Optimizing Energy Reconstruction for nEXO

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on behalf of

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and the nEXO Collaboration

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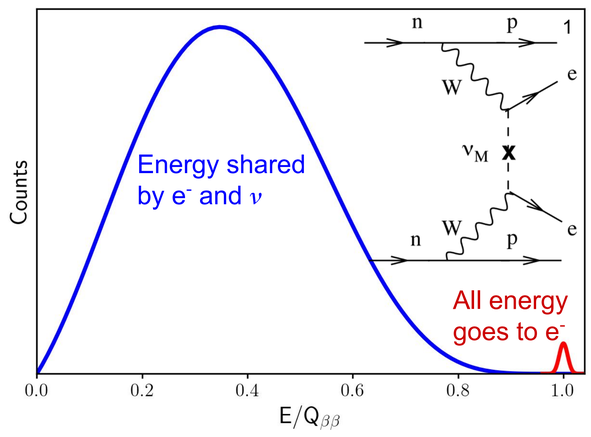
Origin of the Neutrino Mass

2015 Nobel Prize in Physics awarded "*for the discovery of neutrino oscillations, which shows that neutrinos have mass*"



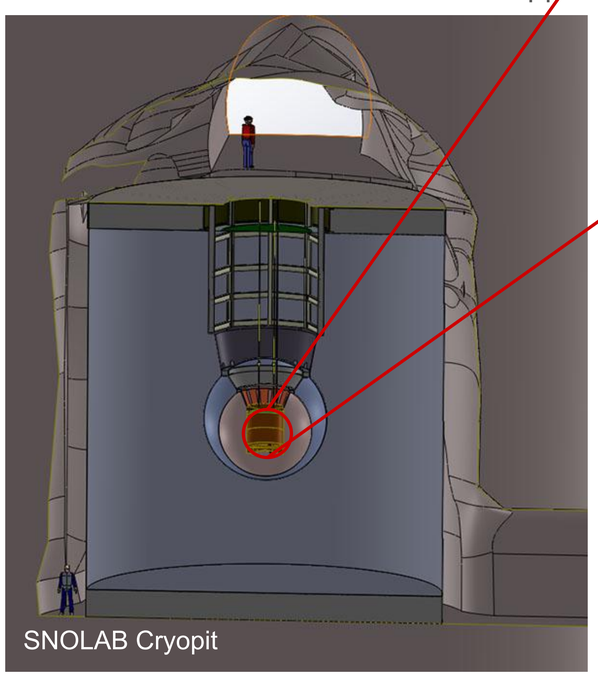
Dirac and/or **Majorana** mass terms?

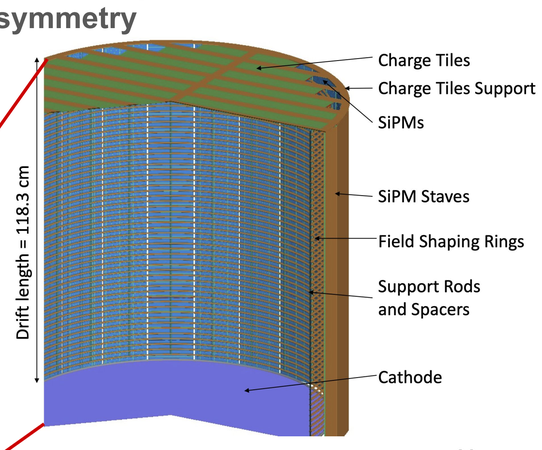
Majorana mass would imply **neutrinoless double beta decay** (0νββ). A discovery would demonstrate:

- ➔ **New physics** beyond the Standard Model
- ➔ **Lepton number** not conserved
- ➔ Possible origin of **matter-antimatter asymmetry**

