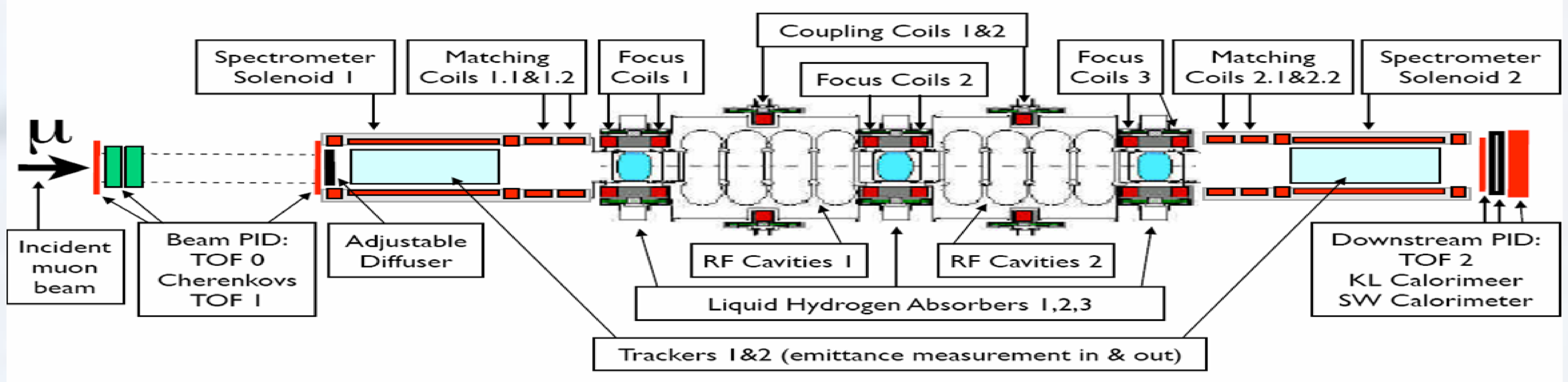
Measurement of Emittance and Emittance Reduction in the Muon Ionization Cooling Experiment

Vassil Verguilov, University of Geneva—DPNC (on behalf of MICE Collaboration)

Neutrino Factory

The Neutrino Factory, in which an intense, high-energy neutrino beam is produced from the decay of stored muon beams, has been proposed to serve a programme of precision measurements of neutrino oscillations. The Neutrino Factory has been shown to outperform second-generation superbeam and beta-beam facilities.

