Probing the LSND mass scale and four neutrino mass models with a neutrino telescope

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Work in collaboration with R. Zukanovich-Funchal and H. Nunokawa, hep-ph/0302039.

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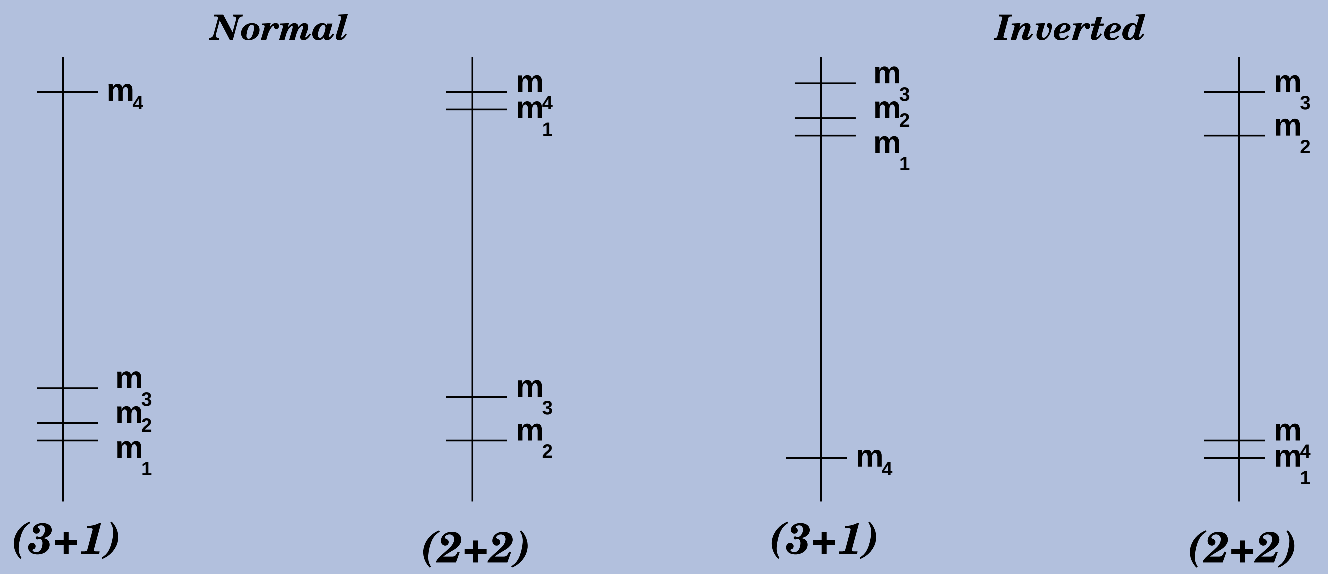
- Until now, no experiment ruled out or con£rm the LSND experiment; Wait for Mini-BooNE

4 neutrino mass schemes



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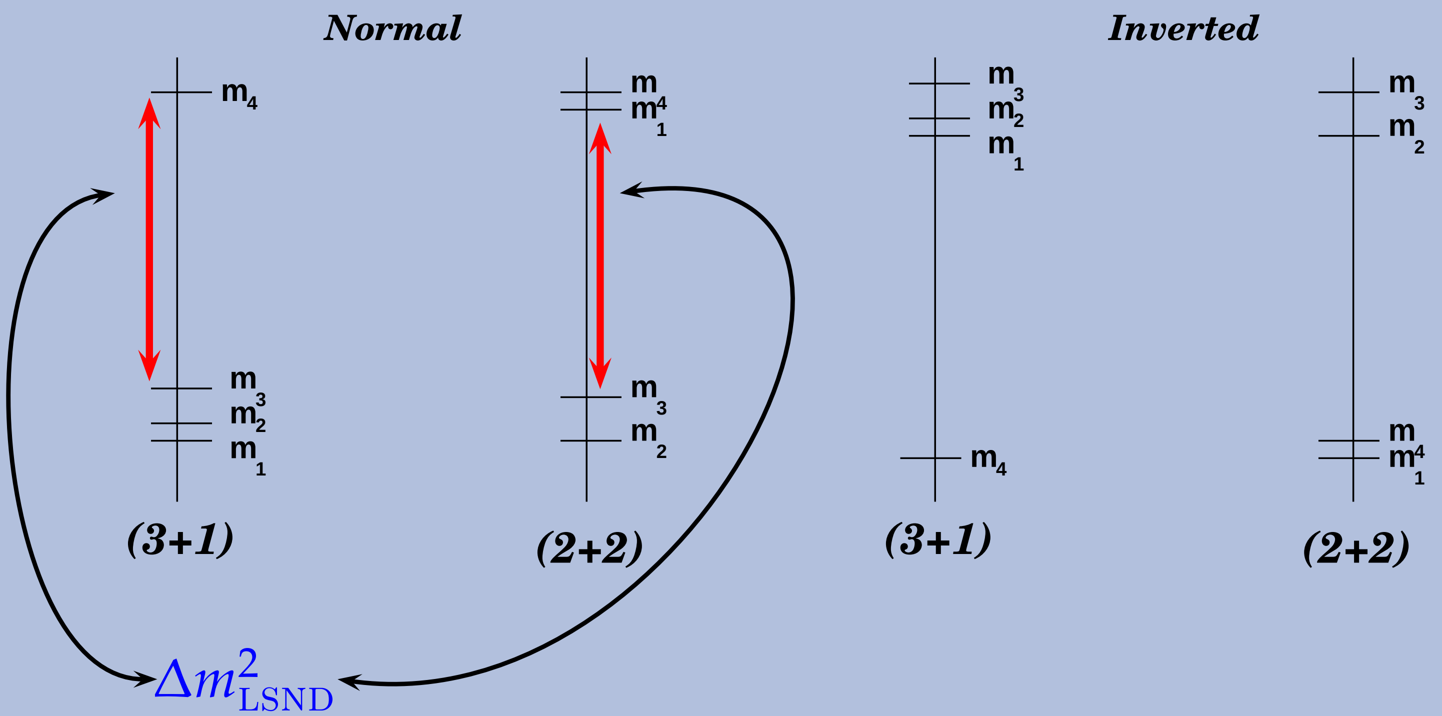

