Exploring the multi-dimensional space of dark neutrinos at the T2K near detector

Nicolò Foppiani – Harvard University, nicolofoppiani@g.harvard.edu

with Carlos Argüelles (Harvard) and Matheus Hostert (Minnesota & Perimeter)

One Minute Summary

Heavy neutrinos coupled to a dark photon - dark neutrinos - as a solution to short-baseline anomalies.

Multiple studies have shown how minimal solutions are not enough to explain the MiniBooNE-LSND puzzle. Here we exploit data from the T2K near detector to place constraints on a non-minimal model. We conclude that T2K data is incompatible with such an explanation for the MiniBooNE anomaly, unless dark neutrinos decay in less than O(1) cm.

Default parameters:

- $\alpha_{dark} = 0.4$
- $m_N = 100$ MeV
- $|V_{\alpha N}|^2 = 2.2 \times 10^{-7}$
- $m_{Z'} = 1.25$ GeV
- $\varepsilon = 2.1 \times 10^{-2}$

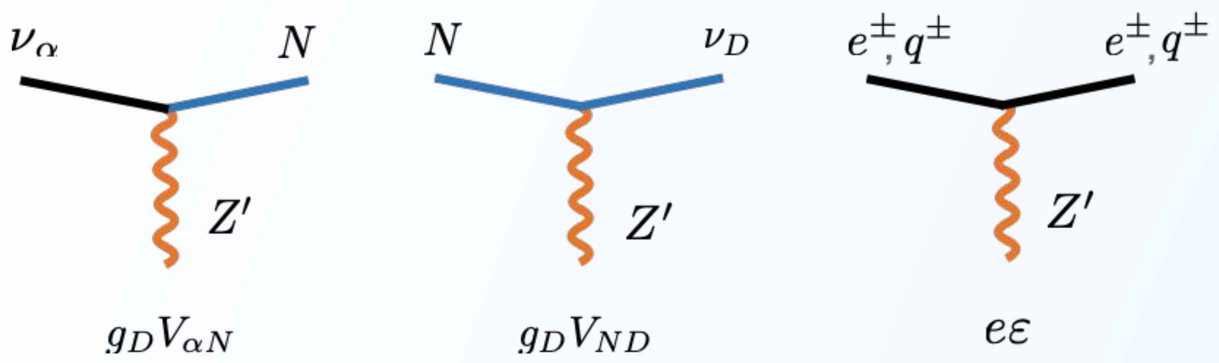
Dark Neutrinos at short-baseline experiments

We study a dark sector with **HEAVY NEUTRINOS** and a **DARK PHOTON.**

The dark sector couples to the Standard Model only via portal couplings: Neutrino mixing and kinetic mixing.

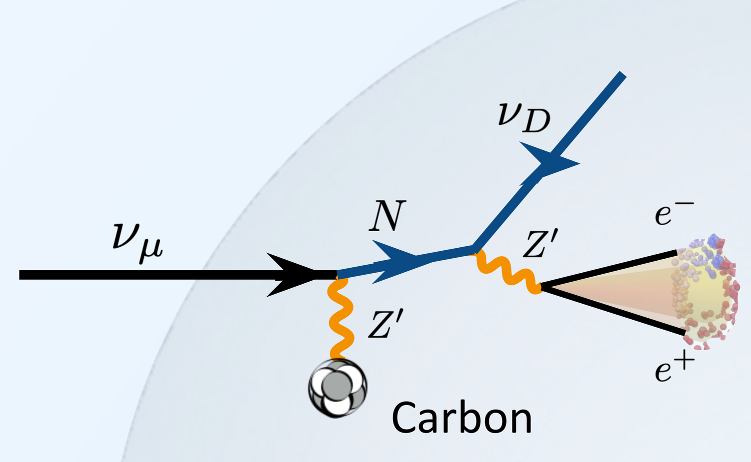
The phenomenological Lagrangian is given by:

$$\mathscr{L} \supset \frac{m_{Z'}^2}{2} Z'^{\mu} Z'_{\mu} + m_N \overline{N} N + Z'_{\mu} \left(e\varepsilon J^{\mu}_{\rm EM} + g_D V_{ND} \overline{N} \gamma^{\mu} \nu_D + g_D \overline{\nu_\alpha} \gamma^{\mu} N \right)$$



Heavy neutrinos N are produced in **scattering** and can **decay to lighter neutral particles ν_D**.