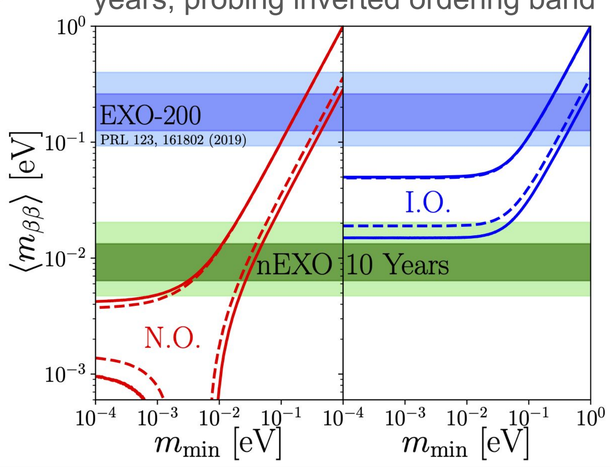
The nEXO Experiment

Single-phase time projection chamber (TPC) with 5 tonnes of liquid xenon (LXe) enriched to 90% **^{136}Xe** to search for 0νββ





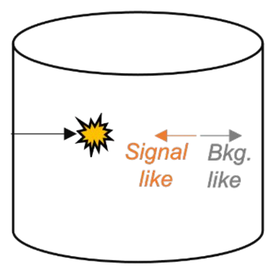
Sensitive to 0νββ half lives > 10^{28} years, probing inverted ordering band[2]



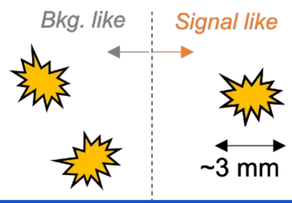
Multi-Parameter Search

Signal/background discrimination in **standoff** (distance to nearest surface), **topology** (single-site/multi-site), and **energy**

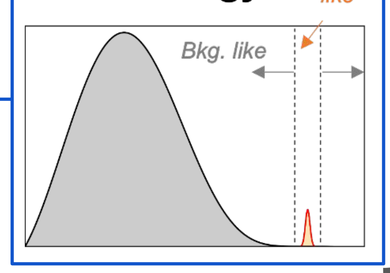
Standoff:

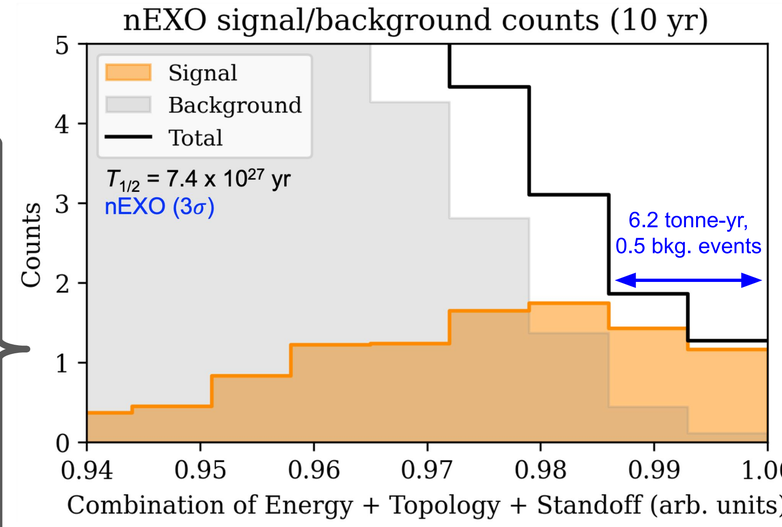


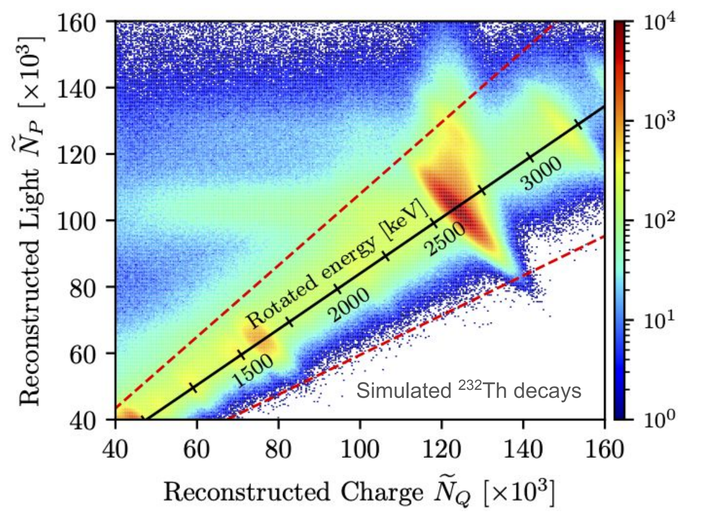
Topology:



Energy:







➔ Energy is the sum of reconstructed **light** and **charge** signals

Objectives

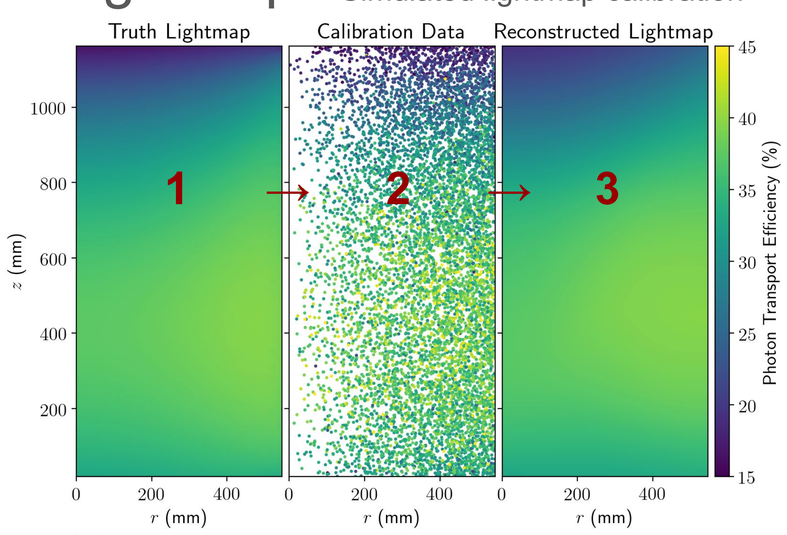
- ➔ Design, test, & characterize a new charge digitization system to meet nEXO's **charge noise** requirement of 150e-
- ➔ Develop a scheme to calibrate the position-dependent light collection efficiency (**lightmap**) to sub-0.5% accuracy

semi-empirical energy resolution model as sum of relative variances — **target at $Q_{ββ}$**

$$\left(\frac{\text{Energy}}{\text{resolution}}\right)^2 = \text{Fano noise} + \text{light collection} + \text{correlated avalanches} + \text{dark current and gain} + \textbf{lightmap} + \text{charge collection} + \text{e- lifetime systematics} + \textbf{charge electronics} < (1\%)^2$$

