



University
of Basel

Heavy Neutrino-Antineutrino Oscillations in QFT

J.Roskopp, 22.02.21

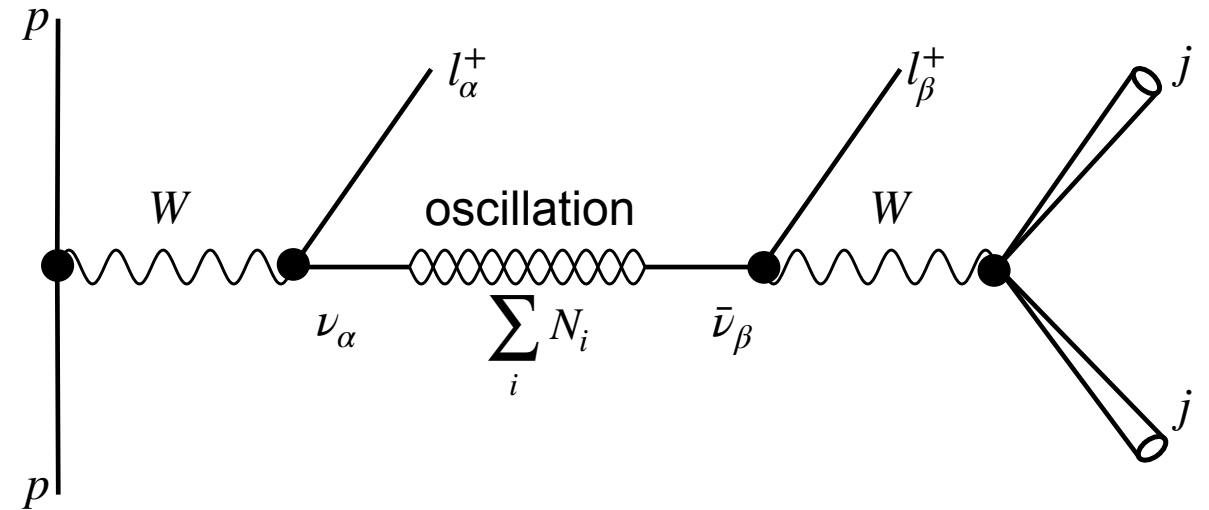
Presentation based on [arXiv:2012.05763](https://arxiv.org/abs/2012.05763)
and therein references