The light states ν_D decouple the couplings responsible for scattering and decay.

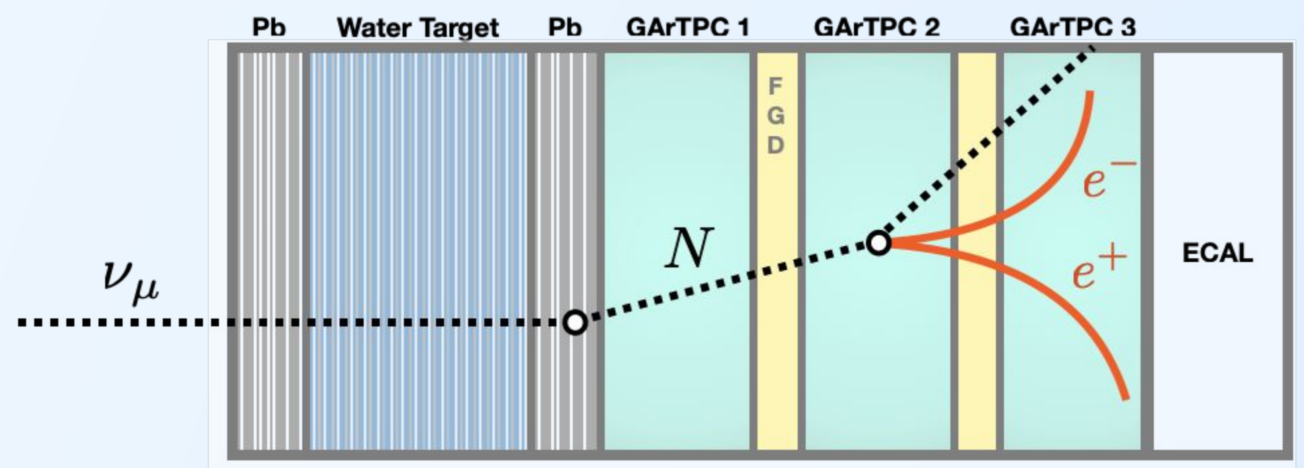


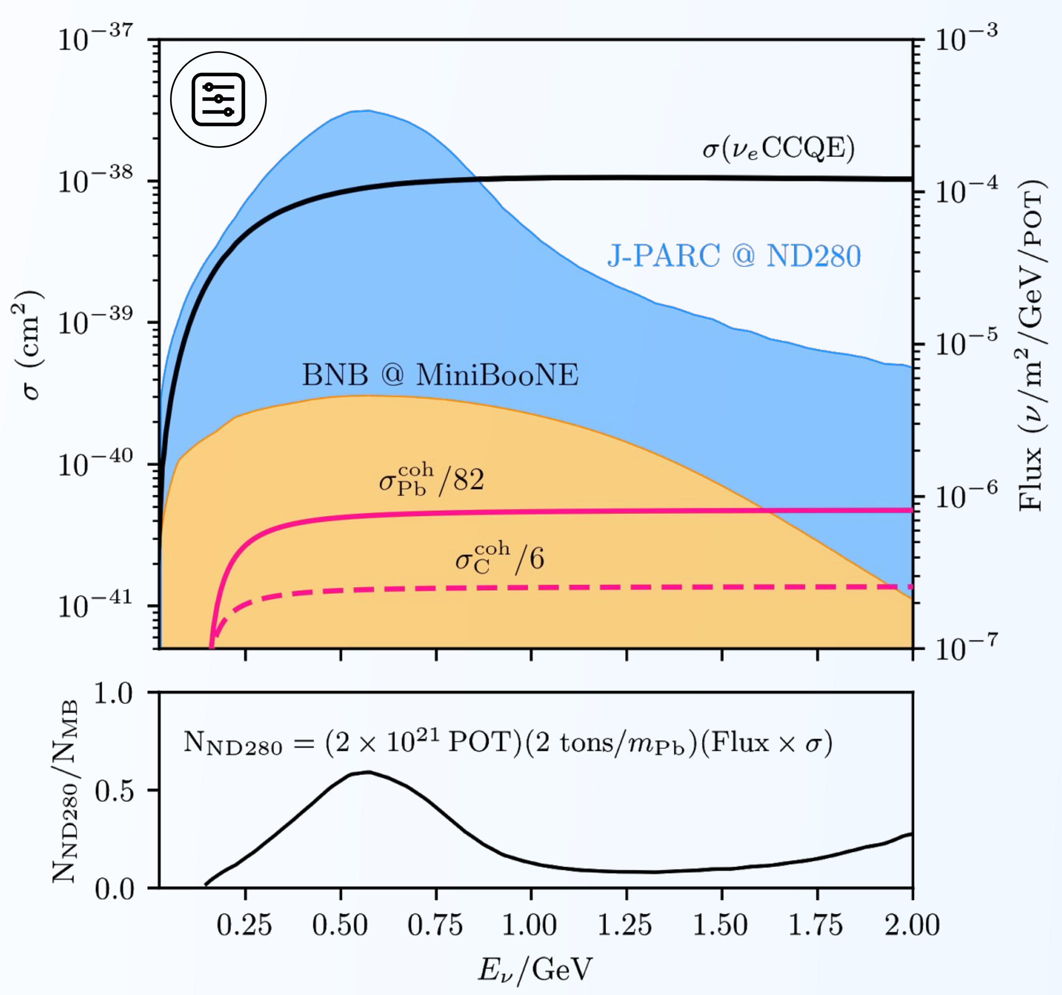
MiniBooNE

Explanation of the excess of electron-like events in dark heavy neutrino models.

Heavy Neutrinos @ ND280

Upscattering in ND280, the off-axis near detector of T2K, produces e+e- in the gaseous Argon