Understanding the Atmospheric Neutrino Data

INSS 2019: Group 11
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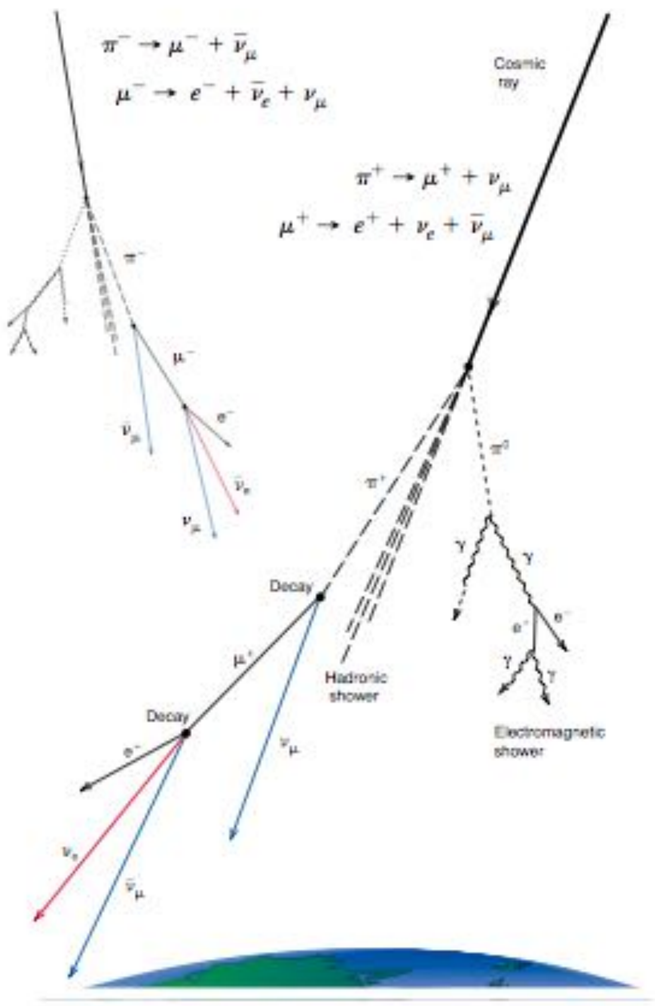
Atmospheric neutrinos



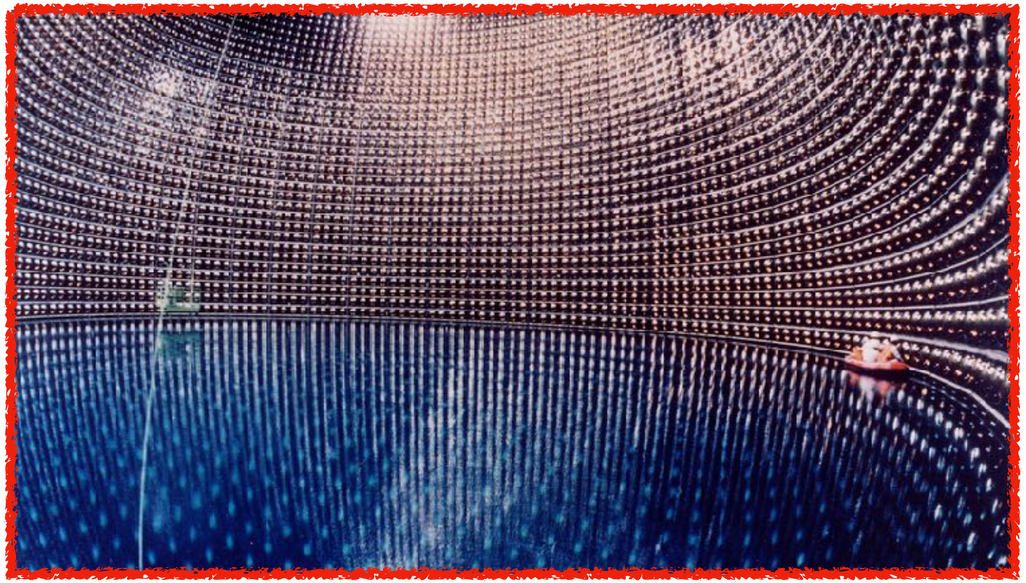
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

