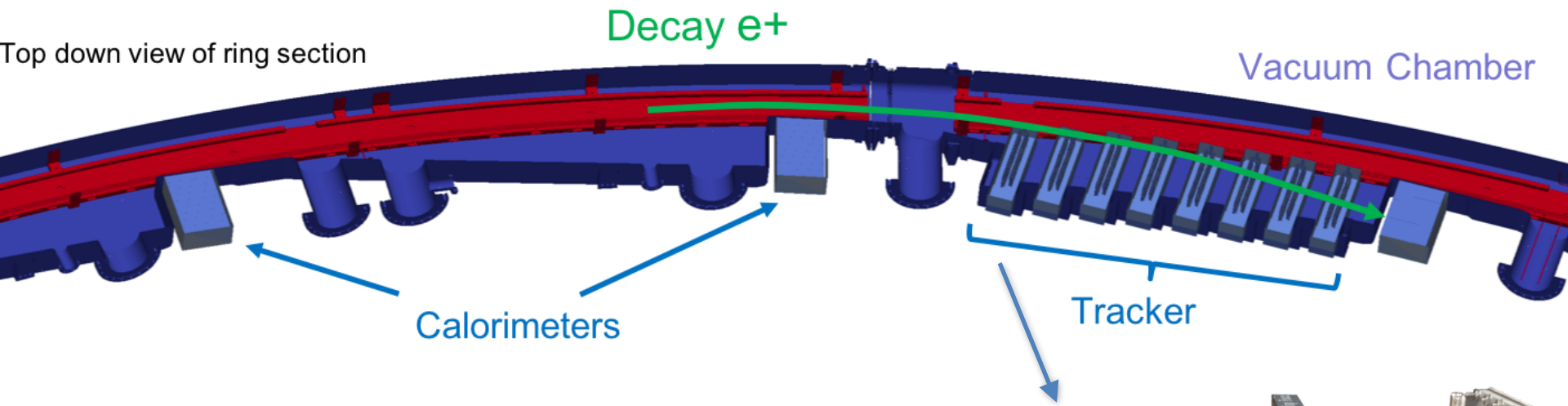
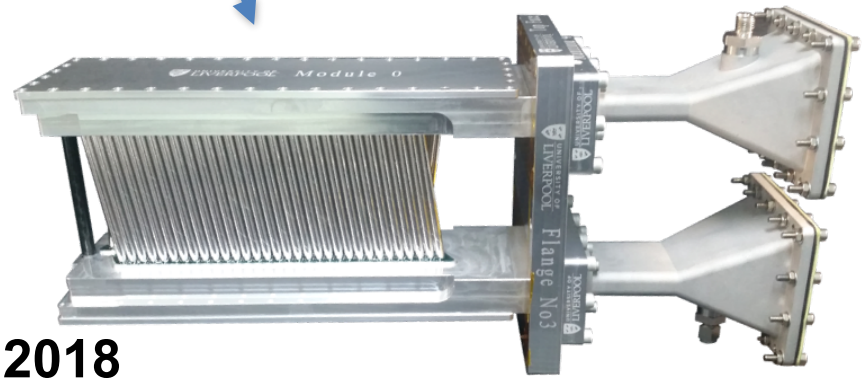
Gleb Lukicov

