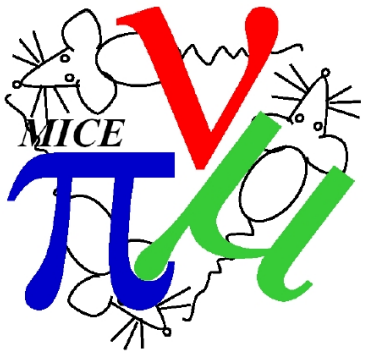
A Totally Active Scintillator Calorimeter

for the Muon Ionization Cooling Experiment

Ruslan Asfandiyarov
On Behalf of MICE Collaboration

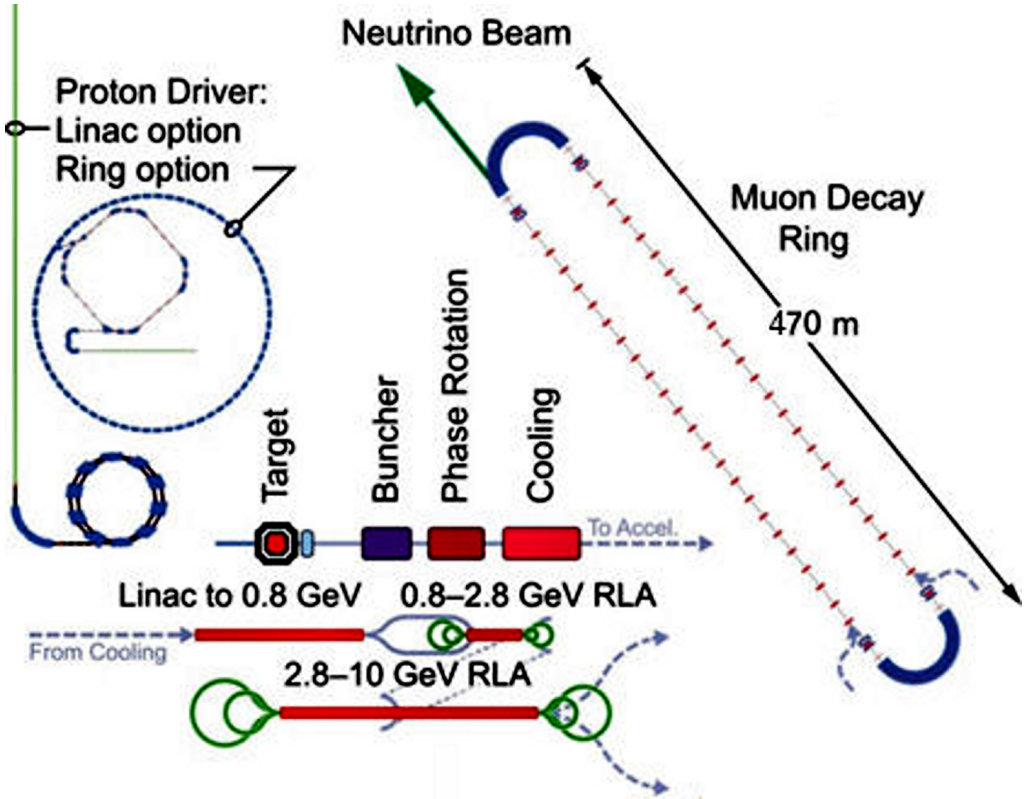
University of Geneva (DPNC)
Switzerland



VCI2013
Vienna
February 11-15, 2013

Table of Contents

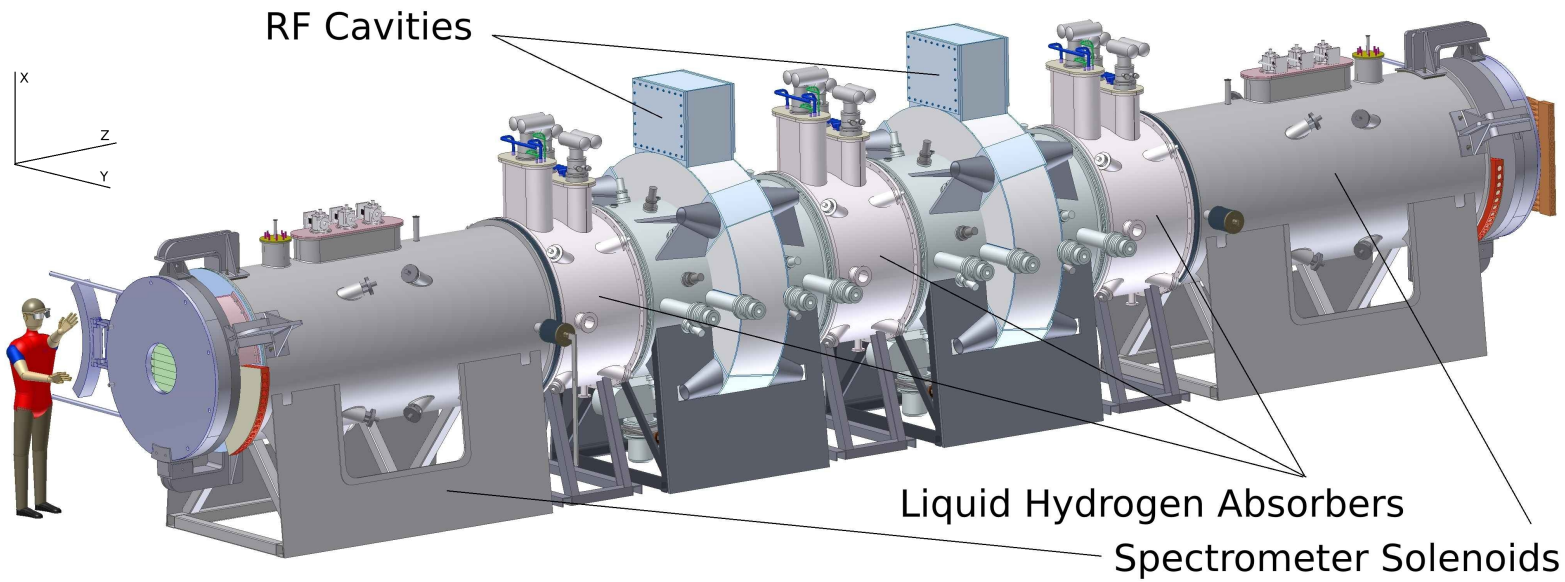
General Motivation



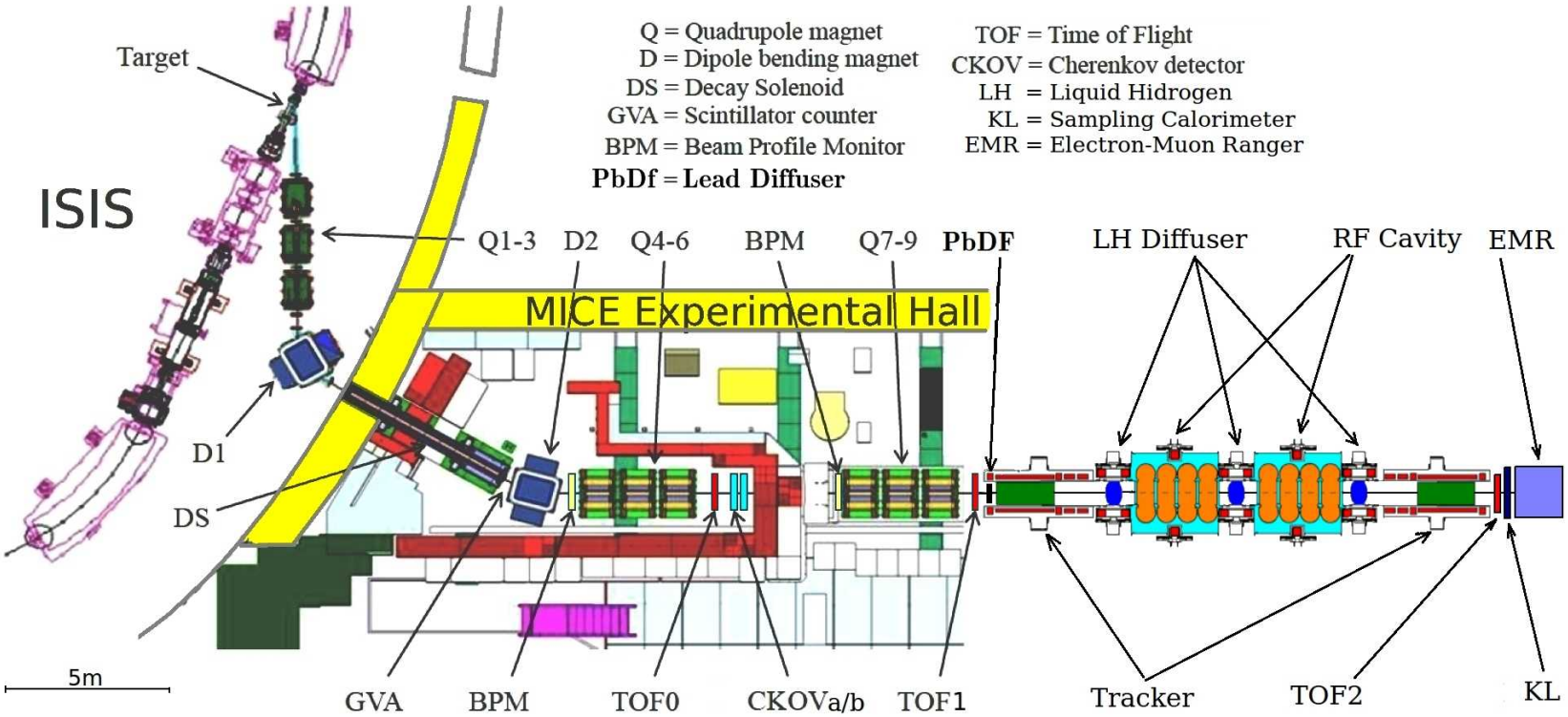
- A Neutrino Factory based on muon storage ring is the ultimate tool for studies of neutrino physics. It is also a step towards a muon collider.
- Ionization cooling has never been demonstrated in practice but has been shown by simulation and design studies to be an important factor both for the performance and for the cost of a Neutrino Factory.

Muon Ionization Cooling Experiment (MICE)

The Muon Ionization Cooling Experiment (MICE) aims to construct a cooling cell with all the equipment necessary to measure the emittance of a muon beam before and after this cell based on single particle measurements and achieve 10% cooling of 200 MeV/c muons. The cooling cell will be sandwiched between two identical trackers inside 4T superconducting solenoids, complemented by upstream and downstream particle detectors.

