MICE and MuCool

PPD Engineering Consumers Meeting

July 24, 2006

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Muon Accelerator R&D

- Our activities focus on studying the accelerator physics of a Neutrino Factory and Muon Collider and developing the accelerator technologies that are required to make these facilities a reality
- This work is being conducted within the Framework of the US Neutrino Factory and Muon Collider Collaboration (NFMCC) and consists of
  - Design and Simulation
    - Includes participation in international studies such as the *International Scoping Study for a Future Neutrino Factory and Super-Beam Facility* (ISS)
  - MuCool
  - MICE @ RAL
  - Targetry – MERIT @ CERN
- Approximately 7 FTE physicist effort

MuCool and MICE

- Muon Ionization Cooling Experiment (MICE)
  - Demonstration of "Study II" muon cooling channel concept
    - Has Phase I UK funding ($20M)
- MuCool Collaboration interface to MICE
  - Design Optimization/develop of Study II cooling channel
    - Simulations
  - Detailed engineering
    - Full component design
    - Systems integration
    - Safety
  - RF cavity development, fabrication, and test
  - Absorber development, fabrication, and test
  - Development of beam line instrumentation
  - MuCool will prototype and test cooling hardware including MICE pieces for which the collaboration is responsible

MICE

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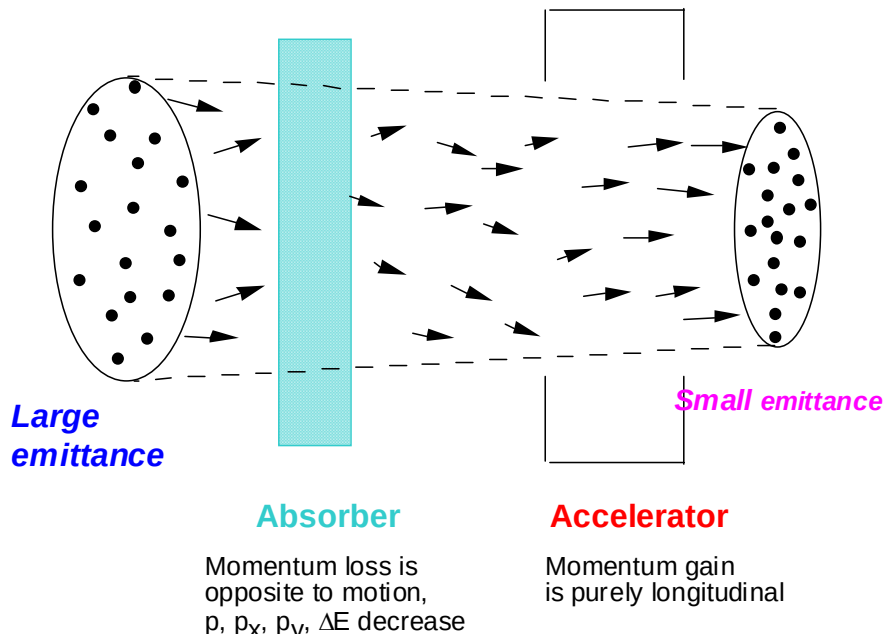
Muon Ionization Cooling

- 2D Transverse Cooling

$$\frac{d\epsilon_N}{ds} = -\frac{1}{\beta^2}\frac{dE_\mu}{ds}\frac{\epsilon_N}{E_\mu} + \frac{\beta_\perp (0.014\ \mathrm{GeV})^2}{2\beta^3 E_\mu m_\mu L_R}$$

and

$$\epsilon_{N,\mathrm{min}} = \frac{\beta_\perp (14\ \mathrm{MeV})^2}{2\beta m_\mu \frac{dE_\mu}{ds} L_R}$$



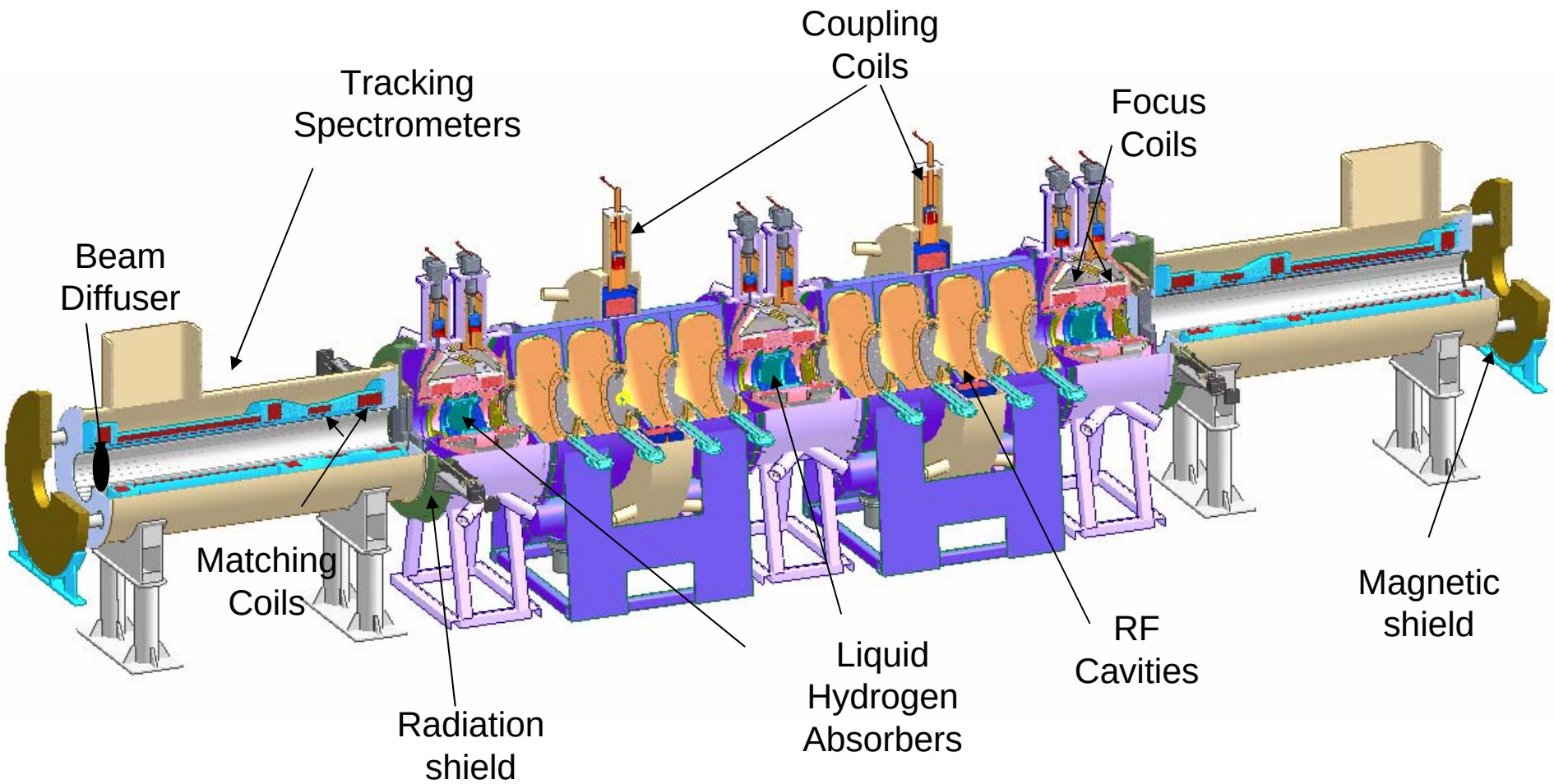
- Figure of merit: $M = L_R dE_\mu/ds$

M^2 (4D cooling) for different absorbers

Material	$\langle dE/ds \rangle_{\mathrm{min}}$ (MeV g^{-1}cm^2)	L_R (g cm^{-2})	Merit
GH_2	4.103	61.28	1.03
LH_2	4.034	61.28	1
He	1.937	94.32	0.55
LiH	1.94	86.9	0.47
Li	1.639	82.76	0.30
CH_4	2.417	46.22	0.20
Be	1.594	65.19	0.18

