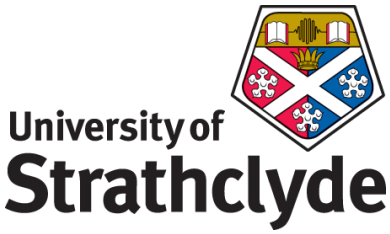

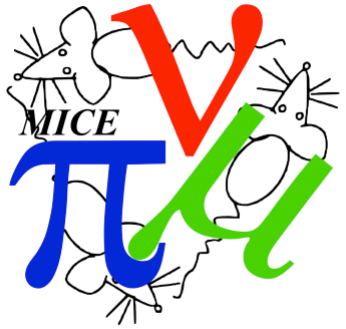

Step V Simulations and Beyond

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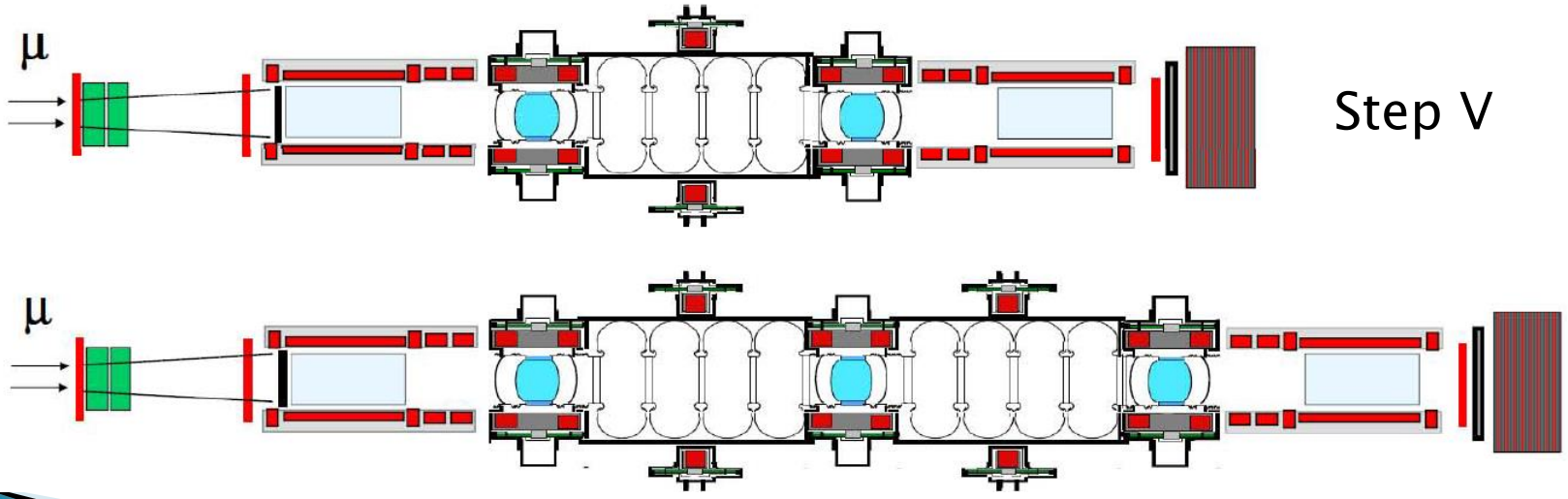
CM39

June 26th, 2014

Background

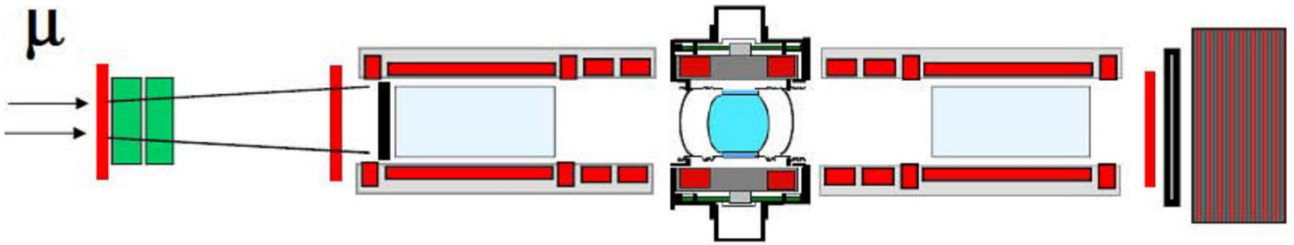
- In 2014, initially working with the MICE Analysis group in considering the Step V vs Step VI question.
- This question has now effectively been answered by the RLSR and MPB outcome, with a decision to terminate on Step V.
- This decision does not drastically impact however on our initially proposed suite of comparative Step V / Step VI MAUS simulations
  - Modelling of the complete cooling cell (Step VI) and extrapolating Step VI performance from Step V data may now be even more critical.