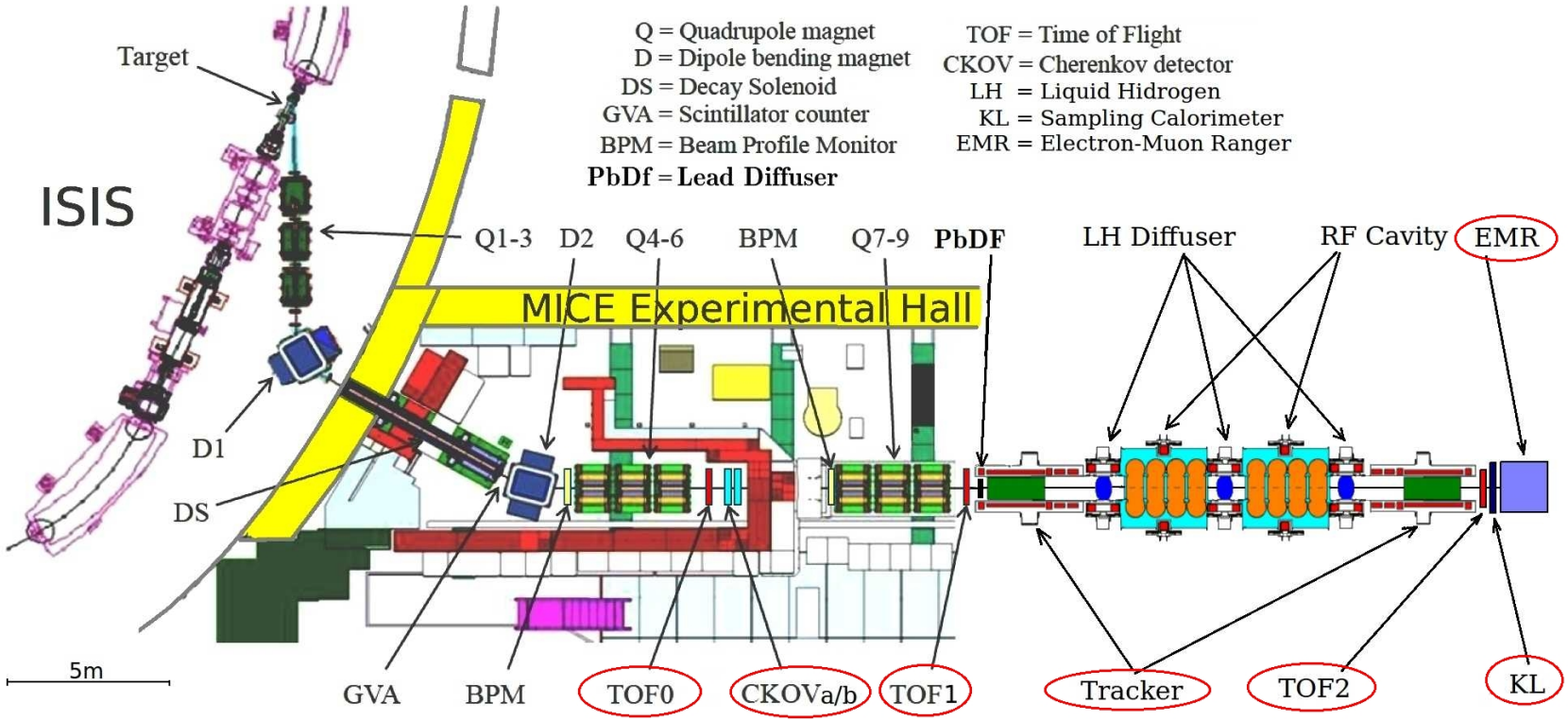


MICE Beam Instrumentation



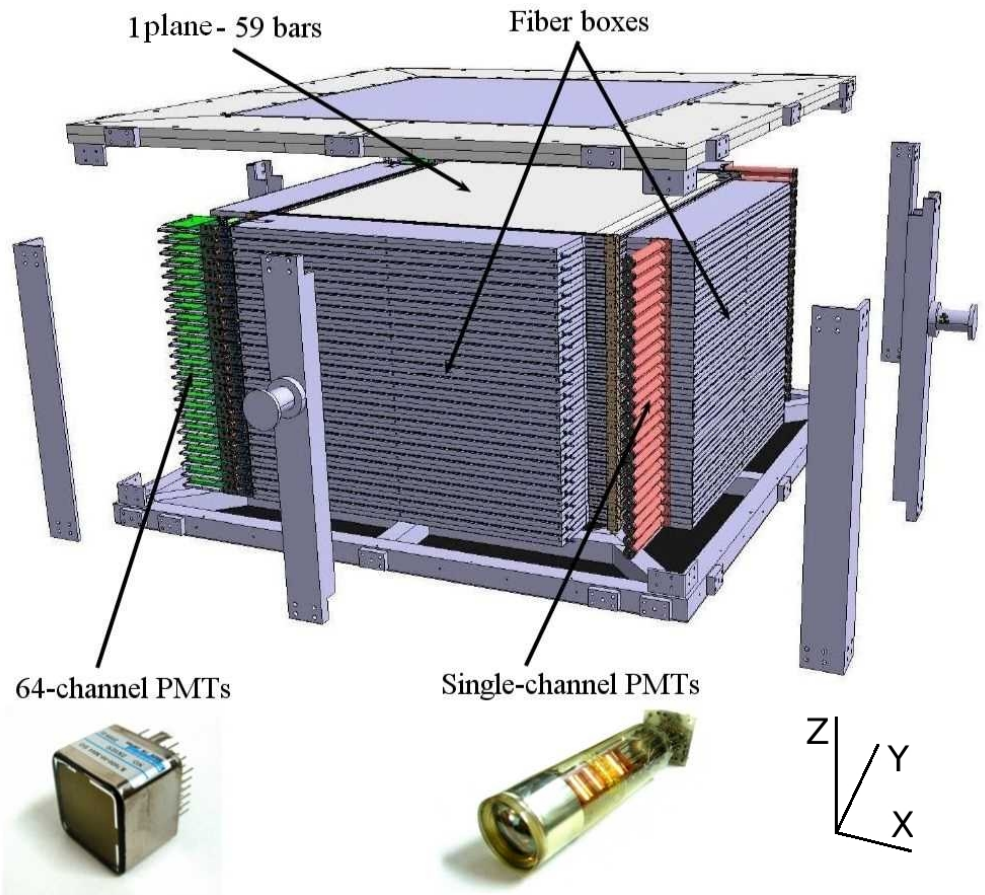
- MICE is designed to produce a 10% cooling effect on the muon beam
- measurement of muon cooling effect to $\sim$1% precision
- different detector technologies are employed
- 140-240 MeV/c *e*,μ,*pi* beam is used

MICE Beam Instrumentation



- TOF - particle identification, trigger and timing
- CKOV - muon/pion/electron separation at high momentum
- Tracker - particle momentum measurement
- KL - electron preshower

Calorimeter: Electron-Muon Ranger (EMR)



