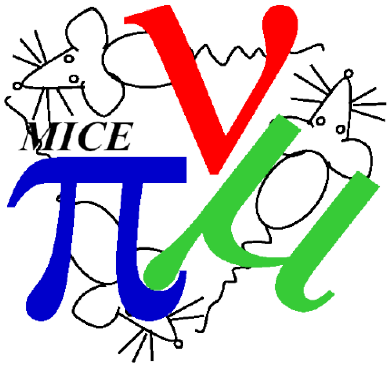
Validating Magnets Using Beam



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Validating Magnets Using Beam

- How do we validate the magnets are performing as expected?
  - Beam is the final arbiter
- Classes of errors
  - Alignment between modules
  - Alignment within a module
  - Model of each coil (number of turns, current, etc)
  - Iron shielding model
    - Hysteresis effects
  - Anything else?
- Coil model and alignment within a module -> field mapping
  - We should try to make a cross-check
- Focus here is alignment between modules
  - Will need to think about the other things
- Assume trackers have been aligned to each other but not to the solenoids
  - Thank you, alignment fairies!

Measuring Module Alignment

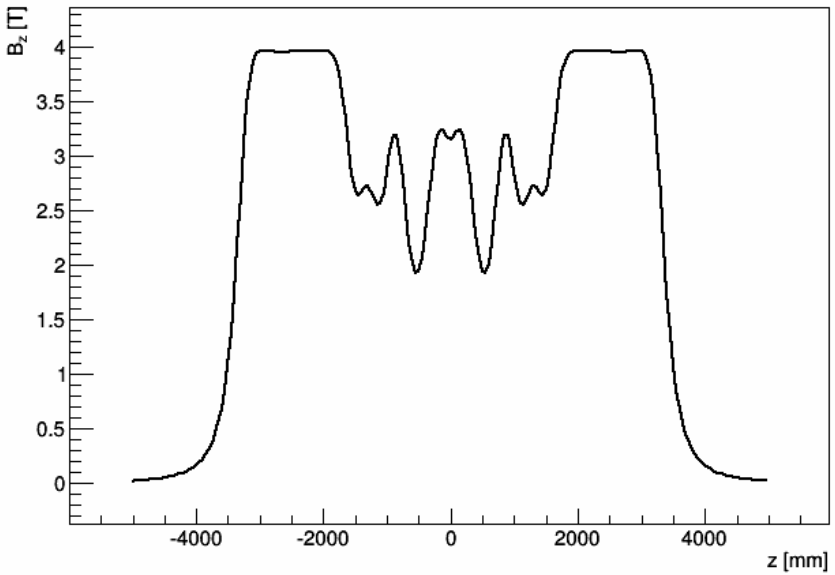
- How do we measure/check that we aligned the modules properly?
  - Standard problem in accelerators
- “Beam based alignment” - standard accelerator technique
  - Vary the current in selected coils
  - Measure beam position upstream and downstream of a magnet
  - Watch the beam wander
  - Deduce the misalignment
- We have fantastic diagnostics, but:
  - While we are doing an alignment, may be prudent not to use momentum information
  - Big intrinsic momentum spread makes the measurement difficult
  - Reduce using a time cut in the TOF, consider only central pixels
- We have 5 position measurement planes U/S and D/S
- We have single particle measurements
- Assume alignment is independent of coil currents

