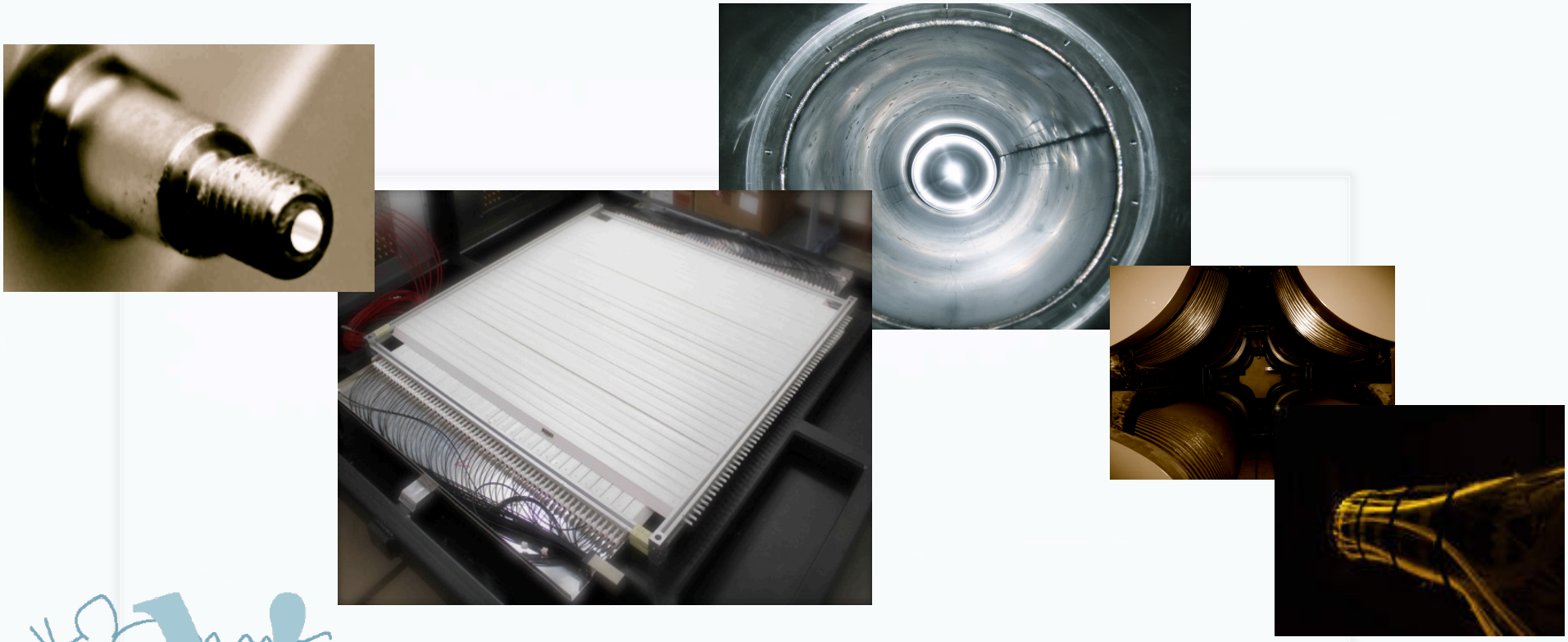

The Progress of MICE-The Muon Ionization Cooling Experiment

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Imperial College London

Institute of Physics HEPP , APP & NP Conference – Manchester 2015

Outline

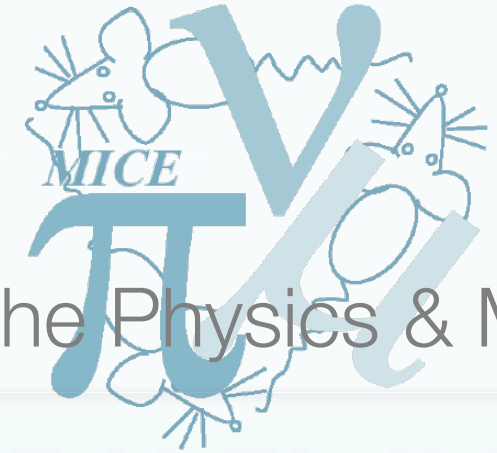
Ionization Cooling

Motivations

MICE: The Experiment

Implementation & Development

Status & Timeline



Introduction

The Physics & Motivations

Ionization Cooling

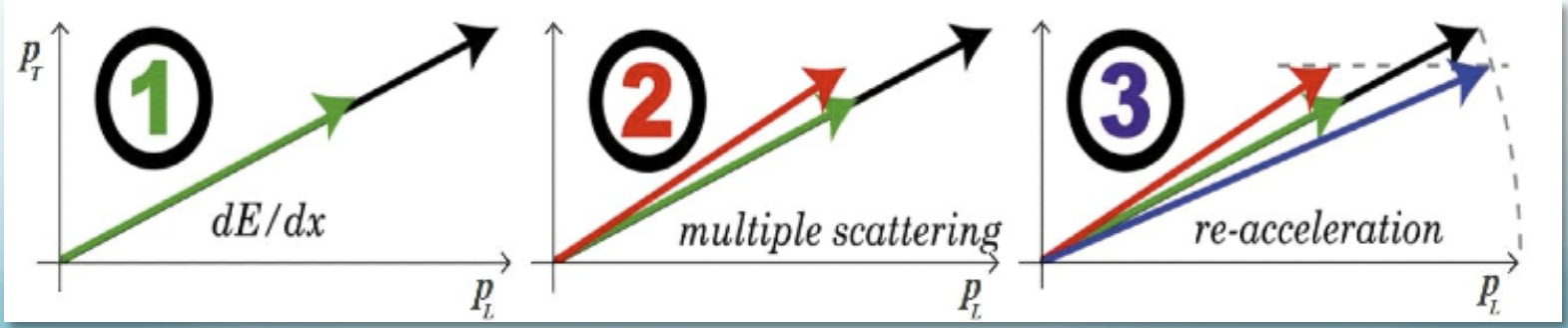
- ***Ionization Cooling : Decrease of transverse emittance (area in phase space) of a charged particle***

