Progress towards completion of MICE demonstration of ionization cooling of muons

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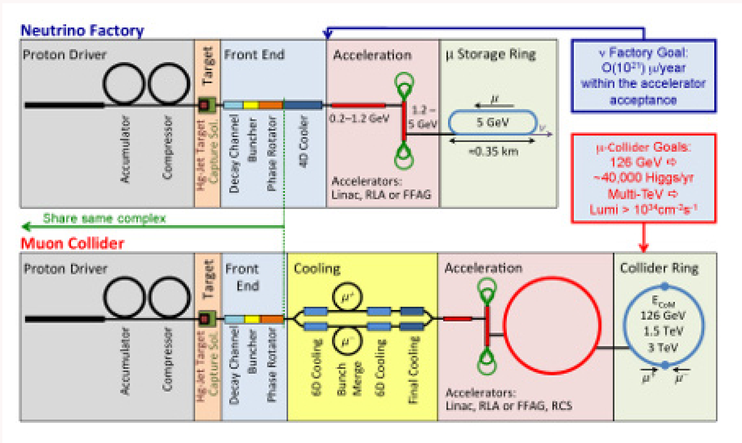
UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

1. Muon Ionization Cooling Experiment (MICE)

Motivation



Ionization cooling technique provides the only practical solution to prepare high brilliance beams necessary for a neutrino factory or muon colliders because it is fast enough to cool the beam within the muon lifetime.

Ionization Cooling

1. Energy loss by ionization (***dE/dx***)
2. Heating from multiple scattering
3. Longitudinal momentum restored by RF cavities

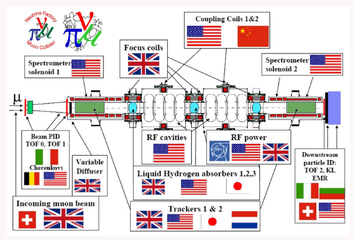
$$\frac{d\varepsilon_N}{dz} = -\frac{\varepsilon_N}{\beta^2 E_\mu}\frac{dE_\mu}{dz} + \frac{\beta_\perp (13.6MeV)^2}{2\beta^3 E_\mu m_\mu X_0}$$

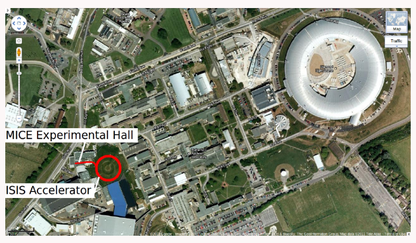
cooling heating

Equilibrium emittance ***cooling = heating***
To maximize cooling we need material with low-Z and beam channel with low $\beta_\perp$.

MICE

Based at Rutherford Appleton Laboratory (UK)



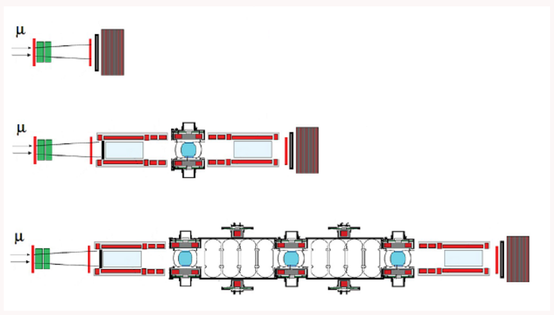


MICE collaboration: Belgium, Bulgaria, China, Holland, Italy, Japan, Switzerland, UK, USA: ∼ 150 collaborators

Goals:

- Build a section of a cooling channel that can demonstrate the principle of ionization cooling
- Achieve emittance cooling of at least 10% with a precision of 1%
- Verify the cooling performance for various configurations and beam conditions

Implementation in Steps



Step I (completed)

Step IV (2015-2016)

Step VI (2019)

The experiment will be assembled, tested and operated in steps. Each step will validate different parts of the setup. Some steps have been removed from the original schedule.

