GeV-scale neutrinos at DUNE

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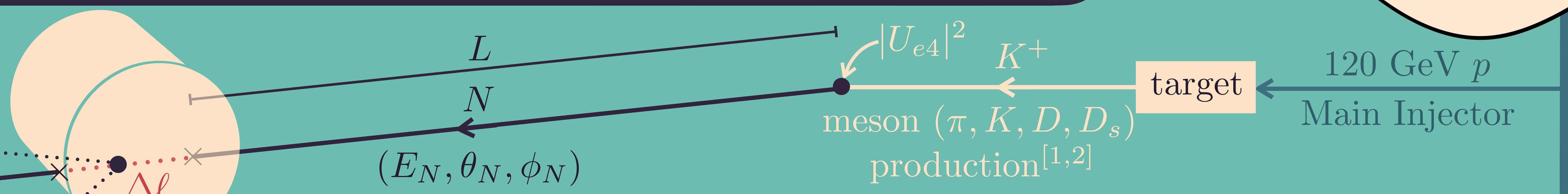
The simplest SM extension to implement ν masses involves addition of at least 2 heavy RH ν (HNLs) ⇒ flavor ν mix with HNLs via mixing matrix U

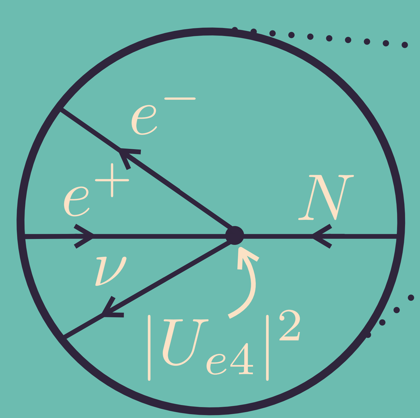
$$\nu_\alpha = \sum_{i=1}^{3} U_{\alpha i}\nu_i + \sum_{j=4}^{3+n} U_{\alpha j} N_j = U_{\alpha i} n_i$$

If only one HNL light enough to be produced in the experiment, phenomenology described by 3 mixings $U_{\alpha 4}$ + 1 mass M_4.

DUNE ND MPD

HPgTPC + ECAL





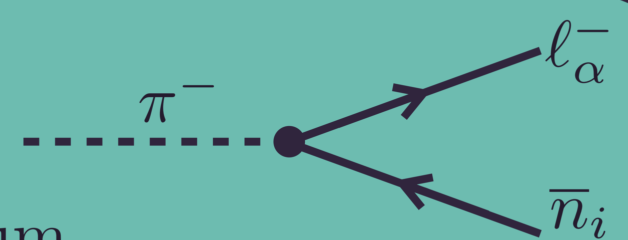
Number of decay events inside DUNE ND for a given channel c

$$N_c(\mathrm{ND}) = \mathrm{BR}_c \int dE_N e^{-\frac{\Gamma L}{\gamma\beta}} \left(1 - e^{-\frac{\Gamma \Delta\ell}{\gamma\beta}}\right) \frac{d\phi_N}{dE_N} \leq 2.44 \Rightarrow 90\%\ \mathrm{CL\ (no\ bg)}^{[3]}$$

Fully differential HNL production & decay events needed ⇒ Monte Carlo generator (MadGraph5[4])

Integrating out the vector bosons & replacing the hadronic matrix elements, effective op. describing interactions between light (up to 2 GeV) mesons and 1 HNL are built:

- Pseudoscalar interactions

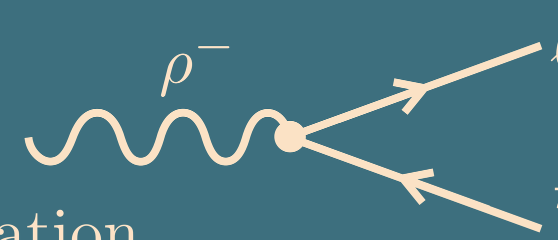


$$\langle 0|j^A_{a,\mu}|P_b\rangle = i\delta_{ab}\frac{f_P}{\sqrt{2}}p_\mu \quad \text{momentum}$$

$$\mathcal{O}_{\pi\ell_\alpha\bar{n}_i} = i\sqrt{2}G_F U_{\alpha i} V_{ud} f_\pi \bar{\ell}_\alpha (m_\alpha P_L - m_i P_R) n_i \pi^- + \mathrm{h.c.}$$

dominated by heavy states (chiral enhancement)

