BooNE: Upgrading MiniBooNE to Two Detectors

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The MiniBooNE detector began to take data on September 1, 2002. The experiment was designed to search for the appearance of excess electron (anti) neutrinos in a primarily muon (anti) neutrino beam. While resources were not available to construct both a near and far detector at the time, it was envisioned that a second detector would be constructed at a location appropriate to the observed signal if MiniBooNE should see a signal. The second detector would be able to differentiate between a true neutrino oscillation effect and an unforeseen new process or background. A number of scientists now believe that a significant signal has been observed at MiniBooNE, and a collaboration of scientists is forming in order to upgrade MiniBooNE to a two-detector experiment: BooNE.

MiniBooNE has enjoyed a remarkable 9 years of smooth operation, during which an astounding 6×10^{20} protons on target (POT) have been delivered in neutrino mode, and an even more astounding 1×10^{21} POT have been delivered in anti-neutrino mode. The neutrino mode data has yielded a low-energy excess of 129 ± 20(stat) ± 38(sys) events at reconstructed neutrino energies below 475 MeV. That low-energy excess is not described well by a simple two-neutrino model, but can be accommodated by an extended 3 active + 2 sterile neutrino model, fit to the world's relevant neutrino data. While the statistical significance of the low-energy excess is ~ 6σ, the overall significance is limited to ~ 3σ by the systematic error in the estimation of the background, either in the low energy range of 200-475 MeV or in the full range 200-1250 MeV where the excess is 129 ± 20(stat) ± 38(sys) events. That systematic error is related to the error in the detector acceptance or efficiency for π^0 background events, and to a lessor extent, the flux of neutrinos, and the neutrino-nucleus cross sections. Similarly, an excess of is observed in anti-neutrino mode of 54.9 ± 17.4(stat) ± 16.3(sys) events events, consistent with the neutrino-mode data. The anti-neutrino-mode excess is limited in statistical power to ~ 3σ and appears to have a higher energy component of ~ 500-600 MeV.

We now believe we have explored all the possible avenues for explaining the excess events by conventional processes and have exhausted the possible ways to reduce the systematic errors via further analysis. We believe the construction of a near detector at ~ 200 meters from the Booster

Neutrino Beam proton target to be the most expedient way understand whether or not the excess events observed by MiniBooNE are caused by an oscillation process or some other process that scales more conventionally by L^{-2}. The primary motivation for building a near detector, rather than a detector further away, is that the neutrino interaction rate will be over 7 times larger, and the measurement will precisely determine the neutrino-related backgrounds within 6 months of running. A far-detector would take much longer to accumulate sufficient statistics. The combination of the present MiniBooNE neutrino-mode data, plus a 4-month (1×10^{20} POT or ~ 700,000 neutrino events) neutrino-mode run with a near detector, would result in a 5σ sensitivity to whether or not the low energy excess is an oscillation effect. With MiniBooNE's anticipated 1.5×10^{21} POT in antineutrino-mode, BooNE will provide a unique measurement of antineutrino appearance and disappearance with an 8 month run (2×10^{20} POT or ~ 140,000 events) required for comparable statistics.

Furthermore, a two-detector BooNE experiment, in conjunction with the ultra-fine-grained MicroBooNE liquid argon TPC, would be a tremendously powerful, oscillation-hunting combination. While MicroBooNE does not anticipate any antineutrino-mode operation, the operation of BooNE during the MicroBooNE neutrino-mode run would double the statistics of the present MiniBooNE neutrino data to 1.2×10^{21} POT. That powerful trio of detectors would yield precise measurements of *both electron-neutrino appearance and muon neutrino disappearance*, which are tightly coupled in nearly all sterile-neutrino oscillation models.