

Observation

The way we have set it up, the efficiency for selecting
A gamma ray from a pizero
is flat $\sim 7\%$ vs. true neutrino energy.

(Really, I want to plot this vs. true pizero energy
or possibly the “effective reco neutrino energy”.)

This suggests two things:
interpreting the background processes today will be easy
and we might be able to patch in a crude sensitivity to this
like reweight the NC efficiency vs. true E_{ν}

Cross section effects available via the FastMC

Dan showed the mechanism for putting together
GENIE events
motivated pseudo-selection
motivated pseudo-reconstruction
and GLOBES oscillation analysis.

This talk, and my focus, is on these questions
Which GENIE uncertainties matter
why do they matter
how much do they matter now

how much better will things be after MicroBooNE + MINERvA

Today, two specific, well-chosen, but somewhat crude items
What affects the NC background in the nue sample
What affects the reconstructed neutrino energy

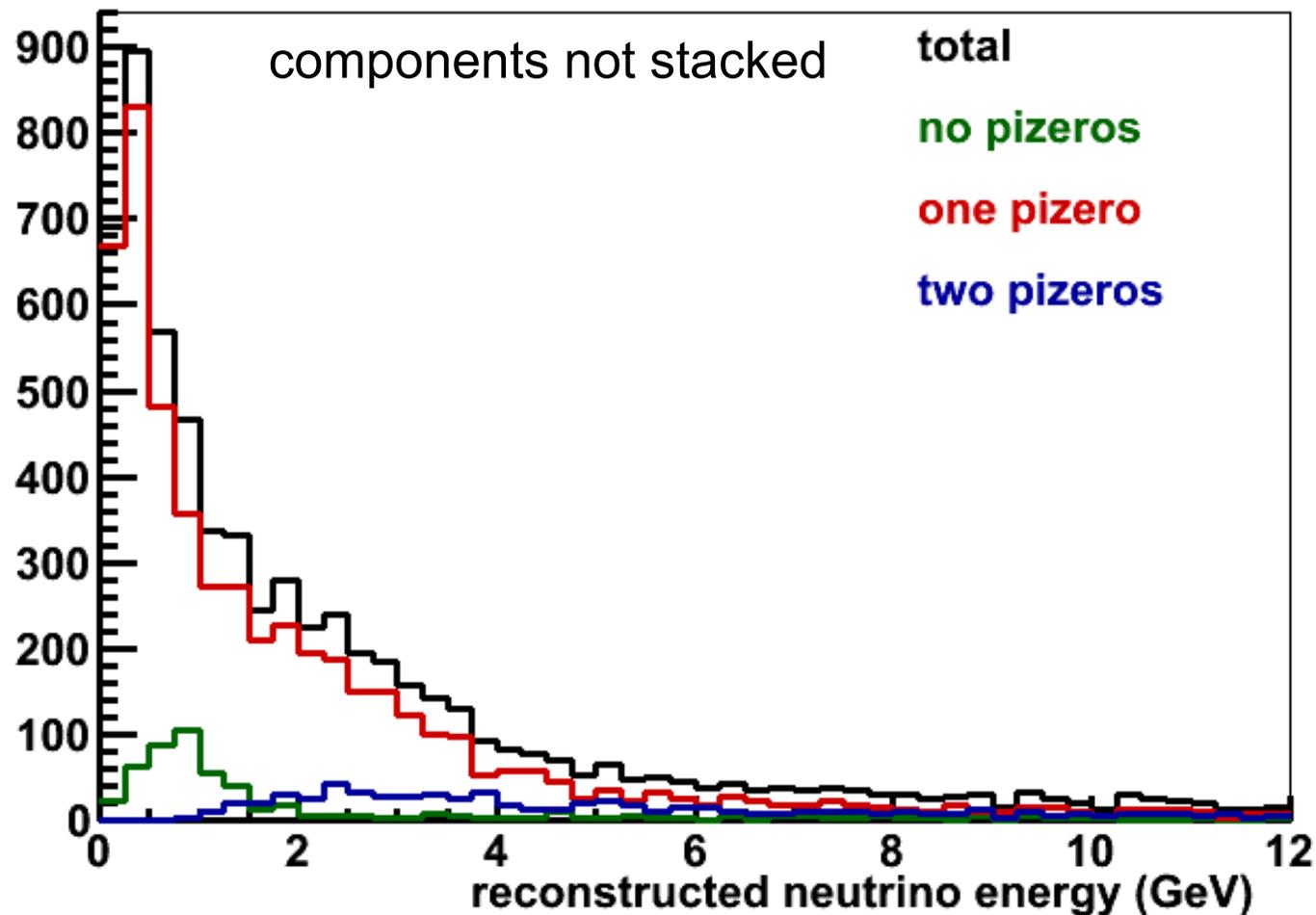
Reco neutrino energy in these plots means:

Smearred energy of the gamma from the pizero
reconstructed like it was an electron

Calorimetric energy of the rest of the hadron system
But NOT yet corrected for GENIE-induced bias.

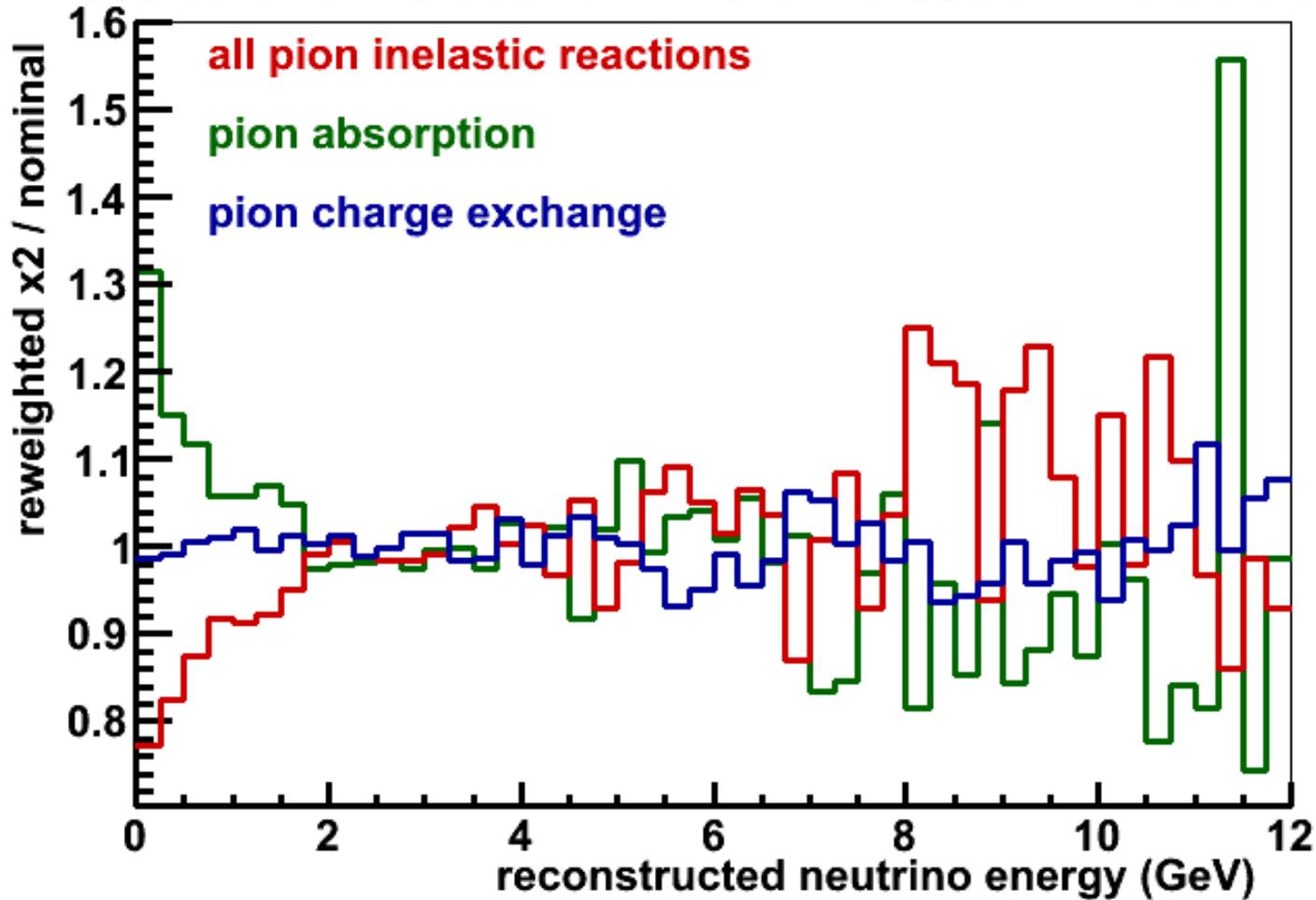
(More on this last point later)

