Recent Results from the Study of Emittance Evolution in MICE

Christopher Hunt

on behalf of

The MICE Collaboration

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Imperial College London

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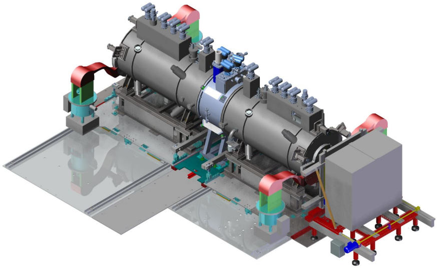

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Introduction

The MICE Experiment is currently evaluating several key measurements:

1. High precision emittance measurement from individual muons tracks,
2. The first measurement of emittance reduction through a LiH absorber,
   [See F. Drielsma]
3. An entire programme of materials physics studies, [See J. Nugent]
4. A detailed study of emittance evolution in the MICE Cooling Channel.

I will focus on 1. and 2., but do please see the excellent work presented by our collaborators.

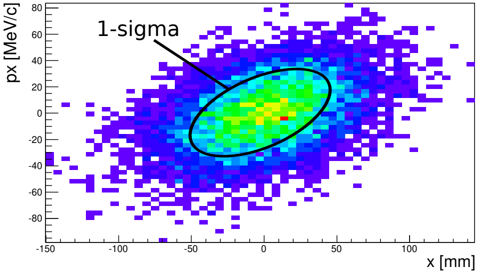
Defining Emittance

The volume of phase-space occupied by an ensemble of particles.

In MICE we focus on the *4-dimensional, transvserse, normalised, RMS emittance*, $\epsilon_\perp$, which corresponds to the central 1-sigma of a Gaussian distribution in x, p_x, y, p_y space.

Calculated from the covariance matrix of the ensemble $\mathbf{\Sigma}$, and the muon mass, m.

$$\epsilon_\perp = \frac{|\Sigma|^{\frac{1}{4}}}{m}.$$



A typical phase-space projection in x-p_x.

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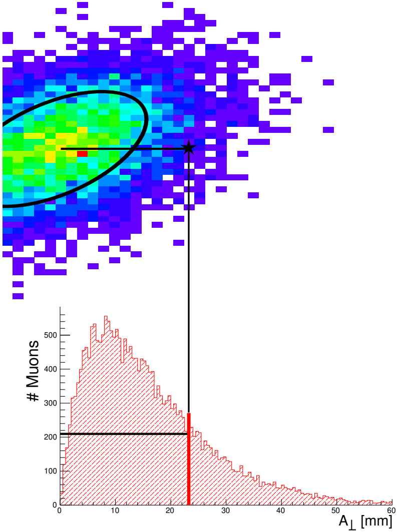
Defining Amplitude



Analysing emittance evolution on a muon-by-muon basis.

The Single Particle Amplitude defined as the scalar distance in phase-space of a particle (with vector $\boldsymbol{v}$) from the centre of the ensemble (with covariance matrix $\boldsymbol{\Sigma}$).

$$A_\perp = \epsilon_\perp \boldsymbol{v}^\intercal \boldsymbol{\Sigma}^{-1} \boldsymbol{v}$$

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Amplitude and Emittance

To demonstrate cooling, we can analyse both RMS emittance measurements and amplitude distributions.

RMS Emittance, Cooling:

Net decrease in the RMS occupied phase-space volume.

Can be affected by high field gradients and hard scattering events.

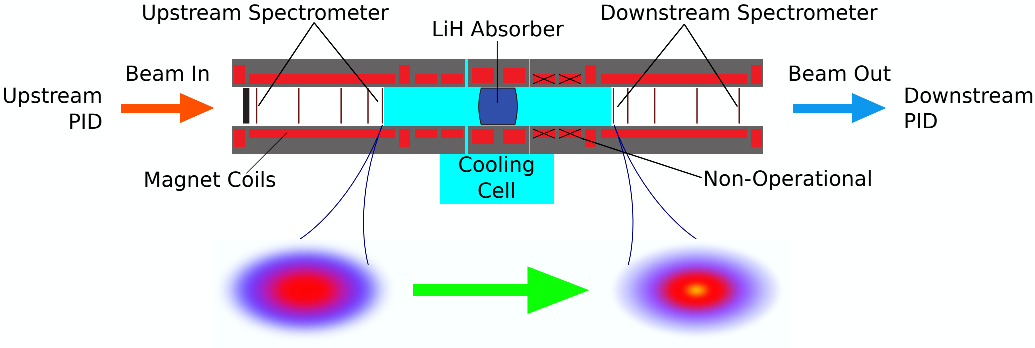
Amplitude Distribution, Cooling:

Net migration of particles from higher amplitudes to lower amplitudes.

Can remove tail effects and examine the core of the beam.

