# The Muon Ionization Cooling Experiment


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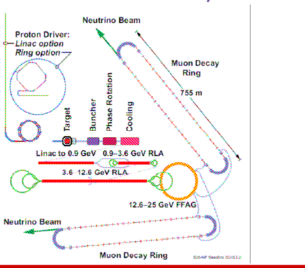
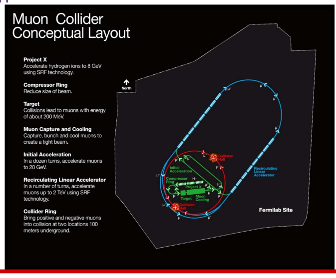
**Motivation:** Muon cooling – key step in the development of future accelerators: Neutrino Factory and Muon Collider. Benefits include:

- NF – ultimate tool for precision neutrino studies
- "Golden channel" for neutrino measurements
- significant cost saving
- increased luminosity in muon collider
- reduced site boundary radiation

$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$



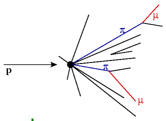




**Cooling:**

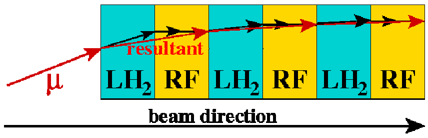
Muons are produced in tertiary reactions:

$p + N \longrightarrow \pi + X$

$\quad\quad\quad\quad \hookrightarrow \mu + X$



Created with large emittance – impractical for an accelerator. "Cooling" reduces beam spread. Short muon lifetime, $\tau_\mu$=2.2μs, dictates ionization cooling as only feasible technique.




**Cooling is:**

**1) Energy loss in all dimensions via dE/dx**

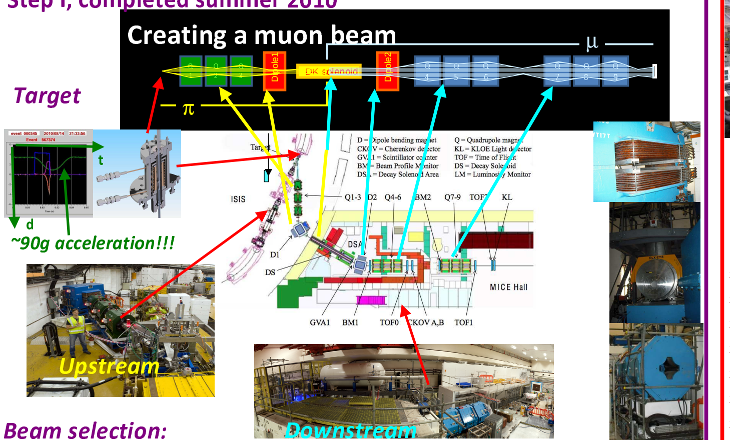
**2) Replace longitudinal momentum with RF**

$$\frac{d\varepsilon_n}{ds} = -\frac{1}{\beta^2}\left\langle\frac{dE_\mu}{ds}\right\rangle\frac{\varepsilon_n}{E_\mu} + \frac{1}{\beta^3}\frac{\beta_\perp(0.014)^2}{2E_\mu m_\mu X_0}$$

cooling     heating

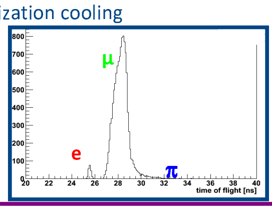
MICE will demonstrate ionization cooling for a variety of beam optics, muon momenta (140-240 MeV/c), absorbers and diffuser settings.

