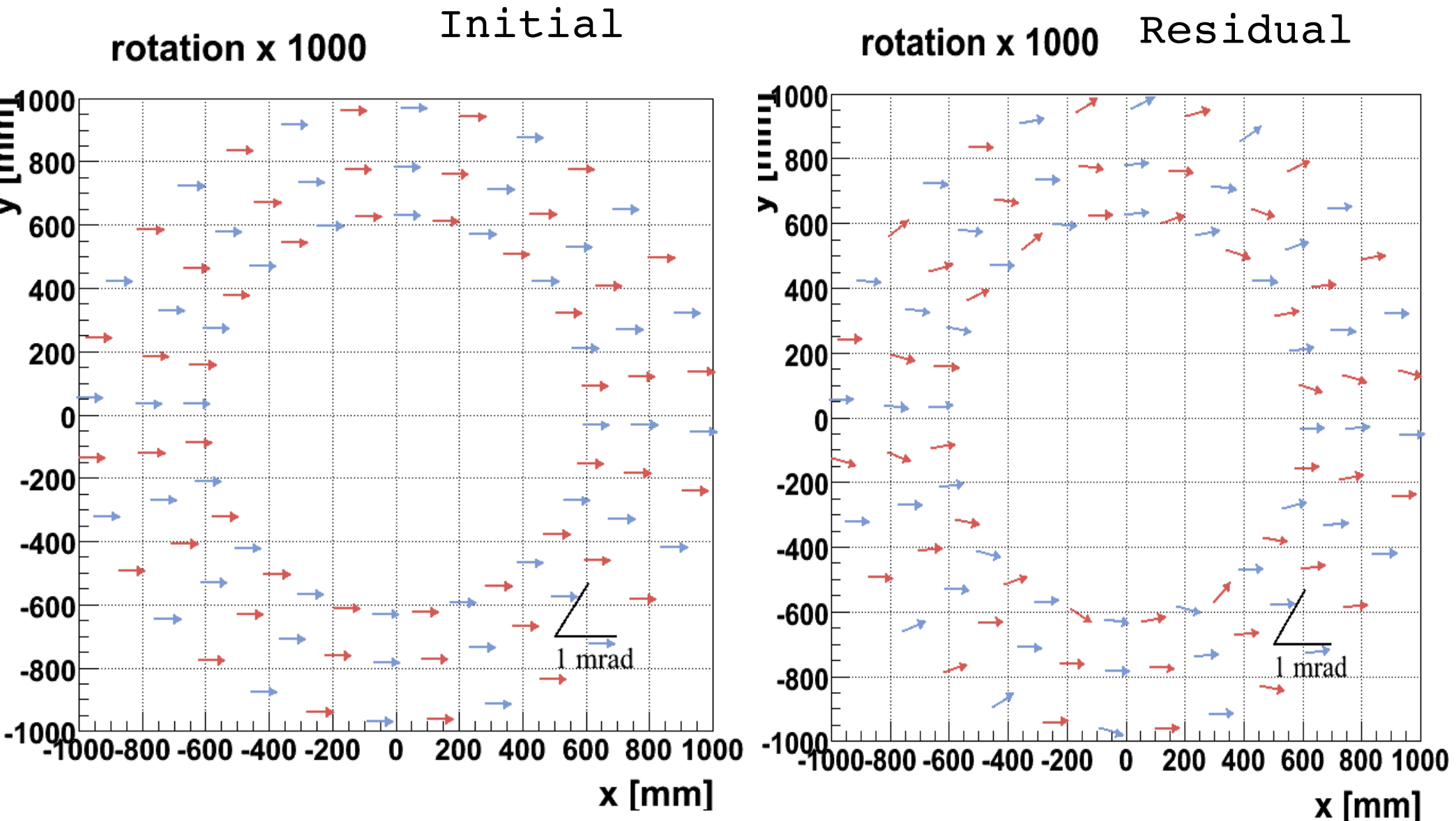
\bar{r} pulls for modules in layer 2



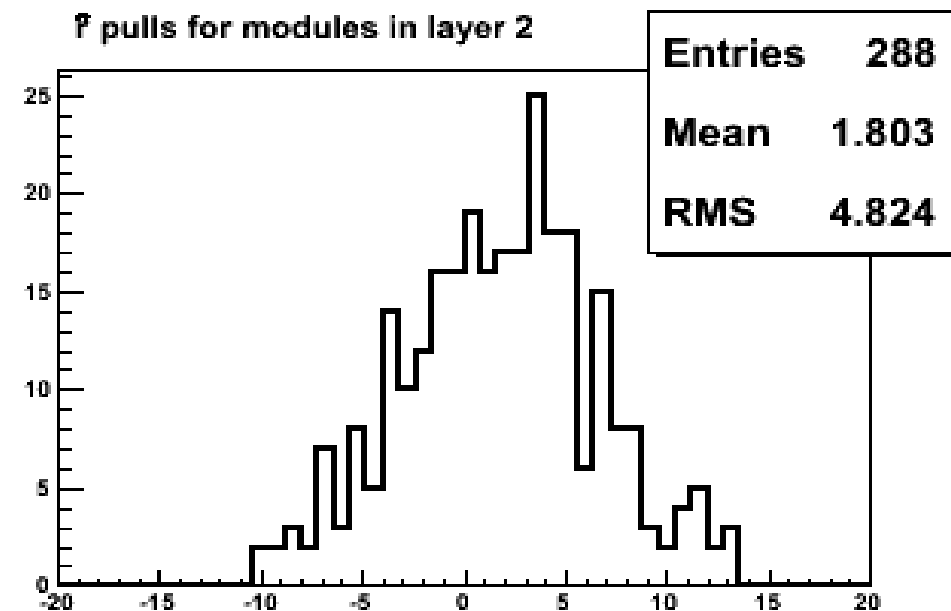
