Results of the material screening program of the NEXT experiment

T. Dafnia, V. Álvarez, I. Bandac, A. Bettinia, F.I.G.M. Borgesc, M. Camargof, S. Cárcelec, S. Cebrián, A. Cerverac, C.A.N. Condee, J. Díaz, R. Esteveg, L.M.P. Fernandese, M. Fernándezh, V. Gehmanj, A. Goldschmidtj, H. Gómez, J.M. Gutiérrez, J. Hauptmann, J.A. Hernando Moratal, D.C. Herrera, F.J. Iguaz, I.G. Irastorza, L. Labarga, A. Laing, D. Lorca, M. Losada, G. Luzón, A. Mafí, J. Martín-Albo, A. Martínez, G. Martínez-Lemait, T. Miller, F. Monraba, M. Monserrate, C.M.B. Monteiro, F.J. Morais, L.M. Moutinho, J. Muñoz Vidal, M. Nebot-Guiot, D. Nygren, C.A.B. Oliveiraj, J. Pérez, J.L. Pérez Aparicio, J. Renner, L. Ripoli, A. Rodríguez, J. Rodríguez, F.P. Santos, J.M.F. dos Santos, L. Seguí, L. Serra, D. Shuman, A. Simón, C. Sofkaj, M. Sorellf, J.F. Toledo, J. Torrentj, Z. Tsamalaidze, J.F.C.A. Veloso, J.A. Villarr, R.C. Webb, J.T. Whitej, N. Yahlalic

aLaboratorio Subterráneo de Canfranc, 22880 Canfranc Estación, Huesca, Spain
bLaboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza, 50009 Zaragoza, Spain
cInstituto de Física Corpuscular (IFIC), CSIC & Universitat de València, 46980 Paterna, València, Spain
dPadua University and INFN Section, Dipartimento di Fisica G. Galilei, 35131 Padova, Italy
eDepartamento de Física, Universidade de Coimbra, 3004-516 Coimbra, Portugal
fCentro de Investigaciones en Ciencias Básicas y Aplicadas, Universidad Antonio Nariño, Bogotá, Colombia
gInstituto de Instrumentación para Imagen Molecular (I3M), U. Politécnica de València, 46022 València, Spain
hCentro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), 28040 Madrid, Spain
iInstitute of Nanostructures, Nanomodelling and Nanofabrication (i3N), U. de Aveiro, 3810-193 Aveiro, Portugal
jLawrence Berkeley National Laboratory (LBNL), Berkeley, California 94720, USA
kDepartment of Physics and Astronomy, Iowa State University, Ames, Iowa 50011-3160, USA
lInstituto Gallego de Física de Altas Energías (IGFAE), U. de Santiago de Compostela, 15782 Santiago de Compostela, Spain
mDepartamento de Física Teórica, Universidad Autónoma de Madrid, 28049 Madrid, Spain
nInstituto de Física Teórica (IFT), UAM/CSIC, 28049 Madrid, Spain
oDpto. de Mecánica de Medios Continuos y Teoría de Estructuras, U. Politécnica de València, 46071 València, Spain
pEscola Politècnica Superior, Universitat de Girona, 17071 Girona, Spain
qDepartment of Physics and Astronomy, Texas A&M University, Texas 77843-4242, USA
rJoint Institute for Nuclear Research (JINR), 141980 Dubna, Russia

Abstract

The Neutrino Experiment with a Xenon TPC (NEXT), intended to investigate neutrinoless double beta decay, requires extremely low background levels. An extensive material screening and selection process to assess the radioactivity of components is underway combining several techniques, including germanium γ-ray spectrometry performed at the Canfranc Underground Laboratory; recent results of this material screening program are presented here.

Keywords: Double beta decay, Radiopurity, Germanium gamma spectrometry

1. Introduction

The NEXT experiment [1] will operate at the Laboratorio Subterráneo de Canfranc (LSC), Spain, a high-pressure xenon time projection chamber (TPC) to search for neutrinoless double beta decay events of 136Xe using 100 kg of enriched xenon at 90%. As in any experiment investigating rare event phenomena, ultra-low background conditions are a must and materials used in
the set-up have to be carefully selected. A thorough material screening program was undertaken to evaluate the radioactivity of all the relevant components of NEXT [2, 3]; new results are presented here.