What pion multiplicity contributes to the NC background



In the energy region we care about, there is a transition where two-pizero processes are important in a way that may affect the shape of the background.

Correlated effects of intranuclear rescattering



The distortion due to intranuke is exaggerated x 2 here, using the reweighting facility in GENIE.

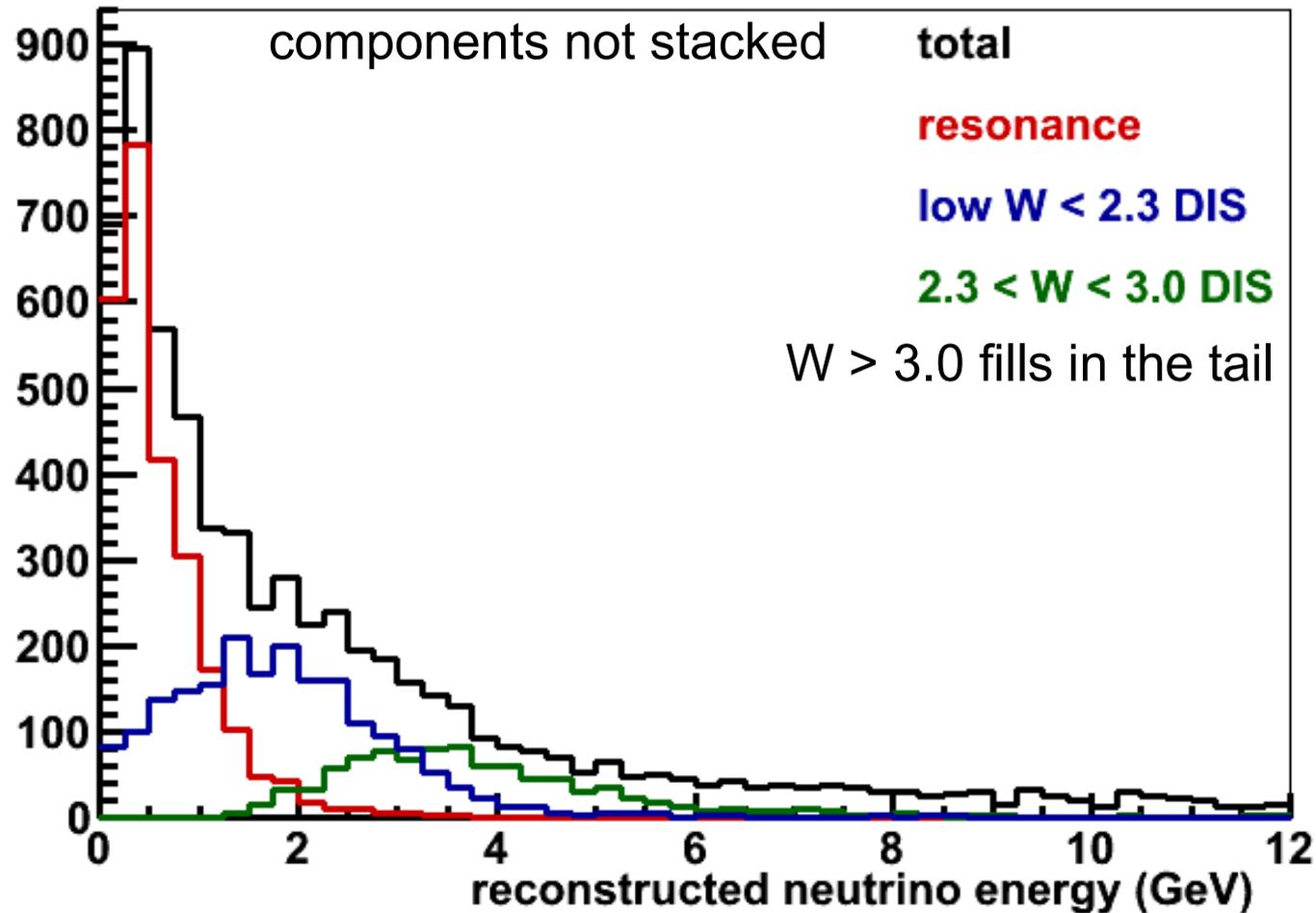
The biggest effect shows up for the lowest gamma ray energies.

THERE IS A PIECE HERE THAT DOESNT MAKE SENSE

The red and green are anti-correlated, which would be okay if the red and something else not shown were correlated. But I don't see that. Hmm. Looking into it.

