Background from Crystal PMTs

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Motivation for the Analysis

Crystal PMTs simulations so far:

- Activity values from material samples (E. Aprile et al., EPJ C, 75:546, 2015, Tables #3 and 4) not coming from a specific, already assembled, PMT.
- In the same paper are also shown measures about pieces extracted directly from a PMT (Table #5). Analysis results highlight higher activities.

Table #5

PMT version (nr. of units)	Batch nr.	t [d]	Activity [mBq/PMT]						
			^{238}U	^{226}Ra	^{235}U	^{228}Ra	^{228}Th	^{40}K	^{60}Co
v-20 (10)	0	15	< 18	< 0.82	< 0.79	0.9(3)	0.9(2)	12(2)	1.3(2)
v-21 (10)	1	26	< 18	0.4(1)	0.5(1)	< 1.1	0.4(1)	12(2)	0.7(1)
v-21 (16)	2	15	< 16	0.5(1)	0.29(9)	< 0.85	< 0.61	13(2)	0.79(8)
v-21 (15)	3	11	< 20	< 0.82	< 0.52	< 1.1	0.5(2)	13(2)	0.73(9)
v-21 (15)	4	22	< 13	0.5(1)	0.35(9)	0.4(1)	0.4(1)	12(2)	0.73(9)
v-21 (15)	5	16	< 17	0.6(1)	< 0.57	< 0.93	< 0.62	14(2)	0.63(7)
v-21 (11)	6	23	< 15	0.6(1)	< 0.55	< 0.77	0.7(1)	14(2)	0.71(7)
v-21 (4)[1]	6b	39	–	0.5(1)	< 0.30	0.3(1)	0.3(1)	8(1)	0.9(1)
v-21 (11)	7	23	< 19	1.0(1)	0.4(1)	< 0.77	0.7(1)	15(2)	1.0(1)
v-21 (15)	8	14	< 20	0.9(2)	< 0.85	0.7(2)	1.0(2)	20(3)	1.2(1)
v-21 (4)[1]	8b	36	–	0.7(1)	< 0.36	0.3(1)	0.2(1)	10(1)	1.4(2)
v-21 (15)	9	20	< 14	0.57(9)	< 0.44	< 0.79	0.5(1)	13(2)	0.81(8)
v-21 (15)	10	26	< 15	0.45(7)	< 0.44	0.5(1)	0.45(8)	13(2)	0.87(8)
v-21 (15)	11	12	< 10	0.5(2)	< 0.47	< 1.17	0.6(1)	12(2)	0.77(9)
v-21 (15)	12	18	< 10	< 0.71	< 0.45	0.7(2)	0.7(1)	11(2)	0.78(8)
v-21 (15)	13	34	< 10	0.50(6)	0.38(8)	0.6(1)	0.50(7)	12(1)	0.82(7)
v-21 (15)	14	21	< 16	0.53(8)	< 0.41	< 0.82	0.5(1)	14(2)	0.81(8)

Activities used so far in MC Analysis

PMT component	Isotope	Activity (mBq/PMT)
Kovar Body	^{40}K	< 0.99
	^{60}Co	7.0 e-02
	^{238}U	< 0.095
	^{226}Ra	< 0.26
	^{232}Th	< 0.0032
	^{228}Th	< 0.34
Quartz Window	^{40}K	< 8.1e-02
	^{60}Co	< 4.5e-03
	^{238}U	< 0.33
	^{226}Ra	0.036
	^{232}Th	< 1.2e-02
	^{228}Th	< 1.2e-02
Ceramic Feedthrough	^{40}K	1.1
	^{60}Co	< 0.02
	^{238}U	2.4
	^{226}Ra	0.26
	^{232}Th	0.23
	^{228}Th	0.11

Newest analysis goal:

- Background estimation by using activities measured from an already assembled PMT.
- Activities re-scaling to spread values in the whole volume (e.g. Body, Window, Feedthrough Plate) since the PMT mass position is unknown.

Activities Re-Scaling Process

PMT version (nr. of units)	Batch nr.	t [d]	Activity [mBq/PMT]						
			^{238}U	^{226}Ra	^{235}U	^{228}Ra	^{228}Th	^{40}K	^{60}Co
v-20 (10)	0	15	< 18	< 0.82	< 0.79	0.9(3)	0.9(2)	12(2)	1.3(2)
v-21 (10)	1	26	< 18	0.4(1)	0.5(1)	< 1.1	0.4(1)	12(2)	0.7(1)
v-21 (16)	2	15	< 16	0.5(1)	0.29(9)	< 0.85	< 0.61	13(2)	0.79(8)
v-21 (15)	3	11	< 20	< 0.82	< 0.52	< 1.1	0.5(2)	13(2)	0.73(9)
v-21 (15)	4	22	< 13	0.5(1)	0.35(9)	0.4(1)	0.4(1)	12(2)	0.73(9)
v-21 (15)	5	16	< 17	0.6(1)	< 0.57	< 0.93	< 0.62	14(2)	0.63(7)
v-21 (11)	6	23	< 15	0.6(1)	< 0.55	< 0.77	0.7(1)	14(2)	0.71(7)
v-21 (4)[1]	6b	39	–	0.5(1)	< 0.30	0.3(1)	0.3(1)	8(1)	0.9(1)
v-21 (11)	7	23	< 19	1.0(1)	0.4(1)	< 0.77	0.7(1)	15(2)	1.0(1)
v-21 (15)	8	14	< 20	0.9(2)	< 0.85	0.7(2)	1.0(2)	20(3)	1.2(1)
v-21 (4)[1]	8b	36	–	0.7(1)	< 0.36	0.3(1)	0.2(1)	10(1)	1.4(2)
v-21 (15)	9	20	< 14	0.57(9)	< 0.44	< 0.79	0.5(1)	13(2)	0.81(8)
v-21 (15)	10	26	< 15	0.45(7)	< 0.44	0.5(1)	0.45(8)	13(2)	0.87(8)
v-21 (15)	11	12	< 10	0.5(2)	< 0.47	< 1.17	0.6(1)	12(2)	0.77(9)
v-21 (15)	12	18	< 10	< 0.71	< 0.45	0.7(2)	0.7(1)	11(2)	0.78(8)
v-21 (15)	13	34	< 10	0.50(6)	0.38(8)	0.6(1)	0.50(7)	12(1)	0.82(7)
v-21 (15)	14	21	< 16	0.53(8)	< 0.41	< 0.82	0.5(1)	14(2)	0.81(8)
Average = Atot			**15.4**	**0.62**	**4.70 e-02**	**0.75**	**0.56**	**12.82**	**0.88**

$$A1' = A1 \times \frac{Atot}{(A1 + A2 + A3)}$$

Re-scaling process:

- Average (Atot) of activities from all PMT parts.
- Redistribution of activity value by using the newest and the previous value.

PMT component	Isotope	Activity (mBq/PMT)	
Kovar Body	^{40}K	< 0.99	A1
	^{60}Co	7.0 e-02	
	^{238}U	< 0.095	
	^{226}Ra	< 0.26	
	^{232}Th	< 0.0032	
	^{228}Th	< 0.34	
Quartz Window	^{40}K	< 8.1e-02	A2
	^{60}Co	< 4.5e-03	
	^{238}U	< 0.33	
	^{226}Ra	0.036	
	^{232}Th	< 1.2e-02	
	^{228}Th	< 1.2e-02	
Ceramic Feedthrough	^{40}K	1.1	A3
	^{60}Co	< 0.02	
	^{238}U	2.4	
	^{226}Ra	0.26	
	^{232}Th	0.23	
	^{228}Th	0.11	

Activities Re-Scaling Outcomes

PMT component	Isotope	Previous Activity (mBq/PMT)	Newest Rescaled Activity (mBq/PMT)	Ratio Rescaled Activity/Previous Activity
Kovar Body	^{40}K	< 0.99	< 5.848	5.9
	^{60}Co	7.0 e-02	6.514 e-01	9.3
	^{238}U	< 0.095	< 5.179 e-01	5.4
	^{226}Ra	< 0.26	< 2.916 e-01	1.1
	^{232}Th	< 0.0032	< 9.749 e-03	3.0
	^{228}Th	< 0.34	< 4.156 e-01	1.2
Quartz Window	^{40}K	< 8.1e-02	< 4.784 e-01	5.9
	^{60}Co	< 4.5e-03	< 4.188 e-02	9.3
	^{238}U	< 0.33	< 1.799	5.4
	^{226}Ra	0.036	4.037 e-02	1.1
	^{232}Th	< 1.2e-02	< 3.656 e-02	3.0
	^{228}Th	< 1.2e-02	< 1.467 e-02	1.2
Ceramic Feedthrough	^{40}K	1.1	6.497	5.9
	^{60}Co	< 0.02	< 1.861 e-01	9.3
	^{238}U	2.4	13.083	5.4
	^{226}Ra	0.26	2.916 e-01	1.1
	^{232}Th	0.23	7.007 e-01	3.0
	^{228}Th	0.11	1.344 e-01	1.2

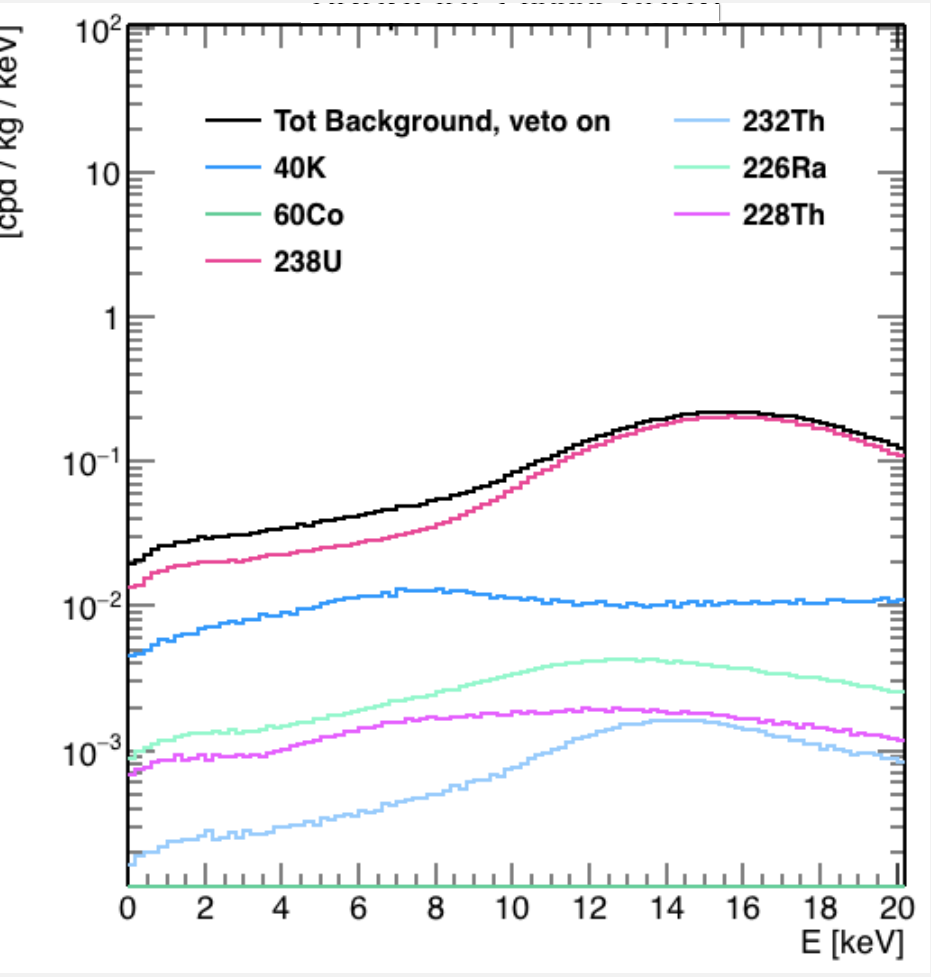
Analysis Results

Isotope	Previous Bkg cpd/kg/keV	Newest Bkg cpd/kg/keV	Ratio
^{40}K	1.73 e-03	1.02 e-02	5.9
^{60}Co	2.18 e-04	2.01 e-03	9.2
^{238}U	4.36 e-03	2.37 e-02	5.4
^{226}Ra	3.13 e-03	3.47 e-03	1.1
^{232}Th	3.39 e-04	1.07 e-03	3.2
^{228}Th	1.83 e-03	2.23 e-03	1.2
Total	1.16 e-02	4.27 e-02	**3.7**

