Imperial College London

Science & Technology Facilities Council

# Introduction

# Contents

Introduction

# OPERATIONS AND COMMISSIONING

# ISIS cycle 2016/01 (Apr16—May16)

- Devoted to:
  - Installation of upgraded SSD/SSU QD/QP system;
  - Preparation for demin/inhibited water system split

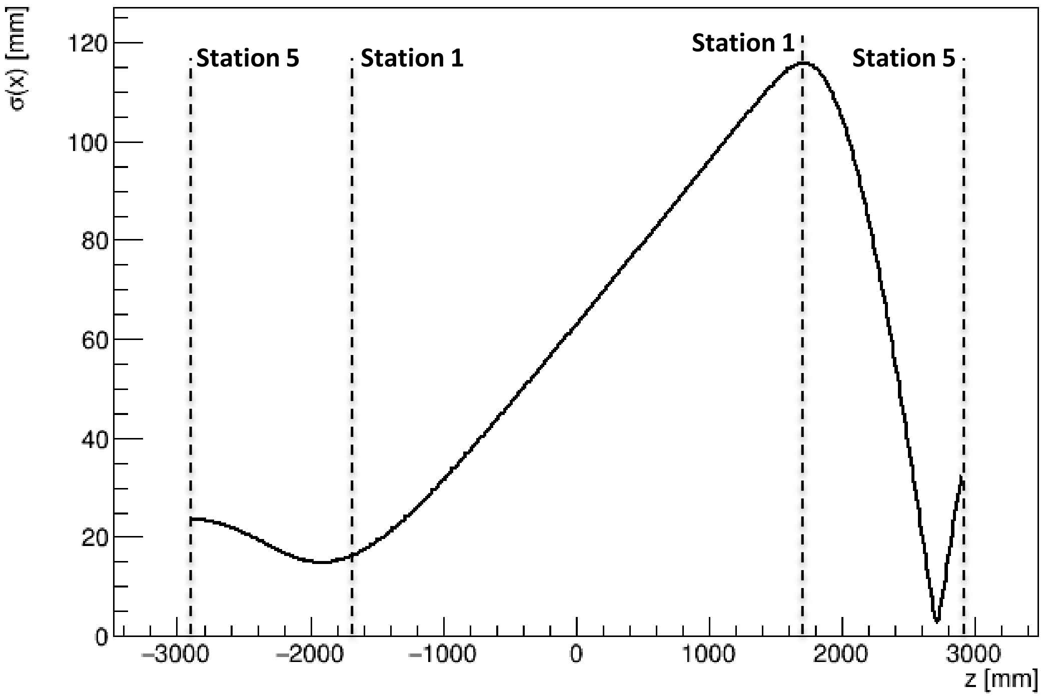
- Duty Coordinator/Operations Manager:
  - System established;
  - Enhanced coordination working well

# ISIS Cycle 2016/02 (Jun16—Jul16)

- **Decision:**
  - solenoid mode only for this
- **Commissioning activities:**
  - Upgraded QD/QP system for SSU and SSD;
  - SSU, FC and SSD individually;
  - SSU + SSD;
  - SSU + FC + SSD
- **FC:**
  - Run to 90A, no quench; declared operational
- **SSs:**
  - Instabilities observed running trim supplies
    - Decide to take trim supplies out of circuit
  - Transients observed on the QD signals:
    - SSU transient rate > SSD rate
    - Absolute size "small”
  - Investigations, inclding:
    - Movement of the PRY/SSs
    - Noise on power supplies;
    - No smoking gun.
  - Decision:
    - Increase the trip threshold to 200mV;
    - Run magnets individually:
    - Observe the rate of transients
  - Transients "stable" in amplitude and rate.

# Set-up and optics

- Wednesday, 20Jul16
  - Data taking with SSU and SSD
    - ECE coils in SSU and SSD only
    - Current of 140A through ECE
      - Roughly corresponds to 2T in the tracking volume
  - Empty channel

