Neutrino fixed-target

A. Motivation: why cross section measurements are necessary?

- in future neutrino oscillation experiments, systematic uncertainties associated with neutrino-nucleus interactions will become increasingly important; they are already a dominant source of error in modern experiments like T2K

- even if one accepts the basic theory for neutrino-nucleon interactions (CCQE, Delta excitation), some fundamental parameters (e.g., nucleon form factors) must still be provided and cannot always be reliably calculated (one exception is that lattice QCD may be able to produce vector QE and axial form-factors predictions in the next few years)

- reliable ab initio computations can only be done for light nuclei (up to Carbon) and in a restricted kinematical region; although efforts are underway to understand how to extend these calculations to argon

- nucleon correlation effects are important and must be included consistently in event generators (avoiding double-counting of processes)

- what is known about electron neutrino interactions on nucleons/nuclei must be extrapolated from muon neutrino scattering; is this sufficiently reliable for supporting the future neutrino oscillation program?

- there are several tensions between recent neutrino cross section measurements that must be sorted out: CCQE and pion production at low (MiniBooNE) vs. higher neutrino energy (MINERvA)

B. Current (and near future) activities

- in the coming few years, one can expect new neutrino and antineutrino results from MINERvA, T2K, MicroBooNE, and the NOvA near detector with additional data on argon from LAR1-ND and CAPTAIN-MINERvA in the foreseeable future

- energy range will extend from ~700 MeV (T2K, BNB) to ~3 GeV or more depending on the beam configuration (NuMI LE and ME)
- a variety of targets (from He to Pb)

- important measurements: CC inclusive, CCQE-like, pion production, DIS

- very little is known about multi-pion production

- less important but contributing to the general picture: coherent pion production, strangeness production

- accurate neutrino flux knowledge is paramount to producing precise neutrino cross section measurements

- to make continued progress, cross sections should not just be measured as a function of historical, model-dependent quantities such as E_ν and Q^2 but rather as a function of physical observables (differential and double-differential cross sections in final state particle kinematics); these new measurements should include a combination of various energy ranges, targets, and final state topologies to constrain uncertainties in theoretical models/simulation tools

C. New ideas of nu cross section measurements

- nuprism
- nuSTORM

Roadmap

– it is difficult to predict how precise our knowledge of neutrino-nucleon/nucleus cross sections will be in 5 ... 10 ... 15 years

  – running and planned measurements will be performed on nuclear targets and it will be challenging to infer the characteristics of neutrino-nucleon scattering from this nuclear data

– more precise cross section measurements and more reliable theoretical models will have to be implemented in the Monte Carlo simulation tools used by experimental groups in order to make progress

– right now there are several neutrino event generators used by experimental groups. These generators can differ in many respects (especially in their treatment of final state effects) ; these differences can pose large uncertainties for experiments; more data and improved theoretical calculations are needed to rectify these differences,

- in the future, it may be desirable for the number of MCs converge to one/two generally accepted tools. This process may be facilitated by the recently formed NuSTEC (Neutrino Scattering Theory Experiment Collaboration) group.