Charged Current Working Group: Status & Plans

CC WG

MINOS Collaboration Meeting

October 2005

CC/ND Joint Sessions
10/05 MINOS Meeting

ND/CC/FD: (Thursday afternoon)

- Flux normalization & DIS HE cross section (Mike Kordosky)
- Quasi-Elastics & Flux (Mark Dorman)
- Updated on Neutrino Energy vs Batch (Peter Shanahan)
- Data Selection in the FD & Related Issues (Niki Saoulidou)
- FD event selection & data/MC comparisons (David Petyt)
- FD Fiducial Optimization & CR Backgrounds (Andy Culling)
- Production of Spectral Data & MC Predictions (Trish Vahle)
- Giving Us Fits (Jenny Thomas)

ND/CC (Friday morning)

- Charm/Dimuon Analysis (Costas Andreopoulos)
- ND Data/MC for the CC Analysis (Masaki)
- ND Data/MC Comparisons (Trish Vahle)
- ND Data/MC in R1.18 for pME, pHE, & LE-10 (Niki Saoulidou)
- LE CC/Non-CC event rates vs POT (Sanjib Mishra)

Bean Systematics WG (Friday morning)

(+ 12 WG conference calls since Ely)

Topical Breakdown

- CC 1 (Jeff, 30 min)
  - > ND PID variable performance
  - > Energy scan results
  - > Spectral errors
- CC 2 (David, 40 min)
  - > LE FD data results
    - Scans
    - Backgrounds
    - Plots of variables
    - Fid volume optimization
  - > Fitting
    - David's (Iterative fitting)
    - Peter (event-by-event extrap)
    - UCL (know nothing χ^2)
    - Brian's (Marquardt method)
- CC 3 (Jeff, 30 min)
  - > Horn current optimization - input
  - > Decision for when we come back after the shutdown
  - > Opening the box check list
  - > Horn off running
- ND
  - > Generators
    - NEUGEN Update
    - Tuning
    - Genie
  - > MC vs data: reconstruction
    - Tracking differences
    - Shower differences
    - Late light fixes
  - > Blessed ND performance plots
  - > ND physics
    - DIS xsections & QE extrapolations
    - X and q^2
    - Dimuon
    - IMD
  - > ND as beam monitor
    - Bunch 2 bunch
    - ND rate vs time

The CC Analysis

- Define some good methods in MC
  - > Look for issues, feedback to RECO, MC …
  - > Repeat…
  - > Did that for a “while”
- Then test the variables in the ND data
  - > Look for issues and feedback to Beam MC, Neutrino Generator, Reco, Detector MC, Ops, Calibration, …
  - > Rinse, repeat… do at a level that is beyond the
  - > Done that for 9 months
- Then test the in the FD data
  - > Look for issues and feedback to Ops, Calibration, RECO, MC, generator …
  - > Rinse, repeat…
  - > Done that for last 4 months
- Use the MC samples to translate to FD
  - > Various concepts proposed and tested
  - > Predict an error envelop based on inputs, reasonable variations in the predicted physics that can impact the ND/FD ratio
    - Constrained by the ND data
  - > Fit for results

When we last left the energy scan…

- At Ely

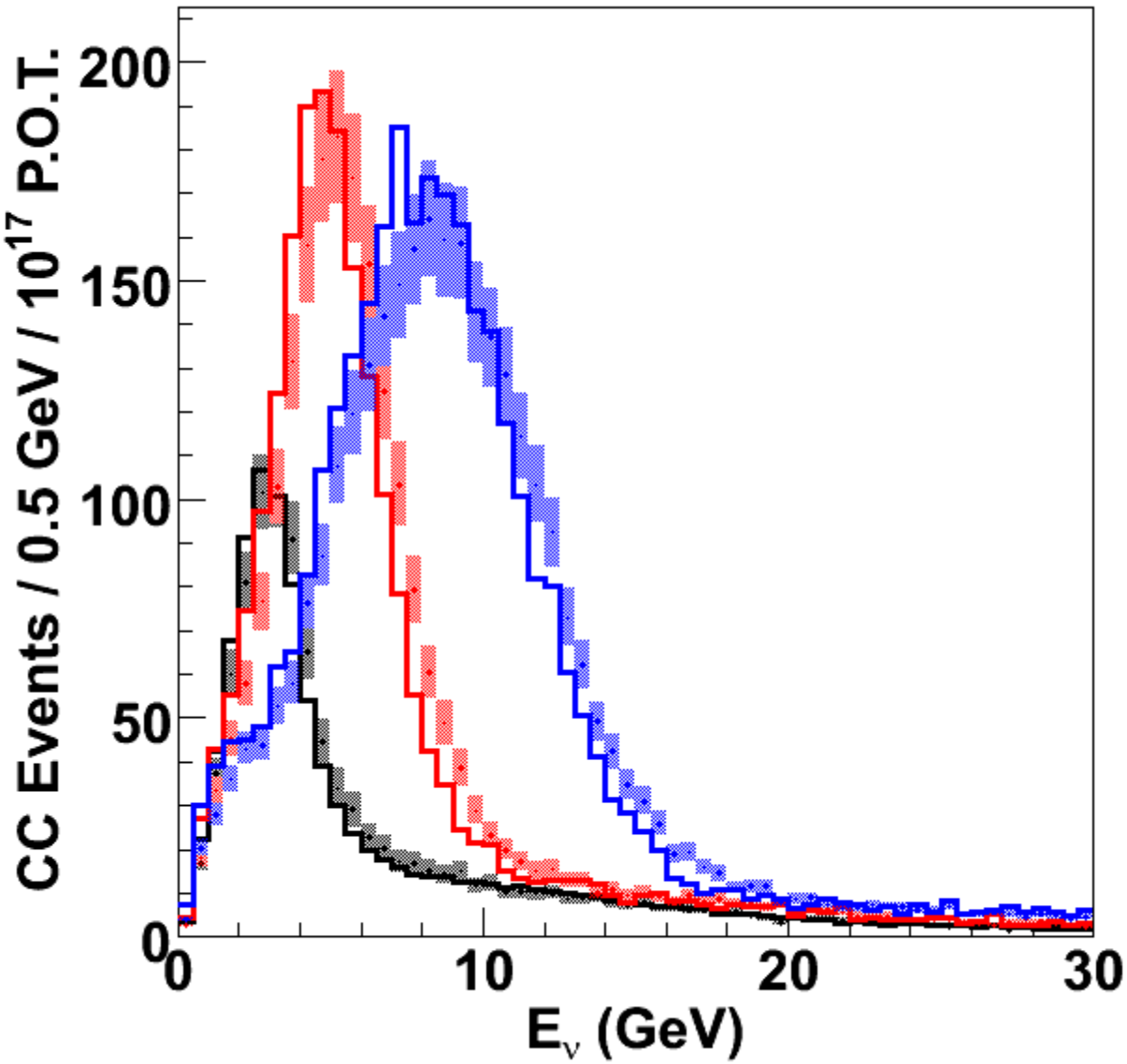
Black—LE
Red—pME
Blue—pHE

Quality

Solid—data
Bands—MC
(w/ beam sys.)

Trish's version

E_ν Distributions Now



- Black—LE10
- Red—pME
- Blue—pHE
- Solid—data
- Bands—MC with beam sys. errors

Much Better!

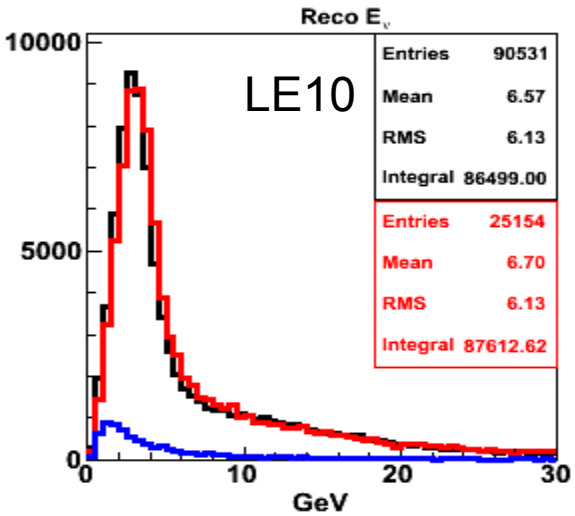
Trish's version

Events Accepted

Beam Config	POT	Events Accepted	Events/1e17 POT	%NC Contamination
LE10 Data	8.7e18	90531	1043.0	
LE10 MC	2.4e18	25154	1061.8	8.6
pME Data	8.0e17	16457	2053.6	
pME MC	3.4e18	74579	2169.1	8.8
pHE Data	5.7e17	17409	3034.6	
pHE MC	1.8e18	56799	3112.5	9.6