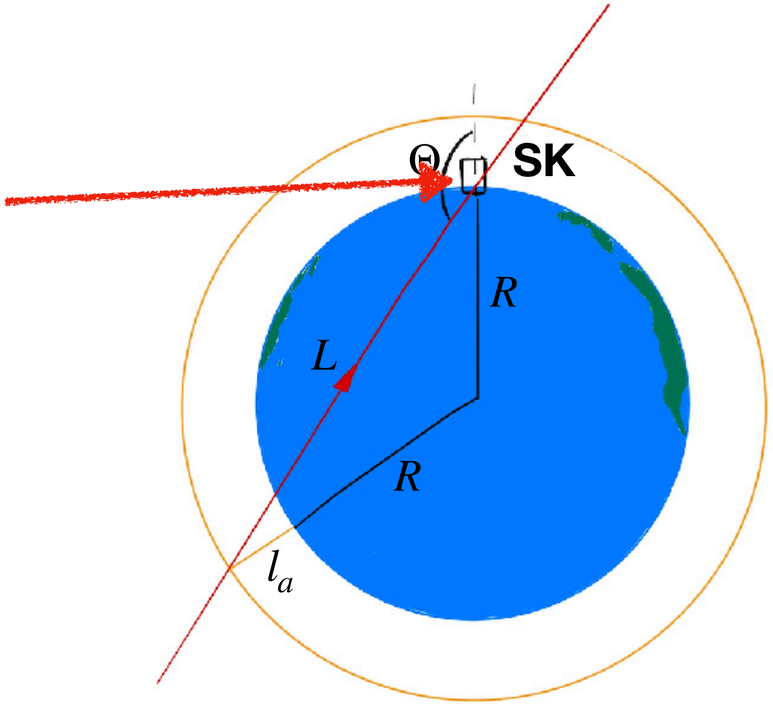
$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

