DPF-PHENO 2024

The Center for Neutrino Physics

VIRGINIA TECH

Heavy Neutral Lepton Decay

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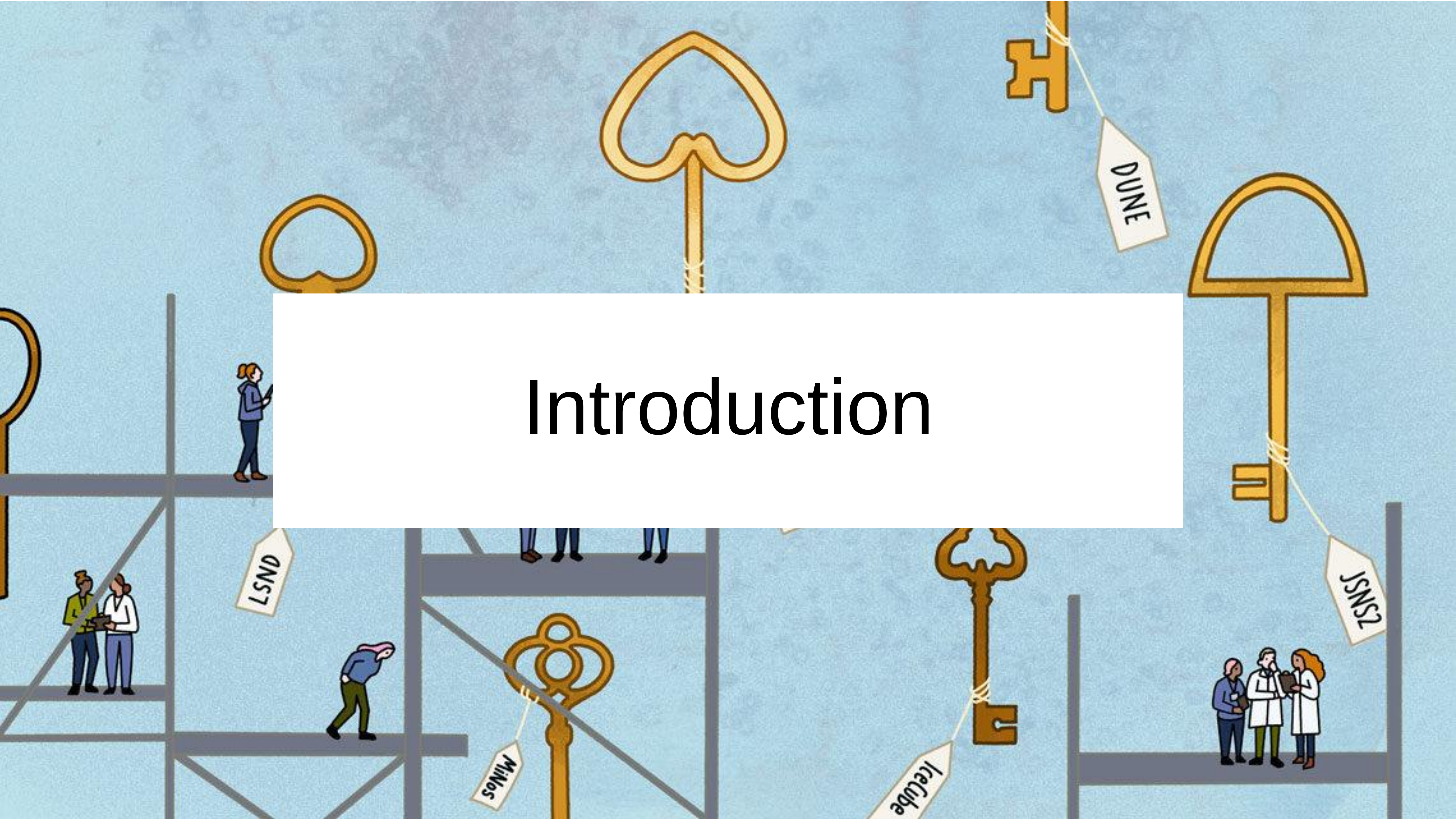
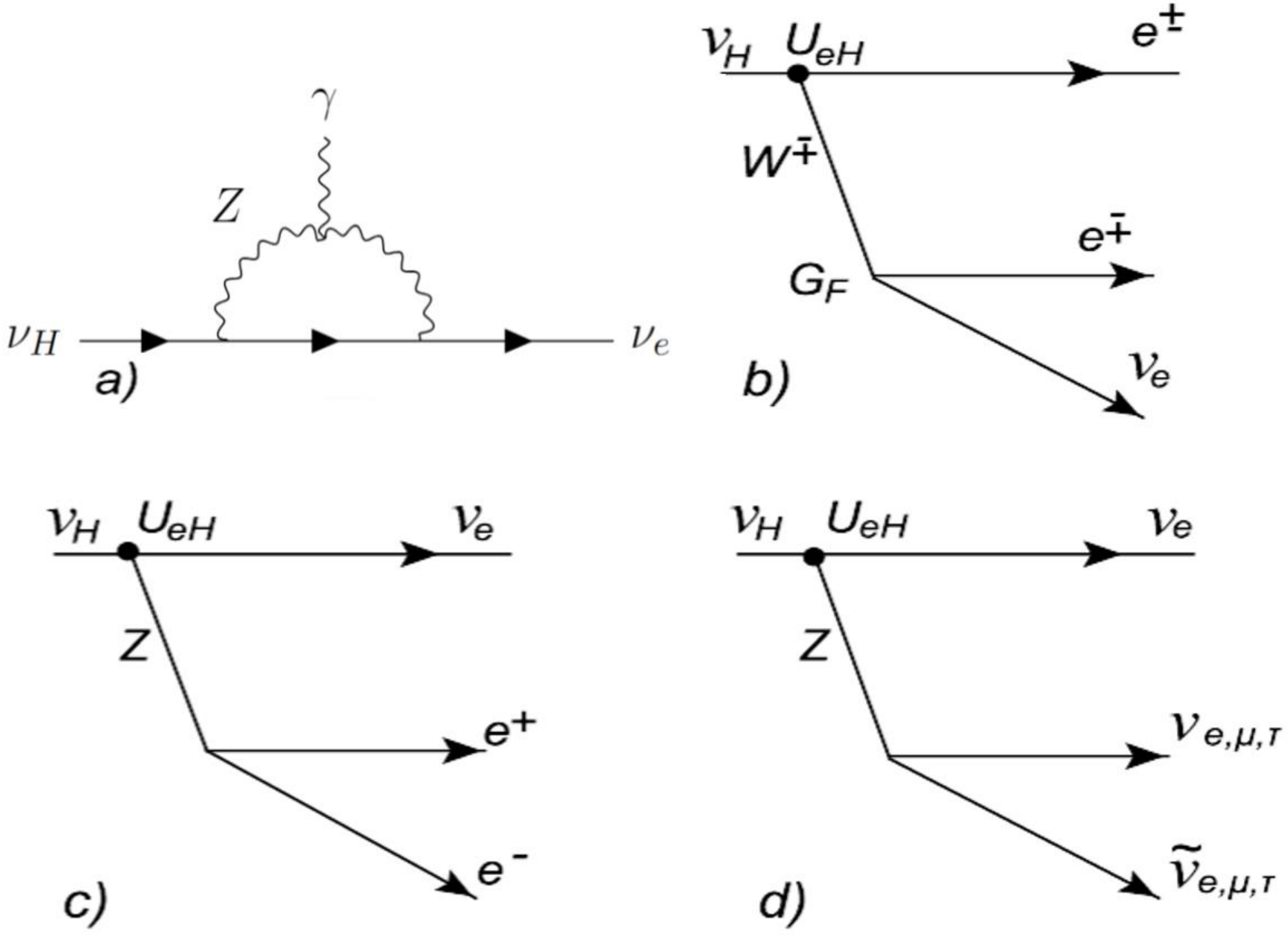
Introduction

