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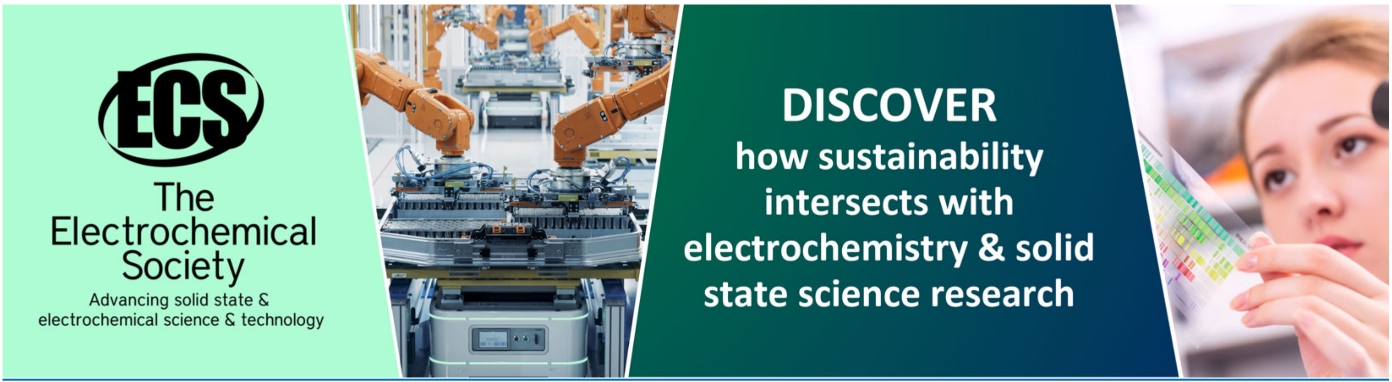

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Discovering neutrinoless double beta decay with NEXT100 detector

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Abstract. NEXT is a new experiment to search for neutrinoless double beta decay processes that will start operation at the LSC laboratory (Canfranc, Spain) in 2013. The apparatus is a high pressure gas xenon chamber (HPGXe) filled with 100–150 kg of gas Xenon enriched at 90% in the ^{136}Xe isotope. NEXT proposes a novel detection technique called SOFT (Separated Optimized Function TPC) which optimizes both the energy resolution and the measurement of the topological signature of the event. This results in a powerful background rejection, which, combined with a carefully screened radiopure detector will allow NEXT to be competitive with existing proposals for next-generation neutrinoless double-beta decay experiments. First prototypes have been operating successfully in different laboratories. First results with large-scale prototypes measure a resolution of 1% FWHM at the ^{137}Cs photopeak. This extrapolates to a resolution better than 0.5% FWHM at $Q_{\beta\beta}$.

1. Introduction

We know that neutrinos (a) have mass, (b) their masses are very small compared with the other fermions of the same generation, and (c) are neutral particles that have no protected charges (see for example[GGM08] and references there in). In the SM neutrinos are massless and all the other fermions are Dirac particles described by a four-component spinor. Neutrinos, on the other hand, could be truly neutral particles, identical to their antiparticles, and could be described as Weyl particles, with only two degrees of freedom. Majorana neutrinos could explain the smallness of neutrino masses (via the see-saw mechanism). They could also be an essential ingredient in leptogenesis theories. If neutrinos are Majorana particles observables related with a lepton number violation are predicted. Of these the best, from the experimental point of view is the detection of a neutrinoless double beta decay [EV02][AIEE08].

In the past years, the field of the experimental search of the neutrinoless double beta decay have been dominated for experiments based on solid state detectors (e.g, Germanium calorimeters) enriched in the isotopes with a double beta decay mode. These are compact devices which display an impressive energy resolution. However, they have a number of limitations, including: (a) a relatively large surface background, (b) relatively poor spatial location of candidate events, and (c) high cost, that makes extrapolation to large and very large masses difficult.

For the next generation of experiments new approaches with more capabilities to handle large masses and to reach better level of background suppression are needed. In this scenario, experiments using ^{136}Xe appear in the field with new techniques and with a competitive sensitivity to the half-life of the process.

2. NEXT Concept

The Neutrino Experiment with a Xenon TPC (NEXT) [Gn^{+}09] will search for $\beta\beta0\nu$ in ^{136}Xe using a 100-150 kg high-pressure gaseous xenon (HPGXe) time projection chamber. To amplify the ionization signal the detector uses electroluminicence (EL), that is, the emission of scintillation light after atom excitation by a charge accelerated by a moderately large (no charge gain) electric field. Electroluminescence is a linear process with a large gain that allows to obtain both good energy resolution and event topological information for background rejection.