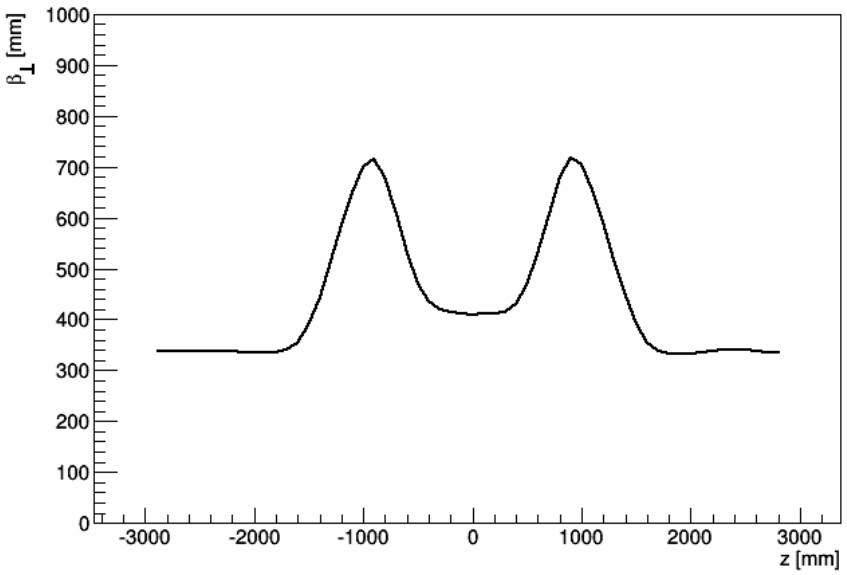
Observables

- Misalignment comes in a variety of forms
  - Tilt looks like a dipole field in the magnet body => pt kick
  - Offset looks like a dipole field in the magnet fringe => pt kick
  - Longitudinal displacement moves the focal point of the magnet
- What is our observable?
  - We can see a displacement at the tracker
  - Use upstream tracker and downstream tracker
  - Focus on position data
    - Don't want to assume momentum reconstruction

Current Settings

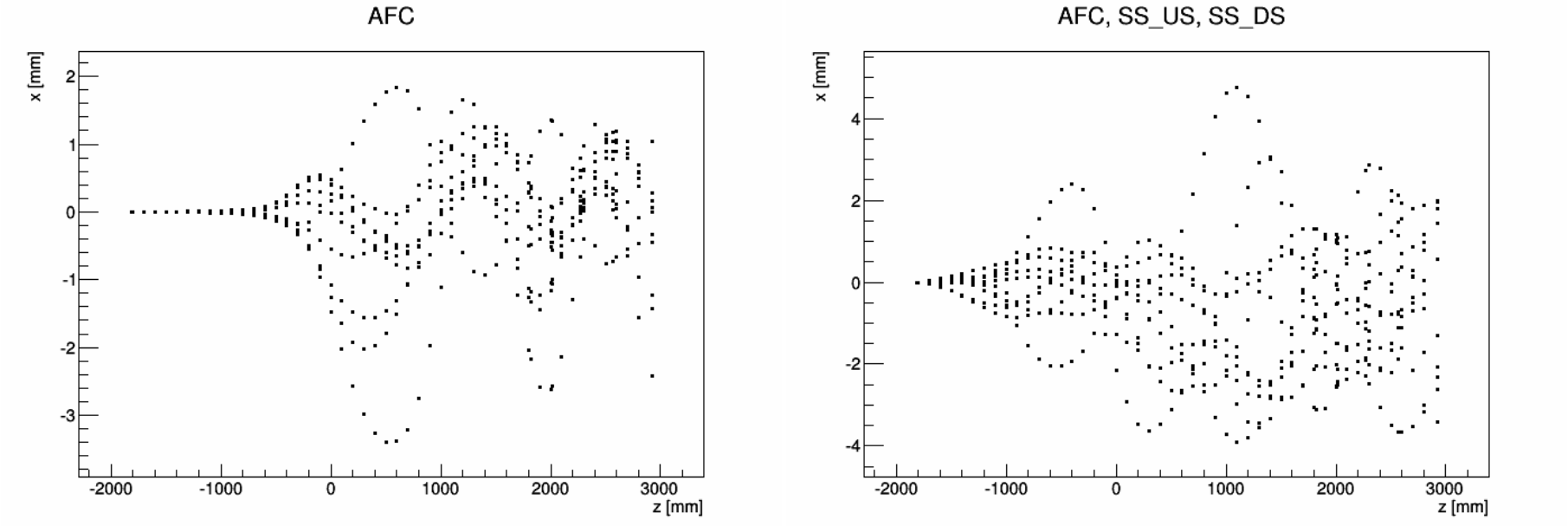
- What current settings?
  - Consider deviations from some “baseline”
  - “Baseline” should be solenoid mode
  - Choose M1: 129 A/mm2 M2: 120 A/mm2 FC: 60 A/mm2
  - Note these are Rogers solenoid mode settings (not “official”)