Expect twice more flux for muon neutrinos than electron neutrinos

Image from https://icecube.wisc.edu/~jkelley/atm/proposal.html

Super-Kamiokande





50 kT of pure water / 22.5 kT FV

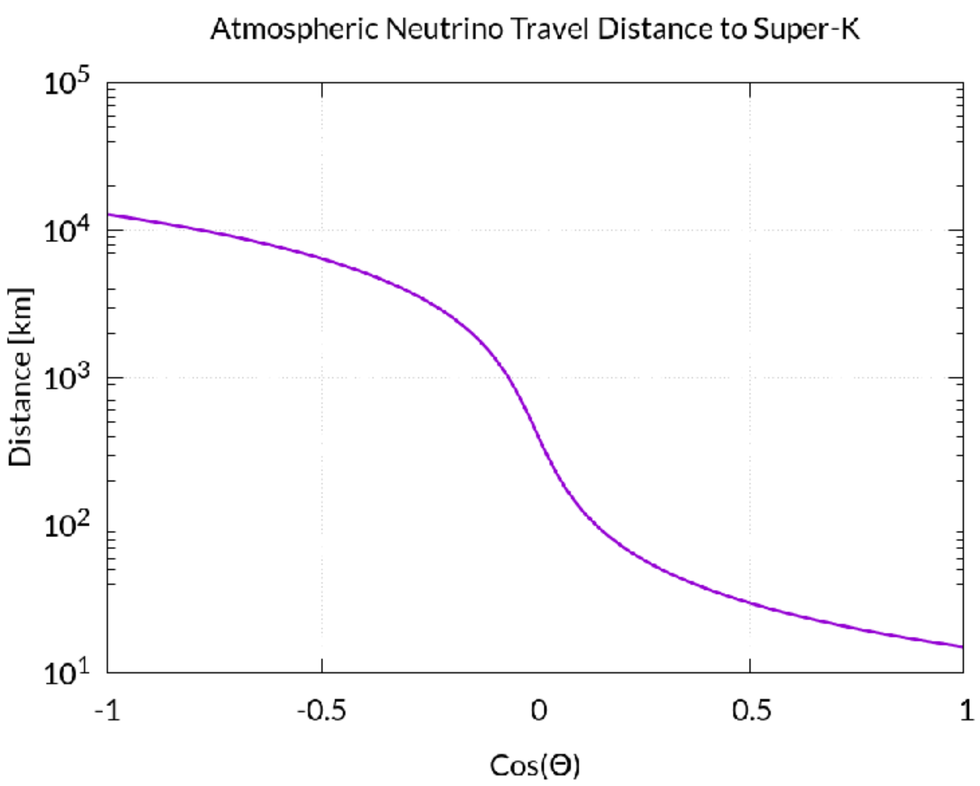
Cherenkov light collected by PMTs

From the law of cosines

$$(R + l_a)^2 = L^2 + R^2 - 2LR\cos(\pi - \Theta)$$

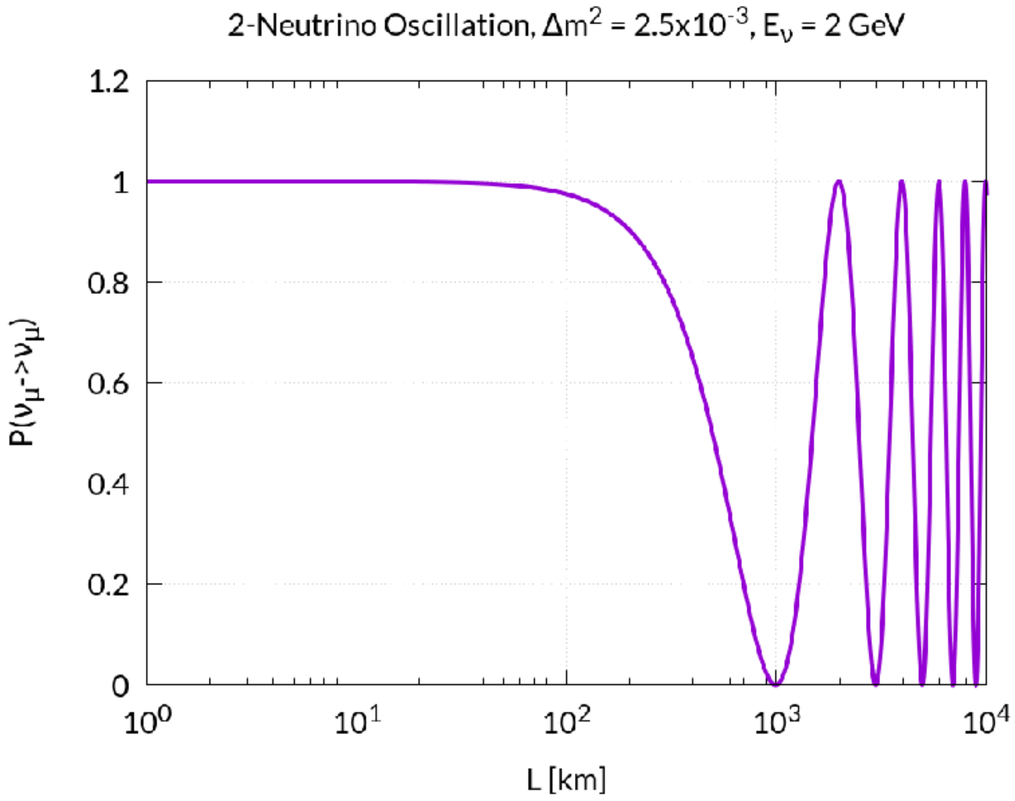
Oscillation probability

$$L^2 + 2RL\cos\Theta - l_a(l_a + 2R) = 0$$



Considering only two flavour transitions

$$P(\nu_\mu \to \nu_\mu) = 1 - \sin^2 2\theta \sin^2 1.27\frac{\Delta m^2 L}{E}$$



