1. Numu CC/ NC Separation in the ND & FD
2. Slicing & Reco Efficiencies in ND & FD
3. Comparison of reco & MC truth quantities between ND & FD

N. Saoulidou, Fermilab, NC phone meeting 12-03-04

Outline

Slicing & Reco Efficiencies in the ND & FD

- Slicing efficiencies for CC & NC events
- Event reconstruction efficiencies for CC & NC events.

Comparison between reco & truth quantities in ND & FD

NC / CC Separation

- Updated Results
- Characteristics of correct – wrong classifications)
- Statistical & systematic errors (initial attempts and thoughts)

Summary and ongoing work

Various Cuts & definitions

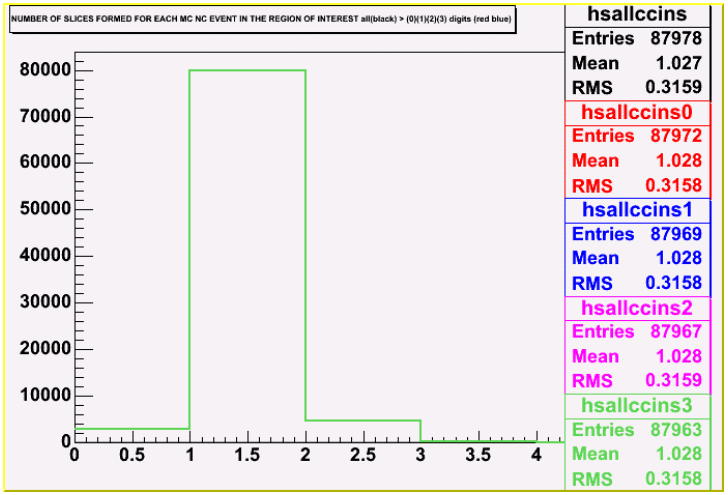
- I am using the MDC R1.12 files.

- The fiducial cuts I am using for all the plots I am showing are :
  - **ND :1m around the beam center and 0.4 < mcz < 6.5**
  - **FD :3m around the detector center and z > 1 && z < 14 OR z> 17 && z < 29**

- The various colors represent the following:
  - **NO CUTS on PH (or equivalently number of digits)**
  - **# Digits in each view > 0**
  - **# Digits in each view > 1**
  - **# Digits in each view > 2**
  - **# Digits in each view > 3**

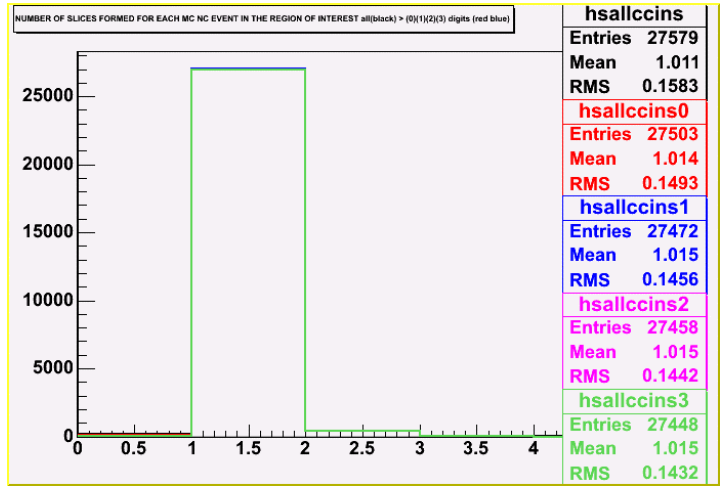
- The final efficiency plots use **# Digits in each view > 1 which is a quite loose cut.**

Slicing & reco efficiencies for CC events: Total Numbers

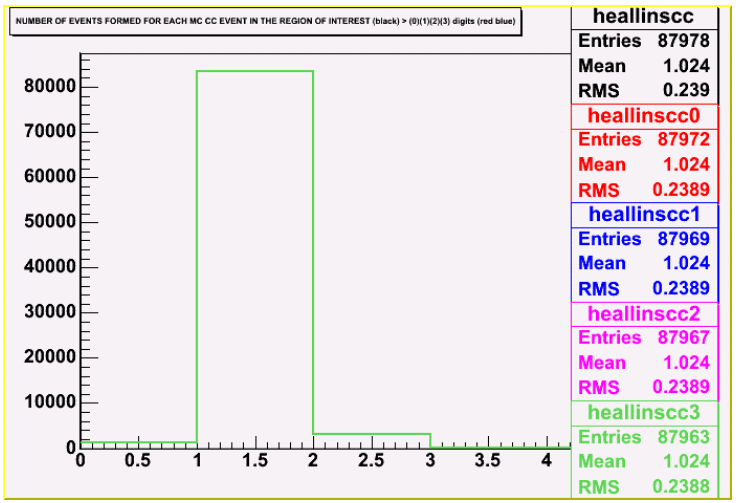


NEAR

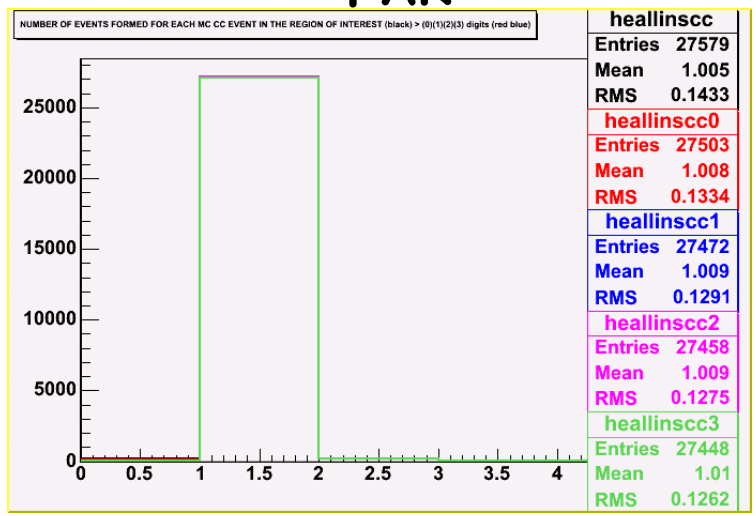
SLICE



FAR

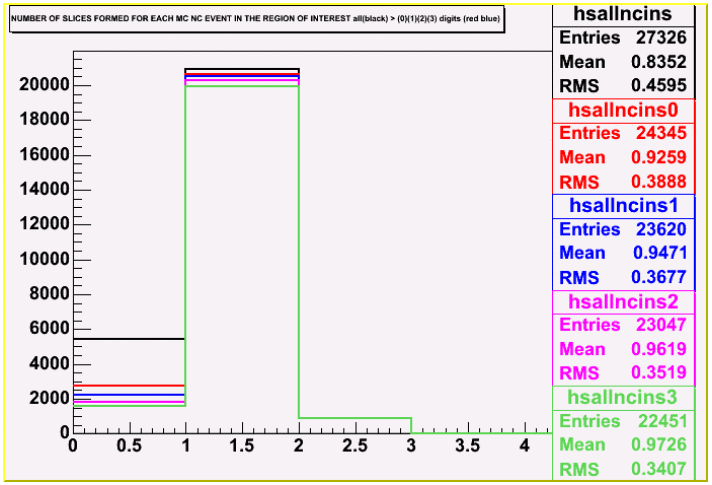


RECO

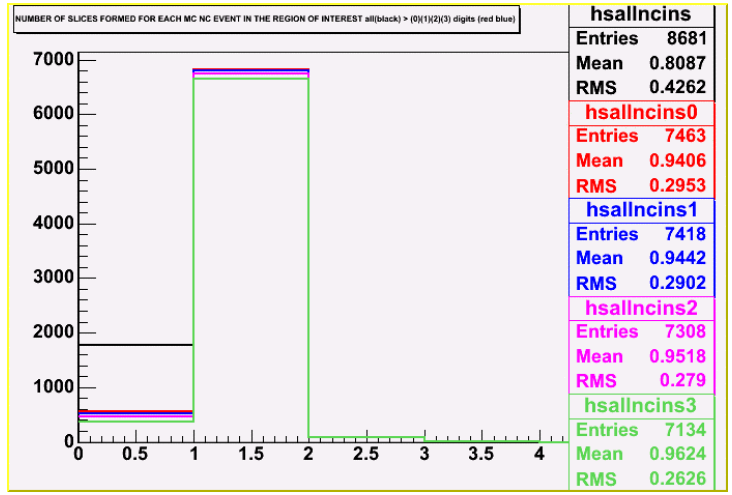


- The slicing & reco efficiencies for CC events for both near and far is very high, practically all CC events end up in a slice.

