Non-Standard Neutrino Interactions in the mu tau sector

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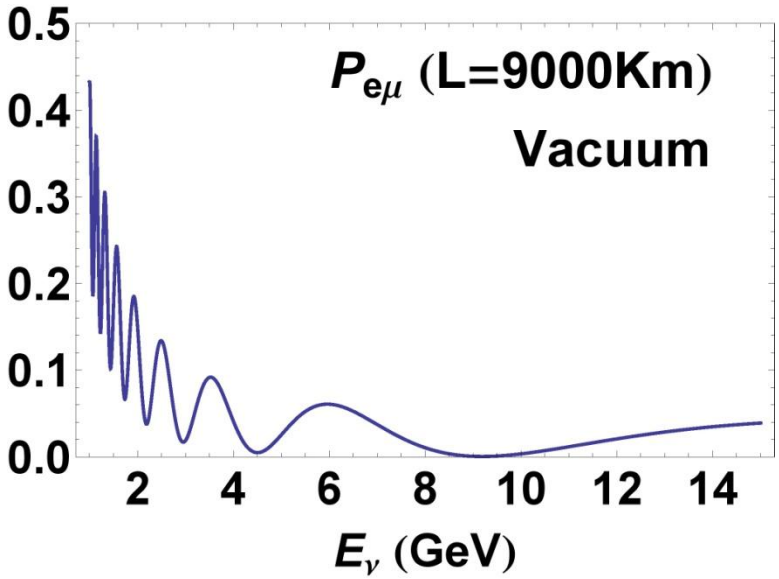
Standard Interactions



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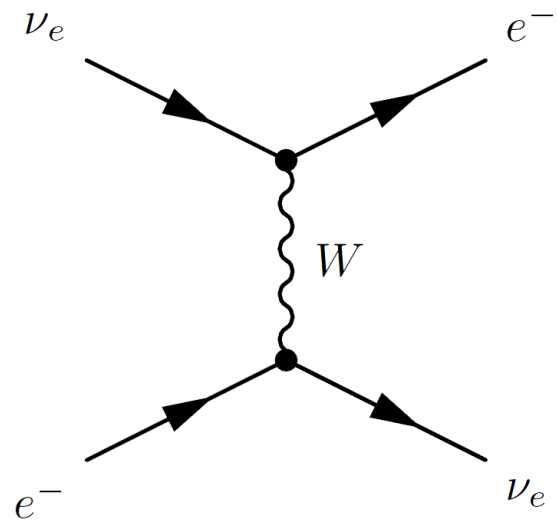

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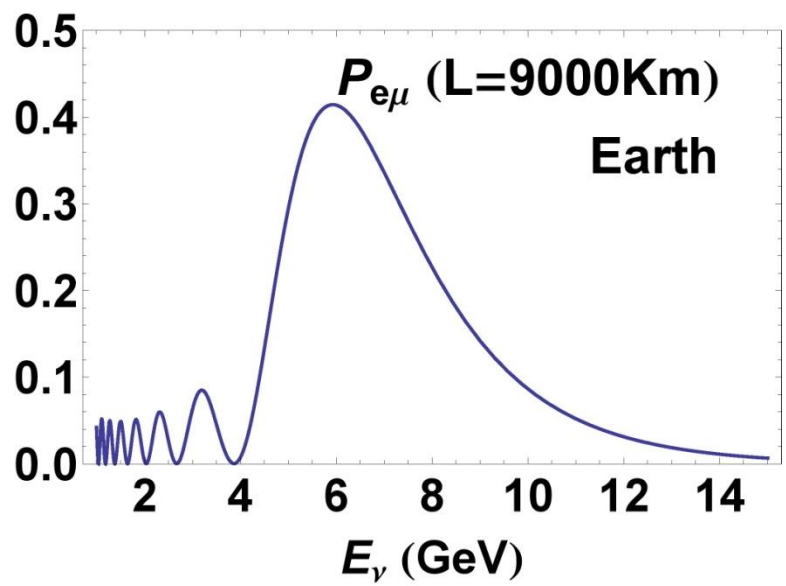

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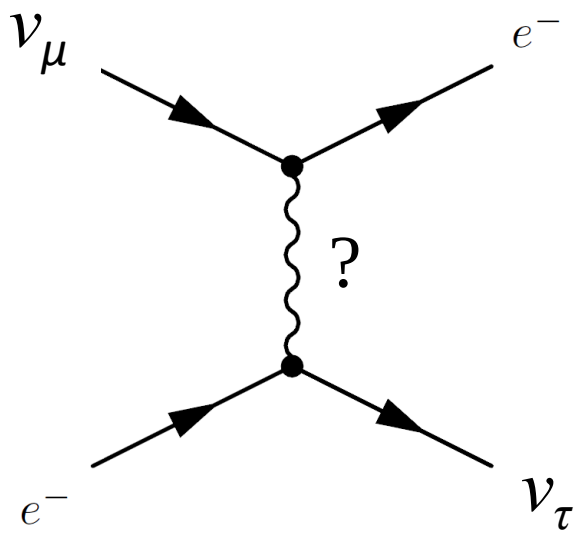
More Interactions?

