Introduction

K. Long, 27 June, 2017

Thanks!

To Dimitrije and the Belgrade group for hosting CM48!

Plan

- Progress since CM47 (Feb17)
- Planning for 2017/02
- Upgrade to demo
- Personnel
- Dates for your diary
- CM48

Introduction

PROGRESS SINCE CM47

OCT16

Publications

Papers CM47

Papers in progress

Title	Contact	Comment
Step IV physics		
First measurement of emittance in Step IV	V. Blackmore	Preliminary results made public. Results being finalised so publication can be prepared.
Measurement of scattering distributions in MICE	R. Bayes	Preliminary results made public. Work continues following meeting with referees.
Ionization cooling demonstration		
Design and expected performance of the MICE demonstration of ionization cooling	J.B. Lagrange	arXiv:1701.06403; submitted to PRAB

Step IV field-on papers

Title	Contact	Comment
Step IV physics		
Field-on measurement of multiple Coulomb scattering	A. Young	Analysis underway
Measurement of energy-loss distributions	S. Wilbur	Analysis underway
Beam-based alignment	A.N. Other	Analsis underway
Emittance reconstruction	A.N. Other	Analsis underway
Emittance evolution; rapid communication	A.N. Other	Analsis underway
Emittance evolution review paper	A.N. Other	Analsis underway

- Completion of "milestsone papers" will require completion of a number of detailed analyses, e.g.:
  - Transfer matrix approach to magnetic alignment;
  - Study of effect of non-linear terms in the Hamiltonian (field) expansion;
- Each of these analysis may warrant a paper of its own.

Papers in progress

Title	Contact	Comment
Technical		
The MICE Analysis and User Software framework	D. Rajaram	In preparation

8

Of papers in progress at CM47:

- Design of demonstration: published
- Measurement of emittance
- Field-off scattering

PRAB

- M. Bogomilov *et al.*, MICE Collaboration, "*Design and expected performance of the MICE demonstration of ionization cooling*", arXiv:1701.06403 [physics.acc-ph]; to be published in PRAB;

IPAC'17

- C. Rogers on behalf of the MICE Collaboration, "*Study of ionization cooling with the MICE experiment*", contribution to the International Particle Accelerator Conference, Copenhagen, May 2017;
- P. Franchini on behalf of the MICE Collaboration, "*Results from Mice Step IV*", contribution to the International Particle Accelerator Conference, Copenhagen, May 2017;
- C. Hunt on behalf of the MICE Collaboration, "" *Layout of the MICE Demonstration of Muon Ionization Cooling*", contribution to the International Particle Accelerator Conference, Copenhagen, May 2017; and
- T. Mohayai, "*Novel Implementation of Non-Parametric Density Estimation in MICE*", contribution to the International Particle Accelerator Conference, Copenhagen, May 2017.

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 063501 (2017)

Lattice design and expected performance of the Muon Ionization Cooling Experiment demonstration of ionization cooling

M. Bogomilov,[1] R. Tsenov,[1] G. Vankova-Kirilova,[1] Y. Song,[2] J. Tang,[2] Z. Li,[3] R. Bertoni,[4] M. Bonesini,[4] F. Chignoli,[4] R. Mazza,[4] V. Palladino,[5] A. de Bari,[6] G. Cecchet,[6] D. Orestano,[7] L. Tortora,[7] Y. Kuno,[8] S. Ishimoto,[9] F. Filthaut,[10] D. Jokovic,[11] D. Maletic,[11] M. Savic,[11] O. M. Hansen,[12] S. Ramberger,[12] M. Vretenar,[12] R. Asfandiyarov,[13] A. Blondel,[13] F. Drielsma,[13] Y. Karadzhov,[13] G. Charnley,[14] N. Collomb,[14] K. Dumbell,[14] A. Gallagher,[14] A. Grant,[14] S. Griffiths,[14] T. Hartnett,[14] B. Martlew,[14] A. Moss,[14] A. Muir,[14] I. Mullacrane,[14] A. Oates,[14] P. Owens,[14] G. Stokes,[14] P. Warburton,[14] C. White,[14] D. Adams,[15] R. J. Anderson,[15] P. Barclay,[15] V. Bayliss,[15] J. Boehm,[15] T. W. Bradshaw,[15] M. Courthold,[15] V. Francis,[15] L. Fry,[15] T. Hayler,[15] M. Hills,[15] A. Lintern,[15] C. Macwaters,[15] A. Nichols,[15] R. Preece,[15] S. Ricciardi,[15] C. Rogers,[15] T. Stanley,[15] J. Tarrant,[15] M. Tucker,[15] A. Wilson,[15] S. Watson,[16] R. Bayes,[17] J. C. Nugent,[17] F. J. P. Soler,[17] R. Gamet,[18] G. Barber,[19] V. J. Blackmore,[19] D. Colling,[19] A. Dobbs,[19] P. Dornan,[19] C. Hunt,[19] A. Kurup,[19] J.-B. Lagrange,[19,*] K. Long,[19] J. Martyniak,[19] S. Middleton,[19] J. Pasternak,[19] M. A. Uchida,[19] J. H. Cobb,[20] W. Lau,[20] C. N. Booth,[21] P. Hodgson,[21] J. Langlands,[21] E. Overton,[21] M. Robinson,[21] P. J. Smith,[21] S. Wilbur,[21] A. J. Dick,[22] K. Ronald,[22] C. G. Whyte,[22] A. R. Young,[22] S. Boyd,[23] P. Franchini,[23] J. R. Greis,[23] C. Pidcott,[23] I. Taylor,[23] R. B. S. Gardener,[24] P. Kyberd,[24] J. J. Nebrensky,[24] M. Palmer,[25] H. Witte,[25] A. D. Bross,[26] D. Bowring,[26] A. Liu,[26] D. Neuffer,[26] M. Popovic,[26] P. Rubinov,[26] A. DeMello,[27] S. Gourlay,[27] D. Li,[27] S. Prestemon,[27] S. Virostek,[27] B. Freemire,[28] P. Hanlet,[28] D. M. Kaplan,[28] T. A. Mohayai,[28] D. Rajaram,[28] P. Snopok,[28] V. Suezaki,[28] Y. Torun,[28] Y. Onel,[29] L. M. Cremaldi,[30] D. A. Sanders,[30] D. J. Summers,[30] G. G. Hanson,[31] and C. Heidt[31]

(The MICE collaboration)

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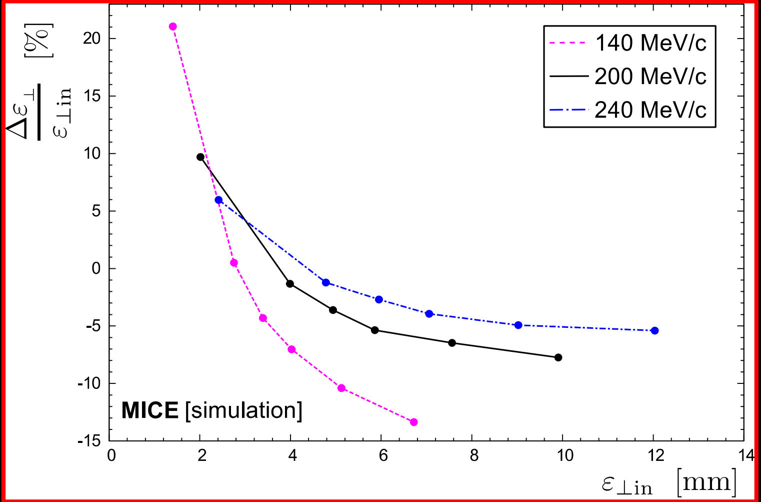
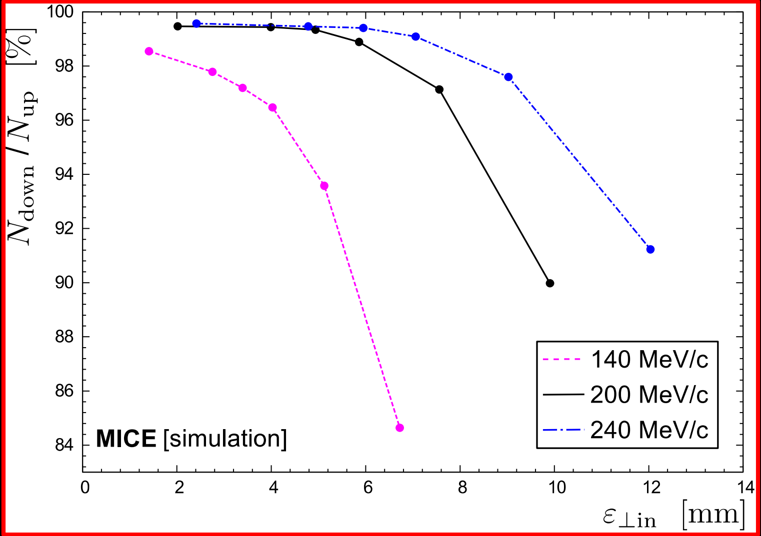
2469-9888/17/20(6)/063501(11) 063501-1 Published by the American Physical Society





