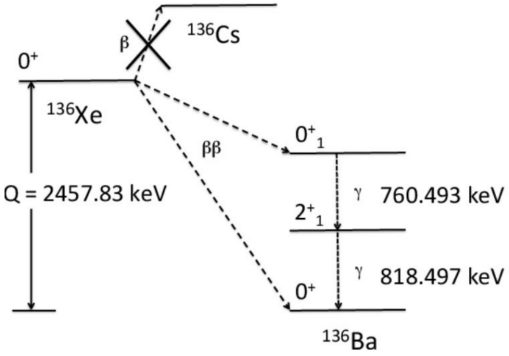
Overview of nEXO neutrinoless double beta decay ($0\nu\beta\beta$) experiment.

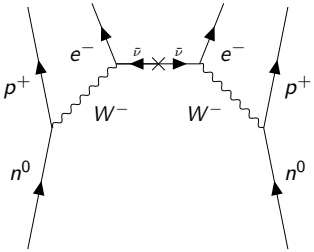
Prakash Gautam

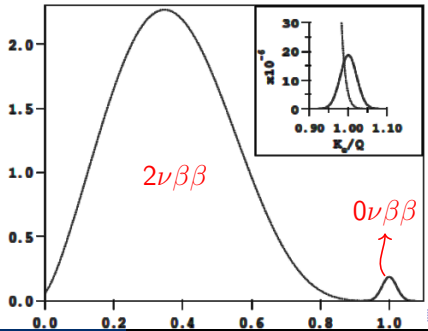
Drexel University

PPC,
June 8, 2022

Neutrinoless double beta decay($0\nu\beta\beta$)





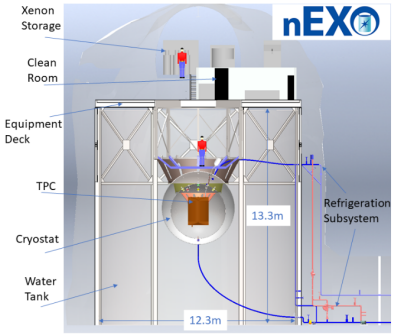


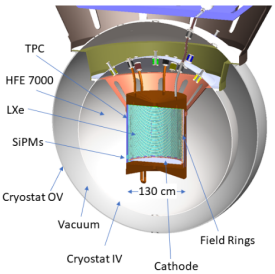
- $(Z, A) \rightarrow (Z + 2, A)^{++} + 2e^{-}$
- Violates lepton number conservation.
- Indicates new physics beyond the Standard Model (SM).

nEXO Collaboration

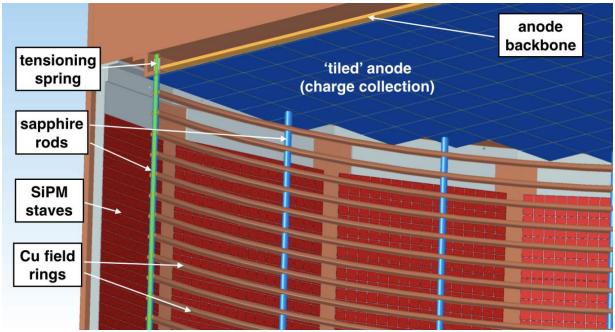
nEXO Detector

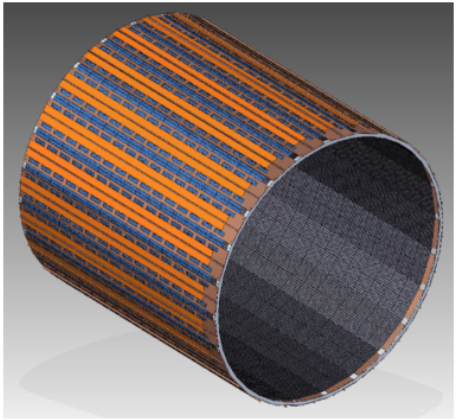
- Single phase homogeneous monolithic Time Projection Chamber (TPC).
- Uses liquid xenon (LXe) enriched to 90% with $^{136}\mathrm{Xe}$.
- 5 ton LXe in a 1.3m x 1.3m cylindrical detector with single drift region.
- Combination of topology, event position, scintillation and charge yield to identify event.

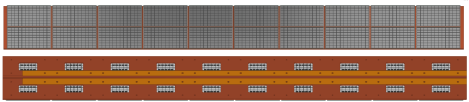




Light and Charge Detection







- Silicon Photo Multipliers (SiPMs) are used to detect scintillation light.
- Charge is detected at anode.
- No high voltage needed.