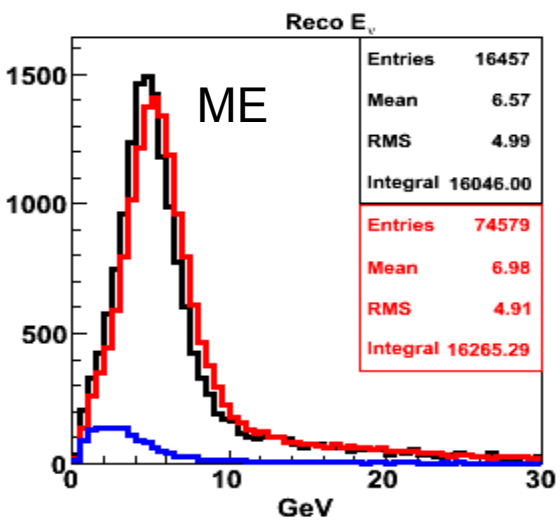
Trish

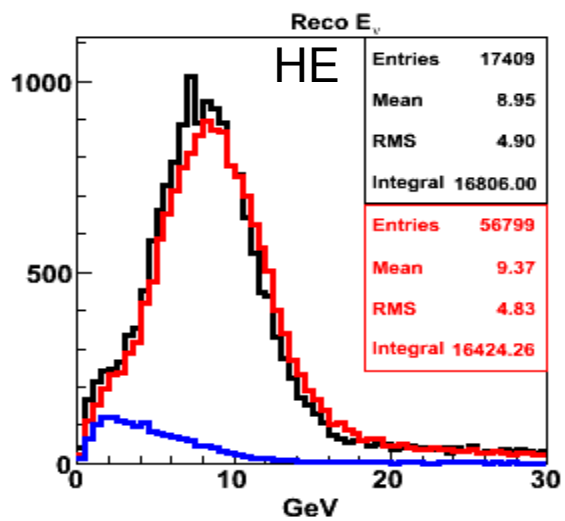
E_ν Distributions Now



Black—Data
Red—MC
Blue—true NC

Scaled to POT



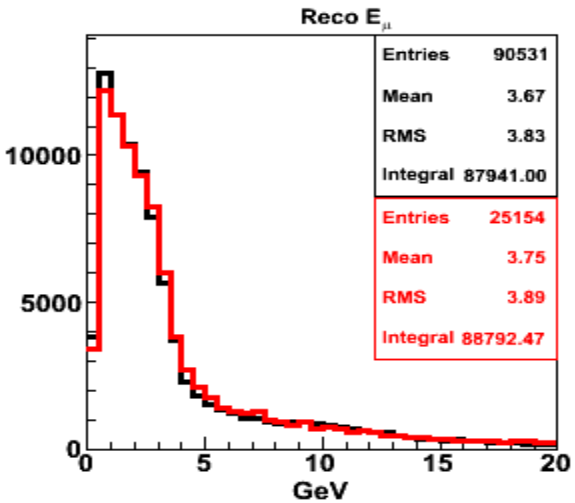


There's still an offset…
Difference in means:
- LE10—1.9%
- ME—5.8%
- HE—4.5%

Trish

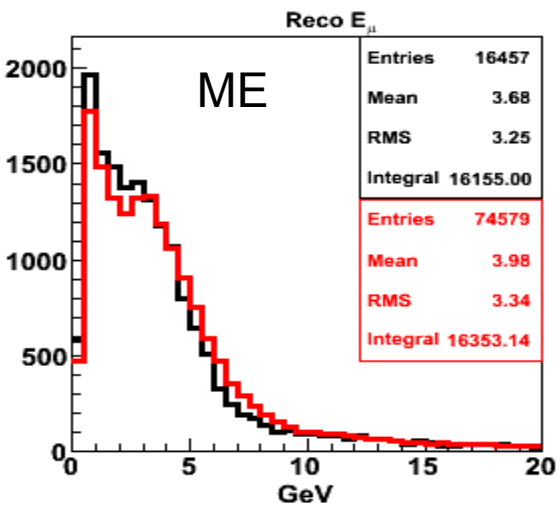
E_μ Distributions Now

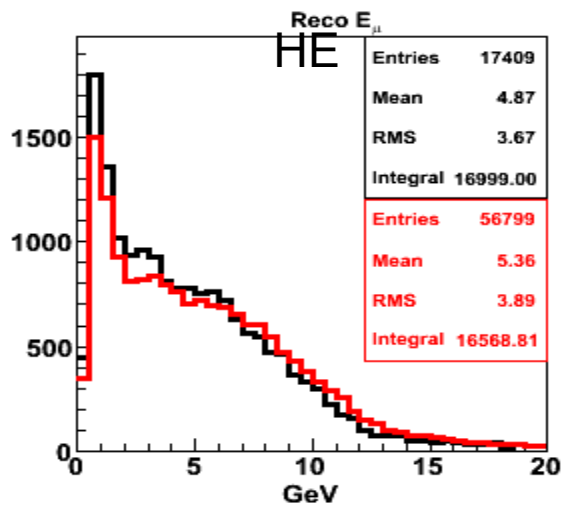
LE10



Black—Data
Red—MC

Scaled to POT



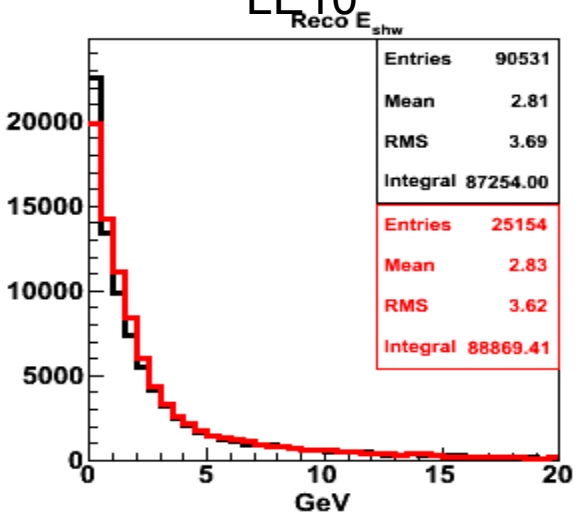


More low E muons in data
More high E muons in MC

Trish

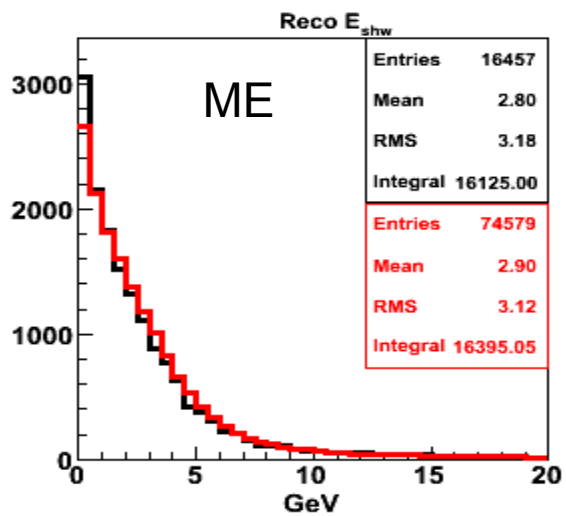
E_{shw} Distributions Now

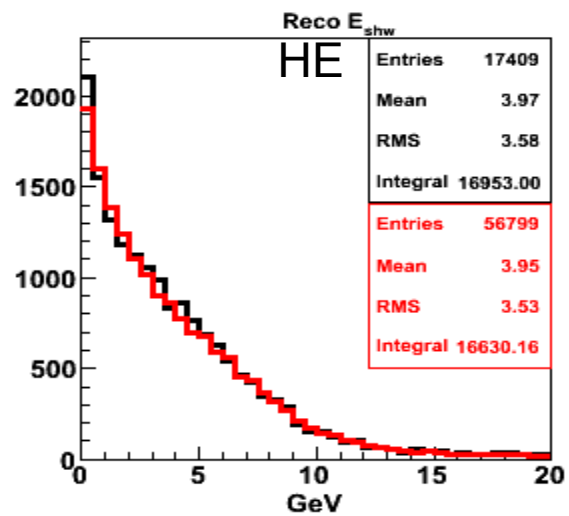
LE10



Black—Data
Red—MC

Scaled to POT



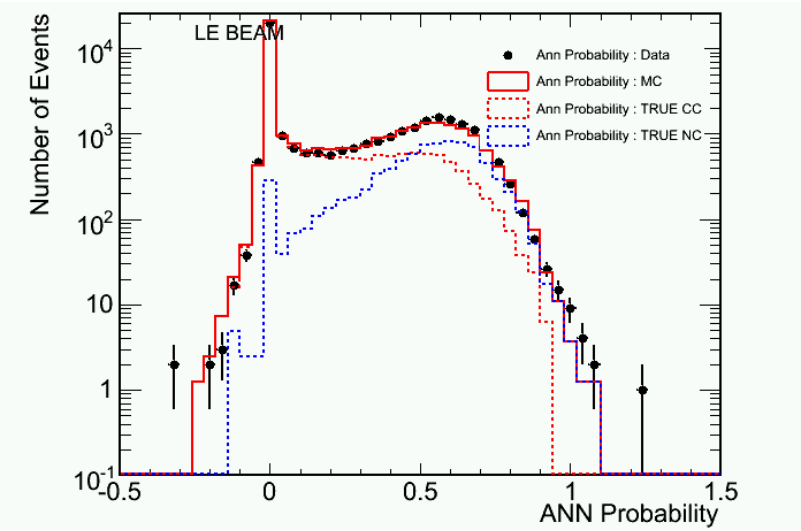


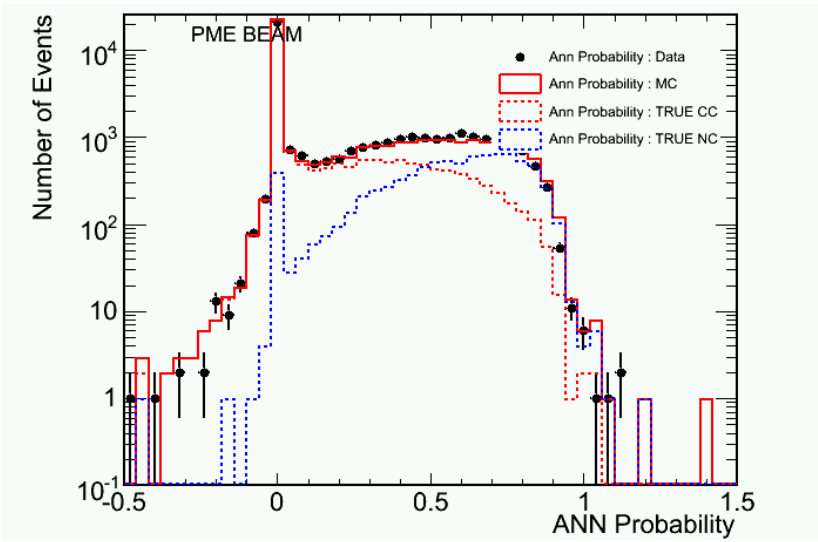
Trish

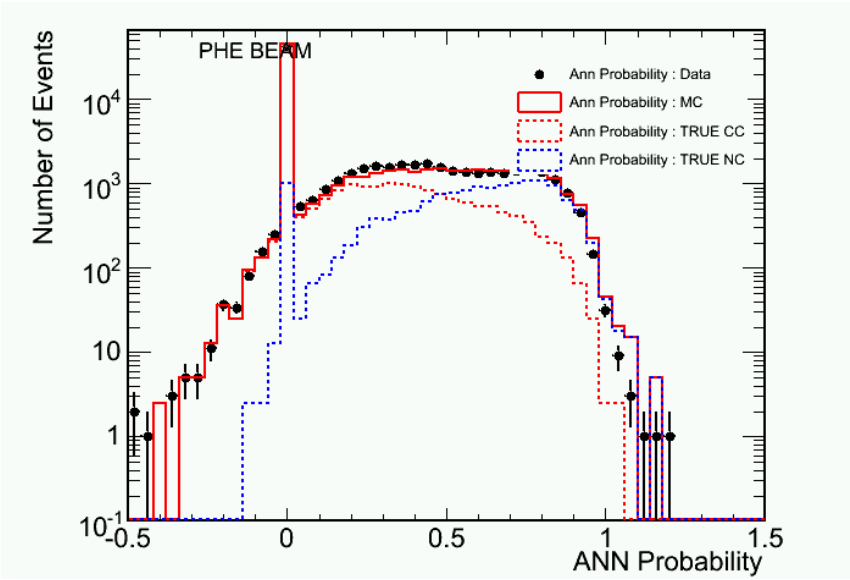
Trish's Conclusions

- Old ME and HE spectra from MC did not have wfluk reweighting
- New MC looks better, but there's still an offset
- Excess of <1 pe hits in showers
- Other low level shower quantities don't look crazy
- Timing quantities differ between data and MC
  - > Time between events—different intensities
  - > Time length of events

ANN PID



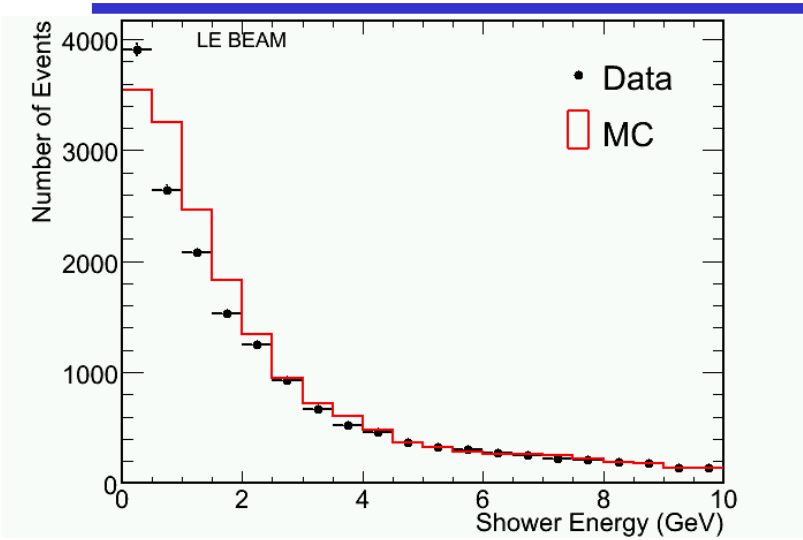


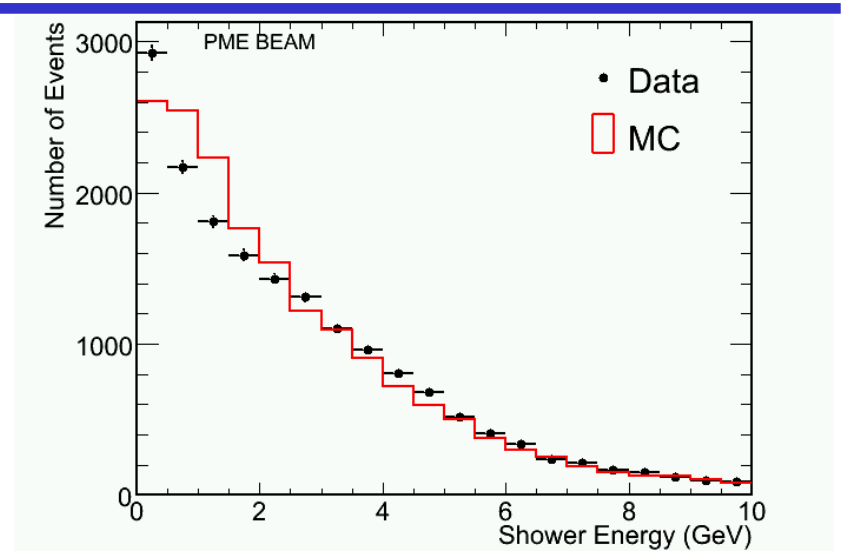


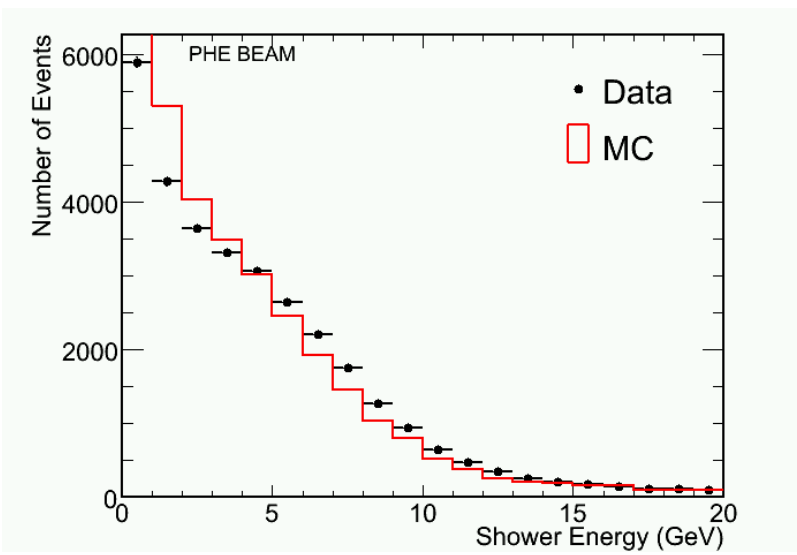
Data – MC agree well

Niki

Shower Energy : CC-like events LE-10 PME PHE



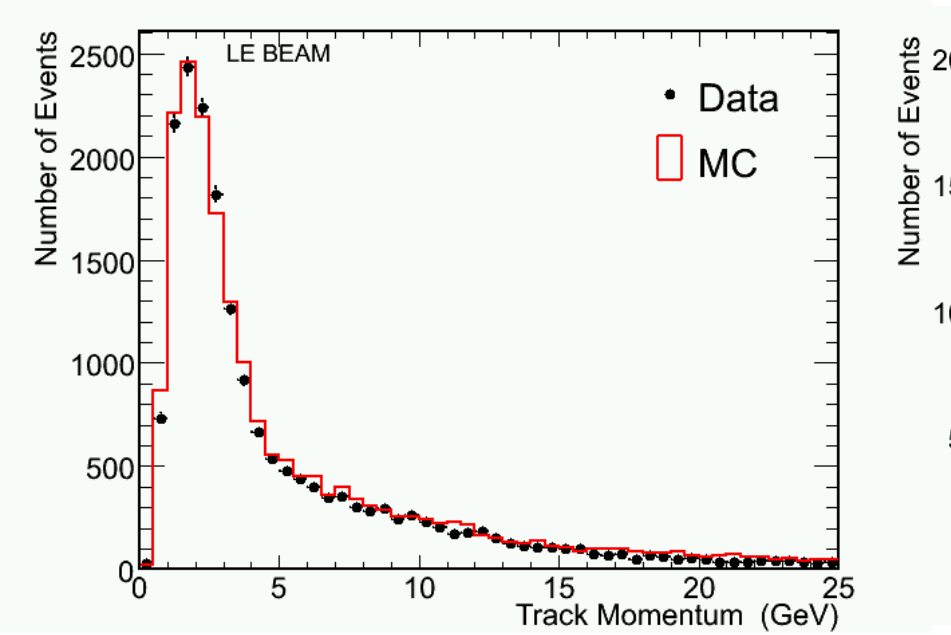


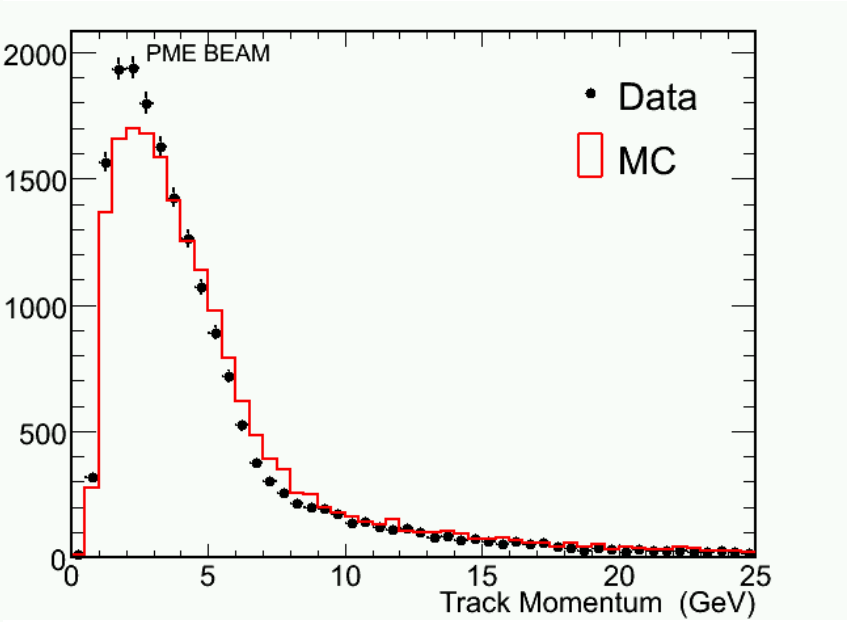


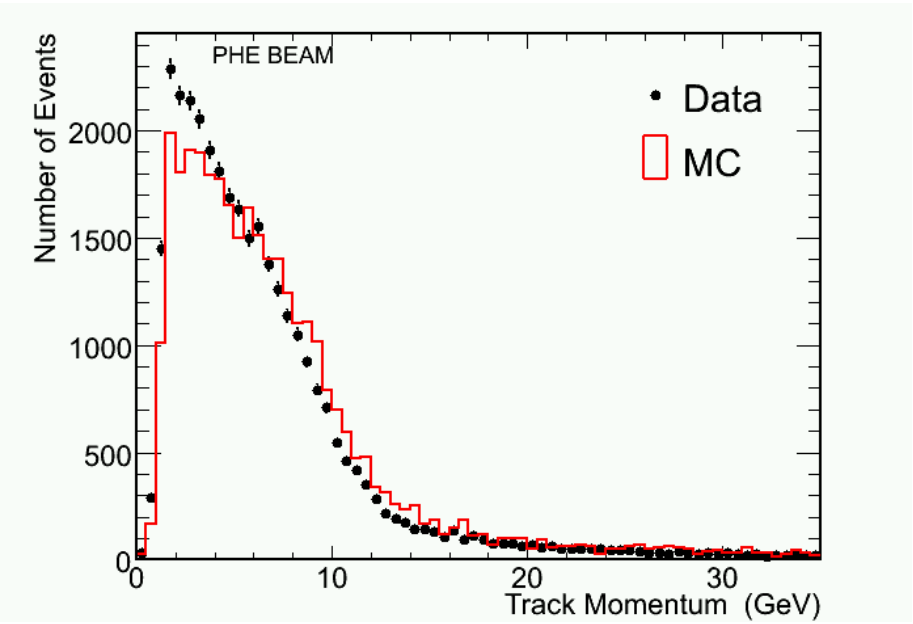
Shower energy in data lower than MC. Shower energy calculation has problems so need to check again when problems fixed.

