SOLID ABSORBER PROGRAM STATUS FOR MICE STEP IV[*]

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Abstract

In the Muon Ionization Cooling Experiment (MICE), muons are cooled by passing through material and then through RF cavities to compensate for the energy loss, which reduces the transverse emittance. In addition to demonstrating the transverse emittance reduction using flat solid absorbers, it is also planned to demonstrate longitudinal emittance reduction via emittance exchange in MICE by using a solid wedge-shaped absorber in MICE Step IV. The current status of the simulation and design effort for both flat and wedge-shaped solid absorbers is summarized.

MICE STEP IV MEASURENT PROGRAM

The Muon Ionization Cooling Experiment (MICE) [1] is an international experiment based at Rutherford Appleton Laboratory in the U.K. Ionization cooling is achieved in the MICE baseline by the placement of absorbing material in the beam line. The absorbing material reduces beam momentum, which is replaced only in the longitudinal direction by acceleration in RF cavities, resulting in a net reduction of emittance. Overall, transverse emittance is reduced while longitudinal emittance stays the same or increases slightly due to stochastic processes in the energy loss.

Transverse muon cooling will be demonstrated in MICE Step IV, first with the liquid hydrogen absorber (Fig. 1(a)), and then with a set of flat solid absorbers (Fig. 1(b)). The primary material to study is LiH (low-Z solid) with some of the essential parameters summarized in Table 1. Depending on the time available for running in the Step IV configuration, other materials will be studied, such as polyethylene and copper. The main aim is to measure equilibrium emittance for different materials and experimentally test cooling theory predictions under a variety of conditions (different emittances, particle momenta and optics parameters).

In addition to that, longitudinal emittance reduction will be demonstrated via emittance exchange. In emittance exchange a dispersive beam is passed through a wedge-shaped absorber (Fig. 1(c)). Muons with higher energy pass through more material and experience greater momentum loss. In this way longitudinal emittance of the beam can be reduced either in addition to, or even instead of,
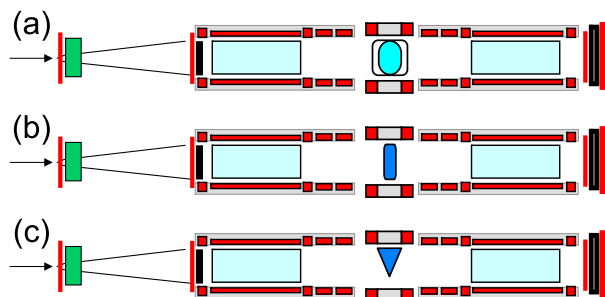
Figure 1: MICE Step IV configurations: (a) with liquid hydrogen absorber, (b) with a flat absorber, (c) with a wedge-shaped absorber.

Table 1: LiH Disk and Wedge Absorber Parameters

Parameter	Value
Material	LiH
Density	0.82 g/cm^3
Radiation length, X_0	79.62 g/cm^2
dE/dx (at 200 MeV)	1.92 MeV/(g/cm^2)
Flat absorber specific	
Thickness	65.0 mm
Disk radius	225 mm
Mass	8.4 kg
Norm. equilibrium emittance	2.9 mm
Wedge (half-wedge) absorber specific	
Thickness	75.4 mm
Wedge radius	160 mm
Wedge height	197.7 mm
Opening angle	90(45) deg
Mass	7.336 (3.668) kg

transverse emittance reduction. Emittance exchange is vital for the cooling section of a Muon Collider and has been considered as an upgrade option to the Neutrino Factory. The measurement of longitudinal emittance reduction in MICE will test the accuracy of the absorber physics models in a different geometry, demonstrate that the physics of emittance exchange is well understood, and demonstrate emittance exchange in a real magnetic lattice. Two configurations will be studied: with a 90° opening angle LiH wedge, and a 45° opening angle half-wedge.
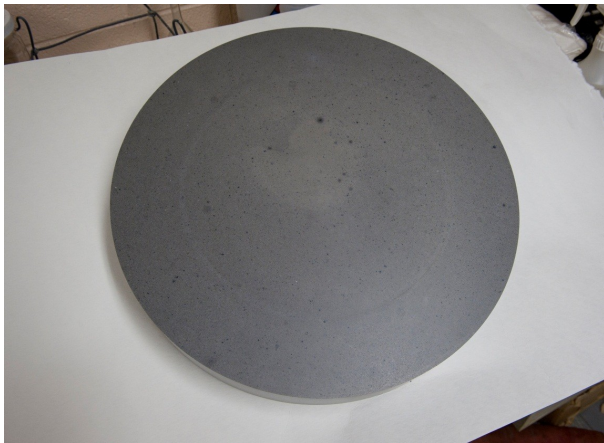
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Figure 2: LiH disk absorber, complete and coated.

