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Science & Technology Facilities Council ISIS

Initial objectives for nuSTORM and Neutrino Factory studies using a short proton pulse option at ESS

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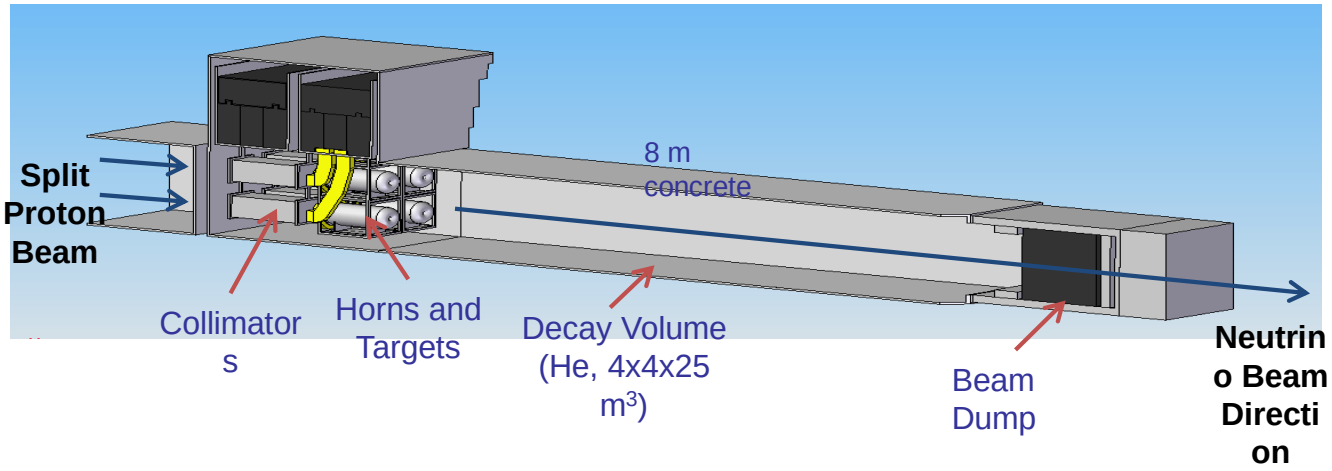
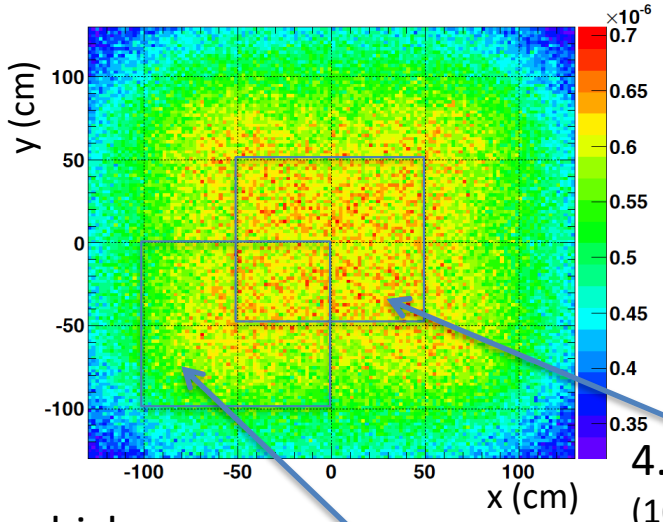
High Intensity Frontier Physics at ESS planning meeting, 29/05/2020

Motivation

- Creation of the ESS facility opens a fantastic opportunity to make a novel high intensity muon source with applications to:
  - Neutrino physics (nuSTORM, SB, the Neutrino Factory)
  - Muon physics (rare muon physics)
  - Energy Frontier (the Muon Collider)
  - Applied science (muon tomography)
  - ….
- We should try to make it happen!

ESSvSB based muon source



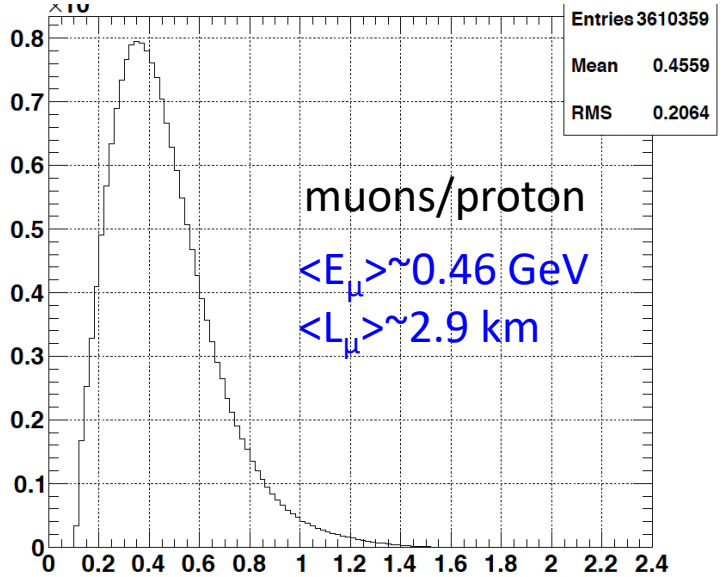


muons at the level of the beam dump (per proton)