- Transverse emittance of beam (ε_n) changes as it traverses thickness (z):

Heating e.g. multiple scattering (✗)

$$\frac{d\epsilon_n}{dz} = \frac{-\epsilon_n}{\beta^2 E}\left\langle\frac{dE}{dz}\right\rangle + \frac{\beta_\perp (14MeV)^2}{2\beta^3 E m_\mu X_0}$$

Cooling (✔)



Motivations

1) *Neutrino Factory:*

To Optimize discovery potential for CP Violation in Lepton sector and understanding of mass hierarchy

Requirements:

- High ν_e ($\bar{\nu}_e$) flux
- Detailed study of sub-leading effects

→ Beam Cooling would provide an advantage in achieving required flux

	Appearance $\nu_\alpha \to \nu_\beta \quad \bar{\nu}_\alpha \to \bar{\nu}_\beta$
CPT:	$P(\nu_\alpha \to \nu_\beta) = P(\bar{\nu}_\beta \to \bar{\nu}_\alpha)$; $P(\nu_\alpha \to \nu_\alpha) = P(\bar{\nu}_\alpha \to \bar{\nu}_\alpha)$
CPiV:	$\frac{P(\nu_\alpha \to \nu_\beta) - P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)}{P(\nu_\alpha \to \nu_\beta) + P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)}$
MH:	$P(\nu_\alpha \to \nu_\beta)$; $P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)$ $[P(\nu_\alpha \to \nu_\alpha)]$
$(\theta - \frac{\pi}{4})$:	$P(\nu_\alpha \to \nu_\beta)$; $P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)$ and $P(\nu_\alpha \to \nu_\alpha)$

Motivations

2) *Muon Collider:*

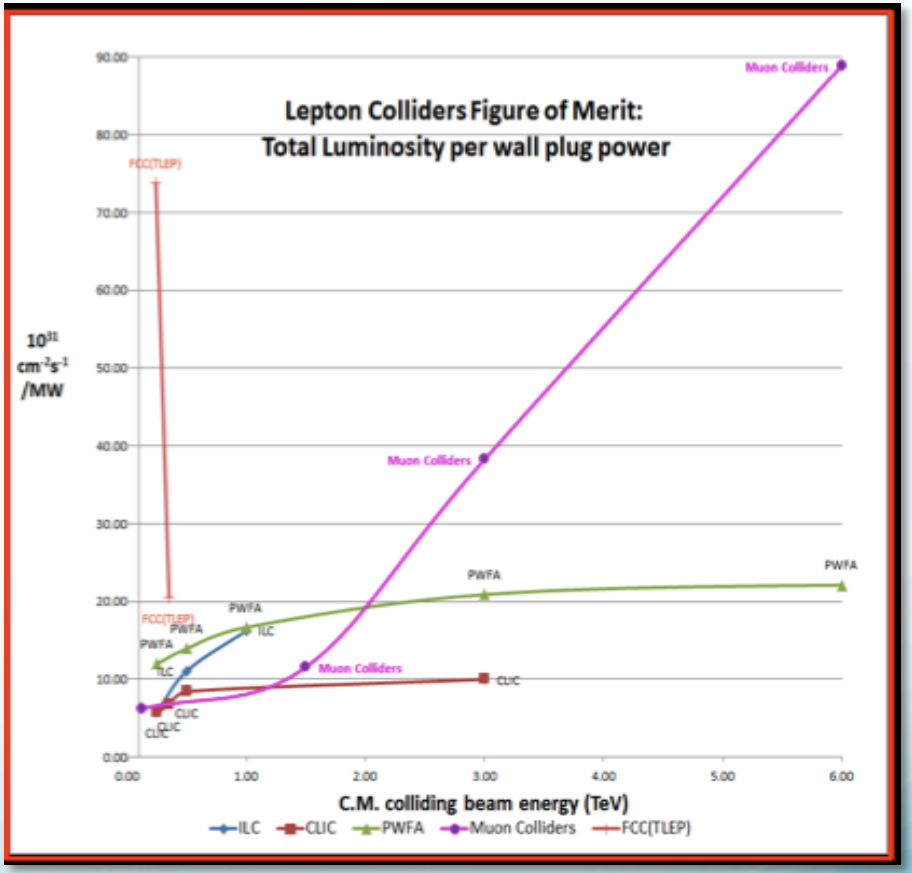
Optimized Higgs Factory

- Larger muon mass means Higgs production increased by factor of 10^4

Optimum route to Multi-TeV lepton-anti-lepton collisions

- Larger muon mass means reduced synchrotron radiation and Bremstrahlung
- Muon rigidity allows efficient acceleration

→ 6D Beam Cooling would provide required high luminosity collisions



MICE

- The International Muon Ionization Cooling Experiment (MICE) *aims to make the first measurements of 4D Ionization cooling* of 140-240 MeV/c muon beams

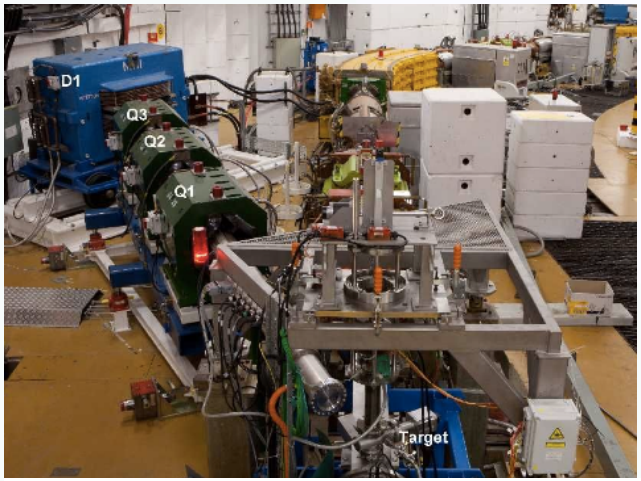
- Experiment is based at the Rutherford Appleton Lab (RAL) in the UK

- International collaboration - Most recently joined by 3 new institutions:
  - Institute of Physics-University of Belgrade
  - Institute of High Energy Physics (IHEP) (Beijing)
  - Sichuan University

