Status of COSINE

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Feb. 20, 2018

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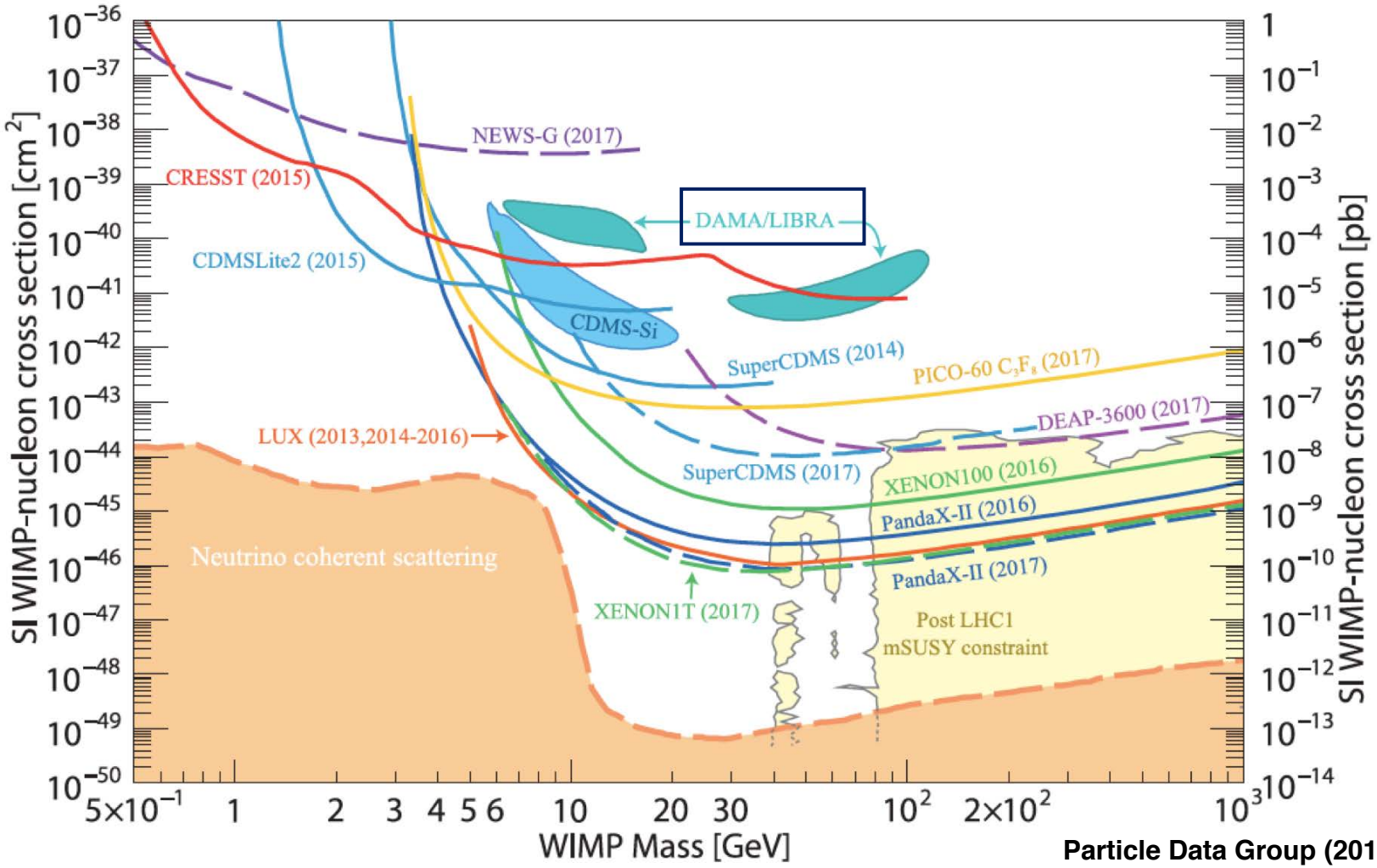
Spin Independent WIMP-Nucleon Cross Section



Particle Data Group (2017)

