Swiss Institute of Particle Physics

CHIPP Plenary Meeting in Appenberg
August 24-25, 2009

- MICE -
The Muon Ionization Cooling Experiment

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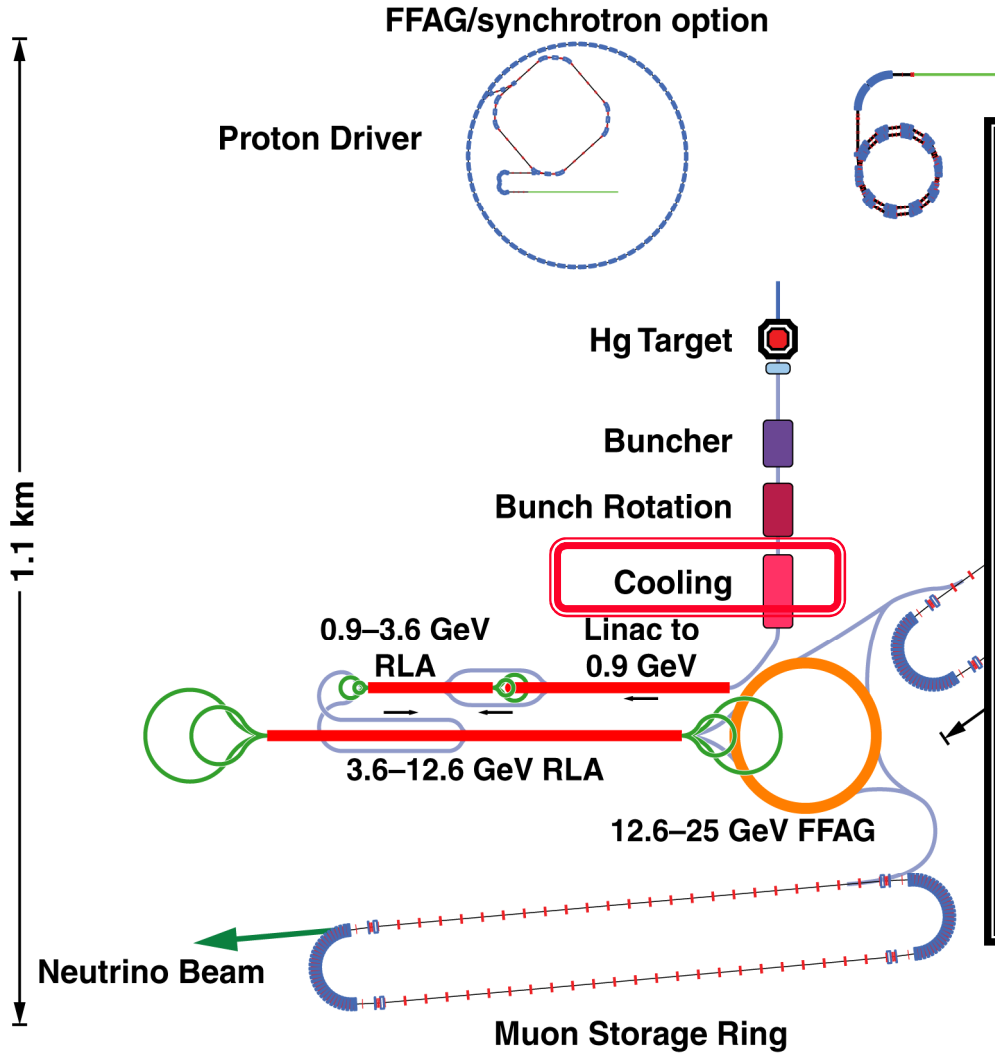
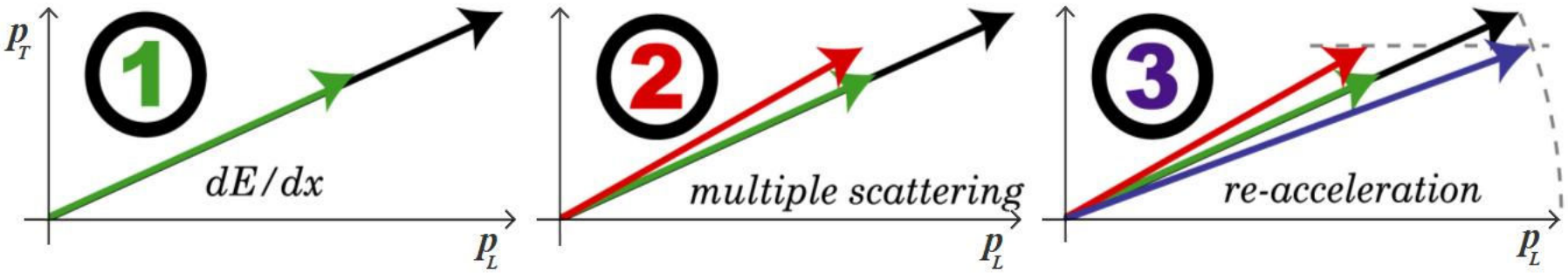
- Introduction: Aims And Concept
- Design
- Infrastructure: Hall, Target and Beamline
- Cooling Channel: Absorbers and RF
- Detectors: Spectrometer and PID
- The Electron-Muon Ranger
- Conclusion

Aims



- MICE is part of the R&D program towards the neutrino factory
- Aim at Demonstrating Ionization Cooling of a muon beam
- Validate new simulation tools for future design
- MICE is Accelerator Physics more than HEP
- MICE should deliver results in 2012-2013

Concept



- **Ionization Cooling**
  - THE only realistic solution for Muon Beam Cooling
  - Trade off between dE/dX cooling and Multiple scattering heating

$$\frac{d\varepsilon}{dz} \approx -\frac{\varepsilon}{E_\mu \beta^2}\frac{dE_\mu}{dz} + \frac{\beta_\perp}{2m\beta^3}\frac{(13.6MeV)^2}{E_\mu X_0}$$

