NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - 316Ti stainless steel
  - Connectors
  - Others

- **Next measurements**

S. Cebrián (on behalf of the radiopurity measurements group)

***NEXT** Collaboration Meeting*

Canfranc, 9th May 2012

LSC
Laboratorio Subterráneo de Canfranc

Universidad Zaragoza
1542

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - 316Ti stainless steel
  - Connectors
  - Others

- **Next measurements**

Screening program

- **Required sensitivity** (Table 3 at TDR, arXiv:1202.0721v2):

Material	Subsystem	Method/Ref.	^{238}U	^{232}Th
Lead, from Cometa	Shielding	GDMS	0.37	0.07
Copper, from Luvata	ICS	GDMS	< 0.012	< 0.004
Steel (316Ti)	PV	[3]	< 1.9	< 1
Bolts Inconel 718	PV	Ge LSC	< 5.6	< 4.6
Bolts Inconel 625	PV	Ge LSC	< 1.8	< 2.0
PEEK, from Sanmetal	FC/EP/TP	Ge Unizar	36.3	11.7
Capacitors (Tantalum)	FC/EP/TP	[4]	320	1230
SMD Resistors, Finechem (per pc)	FC	Ge Unizar	0.022	<0.048
Polyethylene	FC	[3]	0.23	<0.14
TTX	FC	[5]	12.4	<1.6
TPB	FC/EP/TP	[6]	1.63	0.47
PTFE (Teflon)	EP/TP/DB	[7]	0.025	0.031
PMT (R11410-MOD per pc)	EP	[3]	< 2.5	< 2.5
PMT (R11410-MOD per pc)	EP	[8]	< 0.4	< 0.3
Sapphire window	EP	[9]	<0.31	0.12
CUFLON	TP	[10]	0.36	0.28
Kapton cable	TP/EP	[3]	<11	<11

- **Program** submitted to LSC in March, 2012: "*Screening program and request for LbGe detectors time t LSC*", NEXT Collaboration

  (see complete document at http://dl.dropbox.com/u/10977880/NEXT/NEXT100/Screening/RequestLSC2.pdf)

Screening program

List of materials to be screened

Pressure vessel (PV)

1. Stainless steel 316Ti, of thickeness 10, 15 and 50 mm, used for construction of the PV body, end-caps and flanges.
2. Inconel bolts, used to bolt the end-caps to the main body (already measured).
3. Welding rods, needed for the welding of the flanges.

Inner Copper Shield (ICS)

1. Ultra low background copper (probably supplied by Luvata).

Field Cage (FC)

Notice that the field cage is built in the USA by Texas A&M (TAMU). The TAMU group is procuring radiopure materials from American suppliers. Samples of these materials will be sent to LSC for screening.

1. Field cage rings (ultra low background copper, American supplier)
2. EL and cathode grids and frames, HV penetrator (steel, American supplier).
3. High density Polyethylene (HDP).

Tracking plane (TP)

1. Cuflon boards.
2. Resistors and Tantalum capacitors.
3. Board-to-cable connector.
4. Kapton connector.
5. Silver epoxy for glueing the MPPCs
6. Soldering paste for the MPPCs (alternative to Silver epoxy).

Energy plane (EP)

1. PMT R11410MOD.
2. Can (ultra low background copper, same American supplier than FC, no need of an additional measurement).
3. Sapphire windows.
4. PMT bases.

Front end electronics for MPPCs (FEE)

1. Boards (Cuflon)
2. Resistors and capacitors, connectors
3. Kapton cables.

Screening program

➢ **Schedule** To keep up with the fabrication plan of **Dice Boards, PV** and **FC**

Detector 1:

up to August, 2012

Material	Subsystem	Required sensitivity	Time (weeks)	Tentative starting date
SS 316Ti — 10 mm	PV	<1 mBq/kg	4	23/01/2012 (finished)
SS 316Ti — 15 mm thick	PV	<1 mBq/kg	4	7/03/2012 (finished)
SS 316Ti — 50 mm thick	PV	<1 mBq/kg	4	7/04/2012 (finished)
Welding rods	PV	<10 mBq/kg	1	May 2012
SS A. Supplier	FC	<1 mBq/kg	5	
Copper	FC	<50 μBq/kg	8	

Detector 2:

up to July-August, 2012

Material	Subsystem	Required sensitivity	Time (weeks)	Tentative starting date
Cuflon	Tracking Plane	<0.2 mBq/kg	2	May 2012
HDP	FC	<0.2 mBq/kg	8	
PMT R11410MOD	Energy plane	<0.25 mBq/kg	8	

Detector 3:

from May-June, 2012

Material	Subsystem	Required sensitivity	Time (weeks)	Tentative starting date
Connectors	DB	<10 mBq/kg	1	20/04/2012
Capacitors	DB	<500 mBq/kg	1	
Resistors	DB	<500 mBq/kg	1	
Silver epoxy	DB	<10 mBq/kg	1	
Solder paste	FEE	<100 mBq/kg	1	
Cables— Kapton	Tracking plane	<50 mBq/kg	1	
Sapphire windows	Energy plane	<5 mBq/kg	2	
PMT bases	Energy plane	<5 mBq/kg	3	

A very positive answer from LSC has been obtained: two detectors are being used and a third one will be as it is operative.

Obtained results and the real availability of samples, will impose changes on the plan

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - **Study of detection efficiency**
  - 316Ti stainless steel
  - Connectors
  - Others

- **Next measurements**

Study of detection efficiency

- **Measurements**

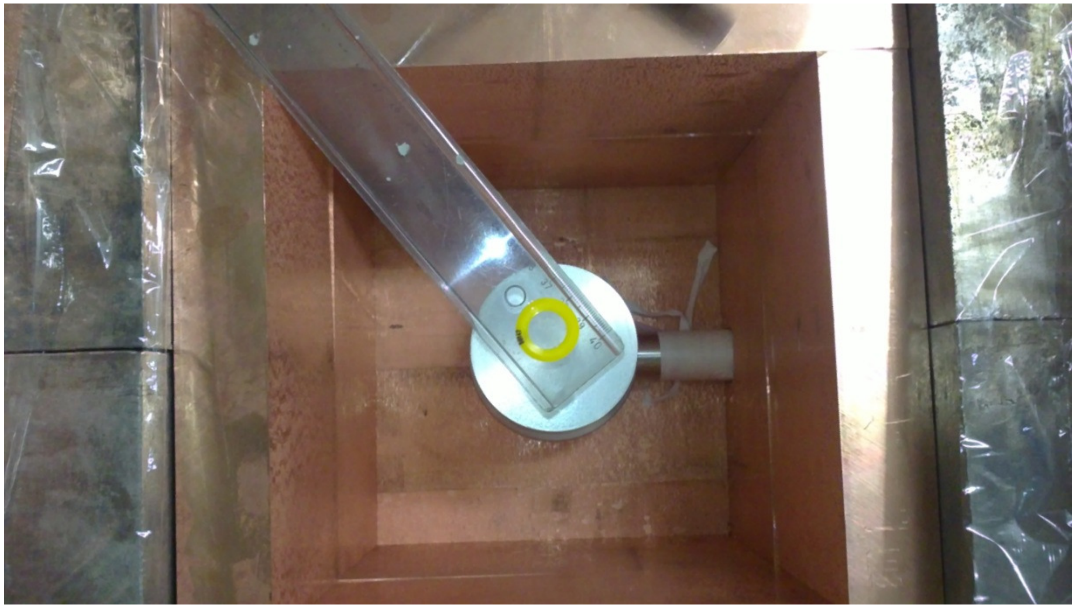
Source: ^{152}**Eu** (main gamma lines from about 0.1 to 1.5 MeV)

Activity: A=39.65 kBq (30/04/2005)

Position: 25 cm above detector on axis (shield partially opened)

Date: April 2012

	^{152}**Eu**
Anayet	T=7164 s R=345 Hz
Tobazo	T=7200 s R=362 Hz
Oroel	T=7137 s R=403 Hz



Study of detection efficiency

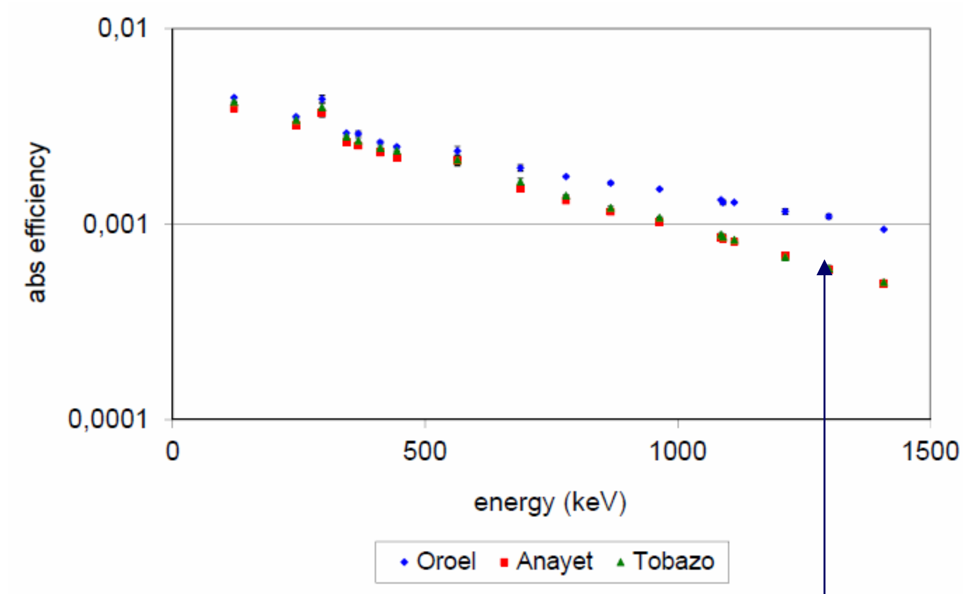
➢ **Absolute (@ 25 cm) and Intrinsic Efficiency**

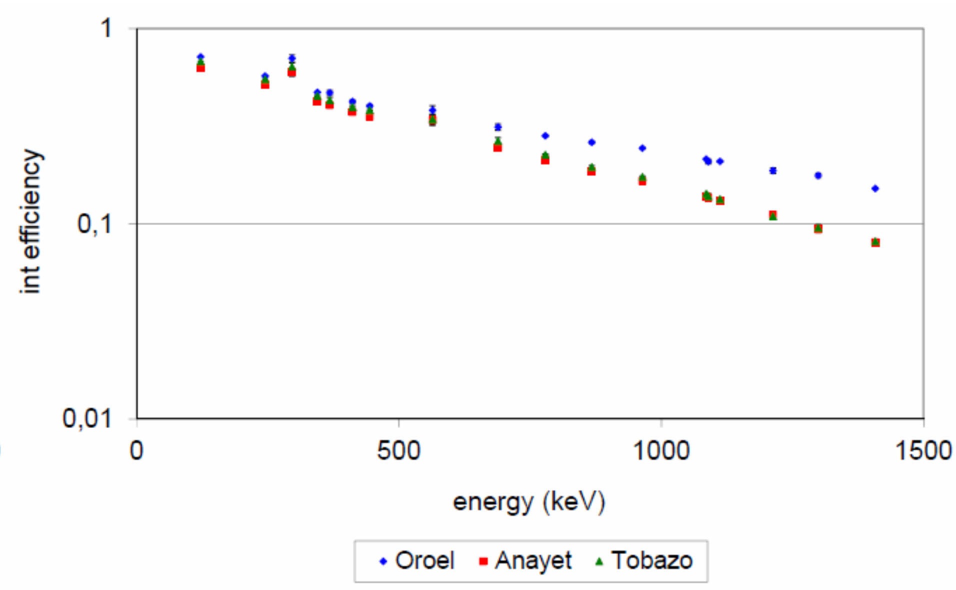
$$\varepsilon_{abs} = \frac{Area}{A_0 \exp(-\lambda t)\ I\ T} \qquad \varepsilon_{\text{int}} = \frac{\varepsilon_{abs}}{\Omega / 4\pi}$$

Area = peak area of a line

I = intensity of the line

T = time of measurement





Both Oroel and Anayet show an abnormal decrease of efficiency with energy:

Relative Efficiencies* are below the expected values for 2 kg detectors (100%)

