# Spokesman’s introduction

K. Long, 7 February, 2019

# Contents

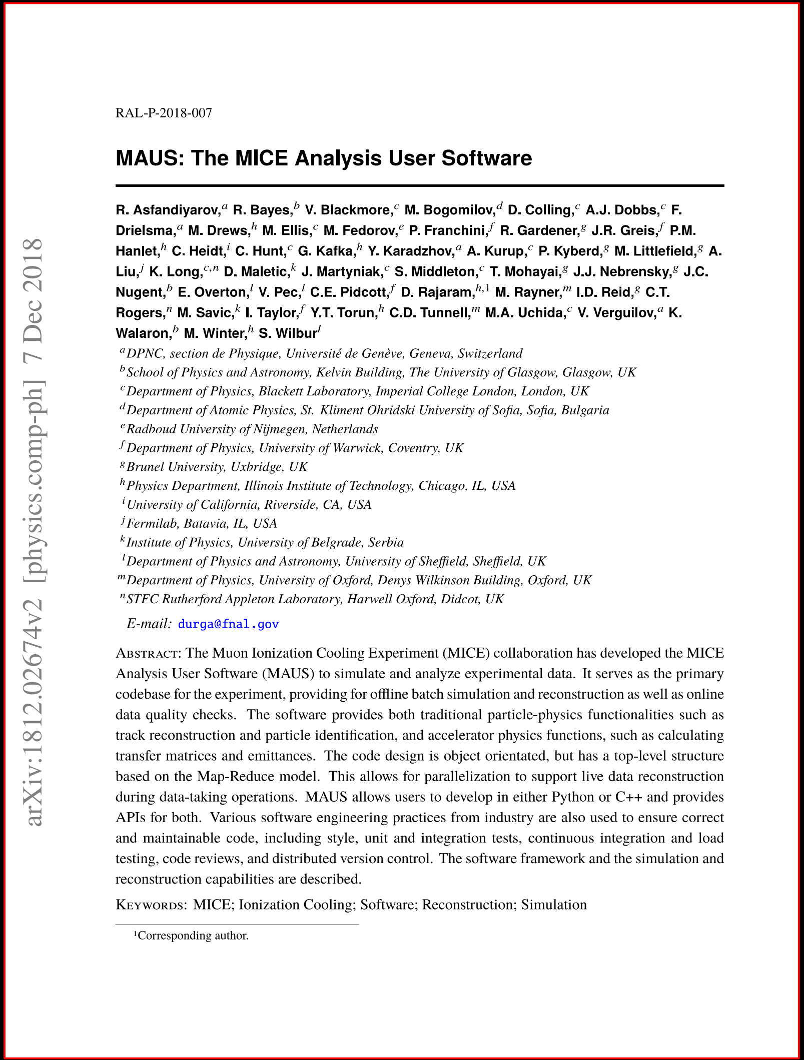
- **Publication update**
- **Analysis update and paper planning**
- **Upcoming meetings**

Spokesman's introduction

# PUBLICATION UPDATE

# MAUS paper: [RAL-P-2018-007; arXiv:1812:02674]

- Submitted to JINST by Durga Rajaram





RAL-P-2018-007

## MAUS: The MICE Analysis User Software

**R. Asfandiyarov,[a] R. Bayes,[b] V. Blackmore,[c] M. Bogomilov,[d] D. Colling,[c] A.J. Dobbs,[c] F. Drielsma,[a] M. Drews,[h] M. Ellis,[c] M. Fedorov,[e] P. Franchini,[f] R. Gardener,[g] J.R. Greis,[f] P.M. Hanlet,[h] C. Heidt,[i] C. Hunt,[c] G. Kafka,[h] Y. Karadzhov,[a] A. Kurup,[c] P. Kyberd,[g] M. Littlefield,[g] A. Liu,[j] K. Long,[c,n] D. Maletic,[k] J. Martyniak,[c] S. Middleton,[c] T. Mohayai,[g] J.J. Nebrensky,[g] J.C. Nugent,[b] E. Overton,[l] V. Pec,[l] C.E. Pidcott,[f] D. Rajaram,[h,1] M. Rayner,[m] I.D. Reid,[g] C.T. Rogers,[n] M. Savic,[k] I. Taylor,[f] Y.T. Torun,[h] C.D. Tunnell,[m] M.A. Uchida,[c] V. Verguilov,[a] K. Walaron,[b] M. Winter,[h] S. Wilbur[l]**

