SENSITIVITY OF NEXT-100 TO NEUTRINOLESS DOUBLE BETA DECAY

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NEXT COLLABORATION MEETING— LSC, MAY 2013

Sensitivity of NEXT-100 to neutrinoless double beta decay

IN PREPARATION

The NEXT Collaboration

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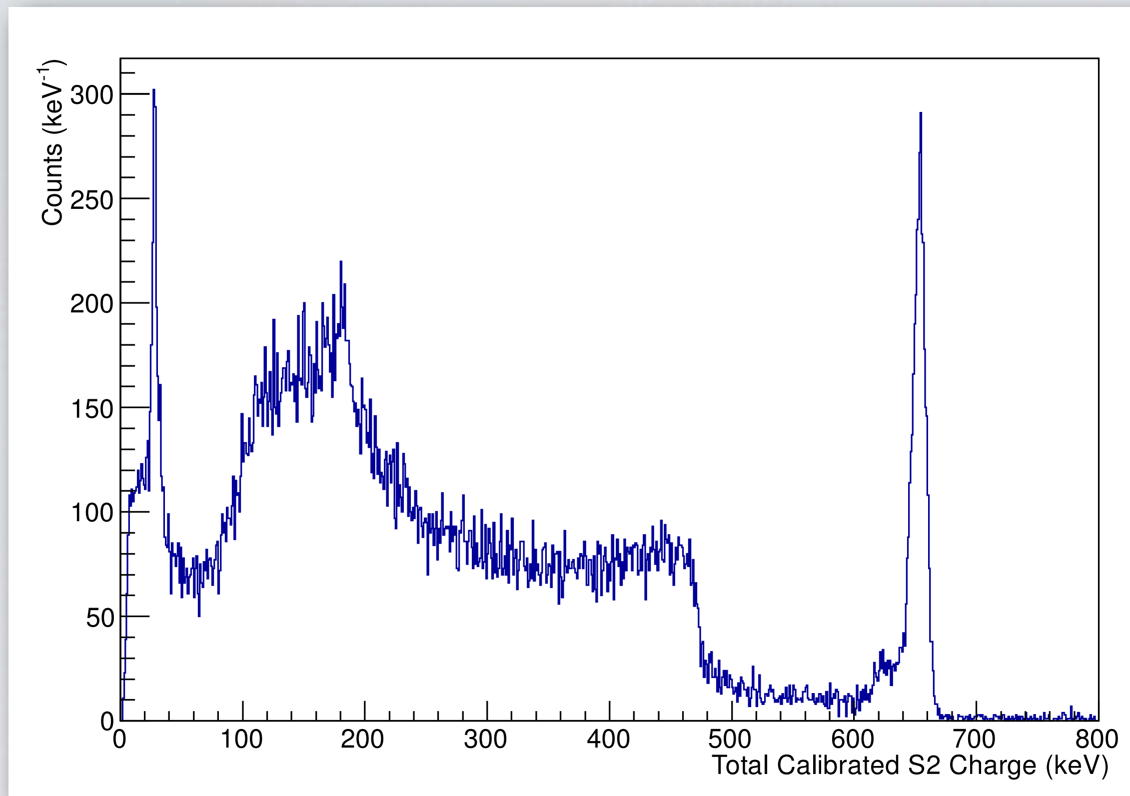
EXPERIMENTAL SENSITIVITY

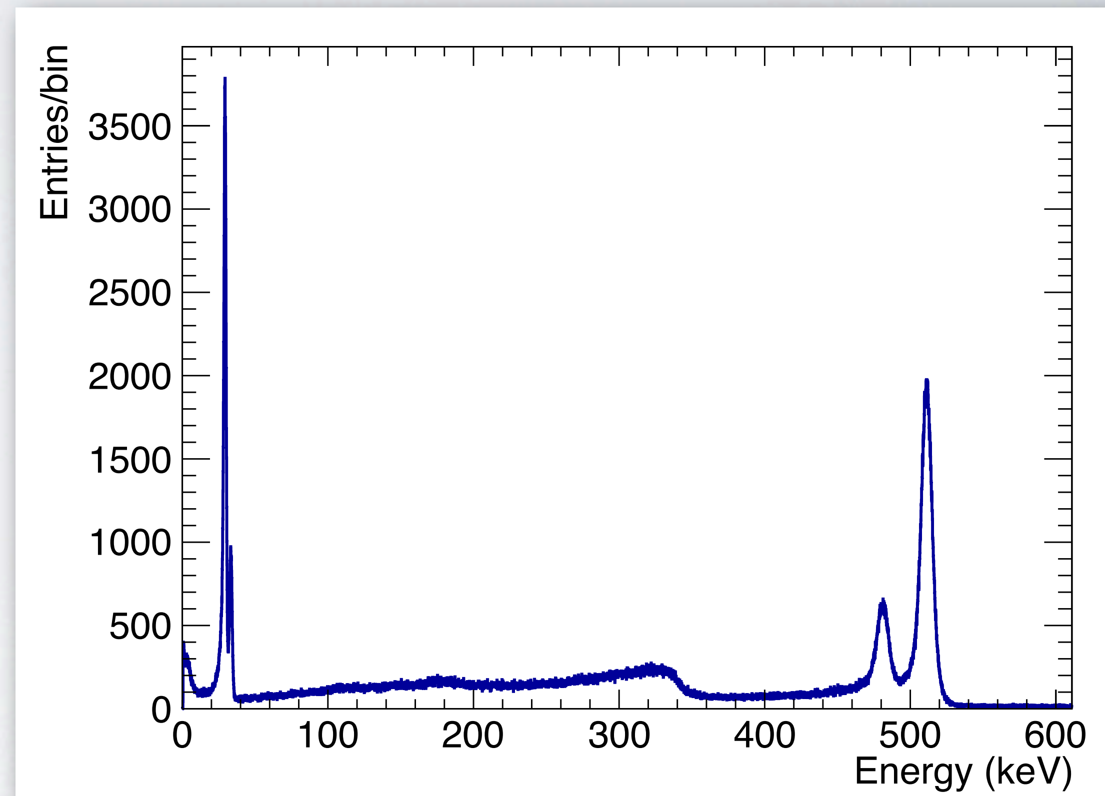
$$\widehat{\mathcal{S}}(m_{\beta\beta}) \propto \sqrt{1/\varepsilon}\ \left(\frac{b\ \Delta E}{M\ t}\right)^{1/4}$$

We define the sensitivity as the smallest (average) signal greater than or equal to a background fluctuation of a chosen significance level.
Compute that upper limit using Feldman-Cousins, as described in arXiv:1010.5112.

