

# Muon Accelerators for Particle Physics Introduction and Working Group Plans

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Proton Accelerators  
for

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# Motivations

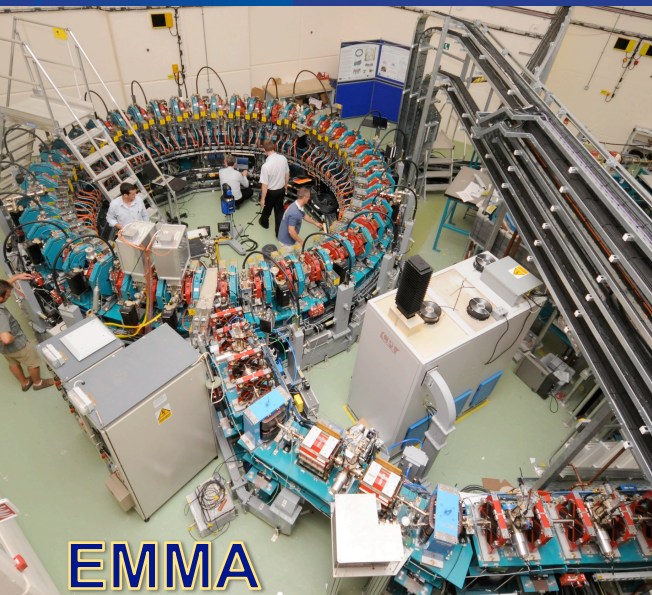
- The muon – an elementary charged lepton:
  - 200 times heavier than the electron
  - 2.2  $\mu\text{s}$  lifetime at rest
- Physics potential for the HEP community
  - Offers a large coupling to the “Higgs mechanism”
  - Can be used in tests of Lepton Flavor Violation
  - The anomalous magnetic moment may offer hints of new physics (g-2)
  - $\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$   
 $\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$  } can provide equal fractions of electron and muon neutrinos at high intensity for studies of neutrino oscillations – the Neutrino Factory concept
  - As with an electron-positron collider, a muon collider would offer a precision probe of fundamental interactions – in contrast to hadron colliders

# Muon Accelerator Physics

- The large muon mass strongly suppresses the emission of synchrotron radiation
  - ⇒ Muons can be accelerated and stored using rings at much higher energy than electrons
  - ⇒ Colliding beams can be of higher quality due to reduced beamstrahlung
- The short muon lifetime has impacts as well
  - The acceleration and storage time of a muon beam is limited
  - In a collider configuration, a new class of decay backgrounds must be dealt with
- Muon beams must be produced as tertiary beams  $p \rightarrow \pi \rightarrow \mu$ 
  - Offers key accelerator challenges...

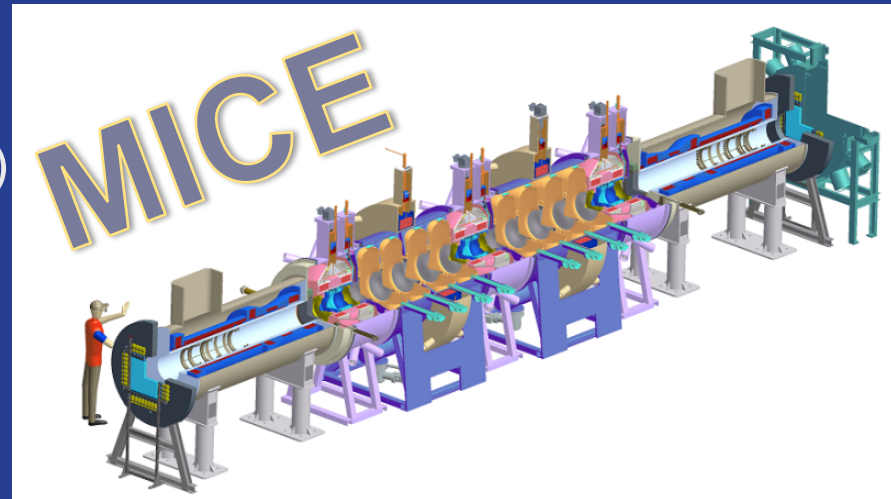
# Muon Accelerators I

- Muons require an ultrafast accelerator chain
  - ⇒ *Beyond the capability of most machines*
- Several solutions for a muon acceleration scheme have been proposed:
  - Superconducting Linacs
  - Recirculating Linear Accelerators (RLAs)
    - eg, CEBAF at Jefferson Lab
  - Fixed-Field Alternating-Gradient (FFAG) Machines
    - EMMA at Daresbury Lab is a test of the most promising non-scaling type
  - Rapid Cycling Synchrotrons (RCS/VRCS)
  - Hybrid Machines



