High Energy Event Reconstruction

Michinari Sakai

University of Hawaii

2014 September 4

Section 1

Energy Calibration

High Energy ($>\sim$1 GeV) Calibration

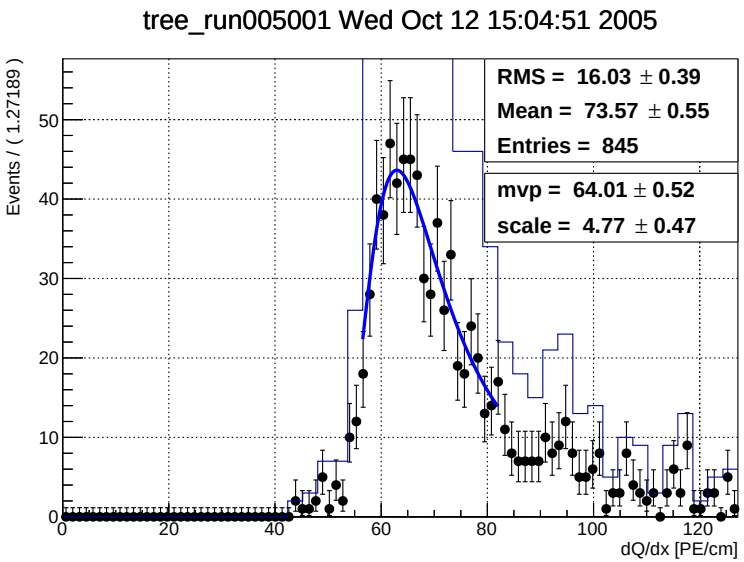
- KamLAND has traditionally used energy calibrations for lower energy regimes ($\sim$MeV)
- Can this calibration be used for higher energy ($\sim$GeV) events too?
- Need energy calibration for higher energies
- Candidates:
  - linac (5 MeV–10 MeV)
  - Michel electron ($\sim$ 50 MeV)
  - cosmic ray muon
- Choose cosmic ray muon b/c it is the only source with GeV range energies

Muon candidate selection

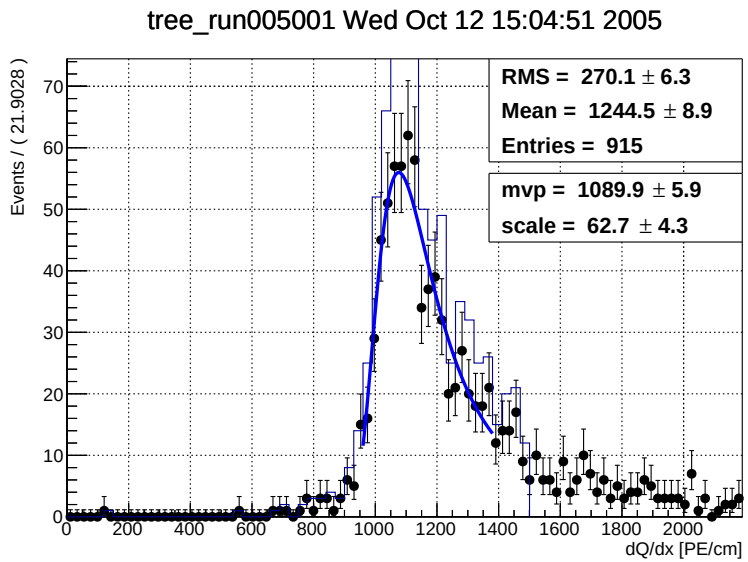
For each run, choose

- 1000 LS muons (impact parameter $< 650\,\text{cm}$)
- 1000 MO muons (impact parameter $> 650\,\text{cm}$)

MO muons (run 5000)



LS muons (run 5000)



Subtract Cherenkov component to get scintillation component of LS muons

Convert dx → dE using muon events in LS (KLG4)

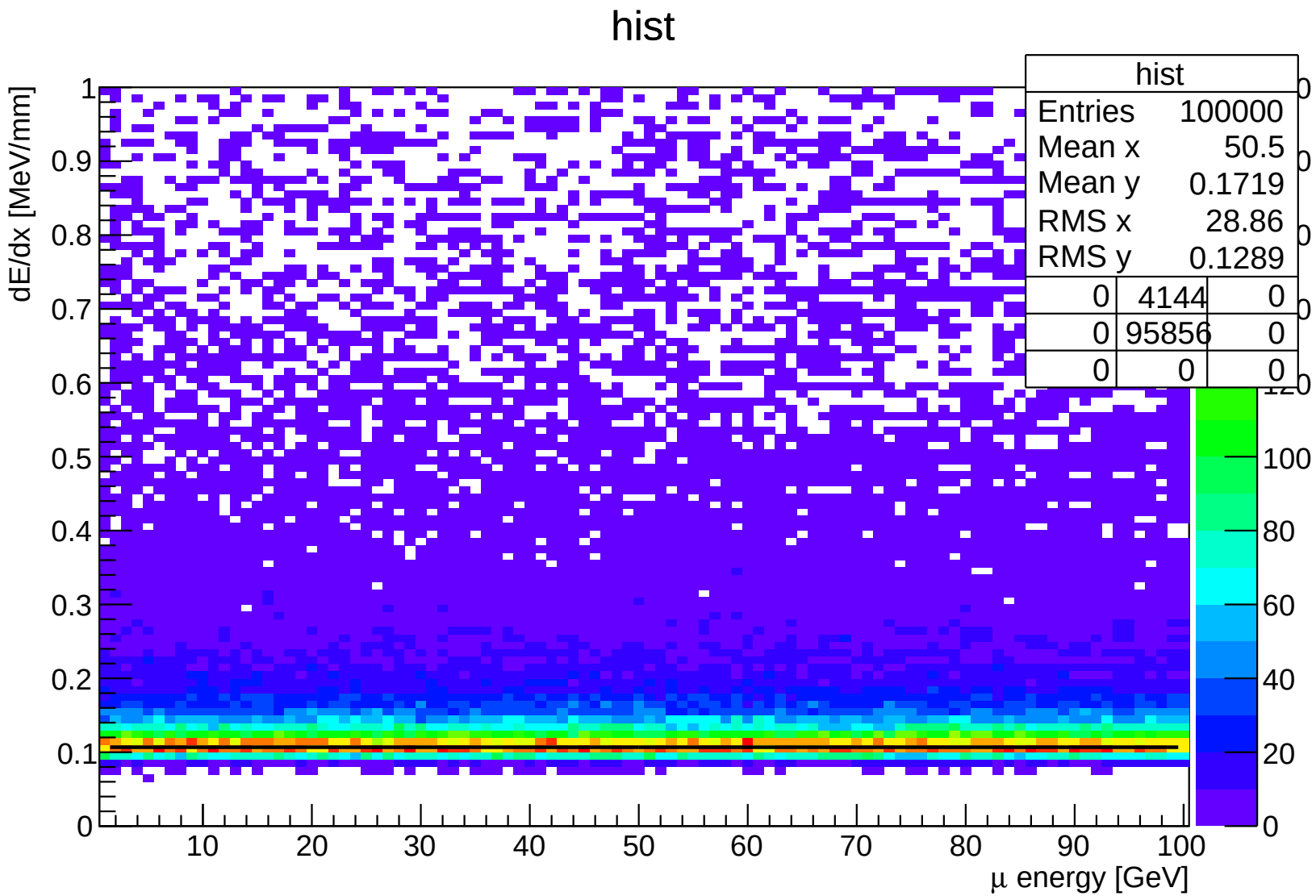
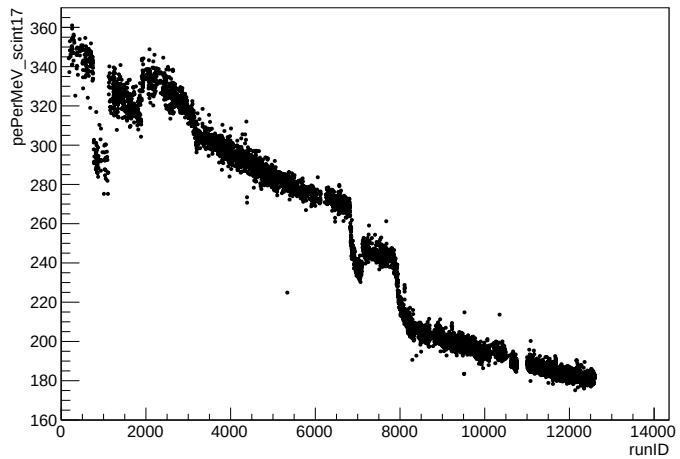
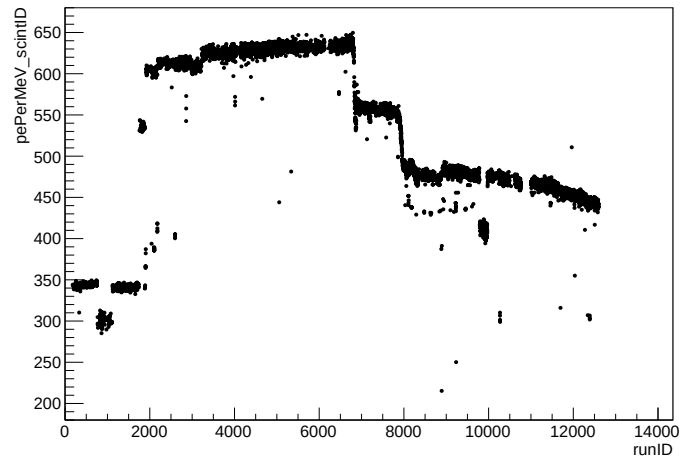
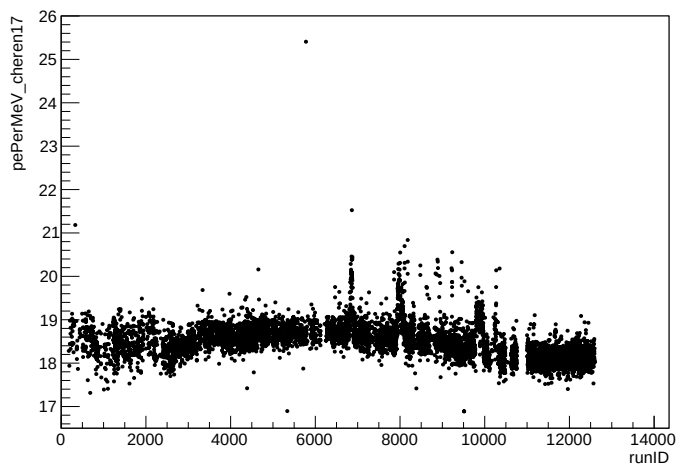
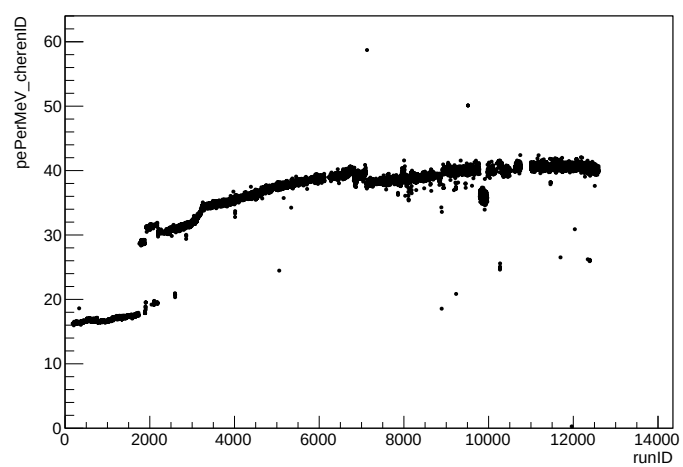


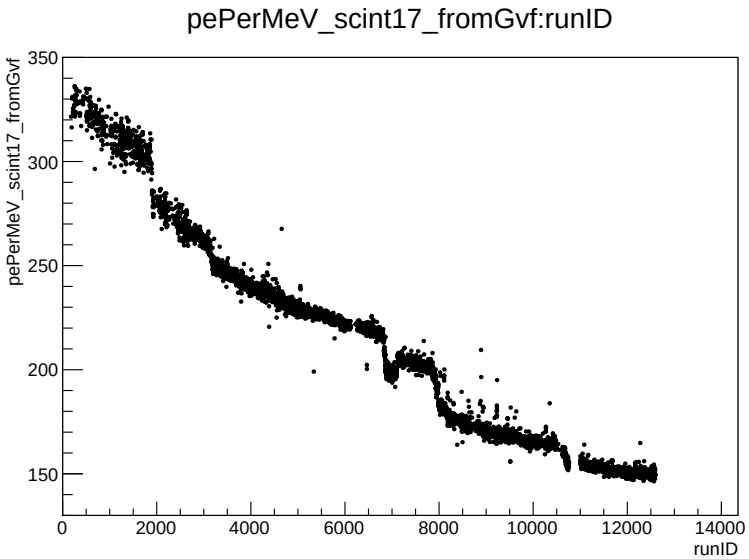
Figure : Use average value of $dE/dx = 1.719\,MeV\,cm^{-1}$

PE/MeV for all runs (new high-energy calibration)

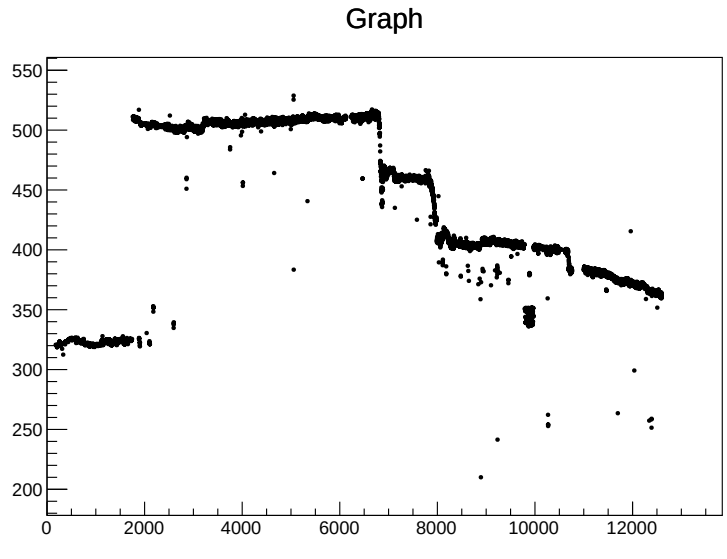
	TotalCharge17	TotalChargeID
PE_{scint}/MeV		
PE_{cheren}/MeV		

PE/MeV for all runs (KAT energy)

PE_{scint}/MeV (TotalCharge17)



PE_{scint}/MeV (TotalChargeID)

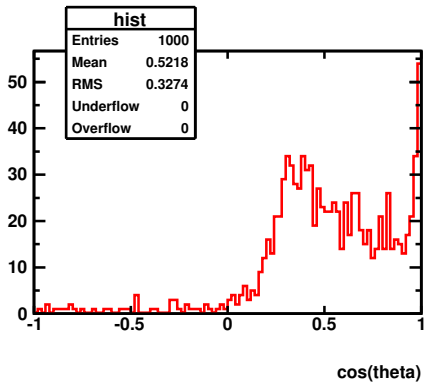


Section 2

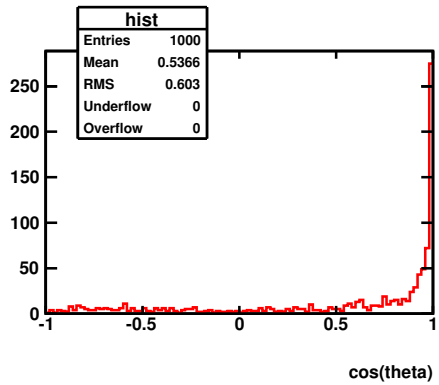
Neutrino Directionality

Test with muon data

Neutrino directionality algorithm was previously tested against KamLAND Muon Fitter using cosmic ray muon data



(a) No cut



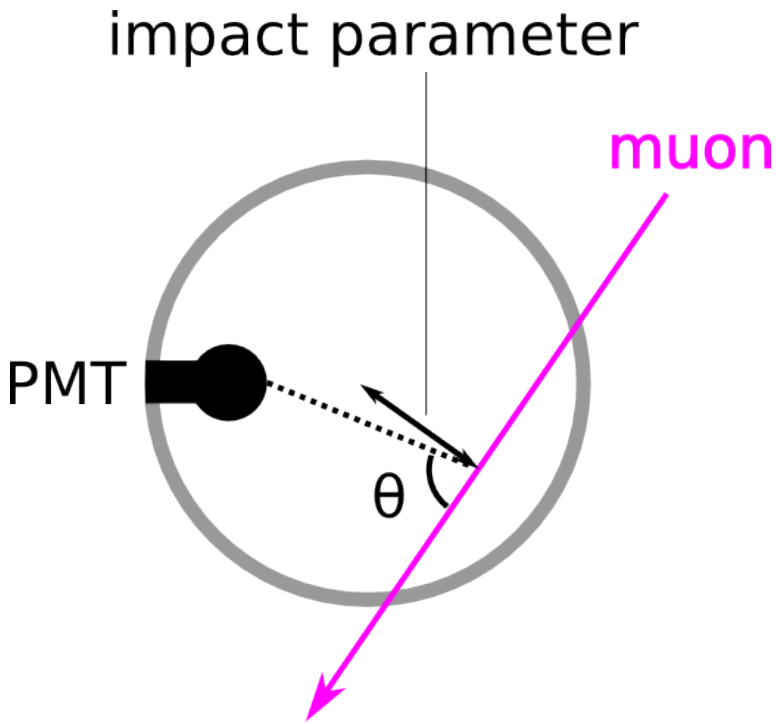
(b) Prepulse cut

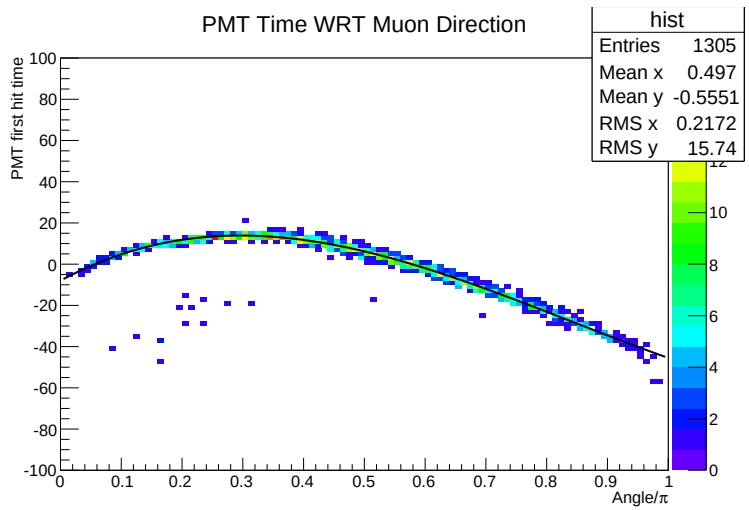
Figure : Agreement between Neutrino & Muon Fitters for 1000 muons in run 5000.

Found prepulsing of PMTs greatly affects direction algorithm.

PMT Prepulsing

PMT prepulsing is seen at few % level



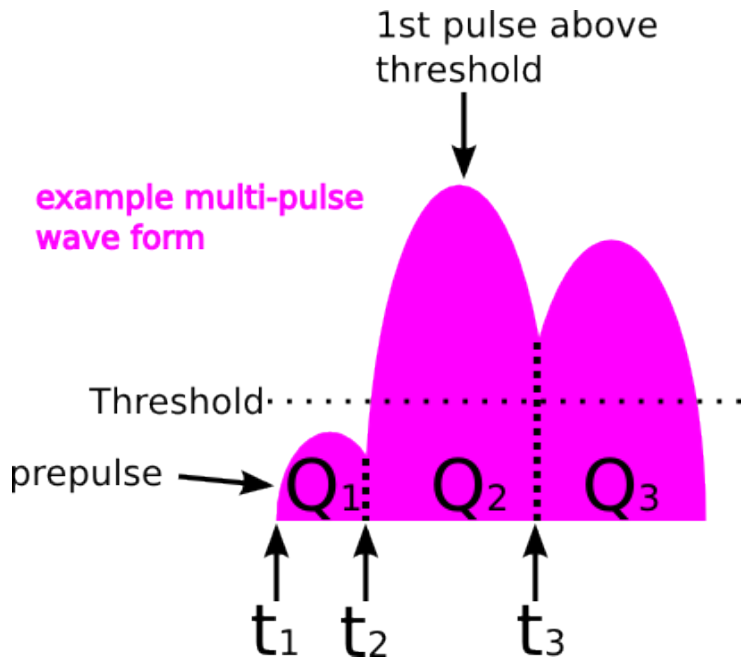


(a) Single muon event with clear prepulse observed

How to resolve prepulsing?

- Throw away PMT hits that look early compared to surrounding neighbor PMTs.
  $\rightarrow$ Throwing away information!
  $\rightarrow$ Cannot remove clusters of prepulsing PMTs
- Can we do better?
  $\rightarrow$ Maybe just throw away first small pulse in multi-pulse waveform and use first big pulse as PMT hit time?

Algorithm to filter prepulse:



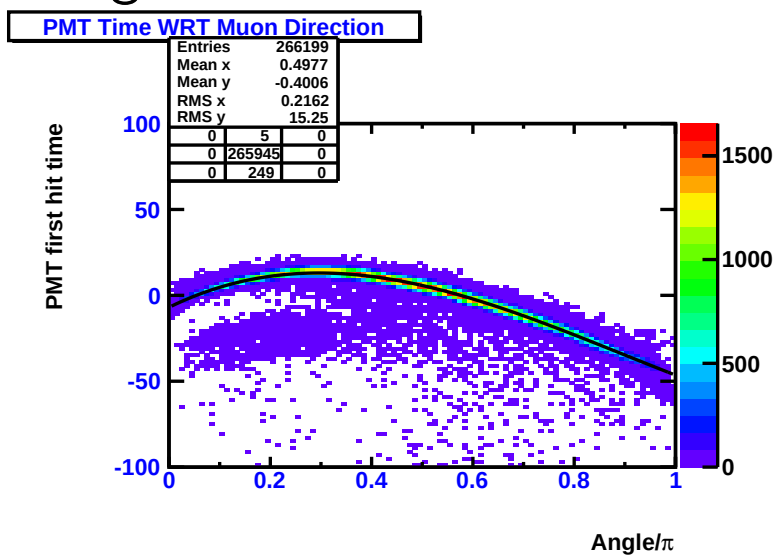
Algorithm:

1. threshold $\equiv 0.05\times$ (charge of largest pulse Q_2)
2. choose first pulse above threshold
3. let hit time $= t_2$
4. let charge $= Q_1 + Q_2 + Q_3$

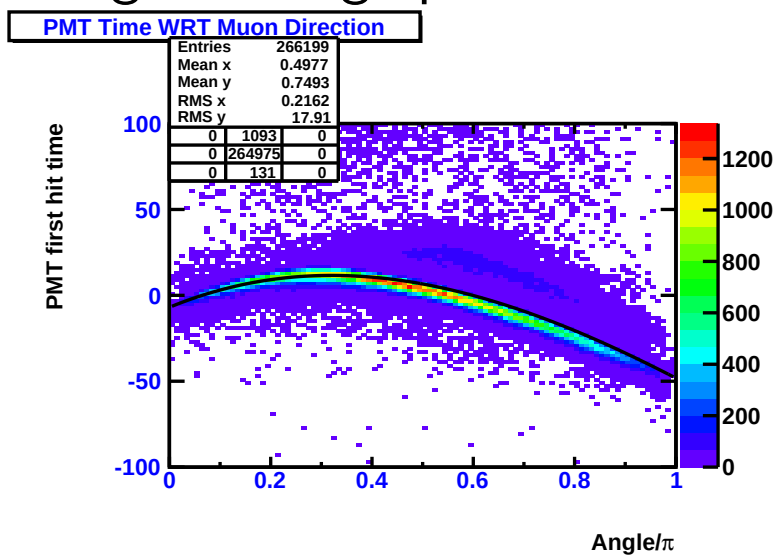
Unfortunately, naively cutting first "small" and using next "large" pulse does not work!