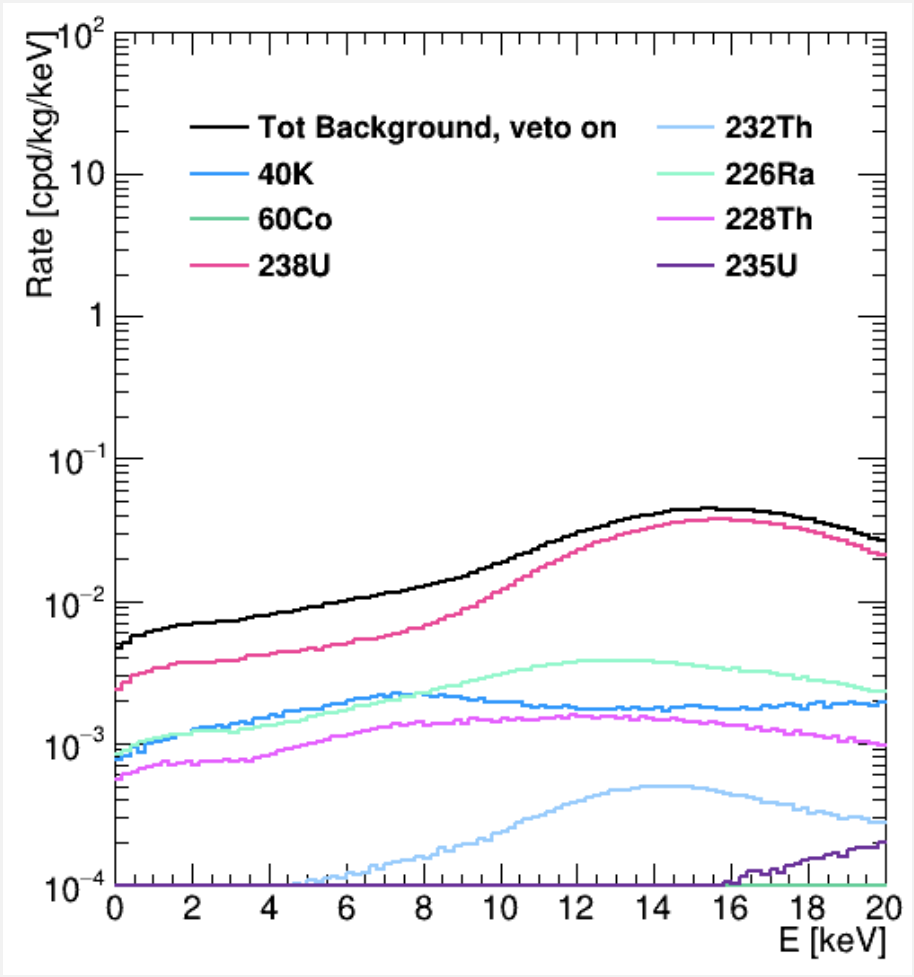
Isotope	Previous Bkg DMM(cpd/kg/keV)	Newest Bkg DMM(cpd/kg/keV)	Ratio	Previous Bkg KMM(cpd/kg/keV)	Newest Bkg KMM(cpd/kg/keV)	Ratio
^{40}K	1.54 e-03	9.04 e-03	5.9	6.08 e-05	3.50 e-04	5.8
^{60}Co	5.44 e-06	4.96 e-05	9.1	4.56 e-05	4.12 e-04	9.0
^{238}U	4.22 e-03	2.29 e-02	5.4	2.47 e-06	9.61 e-06	3.9
^{226}Ra	1.37 e-03	1.52 e-03	1.1	2.10 e-04	2.33 e-04	1.1
^{232}Th	9.41 e-05	2.98 e-04	3.2	1.41 e-05	4.49 e-05	3.2
^{228}Th	8.67 e-04	1.06 e-03	1.2	4.25 e-05	5.19 e-05	1.2
Total	8.10 e-03	3.42 e-02	**4.3**	3.75 e-04	1.13 e-03	**2.9**

Background with veto

Newest Bkg cpd/kg/keV

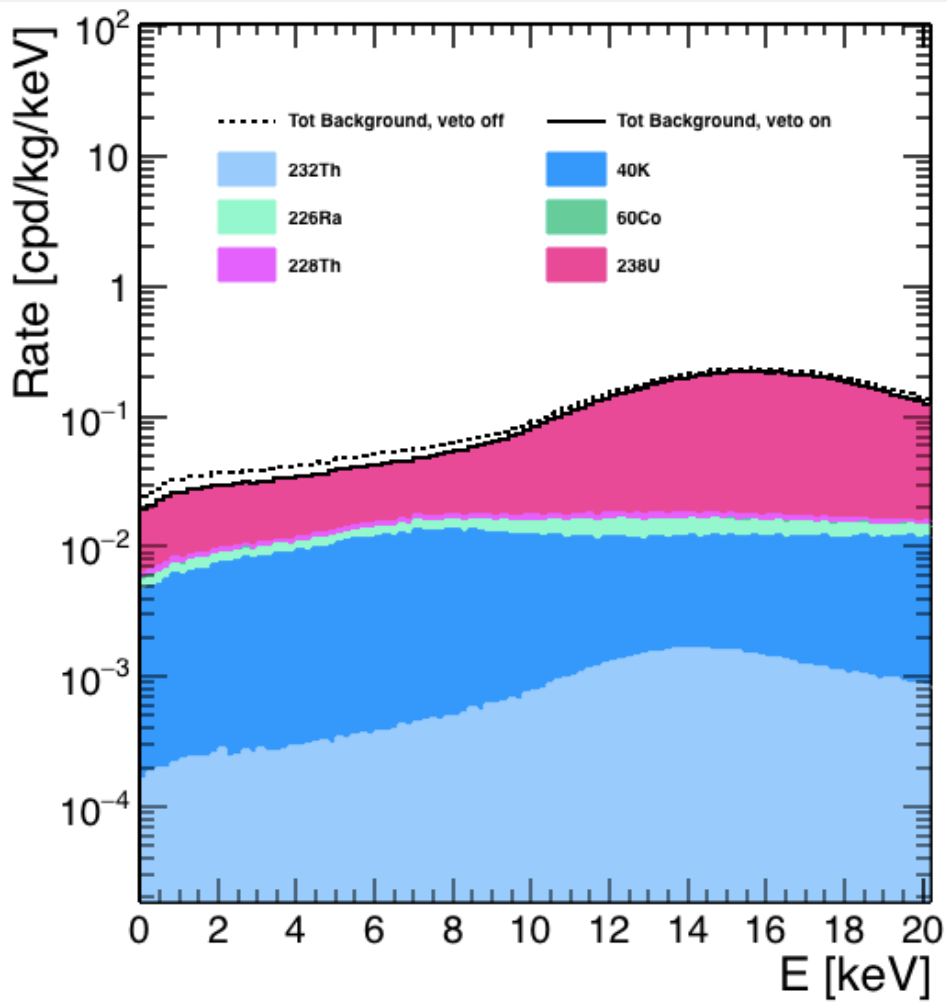


Previous Bkg cpd/kg/keV

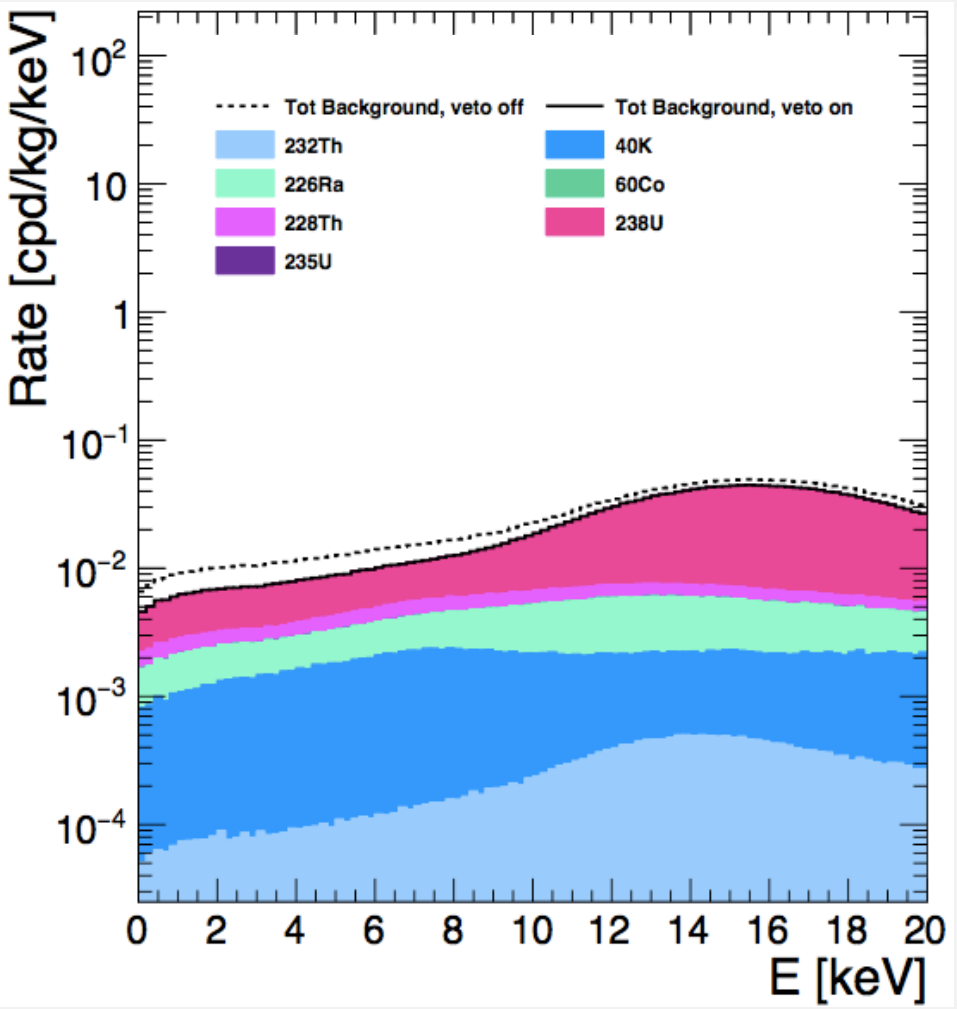


Background comparison veto on/off

Newest Bkg cpd/kg/keV



Previous Bkg cpd/kg/keV



Conclusions

- Activities measured from an already assembled PMT have been taken into account in order to simulate the background.

