The NEXT-100 experiment for Neutrino-less Double Beta decay: Main features, Results from Prototypes and Radio-Purity issues

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next

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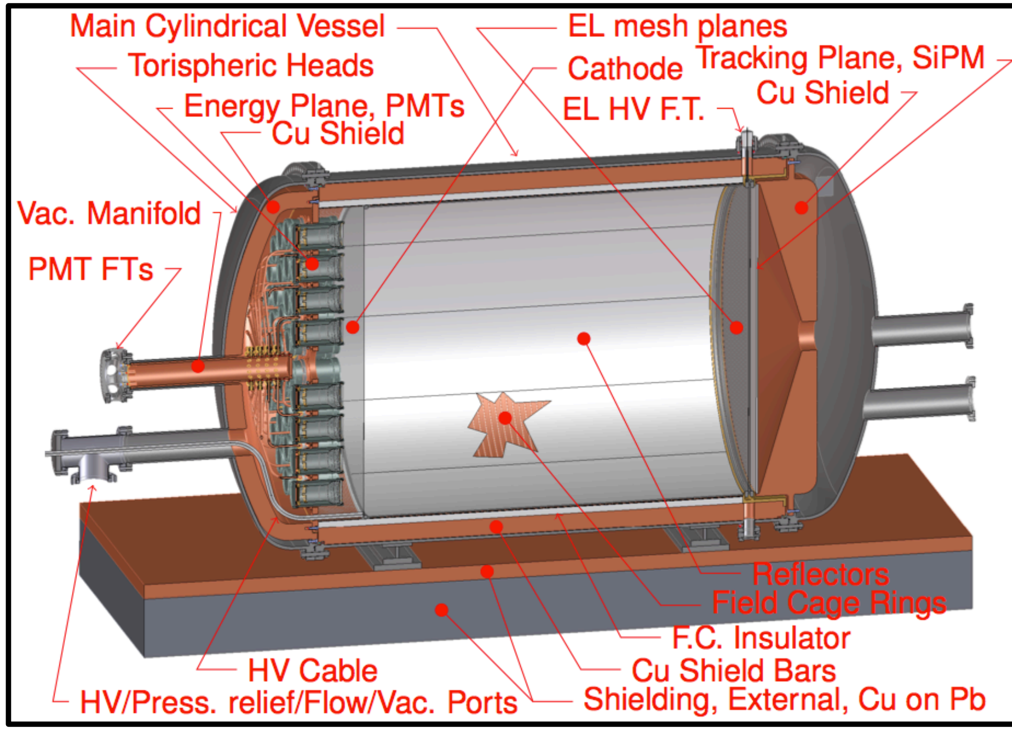
The *NEXT-100* detector: general ideas

NEXT-100 is an asymmetric Time Projection Chamber.
It is filled with 100 kg enriched ^{136}Xe (90%) at 10-15 atm

It features an excellent energy resolution (0.5 - 1 % at $Q_{\beta\beta}$) and tracking, thus allowing a superb Signal-to-Background ratio



NEXT-100 Technical Design Report; Executive Summary 2012 JINST 7 T06001

The design is easily scalable to its next-generation NEXT-1000

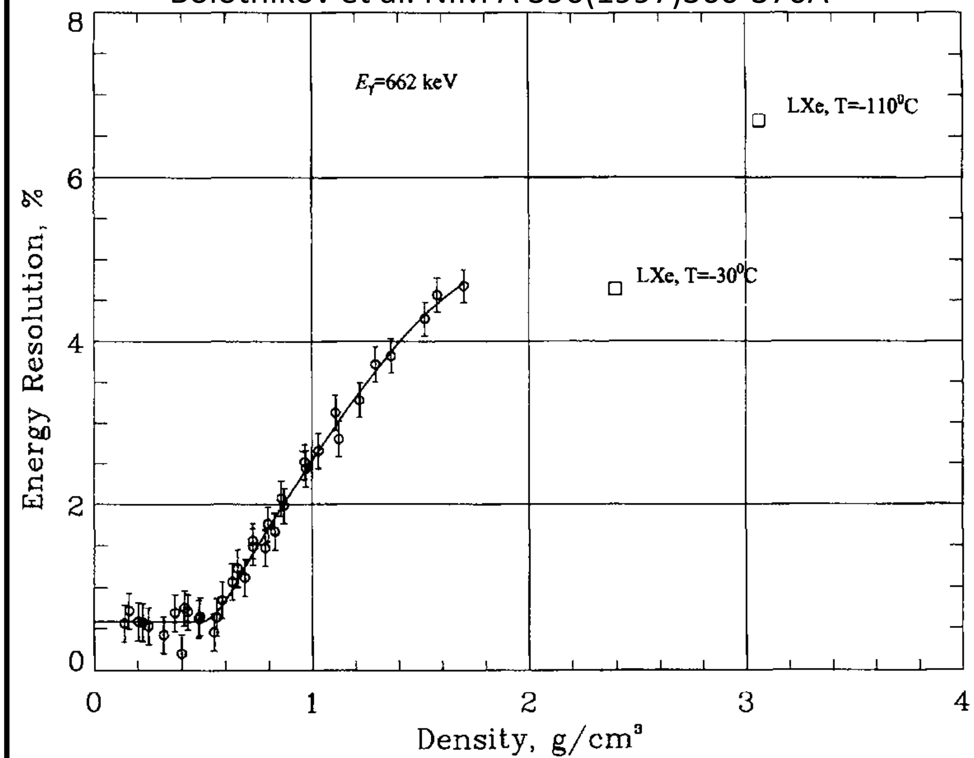
It will operate in the *Canfranc Underground Laboratory* (LSC) in the Spanish Pyrenees under the *Tobazo* mountain (800 m overburden)

Physics runs are expected to start in 2015

NEXT CONCEPTUAL IDEA

- Advantages of Xe: high $Q_{\beta\beta}$, only noble gas (low attach.) with ββ decay, high natural abundance of 136 isotope, easy to enrich.
- Advantages of gas Xe: good energy resolution (<1%), allows tracking
- Tracking and Radio-purity: background minimized
- Scalability: NEXT 100**0**

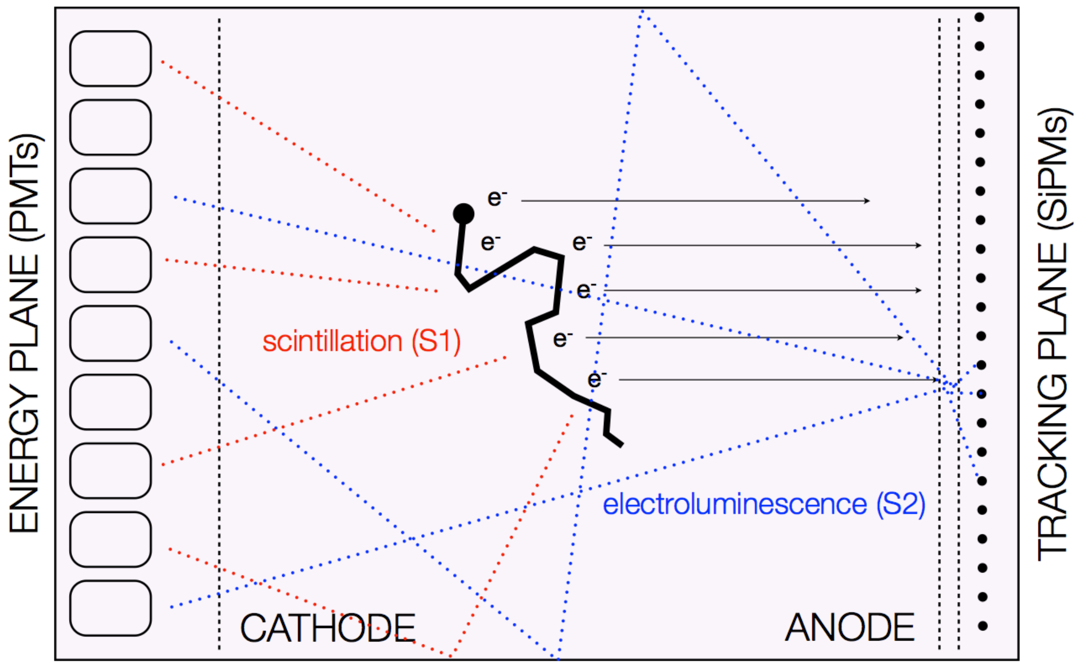
Bolotnikov et al. NIM A 396(1997)360-370A



NEXT CONCEPTUAL IDEA, LIGHT PRODUCTION

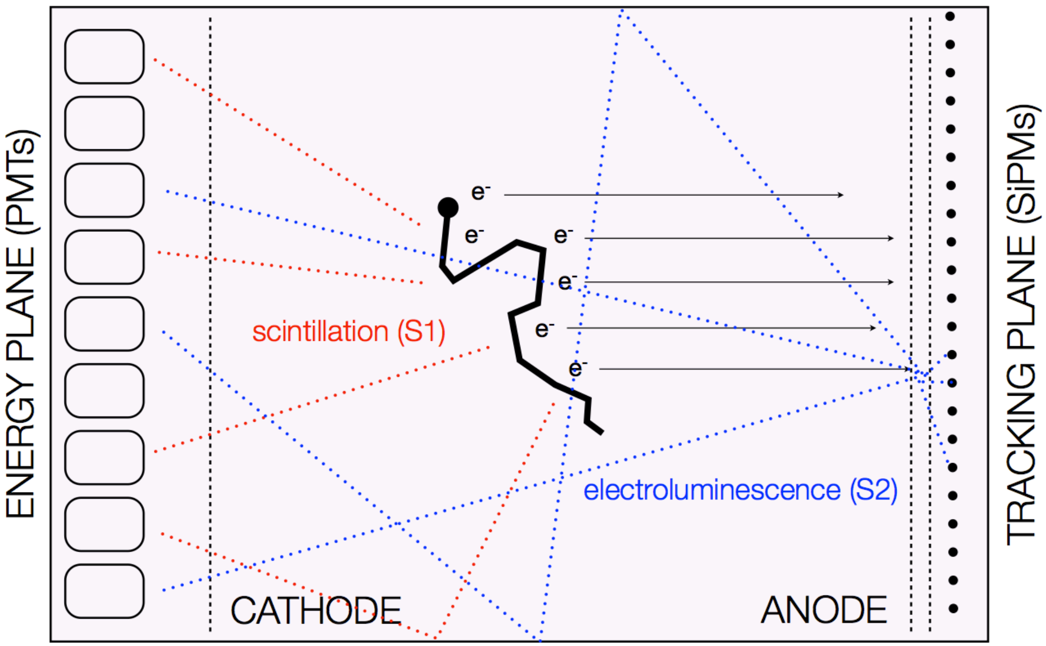
LIGHT PRODUCTION PROCESS

- Electrons excite and ionize Xe
- Excited Xenon emits scintillation light (172nm) that is detected by the PMTs at Energy Plane (SIGNAL 1)
- Electrons from ionization are **drifted** by a weak electric field to the Electro-Luminescence (**EL**) region
- There, a larger E field accelerate electrons such to excite the Xe, but not enough to ionize it. This process produce a large amount of 172nm (SIGNAL 2)
- The **PMTs** in the energy plane will accurately measure the energy
- The **SiPMs** in the tracking plane will allow to reconstruct the track followed by the original particle.

