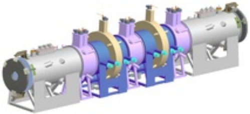
MICE Status

NuFact10

Yağmur Torun

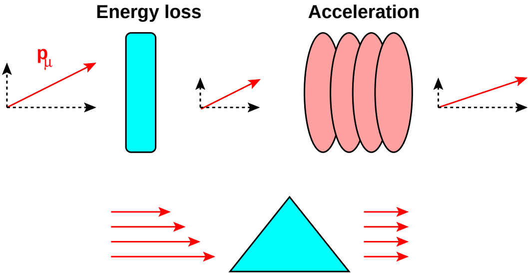
for the MICE Collaboration

Oct 21, 2010 – TIFR, Mumbai



Ionization Cooling

The only muon cooling scheme that appears practical within the muon lifetime (2.2μs).



Mainly transverse; longitudinal cooling requires momentum-dependent path-length through the energy absorbers

Ionization Cooling

Normalized transverse emittance ε of muon beam in solenoidal channel

$$\frac{d\varepsilon}{ds} \simeq \frac{\left\langle \frac{dE}{ds} \right\rangle}{\beta^2 E} (\varepsilon - \varepsilon_0), \quad \varepsilon_0 \simeq \frac{0.875\text{MeV}}{\left\langle \frac{dE}{ds} \right\rangle X_0} \frac{\beta_\perp}{\beta}$$

ε_0: equilibrium emittance (multiple scattering $\sim$ cooling)

- Absorbers with large *dE* per radiation length (LH2: 28.6MeV/m x 8.9m; LiH: 151MeV)
- Strong focusing (large B-field), $\beta_\perp \sim p/B$
- High-gradient rf cavities to replace longitudinal momentum and for phase focusing

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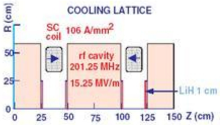

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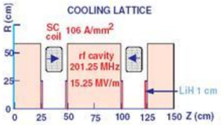

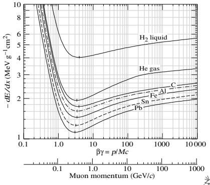

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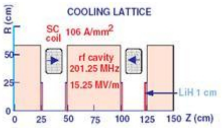
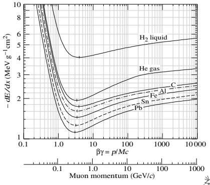


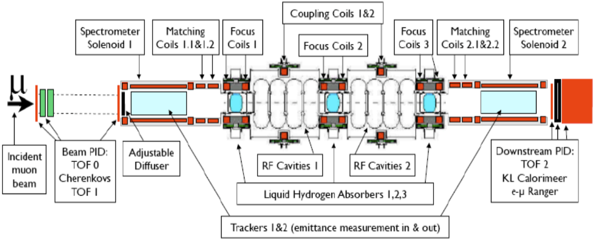


Ionization Cooling

- Many challenges in practice
- Need demonstration with real hardware to establish
  - components can be engineered
  - performance can be accurately predicted
- From the MICE proposal:
  The aims of the International Muon Ionization Cooling Experiment are:
  - To show that it is possible to design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory
  - To place it in a muon beam and measure its performance in various modes of operation and beam conditions, thereby investigating the limits and practicality of cooling

MICE concept

- Beamline to deliver 140-240 MeV/c muons
- Track one μ at a time through one cell of cooling lattice (FS II)
- Momentum measurement before and after the cooling hardware
- Particle ID to remove decays and beam contamination
- Form muon "bunch" in software

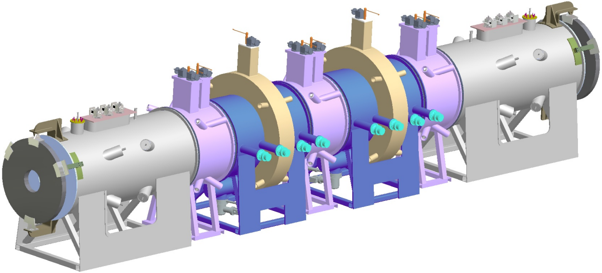


Requires

- High purity muon beam
- Low-mass trackers + PID detectors

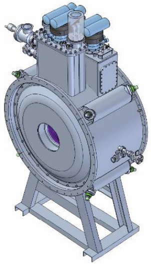
MICE Accelerator Hardware

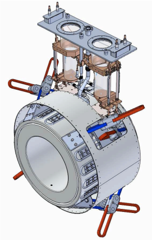
- 3 absorber + focus coil (AFC) modules
- 2 RF cavity + coupling coil (RFCC) modules
- 2 spectrometer modules for trackers and matching

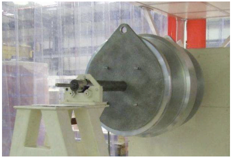


Focus Coils

- Contracted to TESLA Jun 08
  working closely with Oxford and RAL
- Conductor in hand
- Many design iterations to handle interface issues, HTS lead cooling, instrumentation, etc.
- Production started
- Bobbin machined
- Winding about to start
- Delivery of 2 modules expected 2011