[0]Gallina et al., "Characterization of the Hamamatsu VUV4 MPPCs for nEXO".

Physics Goals

- Search for neutrinoless double beta decay ($0\nu\beta\beta$).
- Reach sensitivity of 1.35×10^{28}yr to Xe-136 at 10yr.
- Achieve energy resolution 0.8% [1].

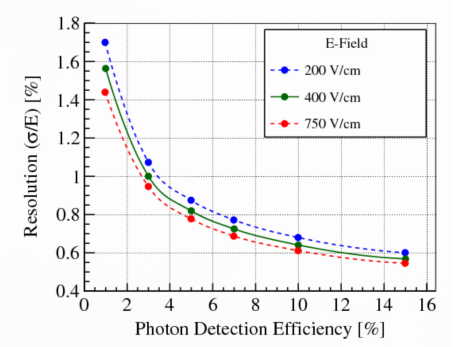
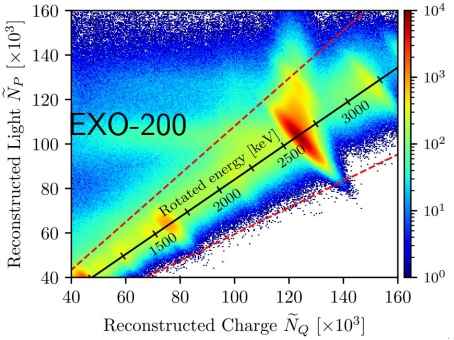
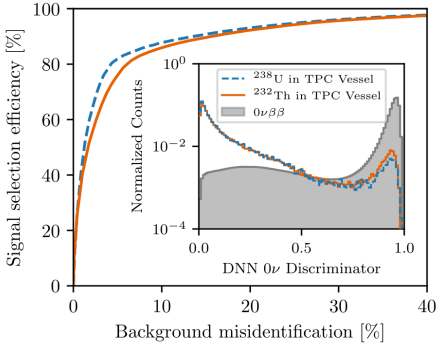


Figure: Energy Resolution vs Photon Detection Efficiency (arXiv:1805.11142)

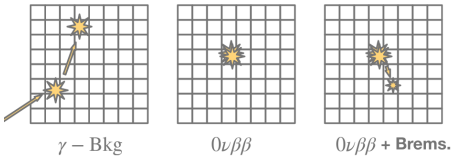
[1] Adhikari et al., "nEXO: neutrinoless double beta decay search beyond 10^{28} year half-life sensitivity".

Multi Dimensional Information



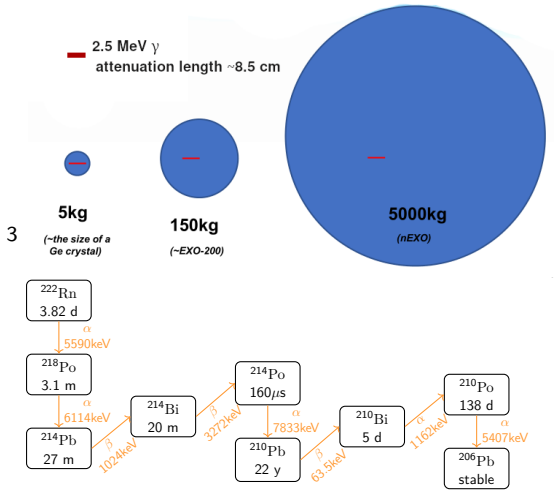


- Anticorrelation of per event scintillation and ionization signal.
- SS vs MS event identification.
- Improved energy resolution: $\frac{\sigma}{Q_{\beta\beta}} \sim 0.8\%$



Self Shielding

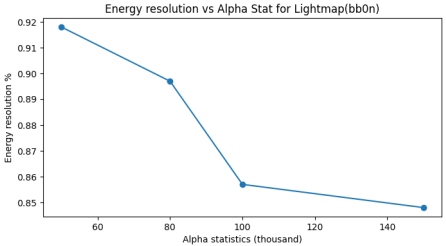
- For gamma calibration source, only few "deep events" detected in inner detector due to self shielding.
- Dissolved sources are better to calibrate inner detector. [2]
- Short lived isotopes of $^{220}\mathrm{Rn}$ and $^{222}\mathrm{Rn}$ can be used to get alpha sources.
- The alphas have higher fraction of their energy in the scintillation channel, which makes light calibration with lightmap more precise.