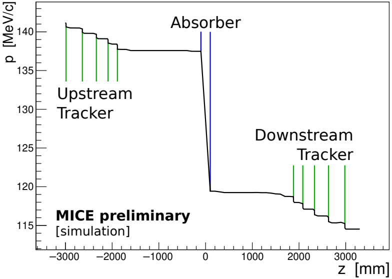
Analysing the MICE Cooling Channel

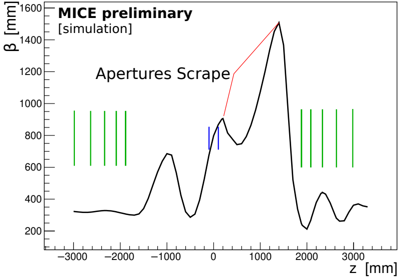
The Experiment



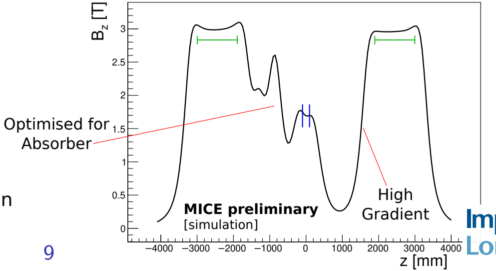
Net migration of particles from higher amplitudes to lower amplitudes.
An increase in core density.

The Experiment





The magnetic lattice has been carefully designed within the hardware constraints of the magnets.



Care must be taken to control filamentation and scraping.

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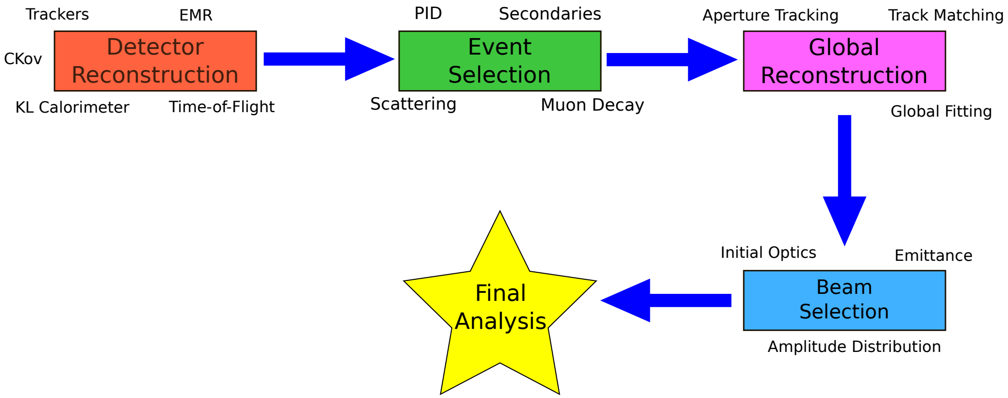
Selection and Reconstruction

Analysis Process



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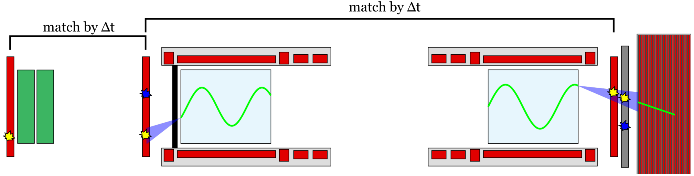
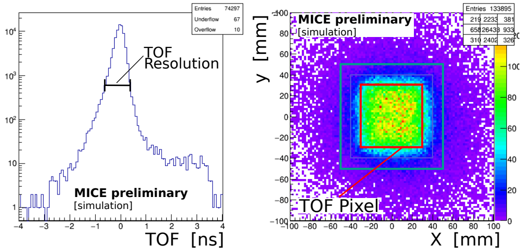
Global Reconstruction



- Use reconstruction from all detectors,
- Involves very precise tracking through CAD geometries,
- Predict which tracks scattered and scraped,
- Ensures a "clean" muon sample.



Tracker→TOF Residuals

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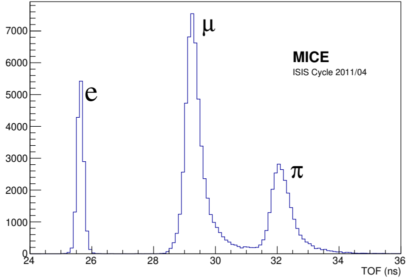
Event Selection

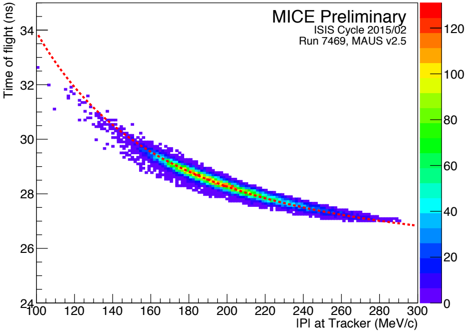
Selecting Good Muons:

- Single tracker events,
- Muonic time of flight,
- Good reconstruction in all detectors,
- No apertures scraped.