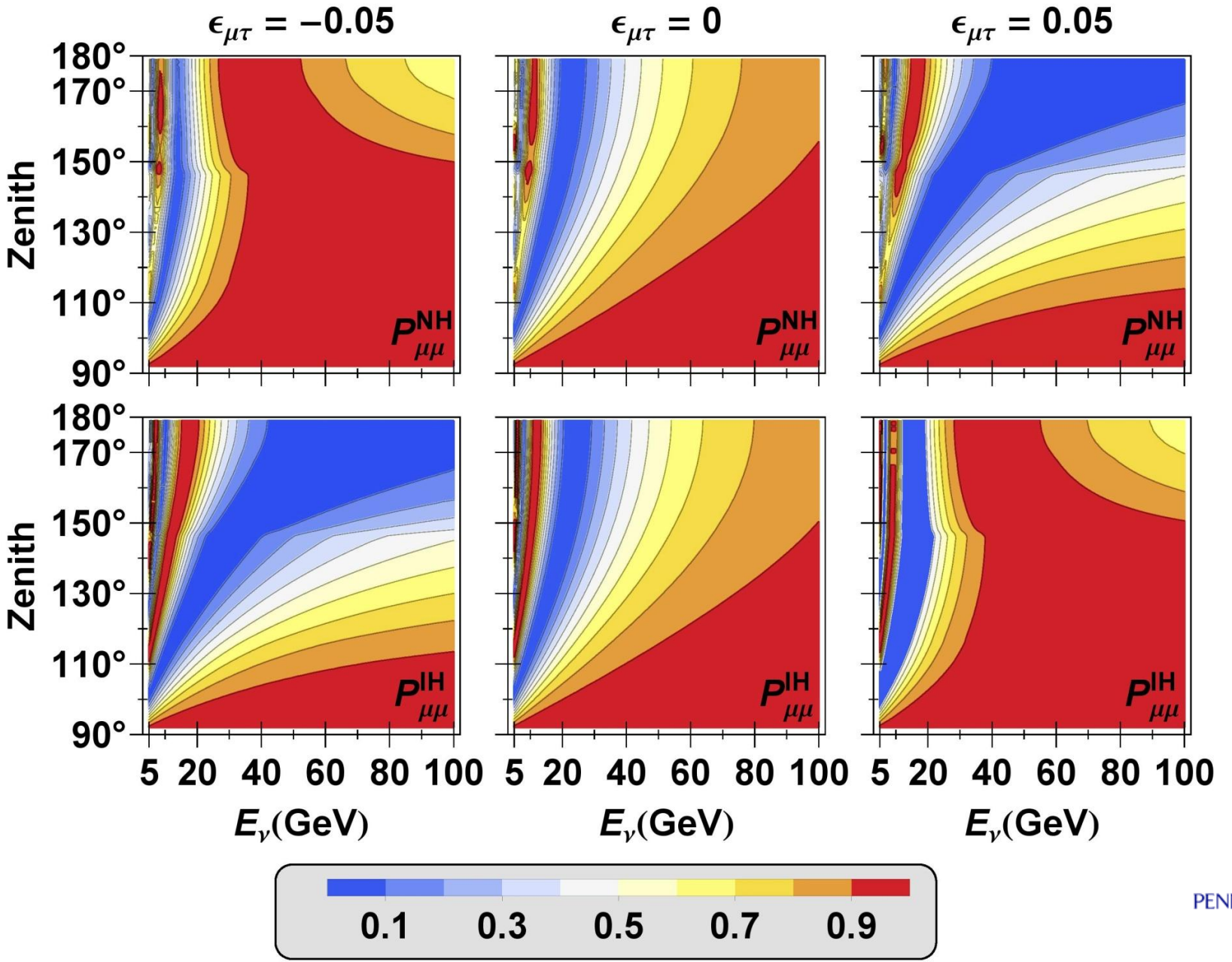
What about:



Non Standard Interactions

- Beyond SM physics is expected
  - Effective theory
  - Many BSM models give NSI
- Neutrino Sector is least constrained
  - New Interactions = New phenomena?
  - Describe current sub-leading phenomena

NSI Effects on Oscillation Probability



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Muon Count in DeepCore

- PREM model
- Atmospheric Fluxes (Agraval, Gaisser, Lipari and Stanev)
- Cross Sections (Gandhi, Quigg, Reno and Sarcevic)
- Sum over contributions from:

$$P_{e\mu}\ ,\ P_{\mu\mu}\ ,\ P_{\overline{e\mu}}\ ,\ P_{\overline{\mu\mu}}$$

- 1yr of IceCube DeepCore Simulated Data
  - Using V_{eff} from ICDC Design Document
- Energy Bin Width = 5GeV
- 3 Zenith Bins: Core, Mantle and Crust