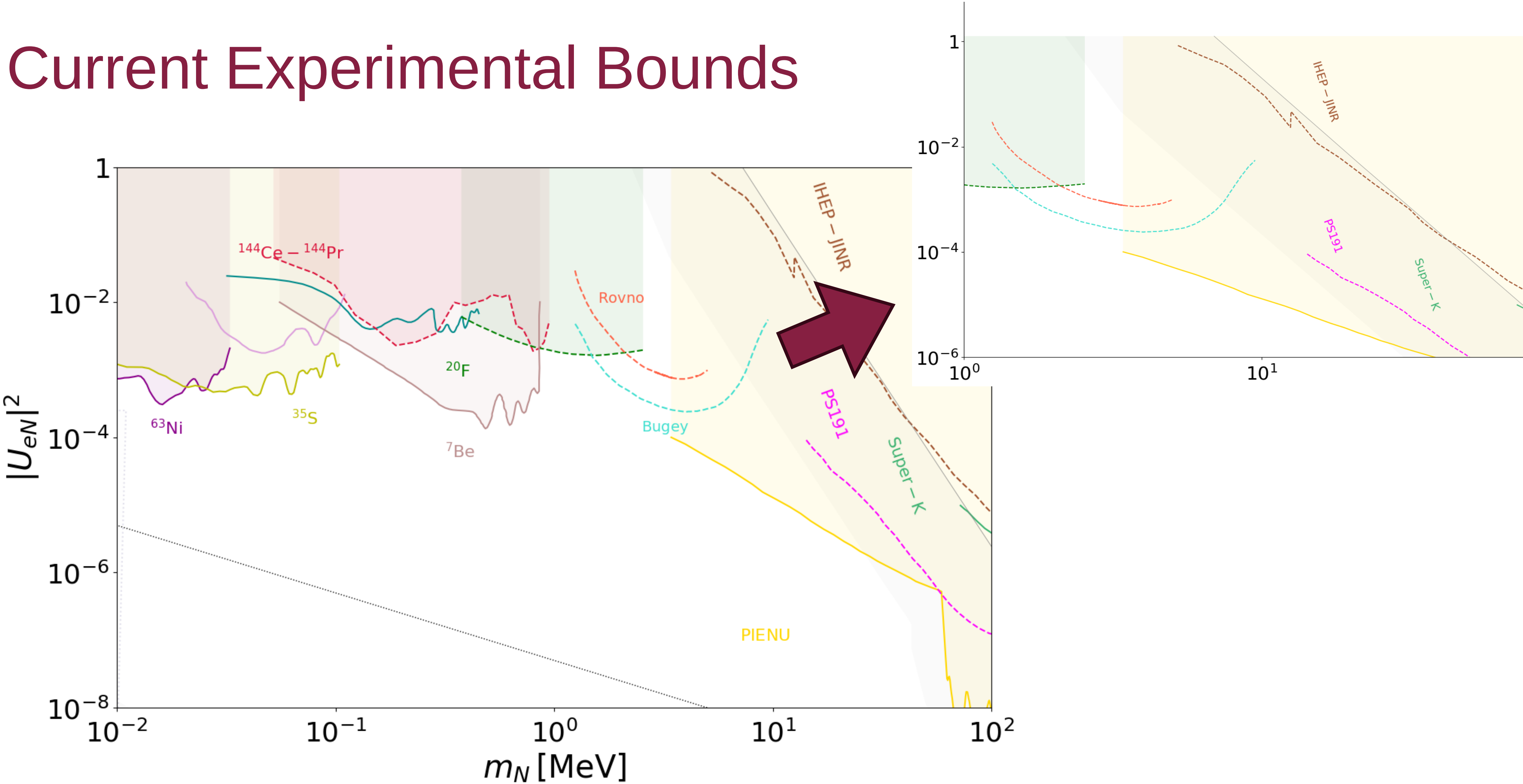


Heavy Neutral Lepton (MeV) Decay



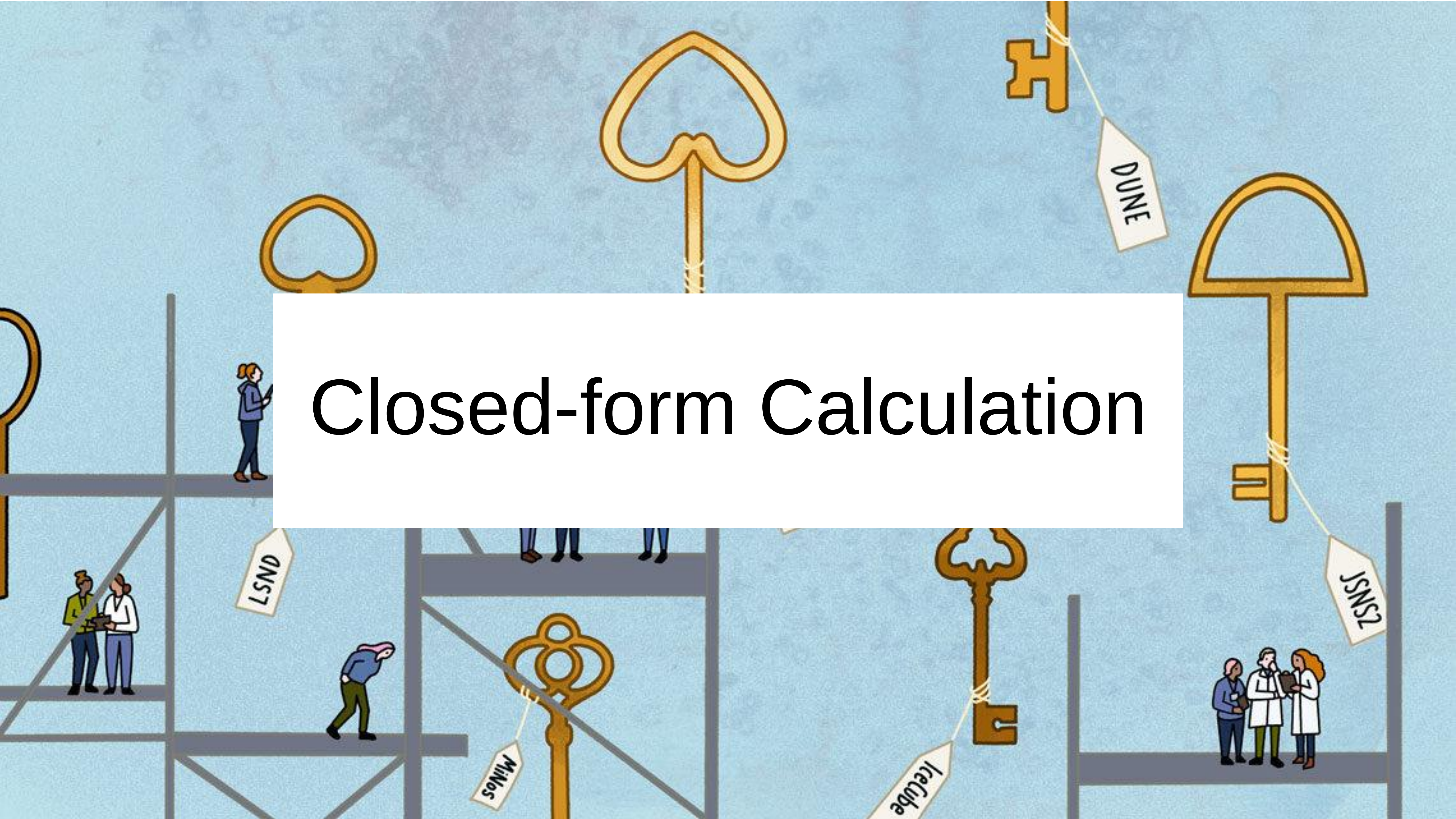
- $\nu_H \to \nu_e + \gamma$
- $\underline{\nu_H \to \nu_e + e^+ + e^-}$
- $\nu_H \to \nu_e \nu_i \tilde{\nu}_i$ (Invisible)