4.2×10^{20} μ/year
(16.3×10^{20} for 4 m^2)

4.1×10^{20} μ/year

- Beam beyond ESSvSB Beam Dump contains a high flux of pions/muons, which can be used for experiments
- **Objective:**
  - Design on a conceptual level a high acceptance (transverse and longitudinal) capture system for the beam originating from the ESSvSB Beam Dump
    - Is it possible and practical to provide the beam for more than one experiment as the beam is very large and very intense?
      Can we feed for example a nuSTORM-like neutrino experiment and a next generation muon to electron conversion experiment based on a muon stored in a ring (like PRISM)?
    - Can we use ionization cooling to improve the beam quality?



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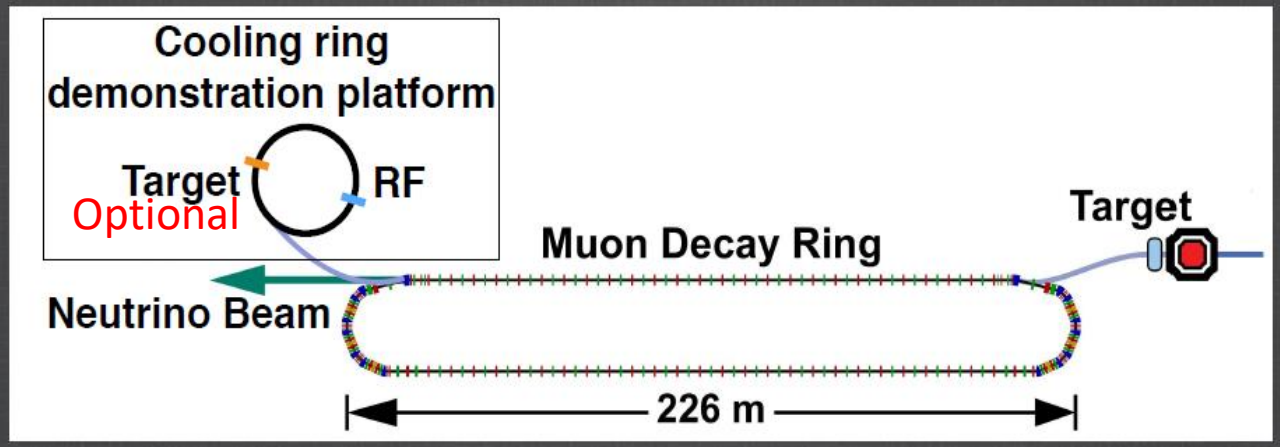
nuSTORM Overview



1. Facility to provide a muon beam for precision neutrino interaction physics
2. Study of sterile neutrinos
3. Accelerator & Detector technology test bed

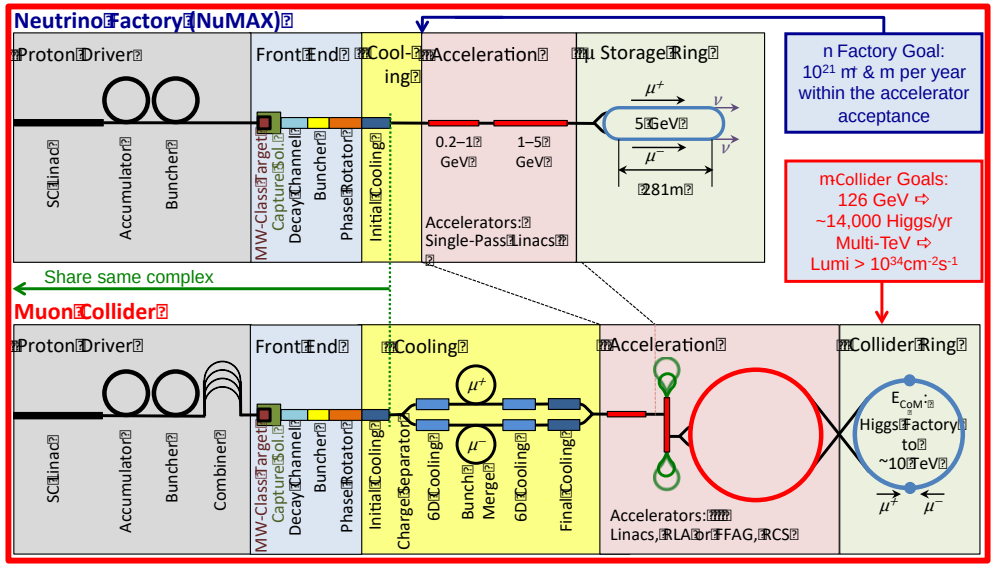
$$\mu^- \longrightarrow e^- + \bar{\nu}_e + \nu_\mu$$
$$\mu^+ \longrightarrow e^+ + \nu_e + \bar{\nu}_\mu$$
$$\pi^- \longrightarrow \mu^- + \bar{\nu}_\mu$$
$$\pi^+ \longrightarrow \mu^+ + \nu_\mu$$

