A Proposal for a High Precision Neutrino Scattering Experiment at the Tevatron

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We propose to carry out a high precision, high statistics neutrino scattering experiment using 50-300 GeV neutrinos and anti-neutrinos from the Tevatron. Approximately three "Snowmass years" of running with 5×10^{19} protons on target each year are needed, with nominally one year running with neutrinos and two years with anti-neutrinos. A 2,000 ton target mass consisting of 2.5 cm ($=X_o/4$) glass panes interleaved with 1 cm proportional tubes detects electromagnetic and hadronic showers and muons with high efficiency and good separation. Three 3 m long toriodal magnets and drift chambers spaced along the target mass determine the muon charge and momentum. The entire detector measures 120 m in length and 5×5 m in cross section. In the course of three years data taking, the detector will collect 100 million deep inelastic scattering (DIS) events, 40,000 $\nu_\mu e^-$ and $\overline{\nu}_\mu e^-$ events and 900,000 inverse muon decay (IMD) events.

The electroweak measurements of this experiment have high discovery potential. The large sample of neutral current neutrino interactions allows probing of the neutrino neutral current couplings in several different ways: $\nu_\mu e^-$, $\overline{\nu}_\mu e^-$, $\nu_\mu N$, $\overline{\nu}_\mu N$ cross section measurements. We will use the large IMD sample to allow an absolute neutrino flux calibration for the neutral current measurements. This represents the first precision measurement from electron elastic scattering, a purely leptonic mode. We expect a factor of two improvement in the errors from quark scattering over those obtained by NuTeV. We will also address the model systematics raised by this measurement.

In the context of the Standard Model, NuTeV's measurement using $\nu_\mu N$ scattering favors a very heavy Higgs boson while combination of all other electroweak measurements favors a light Higgs. We believe LHC will resolve the Higgs issue and, when this experiments runs, $m_{\rm H}$ will be a precise input to the electroweak theory, since $m_{\rm H}$ enters as $\ln(m_{\rm H})$ corrections. If the Higgs question remains unresolved or if a more complex picture of the TeV scale emerges, the combination of these precise measurements of the neutrino couplings will play an important role in advancing the theory.

This experiment can also pursue a wide range of other measurements and searches. The very large sample of DIS events allows factor of 2-3 improvement of weak nuclear structure functions. The high sampling and granularity of our design makes measurements at $x<0.004$ and $Q^2<1$ GeV^2 possible. Our target, SiO_2, is very nearly isoscalar ($N_u/N_d=0.998$) which will allow comparison of our results with those from other experiments and lattice calculations. The access to the low x region also probes the influence of heavy quarks and vector mesons on the parton model. This experiment provides unique access to neutral heavy leptons. NuTeV observed an excess of three events consistent with the dilepton decay of few GeV neutral heavy leptons to two muons. The high statistics of our experiment will extend the mass sensitivity to about 5 GeV and increase the cross section sensitivity by a factor of fifty. This experiment will also carry out a search for the lepton flavor violating process $\overline{\nu}_\mu e^- \to \overline{\nu}_e \mu^-$ with a factor of fifty greater sensitivity. The study of IMD events allows the most precise searches for right handed weak and scalar weak charged couplings.

The construction of the detector will be straightforward, inexpensive and requires very little research and development. High flux at high energy presents the greater challenge and we plan to study the required energy and flux in the coming months. In addition, we will study electron/muon separation, flux calibration using IMD and J/ψ events and π^o identification as well as optimizing sampling density and detector granularity.

The physics goals of this experiment complement those of the LHC and are commensurate with those set forth in EPP2010. We believe this experiment makes the best use of the Tevatron, a unique machine. Finally, the rich, broad physics program will advance physics in the time after the initial results from the LHC.

