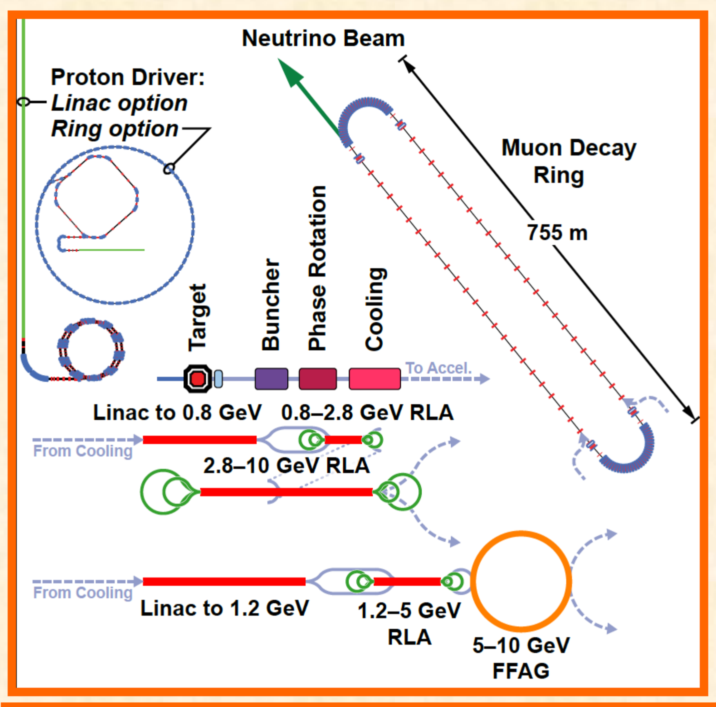
The detector system of the MICE experiment

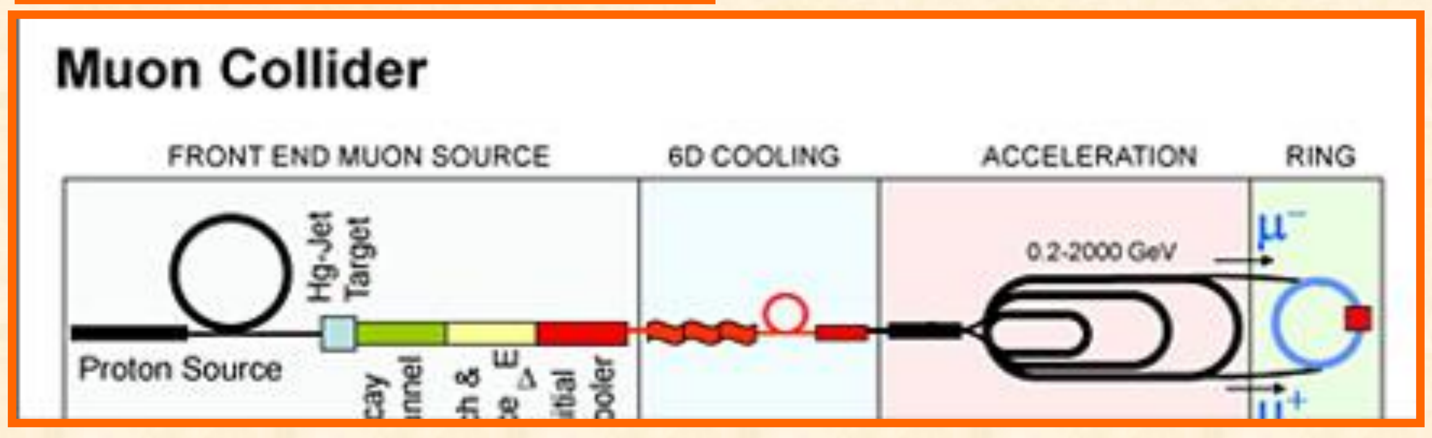
M. Bonesini
INFN Milano Bicocca, on behalf of the MICE Collaboration