Step IV -> Step V: Objectives

Step IV

- First “true” demonstration of ionisation cooling.
- Can evaluate momentum selection and transport of particles through lattice.
- Can undertake beamline alignment studies and perform necessary detector calibrations.
- Emittance generation and beam matching through the diffuser can be evaluated.
- Muon timing studies and spill structure diagnosis can be performed (critical for correlated RF phase / muon TOA diagnostic development).
- Canonical angular momentum studies can be performed (flip / solenoid mode with <u>one</u> set of focus coils).
- Equilibrium emittance may be determined for different absorber media.

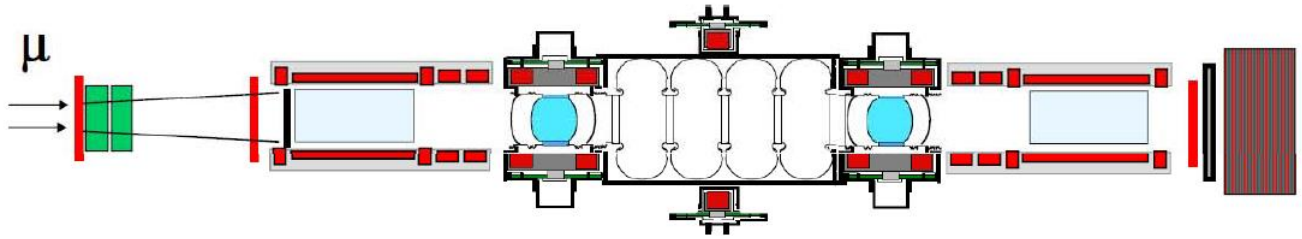


Step IV

Step IV -> Step V: Objectives

Step V

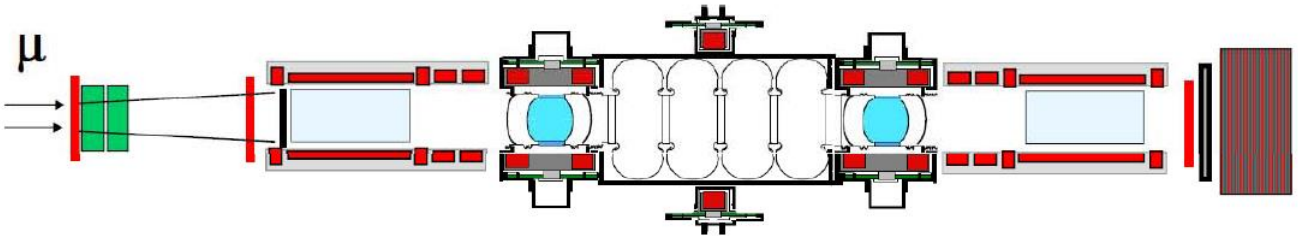
- First demonstration of emittance reduction (transverse cooling) with reacceleration -> measurement of first RF cavity phase wrt particle transit time index critical.
- Demonstration of canonical angular momentum control via flip / solenoid mode for two sets of focus coils with intermediate RF cavities.
- Operation of RF cavities in a magnetic field (really an experimental evaluation / test)
- Evaluate efficiency of axial momentum restoration in RF cavities and overall transport efficiency of extended Step V lattice.



Step V

Step V: Disadvantages over Step VI

- The loss of one absorber and RF cavity set -> cannot demonstrate >10% cooling initially proposed, although base principles of ionisation cooling with reacceleration can be demonstrated.
- A complete cooling “cell” has not been built / demonstrated… but all subcomponents have!
- No direct comparative test of predictive capabilities of MAUS against Step VI lattice… however, extensive Step V simulation benchmarking with experiment should (hopefully) permit extrapolation of Step VI performance with reasonable accuracy.



Step V

Key issues for investigation

- Measurement of particle TOA relative to phase of cavity RF field -> this is critical.
  - Currently, determination of RF phase via undersampling-based signal reconstruction in development at Strathclyde (Alex / Kevin).
  - Need to identify (and quantify) any uncertainties in TOF based (absolute) time index for particle arrival at first RF cavity.

- RF cavities - must consider the impact of cavity misalignment on the operation of Step V.