What GENIE model contributes to the NC background

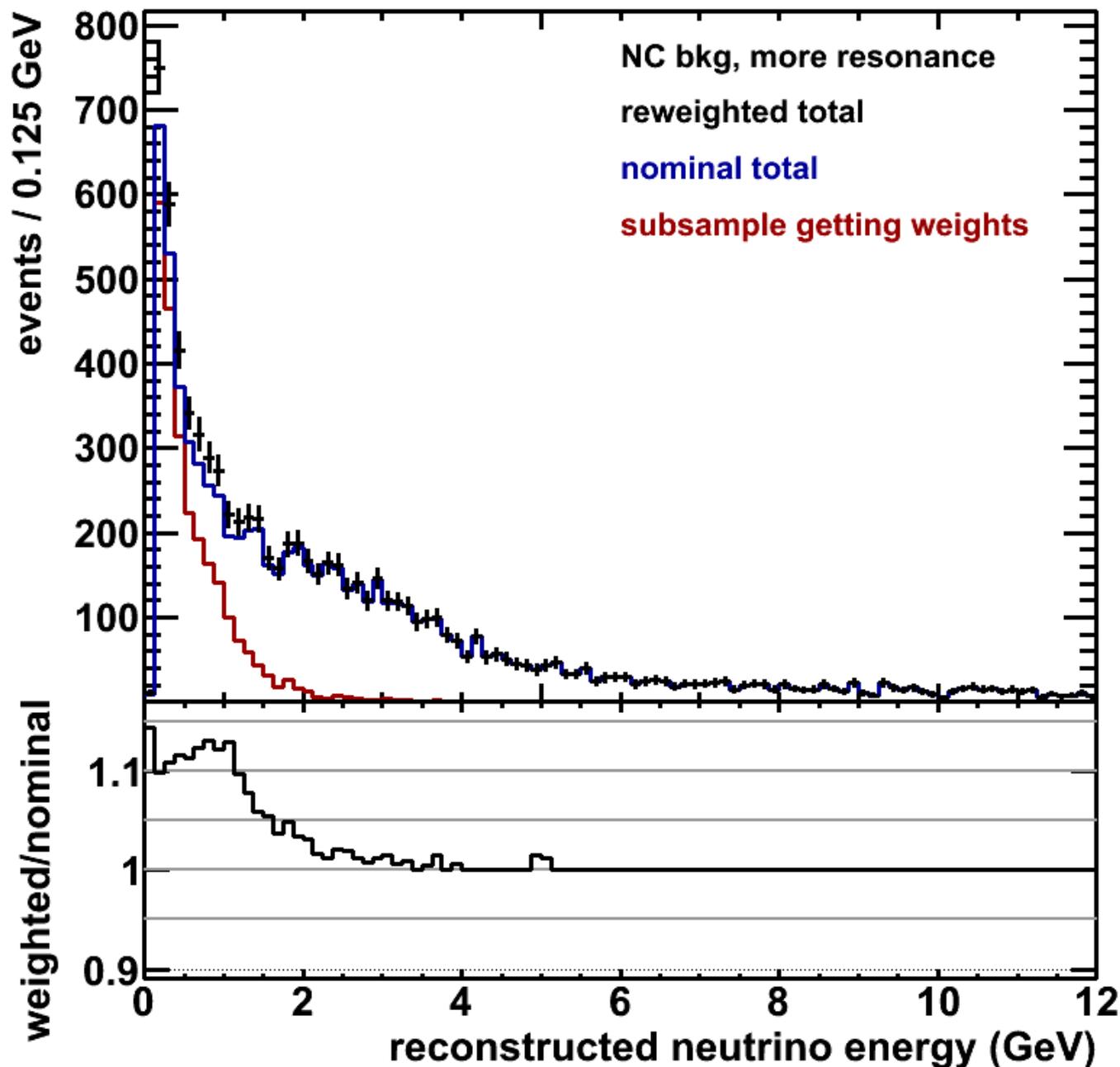
DIS processes vary with hadron system invariant mass W



Together **the resonance** and **low W** have large $\sim 20\%$ uncertainties both absolute and blue relative to red. And the kinematics differ.

The $2.3 < W < 3.0$ GeV is the so-called “AGKY” tuning, pizero multiplicity, kinematics supported by bubble chamber data
In the tail are $W > 3.0$ event kinematics come from PYTHIA.

Enhance resonance background via MA reweight



Binning changed
from previous plots
now 0.125 GeV/bin

one sigma MA
means +15% rate
(and change in
shape of Q2)

Bias in reconstructed neutrino energy for numu

The primary way of reconstructing the neutrino energy is calorimetric: $\text{Reco } E_{\nu} = \text{Reco } E_{\mu} + \text{Reco } E_{\text{had}}$

If everything goes smoothly, this could have very low bias, but modest resolution.

The source of bias that overlaps with cross section comes primarily from the fraction of (and energy fraction of) neutrons produced by the reacting neutrino and target nucleus.

We want to estimate how large an effect on the spectrum how much an effect it has on the oscillation analysis and what constraints are possible.

Toy example of model-induced calorimetric bias

Suppose all events in our sample produce a “Cherdack-boson” expected to produce exactly one baryon in the final state, a proton half the time, and a neutron half the time each with the same energy distribution.

We reconstruct all non-lepton energy in the detector.

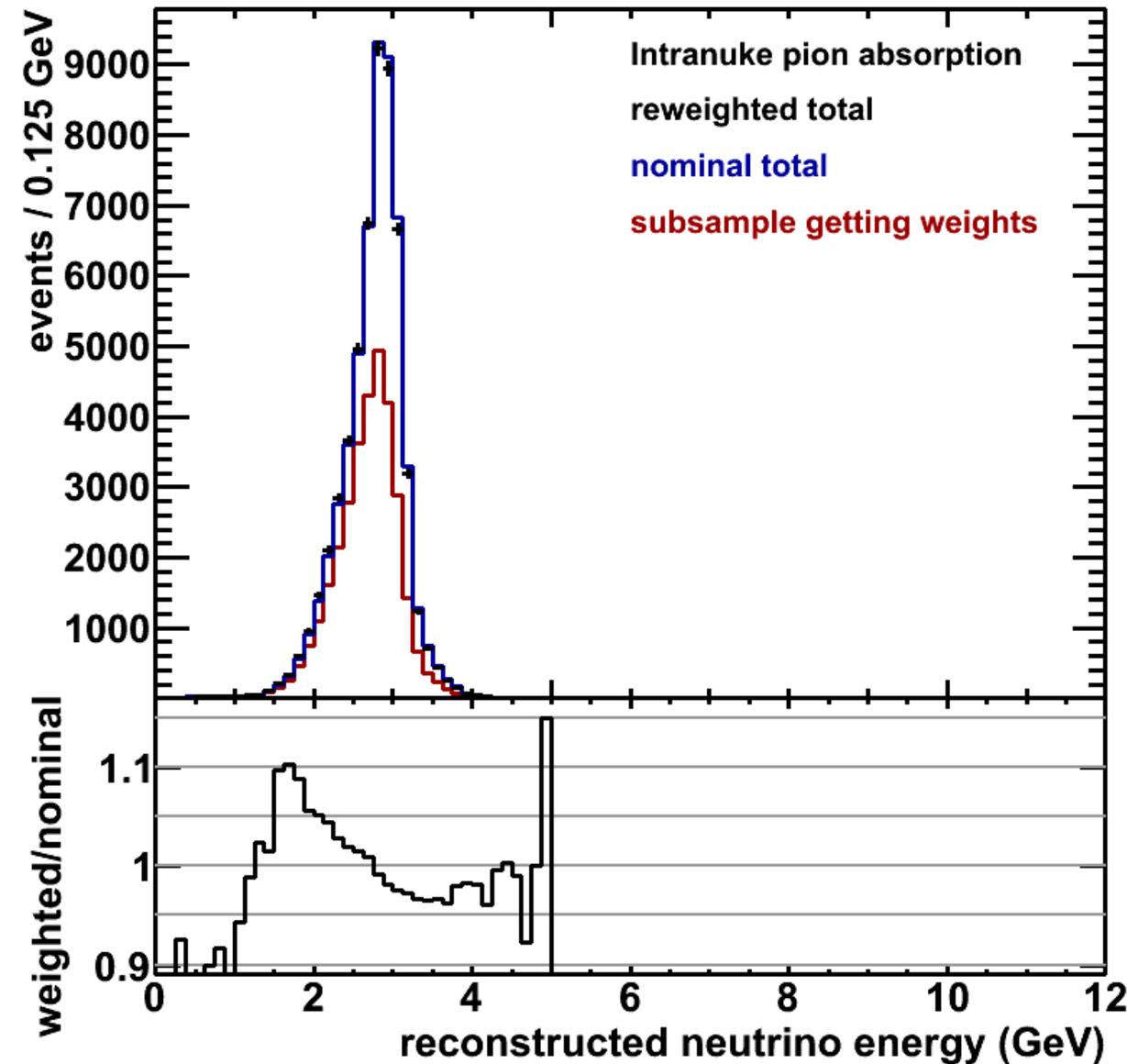
We have a testbeam calibration for both p and n.

The response to protons and neutrons are different (most extreme is the neutron's ability to escape unseen).

The raw energy from the event is boosted by a factor “halfway” between the testbeam measurements for p and n.