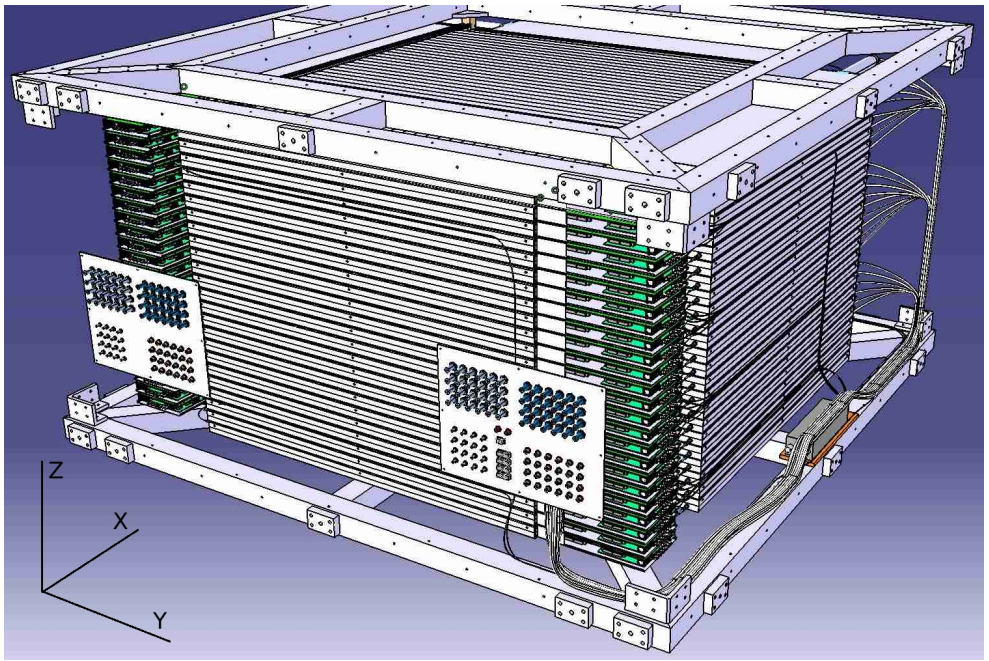
A Fully active scintillator calorimeter will be located at the very end of the cooling channel. It will stop all particles and give very distinct signatures for electrons, muons and pions allowing for a good particle identification. Characteristics:

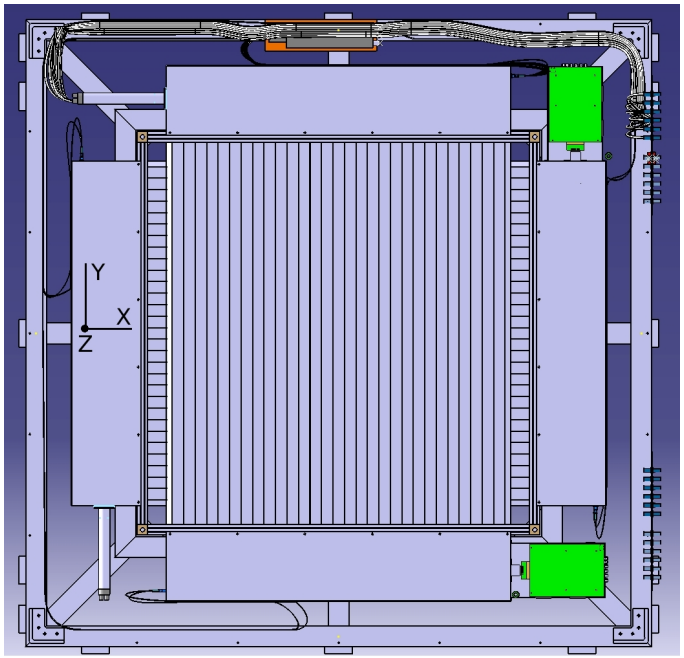
- 1 m^3 of active volume
- 48 planes composed of 59 triangular scintillator bars with glued 1.2 mm wavelength shifting fibers
- light is collected by single-anode PMT on one side of a plane and by 64-channel PMTs - on the other: 3120 channels in total

