Neutral Current Event Reconstruction

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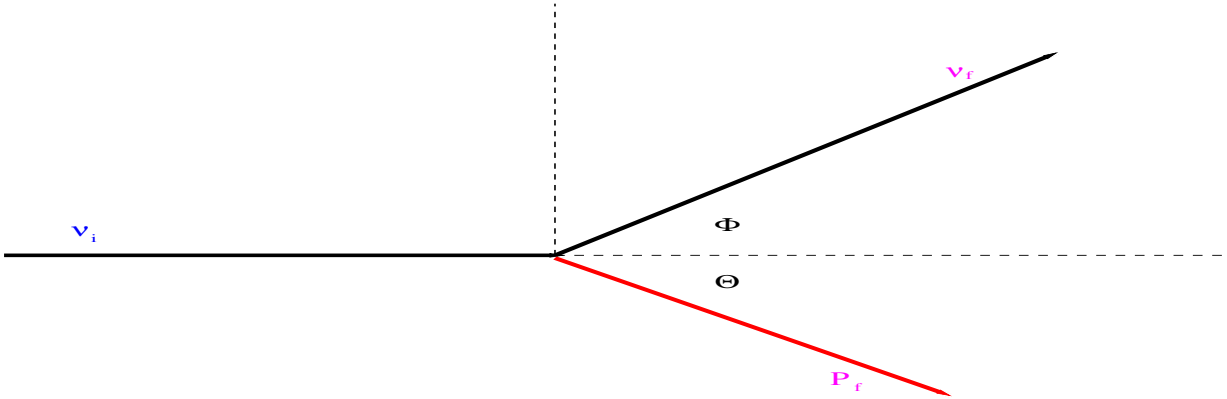
Introduction

- Interest in reconstruction of Neutral Current events
- kinematics ... conservation laws
- MCC 7 simu/reco samples – September 6, 2016
- Used results of the NueAna module
- NueAna basically converts the contents of several classes to an ntuple
  - Reconstructed Events
  - Truth values
  - Geant track list
- Problems
  - Lots of truncated reconstructed tracks
  - So use MC truth information for now.
  - Explore limitations

This talk is about single prong events.

Neutral Current Reconstruction



Neutral current kinematics for a simple final state. p_f and θ can be measured since the beam direction is known.

$$E_f = \sqrt{p_f^2 + M^2}$$

$$\nu_i = \frac{M(E_f - M)}{M + p_f \cos\theta - E_f}$$

$$\nu_f = \nu_i + M - E_f$$

$$\sin\phi = \frac{p_f}{\nu_f} \sin\theta$$

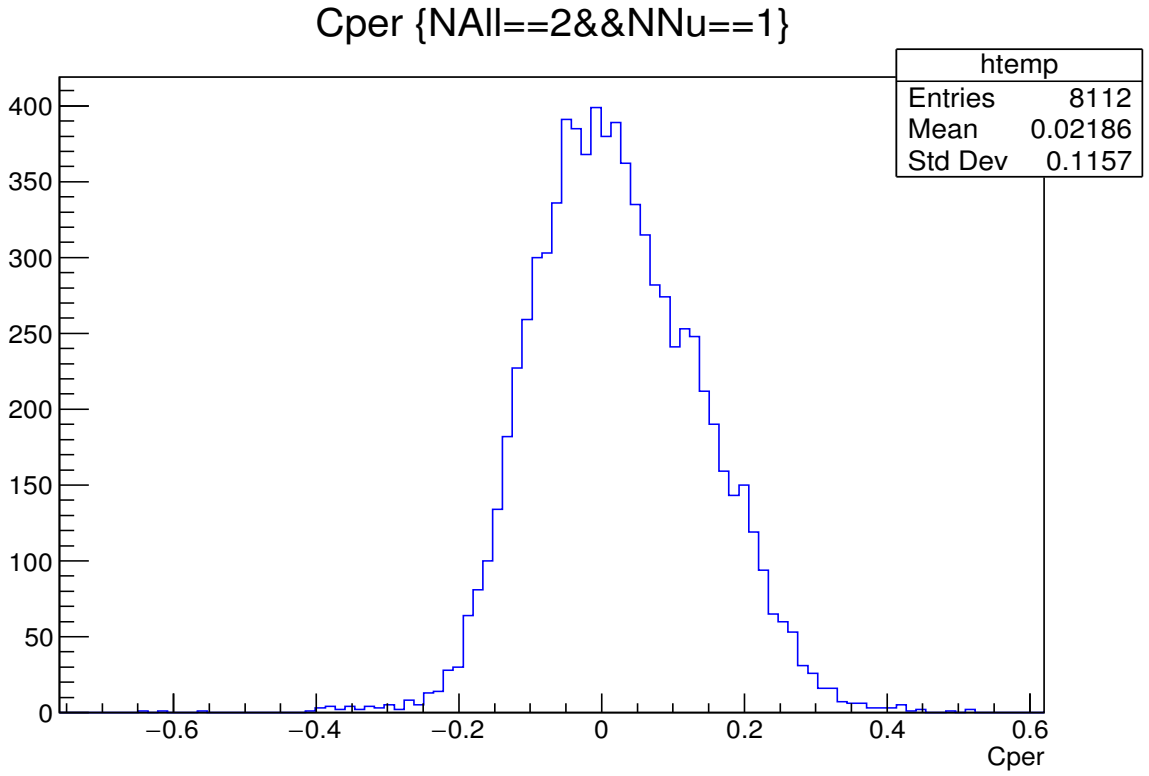
Momentum and Energy Balance

The incoming neutrino direction is known.

But not the initial momentum.

