E_ν at the muon alcove monitors

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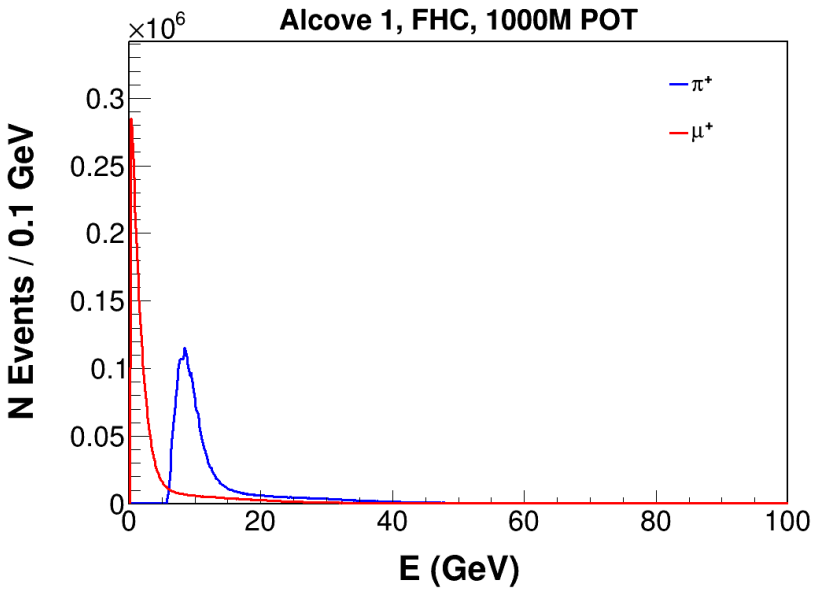
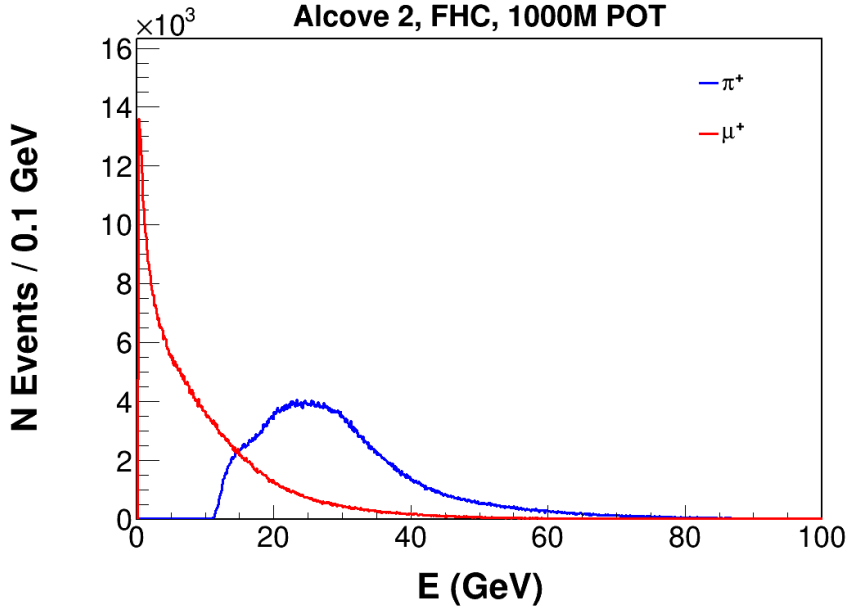
Introduction

