MINERvA and the Global Program in Neutrino Oscillations

The discovery of neutrino masses and mixings from observations of solar and atmospheric neutrinos has set in motion an ambitious new program of neutrino measurements. This program consists of three stages: (I) precise measurements of leading flavor transitions (including MINOS at FNAL), (II) establishing "sub-dominant" flavor transitions and determining the neutrino mass hierarchy (including NOvA at FNAL) and (III) searching for CP violation (future accelerator and detector upgrades under discussion at FNAL and elsewhere). The scientific goals of all three stages require measurements from long-baseline accelerator-based neutrino beams with energies from 700MeV to several GeV.

MINERvA improves current and future oscillation experiments by accurately measuring both the signal and background processes that these experiments will observe. Two of the many processes MINERvA will measure, along with the current state of our knowledge, are shown in the figures below. While independent measurements of the quasi-elastic cross section differ by 30-40%, MINERvA will provide an accurate measurement at the 5% level across a broad energy range (Figure 1). Quasi-elastic interactions provide at least half of the expected signal for future oscillation experiments. For coherent neutrino-nucleus interactions, which are among the least understood backgrounds in future oscillation experiments, MINERvA will again provide unprecedented precision. Figure 2 shows the expected MINERvA precision for the charged current channel. MINERvA's dramatic improvements in precision are largely due to the very high flux and tunable energy of the NuMI beam as well as a choice of detector technology that ensures good identification of exclusive reactions with a multi-ton detector fiducial mass.

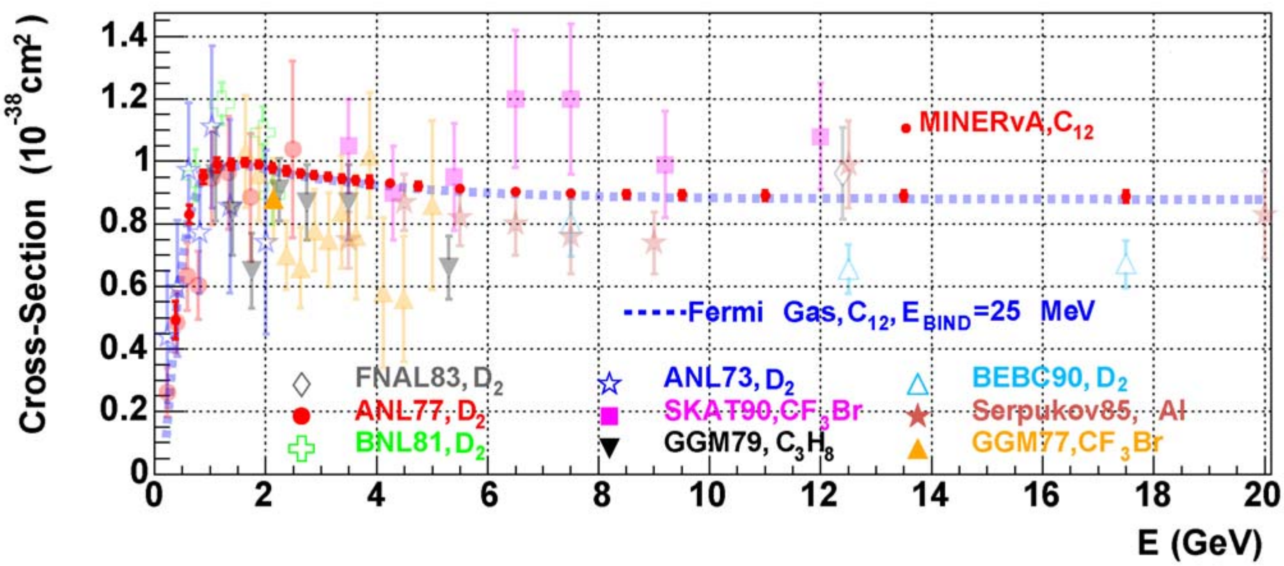
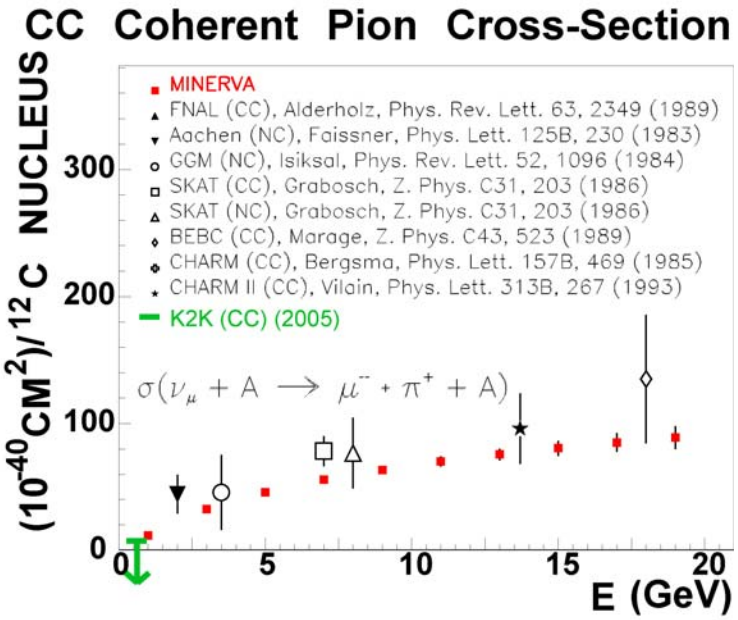