Need 3 constraints momentum and energy conservation

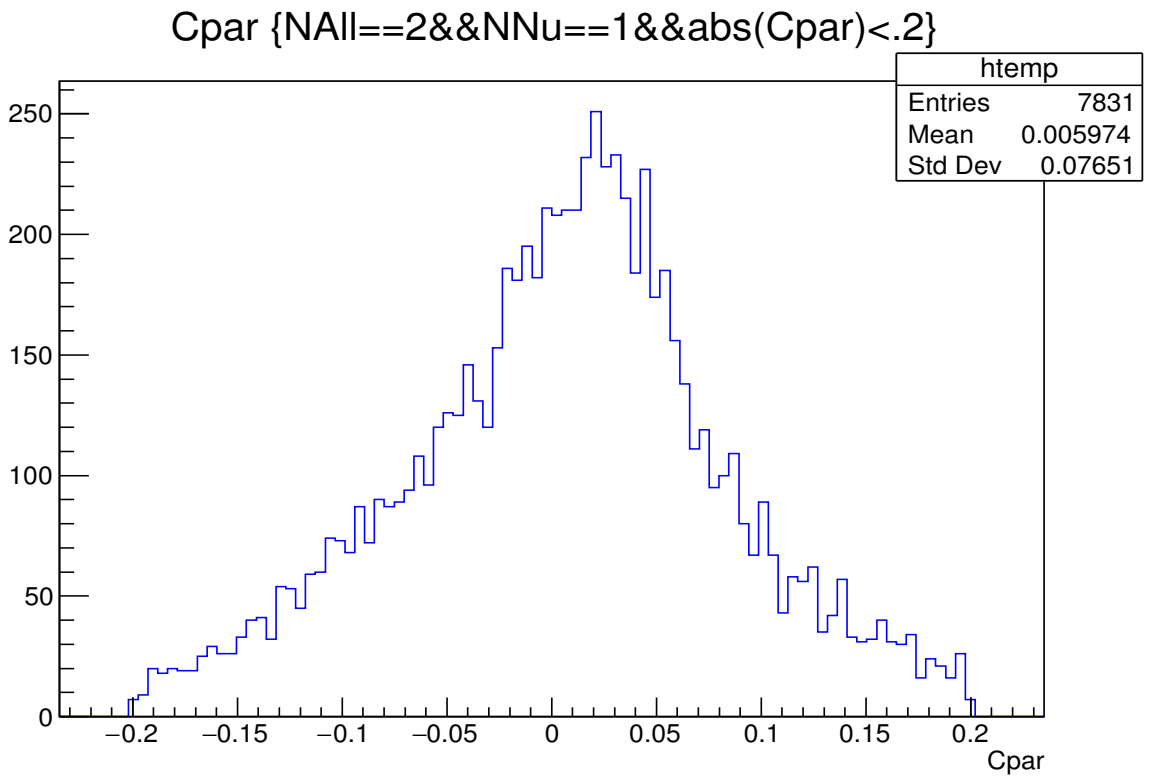
$$\nu_f \sin\phi = p_f \sin\theta$$



P perpendicular ... nuclear Fermi motion

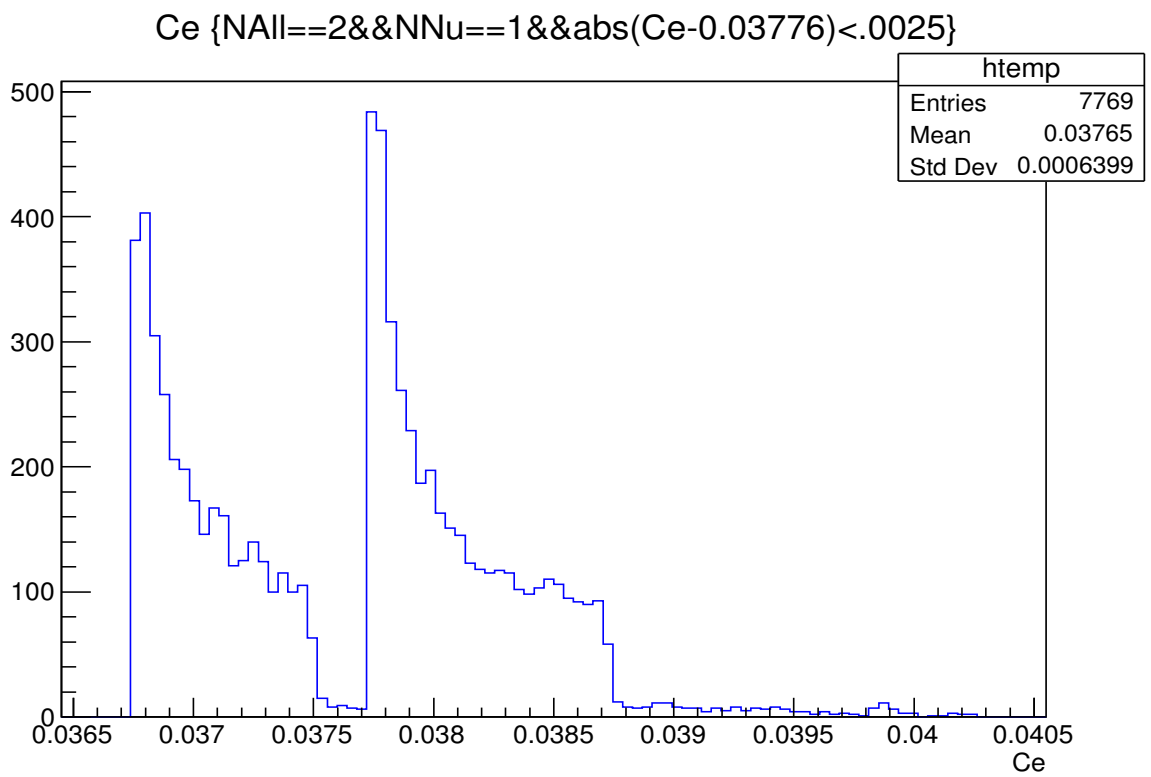
P parallel