[a]*DPNC, section de Physique, Université de Genève, Geneva, Switzerland*
[b]*School of Physics and Astronomy, Kelvin Building, The University of Glasgow, Glasgow, UK*
[c]*Department of Physics, Blackett Laboratory, Imperial College London, London, UK*
[d]*Department of Atomic Physics, St. Kliment Ohridski University of Sofia, Sofia, Bulgaria*
[e]*Radboud University of Nijmegen, Netherlands*
[f]*Department of Physics, University of Warwick, Coventry, UK*
[g]*Brunel University, Uxbridge, UK*
[h]*Physics Department, Illinois Institute of Technology, Chicago, IL, USA*
[i]*University of California, Riverside, CA, USA*
[j]*Fermilab, Batavia, IL, USA*
[k]*Institute of Physics, University of Belgrade, Serbia*
[l]*Department of Physics and Astronomy, University of Sheffield, Sheffield, UK*
[m]*Department of Physics, University of Oxford, Denys Wilkinson Building, Oxford, UK*
[n]*STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot, UK*

*E-mail:* durga@fnal.gov

Abstract: The Muon Ionization Cooling Experiment (MICE) collaboration has developed the MICE Analysis User Software (MAUS) to simulate and analyze experimental data. It serves as the primary codebase for the experiment, providing for offline batch simulation and reconstruction as well as online data quality checks. The software provides both traditional particle-physics functionalities such as track reconstruction and particle identification, and accelerator physics functions, such as calculating transfer matrices and emittances. The code design is object orientated, but has a top-level structure based on the Map-Reduce model. This allows for parallelization to support live data reconstruction during data-taking operations. MAUS allows users to develop in either Python or C++ and provides APIs for both. Various software engineering practices from industry are also used to ensure correct and maintainable code, including style, unit and integration tests, continuous integration and load testing, code reviews, and distributed version control. The software framework and the simulation and reconstruction capabilities are described.

Keywords: MICE; Ionization Cooling; Software; Reconstruction; Simulation

[1]Corresponding author.

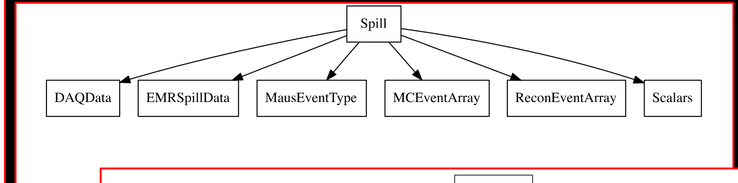




**Figure 4**. T

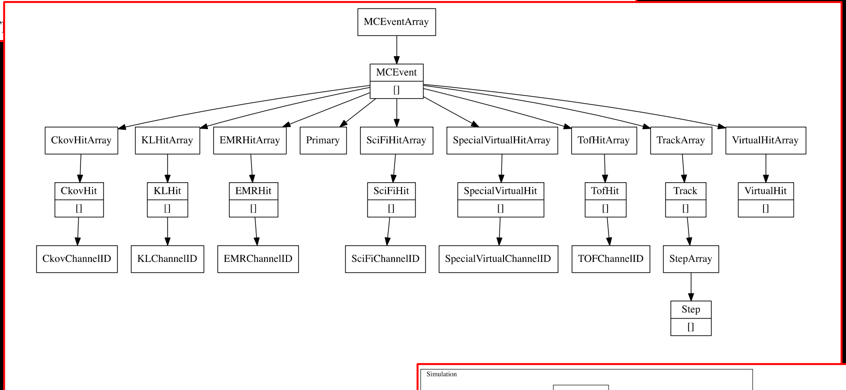
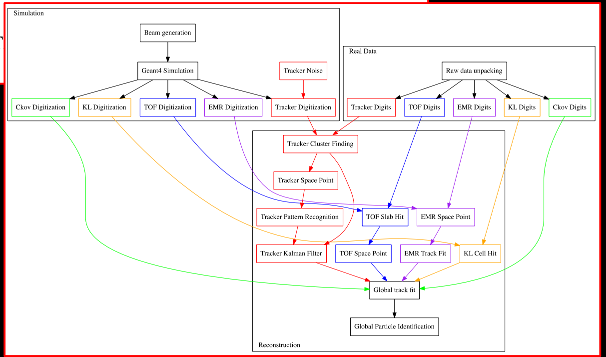