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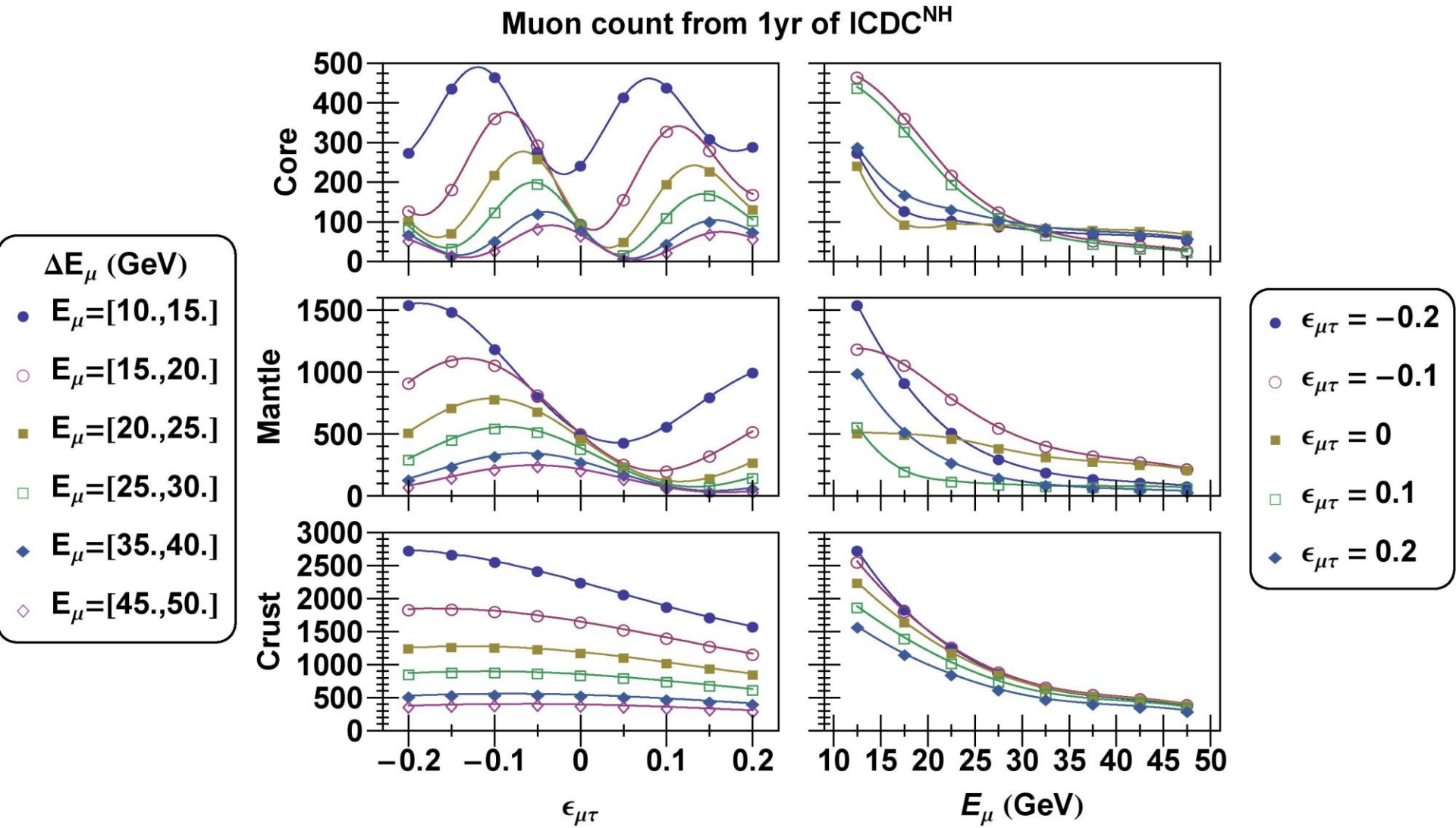
NSI Effects on Muon Count



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Analytical Model

$$
\begin{aligned}
\Delta m^2_{21} &= \theta_{12} = \theta_{13} = \delta_{cp} = \epsilon_{\alpha\beta\neq\mu\tau} = \delta_{\mu\tau} = 0 \\
\theta_{23} &= \frac{\pi}{4} \\
P_{\mu\mu} &= Cos^2\left(L\left(\frac{\Delta m^2_{31}}{4E_\nu} + V_{cc}\epsilon_{\mu\tau}\right)\right) \\
\Delta_\epsilon P_{\mu\mu} &= P_{\mu\mu}\left(\epsilon_{\mu\tau}\right) - P_{\mu\mu}\left(-\epsilon_{\mu\tau}\right) \\
L &= \frac{(2n+1)\,\pi}{\Delta m^2_{31}} E_\nu, \text{ Where } n \in \mathbb{Z} \text{ and } n \geq 0
\end{aligned}
$$