-> Low Z material and low β_T beam

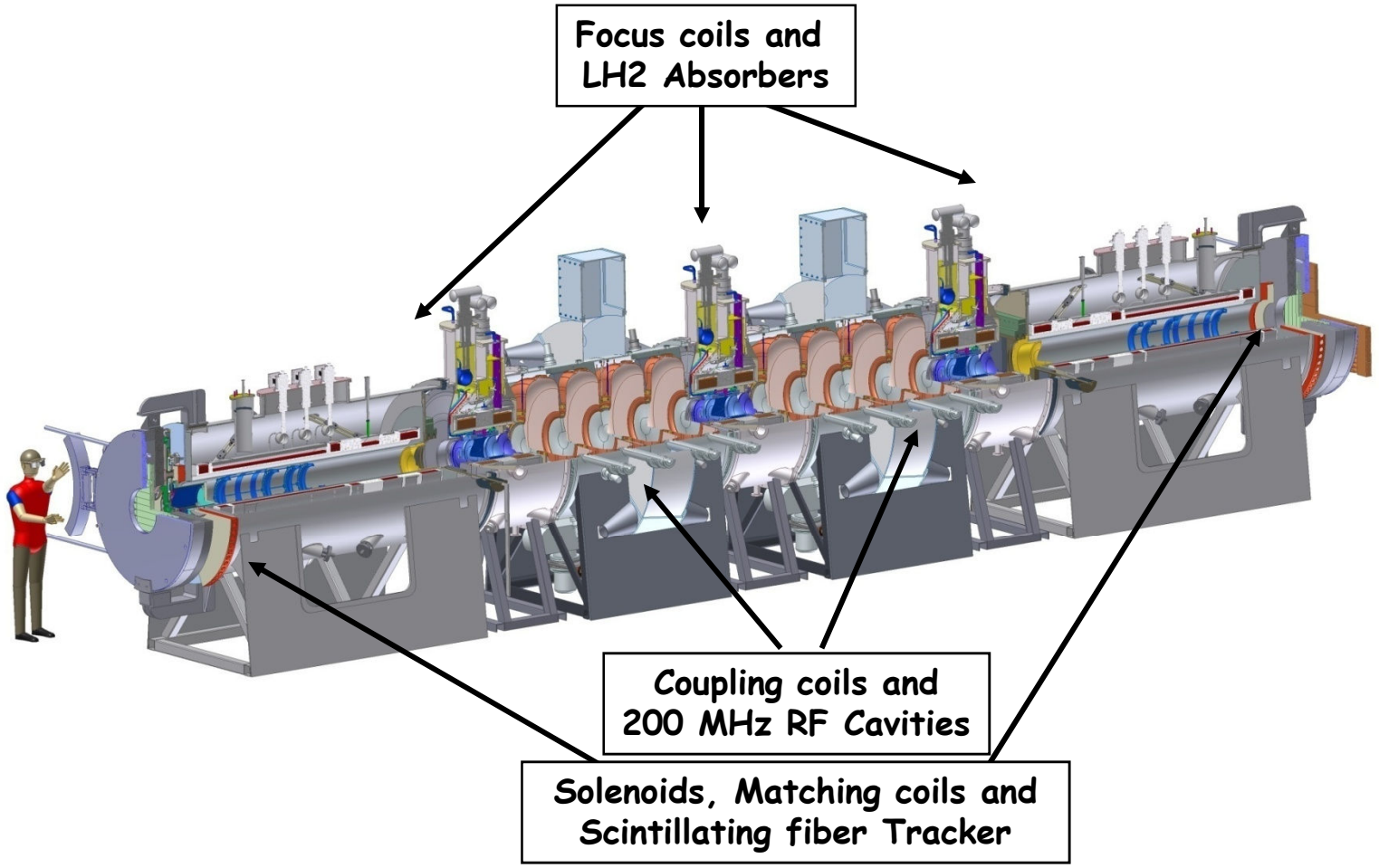
Observables

- **Position (x, y, z) and Momentum (p_x, p_y, p_z)**
  - before and after the Cooling Channel
- **Single Particle measurement necessary:**
  - Small emittance change -> need precision
  - Incoming muons not in phase with the RF
- **We expect ~10% cooling for large ε beam:**

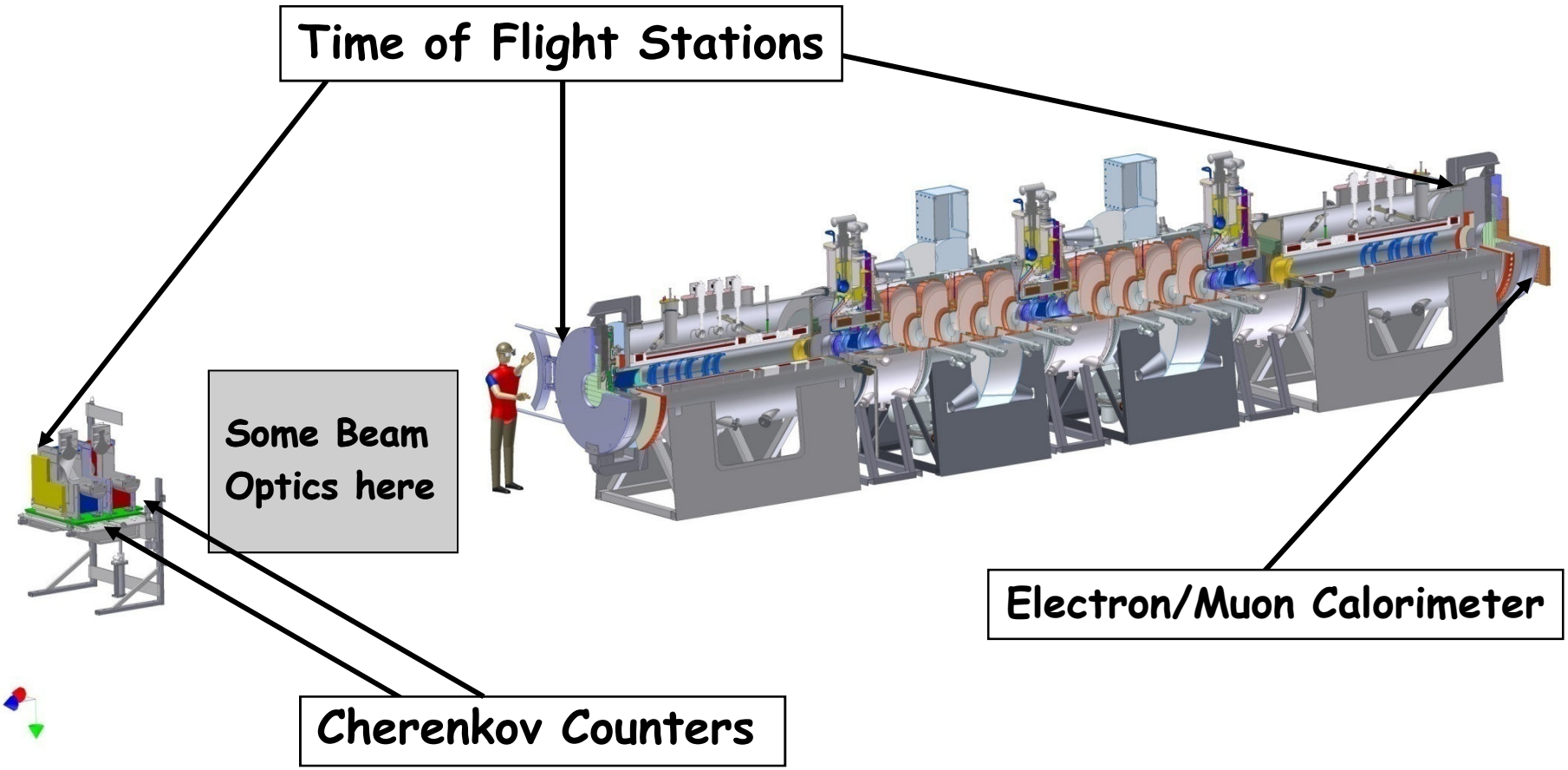
$$\Delta\varepsilon/\varepsilon = -\Delta p/p \cdot (1 - \varepsilon_0/\varepsilon)$$