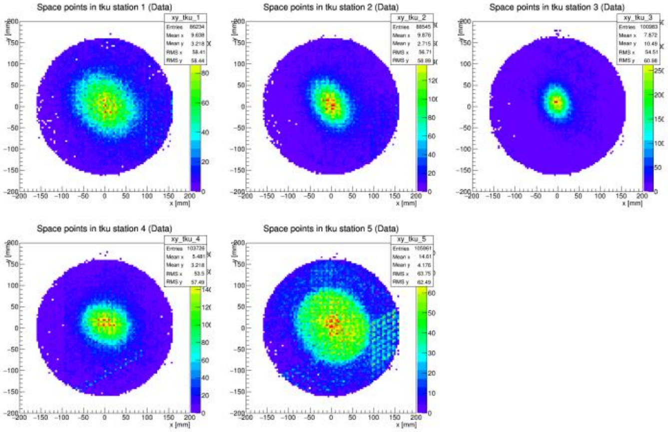


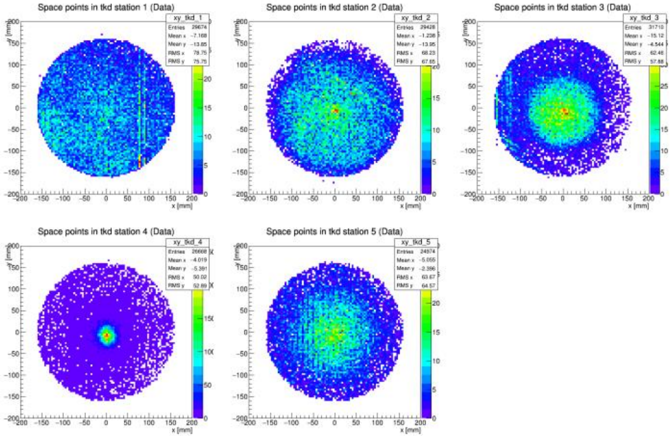

- Rogers' expectation of the beam size (RMS) shown facing

# Tracker space-points

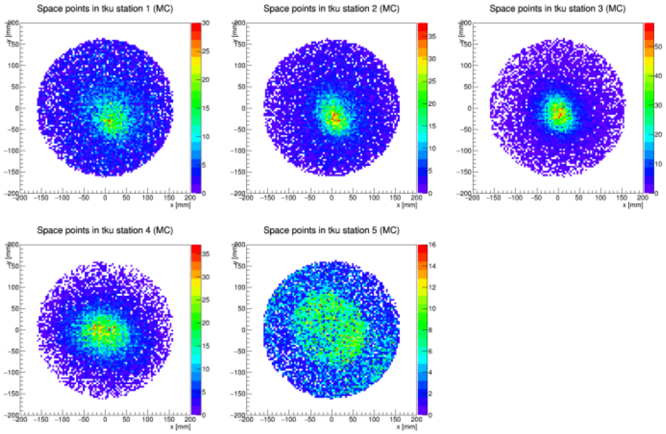
**TKU** **TKD**

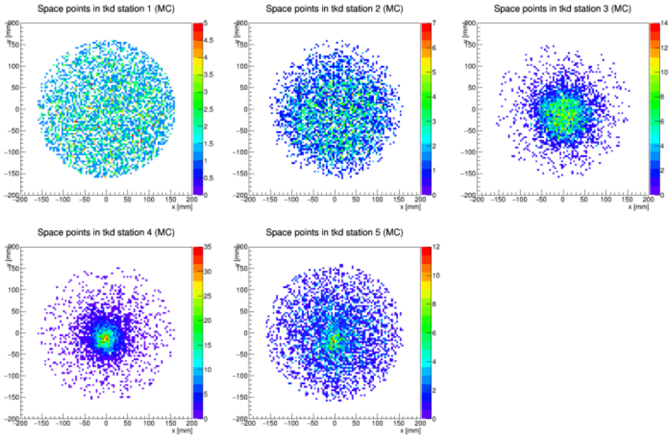
**Data**



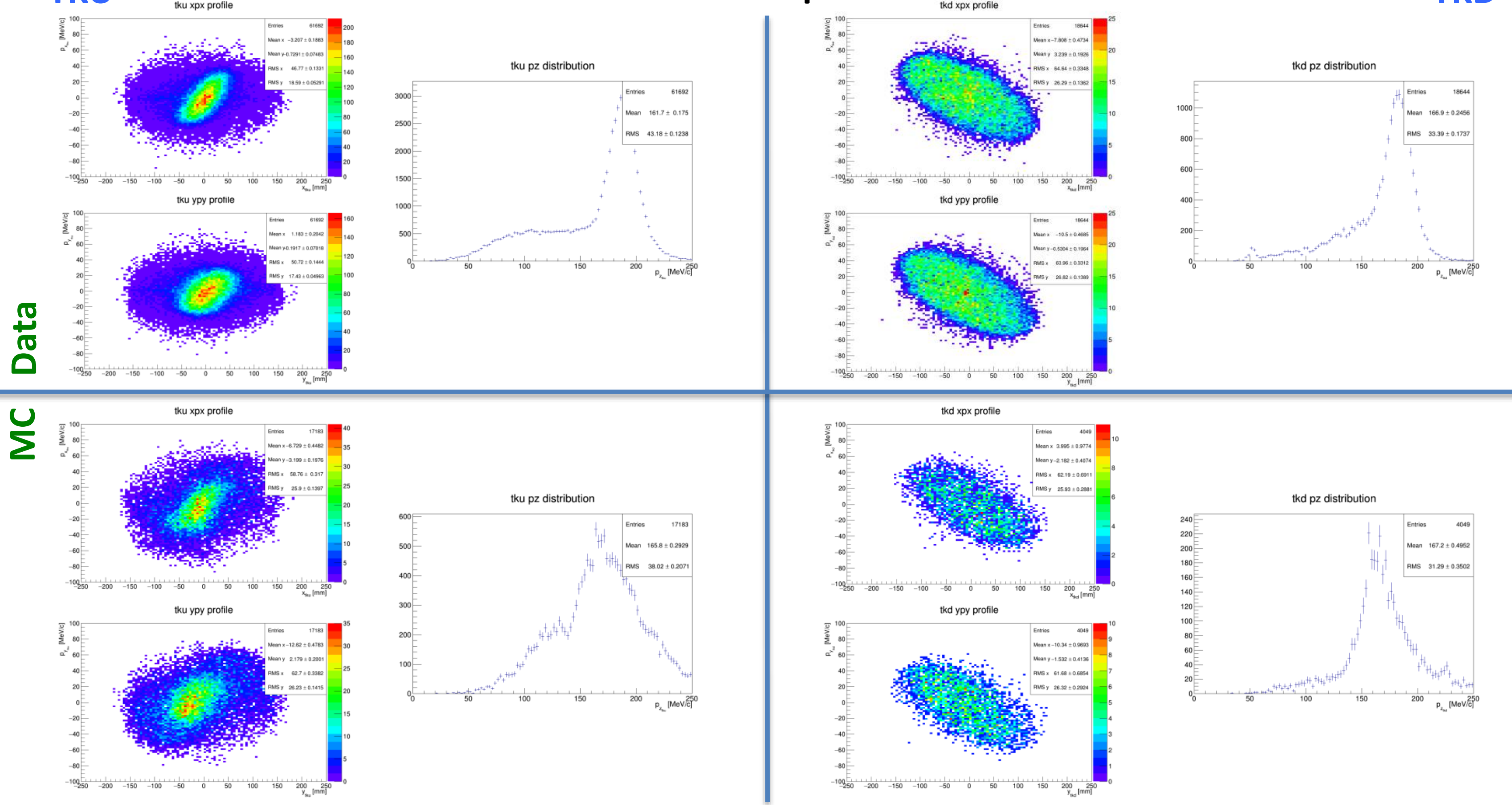




**MC**



# Phase space



TKU
TKD
Data
MC
tku xpx profile
Entries 61692
Mean x −3.207 ± 0.1883
Mean y −0.7291 ± 0.07483
RMS x 46.77 ± 0.1331
RMS y 18.59 ± 0.05291
tku ypy profile
Entries 61692
Mean x 1.183 ± 0.2042
Mean y 0.1917 ± 0.07018
RMS x 50.72 ± 0.1444
RMS y 17.43 ± 0.04963
tku pz distribution
Entries 61692
Mean 161.7 ± 0.175
RMS 43.18 ± 0.1238
tkd xpx profile
Entries 18644
Mean x −7.808 ± 0.4734
Mean y 3.239 ± 0.1926
RMS x 64.64 ± 0.3348
RMS y 26.29 ± 0.1362
tkd ypy profile
Entries 18644
Mean x −10.5 ± 0.4685
Mean y −0.5304 ± 0.1964
RMS x 63.96 ± 0.3312
RMS y 26.82 ± 0.1389
tkd pz distribution
Entries 18644