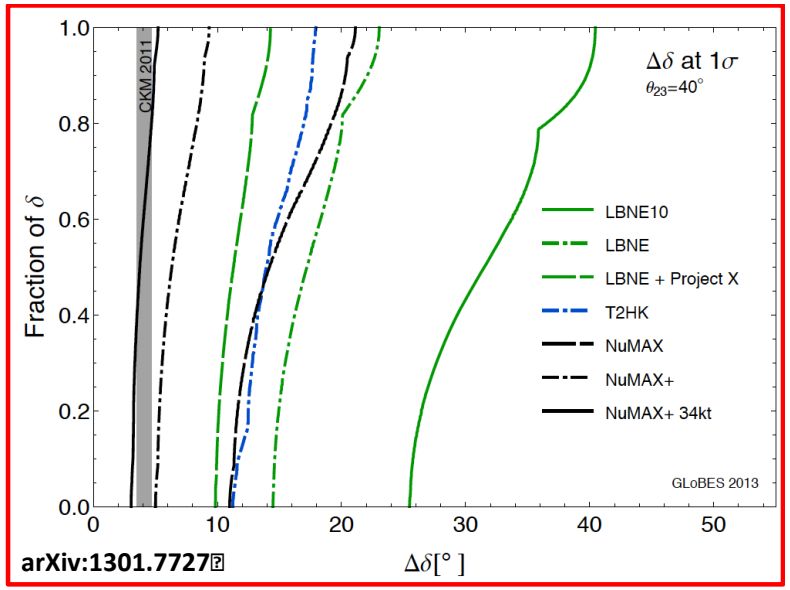
- Potential for intense low energy muon beam
- Enables μ decay ring R&D (instrumentation) & technology demonstration platform
- Provides a neutrino Detector Test Facility
- Test bed for a new type of conventional neutrino beam

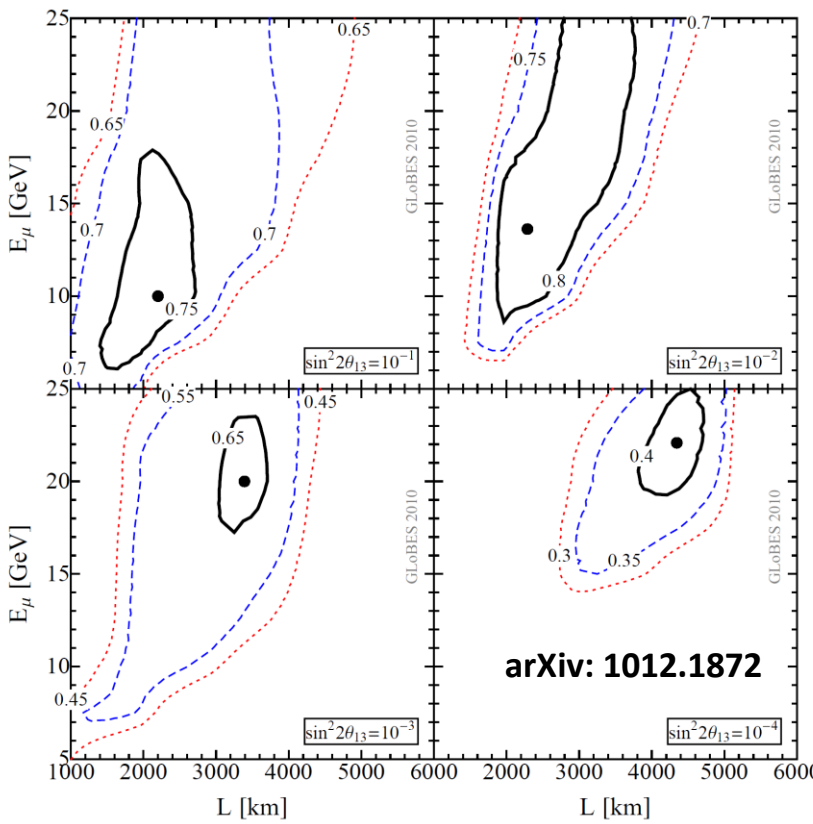
Objectives:

- Further explore physics potentials of a low energy version of nuSTORM
- Adopt the nuSTORM design to ESS parameters
  - Explore the use of stochastic injection
  - Seek the use of ionization cooling
  - Plan for near detectors
- Investigate a feasibility of a scenario with a dedicated target optimised for pion capture feeding the nuSTORM ring

Exploring synergy between Muon Collider and Neutrino Factory







- The Neutrino Factory has long been considered an obvious intermediate step towards a Muon Collider, or a Neutrino Factory is an obvious parallel exploitation of the muon source created for the Muon Collider
  - However optimisation studies pointed to a need for a baseline beyond ~500km using MIND detector.
- **Objectives:**
  - Identify a location for a far detector for a potential Neutrino Factory based on ESS as a proton source and a MIND-type detector (with a baseline length of ~1500km)
  - Consider optimisations based on alternative detection technologies