- the granularity of the detector allows it to reconstruct individual tracks and measure energy deposition in every bar

Table of Contents

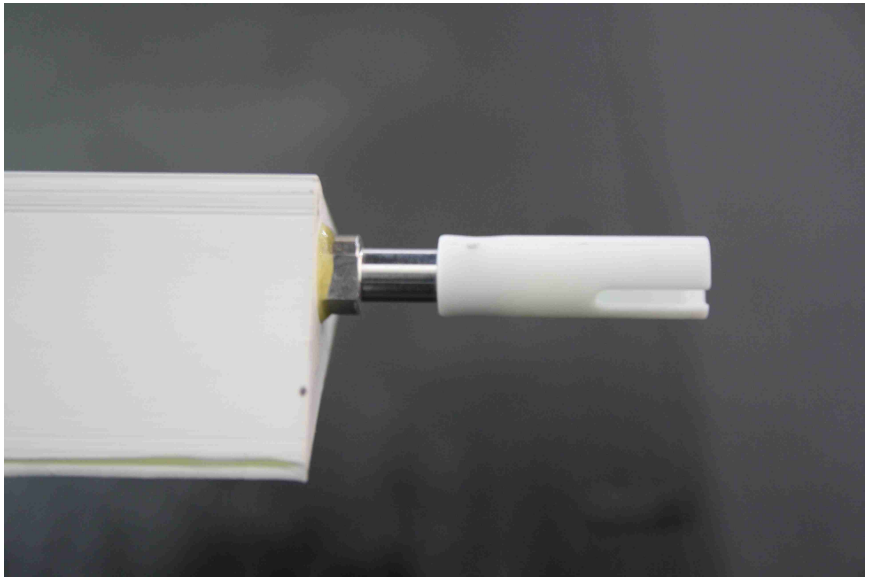
Detector Design

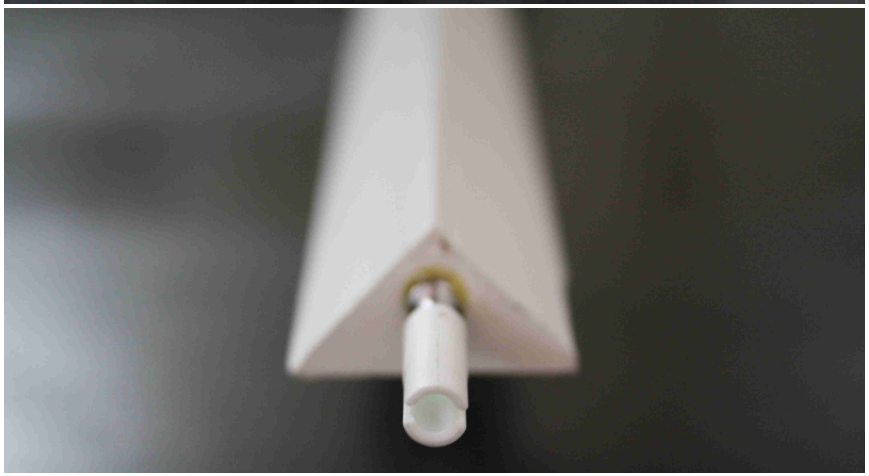


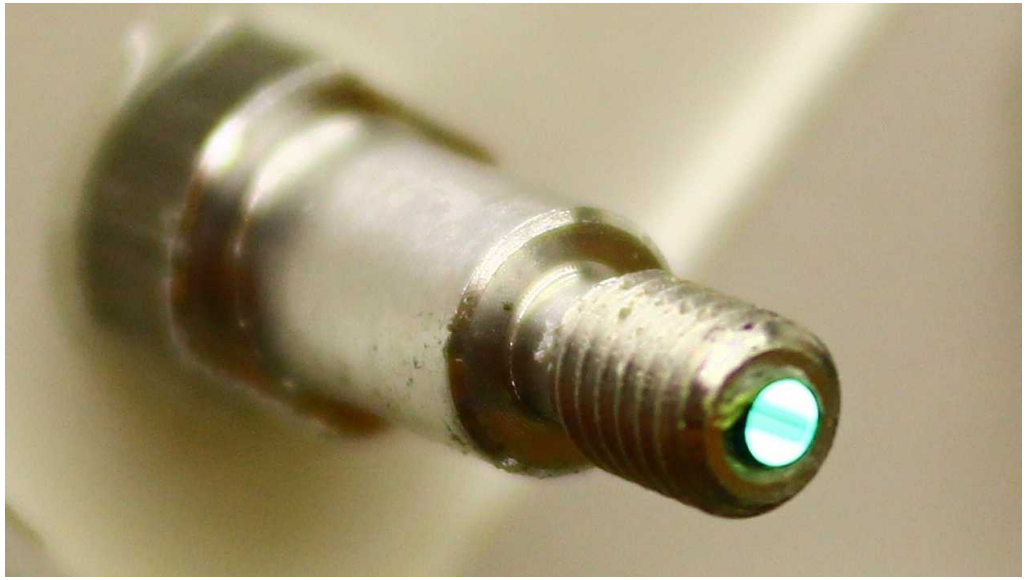


- 48 intersecting planes form 24 modules which allow for measurement of X-Y coordinate of a track, Z coordinate is given by module position
- readout electronics are housed inside the support frame and located next to the PMTs to minimize analog signal distortions, digital signals are sent from the front-end boards
- calibration system based on LED-pulser is installed inside the detector box