Defining and Implementing Heavy Neutrino-Antineutrino Oscillations

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



Introducing The Framework

External States

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

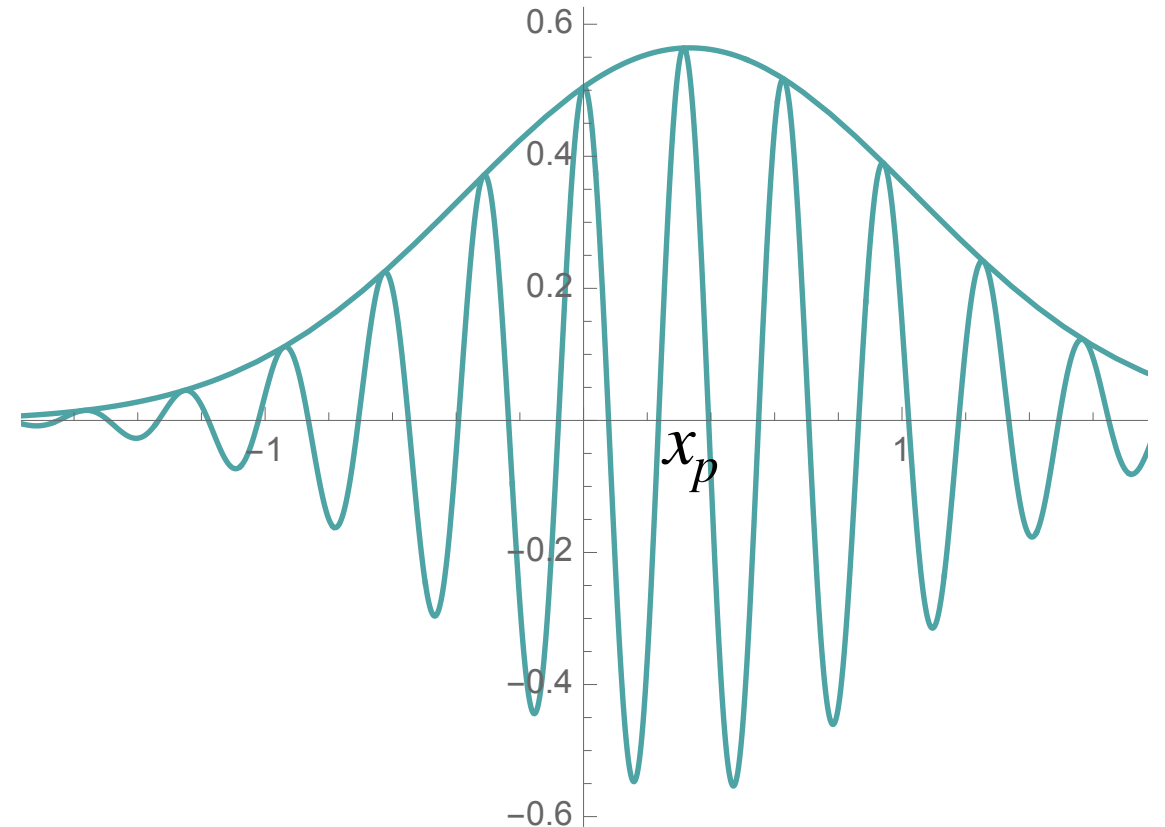
Wave Packet Envelope

Spacetime Translation Operator

Usual Creation Operator

Amplitude that describes the oscillation process

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



Oscillation Formulae

Lepton Number Conserving Probability

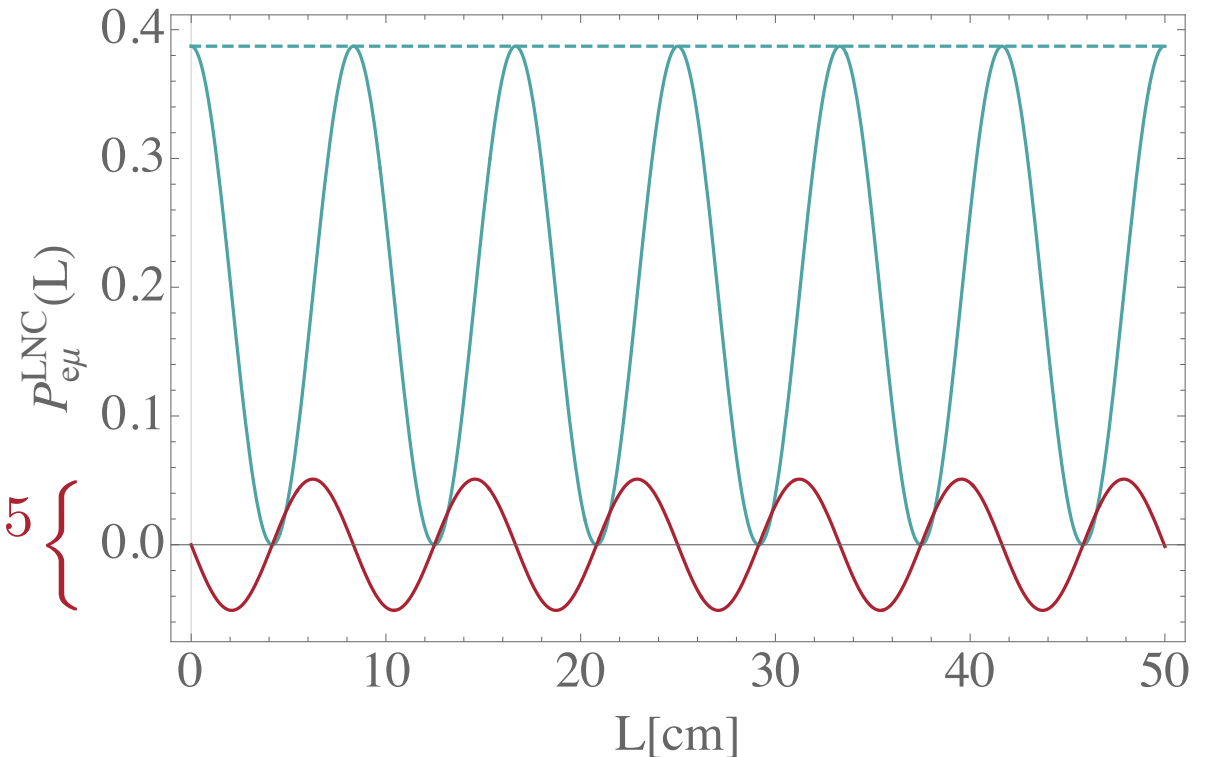
Assuming a minimal low scale linear seesaw model with inverse ordering of light neutrino masses. More general formulae in [arXiv:2012.05763](#).

$$x = L / |L_{osc}| \quad L_{osc} = \frac{4\pi |\mathbf{p}_0|}{\delta m_{45}^2}$$
$$P_{\alpha\beta}^{LNC}(L) = N_{\alpha\beta} \left(1 + \cos(2\pi x) - \epsilon_{\alpha\beta} \sin(2\pi x) \right)$$

$\times 10^5$

Parameters of example point in arXiv:1709.03797:

$$m_0 = 7 \text{ GeV} \quad \gamma = 50 \quad \theta^2 = 10^{-5}$$
$$\alpha = \pi/3 \quad \delta m_{45}^2 = -1.04 * 10^{-11} \text{ GeV}^2$$



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](https://arxiv.org/abs/2012.05763).

