Constraining Oscillation Analysis Inputs at the T2K Near Detector

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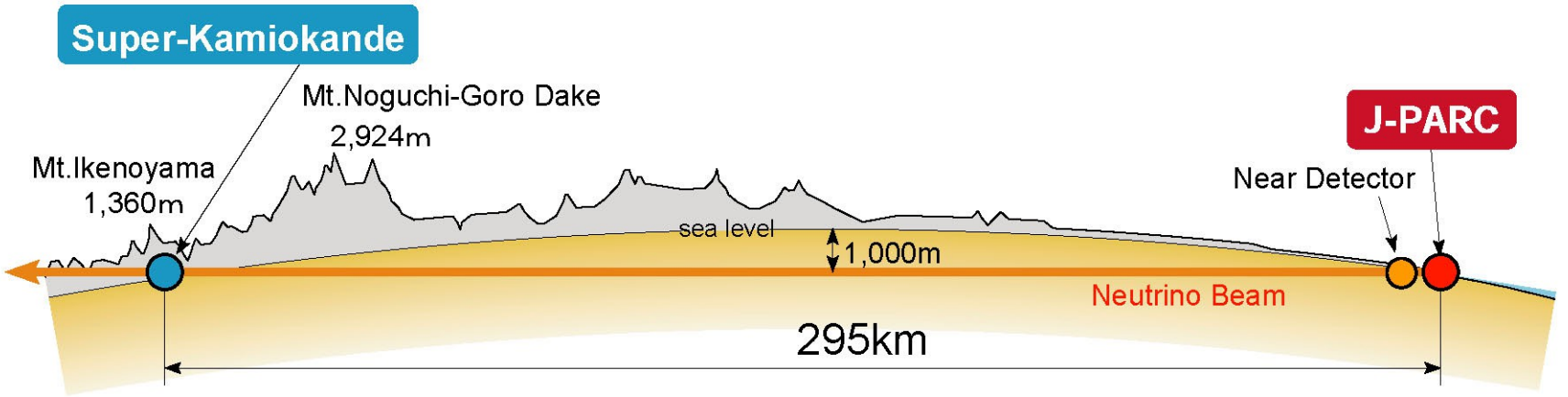
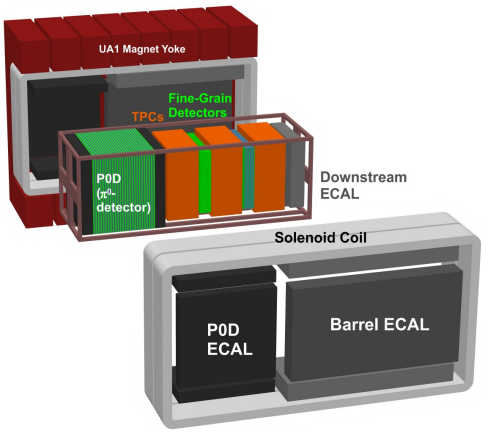
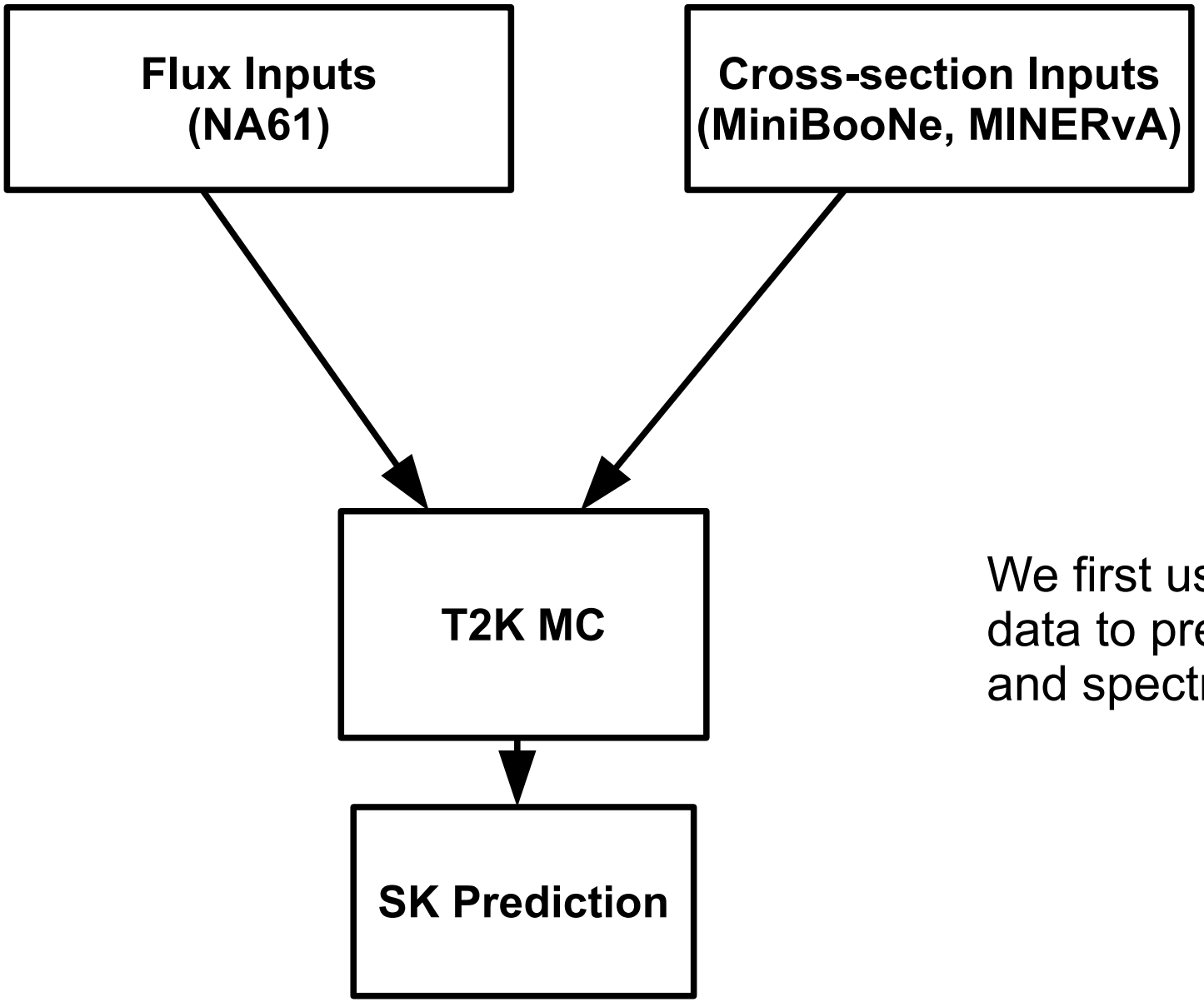
The T2K Experiment



