DUNE-β : Can we expand DUNE's physics program to search for neutrino-less double beta decay?

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R&D Program

We consider a program of percent-level doping the 10kt of LAr in DUNE's 4th module with Xe, and with 2% enrXe loading project a sensitivity to neutrinoless double-beta decay exceeding that of currently-proposed ton-scale experiments. An R&D program to enable this program must address three basic needs:

Background Rejection **Scalability to kton scale** **Energy Resolution**

MeV scale low-energy physics R&D

This concept seeks to explore multiple avenues to expand the physics reach with the 4th DUNE module for MeV-scale signals. The R&D goals are compatible with and complement improvements towards sensitivity to supernova and solar neutrinos.

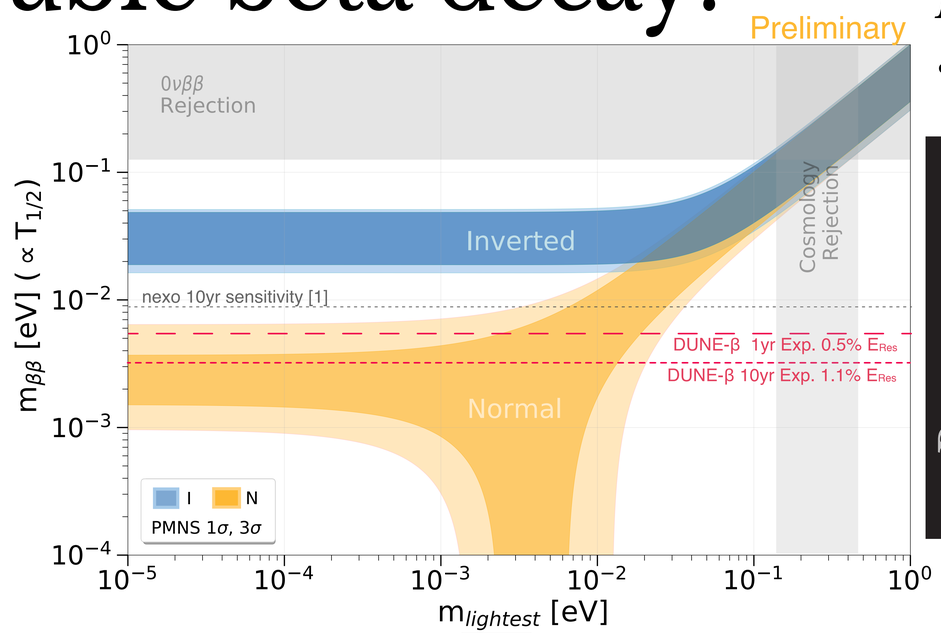

Figure 1: 90% C.L. sensitivity to mββ for DUNE-β . Dotted red lines represent 1 year exposure with 0.5% energy resolution and 10 year exposure at 1.1% energy resolution. Limits assume a 50% signal efficiency, and background efficiency equivalent to the current DUNE solar neutrino event selection[2].

References

[1] nEXO Collaboration, arXiv:1710.05075

[2] Francesco Capozzi, Shirley Weishi Li, Guanying Zhu, John F. Beacom arXiv:1808.08232

[3] Guanying Zhu, Shirley Weishi Li, and John F. Beacom, arXiv: 1811.07912

[4]LUX-ZEPLIN (LZ) Collaboration arXiv:1912.04248

[5]Ionization yield in xenon-doped liquid argon Physics Letters A Volume 49, Issue 5, 7 October 1974,

[6] DUNE Collaboration, arXiv:2002.03005

Background Rejection R&D

A complete characterization of spallation, solar neutrinos, and radioactive backgrounds will be necessary to develop final sensitivity estimates.

Aim to significantly improve low energy background suppression

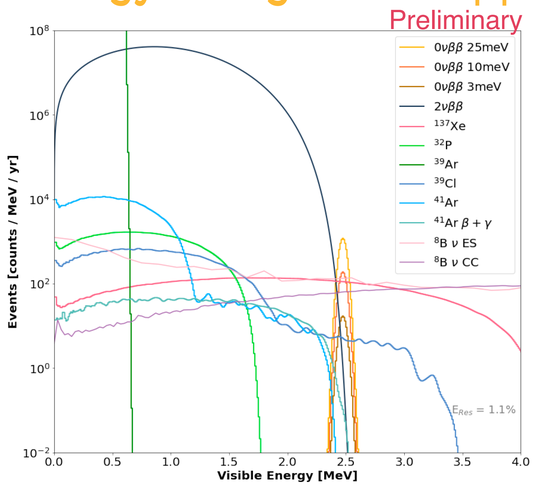

Figure 2: Signal and background estimates with 1.1% E_{Res}. Assuming signal and background efficiency from Figure 1. Background normalization assumptions from [3,4]. Most radiological backgrounds are reduced below 10^{-2} in the fiducial volume and 2.4-2.7 MeV ROI. Po alpha tagging is assumed for 222Rn backgrounds[6].

R&D Needs

- Background studies in DUNE simulation **(ongoing).**
- Perform studies of spallation backgrounds with a test-stand at the MINOS underground area.
- Perform radiological backgrounds tests deep underground.

Scalability R&D

Xe-doped LAr has 13% higher ionization yield [6], which would further enhance energy resolution. However, large-scale Xe doping in LAr has only been demonstrated to ~100ppm concentration.

Demonstrate doping & signal ID are viable at the kt scale

First tests of MeV physics on xenon doped LAr are being developed and will utilize the MicroBooNE detector at Fermilab.

Energy resolution and signal reconstruction will also need to be demonstrated for large-scale TPCs.

* Opportunity for Xe-isolation R&D that would enable enrichment at the ~100t scale.

R&D Needs

- Demonstration of Xe-doping in existing LAr detector **(Funded!)**
- Demonstration of Xe-doping effects in energy resolution.
- Demonstration of large-scale Xe injection.

Energy Resolution R&D

Sub-percent energy resolution would enable sensitivity for mββ below 6meV with one year of running.

Aim to achieve < 1% energy resolution

This could be achieved by combination of scintillation + ionization, or aided by photo-ionizing dopants to increase the ionization yields.

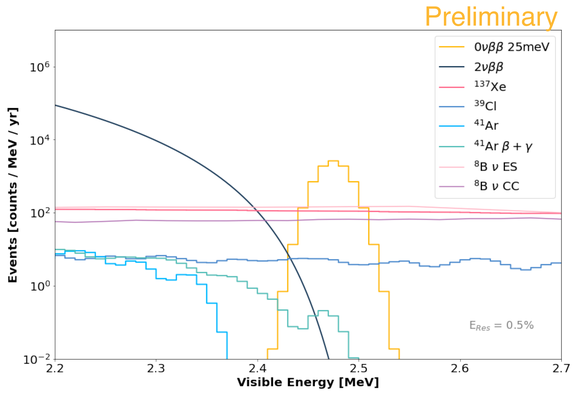

Figure 3: Signal and background estimates with 0.5% E_{Res}. Assuming signal and background efficiency from Figure 1 and background suppression from Figure 2.

R&D Tasks

- Demonstration of MeV-scale energy resolution in LAr test-stand.
- Demonstration of pixel readout reconstruction capabilities for MeV-scale signals.
- Demonstration of the effects of photo-ionizing dopants on light yields in LAr.