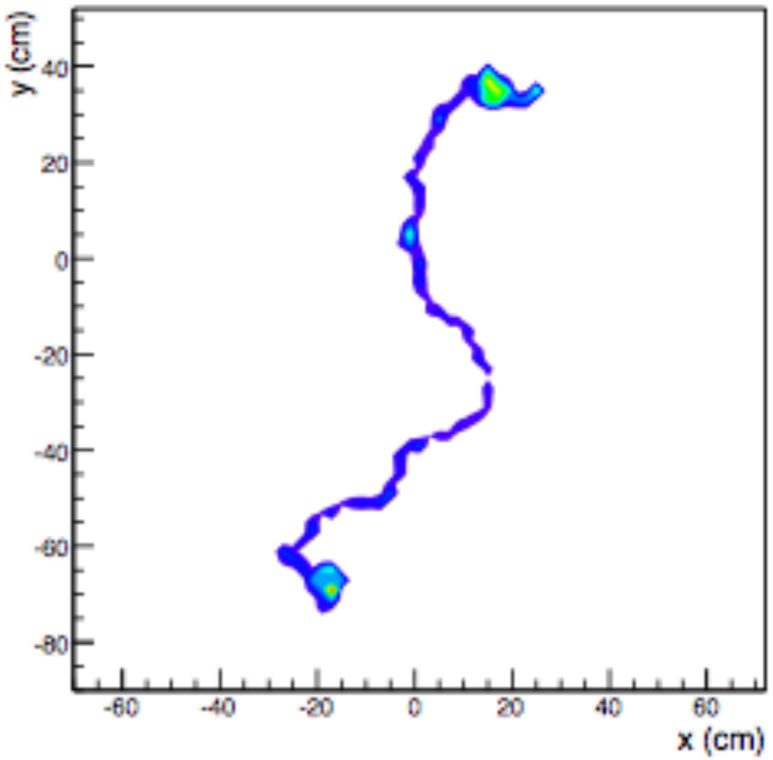


Tetra **P**henyl **B**utadiene (TPB) Wave-Length-Shifter is used to convert the light from UV to 430 nm to make it visible and increase the light production

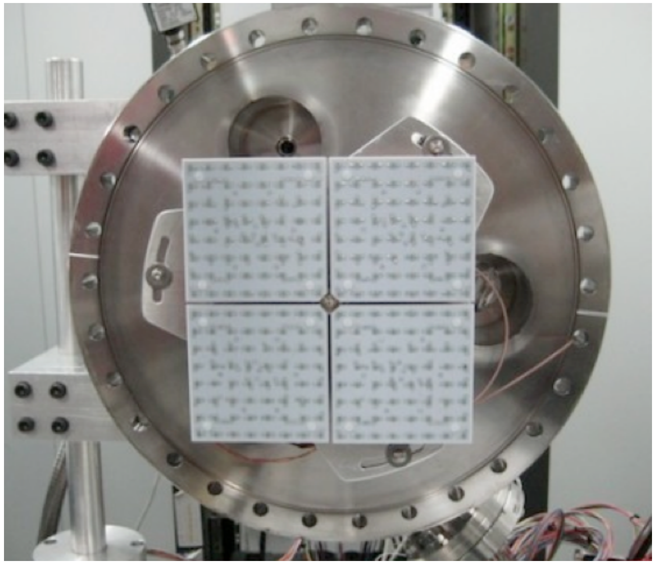
NEXT conceptual idea, tracking



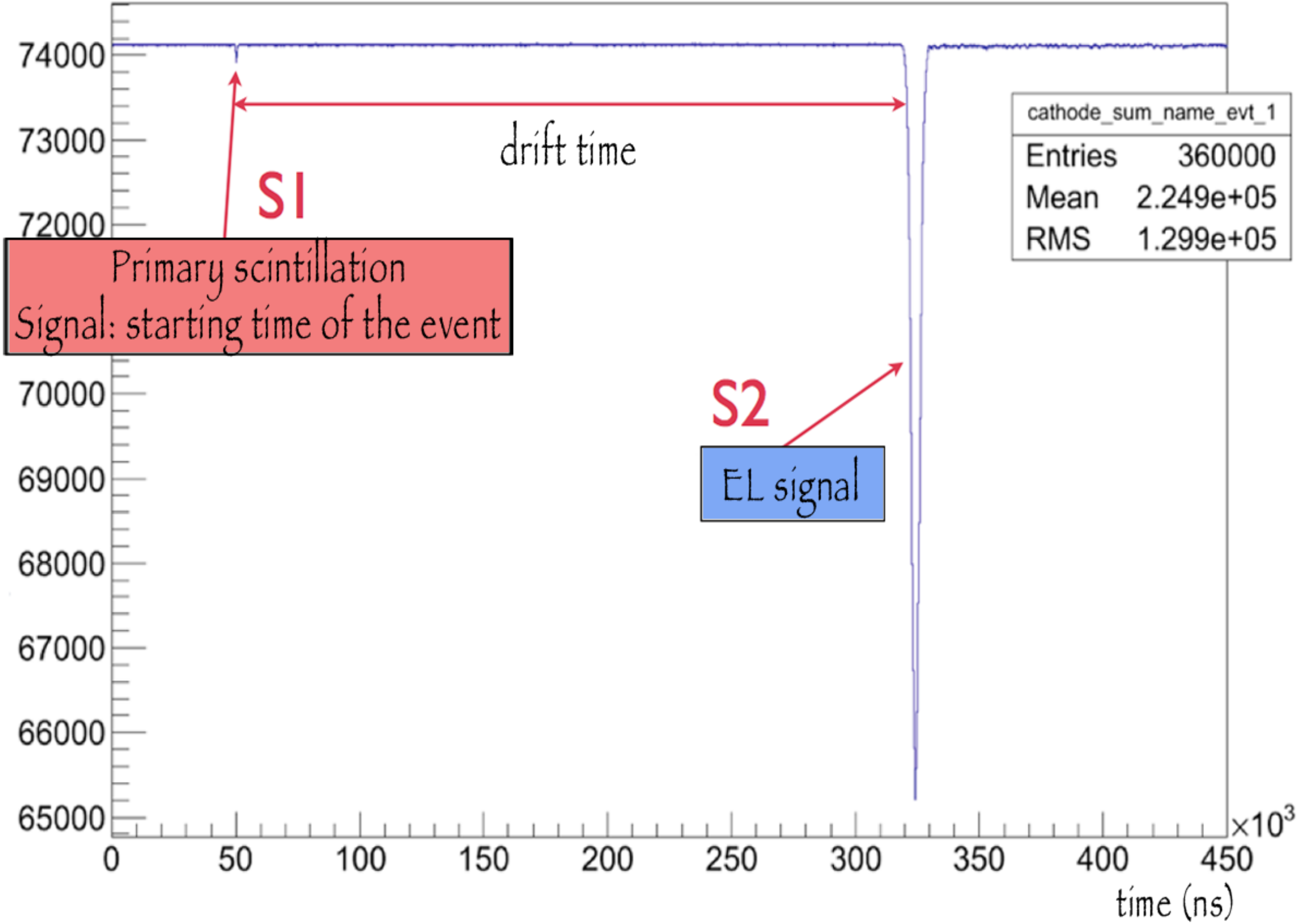
Reconstructed tracks from a MC simulated ββ0ν event



Tracking Plane of NEXT-DEMO, with 256 SiPMs for tracking

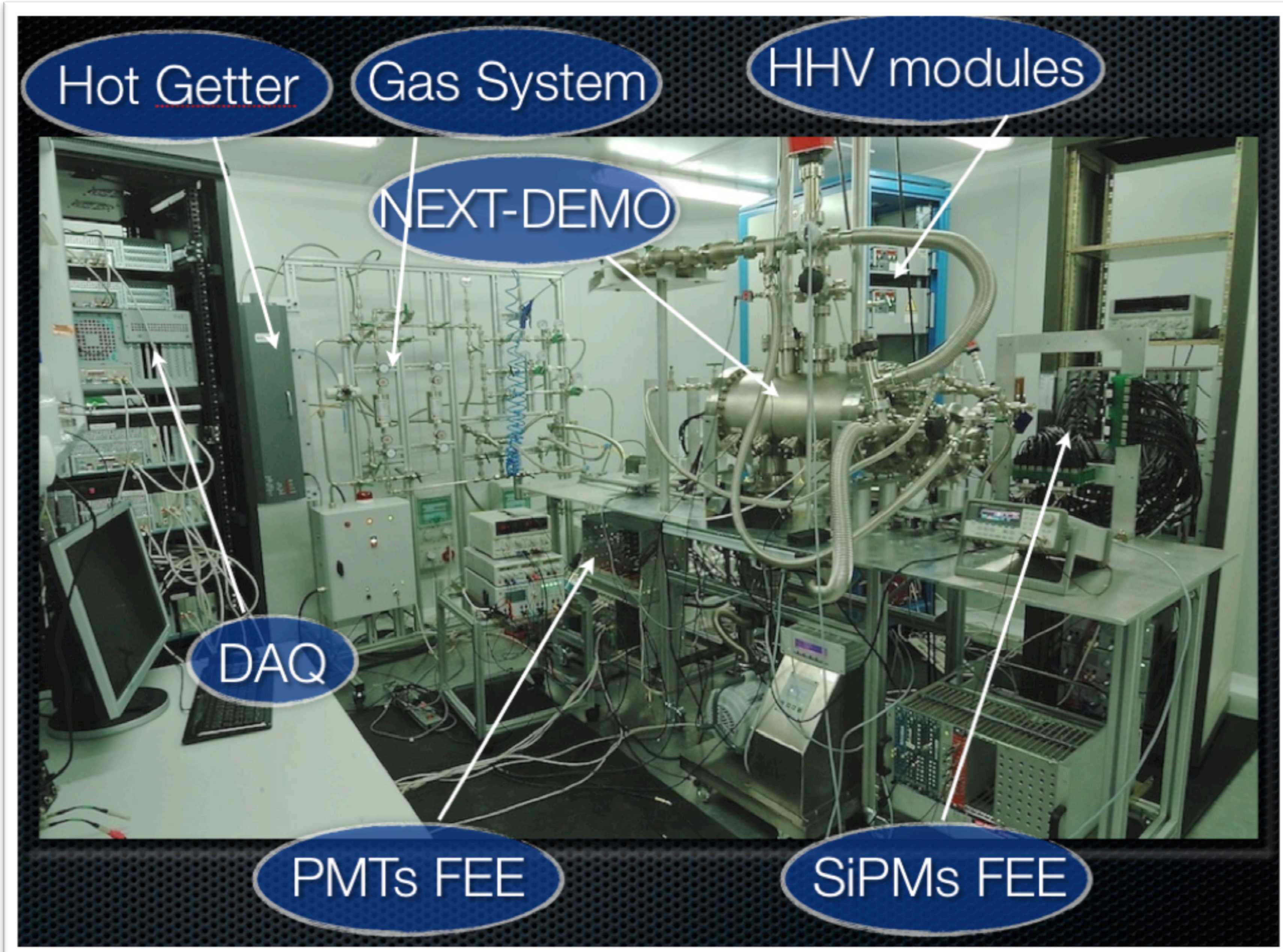


The signature of the electron is a twisted track with a strong energy deposition at its end


