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Heavy Neutrino-Antineutrino Oscillations in QFT

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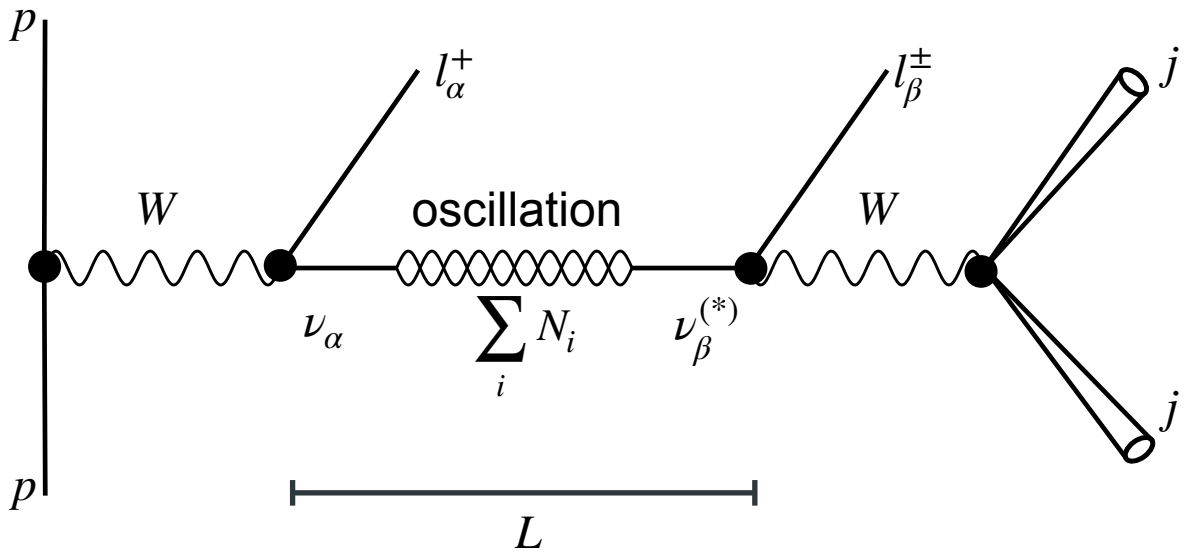
Presentation based on arXiv:2012.05763
and therein references

Defining and Implementing Heavy Neutrino-Antineutrino Oscillations

Adding right handed Neutrinos results in mixing matrix rotating the neutrino flavour states α into mass eigenstes i

$$\nu_\alpha = V_{\alpha i}\ N_i$$

Displaced vertices are possible if heavy neutrinos N_i are long lived.
If they are almost mass degenerate oscillations length is of macroscopic size.



L: distance traveled by heavy neutrino superposition

Introducing The Framework
External States

$$|W\rangle = \int d^3\mathbf{q}\; N\; \Psi(\mathbf{q},\mathbf{Q})\; e^{iqx_P}\; b_W^{\dagger r}(q)\; |0\rangle$$

Wave Packet Envelope
Spacetime Translation Operator
Usual Creation Operator

Amplitude that describes the oscillation process

$$\mathscr{A} = \langle f | \hat{T}\left[\exp\left(-i\int \mathrm{d}^4x\; \mathscr{H}_I\right)\right] - \mathbf{1}\,|\,i\rangle$$

Evaluating amplitude is rather technical.
But the results can be divided in:

A. “Simple” Oscillation Formulae

B. Observability Conditions (if not negligible leads to suppression)

Oscillation Formulae

Lepton Number Conserving Probability

Assuming a minimal low scale linear seesaw model with inverse ordering of light neutrino masses. More general formulae in arXiv:2012.05763.

