ND reco status + More…

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Outline

- **ND "language" (apologies if already known!)**
- **ND events processing : HOW TO… (apologies if already known!)**
  - Correct looping over ND "EVENTS"
  - Usage of very useful Event Displays
- **ND reco : things that seem OK (Data(!) & MC)**
- **ND reco : things that are not well understood.(Especially in Near Far comparisons)**
- **Remaining ND reco pathologies & HOW to find them.**
- **Summary & On going work.**

ND "language"

- In the ND we have a somehow more complicated structure (time & space) than in the FD, namely:
  - **Spills**
  - **Snarls**
  - **Slices**
  - Events
- Spill & Snarl should be more or less equivalent (I don't know all the details but experts do…)
- A Snarl will have multiple physics events from the different spill batches (a single batch will have multiple physics events and a spill will be made by several batches).
- A Slice "ideally" should be a single physics event. The selection ("Slicer" code) is based mainly on the timing properties of the different physics events & on space when physics events overlapping in time. If physics events overlapping in time & space we cannot separate them.
- A reco event will be track(s)+shower(s) generated from a Slice and corresponding to a different physics event.

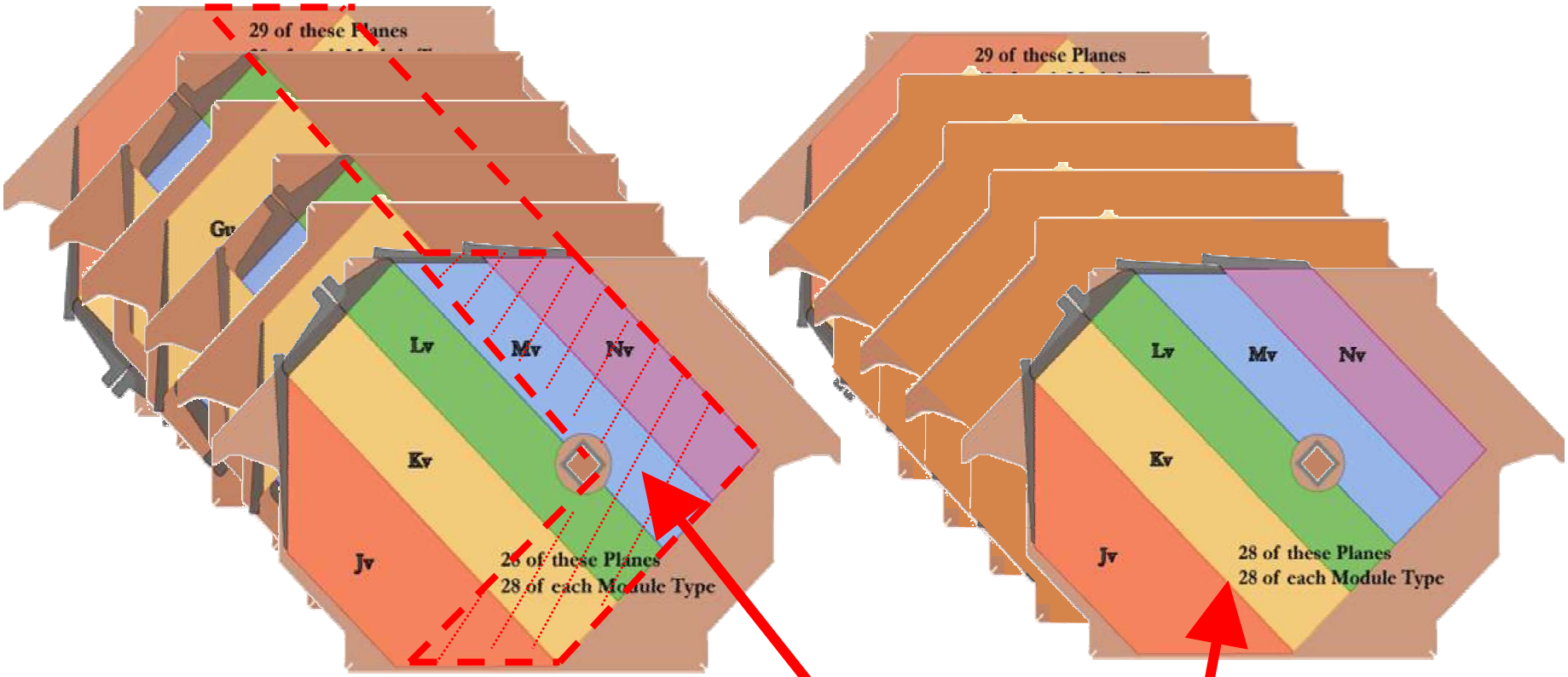
ND "language" (more on slices & events)

- Slices in the spectrometer (plexed region) will NEVER generate reco events (we cannot tell which of the 4 solutions is the correct one).

- Physics events are "reconstructable" if slicer has not split them in pieces. So it is better for the Slicer to "join" physics events than split them in two (or three) pieces.

- Therefore whether a physics event will be properly reconstructed or not depends on:
  - SLICER
  - RECO EFFICIENCY OF TRAKCS & SHOWERS

ND "language" : Detector geometry 1.



Upstream region : No plex, all planes instrumented, 1 every 5th plane fully covered with scintillator, divided into 3 logical regions:

VETO part (first 20 planes)

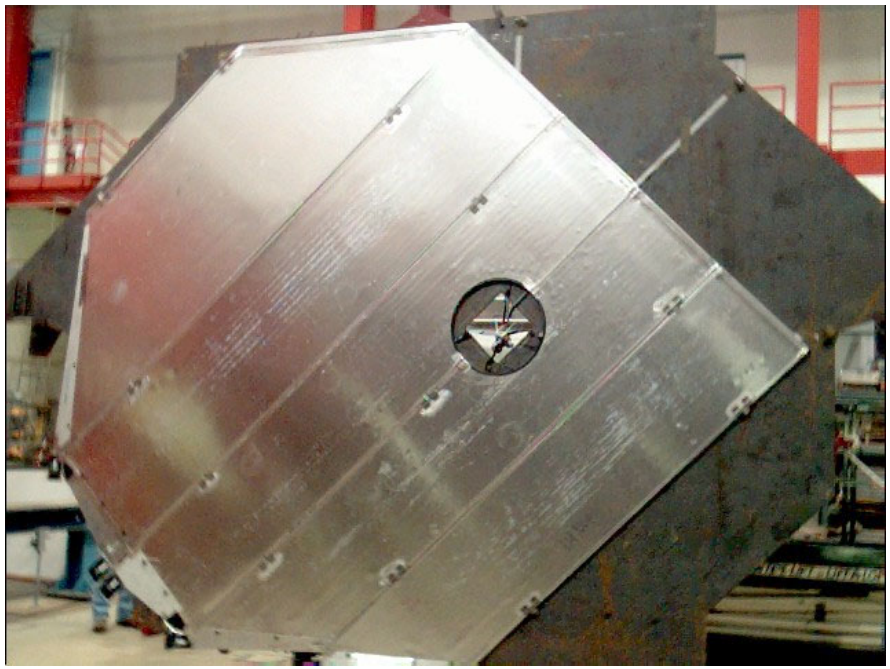
TARGET part (40 next planes)

CALORIMETER part (60 next planes)

SPECTROMETER part : x4 plex, **1 every 5th plane instrumented** & fully covered with scintillator, 162 planes in total.

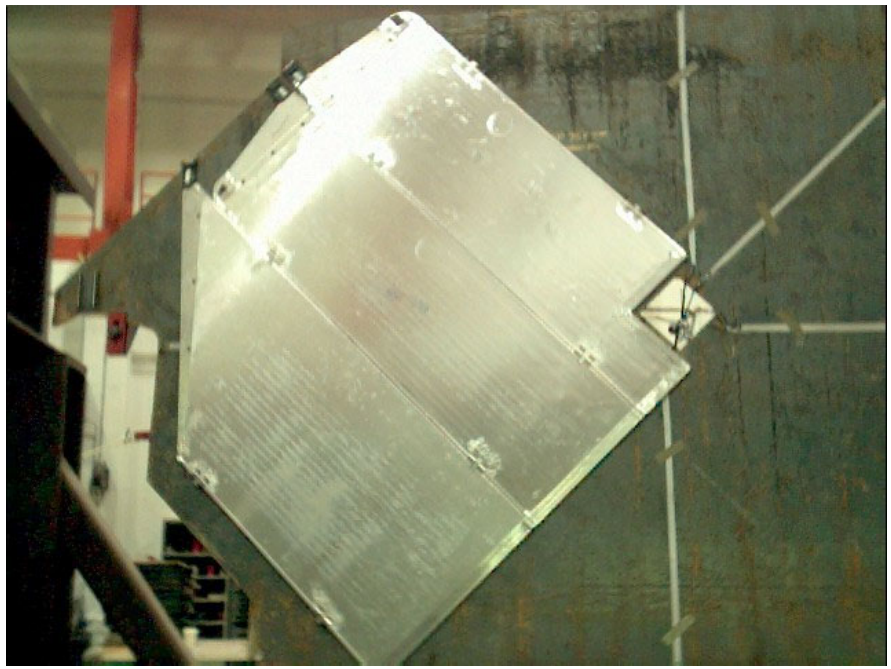
ND "language" : Detector geometry 2.

Fully-instrumented plane



"SPARSE DETECTOR REGION"

Partially-instrumented plane



"DENSE DETECTOR REGION"

ND Standard Ntuples: Why to know How to loop over reco events & which Release to use

- Regardless of whether people want (or going to) use the proposed Reduced (Universal) Ntuple Scheme it is useful to know how to do it (which is not that complicated) in order to understand what they and other people are doing, and more important in order to be able to check/correct/improve things…

- Releases from R1.12 and after are known to be better since a lot of "bug" fixing took place between them and older ones (splitting of tracks and showers in different events, Far beam demuxing tunning, Near & Far track Finder and Fitter corrections especially related with magnetic field corrections, Near Calibration chain corrections + others that I cannot remember).

- Therefore it would be better to try to understand reconstruction and reco failures using R1.12 and after.

- For DATA processing development should be used untill R1.14 is tagged since IMPORTANT bug fixes related with Strip formation Slice formation and in general sorting in time of any array are made.

ND Standard Ntuples:How to loop over reco events

- Each entry in the Standard ntuples (NtpSR NtpTH NtpMC) is the SNARL (corresponding to the physical SPILL).
- NtpMC has all true physical events of each spill along with their truth info.
- NtpSR and NtpTH has all reco Slices & Events of each spill along with strips, tracks & showers.