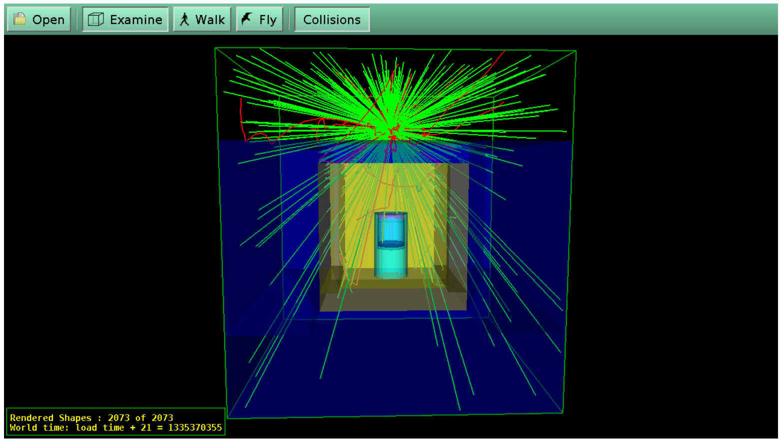
*Efficiency relative to a 3''x3'' NaI detector (at 1332 keV and 25 cm)

Study of detection efficiency

➢ **Simulation**

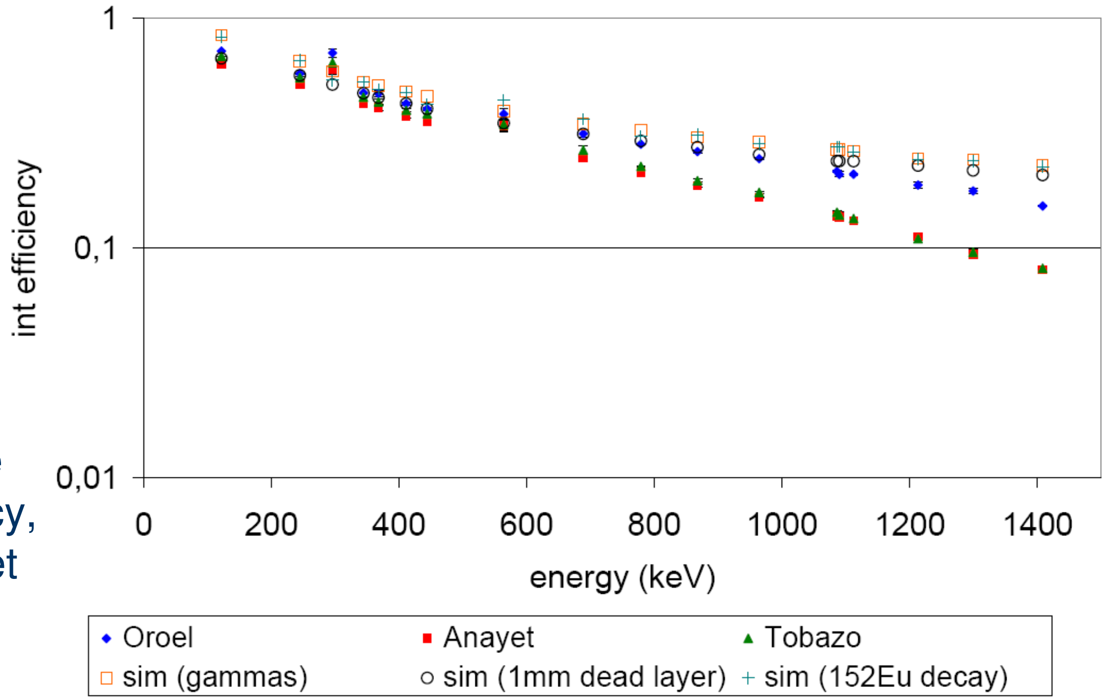
• **Geometry** for Ge detectors and shielding implemented for GEANT4 applications

• GEANT4 **versions** 9.4 and 9.5 tested; no relevant differences found by changing **Physics Lists** (G4EmLivermorePhysics, G4LowEnergy_ processes)



• Simulation of individual main **gamma lines** or of the complete ^{152}**Eu decay** (using GEANT4 Radioactive Decay Model) gives no significant change when estimating the probability of total absorption

• Inclusion of a 1 mm **dead layer** in the Ge crystal reduces slightly the efficiency, but does not explain the Tobazo/Anayet efficency at high energies



Study of detection efficiency

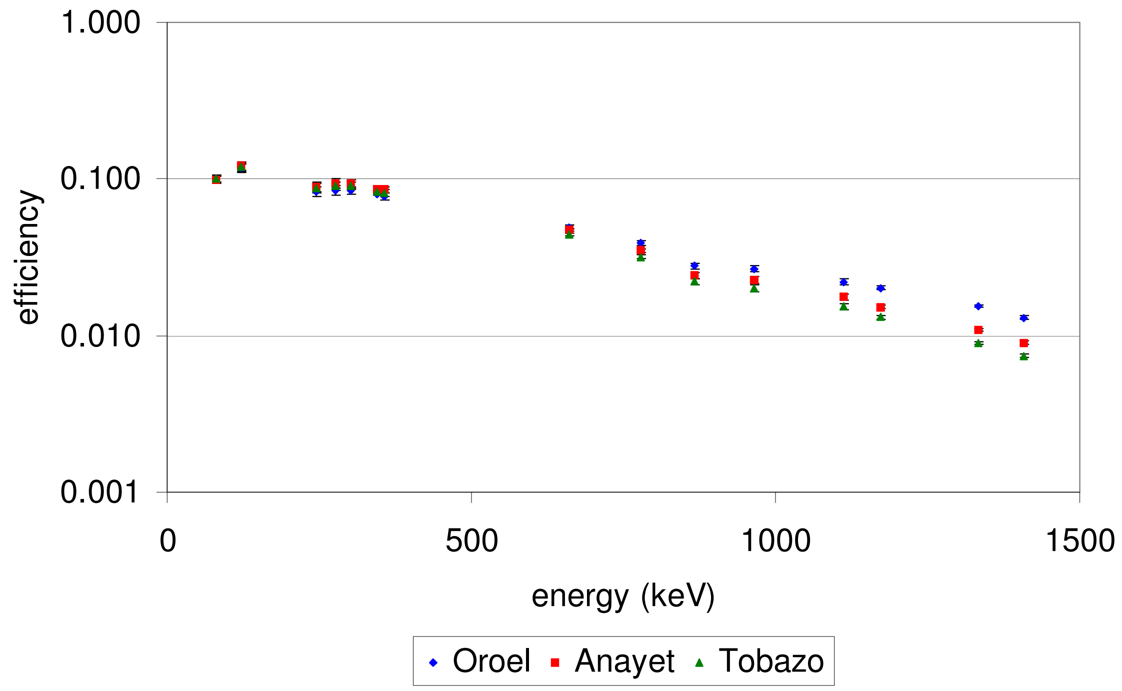
Source: multi-isotope block (^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu)

Activity: γ/s quantified (<5%) for main lines

Position: on marinelli, 4 mm above detector

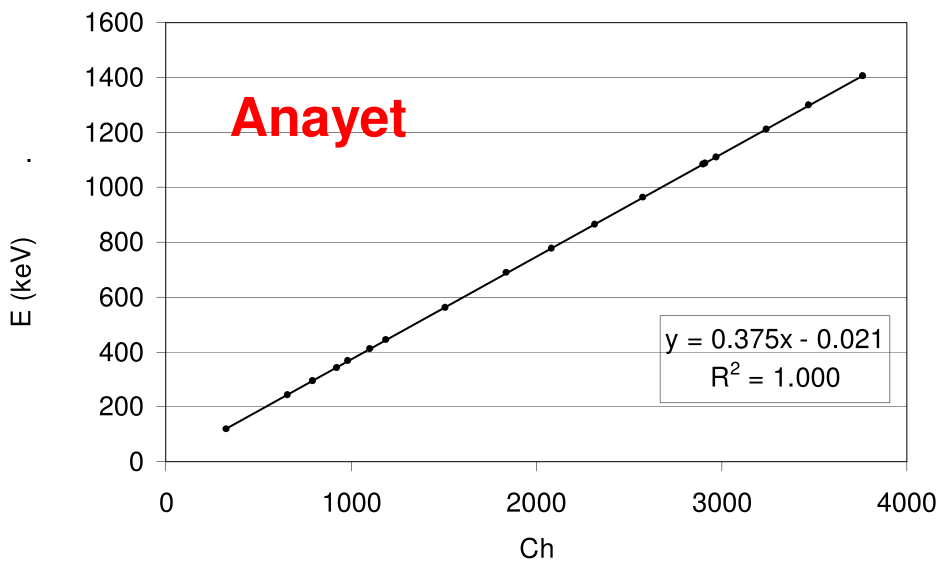
Date: March 2012

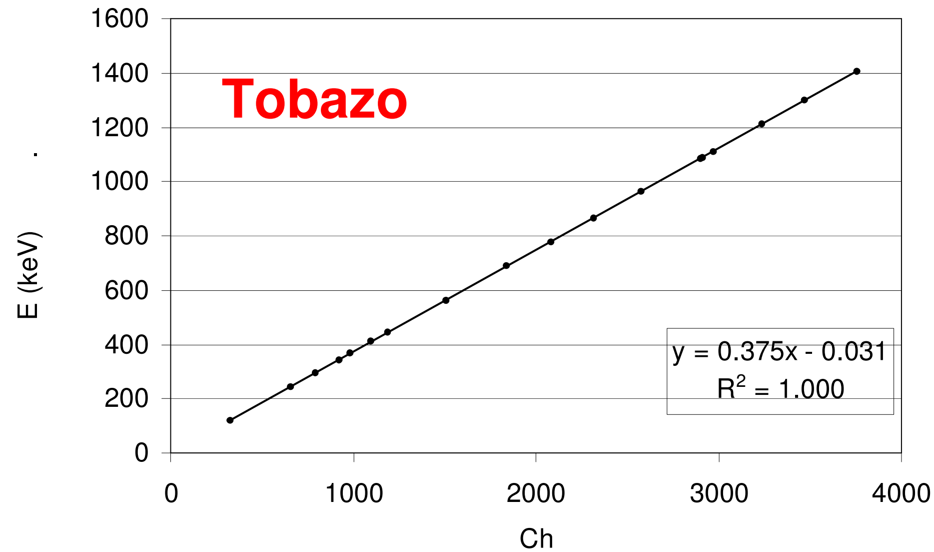
	Multi-isotope block
Anayet	T=72000 s R=259 Hz
Tobazo	T=72000 s R=243 Hz
Oroel	T=71601 s R=252 Hz

