

# 1. Model independent neutrino oscillation diagram

The transition probability from weak eigenstate  $\nu_\alpha$  to  $\nu_\beta$  is (assuming everything is real)

$$P_{\alpha \rightarrow \beta}(t) = \left| \langle \nu_\beta(t) | \nu_\alpha \rangle \right|^2 = -4 \sum_{i>j} (U_{\alpha i} U_{\alpha j} U_{\beta i} U_{\beta j}) \sin^2 \left( \frac{\Delta_{ij}}{2} L \right)$$

Especially, if we want to see the oscillatory maximum of neutrino oscillation,

$$\frac{\Delta_{ij}(E)}{2} L \approx 1 \longrightarrow L \propto [\Delta_{ij}(E)]^{-1}$$

In the case of massive neutrino oscillation model,

$$\frac{\Delta_{ij}(E)}{2} L \approx \frac{\Delta m^2}{4E} L \approx 1 \longrightarrow L \propto E$$

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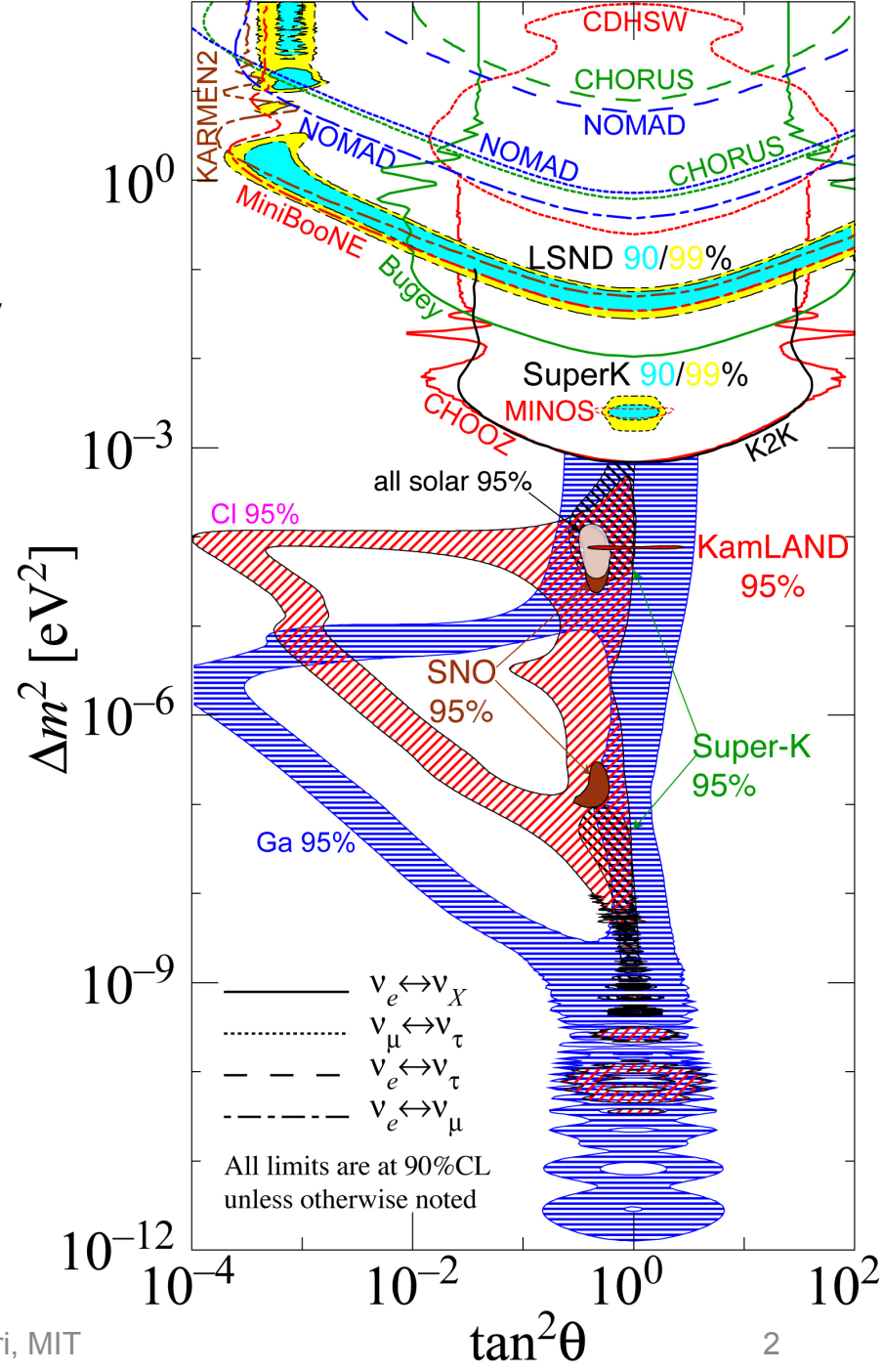
Neutrino Working Group Meeting, Fermilab, Batavia, Oct. 24, 2011

