THE NEXT-100 RADIOPURITY CAMPAIGN: MEASUREMENTS AND RESULTS

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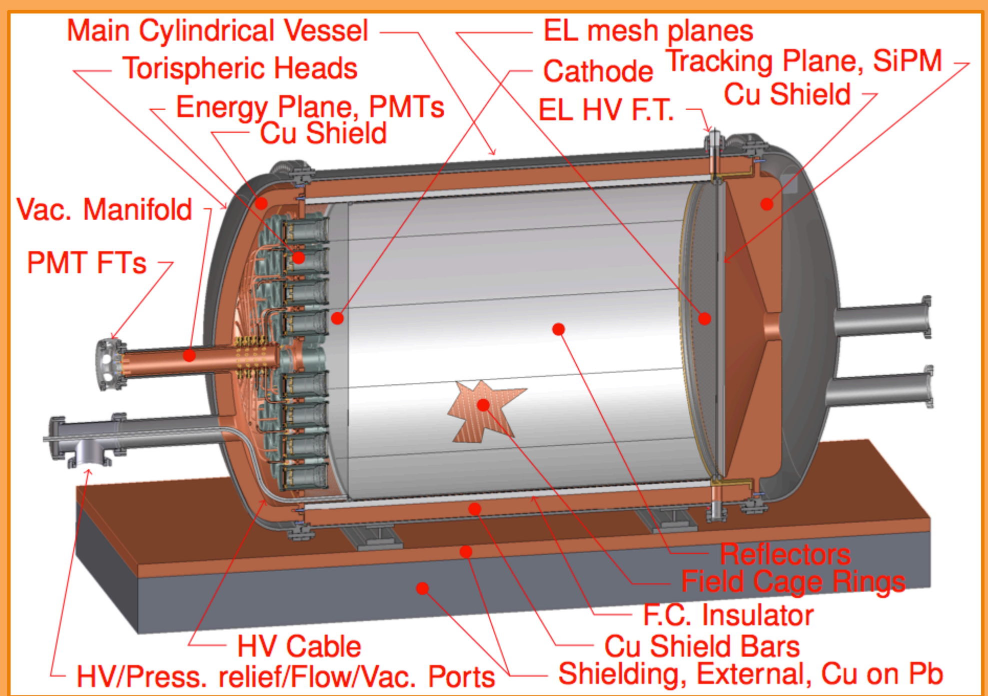
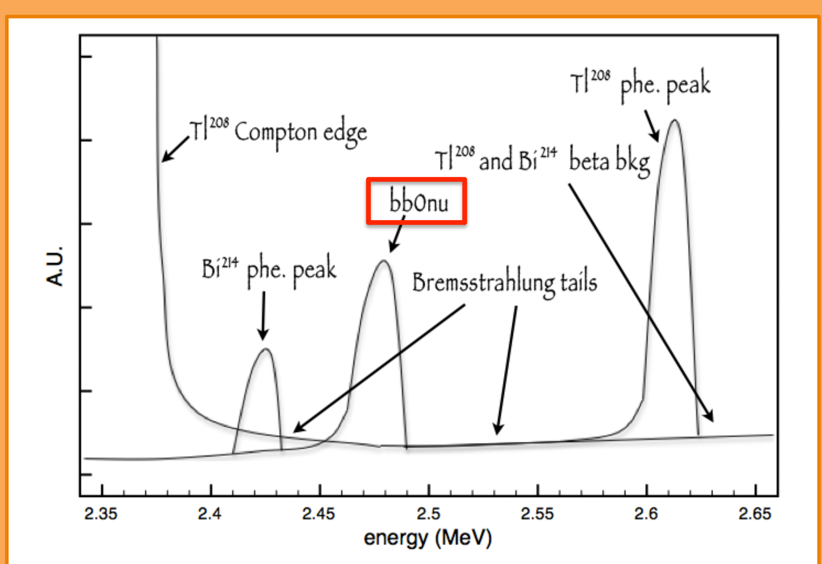
NEXT DETECTOR

NEXT is a detector designed to measure 2β0ν decay using an asymmetric Time Projection Chamber, filled with of enriched ^{136}Xe (90%) at 10-15 atm. It features an easy scalability for further detectors, an excellent energy resolution (< 1 % at Qββ) and tracking of the signals to reduce the background. NEXT will be placed in The Canfranc Underground Laboratory, LSC, (Spain) with approximately 2450 m.w.e. overburden that suppresses the cosmic muon flux by approximately 5 orders of magnitude.