Introduction

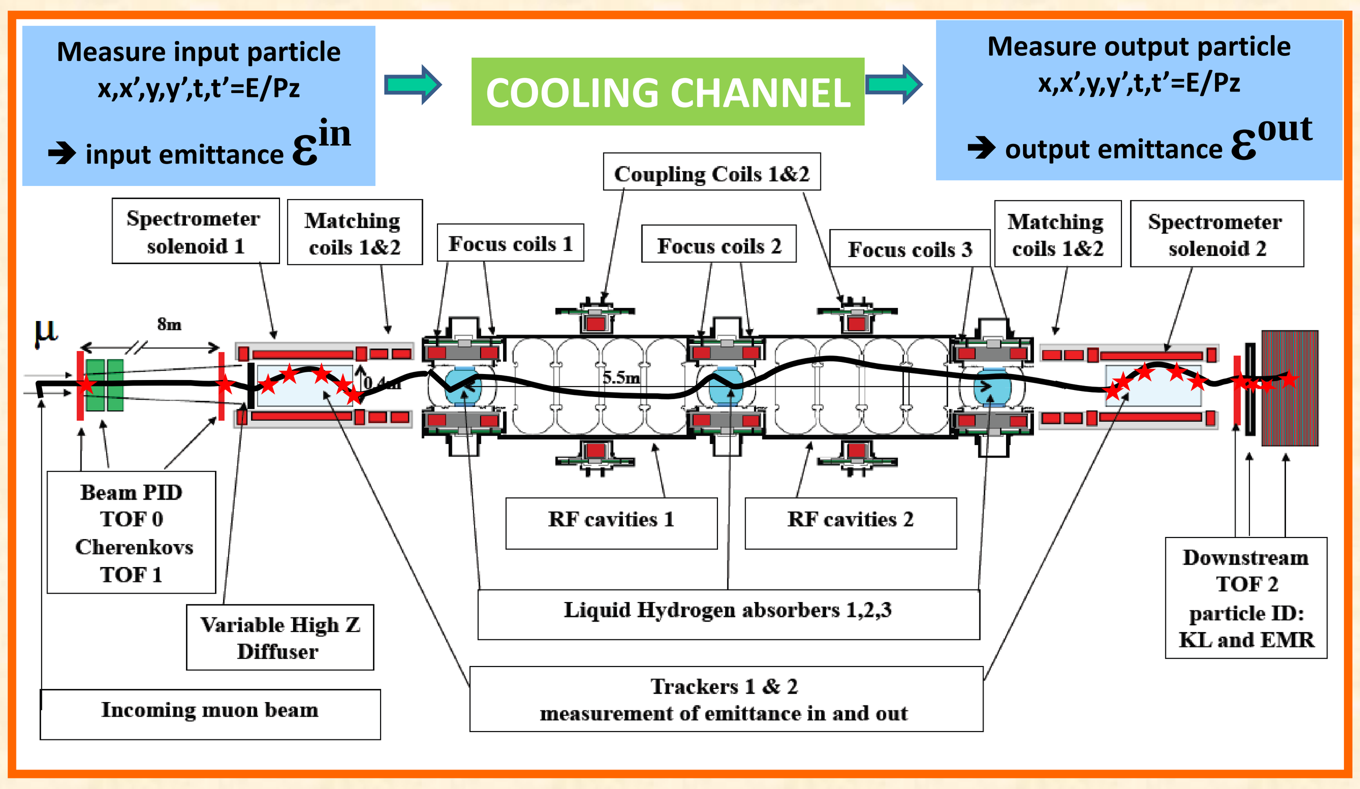


MICE is a critical R&D experiment towards neutrino factories and muon colliders. With the growing importance of neutrino physics and the discovery of a light Higgs (126 GeV), physics could be moving this way soon!