Slicing & reco efficiencies for NC events: Total Numbers

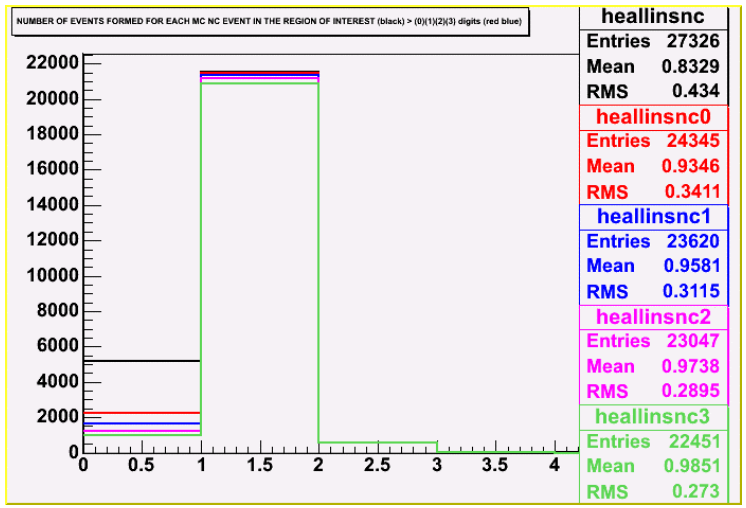


SLICE

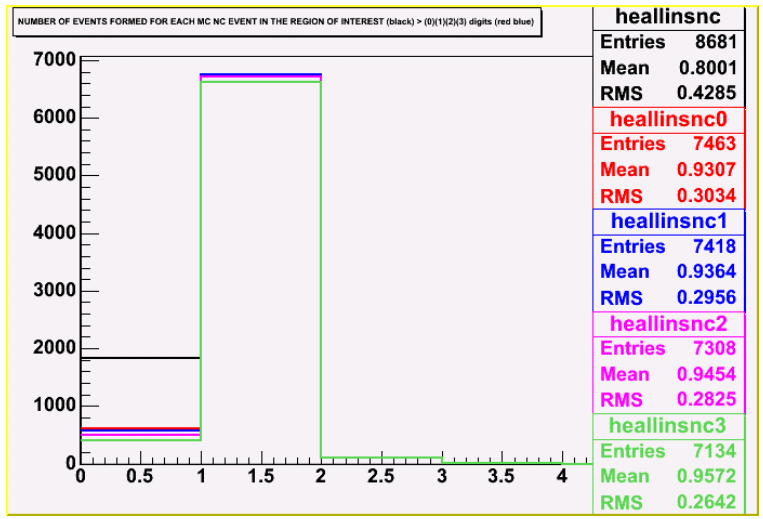


NEAR

FAR

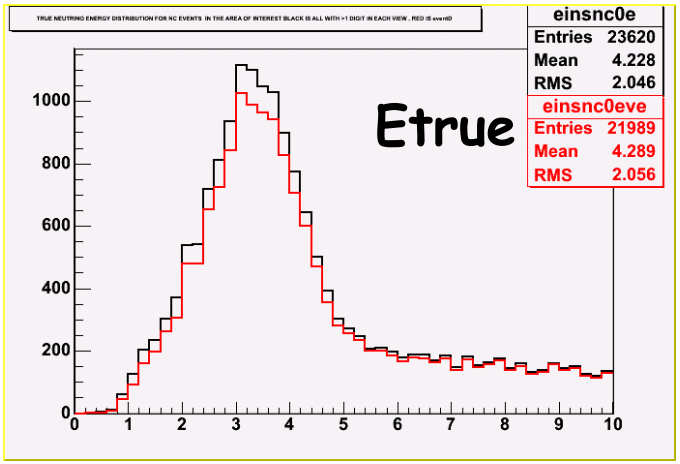


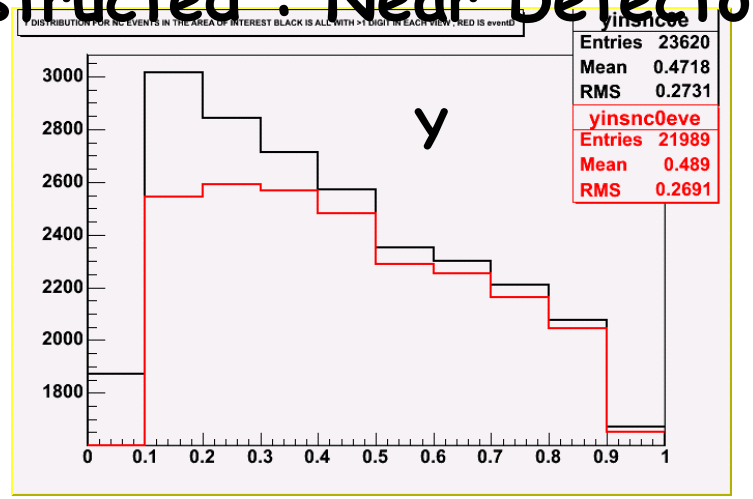
RECO

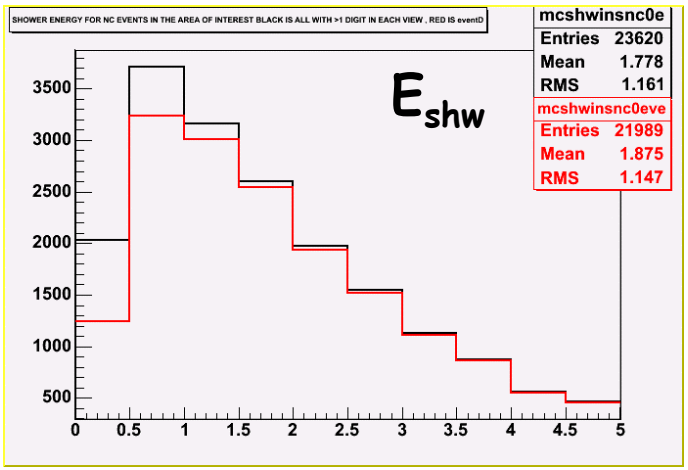


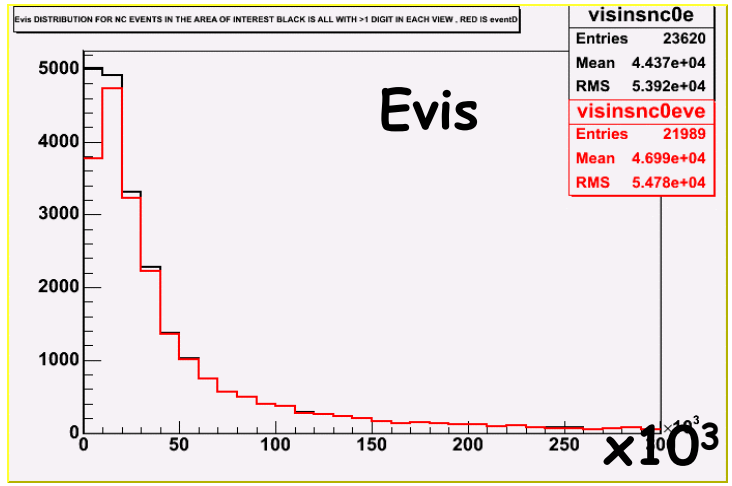
- Slicing & reco efficiency for NC events that have at least 2 digits per view is high for both Near (95 %) and Far (94%)

Etrue,Y, Muon momentum & Evis for all MC NC events and the ones that are reconstructed : Near Detector



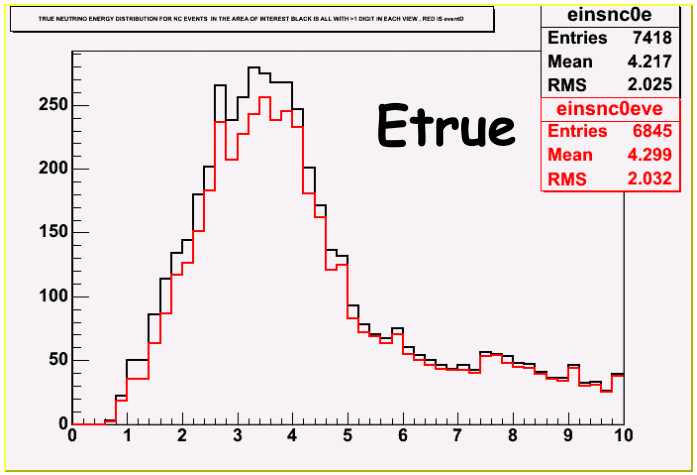


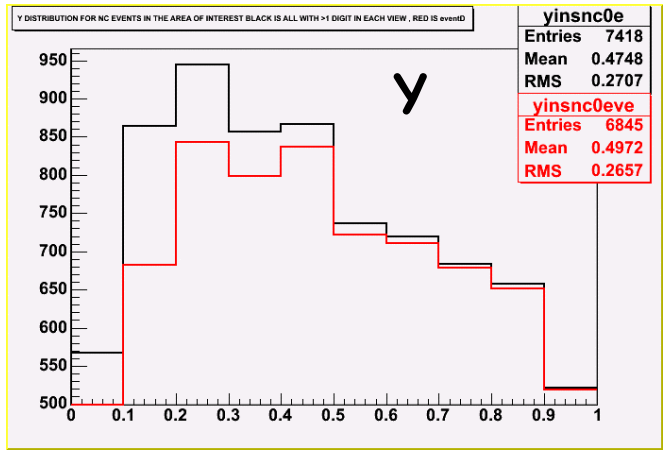


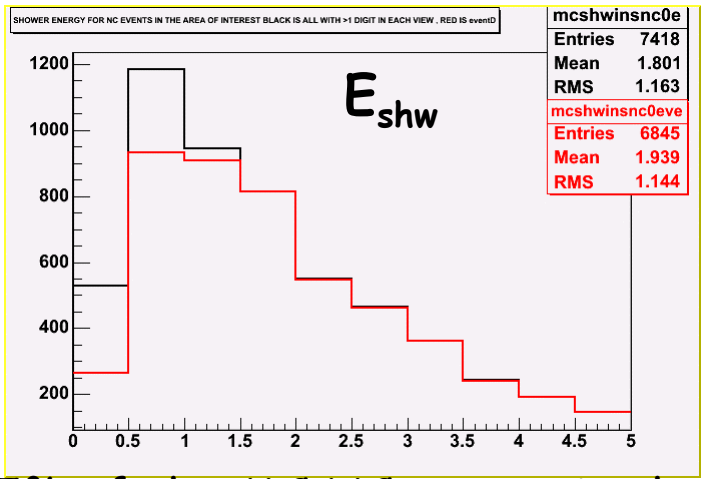


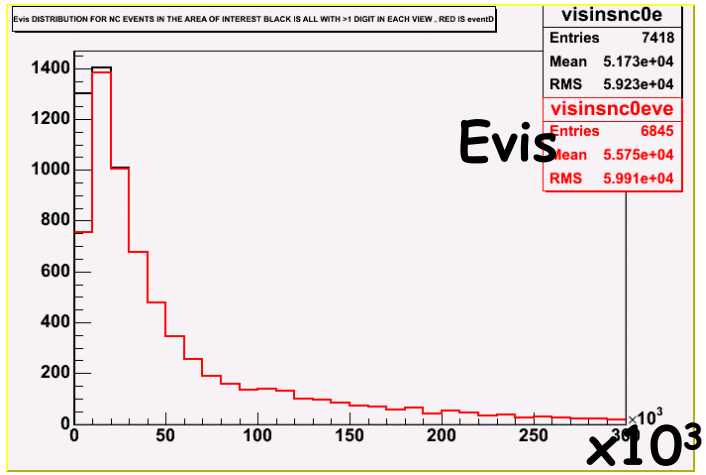
- Nearly 95 % of MC NC events in the "fully" covered calorimeter region (that have at least 2 digits in each view) are sliced & reconstructed. Most of the events missed are in low y & low true shower energy as expected .

Etrue,Y, Eshw & Evis for all MC NC events and the ones that are reconstructed : Far Detector









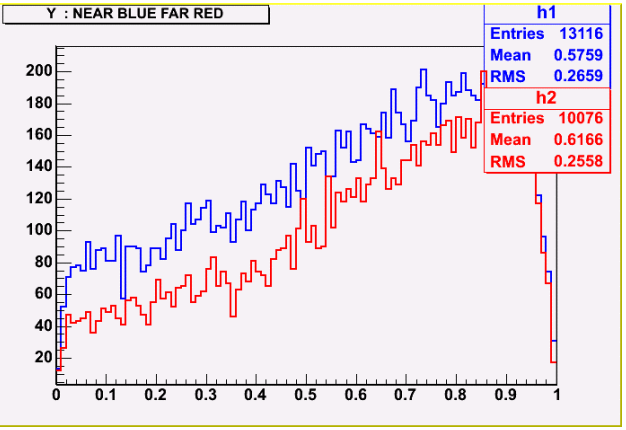
- 95% of the MC NC events in the "fully" covered calorimeter region (with at least 2 digits in each view) are reconstructed. The 5 % that are missed are low y events with very small visible energy that I don't see what we could "do" with them even if we could slice them…

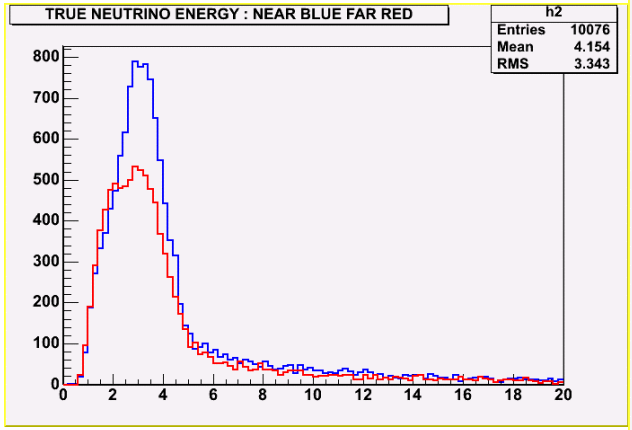
Slicing & Reco Efficiencies : Summary

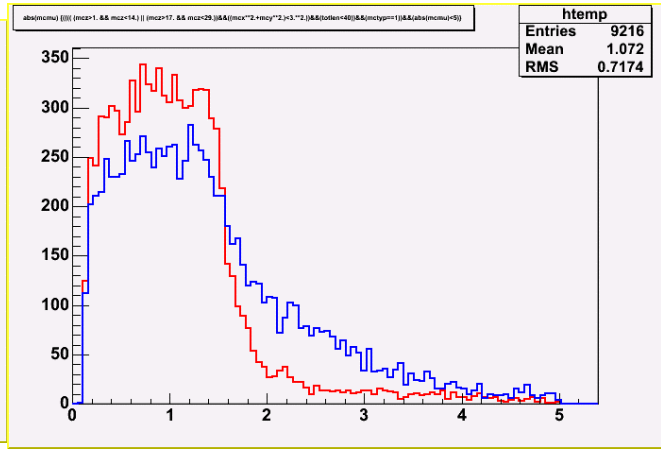
- After imposing a simple "digit" cut (at least 2 digits in each view) the final reconstruction efficiencies (slicing efficiencies included are) for both Near and Far Detectors :
  - 99 % for CC Events
  - 95 % for NC Events
- I can't see how we can recover (as events not slices) the remaining 5 % of missed NC events.
- I think that as far as slicing is concerned it will better to focus on making "nicer" (meaning higher purity and at the same time high completeness) slices for both low AND high intensity beams…
- Next I compare reconstructed and truth quantities between Near and Far events in order to examine differences due to the different detectors (plex, non-symmetrical near geometry, slicing e.t.c) and also due to the different neutrino spectra…

