Status of MIND

OR

An update on neutrino interaction pattern recognition in a large magnetised iron detector

Andrew Laing

University of Glasgow

Contents

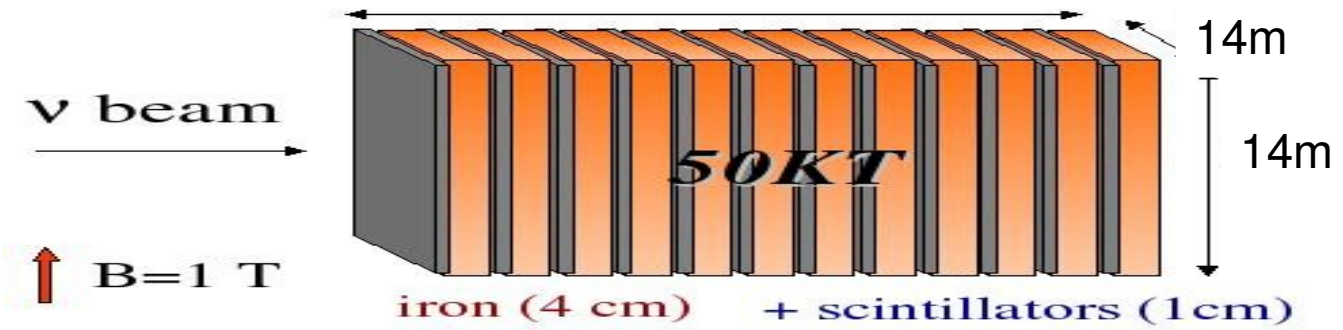
- Pattern recognition results (G3)
  - Charge mis-ID suppression
  - Hadron Energy reconstruction
- Next steps in Physics terms
  - Kinematic analysis using nuance and G4
  - NC suppression
  - Digitization

MIND

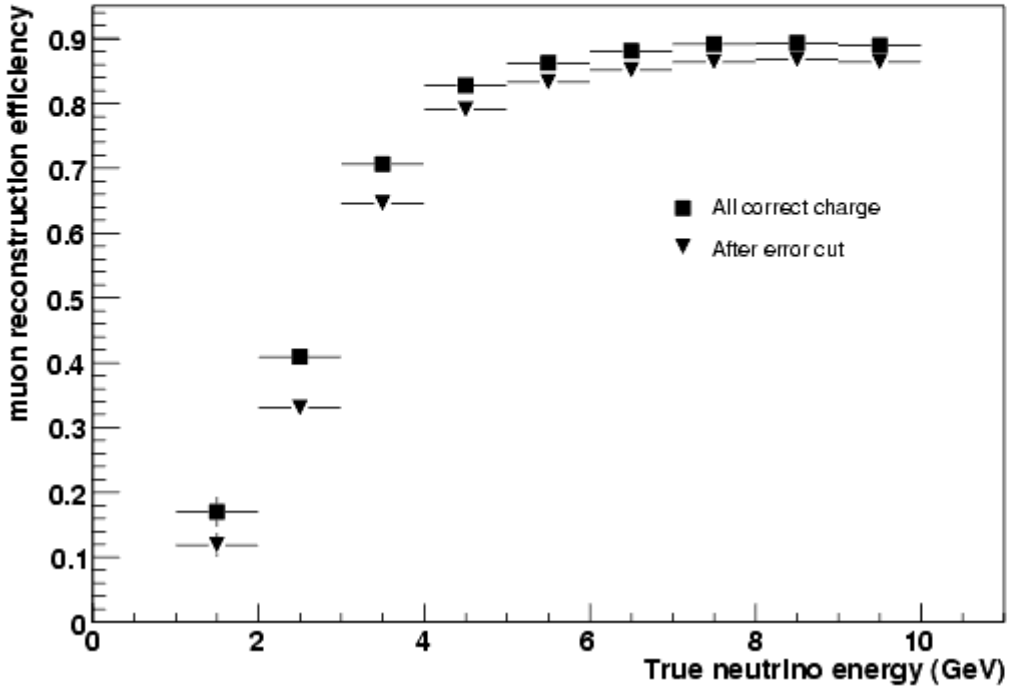
- Magnetised Iron Neutrino Detector is the baseline detector technology for the Neutrino Factory.
- Currently new simulation framework under construction
- First results of reconstruction/pattern recognition presented nufact08

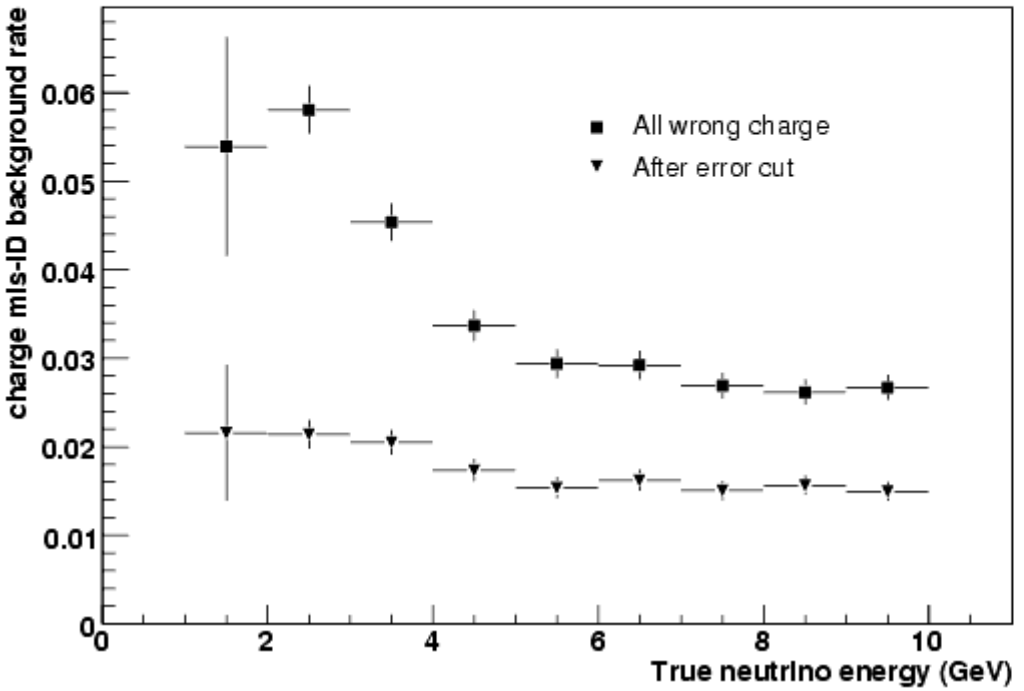
Current Detector Parameters

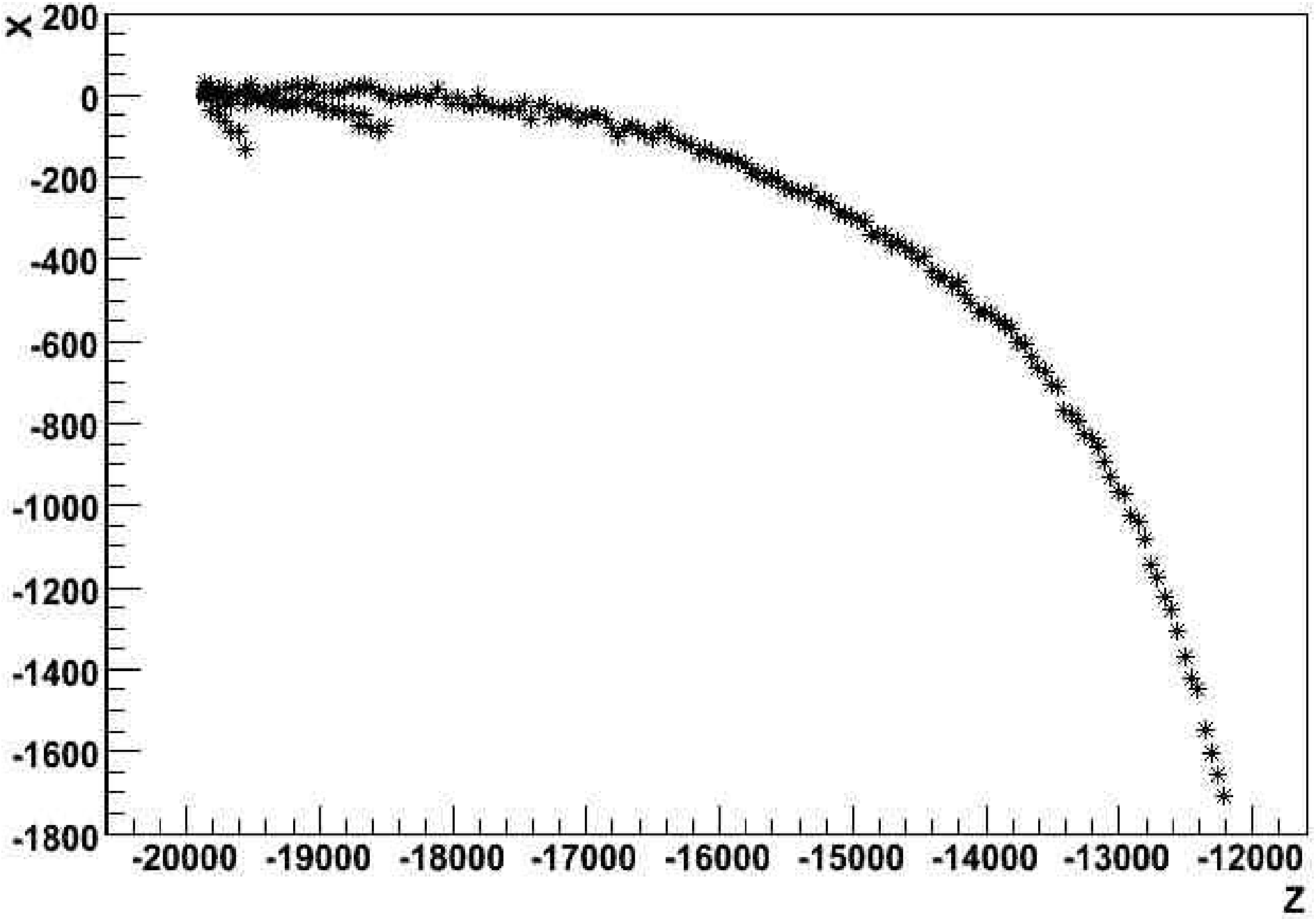
- Detector Dimensions:
  - 14m x 14m square cross section
  - 40m length
  - 'Sandwiches' of 4cm Fe and 1cm Scintillator
- Magnetic Field:
  - 1.0T average field in whole detector



Nufact08


muon reconstruction efficiency
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
True neutrino energy (GeV)
All correct charge
After error cut


charge mis-ID background rate
0
0.01
0.02
0.03
0.04
0.05
0.06
0
2
4
6
8
10
True neutrino energy (GeV)
All wrong charge
After error cut


x
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-20000
-19000
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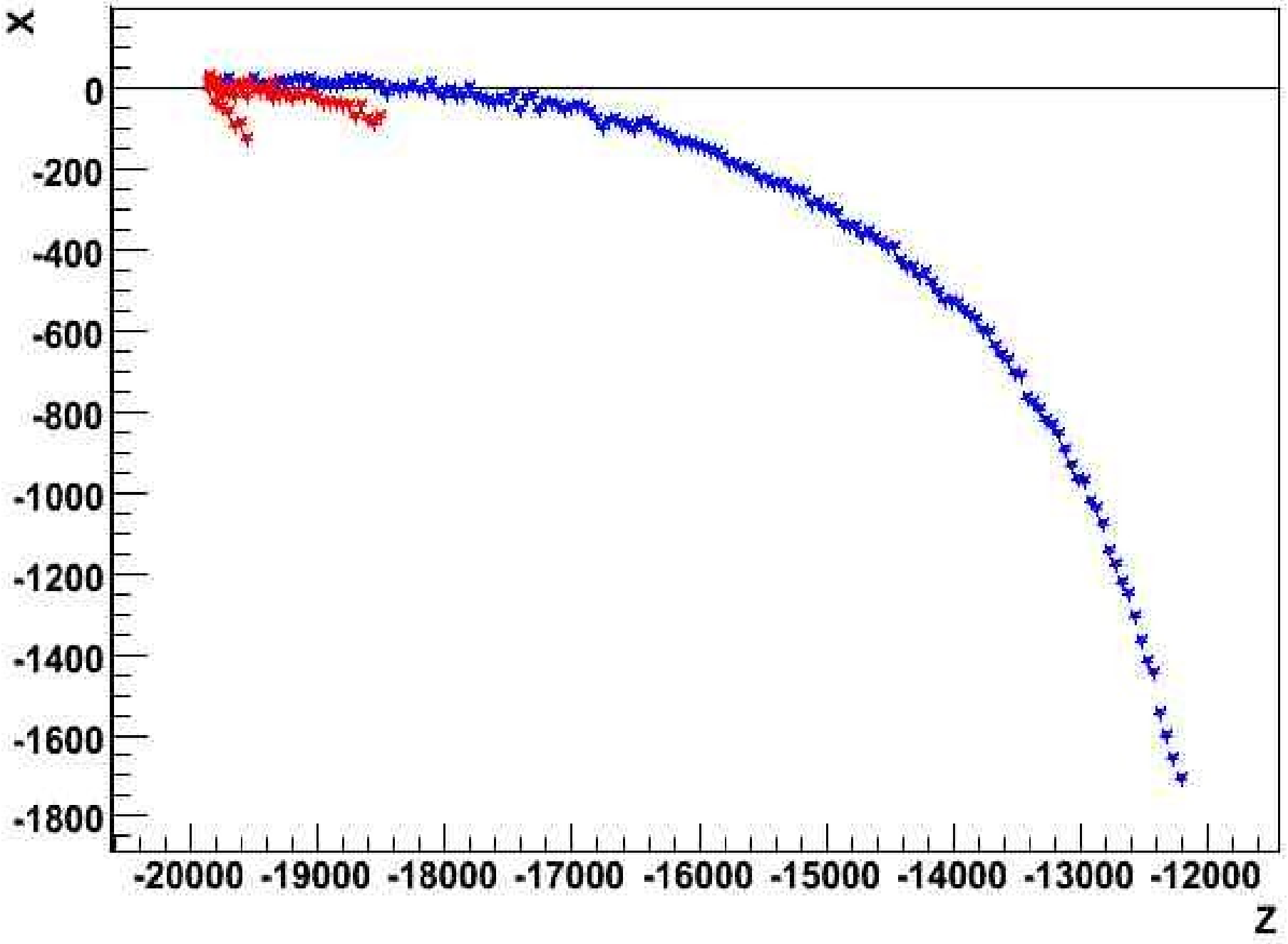
-15000
-14000
-13000
-12000
z