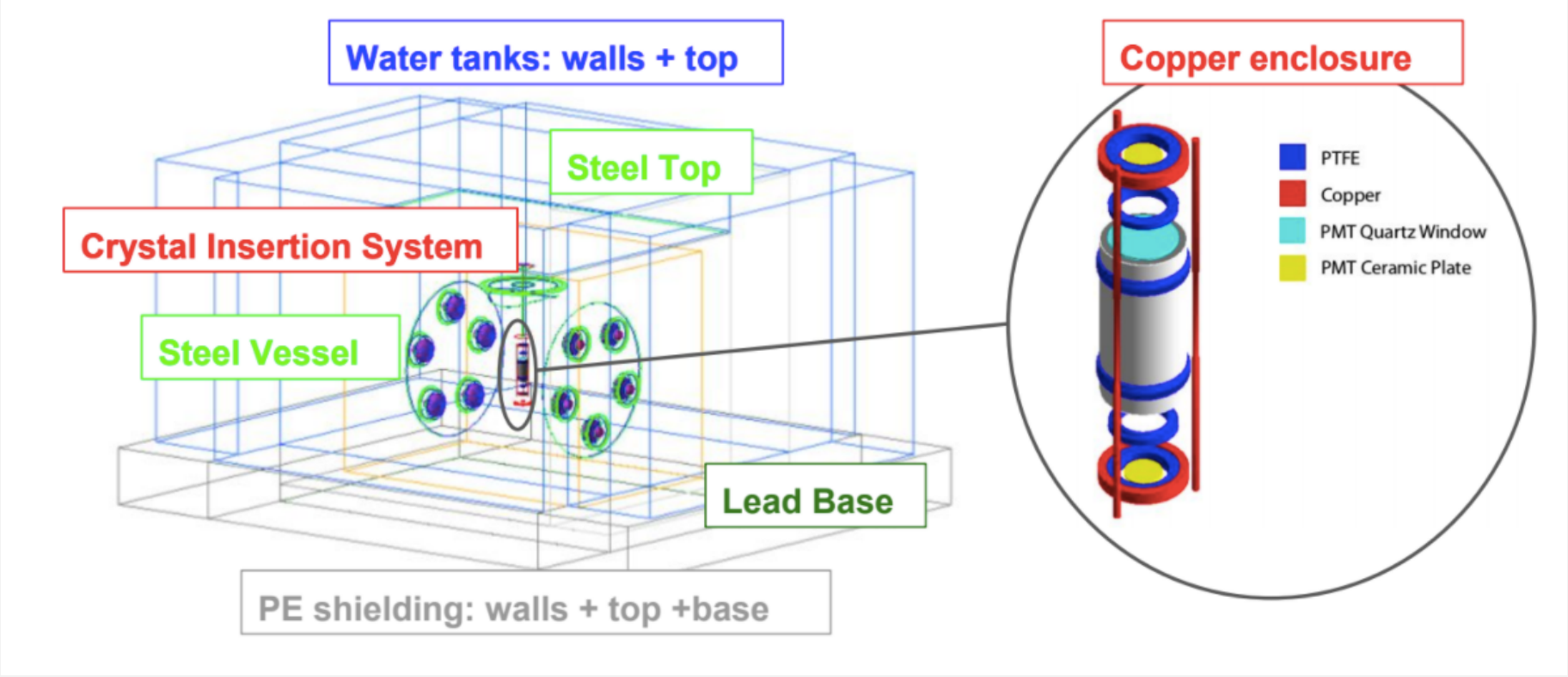
- Final activities have been calculated thru a re-scaling of newest and previous activities in order to spread their values in the whole volume of PMT since the radioactivity position is unknown.

- Final activities are higher than previous ones from a factor 1.1 for ^{226}Ra (lower chain of ^{238}U) to about 9 times higher for ^{60}Co.

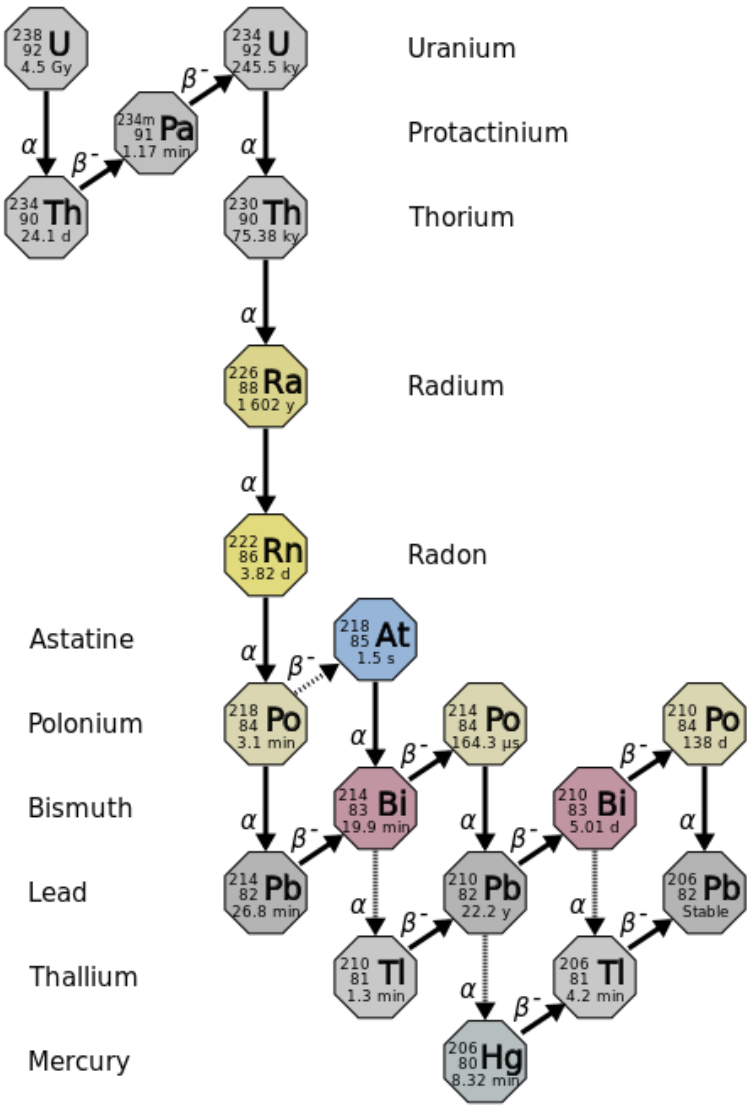
- The overall simulated **background** is **about 4 times higher** than the previous one.

BACK UP

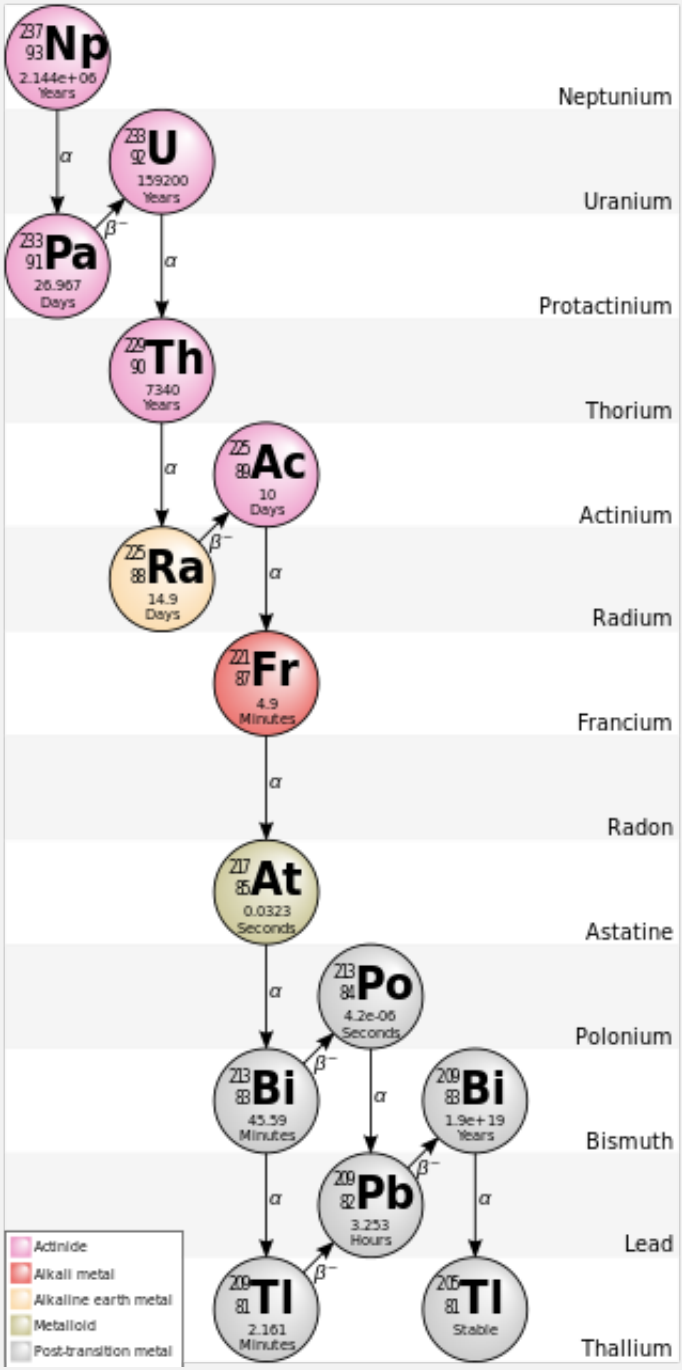
Background simulation of the PoP



parent nuclide	decay mode	branch chance	half life	energy released, MeV
^{238}U	α	100 %	$4.468 \cdot 10^9$ a	4.26975
^{234}U	α	100 %	$2.455 \cdot 10^5$ a	4.8598
^{234}Th	β^-	100 %	24.10 d	0.273088
^{234}Pa	β^-	100 %	6.70 h	2.194285
^{234m}Pa	IT	0.16 %	1.159 min	0.07392
^{234m}Pa	β^-	99.84 %	1.159 min	2.268205
^{230}Th	α	100 %	$7.54 \cdot 10^4$ a	4.76975
^{226}Ra	α	100 %	1600 a	4.87062
^{222}Rn	α	100 %	3.8235 d	5.59031
^{218}Rn	α	100 %	35 ms	7.26254
^{218}Po	β^-	0.020 %	3.098 min	0.259913
^{218}Po	α	99.980 %	3.098 min	6.11468
^{218}At	β^-	0.1 %	1.5 s	2.881314
^{218}At	α	99.9 %	1.5 s	6.874
^{214}Po	α	100 %	164.3 µs	7.83346
^{214}Pb	β^-	100 %	26.8 min	1.019237
^{214}Bi	β^-	99.979 %	19.9 min	3.269857
^{214}Bi	α	0.021 %	19.9 min	5.62119
^{210}Tl	β^-	100 %	1.30 min	5.48213
^{210}Po	α	100 %	138.376 d	5.40745
^{210}Pb	β^-	100 %	22.20 a	0.063487
^{210}Pb	α	$1.9 \cdot 10^{-6}$ %	22.20 a	3.7923
^{210}Bi	β^-	100 %	5.012 d	1.161234
^{210}Bi	α	$13.2 \cdot 10^{-5}$ %	5.012 d	5.03647
206Tl	β^-	100 %	4.202 min	1.532221
^{206}Pb	stable	-	-	-
^{206}Hg	β^-	100 %	8.32 min	1.307649



Nuclide	decay mode	half-life (*a*=year)	energy released, MeV
^{240}Np	β⁻	1.032 h	2.2
^{240}Pu	α	6561 a	5.1683
^{236}U	α	2.3×10^{7} a	4.494
^{232}Th	α	1.405×10^{10} a	4.081
^{228}Ra	β⁻	5.75 a	0.046
^{228}Ac	β⁻	6.25 h	2.124
^{228}Th	α	1.9116 a	5.520
^{224}Ra	α	3.6319 d	5.789
^{220}Rn	α	55.6 s	6.404
^{216}Po	α	0.145 s	6.906
^{212}Pb	β⁻	10.64 h	0.570
^{212}Bi	β⁻ 64.06% α 35.94%	60.55 min	2.252 6.208
^{212}Po	α	299 ns	8.955
^{208}Tl	β⁻	3.053 min	4.999
^{208}Pb	stable	.	.



