0νββ Background Infrastructure Priorities

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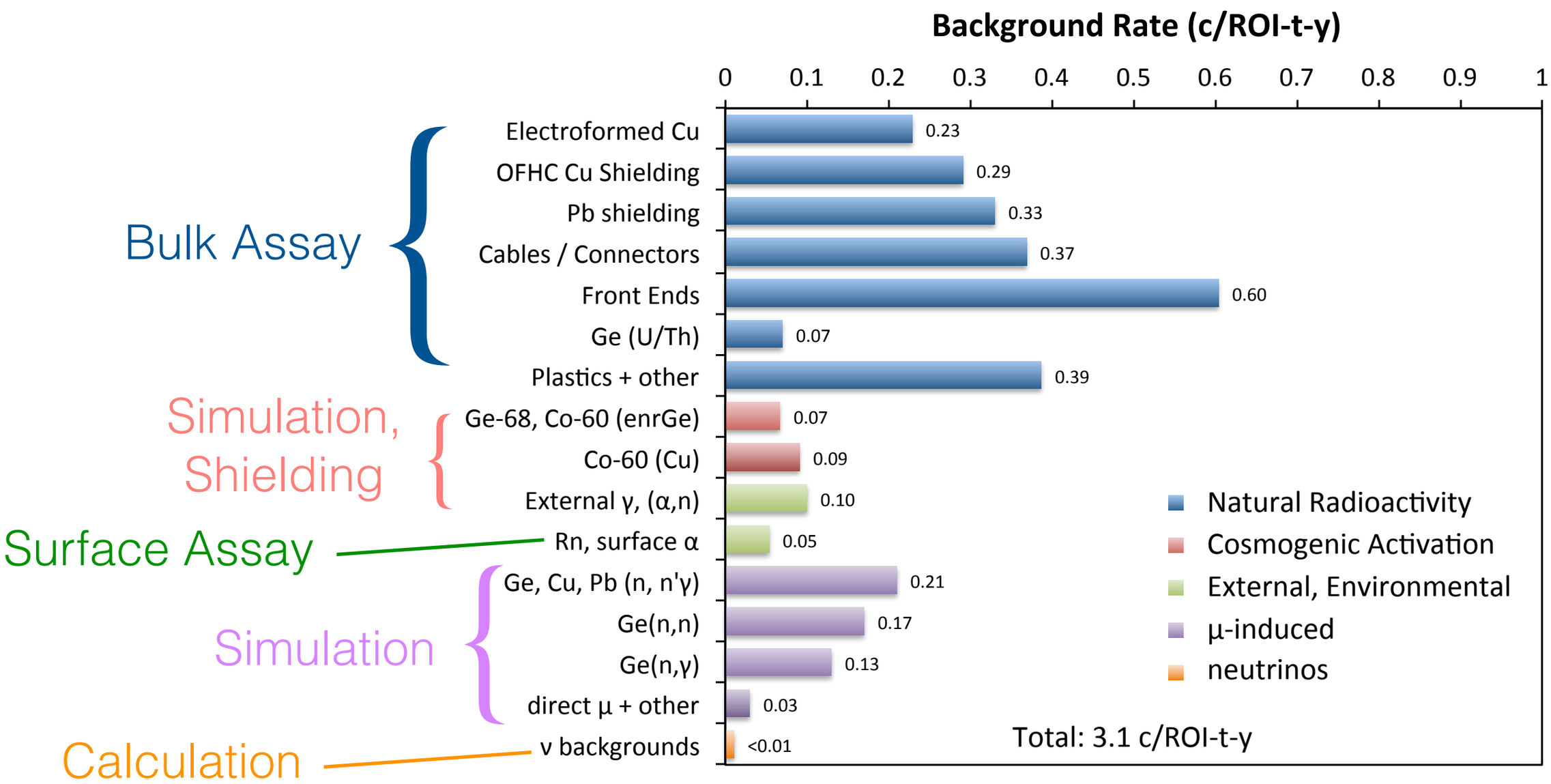
MJD BG Projection



MJD Assay

Material	Part of Demonstrator	Decay Chain	Achieved Assay	
			[mBq/kg]	[c/ROI/t/y]
EFCu	Inner Cu Shield, Cryostat, Coldplate, Thermal Shield, Detector Mounts	Th	0.06	0.15
		U	0.17	0.08
OFHC	Outer Copper Shield (O.Cut)	Th	1.1	0.26
		U	1.25	0.03
Pb	Lead Shield	Th	5	0.20
		U	36	0.26
PTFE	Detector Supports	Th	0.1 ± 0.01	0.01
		U	<5	<0.01
Vespel	Cold Plate Support	Th	<12	<0.01
		U	<1050	<0.4
Parylene	Cu coating, Cryostat seals	Th	2150	0.27
		U	3110	0.09
Silica / Au, Epoxy	Front-End Electronics	Th	6530	0.32
		U	10570	0.28
Cu Wire + PFA	Signal /HV Cable and Connectors	Th	2.2	0.01
		U	145	0.08
Stainless Steel	Service Body	Th	(18 ± 3) x 10^3	<0.04
		U	<5000	<0.03
Completely assembled connector	Connectors	Th	210	0.13
		U	335	0.06