The Experiment

Implementation & Development

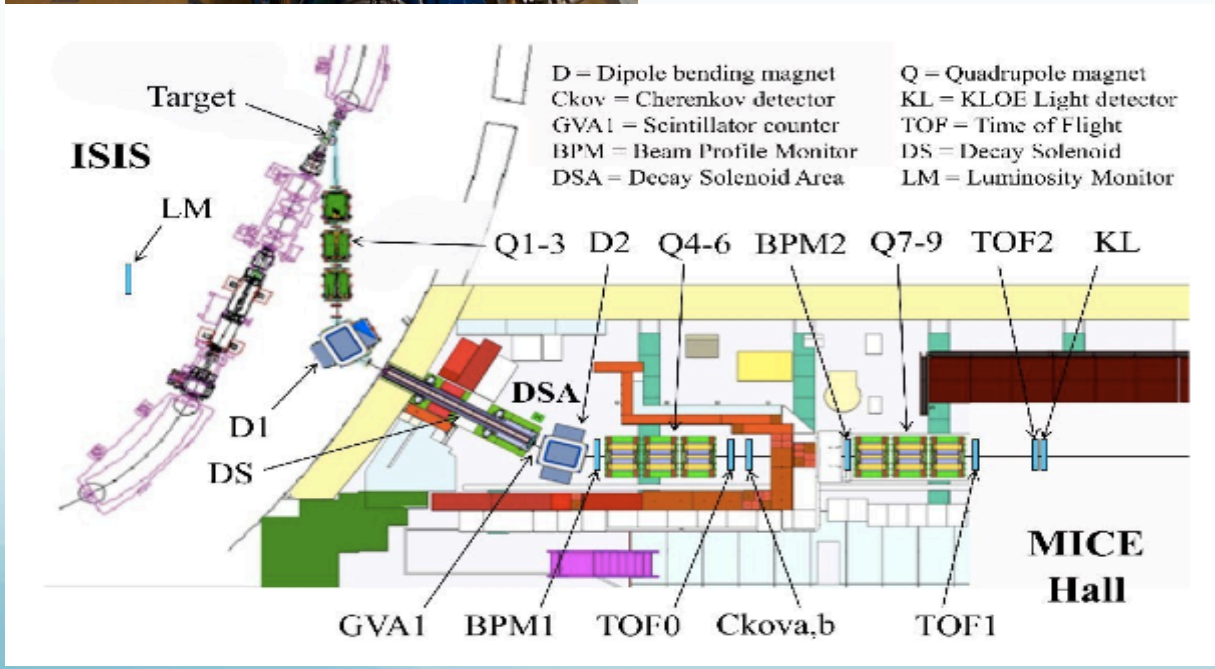
MICE Target/Beamline

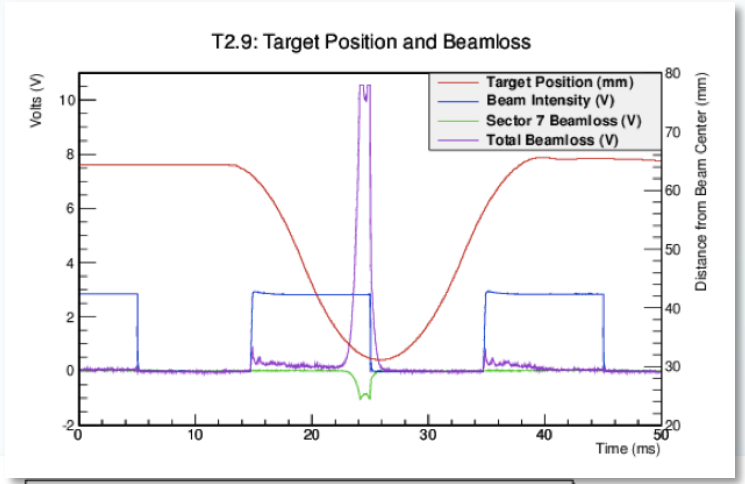


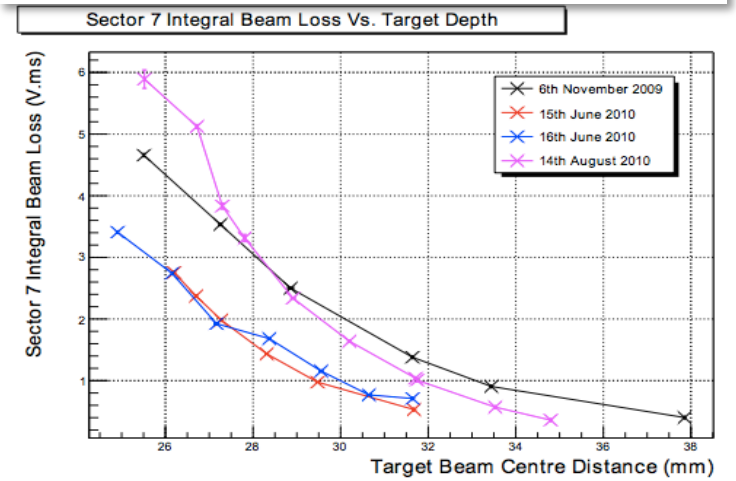
* Titanium target dipped in ISIS accelerator 800 MeV proton beam → Pions → Decay to Muons before entering MICE cooling channel

Performance of Target :

[2013 JINST 8 P03006]