Scintillator Bars

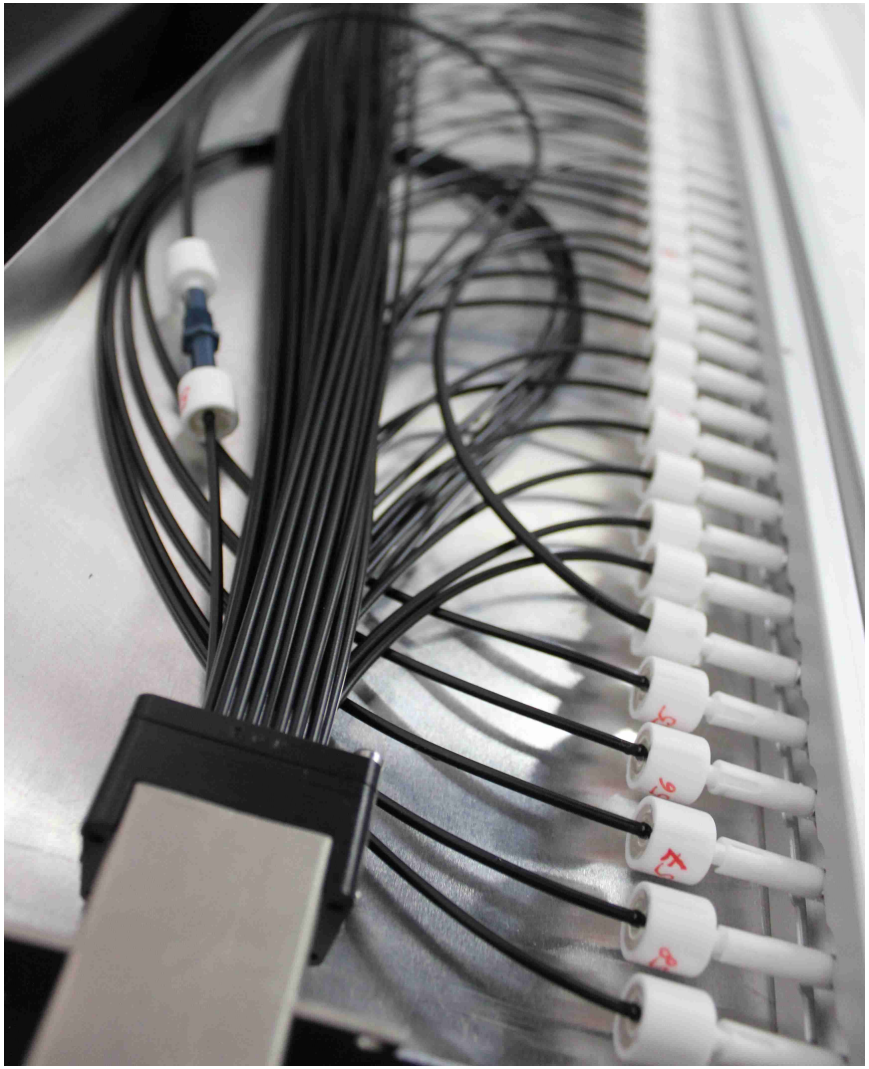


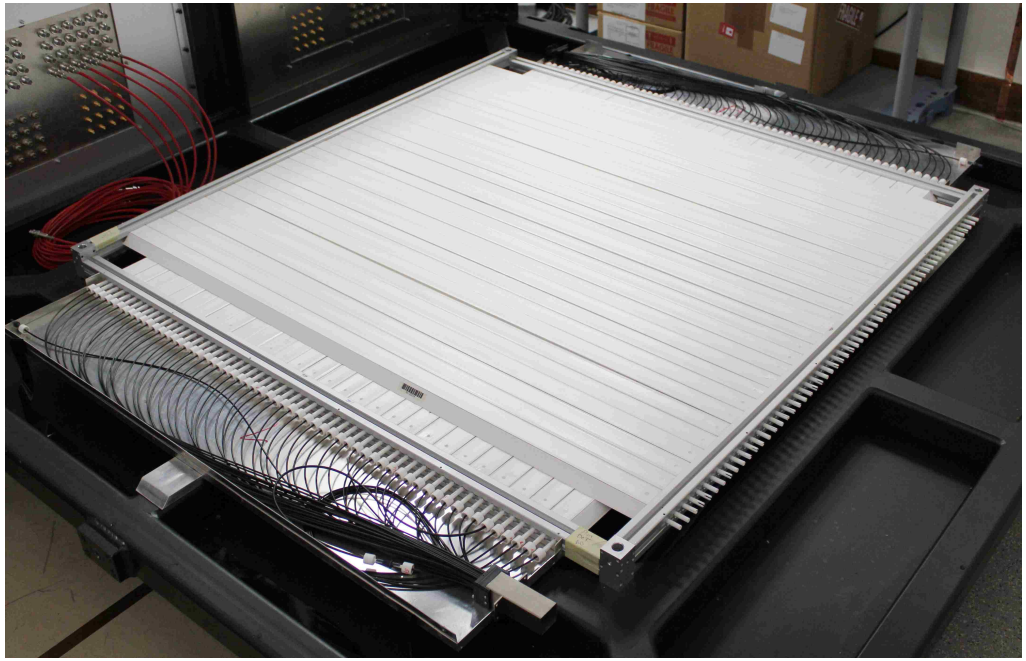




- scintillator bars emit in the blue light
- WLS fibers collect the light and shift it to green
- clear fibers transfer the light to PMT

Scintillator Plane Assembly

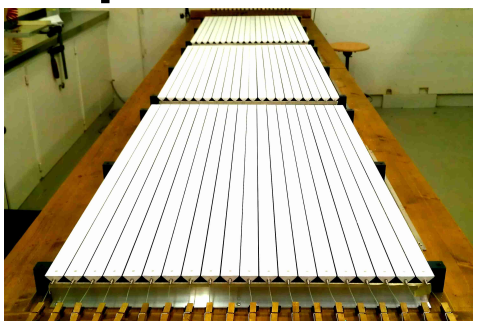




- 59 bars are assembled in a plane
- a bundle of clear fibers is connected to both sides of the plane
- no crimping is used fix the fibers

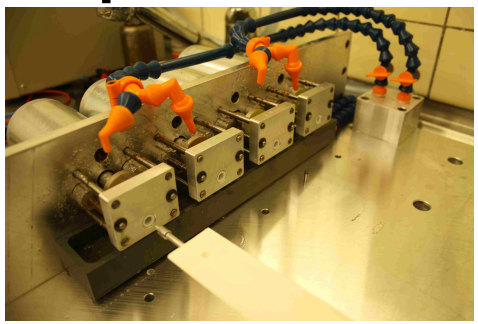
Construction

Step I



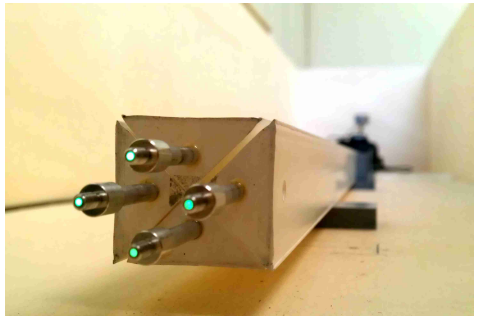
WLS fibers are inserted in triangular scintillator bars and glued with epoxy. 60 bars at a time. 3300 bars have been produced to allow for 15% rejection rate.

Step II



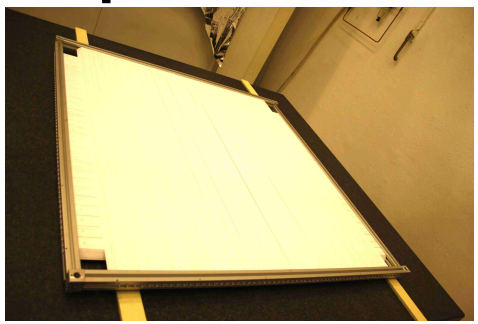
Both faces of bar fiber connectors are polished with a special machine. Four different sanding papers are used. The last polishing paper is 1μm grade diamond based.