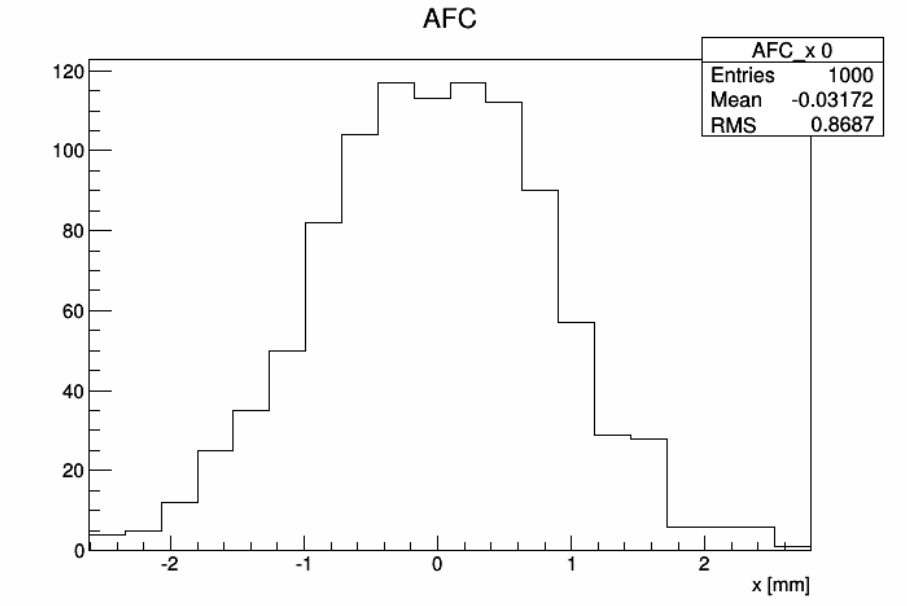
Step IV (Solenoid Mode)

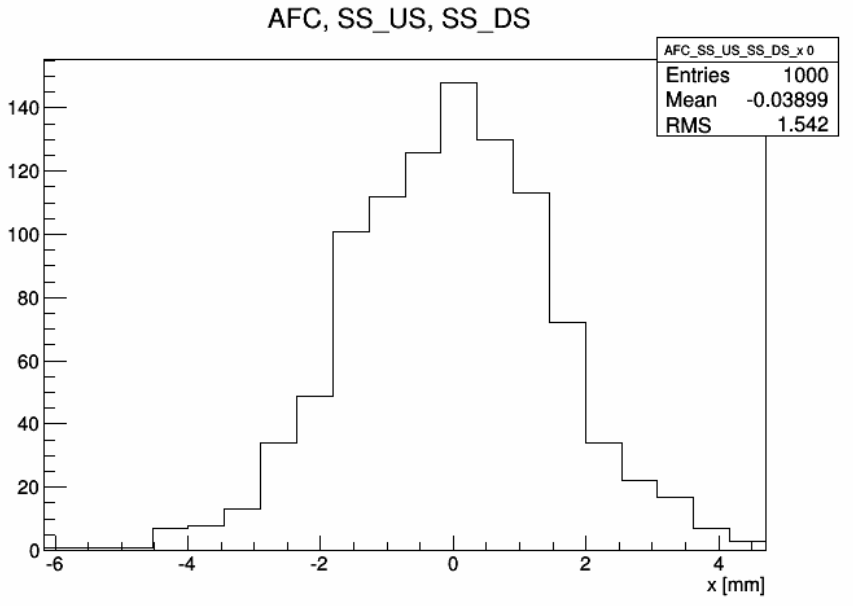
- Kick off axial particle at upstream tracker reference plane (TRP)
- Include 10 sets of random tilts/offsets on modules
  - Normally distributed
  - $\sigma(x)$, $\sigma(y)$, $\sigma(z)$ = 1 mm
  - $\sigma(\theta_x)$, $\sigma(\theta_y)$ = 1 mrad
- What is the kick that is introduced?



