RECENT RESULTS FROM MICE ON MULTIPLE COULOMB SCATTERING AND ENERGY LOSS

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Introduction

Muon beams of low emittance provide the basis for the intense, well-characterised neutrino beams necessary to elucidate the physics of flavour at a neutrino factory and to provide lepton-antilepton collisions at energies of up to several TeV at a muon collider [1].

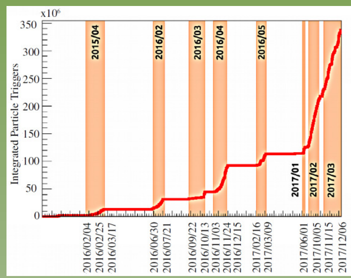
The International Muon Ionization Cooling Experiment (MICE) will demonstrate ionization cooling, the technique by which the phase space volume occupied by muon beams is reduced ("cooled") [2].

In an ionization-cooling channel, a muon beam passes through absorber material in which it loses energy. The longitudinal energy lost is then replaced using radio frequency (RF) cavities.

The combined effect of energy loss and re-acceleration is to reduce the transverse emittance of the beam (transverse cooling).

The configuration that has operated until December 2017 at the Rutherford Appleton Laboratory, has made detailed measurements of multiple Coulomb scattering and energy loss of muons in lithium hydride (LiH) and liquid hydrogen (LH2) absorbers, over a range of momenta from 140 to 240 MeV/c with and without magnetic fields in the cooling channel, in order to characterise the ionization cooling equation [3].

The experiment also seeks to measure transverse normalized emittance reduction in a number of lattice configurations.



Ionization cooling equation

$$\frac{d\varepsilon_N}{ds} \simeq -\frac{\varepsilon_N}{\beta^2 E_\mu}\left\langle\frac{dE}{ds}\right\rangle + \frac{\beta_t (13.6\,[\mathrm{MeV}])^2}{2\beta^3 E_\mu m_\mu X_0}$$

Cooling term **Heating term**

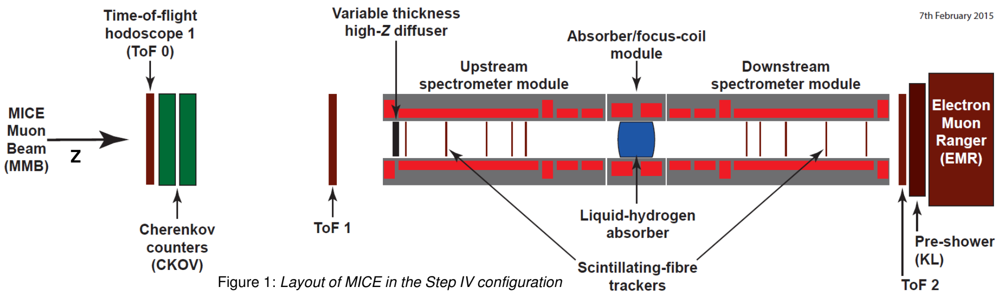


Figure 1: *Layout of MICE in the Step IV configuration*

Measurement of scattering distributions

Though multiple Coulomb scattering is a well understood phenomenon, results from MuScat [4] indicate that the effect in low *Z* materials is not well modelled in simulations such as GEANT4 [5] and therefore it is essential for MICE to validate the scattering model.

Bayesian deconvolution has been applied to data collected at three different momenta (172 MeV/c, 200 MeV/c and 240 MeV/c) with and without the LiH absorber in place, in order to extract the scattering distribution within the absorber material.

The scattering widths taken from the scattering distributions projected in the X-Z and Y-Z planes are Θ=23.3±0.9±0.2 mrad at 172 MeV/c, Θ=17.9±0.4±0.5 mrad at 200 MeV/c and Θ=14.2±0.1±0.5 mrad at 240 MeV/c.

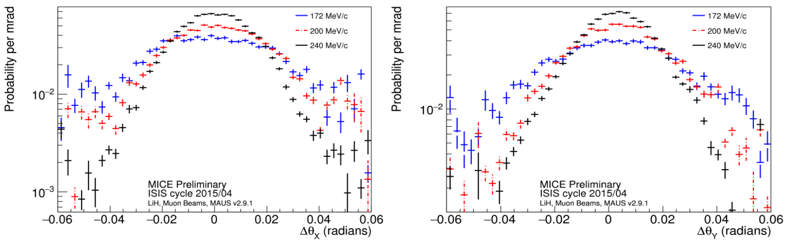


Figure 2: *Scattering distributions projected in Y-Z (left) and X-Z (right) for muons traversing lithium hydride*

Measurement of energy loss

The mean rate of energy loss for relativistic charged heavy particles traversing matter is given by the "Bethe equation" [6]

$$-\left\langle\frac{dE}{dX}\right\rangle = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_ec^2\beta^2\gamma^2W_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$$

where the mean excitation energy *I* in hydrogen is known at the 5% level but has never been measured in lithium hydride.

The momentum of the muons is measured upstream and downstream of the absorber using the scintillating-fibre trackers combined with the time of flight detectors. Preliminary results using a convolution fit for 200 MeV/c muons in magnetic field traversing the LiH absorber show that mean momentum loss is Δp = 12.8 ± 5.3 MeV/c.

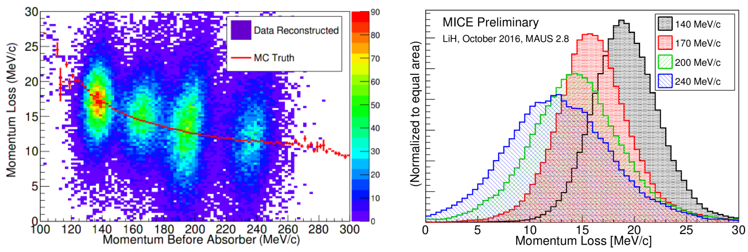


Figure 3: *Reconstructed momentum loss across the LiH absorber for several muon beams*

Acknowledgemnts

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MICE Data

Links to the MICE raw data along with links to other MICE related data can be accessed at https://doi.org/10.17633/rd.brunel.3179644

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