Step III



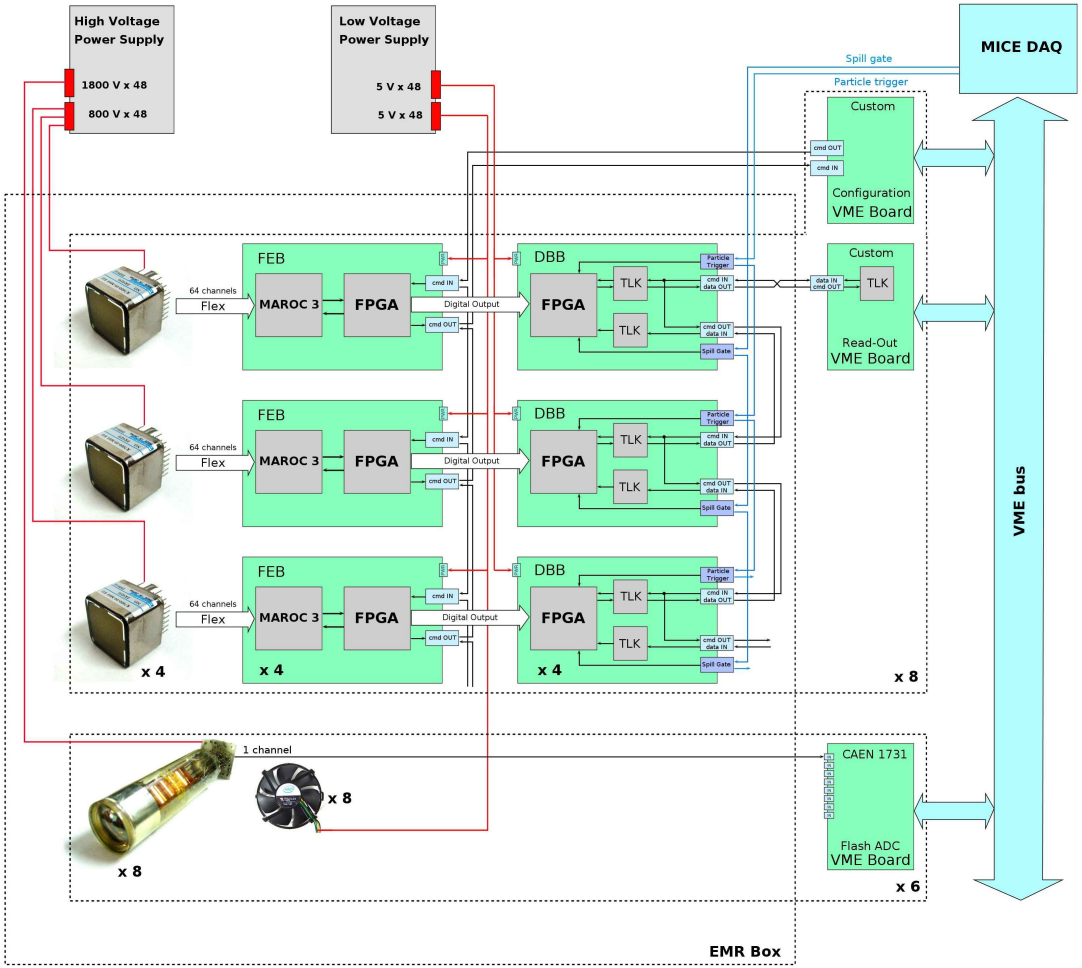
Each bar is tested with an LED and digital camera. Bars with light output more than 15% below the average are rejected. The faults are due to fiber damage during gluing and polishing.

Step IV



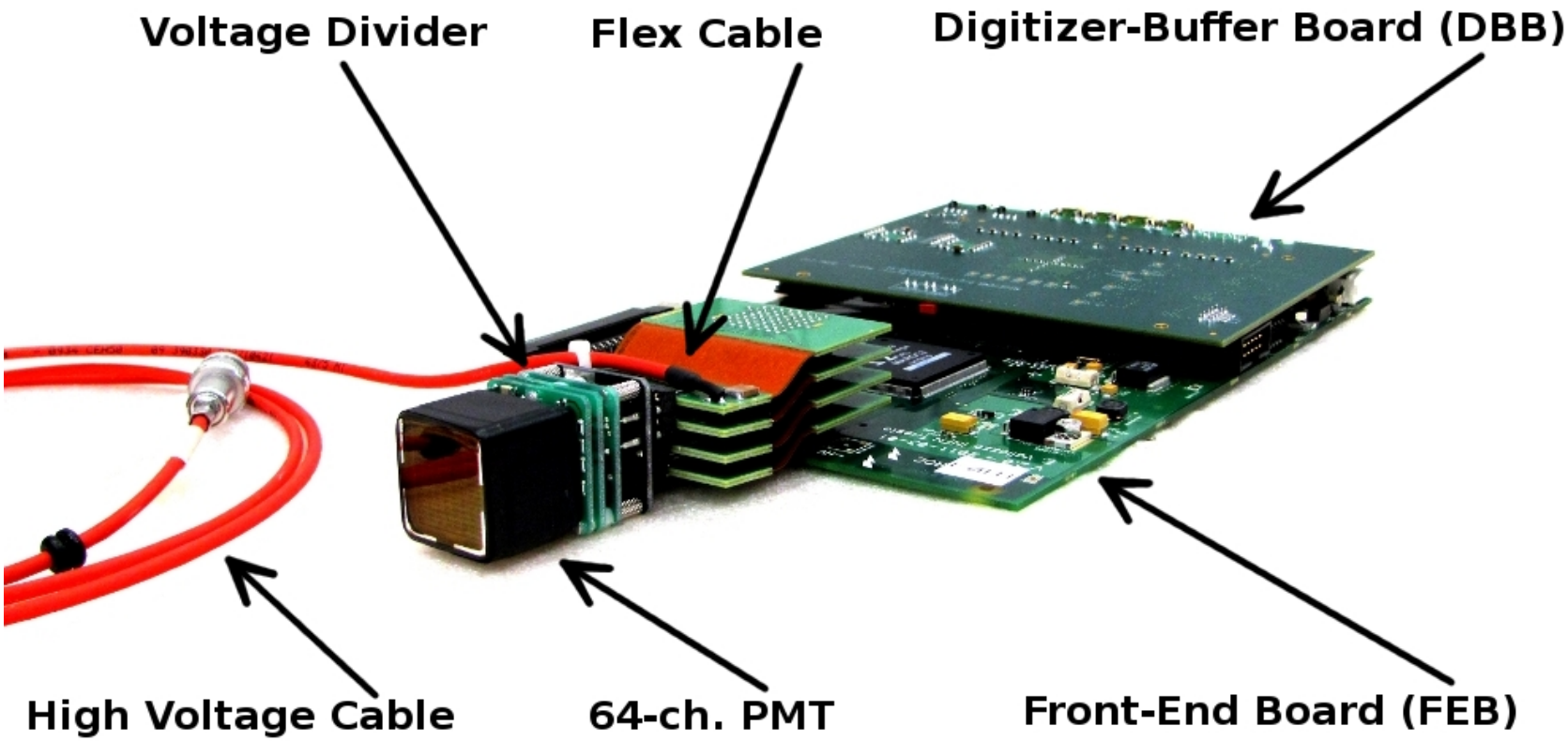
Only tested bars are used for plane assembly. Two clear fiber bundles are clipped to both sides of the plane.

EMR Electronics Readout



- The EMR has a dual readout.
- Fibers from one side of a plane are bunched together and directed to a 1-ch. PMT that gives the total energy in the plane. Eight 1-ch PMTs are readout by one flash ADC (CAEN V1731), there are 6 fADCs in total.
- Fibers from the other side of a plane are coupled to a 64-ch PMT that is readout by custom-made FPGA-based electronics.