This rare event has a $Q_{\beta\beta}$=2458 keV, very close to ^{214}Bi gamma photon (2448 keV) and to ^{208}Tl (2615 keV). As we expect only a few counts of 2β0ν per year, we must work in three directions:

- superb energy resolution to see clearly the signal
- tracking capabilities to discard rare background events
- minimize the number of background events through a complete radiopure campaign to select the less radioactive materials for NEXT



DETECTOR PARTS

To carry out the radiopurity campaign for NEXT detector, we have divided the measured parts into five groups:

Shielding and structure: composed of lead (*Tecnibusa or Mifer or Cometa*), oxygen free copper (*Luvata*), 316Ti Stainless Steel (*Nironit*) and CuA1 (*Lugand Aciers*). To do: foam joints, S275 steel, paint and copper ground connection.

Vessel: composed of titanium (*SMP or Ti Metal Supply*), 304L Stainless Steel (*Pfeiffer*), 316Ti Stainless Steel (*Nironit*), Inconel (*Mecanizados Kanter*) and TIG-MIG welding on 316Ti Stainless Steel (*Movesa*). To do: bolts, joints and gaskets.

High Voltage components: composed of peek (*Sanmetal*), HD polyethylene (*IN2 Plastics*), Semitron ES225 (*Quadrant EPP*), Kynar PVDF (*Boedeker*), Tefzel ETFE (*DuPont*), silver epoxy (*Circuit Works*), Field Cage copper (*Lumetalplastics*). To do: TPB coating, ITO coating, resitors, teflon, steel for grids, cirlex and quartz.

Tracking plane: composed of SMD resitors (*Farnell or Finechem*), Kapton-Cu PCB (*Labcircuits*), Cuflon (*Polyfon*), Bonding films (*Polyflon*), Cuflon DB (*Pyrecap*), Connectors (*Hirose or Panasonic or Molex*), Solder paste and wire (*Multicore*), Ta capacitors (*Vishay Sprague*), Kapton DB (*Flexible Circuits*), PMMA (*Evonik Ind.*), NTC thermistors (*Murata*) and LEDs (*Osram*). To do: SiPMs and feedthrough.

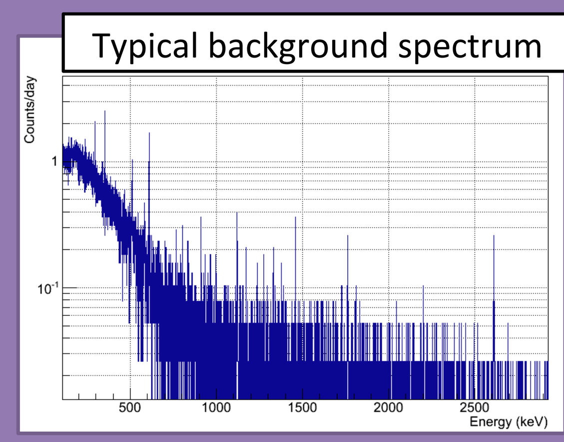
Energy plane: composed of sapphire (*Precision Sapphire Technologies*), 60 PMT R11410-10 (*Hamamatsu*), base capacitors (*AVX*), base resistors (*Finechem*), pin receptables for bases (*Farnell*), CuA1 for PMT cans (*Lugand Aciers*), CuC1 for plates (*Lugand Aciers*)