Papers in progress

Title	Contact	Comment
Step IV physics		
Direct measurement of emittance using the MICE scintillating-fibre tracker	V. Blackmore	**Preliminary results public. Progress this CM.**
Measurement of multiple Coulomb scattering of muons in lithium hydride	J. Nugent	**Preliminary results public. Progress this CM.**

Step IV field-on papers

Title	Contact	Comment
Step IV physics		
Phase-space density/emittance evolution; rapid communication	C. Rogers	**Preliminary results made public at IPAC17.**
Measurement of energy-loss distributions	S. Wilbur	**First preliminary results made public at IPAC17.**
Field-on measurement of multiple Coulomb scattering	A. Young	Analysis underway
Beam-based alignment	To be assigned	Analsis underway
Phase-space density/emittance reconstruction	To be assigned	Analsis underway
Phase-space density/emittance evolution review paper	To be assigned	Analsis underway

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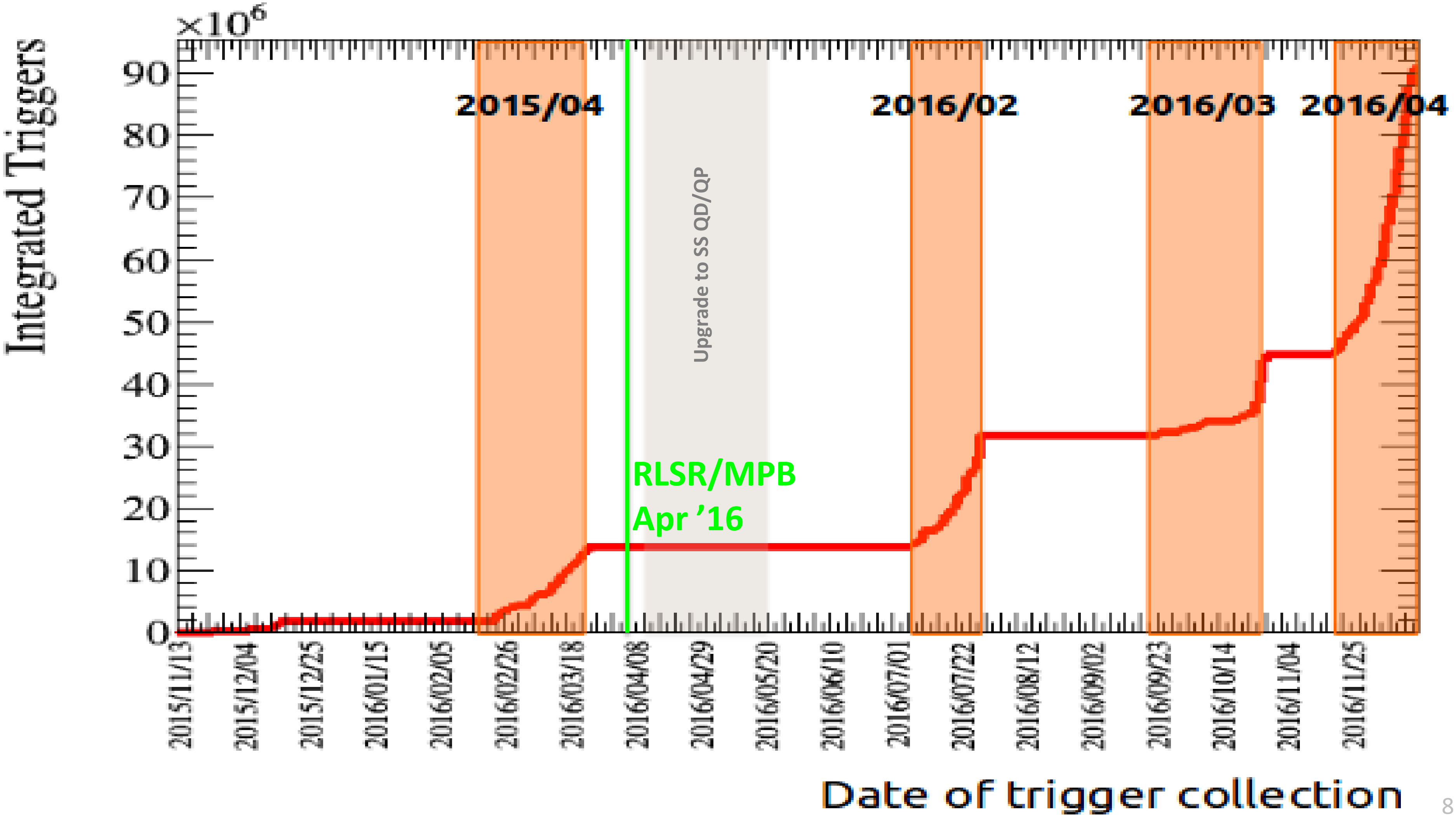
Papers in progress