ENERGY RESOLUTION



NEXT-DBDM: ~0.5% FWHM



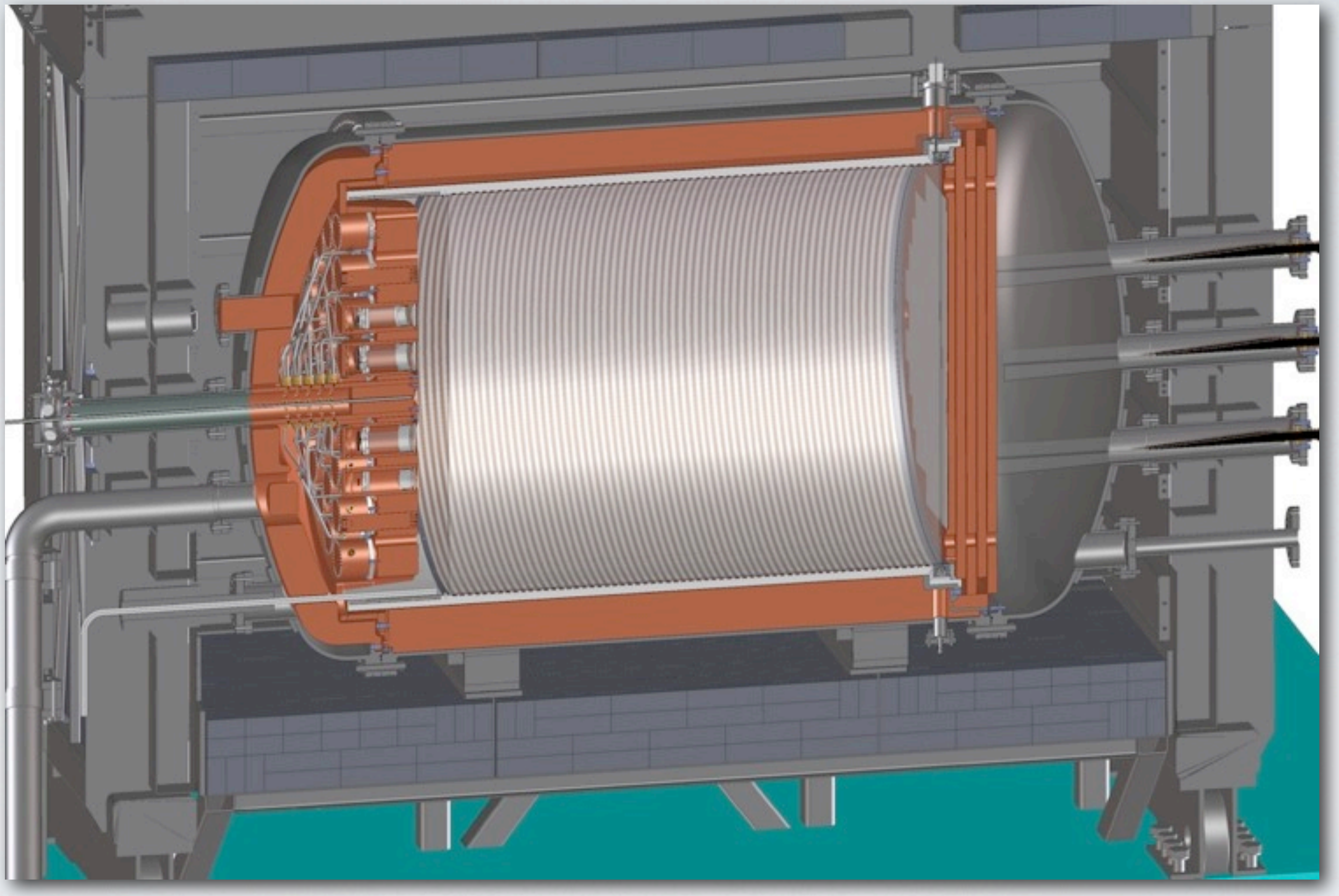
NEXT-DEMO: ~0.8% FWHM

NEXT-100: 0.5–1.0% FWHM @ Q value of Xe-136

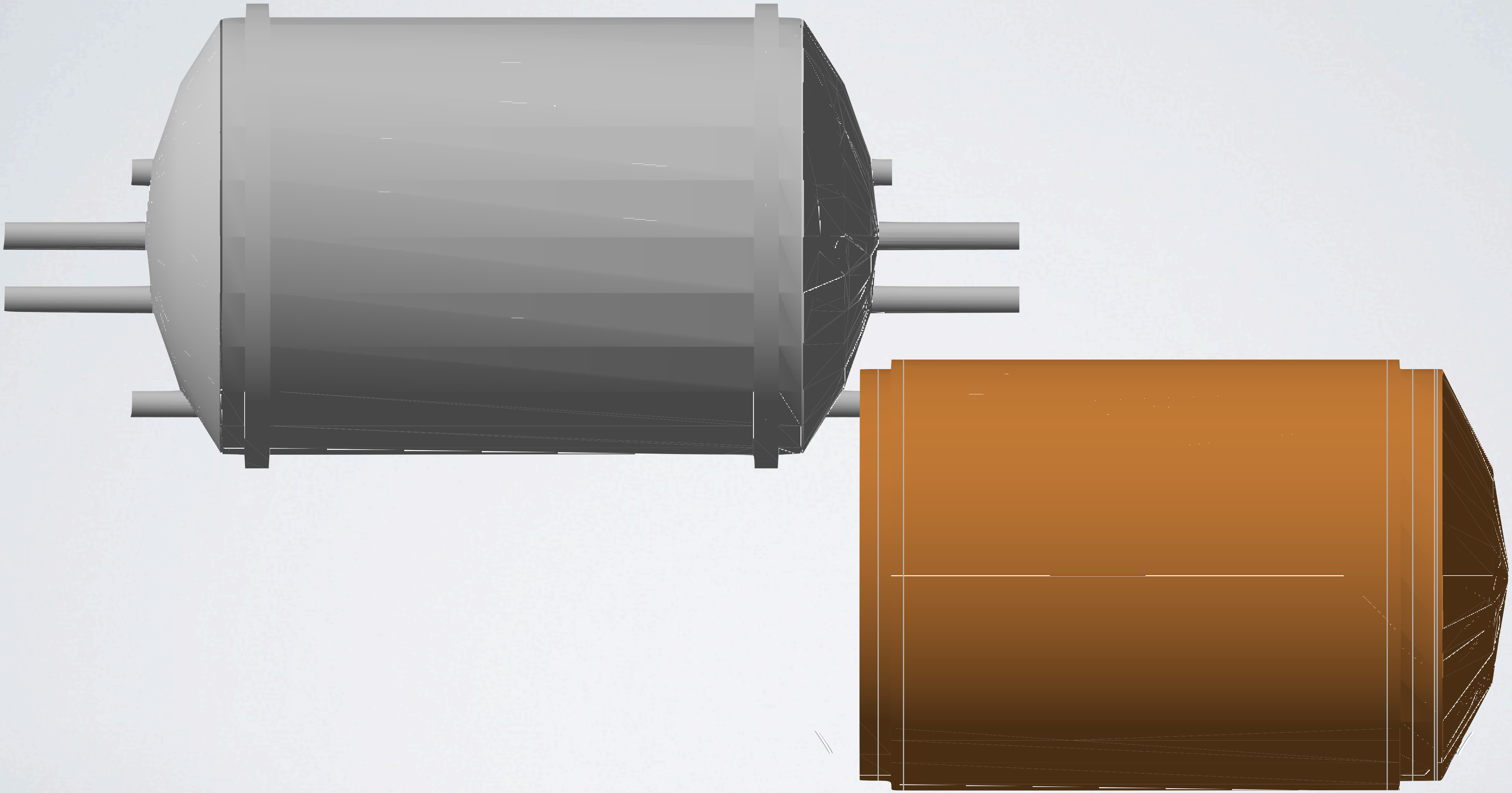
EFFICIENCY & BACKGROUND RATE

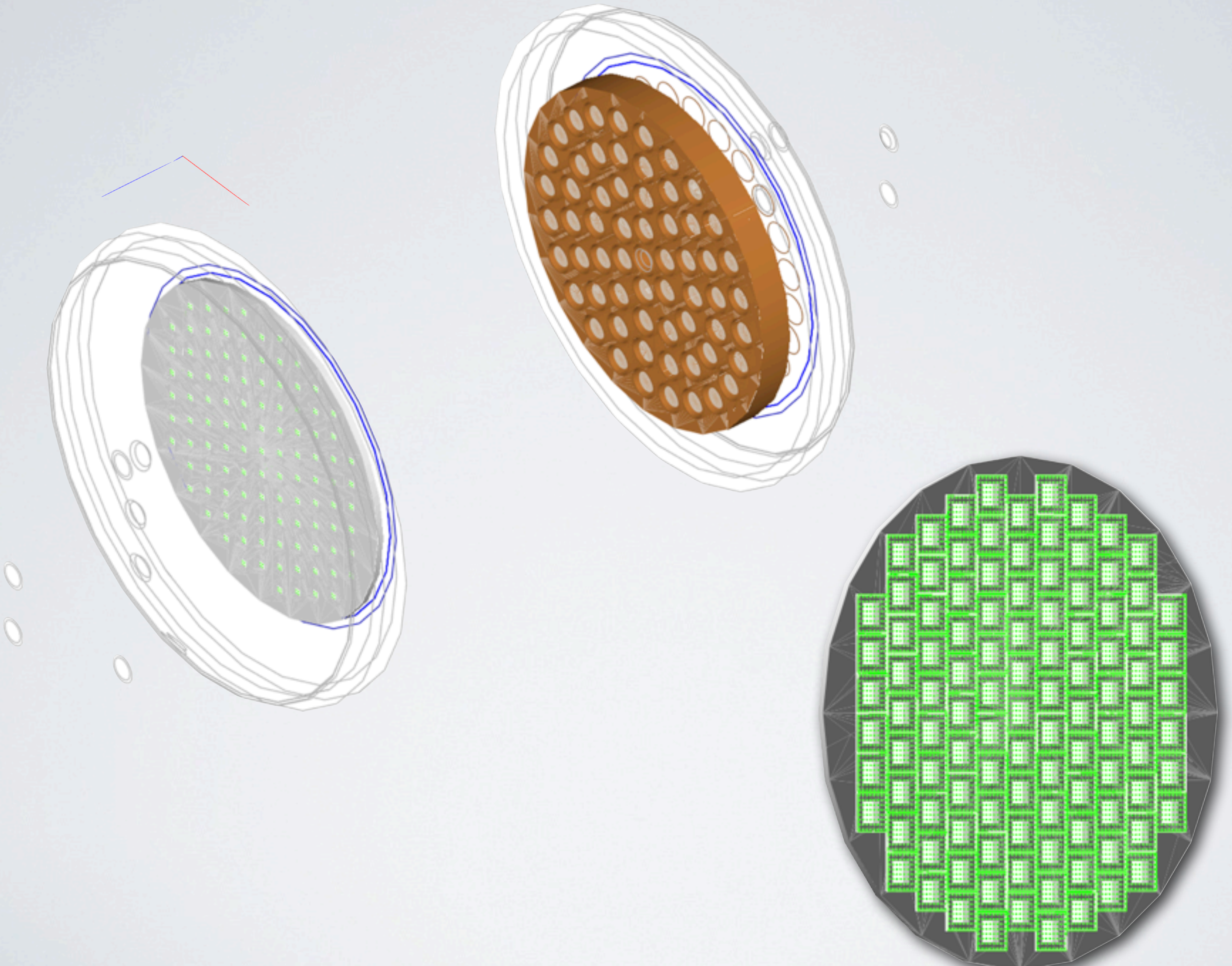
1. Simulate signal events uniformly distributed in the xenon gas.
2. Simulate background events from all detector elements. For a given material, probability of generation proportional to the mass of the volume.
3. Analyze events to decide whether they are signal or background. Selection criteria chosen taking into account the figure of merit $\varepsilon/\sqrt{b\ \Delta E}$
4. Fraction of signal events passing all cuts = efficiency. Fraction of background events passing all cuts = rejection factor.
5. Multiply rejection factor by total activity of the element to obtain its contribution to the background rate of NEXT-100.

THE NEXT-100 DETECTOR...