**Figure 5**. The MAUS data structure for MC events. T
indicates that child objects are array items.



# Emittance paper: [RAL-P-2018-005; arXiv:1812:02674]

- Submitted to JINST by Durga Rajaram



# First particle-by-particle measurement of emittance in the Muon Ionization Cooling Experiment

MICE collaboration

The Muon Ionization Cooling Experiment (MICE) collaboration seeks to demonstrate the feasibility of ionization cooling, the technique by which it is proposed to cool the muon beam at a future neutrino factory or muon collider. The emittance is measured from an ensemble of muons assembled from those that pass through the experiment. A pure muon ensemble is selected using a particle-identification system that can reject efficiently both pions and electrons. The position and momentum of each muon are measured using a high-precision scintillating-fibre tracker in a 4 T solenoidal magnetic field. This paper presents the techniques used to reconstruct the phase-space distributions and reports the first particle-by-particle measurement of the emittance of the MICE Muon Beam as a function of muon-beam momentum.

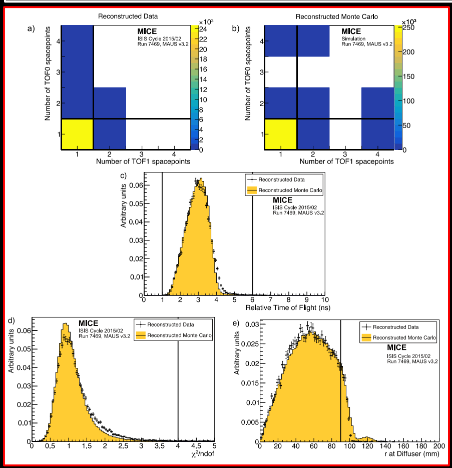


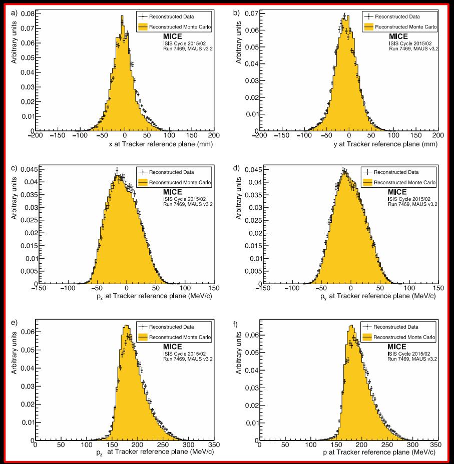
## 1 Introduction

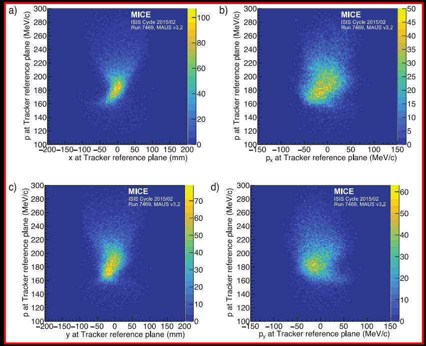
Stored muon beams have been proposed as the source of neutrinos at a neutrino factory [1, 2] and as the means to deliver multi-TeV lepton-antilepton collisions at a muon collider [3, 4]. In such facilities the muon beam is produced from the decay of pions generated by a high-power proton beam striking a target. The tertiary muon beam occupies a large volume in phase space. To optimise the muon yield for a neutrino factory, and luminosity for a muon collider, while maintaining a suitably small aperture in the muon-acceleration system requires that the muon beam be 'cooled' (i.e., its phase-space volume reduced) prior to acceleration. An alternative approach to the production of low-emittance muon beams through the capture of $\mu^+\mu^-$ pairs close to threshold in electron–positron annihilation has recently been proposed [5]. To realise the luminosity required for a muon collider using this scheme requires the substantial challenges presented by the accumulation and acceleration of the intense positron beam, the high-power muon-production target, and the muon-capture systems to be addressed.

