SOI: International Muon Ionisation Cooling Experiment (MICE)


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Ionisation cooling of muon beams is included in the baseline design of both the US and European Neutrino Factories. The physics program for these facilities is broad, and outlined elsewhere. One of the key measurements would be an observation and measurement of CP violation in the lepton sector. [1]

Ionisation cooling is used to reduce the phase space volume of a muon beam generated by pion decay so that the beam can be injected into a conventional accelerator. An increase of at least a factor of ten in neutrino flux from a Neutrino Factory is expected using muon cooling. This increase is crucial for the success of the physics programme at a Neutrino Factory. In addition, the Neutrino Factory cooling system will provide a step toward the cooling necessary to build a muon collider. Muon cooling has never been demonstrated experimentally and such a demonstration is considered a key test before construction of a Neutrino Factory can begin. [2]

The MICE experiment seeks to demonstrate muon cooling in a fully engineered section of cooling channel, and to explore any differences in performance between the realization and simulation of the channel. The experiment is based on the idea of measuring single muons traversing the channel and reconstructing a synthetic beam offline. The emittance of this beam will be calculated and compared to the results of simulation. By varying parameters in both the experiment and the simulation, the full parameter space of the cooling channel can be mapped. The purpose of this mapping is two-fold; it demonstrates that cooling can be achieved in a physically realizable system and it allows tuning of the simulations so that the channel can be optimised with confidence.

Figure 1 shows the layout of the experiment. An incoming beam is scattered by two layers of lead in order to generate a high emittance input beam. Individual particles are tracked through a solenoidal spectrometer in order to determine their momentum and position at the entrance of the cooling channel. They traverse the cooling channel, which contains liquid hydrogen absorbers, RF accelerating cavities and super-conducting magnets. Another spectrometer at the end of the system measures the outgoing position and momentum. A time-of-flight system and an electron identification system are used to remove incoming pion contamination and decay electrons, respectively.

British groups have played a decisive role in creating the MICE collaboration, and the Rutherford Lab will host the experiment. The MICE collaboration is international, however, with strong groups from Europe, North America and Japan. There are four main systems in the experiment; the magnets, the RF, the liquid hydrogen...
absorbers and the instrumentation. The UK has involvement in each of these systems. As the host of the experiment, the UK should plan to make contributions to all of the systems, in order to maximize the benefit of having the focus of Neutrino Factory research in the UK. This benefit can extend to both the scientific and industrial communities in the UK, because the science at a Neutrino Factory is compelling, and the technology required is state of the art. In particular, UK industrial involvement in MICE would generate the expertise and opportunity for the UK to supply some or all of the components for the cooling section of a Neutrino Factory, wherever it is built.

The UK groups have already had a significant impact on the design of the instrumentation, especially in the design of the tracking system. In order to capitalize on this work, it will be necessary to allocate significant resources to the prototyping and construction phases of the tracking system. This should begin as soon as possible and includes engineering effort for the mechanical and electrical design of the experiment, funds for prototyping the electrical design and eventually funds to build the system itself.

An important area that presents both a scientific and industrial opportunity is the design and construction of the magnets. The design of the magnets is driven by the requirements of the tracking system and of the cooling channel. The UK groups therefore have a strong interest in this area. In addition, there is world-class expertise both in academic and industrial groups, that can be brought to bear on the design and construction of the magnets.

The UK is collaborating on the design of the liquid hydrogen absorbers, building on expertise in finite element analysis at Oxford to design ultra thin aluminium windows. This activity naturally expands to include work on the cooling of the absorbers in the presence of RF radiation and the muon beam and safety issues associated with working with large volumes of an explosive cryogenic liquid.

As the host of the experiment, the UK will need to provide infrastructure and support for the RF systems. In addition, refurbishing existing RF equipment will help meet the power amplifier needs of the experiment. A significant amount of expertise and equipment already exists based on work with ISIS. The MICE RF system will achieve higher fields than have ever been produced at that frequency, and draws on expertise from around the world. The UK will need to be involved in the development of these cavities.

A cost estimate for MICE has been prepared [3]. Estimates of the resources required for us to have a decisive impact in each of the four key areas defined above are given in the table that follows. The MICE schedule is to begin construction and commissioning in 04/05. The duration of the experiment will be several years. The estimated costs include requisitions and man-power and are based on a realistic UK share of the total MICE cost. For personnel, there is some overlap with the early sections of the Neutrino Factory SOI.

<table>
<thead>
<tr>
<th>Area</th>
<th>Cost (k£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure refurbishment</td>
<td>1000</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>1000</td>
</tr>
<tr>
<td>Magnets</td>
<td>2500</td>
</tr>
<tr>
<td>RF</td>
<td>1500</td>
</tr>
<tr>
<td>Absorber</td>
<td>1000</td>
</tr>
<tr>
<td>Total</td>
<td>7000</td>
</tr>
</tbody>
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Table 1: Estimated resources required.


