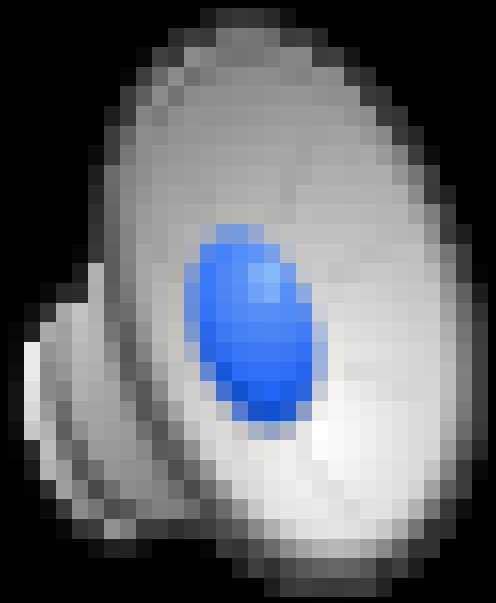
Imperial College London

Science & Technology Facilities Council

Introduction

K. Long, 30 October, 2015



Contents

- Publications and beam-dynamics review
- Commissioning status update
- MICE goals
- Preparation of cooling demonstration
- Collaboration
- International context
- Orientation

Introduction

PUBLICATIONS AND BEAM-DYNAMICS REVIEW

Title	Lead authors
Step I physics	
Electron Muon Ranger: performance in the MICE Muon Beam **EMR paper submitted!** **Pion contam: being prepared for submission** Measurement of the pion contamination in the MICE Muon Beam	A. Blondel, F. Drielsma, R. Asfandiyarov D. Orestano, D. Nugent, P. Soler
Step IV physics	
Commissioning of the MICE experiment in the Step IV configuration **Work organised; perhaps based on 07Oct15 data taking?**	C. Rogers
Ionization cooling demonstration	
Design and expected performance of the MICE demonstration of ionization cooling **Draft in preparation; Wise people: Ronald, Ryne**	V. Blackmore, J. Pasternak, C. Rogers
Technical	
The MICE target upgrade **Draft assembled!** The design construction of the MICE Electron Muon Ranger **Draft under review in the EMR group??** The Reconstruction Software for the MICE Scintillating Fibre Trackers **Draft at advanced stage: issue in track-fit being debugged** The MICE Analysis and User Software framework	C. Booth R. Asfandiyarov, A. Blondel, F. Drielsma S. Dobbs D. Rajaram **Draft being assembled.**

Step I documentation almost complete! Pressure! Cooling demo paper … first Step IV paper?

Beam-dynamics review (MPB recommendation):

Review of the MICE beam-dynamics analysis

Terms of reference

Background

The international Muon Ionization Cooling Experiment (MICE) collaboration [1] has embarked on a programme of measurement designed to demonstrate the feasibility of the ionization-cooling technique [2]. The MICE measurement of the cooling effect is made by comparing the muon-beam parameters upstream and downstream of a single cell of an ionization-cooling lattice. The MICE study of ionization cooling will be performed in two steps. The first, referred to as "Step IV", has been optimised to allow the factors that determine the ionization-cooling effect to be measured [3]. Once Step IV is complete, the experiment will be reconfigured to deliver the demonstration of ionization cooling [4].

The MICE Muon Beam on ISIS [5] at the STFC Rutherford Appleton Laboratory delivers muons one at a time to the experiment [6]. Upstream of the cooling cell, muons are selected using time-of-flight (TOF) hodoscopes [7] and threshold Cherenkov counters [8]. Muons that decay within the experiment are identified by tagging the electron produced in the decay using a TOF counter, lead-scintillator pre-shower detector (KL) [9] and calorimeter (EMR) [10] placed downstream of the cooling cell. A spectrometer composed of a scintillating-fibre tracking detector [11] contained within a 4 T solenoidal magnetic field is used to measure the phase-space coordinates of each muon entering the cooling cell. A second spectrometer measures the phase-space coordinates of each muon leaving the cooling cell.

Analysis of the beam dynamics in MICE presents some unique challenges. First, a bunch must be assembled offline from a collection of single muons recorded by the experiment. The parameters that characterise this bunch such as the emittance must then be derived from the ensemble of single particles. A Geant4-based end-to-end simulation of the experiment will be used to inform the analysis of the data.

The review

The present review of the beam-dynamics analysis will take place when the analysis of the first data from the experiment in the Step IV configuration has just begun. Its purpose is to provide feedback to the collaboration on the analysis techniques that have been developed and to advise on optimal strategies for the analysis of the data, simulation of the experiment and the study of the beam dynamics in MICE.

The format of the review will be a series of presentations in which the reconstruction, simulation and analysis techniques will be described. The results obtained from the analysis of the first data will also be described.

The reviewers are asked to:

- Consider the data reduction, analysis, data-curation techniques and the beam-optics and simulation methodology adopted by the collaboration;
- Identify areas in which improved techniques or methodologies should be developed to improve the analysis or to expedite its completion; and
- Advise on strategies by which the impact and clarity of the results of the experiment can be presented to the accelerator- and experimental-physics communities.

A short report on the findings and recommendations of the reviewers will be prepared and submitted to the collaboration within a month of the review.

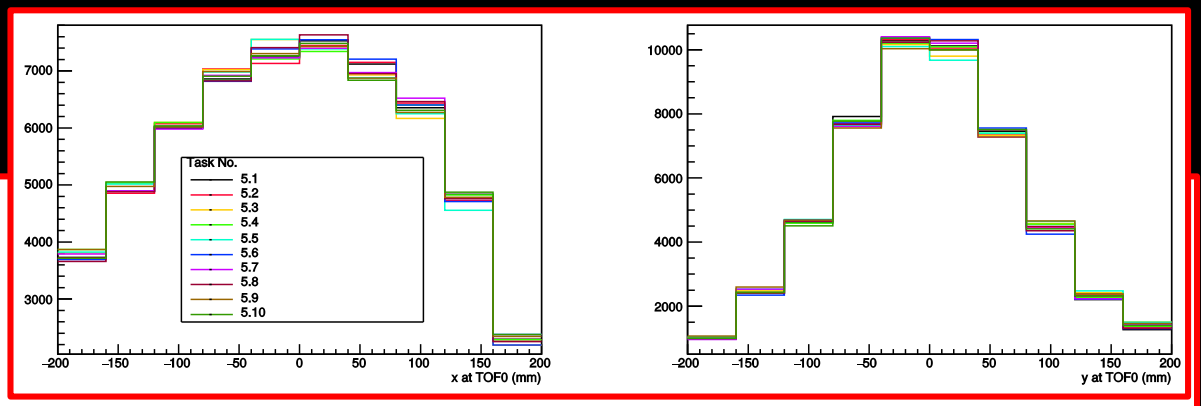
- Date now set for 8th to 10th December 2015
- Reviewers:
  - M. Syphers (MSU)—Chair
  - R. Bartolini (Diamond/JAI)
  - J. Byrd (LBNL)
  - D. Newbold (Bristol)
  - G. Rumolo (CERN)
  - D. Schulte (CERN)
  - A. Seryi (JAI)