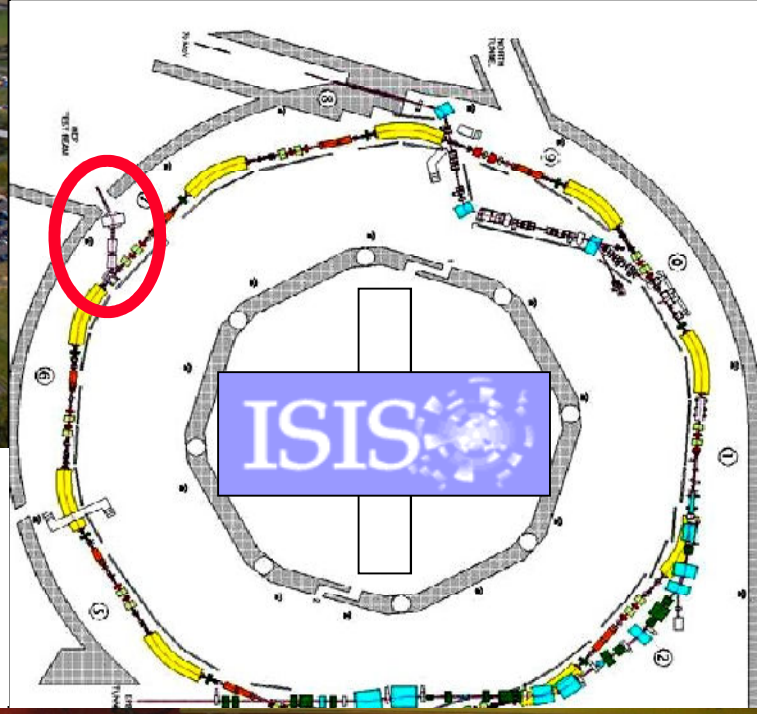
  - ~ 5 % momentum loss per absorber
  - Equilibrium emittance for LH2: ε_0 ~ 2.5 (π) mm-rad (acceptance for ν-Fact 15 – 30 (π) mm-rad)
- **Measure Δε to 1% -> measure ε to 0.1%**

MICE Design

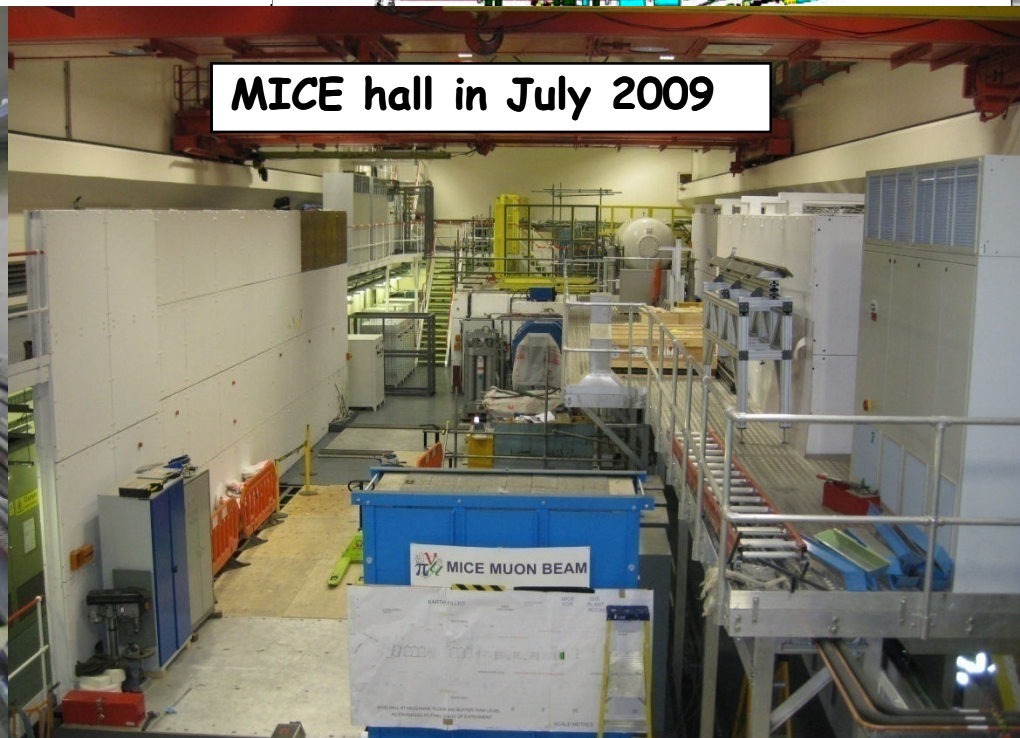

Focus coils and
LH2 Absorbers
Coupling coils and
200 MHz RF Cavities
Solenoids, Matching coils and
Scintillating fiber Tracker

MICE Design- PID



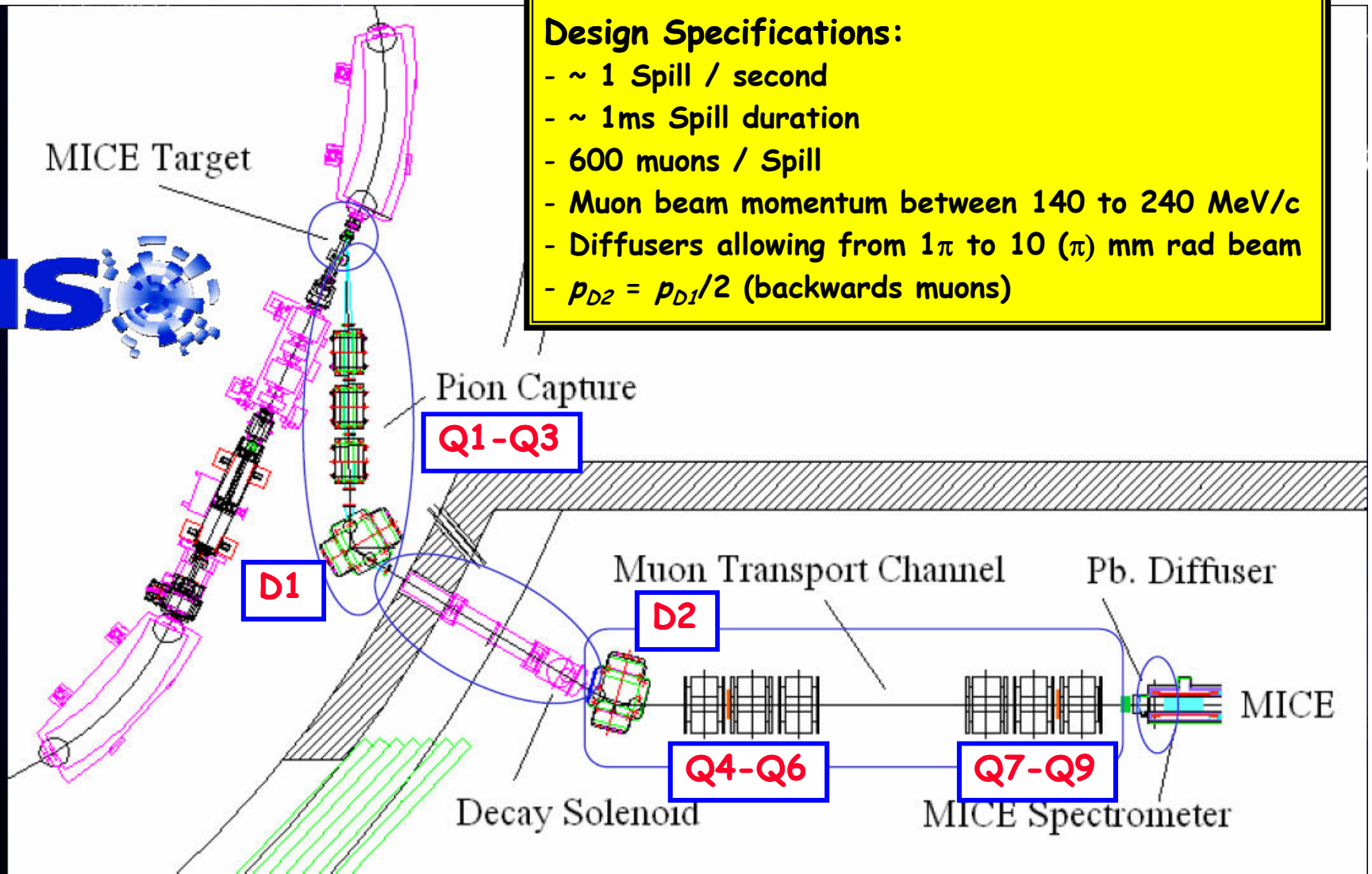


- **MICE is hosted at Rutherford Appleton Laboratory, UK**
  - Brand new muon beam line in construction
  - Built from scratch