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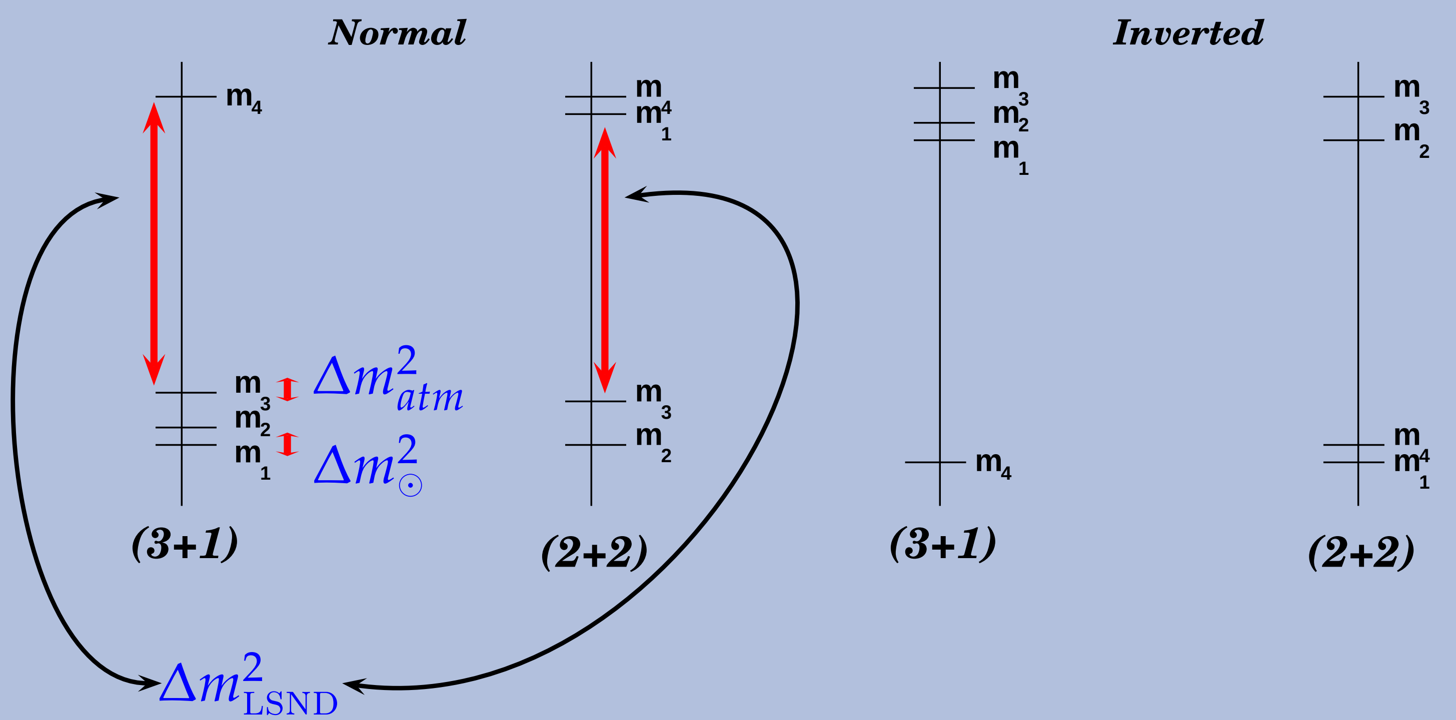

6 mixing angles and 3 mass differences

Constraints on 4ν mass schemes

For the solar pair

$$\cos(\theta_\odot)\nu_e - \sin(\theta_\odot)\tilde{\nu}$$

$$\cos(\theta_\odot)\nu_e + \sin(\theta_\odot)\tilde{\nu}$$

where $\tilde{\nu} = \sqrt{1-\eta_s}\nu_\tau + \sqrt{\eta_s}\nu_s$. In another words, η_s is the sterile content in the solar pair. In the same way we can de£ne a parameter d_s that describe the sterile admixture in the atmospheric pair.

Constraints on 4ν mass schemes

For the short baseline experiments for the ν_e channel, in the 2+2 mass schemes

$$\sqrt{1-d_e}\nu_e - \sqrt{d_e}\nu_\rho$$

$$\sqrt{d_e}\nu_e + \sqrt{1-d_e}\nu_\rho$$

where $\nu_\rho = \sqrt{d_s}\nu_s + \sqrt{1-d_s}\nu_\tau$. Similar for ν_μ channel, $d_e \to d_\mu$.

For the 3+1 mass schemes we replace $d_e \to 1-d_e$.

Constraints on 4ν mass schemes

Using the data from solar+atmospheric and short baseline experiments we have

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- For the 3+1 model, $d_e < 0.02$ and d_μ is very small. And for the global £t we have $1 - \eta_s \sim 0.4$ is small.

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$$
\begin{aligned}
P(\nu_\mu \to \nu_\mu) &\sim 1 - P(\nu_\mu \to \nu_\tau) \\
P(\nu_\mu \to \nu_\tau) &\sim \sin^2 2\theta_{\rm ATM} \sin^2(\Delta m^2_{\rm ATM} L/4E) \\
P(\nu_\mu \to \nu_e) &\sim 0 \; \mathcal{O}(U^2_{e3}) \text{ corrections}
\end{aligned}
$$

- We expect no conversion $\nu_\mu \to \nu_e$ at all and very small $\nu_\mu \to \nu_\tau$ oscillation.