204 events, runs 5000–5009

Using first hits



Using first large pulse hits



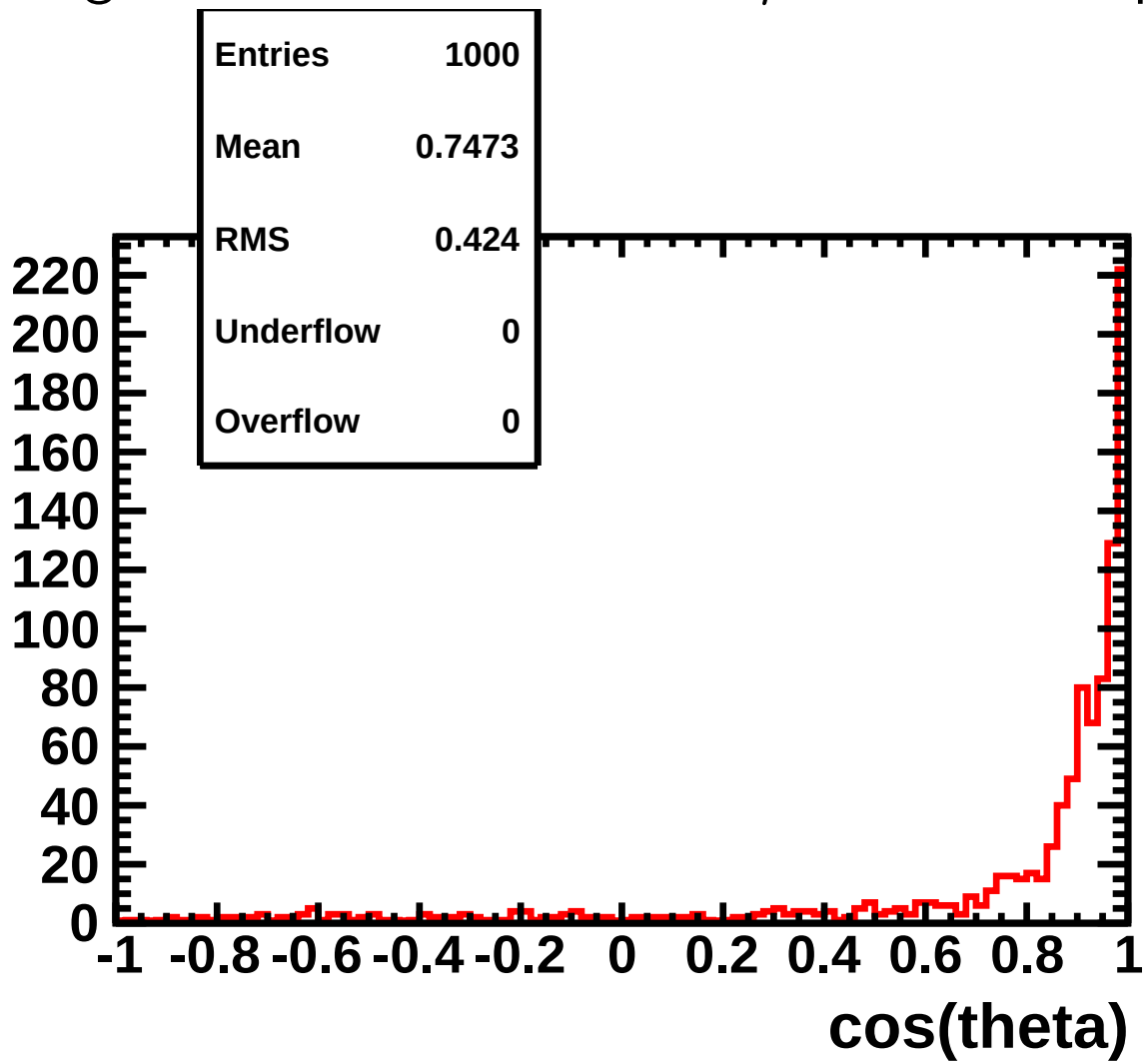
Gain Dependency of Prepulse

- Difficult to cut all of prepulse
  - Prepulse is easy to filter when pulse is from large gain
  - But harder to filter when pulse is from mid/low gain (prepulse is only sometimes seen depending on pulse charge)

Improved ν fitter

Sensitivity to outlier hit times was reduced

$\rightarrow$ ν fitter agreement with KamLAND μ fitter was improved



Test neutrino direction algorithm for simulated events (no prepulsing)

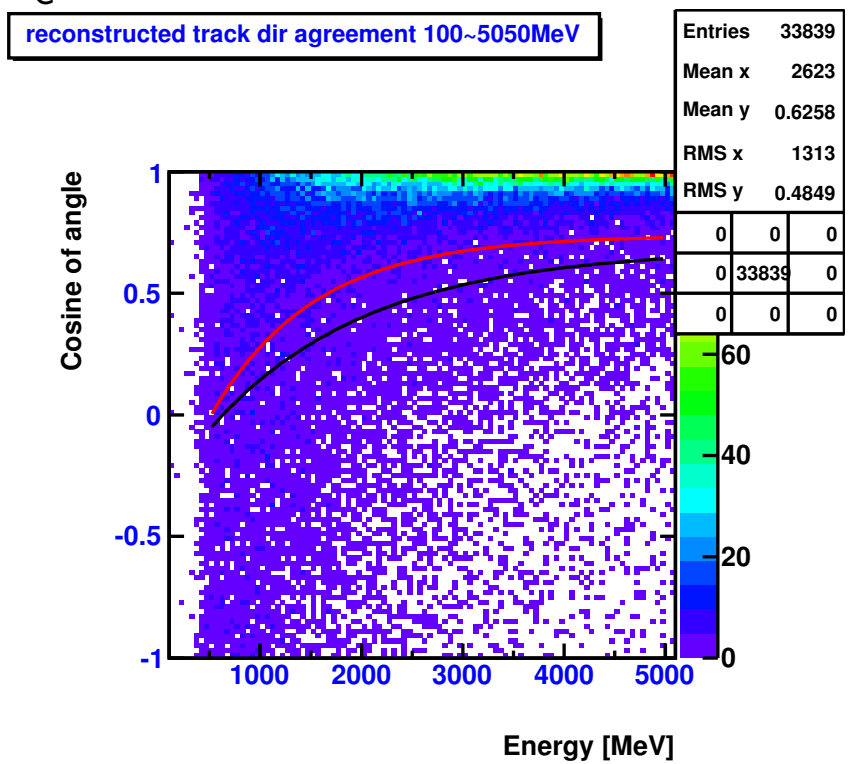
Procedure:

1. Use GENIE to let ν_e (0.1 GeV–5 GeV) interact with main LS nuclei (^{1}H, ^{12}C)
2. Use KLG4 to simulate detector response using uniform distribution of events in ID (no residual nucleus / no prepulsing)
3. Place OD hit < 5
4. Reconstruct event properties using neutrino fitter and KAT

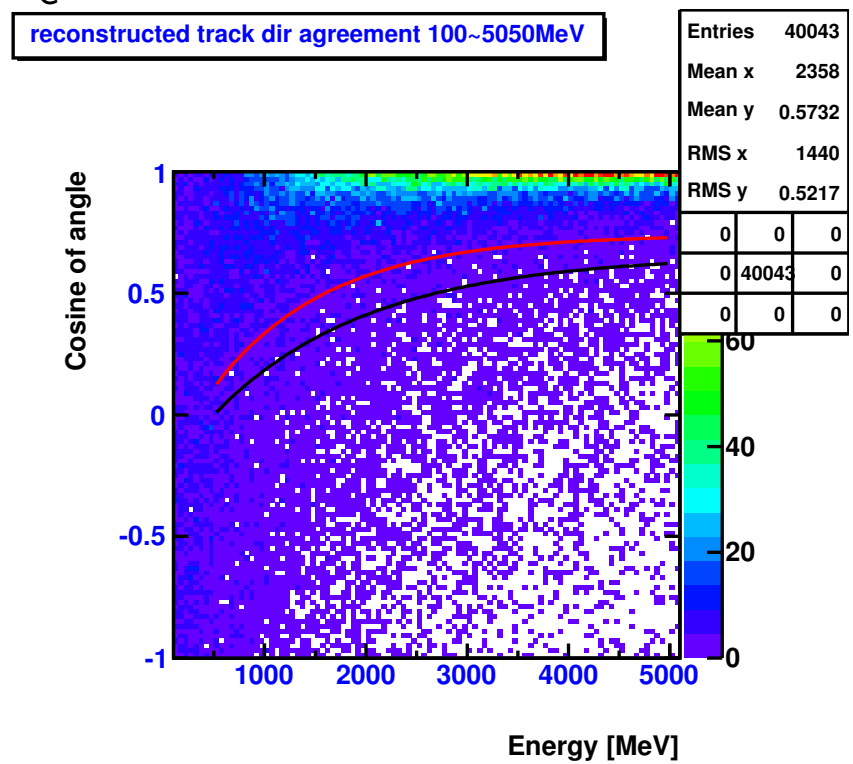
Agreement between true/reconstructed ν angle