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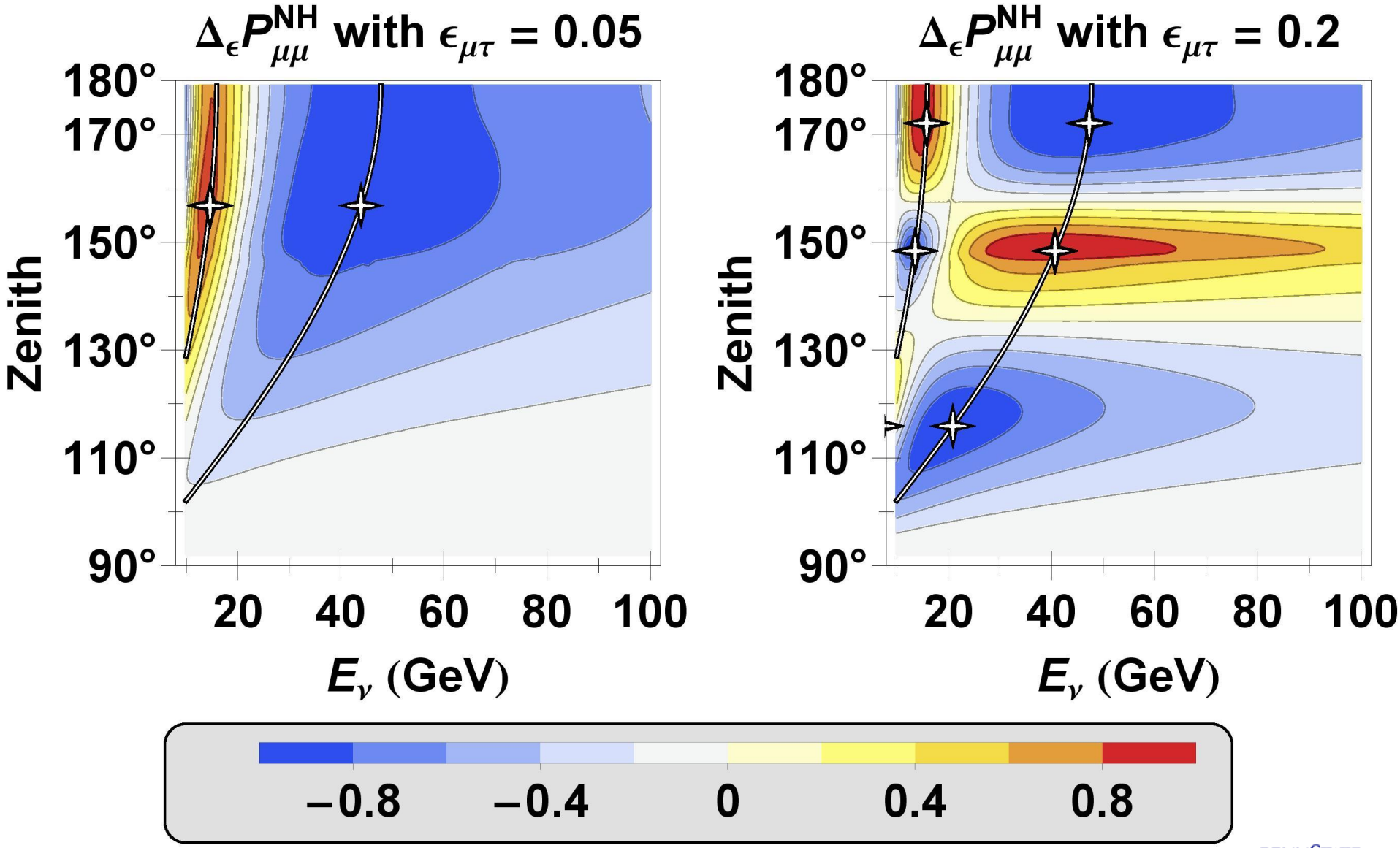
Analytical vs. Numerical