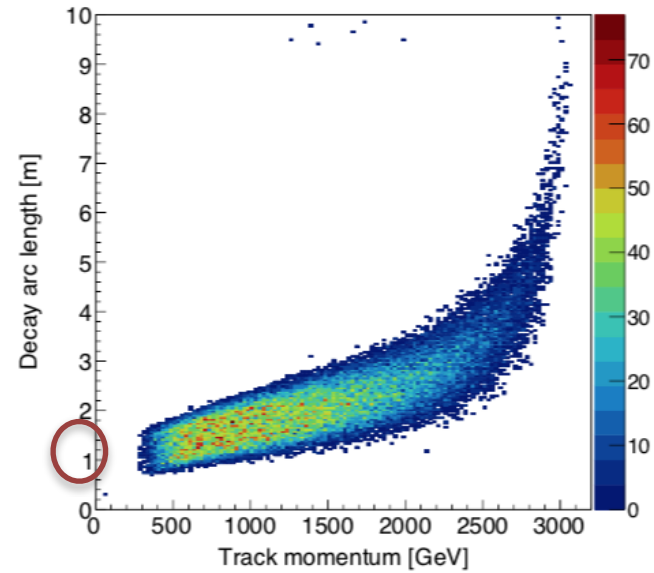
Straw Tracker Alignment

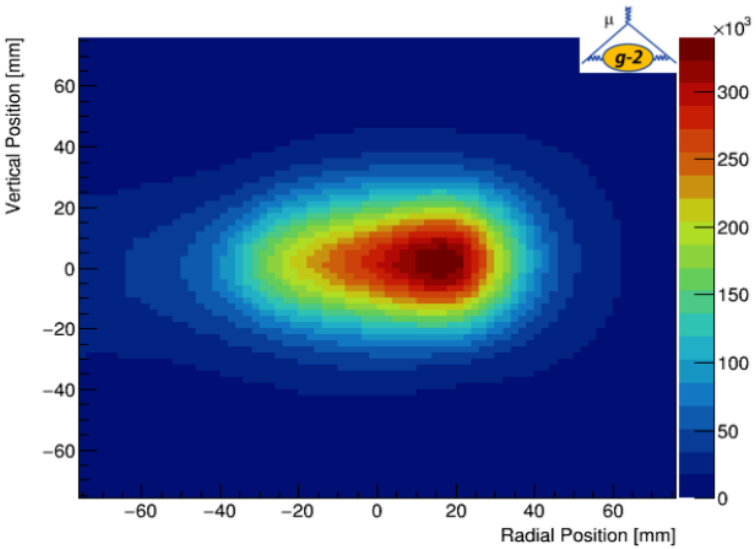


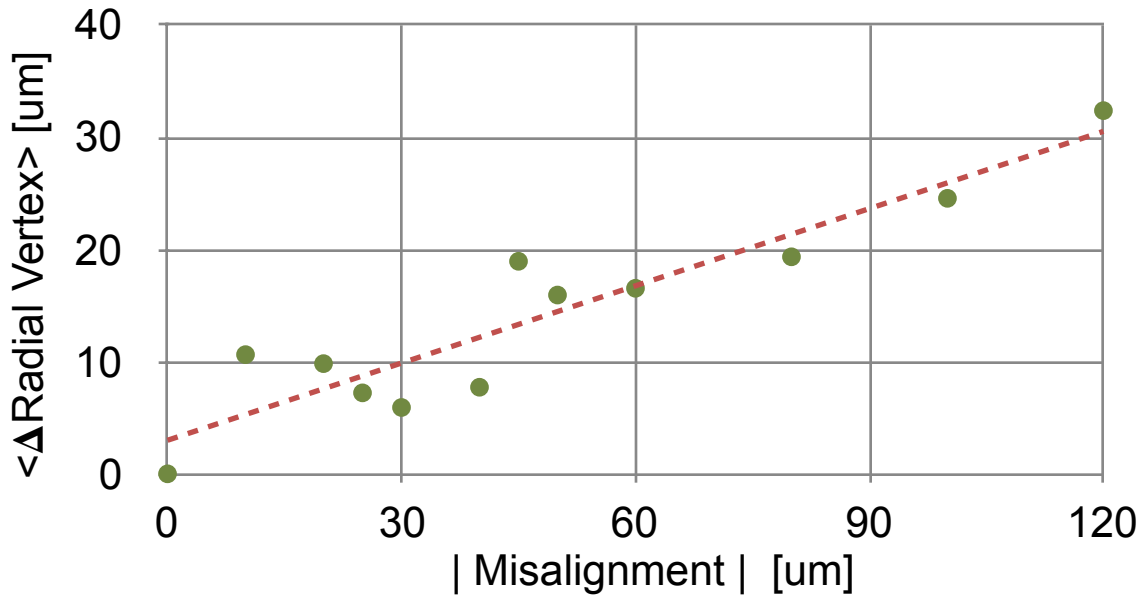


23 October 2018
MUSE General Meeting
Fermilab

- One of the primary aims of the tracker is to reconstruct the beam profile as a function of time.
- The tracking and reconstructed beam distribution are affected by any misalignment in the modules.

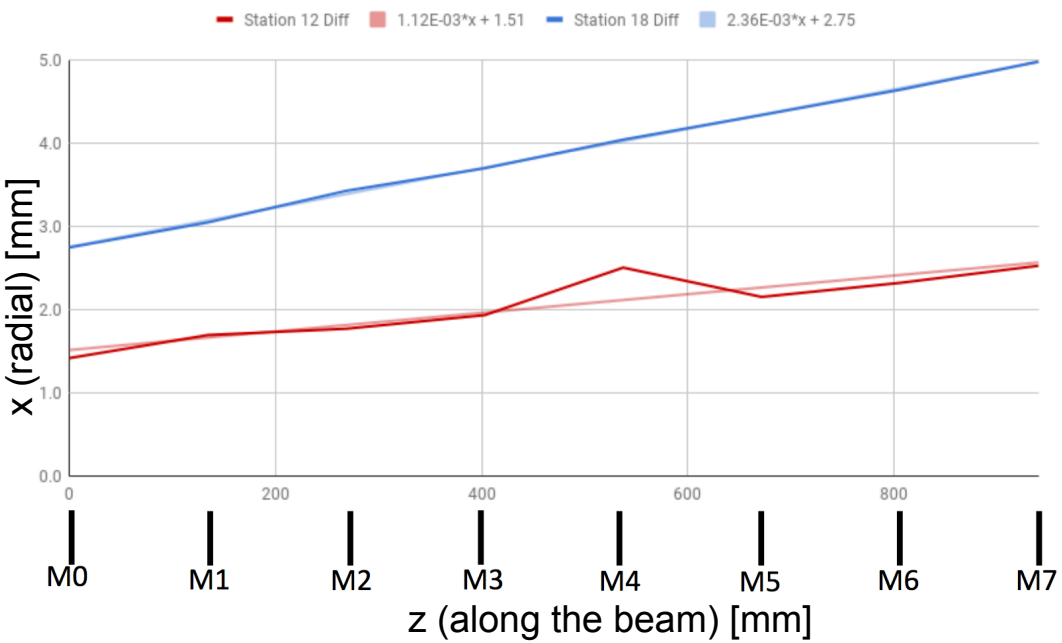


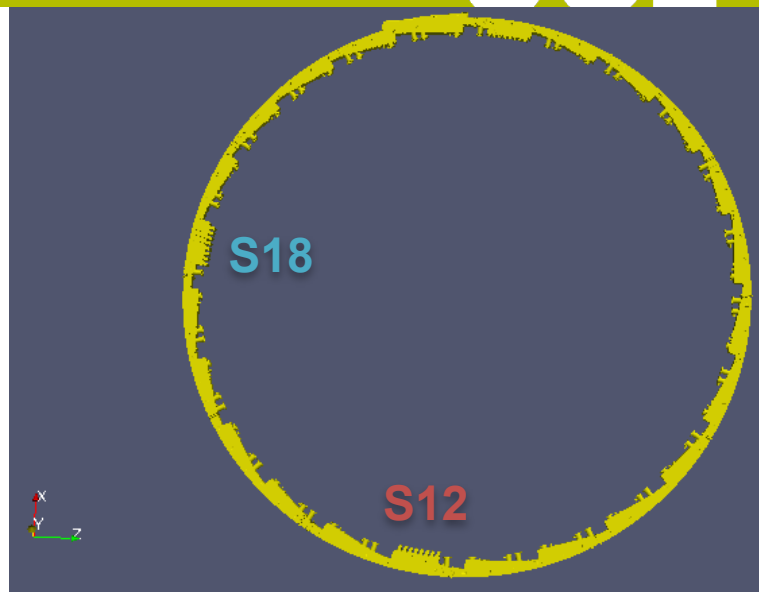




Survey Alignment

- The ***survey alignment*** of the trackers was undertaken.





Two tracker station in the Ring Simulation.

Putting these offsets into the geometry results in a shift in the mean radial position of

- *350 μm for station 12*
- *330 μm for station 18*

- The track-based alignment
  - Improve upon the accuracy
  - Allow for movements of individual straws

S18: Inside the vacuum chamber.