Current Experimental Bounds

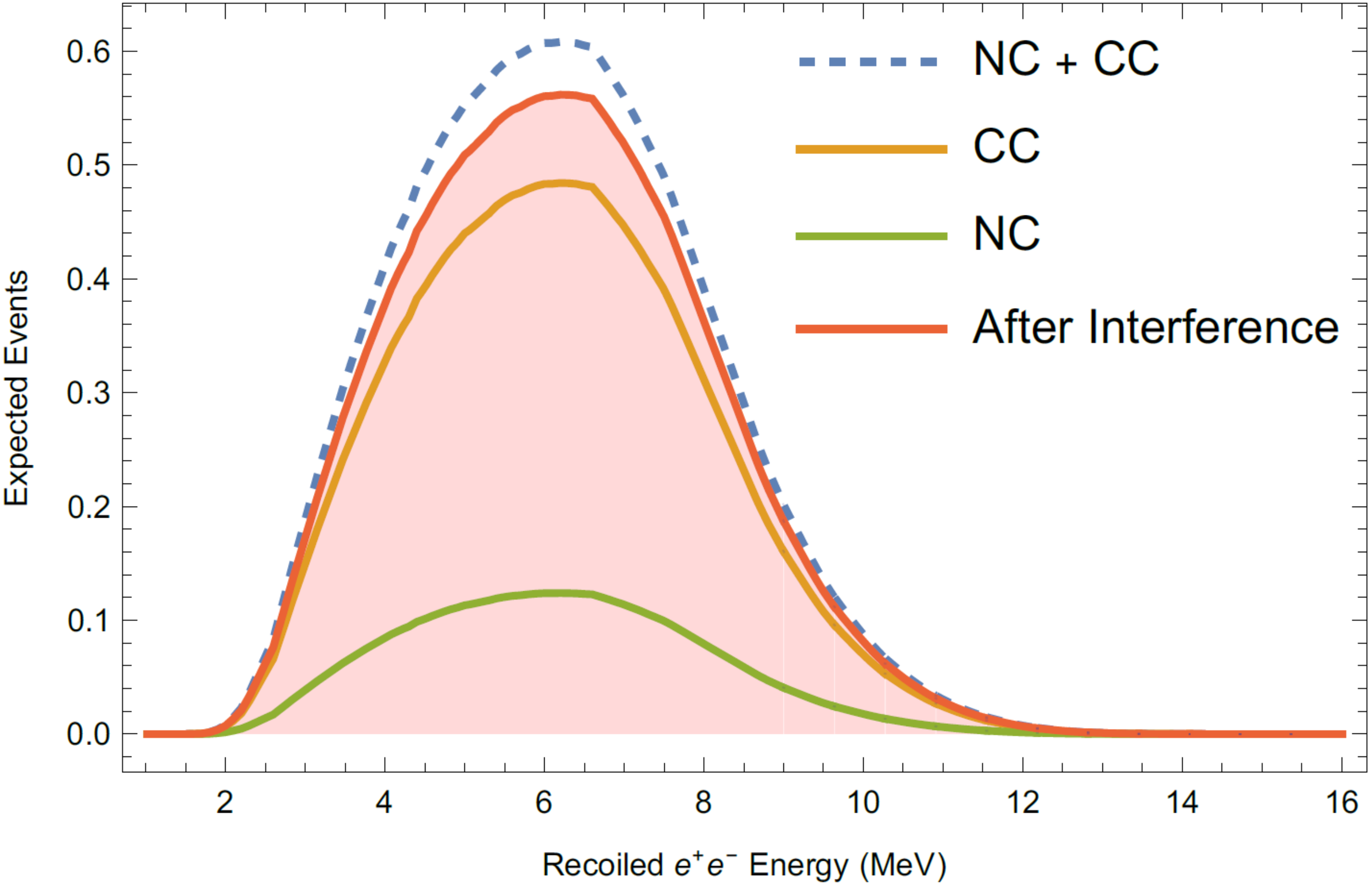


Courtesy of Bolton, Deppisch

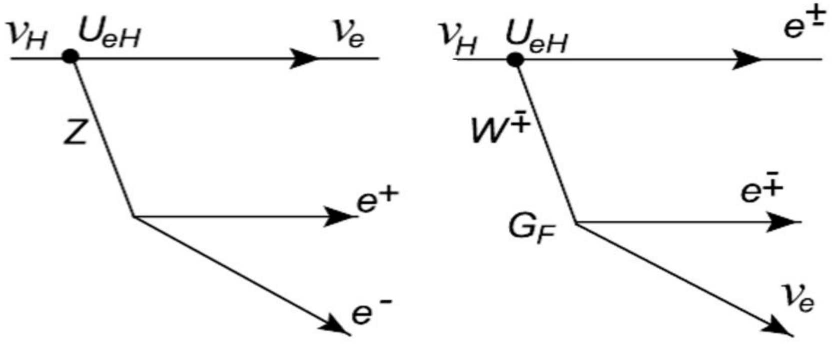
Closed-form Calculation



Interference Between NC and CC[1] Channels



- This is a comparison between the CC channel, NC channel, their interfered channel (in shade), and their incoherently summed channel (dashed).