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- Beside that, we can have MSW effects, at TeV energy range, for the $\nu_\mu \to \nu_e$ channel

$$E_\nu^{\rm R} \sim 1.7\ \text{TeV} \times \left(\frac{|\Delta m^2_{\rm LSND}|}{0.5\,\text{eV}^2}\right) \times \left(\frac{2.0\,{\rm g/cc}}{Y_e \rho}\right).$$

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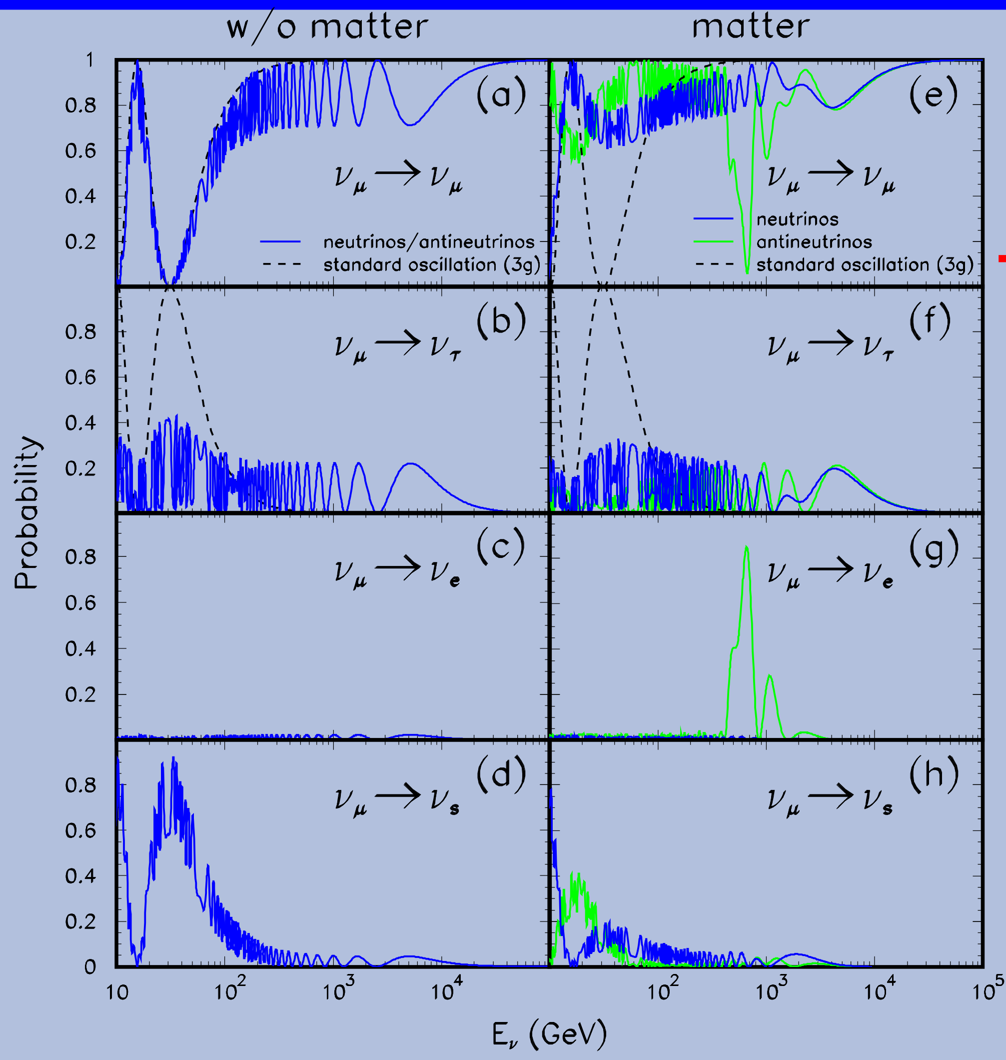
- The large mass scale induce ν_e appearence and ν_τ appearence.

Probabilities



→ $P(\nu_\mu \rightarrow \nu_\mu)$ dip (Yasuda)