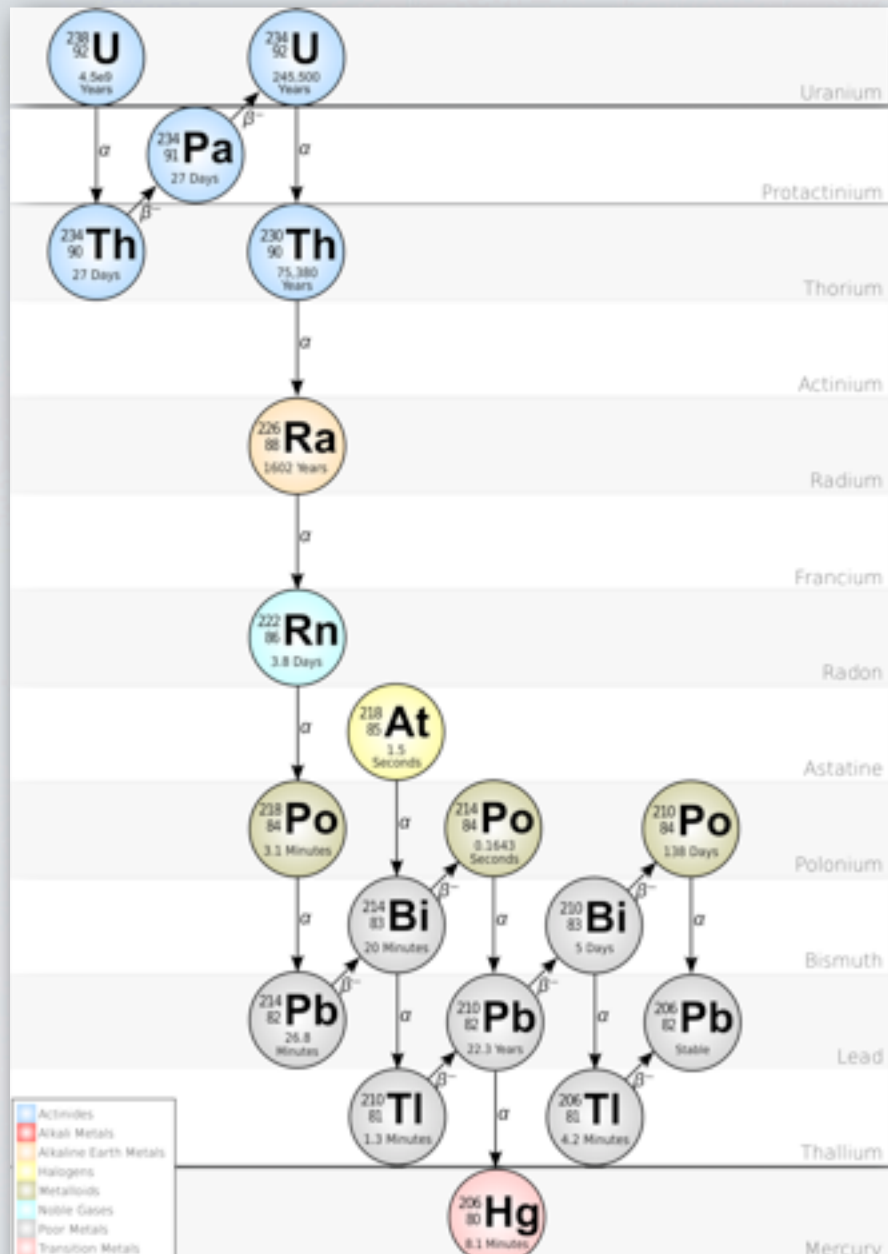


...AND ITS GEANT4 COUNTERPART



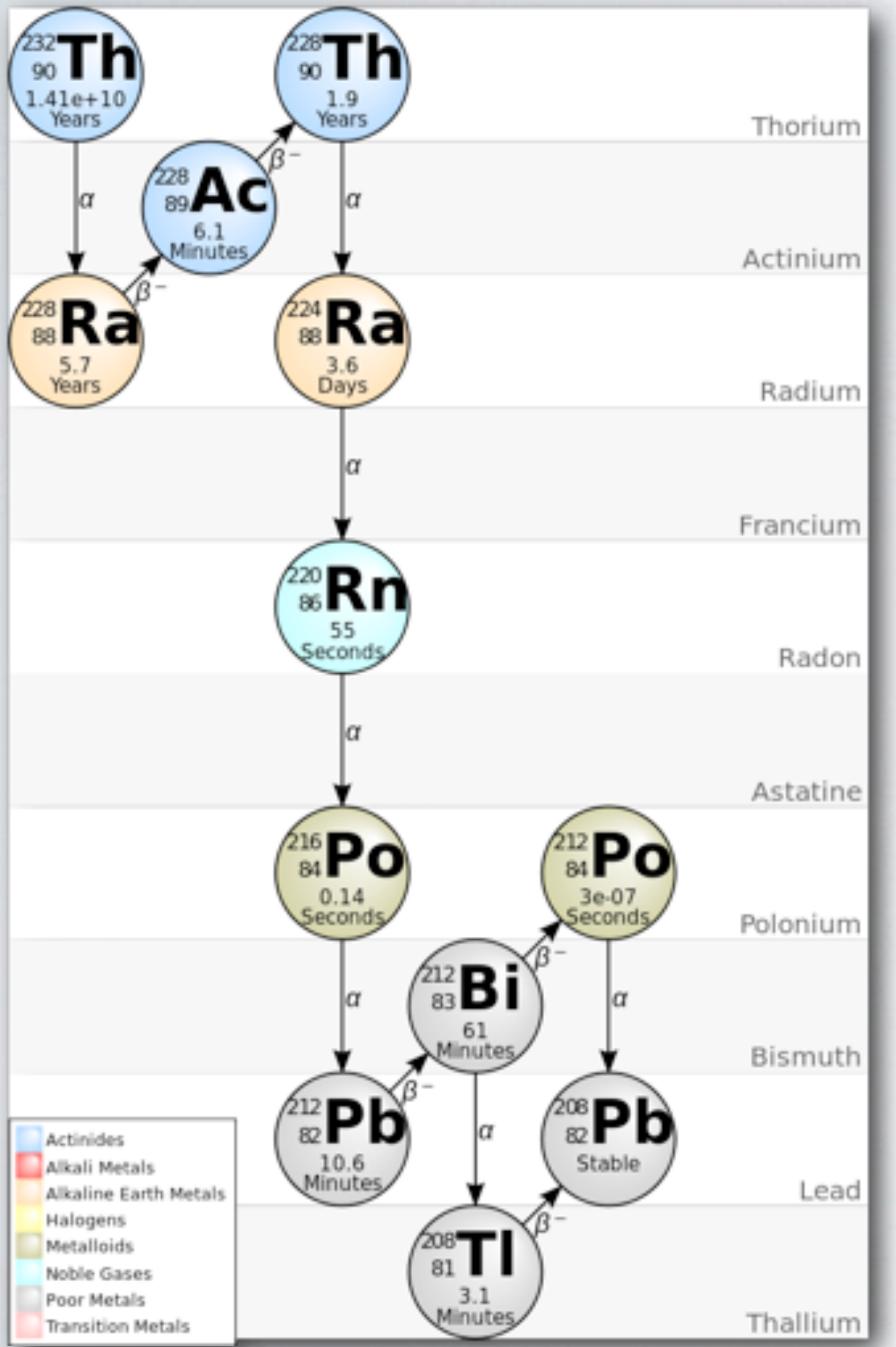


THE BAD GUYS (1)



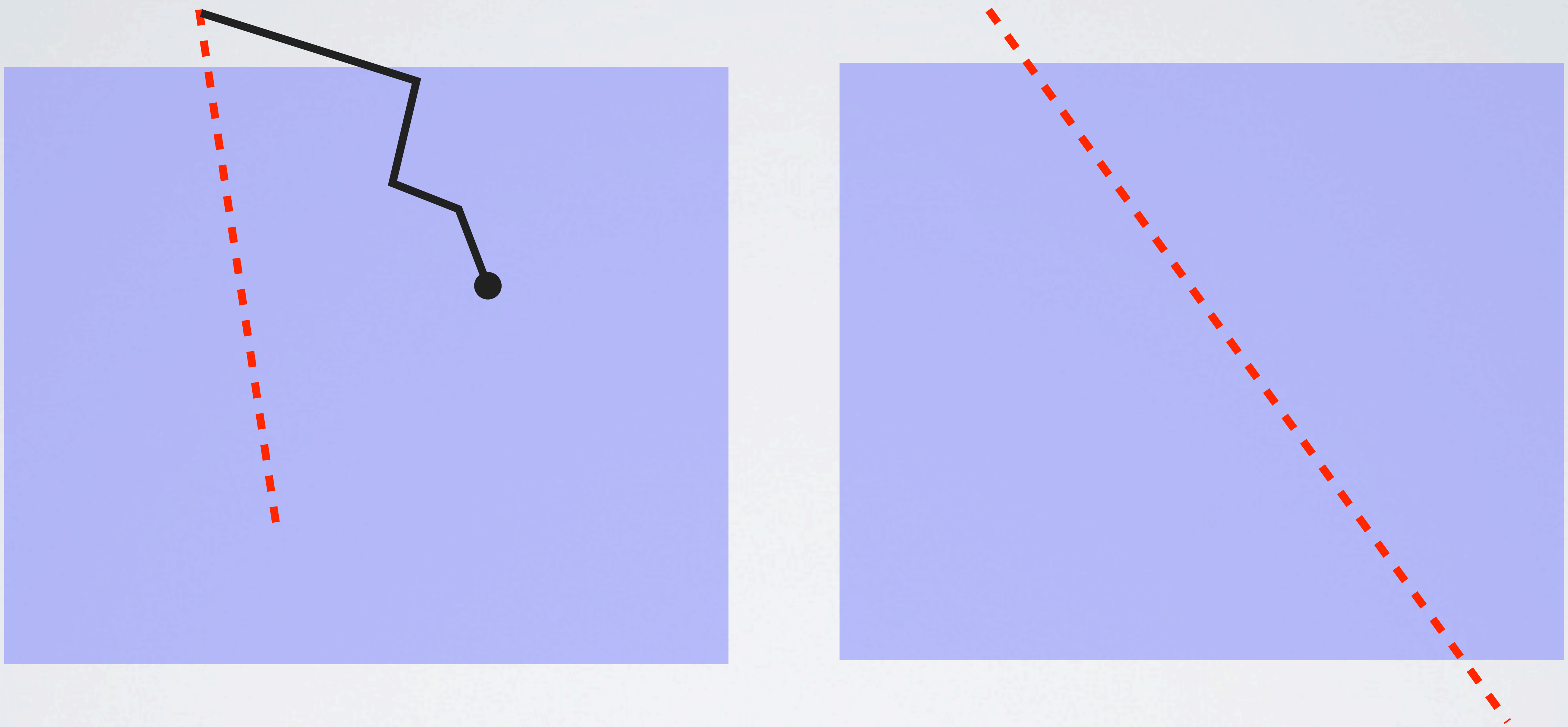
Decay of Bi-214 followed by emission of high-energy gammas. In particular, one at 2448 keV very close to Q value.

