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 near-term focus, is on these limited issues:
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

Energy reconstruction

Reco neutrino energy in the NC background plots means:

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

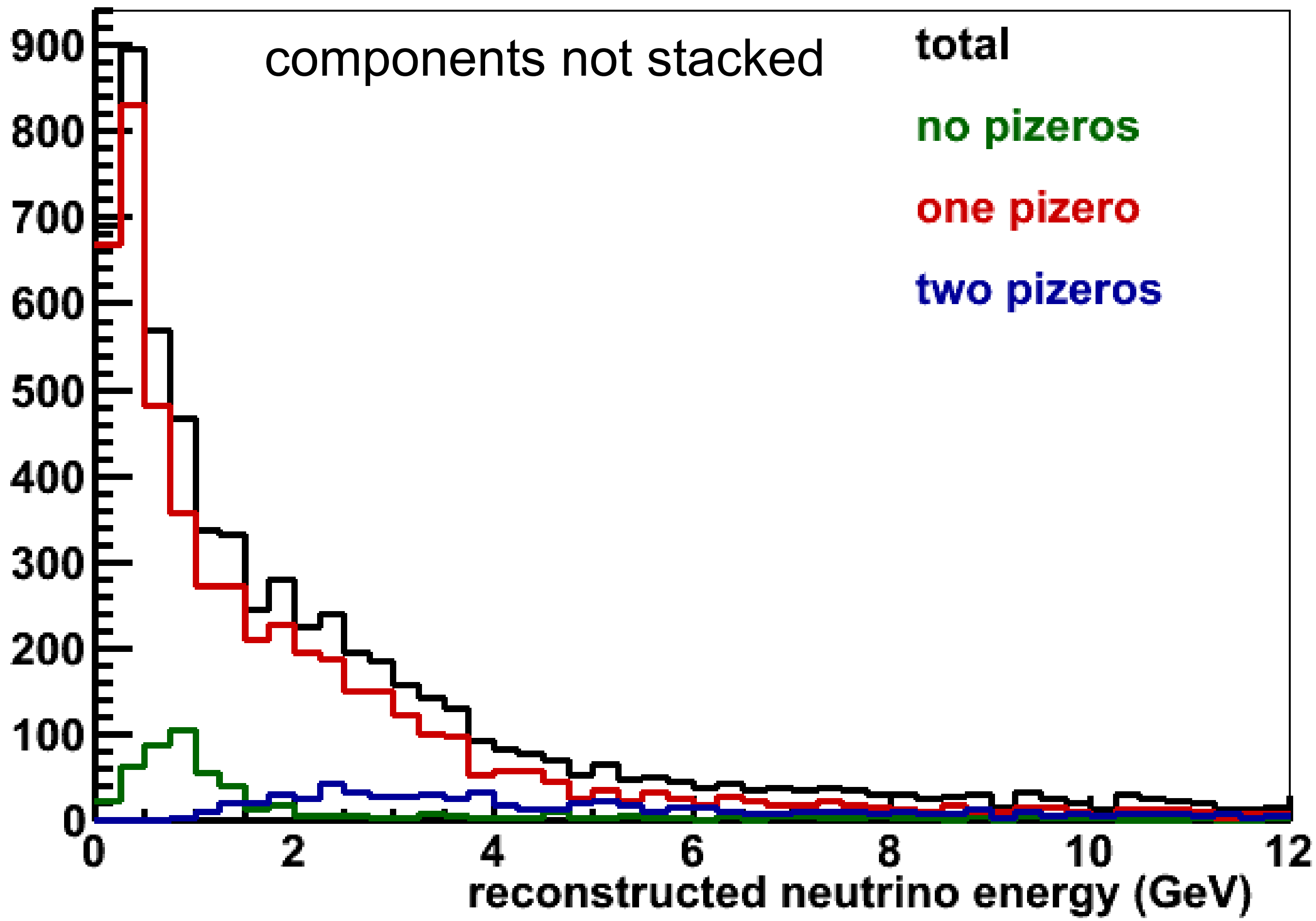
Summed calorimetric energy of the rest of the hadron system
But NOT yet corrected for GENIE-induced bias.

(More on this last point later)

For CC numu disappearance spectra reco energy means
smeared muon energy (by range or exiting)
plus summed calorimetric energy of the hadron system

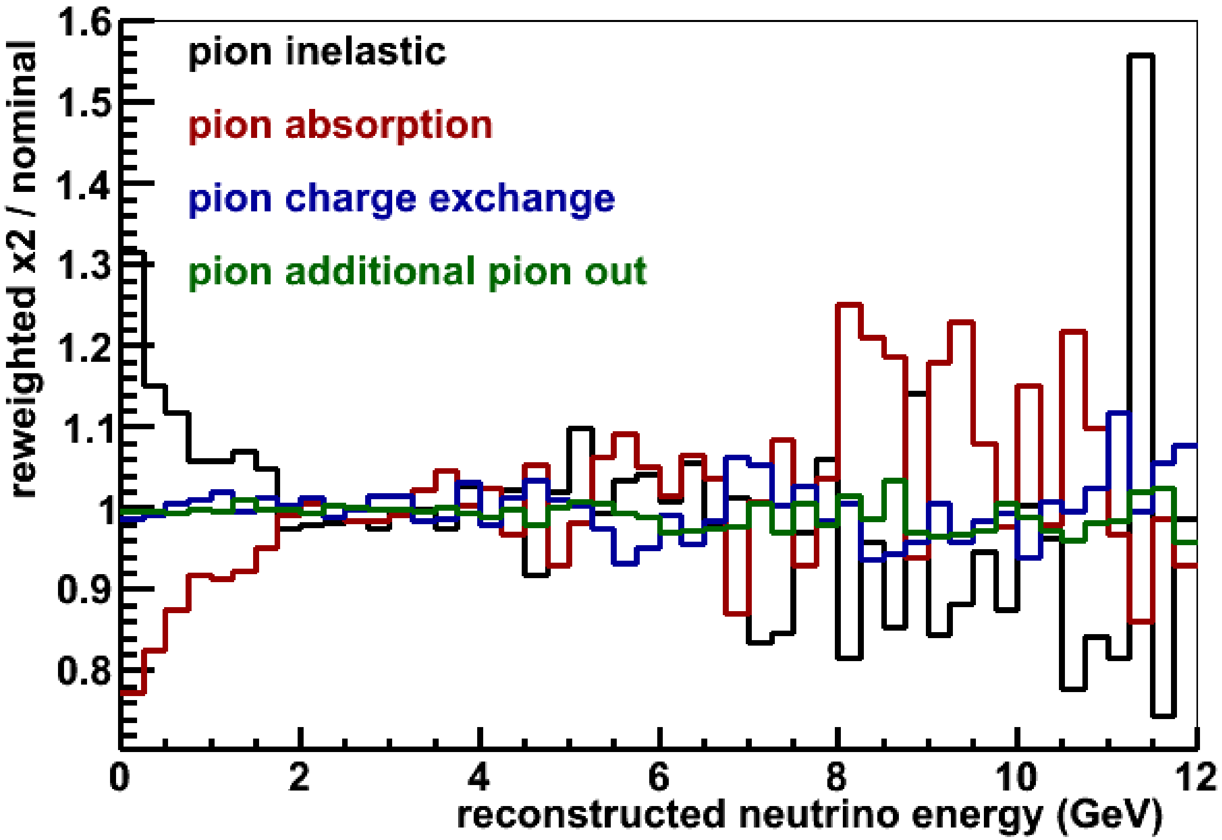
Exception: a couple examples of using QE muon kinematics