The initial chain of capture, bunching, phase rotation, and cooling rely on complex beam dynamics and technology. Muon cooling → high intensity ν factory, high luminosity μ collider

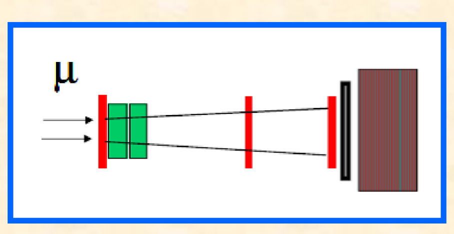


Measurement method



- *Measure parameters particle by particle: accumulate ~10^5 muons $\Delta[(\varepsilon^{in} - \varepsilon^{out})/\varepsilon^{in}] = 10^{-3}$*
- *Challenges: high gradient (>8MV/m) RF cavities embedded in strong (>2T) solenoidal magnetic fields*
- *Experiment in Steps: Step I (beamline+PID detectors), Step IV (trackers+cooling measure), Step VI (cooling + RF)*

Step I workhorses : TOF system and KL calorimeter

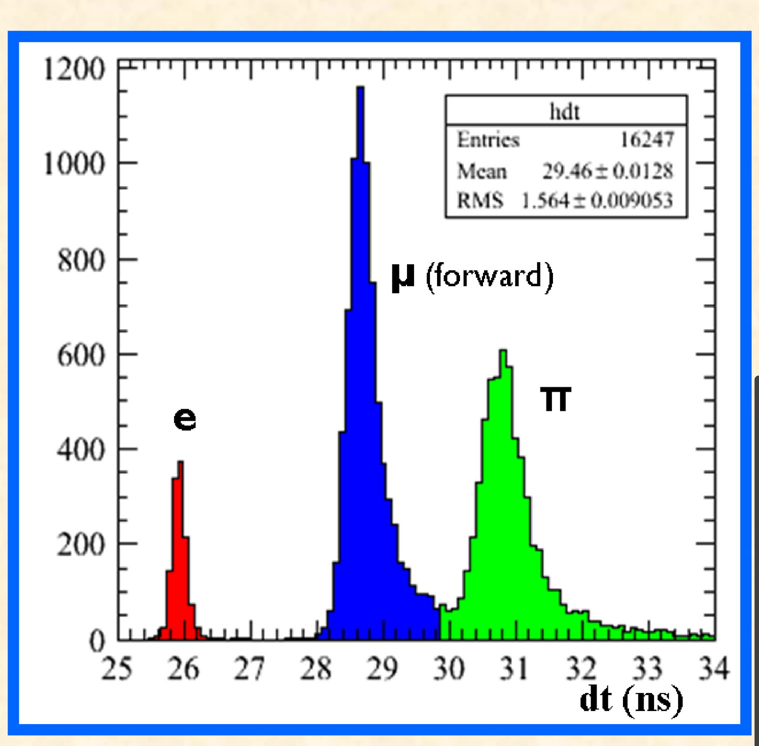


Goals of Step I: characterization of MICE beamline and PID detectors

TOF system

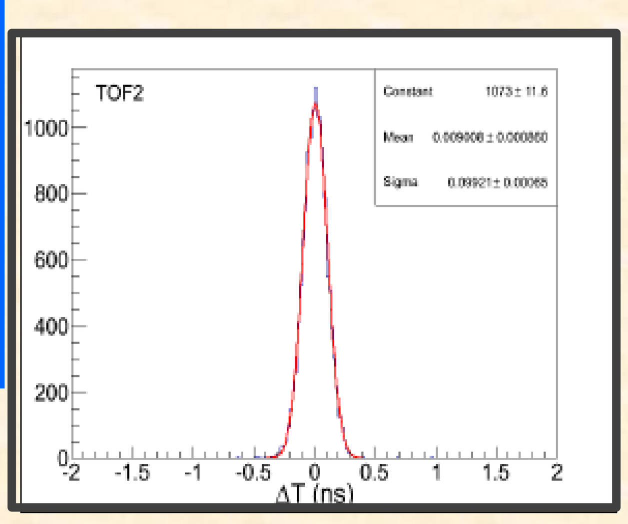
- Three time of flight stations (~40x40cm², 42x42cm², 60x60cm²) are positioned in the MICE channel at the start (TOF0), mid(TOF1) and rear(TOF2) positions.
- TOF0(1,2) station consists of a 10(7,10)X and 10(7,10)Y array made of BC404(420) scintillator bar assemblies with dual R4998 PMT readout with modified high rate active HV divider. Each assembly gives typically Δt_o~50ps timing resolution.
- Calibration issues are critical
- The expected TOF resolution between 2 stations is

