Status of MIND

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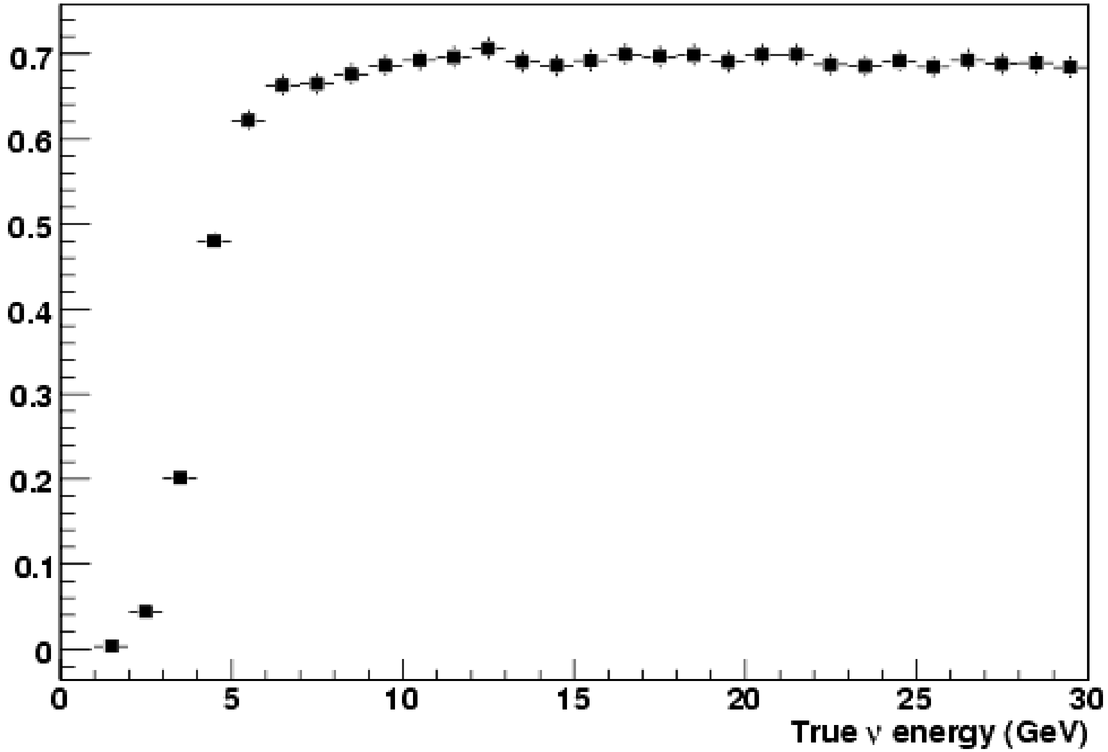
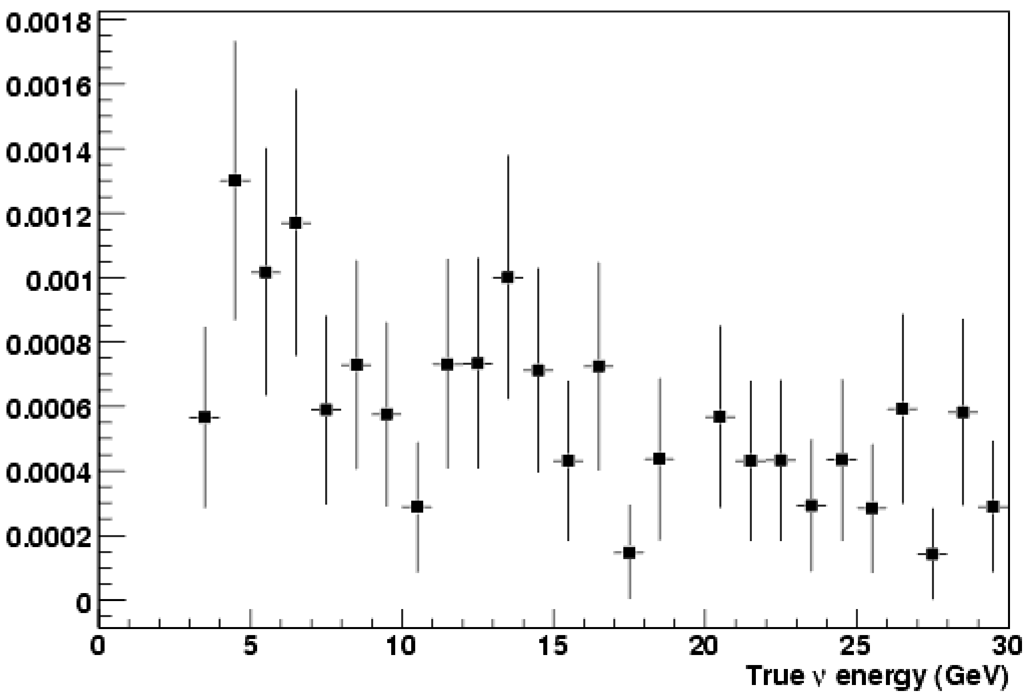
- Geant3 studies final result
- The new simulation
- Parameterised digitization
- Re-optimisation of reconstruction and analysis
- State of the art
- Some thoughts on systematics
- Hadrons

Geant3



Geant3 simulation studies complete. Pattern recognition and new analysis don't seem to degrade the efficiency beyond that reported in ISS.

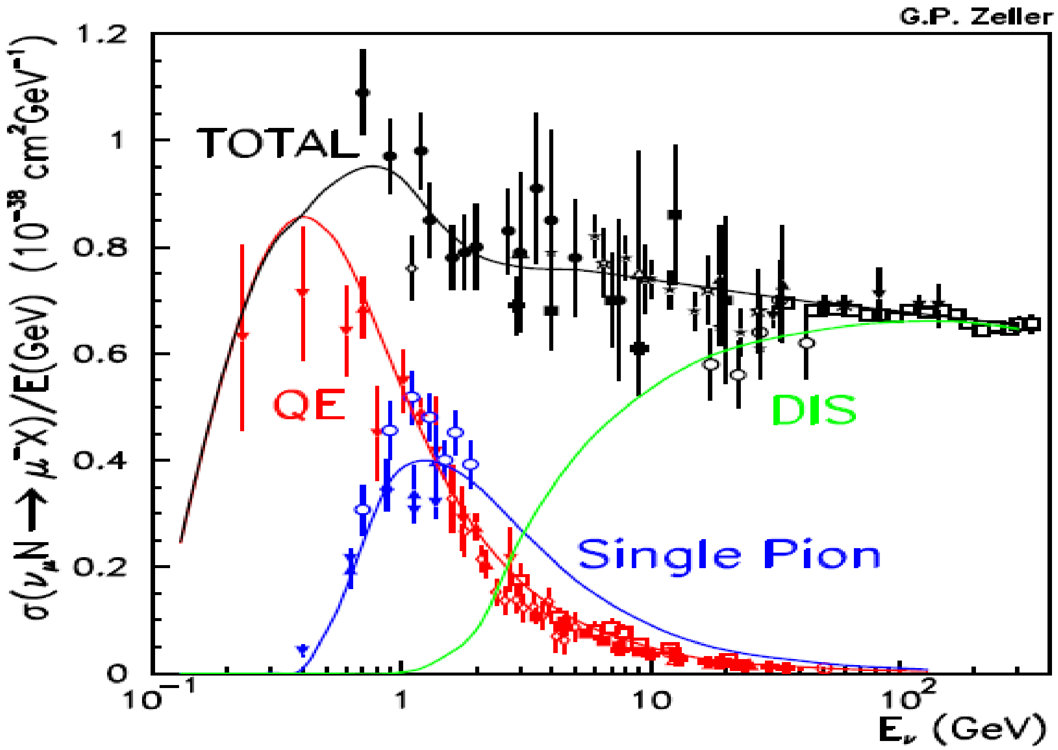


Description of full process and results available on arxiv:1004.0358.
Journal submission iminent.

A new simulation and analysis

- After much debugging the Geant4 simulation is working well.
- Nuance used to generate events
- New digitization package running

Expected impact of Quasi-elastics



Nuance gives all possible interaction types and is well tested. However, should move towards GENIE soon for better comparison to current experiments.

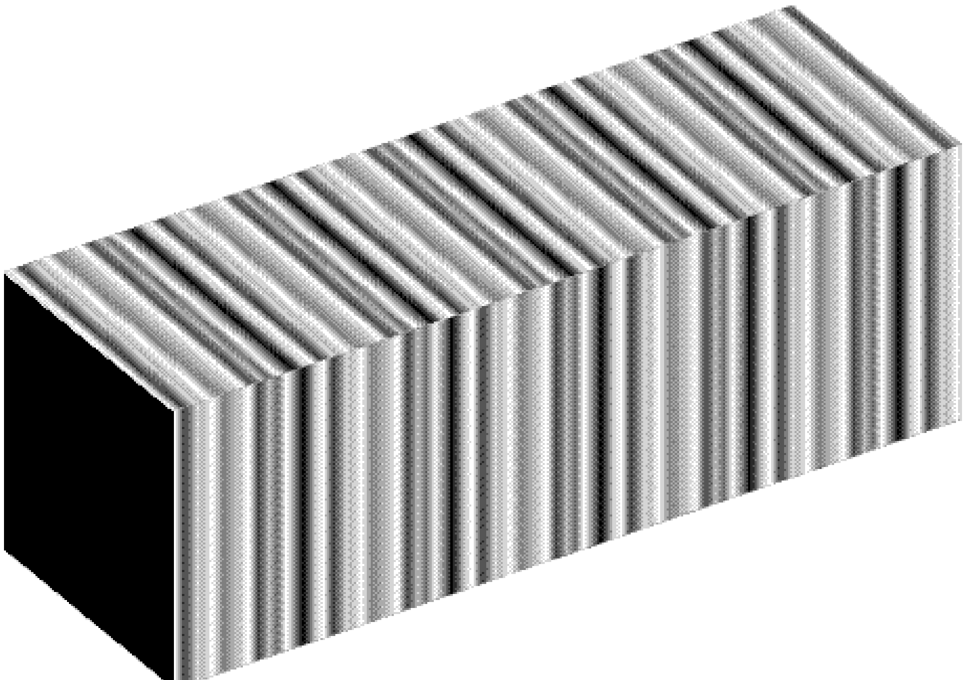
Non-DIS processes dominate at low energies.

Lower multiplicity should make pattern recognition easier and hence improve efficiency at low energy.

However, could also increase backgrounds at low energies.

Simulation

Results to be shown use 3 cm of iron and one 2 cm thick polystyrene plane.