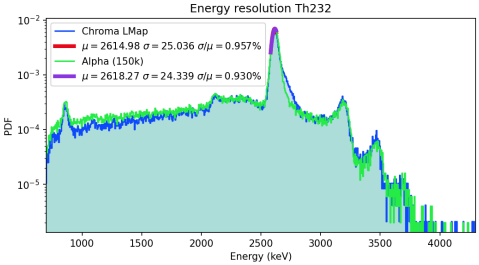


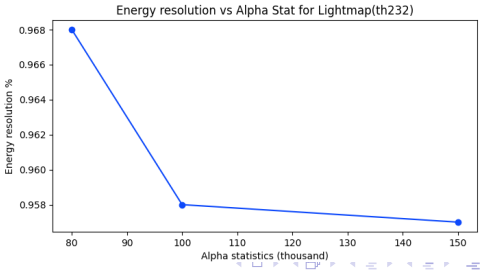
[3] Lenardo et al., "Development of a ^{127}Xe calibration source for nEXO".

Dissolved Source Calibration

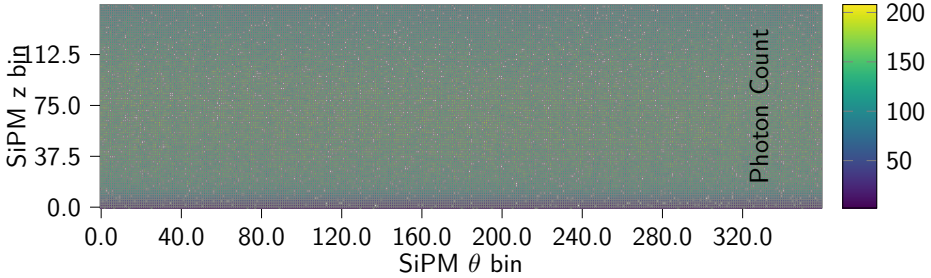
- With ∼150k alphas, the energy resolution with alpha lightmap is comparable to the MC lightmap.
- $0\nu\beta\beta$ and ^{232}Th simulation data show similar behavior.