Introduction

COMMISSIONING STATUS UPDATE

MICE Muon Beam

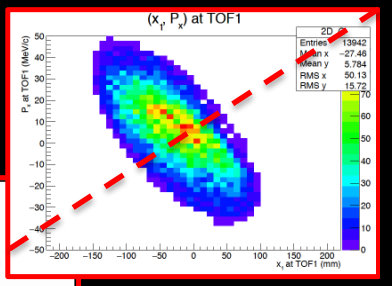
- **Commissioned:**
  - **Decay-solenoid power supply has had a number of issues:**
    - **Rectified by DL or by DL in consultation with FUG;**
      - **Outstanding issue:**
        - » **Over-temperature interlock fires after extended operation at high current;**
          - **Intermittent; under investigation**



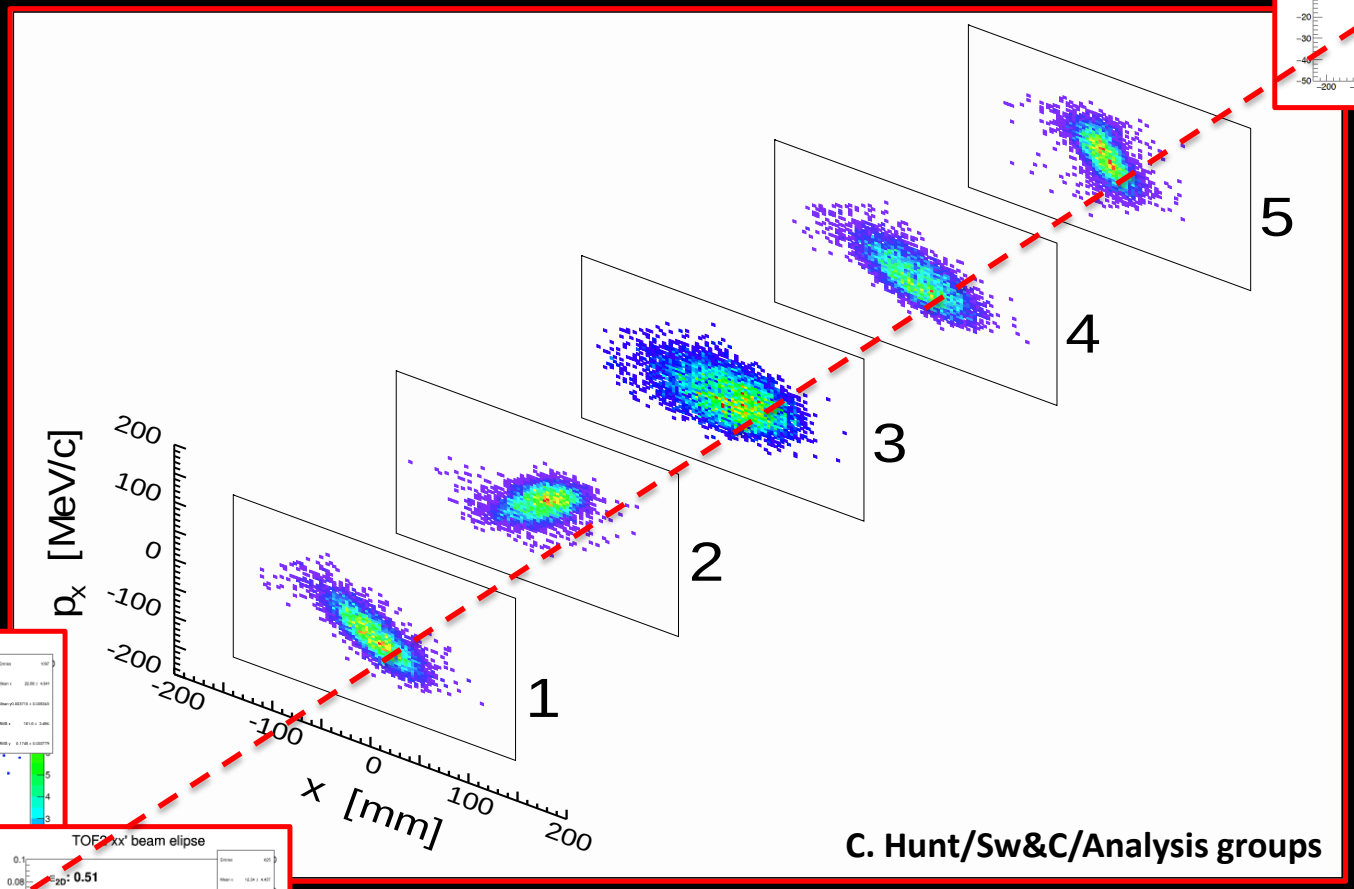
Example:
Optimisation of Q1—Q3

Instrumenation, S/w&C; data pathway

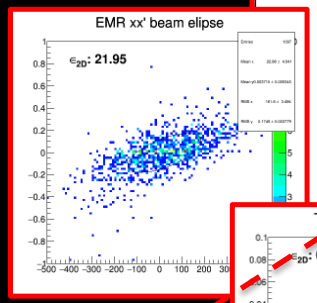
- Data from 7th October: SSU(E-C-E) 4T

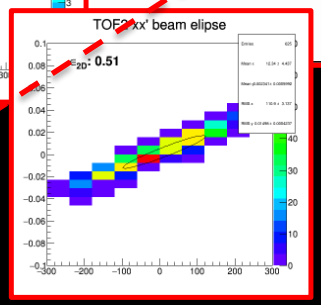