- Vector interactions

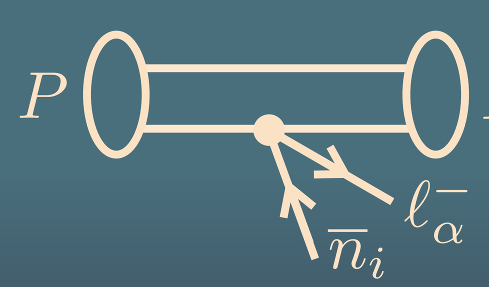


$$\langle 0|j^V_{a,\mu}|V_b\rangle = \delta_{ab}\frac{f_V}{\sqrt{2}}\epsilon_\mu \quad \text{polarization}$$

$$\mathcal{O}_{\rho\ell_\alpha\bar{n}_i} = -\sqrt{2}G_F U_{\alpha i} V_{ud} f_\rho \rho^-_\mu \left(\bar{\ell}_\alpha \gamma^\mu P_L n_i\right) + \mathrm{h.c.}$$

similar results for neutral meson interactions.

- Semileptonic meson decays



$$\langle D|j^V_{W,\mu}|P\rangle = \frac{1}{2}V_{qq'}\left(p_\mu f_+(q^2) + q_\mu f_-(q^2)\right)$$

form factors[5,6]

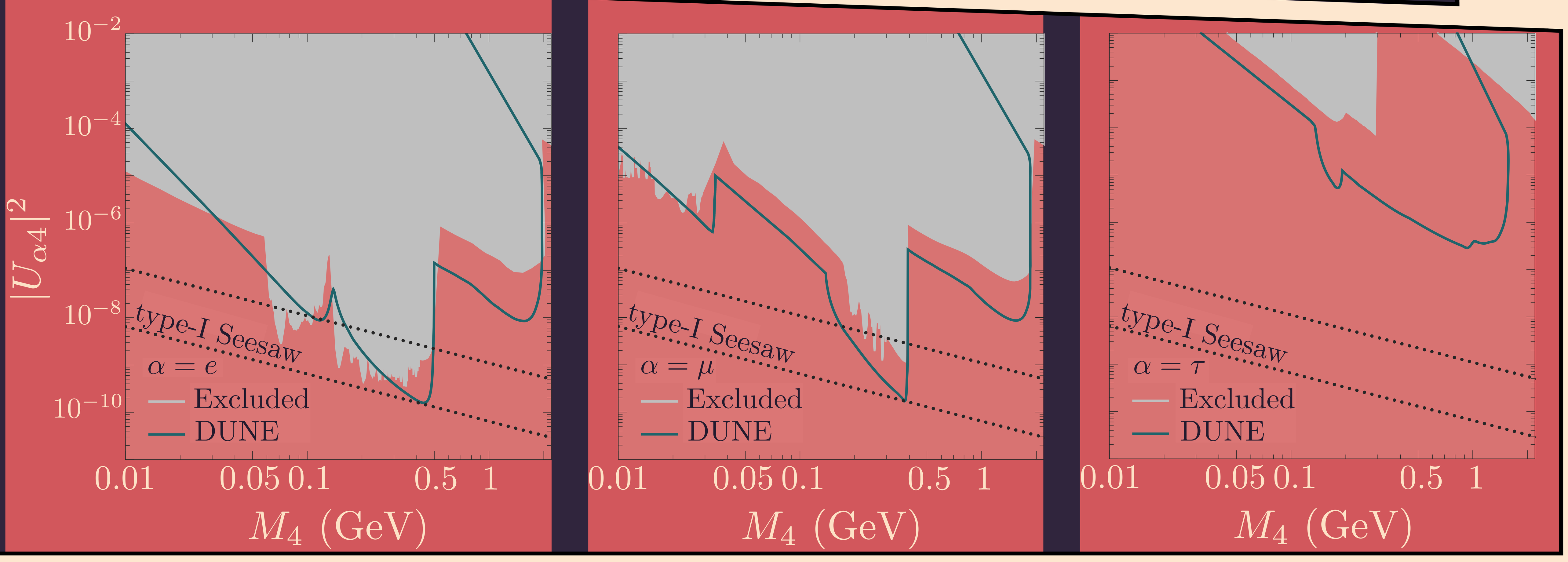
$$\mathcal{O}_{PD\ell_\alpha\bar{n}_i} = \sqrt{2}G_F V_{qq'} U_{\alpha i}\bar{\ell}_\alpha \left[\left(f_+(q^2) - f_-(q^2)\right)(m_\alpha P_L - m_i P_R)\phi_D - 2if_+(q^2)\left(\partial_\mu \phi_D\right)\gamma^\mu P_L\right] n_i \phi_P^\dagger + \mathrm{h.c.}$$

These effective operators have been implemented in a FeynRules[7] model file publicly available[8].

DUNE ND expected sensitivity at 90% CL

- $7.7 \cdot 10^{21}$ PoT
- Background assumed negligible for 20% signal efficiency cuts[9]

Most bounds improved!!



References:

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