EMR Front-End Boards



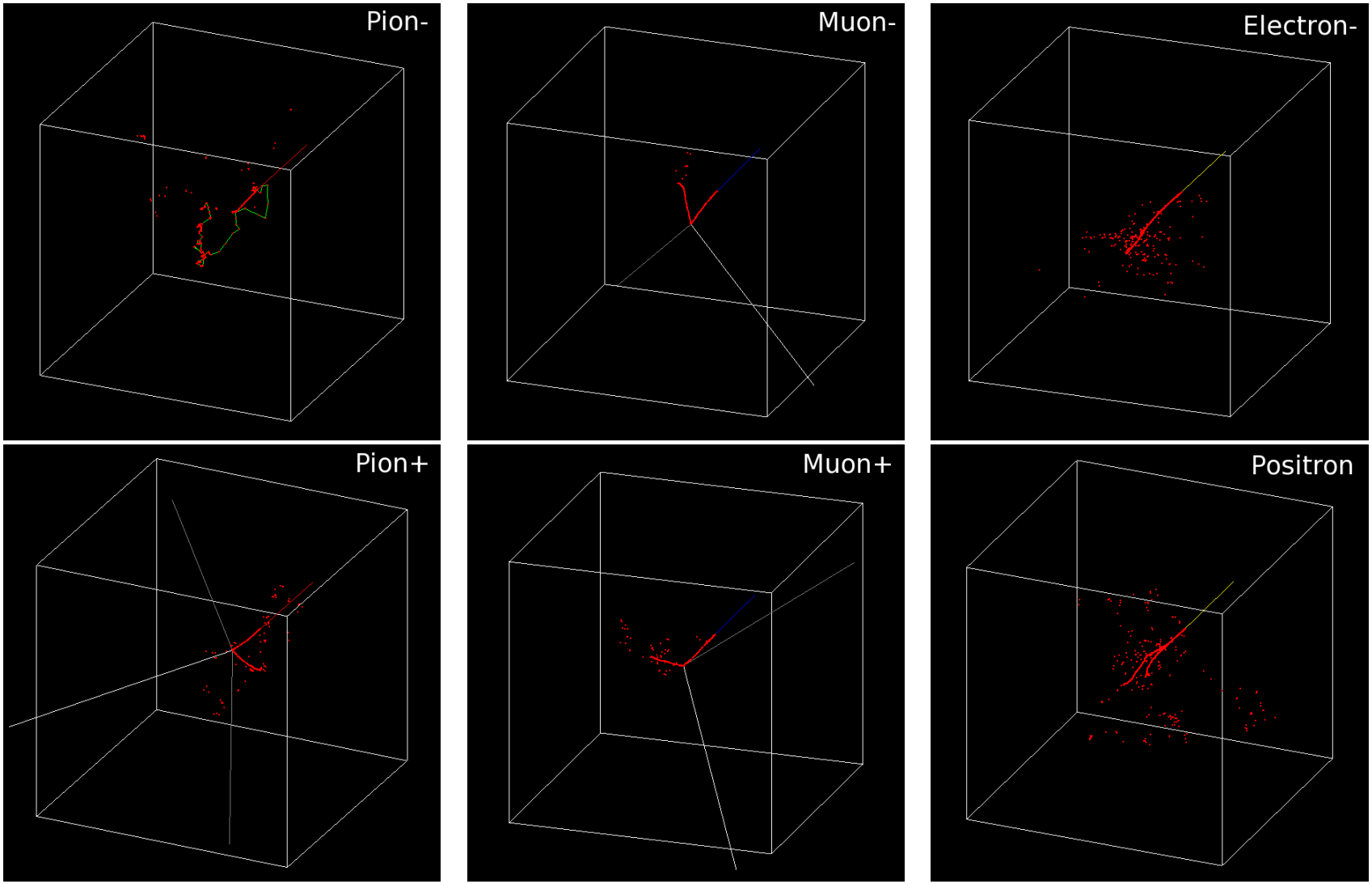
The Front-End Board (FEB) is designed to readout the 64-ch. PMT. It hosts a MAROC ASIC that amplifies, discriminates and shapes all input signals. Pulse height information can be extracted at low rate (during calibration with cosmics). Time over threshold information is directed to a piggy-back buffer board.

The Digitizer-Buffer Board (DBB) receives signals from FEB and stores them in buffer memory. MICE beam is made of 1ms spills every second. Every spill is composed of hundreds of particles. All interactions of these particles are stored in DBB and transferred to PC at the end of a spill.

Table of Contents

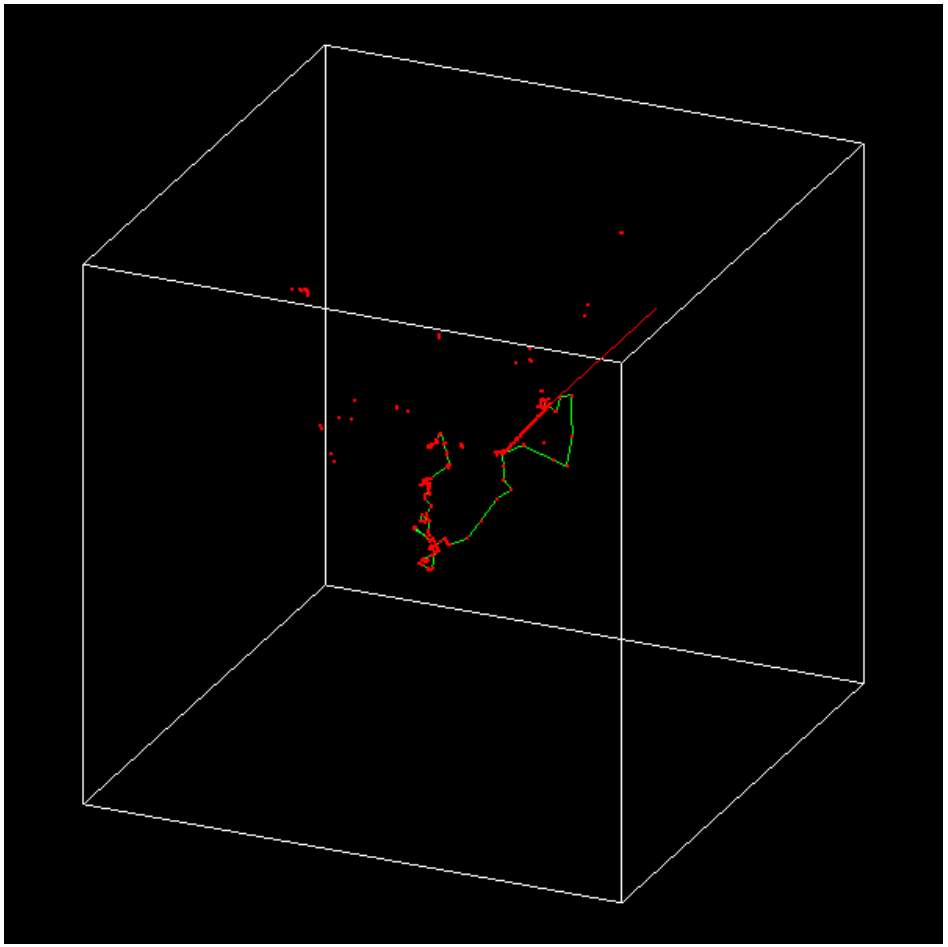
Interaction of Low Energy Particles with EMR