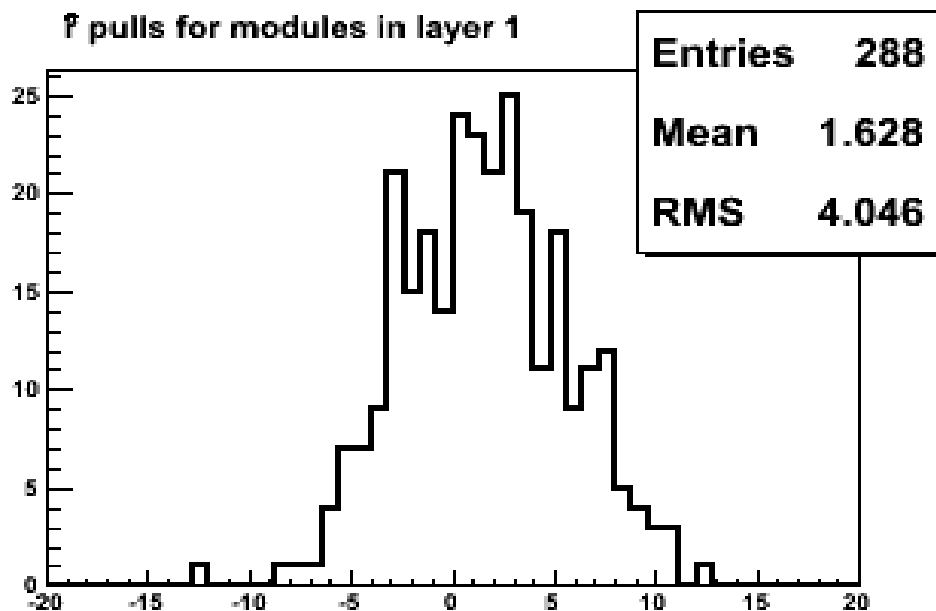
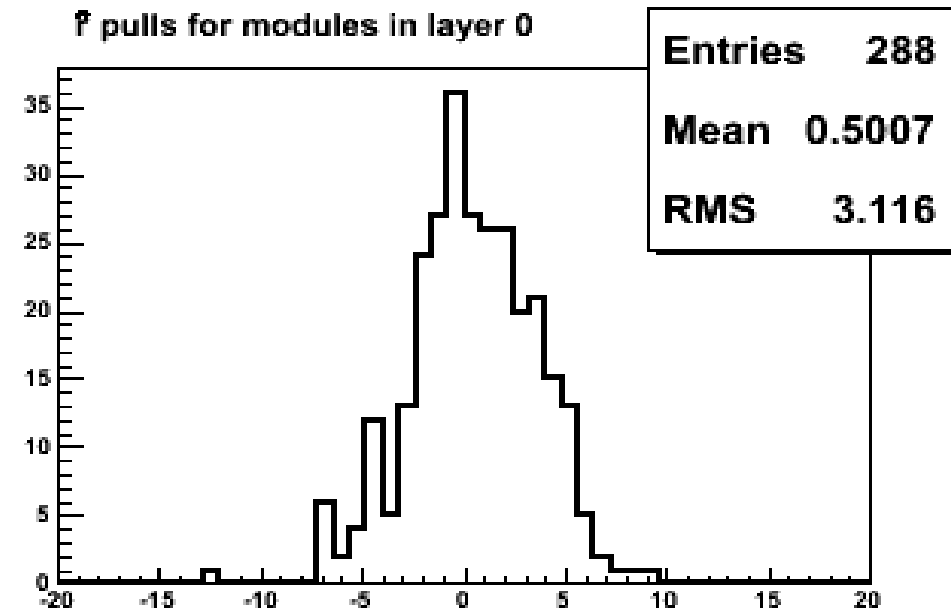
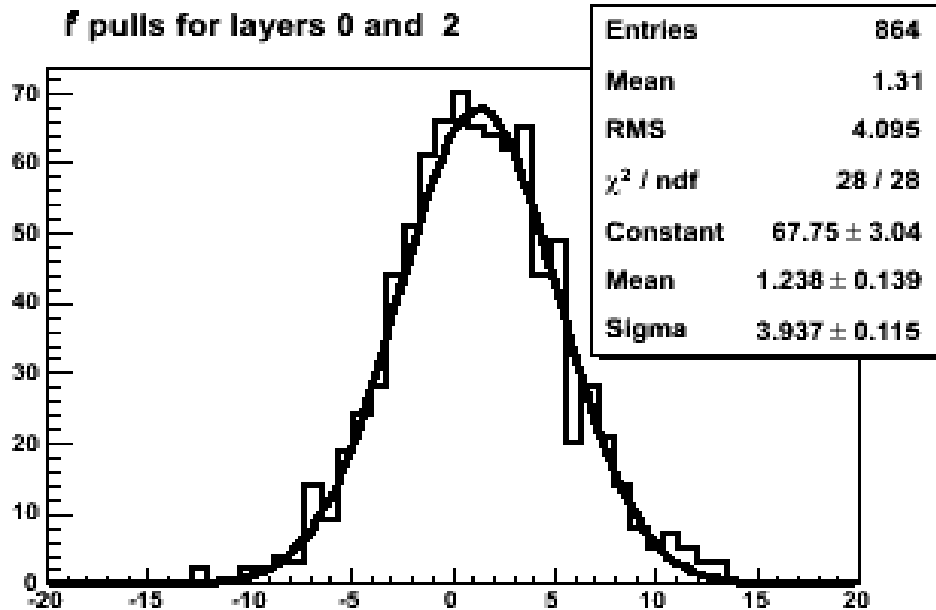
Entries	288
Mean	1.776
RMS	4.997