$$\Delta TOF^2 \sim 2\,\Delta t_o^2 + \sigma^2_{calib} \sim (75ps)^2$$



Time-of-flight (TOF) for 300 MeV/c π beam

Intrinsic time resolution:
- TOF0 – 55 ps
- TOF1 – 53 ps
- TOF2 – 50 ps.

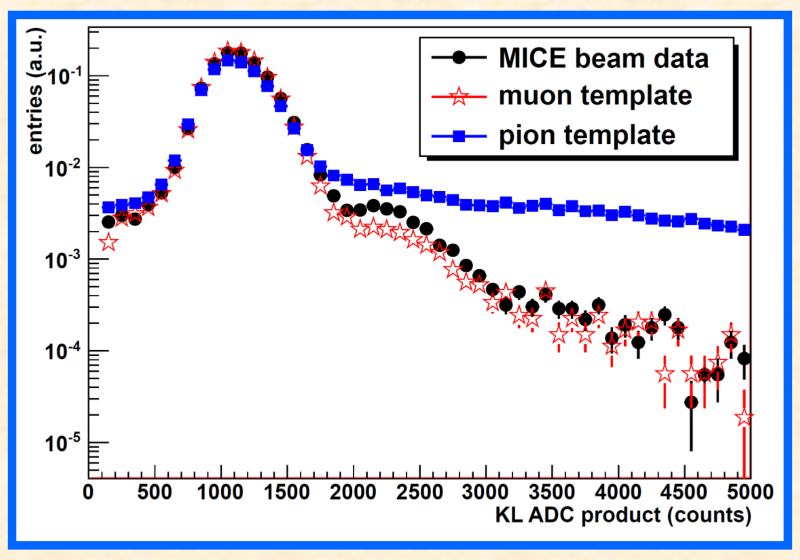


TOF2 resolution

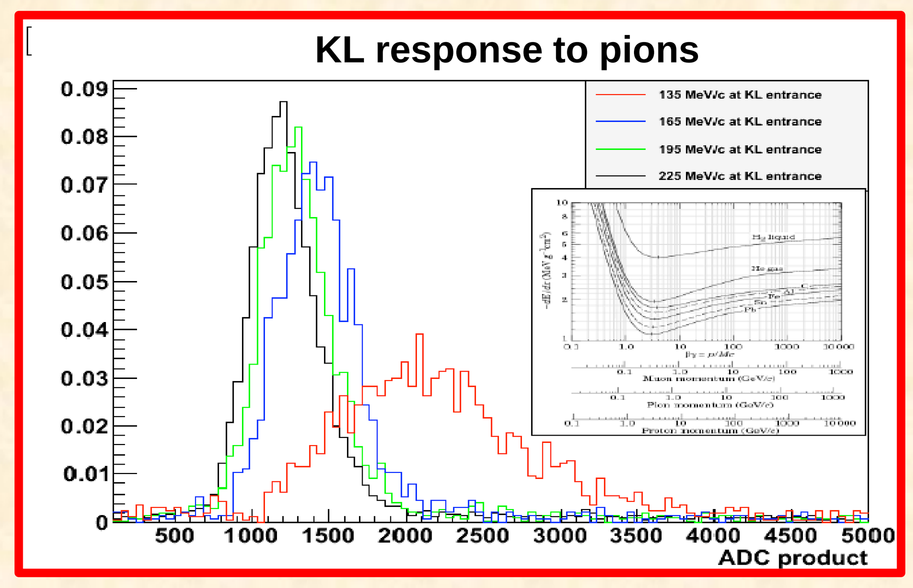
KL calorimeter

- KL – KLOE* Light electron preshower . Made of 0.3mm Pb + BF12 fiber (2.5 Xo, ΔE=7%/ √E, Δt~70ps / √E)

