EFT analysis of the COHERENT experiment with right-handed Dirac neutrinos

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Introduction

The COHERENT experiment represents a very valuable probe to study NP presence in neutrino interactions with high precision in the low energy regime. Such nonstandard effects can affect both the neutrino detection (neutral current) and neutrino production (charged currents) processes.

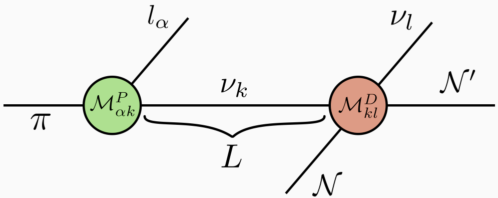
Our goal in this work is to extend the analysis previously done in Ref.[1], by adding 3 right-handed Dirac (RH) neutrinos.

[1] Bresó-Pla, V.; Falkowski, A.; González-Alonso, M.; Monsálvez-Pozo, K. J. High Energ. Phys. 2023, 2023, 74.

EFT formalism

The first element we need is a framework to take into account NP effects in production and detection[1 − 2]:

$$R_{\alpha}^{S} = \frac{N_S(t)}{32\pi L^2 m_S m_{\mathcal{N}} E_\nu} \sum_{j,k,l} e^{-i\frac{L\Delta m_{kl}^2}{2E_\nu}} \int d\Pi_{P'} \mathcal{M}_{\alpha k}^{P} \bar{\mathcal{M}}_{\alpha l}^{P} \int d\Pi_{D'} \mathcal{M}_{jk}^{D} \bar{\mathcal{M}}_{jl}^{D} \tag{1}$$



[1] Bresó-Pla, V.; Falkowski, A.; González-Alonso, M.; Monsálvez-Pozo, K. J. High Energ. Phys. 2023, 2023, 74.

[2] Falkowski, A.; González-Alonso, M.; Tabrizi, Z. J. High Energ. Phys. 2020, 2020, 48.

LNEFT

We will work with a low-energy EFT that includes RH-neutrinos.

$$\delta\mathcal{L}^{NC} \supset \frac{-1}{v^2}\cdot \left\{ \sum_{X,X'} \left[\epsilon^{qq}_{XX'}\right]_{\alpha\beta} \left(\bar{\nu}_\alpha \Gamma_X \nu_\beta\right)\left(\bar{q}\Gamma_{X'} q\right) + \right.$$

$$\left. + \frac{1}{2}\left[\epsilon_F\right]_{\alpha\beta} \bar{\nu}_\alpha \sigma_{\mu\nu} P_L \nu_\beta F^{\mu\nu} + \text{h.c.} \right\}$$

$$\delta\mathcal{L}^{\pi} \supset -\frac{2V_{ud}}{v^2}\cdot \sum_{XX'} \left[\epsilon^{ud}_{XX'}\right]_{\alpha\beta} \left(\bar{\nu}_\alpha \Gamma_X l_\beta\right)\left(\bar{d}\Gamma_{X'} u\right)$$

$$\delta\mathcal{L}^{\mu} \supset -\frac{2}{v^2}\cdot \sum_{X,X'} \left[\rho_{XX'}\right]^{ab}_{\alpha\beta} \left(\bar{l}_\alpha \Gamma_X \nu_\beta\right)\cdot\left(\bar{\nu}_\alpha \Gamma_{X'} l_\beta\right).$$

The Wilson coefficients $\epsilon^{qq}_{XX'}$, $\epsilon^{ud}_{XX'}$ and $\rho_{XX'}$ encapsulate the NP dependence and can be matched to specific NP models.

From quarks to nucleons and nucleus

The nucleus can be considered a non-relativistic particle. For this reason, we will perform a matching between the quark level Lagrangian and the non-relativistic nucleon fields ψ_N, where $N = (p, n)$.

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Our findings about the lack of enhancement for the tensor operator differ from Ref.[3], but are consistent with, e.g., the recent analysis of Ref.[4] in the context of dark-matter searches.

[3] Sierra, D. A.; De Romeri, V.; Rojas, N. Phys. Rev. D 2018, 98, 075018

[4] Glick-Magid, A. Non-relativistic nuclear reduction for tensor couplings in dark matter direct detection and μ to e conversion, arXiv:2312.08339, 2023.

Preliminary results

The differential number of events is

$$\frac{dN}{dt\,dT} = g_\pi(t)\frac{dN^{prompt}}{dT} + g_\mu(t)\frac{dN^{delayed}}{dT} \tag{2}$$

$$\frac{dN^{prompt}}{dT} = \frac{N_\pi N_T \mathcal{F}(q^2)^2 m_\mathcal{N}}{32\pi^2 v^4 L^2} \sum_X \left\{ (\tilde{Q}_x^\mu)^2 f_x^\mu(T) \right\} \tag{3}$$

$$\frac{dN^{delayed}}{dT} = \frac{N_\mu N_T \mathcal{F}(q^2)^2 m_\mathcal{N}}{32\pi^2 v^4 L^2} \times \sum_X \left\{ (\tilde{Q}_x^{\bar{\mu}})^2 f_x^{\bar{\mu}}(T) + (\tilde{Q}_x^e)^2 f_x^e(T) \right\} \tag{4}$$

$$\tilde{Q}_x^l = \tilde{Q}_x^l(\theta_W, \epsilon_{XX'}^{qq}, \epsilon_{XX'}^{ud}, \rho_{XX'}) \tag{5}$$

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- **Second order NP terms.** The number of charges is reduced to 9, since $(\tilde{Q}_V^{\mu})^2$ and $(\tilde{Q}_V^{\bar{\mu}})^2$ are affected by different NP terms in production at this order.