This screening program is mainly based on germanium γ-ray spectrometry using ultra-low background detectors from the Radiopurity Service of LSC (in particular, those named GeOroel, GeAnayet, GeTobazo, Ge-Latua) operated at a depth of 2450 m.w.e.. Detectors are p-type close-end coaxial 2.2-kg High Purity germanium detectors, from Canberra France. For the measurements presented here, shield consisted of 5 cm of copper in the inner part surrounded by 20 cm of low activity lead, with nitrogen flush to avoid airborne radon intrusion. Detection efficiency is estimated for each sample by GEANT4 simulation. Complementing germanium spectrometry results, measurements based on Glow Discharge Mass Spectrometry (GDMS) and Inductively Coupled Plasma Mass Spectrometry (ICPMS) have been also carried out. GDMS is performed by Evans Analytical Group in France, providing concentrations of U, Th and K. An ICPMS measurement was made at CIEMAT (Unidad de Espectrometria de Masas) in Spain.

2. Results

Materials analyzed deal with the shielding, pressure vessel, field cage and electroluminescence (EL) components and the energy and tracking readout planes. Results obtained after those presented in [2, 3] are summarized in table 1 and described in the following: for germanium measurements, reported errors correspond to 1σ uncertainties and upper limits are given at 95% C.L.. Uncertainties for GDMS results are typically of 20%.

Lead and copper from different suppliers to be used as shielding were studied [2, 3]. Finally, refurbished lead from the OPERA experiment with 80 Bq/kg of $^{210}$Pb will be used for external shielding (#1-2) and CuA1 (or ETP) copper will be used for inner shield (#3-4). For the pressure vessel, several samples of 316Ti Stainless Steel were initially screened with germanium detectors: 10-mm-thick for body, 15-mm-thick for end-caps, 50-mm-thick for flanges. Now, complementary results have been obtained from GDMS analysis (#5-7).

Concerning the field cage and EL region, several types of plastics [2, 3] and High Density Polyethylene (PE500) for field cage (#8) have been screened; HD polyethylene has been analyzed also by ICPMS (#9). In addition, results for silver epoxy (CW2400) (#10) and ETP copper for field cage, in rod (#11) and sheet (#12), have been obtained.

The tracking readout in NEXT is based on SiPMs in kapton Printed Circuit Boards (PCB). PCB boards (made of cuflon [2, 3] or kapton and copper (#13)) and different electronic components (capacitors, resistors, connectors, solder paste [2], NTC temperature sensors (#14) and blue LEDs (#15)) have been screened with germanium detectors. Plexiglas sheets which could be placed in front of boards have been also considered (#16). At the opposite side of the vessel, the energy readout is based on photomultipliers (PMTs); 34 (out of 60) Hamamatsu R11410-10 PMTs have been already screened in 3-unit groups (#17) showing equivalent activity. Shappire windows [3] and copper have been studied: CuA1 (or ETP) for PMT cans (#3-4) and CuC1 (or OF) for plates (#18). Several components for PMT bases have been also analyzed: capacitors (#19), resistors (#20), pin receptacles (#21) and thermal epoxy (#22).

In summary, complementary activity measurements based on ICPMS, GDMS and germanium spectrometry performed at LSC have been carried out to help both in the design of the set-up and in the construction of the background model of the NEXT experiment. Radiopure enough samples of copper for inner shielding, stainless steel for pressure vessel and polyethylene for field cage have been found: expected contributions from $^{214}$Bi-$^{208}$Tl at the region of interest are 9.7, 2.9 and 9.4 $10^{-5}$ keV$^{-1}$ kg$^{-1}$ y$^{-1}$ respectively. An extensive work has been carried out, but the screening program is still going on and SiPMs and shielding structure components are now under analysis.

