MULTI-NUCLEON EFFECTS AND THEIR IMPACT ON THE MINIBOONE OSCILLATION ANALYSIS

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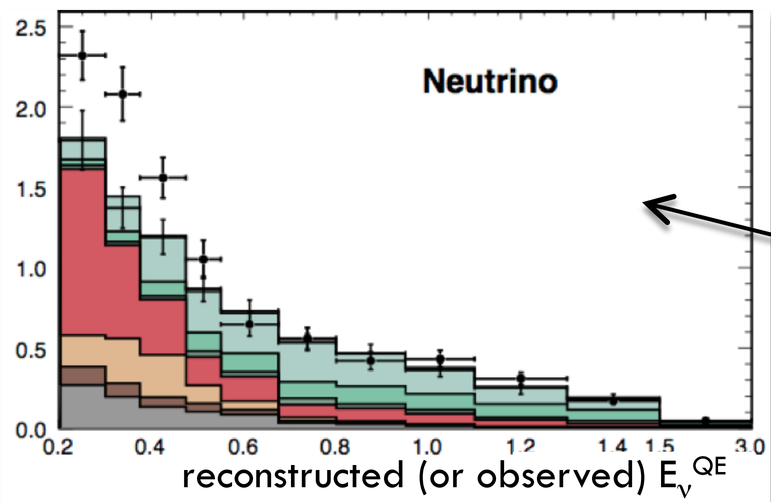
- thanks to input from Warren Huelsnitz (LANL)

The Basic Issue

- we are conducting a search for $\nu_\mu \rightarrow \nu_e$ appearance



(1) we observe a # of events as a function of **reconstructed** $\mathbf{E_\nu^{QE}}$

(data and MC are treated in the same way)

(2) we fit them to an oscillation probability that is necessarily in terms of **true** $\mathbf{E_\nu}$

$$P(\nu_\mu \rightarrow \nu_x) = \sin^2(2\theta)\sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$$

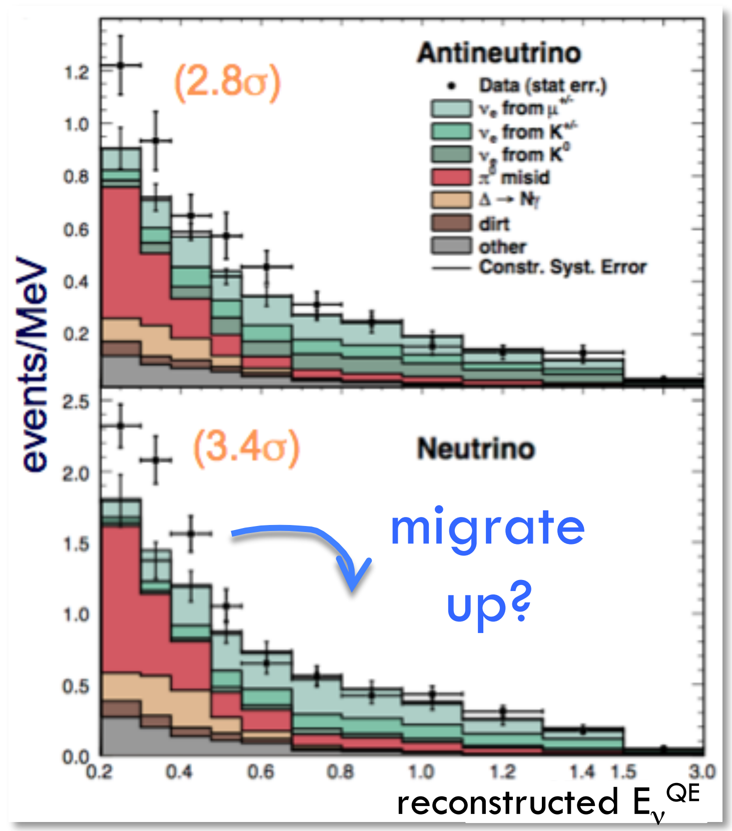
- we need to assume a relationship between reconstructed and true E_ν

So ...

- what if you don't have this mapping correct?

- for ex., we know that there are additional processes (2p2h, MEC) that are not in our simulation which will have a different relationship between observed and true E_ν

- how would our results change if we were to include such effects?