Oscillation probability

$$L^2 + 2RL\cos\Theta - l_a(l_a + 2R) = 0$$

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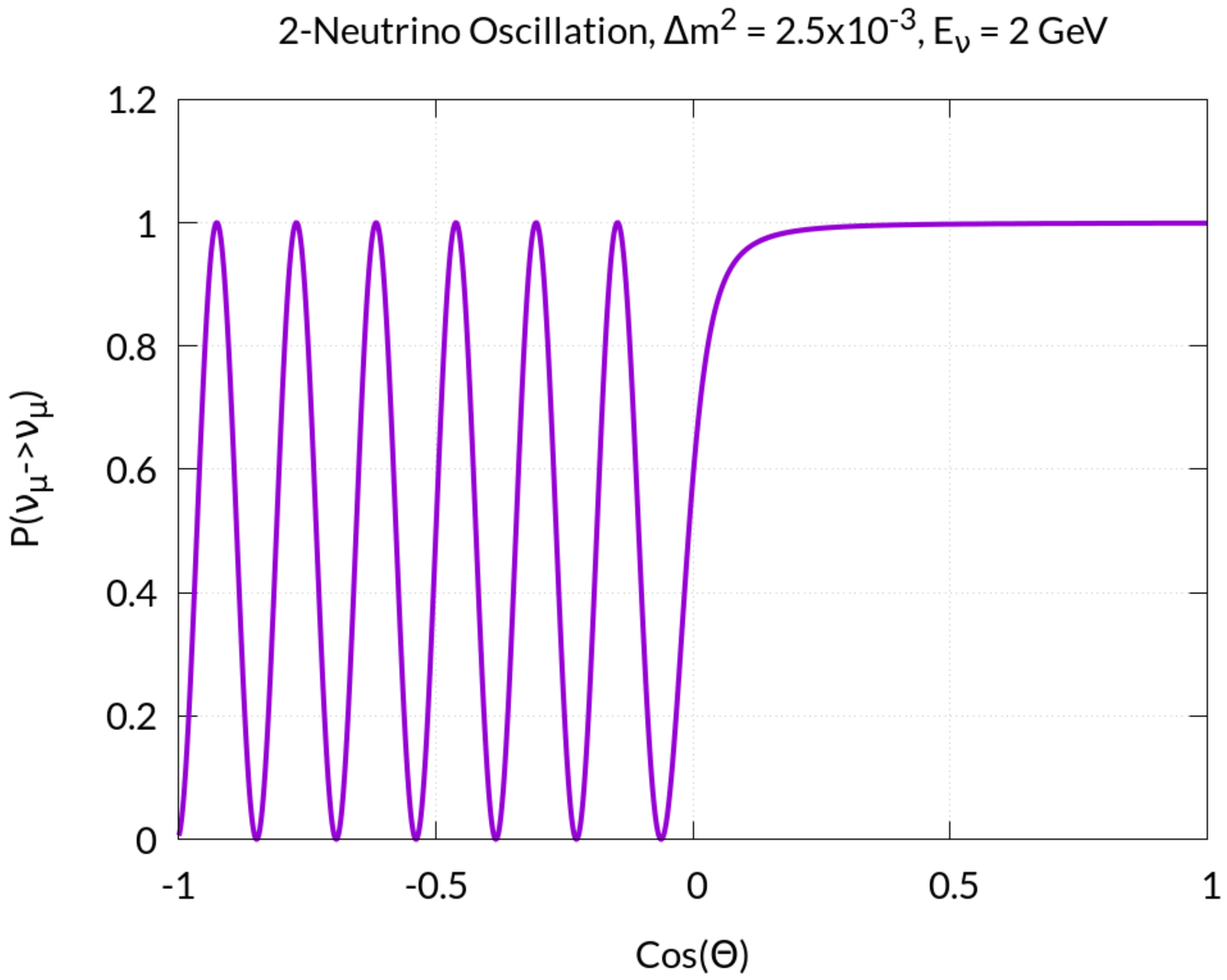
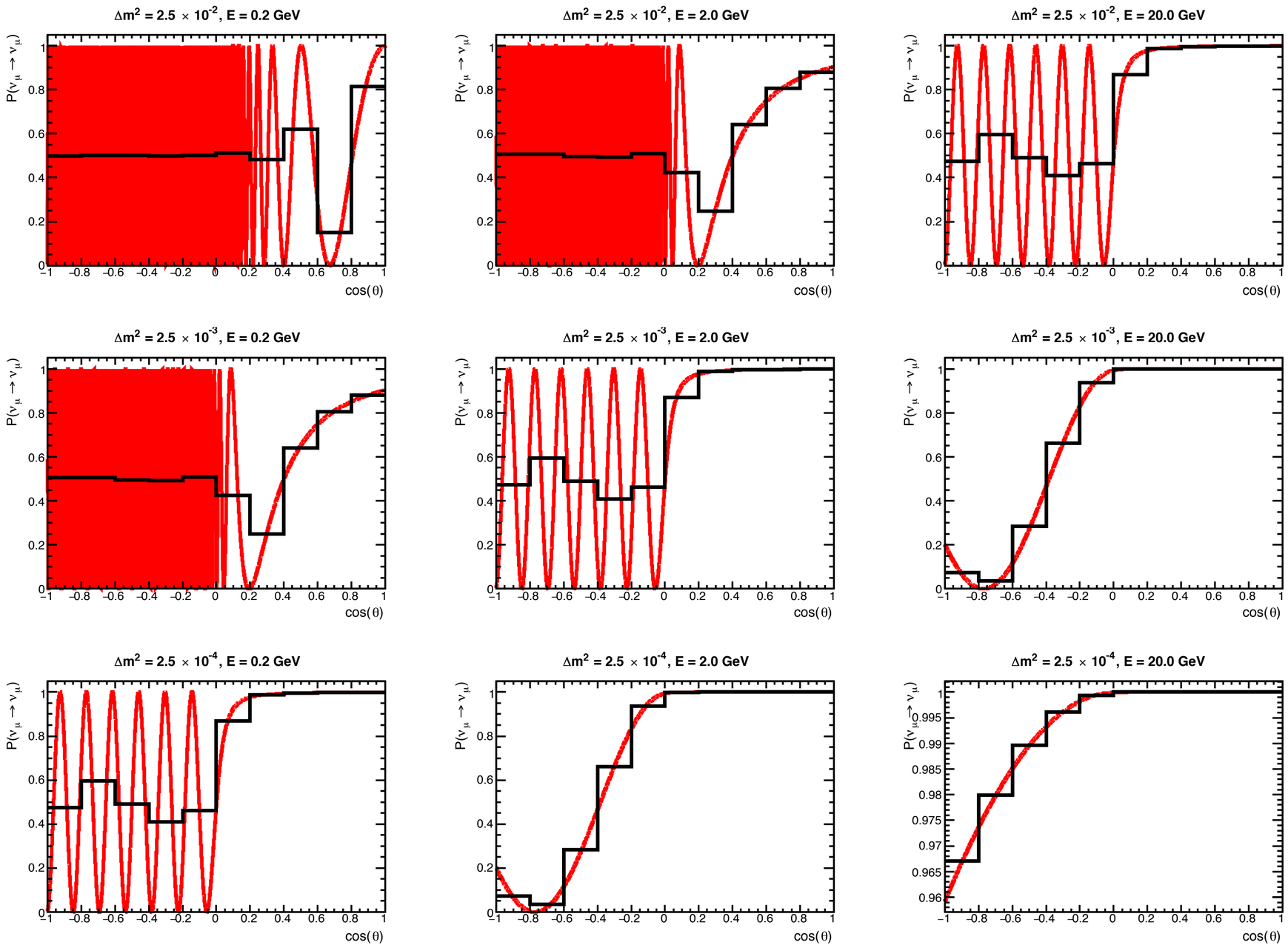