simulation of 200 MeV/c $\pi^-/\pi^+/\mu^-/\mu^+/e^-/e^+$



Interaction of Low Energy Particles with EMR

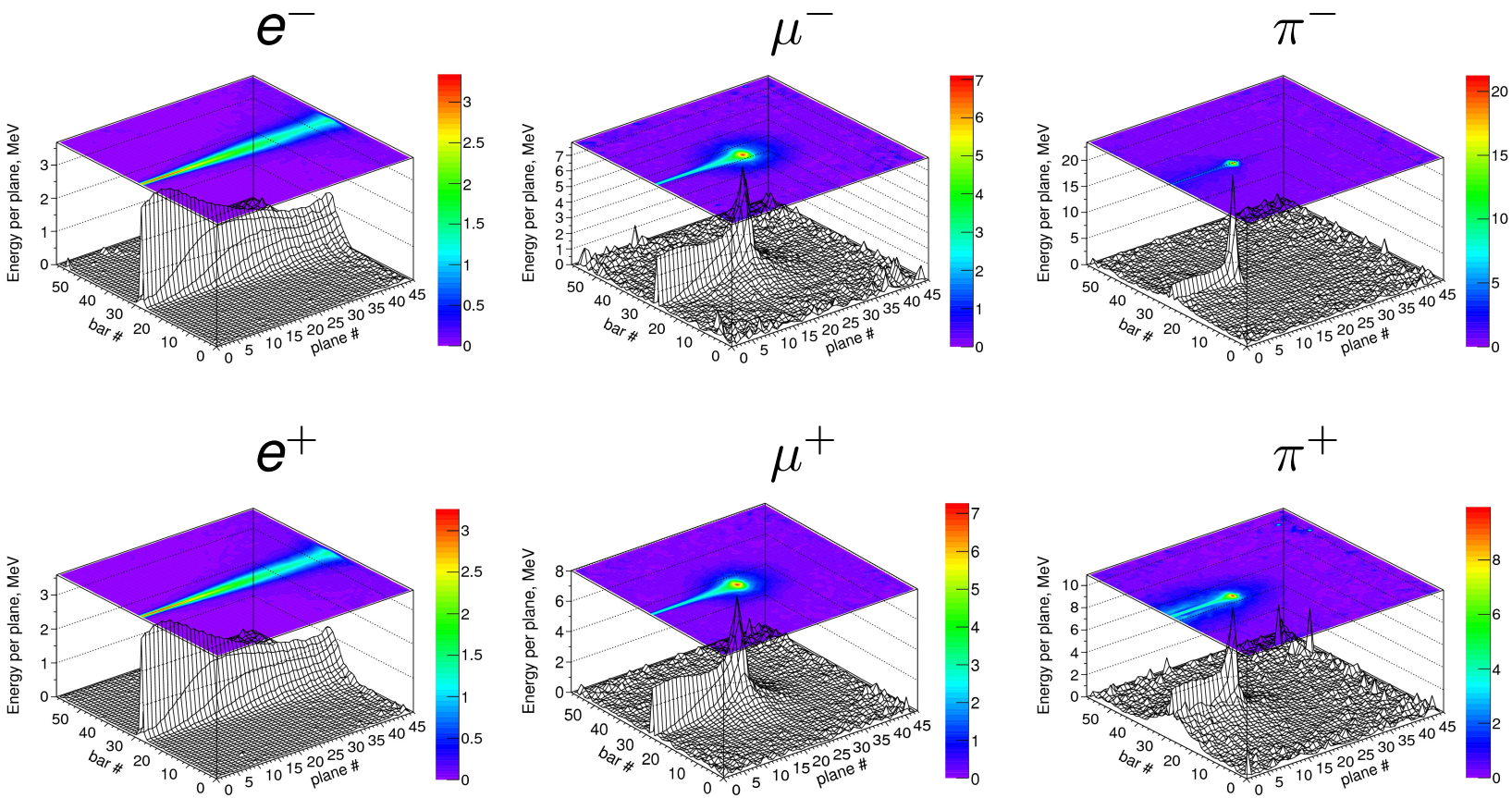
simulation of 200 MeV/c $\pi^-/\pi^+/\mu^-/\mu^+/e^-/e^+$



- $\pi^-/\pi^+/\mu^-/\mu^+/e^-/e^+$ are shown on the left
- stops all particles with momentum less than 300 MeV/c
- allows for measurements of stopping properties:
  - range
  - shower shape
  - event topologies
  - low energy interactions
- in MICE it will allow for very good particle identification for precise measurement of low energy beam emittance

Interaction of Low Energy Particles with EMR

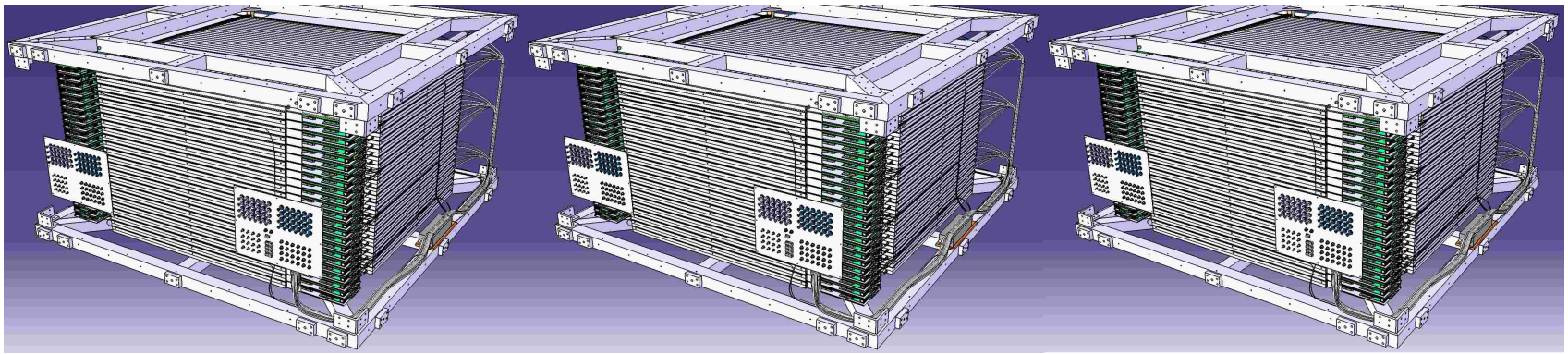
simulation of 200 MeV/c $\pi^+/\pi^-/\mu^+/\mu^-/e^+/e^-$



- good particle identification due to very distinct event topologies
- charge identification is not required for this detector

Table of Contents

Summary



- EMR is a totally active scintillator calorimeter
- designed to measure properties of low energy interactions
- will allow for precise measurement of beam emittance in MICE - R&D for Neutrino Factory
- completion of the construction and beginning beam tests at Rutherford Laboratory (UK) are scheduled for summer this year

Thank you for your attention!