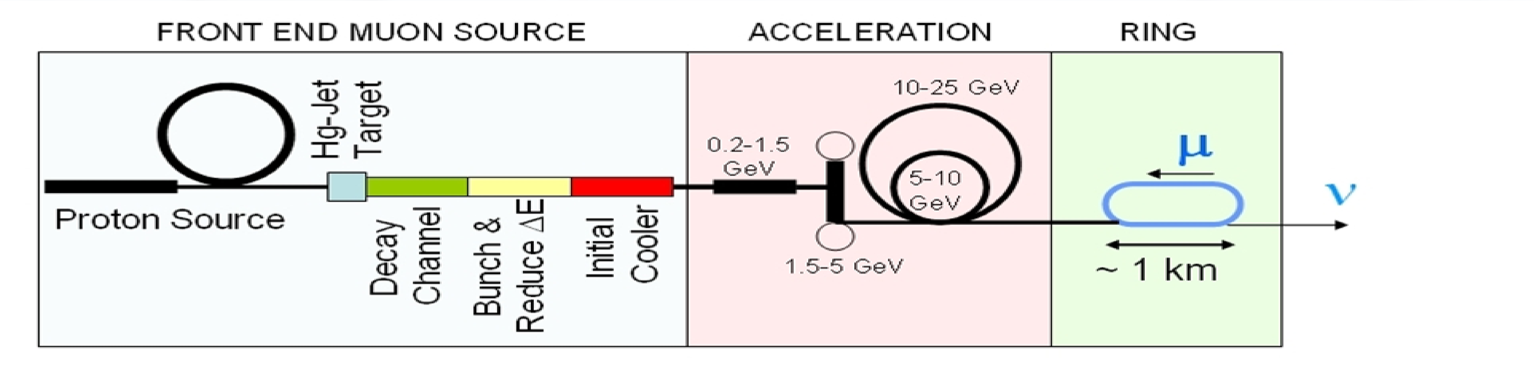
Muon Ionization Cooling Experiment



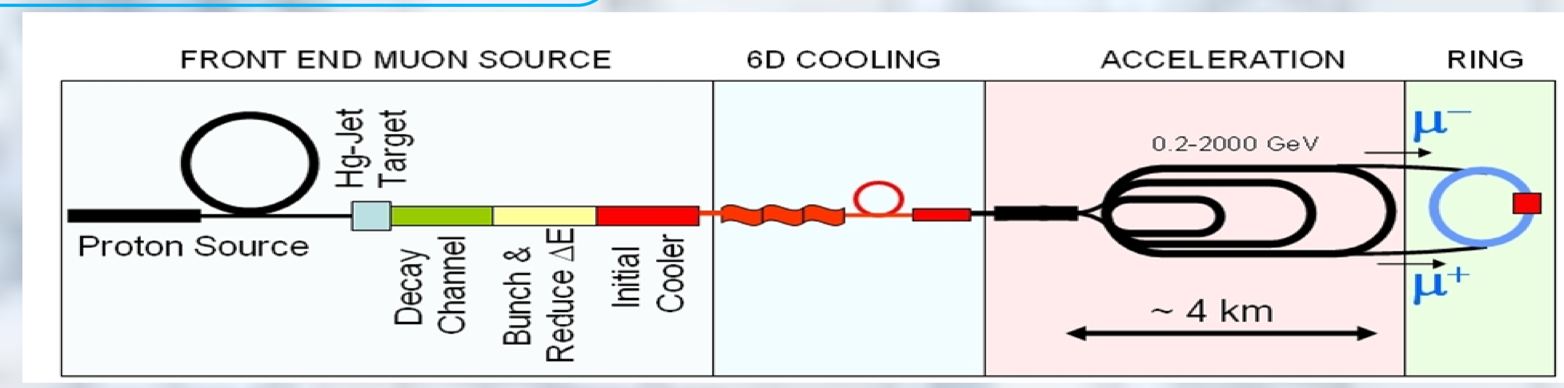
The *Muon Ionization Cooling Experiment (MICE)* is being built at the ISIS 800 MeV proton synchrotron at Rutherford Appleton Laboratory (RAL) to test ionization cooling of a muon beam. Successful demonstration of cooling is required in order to facilitate the creation of future high intensity muon beams in either a *Neutrino Factory* or *Muon Collider*. MICE should measure a 15% reduction in emittance of a muon beam with a precision of 1%.

Muon Collider

If ionization cooling can be pushed to much higher level than for neutrino factories, the phase space can be reduced to the point that significant luminosities can be reached when positive and negative muon beams are stored in the same storage ring and undergo collisions (at 2TeV the lifetime is 0.044 s). Following from this, the concept of muon collider, which accelerates and collides bunches of muons, has been introduced. It promises to be competitive with electron positron colliders and is also the object of much interest and studies.

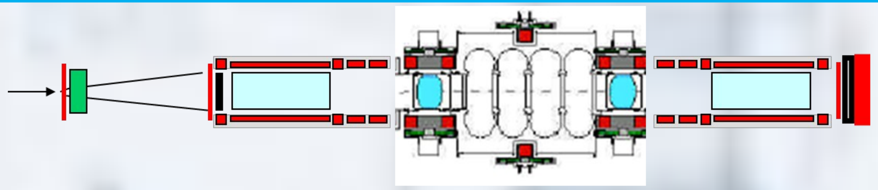


A Neutrino Factory (left) may well be a natural step towards Muon Colliders (right)



