This chapter will present the validation of the BANFF fit using the MC as input. The first such test is using the nominal MC as the data, referred to as an Asimov data fit. The following two validation tests are fake data sets. One alters the flux prediction and is referred to as the High Energy Neutrino Flux Variation fake data set. The other is the Resonant Single Pion Variation fake data set.

0.1 Asimov Data Fit

Asimov data refers replacing the ensemble of simulated data sets by a single representative one [**?**]. In this analysis, this involves fitting the MC data set to itself for the primary purpose of checking the closure of the fitting framework. The Asimov set is produced with the same models as is implemented in the fitter and has all parameters set to their prior central values as defined in Chapter **??**. Instead of statistically sampling from the MC, which can insert statistical variations in the fit, the Asimov data set is created by scaling the set down to the full T2K POT.

In addition to running an Asimov fit, other metrics were examined in the Asmiov set. Shown first is a comparison of the event rates before and after applying weights to the MC. Next is a set of scans of the test statistic space to ensure the penalty and sample terms are already at their minima. .

0.1.1 Event Rate

Shown in Figure 1 is the event rates for the various samples for the Asimov fit. Sequences of weights are applied to understand their affect on the analysis. The "Data" column refers to real T2K data collected in the sample with the rest are MC events. We see that after applying the POT, flux, detector, and cross section weights, the prefit event rate is very similar to the data rate.

Sample	Data	Raw MC	POT only	POT+flux	POT+xsec	POT+det	Prefit
ν_μ 1-Trk Wtr	27151.00	526226.00	26270.98	28766.86	24222.45	26286.14	27327.94
ν_μ N-Trks	31013.00	529538.00	26708.61	31464.27	26267.19	26708.74	31098.20
$\overline{\nu}_\mu$ RHC 1-Trk	8779.00	176007.00	9152.04	9365.78	8321.76	9161.91	8461.37
$\overline{\nu}_\mu$ RHC N-Trks	4613.00	93132.00	4876.93	5014.74	4652.01	4876.81	4802.12
ν_μ RHC 1-Trk	3502.00	56861.00	2933.20	3182.20	2747.29	2938.29	3025.76
ν_μ RHC N-Trks	5424.00	85599.00	4460.10	4988.89	4413.01	4464.45	4956.19
ν_μ 1-Trk Air	23504.00	309373.00	23383.39	25319.17	21594.49	23402.63	23603.03
ν_μ N-Trks	32736.00	371986.00	28495.10	33255.58	27822.42	28505.66	32302.08
$\overline{\nu}_\mu$ RHC 1-Trk	6681.00	75374.00	7374.13	7512.47	6732.25	7381.37	6767.79
$\overline{\nu}_\mu$ RHC N-Trks	4437.00	47951.00	4689.16	4820.43	4446.52	4690.57	4544.72
ν_μ RHC 1-Trk	2324.00	20943.00	2049.01	2198.46	1916.33	2052.56	2067.12
ν_μ RHC N-Trks	4801.00	42098.00	4119.63	4586.22	4050.71	4122.39	4567.72
Total	154965.00	2335088.00	144512.28	160475.06	137186.41	144591.53	153524.03

Table 1: Event rate table for Asimov set. Raw MC refers the number of event in the sample without any weights applied. From left to right, application of various weights is shown with the rightmost "Prefit" column being having all weights applied. The term "xsec" refers to the cross section weights.

0.1.2 One Sigma Variation of Cross Section Parameters

To ensure the cross section spline weight functions were functioning properly, the sample contents were analyzed when the parameters were varied to their $\pm 1\sigma$ values. The results of the variations are shown in **??**, which show the samples are indeed affected by the weight functions.

0.1.3 Log-Likelihood Scans

Log-likelihood scans were examined in the Asimov data set. The results of the scans are shown in Figure 1 on page 4 with comparisons between the ()-only samples and FGD-only samples shown. It demonstrates that same penalties are applied between the ()-only and FGD-only analyses. Also that the ()-only data set has similar sensitivity with flux parameters with that of the FGD-only data.

0.1.4 Fit Results

The postfit results of the Asimov data fit are shown in Figure 2 on page 5 to Figure 5 on page 7. In order to provide a unified graphical representation for all the parameters, the prefit and postfit cross section shape parameters are adjusted to be relative to one (1).