74000
73000
72000
70000
69000
68000
67000
66000
65000
drift time
S1
Primary scintillation
Signal: starting time of the event
S2
EL signal
cathode_sum_name_evt_1
Entries 360000
Mean 2.249e+05
RMS 1.299e+05
0
50
100
150
200
250
300
350
400
450
×10³
time (ns)

Prototypes

NEXT-DEMO PROTOTYPE



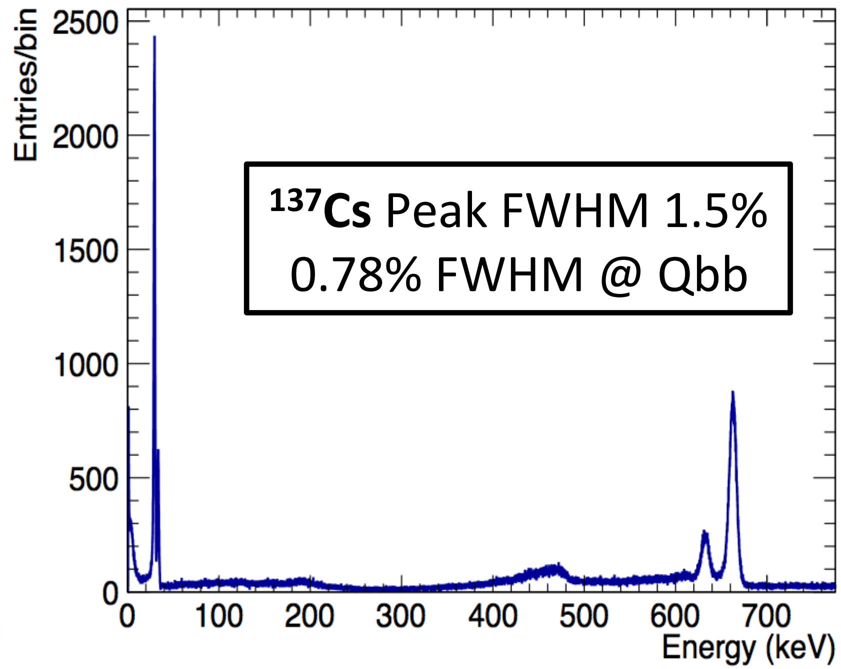
Clean room at IFIC (Valencia)

NEXT DEMO HIGHLIGHTS

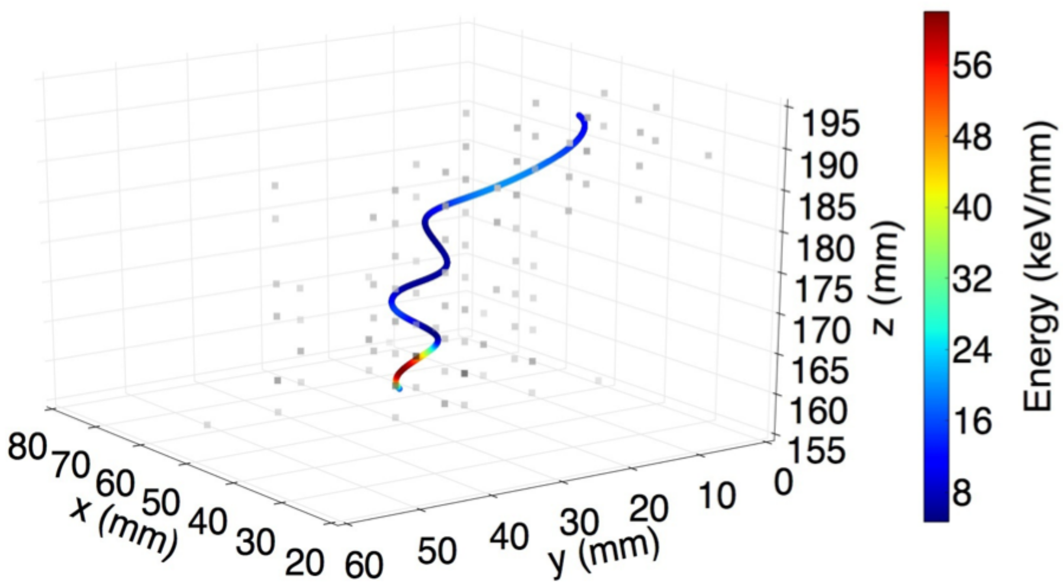
- Energy plane: 19 Hamamatsu R7378A PMTs
- Tracking plane: 256 SiPM coated with TPB
- Electric field drift region ~ 300 V/cm
- Electric field **EL** region ~ 25 kV/cm
- Pressure = 10 atm
- $HV_{cathode}$= 25kV; HV_{anode} = 10kV
- Cylindrical active volume: 30 cm long and 30 cm diameter
- $\rho \sim 5 \cdot 10{-}2$ g/cm^3
- Particles observed: Photons (^{22}Na, ^{137}Cs, Cosmic Muons, Alphas (^{226}Ra)

Initial Results of NEXT-DEMO, a Large-scale Prototype of the NEXT-100 Experiment, 2013 JINST 8 P04002

Operation and First Results of the NEXT-DEMO Prototype using a Silicon Photomultiplier Tracking Array, arXiv:1306.0471



^{137}**Cs** Peak FWHM 1.5%
0.78% FWHM @ Qbb

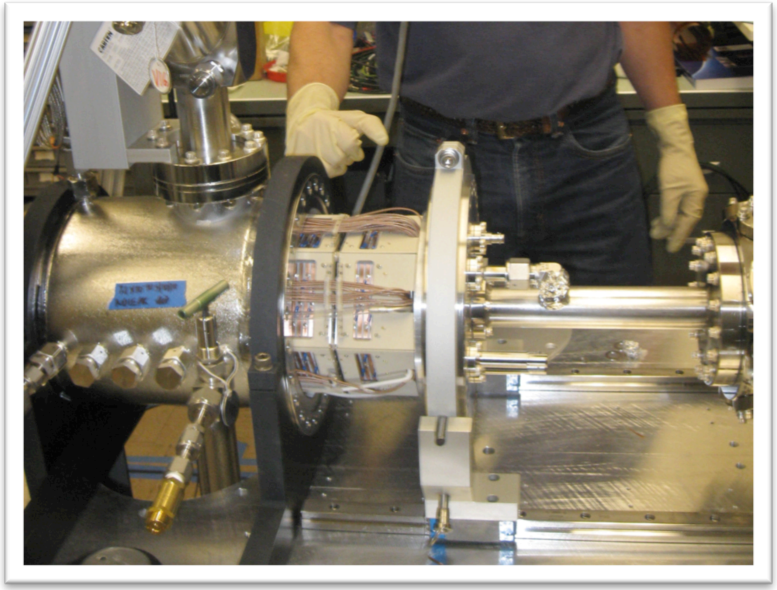


Track of electron photo-produced from 662keV gamma ^{137}**Cs** decay

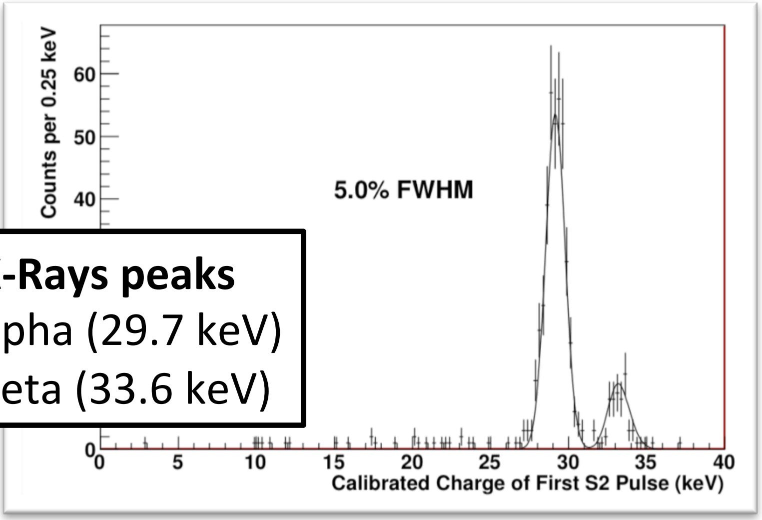
NEXT-DBMD PROTOTYPE: HIGHLIGHTS

Near-Intrinsic Energy Resolution for 30 to 662 keV Gamma Rays in a High Pressure Xenon Electro-luminescent TPC, Nucl. Inst. Meth. A708 (2013) 101

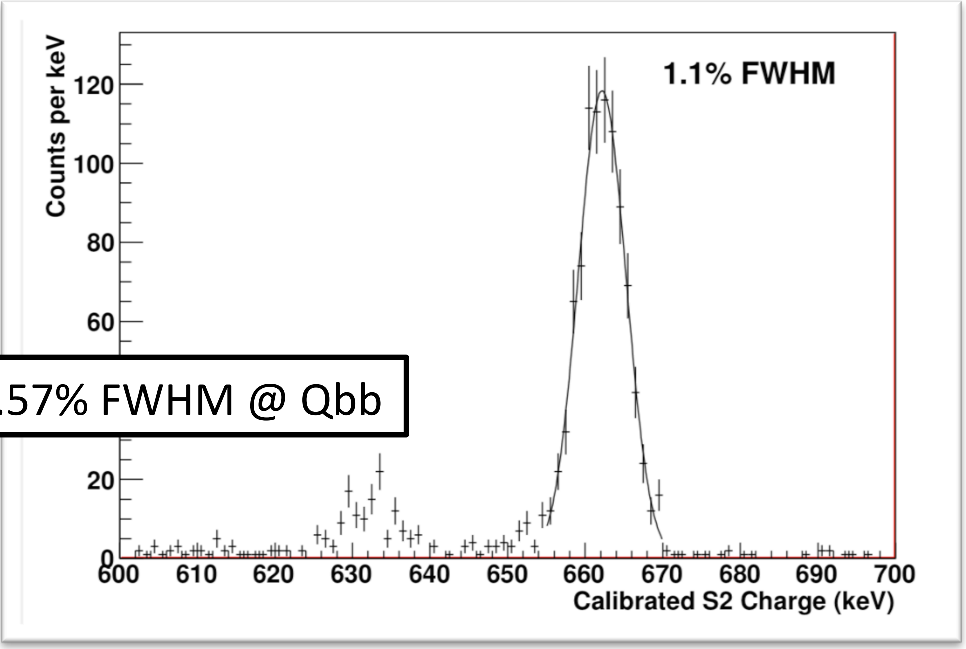
LBNL (CA, USA)