- Near detector at 280m from production target.
- Water Cherenkov detector at Super Kamiokande, 295km from source
- Targets at Near Detector are the Fine Grained Detectors (FGDs)
  - FGD 1: Scintillator Modules
  - FGD 2: Water and Scintillator Modules



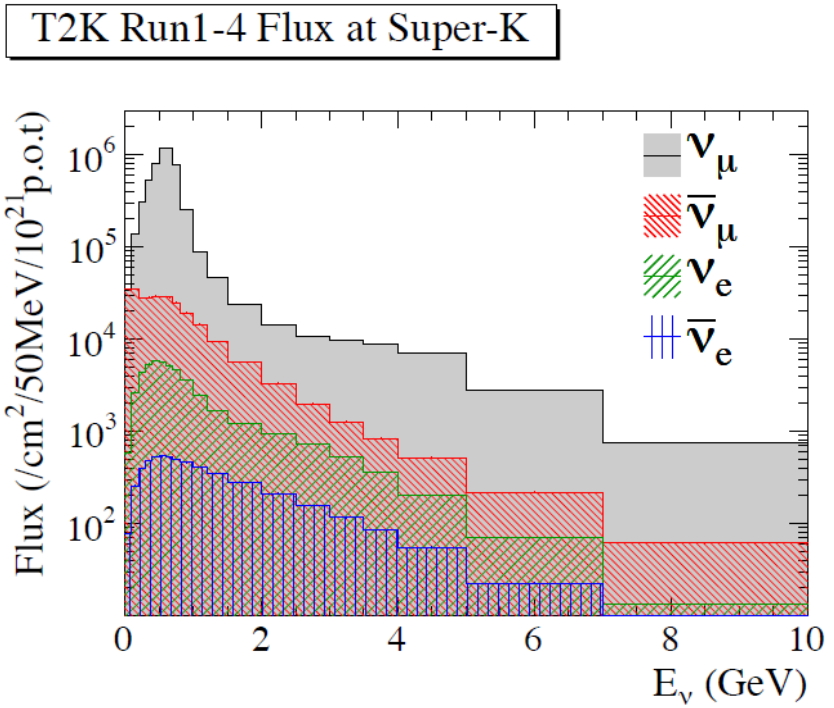
Oscillation Fit Inputs

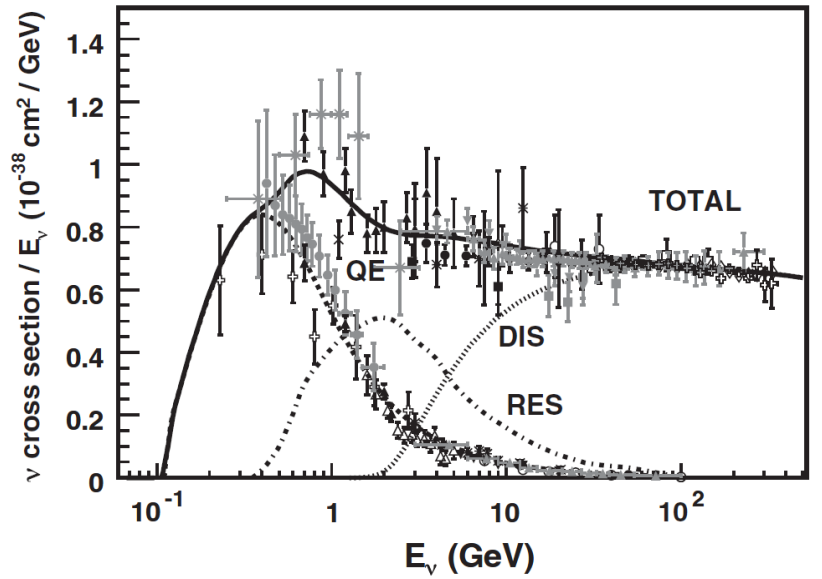


We first use external data to predict rates and spectra at SK.

