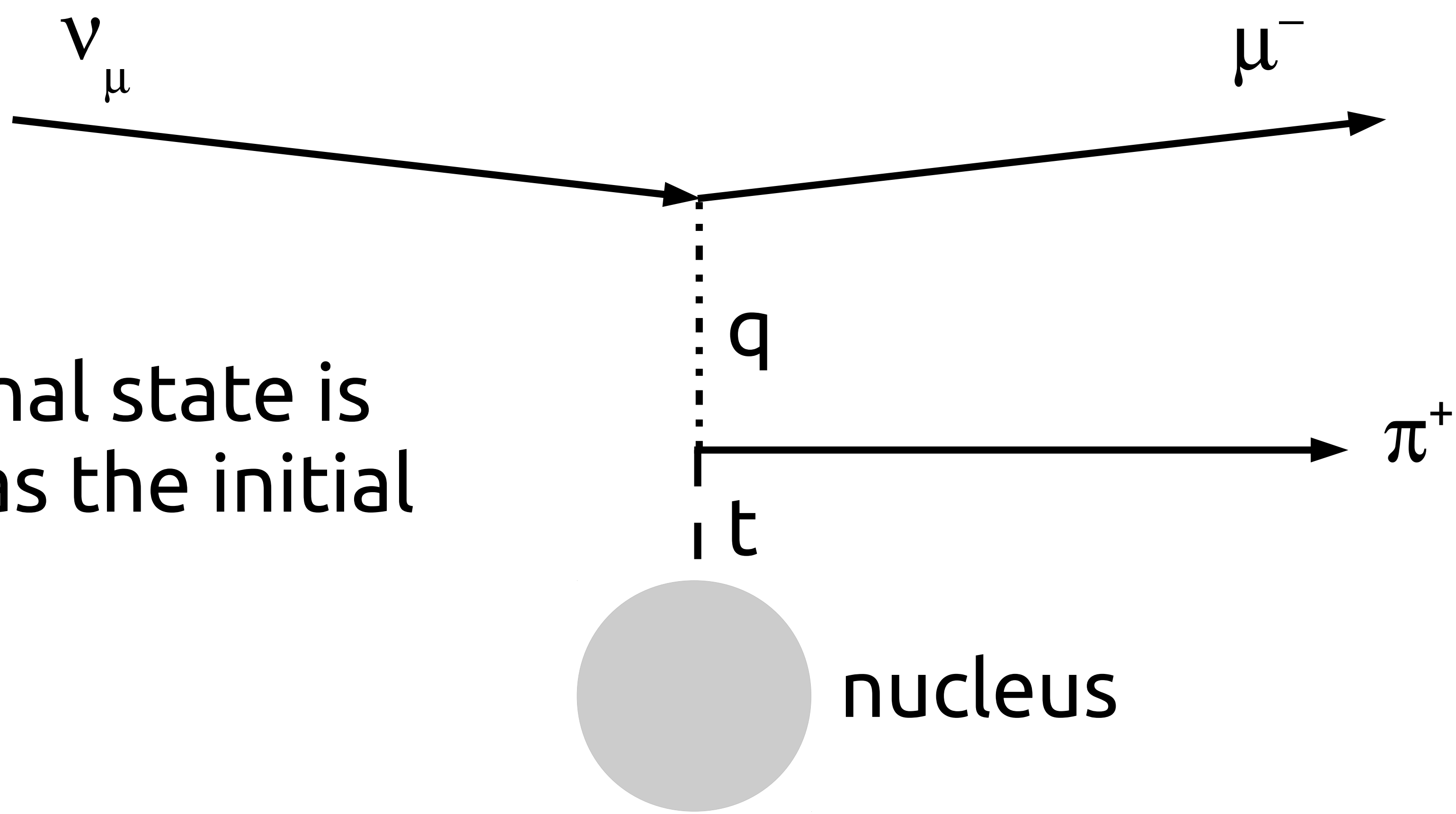
Charged Current Coherent Production

Continuing Dan's study

- Reminder of event selection
- Concerns from the tech-note and subsequent work
- Summary

THE UNIVERSITY OF WARWICK

Charged Current Coherent Production



Nucleus final state is the same as the initial state

- small t
- low vertex activity
- μ/π are forward going

CC Coherent in T2K

- Search for ν_μ CC Coherent production on Carbon (FGD1)
  - ν_μ Inclusive selection
  - Add pion selection and coherent enhancement cuts
- Look for excess over background in a 2-bin analysis.

MC: Production 5F, GENIE, flux reweighted (11a $\rightarrow$ 11b3.2)
Data: Production 5F, Runs 1+2+3+4

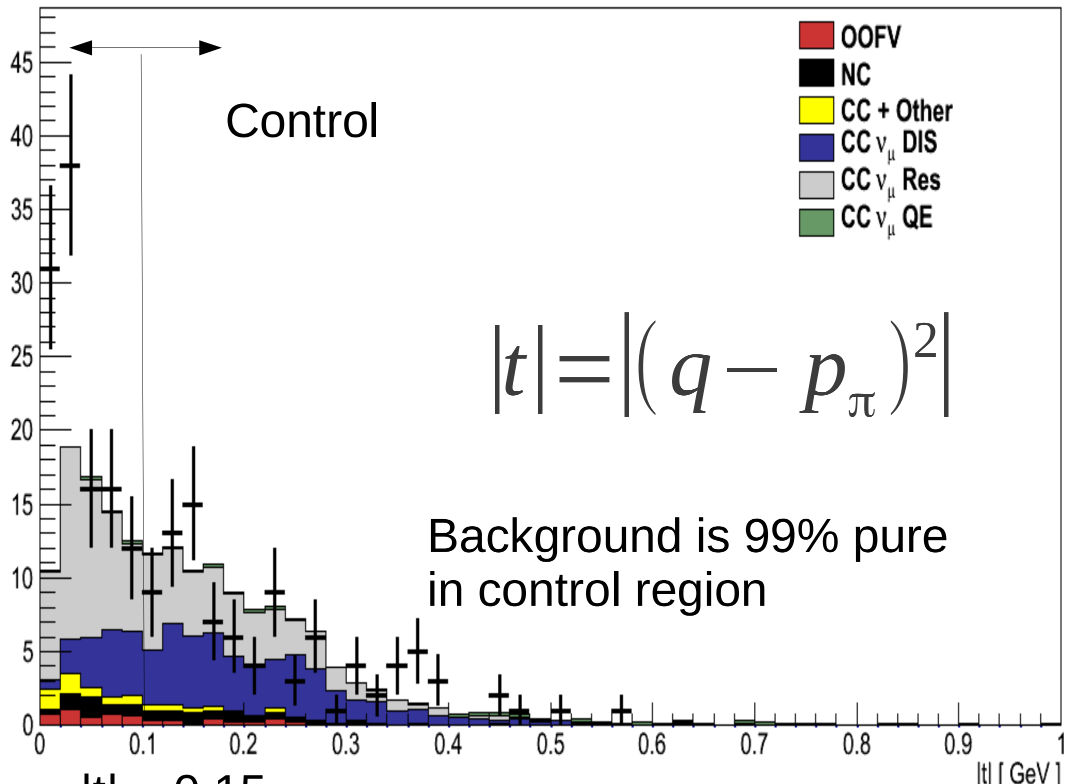
All plots POT normalised
Unless otherwise specified “signal” in the plots is the Rein-Seghal coherent model in GENIE

Event Selection

- $\nu\mu$ Inclusive event selection
- 2 FGD objects of opposite reconstructed charge
- both objects mip-like
- Vertex activity < 290 PEU

Analysis Strategy

Signal



|t| = 0.15

- Analysis strategy:

  Form background scale $\tau = \frac{N^{MC}_{signal}}{N^{MC}_{control}}$

  Background prediction: $N^{DATA}_{bgnd\,;\,signal} = \tau \times N^{DATA}_{control}$

All systematics in τ : τ = 1.51 ± 0.19

= 1.51 ± 0.04 (Flux) ± 0.06 (Det) ± 0.18 (MC)

Tech note

Initial tech-note (TN-191) was reviewed and a number of issues were highlighted.

