SENSITIVITY OF NEXT-100 TO NEUTRINOLESS DOUBLE BETA DECAY

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DOUBLE BETA DECAY EXPERIMENTS

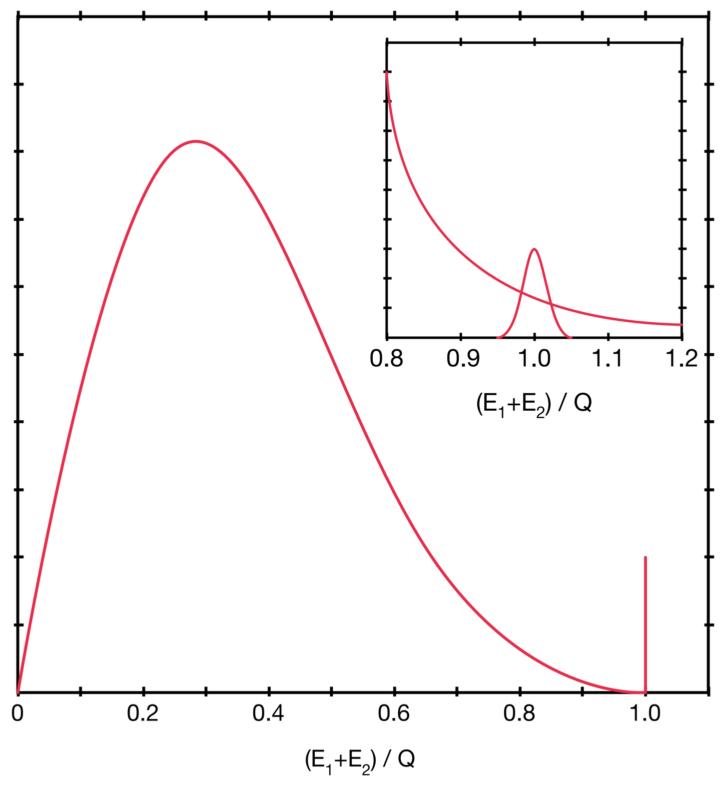
Neutrinoless double beta decay ($0\nu\beta\beta$) is a hypothetical very slow radioactive process in which two neutrons in a nucleus decay into two protons emitting two electrons:

$$(Z, A) \rightarrow (Z+2, A) + 2\,e^-$$

An unambiguous observation of this process would establish a Majorana nature for neutrinos and prove the violation of total lepton number, two results with deep implications for particle physics and cosmology. In addition, a measurement of the $0\nu\beta\beta$-decay rate would provide direct information on neutrino masses.

The detectors used for $0\nu\beta\beta$-decay searches are designed to measure the energy of the radiation emitted by a source. In a $0\nu\beta\beta$ decay, the sum of the kinetic energies of the two emitted electrons is always equal to the Q value of the process. Because of the limited energy resolution of any detector, events of a fixed energy spread Gaussianly over a larger region. Other processes occurring in the detector can fall within that energy range, becoming a background and limiting the sensitivity of the experiment.

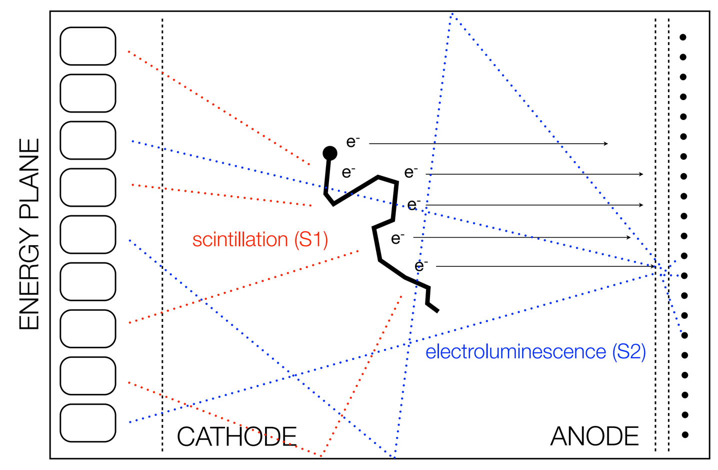
$$\mathcal{S}(T_{1/2}) \propto \varepsilon \sqrt{\frac{M\,t}{b\,\Delta E}}$$