External Inputs

- NA61/SHINE
  - Hadron production measurements at CERN
  - Tune pion and kaon production
- T2K proton beam measurements
- Cross section inputs from MiniBooNe and MINERvA





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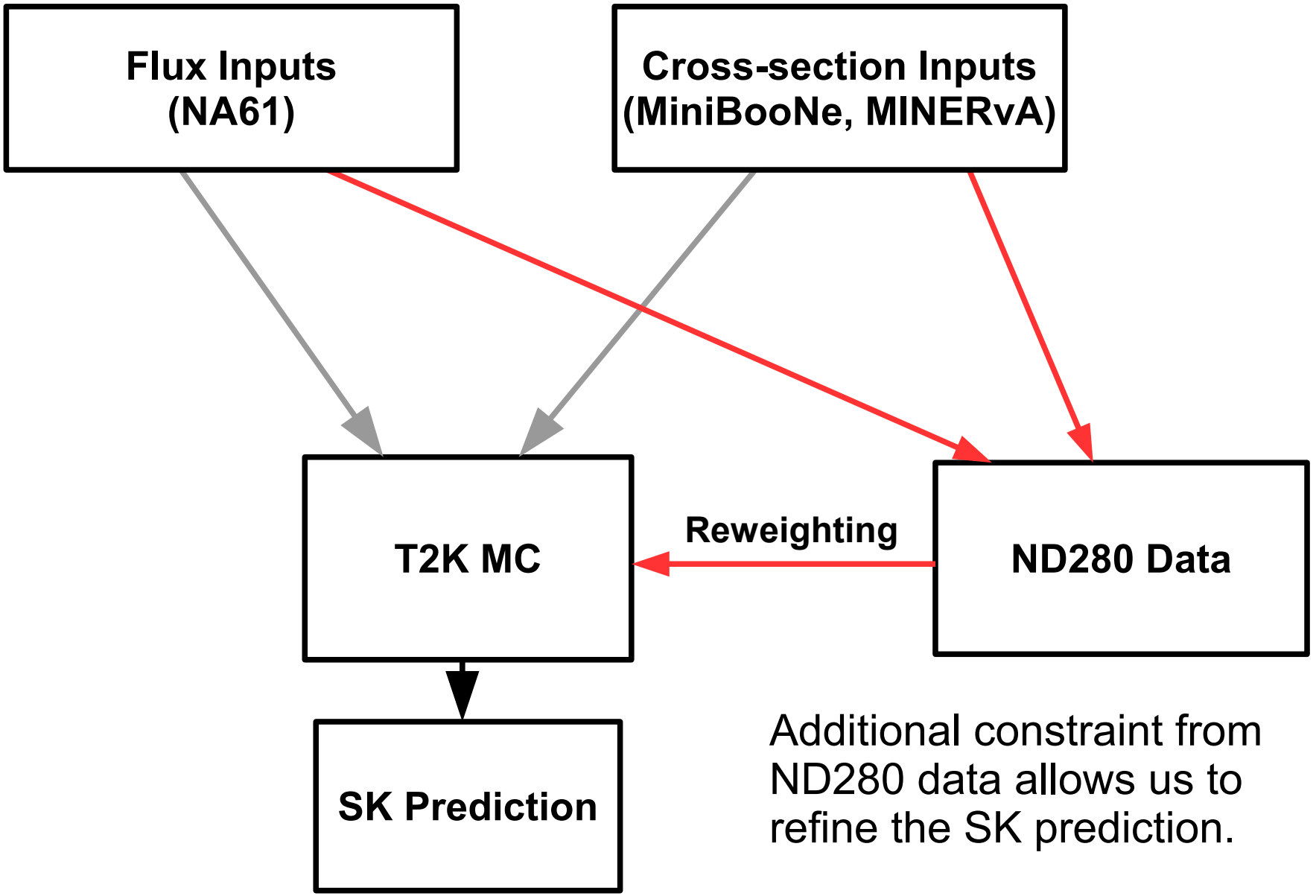
** J. A. Formaggio and G. P. Zeller, "From eV to EeV: Neutrino cross sections across energy scales", Reviews of Modern Physics, Vol. 84 (3), 1307 (2012)