V. Blackmore
TOF group



C. Hunt/Sw&C/Analysis groups





F. Drielsma
TOF/KL/EMR
groups

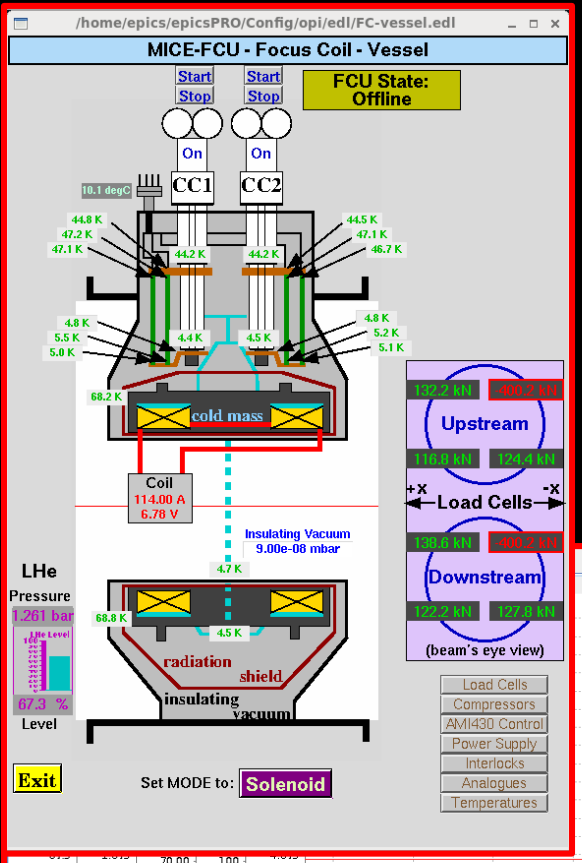
μ

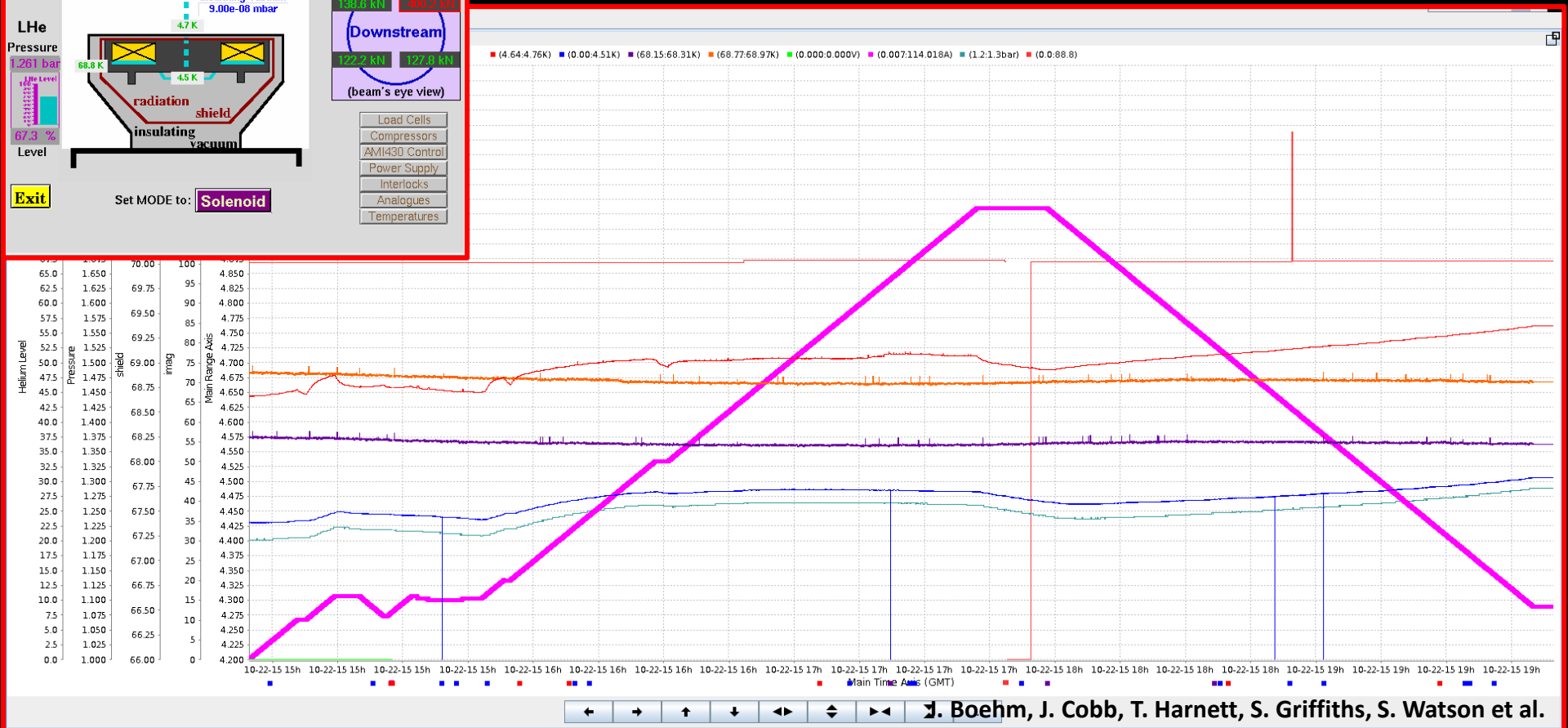
Spectrometer solenoids:

- Upstream solenoid:
  - Training complete; operated at full current +2%
    - Soak test to be completed once power supply and controls issues addressed (an element of solenoid system review)
- Downstream solenoid:
  - Training terminated with failure of M1 coil;
  - Subsequent to failure:
    - E-C-E combination run to quench at 260A
    - M2 operated at 5A
- See presentations later in the meeting

Focus coil:

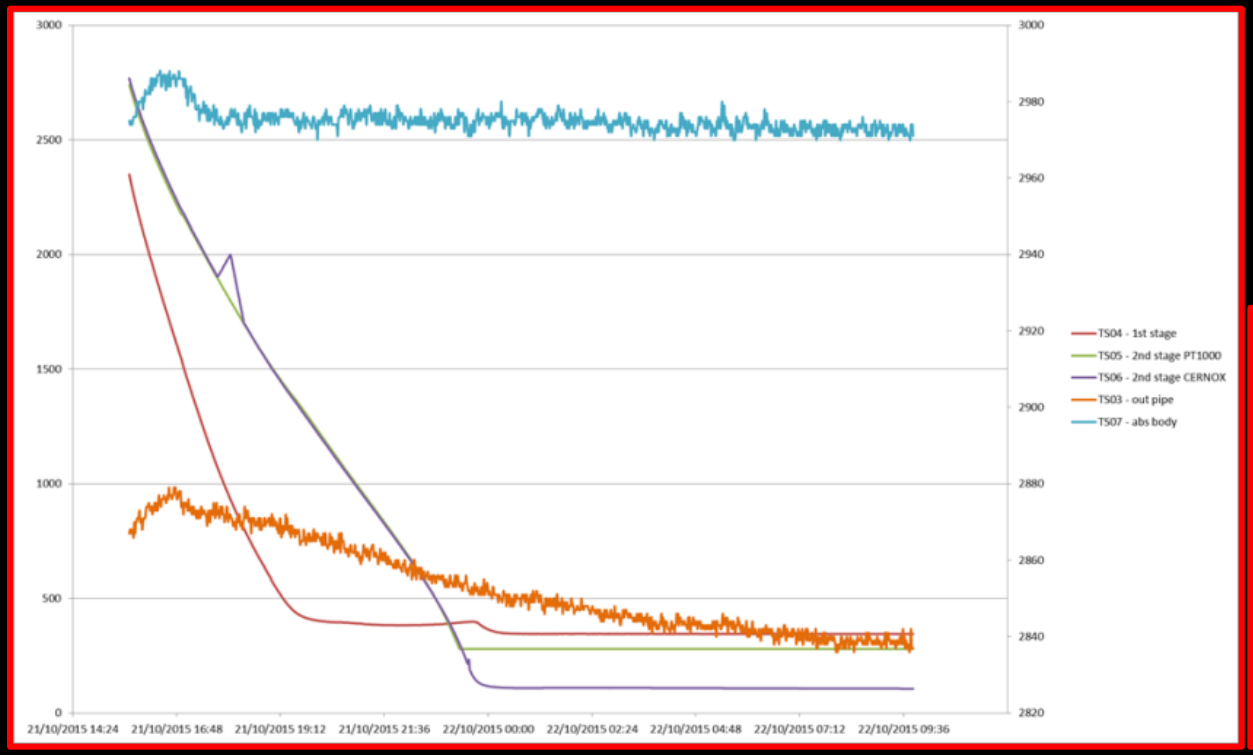
- Run to full current (114A) in solenoid mode:
  - Soak test to be performed; this week if possible

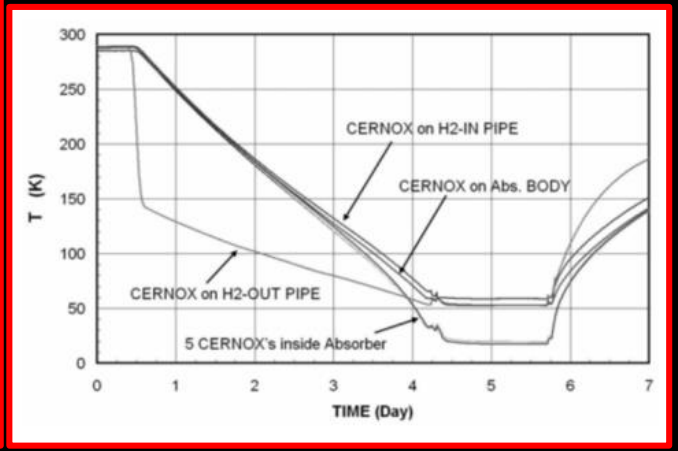




Liquid-hydrogen system:

- System prepared for He-gas test 21st October
  - Cryocooler OK; first stage under low load
  - Absorber body is cooling very slowly
    - Convection of cold He gas only; H2 system would be condensing
    - So, will seek to use LN2 in near future





S. Watson et al.

Support and commissioning issues:

- Support for magnet commissioning:
  - Stretched the resources available at RAL:
    - MICE relies on DL for expert-level electrical engineering
      - Excellent, but scarce resource
    - MICE & ISIS support at technical level at RAL
- Additional effort and coordination:
  - J. Boehm (RAL/TD) recruited @ 100% to coordinate magnet-commissioning-support effort
    - Team includes: magnet, electrical, vacuum, mechanical
  - MICE/ISIS (RAL/DL) liaison improved
  - Run Coordinator:
    - Responsible for coordination of commissioning and control activities in the Hall;
    - Single point of contact … "in charge";
      - V. Blackmore, P. Hodgson in post; additional appointments under discussion.

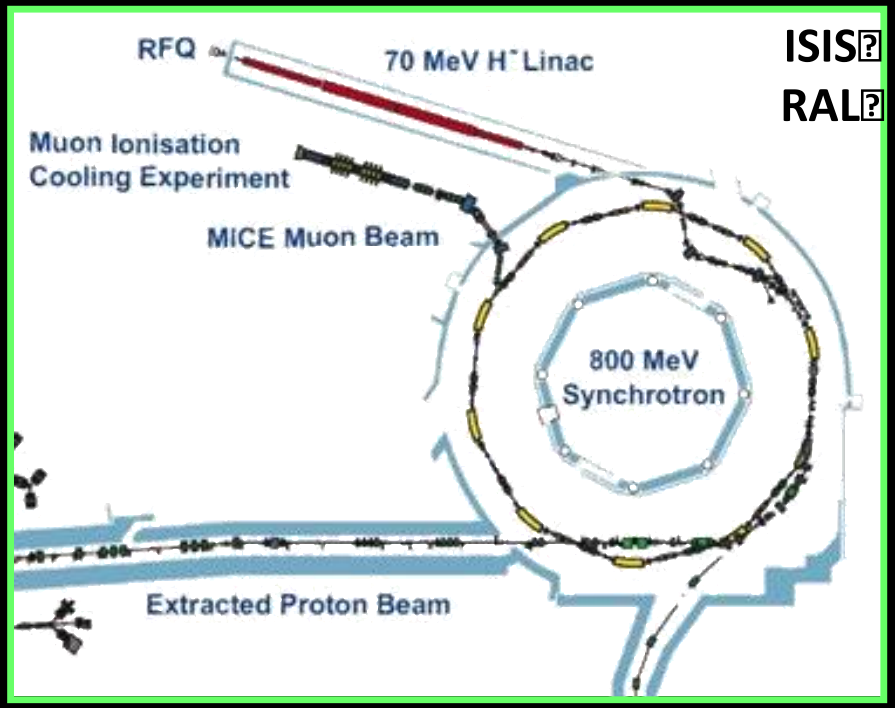
- Power-supply and control issues:
  - Review of power-supply and controls system in the light of vulnerability of spectrometer solenoid to particular failure modes:
    - Kerby review and Bross/Palmer contributions
  - Combined magnet training can not take place until system-level review concludes and its conclusions are implemented