no fiducial volume cut

$\nu_e + {}^1H \longrightarrow e^- + ?$



$\nu_e + {}^{12}C \longrightarrow e^- + ?$



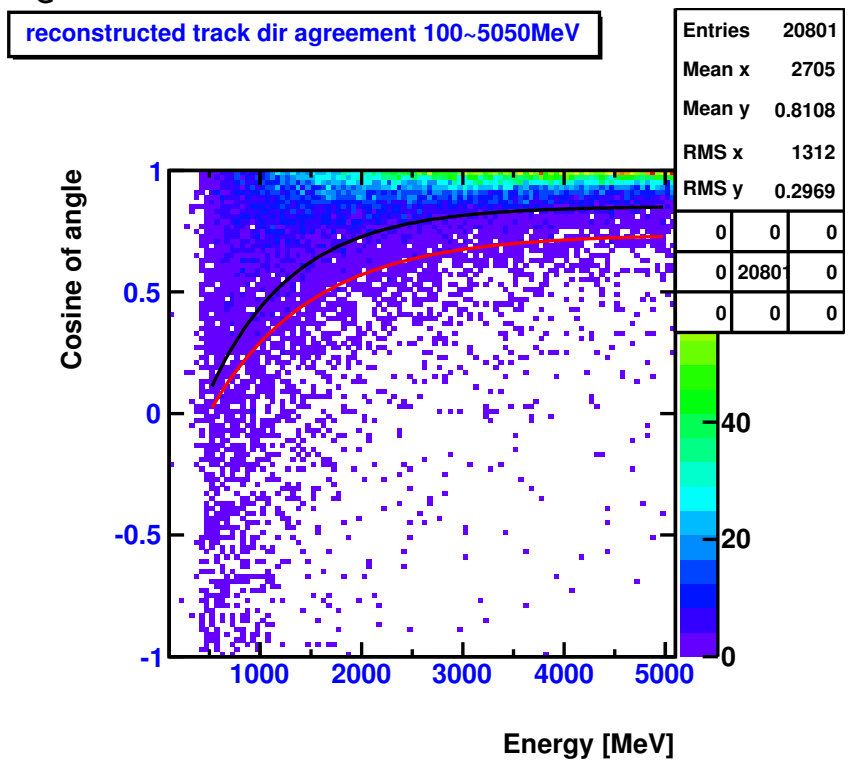
Black line: 1σ of reconstructed angle from ν direction

Red line: 1σ of lepton angle from ν direction

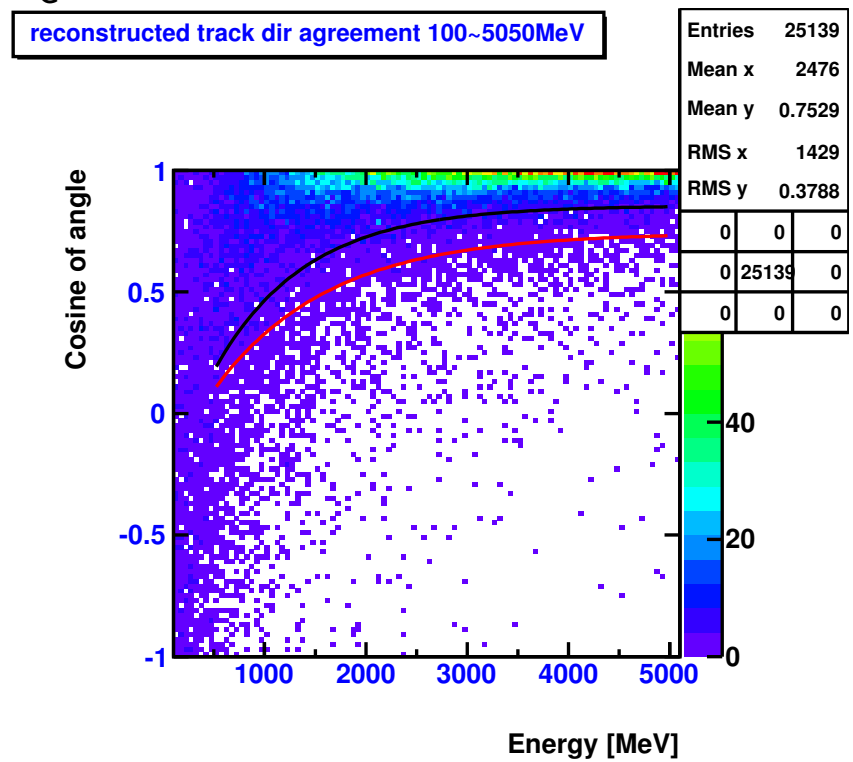
Agreement between true/reconstructed ν angle

vertex $R < 600\,\mathrm{cm}$

$\nu_e + {}^1\mathrm{H} \longrightarrow e^- + ?$



$\nu_e + {}^{12}\mathrm{C} \longrightarrow e^- + ?$

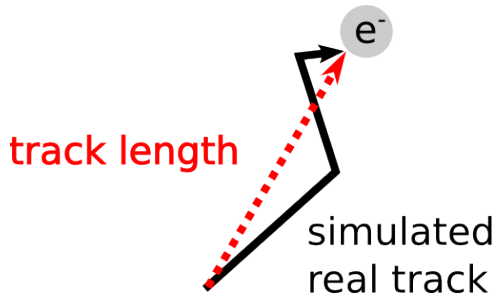


Black line: 1σ of reconstructed angle from ν direction

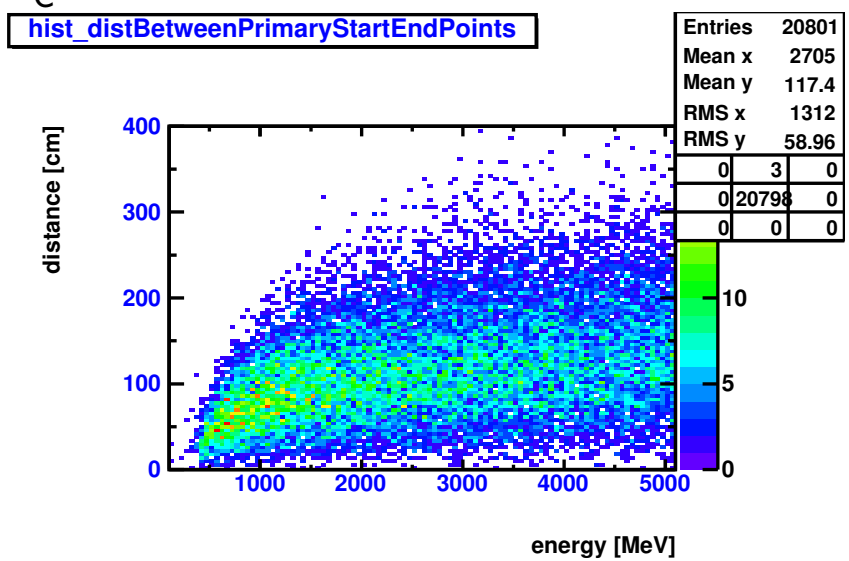
Red line: 1σ of lepton angle from ν direction

- Direction reconstruction is improved by fiducial volume cut on reconstructed vertex.
- What does the vertex mean for an finite size track size event?