Figure 1 shows the current world's data on the quasi-elastic cross section (faded colors) and the expected accuracy of the MINERvA measurement of the same channel (red points with error bars).

Figure 2 shows MINERvA's expected precision (in red) of the measurement of coherent pion production cross sections on carbon.



By making precise measurements of interactions, MINERvA helps NOvA to accurately predict the background level and correctly translate an excess above background to a measurement of sub-dominant oscillations. By simultaneously studying interactions on carbon, iron, and lead, MINERvA will be able to measure the neutrino-nuclear effects which must be incorporated when translating from a measured energy in a detector to neutrino energy. This is currently the dominant systematic uncertainty in the MINOS mass splitting measurement, which depends on measuring an oscillation probability as a function of neutrino energy.

The figure below shows the effective running time in years that would be saved by the inclusion of the MINERvA neutrino-nucleus interaction results to reduce the total systematic errors associated with the MINOS (Stage I) and NOvA (Stage II) primary measurements. ***For the NOvA and MINOS experiments, after 5 years of data taking for each, MINERvA will provide the equivalent of an extra 6 and 1.5 years of running time, respectively.***

Just as MINERvA plays a larger role for NOvA than for MINOS because of NOvA's higher requirements for statistical precision, the importance of the MINERvA measurements will be larger still as the field moves into the third stage of the program outlined above. For measurements of the difference between neutrino and anti-neutrino oscillation probabilities, the experiments will require running times (or detector masses or proton beam exposures) that are an order of magnitude larger than the stage II program. The ultimate goal of this stage is to shed light on the possibility that the source of matter-antimatter asymmetry in today's Universe can be found in the neutrino sector. ***Enabling this goal through a precise and thorough understanding of how neutrinos interact in matter is the mission of MINERvA.***

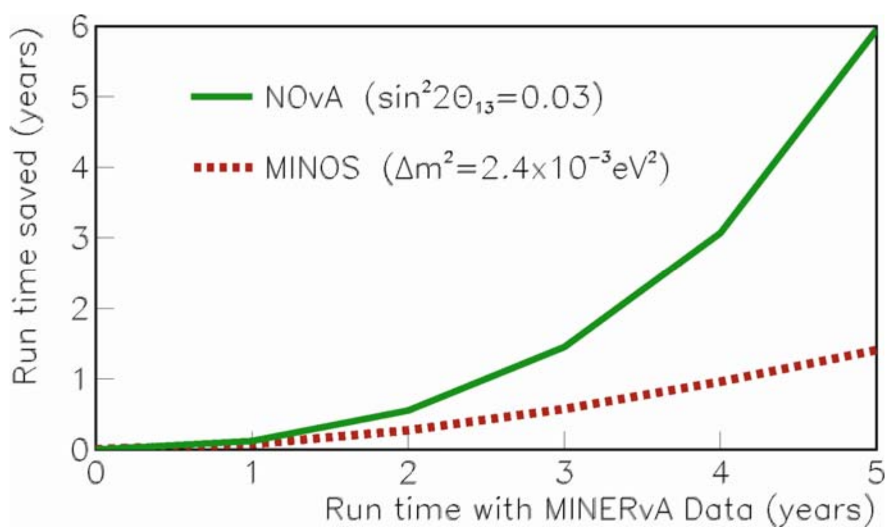


Figure 3 shows the effective running time that would be saved by the inclusion of MINERvA measurements as a function of runing time for the MINOS and NOvA experiments.