# The MICE Beamline Instrumentation for Precise Emittance Measurement

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## Introduction

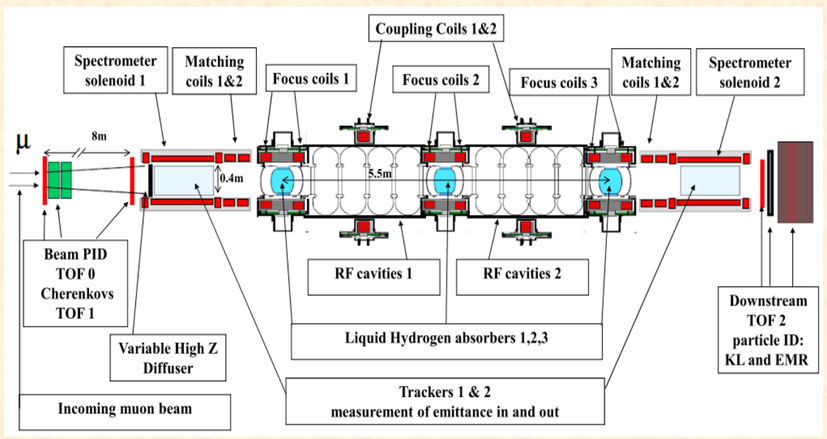
• MICE is a Muon Ionization Cooling Experiment running at the Rutherford-Appleton Laboratory, Chilton UK.

• Cooled muon beams will be a major technological step towards the development of a "neutrino factory" and a "muon collider".

• A minimum ionizing muon beam will be transversely cooled by stations of -dE/dx in LH absorbers and longitudinal energy restoration in 201MHz RF cavities.

• The emittance reduction is measured before and after the cooling stage by tracking individual muons through through tracking and timing detectors.

• Muon purity is assured by three Time-of-Flight (TOF) measurements, two threshold Cherenkovs (μ/π), and a low energy muon/electron ranger KL/EMR (μ/e).




## Time of Flight System

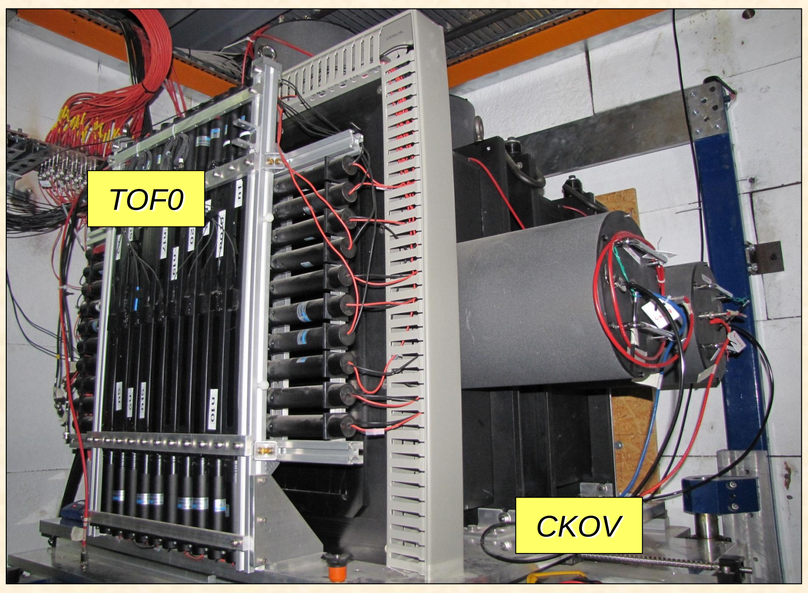
• TOF0,1,2 - Three time of flight stations (~40x40cm$^2$, 42x42cm$^2$, 60x60cm$^2$) are positioned in the MICE channel at the start (TOF0), mid (TOF1), and rear (TOF2) positions.

• TOF0(1,2) station consists of a 10 (7,10)X and 10 (7,10)Y array constructed of BC404(420) scintillator bar assemblies with dual R4998 PMT readout with modified high rate active HV divider. Each assembly gives typically $\Delta t_o$~50-60 ps timing resolution.