Niki

Muon Momenta : CC-like events LE-10 PME PHE



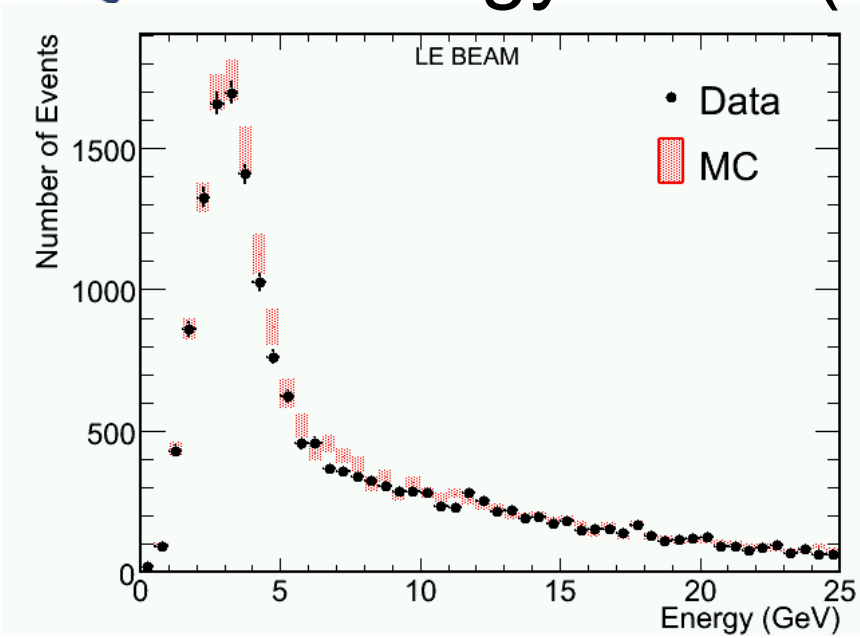


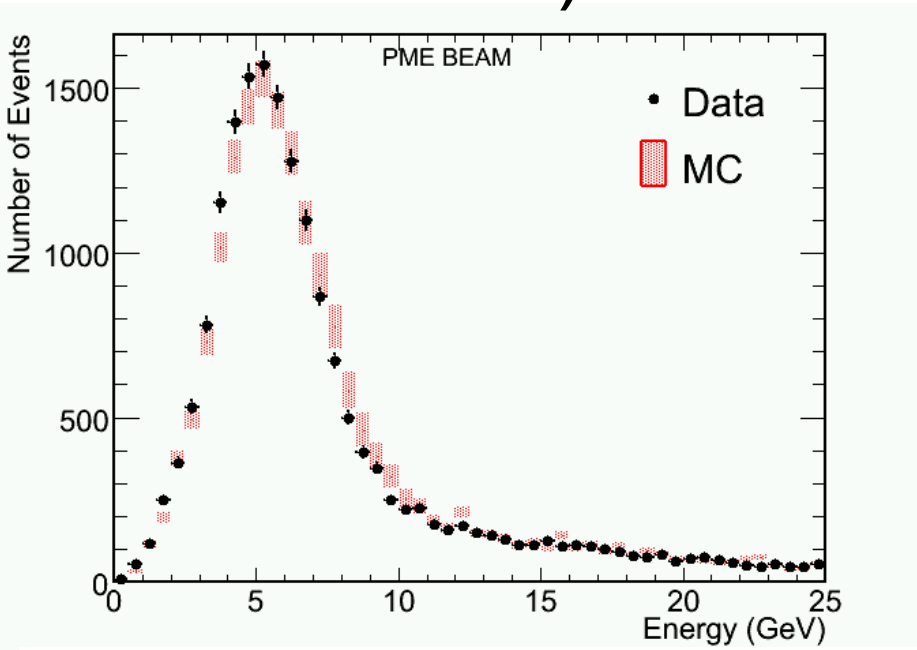


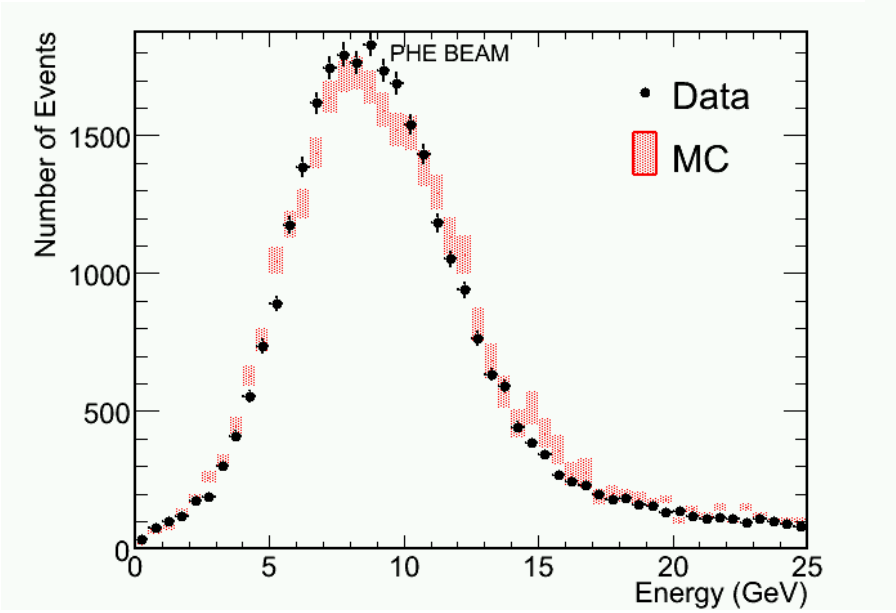
Muon momenta in data lower than MC for PME and PHE effect not clearly seen in LE.

Niki

Energy Scan (CC-Like Events)





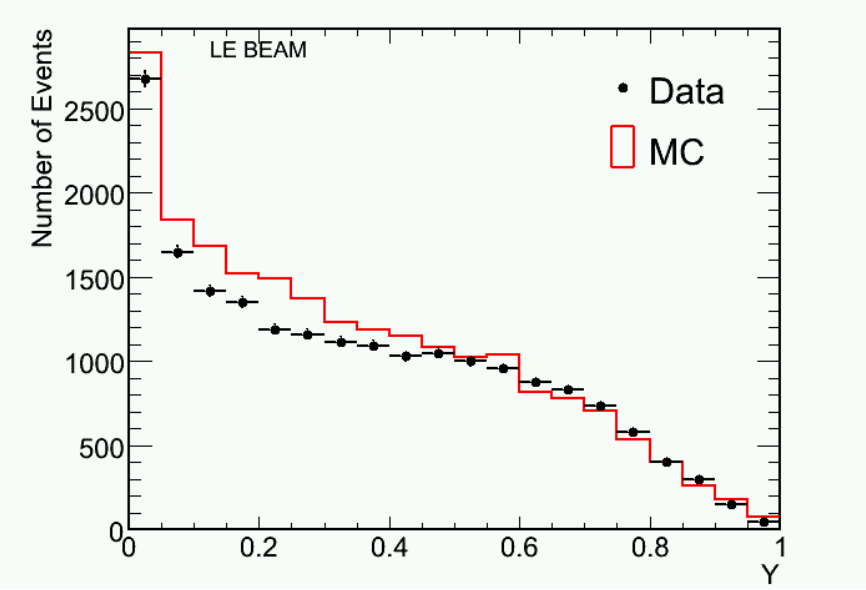


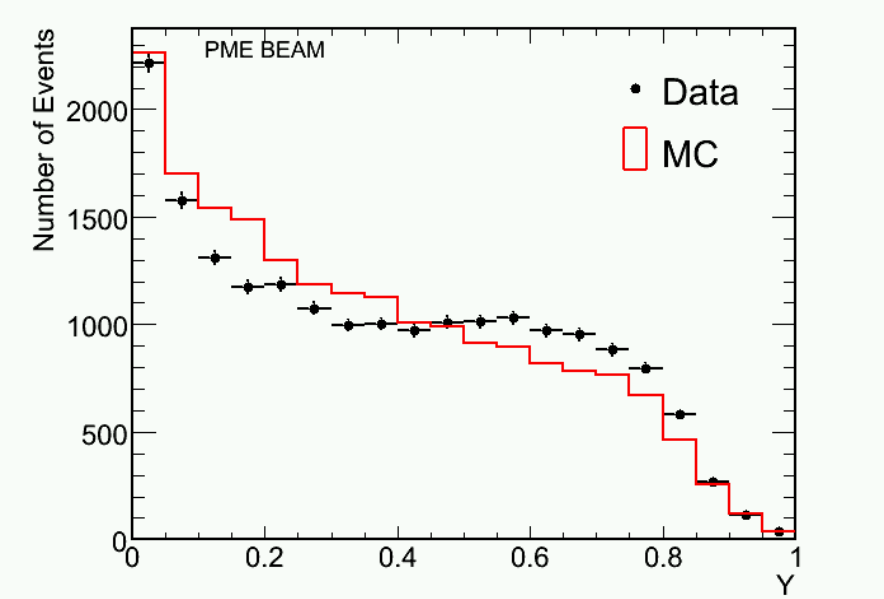
Energy in Data is shifted with respect to MC.

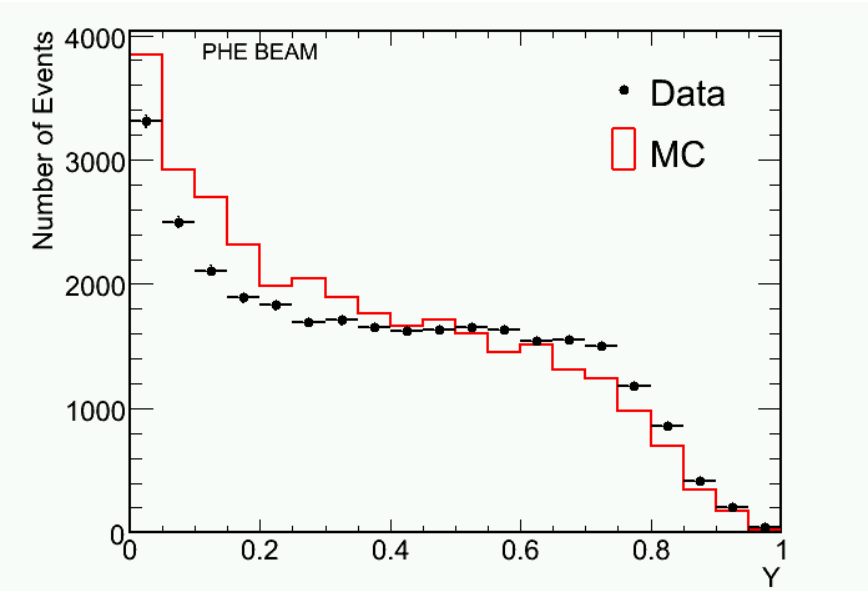
So, the problem is still there.

Niki

Y distribution : CC-like events LE-10 PME PHE



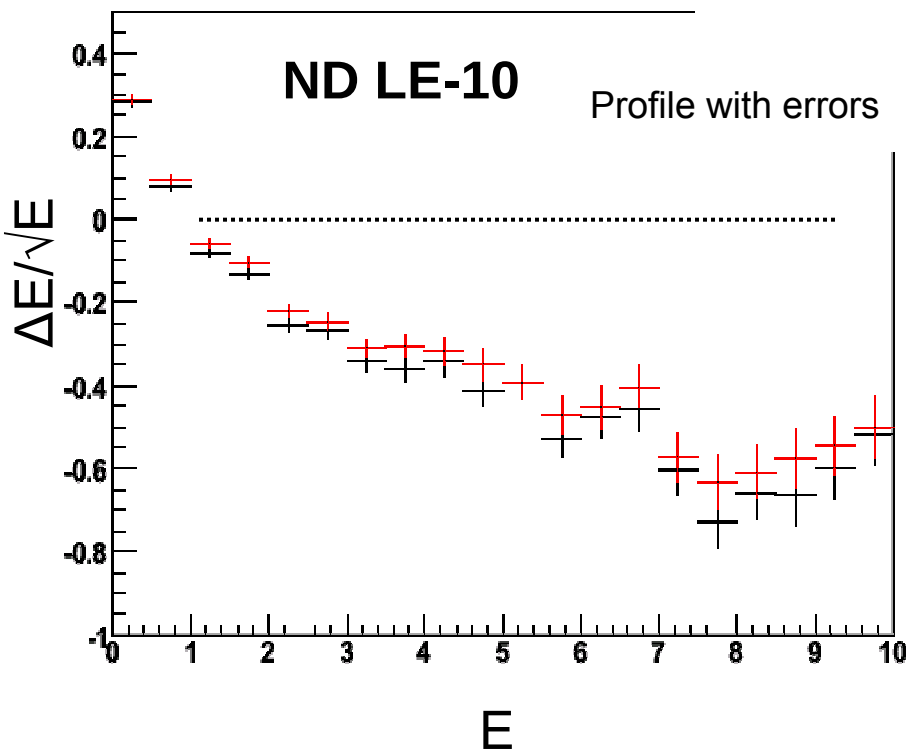


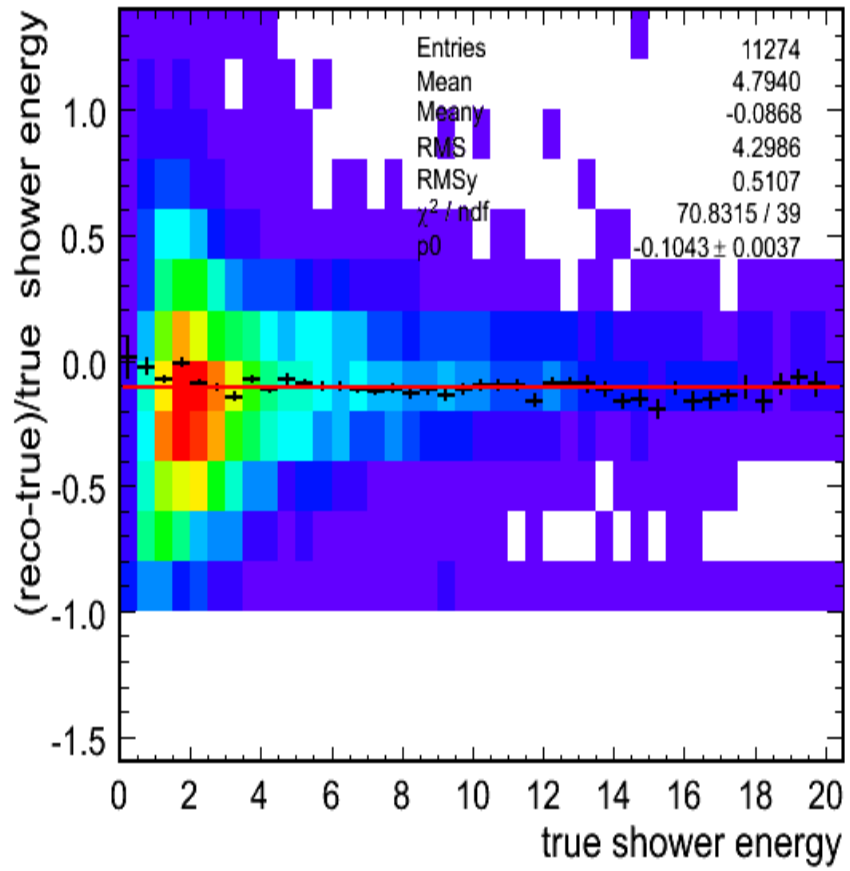


Y distributions don't agree .