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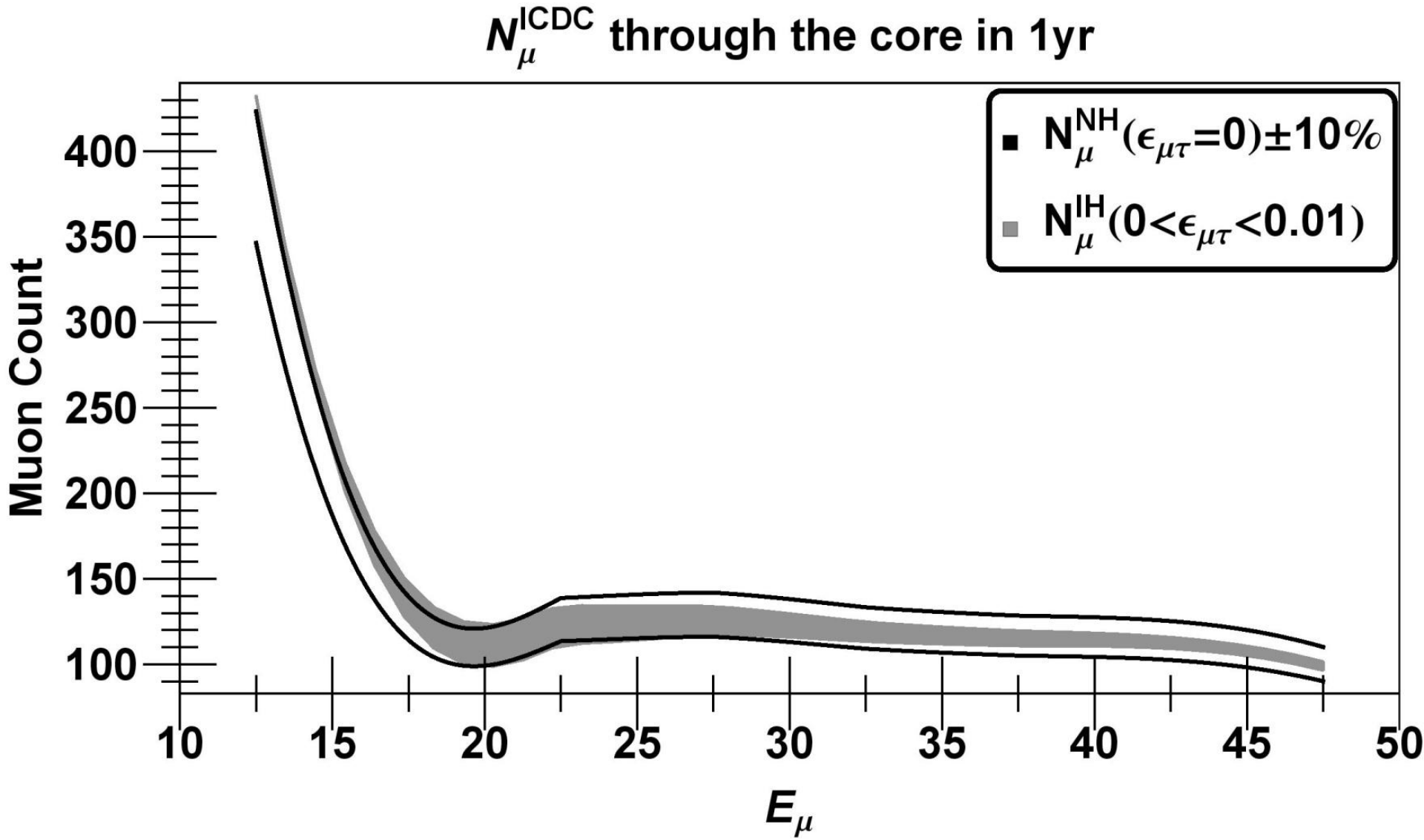
Mass Hierarchy Implications