- Each Slice (entries of slc & thslc[slc.index] array) basically has its corresponding strips.
- Each Event (entries of evt and thevt array) basically has its corresponding:
  - Strips (Index to the STP ARRAY : evt.stp thstp [evt.stp])
  - Tracks (Index to the TRK ARRAY : evt.trk thtrk [evt.trk])
  - Showers (Index to the SHW ARRAY : evt.shw thshw[evt.shw])
  - Index of Slice that came from :
    (Index to the SLC ARRAY : evt.slc thslc[evt.slc]

How to loop over reco events

(for R1.13 & below taken from my script based on Sue's webpage)

```
TFile *mcfile=TFile::Open(fileList[ifile].c_str(),"READ");
TTree* mctree = (TTree*)(mcfile->Get("NtpMC"));  // mc truth
TTree* srtree = (TTree*)(mcfile->Get("NtpSR"));  // reconstruction
TTree* thtree = (TTree*)(mcfile->Get("NtpTH"));  // truth helper
srtree -> AddFriend(thtree);
srtree -> AddFriend(mctree);
// Set the branch addresses where data will be stored on GetEntry
NtpSRRecord* srrec = 0;
srtree -> SetBranchAddress("NtpSRRecord",&srrec);
NtpMCRecord* mcrec = 0;
srtree -> SetBranchAddress("NtpMCRecord",&mcrec);
NtpTHRecord* threc = 0;
srtree -> SetBranchAddress("NtpTHRecord",&threc);
// Loop over entries of the NtpSR tree
Int_t nentries=srtree->GetEntries();
 for (int ient = 0; ient < nentries; ient++ ) { // nentries
   std::cout << " NEW ENTRY  " << ient << std::endl;
   srtree -> GetEntry(ient); // pulls in SR & matching TH/MC entries
   TClonesArray& mcarray    = *(mcrec->mc);
   TClonesArray& thevtarray = *(threc->thevt);
   TClonesArray& stdheparray= *(mcrec->stdhep);
   TClonesArray& thslcarray = *(threc->thslc);
   TClonesArray& evtarray   = *(srrec->evt);
   TClonesArray& trkarray   = *(srrec->trk);
   TClonesArray& shwarray   = *(srrec->shw);
   TClonesArray& stparray   = *(srrec->stp);
```

How to loop over reco events : example script (for R1.13 & below taken from my script based on Sue's webpage) cont'd

```
for(Int_t  ii=0;ii<evtarray.GetEntries();ii++){
     NtpSREvent  * ntpevent  =dynamic_cast<NtpSREvent*>(evtarray[ii]);
  // these entries and the sr entries are the same

     NtpTHEvent* ntpthevent=dynamic_cast<NtpTHEvent*>(thevtarray[ii]);
     Int_t ind=ntpthevent->neumc;

     NtpMCTruth* ntpmctruth=dynamic_cast<NtpMCTruth*>(mcarray[ind]);
     Int_t indmc= ntpmctruth->stdhep[0];

     NtpMCStdHep* ntpstdhep =dynamic_cast<NtpMCStdHep*>stdheparray[indmc]);
     Int_t slicenum=ntpevent->slc;

     NtpTHSlice* ntpthslice=dynamic_cast<NtpTHSlice*>(thslcarray[slicenum]);

slcpurity =ntpthslice->purity;  // SLICE PURITY OF THE SLICE THAT GENERATED THE RECO EVENT

mctyp     =ntpmctruth->iaction; // MC TRUTH TYPE (CC/NC) OF MC EVENT THAT GENERATED THIS
                                // RECO EVENT

tottrk    = ntpevent->ntrack;   // NUMBER OF TRACKS THAT THIS RECO EVENT HAS

 for(Int_t k=0;k<tottrk;k++){ // LOOP OVER THE TRACKS THIS RECO EVENT HAS
       NtpSRTrack *ntptrack = dynamic_cast<NtpSRTrack*>(trkarray[((ntpevent->trk)[k])]);
       trkrange             = ntptrack->momentum.range; // MOMENTUM FROM RANGE OF THE
                                                        // TRACKS THAT THIS RECO EVENTS HAS
  }
 } // FOR EVT ENTRIES
}// FOR TREE ENTRIES
```

Event Displays…

- We all have an event display which we love and trust like our supermarket… This event display might (and usually does) have advantages and features satisfying our own analysis purposes that we might (rarely) not find in the most known two event displays.

- However for

  - Examining reconstruction quality

  - Understanding the characteristics of the physical events and the reco slices, events tracks e.t.c

  - Understanding the timing properties of our detector as well as the geometrical ones

the two most known event displays EVD and MAD are an excellent tool.

Event Displays: When to use each

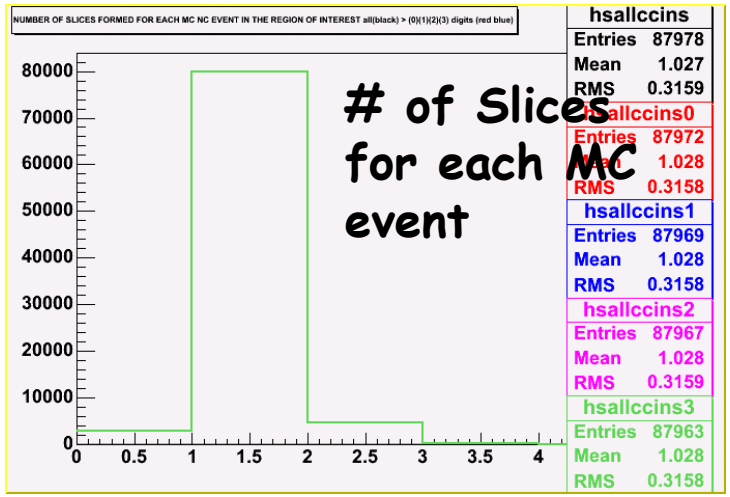
- MAD can be used in reco ntuples and candidate files and so far it loops over reco events for the Near Detector. I have used it and it is simple and useful.
- EVD can be used in :
  - Candidate files using the same cuts that one would use in the reco ntuples and with the freedom to a) loop over events without modifying them b) loop over events after performing part of the reconstruction chain (i.e just tracking keeping digit making, strip making, slice making and shower making as it is). c) loop over events redoing the whole reconstruction chain.
  - Data & rerooted MC files performing the whole reconstruction chain.
- EVD can loop over reconstructed events or reconstructed slices and show (among other things) the details of the timing distribution of ND Snarls, Slices and Events.
- I have used EVD extensively and it is simple and very useful.

Event Displays: How to use each

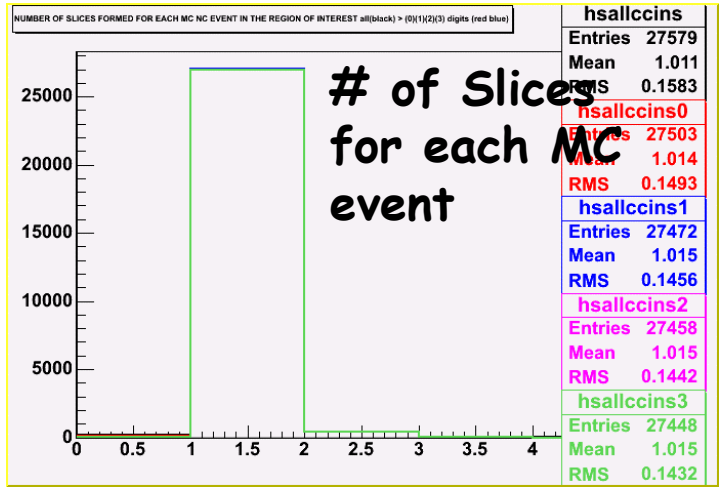
- In order to use MAD compile and link in your test release as described in Chris's Webpage.
- Use the correct script in the EvDisplay.C script and loon it.
- In order to use EVD, loon EVD.C from the EventDisplay package and for performing various tasks read Jim's EVD User Manual.
- Both of them are very well documented & easy to use.

ND Reconstruction : things that are understood and seem OK.

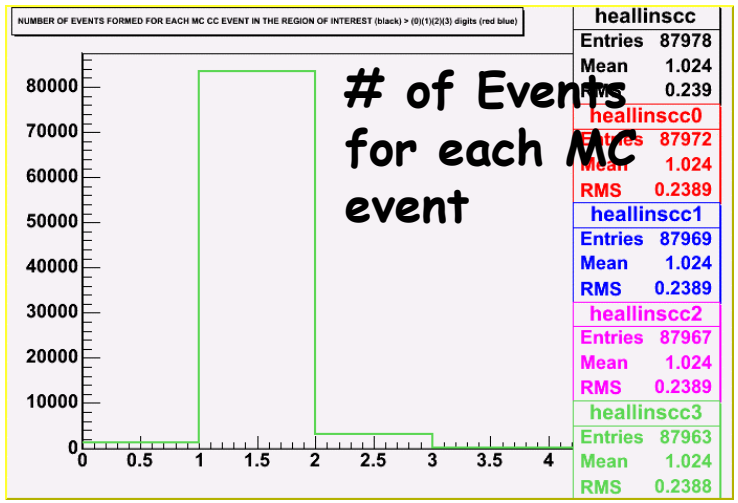
Slicing & reco efficiencies for CC events: Total Numbers



SLICE

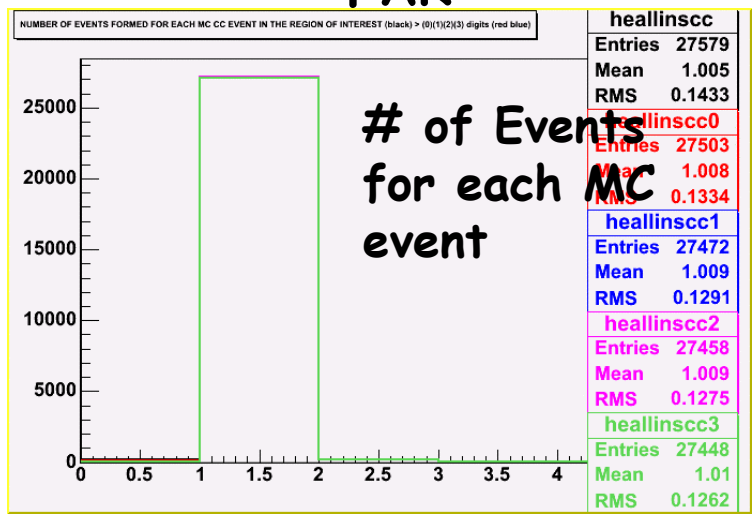


NEAR



RECO

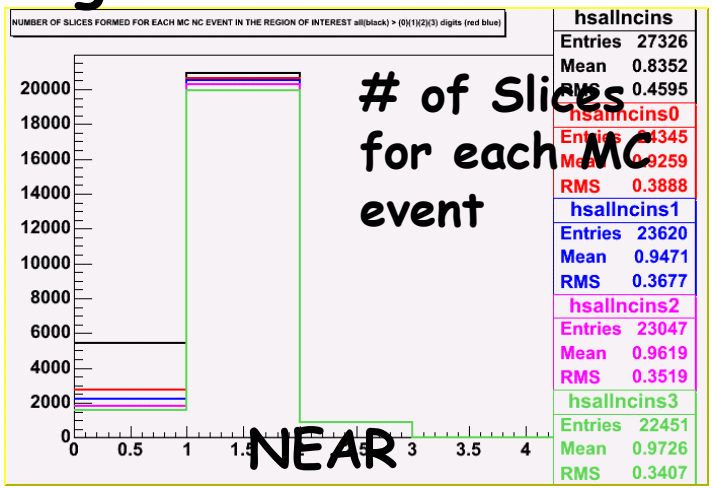
FAR



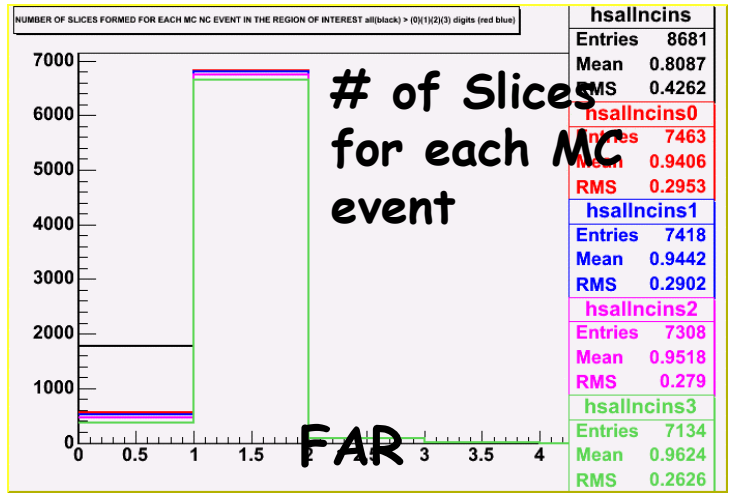
- The slicing & reco efficiencies for CC events for both near and far is very high, practically all CC events end up in a slice.

