



MICE Status & 6D Cooling

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ILLINOIS INSTITUTE
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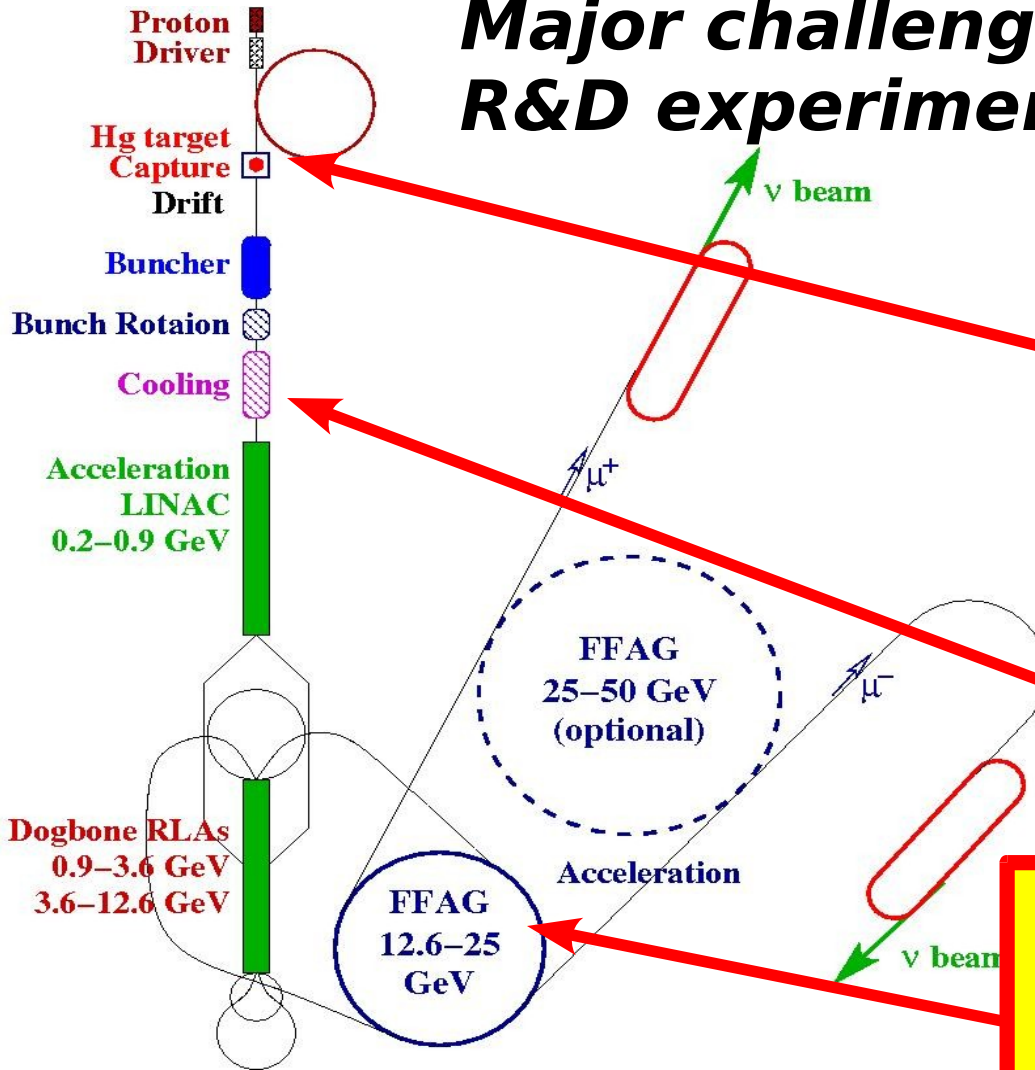




Outline

- I** *Motivation*
- II** *Procedure for cooling muons*
- III** *MICE description*
- IV** *Schedule*
- V** *Status*
- VI** *Summary*

Major challenges being met by R&D experiments



High-power target:

- 4MW
- good transmission

MERIT (CERN)

Fast muon cooling:

MICE (RAL)

Fast, large aperture accelerator (FFAG)

EMMA (Daresbury)



- **“Cooling” muons refers to reducing the emittance of the muon beam.**
- **Muons are created in tertiary interactions, and so are created with large inherent emittance:**
$$p + N \rightarrow \pi + X$$
$$\quad \quad \quad \downarrow$$
$$\quad \quad \quad \mu + X$$
- **Due to short muon lifetime, the only viable option is ionization cooling. *Must cool AND* accelerate rapidly:**





Procedure: MICE

MICE will measure a 0.1% absolute cooling effect

- 1) create beam of muons***
- 2) identify particles and reject background***
- 3) measure single particle emittance***
- 4) “cool” muons in low-Z absorber***
- 5) restore longitudinal momentum component with RF cavities***
- 6) identify particles to reject electrons from muon decay***

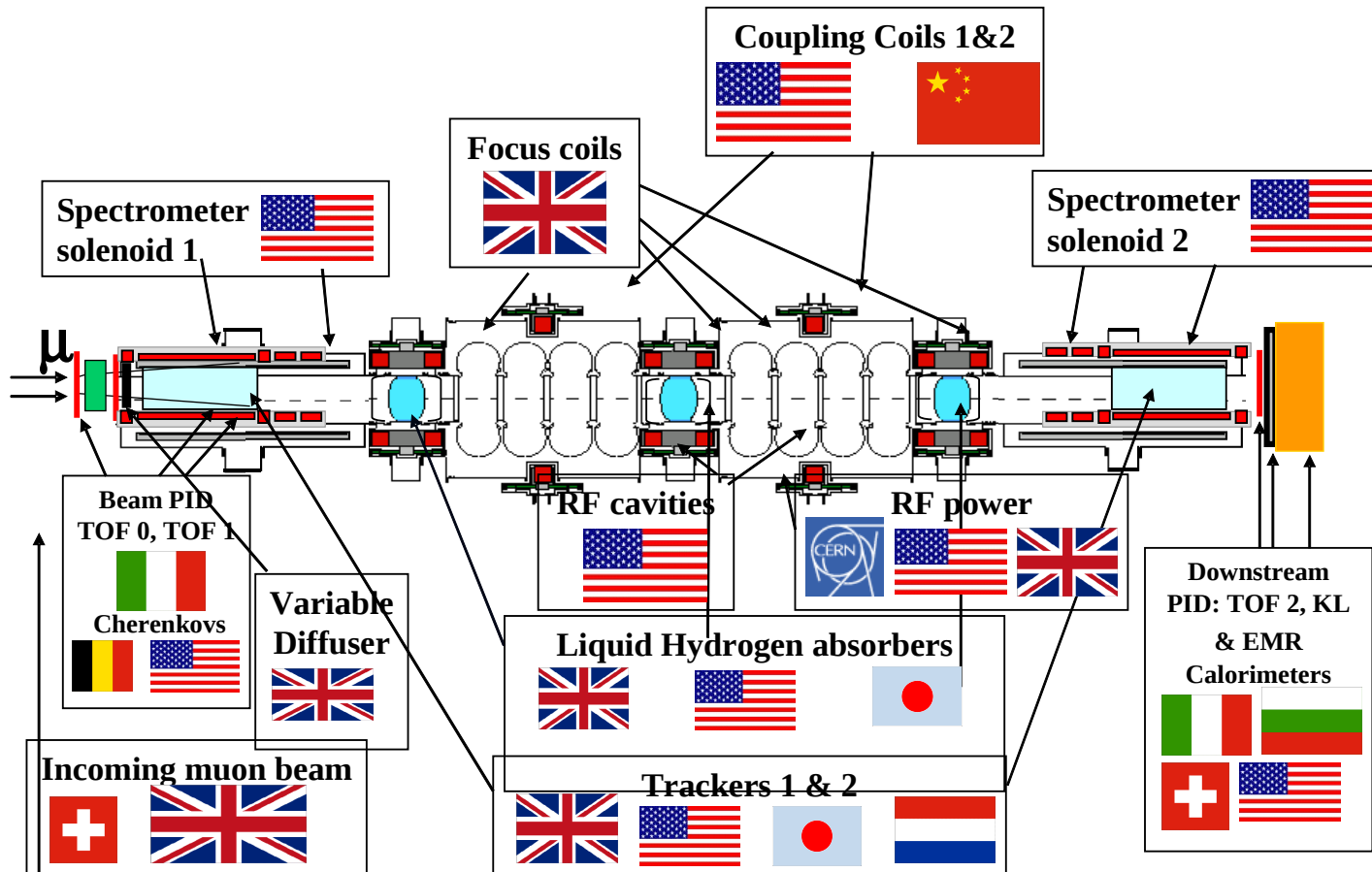


Description





Description: Who are MICE?