Required sensitivity for primary materials: μBq/kg ↔ ppt

MJD Assay Methods

- ICP-MS (PNNL, LBNL Canada, Russia, Oregon)
- (I)NAA (UC Davis, Oak Ridge, NC State)
- Gamma counting (LBNL, KURF, LNGS, WIPP, institutional screeners)
- GDMS (Canada, Russia)
- Other: surface α/β, Rn emanation, …

EXO 200 Samples

Table 3: Measurement results for K, Th, and U concentrations in a variety of materials. Manufacturer production lot numbers or arbitrary identifiers are indicated for materials where multiple lots were studied. Uncertainties are quoted at 68% C.L. and limits are 95% C.L. Results which are less than than 3-σ above zero (not including systematic scaling uncertainties) are reported as upper limits. GD-MS measurements have a factor of two uncertainty. In the "method" column, "A.G. Ge" refers to above ground germanium counting. Measurements with methods of "Balazs Analytical Services" or "Shiva Inc." were performed by the commercial services of the respective companies. Entries 31 and 38 list data taken from Refs. [18] and [19] respectively as indicated. Where available, germanium counting results for ^{60}Co and ^{137}Cs activities are given within the sample descriptions.
* Indicated NAA results may be affected by a neutron flux calibration discrepancy described in Sec. 5. The tabulated results do not include systematic uncertainties arising from this discrepancy.

#	Material	Method	K conc. $[10^{-9}g/g]$	Th conc. $[10^{-12}g/g]$	U conc. $[10^{-12}g/g]$
	Bulk Copper				
1	Norddeutsche Affinerie, NOSV copper made May 2002.	Shiva Inc. GD-MS	0.4	<5	<5
2	Norddeutsche Affinerie, NOSV copper made May 2002.	Ge	<120	<35	<63
3	Norddeutsche Affinerie OFRP copper made May 2006, batch E263/2E1.	ICP-MS	<55	<2.4	<2.9
4	Norddeutsche Affinerie OFRP copper made May 2006 batch E262/3E1.	ICP-MS	<50	<2.4	<2.9
5	Rolled Norddeutsche Affinerie OFRP copper, May 2006 production. Rolled by Carl-Schreiber GmbH.	ICP-MS	-	<3.1	<3.8
6	TIG welded Norddeutsche Affinerie OFRP copper made May 2002. No cleaning after welding. Result are normalized to length of weld.	ICP-MS	-	<9.8 pg/cm	10.2±3.4"pg/cm
7	Valcool VNT 700 metal working lubricant, concentrate.	A.G. Ge	38000±11000	<10000	<3700
8	Water alcohol mixture, lubricant for machining of Cu parts.	A.G. Ge	<44000	<18000	<3800
	Lead				
9	JL Goslar cutting oil. Used for cutting 98% distilled water, 2% cutting oil. ^{60}Co: <1.8 mBq/kg, ^{137}Cs: <12 mBq/kg.	Ge	93500±1000	<790	3650±510
10	Paint for lead bricks, JL Goslar, type: Glasurit MS-Klarlack. Proportions: 2 paint, 1 hardener, 0.1 solvent.	Ge	720±170	<170	790±90
11	EXO Pb, JL Goslar smelting lot 3-706.	ICP-MS	-	<1	<1
12	EXO Pb, JL Goslar smelting lot 3-706.	GD-MS	<15	<6	<6

