Cross Section Uncertainties

Moving beyond the SBN Proposal

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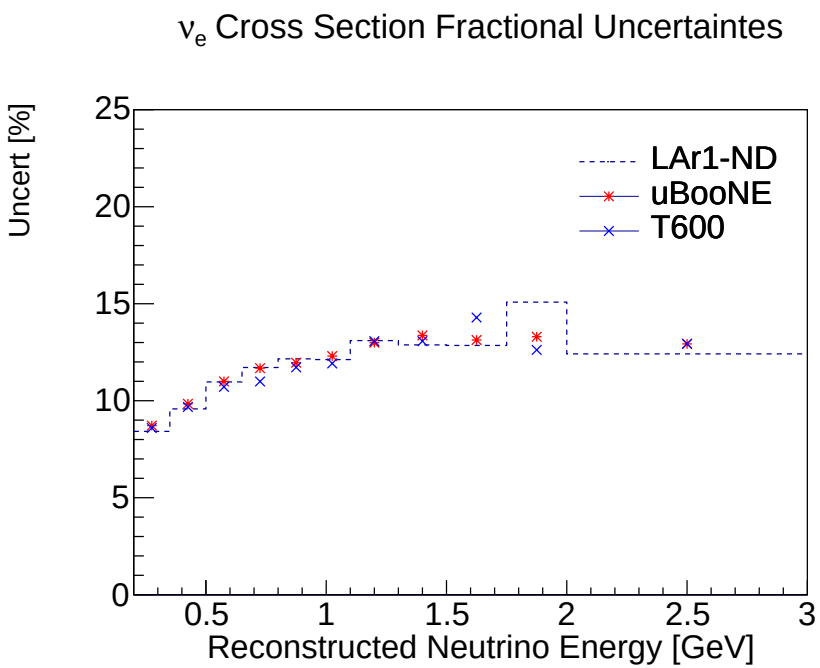
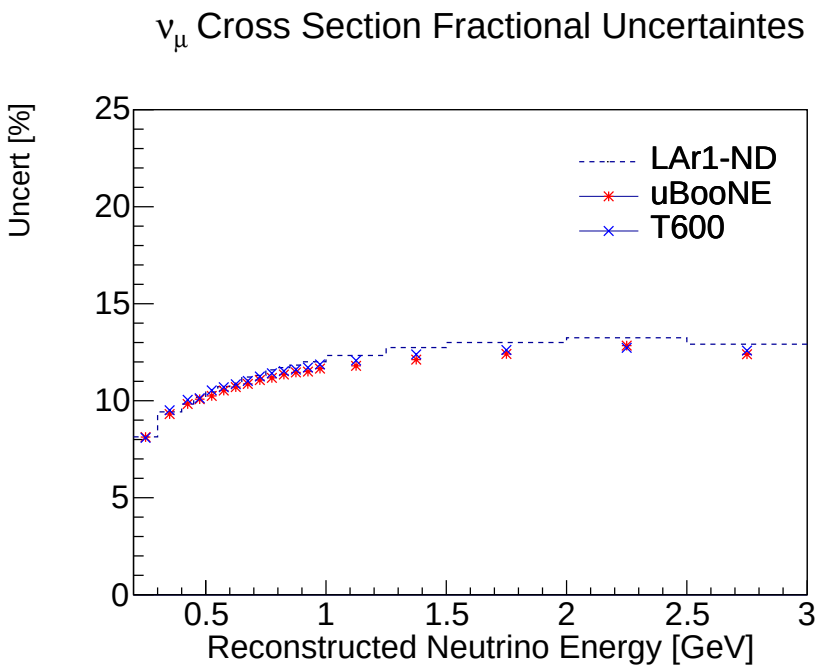
Outline

- What was done for the SBN Proposal?
- What is the current status?
- What are the items moving forward to be useful to Microboone Osc?