Average probability

Assumptions

$$l_a = 20\ km$$

$$\sin^2(2\theta) = 1$$



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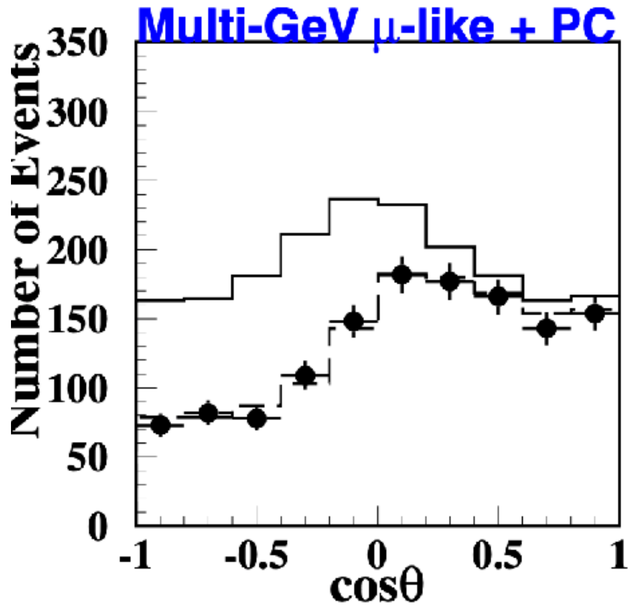
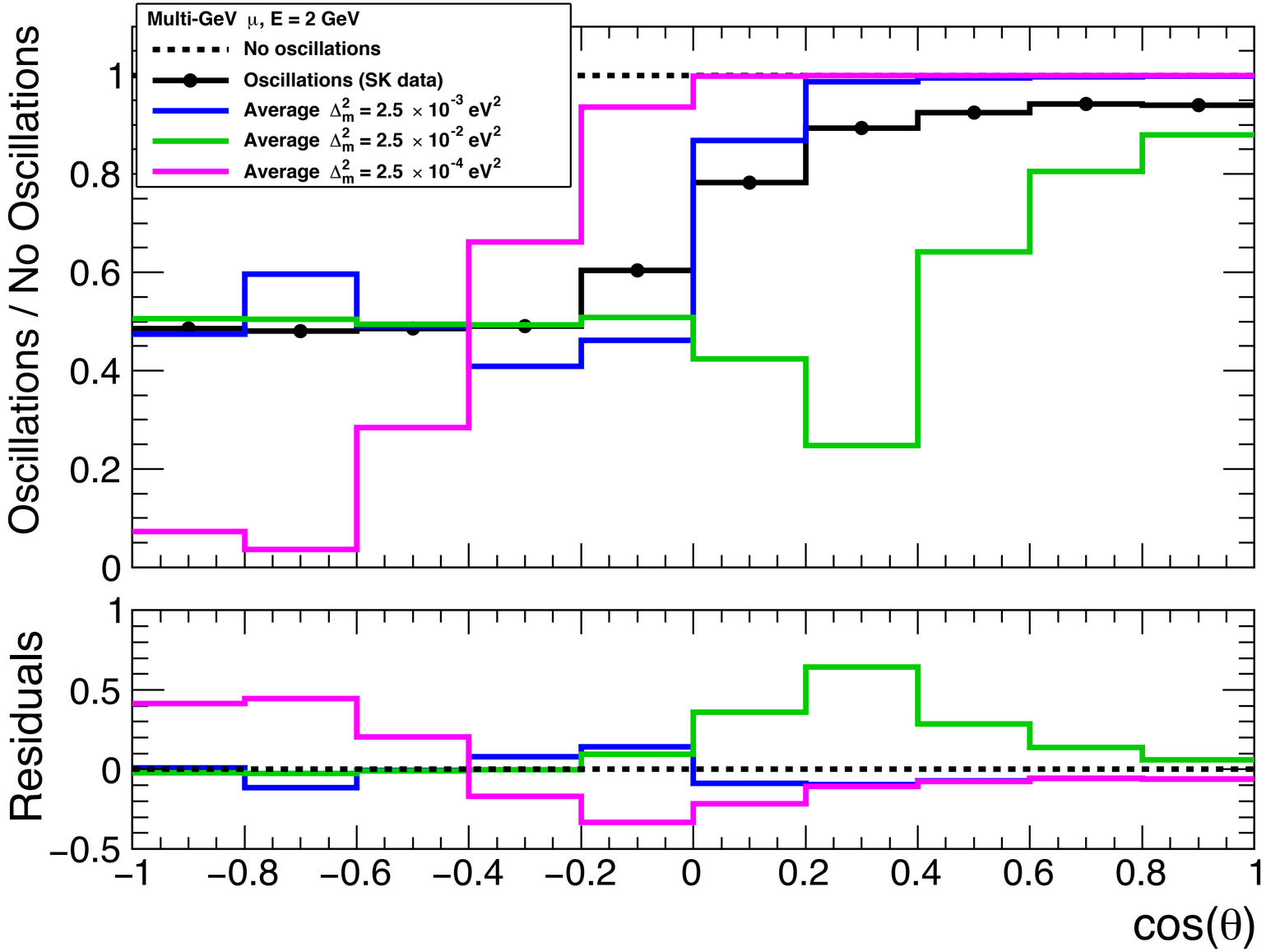
Comparison with SK data