THE BAD GUYS (2)



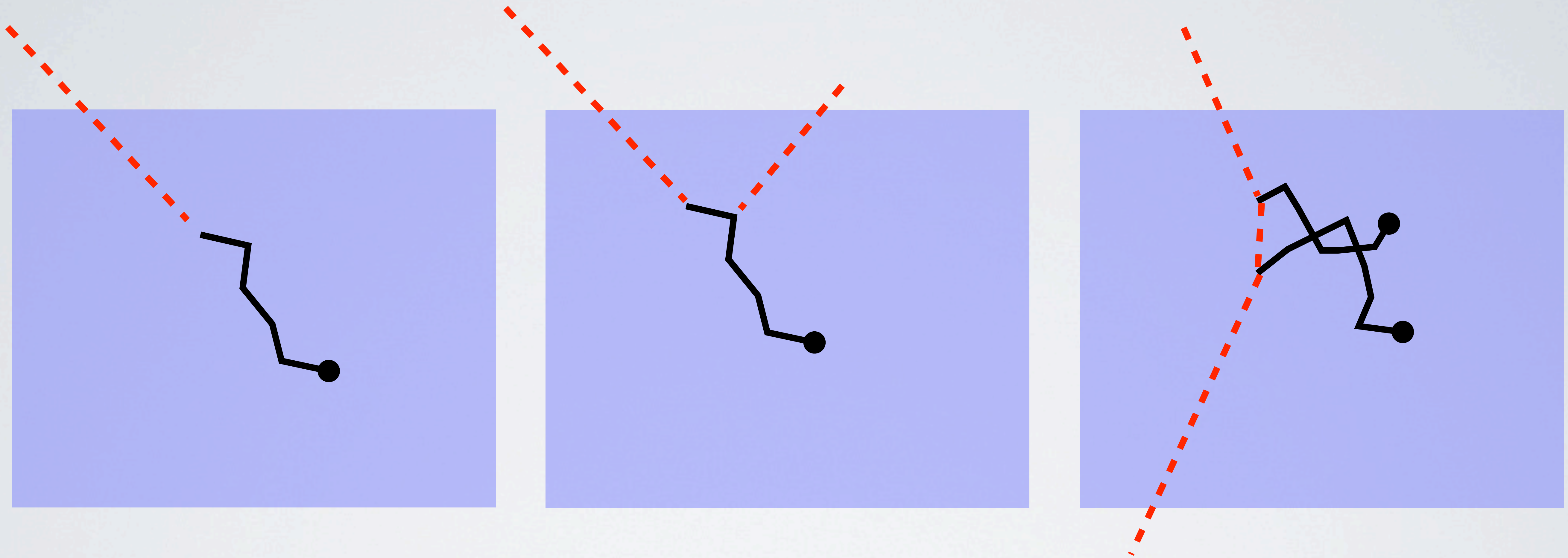
Decay of Tl-208 followed by the emission of a gamma of 2615 keV.

THE TOPOLOGICAL SIGNATURE



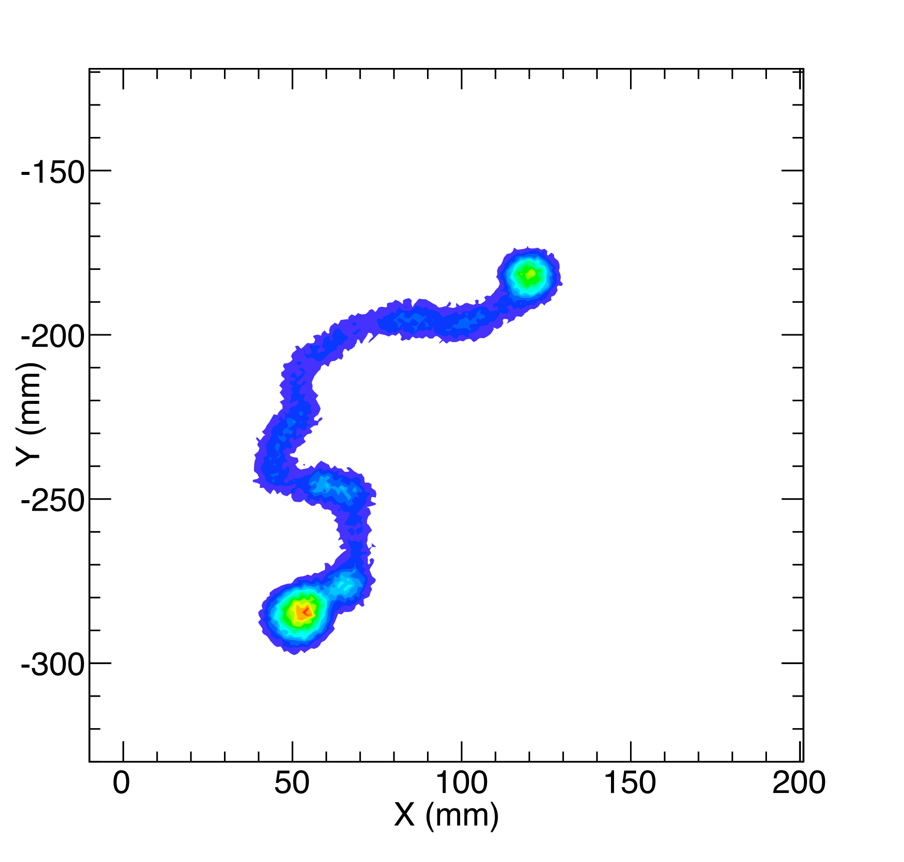
Veto of effectively all charged backgrounds entering the detector (left). High-energy gammas have a long interaction length (>3 m) in HPXe.

