Criteria and simulation plan for Step V and VI assessment

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MICE VC

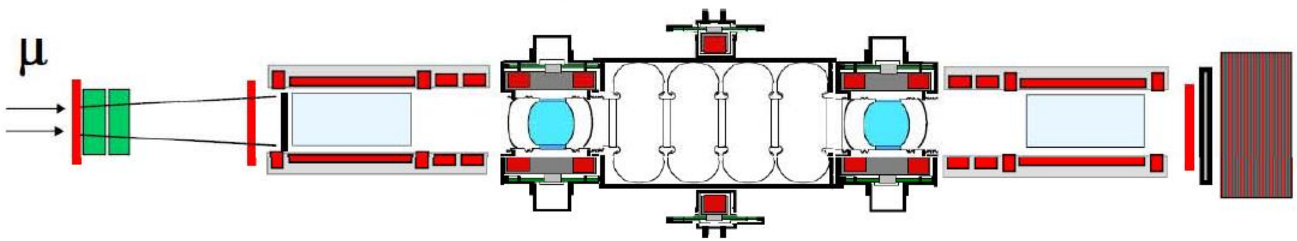
April 10th, 2014

Background

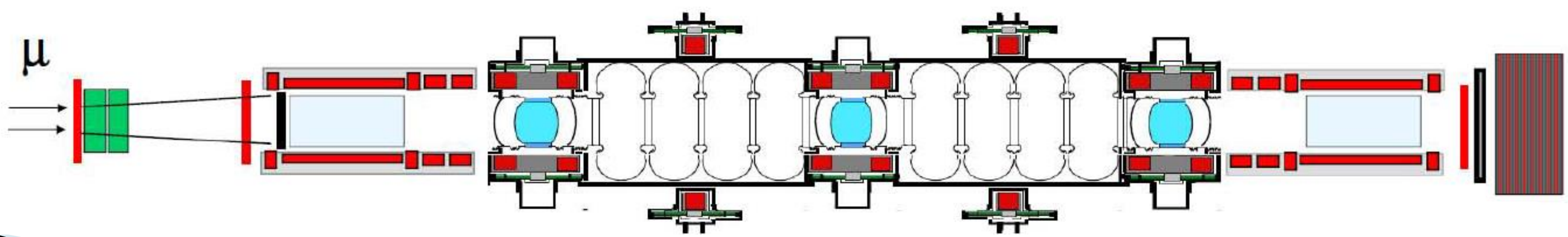
- I currently work in the Atoms, Beams and Plasmas group at the University of Strathclyde in Glasgow.
- The ABP group is already engaged with the RF system development on MICE (Kevin Ronald, Colin Whyte, Alex Dick).
- Recently contributed in satisfying the 500kW TIARA deliverable (December 2013).
- Currently developing code for undersampling-based RF phase determination, to measure RF cavity phase relative to particle TOA (Alex / Kevin).

Background

- In 2014, now working with the MICE Analysis group in considering the Step V vs Step VI question.
- Determine appropriate rational for selection of Step V or VI in terms of the key MICE physics objectives and respective sensitivity of each stage to various factors.
- Proposed analysis to be conducted primarily using the Mice Analysis User Software (MAUS) Package.



Step V



Step VI

Structure of Presentation

Motivation of Work

- Primary rational in choosing between Step V and Step VI as a terminal operational configuration for the experiment rather than progressing between them.

Key potential issues for investigation

- Geometrical tolerances / uncertainties within the experimental apparatus and adverse physical processes occurring over the length of the lattice.
- Uncertainties in measurement / diagnostics.

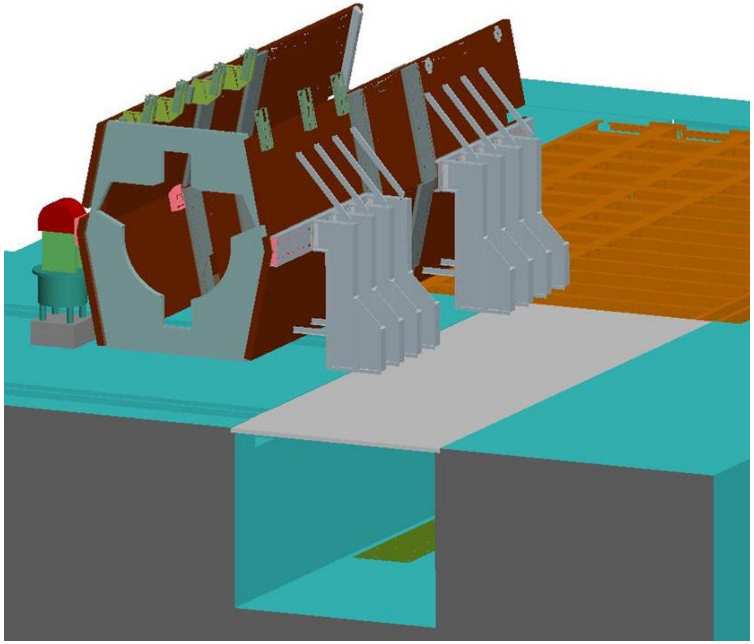
  -> Will these issues be compounded in Stage VI?

Proposed Suite of MAUS simulations to be conducted

- Simulation of perfect baseline Step V and VI simulations using MC truth.
- Simulation of perfect baseline Step V and VI simulations using reconstructed tracks.
- Introduce uncertainties in Step V and VI simulations (e.g. RF Cavity misalignment sensitivity studies.)
- Step IV, V and VI simulation and optimisation using Step I measured beam ellipse.

Step V vs Step VI – Motivation

- Inclusion of a Partial Return Yoke (PRY) in Step V/VI experimental specification – a substantial engineering undertaking.
- Significant issues arise in reconfiguring PRY between Steps V and VI.
- Delay associated with removal, extension and reinstallation of PRY is potentially longer than current projections for RFCC#2 arrival following RFCC#1.
- Refitting of PRY also a costly procedure.
- Solution? – Pick either Step V or Step VI and move straight to configuration from Step IV.
  -> Must qualify benefit of Step VI in view of additional cost and issues of practicality.



Stolen from presentation by Stephen R. Plate, Brookhaven National Laboratory, 6th November 2013

Step V vs Step VI – Motivation

- Can we sufficiently address or at least contribute significantly to the Step V vs Step VI question with an appropriate programme of numerical simulations?

- Does the physics case and principle of building and demonstrating the operation of a *complete* cooling cell (Step VI) mean we should just drive on to Step VI unwavered by any obstacles or potential delays?

- Step VI undoubtedly offers a more flexible configuration, with more modes of operation, but would it be sufficient to operate at Step V and extrapolate the Step VI results using software?

Step V vs Step VI – Motivation

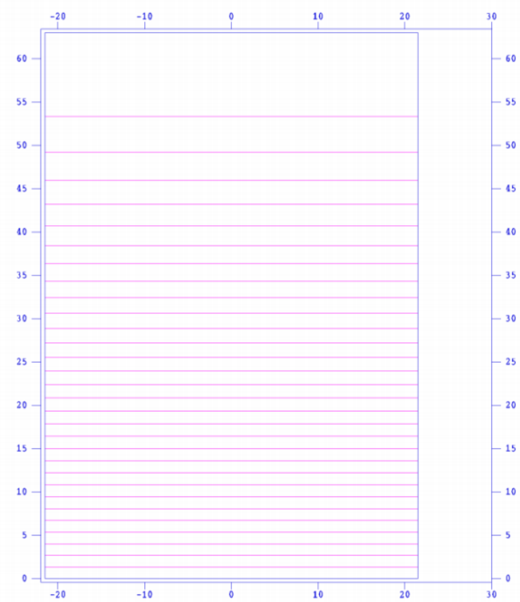
- Need to determine which stage will fundamentally deliver on the MICE objectives, and whether the inclusion of an additional set of RF cavities / tertiary absorber for Step VI are scientifically and economically warranted.
- Must assess the sensitivity of both configurations to various geometrical tolerances / limitations in alignment and positioning.
- Must identify any uncertainties in critical measurements / diagnostics and the potential impact on Step V / VI – will they be compounded and unmanageable in Step VI?
- Fundamentally, we must determine the optimum operational parameters for Step V and VI in view of results of the aforementioned analysis.

Key issues for investigation

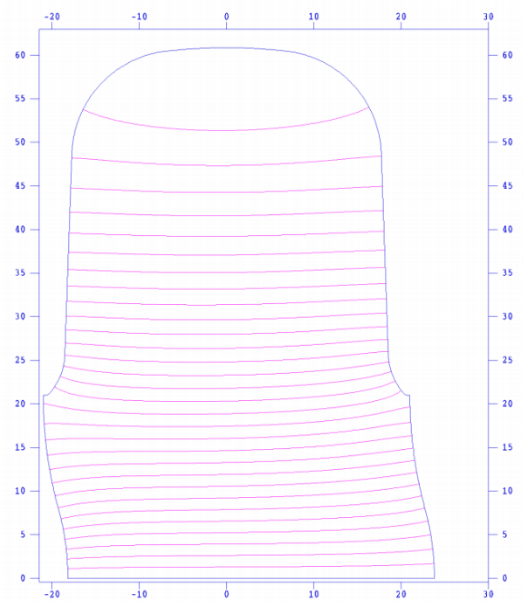
- Must determine the precision with which the Step VI emittance reduction may be extrapolated / predicted from Step V experiments using software.
- Measurement of particle TOA relative to phase of cavity RF field -> this is critical.
  - Currently, determination of RF phase via undersampling-based signal 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 Stage V / VI.
- 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 / Step VI.
- MICE hall floor loading? (Possibly answered now) – With the PRY, Step VI requires 3x the amount of iron in construction as for Step IV. Must confirm absolutely there are no issues with regard to floor loading.

RF Cavity misalignment in MAUS

- Begin with most physically accurate model of RF cavity field in MAUS.
- Two current models exist – Pillbox (analytical) and RFFieldMap (2D cylindrically symmetric imported SuperFish field map).
- RFFieldMap most accurate at present (incorporating non-parallel cavity sides).



Pillbox model



SuperFish7 derived RFFieldMap

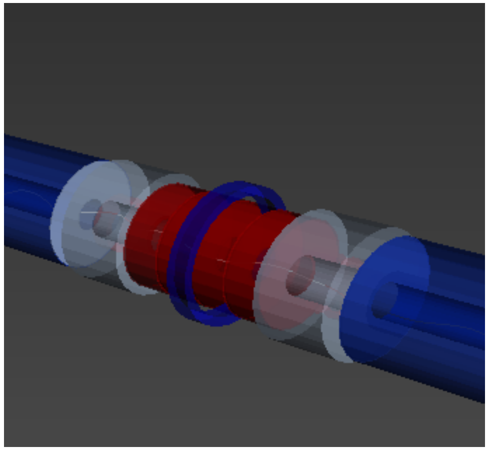
Shamelessly "borrowed" from Chris Rogers Thesis

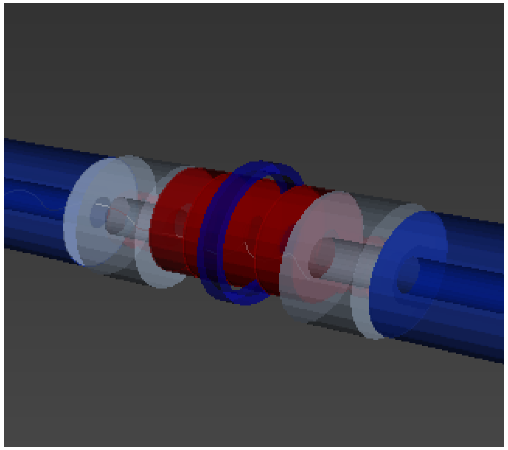
*With suitable modification to MAUS (Chris Rogers), possible to incorporate a new full 3D field map import capability – for currently proposed analysis, this seems unnecessary though…

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 / VI.



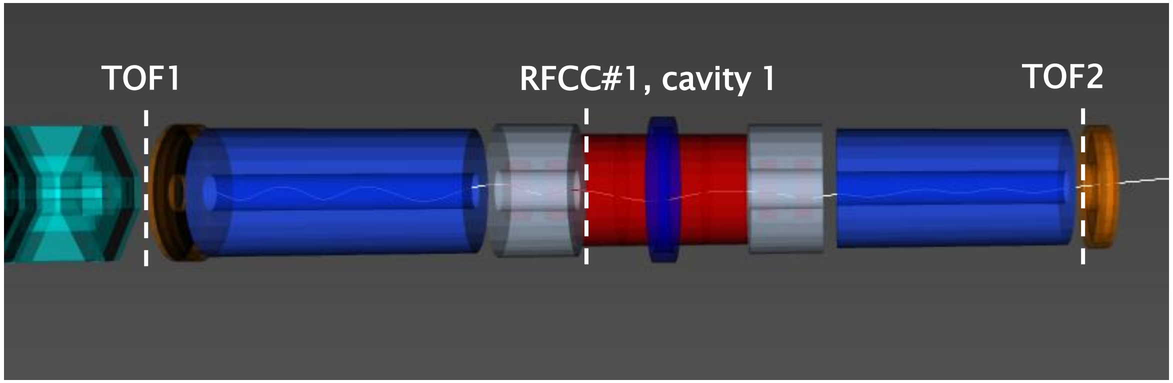


"Slight" exaggeration of a radial translational misalignment in MAUS.

Measurement of particle TOA at first RF cavity

Sources of error / uncertainty

- Although TOF detectors provide ~50ps resolution, the response time of scintillating material (TOF0 & TOF1) may introduce a fixed delay – must quantify this delay.
- Stochastic momentum loss / straggling within the absorbers may introduce an uncertainty in the muon TOA at the RF *(discussed at a previous analysis meeting – conclusion was that effect probably negligible).
- Tracker reconstruction – how accurately can a particle be predicted to arrive at the first RF Cavity?



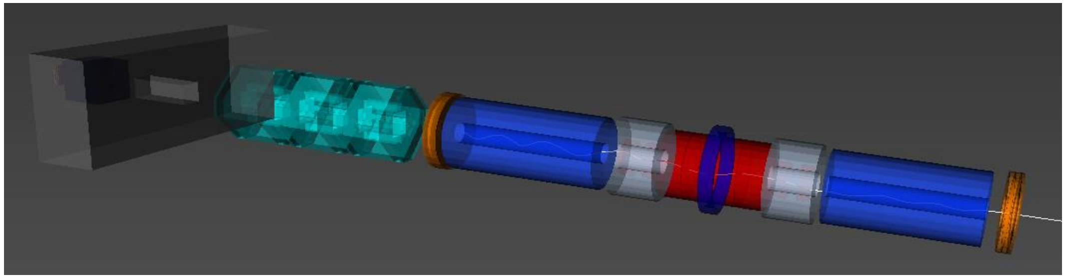
Measurement of particle TOA at first RF cavity

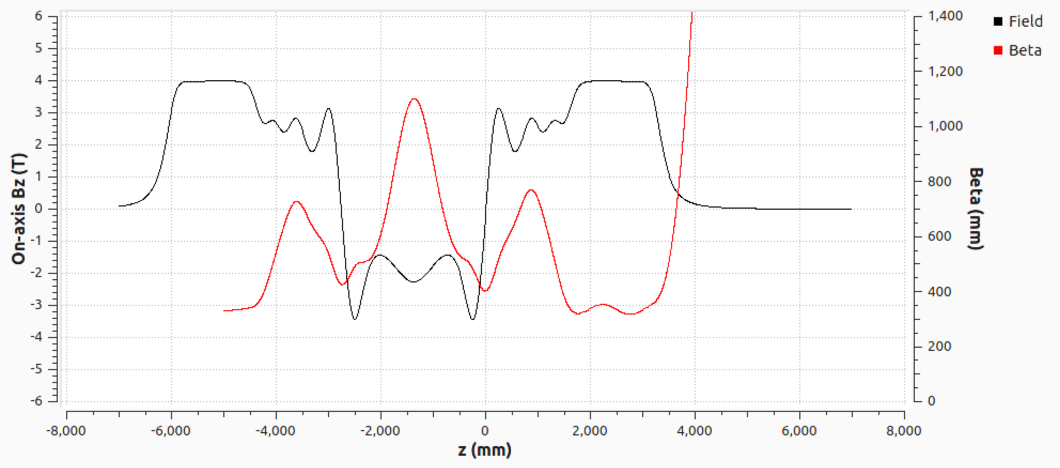
Tracker reconstruction

- Perform tracker reconstruction on Monte Carlo (MC) events in MAUS to determine accuracy of reconstruction.
- Take a muon from a simulated beam upstream of TOF1 and determine using tracker reconstruction how well its TOA can be predicted at the first RF cavity.
- Previous studies (Ed Santos) have determined that reconstruction induced spread is sufficiently low to measure muon cooling to 1%.
- MAUS incorporates the software needed to reconstruct tracks from MC.
- The code required to match up a MC real track with a reconstructed track is being integrated into the MAUS package.

Plan for initial suite of MAUS simulations (in progress)

Step V



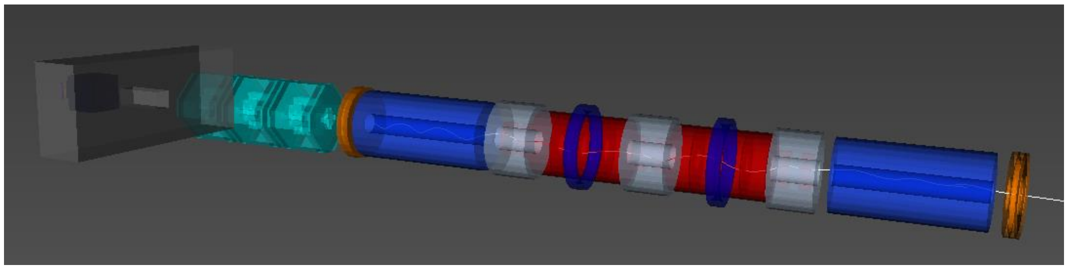


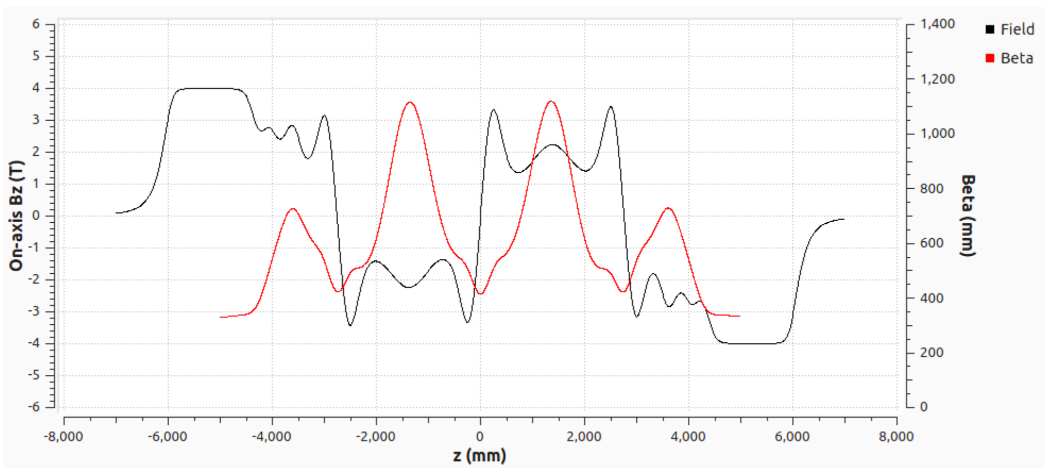
Plot of on-axis B_z and corresponding β for typical flip-mode coil parameters (6mm.rad, 200MeV beam) generated using code provided by V. Blackmore

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

Plan for initial suite of MAUS simulations (in progress)

Step VI



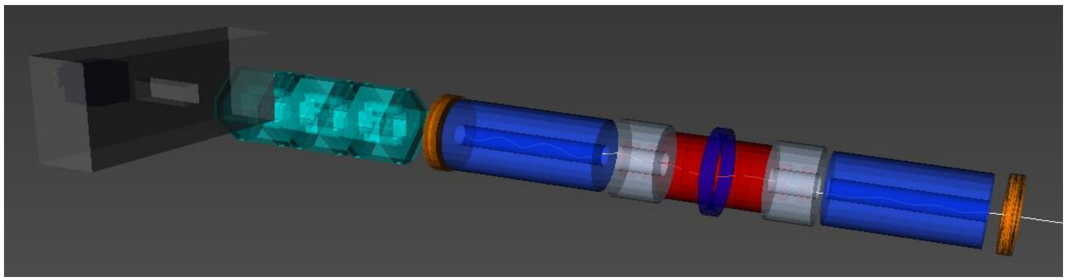


Plot of on-axis B_z and corresponding β for typical flip-mode coil parameters (6mm.rad, 200MeV beam) generated using code provided by V. Blackmore

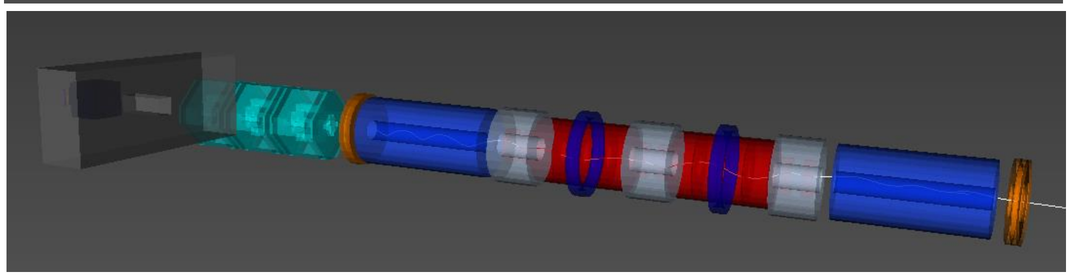
- Simulate a perfect baseline MICE Step V experiment using Monte Carlo tracks.
- Simulate a perfect baseline MICE Step VI experiment using Monte Carlo tracks.
  - **Compare emittance reduction between the two cases.**