D. S. Leonard, *et al.*, NIMA **591**, 490 (2008).

EXO 200 Samples

210	1/2" Cu tubing for heat exchangers. Metallica SA.	ICP-MS	-	<2	<1.5
211	1/2" Cu tubing for heat exchangers. Metallica SA.	Ge	<180	<790	<113
212	1" Cu tubing for HFE. McMaster-Carr, Cu-alloy 122.	ICP-MS	<27	40±2	<1.5
213	Closed cell PE foam, Uline 1/8" × 72" × 550'. ^{60}Co: <23 mBq/kg, ^{137}Cs: <29 mBq/kg.	Ge	<14800	<19200	32000±4600
215	Omega Engineering Inc. thermocouple, part TT-T-30-SL. ^{60}Co: <8.0 mBq/kg.	Ge	<7000	<3800	<1700
216	Polyimide tape from Stanford stock room.	A.G. Ge	<37000	<5400	<5800
217	Sheldal superinsulation, item # 146477, 0.25 mil PET aluminized on one side.	Ge	5550±1300 (4.9±1.2 ng/cm^2)	<4080 (<3.7 pg/cm^2)	4660±380 (4.1±0.4 pg/cm^2)
218	Sheldal superinsulation, item # 146477, 0.25 mil PET aluminized on one side. K result is for dissolved aluminum layer only but normalized to whole sample mass. For U and Th, the PET layer was also partially dissolved and analyzed.	ICP-MS	461±33 (0.41±0.03 ng/cm^2)	<1800 (<1.6 pg/cm^2)	5740±150 (5.1±1.3 pg/cm^2)
219	Sheldal superinsulation, item # 146455, 0.3 mil DuPont Kapton aluminized on one side.	ICP-MS	-	<1640 (<1.75 pg/cm^2)	<6100 (<6.5 pg/cm^2)
220	Sheldal superinsulation, item # 146428, 0.3 mil DuPont Kapton aluminized on both sides, embossed.	ICP-MS	-	<1540 (<1.64 pg/cm^2)	2500±800 (2.64±0.85 pg/cm^2)
221	Jehier candidate superinsulation mix for EXO before installation: 26 layers of Insulray 305 plus 4 layers of Teril-53. ^{60}Co: <3.8 mBq/kg.	Ge	<6500	<4100	7700±1000
222	Jehier superinsulation mix sampled after installation without further cleaning.	NAA	51400±2100	<13900	12300±5540
223	Plastic and metallization of Jehier superinsulation EXO-mix.	ICP-MS	-	<80	<60
224	Jehier superinsulation, EXO-mix. Second purchase. ^{60}Co: <16 mBq/kg, ^{137}Cs: <16 mBq/kg.	Ge	18600±5000	<1700	3900±1300
225	Jehier hook-and-loop fastener to hold superinsulation.	Ge	3090±890	<1670	<920

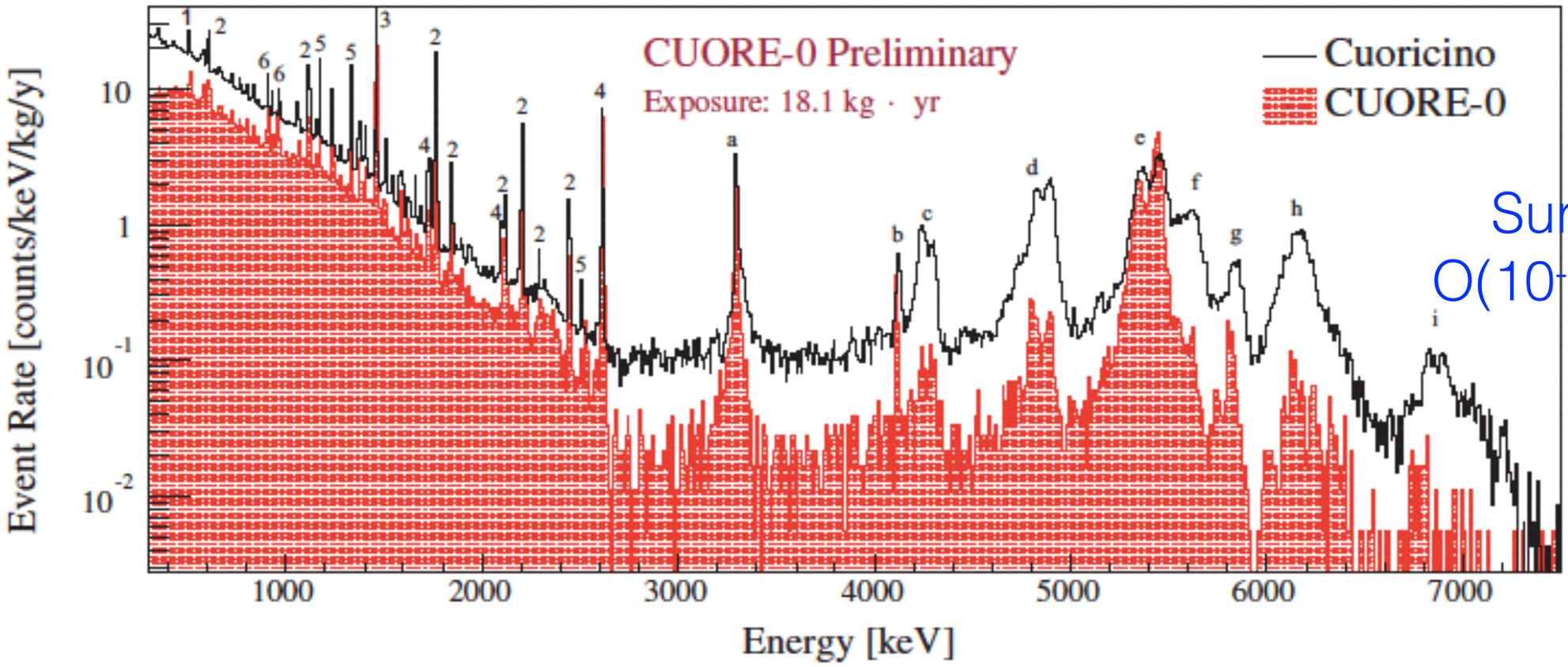
D. S. Leonard, *et al.*, NIMA **591**, 490 (2008).