TPC. Using that no such events were found in a decay-in-flight HNL search, we constrain dark neutrinos interpretations of the MiniBooNE excess.



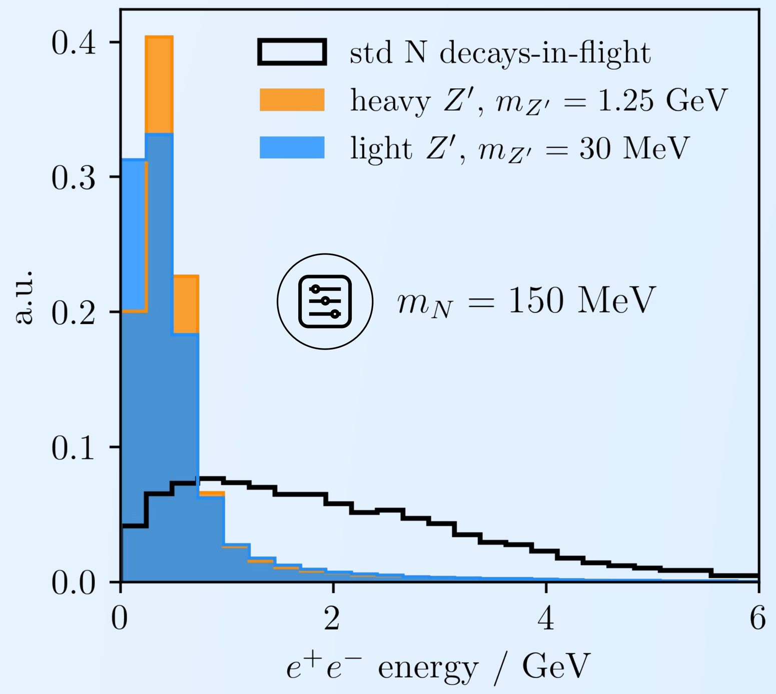


Scattering rates: MiniBooNE vs ND280

- Here we show only the scattering rate on Lead for ND280.
- The rate summed on all materials, before efficiencies, is comparable for the two experiments.

