Cross Section Measurement Update

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Outline

- Expression for Relative Cross Section
- Parameters for Relative Cross Section
  - Number of produced neutrinos which traverse the target
- Cross Check of Relative Cross Section
  - Best method of measuring the energy of the events

Relative Cross Section Expression

To derive a formula for the cross section of the charged current interaction of the ν_τ, begin with the general expression for the expected number of observed events:

$$\langle N_{\nu_\alpha} \rangle = \int n_{\nu_\alpha}(E) \cdot \epsilon_{\nu_\alpha} \cdot \sigma_{\nu_\alpha}(E) \cdot N_{\text{scat}} \cdot N_{\text{POT}} \cdot dE \tag{1}$$

where

$\langle N_{\nu_\alpha} \rangle$	observed number of cc ν_α
$n_{\nu_\alpha}(E)$	number of ν_α per POT
ϵ_{ν_α}	total efficiency
$\sigma_{\nu_\alpha}(E)$	cross section of the ν_α
N_{scat}	number of scat. centers in the target
N_{POT}	number of POT

To calculate the relative cross section, I must choose ν_μ or ν_e. I will choose ν_e because they are virtually all prompt events. Using the ν_es, the expression for the relative cross section is:

$$\frac{\langle N_{\nu_\tau} \rangle}{\langle N_{\nu_e} \rangle} = \frac{\int n_{\nu_\tau}(E) \cdot \epsilon_{\nu_\tau} \cdot \sigma_{\nu_\tau}(E) \cdot N_{\mathsf{scat}} \cdot N_{\mathsf{POT}} \cdot dE}{\int n_{\nu_e}(E) \cdot \epsilon_{\nu_e} \cdot \sigma_{\nu_e}(E) \cdot N_{\mathsf{scat}} \cdot N_{\mathsf{POT}} \cdot dE} \tag{2}$$

Both N_{scat} and N_{POT} are the same for both ν_τ and ν_e, so these cancel. This reduces the equation to:

$$\frac{\langle N_{\nu_\tau} \rangle}{\langle N_{\nu_e} \rangle} = \frac{\int n_{\nu_\tau}(E) \cdot \epsilon_{\nu_\tau} \cdot \sigma_{\nu_\tau}(E) \cdot dE}{\int n_{\nu_e}(E) \cdot \epsilon_{\nu_e} \cdot \sigma_{\nu_e}(E) \cdot dE} \tag{3}$$

Parameters for the Relative Cross Section

σ_{ν_e} for cc interactions at the typical energies in this experiment ($>$ 5 GeV) is assumed to be linear in energy, so it can be rewritten as:

$$\sigma^{cc}_{\nu_e}(E) = E_{\nu_e} \cdot \sigma^{cc}_{\nu_e\ \text{const}} \tag{4}$$

where E_{ν_e} is the energy of the ν_e and $\sigma^{cc}_{\nu_e\ \text{const}}$ is the constant part of the cross section. The cross section for the ν_τ can be written in terms of the ν_e cross section:

$$\sigma^{cc}_{\nu_\tau}(E) = K_F(E) \cdot \sigma^{cc}_{\nu_e}(E) \tag{5}$$

where $K_F(E)$ is a kinematic term that is necessary because of the finite mass of the tau lepton. Equations 4 and 5 can be combined:

$$\sigma^{cc}_{\nu_\tau}(E) = K_F(E) \cdot E_{\nu_\tau} \cdot \sigma^{cc}_{\nu_\tau\ \text{const}} \tag{6}$$

If the ν_τ is a standard model particle, then:

$$\sigma^{cc}_{\nu_e\ \text{const}} = \sigma^{cc}_{\nu_\tau\ \text{const}} \tag{7}$$

Substituting equations 4 and 6 into 3:

$$\frac{\langle N_{\nu_\tau}\rangle}{\langle N_{\nu_e}\rangle} = \frac{\int n_{\nu_\tau}(E)\cdot\epsilon_{\nu_\tau}\cdot K_F(E)\cdot E_{\nu_\tau}\cdot\sigma^{cc}_{\nu_\tau\ \text{const}}\cdot dE}{\int n_{\nu_e}(E)\cdot\epsilon_{\nu_e}\cdot E_{\nu_e}\cdot\sigma^{cc}_{\nu_e\ \text{const}}\cdot dE} \tag{8}$$