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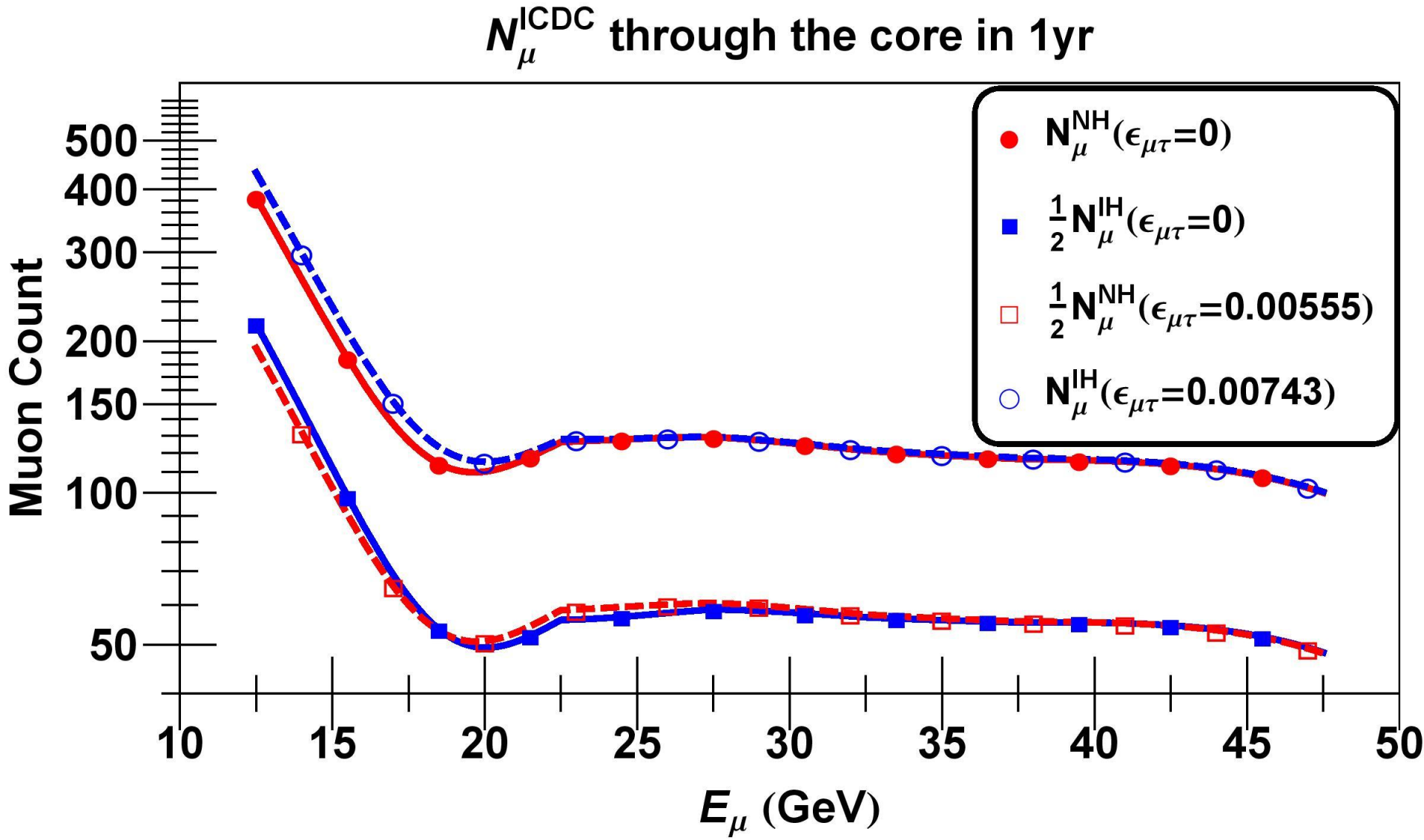
Mass Hierarchy Implications