Upscattering vs decays-in-flight

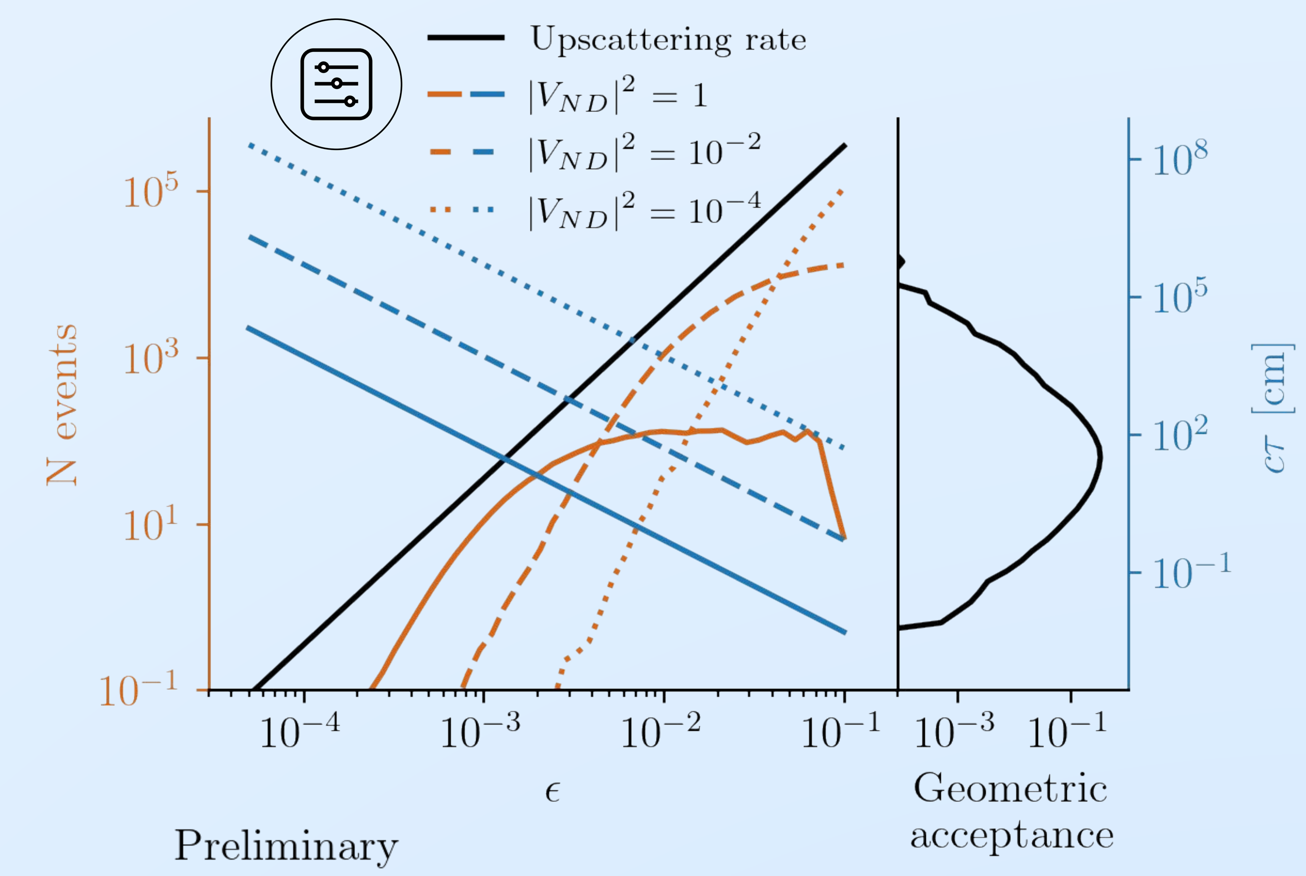
- Similar: no hadronic activity at the vertex in the case of neutrino-nucleus coherent scattering.
- Different: the (e+e-) pairs are softer, but still visible in the TPCs.