X
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-20000
-19000
-18000
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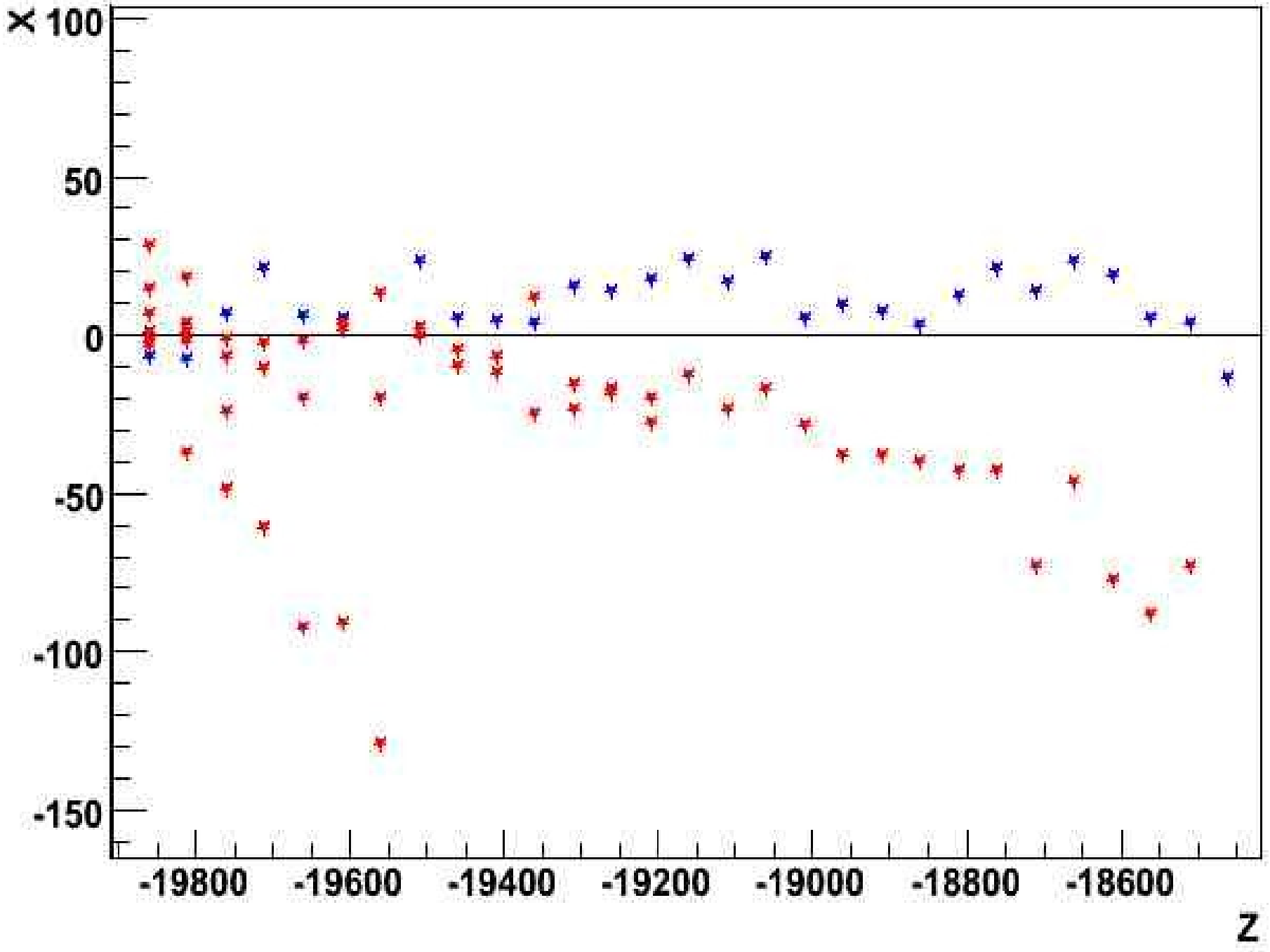
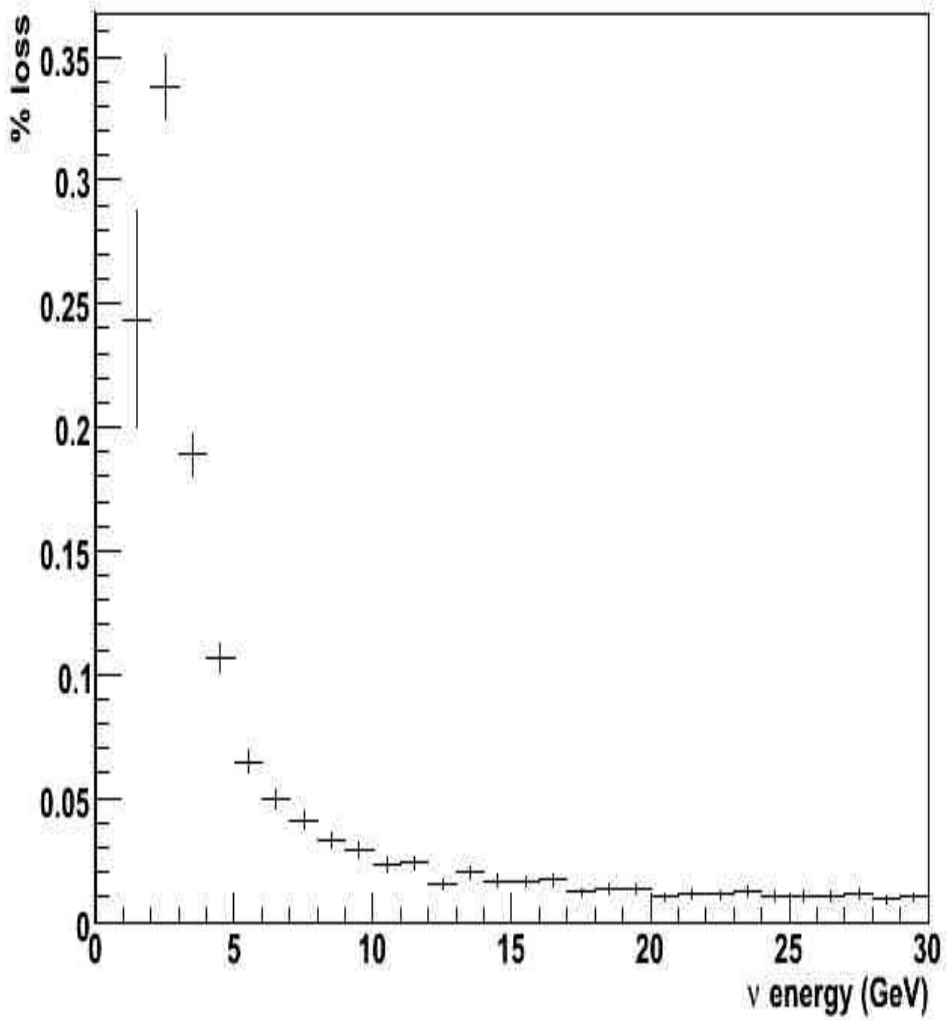
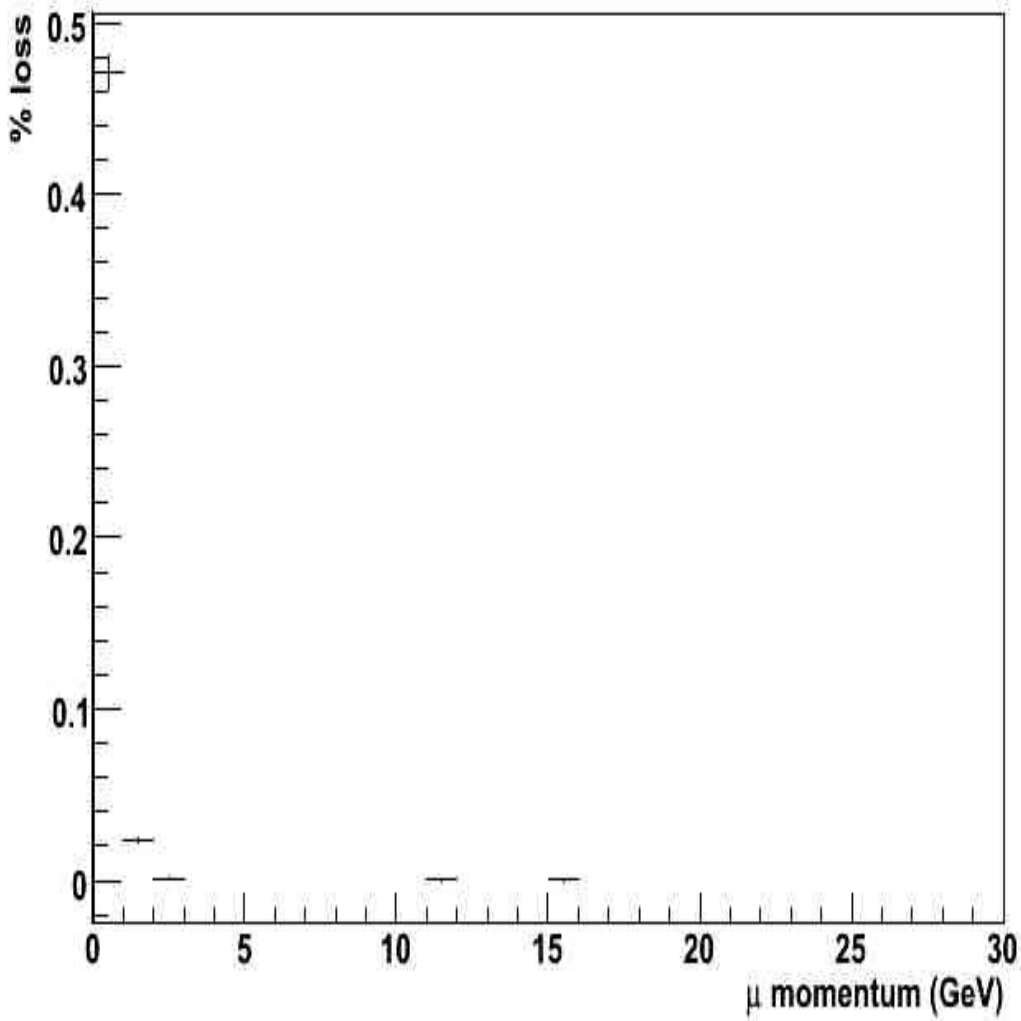
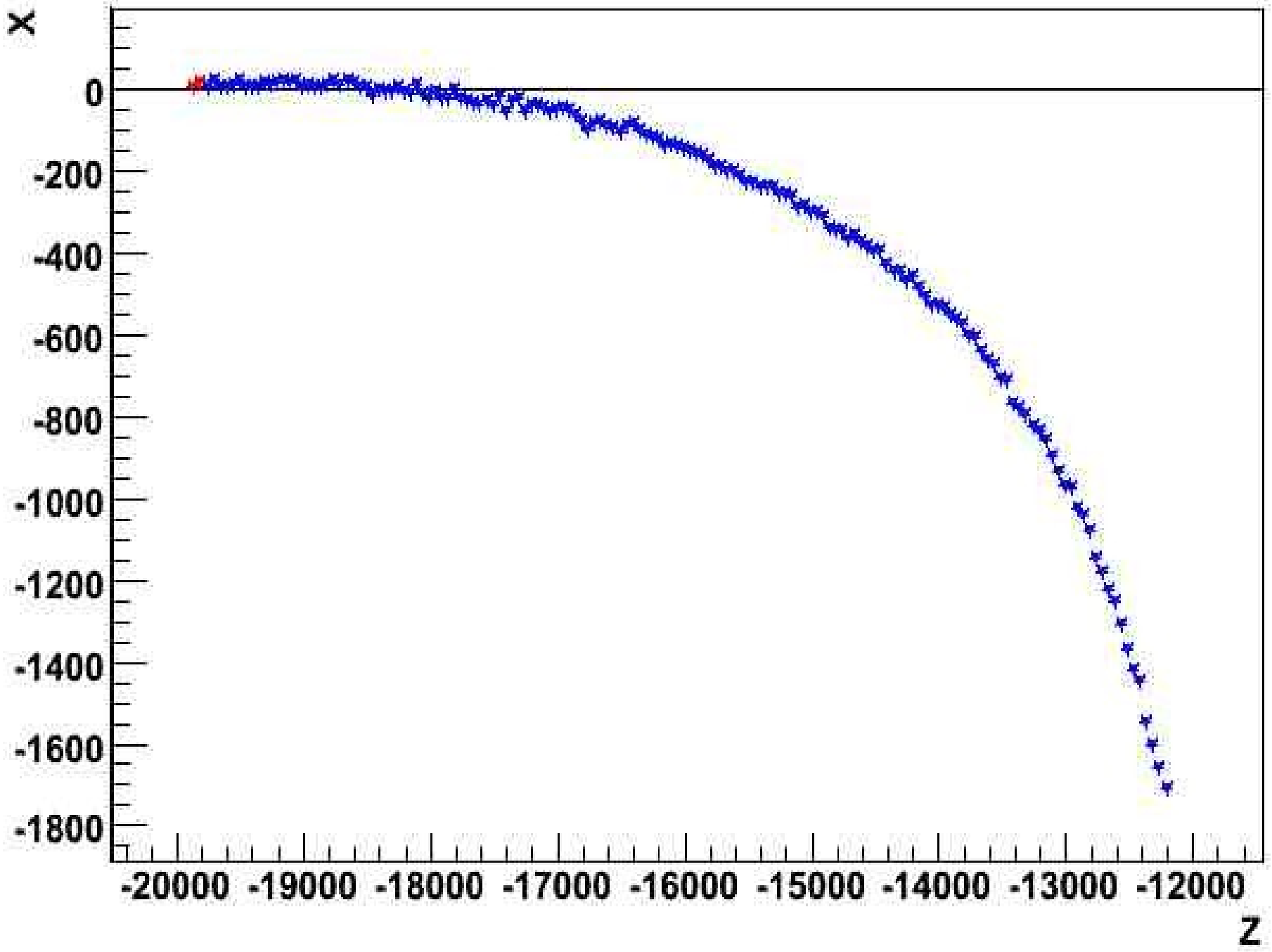
-14000
-13000
-12000
Z