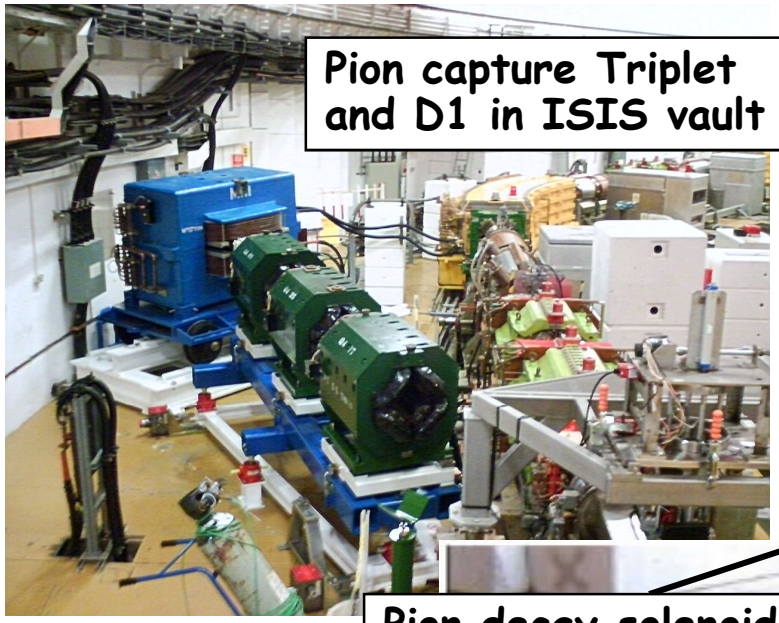


MICE Beam Line

Design Specifications:
- ~ 1 Spill / second
- ~ 1ms Spill duration
- 600 muons / Spill
- Muon beam momentum between 140 to 240 MeV/c
- Diffusers allowing from 1π to 10 (π) mm rad beam
- $p_{D2} = p_{D1}/2$ (backwards muons)

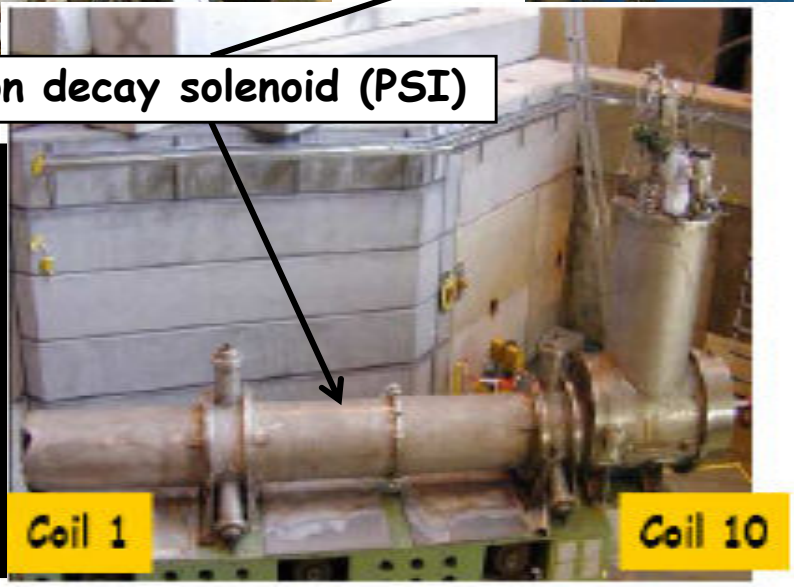


MICE Beam Line



Pion capture Triplet and D1 in ISIS vault

D2 and Second Triplet in Decay Solenoid Area



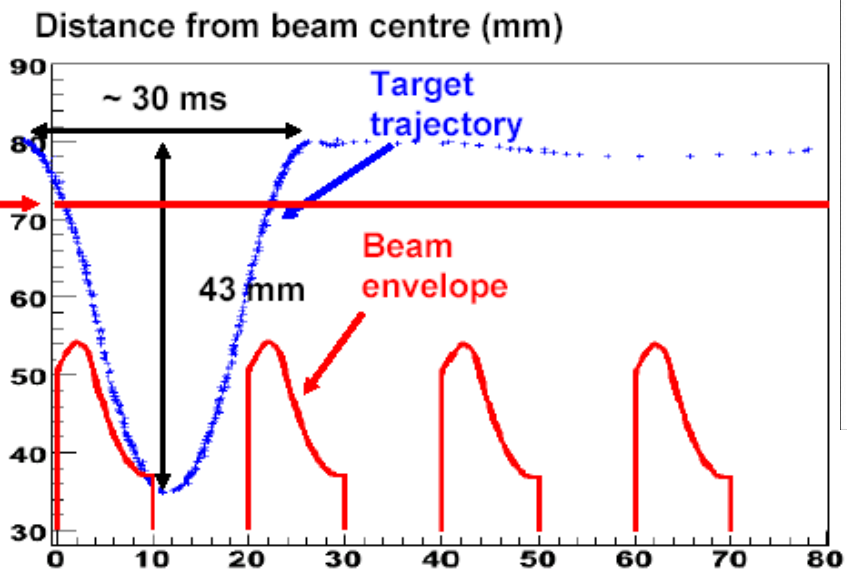
Pion decay solenoid (PSI)

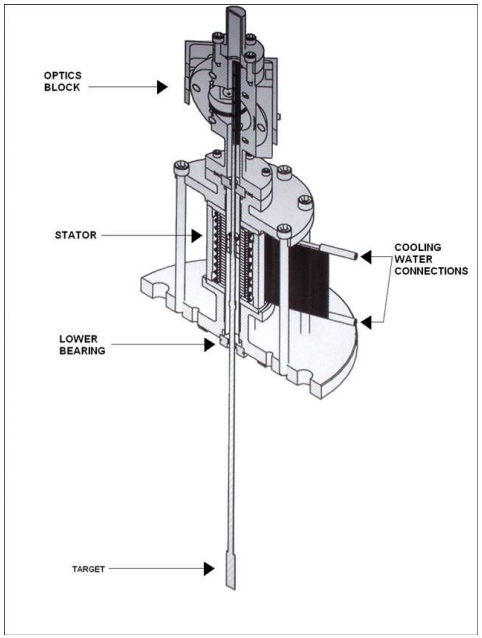
Decay Solenoid:
- Long repair needed
- Cool down to 4.5 K reached in April 09
- 48 h power test (870 Amp; 5 T) in August 09