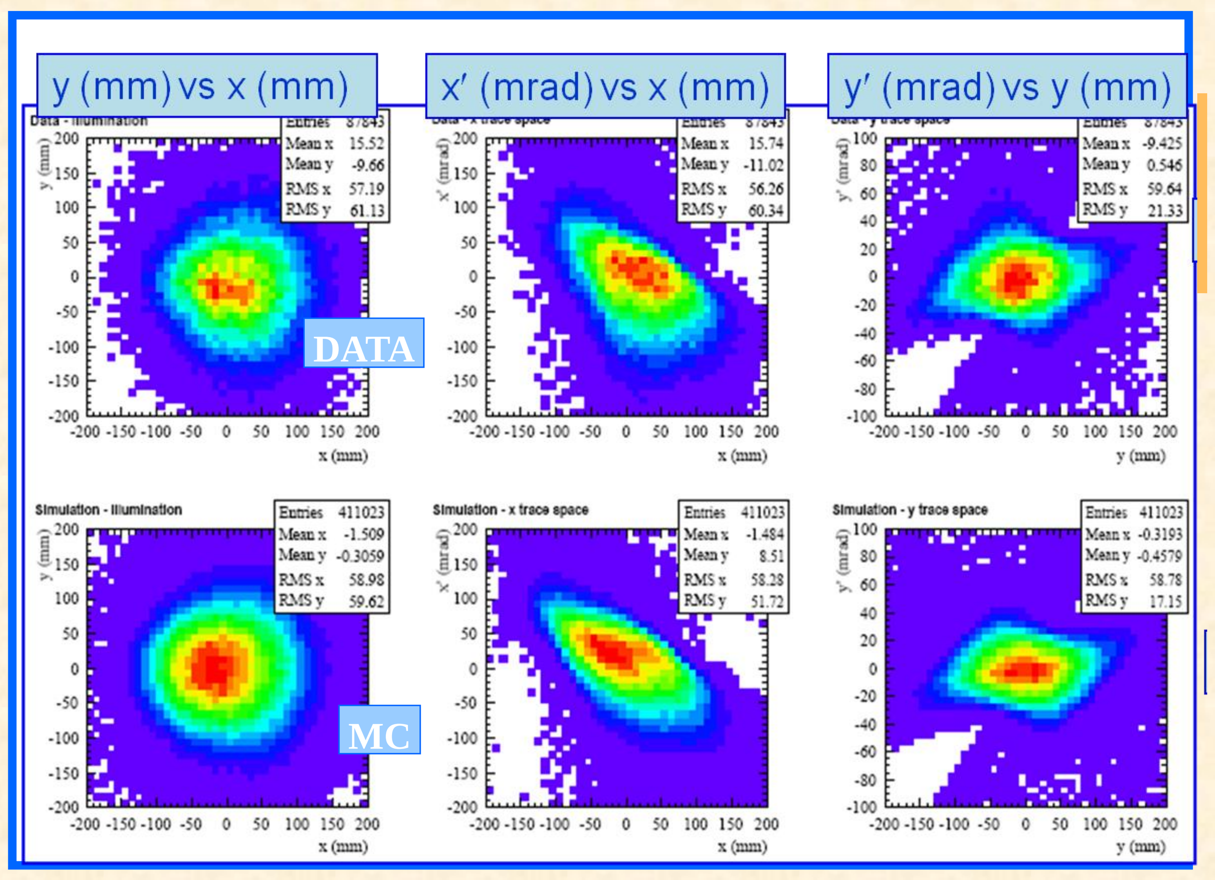
(*KLOE - Nucl.Instrum.Meth.A598:239-243,2009)



π fraction in μ beam < 1% from KL + TOF



MICE Step I beamline characterization with PID detectors



Transverse trace space for (6 π mm-rad, 200 MeV/c) μ beam. Non-linear effects at edges.