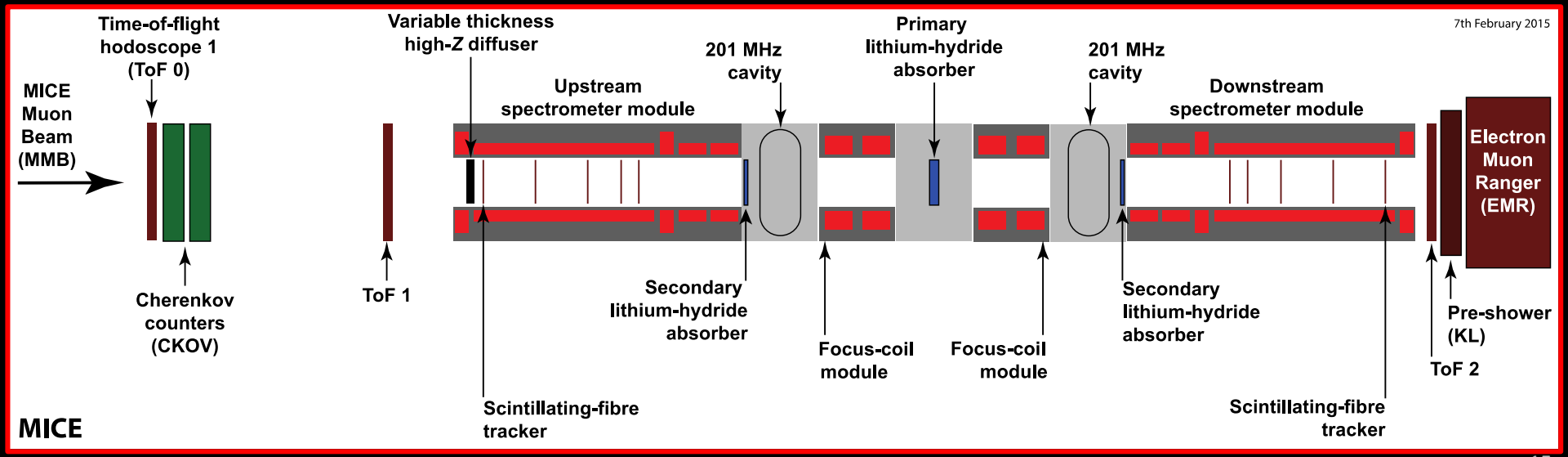
Introduction

MICE GOALS

Muon Ionization Cooling Experiment

- **MICE approved to:**
  - Design, build, commission and operate a realistic section of cooling channel
  - Measure its performance in a variety of modes of operation and beam conditions
    - Results will allow Neutrino Factory [and Muon Collider] complex to be optimised
- **Requirements:**
  - Normalised transverse emittance: 0.1%
    - Requires selection of 99.9% pure muon sample





Headlines of MICE programme:

Table 1: MICE physics programme. $\epsilon_{\perp}^{n}$ denotes the normalised transverse emittance while $\epsilon_{\perp}$ and $\epsilon_{||}$ denote the transverse and longitudinal emittance respectively. The elements of the programme are listed in priority order.

Step IV:
Material properties of LH_2 and LiH that determine the ionization-cooling performance
Observation of $\epsilon_{\perp}^{n}$ reduction
MICE demonstration of ionization cooling:
Observation of $\epsilon_{\perp}$ reduction with re-acceleration
Observation of $\epsilon_{\perp}$ reduction and $\epsilon_{||}$ evolution
Observation of $\epsilon_{\perp}$ reduction and $\epsilon_{||}$ and angular momentum evolution†

† Requires systematic study of "flip" optics.

Prioritised Step IV programme at Nov14:

- At November 2014:

1	Detailed scan (with $\sim$ 20k good muons per point) of the effect of empty, liquid-hydrogen and lithium-hydride absorbers as a function of betatron function (9 points) at the nominal momentum of 200 MeV/c.
2	1 & detailed scan (with $\sim$ 20k good muons per point) of the effect of empty, liquid-hydrogen and lithium-hydride absorbers as a function of momentum (9 points) at the (single) nominal betatron function (β) of 420 mm.
3	1, 2 & 100k good muons per point muons at the nominal $\beta = 420$ mm, $p = 200$ MeV/c, scanning over emittance (3 points) with empty, liquid-hydrogen and lithium-hydride absorbers.
4	1, 2, 3 & detailed scan (with $\sim$ 20k good muons per point) of the effect of liquid-hydrogen and lithium-hydride absorbers as a function of betatron function (9 points) and emittance (3 points) at the (single) nominal momentum of 200 MeV/c.
5	1, 2, 3 & sampling of 3×3 emittance, momentum matrix at three betatron functions with reduced sample size ($\sim$ 25k good muons per point).
6	1, 2, 3 & sampling of 3×3 emittance, momentum matrix at three betatron functions with reduced sample size ($\sim$ 50k good muons per point).
7	1, 2, 3 & sampling of 3×3 emittance, momentum matrix at three betatron functions with reduced sample size ($\sim$ 100k good muons per point).