MOST DANGEROUS COMPONENTS

In terms of radiopurity those that are inside the inner copper shielding of the detector (PMTs, SiPMs, PCBs, resitors, etc) and are those that are very massive (copper, polyethilene and steel)

ACTIVITY MEASUREMENTS

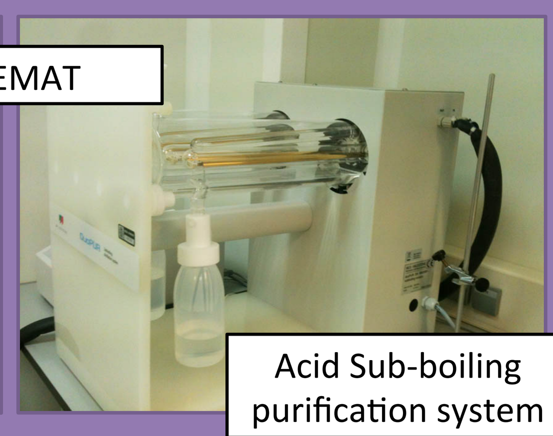
Activities measurements are carried out at the LSC using 7 High Purity Germanium detectors (HPGe). They are p-type, close-end, coaxial with 100 - 110% relative efficiencies and FWHM ≈ 2 keV (1332keV). Each detector is shielded with a 5 cm thick copper layer followed by a 20 cm thick lead layer and an outer methacrylate box with a nitrogen over-pressured atmosphere to avoid radon intrusion.



CONCENTRATION MEASUREMENTS

Mass spectrometers consist on three parts: ion source where using different techniques ionize the sample, ion separator where the ions are separated according their mass and charge and ion detector where you measure de number of ions. This detectors can measure 1 part per trillion (ppt)

We are using Glow Discharge Mass Spectrometer (GD-MS) by *Evans Analytical Group* (France) and Inductively Coupled Plasma Mass Spectrometer (ICP-MS) at *UAM* and at *CIEMAT* (Spain) to carry out our concentration measurements



ADVANTAGES

Due to its characteristics, one should choose what method is better for one's purpose: long life-time isotopes are generally better measured by mass spectrometers. HPGe provides a rather complete, in some cases very precise measurement of most of the radioactive isotopes present in the sample.

