THE NEXT EXPERIMENT
STATUS AND PHYSICS POTENTIAL

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IFIC (CSIC & Univ. de Valencia)

TPC SYMPOSIUM — PARIS, DECEMBER 2012
XE-136 EXPERIMENTS

EXO-200 uses the xenon as both source and detector in a homogeneous, liquid phase TPC. At the operating temperature (167 K) and pressure (147 kPa) the liquid xenon (LXe) has a density of 3.0 g/cm$^3$. The xenon for EXO-200 is enriched to 80.6% in the isotope $^{136}$Xe.

In order to minimize the surface-to-volume ratio while maintaining a practical geometry, the detector is a double TPC, having the shape of a square cylinder with a cathode grid held at negative high voltage at the mid plane. The signal readout is performed at each base of the cylinder, near ground potential. Of the 200 kg of enriched xenon available, 175 kg are in liquid phase, and 110 kg are in the active volume of the detector. A cutaway view of the TPC is shown in Figure 1.

Two considerations were central in designing the detector: the need for good energy resolution at the double beta decay $Q$-value of 2457.8 keV, and the requirement to achieve exceedingly low backgrounds. Early R&D performed by the EXO collaboration showed that the energy resolution in LXe can be substantially improved by using an appropriate linear combination of ionization and scintillation as the energy estimator. This technique was subsequently used in other contexts. In EXO-200 both the ionization and the scintillation signals are recorded.

Charge is collected at each end of the TPC by wire planes, held at virtual ground, while the 178 nm-wavelength scintillation light is collected by two arrays of large area avalanche photo-

KamLAND-Zen

Xe-136 dissolved in liquid scintillator

EXO-200

Liquid xenon TPC
XE-136 EXPERIMENTS

\[ ^{136}\text{Xe-based experiments currently dominating the field.} \]
THE THIRD WAY: \textit{next}

- **Neutrino Experiment** with a **Xenon gas TPC**
- Very good energy resolution: <1\% FWHM @ Q
- Powerful background rejection using the event topological signature.
- Can be extrapolated to large masses.
- It will be located at the Laboratorio Subterráneo de Canfranc (LSC), under the Spanish Pyrenees.
THE NEXT COLLABORATION

U. Girona • IFIC • U. Santiago de Compostela • U. Politècnica Valencia • U. Zaragoza

Iowa State Univ. • LBNL • Texas A&M

U. Aveiro • U. Coimbra

JINR

Univ. Antonio Nariño (Bogotá)

Spokesperson: JJ Gómez Cadenas (IFIC)
Deputy: Azriel Goldschmidt (LBNL)
ENERGY RESOLUTION IN XENON

Bolotnikov and Ramsey, NIM A 396 (1997)

NEXT Collaboration, arXiv:1211.4474
ELECTROLUMINESCENCE

- Figure 6: Relative variance in the number of emitted EL photoelectrons for different values of the reduced electric field.

- The effect of avalanche fluctuations in EL fluctuations, in Figure 6 for reduced electric fields between 1.5 and 3.5 kV cm\(^{-1}\) until secondary electrons begin to be produced and the avalanche region and cross the first mesh without either any recombinations.

- For reduced electric fields, the NEXT detector assumes that all the primary charges produced per event – for high pressure xenon are measured at 1 bar [17].

- The average number of photoelectrons produced in the plane of the drift region and cross the first mesh without either any recombinations.

- Performing a linear fit to the simulation results, we obtain the following dependence:

\[ Q_{\text{exc}} \] and \( Q_{\text{EL}} \) [16] are also shown (open symbols) for comparison.

- The effect of avalanche fluctuations in EL fluctuations, in Figure 6 for reduced electric fields between 1.5 and 3.5 kV cm\(^{-1}\) until secondary electrons begin to be produced and the avalanche region and cross the first mesh without either any recombinations.

- The average number of photoelectrons produced in the plane of the drift region and cross the first mesh without either any recombinations.

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- The FWHM energy resolution, which can be achieved by the NEXT detector. We assume that all the energy of the event is expressed in kV cm\(^{-1}\) bar. 

\[ (4.4) \]

- The contribution of each process happens in optimal conditions, namely. The first term that is a standard deviation,

\[ \sigma = 2 \sqrt{n} \]

- Using the data obtained by the simulation, we can estimate the following dependence:

\[ \text{FWHM} = 2 \sqrt{\text{energy deposited}} \]

- The average number of photoelectrons produced in the plane of the drift region and cross the first mesh without either any recombinations.

\[ \text{FWHM} = 2 \sqrt{\text{energy deposited}} \]

- The average number of photoelectrons produced in the plane of the drift region and cross the first mesh without either any recombinations.

\[ \text{FWHM} = 2 \sqrt{\text{energy deposited}} \]
Simulation of a neutrinoless double beta decay in xenon gas at 10 bar.
THE TOPOLOGICAL SIGNATURE

Veto of effectively all charged backgrounds entering the detector (left). High-energy gammas have a long interaction length (>3 m) in HPXe.
Interaction of high-energy gammas (from Tl-208 and Bi-214) in the HPXe can generate electron tracks with energies around the Q value of Xe-136.
THE TOPOLOGICAL SIGNATURE

A 1-MeV electron track in the MUNU TPC.