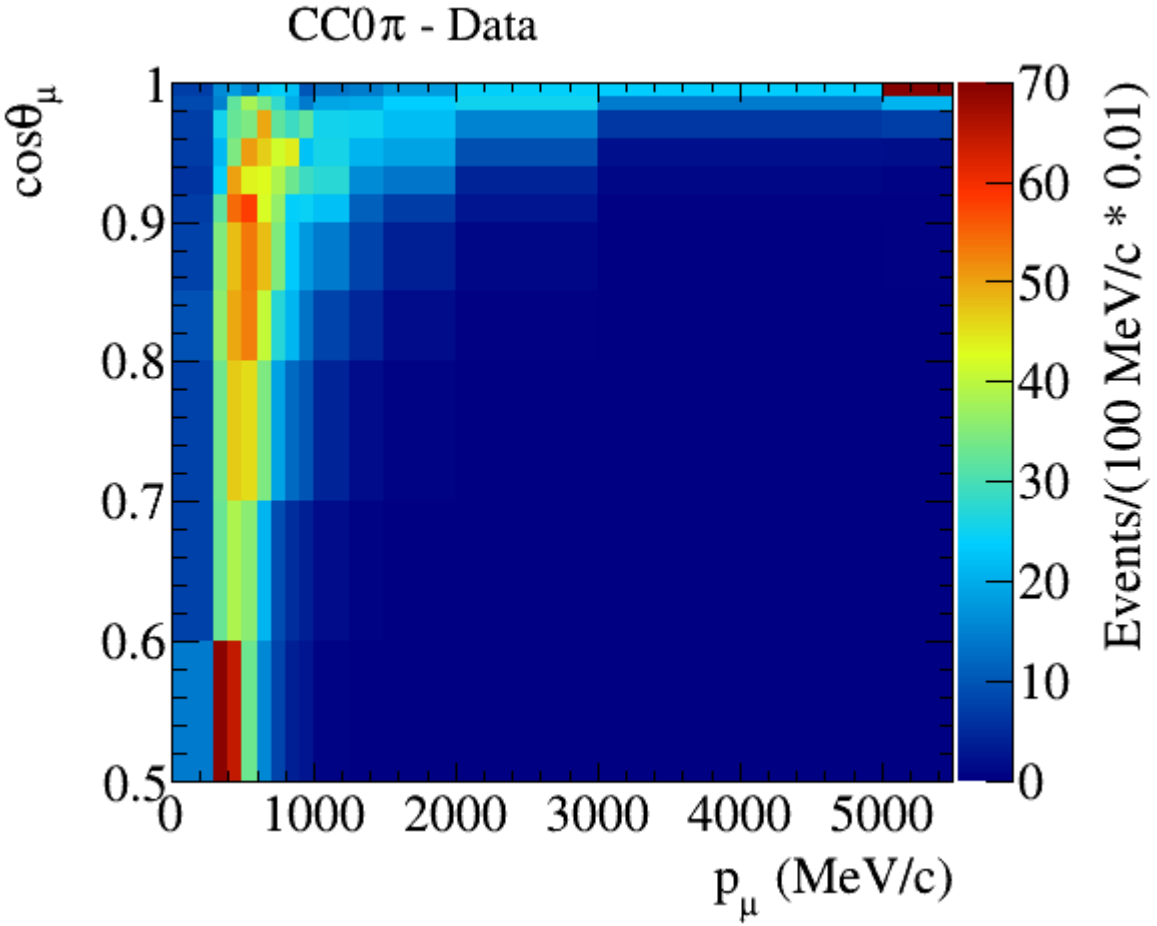
Oscillation Fit Inputs



Additional constraint from ND280 data allows us to refine the SK prediction.

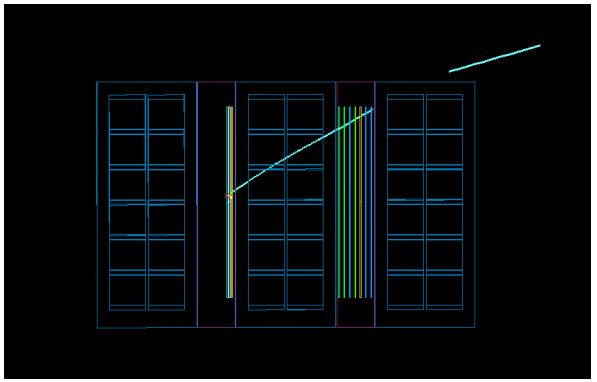
ND280 Event Selections

- Selections use FGD 1 as target
- Selected samples are defined by topology:
  - CC0Pi, CC1Pi and CC Other
  - Samples are binned in muon momentum and angle.