Mean 166.9 ± 0.2456
RMS 33.39 ± 0.1737
tku xpx profile
Entries 17183
Mean x −6.729 ± 0.4482
Mean y −3.199 ± 0.1976
RMS x 58.76 ± 0.317
RMS y 25.9 ± 0.1397
tku ypy profile
Entries 17183
Mean x −12.62 ± 0.4783
Mean y 2.179 ± 0.2001
RMS x 62.7 ± 0.3382
RMS y 26.23 ± 0.1415
tku pz distribution
Entries 17183
Mean 165.8 ± 0.2929
RMS 38.02 ± 0.2071
tkd xpx profile
Entries 4049
Mean x 3.995 ± 0.9774
Mean y −2.182 ± 0.4074
RMS x 62.19 ± 0.6911
RMS y 25.93 ± 0.2881
tkd ypy profile
Entries 4049
Mean x −10.34 ± 0.9693
Mean y −1.532 ± 0.4136
RMS x 61.68 ± 0.6854
RMS y 26.32 ± 0.2924
tkd pz distribution
Entries 4049
Mean 167.2 ± 0.4952
RMS 31.29 ± 0.3502

# Set-up and optics

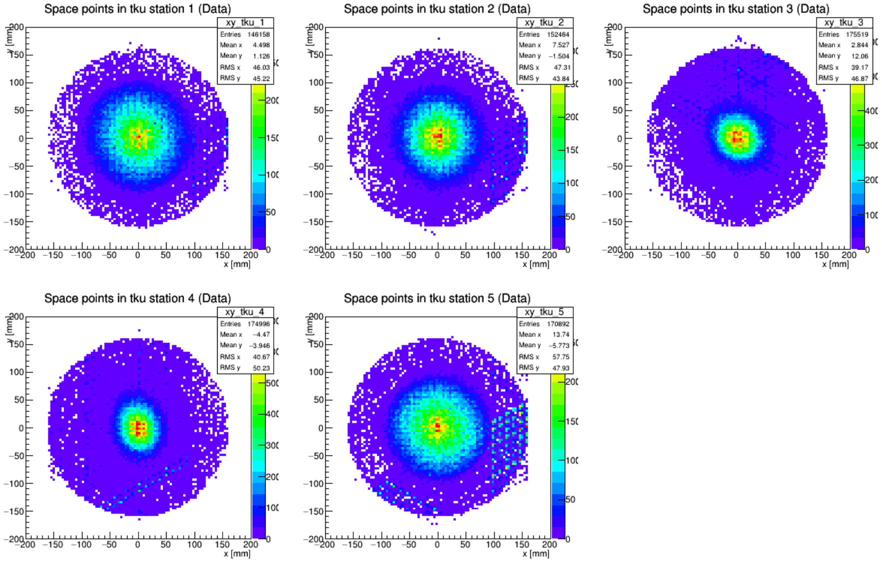
- Tuesday, 26Jul16
  - Data taking with:
    - SSU and SSD:
      - ECE coils in SSU and SSD only
      - Current of 140A through ECE
        - » Roughly corresponds to 2T in the tracking volume
    - FC:
      - Solenoid mode; 44.7A
  - Empty channel