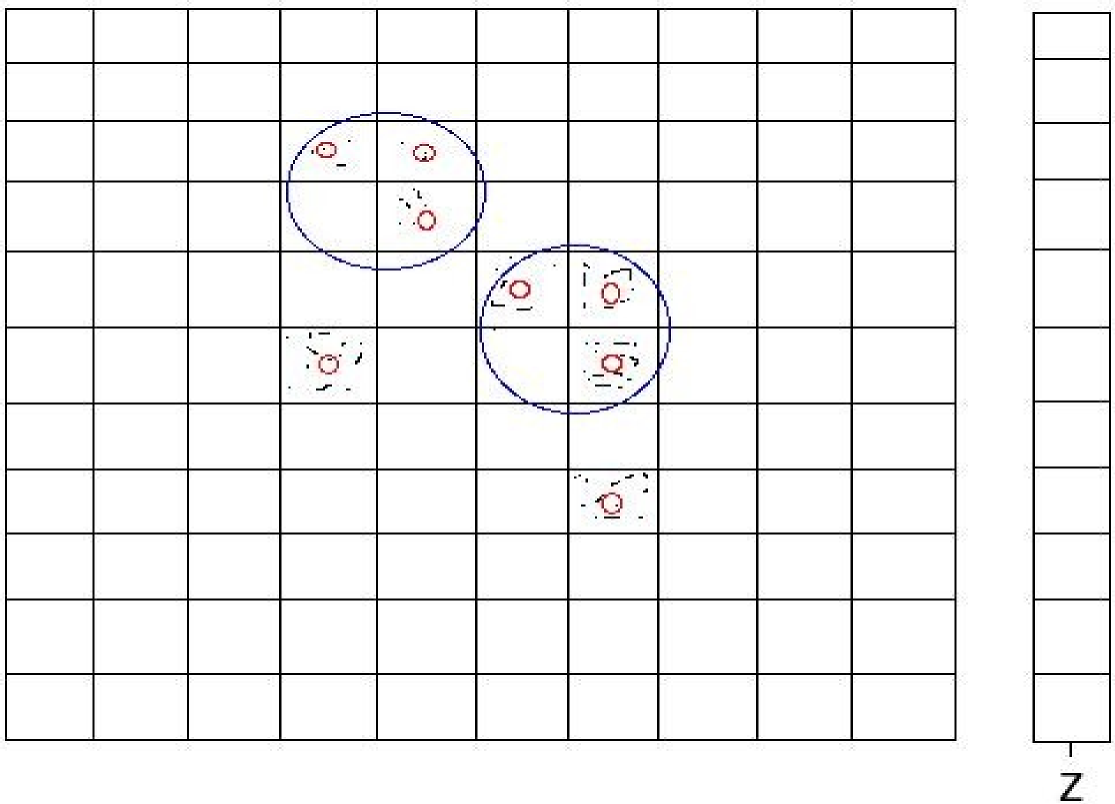
Geant4 simulation of MIND:

- Cuboidal structure
- 1T uniform dipole field*
- Physics via QGSP_BERT

Control over all external and internal dimensions as well as the number of scintillator planes per sandwich.

*While a torroidal field is ultimately what is likely to be built expect that efficiencies will not be changed significantly as should gain in path length. Man-power does not allow for inclusion at the moment.

Digitization



Parameterization of scintillator response. Assumes WLS with λ = 5m.

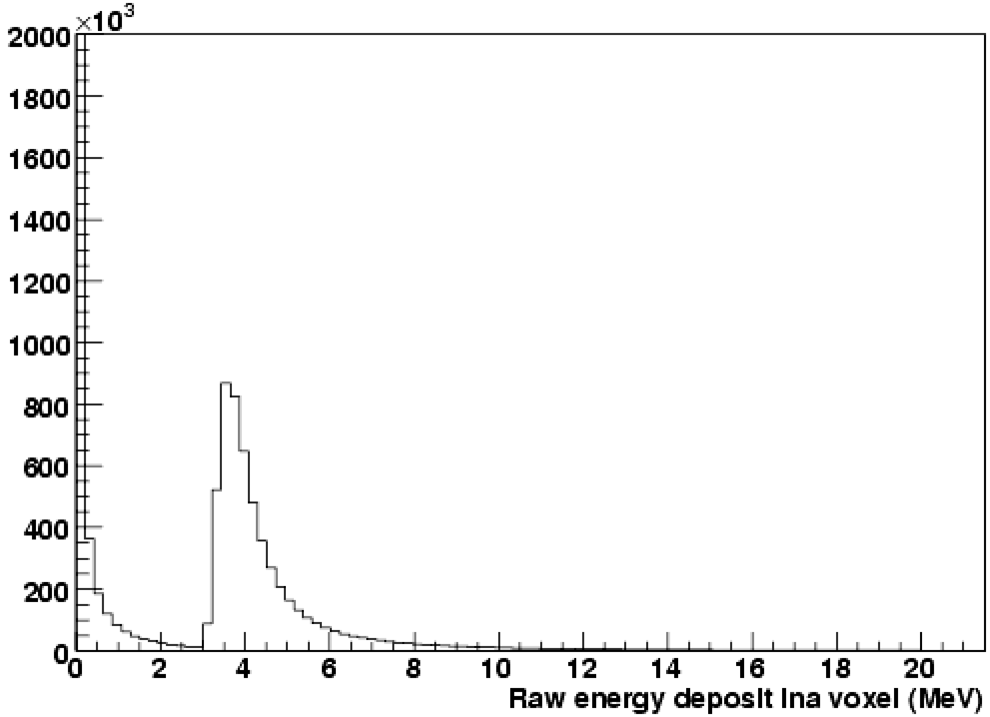
Views assumed matched with low energy in one view giving a larger error to that dimension at fitting.

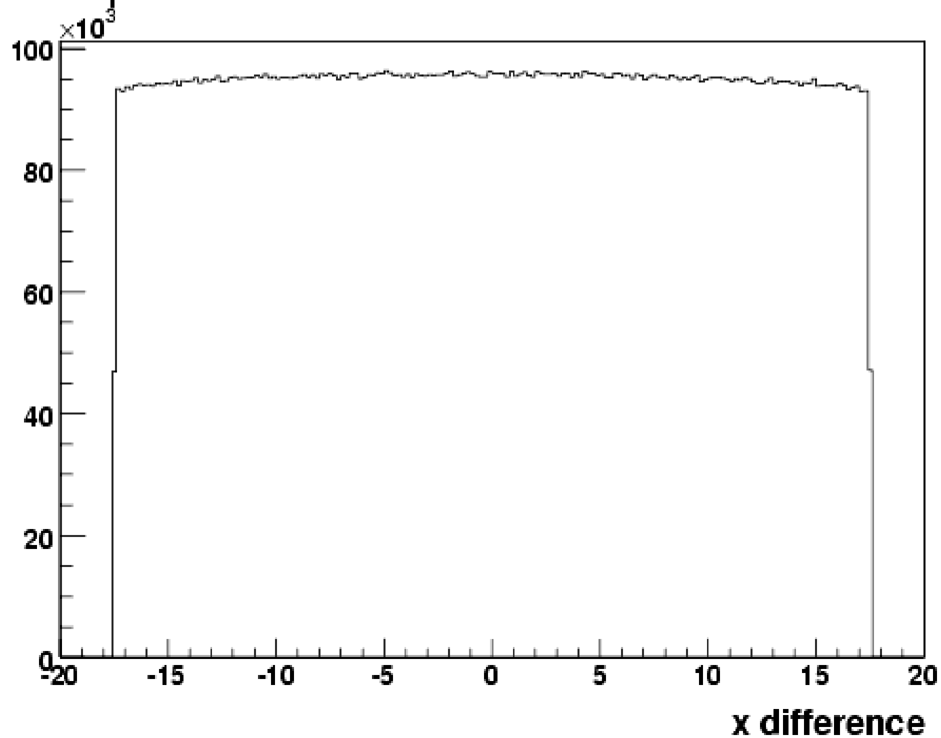
Keeping it simple while being realistic leads us to:

- Boxes to represent view matched x,y readout planes with the x,y,z at the centre of a box.
- Clustering of adjacent boxes at analysis around the largest signal with weighted mean for x,y position.

Digitization (2)

Raw deposit energy per 'voxel' and hit position distribution as expected for voxels 2cm in z, and 3.5x3.5 in the transverse plane.