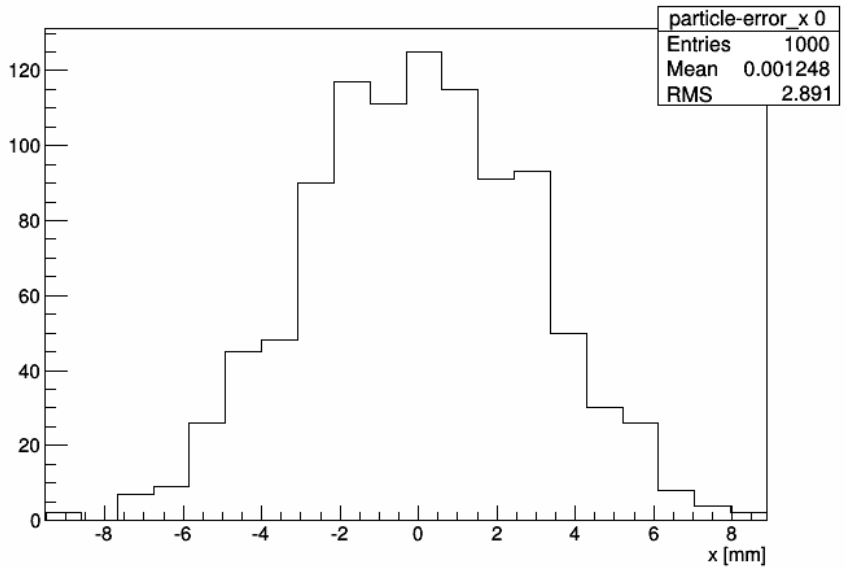
Step IV (Solenoid Mode)

- Run 1000 random tilts/offsets
- What is the displacement of axial particle at downstream TRP?
  - ~ mm, i.e. small but readily measurable



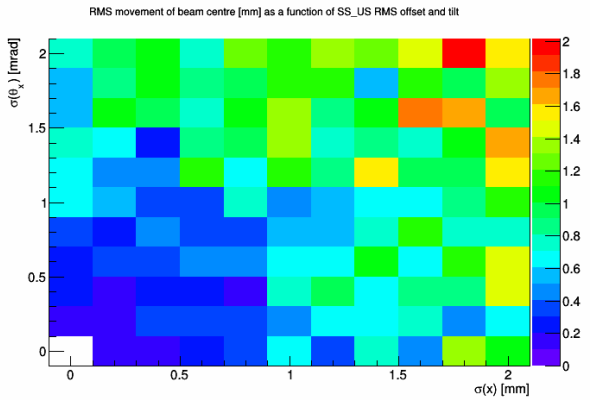


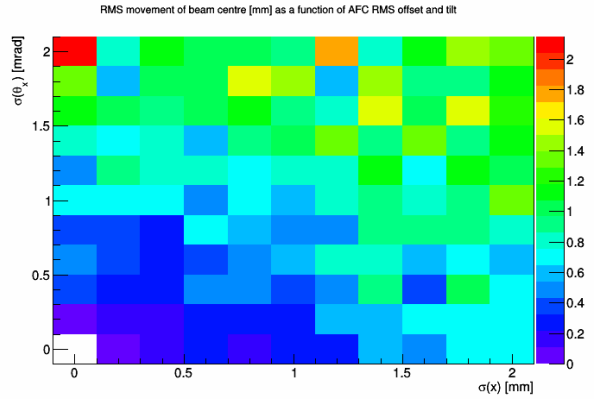
Step IV (Solenoid Mode)

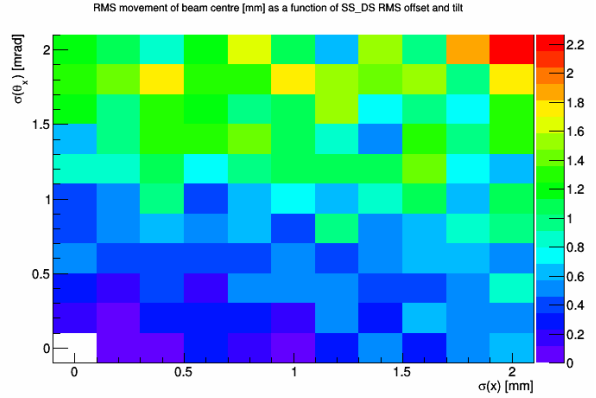


- What about including some measurement error?
- Assume knowledge of particle angular deviation ~ 10 mrad
- Assume knowledge of particle position ~ 0.5 mm
- Gives typical position spread at downstream TRP ~ 3 mm
  - Measurement of angular deviation at US TRP probably dominates the measurement
  - What about pz measurement?
- Nb: there are few windows which are not taken into account here
- Nb: things like hysteresis may introduce a systematic error

Step IV (Solenoid Mode)