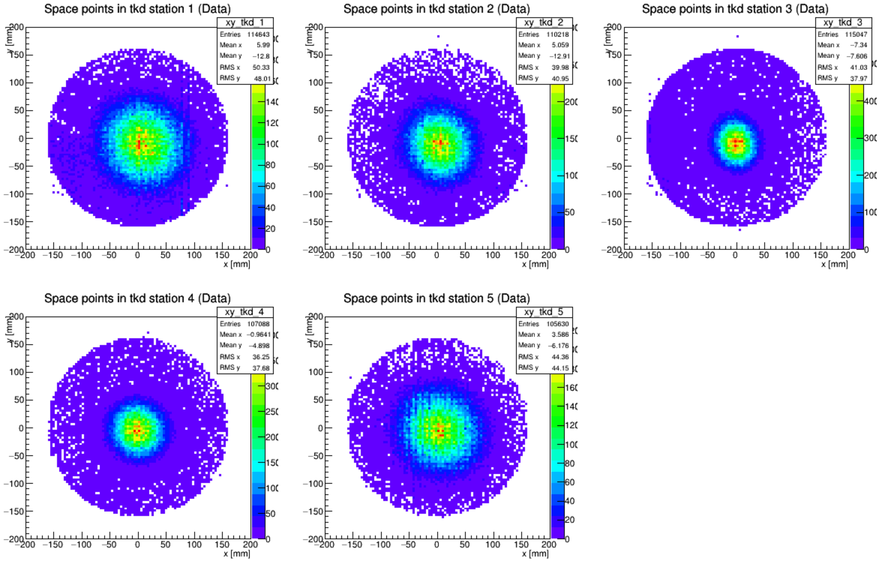
# Tracker space-points

**TKU**

**TKD**

**Data**



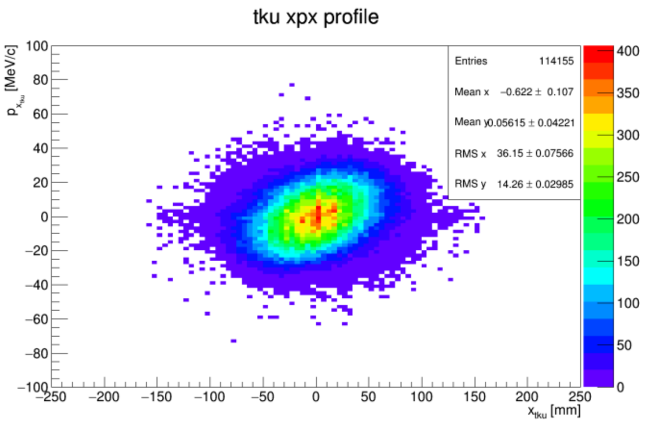



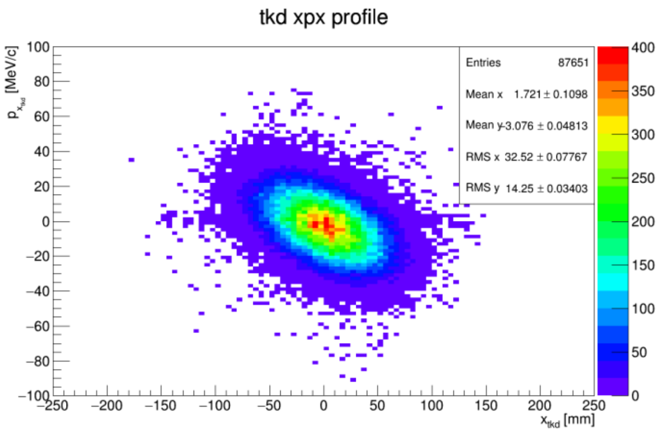
# Phase space

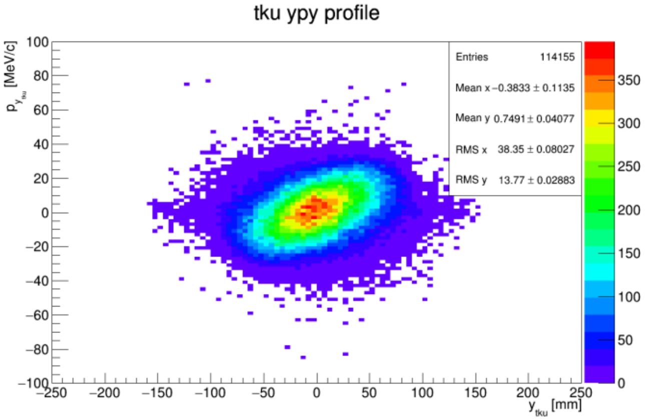
**TKU**

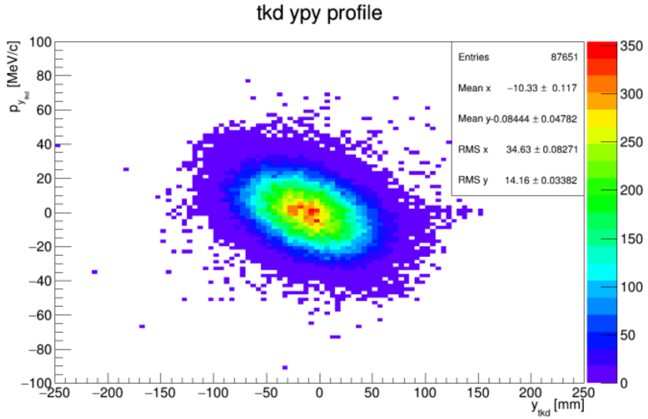
**TKD**

**Data**



# Status @ end ISIS 2016/02

- MICE magnetic channel commissioned
  - SSU(ECE,140A) + FC + SSD(ECE,140A); solenoid mode
- Data taken for:
  - Mechanical alignment and calibration
  - Magnetic alignment of each magnet
  - FC current scan:
    - Will allow validation of optics
- Excellent!
  - We can now make it even better

# Known issues

- Reconstruction:
  - U/s tracker reports muon charge as “-ve”
- Operations:
  - List of issues maintained by Operations Group
- SS control:
  - Feature, manual over-ride of offsets, to be addressed
- Trigger:
  - Prescale
- Overall:
  - Work needed to optimise efficiency

- Must start now!