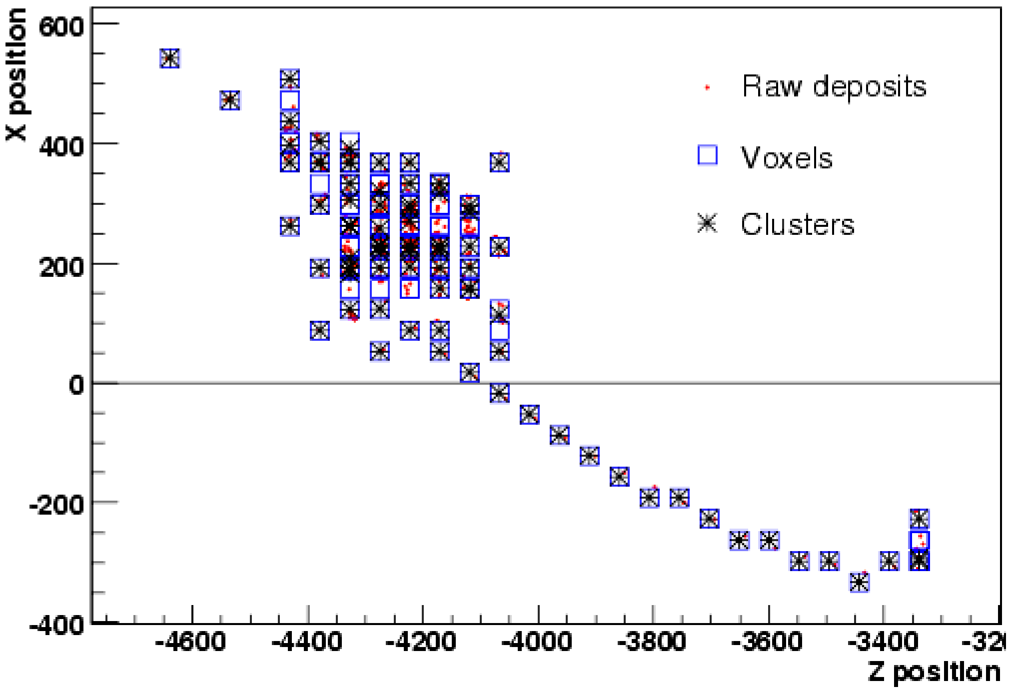


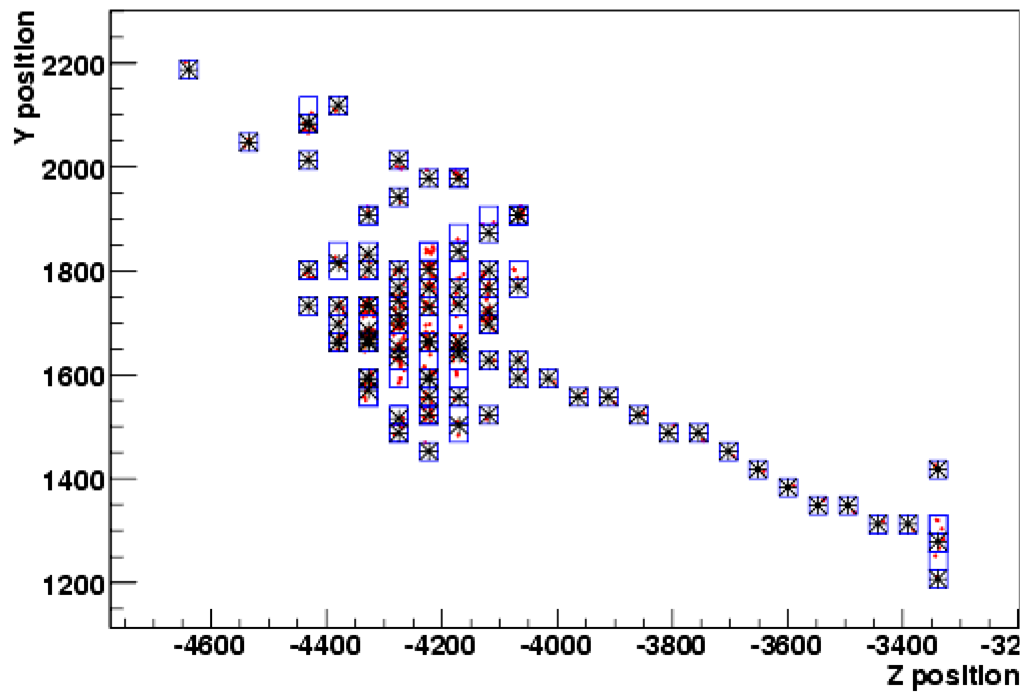


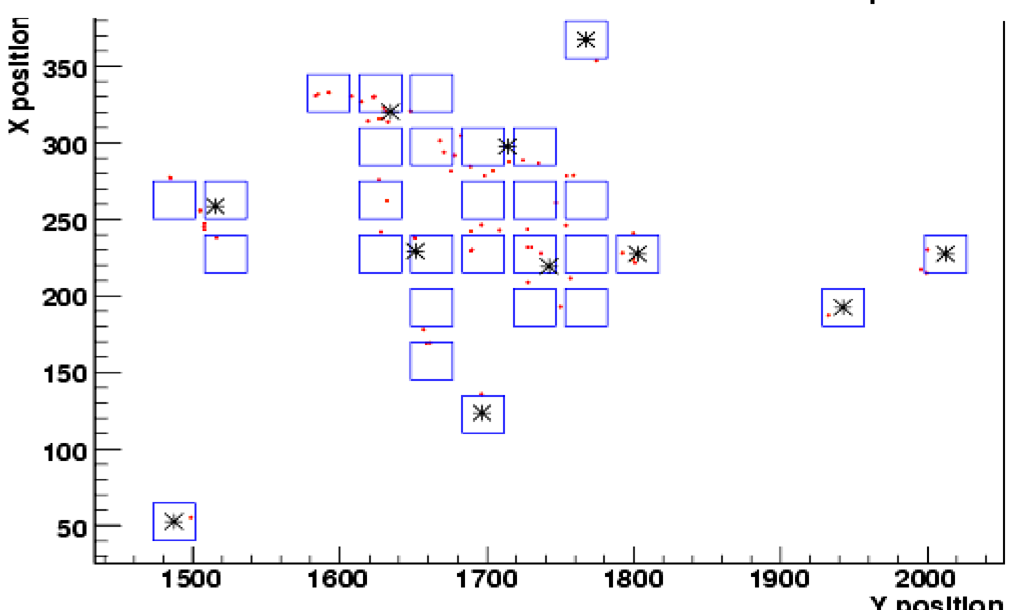
Raw energy in a 'voxel' split in 4 and attenuated to the edges:

- smeared with sigma = 6%E.
- Bad voxels/views rejected, 4.7 pe in 30% QE photodetector.
- recorded to be used by clusterer.

Digitization (3)







Clusterer looks for a high deposit and groups voxels around it using the x,y deposits recorded by digitization

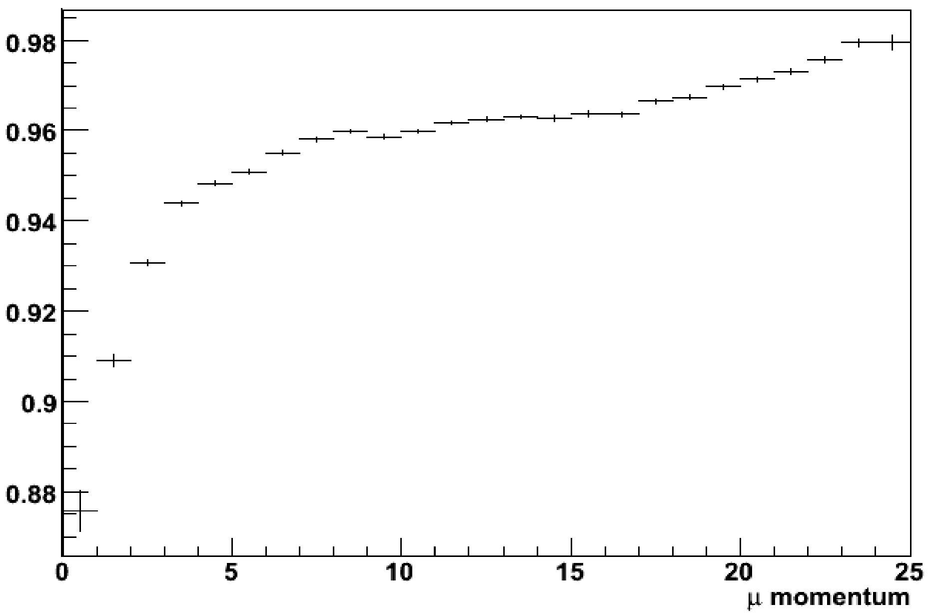
Reconstruction

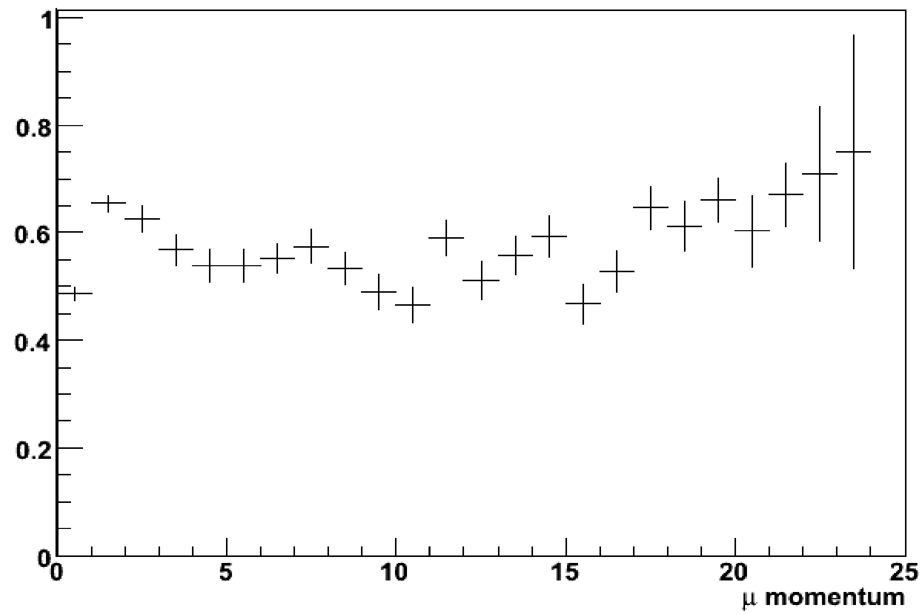
- Reconstruction happens as in G3 with a few additions:
  - Activity at end of muons (particularly μ^-) complicates matters. Endpoint skip allowed where isolated section found within 10% of end.
  - Cluster/voxels make things more digital. Max. chi2 tightened to avoid confusing hits.

Reconstruction (2)

- Reminder of pattern rec. method:
  - Kalman filter projects back through hadronic activity
    - Needs at least 5 free hits to make a seed.
  - Cellular Automaton: More complicated events
    - Walks through event making possible trajectories which are tested for muonness.

Reconstruction (3)





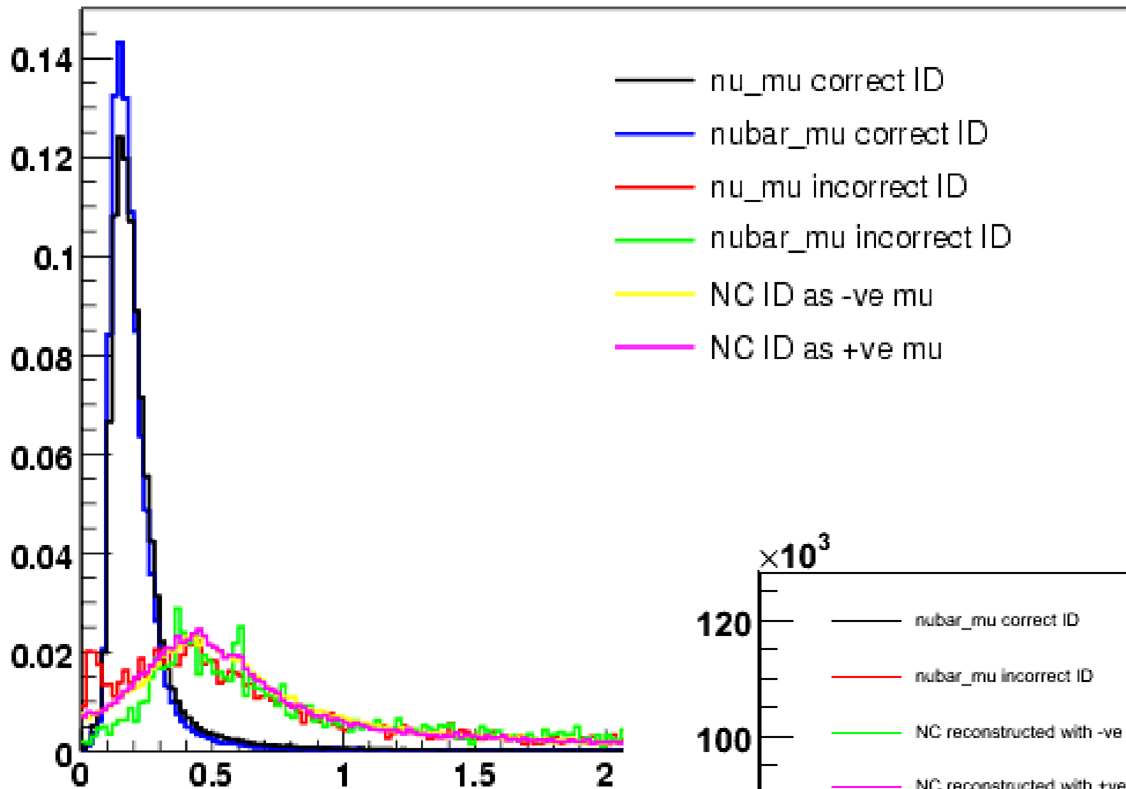
Candidates are in general pure but not quite so well behaved as in the G3 case.

Re-optimized analysis

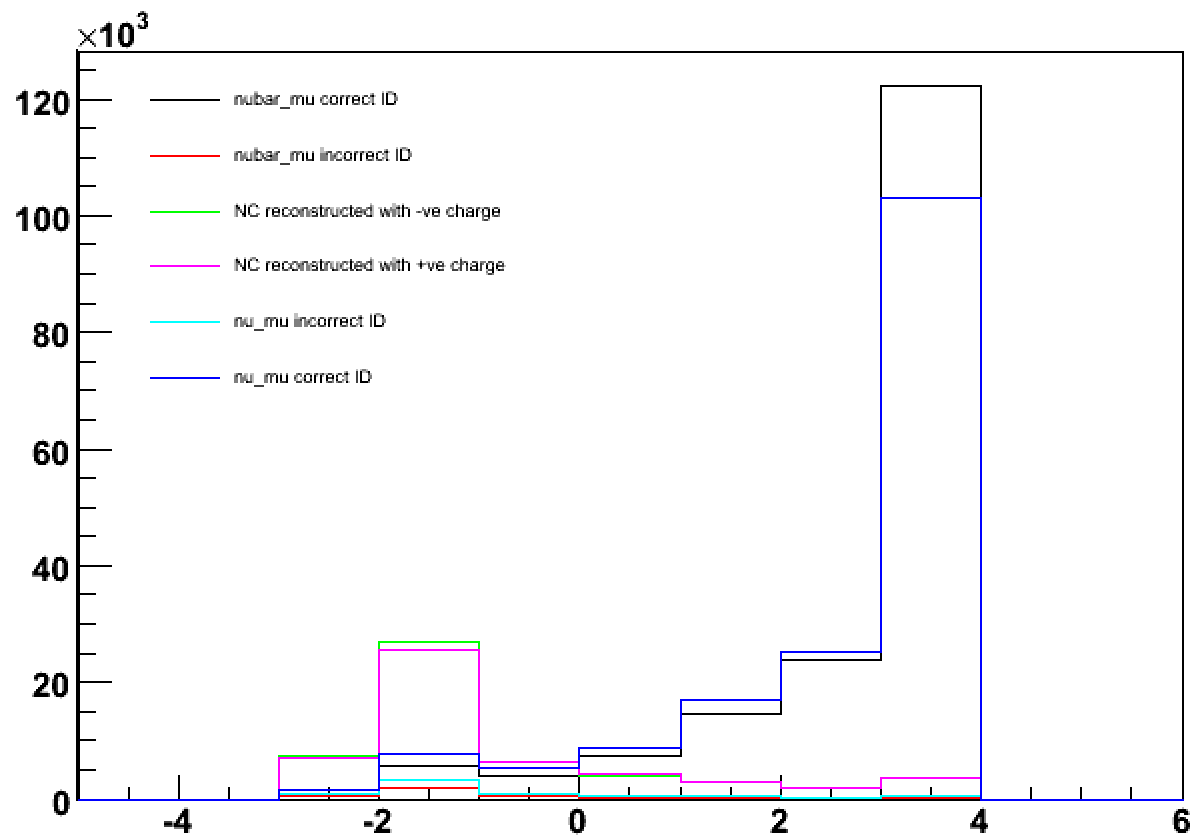
- New likelihoods, re-tuned cuts and a few new things.