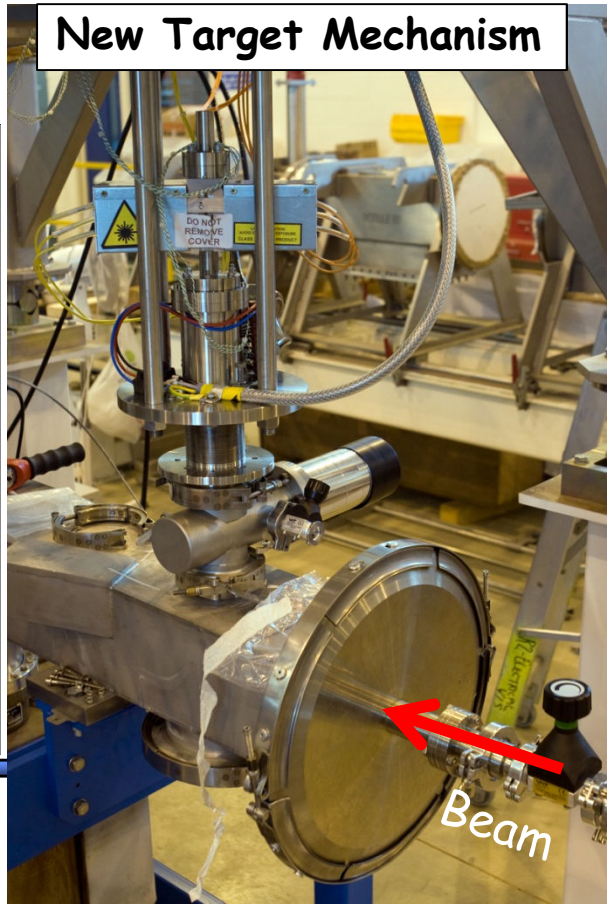
Third Triplet (Q7-Q9) + TOF and KL

MICE Target

- **A 1 mm thick Ti target is dipped into the ISIS proton beam**
  - Intercepts the beam in the last ms of the acceleration cycle
  - 80 g acceleration achieved
  - Up to 1 Hz rate repetition rate
- **Original design found unstable**
  - Engineering improved
  - New Target System being installed now

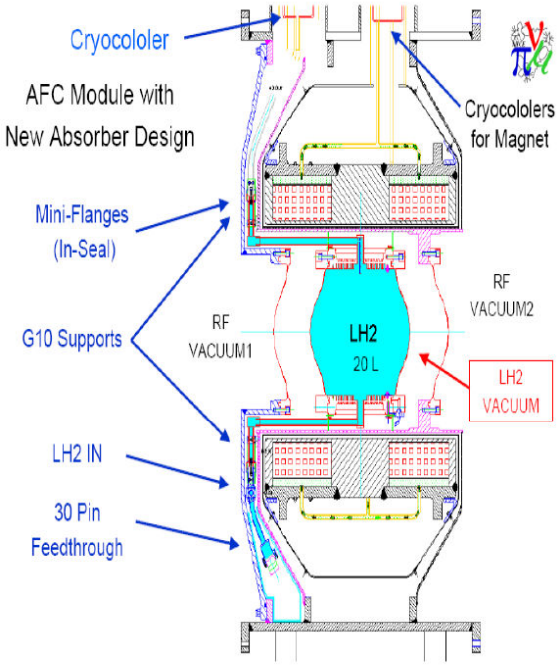






Cooling Channel

- **Liquid Hydrogen Absorbers**
  - Production of the first absorber started
  - SC Focus Coils integrated in the design
  - Delivery expected for end 2010

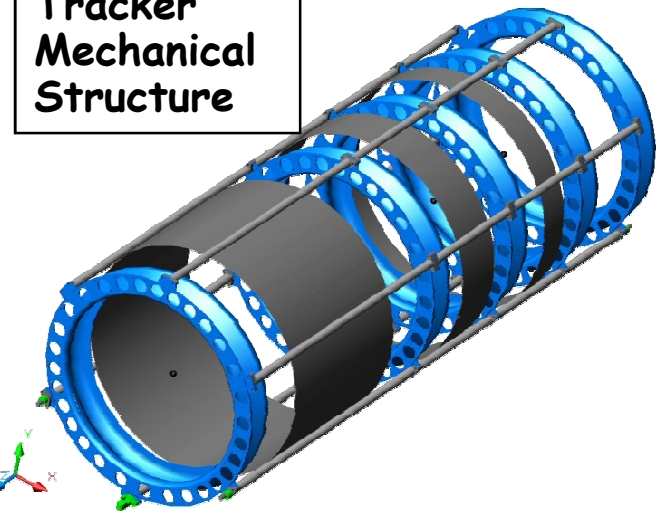


RF Cavity Prototype

- **RF Cavities**
  - 201.25 MHz
  - Copper-niobium
  - 4 cavities per module + 1 large SC Coupling coil
  - Peak input RF power ~ 4.6 MW per cavity
  - Gradient: ~ 16 MV/m
  - Production has started – Delivery end 2011

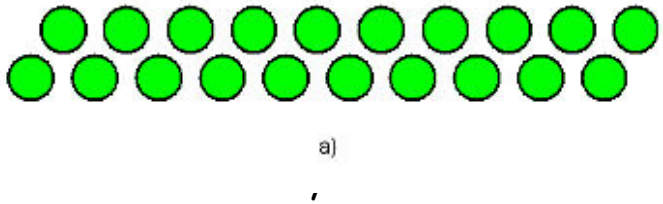
Sci-Fi Tracker

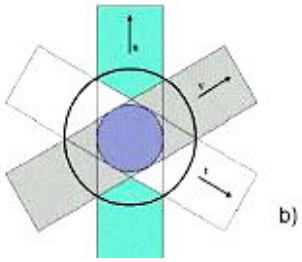
Tracker Mechanical Structure

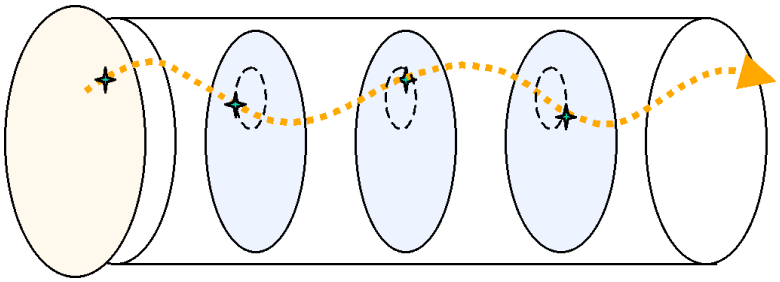


Tracker Fiber routing

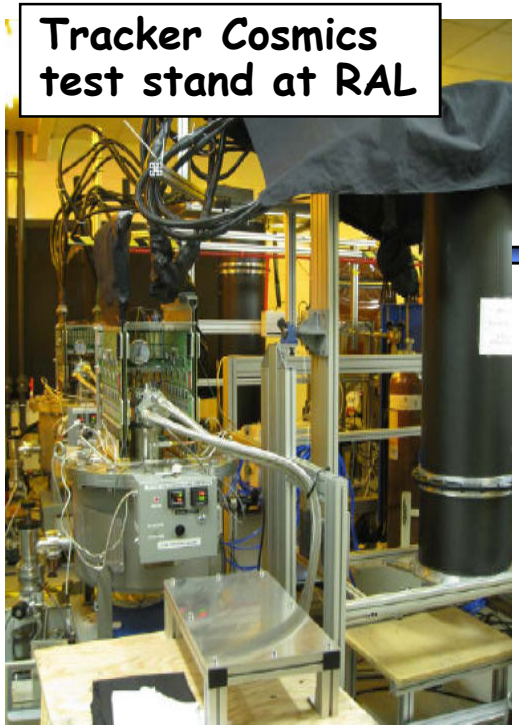
- 5 stations of scintillating fibers
- 3 projections per station
- Two layers, each 350 μm diameter
- Minimize material in beam line
  - Few photons
  - VLPC readout (same as D0)
    - QE = 85%, gain = 50000, dedicated FEE
- Simulated Performance @ B ~ 4T
  - ΔP_T = 1.5 MeV/c; ΔP_Z = 3 MeV/c
    for 200 MeV/c muons, mean P_T