Multi-GeV case:
~ 2 GeV events
(SK > 1.3 GeV)





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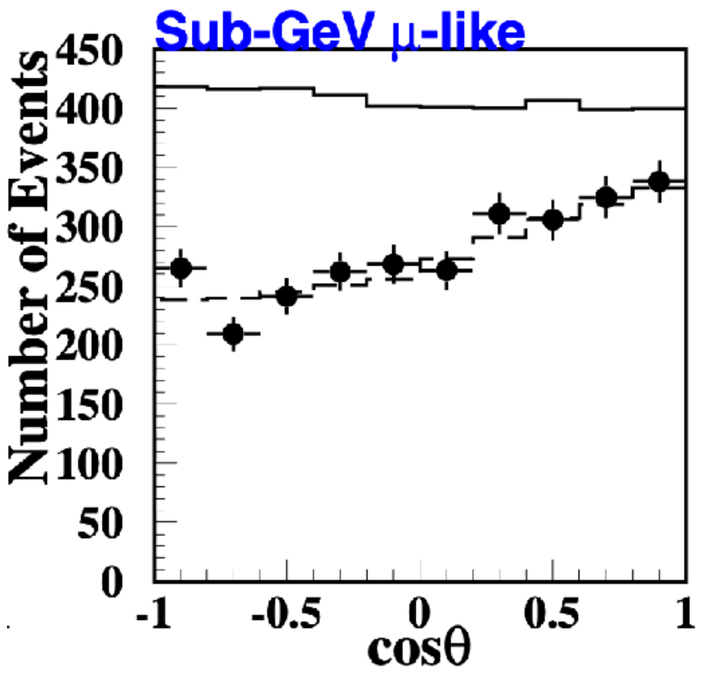
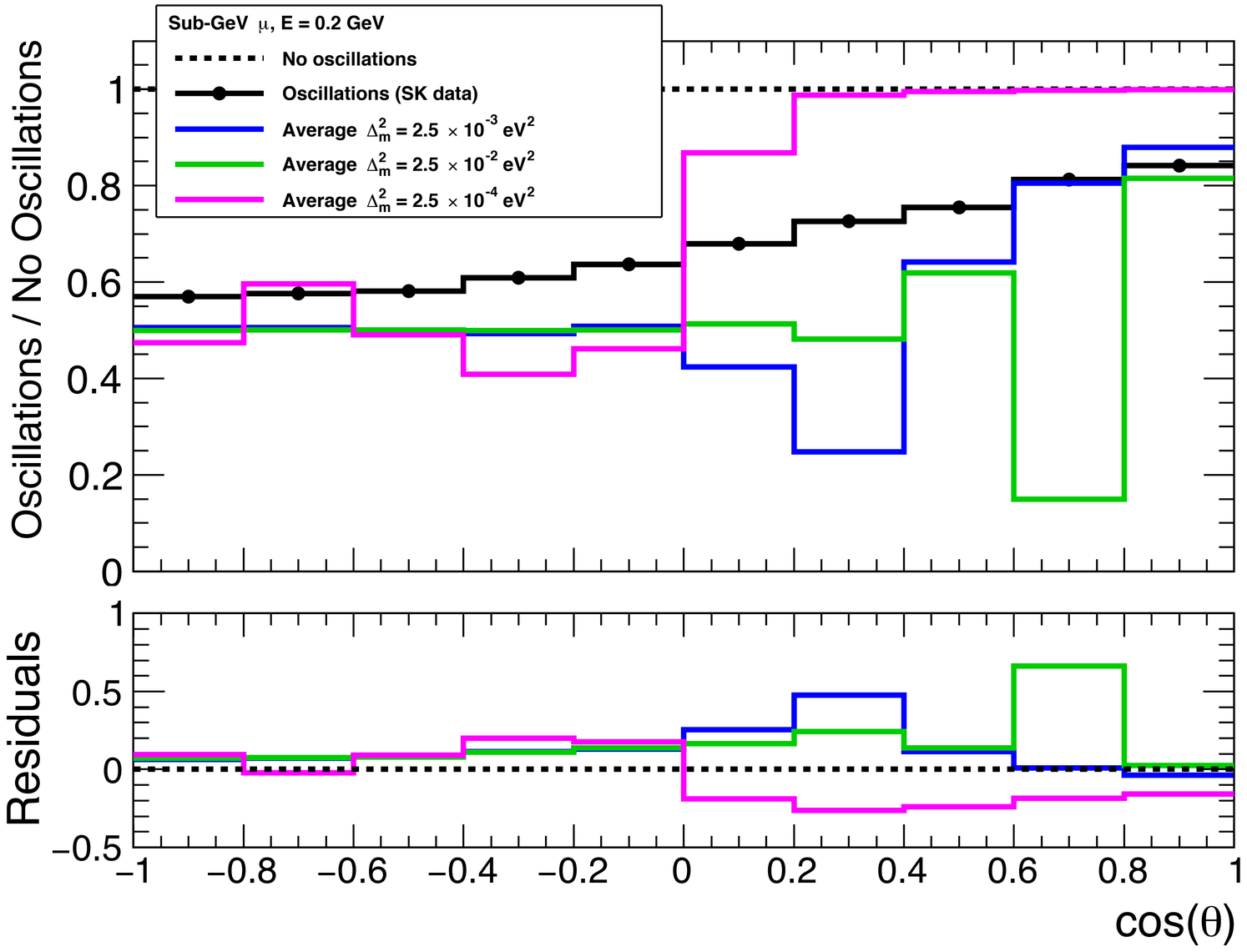
Comparison with SK data