z-rotations (nominal)



pulls along r (perfect)

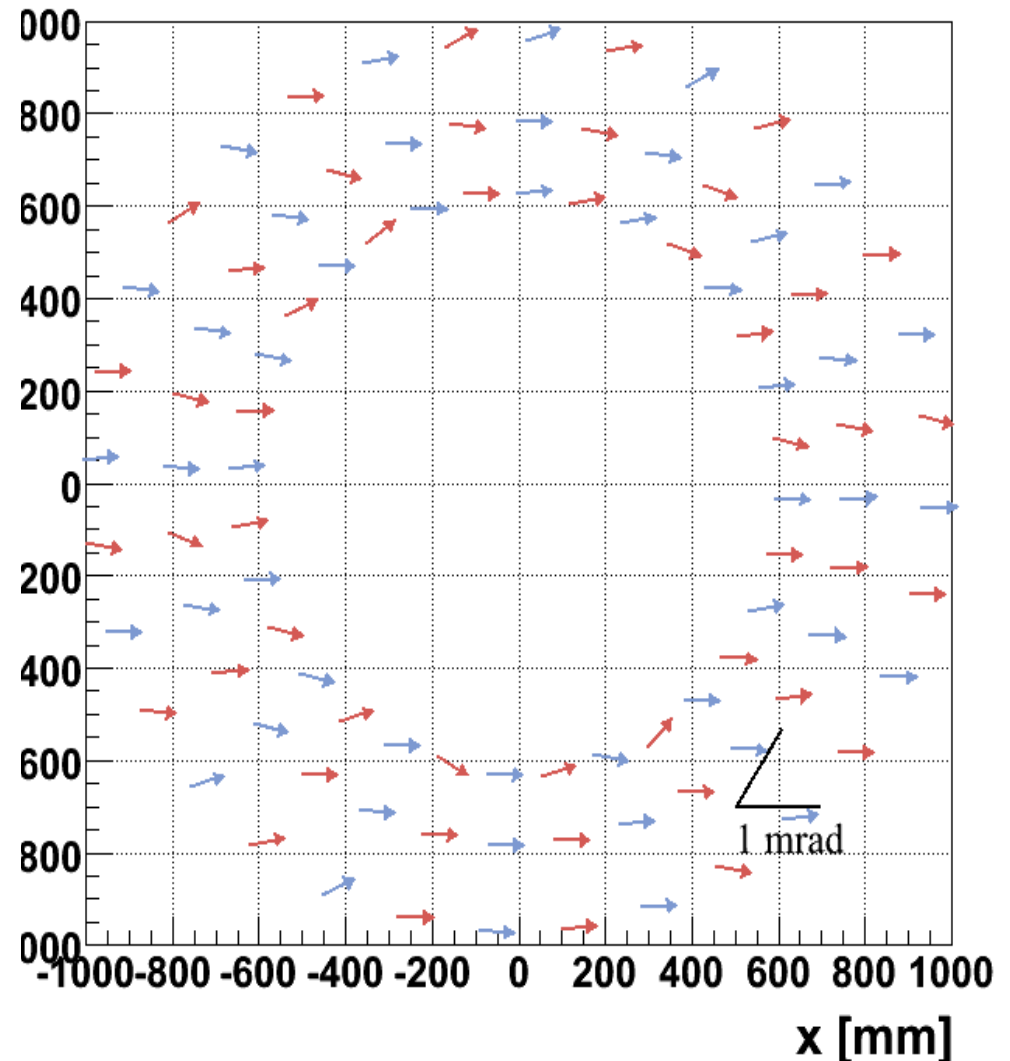
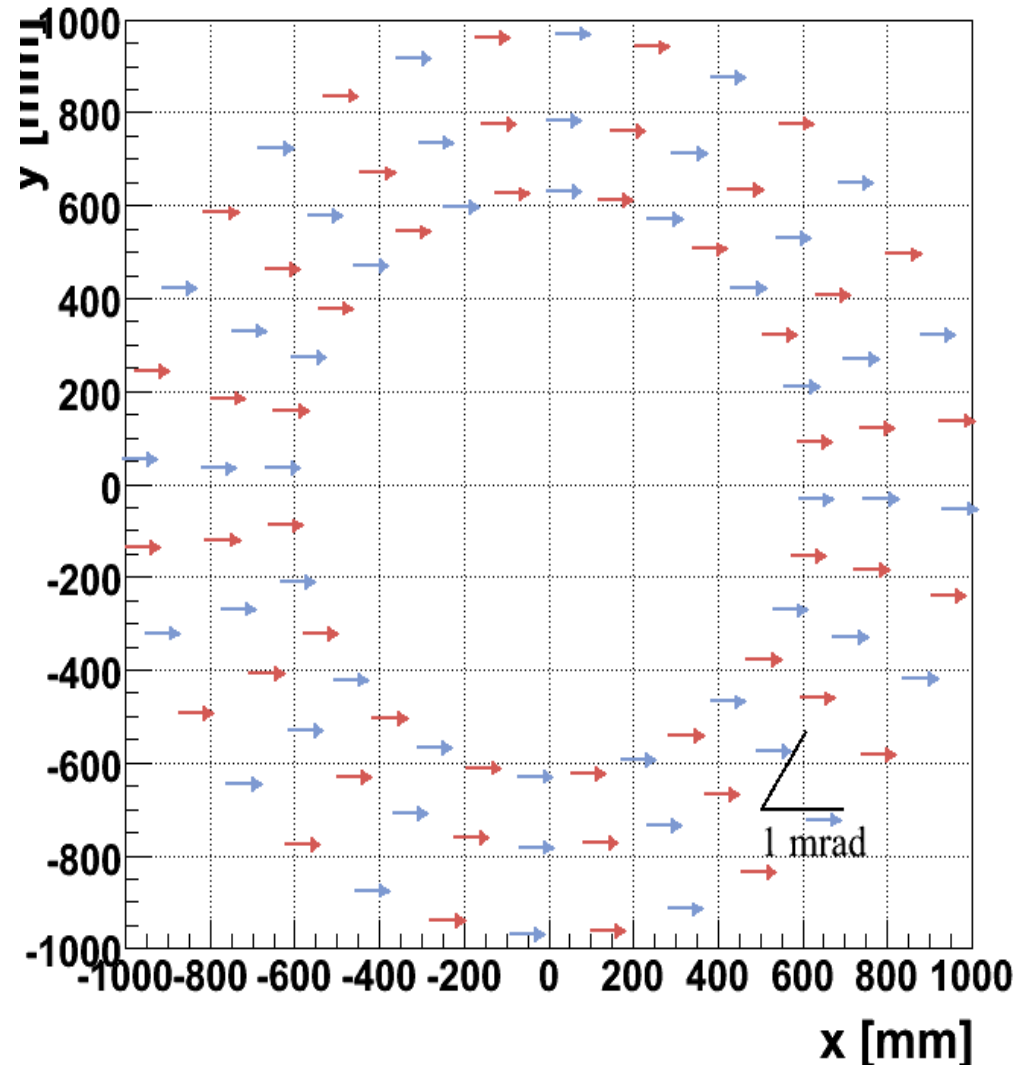