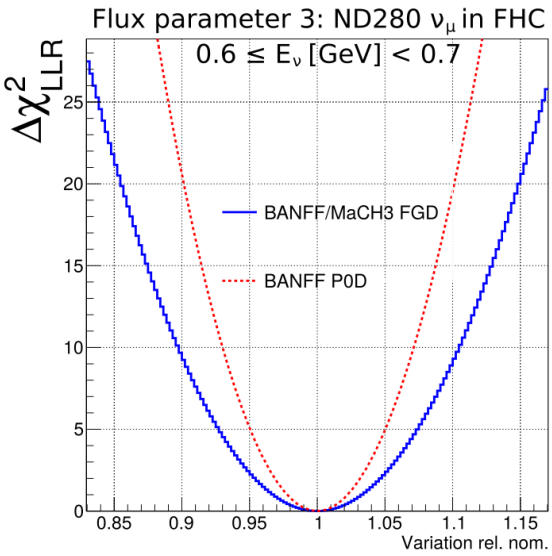
We see that the vast majority of postfit parameters have uncertainties smaller than their prefit.

0.2 Fake Data

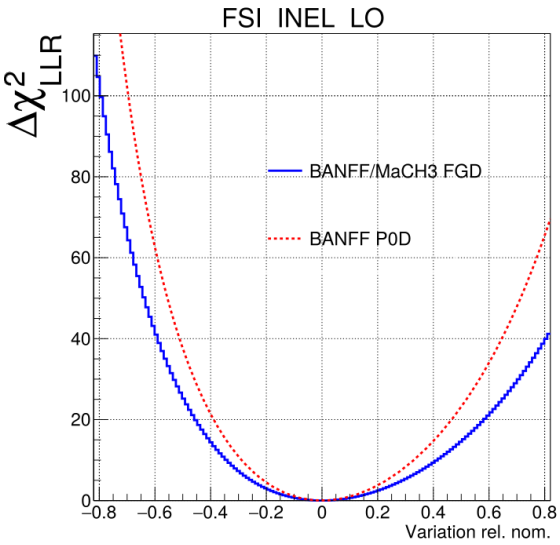
In this section, fake data studies were performed to test of the BANFF fit.

0.2.1 High Energy Neutrino Flux Variation

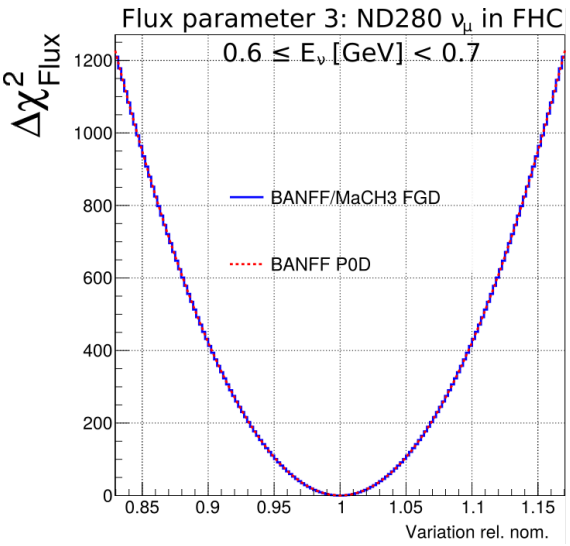
0.2.2 Resonant Single Pion Variation



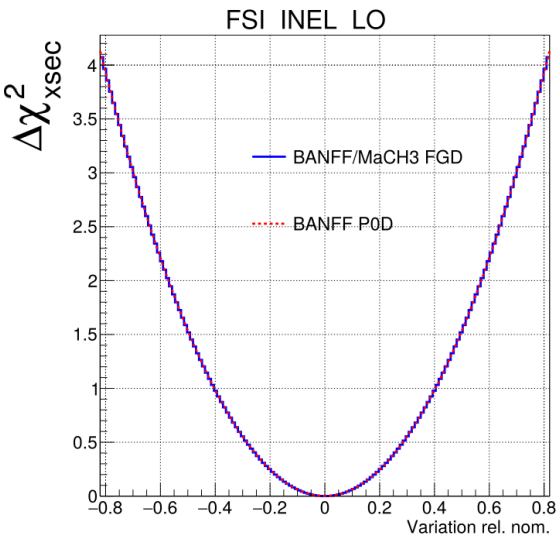
(a) Flux parameter b_3 $\Delta\chi^2_{\text{LLR}}$ scan



