Instructions on how to use April 2007 MiniBooNE public data for muon-to-electron neutrino oscillation fits

MiniBooNE collaboration

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I. MINIBOONE PUBLIC DATA, AND NOTATION

The following MiniBooNE information is made publicly available:

- ntuple file of official MiniBooNE $\sin^2 2\theta_{\mu e}$ sensitivity and upper limit curves as a function of Δm^2, for a 2-neutrino $\nu_\mu \to \nu_e$ oscillation fit. There are 100 rows in the file, one per Δm^2 grid point, and five columns:

  Δm^2: Δm^2 value in eV^2

  $\sin^2 2\theta_{\mu e,\mathbf{max}}$(90% CL): upper limit in $\sin^2 2\theta_{\mu e}$, at 90% confidence level

  $\sin^2 2\theta_{\mu e,\mathbf{max}}$($3\sigma$ CL): upper limit in $\sin^2 2\theta_{\mu e}$, at 3σ confidence level

  $\sin^2 2\theta_{\mu e,\mathbf{sens}}$(90% CL): sensitivity in $\sin^2 2\theta_{\mu e}$, at 90% confidence level

  $\sin^2 2\theta_{\mu e,\mathbf{sens}}$($3\sigma$ CL): sensitivity in $\sin^2 2\theta_{\mu e}$, at 3σ confidence level

- 1D array of bin boundaries in E_ν^{QE} (reconstructed neutrino energy). Numbers given assume 8 bins. This is therefore 9 real numbers.

- 1D array of data events per E_ν^{QE} bin after ν_e cuts: D_i, with $i = 1, \ldots, 8$. This is 8 integer numbers.

- 1D array of background predicted events per E_ν^{QE} bin after ν_e cuts: B_i. This is 8 real numbers.

- 2D array of background fractional covariance matrix in E_ν^{QE} bins. "Fractional" refers to dividing the covariance matrix per pair of numbers of background predicted events per E_ν^{QE} bin: $M_{ij}^B/(B_i \cdot B_j)$, with $i, j = 1, \ldots, 8$. This matrix contains both background statistical and systematic errors. This is 8x8 real numbers.

- ntuple file of 9934 MC full $\nu_\mu \to \nu_e$ transmutation events after ν_e cuts, with one row per event, and four columns:

E_ν^{QE}**:** reconstructed neutrino energy (MeV)

E_ν^{true}**:** true neutrino energy (MeV)

L_ν^{true}**:** distance between neutrino production and detection points (cm)

w**:** weight for this full transmutation event, without including any oscillation probability in the weight, and with weight normalization such that the sum of all weights divided by the number of events in the file equals the number of expected full transmutation events across all E_ν^{QE} after ν_e cuts

Note: full transmutation events are obtained from a ν_μ flux prediction, for which neutrino interactions are generated assuming all these events are ν_e's as opposed to ν_μ's, and then reconstructed and selected according to ν_e cuts. The condition on the weights written above is:

$$\sum_{n=1}^{N} w_n/N = T \tag{1}$$

where $N = 9934$ is the number of events (rows) in the ntuple file, w_n is the weight for that event, and T is the MC prediction for the number of full transmutatione events passing ν_e cuts. From this file, one can also get the full transmutation prediction for each E_ν^{QE} bin: T_i, with $i = 1, \ldots, 8$, and $\sum_i T_i \equiv T$. In total, this file contains $4 \times N$ real numbers.

- 2D array of full transmutation fractional covariance matrix in E_ν^{QE} bins. "Fractional" refers to dividing the covariance matrix per pair of numbers of full transmutation predicted events per E_ν^{QE} bin: $M_{ij}^T/(T_i \cdot T_j)$, with $i, j = 1, \ldots, 8$. This matrix contains only full transmutation systematic uncertainties; statistical uncertainties need to be added according to the oscillation hypthesis (see below). This is 8x8 real numbers.

II. HOW TO USE PUBLIC MINIBOONE DATA IN $\nu_\mu \to \nu_e$ OSCILLATION FITS

In the following, we describe only how to form a χ^2 from MiniBooNE data and predictions, for any given $\nu_\mu \to \nu_e$ oscillation model. How to use these χ^2 numbers depend on the specific analysis the user wishes to make. The χ^2 is defined as follows:

$$\chi^2 = \sum_{i,j=1}^{8} (D_i - (B_i + S_i)) M_{ij}^{-1} (D_j - (B_j + S_j)) \tag{2}$$

where:

S_i**:** number of signal events predicted per E_ν^{QE} bin:

$$S_i = P_{\mu\to e}(E_\nu^{true}, L_\nu^{true}; \text{osc. parameters}) \cdot T_i \tag{3}$$

where $P_{\mu\to e}$ is the oscillation probability, and the oscillation parameters are, for example, Δm^2 and $\sin^2 2\theta_{\mu e}$. In order to compute the number of signal events S_i, one can proceed as follows:

- loop through all events in the full transmutation file, $n = 1, \ldots, N$
- if event n falls into E_ν^{QE} bin i (based from number on first column in the full transmutation ntuple file), then add:

$$S_i = S_i + P_{\mu\to e}(E_{\nu,n}^{true}, L_{\nu,n}^{true}; \text{osc. parameters}) \cdot w_n/N \tag{4}$$

where $E_{\nu,n}^{true}, L_{\nu,n}^{true}, w_n$ are the numbers in the second, third, and fourth column in the full transmutation ntuple file for that event.

M_{ij}^{-1}**:** this is the inverse of the total covariance matrix M_{ij}, built as follows from the pieces above:

$$M_{ij} = M_{ij}^B + (S_i \cdot S_j)M_{ij}^T/(T_i \cdot T_j) + \delta_{ij} \cdot S_i \tag{5}$$

where the third term accounts for the statistical uncertainty associated with the ν_e signal prediction