I am moving through these (albeit slowly). Most concerning of these are

- Vertex activity distribution is not well simulated
  (this was covered in the Collab meeting)
- Background control sample simulation does not match data very well
- Efficiency systematic is based on a model that might not be valid at our energies

Apologies

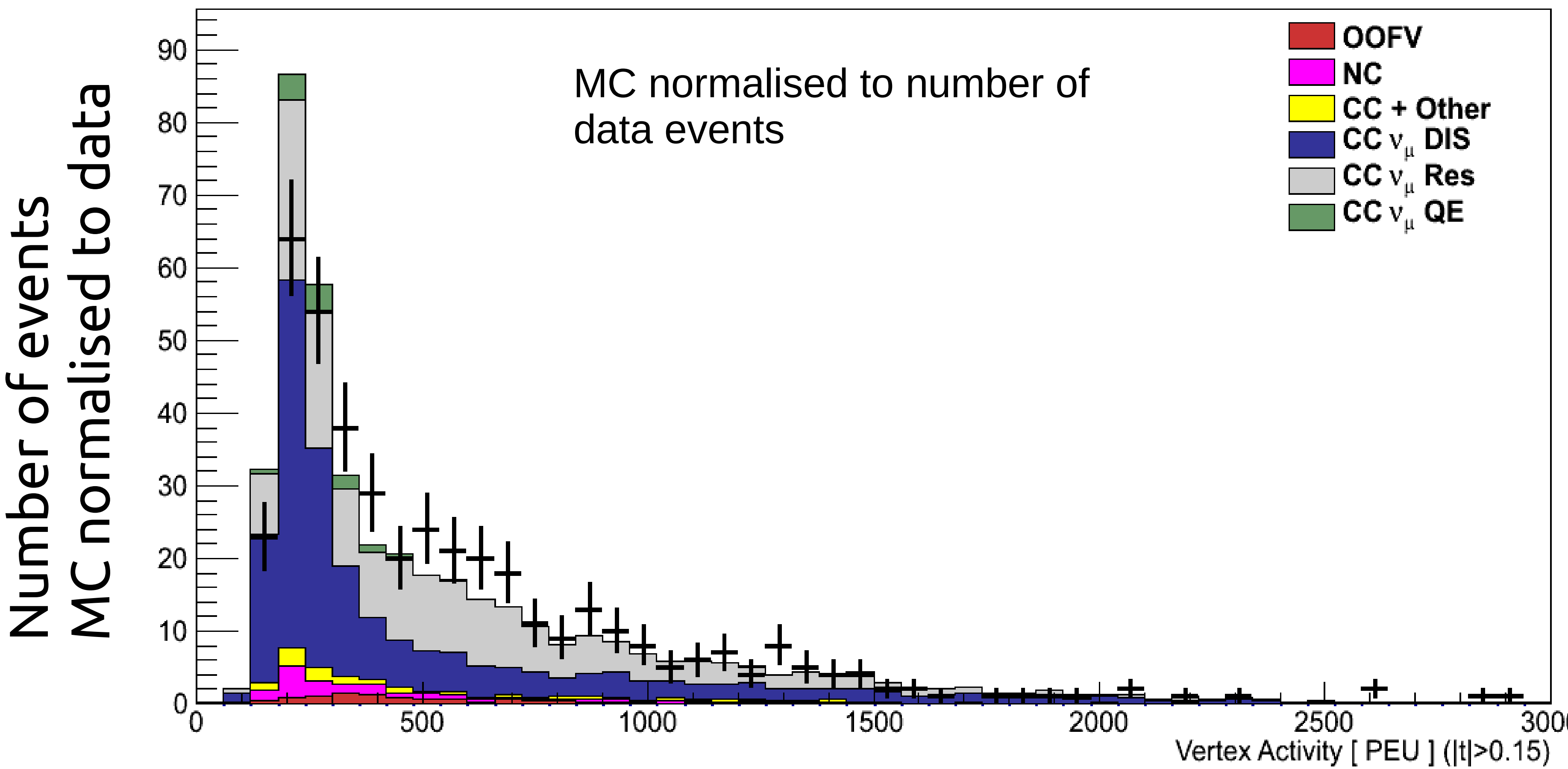
Warwick computing cluster has been down for >2 weeks for a major upgrade

I do all my work on that cluster

What I have in this talk is whatever I have on my laptop at the moment. Numbers are therefore provisional

Vertex activity - The problem

Vertex activity distribution in the control region (|t|>0.15) shows some shape difference



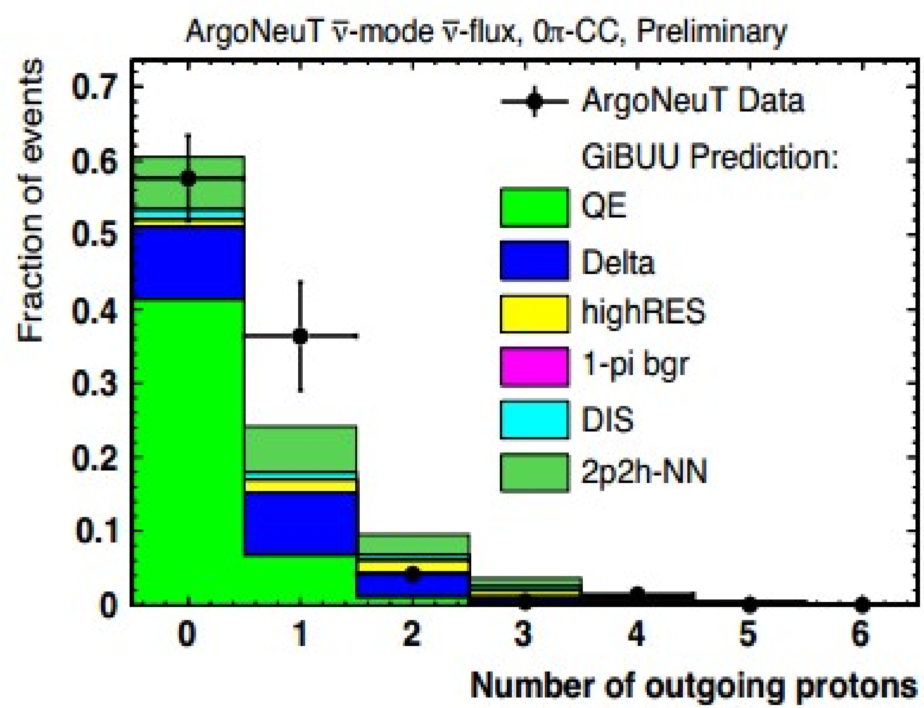
Different particle content at low vertex activity?