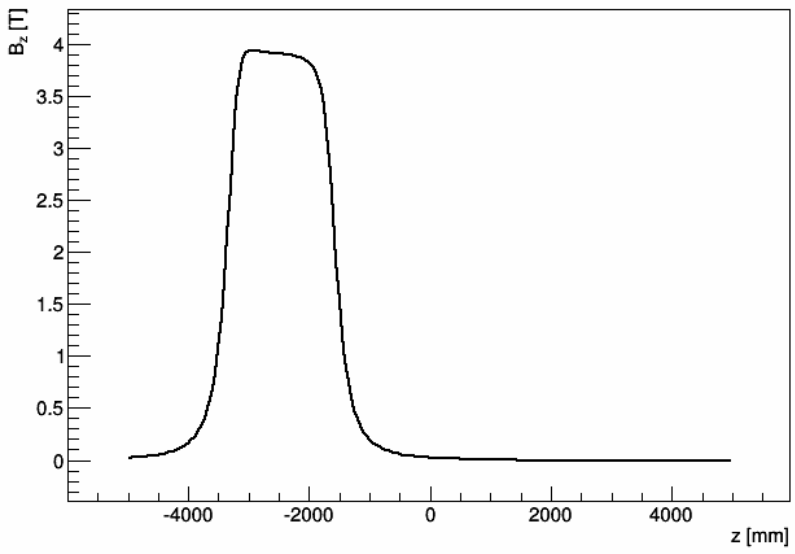


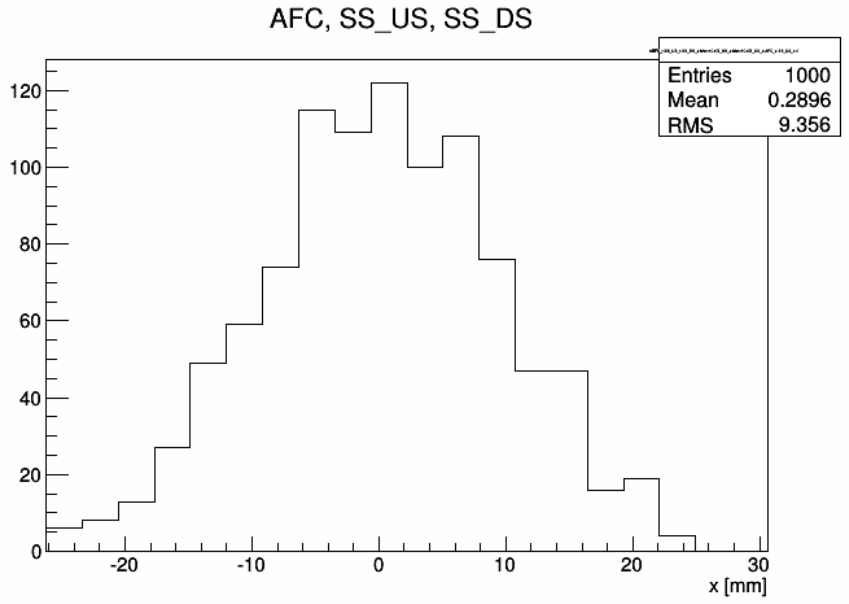


- Move a module
  - Align everything else perfectly
- What is the dependence of downstream position of an axial particle on tilt, offset?
  - Sample size is only 10 axial mu per grid point
- Note that we have a more symmetric situation if we measure angle downstream as well
  - Not yet considered that

