Atmospheric Neutrino Problem

Group 13
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INSS 2019, Fermilab

The Problem :

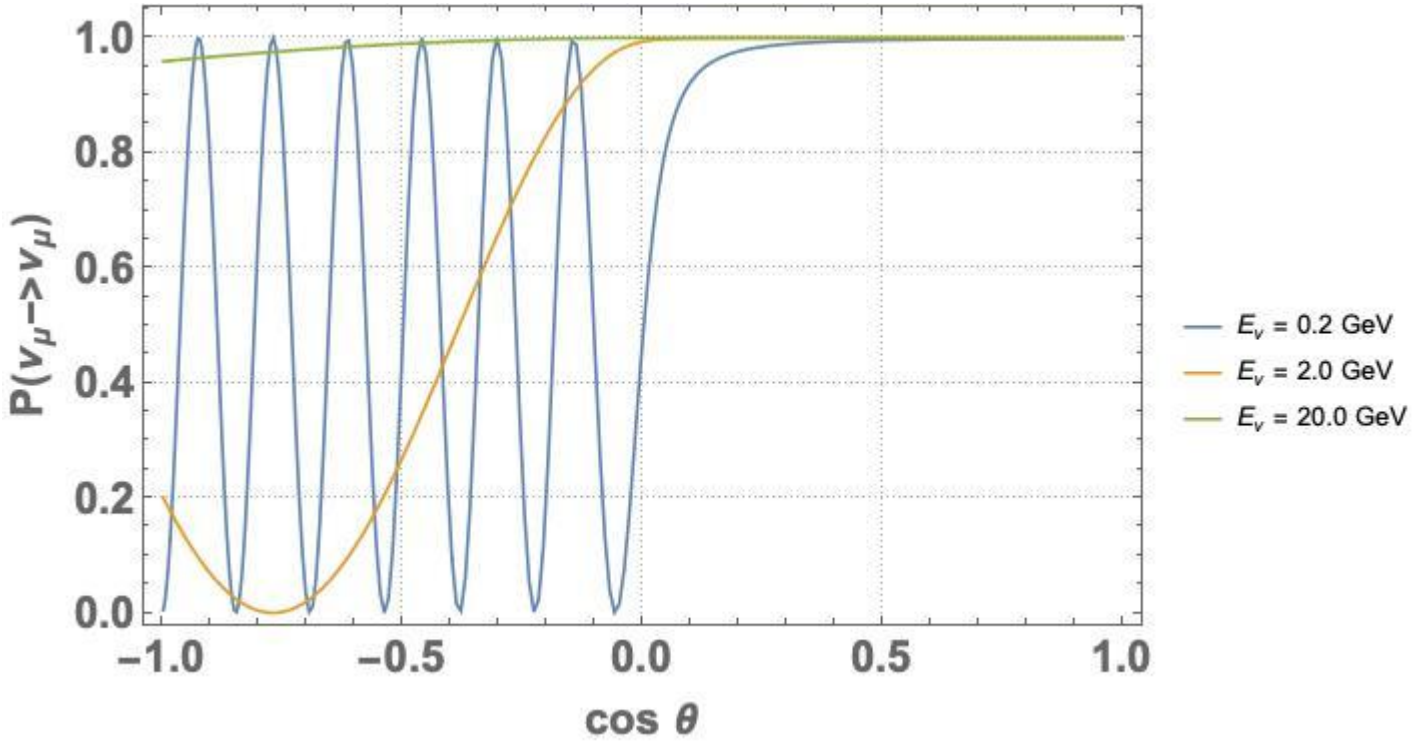
- We read “Super-Kamiokande Atmospheric Neutrino Results” by T. Toshito, hep-ex/0105023

- Part - 1: Numerically calculate and draw histograms of the average muon neutrino survival probability in ten equal-size bins of cos θ where θ is the angle between the neutrino direction and the vertical-axis at the detector’s location. The energies to be considered are 0.2 GeV, 2.0 GeV and, 20.0 GeV