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



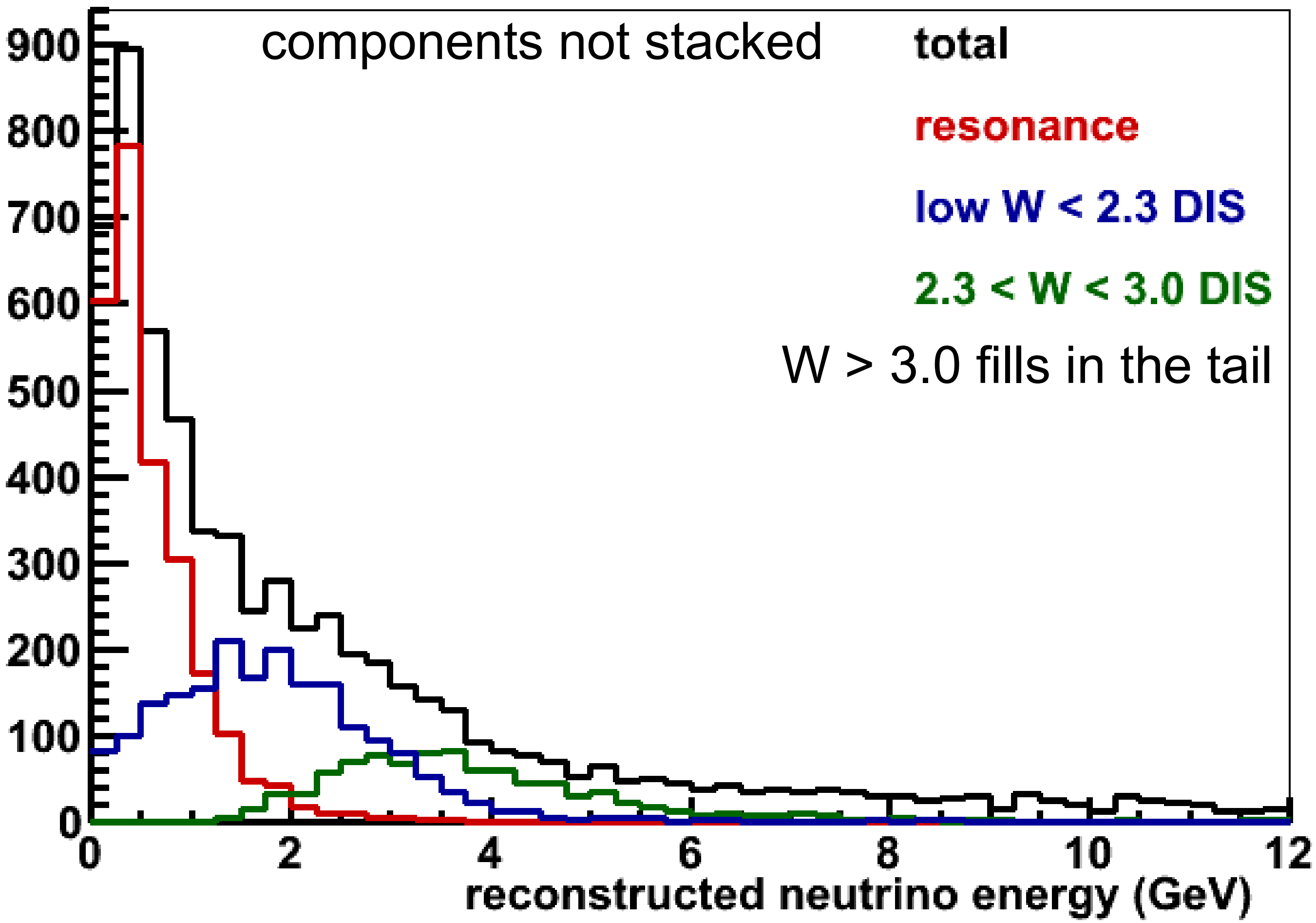
The intranuke reweight has a specific design that nominally preserves rescatter cross sections, while reweighting fates.

And separately we can reweight the rescattering cross sections too.

The distortion due to intranuke is exaggerated x 2 here,
using the reweighting facility in GENIE (elastic is not shown)
For pions, absorption, inelastic, and elastic are the most common modes.
And consequently weighting them has the largest effect.elastic component.
Enhancing one fate reduces the other fates, preserving the total normalization
Absorption and "inelastic" have the largest effect; I suspect here that absorption matters and inelastic is simply anti-correlated with it.