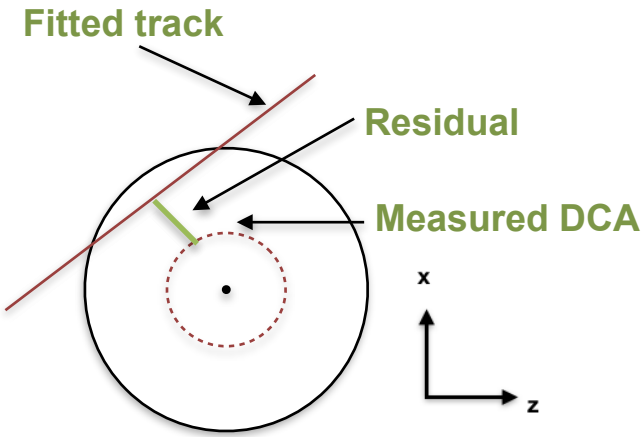
Track-based alignment

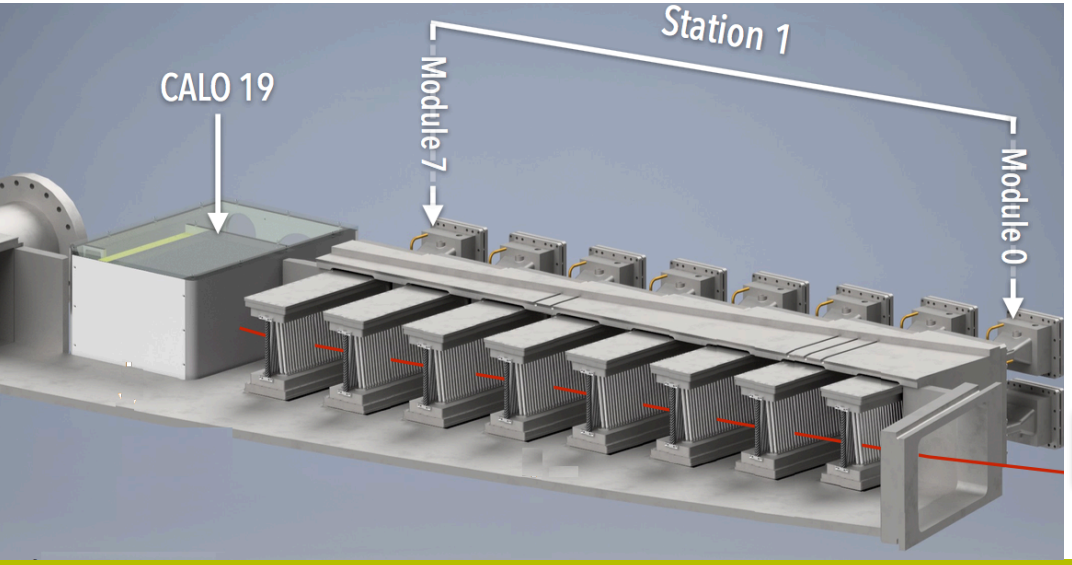
- Alignment is implemented using **Millepede II**, a least square minimiser.

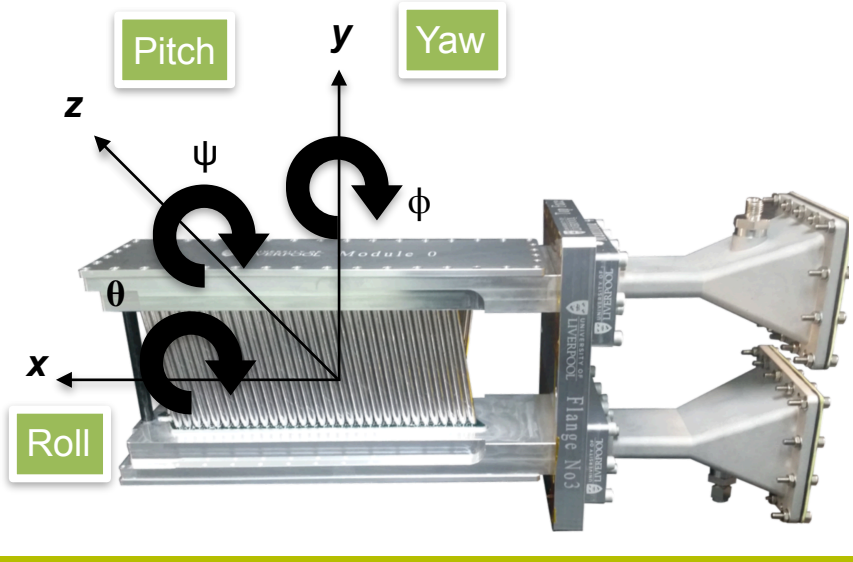
- Inputs are:
  - residual between the track and the hit
  - the rate of change of residual with module position
  - the rate of change of residual with track parameters

- Alignment will be done to predict:
  - translations: radial (*x*) and vertical (*y*)
  - rotations: *pitch* and *roll.*

- Total of **8,192 alignment parameters** (individual straws)