Energy plane: 19 Hamamatsu R7378A PMTs
Tracking plane: 64 SiPM coated with TPB
Pressure = 10 to 15 atm
ρ ~ 5 · 10−2 g/cm3



X-Rays peaks
K-alpha (29.7 keV)
K-beta (33.6 keV)

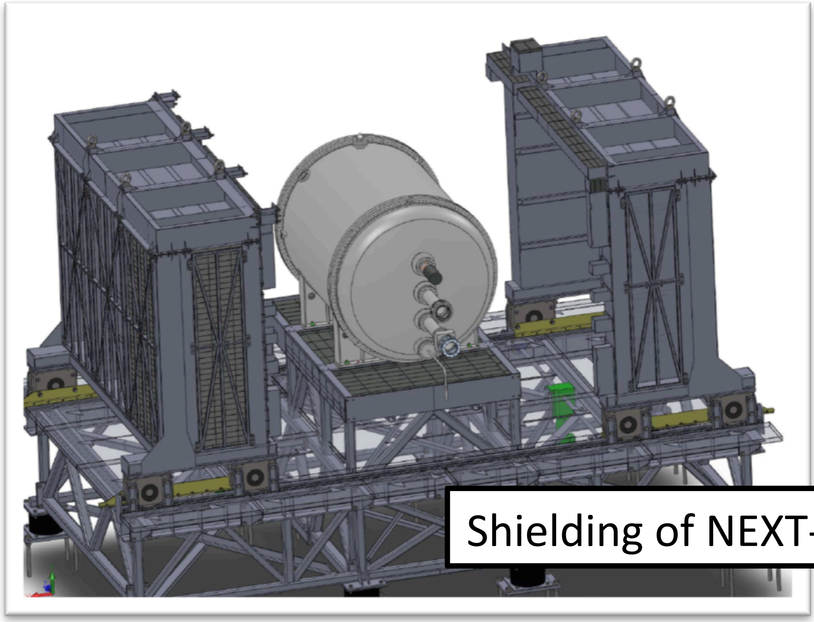


0.57% FWHM @ Qbb

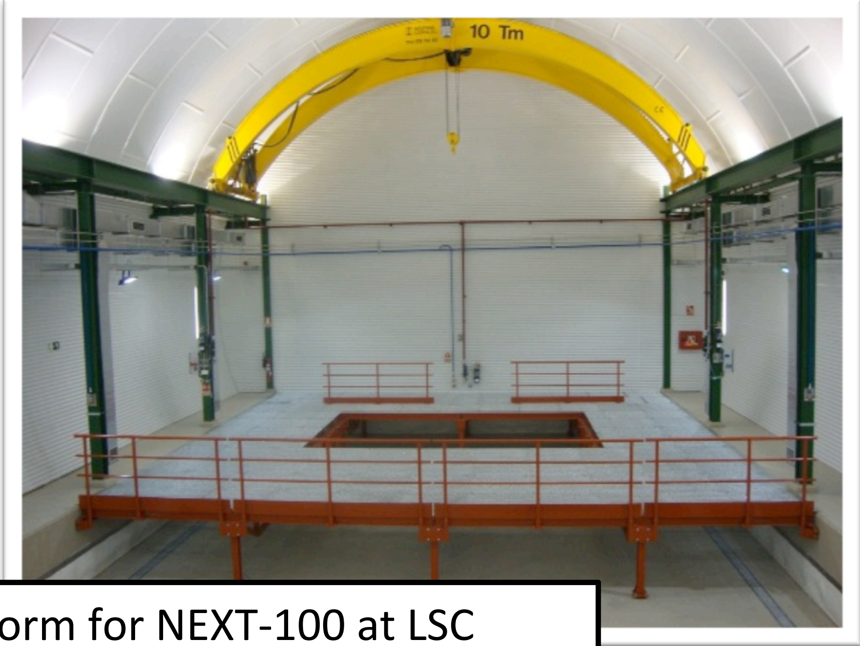
These data were taken at 10.1 atm with a 1.03 kV/cm field in the drift region and 2.68 kV/(cm atm) in the EL region.

These data were taken at 10.1 atm with a 0.16 kV/cm field in the drift region and 2.08 kV/(cm atm) in the EL region

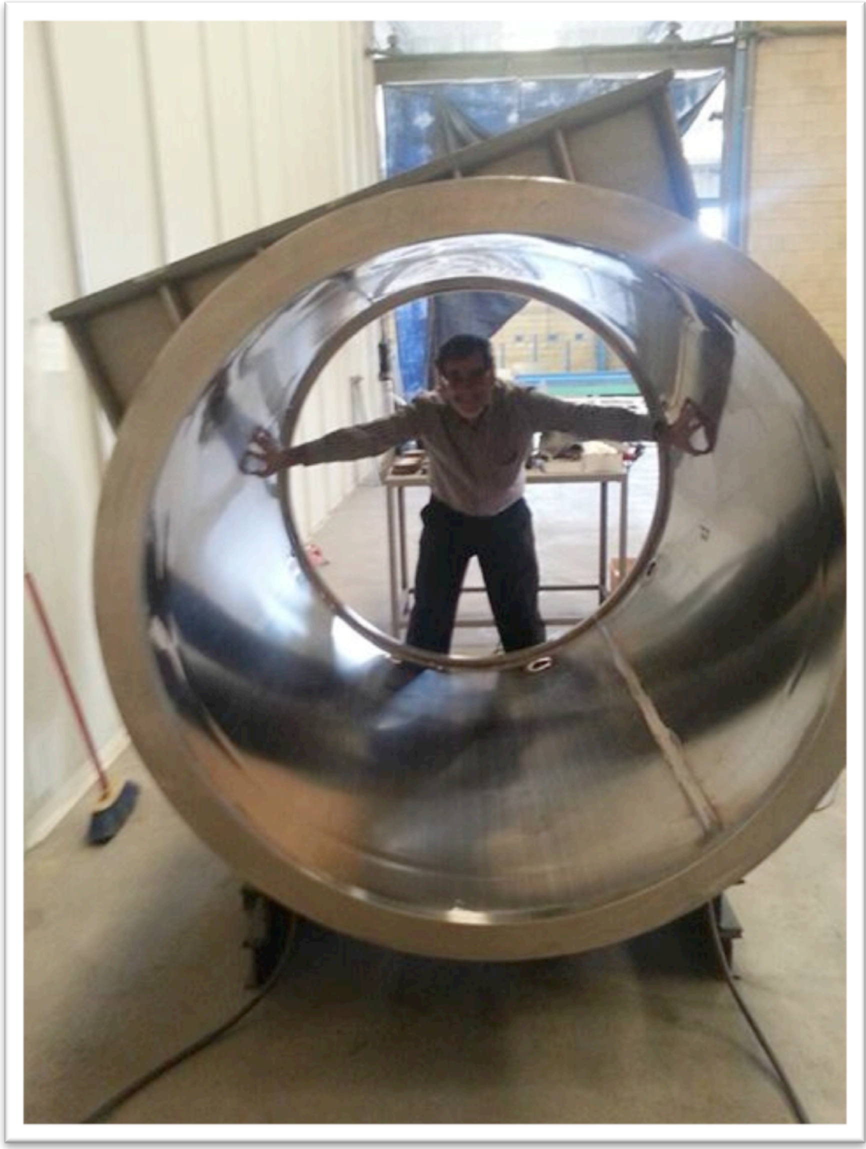
NEXT-100 AT LSC



Shielding of NEXT-100



Platform for NEXT-100 at LSC



NEXT-100 vessel under construction

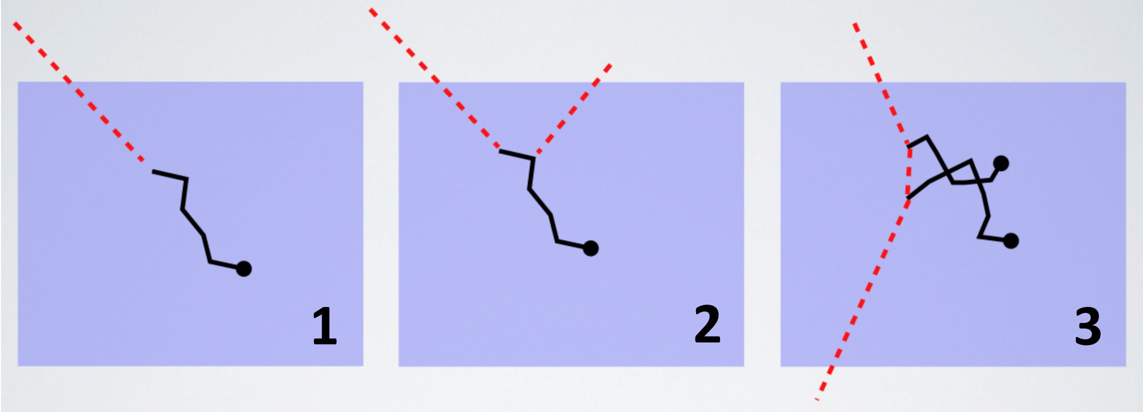
(before cleaning)