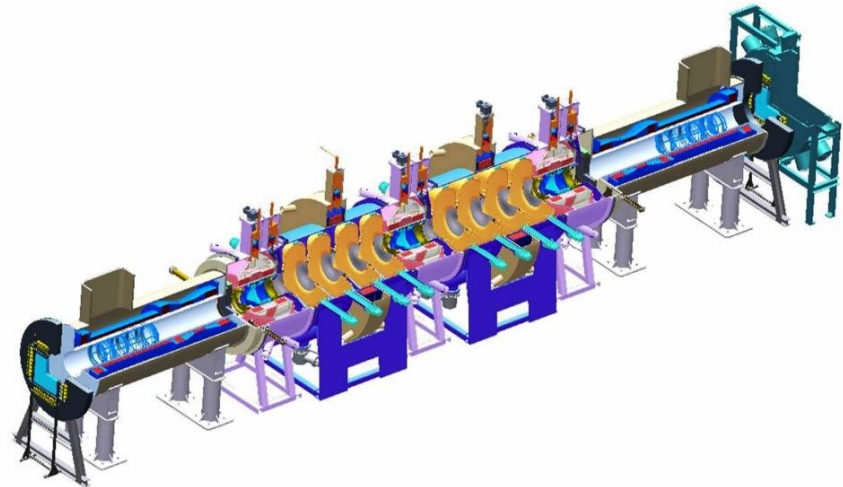




Description: MICE



- **Beamline** – create beam of muons
- **Particle ID** – verify/tag muons
- **Tracker** – measure emittance
- **Absorber (LH2 or LiH)** – cooling
- **RF** – reestablish longitudinal p_z

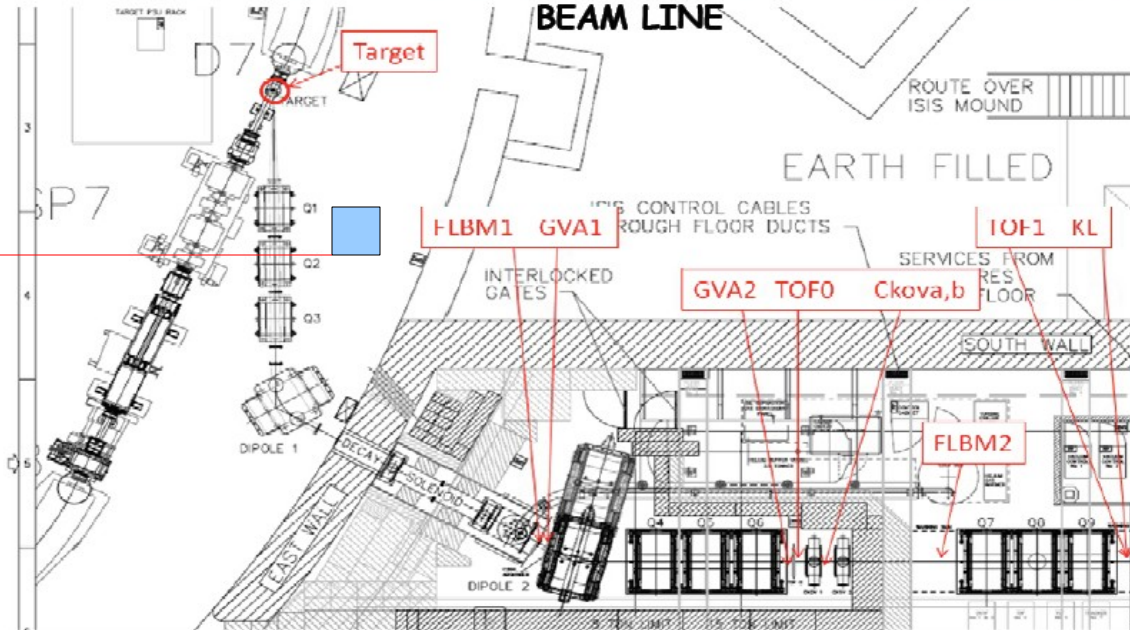




Description: Beamline



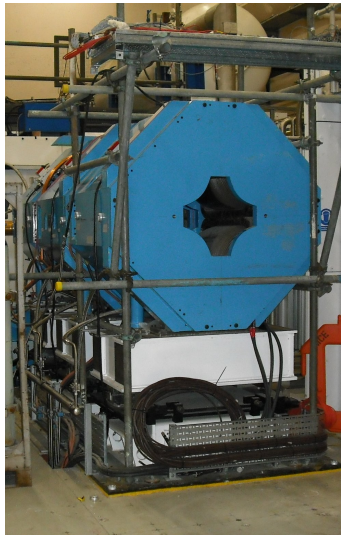
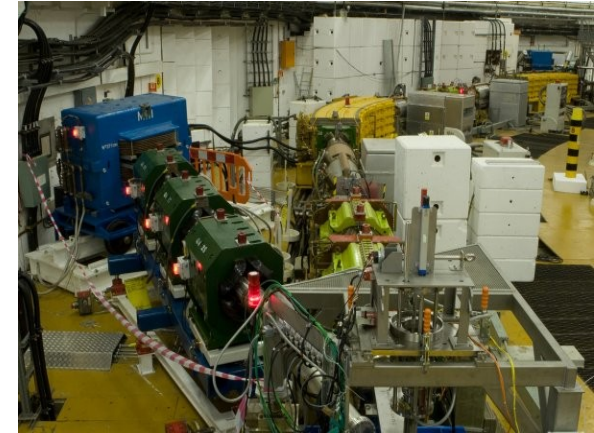
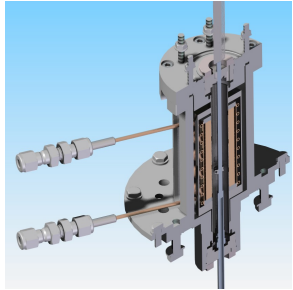
LM (new)

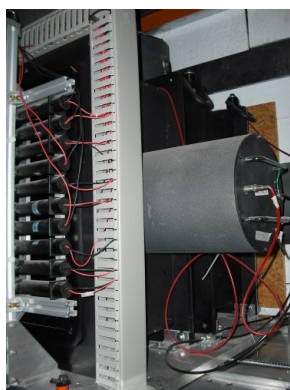


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MICE Beamline consists of:

- **Target**
 - dips into ISIS accelerator
 - 1 Hz
- **Conventional magnets**
 - 2 dipoles – select pion momentum
 - select muon after pion decay
 - 3 quadrupole triplets for focusing
- **Superconducting decay solenoid**
 - extends pion decay path
 - 5 T
 - 5 m long





Upstream PID:

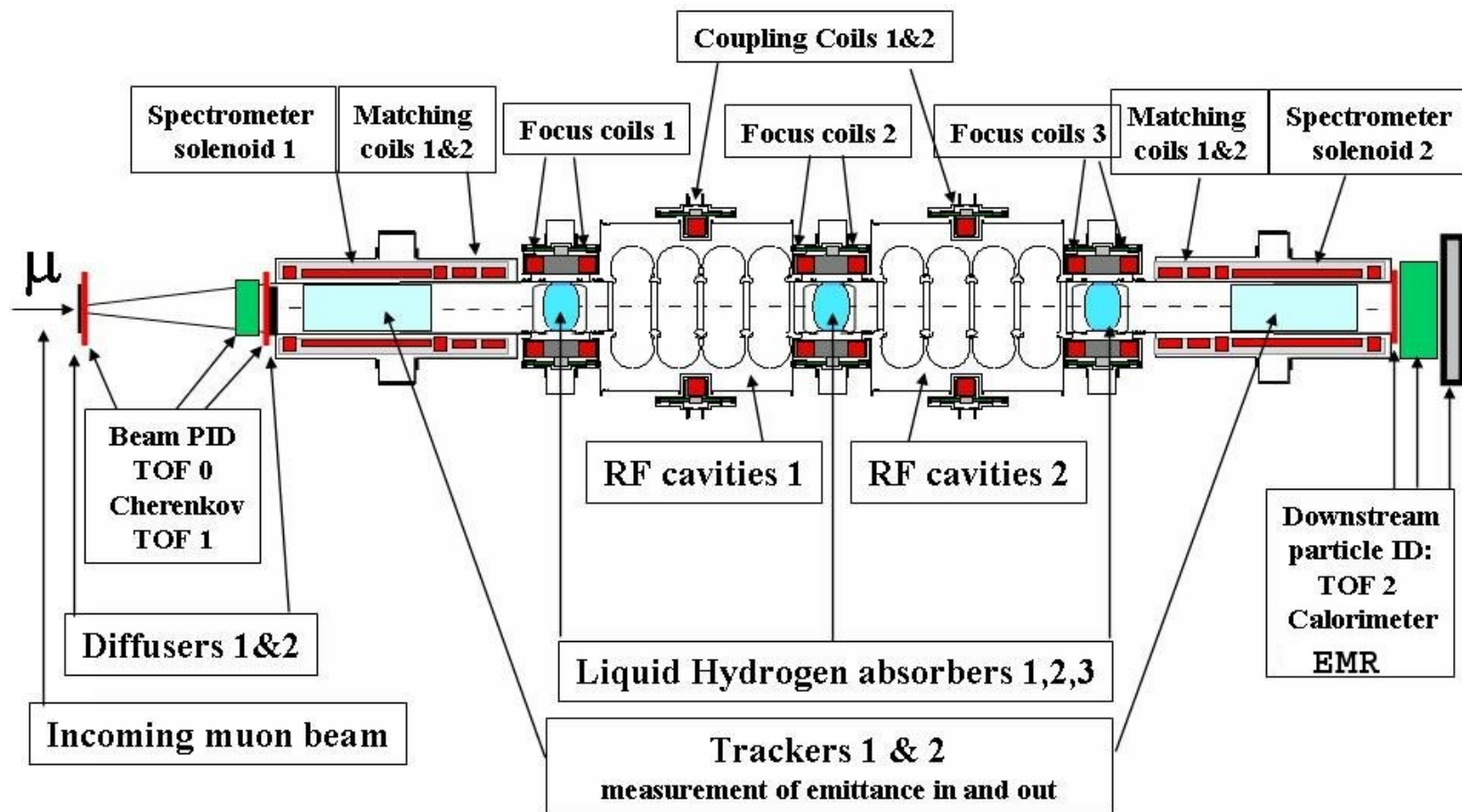
discriminate p , π , μ

- **Beam profile monitors**
- **Threshold Cerenkov**
- **Time of Flight – ToF0 & ToF1**

Downstream PID: reject decay electrons

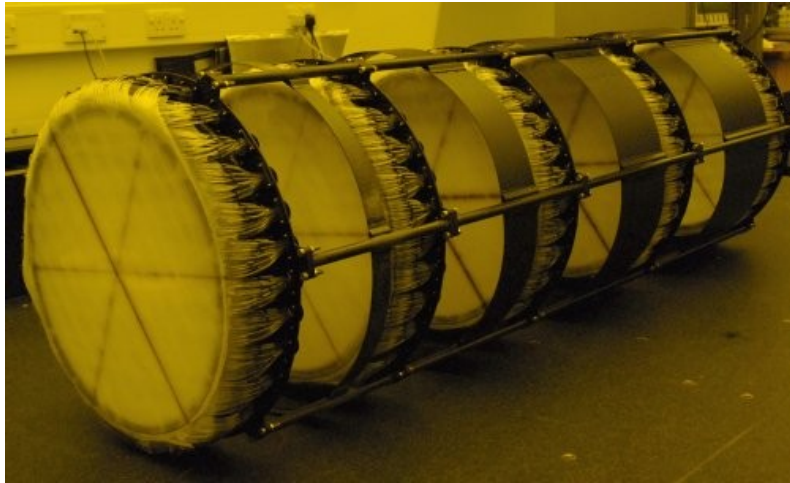
- **Time of Flight - ToF2**
- **Kloe-like Calorimeter - KL**
- **Electron-muon Ranger - EMR**







Description: Tracking



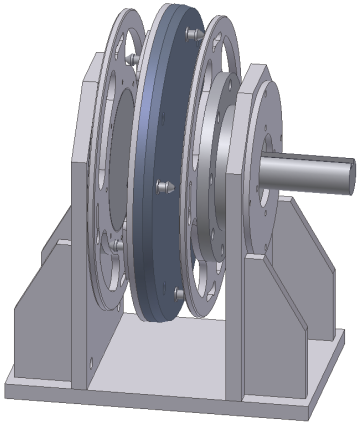
- **Two trackers – before/after absorber**
- **Measures x, y, x', y'**
- **5 stations/tracker**
- **3 stereo planes/station (U/V/W)**
- **1400 $350\mu\text{m}$ fibers/plane**
double layer, 7 fibers/group
- **<0.2% dead channels**
- **>10.5 photoelectrons/MIP**
- **$430\mu\text{m}$ RMS position resolution**

- **4 T superconducting**
- **2 m long**
- **20 cm warm bore**
- **5 coils:**
 - **1 main tracker coil**
 - **2 end coils**
 - **2 matching coils**
- **closed-cycle pulse-tube cryo-coolers**

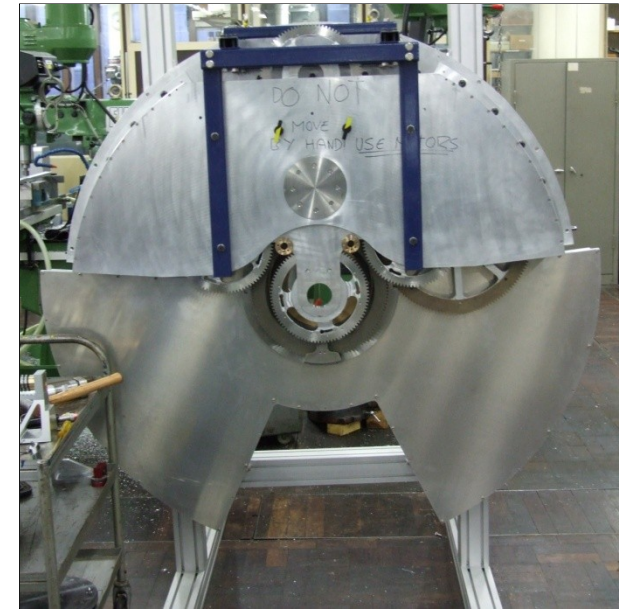


(M. Zisman's talk)

Description: Diffuser



- **Manufacture complete at Oxford, UK**
- **Integral part of Step II**
- **Variable thickness Pb disks**
- **Disks inserted upstream end of 1st tracker**
- **Operate in high magnetic fields:**
 - **non-magnetic components**
 - **air motor driven**



