Physics at a Stopped Pion Neutrino Source

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This document describes briefly what could be done at a FNAL facility optimized for physics with neutrinos in the few tens of MeV range. A stopped pion source provides monochromatic 30 MeV ν_μ from pion decay at rest, followed on a 2.2 μs timescale by $\bar{\nu}_\mu$ and ν_e with a few tens of MeV from μ decay. A $\sim$ GeV, high intensity, small pulse width, high duty cycle proton beam is desirable for this purpose. A rich program of physics is possible with such a ν source, some of which would be in common with physics that could be done at a low energy beta beam; however a stopped pion beam could likely be constructed more quickly and cheaply. Some examples of studies possible at such a facility are given below.

With detectors based on well-understood technology (see *e.g.* [1]), one can measure ν-nucleus cross-sections in the few tens of MeV range in a variety of targets. This territory is almost completely unexplored: so far only ^{12}C has been measured at the 10% level. Understanding of ν-nucleus interactions in this regime is vital for understanding of supernovae: core-collapse dynamics and supernova nucleosynthesis are highly sensitive to ν processes. Neutrino-nucleus cross-section measurements will furthermore enhance our ability to extract information about ν mixing properties (mass hierarchy and θ_{13}) from the observation of a Galactic supernova ν burst, via understanding of both the supernova itself and of the ν detection processes. Another interesting possibility is the detection of nuclear recoils from coherent elastic ν-nucleus scattering, which is within the reach of the current generation of low-threshold detectors[2]. Because the cross-section can be precisely calculated, such an experiment provides a test of the Standard Model. One could measure θ_W at a Q of $\sim$ 0.04 GeV. Sensitivity to non-standard interactions of neutrinos will extend at least an order of magnitude beyond current limits. With detector thresholds below 10 keV, one could look for non-zero neutrino magnetic moment.

The Neutrinos at the Spallation Neutron Source (νSNS) experiment [1] is an existing proposal at the SNS at ORNL, with a timescale of the next several years. If funded, it should make significant progress on the physics described above. However this experiment is essentially parasitic to the SNS; while the neutrinos come for free, there are some experimental challenges. There are several ways in which a next-generation stopped-pion source experiment could take νSNS physics to the next level.

- The list of targets of direct astrophysical and nuclear structure relevance is long and will not be exhausted by the νSNS program.
- The background neutron flux from the SNS beamline and instruments may eventually limit the sensitivity. A designed-from-scratch experiment at FNAL could optimize geometry and shielding to reduce backgrounds significantly. Underground siting of detectors will reduce cosmic ray backgrounds.
- The space available for the νSNS detector suite is limited. With more space for a larger detector, and less background, the possibilities for physics expand. As an example, the measurement of θ_W will be systematically limited; if one can reduce uncertainties sufficiently– for example by normalizing the flux with a well-known rate (*e.g.* νe^- elastic scattering) – a measurement at the few percent level may be possible.
- Next generation low-threshold-detector technology with sub-keV recoil sensitivity could extend the reach of a ν magnetic moment search.
- Control and monitoring of the beam will reduce systematic uncertainties associated with the ν source.

References:

[1]http://www.phy.ornl.gov/nusns/
[2] K. Scholberg, Phys.Rev.D73:033005,2006.

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