# 1. Neutrino standard Model ( $\nu$ SM)

This is the world data of neutrino oscillation, the positive oscillation signals are pinned down in very narrow region, and vast regions are rejected.

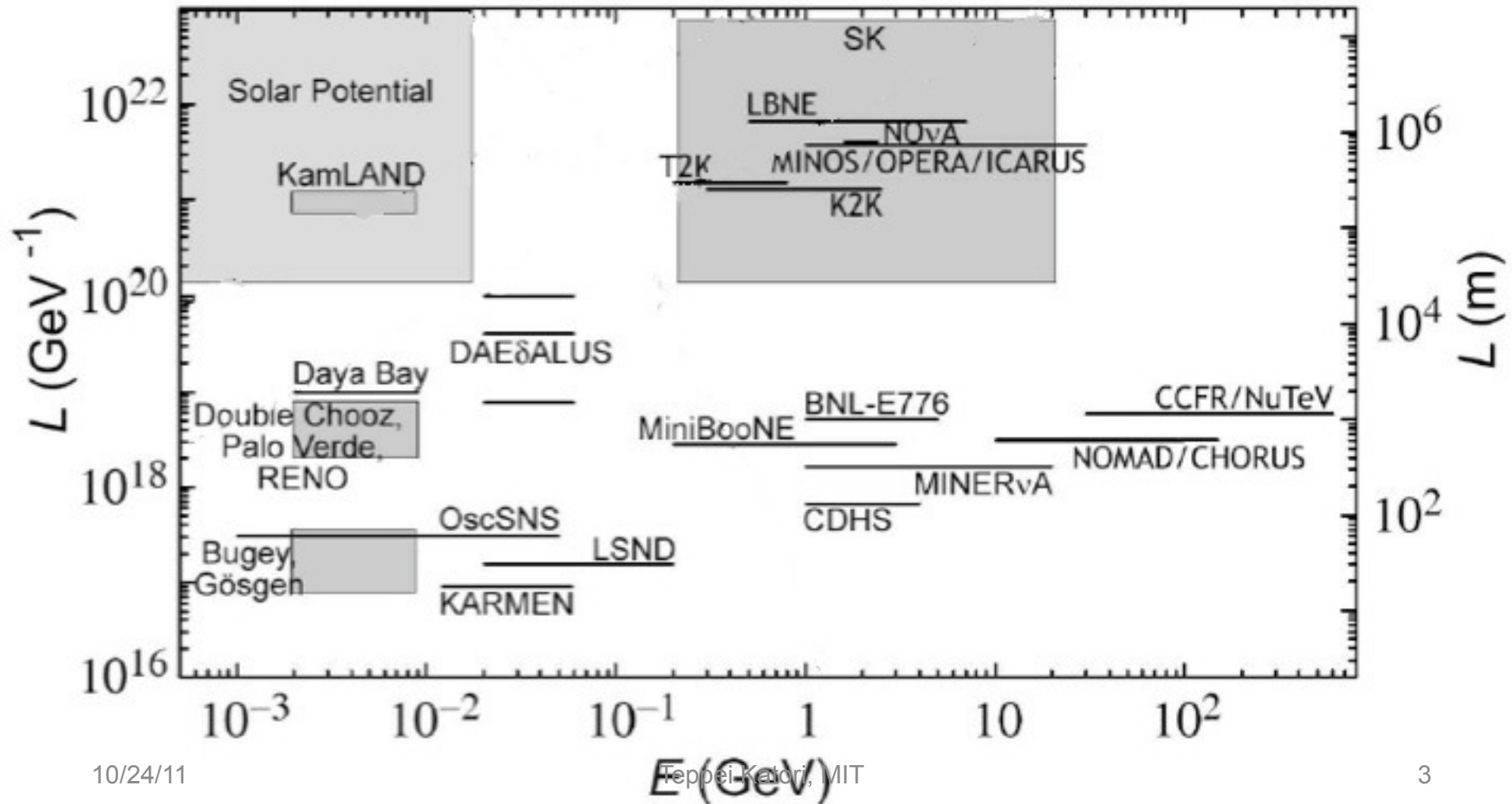
But this is model dependent diagram, because it assumes **neutrino mass as phase, and mass mixing matrix elements as amplitude of neutrino oscillations.**