Ton Scale:

- Stronger background constraints
  - Longer counts
    - Best techniques
    - New methods for improved sensitivity
- Maybe more samples can be expected
- Piepke has a detailed estimate for nEXO needs

Experimental Backgrounds

CUORE-0

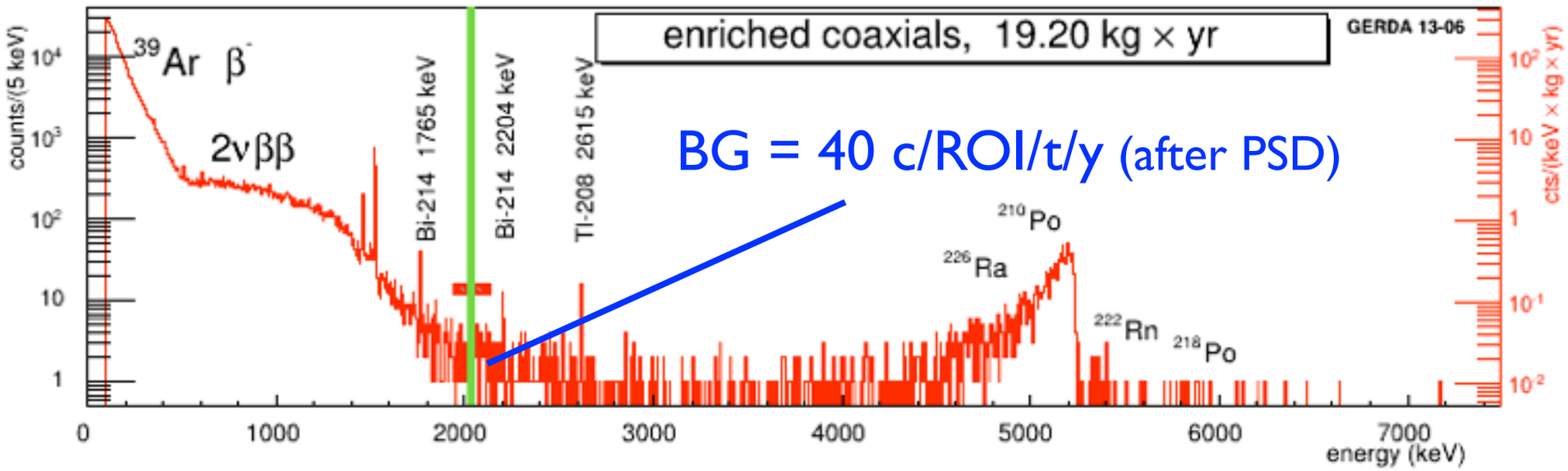


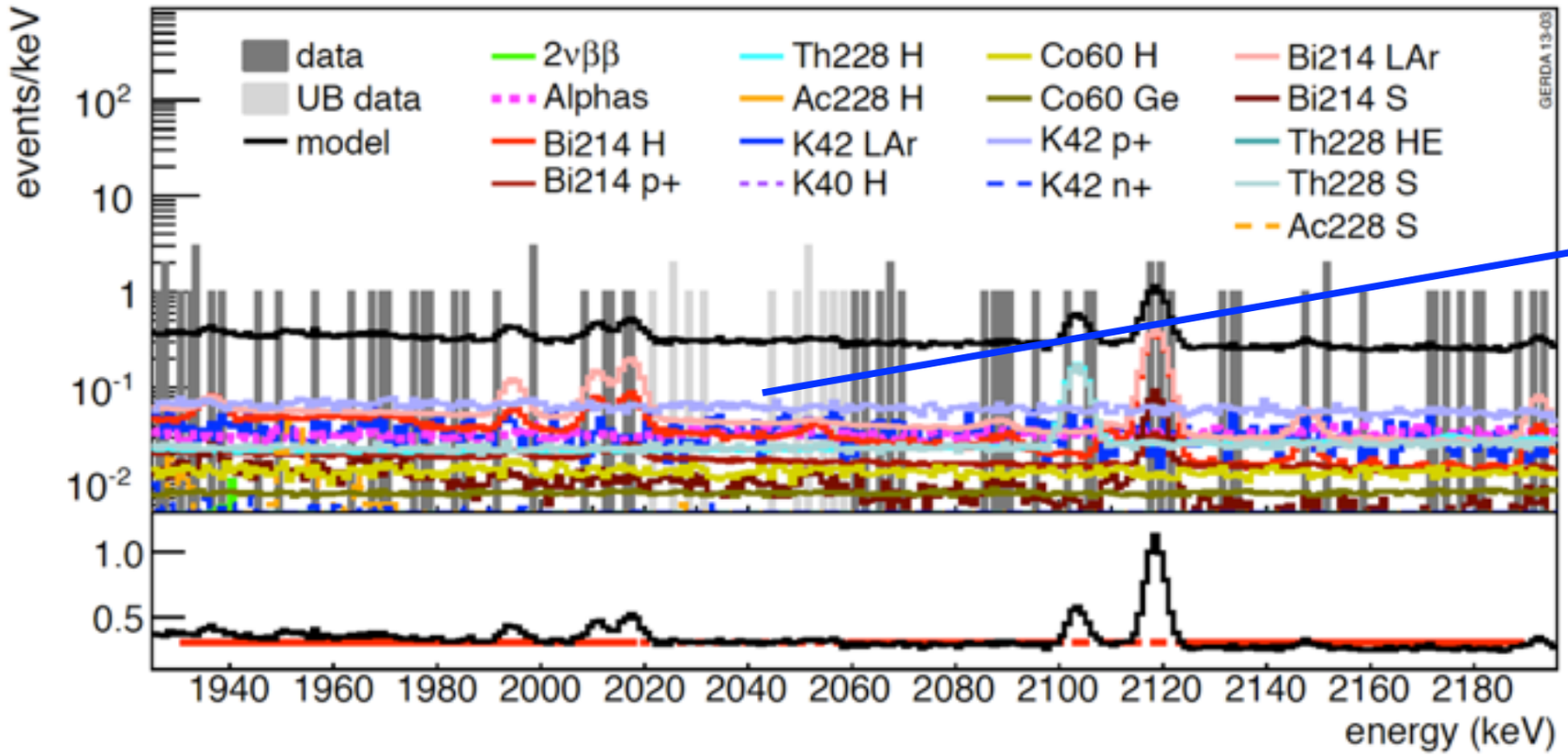
Surface α:
$O(10^{-7})$ Bq/cm^2

FIGURE 2. Cuoricino (line) and CUORE-0 (shaded) background spectra comparison. Only events with a single crystal hit are considered (anti-coincidence mode). Background rates are clearly reduced in CUORE-0 by factors ~2 and ~6 in the α (E>2.7 MeV) and γ dominated regions, respectively. In the γ region, labeled lines are due (1) e+e- annihilation, (2) ^{214}Bi, (3) ^{40}K, (4) ^{208}Tl, (5) ^{60}Co and (6) ^{228}Ac mainly from the cryostat materials. In the αregion they come from (a) ^{190}Pt, (b) ^{232}Th, (c) ^{238}U, (d) ^{230}Th and ^{226}Ra, (e) ^{210}Po, (f) ^{228}Th and ^{222}Rn, (g) ^{224}Ra, (h) ^{218}Po and (i) ^{216}Po from TeO_2 crystals or surface radioactive contaminations of the detector structure materials.

arXiv:1502.02576
CUORE surfaces:
J. Cryst. Growth **312**, 2999 (2010),
Astropart. Phys. **35**, 839 (2012),
Astropart. Phys. **45**, 13 (2013)

