Status of the COSINE-100

Pushparaj Adhikari

On behalf of the COSINE-100 collaboration

Center for Underground Physics (CUP), IBS
Sejong University, Seoul, Korea

The 22nd annual International Conference on Particle Physics and Cosmology

COSMO-18

August 27-31, 2018
IBS Science and Culture Center
Daejeon, Korea

The COSINE collaboration

Joint collaboration between KIMS and DM-Ice to search for dark matter interactions in NaI(Tl) scintillating crystals.

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14 institutes, ~50 members





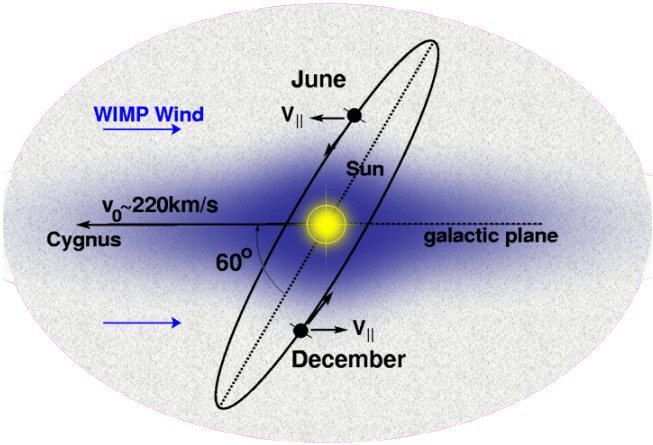
Dark Matter Modulation

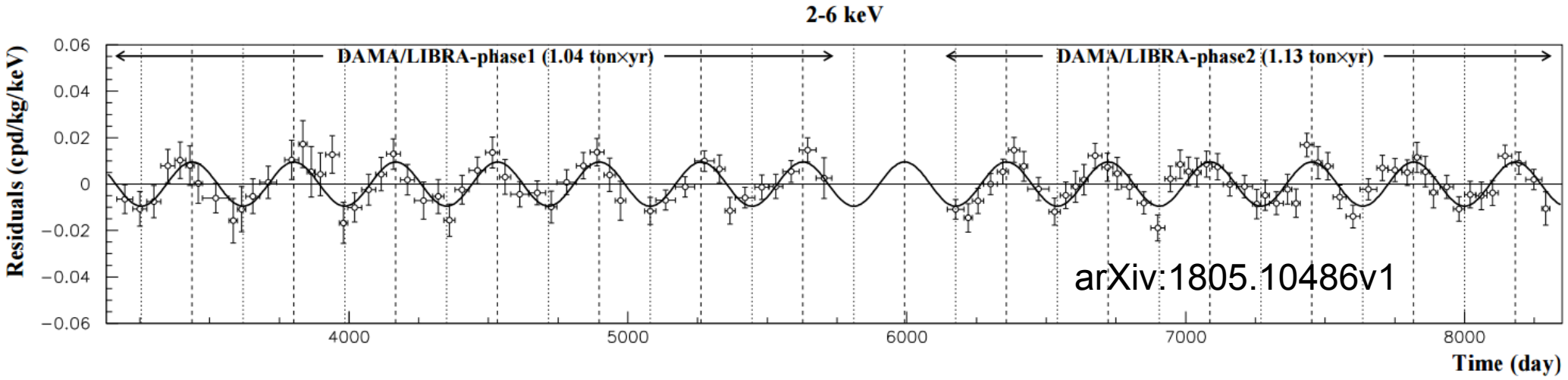
The relative velocity between DM particles in galactic halo and detectors varies over the year.

Approximately sinusoidal modulation for the recoil rate of DM at keVee energies.

Peaks at early June.

Modulation observed by DAMA/LIBRA





Motivation : The DAMA annual modulation signal, to be confirmed with independent measurements by the same NaI(Tl) target material

COSINE-100 experiment

Located at Yangyang underground laboratory (Y2L), South Korea, with ~700 m rock overburden.

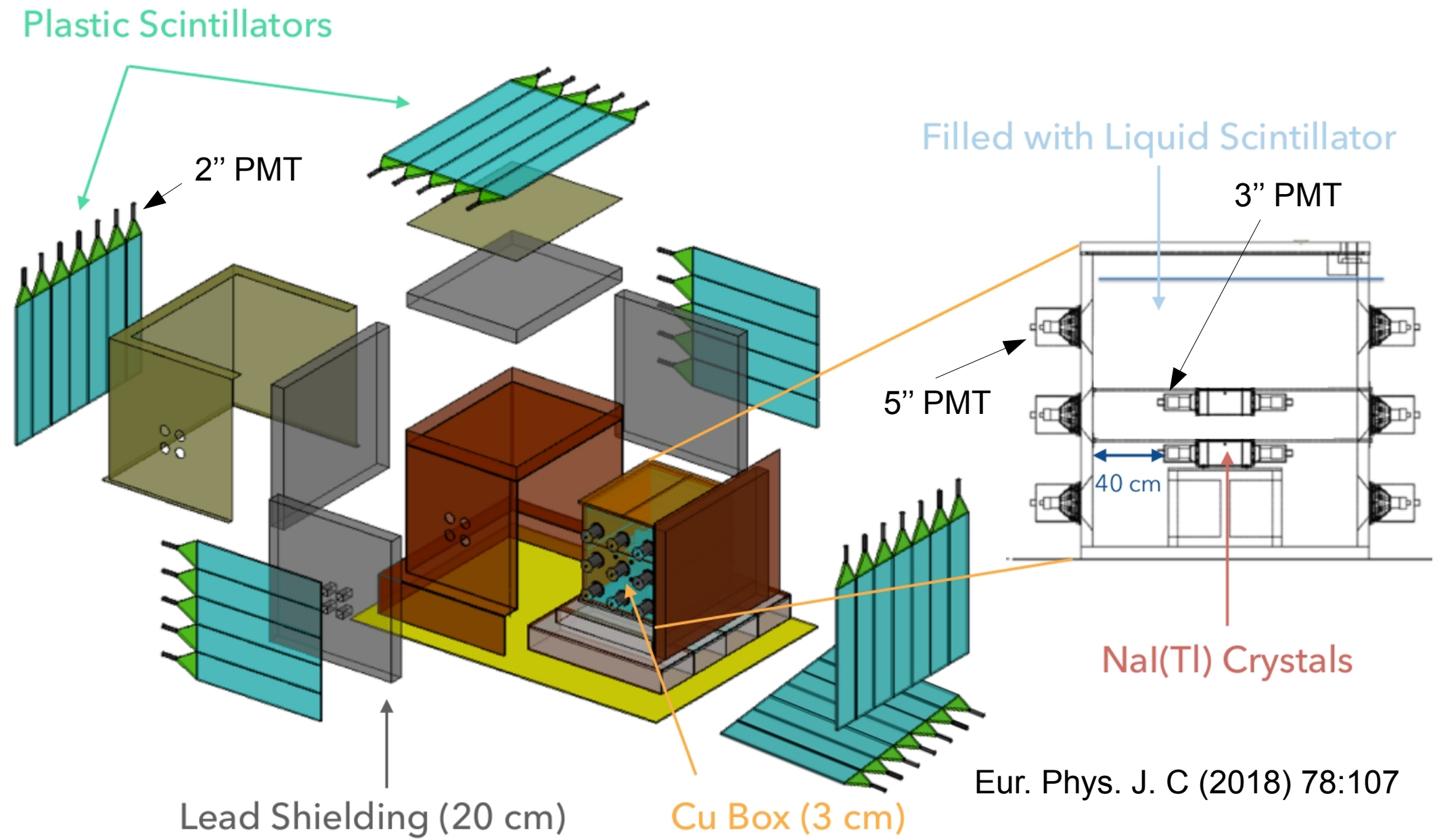
1000 m

700 m

Yangyang Pumped Storage Power Plant

양양양수발전소

Shielding Structure



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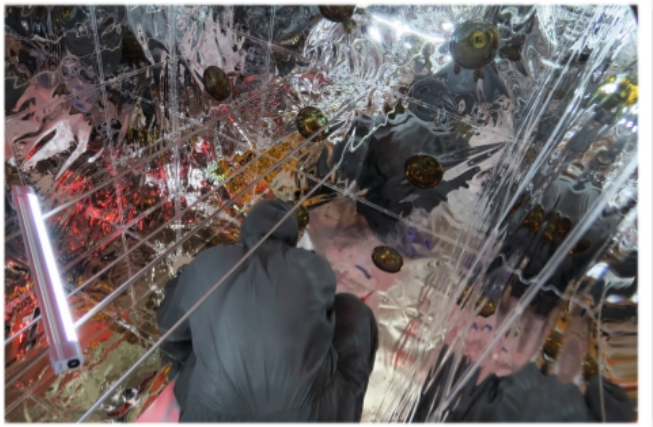
COSINE-100 Construction

Dec. 2015 — Jan. 2016 — Feb. 2016

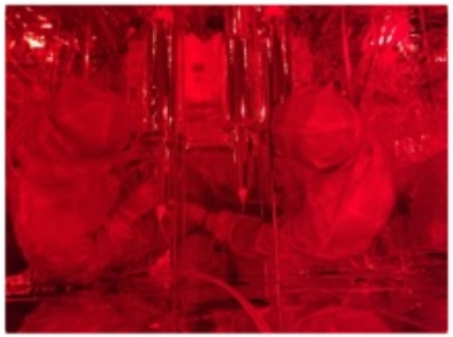



Mar. 2016 — Apr. 2016



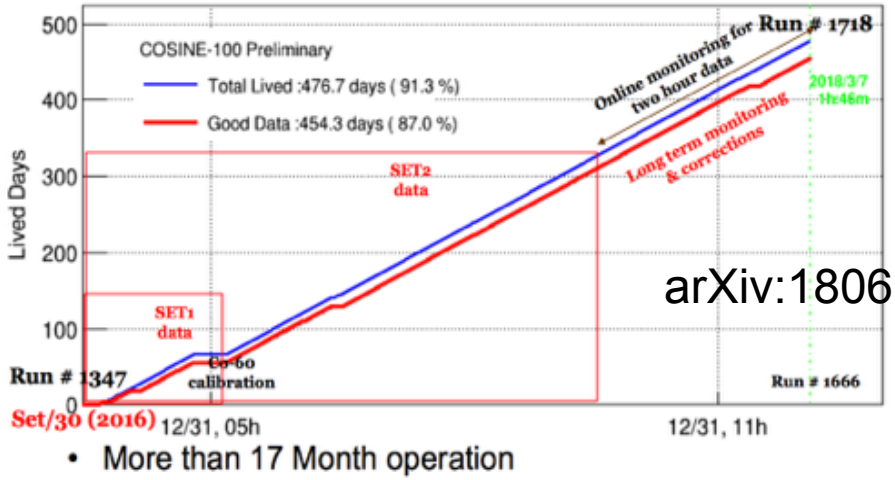



May. 2016 — Jun. 2016 — Sep. 2016





COSINE-100 operation

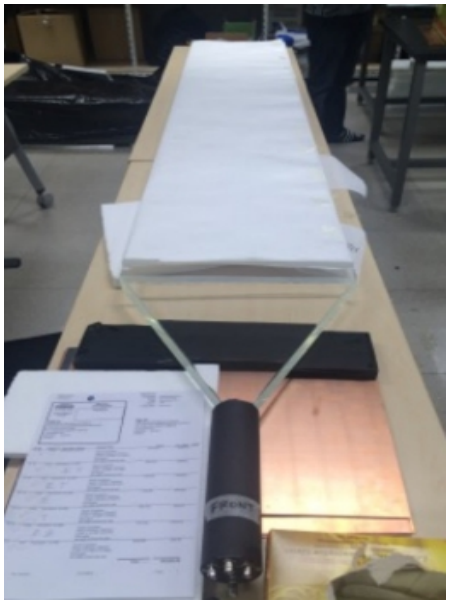


- More than 17 Month operation

arXiv:1806.09788

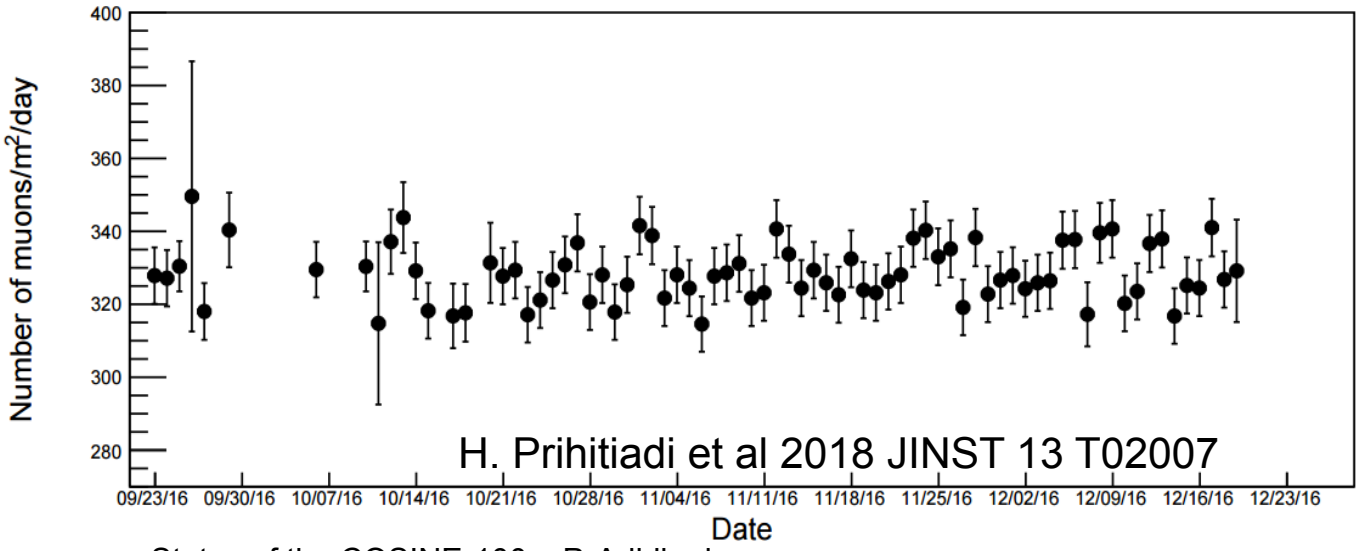
Plastics scintillators

Purpose: To tag cosmic ray muon events

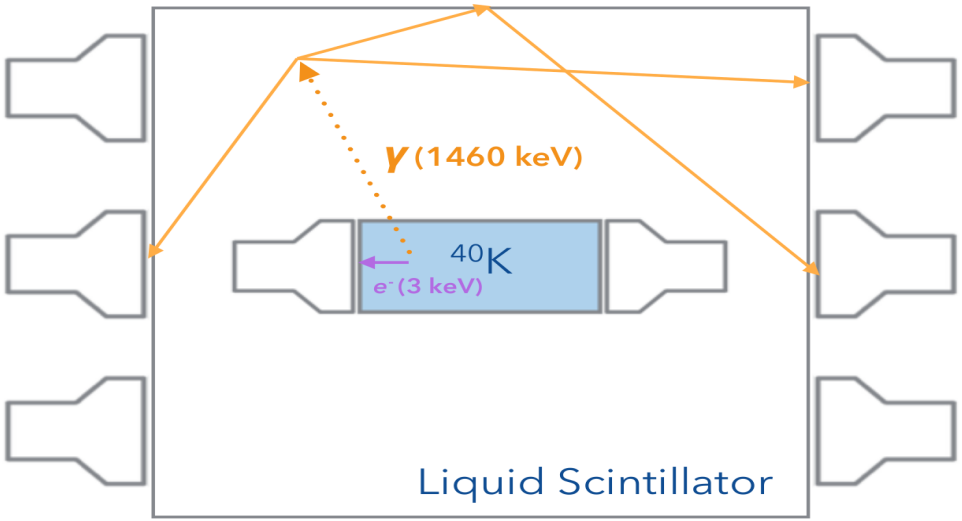


- 37 panels of plastic scintillator (EJ-200), 3cm thick
- Wrapped with diffuse reflector and attached with light guides to 2" PMTs.

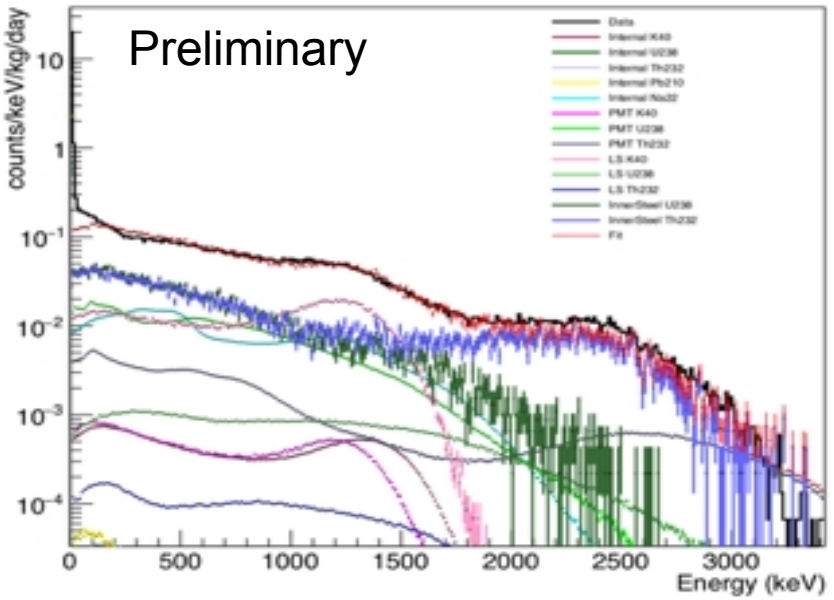
Muon rate



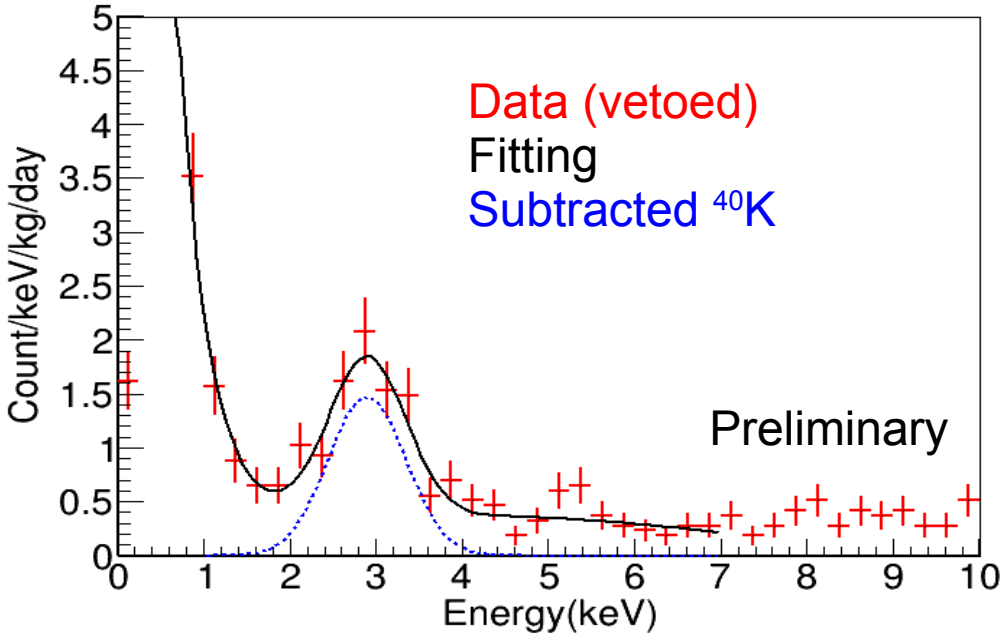
Crystal-LS Coincidence Events



Liquid scintillator Energy spectrum



Vetoed events in Crystal2



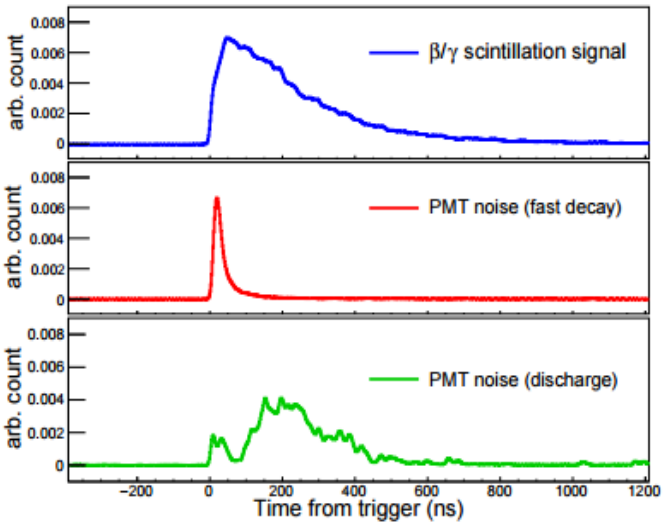
~70% of ^{40}K tag by LS

Low energy noise

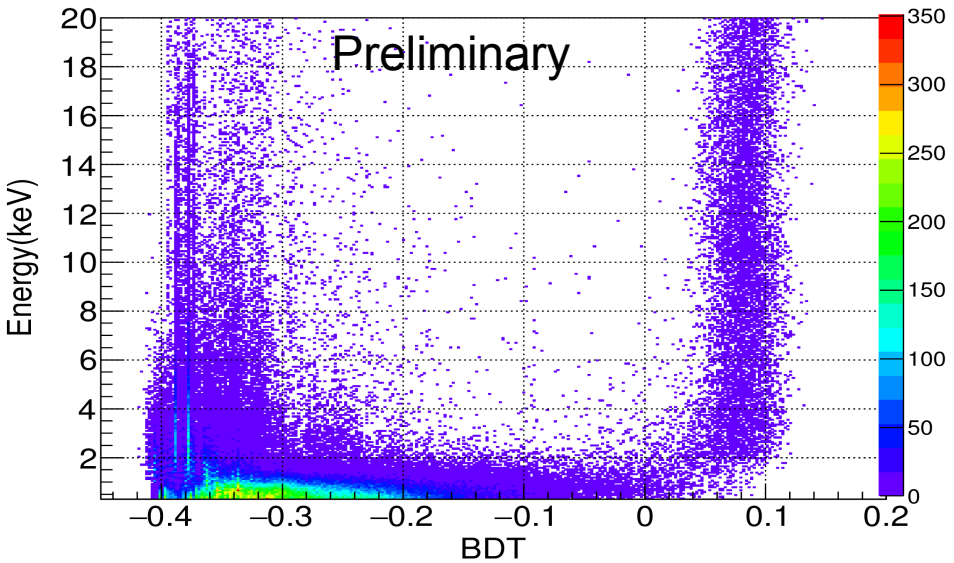
The multi-variate analysis:

Boosted decision tree (BDT) techniques are applied to separate noise from the beta/gamma events.

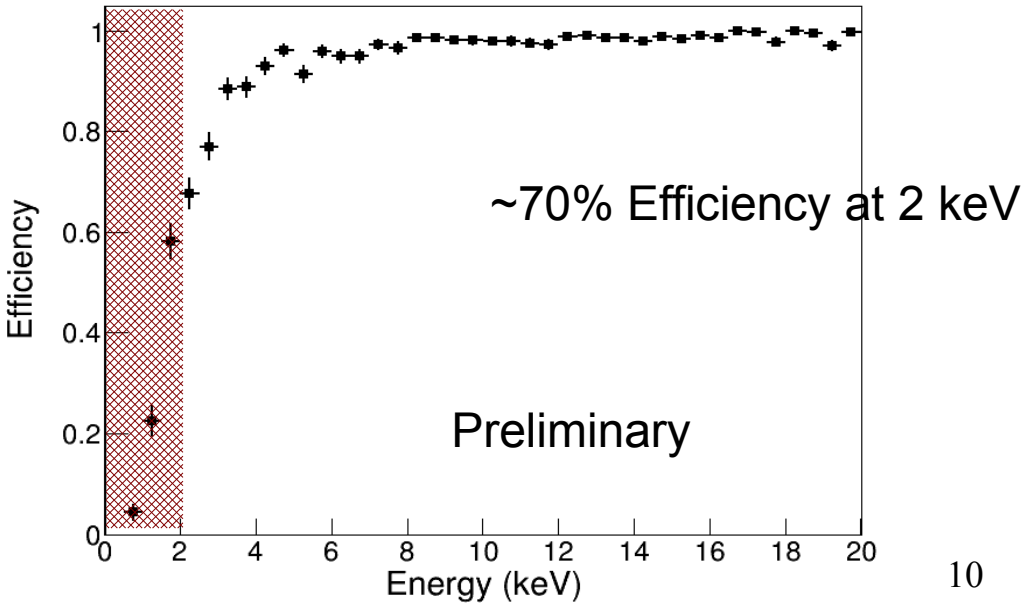
Average waveforms



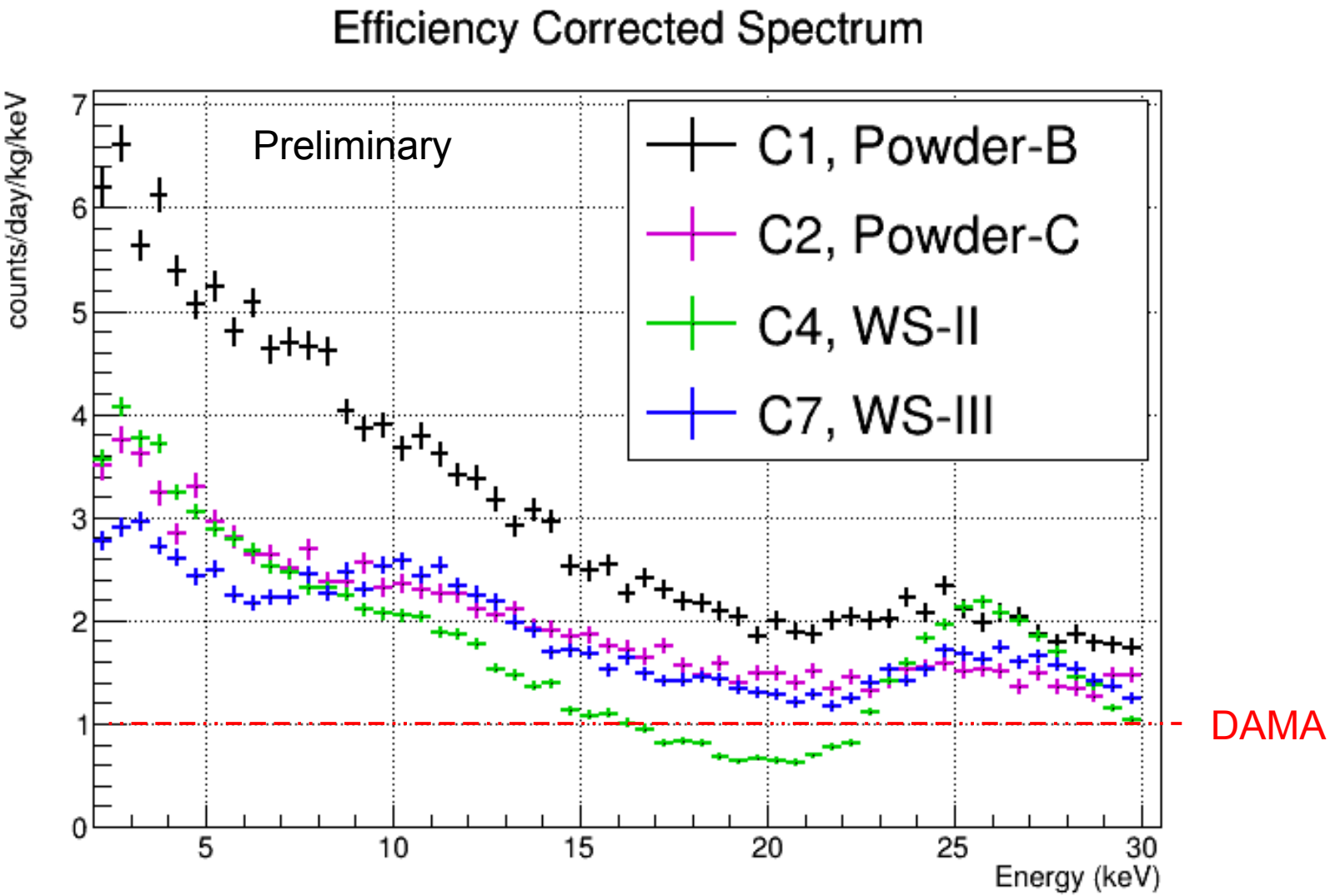
BDT parameter Vs. energy



Signal efficiency



Background spectrum



Average count rate at 2-6 keV is “3.5 counts/day/kg/keV”

Crystal bkg. generally follows Powder bkg.

Background Assessment

4 Channel (low energy, high energy, single hit, multiple hit) simultaneous fitting

2-6 keV region not used in fitting

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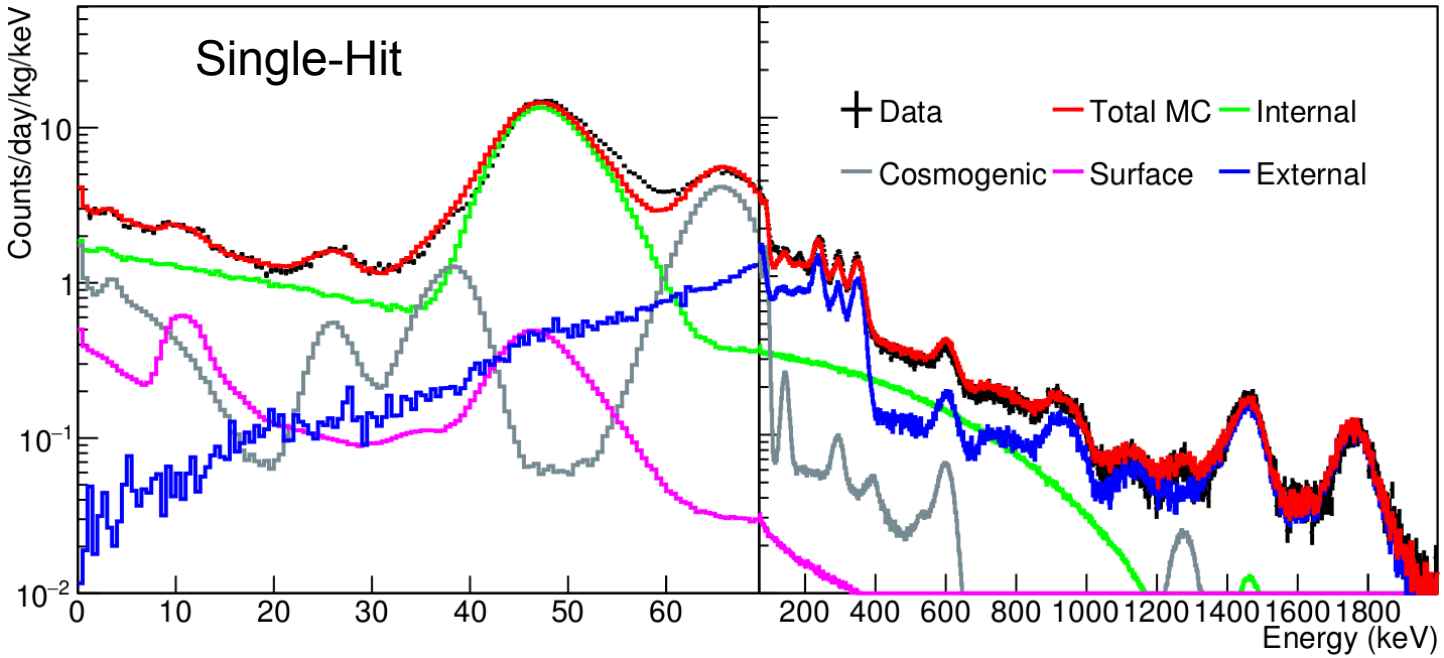
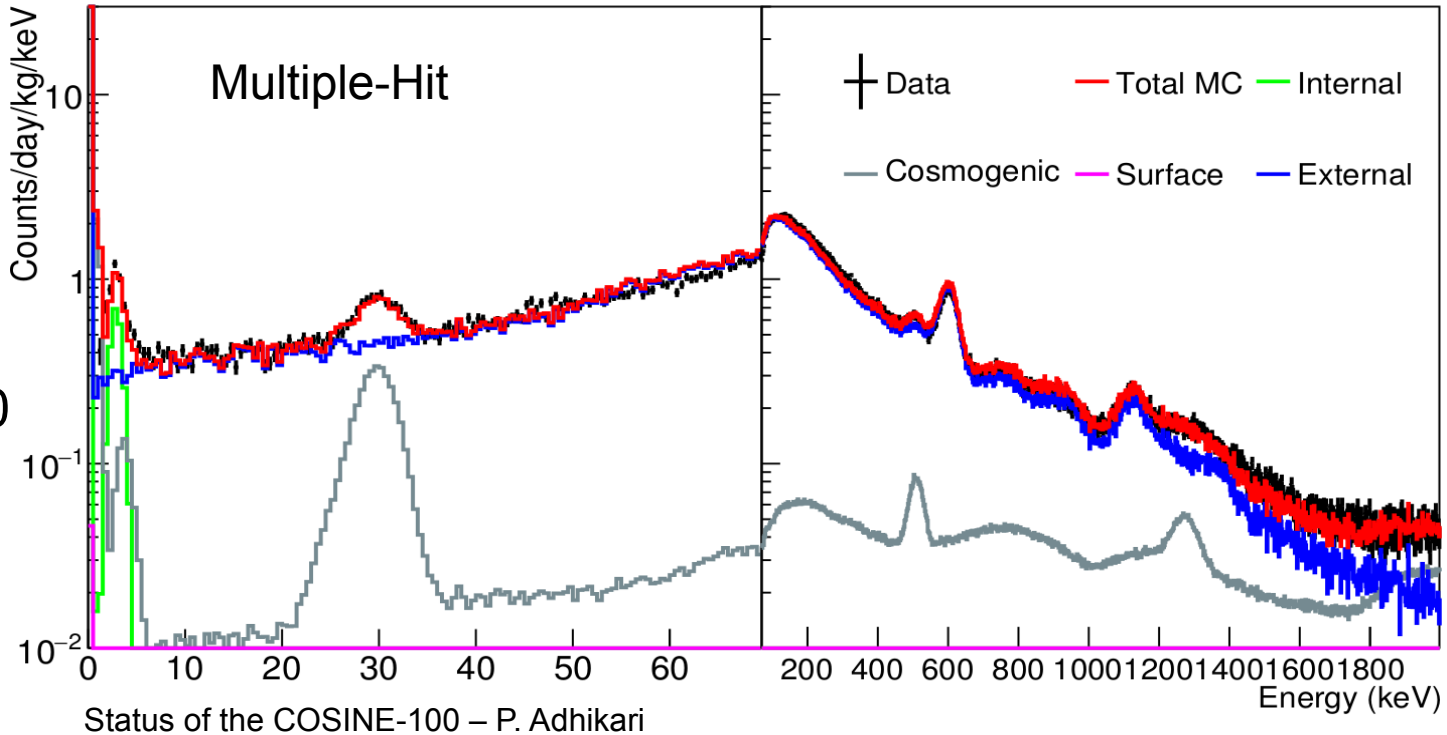
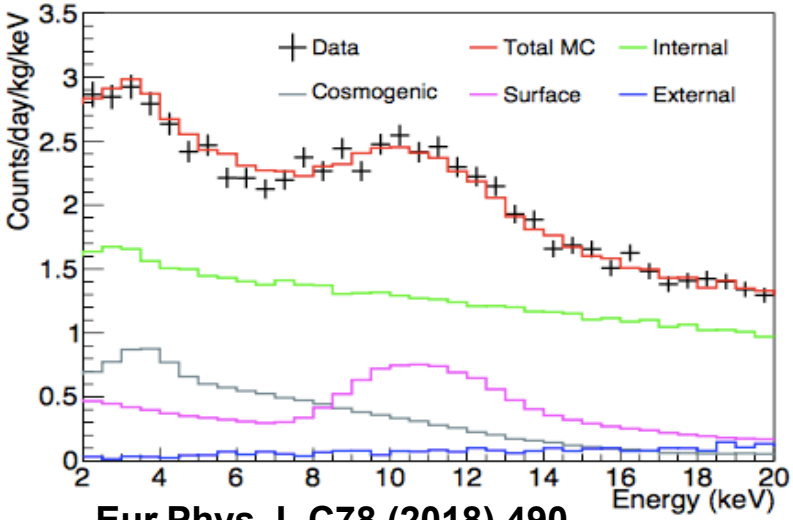




WIMP Search data

59.5 days of Data

8 single-hit spectra are fit simultaneously with an assumed SHM (Standard Halo Model) WIMP signal as described in C. Savage et al., JCAP 04, 39 (2009).



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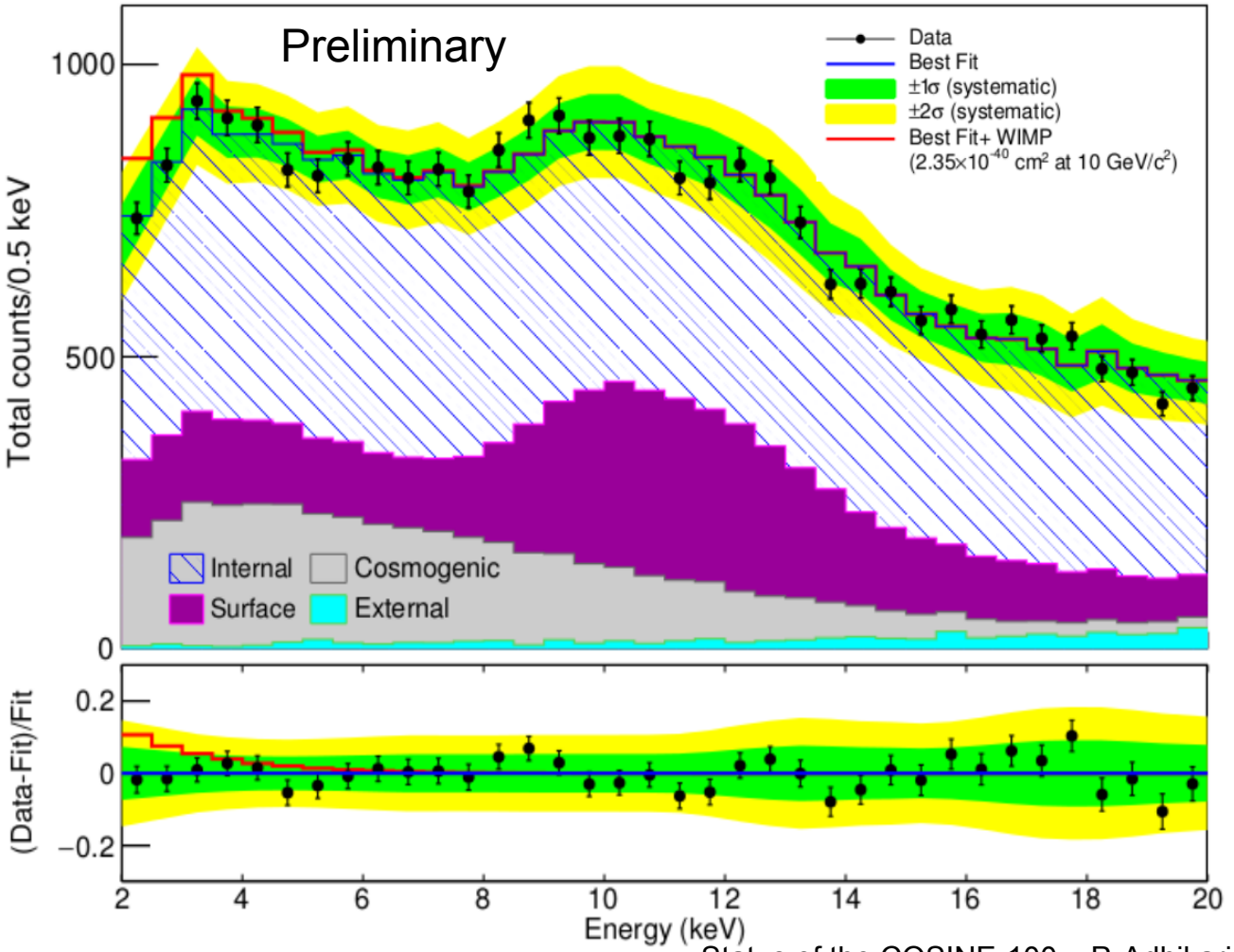
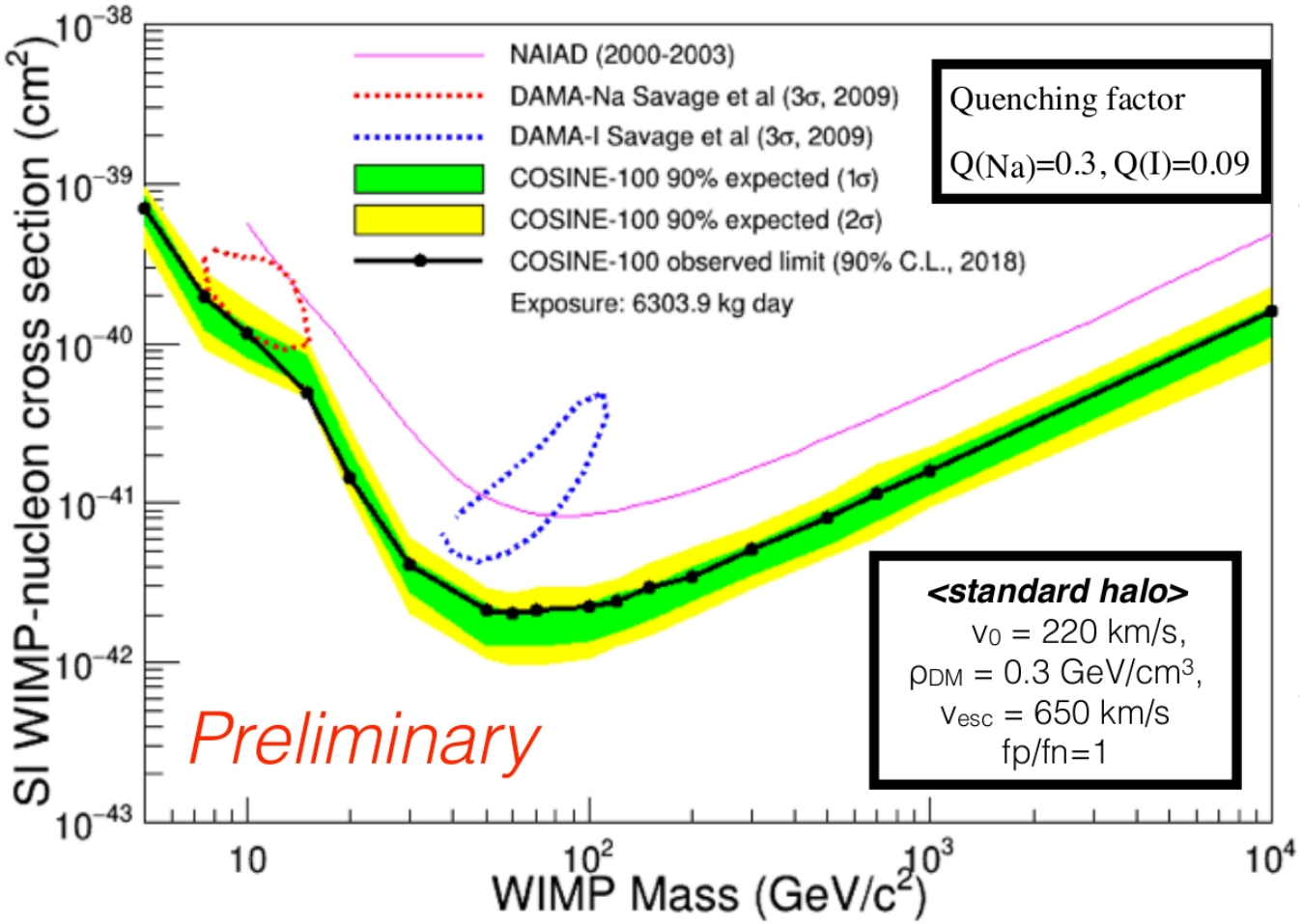


Crystal-6 fitting results

Spin independent WIMP-nucleon cross section limit

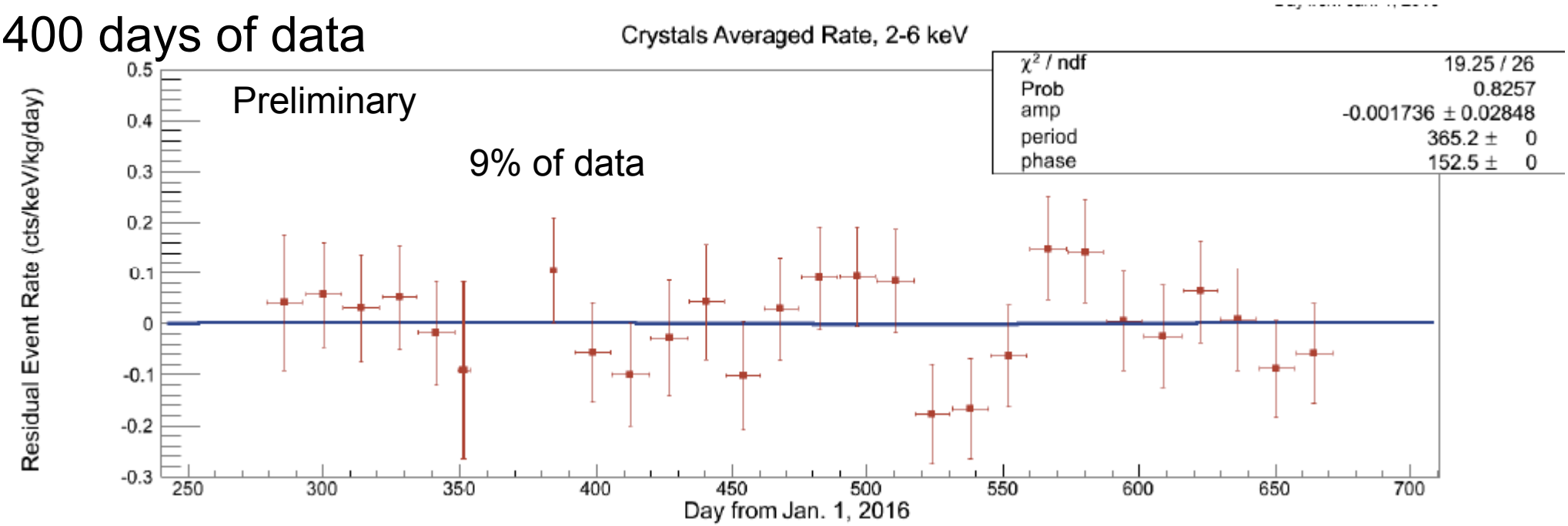
COSINE-100 excludes DAMA/LIBRA-phase1's signal as spin independent WIMP with Standard Halo Model in NaI(Tl)



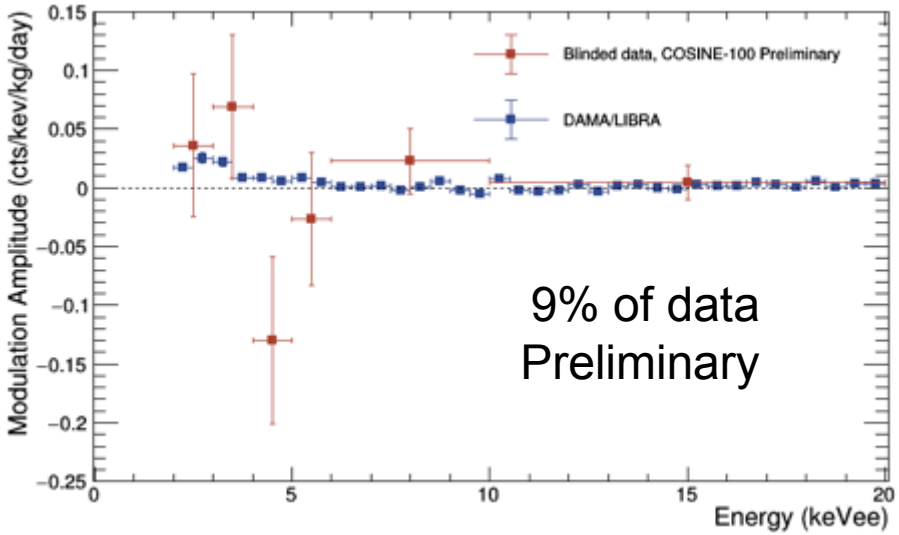
Consistent with null results from other direct detection experiments with different target materials

Annual modulation analysis : Preliminary, Blinded

400 days of data



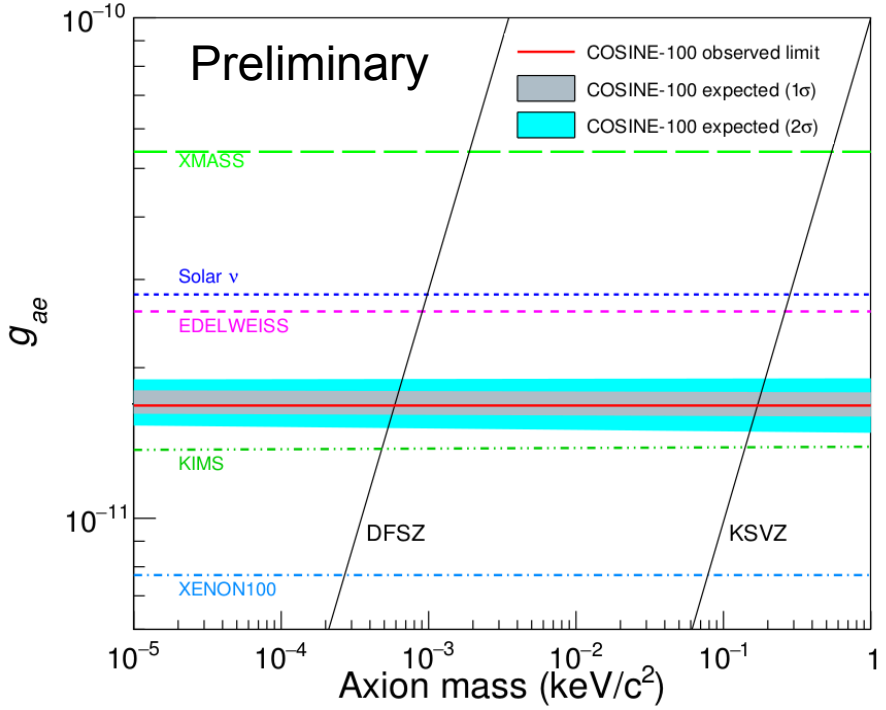
Crystals 1, 5, and 8 are excluded in this analysis due to excessive PMT noise and low light yield



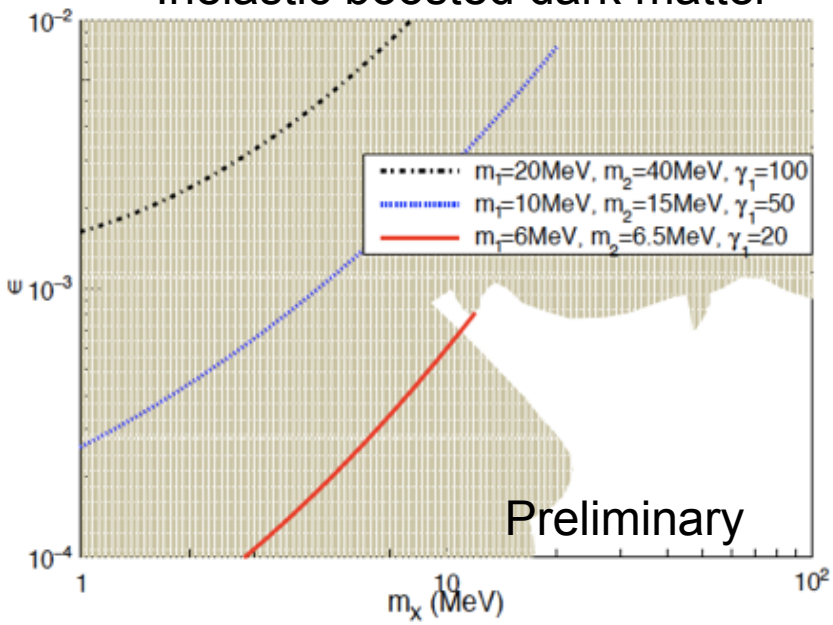
Unblinding soon. Stay tuned!

Other searches

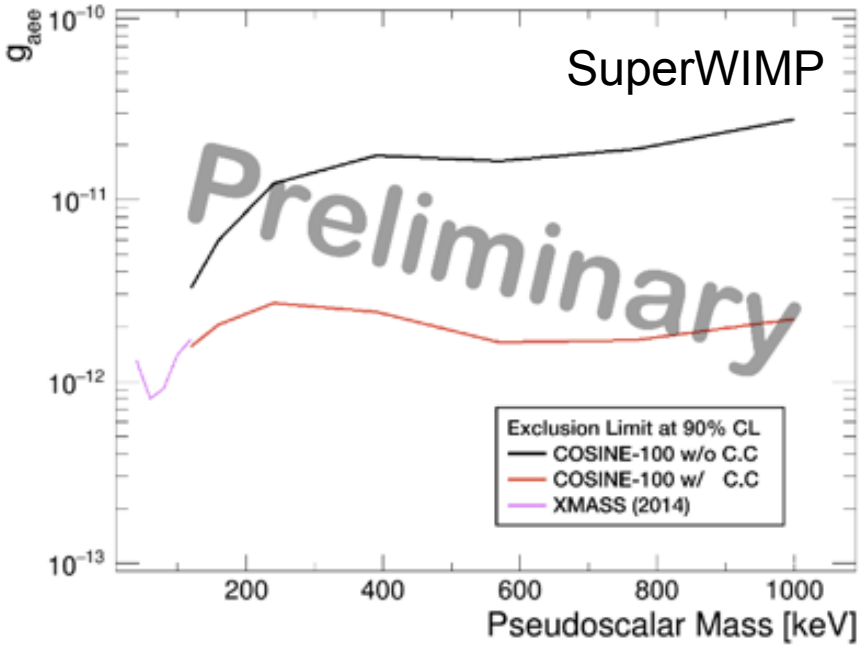
Solar Axion



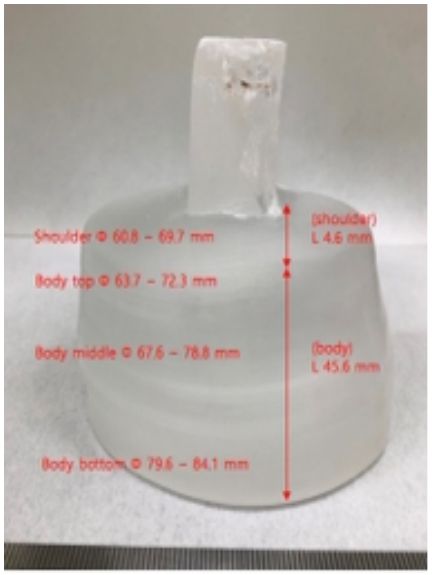
Inelastic boosted dark matter

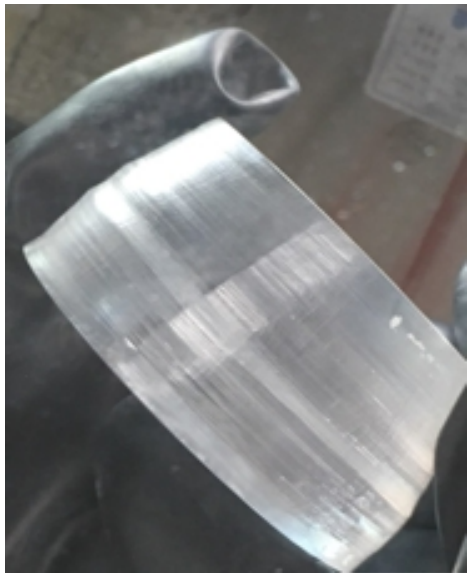


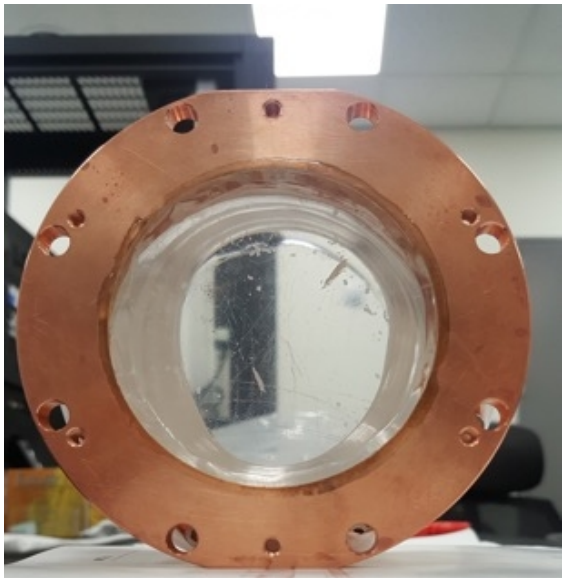
SuperWIMP



Growing low radioactive NaI(Tl) Crystals at CUP

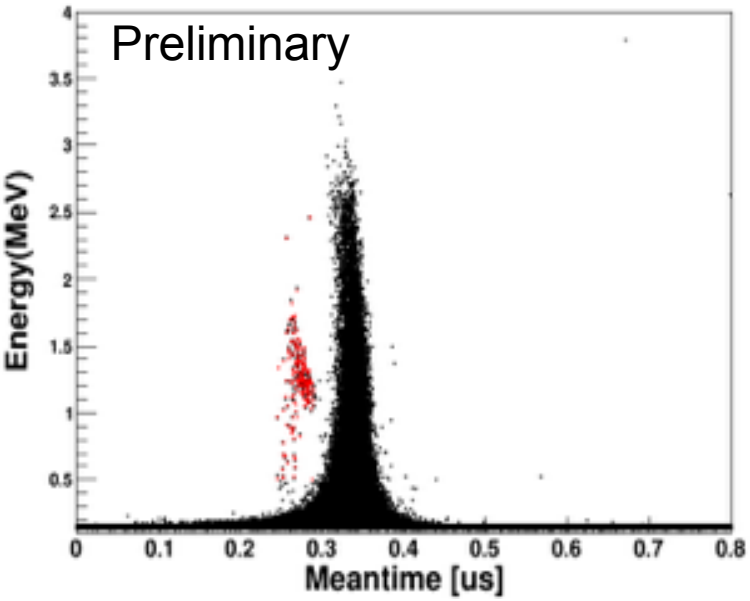




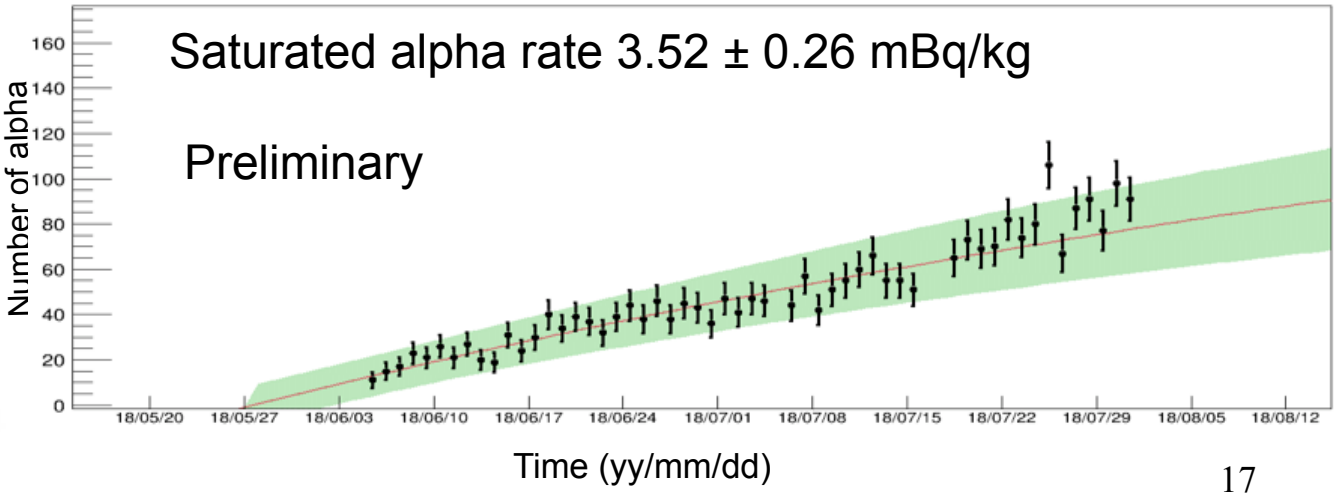


Light Yield : ~ 10.4 p.e./keV,
K-40 : ~100 ppb

Energy vs Meantime



Alpha rate



Summary & Outlook

The COSINE-100 experiment was installed at Y2L and runs smoothly for about two years.

COSINE-100 confirms that DAMA's modulation signal cannot be from standard WIMP & SHM with NaI(Tl).

Modulation analysis is on-going.

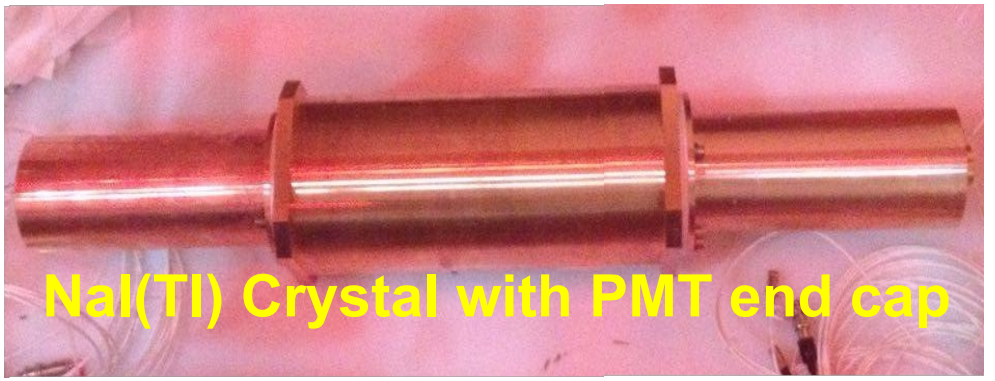
Much progress made in developing the capabilities to grow and encapsulate radio-pure NaI(Tl) crystals at IBS-CUP

Analysis with lower threshold is underway

BACKUP

NaI(Tl) crystals

8 crystals with total mass of ~106 kg

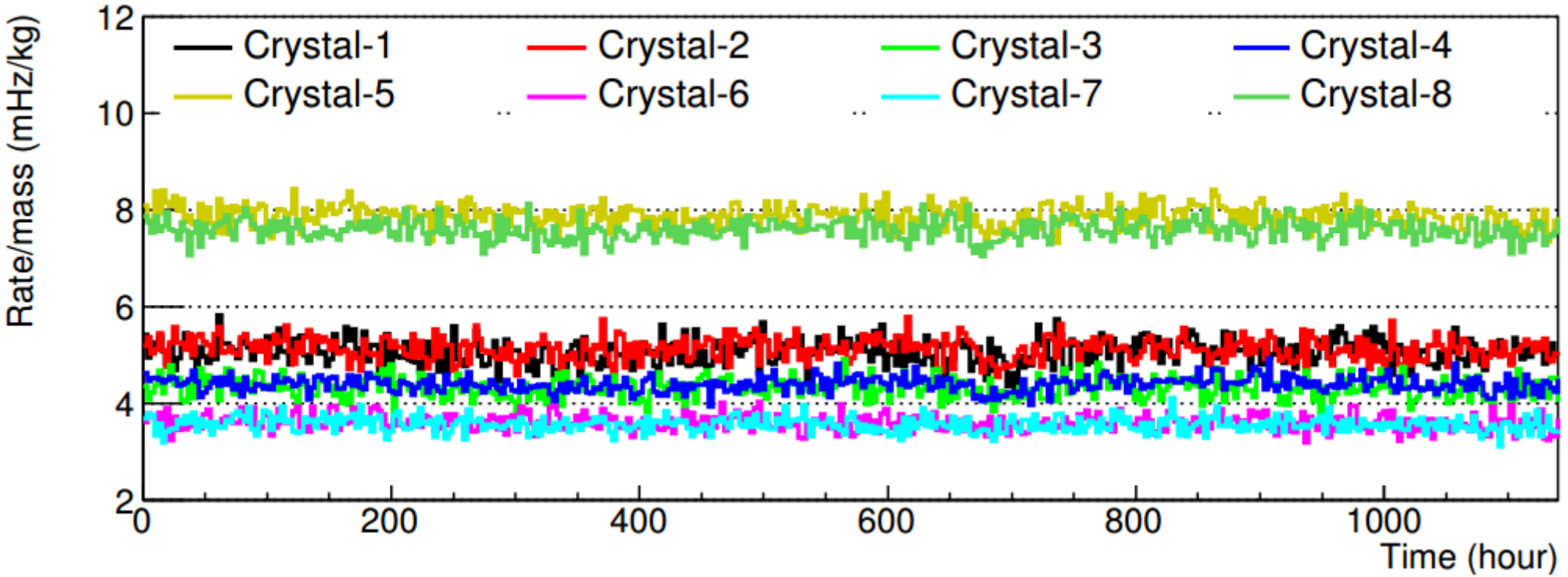


Preliminary background values estimated both at R&D and COSINE setup

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

Event rate

Crystal trigger rates versus time (in hours) for the first physics run (48 days).

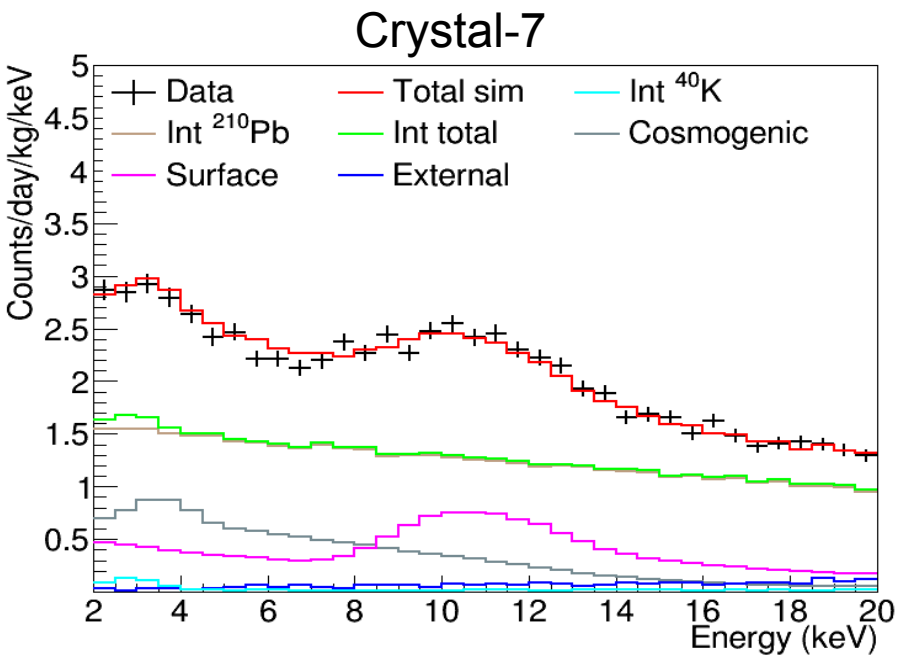


All of the crystals show stable behavior throughout this running period and the rest of data-taking.

Low energy region (Region of interest)

~3.5 counts/day/keV/kg in the (2-6) keV energy

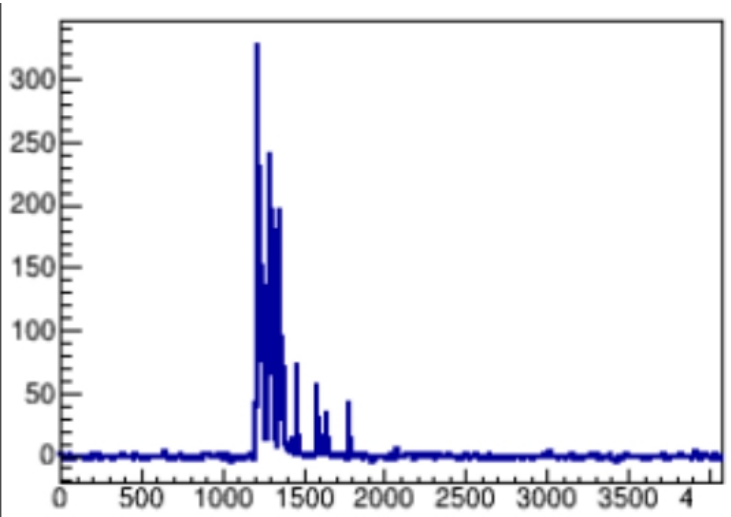
Dominant contributions from 210Pb and 3H.



2-6keV single hit dru level

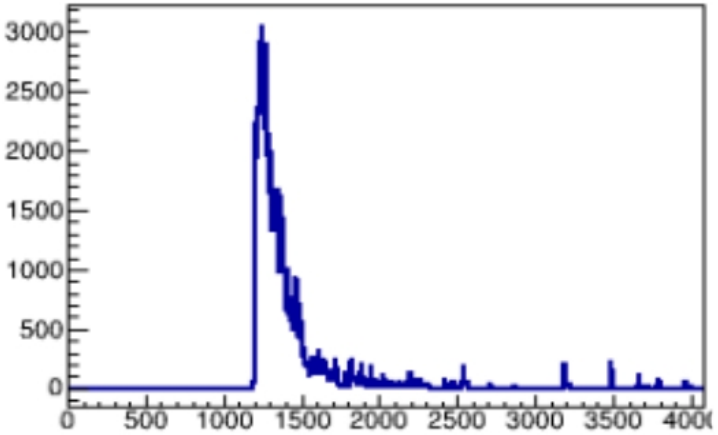
		Crystal-1	Crystal-2	Crystal-3	Crystal-4	Crystal-6	Crystal-7
Internal	^{40}K	0.10 ±0.02	0.20 ± 0.02	0.10 ± 0.01	0.10 ±0.01	0.05 ± 0.01	0.05 ±0.01
	^{210}Pb	2.50 ± 0.10	1.69 ± 0.09	0.57 ± 0.05	0.71 ± 0.05	1.46 ± 0.07	1.50 ± 0.07
	Other ($\times 10^{-4}$)	7.0±0.1	15±1	7.3±0.1	7.7±0.1	14±1	14±1
Cosmogenic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

Examples of Signal Events

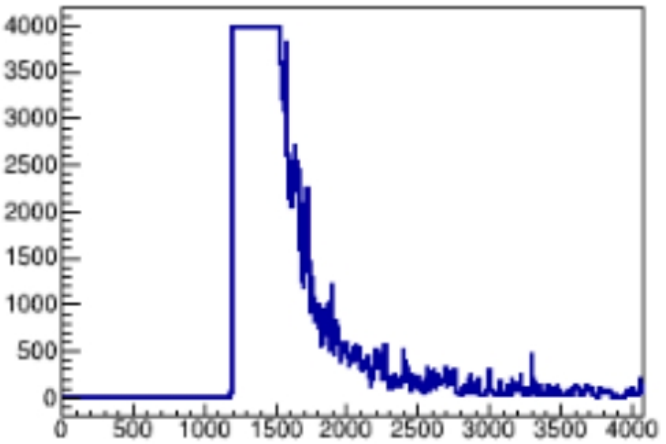


3 keV

100 keV



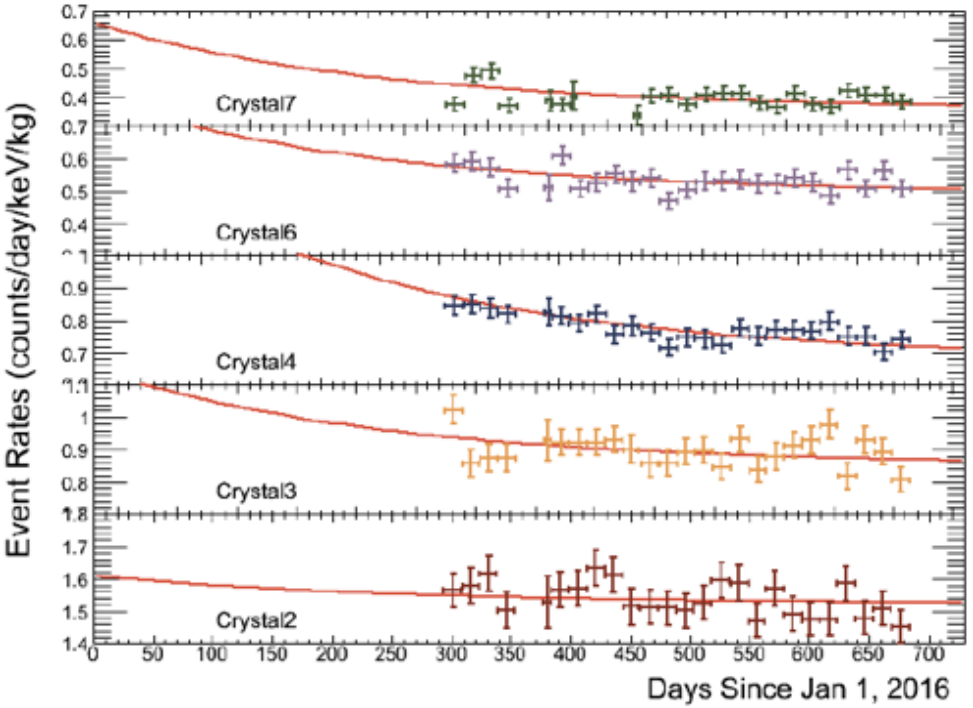
> 1 MeV



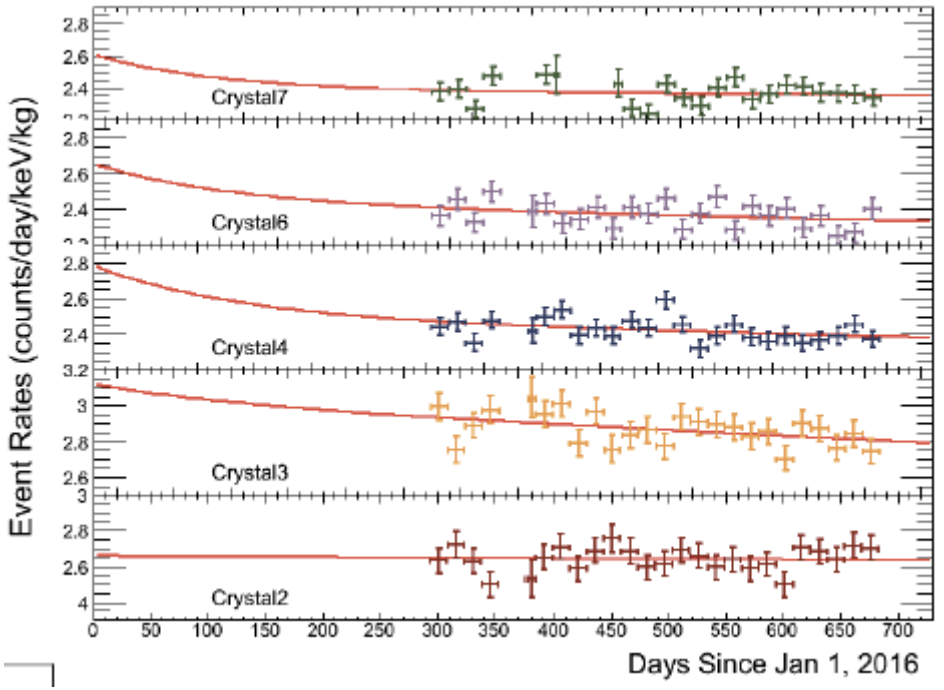
Annual Modulation Analysis

400 days of data

Side band : Multiple-hit (2-6 keV)



Side band :Single-hit (6-10 keV)



Side band data fit well with simple exponential models built from the known cosmogenic components

Crystals 1, 5, and 8 are excluded in this analysis due to excessive PMT noise and low light yield