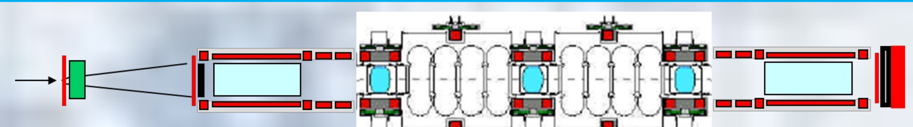
2013

Step V

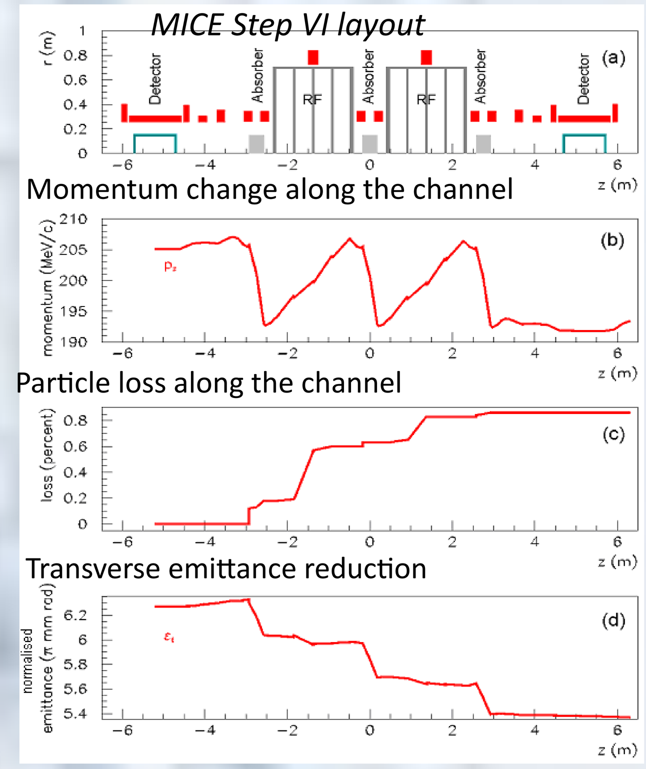


Starting from step V, the real goal of MICE, which is to establish the performance of a realistic cooling channel. 8 201.25 MHZ RF cavities with beryllium windows will be installed in the cooling section of the experiment, allowing up to 8MV/m acceleration.

Step VI

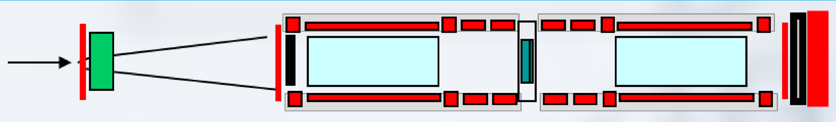


The final configuration of MICE includes a complete cell of the cooling channel. Only the central one of the three absorbers is fully representative of the SFOFO-lattice optics, since the other two must be run so as to match out of or into the spectrometers. The full Step VI configuration will also introduce the flexibility to simulate a variety of proposed lattice designs, including the "no-flip" lattice proposed at CERN.

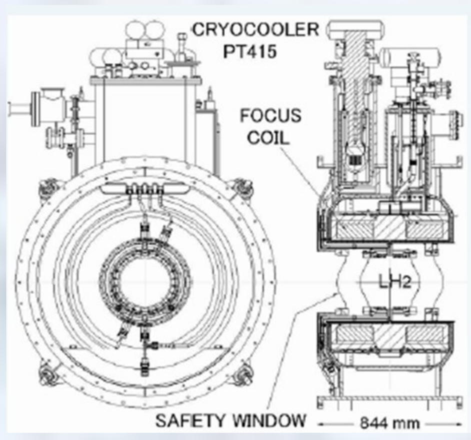


2012

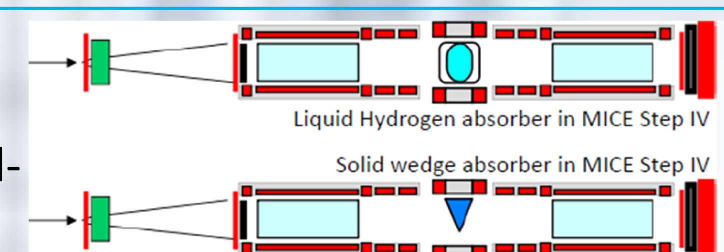
Step III



Step III is fundamental for the understanding of a broad class of systematic errors in MICE. The two spectrometers will work together without any cooling device in between and should measure the same emittance value (up to the small predicted bias due to scattering in the spectrometers material). Characterization of solid state absorbers could be performed in this step.



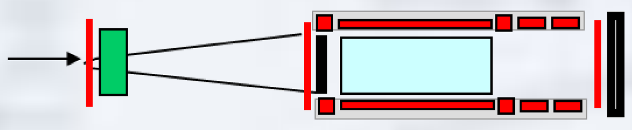
Step IV



Step IV will add one absorber focusing module, ie a Li-H absorber with one pair of focusing coils, between the two spectrometers. It should give a first experience with the operation of the absorber and a precise understanding of energy loss and multiple scattering in it. Several experiments with varying beta-functions and momentum as well as different absorbers can be performed with observation of cooling(i.e. emittance reduction) in both transverse and longitudinal dimensions.