THE NEXT EXPERIMENT

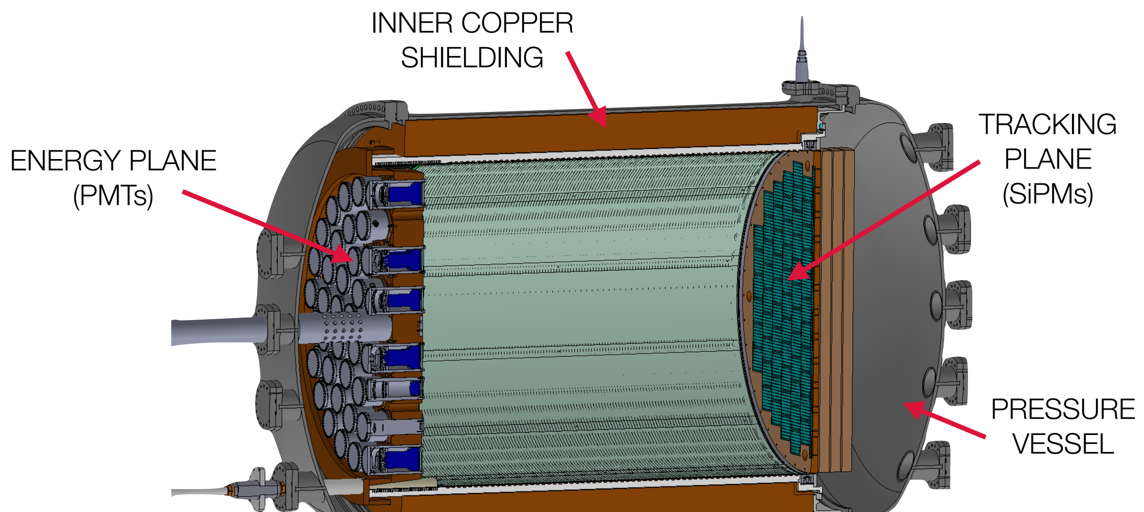
NEXT will search for the neutrinoless double beta decay of ^{136}Xe using a high-pressure xenon gas (HPXe) time projection chamber (TPC). The detector design exploits the electroluminescence (EL) of xenon for the amplification of the ionization signal, and comprises separate readouts for calorimetry and tracking. Such a detector provides three important features for a $0\nu\beta\beta$-decay experiment:

- Very good **energy resolution**; better than 1% FWHM at the Q value of ^{136}Xe.
- Three-dimensional **track reconstruction** for the identification of signal and background.
- **Scalability** to large masses of $0\nu\beta\beta$ isotope.



THE NEXT-100 DETECTOR

NEXT-100, currently under construction, will operate at the **Laboratorio Subterráneo de Canfranc** (LSC), under the Spanish Pyrenees. The **TPC**, with a cylindric active volume 105 cm long and 130 cm in diameter, will contain ~100 kg of xenon gas (enriched to 91% in ^{136}Xe) at a pressure of 15 bar. The **energy plane** is equipped with 60 Hamamatsu R11410-10 PMTs, 3-in devices developed for low-background experiments. To protect them from the high pressure, they are inserted into copper enclosures maintained at vacuum and closed with a sapphire window. The **tracking plane** consists of ~7800 Hamamatsu 1-mm^2 silicon photomultipliers (SiPMs) spaced 1 cm and distributed in 8×8 boards. Both sensor planes and the inner surface of the TPC are coated with TPB, a wavelength shifter that transforms the ultraviolet light emitted by xenon into blue. A 12-cm thick layer of copper shields the TPC from the outside. All these subsystems are contained within a stainless steel (316Ti alloy) pressure vessel. The entire detector is placed inside a 20-cm thick **lead castle**.



