Neutrinos from STORed Muons: νSTORM

A New Paradym for the Study of ν Interactions and Short-baseline Oscillation Physics.

P. Kyberd,[1] D.R. Smith,[1] L. Coney,[2] S. Pascoli,[3] C. Ankenbrandt,[4] S.J. Brice,[4] A.D. Bross[a],[4] H. Cease,[4] J. Kopp,[4] N. Mokhov,[4] J. Morfin,[4] D. Neuffer,[4] M. Popovic,[4] P. Rubinov,[4] S. Striganov,[4] A. Blondel,[5] A. Bravar,[5] E. Noah,[5] R. Bayes,[6] F.J.P. Soler,[6] A. Dobbs,[7] K. Long,[7] J. Pasternak,[7] E. Santos,[7] M.O. Wascko,[7] S.K. Agarwalla,[8] S.A. Bogacz,[9] Y. Mori,[10] J.B. Lagrange,[10] A. de Gouvêa,[11] Y. Kuno,[12] A. Sato,[12] V. Blackmore,[13] J. Cobb,[13] C. D. Tunnell,[13] J.M. Link,[14] P. Huber,[14] and W. Winter[15]

[1] *Brunel University*

[2] *University of California, Riverside*

[3] *Institute for Particle Physics Phenomenology, Durham University*

[4] *Fermi National Accelerator Laboratory*

[5] *University of Geneva*

[6] *University of Glasgow*

[7] *Imperial College London*

[8] *Instituto de Fisica Corpuscular, CSIC and Universidad de Valencia*

[9] *Thomas Jefferson National Accelerator Facility*

[10] *Kyoto University*

[11] *Northwestern University*

[12] *Osaka University*

[13] *Oxford University, Subdepartment of Particle Physics*

[14] *Center for Neutrino Physics, Virginia Polytechnic Institute and State University*

[15] *Institut für theoretische Physik und Astrophysik, Universität Würzburg*

(Dated: August 10, 2012)

[a] Corresponding author: bross@fnal.gov

I. OVERVIEW

The idea of using a muon storage ring to produce a high-energy ($\simeq$ 50 GeV) neutrino beam for experiments was first discussed by Koshkarev [1] in 1974. A detailed description of a muon storage ring for neutrino oscillation experiments was first produced by Neuffer [2] in 1980. In his paper, Neuffer studied muon decay rings with E_μ of 8, 4.5 and 1.5 GeV. With his 4.5 GeV ring design, he achieved a figure of merit of $\simeq 6 \times 10^9$ useful neutrinos per 3×10^{13} protons on target. The facility described here (νSTORM) is essentially the same facility proposed in 1980 and would utilize a 3-4 GeV/c muon storage ring to study eV-scale oscillation physics and, in addition, could add significantly to our understanding of ν_e and ν_μ cross sections. In particular the facility can:

1. address the large Δm^2 oscillation regime and make a major contribution to the study of sterile neutrinos,
2. make precision ν_e and $\bar{\nu}_e$ cross-section measurements,
3. provide a technology (μ decay ring) test demonstration and μ beam diagnostics test bed,
4. provide a precisely understood ν beam for detector studies.

The facility is the simplest implementation of the Neutrino Factory concept [3]. In our case, 60 GeV/c protons are used to produce pions off a conventional solid target. The pions are collected with a focusing device (horn or lithium lens) and are then transported to, and injected into, a storage ring. The pions that decay in the first straight of the ring can yield a muon that is captured in the ring. The circulating muons then subsequently decay into electrons and neutrinos. We are starting with a storage ring design that is optimized for 3.8 GeV/c muon momentum. This momentum was selected to maximize the physics reach for both oscillation and the cross section physics. See Fig. 1 for a schematic of the facility. Muon decay yields a neutrino beam of precisely known flavor content and energy. For example for positive muons: $\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$. In addition, if the circulating muon flux in the ring is measured accurately (with beam-current transformers, for example), then the neutrino beam flux is also accurately known. Near and far detectors are placed along the line of one of the straight sections of the racetrack decay ring. The near detector can be placed at 20-50 meters from the end of the straight. A near detector for disappearance measurements will be identical to the far detector, but only about one tenth the fiducial mass. It will require a μ catcher, however. Additional purpose-specific near detectors can also be located in the near hall and will measure neutrino-nucleon cross sections. νSTORM can provide the first precision measurements of ν_e and $\bar{\nu}_e$ cross sections which are important for future long-baseline experiments. A far detector at $\simeq$ 2000 m would study neutrino oscillation physics and would be capable of performing searches in both appearance and disappearance channels. The experiment will take advantage of the "golden channel" of oscillation appearance $\nu_e \rightarrow \nu_\mu$, where the resulting final state has a muon of the wrong-sign from interactions of the $\bar{\nu}_\mu$ in the beam. In the case of μ^+s stored in the ring, this would mean the observation of an event with a μ^-. This detector would need to be magnetized for the

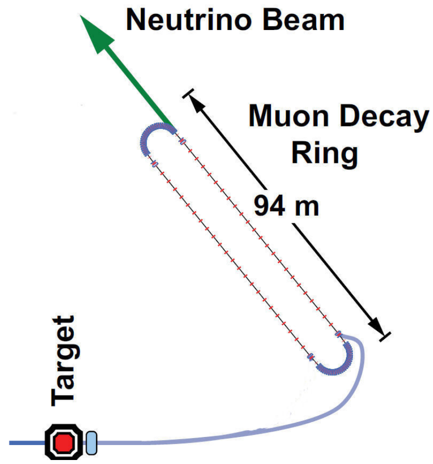

Figure 1. Schematic of the facility

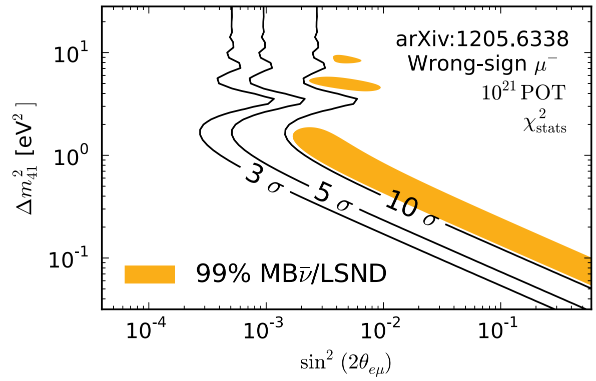

Figure 2. Contour in sterile ν parameter space associated with $\nu_e \to \nu_\mu$ (CPT invariant mode of LSND/MiniBooNE) appearance.

wrong-sign muon appearance channel, as is the case for the current baseline Neutrino Factory detector [4]. A number of possibilities for the far detector exist. However, a magnetized iron detector similar to that used in MINOS is likely to be the most straight forward approach for the far detector design. We believe that it will meet the performance requirements needed to reach our physics goals. For the purposes of the νSTORM oscillation physics, a detector inspired by MINOS, but with thinner plates and much larger excitation current (larger B field) is assumed. Based on an exposure of 10^{21} protons on target, we estimate that the facility will delivery $\simeq 2 \times 10^{18}$ useful μ decays. Our sensitivity to the CPT invariant mode of LSND/MiniBooNE is shown in Fig. 2. A letter of intent has recently been submitted to the Fermilab Physics Advisory Committee (Fermilab proposal P-1028) [5].

---

[1] D. G. Koshkarev, "Proposal for a Decay Ring to Produce Intense Secondary Particle Beams at the SPS," (1974), CERN/ISR-DI/74-62.

[2] D. Neuffer, "Design Considerations for a Muon Storage Ring," (1980), Telmark Conference on Neutrino Mass, Barger and Cline eds., Telmark, Wisconsin.

[3] S. Geer, Phys.Rev. **D57**, 6989 (1998), arXiv:hep-ph/9712290 [hep-ph].

[4] S. Choubey *et al.* (The IDS-NF collaboration), (2011), arXiv:1112.2853 [hep-ex].

[5] P. Kyberd *et al.*, arXiv.org: 1206.0294.