Sensitivity of the DARWIN Observatory to the Neutrinoless Double Beta Decay of ^{136}Xe

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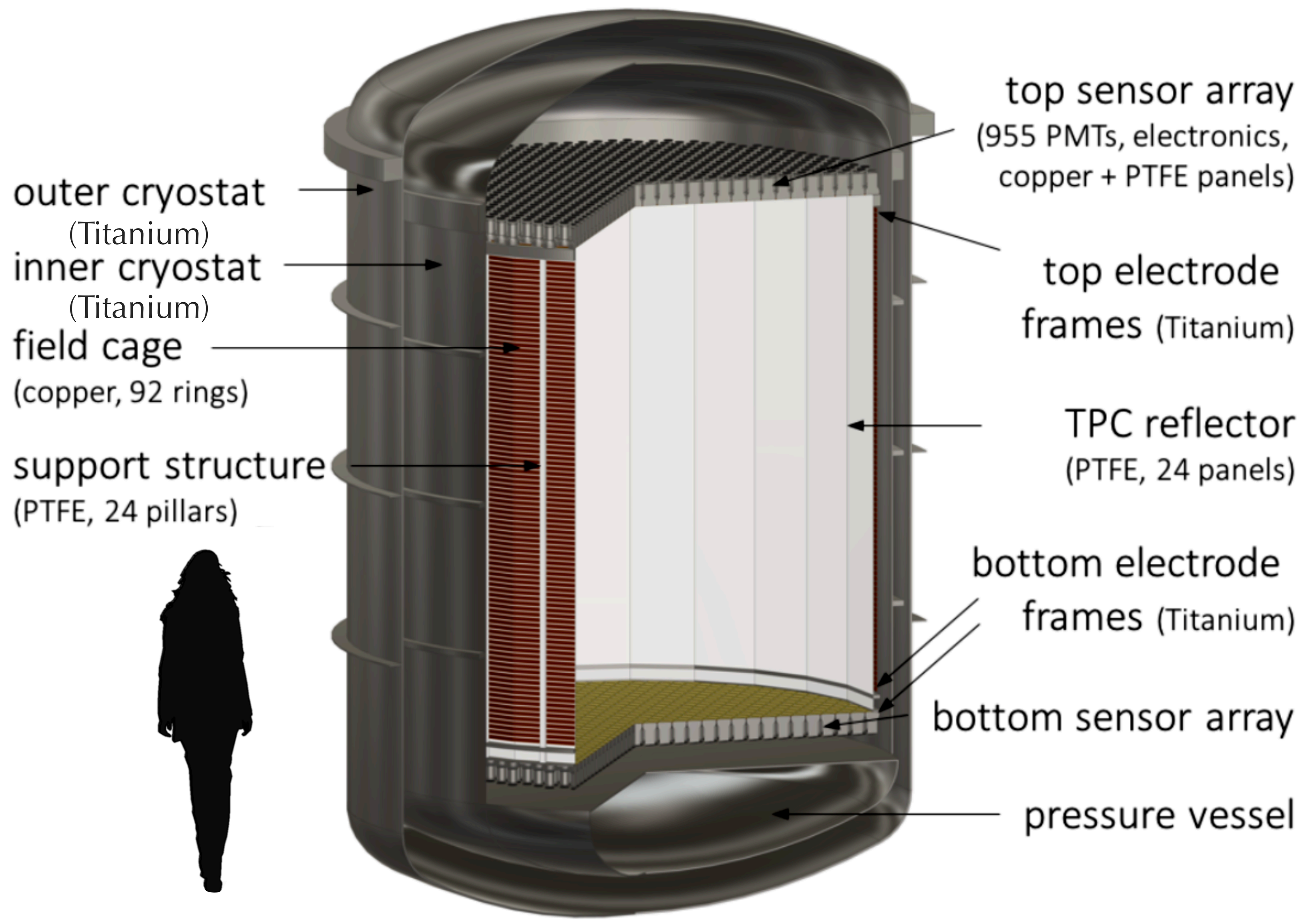
The ***DARWIN observatory*** *is a proposed next-generation experiment to search for particle dark matter and for the neutrinoless double beta decay of* ^{136}Xe.