ND Reconstruction : things that are understood and seem OK.

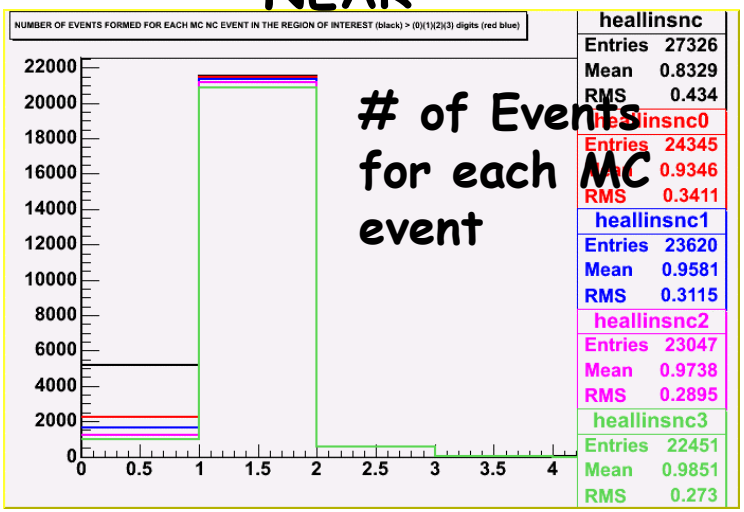
Slicing & reco efficiencies for NC events: Total Numbers



SLICE

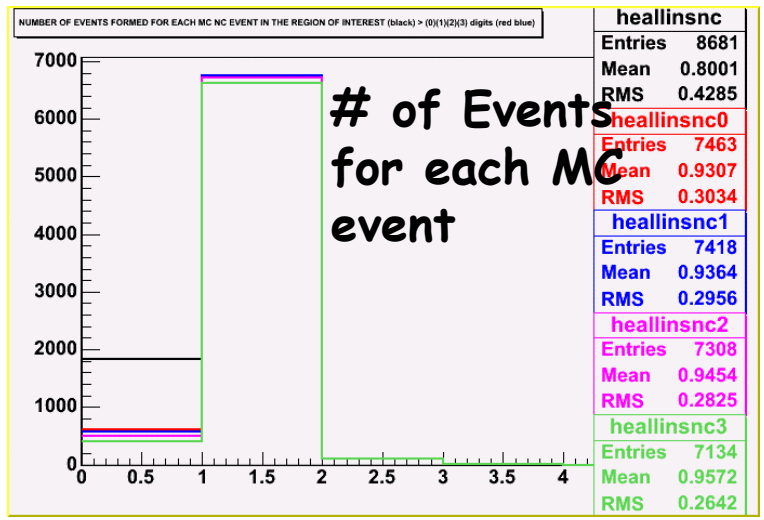


NEAR



RECO

FAR



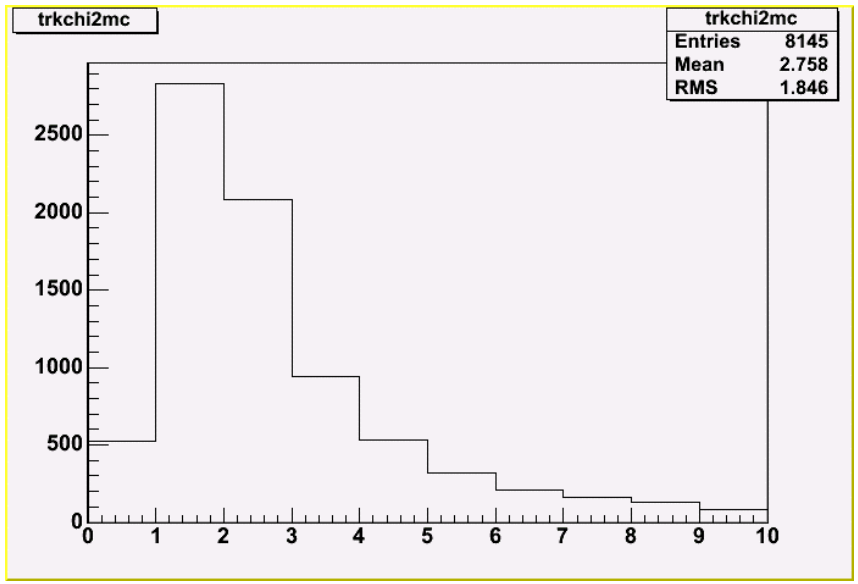
- Slicing & reco efficiency for NC events that have at least 2 digits per view is high for both Near (95 %) and Far (94%)

Slicing & Reco Efficiencies : Summary

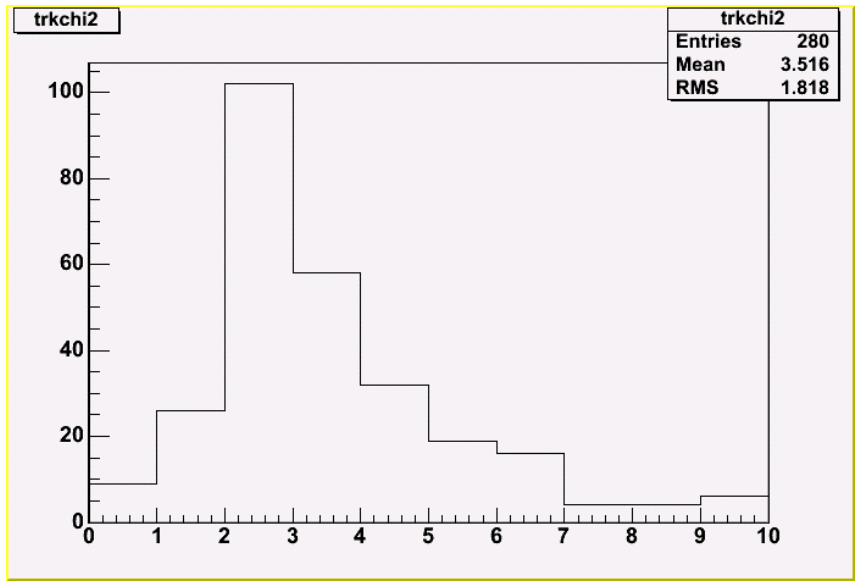
- After imposing a simple "digit" cut (at least 2 digits in each view) the final reconstruction efficiencies (slicing efficiencies included) are for both Near and Far Detectors high and comparable :
  - 99 % for CC Events
  - 95 % for NC Events
- The NEAR detector "shows" a slightly higher reconstruction efficiency for NC most probably due to double counting of split MC events.
- So far I am just asking the simple question : "Does every MC has a corresponding slice & reco event?"
- I am not examining quality of reco slices and events

ND Reconstruction (data): things that are understood and seem OK

Event characteristics : Track Chi-square (All tracks)



Track chi-square: MC

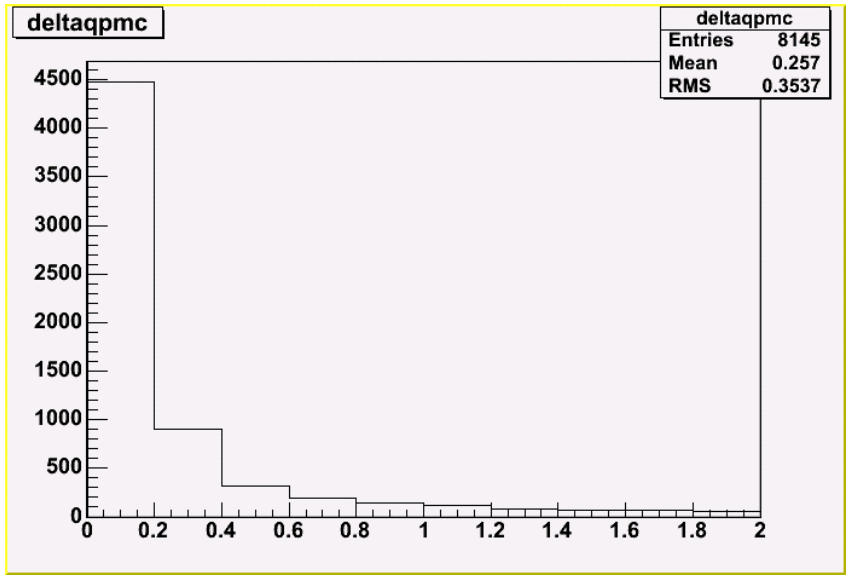


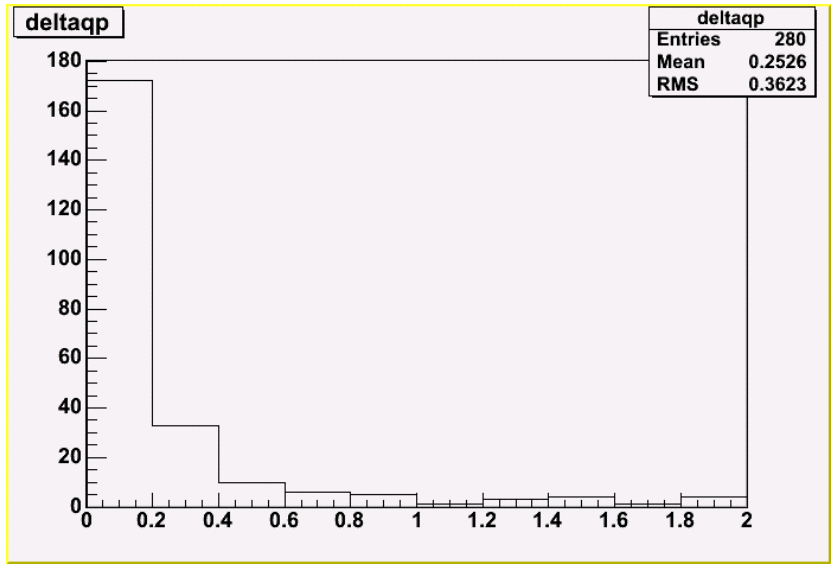
Track chi-square : DATA

- Track chi-square for DATA larger than MC as expected. The magnetic field we are using to reconstruct is the nominal one but the true magnetic field is not the nominal one.
- Re-examine of course when nominal field ON and more data available.