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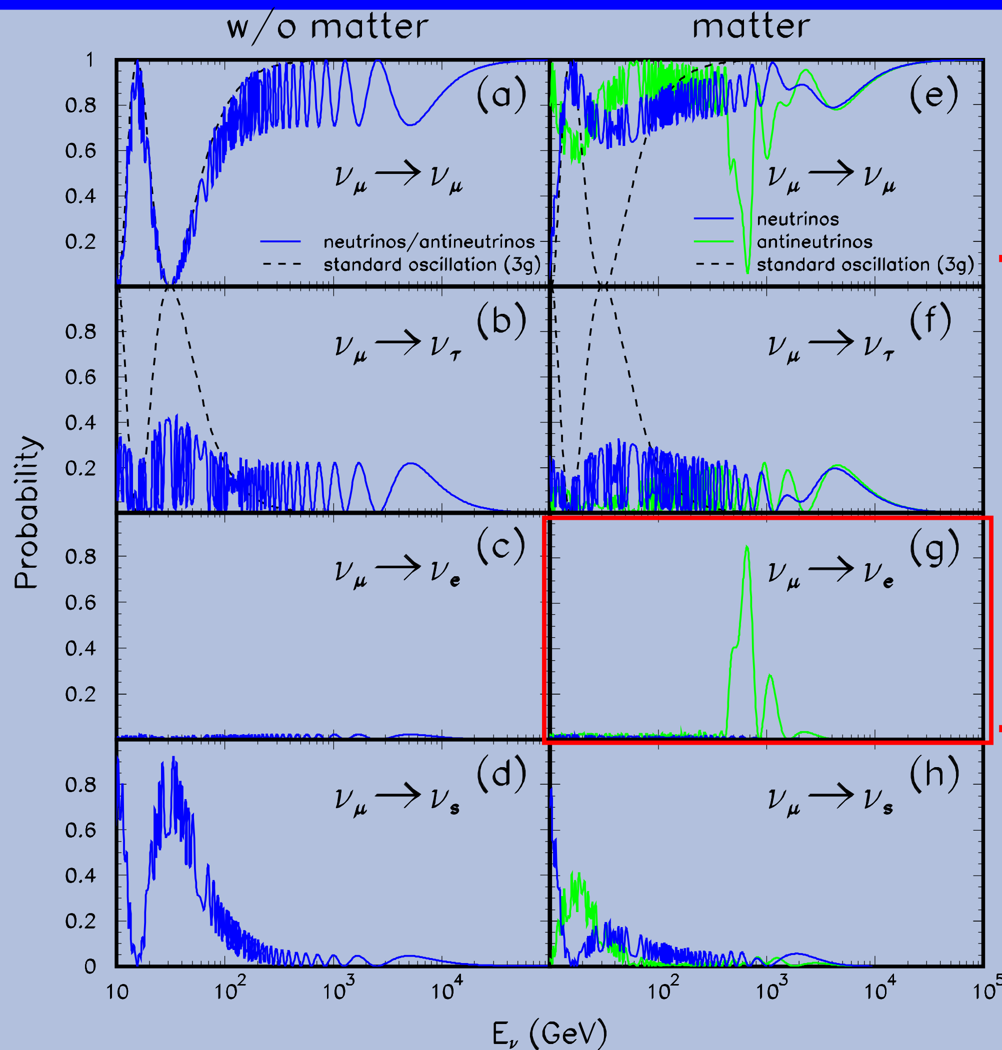

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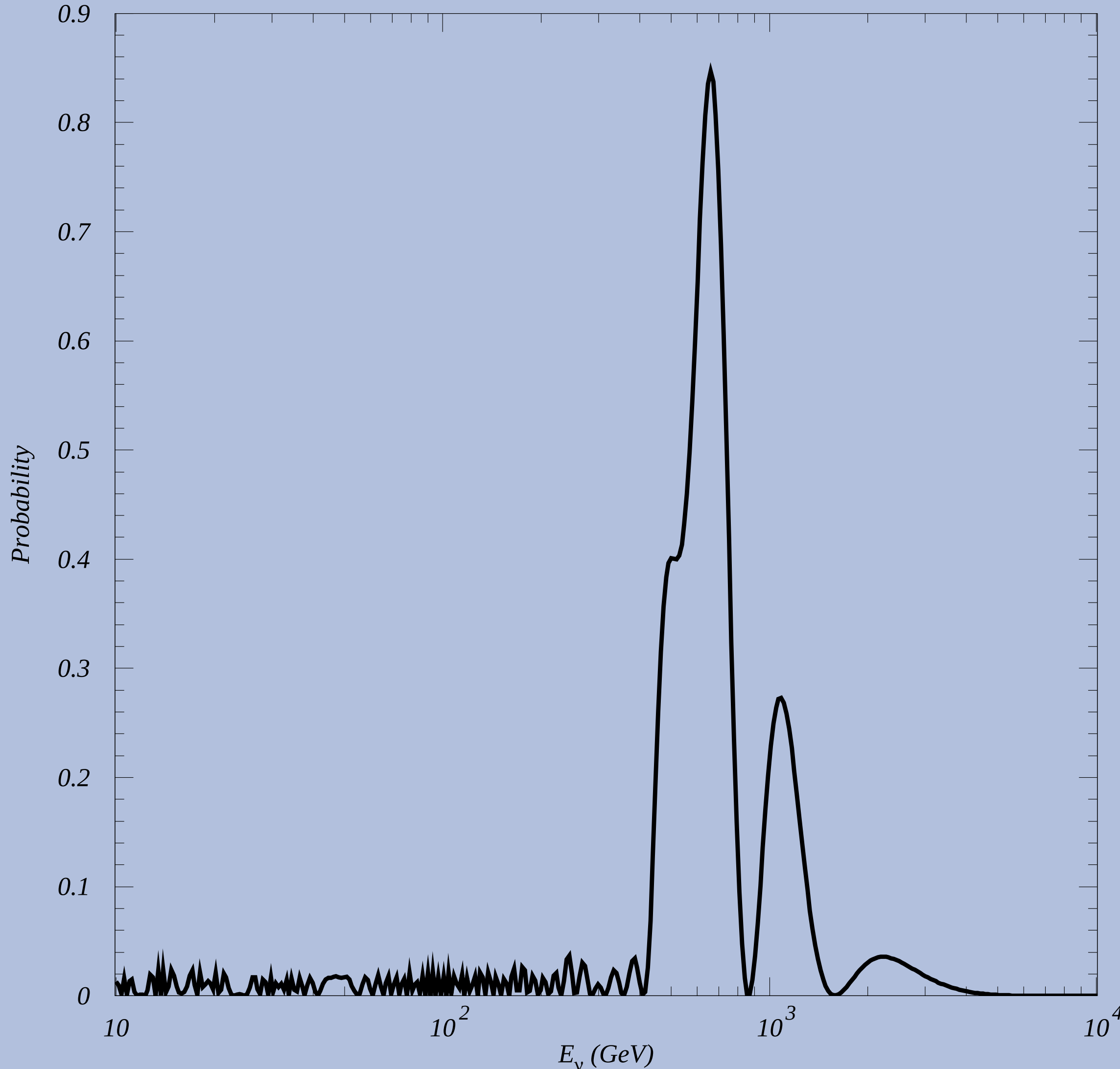
NEW