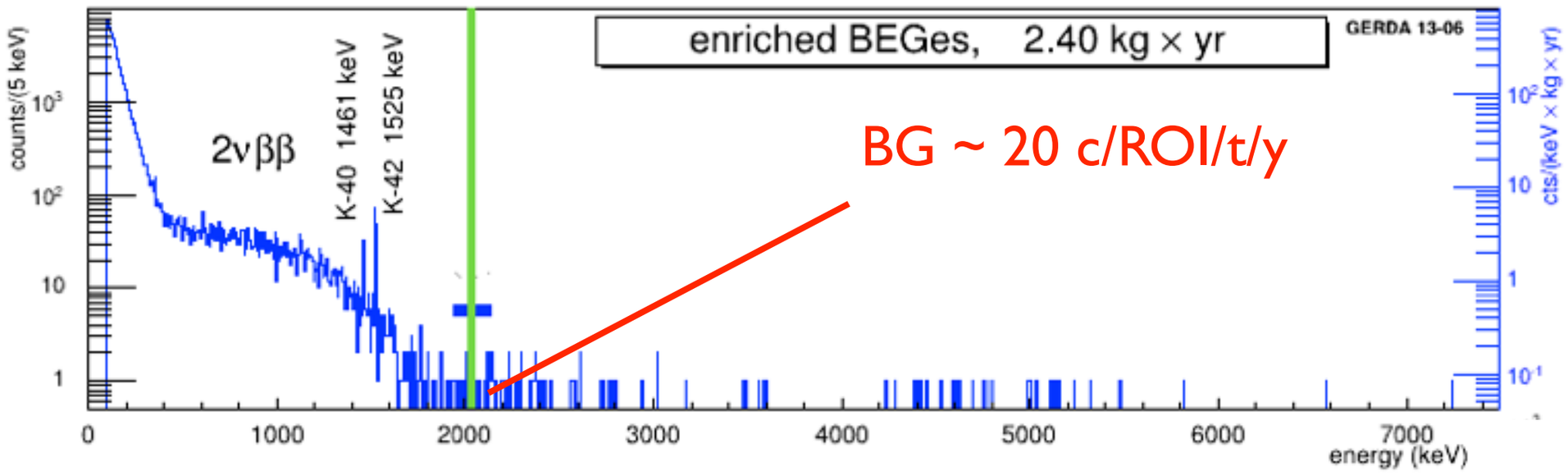
GERDA-I

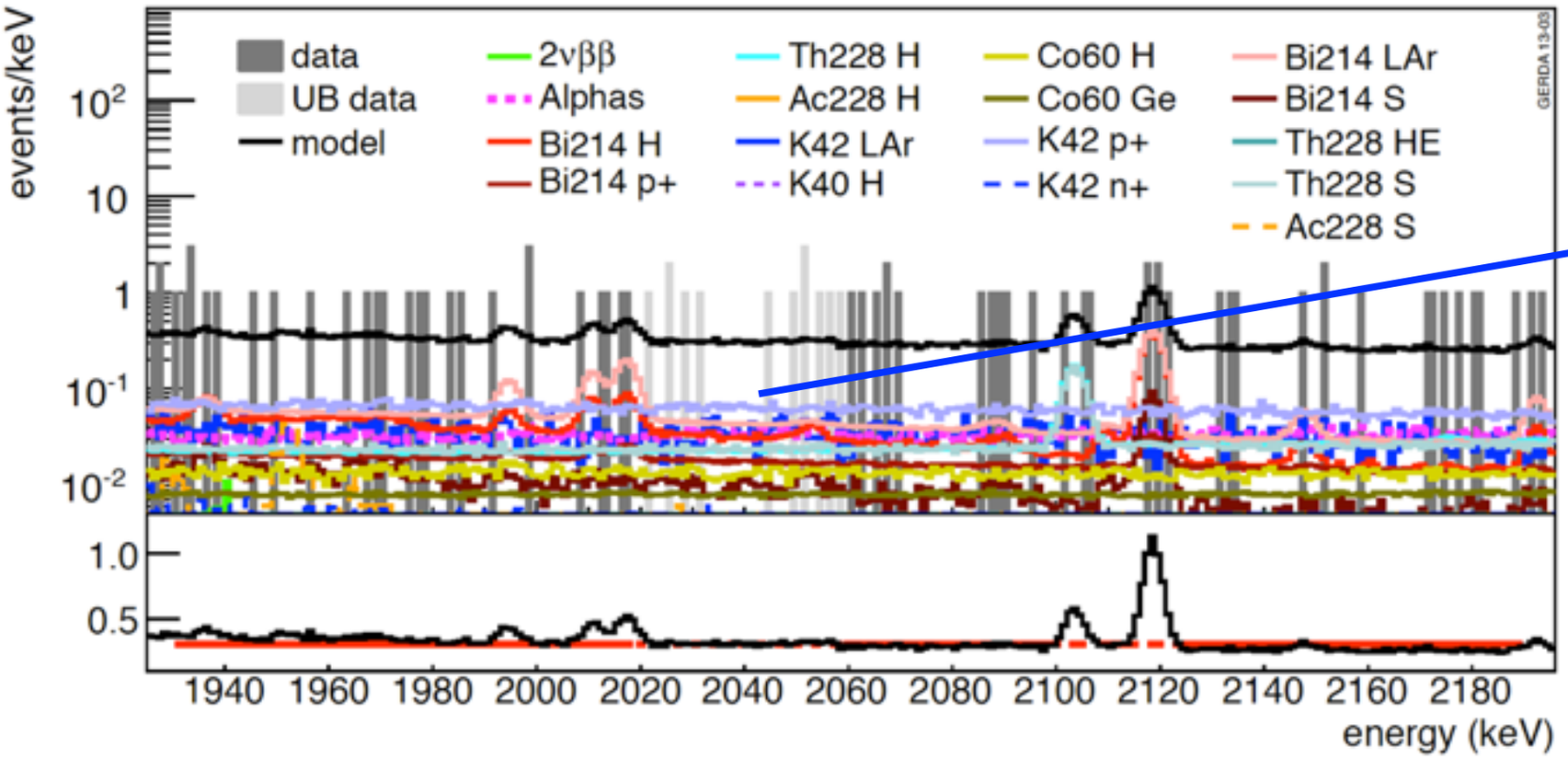




EPJC **74**, 2764 (2014).