z-rotations (perfect)

rotation x 1000 Initial

rotation x 1000 Residual

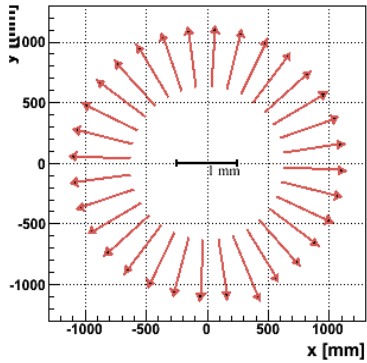




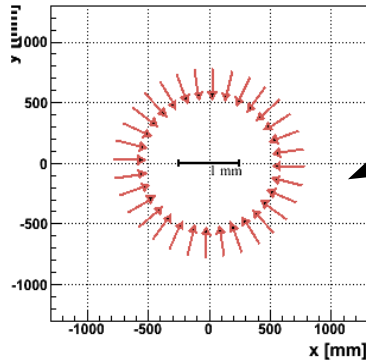
Radial Study

Initial displacements

translation x 500 - Layer 0



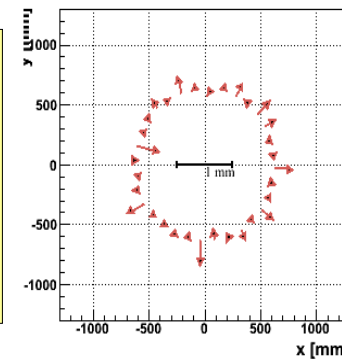
translation x500- Layer 1



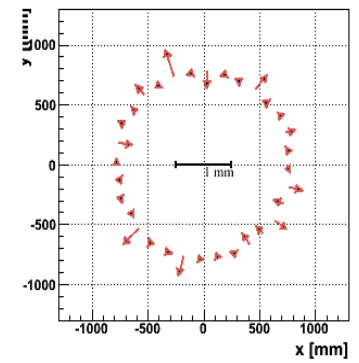
Initial displacements are radially only

Residual displacements

translation x 500 - Layer 0

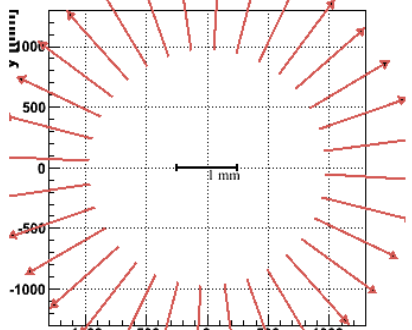


translation x500- Layer 1

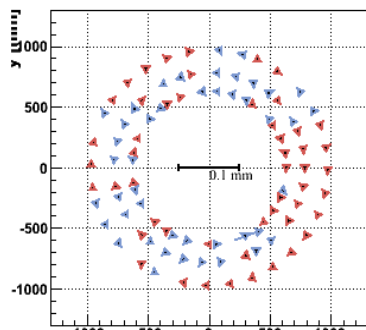


alignment recovers radial displacements while introducing clocking

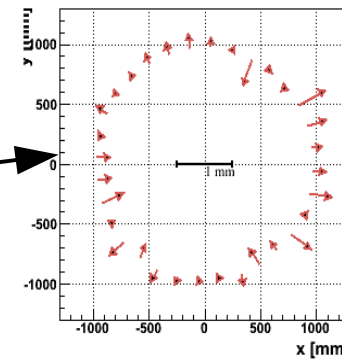
translation x500 - Layer 2



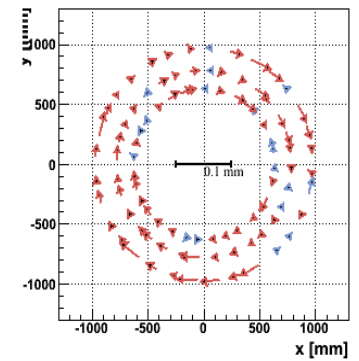
Projection of the translation along #5 x 5000



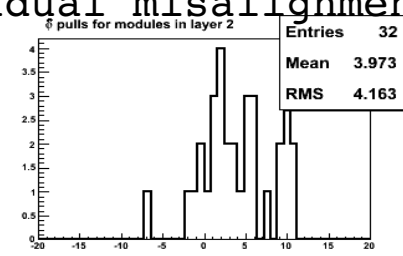
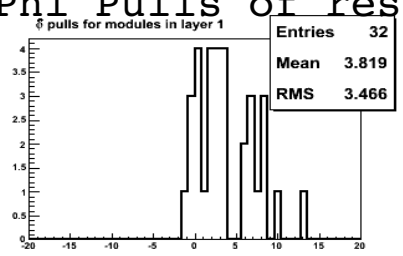
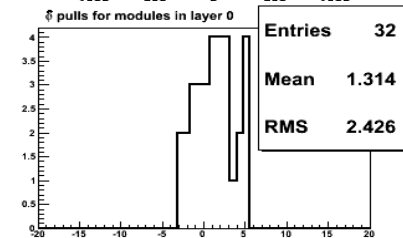
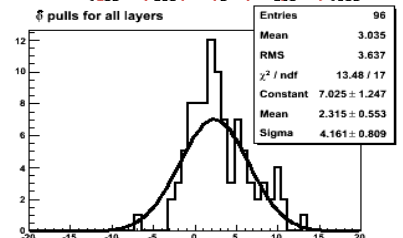
translation x500 - Layer 2



Projection of the translation along #5 x 5000



Alignment done for 9 Iterations using 5000 multi-muon events

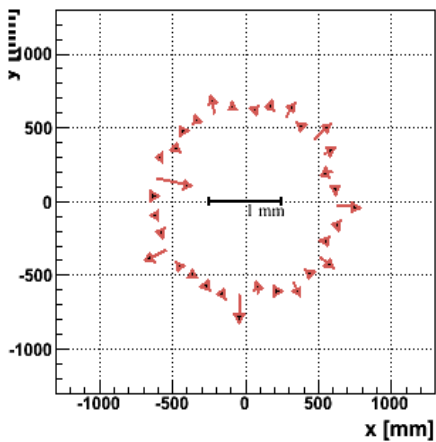


Constrained Dof Study

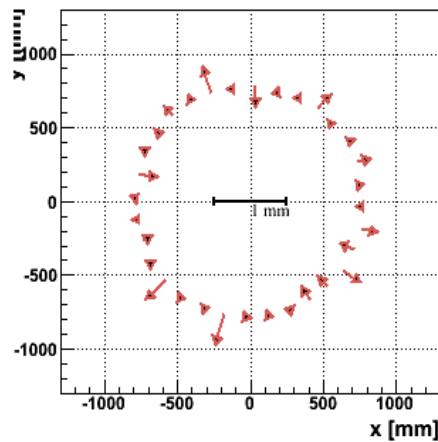
- Ran alignment without poorly constrained Dof, (module rotations around global x and y), ie: only aligning translations in x and y and rotations around z.

