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LETTER OF INTENT TO PERFORM A NEUTRINO EXPERIMENT USING THE FERMILAB 8 GEV BOOSTER

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Motivation

Neutrino Oscillations:

A major motivation for this measurement is the hint of a signal that is presently observed in the Los Alamos experiment LSND. This experiment was designed to search for oscillations of the type $\overline{\nu_\mu} \rightarrow \overline{\nu_e}$ in the range l/E_ν of about one (l in meters, E_ν in MeV). The signal, if true, has a product of mixing times the mass dependent term of about one half percent. We expect, over the remaining data–collection time available, to obtain a statistical precision which will confirm or rule out the observation.

We expect to develop a proposal to Fermilab for a measurement using a neutrino beam derived from the Booster. The goal of the experiment is to measure a distribution of the transition rate $\nu_\mu \rightarrow \nu_e$ as a function of energy. This distribution will then yield a graph as a function of l/E_ν displaying the $\sin^2$ form characteristic of neutrino oscillations. The Booster has many advantages for this measurement. The neutrino energy is large enough for the cross section for quasi-elastic scattering of both ν_μ and ν_e to be near the asymptotic value. The energy, centered about 700 MeV, is low enough that the production of many inelastic channels is limited. The ν_e component of the beam can be limited by proper design of the decay region and by capitalizing on the lower K production cross section at the Booster energy. The experiment is expected to consist of two detectors, one close to the muon shield downstream of the decay region and one on the order of a kilometer away.

Nucleon Form Factors:

A second motivation for this experimental program is the study of nucleon form factors. Over the past several years, there has been some experimental indication that strange quarks play a surprisingly large role in determining the properties of the nucleon. While several new deep inelastic scattering experiments are now under construction to test these conclusions, a measurement of neutral current νp elastic scattering is a crucial component in our efforts to achieve a model–independent understanding of the strange quark contributions to the nucleon spin, mass and magnetic moment. An essential component of this study is a precise determination of the Q^2 dependence of the axial form factor from quasi-elastic scattering up to 1 GeV^2/c^2.

Experimental Overview

Beam:

Protons from the 8 GeV FNAL Booster can provide an outstanding neutrino source for these measurements. The mean neutrino energy of 0.7 GeV allows the LSND result to be checked (with entirely different experimental systematics) with a detector placed on site. The range of Q^2 accesible in νp elastic scattering extends high enough that the dipole mass terms are measurable with precision. The low duty factor of the Booster is also a crucial factor in the proposed experiment.

Filling the Main Injector requires less than 1/2 of the nominal capabilities of the Booster. Through a modification of the MI-10 injection station (for example), it would be possible to divert this otherwise unused capacity to a new low–energy neutrino facility. This facility would produce a neutrino flux sufficient to induce 2500 charged current events per hour in a closely positioned 200 ton detector. With a projected Booster live time of 9 to 11 months per year, this new facility would offer an unparalled opportunity for high precision neutrino physics.

Detectors:

The near detector has two functions. The first is to measure the ν flux by detecting the two body reactions $\nu_\mu + n \rightarrow \mu^- + p$ and $\nu_e + n \rightarrow e^- + p$. The principal energy measurement is through the angle and energy of the outgoing lepton. A Čerenkov detector with dilute scintillator seems attractive in this energy range but much detailed work needs to be done. A problem arises in containing the higher energy leptons in the detector without specifying a detector that is prohibitively expensive, but some limited segmentation seems a likely solution. The second function is to detect the neutral current process of $\nu_\mu p$ elastic scattering and separate the protons that reinteract from those that range out in the detector medium. Again some segmentation is probably called for and the solutions to the two problems may be similar. The techniques that are loosely described here are those with which we have had experience for some time, although the energy range and the demands are different from those at very low energy.

The distant detector places a premium on large mass at low cost. Muon quasielastic and electron quasi elastic events must be separated with good precision. We expect to have a detector volume large enough that this is not a problem; initial estimates have been made with 1000 tons of sensitive volume leading to a satisfactory design and suitable counting rates.

In summary, these two detectors are well within the technical capability of the group and can provide suffient active material with adequate particle identification at costs which we expect to be affordable.