Title	Contact	Comment
Technical		
The MICE Analysis and User Software framework	D. Rajaram	**In preparation**
Muon Ionization Cooling Experiment	C. Whyte	**Work to start soon.**
The MICE RF system	K. Ronald	**Builds on conference publications.**
The MICE magnetic channel	A. Bross, J. Cobb	**Builds on conference publications**
The MICE liquid-hydrogen absorber	V. Bayliss, J. Boehm	**Builds on conference publications**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Integrated Triggers
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2015/04
2016/02
2016/03
2016/04
Upgrade to SS QD/QP
RLSR/MPB
Apr '16
2015/11/13
2015/12/04
2015/12/25
2016/01/15
2016/02/05
2016/02/26
2016/03/18
2016/04/08
2016/04/29
2016/05/20
2016/06/10
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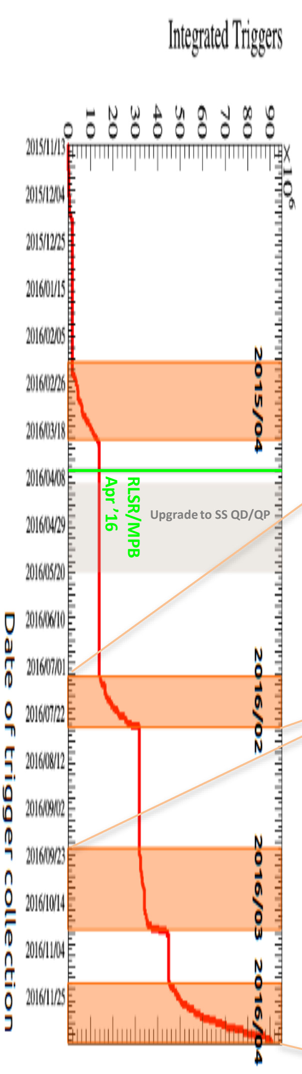
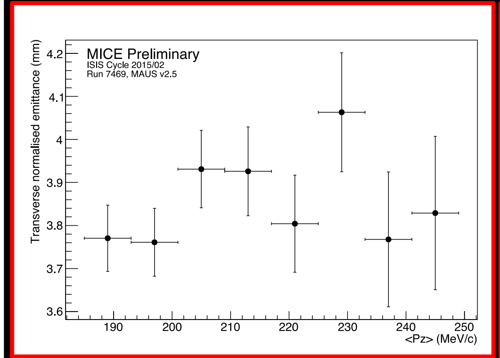
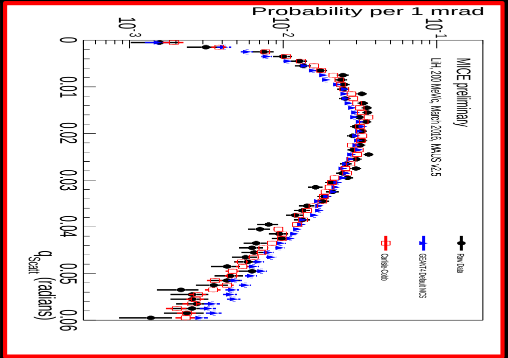
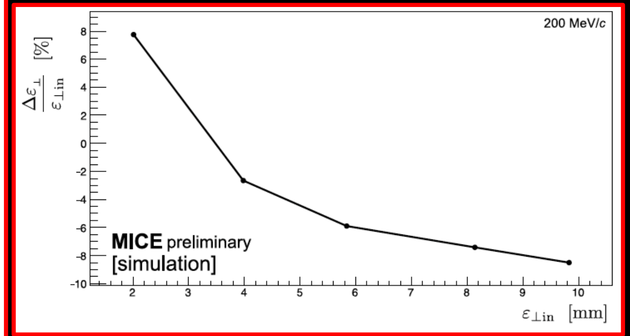
Date of trigger collection



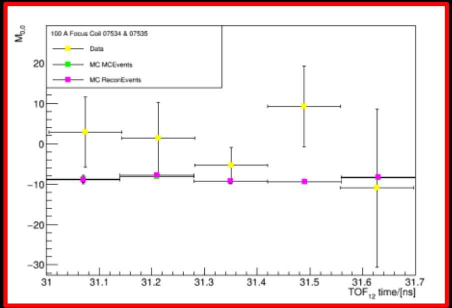


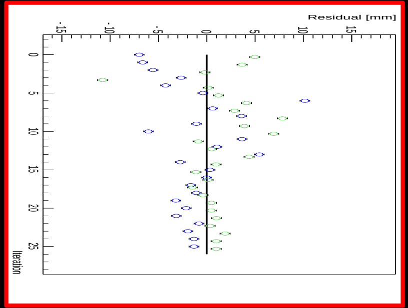


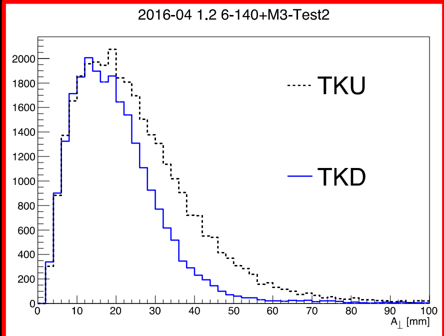


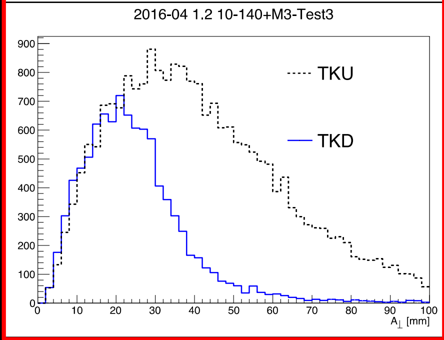
ICHEP'16, Chicago; NuFact16, Quy Nhon

Magnetic alignment

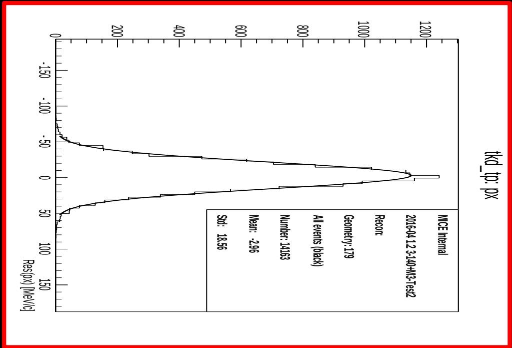


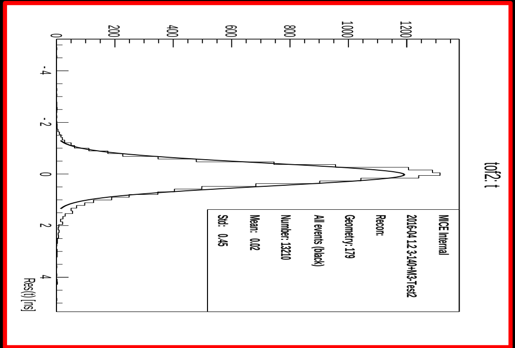






Solenoid mode scattering & emittance evolution





Superconducting magnets

- Conservative approach:
  - Inter-cold-mass force selected as figure of merit:
    - Agreed limit of 15 t
      - Avoid risk that pretension on SSU cold-mass straps is overcome
    - Select lattice settings in order of increasing force
  - Successful! Excellent data “on tape”
  - Operate SSD(M2) when sufficient data taken
- FC:
  - Solenoid mode:
    - Ran to required currents without issue
  - Flip mode:
    - Commissioned to 165A:
      - Derated from max 188A obtained in training
    - Quench at 160A in operation with SSU/ SSD:
      - Training quench or limit in presense of SSU/SSD?
    - ISIS availability limited investigation to two lattice settings only
- SSU:
  - Good cryogenic performance
  - Stable operation once initial issues with end-coil power supplies overcome
- SSD:
  - Cryogenically less good than SSU
  - End-centre-end coils, w/o trims:
    - Trim p/s grounded; resistive path to ground on end-coil current lead
- Resource issues:
  - Support during commissioning: DL, FNAL
  - Going forward:
    - On-site, expert cover for spectrometer solenoids
- Decision point:
  - With LiH and LH2 data in the can, run M2D

Tracker

- Routine maintenance on cold-heads carried out in Mar/Apr17
  - Required warm-up
- After re-cool-down, Cryo 2 found to have unacceptably large number of dead channels
  - Traced to water contamination in the VLPC vacuum space
- All four tracker cryostats were shown to be contaminated with water
  - Batch of low-grade or contaminated helium used?
- Substantial programne to dry out each of the cryostats
  - Warm bake, pump, backfill, cold trap
  - Careful and sustained efforts of E. Overton, A. Bross and C. Macwaters
  - Full tracker readout system back in operation for the 24/7 data taking at end of Cycle.

Data taking in 2017/02

- In parallel to LH2 work:
  - Straight-track calibration and alignment data
- At end of the Cycle:
  - The liquefaction-system test successfully underway:
    - Data set was taken cold, gaseous neon
      - Investigate of the aperture introduced by the absorber vessel
      - Attempt a scattering measurement with cold neon gas.

Liquid-hydrogen system: in R9

- Initial (Nov15) cool-down in MICE Hall unsuccessful
- Moved to R9 for remedial work:
  - Modifications to vessel and condensing turret. Operation in R9 also required:
    - Manufacture of endplates for FC; was holding item

- Cooldown 1: Nov16:
  - Cold! But too little margin
- Cooldown 2: Dec16/Jan17:
  - LH2 vessel @ ~20K, but, "condensing pot" at 13k (H2 solid)

- Proof test with neon:
  - Neon is liquid between 25K and 28K
  - Liquefied, and held level, 2l neon;
    - Temperature difference vessel to condensing pot ~1--2K
      - Success!