The method continues with fit quality cuts, likelihood NC rejection and kinematical cuts but the new geometry, digitization and processes lend new oportunities and difficulties.

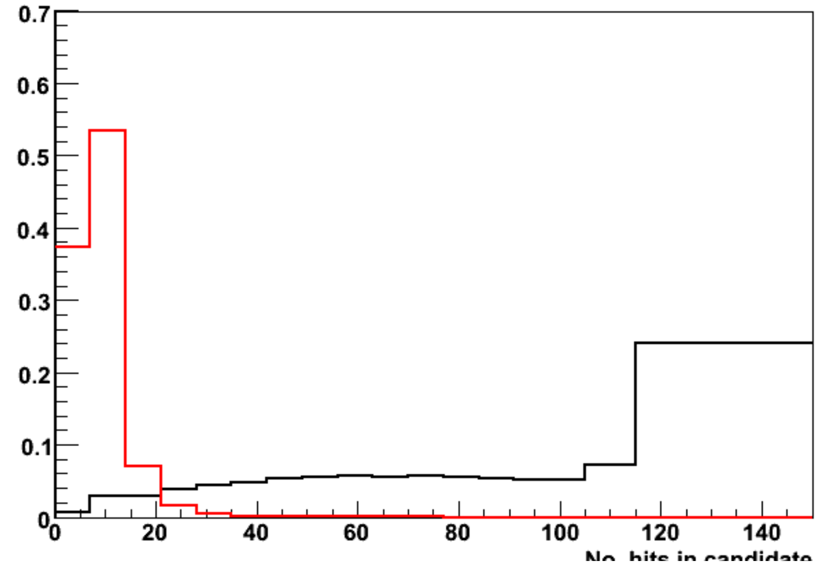
Curvature error

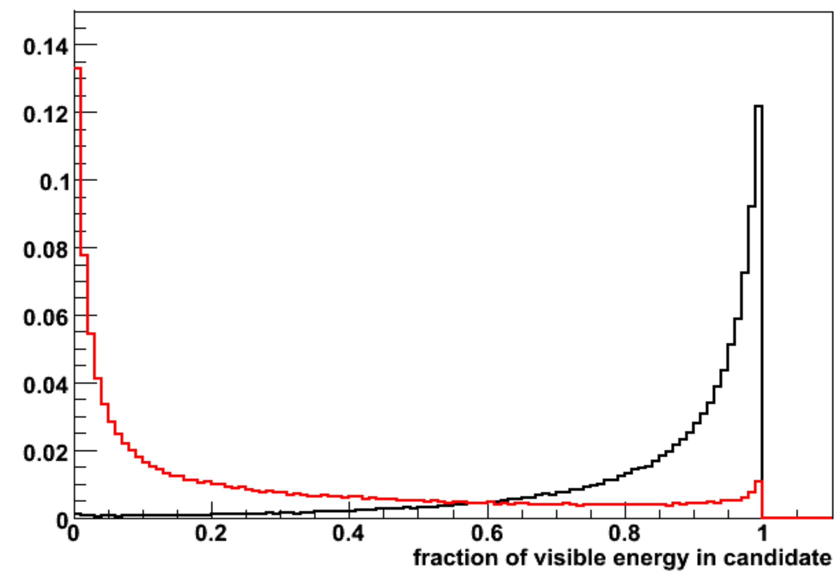


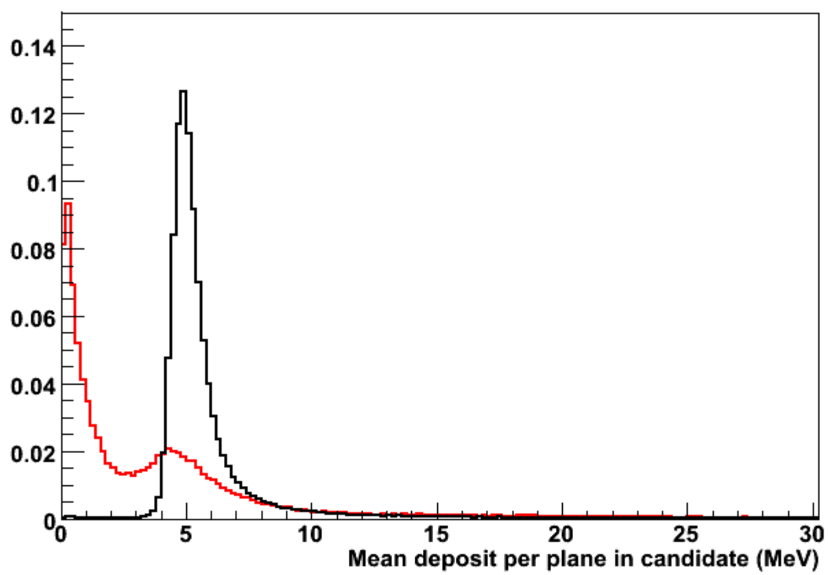
Curvature error still a good separator, use the likelihood method to tune the cut.



Likelihood analysis





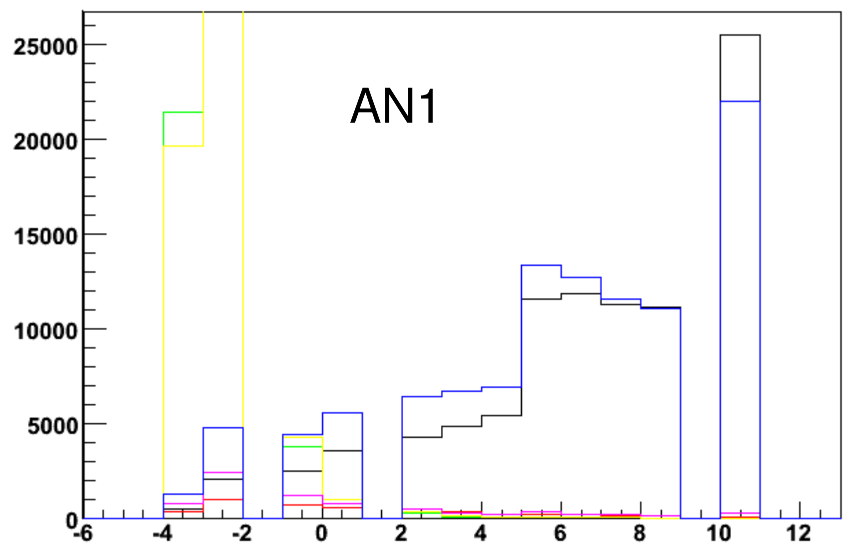


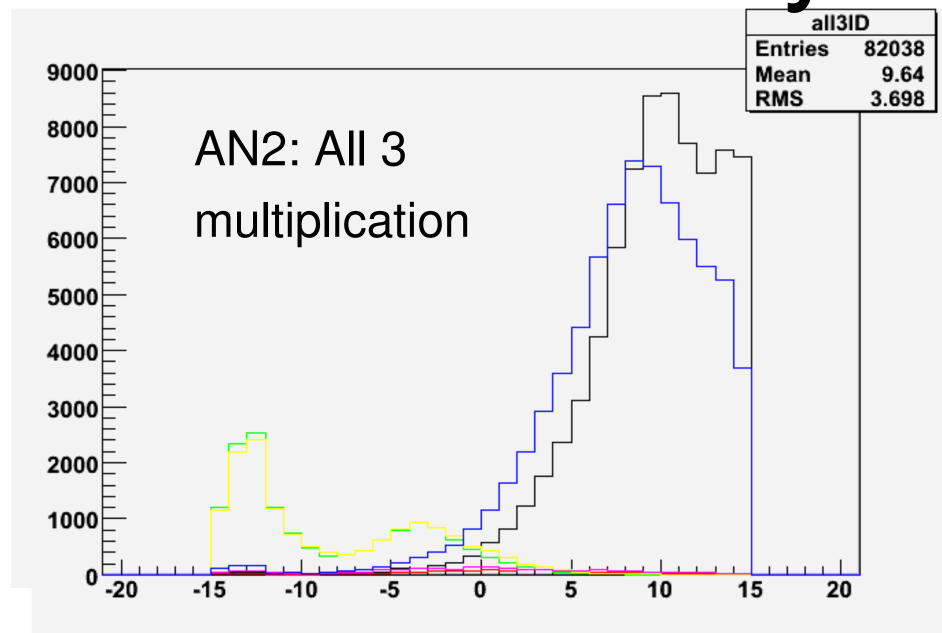
Parameters taken from MINOS.

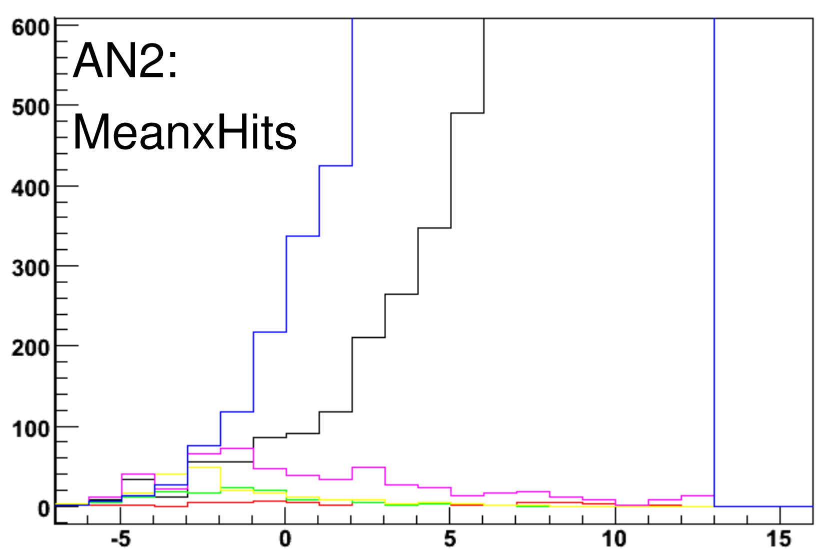
Since energy deposit involves assumptions define two likelihood analyses:

1) Use hit parameter only.
2) Use combination of all three where available.

Likelihood analysis







Second analysis using energy deposit information still under study. Presented results will use only hit information.