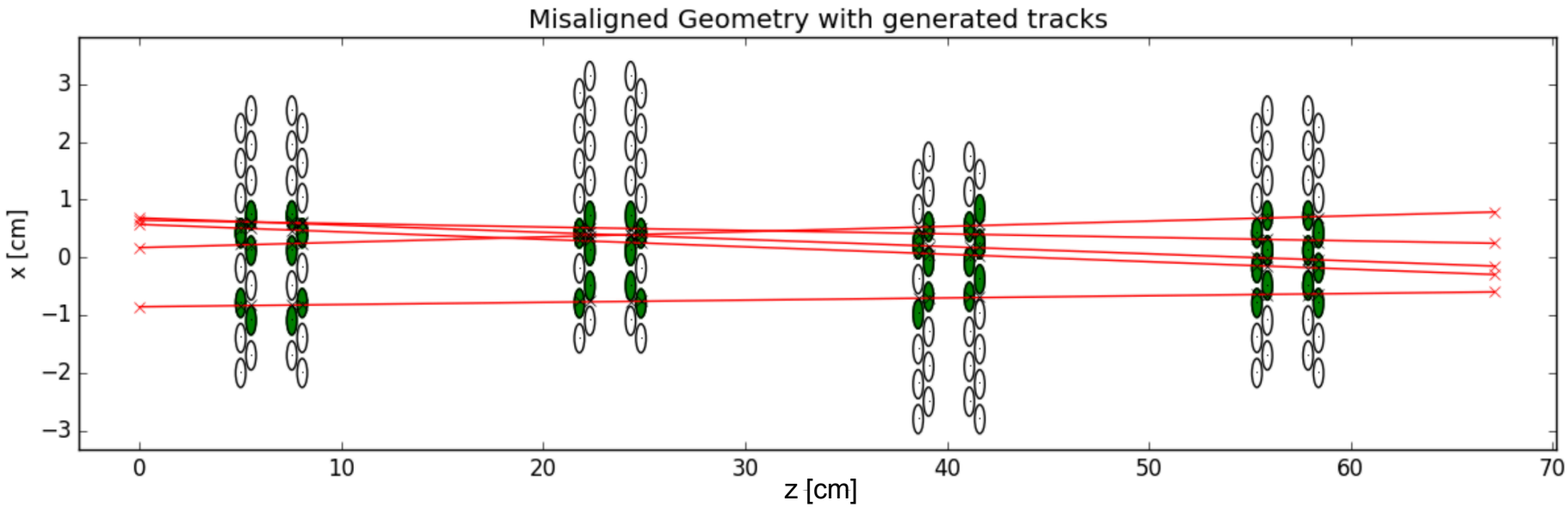


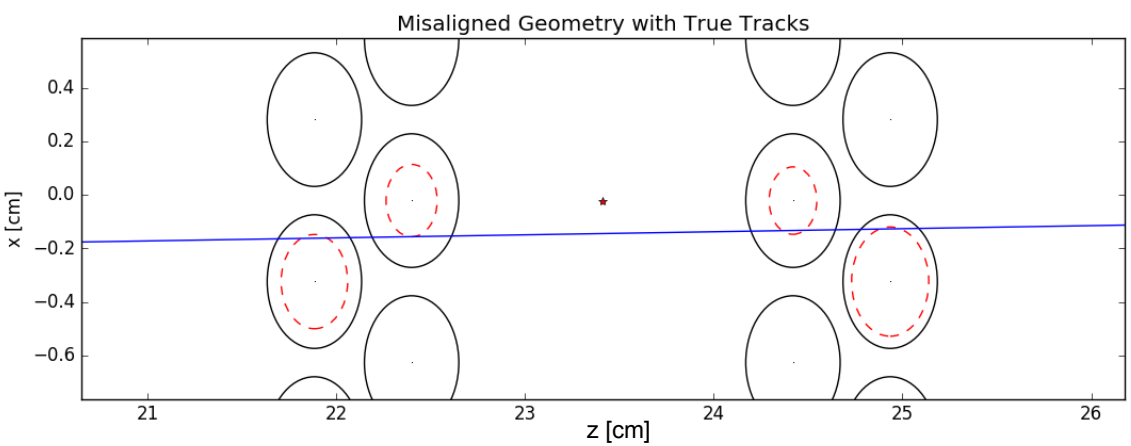




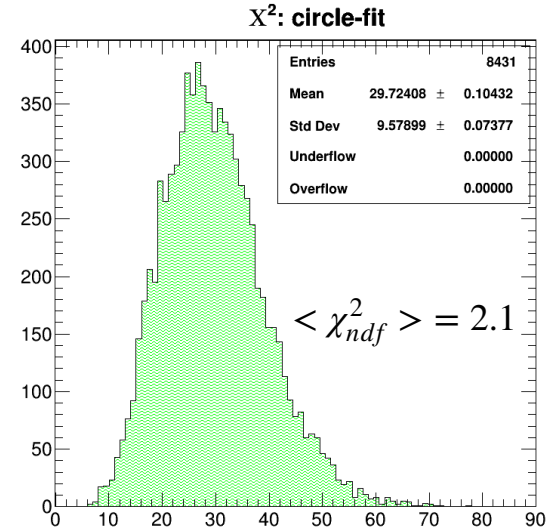
Toy Model

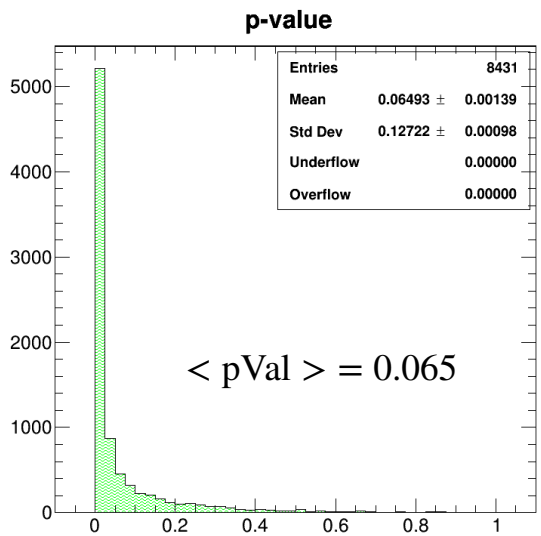
- A standalone simulation was developed to understand the detector geometry.
- Straight tracks (no magnetic field), and no scattering effects (no detector material).

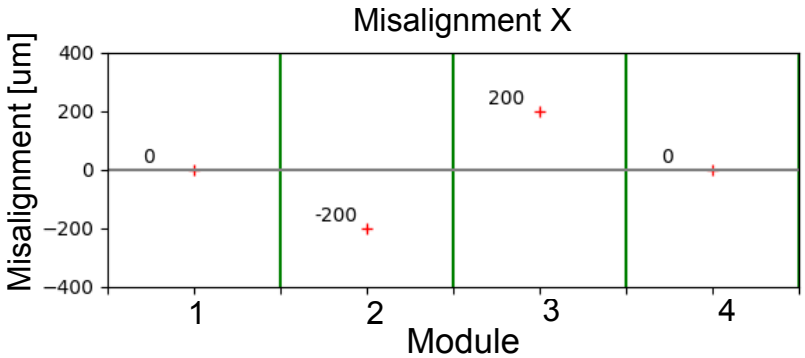




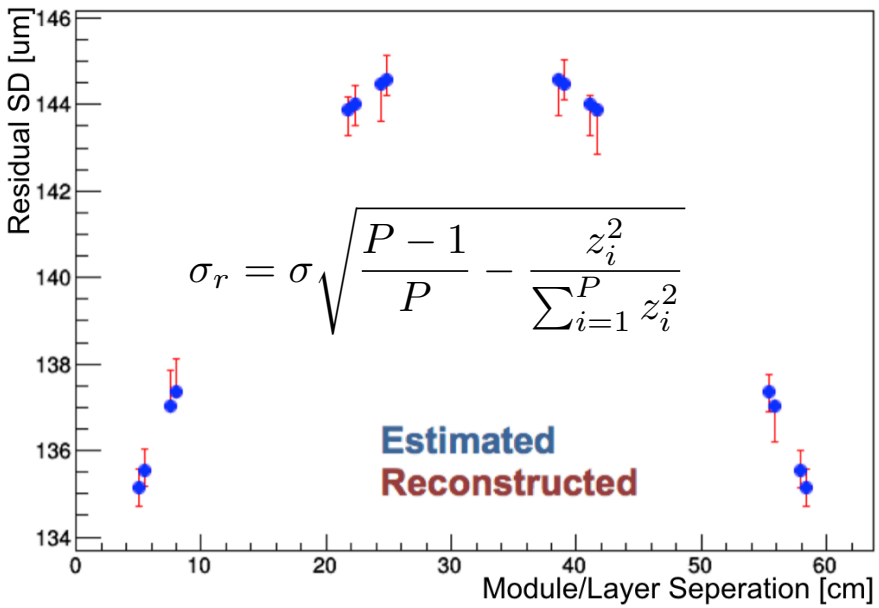
A zoom-in in module 2 shows fitted track through generated drift circles.







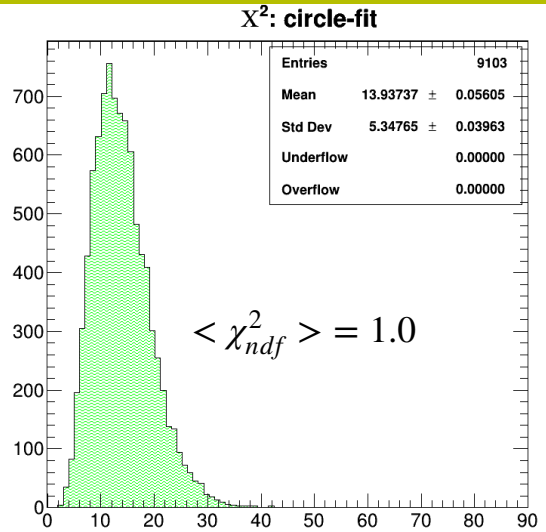
Input misalignment in simulation.