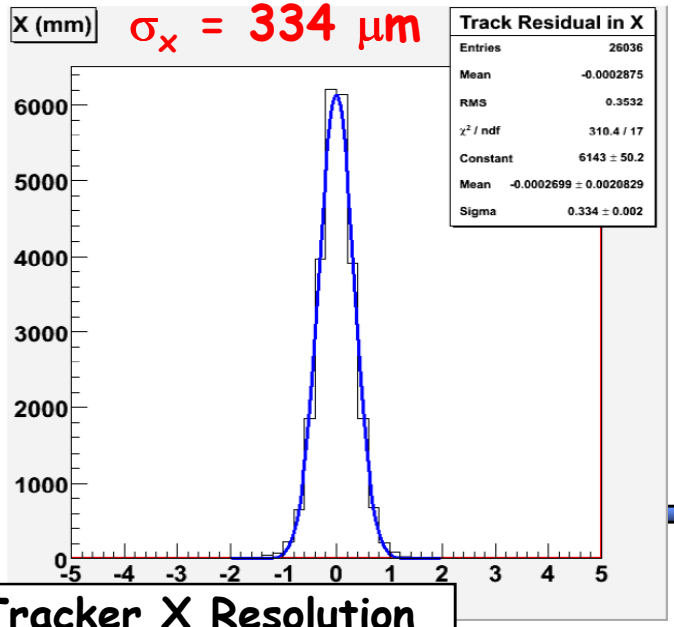




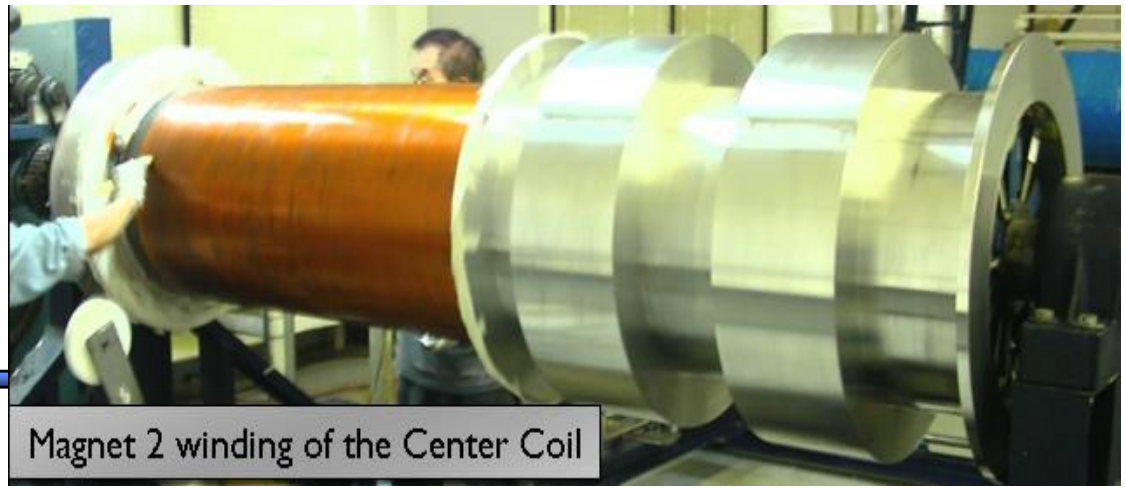
Spectrometers



- The two trackers are operational
- Performances confirmed with cosmics
- Serious problems with the two solenoids
  - Production finished BUT
  - One failed to cool down and needs repair
  - The second failed during power test and revealed a weakness in the design
  - Significant delay resulted



Tracker X Resolution


Magnet 2 winding of the Center Coil

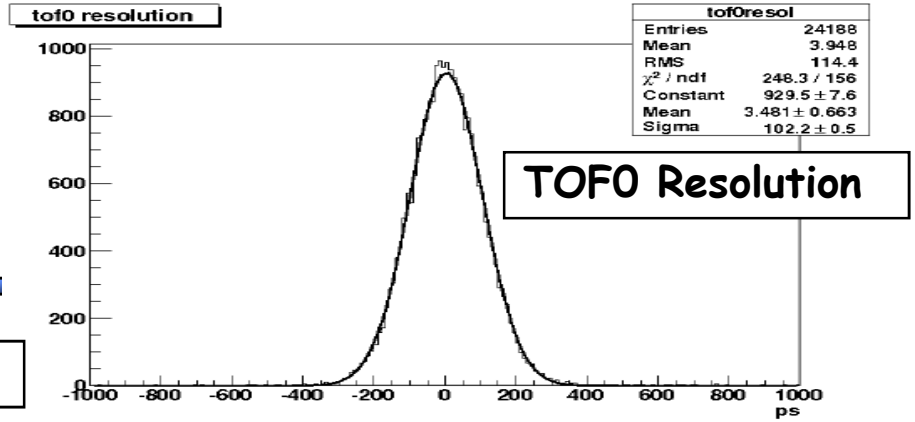
PID Detectors

CKOV installed at RAL

- **Two threshold Cherenkov**
  - Aerogel radiator: n = 1.07 and 1.12
  - Light reflected toward four 8" PMTs
  - Provide pion rejection at large momentum and clean low momentum e^+ sample
- **Three TOF Stations**
  - Crossed scintillator slabs, 1" thick
  - Conventional PMTs
  - TOF0 and TOF1 already commissioned 51 and 62 ps resolution resp.
  - TOF0-TOF1 allows π rejection
  - TOF1-TOF2 allows e^- rejection

