NEXT

Searching for the $\beta\beta 0\nu$ decay at the LSC

EPS 2015 @ Vienna, Austria

Pau Novella (IFIC/CSIC)

On behalf of the NEXT collaboration
Contents

- Searching for the $\beta\beta0\nu$ decay
- The NEXT TPC concept
- R&D: technology performance
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- Summary
Searching for the $\beta\beta0\nu$ decay

$T^{2\nu}_{1/2} \sim 10^{19} - 10^{21}$ year

$T^{0\nu}_{1/2} > 10^{25}$ year

Energy resolution
Background rejection
Scalability


$\beta\beta0\nu$ experiment
NEXT
Calorimeters
Tracko-calos
Bolometers
NEXT: HP Gas-Xe TPC

\[ T_{1/2}^{-1} \propto a \cdot \epsilon \cdot \sqrt{\frac{M_{t}}{\Delta E \cdot B}} \]

- \( Q_{\beta\beta} = 2.48 \text{ MeV} \)
- Scint/Ionization
- Cheap/Easy to enrich
- Long \( \beta\beta{2}\nu \) mode

\( ^{136}\text{Xe} \)

Source=Detector

S/N improves with \( L \)

Good \( \Delta E \)

3D track


P. Novella, NEXT, EPS 2015
The TPC concept

Gas TPC with 2 dedicated readout planes

TPB coated surfaces
15 bar

scintillation (S1)

TPC with 2 dedicated readout planes

136Xe

electron luminescence (S2)

EL: linear gain, no avalanche fluctuations: optimize ΔE

P. Novella, NEXT, EPS 2015
Fighting the non-$$\beta\beta$$ events

Powerful BG rejection: track topology and dE/dx
R&D: Proving the technology

2012-2014

The NEXT-DBDM @ LBL (1 kg Xe):

The NEXT-DEMO @ IFIC (1.5 kg Xe):

Gas Xe EL-TPC: Energy resolution (only PMTs)

Complete prototype: PMT+SiPM

JINST 8 (2013) P0400
JINST 8 (2013) P09011
JINST 9 (2014) 10, P10007
JINST 8 (2013) P05025
JINST 10 (2015) 03, P03025
R&D: Energy Resolution

NEXT-DBDM: $^{137}$Cs
1.0% FWHM @ 660 keV
0.5% FWHM @ $Q_{\beta\beta}$ of $^{136}$Xe

NEXT-DEMO: $^{22}$Na
1.6% FWHM @ 511 keV
Over large fiducial volume
0.63% FWHM @ $Q_{\beta\beta}$ of $^{136}$Xe
R&D: Event topology

- The NEXT-DEMO @ IFIC (1.5 kg Xe): arXiv:1507.05902

$^{228}\text{Th}$

$(e^{-}e^{+})$

$E=1.6 \text{ MeV}$

$^{22}\text{Na}$

$E=1.3 \text{ MeV}$

2e cut: $\varepsilon_{\text{Na}} = 24.13 \pm 1.4\% \ (MC: 21.9\%)$

$\varepsilon_{\text{Th}} = 66.7 \pm 0.6 \% \ (MC: 65.9\%)$

BG rejection demonstrated

Monte Carlo validated
NEXT-NEW: Physics @ LSC

TPC:
- 10 kg active region
- 50 cm drift length

Tracking plane:
- 1800 SiPM
- 1 cm pitch

Pressure Vessel:
- Steel, up to 30 bar

Energy Plane:
- 12 PMTs
- 30% coverage

Inner shield:
- 6 cm of copper

2015-2016

Physics program:
- $\Delta E = 0.5\%$ FWHM
- Event Topology
- Measure the BG
- Certify technology
- ...

Ultimate goal:

First phase of the NEXT-100 experiment
NEXT-NEW @ LSC

- Infrastructures ready: platform, lead castle, gas system
- Xenon available: 100 kg of enriched $^{136}\text{Xe}$ and 100 kg of depleted Xe

- NEXT-NEW: vessel @ LSC since early 2015, energy plane installed
NEXT-NEW Energy Plane

Energy plane mounted in July 2015

Sapphire windows to hold the pressure

PMT: Hamamatsu R11410-10

Testing and commissioning in Summer 2015
**NEXT-100: the degenerate land**

- **TPC:**
  - 100 kg active region
  - 130 cm drift length

- **Pressure Vessel:**
  - Steel, up to 15 bar

- **Energy Plane:**
  - 60 PMTs
  - 30% coverage

- **Tracking plane:**
  - 7000 SiPM
  - 1 cm pitch

- **Inner shield:**
  - 12 cm of copper

2016-2020
Status of NEXT-100

Vessel: 316Ti Stainless Steel

PMT: Hamamatsu R11410-10

SenSL 1x1mm² SMD C


2e - cut: 

\[ \varepsilon_{\beta\beta} \approx 70\% \]

\[ \varepsilon_{\beta} \approx 10\% \]

(room for improvement!)
Radiopurity measurements 4x10^{-7}

Background rejection factors

Total BG: 4x10^{-4} c/keV kg y


m_{\beta\beta} < 100 \text{ meV (3 years of data)}
Summary

- Energy resolution
- Background rejection
- Scalability

Topologies:
- NEXT-NEW
- NEXT-100
- NEXT-1ton?