MEASUREMENTS RESULTS

	Supplier	Method	Units	238U	214Bi	232Th	208Tl	40K	60Co
SHEILDING									
Pb	Cometa	GDMS	mBq/kg	0.37		0.073		< 0.31	
Pb	Mifer	GDMS	mBq/kg	< 1.2		< 0.41		0.31	
Pb	Mifer	GDMS	mBq/kg	0.33		0.10		1.2	
Pb	Tecnibusa	GDMS	mBq/kg	0.73		0.14		0.91	
Pb	Tecnibusa	HPGe	mBq/kg	< 94	< 2.0	< 3.8	< 4.4	< 2.8	< 0.2
Pb	Tecnibusa	HPGe	mBq/kg	< 57	< 1.9	< 1.7	< 2.8	< 1.7	< 0.1
Cu (ETP)	Sanmetal	GDMS	mBq/kg	< 0.062		0.020			
Cu (C10100)	Luvata (hot rolled)	GDMS	mBq/kg	< 0.012		<0.0041		0.061	
Cu (C10100)	Luvata (cold rolled)	GDMS	mBq/kg	< 0.012		<0.0041		0.091	
Cu (C10100)	Luvata(h + c rolled)	GDMS	mBq/kg		< 7.4	< 0.8	< 4.3	< 18	< 0.8
VESSEL									
Ti	SMP	HPGe	mBq/kg	< 233	< 5.7	< 8.8	< 9.5	< 22	< 3.3
Ti	SMP	HPGe	mBq/kg	< 361	< 6.6	< 11	< 10	< 15	< 1.0
Ti	Ti Metal Supply	HPGe	mBq/kg	< 14	< 0.22	< 0.5	3.6±0.2	< 0.6	< 0.07
304L SS	Pfeiffer	HPGe	mBq/kg		14 ± 3	9.7±2.3	16 ± 4	< 17	11 ± 3
316Ti SS	Nironit (10mm)	HPGe	mBq/kg	< 21	< 0.57	< 0.59	< 0.54	< 0.96	2.8±0.2
316Ti SS	Nironit (15mm)	HPGe	mBq/kg	< 25	< 0.46	< 0.69	< 0.88	< 1.0	4.4±0.3
316Ti SS	Nironit (50mm)	HPGe	mBq/kg	67 ± 22	< 1.7	2.1±0.4	2.0±0.7	< 2.5	4.3±0.3
Inconel 625	Mec. Kanter	HPGe	mBq/kg	< 120	< 1.9	< 3.4	< 3.2	< 3.9	< 0.4
Inconel718	Mec. Kanter	HPGe	mBq/kg	309±78	< 3.4	< 5.1	< 4.4	< 13	< 1.4
HIGH VOLTAGE COMPONENTS									
PEEK	Sanmetal	HPGe	mBq/kg		36 ± 4	15±5	11±2	8.3±3.0	< 3.3
Polyethylene	IN2 Plastics	HPGe	mBq/kg	< 140	< 1.9	< 3.8	< 2.7	< 8.9	< 0.5
Semitron ES255	Quadrant EPP	HPGe	mBq/kg	< 101	< 2.3	< 2.0	< 1.8	513±52	< 0.5
SMD resitor	Farnell	HPGe	mBq/pc	2.3±1.0	0.16 ± 0.03	0.30 ± 0.06	0.30 ± 0.05	0.19± 0.08	< 0.02
SM5D resitor	Finechem	HPGe	mBq/pc	0.4±0.2	0.022 ± 0.007	< 0.023	< 0.016	0.17 ± 0.07	< 0.005
Kynar PVDF	Boedeker	HPGe	mBq/kg	< 101	< 3.0	< 2.2	< 6.8	513±52	< 0.6
Tefzel ETFE	DuPont	HPGe	mBq/kg	< 566	< 5.7	< 14	< 9.2	< 30	< 1.2
ENERGY AND TRACKING PLANES									
Kapton PCB	LabCircuits	HPGe	mBq/cm²	< 0.26	< 0.014	< 0.012	< 0.008	< 0.04	< 0.002
Cuflon	Polyflon	HPGe	mBq/kg	< 33	< 1.3	< 1.1	< 1.1	4.8±1.1	< 0.3
Bonding films	Polyflon	HPGe	mBq/kg	499±37	479±29	79.8 ± 6.6	65.0 ± 7-0	832±87	< 3.0
FFC/FCP conn.	Hirose	HPGe	mBq/pc	< 50	4.6±0.7	6.5±1.2	6.4±1.0	3.9±1.4	< 0.2
P5K connector	Panasonic	HPGe	mBq/pc	< 42	6.0±0.9	9.5±1.7	9.4±1.4	4.1±1.5	< 0.2
Thermop. conn.	Molex	HPGe	mBq/pc	< 7.3	1.8±0.1	3.0±0.2	2.8±0.2	2.1±0.3	< 0.022
Solder paste	Multicore	HPGe	mBq/kg	< 310	< 4.9	< 8.0	< 6.0	< 13	< 1.0
Solder wire	Multicore	HPGe	mBq/kg	< 4900	770±120	< 147	< 14	< 257	< 30
Ta capacitor	Vishay Sprague	HPGe	mBq/pc	< 0.8	0.043 ± 0.003	0.034 ± 0.004	0.032 ± 0.003		< 0.002
Sapphire	Prec. Sapph. Tech.	HPGe	mBq/kg	< 275	< 2.7	< 7.6	< 5.5	< 18	< 0.7

