Emittance Analysis in Step IV

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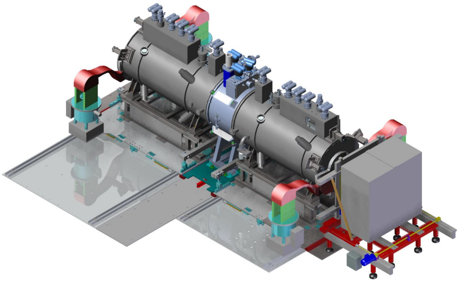
with help from a *lot* of people

27th October 2014

MICE Step IV

We are *the* experiment to demonstate ionisation cooling.



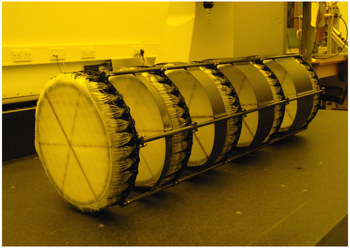
The SciFi Trackers provide our transverse measurement power.

Global Reconstruction improves our PID, purity, and longitudinal measurement accuracy.

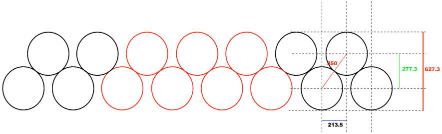
Beamline physicists provide the magnetic conditions to see it

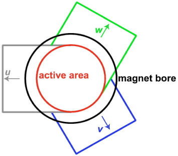
The SciFi Trackers

Each solenoid has 1 Tracker, with 5 Stations, each with 3 Planes.



Each plane is a layer of scintillating fibres, rotated 120° to their neighbours.

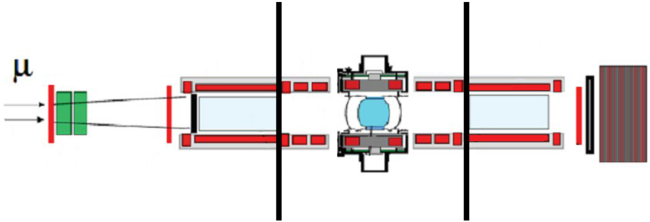




The Emittance Measurement

Each of the 3 planes in each Tracker station is individually analysed in the Kalman fitting algorithm - using the seeds provided by pattern recognition algorithms.

Officially the Trackers reconstruct the emittance at the Tracker Plane nearest the absorber.



The Last CM

What I haven't done:

1. Implement G4Beamline beams and use the MICE CDB Geometry.

This is now being covered with the famous "Physics Block Challenge". A copy of the fist data set has started to be analysed!

2. Write documentation and a MICE Note

Still on the todo list - however the understanding of the processes and physics have been improved.

3. A simulated run with a predetermined correction matrix

Concept has been tested with various success. Unfortunately no plots today.

The Last CM

What I have done:

1. More detailed optics studies
working with Jaroslaw and Jean-Baptiste
We have a well tried and tested process to determine magnet current densities. Confusion in the geometry recently means we need to do it again unfortunately.

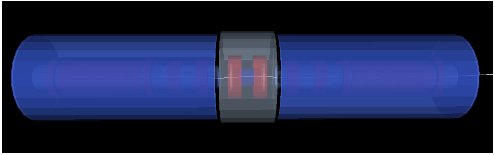
2. Repeat datasets with solenoid mode
Simulated both solenoid and flip modes of Step IV and found Solenoid mode performed better. This needs to be repeated after rematching.

Recent Developments

Currently using a Legacy-Derived Geometry due to quick turnaround with jobs.

Planning to turn to CDB geometry when we have stop fiddling with settings!

Using a nominal Step IV Cooling Channel Geometry with no outside detectors or beamline



Virtual Planes Data

Only implement three cuts which allows a full cooling channel emittance plots to be constructed.

1. PID
   Only muons are included in the analysis. Not structured to deal with other particles so they are removed.
2. Transmission
   Only muons that reach the final virtual plane are included (no decays or large scatters).
3. Aperture (200mm)
   Muons must not leave the cooling channel.

You need a constant particle number through the cooling channel to accurately depict emittance and beta function

Reconstructed Data

Depends on your analysis

1. Transverse Momentum < 150 MeV/c
2. Longitudinal Momentum < 300 MeV/c

   Remove spurious events from poor reconstruction. Adam has a plan to tag candidate events!
3. Kalman Fit P-Value $> 5\%$

   Kalman appears to have a pretty good Chi-Squared distribution so we remove the tail
4. Only Helical Tracks
5. Clean tracks in *both* trackers

   Makes our life easier. With a MC Trigger we can model ways to account for these.

To pass as a "Helical Track" in software, pattern recognition must be able to reconstruct the helix with a low enough χ-squared value to pass a cut.

The Beam

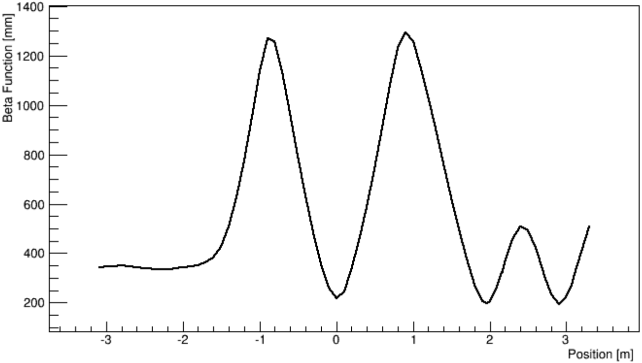
Current simulations still using a simple Gaussian Beam

Profile	Gaussian
Transverse Emittance	6πmm
Transverse Beta Function	338mm
Momentum	200MeV/c (0.0001 MeV/c RMS)
Start	Within upstream solenoid (-3100mm)
Content	100% Positive Muons

Plans to include G4Beamline simulated distributions once the settings are finalised.

Beam Optics

The Beta Function for the cooling channel using our current settings

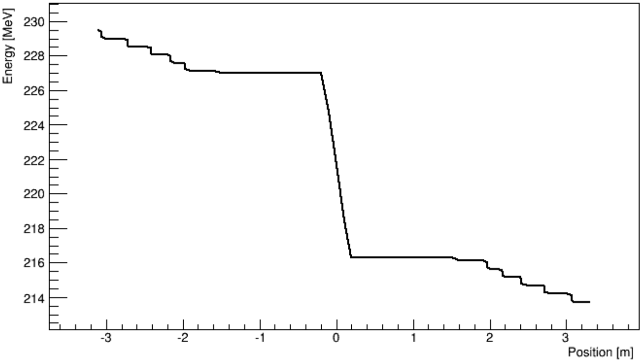


Note the mismatch in the downstream solenoid.

this is currently being fixed

Beam Optics

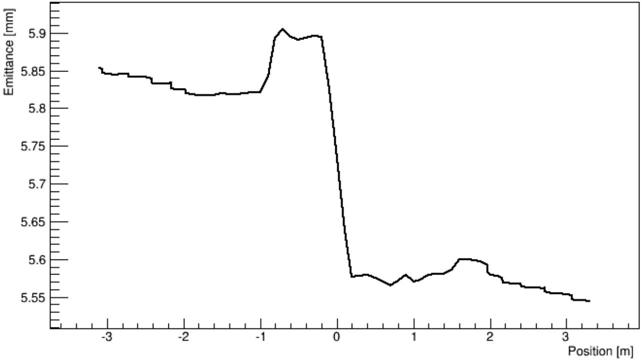
The mean energy for the cooling channel using our current settings



Simulation now includes the Helium windows

Emittance

The Monte Carlo beam emittance for our current settings

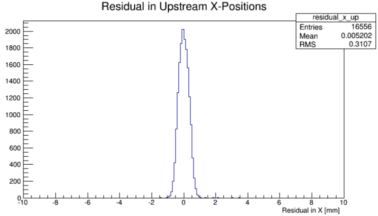


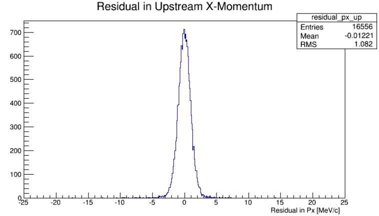
Looks like a possible, measurable 4.5% acheivable with better beta function.

Kalman Updates

Our resident expert, Ed Santos, has now finished...

But he did leave us with a parting gift: Updates to Kalman!





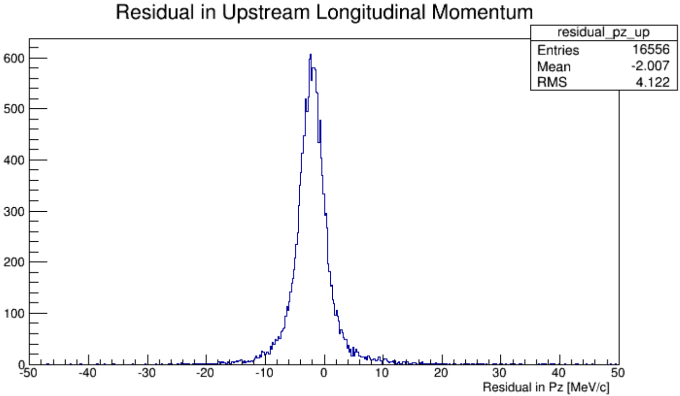
Upstream Position and Momentum residuals in X

Position RMS: 320 μm
Momenutm RMS: 1 MeV/c

Kalman Issues

But we still have a couple of issues to nail down.

Longitudinal momentum has acquired a offset



We are looking into this - Stay tuned!

Emittance Reconstruction

The emittance reconstruction is currently very reliable.

An Example Run for 16,000 Muons:

Parameter	Monte Carlo	Reconstructed	Deviation
Emittance Upstream	5.705 mm	5.635 mm	-1.228%
Emittance Downstream	5.503 mm	5.420 mm	-1.517%
Beta Upstream	338.9 mm	339.6 mm	+0.187%
Beta Downstream	201.4 mm	200.9 mm	-0.257%

We need to find the source of this systematic error and see if we can correct it.

(By "we" I probably mean "I")

But we always see it at the same disagreement!

Issues

So what's still to consider:

1. Matching the beam perfectly is difficult using simple techniques
2. Global reconstruction/PID will become usable at some point we need to take account of these
3. Kalman Filter Pz Reconstruction. Currently a priority
4. Origin of the Emittance Reconstruction systematic
5. Issues with memory limits and large datasets

Future Plans

So what's next:

1. Push current scripts to MAUS for people to test.
2. Write a C++ version - faster and more powerful for those LARGE datasets we have coming!
3. Full selection of settings - LH2, LiH, Solenoid, Flip, etc
4. What is the sensitivity of any Covariance Matrix Corrections?
5. Beam Selection Functionality - The last missing piece...

...and eventually: StepIV Emittance Analysis

Thank you for listening.

Any Questions?