ND Reconstruction (data): things that are understood and seem OK

Event characteristics : Track sigma(q/p)/(q/p) (All tracks)



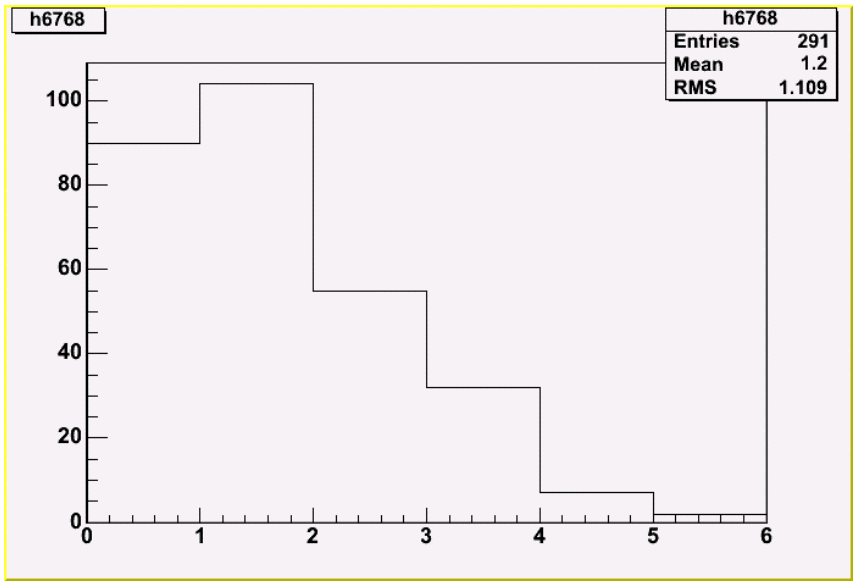


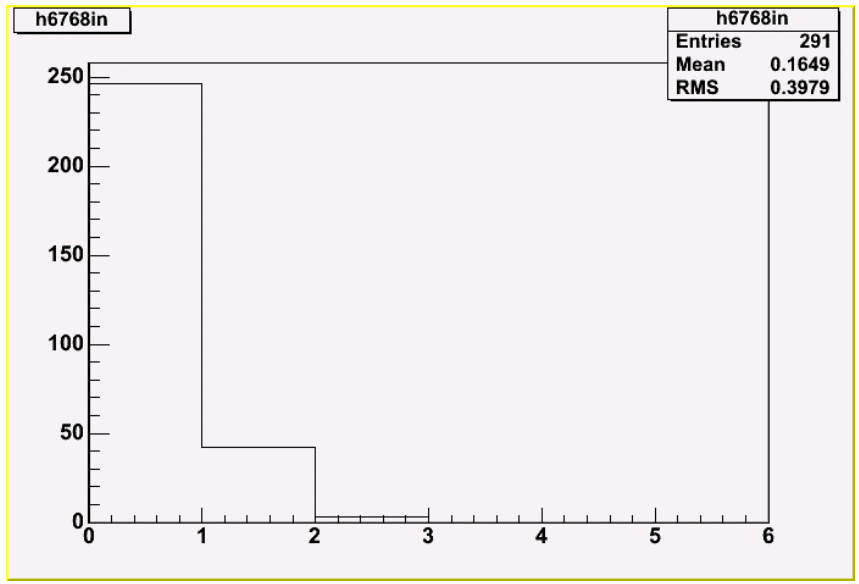
Track sigma(q/p)/(q/p) : MC **Track sigma(q/p)/(q/p) : DATA**

- **Track sigma(q/p)/(q/p)** is similar between data and MC although we are not using the correct field map…
- Re-examine of course when nominal field ON and more data available.

ND Reconstruction (data): things that are understood and seem OK

Event Numbers PRELIMINARY : observed events per spill





Total events per spill, mean at 1.2, ~1.3 expected

Total events per spill satisfying track and fiducial cuts, mean at 0.17 ~ 0.19 expected

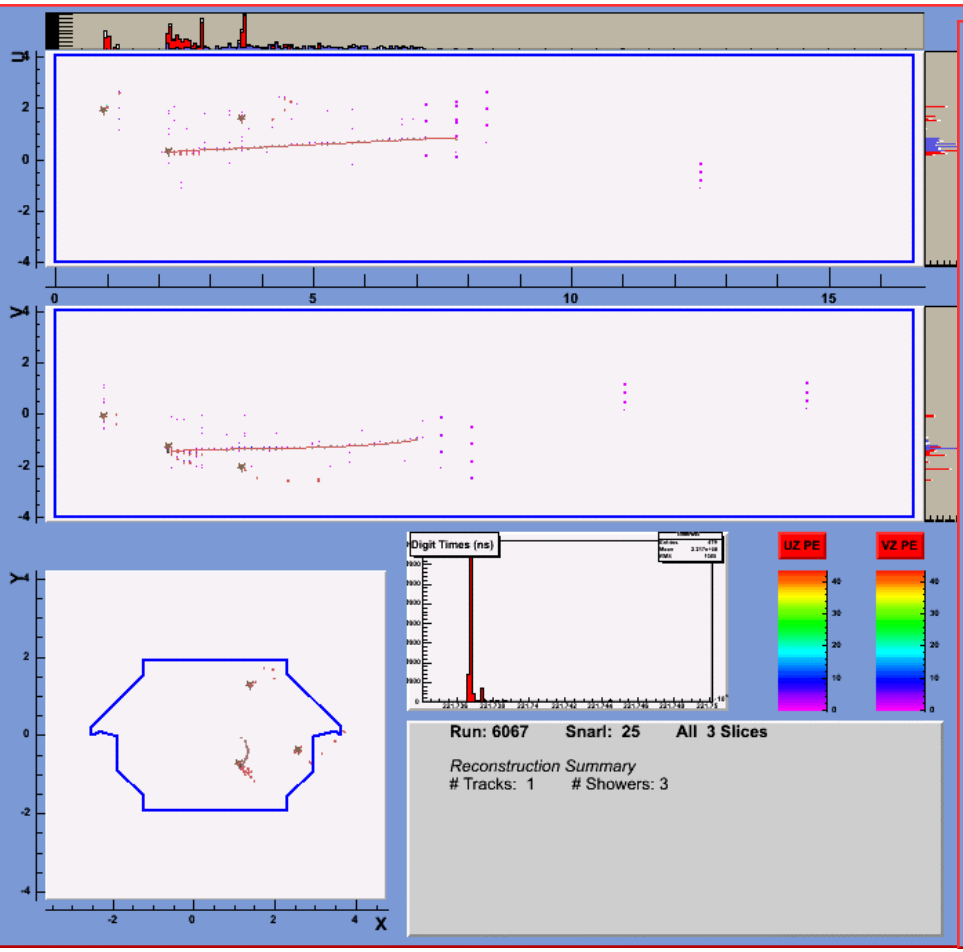
Visual Scan of the Events

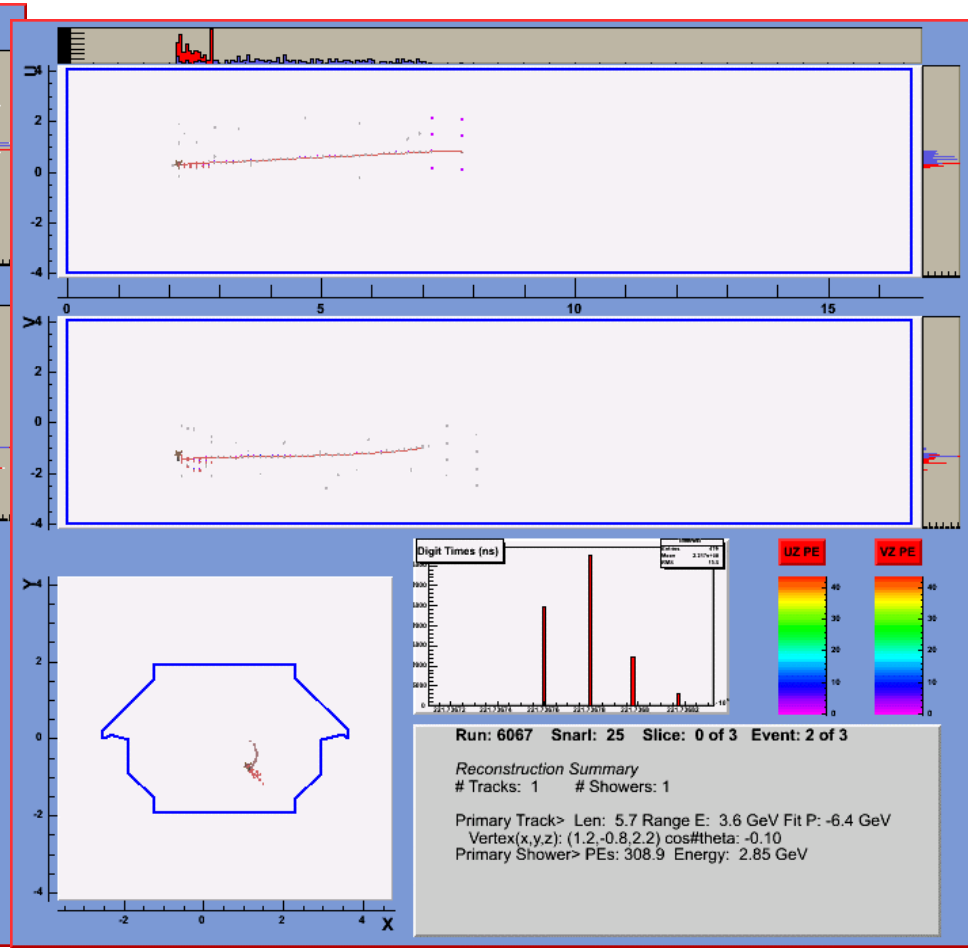
- So far what we see is close to what we expect…(preliminary results that are going to be checked and studied again).

- From a visual scan of many events and in particular here the first 10-15 which satisfy the fiducial cuts the reconstruction seems to be doing a quite decent job with a few failures of course that need to be checked more carefully and in detail.