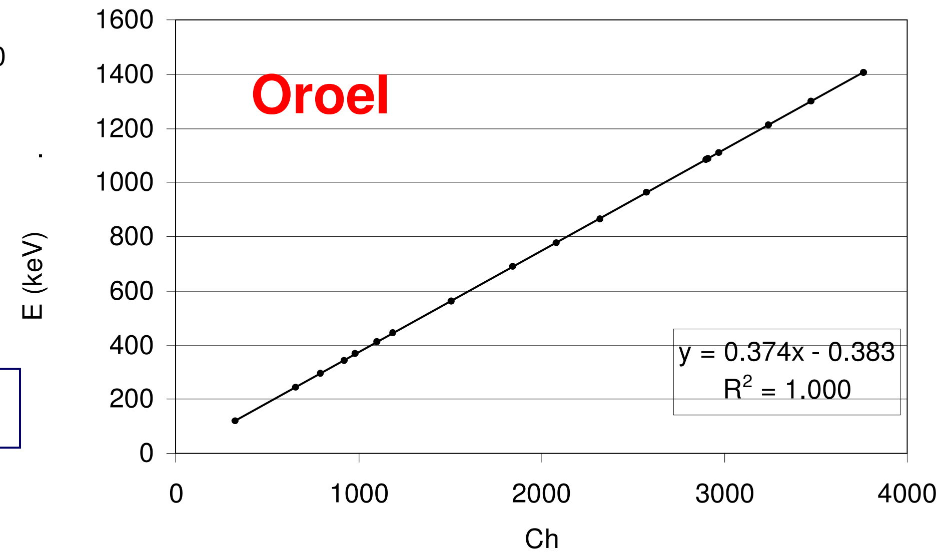


Study of detection efficiency

➢ **Energy calibration**



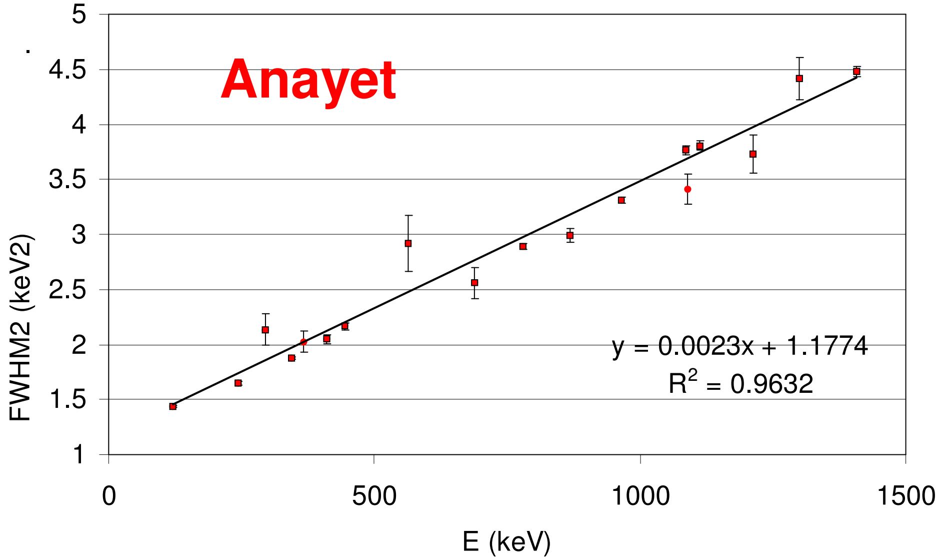


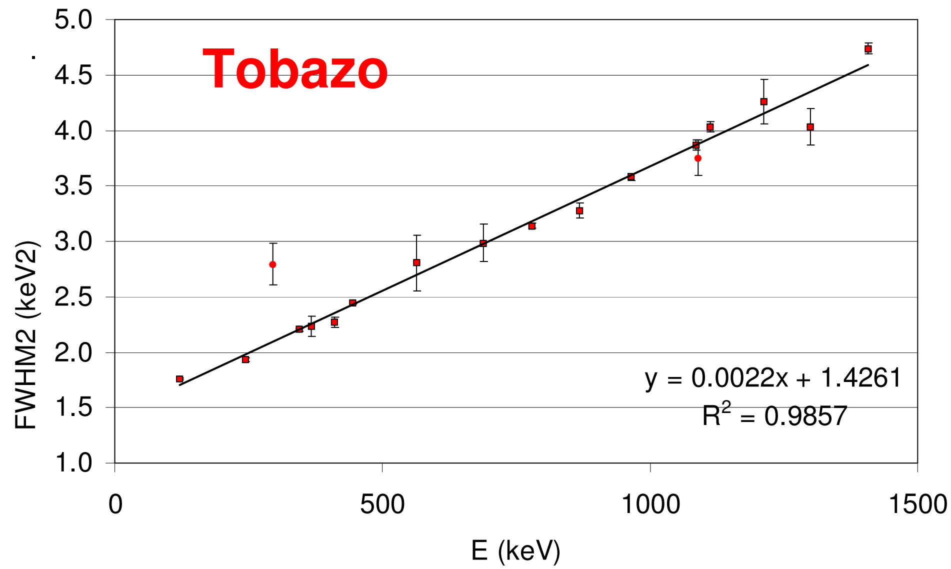


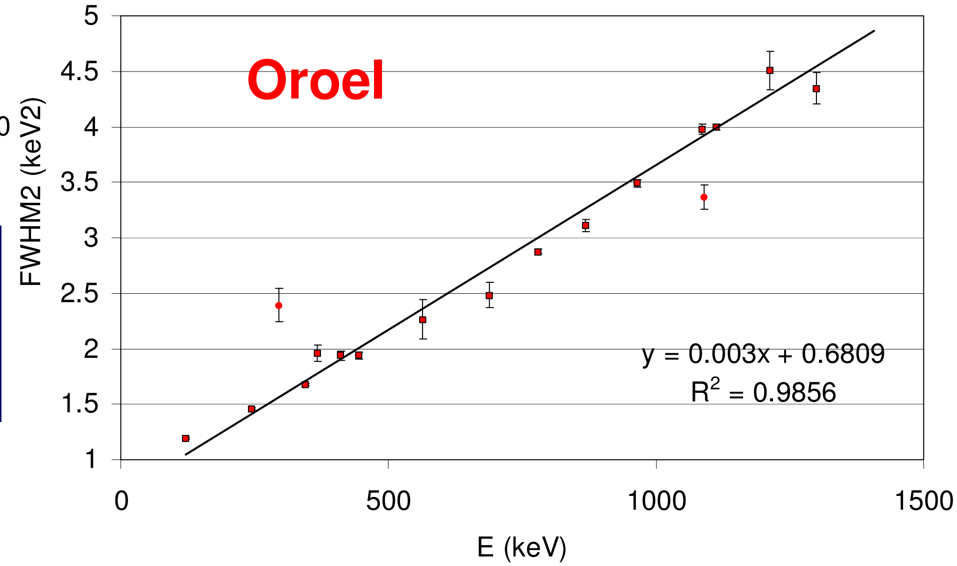
Good linearity observed for all detectors

Study of detection efficiency

➢ **Energy resolution**







Values estimated at 122 and 1332 keV are in agreement with guaranteed resolutions by Canberra for all detectors

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - **316Ti stainless steel**
  - Connectors
  - Others

- **Next measurements**

Results: 316Ti stainless steel

Material: 316Ti stainless steel

Supplier: Nironit

- **10 mm** (PV body)

Sample: 49 pieces ~45x45x11 mm^3

Mass: **7.6837 kg**

Detector: GeTobazo

Time: 25 January - 8 March 2012, **33 d**

- **15 mm** (PV end-caps)

Sample: 40 pieces ~45x45x15 mm^3

Mass: **10.2051 kg**

Detector: GeTobazo

Time: 11 March – 24 April 2012, **35.61 d**

- **50 mm** (PV flanges)

Sample: 6 pieces ~45x45x50 mm^3

Mass: **4.8159 kg**

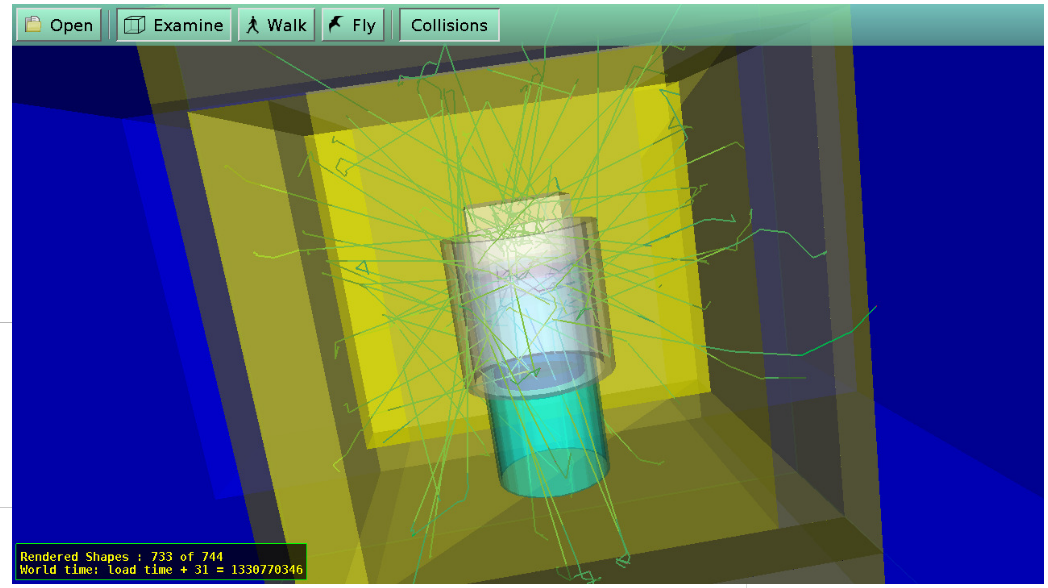
Detector: GeAnayet

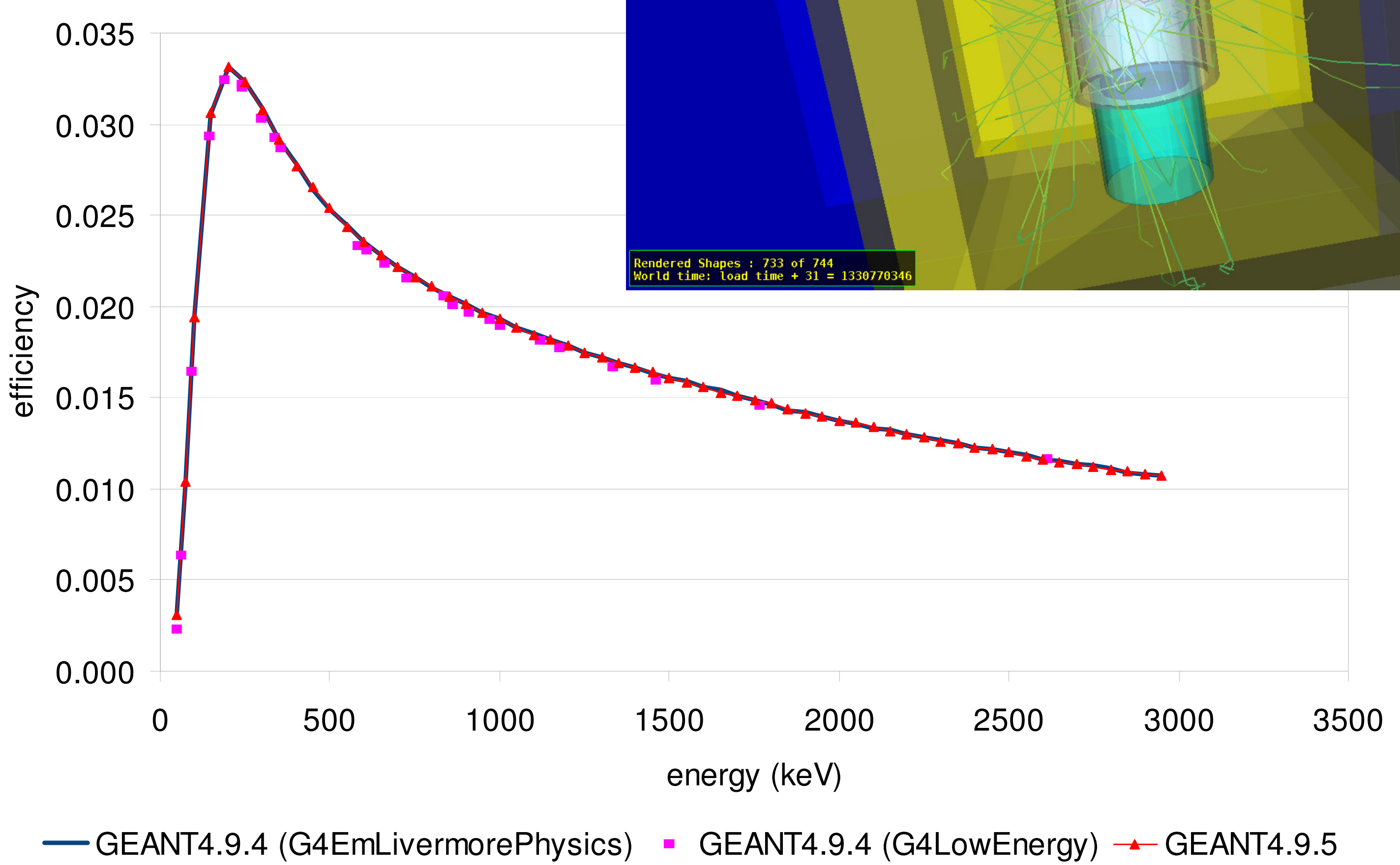
Time: 8 March – 19 April 2012, **34.72 d**

