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Results of the material screening program of the NEXT experiment

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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 Subterrneo de Canfranc (LSC), Spain, a high-pressure xenon time projection chamber (TPC) to search for neutrinoless double beta decay events of ^{136}Xe 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

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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, GeLatuca) 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 Poliethylene (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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	Material	Supplier	Technique	units	^{238}U	^{226}Ra	^{232}Th	^{228}Th	^{235}U	^{40}K	^{60}Co	^{137}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	<0.81	<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 10^3	13.6±2.8	<18	< 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±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)10^3	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}U and ^{232}Th correspond to the upper part of the chains (derived from ^{234m}Pa and ^{228}Ac emissions) and those of ^{226}Ra and ^{228}Th give activities of the lower parts.