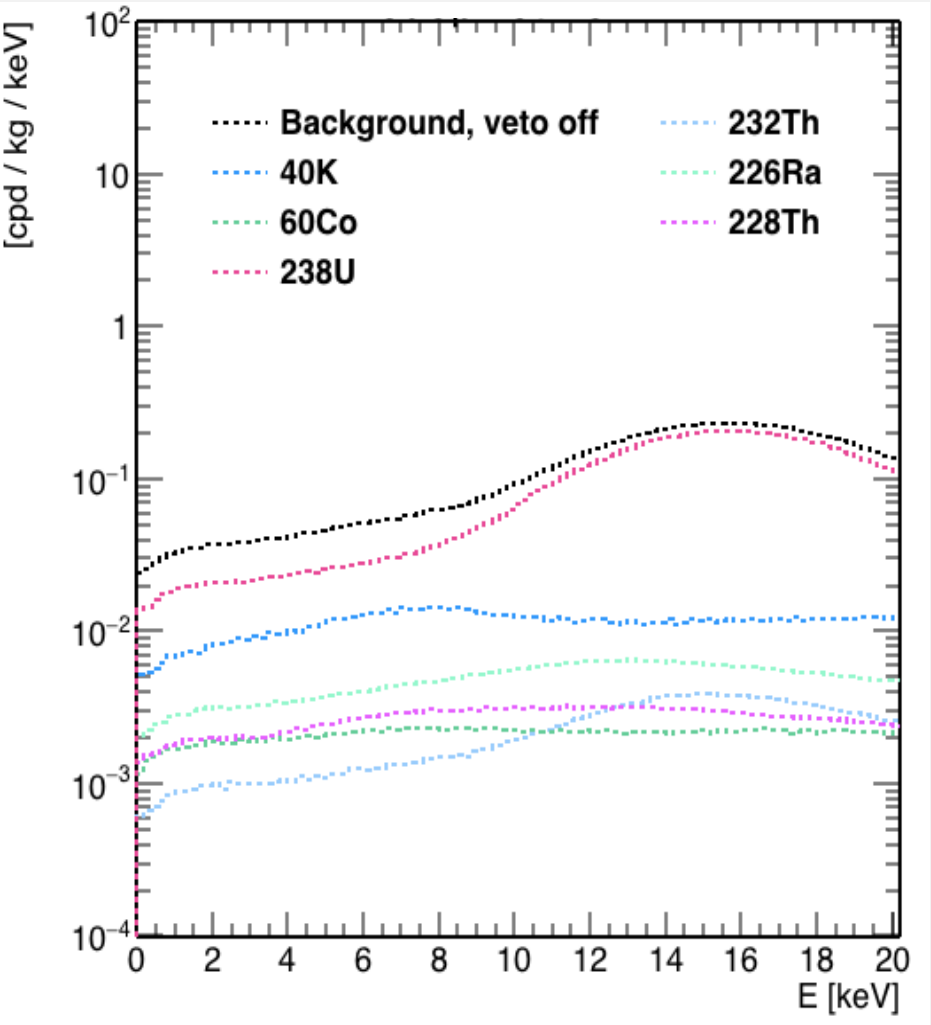
Analysis Results with MC errors– Rescaled Activities

Isotope	Previous Bkg cpd/kg/keV	Newest Bkg cpd/kg/keV	Ratio
^{40}K	1.73 e-03 ± 1 e-05	1.02 e-02 ± 6 e-05	5.9
^{60}Co	2.18 e-04 ± 1 e-06	2.01 e-03 ± 9 e-06	9.2
^{238}U	4.36 e-03 ±1 e-05	2.37 e-02 ± 7 e-05	5.4
^{226}Ra	3.13 e-03 ± 7 e-06	3.47 e-03 ± 8 e-06	1.1
^{232}Th	3.39 e-04 ± 2 e-06	1.07 e-03 ± 6 e-06	3.2
^{228}Th	1.83 e-03 ± 6 e-06	2.23 e-03 ± 7 e-06	1.2
Total	1.16 e-02 ± 2 e-05	4.27 e-02 ± 4 e-04	**3.7**

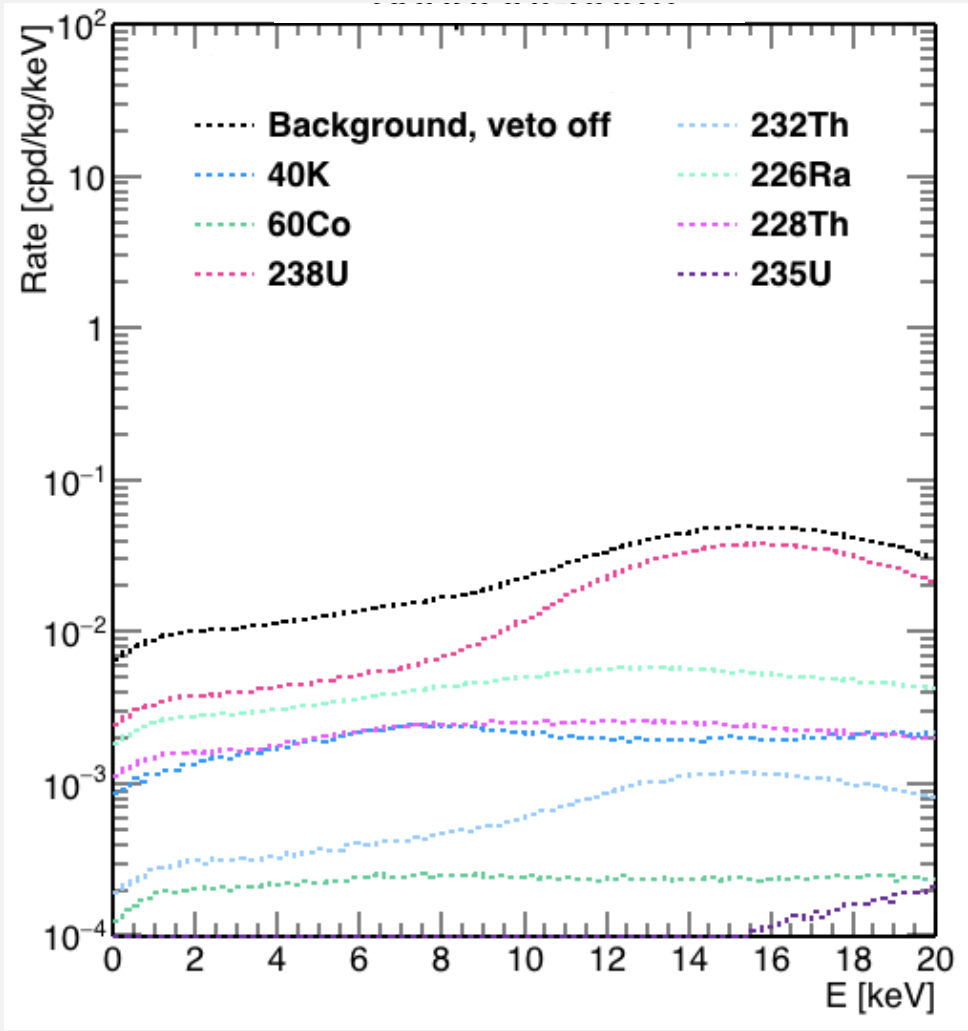
Isotope	Previous Bkg DMM(cpd/kg/keV)	Newest Bkg DMM(cpd/kg/keV)	Ratio	Previous Bkg KMM(cpd/kg/keV)	Newest Bkg KMM(cpd/kg/keV)	Ratio
^{40}K	1.54 e-03 ± 9 e-06	9.04 e-03 ± 5 e-05	5.9	6.08 e-05 ± 3 e-06	3.50 e-04 ± 2 e-05	5.8
^{60}Co	5.44 e-06 ± 2 e-07	4.96 e-05 ± 1 e-06	9.1	4.56 e-05 ± 7 e-07	4.12 e-04 ± 6 e-06	9.0
^{238}U	4.22 e-03 ± 1 e-05	2.29 e-02 ± 7 e-05	5.4	2.47 e-06 ± 5 e-07	9.61 e-06 ± 2 e-06	3.9
^{226}Ra	1.37 e-03 ± 4 e-06	1.52 e-03 ± 5 e-06	1.1	2.10 e-04 ± 3 e-06	2.33 e-04 ± 3 e-06	1.1
^{232}Th	9.41 e-05 ± 1 e-06	2.98 e-04 ± 3 e-06	3.2	1.41 e-05 ± 5 e-07	4.49 e-05 ± 2 e-06	3.2
^{228}Th	8.67 e-04 ± 4 e-06	1.06 e-03 ± 5 e-06	1.2	4.25 e-05 ± 1 e-06	5.19 e-05 ± 1 e-06	1.2
Total	8.10 e-03 ± 2 e-05	3.42 e-02 ± 9 e-05	**4.3**	3.75 e-04 ± 4 e-06	1.13 e-03 ± 2e-05	**2.9**