Liquid-hydrogen system: in the MICE Hall

- Good progress, culminating in:
  - Successful liquefaction of approximately 2 l of neon; and
  - Stable operation of the system for a period of several days.
- Hydrogen safety case:
  - Revisited in the light of changes to the hydrogen-liquefaction system and experience gained in operating the focus coil
  - Re-analysis of the possible consequences of freezing hydrogen:
    - Showed possible for an unacceptably large pressure rise in the hydrogen-safety volume to if hydrogen window ruptured
    - Modifications that remove the risk of such a pressure rise implemented
  - Decided to execute another HAZOP review; 15/16 May 2017:
    - No outstanding issues that would prevent the commissioning of the system with liquid hydrogen
- Additional work required to:
  - Remediate issues that arose in the installation;
  - Re-analysis the safety case;
  - Prepare for and execute the HAZOP review
- Operation with H2 still requires some preparation

Summary of Step IV data taking

- **Lithium hydride:**
  - Field-off scattering, complete
  - Field-on scattering, complete
  - Emittance evolution:
    - Solenoid mode:
      - Data taking:
        - » Range of initial emittance and momentum
        - » Various magnetic lattice settings
    - Flip mode:
      - Cycle 2016/04 (Feb17—Mar17):
        - » 140 MeV/c; various initial emittance
        - » Various magnetic lattice settings

- **Liquid hydrogen:**
  - Planned stop in LiH ops in Cycle 2016/05 to begin LH_2 installation programme
  - Goal to take some data with LH2 in Cycle 2017/01 thwarted
  - LH2 team pushing to get LH2 complete and commissioned by Jul17

Introduction

PLANNING FOR 2016/05 AND 2017/01

Scientific programme

Step IV:

Material properties of LH_2 and LiH that determine the ionization-cooling performance

Observation of $\epsilon_\perp^{\rm n}$ reduction

MICE demonstration of ionization cooling:

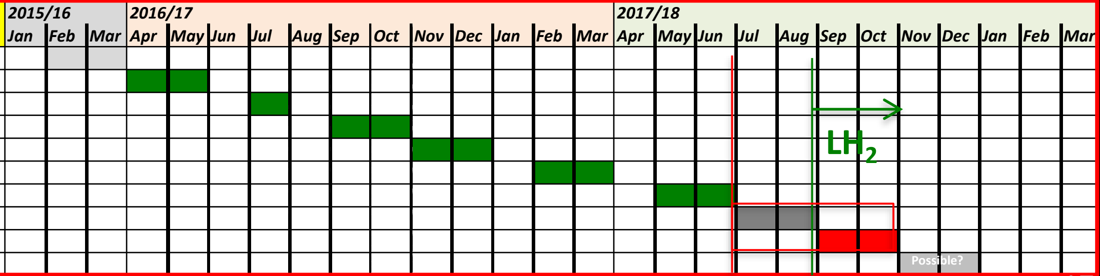
Observation of $\epsilon_\perp$ reduction with re-acceleration

Observation of $\epsilon_\perp$ reduction and $\epsilon_{||}$ evolution

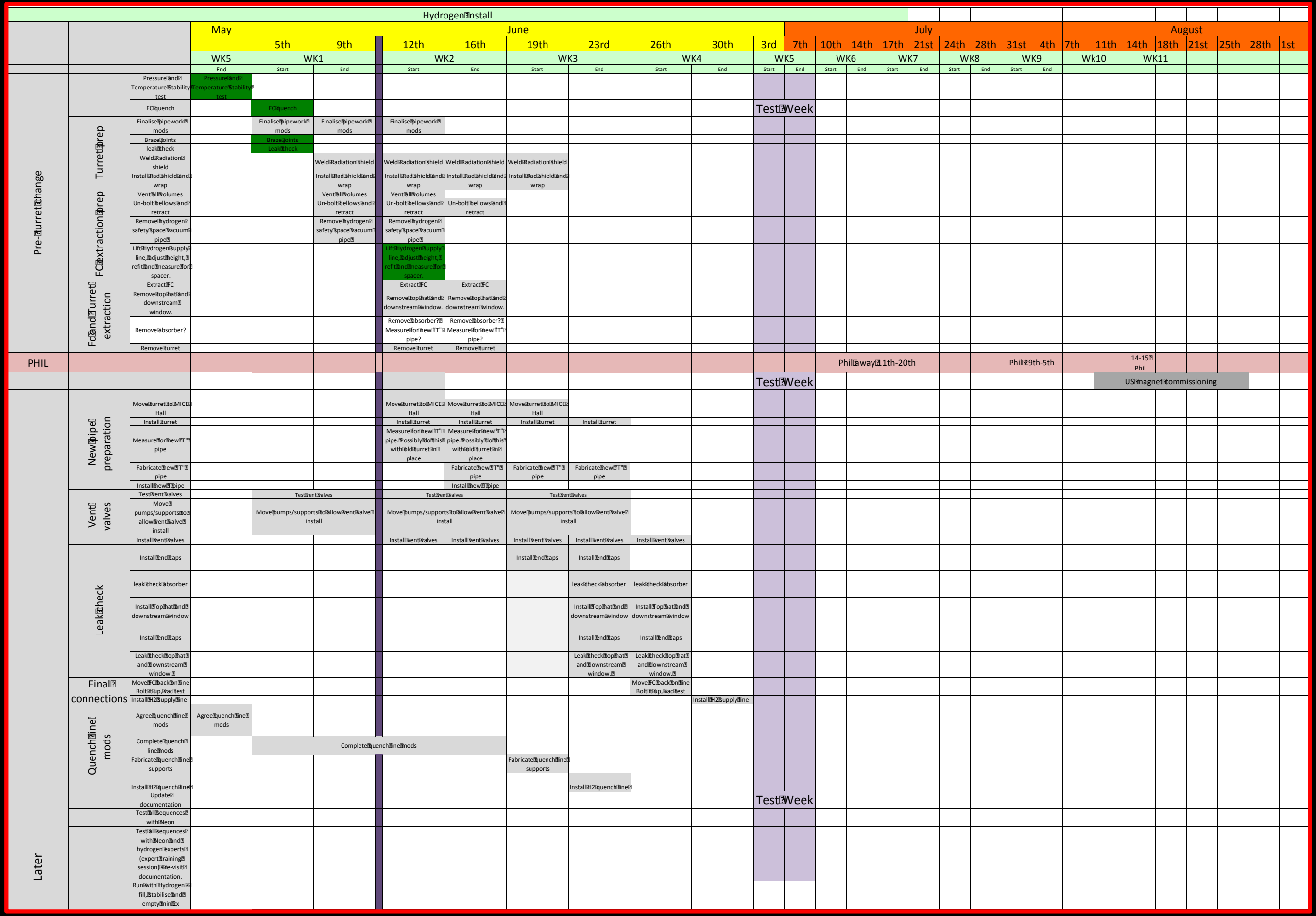
Observation of $\epsilon_\perp$ reduction and $\epsilon_{||}$ and angular momentum evolution†

† Requires systematic study of “flip” optics.