Sub-GeV case:
~ 0.2 GeV events
(SK < 1.33 GeV)





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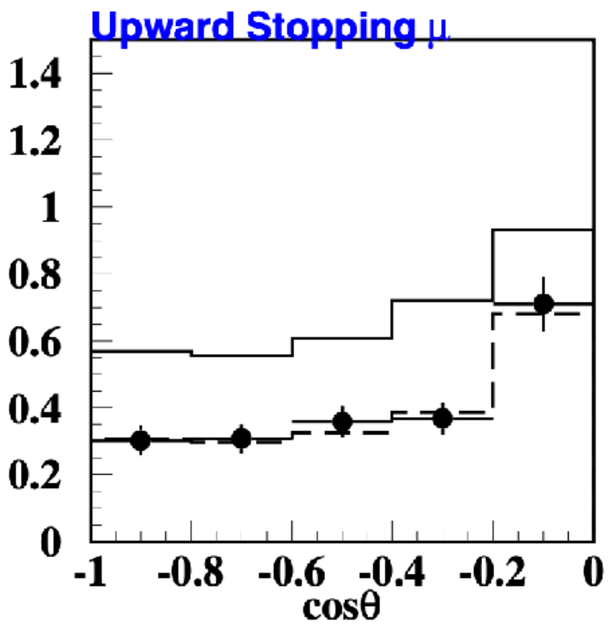
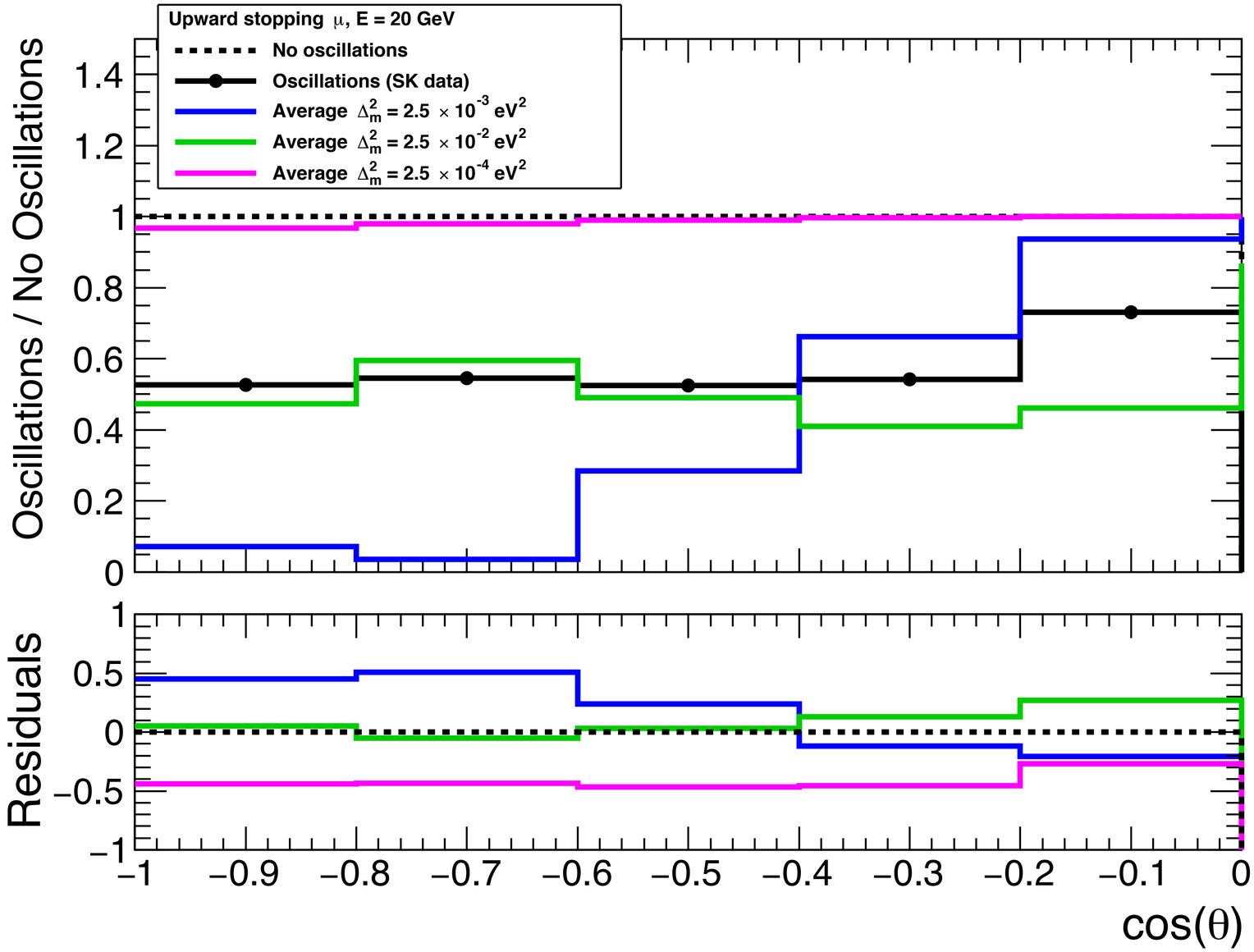
Comparison with SK data