- I just show in the next page these first 10-15 events…

Run 6067 Snarl 25 Event 1

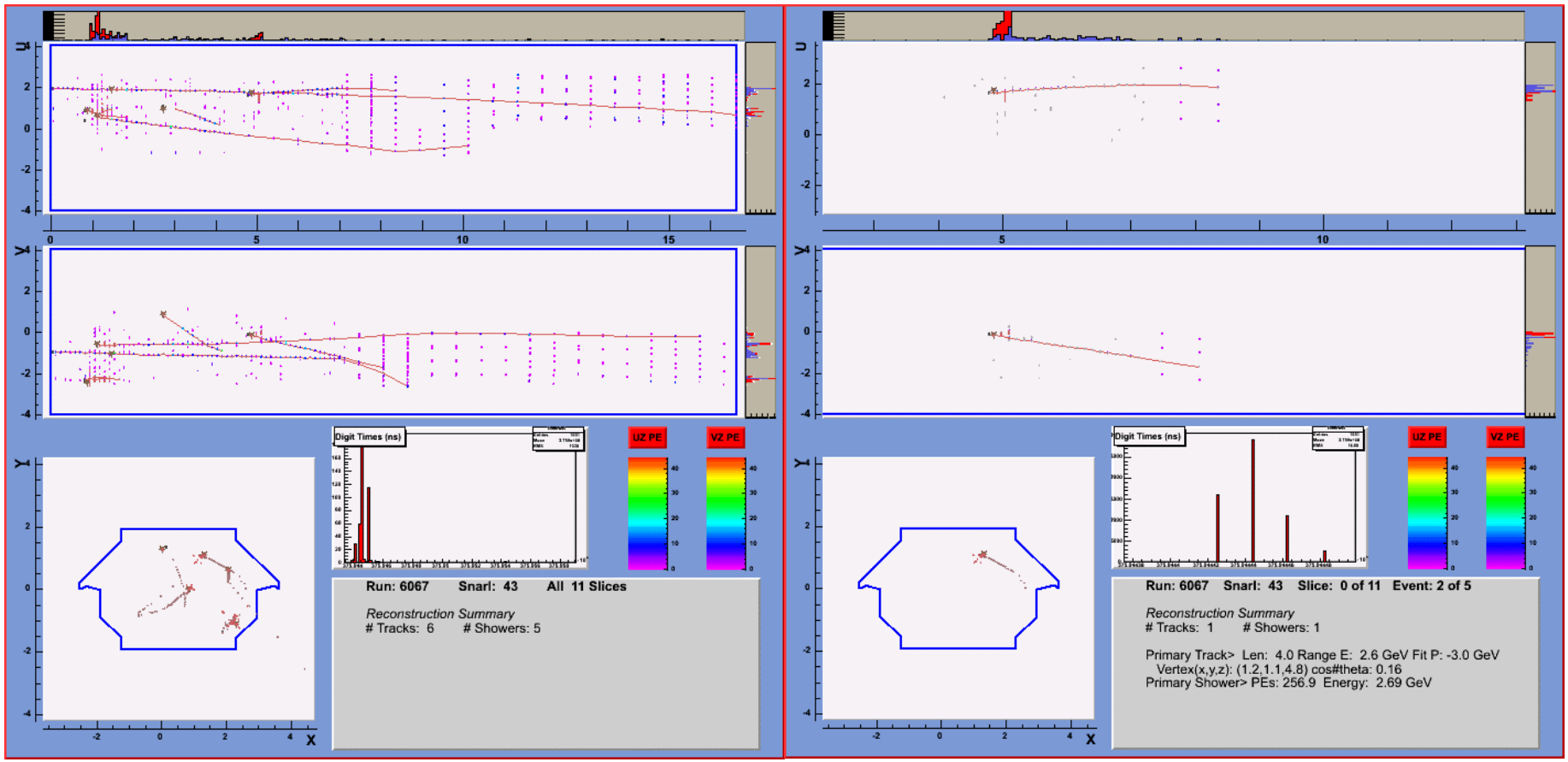




SPILL

EVENT

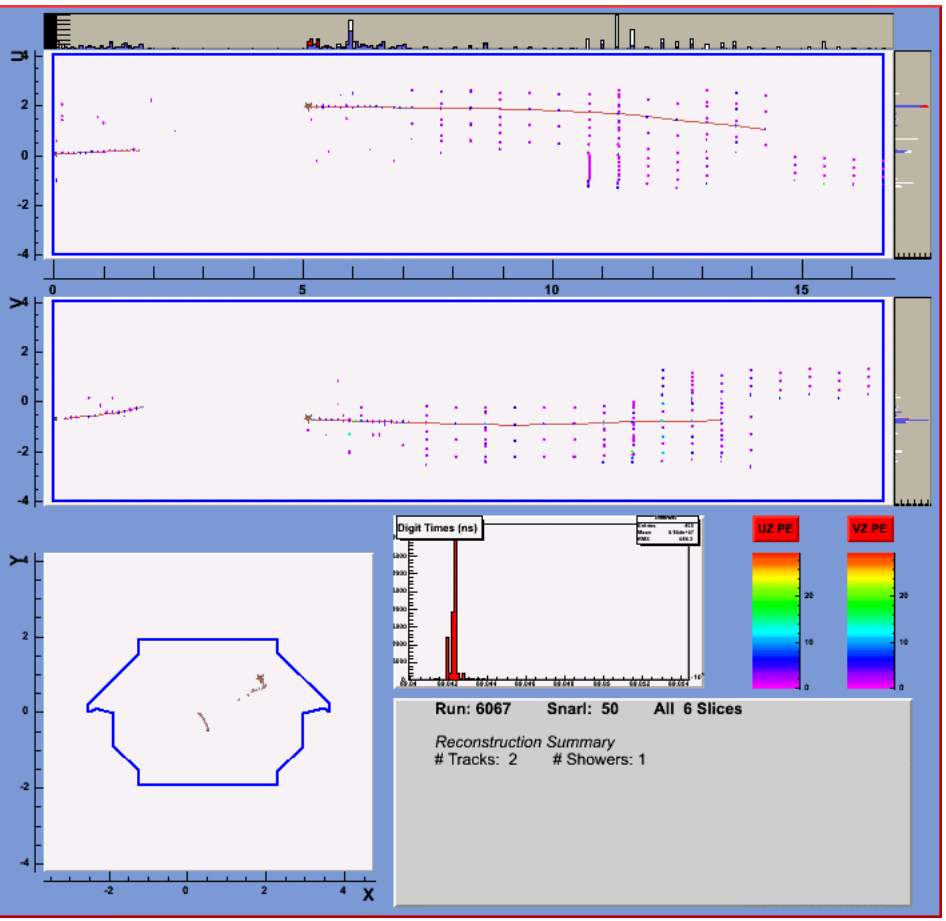
Run 6067 Snarl 43 Event 1



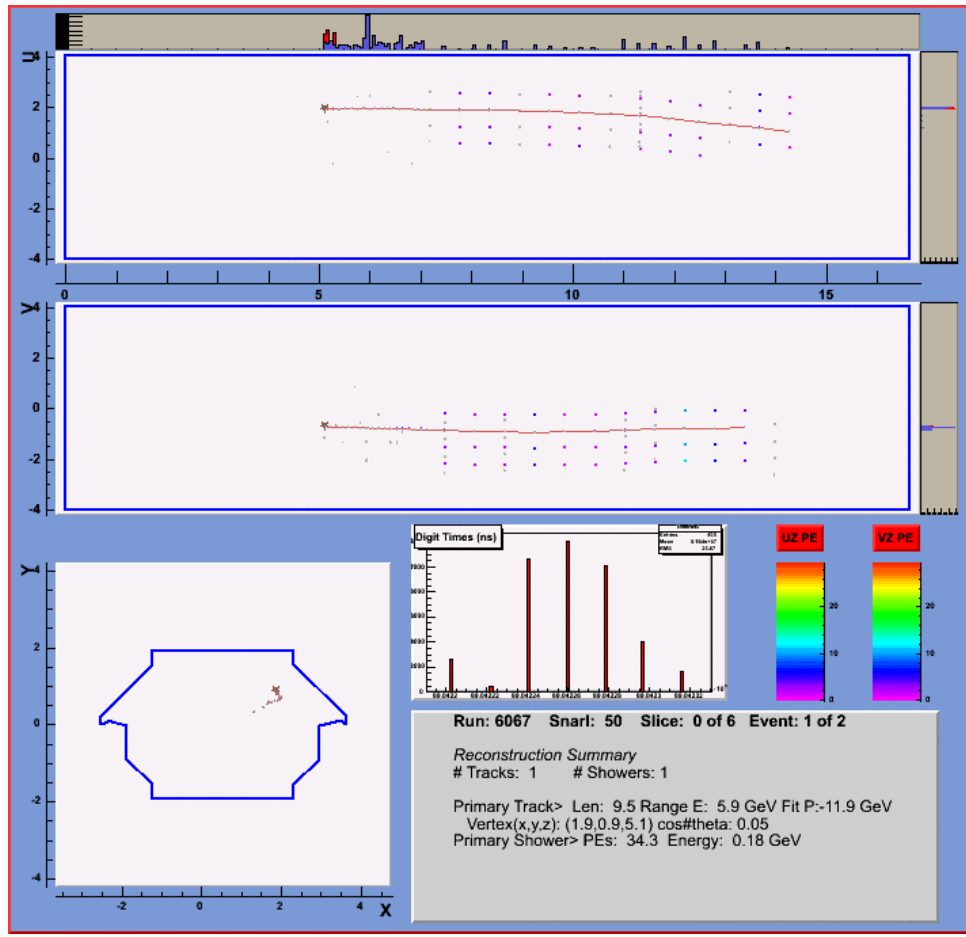
SPILL

EVENT

Run 6067 Snarl 50 Event 0

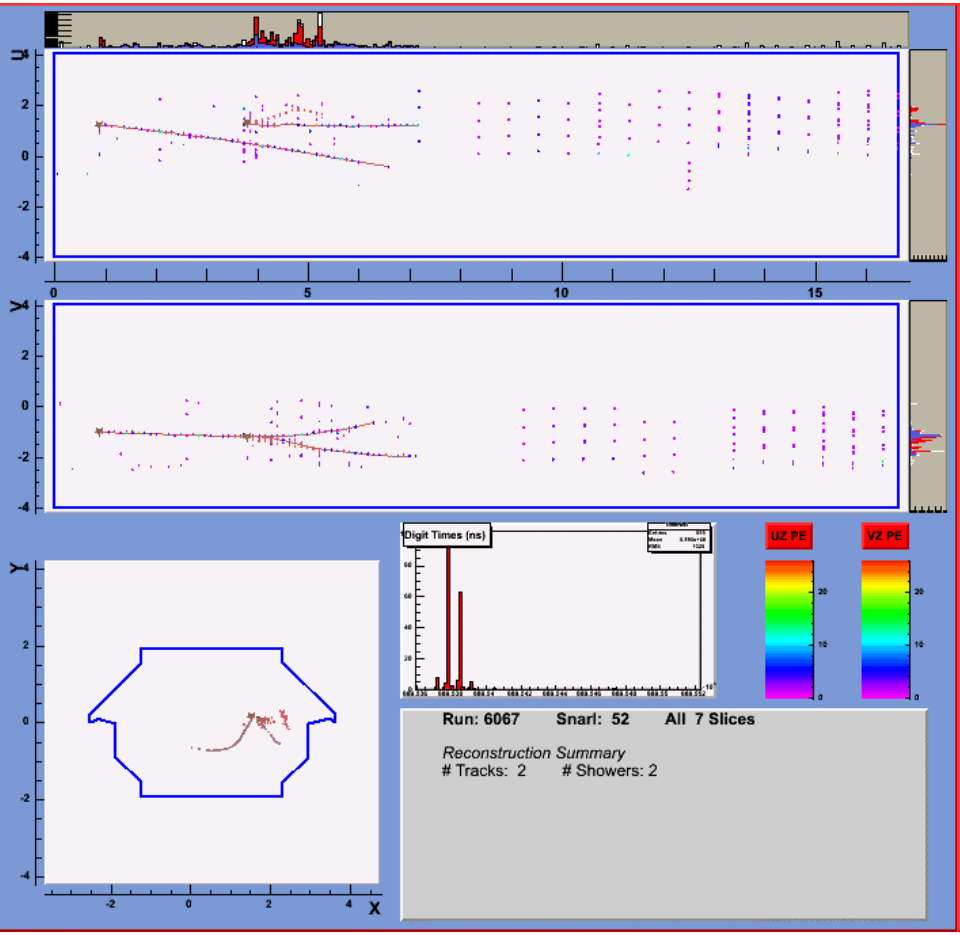


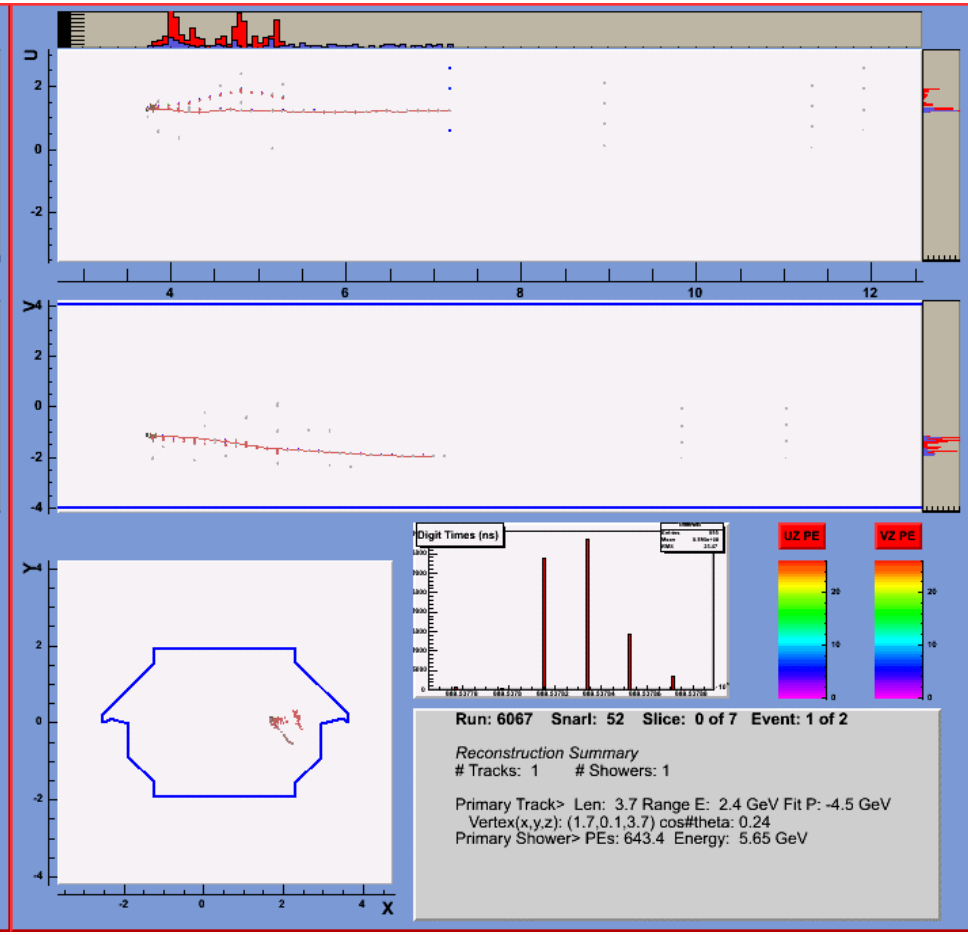
SPILL



EVENT

Run 6067 Snarl 52 Event 0





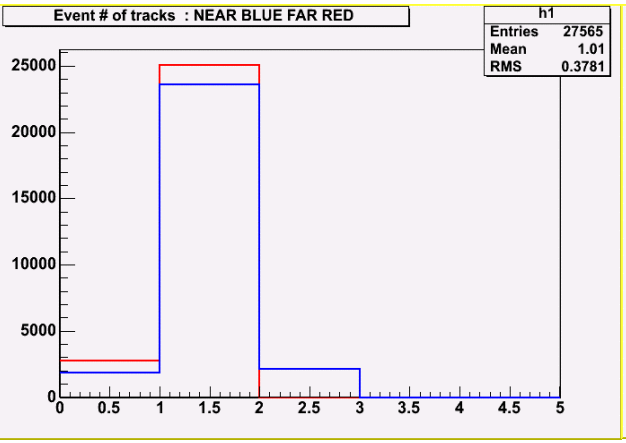
SPILL

EVENT

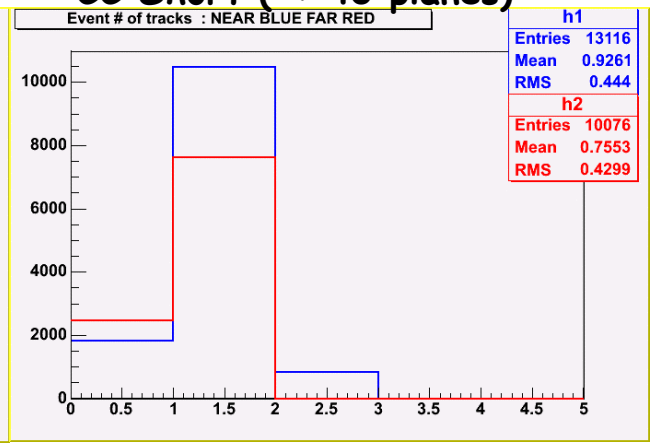