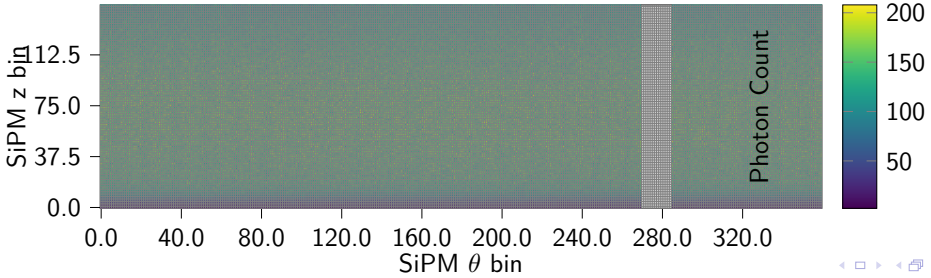






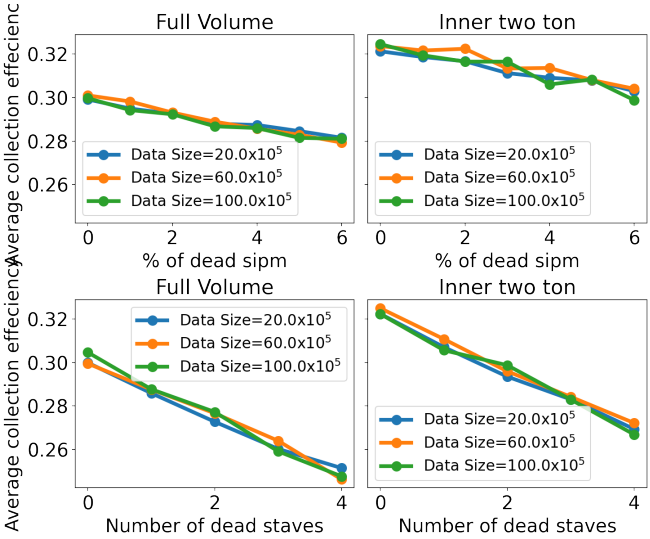
SiPM Quality Control Studies





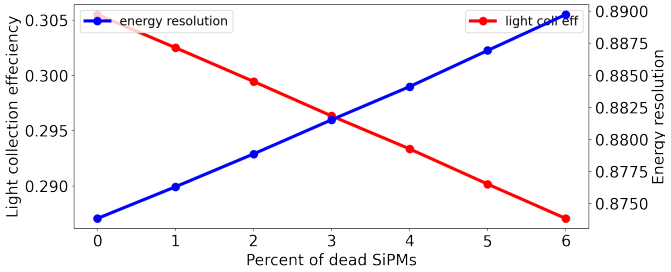
SiPM Quality Control Studies

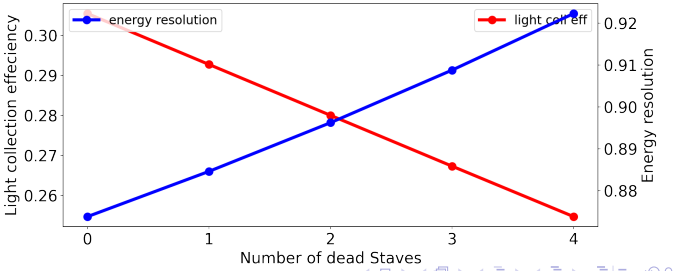
- Different % of dead SiPM and number of dead stave considered.
- Collection efficiency goes down linearly as the lost SiPM area.
- Energy resolution still within 1% for few % lost SiPM.



SiPM Quality Control Studies

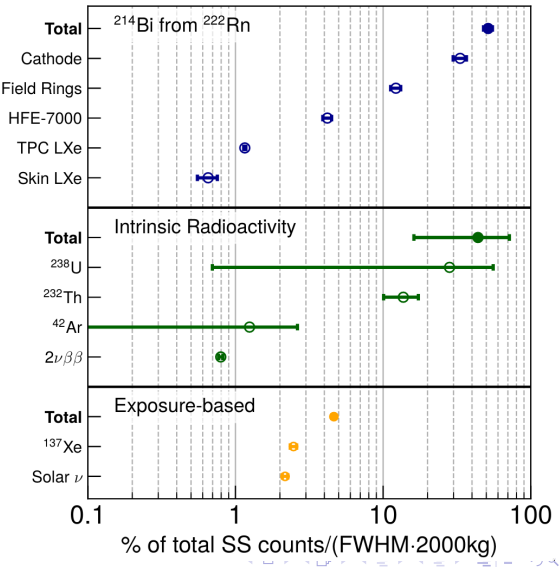
- Different % of dead SiPM and number of dead stave considered.
- Collection efficiency goes down linearly as the lost SiPM area.
- Energy resolution still within 1% for few % lost SiPM.



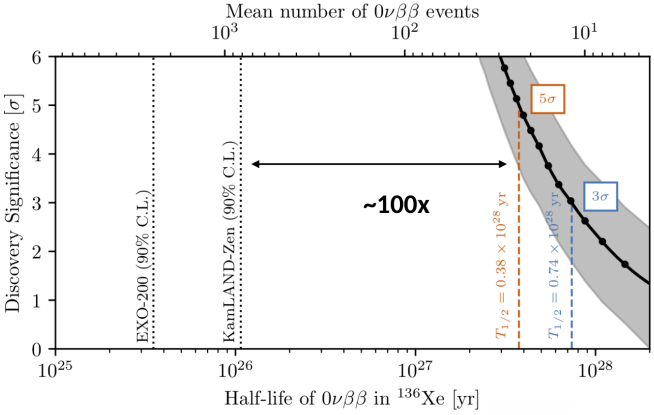


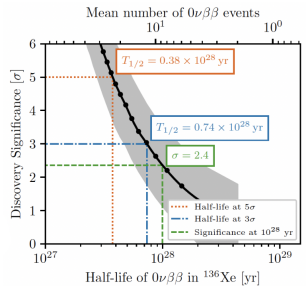
Background

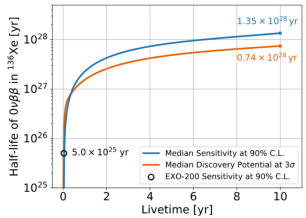
- Well understood external backgrounds.
- Bottom up approach in constraining the internal background.