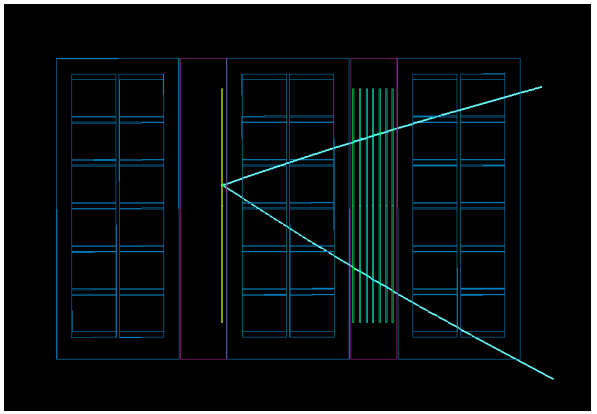


ND280 Event Selections

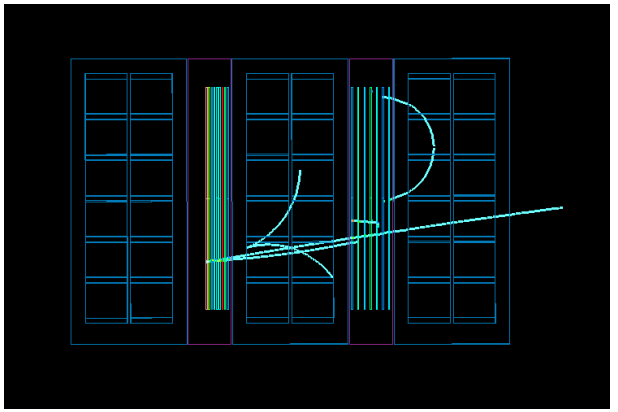
CC0Pi $\nu_\mu + n \rightarrow \mu + p$



CC1Pi $\nu_\mu + N \rightarrow \mu + \Delta \rightarrow \mu + \pi + N'$



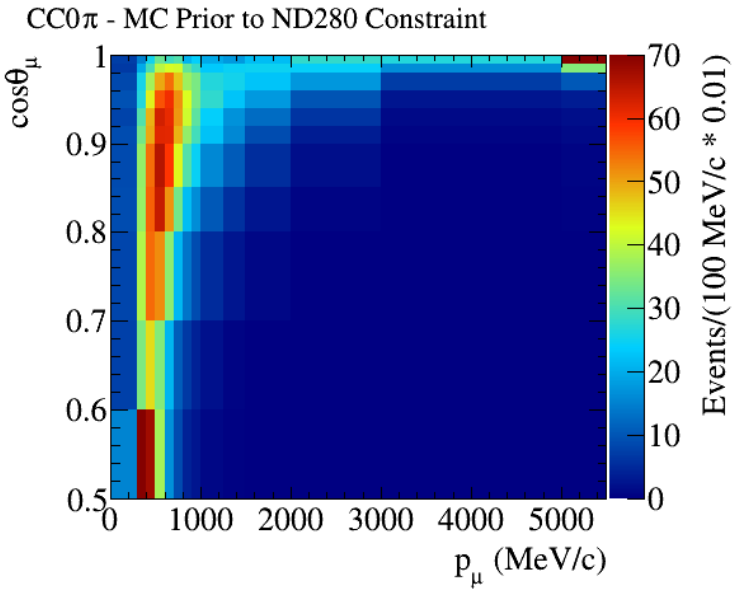
CCNPi $\nu_\mu + N \rightarrow \mu + N' + n\pi$

