The MSW Matter Potential at the One-loop Level in the Standard Model

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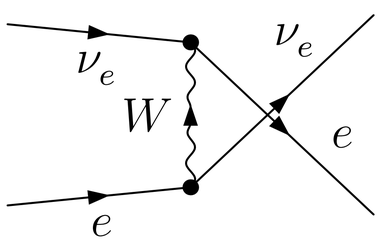
Based on Work in Preparation

Neutrino MSW Matter Potential

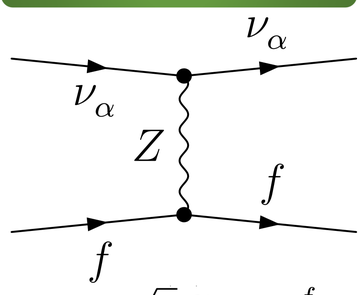
When neutrinos propagate in matter, the coherent forward scattering off the background particles leads to the **Mikheyev-Smirnov-Wolfenstein (MSW) matter potential** and could modify neutrino flavor conversions remarkably [1].

Charged-current



$$\mathcal{V}_{\rm CC} = \sqrt{2} G_\mu N_e \, c^e_{\rm V,CC}$$

Neutral-current



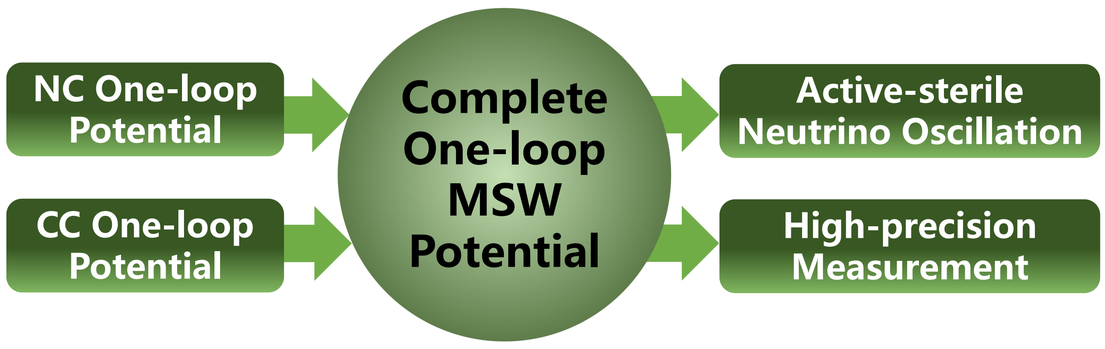
$$\mathcal{V}_{\rm NC} = \sqrt{2} G_\mu N_f c^f_{\rm V,NC}$$

At the one-loop level, the NC potential depends on the charged-lepton masses. In the Standard Model (SM), the ratio of the **flavor-dependent** part to the tree-level CC potential is [2]

$$\epsilon_{\mu\tau} \approx -\frac{3\alpha}{2\pi \sin^2\theta_{\rm w}} \frac{m_\tau^2}{m_W^2} \left[\ln\left(\frac{m_\tau^2}{m_W^2}\right) + \frac{5}{6} \right] \approx 10^{-5} .$$

- Previous works only concentrate on the flavor-dependent corrections.
- The one-loop corrections to the CC potential have not been studied thus far.

A complete one-loop calculation of the MSW potential is necessary.



Strategy for One-loop Calculations

1 Perform the one-loop renormalization of the SM in the on-shell scheme.

2 Compute the one-loop neutrino scattering amplitudes in ordinary matter.

↓ Finite scattering amplitudes

3 Extract corrections to the vector-type couplings of CC and NC interactions.

↓ The latest values of all physical parameters

4 Evaluate the one-loop corrections to the MSW matter potentials.

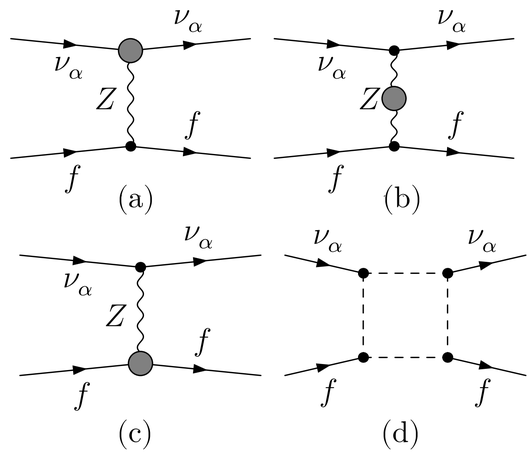
One-loop Scattering Amplitudes

Neutral-current

With equal number densities of protons and neutrons, the relative correction to NC potential is

$$\frac{\Delta c_{\rm V,NC}}{c_{\rm V,NC}} \approx 0.062 + 0.02 k^{-1} \approx 8\% .$$