Niki

Reco'd Shower Energy vs Truth





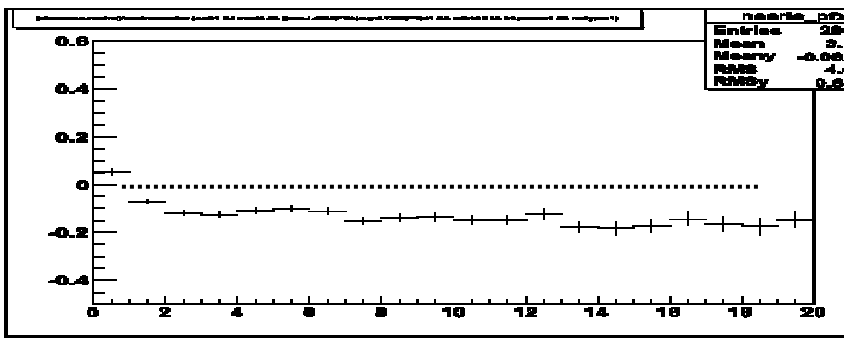
Niki – ND & FD different

Mike

Reco'd Shower Energy vs Truth

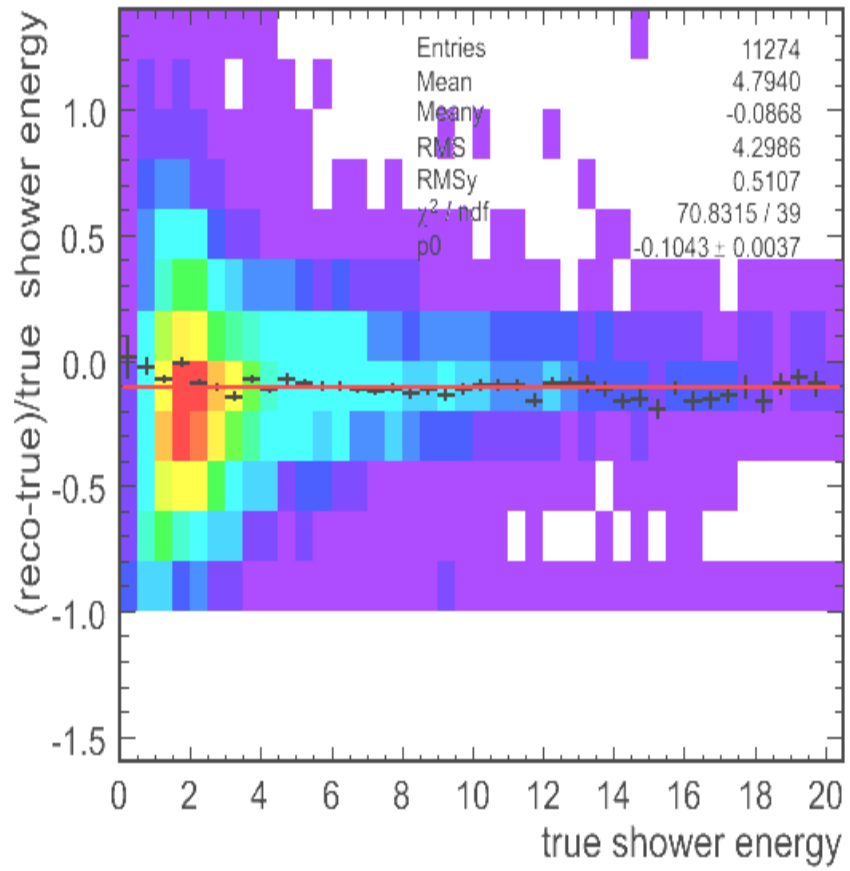
Profile with errors

ΔE/E



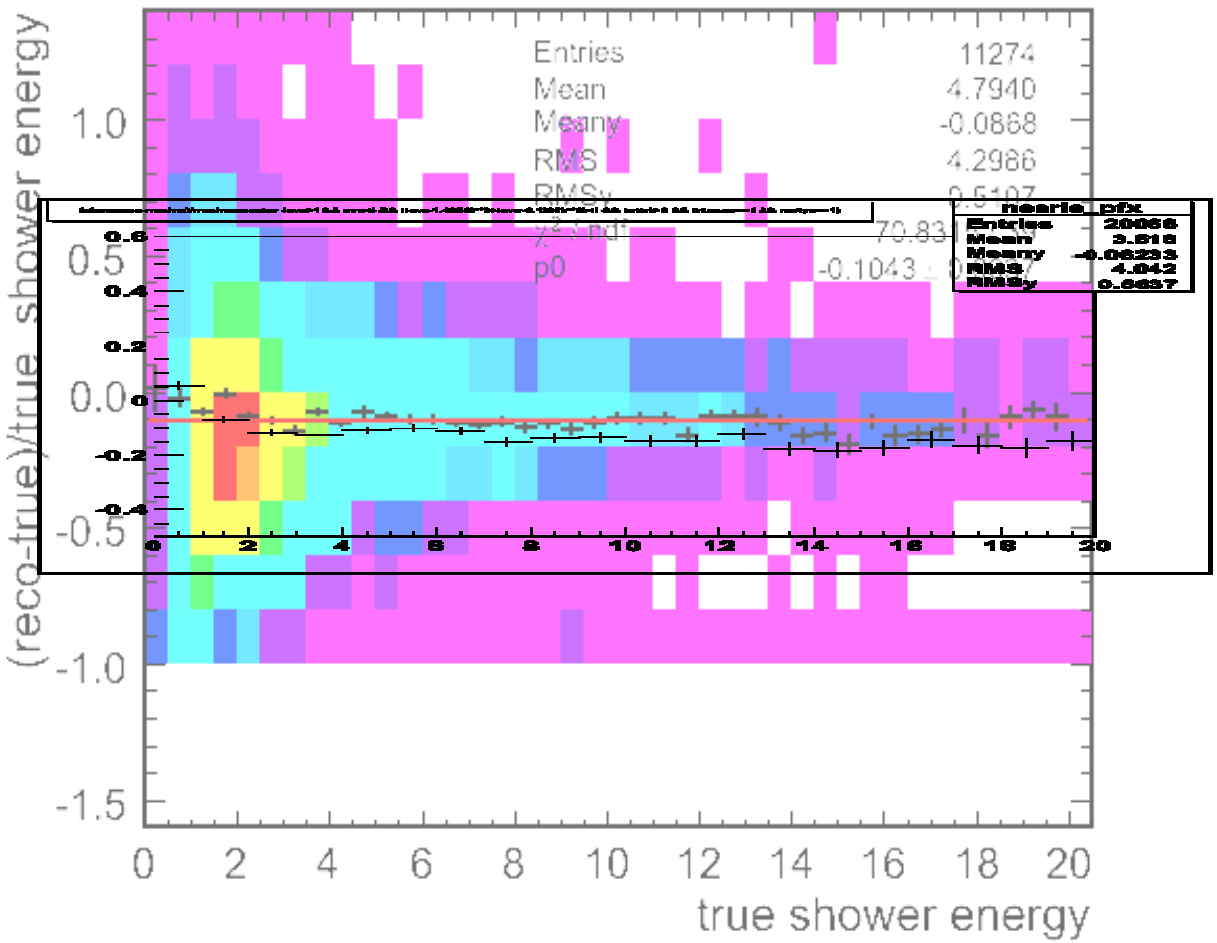
E

Niki



Mike

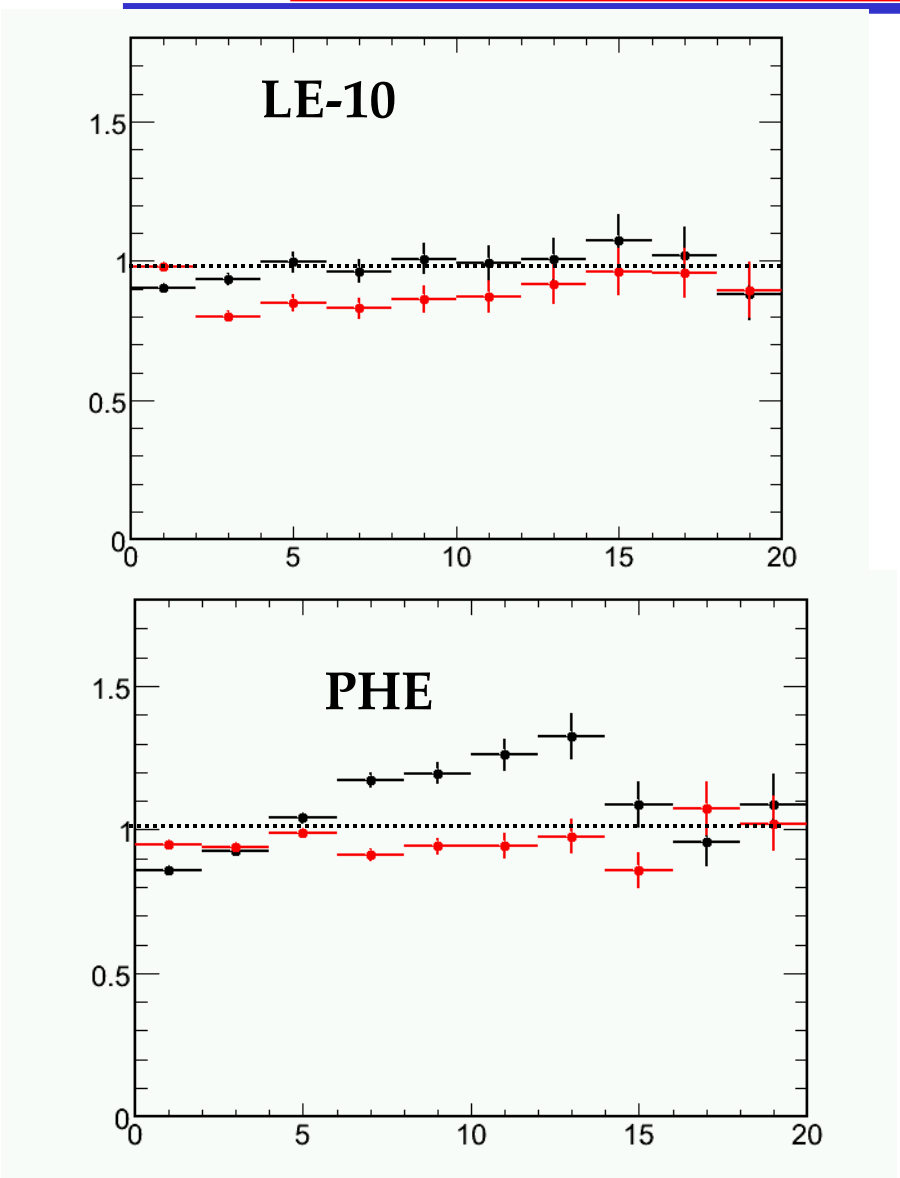
Reco'd Shower Energy vs Truth

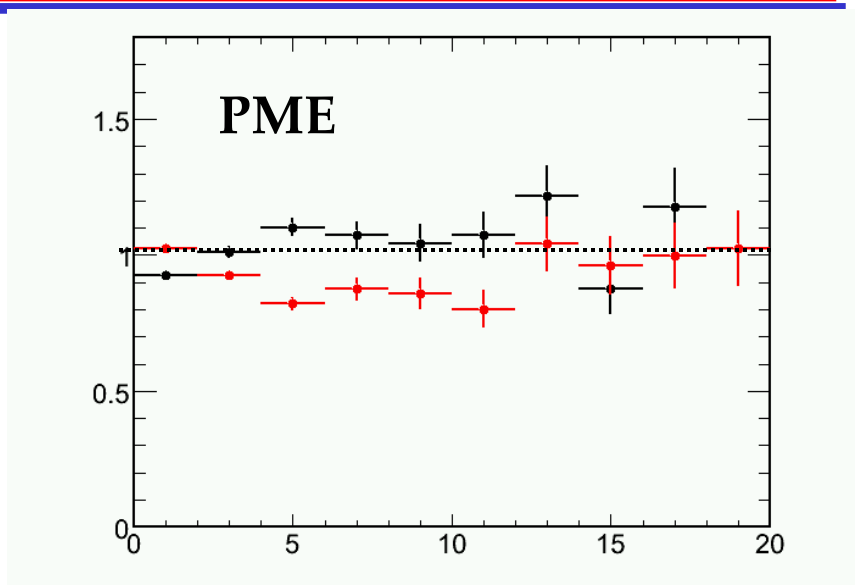


Not so different

Shower energy Ratios DATA/MC before – after cleaning

BLACK : AFTER CLEANING RED : BEFORE CLEANING

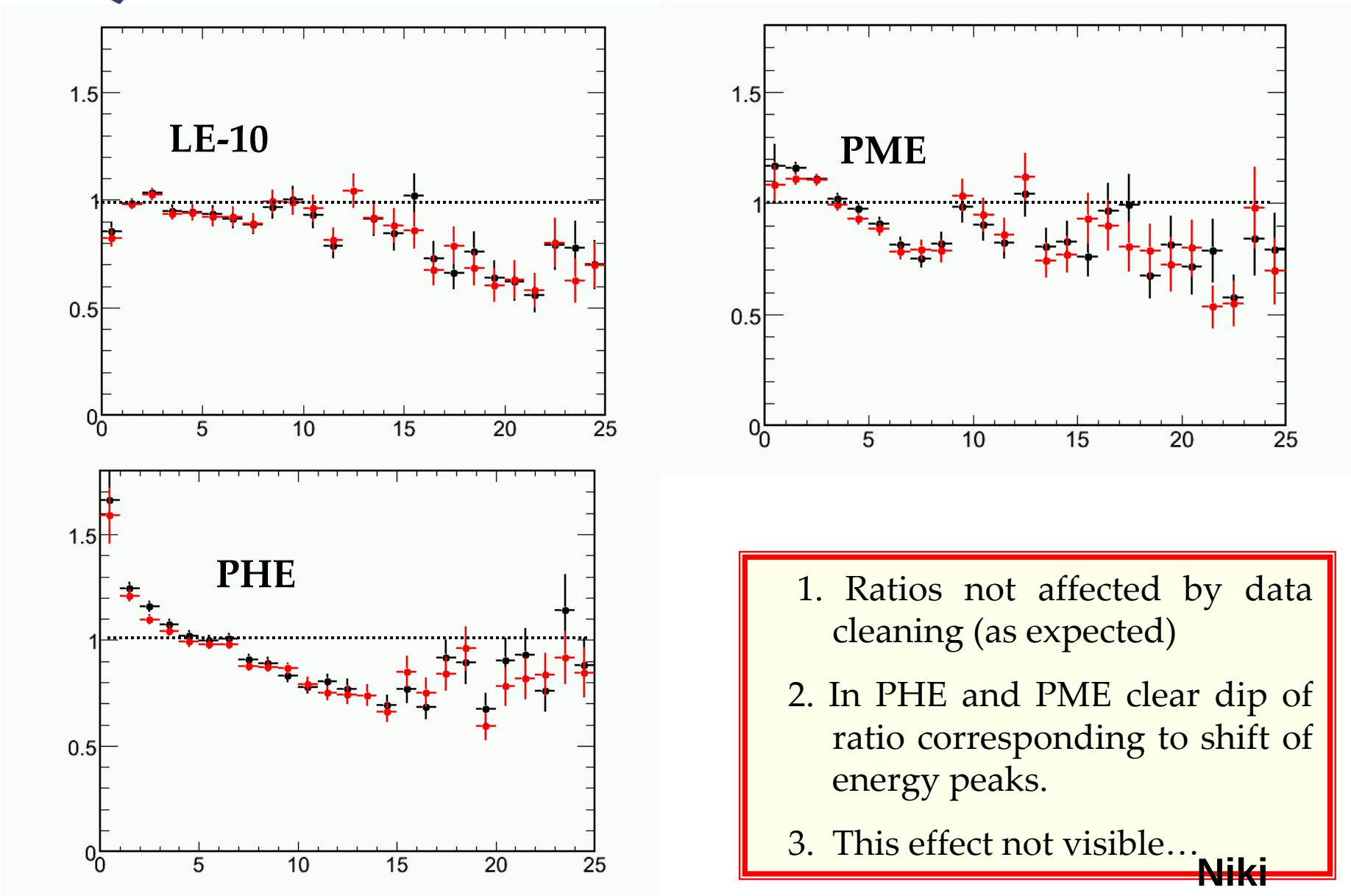




1. Shower energy reconstruction does change depending on whether low ph noise is removed or not
2. Shower energy increases as we remove low ph hits.

Niki

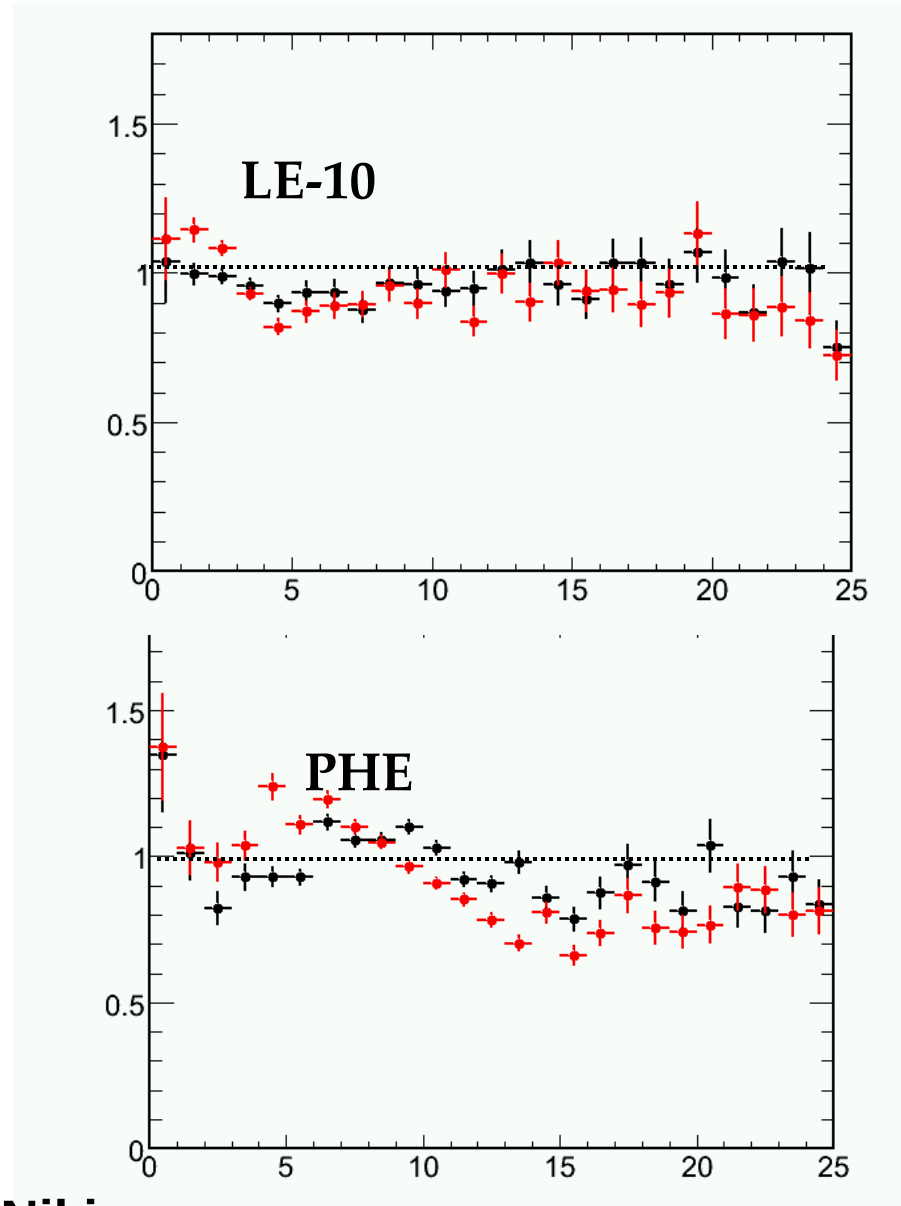
Muon Momenta Ratios DATA/MC before – after cleaning

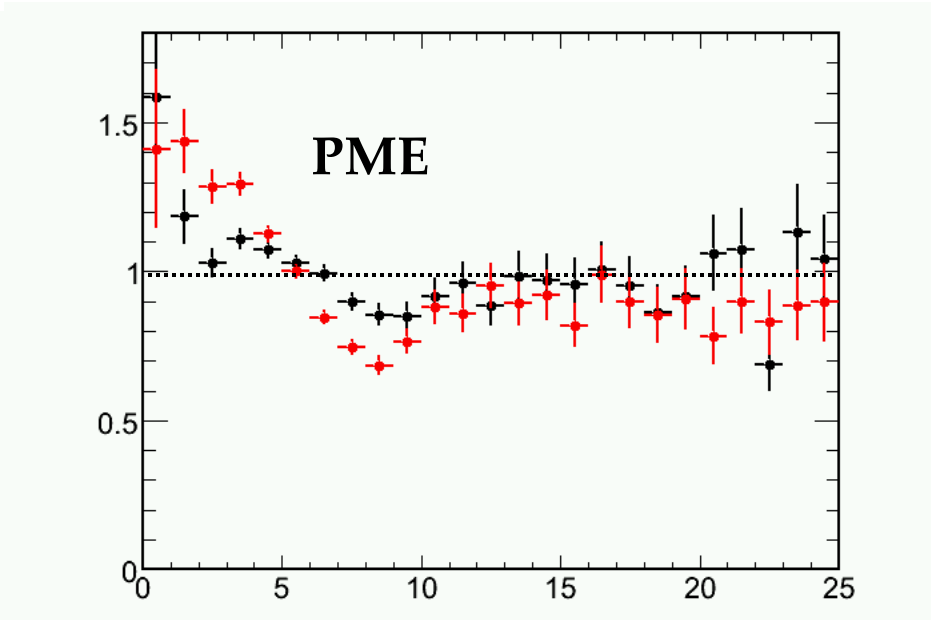


1. Ratios not affected by data cleaning (as expected)
2. In PHE and PME clear dip of ratio corresponding to shift of energy peaks.
3. This effect not visible…