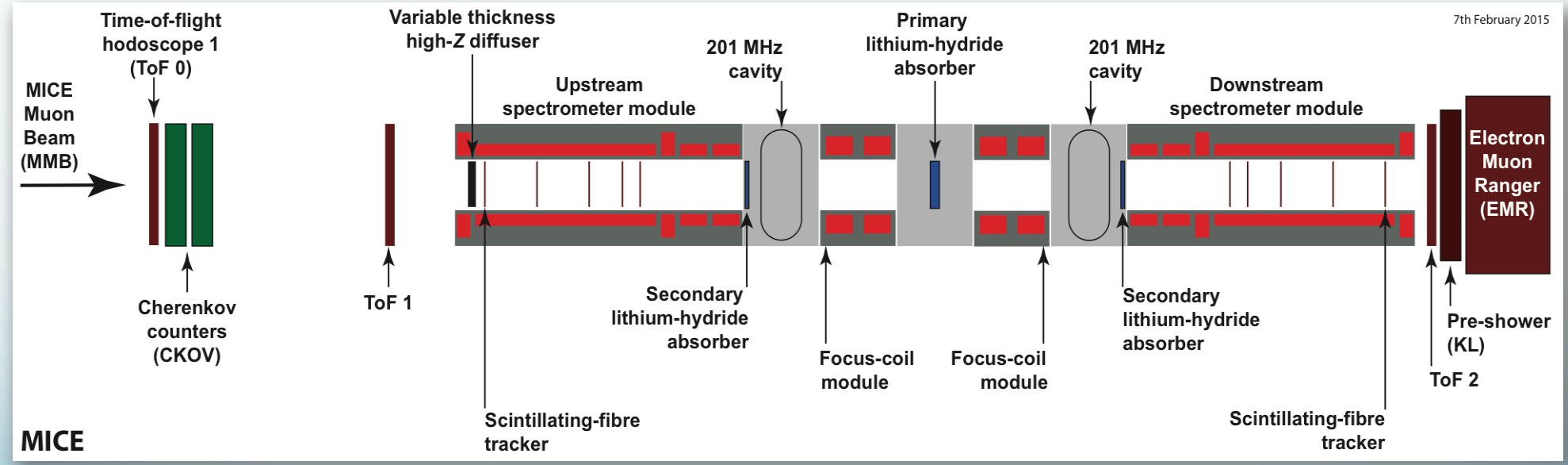




Cooling Demonstration Configuration

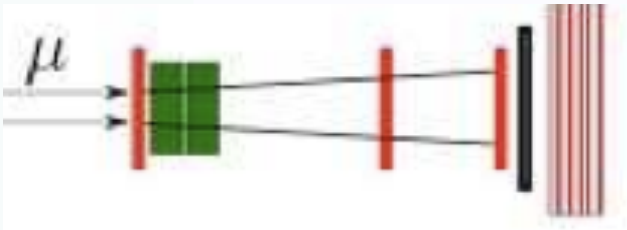
* P5 recommendations → we have now changed from our plan of two further stages to just one final step which will be our cooling demonstration configuration

* Formal re-baselining was agreed at the November 2014 review

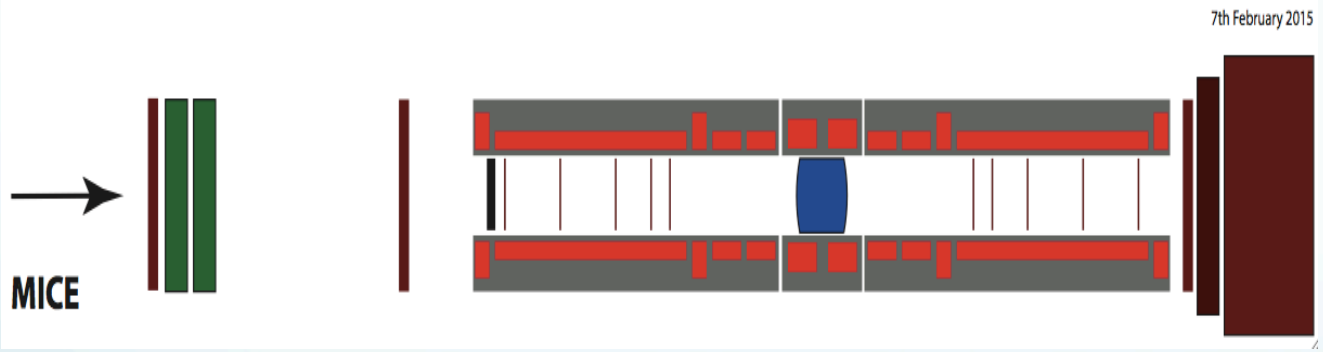


Staged Implementation

* Development split into stages- these have been re-defined:



Step I: Beamline commissioning, complete. Beamline understood, published. Small pion contamination
(Completed)



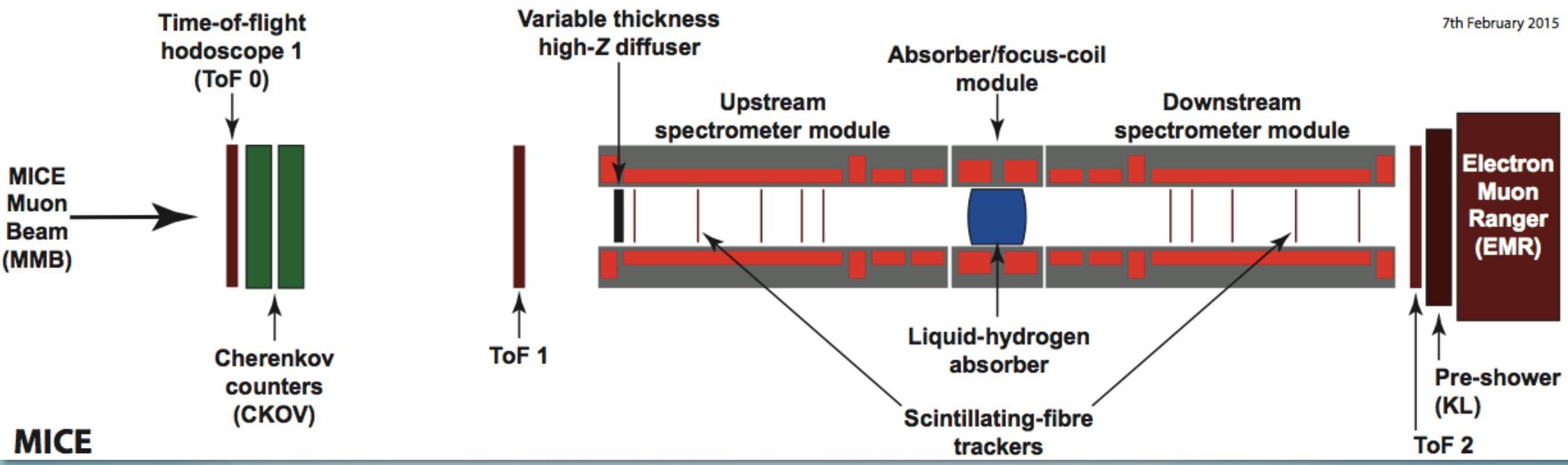
Step IV: Tracking spectrometers and single Absorber Focus Coil.
(2015-16)