Cross Secion Uncertainties in the SBN Proposal

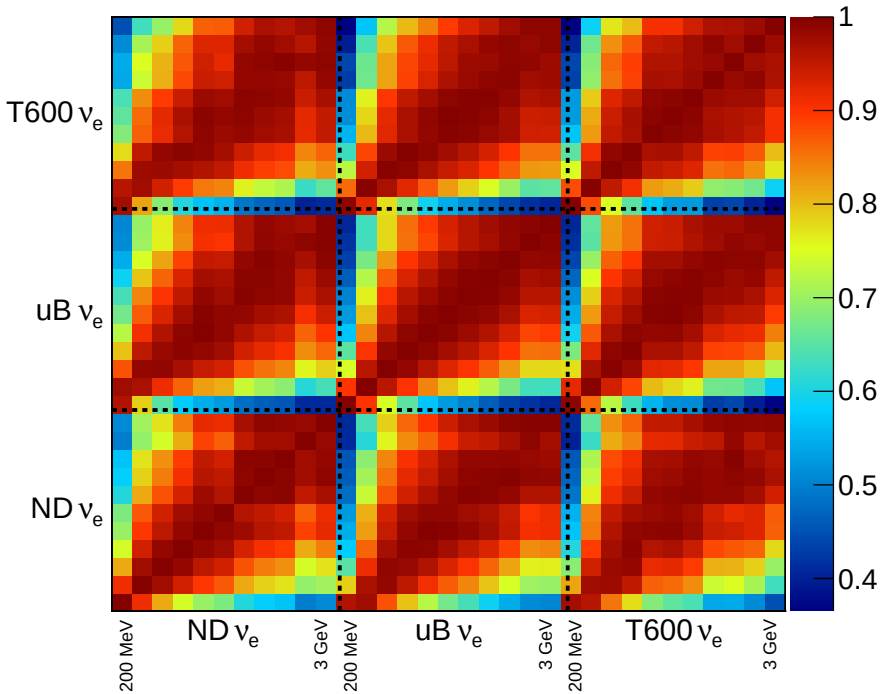




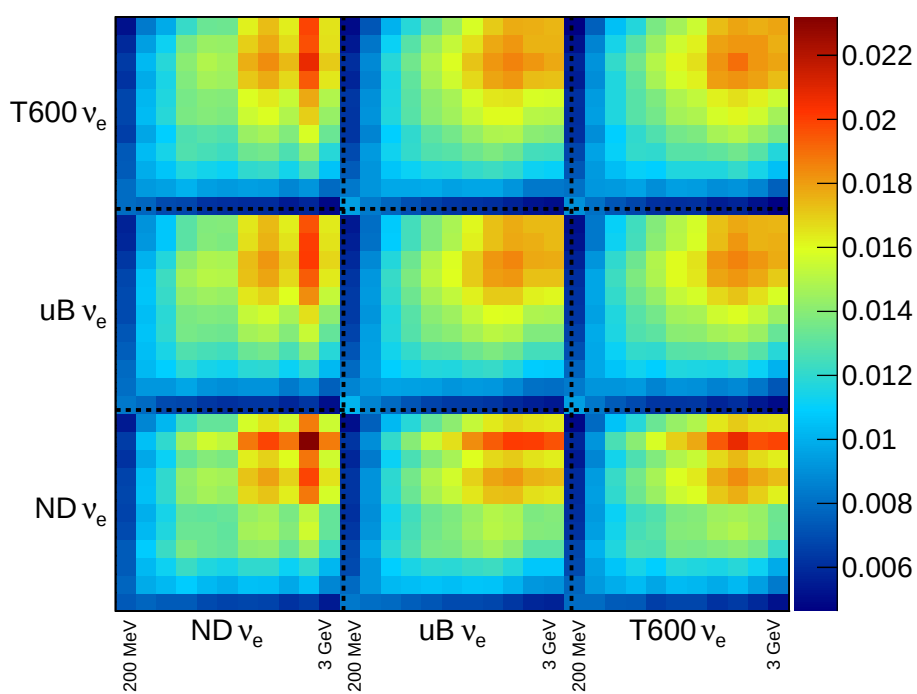
These plots show the total fractional uncertainty in event rates due to cross section uncertainties as reported in the SBN proposal.