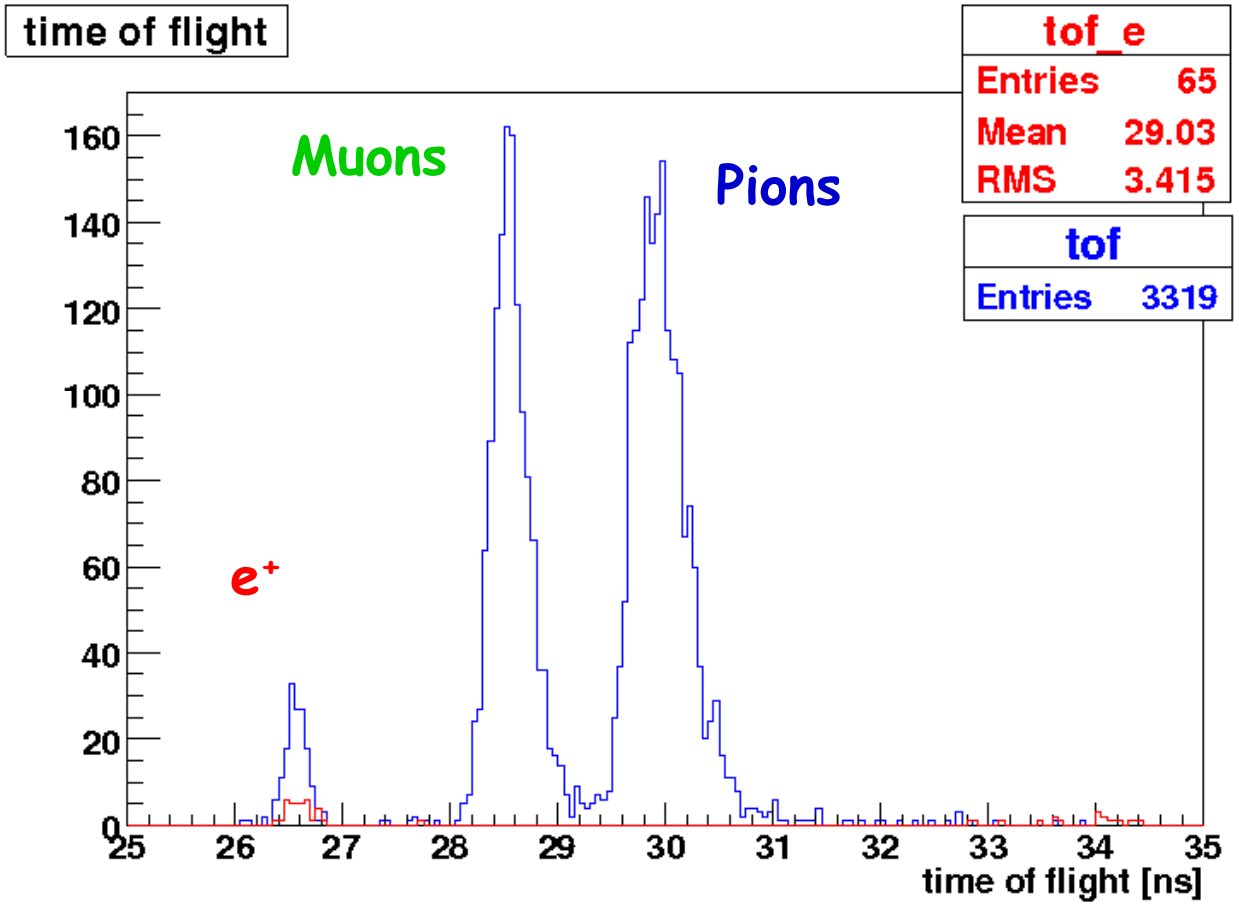
TOF1 installed at RAL

TOF Scintillator



TOF0 Resolution

First muons observed

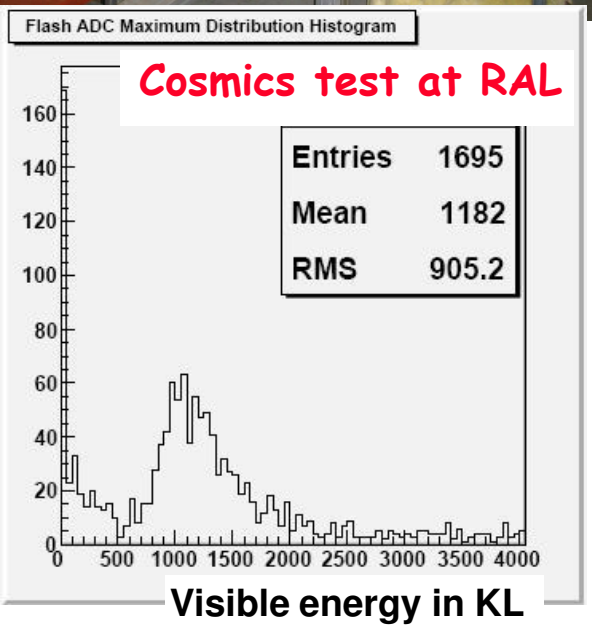


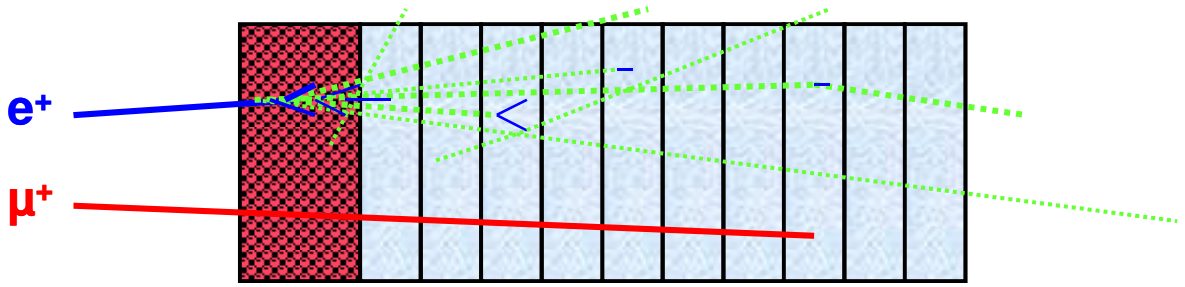
Time of Flight spectrum between TOF0 and TOF1 after calibration and time walk corrections. The red spectrum is obtained with the positron beam at 100 MeV/c.

It is used to fix the horizontal scale. The blue spectrum is obtained at 300 MeV/c. The positron, muon and pion components are clearly separated. The shift between muon and pion peeaks corresponds to the difference in time of flight at 300 MeV/c.

E-M Calorimeter

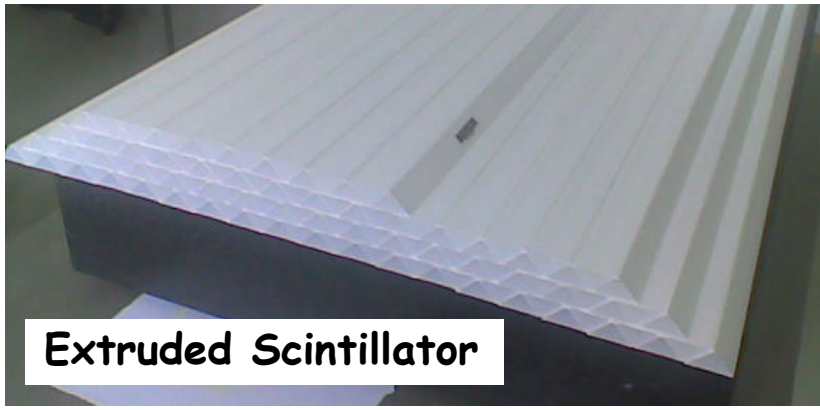
- Electron-muon separation downstream
- Made of two parts:
- KL (KLOE Like)
  - 4 cm thick preshower
  - Made of scintillating fibers interleaved with grooved lead foils
- EMR (Electron-Muon Ranger)
  - 70 cm of fully active plastic scintillator
  - Measures energy, range and track integrity