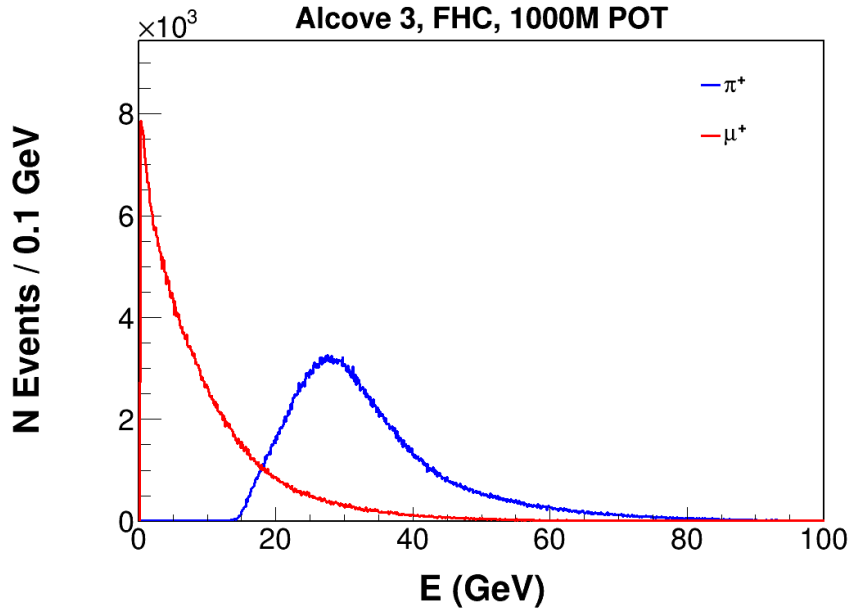
- We are interested in seeing the neutrino energy distribution at each alcove.
- This information is not included in the simulation files. However, we can calculate the neutrino energy using the information from the parent and daughter.
- The files are located at:
  - /pnfs/dune/persistent/users/pweather/fluxfiles/g4lbne/v3r5p9/QGSP_BERT/OfficialEngDesignSept2021/neutrino/flux
  - /pnfs/dune/persistent/users/pweather/fluxfiles/g4lbne/v3r5p9/QGSP_BERT/OfficialEngDesignSept2021/antineutrino/flux
- The neutrino energy is calculated assuming a two-body decay and the neutrinos travel in the forward direction.

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

Parent and daughter energy distributions at each alcove after looking for parent PDG = 211 and daughter PDG = -13.