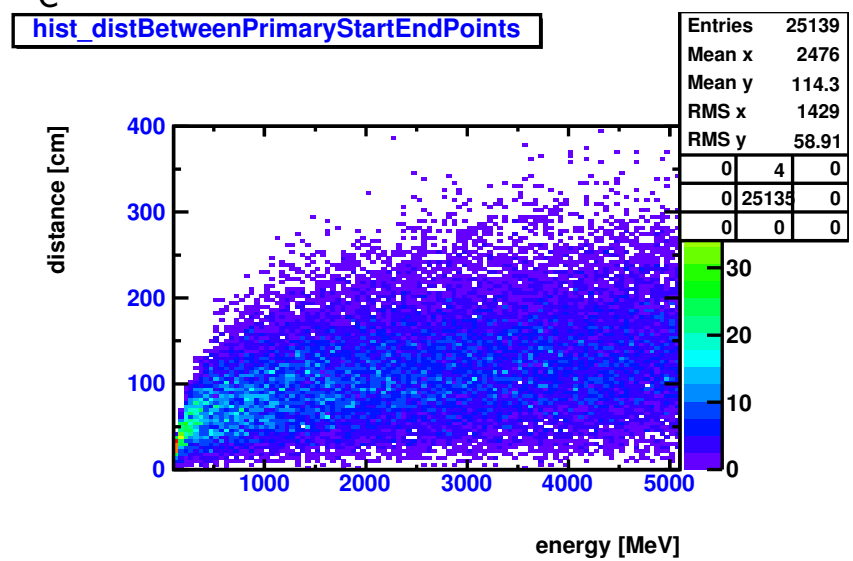
Define lepton track length as (does not include shower):