**Step I, completed summer 2010**

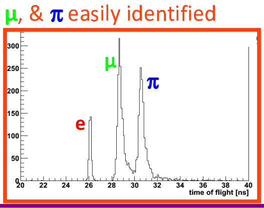



*Beam selection:*

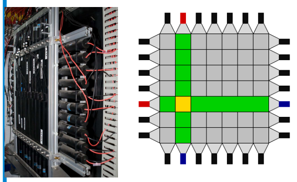
**High purity:** μ⁻ beam, small **e** & **π** contamination. Used to demonstrate ionization cooling




**Low momentum spread:** beam for calibration of the detectors: **e**, **μ**, & **π** easily identified

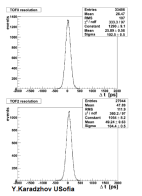



**Particle ID – *tag muons (before/after cooling)*:** measure the particle content of the muon beam, using time-of-flight detectors (TOF0, TOF1, TOF2), Čerenkov detectors, beam profile monitors, and KL (KLOE Light) calorimeter that help identify protons, pions, electrons, and muons.

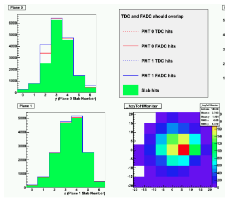


**3 Time of Flight detectors**

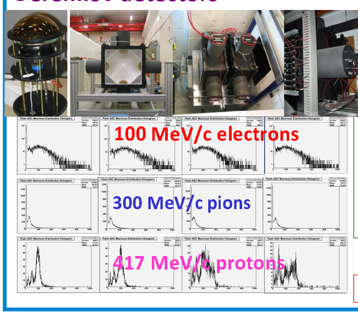
- 2 PMTs per ToF bar
- each PMT read out with:
  - TDC – time
  - Flash ADC – pulse height
- coincident PMTS – green bar
- coincident bars – space point

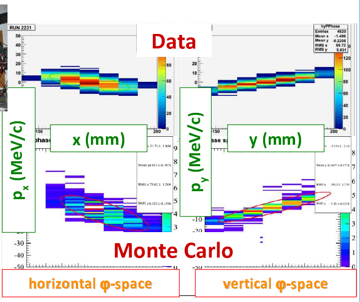



- *Time resolution after calibration:*
- *TOF0 – 51ps*
- *TOF1 – 62ps*
- *TOF2 – 52ps*
- *Resolution meets design goals for TOFs*



**Čerenkov detectors**



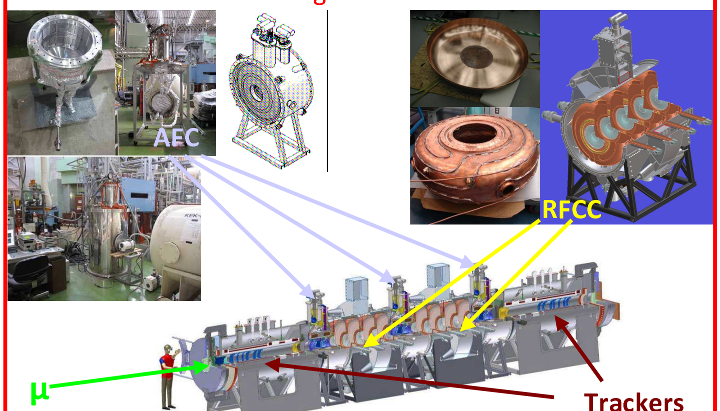




**Beyond Step I** – ***the MICE Cooling Channel***

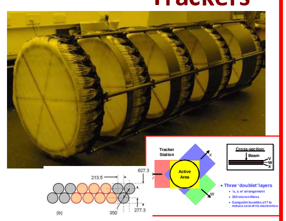
**Trackers** – measure emittance (before/after)

**AFC:** Absorber ($LH_2$ or LiH) – cooling

**RFCC:** RF–re-establish longitudinal momentum




- Two trackers – before and after
- Each measures x, y, x', y'
- 5 stations/tracker
- 3 stereo planes/station – U/V/W
- 1400 350 μm fibers/plane
- double layer, 7 fibers/group
- <0.2% dead channels
- >10.5 photoelectrons/MIP
- 430μm RMS position resolution



- *4 T superconducting*
- *2 m long*
- *20 cm warm bore*
- *5 coils:*
  - *1 main tracker coil*
  - *2 end coils*
  - *2 matching coils*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