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References

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[2] V. Alvarez et al, JINST 8 (2013) T01002.
[3] V. Alvarez et al, AIP Conf. Proc. 1549 (2013) 46.
| Material                  | Supplier         | Technique | units | $^{238}\text{U}$ | $^{226}\text{Ra}$ | $^{232}\text{Th}$ | $^{228}\text{Th}$ | $^{235}\text{U}$ | $^{40}\text{K}$ | $^{60}\text{Co}$ | $^{137}\text{Cs}$ |
|--------------------------|------------------|-----------|-------|----------------|------------------|------------------|------------------|----------------|----------------|----------------|----------------|
| 1 Pb                      | Britannia       | Ge        | mBq/kg| <0.83          | <0.48            | <1.3             | <0.08            |                |                |                |                |
| 2 Pb                      | Britannia       | GDMS      | mBq/kg| 0.35           | 0.094            | 0.12             |                 |                |                |                |                |
| 3 Cu                      | Lugand Aciers   | Ge        | mBq/kg| <4.1           | <0.16            | <0.15            | <0.13            | <0.17          | <0.37          | 0.04±0.01      | <0.04          |
| 4 Cu                      | Lugand Aciers   | GDMS      | mBq/kg| <0.012         | <0.004           | 0.062            |                 |                |                |                |                |
| 5 316Ti SS, 10mm          | Nironit         | GDMS      | mBq/kg| <5.0           | <0.12            | <0.16            |                 |                |                |                |                |
| 6 316Ti SS, 15mm          | Nironit         | GDMS      | mBq/kg| <9.9           | <0.41            | <0.12            |                 |                |                |                |                |
| 7 316Ti SS, 50mm          | Nironit         | GDMS      | mBq/kg| <7.4           | <0.12            | <0.09             |                 |                |                |                |                |
| 8 Polyethylene            | In2Plastics     | Ge        | mBq/kg| <18            | <0.88            | <0.70            | <0.4             | <3.4           | <0.14          | <0.14          |                |
| 9 Polyethylene            | Simona          | ICPMS     | mBq/kg| <0.062         | <0.021           |                 |                |                |                |                |                |
| 10 Silver epoxy          | Circuit Works   | Ge        | mBq/kg| <1.0 x10$^3$  | 13.6±2.8        | <18              | 1.8              | <16            | <4.5           | 52             | 1.9±2.2        |
| 11 Cu, rod                | Lumetalplastics | GDMS      | mBq/kg| 0.66±0.09     | 0.45±0.08        | 0.16             |                 |                |                |                |                |
| 12 Cu, sheet              | Lumetalplastics | GDMS      | mBq/kg| 0.041±0.007   | 0.014±0.002     | 0.031            |                 |                |                |                |                |
| 13 Kapton-Cu PCB          | Flexiblecircuits| Ge        | mBq/unit| <1.3           | 0.031±0.004     | 0.027±0.008     | 0.042±0.004     | 12.1±2         | 0.01           | 0.01           |                |
| 14 NTC sensors            | Murata          | Ge        | mBq/unit| <96            | <1.5             | <1.6             | <1.3             | <0.3           | <2.9           | 0.2±0.2        |                |
| 15 LEDs                   | Osram Ge        | mBq/unit| <90    | 1.4±0.2        | 3.5±0.4         | 3.0±0.3          | <0.6             | <4.0           | <0.2           | <0.3           |                |
| 16 Plexiglas/PMMA         | Evonik          | Ge        | mBq/kg| <208          | <2.2             | <3.9             | <3.4             | <1.1           | <8.1           | 0.4±0.6        |                |
| 17 PMTs                   | Hamamatsu       | Ge        | mBq/unit| <87           | <0.96             | 2.5             | 0.69±0.35       | 0.4±0.2        | 11.5±2.1       | 3.7±0.3        | <0.3           |
| 18 Cu                     | Lugand Aciers   | GDMS      | mBq/kg| 0.025±0.005   | 0.015±0.004     | 0.19             |                 |                |                |                |                |
| 19 Capacitors             | AVX             | Ge        | mBq/unit| <360         | 72±3             | 749±3            | 32±2             | 71±9           | <1           | 1               |                |
| 20 Resistors              | Finechem        | Ge        | mBq/unit| 85±23        | 4.1±0.3          | 5.6±0.5          | 4.4±0.3          | 83.6±8.7       | <0.2           | 104±11         |                |
| 21 Pin receptacles        | Farnell         | Ge        | mBq/unit| 217±42      | <1.1             | 5.6±0.5          | 4.5±0.4          | 6.1±0.5        | 20.5±2.4       | <0.3          | <0.2           |
| 22 Thermal epoxy          | Electrolube     | Ge        | mBq/kg| (1.0±0.2) x10$^3$ | 169.4±7.9     | 52.1±3.7         | 54.4±3.2        | 105±12         | <1.1           | <1.3           |                |

Table 1: Activities measured in relevant materials for NEXT following different techniques. GDMS and ICPMS results were derived from U, Th and K concentrations. Germanium γ-ray spectrometry results reported for $^{238}\text{U}$ and $^{232}\text{Th}$ correspond to the upper part of the chains (derived from $^{234}\text{Pa}$ and $^{228}\text{Ac}$ emissions) and those of $^{226}\text{Ra}$ and $^{228}\text{Th}$ give activities of the lower parts.