Blue and Black signal. Other colours background

Hadron reconstruction

- Events identified as single track have energy reconstructed with quasi formula.
- Wider hadron reconstruction under study.
- Smear on the true quantities on non-single track for now:

$$\frac{\delta E}{E} = \frac{0.55}{\sqrt{E}} + 0.03$$

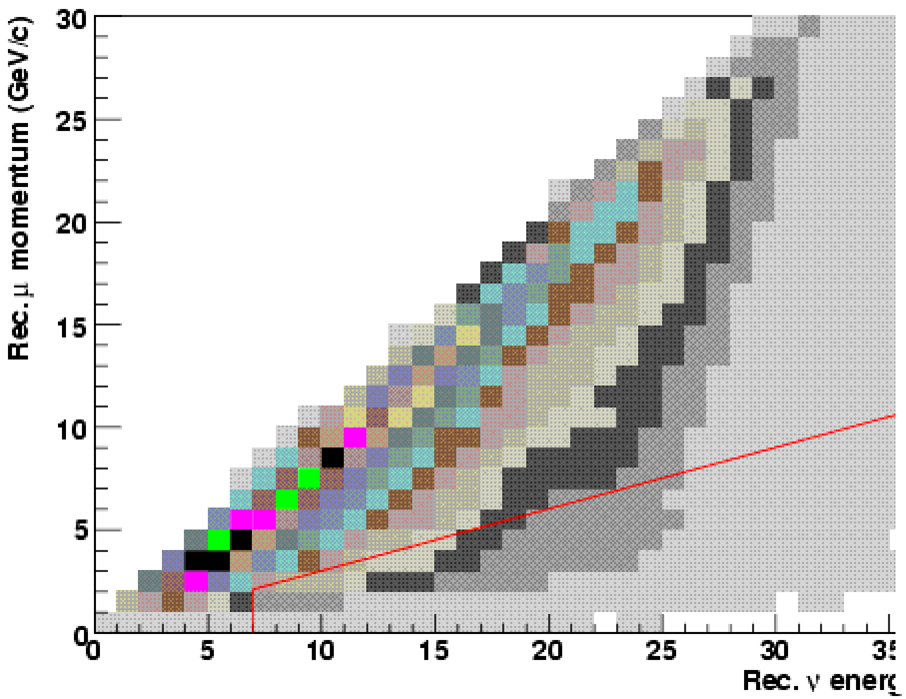
From MINOS CalDet result.

$$\delta \theta = \frac{10.4}{\sqrt{E}} + \frac{10.1}{E}$$

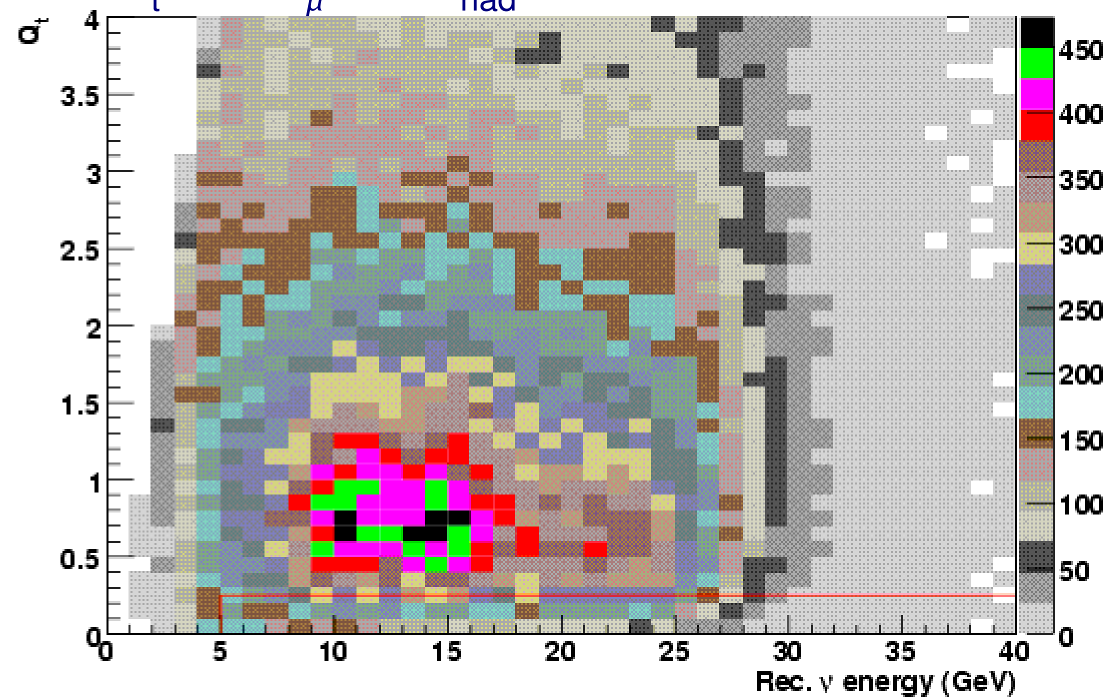
From Monolith proposal.

Kinematic cuts

$P_{\mu} \geq 0.3E_{\nu}$



$Q_t = P_{\mu} \sin^2\theta_{had} \geq 0.25$

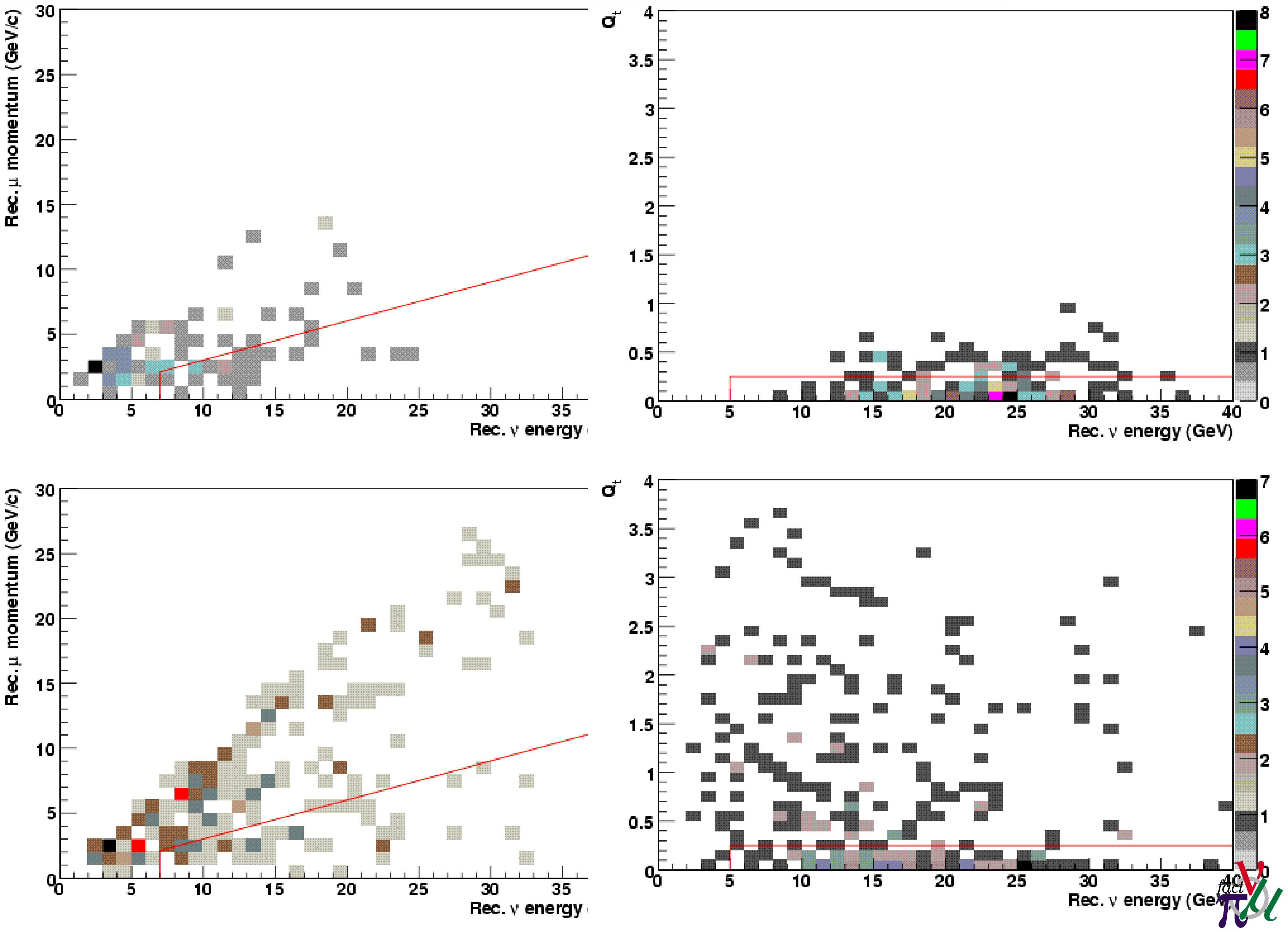


Neutrino energy reconstructed as $E_{\nu} = E_{\mu} + E_{had}$ or via quasi formula.

Quasi reconstructed events not subject to Q_t cut.

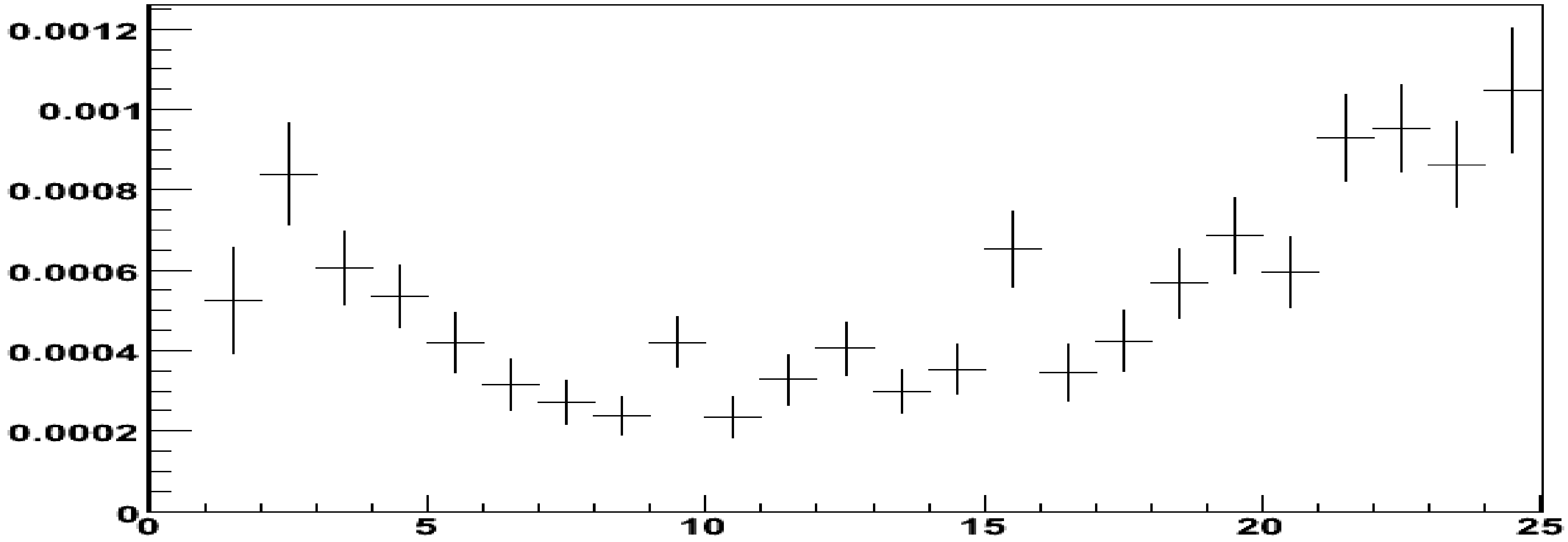
Q_t cut only applied at above 5 GeV rec. eng.