$$\nu_i = \nu_f \cos\phi + p_f \cos\theta$$



Energy

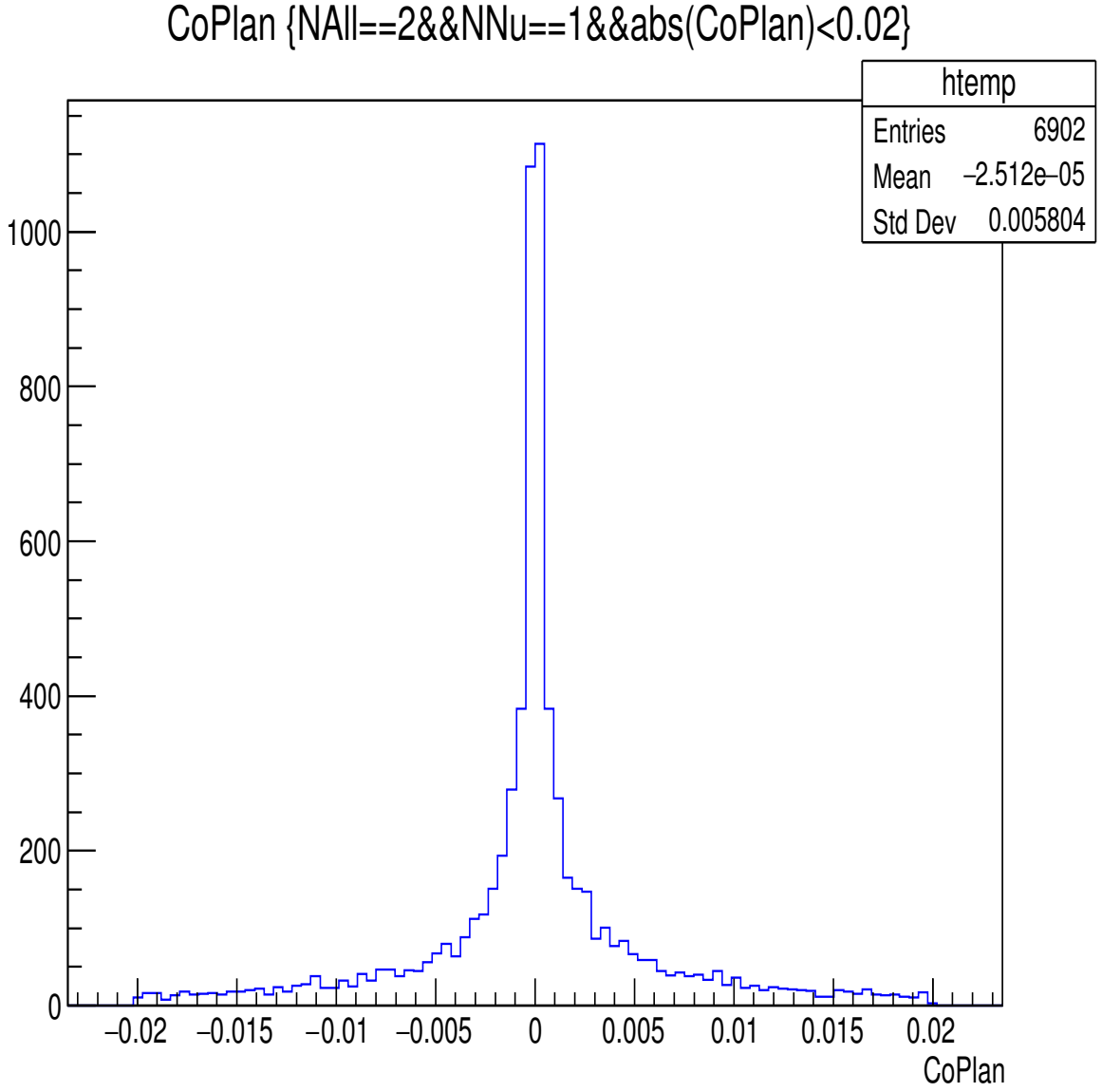
$$\nu_i + M = \nu_f + E_f$$



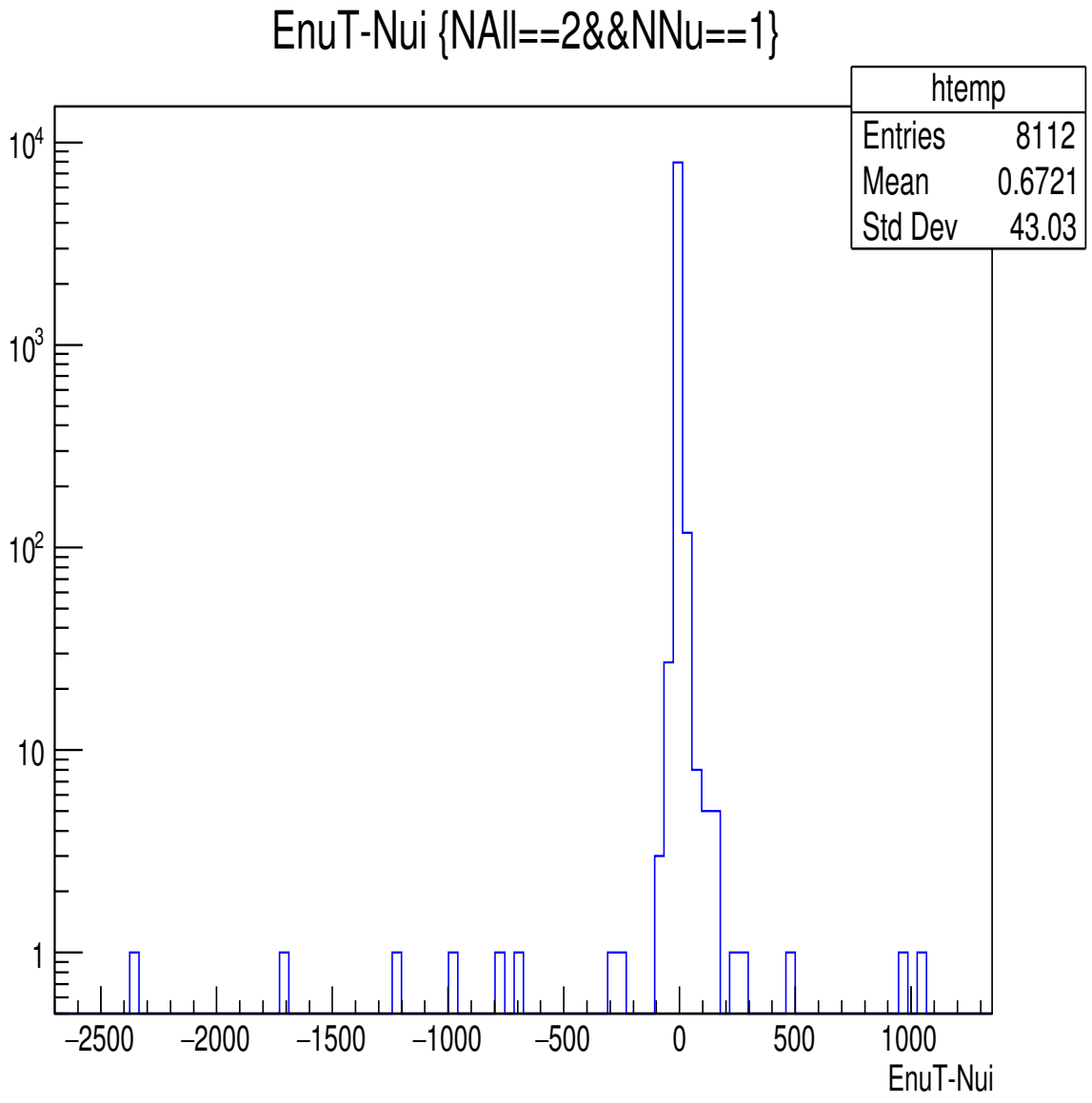
Binding energy of the single nucleon.

Coplanarity