(b) FSI low energy inelastic $\Delta\chi^2_{\text{LLR}}$ scan

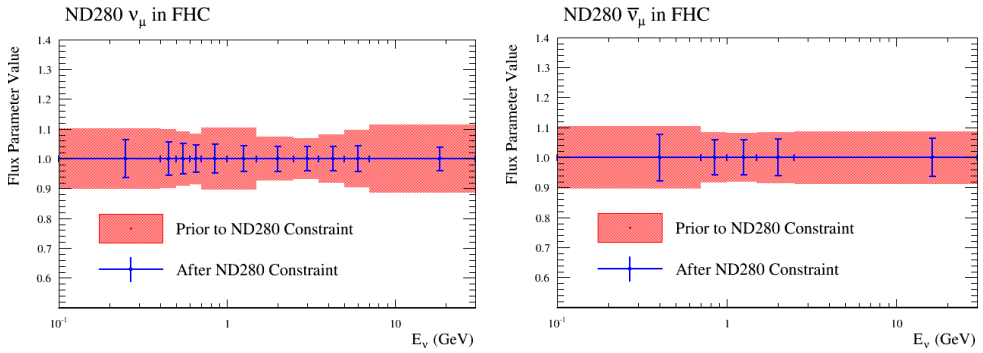


(c) Flux parameter b_3 $\Delta\chi^2_{\text{Flux}}$ scan



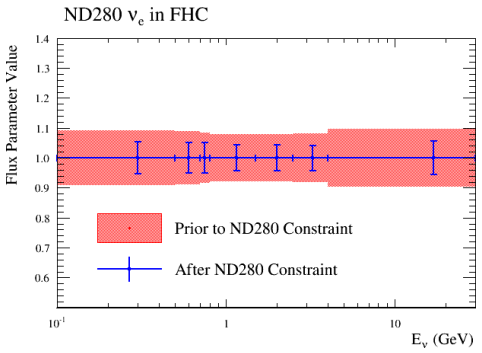
(d) FSI low energy inelastic $\Delta\chi^2_{\text{xsec}}$ scan

Figure 1: Comparison of $\Delta\chi^2$ scans for variations in fit parameters in the Asimov set. Two parameters are varied: parameter 3 (left) corresponding to a flux bin and 562 (right) corresponding to a FSI parameter. The top panel shows the change in the LLR test statistic $\Delta\chi^2_{\text{LLR}}$ while the bottom panel shows the penalty terms. In all sub-figures are comparisons between the BANFF/MaCH3 FGD 2017 results [**?**] against the BANFF ()-only results. Special thanks goes to Clarence Wret (c.wret@rochester.edu) of the University of Rochester for generating the plots.

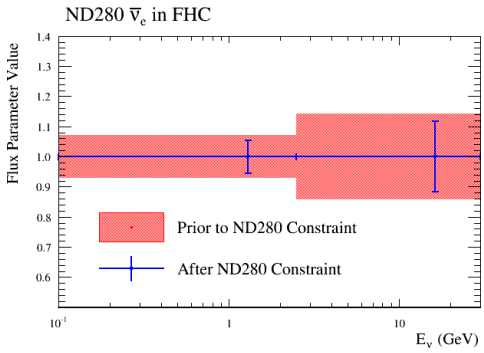


(a) ND280 in FHC (0-10)

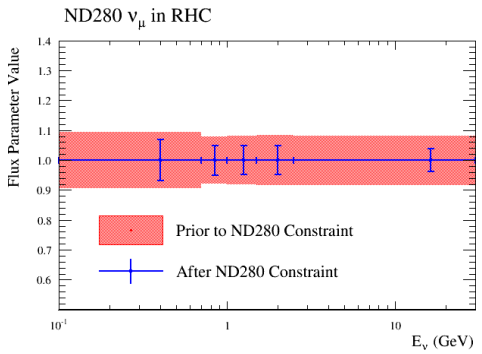
(b) ND280 in FHC (11-15)



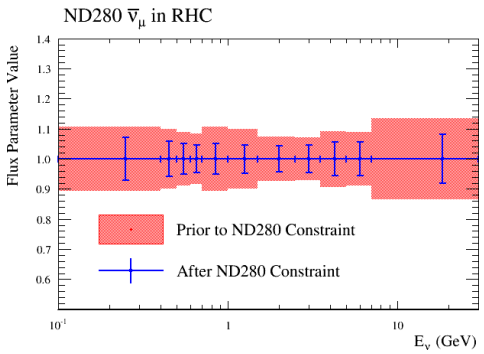
(c) ND280 in FHC (16-22)



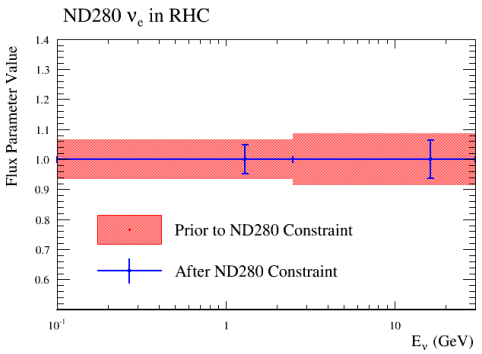
(d) ND280 in FHC (23-24)