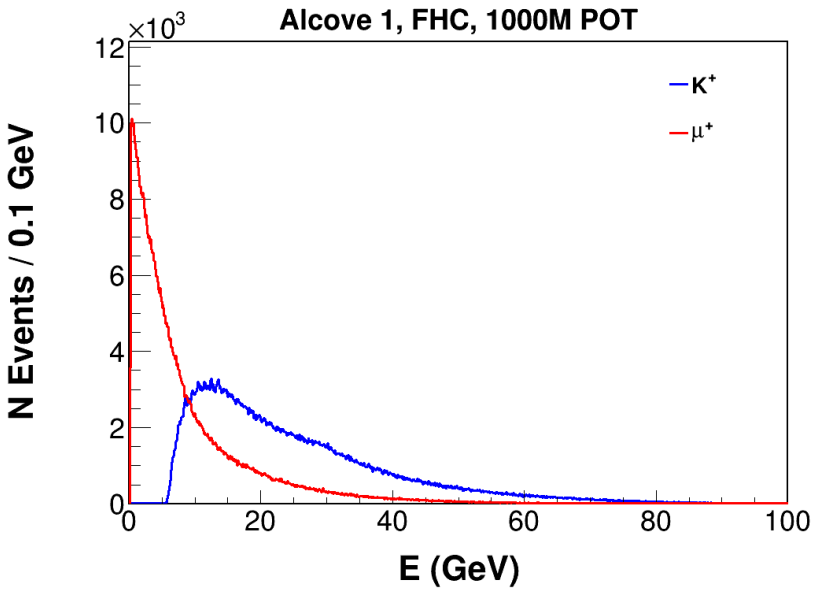


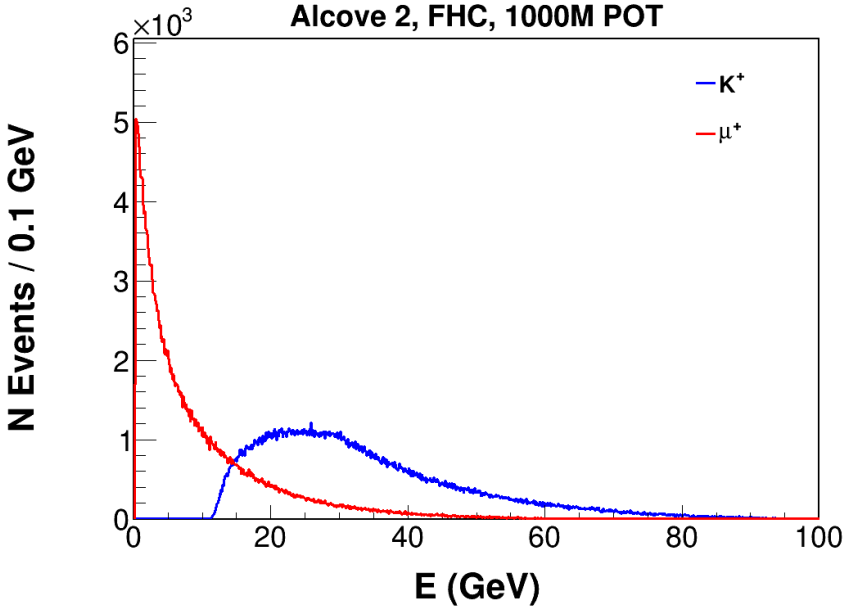


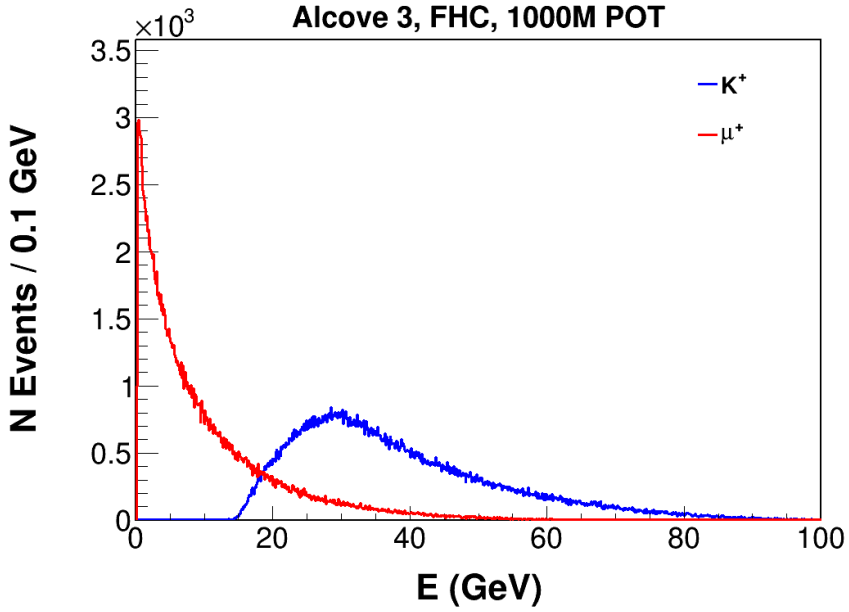


$$K^+ \rightarrow \mu^+ + \nu_\mu$$

Parent and daughter energy distributions at each alcove after looking for parent PDG = 321 and daughter PDG = -13.







Method

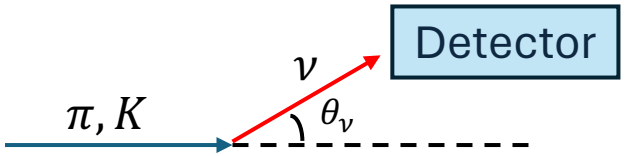
Leo Aliaga's thesis

Decay	Chanel	Branching ratio (%)
1	$\pi^{\pm} \to \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$	99.9877
2	$\pi^{\pm} \to e^{\pm} + \nu_{e}(\bar{\nu}_{e})$	0.0123
3	$K^{\pm} \to \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$	63.55
4	$K^{\pm} \to \pi^{0} + e^{\pm} + \nu_{e}(\bar{\nu}_{e})$	5.07
5	$K^{\pm} \to \pi^{0} + \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$	3.353
6	$K^{0}_{L} \to \pi^{\pm} + e^{\mp} + \nu_{e}$	40.55
7	$K^{0}_{L} \to \pi^{\pm} + \mu^{\mp} + \nu_{\mu}$	27.04
8	$\mu^{\pm} \to e^{\pm} + \nu_{e}(\bar{\nu}_{e}) + \bar{\nu}_{\mu}(\nu_{\mu})$	100.0

TABLE 2.1: Main decay modes and their branching ratios of charged pion, charged kaons, neutral kaons and muons to neutrinos.

Two-body decay

$$E_{\nu} \approx \frac{(1 - \frac{m_{\mu}^2}{M^2})E_{\pi(K)}}{1 + \gamma^2 \tan^2\theta_{\nu}} \qquad \gamma = E_{\pi(K)}/M$$