Simplifying this equation:

$$\frac{\langle N_{\nu_\tau}\rangle}{\langle N_{\nu_e}\rangle} = \frac{\epsilon_{\nu_\tau}\cdot\sigma_{\nu_\tau}\text{const}\cdot\int n_{\nu_\tau}(E)\cdot K_F(E)\cdot E_{\nu_\tau}\cdot dE}{\epsilon_{\nu_e}\cdot\sigma_{\nu_e}\text{const}\cdot\int n_{\nu_e}(E)\cdot E_{\nu_e}\cdot dE} \tag{9}$$

Solving for $\sigma_{\nu_\tau}\text{const}$:

$$\sigma_{\nu_\tau}\text{const} = \frac{\langle N_{\nu_\tau}\rangle\cdot\epsilon_{\nu_e}\cdot\sigma_{\nu_e}\text{const}\cdot\int n_{\nu_e}(E)\cdot E_{\nu_e}\cdot dE}{\langle N_{\nu_e}\rangle\cdot\epsilon_{\nu_\tau}\cdot\int n_{\nu_\tau}(E)\cdot K_F(E)\cdot E_{\nu_\tau}\cdot dE} \tag{10}$$

Parameters Cont.

$\langle N_{\nu_\tau} \rangle$ and $\langle N_{\nu_e} \rangle$ are the number of identified ν_τ and ν_e events, which comes from the data.

The efficiencies have been measured using Monte Carlo previously by many people

Assuming lepton universality, $\sigma_{\nu_e}\text{const} = \sigma_{\nu_\mu}\text{const}$. $\sigma_{\nu_\mu}\text{const}$ is listed in the particle data book. The average for ν and $\bar{\nu}$ is:

$$\sigma_{\nu_e}\text{const} = 0.505 \pm 0.016\text{x}10^{-38} cm^2 GeV^{-1} \tag{11}$$

K_f has been calculated as a function of energy.

Parameters Cont.

n_{ν_τ}, the number of neutrinos which hit the target is:

$$n_{\nu_\tau}(E) = N_{\nu_\tau \text{prod}}(E) \cdot \eta \cdot \frac{dN_\nu}{dE} \qquad (12)$$