What is model independent diagram look like?



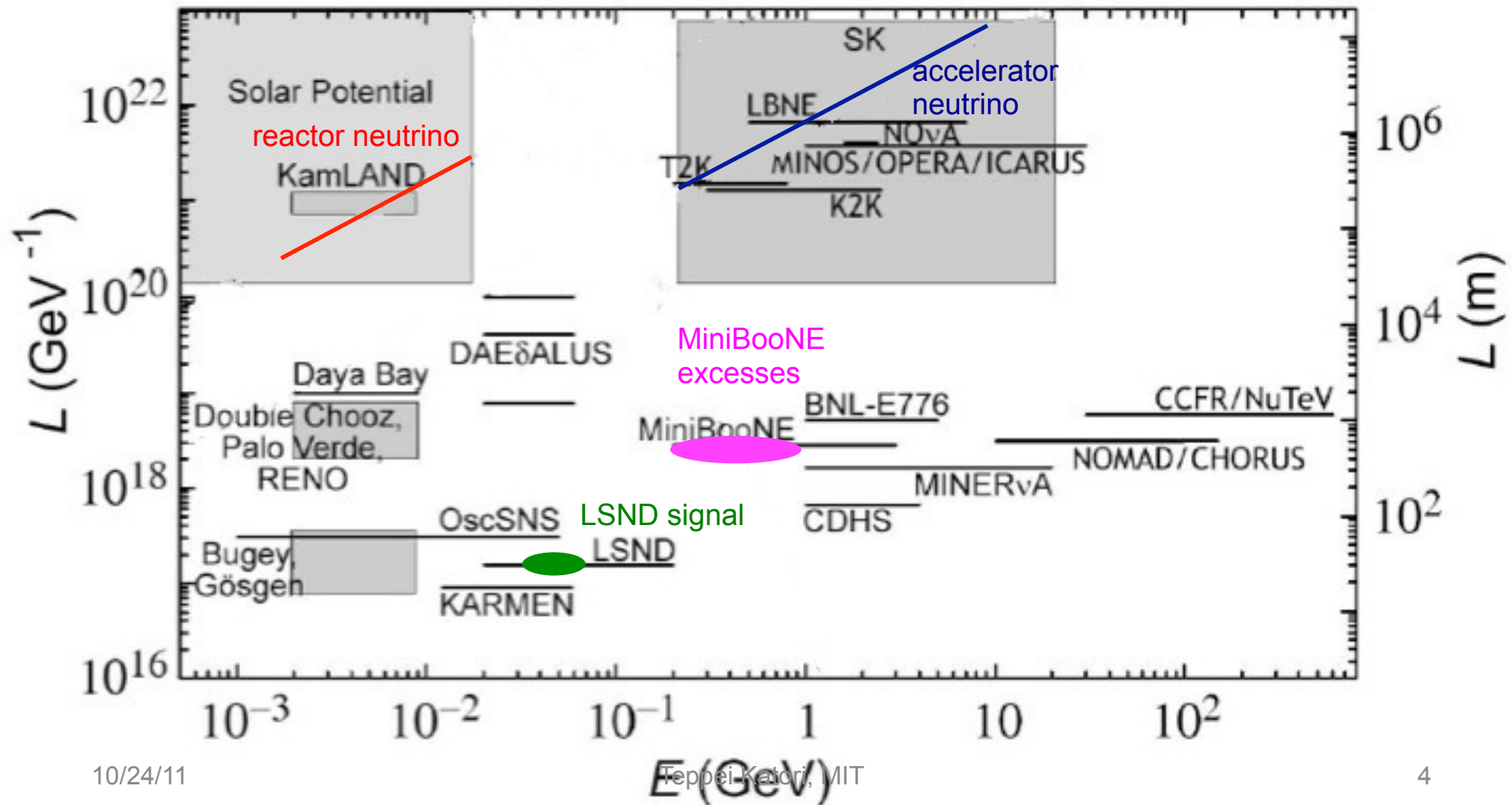
# 1. L-E plot

Model independent neutrino oscillation data is the function of neutrino energy and baseline.