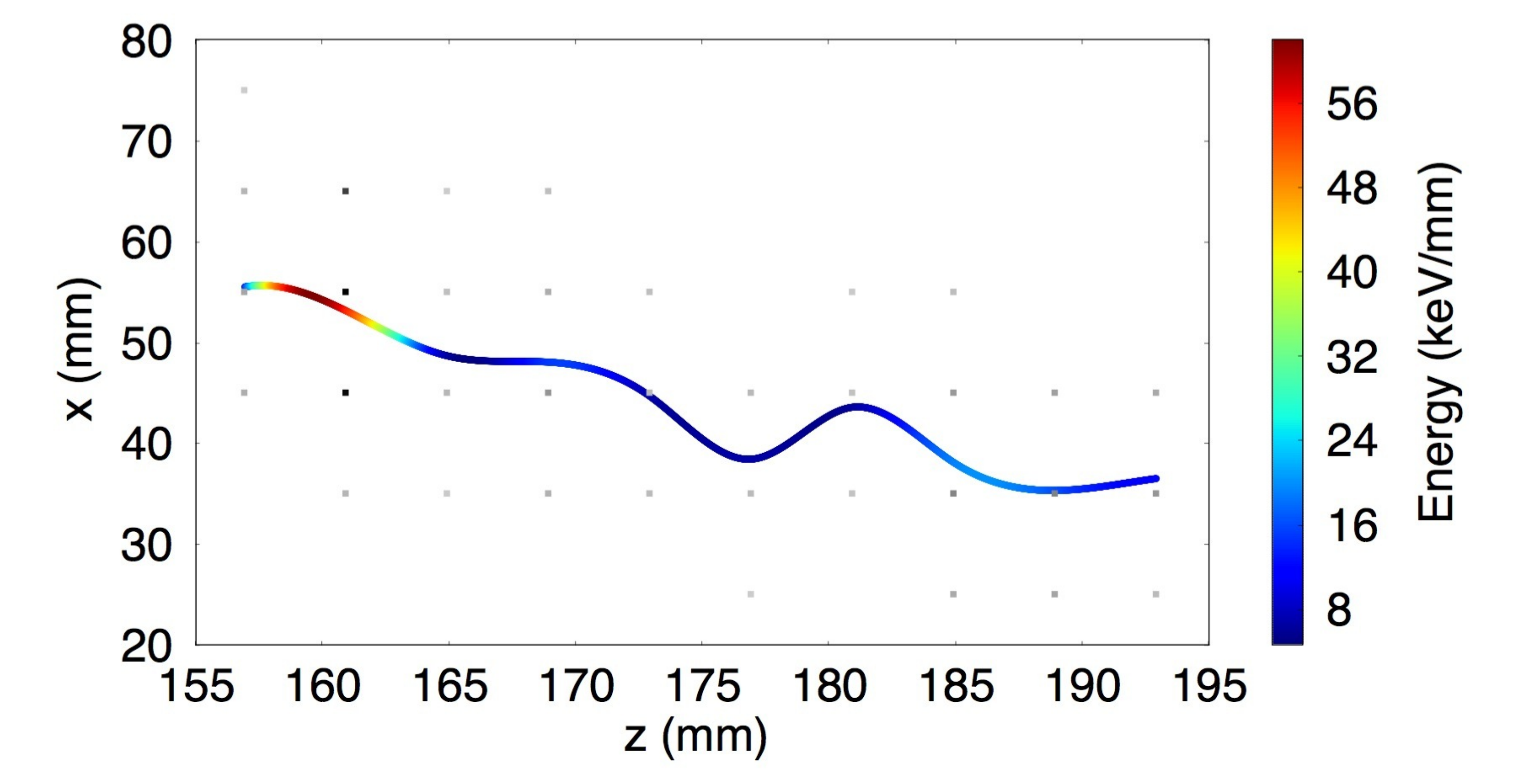
THE TOPOLOGICAL SIGNATURE



Interaction of high-energy gammas in the HPXe can generate electron tracks with energies around the Q value of Xe-136.