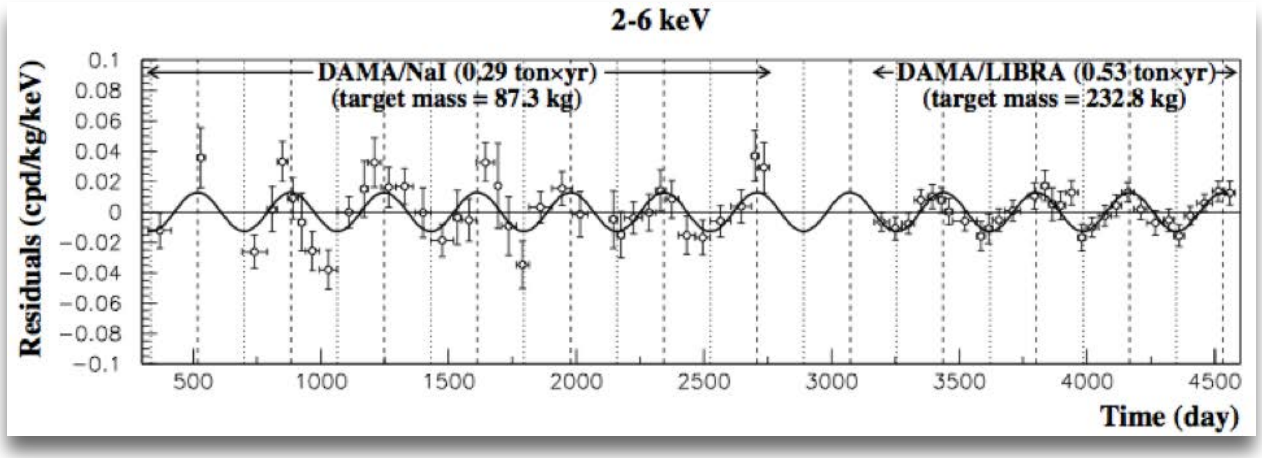
- Direct dark matter detection has made impressive advances in the past decade.
- DAMA NaI annual modulation signal is in conflict with several other experiments

Annual Modulation Observed by DAMA

Longest standing and the largest signal: **9.3 σ modulation over 14 years**

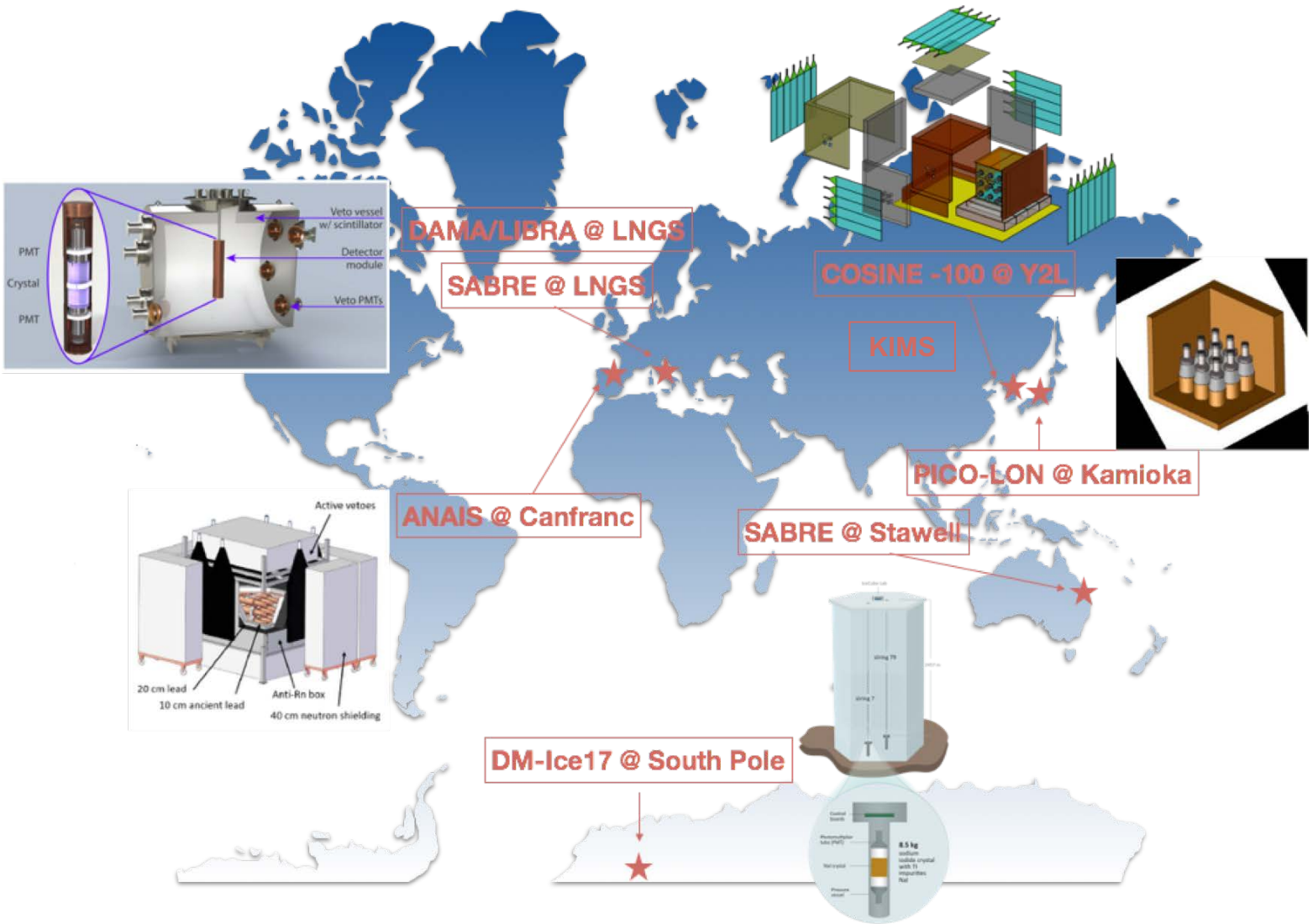
- Modulation consistent with dark matter:
  - **Phase:** 144 ± 7 days (peak on May 24)
  - **Period:** 0.998 ± 0.002 yr
  - **Background:** ~ 1 cnts/keV/kg/day (DRU)
  - **Amplitude:** 0.0112 ± 0.0012 cnts/keV/kg/day
- Two generations:
  - DAMA/NaI: 100 kg (1996 - 2003)
  - DAMA/LIBRA-phase1: 250 kg (2003 - 2010)
- 1.33 ton-yr over 14 annual cycles