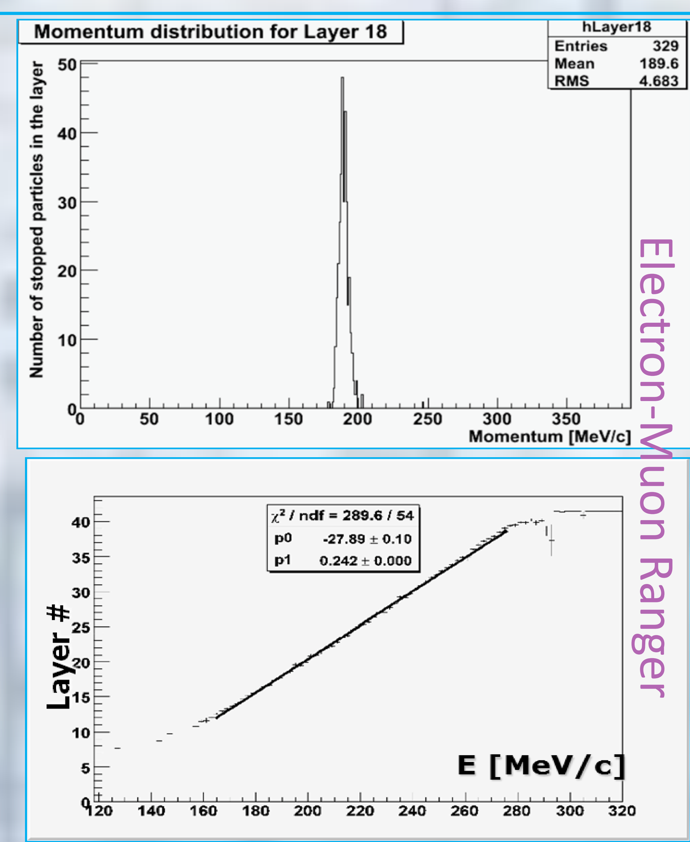
2011

Step II

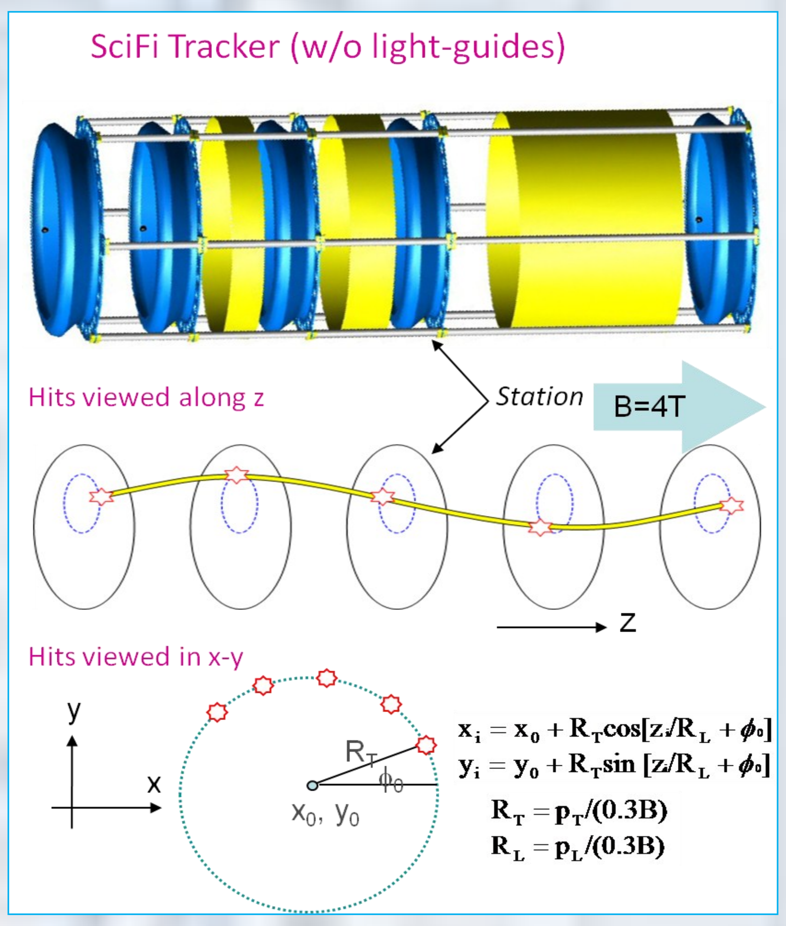


In step II the first tracker, housed in a spectrometer solenoid, allows a first measurement of 6D emittance with high precision and comparison with the beam simulation. This should allow a systematic study of the performance of the emittance measurements. The tracker has 5 stations with three planes of 350 mm fiber doublets to give an accurate point in space. MICE has two identical (upstream and downstream) trackers. Both trackers have been built and tested with cosmic rays. Each tracker will be immersed in a uniform 4 T field provided by the superconducting spectrometer solenoid magnets.