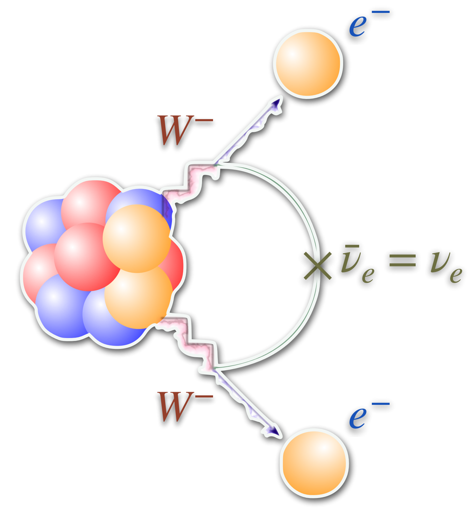
LXe → 40 t = 3.6 t → ^{136}Xe

The DARWIN Observatory goals

- Search for **WIMPs** via nuclear scattering
- Search for the **neutrinoless double beta decay** ($0\nu\beta\beta$) and 0νECEC
- Real-time detection of **solar pp neutrinos** via electron scattering
- Observation of **supernova and solar ^{8}B neutrinos via CEvNS**
- **Solar axions**, galactic **axion-like particles** and **dark photons**



$0\nu\beta\beta$-decay process



- The most sensitive probe for the **Majorana nature** of neutrinos
- Hypothetical rare nuclear decay process
- A nucleus with mass number A and charge Z **decays by emitting only two electrons** and changes its charge by two units

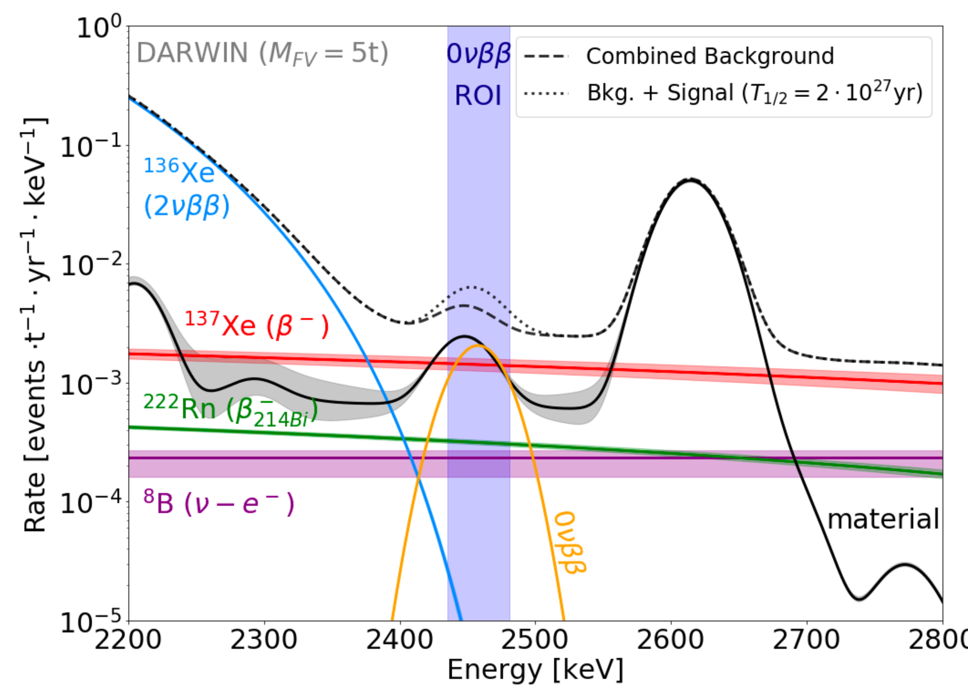
Background spectrum

Estimator figure-of-merit for the half-life sensitivity:

$$T_{1/2}^{0\nu} = \ln 2 \frac{\epsilon\, f_{ROI}\, \alpha\, N_A}{1.64\, M_{Xe}} \frac{\sqrt{Mt}}{\sqrt{B \Delta E}},$$