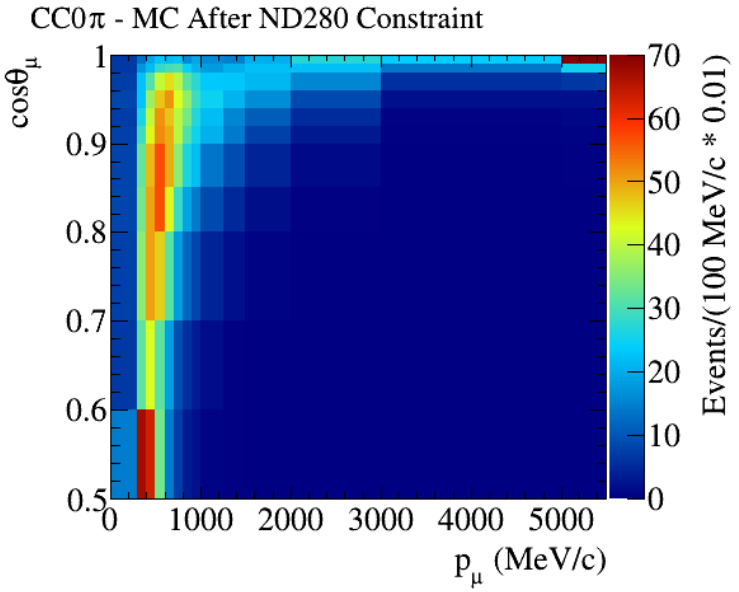


ND280 Fit

The ND280 + Beam Fit is a maximum likelihood fit that uses priors from beam flux and external cross section measurements:

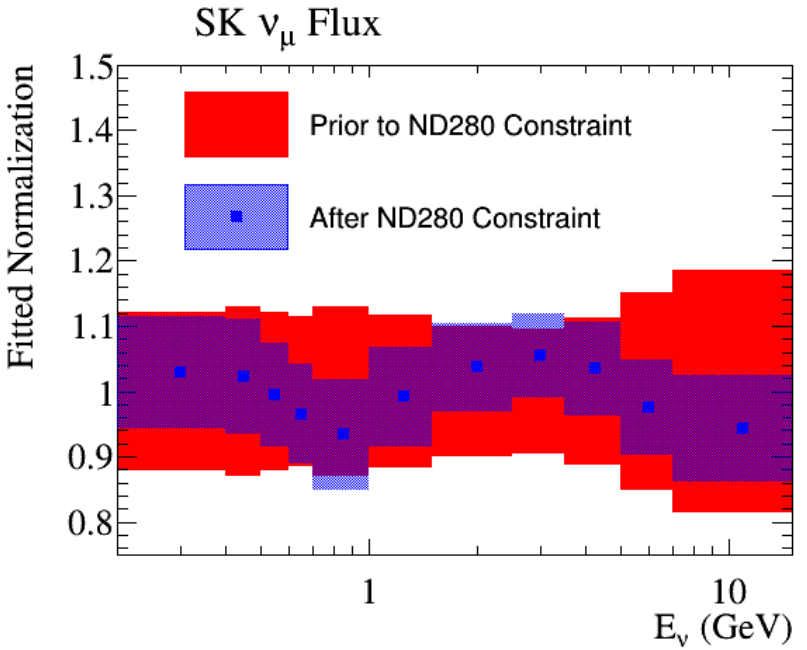
$$L(\text{flux},\ \text{xsec}) = L_{ND280}(\text{flux},\ \text{xsec}) \times L_{ext}(\text{flux}) \times L_{ext}(\text{xsec})$$