ISIS Cycle	From	To	MICE Step IV Programme	Absorber
2015/04	16-Feb-16	25-Mar-16	*Field-off scattering*	*Lithium-hydride*
2016/01	12-Apr-16	20-May-16	*QD/QP upgrade*	*Lithium-hydride*
2016/02	28-Jun-16	29-Jul-16	*Magnetic-channel commissioning*	*Lithium-hydride*
2016/03	13-Sep-16	28-Oct-16	*Field-on scattering*	*Lithium-hydride*
2016/04	15-Nov-16	16-Dec-16	*Solenoid-mode emittance evolution*	*Lithium-hydride*
2016/05	14-Feb-17	31-Mar-17	*Flip-mode emittance evollution*	*Lithium-hydride*
2017/01	02-May-17	02-Jun-17	*Emittance evolution/scattering*	*Liquid hydrogen*
2017/02	11-Jul-17	04-Aug-17	*Cancelled/postponed*	
	19-Sep-17	27-Oct-17	*Emittance evolution/scattering*	*Liquid hydrogen*
2017/03	14-Nov-17	20-Dec-17		



Preparation: LH2, SSU, FC, SSD

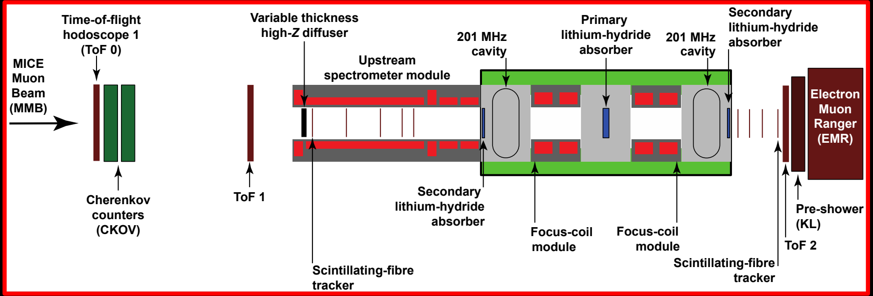


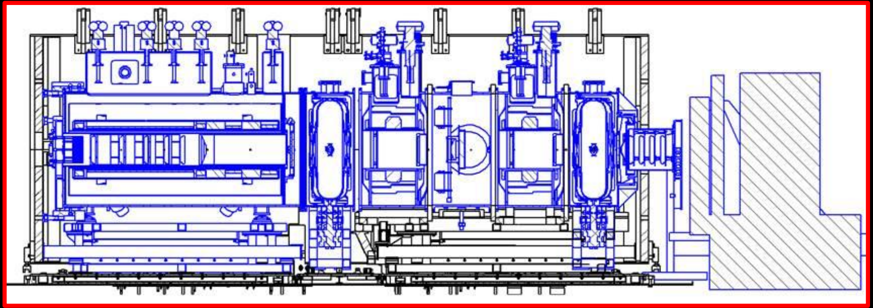
- (Re)commissioning:
  - C. Whyte “owns” s/d schedule
  - Under pressure to complete:
    - LH2 in Jul17
    - Magnets Aug17
- Extended expert-led start-up:
  - Esssential, we can not afford to “catch a cold” in Sep17
  - S. Boyd will call the shorts!

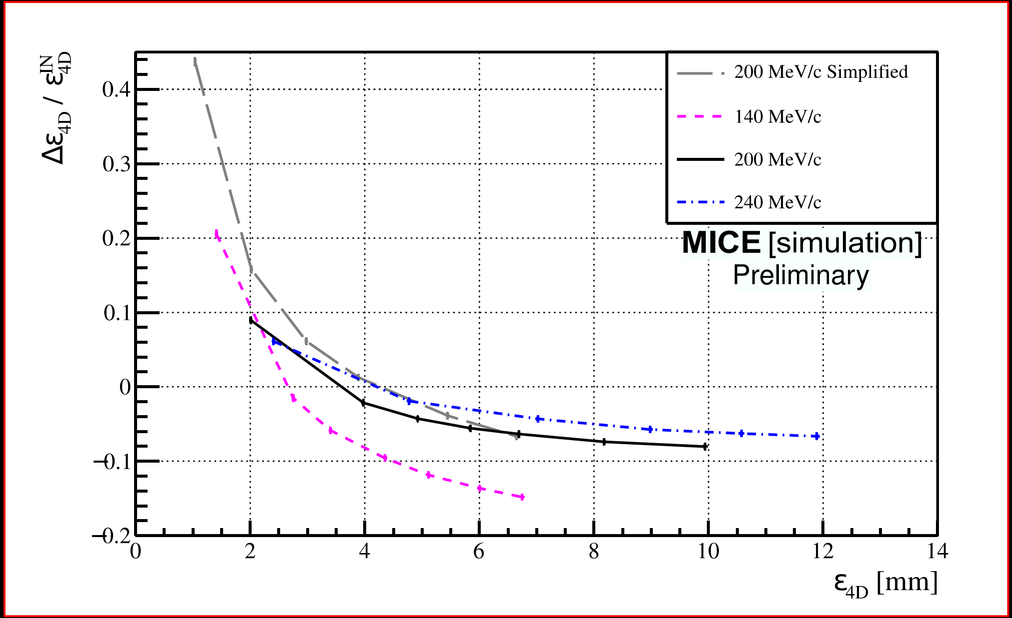
Introduction

UPGRADE TO DEMO

Simplified demonstration







- "Simplified design":
  - Comparable cooling performance
  - Transmission not as good as in demo configuration

Professor G. Blair
STFC Executive Director, Programmes
Polaris House
North Star Avenue
Swindon, SN2 1SZ

Kenneth Long
Professor of Experimental Particle Physics
MICE spokesperson

7th March 2017

On behalf of the MICE Collaboration

The Muon Ionization Cooling Experiment has been constructed with the intention of providing a realistic demonstration of the ionization cooling of muon beams, to prove the principle of the technique for future applications such as a muon collider or neutrino factory. The collaboration has built and commissioned the beam-line, elements of the cooling cell and the instrumentation necessary to perform such a demonstration. The collaboration is presently executing "Step IV" of its scientific programme that is optimised for the measurement of the factors that determine the size of the ionization-cooling effect. These factors include multiple Coulomb scattering, energy loss, the focusing strength of the magnetic lattice and the initial momentum and emittance of the muon beam. The Step IV configuration will also be used to study the evolution of normalised transverse emittance.

A realistic demonstration of ionization cooling, however, requires the acceleration of the beam using radio frequency cavities; i.e. the measurements which will be made with the present configuration of the experiment will not constitute a proof of the principle of the ionization-cooling technique. A set-up to complete the demonstration of ionization cooling that uses existing equipment with a limited amount of additional construction has been conceived and designed and a proposal is being developed by the collaboration. We consider that this is an opportunity to complete the MICE program in a convincing way, that will have a lasting legacy as a major achievement for the future of the field.

The experiment, the MICE Muon Beam as well as large parts of the infrastructure required to support it have been built by the international collaboration. Significant contributions in the build phase were made by Belgium, Bulgaria, CERN, China, Italy, Japan, the Netherlands, Switzerland, the UK and the US. International recognition of the importance of the MICE programme is confirmed by the fact that new groups are still joining the collaboration: IHEP and Sichuan (China) and Belgrade (Serbia) joined in 2015, Novi Sad (Serbia) joined last year, and UNIST (Korea) joined last month.

The international collaboration remains fully committed to delivering a demonstration of ionization cooling and has made substantial commitments of time and manpower in bringing the experiment to its present state of readiness, running shifts and providing operational support, as well as analysing the data.

As a collaboration, we urge you to ensure that the maximum benefit is derived from the substantial investments made both by overseas researchers and funding agencies and also by the UK, by supporting the collaboration in its plans to upgrade the Step IV apparatus.