1. NC: Neutral Current; CC: Charged Current.

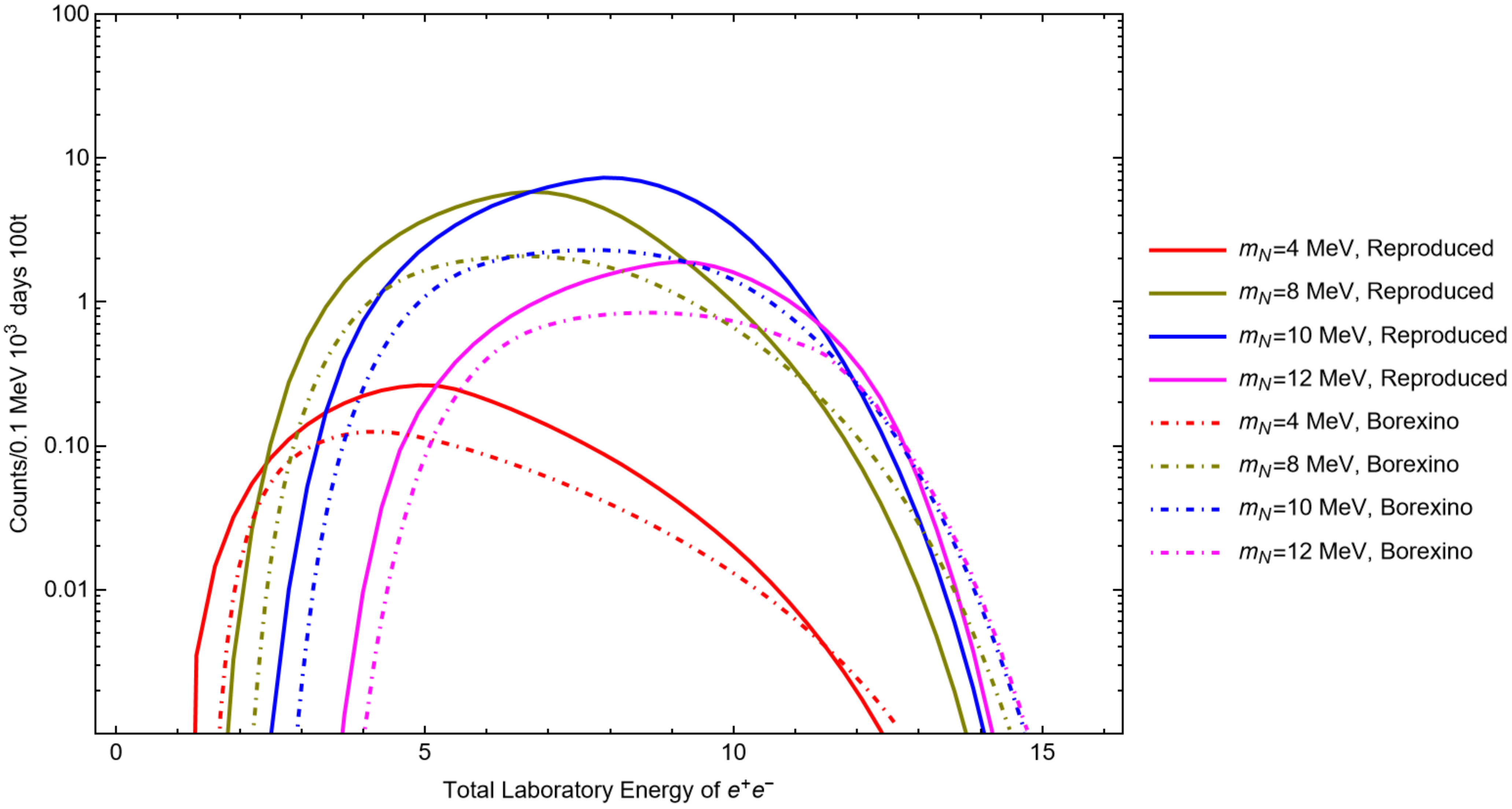
Expected Decay Width

$$\Gamma_0 = \frac{G_F^2 m_{\nu_H}^5}{192\pi^3}, \qquad \frac{d^2\Gamma}{dl^0 d\cos\theta} = \Gamma_0 |U_{s1}|^2 \frac{d^2\overline{\Gamma}}{dl^0 d\cos\theta}$$

$$\begin{aligned}\frac{d^2\overline{\Gamma}}{dl^0 d\cos\theta} \quad = \quad & 2(1-Q^2)^2 \sqrt{1-\frac{4m_e^2}{Q^2}}\,\frac{1}{Q^2}\Bigg\{ \\ & \left[X^1\left(Q^2+2Q^4-2m_e^2(Q^2-1)\right)-6ZQ^2m_e^2\right] \\ & -|\vec{s}|\cos\theta\left[X\left(Q^2-2Q^4+2m^2(1+Q^2)\right)+6ZQ^2m_e^2\right]\Bigg\}\end{aligned}$$

1. $X = [(g_V+1)^2 + (g_A+1)^2]$, $Y = [(g_V+1)(g_A+1)]$, and $Z = [(g_V+1)^2 - (g_A+1)^2]$.

