Imperial College London

Science & Technology Facilities Council

Spokesman’s update

K. Long, 10 December, 2015

Plan

- Update
- Step IV
- Cooling demonstration
- Papers
- CM44

Spokesman’s update

UPDATE

Step IV: magnets

- Focus coil:
  - Solenoid mode:
    - Run to 114A and soak tested
  - Flip mode:
    - Trained to 225A and soak tested
  - Module has been validated on its own for Step IV

- Spectrometer solenoid (see ABr/MP this VC):
  - Understand how M1 was rendered inoperable
    - Power and QP-system refit required for Step IV
    - Magnet re-build required for cooling demonstration
  - MAP Director’s Review of recovery plans 03/04Dec15:
    - Must re-fit QP system before operating at Step IV
    - Step IV science crucial; so execute the programme properly
      - Build of new cold-mass allows Step IV operations to Dec16
    - Build new cold-mass in parallel to Step IV operation:
      - Fit new cold mass into cryostat in parallel to cooling demo build

- Decay solenoid (power supply):
  - Repair under warranty agreed with FUG
  - Schedule:
    - Present plan is that refurbished power supply returns to RAL Feb16

Liquid-hydrogen system

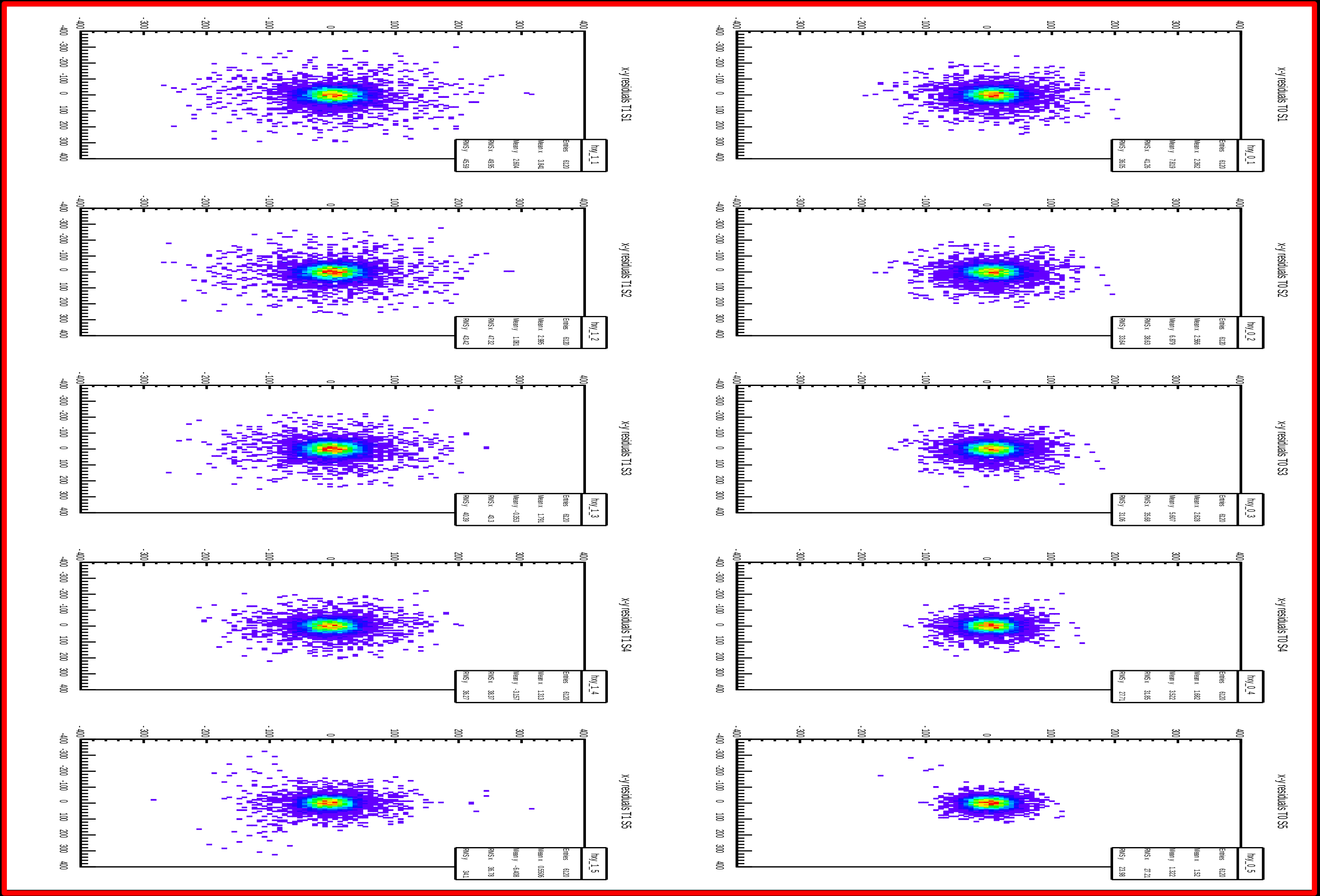
- Two attempts to cool absorber to operating temp:
  - Neither was successful:
    - Two leaks identified:
      - Air to insulating/safety vacuum at Fisher connector
      - LH2 volume to safety vacuum space:
        - Likely to be due to a failed indium seal
        - Requires module to be extracted for repair
  - Schedule:
    - Plans being laid;
      - Hope to complete to allow next cool down Feb16