Time Of Flight TOF1→2.

TOF - Momentum Correlation.



Shown previously a muon purity of >99.85%

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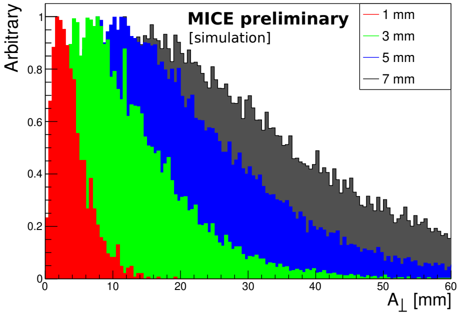
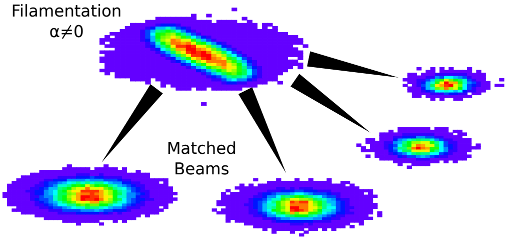
Beam Selection



A rigorous procedure is used to select a matched beam for the individual magnetic lattice.

- Accept/reject sampling or statistical weighting,
- Select a different amplitude distribution,
- Select a matched beam from an unmatched one.



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Recent Results

Recent Results

I will present the most recent results from two of the key analyses for MICE:

The Precise Measurement of Beam Emittance

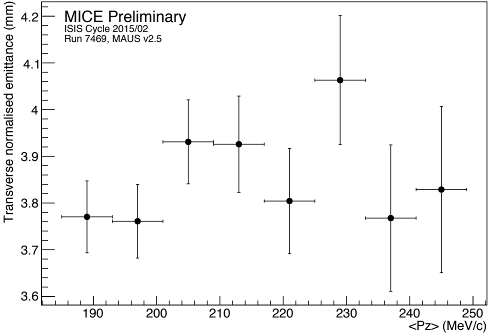
Precise calculation of the normalised emittance within the upstream tracker.

A Measurement of Emittance Evolution through a LiH Absorber

Comparison of the upstream and downstream amplitude distributions for a 3 mm beam and a 6 mm beam (nominal normalised emittance).

Precise Measurement of Beam Emittance

- Time-of-flight counters used for primary event selection,
- Upstream spectrometer used for emittance reconstruction,
- Single-track events with a muonic time of flight and a good reconstruction,
- Analyse beam in 8 MeV/c momentum bins, twice the momentum uncertainty,
- Statistical and systematic errors evaluated from all correlations in covariance matrix.



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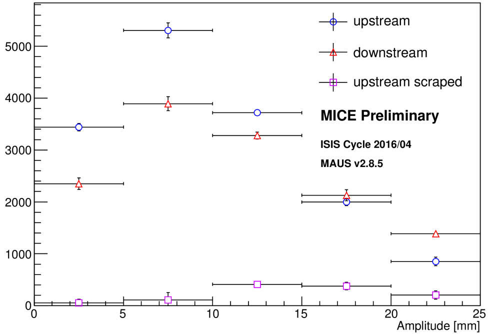
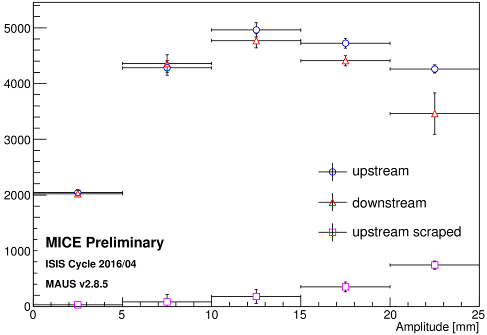
Measurement of Emittance Evolution

Nominal 3mm Beam



Nominal 6mm Beam



Consistent with emittance increase/heating. Core density decrease.

Consistent with equilibrium emittance. No change in core density.

Conclusions

1. *Direct Measurement of Emittance Using the Scintillating Fibre Trackers*
    - Demonstrated an emittance measurement with single muons,
    - Acheived small statistical and systematic errors.

2. *Measurement of Emittance Evolution through LiH Absorber*
    - First results of evolution of amplitude distribution have been presented,
    - Characteristic effects of heating and emittance equilibrium demonstrated,
    - Final dataset, 10 mm nominal emittance, currently being finalised.

3. *Liquid Hydrogen Data*
    - Currently being recorded...

Thank you for your attention.

Watch this space! $\rightarrow$