Description: Absorber - AFC



Absorber-Focusing Coil – AFC

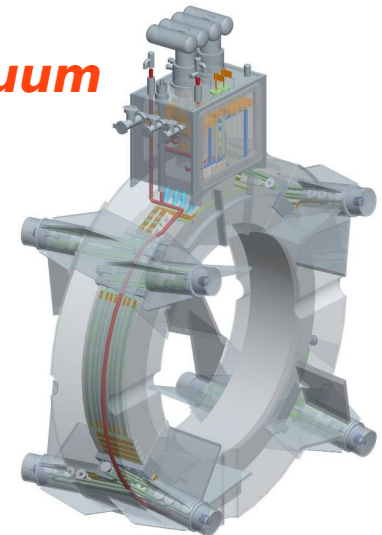
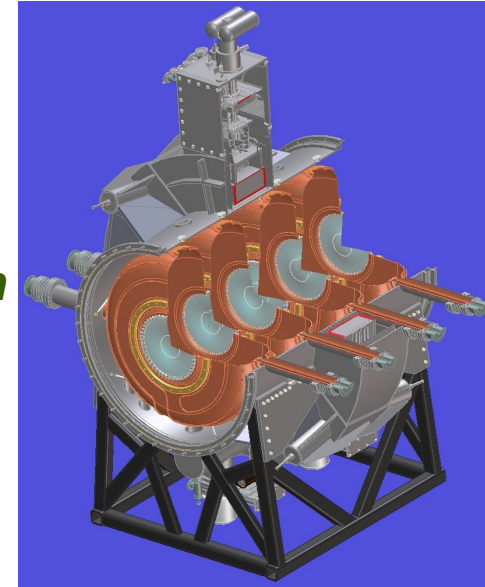
- Absorber Built at KEK
- Focusing Coils designed by Tesla
- 3 modules
- Absorber:
 - 20.7 l LH_2 or LiH
 - 35 cm long (on axis)
 - 15 cm radius
 - 2 180 μm thick Al windows
- Focusing Coils:
 - 2 coils
 - 26.3 cm radius
 - 5.0 T in solenoid mode
 - 7.7 T in gradient mode
- Separate vacuum vessels
- Single 4.2 K cryocooler for AFC





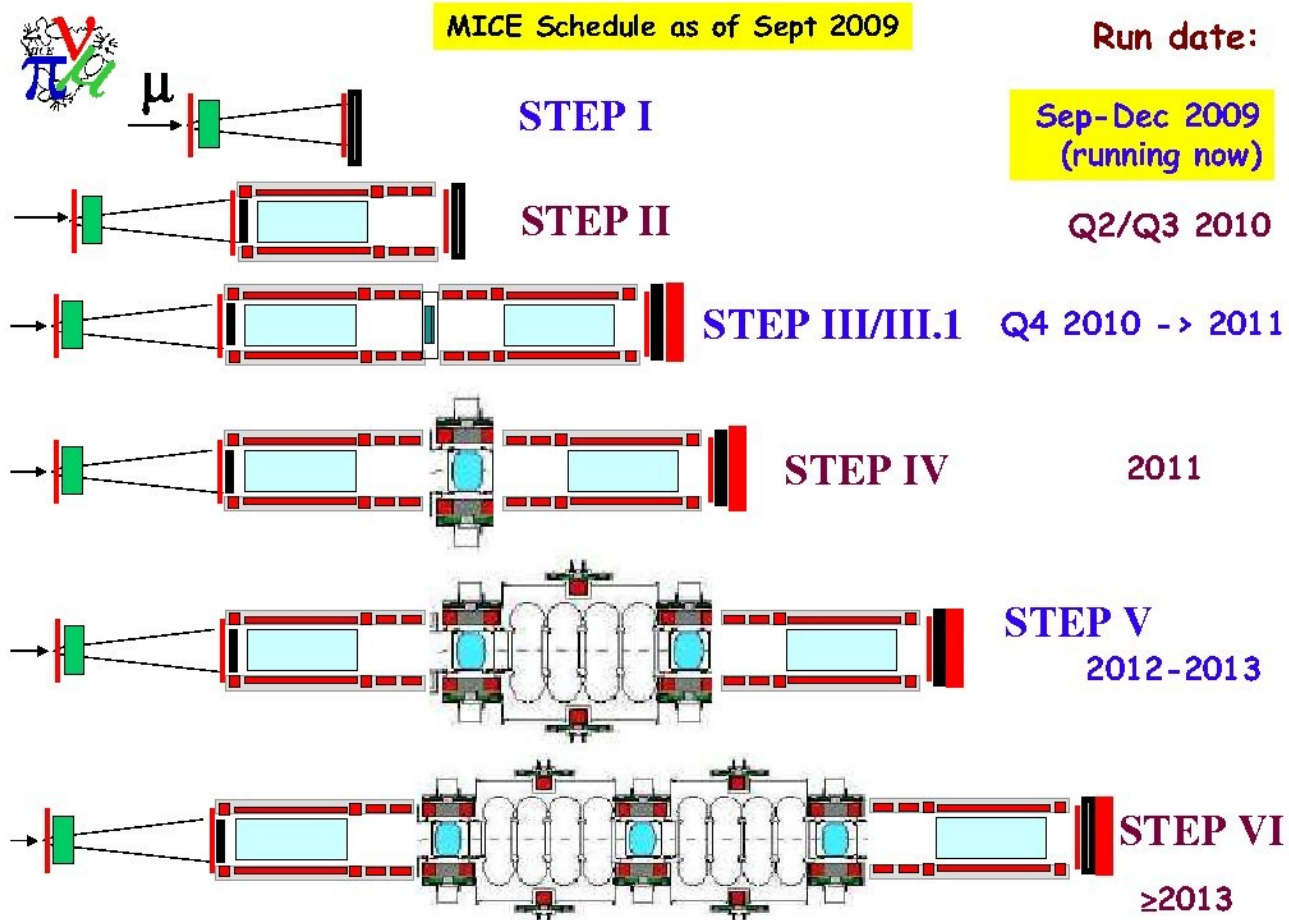
RF Coupling Coil – RFCC

- 2 modules
- Restore longitudinal momentum
- RF cavities from Applied Fusion
- Coupling coils designed at Harbin
- **RF Cavities:**
 - 4 cavities/module
 - 201.25 MHz
 - 8 MV/m (supply limited)
 - e-beam welded Cu half shells
 - Be windows
 - Structures & cavities share vacuum
- **Coupling Coil:**
 - single coil
 - 72.5 cm radius
 - 11.6 cm long
 - 7.8 T
 - single cryocooler





Schedule



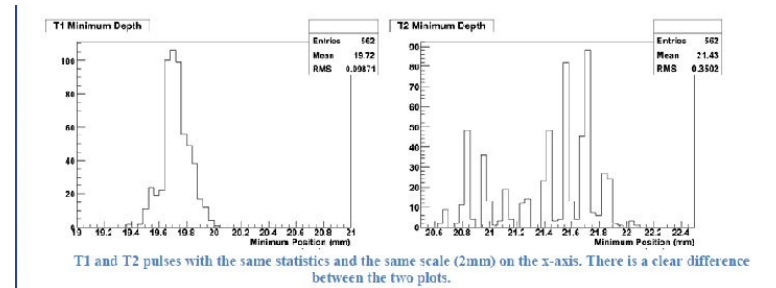
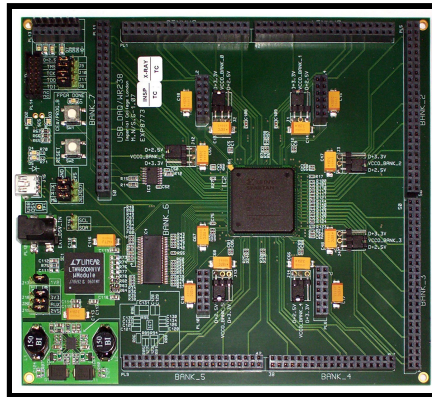
Status: Target

Since December 2008:

- new target hardware design
- first target works flawlessly
- demo target failed immediately
- new demo target!
- new target DAQ (coming soon)



December 2008 melted target

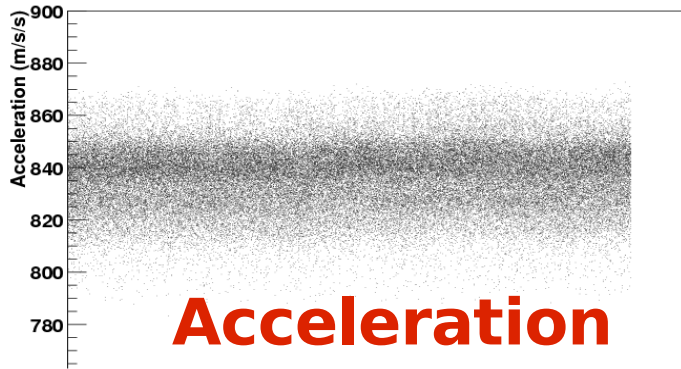




Status: Demonstrator Target

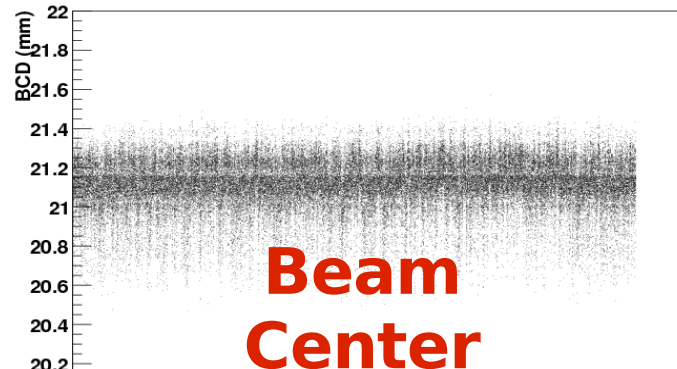
Installed and operated for 2.16M pulses!!!