(I discuss only the quantities that show characteristic differences)

Y & Neutrino energy for short (< 40 planes) CC events







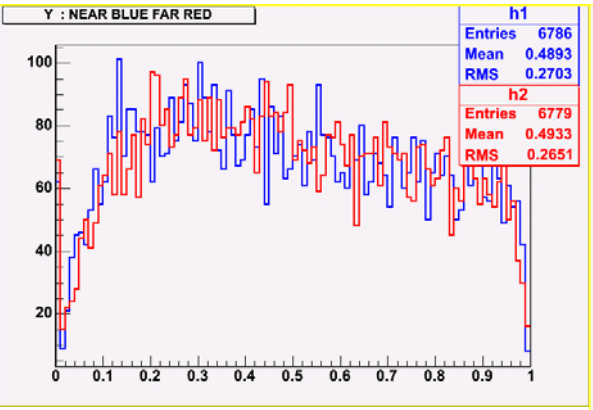
Y

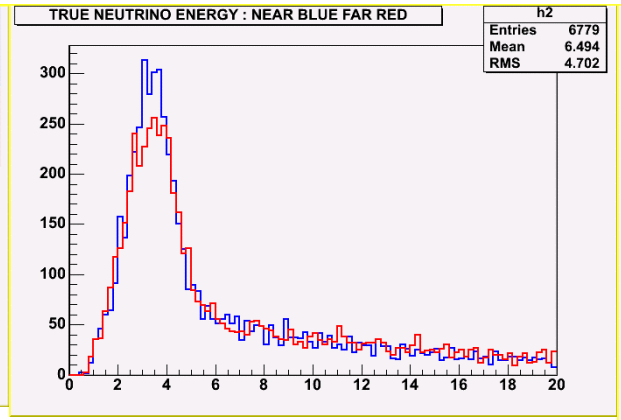
Enu

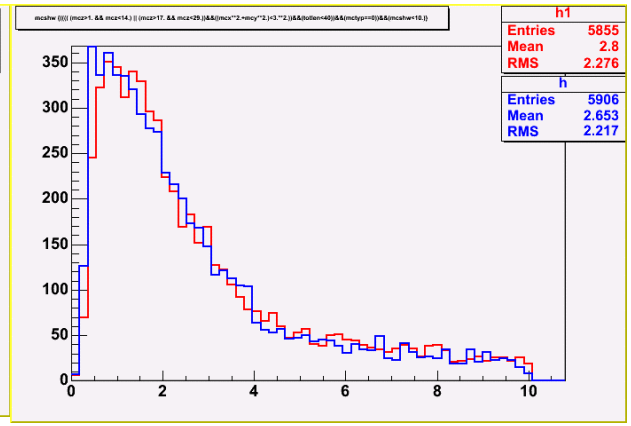
Pmu

- I am looking at short events since total CC events revealed no difference in these quantities and furthermore it is the sample I am using for the event classification.
- FAR (RED) CC short events appear to be higher Y and lower visible energy. This in general would mean shorter muons => less reconstructed tracks (TRUE MUON MOMENTUM is indeed lower for FAR events)

Y & Neutrino energy for short (< 40 planes) NC events



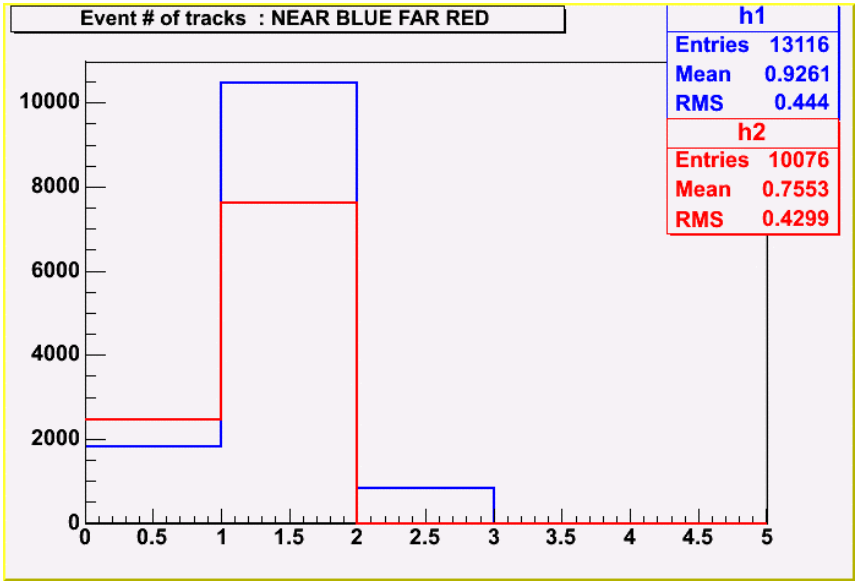


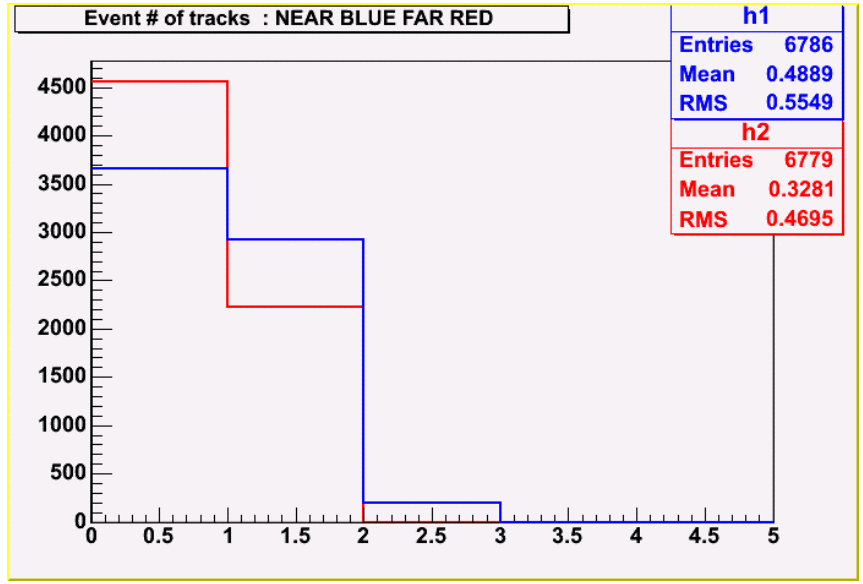


y **Enu** **Eshw**

- FAR (RED) NC events seem to have slightly higher Y and higher neutrino energy which means higher shower energies and in general fewer tracks. (Shower energy is higher).
- In addition
  - CC/NC ratio NEAR ~ 1.9
  - CC/NC ratio FAR ~ 1.4 (NO OSCILLATIONS)

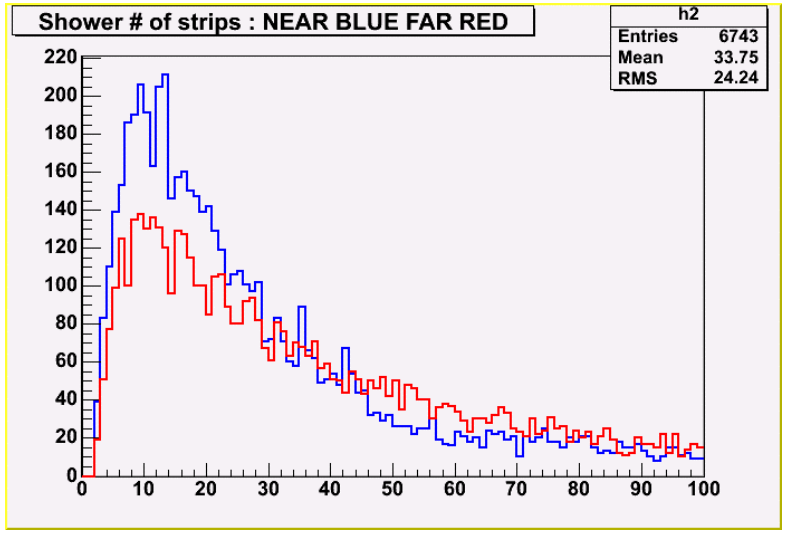
Tracks for CC & NC short Events

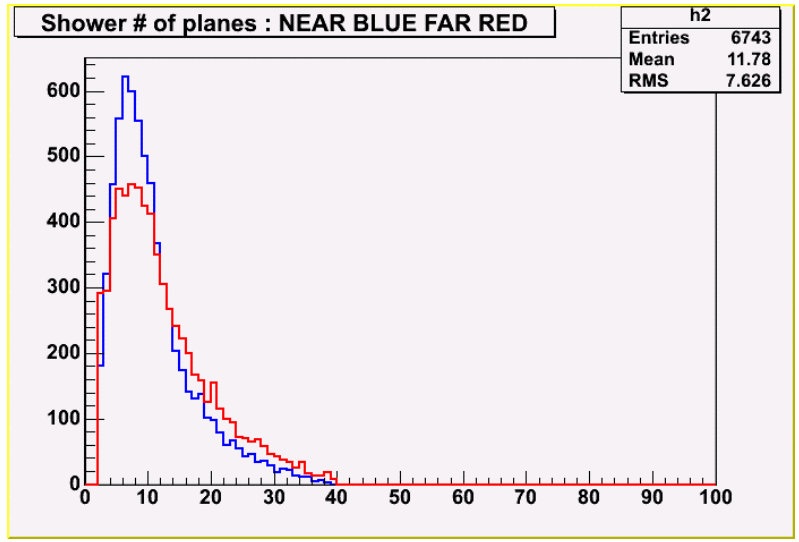




- The higher percentage of CC events with tracks AND NC events with tracks in the NEAR detector is in agreement with the Y and Enu distributions shown in the previous slides.