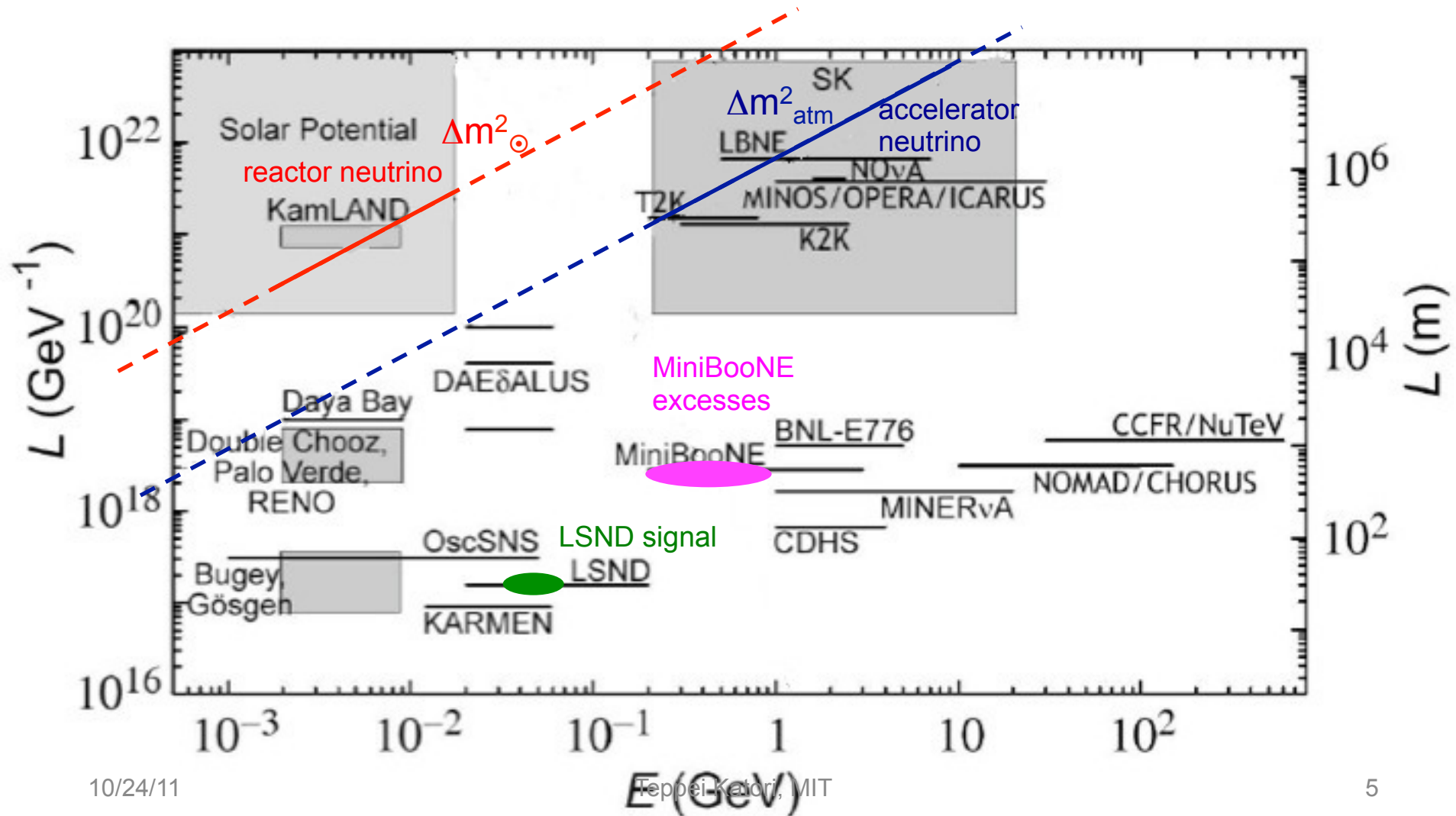
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