Acceleration vs Time Calibration 10th Feb



Acceleration

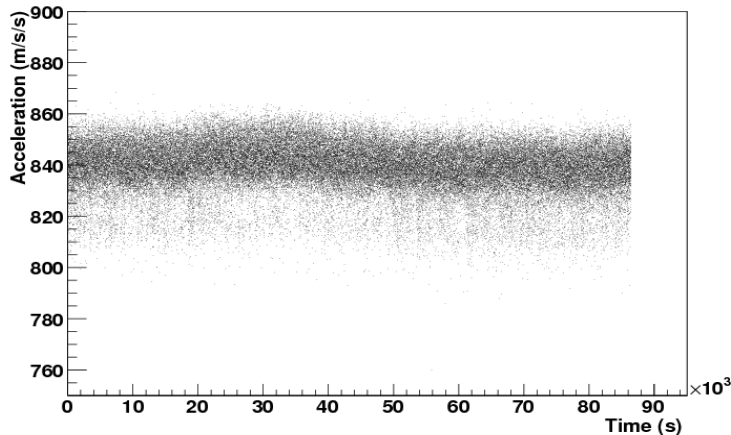
BCD vs Time Calibration 10th Feb



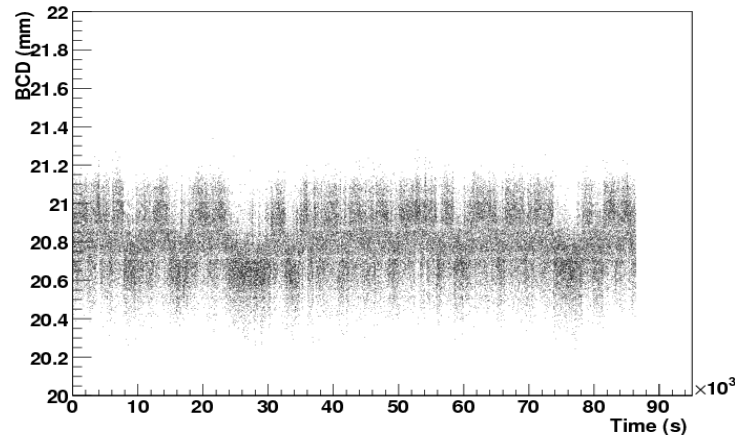
**Beam
Center
Distance**

10 Feb

Acceleration vs Time Calibration 21st Feb



BCD vs Time Calibration 21st Feb



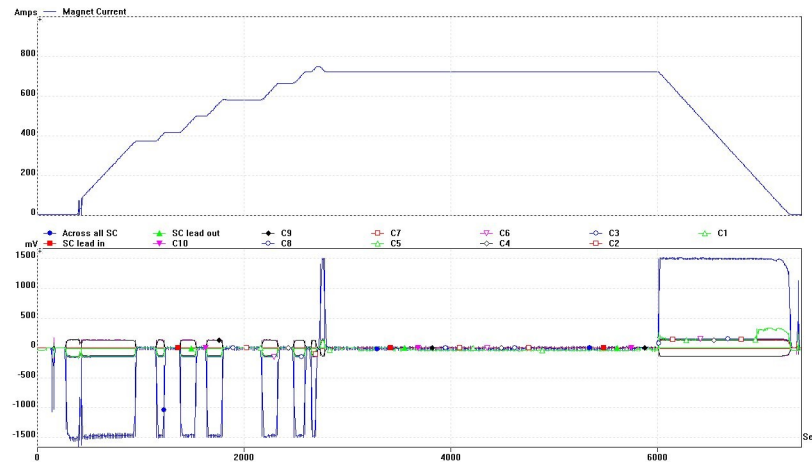
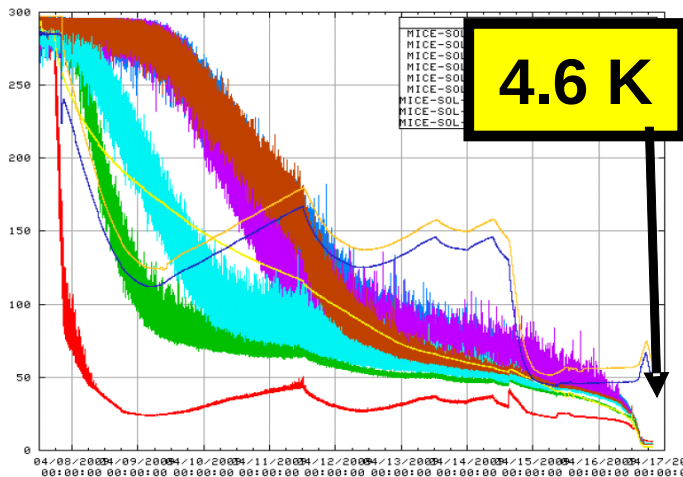
21 Feb



Status: Decay Solenoid

Since January 2009:

- Decay solenoid repaired with new MLI
- Operating regularly since summer
- Added to alarm monitoring
- Linde Decay solenoid compressor & cold box annual maintenance left DS inoperable



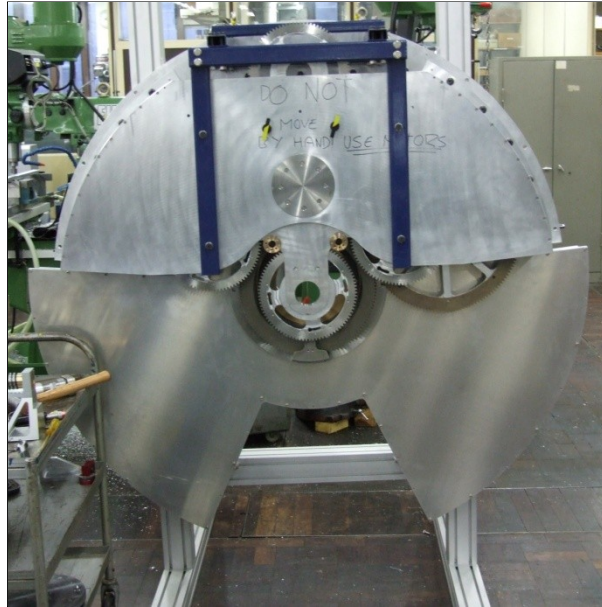


Status: Decay Solenoid

Since January 2010: January 2010:

- **Large concentrations of N₂ impurities in DS coldbox after Linde service work**
- **Leak found in coldbox regulator**
 - **Regulator designed to seal with internal pressure, not at vacuum**
- **Leak unlikely when refilled with He**
- **Likely cause: leaks in Swagelok joints which have been tightened**
- **He cleaning underway, now at about 15 ppm impurities. Cooling can start when < 10 ppm**