MiniBooNE final results, PRL 110, 161801 (2013)

First …

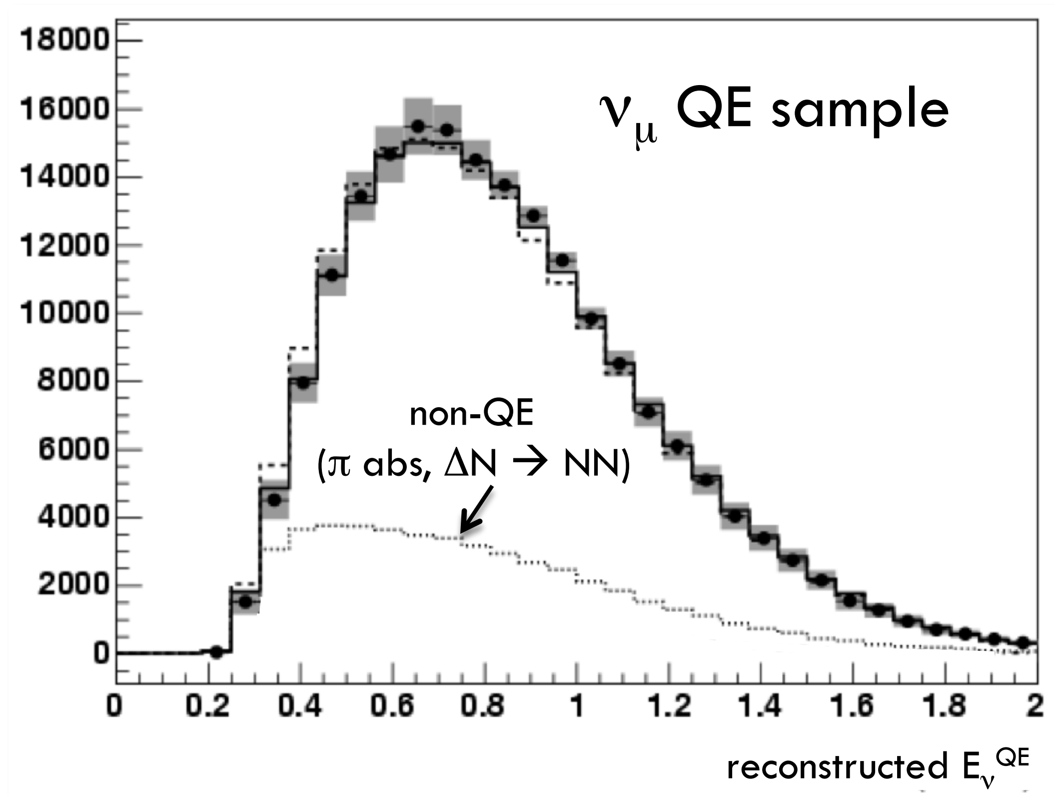
- we considered a (naive) place-holder for MEC effects, namely an add'l contribution of events that look QE but come from higher true energies

- we have a sample like this that we already take into account … π absorption

  - *they have a much larger reconstructed → true E_ν migration than QE events*

- x2 increase in π absorption contribution did not have an appreciable effect due to high statistics ν_μ constraint

(we perform a combined fit to both ν_e and ν_μ QE event samples)