$\nu_e + {}^1H \longrightarrow e^- + ?$

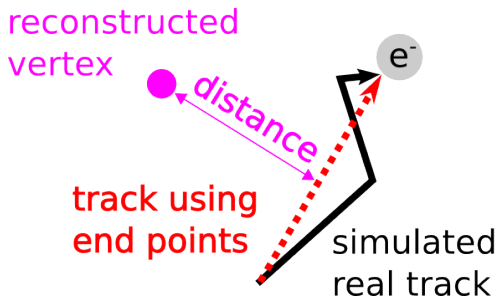


$\nu_e + {}^{12}C \longrightarrow e^- + ?$

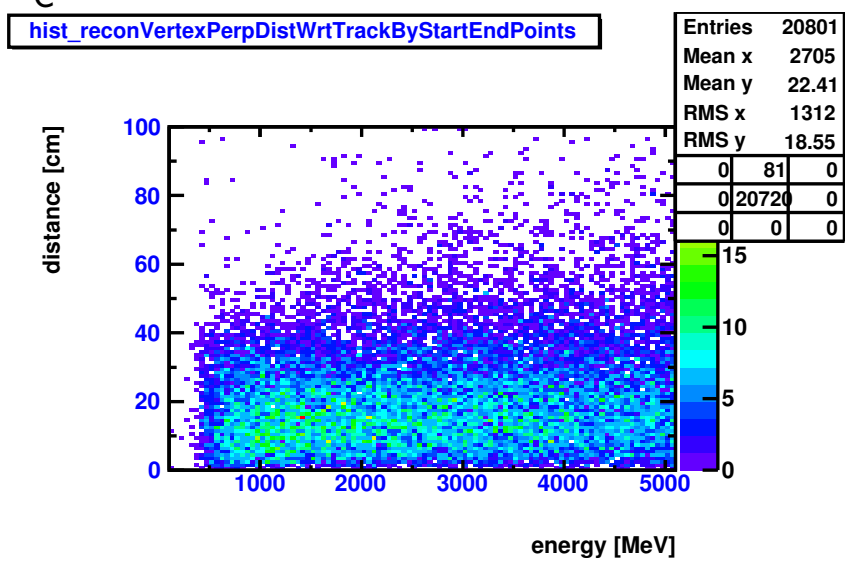


Perpendicular distance from reconstructed vertex to track

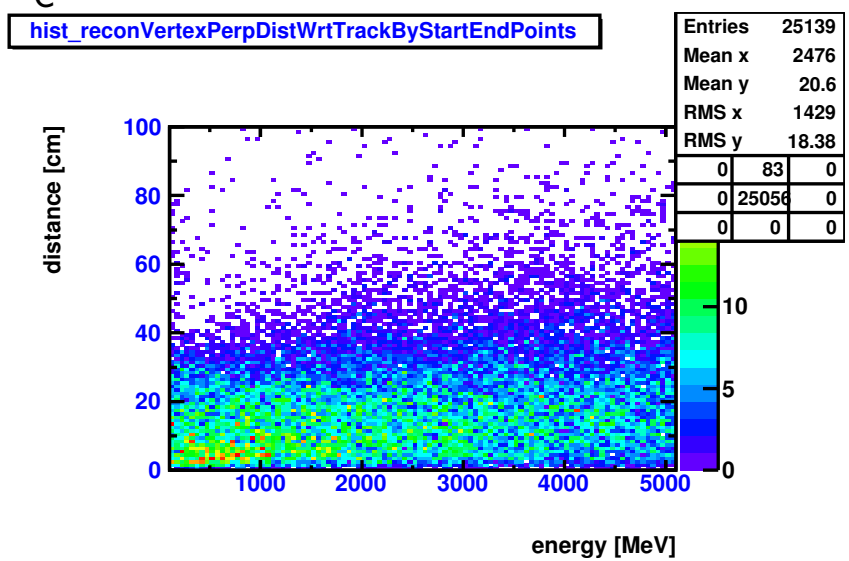
track using simulated track end points



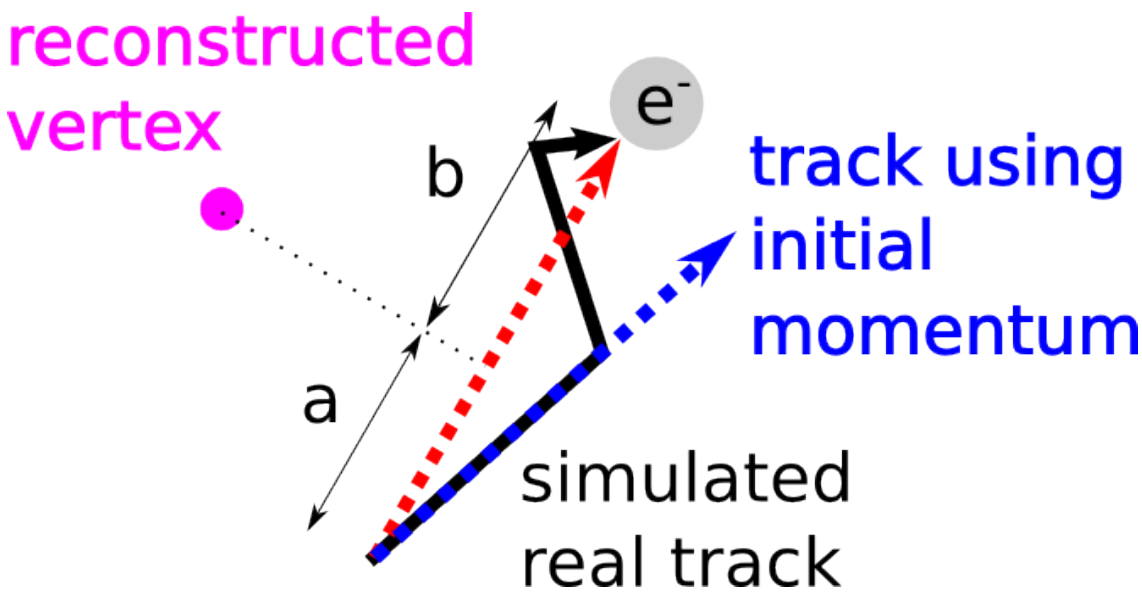
$\nu_e + {}^1H \longrightarrow e^- + ?$



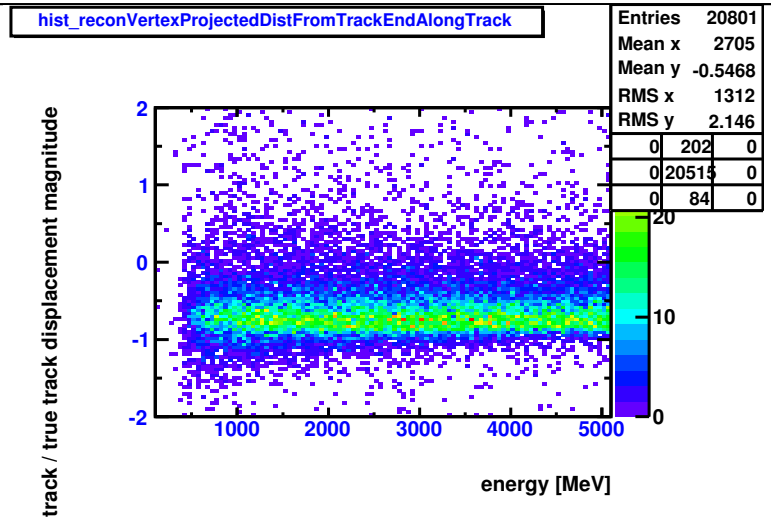
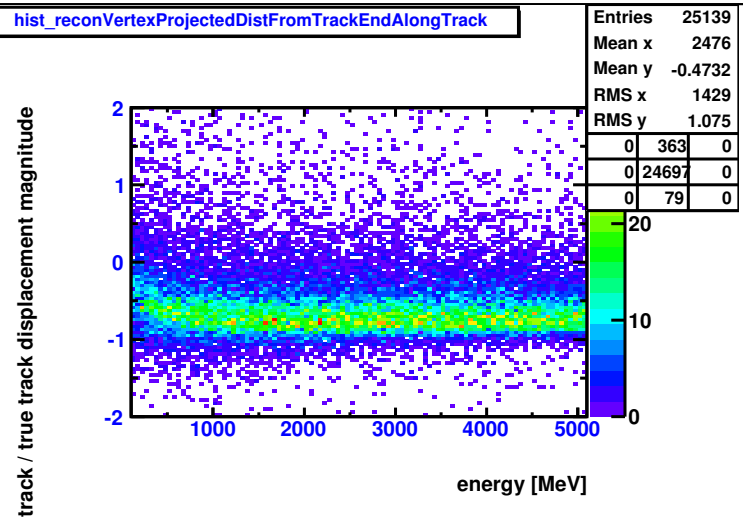
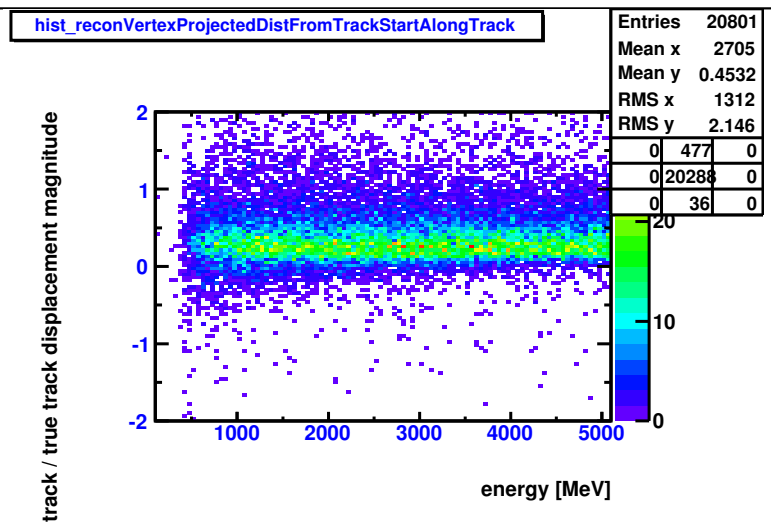
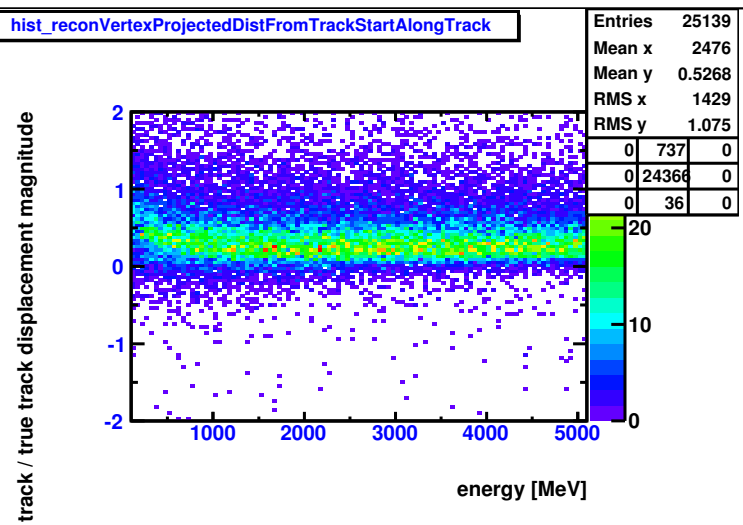
$\nu_e + {}^{12}C \longrightarrow e^- + ?$



Is the vertex reconstructed at the middle of the track?



Distance of reconstructed vertex from track end points projected along tracks

	$\nu_e + {}^1H \longrightarrow e^- + ?$	$\nu_e + {}^{12}C \longrightarrow e^- + ?$
b		
a		

Conclusion for reconstruction vertex

For ν_e energies 0.1 GeV–5 GeV:

- Vertex is within $\sim$40 cm perpendicular from track
- Vertex is on average at $\sim$middle of track
- peak of vertex distribution is biased toward track beginning.

Summary

- High energy calibration was done using minimum ionizing muon events
- Explored ways to cut PMT prepulsing
  $\rightarrow$ still work in progress (minor issue)
- Tested neutrino fitter with simulation for energies 0.1 GeV–5 GeV
- Have minimum tools to start doing analysis for indirect Dark Matter search