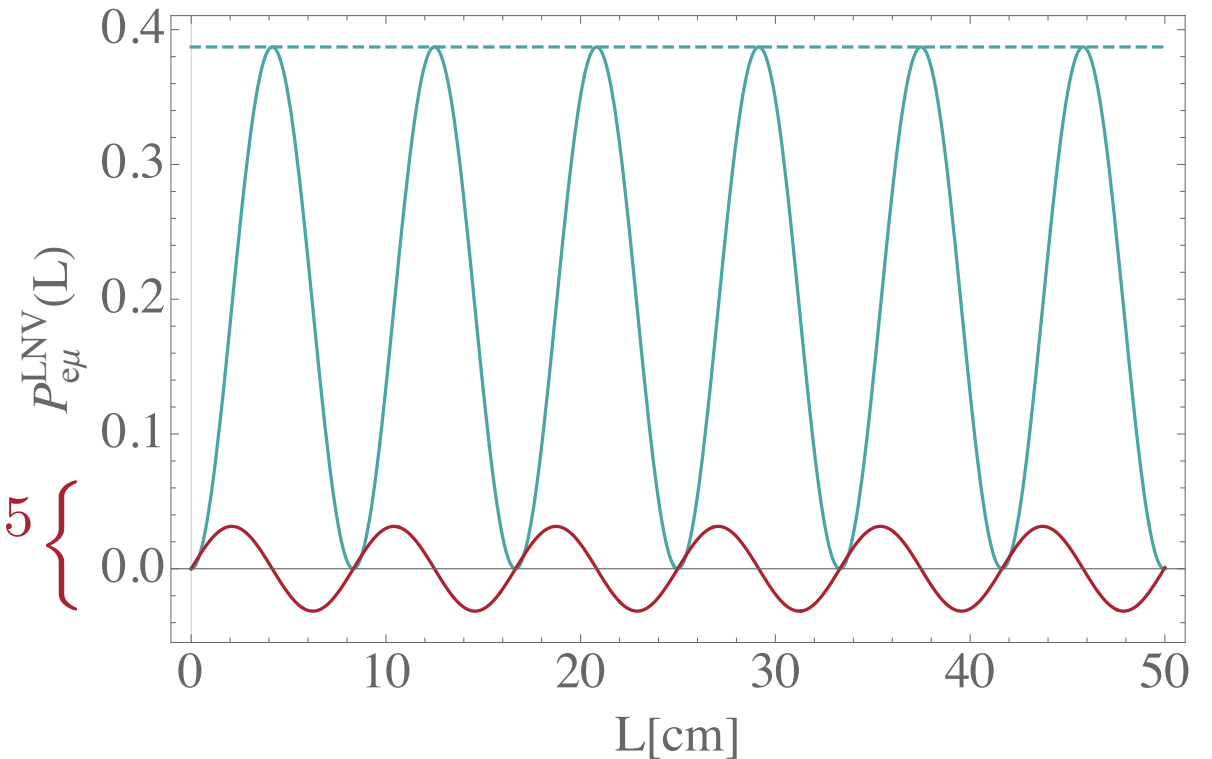
$$x = L / |L_{osc}| \quad L_{osc} = \frac{4\pi |\mathbf{p}_0|}{\delta m_{45}^2}$$
$$P_{\alpha\beta}^{LNV}(L) = N_{\alpha\beta} \left(1 - \cos(2\pi x) - \epsilon'_{\alpha\beta} \sin(2\pi x) \right)$$

$\times 10^5$ {

Parameters of example point in arXiv:1709.03797:

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

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



Observability Conditions

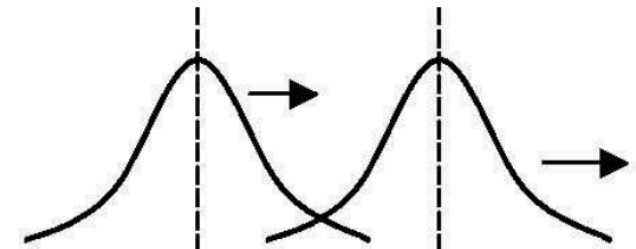
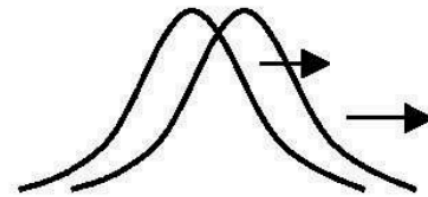
Decoherence Term

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

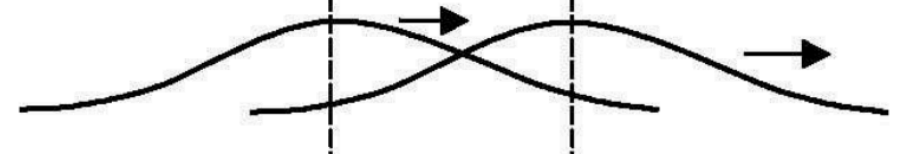
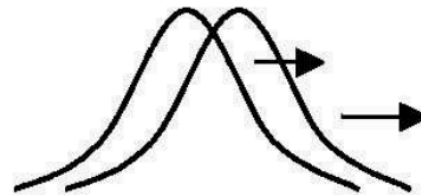
$$\exp\left(-\frac{L}{L_{ij}^{coh}}\right)$$

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

II



III



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](https://arxiv.org/abs/2012.05763)

Thank you
for your attention.