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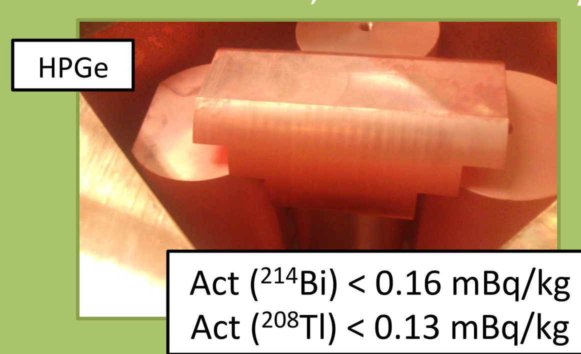
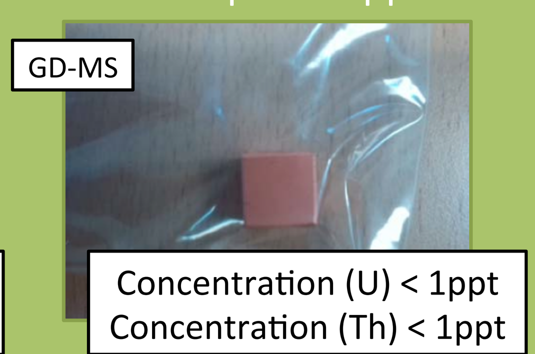
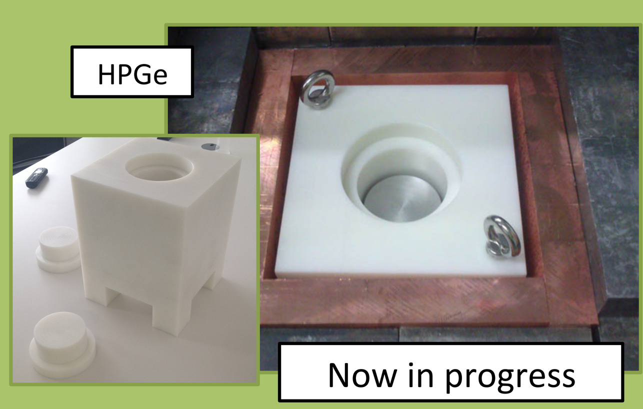
SPECIAL MEASUREMENTS

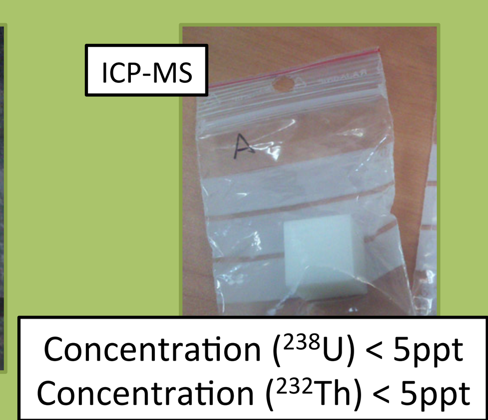
Copper will be used in NEXT in the inner copper shielding, radon shielding, tracking plane plate, energy plane plate and PMTs cans. Then, it's mandatory to use radiopure copper.





High Density Polyethylene is used for the Field Cage of the detector. Its position and its large amount of mass make its radiopurity a critical issue.





PMTs are possibly one of our largest background source. Because of the large size of the sample (60 units) and the limited measurement time, all the PMTs are being measured in a mode pass/don't pass (approx. 20 days). We want to identify PMTs with high activity making short measurements with 3 PMTs simultaneously. Once this phase is finished, we will proceed with individual precision measurements.