Probabilities



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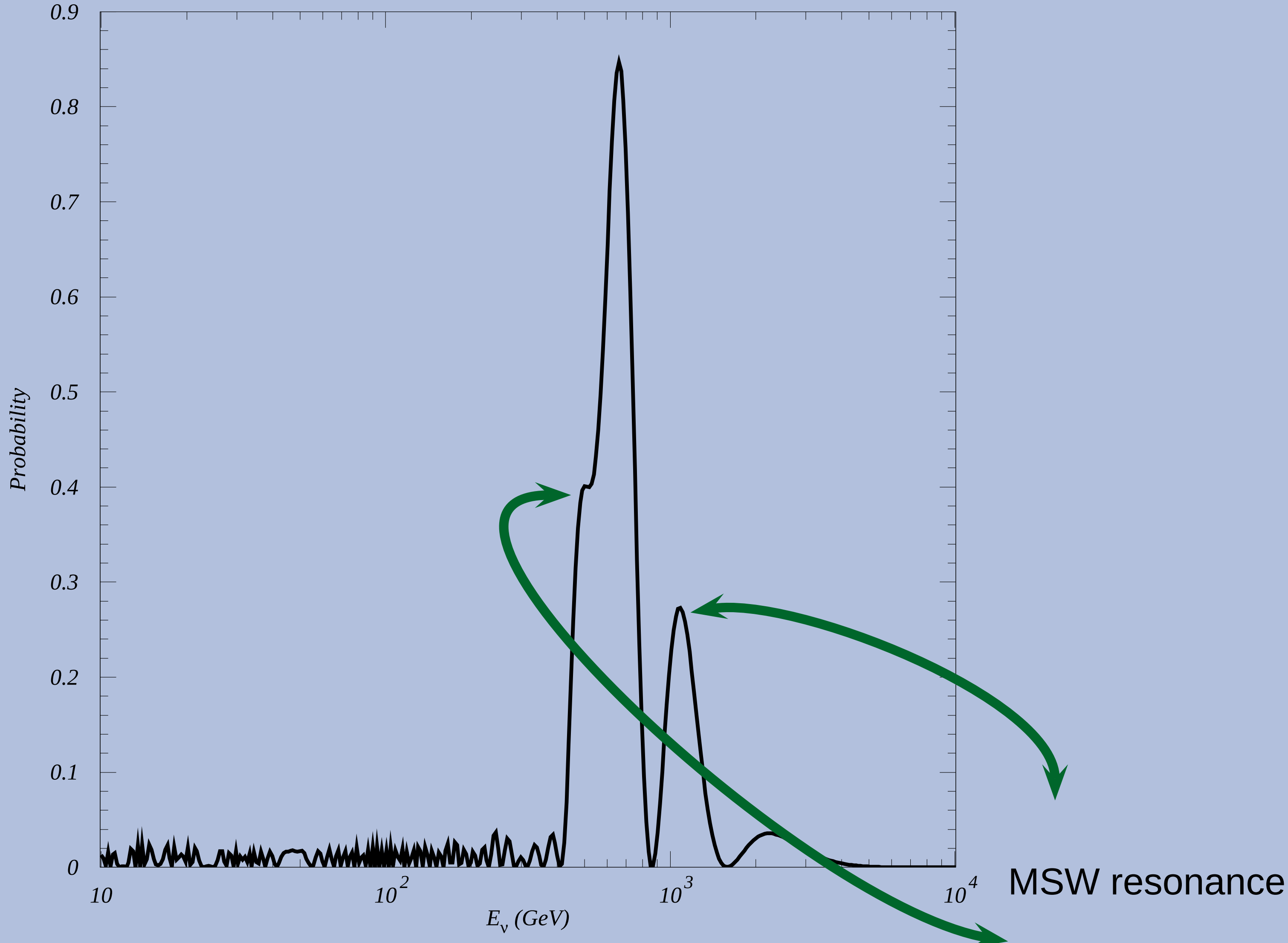