ND Reconstruction, things that are not yet well understood

Number of Tracks for CC & NC Events Near – Far

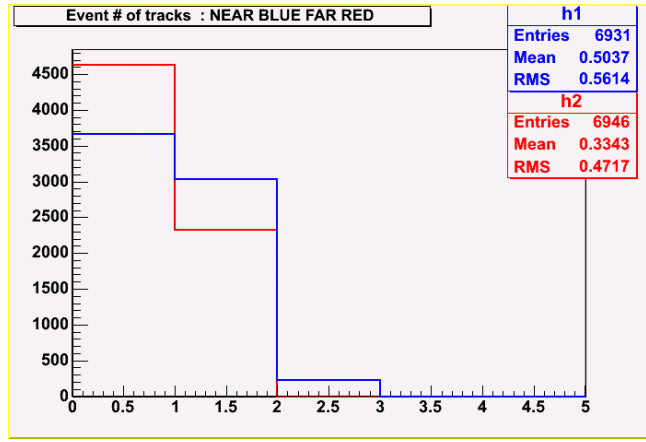
CC All



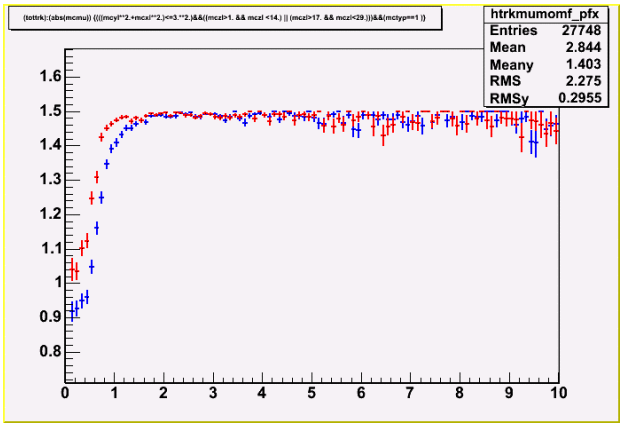
CC Short (< 40 planes)

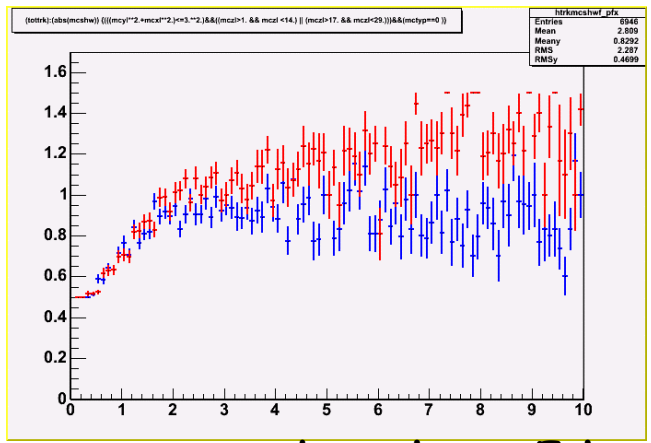


NC All



COLOR CODE : RED NEAR - BLUE FAR



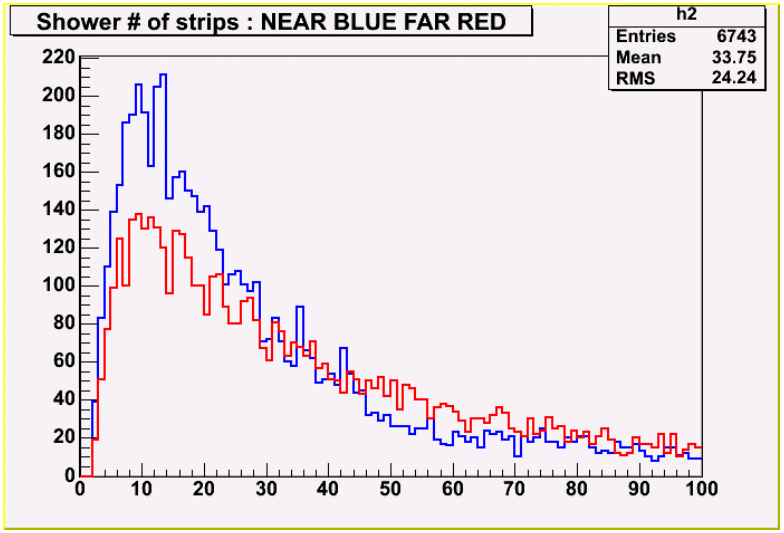


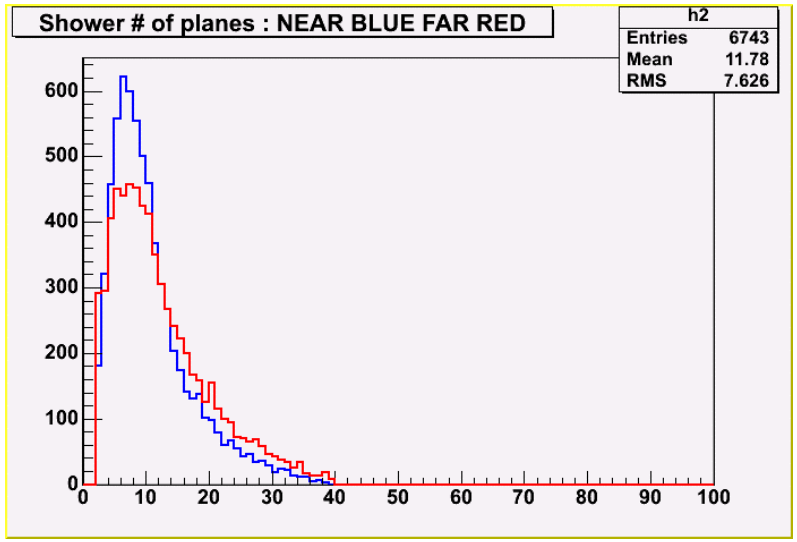
CC : % reconstructed tracks vs Pmu true **NC : % reconstructed tracks vs Eshw true**