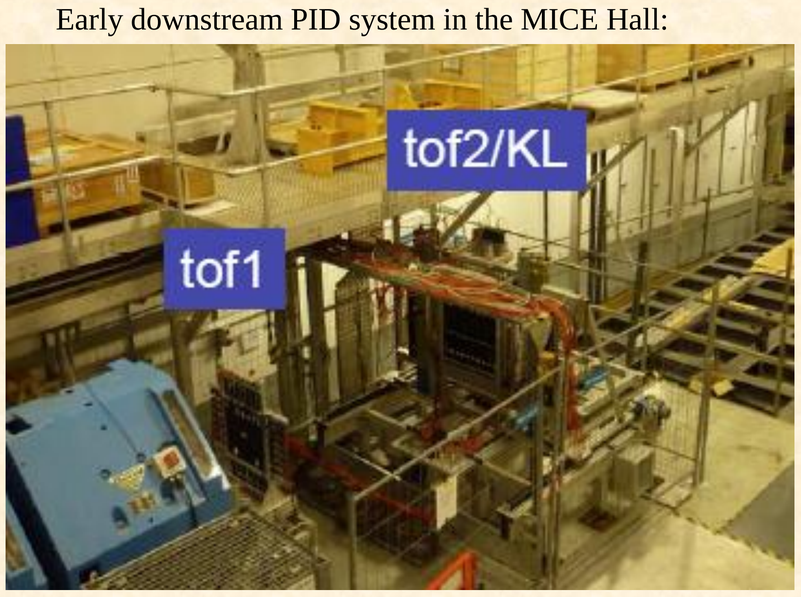
• The expected resolution on TOF between 2 stations is

$$\Delta TOF^2 \sim 2\,\Delta t_o^2 + \sigma^2_{calib} \sim (80\ ps)^2$$

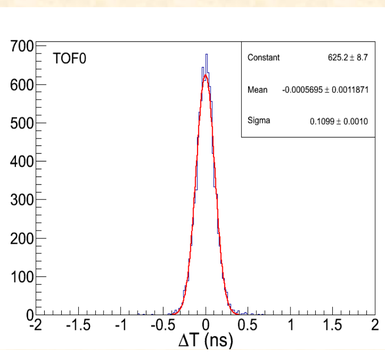
well matched to a 100 ps requirement




Early downstream PID system in the MICE Hall:

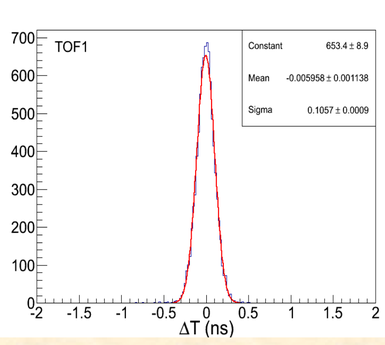


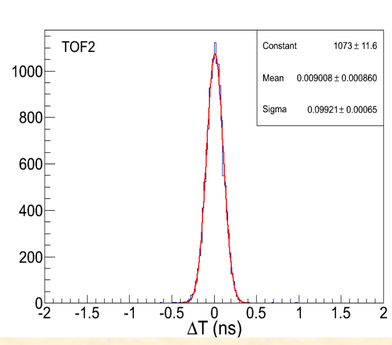

• TOF0, TOF1 and TOF2 timing resolutions as measured in MICE pion and electron beams in 2011.




Intrinsic time resolution:

- TOF0 – 55 ps
- TOF1 – 53 ps
- TOF2 – 50 ps.