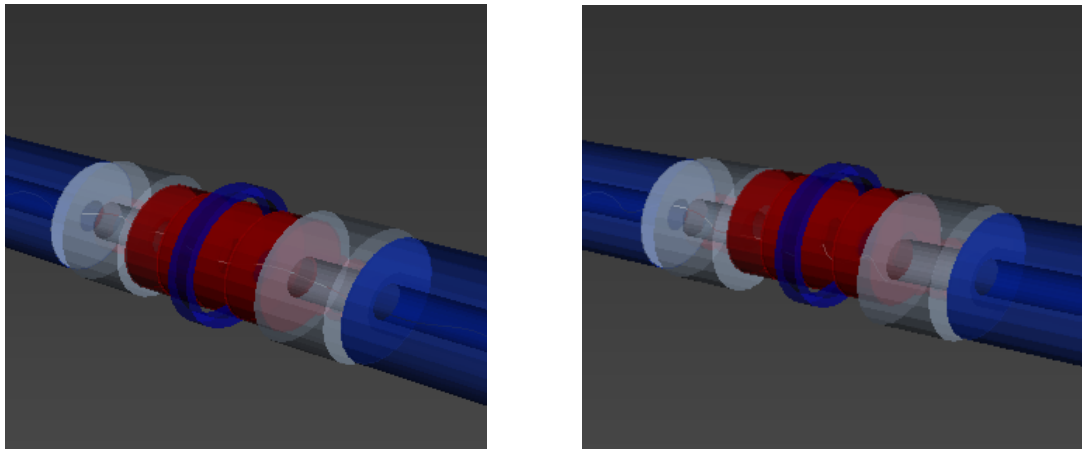
- Tracker reconstruction errors? – must determine (using MAUS) the temporal accuracy of predicted particle TOA at RFCC#1 / first cavity. Determine reconstruction induced spread and assess impact on Step V.

- Must determine the precision with which the Step VI emittance reduction may be extrapolated / predicted from Step V experiments using software.

RF Cavity misalignment in MAUS

Proposed analysis

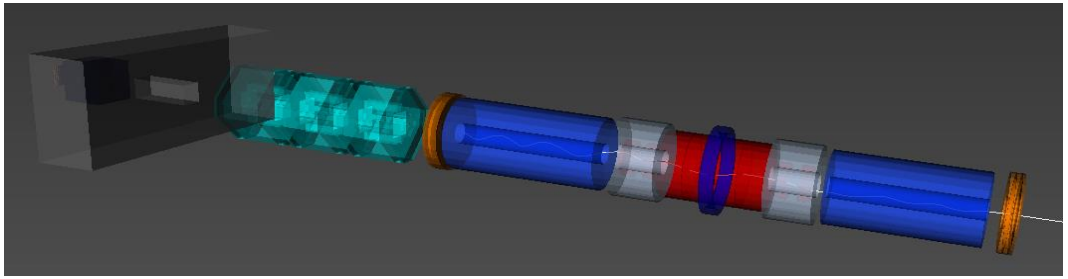
- Consider sources / locations of misalignment and propagation / impact of misalignment through associated mounting structures.
- Conduct iterative magnitude analysis for discrete misalignments (and combinational misalignments) within MAUS.
- Perform this analysis for multiple operational modes of interest under Step V.

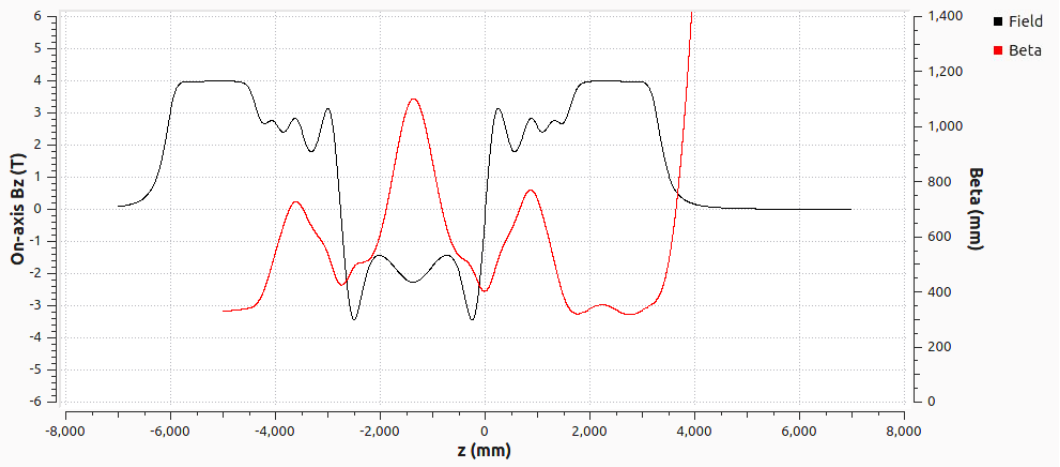


"Slight" exaggeration of a radial translational misalignment in MAUS.