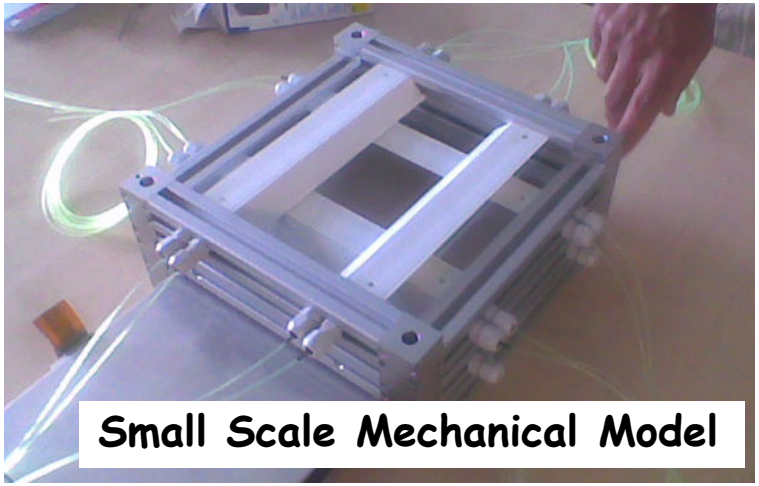


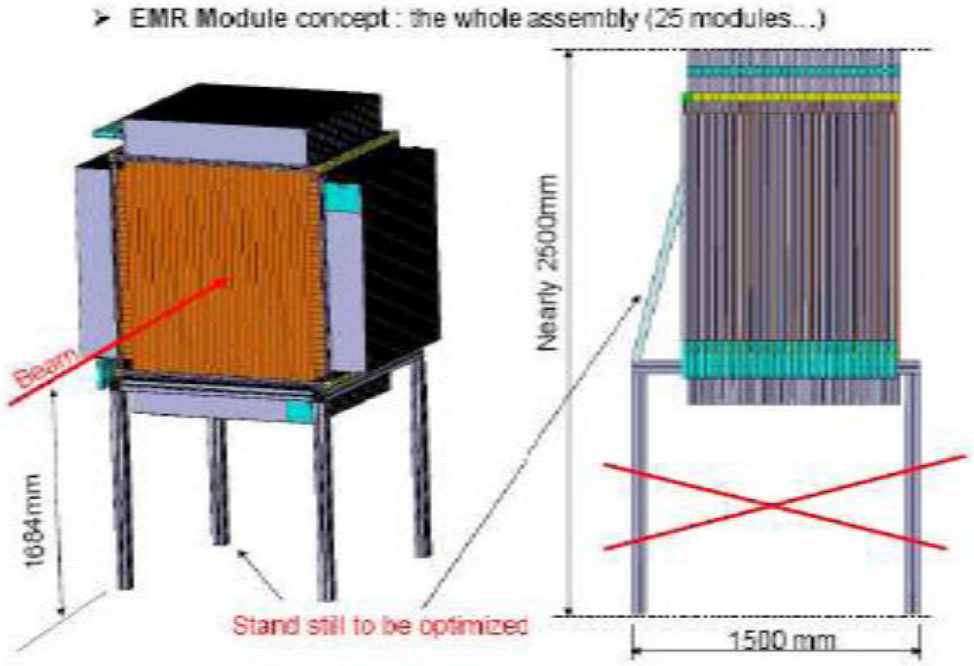


The Electron Muon Ranger

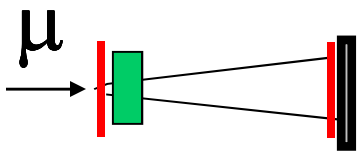
- **Major Contribution from Univ. of Geneva:**
  Conceptual Idea, Simulation, Design, Electronics and Construction
- **In Collaboration with Como/Trieste for the front end and readout electronics**
- **3000 digital channels read out by Multi-Anode PMTs**
- **50 layers with one common charge readout each**
- **First delivery in spring 2010**



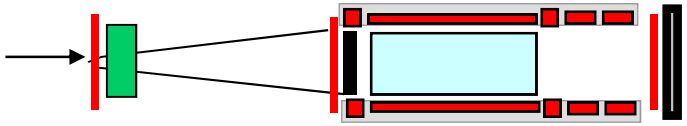




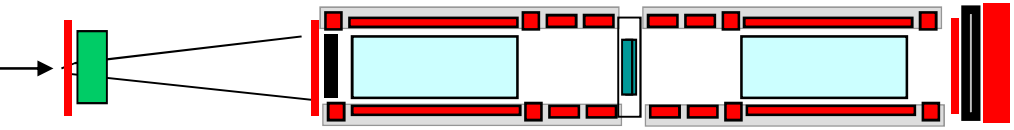
MICE Schedule



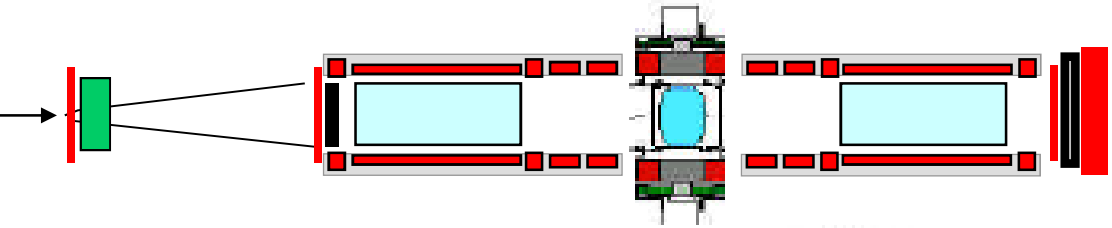
STEP I → Sep09



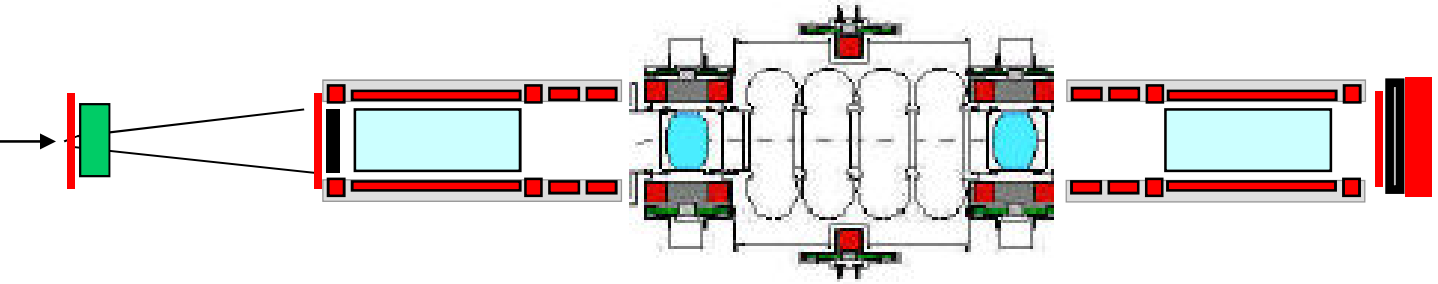
STEP II Q1-2 2010



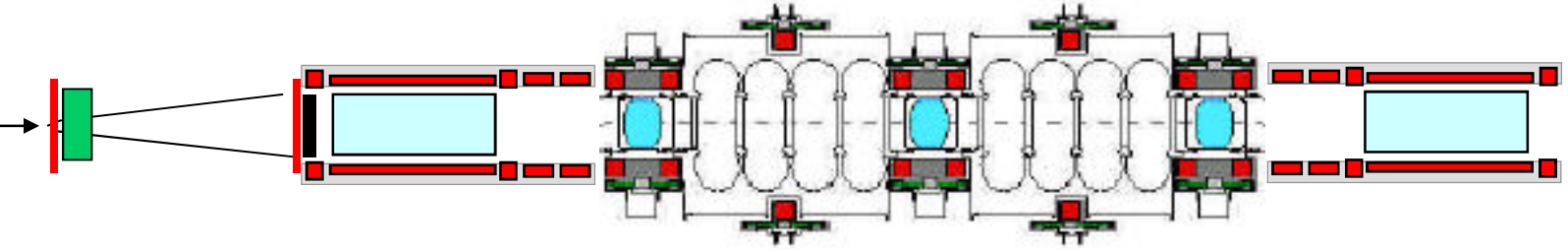
STEP III / III.1 Q3 2010 -> Q2 2011



STEP IV Q3 2011



STEP V Q1 2012



STEP VI 2012-2013

Conclusion

- MICE is running !
- Commissioning of PID detectors has started in 2008
- Muons have been seen in the beam at RAL
- Decay Solenoid is operational
  -> Muon beam expected for this fall
- A new target system is under installation
- Spectrometer solenoid is delayed to 2010
- Univ. of Geneva is developing a highly segmented fully active scintillator (EMR)
- First LH_2 Absorber expected for Mid 2011
  -> Observation of Ionization Cooling
- Final results wih RF in 2012-2013