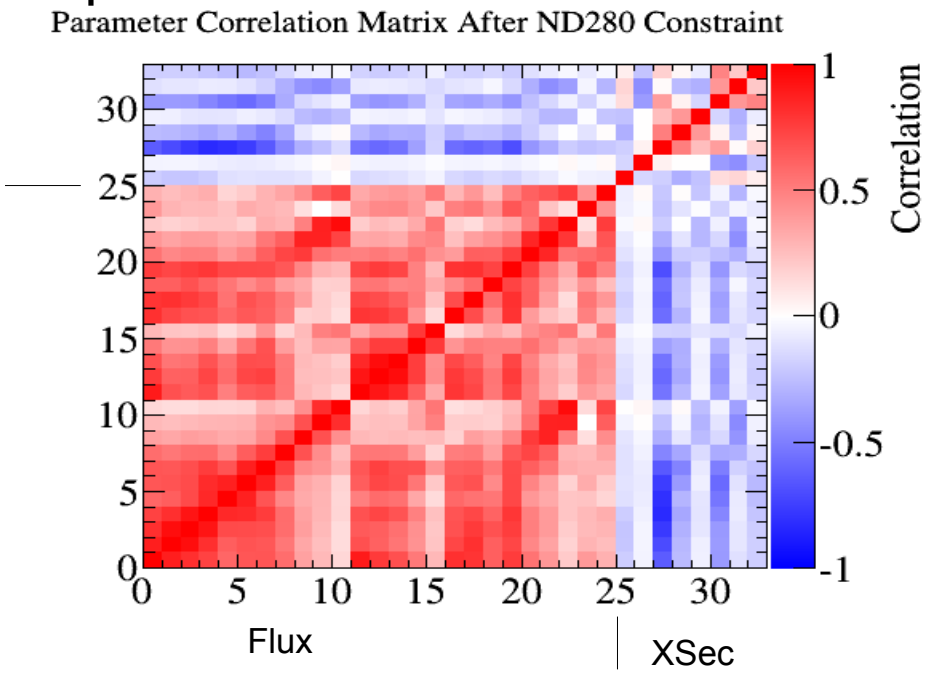


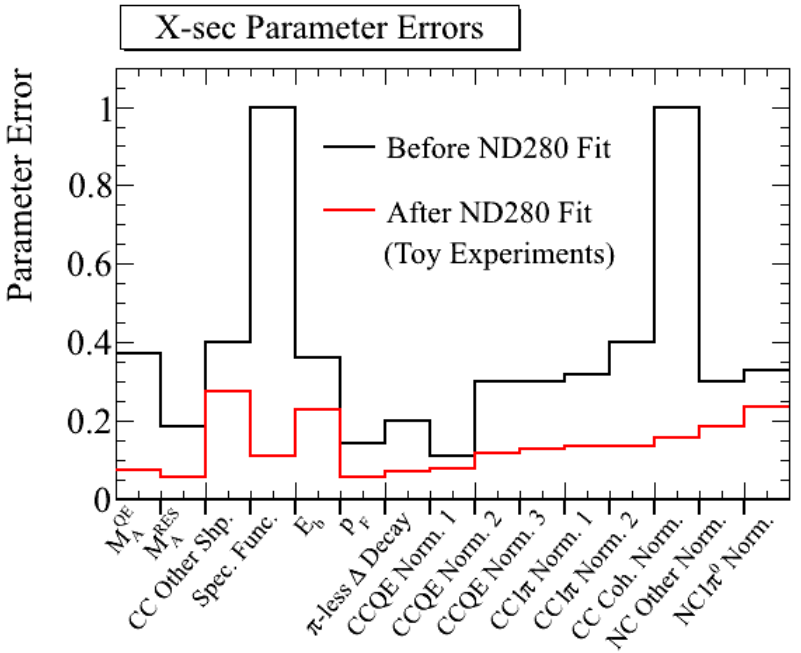


ND280 Fit Outputs

- Large improvement in cross-section parameter constraints and flux prediction.
- ND280 constrains the product of flux times cross section, which results in anticorrelations that reduce uncertainty in SK rate prediction.







T2K systematic uncertainty

		ν_μ sample	ν_e sample
ν flux and cross section	w/o ND measurement	21.8%	26.0%
	w/ ND measurement	2.7%	3.1%
ν cross section due to difference of nuclear target btw. near and far		5.0%	4.7%
Final or Secondary Hadronic Interaction		3.0%	2.4%
Super-K detector		4.0%	2.7%
total	w/o ND measurement	23.5%	26.8%
	w/ ND measurement	7.7%	6.8%

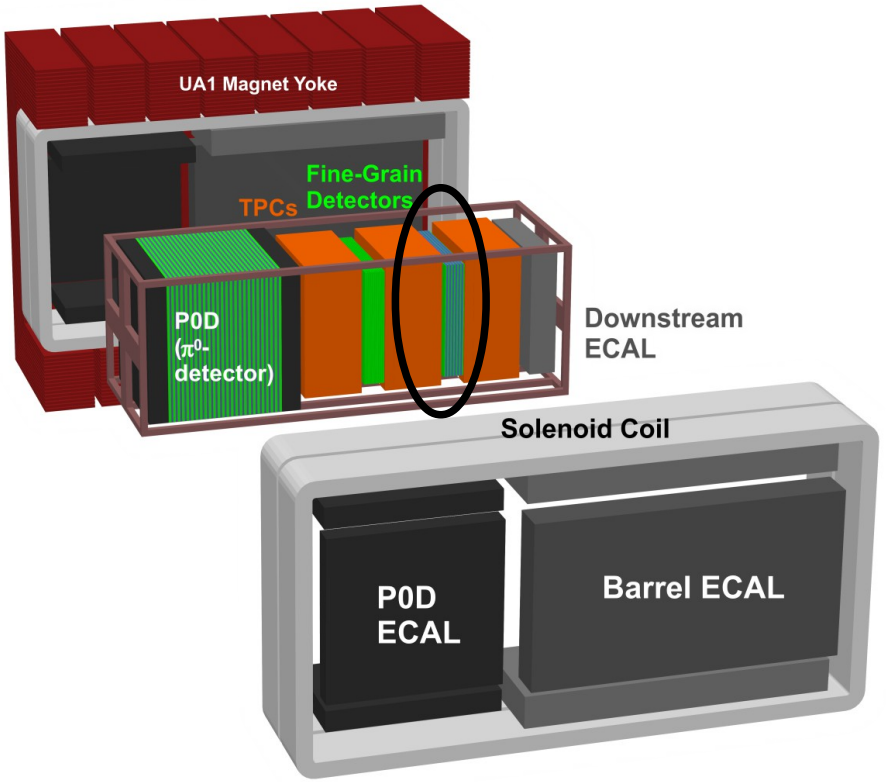
Fractional error on number-of-event prediction

Due to difference in target material, not all parameters fit at ND280 can be passed on to SK.