Movesa factory, Madrid (Spain). June 2013

radio-purity issues

RADIOPURITY: BACKGROUND MODEL

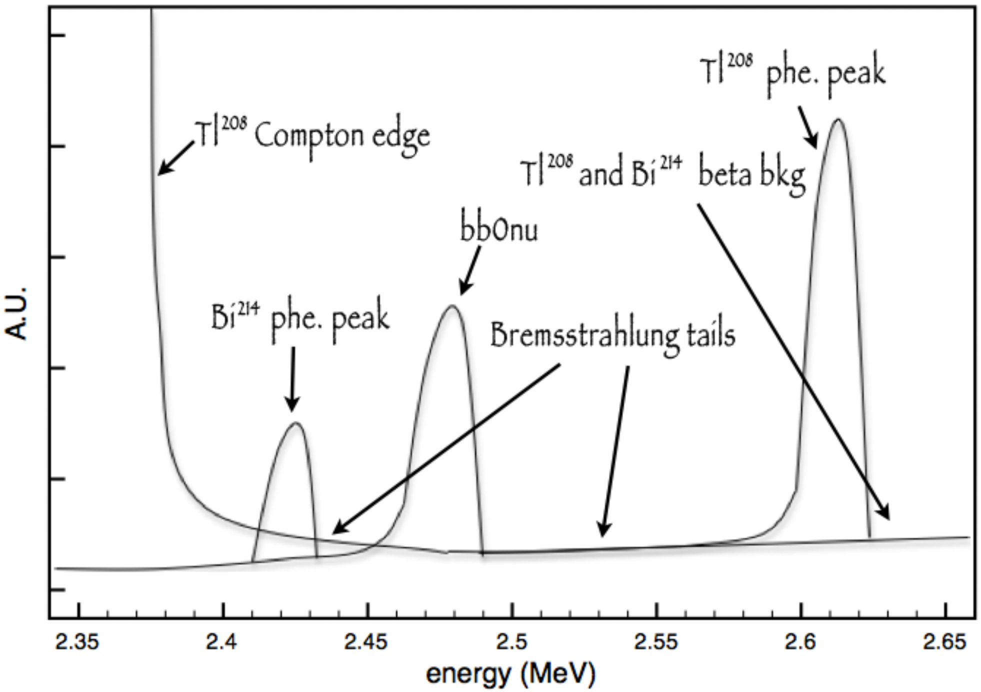
Simulations of the Background Model are made with **NEXUS**, a GEANT4 based software developed by NEXT



Example 1: Electron photo-produced by 2448 keV gamma from ^{214}Bi decay

Example 2: Electron photo-produced by 2448 keV gamma from ^{208}Tl decay that undergoes Bremsstrahlung

Example 3: Two electron Compton scattered from 2615 keV gamma from ^{208}Tl decay



Preliminary estimates from Background Model

(counts/kg/keV/year)

^{214}Bi: 0.18 - 0.40·10^{-3}

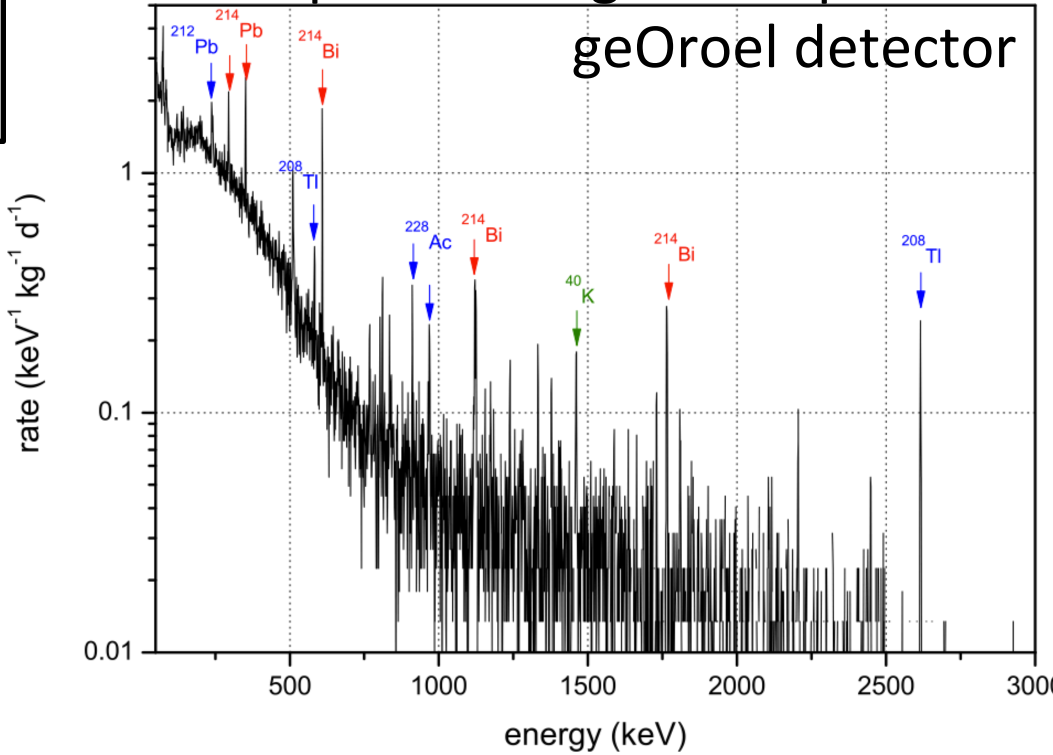
^{208}Tl: 0.21 - 0.48·10^{-3}

Total: 0.38 - 0.88·10^{-3}

RADIOPURITY: MEASUREMENTS

They are carried out at the
LSC's HPGe facility

Example of background spectrum:
geOroel detector



Background counting rates of detectors used by NEXT (counts/day/Kg)

Detector name	Mass (kg)	100–2700 keV	583 keV	609 keV	1461 keV
GeOroel	2.230	490±2	0.8±0.1	3.0± 0.2	0.41±0.07
GeAnayet	2.183	714±3	3.8±0.2	1.7±0.1	0.38±0.07
GeTobazo	2.185	708±3	4.0±0.2	1.3±0.1	0.40±0.06
GeLatuca	2.187	710±3	3.3±0.2	5.9±0.3	0.56±0.08
Paquito	1	79±2	0.27±0.09	0.5±0.1	0.25±0.09

Radiopurity control in the NEXT-100 double β decay experiment: procedures and initial measurements. 2013 JINST 8 T01002

Radiopurity: NEXT screening program

#	Material	Supplier	Technique	Unit	^{238}U	^{226}Ra	^{232}Th	^{228}Th	^{235}U	^{40}K	^{60}Co	^{137}Cs
	Shielding											
1	Pb	Cometa	GDMS	mBq/kg	0.37		0.073			<0.31		
2	Pb	Mifer	GDMS	mBq/kg	<1.2		<0.41			0.31		
3	Pb	Mifer	GDMS	mBq/kg	0.33		0.10			1.2		
4	Pb	Tecnibusa	GDMS	mBq/kg	0.73		0.14			0.91		
5	Pb	Tecnibusa	Ge	mBq/kg	<94	<2.0	<3.8	<4.4	<30	<2.8	<0.2	<0.8
6	Pb	Tecnibusa	Ge	mBq/kg	<57	<1.9	<1.7	<2.8	<22	<1.7	<0.1	<0.5
7	Cu (ETP)	Sanmetal	GDMS	mBq/kg	<0.062		<0.020					
8	Cu (C10100)	Luvata (hot rolled)	GDMS	mBq/kg	<0.012		<0.0041			0.061		
9	Cu (C10100)	Luvata (cold rolled)	GDMS	mBq/kg	<0.012		<0.0041			0.091		
10	Cu (C10100)	Luvata (hot+cold rolled)	Ge	mBq/kg		<7.4	<0.8	<4.3		<18	<0.8	<1.2
	Vessel											
11	Ti	SMP	Ge	mBq/kg	<233	<5.7	<8.8	<9.5	3.4±1.0	<22	<3.3	<5.2
12	Ti	SMP	Ge	mBq/kg	<361	<6.6	<11	<10	<8.0	<15	<1.0	<1.8
13	Ti	Ti Metal Supply	Ge	mBq/kg	<14	<0.22	<0.5	3.6±0.2	0.43±0.08	<0.6	<0.07	<0.07
14	304L SS	Pfeiffer	Ge	mBq/kg		14.3±2.8	9.7±2.3	16.2±3.9	3.2±1.1	<17	11.3±2.7	<1.6
15	316Ti SS	Nironit, 10-mm-thick	Ge	mBq/kg	<21	<0.57	<0.59	<0.54	<0.74	<0.96	2.8±0.2	<0.12
16	316Ti SS	Nironit, 15-mm-thick	Ge	mBq/kg	<25	<0.46	<0.69	<0.88	<0.75	<1.0	4.4±0.3	<0.17
17	316Ti SS	Nironit, 50-mm-thick	Ge	mBq/kg	67±22	<1.7	2.1±0.4	2.0±0.7	2.4±0.6	<2.5	4.2±0.3	<0.6
18	Inconel 625	Mecanizados Kanter	Ge	mBq/kg	<120	<1.9	<3.4	<3.2	<4.6	<3.9	<0.4	<0.6
19	Inconel 718	Mecanizados Kanter	Ge	mBq/kg	309±78	<3.4	<5.1	<4.4	15.0±1.9	<13	<1.4	<1.3
	HV, EL components											
20	PEEK	Sanmetal	Ge	mBq/kg		36.3±4.3	14.9±5.3	11.0±2.4	<7.8	8.3±3.0	<3.3	<2.6
21	Polyethylene	IN2 Plastics	Ge	mBq/kg	<140	<1.9	<3.8	<2.7	<1.0	<8.9	<0.5	<0.5
22	Semitron ES225	Quadrant EPP	Ge	mBq/kg	<101	<2.3	<2.0	<1.8	1.8±0.3	513±52	<0.5	<0.6
23	SMD resistor	Farnell	Ge	mBq/pc	2.3±1.0	0.16±0.03	0.30±0.06	0.30±0.05	<0.05	0.19±0.08	<0.02	<0.03
24	SM5D resistor	Finechem	Ge	mBq/pc	0.4±0.2	0.022±0.007	<0.023	<0.016	0.012±0.005	0.17±0.07	<0.005	<0.005
	Energy, tracking planes											
25	Kapton-Cu PCB	LabCircuits	Ge	mBq/cm^2	<0.26	<0.014	<0.012	<0.008	<0.002	<0.040	<0.002	<0.002
26	Cuflon	Polyflon	Ge	mBq/kg	<33	<1.3	<1.1	<1.1	<0.6	4.8±1.1	<0.3	<0.3
27	Bonding films	Polyflon	Ge	mBq/kg	1140±300	487±23	79.8±6.6	66.0±4.8	60.0±5.5	832 ±87	<4.4	<3.8
28	FFC/FCP connector	Hirose	Ge	mBq/pc	<50	4.6±0.7	6.5±1.2	6.4±1.0	<0.75	3.9±1.4	<0.2	<0.5
29	P5K connector	Panasonic	Ge	mBq/pc	<42	6.0±0.9	9.5±1.7	9.4±1.4	<0.95	4.1±1.5	<0.2	<0.8
30	Thermopl. connector	Molex	Ge	mBq/pc	<7.3	1.77±0.08	3.01±0.19	2.82±0.15	<0.31	2.12±0.25	<0.022	0.27±0.03
31	Solder paste	Multicore	Ge	mBq/kg	<310	<4.9	<8.0	<6.0	<5.2	<13	<1.0	<1.6
32	Solder wire	Multicore	Ge	mBq/kg	<4900	(7.7±1.2)10^2	<147	<14		<257	<30	<36
33	Ta capacitor	Vishay Sprague	Ge	mBq/pc	<0.8	0.043±0.003	0.034±0.004	0.032±0.003	< 0.010		<0.002	<0.003