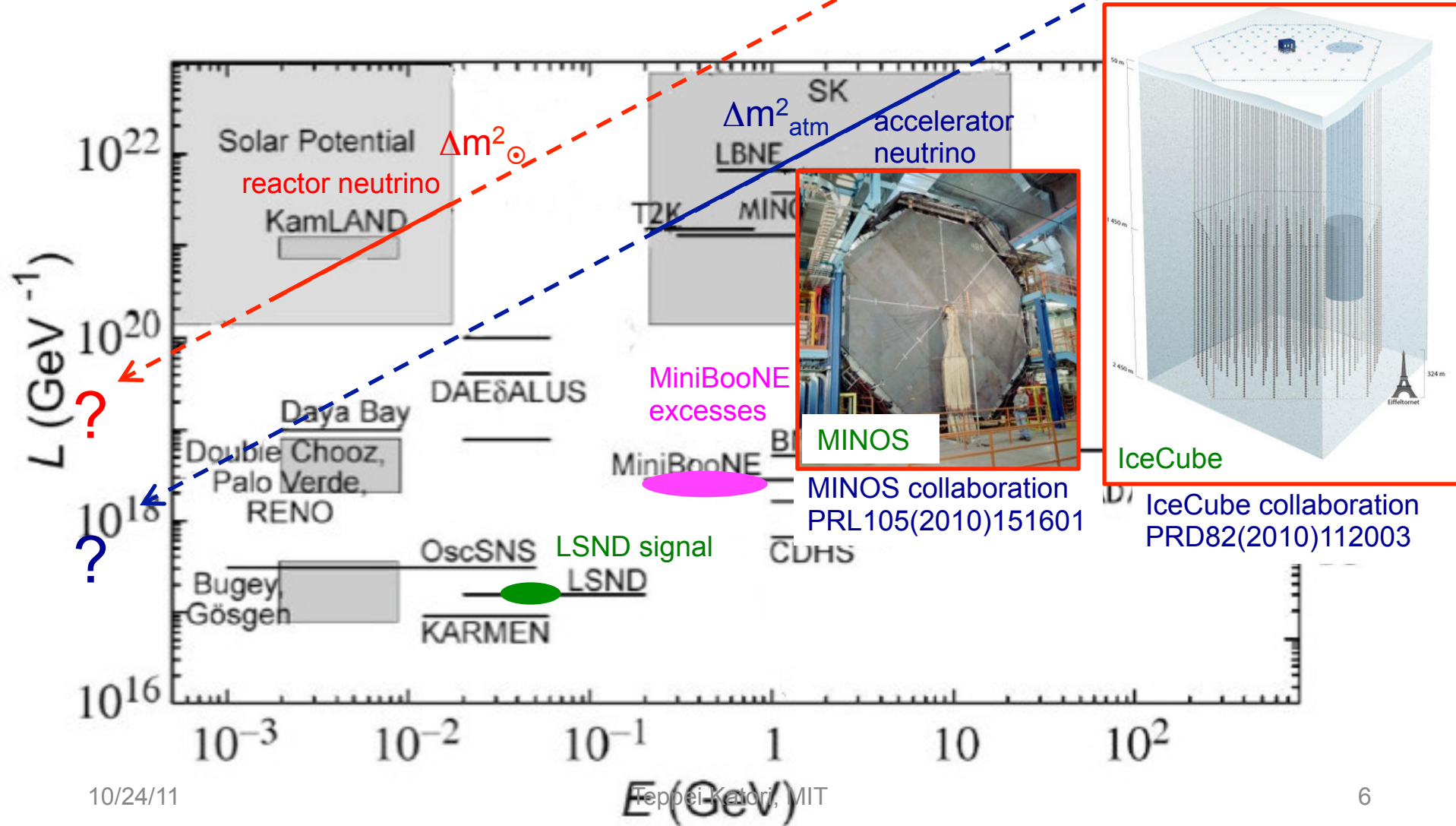
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