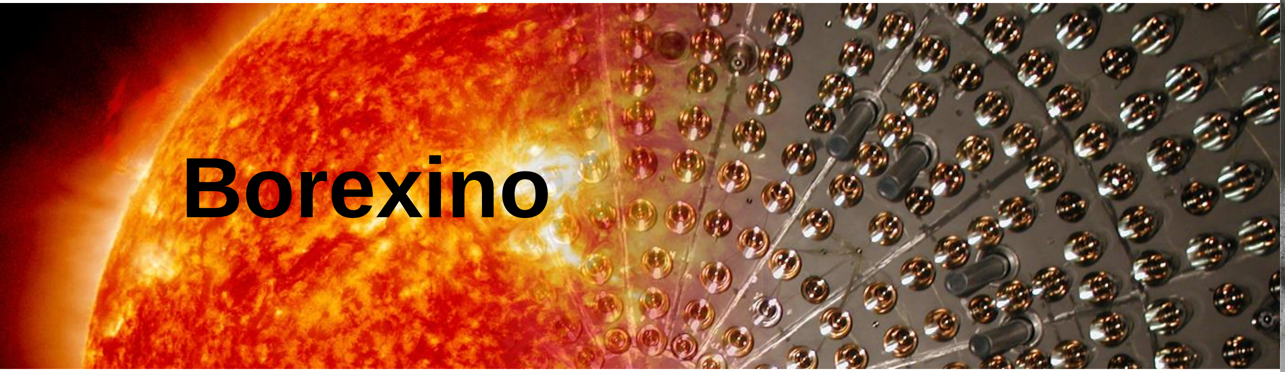
Expected Events from the Decay



Bellini et al (2013).

