ANNIE: The Atmospheric Neutrino Neutron Interaction Experiment

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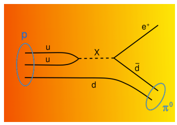
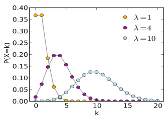
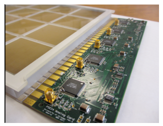
http://annie.uchicago.edu

ANNIE

A key physics measurement, a technology demonstration

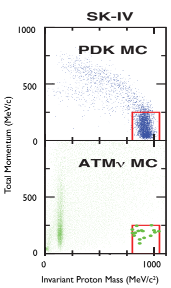






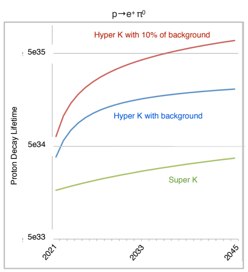
- A measurement of the abundance of final state neutrons from neutrino interactions in water, as a function of energy.
- Demonstration of a new approach to neutrino detection: **Optical Time Projection Chamber** using new photosensor technology.

Reducing the most significant background on proton decay

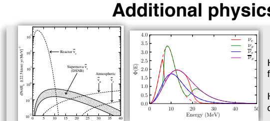


- Atmospheric neutrino interactions provide the most significant background on proton decay.
- Though rare, the occurrence of these events is expected to exceed 1 event per year in a megaton detector.
- Fortunately, these high energy interactions are expected to typically generate one or more neutrons in the final state, whereas proton decays will rarely generate neutrons.
- The ability to identify and tag final-state neutrons, based on the light they produce when captured on Gd doped water, could greatly reduce this background.

- Proton decay (PDK) searches in planned megaton-scale water Cherenkov detectors such as Hyper-K could achieve unprecedented sensitivity for the key $p \rightarrow e^+ \pi^0$ mode.
- Atmospheric neutrinos would limit this sensitivity.
- Techniques capable of reducing this background would have a large impact on the potential physics reach.



Additional physics impact

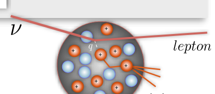


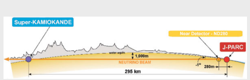
Help separate diffuse cosmic SN neutrinos from various backgrounds

Help disentangle the various fluxes from core collapse SN

Neutrino interaction Physics

Help constrain and distinguish between various models of neutrino nucleon interactions



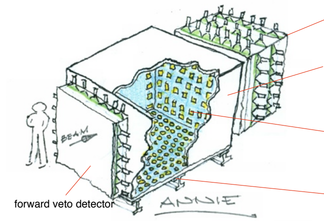


Precision Neutrino Oscillation Measurement

Help reduce uncertainties on neutrino cross-sections (largest systematic in T2K)

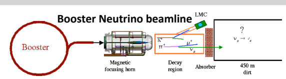
Concept and Measurement Strategy

- We propose to make a systematic measurement of the neutron yield from neutrino interactions for energies similar to atmospheric neutrinos.
- The detector concept is a water target doped with gadolinium and instrumented to be able to detect and identify neutrino interactions as well as capture gammas from primary and secondary neutrons.

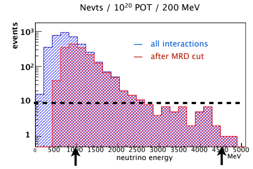


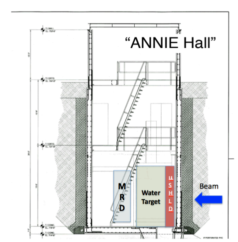
ANNIE takes advantage of existing facilities

- Expected proton decay backgrounds come from interactions between 1-5 GeV.
- The Booster neutrino beam line provides an energy spectrum peaked near 1 GeV.
- We will see several hundreds of ν_μ CC interaction per 10^{20} protons on target (POT) per ton in the energy region of interest.
- The water target is designed to fit into the former SciBooNE pit using existing veto shield and muon range detector (MRD).



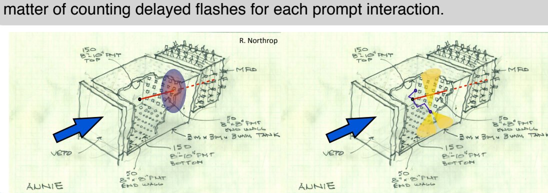
Expected Event Rates in Booster Neutrino Beam
Nevts / 10^{20} POT / 200 MeV





The measurement strategy

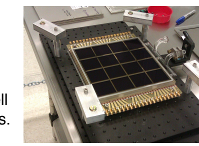
- We are interested in the neutron yield as a function of momentum transfer and for different neutrino event types.
- A prompt event is used to identify the event type and reconstruct the momentum transfer. The momentum transfer of neutrino charged current events is well determined by MRD measurements of the muon.
- Neutrons thermalize in the water and capture on Gd. Counting neutrons is a matter of counting delayed flashes for each prompt interaction.

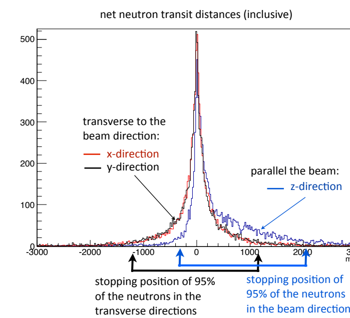


High Resolution Reconstruction

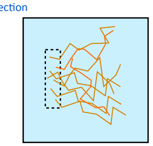
- Interactions must be sufficiently far from the walls of the detector, so that neutrons do not escape. We must identify the interaction point with enough accuracy to define this small fiducial volume. This requires photosensors with excellent position and time resolution.

- To achieve this capability, we will use Large Area Picosecond Photodetectors (LAPPD), now in the commercialization phase. This will require application specific development of LAPPDs as well as further development of reconstruction algorithms.

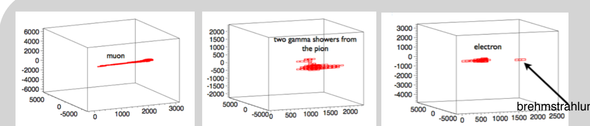




- The majority of neutrons stop within +/- 1 m of their starting point in the directions transverse to the beam. They fall in a ~ 2m forward region from their starting position in the beam direction. The fiducial volume, shown schematically with the dashed lines, must be defined accordingly.



New photosensors enable high resolution reconstruction



- We have developed three-dimensional event reconstruction using a causality-based, generalized Hough transform. Events are full Geant4 simulations in a 3 m³ detector, including all optical effects and sub-nanosecond time resolution.

- Work developed for large water Cherenkov detectors shows vertex reconstruction resolution of less than 5 cm (*see I. Anghel et. al. poster*).
- Precision reconstruction of the neutron capture positions along the beam direction will also help understand background neutrons produced by the beam in the rock upstream of the detector.

Plans and Timeline

In order to capitalize on the the operation of the Booster Neutrino Beam for MicroBooNE, and to develop the LAPPD technology in a timely manner, we plan to build and begin running the experiment in a 3 year timescale. Year 1 will mostly involve testing and development work. Construction would begin in year 2. Year 3 would see commissioning and first data.