A double beta candidate in the Gotthard TPC.
Cylindrical TPC filled with enriched xenon gas at 10-15 bar pressure. TPC walls covered with a highly reflective material (PTFE coated with TPB).
Charged particles (like the two electrons emitted in a double beta decay) propagate through the xenon exciting and ionizing its atoms.
Prompt primary scintillation light emission in the VUV. About 75 eV needed to create one photon. Light bouncing in the walls is converted to the blue by the TPB. A plane of PMTs behind the transparent cathode detects this signal, which is used to establish the start-of-event time.
Ionization electrons drift toward the anode under the influence of an electric field (300 V/cm) with velocity 1 mm/μs. 25 eV needed to create an ionization pair. Non negligible diffusion in HPXe: 9 mm/√m transverse, 2 mm/√m longitudinal.
Ionization electrons enter a second electric field region defined between two meshes separated 5 mm. Secondary scintillation light (EL) is generated there. A plane of SiPMs behind the anode detects the forward light, which is used for tracking.
EL light also reaches the cathode and is detected by the PMT plane, providing an energy measurement.
THE PRESSURE VESSEL

Dimensions: 140 cm diameter, 230 cm long. Stainless steel grade 316Ti. Rated to 15 bar. Currently under construction.
TIME PROJECTION CHAMBER

Dimensions: 106 cm diameter, 130 cm long. Thick poliethylene cylinder providing insulation. Three 88% transparent meshes defining the two electric field regions (drift and EL). Copper rings form the field cage. PTFE panels coated with TPB to improve the light collection.
HV FEEDTHROUGHS

HV feedthroughs custom made by pressing a stainless steel rod into a Tefzel bar. They can hold up to 50 kV.
PHOTOMULTIPLIER TUBES

Hamamatsu R11410-10 specially developed for low-background operation in xenon. Protected from pressure by a copper enclosure with a sapphire window.
60 3-inches photomultiplier tubes. 33% photocathode coverage. All PMT enclosures connected through a manifold to a vacuum pump.
SILICON PHOTOMULTIPLIERS


Hamamatsu S10362-11-050P MPPCs mounted onto Cuflon boards with common power. Sensors spaced 1 cm. The boards are coated with TPB.
THE TRACKING PLANE

Boards mounted onto a copper structure. About 7000 channels extracted through 3 custom-made pressure-tight connectors using flat cables.
Lead castle built with 15-cm thick bricks. Both the detector and the shielding are mounted onto a anti-seismic pedestal. Currently under engineering review. Construction expected to start early next year.
LOCATION AT THE LSC

The experiment will be located at Hall A at the LSC. Working platform and basic gas system already in place.
MATERIAL SCREENING

Radiopurity Service at Hall C of the LSC
<table>
<thead>
<tr>
<th>#</th>
<th>Material</th>
<th>Supplier</th>
<th>Technique</th>
<th>Unit</th>
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**Vessel**

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**HV, EL components**

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<td>20</td>
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**Energy, tracking planes**

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NEXT Collaboration and LSC, arXiv:1211.3961
BACKGROUND PREDICTION

Geant4 simulation of the detector including all sources of background in the detector.
BACKGROUND PREDICTION

Topological analysis of simulated data.
## BACKGROUND PREDICTION

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Contribution to the background rate (counts/keV/kg/yr) of different subsystems of NEXT-100.
Figure 22. Sensitivity (at 90% CL) of NEXT-100 to the effective neutrino Majorana mass $m_{bb}$, computed following the method described in [10]. The solid, blue line corresponds to the baseline scenario where 100 kg of enriched xenon are used, whereas the dashed, red line shows the sensitivity of the detector with 150 kg of source mass.

The expected background rate is $8 \times 10^{-4}$ counts $(\text{keV} \cdot \text{kg} \cdot \text{y})$; this results in a sensitivity (see figure 22), after 5 years of data-taking, of about $5.9 \times 10^{-25}$ years or, in terms of $m_{bb}$, better than 100 meV.

NEXT-100 is approved for operation in the Laboratorio Subterráneo de Canfranc (LSC), in Spain. The installation of shielding and ancillary systems will start in the second half of 2012. The assembly and commissioning of the detector is planned for early 2014.

Acknowledgments

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• The NEXT-100 detector is already under construction.

• Commissioning expected for the first semester of 2014.

• A run with depleted xenon for measuring the background will be followed by the run with enriched xenon (2015).

• If the performance matches the expectation, NEXT might be the way to go for the ton-scale experiments.