Our model-induced bias comes from the word “halfway”, if reality is not half and half, but $1/3$ and $2/3$, our reco Enu spectrum will be biased.

Monoenergetic 3 GeV, increase pion absorption

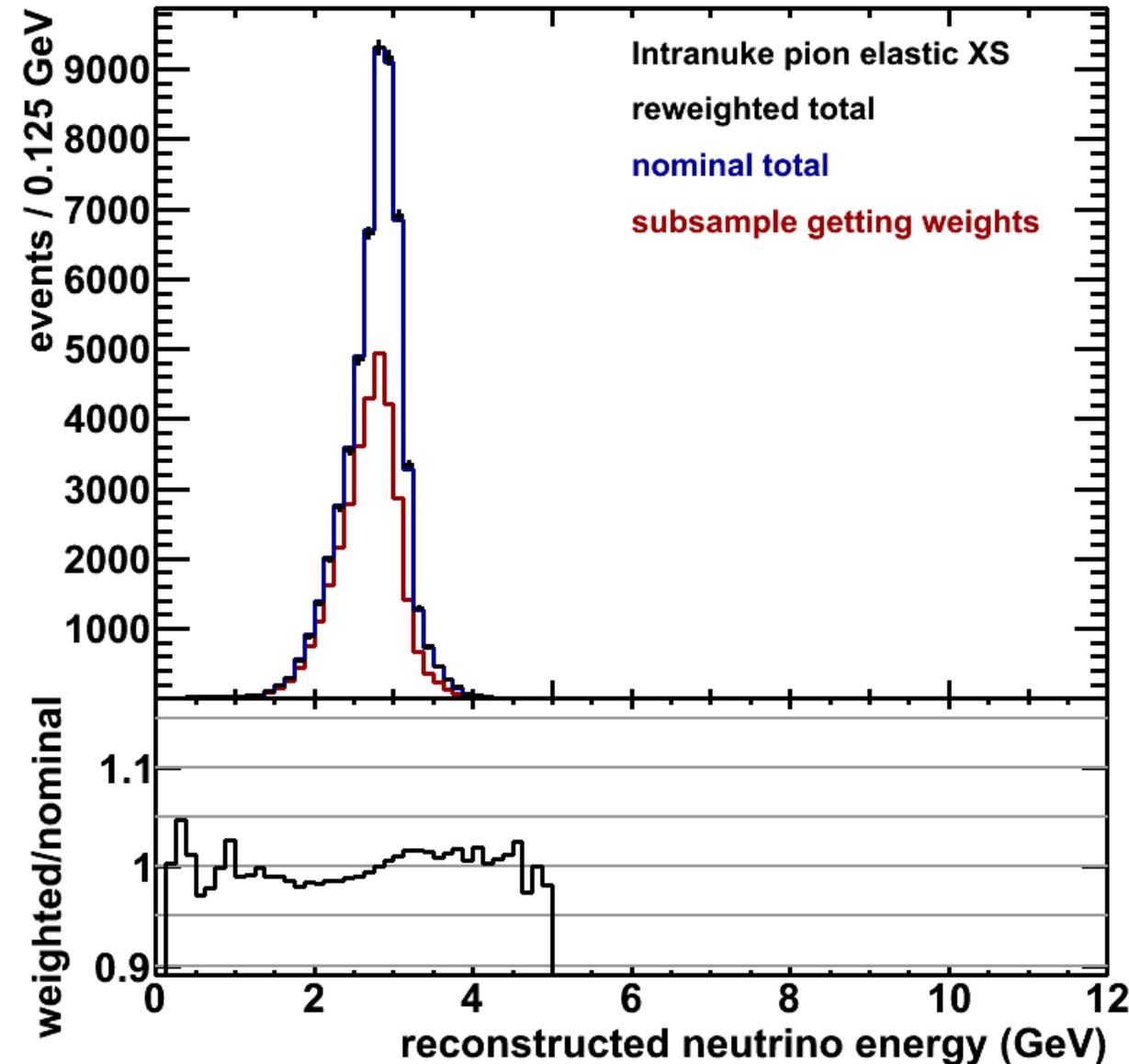


Effect is primarily a bias in the reco energy

In the central region there is large slope (15% change) to the reco energy corresponding to $\sim 1\%$ systematically lower E

Primarily, absorption increases final state Neutrons.

Monoenergetic 3 GeV, increase pion elastic scattering



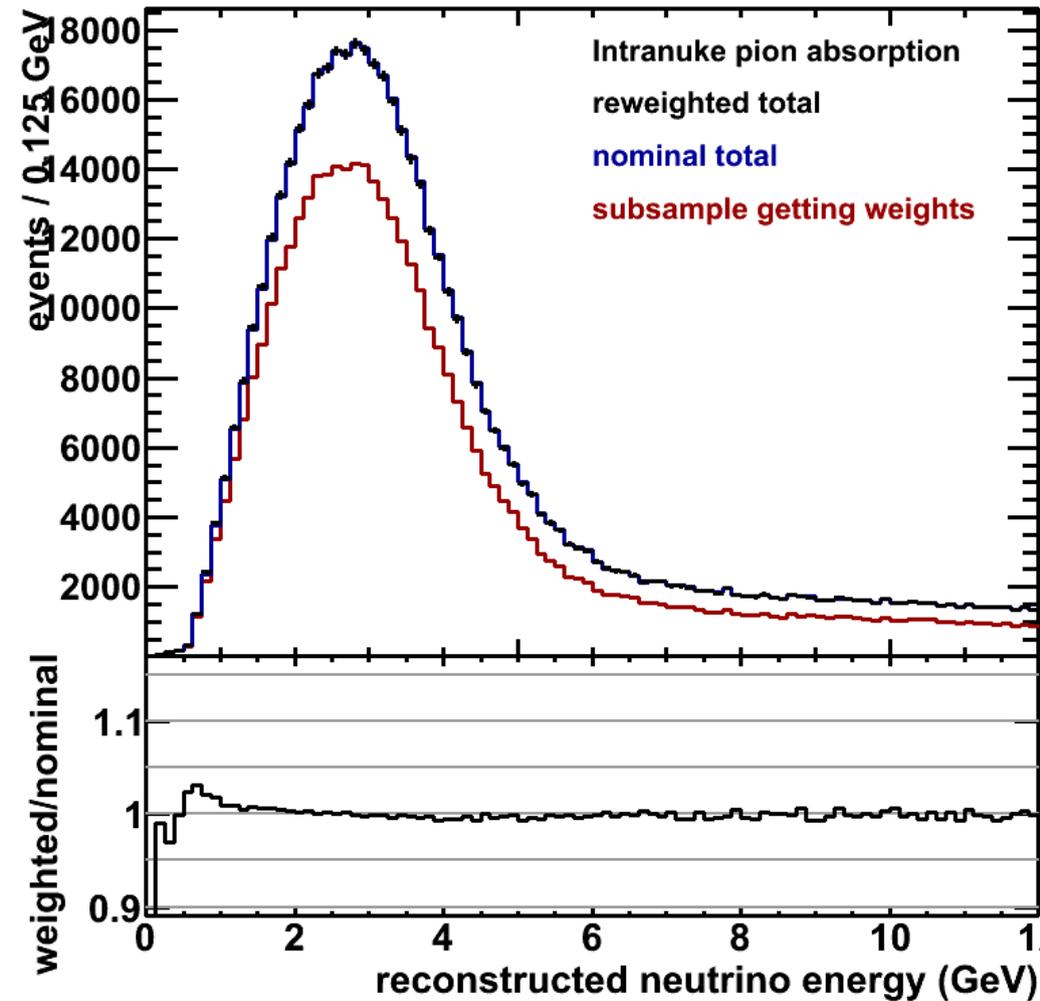
This effect is smaller,
About 5% slope.