- Pressures @ Oct15
  - Completion of commissioning of Step IV;
  - Start of reconfiguration for cooling demo (01Jun16)
  - Re-definition of programme without M1 of SSD

STEP IV WITHOUT SSD/M1

Measurement of material properties:

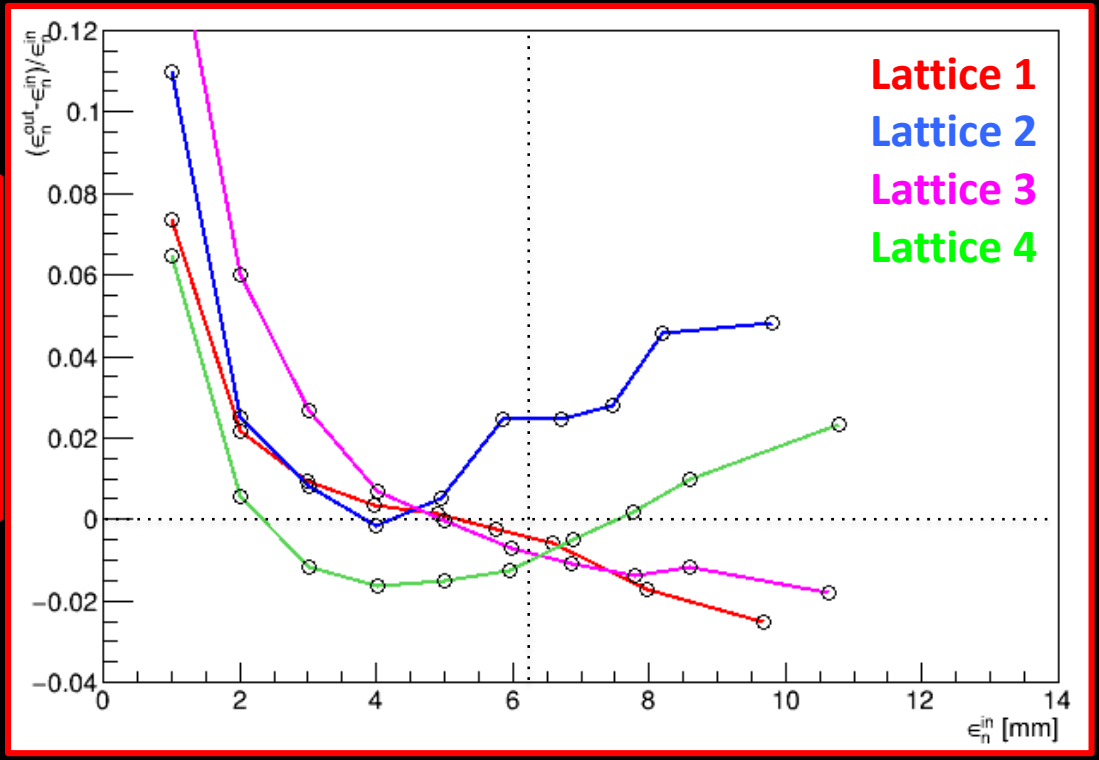
- MCS and *dE*/*dx* measurement:
  - Need sufficient well measured, through-going muons;
    - Insensitive to channel optics, need adequate transmission
- MCS measurement:
  - Two approaches: field off and field on:
    - Ideally "some of" both to cross check systematic error
- *dE*/*dx* requires field in tracking volume:
  - Minimum requirement: E-C-E in SSU and SSD
- Initial estimate of rate:
  - Resent run with SSU/E-C-E (@ 4T) and no FC or SSD:
    - 13k through-going muons per hour
  - Anticipate improvement in rate through use of match coils and/or focus coils

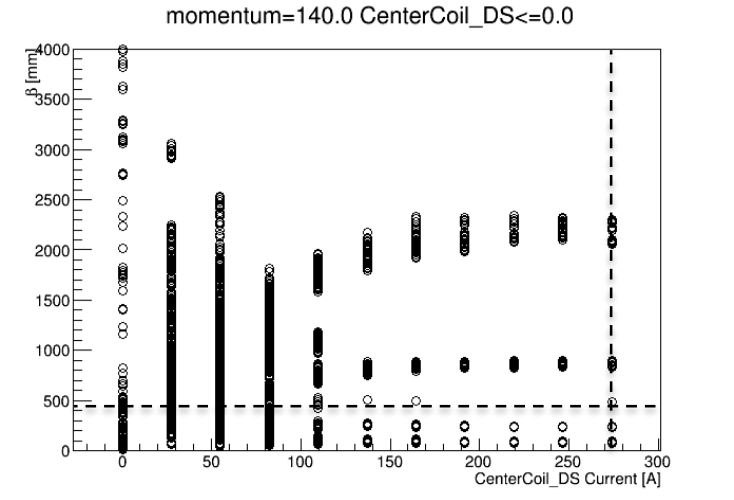
Reduction of normalised emittance:

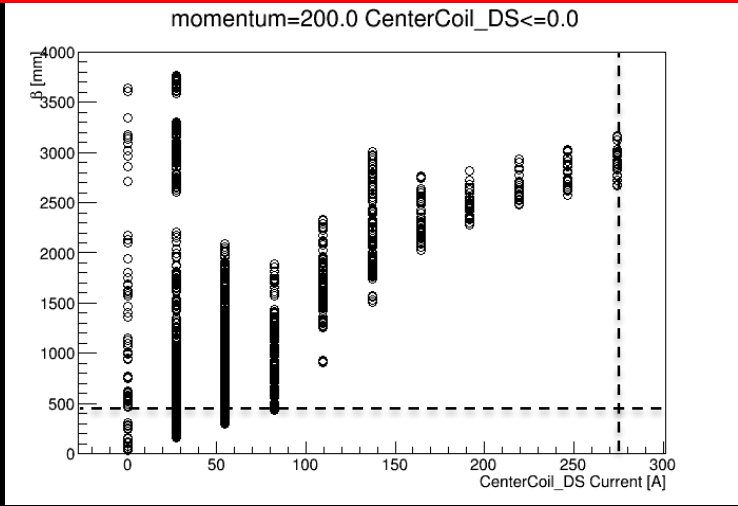
- Need care with optics of channel:
  - Require:
    - Sufficiently small β at the absorber;
      - Measurable cooling effect
    - Acceptance sufficiently large;
      - Acceptable transmission of beams with emittance $\varepsilon > \varepsilon_{equil}$
- Sample of revised optics considered:
  - β constant in the tracker; asymmetric optics; release 4T constraint in tracker
  - β beats allowed tracker; symmetric optics; 4T constrain maintained
  - β beats allowed tracker ; asymmetric optics; release 4T constraint in tracker

