Review of the MICE beam-dynamics analysis

Terms of reference

Background

The international Muon Ionization Cooling Experiment (MICE) collaboration [1] has embarked on a programme of measurement designed to demonstrate the feasibility of the ionization-cooling technique [2]. The MICE measurement of the cooling effect is made by comparing the muon-beam parameters upstream and downstream of a single cell of an ionization-cooling lattice. The MICE study of ionization cooling will be performed in two steps. The first, referred to as "Step IV", has been optimised to allow the factors that determine the ionization-cooling effect to be measured [3]. Once Step IV is complete, the experiment will be reconfigured to deliver the demonstration of ionization cooling [4].

The MICE Muon Beam on ISIS [5] at the STFC Rutherford Appleton Laboratory delivers muons one at a time to the experiment [6]. Upstream of the cooling cell, muons are selected using time-of-flight (TOF) hodoscopes [7] and threshold Cherenkov counters [8]. Muons that decay within the experiment are identified by tagging the electron produced in the decay using a TOF counter, lead-scintillator pre-shower detector (KL) [9] and calorimeter (EMR) [10] placed downstream of the cooling cell. A spectrometer composed of a scintillating-fibre tracking detector [11] contained within a 4 T solenoidal magnetic field is used to measure the phase-space coordinates of each muon entering the cooling cell. A second spectrometer measures the phase-space coordinates of each muon leaving the cooling cell.

On the 13^{th} September 2015 one of the match coils (M1) in the downstream solenoid (SSD) was rendered inoperable as a result of a quench that occurred as the magnet was ramping down. The flexibility of the lattice at Step IV has allowed the Analysis Group to develop optics by which the principal elements of the Step IV programme, the study of material properties and the observation of the reduction in the normalised transverse emittance, may be carried out without M1 in SSD. The optics of the cooling-demonstration configuration is less flexible making it necessary to consider all options by which the full functionality of SSD can be recovered. These options were formally considered in a Muon Accelerator Programme Director's review which was held at FNAL on the 3^{rd} and 4^{th} December 2015. The review panel "greatly acknowledged" the importance of executing Step IV to deliver the necessary measurements and therefore recommended the manufacture of a new cold mass in parallel to Step IV operation.

Analysis of the beam dynamics in MICE presents some unique challenges. First, a bunch must be assembled offline from a collection of single muons recorded by the experiment. The parameters that characterise this bunch such as the emittance must then be derived from the ensemble of single particles. A Geant4-based end-to-end simulation of the experiment will be used to inform the analysis of the data.

The review

The present review of the beam-dynamics analysis will take place when the analysis of the first data from the experiment in the Step IV configuration has just begun. Its purpose is to provide feedback to the collaboration on the analysis techniques that have been developed and to advise on optimal strategies for the analysis of the data, simulation of the experiment and the study of the beam dynamics in MICE. In the light of the failure

of the M1 coil in SSD, the review will also consider the solutions for the operation of Step IV that have been developed.

The format of the review will be a series of presentations in which the reconstruction, simulation and analysis techniques will be described. The results obtained from the analysis of the first data will also be described.

The reviewers are asked to:

- Consider the data reduction, analysis, data-curation techniques and the beam-optics and simulation methodology adopted by the collaboration;
- Identify areas in which improved techniques or methodologies should be developed to improve the analysis or to expedite its completion;
- Consider the Step IV programme in the light of the loss of the M1 coil in the downstream-spectrometer solenoid, comment on the degree to which the Step IV programme can be executed using the configurations presented by the collaboration and advise on improved strategies to maximise the physics output of Step IV; and
- Advise on strategies by which the impact and clarity of the results of the experiment can be presented to the accelerator–and experimental–physics communities.

A short report on the findings and recommendations of the reviewers will be prepared and submitted to the collaboration within a month of the review.

K. Long
17$^{\text{th}}$ December 2015

References

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[4] V. Blackmore *et al.*, "The MICE Demonstration of Ionisation Cooling: Technical Note." `http://mice.iit.edu/micenotes/public/pdf/MICE452/MICE0452.pdf`, 2014.

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