Extra particle content?

Multi-nucleon knockout can occur in resonance events as well as CCQE through Spectral Functions / MEC / ?

There is no theory for this. There is no data to constrain the non-theory. There is minimal data in CCQE which might be the same sort of process (but probably not)

Some evidence from Argoneut that there is an extra low energy proton in μ+Np events



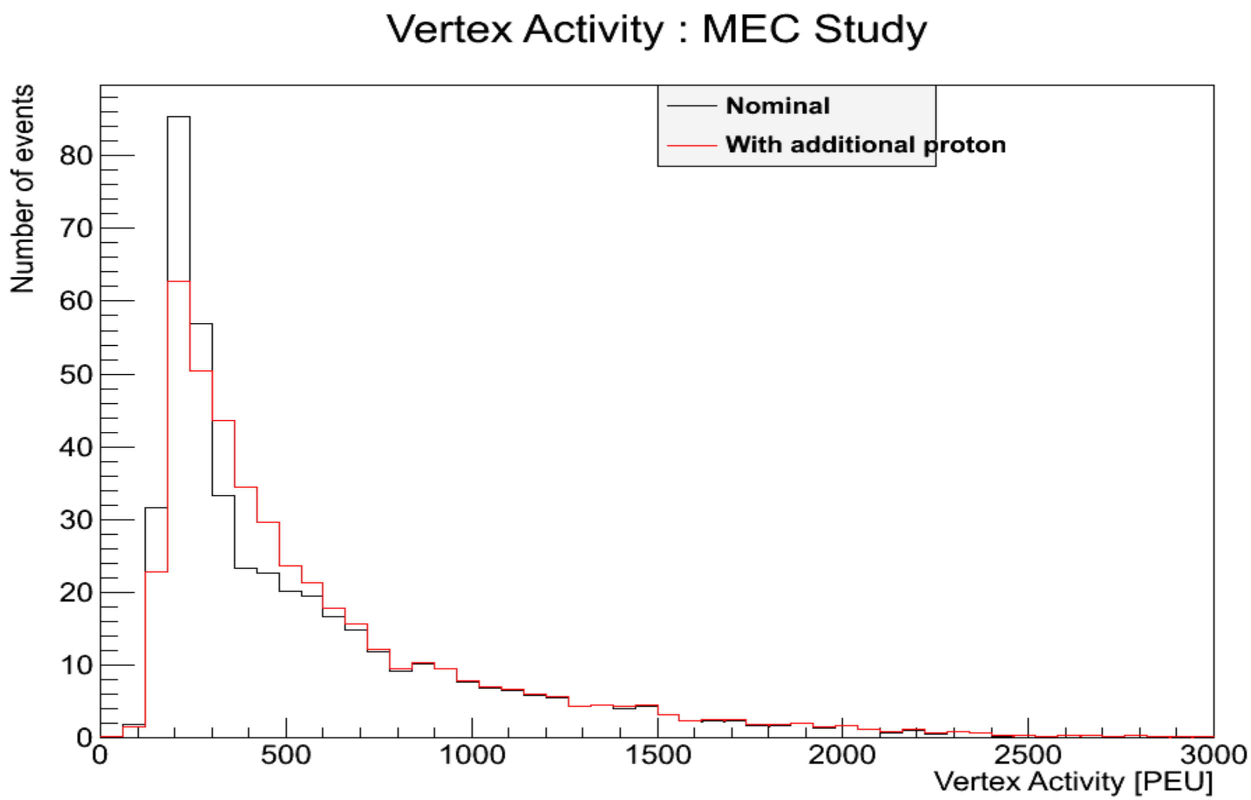
Kevin: "The MINERvA result had a definite physics interpretation we offer which is 25% of events from a neutron target have an extra proton with momentum below 250 MeV"

Method

This is a preliminary look at the contribution of addition nucleons to the VA distribution.

- Generate protons with a flat KE spectrum from 0 to 175 MeV/c2 in the FGD (why flat? MINERvA data suggests flat. Not much else to inform the choice and easy to do in ND280MC)
- Calculate the vertex activity distribution for these protons at the reco level, so that global reconstruction thresholds are not yet applied
- Make a plot of vertex activity for these protons
- Assume linearity I.e the vertex activity from an extra proton can just be added to that of an already reconstructed event from Prod 5

Effect on VA including additional proton

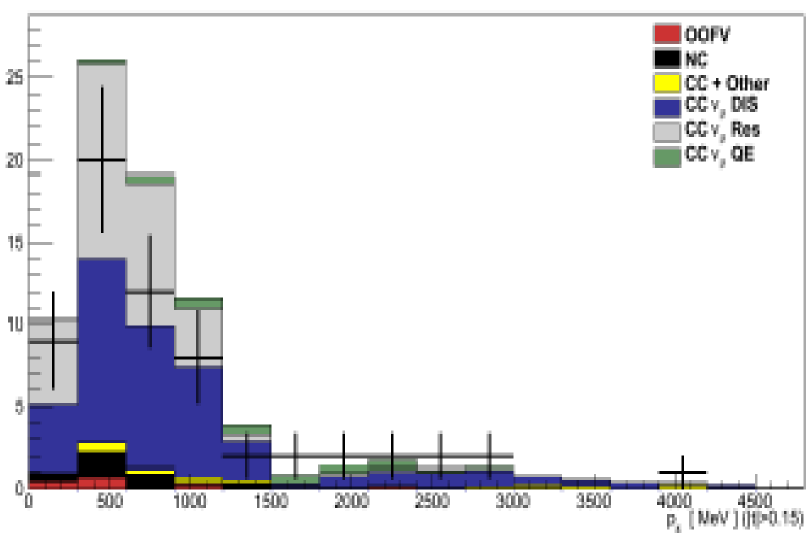


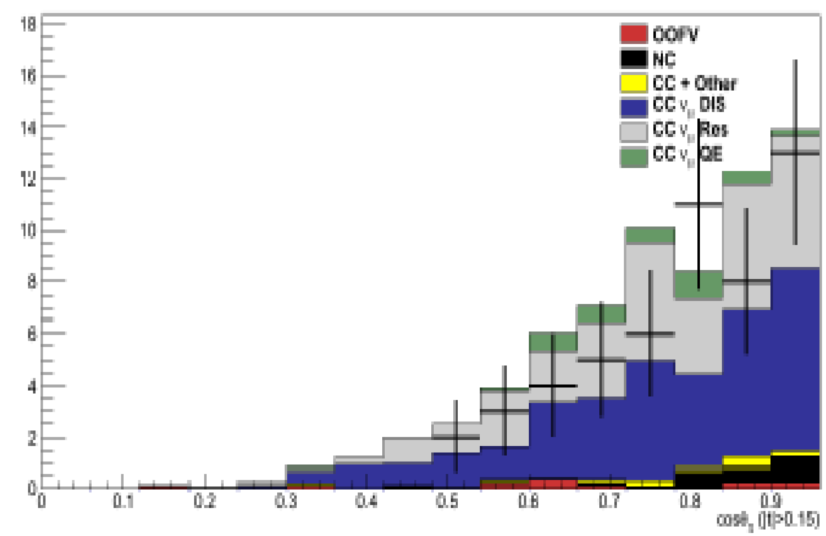
No plot (sorry) but this additional effect, along with existing systematics, cover the difference between data and vanilla Monte Carlo.