C. Rogers/Physics Group/MICE Note 475

Lattice index	Momentum MeV/c	β_{abs} mm	β_{in} mm	α_{in}
1	200	447	1102	0
2	200	574	600	-1.5
3	200	687	600	-1.5
4	200	411.	743.19	-0.748







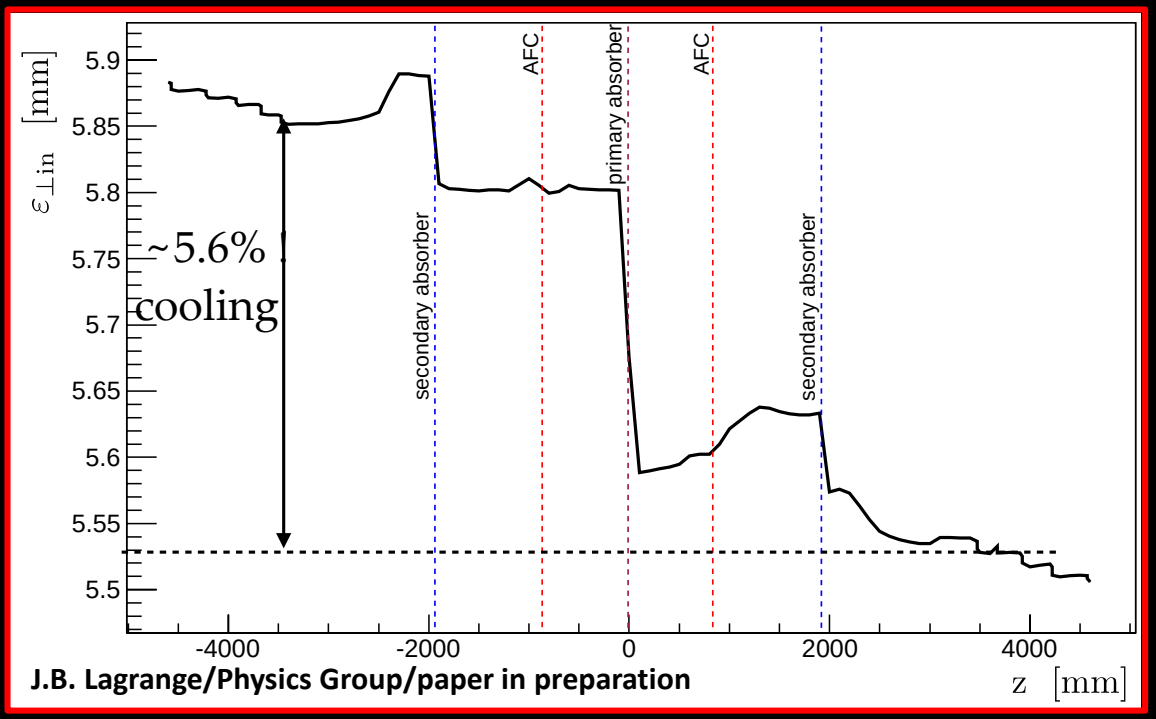
Flip mode optical functions at the absorber as a function of current in the centre coil. 140 MeV/c (left); 200 MeV/c (right). 4 T in the tracker requires 274 A.

Step IV run plan:

ISIS Cycle	Start	End
2015/03	03-Nov-15	18-Dec-15
2015/04	16-Feb-16	25-Mar-16
2016/01	12-Apr-16	20-May-16
2016/02	28-Jun-15	29-Jul-16

- Step IV run plan revised in light of extended commissioning:
  - Cycle 2015/03:
    - Completion of magnet commissioning
    - Maintain option of taking data at the end of the Cylce
  - Cycle 2015/04:
    - Data taking with LH2; full and empty
  - Cycle 2016/01:
    - Data taking with LiH
- Little contingency:
  - Contingency in running-time estimates made by Rogers/Boyd:
    - Can't afford to slip across a User Cycle
  - Project team have evaluated consequence of using 2016/02 for data taking:
    - One month delay to start of cooling demonstration (see C. Whyte)

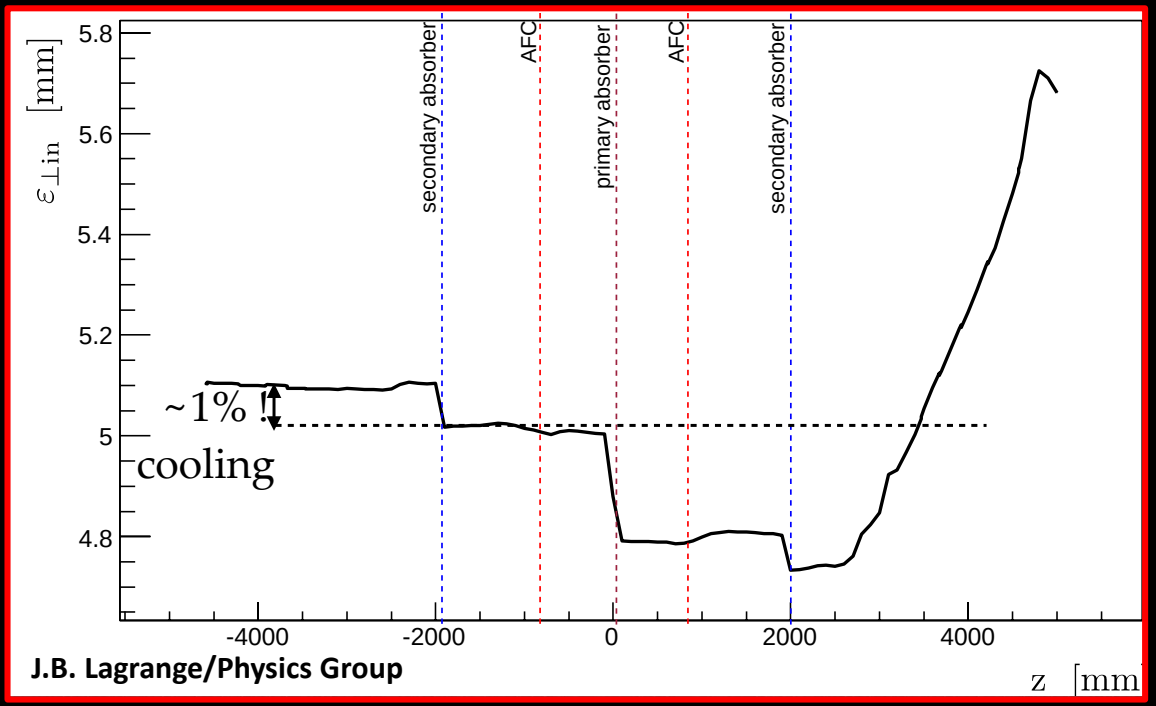
COOLING DEMO WITHOUT SSD/M1



Baseline cooling demo:

200 MeV/c; 6 πmm i/p

- 5.6% cooling effect between tracker reference planes



Cooling demo: no M1 in SSD

200 MeV/c; 6 πmm i/p

- 1% cooling effect between tracker reference planes
- Chromatic abarations difficult to manage

Introduction

PREPARATION OF COOLING DEMONSTRATION

Preparation for the cooling demo:

- Principal area of concern resourcing for RF system:
  - RF-system review (M. Palmer chair) 9 & 10 Sep 15:
    - Endorsed technical programme
    - Concluded that staff resource, in particular for the commissioning of the system in the MICE Hall, was too low by a factor of 1.5
- Addressing the resourcing issues:
  - Two stage process:
    - Project plan revised in the light of the recommendations:
      - Re-evaluation of tasks, contingency and staff resource:
        - » Substantial increase in resource (C. Whyte, K. Ronald)
    - Seek to secure additional resource:
      - Partially successful:
        - » ISIS:
          - R. Anderson (ISIS) full time; discussion of additional "management-level" support
          - Electrical engineering support as part of MICE/ISIS arrangement
          - Bring teams together now!
        - » Imperial:
          - S. Alsari (RF engineer); A. Kurup (controls)
      - Support through secondment:
        - » E.g.: US Labs; CERN? …

Introduction

COLLABORATION

Operations; resources

- Collaboration actively seeking resources to support full exploitation:
  - Bids have been submitted to:
    - NIKHEF:
      - Seeking student part of whose PHD will be MICE
  - Bid to Royal Society:
    - Newton Fund:
      - Post doc; collaboration with TATA Institute, Mumbai; joint MICE/DINE
  - Bid to STFC:
    - MICE-UK:
      - Bridging funds secured 01Apr15 – 31Dec16
      - Cost to complete review in the New Year:
        - » Principal investigator: P. Soler (Glasgow);

Introduction

INTERNATIONAL CONTEXT

Redefining the muon programme

- Presentation to R-ECFA at time of EPS2015:
  - Outlined the capabilities that muon beams could provide.
- Noting that:
  - Discovery programmes are underway:
    - Energy frontier—LHC and its upgrades
    - Neutrinos—LBNF/DUNE, Hyper-K, reactor and astroparticle …
- ECFA is considering:
  - Assessing scientific opportunities/community interest in muon programme.
- Propose one-day meeting on the 18th November 2015 at CERN:
  - Consider the scientific merits of muon beams and the R&D required to realise them.
  - Date and venue chosen so that the conclusions of the meeting can be presented to ECFA during its meeting (at CERN) on the 19th and 20th November 2015.

Introduction

ORIENTATION

Friday 30 October 2015

Welcome and introduction: Plenary session 1 - (09:00-10:40)

- Conveners: Bross, Alan

time	[id] title	presenter
09:00	[0] Welcome and introduction	LONG, Kenneth Richard
09:20	[1] Project Managers report	WHYTE, colin
09:40	[2] Progress commissioning MICE since June 2015	HANLET, Pierrick
10:00	[3] STFC codes of practice--introduction	WARK, Dave
10:10	[4] Safe commissioning and operation of MICE	NICHOLS, Andy

Coffee - (10:30-11:00)

Step IV commissioning and operation - (11:00-13:00)

- Conveners: Pasternak, Jaroslaw; Boyd, Steven; Hodgson, Paul; Dr. Boehm, Josef

time	[id] title	presenter
11:00	[60] Operations Co-ordinator Report	BOYD, Steven
11:30	[61] Focus Coil report	COBB, John
12:00	[62] Spectrometer Solenoid Report and Discussion	

Lunch - (13:00-14:00)

Physics and analysis: Plenary session 3 - (14:00-15:30)

- Conveners: Rogers, Chris

time	[id] title	presenter
14:00	[56] Physics Group Status and Plans	ROGERS, Chris
14:30	[57] Tracker Alignment, Efficiency and Resolution	HUNT, Christopher
14:50	[58] MICE Demonstration of Ionisation Cooling - Update	PASTERNAK, Jaroslaw LAGRANGE, Jean-baptiste
15:10	[59] Discussion	

Tea - (15:30-16:00)

Software and computing: Plenary session 4 - (16:00-17:30)

- Conveners: Rajaram, Durga

time	[id] title	presenter
16:00	[32] Computing and Software Status	RAJARAM, Durga
16:15	[33] Controls & Monitoring	HANLET, Pierrick
16:35	[34] Online	KARADZHOV, Yordan Ivanov
16:55	[36] Offline	DOBBS, Adam
17:15	[35] Infrastructure	FRANCHINI, Paolo

Safety
Quality
Schedule

Saturday 31 October 2015

Cooling demonstration construction: Cooling Demo Plan - (09:00-09:15)
- Conveners: whyte, colin

Cooling demonstration construction: RF Project - (09:15-09:30)
- Conveners: whyte, colin

Cooling demonstration construction: Mechanical Intgration - (09:30-09:45)
- Conveners: whyte, colin

Coffee - (10:30-11:00)

Closing session: Plenary session 6 - (11:00-12:00)
- Conveners: Bross, Alan

time	[id] title	presenter
11:00	[5] Collaboration Board Summary	BLONDEL, Alain
11:20	[6] Concluding remarks	LONG, Kenneth Richard

Lunch - (12:00-13:00)

Executive Board - (13:00-15:00)
- Conveners: Long, Kenneth Richard

- **This meeting:**
  - **Renew and refresh our planning for Step IV**
    - **Is there a configuration [e.g. SSU(ECE)-FC-SSD(ECE)] that makes sense in the short term (e.g. before Christmas)?**
  - **Begin the discussion of the recovery of SSD**
  - **Continue the planning of the cooling-demo, and the RF-power project in particular**