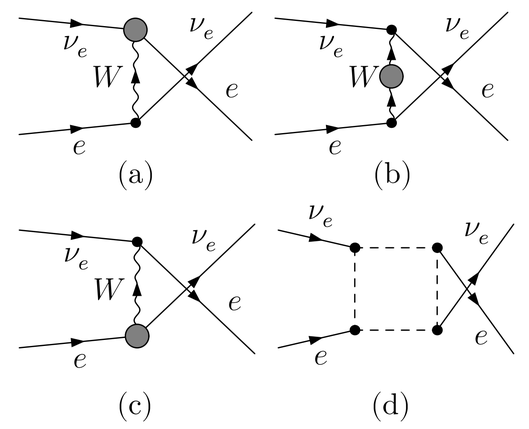
- It is the **same** for all-flavor neutrinos.
- The flavor-dependent difference is two orders of magnitude smaller.



Charged-current

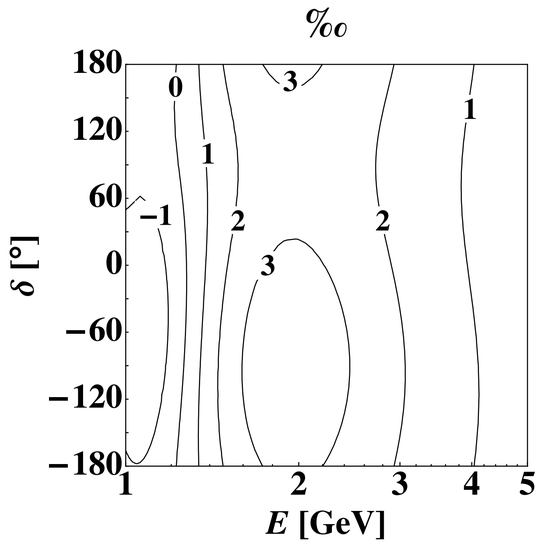
The relative correction to CC potential turns out to be **6%**.

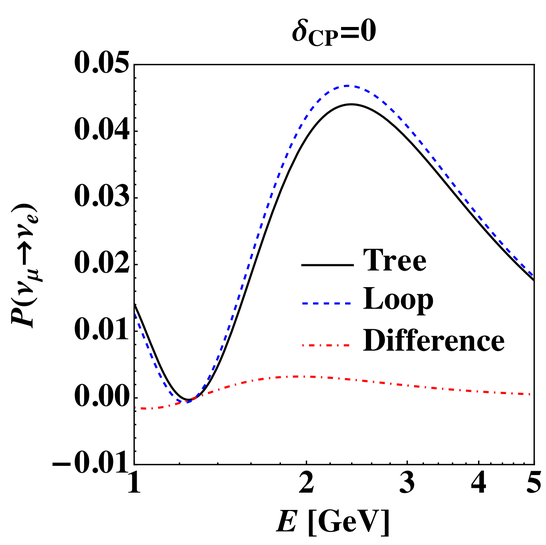
- This correction is only for electron-neutrinos and could **affect neutrino flavor conversions**.
- It can be probed in the next-generation long-baseline accelerator experiments, such as **DUNE** and **T2HK**.

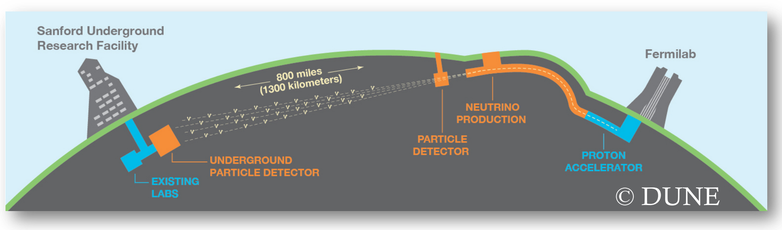


Sensitivity on DUNE

The difference between oscillation probabilities in two cases of neutrino mass ordering could be resolved at DUNE [3]. So the distinction at the sub-percent level induced by quantum corrections is promising to be detected.







DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

Summary

- A complete one-loop calculation of the MSW matter potential is presented in the SM.
- The relative size of the correction to CC potential of electron-neutrinos is 6%, while that to NC potential of all-flavor neutrinos can be as large as 8%.
- Such corrections could affect the neutrino oscillations and be examined in the next-generation experiments.

References

[1] L. Wolfenstein, Phys.Rev.D 17 (1978) 2369-2374
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S.P. Mikheyev and A.Y. Smirnov, Sov.J.Nucl.Phys. 42 (1985) 913-917
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[3] DUNE Collaboration, Conceptual Design Report (Vol. 2), 1512.06148

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