THE TOPOLOGICAL SIGNATURE



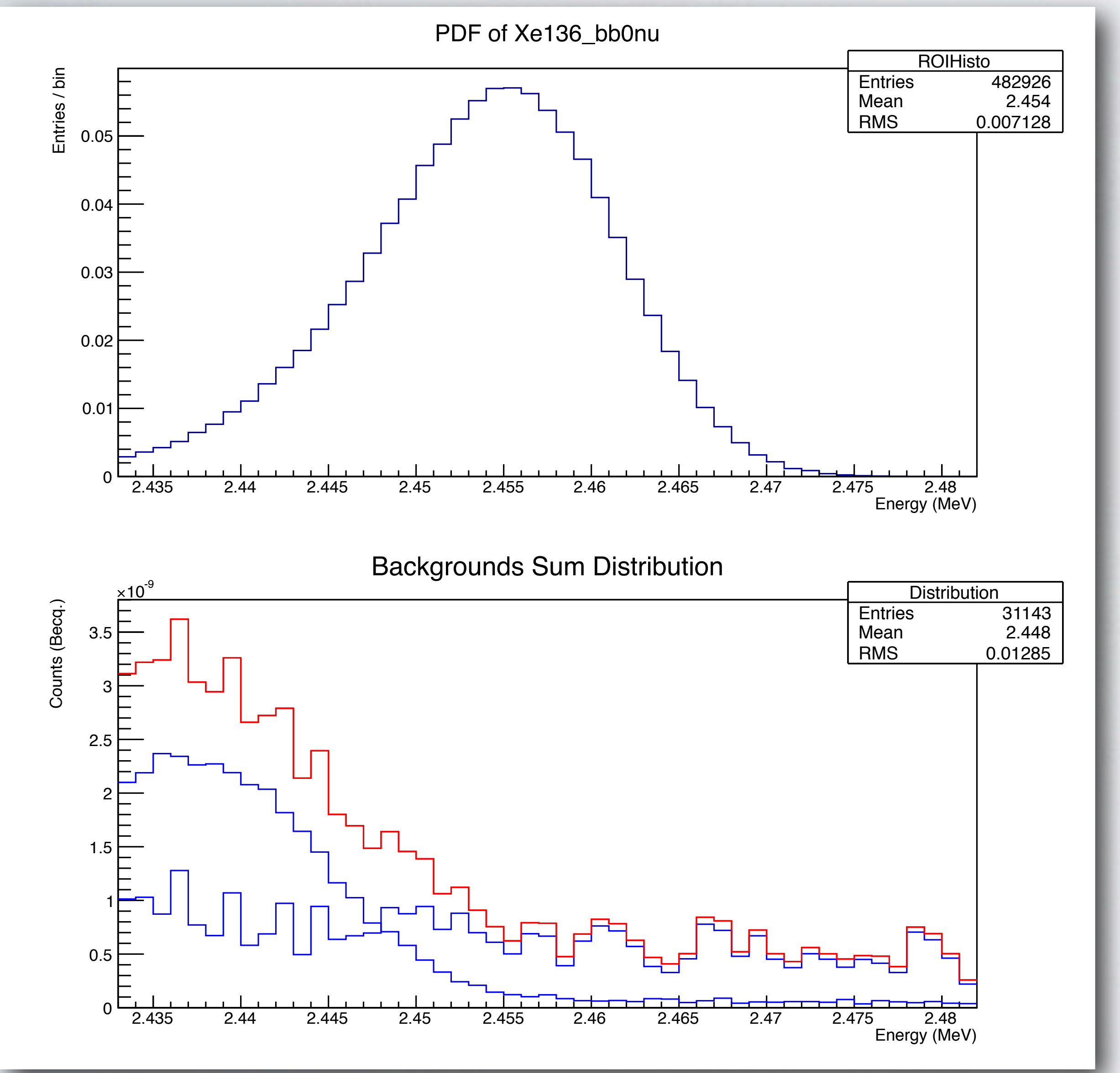


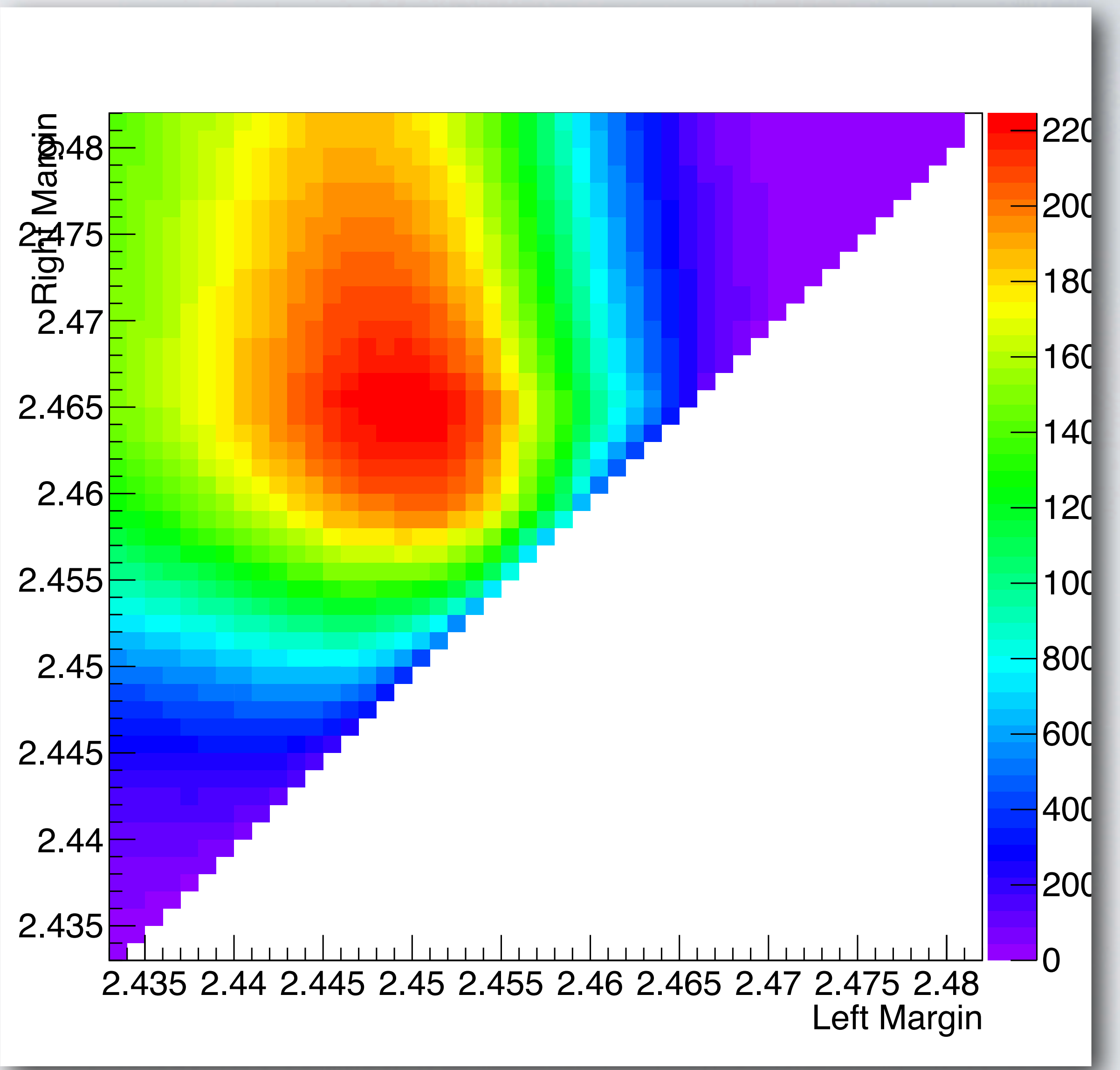
Energy deposition pattern (dE/dx) used to distinguish single electrons from double beta decay events.

NUMBER OF TRACKS

	1 track	2 tracks	3 tracks	More
Signal	**0.755**	0.168	0.058	0.020
Tl-208	**0.042**	0.340	0.315	0.303
Bi-214	**0.150**	0.323	0.280	0.248

ENERGY REGION OF INTEREST





SELECTION CUTS

Selection cut	Fraction of events			
	$\beta\beta0\nu$	$\beta\beta2\nu$	^{214}Bi	^{208}Tl
$E \in (2.3, 2.6)$ MeV	0.776	3.31×10^{-6}	1.52×10^{-4}	8.02×10^{-3}
Fiducial	0.678	2.95×10^{-6}	1.13×10^{-4}	4.77×10^{-3}
Single track	0.508	2.27×10^{-6}	1.36×10^{-5}	8.44×10^{-4}
$\mathrm{d}E/\mathrm{d}x$	0.381	1.70×10^{-6}	1.36×10^{-6}	8.10×10^{-5}
ROI				
0.5% FWHM	0.311	3.24×10^{-12}	1.23×10^{-7}	3.23×10^{-7}
1.0% FWHM	0.315	3.57×10^{-11}	3.69×10^{-7}	5.40×10^{-7}

RADIOACTIVE BUDGET