Niki

Energy Ratios DATA/MC before – after cleaning

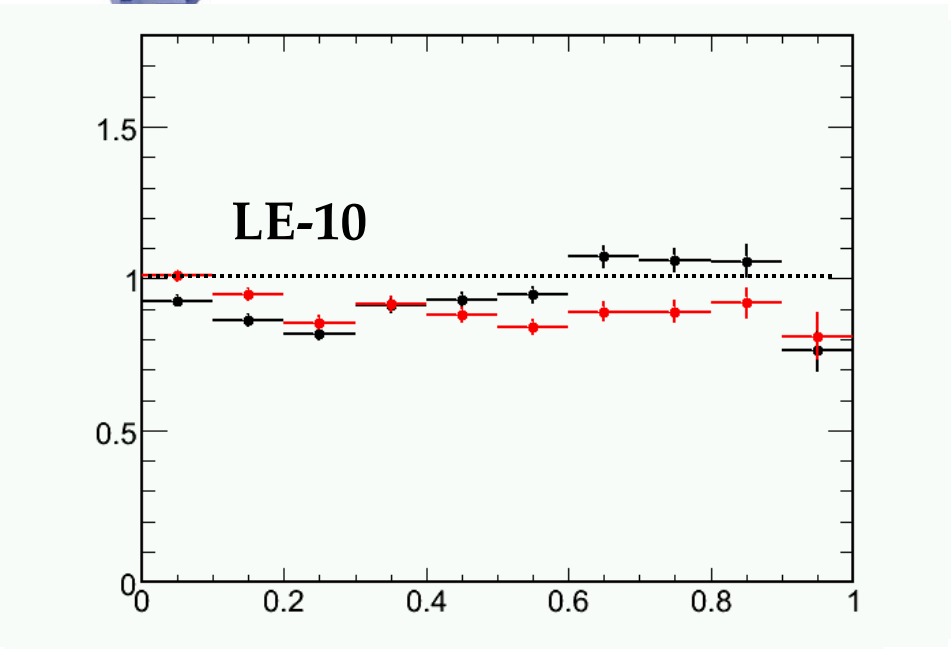


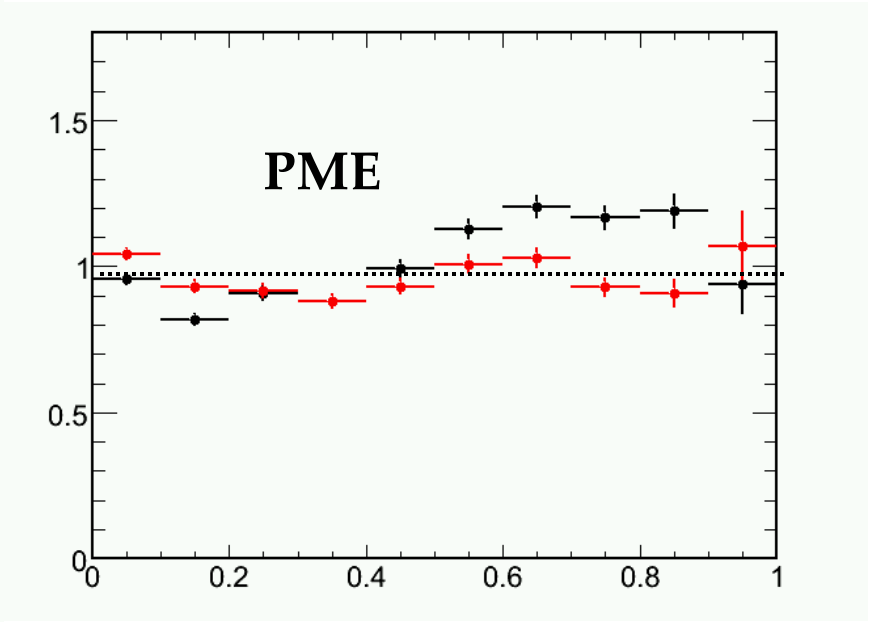


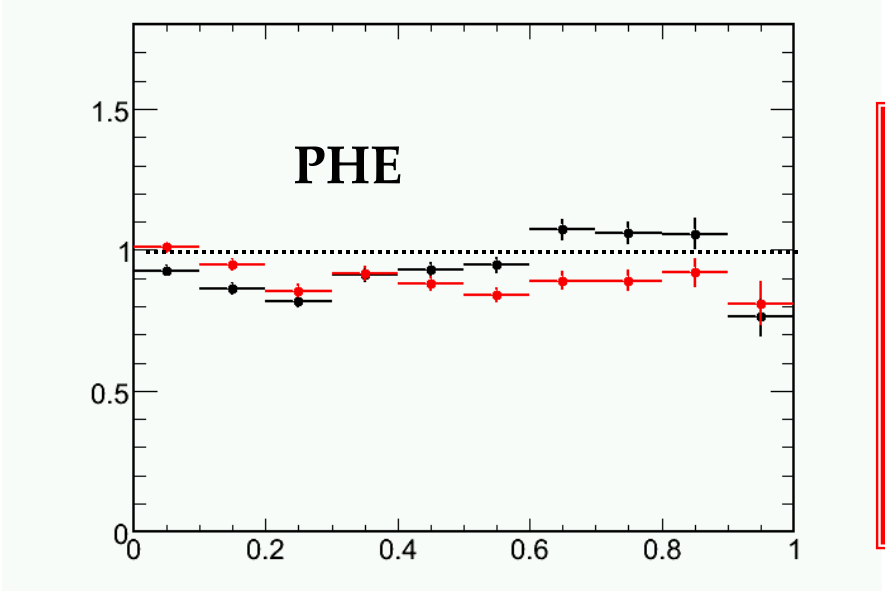
1. Ratios not affected by data cleaning (as expected)
2. In PLE , PHE and PME clear dip of ratio corresponding to shift of energy peaks.
3. Dip becomes less pronounce after "low ph cleaning"
4 . Dip moves with energy so most likely not cross-section…

Niki

Y Ratios DATA/MC before – after cleaning







1. Ratios do get affected by low ph noise removal which affects shower formation especially
2. The trend is very similar for all three energies.

Niki

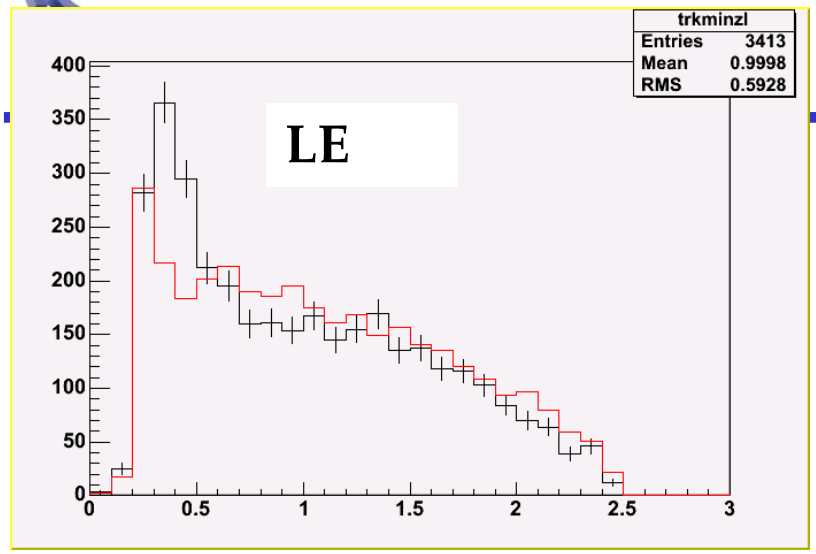
Conclusions - Plans

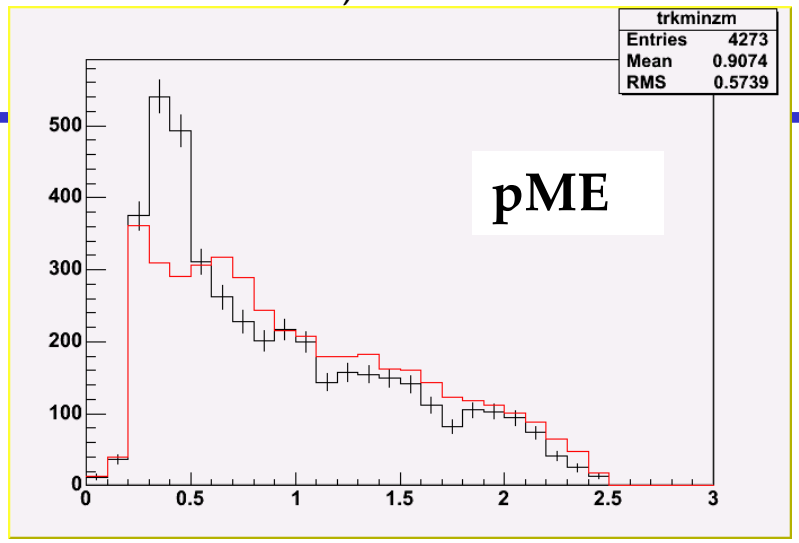
- Differences in muon momenta, shower energies and neutrino energy still there for NEW MCs and R1.18 (effect reduced)
- Removing Low ph activity does not change muon momenta estimation (or track formation) but does change shower energy estimation in CC events.
- This also affects total neutrino energy estimation and Y distributions.
- Y distributions in energy slices do not look dramatically different for LE, PME and PHE which indicates that differences in energy of data and MC are not related with increasing detector activity due to higher energies.

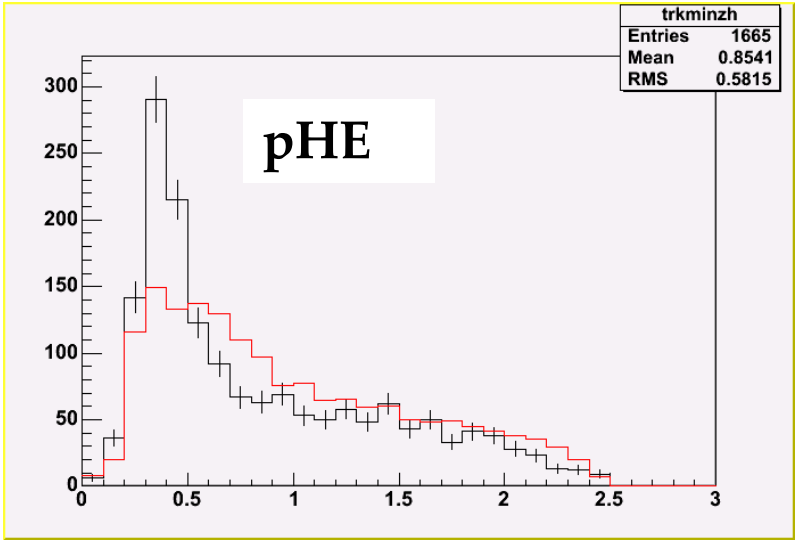
Niki

Tracks Proximity to Coil hole for contained interactions

Red MC , Black Data







- The difference in “closest hit distance to coil hole” is dramatic
- The proximity to the coil would agree with lower track momenta in data.

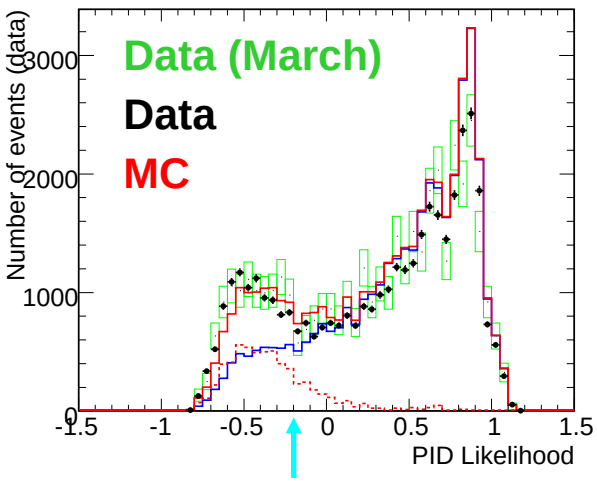
Niki

Masaki

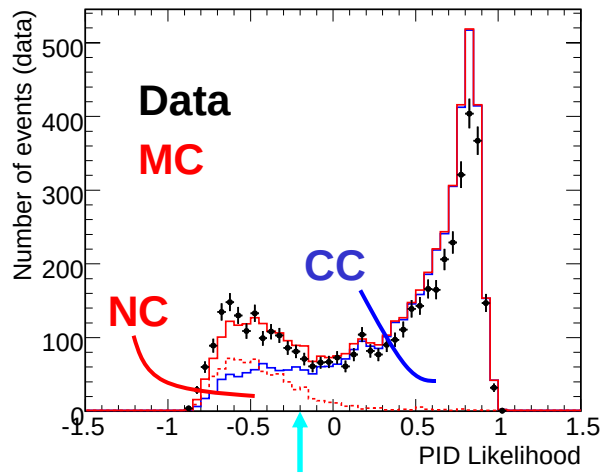
Select CC enriched sample (using David's PID variables)

R1.18

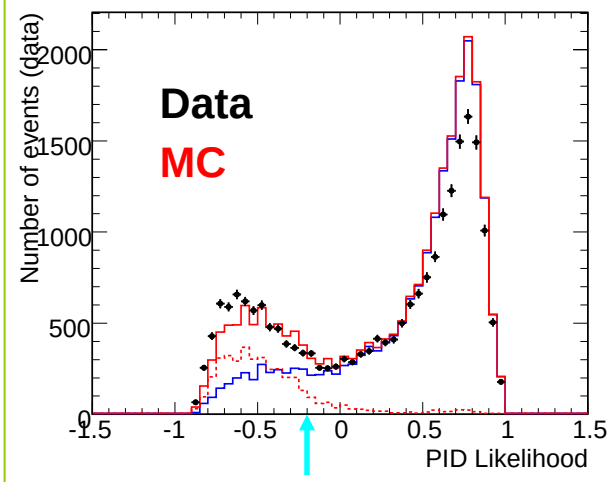
LE

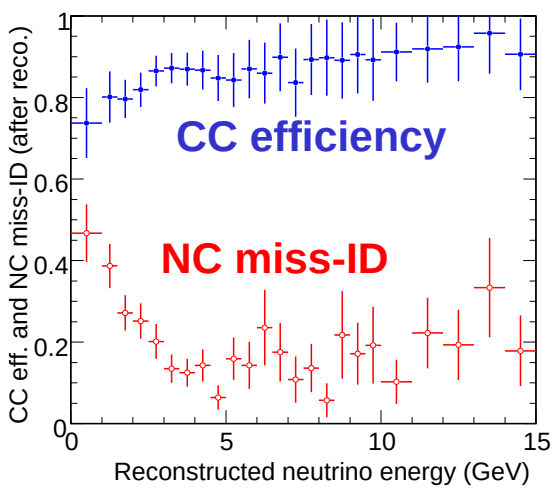


pME



pHE





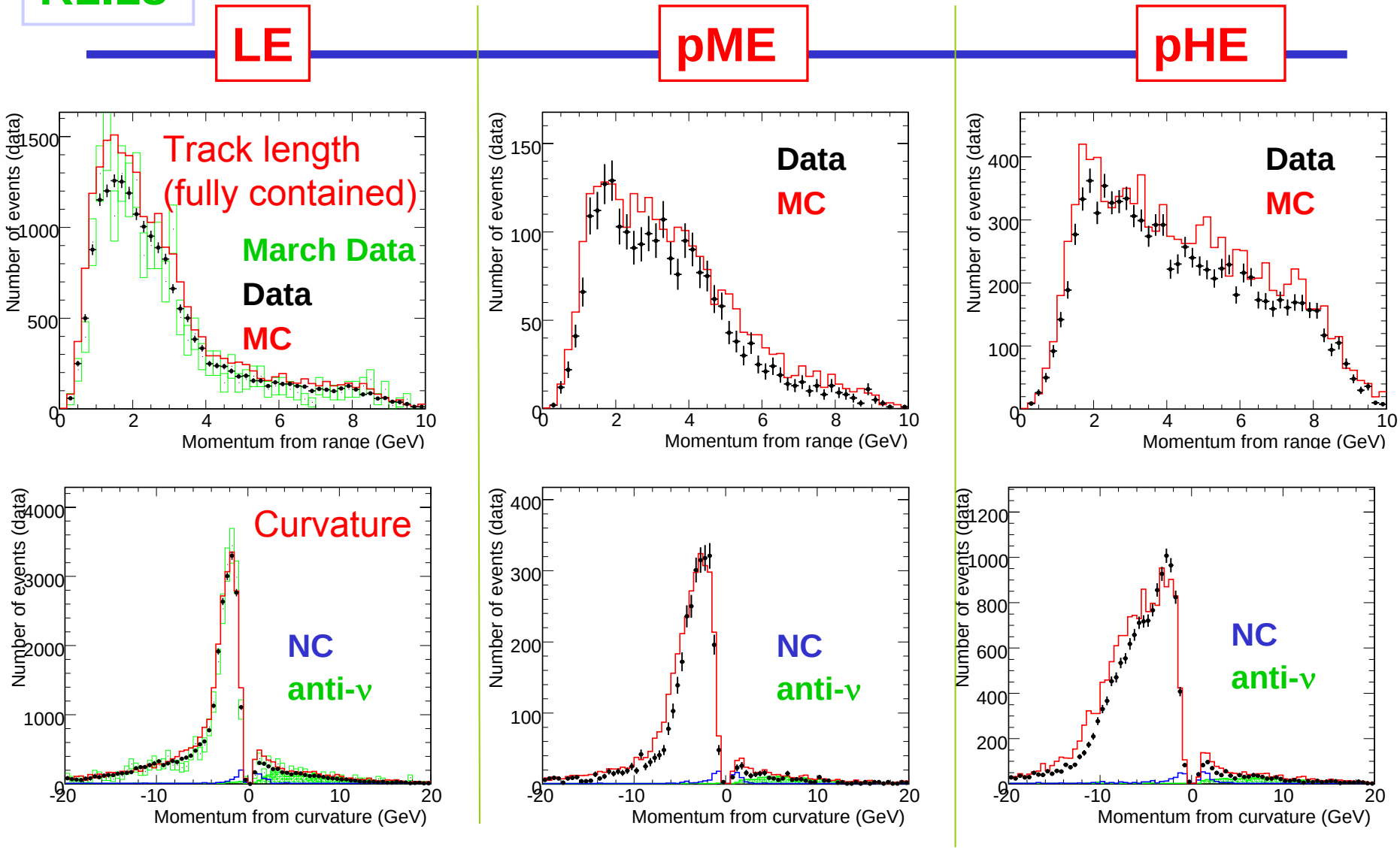
#events/10^{17}POT before and after PID cut (CC fraction %)