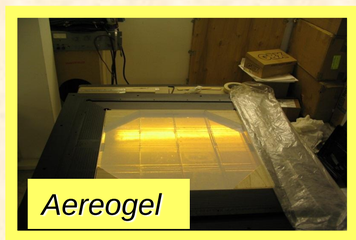




## Cherenkov detectors

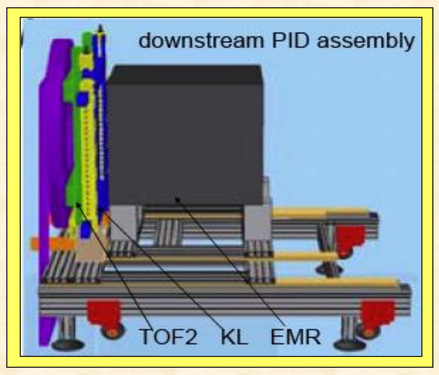
• CKOVab- Two threshold Cherenkov detectors positively identify muons from pions in the upstream MICE beamline.

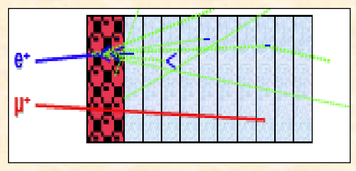
• High density aerogels of n=1.12 and n=1.07 were chosen with momentum thresholds for muon I.d. between 220-360 MeV/c.

| | $P^{th}\mu$(MeV/c) | $P^{th}\pi$(MeV/c) |
|---|---|---|
| Aerogel 1.12 | 220 | 280 |
| Aerogel 1.07 | 280 | 360 |




## Downstream PID Assembly



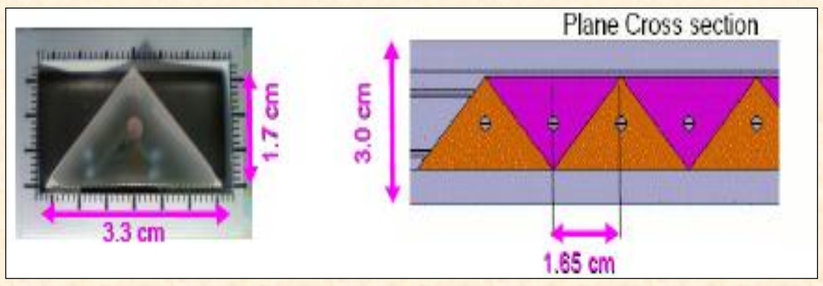



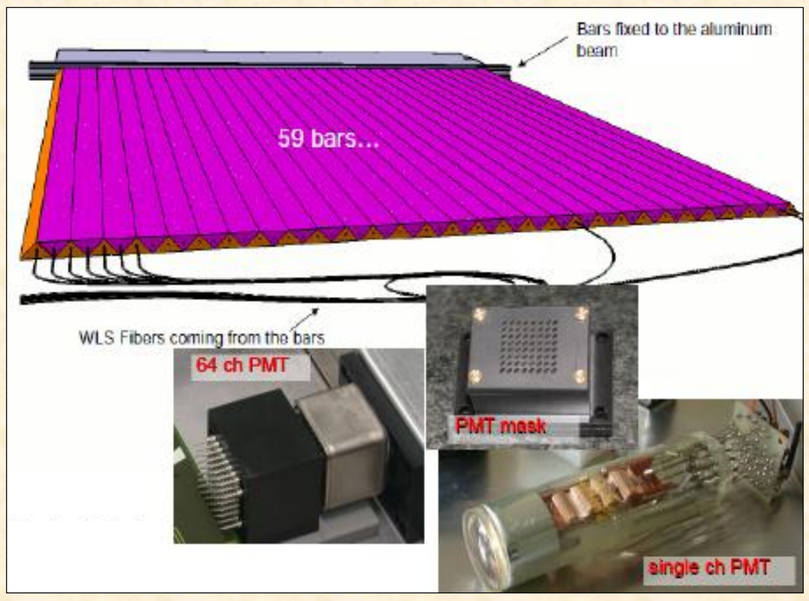

0.5% of μ s decay in flight:

- need electron rejection at $10^{-3}$ to avoid bias on emittance reduction measurement
- TOF2 X/Y hodoscope,
- EMC Calorimeter for MIP vs E.M. Shower : KL (built) + EMR (in construction )