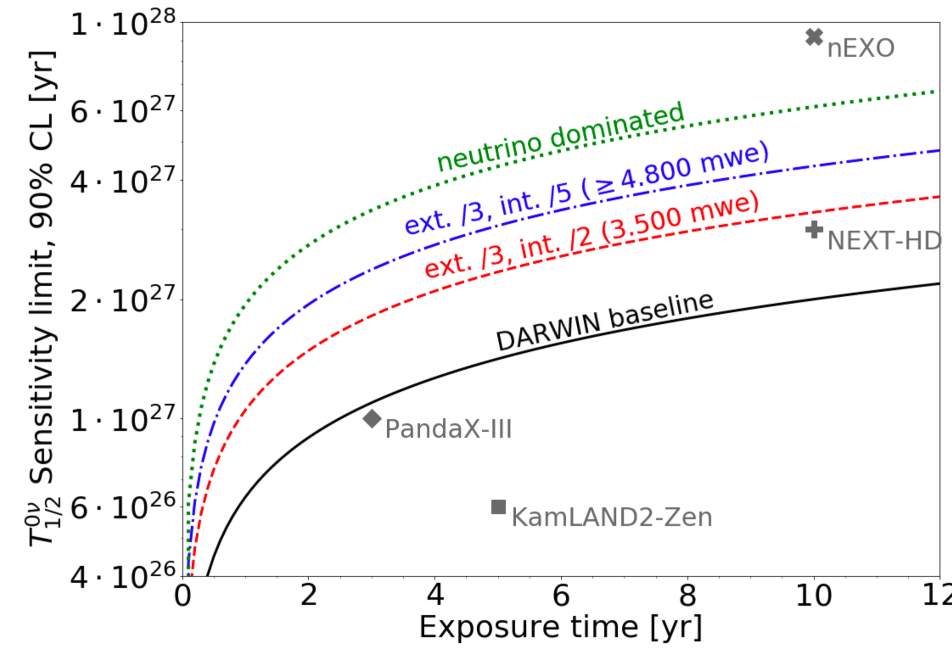
Gives an optimal fiducialized mass of 5 t with 10 years of data taking.

Shown is the predicted background spectrum around the $0\nu\beta\beta$-ROI [2435 - 2481] keV for a 5 t fiducial mass with a signal corresponding to $T_{1/2}^{0\nu} \approx 2 \cdot 10^{27}$yr.

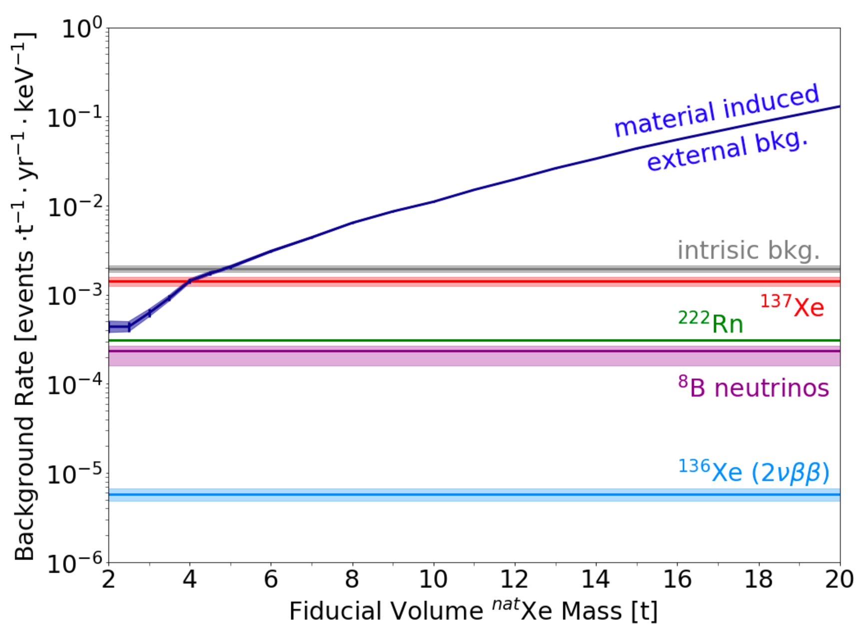


Projected half-life sensitivity

Profile likelihood test: $2.4 \cdot 10^{27}$ yr (conservative), $6 \cdot 10^{27}$ yr (neutrino-dominated).



Intrinsic backgrounds



- Muon-induced neutrons, captured on a ^{136}Xe nucleus, producing ^{137}Xe, that decays via a $\beta-$.