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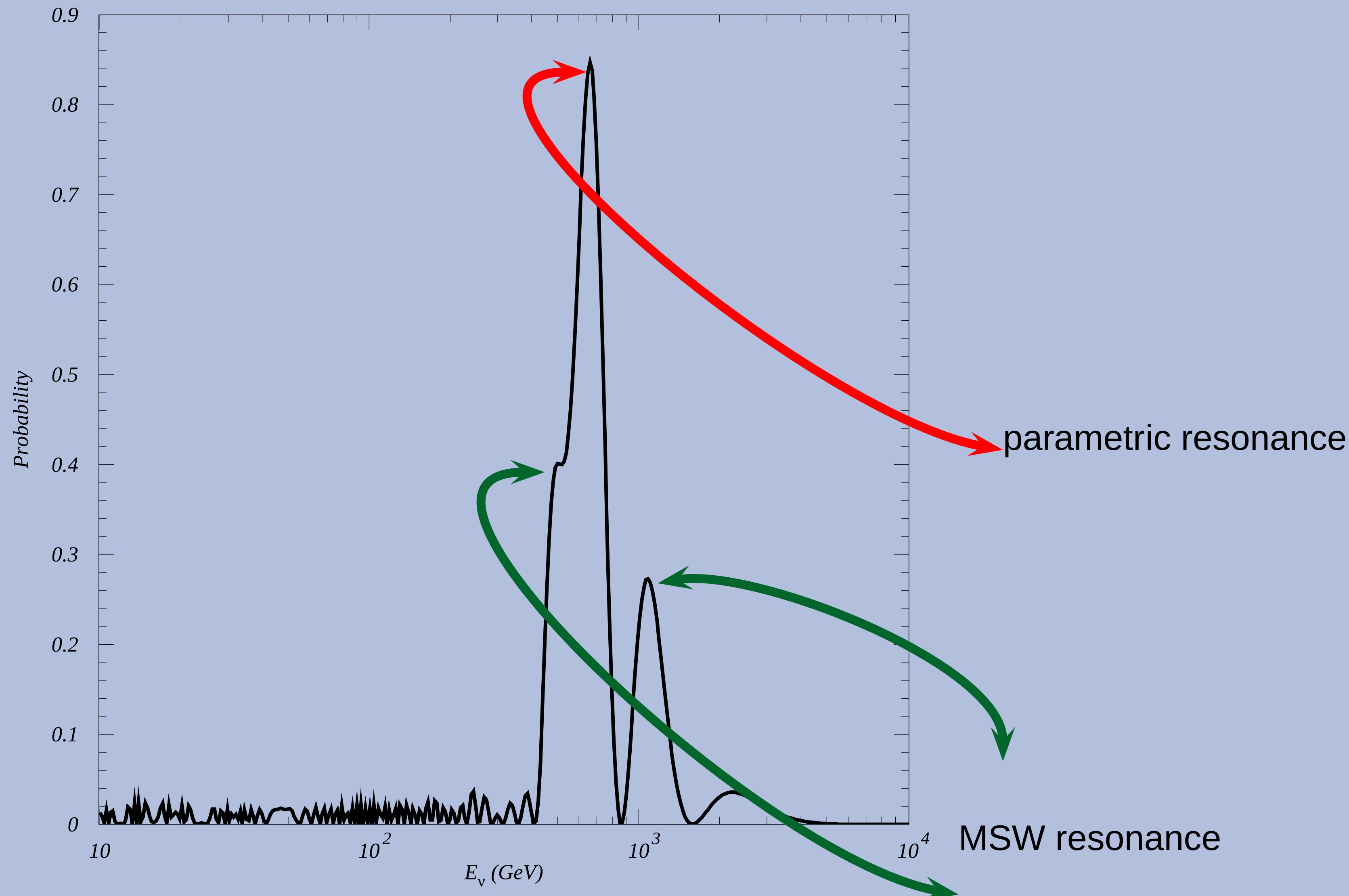

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At high energy, $\mu^+ \not\rightarrow e^+ + \bar{\nu}_\mu + \nu_e$

and always , $\phi(\nu_\tau + \bar{\nu}_\tau)/\phi(\nu_\mu + \bar{\nu}_\mu) \sim 10^{-4} - 10^{-5}$

We have a almost pure ν_μ beam

Upward going μ and cascades

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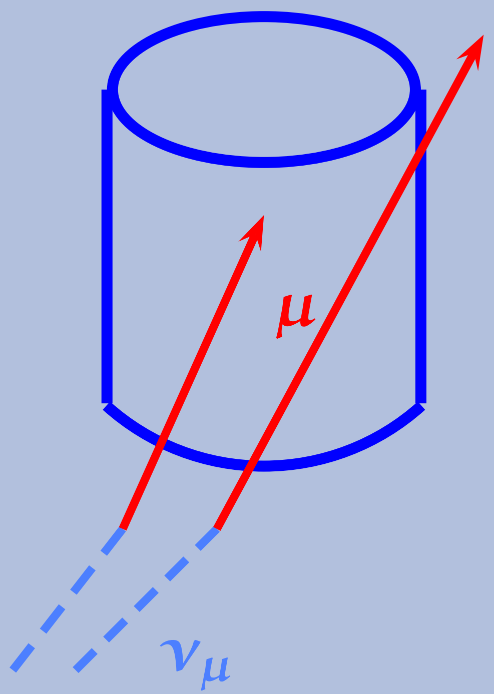
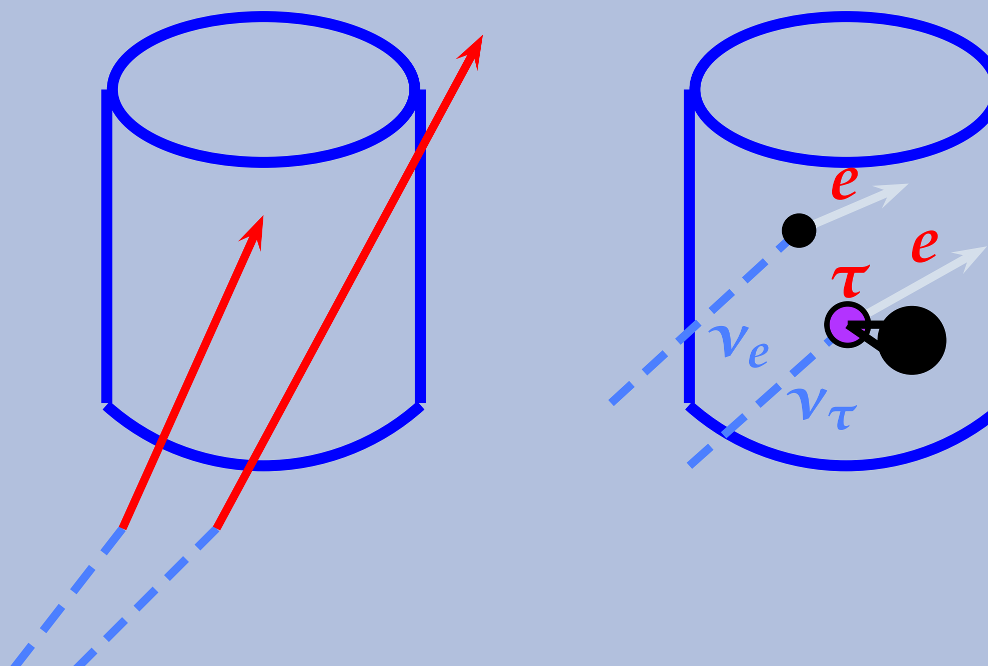
Upward Muons