Signed by:

R. Tsenov	University of Sofia, Bulgaria
J. Tang	Institute of High Energy Physics, Beijing, China
Z. Li	Sichuan University, China
M. Bonesini	Sezione INFN Milano Bicocca & Dipartimento di Fisica Università di Milano Bicocca, Italy
V. Palladino	Sezione INFN & Dipartimento di Fisica di Università Napoli, Italy

PTO

A. de Bari	Sezione INFN Pavia & Dipartimento di Fisica Università degli Studi di Pavia, Italy
D. Orestano	Sezione INFN & Dipartimento di Matematica e Fisica Università Roma Tre, Rome Italy
M. Chung	Ulsan National Institute of Science and Technology, South Korea
F. Filthaut	NIKHEF, Netherlands
D. Maletic	University of Belgrade, Serbia
J. Nikolov	University of Novi Sad, Serbia
M. Vretenar	CERN, Switzerland
A. Blondel	University of Geneva, Switzerland
P. Kyberd	Brunel University, U.K.
A. Grant	Daresbury Laboratory, U.K.
P. Soler	University of Glasgow, U.K.
J. Pasternak	Imperial College, London, U.K.
R. Gamet	University of Liverpool, U.K.
J. Cobb	Emeritus (University of Oxford, U.K.)
C. Rogers	Rutherford Appleton Laboratory, U.K.
K. Ronald	University of Strathclyde, U.K.
S. Boyd	University of Warwick, U.K.
D. Kaplan	Illinois Institute of Technology, U.S.A.
Y. Onel	University of Iowa, U.S.A.
D. Li	Lawrence Berkeley National Laboratory, U.S.A.
D. Summers	University of Mississippi, U.S.A.

MPB

There is a tentative proposal to the STFC to fund an additional data-taking cycle with RF re-acceleration in 2018 (in the cooling demonstration configuration shown in Appendix A), after the 2017 MICE program ends. The cost would be approximately £3M. The MPB feels that the scientific benefits would be significant, but it is not in a position to comment on the technical details and schedule of the proposal.

Roadmap for the international, accelerator-based neutrino programme

The ICFA Neutrino Panel

arXiv:1704.08181v1 [hep-ex] 26 Apr 2017

Overview

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

In line with its terms of reference [1] the ICFA Neutrino Panel [2] has developed a roadmap for the international, accelerator-based neutrino programme. A "roadmap discussion document" [3] was presented in May 2016 taking into account the peer-group-consultation described in the Panel's initial report [4]. The "roadmap discussion document" was used to solicit feedback from the neutrino community—and more broadly, the particle- and astroparticle-physics communities—and the various stakeholders in the programme. The roadmap, the conclusions and recommendations presented in this document are consistent with the conclusions drawn in [4] and take into account the comments received following the publication of the roadmap discussion document.

With its roadmap the Panel documents 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.

4.10: 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.

Name	Institution
J. Cao	IHEP/Beijing
A. de Gouvêa	Northwestern University
D. Duchesneau	CNRS/IN2P3
S. Geer	Fermi National Laboratory
R. Gomes	Federal University of Goias
S.B. Kim	Seoul National University
T. Kobayashi	KEK
K. Long (chair)	Imperial College London and STFC
M. Maltoni	Universidad Automata Madrid
M. Mezzetto	University of Padova
N. Mondal	Tata Institute for Fundamental Resarch
M. Shiozawa	Tokyo University
J. Sobczyk	Wroclaw University
H. A. Tanaka	University of Toronto, IPP, TRIUMF
M. Wascko	Imperial College London
G. Zeller	Fermi National Accelerator Laboratory

Formal feedback from STFC

- **STFC MICE-UK Oversight Committee; 28Apr17:**
  - **STFC:**
    - **At this time STFC does not have the resources necessary to entertain a proposal to upgrade the experiment**
  - **OsC comment:**
    - **UK and international collaborations should plan on this basis**

- **ASB (in letter to P. Soler, 11May17):**
  - **In response to the SOI from MICE-UK:**
    - **The "… *ASB noted the statement from STFC that there is no available funding at present within the accelerator programme to fund the presented project, so (barring some change in circumstances) a full proposal will not be invited for evaluation."***

MICE-UK SOI for upgrade

Muon Ionization Cooling with Re-acceleration - an upgrade for MICE

The MICE-UK Collaboration[1]

1 Introduction

The Muon Ionization Cooling Experiment (MICE) at the Rutherford Appleton Laboratory will complete data-taking in October 2017. The experiment will measure reduction of normalised emittance of a muon beam. Ionization cooling is the key technology required to construct a neutrino factory, in which neutrino beams are created from muon decay, and a high intensity muon collider, in which high-energy muon beams collide to probe physics beyond the Standard Model.

In a neutrino factory, secondary pions from protons impinging on a target decay to produce a muon beam of large emittance. The phase-space volume occupied by the beam is reduced (cooled) using an ionization-cooling channel. The muon-cooling channel consists of a series of low-Z absorbers (either liquid hydrogen or lithium hydride – LiH) inside focussing magnets, with RF cavities to restore the longitudinal momentum of the muons. The transverse four-dimensional (4D) emittance of the muons is reduced due to the effect of energy loss and restoration of momentum by the RF cavities. The cool beam of muons is then accelerated and injected into a storage ring, where the muons decay to produce intense beams of neutrinos with a well-known flavour content. Neutrino beams may then be used to carry out long-baseline neutrino oscillation experiments and perform high-precision CP violation measurements, to resolve the puzzle of the matter-antimatter asymmetry of the universe. Muon colliders offer a very attractive and compact way to achieve a multi-TeV lepton-antilepton collider, to probe new physics at the highest energy scales. Muon collider designs, achieving luminosities of order 10^{34} cm^{-2}s^{-1} require the development of six-dimensional (6D) ionization cooling of muons (including additional longitudinal cooling). *The physics of ionization cooling is being studied for the first time using the world-class MICE facility, after significant investment from STFC and the international collaboration.*

MICE is completing its approved scientific mission of demonstrating reduction of normalised transverse emittance using LiH and liquid hydrogen absorbers, but without re-acceleration. This programme will measure multiple scattering and energy loss for ∼200 MeV/c muons in LiH and liquid hydrogen absorbers, and will measure reduction of normalised emittance in the muon beam for the first time. However, it will not demonstrate sustainable cooling with re-acceleration. In this Statement of Interest to STFC, we propose an upgrade to MICE to allow ionization cooling to be demonstrated. The upgrade consists of inserting two 201 MHz RF cavities, two additional secondary absorbers and a second focus coil in the MICE beam. This programme could be completed in 18 months and would cost £3.0M.

2 Ionization-cooling with re-acceleration experiment

The MICE Collaboration has been working on a simplified design, to reduce cost and risk of the cooling demonstration with re-acceleration. In this design (Figure 1) the initial emittance is measured with the upstream spectrometer solenoid and the downstream emittance is measured with a short tracker and a totally active calorimeter that measures the total energy of the muon. The cooling channel consists of a principal LiH absorber, two secondary absorbers, two focus coils and two RF cavities. This design fits inside the existing Partial Return Yoke (PRY). The hardware is in hand so no new hardware would have to be built and no major modifications to the MICE Hall would be required.

The cooling performance has been evaluated. Figure 2 (left) shows the estimated emittance reduction for a nominal ∼6 mm emittance muon beam of 200 MeV/c momentum. An emittance reduction of 6.3% is predicted for an input emittance of 5.5 mm, if two secondary LiH absorbers are in place. The fractional emittance reduction can be measured with an estimated systematic uncertainty of 0.1-0.2%. The reduced acceptance of the downstream instrumentation in this configuration causes a reduction in the transmission of the channel (the fraction of particles accepted by the downstream instrumentation) to about 96%, which is an acceptable transmission loss and a significant improvement compared with the current configuration. Figure 2 (right) shows the ionization cooling performance as a function of input emittance for a number of different design scenarios. The baseline includes LiH secondary absorbers (in black) with three downstream tracker planes. Other scenarios include polyethylene absorbers and varying the number of tracker planes and their position in the design. The equilibrium emittance is around 3 mm, so any beam with a larger emittance is likely to cool. These data can then be used to predict the cooling performance of a cooling channel deployed at future muon beam facilities.

[1] Author list in the appendix.