Background without veto

Newest Bkg cpd/kg/keV

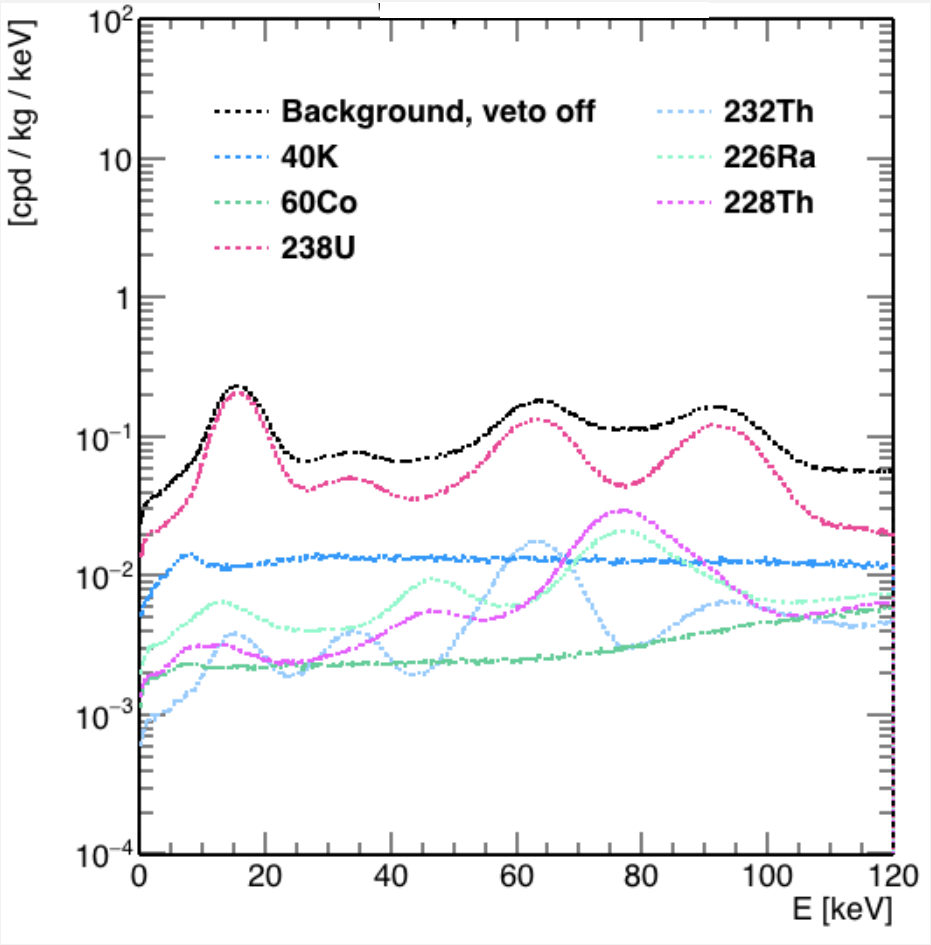


Previous Bkg cpd/kg/keV

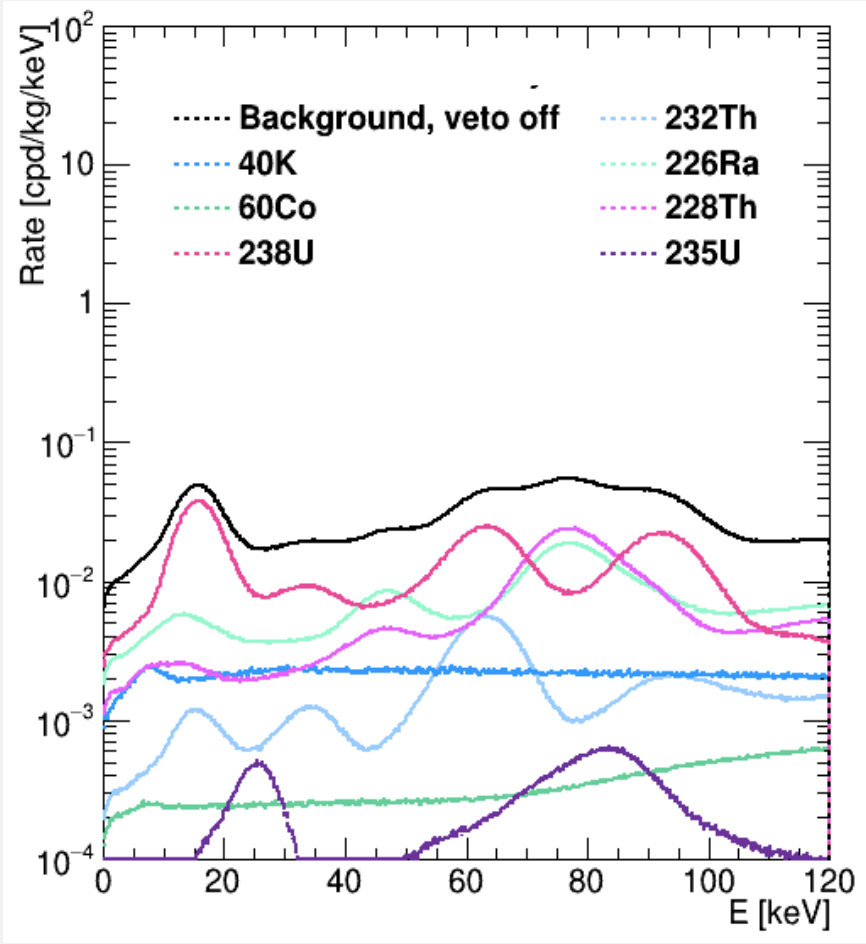


Background without veto

Newest Bkg cpd/kg/keV

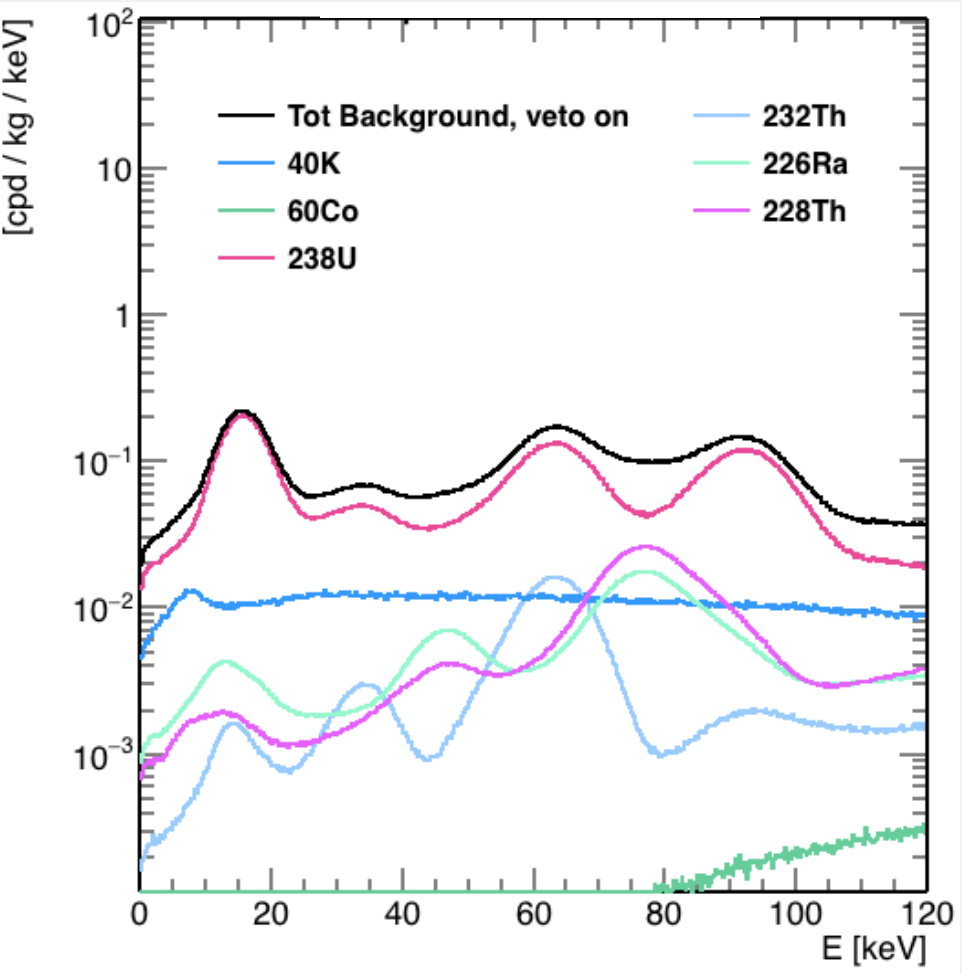


Previous Bkg cpd/kg/keV

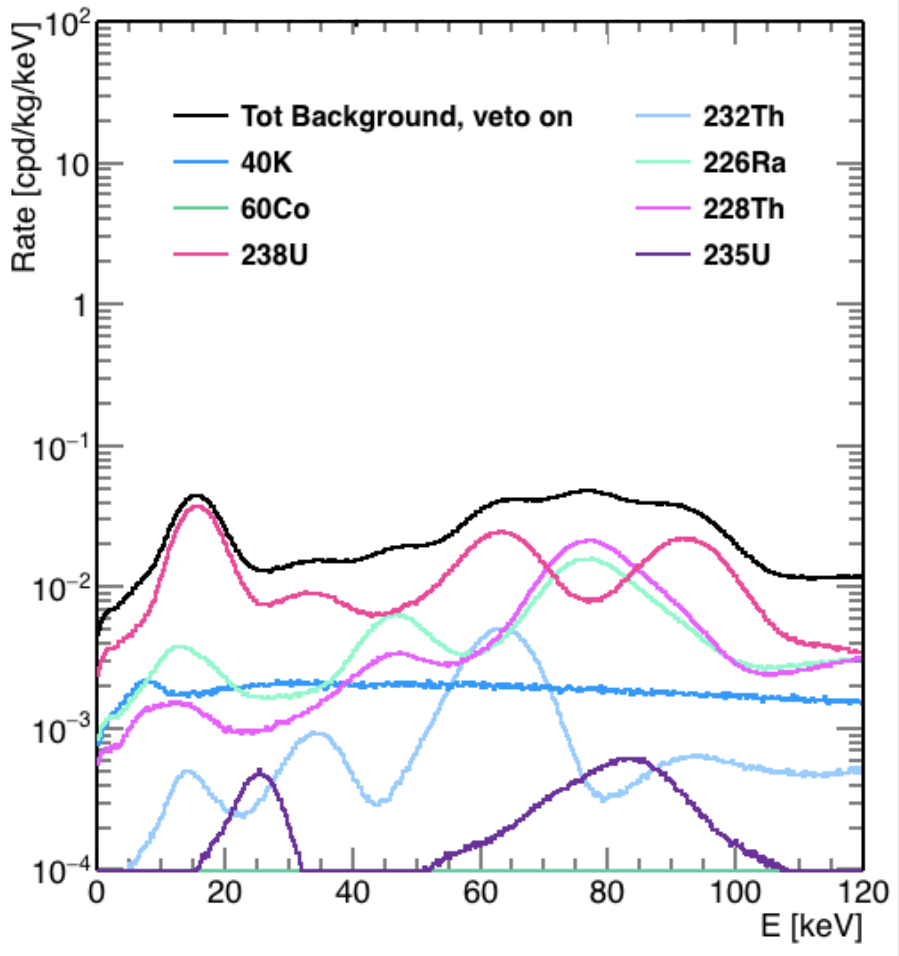


Background with veto

Newest Bkg cpd/kg/keV

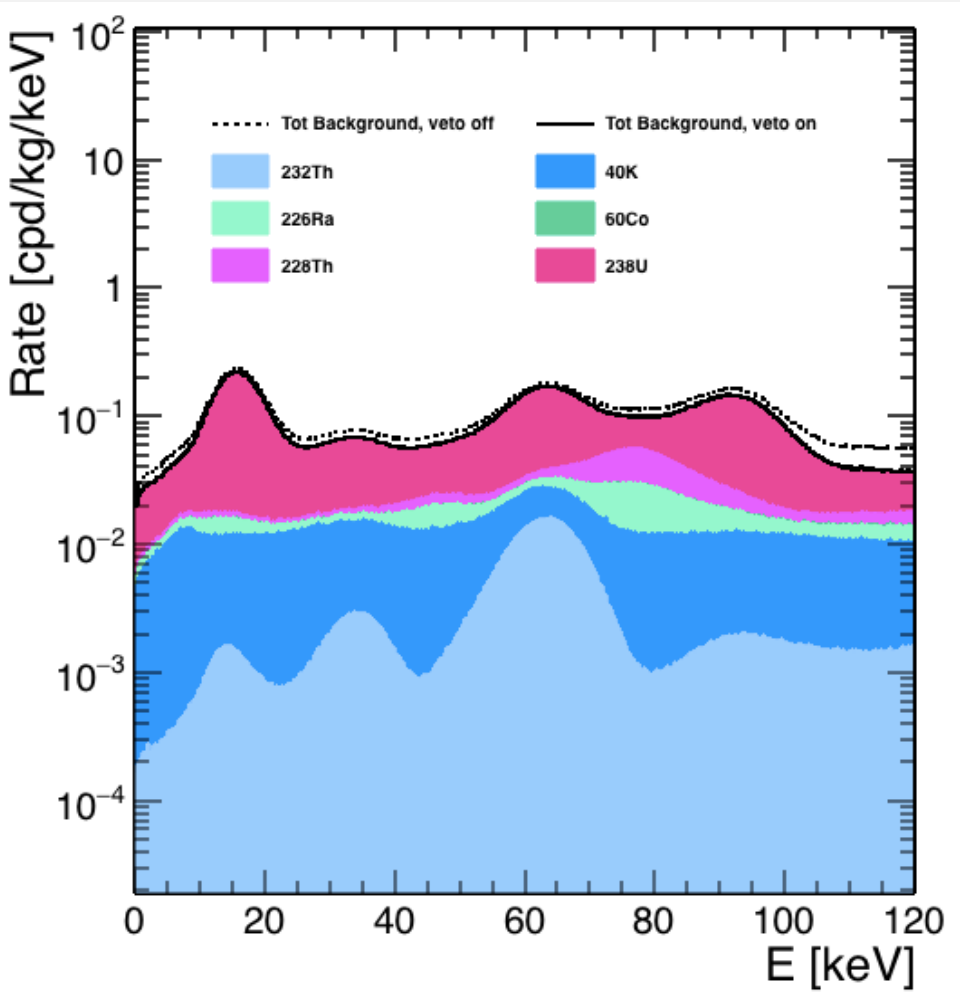


Previous Bkg cpd/kg/keV

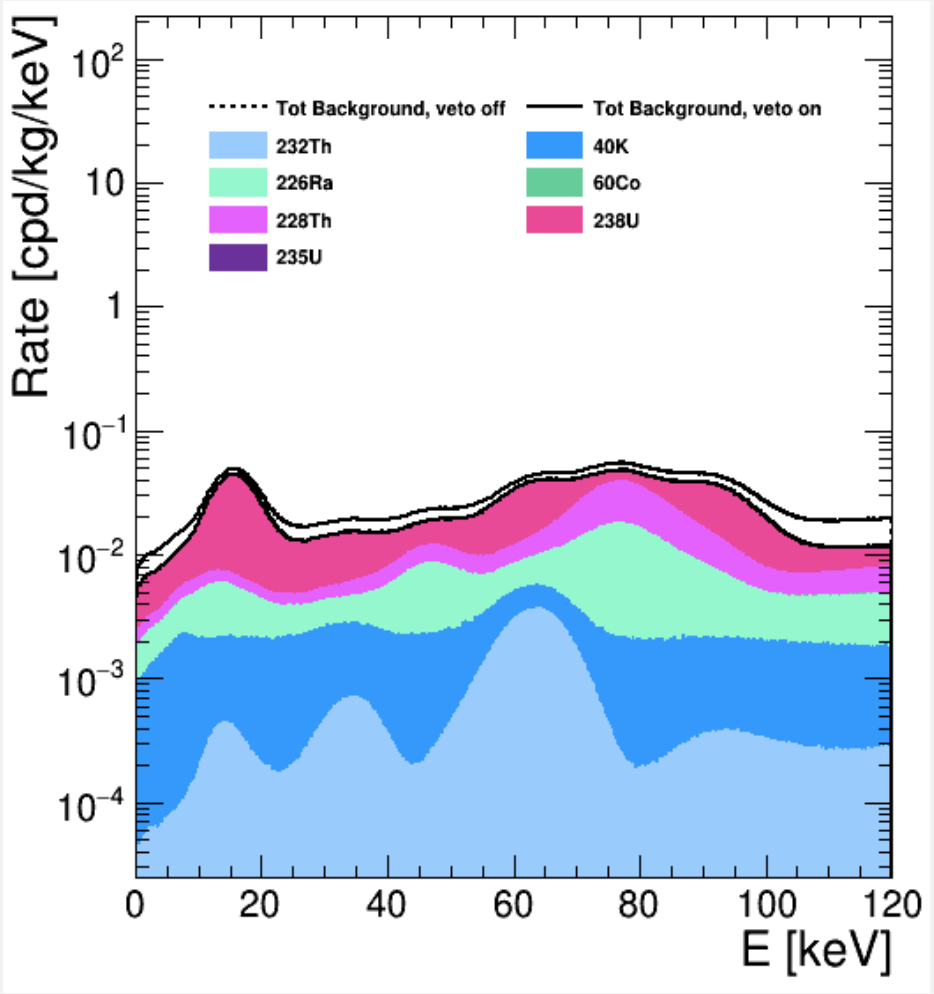


Background comparison veto on/off

Newest Bkg cpd/kg/keV