Operations

- Routine operations (see SB, this VC)!
  - Recently data taking with FC in solenoid and flip mode
    - Determination of magnetic axis of FC module

Track reconstruction

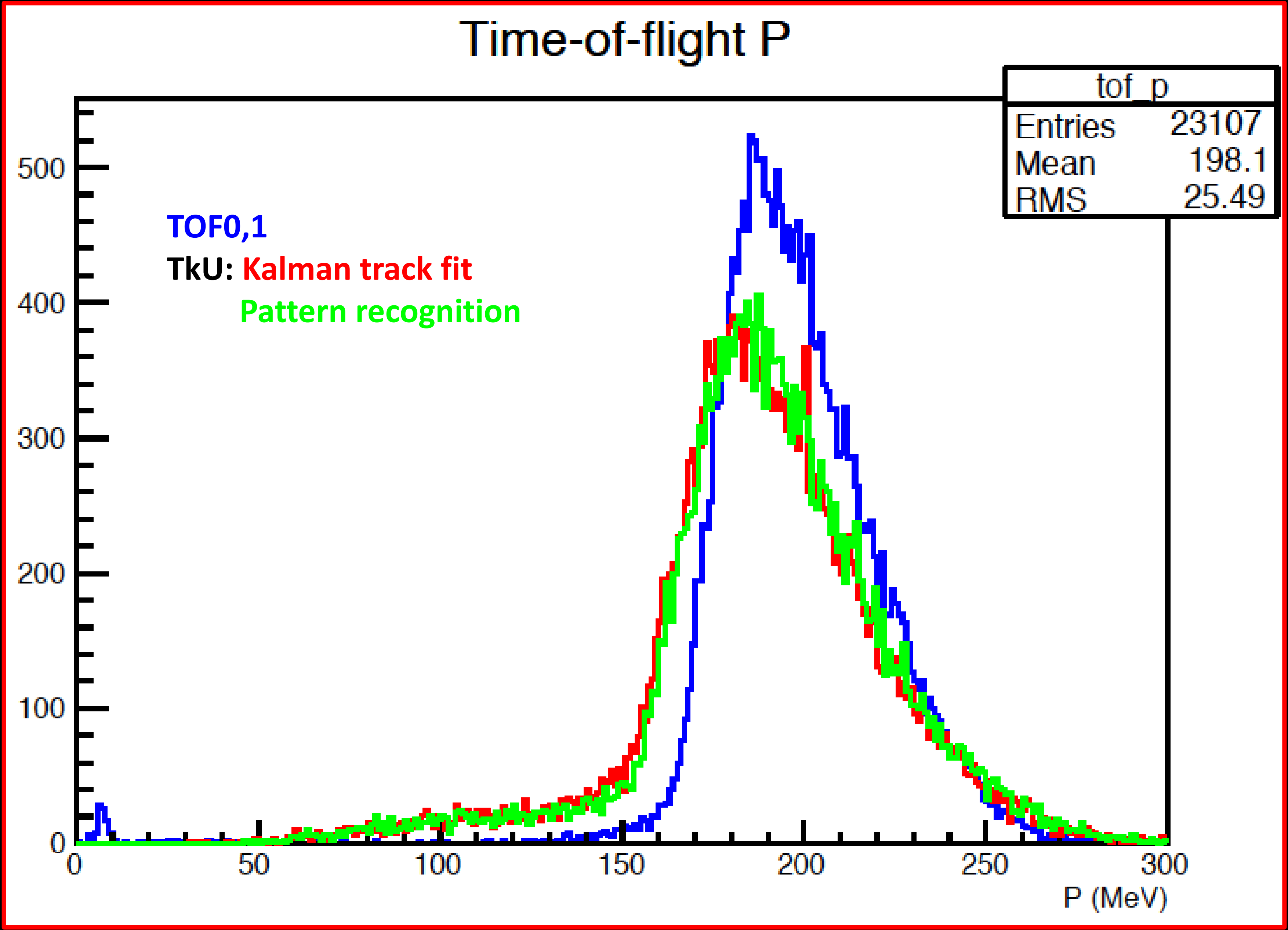
- !@£$%^& sign flips …
- Dobbs et al taking systematic approach:



- MAUS validated to space-points/pattern recognition

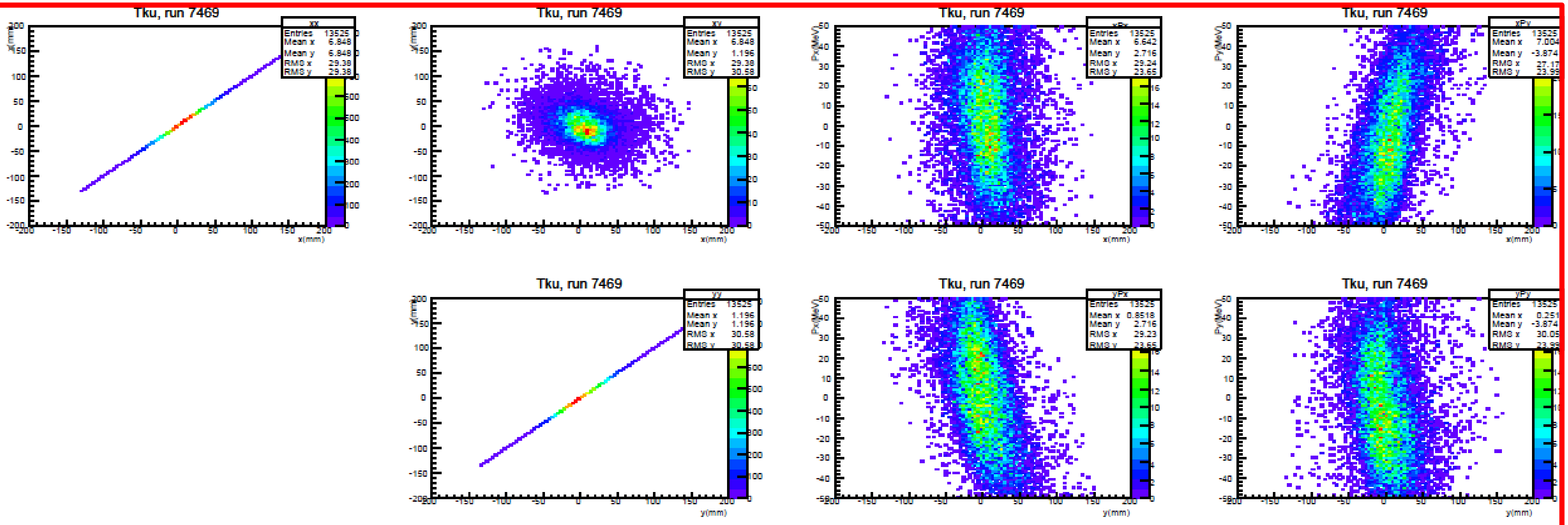
V. Blackmore

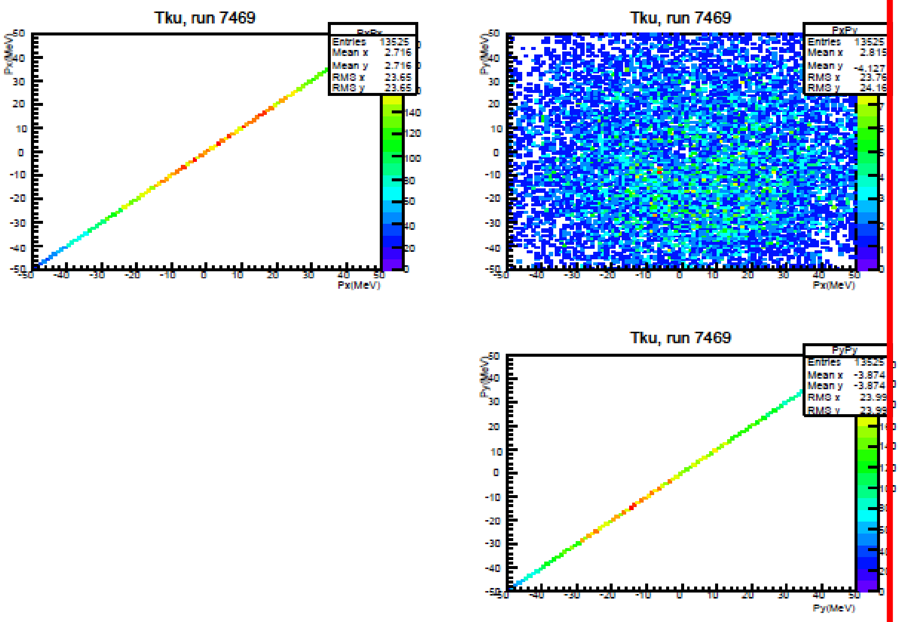
Momentum scale (07Oct15 data)



V. Blackmore

Emittance analysis (07Oct15 data)





$$\begin{pmatrix} \langle x\,x\rangle & \langle x\,y\rangle & \langle x\,p_x\rangle & \langle x\,p_y\rangle \\ \langle y\,x\rangle & \langle y\,y\rangle & \langle y\,p_x\rangle & \langle y\,p_y\rangle \\ \langle p_x\,x\rangle & \langle p_x\,y\rangle & \langle p_x\,p_x\rangle & \langle p_x\,p_y\rangle \\ \langle p_y\,x\rangle & \langle p_y\,y\rangle & \langle p_y\,p_x\rangle & \langle p_y\,p_y\rangle \end{pmatrix}$$

Spokesman’s update

STEP IV

Operations

- SS recovery;
  headline milestones from 03/04Dec15 review:
  - QP system mods complete: 15Apr16
    - Goal: implement in stages so that u/s available sooner
  - Cold mass 1 complete: 14Apr17
  - Magnet disassembly complete: 29Apr17
  - Magnet reassembly complete: 30Aug17
  - Complete on beamline: 08Nov17
  - Commissioning complete: 15Feb18
- Detailed planning work already underway:
  - These dates will change

- Consequence:
  - Step IV operations through calendar year 2016
    - C. Rogers, S. Boyd have begun re-evaluation of Step IV run plan