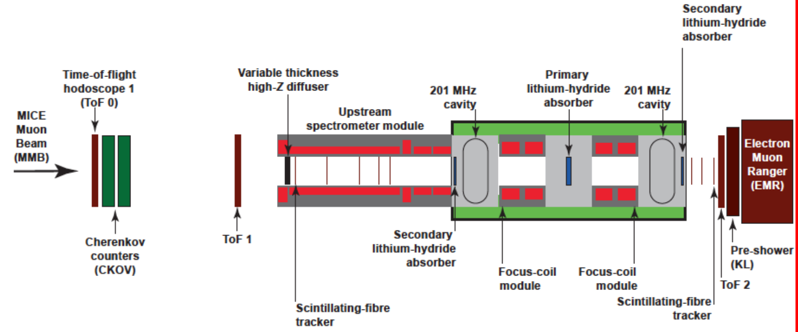
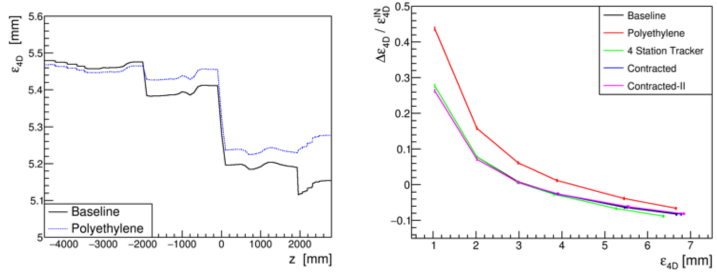
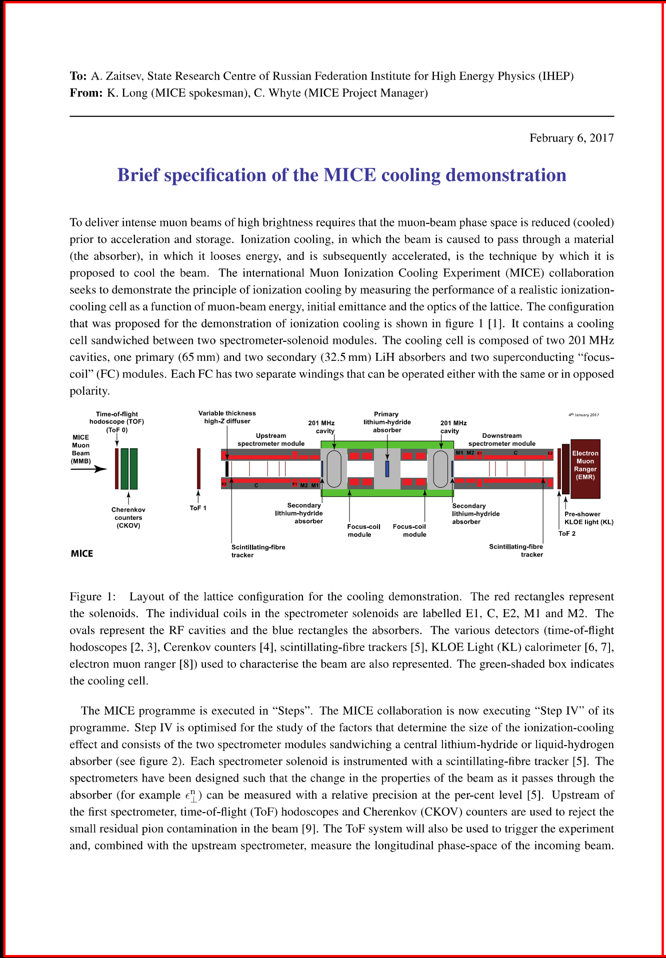


Figure 1: Muon ionization cooling demonstration with re-acceleration.



- **Submitted to ASB for its meeting on the 22Mar17:**
  - **Cost £3.02M**
  - **Schedule:**
    - **Given Oct17 start, project complete by Mar19**

Institute of High Energy Physics; Protvino



To: A. Zaitsev, State Research Centre of Russian Federation Institute for High Energy Physics (IHEP)
From: K. Long (MICE spokesman), C. Whyte (MICE Project Manager)

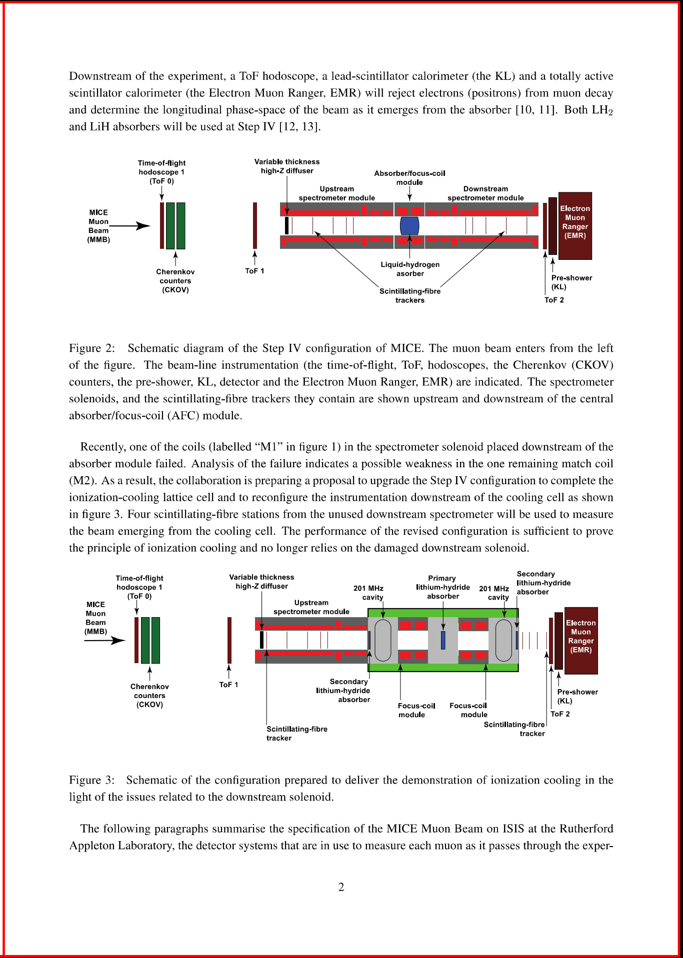
February 6, 2017

Brief specification of the MICE cooling demonstration

To deliver intense muon beams of high brightness requires that the muon-beam phase space is reduced (cooled) prior to acceleration and storage. Ionization cooling, in which the beam is caused to pass through a material (the absorber), in which it looses energy, and is subsequently accelerated, is the technique by which it is proposed to cool the beam. The international Muon Ionization Cooling Experiment (MICE) collaboration seeks to demonstrate the principle of ionization cooling by measuring the performance of a realistic ionization-cooling cell as a function of muon-beam energy, initial emittance and the optics of the lattice. The configuration that was proposed for the demonstration of ionization cooling is shown in figure 1 [1]. It contains a cooling cell sandwiched between two spectrometer-solenoid modules. The cooling cell is composed of two 201 MHz cavities, one primary (65 mm) and two secondary (32.5 mm) LiH absorbers and two superconducting "focus-coil" (FC) modules. Each FC has two separate windings that can be operated either with the same or in opposed polarity.

Figure 1: Layout of the lattice configuration for the cooling demonstration. The red rectangles represent the solenoids. The individual coils in the spectrometer solenoids are labelled E1, C, E2, M1 and M2. The ovals represent the RF cavities and the blue rectangles the absorbers. The various detectors (time-of-flight hodoscopes [2, 3], Cerenkov counters [4], scintillating-fibre trackers [5], KLOE Light (KL) calorimeter [6, 7], electron muon ranger [8]) used to characterise the beam are also represented. The green-shaded box indicates the cooling cell.