We Can Do Better

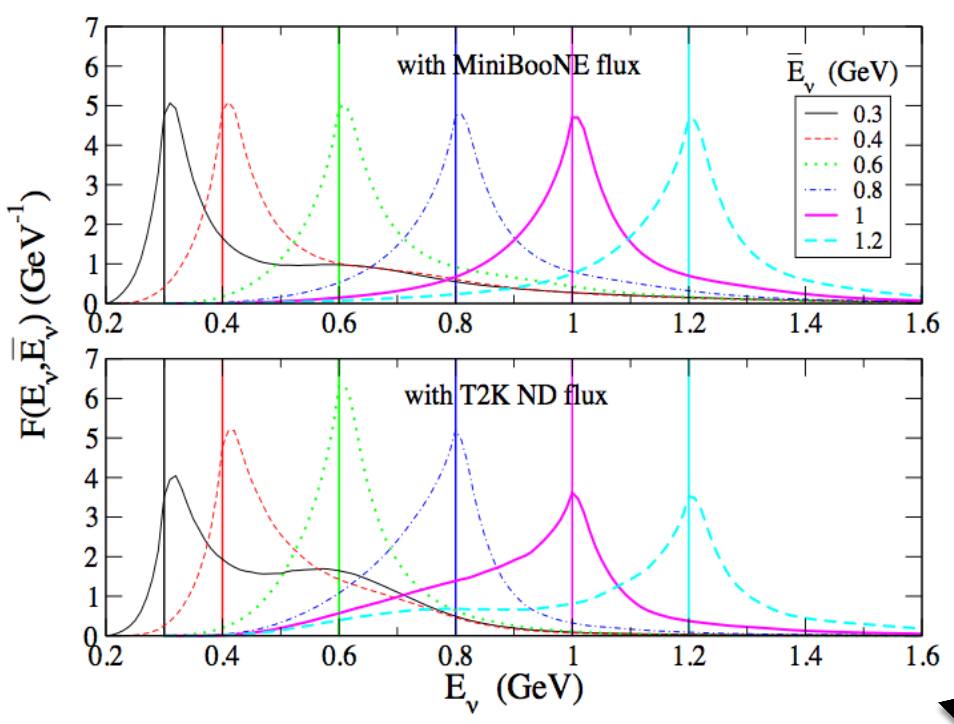
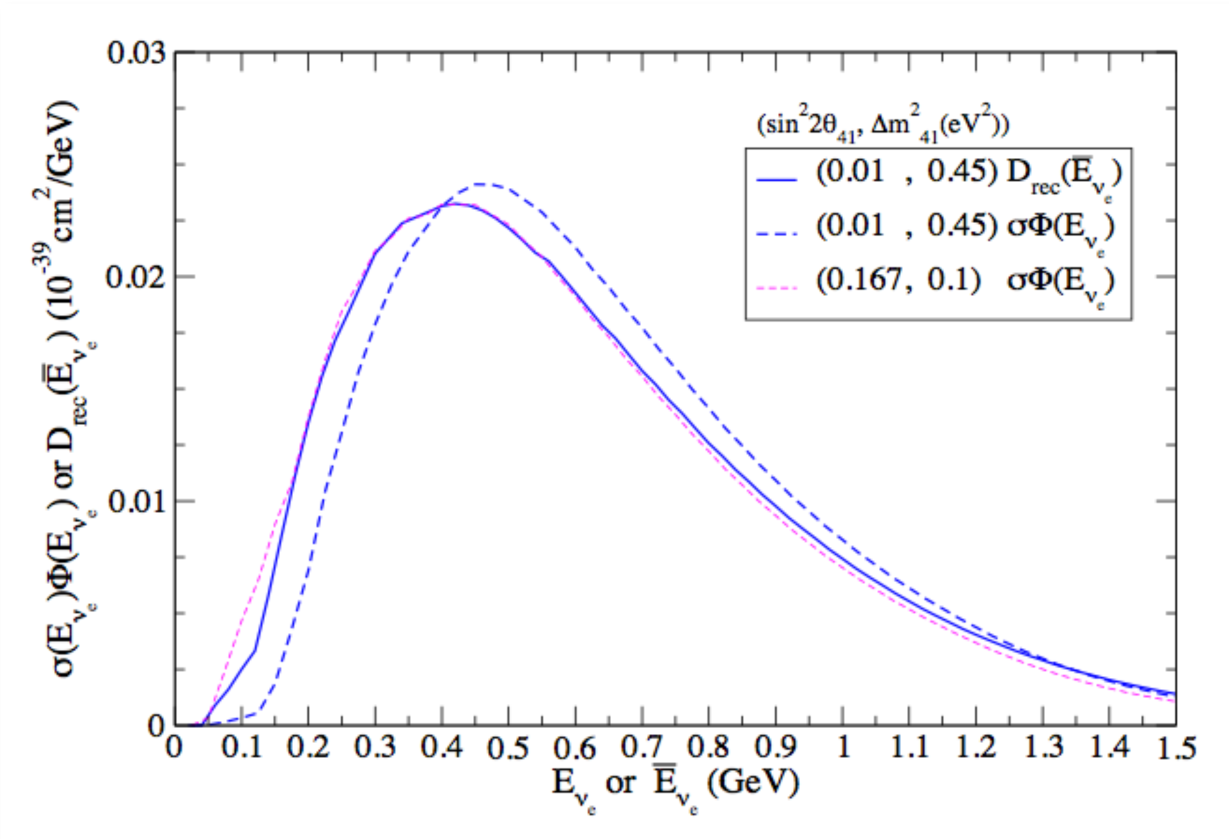


FIG. 8: (Color online) Probability distributions for several $\overline{E_\nu}$ values corresponding to the different vertical lines. Upper panel: using the MiniBooNE flux. Lower panel: using the T2K near detector flux.

