



Neutrinoless Double Beta Decay in the LUX-ZEPLIN Experiment



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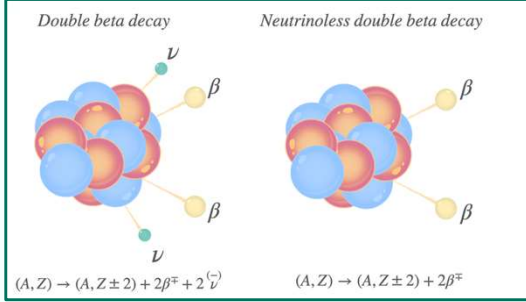


Figure 1: Diagram of $2\nu\beta\beta$ (left) and $0\nu\beta\beta$ (right). © V. Palušová, JGU. source: <https://nudoubt.uni-mainz.de/public.php>

Neutrinoless Double Beta Decay ($0\nu\beta\beta$)

- Distinct from other modes of $2\nu\beta\beta$ in isotopes ^{124}Xe , ^{126}Xe , ^{134}Xe , and ^{136}Xe (Figure 1).
- Possible in ^{134}Xe ($Q = 826$ keV) and ^{136}Xe ($Q = 2458$ keV) [1].
- Implies neutrino is a Majorana particle.
- Observation means lepton number violation is allowed in the standard model.
- Other implications vary depending on the neutrino mass hierarchy.

LUX-ZEPLIN (LZ)

- Dual-phase xenon time projection chamber (Figure 2), 7 tonne active volume of liquid xenon [2].
- Located 4850 ft underground at SURF, South Dakota, US.
- Primarily a WIMP search experiment but capable of searches for ^8B solar neutrinos, $0\nu\beta\beta$ and alternative dark matter models.

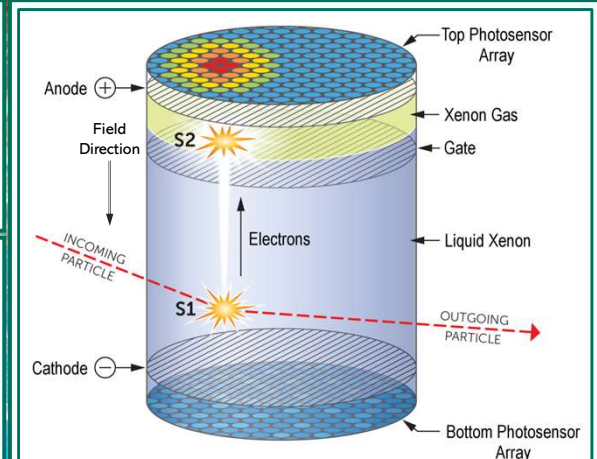


Figure 2: An example particle interaction and response in a dual-phase xenon time projection chamber [3].

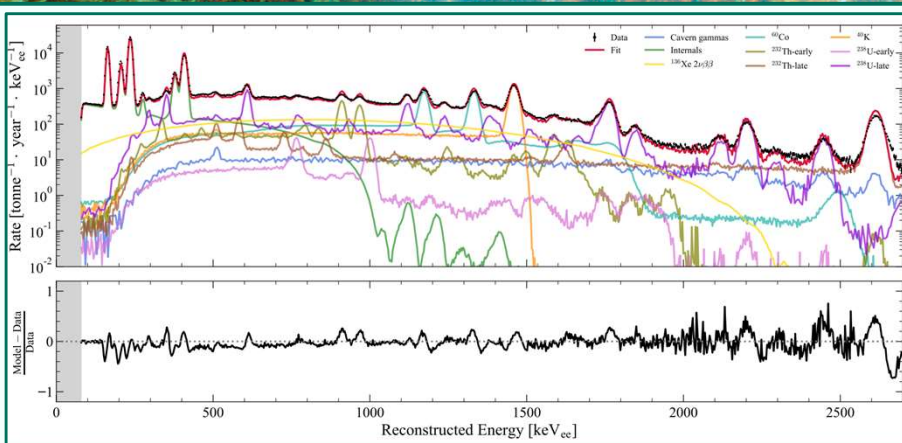


Figure 3: Background energy spectrum from the first LZ science run. Backgrounds are simulated and measured, then fitted to the science run data [4].

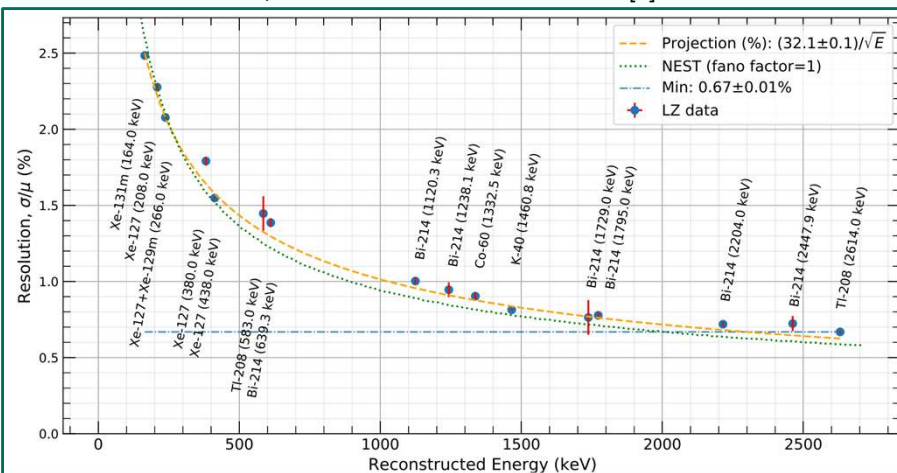


Figure 4: Projected and measured energy resolution against reconstructed event energy. Data points are taken from measurements of the electron recoil background spectrum [1].

Methods for minimising background effects

- Well-modelled simulations of known, measured backgrounds (Figure 3).
- Strict fiducial volume cut to 5.6 tonnes [2].
- Vetoing of particles such as muons from xenon skin and outer detector.
- Removal of multiple scatter events as $0\nu\beta\beta$ interactions are single scatters.
- High energy resolution, $0.67 \pm 0.01\%$ at 2614 keV (Figure 4).

Sensitivities and future work:

- Sensitivity is inversely proportional to square root of energy resolution.
- LZ sensitive to a half-life of 1.06×10^{26} years and a ν mass of 53 – 164 meV [2].
- Future experiments such as XLZD that have higher target masses and lower backgrounds have potential for world leading sensitivities (1.0×10^{27} years with 40 tonnes of xenon after 3 years) [5].

References

- [1] G. Pereira et al. (LZ Collaboration), Energy resolution of the LZ detector for high-energy electronic recoils. *J. Instrum.*, **18**:C04007, Apr 2023.
- [2] D. S. Akerib et al. (LZ Collaboration), Projected sensitivity of the LUX-ZEPLIN experiment to the $0\nu\beta\beta$ decay of ^{136}Xe . *Phys. Rev. D*, **102**:092004, 2020.
- [3] Aalbers et al. (XLZD Collaboration), A next-generation liquid xenon observatory for dark matter and neutrino physics. *J. Phys. G: Nucl. Part. Phys.*, **50**(1):013001, Jan 2023.
- [4] J. Aalbers et al. (LZ Collaboration), Background determination for the LUX-ZEPLIN dark matter experiment. *Phys. Rev. D*, **108**(1):012010, Jul 2023.
- [5] J. Aalbers et al. (XLZD Collaboration), Neutrinoless double beta decay sensitivity of the XLZD rare event observatory. *J. Phys. G: Nucl. Part. Phys.*, **52**(4):045102, Apr 2025.