Surviving background subject to p cut if rec. eng. > 7 GeV.


University of Glasgow
Experimental Particle Physics
Rec. μ momentum (GeV/c)
Rec. ν energy
q_t
Rec. ν energy (GeV)

Some additions and redundancies

Initial studies showed excess of high energy mu CC background



Two classes of event seemed to cause this:

1) Quite straight muons being essentially completely straight due to the level of digitization but not always failing the fit.

2) Very smoothly curving muons which somehow confused the fitter

Additions

- Fit remainder with parabola:
  - If flips charge and error/quadConst low kill.
- Require dispX/dispZ > 0.18 – $0.0026N_{hit}$.
- Require rec. mom. < 3dispZ for dispZ<6000mm
- Cut all events with candidate first hit within 2m of detector end in z.
- Redundant for Now: χ^2 proability. And energy likelihoods.

Cut summary

Cut	Acceptance level
Fiducial	$z1 \leq 18000$ mm where *z1* is the lowest *z* cluster in the candidate
Track quality	$\mathcal{L}_{q/p} > -0.5$
Max. momentum	$P_\mu \leq 40$ GeV
CC selection	$\mathcal{L}_1 > 1.0$
Fitted proportion	$N_{fit}/N_h \geq 0.6$
Kinematic	$E_{rec} \leq 5\ GeV$ or $Q_t > 0.25$ $E_{rec} \leq 7\ GeV$ or $P_\mu \geq 0.3E_{rec}$
Displacement	$dispX/dispZ > 0.18 - 0.0026N_h$ $dispZ > 6000\ mm$ or $P_\mu \leq 3dispZ$
Quadratic fit	if charge reversed, $-\left\lvert\frac{\sigma_c}{c}\right\rvert < -1.0$