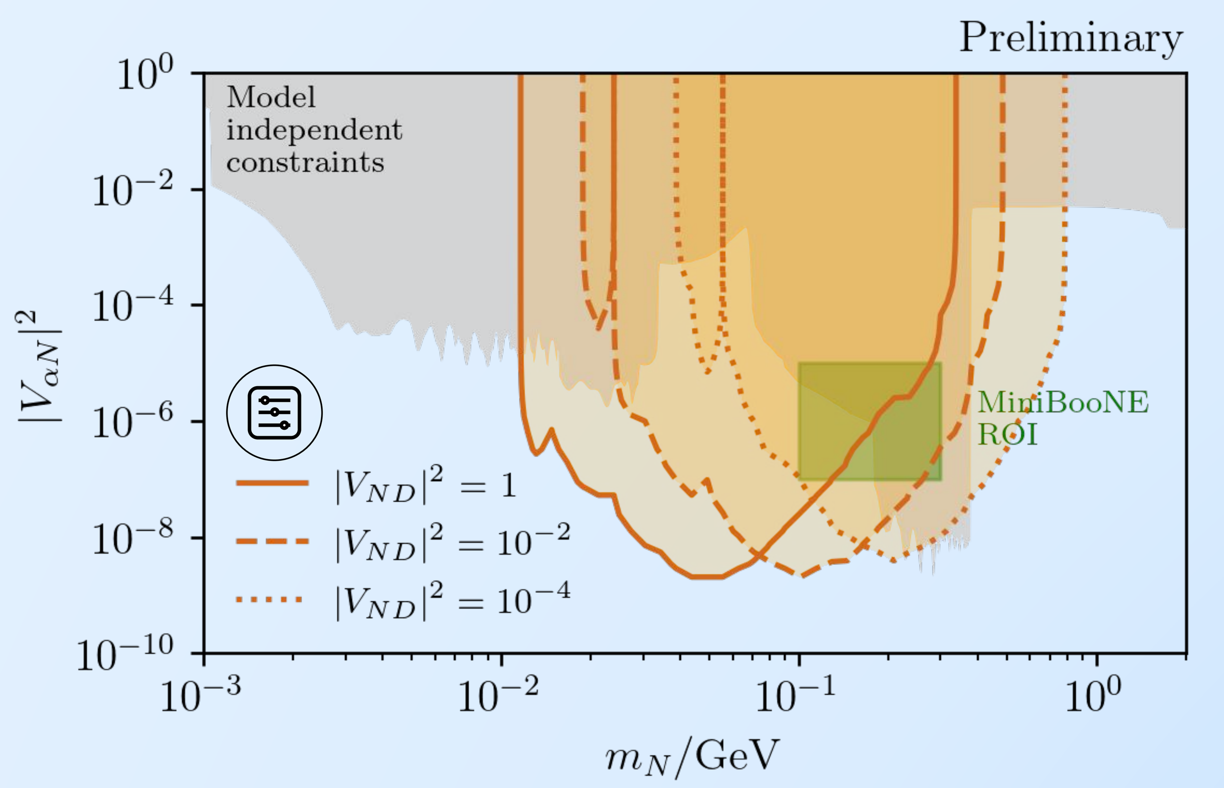


Dark NEW constraints

Where is the decay?

- The number of signal events depends on the upscattering rate and on the HNL lifetime.
- e+e- showers are selected if the decay vertex lies within the TPC volumes. This corresponds to HNL lifetimes of O(1-500) cm.
- Prompt decays are vetoed from the analysis, so the light mediator case is not constrained.