Plan for initial suite of MAUS simulations (in progress)

Step V



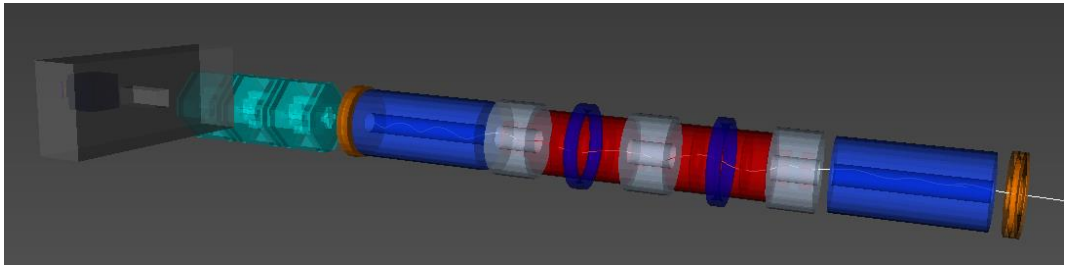


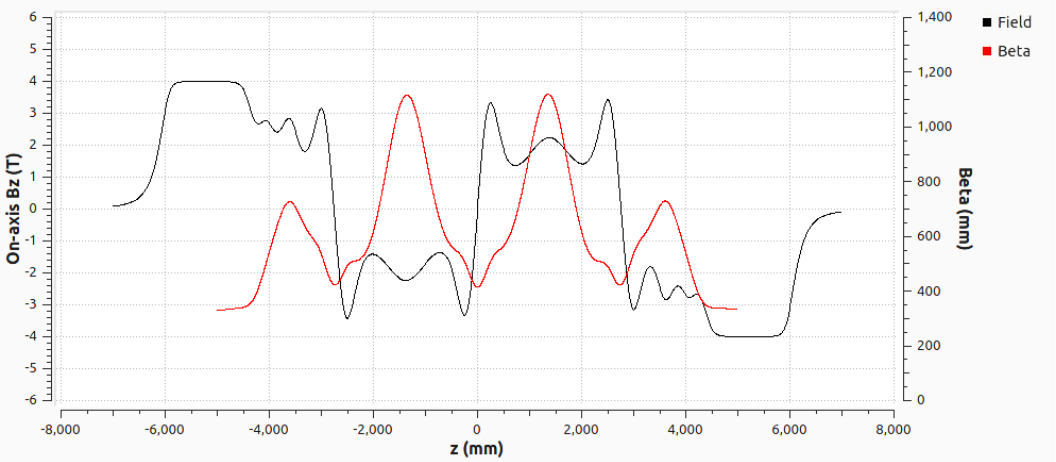
Plot of on-axis B_z and corresponding β for typical flip-mode coil parameters (6mm.rad, 200MeV/c beam) generated using code provided by V. Blackmore

- Simulate a perfect baseline MICE Step V experiment using Monte Carlo tracks.

Plan for initial suite of MAUS simulations (in progress)

Step VI



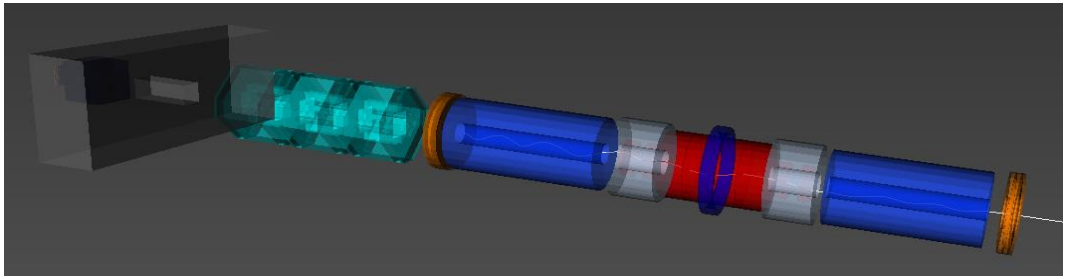


Plot of on-axis B_z and corresponding β for typical flip-mode coil parameters (6mm.rad, 200MeV/c beam) generated using code provided by V. Blackmore