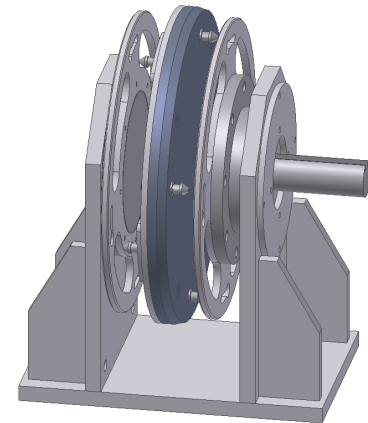
Status: Diffuser

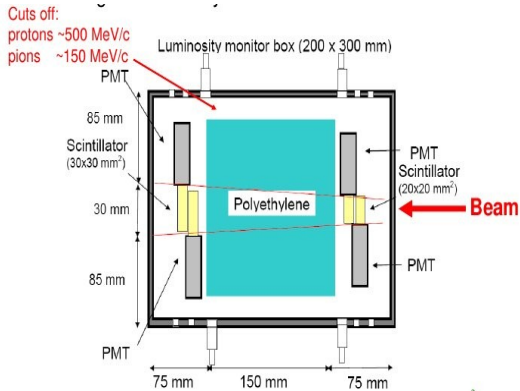


- **Pb disc transfer, making mock-up on bench to try principle**
- **Air pressure problems - affects motor speed, should be better at RAL with 7 bar supply**
- **Manual control interface is working, would do in extremis for Step II operation**
- **Automated system ready by Easter**
- **Diffuser delivery to RAL still under review, regular Friday meetings**

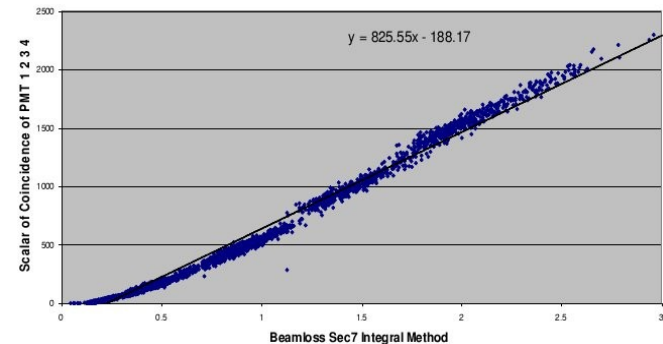


Not on Critical path till late Autumn 2010





- **Commissioned: 12-15 January & 7 February**
- **Purpose: define detector HV conditions, discriminator levels, synchronize with ISIS signals, scalers, run conditions**
- **Tuning models to match data**





Status: Where are we?

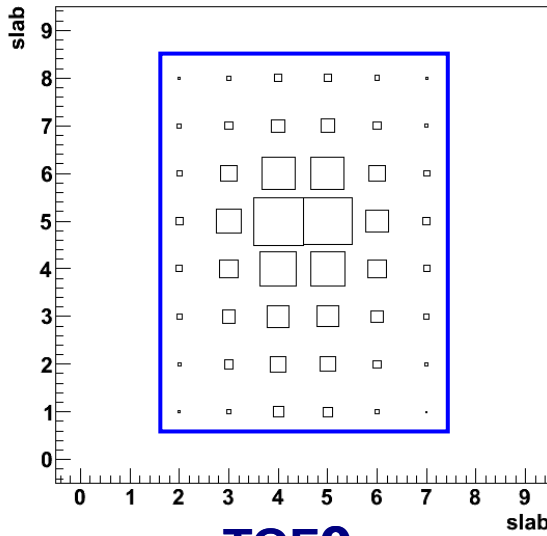
- **Beamline magnets ready (faulty flow meters being replaced)**
- **All PID detectors (other than EMR), installed**
- **ToF0, ToF1, Ckov calibrated**
- **Collecting data for calibration of ToF2 and KL**

Step I nearing completion!



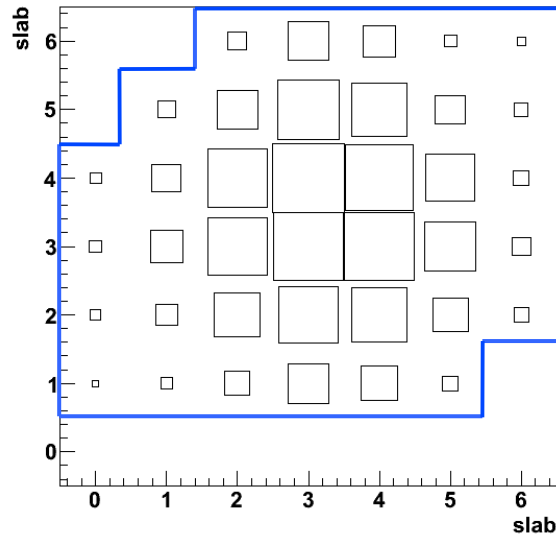
Status: Where are we?

TOF0 profile



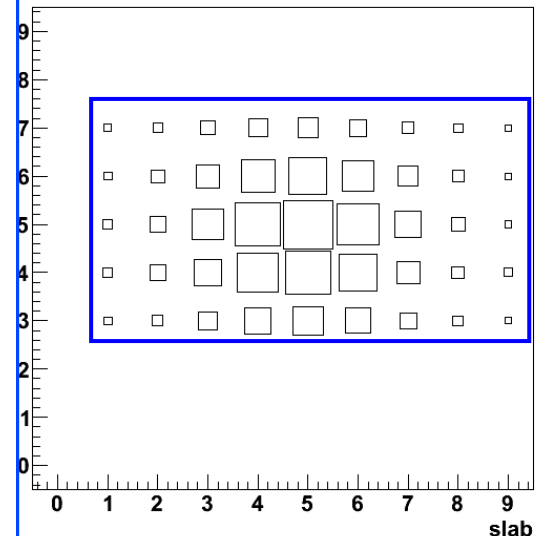
TOF0

TOF1 profile



TOF1

F2 profile



TOF2

The blue line encloses the calibrated area in the TOF stations.



Status: EMR

**Scintillator planes are well in
manufacture and QA at UNIGE**

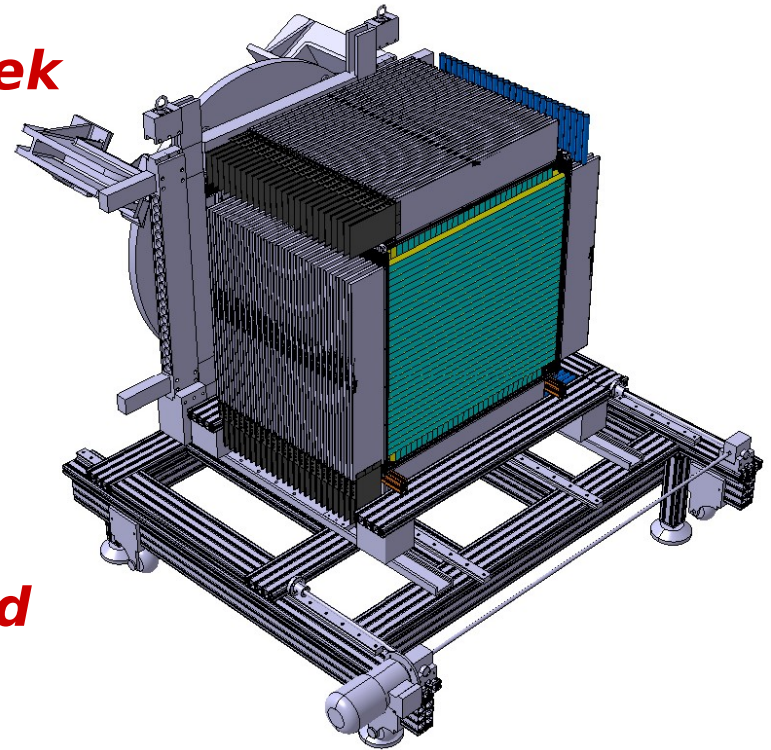
**Need to go at two planes per week
for schedule**