Its not from the elastic
scattering itself,
its because the reweight
preserves the total XS.

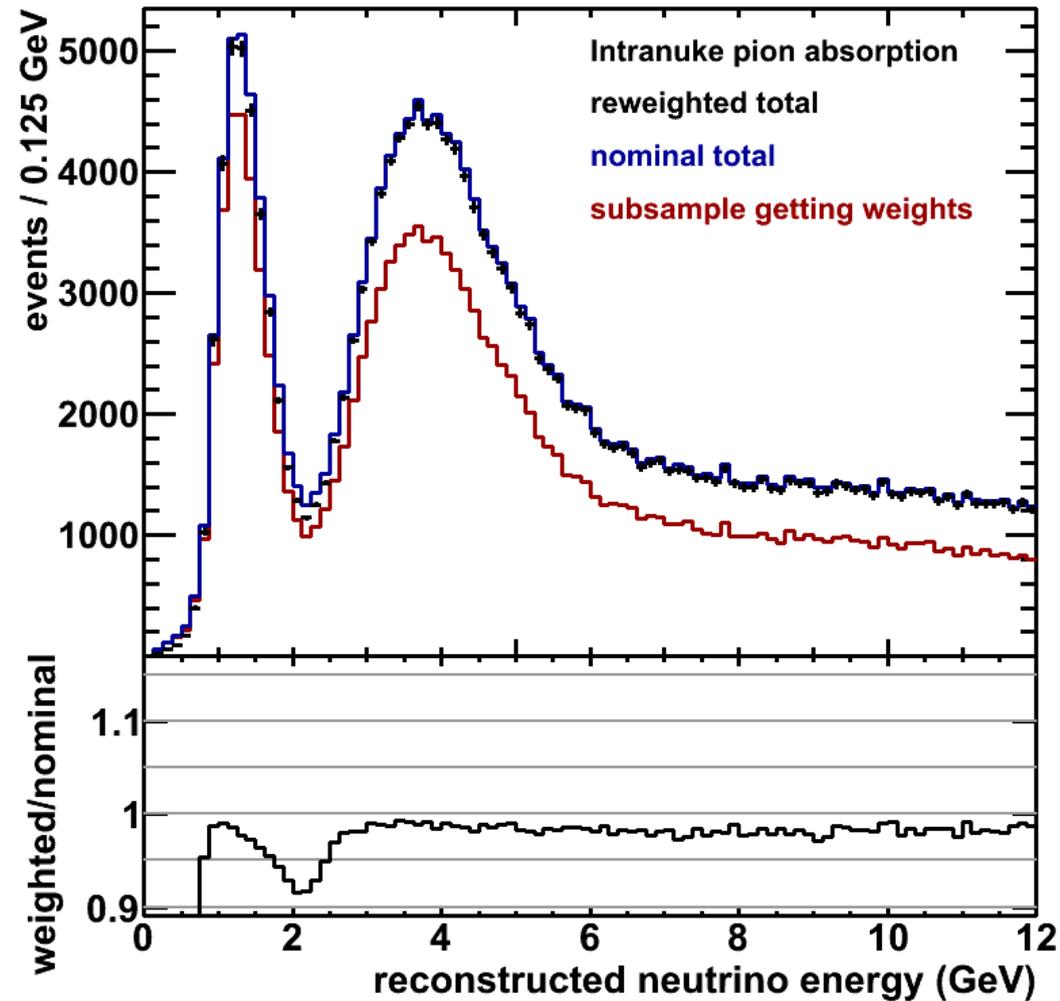
Turning up elastic
turns down absorption
(previous slide)
which is a fraction of
the inelastic XS.

Full spectrum, increase pion absorption

not oscillated

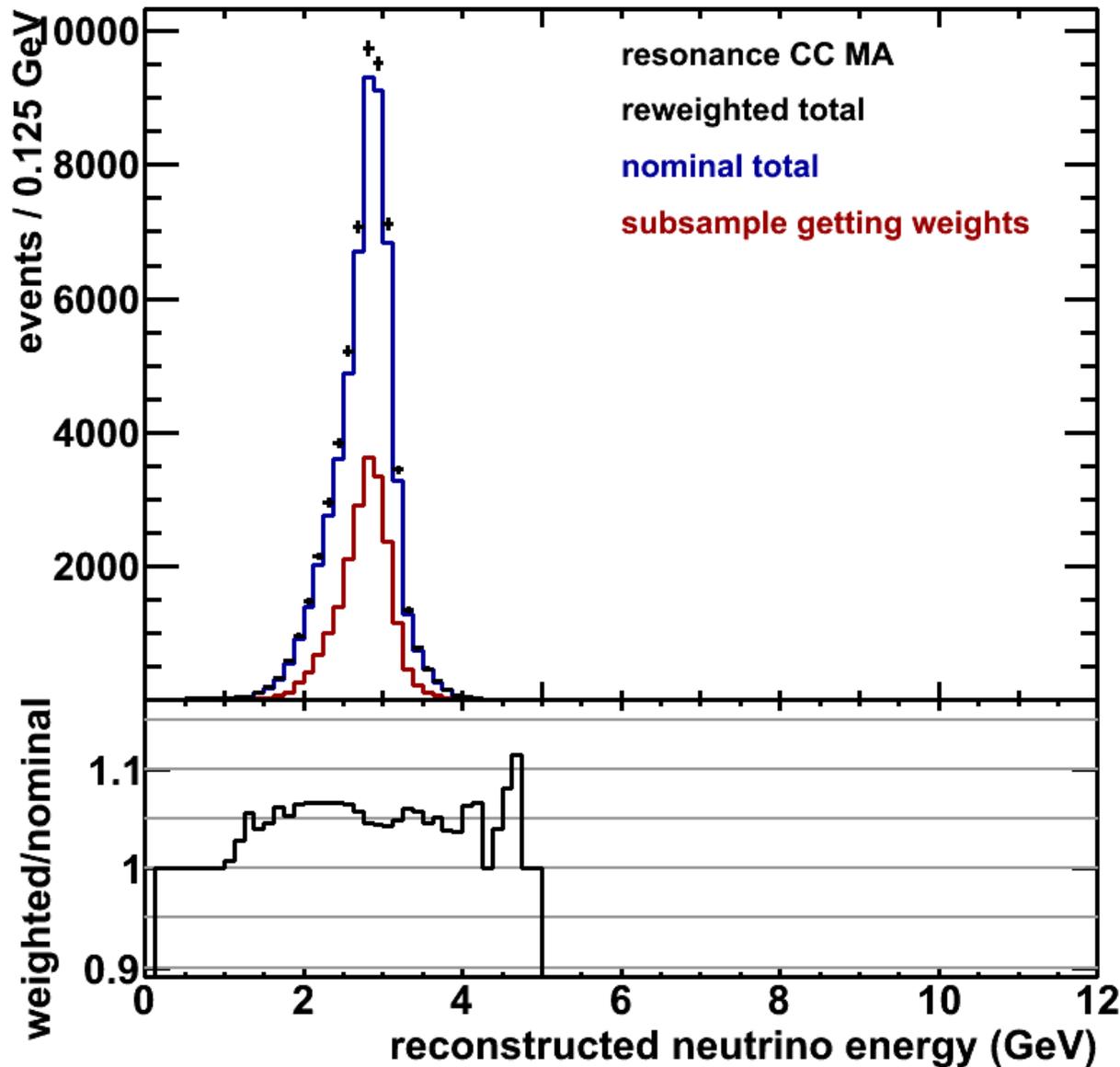


two-flavor oscillated



The energy distortion, convoluted with the oscillation spectrum yields something that should be picked up by oscillation fits.

