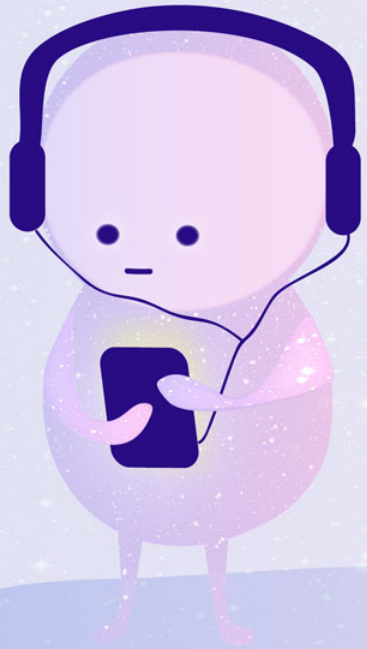
UCL

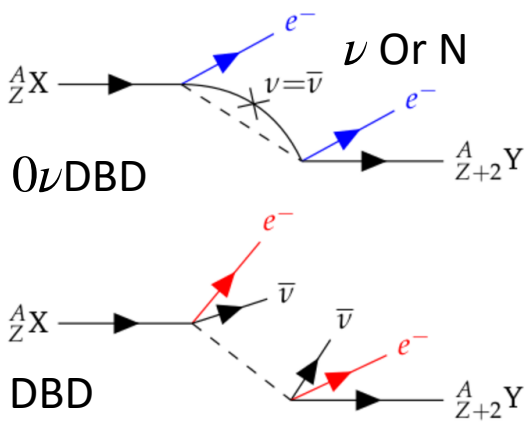
Constraining Heavy Neutral Leptons with DUNE & Neutrinoless Double Beta Decay



Zhong Zhang
zhong.zhang.19@ucl.ac.uk
University College London
In Collaboration with:
P.D.Bolton, F.F.Deppisch, M.Rai
arXiv:2211.xxxxx

UK HEP Forum 2022
22/11/2022

Neutrinoless Double Beta Decay (0νDBD)



$${}^A_Z\mathrm{X} \rightarrow {}^A_{Z+2}\mathrm{Y} + 2e^-$$

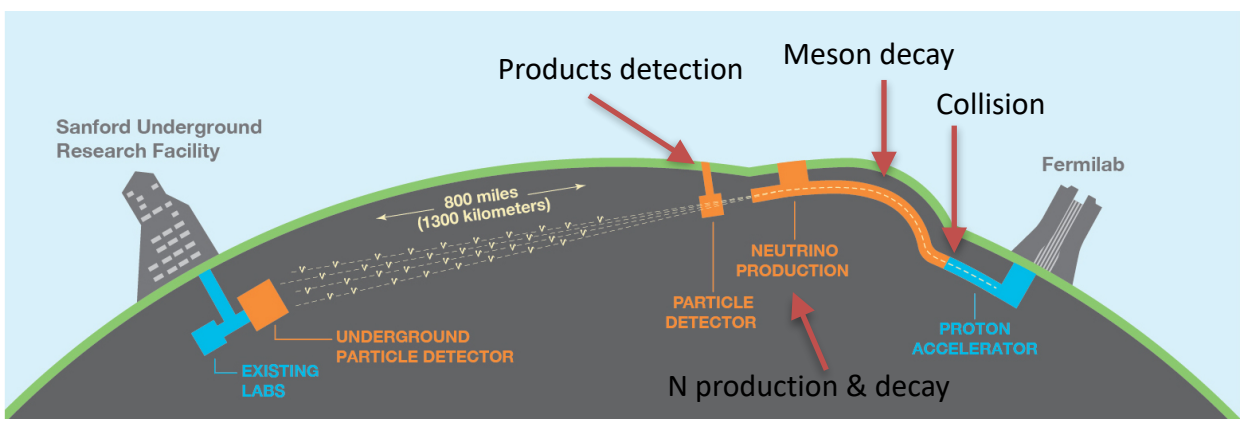
Atomic phase space

Decay half-life: $$T_{1/2}^{-1} = \left|m_{\beta\beta}\right|^2 G^{0\nu} \left|M^{0\nu}\right|^2$$

Particle Physics: $$m_{\beta\beta} = \sum_{i=1}^{3} U_{ei}^2 m_{\nu_i}$$

Nuclear Physics

DUNE Experiment



Proton-target interaction

Mesons

$$K/\pi^+ \rightarrow l^\pm N \rightarrow l^\pm \nu$$

Detected at ND

Heavy Neutral Leptons in Seesaw Scenario

$$\mathscr{M}_\nu = \begin{pmatrix} 0 & m_{D,1} & m_{D,2} \\ m_{D,1} & \mu_R & m_S \\ m_{D,2} & m_S & \mu_S \end{pmatrix} = U \begin{pmatrix} m_\nu & 0 & 0 \\ 0 & m_N & 0 \\ 0 & 0 & m_N\left(1+r_\Delta\right) \end{pmatrix} U^T$$

1-generation Mixing Matrix:

$$U_{1-d} \approx \begin{pmatrix} 1 & s_{e1} & s_{e2}e^{-i\delta} \\ -s_{e1}c_{12} - s_{e2}s_{12}e^{i\delta} & c_{12} & s_{12} \\ s_{e1}s_{12} - s_{e2}c_{12}e^{i\delta} & -s_{12} & c_{12} \end{pmatrix} \cdot diag(1, e^{i\phi_1}, e^{i\phi_2}) + \mathcal{O}\left(s_{ei}^2\right)$$

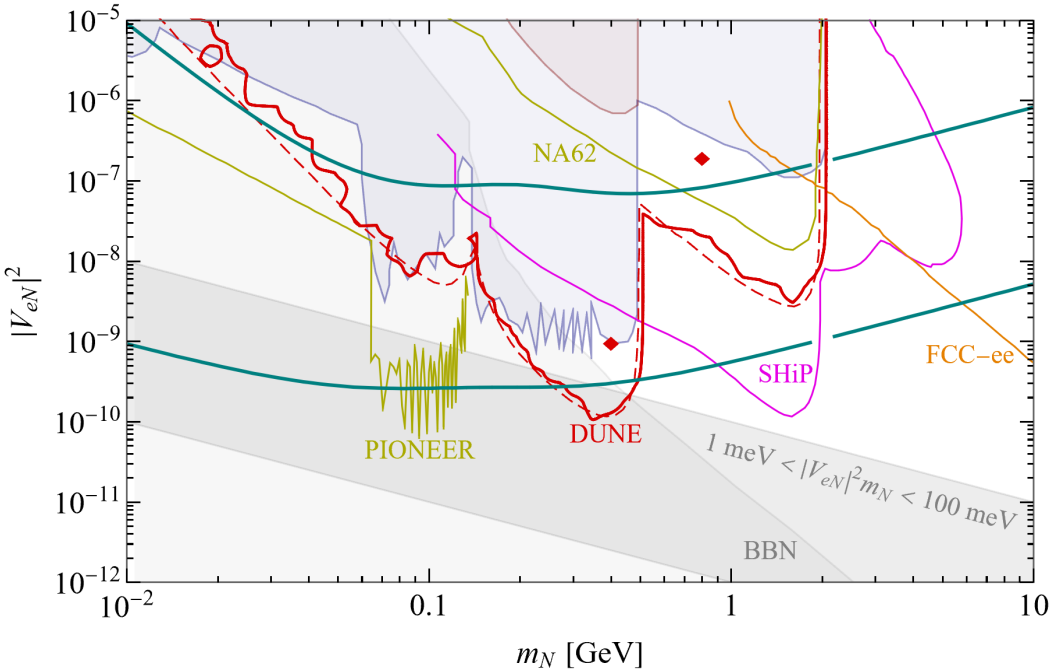
DBD Decay Time (effective mass)

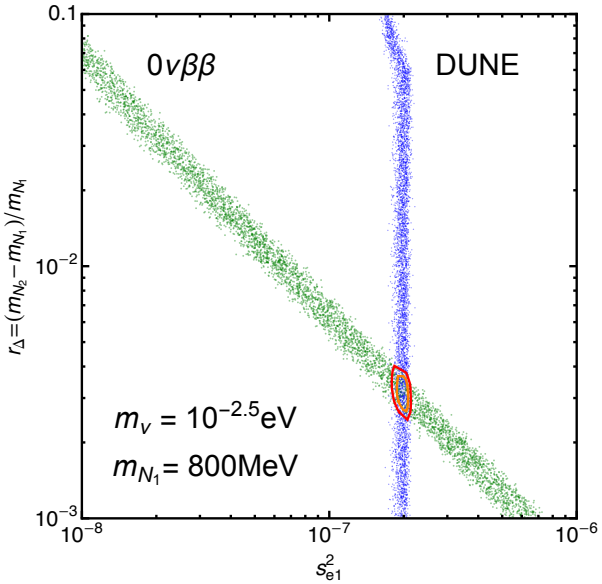
Light neutrino contribution

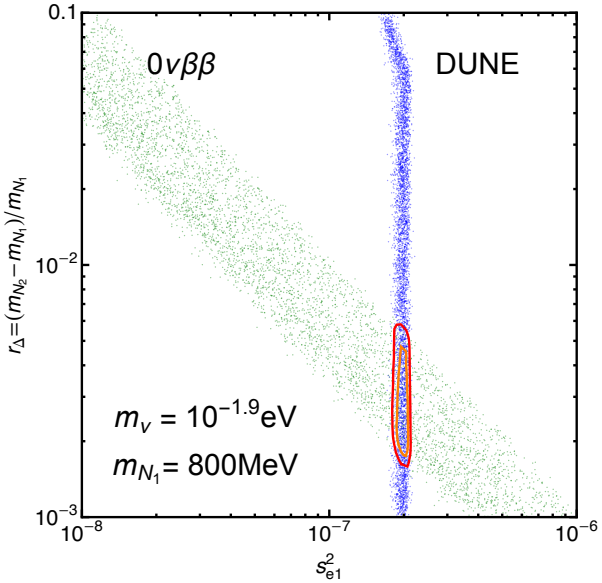
$$\frac{1}{T_{1/2}^{0\nu}} = G^{0\nu} g_A^4 m_p^2 \left| m_\nu M_\nu^{0\nu} + \sum_{i=1}^{2} V_{eN_i}^2 m_{N_i} M^{0\nu}\left(m_{N_i}\right) \right|^2$$

Two HNL contributions

DUNE & DBD Constraints







Benchmark: 400MeV at $|V_{eN}|^2 = 10^{-9}$

800MeV at $|V_{eN}|^2 = 2 \times 10^{-7}$

1. DUNE-mixing
2. DBD-splitting
3. Overlap

Thanks for listening

Questions