Correlations in Cross Section Uncertainties

Correlation Matrix



Fractional Error Matrix

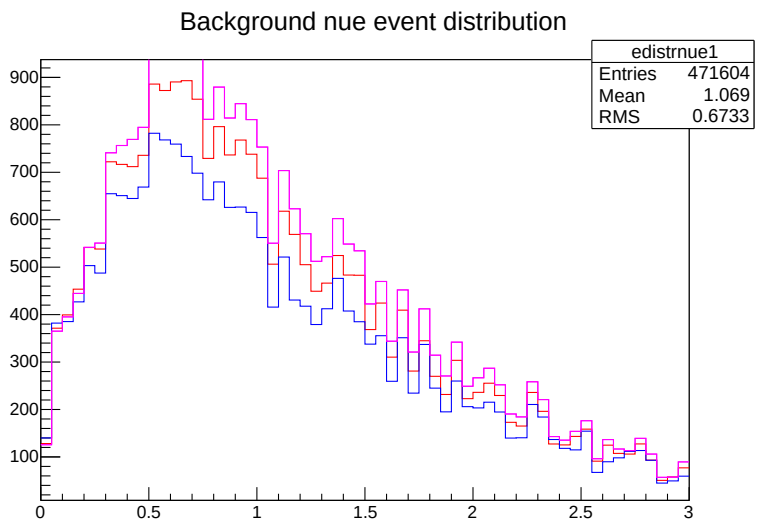


The uncertainties in the event rates are highly correlated, leading to large cancellations of the systematic uncertainty from cross sections.

Calculating Correlations

For each neutrino interaction, GENIE can be used to recalculate the cross section for that interaction with slight changes in the underlying physical paramaters. The ratio of cross sections has information about the relative probability of that interaction as parameters change.

$$\omega_i = \frac{\sigma_i}{\sigma_{Nom.}}$$



Weigh each neutrino with the weight calculated for it's cross section in the same set of alternate parameters to obtain a varied distribution.

Varying physical parameters

Parameter	Description	1σ Uncertainty (%)
M_A^{CCQE}	Axial mass for CC quasi-elastic	-15%+25%
M_A^{CCRES}	Axial mass for CC resonance neutrino production	$\pm$20%
M_A^{NCRES}	Axial mass for NC resonance neutrino production	$\pm$20%
$R_{bkg}^{\nu p,CC1\pi}$	Non-resonance background in νp, CC 1π reactions.	$\pm$50%
$R_{bkg}^{\nu p,CC2\pi}$	Non-resonance background in νp, CC 2π reactions.	$\pm$50%
$R_{bkg}^{\nu n,CC1\pi}$	Non-resonance background in νn, CC 1π reactions.	$\pm$50%
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NC	Neutral current normalization	$\pm$25%
DIS-NuclMod	DIS, nuclear model	Model switch

From the SBN Proposal: A table of the physical parameters that were considered and the 1 σ uncertainties in their nominal values.

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- To find the event rates in an alternate universe, bin each neutrino with the weight ω_i.

  $\rightarrow$ See Slide 5 for example with 3 Universes used in the SBN uncertainty calculation.

Useful tool for exploring systematic Uncertainties

Covariance Matrix:

$$E_{ij} = \frac{1}{\mathcal{N}} \sum_{m=1}^{\mathcal{N}} [N^i_{\mathrm{CV}} - N^i_m] \times [N^j_{\mathrm{CV}} - N^j_m]$$

Correlation Matrix:

$$\rho_{ij} = \frac{E_{ij}}{\sqrt{E_{ii}}\sqrt{E_{jj}}} \qquad [-1 \leq \rho \leq 1],$$