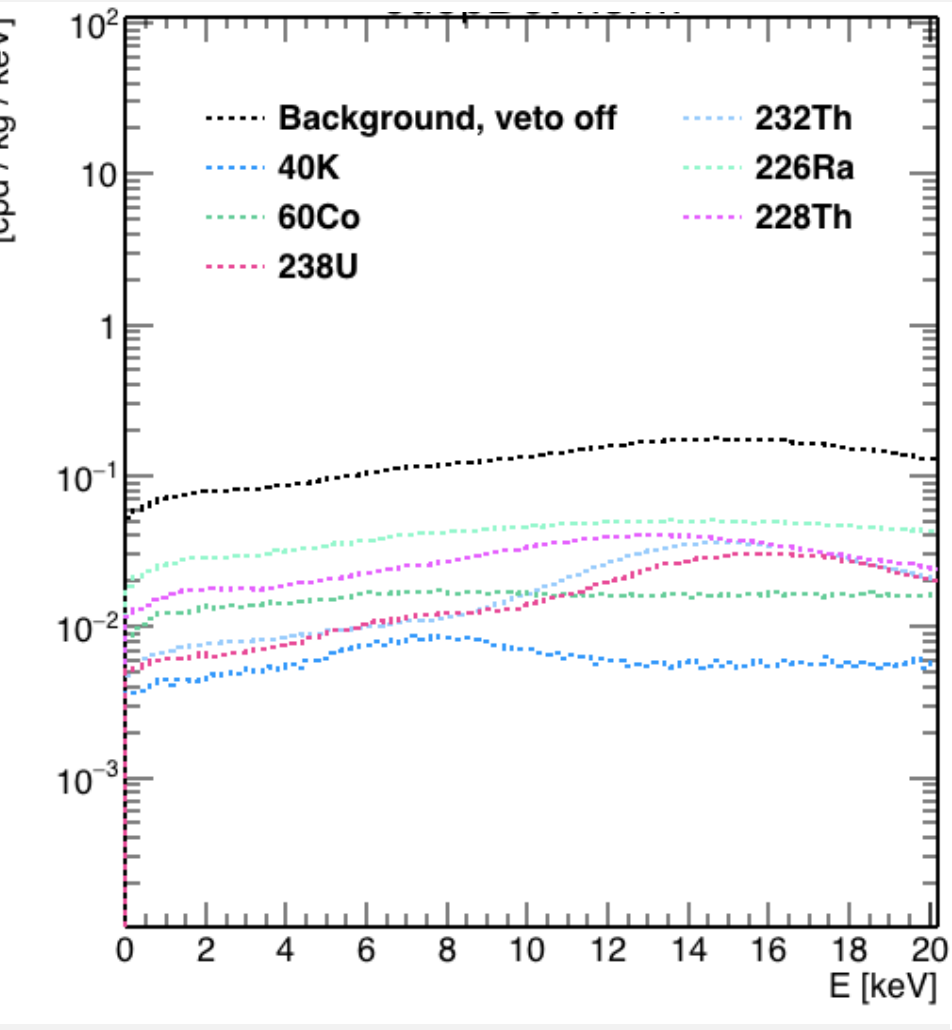


Previous Bkg cpd/kg/keV

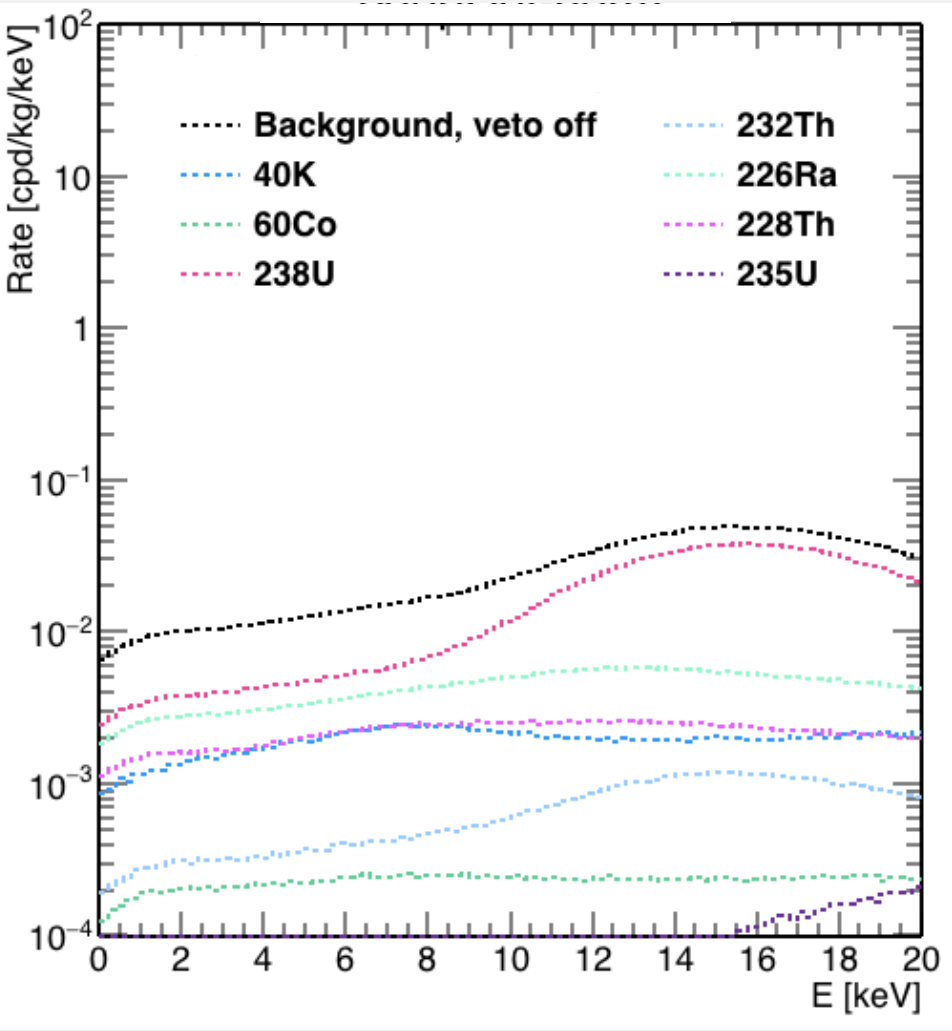


Background without veto – Hamamatsu Measurements

Newest Bkg cpd/kg/keV

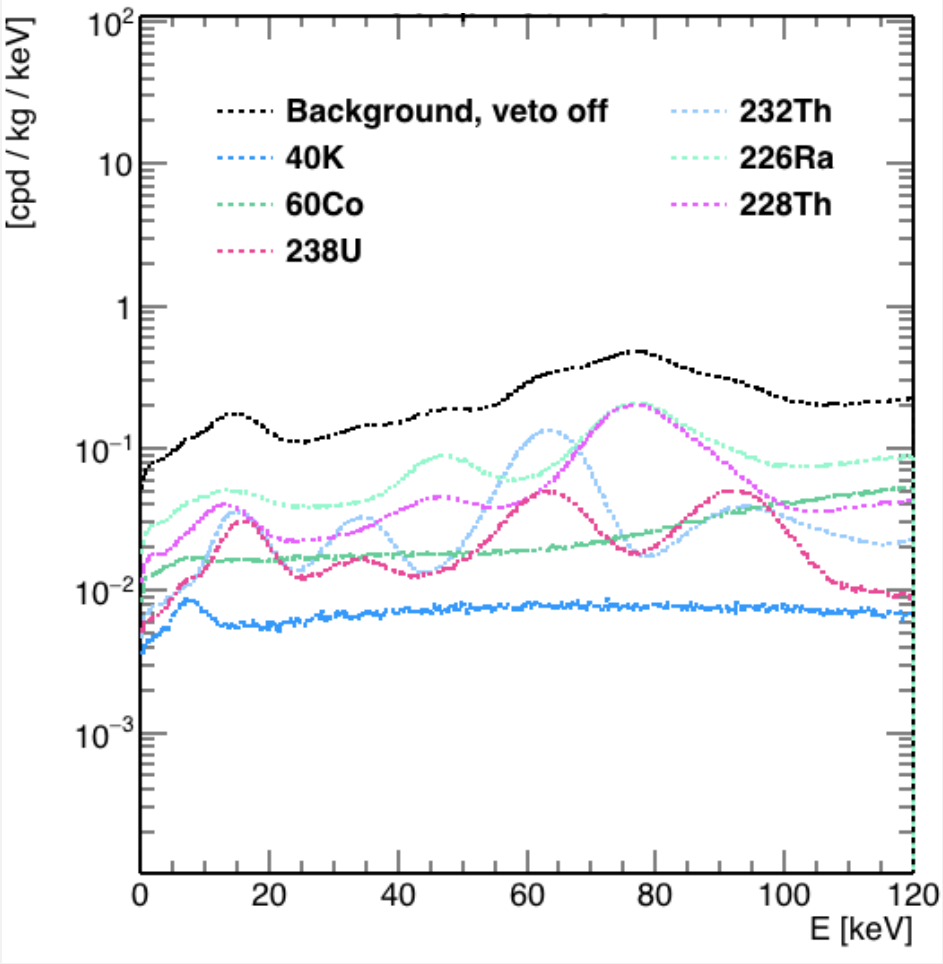


Previous Bkg cpd/kg/keV

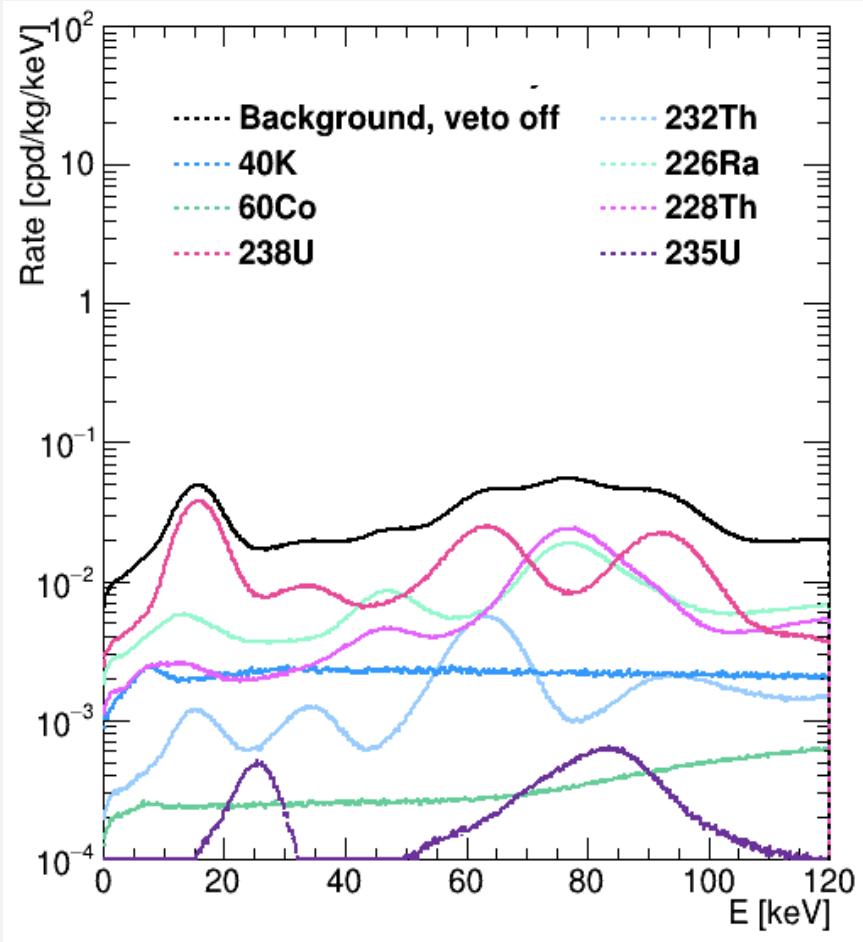


Background without veto – Hamamatsu Measurements

Newest Bkg cpd/kg/keV

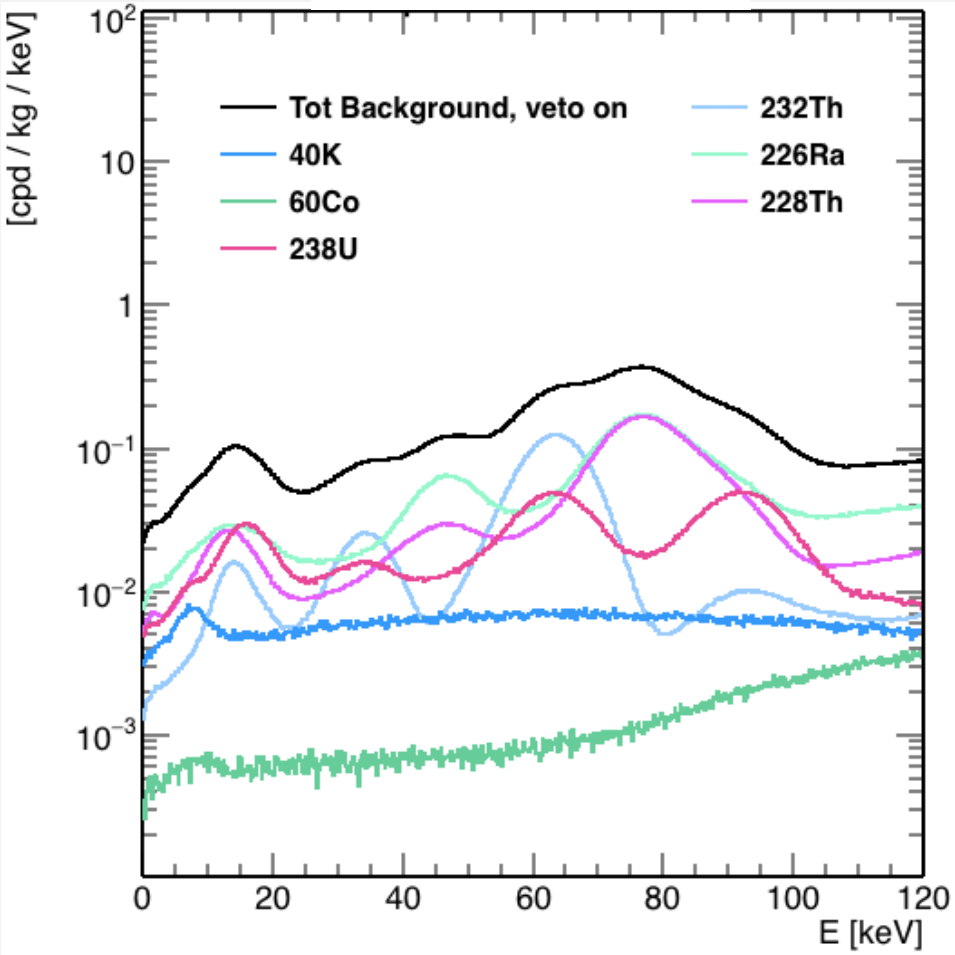


Previous Bkg cpd/kg/keV

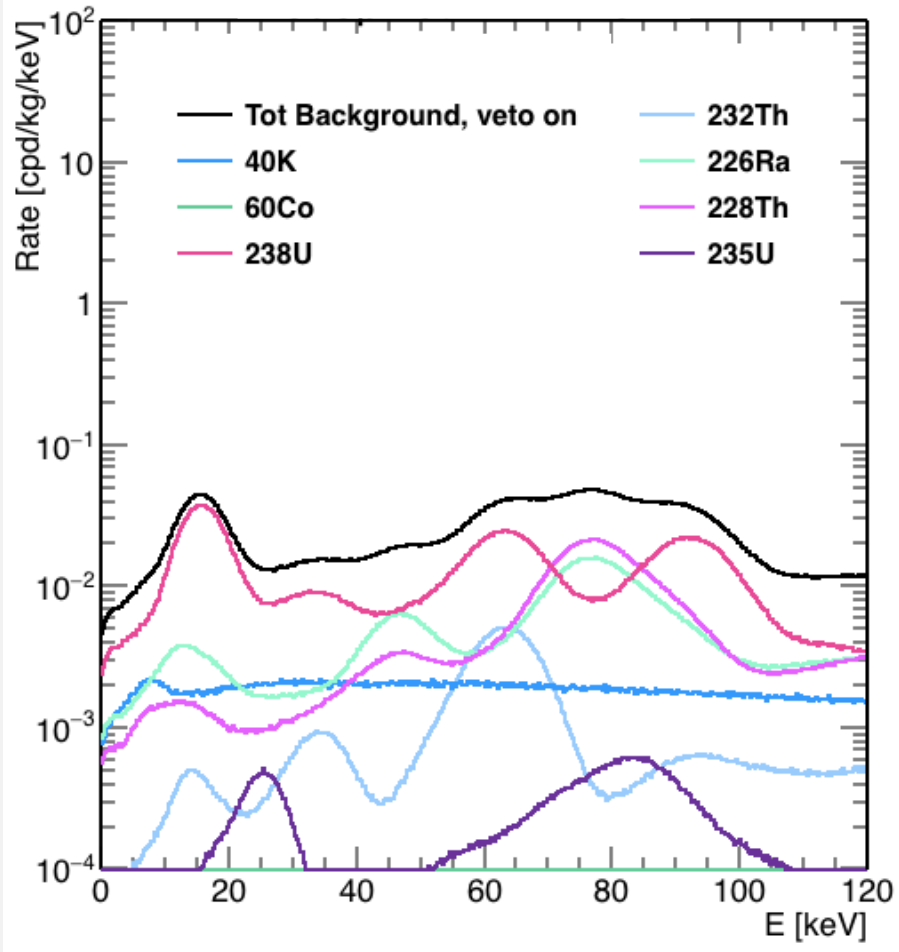


Background with veto – Hamamatsu Measurements