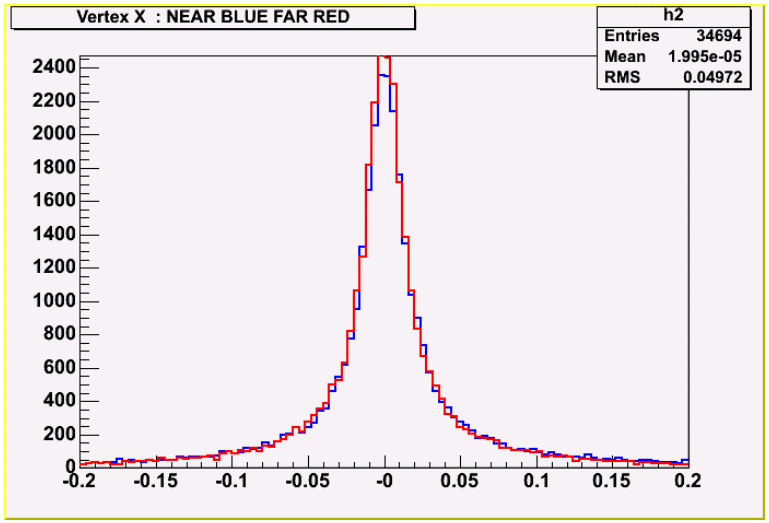
Shower # of strips & # of planes for NC short Events



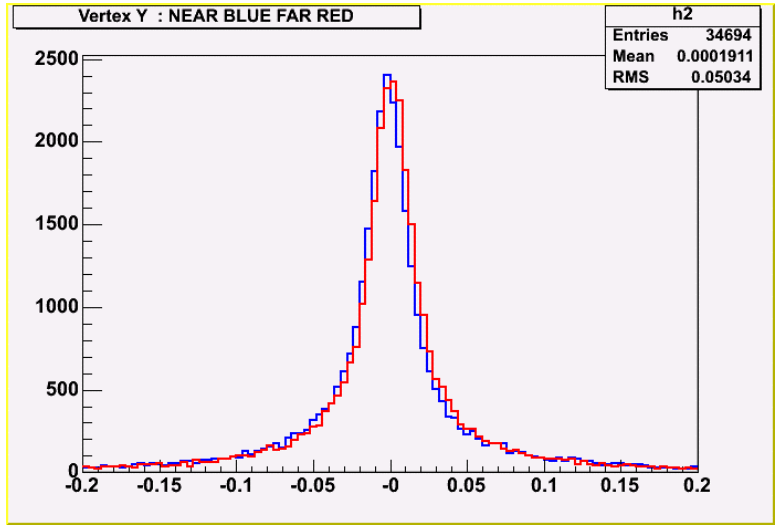


- I don't want to compare the total PH due to the fact that (as discussed in a previous reco meeting) the NEAR detector PH might be lower/higher (?) I can't remember by factors of 10-20%.
- However the total shower strips and planes are a more unbiased quantity to compare.
- The fact that the FAR detector has in general larger showers is in agreement with the Y Enu FAR distributions (higher shower energies)

Vertex accuracy (all events)



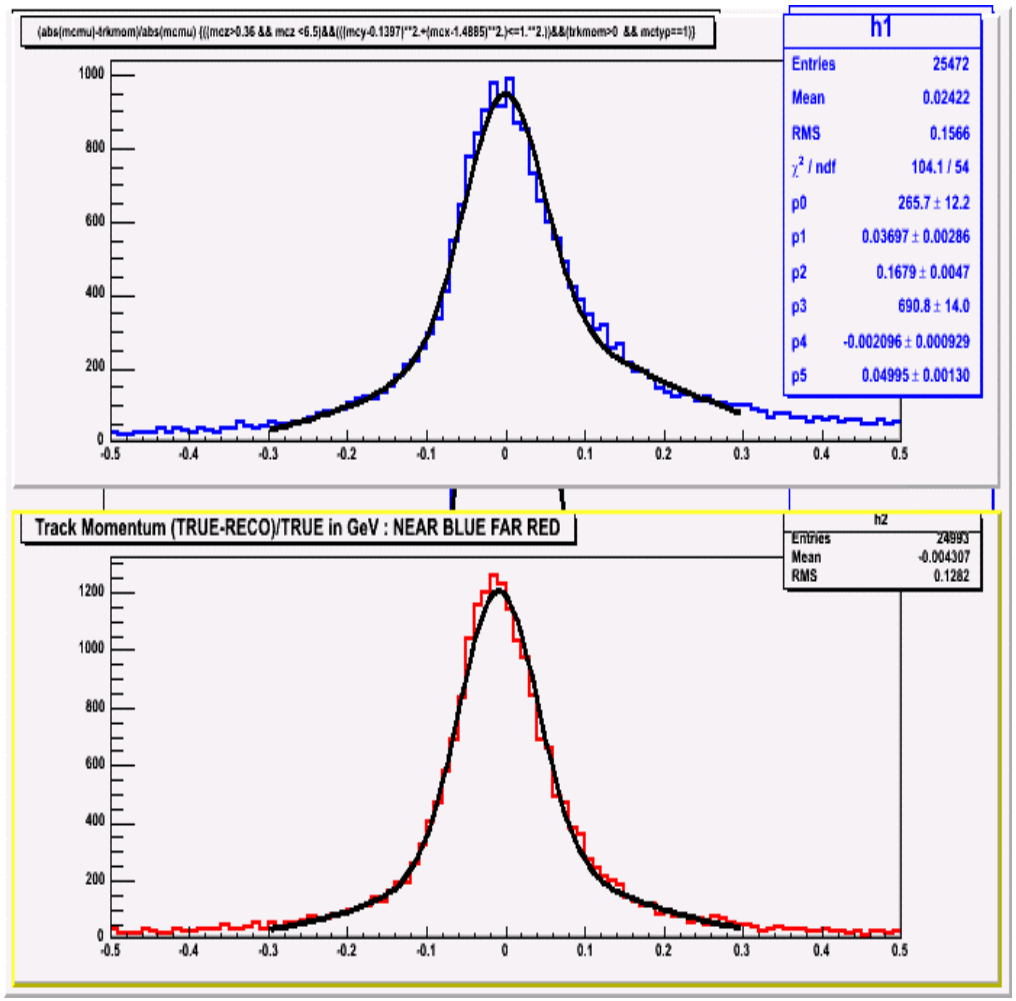
Vertex X (true-reco)/true



Vertex Y (true-reco)/true

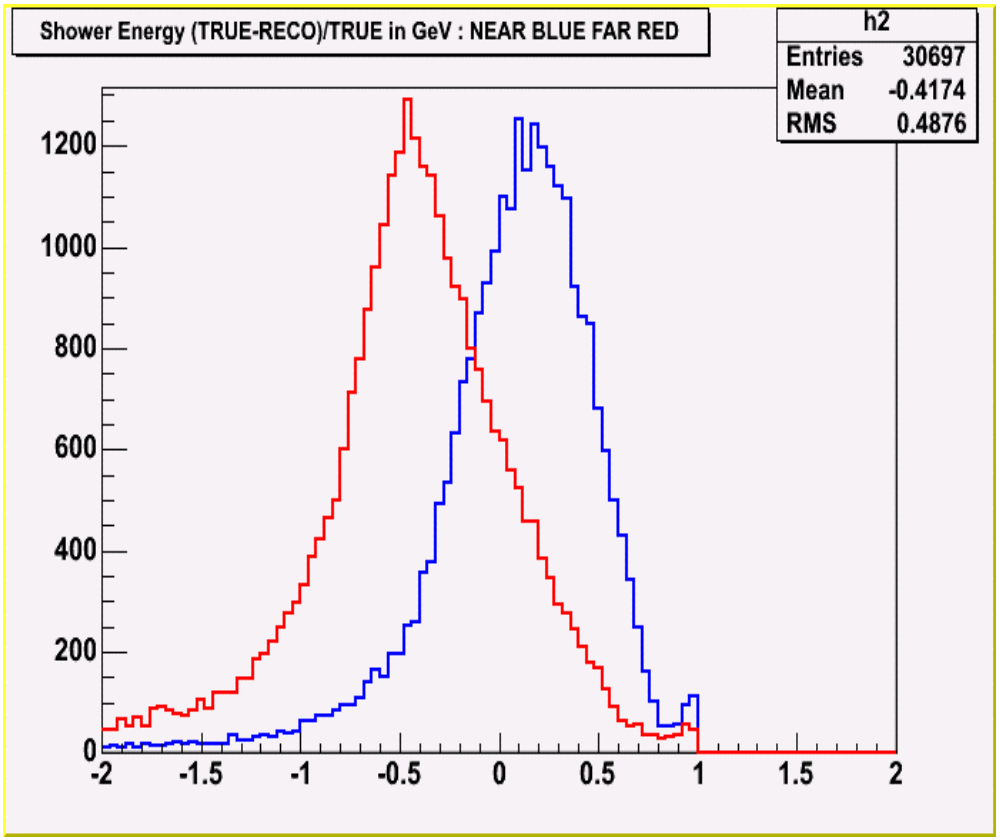
- Most of the events have a reconstructed vertex with an accuracy of 2 cm (or less). There are some long tails in both directions (?). Near Far results are the same.

Momentum resolution (ALL CC Events)



- Muon momentum in NEAR detector slightly more asymmetric (maybe not very efficient "stopping track definition given the difficult Near detector geometry).
- Distribution not gaussian (I fitted with two gaussians). False solutions?
- In general resolution of the order of 11%-12% for both detectors and Near – Far very similar.

Shower resolution (ALL Events) !!!!



- Shower energy resolution in GeV (shw.ph.gev) makes no sense.

  Near and Far detectors are completely off with respect to each other!

  Near seems to center to zero BUT maybe just a coincidence.

  I examined ADC/PE, PE/MIP, MIP/GeV factors for both and they are identical except from the ADC/PE:
  - ADC/PE NEAR ~ 94 (expected gain)
  - ADC/PE FAR ~ 67

  Help from the experts of the calibration would be very valuable to clear my confusion.

- At the moment I cannot use the estimated neutrino energy for anything…

Strategy for any CC NC comparison between NEAR & FAR

1. Event selection in NEAR and FAR

2. Corrections (and errors statistical & systematic) for
   - Reconstruction efficiency
   - Selection efficiency
   - Selection purity

3. Extrapolation (and systematic errors) from NEAR to FAR in order to get the reference (unoscillated numbers and spectra) in FAR to be able to compare.

4. True neutrino energy reconstruction (and systematic errors) for CC analysis)

Event Selection

- Event selection method I am using : ANN

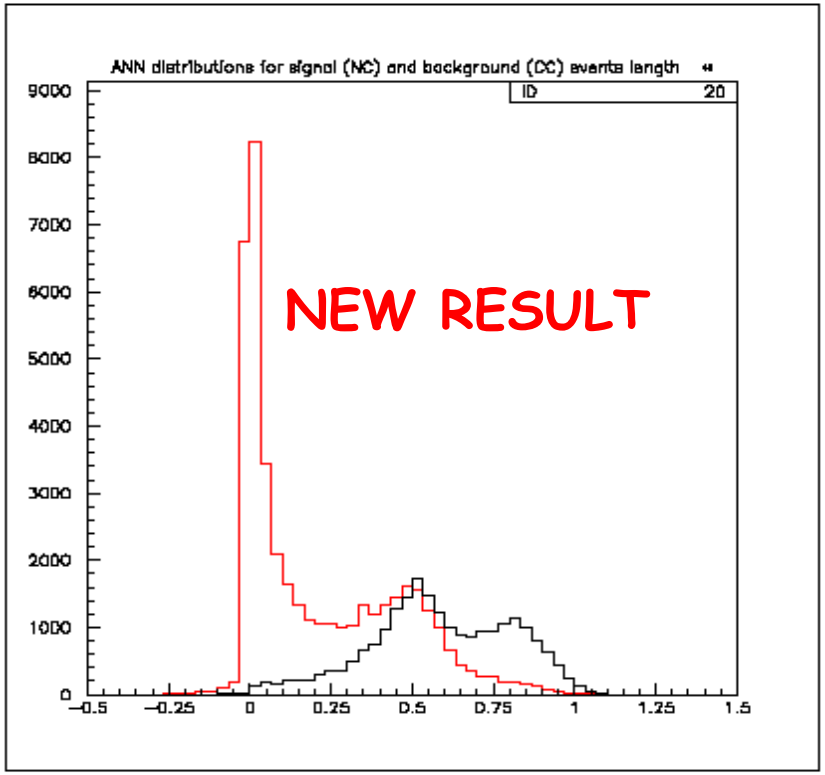
- Train ANNs in :

  - NEAR
  - FAR unoscillated
  - FAR oscillated with 2 different dm2 (0.002eV^2 and 0.0025 eV^2 with sin^2(2theta) = 1.