Spokesman’s update

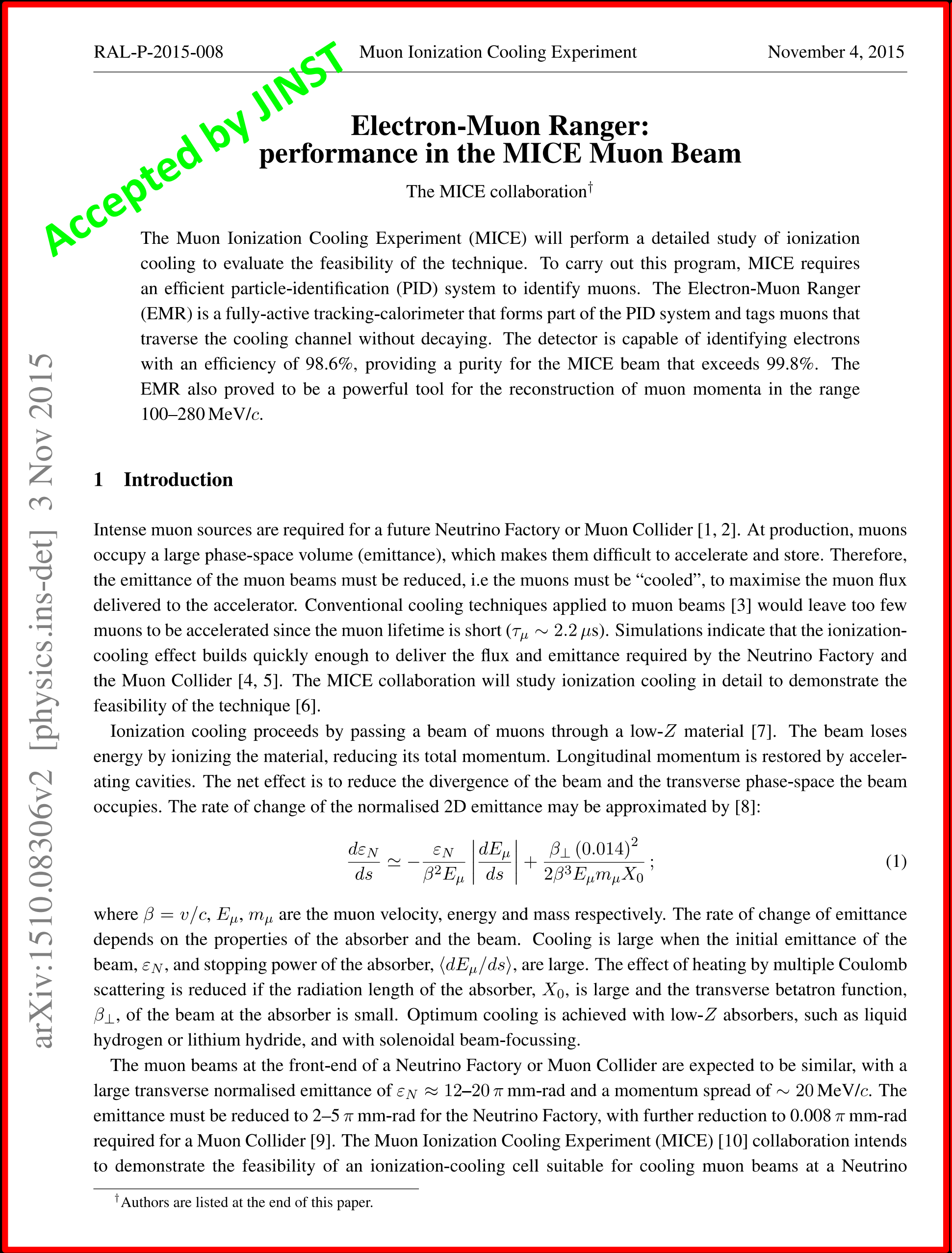
COOLING DEMONSTRATION

RF and project plan

- Single-cavity modules remain on track;
  - First module to arrive RAL May16
- RF power project:
  - Additional resources being brought to bear:
    - UK lab and university
      - Some already delivered
    - CERN
      - Discussions started; meeting at CERN 06Jan16
    - IHEP
      - Expert identified; details of travel etc. being discussed
- Cooling demo construction:
  - Replanning of project in light of recent events initiated

Spokesman’s update

PAPERS



Accepted by JINST

RAL-P-2015-008 Muon Ionization Cooling Experiment November 4, 2015

Electron-Muon Ranger: performance in the MICE Muon Beam

The MICE collaboration†

The Muon Ionization Cooling Experiment (MICE) will perform a detailed study of ionization cooling to evaluate the feasibility of the technique. To carry out this program, MICE requires an efficient particle-identification (PID) system to identify muons. The Electron-Muon Ranger (EMR) is a fully-active tracking-calorimeter that forms part of the PID system and tags muons that traverse the cooling channel without decaying. The detector is capable of identifying electrons with an efficiency of 98.6%, providing a purity for the MICE beam that exceeds 99.8%. The EMR also proved to be a powerful tool for the reconstruction of muon momenta in the range 100–280 MeV/c.

1 Introduction

Intense muon sources are required for a future Neutrino Factory or Muon Collider [1, 2]. At production, muons occupy a large phase-space volume (emittance), which makes them difficult to accelerate and store. Therefore, the emittance of the muon beams must be reduced, i.e the muons must be “cooled”, to maximise the muon flux delivered to the accelerator. Conventional cooling techniques applied to muon beams [3] would leave too few muons to be accelerated since the muon lifetime is short ($\tau_\mu \sim 2.2\,\mu$s). Simulations indicate that the ionization-cooling effect builds quickly enough to deliver the flux and emittance required by the Neutrino Factory and the Muon Collider [4, 5]. The MICE collaboration will study ionization cooling in detail to demonstrate the feasibility of the technique [6].