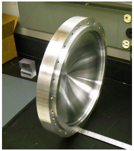




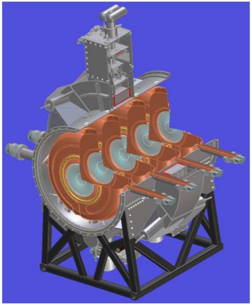
Absorbers

- First body built at MIRAPRO
- Includes temperature/level sensors, heaters and LH2 piping
- Taken to KEK absorber test area
- Window production at Mississippi (including backing plates, jigs)
- Burst test, QA procedure being worked out
- Solid disks and wedges (LiH) also in production
- LH2 infrastructure at RAL engineered



RFCC Module



- 4 201-MHz pillbox cavities (LBNL)
- with curved Be windows
- Large coupling coil outside (LBNL/HIT)
- Cavities to provide 8 MV/m
- In 1.5-2.5T field
- 1/2 modules needed in MICE Step V/VI
- Integration at LBNL
- RF power: CERN amplifiers reconditioned at Daresbury, infrastructure plan in place at RAL

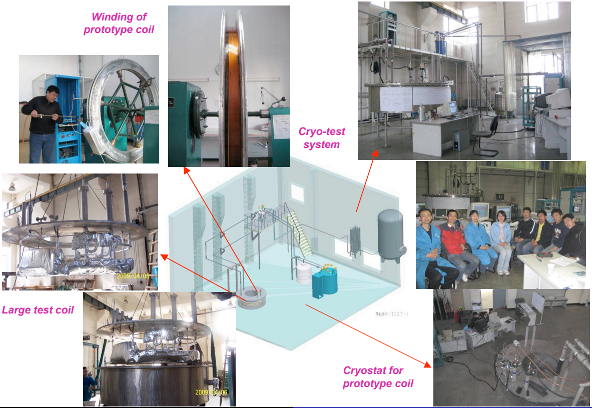
RF Cavities

- Design (LBNL) based on successful MuCool prototype
- 16 MV/m at B=0
- Includes provisions for LN2 cooling
- Half shells at ACME Spinning, production at Applied Fusion
- Be windows at Brush Wellman
- Cavity production ahead of schedule!
  First batch of 5 delivered to LBNL last year and RF measurements carried out
  Second set of 5 to be completed October 2010




Coupling Coils

- Test coil set up with cryogenic system at ICST, HIT, Harbin
- Cold mass test before magnet assembly
- Cryostat design by LBNL and SINAP
- Production at Qi Huan (Beijing); 1st (MuCool) coil 2011, MICE coils 2012

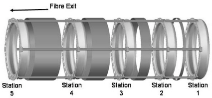


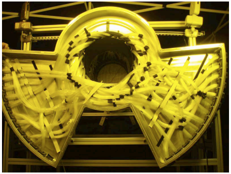
MICE Detectors

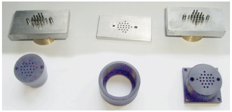
- 2 scintillating fiber trackers
- 3 Time-of-Flight walls
- 2 aerogel threshold Cherenkov counters
  n=1.12 and 1.07, 4 PMTs
- 2-part "calorimeter": Kloe-Light fiber-lead sandwich + Electron Muon Ranger

Scintillating Fiber Trackers

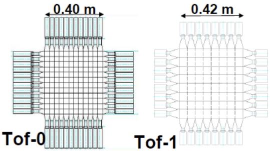
- Built and successfuly tested
- 5 stations/tracker x 3 views per station
- 2 doublet layers/plane with 0.35mm fibers
- VLPC readout, 7 fibers/channel
- 30cm diameter x 1.1m sensitive area
- in 4T uniform field
- Light yield >10pe, dead channels <0.2%
- 0.47mm resolution

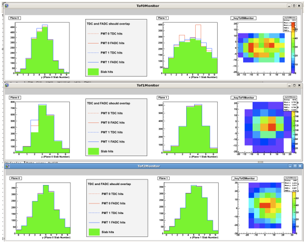






TOF Walls





- Commissioned successfully
- Required resolution for PID achieved: 50-60ps
- Served double duty for momentum measurement in the absence of tracker solenoids
- Further upgrades to replace some PMTs before the next run

The MICE Experience

- Hybrid project: HEP experiment $\Leftrightarrow$ accelerator hardware test
- Diverse collaboration (HEP, accelerator, engineering)
- Virtual beam (one μ at a time) $\Rightarrow$ new tools required for measuring cooling with unprecedented precision
- Mixed toolbox (G4MICE, ICOOL, G4beamline, Transport/Turtle, ..)
- Measuring accelerator physics quantities correctly (emittance, phase space density, transmission, cooling, ..),
- NF cooling channel is a moving target
- 5 MICE Ph. D.'s granted so far (K. Walaron, R. Sandström, C. Rogers, A. Fish, H. Sakamoto), several more in the pipeline

Outlook

- MICE Step I successfully completed
  data analysis under way (M. Rayner talk)
- Beamline operational (K. Long talk)
  - Magnets
  - Proton absorbers
  - GVAs, BPMs, luminosity monitor
- Detectors mostly in place
  - Trackers have been ready for a long time
  - Most PID detectors commissioned in beam (TOF0, TOF1, TOF2, CKOVa, CKOVb, KL)
  - EMR should be done by next run
- Controls and monitoring, online reconstruction work
- Operations streamlined, offline analysis mature
- On track for establishing ionization cooling as a practical technology for muon accelerators in the next 2 years