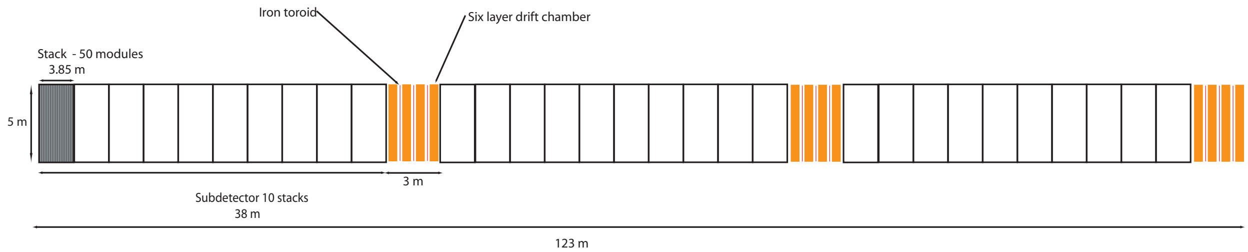

Figure 1: Conceptual design of the detector. Each module consists of a 2.5 cm glass plate followed by a 1 cm thick layer of 1×1 cm proportional tubes. The muon detectors are 2.5 cm magnetized iron (B=1T) interleaved with three coordinate drift chambers. The neutrinos impinge from the left.

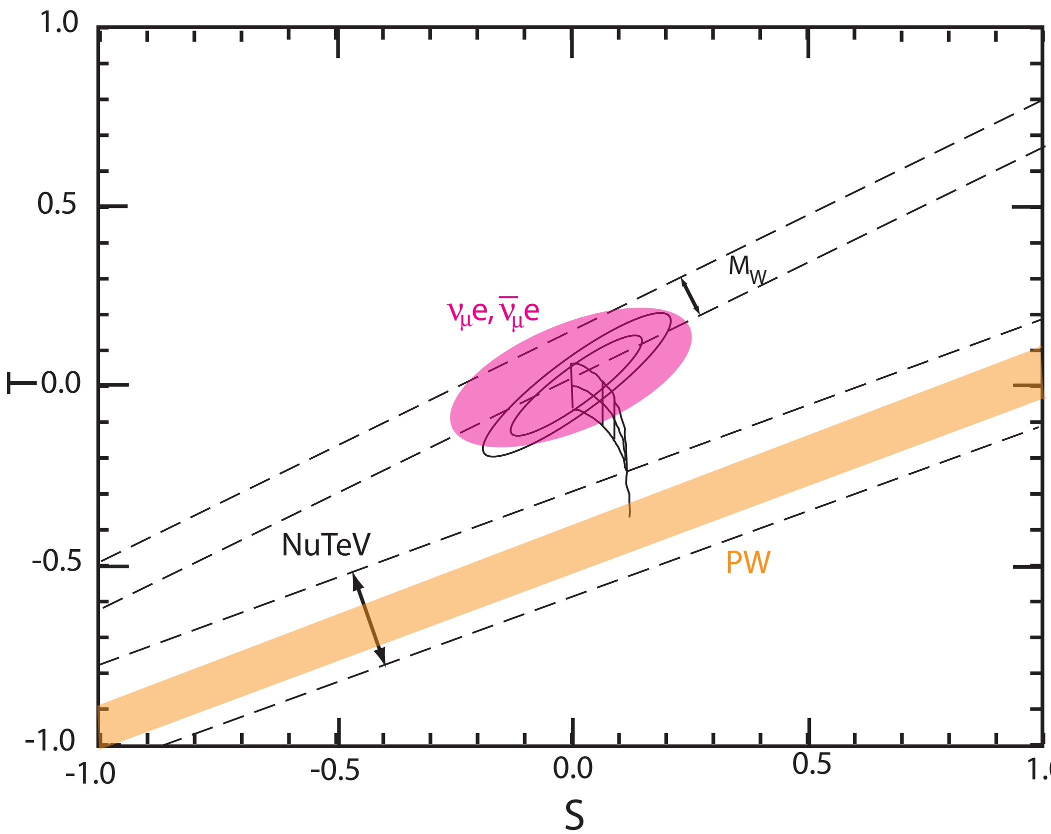

Figure 2: $S-T$ **plot showing the allowed region from electroweak experiments at LEP, SLD and the Tevatron (black ellipses), the allowed region from NuTeV (black dashed lines), the projected allowed region from** $\nu_\mu e^-$ **and** $\overline{\nu}_\mu e^-$ **cross section measurements for this experiment (shaped ellipse, assumes consistency with LEP, SLD and Tevatron measurements) and the projected allowed region for** $\nu_\mu N$ **measurement using the Paschos-Wolfenstein technique for this experiment (shaded band, assuming consistency with the NuTeV measurement). The oblique grid in the center of the ellipse shows the influence of the Higgs and top quark masses, the point at** $S=T=0$ **corresponds to** m_{H}**=115 GeV,** m_{t}**=176 GeV and the long tail extending downward corresponds to** m_{H}**=1 TeV.**