What GENIE model contributes to the NC background

DIS processes vary with hadron system invariant mass W

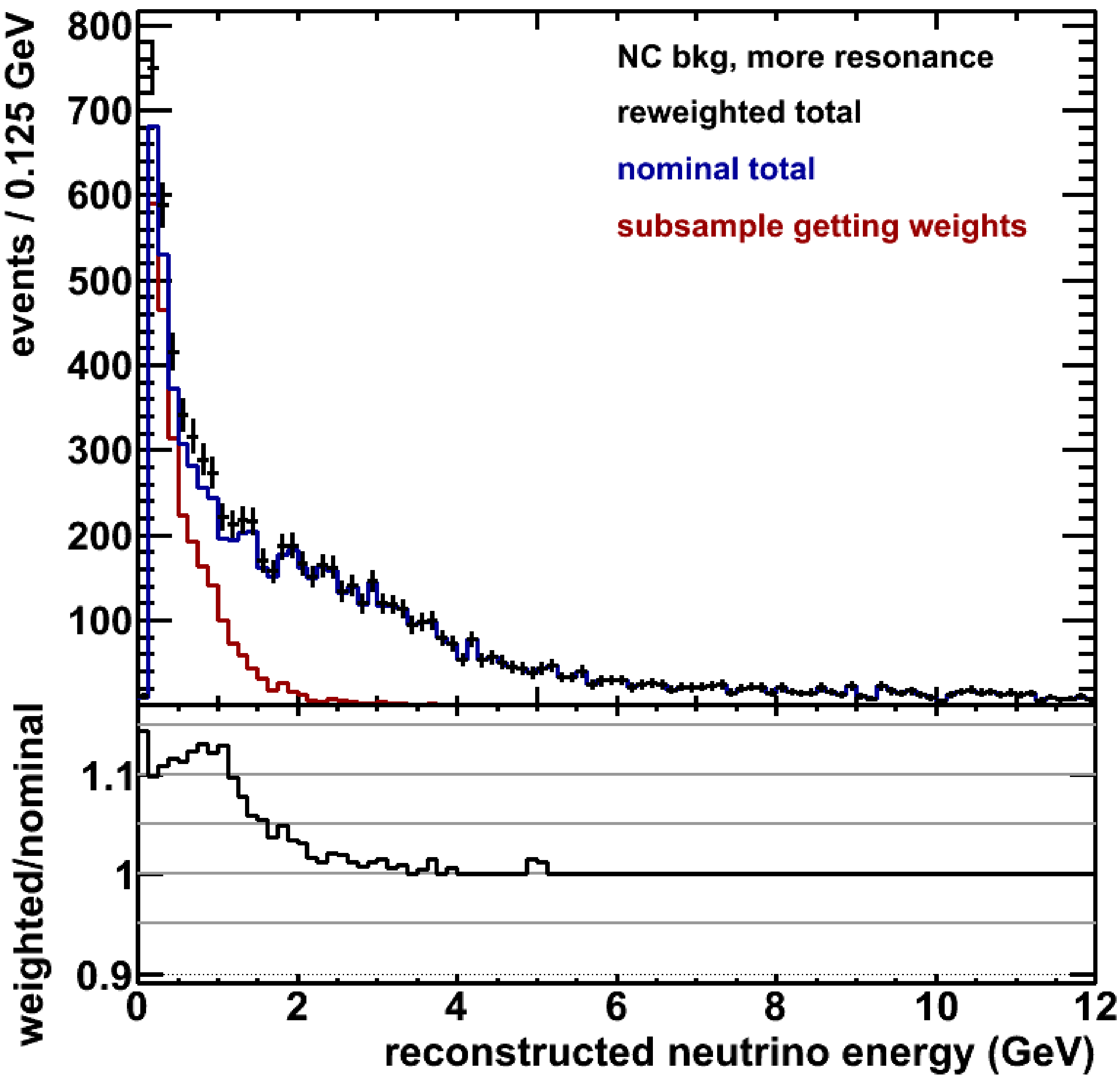


Together the resonance and low W have large ~20% uncertainties both absolute and blue relative to red. And the kinematics differ.

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: Reco Enu = Reco Emu + Reco Ehad

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

The source of bias that overlaps with interaction model 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

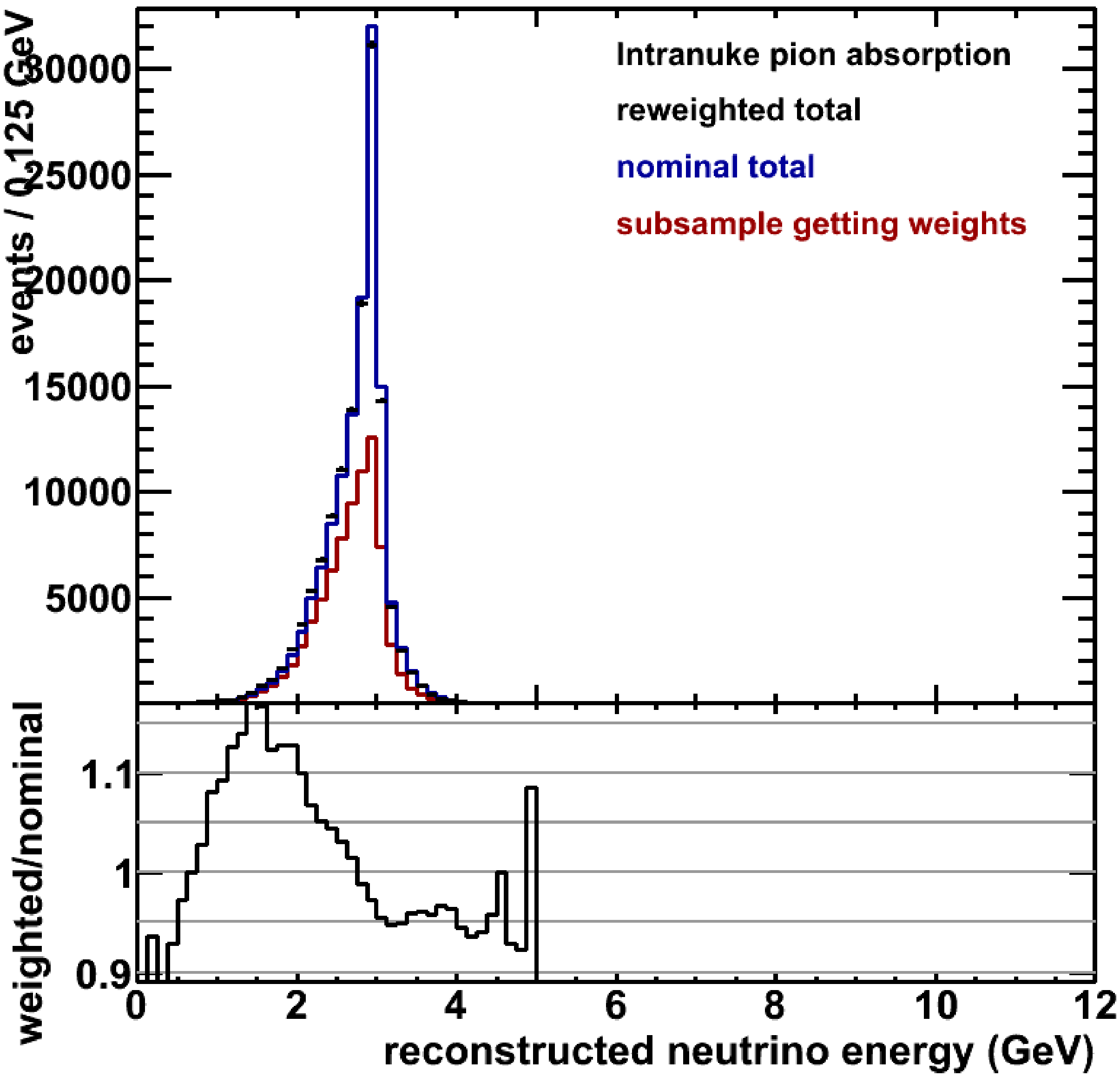
Suppose all events in our sample produce a “Cherdack-boson” expected to produce exactly one baryon in the final state, a proton half the time, and a neutron half the time each with the same energy distribution.