Monoenergetic 3 GeV, increase resonances



Effect is primarily normalization of the resonance sample,

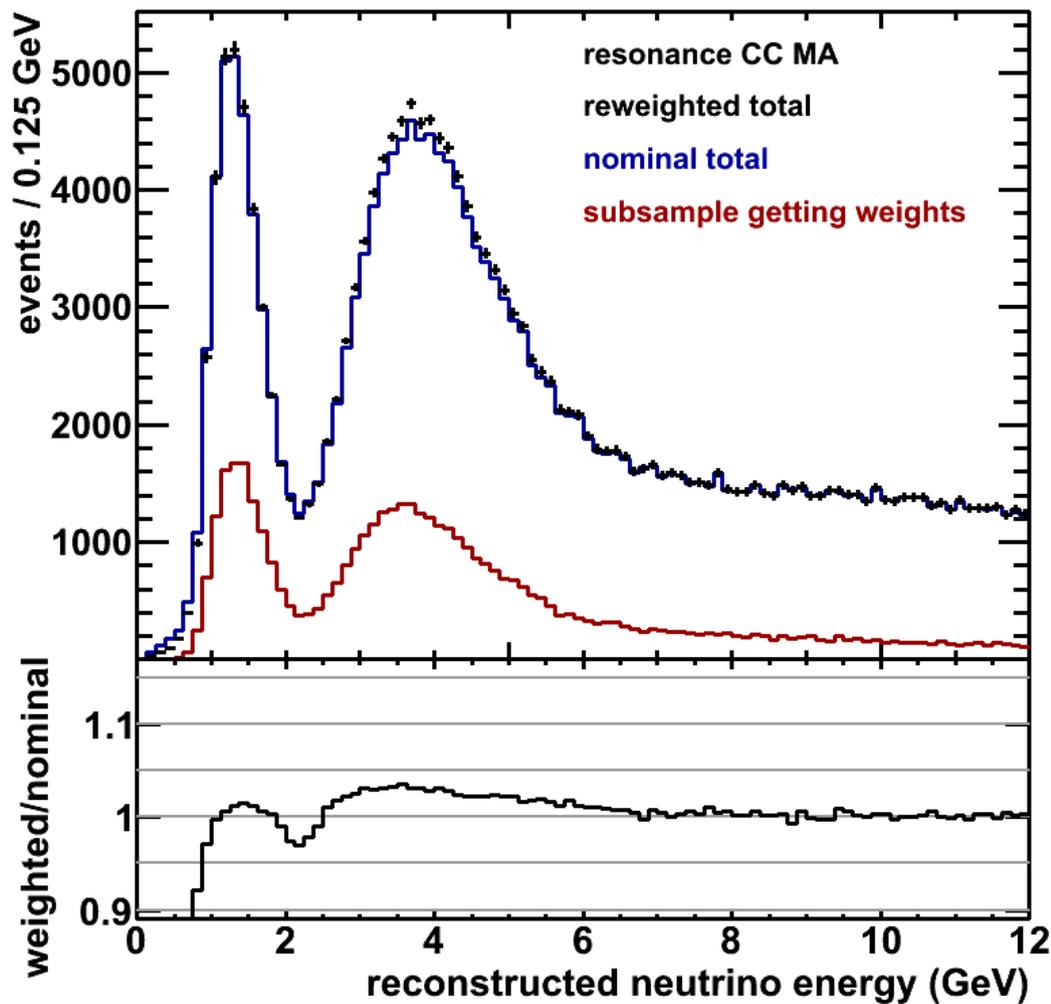
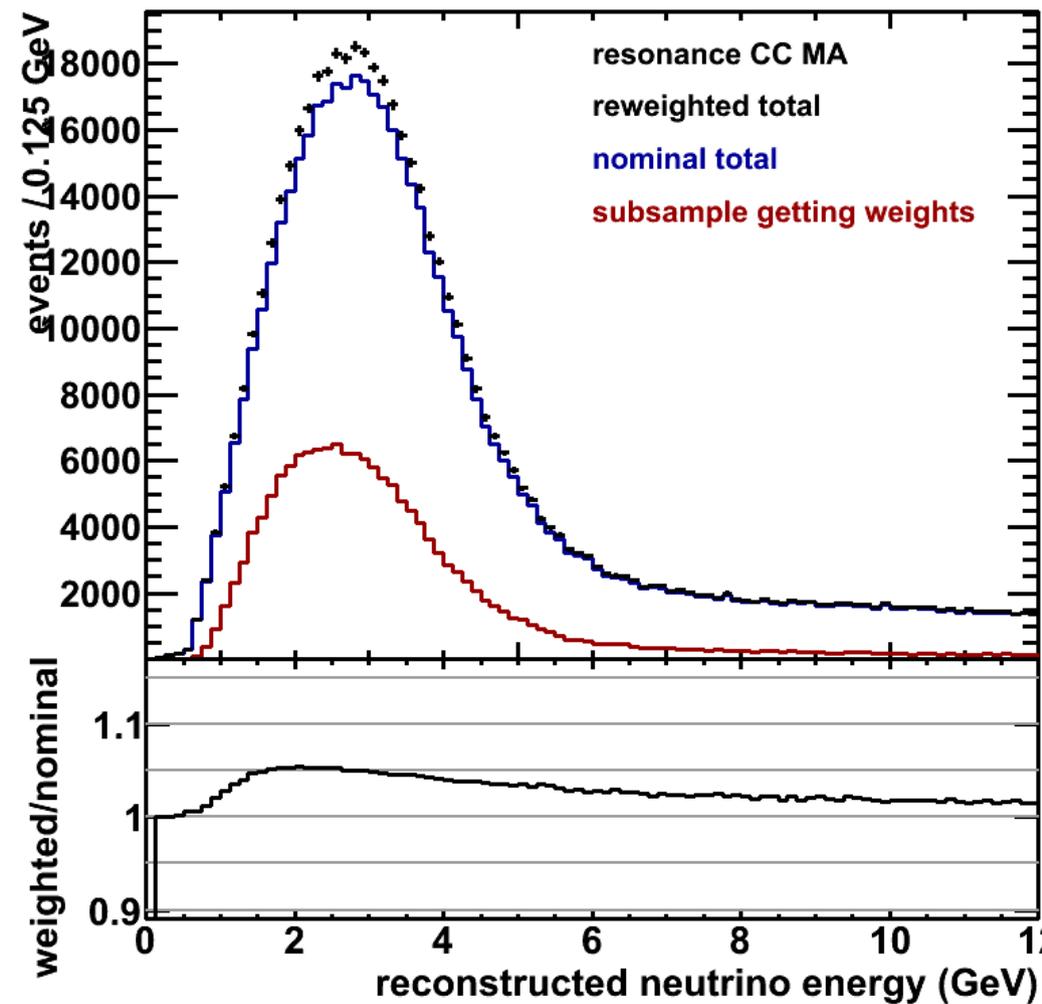
In the central region there is little slope or shape distortion (less than 2% change) to the reco energy.

This systematic will yield a distortion because the fraction of resonance events increases as we go to lower energy.

Full spectrum, increase resonances

not oscillated

two-flavor oscillated



This is primarily a $\sigma(E)$ effect, not an reco E effect
But convoluted with the shape, yields a similar effect.