Introduction

# PAPERS

Published by IOP Publishing for Sissa Medialab

Received: *March 24, 2016*
Accepted: *April 12, 2016*
Published: *May 5, 2016*

# The design and performance of an improved target for MICE

**C.N. Booth,[a,1] P. Hodgson,[a] J. Langlands,[a] E. Overton,[a] M. Robinson,[a] P.J. Smith,[a] G. Barber,[b] K.R. Long,[b] B. Shepherd,[c] E. Capocci,[d] C. MacWaters[d] and J. Tarrant[d]**

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[b] *Department of Physics, Blackett Laboratory, Imperial College London, Exhibition Road, London SW7 2AZ, U.K.*

[c] *STFC Daresbury Laboratory, Keckwick Lane, Daresbury, Cheshire WA4 4AD, U.K.*

[d] *STFC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, U.K.*

*E-mail:* C.Booth@sheffield.ac.uk

Abstract: The linear motor driving the target for the Muon Ionisation Cooling Experiment has been redesigned to improve its reliability and performance. A new coil-winding technique is described which produces better magnetic alignment and improves heat transport out of the windings. Improved field-mapping has allowed the more precise construction to be demonstrated, and an enhanced controller exploits the full features of the hardware, enabling increased acceleration and precision. The new user interface is described and analysis of performance data to monitor friction is shown to allow quality control of bearings and a measure of the ageing of targets during use.

Keywords: Control and monitor systems online; Instrumentation for particle accelerators and storage rings - high energy (linear accelerators, synchrotrons); Overall mechanics design (support structures and materials, vibration analysis etc); Targets (spallation source targets, radioisotope production, neutrino and muon sources)

ArXiv ePrint: 1603.07143

[1]Corresponding author.



doi:10.1088/1748-0221/11/05/P05006

2016 JINST 11 P05006

# Papers in progress

| Title | Contact | Comment |
|---|---|---|
| **Step IV physics** | | |
| First measurement of emittance in Step IV | V. Blackmore | **Analysis being finalised.** Preliminary results to go to ICHEP'16. |
| Measurement of scattering distributions in MICE | J. Nugent | **Analysis underway.** Preliminary results to go to ICHEP'16. |
| **Ionization cooling demonstration** | | |
| Design and expected performance of the MICE demonstration of ionization cooling | J.B. Lagrange | **Draft with collaboration** Paper being prepared for arXiv/journal |

| Title | Contact | Comment |
|---|---|---|
| **Technical** | | |
| The design construction of the MICE Electron Muon Ranger | F. Drielsma | **Paper being prepared for arXiv/journal** |
| The Reconstruction Software for the MICE Scintillating Fibre Trackers | A. Dobbs | **Being prepared for arXiv/journal submission** Final details in efficiency plots being resolved. |
| The MICE Analysis and User Software framework | D. Rajaram | **In preparation** |

# The Reconstruction Software for the MICE Scintillating Fibre Trackers

A. Dobbs, C. Hunt, K. Long, E. Santos, M. A. Uchida
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C. Heidt
*University of California Riverside, 900 University Ave, Riverside, CA 92521, U.S.A.*
E. Overton
*University of Sheffield, Western Bank, Sheffield, S10 2TN, U.K.*

The Muon Ionization Cooling Experiment (MICE) will demonstrate the principle of muon beam phase-space reduction via ionization cooling. Muon beam cooling will be required for the proposed Neutrino Factory or Muon Collider. The phase-space before and after the cooling cell must be measured precisely. This is achieved using two scintillating-fibre trackers, each placed in a solenoidal magnetic field. This paper describes the software reconstruction for the fibre trackers: the GEANT4 based simulation; the implementation of the geometry and configuration data; digitisation; space-point reconstruction; pattern recognition; and the final track fit based on a Kalman filter. The performance of the software is evaluated by means of Monte Carlo studies and the precision of the final track reconstruction is evaluated.

## 1 The MICE Experiment

### 1.1 Overview

The Muon Ionization Cooling Experiment (MICE) will perform a practical demonstration of muon ionization cooling. Cooling refers to a reduction in the emittance of a beam, that is, the reduction of the phase-space volume occupied by the beam. Beam cooling is required for any future facility based on high intensity muon beams, such as a Neutrino Factory [1], the ultimate tool to study leptonic CP-invariance violation, or a Muon Collider [2], a potential route to multi-TeV lepton – anti-lepton collisions. Muon beams are generated via pion decay, and therefore have a large emittance, which must be reduced so that a reasonable fraction of the beam will fall within the acceptance of the downstream acceleration system.

The short muon lifetime requires fast beam cooling which traditional techniques are unable to provide. Ionization cooling was proposed in the early 1970s [3, 4], but has not yet been demonstrated at the energies of interest for the Neutrino Factory or Muon Collider. Ionization cooling reduces emittance by passing a beam through some suitable material of low atomic-number such a hydrogen. This leads to the reduction of all components of momentum due to ionization energy loss. Low atomic number absorbers are preferred because they minimise multiple scattering which "heats" the beam.

MICE is based at the Science and Technology Facilities Council Rutherford Appleton Laboratory in the U.K., using the ISIS proton synchrotron to generate the muon beam [5]. The MICE beamline is described in detail in [6]. A schematic of the full MICE experiment is shown in figure 1. MICE has completed the first step of its programme, consisting of the muon beamline with particle identification in which the MICE muon beam was

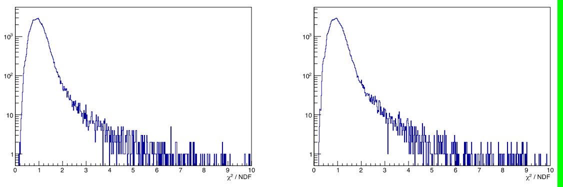



Figure 11: The $\chi^2$ per degree of freedom in the upstream (left) and downstream (right) trackers.