Final Step: cooling demonstration configuration – RF Cavities used to allow final demonstration of sustainable cooling (2017-18)

Step IV: Physics Goals

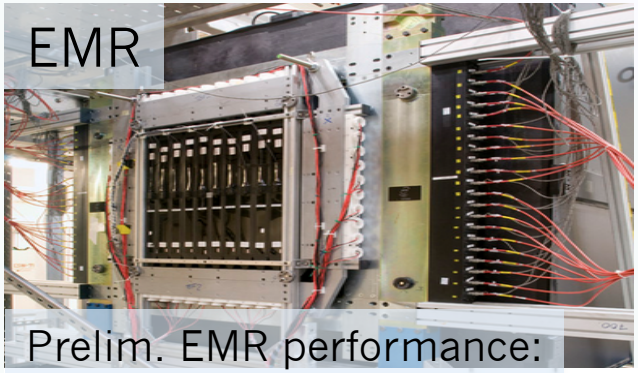
DATA TAKING 2015-2016

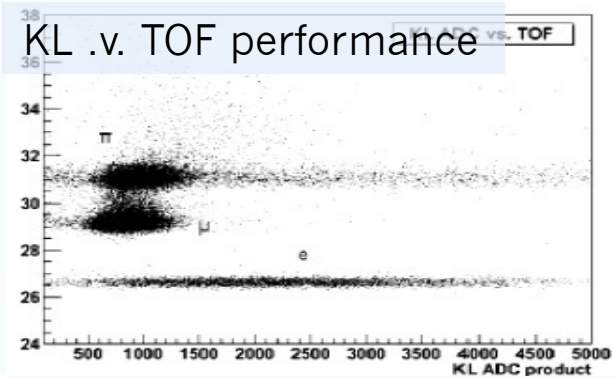
- Step IV comprises of spectrometer tracking system and single absorber coil - Absence of RF cavities mean no sustainable cooling
- Will test beam propagation in the magnet system and some cooling properties of the absorbers only

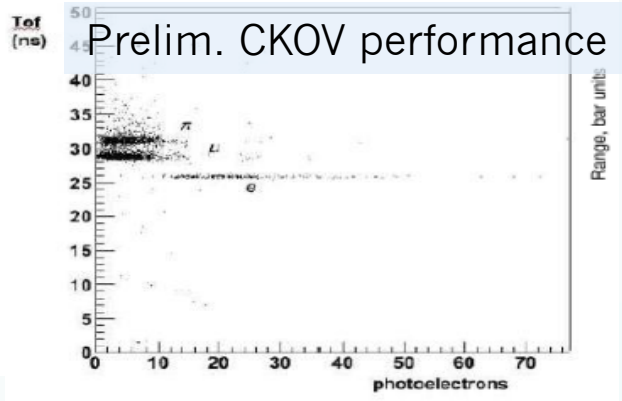


Step IV Components

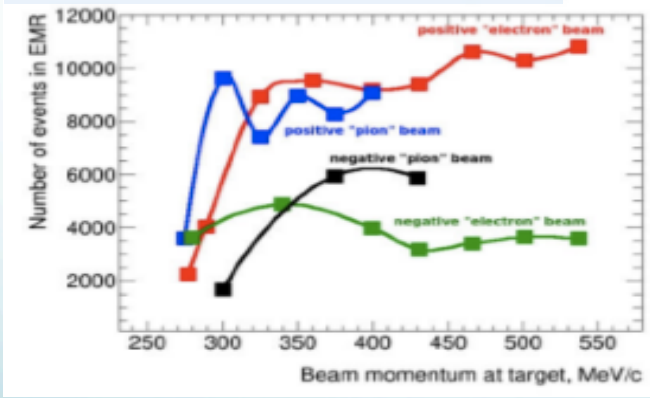
Particle ID :- Time-of-Flight, Cerenkov–reduce pion/electron background and downstream TOF/KL/Electron Muon Ranger – separate muons from decay electrons and pions

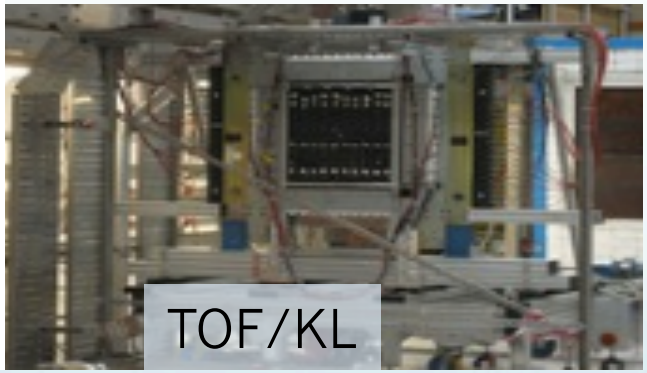


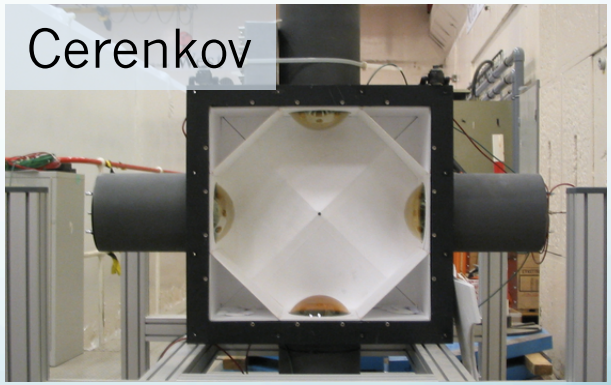




Prelim. EMR performance:

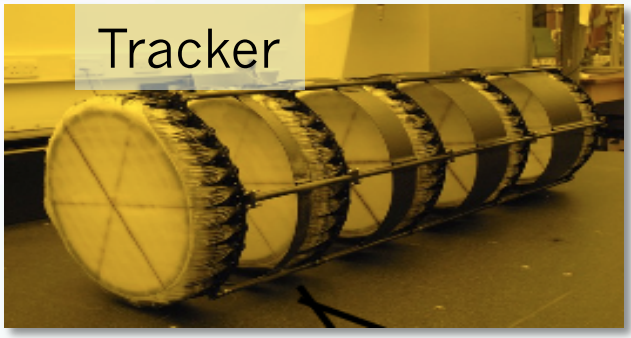






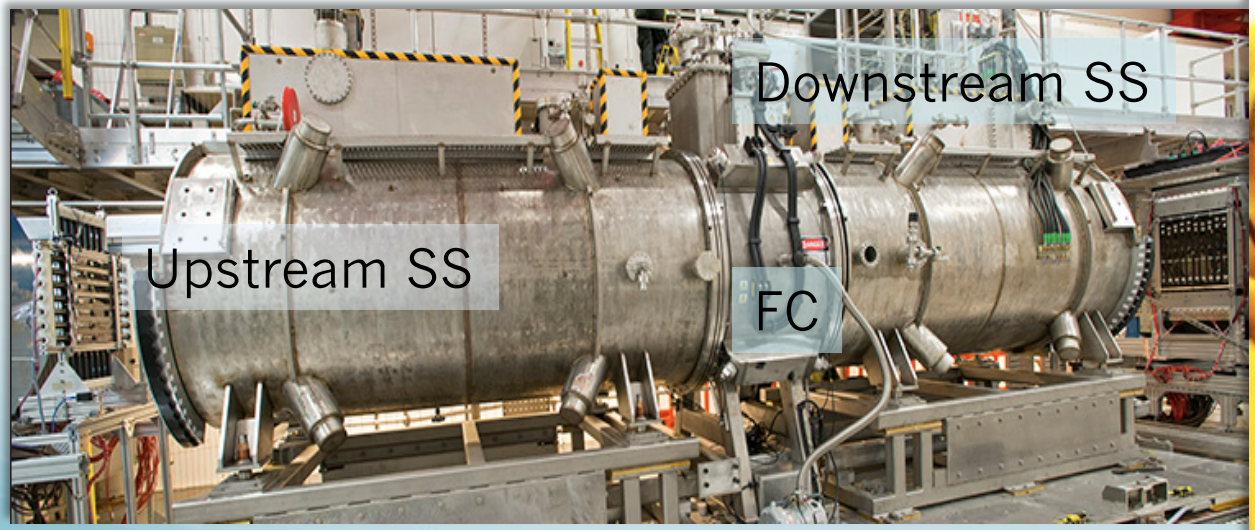
✳ All detectors installed in MICE hall. Data taken with all detectors Oct 2013

Step IV Components



Tracking Spectrometer and Spectrometer Solonoids:-

* Spectrometer Solenoids have been mapped
* Both upstream and downstream Sci Fi trackers fitted into solenoids, and installed into MICE hall

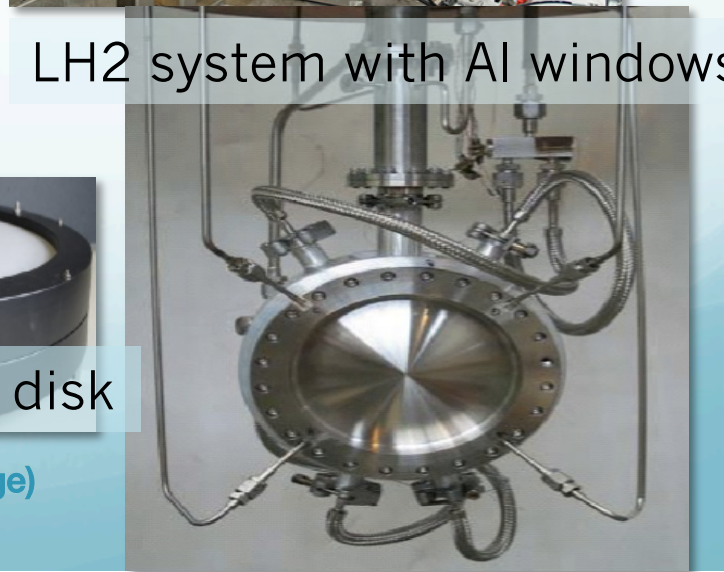


Step IV Components

Focus Coil and Absorbers:-

- 2 Focusing coils : FC1 and FC2 ready but only one required for Step IV
- FCs trained and mapped and installed in MICE hall
- LH2 or LiH absorbers placed in FC:
  - LH2 system has been commissioned and tested
  - Lithium Hydride disks now at RAL