Bias in reco QE neutrino energy for CC numu

The other technique that seems okay is to use the subsample of QE-like events the well-measured muon angle and energy (maybe also the proton angle and energy) and QE billiard-ball kinematics.

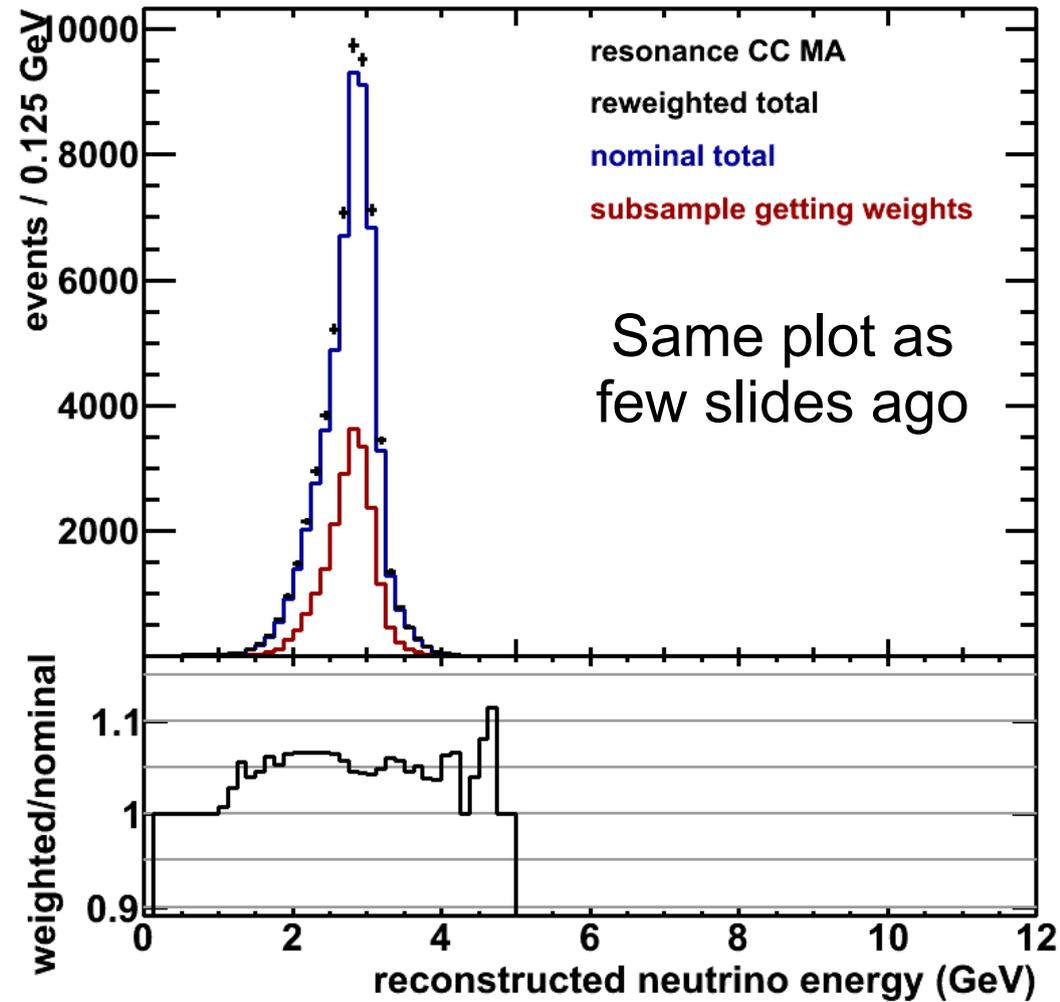
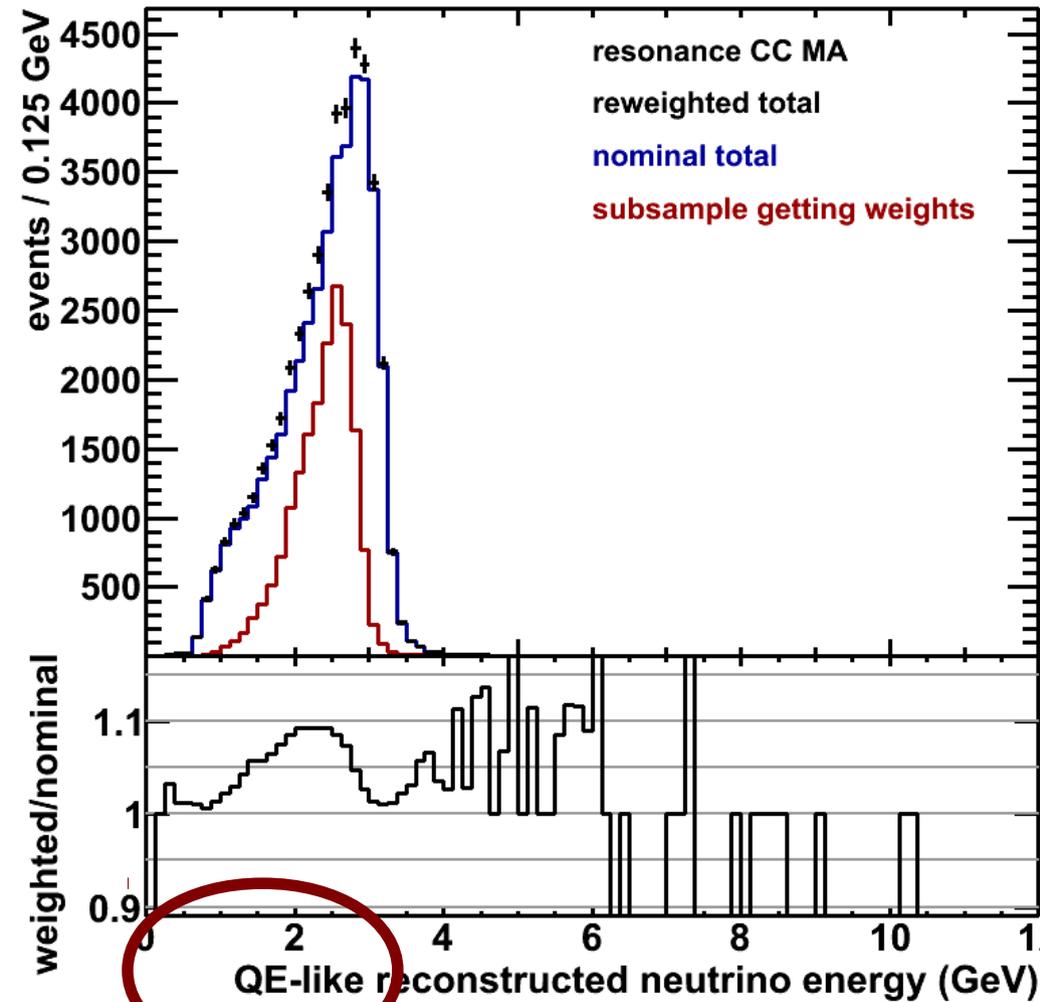
The danger that can produce a bias comes from the fact that events that are QE-like but are not actually QE will get a systematically wrong (lower) energy.

Resonance production and meson exchange currents are the favorite, irreducible non-QE background here.

To the extent that the MC has a different non-QE component in the selected sample than data we will get a data/mc bias.

Monoenergetic 3 GeV, increase resonances, QE reco

Super crude QE-like selection, events with zero or one pion.



