MICE Construction

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On behalf of the MICE collaboration
Outline

• Experiment overview
• Magnets
• Cold Heads and Compressors
• Absorber
• Partial Return Yoke
• Diffuser
• Magnet infrastructure
• Approvals for operations
• Demonstration of Ionisation Cooling
• Conclusions
MICE Experiment

- MICE, the Muon Ionisation Cooling Experiment is an international collaboration aiming to demonstrate that the emittance of a muon beam can be reduced, the muon beam can be “cooled”
- Measure the reduction in muon ‘beam’ emittance due to ionisation cooling in liquid Hydrogen and LiH.
- To do this would be to establish the feasibility of muon accelerators for particle physics.
- Muon accelerators are one of the enabling technologies for investigating neutrino physics.
- Capability to deliver constituent collisions more energetic than those that can be achieved at the LHC.
- MICE will deliver the necessary, seminal, demonstration of cooling required for these future experiments.
MICE Experiment

MICE will be completed in 2 stages

• Step IV
  • Measure absorber properties
    • liquid hydrogen
    • lithium hydride, LiH

• Demonstration of Ionisation Cooling
  • Demonstrate cooling of Muon beam using LiH absorber with re-acceleration from 2 normally conducting RF cavities.
MICE Step IV

Modules
• 3 superconducting magnets, comprising 12 coils
• Liquid hydrogen/LiH absorber
• High Z variable diffuser

Detectors
• 2 scintillating-fibre trackers, 5 planes each
• 3 Time of Flight hodoscopes
• 2 Cherenkov counters
• Kloe Light (KL) detector
• Electron Muon Ranger (EMR)
MICE Step IV
Step IV: Magnets

2 spectrometer solenoids with matching coils
• Fabricated in US
• Trained successfully to operating current
  • 10-20 quenches each, training not retained after warming.
  • Field mapped.
• Shipped to UK
• Installed on translation stages in hall
• Compressors installed plumbed, wired and connected
• Successful cool-down
• Independent training in progress.
2 Focus coils (only one required in current configuration)
• Constructed in UK
• Trained to operating current
• Installed in hall
Absorber

• Liquid hydrogen absorber operated successfully.
  – Moved to bottled hydrogen, not hydride bed.
  – 2 to 3 bottles required per fill.
  – Dual thin aluminium windows per side
  – Secondary window required to define vent route should primary window fail
  – Thin window burst tested to verify predictions
  – All safety tests passed

• LiH absorber procured/ready for use.
• Liquid hydrogen absorber currently installed in Focus Coil
Cold Heads and Compressors

Each Spectrometer solenoid has 5 cold heads
- 1 compressor per cold head
- Compressors installed 30m distant on ‘West Wall’
- Conventional specification; max hose length = 20m
  - 30m hoses produce insignificant losses for SS

Focus Coil, 2 cold heads
- 1 Compressor per cold head
- Compressors installed 30m distant on ‘West Wall’
  - Cooling margin appears to be reduced
  - Moving compressors closer.
He compressors and lines
Magnetic Alignment

Spectrometer solenoids and Focus coil connected with hydro-formed bellows

- Measured offsets between warm bores and magnetic field at manufacture.
- Slight mis-alignment.
- Verify with particle tracks
- Correct with bespoke offset bellows
- Hydro-formed bellows are relatively ‘stiff’ and allow angular but not axial offset
- Quench forces must be considered.
Partial Return Yoke (PRY)

Flux return path to protect sensitive equipment from fringe field of magnet chain.
- 100mm thick soft iron plate
- 2 angled plates per side, each fabricated from 3 sections
- End plates made in 2 sections each
- Bracing structures
- Made in the USA
- Support structure made in UK
- Shipped to UK and installed to schedule

5 Gauss perimeter now runs just outside PRY supports.
- stray field concerns in critical areas eliminated

NuFact15 10th August 2015
Partial Return Yoke (PRY)
Diffuser Frame

- Pre-existing (small) leak due to flaw in frame.
- Results in small increase in scattering as air leaks into beam line volume.
- New part fabricated.
- Planning replacement schedule for later this month.
- Integrate with magnet training plan as PRY must be partially dismantled.
- Down-time of a few days
Magnet infrastructure

- New link boxes installed to allow magnet polarity changes without working inside PRY
- ODH (Oxygen Depletion Hazard) detection system installed and commissioned
- PRY deflection detection system installed
- Magnet quench detection system installed and tested
- Magnet ground fault detection system installed and tested
- Magnet power supplies installed and tested
- Magnet vessel pressure regulation installed and tested
- Anti-icing heaters installed.
- Cold head compressors installed, wired, tested.
- Control racks installed and commissioned
Approvals for operations

- Safety paperwork for each sub-system completed.
- Overarching safety case completed
- Monitoring installed and operational
- Procedures agreed.
- MICE is now operational.

- 1st operations in July 2015
- Experimental hall closed each night to allow measurements, opened each morning to resume magnet conditioning/installation work.
Cooling Demonstration

Installation start 1\textsuperscript{st} June 2016.
2 RF cavities, 2 secondary absorbers bracketing main absorber

- 2 x 2MW 201MHz amplifier chains – UK
- RF infrastructure support - UK
- RF controls and monitoring – UK
- Muon phase determination - UK

- Extended Partial Return Yoke – USA
- 2 x 201MHz cavities - USA
  - Be windows
  - Tested in B field to 14MV/m
Demonstration of Ionisation Cooling

- RF power transmission overhead
- SF₆ filled co-axial lines
- Relatively easily de-mountable
- Independent vacuum system for cavities
RF Power

- Simplified distribution network - overhead
- Off-centre mounting of hybrid takes up phase shift
- Minimised length of 4” line - minimises losses
Conclusions

MICE has completed an intensive ‘build’ phase

• Built, trained, installed and commissioning magnets
• Installed and tested liquid hydrogen absorber
• Designed, constructed, installed - Partial Return Yoke
• Diffuser upgrades in progress
• Electrical installation complete
• Safety – approved for operations
• First data with magnetic field taken

Future Work: Demonstration of Ionisation Cooling