An Electron-Muon Ranger calorimeter made of 40 layers of extruded plastic scintillators will be added downstream to complement KL in electron/muon selection as well for additional tracking.

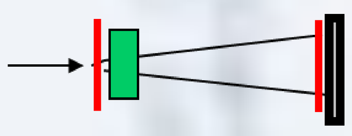


Muon range simulation in the EMR. Sum(E) vs Layer # is plotted. Muons above 270 MeV/c will range through.



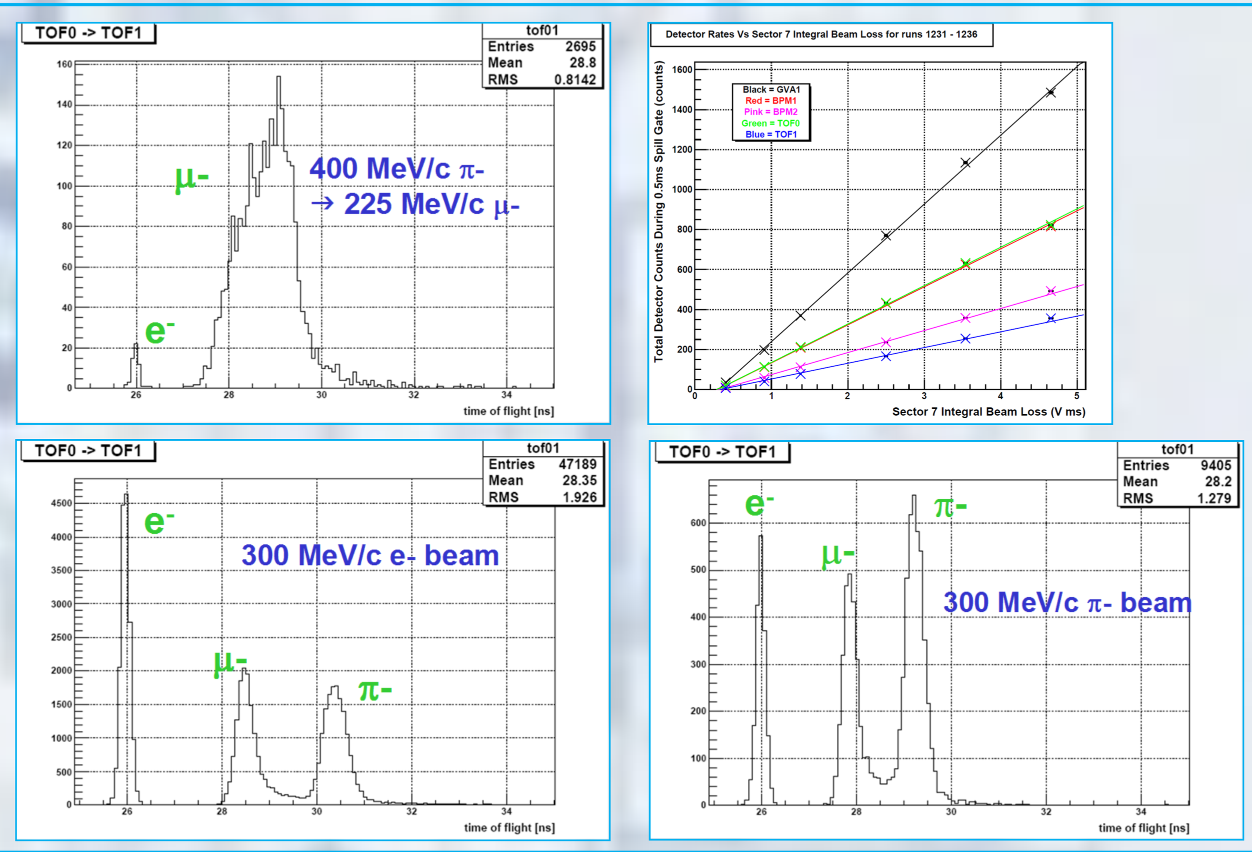
2010

Step I



The first step of MICE is the establishment and precise measurement of a muon beam. The beamline consists of a titanium target, a sets of dipole and quadrupole magnets to select and steer the beam, a solenoid to keep the pions focused while they decay, and a diffuser to generate the desired emittance. A set of particle identification detectors (3 time-of-flight hodoscopes, 2 Cerenkov counters and KL preshower (a light version of KLOE calorimeter) are used to distinguish between muons and other particles. First beam was observed in March 2008.

<u>All of the beamline components are operating according to specifications. Commissioning of the beamline and calibration of the PID detectors is almost completed.</u>



2009