Results: 316Ti stainless steel

- **10 mm**

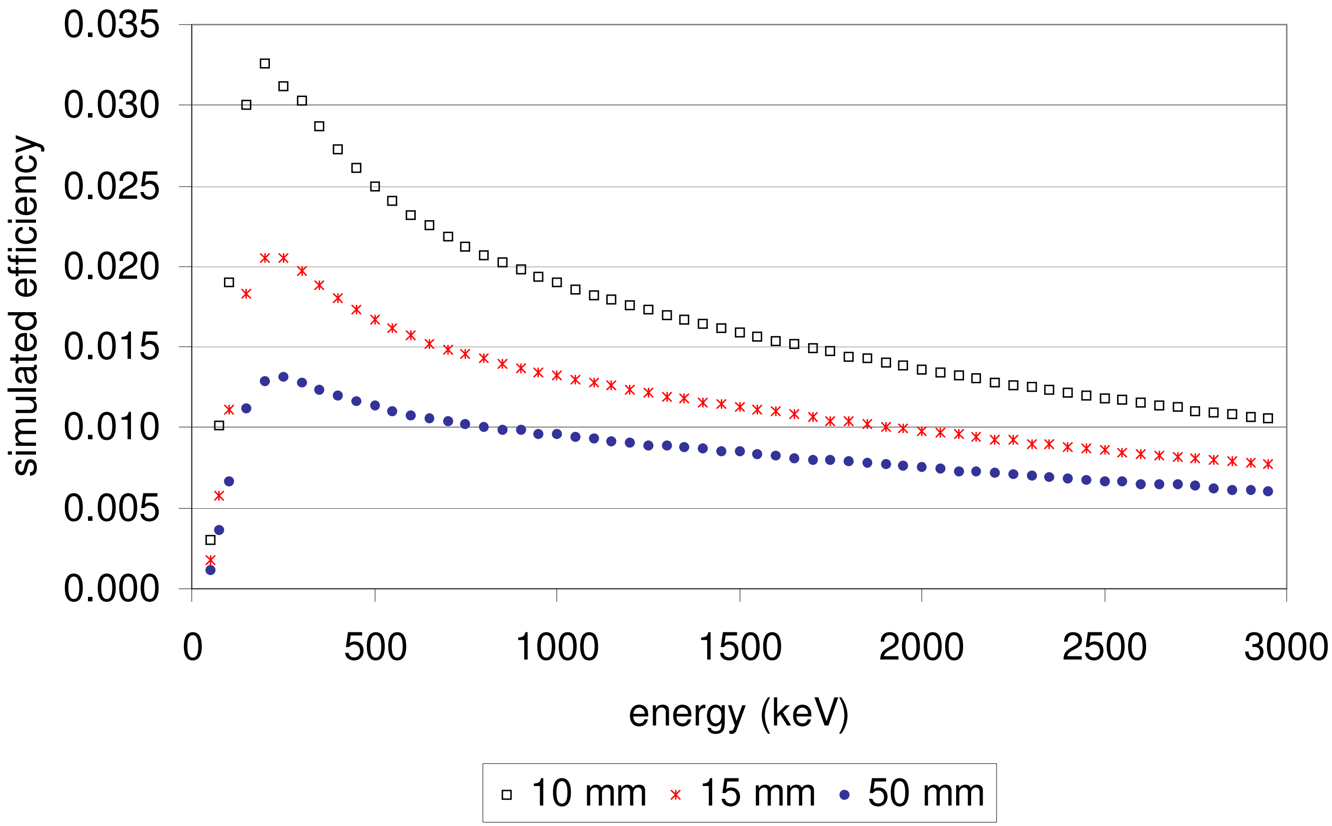
Simulated efficiency:





Results: 316Ti stainless steel

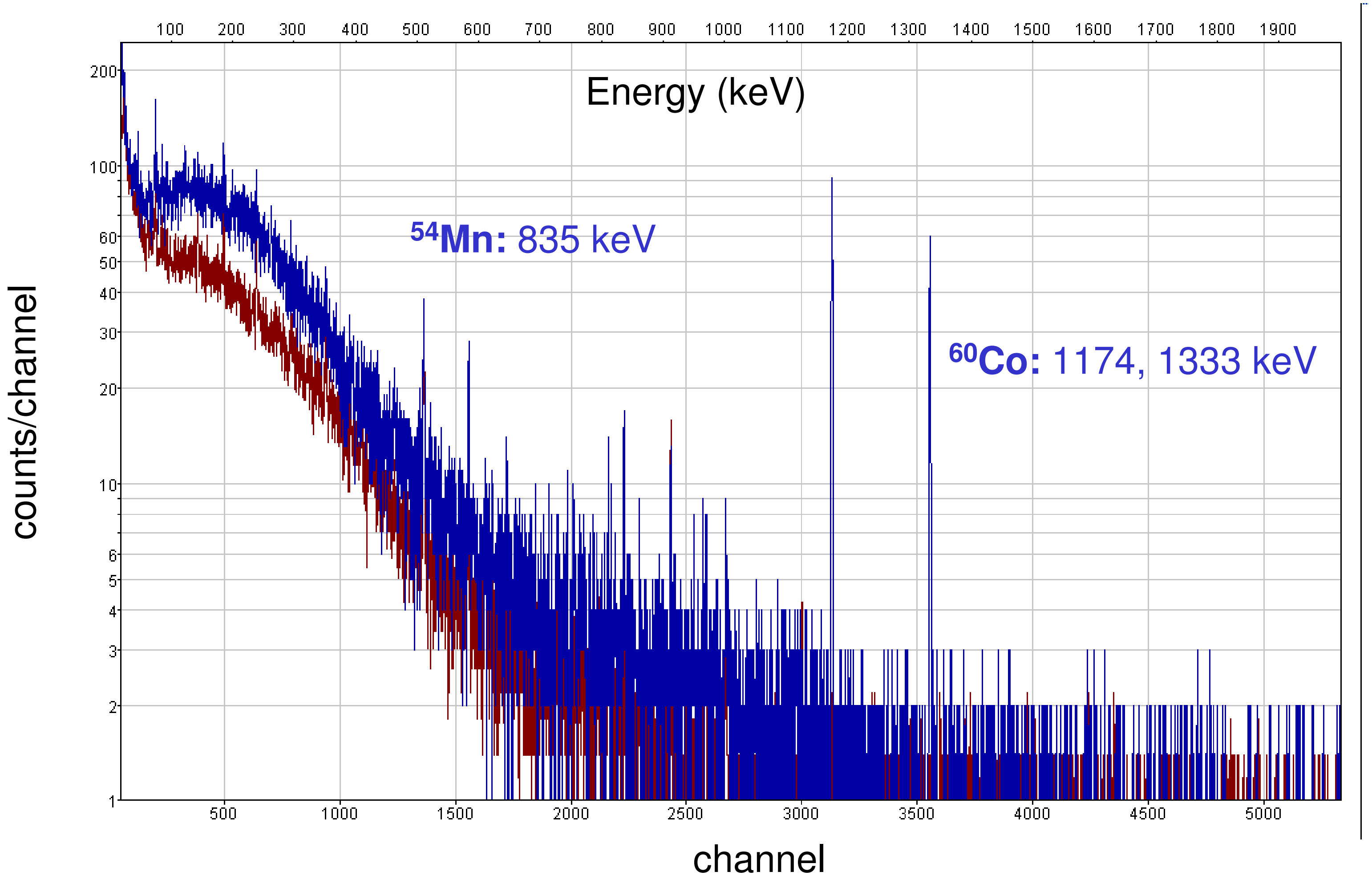
Simulated efficiency:



Results: 316Ti stainless steel

➢ **10 mm**

27 d: steel and background (normalized)



S. Cebrián, NEXT Collaboration Meeting, Canfranc, 9th May 2012

Results: 316Ti stainless steel

PRELIMINARY !

Activities: mBq/kg

10 mm

U-238/Th-234	<	9.1	
U-238/Pa-234m	<	15	
U-238/Pb-214	<	0.61	
U-238/Bi-214	<	0.26	
Th-232/Ac-228	<	0.58	
Th-232/Pb-212	<	0.54	
Th-232/Bi-212	<	1.6	
Th-232/Tl-208	<	0.29	→0.47
K-40	<	0.54	
Cs-137	<	0.10	
Co-60	=	1.21	0.10
Mn-54	=	0.20	0.03

15 mm

U-238/Th-234	<	12	
U-238/Pa-234m	<	18	
U-238/Pb-214	<	0.63	
U-238/Bi-214	<	0.42	
Th-232/Ac-228	<	0.69	
Th-232/Pb-212	<	0.78	
Th-232/Bi-212	<	1.9	
Th-232/Tl-208	<	0.28	→0.76
K-40	<	0.54	
Cs-137	<	0.14	
Co-60	=	1.89	0.15
Mn-54	=	0.39	0.06

50 mm

U-238/Th-234	<	65	
U-238/Pa-234m	<	79	
U-238/Pb-214	<	2.3	
U-238/Bi-214	<	1.0	
Th-232/Ac-228	<	2.8	
Th-232/Pb-212	<	1.9	
Th-232/Bi-212	<	6.0	
Th-232/Tl-208	<	1.1	→3.1
K-40	<	1.5	
Cs-137	<	0.44	
Co-60	=	1.70	0.15
Mn-54	=	0.62	0.10

(Upper limits at 95% C.L.)

Including only lines <600 keV

- Lower sensitivity: lower mass, higher self-absorption
- Hints of peaks of natural chains

Results of Nironit stainless steel from XENON

Table 1
Screening results, see text for discussion.

	Material	Supplier	Use	Detector	Time [d]	Amount	Unit	^{228}Ra	^{228}Th	^{238}U	^{226}Ra	^{235}U	^{40}K	^{137}Cs	^{60}Co
	Metal														
1.	Lead	Plombum	Outer Pb shield	Gator	18.4	2.27 kg	mBq/kg	<6.9	<0.52	<260	<4.2	<12	14(3)	<0.81	<0.11
2.	Lead	Plombum	Outer Pb shield	LNGS	14.5	44 kg	mBq/kg	<6.6	<1.6	<130	<5.7	<51	14(6)	<2.1	<1.1
3.	Lead	Foundaries de Gentilly	Inner Pb shield	Gator	17.8	2.27 kg	mBq/kg	<0.66	<0.42	<24	<0.71	<1.8	<1.46	0.63(6)	<0.11
4.	Lead	Foundaries de Gentilly	Inner Pb Shield	LNGS	18.7	44 kg	mBq/kg	<3.9	<4.3	<33	<6.8	<20	<28	<0.85	<0.19
5.	Copper	Norddeutsche Affinerie	Shield	Gator	51.4	512 kg	µBq/kg	21(7)	21(7)	70(20)	70(20)	3.4	23(6)		2(1)
6.	Copper	Norddeutsche Affinerie	TPC	Gator	20.3	18.1 kg	mBq/kg	<0.37	<0.33	<11	<0.37	<0.47	<1.3	<0.14	0.24(6)
7.	Stainless steel 316Ti (1.5 mm)	NIRONIT	Cryostat wall	LNGS	6.87	1.2 kg	mBq/kg	<2.4	<1.0	<130	<1.9	<2.0	10(4)	<0.9	8.5(9)
8.	Stainless steel 316Ti (2.5 mm)	NIRONIT	Cryostat bottom	LNGS	20.6	1.97 kg	mBq/kg	<3.1	<1.5	<42	<2.7	<1.4	<12	<0.88	13(1)
9.	Stainless steel 316Ti (3.0 mm)	NIRONIT	Grid frame	Gator	6.76	6.6 kg	mBq/kg	<4.1	<1.8	<130	3.6(8)	<5.8	<5.7	<1.1	7(1)
10.	Stainless steel 316Ti (25 mm)	NIRONIT	Top flange/support bars	LNGS	5.58	1.52 kg	mBq/kg	<0.92	2.9(7)	<20	<1.3	<1.3	<7.1	<0.82	1.4(3)
11.	Screws 2–56 7/16"	McMaster	Standard screw	Gator	12.1	0.27 kg	mBq/kg	24(5)	<21	<550	<13	<25	< 47	<5.1	6(2)

Results of Nironit stainless steel from GERDA

Table 3
Part1: concentrations of primordial, anthropogenic and cosmogenic radionuclides given in (mBq/kg) for the 1.4571 stainless steel measured with the detectors DARIO (D) at MPI-K (Heidelberg, Germany) and GeMPI (G) at LNGS (Gran Sasso, Italy)