LE data (March)	511.1+/-11.0	→ 384.3+/-9.5
LE data	486.7+/-2.4	→ 365.6+/-2.1 -9.3%
LE MC	537.1+/-4.4(86.3%)	→ 423.9+/-3.9(95.8)
pME data	911.8+/-13.3	→ 655.3+/-11.3 -16.1%
pME MC	1022.7+/-8.6 (85.0)	→ 781.1+/-7.5 (96.4)
pHE data	1395.8+/-9.4	→ 988.7+/-7.9 -14.2%
pHE MC	1521.8+/-12.5 (83.9)	→ 1151.8+/-10.9 (96.8)

Masaki

Track momentum

R1.18

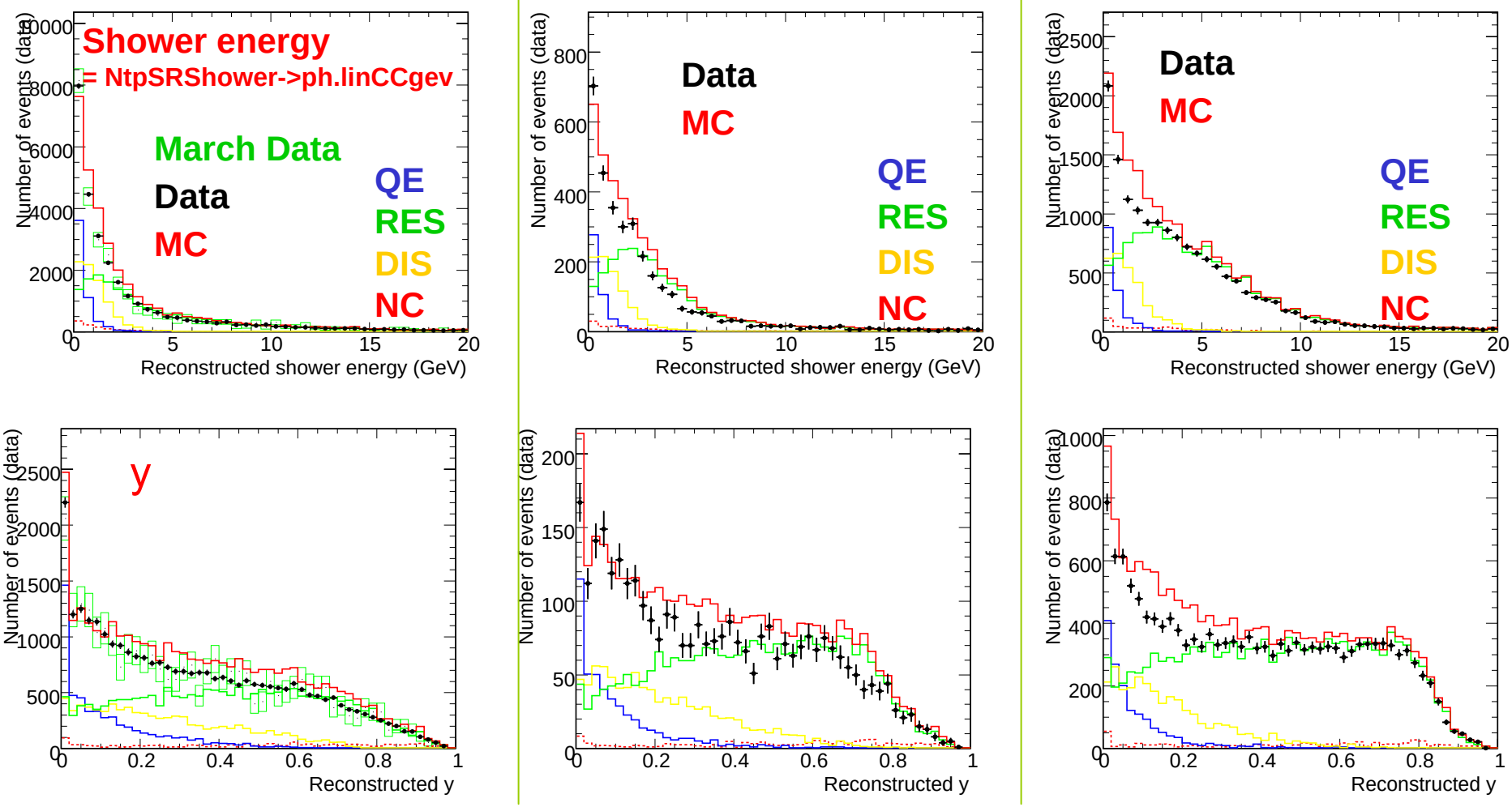


Masaki

Reconstructed shower energy and y

R1.18

LE | pME | pHE

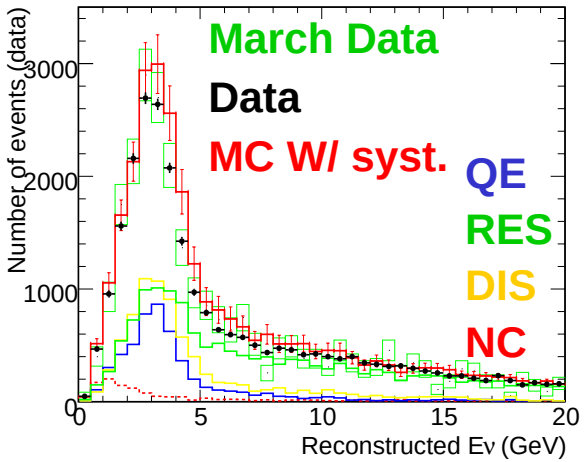


Masaki

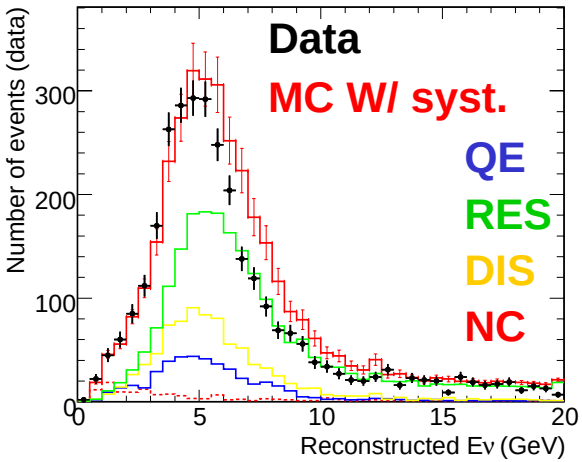
Reconstructed Eν (= Eμ + Eshw)

R1.18

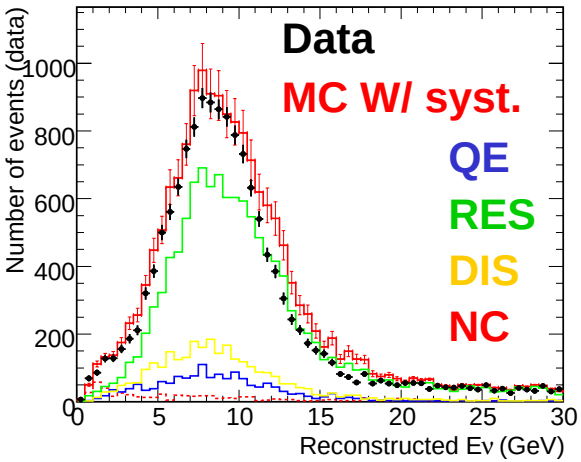
LE

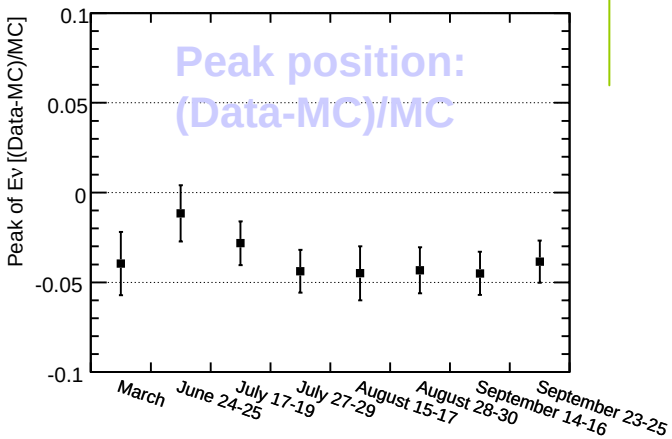


pME



pHE



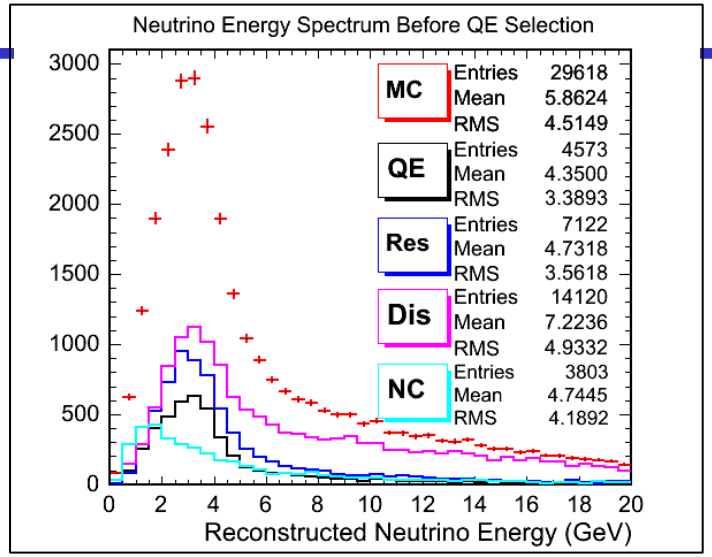


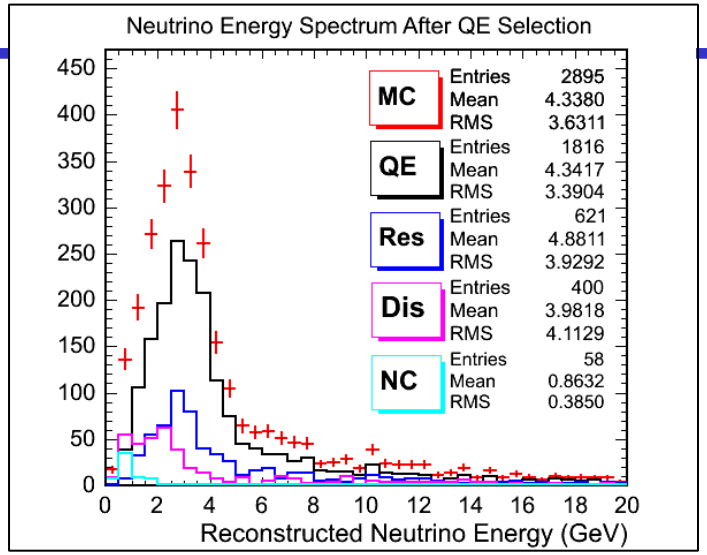
✓ Better agreement than Ely plots W/ nuclear effect (pME and pHE)

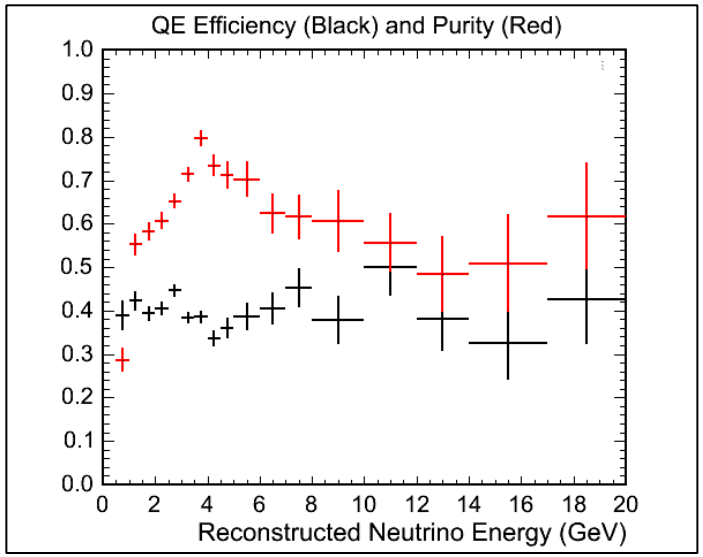
✓ ~1 GeV shift still exist → better agreement W/ de-weighted shower energy

Mark

Efficiencies and Purities of QE-like Sample





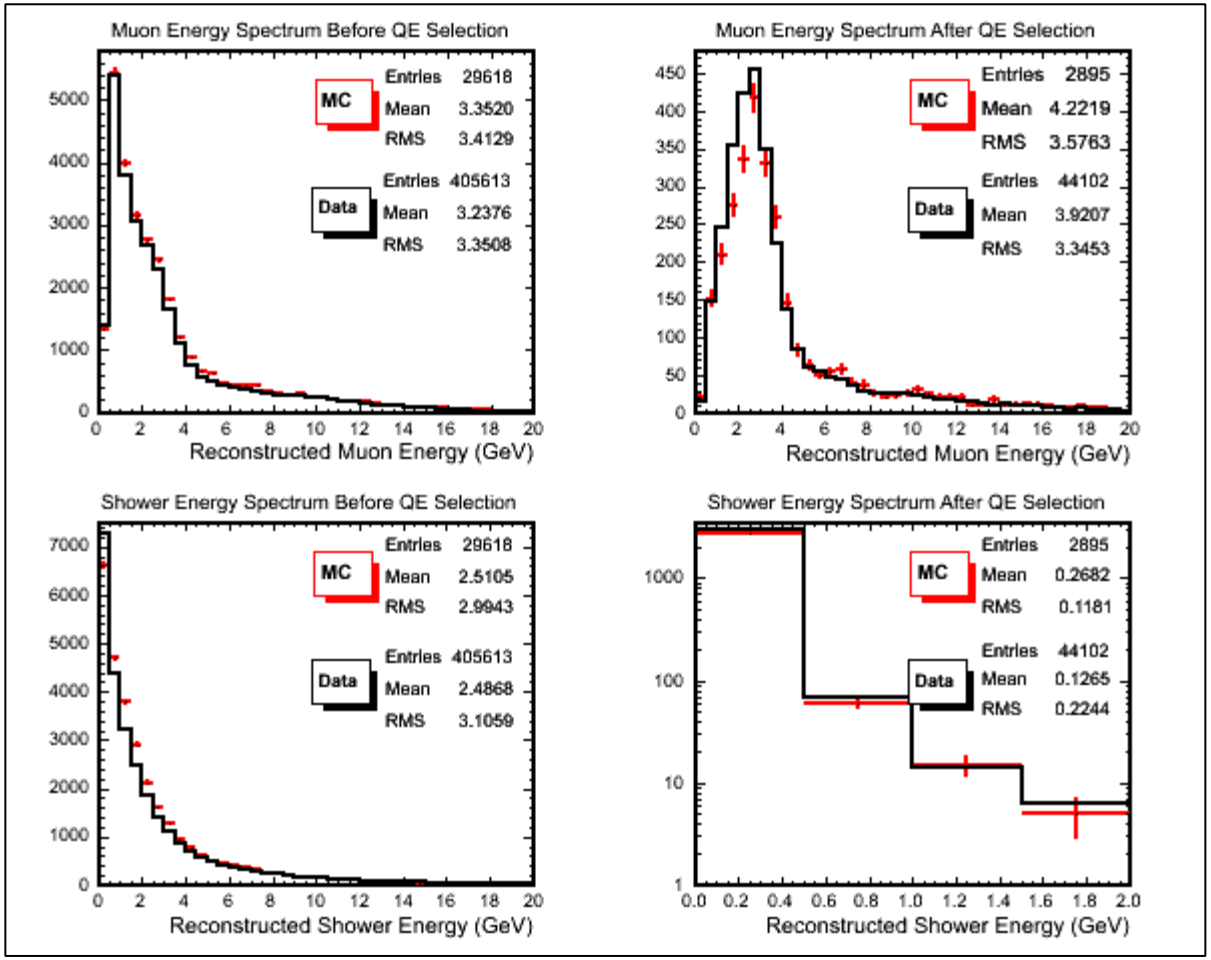


Selection removes:

- ~60% QE events
- ~91% RES events
- ~97% DIS events
- ~98% NC events

Data/MC Comparisons – Other Energy Spectra

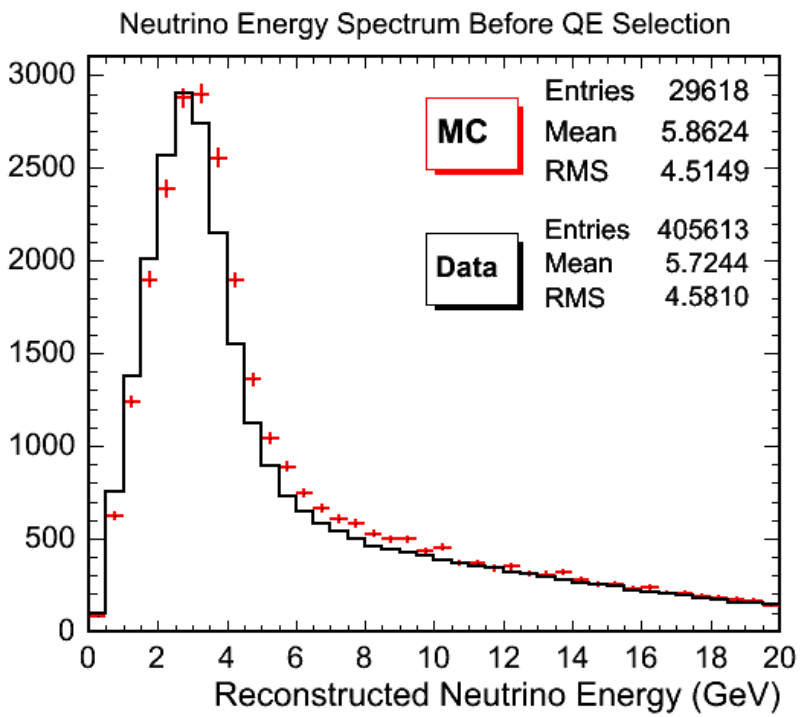
Mark



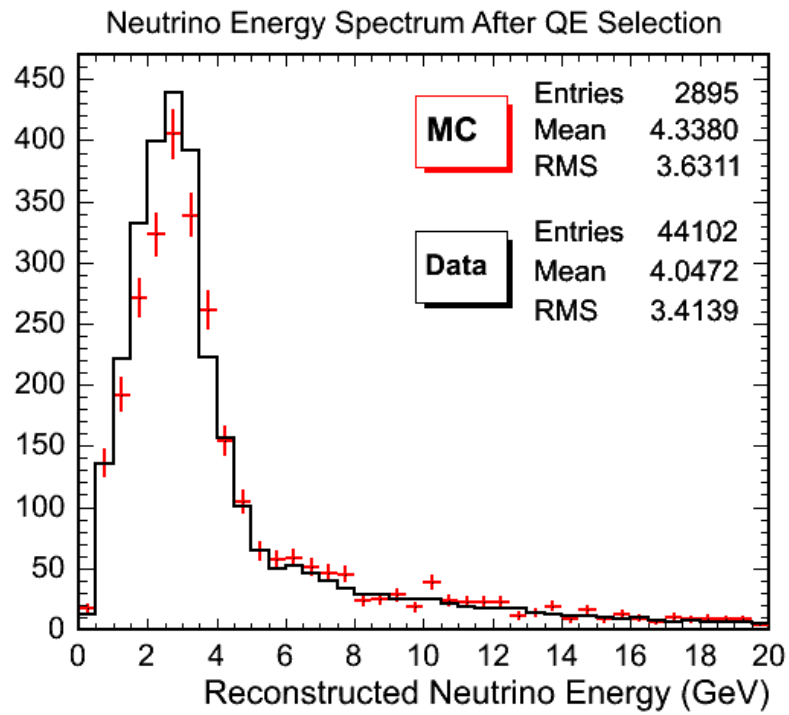
- Shift still visible in muon and shower energies.

Mark

Data/MC Comparisons – Neutrino Energy Spectra



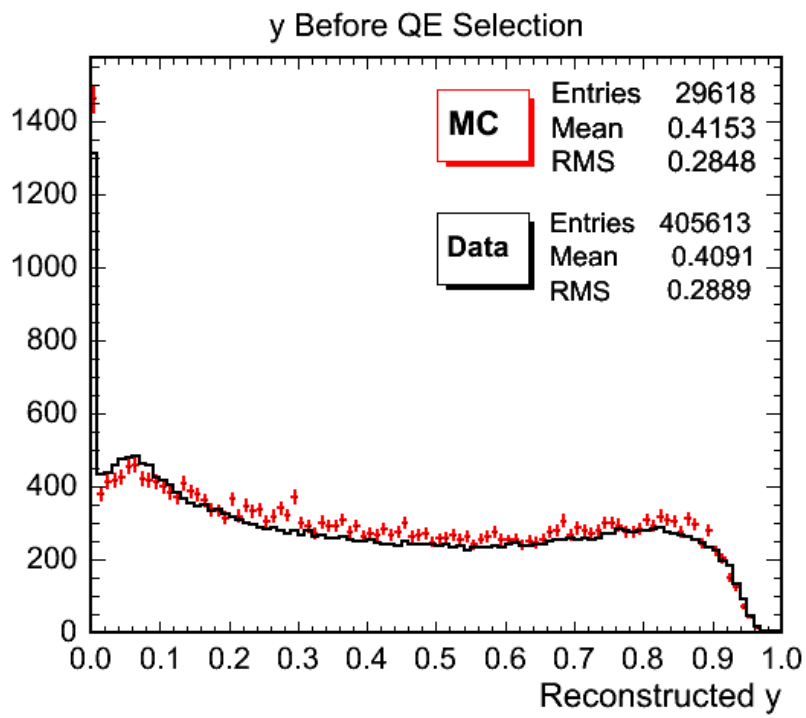
MC is shifted to the right relative to data



Agreement good, though

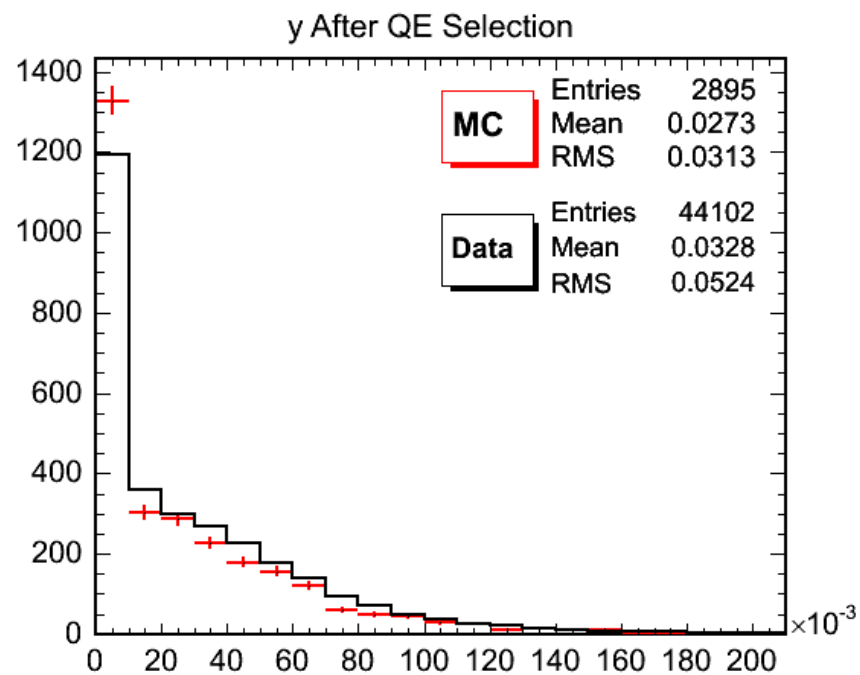
Mark

Data/MC Comparisons – y Distributions



- Slight excess of y=0 events in MC.

- Again the agreement is fairly good.



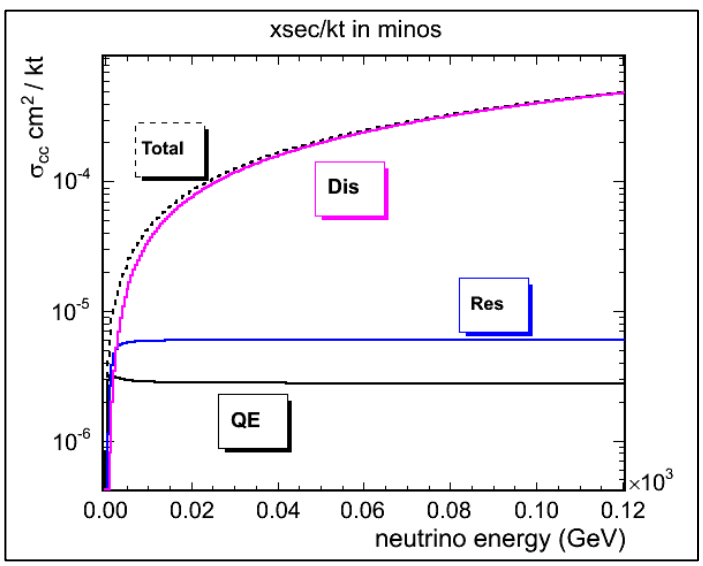
Mark

Flux Estimation Methodology

- For a given energy bin i:

number of QE-like events = flux * (QE xsec*QE efficiency + BG xsec*BG efficiency)

From Neugen:



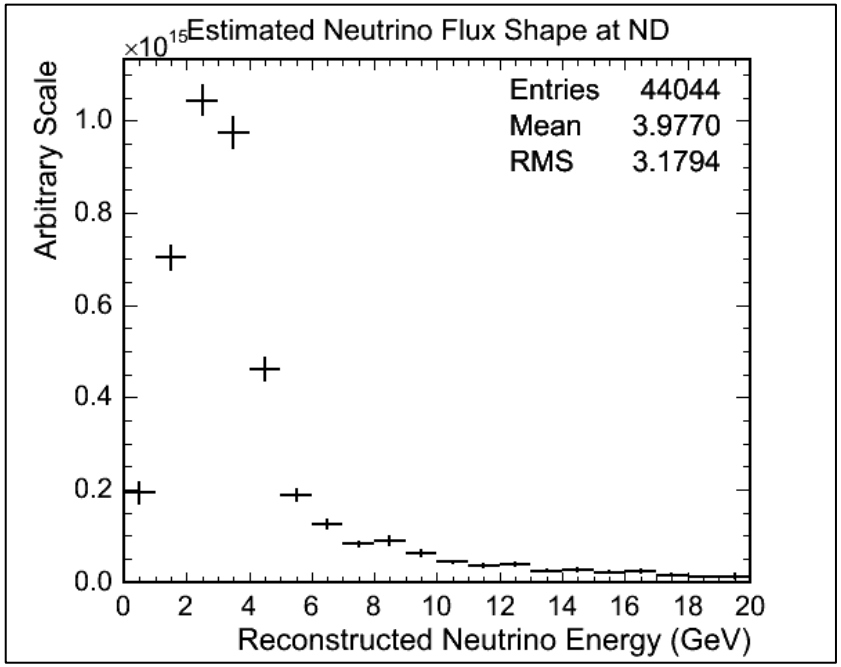
= RES xsec*RES efficiency
+ DIS xsec*DIS efficiency
~~+ NC xsec*NC efficiency~~

- Get efficiencies from MC.
- Can't use NC xsec so use MC to estimate number of NC background events and subtract off.

Mark

Flux Estimate

- The following is then an estimate of the shape of the flux:



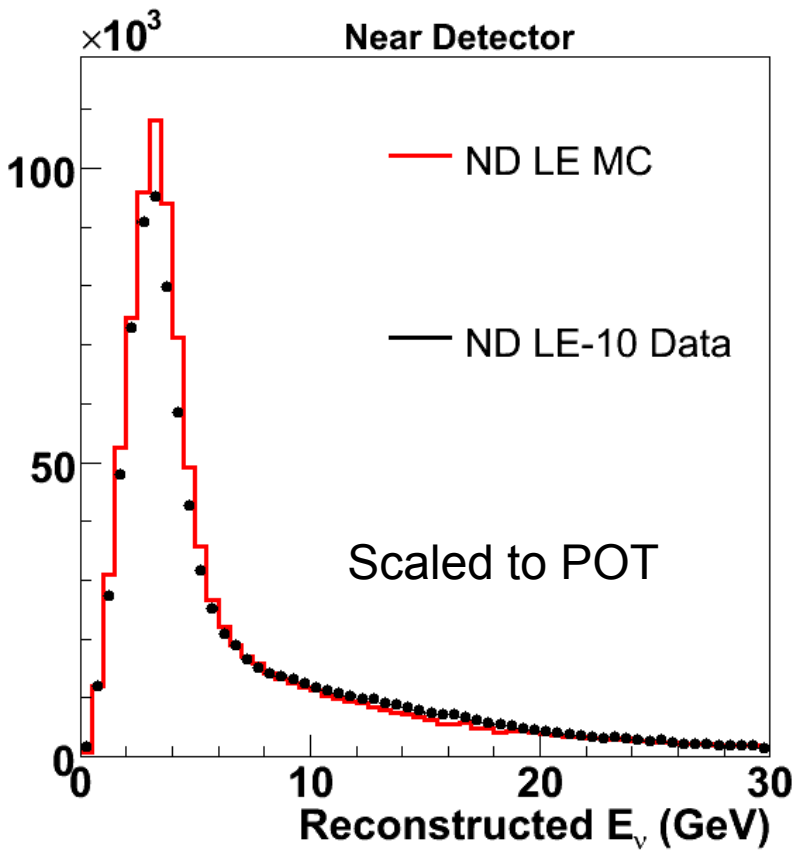
- Next want to normalize to a MC flux based on the total cross section in the 10-20 GeV region to put an absolute scale on this plot.

Further Work

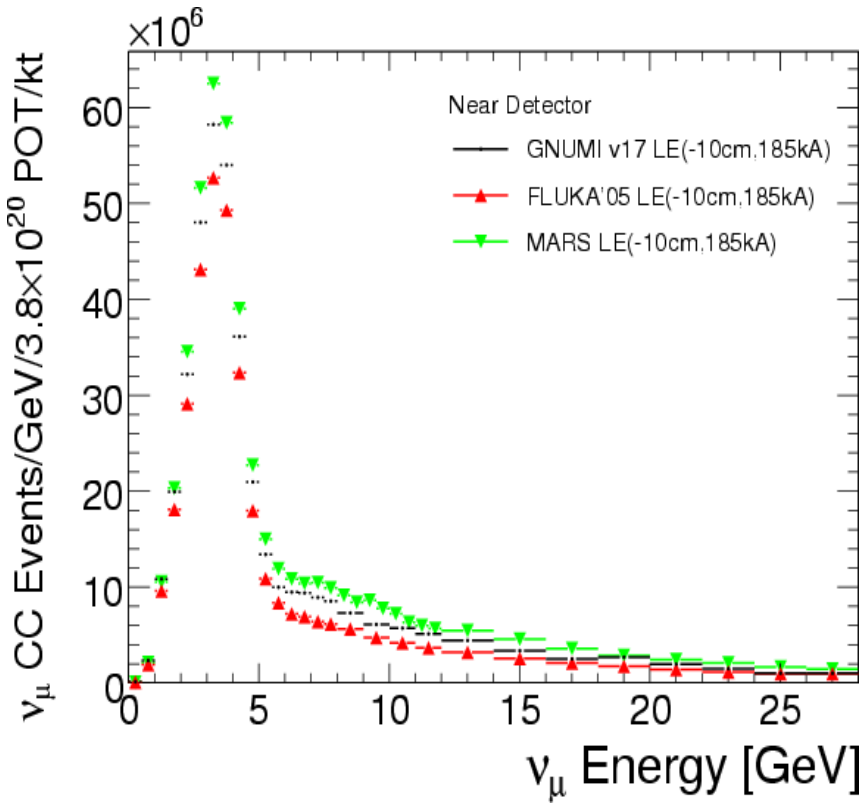
- There are some issues that need to be resolved...
- Am going to normalize my flux to a Gnumi flux that was produced using true neutrino energies and so must take account of events moving into different reconstructed neutrino energy bins (energy resolution for my events ~20%).
- Cannot completely decouple the NC background subtraction from the flux itself and this causes problems in the low energy bins where the NC events occupy a larger fraction of the total events in the sample. Need to redo the analysis with a harder cut to get the QE purity up and the background contributions down.
- Need more LE-10 MC to reduce the errors that come from estimating my QE, RES and DIS efficiencies/inefficiencies.