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



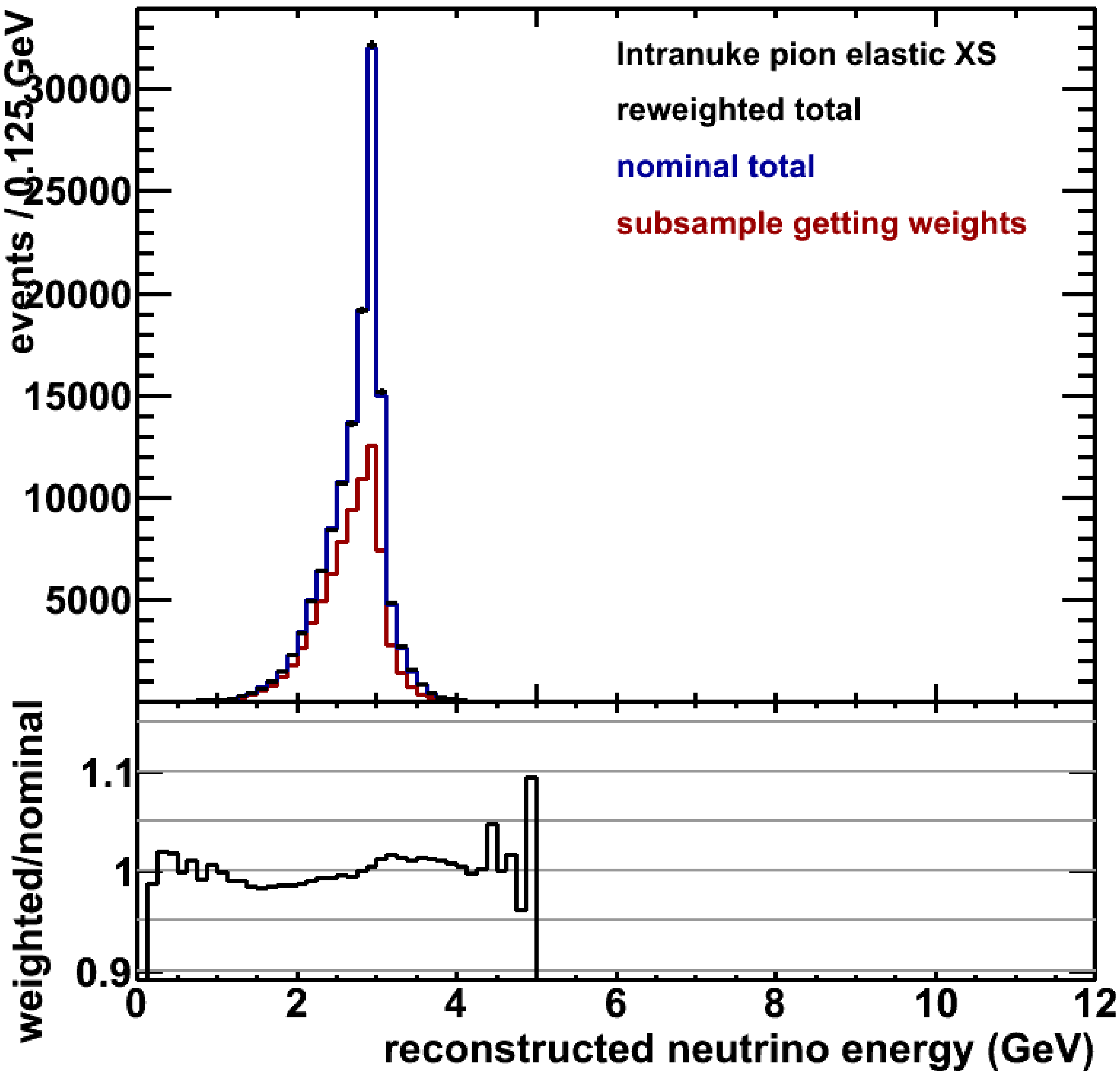
Effect is primarily a bias in the reco energy

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

Primarily, absorption Increases final state Neutrons.