Sample	D1	D2	D3	D4	D5	D6	D7
Exposure	158.5	243.2	384.8	443.6	241.8	521.3	217.56
Vendor	IS	IB	IB	IB	IB	IB	IB
^{228}Ra	<3.0	<3.5	<3.6	<3.8	<1.8	<1.4	<4.2
^{228}Th	3.4 ± 1.0	<1.7	<1.9	<1.8	<1.1	<0.8	<1.0
^{226}Ra	<2.6	<2.0	<0.9	<1.6	<1.5	<0.6	<1.4
^{234m}Pa	<155	<100	<84	<53	<76	<38	<152
^{40}K	<4.0	<4.7	<3.4	<3.3	<3.2	<1.8	<7.2
^{60}Co	6.6 ± 1.1	14.4 ± 2.1	15.4 ± 2.2	14.8 ± 2.1	16.8 ± 2.5	16.8 ± 2.4	17.5 ± 2.6
^{7}Be		34.6 ± 5.3					
Sample	G1	G2	G3	G4	G5	G6	G7
Exposure	174.9	1072.4	178.9	195.6	510.1	294.1	331.3
Vendor	IB	IB	U	A	A	IB	A
^{228}Ra	<2.6	<0.86	<1.0	<3.0	1.0 ± 0.5	<1.1	1.9 ± 1.0
^{228}Th	<0.20	<0.11	<0.41	5.1 ± 0.5	1.5 ± 0.2	<0.27	5.2 ± 0.5
^{226}Ra	<1.3	<0.24	<0.74	<1.3	1.0 ± 0.6	<0.35	3.9 ± 1.6
^{234m}Pa	<94	<12	<45	<41	54 ± 16	<38	<56
^{235}U	<2.6	<0.63	<1.5	<1.9	2.5 ± 1.5	<1.5	<3.9
^{40}K	<2.8	<0.93	<1.1	<1.7	<0.81	<1.1	<1.7
^{60}Co	45.5 ± 2.1	14.0 ± 0.1	13.8 ± 0.7	20 ± 1	18.3 ± 0.7	13 ± 0.6	42.1 ± 1.9
^{137}Cs	0.77 ± 0.43	<0.16	<0.26	<0.36	<0.1	<0.39	<0.6
^{7}Be	<3.9	<3.0	<5.7	9.6 ± 2.9	4.8 ± 1.7	13.6 ± 2.5	<5.9
^{54}Mn	1.3 ± 0.4	1.5 ± 0.1	0.92 ± 0.24	2.0 ± 0.3	1.7 ± 0.2	1.4 ± 0.2	1.6 ± 0.3
^{58}Co	0.67 ± 0.34	0.99 ± 0.12	0.56 ± 0.23	0.71 ± 0.26	0.69 ± 0.16	0.59 ± 0.20	0.54 ± 0.27
^{56}Co	<0.32	0.17 ± 0.06	<0.62	<0.71	0.28 ± 0.10	<0.42	<0.6
^{46}Sc	<0.35	0.24 ± 0.06	<0.54	<0.67	0.47 ± 0.14	<0.31	0.61 ± 0.26
^{48}V	0.30 ± 0.11	0.36 ± 0.07	0.27 ± 0.11	0.31 ± 0.13	0.22 ± 0.09	0.40 ± 0.12	0.39 ± 0.13

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - 316Ti stainless steel
  - **Connectors**
  - Others

- **Next measurements**

Results: connectors

Material: board-to-board connectors made of Liquid Crystal Polymer (LCP)

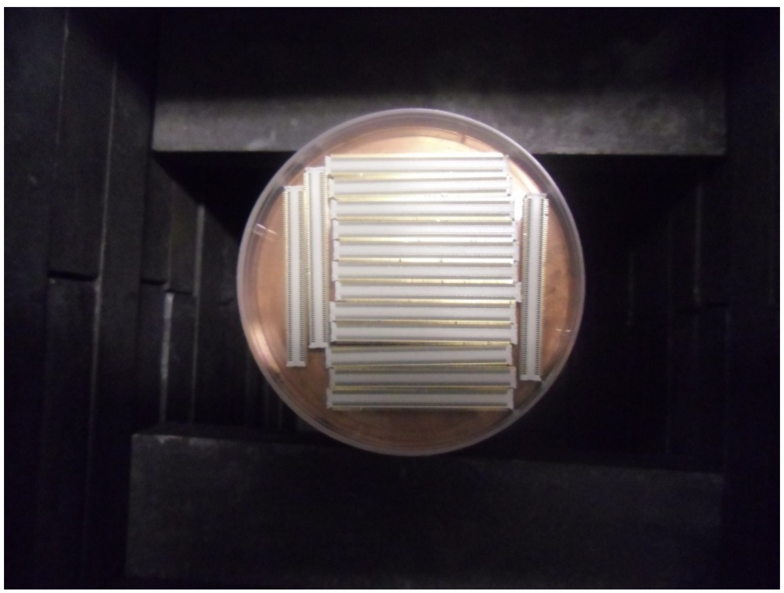
Supplier: Panasonic

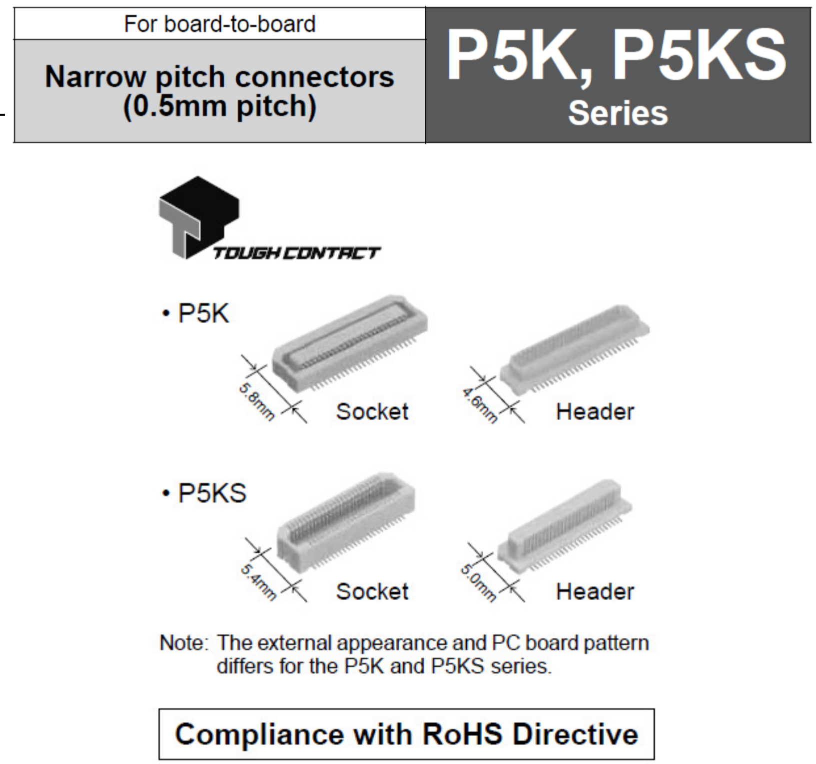
Sample: 15 units

Mass: 0.67 g (per connector)

Detector: Paquito (University of Zaragoza)

Time: 7.58 d (February 2012)





Results: connectors

Material: Flexible Printed Circuit & Flexible Flat Cable (FPC/FFC) ZIP connectors, made of Liquid Crystal Polymer (LCP)

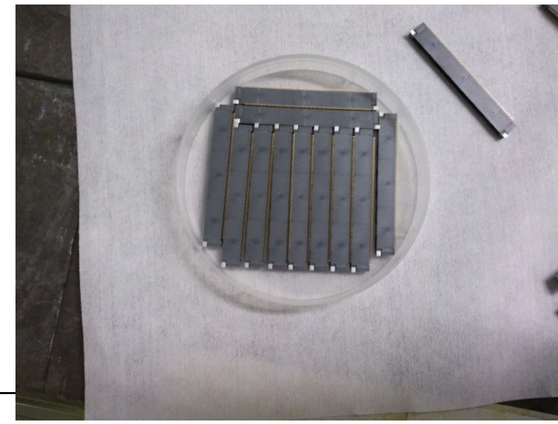
Supplier: Hirose

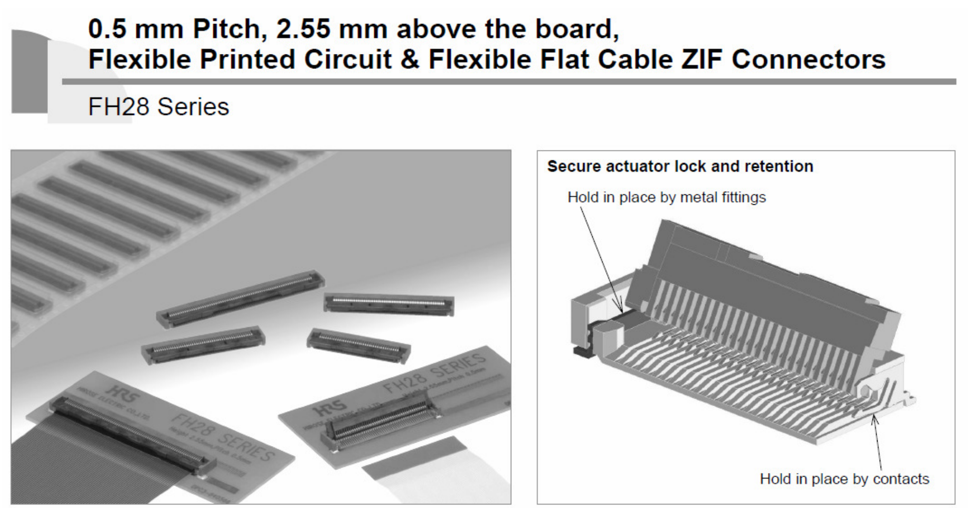
Sample: 19 units

Mass: 1.28 g (per connector)

Detector: Paquito (University of Zaragoza)

Time: 6.83 d (March2012)





S. Cebrián, NEXT Collaboration Meeting, Canfranc, 9th May 2012

Results: connectors

Activities: mBq/unit

Panasonic

	Isótopo	A (mBq/unidad)
232Th (9.6±1.0)	228Ac	9.5±1.7
	212Bi	11.5±3.8
	212Pb	14.8±4.5
	208Tl	3.2±0.5 (8.8±1.5 232Th)
238U	234mPa	<42
	214Pb	6.5±1.4
	214Bi	6.0±1.0
235U	235U	<0.95
	137Cs	<0.79
	40K	4.1±1.5
	60Co	<0.24

Hirose

	Isótopo	A (mBq/unidad)
232Th (6.4±0.7)	228Ac	6.5±1.2
	212Bi	6.7±2.3
	212Pb	10.7±3.2
	208Tl	2.1±0.4 (5.8±1.0 232Th)
238U	234mPa	<50
	214Pb	4.8±1.1
	214Bi	4.8±0.8
235U	235U	<0.75
	137Cs	<0.49
	40K	3.9±1.4
	60Co	<0.18

Activities of several mBq/unit for ^{232}Th, ^{238}U isotopes and for ^{40}K seem to be related to LCP material, which should be avoided
Solution: clamp and bonding to make connections at Dice Boards.

Results: connectors

Material: connectors, made of Liquid Crystal Polymer (LCP)

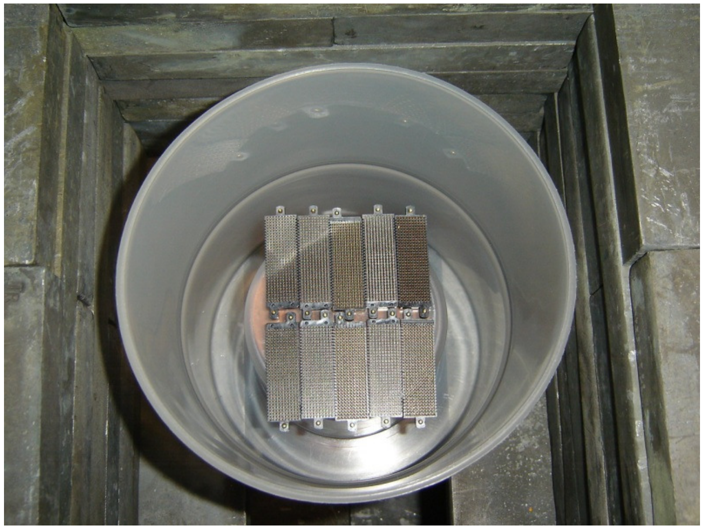
Supplier: Samtec

Sample: 10 units

Mass: 2.2 g (per connector)

Detector: Paquito (University of Zaragoza)

Time: 13.76 d (2011)



	Isótopo	Ae (mBq/pc)
232Th	228Ac	19.6 (3.6)
	228Th	--
18.5 (2.2)	212Pb	22.1 (6.7)
	208Tl	16.9 (3.01)
238U	234Th	< 76.9
	234Pa	--
	226Ra	< 39.8
9.2 (1.1)	214Pb	11.1 (2.4)
	214Bi	8.7 (1.2)
	210Pb	--
235U	235U	1.5 (0.4)
	137Cs	< 1.3
	40K	12.2 (4.1)
	60Co	< 0.6

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - 316Ti stainless steel
  - Connectors
  - **Others**

- **Next measurements**

Other results

Updated compilation of radiopurity information for NEXT at the radiopurity section of the report to the SC of LSC (May 2012)

http://dl.dropbox.com/u/10977880/PUBLICNEXT/LSC/May2012/radiopurity_report_apr2012.pdf