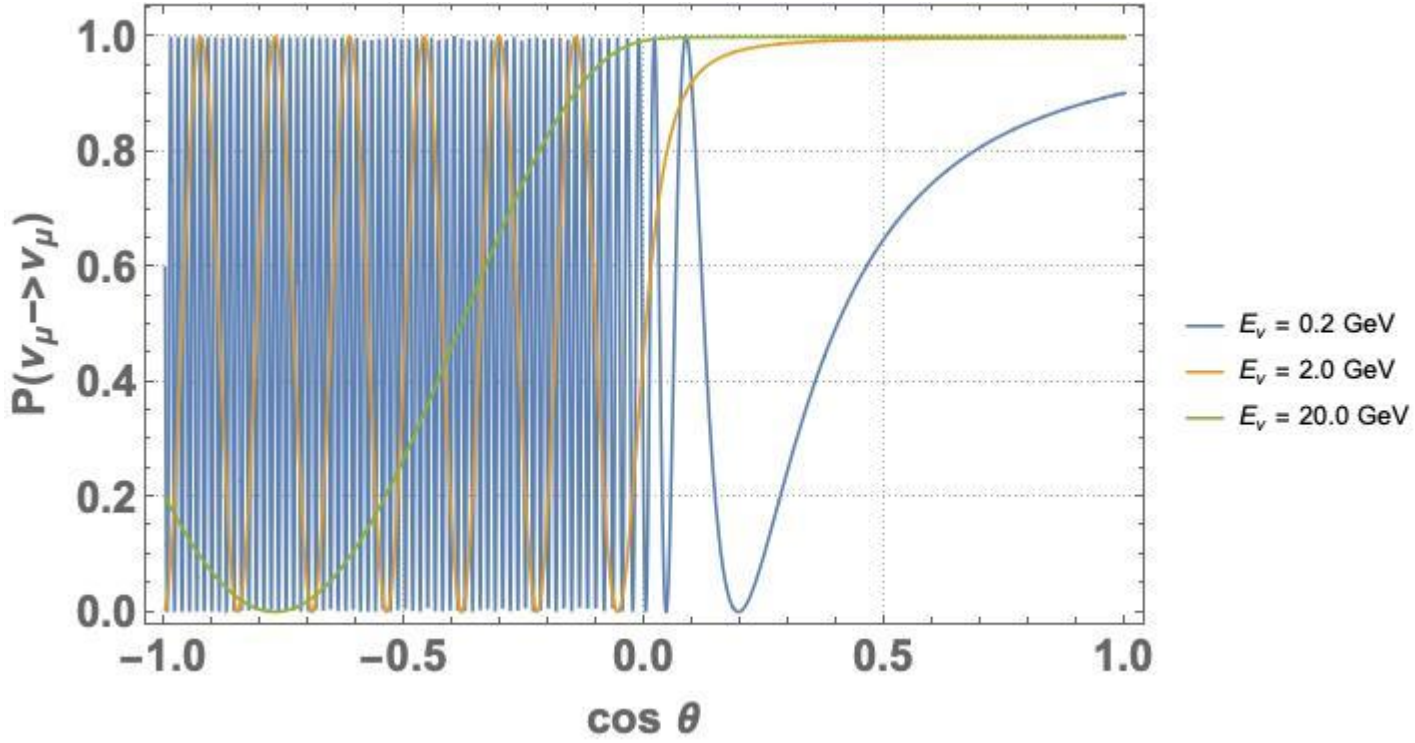
- Part- 2: Compare, Verify and analyze!!

- Part- 3: Obtain an order of magnitude estimate of the electron neutrino flux for sub-GeV like events.

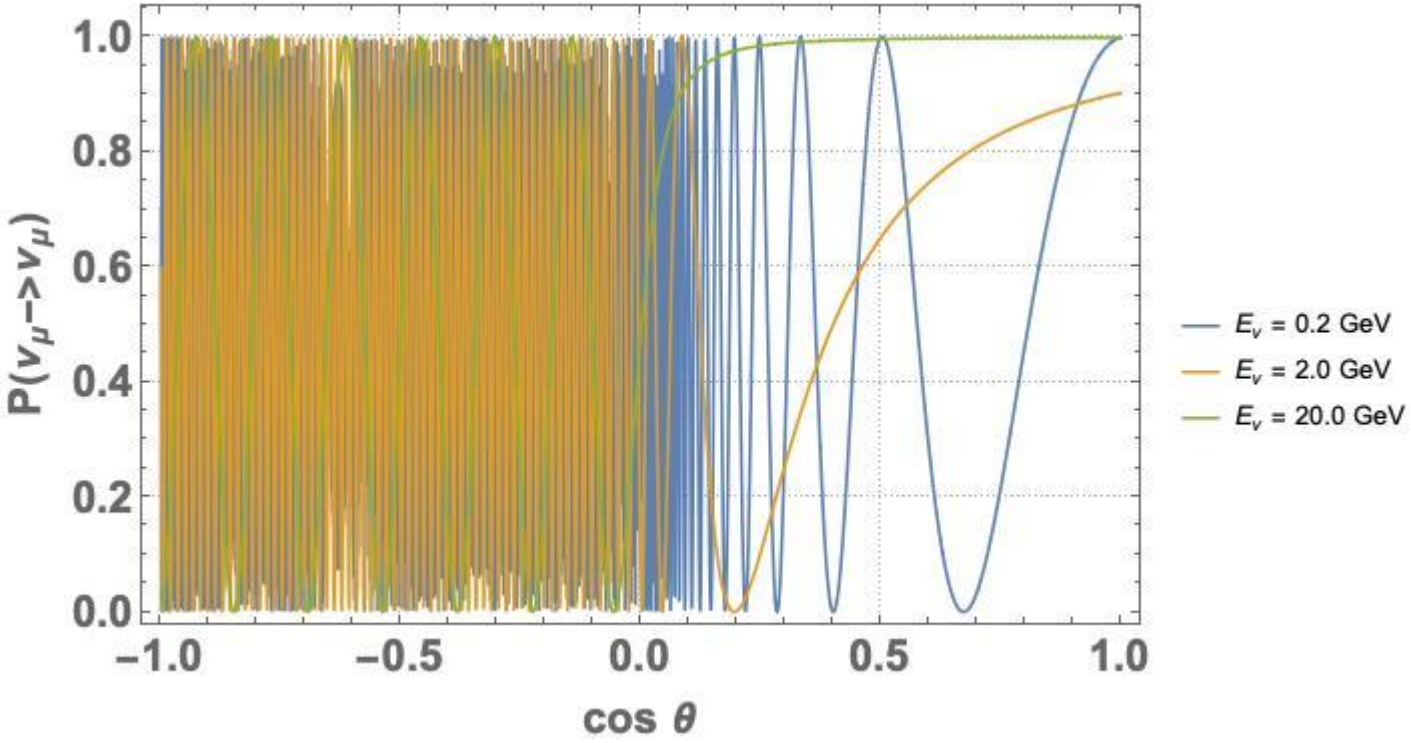
Survival Probability for $\Delta m^2 = 2.5 \times 10^{-4} eV^2$