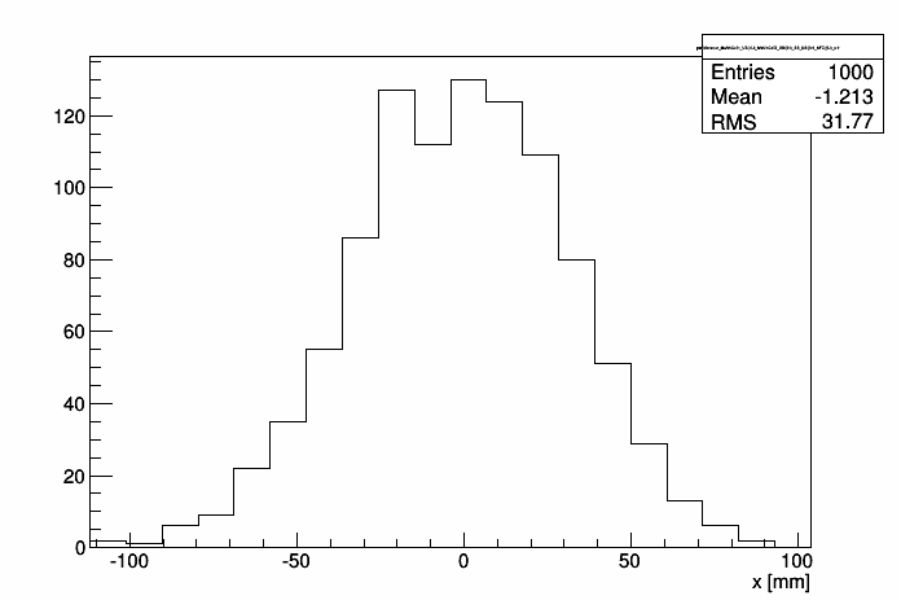
Step IV (SS_US alignment)

- Consider powering only one magnet
  - e.g. switch off AFC, SS_DS, M1_US, M2_US
  - Isolate alignment of a single magnet
  - Non-linear effects from iron, etc may look different
- Now offset at downstream TRP looks more like ~9 mm



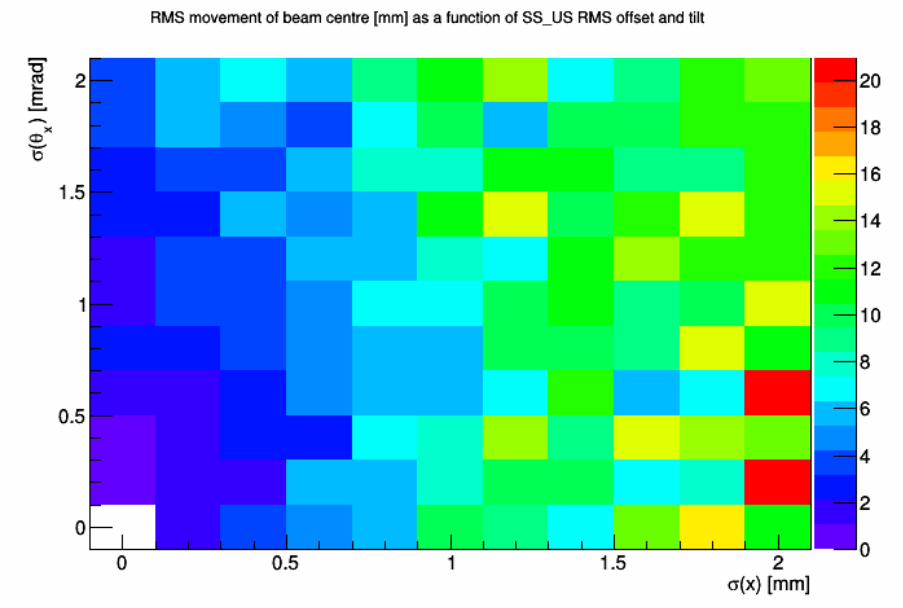


Step IV (SS_US alignment)



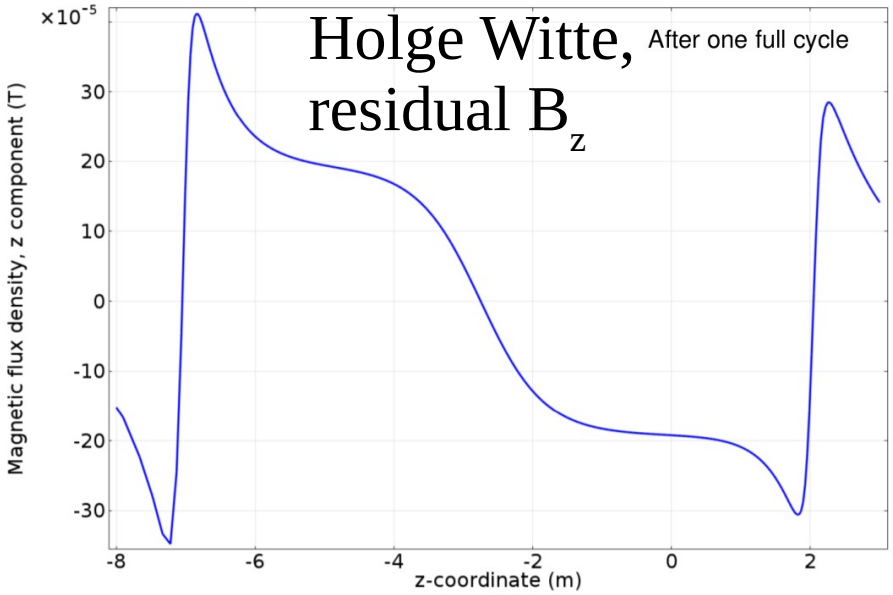
- But measurement error at upstream introduces a bigger spread in downstream positions
  - We are more sensitive to measurement error at upstream