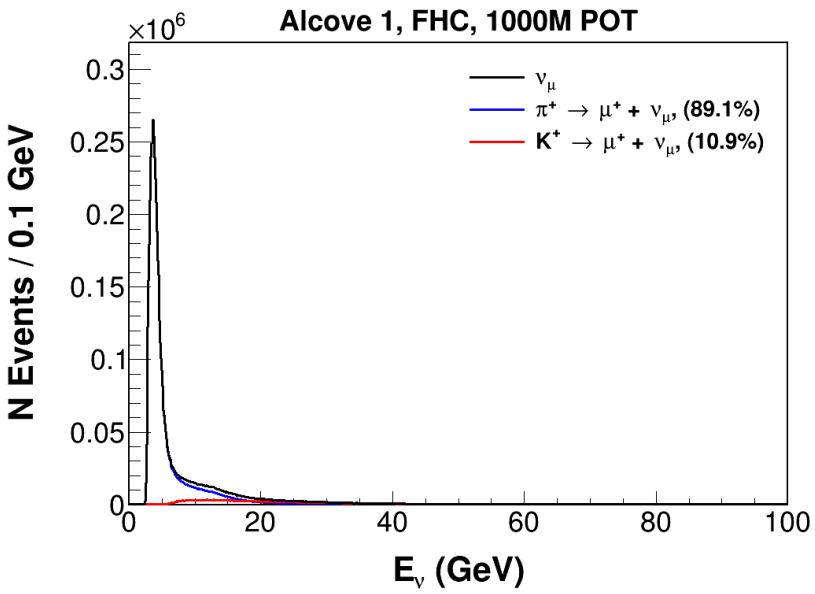
If the detector is on-axis → $\theta_{\nu} = 0$