AFC installation



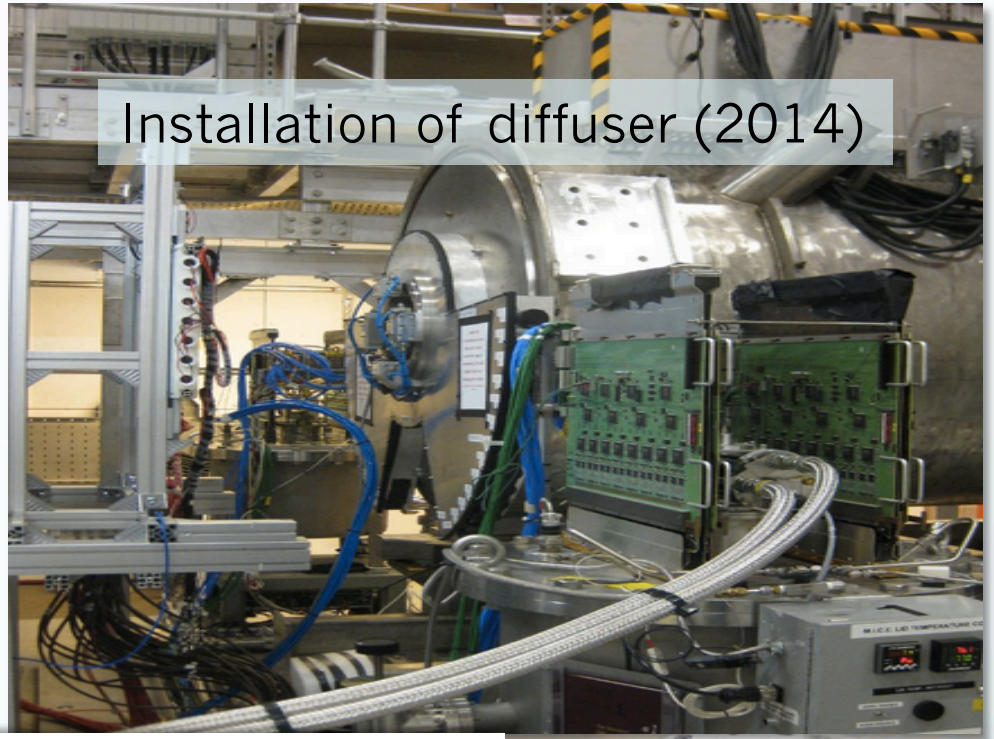
LH2 system with Al windows

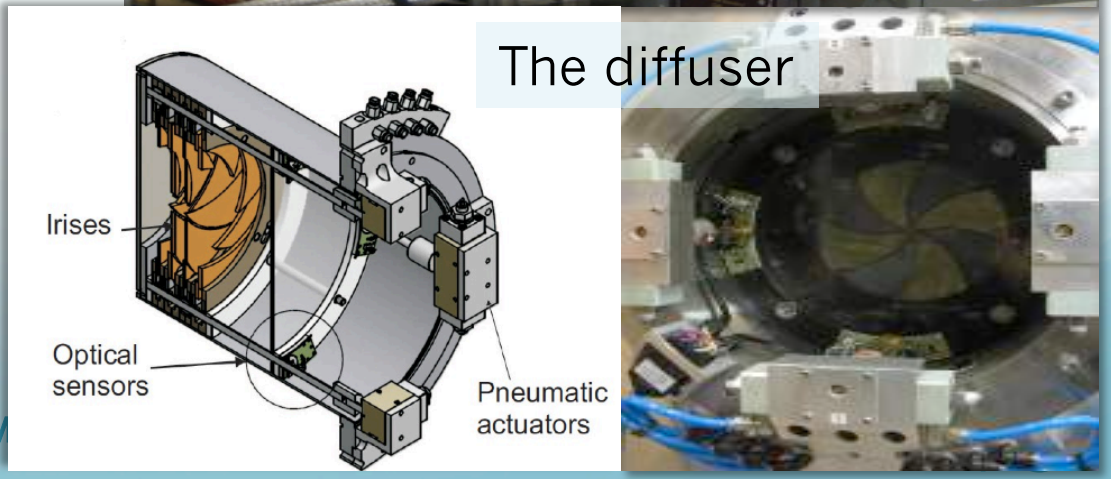
LiH absorber disk

Step IV Components

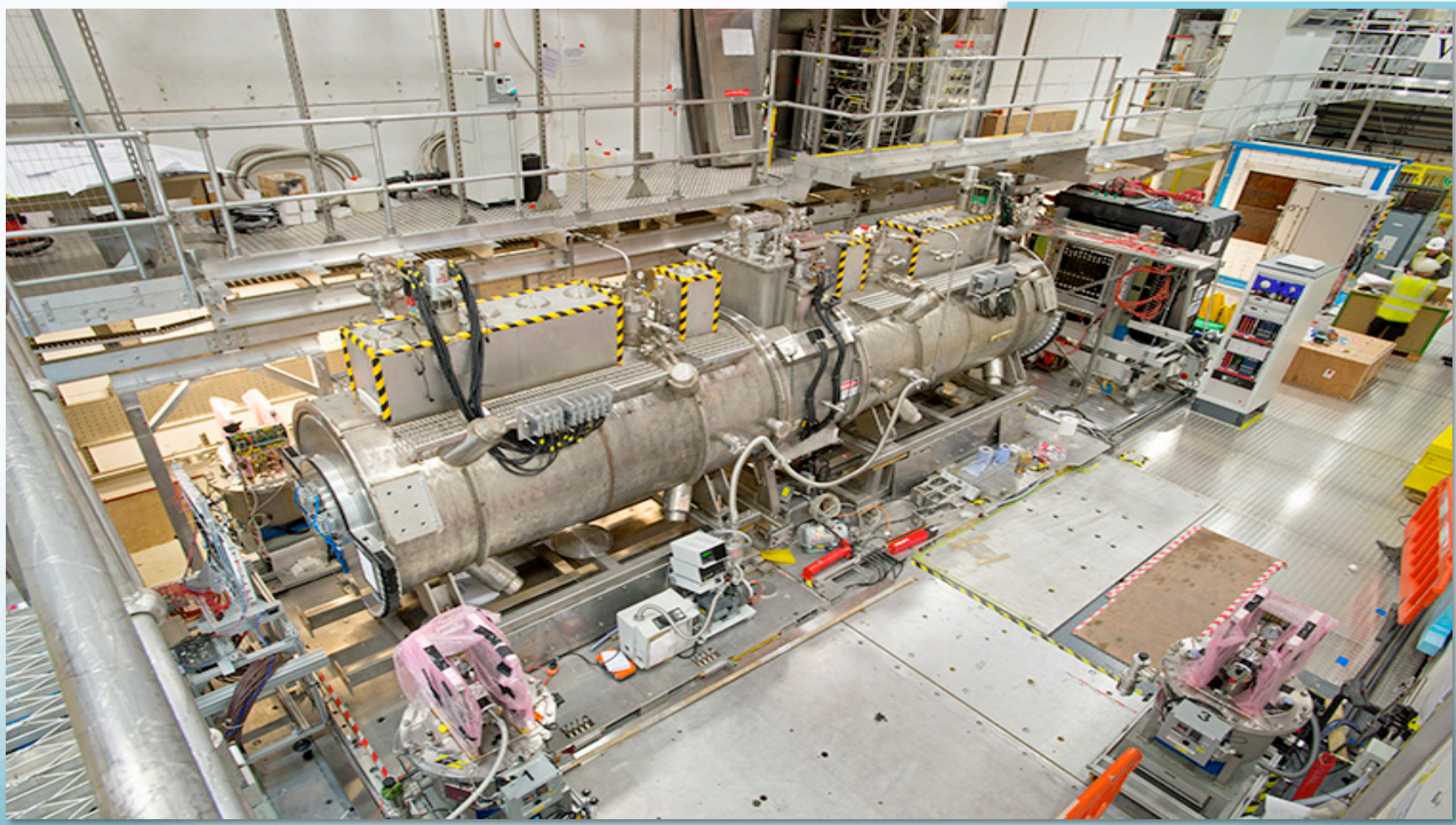
Diffuser:-

- Consists of 4 irises of brass and tungsten, with different thicknesses
- Used for enlarging the emittance
- Installed into upstream spectrometer solenoid end of 2014





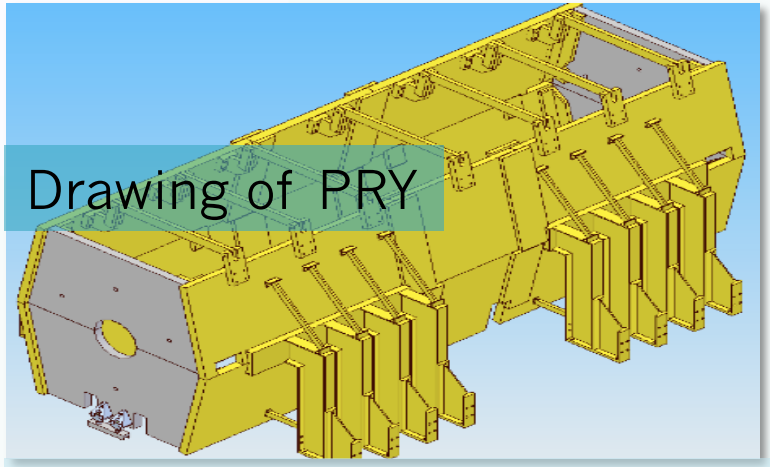
The Hall



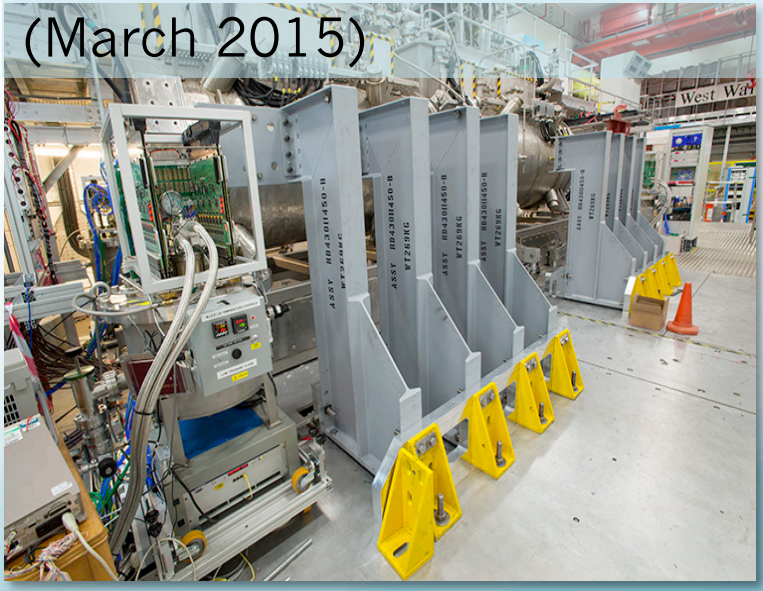
Partial Return Yoke

Partial Return Yoke (PRY) and its Installation in the Hall:

* MICE magnets built without yoke
* A partial return yoke necessary to reduce effects of external magnetic fields – reduces 3-4T to < 0.1 mT out side of PRY
* PRY consists of ~55t of iron
* Supports/legs currently been worked on in/around the hall



PRY Installation continues … (March 2015)



Status & Timeline

Plans for Step IV & Completion

Step IV: Timeline

- *"Now" until 01/05/15:*
  - Commissioning of MICE muon beam
  - TO2/KL/EMR (downstream calorimetry system) commissioning with beam
  - Alignment and calibration
- *02/06/15 – 24/07/15:*
  - Tracker commissioning and magnet training
- *08/09/2015-01/04/2016:*
  - Physics data taking (plan in progress)
  - But expect empty AFC, LH2 and LiH absorbers each in both flip and solenoid mode to be used

Towards Cooling Demonstration

- Step IV is expected to be complete by June 2016
- Preparation then begins for completion and the cooling demonstration