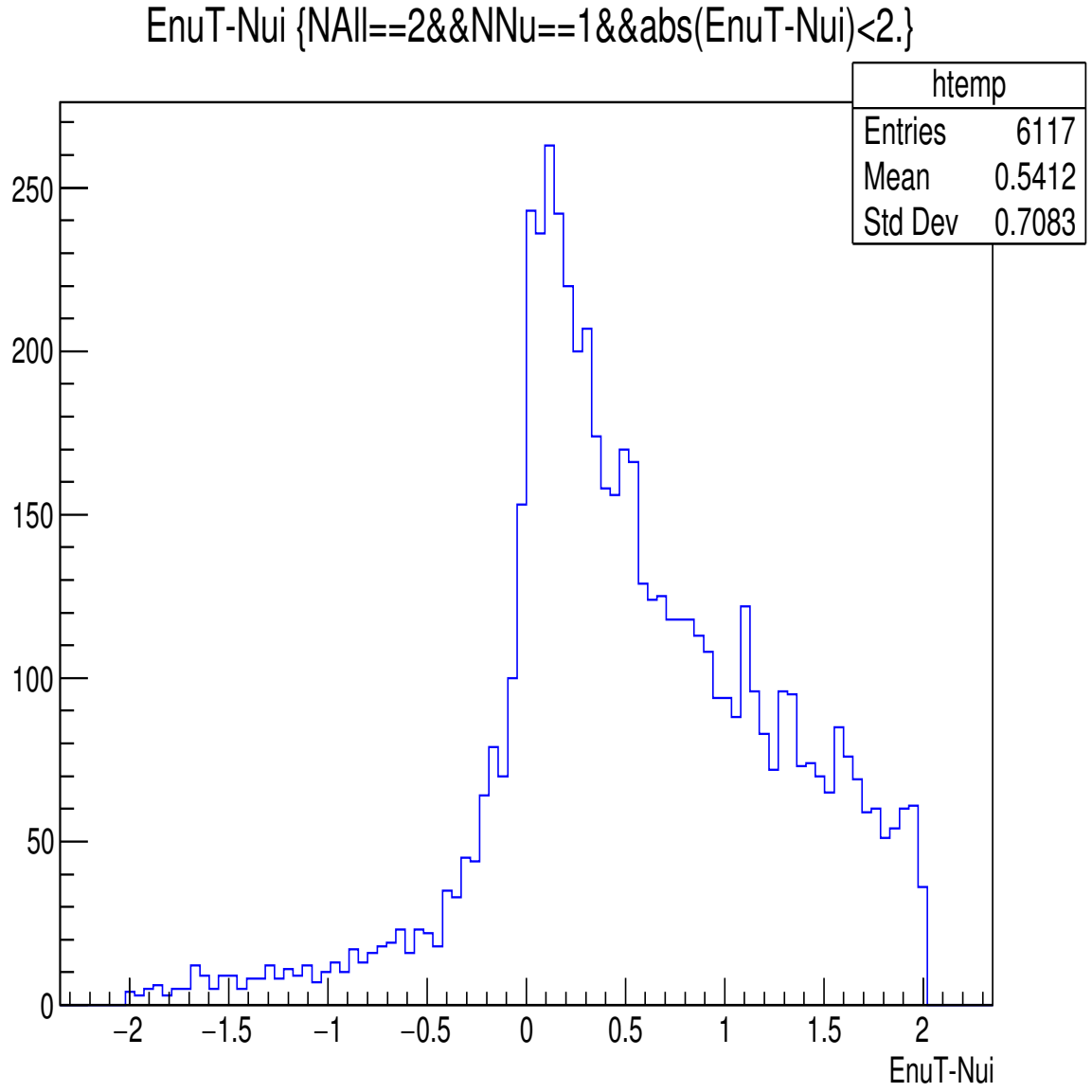
Coplanarity check for missing momentum $\nu_i \cdot (\nu_f \times p_f) = 0$ or $\hat{\nu}_i \cdot (\hat{\nu}_f \times \hat{p}_f) = 0$ or $(\hat{\nu}_i \times \hat{\nu}_f) \cdot p_f = 0$