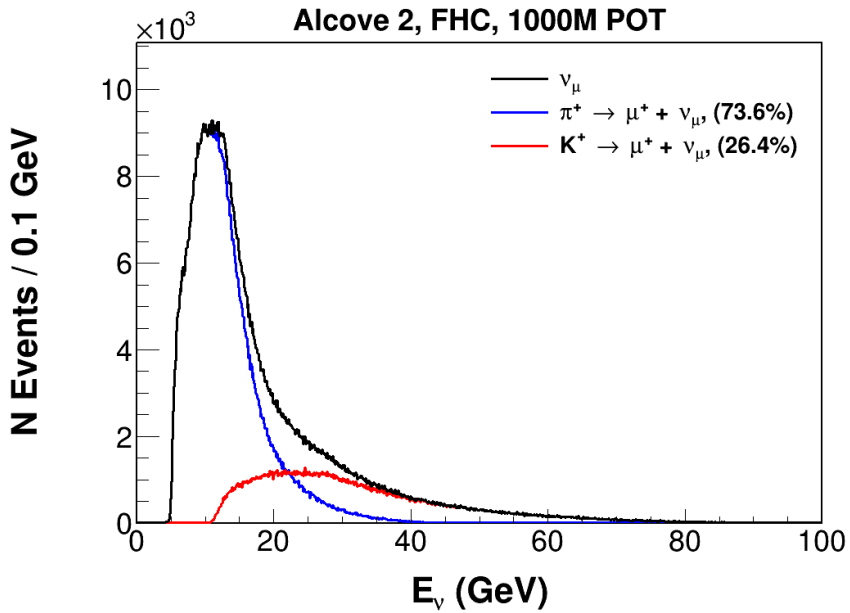
$$E_{\nu} \approx 0.43 E_{\pi}$$

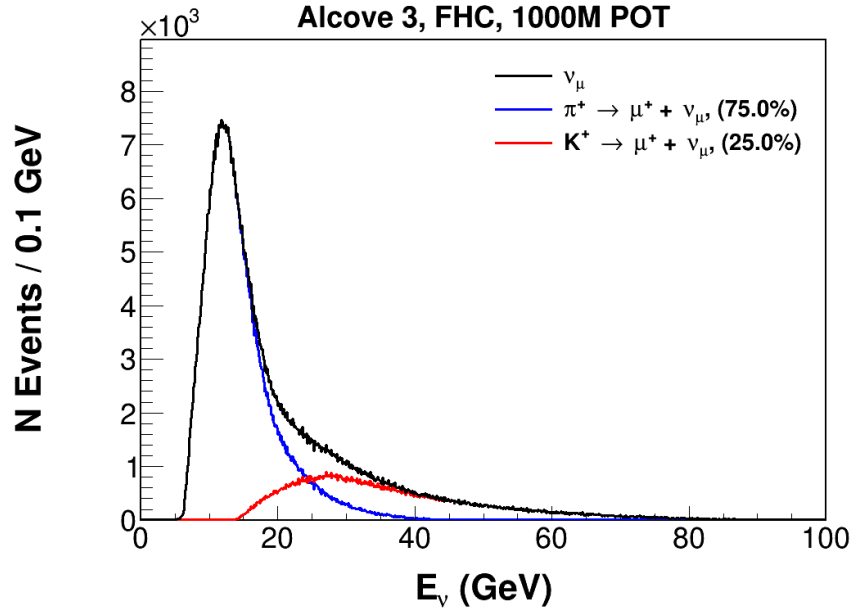
$$E_{\nu} \approx 0.95 E_{K}$$

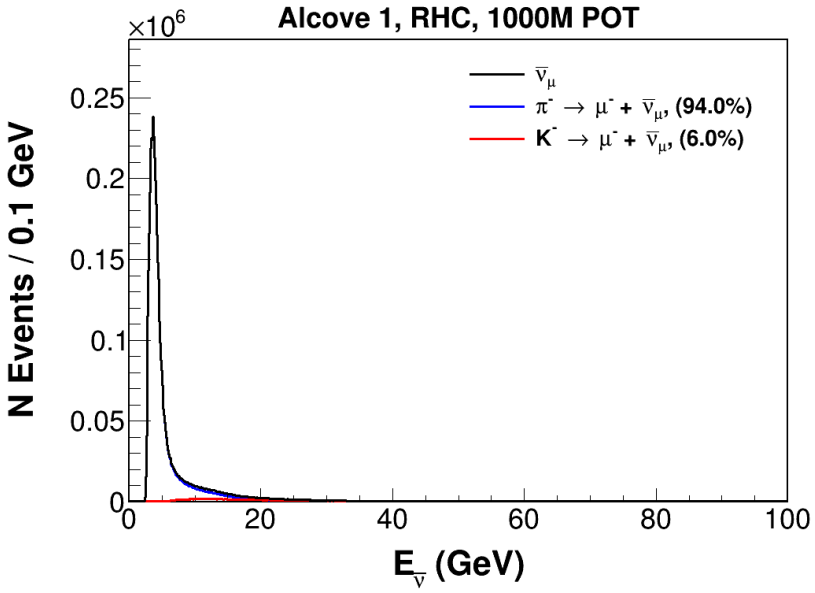
Decays 1 and 3 are considered in this study

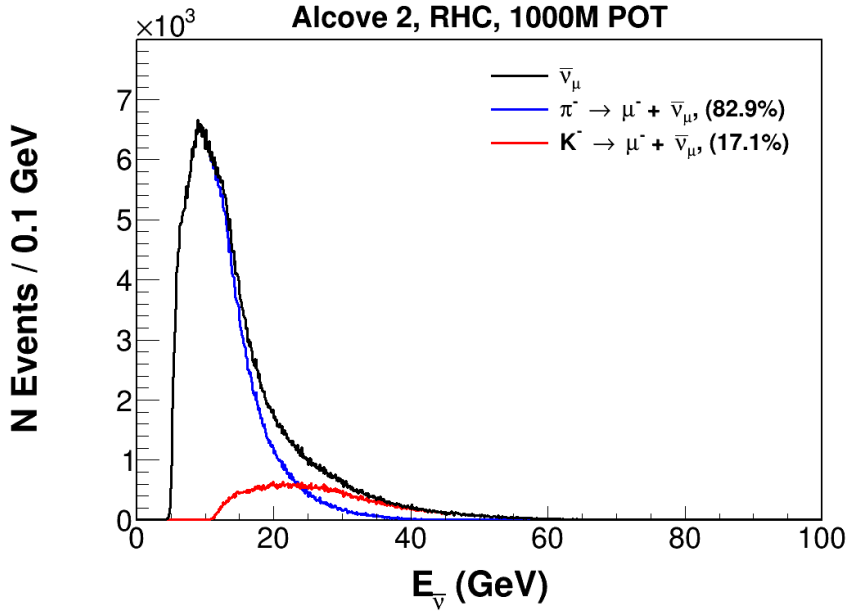
```
// Return the decay mode according to Leo's thesis, table 2.1 in fermilab-thesis-2016-03 Leo Aliaga.pdf
int Channel( int parentPDG, int daughterPDG )
{
    int channel = 0; // Other decay mode

    if( parentPDG == 211 && daughterPDG == -13 ) // Decay 1, pi+ -> mu+ + numu
        channel = 1;

    if( parentPDG == -211 && daughterPDG == 13 ) // Decay 1, pi- -> mu- + numubar
        channel = 2;

    if( parentPDG == 321 && daughterPDG == -13 ) // Decay 3, K+ -> mu+ + numu
        channel = 3;

    if( parentPDG == -321 && daughterPDG == 13 ) // Decay 3, K- -> mu- + numubar
        channel = 4;

    return channel;
}
```

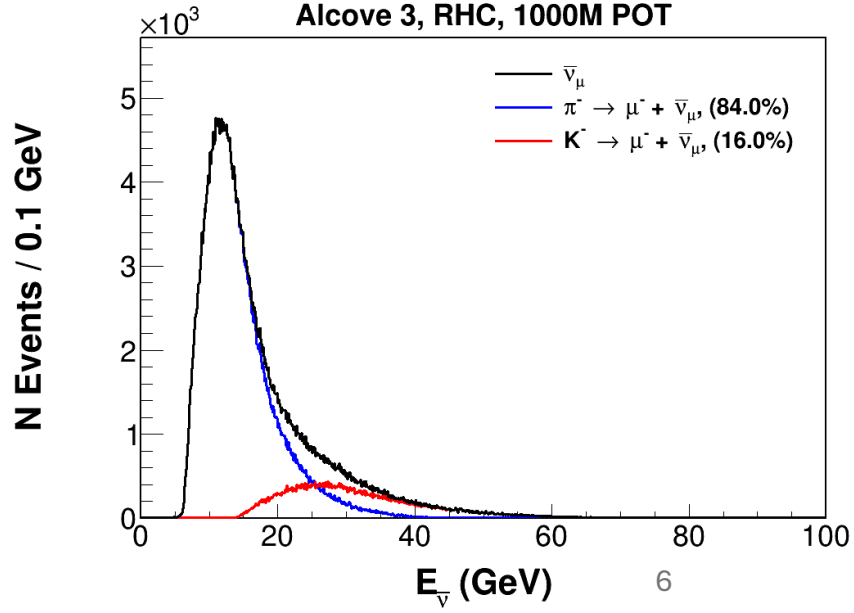

Alcove 1, FHC, 1000M POT
×10^6
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (89.1%)
K⁺ → μ⁺ + ν_μ, (10.9%)

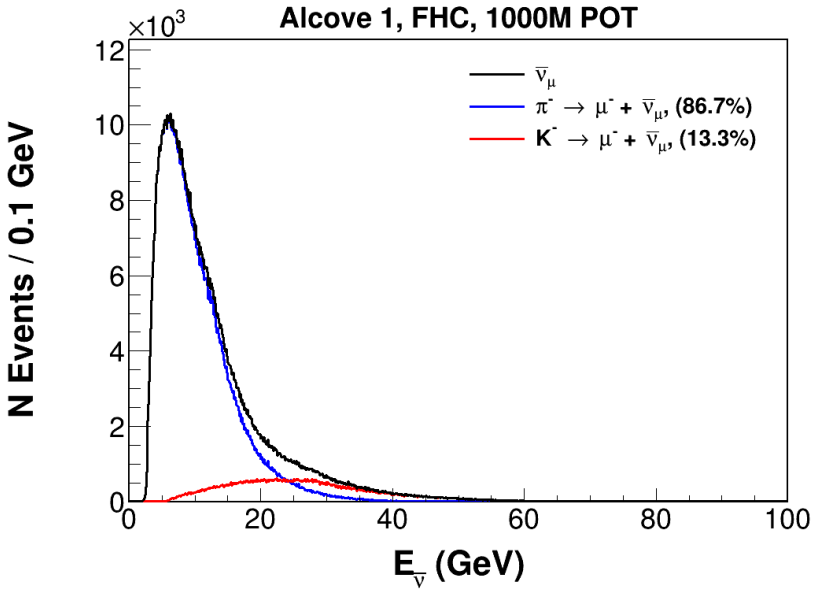

Alcove 2, FHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (73.6%)
K⁺ → μ⁺ + ν_μ, (26.4%)