- we have a prescription for how the E_ν assignment could be altered by multi-nucleon effects
- we used the model from Martini, Ericson, Chanfray (the 1st to calculate this)
- you saw this plot yesterday

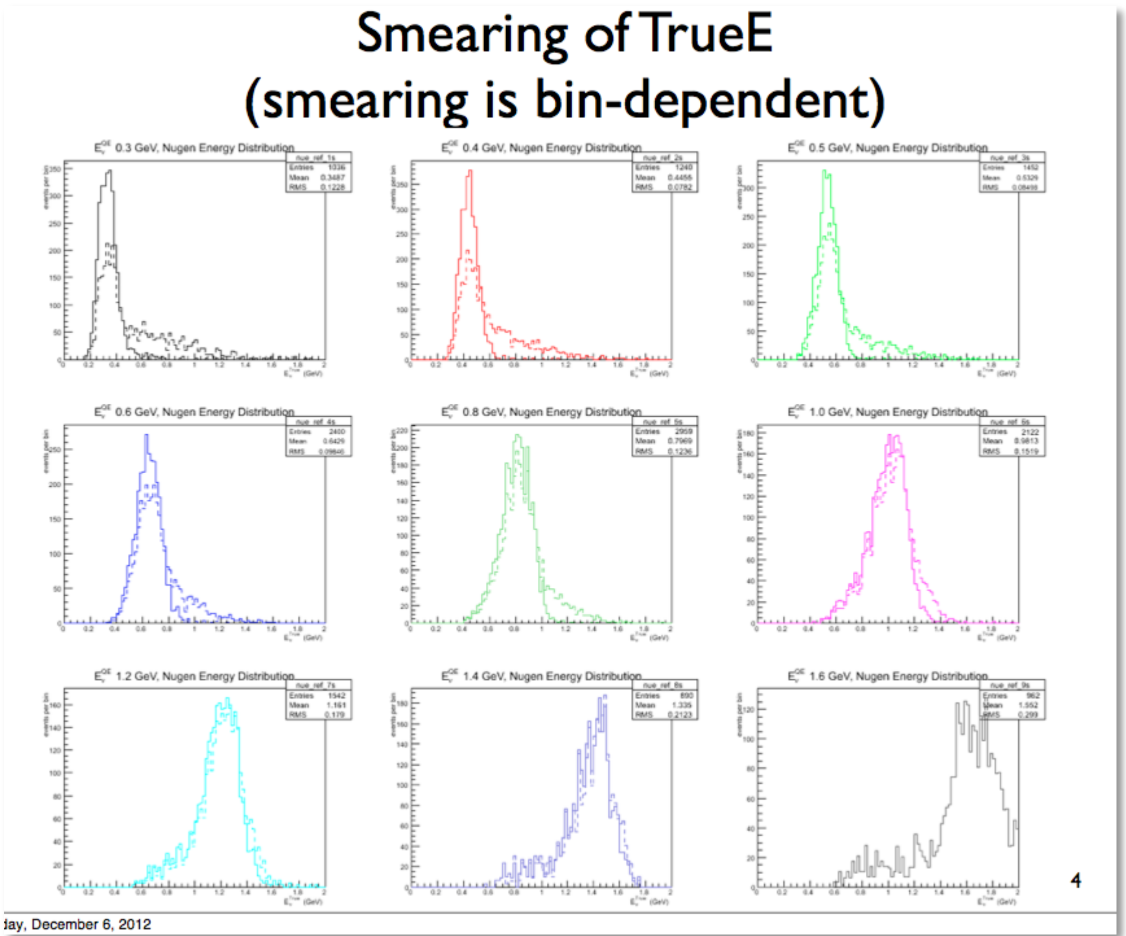
Martini, Ericson, Chanfray, PRD 85, 093012 (2012)

Effect on Energy Distribution of Signal Events



Martini, Ericson, Chanfray, PRD 87, 013009 (2013)

Implementation



- just smear the energies of some events to mimic the behavior of the main features of the Martini *et al.* model

- we assume that some fraction of events must come from ν's with much higher E_ν than in our MC
- so, for some % of events we shift the true E_ν to a higher value *(bin-dependent)*
- the % of events smeared and the magnitude of the smearing was chosen to match Martini *et al.* paper

The Test

- so, for a certain fraction of events the true E_ν was modified which changed the oscillation predictions

"standard" QE: rec E_ν^{QE} → true E_ν (RFG)

