Measurement of Relative Cross-Section of ν_τ to prompt ν Part 1

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Introduction

I am working to calculate a relative cross section. As a first step, I am following Patrick's analysis with the hopes of improving it.

In this presentation, I will outline my progress with the calculations of the following components of the cross section:

- $N_{\nu_\tau}/N_{\nu_{\text{prompt}}}$ This is the ratio of produced tau neutrinos to prompt neutrinos.

- $\epsilon_{\nu_\tau}/\epsilon_{\nu_{\text{prompt}}}$ This is the ratio of efficiencies (trigger, selection, and location).

I will start with the questions I have.

Questions

- When I calculate the ratio of $N_{\nu_\tau}/N_{\nu_{\text{prompt}}}$ using the numbers in Patrick's thesis, I arrive at a different value than Patrick. I will show the exact calculation, and maybe someone can see what I am doing incorrectly.

- Initially I would think the efficiency is energy dependent, but most people (Jason, Niki, Patrick) just quote a number for efficiencies (trigger, selection, and location). I assume these are averages. Do you have to worry about energy dependence for efficiencies?

- I will have a different efficiency for trident events because we apply different selection cuts to these events. What are these selection cuts are we applying to the trident events?

Number of Neutrinos Produced

Using the following numbers,

Charm	$\sigma(pN, 800 GeV, \mu\text{barn})$
D_s	5.2 ± 0.8
$D^{\pm}$	11.3 ± 2.2
D^0	27.4 ± 2.6
Λ_c	5.4 ± 2.1

	$\rightarrow \nu_e X$	$\rightarrow \nu_\mu X$	$\rightarrow \nu_\tau X$
D_s	$0.08^{+0.06}_{-0.05}$	$0.08^{+0.06}_{-0.05}$	0.063 ± 0.05
$D^{\pm}$	0.172 ± 0.019	0.160 ± 0.03	0.00072
D^0	0.068 ± 0.0029	0.066 ± 0.008	Not Allowed
Λ_c	0.021 ± 0.006	0.020 ± 0.007	Not allowed

and the following equation:

$$\frac{N_{\nu_x \text{Prod}}}{\text{pot}} = \frac{\Sigma \sigma(pN \rightarrow C_i X) BR(C_i \rightarrow \nu_x X)}{\sigma(pN)_{\text{total}}} \quad (1)$$

$$\frac{N_{\nu_\tau}}{N_{\nu_{prompt}}} = \frac{N_{\nu_\tau}}{N_{\nu_\tau} + N_{\nu_\mu} + N_{\nu_e}} \tag{2}$$

$$\begin{aligned}
\frac{N_{\nu_\tau}}{N_{\nu_{prompt}}} = {} & \Big[2 \cdot \sum_j \sigma(j) BR(j \to \nu_\tau \tau)\Big] \Big/ \Big[2 \cdot \sum_j \sigma(j) \\
& BR(j \to \nu_\tau \tau) + \sum_i \sigma(i) BR(i \to \nu_\mu \mu) \\
& + \sum_i \sigma(i) BR(i \to \nu_e e)\Big] \\
= {} & [2 \cdot 5.2 \cdot 0.063 + 2 \cdot 11.3 \cdot 0.00072]/ \\
& [5.2 \cdot (2 \cdot 0.063 + 0.08 + 0.08) \\
& +11.3 \cdot (2 \cdot 0.00072 + 0.16 + 0.172) \\
& +27.4 \cdot (0.066 + 0.068) + 5.4 \cdot (0.02 + 0.021)] \\
= {} & 0.0734
\end{aligned} \tag{3}$$

where i is a sum over relevant charm particles: D_s, $D^\pm$, D^0, and Λ_c and j is over D_s and $D^\pm$.

The ratio, $N_{\nu_\tau}/N_{\nu_{\text{prompt}}}$ can be calculated. Patrick's number for is ratio is:

$$N_{\nu_\tau Produced}/N_{PromptProduced} = 0.059 \pm 0.011 \tag{4}$$

Although when I calculate this ratio, I get:

$$N_{\nu_\tau Produced}/N_{PromptProduced} = 0.0734 \tag{5}$$

Any ideas why these are different?

Efficiency

We need the ratio of $\epsilon_\tau/\epsilon_{\text{prompt}}$.

From Patrick's thesis, the trigger, selection, and location efficiency for the prompt neutrino interactions is:

$$\epsilon_{\text{prompt}} = 0.55 \tag{6}$$

and the trigger, selection, and location efficiency for the tau neutrino interaction is:

$$\epsilon_\tau = 0.56 \tag{7}$$

The ν_τ efficiency need an extra term to account for the cuts we apply to the event parameters.

Each selection criterion had a certain efficiency. This efficiency was found by simulating tau decays and finding the fraction that passed each cut. These are summarized in the following table

Criterion	Cut	Efficiency
Decay Length	< 5 mm	81%
Decay Angle	> 10 mrad	84%
Daughter IP	< 500 μm	97%
Daughter P	> 1 GeV/c	96%
Daughter P_t	> 250 MeV/c	78%
Total		51.3%

For the 203 data set, this factor, $F_{top} = 0.513$. This includes a cut on decay length of less than 5 mm. Currently our cut is less than 10 mm. The 5 mm cut included 81% of τ deays, while the 10 mm cut includes 90% of τ decays *.

*From "Tau Neutrino Discovery" Note by N. Nonaka.

We can scale F_{top}:

$$F_{top} = 0.513 \cdot \frac{.90}{.81} = 0.57 \tag{8}$$

This gives a total efficiency and a ratio for the single kink tau events:

$$\epsilon_\tau = 0.56 \cdot 0.57 = 0.32 \tag{9}$$

$$\epsilon_\tau / \epsilon_{\text{prompt}} = 0.58 \tag{10}$$

The trident events are going to have a separate efficiency because there are different cuts. What are the trident cuts?

Criterion	Cut	Efficiency
Decay Length	< 10 mm	90%
Decay Angle	> 10 mrad	?
Daughter IP	$< 500\ \mu$m	?
Daughter P	> 1 GeV/c	?
Daughter P$_t$	> 250 MeV/c	?
Total		?