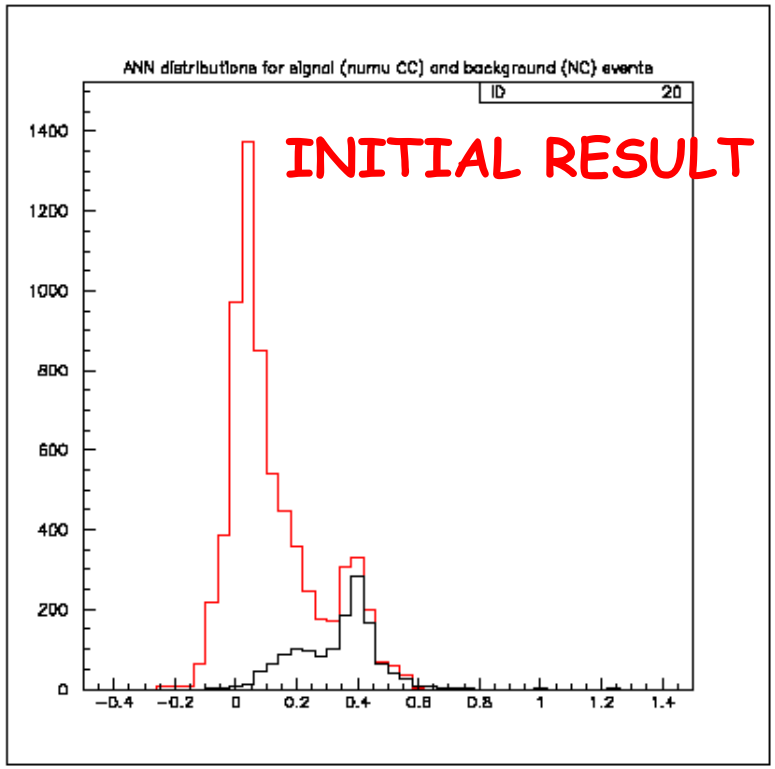
- In order to study the differences especially in the FAR detector and determine how I should train/tune my selection procedure for the FAR detector and also estimate its systematic error.

ANN Results NEAR (length<40)

A priori probabilities 1:1.9



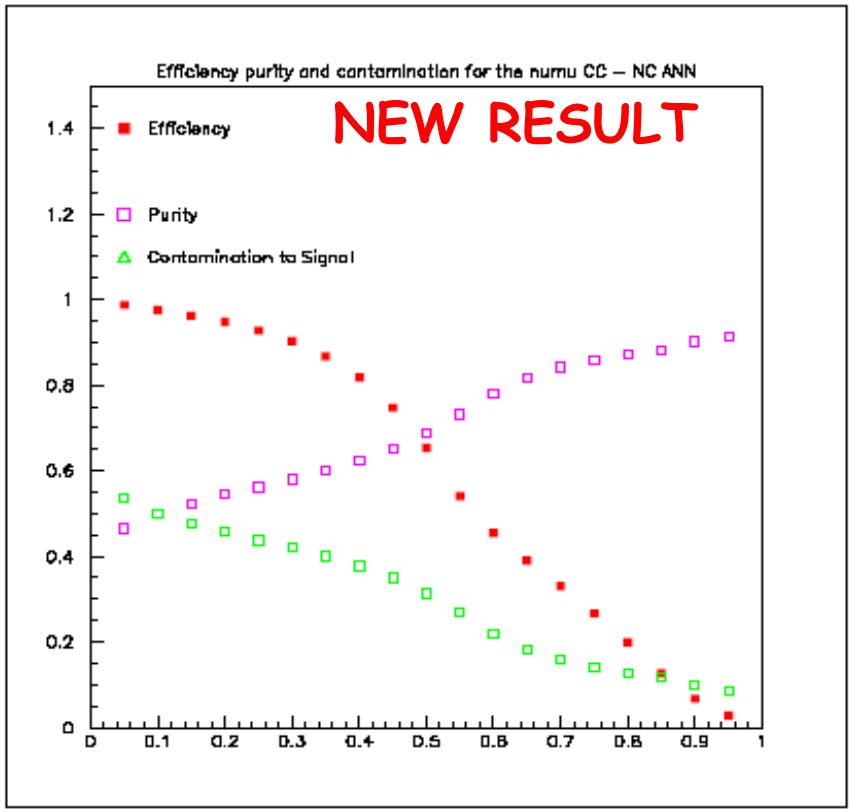
A priori probabilities 1:4.5

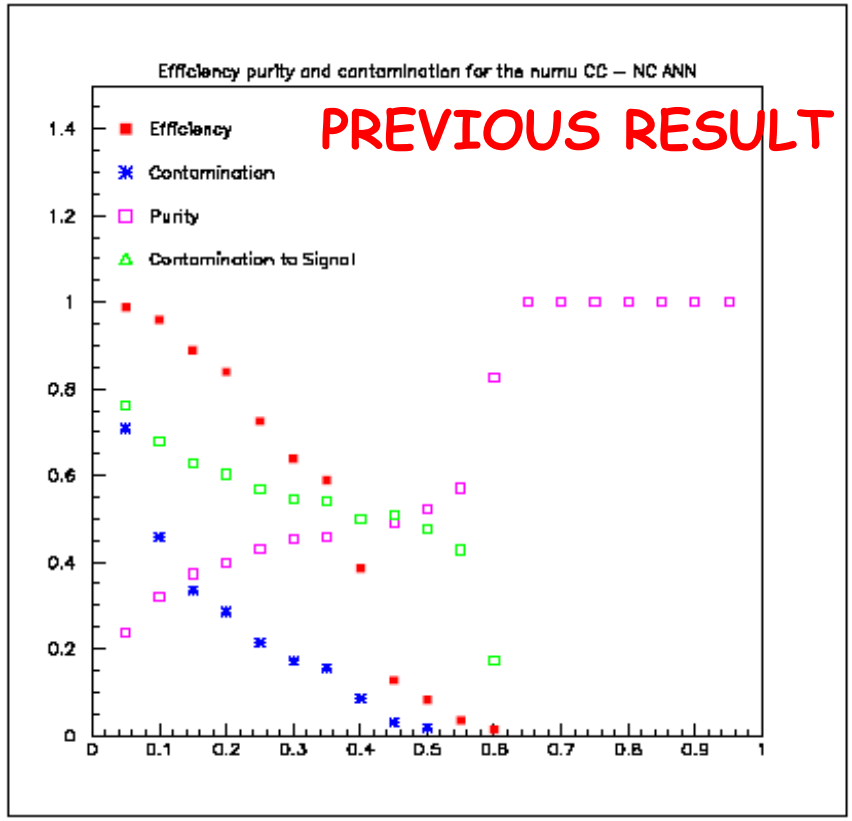


Event Probability

- The ANN performs as expected : Higher purity for CC selection and lower for NC selection but the new results are improved compared to the ones I showed in the previous meeting. This improvement mainly comes from Jim's changes to the event formation which resulted in more reconstructed NC events and also improvement on my input variables.

ANN Results NEAR con't

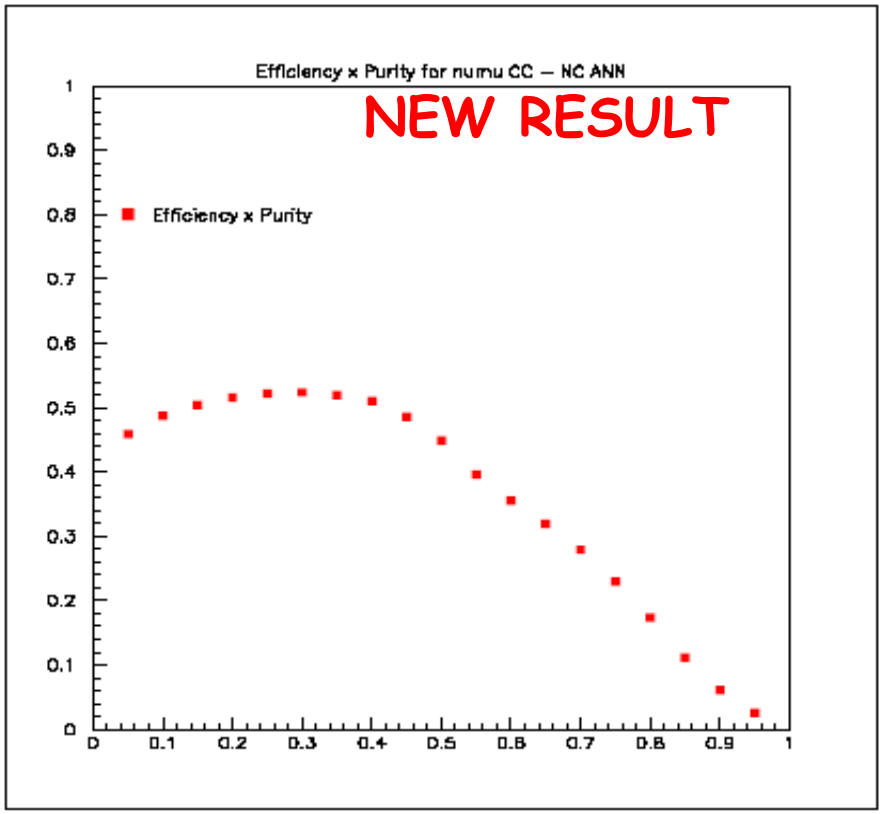


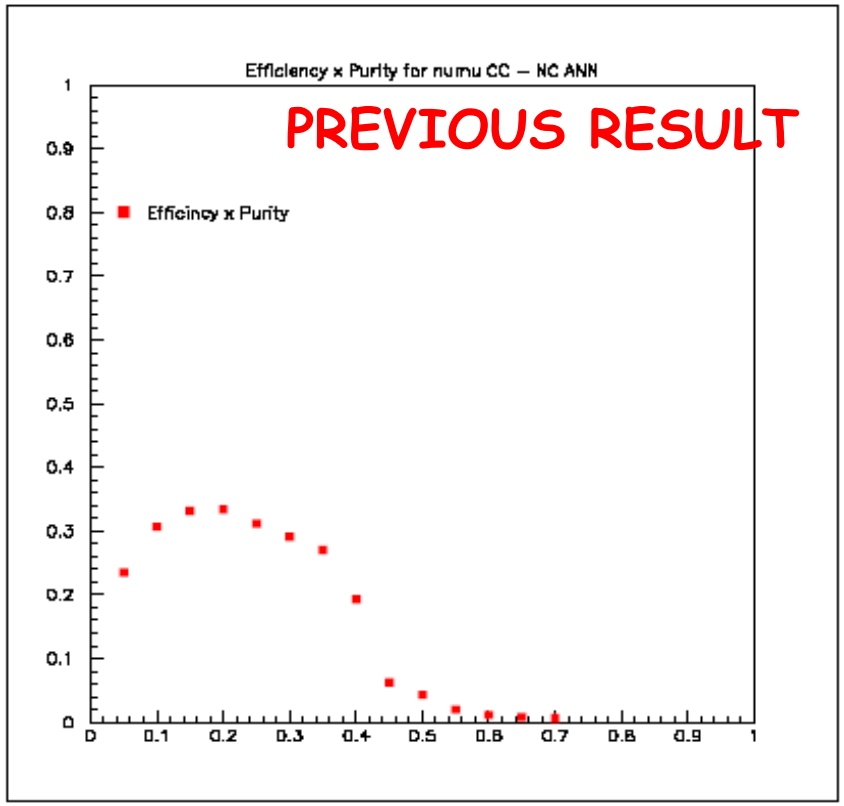


Efficiency (red) and purity (magenta) as a function of cut in the ANN output function for the signal (NC events)

- **If we set the cut @ 0.45 (i.e) we have an efficiency of 75% and a purity of 65% which is a significant improvement.**

ANN Results NEAR con't

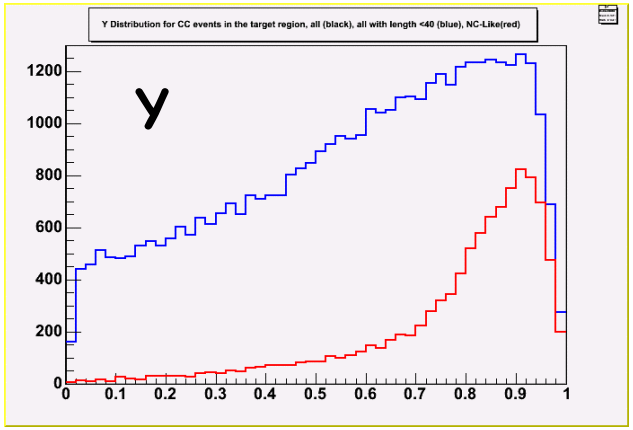


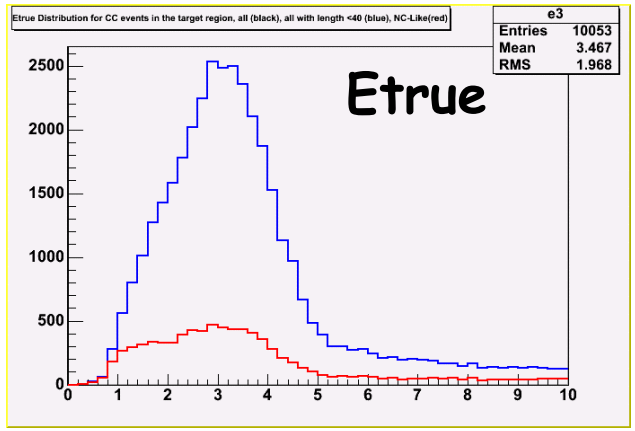


Efficiency x Purity

- **The new results are clearly improved.**

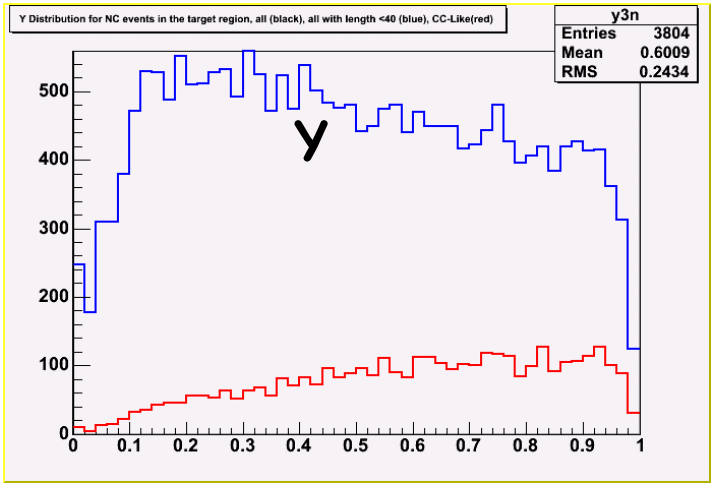
Characteristics of correct classifications : CC events -> "NC-Like"

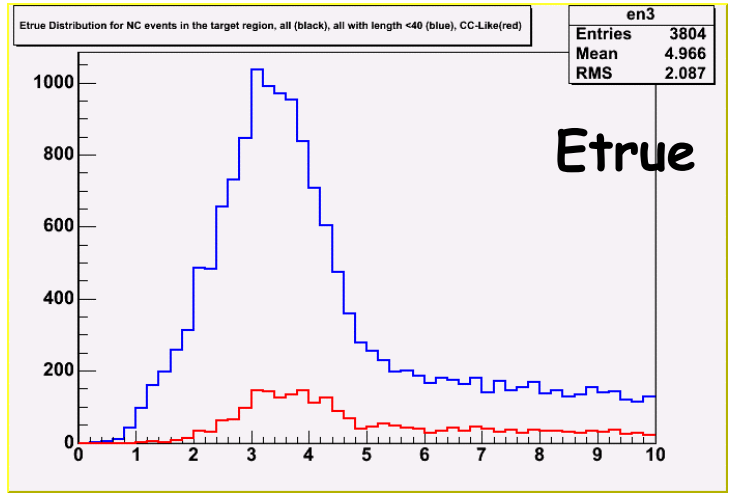




- **Blue are ALL CC events that have total length < 40 planes**
- **Red are the ones that are mis-classified as NC-Like (P>0.45)**
- Most of the misclassified CC events are high Y low neutrino energy events where the muon is low momentum.
- These events will either have zero or quite sort tracks.
  - When I scanned CC events that are classified as NC-Like (20 of them as they appeared in one of the input files) I saw that the vast majority of those really looked like a NC with no visible muon track that could be reconstructed

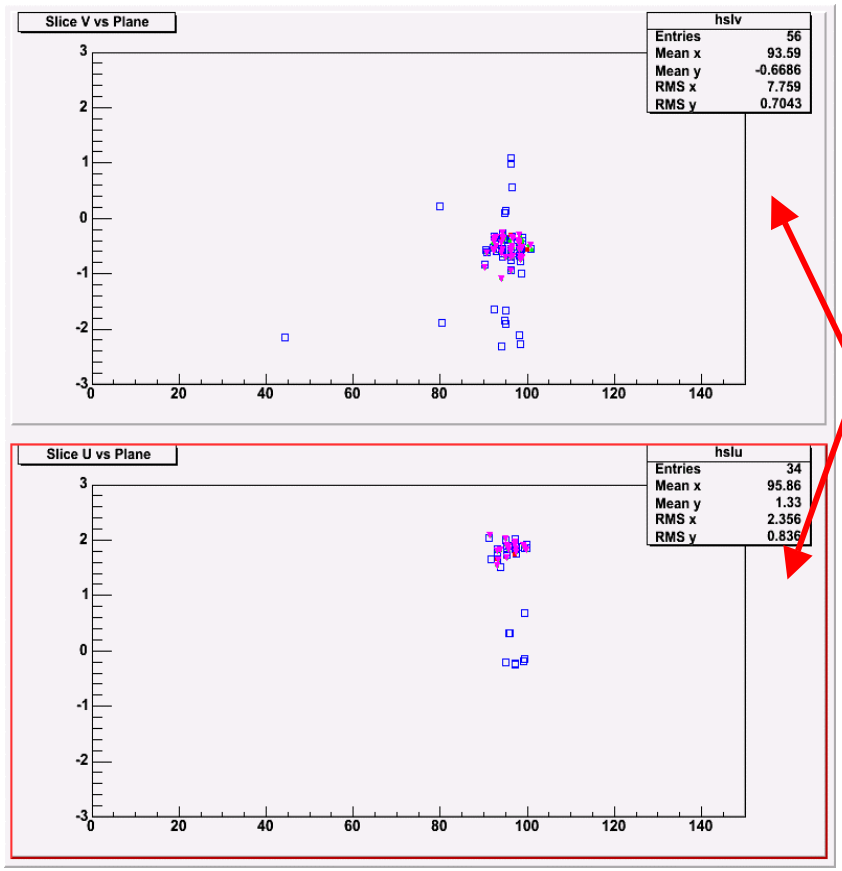
Characteristics of correct classifications : NC events -> "CC-Like"

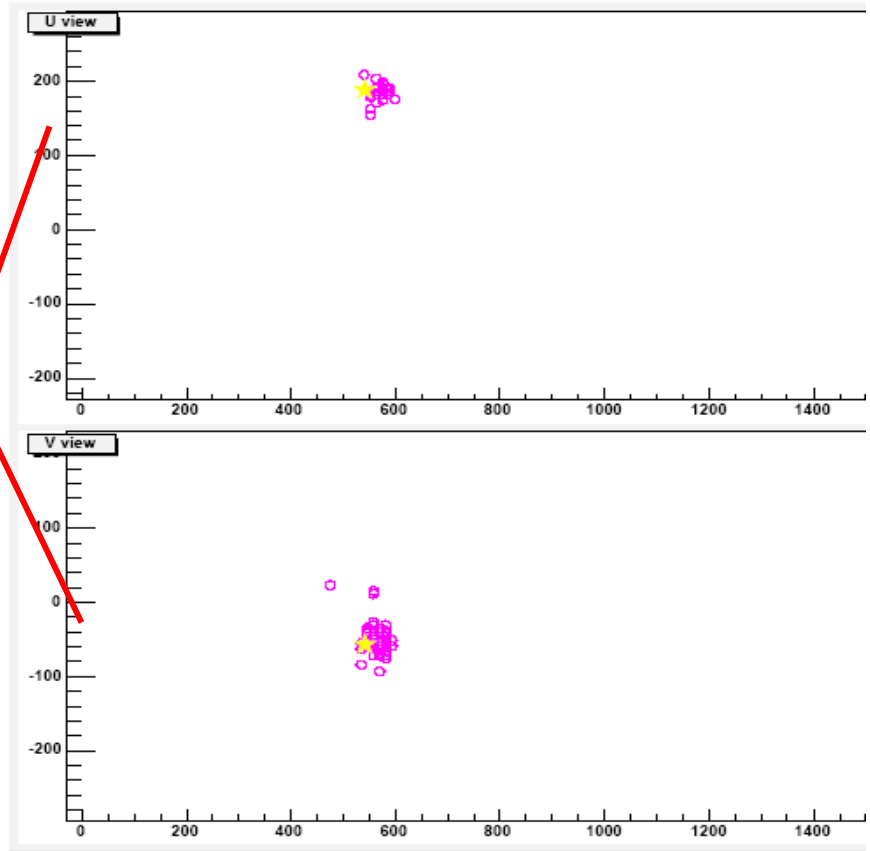




- **Blue are all NC events that have total length < 40 planes**
- **Red are the ones that are mis-classified as CC-Like (P<0.45)**
- The misclassified NC events are higher Y and higher neutrino energy events. Therefore it is easy to reconstruct short tracks and classify them as "CC-Like".
  - I scanned a few of those as well and I believe there is some room for improvement in the sense that a large fraction of these events have bad tracks (I haven't done the same yet for CC events that are characterized as CC and have short tracks, if the picture is the same there as well then whatever you gain from the NCs you will loose from the CCs…more in nedxt meeting).

CC event classified as NC-like 2





Blue squares : slice hits

Red triangles : track hits

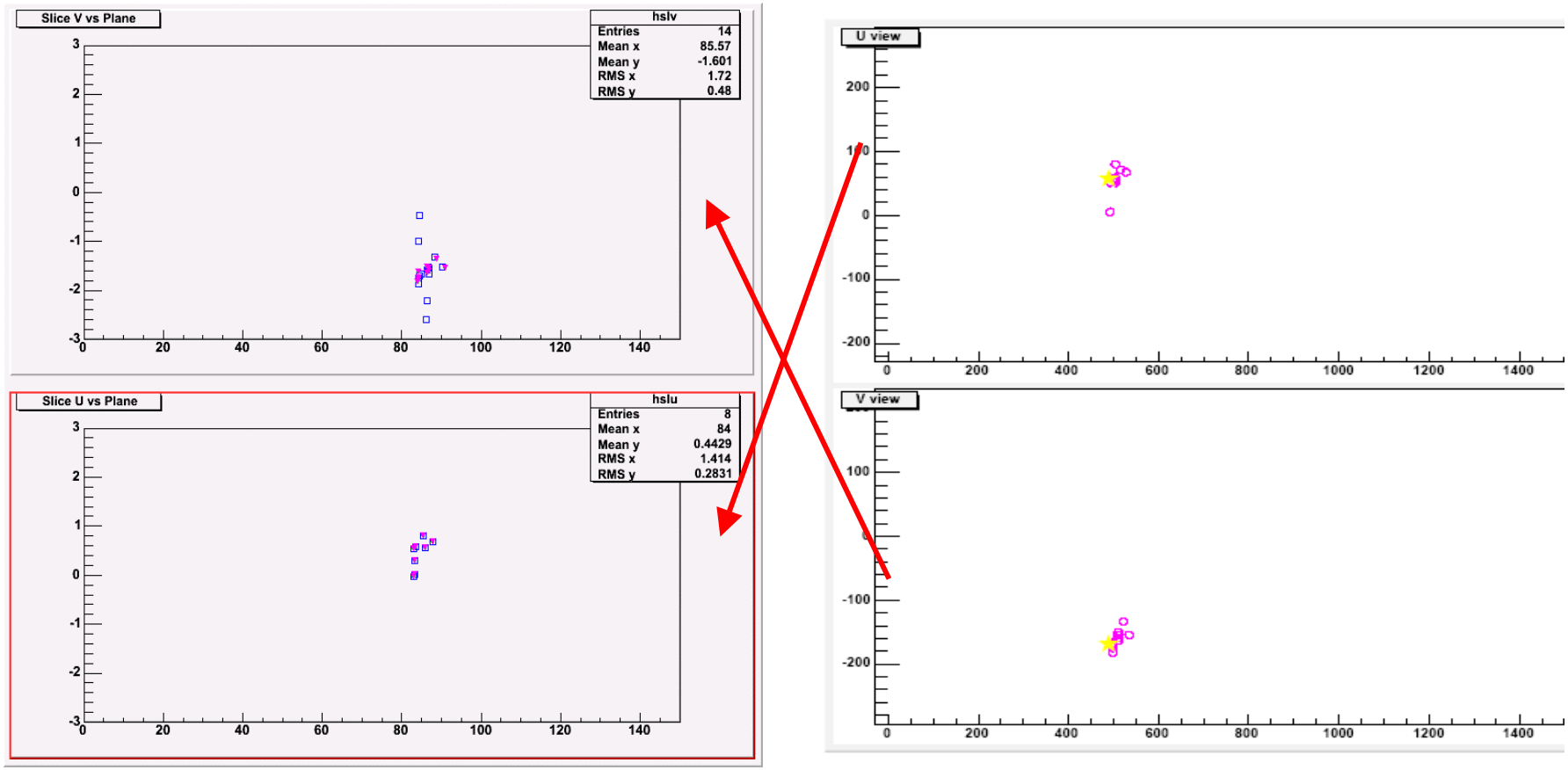
Magenta triangles : shower hits

TRUTH DISPLAY

Etrue =4.5 Emu =0.7 Y=0.8

No obvious & reco track, resembling NC

CC event classified as NC-like 4



Blue squares : slice hits

Red triangles : track hits

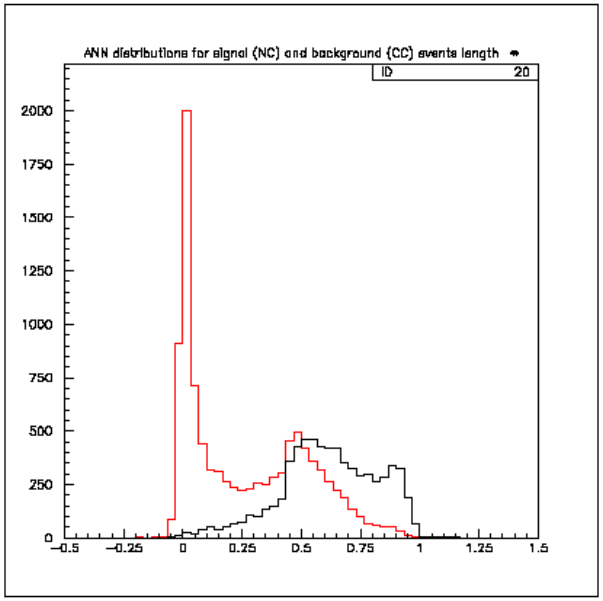
Magenta triangles : shower hits

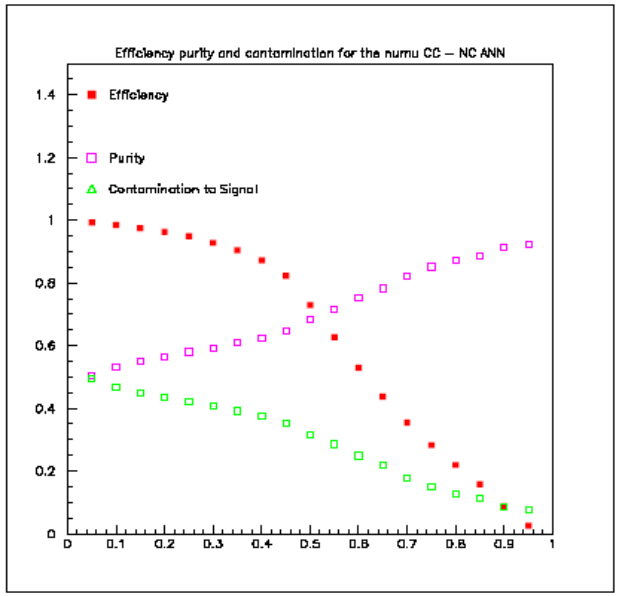
TRUTH DISPLAY

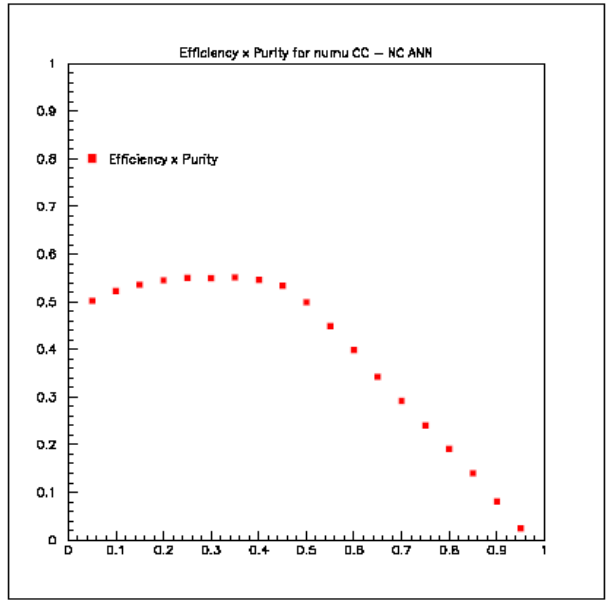
Etrue =2.1 Emu =0.3 Y=0.9

No obvious and reco rack, resembling NC

ANN Results FAR no oscillations (length<40)





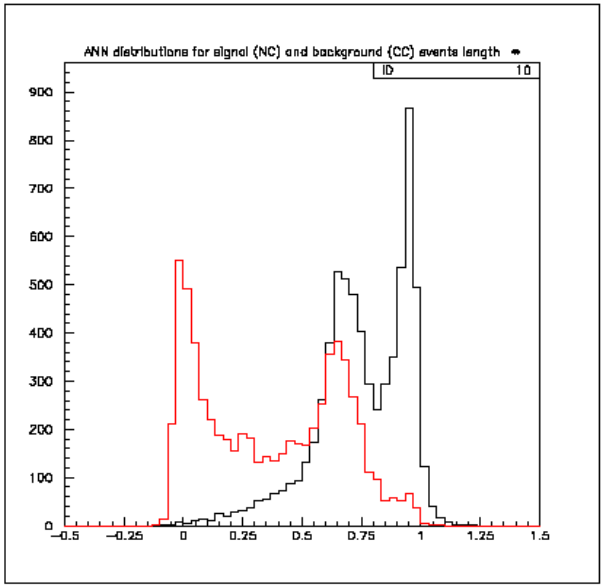


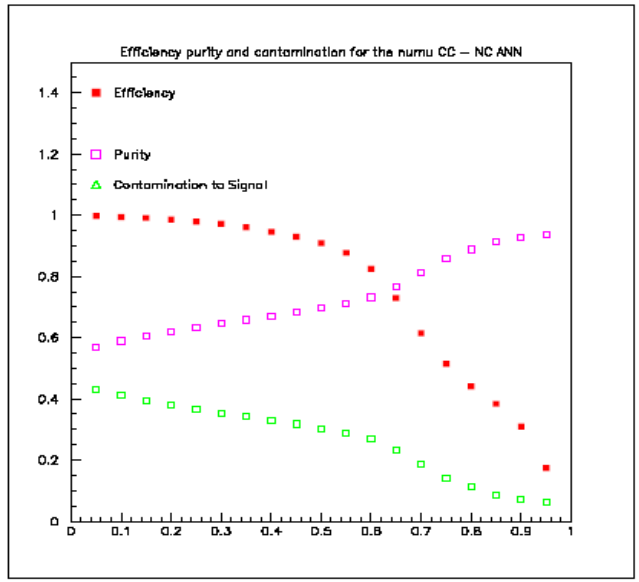
A priori probabilities 1:1.4 Efficiency (red) Purity (magenta) Efficiency x Purity

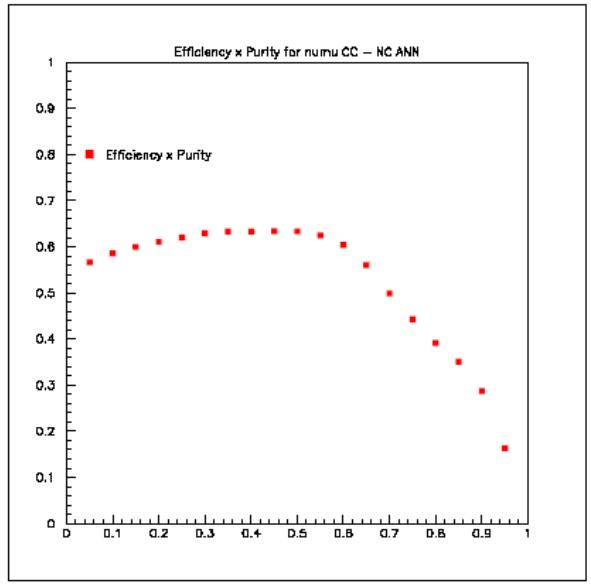
- The results are better & more important different than in Near mostly due to improved S/B ratio (1:1.9 Near vs 1:1.4 Far)
- If we set the cut @ 0.45 (i.e) we have an efficiency of 75% and a purity of 65%.
- I expect that as I "oscillate" numu events the results are going to get better because mainly of even larger S/B ratio

ANN Results FAR oscillations (length<40)

$$\sin^2(2\cdot\theta)=1 \,\&\, \Delta m^2=0.002$$





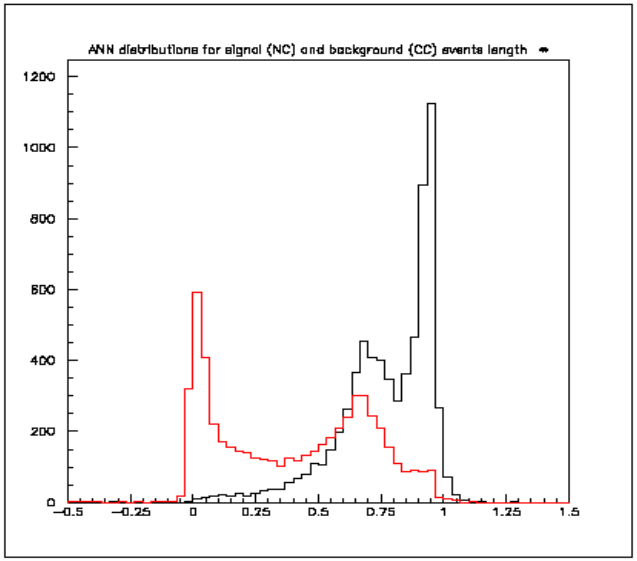


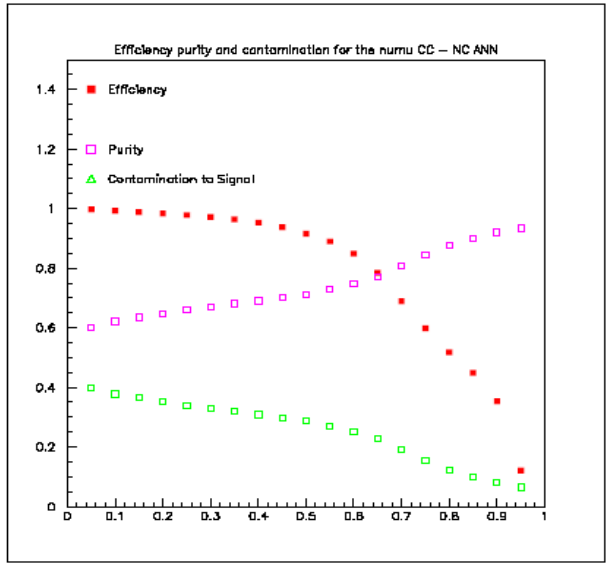
A priori probabilities 1:1.4 Efficiency (red) Purity (magenta) Efficiency x Purity

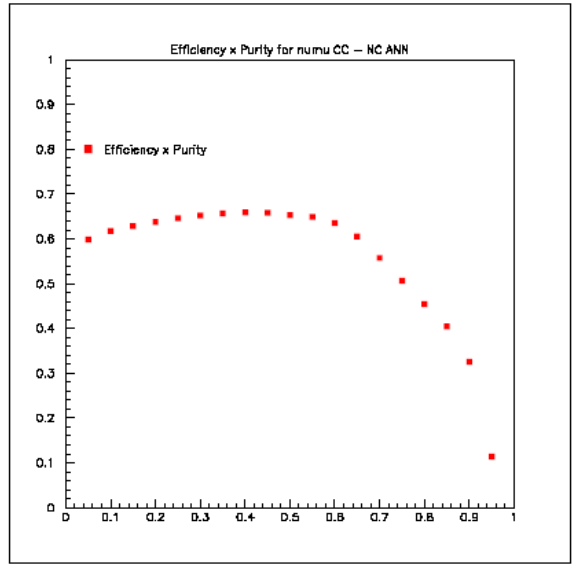
- **The results are different than the unoscillated mostly due to the even higher S/B ratio.**
- **If we set the cut @ 0.45 (i.e) we have an efficiency of 93% and a purity of 68%.**
- Indeed as numus "oscillate" the results are getting better (and different than the not oscillated) because mainly of even larger S/B ratio

ANN Results FAR oscillations (length<40)

$$\sin^2(2\cdot\theta)=1 \,\&\, \Delta m^2=0.0025$$







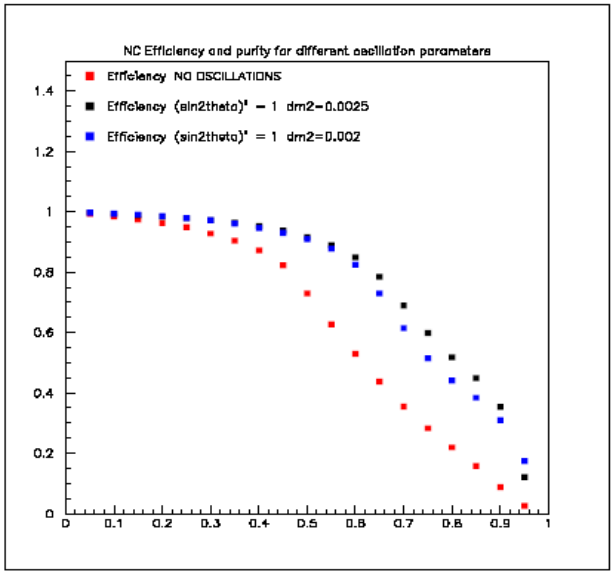
A priori probabilities 1:1.4 Efficiency (red) Purity (magenta)

Efficiency x Purity

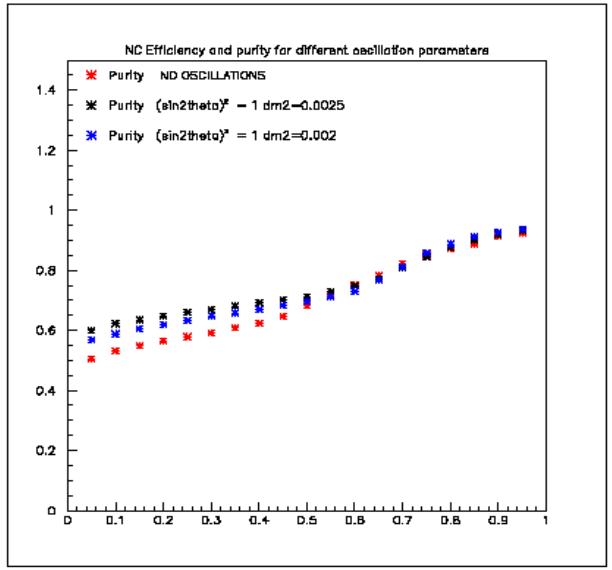
- The results are not that much different than the previous oscillation scenario.
- If we set the cut @ 0.45 (i.e) we have an efficiency of 89% and a purity of 73%.
- The results between Near and Far and furthermore Near and oscillated Far are quite different.

ANN Results FAR :

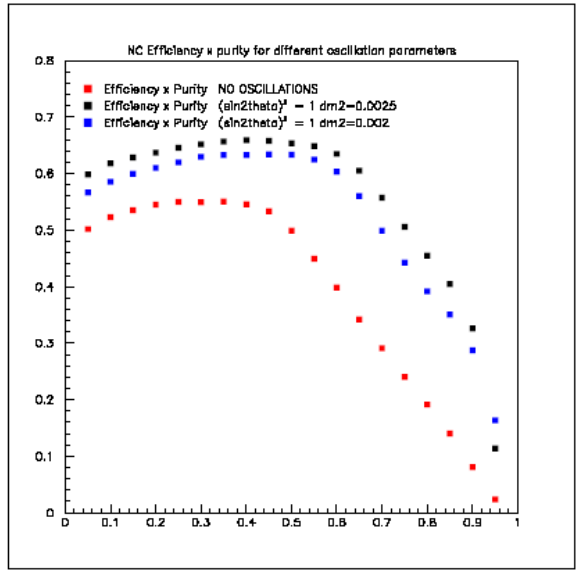
No oscillations – $\sin^2(2\cdot\theta)=1 \& \Delta m^2=0.0025$ – $\sin^2(2\cdot\theta)=1 \& \Delta m^2=0.0025$



Efficiency



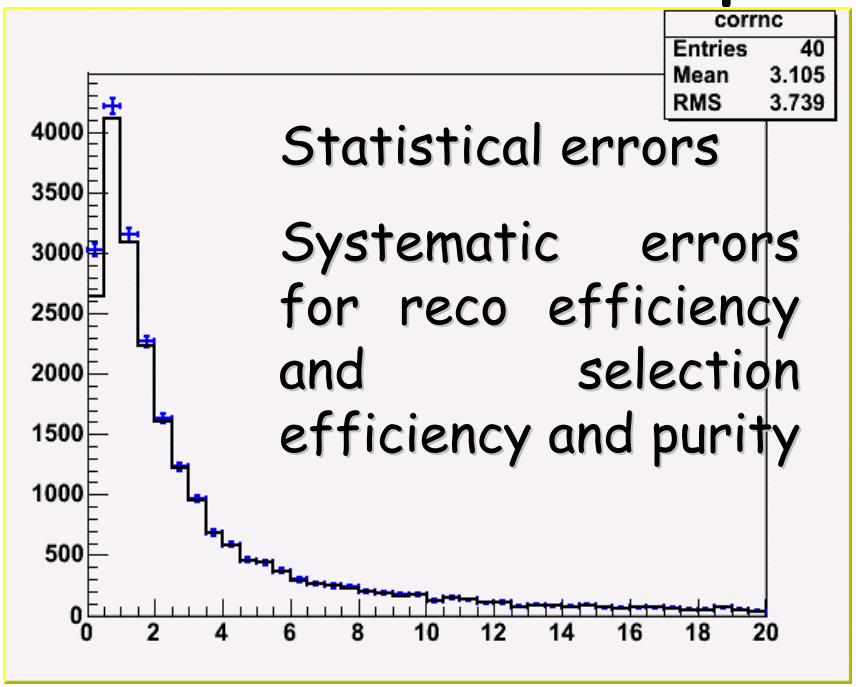
Purity

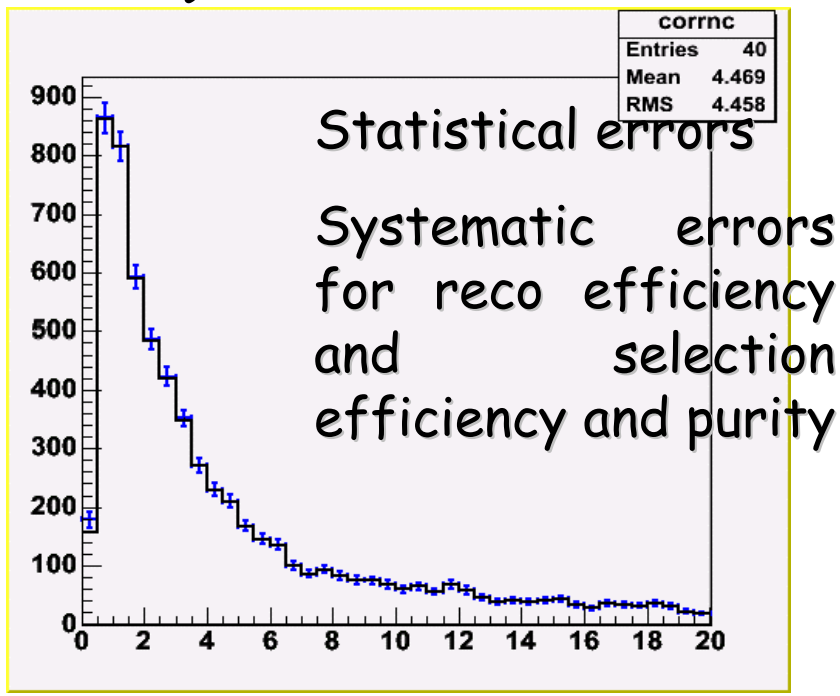


Efficiency x Purity

- Since results with ANN (and any method) truly differ it is important to
  - Train ANN that will be used for the Far detector with Far events
  - Construct maybe a more stable ANN
  - Get the best possible approximation to the oscillation parameters to tune ANN and by doing variations to them estimate the systematic error of the method.

Reconstructed NC spectrum in Near-Far(just simple exercise)





- **Black is true NC reconstructed spectrum** (as a function of "reco" energy which is doing funny things for NEAR and FAR) and blue is the estimated after correction for reconstruction efficiency, ANN selection efficiency and ANN purity.
- I did that as an exercise and surprisingly the results are quite close to the truth.

Summary / On going work

- The slicing and reco efficiencies are high for both NC and CC events and also very similar between Far and Near.

- The reconstruction lookes quite similar between Near and Far given the N-F difference in neutrino event characteristics.

- There is possibly something wrong in the way the Shower energy is estimated for Near and Far detector. The difference between Near and Far shower energy resolution is very big.

- The track momentum resolution is ~ the same between Near and Far.

- I started looking at selection efficiencies in Near and Far as well as systematic and statistical errors in the way I select events and I will have more results in the next meeting.