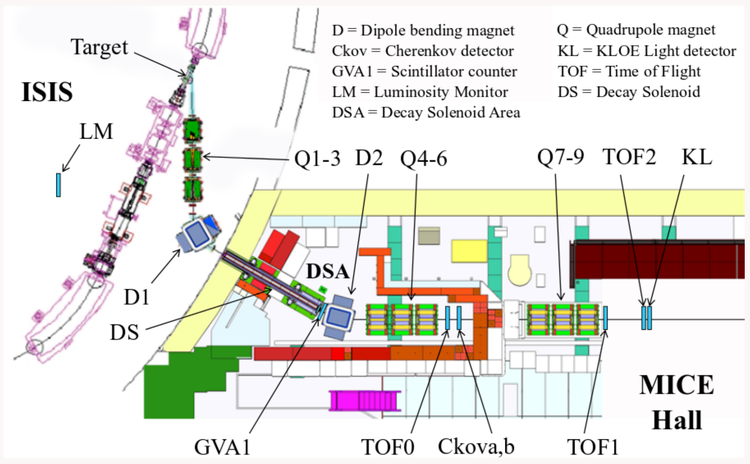
Conclusion

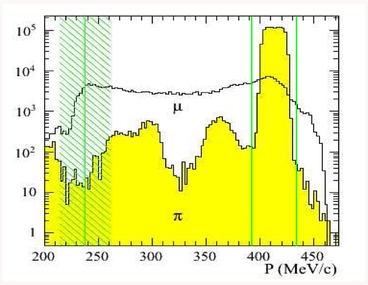
- MICE is a key R&D towards Neutrino Factory and Muon Collider

2. Step I - completed

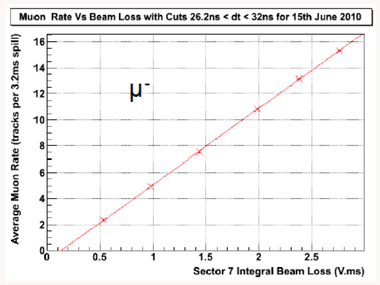
MICE beam line

MICE beam and instrumentation fully constructed and operational.



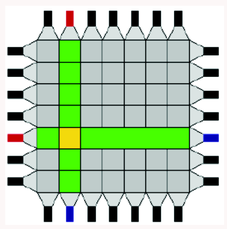


Select muons flying backward in c.m.s ⇒ optimal muon purity



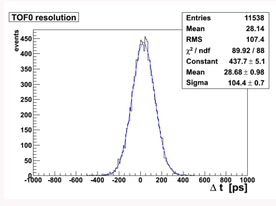
Particle rate linear with target depth/ISIS beam loss

Time-of-flight system

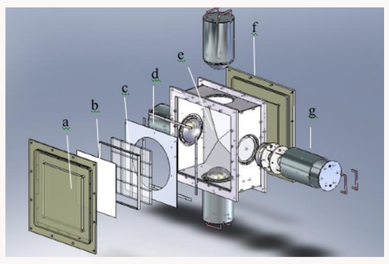


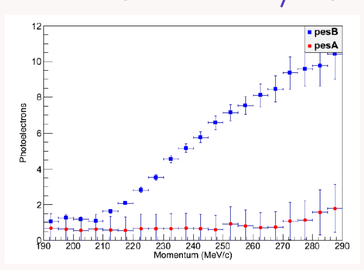
- ***X*** \ ***Y*** scintillator hodoscopes.
- Hamamatsu R4998 PMT
- CAEN V1724 FADC
- CAEN V1290 TDC

- Time resolution $\sigma_t \approx$ **50** ***ps***
- Position resolution $\sigma_x \approx$ **1** ***cm***



Two aerogel threshold Cherenkov counters (Ckov$_{A/B}$)

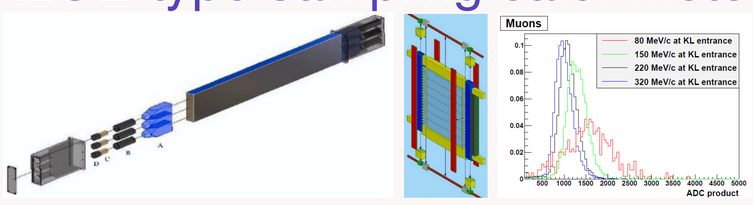




- ***Ckov$_A$*** $n_A = 1.07$
- ***Ckov$_B$*** $n_B = 1.12$

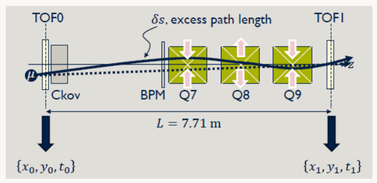
Photoelectron distributions (data, preliminary)

KLOE-type sampling calorimeter

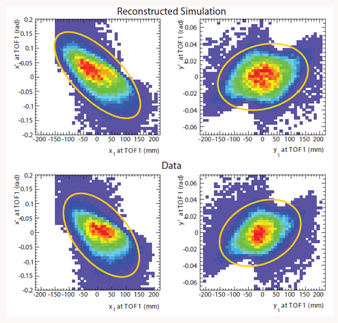


Performs electron-muon separation for 0.5 % of muons that decay inside the cooling channel.