GERDA-I

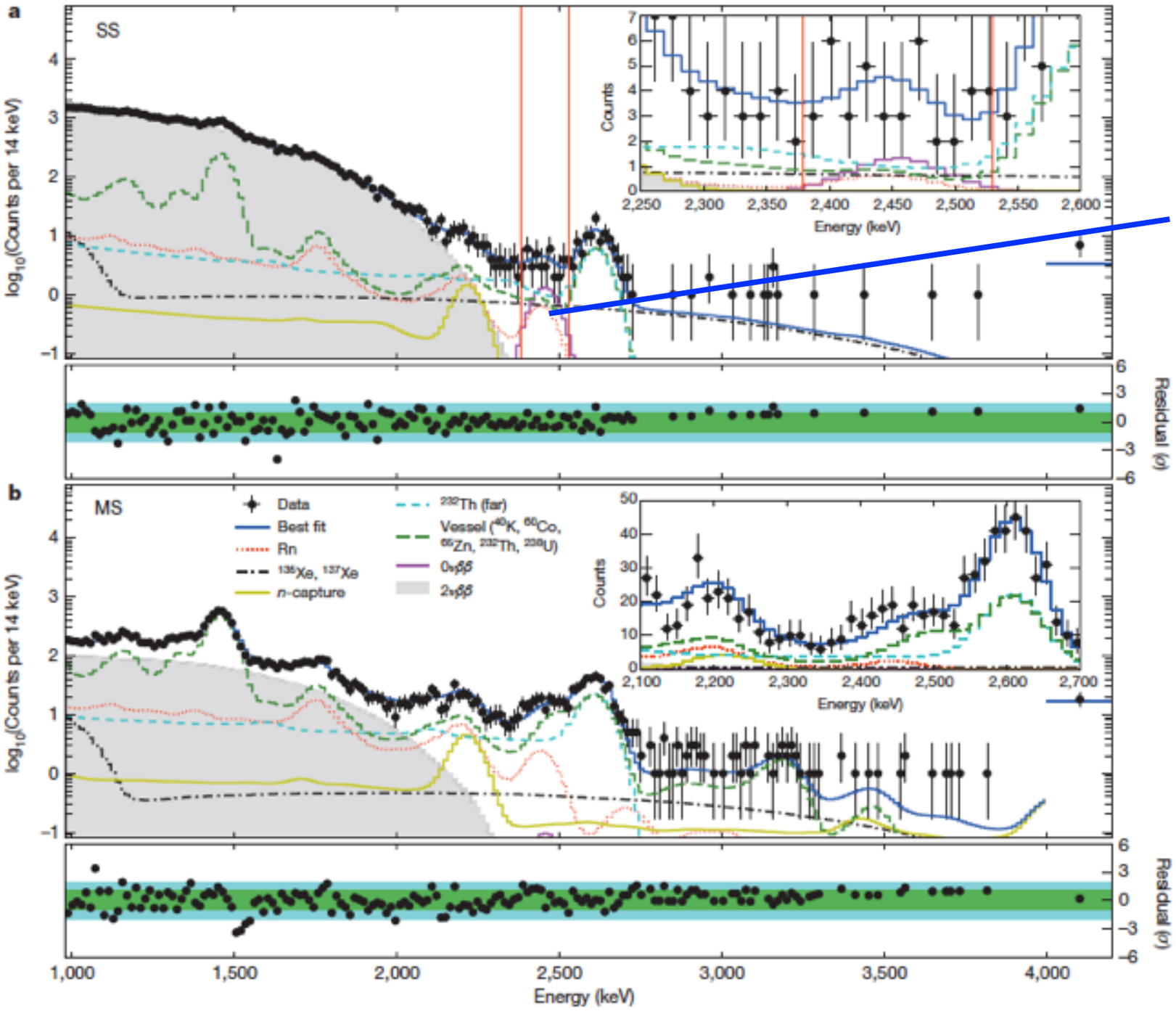




LAr Cosm. Activation, Bulk U/Th

EPJC **74**, 2764 (2014).