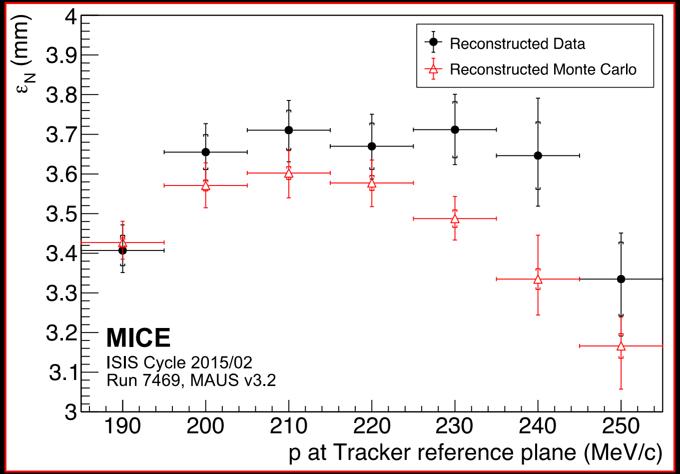
A muon is short-lived, with a lifetime of 2.2 $\mu$s in its rest frame. Beam manipulation at low energy ($\leq$ 1 GeV) must be carried out rapidly. Four cooling techniques are in use at particle accelerators: synchrotron-radiation cooling [6]; laser cooling [7, 8, 9]; stochastic cooling [10]; and electron cooling [11]. In each case, the time taken to cool the beam is long compared to the muon lifetime. In contrast, ionization cooling is a process that occurs on a short timescale. A muon beam passes through a material (the absorber), loses energy, and is then re-accelerated. This cools the beam efficiently with modest decay losses. Ionization cooling is therefore the technique by which it is proposed to increase the number of particles within the downstream acceptance for a neutrino factory, and the phase-space density for a muon collider [12, 13, 14]. This technique has never been demonstrated experimentally and such a demonstration is essential for the development of future high-brightness muon accelerators or intense muon facilities.

The international Muon Ionization Cooling Experiment (MICE) has been designed [15] to perform a full demonstration of transverse ionization cooling. Intensity effects are negligible for most of the cooling channels conceived for the neutrino factory or muon collider [16]. This allows the MICE experiment to record muon trajectories one particle at a time. The MICE collaboration has constructed two solenoidal spectrometers, one placed upstream, the other downstream, of the cooling cell. An ensemble of muon trajectories is assembled offline, selecting an initial distribution based on quantities measured in the upstream particle-identification