Propose to add an “additional VA” as a systematic to the study

Background shape – The problem

- Background correction algorithm used in this study assumes that the shape of various event topologies (e.g. DIS, Resonance etc) is modelled by MC and that systematics on the ratio take the model errors into account
- Also assumes that the relative fraction of each is modelled by the MC
- Problem is that the background control samples do not match data in shape





Second method

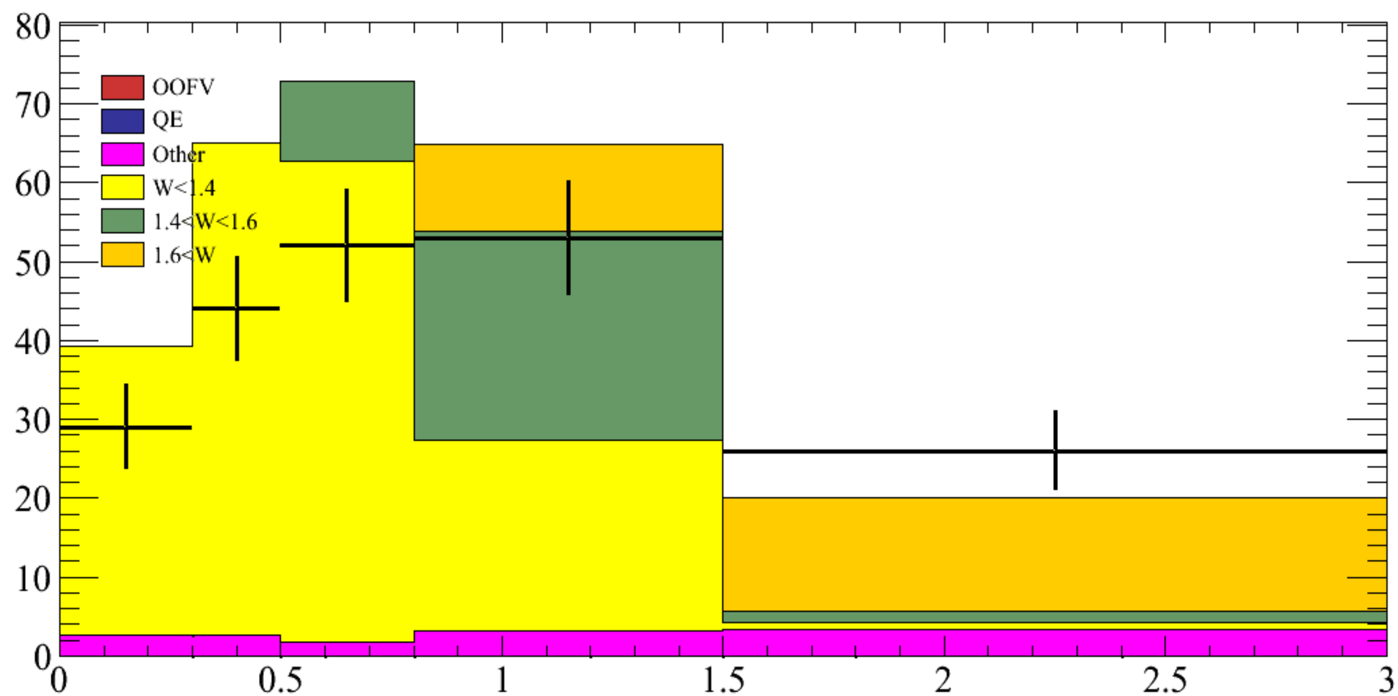
Fit the fraction of background components in the control region to the data.

Make the pion momentum spectrum for events in the control region and split into true W bins (to avoid dependency on MC codes)

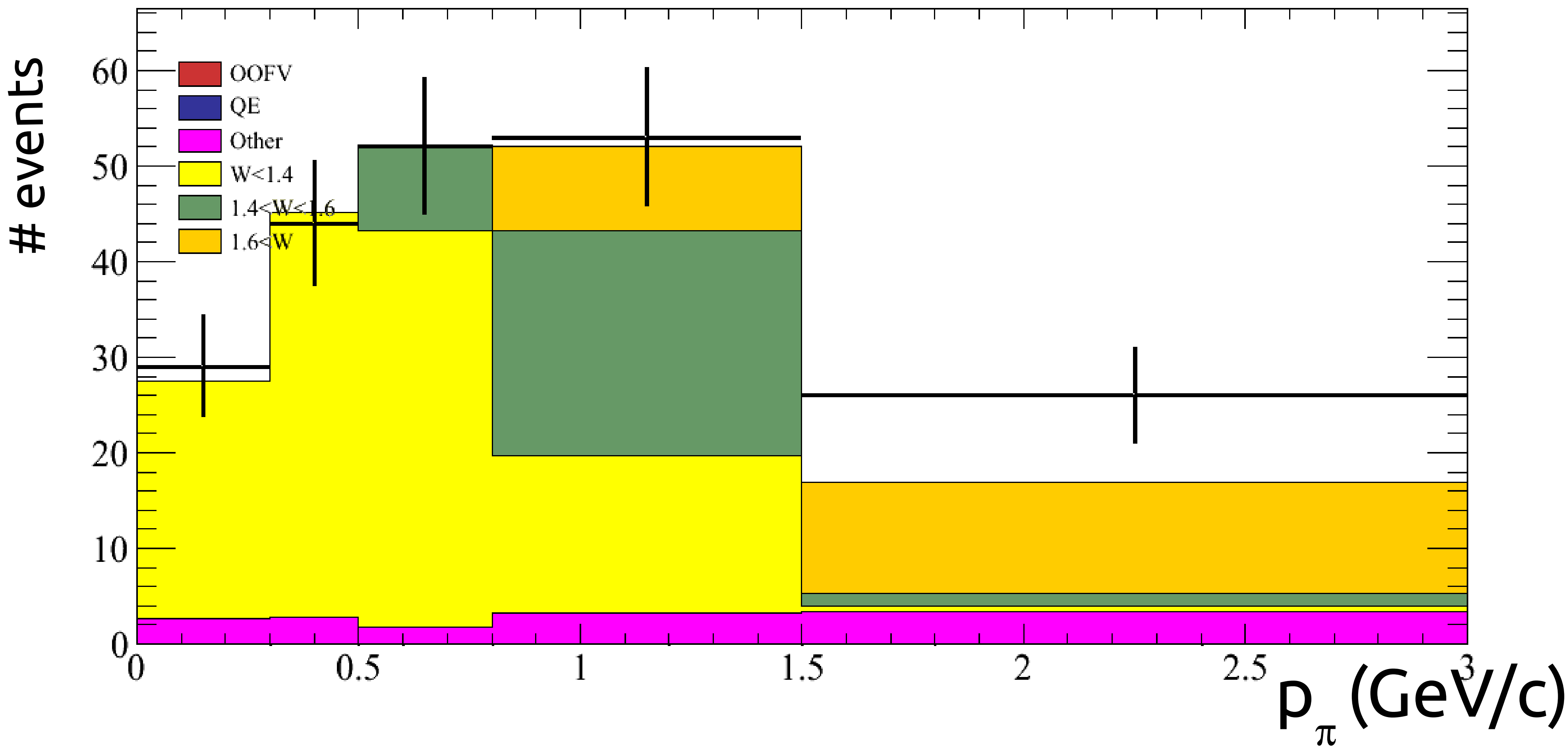
Before fit

Background control sample $|t| > 0.15\ (GeV/c)^2$

POT normalised



p_π (GeV/c)