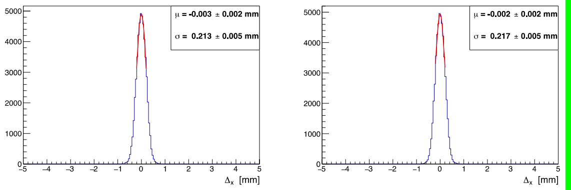



Figure 12: The $x$ residuals of the upstream (left) and downstream (right) trackers.

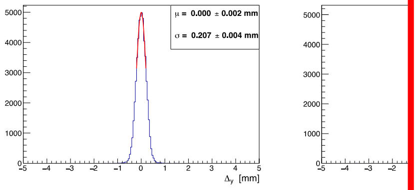



Figure 13: The $y$ residuals of the upstream (left) and downstrea

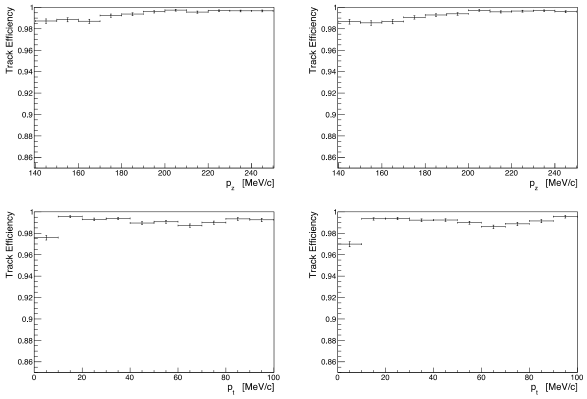



Figure 9: The efficiency of reconstructing tracks in the upstream (left) and downstream (right) trackers as a function of the simulated longitudinal (top) and transverse (bottom) momentum.

# The next wave

- From data taking in 2016/02:
  - Magnetic alignment with tracks:
    - Spectrometers; at the “end” of the lattice;
    - Focus coil; in the “middle”:
      - Transfer matrix approach
  - Optics of Step IV, reconstruction of emittance change:
    - Exploit FC scan in SSU(ECE,140A) + FC + SSD(ECE,140A)
  - Other ideas …

Introduction

# GOING FORWARD

# Routine operation

- Established operation of Step IV:
  - SSU(ECE,140A) + FC + SSD(ECE,140A)
- Build on this!

- Building blocks:
  - Solenoid mode:
    - 3T (ECE,210A) operation;
    - Trim end coils;
    - SSU(M1,M2)
    - LiH … and … LH2
  - Flip mode
    - LiH … and … LH2
  - SSD(M2)

**Magnet operation must be as robust as detectors**

Introduction

# COOLING DEMONSTRATION

# STFC MICE-UK cost-to-completion

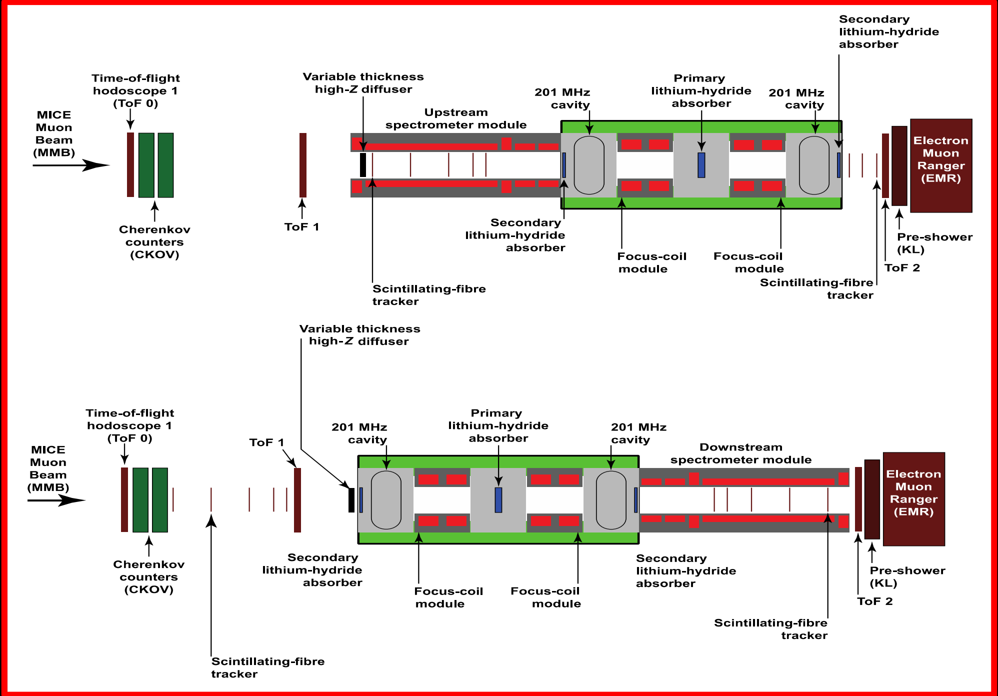
- Risks (financial, reputational, schedule) associated with recovery of SSD too large;
  - Also; timing of the long ISIS shutdown may start just as the recovered solenoid is delivered;