Residual misalignments

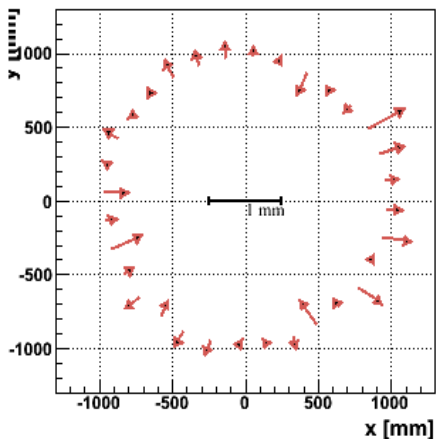
translation x 500 - Layer 0



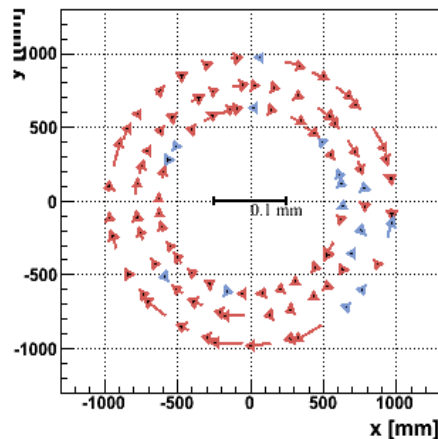
translation x500- Layer 1



translation x500 - Layer 2

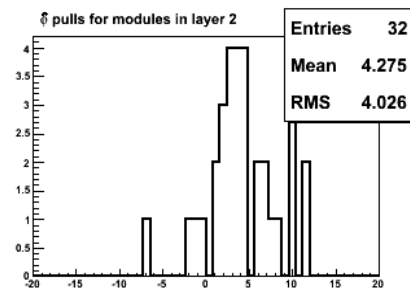
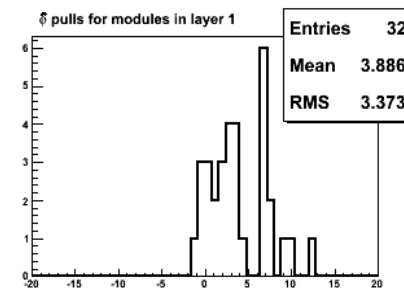
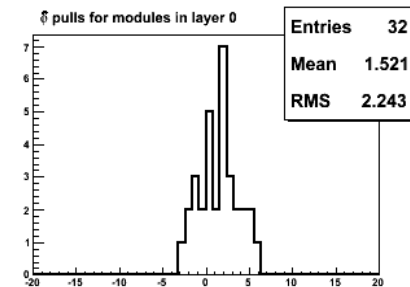
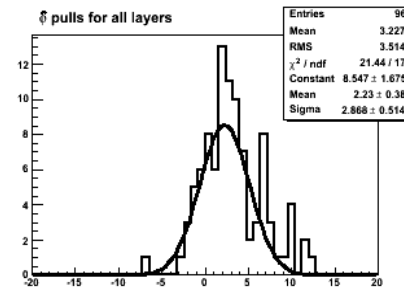


Projection of the translation along #φ x 5000



-9 iterations of 5000 events, starting from ideal alignment

Phi Pulls of residual misalignments



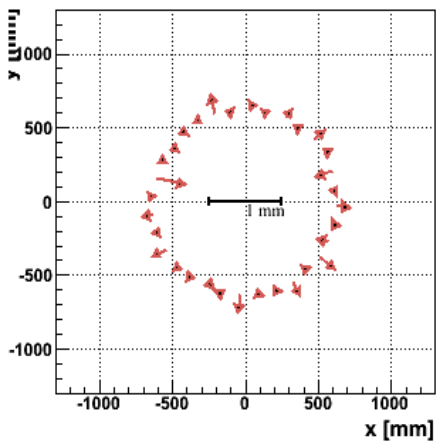


Translations only Study

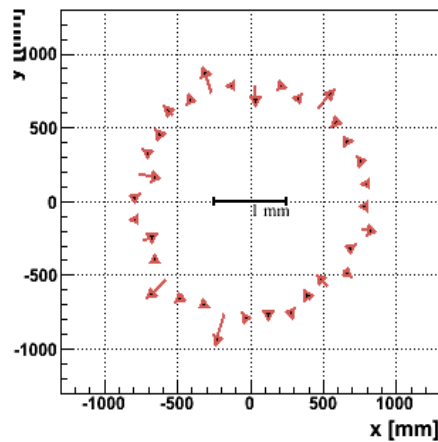
- Ran alignment without aligning rotations, ie: only aligning translations in x and y