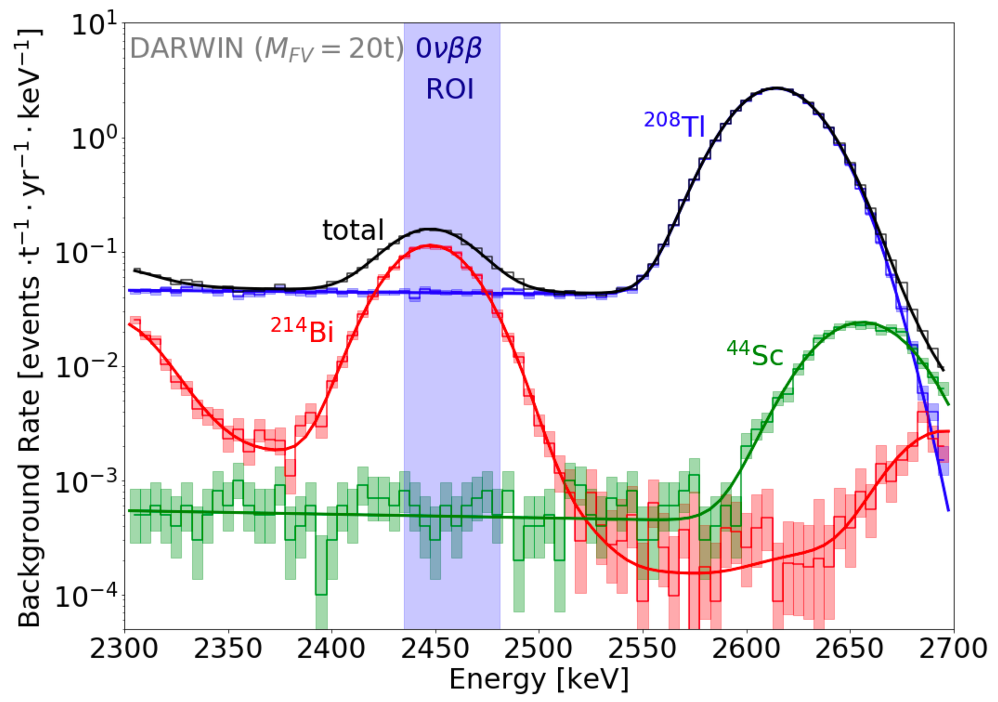
- ^{8}B solar neutrinos: irreducible background source, the expected rate of neutrino-electron scatters is derived assuming a ^{8}B-ν flux of ϕ= (5.46 ±0.66)·10^6 cm^{-2} s^{-1}.

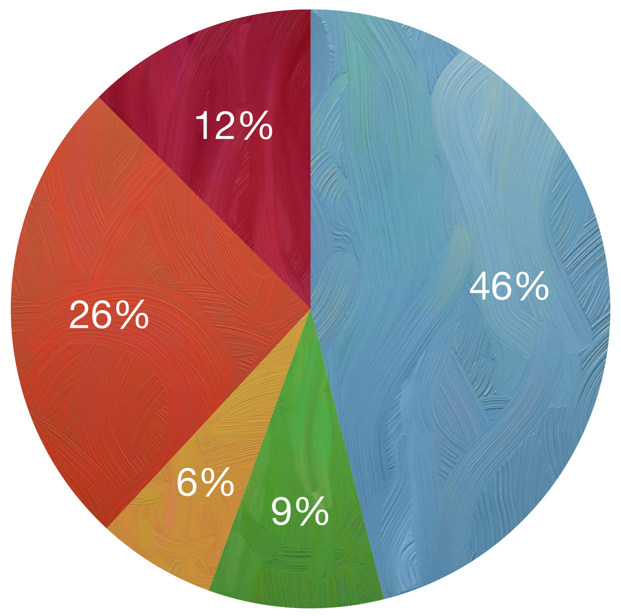
- The $2\nu\beta\beta$ decay spectrum of ^{136}Xe, assuming the measured half-life of $T_{1/2} = (2.165 \pm 0.061) \cdot 10^{21}$yr.

- ^{222}Rn in LXe reduced by online cryogenic distillation and stringent material selection to a concentration equivalent to 0.1μBq ^{222}Rn activity per kg of xenon.

