The NEXT experiment

J.J. Gomez Cadenas
Instituto de Física Corpuscular (CSIC & UVEG)
On behalf of the NEXT collaboration

DBD11 — November 2011
NEXT Collaboration

U. Girona • IFIC (Valencia) • U. Santiago de Compostela
• U. Politécnica Valencia • U. Zaragoza • U. A. Madrid

LBNL • Texas A&M • John Hopkins

CEA (Saclay)

U. Coimbra • U. Aveiro

JINR (Dubna)

UAN (Bogotá)

jueves 17 de noviembre de 2011
NEXT concept

HPGXe

Main Cylindrical Vessel
Torispheric Heads
Energy Plane, PMTs
Cu Shield

Vac. Manifold
PMT FTs

HV Cable
HV/Press. relief/Flow/Vac. Ports

Field Cage Rings
Reflectors
Shieldings Externals Cu on Pb

EL mesh planes
Cathode Tracking Plane, SiPM
EL HV F.T.

SOFT

Readout Plane A
- position

Readout Plane B
- energy

Electroluminescent Layer

Energy resolution

Topological signature

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The SOFT concept
Intrinsic resolution (Fano factor) at $Q_{\beta\beta}$ (2458 keV): $3 \times 10^{-3}$ FWHM.  
Achieved in NEXT large prototypes: $5 \times 10^{-3}$ FWHM.  
NEXT target: 0.5% FWHM appears feasible.
Energy resolution

Energy resolution of 1 % FWHM at 662 keV measured by NEXT-DBDM

Full energy spectrum for a Cs-137 calibration source. Resolution is quite stable against pressure, drift field (0.3-2 kV/cm) and EL (2.0-3.5 kV/cm bar), but careful calibration and monitoring needed.
Electrons travel on average ~15 cm each. Clear topological signature. Electrons behave as MIPs except near the endpoints (*blobs*).
Topological signature

Tracks reconstructed at 662 keV by NEXT-DEMO

Single blobs clearly visible at the end of the track

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Detection process

- Cylindrical TPC filled with highly enriched (>90%) $^{136}$Xe gas at 15 bar pressure.
- TPC walls lined with material highly reflective.
- Signals read by photosensors
- Baseline detector with ~100-150 kg mass (2 m$^3$): NEXT-100.
A $^{136}$Xe isotope decays emitting the two electrons. They propagate through the HPXe ionizing and exciting its atoms.
Detection process

- Prompt primary scintillation light emission in VUV (~175 nm). About 100 eV needed to create a primary scintillation photon.
- Detect faint signal via sensitive photo-detectors (PMTs) behind transparent cathode.
- Determine $t_0$ and therefore event position along drift.
Detection process

- Create ionization charge in Xe: ~25 eV to create one electron-ion pair.
- Electrons drift toward anode with velocity ~1 mm/us in a ~0.5 kV/cm electric drift.
- At 10 bar pressure, non-negligible diffusion: 9 mm/√m transverse, 4 mm/√m longitudinal.
Detection process

- Additional grid in front of anode creates $\approx 0.5$ mm thick region of more intense field: $E/p \approx 4$ kV/cm/bar.

- Secondary scintillation light (electroluminescence) created in between grids by atomic de-excitation, with very linear gain of order $10^3$ and over a $\approx 2$us interval.

- Finely segmented photo-detector plane (MPPCs) just behind anode performs “tracking”.

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Detection process

- Electroluminescence, emitted isotropically, also reaches cathode.
- Same array of photo-detectors used for \( t_0 \) measurement is also used for accurate calorimetry.
The only relevant background for NEXT are gammas from Bi-214 and TI-208.

3D reconstruction of event suppresses most background events including identification of 30 keV X-rays from Xe de-excitation.
Bi-214 line very close to Xe Qbb.

Energy resolution (and radiopurity) are essential to separate signal from background.