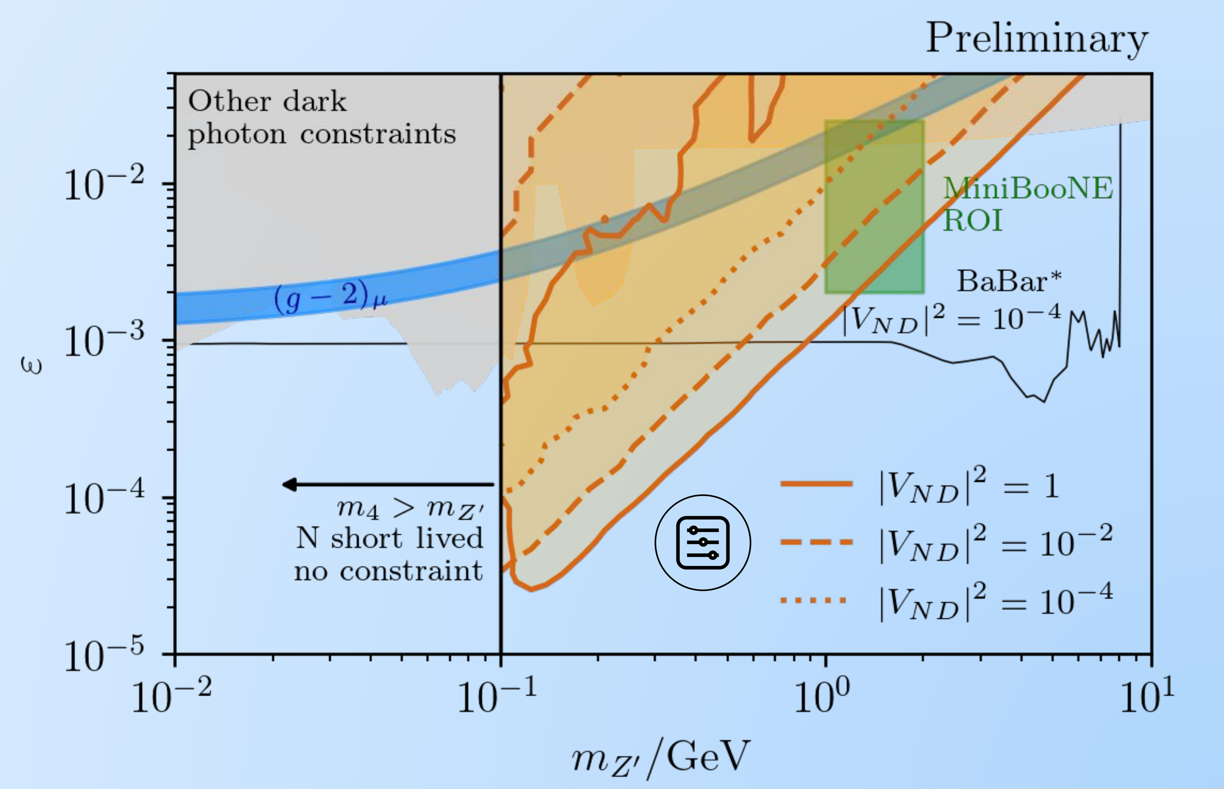


The HNL parameter space

- Most of the interesting parameter space for the MiniBooNE explanation is ruled out by this analysis.
- The only available corner requires short-lived HNL and larger HNL mass.

The dark photon parameter space

- The region of interest for MiniBooNE in the heavy mediator case is excluded, except for the largest decay couplings at large N masses and/or lighter Z' masses.
- We will explore the entire parameter space of the model in the future, including the light mediator case.



[1] Search for heavy neutrinos with the T2K near detector ND280, T2K collaboration, arXiv:1902.07598 [2] A Dark Seesaw Solution to Low Energy Anomalies: MiniBooNE, the muon (g−2), and BaBar, Abdullahi et al., arXiv:2007.11813 [3] Dark Neutrino Portal to Explain MiniBooNE excess, Bertuzzo et al., arXiv:1807.09877 [4] U(1)' mediated decays of heavy sterile neutrinos in MiniBooNE, Ballett et al., arXiv:1808.02915 [5] Model Independent Bounds on the Non-Oscillatory Explanations of the MiniBooNE Excess, Brdar et al., arXiv:2007.14411