Survival Probability for $\Delta m^2 = 2.5 \times 10^{-3} eV^2$

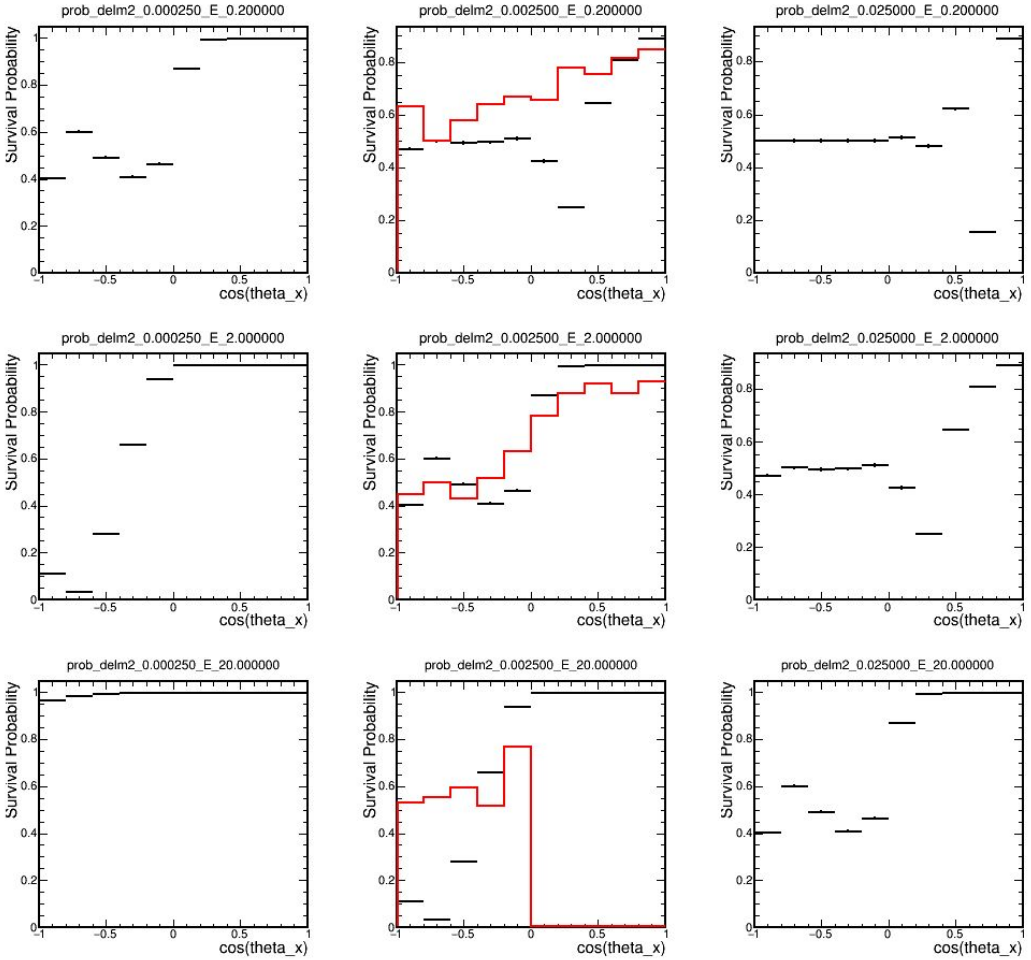


Survival Probability for $\Delta m^2 = 2.5 \times 10^{-2} eV^2$



Δm^2

E_ν

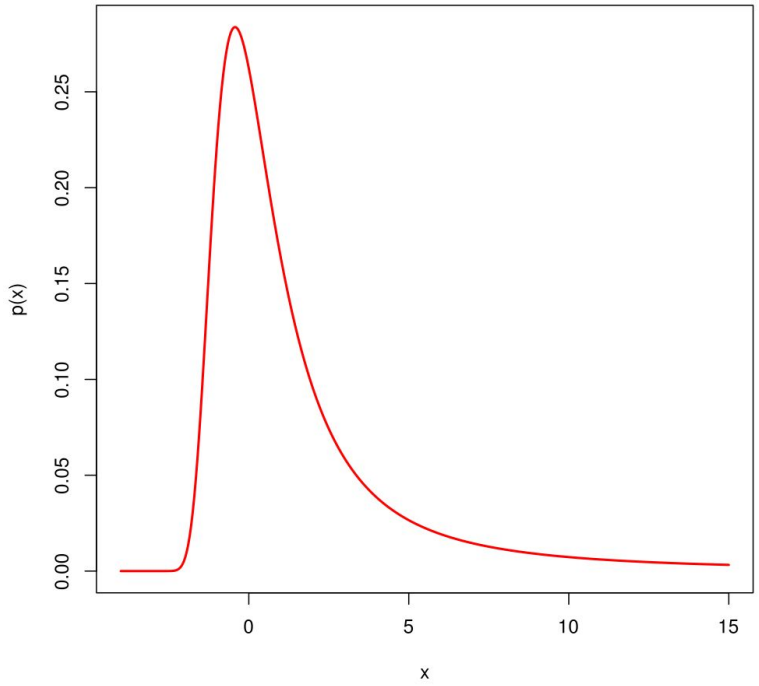


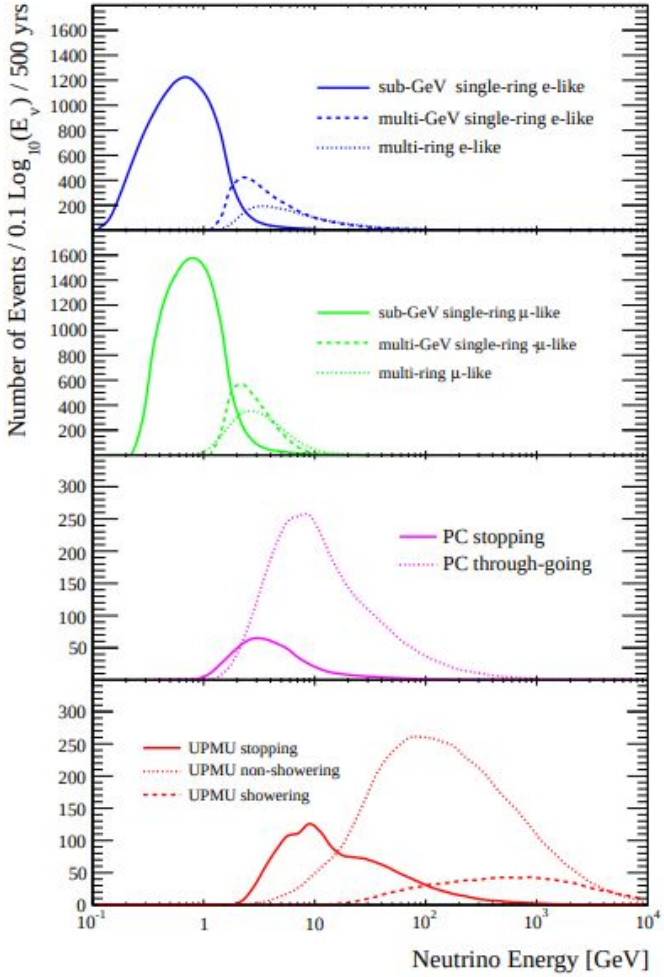
Probability from Data
Our Calculation

Probabilities calculated with uniform energies

...Agreement is not so great

- But... Should our simulated neutrinos be mono-energetic?
- **NO**
- Then let's spread them!
- **HOW?**
- With Landau functions, of course.