Radiopurity control in the NEXT-100 double β decay experiment: procedures and initial measurements. 2013 JINST 8

RADIOPURITY: PMTS

- 64 PMTs in NEXT-100's energy plane
- Expected to be [one of] the largest source of background to the ββ0ν signal

  → a complete screening of all PMTs is a must

  → aim for as much measured info as possible to minimize systematics from MC description

Further:

- The PMT Hamamatsu R11410-MOD is the first low background-designed commercial PMT

- Our sample of R11410-MODs is rather large: their Measured radio-purities will provide very valuable information to the low background physics community

- For instance: the LUX and XENON experiments have measured several units, but wee need more information

→ Our strategy: measure ***first*** all the PMTs making sure that they pass the requirements of NEXT, as estimated with the background model; perform ***afterwards*** as many detailed measurement as time permits before NEXT-100 final assembly

RADIOPURITY: PMTS

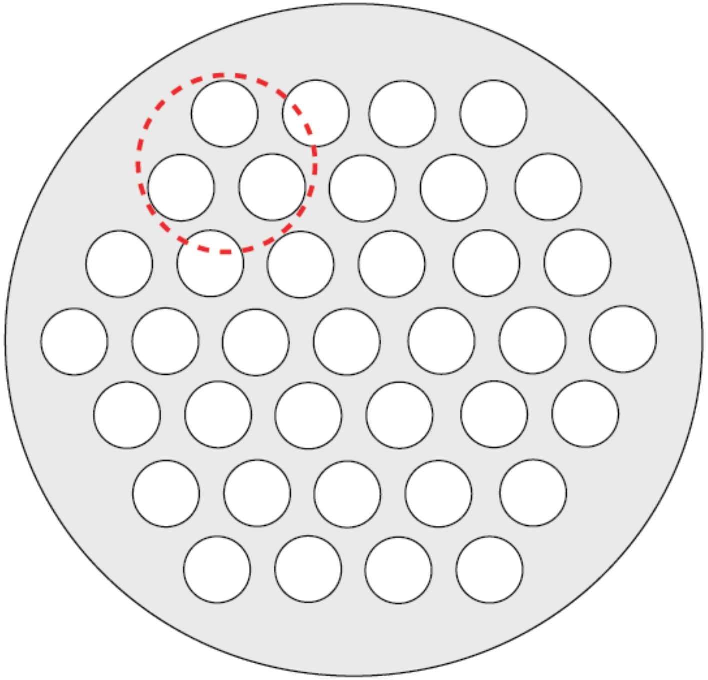
our ultimate goal is to classify the PMTs as

Bad PMT	act > 10 mBq
Dangerous PMT	5 mBq < act <10 mBq
Good PMT	3 mBq < act < 5mBq
Very good PMT	1 mBq < act < 3mB
Excellent PMT	act < 1mBq

(activities considered separately for both isotopes)

As time runs short we ***first*** ensure the rejection of **Bad** and the identification of **Dangerous** PMTs

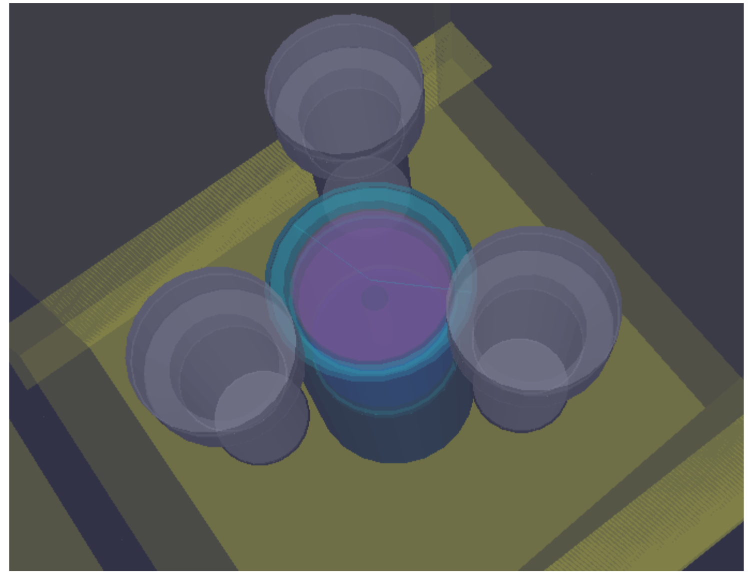
In order to finish this phase by beginning 2014 we measure groups of 3 PMTs simultaneously

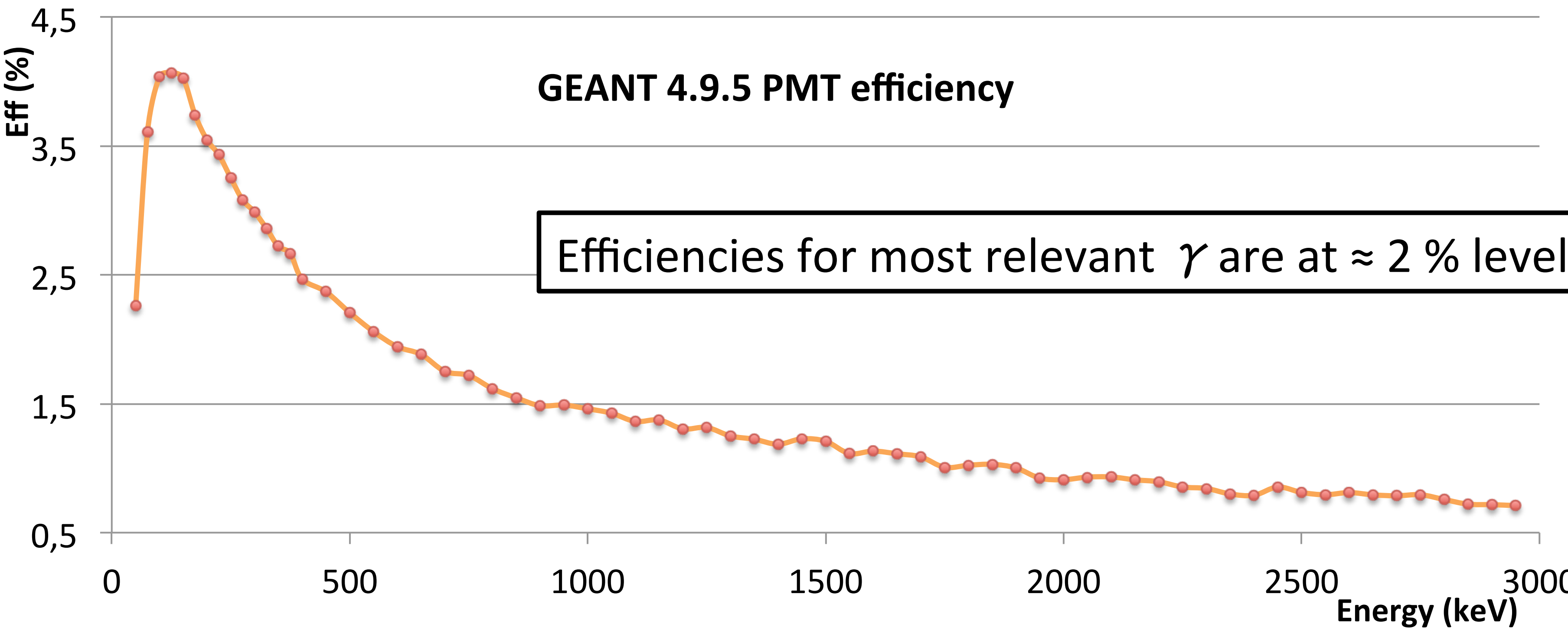


In addition to pass/don't-pass, this method provides the upper limit of the activity in the region, where the 3 PMTs from the same measurement will be placed in the detector

MONTECARLO SIMULATIONS (GEANT 4.9.5)

VS.





Efficiencies for most relevant γ are at ≈ 2 % level

Radiopurity: PMTs, work plan and results

- So far 5 measurement of 3 PMT ensembles + 1 single PMT
- Typical duration of measurement: ≈ 20 days
- *Preliminary* results are (activity/3PMTs):

	3PMT01	3PMT02	3PMT03	3PMT04	3PMT05
Time of measurement [days]	30.64	20.22	16.57	18.31	26.81
^{232}Th Chain (^{208}Tl) [mBq]	< 7.1	< 9.2	< 8.8	< 7.9	< 7.5
^{232}Th Chain (^{228}Ac) [mBq]	< 9.5	< 11.1	< 11	< 11	< 9.1
^{238}U Chain (^{214}Bi) [mBq]	< 3.2	< 3.9	< 4.2	< 5.0	< 3.7
^{238}U Chain (^{234}Pa(m)) [mBq]	< 329	< 420	< 610	< 386	< 307
^{40}K [mBq]	37.2 ± 9.9	< 73	< 58	< 68	< 51
^{60}Co [mBq]	14.6 ± 1.1	13.3 ± 1.1	12 ± 1	13 ± 1	13 ± 1
^{54}Mn [mBq]	1.40 ± 0.35	< 2.1	< 2.2	< 1.6	< 1.3

- The measured activities are well within expectations and appropriate for the experiment
- We expect to finish this pass/don't-pass phase by beginning of next year
- Afterwards we will proceed with as many precision measurements as possible

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^{238}U Chain (^{214}Bi) [mBq]	**< 3.2**	**< 3.9**	[illegible]	**< 5.0**	**< 3.7**
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^{60}Co [mBq]	[illegible]	**13.3 ± 1.1**	**12 ± 1**	**13 ± 1**	**13 ± 1**
^{54}Mn [mBq]	**1.40 ± 0.35**	**< 2.1**	**< 2.2**	**< 1.6**	**< 1.3**

PROVISIONAL

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Summary and Conclusions

- NEXT is an excellent option for this generation of $\beta\beta0\nu$ experiments, thanks to its energy resolution, its ability to reject background and its scalability
- The results from the DEMOs are extremely important milestones. That have proven the technology, the energy resolution and tracking