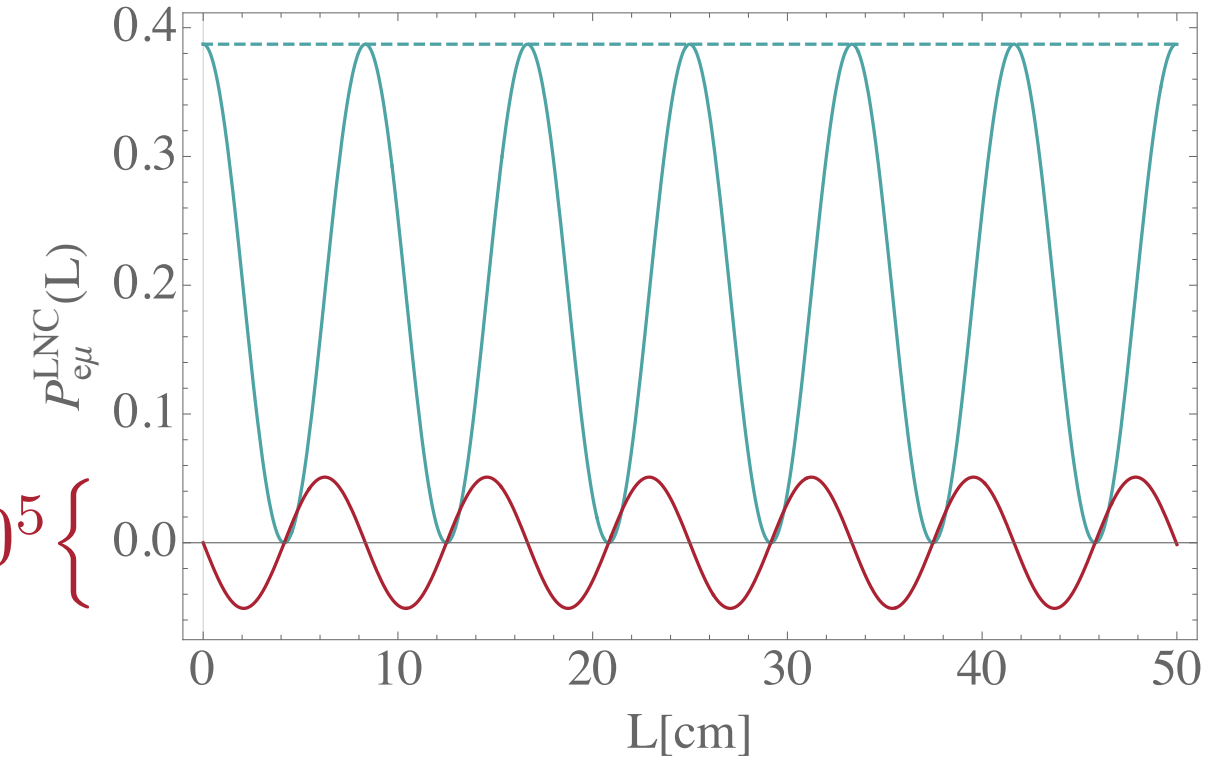
$$x = L/|L_{osc}| \qquad L_{osc} = \frac{4\pi|\mathbf{p}_0|}{\delta m^2_{45}}$$

$$P^{LNC}_{\alpha\beta}(L) = N_{\alpha\beta}\Big(1 + \cos(2\pi x) - \epsilon_{\alpha\beta}\sin(2\pi x)\Big)$$

Parameters of example point in arXiv:1709.03797:

$m_0 = 7$ GeV $\quad \gamma = 50 \quad \theta^2 = 10^{-5}$

$\alpha = \pi/3 \quad \delta m^2_{45} = -1.04 * 10^{-11}$ GeV^2



Oscillation Formulae

Lepton Number Violating Probability

Assuming a minimal low scale linear seesaw model with inverse ordering of light neutrino masses. More general formulae in arXiv:2012.05763.

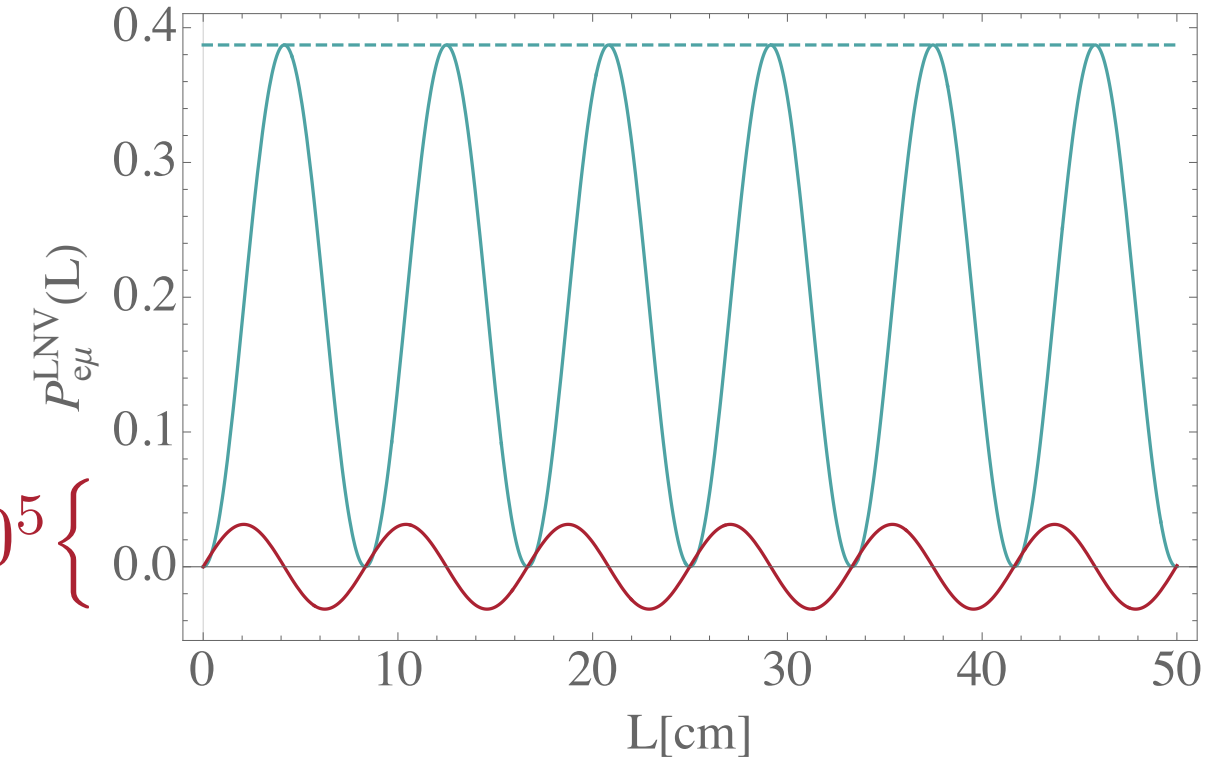
$$x = L/|L_{osc}| \qquad L_{osc} = \frac{4\pi|\mathbf{p}_0|}{\delta m^2_{45}}$$