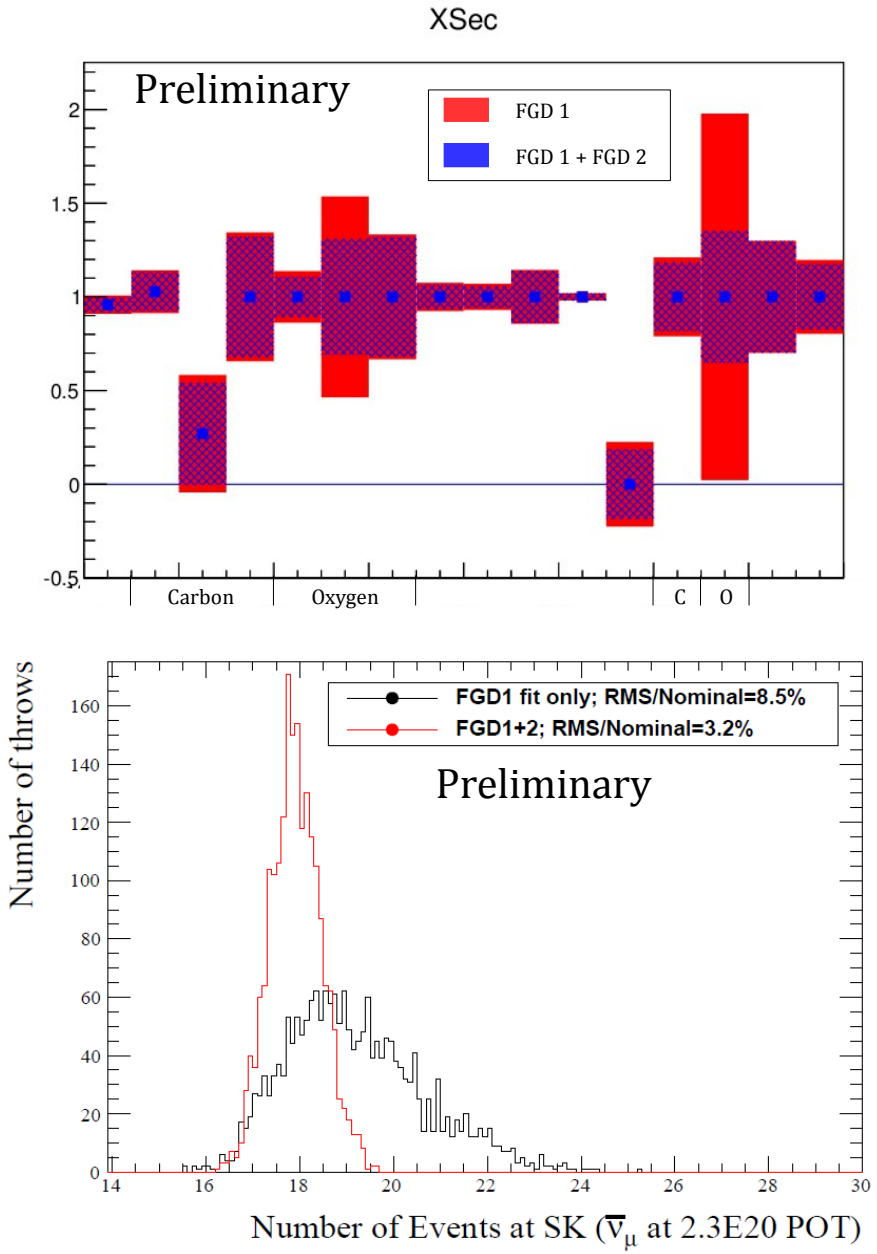
Future Improvements

- Current fits have only used FGD 1 as a target mass. The next step is adding FGD 2 to include an Oxygen target.
  - FGD 2 has both scintillator layers and water layers.

- Events in FGD 2 are divided into similar topological samples as FGD 1
  - CC0Pi, CC1Pi, CC Other
- By using both FGD 1 and FGD 2 samples, we can effectively make a subtraction measurement for the water target.



Future Improv. (cont.)



- Initial studies show improvement in constraints on oxygen cross section parameters
  - Plot show is a comparison of fits to MC using FGD 1 and using FGD 1 + FGD 2.
- Predicted event rate width at SK may also see an improvement over previous fits.

Summary

- Oscillation fits take flux and external cross section measurements as input.
- By fitting these with ND280 data, we can improve the constraints on our parameters and pass this on for reweighting the T2K MC.
- Future plans are to include a water target mass selection in the ND280 fit.
  - Will improve constraints on Oxygen cross section parameters