- Recommended that MICE-UK be invited to submit a proposal for the execution of the cooling demonstration that:
  - Exploits those components that are already in hand or are being manufactured;
  - Reduces cost and risk to STFC

http://micewww.pp.rl.ac.uk/attachments/6188/2016-05-04-Descope.pdf

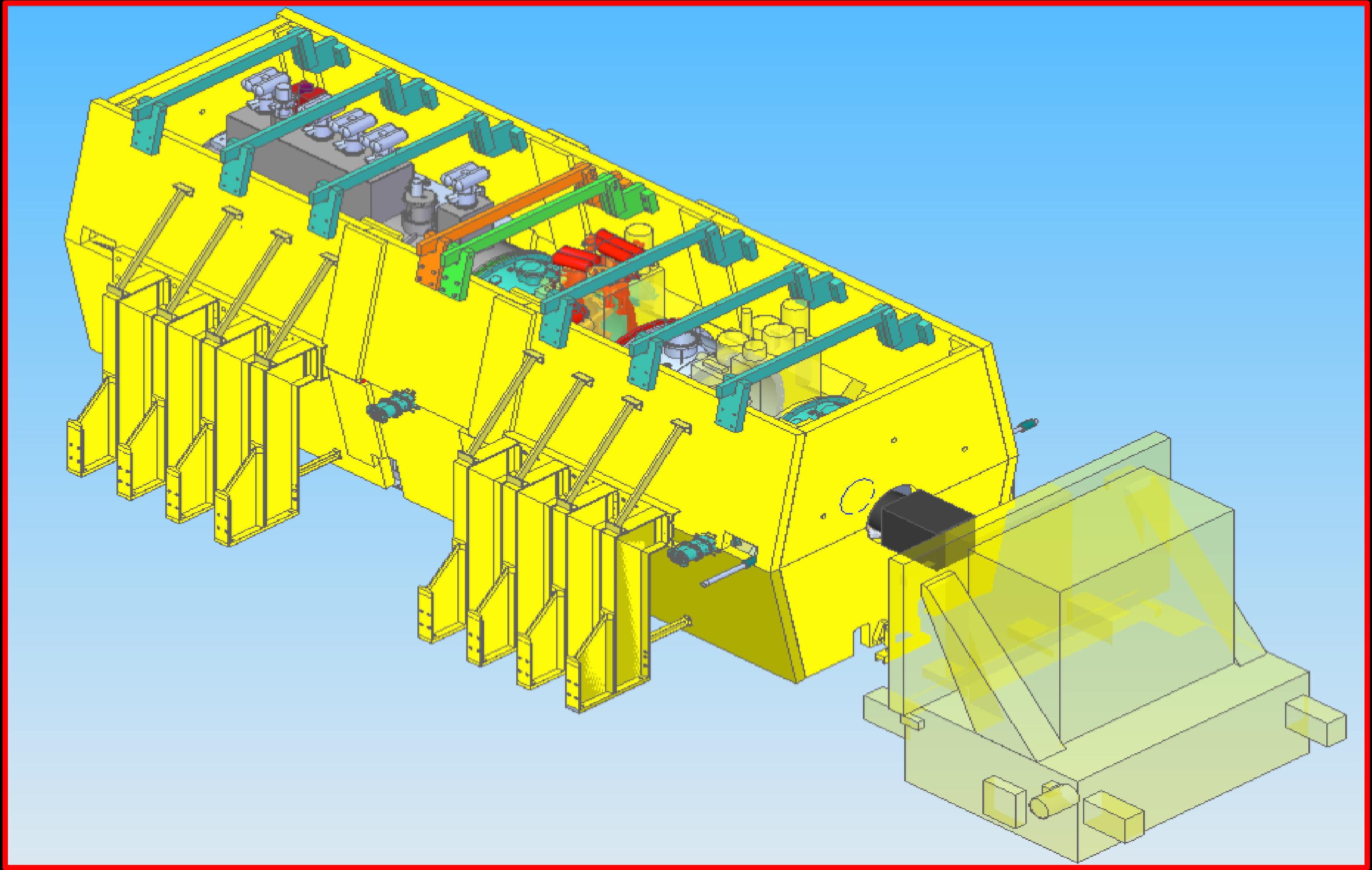
# Options presented in outline to STFC

- Use only one spectrometer solenoid:
  - Two "generic" possibilities



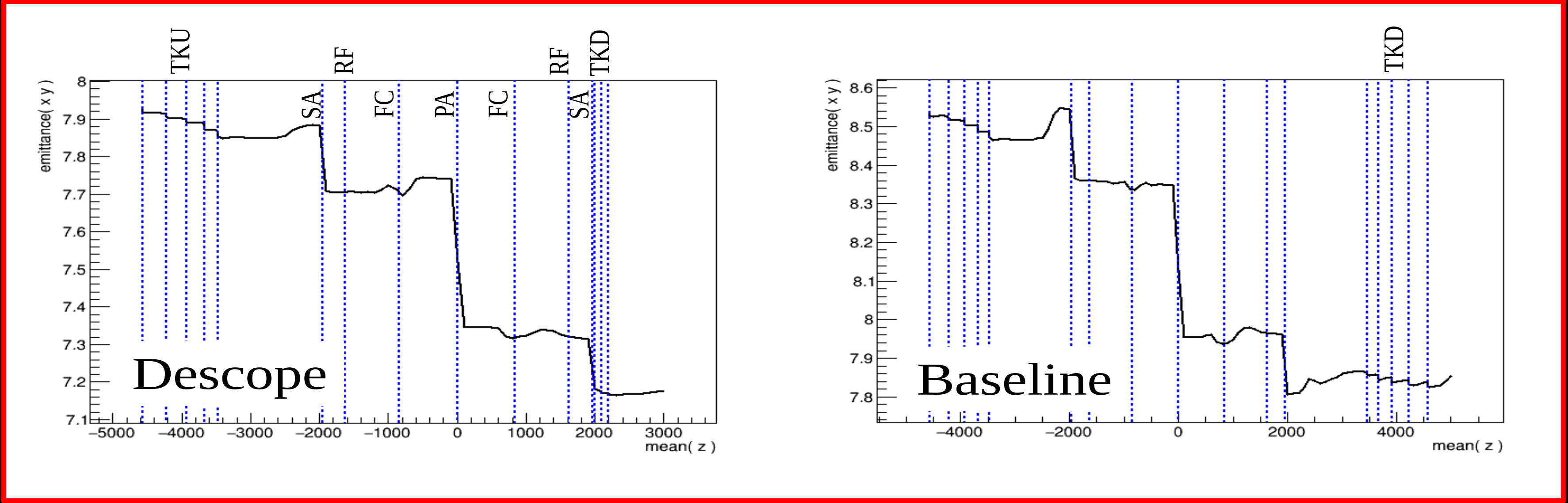

http://micewww.pp.rl.ac.uk/documents/177

J. Tarrant



http://micewww.pp.rl.ac.uk/documents/177

# "Option A": solenoid upstream




- **Initial estimate of performance:**
  - **Cooling effect: 8% at emittance of 7.9 mm;**
    - **Comparable to baseline**
  - **Transmission 85% vs 91% of baseline:**
    - **Issue is systematic error:**
      - **Modest decrease in transmission can be understood to keep and systematic error under control**

http://micewww.pp.rl.ac.uk/documents/177

# STFC EB decision; formal notification

S. Garlick; 21Jun16

Further to the Review, STFC Executive Board met on 26th May and the EB members had received the report from the Cost to Completion Review Panel and the MICE Collaboration's document titled "Progress in redefining the scope of the MICE cooling demonstration". After having given this consideration, Executive Board concluded that the MICE project should only be funded for extended Step IV operations which allows a full set of measurements of the phase space which should be completed by mid-2017. This decision was made because of the current financial situation and the financial pressures. Whilst we appreciate that this may be a disappointment it is hoped that it provides a level of certainty to the future of the MICE project.

# Interim response

KL, PS

- Welcomes the extended Step IV run:
  - It allows full characterisation of the cooling equation fully;
- Notes that a cooling demo was not approved on grounds of cost;
- Points out that:
  - Collaboration remains committed to the cooling demo and that commitments in principle to raise additional resource from outside the UK have been made;
  - Two new groups (UNIST, Korea; Novi Sad, Serbia) still seek to join the experiment to exploit Step IV and to carry out a cooling demo;
- Promises to bring forward a revised proposal for a cooling demo when:
  - Operation ***for physics*** of the Step IV magnetic channel has been established.

- So, it is as critical as ever that we deliver on our commitment to bring Step IV online and to expedite the publication of our results

Introduction

# INTERNATIONAL PERSPECTIVE

http://icfa.fnal.gov/wp-content/uploads/2016-05-07-nuPanel-roadmap-Final.pdf



# Roadmap for the international, accelerator-based neutrino programme

*Discussion document*

The ICFA Neutrino Panel

## Overview

The neutrino, with its tiny mass and large mixings, offers a window on physics beyond the Standard Model. Precise measurements are required to understand the nature of the neutrino and to elucidate the phenomena that give rise to its unique properties. Accelerator-driven sources of neutrinos will play a critical role in determining these properties since such sources provide the only means by which neutrino and anti-neutrino transitions between all three neutrino flavours can be studied precisely.