x 100
50
0
-50
-100
-150
-19800
-19600
-19400
-19200
-19000
-18800
-18600
z

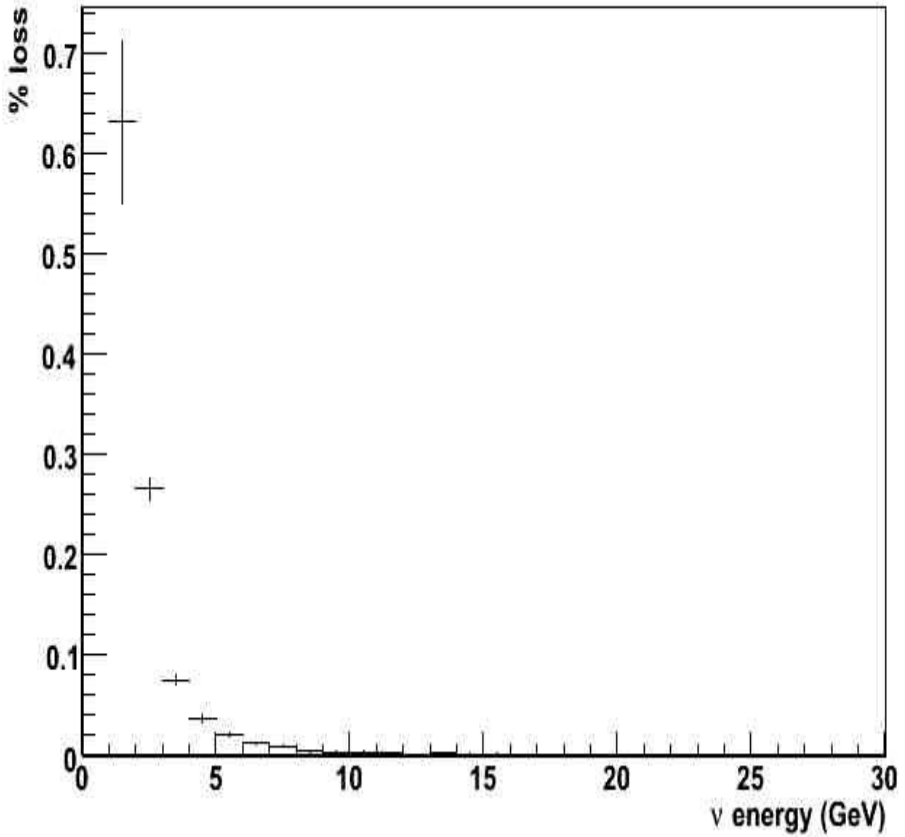
Losses in seed finding

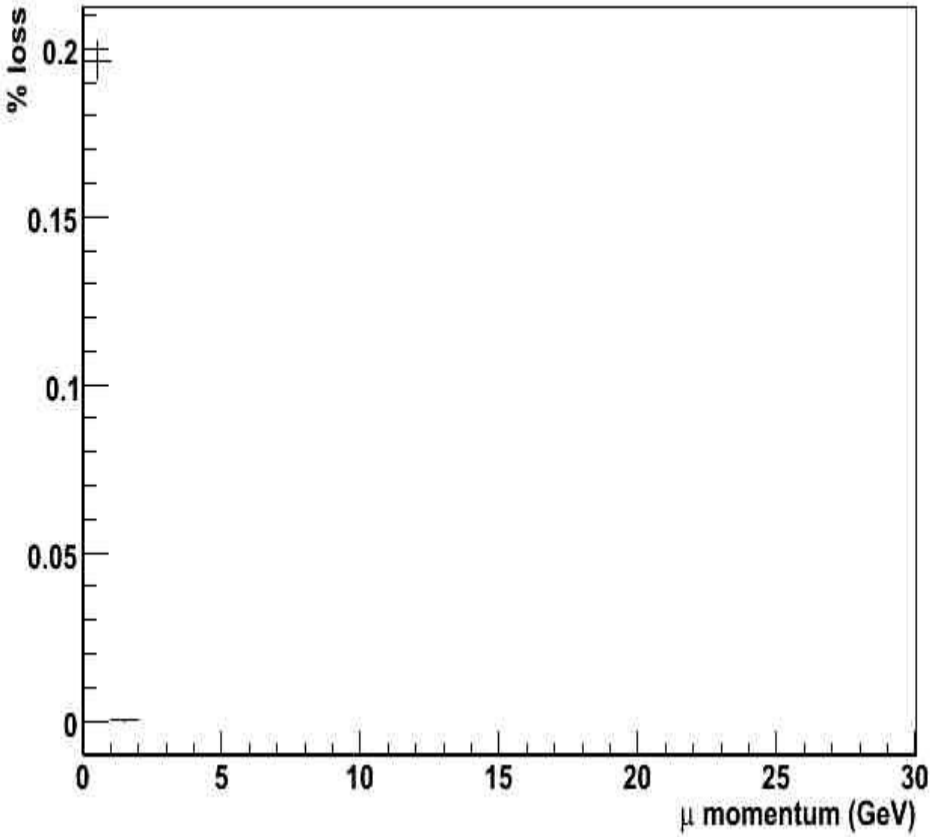





X
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-20000
-19000
-18000
-17000
-16000
-15000
-14000
-13000
-12000
Z

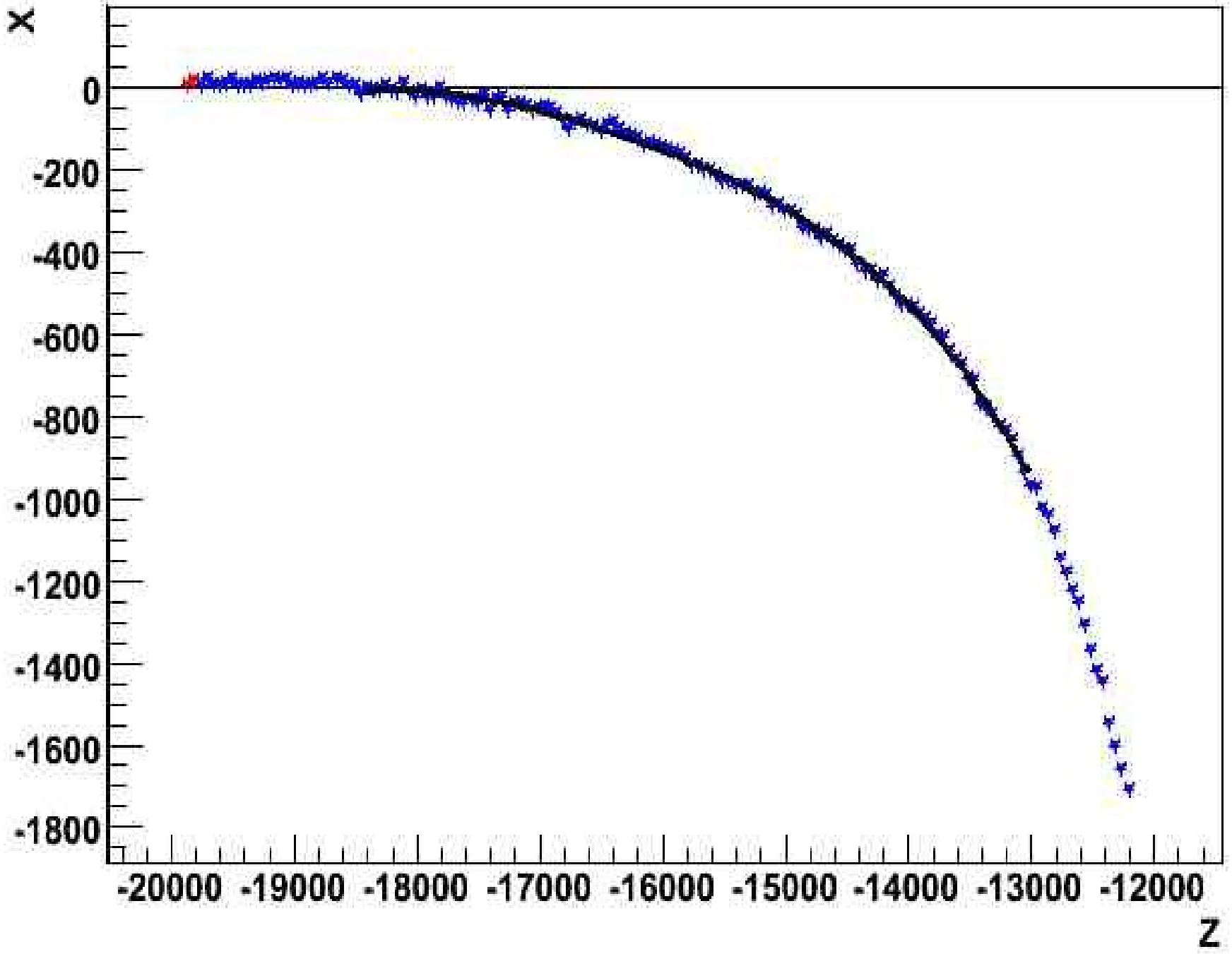
Losses due to low hits

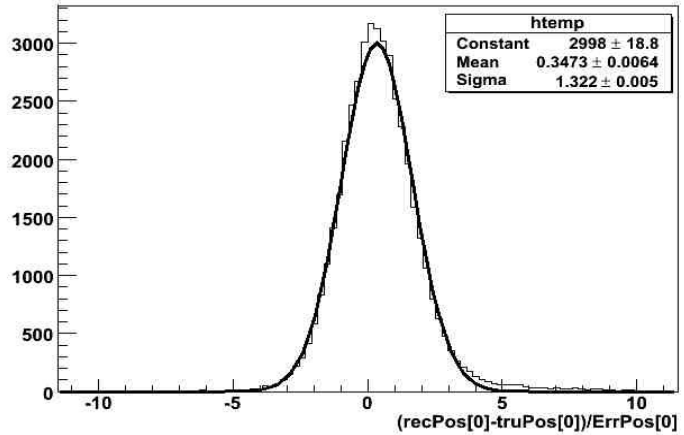


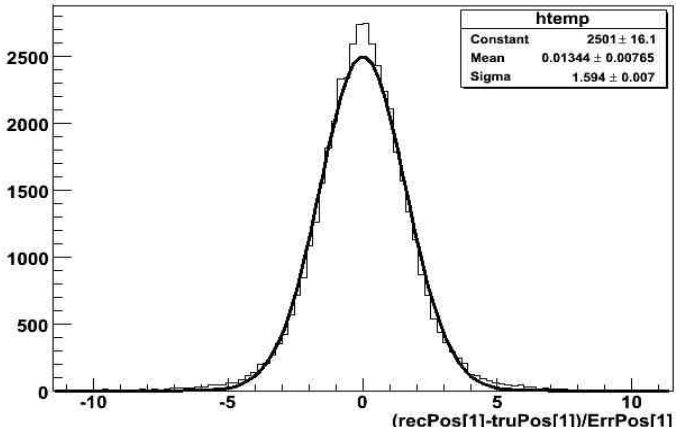


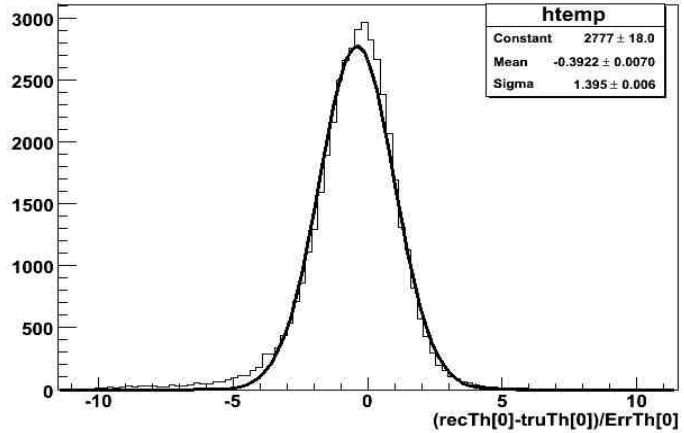
Fitting the Candidate

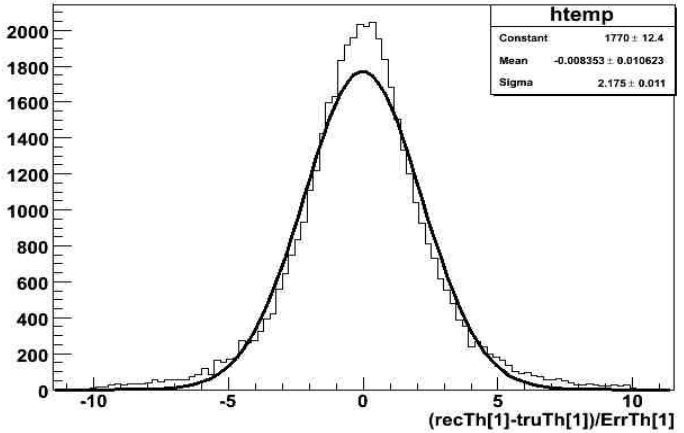
- Kalman Fitter to reconstruct charge
  - Basic kink finder based on local χ^2
  - Loose cut on trajectory χ^2/ndof
  - Fit performed in the forward direction on all candidates
  - Failed fits and those with < 50% fitted nodes are re-fit in the reverse direction.
- Momentum estimated by range for successful fits.