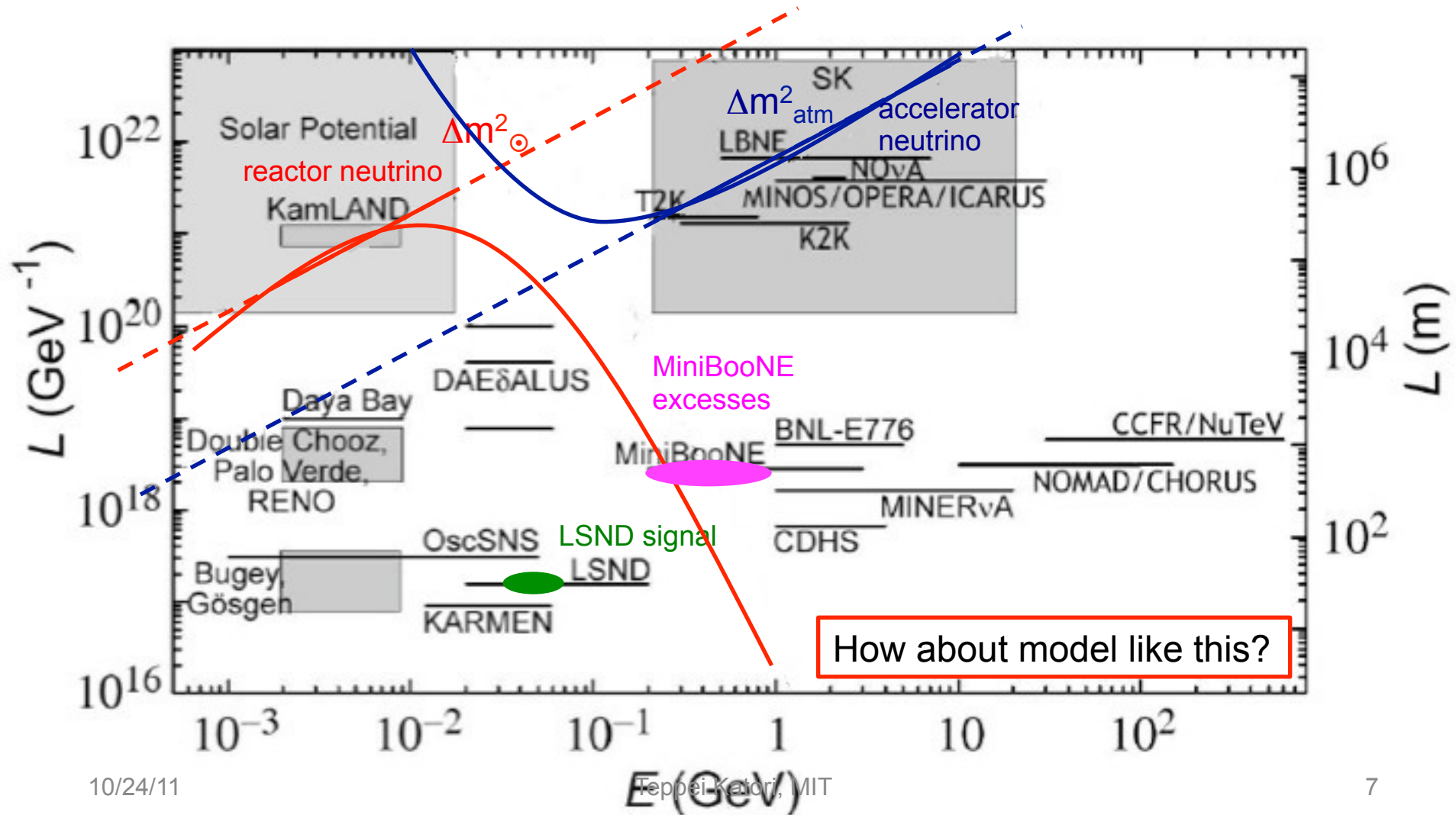
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