1. NAME OF INITIATIVE: FINeSSE: High Intensity Neutrino Scattering Experiment
http://www-finesse.fnal.gov

List of major collaborating institutions (including non-US partners).

Columbia University, Nevis Labs, Irvington, NY 10533
Fermi National Accelerator Laboratory, Batavia, IL 60510
University of Illinois at Urbana-Champaign, Urbana, IL 61801
Indiana University, Bloomington, IN 47408
Los Alamos National Laboratory, Los Alamos, NM 87545
Louisiana State University, Baton Rouge, LA 70803
New Mexico State University, Las Cruces, NM 88003
University of Virginia, Charlottesville, VA 22901
Yale University, New Haven, CT 06520

2. SCIENTIFIC JUSTIFICATION:

Physics goals. How does it fit into the global physics goals for the entire field.

Neutrino Scattering physics measurements form the foundation of the FINeSSE program: the measurement of the strange spin of the proton, Δs, using ν-p elastic scattering; precision measurement of low energy (1 GeV) neutrino cross sections necessary for oscillation experiments, and the search for ν_μ disappearance in an astrophysically interesting region. These topics are very compelling, and can be addressed with the Fermilab booster neutrino beam design, the world's highest intensity neutrino beam in the 0.5-1.0 GeV energy range. A possible neutrino beamline at the Brookhaven AGS can also provide a very high intensity, low energy, neutrino beam ideal for these measurements. This physics program and how it fits into the worldwide neutrino program is outlined below.

Understanding the quark and gluon substructure of the nucleon has been a prime goal of both nuclear and particle physics for more than thirty years and has led to much of the progress in strong interaction physics. Still the flavor dependence of the nucleon's spin is a significant fundamental question that is not understood. Experiments measuring the spin content of the nucleon have reported conflicting results on the amount of nucleon spin carried by strange quarks. Neutral current elastic ν-p scattering, provides one of the only theoretically clean, robust measurements of this quantity necessary to resolve this modern day spin-crisis. The FINeSSE "Scibath" detection technique, an open volume of liquid scintillator readout with a 3-D grid of wave length shifting fibers strung throughout, well measures low Q2 ν-p elastic scatters most important for extraction of Δs.

Currently, oscillation experiments rely on modeling of neutrino interactions in a regime that is poorly constrained by experimental data. Although accelerator-based neutrino beams have existed since the 1970s, our primary knowledge of neutrino interactions at low energy comes almost entirely from bubble chamber measurements made decades ago at ANL, BNL, CERN, and FNAL, all of which were limited both by low statistics and by large neutrino flux systematics. In addition to (or perhaps because of) these large uncertainties (typically $10 - 30\%$) the experimental results often conflict and are difficult to interpret, mainly because of nuclear corrections and exclusive final state ambiguities. Improved knowledge of low energy neutrino cross sections will become increasingly important as experiments move from The FINeSSE Initiative/page 2 discovery to precision measurements of oscillation parameters. Precision cross section measurements with FINeSSE's "Scibath" detector, and possibly with a small Liquid Argon TPC detector under consideration, are crucial for the next generation of neutrino cross section measurements.

In addition to these cross section measurements, the Booster neutrino beamline at Fermilab is an optimal place to search for neutrino oscillations at high Δm2 in an astrophysically interesting region, in conjunction with the MiniBooNE experiment. Models of the r-process in supernovae which include high-mass sterile neutrinos may explain the abundance of neutronrich heavy metals in the universe. These high-mass sterile neutrinos are outside the sensitivity region of any previous neutrino oscillation experiments.

The Booster neutrino beamline at Fermilab or a similar beamline at Brookhaven, can provides the world's highest intensity neutrino beam in the 0.5-1.0 GeV energy range, a range ideal for this program of measurements. The FINeSSE detector located upstream of the MiniBooNE detector, 50-100 m from the recently commissioned Booster neutrino source, can definitively measure the strange quark contribution to the nucleon spin and make precision measurements of low energy neutrino cross sections. This detector, in conjunction with the MiniBooNE detector, can also investigate ν_μ disappearance in a currently unexplored, cosmologically interesting region. This program is complimentary to measurements from neutrino beams existing and under construction in Japan (K2K, T2K) and Europe (CNGS) which sit higher in energy.

3. VALIDATIONS FOR SCIENTIFIC JUSTIFICATION:

Examples of recommendations and supporting statements from the committees, panels, and the community at large.

Determination of the spin carried by the strange quarks in the nucleon has been an ongoing effort for many years. Leaders in the nuclear community recognize the unique ability of high intensity, low energy, neutrino scattering experiments to determine Δs in a robust, clean way. During the course of the FINeSSE proposal process, FINeSSE received encouragement from the leading theorists in the field including Bob Jaffe, Mike Ramsey-Musolf, Wanda Alberico, and Al Mueller. In a letter to the Fermilab director, Al Mueller emphasized the importance and timeliness of this measurement. He wrote, in part:

"The story of theorists and experimentalists struggling to understand the role of strange quarks in the nucleon has been interesting and exciting. The FINeSSE collaboration and Fermilab could have an important role in writing the final chapters of that story if FINeSSE is approved for running"

Indications of neutrino oscillations at relatively low energies (E_ν=0.1-10 GeV) have rekindled interest in cross sections at low energies, first measured in bubble chamber experiments of about 30 years ago. New intense neutrino beams and near detectors provide a venue for studying these cross sections both for their contribution to oscillation measurements and for what they tell us about neutrinos, the Standard Model, and the universe.