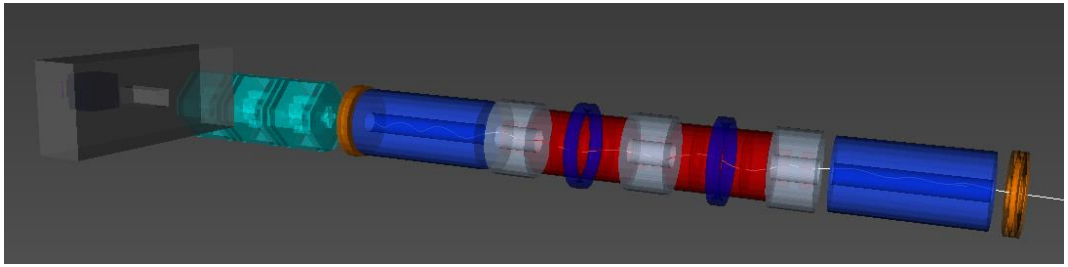
- Simulate a perfect baseline MICE Step V experiment using Monte Carlo tracks.
- Simulate a perfect baseline MICE Step VI experiment using Monte Carlo tracks.
- **Compare emittance reduction between the two cases.**

Plan for initial suite of MAUS simulations (in progress)

Step V



Step VI



- Simulate a perfect baseline MICE Step V experiment using Monte Carlo tracks.
- Simulate a perfect baseline MICE Step VI experiment using Monte Carlo tracks.
- **Compare emittance reduction between the two cases.**
- Simulate perfect baseline MICE Step V and VI experiments using reconstructed tracks.
- **Compare emittance reduction between steps V and VI reconstructed.**
- **Compare MC truth with reconstructed emittance reduction predictions for steps V and VI.**
- Simulate alternative operating modes for steps V using both Monte Carlo and reconstructed particle tracks.

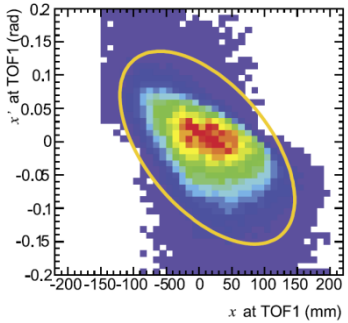
The overall objective of this analysis is to determine (for a range of Step V operating modes) the useful analyses that may be conducted, sensitivity of each mode to various spurious effects and for the step VI operational modes, the precision with which the cooling performance may be predicted from Step V data using software

Critical : Must now incorporate reduced limiting flip-mode FC current of 160A into simulated lattice configurations

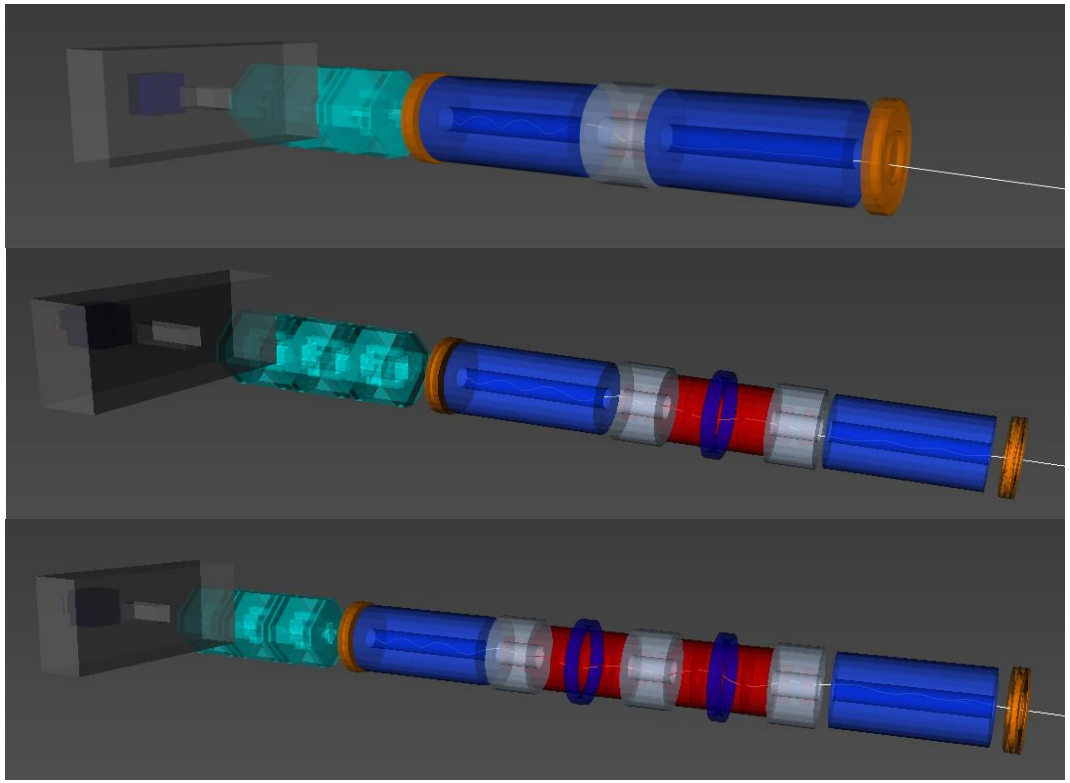
MAUS simulations with Step I measured beam parameters