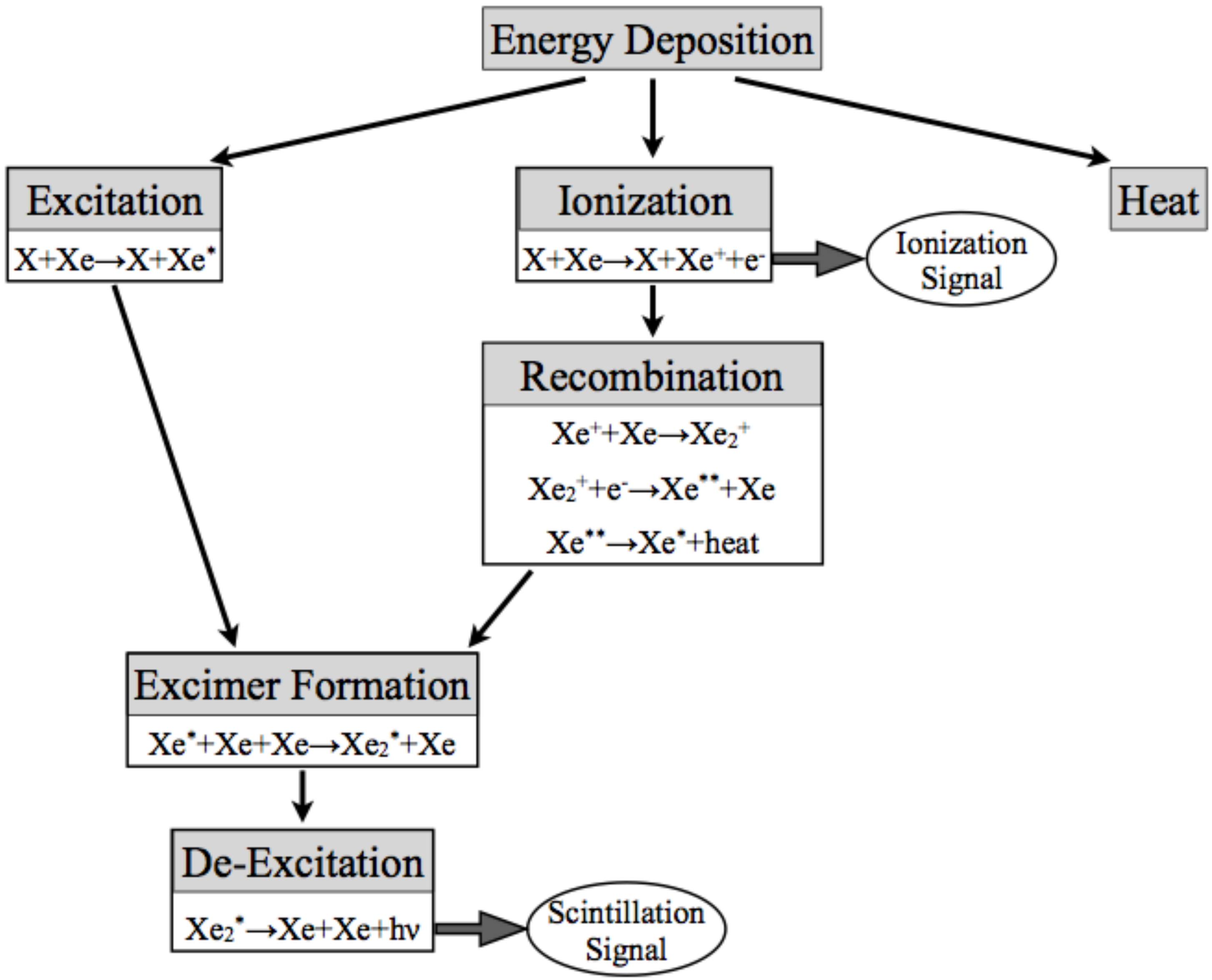
- A thorough screening program is being carried out at the LSC
- The materials chosen for NEXT are showing good radio-purity properties
- A special campaign for the 64 PMTs is also ongoing. The units measured so far show very small radioactive contamination.

THAT'S ALL

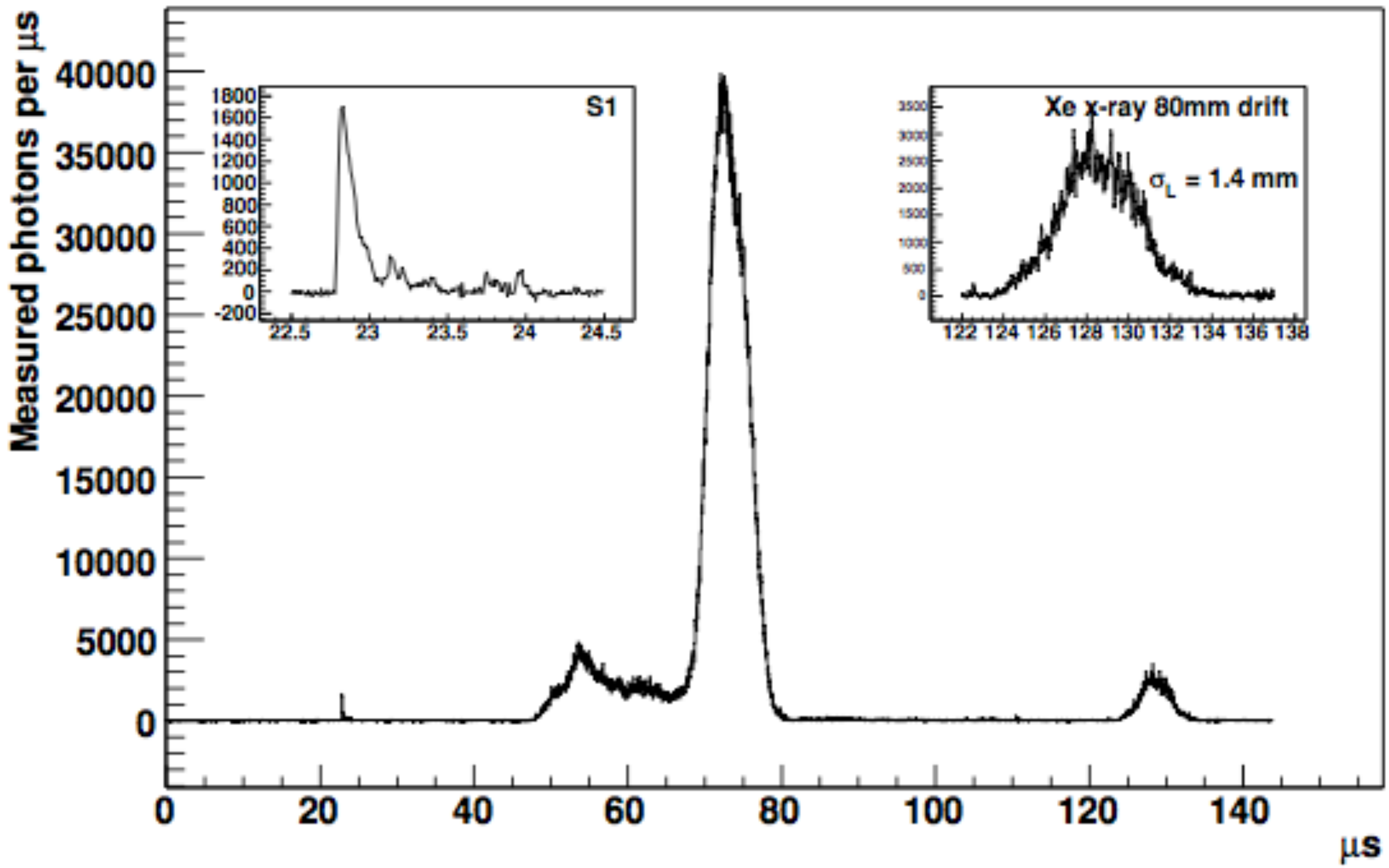

IFIC (Valencia) • Zaragoza • Politécnica Valencia • Santiago de Compostela • Autónoma Madrid • Girona
LBNL • Iowa State • Texas A&M
Coimbra • Aveiro
JINR (Dubna)
Antonio Nariño (Bogotá)
next

APPENDIX

Xenon Scintillation

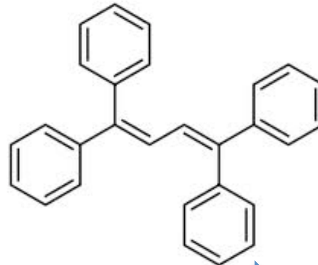


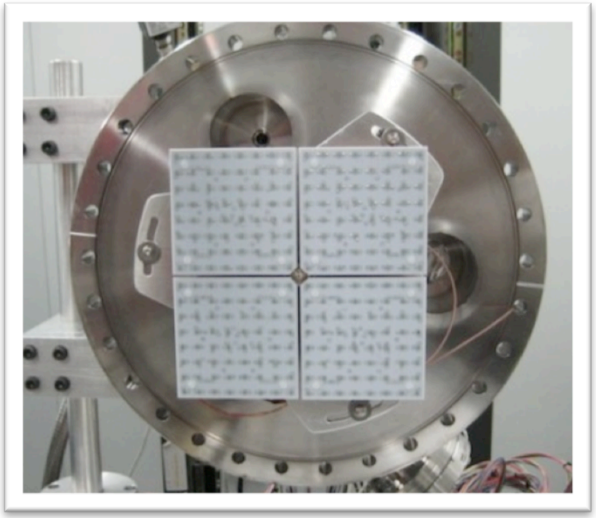
Event from NEXT-DBDM with X-rays

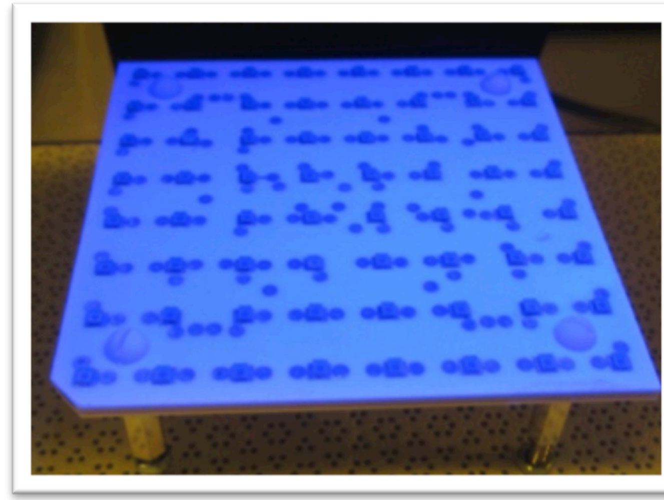


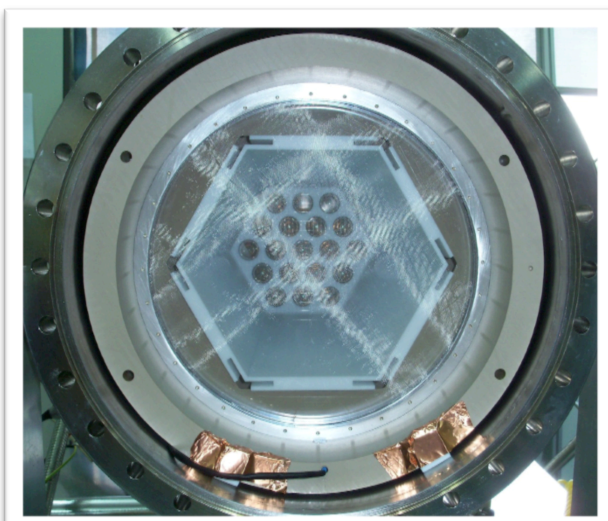
TPB EFFECTS ON NEXT-DEMO

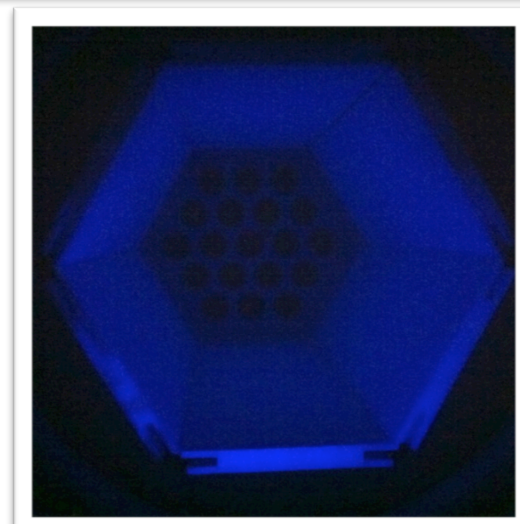
Tetra**P**henyl **B**utadiene (TPB) converts UV light to blue (peak at ~430 nm)