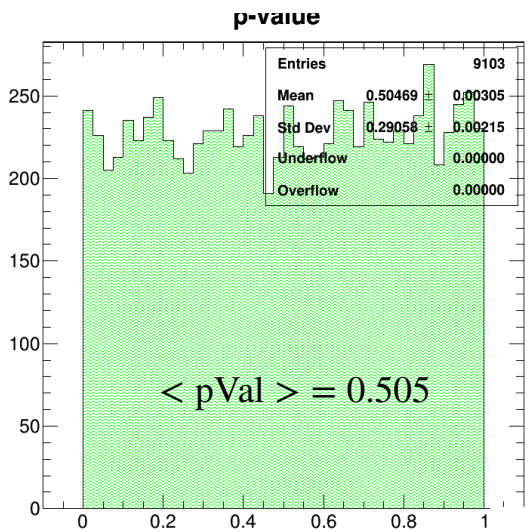


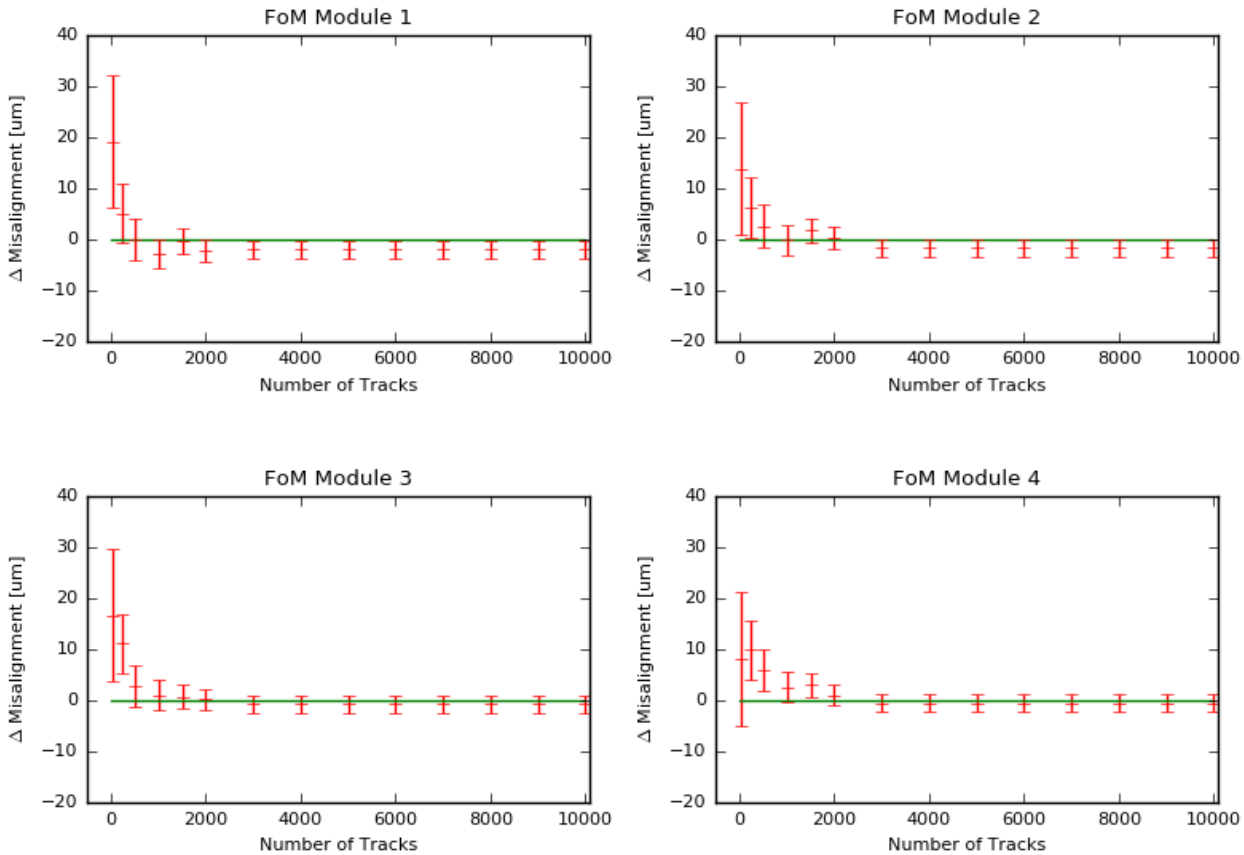
The residual SD is smaller on the outer modules due to the effect of the fitting.

<u>Before Alignment:</u>

χ^2 and p-value distributions are indicative of poor detector alignment.







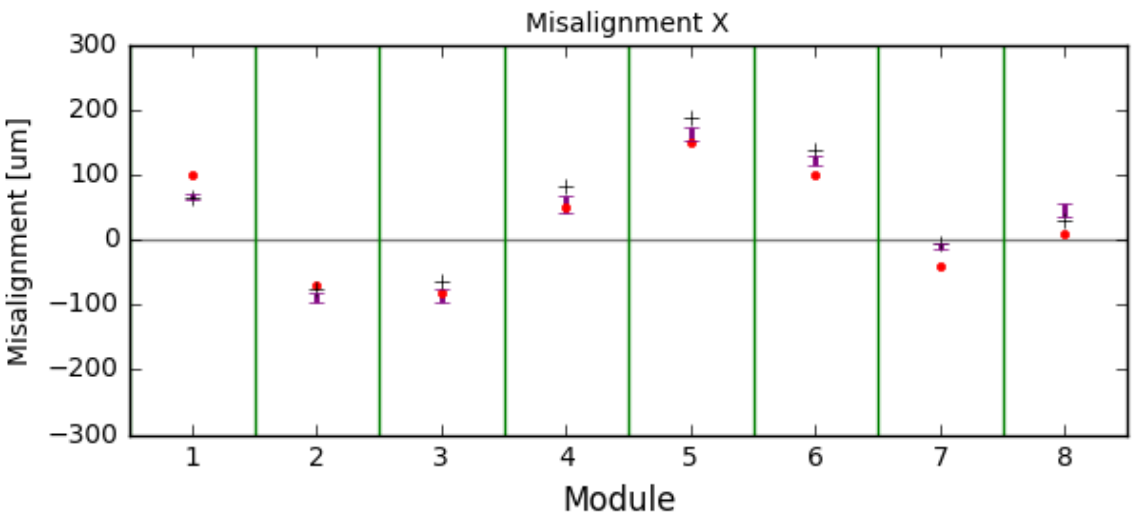
The difference in misalignment (in the x direction) between the truth and PEDE prediction vs. number of generated tracks.