H_2 is clearly Best -
Neglecting Engineering Issues
Windows, Safety

Muon Ionization Cooling Experiment MICE

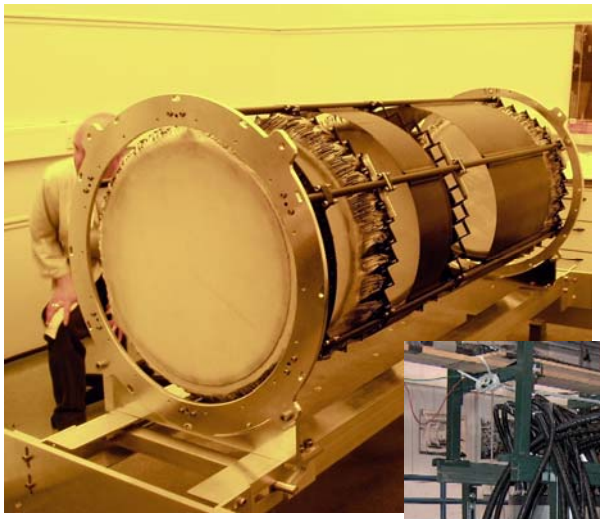


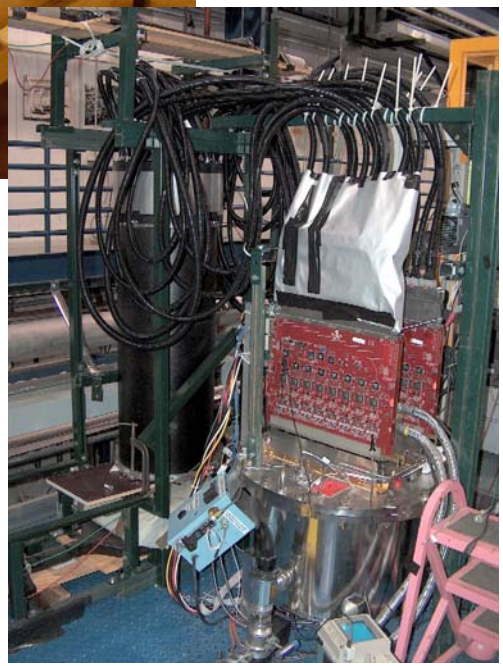
MICE – Precision Emittance Measurement

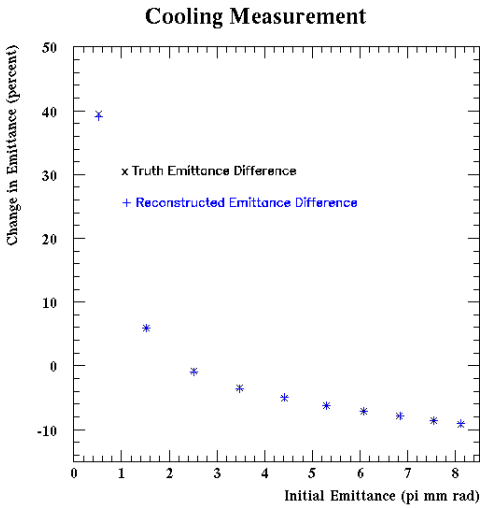
- Expect 10% cooling (input 6π mm rad beam).
- Wish to measure this change to ~ 1%.
- Require measurement of emittance of beams into and out of cooling channel to 0.1%!
- Cannot be done with conventional beam monitoring devices.
- Instead, perform a single particle experiment:
  - High precision measurement of each track (position, momentum, time, energy).
  - Build up a virtual bunch offline.
  - Analyse effect of cooling channel on many different bunches.
  - Study cooling channel parameters over a range of initial beam momentum and emittance.
- Presence of X-rays and electrons from RF cavities and safety issues relating to operation of LH_2 absorbers affects specification of tracker.
- Solution chosen – Scintillating Fibres readout with VLPCs.

Fermilab MICE Responsibilities

- Scintillating Fibre Tracker:
  - Fibre Mirroring
  - Ribbon fabrication
  - Connector polishing
- VLPC readout system:
  - VLPC cassettes
  - Cryostats (4)
  - AFEIIt
  - VLSB
- Software:
  - G4MICE
  - DAQ / Controls and Monitoring
  - Tracker Quality Assurance