- The percentage of reconstructed tracks in the NEAR detector is higher than in the FAR and that is not a geometric effect. It is due to the looser reconstruction code cuts for the NEAR detector. (Me & Panos are currently working on that and will have results soon)

ND Reconstruction, things that are not yet well understood

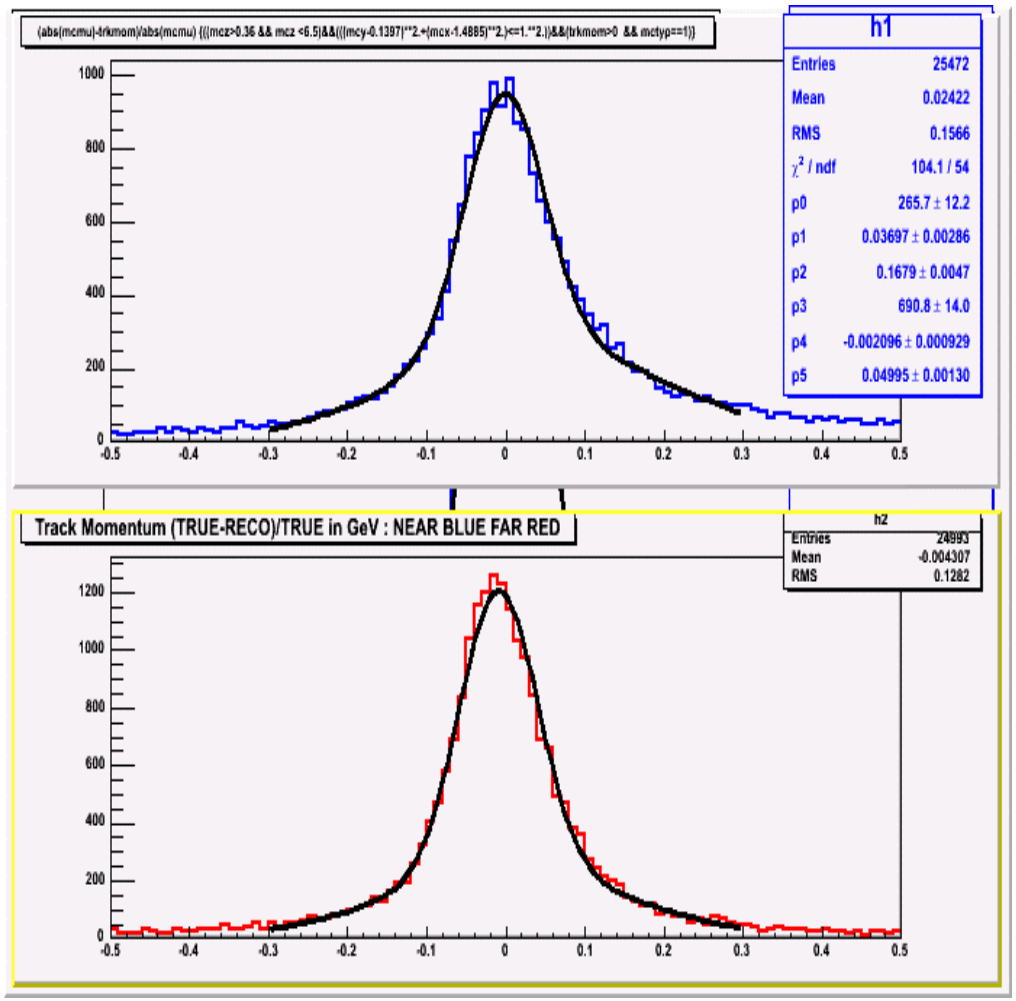
Shower # of strips & # of planes for NC events Near – Far





- The fact that the FAR detector has in general larger showers needs investigation.
- Me & Panos are currently working on that . Other volunteers are welcome.
- Chris and Hai recently committed their alternative code for shower reconstruction . It would be interesting if someone could perform the same comparison using their new package.

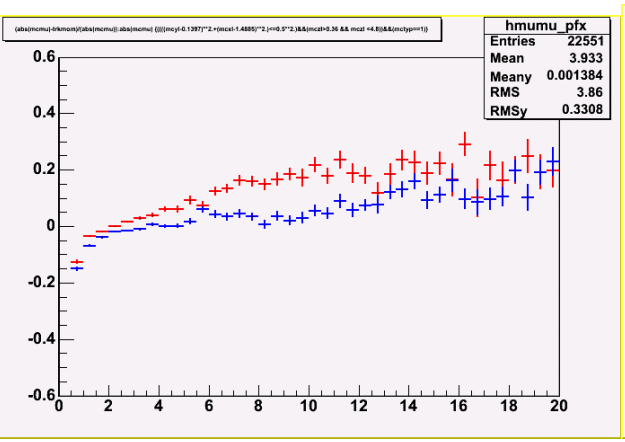
ND Reconstruction, things that are not yet well understood
Momentum resolution (ALL CC Events) Near – Far

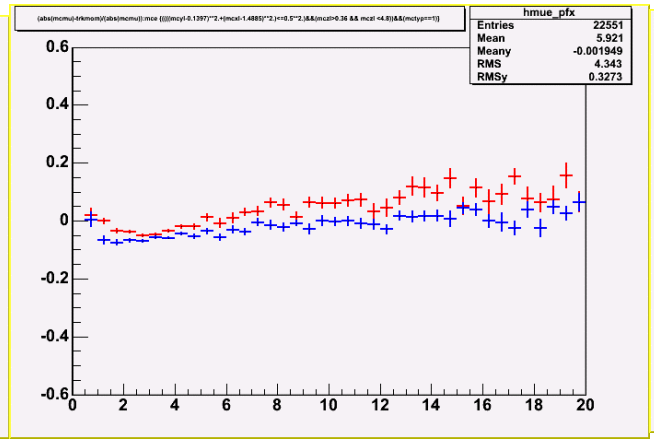


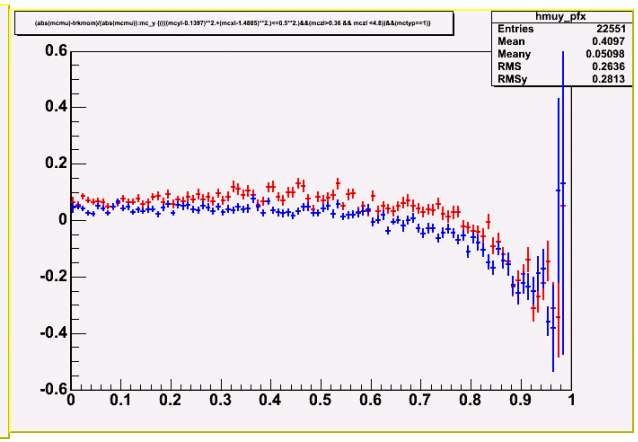
- Muon momentum in NEAR detector slightly more asymmetric (maybe not very efficient "stopping track definition given the difficult Near detector geometry).
- In general resolution of the order of 11%-12% for both detectors and Near – Far short of similar.
- Near detector has systematic overestimated muon energy most probably due to smaller size:
  - True exiting tracks in Near Detector might appear as "contained in the detector" in which case I calculated momentum from range.
  - Should plot separately momentum from curvature and momentum from range to better study – understand differences,

ND Reconstruction, things that are not yet well understood

Estimated muon momentum (Dp/p) vs Pmu Enu and Y Near – Far





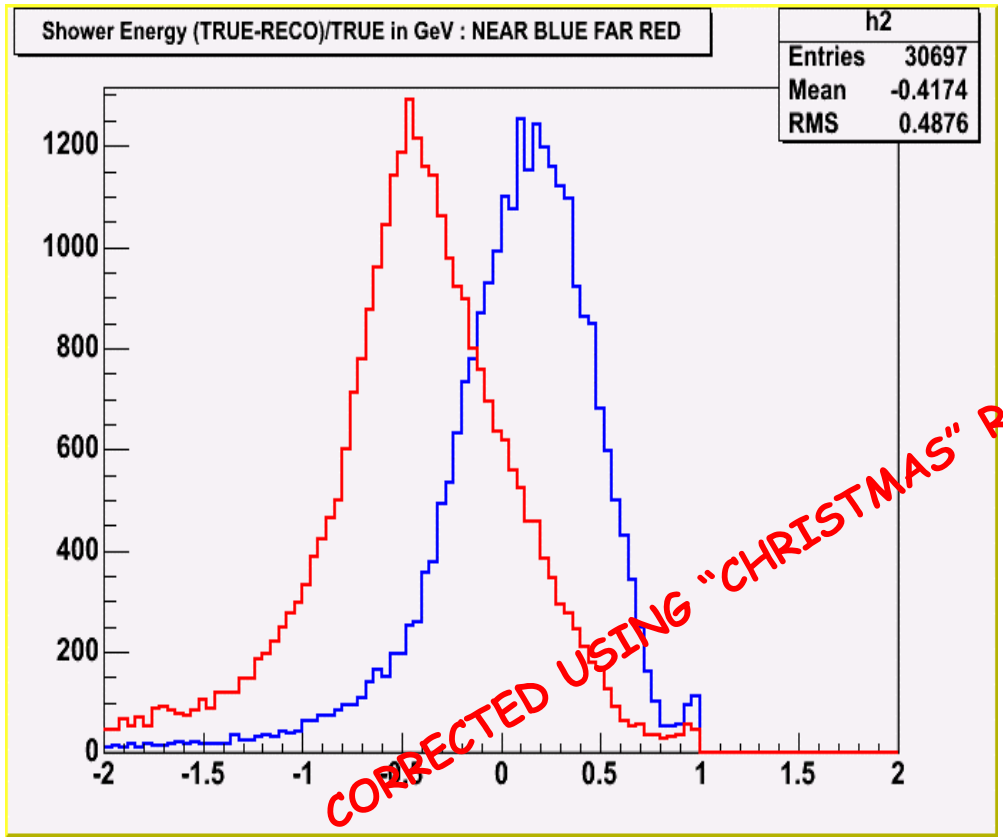


COLOR CODE : RED NEAR - BLUE FAR

- Profiling histograms of Dp/p (True – Reco/True) vs Pmu true, Enu true and Y.
- Near detector shows systematically lower estimated muon momentum than true and than the FAR detector.
- Alysia Marino is currently working on correcting estimation of momentum from range that is currently incorrect and different for Near & Far (due to different geometry of dense and sparse regions).
- I am looking into that from a different perspective more track reconstruction related.