## EMR

• EMR – Electron-Muon Ranger (under construction)
  - 50 layers of fully active scintillator bars organized in x-y array
  - 59 triangular shape bars in each plane - 1m$^2$ active region
  - Light carried out by a single 1.2 mm diameter WLS fiber
  - Fiber connected on one side to a single channel photomultiplier
  - On the other side to a 64 channel multianode photomultiplier



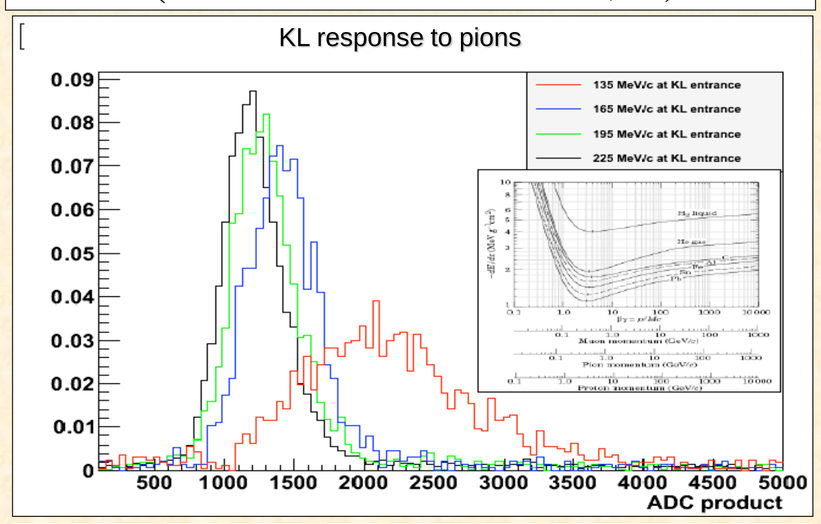



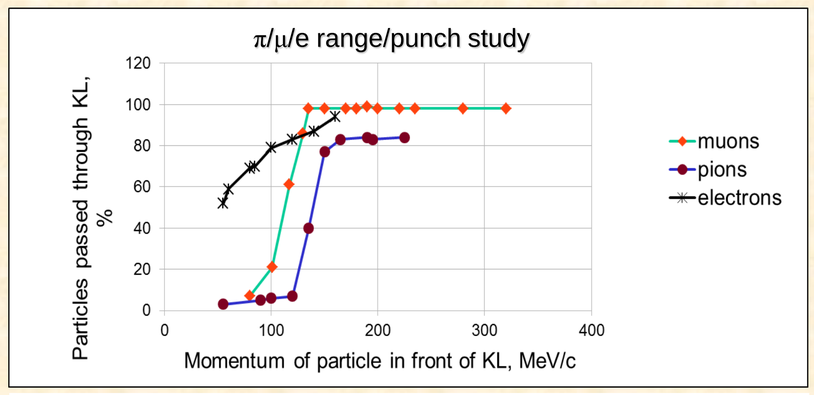

http://mice.iit.edu/

## KL

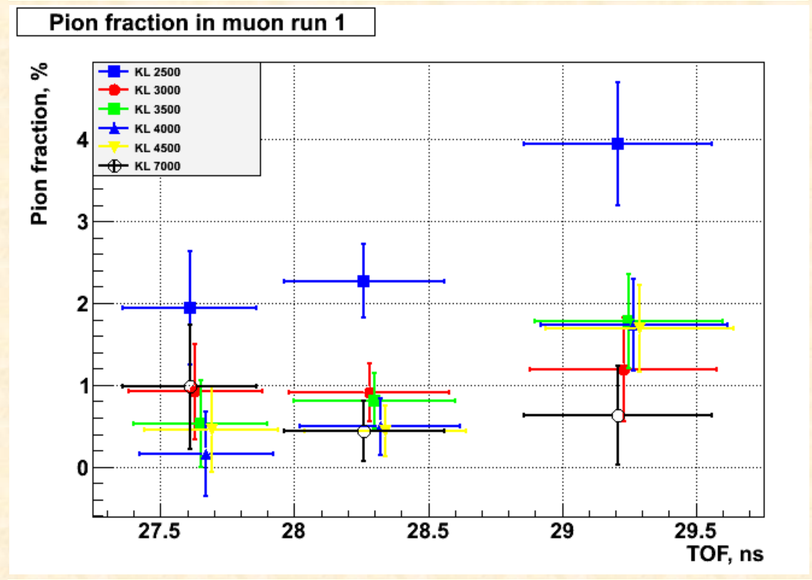
• KL, a lighter version of a KLOE* detection plane, electron preshower . Constructed of 0.3mm Pb + BF12 fiber ( 2.5 Xo, ΔE~7%/ √E, Δt~70ps / √E )