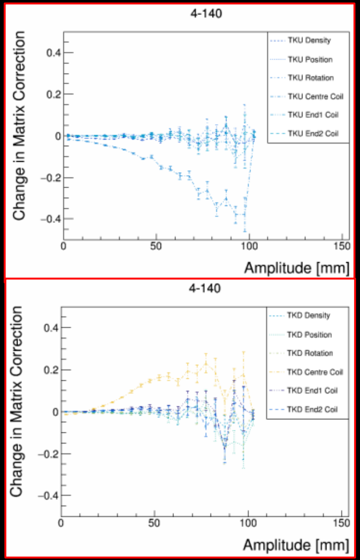



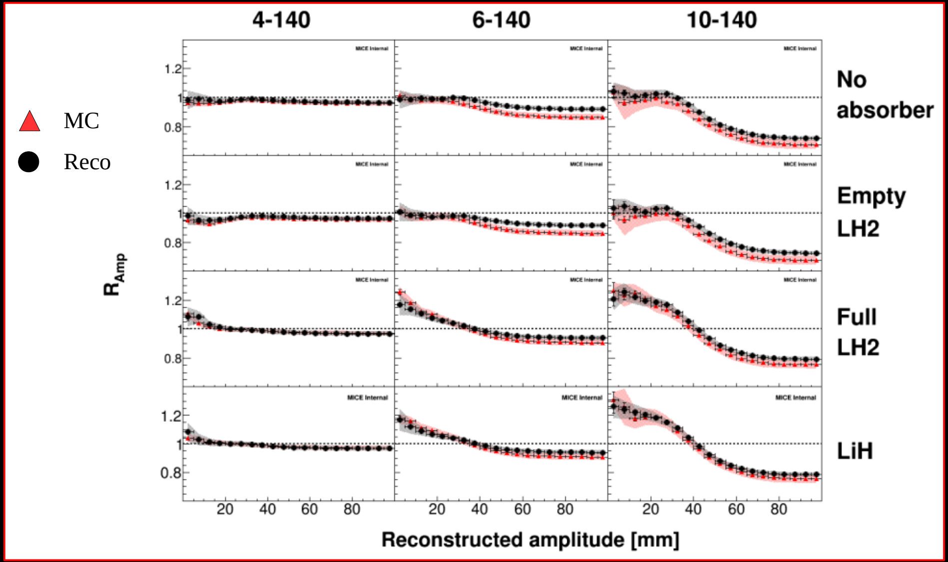
Spokesman's introduction

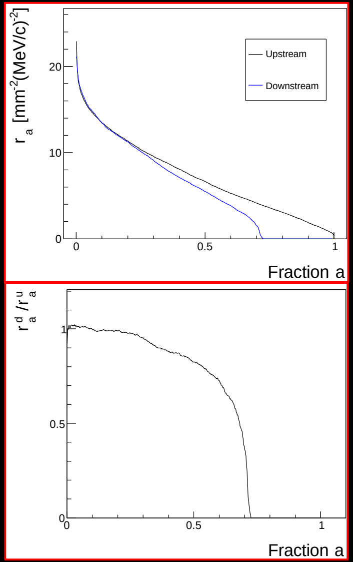
# ANALYSIS UPDATE AND PAPER PLANNING

# Amplitude evolution

- Chris Rogers and Francois Drielsma:




- Status of progress through referee process:
  - 3 referees’ meetings to date:
    - Focus now moving to *NATURE* paper and revised MICE Note
  - 4$^{th}$ referees meeting at/around CM54

# Publication planning

| | | 09-Jan-19 | v12 | 2019 refresh |
|---|---|---|---|---|
| **Title** | **Contact** | **Target date** | | **Comments** |
| | | **Preliminary** | **Final** | **Jan-19** |
| | | | | |
| Phase-space density/emittance evolution; rapid communication | C. Rogers | Apr18 w/s | Apr19 | Looking for date for 3rd referees meeting before end Jan19 |
| Measurement of multiple Coulomb scattering of muons in lithium hydride | J. Nugent | Jun18; CM51 | Apr19 | Unfolding issues; pick up now that JN is back from Japan |
| Performance of the MICE diagnostic systems | P. Franchini | Feb19; CM53 | | Almost complete draft |
| Phase-space density/emittance evolution review paper | C. Hunt | TBD | | Analysis now advancing |
| | | | | |
| | | | | |
| Phase-space density/KDE/6D-emittance evolution | C. Brown | TBD | | Thesis published on initial analysis; taken over by C.Brown |
| Measurement of multiple Coulomb scattering of muons in LH2 | J. Nugent | TBD | | Awaits completion of LiH paper |
| Field-on measurement of multiple Coulomb scattering | A. Young | TBD | | Analysis underway |
| Beam-based alignment | TBD | TBD | | |
| | | | | |
| | | | | |
| Direct measurement of emittance using the MICE scintillating-fibre tracker | V. Blackmore | | Jun18, CM51 | Submitted to EU J C; awaiting referees comments |
| The MICE Analysis and User Software framework | D. Rajaram | May18 w/s | Jun18, CM51 | RAL-P-2018-007; 1812.02674; submission to JINST in progress |

Spokesman's introduction

# UPCOMING MEETINGS

# MICE CM53

21-22 February 2019
Other Institutes
Europe/London timezone

Search...

- Overview
- Timetable
- Participant List

**MICE Admin**

miceadmin@stfc.ac.uk
+44 1235 445509

The 53rd Muon Ionization Cooling Experiment (MICE) Collaboration Meeting will be held at the Rutherford Appleton Laboratory on Thursday 21st and Friday 22nd February 2019.

The MICE Analysis will preceed this and will be held on the 19th and 20th February 2019 in the PPD Meeting Room, R1 2nd Floor.

**Registration: £45** **Collaboration Dinner: £35**

**Payment method: Overseas attendees cash only**

**Starts** 21 Feb 2019, 08:00
**Ends** 22 Feb 2019, 17:00
Europe/London

Other Institutes
Conference Rooms 12 and 13 Building R68
STFC, Rutherford Appleton Laboratory
Harwell Oxford Campus
Chilton
Oxfordshire OX11 0QX UK

www.stfc.ac.uk

Attendees from outside of the UK please bring cash to pay for CM53 as there are no electronic payment facilities.

***Phone conference information:***

The usual MICE phone-conference connection will be used. Please see:

**MICE phone bridge**