This rekindled interest is evident from the newly formed NuINT workshop series, in its fourth year, with attendances around 100 scientists from neutrino experiments in the US, Europe, and Japan. Collaboration between different experiments is helping to bring together all existing neutrino and electron scattering data to improve generalized neutrino cross section models. Unfortunately, there is very little data on heavy targets (Carbon or Water) at these

Task/Milestonr	Date(s)
Project Approval	01/05
Civil Construction	01/06-07/06
Detector Detailed Design	01/05-09/05
Detector Fabrication	09/05-06/07
Detector Installation	07/06-06/07
Ready for Beam	06/07
Data Taking	06/07-06/10

Table 1: Dates and durations of major tasks and milestones of this project.

low energies, right in the energy range that future precision oscillation experiments will need to know these cross sections.

In response to the importance of this physics, preliminary recommendations discussed at the final workshop for the yearlong APS neutrino study highlights the importance of measuring neutrino cross sections. One of the six top level recommendations cites measuring neutrino cross sections in the MeV to GeV range as crucial for the neutrino program.

In addition to the recognition from the neutrino community of the importance of this physics, leaders in the wider community also cite the need for these measurements. In a letter to the leaders of the APS Neutrino Study, following the Fermilab summer PAC in Aspen, Mike Witherell outlined the views from the PAC on neutrino cross section measurements on the Booster neutrino beamline. He writes:

“The report of the Fermilab Long Range Planning Committee presents a vision of a potential future neutrino program. This vision includes further oscillation measurements with the Booster, if MiniBooNE results lead in that direction, and a program of low energy neutrino cross section measurements.”

4. DESIRED SCHEDULE:

List major milestones (month & year) such as design complete, construction start, construction complete, etc.

The estimated duration to build this project is 2.5 years, which includes detector fabrication and civil construction. A start date in early 2005 would allow for data taking to begin in 2007. The data-taking phase is expected to take approximately 3 years. A list of major project milestones are given in Table 3. This project is relatively small, does not require construction of a beamline, and the detector R&D is well-advanced. Because of these things, the experiment may be built quickly.

5. ROUGH ESTIMATE OF COST RANGES:

Whatever the best information available (eg. $M +/-30~50%, $150~250M, etc.). Total cost range including non-DOE funding (if any other funding sources are assumed and if known, state from where and how much. Also indicate remaining R&D cost to go.
The detector cost for this project is estimated to be $2.25 M ($2.8 M with contingency) for a baseline detector consisting of a vertex detector and muon range stack. These estimates, vetted by MiniBooNE's project manager and Fermilab scientist, Ray Stefanski, do not include EDIA or indirect costs. It is anticipated that the funding for the detector will come from the university funding agencies.

The enclosure cost for a detector at FNAL, partially buried at the correct height to match the FNAL 8 GeV neutrino line, is estimated to be $800K ($1.6 M including contractor O&H, EDIA, management reserve, and indirect costs) as determined through a Preliminary Design Report written by the Fermilab Facilities Engineering Section (FESS). Funding for the enclosure will be sought through Fermilab. The R&D for the baseline detector is essentially complete and requires no significant additional funding.

6. DESIRED NEAR TERM R&D:

Major activities needed to be completed before start construction.
The baseline detector will employ the "scibath" technology which uses wavelength-shifting fibers immersed in a bath of liquid scintillator. This technique, while novel, uses readily obtainable components and has been tested on a small scale over the last year. No additional R&D is required to implement this technology. The muon rangestack will also use "triedand-true" technology and will need no R&D.

These two sub-detectors will form the baseline detector for this experiment. There is an option to add a liquid-Argon TPC to extend the physics reach. This detector does require a moderate level of R&D which is currently underway and will result in a small prototype by the end of 2004 and more extensive prototype work in 2005. This effort is currently underway at FNAL and Yale.

7. BRIEF DESCRIPTION OF LABORATORY'S ANTICIPATED ROLE:

Expected unique capabilities to be provided by lab. Rough estimate of human resources from lab (#FTE in what type labor).
As a center for neutrino physics in the United States, Fermilab would be host to a slate of present and future experiments on the NuMI and Booster Neutrino Beamlines. As a near detector running on an existing beamline in conjunction with an existing experiment, FINeSSE helps to capitalize on investments already made in the neutrino program at Fermilab. The financial impact on the program is therefore, relatively small in particular

compared to the physics potential. Specific impact on the Fermilab program is outlined below. It comes from a preliminary impact assessment made by John Cooper, head of the Particle Physics Division at Fermilab, as requested by the director prior to the Fall 2003 PAC.

- Near Term FINeSSE needs upon approval
  - FESS design work for detector enclosure: 100K
  - Office space for FINeSSE collaborators in the High Rise
  - Lab space for detector prototype and design work.
  - Technical Assistance: 1 FTE in the first year
- Far Term FINeSSE needs
  - Detector Enclosure construction: the remaining 1.5M
  - Detector assembly area including clean room
  - Technical assistance: 4 FTEs during detector construction
  - Time at FNAL Lab 5 extrusion factory for range-stack: 40 hours
  - Dark room at New Muon Lab for PMT testing