https://arxiv.org/pdf/1510.08127.pdf

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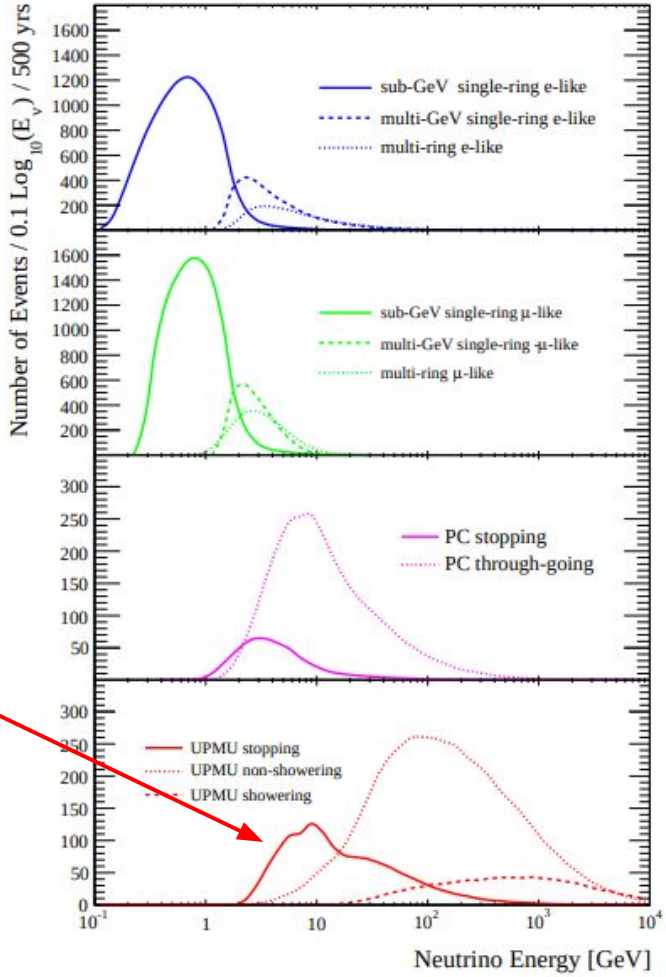
→ We took a neutrino energy from a Landau distribution with a sigma value equal to the square root of the mono-energetic values (0.6, 1 for sub and multi GeV resp.) to better match the real energy distributions.

→ Naturally, this didn't work for the UP stopping muon neutrinos as the distribution is not even close to a Landau function…



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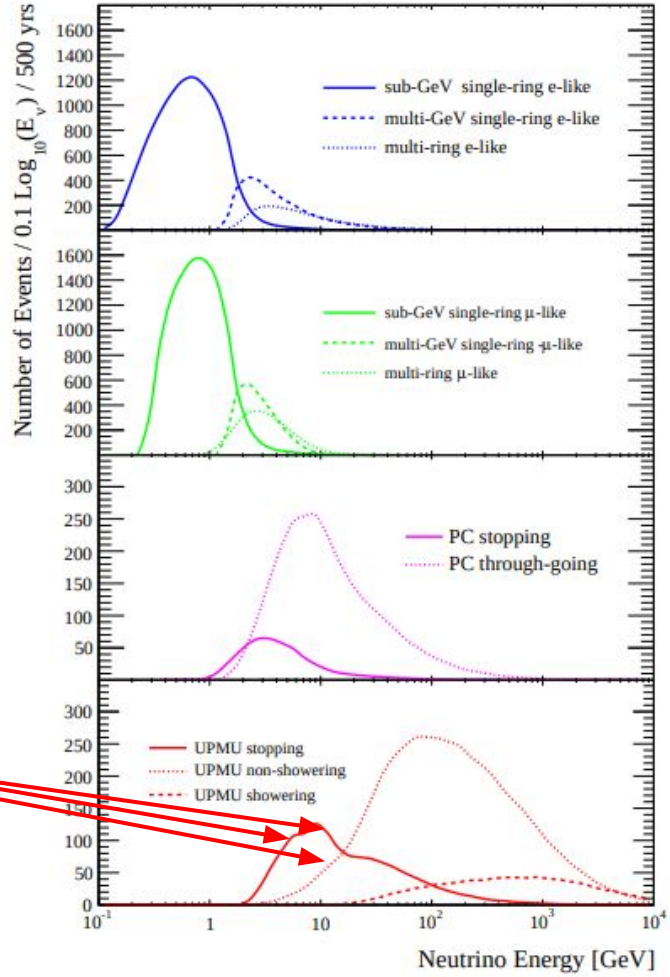
→ But if we take multiple Landaus...