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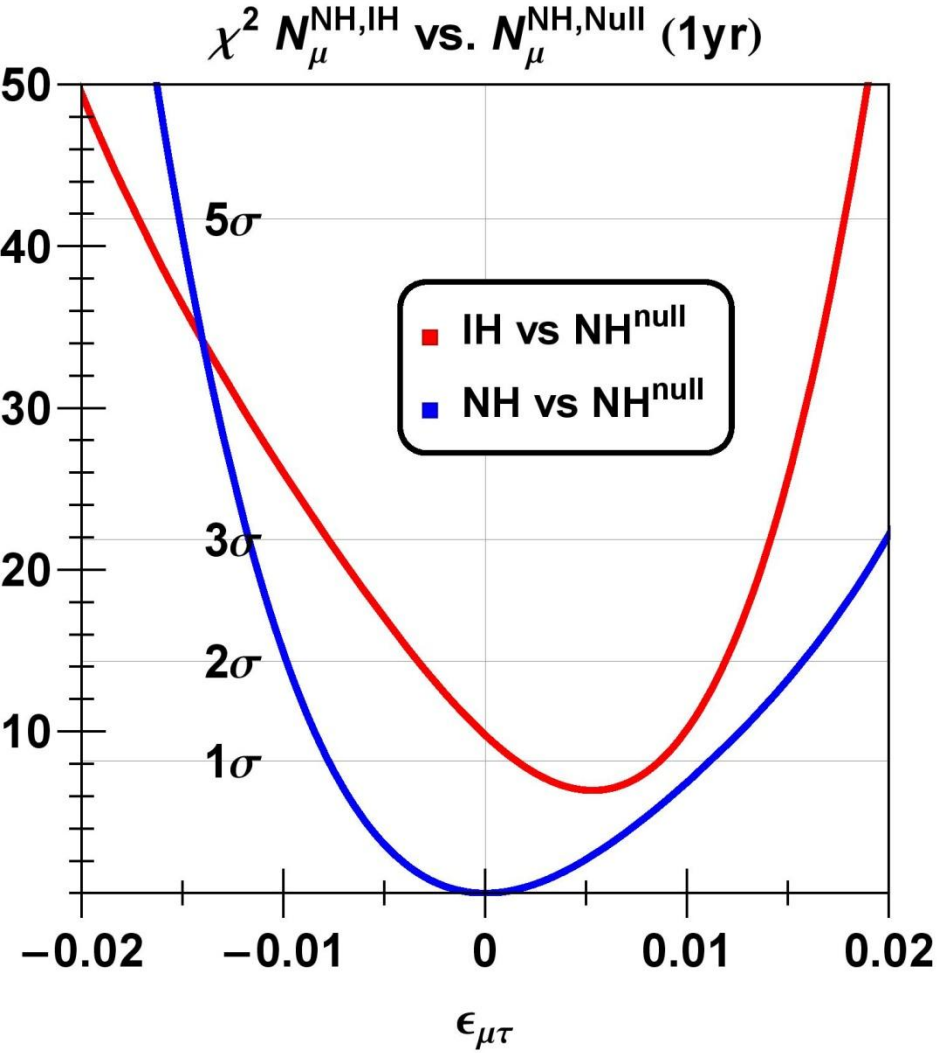
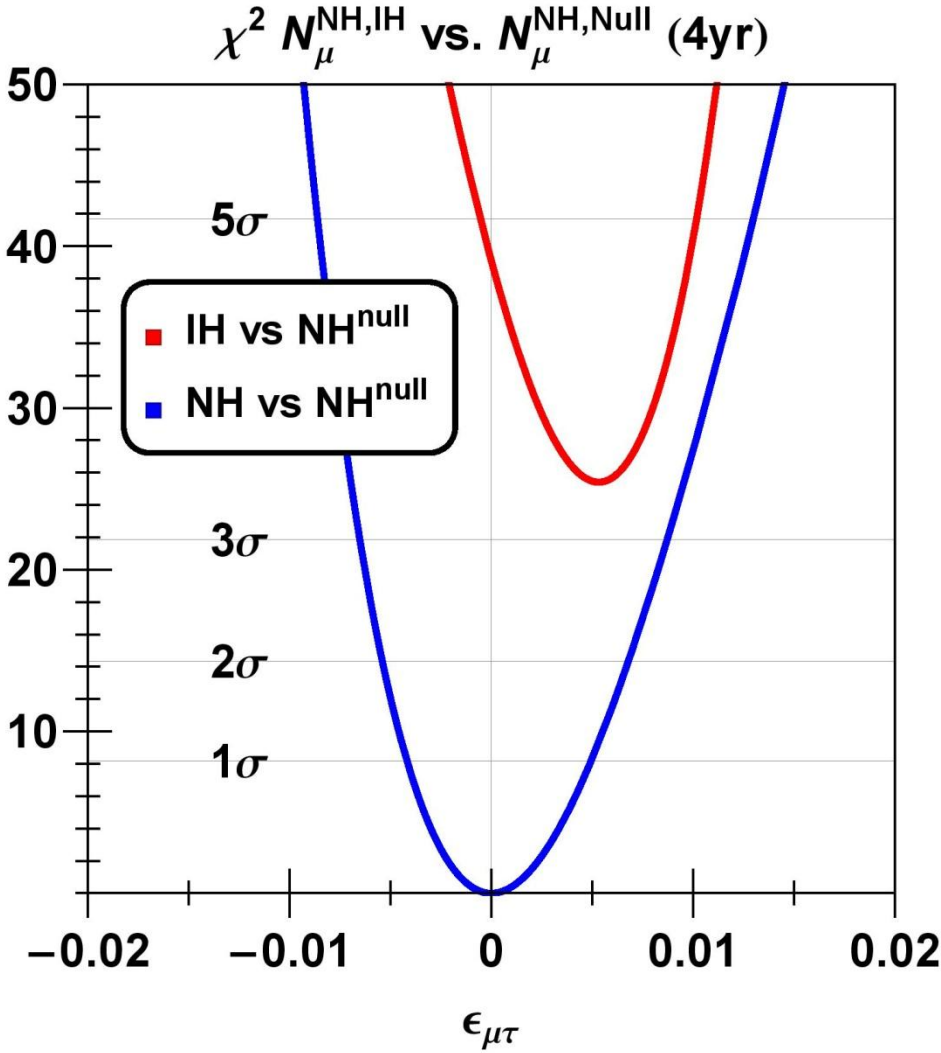
Sensitivity (NH True)