Newest Bkg cpd/kg/keV

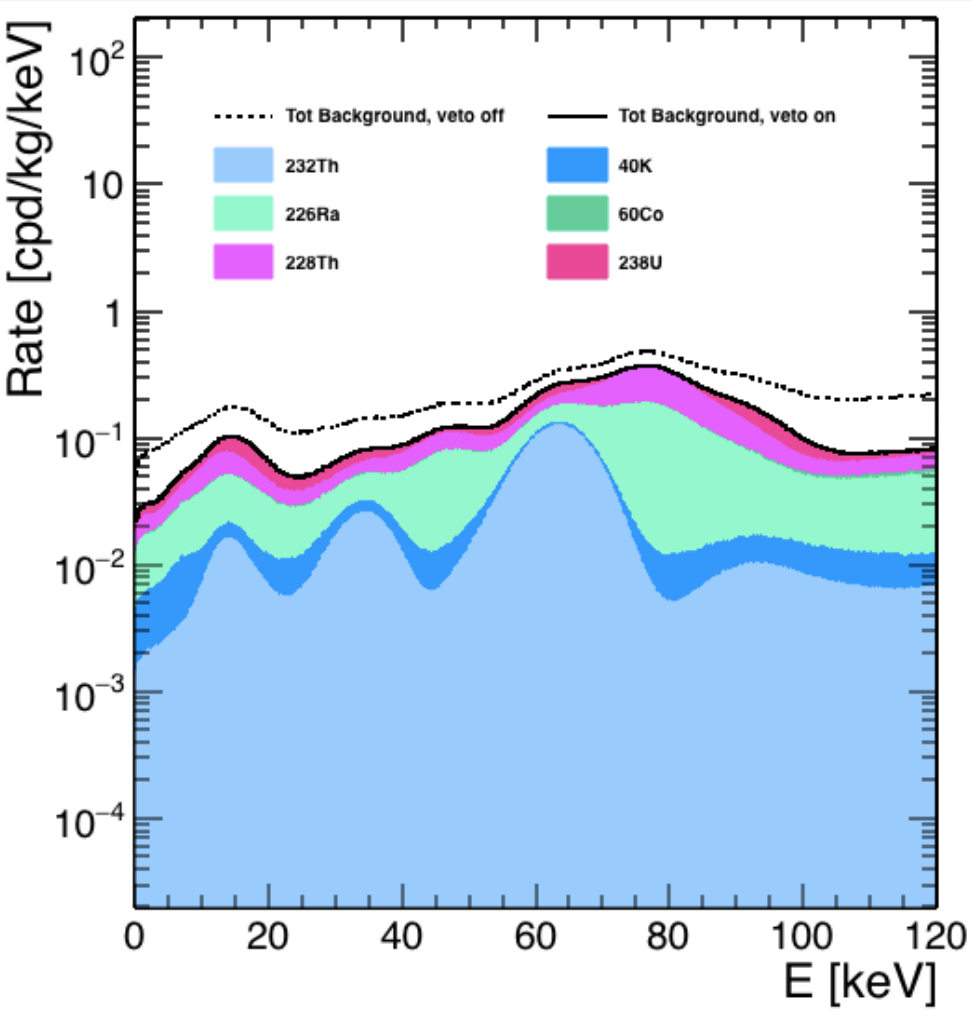


Previous Bkg cpd/kg/keV

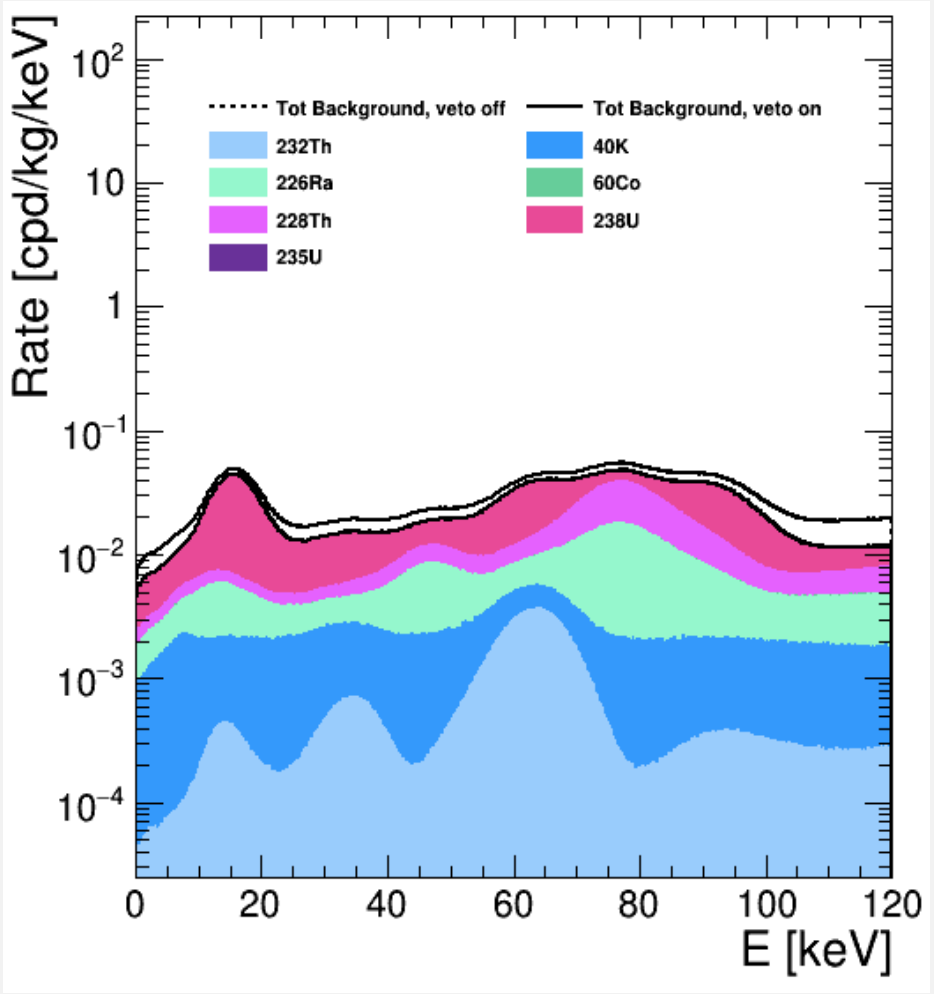


Background comparison veto on/off – Hamamatsu Measurements

Newest Bkg cpd/kg/keV



Previous Bkg cpd/kg/keV



Motivation for the Analysis

- Hamamatsu provided activity values divided by PMT parts for the same PMT model.
- Activities are different from Xenon measurements.
- The goal of the analysis is to check how background changes taking into account Hamamatsu measurements.