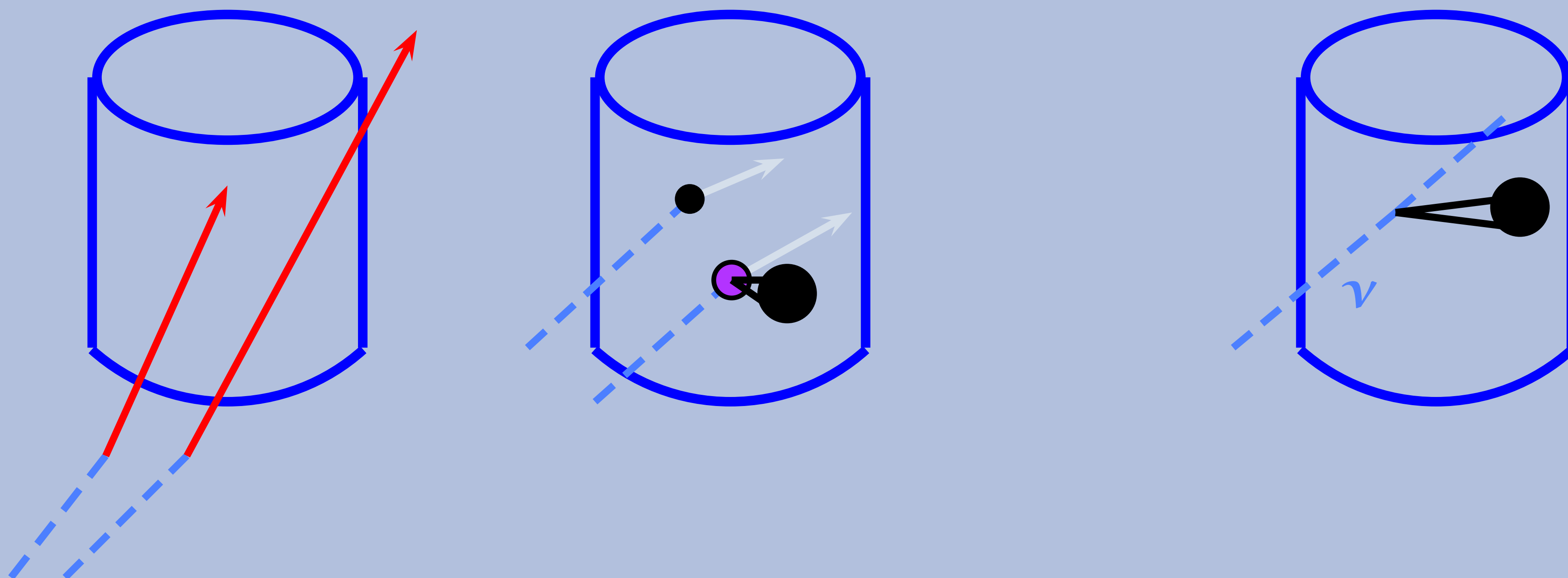
Upward going μ and cascades

Upward Muons   Cascade Events-CC

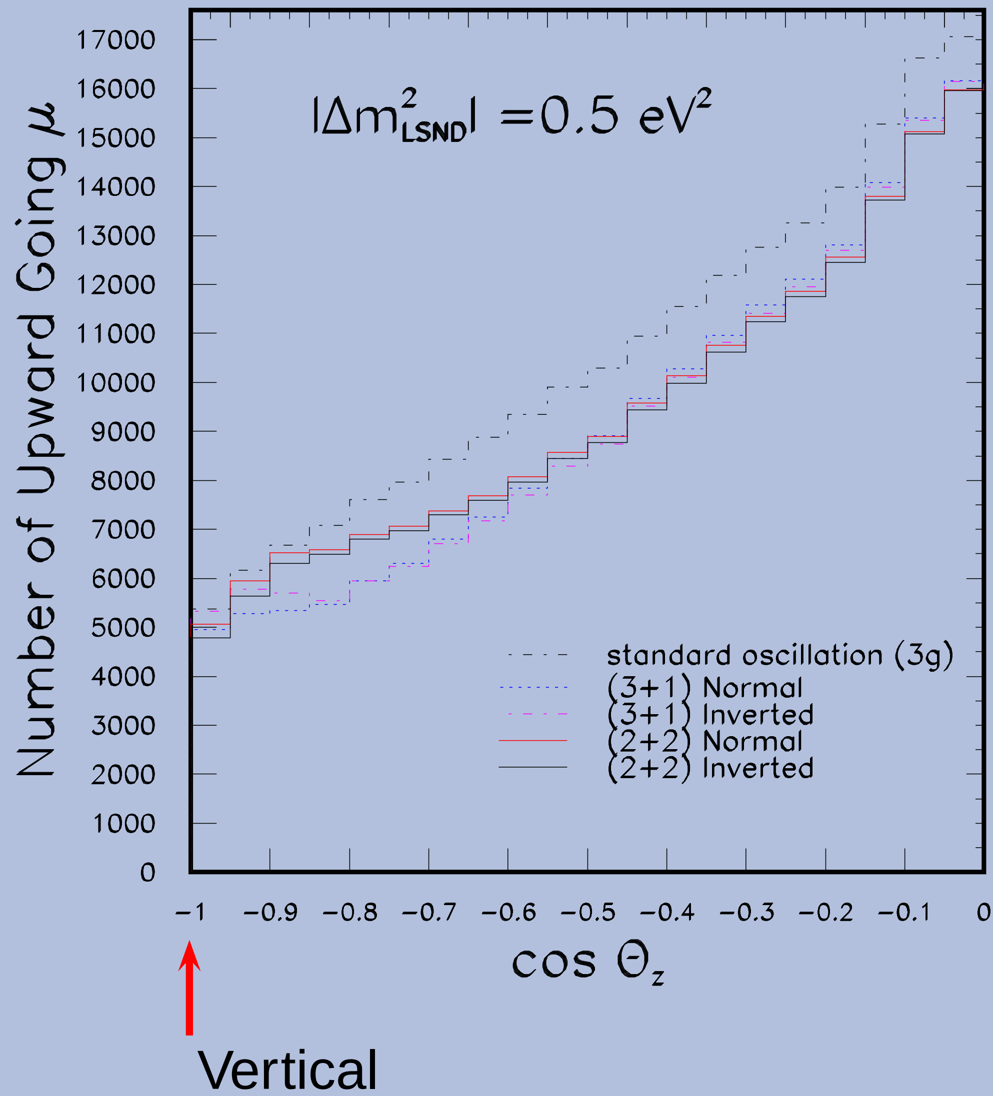


Upward going μ and cascades

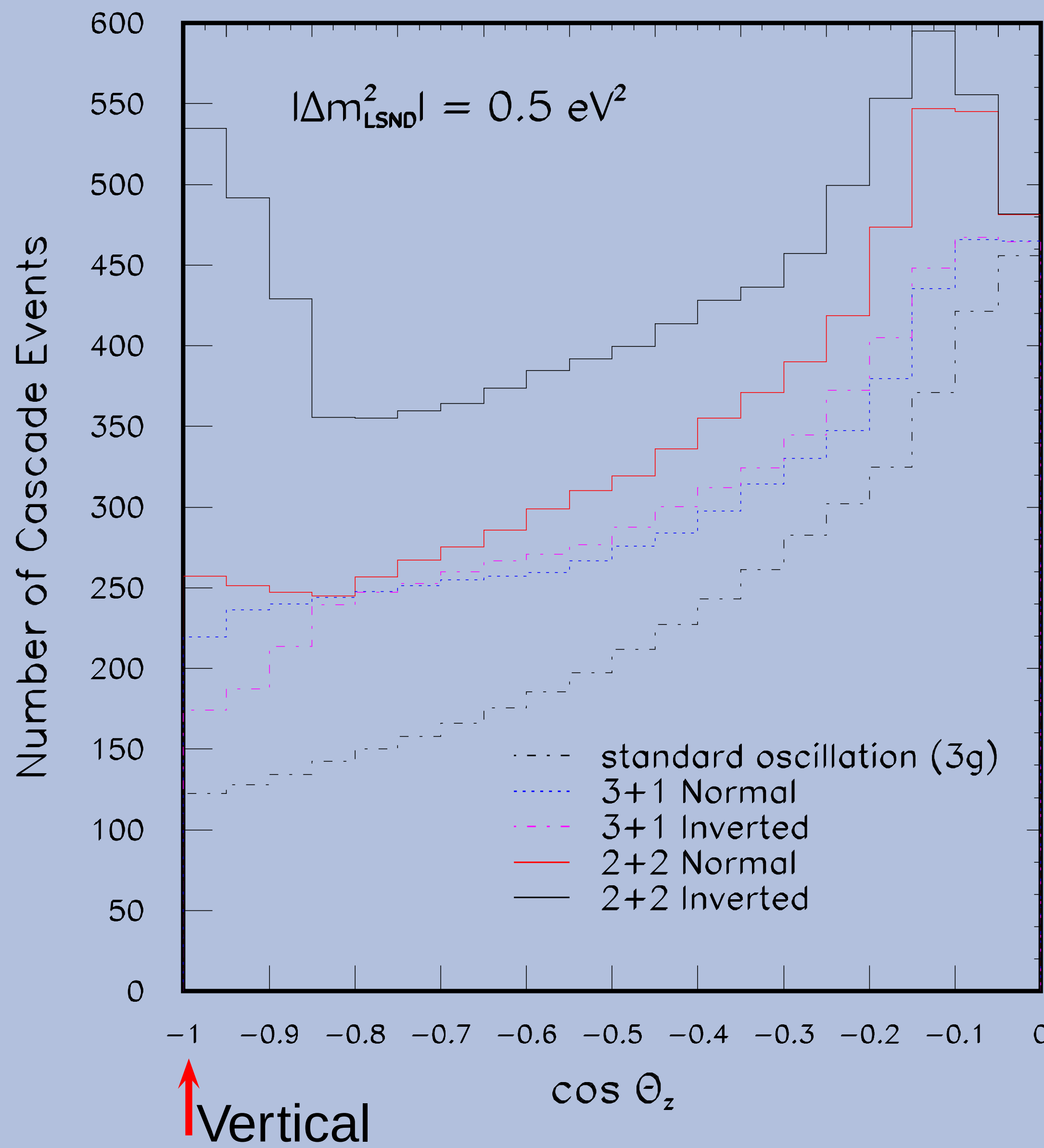
Upward Muons   Cascade Events-CC   Cascade Events-NC



Upward going μ



Cascade events



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- Large scale mass in the range $\Delta m^2_{\rm LSND} \sim 0.5 - 2.0$ eV^2 may affect the behaviour of neutrino probabilities in the TeV energy range;
- $\nu_\mu \to \nu_e/\nu_\tau$ appearence is the signal predicted by four neutrino mass models;
- Looking for zenith distribuition of upward going muons and cascade events may discriminate the sign of $\Delta m^2_{\rm LSND}$ and possibly the four neutrino mass scheme.