The MICE programme is executed in "Steps". The MICE collaboration is now executing "Step IV" of its programme. Step IV is optimised for the study of the factors that determine the size of the ionization-cooling effect and consists of the two spectrometer modules sandwiching a central lithium-hydride or liquid-hydrogen absorber (see figure 2). Each spectrometer solenoid is instrumented with a scintillating-fibre tracker [5]. The spectrometers have been designed such that the change in the properties of the beam as it passes through the absorber (for example $\epsilon_\perp^n$) can be measured with a relative precision at the per-cent level [5]. Upstream of the first spectrometer, time-of-flight (ToF) hodoscopes and Cherenkov (CKOV) counters are used to reject the small residual pion contamination in the beam [9]. The ToF system will also be used to trigger the experiment and, combined with the upstream spectrometer, measure the longitudinal phase-space of the incoming beam.



Downstream of the experiment, a ToF hodoscope, a lead-scintillator calorimeter (the KL) and a totally active scintillator calorimeter (the Electron Muon Ranger, EMR) will reject electrons (positrons) from muon decay and determine the longitudinal phase-space of the beam as it emerges from the absorber [10, 11]. Both LH_2 and LiH absorbers will be used at Step IV [12, 13].

Figure 2: Schematic diagram of the Step IV configuration of MICE. The muon beam enters from the left of the figure. The beam-line instrumentation (the time-of-flight, ToF, hodoscopes, the Cherenkov (CKOV) counters, the pre-shower, KL, detector and the Electron Muon Ranger, EMR) are indicated. The spectrometer solenoids, and the scintillating-fibre trackers they contain are shown upstream and downstream of the central absorber/focus-coil (AFC) module.

Recently, one of the coils (labelled "M1" in figure 1) in the spectrometer solenoid placed downstream of the absorber module failed. Analysis of the failure indicates a possible weakness in the one remaining match coil (M2). As a result, the collaboration is preparing a proposal to upgrade the Step IV configuration to complete the ionization-cooling lattice cell and to reconfigure the instrumentation downstream of the cooling cell as shown in figure 3. Four scintillating-fibre stations from the unused downstream spectrometer will be used to measure the beam emerging from the cooling cell. The performance of the revised configuration is sufficient to prove the principle of ionization cooling and no longer relies on the damaged downstream solenoid.

Figure 3: Schematic of the configuration prepared to deliver the demonstration of ionization cooling in the light of the issues related to the downstream solenoid.

The following paragraphs summarise the specification of the MICE Muon Beam on ISIS at the Rutherford Appleton Laboratory, the detector systems that are in use to measure each muon as it passes through the exper-

2

- In discussion of:
  - MICE
  - MICE demo @ IHEP
  - 6D cooling experiment beyond MICE

Institute of High Energy Physics; Protvino

- Reply received Mar17

Phone call re involvement of Protvino

Phone call (Skype): 13Mar17; 14:00

Present: K. Long (MICE spokesman, Imperial/STFC);
C. Whyte (via mobile, Project Manager, Strathclyde/STFC);
V. Garkusha (Head of Beam Department);
A. Zaitsev (Deputy Director, responsible for experimental physics)

- Follow-up phone call 13Mar17:
  - Discussed possible implementation and issues
  - Agreed:

We discussed the next steps and agreed:
- To work towards a second phone call at the end of March or beginning of April to discuss outcomes of the above SoI process and progress in thinking on both sides;
- To include in the discussions longer term items such as a 6D-cooling experiment for which there is not yet a completed design.
- To work towards appropriate personnel from IHEP attending the MICE collaboration meeting in Belgrade, Serbia, 27-29 June 2017.
- KL will include AZ and VG in CC in emails relevant to the issues outlined above.

08/03/2017

Feasibility of the implementation of the MICE cooling demonstration at NRC KI IHEP

Here is a feasibility study of the MICE cooling demonstration at the 70-GeV machine at IHEP. In this analysis, the materials presented in Dr. K. Long's letter of 6 February 2017 and in the publications indicated in this letter are used. All findings are preliminary.

1. Layout

Experimental hall serving to place the installation, shown in Figure 1.

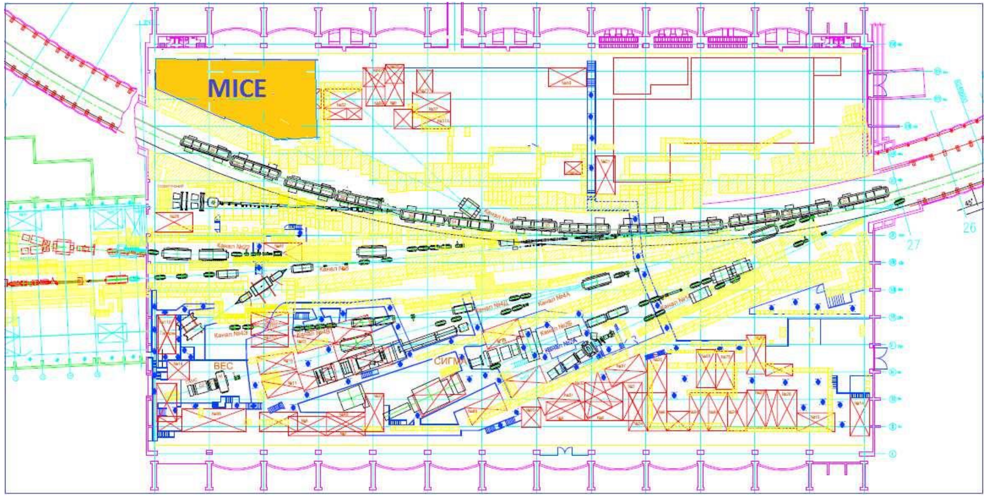


Fig. 1 Experimental hall

Collaboration Board at CM48

- Consider means by which to raise resource s.t.
  - Cost to STFC is reduced (substantially) allowing MICE-UK to argue that the situation has changed
- Consider alternative strategies:
  - E.g. implementation of demo at IHEP Protvino

Introduction

PERSONNEL

Personnel

- Ed Overton will leave for new employment …
  - He will be missed!
  - Planning has started:
    - MICE DAQ
    - Tracker DAQ
  - Will have to distribute his responsibilities:
    - Tracker Group; DAQ/S/w&C group

Introduction

DATES FOR YOUR DIARY

Physics Beyond Colliders

http://pbc.web.cern.ch

Organization **PBC@work** **Resources**

Physics Beyond Colliders is an exploratory study aimed at exploiting the full scientific potential of CERN's accelerator complex and its scientific infrastructure through projects complementary to the LHC, HL-LHC and other possible future colliders. These projects would target fundamental physics questions that are similar in spirit to those addressed by high-energy colliders, but that require different types of beams and experiments. The mandate of the study team may be found here.

The kick-off workshop held in September 2016 identified a number of areas of interest. Working groups have been set-up to pursue studies in these areas. See organization for a detailed breakdown of the current structure. The Physics Beyond Colliders study remains open to further ideas for new projects.

Should you wish to receive general announcements and occassional updates, please subscribe to the e-group PBC-info here.

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Workshops and General meetings

Create event Parent category

November 2017

21 Nov - 22 Nov Physics Beyond Colliders Annual Workshop

Introduction

CM48

MICE CM48

27-29 June 2017
Europe/Belgrade timezone

Search...

- Overview
- Timetable
- Contribution List
- Registration
- Participant List

The 48th Muon Ionization Cooling Experiment (MICE) Collaboration Meeting will be held at the Institute of Physics Belgrade, Serbia from 27th to 29th June 2017 inclusive

Registration 30 EUR **Collaboration Dinner 25 EUR**

Payment method: Bank transfer. Instructions bellow. Or in Belgrade upon arrival.

(as this meeting is being held in Belgrade, registration via the ISIS database is NOT required)

Starts 27 Jun 2017 09:00
Ends 29 Jun 2017 18:00
Europe/Belgrade

Institute of Physics Belgrade

Pregrevica 118, 11080 Zemun-Belgrade