**Magnetic shielding around PMTs
needs to be understood**

**Design of flex circuits to PMTs
need to be frozen soon**

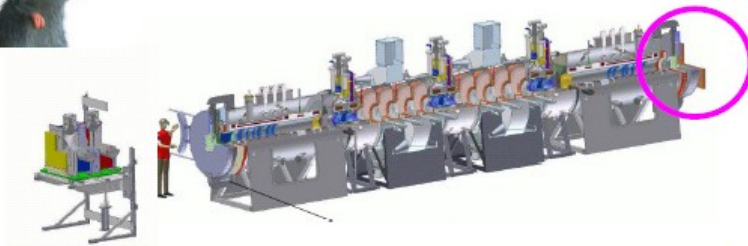
**Some minor clashes with R5.2
infrastructure anticipated –
exchange of CAD models required**

**Delivery of EMR scheduled for
July/August, 2010**

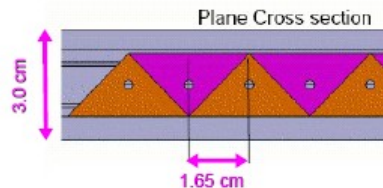
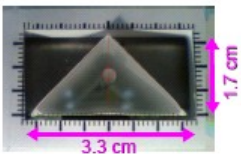




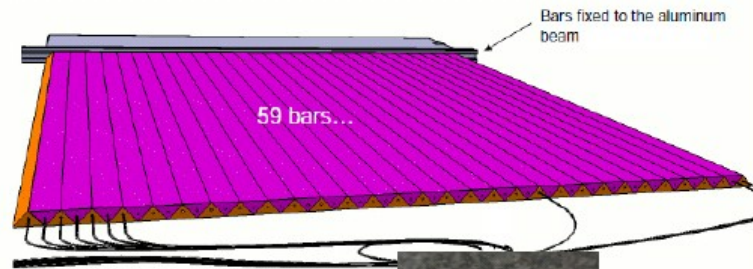
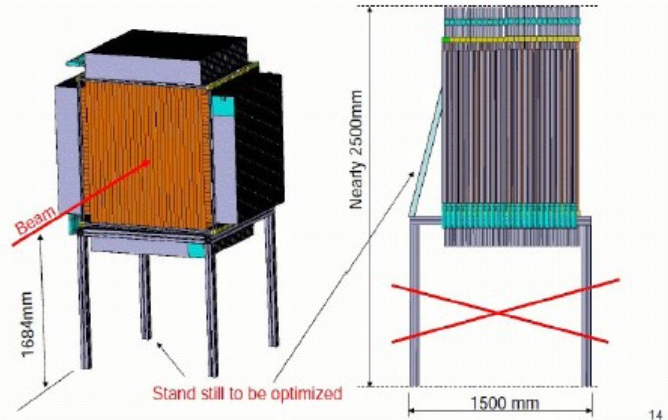
About EMR...



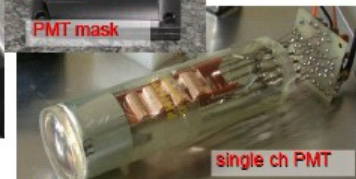
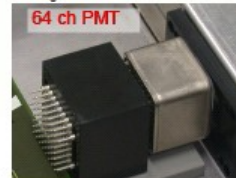
- ✓ 50 layers of fully active scintillator bars organized in a x-y way
- ✓ 59 triangular shape 1.1m long bars (produced by Fermilab) in each plane → one EMR-plane = 1m² active region
- ✓ light carried out by a single 1.2 mm diameter WLS fiber (inserted and glued in the bar hole)
- ✓ fiber connected on one side to a single channel photomultiplier (XP2972, Philips) → calibration & charge measurements
- ✓ on the other side to a 64 channel multianode photomultiplier (H7546B, Hamamatsu)



Daniela Lietti - MICE Collaboration Meeting 4-7 Nov. 2009



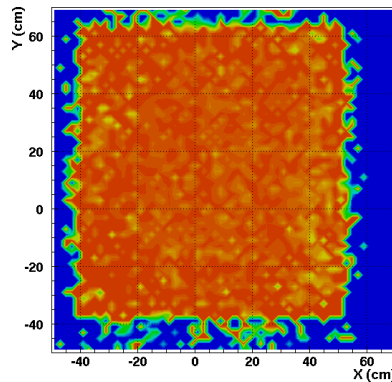
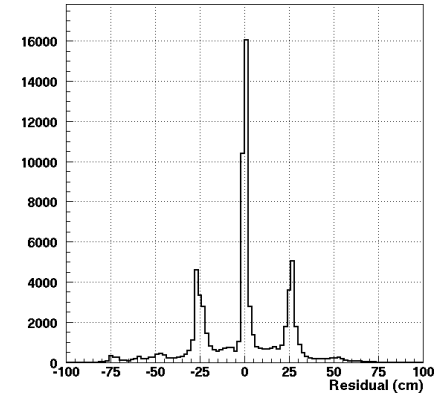
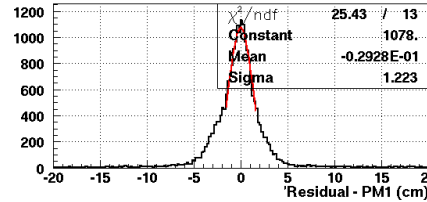
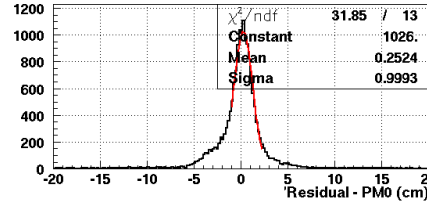
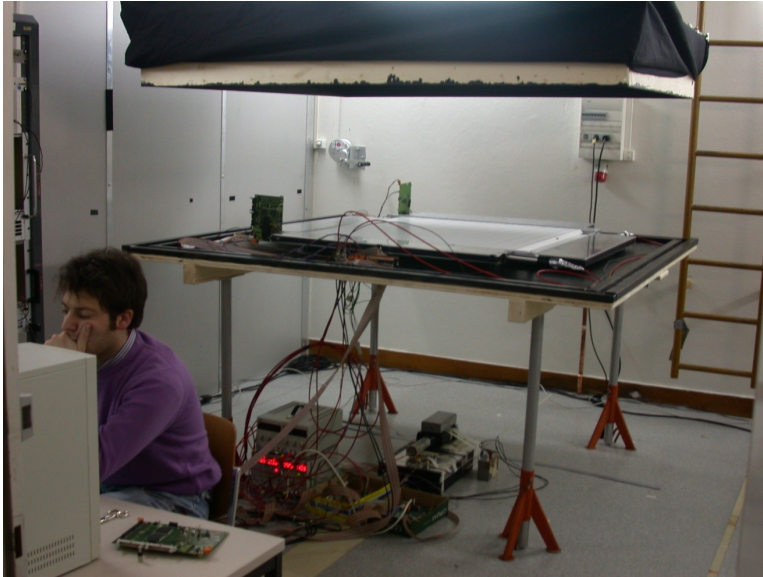
WLS Fibers coming from the bars



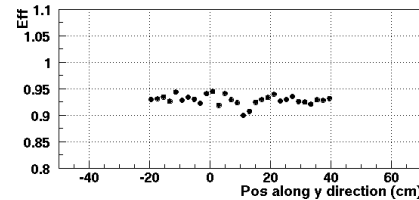
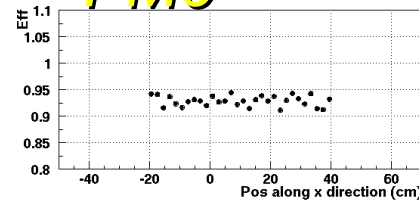
* Thanks to Florian for the photos!