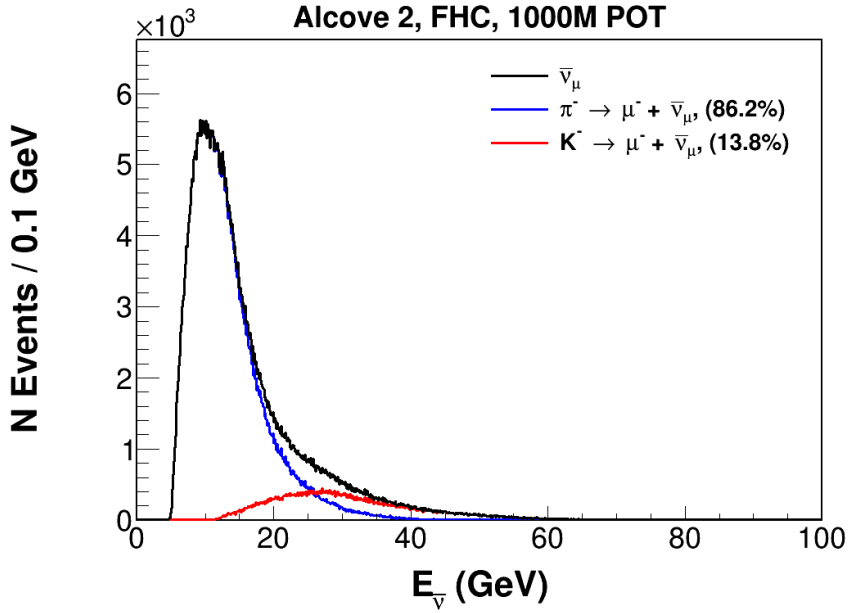

Alcove 3, FHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (75.0%)
K⁺ → μ⁺ + ν_μ, (25.0%)

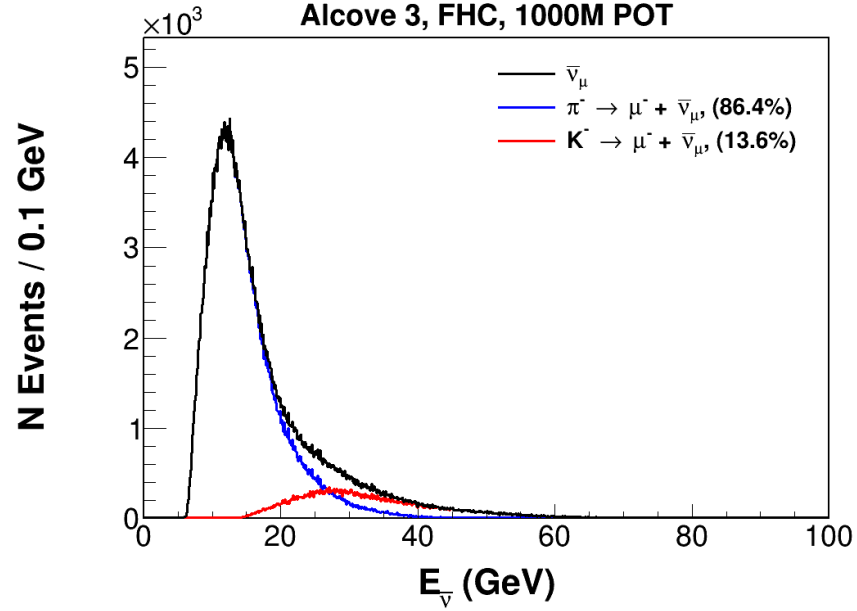

Alcove 1, RHC, 1000M POT
×10^6
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (94.0%)
K⁻ → μ⁻ + ν̄_μ, (6.0%)

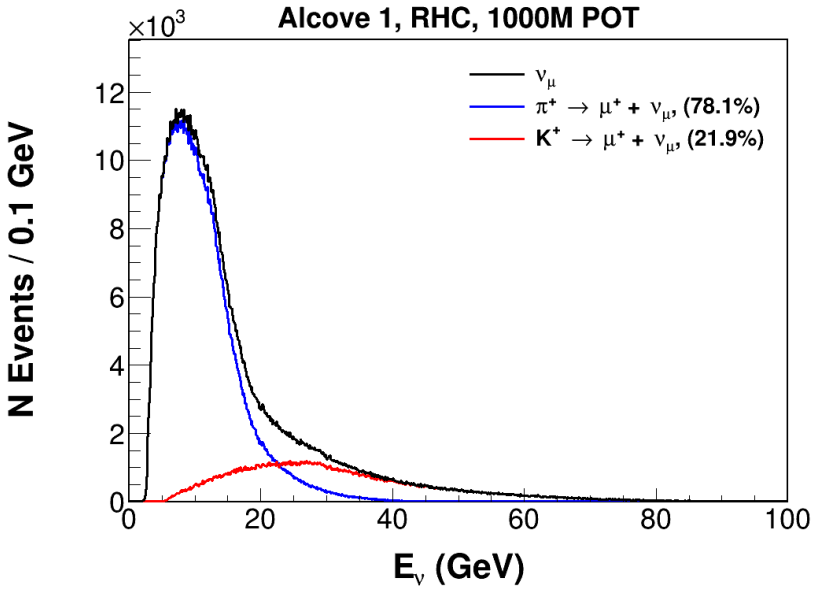

Alcove 2, RHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (82.9%)
K⁻ → μ⁻ + ν̄_μ, (17.1%)