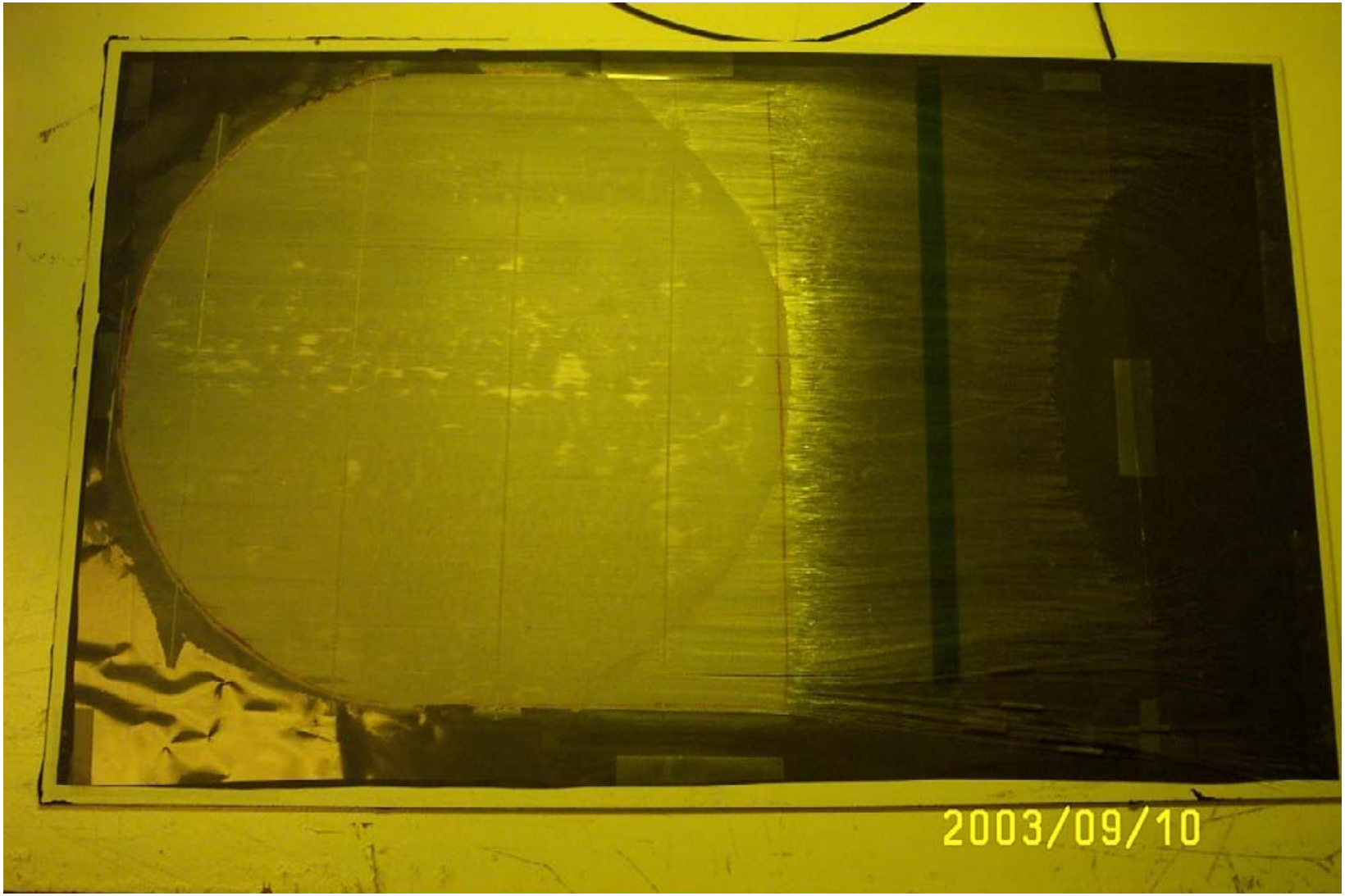




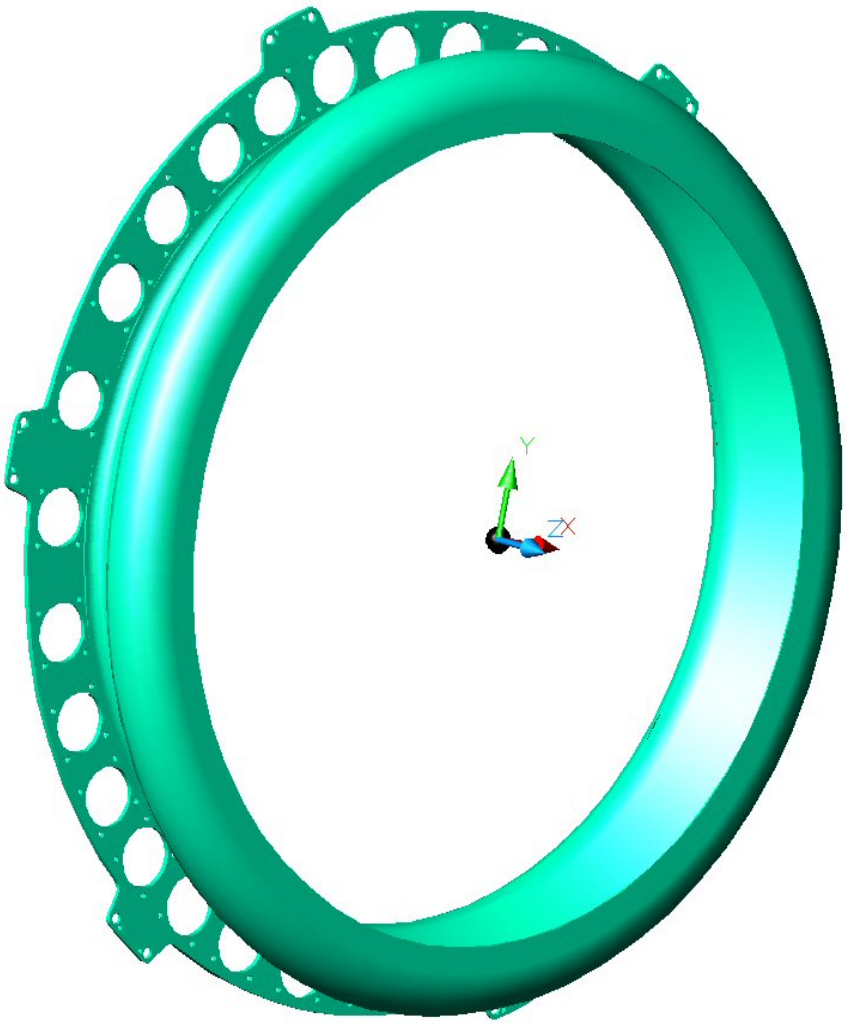
Scintillating Fibre Tracker

- Design based on D0 experience, optimised for performance with 200 MeV/c muons.
- Doublet ribbons made from 350 μm fibre (835 μm in D0).
- Smaller fibre minimises radiation length of tracker.
- Neighbouring groups of seven fibres in a plane are ganged together to be readout as one channel to reduce electronics cost.
- Each tracker consists of five measurement stations.
- A station is made from three fibre ribbons arranged at 120° to each other.
- Station is supported by a carbon fibre structure that is wholly outside of the fiducial volume of the tracker.
- Clear fibre waveguides take the light from each station outside of the 4T solenoid to VLPC cassettes.

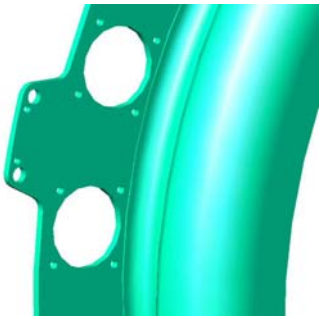
Fibre Plane/Ribbon/Doublet



Stations
Modifications to the Carbon Fibre



The New station has had its outer diameter reduced to 396 to take into account the fact that the bore of the solenoid is not machined but a rolled tube. The connector flange has been thickened to 3mm to allow machining. This is to ensure that there is a uniform thickness thus ensuring that the completed tracker is 'of one axis' and all planes are parallel. Also the face that seats the connectors has a completely machined face to allow all of the connectors to sit down flat thus keeping the axis of the fibres perpendicular to the plane



Station 4 Fabrication (Finished)