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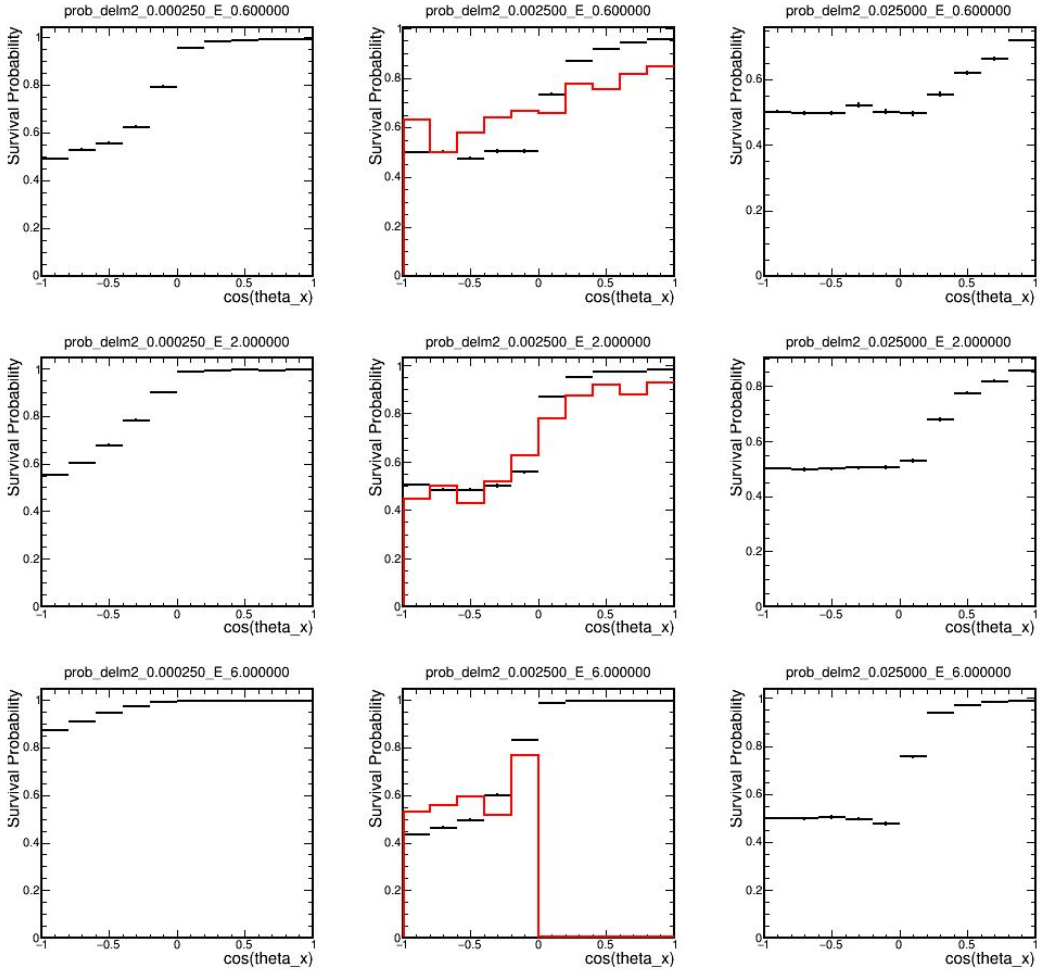
Δm^2

E_ν



Probability from Data

Our Calculation

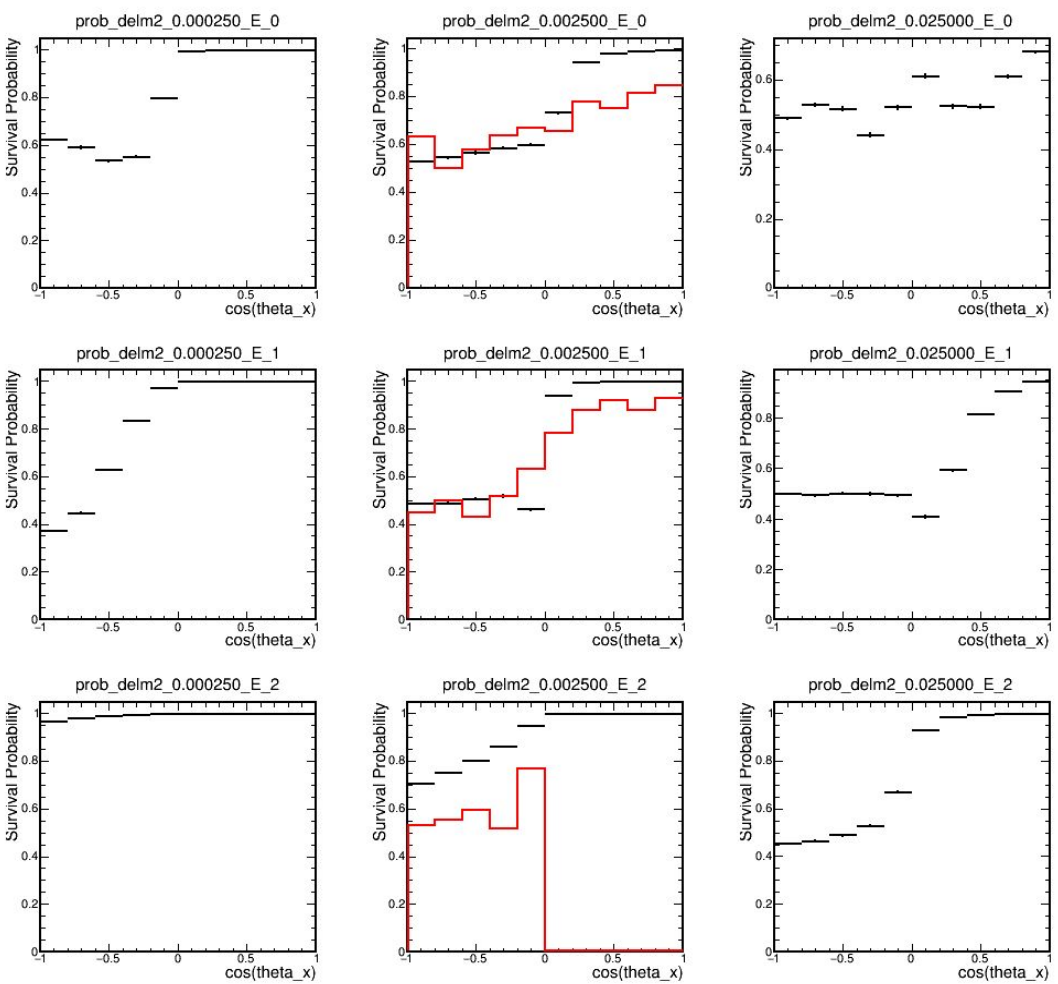
Much better agreement!