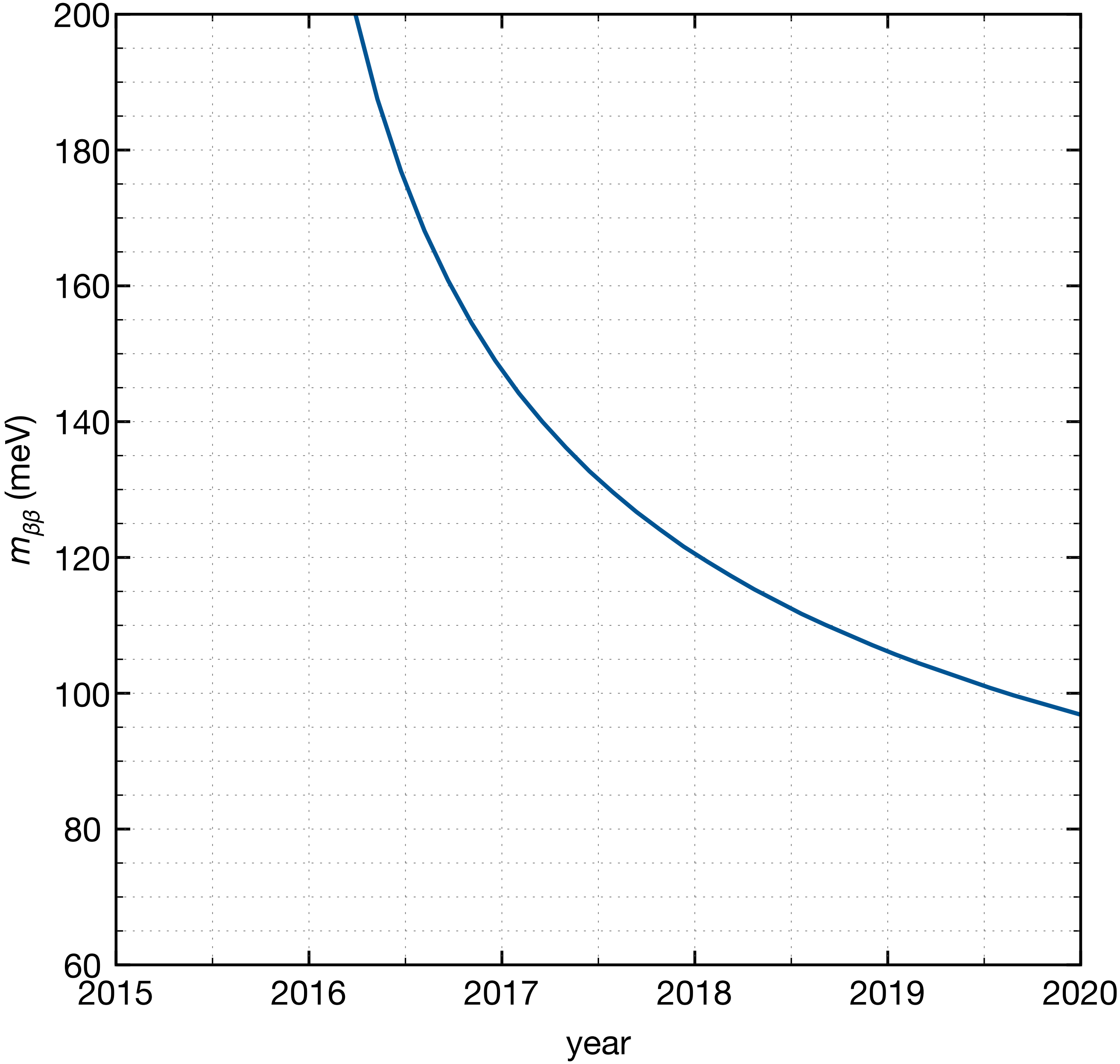






Illuminated with UV light

NEXT-100 SENSITIVITY



HAMAMATSU R11410-MOD

Maximum Ratings (Absolute Maximum Values)

Parameter		Value	Unit
Supply voltage	Between Anode and Cathode	1750	V
	Between Anode and Last Dynode	300	V
Average Anode Output		0.1	mA
Pressure-resistance (Gauge)		0.2	Mpa

Characteristics at 25 deg. C

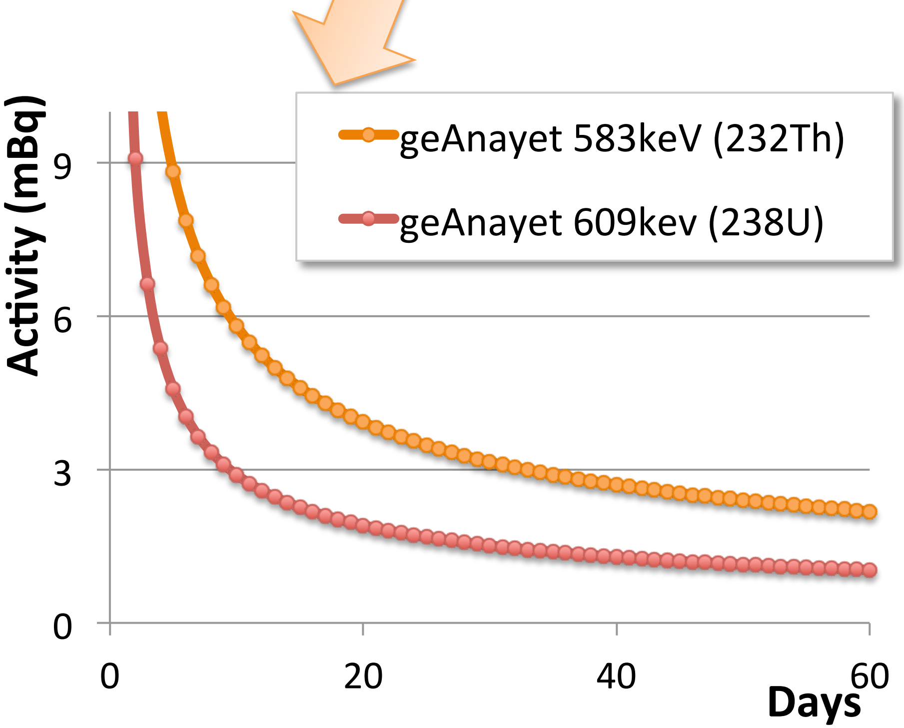
Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856K)	-	90	-	uA/lm
	Quantum Efficiency at 175 nm	-	26	-	%
	Blue Sensitivity Index (CS 5-58)	-	10	-	-
Anode Sensitivity	Luminous (2856K)	-	450	-	A/lm
Gain		-	5.0×10^6	-	-
Anode Dark Current (after 30 min. storage in darkness)		-	10	100	nA
Time Response	Anode Pulse Rise Time	-	5.5	-	ns
	Electron Transit Time	-	46	-	ns
	Transit Time Spread (FWHM)	-	6.5	-	ns
Pulse Linearity at +/-2% deviation		-	20	-	mA

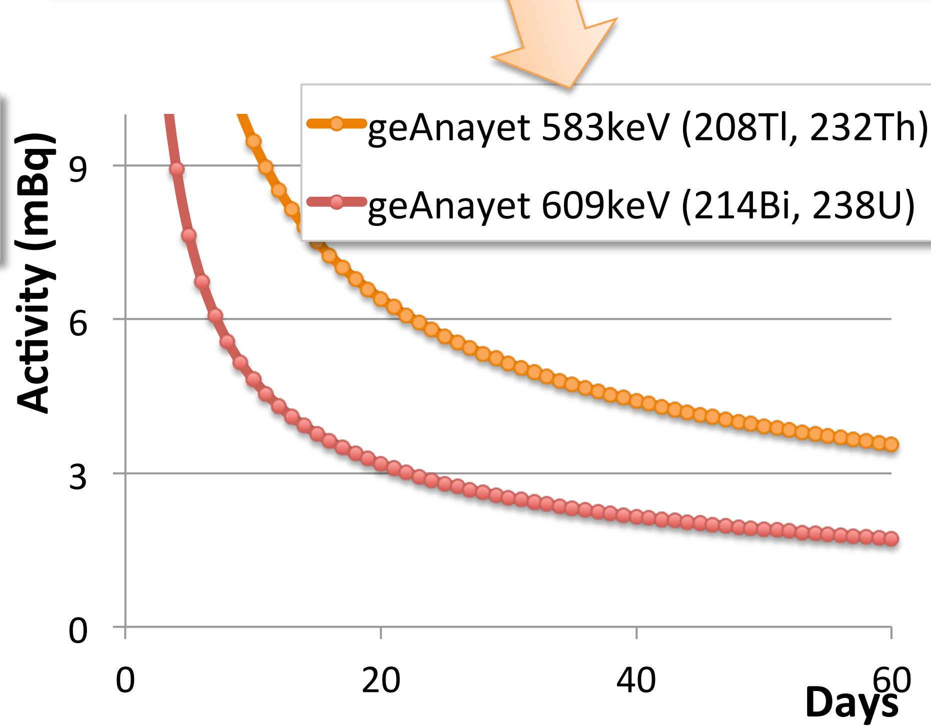
RESULTS: PMT HORIZONTAL MODE

PMT_hor01: (04-03-13 to 09-04-13)

	PMT_hor01
Time of measurement	33.70 days
^{232}Th (^{208}Tl)	< 3.4 mBq
^{232}Th (^{228}Ac)	< 5.4 mBq
^{238}U (^{214}Bi)	< 1.8 mBq
^{238}U (^{234}Pa(m))	< 187 mBq
^{40}K	< 29 mBq
^{60}Co	2.82 ± 0.27 mBq

RESULTS: DETECTION LIMIT, L_D (95% C.L.)





3PMT02 - Gamma Spectrum