(*KLOE – Nucl.Instrum.Meth.A598:239-243,2009)



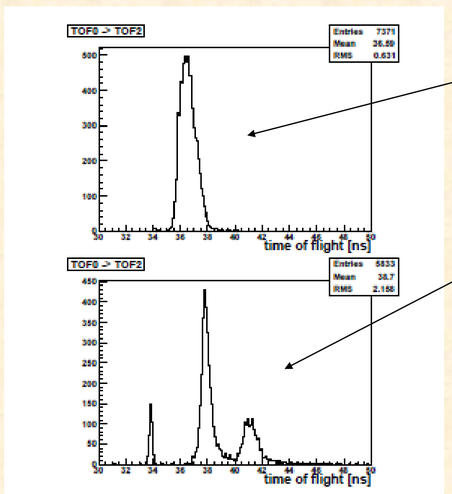




Pion fraction in muon run 1



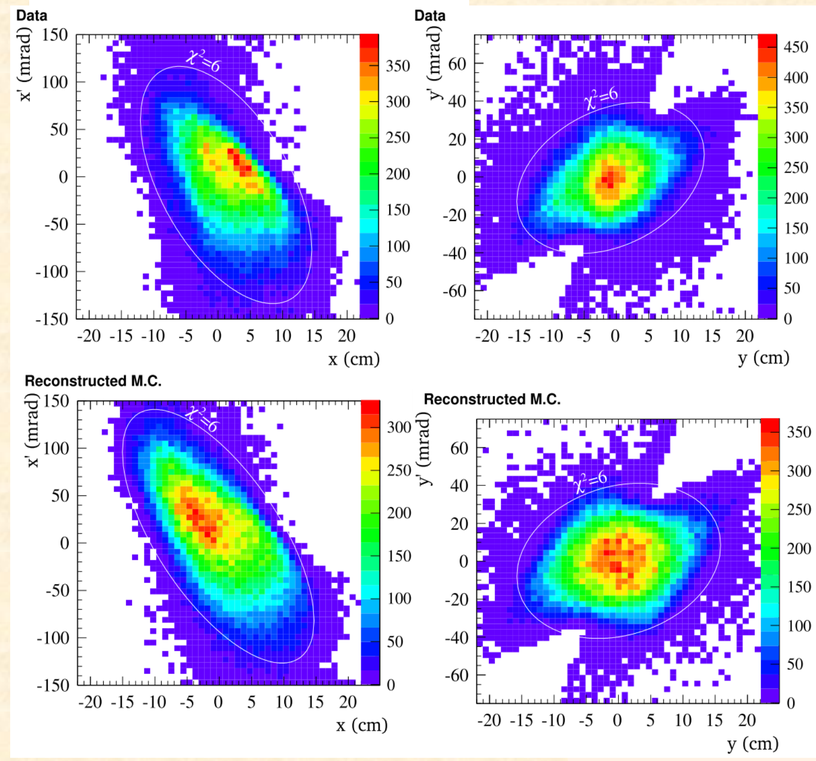

Using a TOF window + KL response:
π contamination less than 1 – 2 % of MICE μ–beam

## MICE beamline characterization with PID detectors




High emittance muon beam (to study μ cooling)

Low emittance calibration beam, for detectors characterization




Reconstructed trace space (ε = 6, p = 200 μ⁻ beam) compared to reconstructed Monte Carlo