$$P^{LNV}_{\alpha\beta}(L) = N_{\alpha\beta}\Big(1 - \cos(2\pi x) - \epsilon'_{\alpha\beta}\sin(2\pi x)\Big)$$

Parameters of example point in arXiv:1709.03797:

$m_0 = 7$ GeV $\quad \gamma = 50 \quad \theta^2 = 10^{-5}$

$\alpha = \pi/3 \quad \delta m^2_{45} = -1.04 * 10^{-11}$ GeV^2



Oscillation Formulae

Flavour Oscillations

Assuming a minimal low scale linear seesaw model with inverse ordering of light neutrino masses. More general formulae in arXiv:2012.05763.

$$x = L/|L_{osc}| \qquad L_{osc} = \frac{4\pi|\mathbf{p}_0|}{\delta m^2_{45}}$$

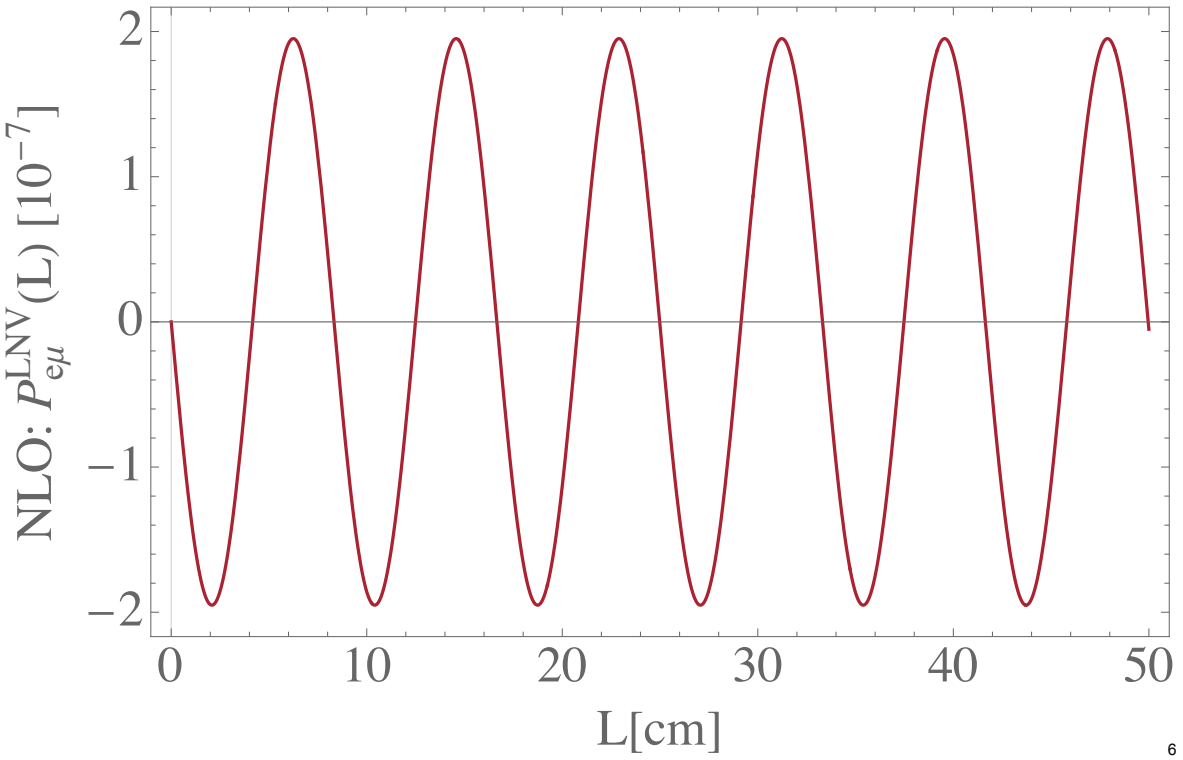
$$P^{LNC+LNV}_{\alpha\beta}(L) = N_{\alpha\beta}\Big(2 - \epsilon_{\alpha\beta}\sin(2\pi x) - \epsilon'_{\alpha\beta}\sin(2\pi x)\Big)$$