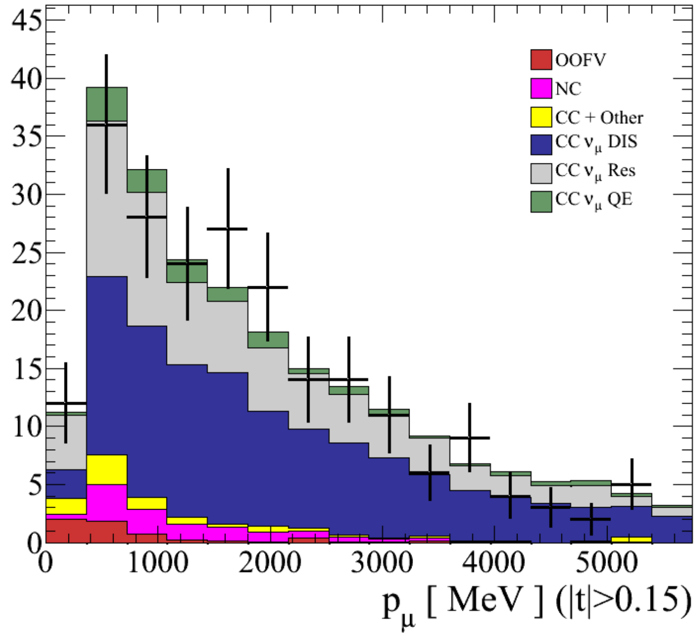
Scale factors

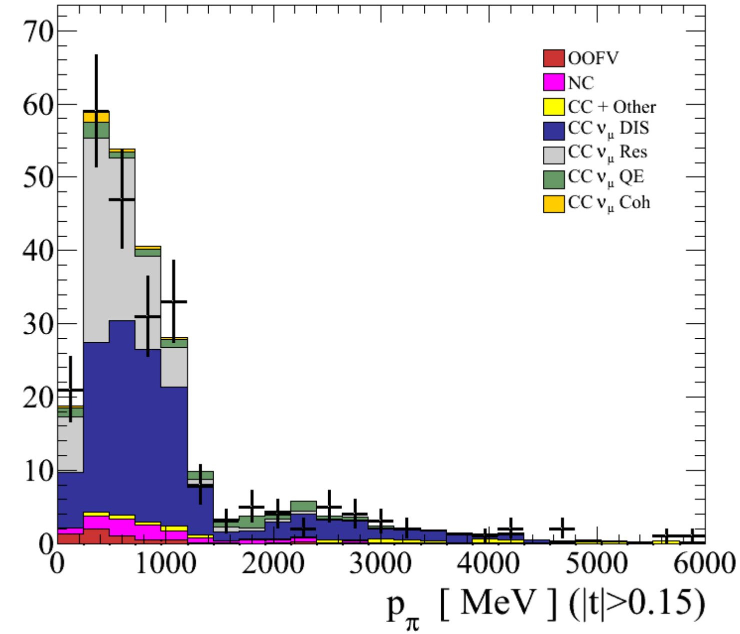
Source	Scale
W < 1.4	0.68 ± 0.07
1.4 < W < 1.6	0.91 ± 0.29
1.6 < W	0.82 ± 0.21
Other/QE/OOFV	1.0

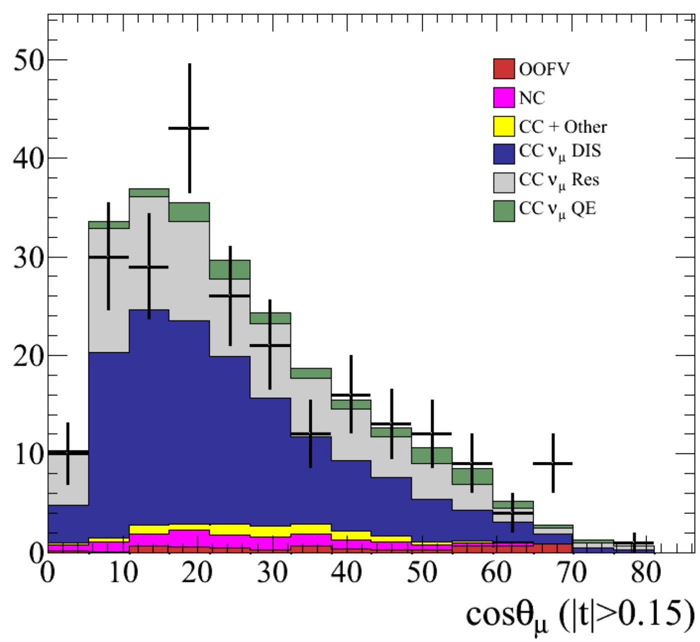
Correlation matrix

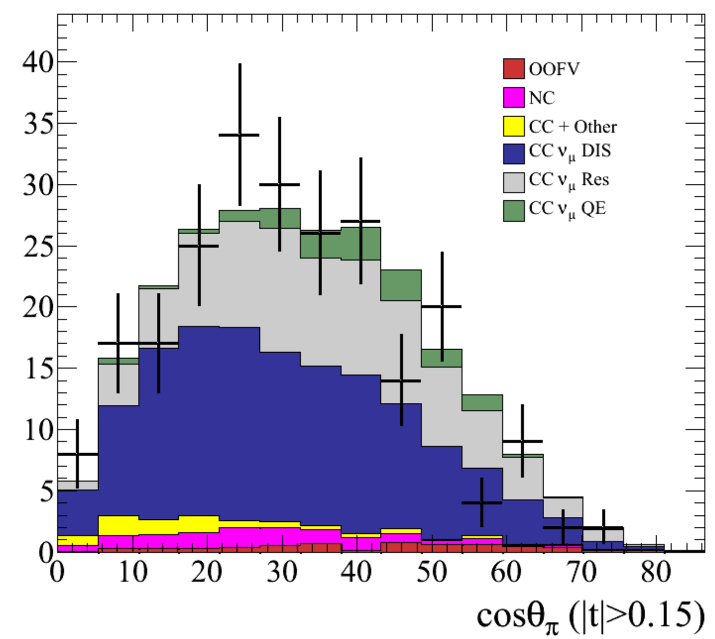
	W<1.4	1.4<W<1.6	1.6<W
W<1.4	1	-0.4	0.07
1.4<W<1.6		1	-0.35
1.6 < W			1