Ionization cooling proceeds by passing a beam of muons through a low-Z material [7]. The beam loses energy by ionizing the material, reducing its total momentum. Longitudinal momentum is restored by accelerating cavities. The net effect is to reduce the divergence of the beam and the transverse phase-space the beam occupies. The rate of change of the normalised 2D emittance may be approximated by [8]:

$$\frac{d\varepsilon_N}{ds} \simeq -\frac{\varepsilon_N}{\beta^2 E_\mu}\left|\frac{dE_\mu}{ds}\right| + \frac{\beta_\perp (0.014)^2}{2\beta^3 E_\mu m_\mu X_0}\,; \qquad (1)$$

where $\beta = v/c$, E_μ, m_μ are the muon velocity, energy and mass respectively. The rate of change of emittance depends on the properties of the absorber and the beam. Cooling is large when the initial emittance of the beam, ε_N, and stopping power of the absorber, $\langle dE_\mu/ds\rangle$, are large. The effect of heating by multiple Coulomb scattering is reduced if the radiation length of the absorber, X_0, is large and the transverse betatron function, $\beta_\perp$, of the beam at the absorber is small. Optimum cooling is achieved with low-Z absorbers, such as liquid hydrogen or lithium hydride, and with solenoidal beam-focussing.

The muon beams at the front-end of a Neutrino Factory or Muon Collider are expected to be similar, with a large transverse normalised emittance of $\varepsilon_N \approx$ 12–20 π mm-rad and a momentum spread of $\sim$ 20 MeV/c. The emittance must be reduced to 2–5 π mm-rad for the Neutrino Factory, with further reduction to 0.008 π mm-rad required for a Muon Collider [9]. The Muon Ionization Cooling Experiment (MICE) [10] collaboration intends to demonstrate the feasibility of an ionization-cooling cell suitable for cooling muon beams at a Neutrino

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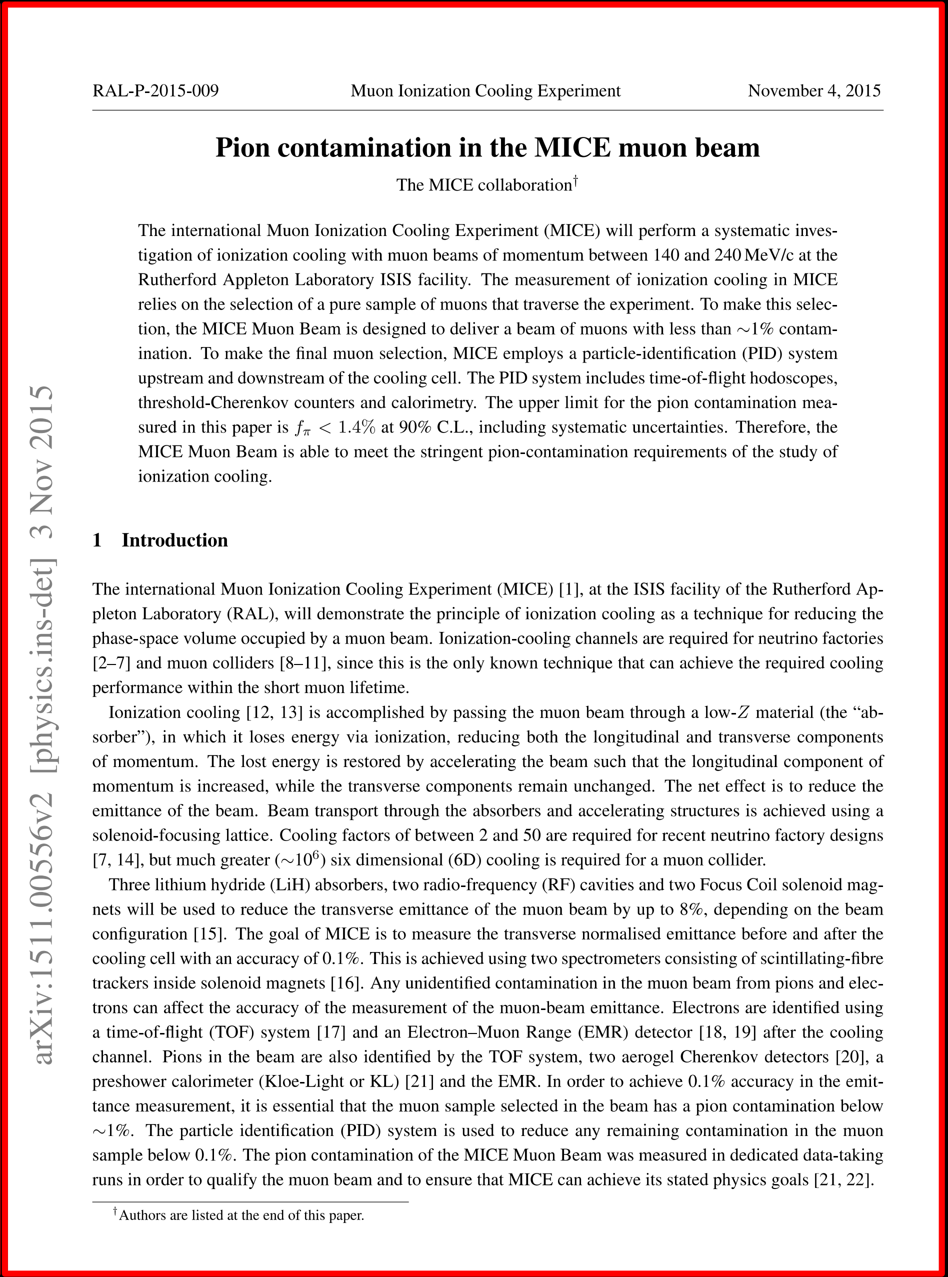
† Authors are listed at the end of this paper.