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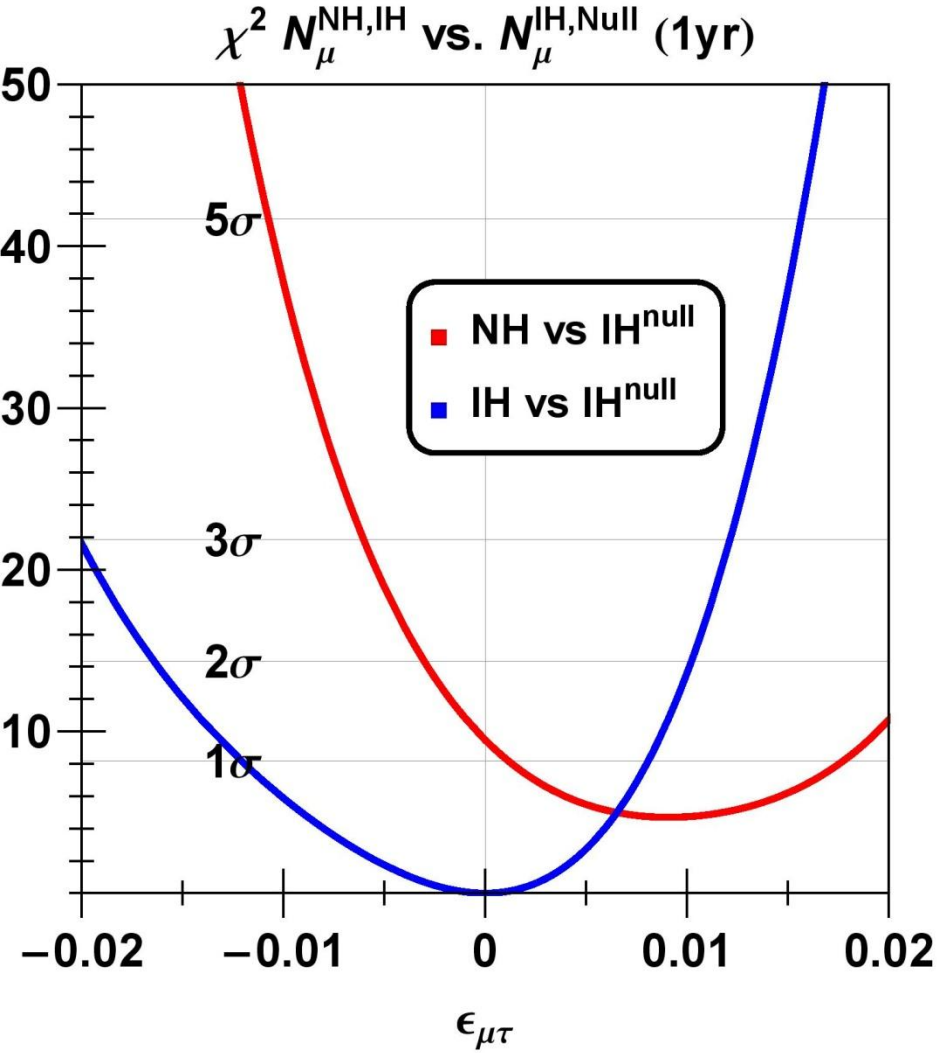
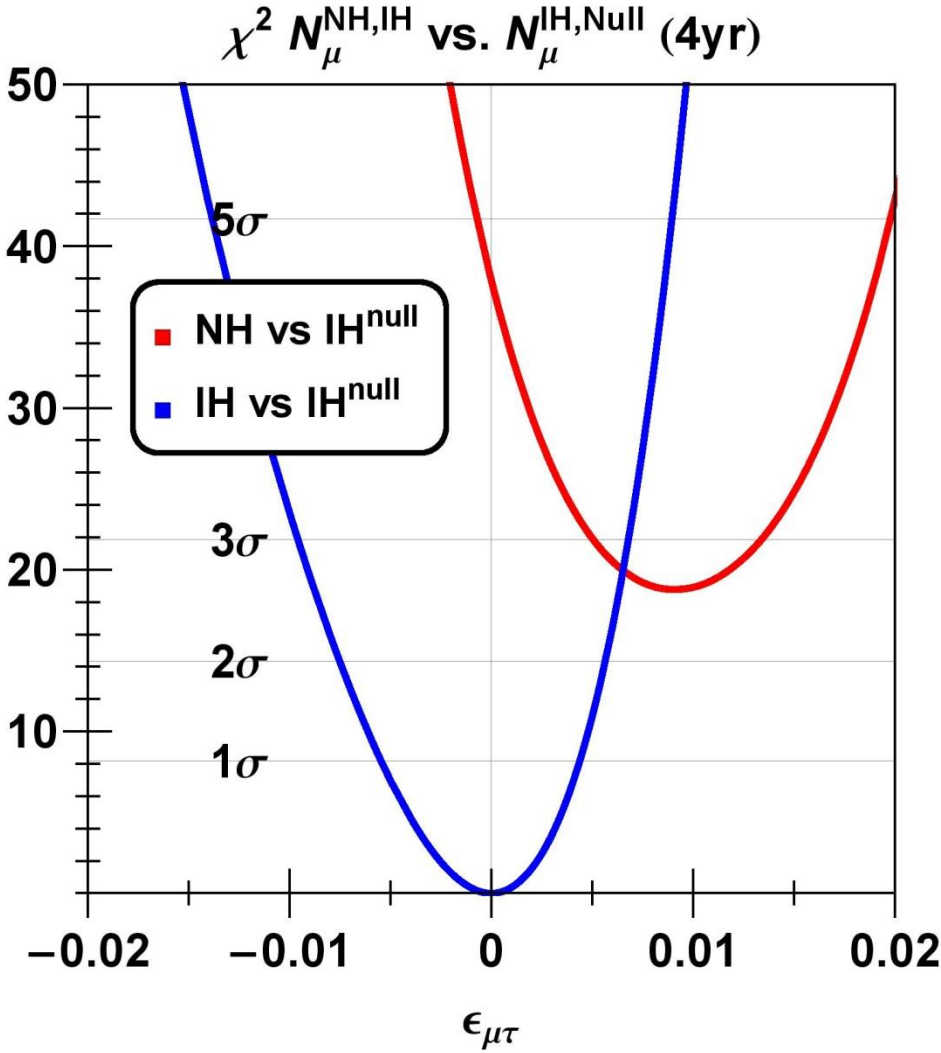
Sensitivity (IH True)





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Summary

- NSIs have significant effects on:
  - Oscillation probability
  - Muon count
- EpsilonMuTau is sign asymmetric (unlike other NSI)
  - From numerical simulations
  - From a reduced analytic model
- This asymmetry has mass hierarchy implications
  - Hierarchy imitation
  - Hierarchy misidentification
  - Can separate effects with different experiments

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