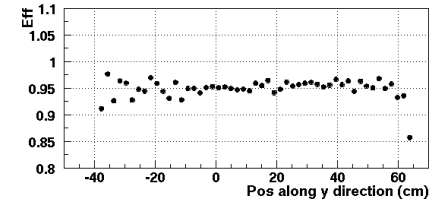
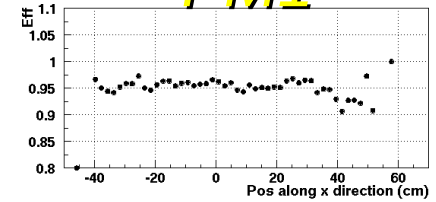
Status: EMR Cosmic Tests



PM0



PM1



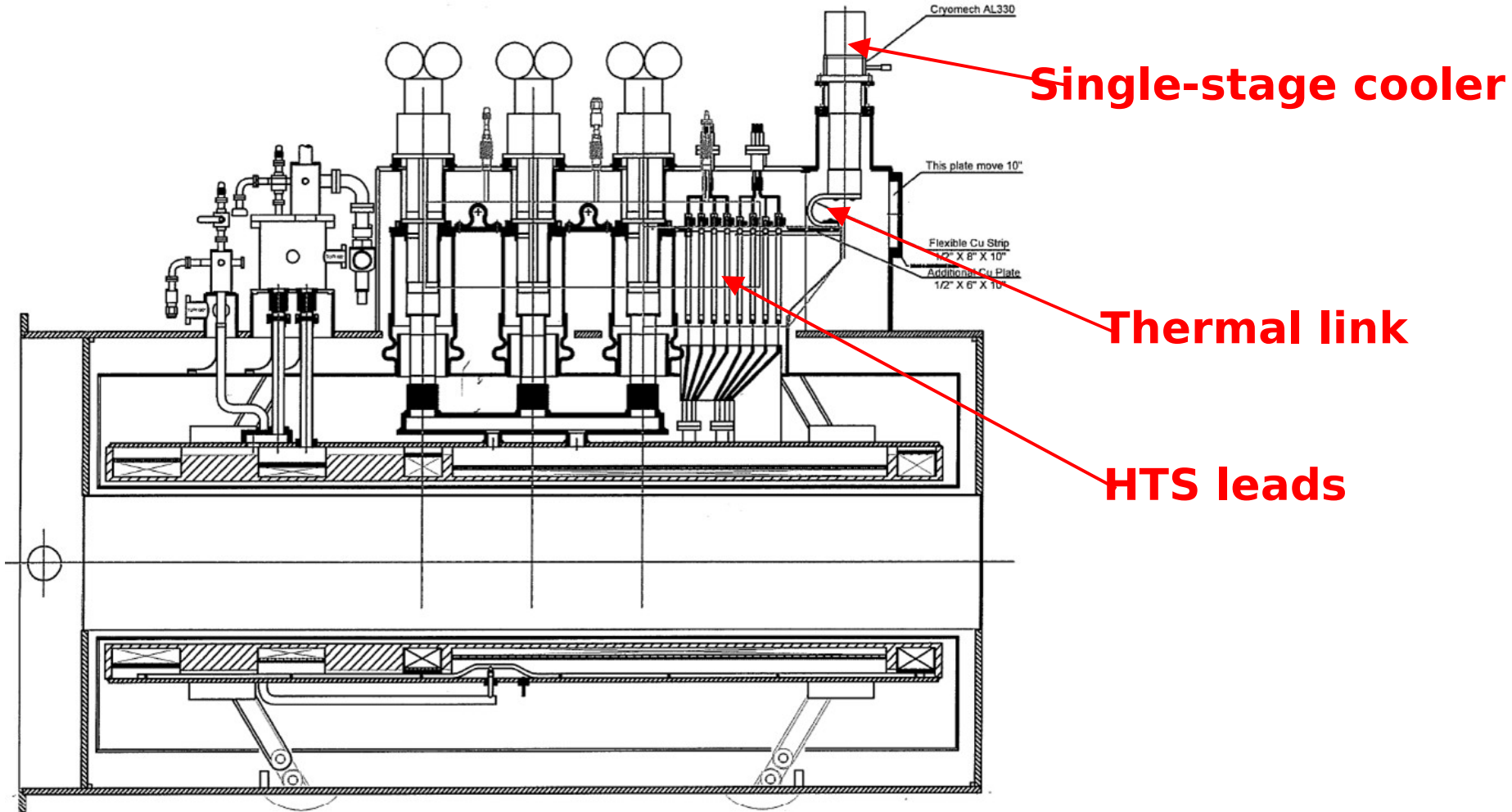


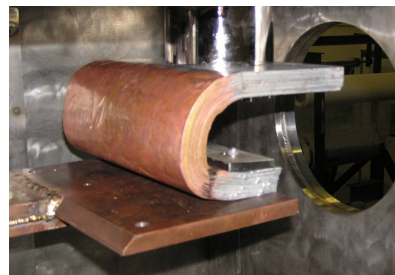
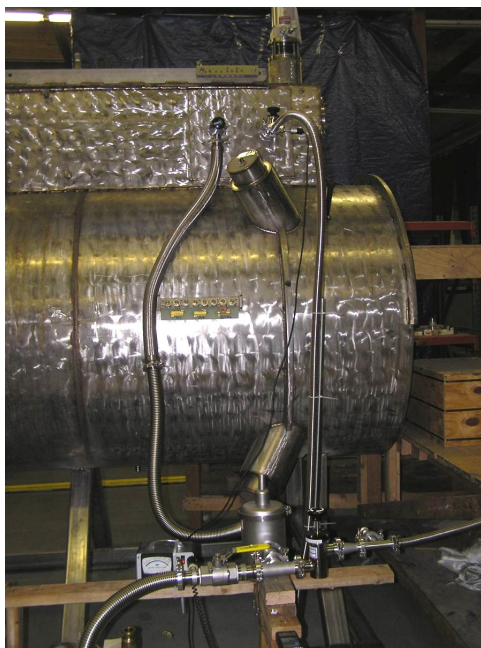
Status: Tracker

Steps II and III require trackers for first emittance measurements

- ***Both trackers ready and tested with cosmic rays***
 - ◆ ***High efficiency tracking***
- ***Delays in spectrometer solenoids – critical path***

Status: Tracker Solenoid





- **The Magnet 2 turret area modified to install a single stage cooler**
- **New HTS and warm leads have been tested and reinstalled**
- **Additional temperature sensors installed**
- **Pumping down now-
1 week pumping +
1 week cooldown**



Status: AFC

Steps IV requires absorber for first cooling measurements

- **Absorber 1 ready and tested**
 - **Cool down to 20K: 1 day with LN₂**
 - **LH₂ liquification at 2.5 l/day**
 - **Delivery end January or early February**
- **Absorber 2 being tested, delivery May**
- ♦ **Focusing coils are delayed (Zisman)**



Status: RFCC

Steps V requires RFCC module for replenishing longitudinal component of momentum

- **RF cavity fabrication underway**
 - **5 delivered to LBNL in December 2009**
- **Power infrastructure being refurbished at Darsebury**
- ♦ **Coupling coils are delayed**



Status: Step VI

Steps VI has approval but awaits full funding



Status: Hall miscellaneous

- **Water system for CCR compressor cooling is 95% done**
- **Luminosity monitor & cabling and connectors installed**
- **PPS safety accreditation is approaching final hurdle**
- **Next step is to integrate with ISIS PPS**
- **Drilling of false floor for Step III is 50% complete**
- **All electrical work that can be done up to delivery of spectrometer solenoid is complete**
- **Material for CCR compressor stands (for Step II & III) is on order, arrives in next week or so.**
- **Remote level sensing of magnet header tank working**
- **Lighting & fire alarm project finally finished**
- **Painting will be completed before end January**
- **To sum up, there is nothing (known) on the critical path to get Steps II & III ready for February 2011 (end of ISIS moderator change long shutdown)**



Status: 6D Cooling

- **MICE is principally designed to demonstrate 4D cooling**
- **Can be modified for 6D measurements**
- **Options include:**
 - ◆ Wedge absorber – See Pavel's talk
 - ◆ MANX – proposed by Muons, Inc. for more information see <http://trshare.triumf.ca/~pac09proc/Proceedings/papers/we6pfp090.pdf>



Summary

- ***Muons observed at MICE!***
- ***Target and Decay Solenoid operational***
- ***PID detectors in place and being calibrated***
- ***Step 1 is well underway!***
- ***Absorber and RF cavities near delivery***
- ***Infrastructure mostly in place***
- ***Delay in spectrometer solenoid (on its way?)***
- ***Delay in focusing coil – not a show stopper yet***
- ***Delay in coupling coil – not a show stopper yet***