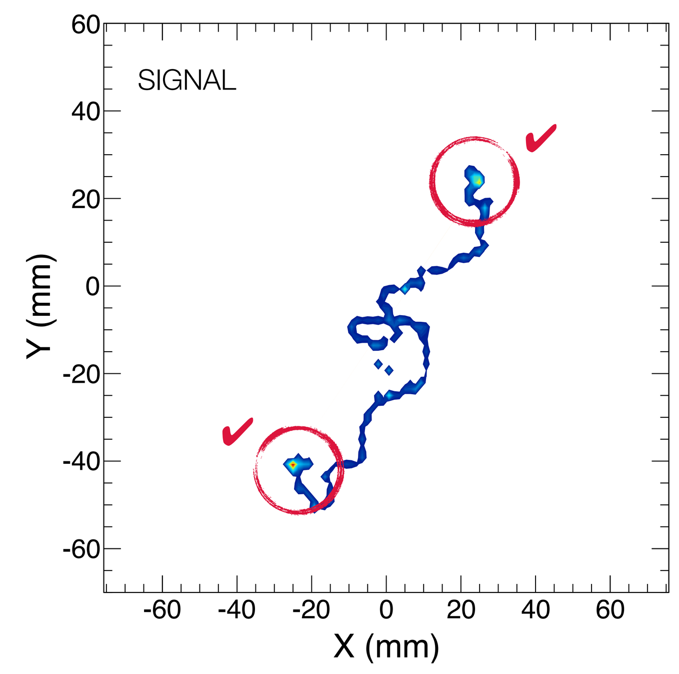
SIGNAL AND BACKGROUND IN NEXT

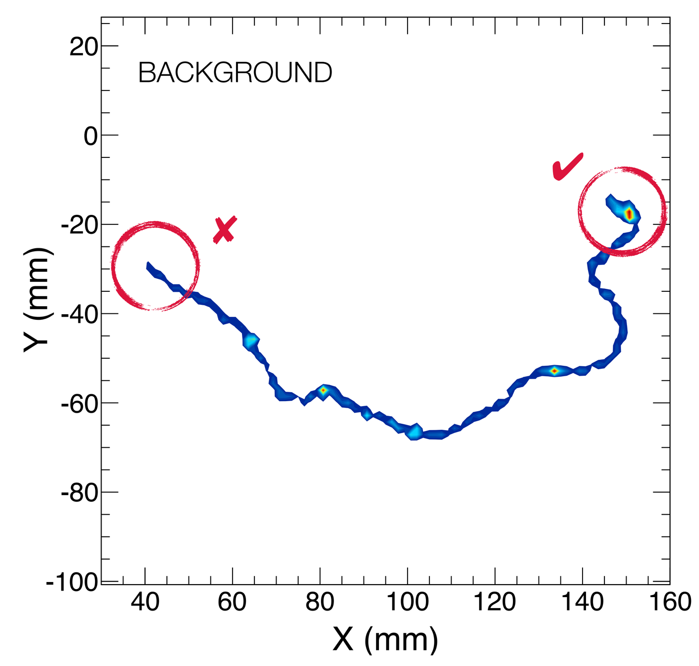
Neutrinoless double beta decay events leave in HPXe tracks with a distinctive pattern: about 10–15 cm long at 15 bar, tortuous because of multiple scattering, and with larger energy depositions (*blobs*) at both ends. Misidentified single electrons from natural gamma radioactivity are the main source of background in NEXT. In particular, the $0\nu\beta\beta$ peak of ^{136}Xe, located at 2458 keV, is surrounded by a ^{214}Bi (from the uranium series) gamma line at 2448 keV and a ^{208}Tl (from the thorium series) line at 2615 keV.

Using trillions of simulated signal and background events, we have estimated the acceptance of a set of basic selection cuts:

1. The event must be fully contained within the active volume of the detector
2. The event must be composed by a single track.
3. The tracks must have a blob at both ends.
4. The energy of the event must fall within the region of interest (ROI) defined by the energy resolution of the detector.

Selection cut	Fraction of events			
	$\beta\beta0\nu$	$\beta\beta2\nu$	^{214}Bi	^{208}Tl
$E \in (2.3, 2.6)$ MeV	0.776	3.31×10^{-6}	1.52×10^{-4}	8.02×10^{-3}
Fiducial	0.678	2.95×10^{-6}	1.13×10^{-4}	4.77×10^{-3}
Single track	0.508	2.27×10^{-6}	1.36×10^{-5}	8.44×10^{-4}
$\mathrm{d}E/\mathrm{d}x$	0.381	1.70×10^{-6}	1.36×10^{-6}	8.10×10^{-5}
ROI	0.319	3.24×10^{-12}	1.23×10^{-7}	3.23×10^{-7}