Gas Xe TPC

R&D

ΔE<1%FWHM

NEXT-100

90% CL. (1 dof)

Lightest neutrino mass in eV

NEXT-NEW

NEXT-100

136Xe
Back up
NEXT-DEMO Results

TPC characterization

X-ray analysis

α analysis

Spatial calibration

JINST 8 (2013) P0400
JINST 8 (2013) P09011
JINST 9 (2014) 10, P10007
JINST 8 (2013) P05025
JINST 10 (2015) 03, P03025

\[ W_{\text{ex}} = (39.2 \pm 3.2) \text{ eV}. \]
NEXT-100: Rn and Radioactivity

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>Technique</th>
<th>units</th>
<th>$^{228}$U</th>
<th>$^{226}$Ra</th>
<th>$^{232}$Th</th>
<th>$^{228}$Th</th>
<th>$^{235}$U</th>
<th>$^{40}$K</th>
<th>$^{50}$Co</th>
<th>$^{137}$Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lead</td>
<td>Britannia</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;126</td>
<td>&lt;2.8</td>
<td>&lt;3.2</td>
<td>&lt;6.9</td>
<td>&lt;0.3</td>
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<tr>
<td>2 S-275 steel</td>
<td>Poycon</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>32±9</td>
<td>1.2±0.1</td>
<td>1.9±0.2</td>
<td>4.7±0.3</td>
<td>3.2±0.7</td>
<td>1.8±0.1</td>
<td>&lt;0.2</td>
<td></td>
</tr>
<tr>
<td>3 Steel+primer</td>
<td>Poycon</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>(1.1±0.3) x 10^3</td>
<td>444±21</td>
<td>125±9</td>
<td>106±6</td>
<td>(1.6±0.2) x 10^3</td>
<td>94±7</td>
<td>&lt;3.9</td>
<td></td>
</tr>
<tr>
<td>4 Steel+primer+painting</td>
<td>Poycon</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>(0.8±0.2) x 10^3</td>
<td>437±20</td>
<td>76±5</td>
<td>58±3</td>
<td>(1.2±0.1) x 10^3</td>
<td>2.2±0.3</td>
<td>&lt;1.4</td>
<td></td>
</tr>
<tr>
<td>5 Lead wool</td>
<td>Tecnibusas</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;368</td>
<td>&lt;12</td>
<td>&lt;15</td>
<td>36.9±6.5</td>
<td>&lt;1.1</td>
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<tr>
<td>6 EPDM foam</td>
<td>Moss Express</td>
<td>Ge</td>
<td>mBq/m</td>
<td>&lt;437</td>
<td>33.6±1.7</td>
<td>106±7</td>
<td>95.5±5.2</td>
<td>758±78</td>
<td>&lt;1.4</td>
<td>&lt;1.3</td>
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<tr>
<td>7 EPDM foam</td>
<td>Artein Gaskets</td>
<td>Ge</td>
<td>mBq/m</td>
<td>&lt;215</td>
<td>4.3±0.4</td>
<td>5.1±1.6</td>
<td>&lt;5.4</td>
<td>11.2±2.9</td>
<td>&lt;0.6</td>
<td>&lt;0.6</td>
<td></td>
</tr>
<tr>
<td>8 Glue</td>
<td>Ceys</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;(3.2) x 10^3</td>
<td>&lt;18</td>
<td>&lt;75</td>
<td>&lt;31</td>
<td>&lt;13</td>
<td>(33.0±3.3) x 10^3</td>
<td>&lt;12</td>
<td>&lt;10</td>
</tr>
<tr>
<td>9 Resistors</td>
<td>Ohmcraft</td>
<td>Ge</td>
<td>µBq/pc</td>
<td>(0.56±0.15) x 10^4</td>
<td>217±10</td>
<td>44±4</td>
<td>36±3</td>
<td>95±13</td>
<td>&lt;2</td>
<td>&lt;2</td>
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<tr>
<td>10 Brazing paste</td>
<td></td>
<td>GDMS</td>
<td>µBq/kg</td>
<td>55±10</td>
<td>49±4</td>
<td>&lt;31</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11 Brass bolts</td>
<td></td>
<td>GDMS</td>
<td>µBq/kg</td>
<td>8.9±0.7</td>
<td>6.9±0.2</td>
<td>&lt;31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 SS screws</td>
<td></td>
<td>GDMS</td>
<td>µBq/kg</td>
<td>3.25±0.25</td>
<td>0.57±0.08</td>
<td>&lt;0.19</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>13 Optical gel</td>
<td>Nye Lubricants</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;1.7 x 10^3</td>
<td>&lt;22</td>
<td>&lt;49</td>
<td>&lt;18</td>
<td>&lt;16</td>
<td>&lt;173</td>
<td>&lt;4.5</td>
<td>&lt;5.8</td>
</tr>
<tr>
<td>14 Epoxy</td>
<td>Araldite</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;182</td>
<td>&lt;3.7</td>
<td>&lt;2.5</td>
<td>&lt;0.8</td>
<td>15.9±2.4</td>
<td>&lt;0.4</td>
<td>&lt;0.4</td>
<td></td>
</tr>
<tr>
<td>15 Kapton-Cu cable</td>
<td></td>
<td>Ge</td>
<td>mBq/kg</td>
<td>&lt;1.1 x 10^3</td>
<td>46.8±3.3</td>
<td>&lt;40</td>
<td>&lt;32</td>
<td>166±27</td>
<td>&lt;5.2</td>
<td>&lt;4.4</td>
<td></td>
</tr>
<tr>
<td>16 PMTs (R11410-10)</td>
<td>Hamamatsu</td>
<td>Ge</td>
<td>µBq/pc</td>
<td>&lt;67</td>
<td>&lt;0.94</td>
<td>&lt;2.2</td>
<td>0.56±0.14</td>
<td>0.58±0.13</td>
<td>11.8±1.7</td>
<td>3.73±0.27</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>17 Connectors</td>
<td>Hirose</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>6.4±1.9</td>
<td>2.8±0.1</td>
<td>5.6±0.3</td>
<td>5.9±0.3</td>
<td>3.4±0.4</td>
<td>&lt;0.03</td>
<td>&lt;0.04</td>
<td></td>
</tr>
<tr>
<td>18 Adhesive films</td>
<td>Flexible Circuits</td>
<td>Ge</td>
<td>mBq/kg</td>
<td>(1.8±0.6) x 10^3</td>
<td>&lt;19</td>
<td>&lt;50</td>
<td>&lt;34</td>
<td>16.8±3.0</td>
<td>&lt;107</td>
<td>&lt;4.8</td>
<td>&lt;4.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Situation</th>
<th>NaI(Tl) detector rate (Hz)</th>
<th>Rn activity (Bq/m^3) at Hall A mean</th>
<th>σ</th>
<th>Rn activity (Bq/m^3) at NEXT castle mean</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Open castle</td>
<td>59.56±0.01</td>
<td>80</td>
<td>79</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>2 Closed castle</td>
<td>1.089±0.001</td>
<td>74</td>
<td>30</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>3 Better closed castle</td>
<td>0.694±0.002</td>
<td>66</td>
<td>30</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4 After N2 purge</td>
<td>0.658±0.001</td>
<td>66</td>
<td>22</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>5 N2 purge+flux 180 l/h</td>
<td>0.600±0.001</td>
<td>59</td>
<td>26</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6 Without N2 flux</td>
<td>0.638±0.001</td>
<td>73</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
## NEXT-100 BG rejection