SOLID ABSORBER STATUS

Depending on the time available for running in the Step IV configuration, one or more materials will be tested. A solid LiH disk, shown in Fig. 2, will be studied in detail under a variety of conditions, with other materials getting less priority. The LiH disk is now complete, coated and ready to be shipped to Fermilab for further testing.

A recent study of the disk positioning tolerances and overall support structure requirements yields the following results. The absorber support structure should support a range of thicknesses from 8 mm (copper) to 65 mm (LiH), and a mass range of 8.4 to 11.3 kg for 450 mm diameter disks. The absorber must be placed at the magnetic center of the absorber focusing coil (AFC) module and aligned to be perpendicular to the beam axis (Fig. 3(a)). The magnetic center of the module is taken to be on the longitudinal axis of the two coils and midway longitudinally between the coils. The beam axis should be taken to be the same as the longitudinal axis of the coils; i.e. of the cold mass. The absorbers should be positioned to better than ± 2 mm transversely with respect to the beam axis, and to better than ± 2 mm longitudinally with respect to the magnetic center of the AFC module. The absorbers should be aligned to be perpendicular to within $0.5°$ of the beam axis. The support should provide sufficient mechanical support to allow safe and easy insertion of the disks into the bore of the module and hold the disks securely in place. No ferromagnetic materials should be used in the construction of the supports; materials with a high electrical conductivity should generally be avoided.

WEDGE ABSORBER STATUS

The choice of wedge absorbers was narrowed down based on previous studies [2, 3, 4]. Two opening angles were chosen to be $45°$ and $90°$ so that the full wedge could be comprised of two half-wedges for which the parameters are shown in Fig. 4 and listed in Table 1. A single half-wedge can also be mounted inside the AFC module inde-
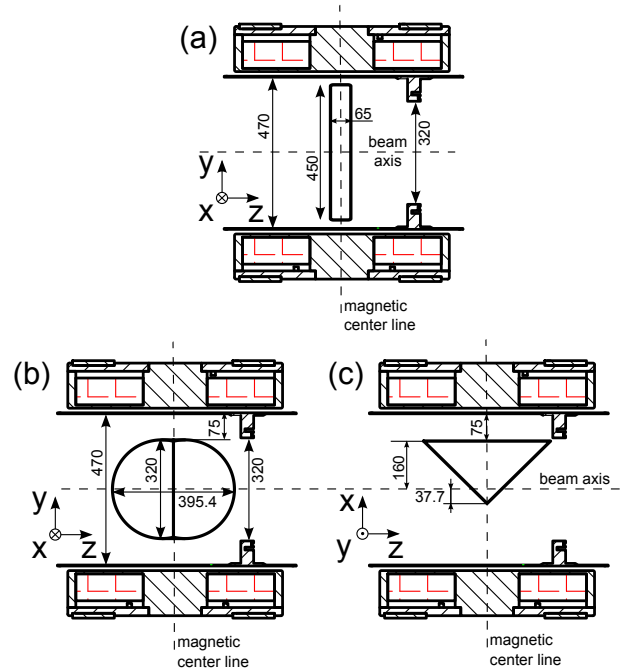

Figure 3: Positions of solid absorbers inside the AFC module: (a) flat absorber, (b) wedge absorber side view, (c) wedge absorber top view.

pendently. The support is being designed allowing both configurations. One of the preliminary designs is shown in Fig. 5.
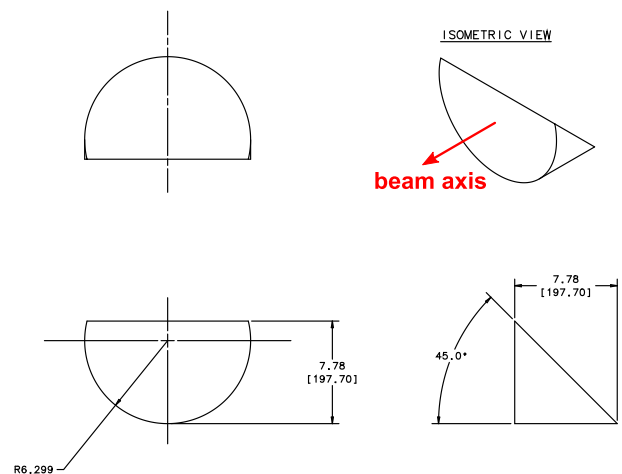

Figure 4: Engineering drawing of the half-wedge. The wedge is comprised of two identical half-wedges that could also be used separately.