Emittance Measurement



Developed novel method to measure emittance using TOF detectors



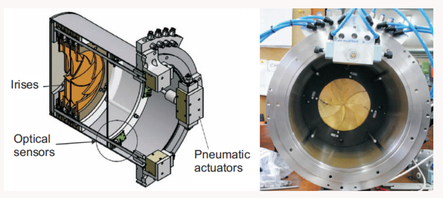
Conclusions (Step I)

- MICE beamline commissioned: over **13** $\times$ $\mathbf{10^6}$ triggers collected in Step I
- PID detectors (TOF0, TOF1, Ckov, TOF2, KL) installed and working well
- MICE Muon Beam meets requirements

3. Step IV - 2015-2016

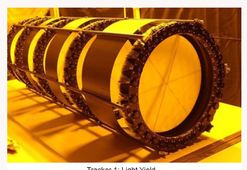
- Measure equilibrium emittance of given absorber and for given beta function
- Measurement of 6D emittance change
- Precision measurements of multiple scattering

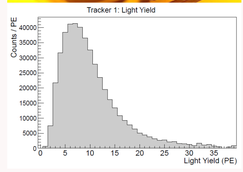
MICE diffuser



Multiple scattering in small radiation length material is used to increase the emittance

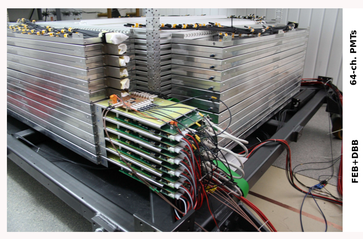
Trackers

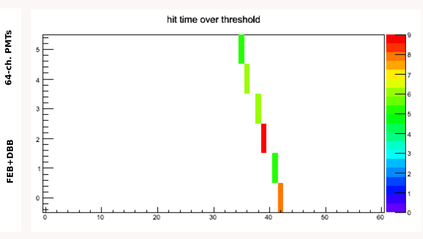




- Both trackers have been extensively tested with cosmic rays
- A spare single station of the tracker has been tested at MICE beamline
- Single station test used also to demonstrate the integration of the tracker front-end electronics with the MICE DAQ system

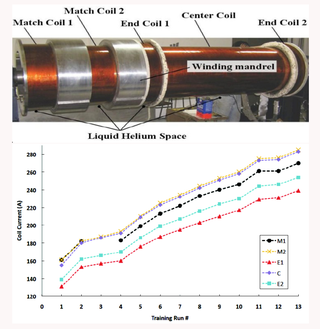
Electron-Muon Ranger (EMR)

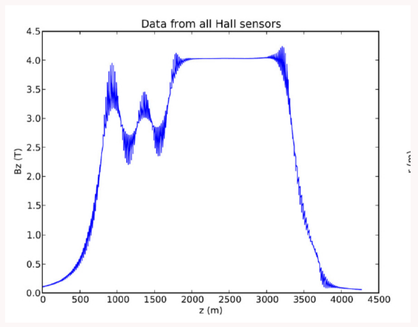




Construction is almost completed. First cosmic tracks seen. Shipping to RAL, Oct 2013.

Spectrometer Solenoids





Both Spectrometer Solenoids assembled and tested. Field mapping of SS2 completed. Shipping to RAL, Sept 2013.

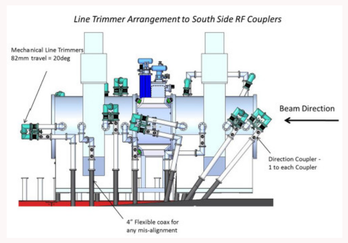
Absorber Focus Coils (AFC)

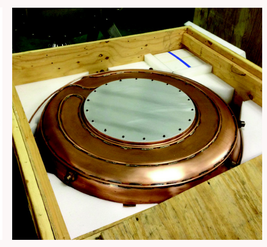
- Liquid H_2 system has been tested
- Liquid H_2 and ***LiH*** absorbers manufactured
- First AFC module being trained at RAL
- Second module to be delivered August 2013

Conclusions (Step IV)

- Trackers completed but need to be integrated with superconducting solenoids
- STEP IV in preparation and ready to take data in 2015

4. Step VI - 2019





RF cavity tests in progress.

Conclusions (Step VI)

- STEP VI ready to take data in 2019