Primary Neutrino Energy

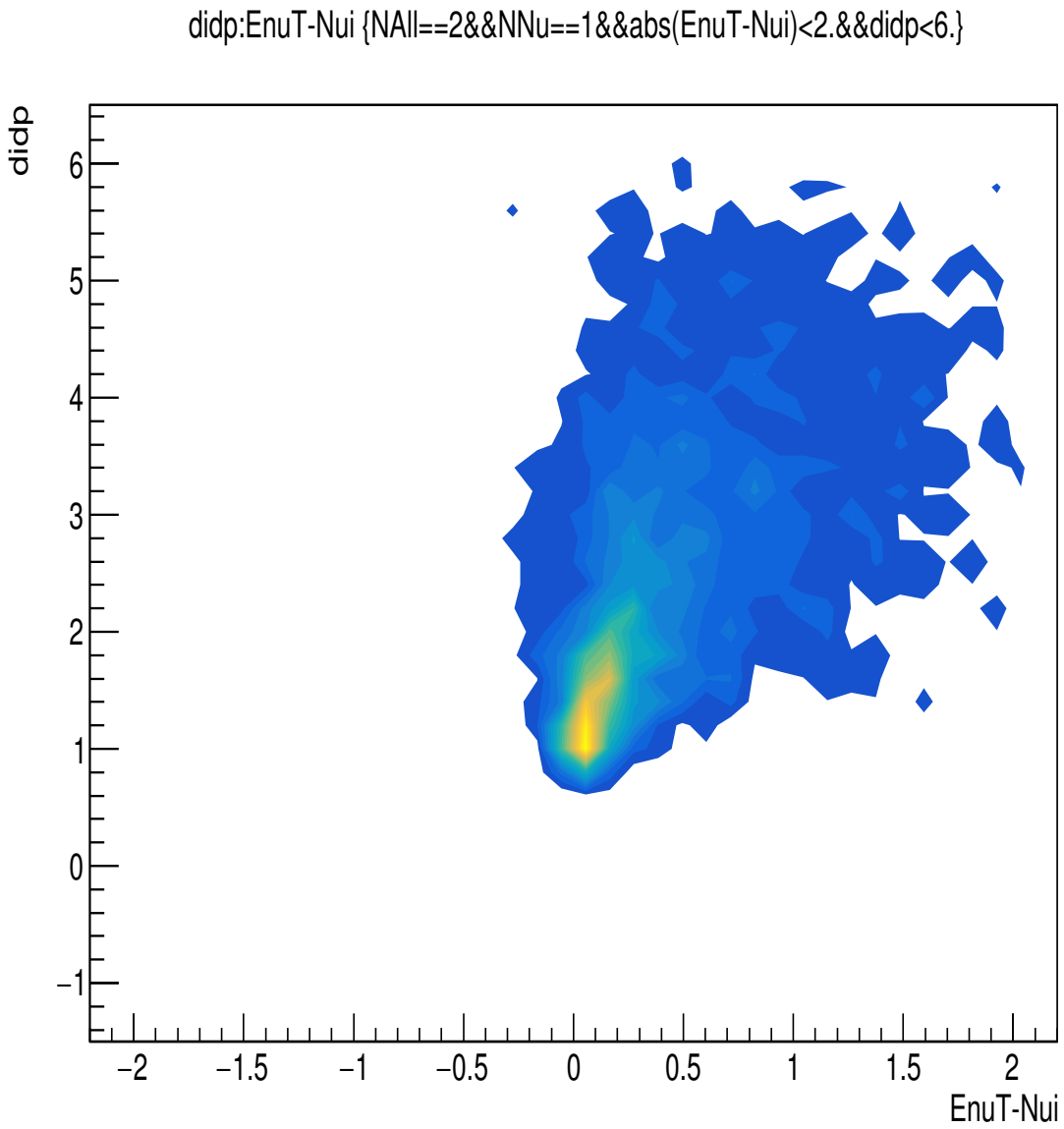


Primary Neutrino Energy – Zoom in

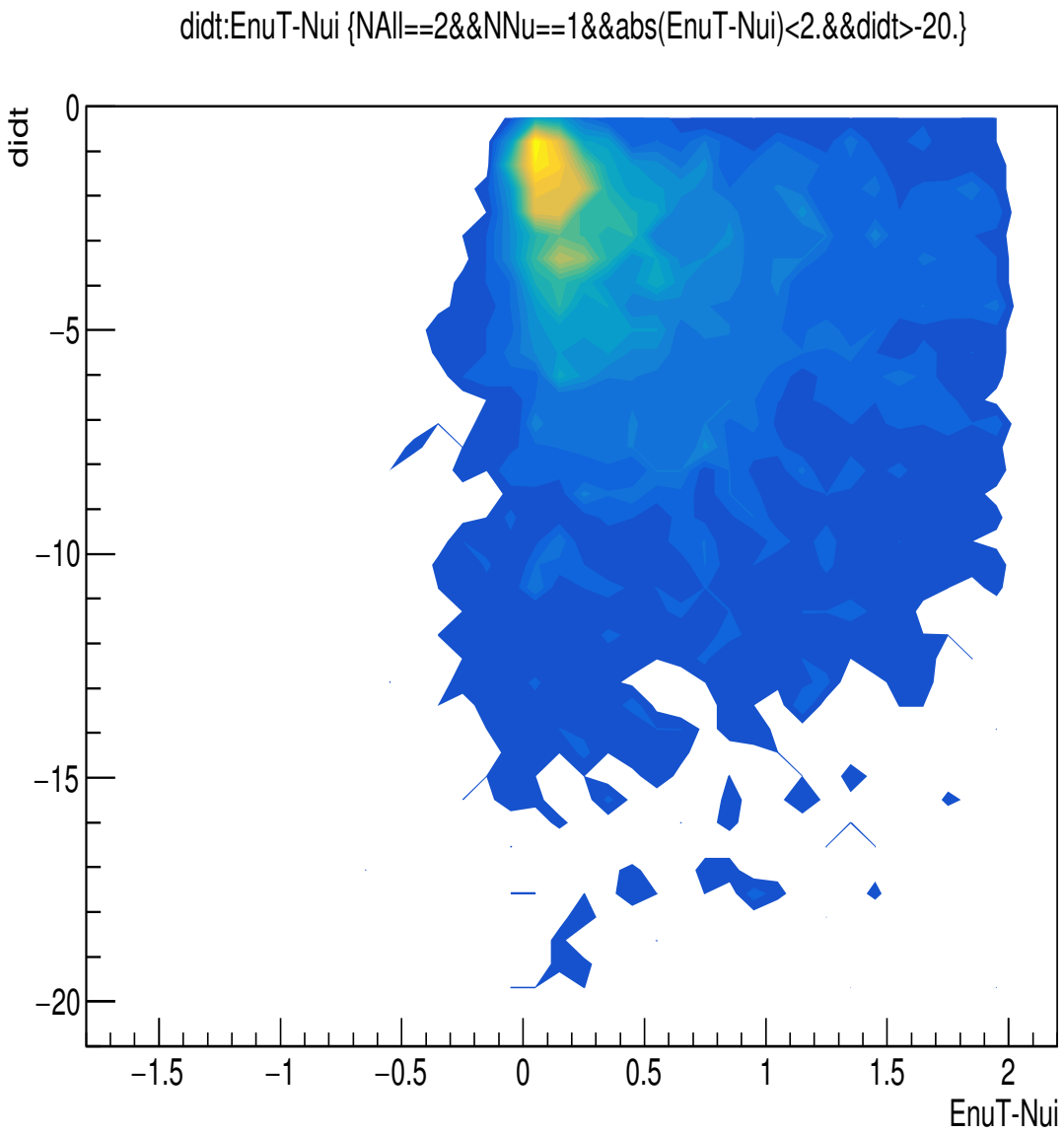


Raw resolution ... hundreds of MeV.

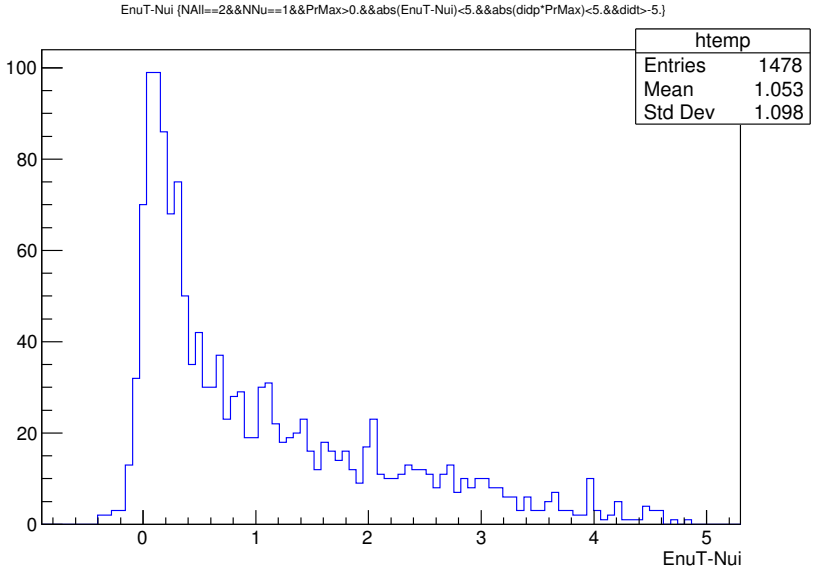
Derivatives – $\frac{d\nu_i}{dp}$

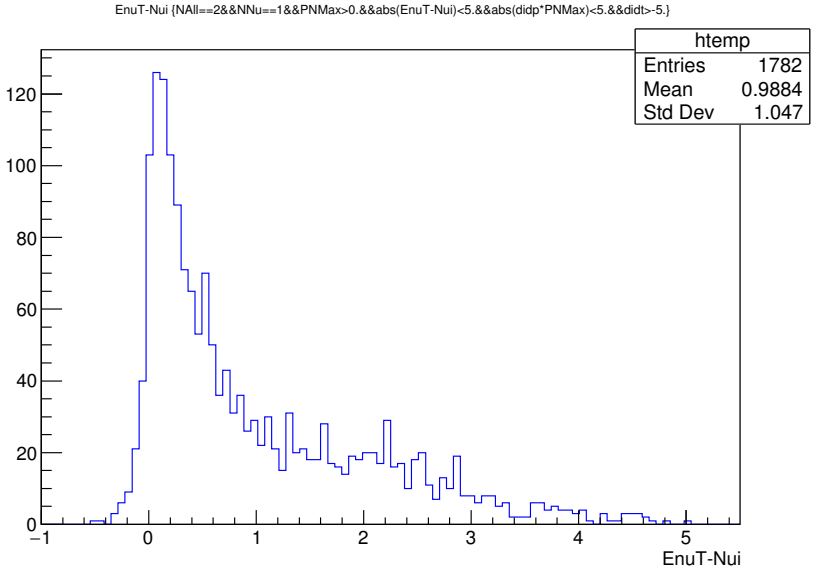


Derivatives – $\frac{d\nu_i}{dt}$



Cut on Errors – Primary Neutrino Energy

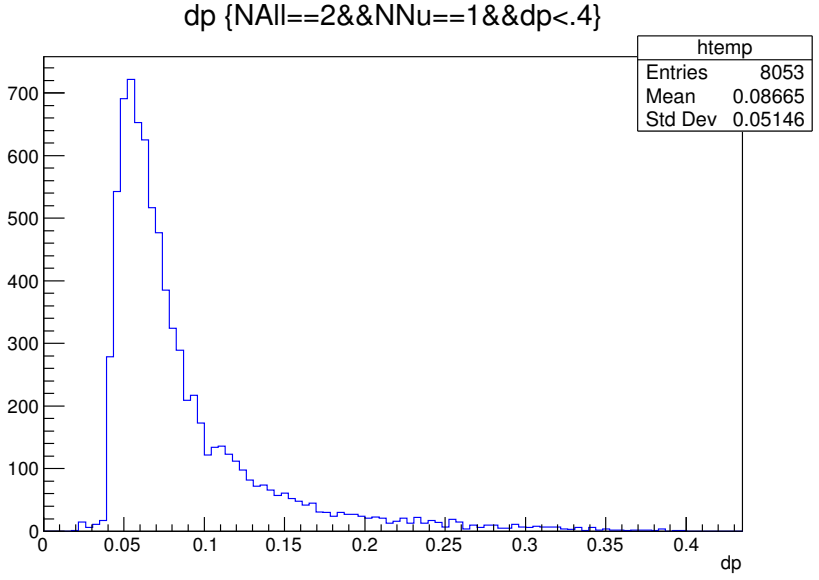


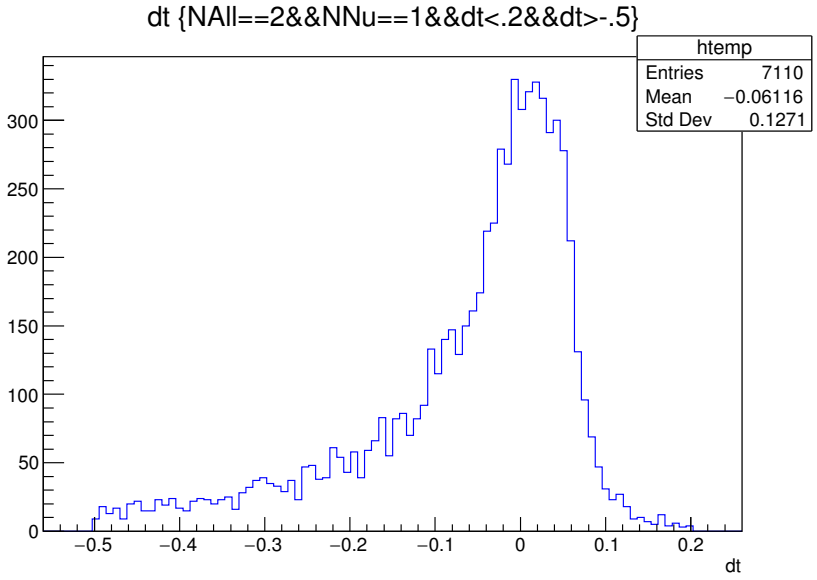


Left, proton recoil Right, neutron recoil

Invert to Get Errors on Measurements

The errors on the recoil momentum and direction cosine based on the difference between the MC truth values and the calculated values of the 2 neutrino energies, ν_i and ν_f.



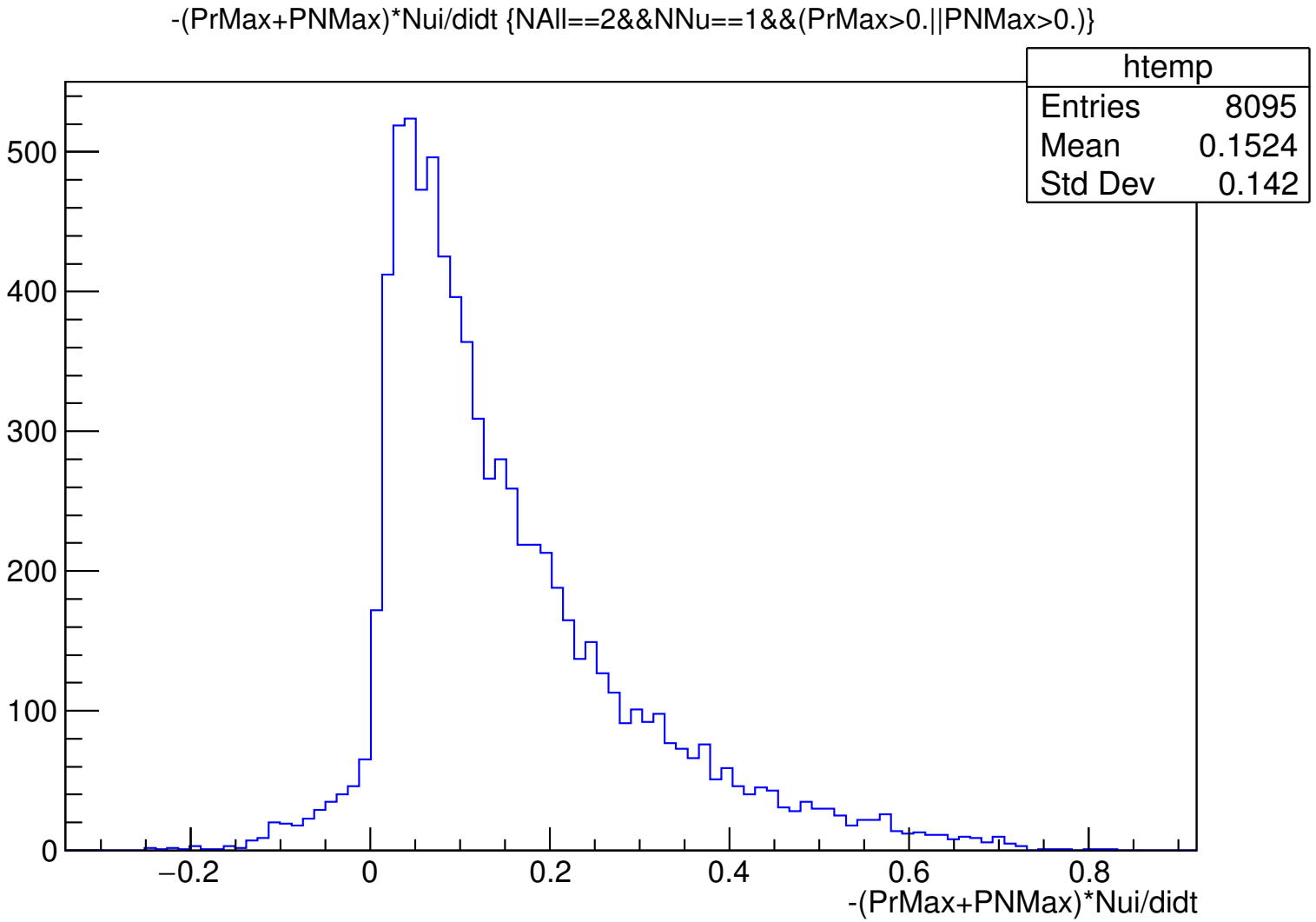


Left, momentum Right cosine of the recoil angle.

$$d\nu_i = \frac{\partial \nu_i}{\partial p} dp + \frac{\partial \nu_i}{\partial t} dt$$

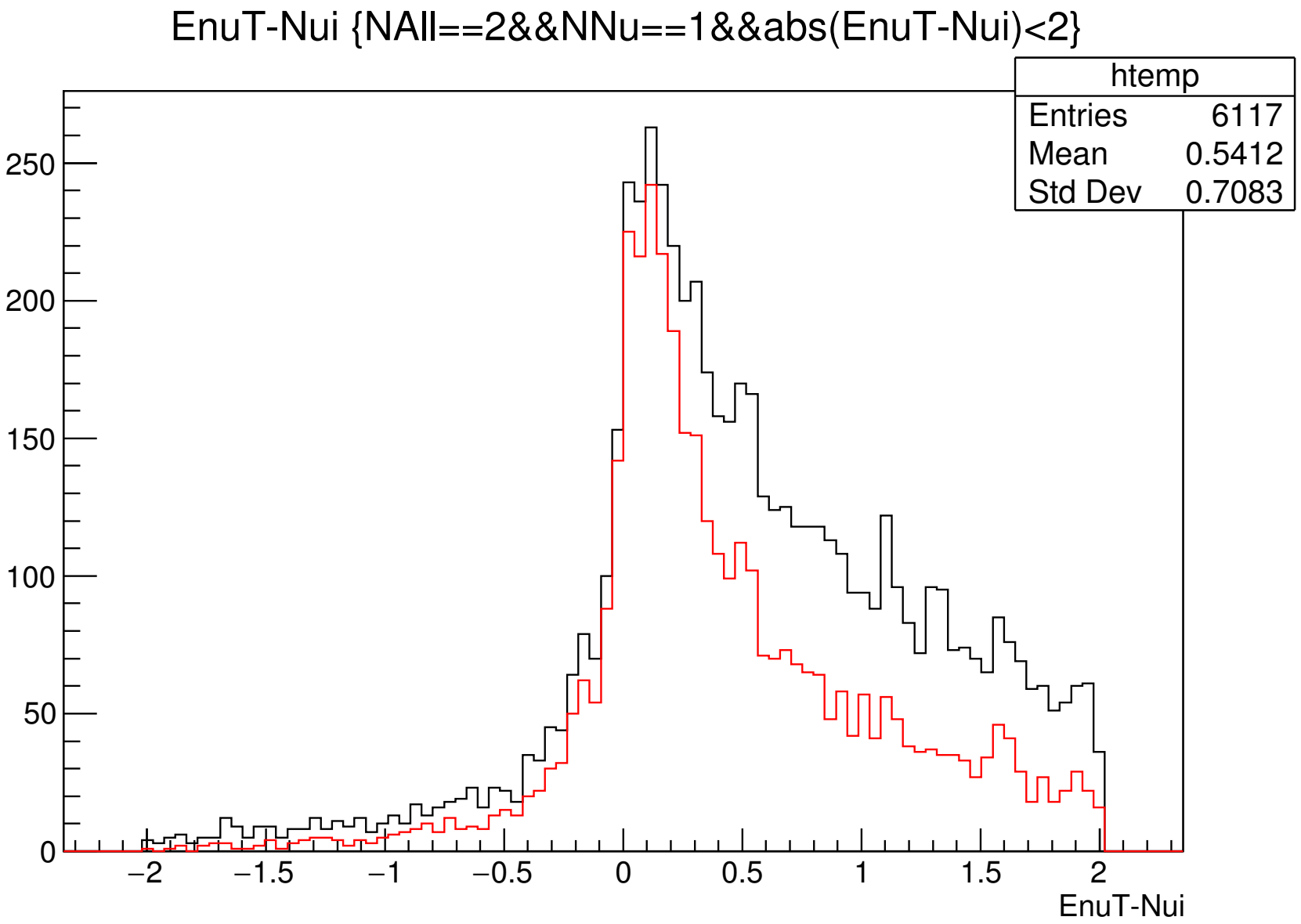
$$d\nu_f = \frac{\partial \nu_f}{\partial p} dp + \frac{\partial \nu_f}{\partial t} dt$$

Sensitivity

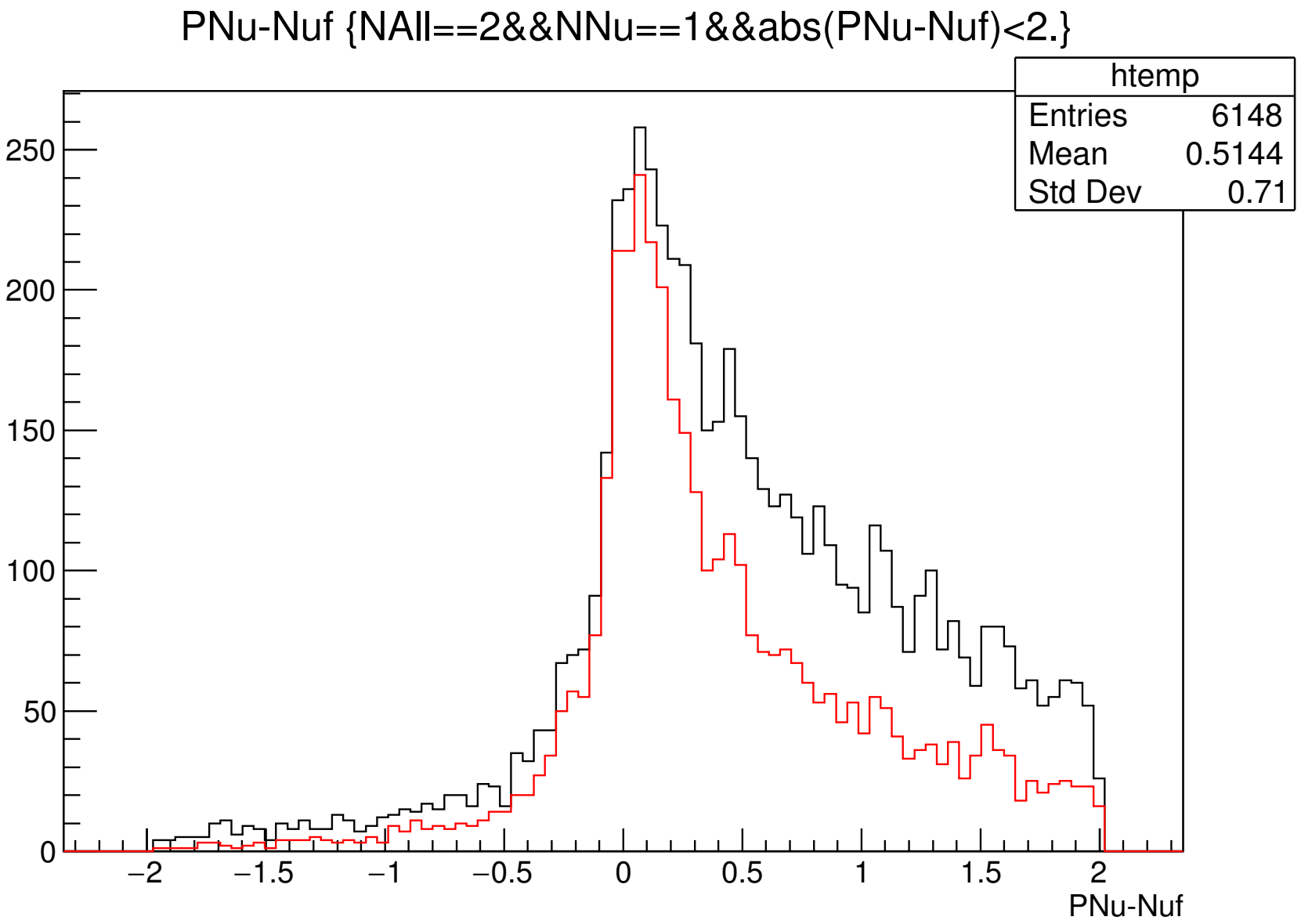


Equation for ν_i involves dividing by $M + p_f \cos\theta - E_f$ The plot shows this can go to zero.