#	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

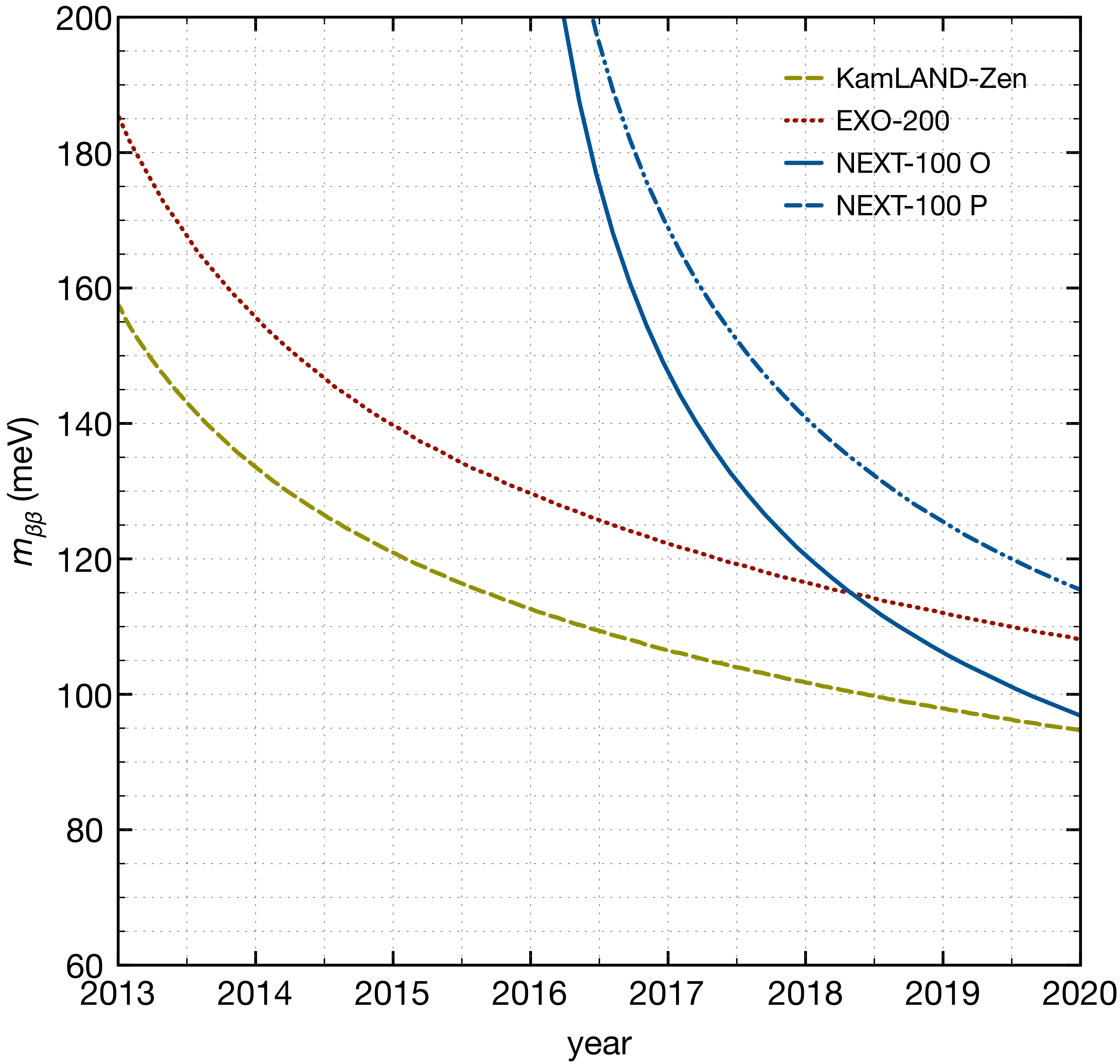
System	Activity [mBq]		Rejection factor		Backg. rate $[10^{-3}$ ckky$]$	
	^{214}Bi	^{208}Tl	^{214}Bi	^{208}Tl	^{214}Bi	^{208}Tl
Pressure vessel						
Total	560.5	282.5	4.00×10^{-10}	4.80×10^{-9}	0.0032	0.0194
Energy plane						
R11410-10 PMTs	96.6	121.8	4.12×10^{-8}	1.56×10^{-7}	0.0142	0.0145
Enclosures	25.4	2.5	2.15×10^{-8}	1.03×10^{-7}	0.0008	0.0004
Shapphire windows	18.6	2.6	1.09×10^{-7}	2.77×10^{-7}	0.0103	0.0290
Support plate	4.1	0.4	2.11×10^{-8}	1.32×10^{-7}	0.0008	0.0012
Total	—	—	—	—		
Tracking plane						
Dice boards	30.0	26.8	1.23×10^{-7}	3.23×10^{-7}	0.0527	0.1237
Total	—	—	—	—		
Field cage						
Barrel	29.6	6.5	1.14×10^{-7}	2.72×10^{-7}	0.0481	0.0252
Total	—	—	—	—		
Shielding						
Outer (Pb)						
Inner (Cu)	92.1	9.2	1.26×10^{-8}	7.87×10^{-8}	0.0166	0.0139
Total	—	—	—	—		