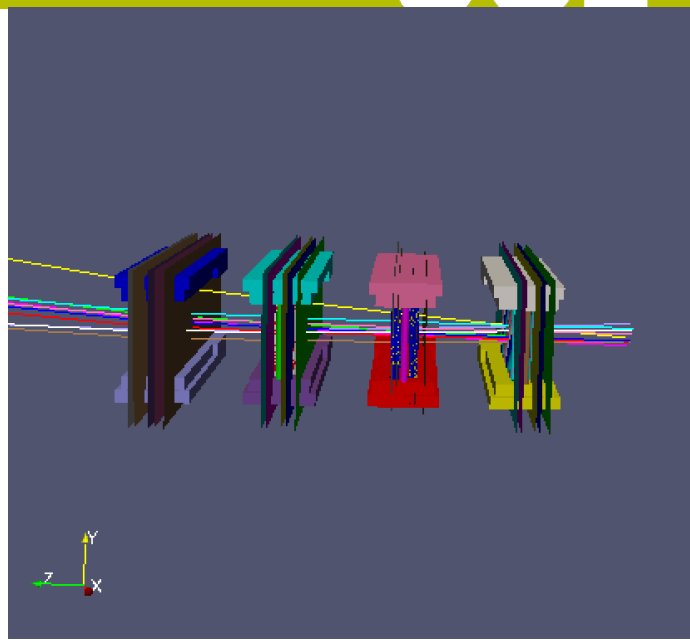
<u>After Alignment:</u>

The predicted offsets from Millepede were added to the assumed geometry of the tracker, and re-fitting of the tracks was done.

Uniform Magnetic Field

- Simulation with curved tracks in a uniform magnetic field.
- Using the official tracking chain.
- Using an iterative process (align, re-track, align again)





Selection of tracks going through 4 modules.

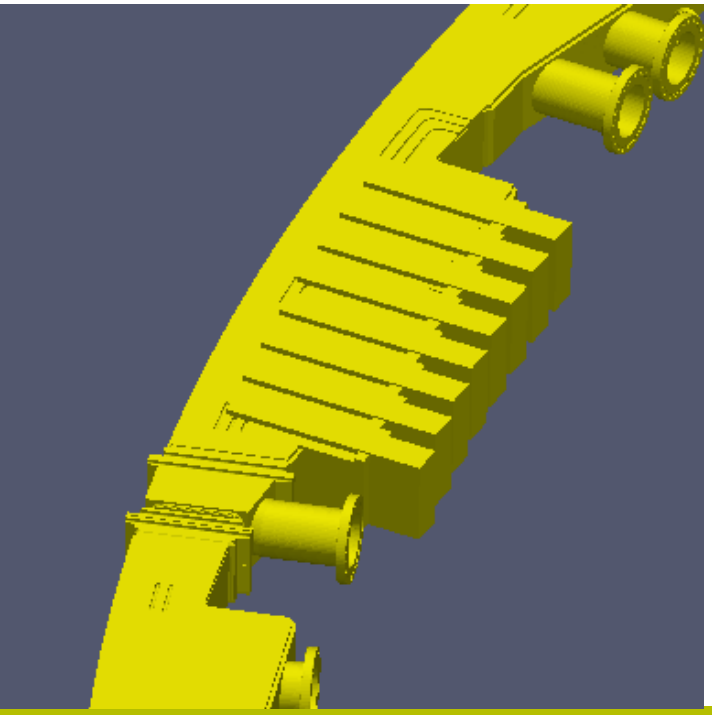
*Truth misalignment (**red**) and Millipede II prediction (**purple**): for iteration 1 (+) and iteration 2 (⌷).*

Ring Simulation

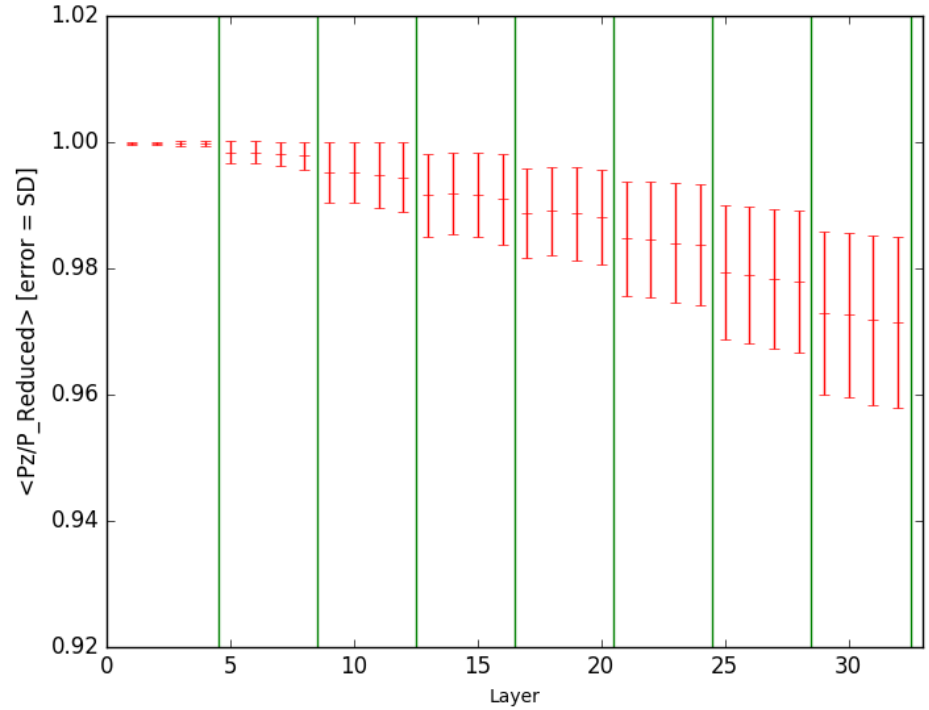
Moving to the full simulation incorporates the varying magnetic field in the tracker region (and other more realistic effects)

The following cuts on the selected tracks are used for the alignment to yield the best results:

- Track p-value < 0.005
- Tracks with number of hits < 11
- Tracks with any hit with Pz/P < 0.93
- Hit DCA < 500 um