Lightmap

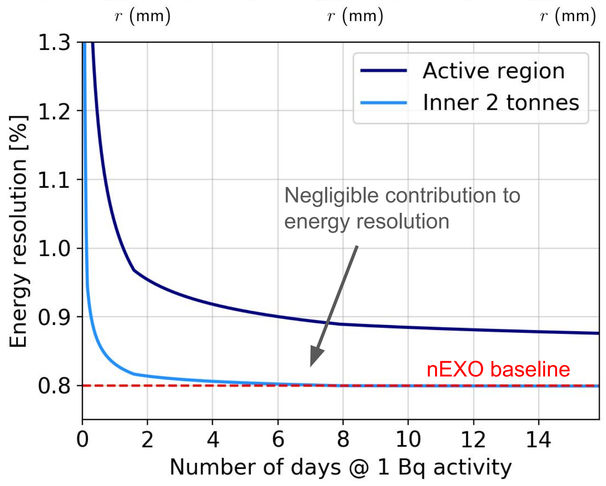
Simulated lightmap calibration



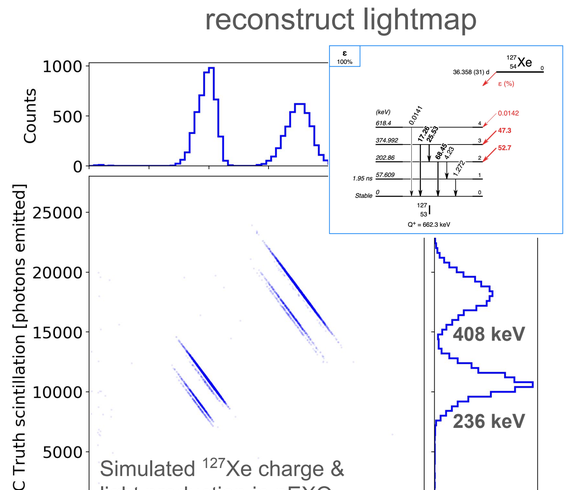
Calibration source types

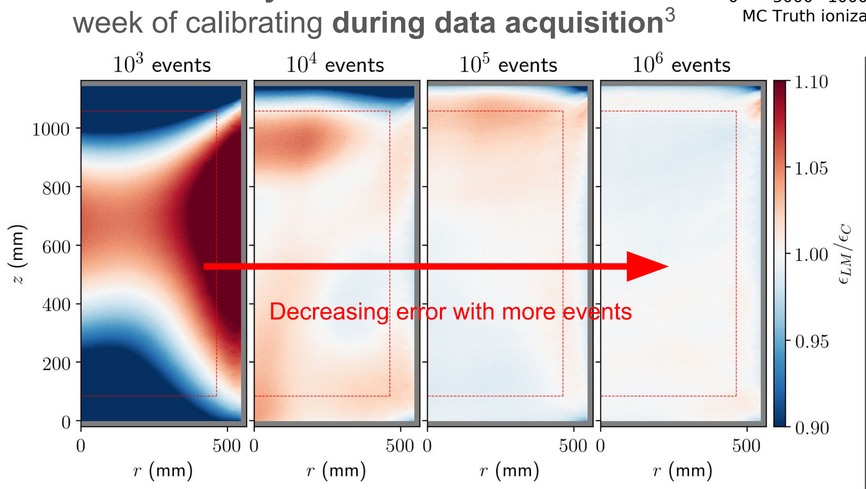
	External γ	Internal α
Full energy range	✓	✘
No risk of background introduction	✓	✘
Complete illumination	✘	✓
No downtime	✘	✘

- ➔ Mix **^{127}Xe** throughout TPC for in-situ calibrations (EC, Q=662 keV, $T_{1/2}$=36 days)
- ➔ Use **neural net** to reconstruct lightmap



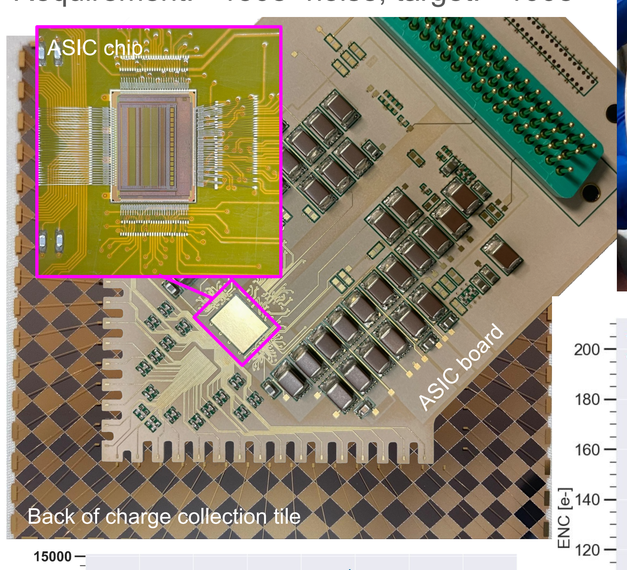
- ➔ **0.5% accuracy** in inner 2 tonnes after ~1 week of calibrating **during data acquisition**[3]