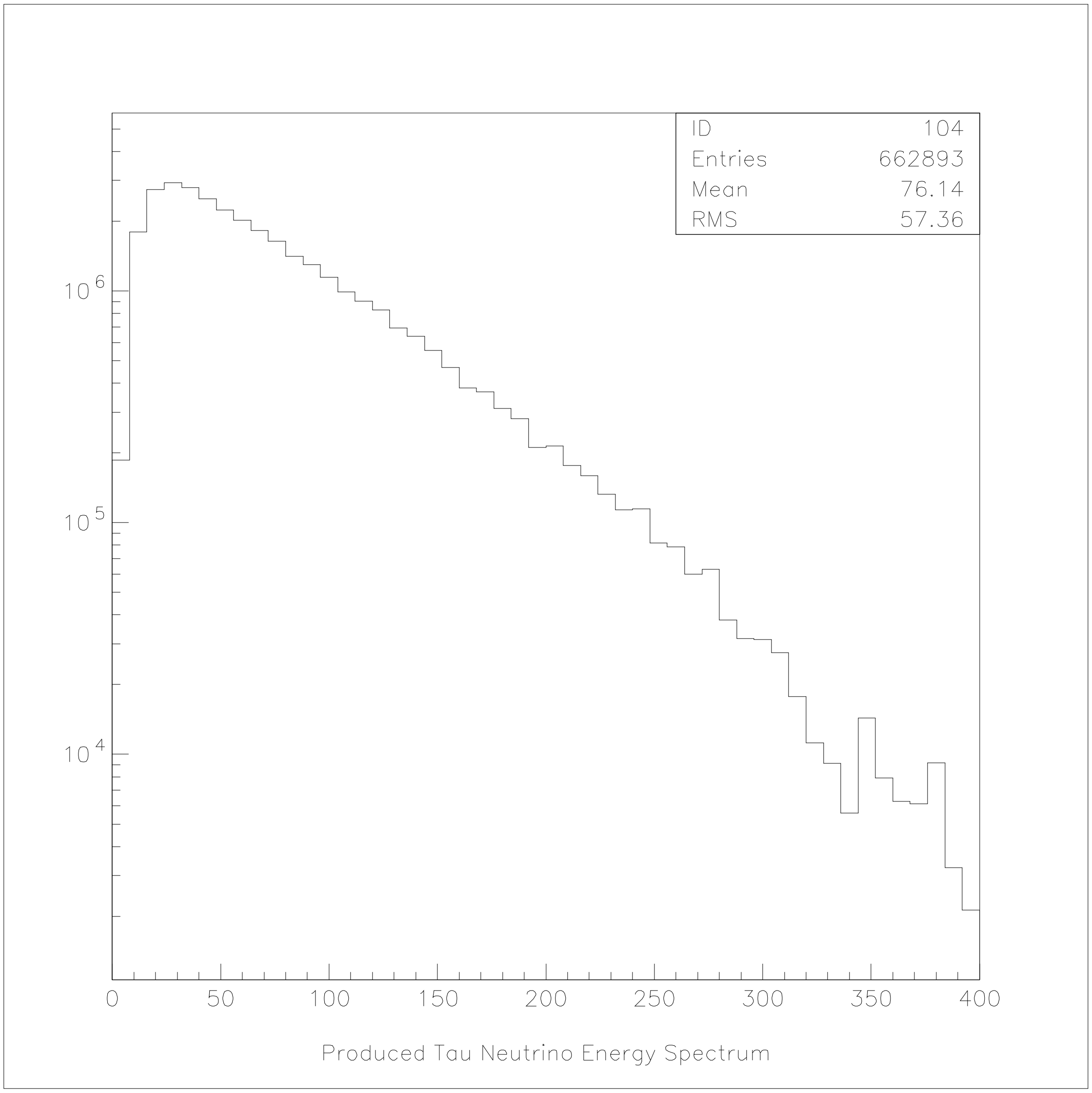
where

η is the target angular acceptance which will cancel

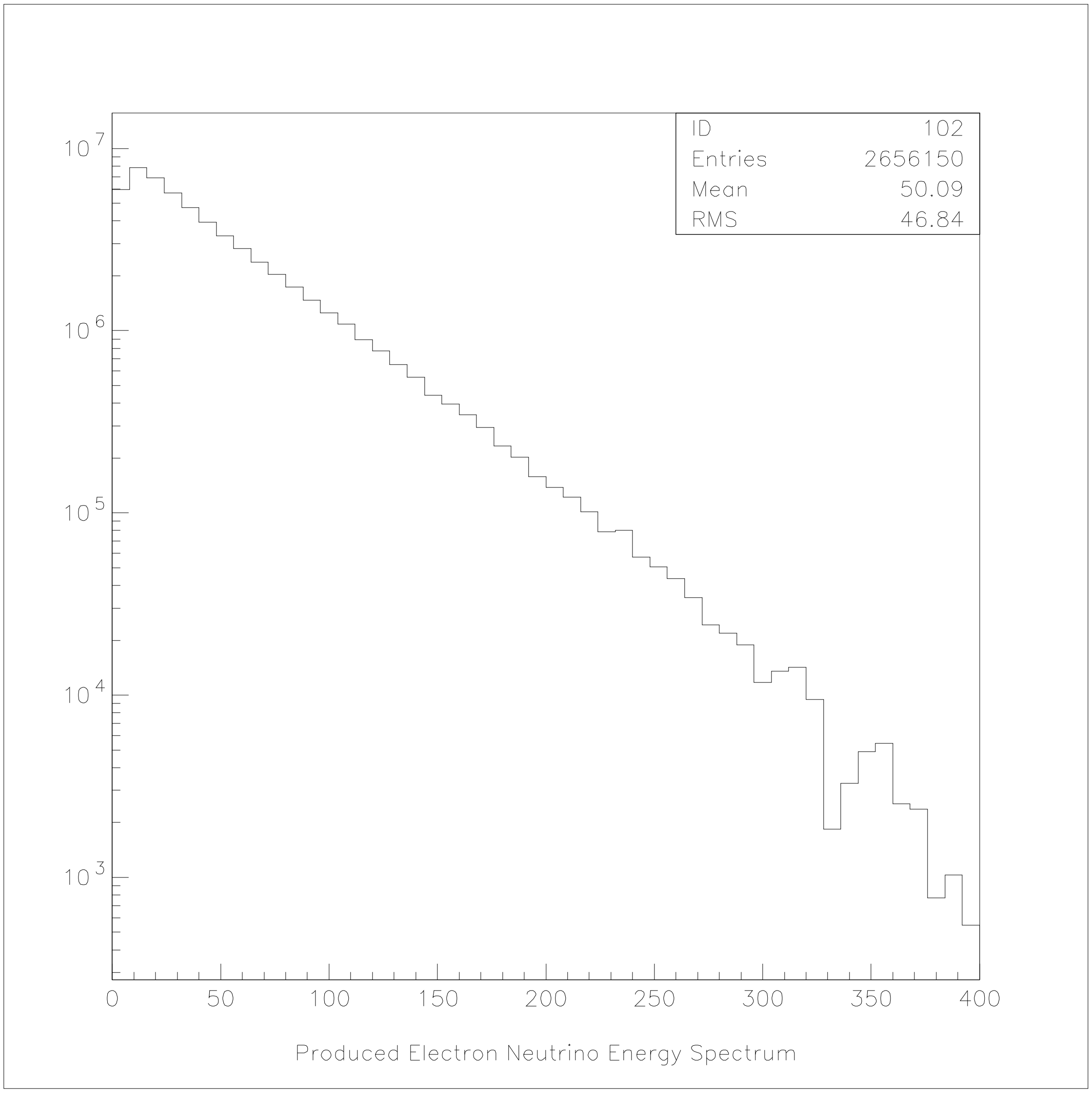
$N_{\nu_\tau \text{prod}}(E)$ is the number of neutrinos produced as a function of energy, which is calculated using charm production cross sections and charm branching ratios

$\frac{dN_\nu}{dE}$ is the energy spectrum of the produced neutrinos. I calculated this using the Monte Carlo. The results follow:

For ν_τ, $\frac{dN_\nu}{dE}$ is:



For ν_e, $\frac{dN_\nu}{dE}$ is:



Currently I am using another fixed-target neutrino experiment, E613, to cross check these plots. E613 is an experiment which used 400 GeV protons to produce prompt ν_μs and ν_es.

Cross Check for Cross Section

As a cross check for the relative cross section measurement, I will compare the ν_e and ν_τ energy spectra. The procedure is:

- Use the identified ν_e events to produce a ν_e energy spectrum.

- Assume lepton universality between the ν_e and the ν_τ, that is, assume their cross sections are equal

- Use the ν_e energy spectrum to predict the ν_τ energy spectrum. This is accomplished by correcting the ν_e energy spectrum for the the difference in charm cross branching ratios, efficiencies, and kinematics for the . ν_e and the ν_τ.

- Compare the ν_τ energy spectrum predicted by the ν_e energy spectrum and the actual ν_τ energy spectrum (only a handful of events).

To complete this, I must decide on a method of measuring the energy of the events. Possible methods are multiple scattering, EMCAL, and showers in scintillating fibers. I am still working on this.

Conclusion/Future Work

Cross section measurement is coming along

I will finish using E613 to cross check the produced neutrino energy spectra

I will finalize the method of measuring energy and compare the ν_τ energy spectrum and the ν_e energy spectrum