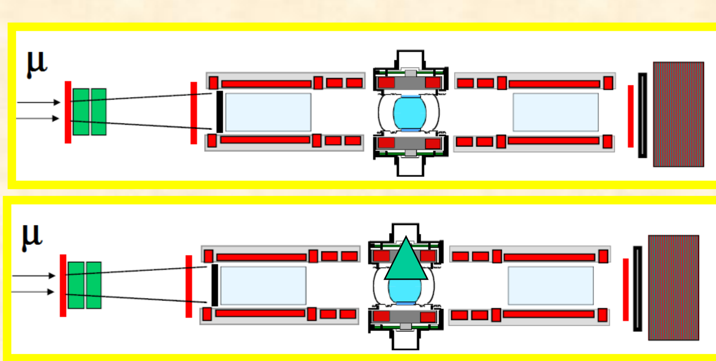
Emittance measurement:

- Muons identified with time-of-flight system
- Measure x,y and t at TOF0, TOF1
- Use momentum-dependent transfer matrices to determine trace space at TOF1
- measured p_z & computed matrix $M(p_z)$

$$\begin{pmatrix} x_1 \\ x_1' \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \begin{pmatrix} x_0 \\ x_0' \end{pmatrix}$$

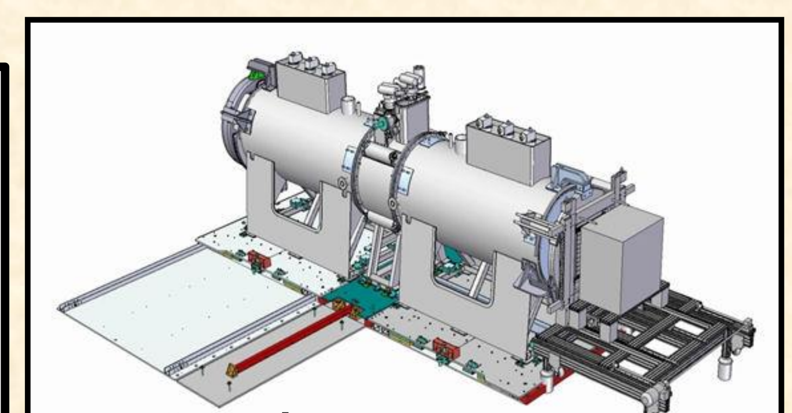
$$\begin{pmatrix} x_0' \\ x_1' \end{pmatrix} = \frac{1}{M_{12}} \begin{pmatrix} -M_{11} & 1 \\ -1 & M_{22} \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \end{pmatrix}$$

Step IV detectors



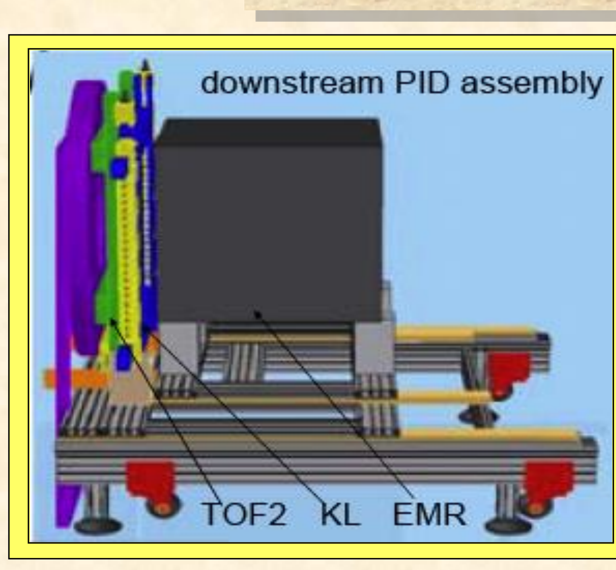
Goal of STEP IV: precise measure of cooling