<table>
<thead>
<tr>
<th></th>
<th>$0\nu\beta\beta$</th>
<th>TI-208</th>
<th>Bi-214</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiducial E&gt;2 MeV</strong></td>
<td>67.86%</td>
<td>0.25%</td>
<td>0.01%</td>
</tr>
<tr>
<td><strong>ROI</strong></td>
<td>95.52%</td>
<td>8.99%</td>
<td>64.66%</td>
</tr>
<tr>
<td><strong>1 track</strong></td>
<td>74.60%</td>
<td>1.86%</td>
<td>12.54%</td>
</tr>
<tr>
<td><strong>2 blobs</strong></td>
<td>73.76%</td>
<td>9.60%</td>
<td>9.89%</td>
</tr>
</tbody>
</table>

**Signal efficiency:** ~35%

**Total BG rejection:** $> 4 \times 10^{-7}$
NEXT-1ton

- It is a symmetric TPC filled with O(1 ton) of Xenon enriched at 90% in Xe-136 at a pressure of 15 bar
- The drift length is 2 x 2 m (2 ms drift, DEMO measures lifetimes of > 10 ms)
- The TPC radius is about 1 m.
- The active volume is about 12 m³ (1 ton at 15 bar)
- The event energy is integrated by wavelength shifting light guides surrounding the gas and read by PMTs located outside the fiducial volume.
- The event topology is reconstructed by two planes of radiopure silicon pixels (MPPCs by default).

$\beta\beta_{0v} (20 \text{ meV})$