Other results

#	Material	Technique	Unit	^{238}U	^{232}Th	^{40}K	Ref.
	Shielding						
1	Pb, Cometa	GDMS	mBq/kg	0.37	0.073	<0.31	NEXT
2	Pb, Cometa		mBq/kg	<0.5	<0.5	<1	Cometa
3	Pb, Mifer	GDMS	mBq/kg	1.24	0.32		NEXT
4	Pb, Mifer, new provider	GDMS	mBq/kg	0.33	0.10	1.21	NEXT
5	Pb, Tecnibusa	GDMS	mBq/kg	0.73	0.14	0.91	NEXT
6	Pb, Tecnibusa	Ge (by LSC)	mBq/kg	<1.3 (e)	<0.9 (f)	<1.8	NEXT (+)
7	Pb, Tecnibusa	Ge (by LSC)	mBq/kg	<0.9 (e)	<0.7 (f)	<1.1	NEXT (+)
8	Cu, Luvata C10100	Ge (by UZ)	mBq/kg	<11.0	<9.7	<17.7	NEXT
9	Cu, Luvata C10100 hot rolled	GDMS	mBq/kg	<0.012	<0.004	0.061	NEXT
10	Cu, Luvata C10100 cold rolled	GDMS	mBq/kg	<0.012	<0.004	0.091	NEXT
11	Cu, Electroformed	GDMS	mBq/kg	<0.062	<0.020		NEXT
12	Cu, ETP Sanmetal	GDMS	mBq/kg	<0.062	<0.020		NEXT
	Vessel						
13	Ti, Nironit, XENON	Ge	mBq/kg	0.93±0.24 (b)	0.22±0.10	0.90±0.30	[11]
14	Ti, LUX	Ge	mBq/kg	6.2±1.2, <0.19	<0.25	<0.9	[12]
15	Ti, LUX	GDMS	mBq/kg	52	2.5	<1.5	NEXT
16	Ti, LUX	Ge (by UZ)	mBq/kg	238±28	417±54	49±11	NEXT
17	Ti, LUX, after polishing	Ge (by UZ)	mBq/kg	<15	4.2±1.4	<22	NEXT
18	Ti, SMP	Ge (by LSC)	mBq/kg	<9.4 (e)	<9.4 (f)	<19	NEXT (+)
19	Ti, SMP	Ge (by LSC)	mBq/kg	<6.3 (e)	<7.7 (f)	<9.3	NEXT (+)
20	Ti, Ti Metal Supply	Ge (by LSC)	mBq/kg	<0.30 (e)	3.2±0.3 (f)	<0.52	NEXT (+)
21	Stainless Steel, Pfeiffer 304L	Ge by UZ	mBq/kg	14.8±2.8 (a)	10.4±2.0 (a)	<16.6	NEXT
22	Stainless steel 316L, Elantic, UK, DRIFT	GDMS	mBq/kg	17.4±1.2	3.3±0.4	<9.3	[4]
23	Stainless steel 316L, block, Italy, DRIFT	GDMS	mBq/kg	<6.2	8.2±0.8	<9.9	[4]
24	Stainless steel 316L, SNOlab	Ge	mBq/kg	0.63±0.15 (b)	0.62±0.15	<0.97	[6]
25	Stainless steel 316Ti, Nironit, XENON	Ge	mBq/kg	<1.9 (b)	<1.0 (d)	10±4	[3]
26	Stainless steel Austenitic 1.4571, GERDA	Ge	mBq/kg	<0.24 (b)	<0.11 (d)	<0.93	[13]
27	Stainless steel 316Ti, Nironit	Ge (by LSC)	mBq/kg	<0.26 (e)	<0.29 (f)	<0.54	NEXT (+)
28	Stainless steel TIG, SNOlab	Ge	mBq/kg	1.01±0.71 (b)	2.8±0.8	<1.45	[6]
29	Inconel 718	Ge (by LSC)	mBq/kg	<5.6 (e)	<4.6 (f)	<11	NEXT (+)
30	Inconel 625	Ge (by LSC)	mBq/kg	<1.8 (e)	<2.0 (f)	<2.6	NEXT (+)

(Follows at next page)

Other results

(Continuation)

#	Material	Technique	Unit	^{238}U	^{232}Th	^{40}K	Ref.
31	PCTFE, Daikin Neoflon, EXO	Ge	mBq/kg	5.6±1.2	<2.3	<30	[9]
32	Viton, O-ring seal, Johannsen AG, EXO	Ge	mBq/kg	868±87	130	2170±226	[9]
	HV and EL components						
33	Peek, Sanmetal	Ge (by UZ)	mBq/kg	36.3±4.3	11.7±2.2	8.3±3.0	NEXT
34	Peek	Ge	mBq/kg	<70 (b)	<50 (d)	<260	[14]
35	SM5D, 700MΩ resistors, Finechem, XENON	Ge	mBq/pc	0.027±0.003 (b)	0.014±0.003 (d)	0.19±0.03	[3]
36	SM5D resistors, Finechem	Ge (by UZ)	mBq/pc	0.022±0.007 (e)	<0.016 (f)	0.17±0.07	NEXT
37	SMD resistors, Farnell	Ge (by UZ)	mBq/pc	0.15±0.04 (e)	0.28±0.06 (f)	0.19±0.08	NEXT
38	Polyethylene, EDELWEISS	Ge	mBq/kg	16±10 (e)	<6 (f)	70±50	[4]
39	Polyethylene, XENON	Ge	mBq/kg	0.23±0.05 (b)	<0.14 (d)	0.7±0.4	[3]
40	Polyethylene insulator, EXO	NAA	mBq/kg	<2.9	<0.57	1.46±0.22	[9]
41	Tetratex, ArDM	ICPMS	mBq/kg	12.4±3.7	<1.6	<16	[5]
42	TPB, Sigma-Aldrich, SNOlab	Ge	mBq/kg	1.63±1.01 (b)	0.47±1.11	8.22±12.03	[6]
43	TPB, American Chemicals, SNOlab	Ge	mBq/kg	<4.33 (b)	<1.69	<36.29	[6]
44	Teflon, Du Pont TE-6472, EXO	NAA	mBq/kg	<0.0096	<0.0011	0.0558±0.0062	[9]
45	PTFE, Dyneon TF 1620, GERDA	Ge	mBq/kg	0.025±0.009 (b)	0.031±0.014 (d)	0.60±0.11	[7]
	Detector components: energy plane						
46	PMT, Hamamatsu R8520, XENON	Ge	mBq/PMT	0.19±0.01 (b)	0.20±0.02(d)	9.9±0.4	[3]
47	PMT base, Hamamatsu R8520, XENON	Ge	mBq/base	0.16±0.02 (b)	0.07±0.02 (d)	<0.16	[3]
48	PMT, Hamamatsu R11410MOD, XENON	Ge	mBq/PMT	<2.4 (b)	<2.6 (d)	13±4	[3]
49	PMT, Hamamatsu R11410MOD, LUX		mBq/PMT	<0.4	<0.3	<8.3	[8]
50	PMT, Hamamatsu R11410MOD		mBq/PMT	3.3	2.3	5.7	[15]
51	Sapphire, Czochralsky Type, ROSEBUD	Ge	mBq/kg	<5 (e)	<5(f)	<30	[4]
52	Sapphire, Verneuil Type, ROSEBUD	Ge	mBq/kg	<3 (e)	<3(f)	<12	[4]
53	Sapphire window, EXO	NAA	mBq/kg	<0.31	0.123±0.029	<0.20	[9]
54	Quartz, Heraeus 2, EXO	NAA	mBq/kg	0.068±0.027	0.027±0.005	0.062±0.016	[9]
	Detector components: tracking plane						
55	Cuflon, circuit board, EDELWEISS	Ge	mBq/kg	<23 (e)	<30 (f)	400±200	[4]
56	Cuflon, Crane Polyflon, GERDA	Ge	mBq/kg	<0.85 (b)	<1.9 (d)	48±15	[7]
57	Cuflon	Ge	mBq/kg	<0.84 (b)	<1.9	48±15	[10]
58	Cuflon	ICPMS	mBq/kg	$0.36^{+0.07}_{-0.04}$	$0.28^{+0.04}_{-0.03}$	6^{+9}_{-2}	[10]
59	ARJOPROX, ARLON	Ge	Bq/kg	<0.044 (e)	<0.065 (f)	0.3±0.2	[4]
60	ARAMID paper, CIMULEC	Ge	Bq/kg	<0.06 (e)	0.04±0.03 (f)	0.15±0.14	[4]
61	Kapton, AXON	Ge	Bq/kg	0.07±0.03 (e)		0.3±0.2	[4]

(Follows at next page)

Other results

(Continuation)

#	Material	Technique	Unit	^{238}U	^{232}Th	^{40}K	Ref.
62	Kapton+Cu, KAPPA Industrie	Ge	Bq/kg	0.014±0.012 (e)	0.013±0.012 (f)	<0.09	[4]
63	Kapton+Cu, SOGGEG (g)	Ge	Bq/kg	<0.08 (e)	0.05±0.04 (f)	<0.9	[4]
64	Kapton+Cu, CIRE (g)	Ge	Bq/kg	0.09±0.05 (e)	<0.08 (f)	0.7±0.4	[4]
65	Kapton+Cu, CIRE (g)	Ge	Bq/kg	0.28±0.26 (e)	0.3±0.2 (f)	<2.1	[4]
66	Kapton+Cu ATLANTEK (g)	Ge	Bq/kg	<0.06 (e)	<0.02 (f)	0.4±0.2	[4]
67	Polyamide+Cu VISHAY	Ge	Bq/kg	9.1±0.2 (e)	3.3±0.2 (f)	7.0±0.7	[4]
68	FR4 PCB	Ge (by UZ)	Bq/kg	0.4	0.24	1.5	
69	Kapton-copper foil	Ge (by UZ)	mBq/cm^2	<0.011	<0.0046	<0.0077	[16]
70	Kapton-copper PCB, LabCircuits	Ge (by UZ)	mBq/cm^2	<0.014 (e)	<0.003 (f)	<0.040	
71	Kapton HN, DuPont, GERDA	Ge	mBq/kg	14.6±1.3 (b)	<1.1 (d)	<5.5	[7]
72	Kapton PMT HV cable, Caburn-MDC, XENON	Ge	mBq/kg	<11 (b)	<11 (d)	610±80	[3]
73	EPO-TEK 301-2FL, Epoxy Tech.	Ge	mBq/kg	9±3 (b)	<60 (d)	<25	[17]
74	EPO-TEK H20E, silver, Epoxy Tech.	Ge	mBq/kg	<25 (e)	<40 (f)	600±400	[4]
75	EPO-TEK 417F, silver, Epoxy Tech.	Ge	mBq/kg	68±11 (b)	<131 (d)	<65	[17]
76	Tra-Con Tra-Duct 2902 silver epoxy, Ellsworth	ICPMS	mBq/kg	0.98±0.05	0.045±0.004		[18]
77	FFC/FCP connector, Molex	Ge	mBq/unit	3.0±0.2 (e)	1.8±0.1 (f)	3.5±0.5	[4]
78	FFC/FCP connector, Hirose	Ge (by UZ)	mBq/unit	4.8±0.8 (e)	5.8±1.0 (f)	3.9±1.4	NEXT
79	P5K board-to-board connector, Panasonic	Ge (by UZ)	mBq/unit	6.0±1.0 (e)	8.8±1.5 (f)	4.1±1.5	
80	Samtec connector	Ge (by UZ)	mBq/unit	8.7±1.4 (e)	16.9±3.0 (f)	12.2±4.1	
81	Tantalum capacitor, AVX	Ge	Bq/kg	0.32±0.05 (e)	0.41±0.05 (f)	0.3±0.2	[4]

(a) Average on different isotopes
(b) Activity of ^{226}Ra
(c) Two values for early/late part of chain
(d) Activity of ^{228}Th
(e) Activity from ^{214}Bi
(f) Activity from ^{208}Tl
(g) Special fabrication
(+) Preliminary result.

Results

[1] NEXT Collaboration, "Screening program and request for LbGe detectors time to LSC", March 2012.

[2] NEXT Collaboration, "NEXT-100 Technical Design Report (TDR). Executive Summary", arXiv:1202.0721v2.

[3] E. Aprile et al, "Material screening and selection for XENON100", Astropart. Phys. 35 (2011) 43-49.

[4] ILIAS Database, http://radiopurity.in2p3.fr.

[5] V. Boccone et al, "Development of wavelength shifter coated reflectors for the ArDM argon dark matter detector", JINST 4 (2009) P06001.