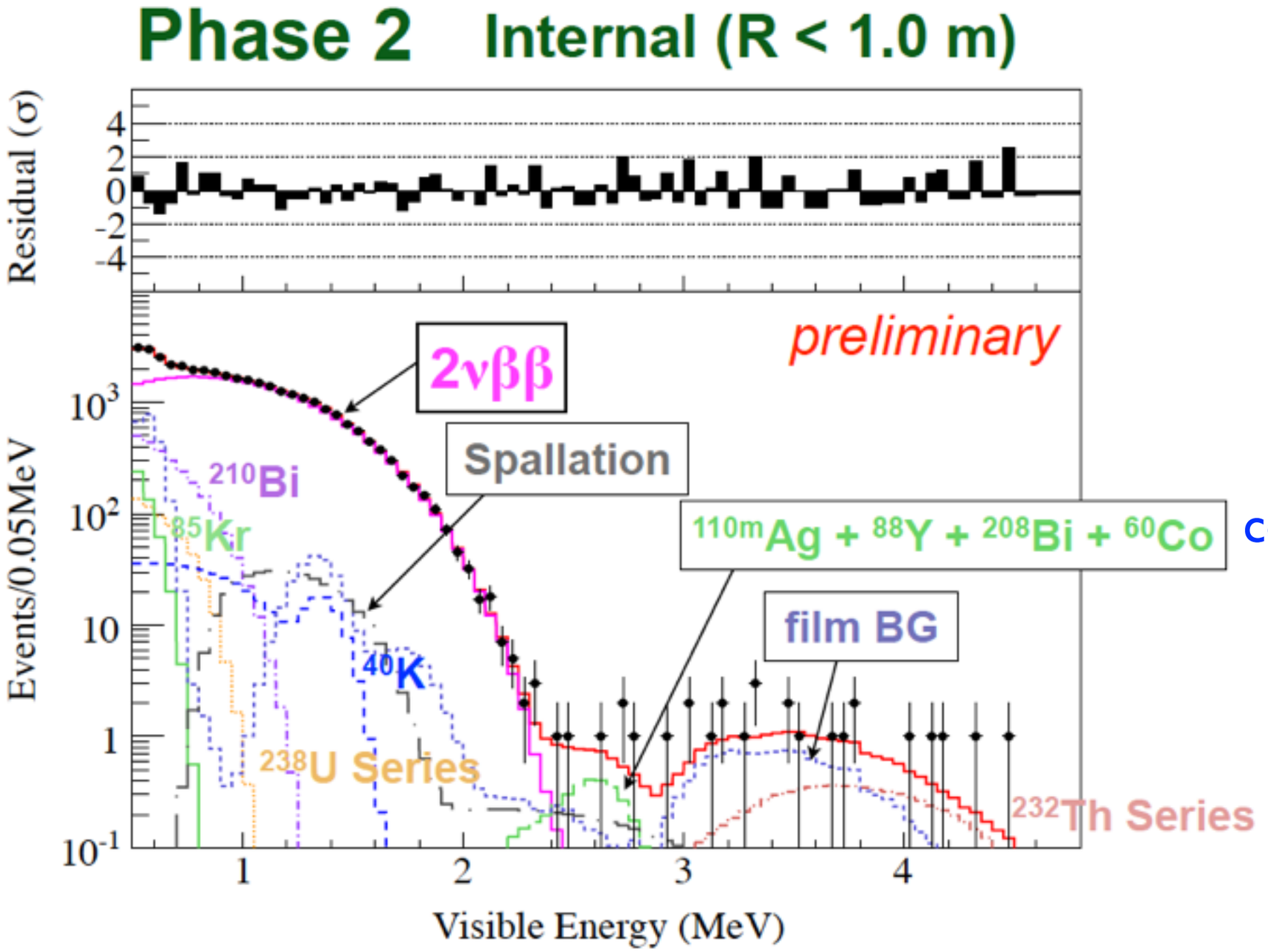
EXO 200



Bulk U/Th,
Rn,
n capture

Nature **510**, 229 (2014).

KamLAND-Zen

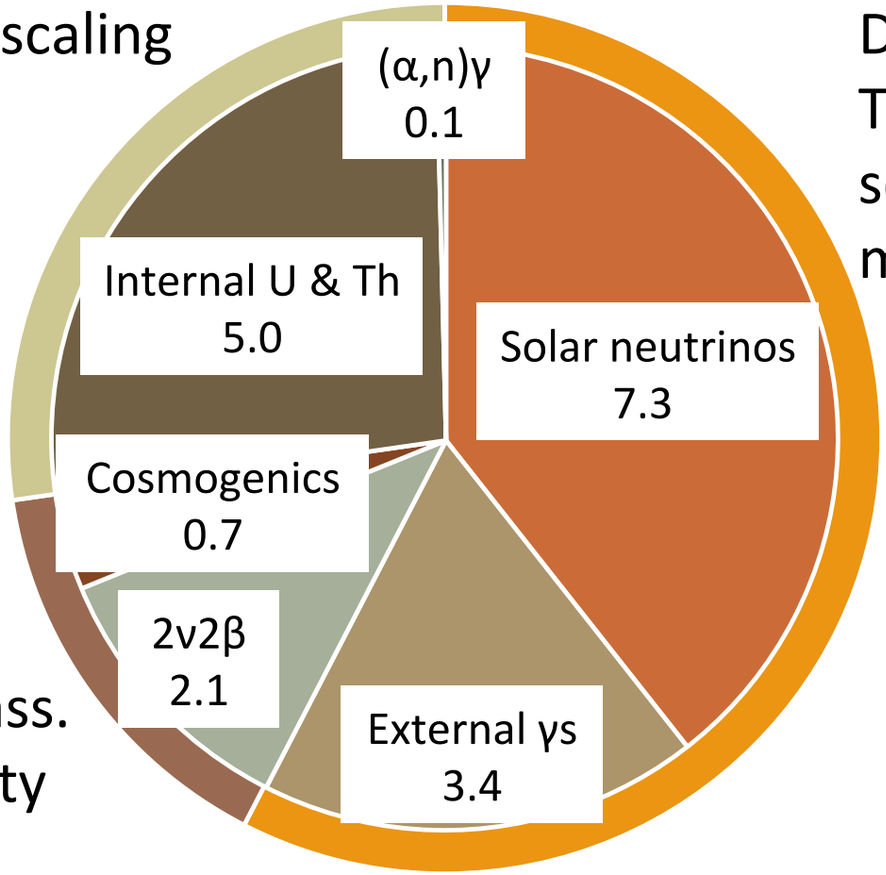


Surface contamination, Cosmogenic Activation

Shimizu, Neutrino 2014.

SNO+ Backgrounds

Intermediate scaling with Te mass.



Do not scale with Te mass. Half-life sensitivity scales as $m^{-1}t^{-½}$

Scale with Te mass. Half-life sensitivity scales as$(mt)^{-½}$

Tolich, private communication.