Also notice the absolute bias, the mean is 2.73 GeV.
We need to, but have not yet taken that out the way an experiment would

Monoenergetic 3 GeV, increase pion elastic scattering

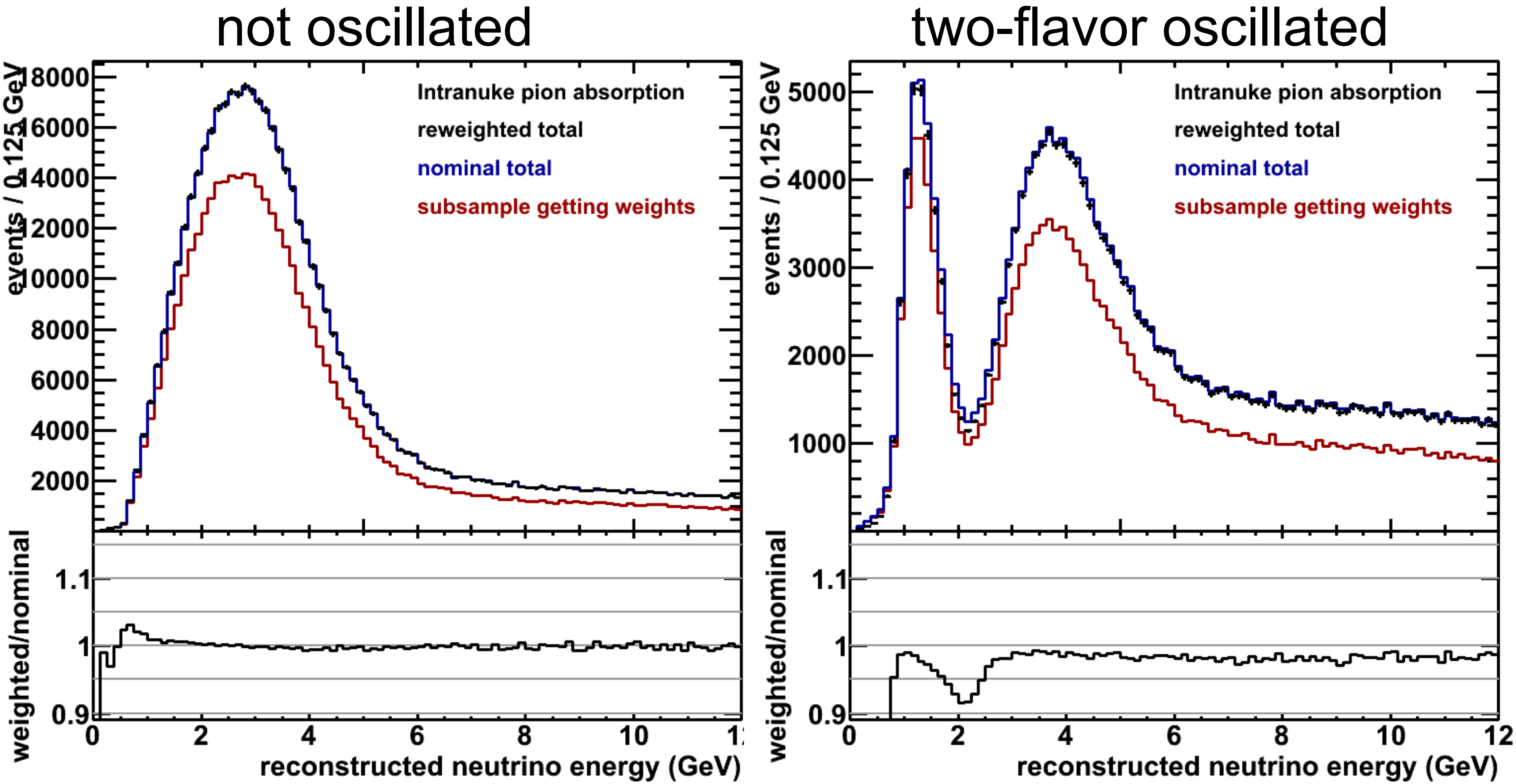


This effect is smaller, About 5% slope.

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

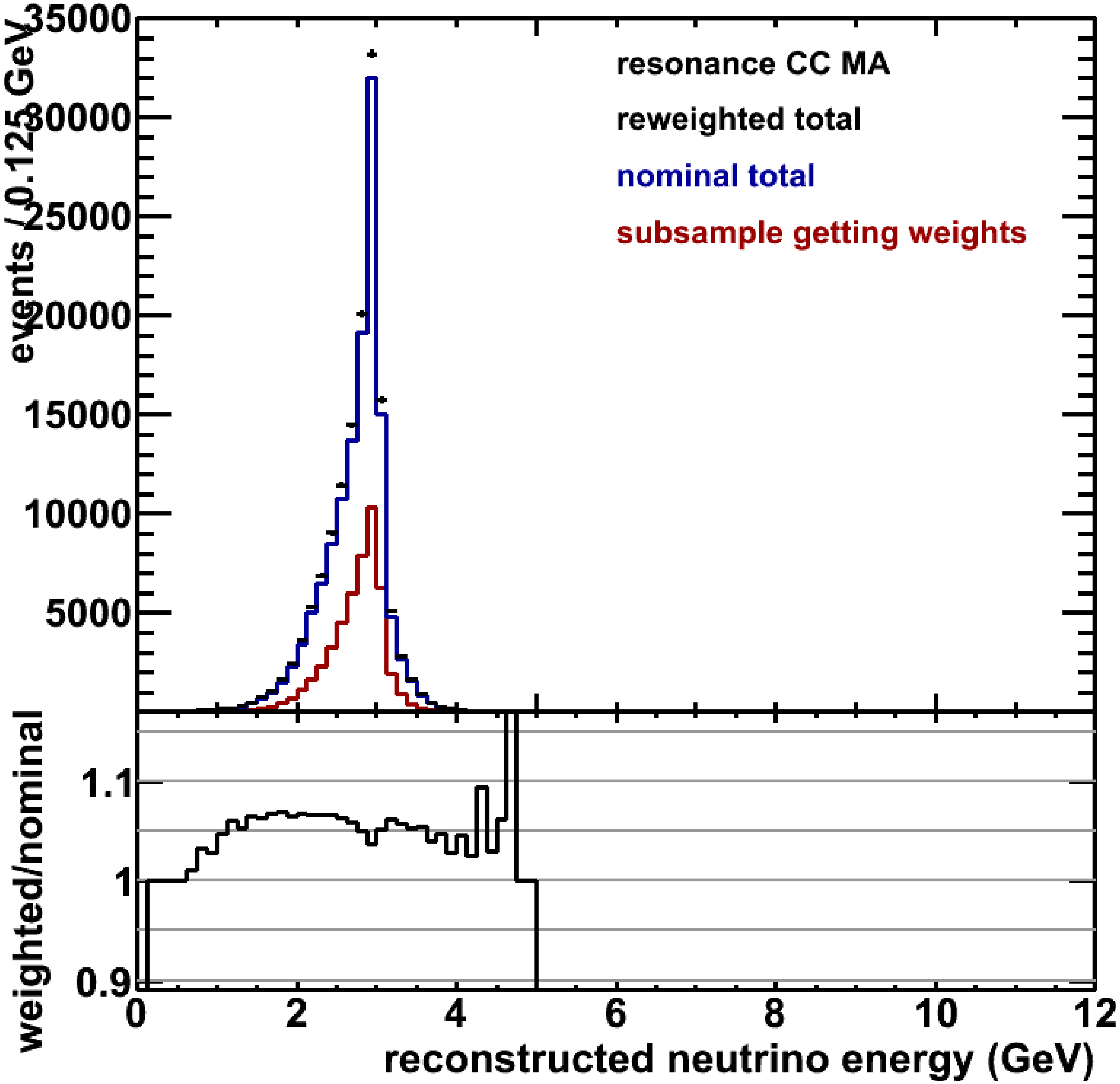
Turning up elastic turns down absorption (previous slide) which is a fraction of the inelastic XS.