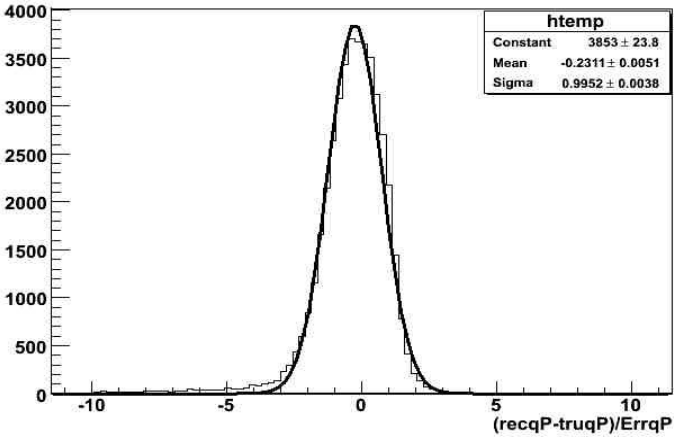

X
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-20000
-19000
-18000
-17000
-16000
-15000
-14000
-13000
-12000
Z

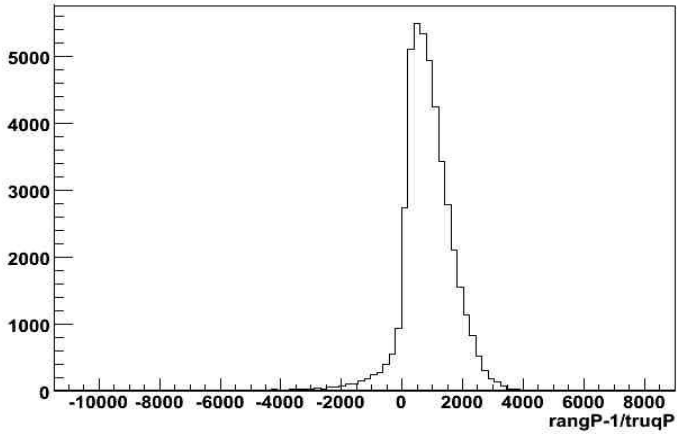

htemp
Constant 2998 ± 18.8
Mean 0.3473 ± 0.0064
Sigma 1.322 ± 0.005
(recPos[0]-truPos[0])/ErrPos[0]


htemp
Constant 2501 ± 16.1
Mean 0.01344 ± 0.00765
Sigma 1.594 ± 0.007
(recPos[1]-truPos[1])/ErrPos[1]


htemp
Constant 2777 ± 18.0
Mean -0.3922 ± 0.0070
Sigma 1.395 ± 0.006
(recTh[0]-truTh[0])/ErrTh[0]


htemp
Constant 1770 ± 12.4
Mean -0.008353 ± 0.010623
Sigma 2.175 ± 0.011
(recTh[1]-truTh[1])/ErrTh[1]


htemp
Constant 3853 ± 23.8
Mean -0.2311 ± 0.0051
Sigma 0.9952 ± 0.0038
(recqP-truqP)/ErrqP

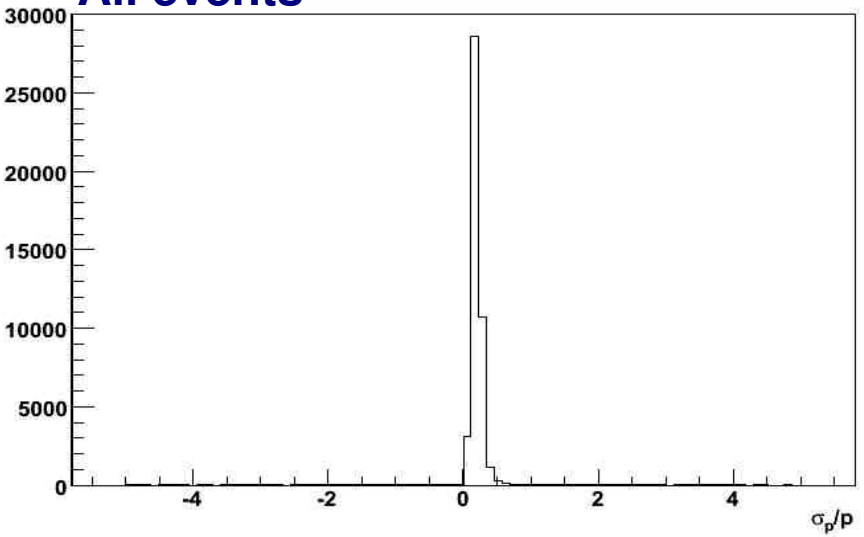

rangP-1/truqP

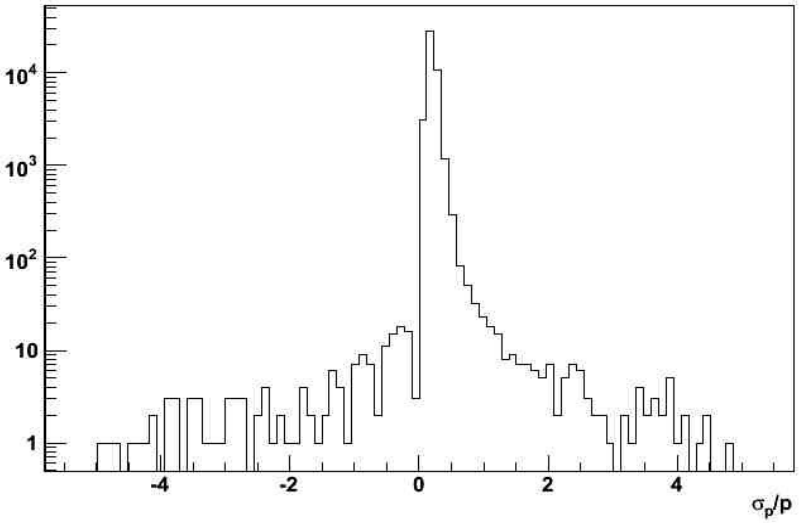
Offline cuts

- Currently use three basic cuts on results to suppress charge misidentification:
  - Curvature momentum relative error (σ_p/p)
  - Trajectory χ^2/ndof
  - Difference in range and curvature momenta relative to the error