Plan for initial suite of MAUS simulations (in progress)

Step V



Step VI



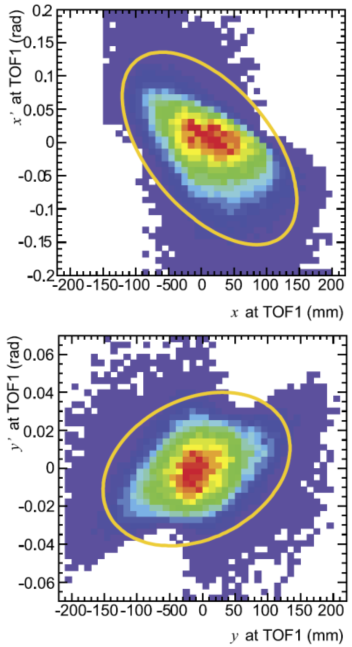
The overall objective of this analysis is to determine (for a range of Step V / VI operating modes) the useful analyses that may be conducted, sensitivity of each mode to various spurious effects and for the step VI operational modes, the precision with which the cooling performance may be predicted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

- 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 and VI using both Monte Carlo and reconstructed particle tracks.

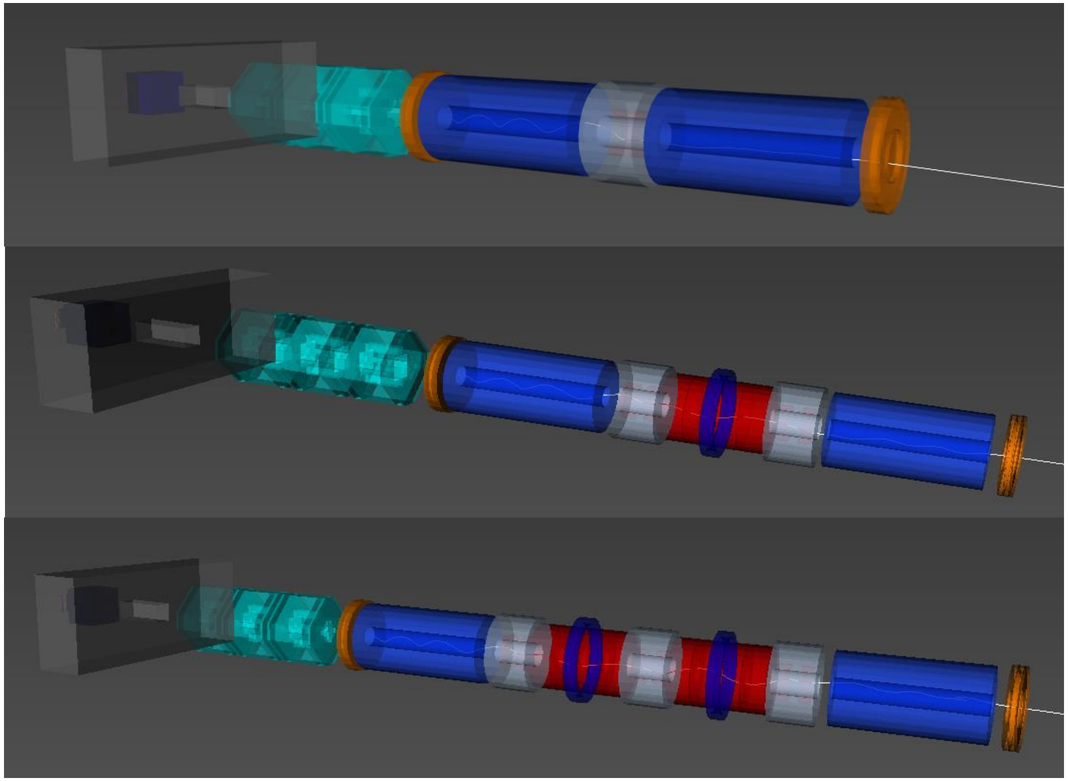
MAUS simulations with Step I measured beam parameters

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.



Step IV

Step V

Step VI

Criteria and simulation plan for Step V and VI assessment– Summary

- We 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).