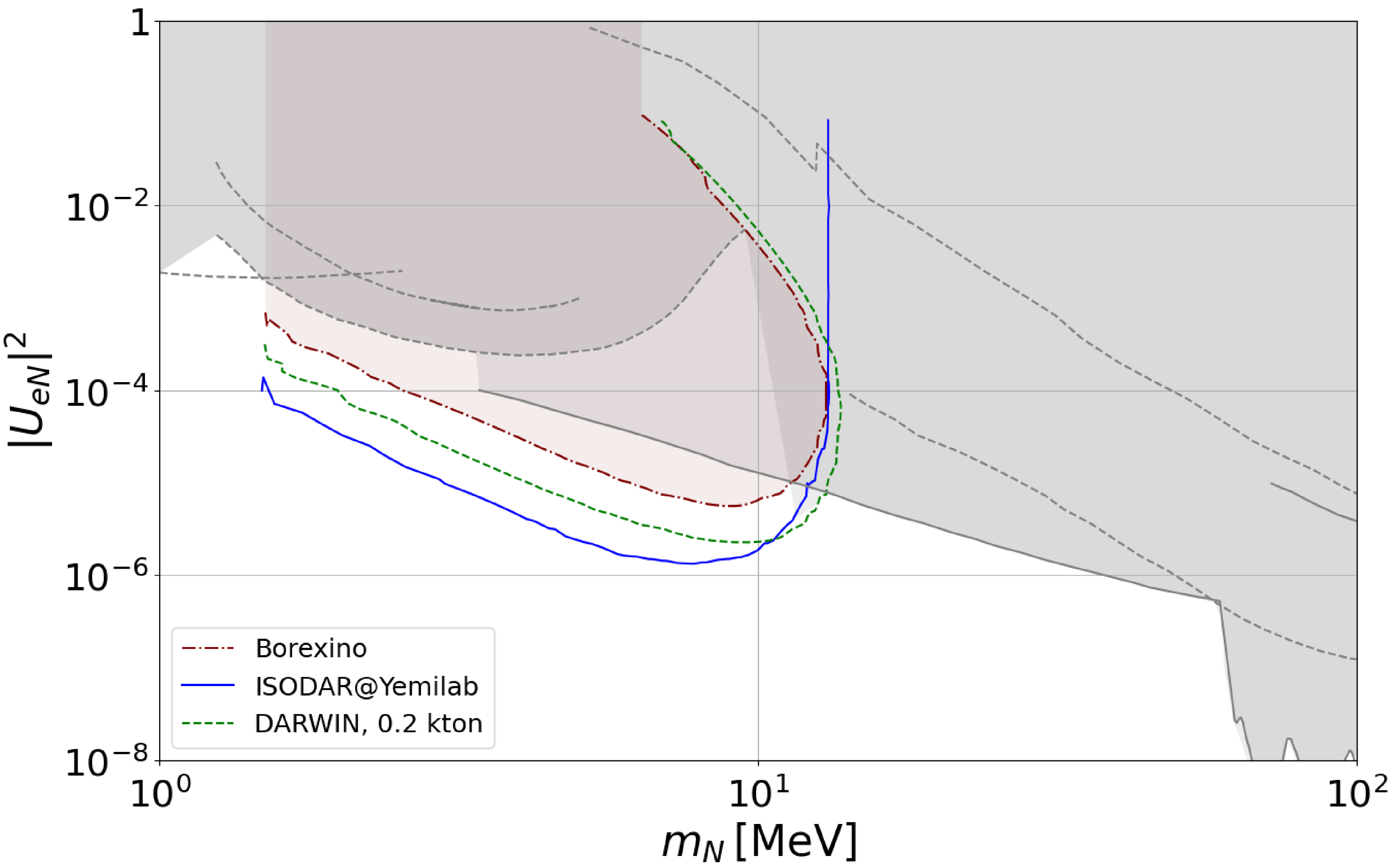
Sensitivities of Experiments

Experiments we considered



DAEδALUS
IsoDAR

Our imposed bounds for this interaction

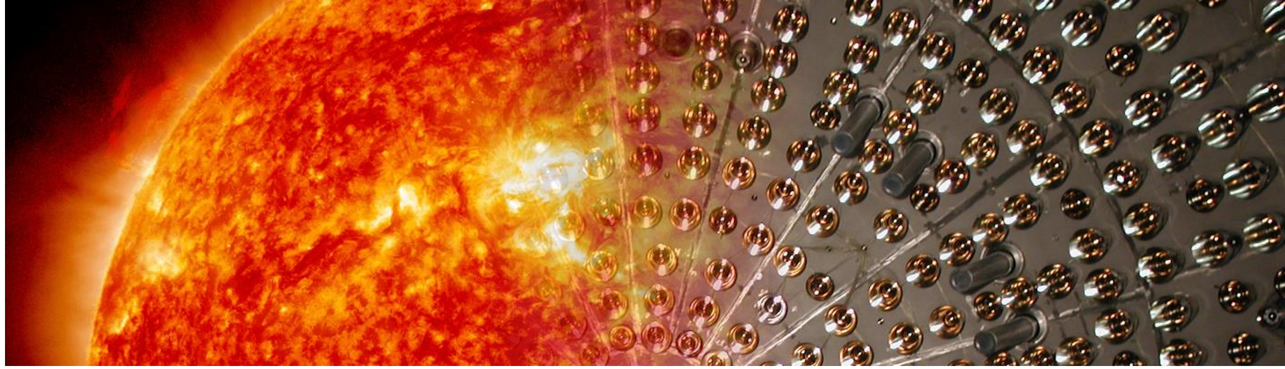


Summary

- We presented our closed-form calculations of heavy neutral lepton decay which correctly considered interference.
- The sensitivities from the solar neutrino gets more significant if increasing the detector’s volume.
- Reactor neutrino’s sensitivity stops increasing at a point when increasing detector’s volume further.
- Liquid argon detector has less background compared to scintillator.
- The sensitivity increases when increasing the running time.

Thank You

Borexino (Backup slide 1)



- 100 ton fiducial volume of scintillator
- Running for 446 days
- Bin size: 200 keV
- Assumed the background to be well constrained
- Poisson likelihood

Yemilab (Backup slide 2)

- 1.16 kton fiducial volume
- Running for 5 years (with 4 years reactor ON if considering ISODAR)
- Bin size: 100 keV
- Assumed background from
- Poisson likelihood
- Energy resolution $6.4\%/(\sqrt{[\mathrm{E}(\mathrm{MeV})]})$
- 32% Efficiency

DUNE (Backup slide 3)

- 40 kton fiducial volume of liquid argon (just for fun)
- Running for 5 years
- Bin size: 300 keV
- Assumed the background to be well constrained
- Poisson likelihood
- Energy resolution 1.53%/$(\mathrm{E}(\mathrm{MeV}))$

Darwin (Backup slide 4)

- 0.2 kton fiducial volume of liquid argon
- Running for 5 years
- Bin size: 160 keV
- Assumed the background to be well constrained
- Poisson likelihood
- Energy resolution 1.53%/$(\mathrm{E}(\mathrm{MeV}))$