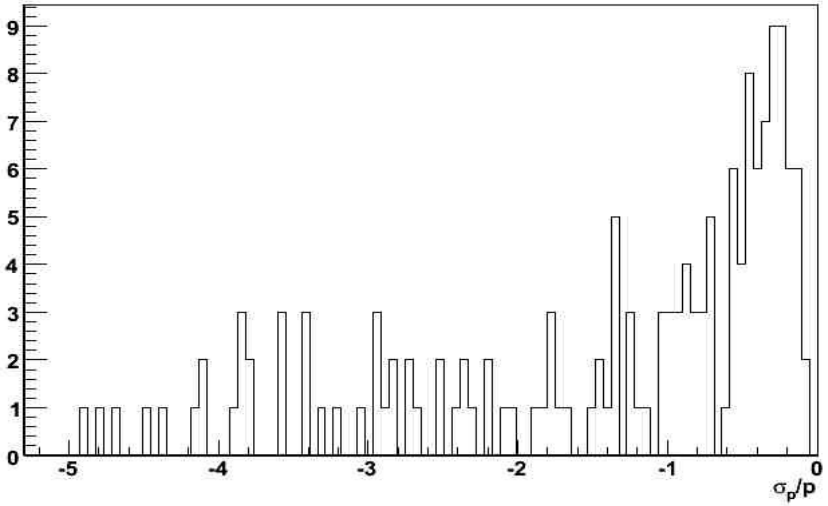
Relative error

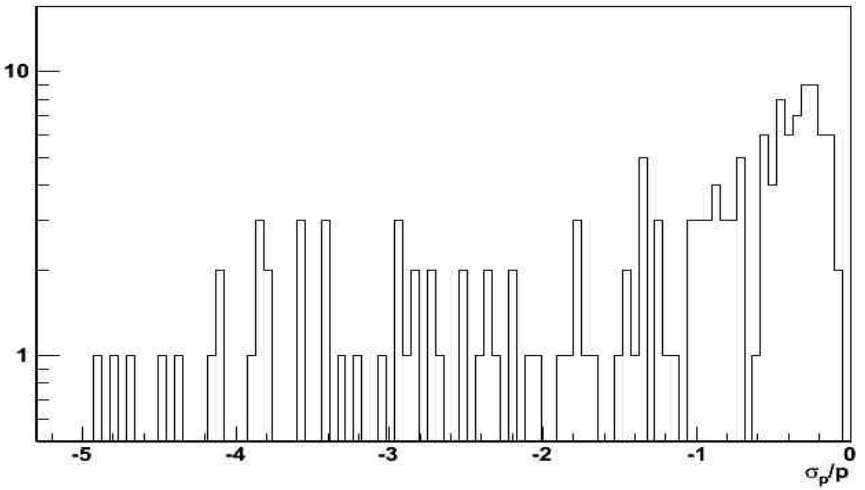
All events



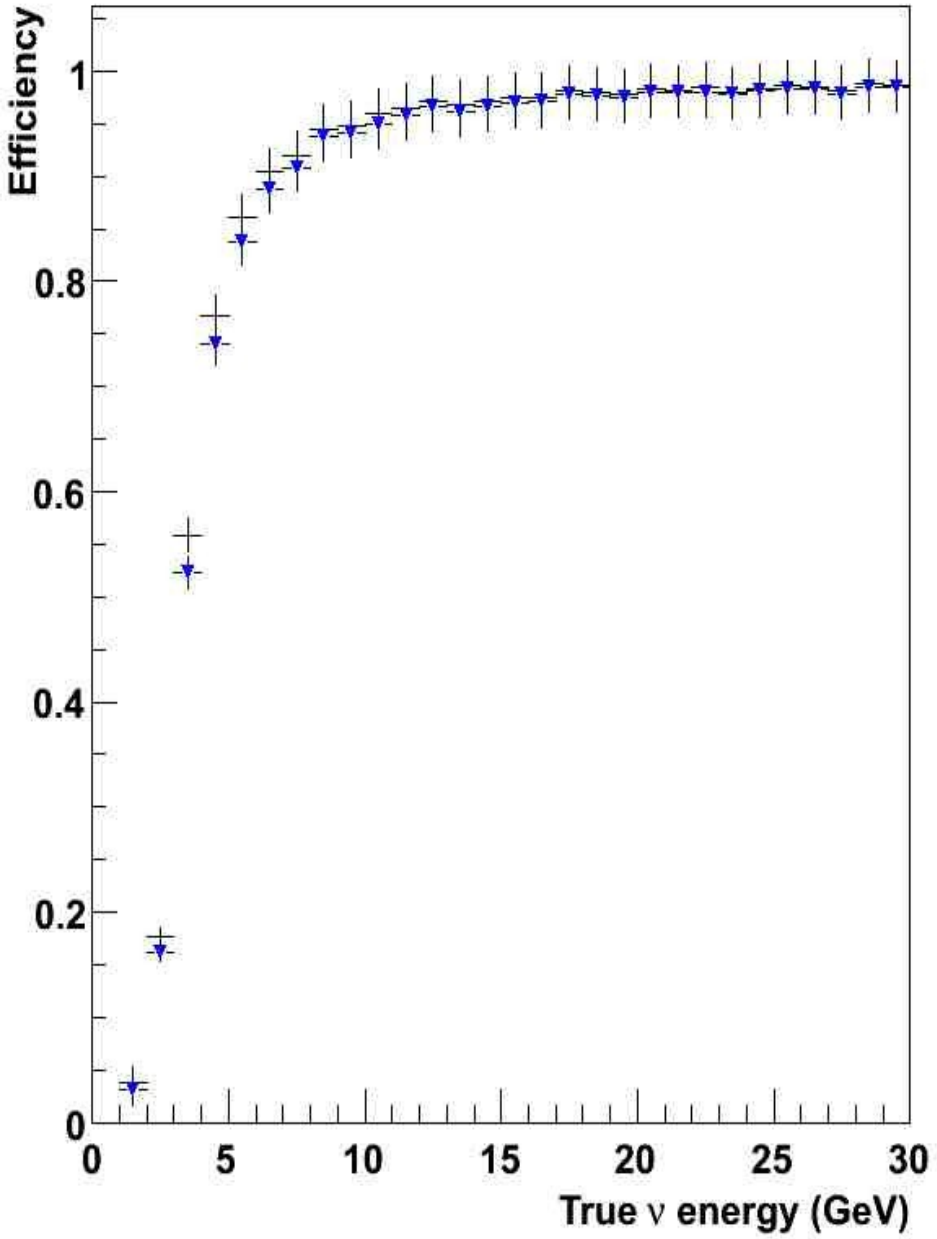


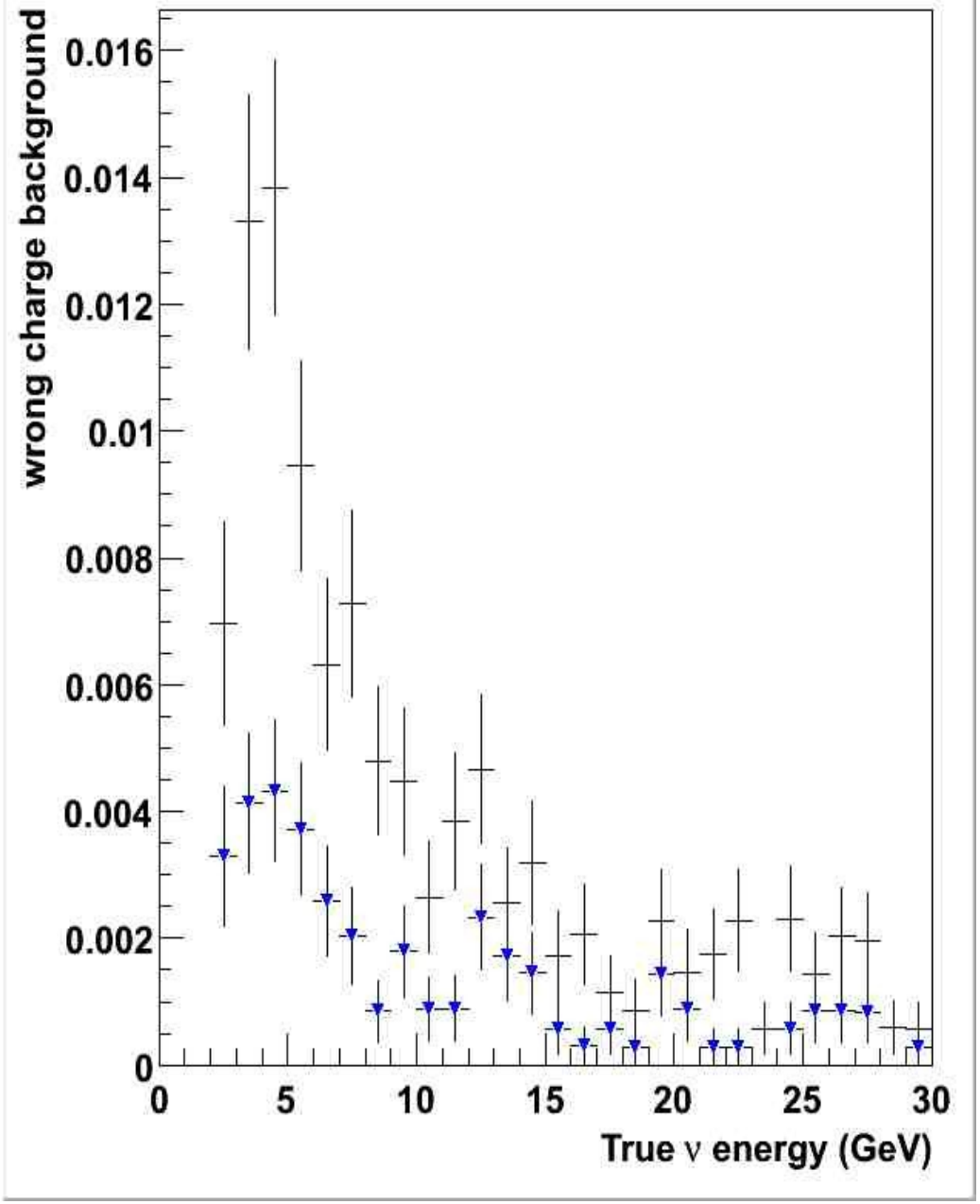
Wrong charge



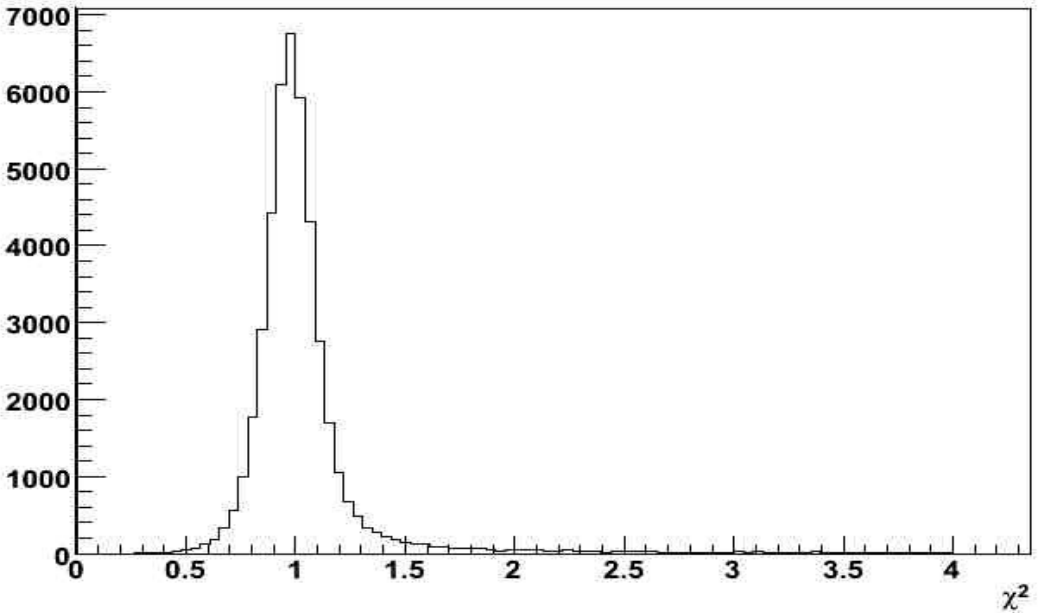


Relative error



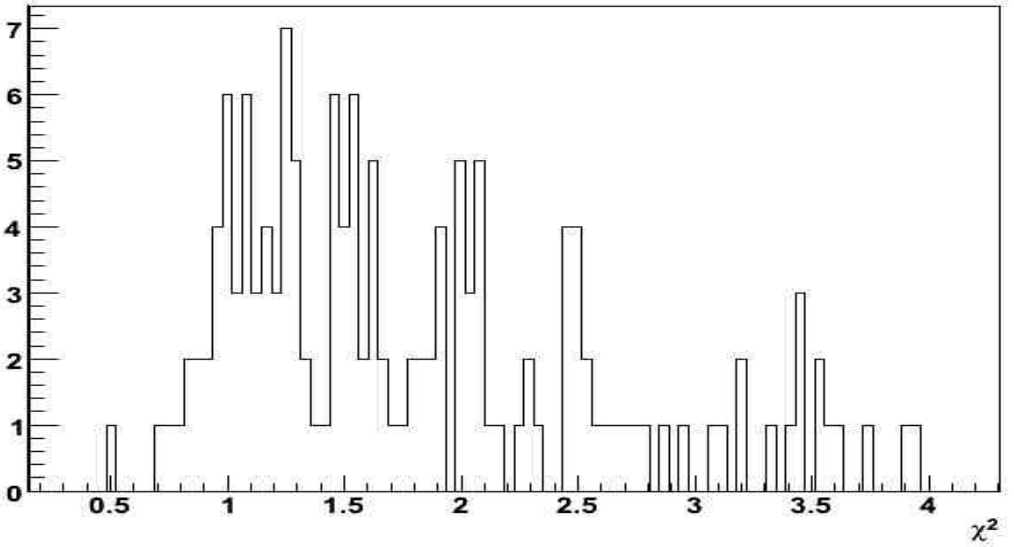


Trajectory χ^2/ndof

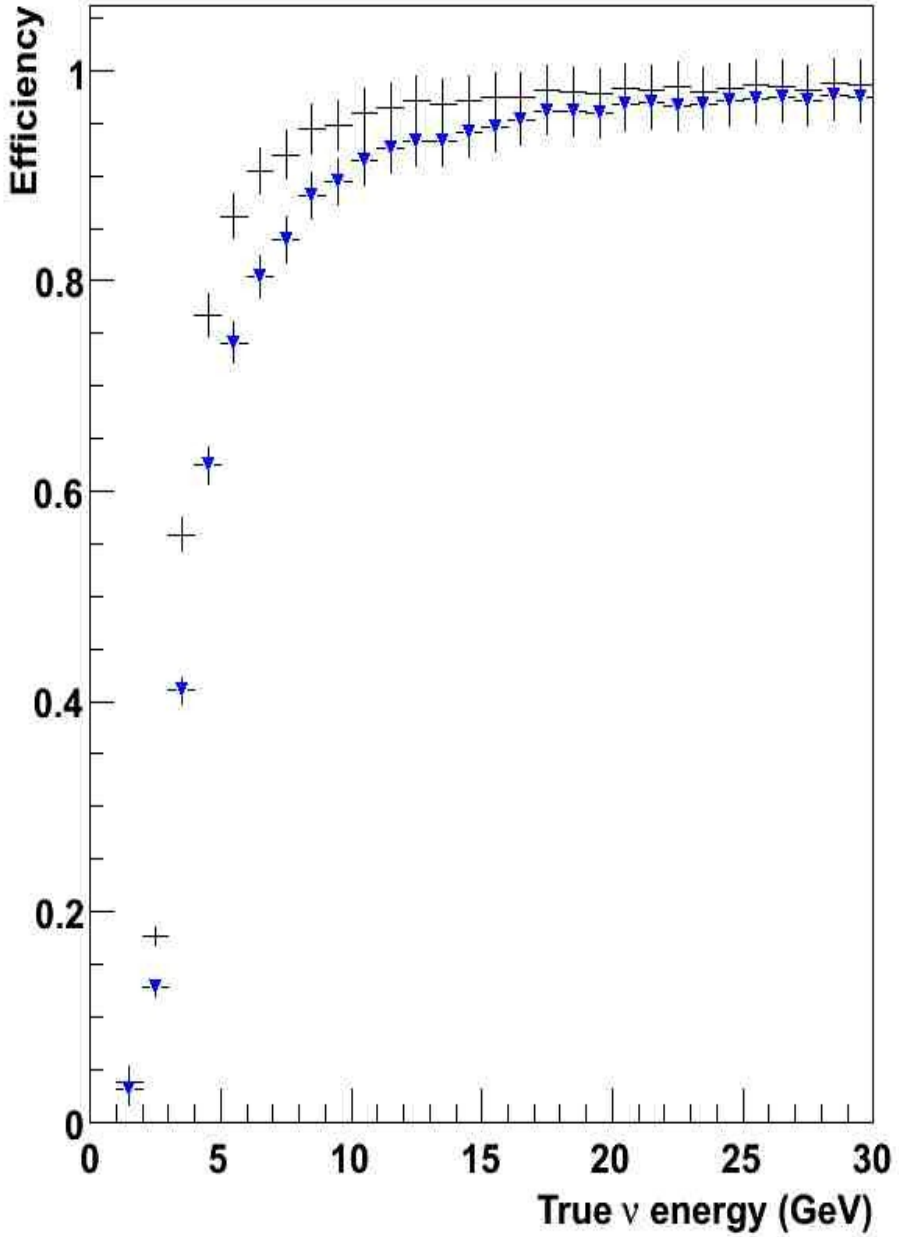


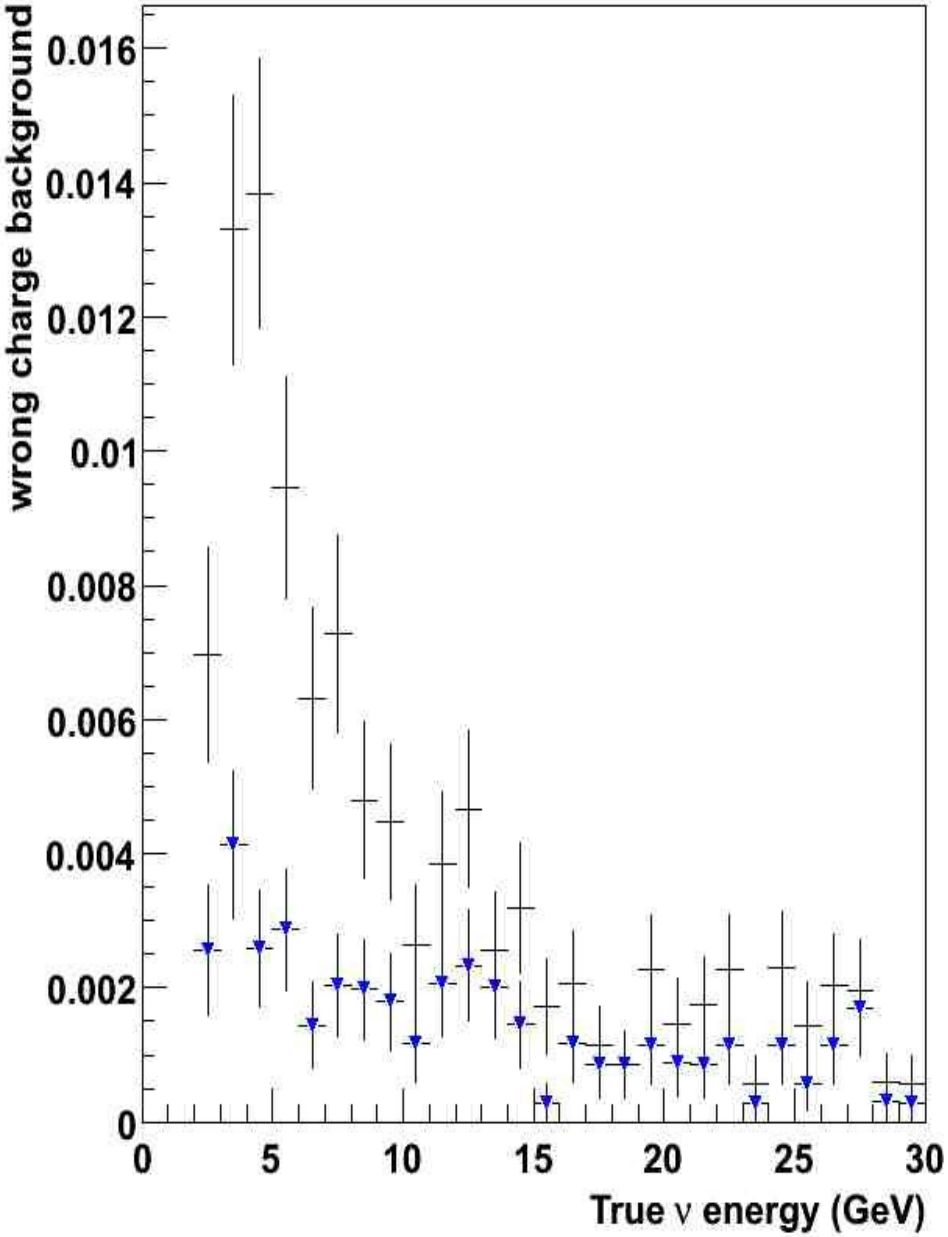
All events

Wrong charge

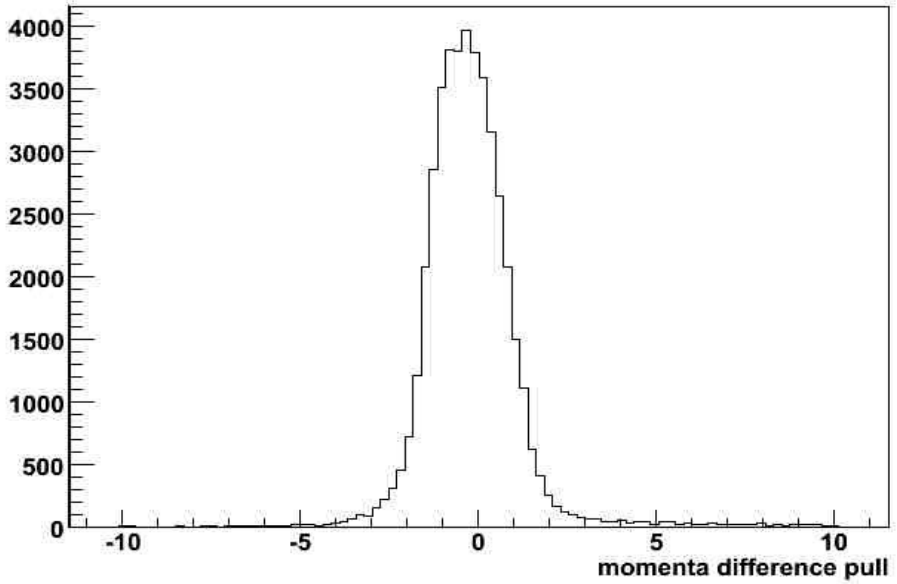


Trajectory χ^2/ndof





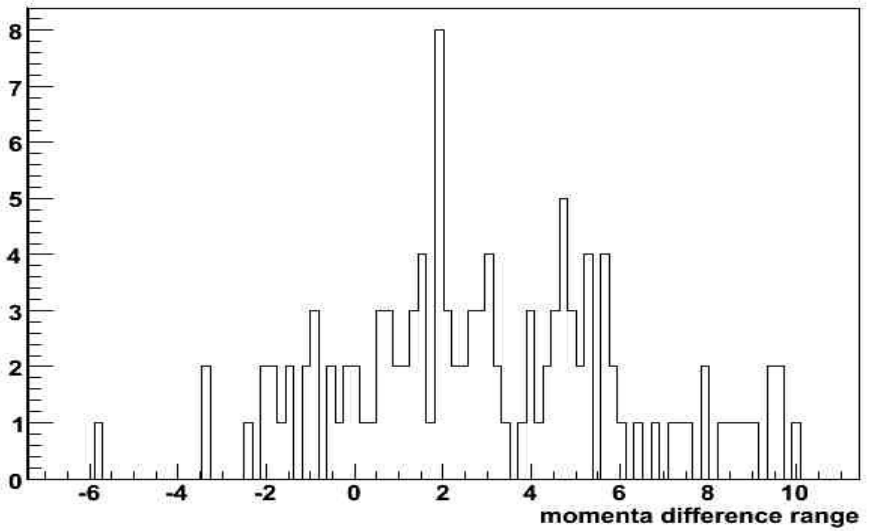
Range variable



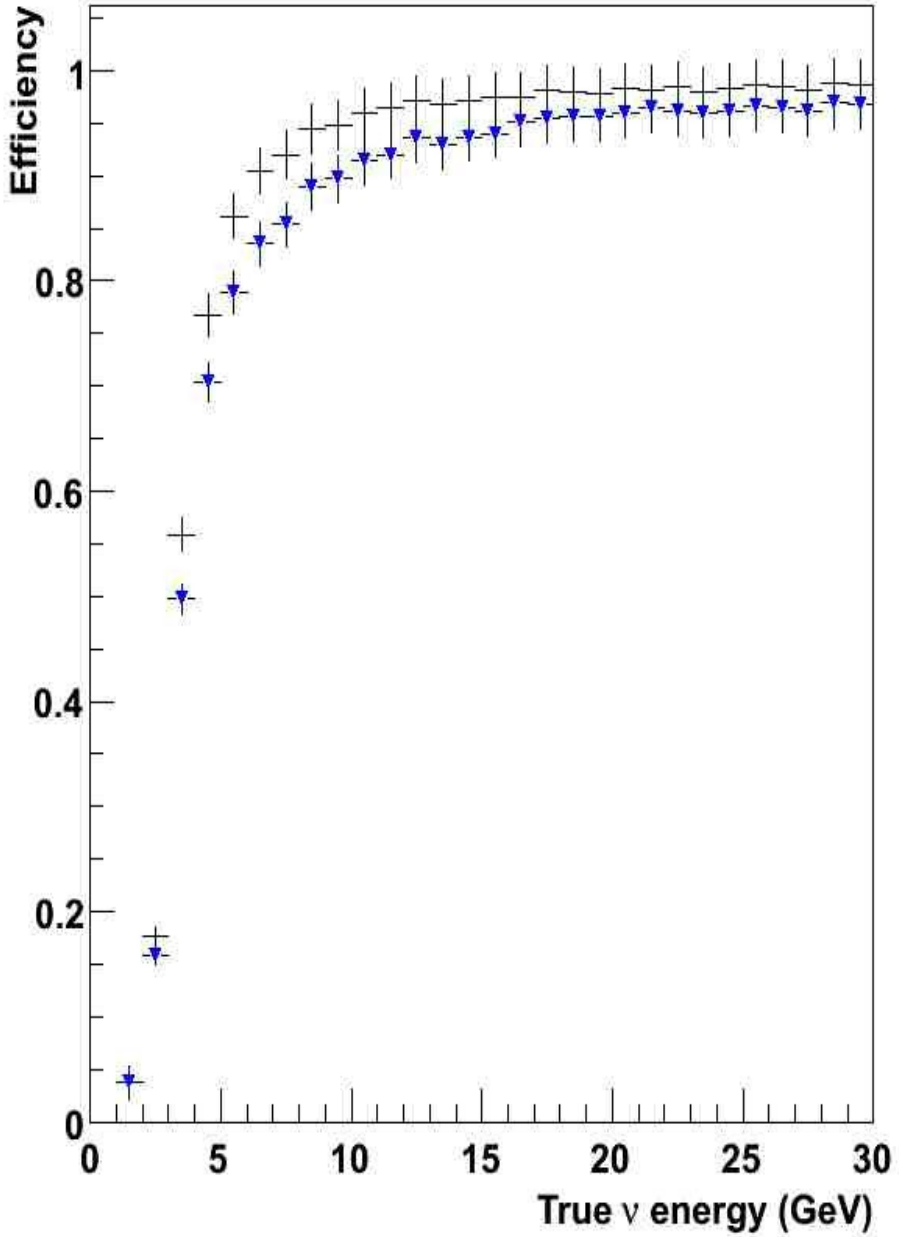
$(1/p_{range} - 1/p_{curv})/\sigma_{curve}$

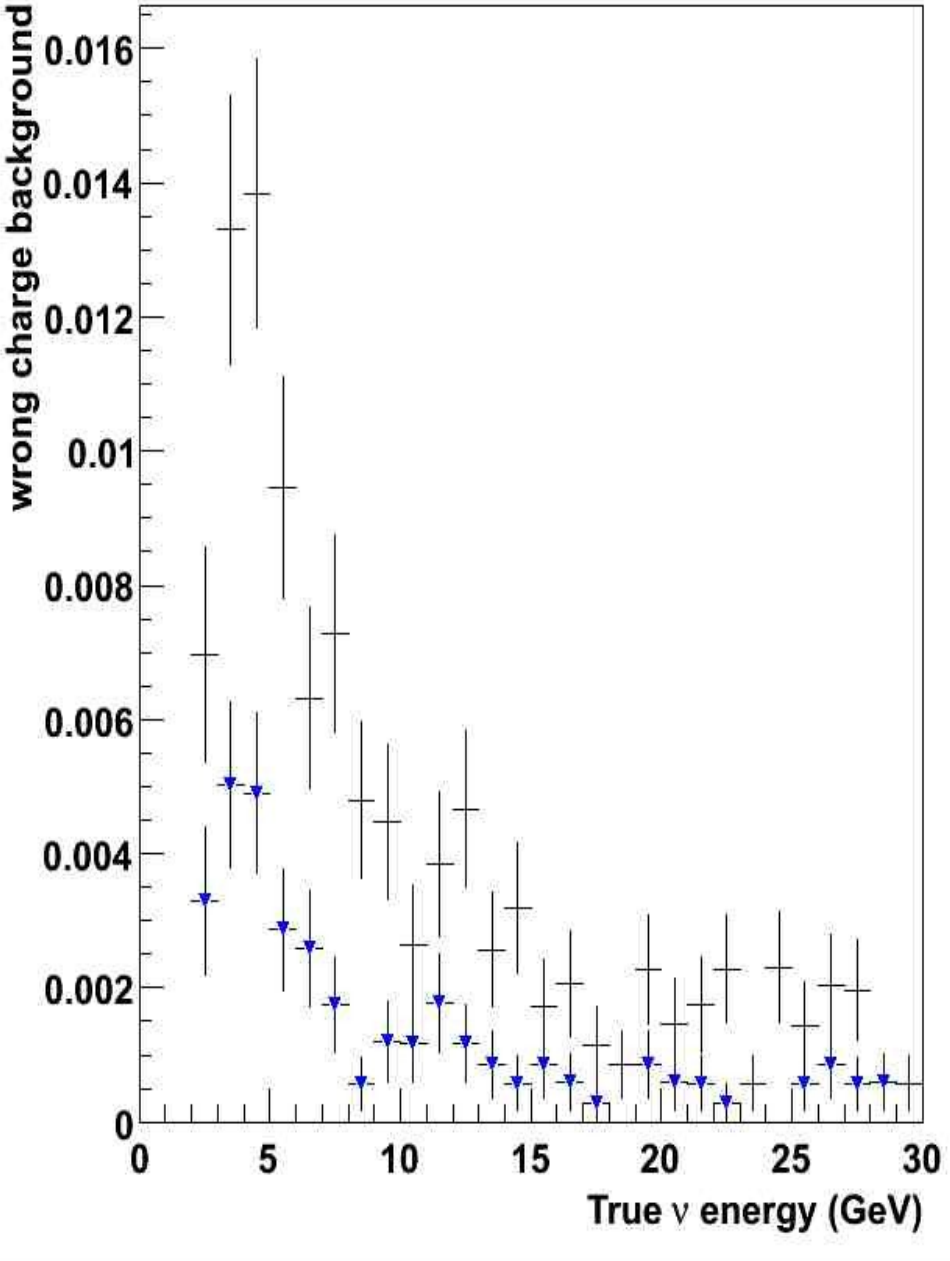
All events

Wrong charge

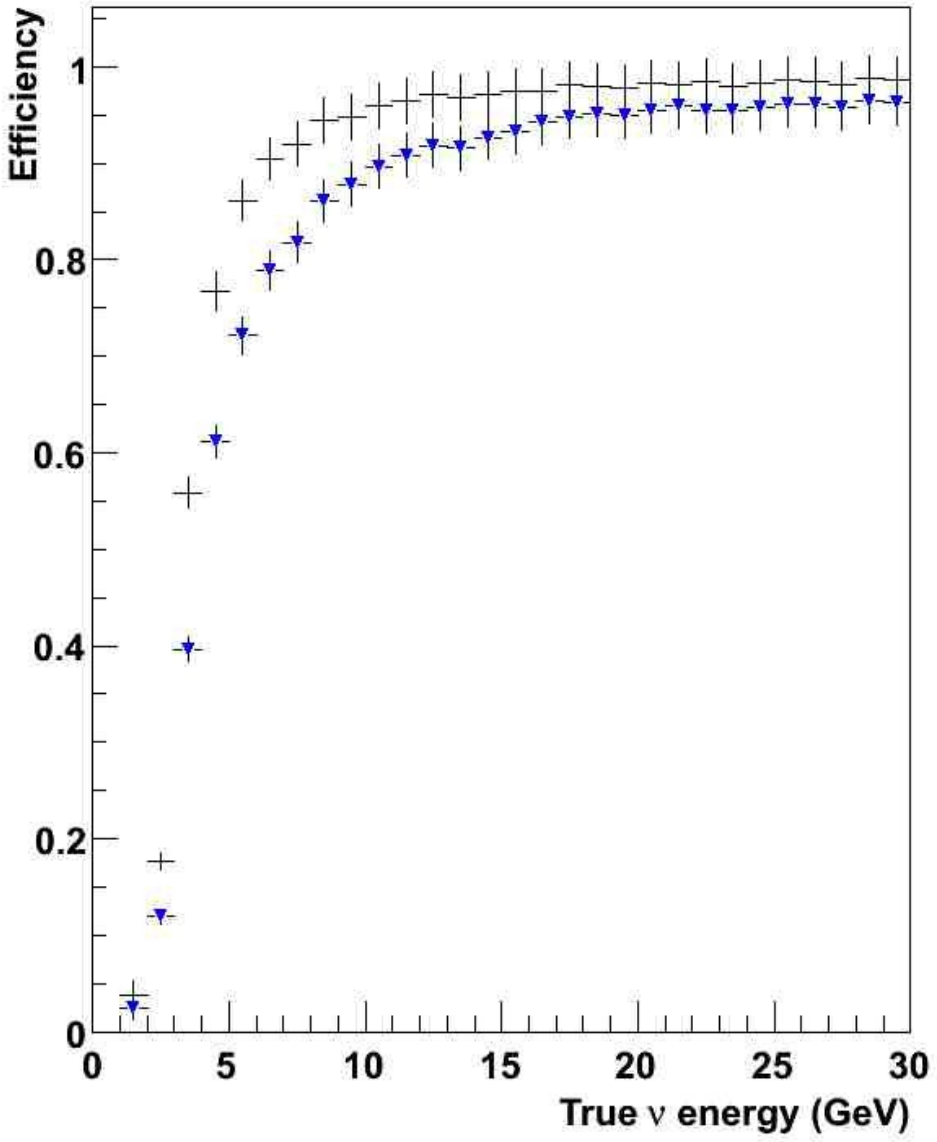


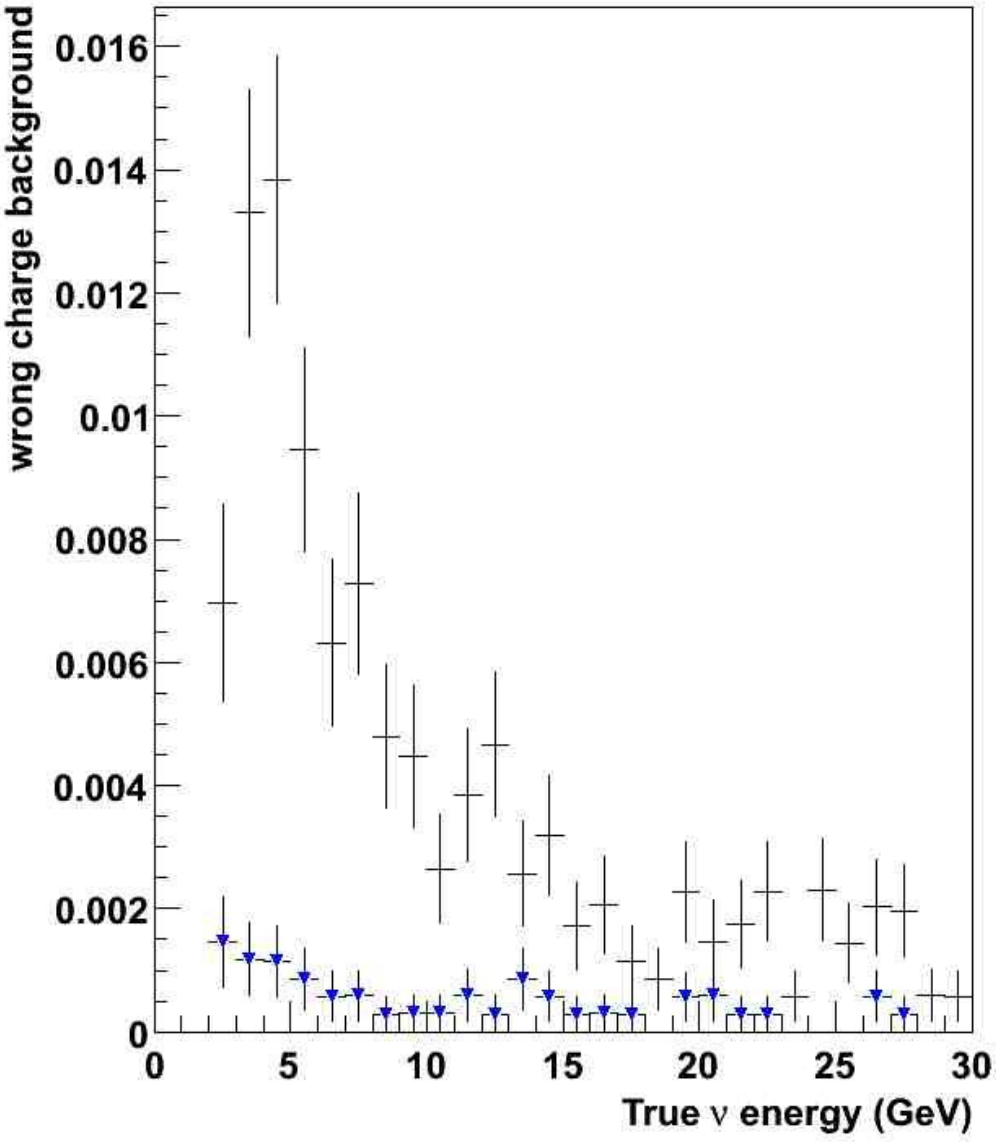
Range variable





All cuts

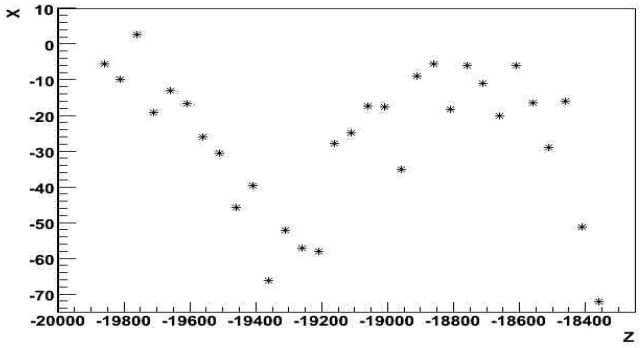

Efficiency
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
True ν energy (GeV)


wrong charge background
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
5
10
15
20
25
30
True ν energy (GeV)

What mis-IDs still remain

- The current result achieves the required 10^{-3} suppression of wrong charge assignment for low neutrino energies (< 5 GeV)
- But where do we fail and what can be done to further reduce these fails?
- We can classify the failures into approximately 3 groups.

High Multiple scattering

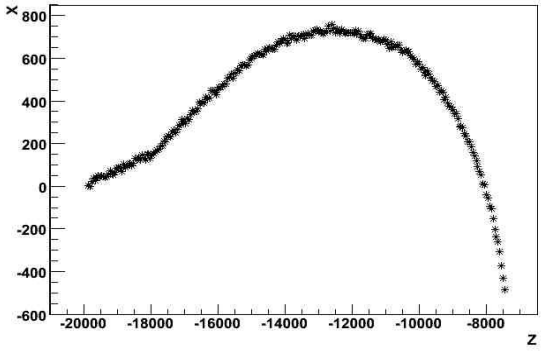


Constitute approximately 40% of remaining background

High level of multiple scattering early in trajectory reduces efficiency of kink finder

Could be rejected by eye but automatic rejection should be possible

High continuous curvature

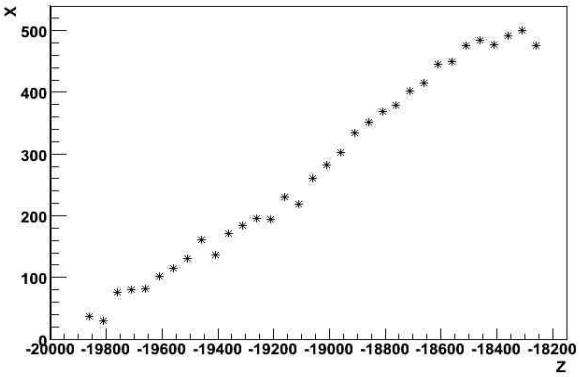


Constitute approximately 15% of remaining background.

High curvature can cause early fails but can be 100% fit due to continuity and still misID

Easily rejected by eye

Low or zero curvature



Constitute approximately 45% of remaining background

Not enough curvature over the whole trajectory to see true charge, generally low energy

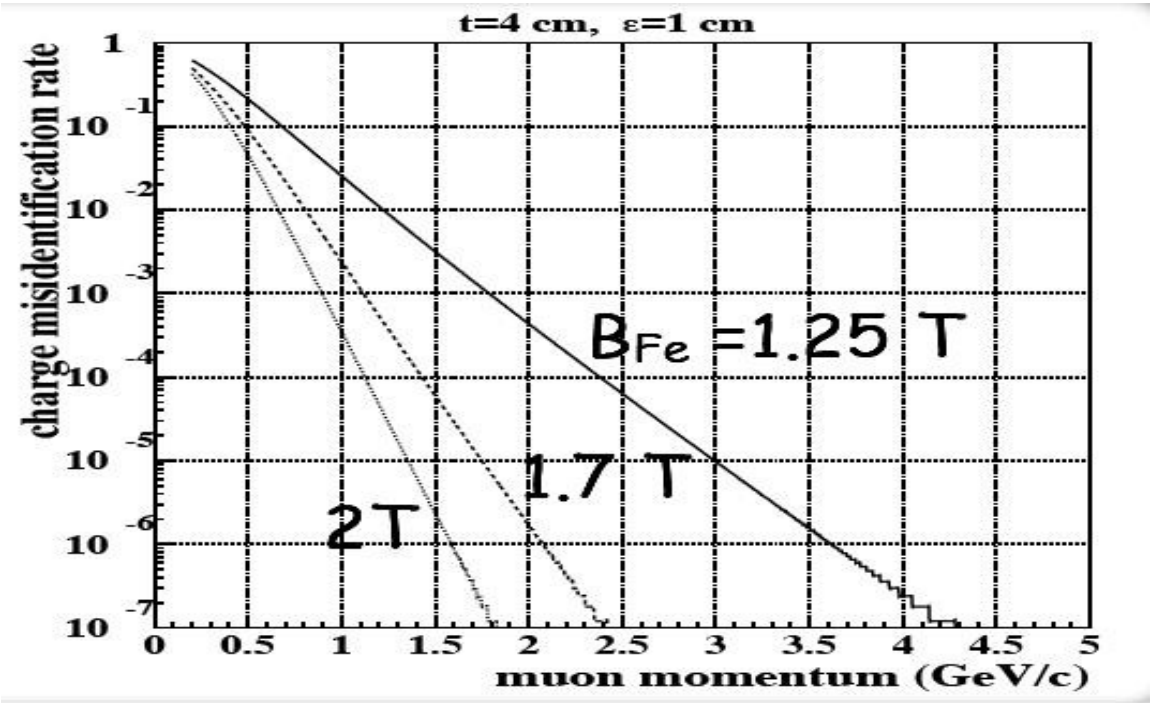
Should be able to reject some automatically but could cause low efficiency at low energy

Possible improvements

- χ^2 probability as mentioned before
- A more sophisticated kink finder able to compare slopes
  - Currently only compare Local χ^2 based on positions the slope change should prove more powerful
- Greater rejection power could also be achieved by forming a likelihood function based on all charge discriminating variables

Improvements (cont.)

- Increasing magnetic field
  - 1T average field equivalent to 1.25T in iron. Order of magnitude improvement possible with feasible increase to 1.7T in iron

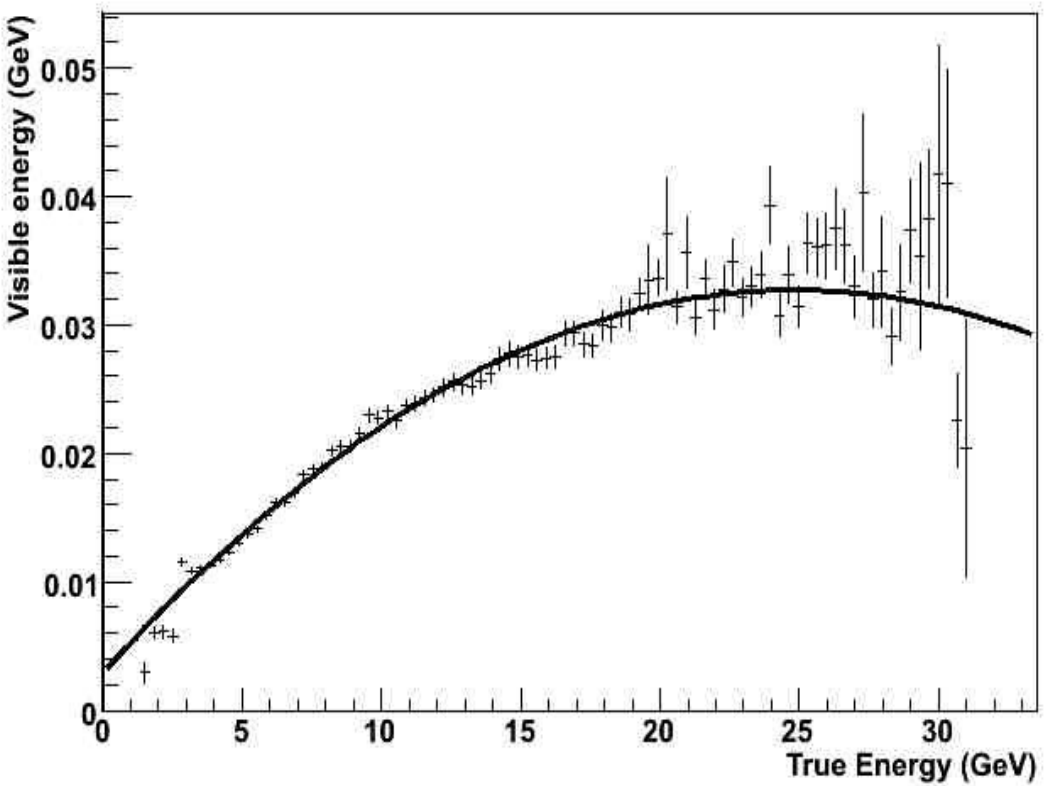


Hadron Shower

- All hits rejected as being part of the candidate muon are considered as hadronic activity.
  - Need to reconstruct the energy of the hadron shower in order to reconstruct neutrino energy
  - Also interested in the momentum of the shower, especially in terms of background rejection using angular separation (Q_t)

Initial studies, Energy

- Expect approximately linear relation between the visible and true energy.

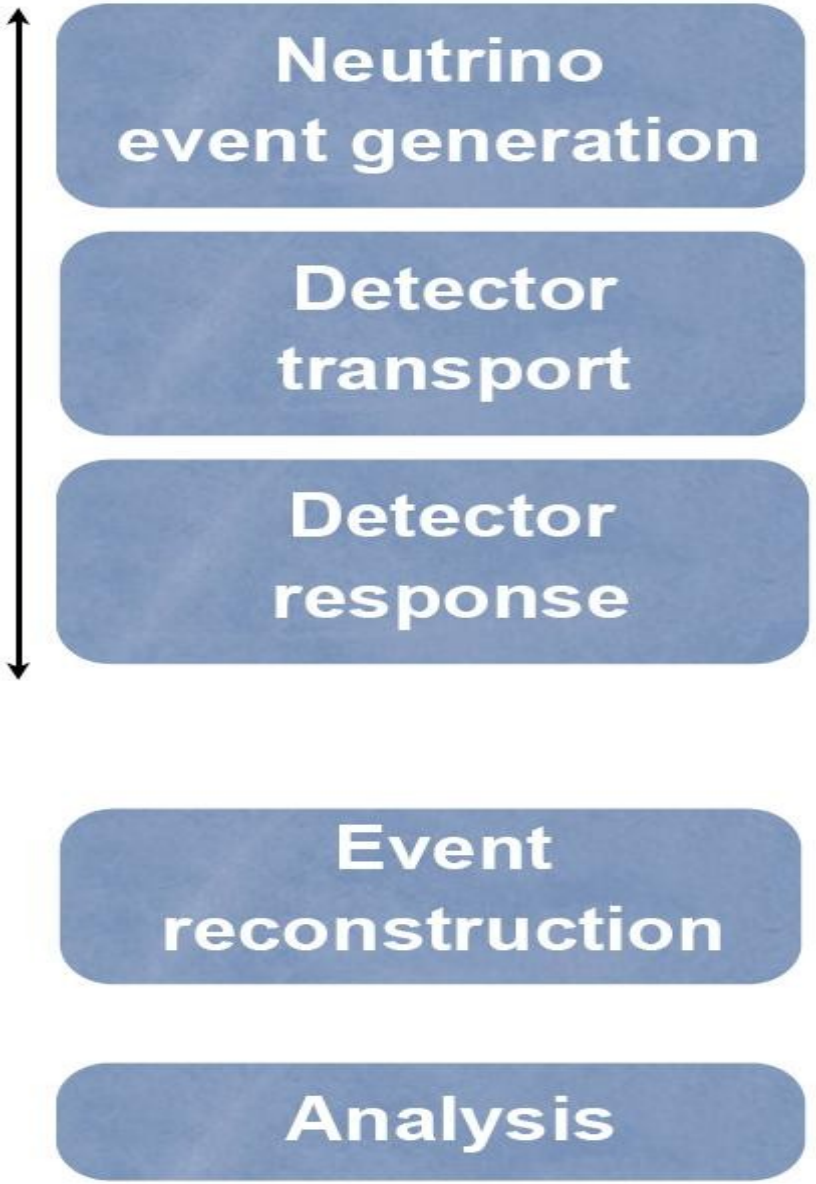


Could be missing hits due to photons in the ntuple

Initial studies, direction

- Initial fit to weighted mean position per plane gives some indication of vector direction.
- For full 3-momentum reconstruction need either:
    - Jet/Cone fitting algorithms

Physics Strategy 1



Analyses 0/1

Geant3

Simple smear

Reconstruction analysis

Analysis 2

Nuance (DIS only)

Geant4

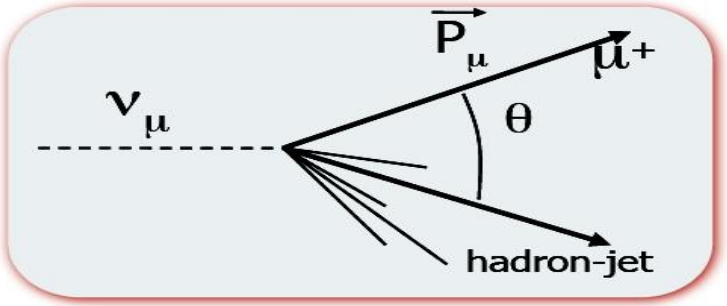
Kinematical cut analysis (p, Q_t)

Analyses 1/2: 2007 cut analysis

- Analysis based on length difference, momentum and Q_t

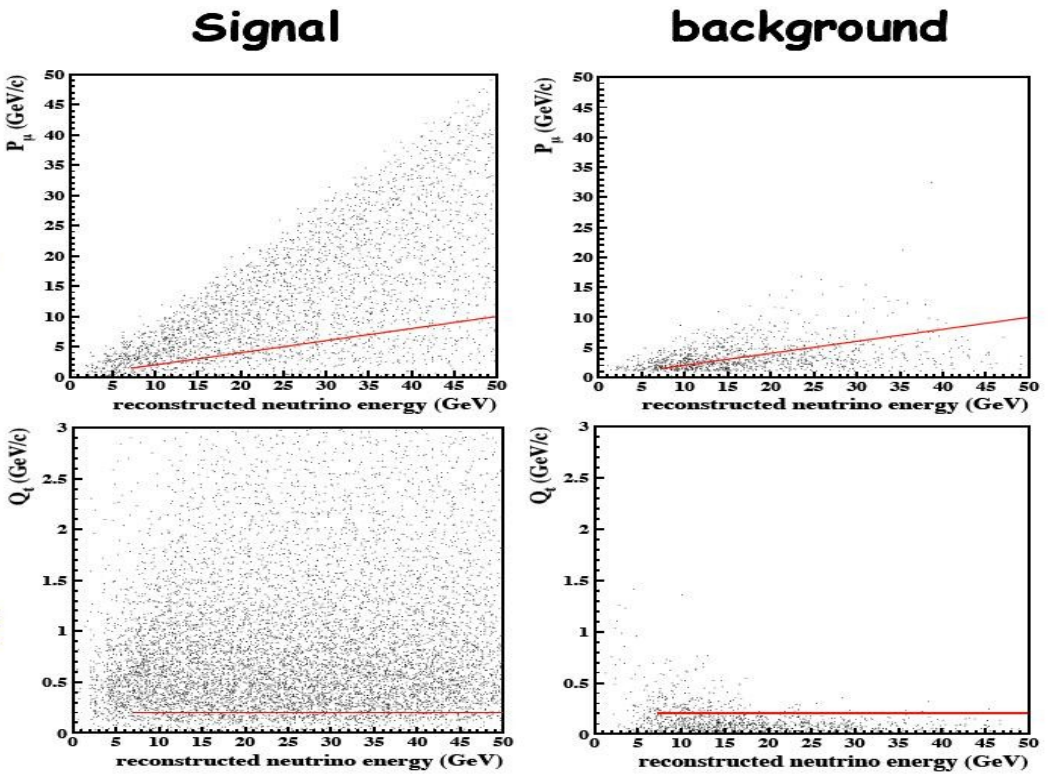
$P_\mu = |P_\mu|$

$Q_t = P_\mu \sin^2\theta$



P_μ

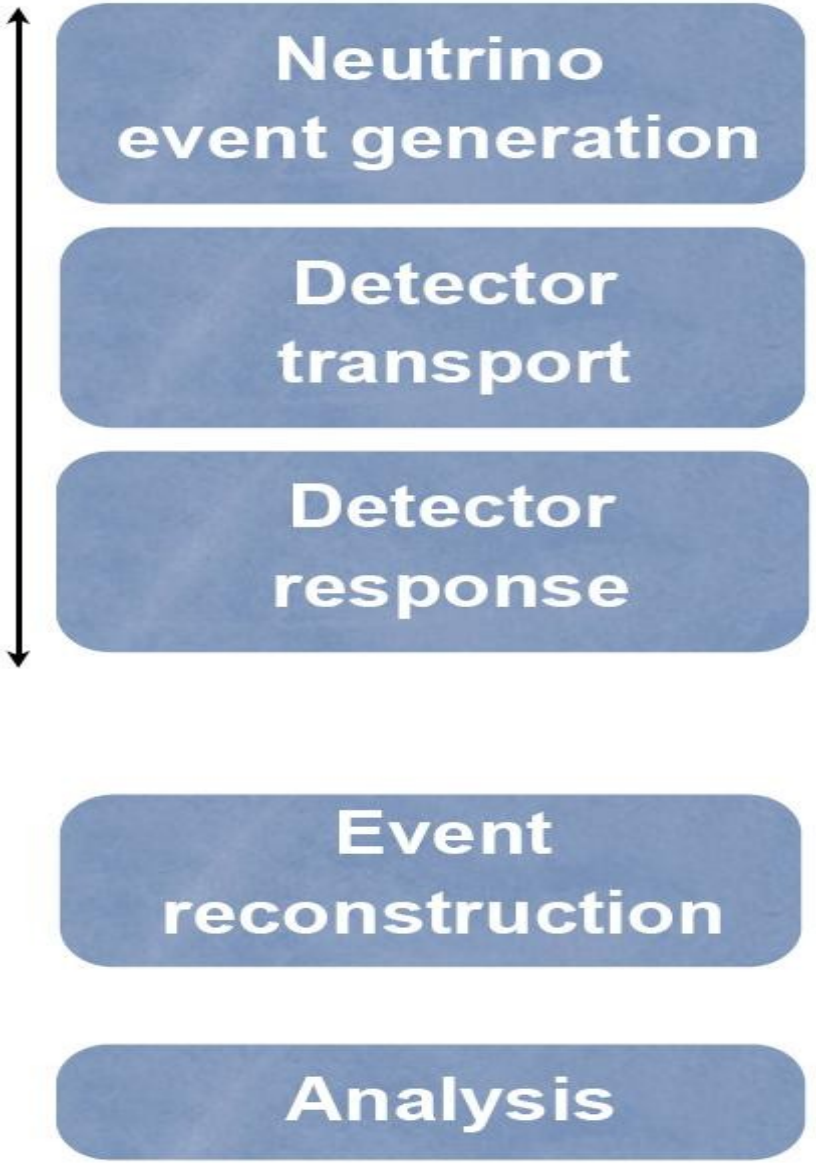
Q_t



Analyses 1/2: 2007 cut analysis (2)

- Analysis first performed on G3 data as a check (Analysis 1)
- Then using the nuance event generator with only Deep Inelastic events and G4 for transport (Analysis 2)
- What does G4 change?

Physics Strategy (cont.)



Analysis 3

Nuance

Geant4

Kinematical cut analysis (p, Q_t)

Analysis 4

Nuance (DIS only)

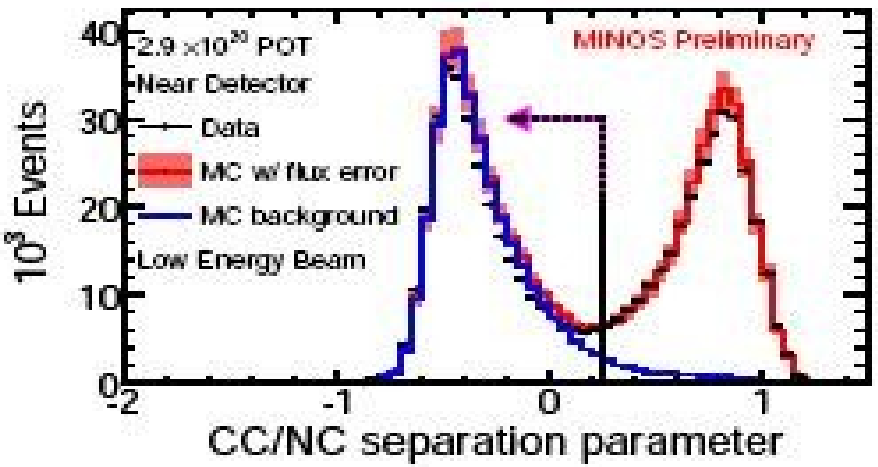
Geant4

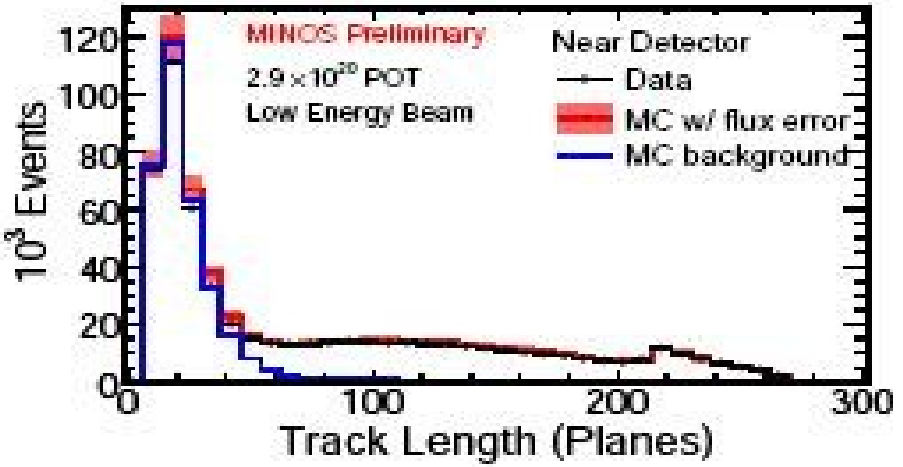
Reconstruction analysis

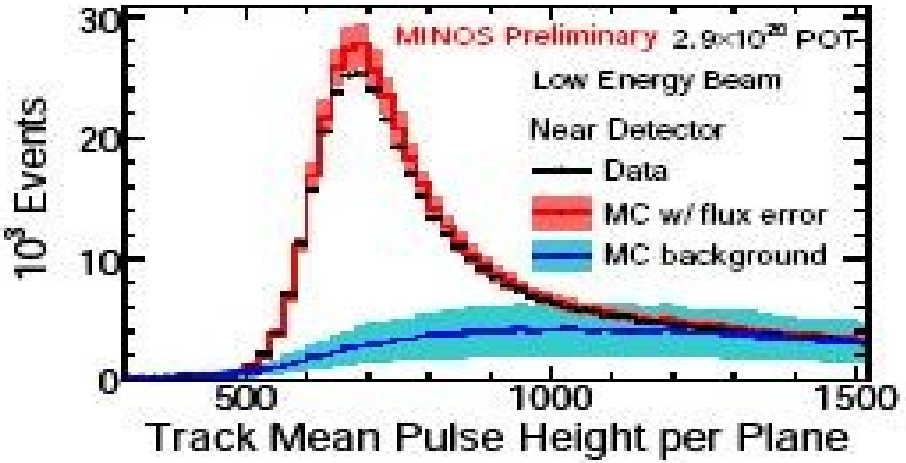
Physics Strategy, NC rejection

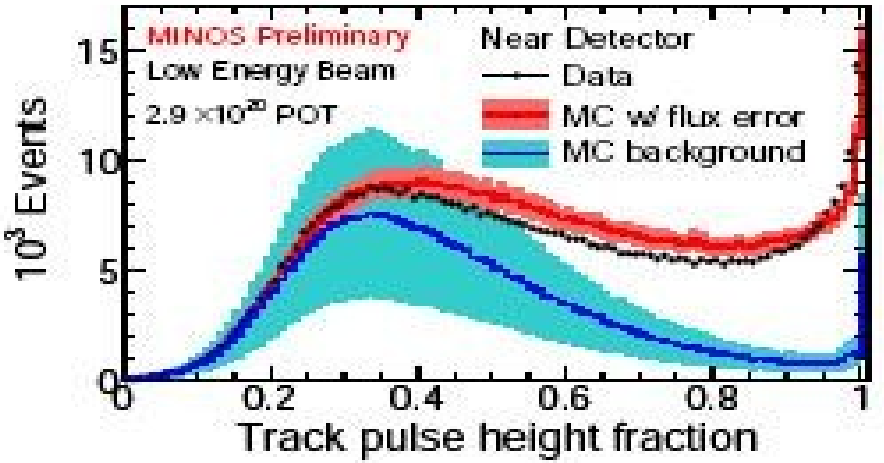
- Initial studies started into likelihood based rejection of background interactions
- Need to be able to reject effectively NC with penetrating pions and secondary muons

Minos algorithm









Plot courtesy of G. Lefeuvre and J. Hartnell

Possible variables

- Minos variables good starting point
- Need better resolution so need to investigate the power of these variables as well as others
- Combined likelihood in 2/3 dimensions to for correlated variables
- Q_t, p total event energy as well as charge rejection variables could contribute here.

Further steps

- Once the first analyses are complete and the likelihood functions understood these will be implemented together.
- A more realistic digitisation will then be implemented (discussed by Anselmo)

Summary

- Reconstruction on track with wrong charge suppression working effectively.
- Plan for physics studies developed

Thanks to Anselmo for all his help with the analysis and to Paul, JJ and others for all their advice