EMITTANCE EVOLUTION AT MICE

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on behalf of the MICE Collaboration

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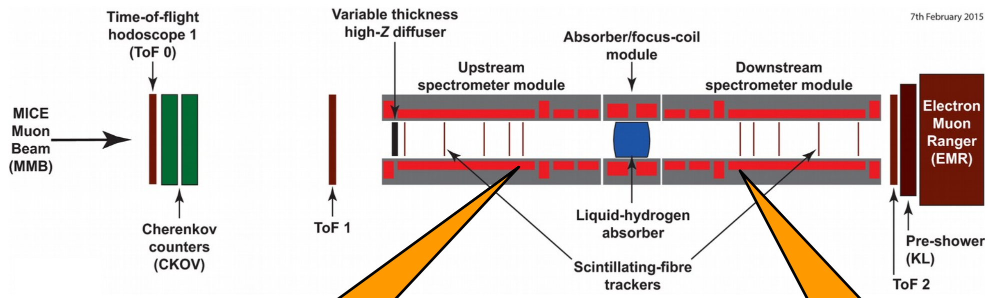
Abstract

The Muon Ionization Cooling Experiment has studied the evolution of emittance due to ionization energy loss. Muons were focussed on Lithium Hydride and liquid Hydrogen absorbers using a large aperture solenoid. Particle tracking and identification detectors upstream and downstream of the absorber enabled the reconstruction of the phase space coordinates of individual muons. The evolution of beam emittance was measured by studying the properties of ensembles of single muons using muon beams with varying input emittance and momenta. Data taken in 2016 and 2017 are currently being analysed. The current status and most recent results are presented.

Muon Ionisation Cooling Experiment (MICE)

- Methods to reduce large muon beam emittance are required for Neutrino Factories.
- Ionization cooling is the most viable technique to cool a muon beam
- MICE measures individual muons crossing :
  - Empty absorber
  - 35 cm LH_2
  - 65 mm LiH disc
- Muon phase space parameters are measured before and after absorber in a uniform 3 T magnetic field
- Beam emittance change after the absorber is measured by studying upstream and downstream muon phase space volumes.

Fig 1. The MICE channel. The muon position and momentum is measured in the upstream tracker, before passing through the absorber module. Having lost momentum, the muon is measured in the downstream fibre tracker. Particle identification detectors are located at the beginning and end of the channel.



Before absorber

After absorber

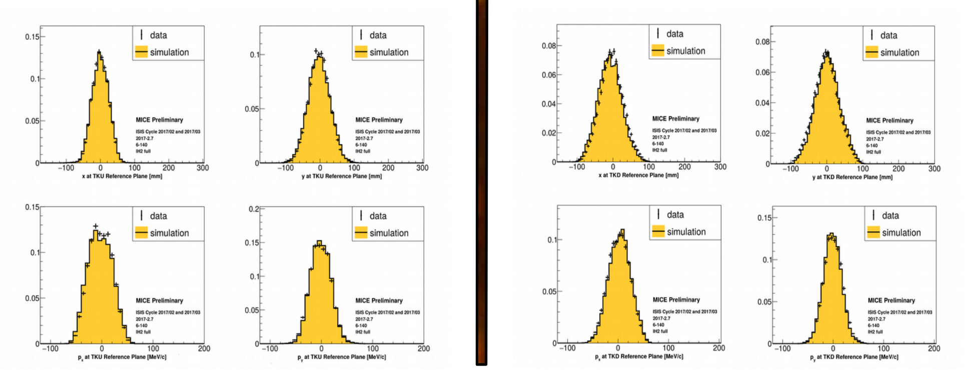


Fig 2. The position and momentum distributions of 140 MeV/c muons before and after crossing the LH_2 absorber as measured in the fibre trackers. Reconstructed data (black circles) compare well with Monte Carlo simulations (filled histograms).

Muon Selection

- Ensembles of muons selected with:
  - an upstream Time-of-Flight consistent with a muon particle hypothesis
  - 135 MeV/c < p_μ < 145 MeV/c
  - a single, well-reconstructed track in the upstream tracker with momentum consistent with that measured in the upstream TOF
- Reconstructed Monte Carlo and data distributions before and after absorber agree well (Fig 2.)

Emittance Evolution

$$\epsilon_N = \frac{1}{m_\mu}\sqrt[4]{|det\,\Sigma_\perp|}$$

Normalised transverse emittance of phase space defined by ensemble of individual muons. Here $\Sigma_\perp$ is the 4-dimensional beam size matrix.

$$\Delta = (\boldsymbol{v} - \boldsymbol{\mu})$$

Distance of individual muon from beam centre in phase space: $\boldsymbol{v} = (x, y, p_x, p_y)^T$ $\boldsymbol{\mu} = (\langle x\rangle, \langle y\rangle, \langle p_x\rangle, \langle p_y\rangle)^T$

$$A_\perp = \epsilon_N \Delta^T \Sigma_\perp^{-1} \Delta$$

Single particle transverse amplitude

$$R_{amp}(A_\perp^0) = \frac{N(A_\perp < A_\perp^0 | After)}{N(A_\perp < A_\perp^0 | Before)}$$

Ratio of cumulative amplitude after absorber to that before absorber

Cooling : movement of muons to low amplitudes after absorber $R_{amp}(A_\perp^0) > 1$ at low $A_\perp^0$

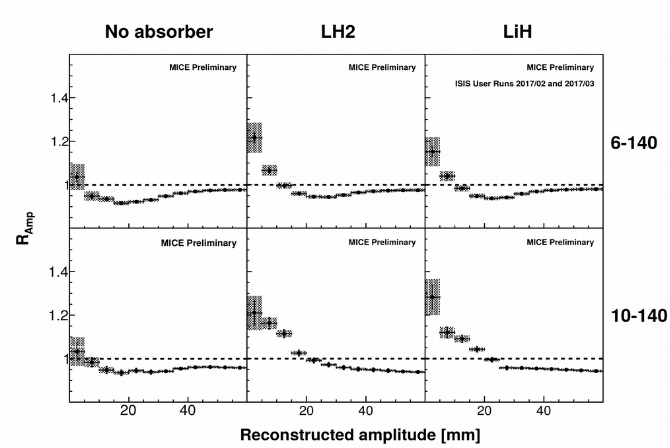


Fig 3. The ratio of the downstream to upstream cumulative amplitudes for two input beam configurations with nominal momenta of 140 MeV/c and nominal emittance of 6 (top) and 10 (bottom) mm. Cooling is observed where $R_{amp} > 1$.

Acknowledgements

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