[6] I. Lawson and B. Cleveland, "Low Background Counting At SNOLAB", Topical Workshop on Low Radioactivity Techniques LRT 2010, AIP Conf. Proc. 1338 (2011) 68-77.

[7] D. Budjas et al, "Gamma-ray spectrometry of ultra low levels of radioactivity within the material screening program for the GERDA experiment", Applied Radiation and Isotopes 67 (2009) 755.

[8] C. Faham, Presentation "Performance and Radioactivity Measurements of the PMTs for the LUX and LZ Dark Matter Experiments'" at TIPP2011, http://conferences.fnal.gov/tipp11/.

[9] S. Leonard et al, "Systematic study of trace radioactive impurities in candidate construction materials for EXO-200", NIMA 591 (2008) 490.

[10] S. Nisi et al, "Comparison of inductively coupled mass spectrimetry and ultra low-level gamma-ray spectroscopy for ultra low background material selection", Applied Radiation and Isotopes 67 (2009) 828.

[11] Communication from L. Baudis.

[12] D. S. Akerib et al, "Radio-assay of Titanium samples for the LUX Experiment", arXiv:1112.1376 [physics.ins-det].

[13] W. Maneschg et al, "Measurements of extremely low radioactivity levels in stainless steel for GERDA", NIMA 593 (2008) 448.

[14] P. Finnerty et al, "Low-background gamma counting at the Kimballton Underground Research Facility", Nucl. Instrum. Meth. A 642 (2011) 65-69.

[15] K. Lung et al, " Characterization of the Hamamatsu R11410-10 3-Inch Photomultiplier Tube for Dark Matter Direct Detection Experiments", arXiv:1202.2628 [physics.ins-det].

[16] S. Cebrian et al, "Radiopurity of micromegas readout planes", Astropart. Phys. 34 (2011) 354-359.

[17] J. Busto et al, "Radioactivity measurements of a large number of adhesives", NIMA 492 (2002) 35-42.

[18] Communication from A. Goldschmidt.

References at tables

NEXT radiopurity measurements: status and results

- **Screening program**

- **Recent results:**
  - Study of detection efficiency
  - 316Ti stainless steel
  - Connectors
  - Others

- **Next measurements**

Next measurements

- **Components for tracking plane and electronics**
  - **Capacitors:**
    - Tantalum: ~300 units being screened by Anayet
    - Ceramic: (+ resistors) ready at LSC
  - **Connectors:** from Molex
    - made of LCP, ready at LSC
    - made of thermoplastic, ready at LSC
  - **Cuflon:** ~0.5 kg sample cut in Valencia, ready at LSC
    Bonding films to prepare multilayer PCB ready at LSC
  - **Silver epoxy:** ready at LSC
  - **Soldering paste:** the one used at IFIC could not be bad
  - **NTC sensors:** ready at LSC
- **High density polyethylne:**
  - **From Texas:** ~2 kg samples of 2'' diameter rods ready at LSC
  - **From in2plastic company** (giving best radiopurity, measured by XENON): sample being prepared in Valencia
- **Other steels:**
  - **S-275 steel** for shielding supporting structure?
  - 316Ti stainless steel after **welding**?

Summary and outlook

➢ A detailed **screening program** using the LSC Ge detectors has been defined, taking into consideration the constraints imposed by the construction of different basic elements, and submitted to LSC

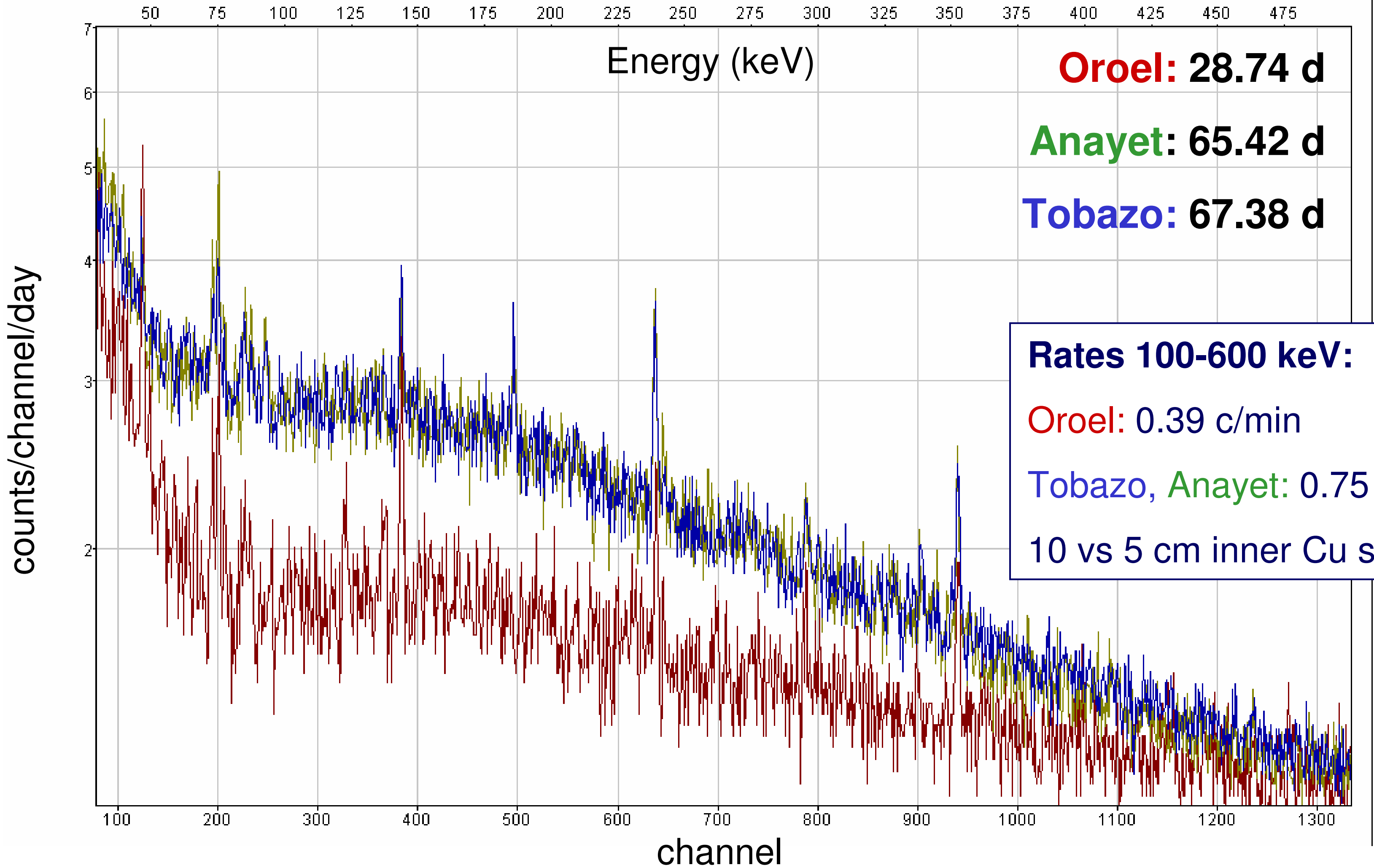
- Two, even three Ge detectors, can be used simultaneously for NEXT

➢The screening campaign at LSC has started, having produced some important results, dealing with **stainless steel** for Pressure Vessel and **connectors** for Dice Boards

- Preliminary numbers will probably have to be revised
- Intensive work will go on for the next months

Comparison of detector backgrounds

- 2011 backgroud measurements for the three detectors



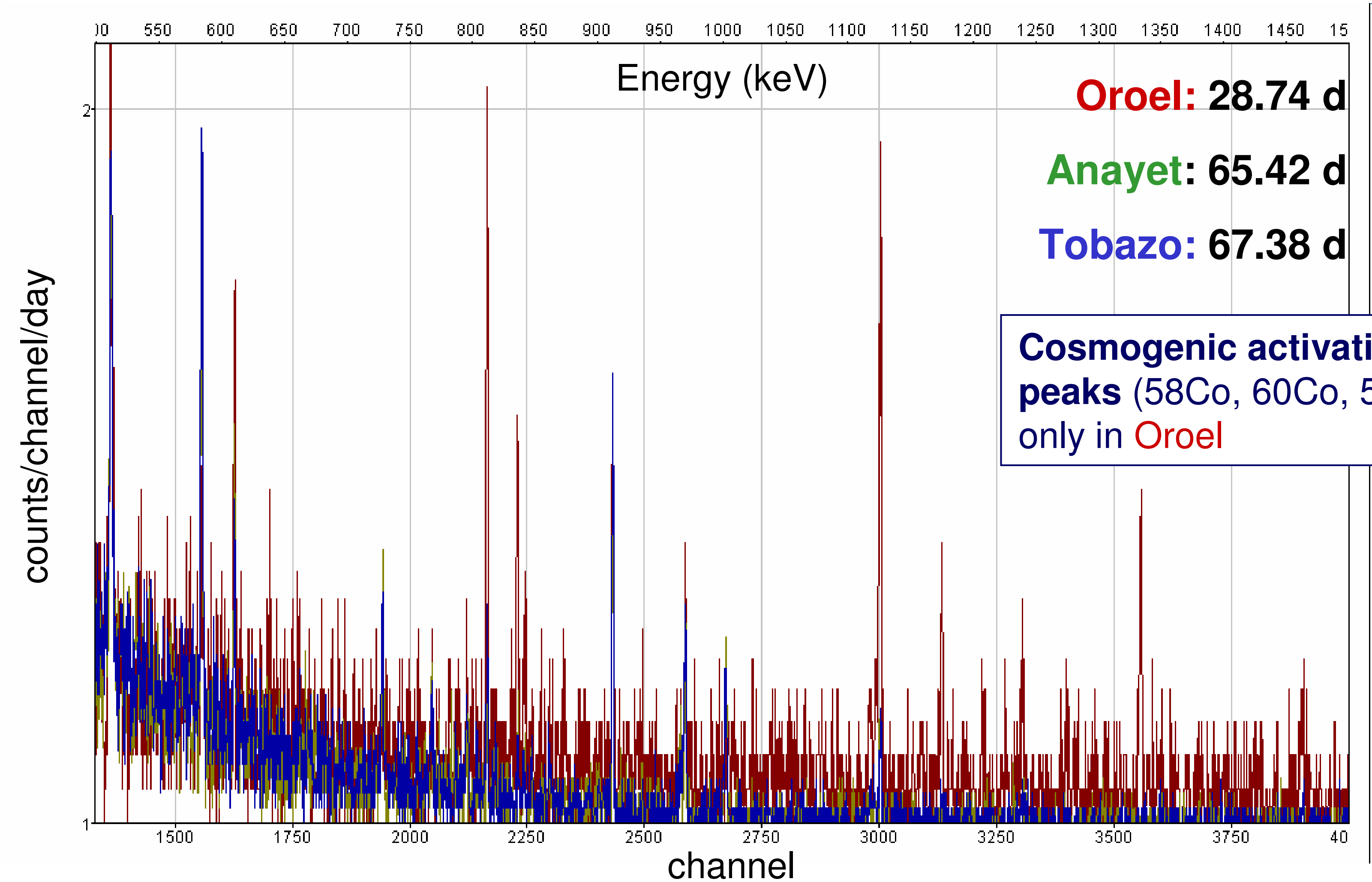
Rates 100-600 keV:

Oroel: 0.39 c/min

Tobazo, Anayet: 0.75 c/min

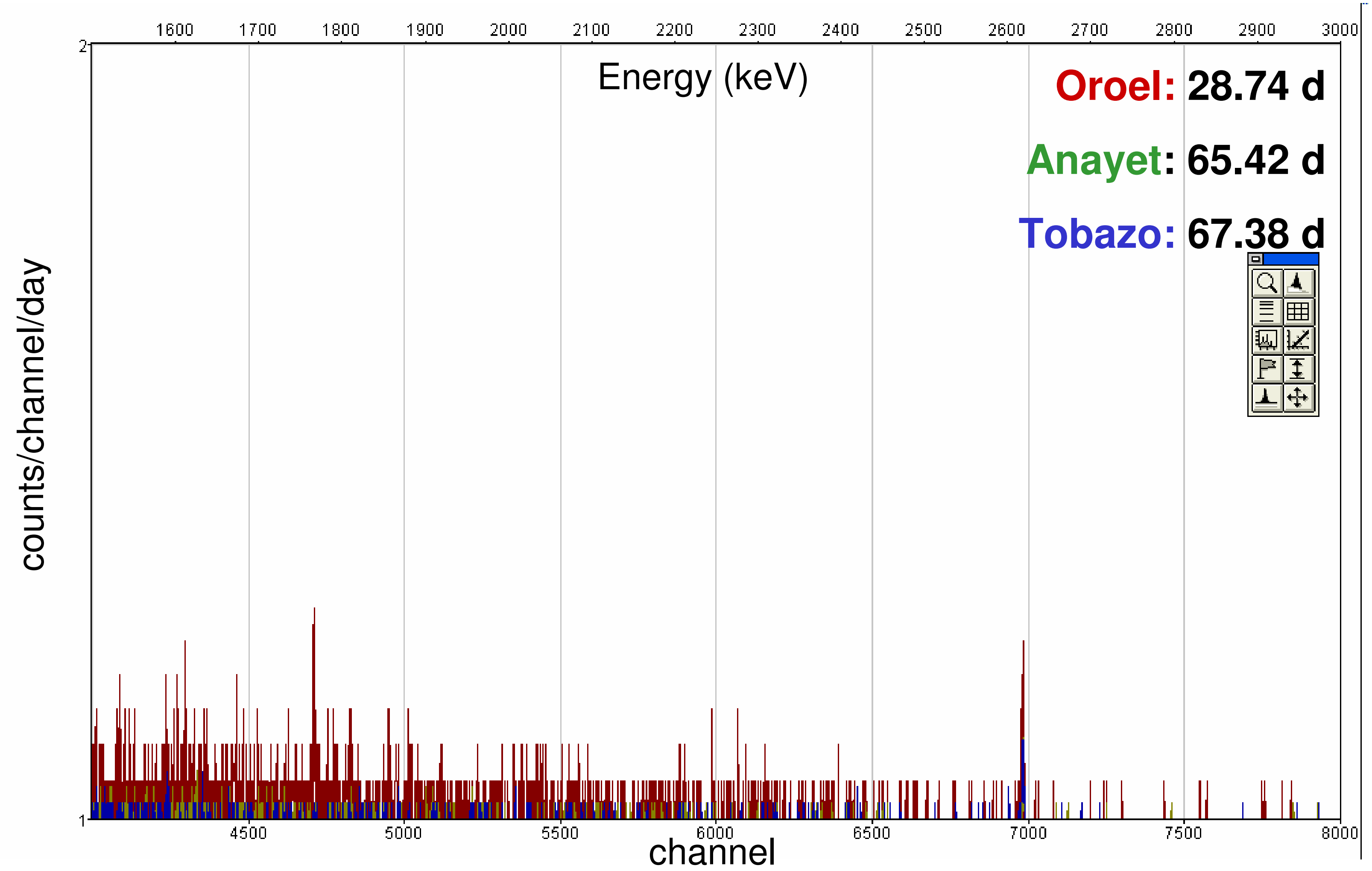
10 vs 5 cm inner Cu shield

Comparison of detector backgrounds



Cosmogenic activation peaks (58Co, 60Co, 54Mn) only in Oroel

Comparison of detector backgrounds



- 2011 and 2012 backgroud measurements for Anayet well compatible

Measurements at LSC: method

Activity *A* from γ spectrometry:

$$A = \frac{S_{net}}{\varepsilon\, B.R.\, T}$$

S_{net} = signal at the γ line after subtracting background
ε = detection efficiency at the γ line energy
B.R. = branching ratio of the γ emission
T = time of measurement

- **Peak analysis:**

When can the gross signal be considered to statistically differ from the background signal?

- *Limits for qualitative detection and quantitative determination. Application to radiochemistry*, Ll. A. Currie, Anal. Chem. 40 (1968) 586-377
- *Revisiting Currie: how long can you go?* Ch. Hurtgen et al, Appl. Rad. Isot. 53 (2000) 45-40
- *Gator: a low-background counting facility at the Gran Sasso Underground Laboratory*, L. Baudis et al, JINST 6 (2011) P08010

1 ppb Th = 4 mBq/kg ^{232}Th	1 ppb U = 12.4 mBq/kg ^{238}U	1 ppm K = 30 mBq/kg ^{40}K
0.245 ppb Th = 1 mBq/kg ^{232}Th	0.081 ppb U = 1 mBq/kg ^{238}U	0.033 ppm K = 1 mBq/kg ^{40}K

Measurements at LSC: method

1. $S_{\text{net}} < 0$: the upper limit is set to L_d (no net contribution from a signal)
2. $0 < S_{\text{net}} < L_d$: the upper limit is set to $S_{\text{net}} + L_d$ (there is an indication of a signal, but it can not be confirmed for the existing background level and sample exposure)
3. $S_{\text{net}} > L_d$: the detection limit is exceeded (clear indication for a signal at 95% C.L.)

$$S_{\text{net}} = S - B \cdot t_S / t_B - B_C$$

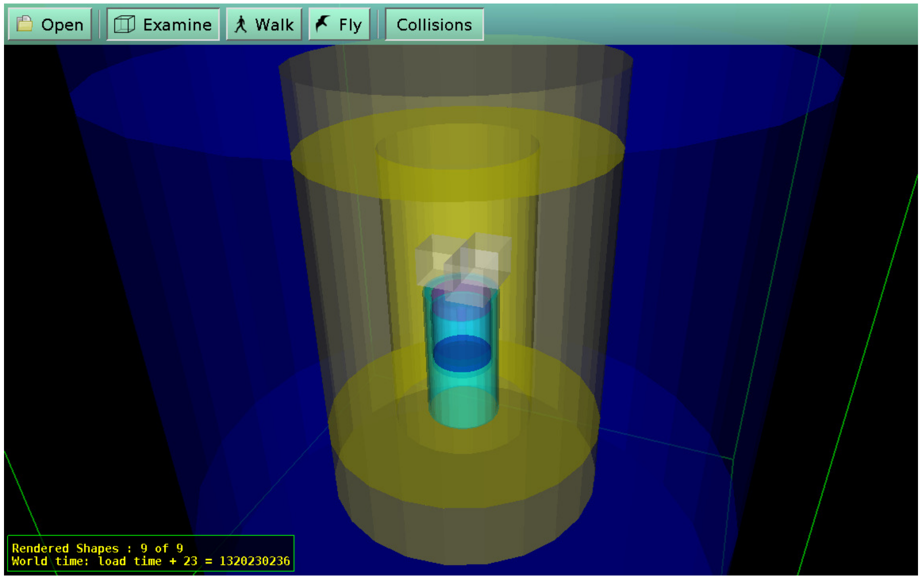
$$L_d = 2.86 + 4.78\sqrt{B_C + B \cdot \frac{t_S}{t_B} + 1.36}.$$

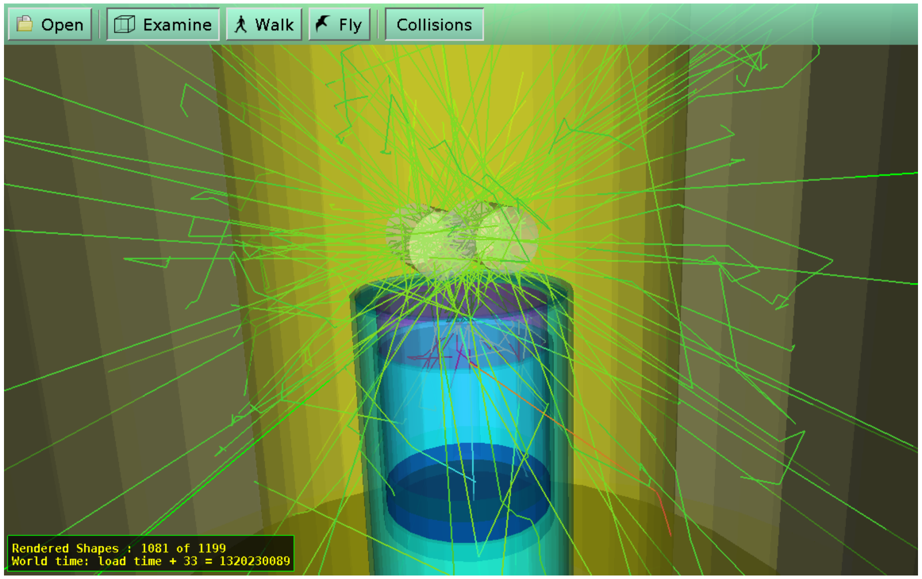
Detection Limit: true signal that, if present, will be detected with a given probability

Measurements at LSC: method

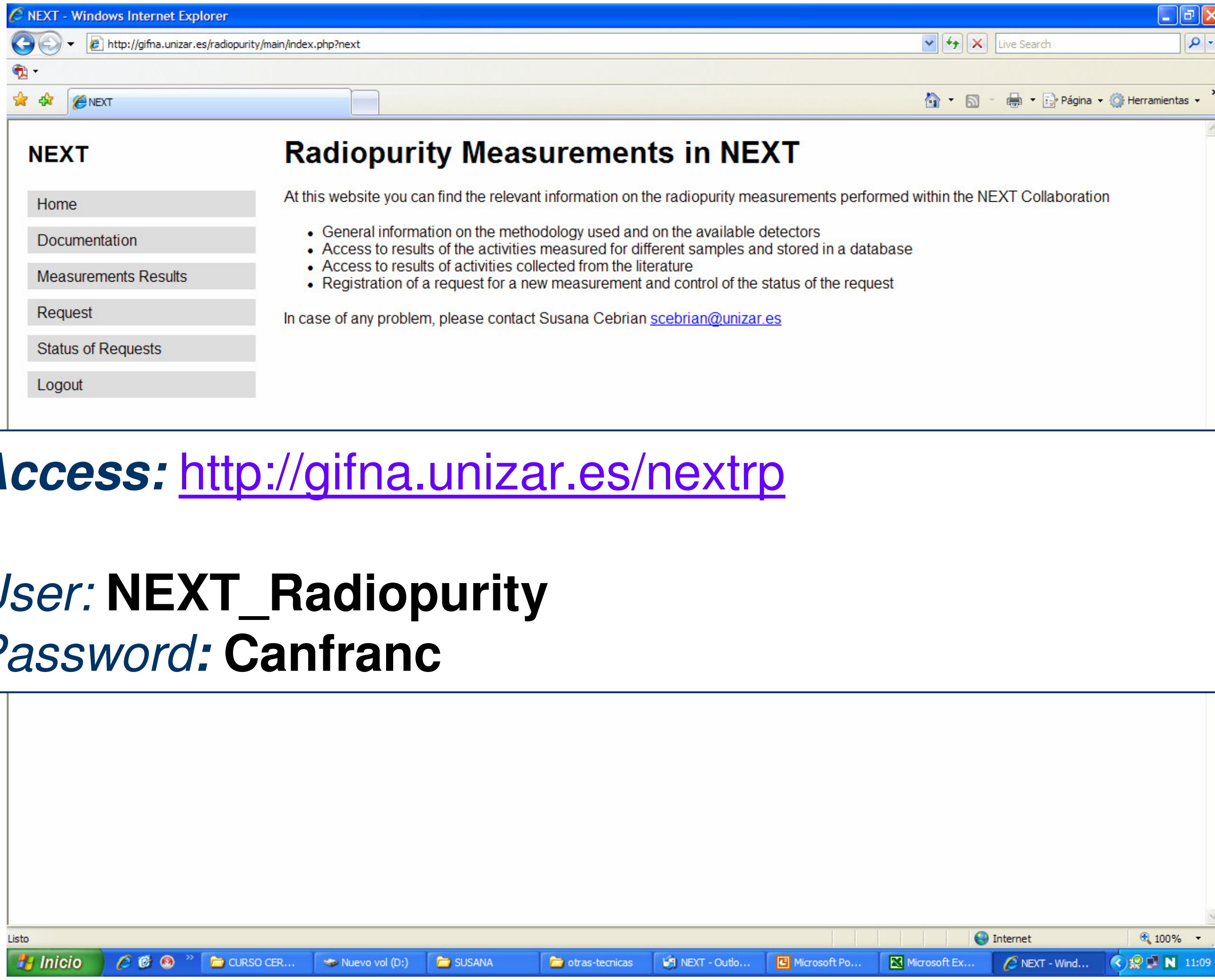
- **Efficiency:**
- Curve of efficiency vs energy for each sample based on GEANT4 simulations including the detection system and the sample:
Intrinsic probability + Geometric factor + Autoabsorption at sample
- Validation using a reference source (^{60}Co, ^{133}Ba, ^{152}Eu, ^{137}Cs): analysis pending

Consider the following results as preliminary!





Information on radiopurity



Access: http://gifna.unizar.es/nextrp

User: **NEXT_Radiopurity**
Password: **Canfranc**