The exact position of the full wedge inside the AFC module is shown in Figs. 3 (b) and (c). It can be seen immediately that the primary orientation of the wedge is not symmetric with respect to the plane defined by the vertical axis and the beam axis, which the wedge support should account for. The other requirements were defined based on the same approach as for the flat absorber, but the out-
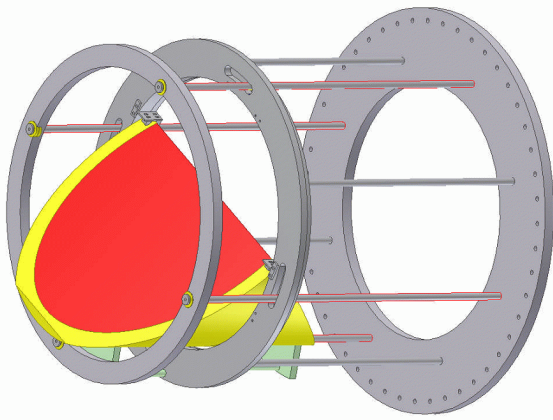
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Figure 5: One of the preliminary wedge absorber support designs.

Table 2: Summary of Position and Alignment Tolerances for the Wedge and Half-wedge Absorbers

	Wedge	Half-wedge
Positional tolerances		
Vertical (along y)	± 10 mm	± 10 mm
Horizontal (along x)	± 2 mm	± 4 mm
Long. (along z)	± 2 mm	± 2 mm
Rotational tolerances		
Rot. around x (at $R = 160$ mm)	0.14 rad ± 22 mm	0.14 rad ± 22 mm
Rot. around y (at $R = 160$ mm)	0.082 rad ± 13 mm	0.02 rad ± 3.2 mm
Rot. around z (at $R = 160$ mm)	0.013 rad ± 2 mm	0.025 rad ± 4 mm

come is quite different due to the fact that the absorber is no longer flat.

The wedge absorber support should meet the following specifications:

- Should accommodate both the full 90° wedge and the 45° half-wedge in such a way that the absorber thickness on the beam axis is 75.4 mm.

- A 90° wedge comprised of two half-wedges should be locked onto the support in such a way that the pressure between the two half-wedges is uniform over the contact surface.

- The two half-wedges should not be glued or otherwise connected together permanently so that a single 45° half-wedge can be used separately.

- Besides the primary position of the wedge, other positions should be supported representing a rotation around the beam axis in increments of 90° (this can be achieved by re-mounting the wedge absorber support onto the upper flange of the AFC in different orientation no moving parts required in the support itself).

- The position and alignment of the wedge and half-wedge should lie within the tolerances summarized in Table 2, where the axes are as shown in Figs. 3 (b) and (c). Details on how these numbers were obtained are presented in [5].

The rest of the requirements repeat those for the flat absorbers:

- Provide sufficient mechanical support to allow safe and easy insertion of the wedge (7.336 kg) into the bore of the module.

- Hold the wedges securely in place whilst the module is inserted into, or removed from, the beam line, taking into account that the primary orientation of the wedge and half-wedge is not symmetric in the transverse direction with respect to the vertical axis.

- No ferromagnetic materials should be used in the construction of the supports; materials with a high electrical conductivity such as aluminium should be avoided.

SOLID ABSORBER PROGRAM RUN SCHEDULE

Step IV measurements span at least three running periods for the minimum program and can span over a full year with useful but of lesser priority measurements. Two different absorbers can be studied per period, so at least six different configurations will be studied altogether:

- No absorber and LiH flat absorber.

- Copper or polyethylene flat absorber and half-wedge absorber.

- Full wedge absorber (two spatial orientations).

The Step IV solid absorber program is expected to start by the end of 2012.

REFERENCES

[1] An International Muon Ionization Cooling Experiment (MICE), Proposal to the Rutherford Appleton Laboratory, Tech. rep. MICE-NOTE-GEN-0021, 2003.

[2] C. T. Rogers, P. Snopok, Wedge Absorber Simulations for the Muon Ionization Cooling Experiment, Proc. COOL 2009.

[3] C. T. Rogers, P. Snopok, L. Coney, A. Jansson, Wedge Absorber Design for the Muon Ionisation Cooling Experiment, Proc. IPAC 2010.

[4] C. T. Rogers, P. Snopok, L. Coney, G. Hanson, Wedge Absorber Design and Simulation for MICE Step IV, Proc. PAC 2011.

[5] P. Snopok, MICE wedge absorber support specifications, Tech. rep. MICE-NOTE-GEN-0354, 2011.