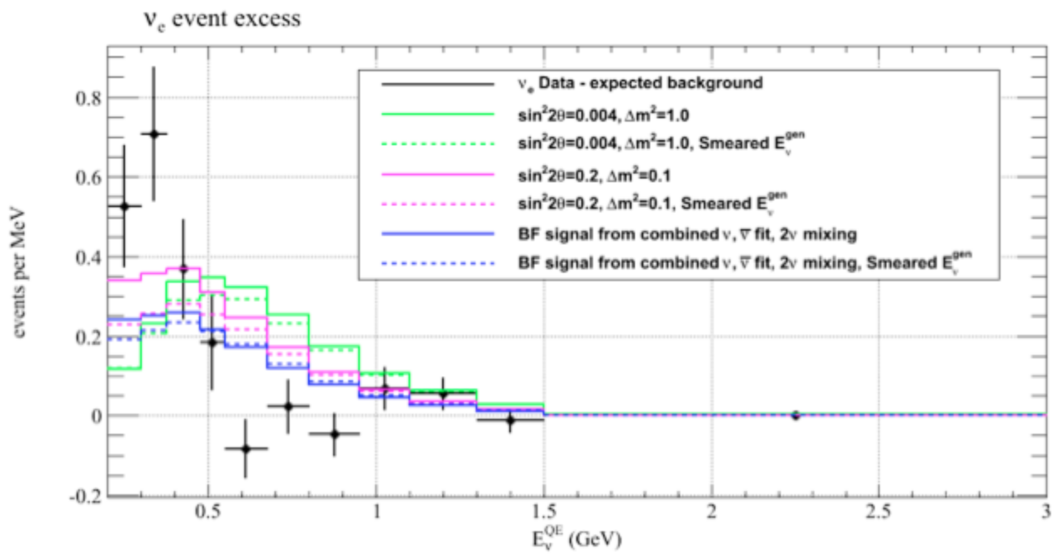
fraction of events: rec E_ν^{QE} → true E_ν (Martini *et al.*)

(fraction ranged from 30-50%)

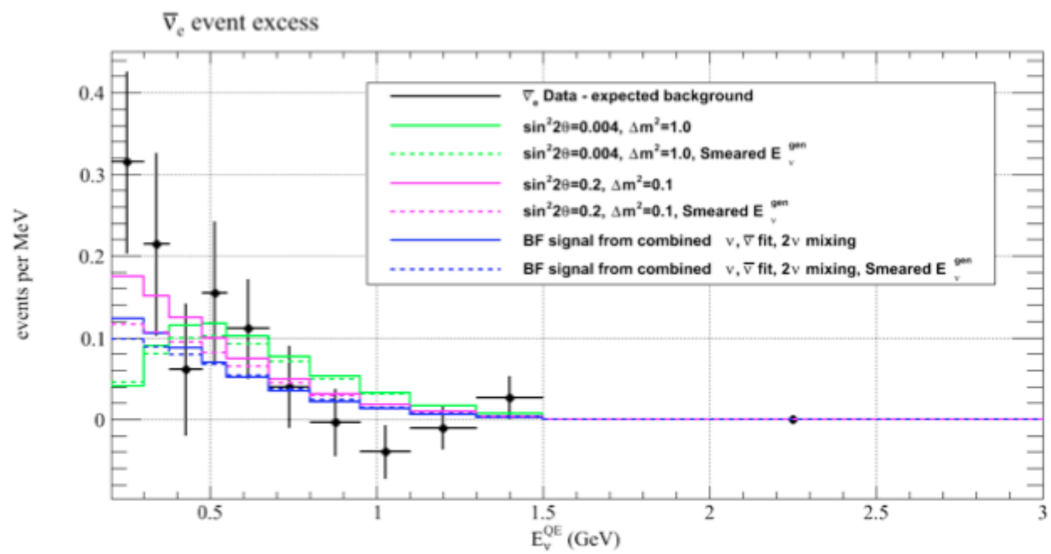
$$P(\nu_\mu \to \nu_x) = \sin^2(2\theta)\sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$$

Results

ν_e



$\bar{\nu}_e$



	default analysis	modified predictions
$\sin^2(2\theta)_{BF}$	1.0	0.3726
Δm^2_{BF}	0.0373	0.0669
χ^2_{BF}	317.6	320.0
χ^2_{null}	333.1	333.1
$\Delta\chi^2$	15.5	13.1

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Backups

Energy Shift

- the shift was chosen from the absolute value of a random # drawn from a Gaussian distribution; magnitude of the mean shift depended on the σ of the Gaussian, which was also bin-dependent

Bin (MeV)	Fraction of Events Smeared	Mean for Gaussian (MeV)	Sigma for Gaussian (MeV)
< 350	50 %	300	400
350 – 450	50 %	150	350
450 – 550	40 %	150	330
550 – 700	30 %	130	300
700 – 900	30 %	100	250
900 – 1100	30 %	50	150
1100 - 1300	30 %	50	100
1300 – 1500	30 %	50	50

Bin Center (Reco E, MeV)	Average true E in bin, with smearing applied	Average true E in bin, without smearing
300	545	349
400	580	446
500	638	533
600	720	643
800	863	797
1000	1020	981
1200	1188	1161
1400	1353	1335
1600	1552	1552