Full spectrum, increase pion absorption



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

Monoenergetic 3 GeV, increase resonances

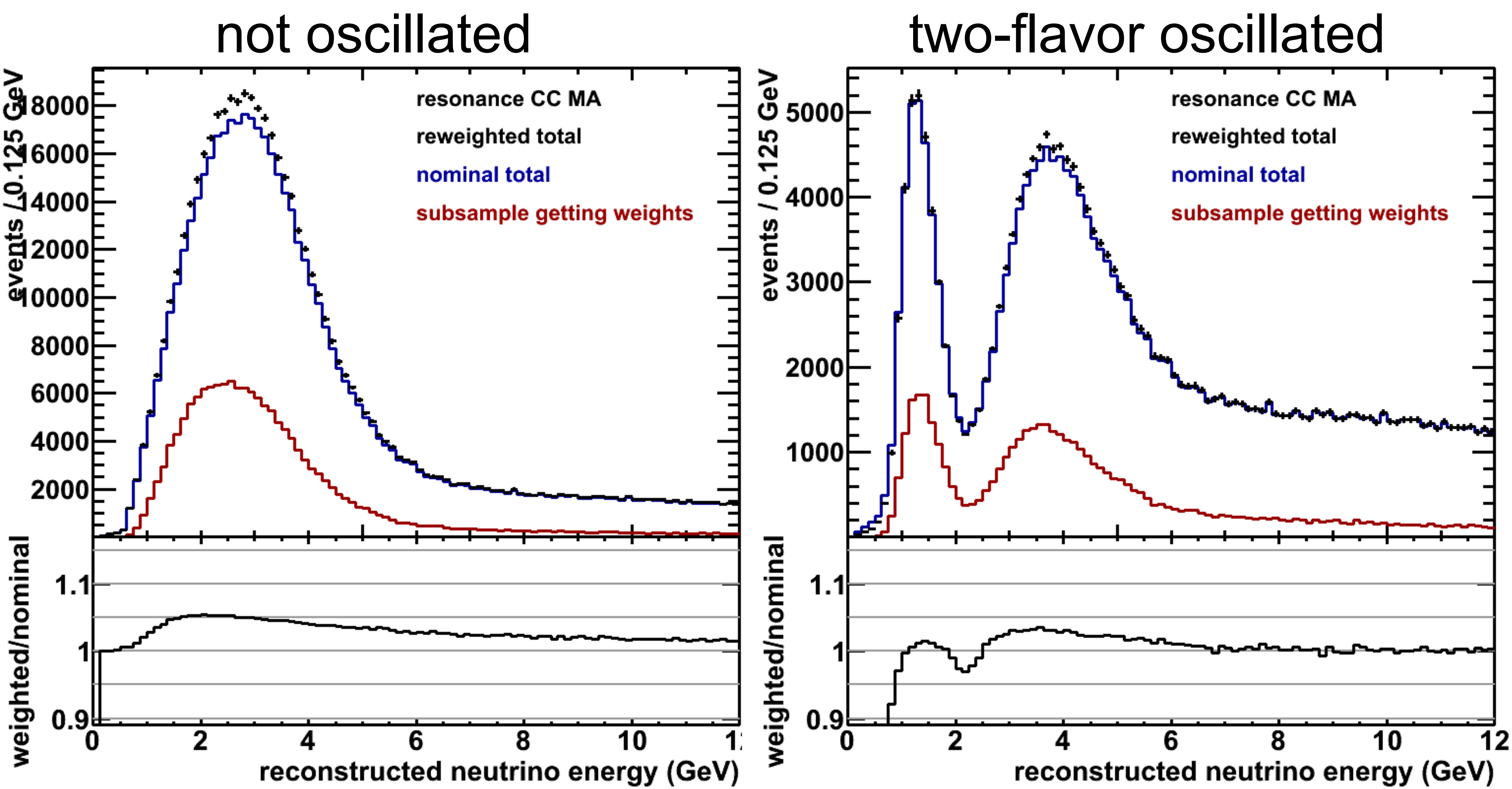


Effect is primarily normalization of the resonance sample,

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



This is primarily a σ(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.