But is it dark matter or seasonal background?



Bernabei, R., Belli, P., Cappella, F. et al. Eur. Phys. J. C (2013) 73: 2648

Global NaI efforts

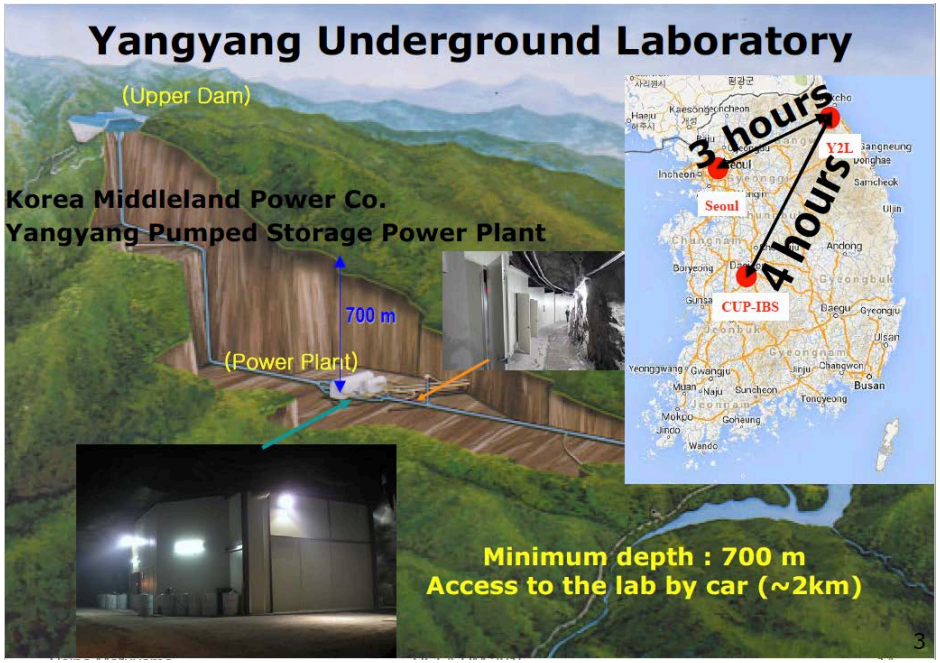


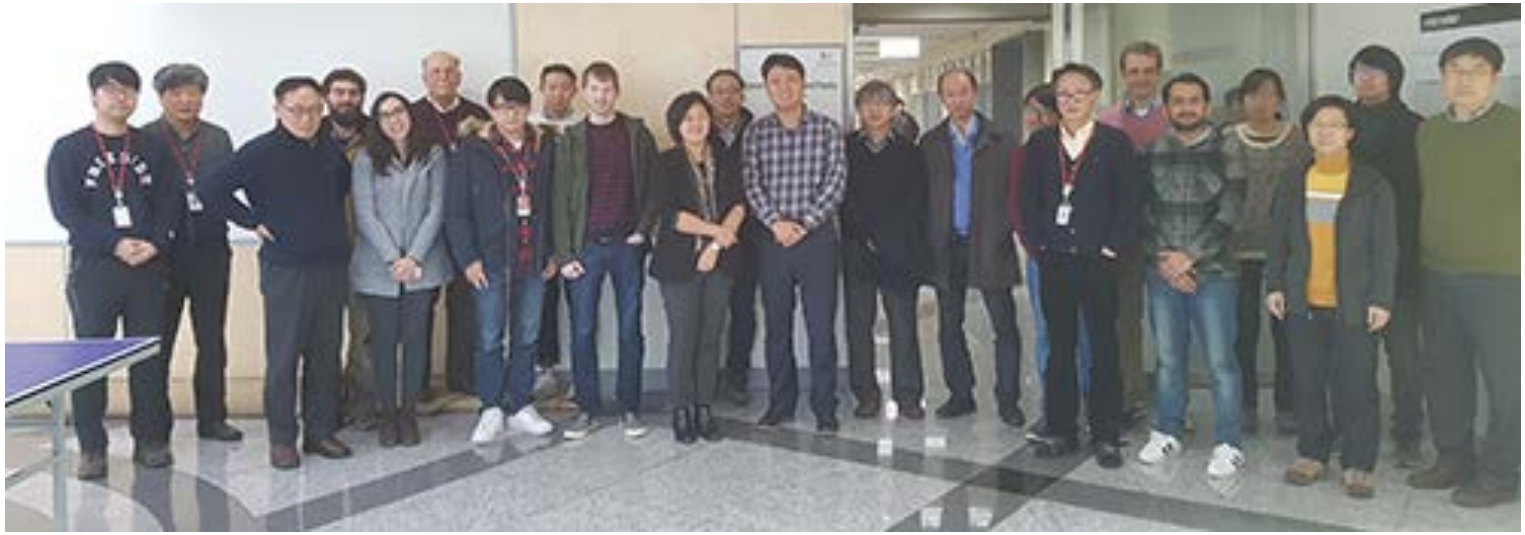
To do a definitive test, one needs to use the same target material.