RAL-P-2015-009 Muon Ionization Cooling Experiment November 4, 2015

Pion contamination in the MICE muon beam

The MICE collaboration†

The international Muon Ionization Cooling Experiment (MICE) will perform a systematic investigation of ionization cooling with muon beams of momentum between 140 and 240 MeV/c at the Rutherford Appleton Laboratory ISIS facility. The measurement of ionization cooling in MICE relies on the selection of a pure sample of muons that traverse the experiment. To make this selection, the MICE Muon Beam is designed to deliver a beam of muons with less than ~1% contamination. To make the final muon selection, MICE employs a particle-identification (PID) system upstream and downstream of the cooling cell. The PID system includes time-of-flight hodoscopes, threshold-Cherenkov counters and calorimetry. The upper limit for the pion contamination measured in this paper is $f_\pi < 1.4\%$ at 90% C.L., including systematic uncertainties. Therefore, the MICE Muon Beam is able to meet the stringent pion-contamination requirements of the study of ionization cooling.

1 Introduction

The international Muon Ionization Cooling Experiment (MICE) [1], at the ISIS facility of the Rutherford Appleton Laboratory (RAL), will demonstrate the principle of ionization cooling as a technique for reducing the phase-space volume occupied by a muon beam. Ionization-cooling channels are required for neutrino factories [2–7] and muon colliders [8–11], since this is the only known technique that can achieve the required cooling performance within the short muon lifetime.

Ionization cooling [12, 13] is accomplished by passing the muon beam through a low-Z material (the “absorber”), in which it loses energy via ionization, reducing both the longitudinal and transverse components of momentum. The lost energy is restored by accelerating the beam such that the longitudinal component of momentum is increased, while the transverse components remain unchanged. The net effect is to reduce the emittance of the beam. Beam transport through the absorbers and accelerating structures is achieved using a solenoid-focusing lattice. Cooling factors of between 2 and 50 are required for recent neutrino factory designs [7, 14], but much greater ($\sim 10^6$) six dimensional (6D) cooling is required for a muon collider.

Three lithium hydride (LiH) absorbers, two radio-frequency (RF) cavities and two Focus Coil solenoid magnets will be used to reduce the transverse emittance of the muon beam by up to 8%, depending on the beam configuration [15]. The goal of MICE is to measure the transverse normalised emittance before and after the cooling cell with an accuracy of 0.1%. This is achieved using two spectrometers consisting of scintillating-fibre trackers inside solenoid magnets [16]. Any unidentified contamination in the muon beam from pions and electrons can affect the accuracy of the measurement of the muon-beam emittance. Electrons are identified using a time-of-flight (TOF) system [17] and an Electron–Muon Range (EMR) detector [18, 19] after the cooling channel. Pions in the beam are also identified by the TOF system, two aerogel Cherenkov detectors [20], a preshower calorimeter (Kloe-Light or KL) [21] and the EMR. In order to achieve 0.1% accuracy in the emittance measurement, it is essential that the muon sample selected in the beam has a pion contamination below ~1%. The particle identification (PID) system is used to reduce any remaining contamination in the muon sample below 0.1%. The pion contamination of the MICE Muon Beam was measured in dedicated data-taking runs in order to qualify the muon beam and to ensure that MICE can achieve its stated physics goals [21, 22].