Compared with the other two Xenon experiment, EXO [Hal10] and KamLAND-ZEN [Koz11], NEXT displays a much better energy resolution, which can be as good as 0.5% at $Q_{\beta\beta}$ (to compare with ∼5% expected by EXO and 10% by KamLAND-ZEN) FWHM in all cases, and the ability to use the topological information of the event to characterize the signal.

2.1. Detection process

The detection process is as follows. A charged particle propagating in the HPXe losses its energy through ionization and excitation of xenon atoms. The de-exitations of the atoms emits VUV light (∼175nm) that is read using photodetectors behind a transparent cathode. Such fast signal, called S_1, provides the initial time of the event. A strong electric field is used to prevent the ionization electrons produced in the path of the charged particle to recombine with the positive ions (also generated for the primary charged particle), and also used to drift the negative charge towards the TPC anode. In the very last region of the TPC the charge enter inside a region of higher electric field exiting the Xenon atoms. Their de-exitation produces a huge number of VUV photons isotropically (EL process). The light propagated forward is detected with a set of small photosensors (MPPCs) of 1mm^2 placed in a matrix of 1cm^2 pitch giving a total coverage of 1%, those photosensor are placed a few millimiters behind the anode and provide information about the event topology. In the other hand, the light propagated backwards are read with the same photodetectors used to read the primary light, with those photodetectors the energy information of the event is reconstructed with a resolution of ∼0.5% FWHM at $Q_{\beta\beta}$.

3. NEXT R&D

In addition of a number of small prototypes, the NEXT collaboration has built three large prototypes to study the various concepts involved in the detection process, as well as to demonstrate energy resolution and the ability to reconstruct the event topology. The prototypes are:

- *NEXT-DBDM.* This prototype is operative LBNL (Berkeley, USA). During 2010 the apparatus has operated with only one plane of PMTs in the cathode, and has focused in the measurement of the energy resolution with electroluminescence. The first program of NEXT-DBDM, largely accomplished is to reach the maximum energy resolution and to study how effects like gain in the EL region, intensity of the electric field or pressure affect such energy resolution. In 2011, the prototype will also be used to address where HPGXe's can also be competitive as Dark Matter detectors.

  In its current implementation, NEXT-DBDM consists of an hexagonal field cage with an active drift region of 8 cm and a 14 cm transversal span. In the current implementation the TPC has 19 PMTs on the energy measurement side and no dedicated tracking sensor. The vessel and the gas system are designed to operate up to 15 bar and the voltage supply configuration allows large flexibility in the configuration of the electric field for both drift and electroluminescence regions. Typical high voltage differences across the EL gap are 8 to 15 kV depending on the pressure and typical voltage differences across the drift region are 4 to 16 kV. The PMTs are typically operated at a gain of 1.4 × 10^6.

- *NEXT-DEMO.* This large prototype, operating at IFIC (Valencia, Spain) is a demonstrator of the full NEXT-100 concept. It has two planes of photodetectors, one at the cathode and one at the anode, a long drift region (30cm) and a field cage capable to withstand large voltages. The design operative pressure is 10 bar. The vessel is a stainless steel cylinder, 60 cm long and 30 cm diameter. The fiducial volume is defined by a hexagonal light-tube made of PTFE reflector panels, 160 mm across the diagonal and 300 mm drift region. The electroluminescence region is made of two parallel grids separated by 5 mm. The maximum designed drift field is 1 kV/cm and the maximum electroluminescence field is 40 kV/cm.
- *NEXT-MM.* This is a prototype, located at U. Zaragoza (Zaragoza, Spain), that uses micromegas instead of light-pixels in the tracking plane. Its main goal is to study the capability of the micromegas to operate in a HPGXe EL TPC.

3.1. Results

First runs of the prototypes have been done with a ^{137}Cs source focusing in the study of the spectrum of its 662 keV gamma and the resolution at the photoelectric peak.

A typical event is shown in Fig 1. Primary light signal gives us the initial time of the event, the secondary light produced in the electroluminescent region gives us information about total event energy but also its structure represents event topology. The time difference between primary and secondary signal gives us the z position of the event inside the chamber with very high precission (<1mm).

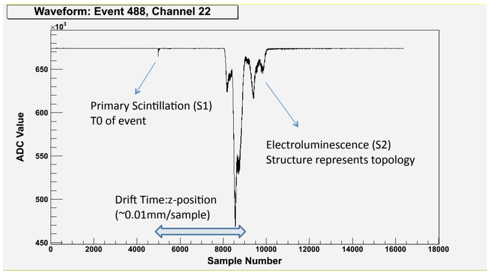


Figure 1: Typical ^{137}Csevent with the t0 signal from primary scintillation light and secondary light produced in the electroluminescent region.