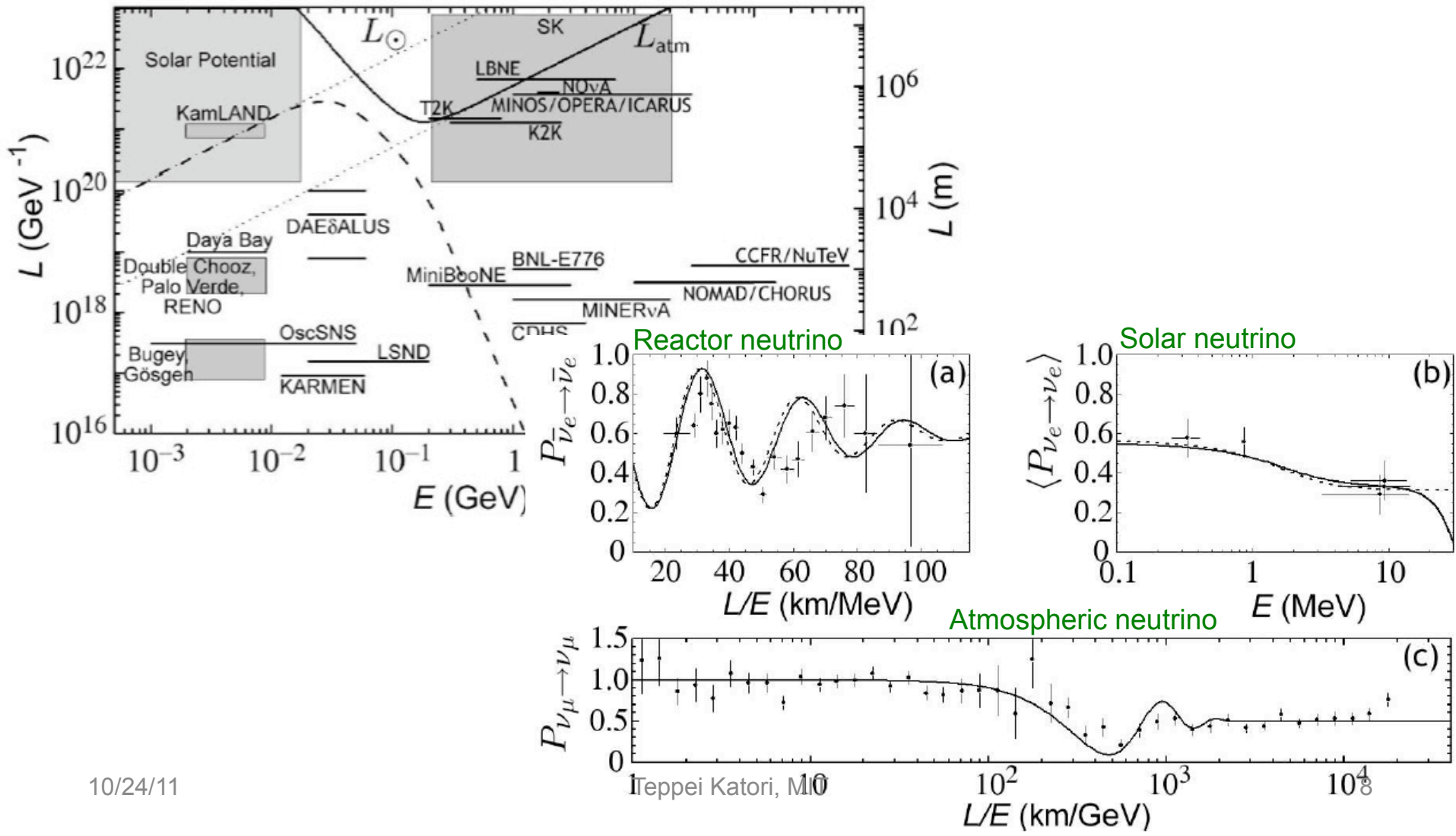
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# 1. Puma model