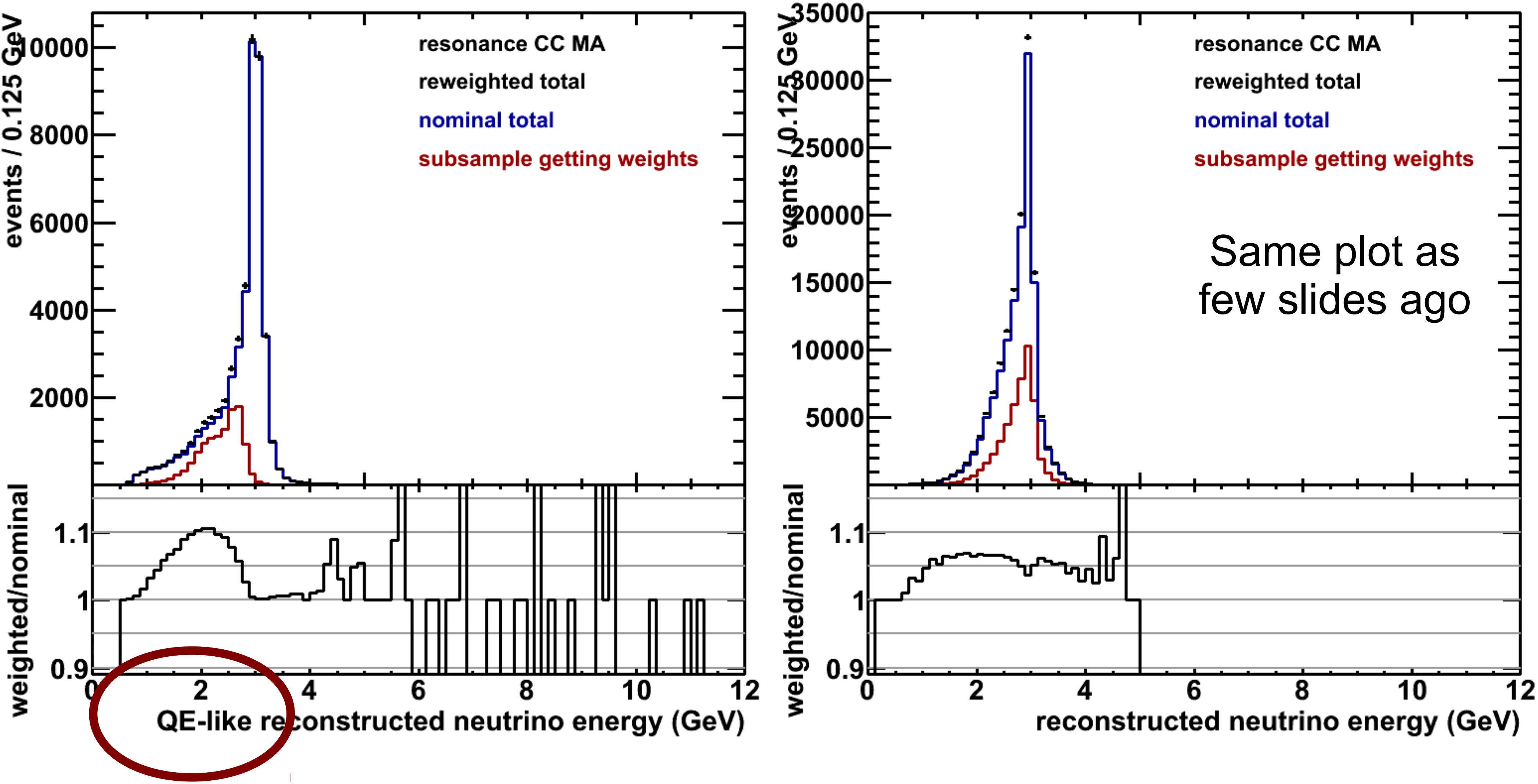
The danger that can produce a bias comes from the fact
that events that are QE-like but are not actually QE
will get a systematically wrong (lower) energy.

Resonance production and meson exchange currents
are the favorite, irreducable 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.