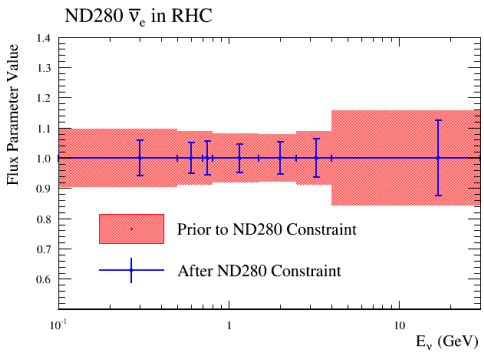
(e) ND280 in RHC (25-29)



(f) ND280 in RHC (30-40)

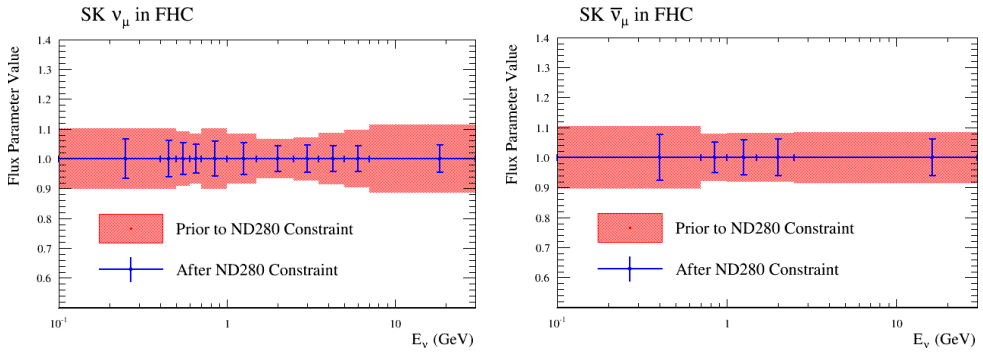


(g) ND280 in RHC (41-42)



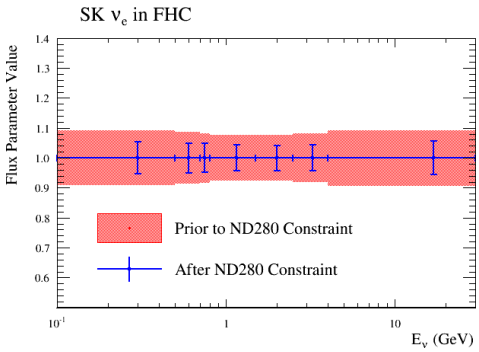
(h) ND280 in RHC (43-49)

Figure 2: Asimov fit results for the Flux at ND280. The numbers in parentheses indicate the fit indices in Table **??** on page **??**.

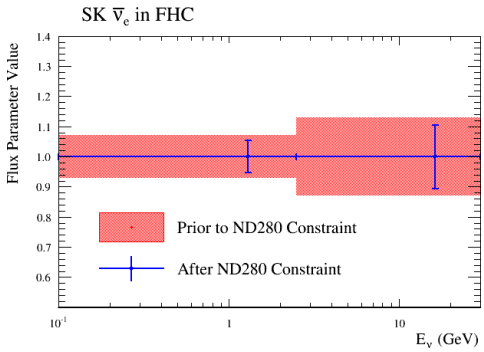


(a) SK in FHC (50-60)

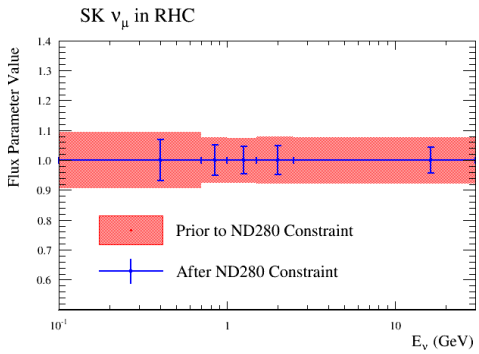
(b) SK in FHC (61-65)



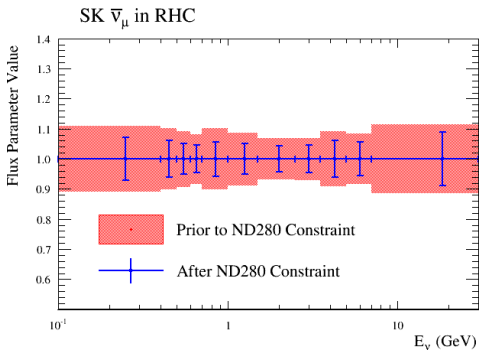
(c) SK in FHC (66-72)