$$= N_{\alpha\beta}\Big(2 - \epsilon''_{\beta}\sin(2\pi x)\Big)$$

Parameters of example point in arXiv:1709.03797:

$m_0 = 7$ GeV $\quad \gamma = 50 \quad \theta^2 = 10^{-5}$

$\alpha = \pi/3 \quad \delta m^2_{45} = -1.04 * 10^{-11}$ GeV^2



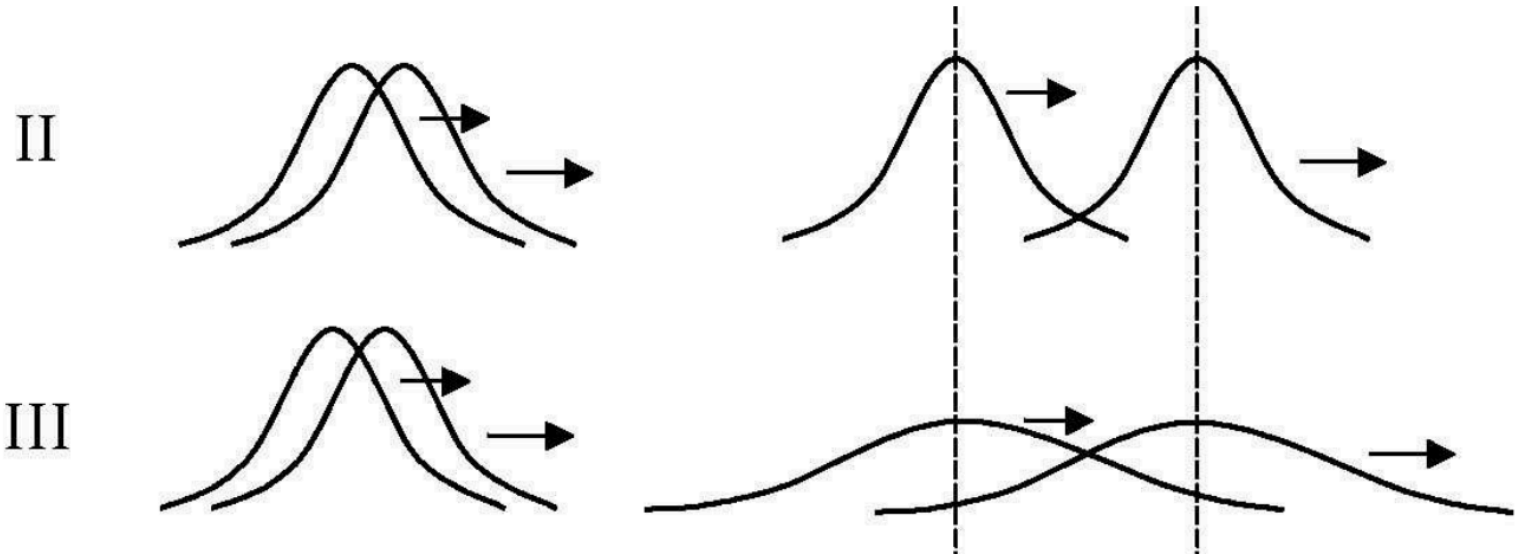
Observability Conditions

Decoherence Term

Effect that suppresses oscillations if wave packets separate
or variation over the wave packet width averages phase to zero.

$$\exp\left(-\frac{L}{L_{ij}^{coh}}\right)$$

$$L_{ij}^{coh} = \frac{1}{\sqrt{2}\pi}\frac{|\mathbf{p}_0|}{\sigma_{peff}}L_{ij}^{osc}$$



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Summary

- Displaced vertices and almost mass degenerate heavy neutrinos arise in low scale seesaw models with heavy neutrino masses below m_W
- Observing oscillations could yield great insight in the mechanism of neutrino mass generation
- Heavy Neutrino-Antineutrino Oscillations in QFT describable by “simple” oscillation formulae and observability conditions as shown in arXiv:2012.05763

Thank you
for your attention.