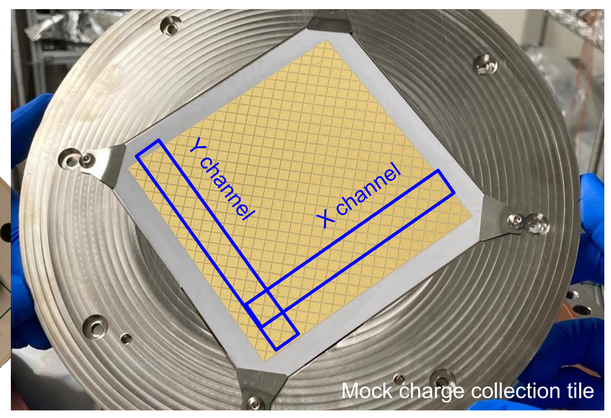


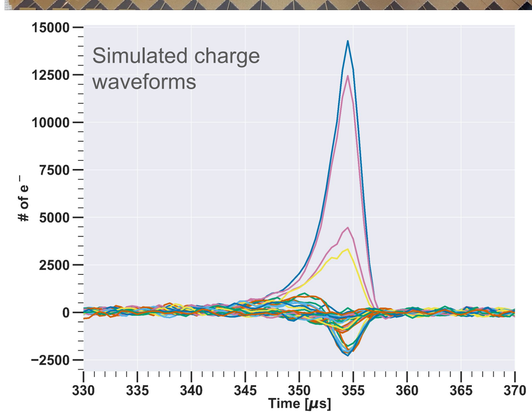


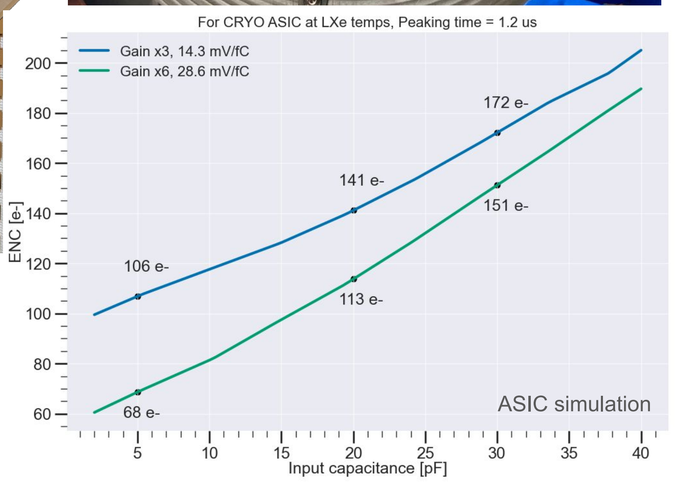
Charge Electronics

Requirement: <150e- noise; target: <100e-









- ➔ Optimized geometry to balance single/multi-site discrimination with sensor capacitances
- ➔ On-tile ASIC for digitization **in liquid xenon** to significantly reduce cabling & resulting noise

Conclusions

- ➔ Demonstrated calibration scheme to eliminate lightmap error contribution without interrupting data acquisition
- ➔ Ongoing R&D program to test in-liquid-xenon digitization to eliminate a significant contributor to charge noise

References

1. F. T. Avignone *et al* 2008 *Rev. Mod. Phys.* **80** 481 [arXiv:0708.1033]
2. G Adhikari *et al* 2022 *J. Phys. G: Nucl. Part. Phys.* **49** 015104 [arXiv:2106.16243]
3. B. G. Lenardo *et al* 2022 *JINST* **17** P07028 [arXiv:2201.04681]

To learn more about nEXO, visit: