



Yale



**Wright
Laboratory**

Background Assessment of the COSINE-100 Experiment

Estella Barbosa de Souza
on behalf of the COSINE-100 collaboration

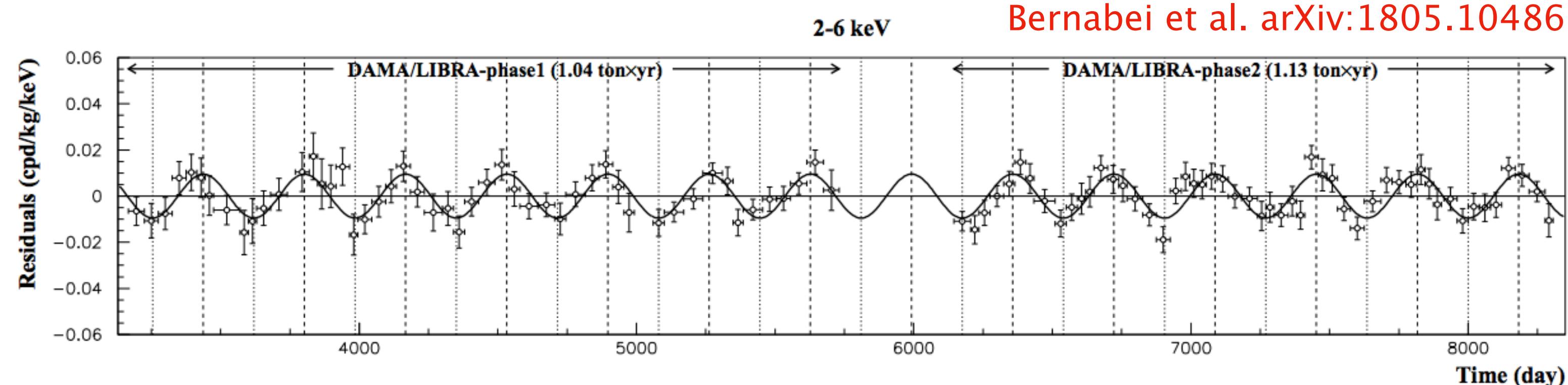
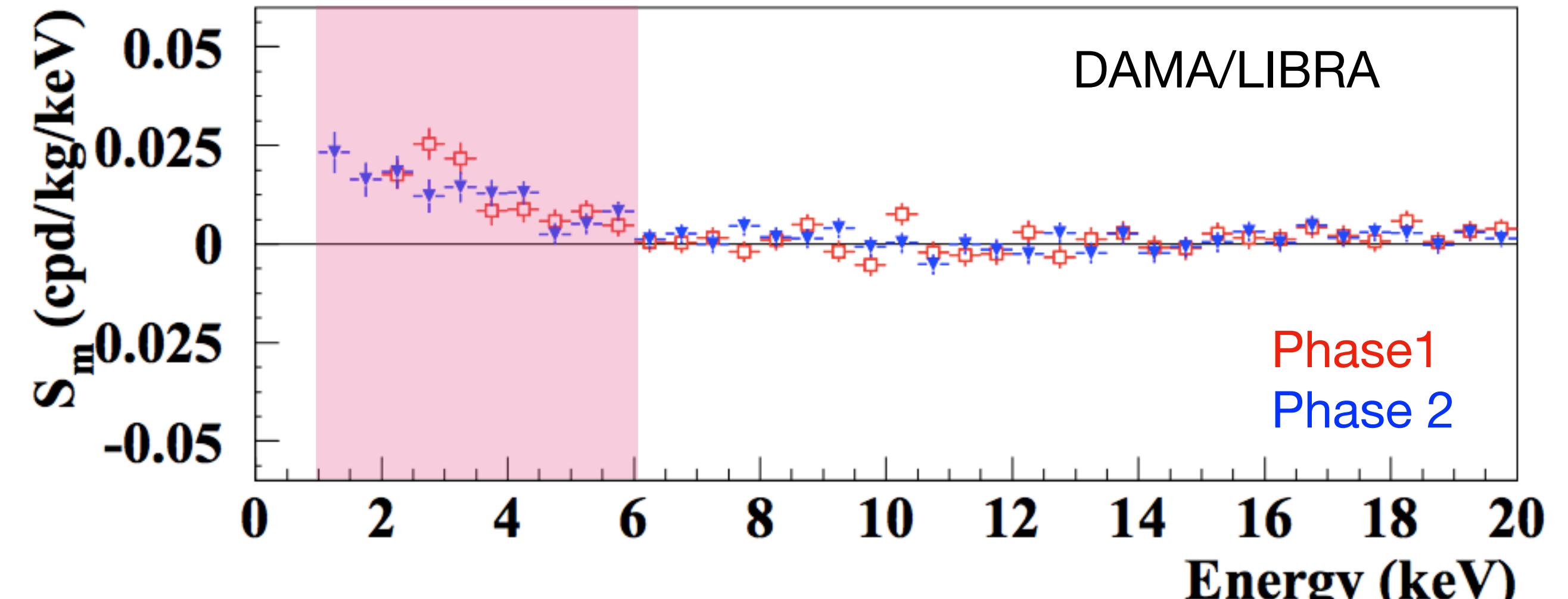
Yale University

IDM 2018
07-27-18

The DAMA Experiment

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- DAMA experiment:
 - NaI(Tl) experiment
 - Sees modulation for 14+ cycles
 - Signal $> 9 \sigma$ in DAMA/LIBRA
- How to confirm this signal?
 - Use same target material: NaI(Tl)
 - Have low enough backgrounds: modulation amplitude is small
 - Look for time dependent components in backgrounds



COSINE-100



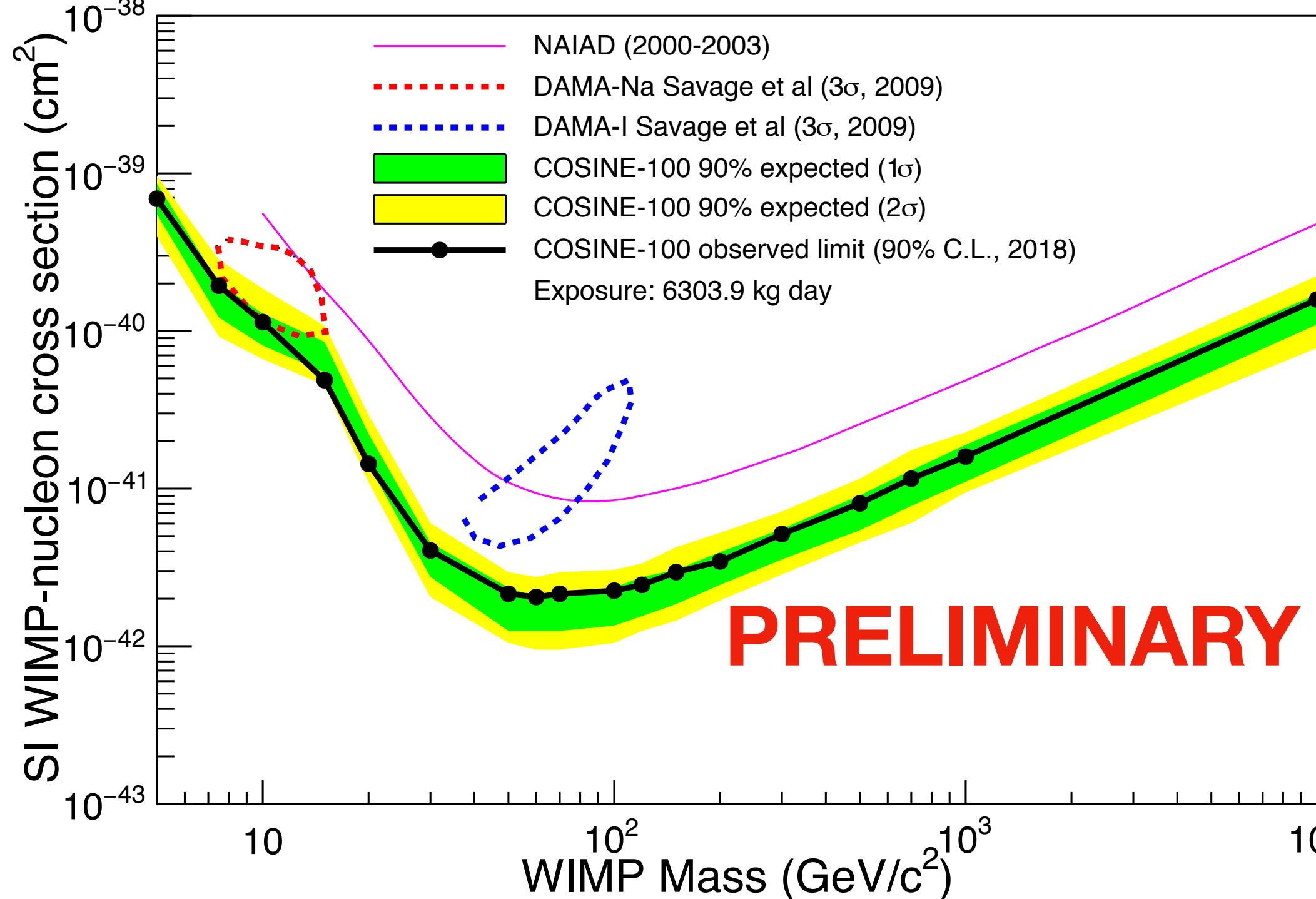
- DM-Ice + KIMS collaborations = COSINE
- 106 kg of NaI(Tl) from Alpha Spectra
- 2 tons of passive liquid scintillator veto for background tagging
- Location: Yangyang Underground Laboratory (Y2L), South Korea (~700 m rock overburden)



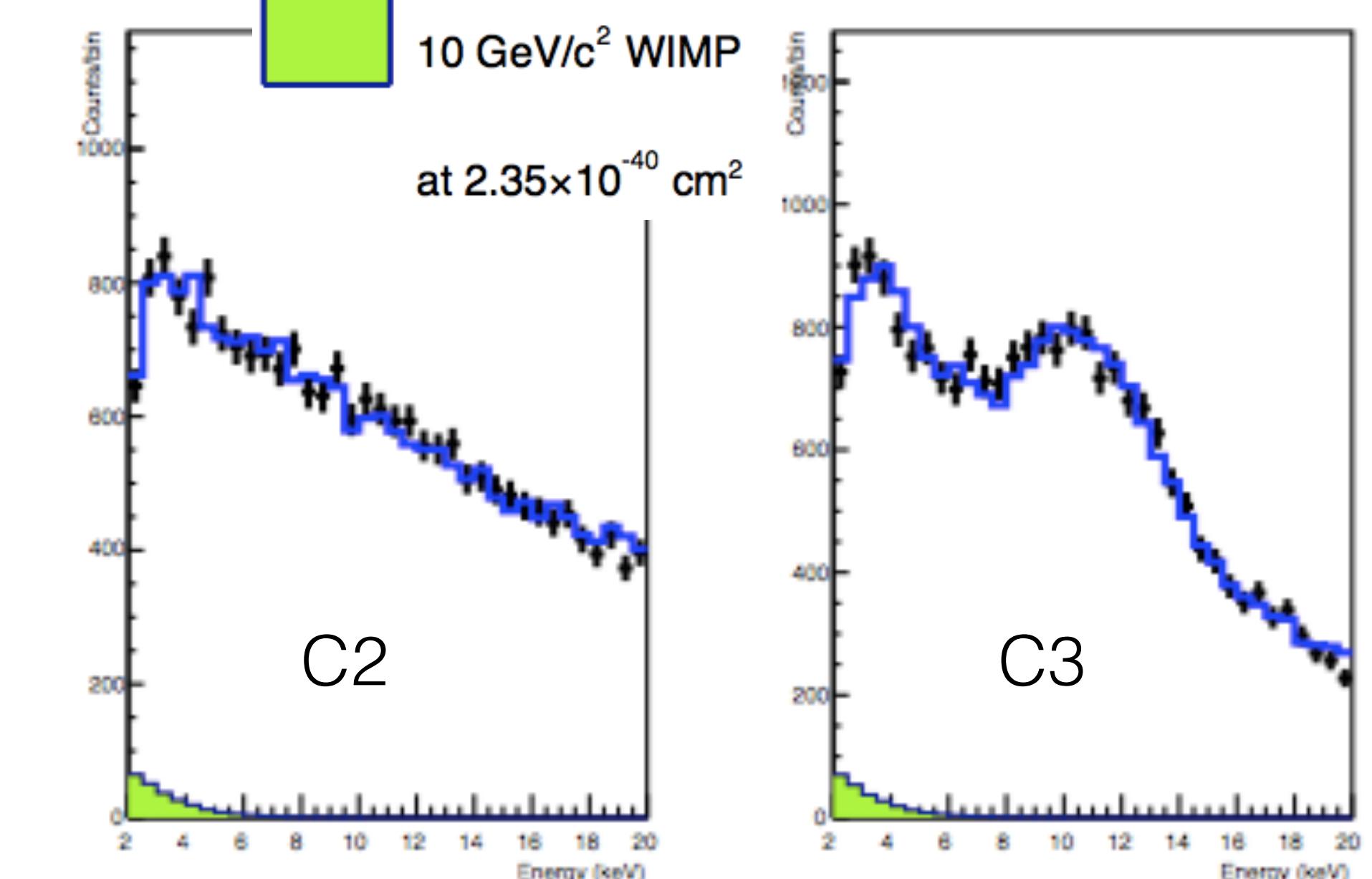
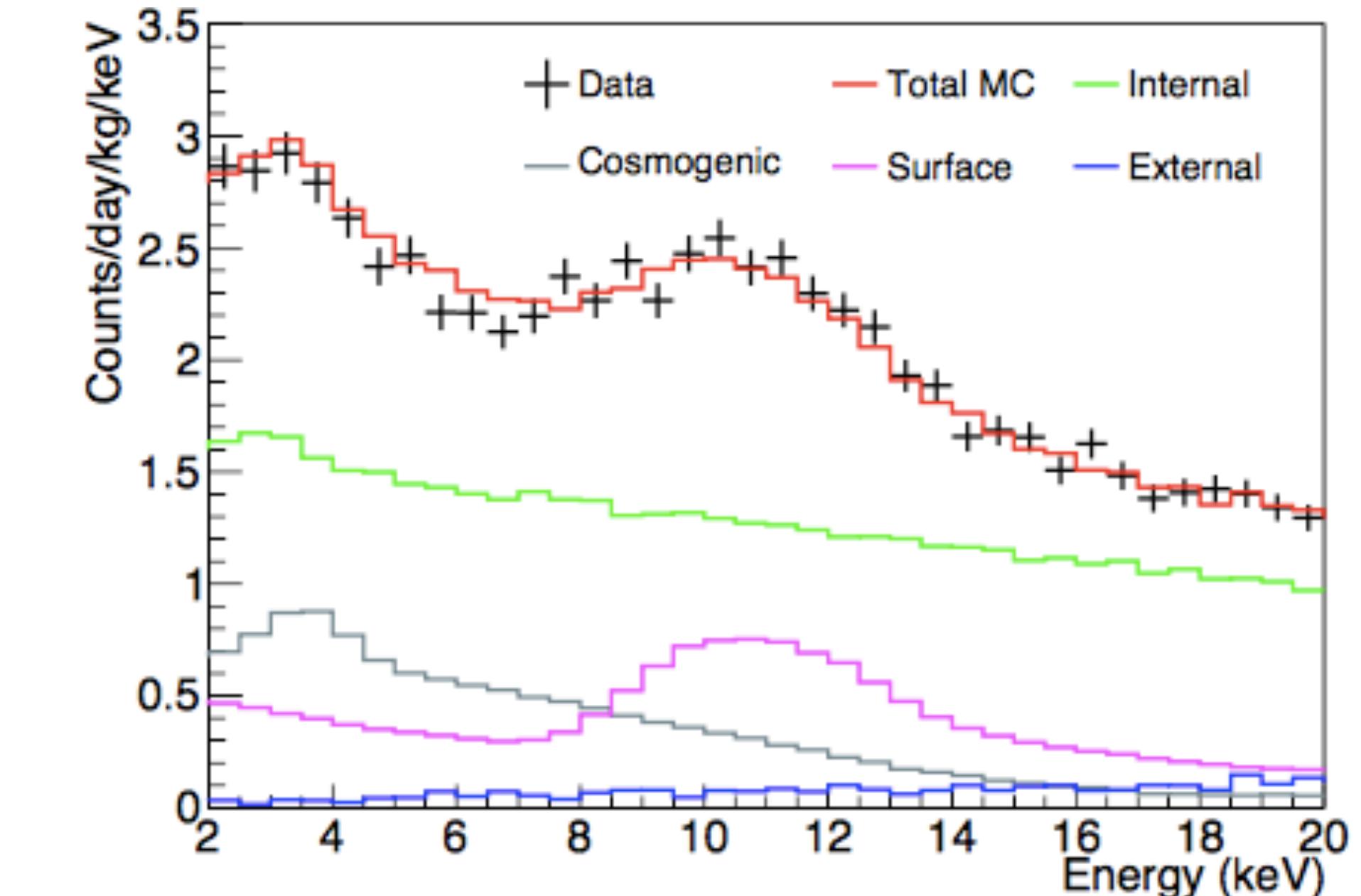
Physics run:
Since Sept 2016

Recent Results: WIMP Analysis

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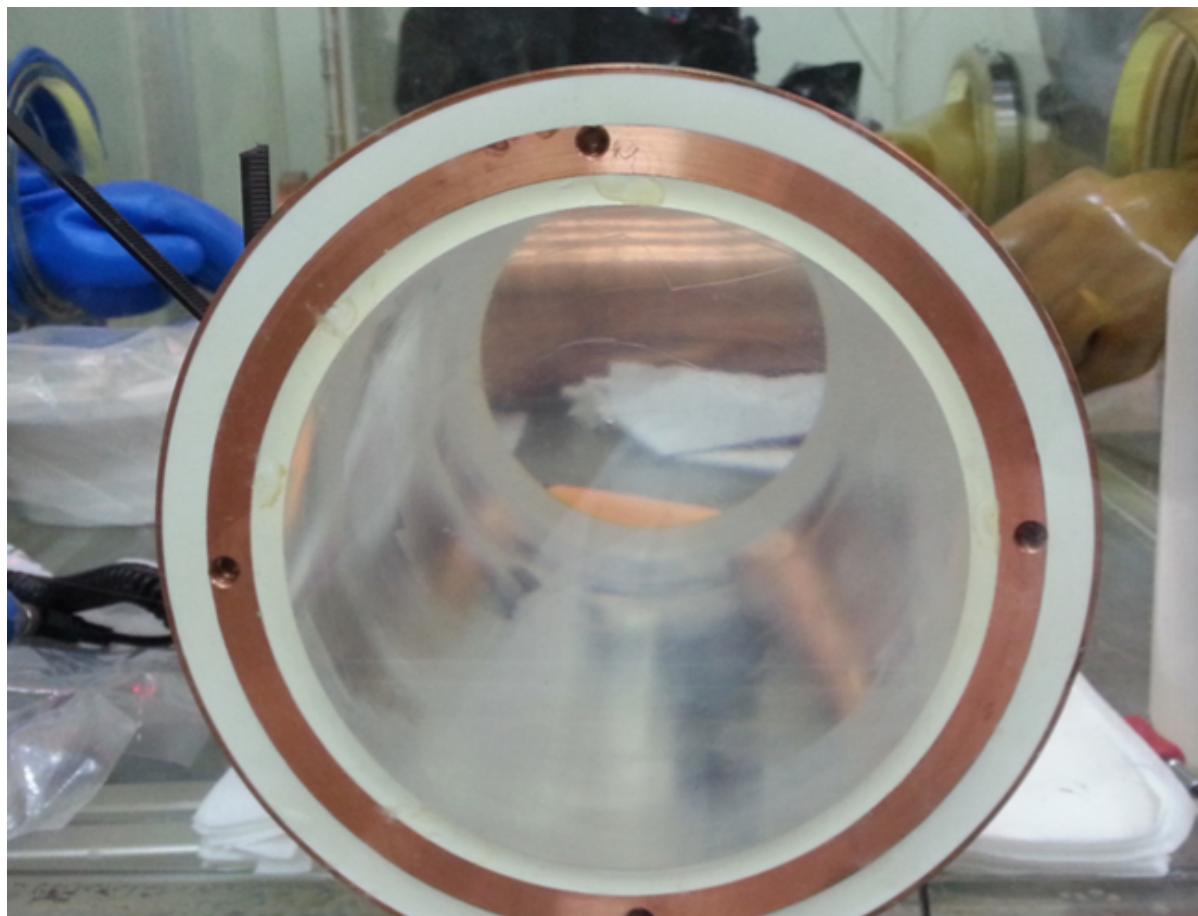


See Jay Hyun Jo's
talk for details.



COSINE-100 NaI(Tl) Crystals

~~COSINE~~



Crystal	Mass (kg)	Size (inches) diameter×length	Powder	α Rate (mBq/kg)	^{40}K (ppb)	^{238}U (ppt)	^{232}Th (ppt)	Light Yield (PEs/keV)
Crystal-1	8.3	5.0 × 7.0	AS-B	3.20 ± 0.08	34.7 ± 4.7	<0.02	1.3 ± 0.4	14.9 ± 1.5
Crystal-2	9.2	4.2 × 11.0	AS-C	2.06 ± 0.06	60.6 ± 4.7	<0.12	<0.6	14.6 ± 1.5
Crystal-3	9.2	4.2 × 11.0	AS-WSII	0.76 ± 0.02	34.3 ± 3.1	<0.04	0.4 ± 0.2	15.5 ± 1.6
Crystal-4	18.0	5.0 × 15.3	AS-WSII	0.74 ± 0.02	33.3 ± 3.5		<0.3	14.9 ± 1.5
Crystal-5	18.3	5.0 × 15.5	AS-C	2.06 ± 0.05	82.3 ± 5.5		2.4 ± 0.3	7.3 ± 0.7
Crystal-6	12.5	4.8 × 11.8	AS-WSIII	1.52 ± 0.04	16.8 ± 2.5	<0.02	0.6 ± 0.2	14.6 ± 1.5
Crystal-7	12.5	4.8 × 11.8	AS-WSIII	1.54 ± 0.04	18.7 ± 2.8		<0.6	14.0 ± 1.4
Crystal-8	18.3	5.0 × 15.5	AS-C	2.05 ± 0.05	54.3 ± 3.8		<1.4	3.5 ± 0.3
DAMA				< 0.5	< 20	0.7–10	0.5–7.5	5.5–7.5

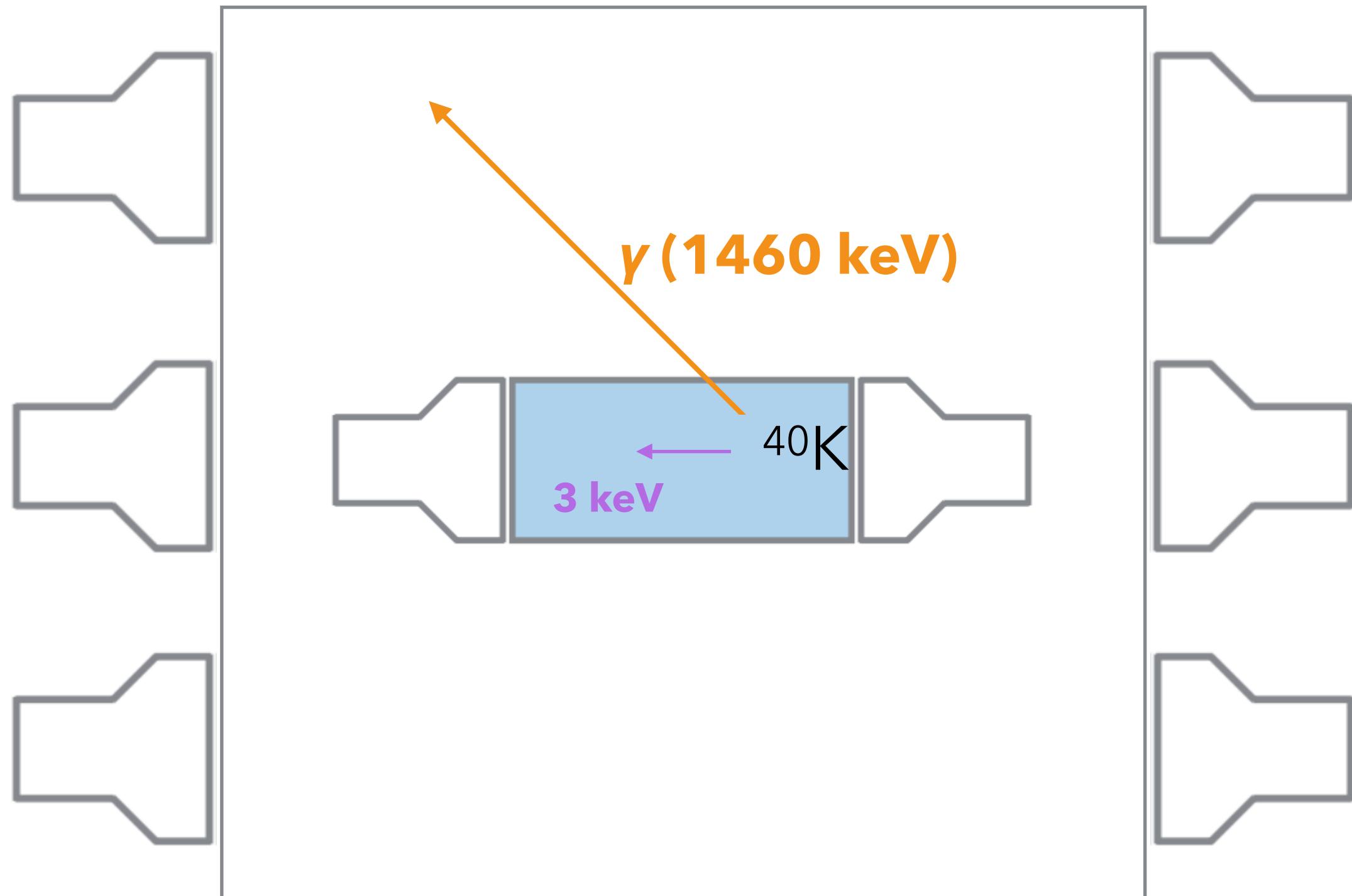


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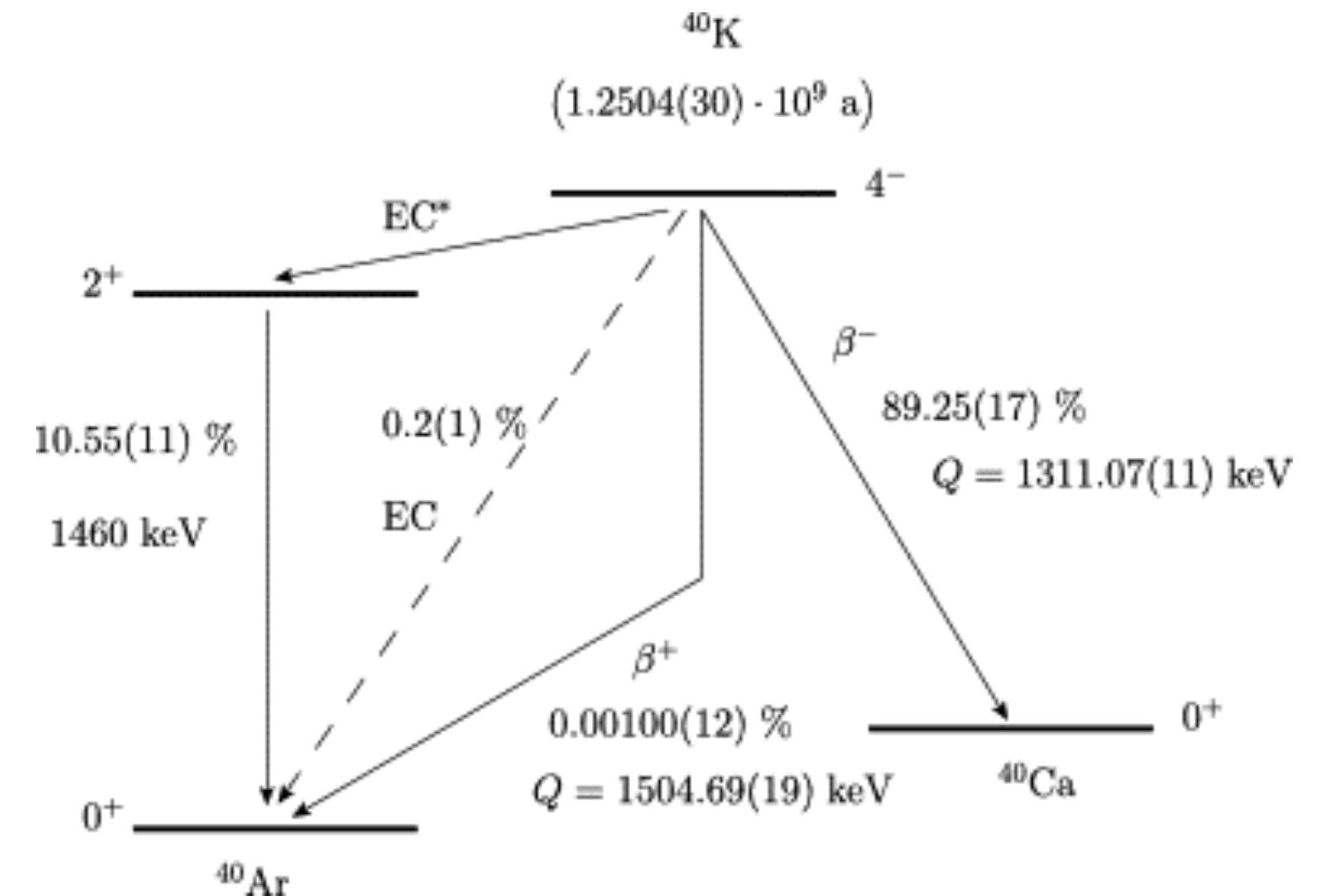
- ▶ Intrinsic backgrounds: from crystal powder/growing
- ▶ R&D goal: intrinsic background ~DAMA's
- ▶ Light yield: up to 15 p.e./keV
- ▶ Main challenge: produce crystal with desirable levels of ^{40}K & ^{210}Pb

Internal 40K Tagging

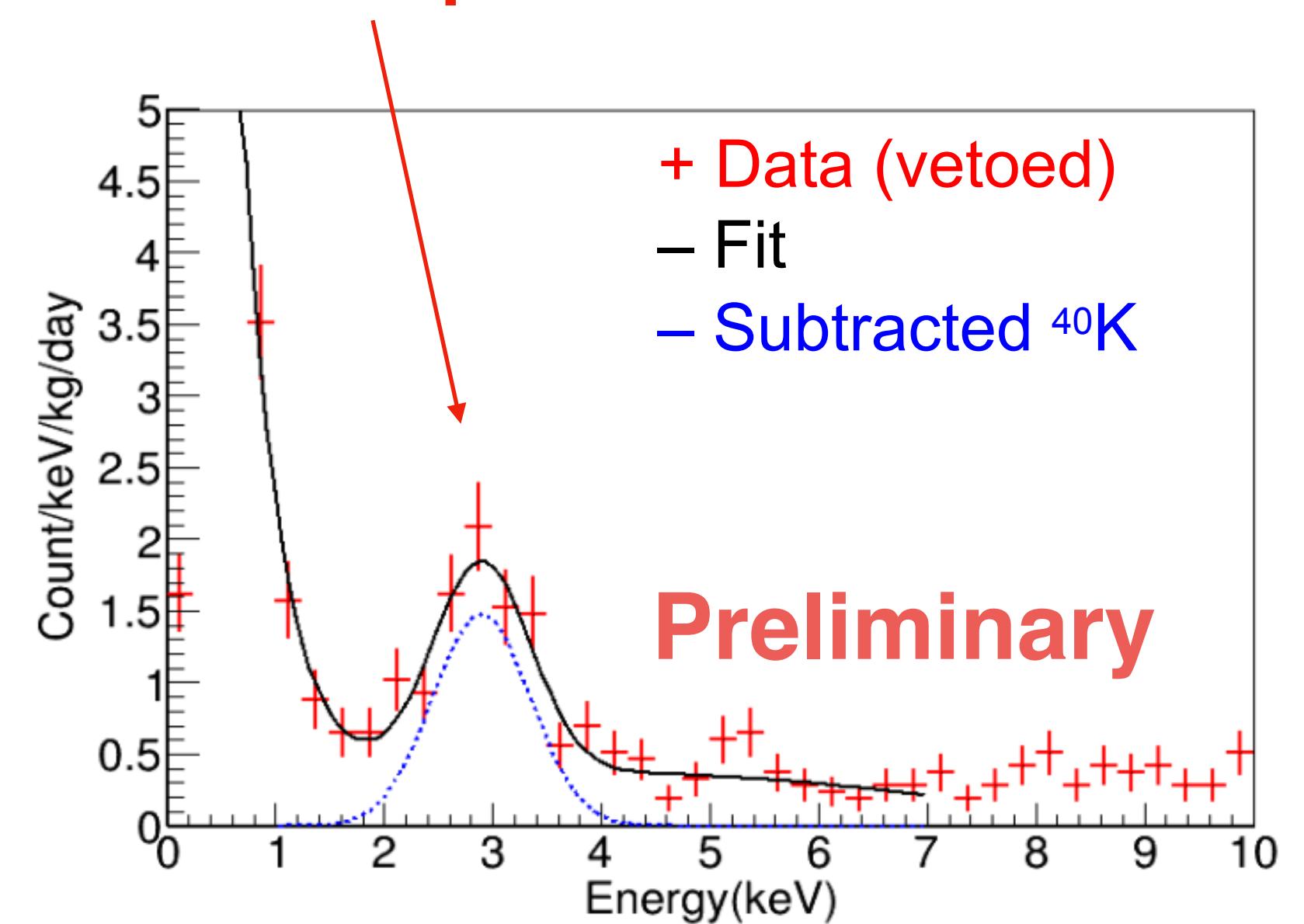
~~COINFE~~



- ▶ ^{40}K emits 1460 keV gamma (LS) with 3 keV Auger electron (crystal)
- ▶ LS tags gamma to **veto the ^{40}K 3 keV background events**



3 keV ^{40}K peaks

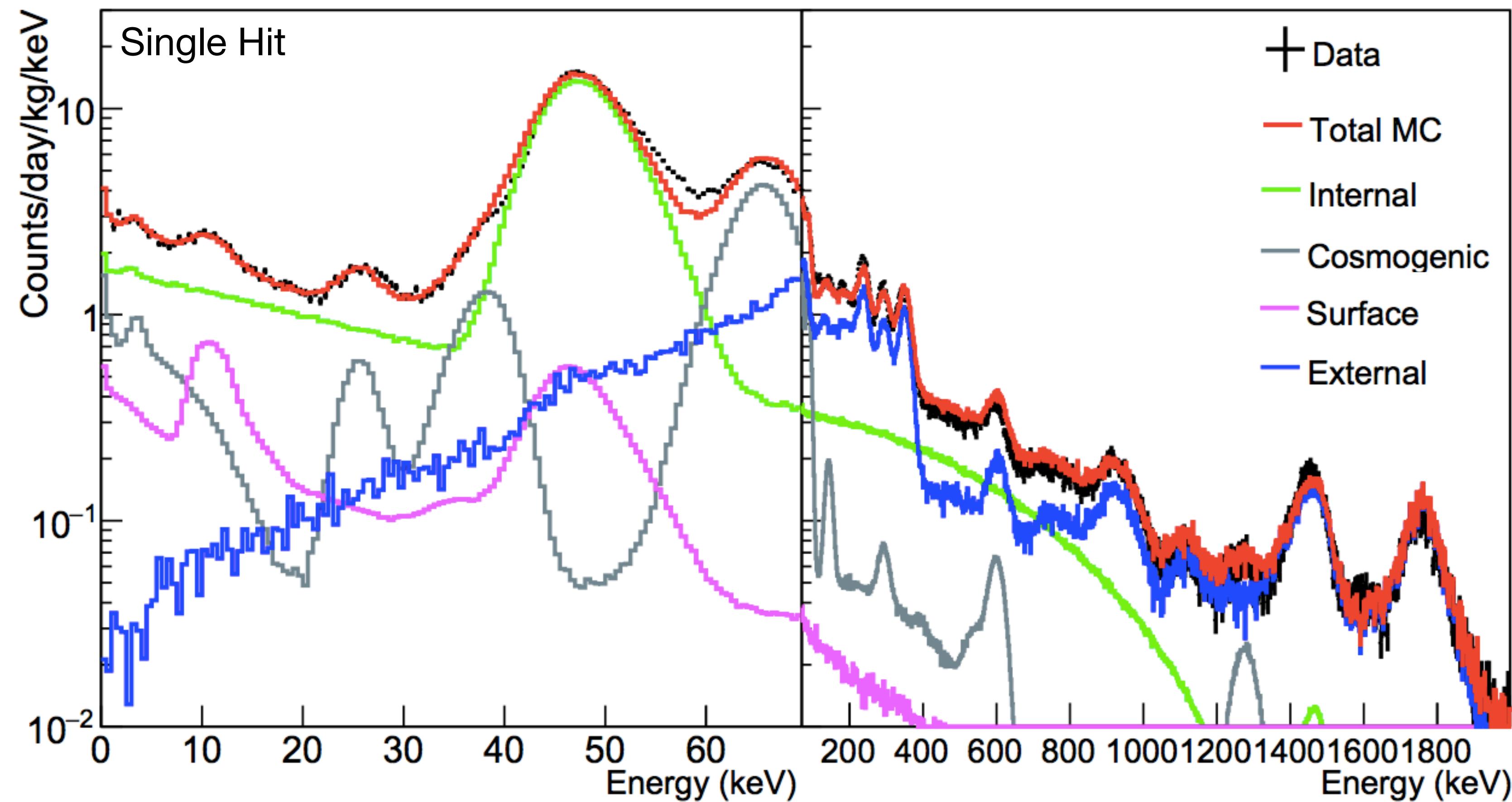


COSINE-100 Backgrounds

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- ▶ Full detector simulation with Geant4 + simultaneous fit
- ▶ Main low energy backgrounds:
 - Internals: crystals' intrinsic contaminants - ^{40}K & ^{210}Pb
 - Cosmogenics: dominated by ^3H in R.O.I (2-20 keV)
 - Surface: ^{210}Pb in crystals and teflon surfaces
- ▶ Other internal contaminants: contribution on the order of ~0.001 dru in 2 - 6 keV

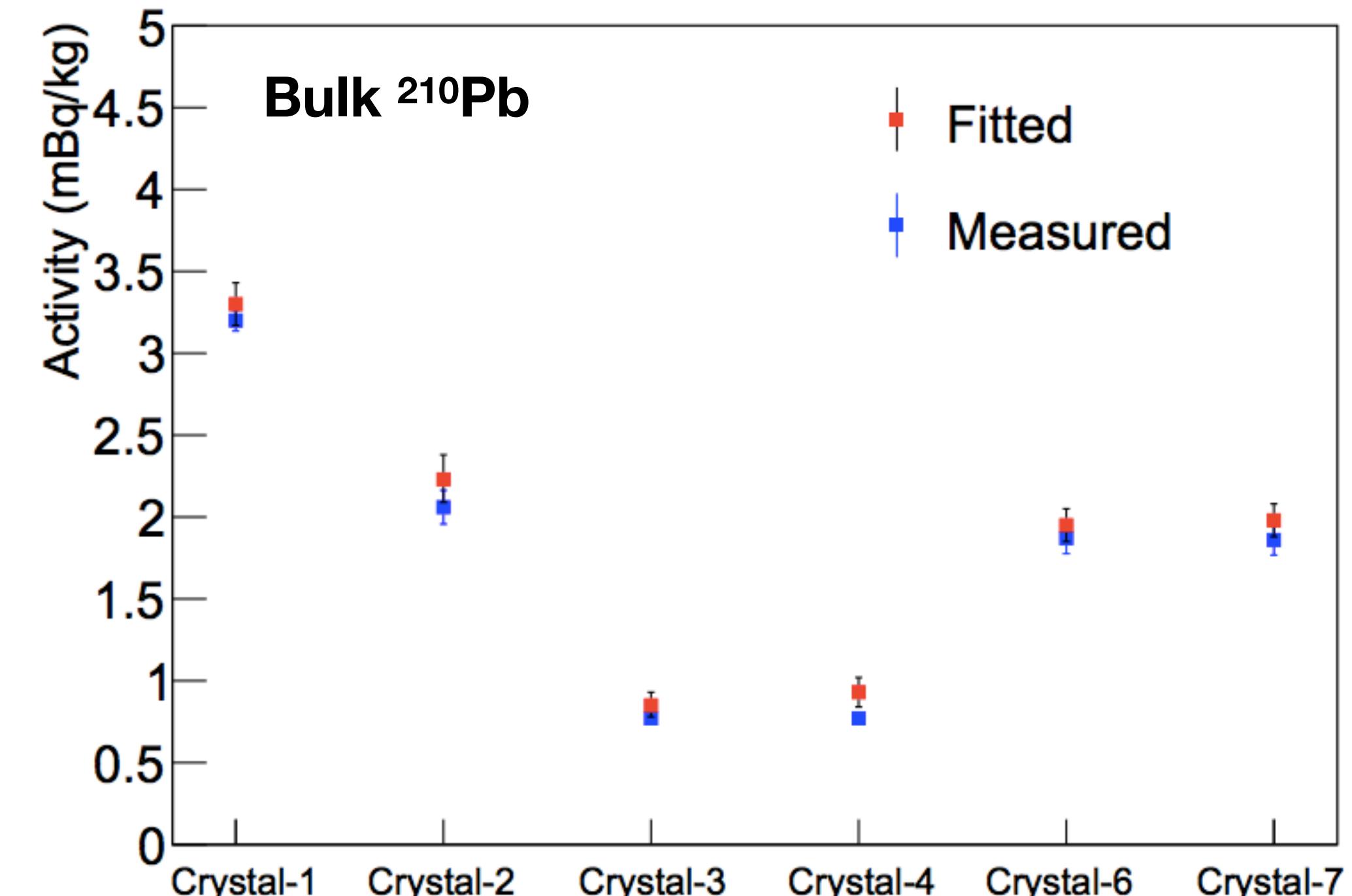
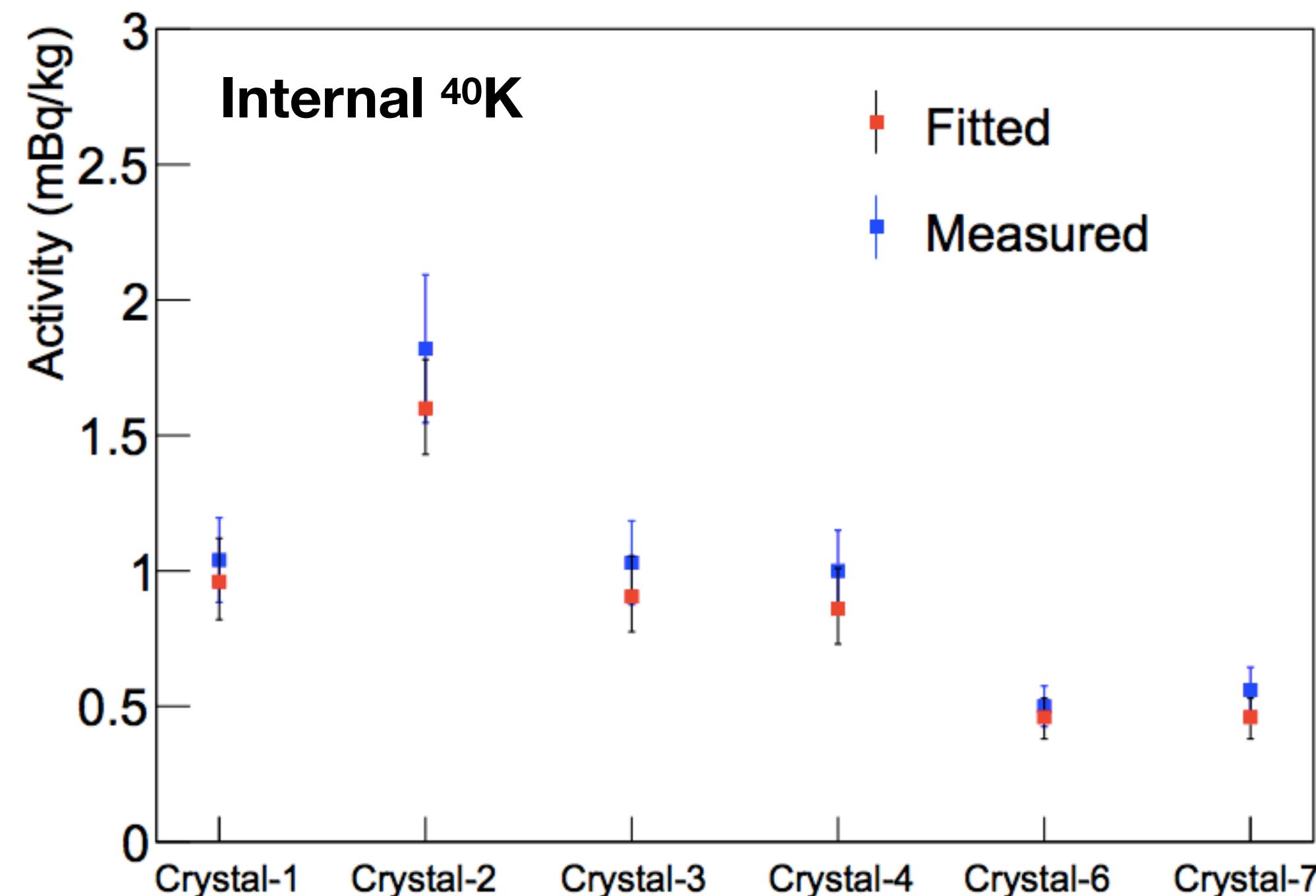
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Internal Backgrounds

- ▶ ^{40}K and ^{210}Pb from measurement and fitting result are consistent within errors
- ▶ ^{40}K measurement: gamma coincidence
- ▶ ^{210}Pb measurement: alpha rates

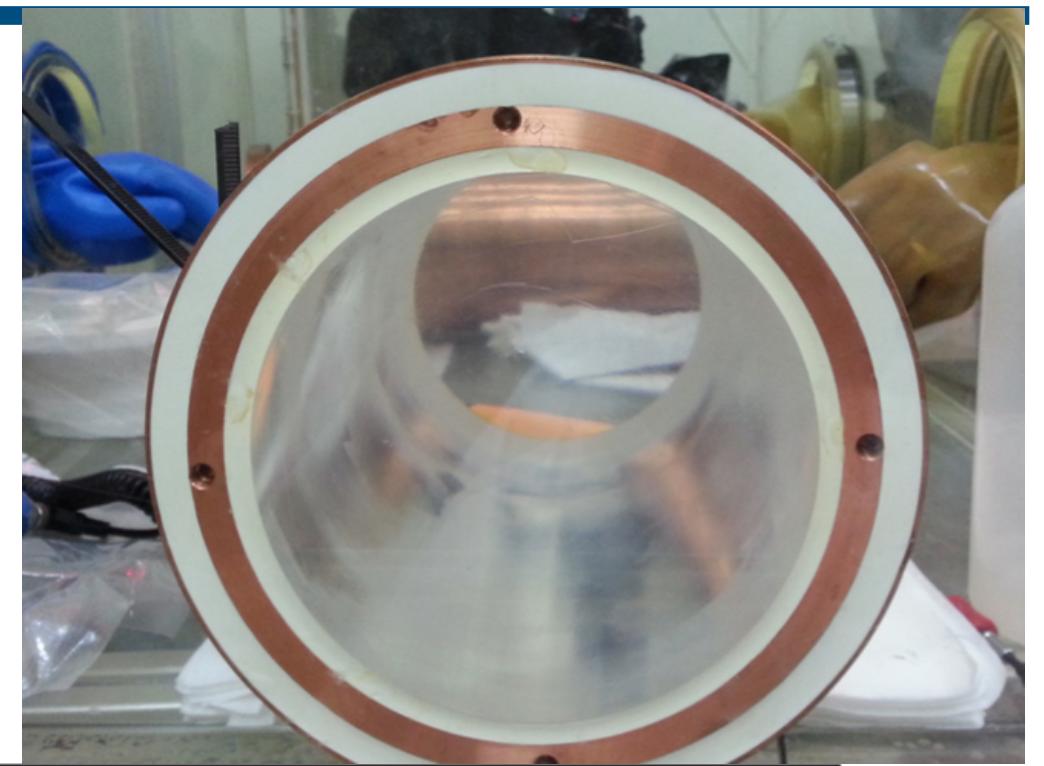
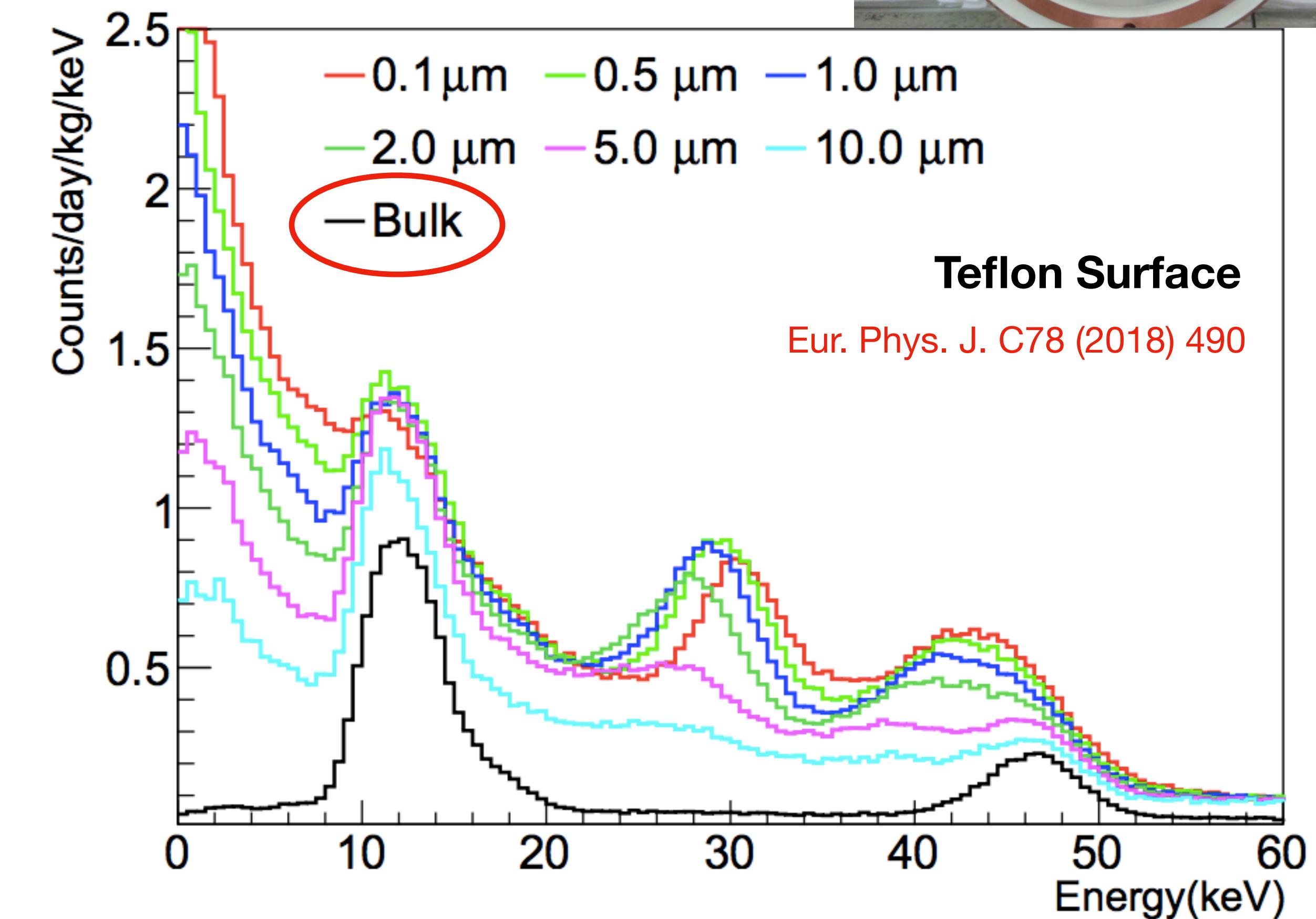
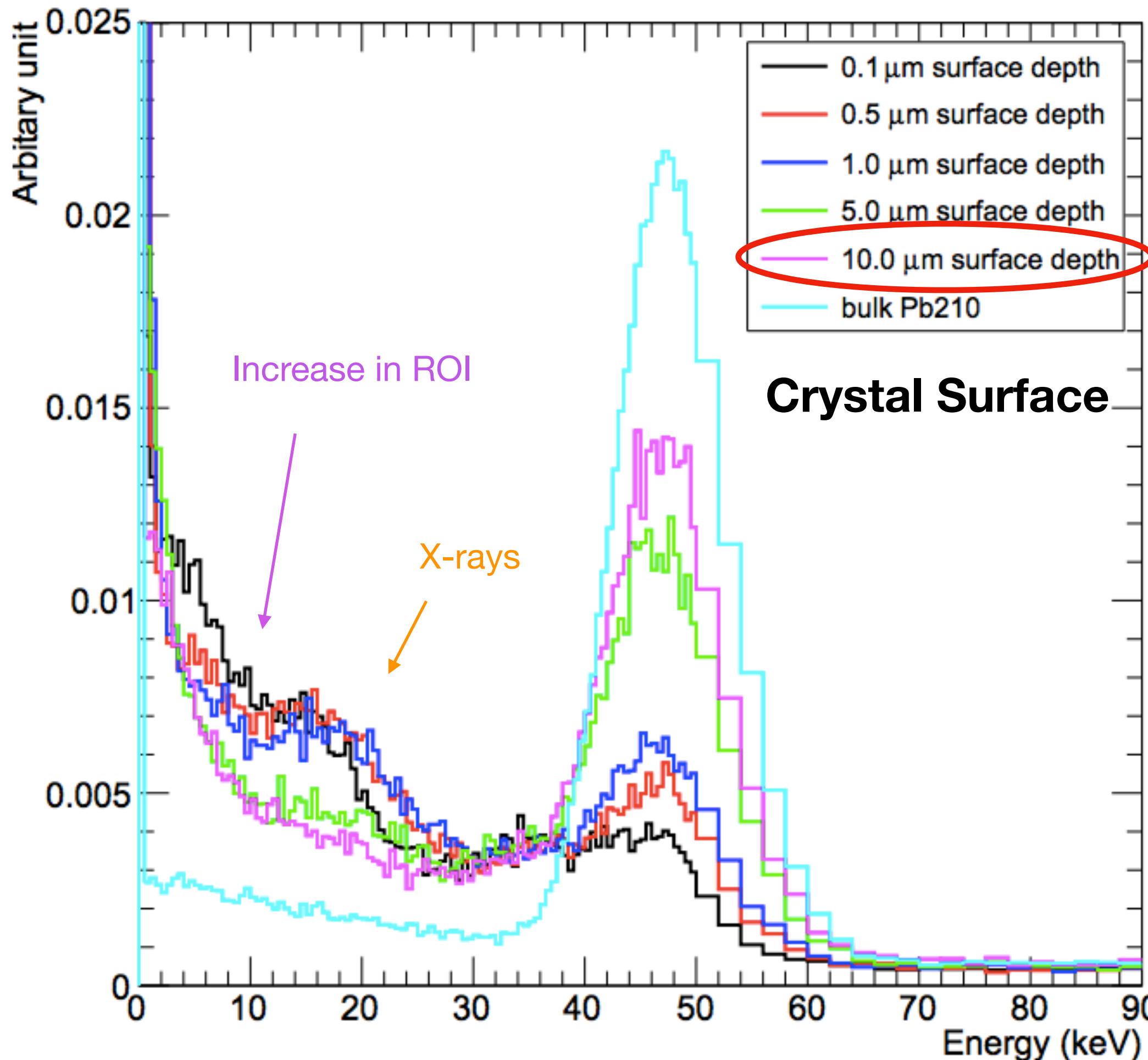
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Surface Backgrounds

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- ^{210}Pb in crystal and teflon surfaces
- Different depths results in distinct features in the spectra



Activation of COSINE-100 Crystals



- ▶ Exposure of crystals to cosmic rays:
 - Production: Colorado, ~1400 m elevation
 - Transportation: land and sea

- ▶ **Most cosmogenic isotopes come from the activation of Na and I**

- ▶ Exposure time varies from 0.3 to 2 yrs

Cosmogenic isotopes	Half-life (days)	Production rate at sea level [24] (counts/kg/day)
^{125}I	59.4	221
^{121}Te	19.17	93
^{121m}Te	164.2	93
^{123m}Te	119.2	52
^{125m}Te	57.4	74
^{127m}Te	106.1	93
^{113}Sn	115.1	9.0
^{109}Cd	461.4	4.8
^3H	4500	26
^{22}Na	951	66

Crystal	Exposure time (see text) (years)	Radioactivity cooling time at Y2L (years)
Crystal-1	2	3
Crystal-2	0.75	2.75
Crystal-3		1.2
Crystal-4	1.7	0.5
Crystal-6	0.3	0.6
Crystal-7	0.3	0.6

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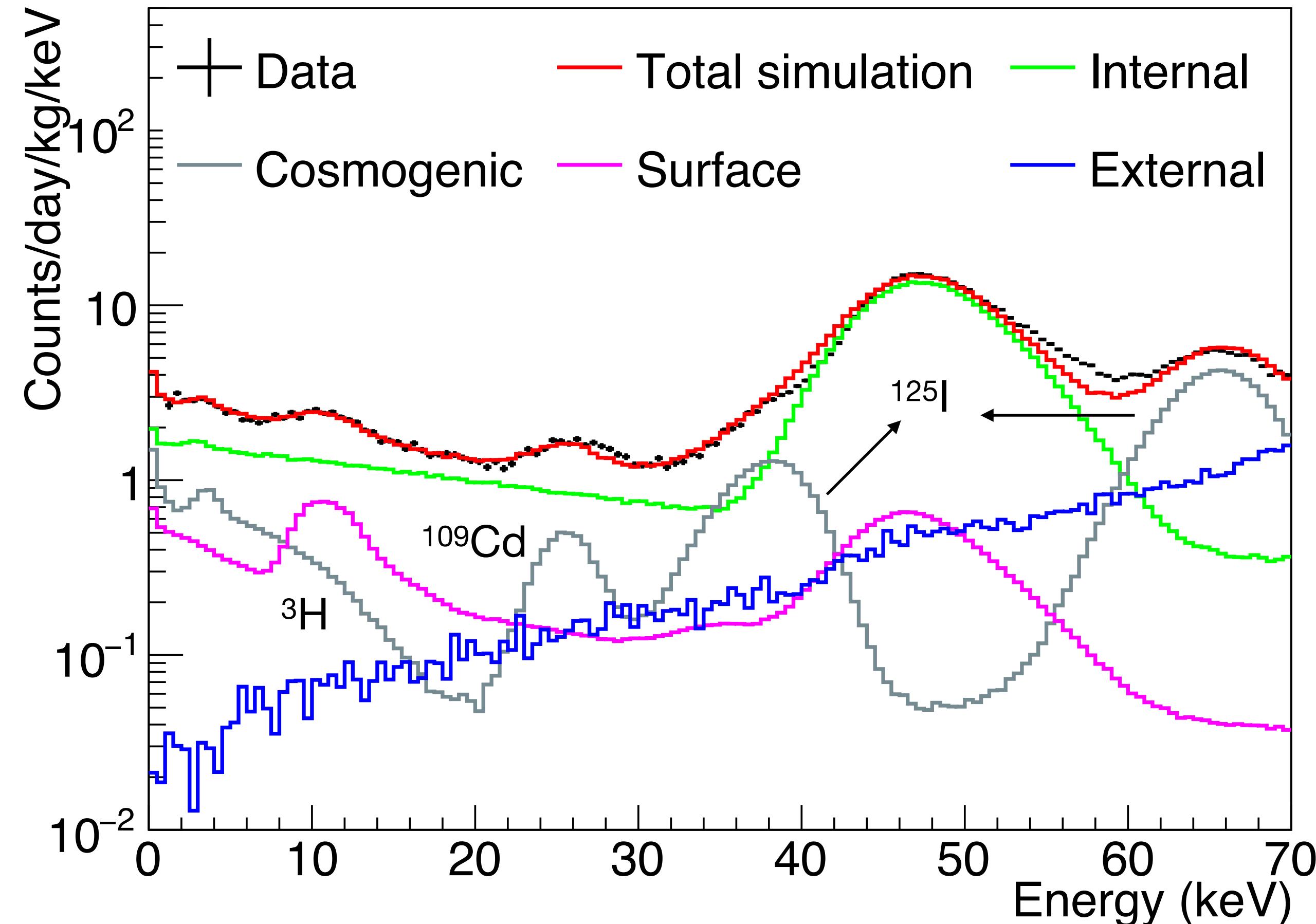
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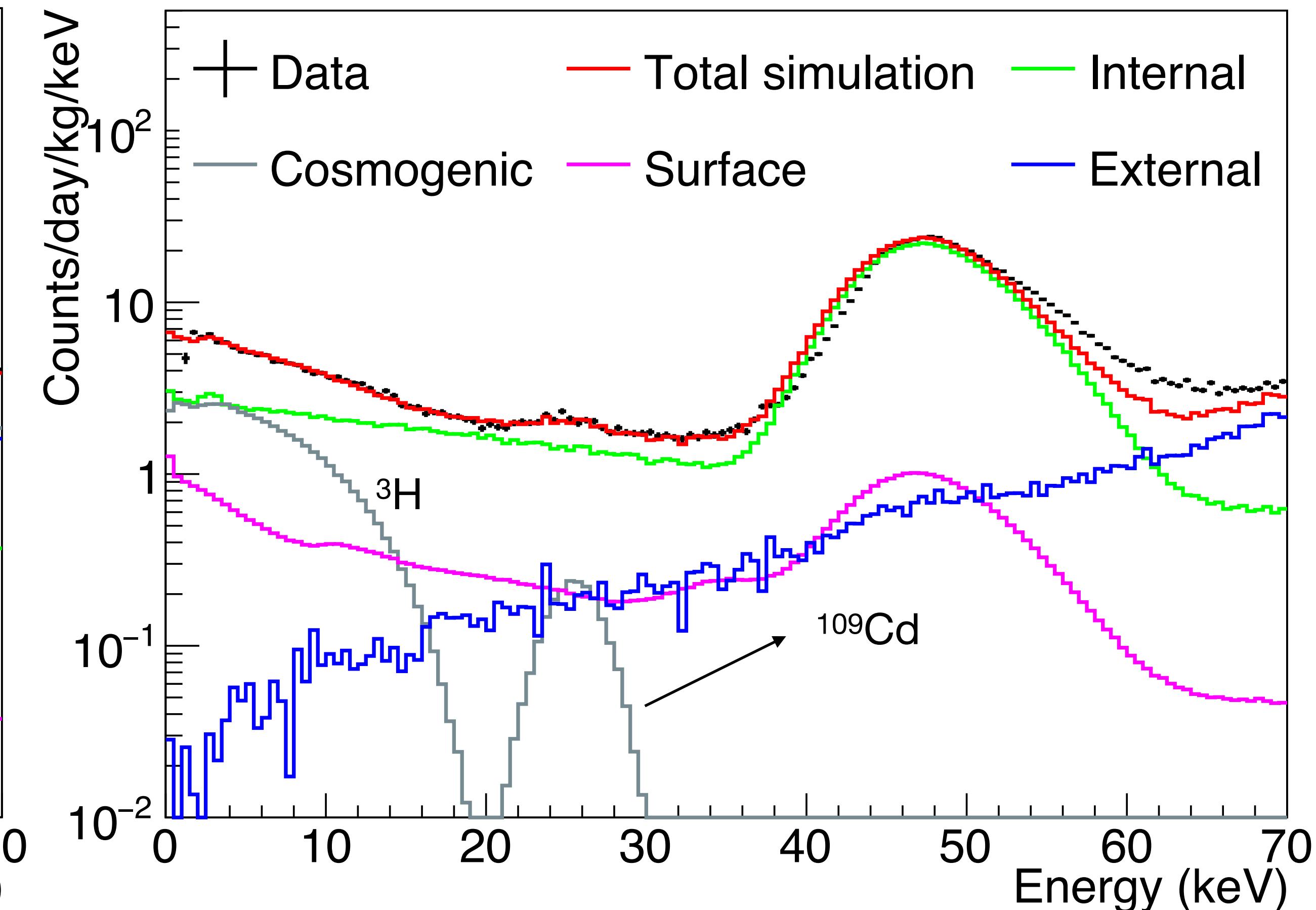
Crystal Cosmogenics

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Crystal 7



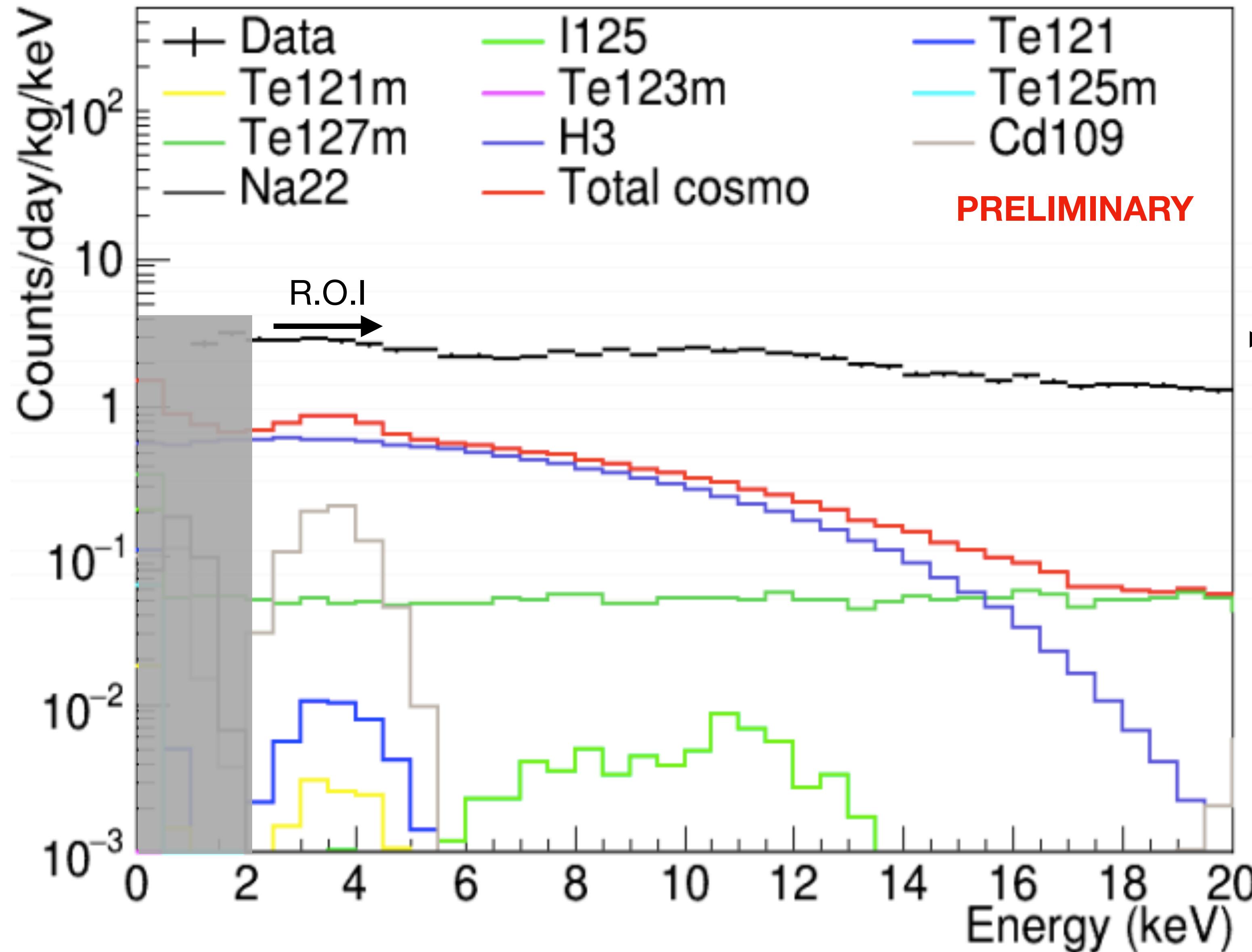
Crystal 1



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Crystal Cosmogenics

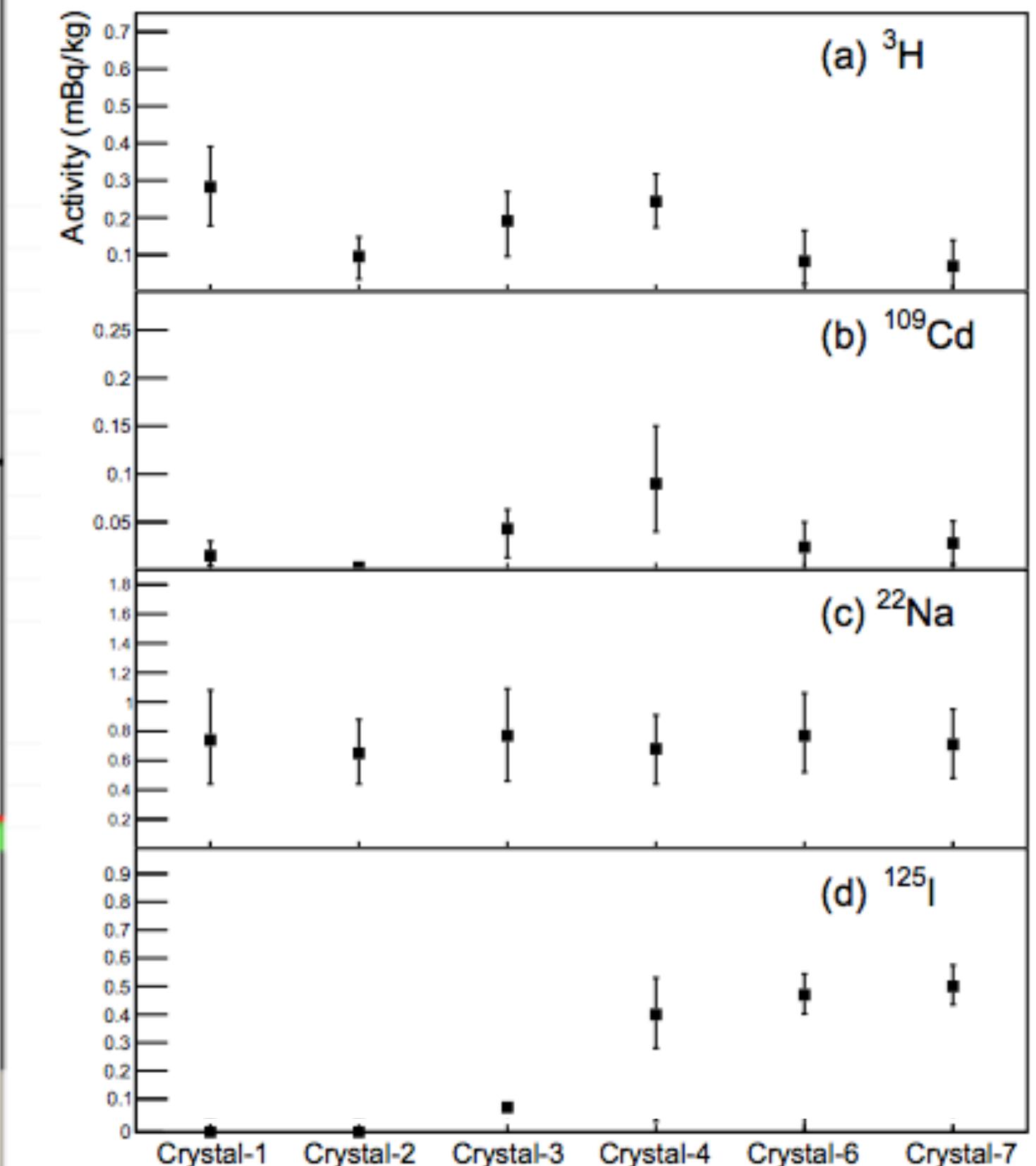
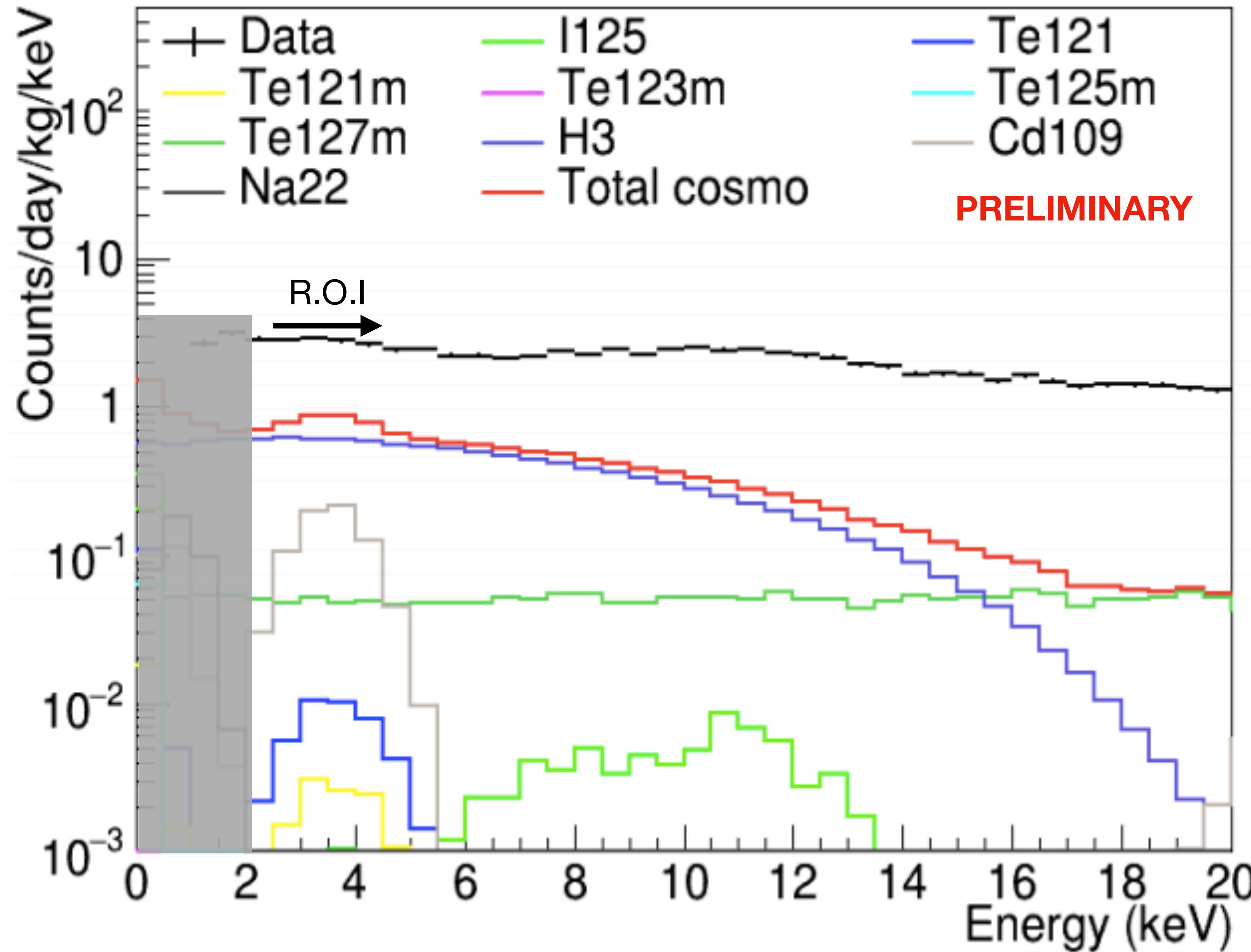
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- ▶ Main contributions in modulation region (2 - 6 keV): ^{3}H and ^{109}Cd

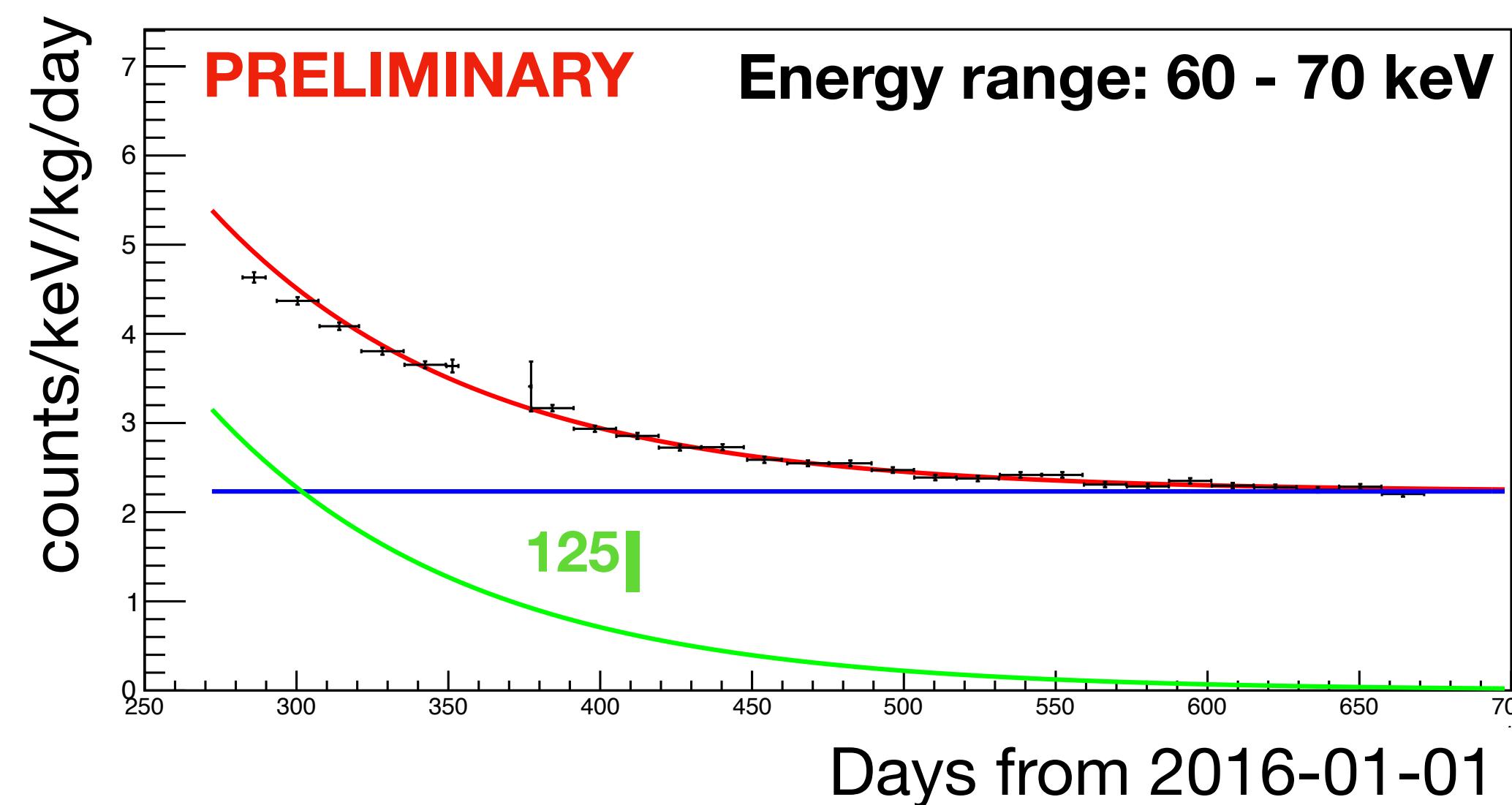
Crystal Cosmogenics

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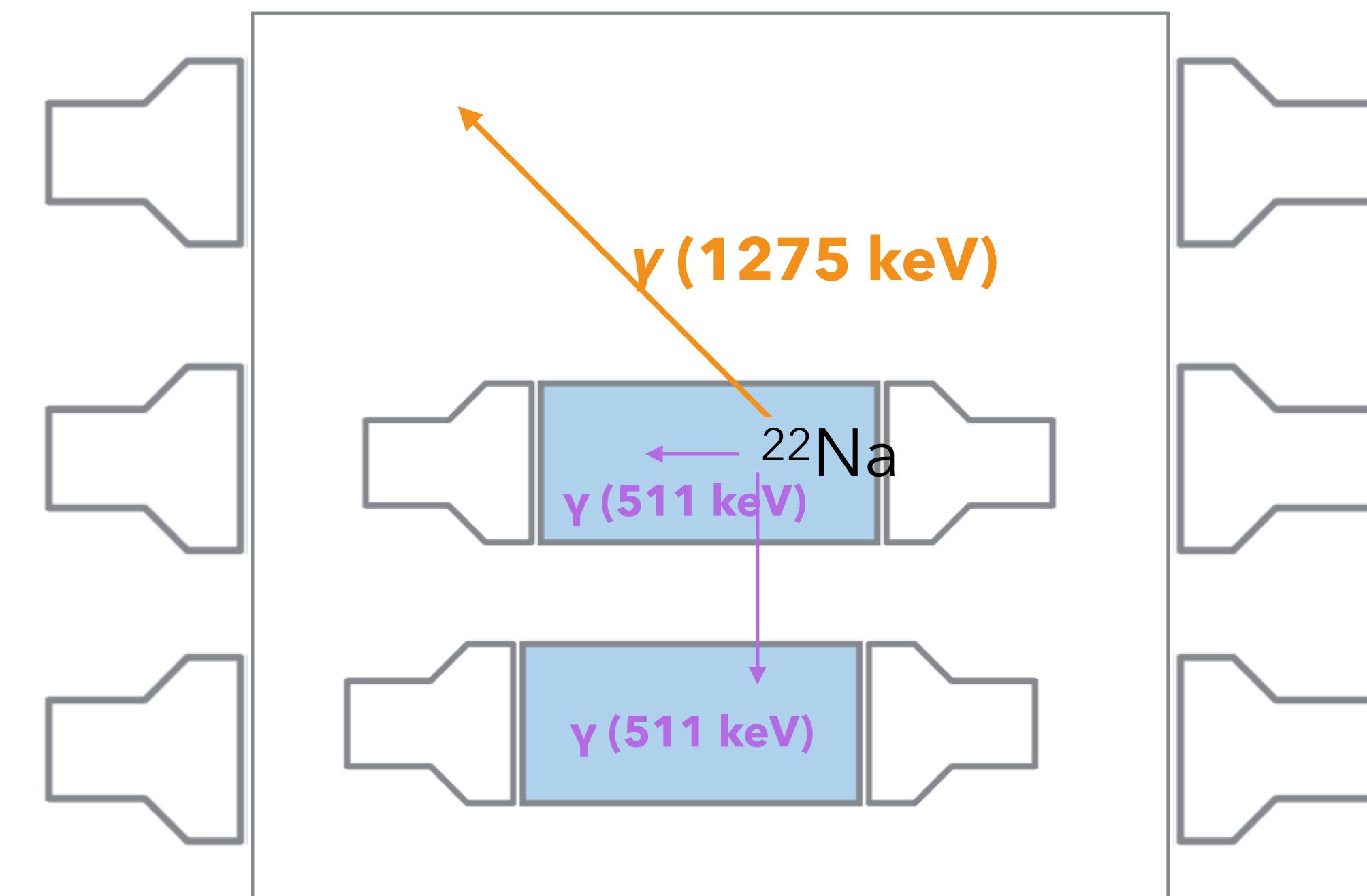


Identifying Cosmogenics

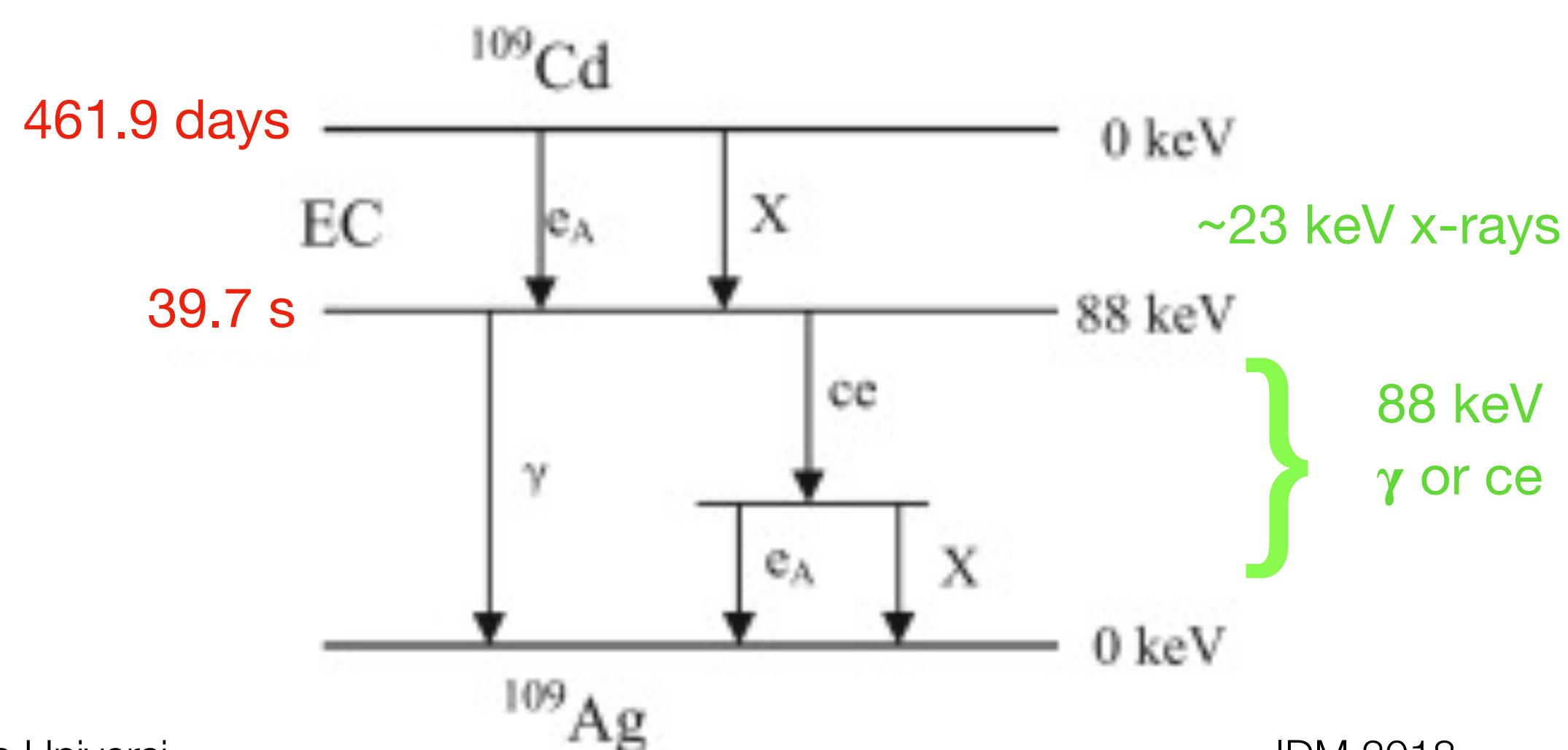
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- Short-lived cosmogenics: decay rate fit



