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The NEXT detector: an Electroluminescence Xenon TPC for neutrinoless double beta decay detection

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The NEXT Experiment aims to detect neutrinoless double beta decay using an HPXe TPC based on electroluminescence to be deployed in the Canfranc Underground Laboratory.
New-generation experiments for double beta decay detection need to be sensitive to lifetimes longer than 1025 years. One remarkable challenge is the conception of a detector that enables an efficient and unambiguous identification of such a signal. Of the different detection techniques available, one has been chosen based on its suitability for complying with the key demands of this particular experiment: the capability to achieve an optimal energy resolution at the Xe Qββ energy (2.458 MeV), the event topology reconstruction competence to identify the distinct dE/dx of electron tracks, capability of high background suppression and the aptitude to be expanded to a large-scale system. Electroluminescence as the amplification technique for the primary ionisation and SiPM as the readout sensors for the topological recognition have been the elected means to integrate the experiment, combined in a high-pressure xenon Time Projection Chamber. Prototypes on which extensive studies have been performed already offered very promising results. One of these large prototypes is NEXT-DEMO, a TPC based on electroluminescence that validates the feasibility of the NEXT detector concept. This prototype is being upgraded to NEXT-NEW, which will fully operate in Canfranc Underground Laboratory. In this work, results will be presented and considerations will be made on both NEXT-DEMO and NEXT-NEW.

Summary

The Neutrino Experiment with a Xenon TPC (NEXT) aims to detect neutrinoless double beta decay using a high-pressure Xe-136 TPC based on electroluminescence to be deployed in the Canfranc Underground Laboratory, Spain.
New-generation experiments for double beta decay detection need to be sensitive to lifetimes longer than 1025 years. One remarkable defy is the conception of a detector that enables an efficient and unambiguous identification of such a signal.
For NEXT, the detection technique has been chosen based on its suitability for complying with the key demands of this particular experiment: the capability to achieve an optimal energy resolution at the Xe Qββ energy (2.458 MeV), the event topology reconstruction competence proving the possibility to identify the distinct dE/dx of electron tracks, capability of high background suppression and the aptitude to be expanded to a large-scale system.
To achieve optimal energy resolution, electroluminescence has been chosen as the amplification technique for the primary ionisation of xenon, over the charge amplification technique.
As for the readout planes, the chamber will have distinct detection planes for calorimetry and tracking, behind cathode and anode, respectively. SiPMs have been elected as the readout sensors for the topological recognition and PMTs for the energy plane.
The detection process is as follows: Particles interacting in the HPXe transfer their energy to the medium through ionisation and excitation. The excitation energy is patent in the prompt emission of VUV (around 178 nm) scintillation light from the xenon gas. The ionisation tracks (positive ions and free electrons) left behind by the particle are prevented from recombine applying an electric field of 0.3–0.5 kV per cm. The ionisation electrons drift toward the TPC anode, entering a region, delimited by two highly-transparent meshes,

with an even more intense electric field, 3 kV per cm per bar. There, further VUV photons are formed isotropically by electroluminescence processes. Hence, both primary scintillation and primary ionisation produce an optical signal, which is detected in the energy plane with PMTs, located behind the cathode.
The detection of the primary scintillation light constitutes the start-of-event, whereas the detection of electroluminescence light provides an energy measurement. Electroluminescent light provides tracking as well, since it is detected also at the anode plane, by means of an array of 1-mm2 SiPMs, 1cm in pitch, placed a few millimetres away from the electroluminescence region, Fig.1.
Prototypes using the above described features, on which extensive studies have been performed, already offered very promising results. One of these large prototypes is NEXT-DEMO, which validates the feasibility of the NEXT detector concept. NEXT-DEMO has been fully operational at IFIC, Valencia, since 2011.
A near-intrinsic energy resolution has been reached in the NEXT-DEMO prototype with a value of about 1.8% FWHM for 511 keV electrons, extrapolating to about 0.8% FWHM at Qββ=2.458 MeV, Fig.2.

Fig.1: The Separate, Optimized Functions (SOFT) concept in the NEXT experiment: EL light generated at the anode is recorded in the photosensor plane right behind it and used for tracking; it is also recorded in the photosensor plane behind the transparent cathode and used for a precise energy measurement.

Fig. 2: Energy spectrum for 511 keV gammas interacting in NEXT-DEMO. From the low- to the high energy-region, one can clearly identify the X-ray peak (˜30 keV), the Compton continuum (100-340 keV), the X-ray escape peak (˜480 keV) and the photo-electric peak (full energy).

The SiPM-based read-out planes in NEXT-DEMO have clearly demonstrated the good tracking capability of the chosen design. Straight cosmic-ray muon tracks, ˜500 keV electron tracks dominated by multiple Coulomb scattering, and isolated X-ray energy deposition of about 30 keV have been reconstructed. On the other hand, the tracking plane information can be combined with the energy (PMT) plane information in order to identify the number of Bragg peaks signaling the number of electrons ranging out in the detector. This is useful for ββ0⊠ searches, since the "blob", i.e., a track segment with higher energy deposition, multiplicity per event is expected to provide an additional background suppression factor. Signal events tend to yield two "blobs" from two electrons emanating from a common vertex. In the case of background, dominated by gamma interactions, only one "blob" per event is typically expected. Energy blobs where electron tracks range out have been clearly identified in NEXT-DEMO using the energy plane information, by projecting the electron tracks'dE/dx pattern along the drift direction, Fig.3.

Fig. 3: The reconstructed track left by a photoelectric electron produced by the interaction of a 662-keV gamma (from a 137Cs calibration source) detected by NEXT-DEMO.

NEXT-DEMO has been upgraded to NEXT-NEW, which will fully operate in Canfranc Underground Laboratory. The assembly and commissioning of the detector is planned for 2014.
In this presentation, results from NEXT-DEMO will be presented and considerations will be made on both NEXT-DEMO and NEXT-NEW.

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