Proposed analysis

- Simulate individual muons from the Step I measured / reconstructed beam ellipse (M. Rayner/V. Blackmore) through the Step IV, V and VI cooling channels.



Experimental reconstructed x,x' and y,y' trace space distributions at TOF1.

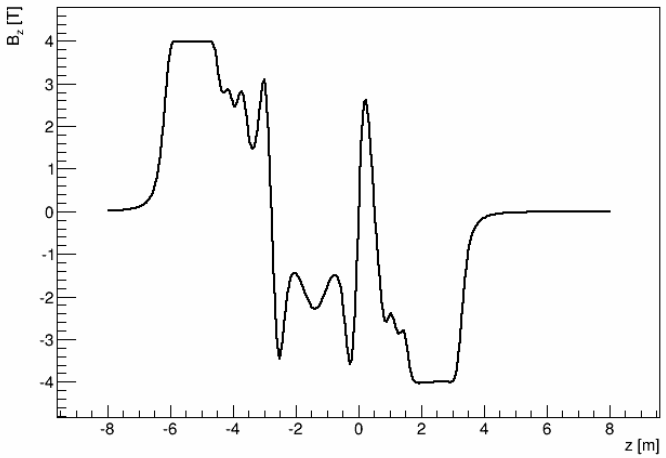


MAUS Simulation progress so far…

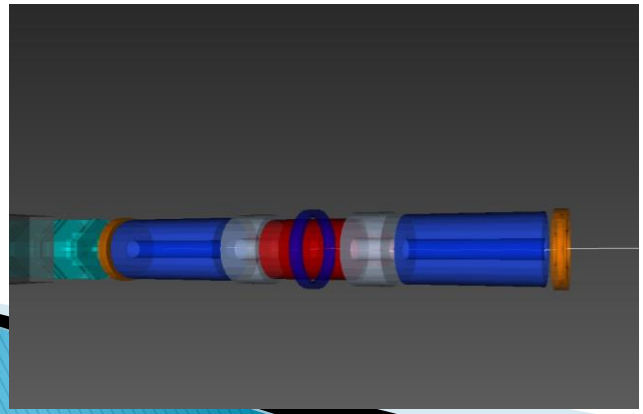
- Baseline step V simulation – results available!
- Baseline step VI simulation – results available!
- Baseline step V simulation with reduced FC current – in progress.
- Baseline step VI simulation with reduced FC current – in progress.

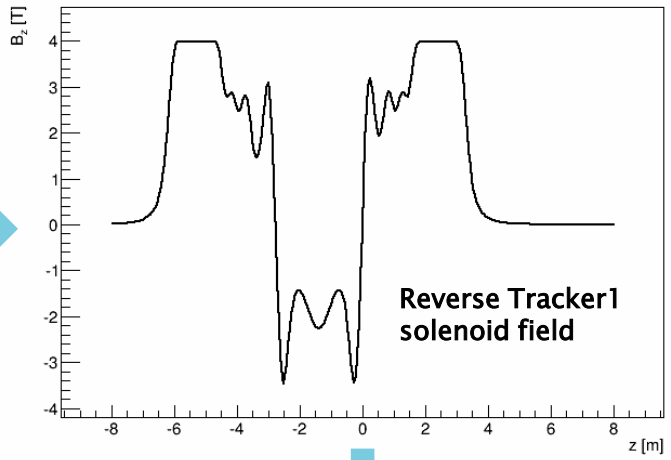
MAUS Simulation progress so far…

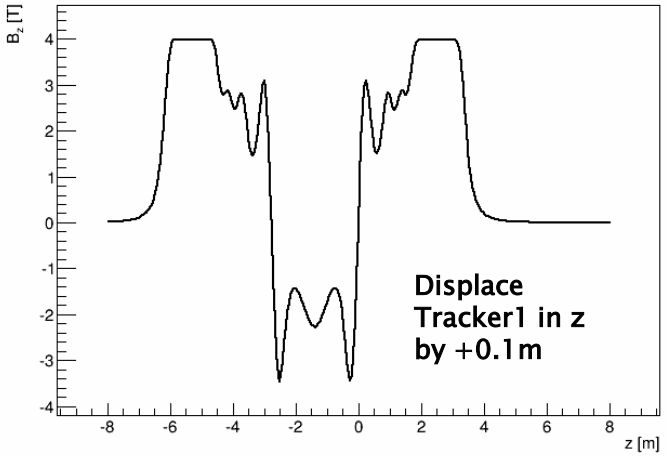
Step V simulations



Default Step V magnetic field configuration in legacy geometry.

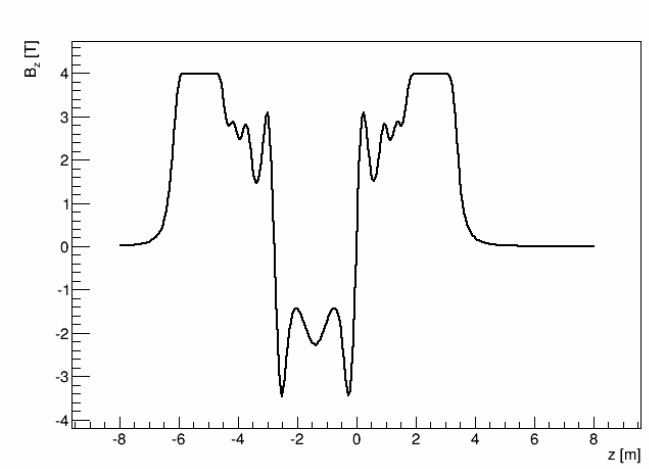


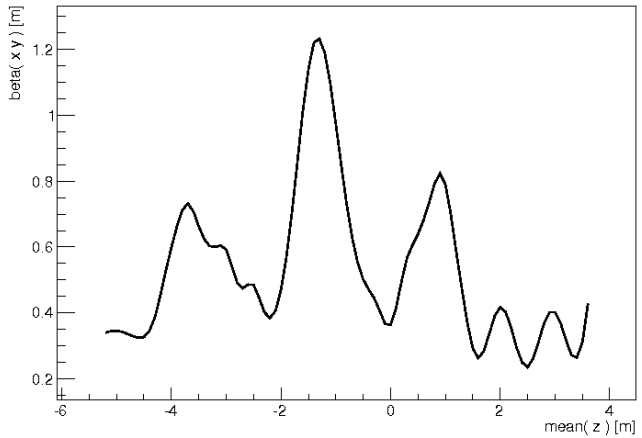


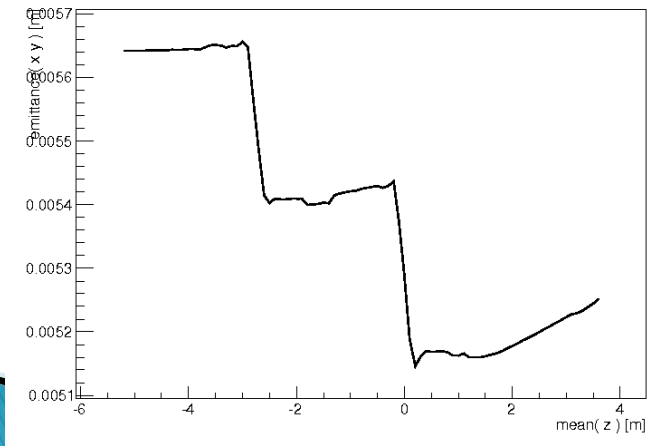


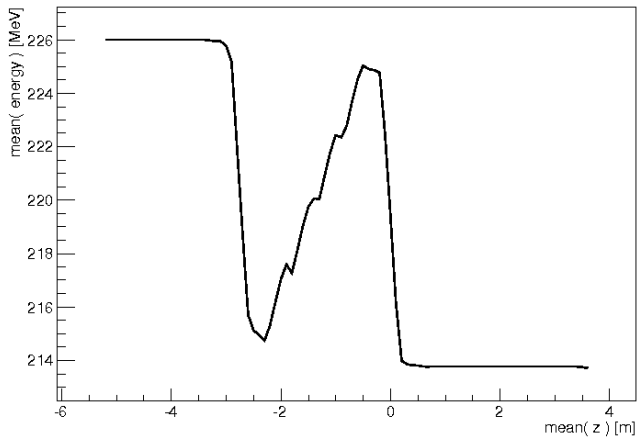
MAUS Simulation progress so far…

Step V simulations* (very preliminary results…)





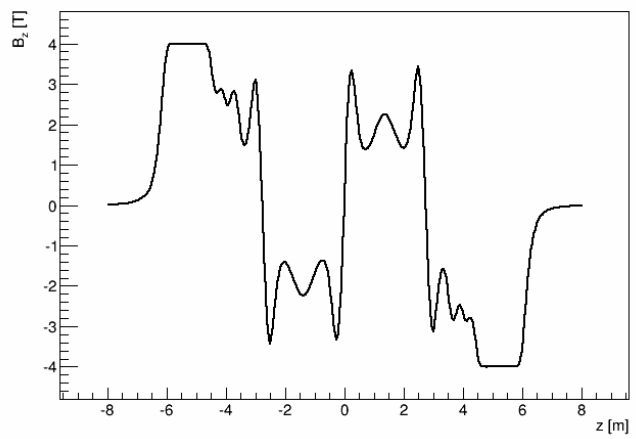


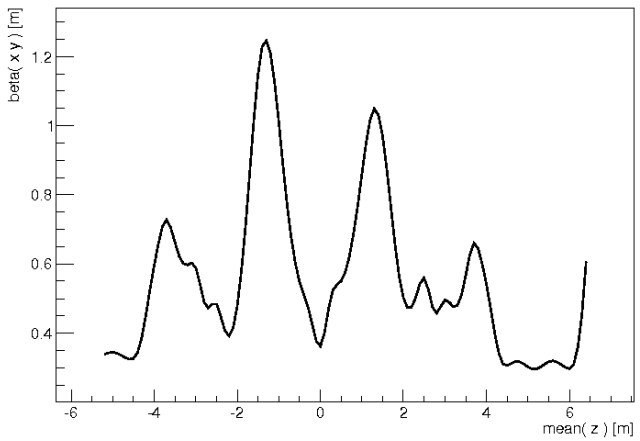


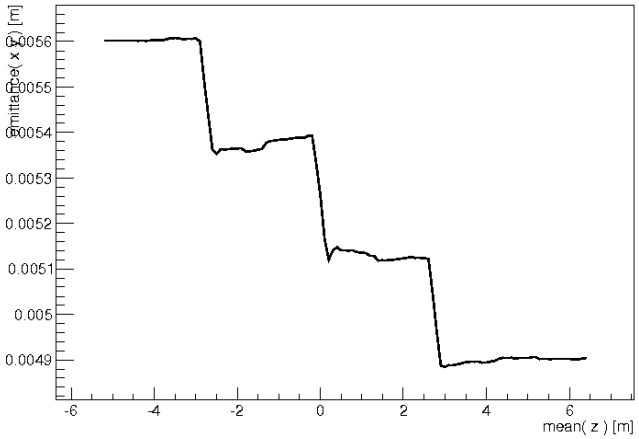
*(6mm.rad, 226MeV/c)

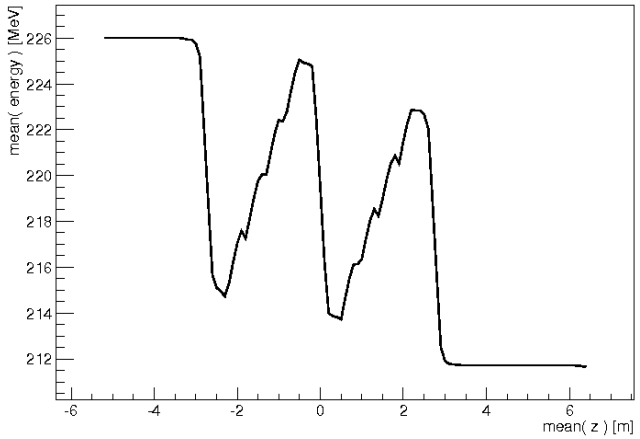
MAUS Simulation progress so far…

Step VI simulations* (very preliminary results…)









*(6mm.rad, 226MeV/c)

Simulation plan for Step V and beyond – Summary

- We still have a lot of work to do here (including analysis and simulation based on the Step IV results, extrapolating to Step V).
- I welcome any and all suggestions of how we should proceed with this and factors we should consider (email: david.c.speirs@strath.ac.uk).