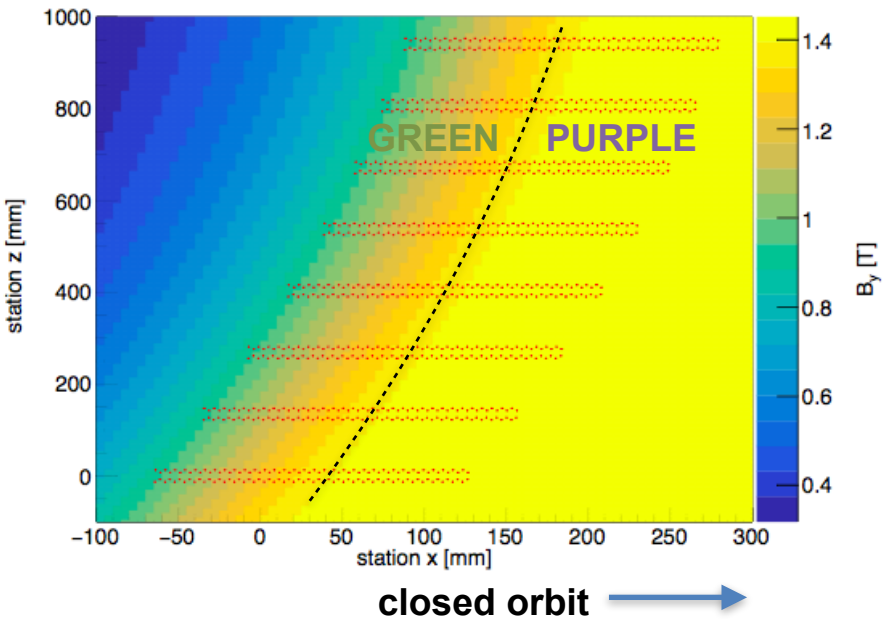


Station 18 in the ring simulation.

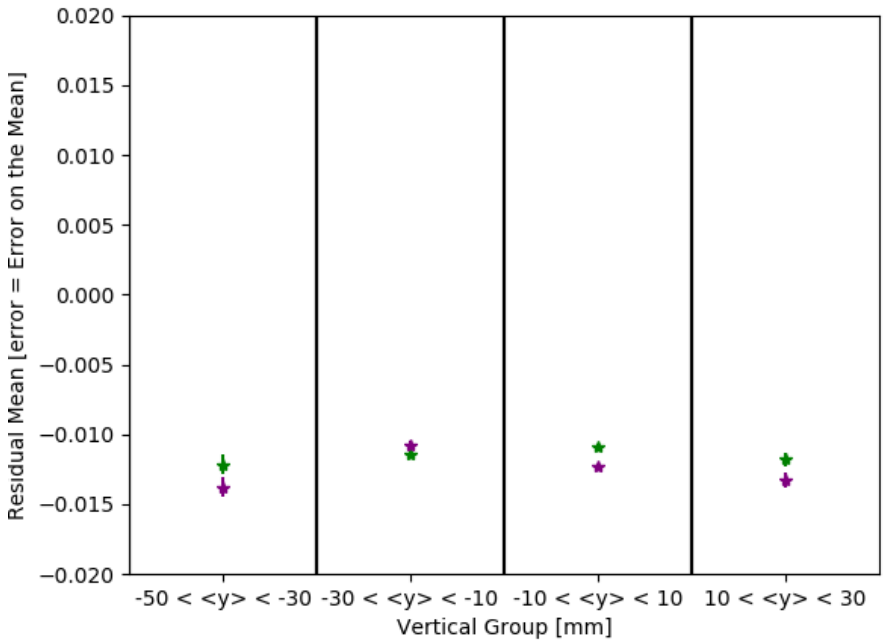


Pz/P plot for individual layers in Station 18.

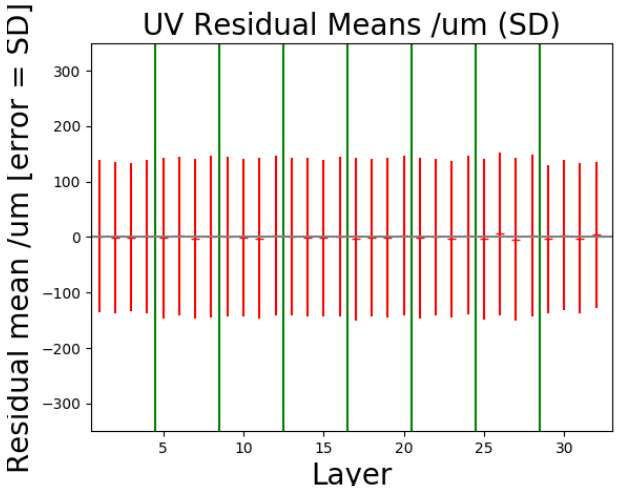
- The magnetic field has a large gradient across the tracking detectors.

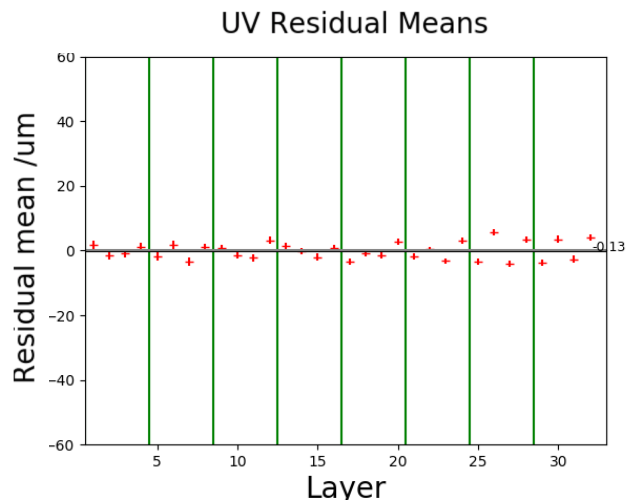


*Expected field map vertically in the middle of a station. There are two regions: (1) near uniform field (**purple**) and (2) non-uniform region (**green**).*