But extra handles become a must.
Topological signature

Monte Carlo bkgnd event from Bi-214
Topological signature

NEXT-DEMO event from Na-22 with X-ray
Good rejection factor (1/10) with very high signal efficiency (>80%)

Or higher rejection factors (1/50 or better) at higher efficiency cost (50% or lower)
Prototypes
EL prototypes

NEXT-DBDM
Energy resolution in HPXe
Possible application to DM searches

NEXT-DEMO
NEXT detector concept
Very clean waveforms. Both scintillation (S1) and ionization (S2) signals clearly visible.
Analysis corrections

Long electron lifetime (>4 ms) in the gas.

Radial dependence (solid angle) of collected light easily corrected.
NEXT-DBDM

Energy resolution of 1 % FWHM at 662 keV!

Full energy spectrum for a Cs-137 calibration source. Data taken at 15 bar, drift field of 0.7 kV/cm and EL gain of 2 kV/cm/bar.
NEXT-DEMO

SiPM Plane

0.5 cm EL gap

Anode

Gate

30 cm drift field

Cathode

10 cm buffer region

PMT Plane

PMT Shield
NEXT-DEMO

• Mesh grids with 88% optical open area (gate and anode)
NEXT-DEMO

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NEXT-DEMO

Field Cage Breakdown – PMT Plane

PTFE Reflector

PEEK Support Plate
(Poly Ether Ether Ketone Plastic)

~ 6 mm
NEXT-DEMO
S1, S2 and S2 due to X ray clearly visible

NEXT-DEMO
Reconstructed electrons from Cs-137 source.
2.3 Electroluminescent Grids

Figure 2.11 shows the electroluminescent (EL) grids built for the NEXTkDEMO prototype. The grids were constructed using a stainless steel mesh with pitch of $n$ mm and wire diameter of $q$ micron, which results in an open area of $v$. The grids are formed by clamping in a ring with a tongue and groove to hold the mesh and using a tensioning ring that is torqued with set screws to achieve the optimum tension.

One important issue is that for the large diameter required in NEXTkon, preliminary estimates show that electrostatic attraction will cause the EL grids to bow more than acceptable to achieve the required energy resolution. The solutions are to use a slightly larger EL gap and/or to use a larger gauge wire. For example, a wire mesh is available with $n$ micron $pw$.
Figure 2.9: NEXT-100 Field Cage

Figure 2.10: Field Cage copper rings

Figure 2.11: Electric field lines (red vertical lines) and equipotential contours are shown in a 50 cm section of the drift region. The lines are fairly uniform starting from a distance of approx. 2 cm from the field cage inner wall surface.

Figure 2.12: Cathode high voltage feedthrough (HVFT) designed for up to 100 kV operating voltage.
EL Grids
NEXT-100 sensors

PMTs for calorimetry and start-of-event
- Excellent charge resolution and linearity, single-pe detection, large dynamic range, etc.
- Favorite candidate: Hamamatsu R1141MOD.
- No. channels ~60.

MPPCs for tracking:
- Fine pixelization (~1cm pitch), low cost, some energy information.
- No. channels ~7500
RI Level for R11410MOD

### Estimated RI level

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weight (g)</th>
<th>40K</th>
<th>U</th>
<th>Th</th>
<th>Co60</th>
<th>Sub Total</th>
</tr>
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<tbody>
<tr>
<td>Quartz Faceplate</td>
<td>35</td>
<td>0.0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Metal Bulb</td>
<td>95</td>
<td>5.7</td>
<td>2.9</td>
<td>1.0</td>
<td>3.5</td>
<td>13.1</td>
</tr>
<tr>
<td>Stem (ceramic)</td>
<td>25</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
<td>5.5</td>
<td>6.2</td>
</tr>
<tr>
<td>Insulating Plates</td>
<td>16</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Electrodes</td>
<td>31</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>202</strong></td>
<td><strong>5.7</strong></td>
<td><strong>3.3</strong></td>
<td><strong>2.3</strong></td>
<td><strong>9.1</strong></td>
<td><strong>20.4</strong></td>
</tr>
</tbody>
</table>

**Expected RI level** : 10~30 mBq/PMT

Typical QE Curve

In case of R11410, QE at 175 nm could be improved further.