Effect on background distributions



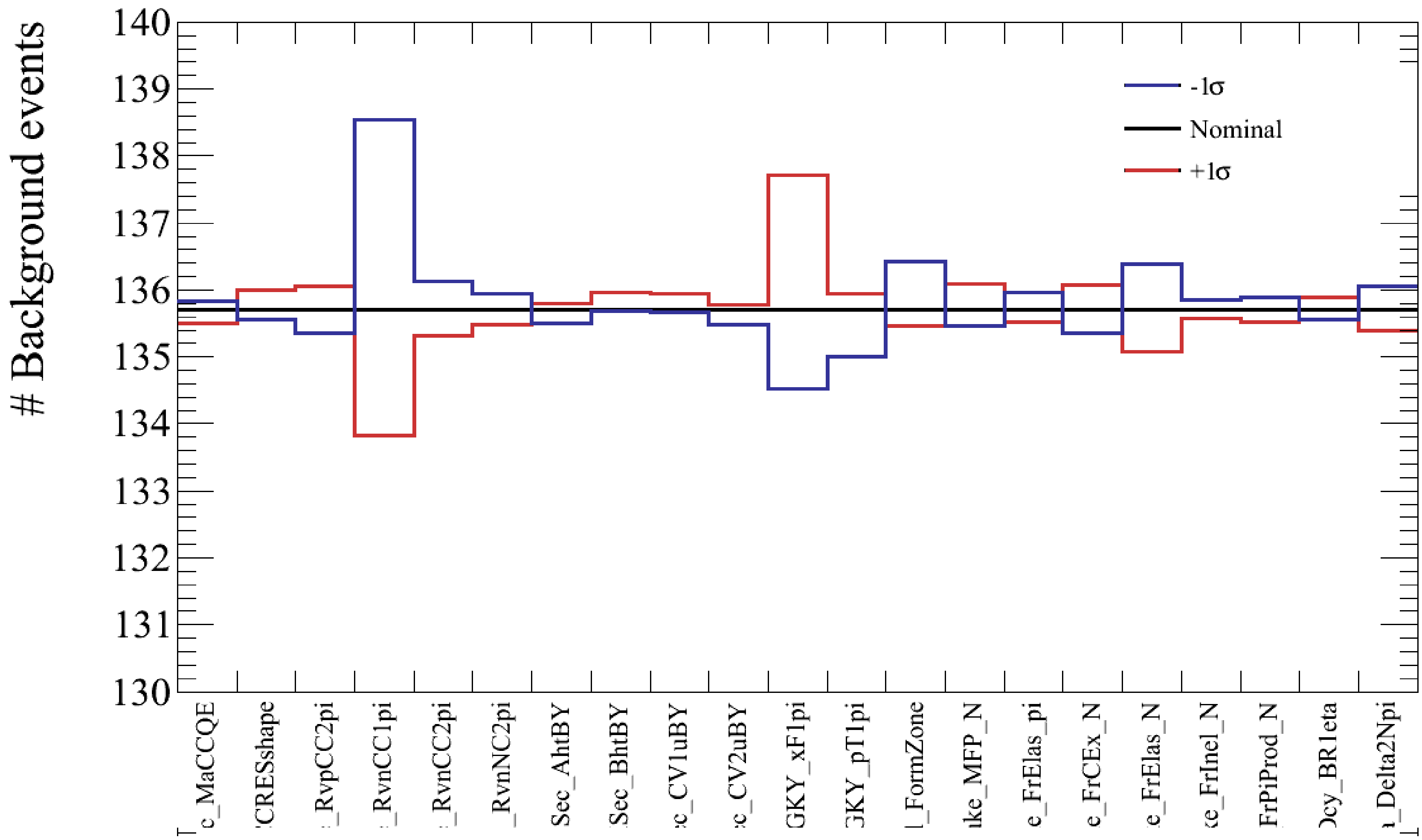






Background Systematics

Model systematics : For each model systematic, repeat this procedure



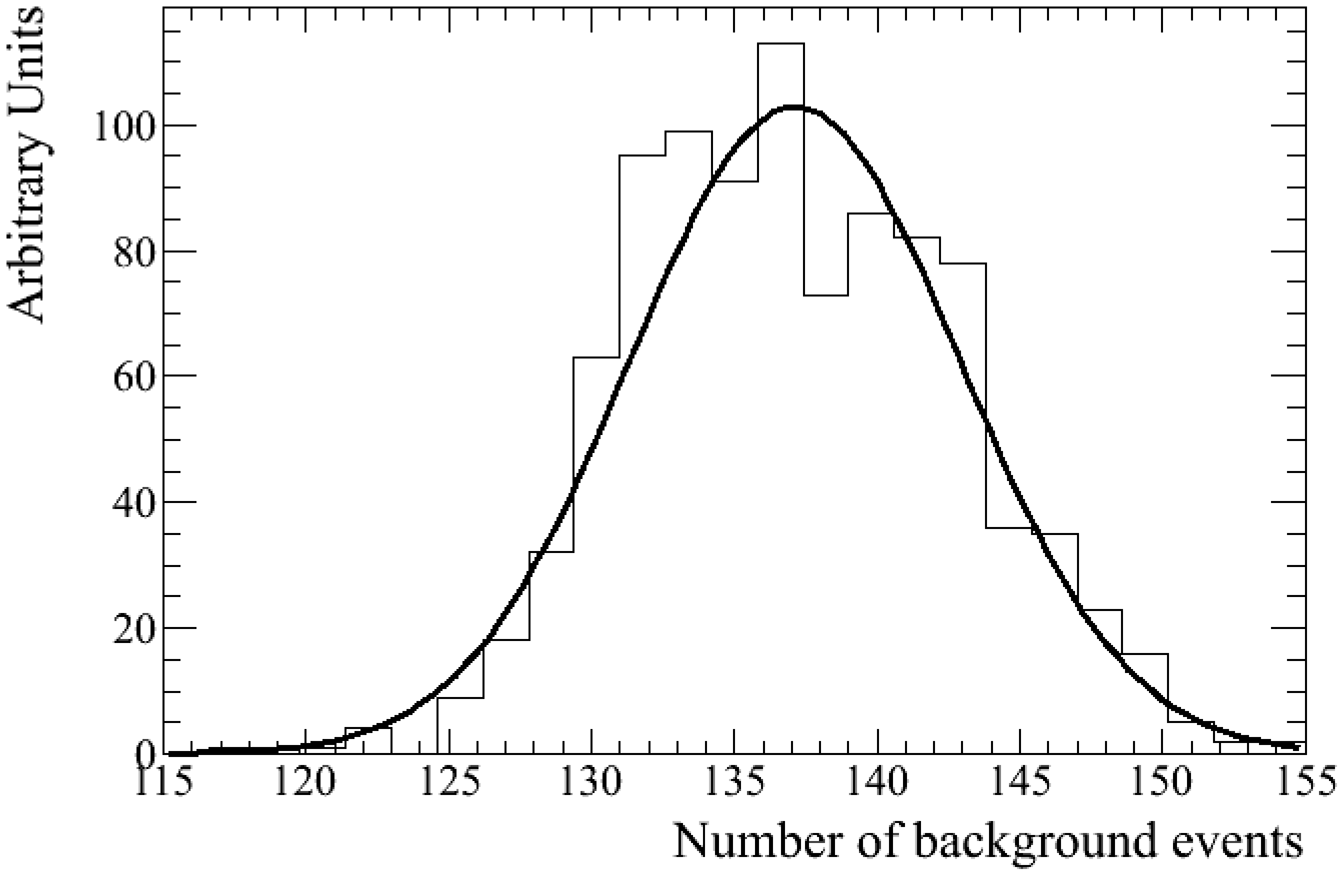
Background = 136 +/- 3 (model) events

Detector

Systematic Source	Systematic Size
Pion Reinteractions	0.8
TPC Charge Confusion	0.06
TPC-FGD Matching	0.16
OOFV	1.0
Vertex Activity	3.7
TPC Momentum Scale	1.2
TPC Momentum Resolution	0.3
TPC PID	0.19