Residual misalignments

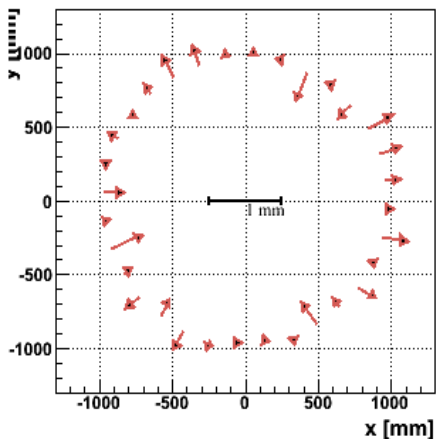
translation x 500 - Layer 0



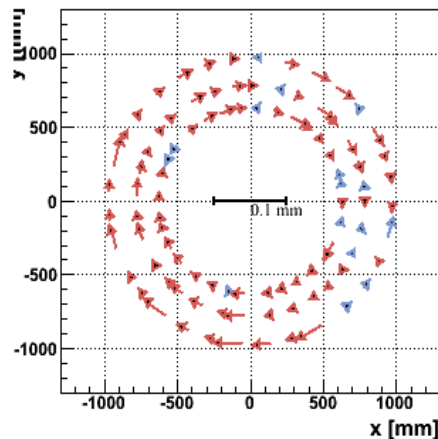
translation x500- Layer 1



translation x500 - Layer 2

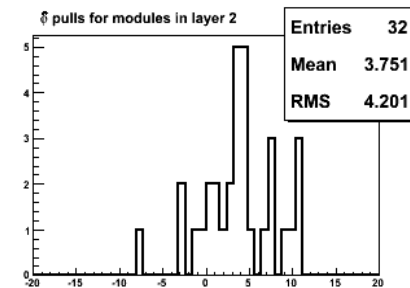
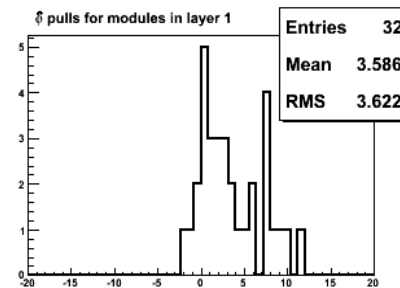
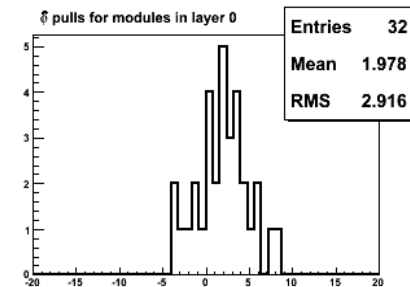
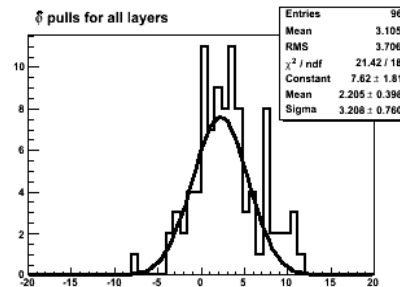


Projection of the translation along ϕ x 5000



-9 iterations of 5000 events, starting from ideal alignment

Phi Pulls of residual misalignments



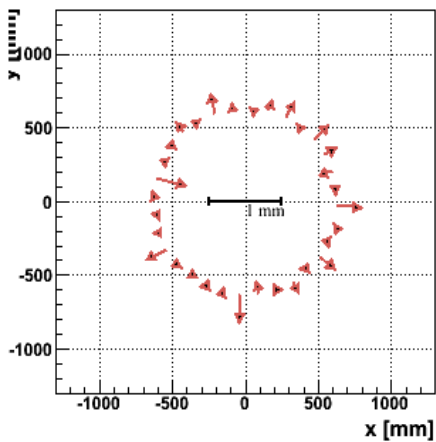


Global Chi2 Method

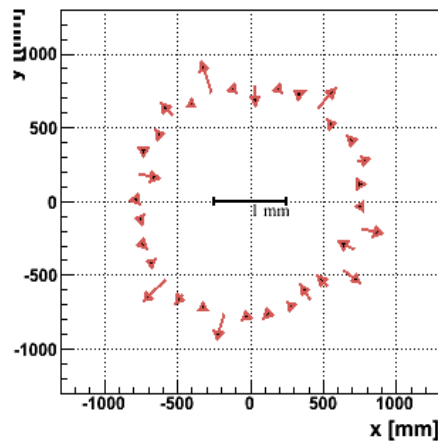
- Ran alignment using the Global chi2 method in TRTAlignAlg to solve for the alignment constants.