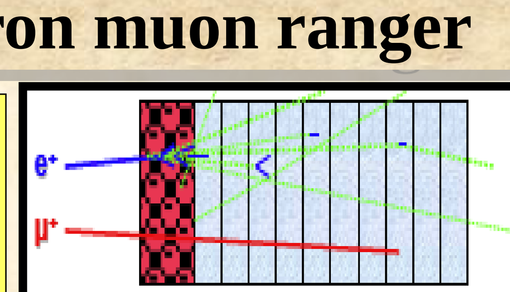
- No absorber: alignment & beam optics
- Liquid H2 absorber (full/empty)
  - Multiple scattering, Energy loss → COOLING
- Solid absorbers: LiH, Plastic, C, Al, Cu
- LiH wedge absorber: emittance exchange



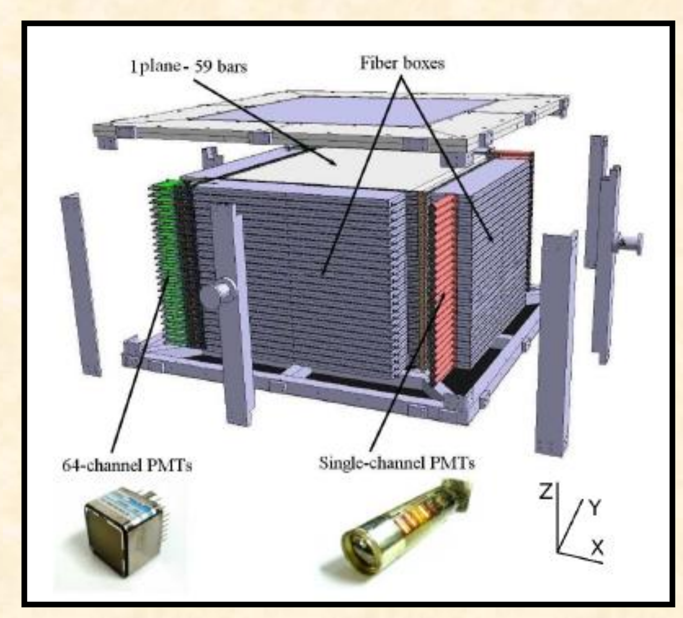
Step IV layout

EMR: Electron muon ranger





0.5% of μ decay in flight:
- need electron rejection at 10^{-3} to avoid bias on emittance reduction measurement
- TOF2 X/Y hodoscope
- Calorimeter for MIP vs E.M. Shower: KL+EMR

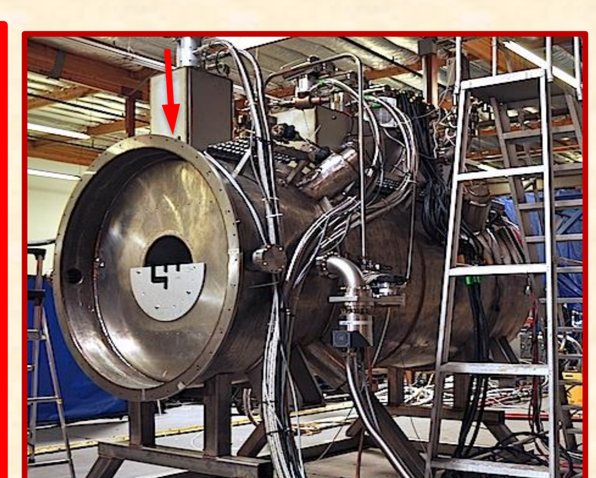


- 1 m³ active volume
- 48 planes of 59 triangular scintillator bars organized in x-y way
- Light carried out by a 1.2 mm diameter WLS fiber
- Fiber connected on one side to a single channel photomultiplier
- On the other side to a 64 channel multianode photomultiplier

Trackers:

- 5 stations, with 3 doublet layers each (at 120 ⁰) inside a 4T SC solenoi
- Doublet layers of 7 fibers to a single readout channel
- Readout with VLPC with high Q.E. + AFE-IIt boards
- Measure x,x',y,y',p_z
- 470 μm point resolution

4T superconducting spectrometer solenoids (fiber tracker inside)



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http://mice.iit.edu/