Sensitivity





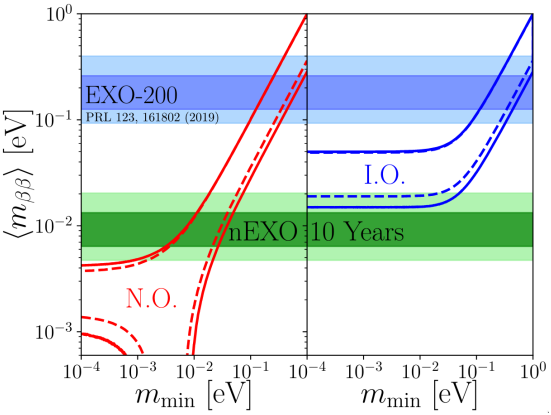


- Projected to reach 1.35×10^{28}yr of sensitivity at 10 years of data taking.
- ~100X sensitivity than current generation experiments.

Parameter Space Coverage

$$\left[T^{0\nu}_{1/2}\right]^{-1} = \frac{\langle m_{\beta\beta}\rangle^2}{m_e^2} G^{0\nu} \left|M^{0\nu}\right|^2$$

- Search for $0\nu\beta\beta$ which is a strong probe for physics beyond the SM.
- nEXO will fully cover the inverted hierarchy parameter space.
- nEXO is next generation tonne scale $0\nu\beta\beta$ experiment.
  - Very good energy resolution.
  - Very low internal background and strong external background discrimination.
  - Projected to reach sensitivity of 1.35×10^{28}yr with 10 yr of data taking.



Thank You

Backup

Rn alpha Lightmaps

- ^{214}Po alpha from ^{222}Rn simulated to study the lightmap calibration with alphas.
- Only includes events in the active region.
- The collection efficiency is scaled to

$$PTE = \frac{CollectedLight}{median(CollectedLight)}$$

- Used Neural Network to make lightmap.
  - Neural network model favored over others.

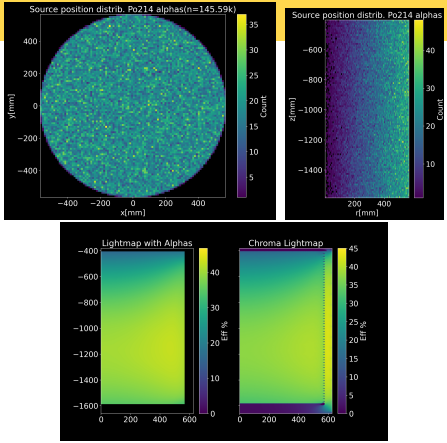
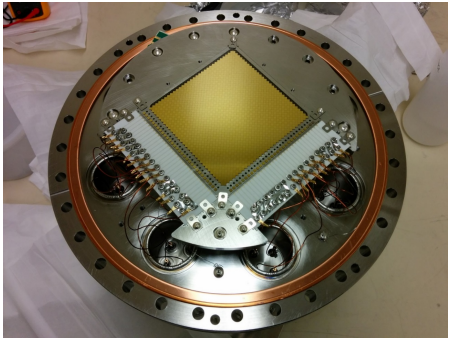


Figure: Source position distribution alphas simulation data (top), lightmap with alpha simulation (bottom left), lightmap with chroma optical simulation (bottom right)

Charge Detection



- Prototpye: 10cm $\times$ 10cm and 300 μm thick tile.
- Substrate: Fused silica wafer
- 30 "X" and 30 "Y" strips

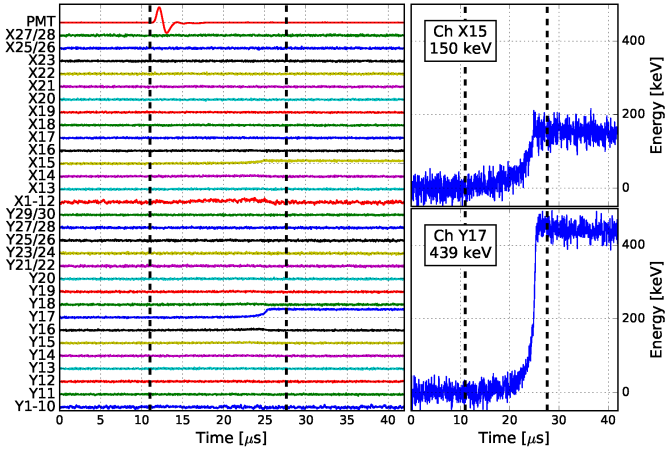


Figure: Sample event: waveforms form all channels and PMT for ^{207}Bi at 570 keV. State of the art charge resolution 5.5%