Station Layout/Pitch

The final pitch has still to be decided but the two alternatives shown are

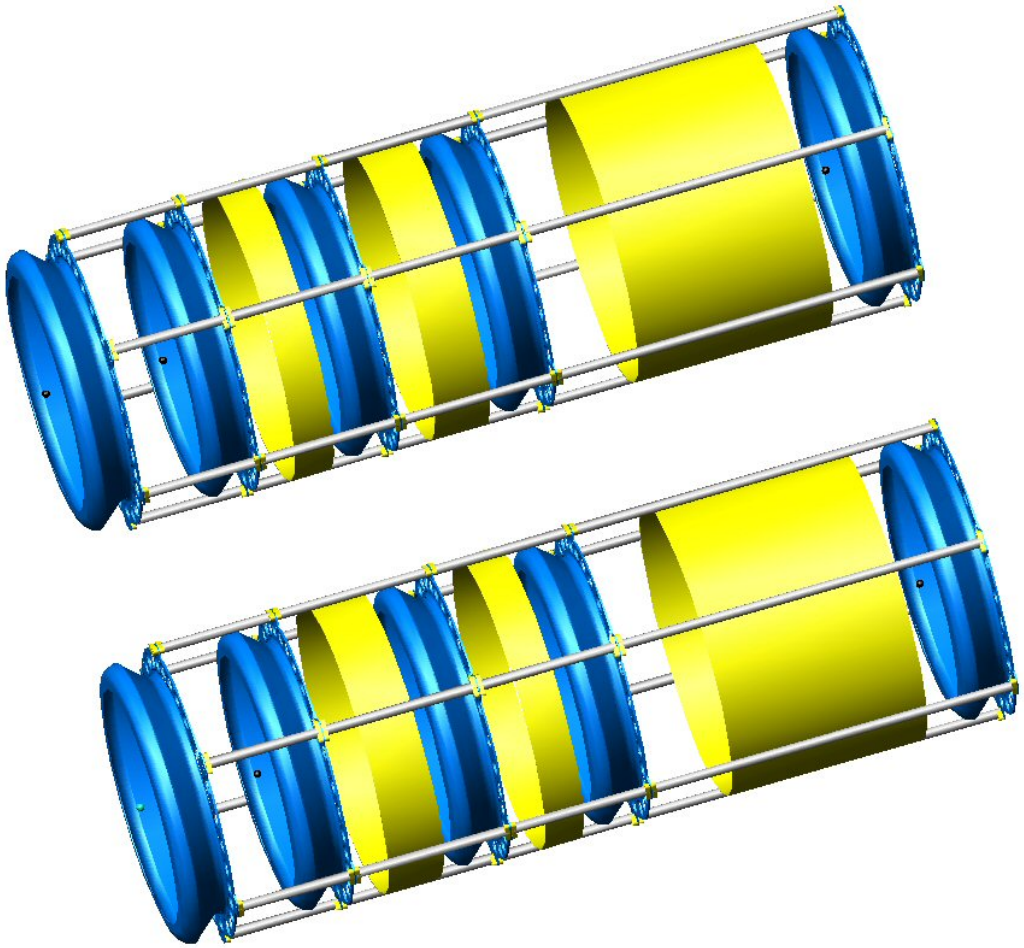
Top:-

15cm, 23cm, 25cm and 47cm

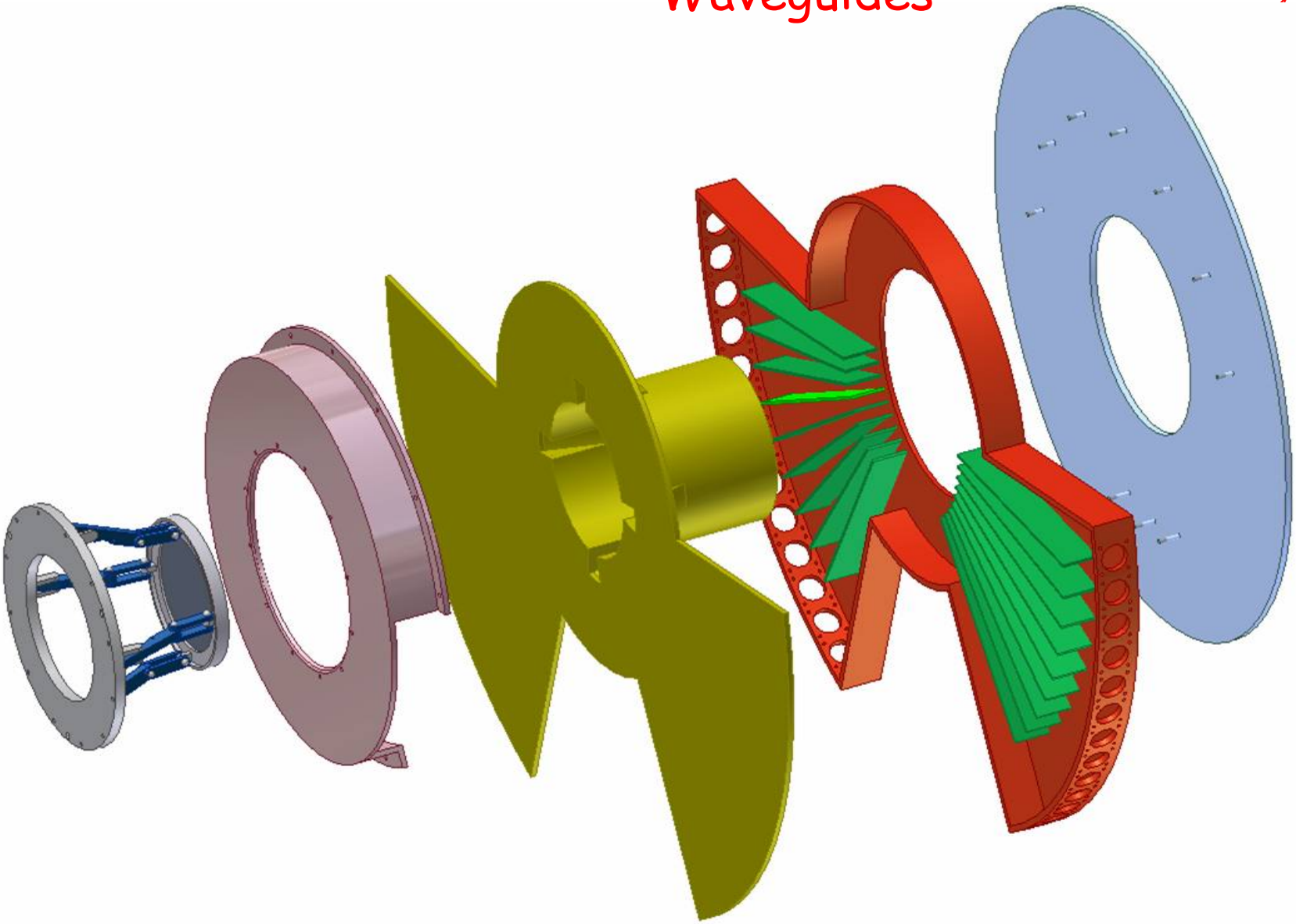
Bottom:-

15cm, 25cm, 23cm and 47cm

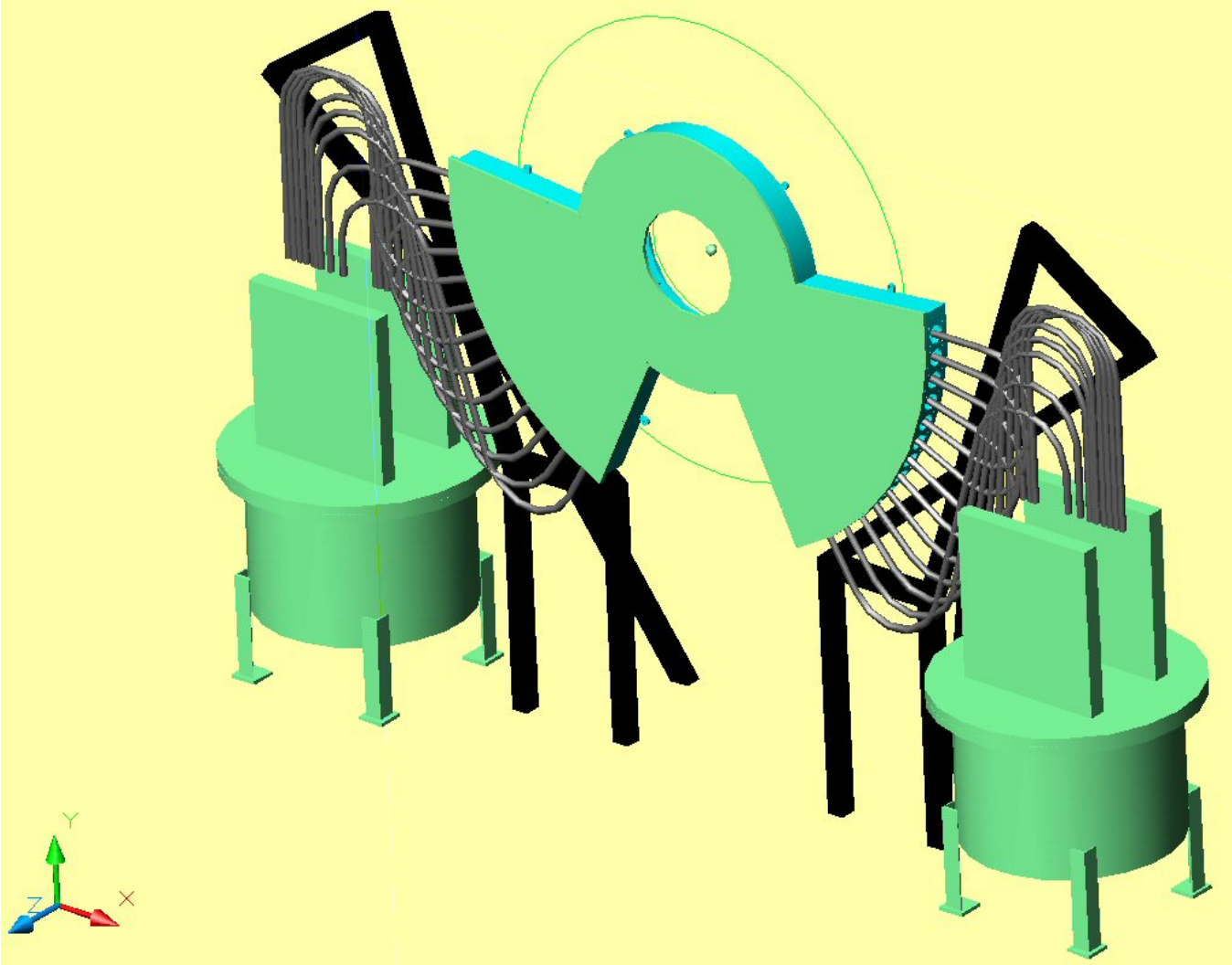
If this is the case the only need for a decision is to accommodate the length of wave guide and I'm sure we can accommodate a 2cm change in the lengths by making them the longest required.



Optical Interface to External Waveguides

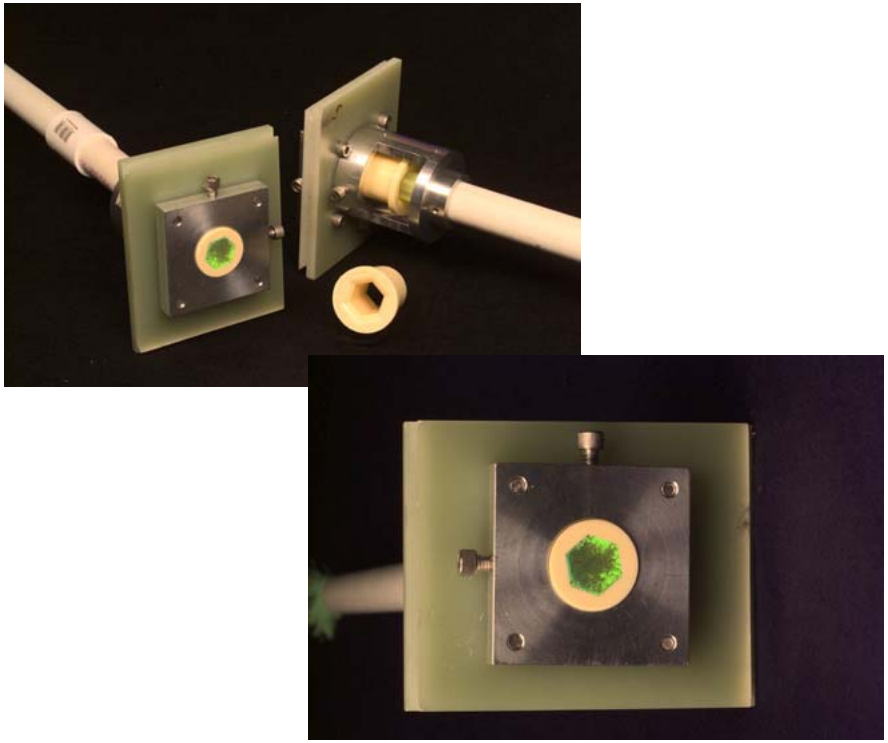


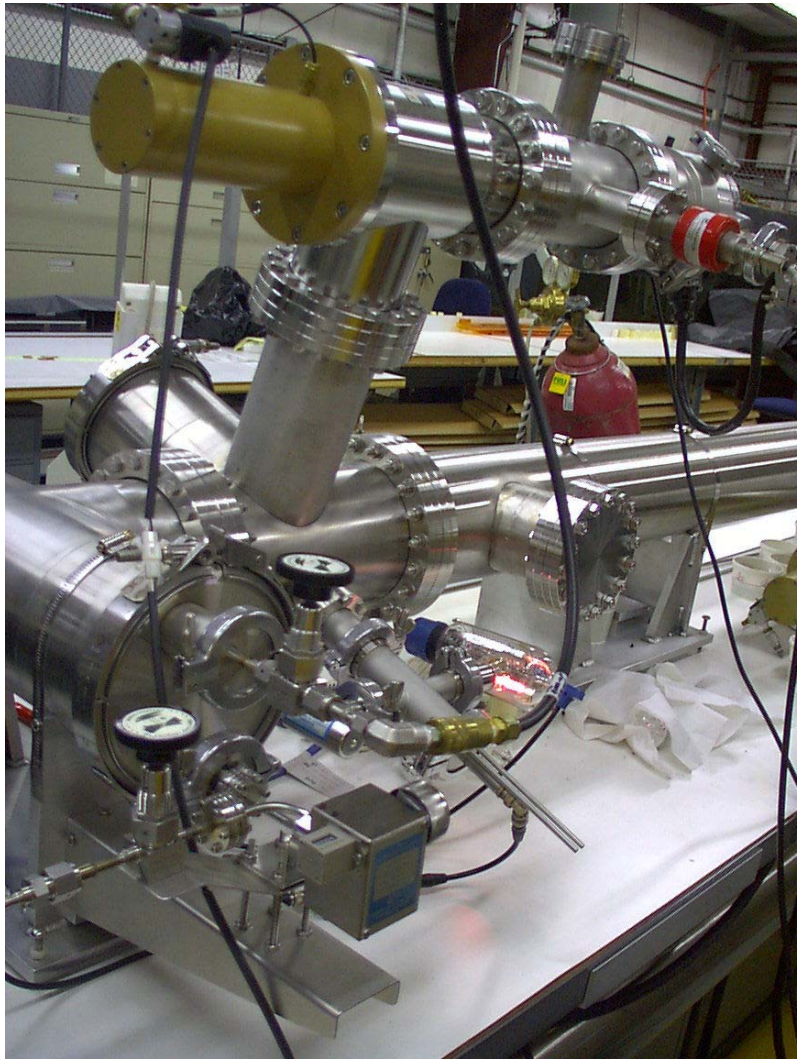
Layout 1st Attempt



Fibre Mirroring

- Mirrors are added to one end of each scintillating fibre before the ribbon is made.
- Vapour deposition of Aluminium performed in Lab 7.



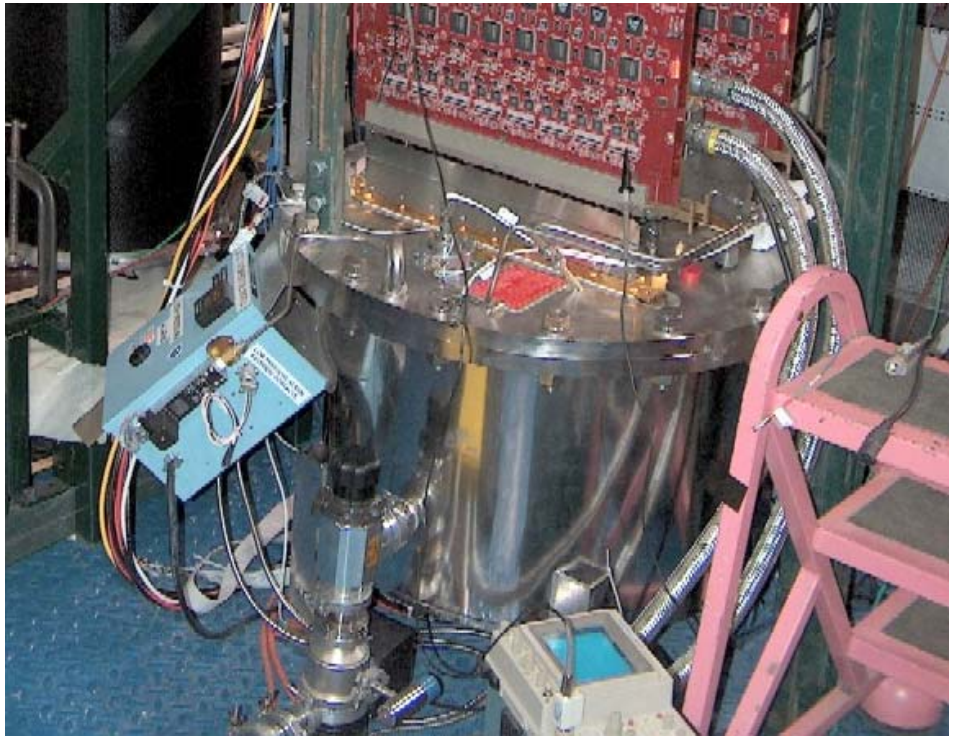


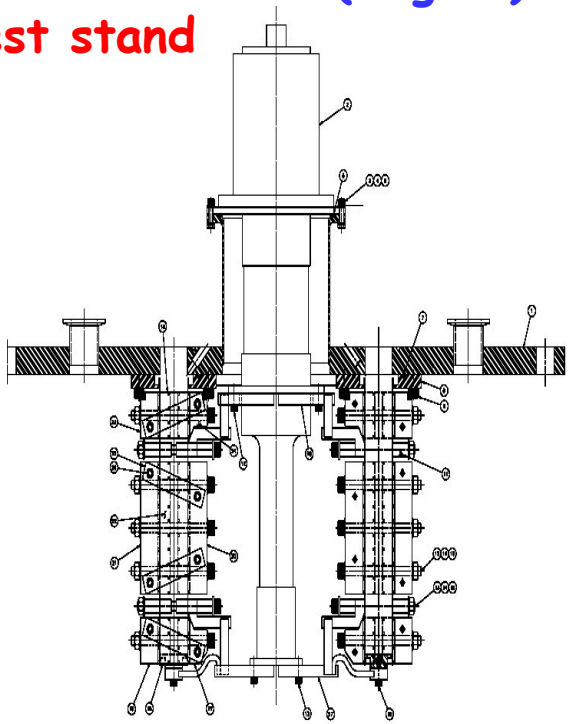
Connector Polishing

- A station is built up by precisely aligning each fibre doublet on the carbon fibre support structure.
- The bundles of fibre are placed into connectors on the station and potted.
- Once all fibres in a station are potted, the ends are cut off and then the connector face is diamond polished to produce a flat optical surface.

VLPC Cryostat

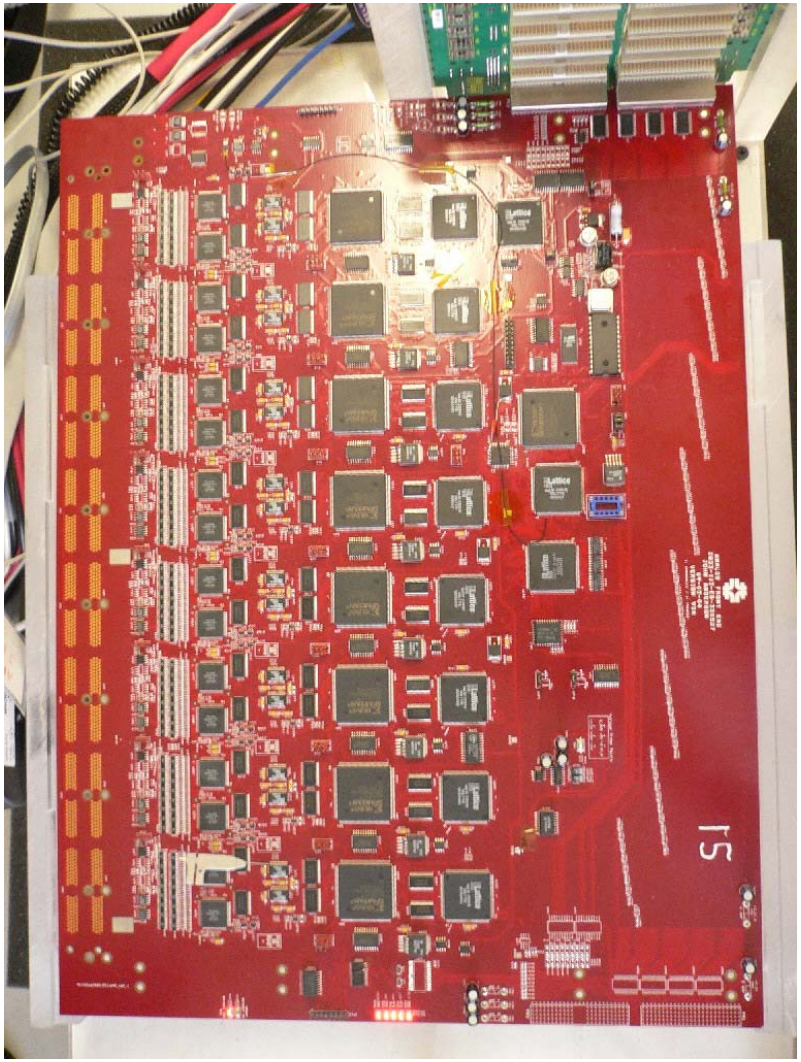
- Fermilab design specifically for MICE.
- Each cryostat holds two cassettes (2048 channels total).
- Sumitomo cryocoolers provide cooling (5.40 ±0.02 K).
- First MICE design cryostat was built and operated at Fermilab from March 2005 and used to test a prototype tracker at D0 (August) and KEK (October). MICE will require 4 + 1 test stand





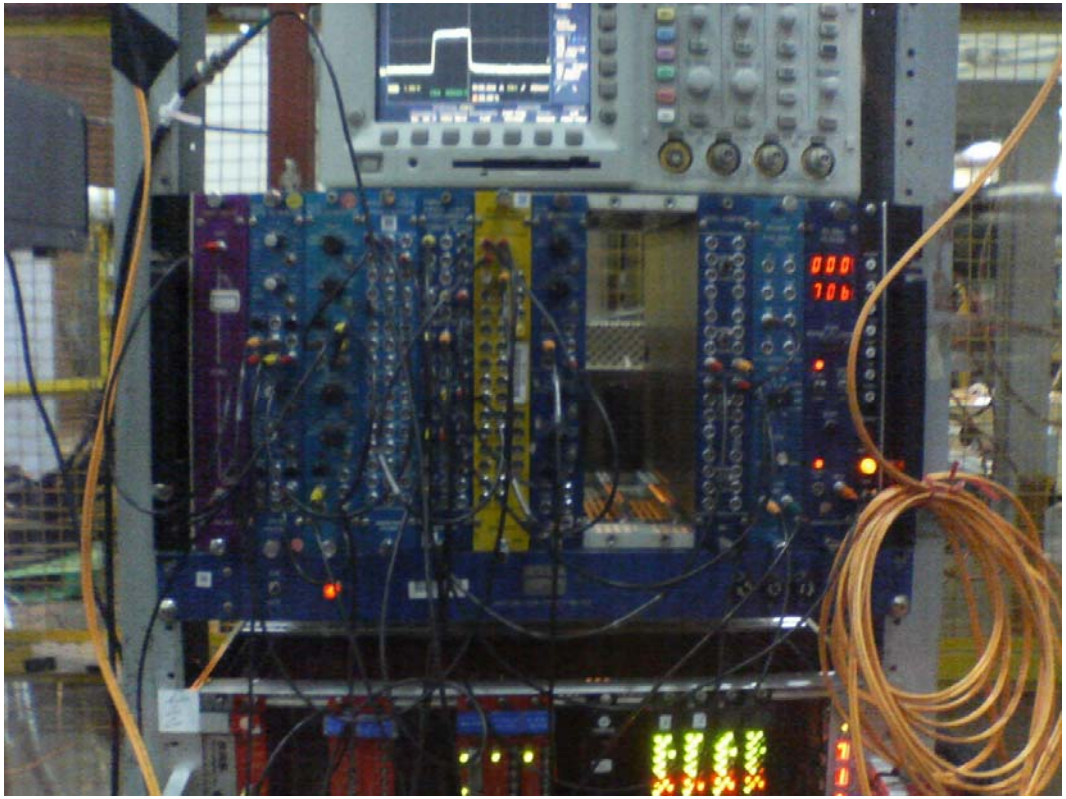
AFEIIt

- Analogue Front End electronics board.
- Signal from VLPCs is digitised and readout through a pipeline (TRIP chip).
- AFEI used by D0.
- Improved design including ~2ns timing information: AFEIIt.
- Prototype board (AFEII) was tested over the past year and used for tests of the prototype MICE tracker.
- AFEIIt boards for MICE will be prepared during the same production as those needed for D0.



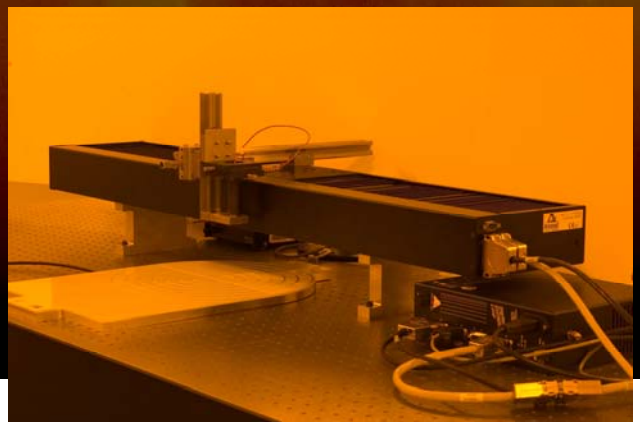
DAQ, Controls and Monitoring

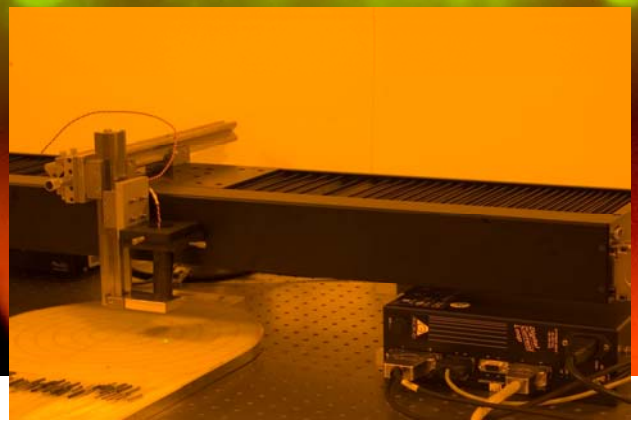
- Working group on data acquisition, controls and monitoring started in September.
- Work in progress to define needs for MICE DAQ.
- UniDAQ was used for the tracker test at KEK.
- Several other options are also under investigation.
- EPICS has been chosen by MICE to provide slow control and monitoring.



Tracker Quality Assurance

- Each stage of the tracker construction involves testing to ensure the quality of the tracker.
- Plan to build sufficient components for three trackers, and assemble the best into the two trackers for data taking.
- QA techniques developed from experience gained building the D0 fibre tracker.





MuCool

A. Bross, S. Geer, A. Moretti, B. Norris, Z. Qian

MuCool Program

- Mission
  - Design, prototype and test all cooling channel components (SFOFO)
    - 201 MHz RF Cavities, absorbers, SC solenoids
  - Support MICE (cooling demonstration experiment)
  - Perform high beam-power engineering test of cooling section components

- Currently consists of 9 institutions from the US and Japan

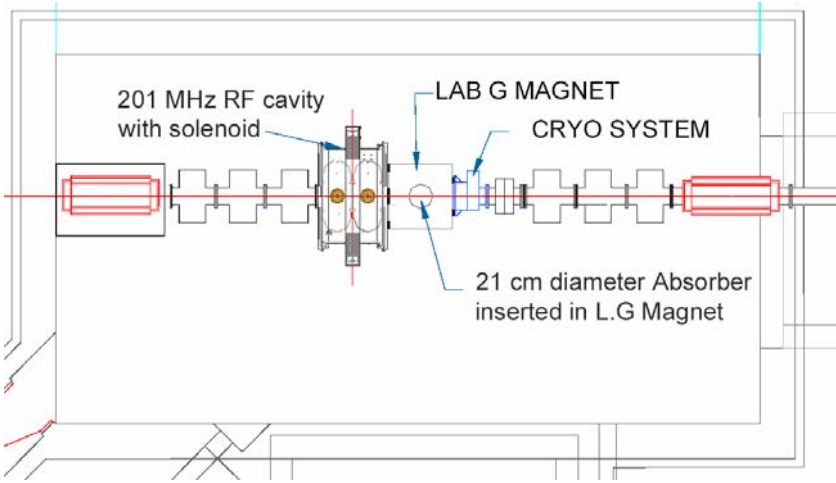
RF Development
ANL
Fermilab
IIT
JLAB
LBNL
Mississippi

Solenoids
LBNL
Mississippi

Absorber R&D
Fermilab
IIT
KEK
NIU
Mississippi
Osaka

MuCool Test Area

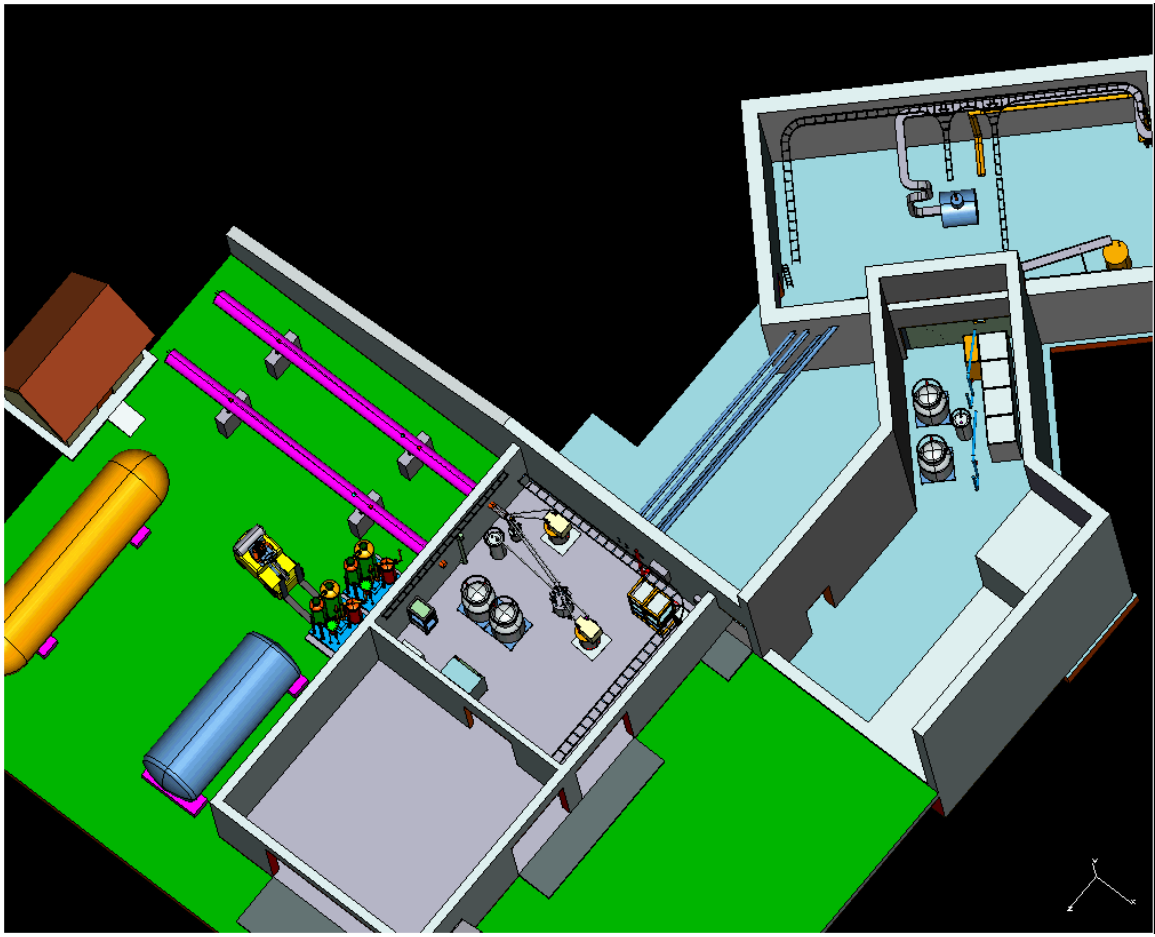
- Facility to test all components of cooling channel (not a test of ionization cooling)
  - At high beam power
    - Designed to accommodate full Linac Beam
    - 1.6 X 10^{13} p/pulse @15 Hz
      - 2.4 X 10^{14} p/s
      - ≈ 600 W into 35 cm LH_2 absorber @ 400 MeV
  - RF power from Linac (201 and 805 MHz test stands)
    - Waveguides pipe power to MTA



MTA Hall

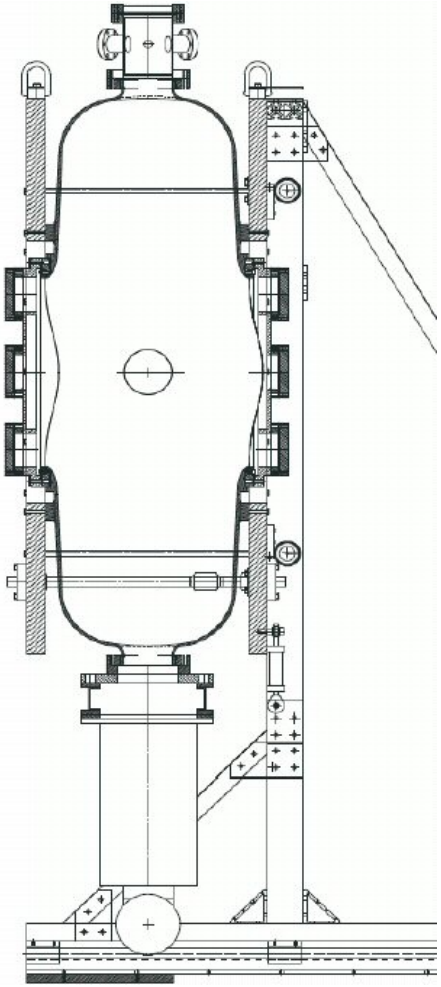
MTA

- The MTA is the focus of our Activities
  - RF testing (805 and 201 MHz)
  - High pressure H_2 gas-filled RF
  - LH_2 Absorber tests
- Two parts of infrastructure yet to be completed
  - Cryo Plant
  - Beam Line



RF R&D – 201 MHz Cavity Design

- The 201 MHz Cavity is now operating
  - Recently reached 16MV/m at B=0 (design gradient!)



MICE PPD Activities

- Lab 7 – Fiber Aluminization
  - 75 Batches of 1000 fibers each to be done (6 completed)
  - Connector polishing
- Lab 3 – Ribbon Fabrication
  - Fixturing complete ready to start
  - Will make 50 ribbons
- EED
  - AFE IIt
    - MICE Collaboration is supporting test of boards (IIT & RAL)
- Mechanical Department
  - Assembly and test of VLPC cryostats
    - All parts out for fab – Due soon
    - Finalizing procedure for in-house brazing
- The work is supported by
  - NSF MICE Funds
  - UK MICE Funds
  - Technician support from Imperial College
  - Physicist support from MICE University Groups

MuCool PPD Activities

- PPD technicians were involved with the setup of the MTA and provided tremendous support. This work is essentially complete now
- We still will need some technician help (in the on-going experimental RF program) with mechanical setup of counters and diagnostic systems from time to time.