	^{208}Tl	^{214}Bi	^{60}Co	^{40}K
3PMT01	< 6.1	< 2.7	12.2 ± 1.0	30.4 ± 8.1
3PMT02	< 7.9	< 3.3	11.1 ± 0.9	< 60
3PMT03	< 7.3	< 3.3	10.4 ± 0.9	39.5 ± 9.4
3PMT04	< 9.6	< 4.3	11.5 ± 1.0	41 ± 10
3PMT05	< 7.2	< 2.5	10.8 ± 0.8	32.2 ± 7.7
3PMT06	< 6.2	< 2.7	10.4 ± 0.8	30.0 ± 7.5
3PMT07	< 6.5	< 4.3	10.9 ± 0.9	34.2 ± 8.9
3PMT08	< 5.9	< 3.0	12.3 ± 1.0	35.5 ± 7.9
3PMT09	< 10	< 3.4	11.3 ± 0.9	34.8 ± 9.5
3PMT10	< 6.3	< 3.9	12.0 ± 0.9	36.9 ± 8.6

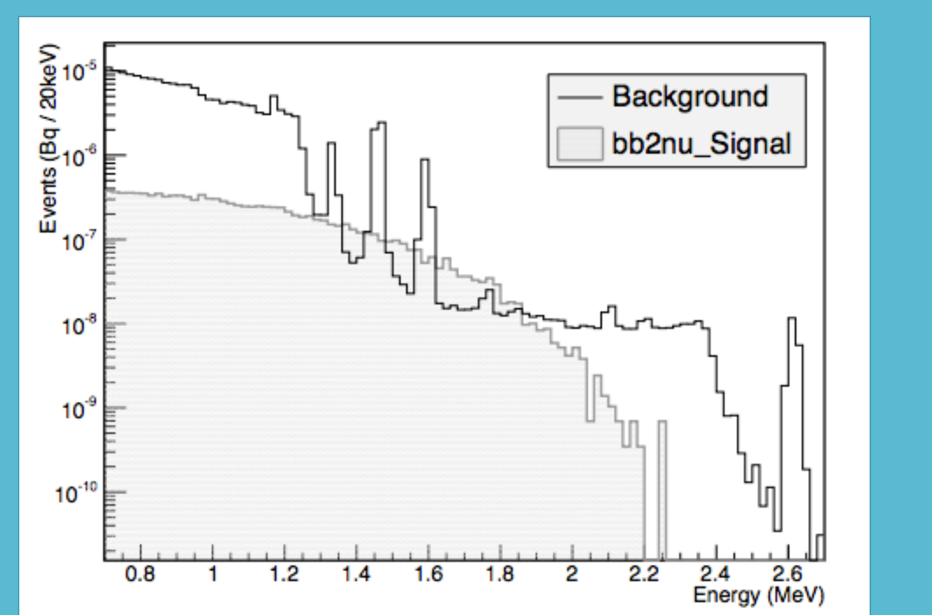
(mBq / measurement)

Additionally, you can provide a high precision estimate of the activity per PMT under the supposition of an equal activity in all measured PMTs. We obtain:

Act(^{214}Bi) < 0.67mBq/PMT
Act(^{208}Tl) < 0.69mBq/PMT

BACKGROUND MODEL

The NEW (NEXT-WHITE a memorial to J. White) detector is a NEXT prototype designed to measure 2β2ν, to test to technologies and to validate the background model.



To evaluate the realistically effect of the radioactive contaminations, we simulate the detector with NEXUS, a custom version of GEANT4 software.

We can observe in the figure, the expected background spectrum. Measured upper limits are considered as real activities. Most dangerous for NEW are:

- 2β2ν: 1173keV, 1333keV gammas from ^{60}Co decay, 1461 keV gamma from ^{40}K and double scape peak from ^{208}Tl
- 2β0ν: 2448 keV gamma from the decay of the ^{214}Bi and 2615 keV gamma from ^{208}Tl

FUTURE WORK PLAN

These are the future steps for radiopurity campaign:

- Complete the screening of all detector components
- Finish the PMT pass/don't pass campaign. Perform precise measurements on selected units
- Improve the results of the measurements to reduce background upper limits
- Explore new measurement techniques for improving the knowledge of the most critical components

We acknowledge the support of the ERC under AdG proposal 339787