Systematic Effects of Misalignments in the MICE Cooling Channel

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1. Use a low-Z material to reduce the particle momenta
2. Beware the effects of Multiple Coulomb Scattering, which increase transverse momentum
3. Provide reacceleration to restore the lost energy
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:

$$\epsilon_{nD} = \frac{1}{mc} \sqrt{\det V}$$

where $m$ is the particle species mass, $c$ is the speed of light, $\epsilon_{nD}$ is the n-Dimensional, Normalised RMS Emittance and $V$ corresponds to the $n \times n$ covariance matrix for the analysed ensemble of particles.
Currently under construction, commissioning to start next month!
MICE Step IV

Step IV Cross Section

Upstream
Spectrometer Solenoid

Absorber
Focus Coil

Downstream
Spectrometer Solenoid

Measure Input
Emittance

Ionisation
Energy Losses

Measure Output
Emittance
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.

Position Resolution: $\approx 0.4$ mm  
Momentum Resolution: $< 1$ MeV

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Transmission ≈ 99.5%

10 MeV Energy Drop

Transmission

Mean Energy

Liquid Hydrogen Absorber

Tracker Station Positions

Magnetic Field

20 cm LH2 Absorber

Peak $B_z = 4.0 \, \text{T}$
The Cooling Channel

True Monte Carlo 4D Normalised Emittance

![Graph showing the True Monte Carlo 4D Normalised Emittance](image-url)
We are a precision experiment, and as such all components must be installed and commissioned with a high accuracy.

We have in place, plans for:

- Magnetic Alignment
- Detector Alignment
- Beamline and Cooling Channel Commissioning

But what if we miss something?
AFC Translations

Before

After

RMS displacement of 0.500mm
Sample 100 times
AFC Translations

Distribution of Reconstructed Downstream Emittance.

- **Entries**: 100
- **Constant**: 36.68
- **Mean**: 5.648
- **Sigma**: 0.02185
AFC Rotation

Before

After

RMS angular displacement 0.300°
Sample 100 times

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AFC Rotations

Distribution of Reconstructed Downstream Emittance.

![Graph showing frequency distribution of reconstructed downstream emittance. The graph includes data points for entries, constant, mean, and sigma.]
Analysis

Typical emittance precision of MICE is $\sim 0.01$mm

RMS deviation in emittance estimated at $\sim 0.02$mm

So we will be sensitive to this magnitude of misalignment.

But these are the most pessimistic cases.
We can do better than this!

Alignment tolerances are $< 0.5$mm and survey information is correct to $< 0.1$mm.

Currently examining more realistic data.
Future Plans

So what’s next?

• More Statistics!
• AFC Rotations and Displacements Combined
• Repeat for the Downstream Spectrometer Solenoid
• Different input beams, only used the default so far

And:

*Given the deviation from Monte Carlo - can we predict the misalignment?*
Thank you for your attention.

Questions?