- Final PRY installation: 01/02/2017
- Commissioning: 02/05/2017
- Data taking complete by 31/03/2018

9	End of Step IV Data taking	1st June 2016
Cooling demonstration		
10	Partial Return Yoke materials arrive at RAL	10th May 2016
11	RF Cavities arrive at RAL	18th May 2016
12	Step IV De-Commissioning complete	22nd July 2016
13	RF Amplifier delivered	31st August 2016
14	RF Amplifier 1 ready for electrical commissioning	6th October 2016
15	RF Amplifier 2 ready for electrical commissioning	7th November 2016
16	Installation of PRY South starts	14th December 2016
17	Installation of the RF Cavities and Chambers starts	19th January 2017
18	Installation of North PRY complete	1st February 2017
19	Cooling Demonstration construction complete	24th March 2017
20	Cooling Demonstration commissioning complete	2nd May 2017
21	End of data taking in the cooling-demonstration configuration	31st March 2018

Conclusions

- Step I was completed and papers published
- MICE Step IV is imminent…we hope to have commissioning completed soon and start data taking! Run until June 2016
- This will give understanding of properties but we need RF cavities to be installed for full demonstration of sustainable cooling
- Final cooling demonstration configuration installation expected to be complete by mid-2017
- Data taking in cooling configuration including first demonstration of sustainable cooling completed in 2018

Thank You For Listening

Any Questions?