Imperial College London

Science & Technology Facilities Council

Closing remarks

Electron-Muon Ranger: performance in the MICE Muon Beam

The MICE collaboration†

The Muon Ionization Cooling Experiment (MICE) will perform a detailed study of ionization cooling to evaluate the feasibility of the technique. To carry out this program, MICE requires an efficient particle-identification (PID) system to identify muons. The Electron-Muon Ranger (EMR) is a fully-active tracking-calorimeter that forms part of the PID system and tags muons that traverse the cooling channel without decaying. The detector is capable of identifying electrons with an efficiency of 98.6%, providing a purity for the MICE beam that exceeds 99.8%. The EMR also proved to be a powerful tool for the reconstruction of muon momenta in the range 100–280 MeV/c.

1 Introduction

Intense muon sources are required for a future Neutrino Factory or Muon Collider [1, 2]. At production, muons occupy a large phase-space volume (emittance), which makes them difficult to accelerate and store. Therefore, the emittance of the muon beams must be reduced, i.e the muons must be "cooled", to maximise the muon flux delivered to the accelerator. Conventional cooling techniques applied to muon beams [3] would leave too few muons to be accelerated since the muon lifetime is short ($\tau_\mu \sim 2.2\,\mu$s). Simulations indicate that the ionization-cooling effect builds quickly enough to deliver the flux and emittance required by the Neutrino Factory and the Muon Collider [4, 5]. The MICE collaboration will study ionization cooling in detail to demonstrate the feasibility of the technique [6].

Ionization cooling proceeds by passing a beam of muons through a low-Z material [7]. The beam loses energy by ionizing the material, reducing its total momentum. Longitudinal momentum is restored by accelerating cavities. The net effect is to reduce the divergence of the beam and the transverse phase-space the beam occupies. The rate of change of the normalised 2D emittance may be approximated by [8]:

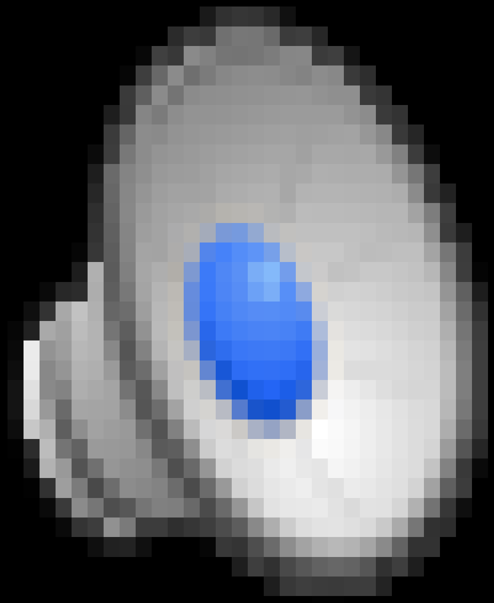
$$\frac{d\varepsilon_N}{ds} \simeq -\frac{\varepsilon_N}{\beta^2 E_\mu}\left|\frac{dE_\mu}{ds}\right| + \frac{\beta_\perp\,(0.014)^2}{2\beta^3 E_\mu m_\mu X_0}\,; \qquad (1)$$

where $\beta = v/c$, E_μ, m_μ are the muon velocity, energy and mass respectively. The rate of change of emittance depends on the properties of the absorber and the beam. Cooling is large when the initial emittance of the beam, ε_N, and stopping power of the absorber, $\langle dE_\mu/ds\rangle$, are large. The effect of heating by multiple Coulomb scattering is reduced if the radiation length of the absorber, X_0, is large and the transverse betatron function, $\beta_\perp$, of the beam at the absorber is small. Optimum cooling is achieved with low-Z absorbers, such as liquid hydrogen or lithium hydride, and with solenoidal beam-focussing.

The muon beams at the front-end of a Neutrino Factory or Muon Collider are expected to be similar, with a large transverse normalised emittance of $\varepsilon_N \approx$ 12–20 π mm-rad and a momentum spread of ~ 20 MeV/c. The emittance must be reduced to 2–5 π mm-rad for the Neutrino Factory, with further reduction to 0.008 π mm-rad required for a Muon Collider [9]. The Muon Ionization Cooling Experiment (MICE) [10] collaboration intends to demonstrate the feasibility of an ionization-cooling cell suitable for cooling muon beams at a Neutrino

† Authors are listed at the end of this paper.

Title	Lead authors
Step I physics	
~~Electron Muon Ranger: performance in the MICE Muon Beam~~	A. Blondel, F. Drielsma, R. Asfandiyarov
Measurement of the pion contamination in the MICE Muon Beam	D. Orestano, D. Nugent, P. Soler
Step IV physics	
Commissioning of the MICE experiment in the Step IV configuration	C. Rogers
Ionization cooling demonstration	
Design and expected performance of the MICE demonstration of ionization cooling	V. Blackmore, J. Pasternak, C. Rogers
Technical	
The MICE target upgrade	C. Booth
The design construction of the MICE Electron Muon Ranger	R. Asfandiyarov, A. Blondel, F. Drielsma
The Reconstruction Software for the MICE Scintillating Fibre Trackers	S. Dobbs
The MICE Analysis and User Software framework	D. Rajaram



READINESS

Readiness Step IV

- From draft MPB report:

> In general, all recommendations from the last review in this area have been address, and the collaboration is to be commended on having achieved a high state of technical readiness for Step IV data-taking.

- Still to do for Step IV:
  - Define and implement revised spectrometer-solenoid powering scheme;
  - Review and implement system-level QD/QP system
  - Combined magnet training
  - LH2 system commissioning

- Obviously some pressure

COMMISSIONING AND OPERATION

The next two User Cycles:

ISIS Cycle	Start	End
2015/03	03-Nov-15	18-Dec-15
2015/04	16-Feb-16	25-Mar-16
2016/01	12-Apr-16	20-May-16
2016/02	28-Jun-15	29-Jul-16

- **Cycle 2015/03:**
  - **FC and LH2 commissioning**
  - **Field-off material physics measurements**
- **Cycle 2015/04:**
  - **Data taking with LH2; full and empty**

- **Need to plan these activities with care**

NEXT VCs AND CMs

CMs, VCs and physics workshops:

- **CMs:**
  - **2016 (all TBC):**
    - **CM44 (15th to 19^{th}) February 2016**
      - **?CM light?**
        - » **To be defined by EB asap**
    - **CM45 20th to 24th June 2016**
    - **CM46 03rd to 07th October 2016**
- **VCs (to be defined by M. Uchida):**
  - **…**
- **Physics w/s in between CMs:**
  - **Review status of analysis and improve cross communication**
  - **Date to be announced by C. Rogers asap**

AND FINALLY …

And finally …

- Thanks to the local organisers:
  - Debbie Loader
  - Rose Hayes

- Thanks for coming and contributing;
  - Have a safe journey home …

Executive Board

- **In Atlas (in the Pod)**
  - **Lets start at …**