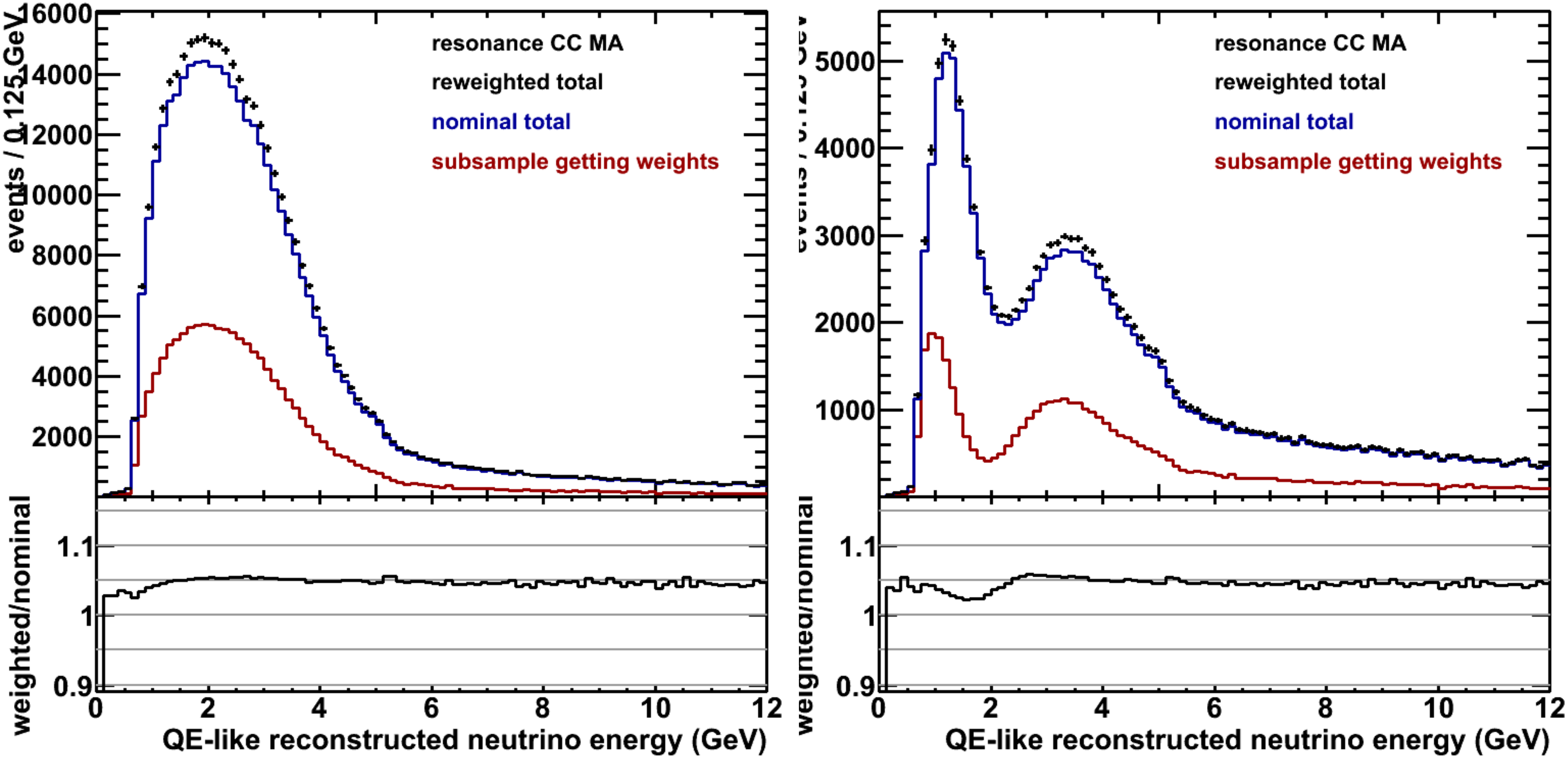


Using the QE assumption gives a biased result for resonances (and effective for 2p2h "meson exchange current" contribution) A distorted XS model distorts the reco energy spectrum.

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

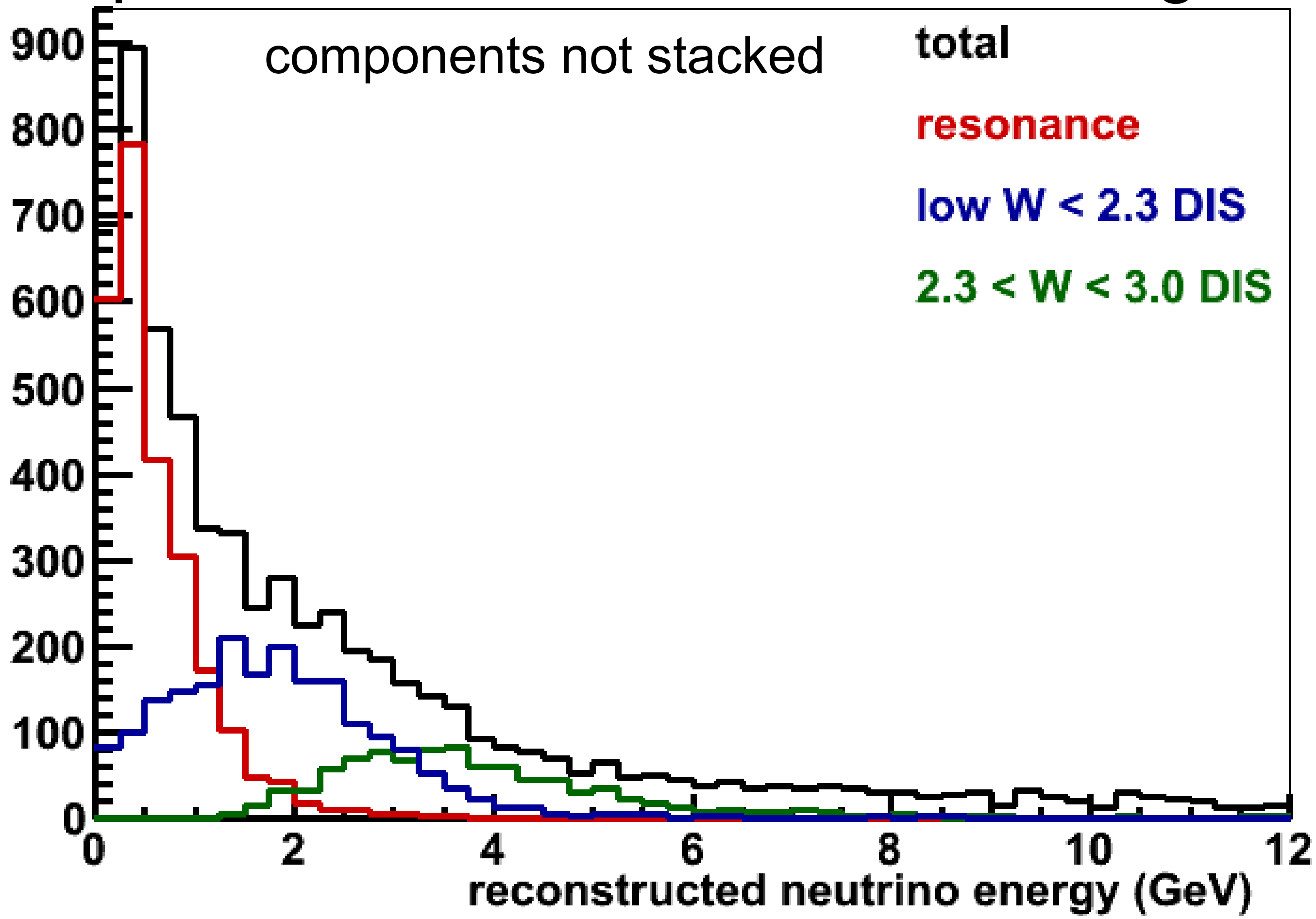
Demonstration of several mechanisms where
the neutrino interaction model
could affect LBNE physics measurements.

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
Example on next page

What GENIE model contributes to the NC background

My intuition: put more effort into understanding blue and green



The available GENIE knobs don't have as large an effect
on the blue or green regions, compared to my expectation.
This is the non-resonance background to the resonance region
And the AGKY tuned KNO model just above the resonances.
Am I using the knobs correctly? Do they cover the right uncertainties?
What do we know and not know from existing pizero vs. W?