Figure 2 shows two well know effects of energy degradation due to electron attachment to oxygen impurities in the gas during the drift and a radial dependence that is a solid angle effect due to the finite reflectivity of the field cage material (PTFE).

After those correction and a selection of the events inside a fiducial volume the improvement in the energy resolution is of a factor ∼3 reaching a resolution of 1.04% FWHM at the energy of ^{137}Cs photoelectric peak (Fig. 3a).

In the NEXT-DEMO prototype first tracks have been already reconstructed using the PMT plane in the anode (Fig. 3b). The topology

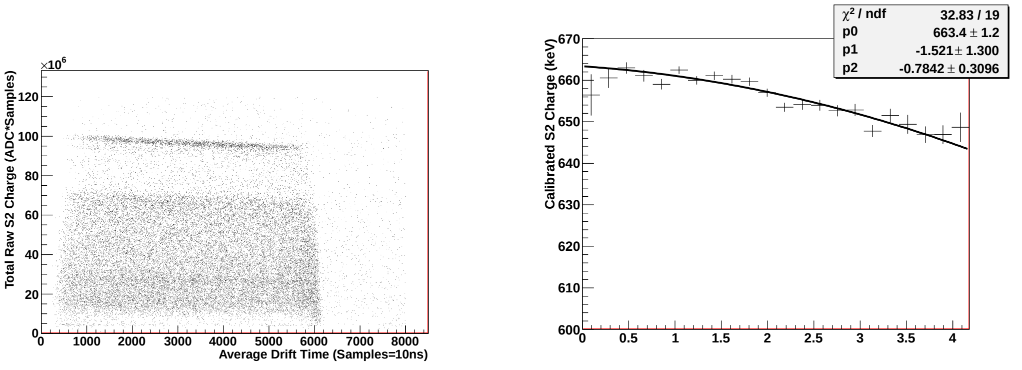
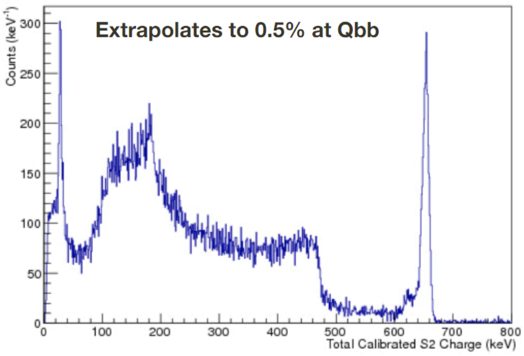
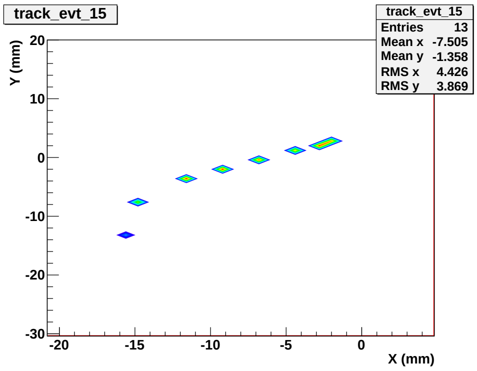


Figure 2: Energy Resolution is affected for energy losses due to electrons attachment (left) and radial dependence (right). Both effects are well understood and can be easily corrected.



(a) Resolution achieved after event selection is 1.04% at 662keV. Extrapolation at $Q_{\beta\beta}$ gives a value of 0.5%



(b) Typical track from a ^{137}Cs event. The blob at the end of the event can be very well differenciated from the track thanks to the differences in the energy deposition of the electron.

reconstruction capability of the detector with PMTs will be compared with the reconstruction with SiPMs in the next runs.

4. NEXT Physics case

Thanks to the good energy resolution and the extra handle of the topology information of the event NEXT detector provides an impressive background rejection potential of the order of $\sim 10^{-7}$ after all cuts for the two more pernicious background for ^{136}Xe ^{208}Tl and ^{214}Bi. Such background rejection potential provides a background rate of $2{\cdot}10^{-4}$counts/(keV $\cdot$ kg $\cdot$ y) when all possibles sources of background are computed.

As its shown NEXT will be able to confirm/disclaim KK's claim after one year running. Furthermore, it will be able to reach a sensitivity of 100 meV after 6 years running [GC^{+}10].

5. Conclusions

NEXT is a new DBD experiment that will be operating soon at the Laboratorio Subterraneo de Canfranc. It Marries two classical instrumental concepts (TPCs and EL) in a novel approach, providing very good energy resolution and tracking for background rejection. First results of prototypes (NEXT-DEMO, NEXT-DBDM) demonstrate energy resolution and tracking reconstruction, clearly validating the experiment technology.

6. Acknoledgments

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