Long Baseline Neutrino Experiments and Underground Facilities

February 16, 2001

There have recently been several design studies of very high intensity neutrino beams at Fermilab, BNL, KEK and CERN. [1, 2, 3, 4]. Both muon storage rings (neutrino factories) and conventional hadron decay beams are being considered. The purpose of these high intensity beams is the study of neutrino oscillations over terrestrial distances of 100-10,000km, with emphasis on studies of the more subtle effects (CP violation, matter effects and θ_{13}) which should be observable in $\nu_\mu \leftrightarrow \nu_e$ transitions. One common realization in these studies is the need for very large neutrino detectors of order 100 kt fiducial mass at significant distances from accelerator facilities. Several of the detectors already proposed for a new underground facility are very similar to the detectors envisaged for such accelerator-based experiments. A cooperative effort between the accelerator neutrino physics community and the proponents of large detectors for astrophysical neutrinos could well eliminate the need to build separate detectors and result in significant cost savings. We are therefore writing this letter to indicate substantial support for an underground laboratory from a community which traditionally has not used such facilities.

A detector for accelerator based neutrino oscillation studies requires either excellent electron/π^0 separation (for a hadron-decay beam) or good hadron calorimetry and muon charge identification (for a muon-decay beam). Liquid argon detectors are promising candidates for low energy $\nu_\mu \to \nu_e$ experiments. If magnetic fields are added, these detectors as well as Cherenkov detectors with magnetic spectrometers, and large magnetized iron calorimeters are all strong candidate detectors for $\nu_e \to \nu_\mu$ detection at a neutrino factory.

The siting requirements for accelerator-based neutrino experiments are slightly different from but compatible with those of traditional underground experiments.

Overburden: Accelerator-based experiments have the advantage of a pulsed beam with known timing. For this reason, background rejection is easier than for astrophysical sources and a large overburden is not a requirement for such experiments.

Location: The optimal baseline for an accelerator-based experiment depends on the beam energy and the process one wishes to study. For beams of neutrinos from muon storage rings, the optimal baselines for studies of CP violation and matter effects are around 3000 km; shorter baselines require higher statistics to disentangle CP from matter effects. For studies using neutrinos from pion and kaon decays, electron detection considerations may make lower energies and hence shorter baselines as well as longer baselines suitable.

Summary:

Large fiducial mass neutrino detectors at an underground facility are of significant interest as detectors for intense neutrino beams. Many of the detectors being proposed for astrophysical neutrino physics and for proton decay can serve as detectors for accelerator based experiments with reasonable modifications. The siting of the underground facility does have some effect on the physics reach; locations either quite close to or very far away from an accelerator are favored. We strongly support construction of an underground research facility and hope to participate in one or more of the large detectors proposed.

References

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[2] D. Ayres *et al.* [Neutrino Factory and Muon Collider Collaboration], "Expression of interest for R+D towards a neutrino factory based on a storage ring and a muon collider," physics/9911009.

[3] A Long Baseline Neutrino Oscillation Experiment using the JHF 50 GeV Proton-Synchrotron and the Super-Kamiokande Detector, letter of intent, http://neutrino.kek.jp/jhfnu/loi/jhfnu_loi.pdf.

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