In case of R11065, QE at 420 nm would be improved further.
Figure 3.4: A PMT inside its enclosure.
PMT plane
SiPM plane
Coating of sensors and reflectors with a WLS (TPB) to improve light collection.
NEXT-100: shielding

Shielding design completed.
Construction starts early January

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NEXT-100: xenon

100 kg of enriched xenon (and 100 of depleted) already procured, and waiting at the LSC.
## NEXT-100 performance

<table>
<thead>
<tr>
<th></th>
<th>Signal</th>
<th>$^{214}$Bi</th>
<th>$^{208}$Tl</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 track cut</td>
<td>0.48</td>
<td>$6.0 \times 10^{-5}$</td>
<td>$2.4 \times 10^{-3}$</td>
</tr>
<tr>
<td>ROI</td>
<td>0.33</td>
<td>$2.2 \times 10^{-6}$</td>
<td>$1.9 \times 10^{-6}$</td>
</tr>
<tr>
<td>Topological cut</td>
<td>0.25</td>
<td>$1.9 \times 10^{-7}$</td>
<td>$1.8 \times 10^{-7}$</td>
</tr>
<tr>
<td>Rejection Potential</td>
<td></td>
<td>$\sim 10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td></td>
<td>$2.0 \times 10^{-4}$ counts/keV/kg/yr</td>
<td></td>
</tr>
</tbody>
</table>
**NEXT-100 sensitivity**

Fig. 30. – Sensitivity of the different experiments to the neutrino effective mass $m_{\beta\beta}$ computed assuming a 5 years exposure, the PMR intervals for the nuclear matrix elements (see sec. 4.3), and for both the optimistic and pessimistic experimental parameters of table IV. A statistical 90% CL is computed according to the Feldman-Cousins method [132], assuming a signal region of one FWHM and the corresponding efficiency. For each experiment, the sensitivities for the two experimental parameter sets are drawn as overlapping rectangles. A sensitivity line corresponding to a 10 years exposure, and to the most optimistic NM experiment parameters, is also shown. The upper grey region represents the KK claim [66] while the lower grey region represents the inverted hierarchy region (see fig. 10).

On the other hand, several experiments appear to have a very good chance to reach a sensitivity of 100 meV or better, in particular CUORE, KamLAND-Zen, NEXT and EXO-200. In our most optimistic scenario concerning NME values and experimental performances, this target may also be reached by GERDA during its second phase.

Given our uncertainties, we cannot predict which, among these 4–5 different experimental proposals, will provide the best $m_{\beta\beta}$ sensitivity after a 5 years exposure. To this end, a better knowledge of the actual (as opposed to expected) values for the background rates, of the systematic uncertainties affecting the measurement, and of the NME values would be necessary for all experiments.

From figure 30, our expectation is that it will be almost impossible for the new-generation experiments discussed here to discover $\beta\beta_0\nu$ after 5 years of exposure if the neutrino mass spectrum is hierarchical ($m_{\text{light}} \simeq 0$) rather than degenerate, since essentially no overlap exists between the experimental sensitivities and the 17–52 meV HM experiment.
TDR in December, 2011

Construction and commissioning of shielding and gas system (January 2012—June 2012).

Complete design of pressure vessel and manufacture (Sept 2011—Sept 2012).

Construction and characterization of detector planes (Second half 2012).

Construction of field cage and HV system (Second half 2012).

Commissioning of the NEXT-100 detector at the LSC (early 2013).

Running in 2014
Summary

- NEXT is a new-generation double beta decay experiments, lead by Spanish and American groups, and to be installed at the Laboratorio Subterráneo de Canfranc (Spain).

- Marries two old instrumental concepts (TPCs and EL) in a novel approach, providing very good energy resolution and tracking for background rejection.

- A crash R&D program has produced to EL prototypes which have already demonstrated the feasibility of the idea.

- Technical design of the NEXT-100 detector essentially completed.

- Pushing ahead on a very tight schedule to be running in 2014.

- Hoping to be there on time!
ありがとうございます