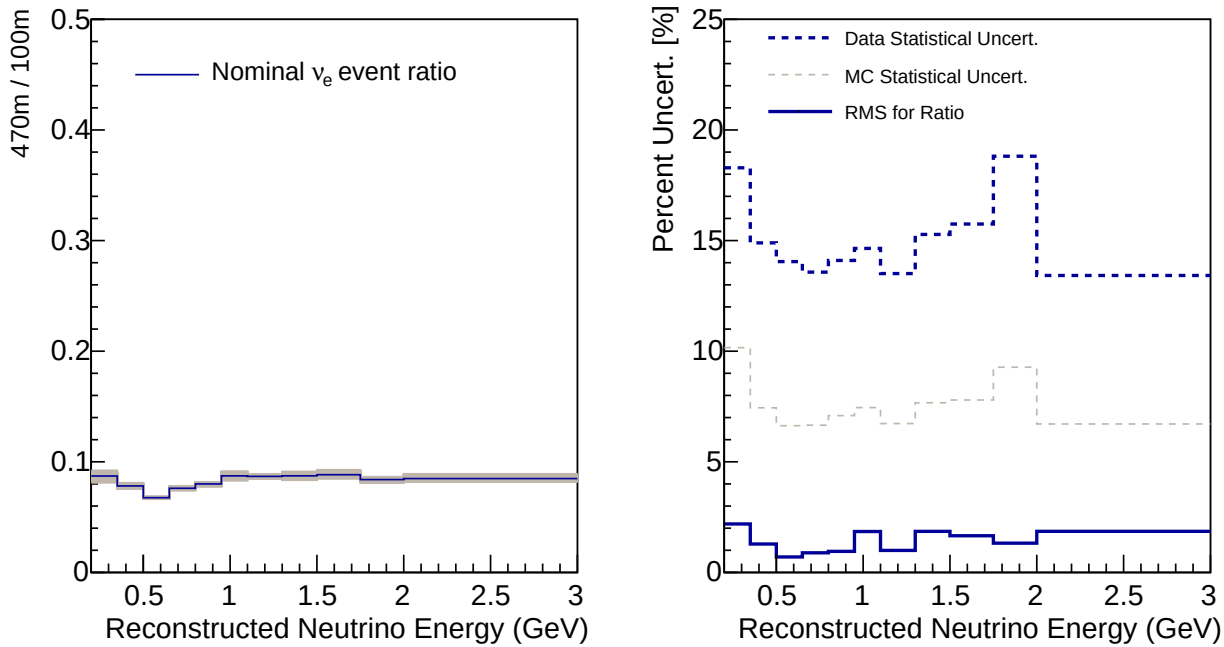
Bin-by-Bin Uncertainties:

$$\sigma_i = \sqrt{\frac{1}{\mathcal{N}} \sum_{m=1}^{\mathcal{N}} [N_i^{\mathrm{CV}} - N_i^m]^2}$$

Uncertainty in Event Rate Ratios (between detectors):

$$R_i = \frac{E_i^{uB}}{E_i^{ND}}, \quad \sigma_{R_i} = \sqrt{\frac{1}{\mathcal{N}} \sum_{m=1}^{\mathcal{N}} [R_i^{\mathrm{CV}} - R_i^m]^2}$$

Using Different "Universes" to Extract Physics



Each gray line on the left frame is the ratio of event rates (uB/ND) in each universe. They fall so closely together that the appear as a band and not individual lines.

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  - This is a discussion to be had with larsoft experts - how can we ensure the framework suits our analysis needs?
- By merging in to larana I hope to encourage a discussion about dealing with weights inside larsoft.
  - Wouldn't it be nice for the analysis challenge if we had a larsoft package to allow us to easily compute systematic uncertainties, including flux uncertainties, cross section uncertainties, detector systematics ...

Cross Section Systematics "To Do"

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- **Most Important:** The list of uncertainties used in the SBN analysis is hardly complete and the variation of underlying physical parameters needs to be reviewed by experts before MicroBooNE can use it with confidence on data.
- Secondary Importance: The framework and algorithms for computing these uncertainties could use some work and development. Largely this is my responsibility, but by moving it into larana I am embracing this becoming a task that the working groups in MicroBooNE will take ownship of and oversee.

Questions?