Background = 136 +/- 3 (model)
+/- 4 (det)

Flux



Background = 136 +/- 3 (model)
+/- 4 (det)
+/- 6 (flux)

Error from the scale fit

The fit to p_{π} returns a covariance matrix. A systematic is needed to account for variation of the W-scales within the fit errors

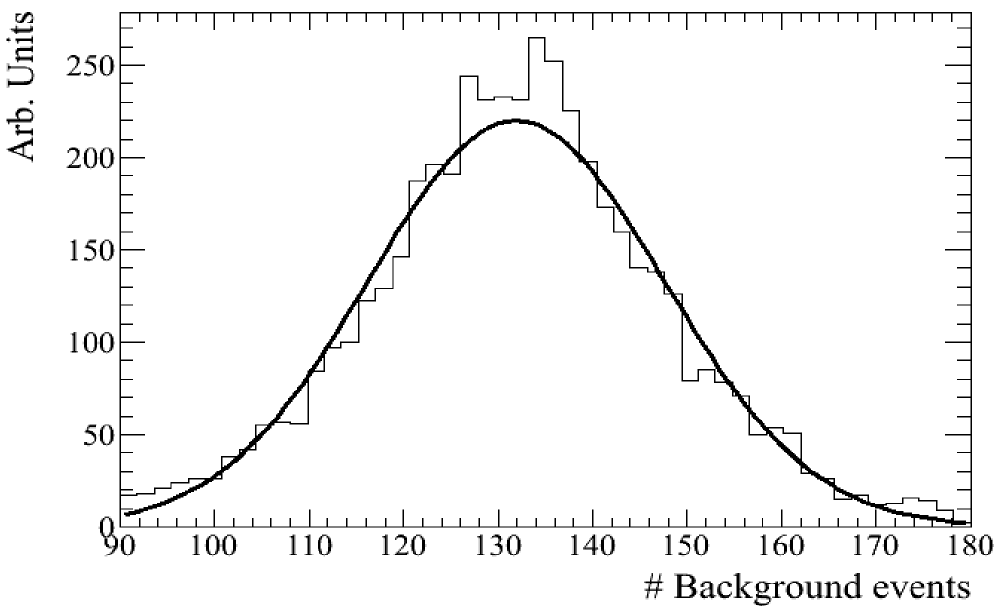
	W<1.4	1.4<W<1.6	1.6<W
W<1.4	1	-0.4	0.07
1.4<W<1.6		1	-0.35
1.6 < W			1

1000 experiments were run using scales drawn from the covariance matrix from the fit

Background = 136 +/- 3 (model)
+/- 4 (det)
+/- 6 (flux)
+/- 16 (covar)
+/- 14 (stat)

= 136 +/- 23 events

Original = 154 +/- 34



Efficiency Studies

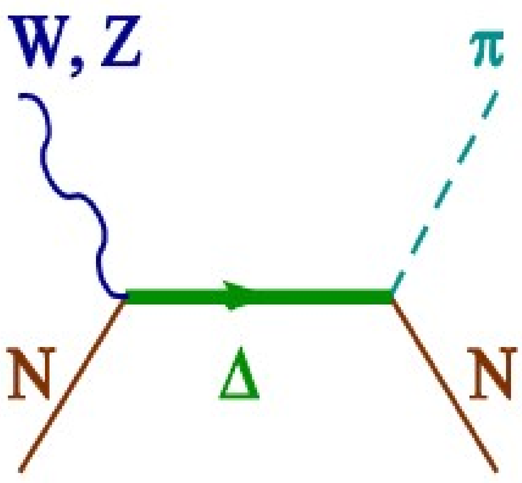
Tech-note suggestions included doing some efficiency studies with different models. Simulations generally only use one model which is stated to be inaccurate at energies less than a few GeV

PCAC-based Rein-Seghal Model in Genie v 2.6

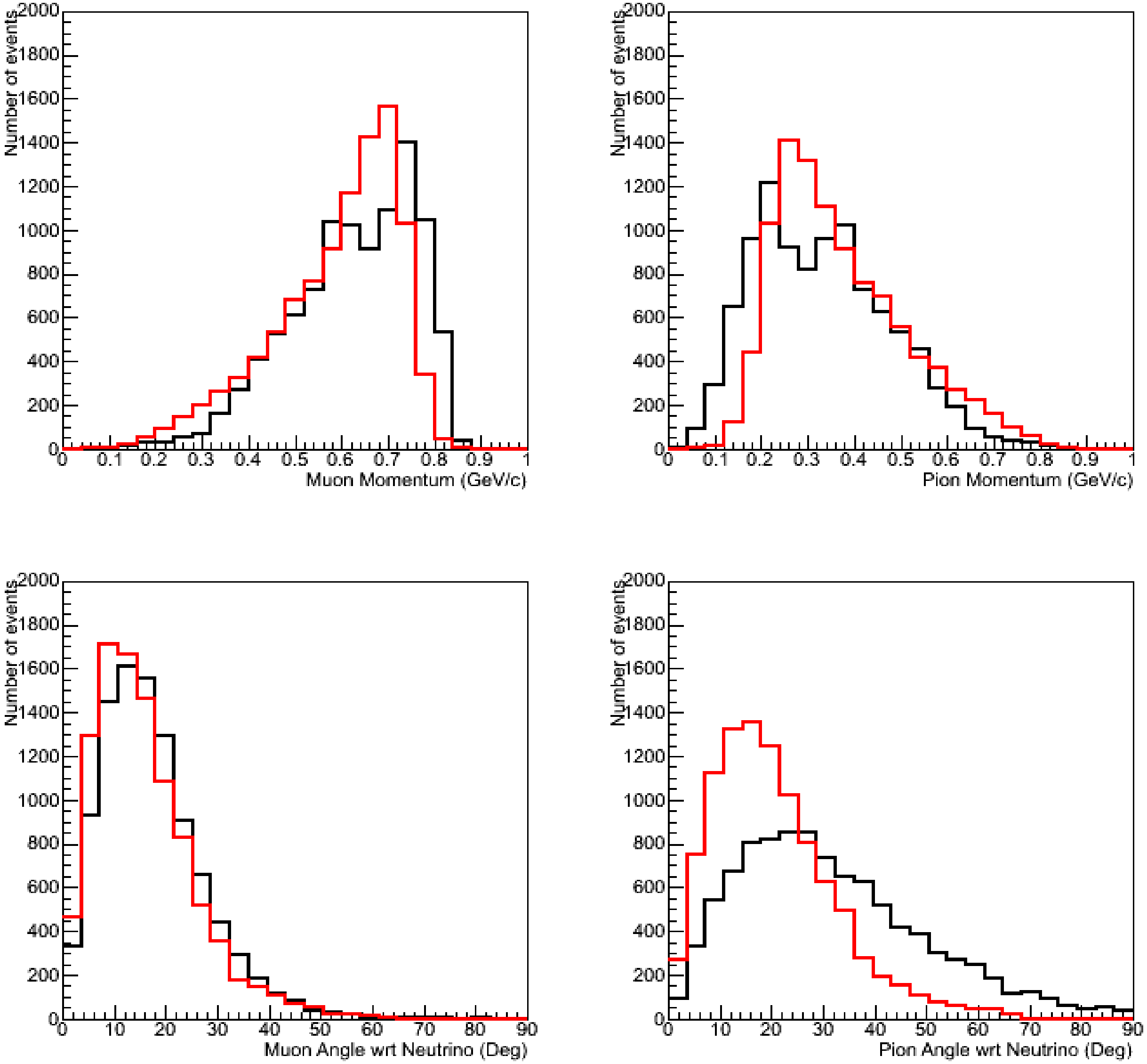
$$\frac{d^3\sigma}{dx\,dy\,dt}=\left(\frac{G_F^2 m_N}{32\pi^3}\right) f_\pi^2 A^2 E_\nu (1-y)(\sigma_{TOT}^{\pi N})^2 (1+r^2) \frac{m_A^2}{m_A^2+Q^2} \exp\left[-\frac{1}{3}R_0^2 A^{2/3} t\right] \exp\left[\frac{-9A^{1/3}}{16\pi R_0^2}\sigma_{inel}^{\pi N}\right]$$