External background

- Long-lived radionuclides are present in each detector material.
- Introduce background events in the target.
- Decay chains of ^{238}U and ^{232}Th yield a background contribution primarily from γ-rays emitted by ^{214}Bi and ^{208}Tl-decays.
- ^{44}Ti in the cryostat material has a long half-life and the subsequent decay of ^{44}Sc yield a γ-ray at 2.66 MeV.





Titanium, Copper, PTFE, PMTs, Electronics

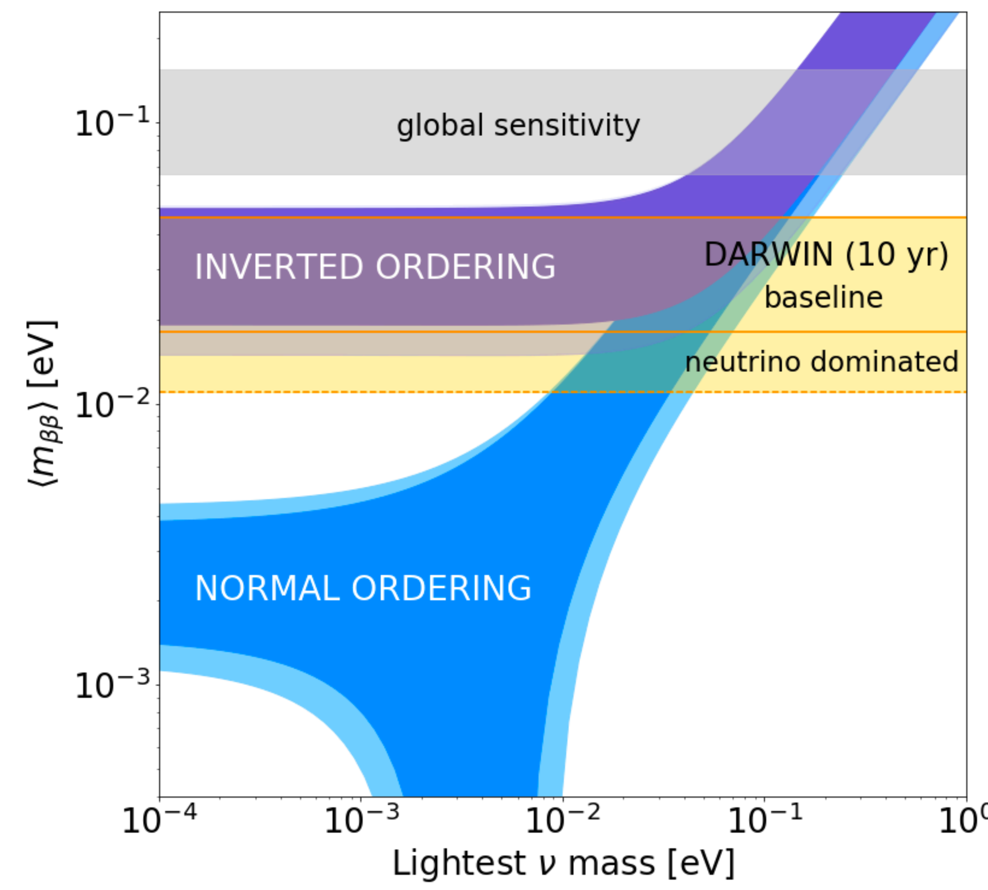
Contribution to the background in %

Effective Majorana mass predictions

Half-life sensitivity translates to an effective Majorana neutrino mass $m_{\beta\beta}$ using:

$$\frac{1}{T_{1/2}^{0\nu}} = \frac{\langle m_{\beta\beta} \rangle^2}{m_e^2} G^{0\nu} |M^{0\nu}|^2$$

$m_{\beta\beta}$ limit of **(18-46)** meV (conservative) and **(11-28)** meV (neutrino-dominated).



In the presented baseline scenario DARWIN will reach sensitivity that approaches that of proposed tonne-scale $0\nu\beta\beta$ experiments.

References
DARWIN collaboration, Agostini, F., et al. "Sensitivity of the DARWIN observatory to the neutrinoless double beta decay of ^{136}Xe." arXiv preprint arXiv:2003.13407 (2020).

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