ND Reconstruction, things that are not yet well understood

Shower energy resolution (ALL Events) Near – Far

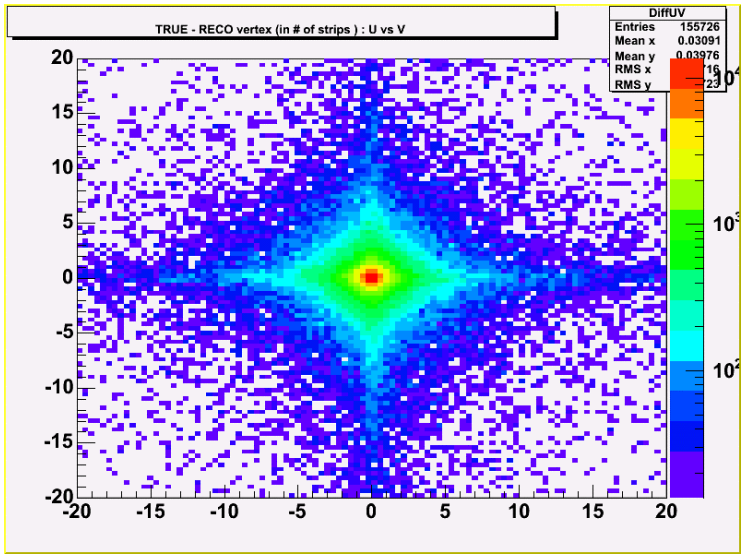


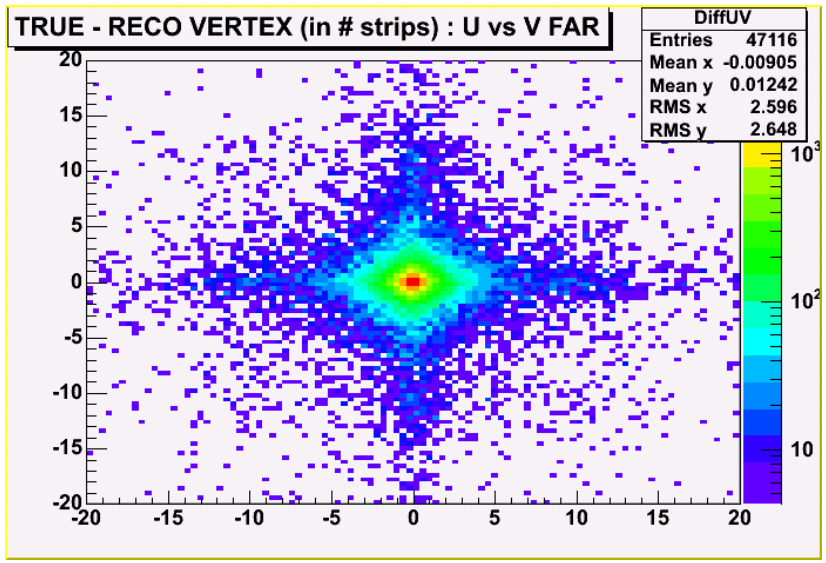
- Shower energy resolution in GeV (shw.ph.gev) makes no sense.
- Near and Far detectors are completely off with respect to each other and off from zero.

  Near Detector Calibration code was using wrong strip coordinates. This is now corrected and needs one more pass of ALL near MDC files to examine the effect of the correction.
- Differences in the shower energy estimation need to be minimized to avoid energy shifts between Near and Far detectors. This need to be studied.

ND Reconstruction, things that are not yet well understood

Vertex finding precision





Near Far

Difference in number of strips of True – Reco U vs V vertex

- Near vertex finding is slightly worse than Far and the outliers need to be investigated & if possible corrected given our simple event structure.
- Mike pointed out in the previous reco meeting that such inefficiencies might heavily affect analyses dealing with high energy ND events.

ND Reconstruction, things that might need constant improvement (if possible!!) found by Visually Scanning Events!

Track finding

- There are remaining tracking failures (relatively small percentage) especially in the spectrometer and sparse area of the detector that need to be fixed (if they are fixable without cost).

- Mike & Brian showed interest (in the previous reco meeting) on writing code that would allow the track finder to "know" if it is entering the sparse or dense area of the detector and thus adjust tracking cuts accordingly. Such a method does not currently exist.

- That would most probably improve tracking in the sparse area but not the spectrometer since the later is a well defined area as far as the tracking code is concerned. Failures in this region could also originate from Slicing.

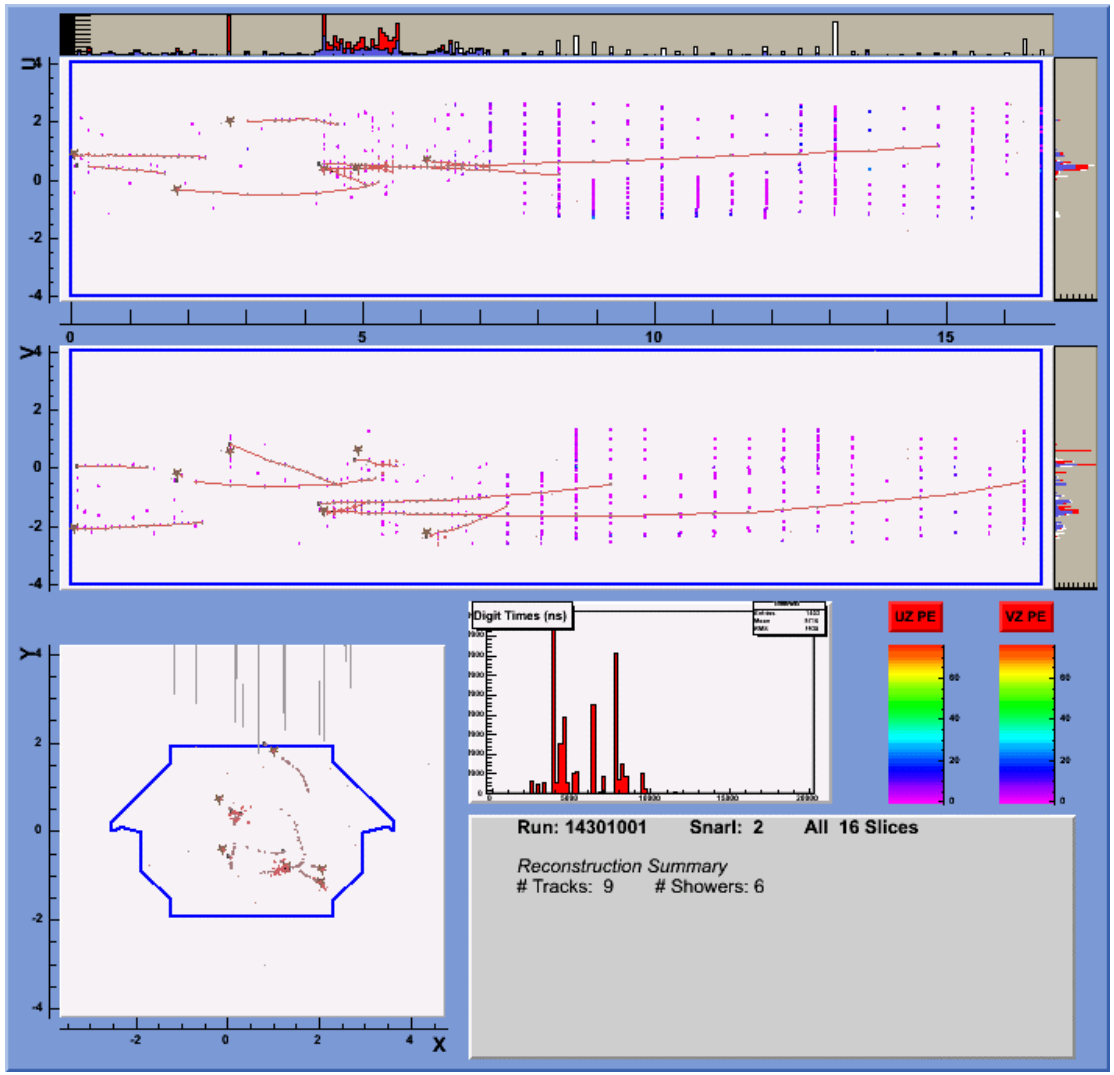
ND Reconstruction, things that might need constant improvement (if possible!!) found by Visually Scanning Events!

Snarl Slicing

- So far Slicing has been examined using overall characteristics of the events such as Purity & Completeness.
- It is useful to visually examine Slicing performance using all available Slicers (SR ASAP & MST) in MC and also existing available data.
- Existing ND Data might be limited but is very important to Visually examine events and make sure that there are no significant slicing failures (as well as tracking & vertexing).
- If Slicing failures are found people should notify Tom O for the SR and me for the ASAP and MST slicers.

ND Reconstruction, things that might need constant improvement (if possible!!) found by Visually Scanning Events!

Events will look like …



- This!
- 2.5 x 10^{13} POTs per spill which meanse 6-7 physical events on the average in the calorimeter region
- Therefore careful examination and visual scanning of events is needed in order to make sure that we understand and are satisfied with the ND reconstruction.

On going work

- **Understanding of Near Far reco differences:**
  - **Tracking efficiency : Me & Panos**
  - **Track Momentum estimation : Me & Alycia**
  - **Shower reconstruction : Me, Panos + ?? to test Chris-Hai package**
- **Near – Far Calibration : ??**

(Do calibration chains in two detectors give similar results?)

- **Track finding improvement : Brian & Mike**
- **Track fitting improvement/understanding : Brian & Sergei (Both fitters are very easy to use, the SA is easier to understand since Roys code is somewhat complicated but Brian seems to have a good understanding)**
- **Slicing improvement : Me & Tom**
- **Vertex finding improvement : ??**
- **Finding/reporting/understanding pathologies in MC and available ND DATA using Event Displays : ?? (a lot of people should participate on that).**
- **If there are questions on Event Displays please ask the authors (Chris& Jim) and me that I have used extensively for ND.**

Summary

- **The overall performance of the ND reco chain on both MC and recent data is quite satisfactory.**

- **There are Near – Far differences that need to be understood**

- **There is room for improvement in all steps of the ND reco chain.**

- **The more people look at all aspects of the ND reconstruction and use the Event Displays to visually scan the events, the higher the chance of finding & improving reco failures (and of course understanding our events) before physics data taking starts.**