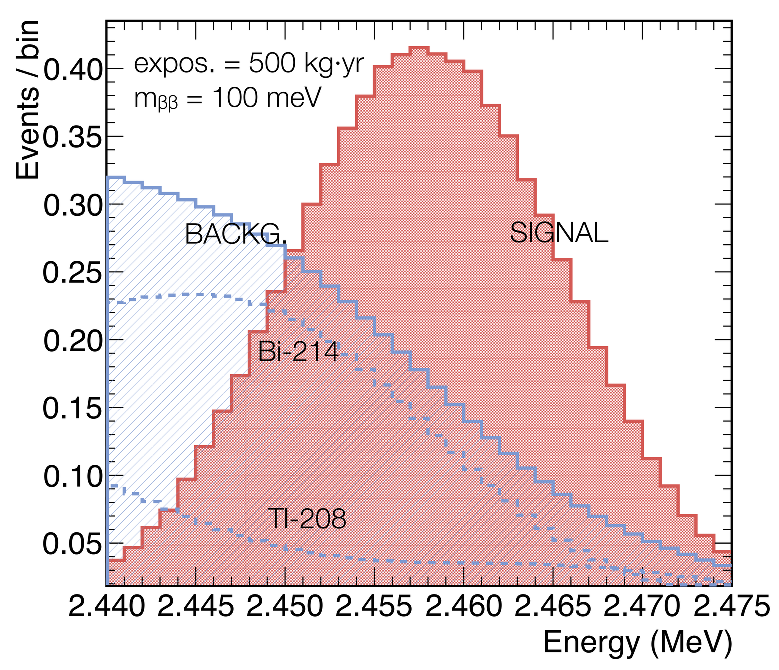


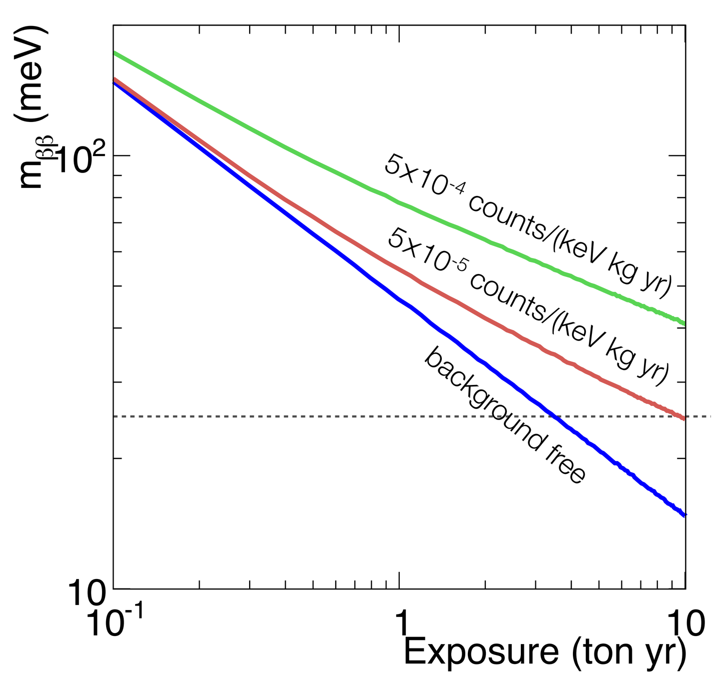


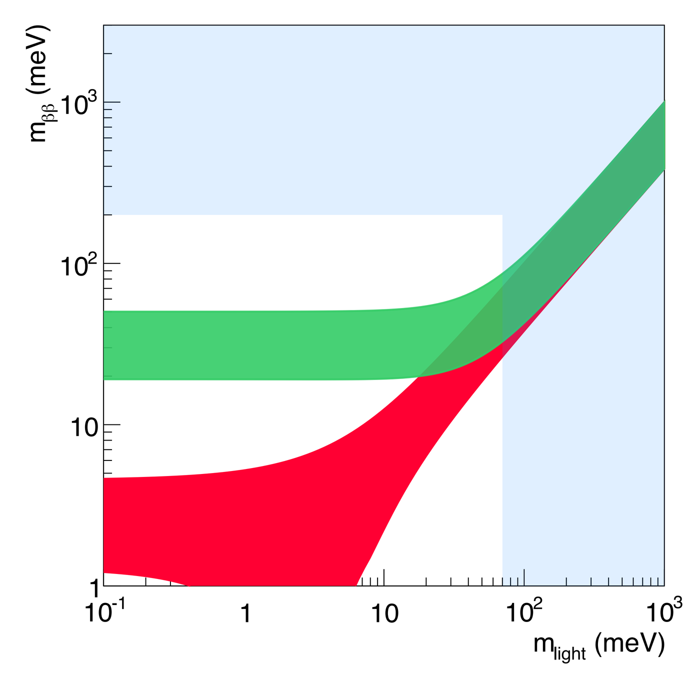
BACKGROUND RATE & SENSITIVITY

The activity levels of ^{214}Bi and ^{208}Tl in all materials and components used in NEXT-100 have been measured by the Collaboration and the LSC Radiopurity Service. These data and the computed acceptances are combined to estimate the **background rate** expectable in NEXT-100 to be **~5×10^{-4} counts keg^{-1} kg^{-1} year^{-1}**. This will result in a sensitivity close to **100 meV** after accumulating 500 kg·year of exposure.

System	Background rate $[10^{-4}$ cts/(keV kg yr)$]$		
	^{214}Bi	^{208}Tl	Total
Energy plane	0.7	0.3	1.0
Tracking plane	0.3	0.3	0.6
TPC	0.9	0.1	1.0
Pressure vessel	0.1	0.2	0.3
Inner shielding	0.1	0.2	0.3
Others	1.4	0.4	1.8
Total (incl. others)	3.5	1.5	5.0







The authors would like to acknowledge the collaboration of the members of the NEXT experiment and the support of the Ministerio de Economía y Competitividad of Spain under grants CONSOLIDER-Ingenio 2010 CSD2008-0037 (CUP), FPA2009-13697-C04-04 and FIS2012-37947-C04. Moreover, we would like to acknowledge the support of the European Research Council Advanced Grant 339787 (NEXT).

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