Cut when $M + p_f \cos\theta - E_f$ is small



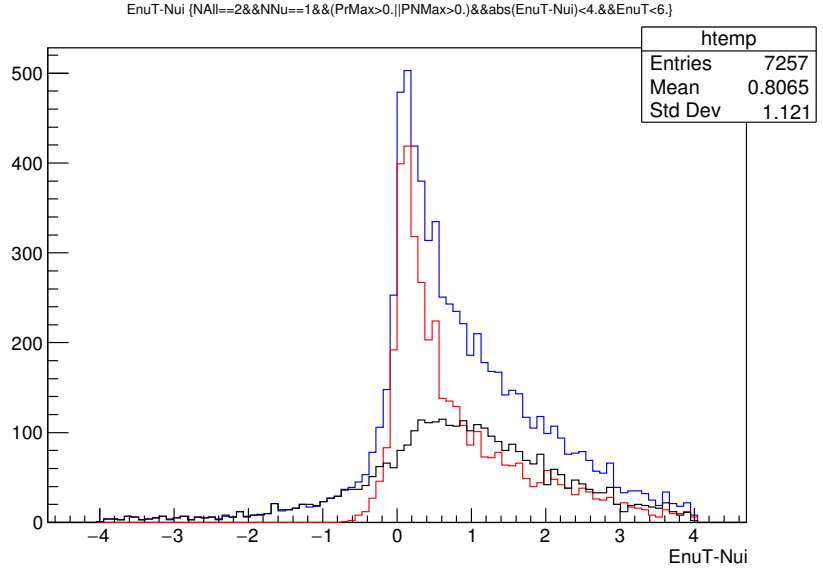
Recoil Neutrino Momentum

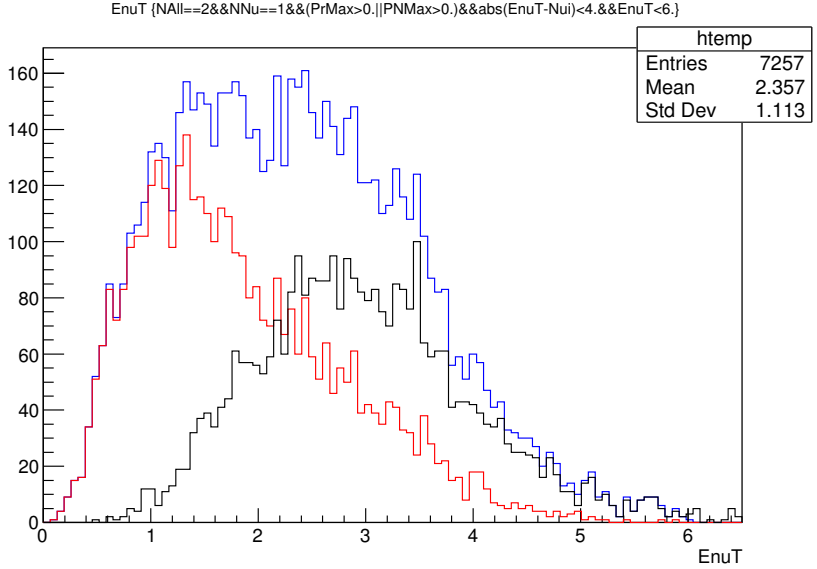


Problem Kinematics

$$\nu_i = \frac{M(E_f - M)}{M + p_f \cos\theta - E_f} = \frac{M}{\frac{p_f \cos\theta}{E_f - M} - 1}$$

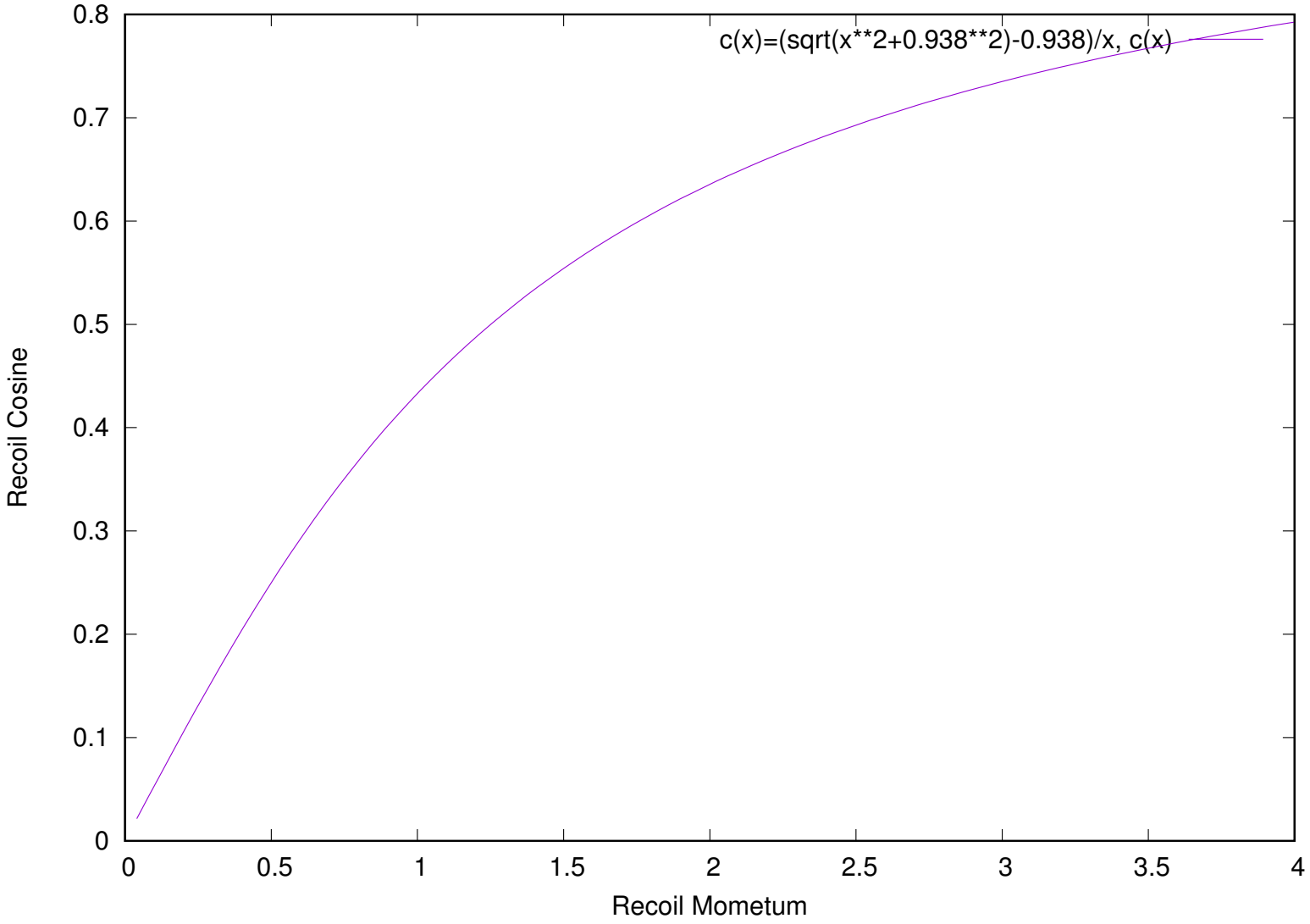
At high energies $E_f \to p_f$.
$E_f - M$ the kinetic energy is $< E_f$ and $p_f \cos\theta < p_f$





The true minus reconstructed neutrino energy (left) and the primary neutrino energy (right). Blue is all 2 prong NC events. Red are those with $\frac{E_f - M}{p_f} - \cos\theta < -.2$. Black are those with $\frac{E_f - M}{p_f} - \cos\theta > -.2$

Problem Kinematics



The dangerous region of $\cos\theta$ as a function of the recoil momentum

What next?

- More prongs
- Reconstructed tracks
- Background? Fiducial volume and timing cuts.
- Comparison with CC events