Tracker Emittance Reconstruction

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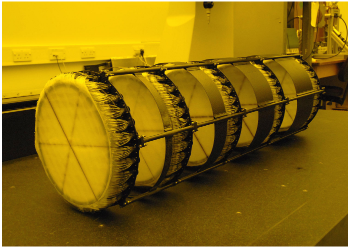
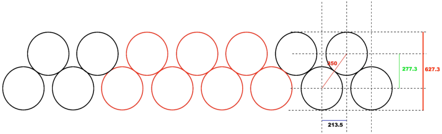
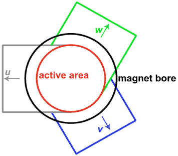
The SciFi Trackers

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



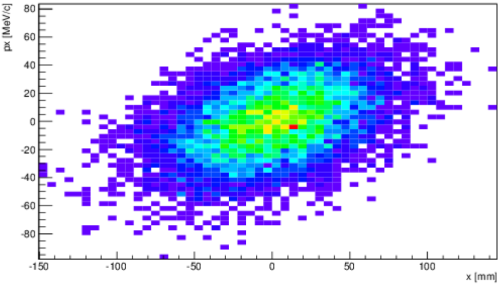
Each plane is a layer of scintillating fibres, rotated 120° to their neighbours.





Emittance

The volume of the phasespace occupied by an ensemble of particles



We may take a subset of the 6D phasespace $(x\ , y,\ z,\ p_x,\ p_y,\ p_z)$ and discuss 2D, 4D or 6D emittances.

Crucial for MICE is the 4D transverse emittance.

Emittance

We typically assume a gaussian distribution and consider the RMS values of particle distribution only.

We may now define the n-Dimensional Emittance as a statistical property, defined by:

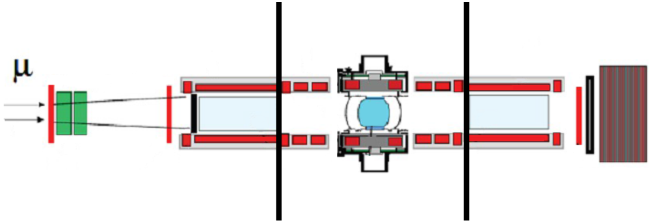
$$\epsilon_{nD} = \frac{1}{mc} \sqrt[n]{|V|}$$

where m is the particle species mass, c is the speed of light, ϵ_{nD} is the n-Dimensional emittance and V corresponds to the n×n covariance matrix for the particles analysed.

Where We Measure It

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.



Reconstruction Proceedure

The tracker reconstruction goes through several stages using and intial list of triggered fibres.

1. Digit Creation

   If there is enough light collected in fibres within the same channel, that channel is considered to be a “digit”.

2. Clustering

   Digits in neighbouring channels are grouped to form clusters in each plane.

3. Space Point Creation

   Clusters in neighboring planes are combined, if they are close enough in x and y to for a spacepoint for that station.

From here Adam will tell you how the pattern recognition works!

Kalman Filtering

The Kalman Filter is an iterative process that tries to account for multiple scattering and energy loss during the propagation between consecutive planes.

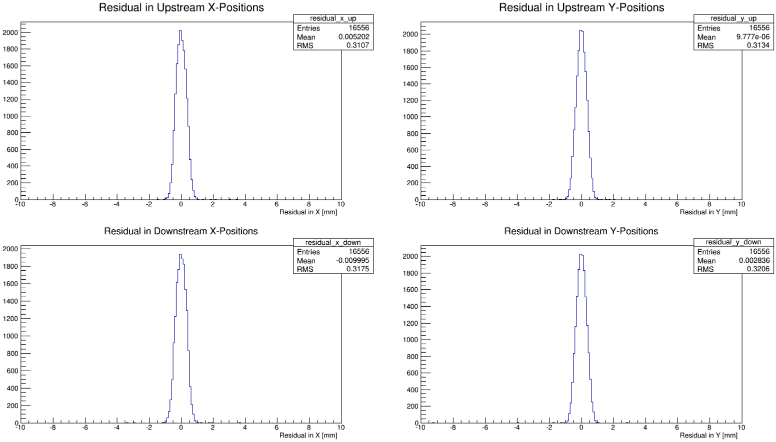
1. The results of pattern recognition provide the starting guesses of momentum.
2. The Clusters are used to define the values of position.
3. The algorithm starts at the plane nearest the absorber and propagates outwards.
4. The algorithm reverses direction at Station 5 and finishes at the reference plane, Station 1.

The process gathers the prior information to ensure the reference plane has the most accurate value.

Thanks Ed!

Kalman Residuals

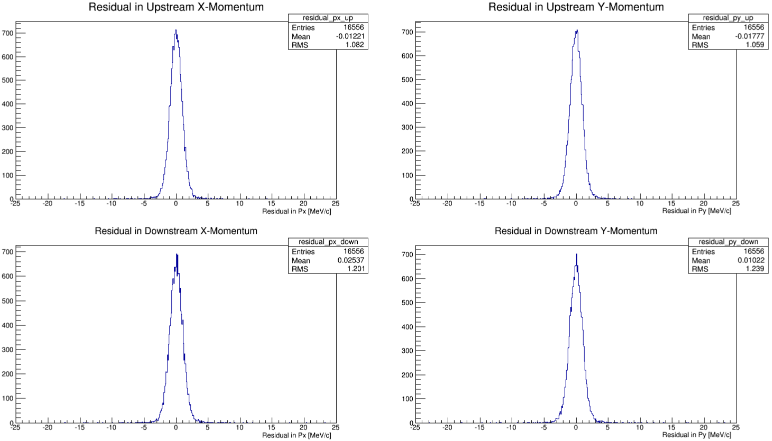
X & Y Positions



All Mean ≈ 0, RMS $\approx 320\,\mu$m

Kalman Residuals

X & Y Momenta



All Mean ≈ 0.0, RMS $\approx 1.2\,\mathrm{MeV}/c$

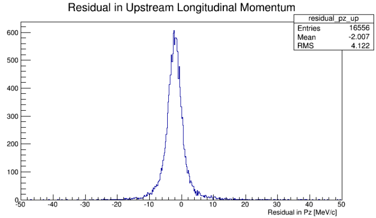
Kalman Residuals

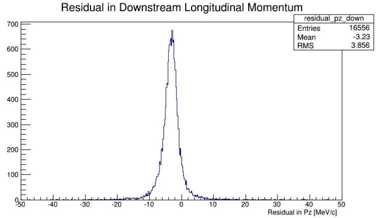
Z Momentum

Upstream and downstream Z Momentum are currently systematically shifted.

Upstream Mean = -2.0 MeV/c   Downstream Mean = -3.9 MeV/c

Both RMS $\approx$ 4.0 MeV/c





Emittance Measurement

An example: The upstream tracker of my current, legacy-derived Step IV geometry.

Parameter	Monte Carlo	Reconstructed	Deviation
Emittance	5.705 mm	5.635 mm	-1.228%
Beta	338.9 mm	339.6 mm	+0.187%
Energy	227.1 MeV/c	225.3 MeV/c	-0.797%

These systematic differences are very consistent.

Not bad, except the emittance is constantly shifted by 1.2% - 1.3%

Finding and removing (if possible) this systematic error is a priority!

Errors and Sources of Error

- Virtual Planes

  Need to assign the correct virtual plane to each tracker plane.
- Kalman Seeds

  Uses values taken from Pattern Recognition. Ensure these are correct.
- Tracker Plane Association

  There are 15 planes - make sure we're looking at the correct one.
- Comparisons with Pattern Recognition

  We don't see the longitudinal momentum systematic.
- Correlations

  Need to check if this a physical limit due to the beam we used.

Some of these may be obvious, but I'm not ruling everything out before we check!

Conclusions

So where are we?

- A lot of experience with performing reconstruction and calculating emittances
- Learned a lot (from MC) about the optics of the cooling channel
- The code is looking good, well behaved, much cleaner and very consistent
- Reconstruction code is being used on multiple geometries and settings by multiple people

Just a small issue with the systematics. . .

Future Plans

So what's next?

1. Dive into Kalman.
   I have some ideas for the source of the systematics.

2. Update the emittance reconstruction code.
   Push python scripts to MAUS and re-write in C++. Faster and higher stats.

3. Perform full momentum scan to plot deviations as a function of p_t and p_z

Plan to have a user-friendly emittance calculation program/framework by the next CM!

Thank you for listening.

Any Questions?