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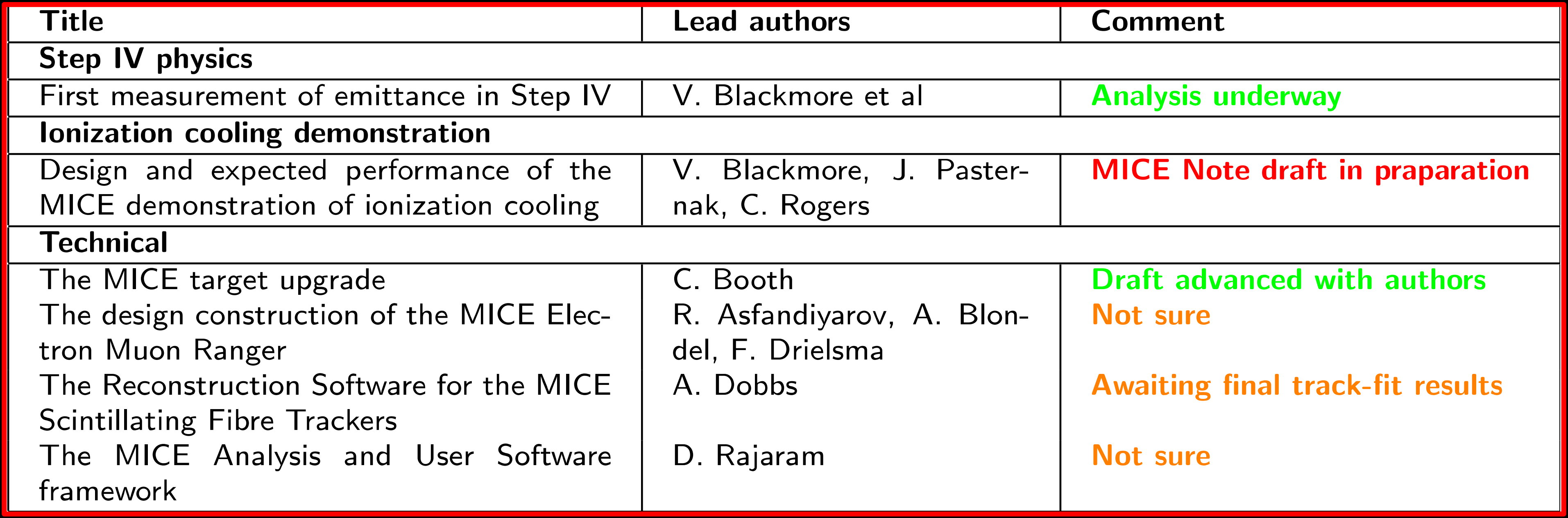
† Authors are listed at the end of this paper.

Papers in progress



Title	Lead authors	Comment
Step IV physics		
First measurement of emittance in Step IV	V. Blackmore et al	Analysis underway
Ionization cooling demonstration		
Design and expected performance of the MICE demonstration of ionization cooling	V. Blackmore, J. Pasternak, C. Rogers	MICE Note draft in praparation
Technical		
The MICE target upgrade	C. Booth	Draft advanced with authors
The design construction of the MICE Electron Muon Ranger	R. Asfandiyarov, A. Blondel, F. Drielsma	Not sure
The Reconstruction Software for the MICE Scintillating Fibre Trackers	A. Dobbs	Awaiting final track-fit results
The MICE Analysis and User Software framework	D. Rajaram	Not sure

Spokesman’s update

OPTICS REVIEW AND CM44

Optics review and CM44

- Optics review:
  - Will now take place 14 and 15 January 2015
    - C. Rogers et al preparing for it!

- CM44:
  - Previously posted dates do not work;
    - Clash with RLSR/MPB/FAC
  - Target dates:
    - 30 & 31 March 2016 and 01 April 2016
  - To be confirmed