(at least by eye)

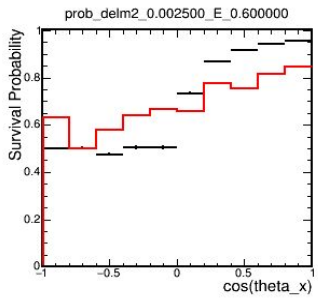
Δm^2

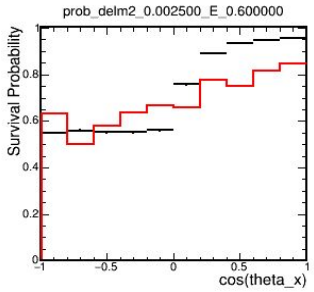
E_ν

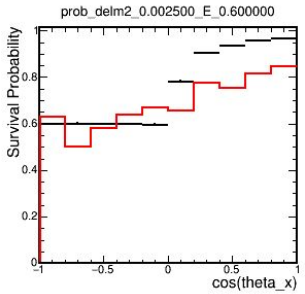
Or if we use the actual energy distributions, we get these results, which by eye actually look worse

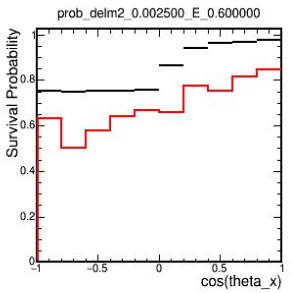


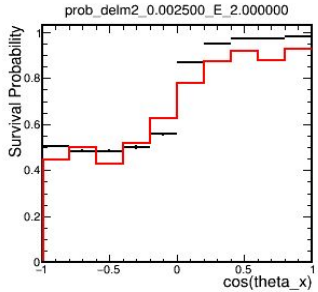
Probability from Data
Our Calculation

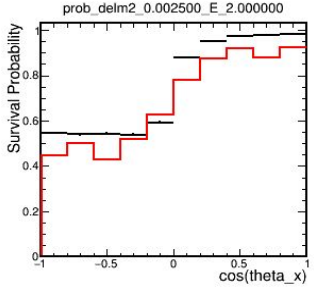


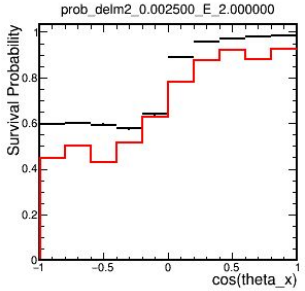


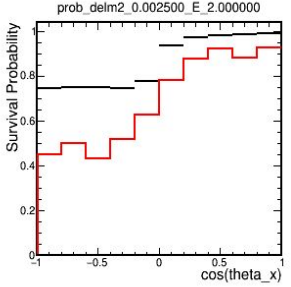


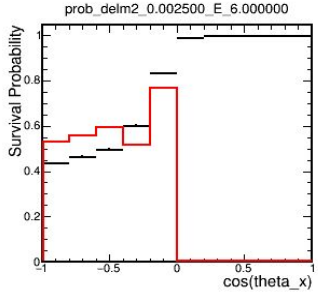


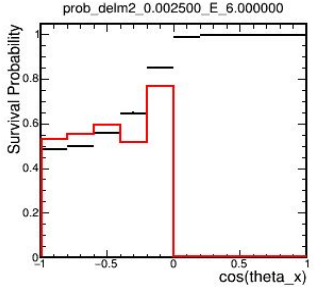


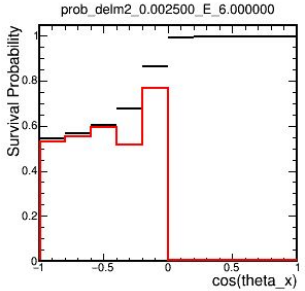


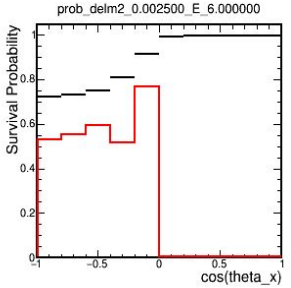












$\sin^2(2\theta) = 1$ $\sin^2(2\theta) = 0.9$ $\sin^2(2\theta) = 0.8$ $\sin^2(2\theta) = 0.5$

Calculation for approximate sub-GeV electron like events

$$N = \Phi \times N_{tgt} \times T \times \sigma$$

N = Number of events

ϕ = Flux of the neutrinos