Microscopic model

- Model the ν + N $\rightarrow$ l N π amplitude
- Coherent sum over all nucleons
- Apply medium effects to Δ and distortion to outgoing pion wavefunction
- Alvarez-Ruso model implemented in GENIE 2.8



Event distributions



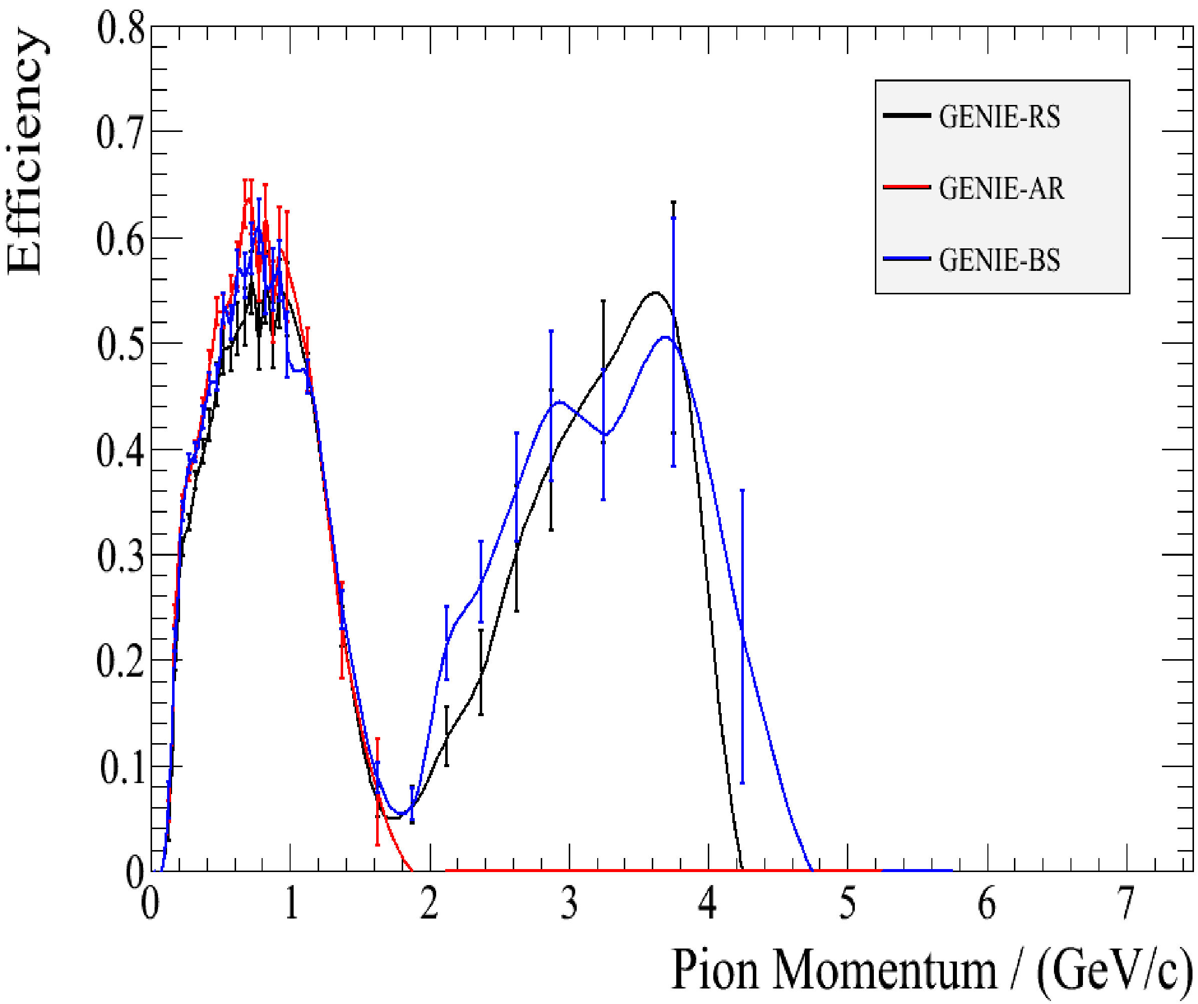
CC ν_μ Coherent

E_ν = 1.0 GeV

GENIE Rein-Seghal

GENIE Alvarez-Ruso

Efficiency



- Standard Rein-Seghal
- Berger-Seghal
- Alvarez-Ruso

Dip comes from the hard proton/pion PID cut. Maybe this should be relaxed.

Alvarez-Ruso model constrained to $E_\nu < 5$ GeV

For p_π<1.8 GeV, models differ by at most 10%

- Should look at efficiency in (p_π, θ_π) space

Summary

- Work is continuing (albeit slowly). Now that teaching/exams/ are complete I should be able to work more on this (once the cluster is up, of course)

- Vertex activity mismatch will be dealt with by including an additional systematic.

- New background estimation method ensures that the data is reasonably well described. Results are similar to the original method.

- Efficiency is being looked at with as many models as I can find. What would a systematic on the efficiency be when no model has been tested at these energies? Maximum difference between models?