Spokesman's introduction

K. Long, 16 May, 2019

Contents

- Publication update
- Analysis update and paper planning
- Outreach to go along with Nature paper submission
- Muon collider and nuSTORM @ ESPPU Granada
- Upcoming meetings

Spokesman's introduction

PUBLICATION UPDATE

Published by IOP Publishing for Sissa Medialab

Received: *February 1, 2019*
Revised: *March 26, 2019*
Accepted: *April 15, 2019*
Published: *April 30, 2019*

Muon Accelerators for Particle Physics — MUON

MAUS: the MICE analysis user software

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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

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https://doi.org/10.1088/1748-0221/14/04/T04005

MAUS paper: [RAL-P-2018-007; arXiv:1812:02674, JINST 14 T04005]

https://doi.org/10.1088/1748-0221/14/04/T04005

- ***Published*** by JINST [Durga Rajaram];

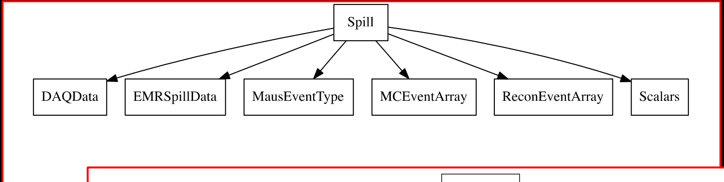


Figure 4. T

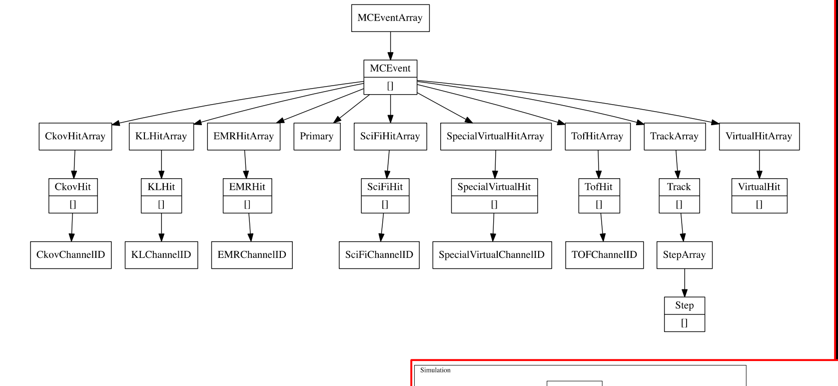
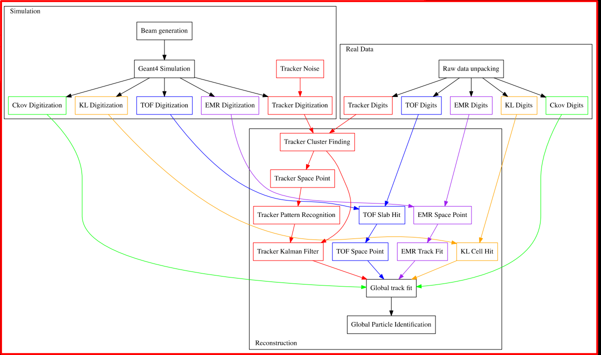


Figure 5. The MAUS data structure for MC events. T
indicates that child objects are array items.



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ANALYSIS UPDATE AND PAPER PLANNING

Amplitude evolution

- Chris Rogers and Francois Drielsma:

More in moment from CR

May 15, 2019 Muon Ionization Cooling Experiment Version 1.1

First demonstration of ionization cooling using the Muon Ionization Cooling Experiment

MICE collaboration

Muon beams of energy and power comparable to state-of-the-art electron, proton and ion accelerators have not yet been realised. Such beams have the potential to carry the search for new phenomena in lepton-antilepton collisions to extremely high energy and provide uniquely well-characterised neutrino beams. A muon beam may be created through the decay of pions produced in the interaction of a proton beam with a target. To produce a high-brightness beam from such a source requires that the phase-space volume occupied by the muons be reduced (cooled). Ionization cooling is the novel technique by which it is proposed to cool the beam. The Muon Ionization Cooling Experiment collaboration has constructed a section of an ionization cooling cell and used it to provide the first observation of ionization cooling. We present these pioneering measurements.

Fundamental insights into the structure of matter and the nature of its elementary constituents have been achieved by using beams of charged particles. The use of time-varying electromagnetic fields to produce sustained acceleration was pioneered in the 1930s [1–6]. Since then, high energy and high brightness particle accelerators have delivered electron, proton, and ion beams for applications that range from the search for new phenomena in the interactions of quarks and leptons, to the study of nuclear physics, materials science, and biology.

Muon beams are created using a proton beam striking a target to produce a secondary beam of mesons. The mesons decay into muons which are captured to produce a tertiary muon beam. Electromagnetic beam-line elements are used to capture and transport the muons. The energy of the muon beam is limited by the energy of the primary proton beam and the intensity is limited by the efficiency with which muons are accepted into the transport channel. The maximum energy and brightness of such muon beams falls short of that which has been achieved in electron and proton beams.

Accelerated high-brightness muon beams have been proposed as a source to provide neutrinos at a neutrino factory and to deliver multi-TeV lepton-antilepton collisions at a muon collider [7–10]. These proposals exploit the proton-driven muon-beam production scheme outlined above. The tertiary muon-beam phase space must be compressed (cooled) before it is accelerated and stored. 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 been proposed [11].

Four cooling techniques are in use at particle accelerators: synchrotron-radiation cooling [12]; laser cooling [13–15]; stochastic cooling [16]; and electron cooling [17]. In each case, the time taken to cool the beam is long compared to the 2.2 μs muon lifetime at rest. Frictional cooling of muons, in which muons are electrostatically accelerated through an absorbing medium at energies significantly below an MeV, has also been demonstrated [18–21].

Ionization cooling occurs when a suitably prepared beam passes through an appropriate material and loses energy through ionization. Energy lost by the beam can be restored through acceleration. Repeatedly passing the muon beam through material and re-accelerating causes the ionization-cooling effect to build up on a timescale much shorter that the muon lifetime. Ionization cooling is the technique by which it is proposed to compress the muon-beam phase space for a neutrino factory and muon collider [22, 23]. Acceleration of a muon beam in a radio-frequency accelerator was demonstrated for the first time in 2017 [24] but ionization cooling has never been demonstrated despite significant advances in cooling-channel design [25–27]. Such a demonstration is important for the development of future high-brightness muon accelerators.

- Status of progress through referee process:
  - 6 referees' meetings to date:
    - Now working on:
      - Full reprocessing of data and MC with latest MAUS release
      - Method (supplementary material) section and update of MICE Note
  - 7th referees meeting tomorrow

Publication planning

Title	Contact	Target date Preliminary	Final	Comments Jan-19
Phase-space density/emittance evolution; rapid communication	C. Rogers	Apr18 w/s	Apr19	4th referees meeting before around CM53 (21, 22Feb19, RAL)
Measurement of multiple Coulomb scattering of muons in lithium hydride	J. Nugent	Jun18; CM51	Apr19	Unfolding issues; perhaps resolved; CM53, 21,22Feb19, RAL
Performance of the MICE diagnostic systems	P. Franchini	Feb19; CM53		Almost complete draft
Phase-space density/emittance evolution review paper	C. Hunt	TBD		Full analysis chain in place.
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

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OUT-REACH

to go along with NATURE-paper submission

Outreach to go alongside Nature paper

- Press release:
  - STFC lead, coordinate through existing lab network
    - Need to coordinate at institute level through CB
- Event at RAL/DL:
  - Peer-group meeting:
    - MICE results, impact on muon collider/neutrino factory
    - nuSTORM
  - Early-evening public lecture
- Film with Science Animated
- News/article in, e.g., CERN Courier, Symmetry
  - Perhaps also newspaper

Memo to STFC in preparation

P.Kyberd, KL, C.Rogers

European Particle Physics Strategy Update 2018 – 2020

Home | About | Process | Submitted input | Organisation | Resources

- Call for Input
- Open Symposium
- Drafting Session
- Received Inputs
- Briefing Book

Open Symposium

The Open Symposium will take place in **Granada, Spain, from May 13 to 16, 2019**.

Registration is open.

CERN Council Open Symposium on the Update of

European Strategy for Particle Physics

13-16 May 2019 - Granada, Spain

Spokesman's introduction

Muon collider and nuSTORM in Granada

European Strategy Update

Accelerators summary

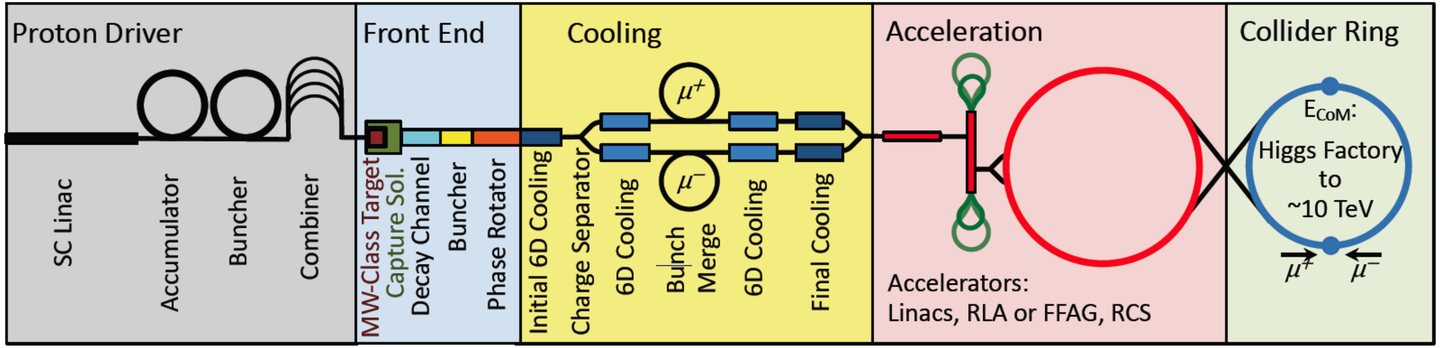
Caterina Biscari and Lenny Rivkin, Phil Burrows, Frank Zimmermann

Open Symposium towards updating the European Strategy for Particle Physics

May 13-16, 2019, Granada, Spain

Proton-driven Muon Collider Concept

Muon-based technology represents a unique opportunity for the future of high energy physics research: the multi-TeV energy domain exploration.



Short, intense proton bunches to produce hadronic showers

Pions decay into muons that can be captured

Muon are captured, bunched and then cooled

Acceleration to collision energy

Collisio
n

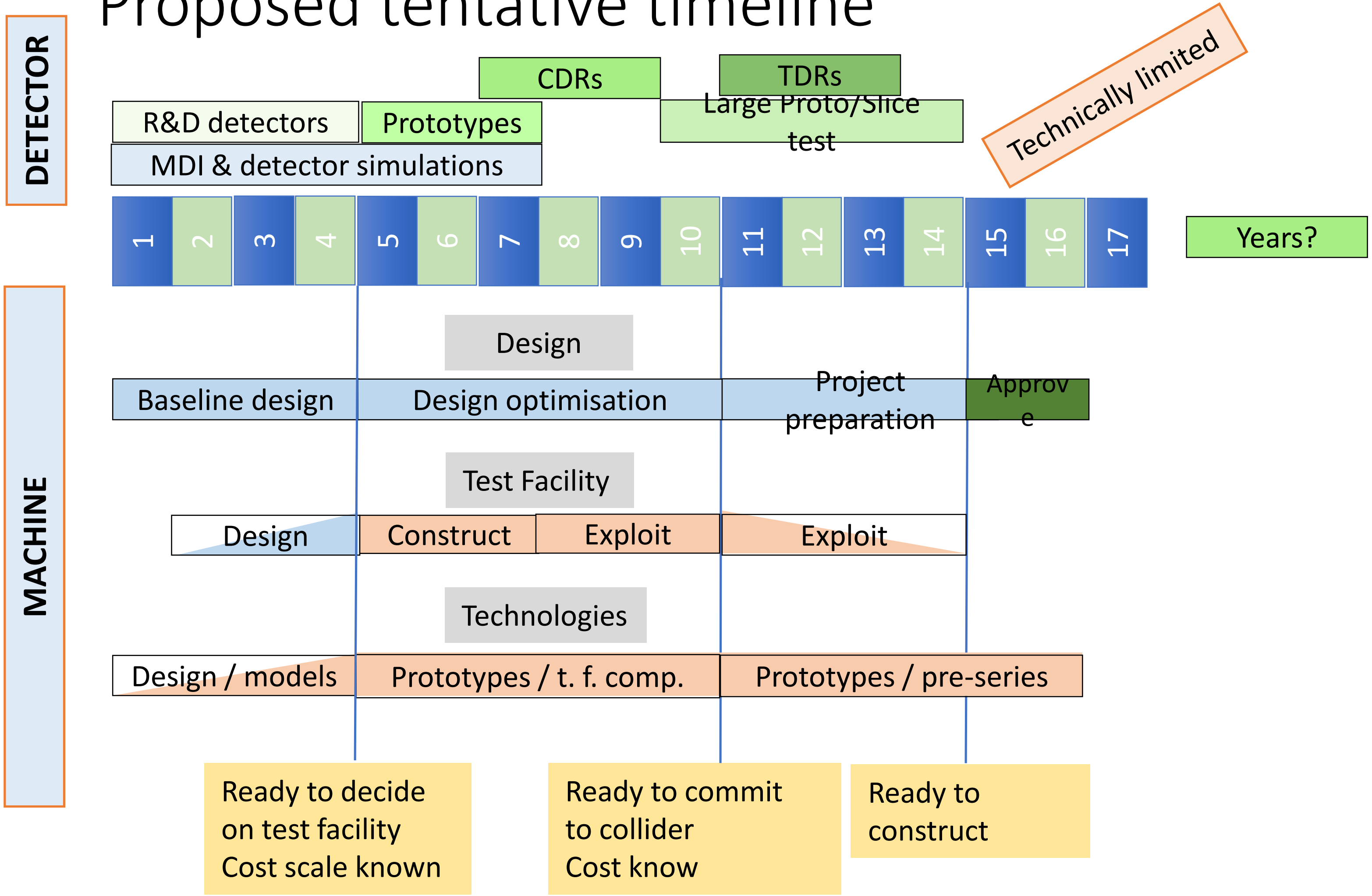
Answers to the Key Questions

- **Can muon colliders at this moment be considered for the next project?**
  - Enormous progress in the proton driven scheme and new ideas emerged on positron one
  - But at this moment not mature enough for a CDR, need a careful design study done with a coordinate international effort

- **Is it worthwhile to do muon collider R&D?**
  - Yes, it promises the potential to go to very high energy
  - It may be the best option for very high lepton collider energies, beyond 3 TeV
  - It has strong synergies with other projects, e.g. magnet and RF development
  - Has synergies with other physics experiments
  - **Should not miss this opportunity?**

- **What needs to be done?**
  - Muon production and cooling is key => A new test facility is required.
    - Seek/exploit synergy with physics exploitation of test facility (e.g. nuSTORM)
  - A conceptual design of the collider has to be made
  - Many components need R&D, e.g. fast ramping magnets, background in the detector
  - Site-dependent studies to understand if existing infrastructure can be used
    - limitations of existing tunnels, e.g. radiation issues
    - optimum use of existing accelerators, e.g. as proton source
  - **R&D in a strongly coordinated global effort**

Proposed tentative timeline



D. Schulte

Neutrino Physics
(accelerator and non-accelerator)
summary of the session

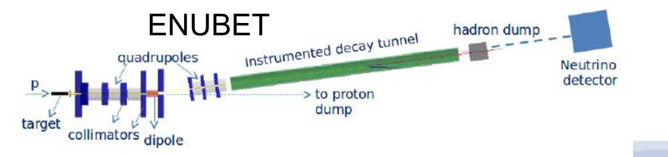
Conveners: Stan Bentvelsen, Marco Zito

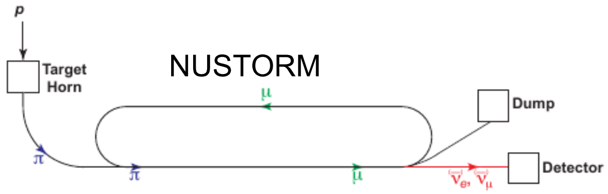
ESPPU Open Symposium Granada
May 16, 2019

In the session we also covered astroparticle physics

Precision program in Europe

- Squeezing every bit of information out of the future experiments requires a complementary program (special rôle for Europe) to
  - Measure hadroproduction for the neutrino flux prediction (NA61)
  - Understand the neutrino-nucleus cross-section at the % level, both theoretically and with new facilities (Enubet, Nustorm)
  - Collaboration to be developed with nuclear physicists
- Next-to-next generation facilities (ESSnuSB, …) are also under study





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Neutrino oscillations

- Vibrant program (DUNE, Hyper-Kamiokande, JUNO, ORCA) to fully measure the PMNS mixing matrix and especially the Mass Ordering and the CP violation phase delta, with strong European contribution. Perceived by the community as a priority.
- Neutrino experiments need cutting-edge detectors and % precision on the flux and cross-sections: leading rôle for Europe (NA61, Neutrino Platform). New facilities currently under study.
- Long term future for high precision LBL measurements with new techniques. Time to prepare for it !

Comments

- An excellent outcome …
- Opportunity:
  - Muon collider R&D developed in collaboration with CERN
  - nuSTORM as centrepiece:
    - MC R&D platform, serving 6D cooling experiment
    - Science programme:
      - Neutrino scattering
      - Sterile neutrinos
- Europeans:
  - Seek to make case to your representatives!

Spokesman's introduction

UPCOMING MEETINGS

Upcoming meetings

- **CM54:**
  - **27/28 June 2019 at RAL**