# Muon Accelerators II

- Tertiary production of muon beams  $\Rightarrow$ 
  - The initial beam emittance is intrinsically quite high
  - A cooling mechanism is required, but radiation damping is not effective
- Muon Cooling Effort
  - Ionization Cooling is the targeted method
    - $dE/dx$  energy loss in materials
    - RF to replace longitudinal momentum component
    - Process must be carried out while preserving a viable lattice to control the beam
  - The Muon Ionization Cooling Experiment (MICE) at RAL is targeted at validating key elements of the process



# Muon Accelerators III

- A Viable Cooling Channel requires
  - Strong focusing and a large accelerating gradient to compensate for the energy loss in absorbers
    - ⇒ Large B- and E-fields superimposed
- Operation of RF cavities in high magnetic fields is a necessary element for muon cooling
  - Control of RF breakdown in the presence of high magnetic fields is necessary
  - The MuCool Test Area (MTA) at Fermilab is actively investigating operation of RF cavities in the relevant regimes
  - Development of concepts to mitigate this problem are being actively pursued



# A Muon Accelerator Road Map

Currently, there exist muon beam lines for pure and applied science (CERN, FNAL, PSI, RAL, ...)

- ⇒ Next generation beam lines (higher intensity and beam quality) have been proposed (COMET, Mu2e)
- ⇒ Muon storage rings could provide a subsequent generation of applications (VLENF, PRISM)
- ⇒ A Neutrino Factory would produce an intense, high-quality neutrino beam for oscillation physics
  - Muon acceleration and cooling required
- ⇒ A Muon Collider would provide an energy frontier lepton machine
  - A more advanced muon acceleration, cooling scheme, and collider ring required

# Collaboration Basis Between the UK & US

- Mu2e and COMET/PRISM: search for muon to electron conversion
- g-2: measure the anomalous magnetic moment of the muon
- MICE: demonstrate the principles of 4D muon ionisation cooling
- MTA: explore the operation of RF cavities in strong magnetic fields
- EMMA: explore the design and operation of a non-scaling FFAG
- IDS-NF: prepare the International Design Study for a Neutrino Factory
- MAP: support the NF design effort and Muon Collider R&D activities

# Working Group Goals

- Review the current status of the projects and ongoing programmes
  - Present future directions and new ideas
  - Underline the synergies between the UK and the US programmes
  - Discuss the possible synergies and a strategy to strengthen the collaborative efforts
- ⇒ *Target areas where enhanced collaboration can enable significant strides forward*

# Parallel Session Agenda – Day 1

- First day targeted at reviewing ongoing efforts and identifying potential areas of additional collaboration:
- ***Near-term Efforts***
  - Mu2e and g-2 at FNAL – E. Prebys
  - COMET – Y. Uchida
- ***Mid-term Future Efforts***
  - VLENF – A. Bross
  - PRISM – J. Pasternak
  - Next Generation Mu2e and g-2 at FNAL – V. Lebedev
- ***Long-term Future Efforts***
  - IDS-NF – N. Bliss
  - Muon Collider Options – S. Geer
- ***Key R&D Demonstrations***
  - MICE 4D Cooling Program – P. Soler
  - EMMA FFAG Demonstration – J. Pasternak (+plenary by S. Machida)
  - 6D Cooling Options – R. Palmer

+ Discussions

# Parallel Session Agenda – Day 2

- Second day targeted at exploring the synergies between the UK and US programmes and preparing the working group recommendations:
- ***Review of Potential Synergies in the UK-US Programmes***
  - UK Perspective – A. Seryi
  - US Perspective – M. Zisman
- ***Discussion***
- ***Documentation***

# Summary

- The speakers have been asked to flag synergies that they see which could be pursued to strengthen the UK-US collaboration
- We hope that the working group will find the agenda stimulating!
- Two talks are explicitly targeted at identifying synergies in the programmes from both the US and UK perspective (Saturday morning: by M. Zisman and A. Seryi)
- The working group will provide a written summary

# Summary

- The speakers have been asked to flag synergies that they see which could be pursued to strengthen the UK-US collaboration.
- The agenda looks very interesting.
- Two talks are explicitly targeted at identifying synergies in the programmes from both the US and UK perspective (Saturday morning: by M. Zisman and A. Seryi).
- The working group will prepare a written summary.



## Muon Collider Concept

*The future for muon accelerators holds great promise! Our working group task at this workshop is to establish the basis for a fruitful and expanded UK-US collaboration. Our long-term goal is to take another step towards enabling a program that will fully exploit this promise!*