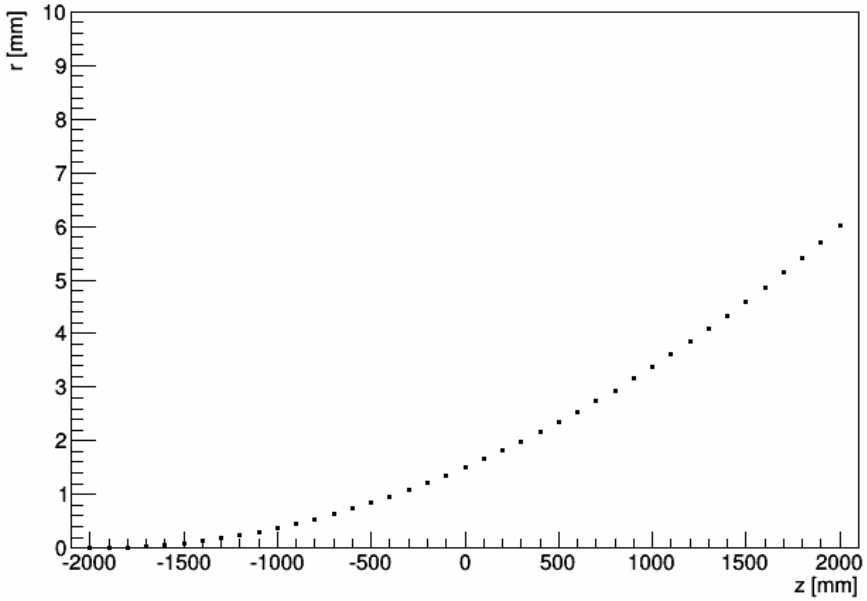
Step IV (SS_US alignment)