ND Spectrum

- The current data & MC



- The future
  - > Difference is a guess at systematic
  - > Real errors = more work
  - > MIPP in a while



Masaki

Measurement of neutrino spectrum and y by the ND data

- motivation

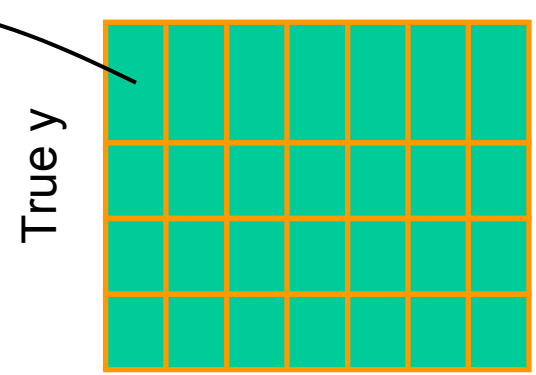
$$N = \int \Phi(E_\nu) \cdot \sigma(E_\nu) \cdot \varepsilon(E_\nu) \cdot M dE_\nu$$

Flux, cross-section, efficiency, Fiducial mass

Parameters → measure by the ND data

- procedure

$$\chi^2 = \frac{(N_{Data} - (1 + \sum f_i^j) N_{MC})^2}{\sigma_{Data}^2 + \sigma_{MC}^2} \left(+ \frac{\varepsilon^2}{\sigma^2} \right)$$



δEμ (10%) and δEshw (10%) are also considered in fit

Masaki

Data and bin in this analysis

Data 2.20x10^{18}pot

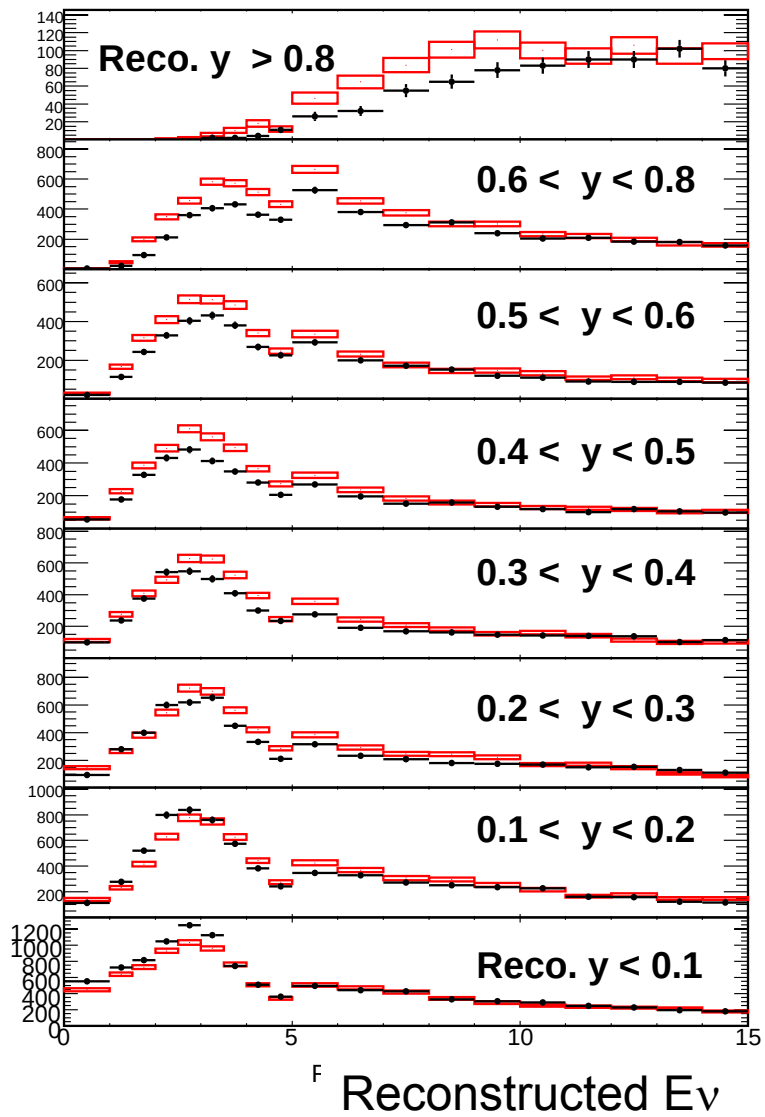
MC 2.80x10^{18}pot

- ✓ Beam quality cut
- ✓ W/ reconstructed track
- ✓ R<1m & 1<z<5 m
- ✓ DP's PID > -0.2

Data: black

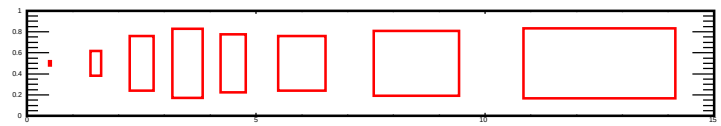
MC: red (normalized by POT)

χ^2 = 919.2/152d.o.f.



MC parameters bin and profile

NC (8)

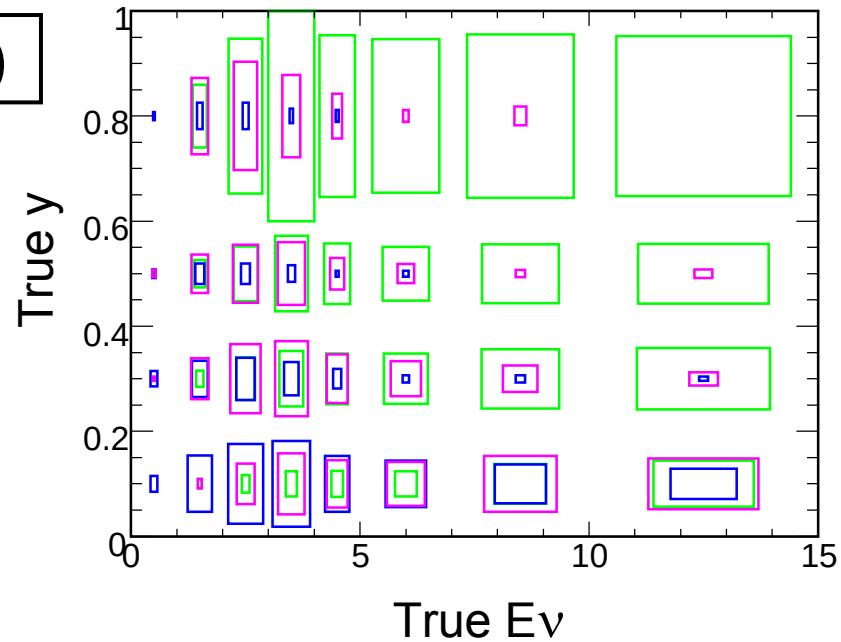


CC (8x4)

QE

RES

DIS



Masaki

Result of fit (1-σ=20% for all parameters)

Data: black

MC: red (normalized by POT)

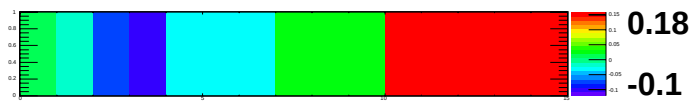
Best fit: blue

χ^2 = 136.6/152d.o.f.

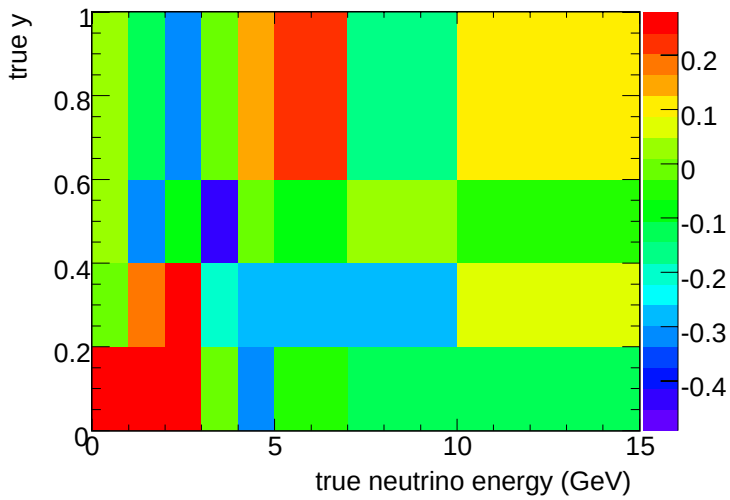
Best-fit parameters

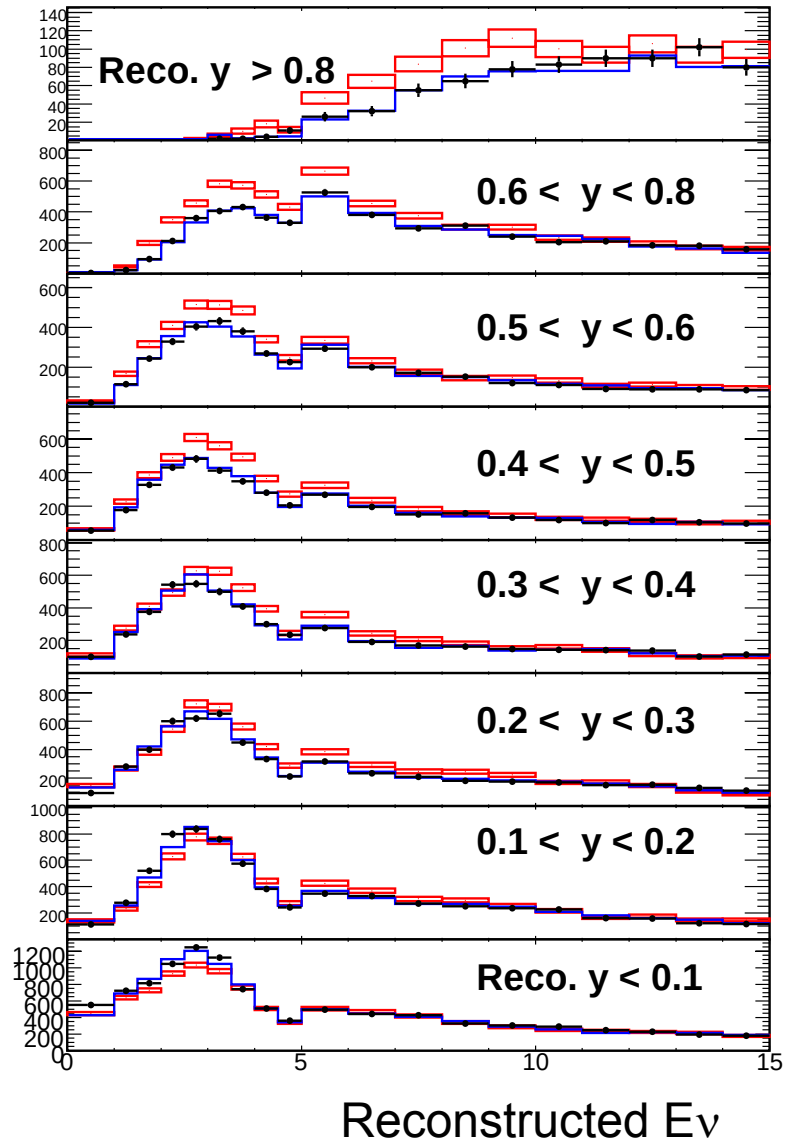
$\delta E\mu$=+5%, δEshw=-13%

NC



CC

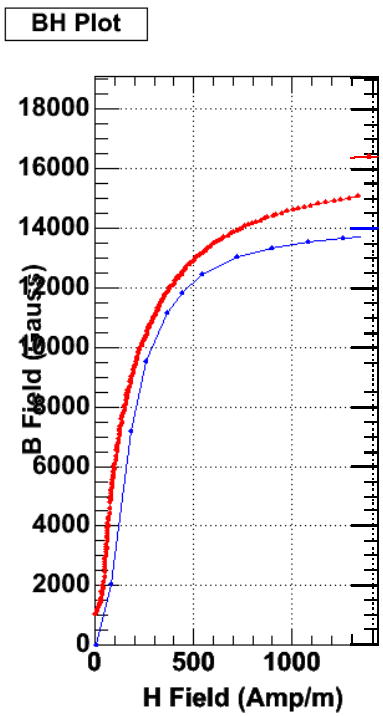




Reconstructed Eν

Tracking improvements

- New version for processing soon
- Full 3D models done for end effects in both detectors
  - > 12 planes into each torus
- New B-H coming
  - > Lower in most of the interesting B-H range
  - > Mostly converges above 1.5T
    - Some of effect seen in plot is a P/S limit

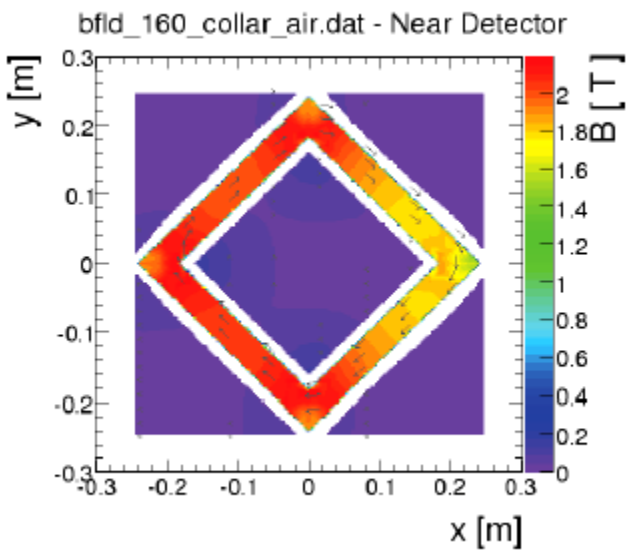


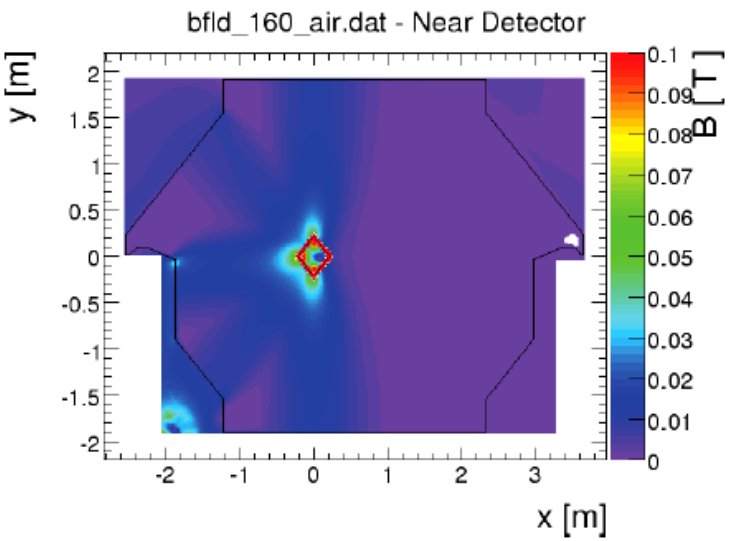
Blue – MINOS torus average

Red – Preproduction steel

Tracking improvements needed

- Currently swimmer ignores the collar & coil mass
  - > Current MC and swimmer ignore the fields in the collar in side the ND coils & air
  - > 0.06T air fields near the coil
  - > 1.8T fields in the collar
  - > Coming soon – no effect?





Magnetic Modeling Status

- Summary
  - > New field maps for both ND (160) and FD (205) are available
    - Air fields & collars too
  - > End-effects maps for FD & ND have been produced
    - Analyzing best method to implement these maps in the code
    - Implementation in MC on hold until new geometry package is ready
- Plans
  - > B-H results for MINOS steel
    - Insignificant systematic effects between different steel samples
    - Tuning the MINOS B-H curve (slightly lower fields)
    - When this curve is done, will produce a final set of maps
  - > ND BDOT retrofit 97% done; plan to finish during shutdown
  - > SM1 BDOT needs planned down time to fix a relay

Noted Issues & Progress

- In new MC/data
  - > Intranuke was an important factor – turned on
  - > Error in flux input implementation for pME & pLE - fixed
  - > Newer field maps
  - > New subshower package
  - > New demuxer
  - > First LE10 MC
- Conventions converging
  - > Basic data quality
  - > Basic beam quality
  - > Standard Fiducial
- Plan for processing pass in 1-2 weeks
- Things in the pipe for repass
  - > GNUMI V18 fluxes
    - FLUKA for target, GNUMI for rest of simulation
    - Alternative production model
  - > Late hit cleaner for ND
  - > Showers
    - Calibr fix
  - > Tracking
    - Final field maps w/real B-H
    - Collar fields & swimming in the coil (data only)
- Further Future
  - > Modern geometry/transport with full field maps
    - Same models in data & MC
  - > New tracker
  - > G4NUMI

More on the big picture later…

- Data
  - > Goals is a fast reprocessing to get V18 beam & other things that are basically ready
- Want processed data to be analyzed by 2nd week of December
  - > The tight side of Mayly