BACKGROUND RATE

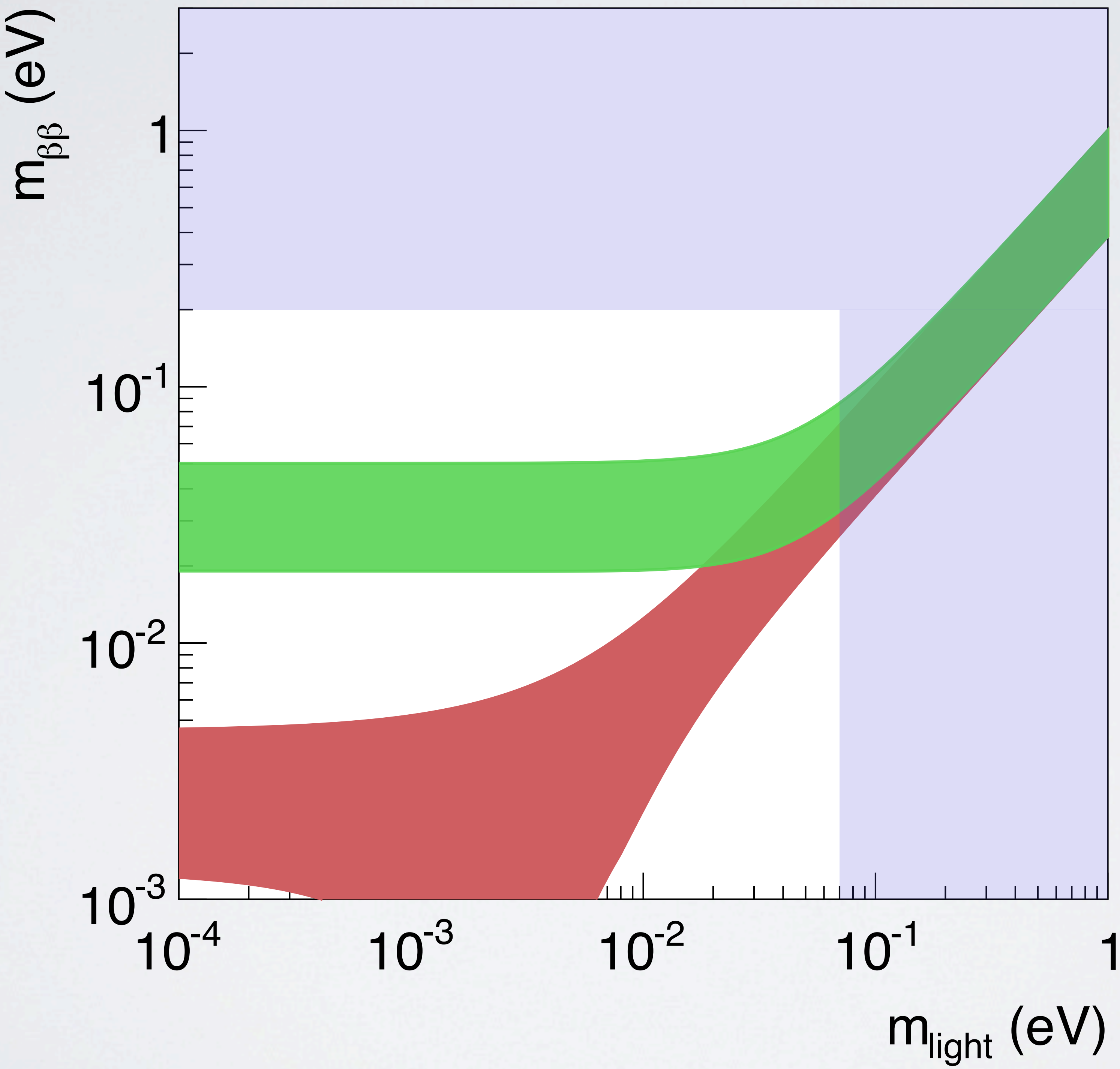
System	Bi-214 (10^{-3} ckky)	Tl-208 (10^{-3} ckky)	Total (10^{-3} ckky)
Vessel	<0.01–0.01	0.02–0.03	0.02–0.04
Energy plane	0.05–0.17	0.03–0.28	0.08–0.45
Tracking plane	0.05–0.10	0.12–0.13	0.17–0.23
Inner shielding	0.02–0.03	0.01–0.01	0.03–0.04
Field cage	0.05–0.09	0.03–0.03	0.08–0.12
Total	0.18–0.40	0.21–0.48	0.38–0.88

THE COMPETITION

Experiment	M (kg)	enrichment (%)	efficiency (%)	resolution (% FWHM)	b (10^{-3} ckky)
EXO-200	110	81	52	3.9	1.5
KamLAND-Zen	330	91	62	9.9	1.0
NEXT-100	100	91	31	0.5–1.0	0.4–0.9


KamLAND-Zen
EXO-200
NEXT-100 O
NEXT-100 P
$m_{\beta\beta}$ (meV)
200
180
160
140
120
100
80
60
2013
2014
2015
2016
2017
2018
2019
2020
year

THE PHYSICS LANDSCAPE



SUMMARY

- Detailed background model developed with detector simulation.
- Predicted a signal efficiency of about 31% and a background rate between 0.4–0.9 × 10^{-3} cts/keV/kg/yr with standard set of selection cuts.
- Several contributions to the background still to be determined (tracking plane, PMT bases, field cage).