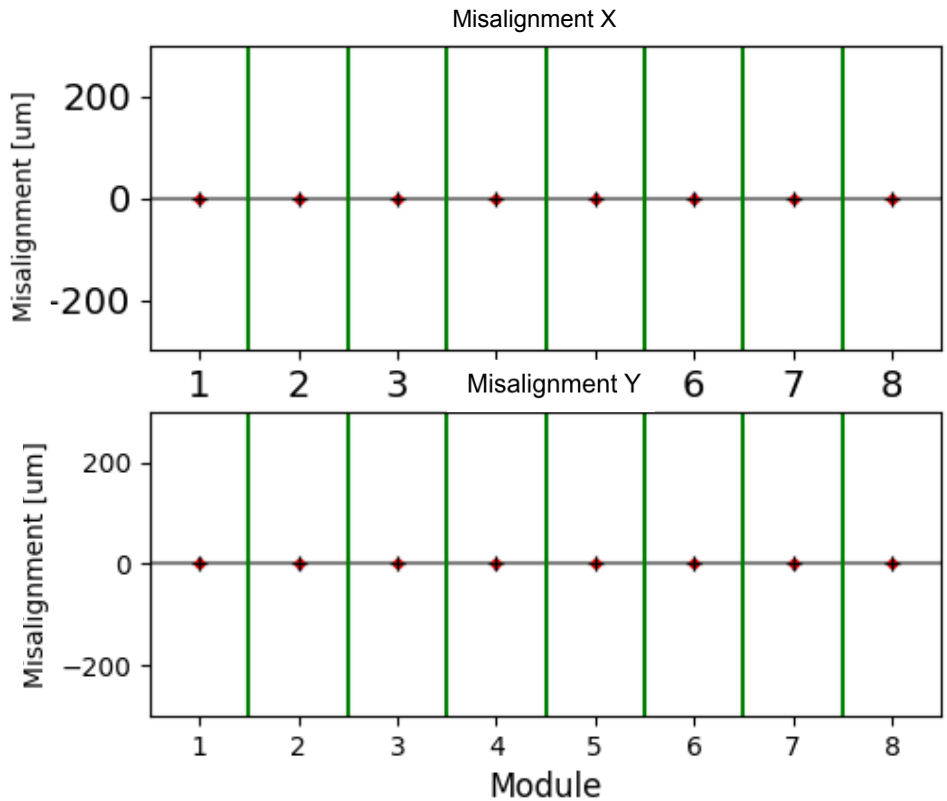
The mean value of the residuals for the two groups as a function of vertical position.



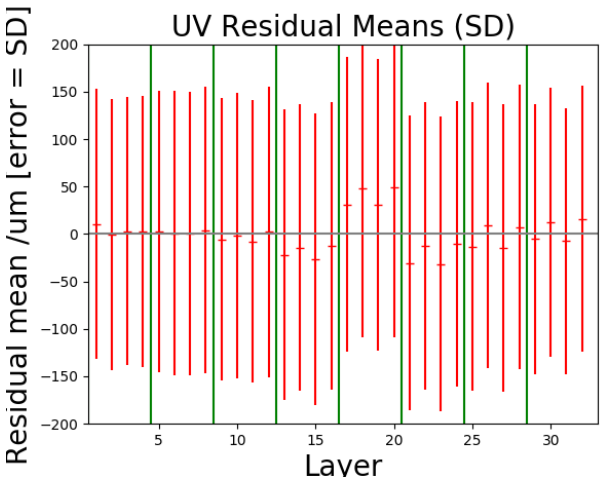


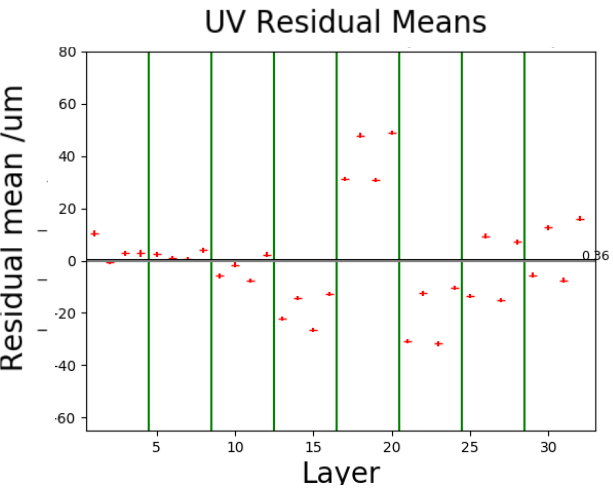
The mean of residuals per layer is consistent with zero with no misalignment.

- *Testing alignment framework with no input misalignment.*



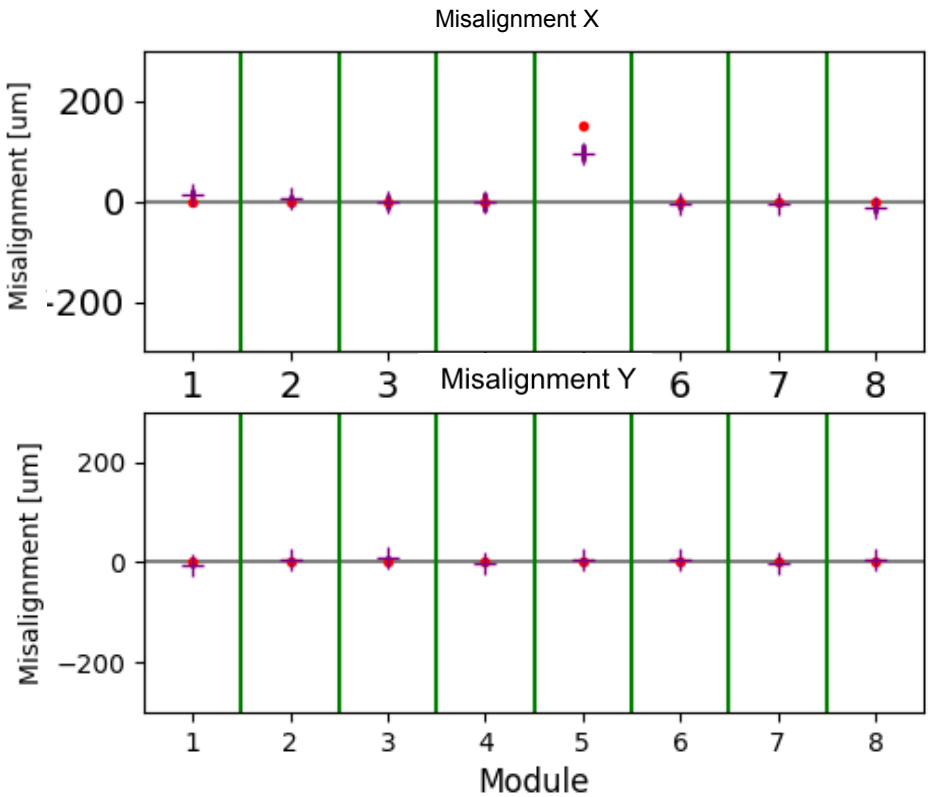
*Truth misalignment (**red**) and Millipede II prediction (**purple**). Millipede correctly handles the case of no misalignment.*





In this scenario, the truth misalignment of Module 5 was +150 µm radially (X).

- *Testing alignment framework with single module misaligned.*



*Truth misalignment (**red**) and Millipede II prediction (**purple**). Whether the difference (30 µm) between truth and predicted misalignment can be improved is under investigation.*

Summary and Next Steps

- Tracker alignment has been successfully demonstrated in MC with a uniform magnetic field with an accuracy better than 30um.
- The tests performed so far in the main ring simulation have performed well.
- Currently looking at moving all modules in multiple directions.
- The alignment parameters will be stored in the database and checked on a regular basis.
- The alignment will improve the beam profile and track reconstruction.