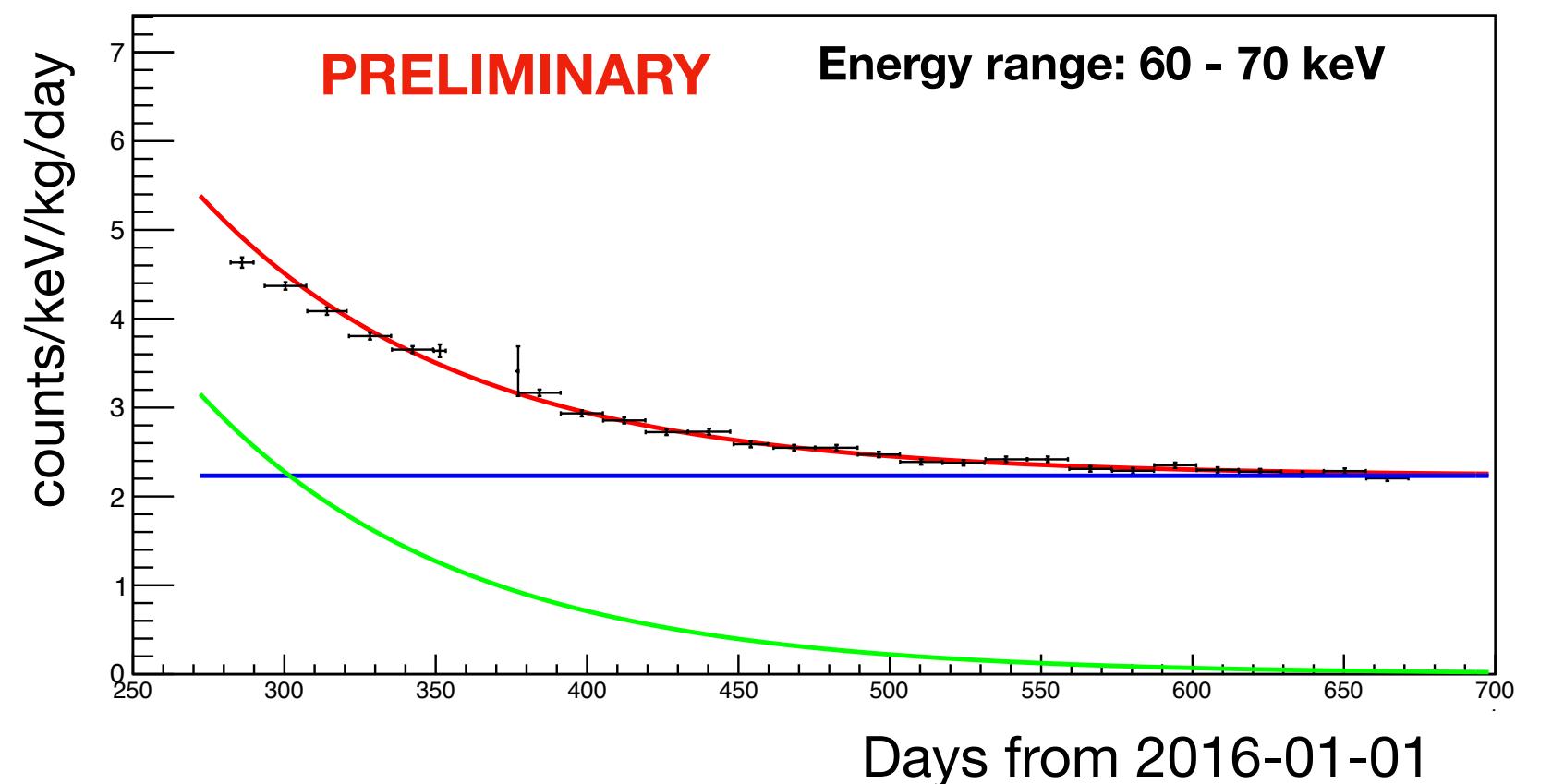
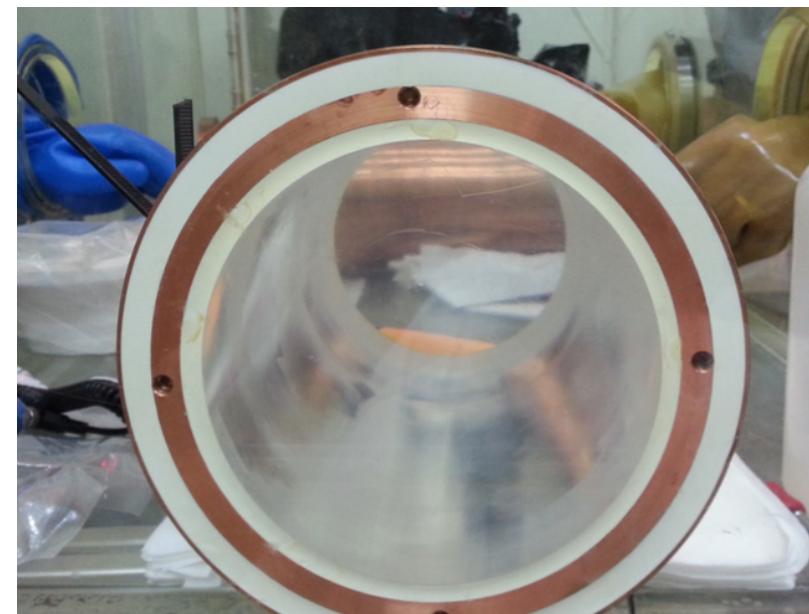
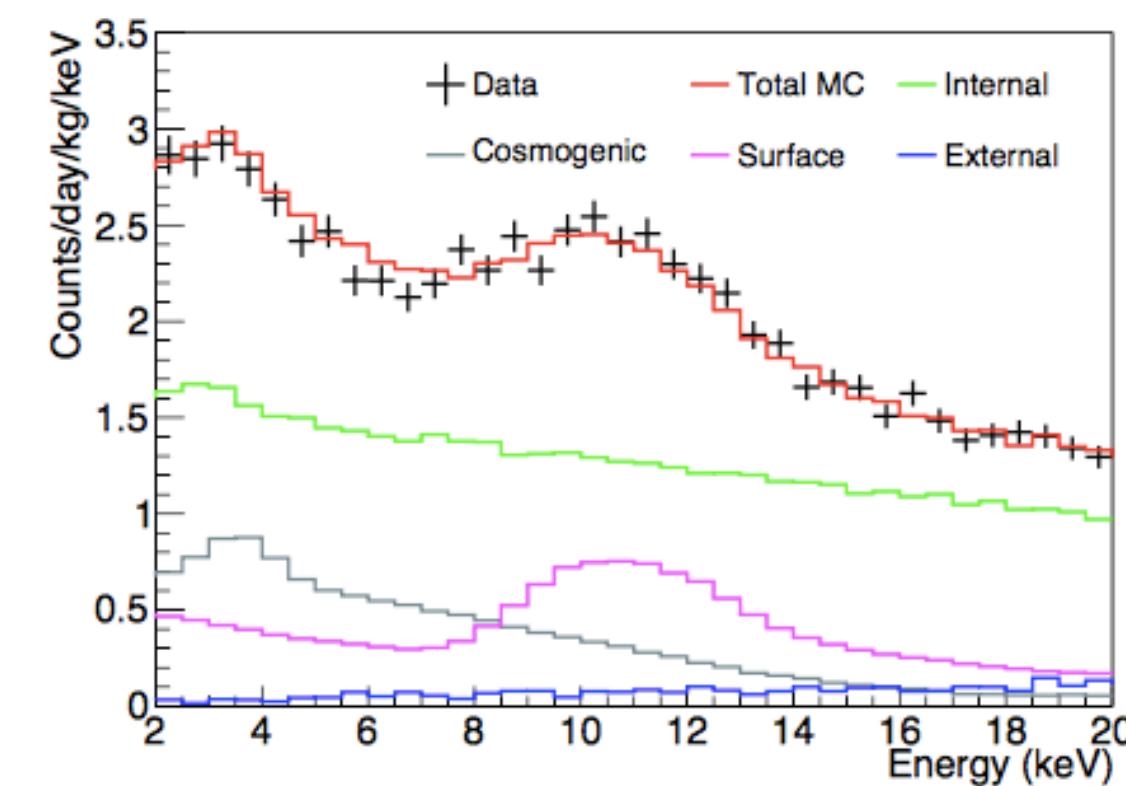
- ^{22}Na : double and triple coincidence measurements
- ^{109}Cd : ~40 sec coincidence measurement



Summary

- ▶ COSINE-100 has been running since Sept 2016
- ▶ Detectors' backgrounds have been successfully modeled
- ▶ Fitted values are in agreement with independent measurements
- ▶ Cosmogenic isotopes are the main backgrounds in low energy after intrinsic internal backgrounds
- ▶ Surface backgrounds have been studied and accounted for in modeling
- ▶ Time dependent components are incorporated into modulation analysis

Thanks!



Backup

COSINE-100 Backgrounds

Energy range: 2 - 6 keV
counts/keV/kg/day (dru)

		Average Rates					
		Crystal-1	Crystal-2	Crystal-3	Crystal-4	Crystal-6	Crystal-7
Internal	^{40}K	0.10 \pm 0.02	0.20 \pm 0.02	0.10 \pm 0.01	0.10 \pm 0.01	0.05 \pm 0.01	0.05 \pm 0.01
	^{210}Pb	2.50 \pm 0.10	1.69 \pm 0.09	0.57 \pm 0.05	0.71 \pm 0.05	1.46 \pm 0.07	1.50 \pm 0.07
	Other ($\times 10^{-4}$)	7.0 \pm 0.1	15 \pm 1	7.3 \pm 0.1	7.7 \pm 0.1	14 \pm 1	14 \pm 1
Cosmogenic	^3H	2.35 \pm 0.90	0.81 \pm 0.40	1.54 \pm 0.77	1.97 \pm 0.66	0.69 \pm 0.67	0.58 \pm 0.54
	^{109}Cd	0.05 \pm 0.04	0.009 \pm 0.009	0.13 \pm 0.06	0.33 \pm 0.16	0.09 \pm 0.09	0.09 \pm 0.09
	Other	-	-	0.02 \pm 0.01	0.05 \pm 0.02	0.05 \pm 0.03	0.05 \pm 0.03
Surface	^{210}Pb	0.64 \pm 0.64	0.51 \pm 0.51	1.16 \pm 0.51	0.22 \pm 0.16	0.34 \pm 0.20	0.38 \pm 0.21
External		0.03 \pm 0.02	0.05 \pm 0.04	0.03 \pm 0.02	0.03 \pm 0.02	0.04 \pm 0.03	0.03 \pm 0.02
Tolal simulation		5.68 \pm 1.04	3.28 \pm 0.67	3.57 \pm 0.76	3.41 \pm 0.75	2.74 \pm 0.61	2.70 \pm 0.51
Data		5.64 \pm 0.10	3.27 \pm 0.07	3.35 \pm 0.07	3.19 \pm 0.05	2.62 \pm 0.05	2.64 \pm 0.05

Calculating Initial Activities

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- ▶ ^{109}Cd :
 - Measuring time interval between the prompt x-ray and the 88 keV from the secondary decay
 - $^{109}\text{Ag}^*$ half-life = 39.7s
 - Fit time interval to exponential decay
 - Measurement with good precision

