THE MICE MUON BEAMLINE AND HOST ACCELERATOR BEAM BUMP

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Abstract

The international Muon Ionization Cooling Experiment (MICE) is designed provide a proof of principle of the technique of ionization cooling, that is the reduction of the phase space of a muon beam via absorbers. Subsequent reacceleration is then provided by RF cavities ("sustainable cooling"). Ionisation cooling represents an important step toward future facilities based on stored muons beams, such as a future Neutrino Factory or Muon Collider.

The MICE Muon Beamline begins with the decay of pions produced by a cylindrical titanium target dipped into the circulating proton beam of the 800 MeV ISIS synchrotron at the Rutherford Appleton Laboratory, U.K. This generates a pion shower which is captured and subsequently decays producing the muon beam. A secondary effect of the MICE target is to cause an increase in the number of protons lost from the ISIS beam, known as beam loss.

An overview is presented here of the MICE Muon Beamline, including the results of a study in to the effect of raising the vertical position of the ISIS beam (a "beam bump") in the vicinity of the MICE target.

THE MICE MUON BEAMLINE

The MICE cooling channel will consist of three absorber modules, used to reduce beam momenta in all directions, interspersed with two RF cavities, used for longitudinal reacceleration. It is required to produced an $\sim$10% reduction in beam emittance, measured by scintillating fibre trackers at either end of the channel to 1% accuracy (an absolute emittance measurement of 0.1%). The MICE Muon Beamline is to supply the muon beam to the cooling channel, with tunable emittance of 140 MeV/c to 240 MeV/c [1].

The current layout of the MICE Muon Beamline is shown in Figure 1. The ISIS synchrotron serves as a proton driver, supplying $\sim$800 MeV protons to a cylindrical titanium target. The target is pulsed into the circulating beam towards the end of the 10 ms ISIS injection-extraction cycle, using a magnetic drive, to a variable dip depth. Hadronic interactions between the protons and the titanium nuclei lead to a pion shower, part of which is captured by a quadrupole triplet, set at an approximately 25° angle. Following this first triplet a dipole is used to perform a first momentum selection on the beam and direct it into the MICE experiment hall. The beam then traverses 5 T superconducting decay solenoid, increasing the pion path length, and so the muon content downstream. After the solenoid a second dipole performs a second momentum selection and again redirects the beam. Two further quadrupole triplets provide focusing as the beam approaches the cooling channel.

Positioned at various points along the beamline are various diagnostic detectors, including a simple scintillator counter (GVA1), two threshold aerogel Cherenkov detectors (CKOVa,b), three time-of-flight stations (TOF0-2), and KLOE Light calorimeter. The cooling channel is to be positioned between TOF1 and TOF2 in Figure 1. A detailed description of the MICE beamline can be found in [2].

In addition to creating the pion shower used to generate the muon beam, the action of the MICE target has the secondary effect of increasing the number of circulating protons lost from the ISIS beam, known as beam loss. Increased beam loss levels are undesirable as it can lead to machine activation, making hands on maintenance more difficuly. It has been shown that particle rate in the MICE beamline increases linearly with target-induced ISIS beam loss [3]. Hence, it is important to achieve the most efficient way of creating beam in the MICE beamline for the minimum cost in beam loss in ISIS.

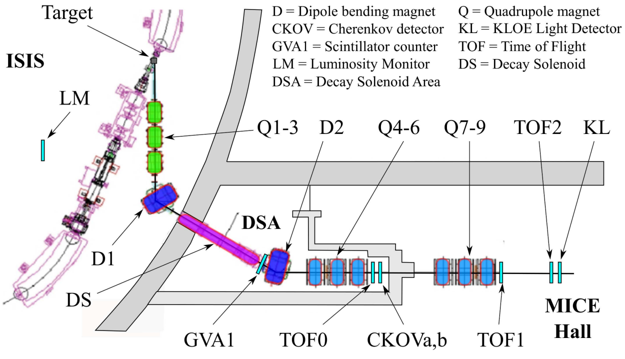

Figure 1: The MICE Beamline.

THE ISIS BEAM BUMP

Under normal operation the MICE target dips vertically into the circulating ISIS beam from 6-10 ms of the cycle depending on dip depth. However the actual muon measurement time of interest is only 9-10 ms, hence there is unnecessary beam loss and activation due to losses from 6-9 ms. Active control of the vertical beam position could

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mitigate this unwanted beam loss and could increase the relative beam dip depth.

A vertical closed orbit bump generated using 4 steering magnets, 2 either side of the MICE target can be used to control beam position at the target. Some of these steering magnets are also used to produce a bump from 8-10 ms to facilitate extraction under normal operation. This adds a layer of complication onto operation of an acceleration cycle in which MICE operates but is within the power supply specifications. The closed orbit bumps for MICE, extraction and their sum are shown in Figure 2. A MICE bump amplitude of 10 mm has been arbitrarily chosen.

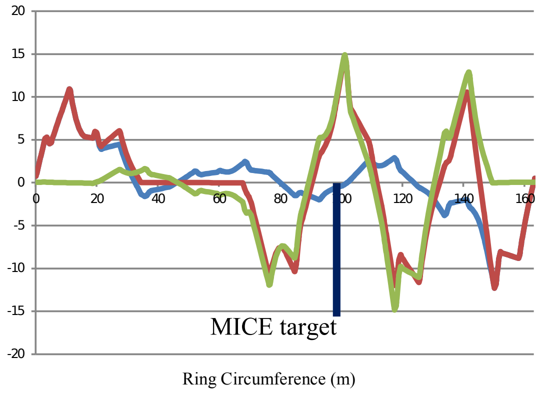

Figure 2: MICE op trajectory (green), ISIS extraction trajectory (blue), Sum Trajectory (red).

During commissioning a 2 mm bump was applied to the beam and the MICE target measured a 1.8 mm movement in the beam edge. Beam losses could be optimised by steering the beam away from the target from 6-8 ms (∼ -2 mm), towards the target from 8-9 ms and then holding beam position constant from 9-10 ms (+4 mm). Figure 3 shows this has reduced almost all ring beam loss from 6-8 ms.

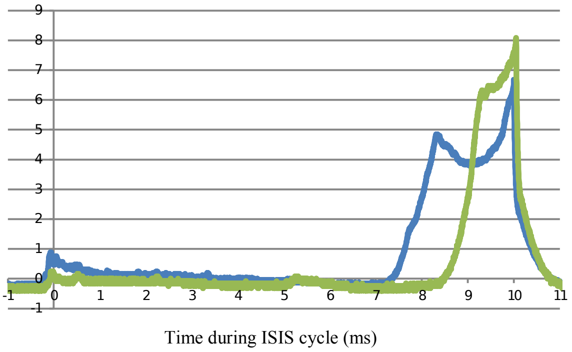

Figure 3: Total Ring beam loss bump off (blue), on (green).

The addition of recent power supply upgrades to vertical steering magnets and new control software will enable +/- 10 mm bumps to be applied as requested for any given target depth.

EFFECT OF THE BUMP ON MICE

... is helpful.

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