- Sensitive to transverse offsets
- Less sensitive to tilts

Iron Stuff

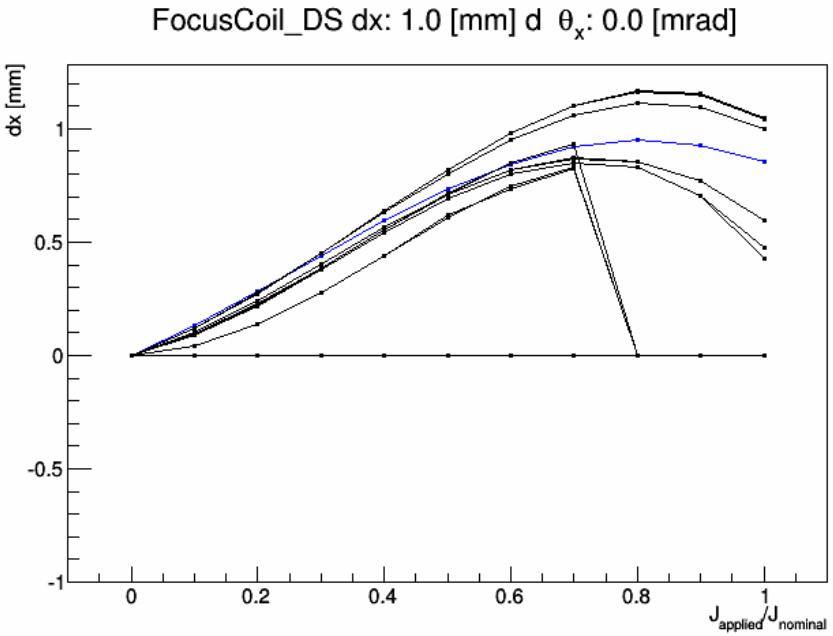


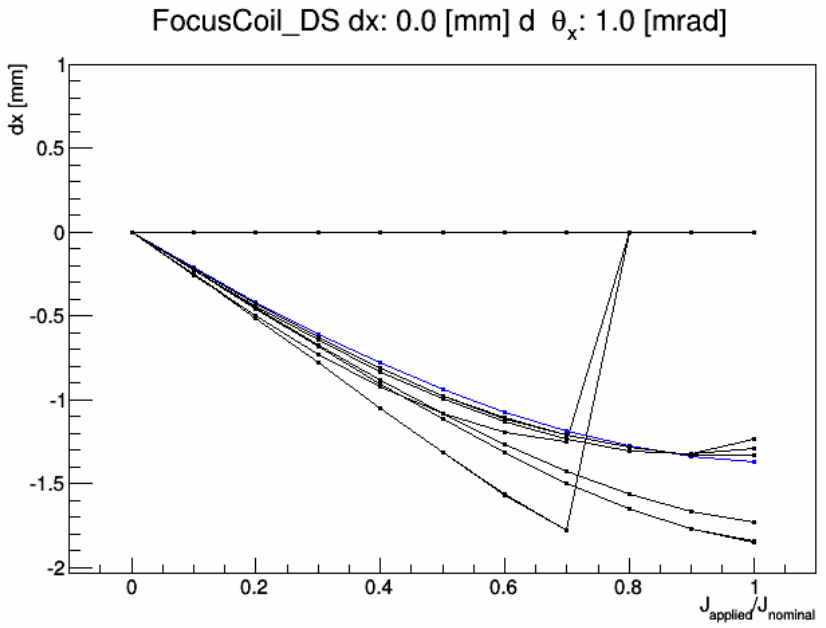


- Effect of 5e-4 transverse field gives ~ 5-6 mm transverse kick to the beam
  - Supported by back of envelope calculation
- Obviously a worst case
  - Guess too high estimate of transverse kick by factor 5

Scaling currents

- What current settings?
  - Consider deviations from the baseline settings
  - Scale FC down
  - Look at movement of beam centre





Thinking about algorithms

- What is the algorithm we use?
- Multiparameter minimisation
  - Fix currents, apply minimisation
    - Minimise chi2 of upstream tracker propagated to downstream tracker
  - 3 modules * 5 parameters = 15 parameter fit
  - Many data points, it may work
- Single magnet powered
  - Power one magnet, apply minimisation
  - 5 parameter fit, many data points, it should work
  - But effects due to non-linearities may dominate
- Scale magnet power
  - Move current on one magnet up and down, look at movement of beam centre
    - Should be possible to use individual tracks, but I haven't thought how
  - 5 parameter fit, not many data points, it may work
  - Effects due to non-linearities may be less significant

Alignment between Modules

- What is the algorithm we use?
- Multiparameter minimisation
  - Fix currents, apply minimisation
    - Minimise chi2 of upstream tracker propagated to downstream tracker
  - 3 modules * 5 parameters = 15 parameter fit
  - Many data points, it may work
- Single magnet powered
  - Power one magnet, apply minimisation
  - 5 parameter fit, many data points, it should work
  - But effects due to non-linearities may dominate
    - e.g. effect of iron is likely to be different if the field is in the linear regime
- Scale magnet power
  - Move current on one magnet up and down, look at movement of beam centre
    - Should be possible to use individual tracks, but I haven't thought how
  - 5 parameter fit, not many data points, it may work
  - Effects due to non-linearities may be less significant

Effect of Iron/Non-linearities

- Open question about how we model iron
  - At the moment we need to hand current settings to Holge
  - Holge builds a field map in OPERA/whatever
- This is not really manageable
  - Need a reasonable model for mapping currents to field maps
    - E.g. Enge model, what are the parameters?
  - Need to validate that model somehow

Job List

- Analysis routine
  - Develop analysis algorithm
  - **Depends on global track fitting...**
- Batch MC
  - Set up a “typical” misalignment
  - Run settings as per previous slide
  - Attempt to recover misalignments including error
- Is that as far as we go in MC?
  - Do we want to try to model large misalignments?
  - Do we want to try to model hysteresis/non-linearity?
  - Do we want to try to do an uber-statistics to get the errors?
  - Probably won't have time
- Data taking starts October...