The ICFA Neutrino Panel [1] is developing a roadmap for the international, accelerator-based neutrino programme. The roadmap presented in this discussion document was drawn up after the peer-group-consultation process presented in the Panel's initial report [2]. The roadmap is consistent with the conclusions drawn in [2].

With its roadmap the Panel will document the approved objectives and milestones of the experiments that are presently in operation or under construction. Approval, construction and exploitation milestones are presented for experiments that are being considered for approval. The timetable proposed by the proponents is presented for experiments that are not yet being considered formally for approval. Based on this information, the evolution of the precision with which the critical parameters governing the neutrino are known has been evaluated. Branch or decision points have been identified based on the anticipated evolution in precision. The branch or decision points have in turn been used to identify desirable timelines for the neutrino-nucleus cross section and hadro-production measurements that are required to maximise the integrated scientific output of the programme. The branch points have also been used to identify the timeline for the R&D required to take the programme beyond the horizon of the next generation of experiments. The theory and phenomenology programme, including nuclear theory, required to ensure that maximum benefit is derived from the experimental programme is also discussed.

The roadmap, interim conclusions and draft recommendations presented in this document will be used as the basis for discussion amongst the neutrino community—and more broadly, the particle- and astroparticle-physics communities—and with the various stakeholders in the programme. These discussions will take place over the summer and autumn of 2016. An important element of these discussions will be those following the presentation of the roadmap at Neutrino 2016 [3]. After a period of revision and further consultation the document will be revised in time for it to be presented to ICFA at its meeting in February 2017.

4.9: The development of MW-class sources at FNAL and J-PARC are critical to the delivery of the experimental programme. To go beyond the sensitivity and precision of the next generation of accelerator-based experiments is likely to require the development of novel accelerator capabilities. It is likely that increased international cooperation and collaboration will be required to deliver these programmes. The MICE experiment and the RaDIATE programme are recognised as important contributions to the field, each offering the possibility of generating a legacy of enhanced capability.

Recommendation 4.6: Opportunities for international cooperation and/or collaboration in the development of MW-class neutrino sources should be actively pursued.

Recommendation 4.7: The MICE experiment should be completed to deliver the critical demonstration of ionization cooling. ICFA should encourage the timely consideration of the accelerator R&D programme that is required beyond MICE to develop the capability to deliver high-brightness muon beams.

https://kds.kek.jp/indico/event/20176/material/0/

Introduction

# CM45

# CM45

- **Collaboration photo lunchtime today!**
- **Very much looking forward to our meeting …**