N_{tgt}= Number of targets

T = Running time

σ = Cross-section for detecting neutrinos at this energy

Number of events:

N = 2864 (From the paper hep-ex/0105023)

Running time:

T = 1289 days (From the paper hep-ex/0105023)
= (1289 x 86400) seconds

1 day has 86400 seconds

Cross section:

σ = 5fb (Given)
= (5 x 10^{-39}) cm^{-2}

Fiducial Mass of SK is 22.5 kt

8 neutrons per water molecule

Number of targets:

$$N_{tgt} = \frac{6.023 \times 10^{23} \times 22.5 \times 10^{9} \times 8}{18}$$

18 grams of water per mole

Putting it all together to get the flux.....

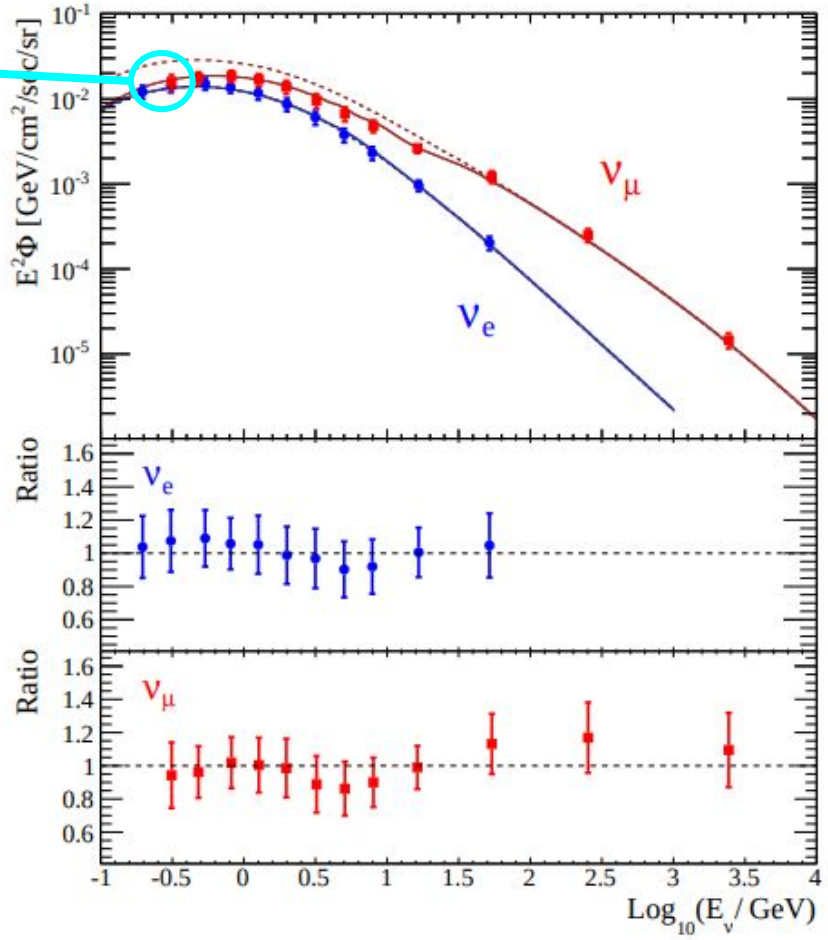
$$\phi = 0.683\ cm^{-2}s^{-1}$$

~ 0.25 cm^{-2} s^{-1}

vs

~ 0.68 cm^{-2} s^{1}

Order of magnitude agreement!



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THANK YOU
TAKK
감사합니다
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TEŞEKKÜR EDERIM
DZIĘKUJĘ
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