Residual misalignments

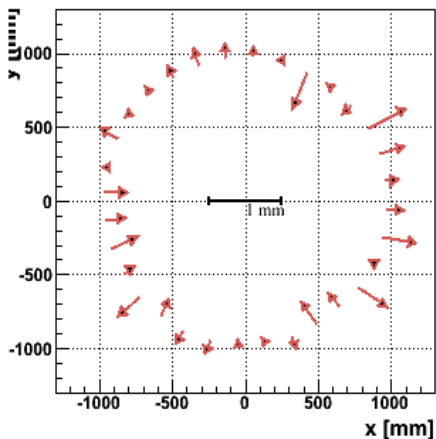
translation x 500 - Layer 0



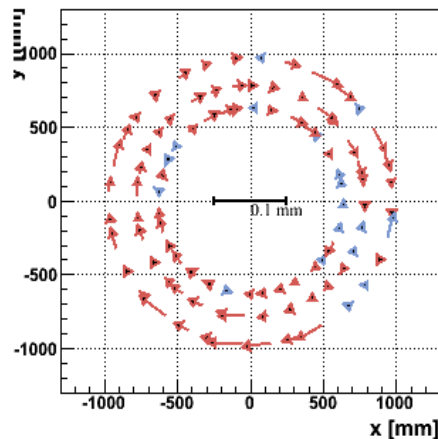
translation x500- Layer 1



translation x500 - Layer 2

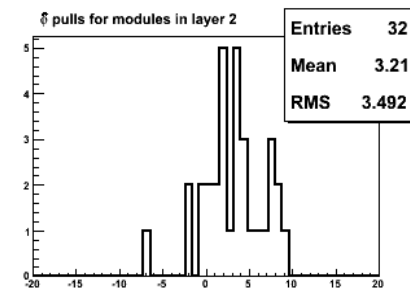
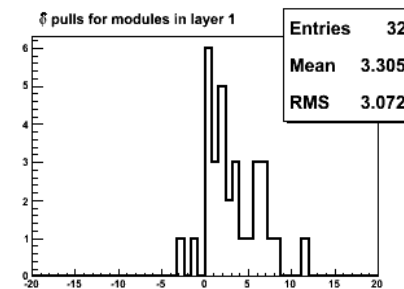
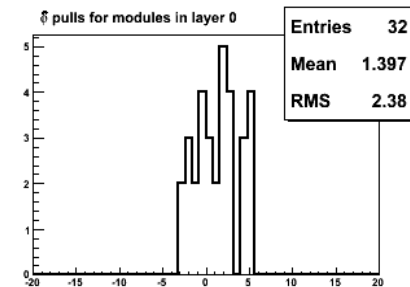
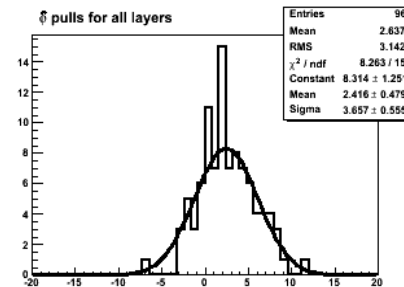


Projection of the translation along #φ x 5000



-9 iterations of 5000 events, starting from ideal alignment

Phi Pulls of residual misalignments



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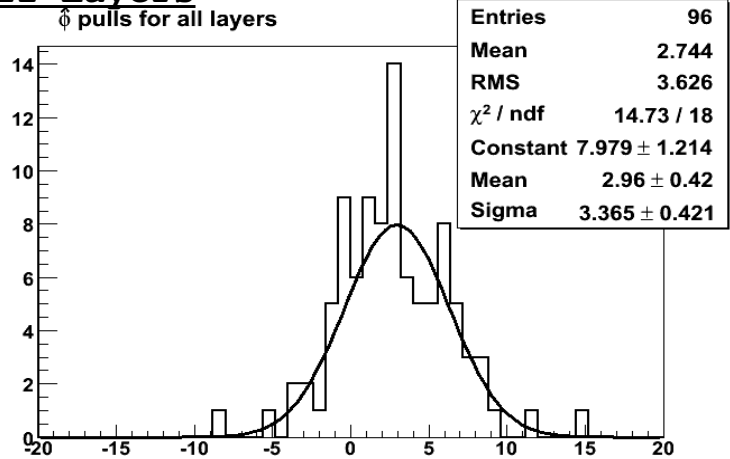




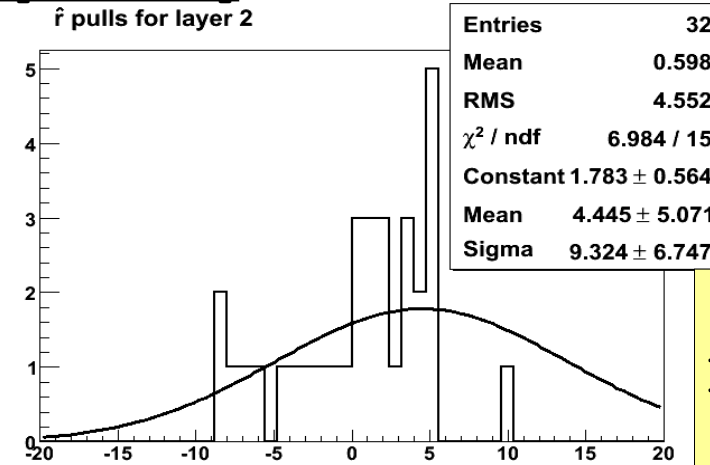
alignment by layer

- ran alignment, as before, aligning different combinations of individual layers
- Phi Pulls:

All Layers

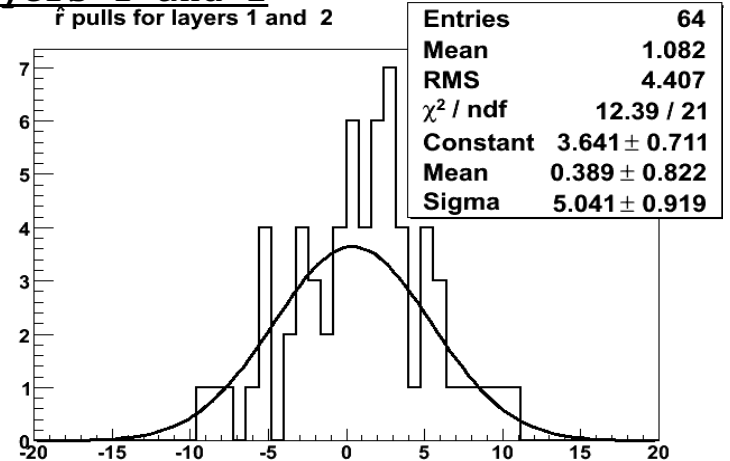


Layer 2 only



Layers conspire to give/enhance clocking effect

Layers 1 and 2



Layers 0 and 2