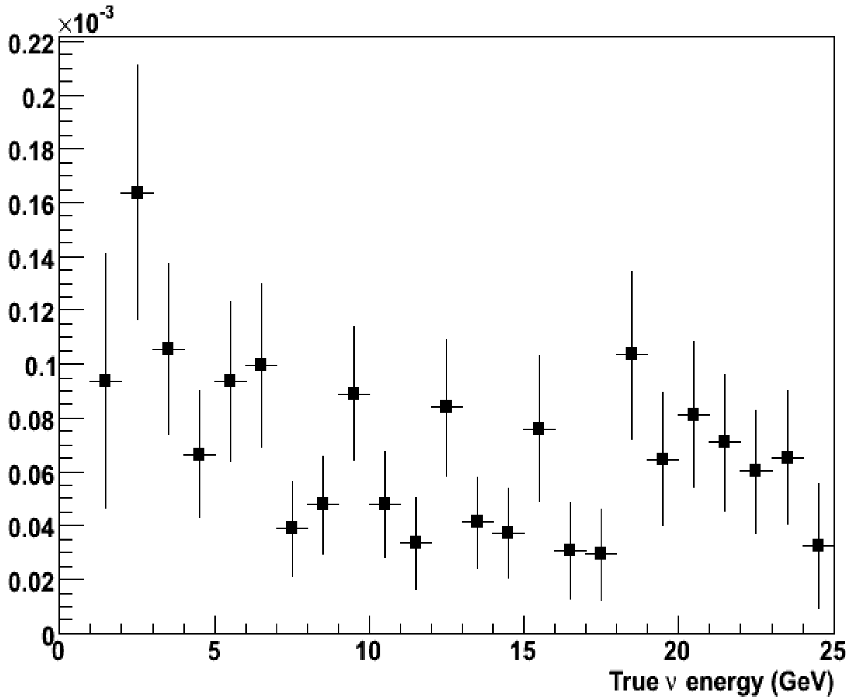
Current benchmark Efficiencies

A bit

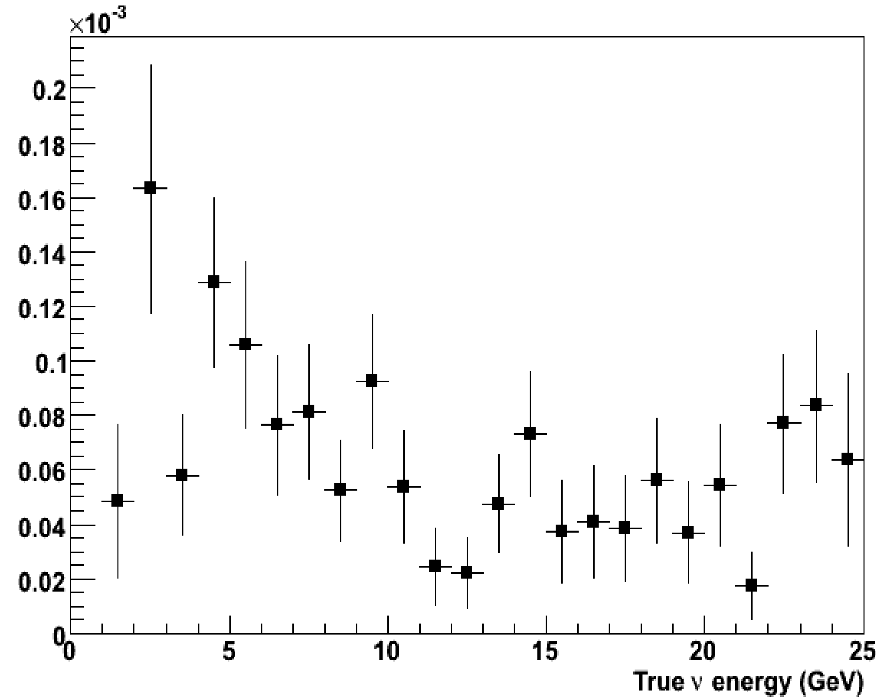
PRELIMINARY

Mu CC backgrounds

Background to μ^- appearance

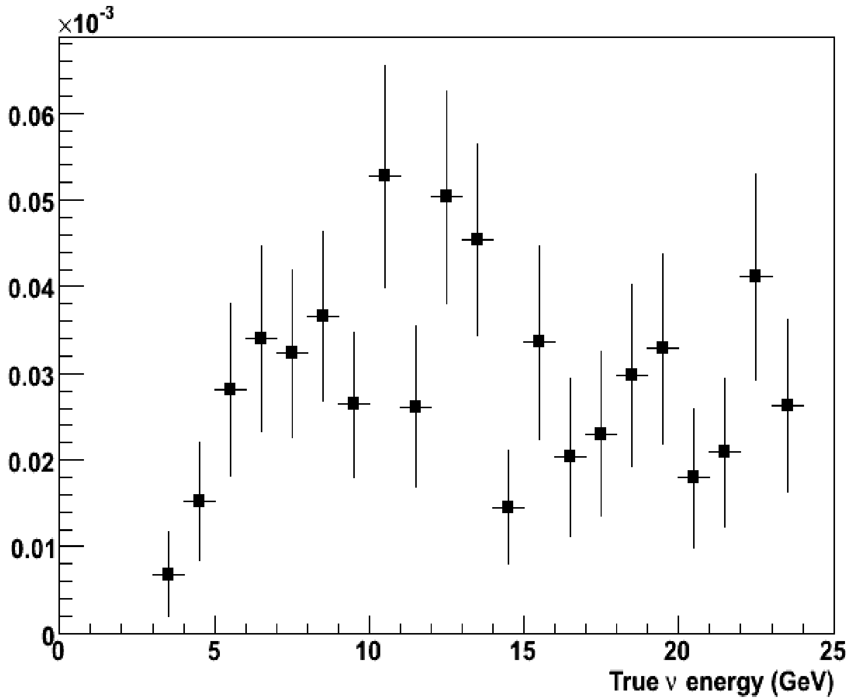


Background to μ^+ appearance

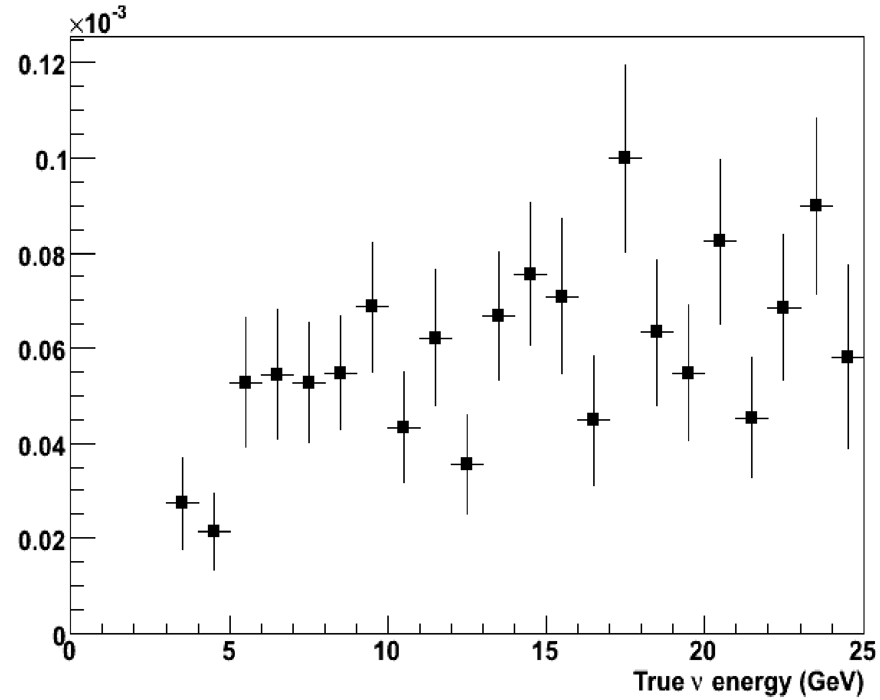


NC backgrounds

Background to μ^- appearance

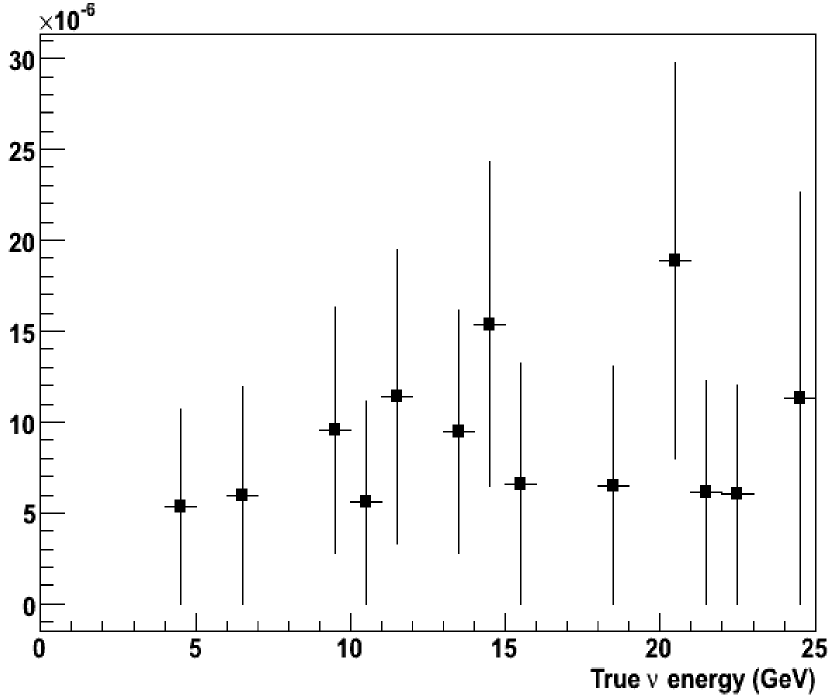


Background to μ^+ appearance

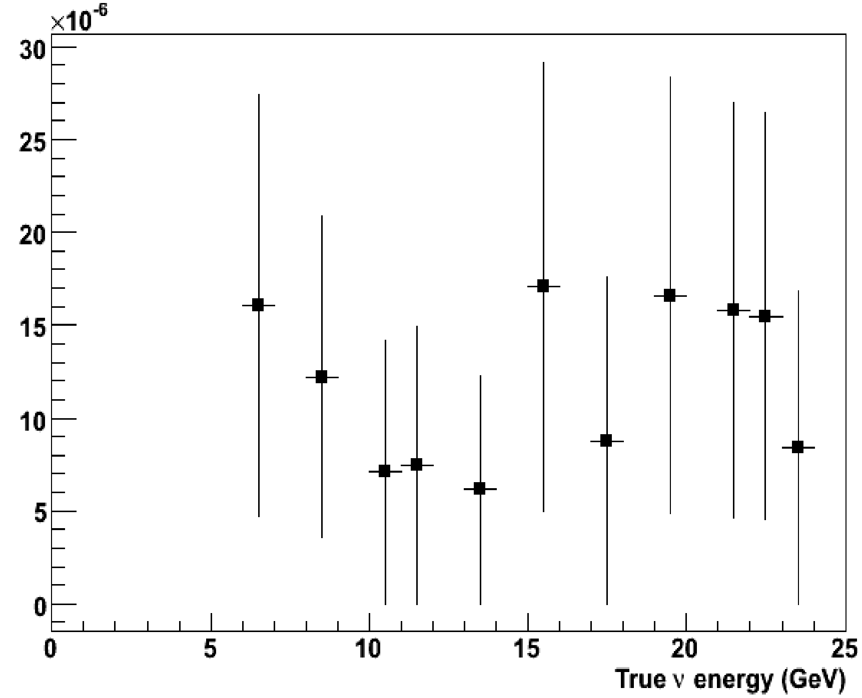


E CC backgrounds

Background to μ^- appearance

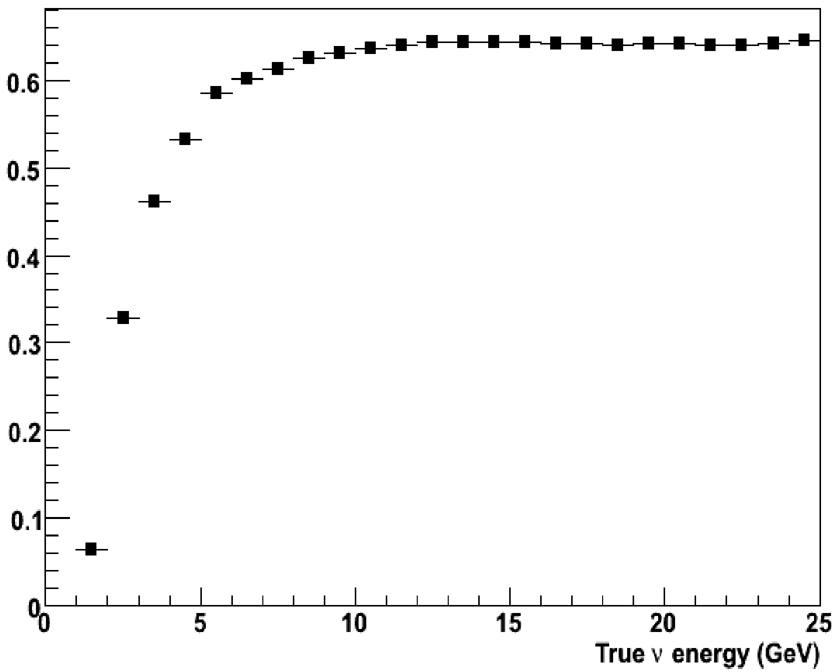


Background to μ^+ appearance

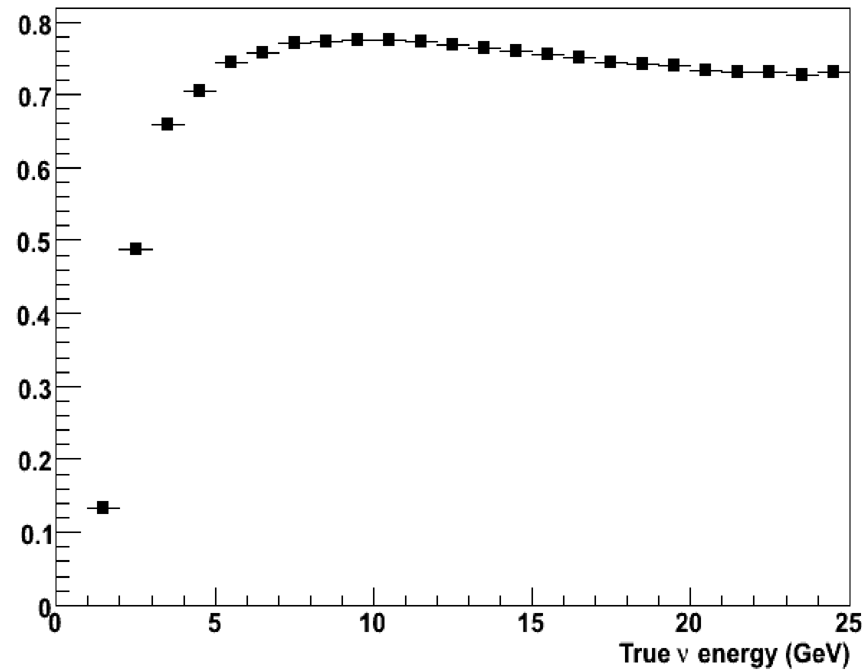


Signal Efficiencies

Identification of μ^-



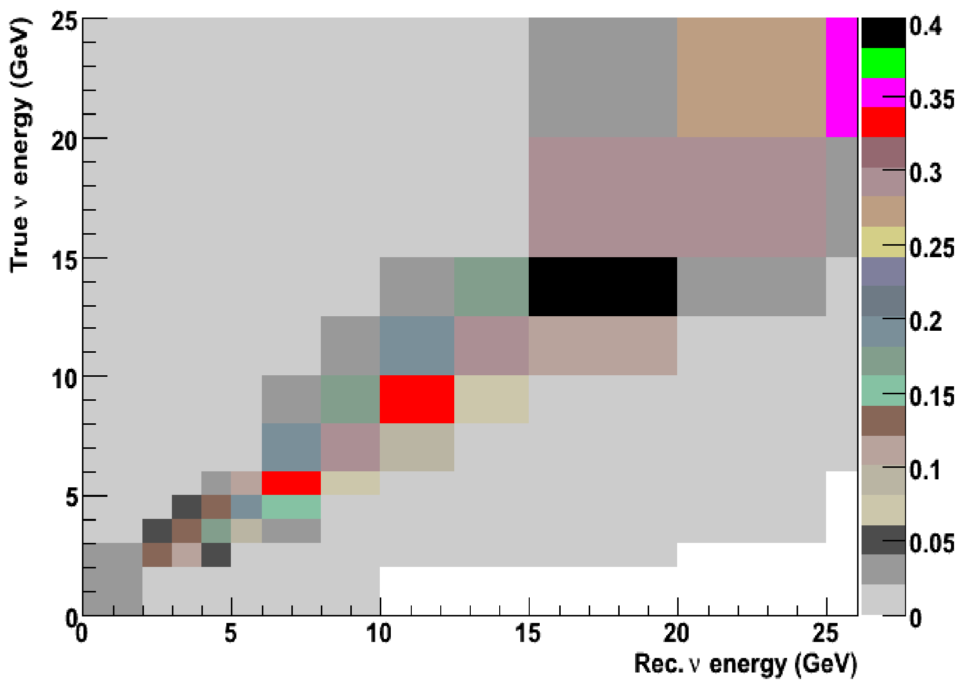
Identification of μ^+



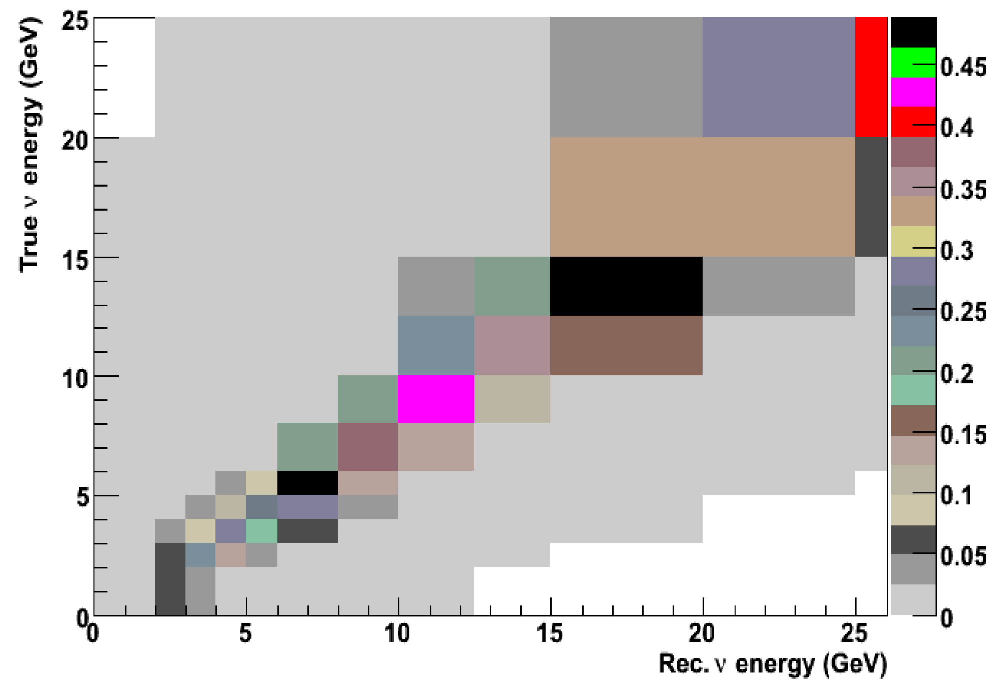
Efficiency is clearly better for anti neutrino channel. While this is fine in principle it has to be understood.