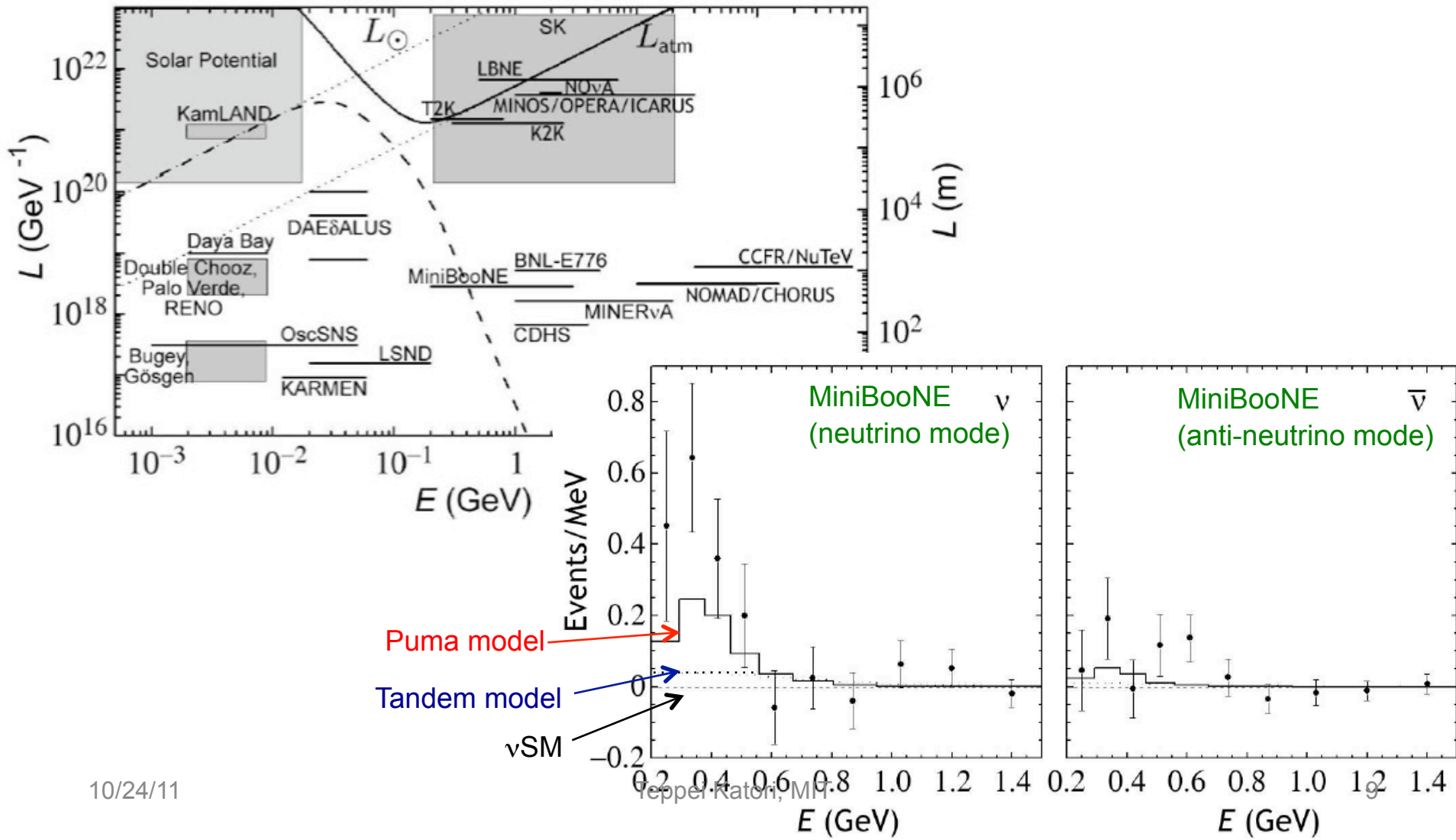
Puma model has only 3 parameters, and perfectly describe all neutrino oscillation signal, including MiniBooNE low energy excess (neutrino mode only!)





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# 1. Lorentz violation with neutrino oscillation

Model independent neutrino oscillation data is the function of neutrino energy and baseline.