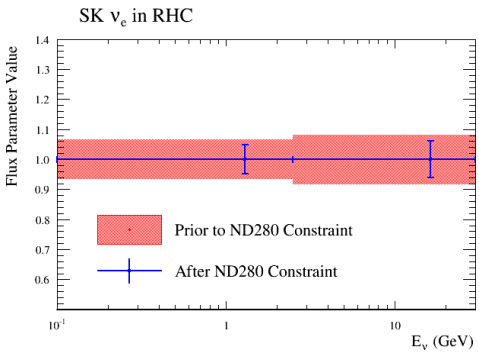
(d) SK in FHC (73-74)



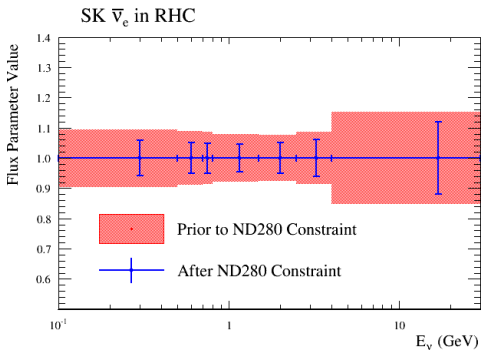
(e) SK in RHC (75-79)



(f) SK in RHC (80-90)

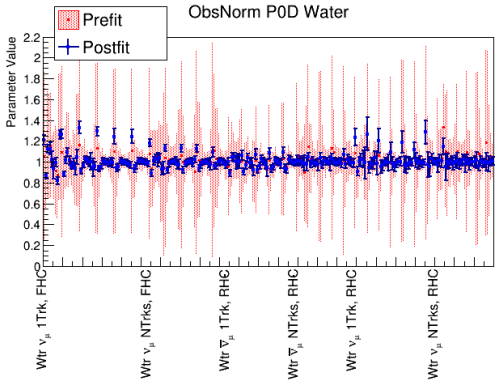


(g) SK in RHC (91-92)

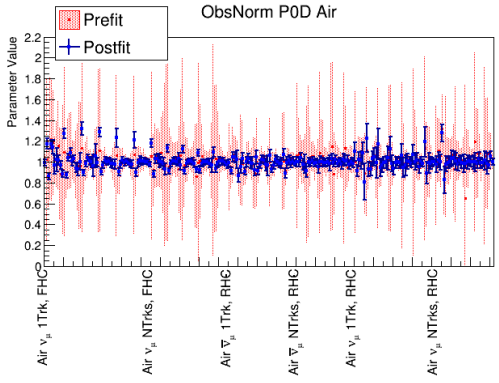


(h) SK in RHC (93-99)

Figure 3: Asimov fit results for the Flux at Super-K. The numbers in parentheses indicate the fit indices in Table **??** on page **??**.

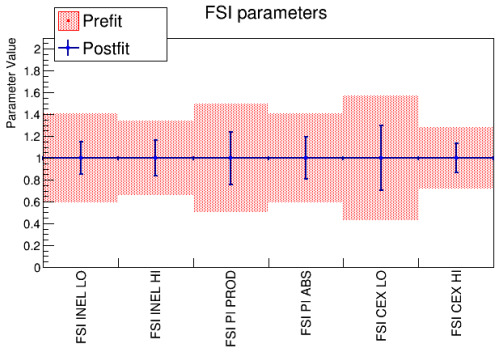


(a) These are bad, replaceObsnorm (100 - 330)

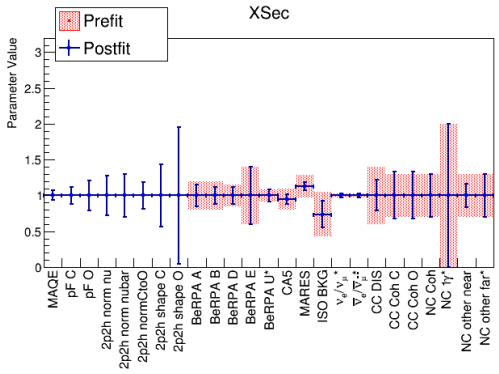


(b) These are bad, replaceObsnorm (331-561)

Figure 4: These are bad, turn off load the detector parameters from the external interface. < BANFF.RunFit.LoadDetParams = 0 > Asimov fit results for the FSI and cross section parameters. The numbers in parentheses indicate the fit indices in Table **??** on page **??**.



(a) FSI (562-567)



(b) Cross Section (568-592)

Figure 5: Asimov fit results for the FSI and cross section parameters. The numbers in parentheses indicate the fit indices in Table **??** on page **??**.