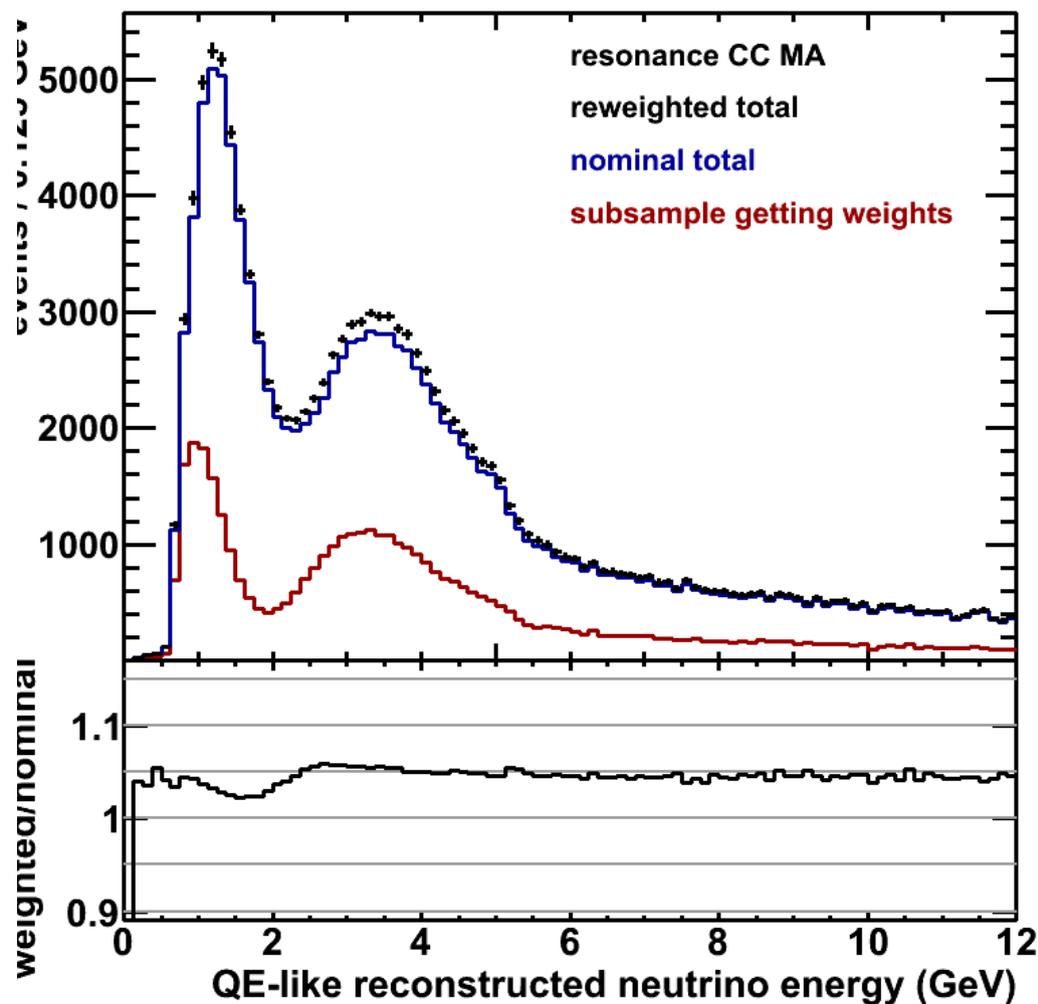
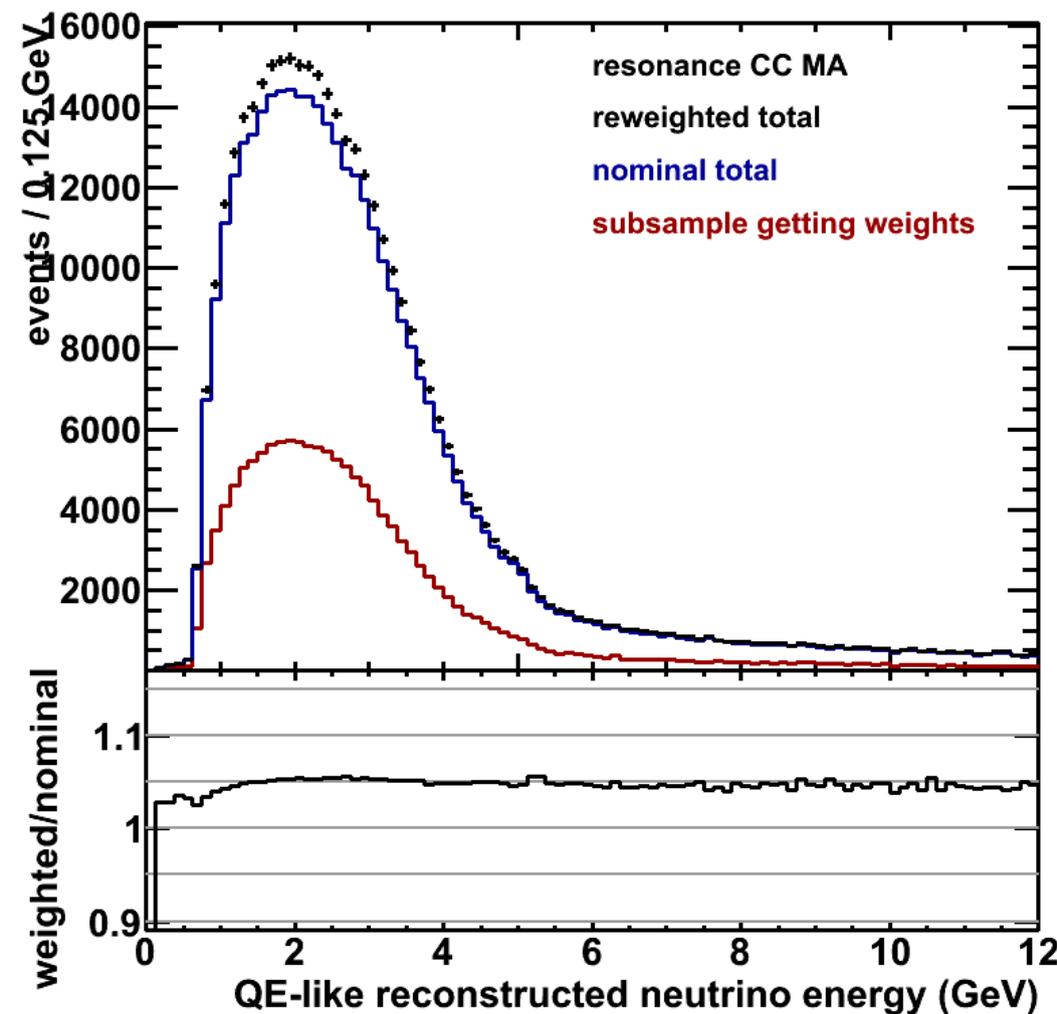
Using the QE assumption gives a biased result for resonances (and for the 2p2h “meson exchange current” contribution)
A distorted XS model distorts the reco energy spectrum.

Full spectrum, increase resonances, QE reco

Super crude QE-like selection, events with zero or one pion.

not oscillated

two-flavor oscillated



Appears to be smaller effect than before.
Distortion is similar if I require zero pions.
But now also need to evaluate a selection effect.

Conclusions

Demonstration of several mechanisms where the neutrino interaction model could affect LBNE physics measurements.

To-do

Propagate to oscillation fits (Dan and Matt and Elena)

Expand systematics more thoroughly

Look at neutrino and anti-neutrino differences.

Bring these elements together into one story.

More to-do

Followup on the most important systematics

Check the constraints from existing data

Understand what MicroBooNE and MINERvA will constrain