Upward stopping case:
~ 20 GeV events
(SK > 10 GeV)





Flux estimate

$$N_{events} \sim \phi P_{\alpha\to\beta} S_{eff} \Omega T \to \phi \sim \frac{N_{events}}{S_{eff}\Omega T}$$

$$P(\nu_e \to \nu_e) \simeq 1$$

$$S_{eff}\Omega = \epsilon \times \pi r^2 \times 4\pi \to = \sigma \times \rho_{proton} \times \lambda_{eff} \times \pi r^2 \times 4\pi$$

Putting in the numbers

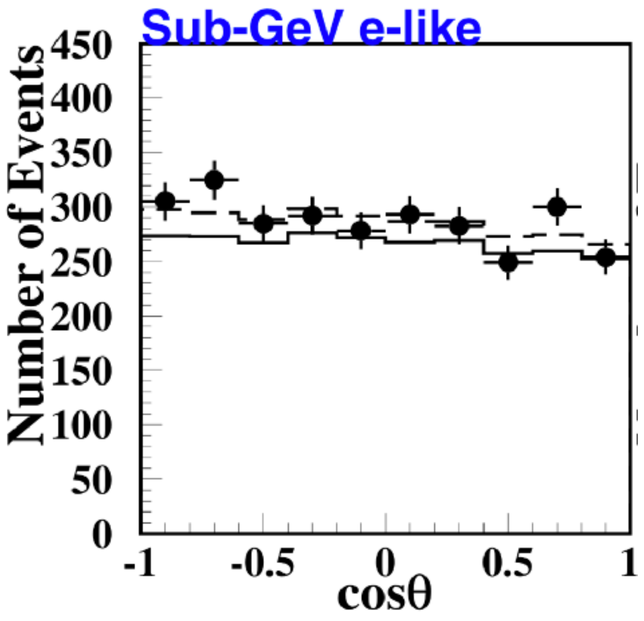
$N_{events} \sim 3000 \qquad T = 111369600\ s$

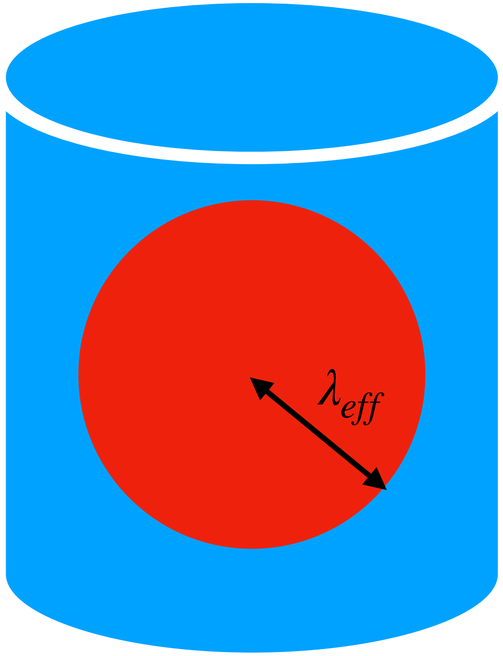
$\sigma = 5 \times 10^{-39} cm^2 \qquad \rho_{proton} = \rho_{H_2O} \times N_A/A\ cm^{-3}$

Assuming a spherical FV

$\lambda_{eff} = r = 1750\ cm$

$\phi_{av} = 0.76\ cm^{-2} s^{-1} sr^{-1}$





Thank you!