Response Matrices

Identification of μ^-



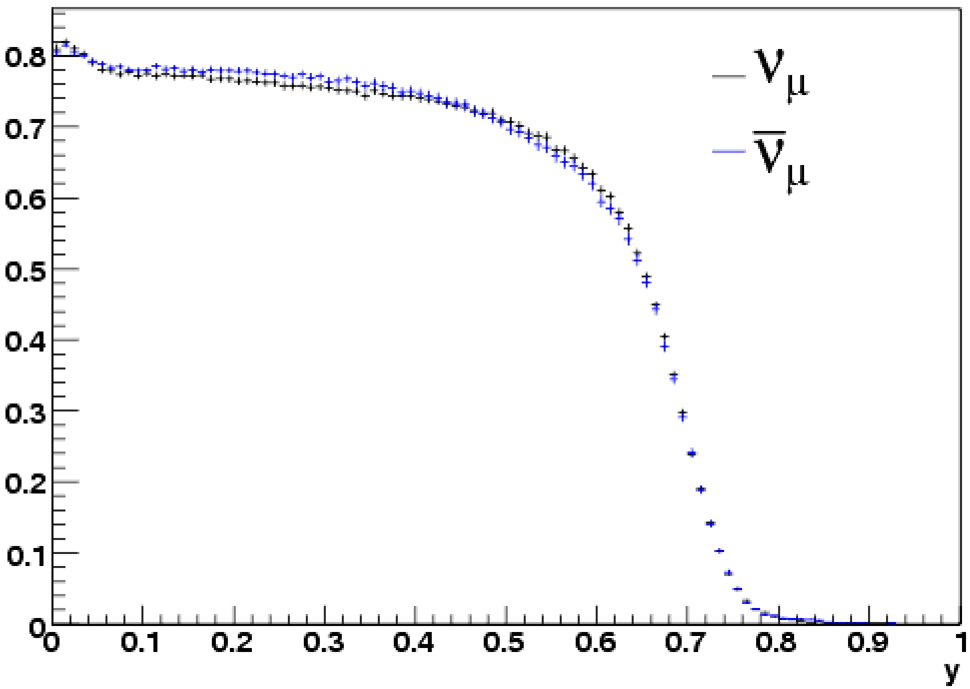
Identification of μ^+



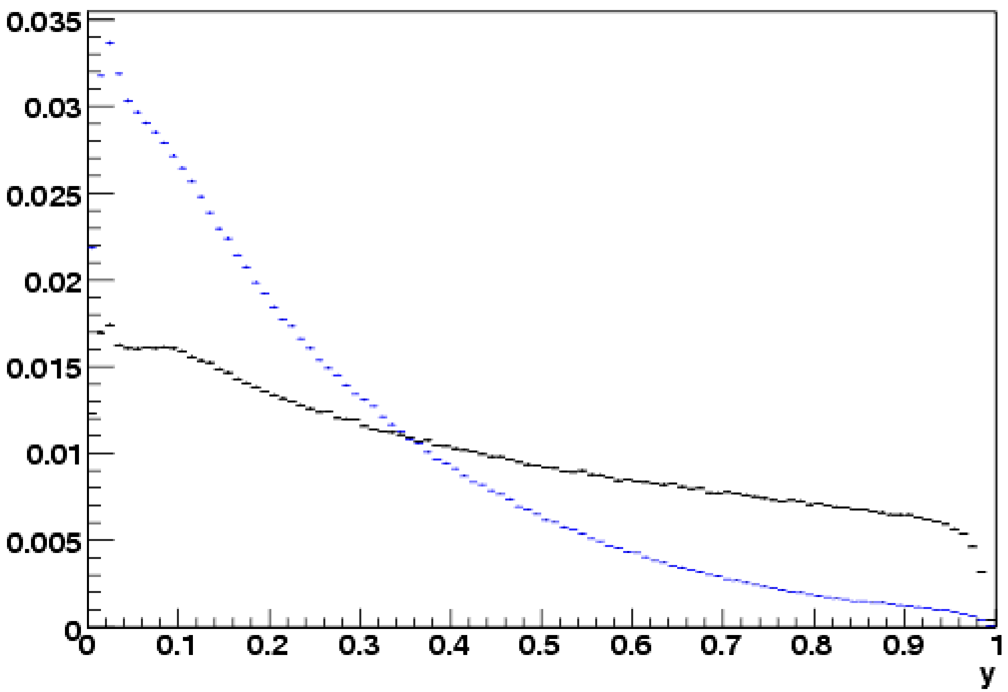
Matrices combining the true energy efficiencies and at what energy they would be expected to be reconstructed calculated for all channels.

Efficiency and inelasticity

Efficiency as a function of y



y distributions for both species



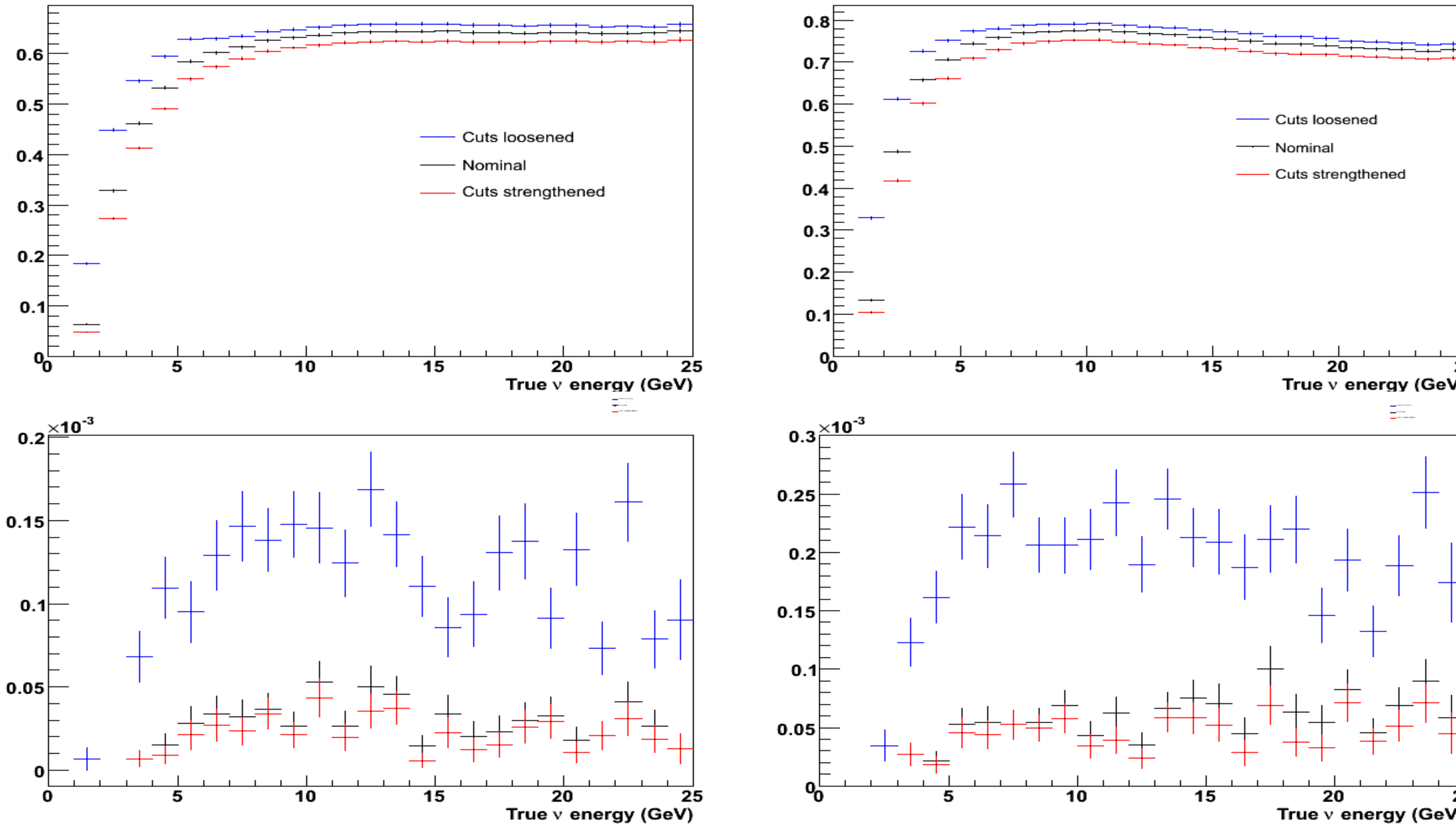
Efficiencies are essentially equal plotted with the inelasticity. The difference in distribution explains the observed true energy difference.

What Systematics?

- What Systematics will affect the efficiencies?
  - Hadron Energy resolution.
  - Hadron direction resolution.
    - Both can be studied easily using the smear.
  - Cross-sections of different processes.
  - Electronics 'noise cut'.
  - Errors in the variables used for the cuts.

Anselmo will host a more complete discussion of systematics

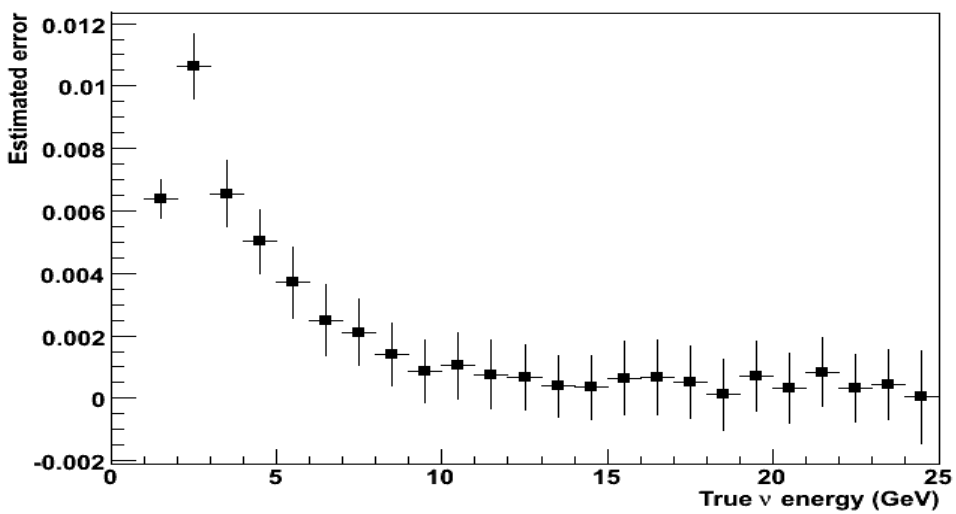
Harden or soften the cuts

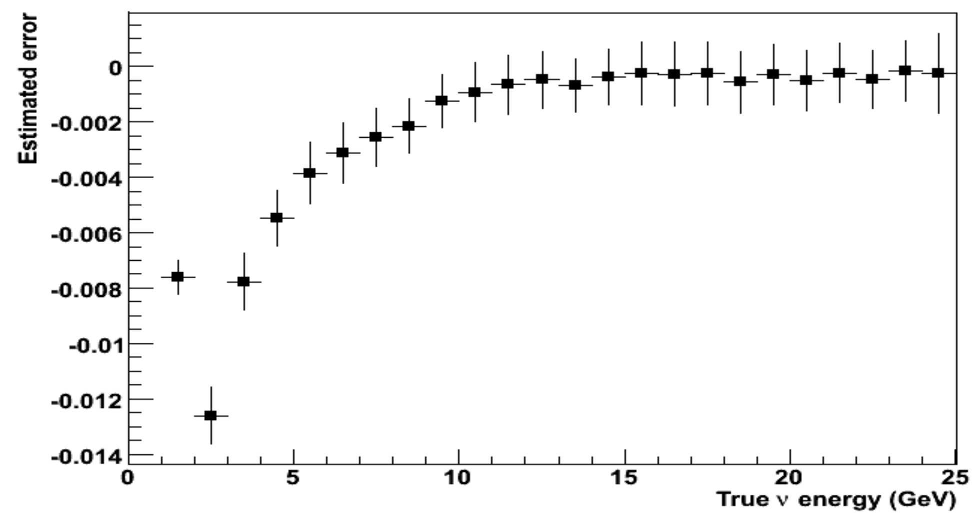


While not capable of giving the 1 sigma systematic the errors on the cut parameters can give some indication of the maximum variation expected.

Proportion of different interactions

- Initial study of QE systematic contribution done by varying proportion of QE in sample according to NOMAD and MiniBoone errors.





While the error on the total cross-section does not affect the efficiencies the proportion of the different interaction types and hence the errors on these measurements are important.

Under study or pending

- Hadron reconstruction understudy
- How does single sided readout change results.
- Change the 2cm single plane for 2 1cm planes to be different views.
- Toroidal field map. <- Study performed at FermiLab, STL seems the most viable technology option. Integration of field map with simulation important step.

Conclusion

- Although there are still some things to understand the new results are promising.
- New people needed to keep the momentum going.

Thank you to all colleagues and for your attention