Estimated RI level

< Unit : mBq/PMT >

Materials	Weight (g)	40K	U	Th	Co60	Sub Total
Quartz Faceplate	35	0.0	0.2	0.4	0.1	0.7
Metal Bulb	95	5.7	2.9	1.0	3.5	13.1
Stem (ceramic)	25	0.0	0.0	0.7	5.5	6.2
Insulating Plates	16	0.0	0.1	0.2	0.0	0.3
Electrodes	31	0.0	0.1	0.0	0.0	0.1
Total	202	5.7	3.3	2.3	9.1	20.4

Expected RI level : 10~30 mBq/PMT

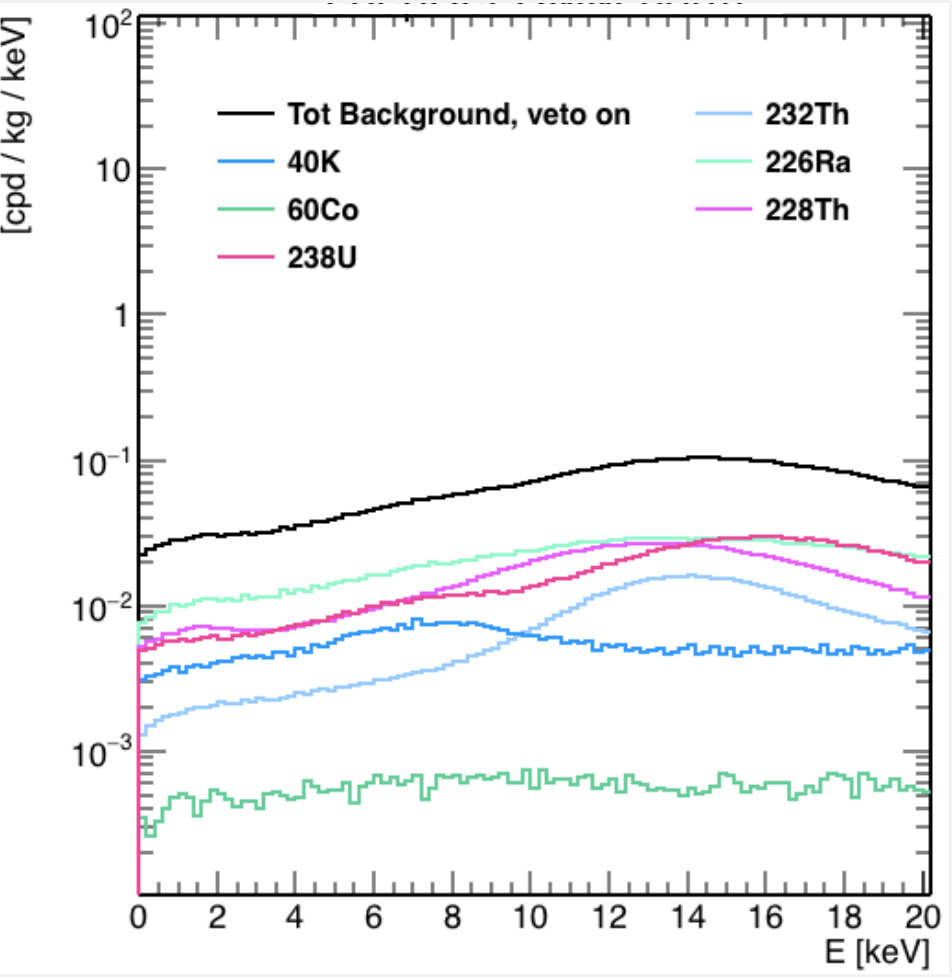
Analysis Results – Hamamatsu measurements

Isotope	Previous Bkg cpd/kg/keV	Hamamatsu Bkg cpd/kg/keV	Ratio
^{40}K	1.73 e-03	5.75 e-03	3.3
^{60}Co	2.18 e-04	1.45 e-02	66.5
^{238}U	4.36 e-03	7.87 e-03	1.8
^{226}Ra	3.13 e-03	3.20 e-02	10.2
^{232}Th	3.39 e-04	8.64 e-03	25.5
^{228}Th	1.83 e-03	1.93 e-02	10.5
Total	1.16 e-02	8.81 e-02	**7.6**

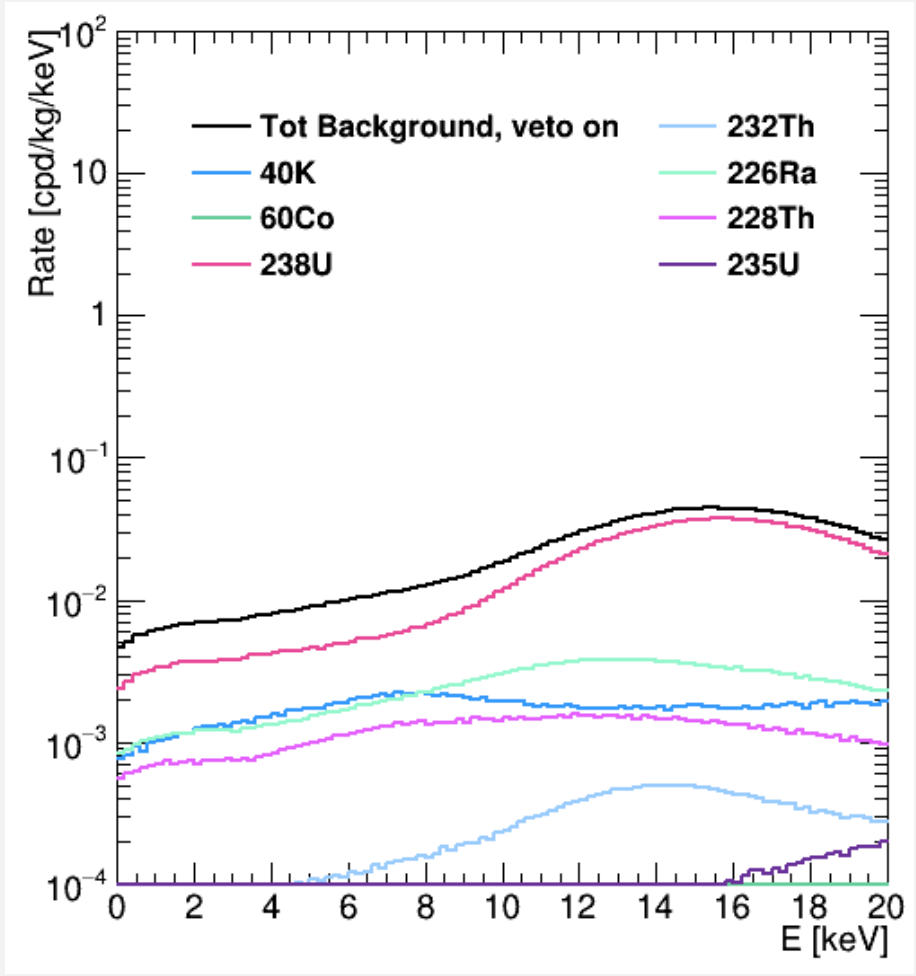
Isotope	Previous Bkg DMM(cpd/kg/keV)	Hamamatsu Bkg DMM(cpd/kg/keV)	Ratio	Previous Bkg KMM(cpd/kg/keV)	Hamamatsu Bkg KMM(cpd/kg/keV)	Ratio
^{40}K	1.54 e-03	5.10 e-03	3.3	6.08 e-05	2.14 e-04	3.5
^{60}Co	5.44 e-06	5.08 e-04	93.4	4.56 e-05	2.96 e-03	64.9
^{238}U	4.22 e-03	7.44 e-03	1.8	2.47 e-06	4.36 e-06	1.8
^{226}Ra	1.37 e-03	1.28 e-02	9.3	2.10 e-04	2.29 e-03	10.9
^{232}Th	9.41 e-05	2,46 e-03	26.1	1.41 e-05	4.60 e-04	32.6
^{228}Th	8.67 e-04	7.54 e-03	8.7	4.25 e-05	5.68 e-04	13.4
Total	8.10 e-03	3.58 e-02	**4.4**	3.75 e-04	6.50 e-03	**17.3**

Background with veto – Hamamatsu measurements

Newest Bkg cpd/kg/keV

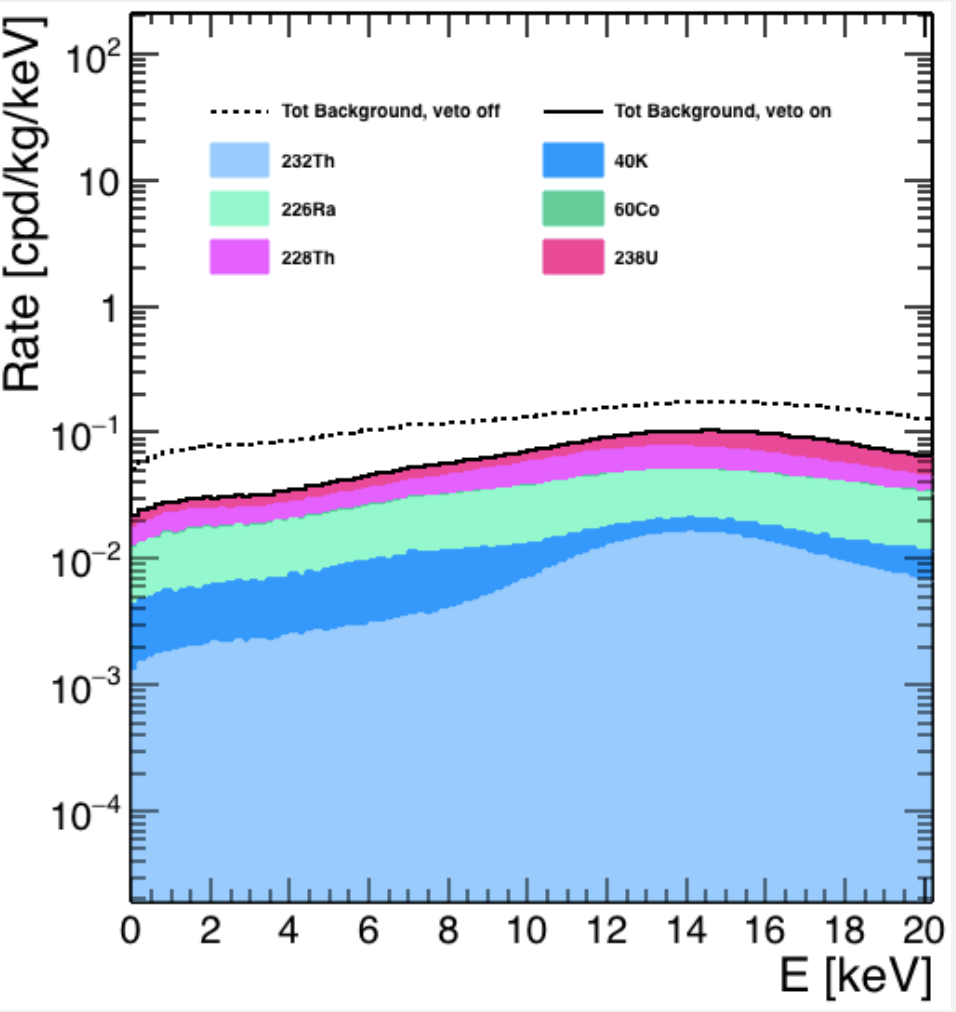


Previous Bkg cpd/kg/keV



Background comparison veto on/off – Hamamatsu measurements

Newest Bkg cpd/kg/keV



Previous Bkg cpd/kg/keV