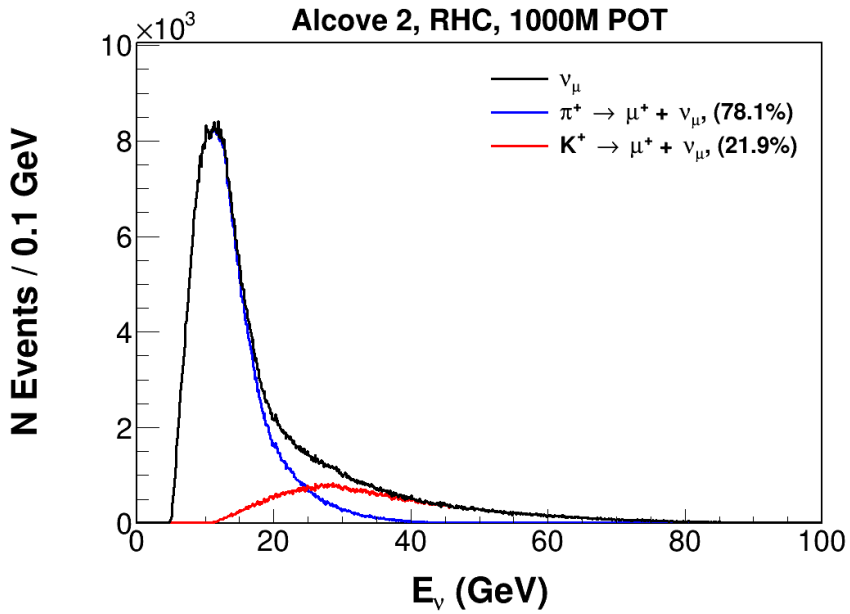

Alcove 3, RHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (84.0%)
K⁻ → μ⁻ + ν̄_μ, (16.0%)

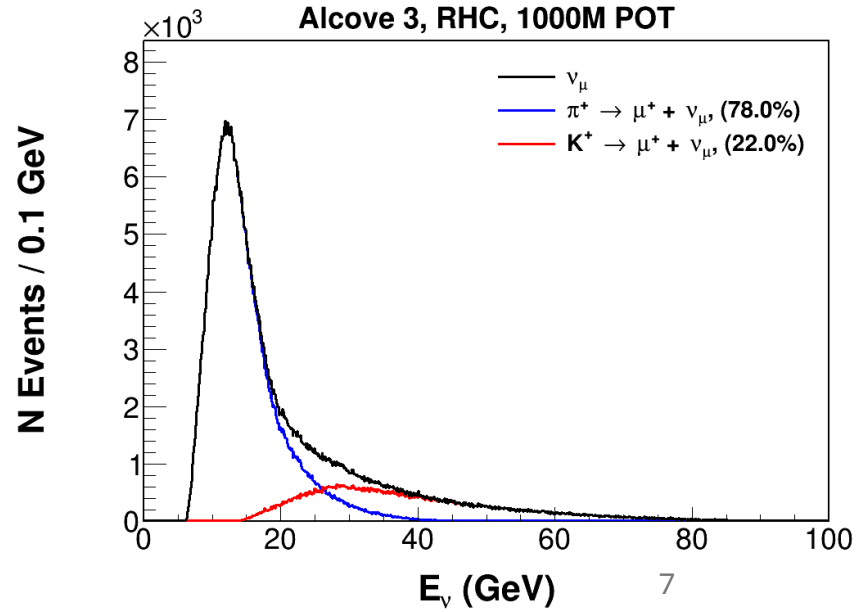

Alcove 1, FHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (86.7%)
K⁻ → μ⁻ + ν̄_μ, (13.3%)


Alcove 2, FHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (86.2%)
K⁻ → μ⁻ + ν̄_μ, (13.8%)


Alcove 3, FHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν̄ (GeV)
ν̄_μ
π⁻ → μ⁻ + ν̄_μ, (86.4%)
K⁻ → μ⁻ + ν̄_μ, (13.6%)


Alcove 1, RHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (78.1%)
K⁺ → μ⁺ + ν_μ, (21.9%)


Alcove 2, RHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (78.1%)
K⁺ → μ⁺ + ν_μ, (21.9%)


Alcove 3, RHC, 1000M POT
×10^3
N Events / 0.1 GeV
E_ν (GeV)
ν_μ
π⁺ → μ⁺ + ν_μ, (78.0%)
K⁺ → μ⁺ + ν_μ, (22.0%)

Next Steps

- I am working on getting the actual neutrino energy into the ntuples.