COSINE Project

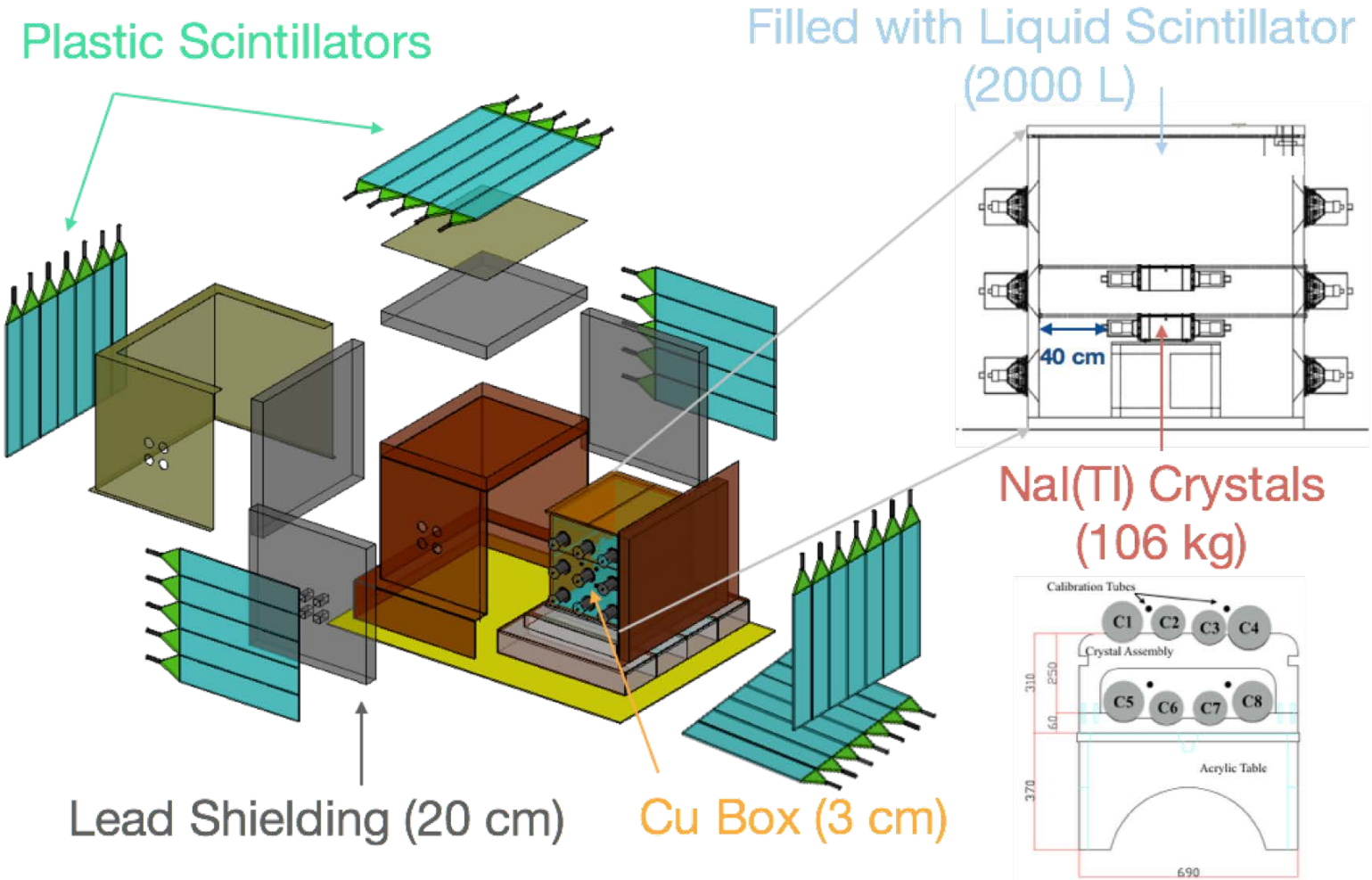
The joint experiments between KIMS and DM-Ice to search for dark matter interactions in NaI(Tl) scintillating crystals. (Goal to **do a definitive test of DAMA**)

5 countries,
14 institutes, ~50 members





Shielding Design of COSINE-100



Use liquid Scintillator to Veto ^{40}K background

Eur. Phys. J. C (2018) 78: 107.
arxiv.org/abs/1712.02011

Installation of COSINE-100

Dec. 2015 Jan. 2016 Feb. 2016




Mar. 2016 Apr. 2016

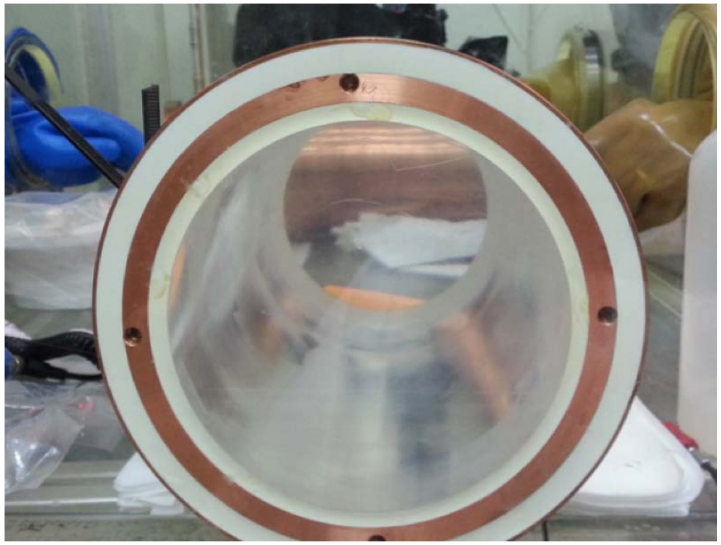



May. 2016 Jun. 2016 Sep. 2016



COSINE-100 Crystals

- **8 crystals, total 106 kg**
- **Culmination of R&D program with Alpha Spectra**
- **Light yield ~15 p.e./keV**
- **Total Background: 2 - 4 x DAMA's avg.**



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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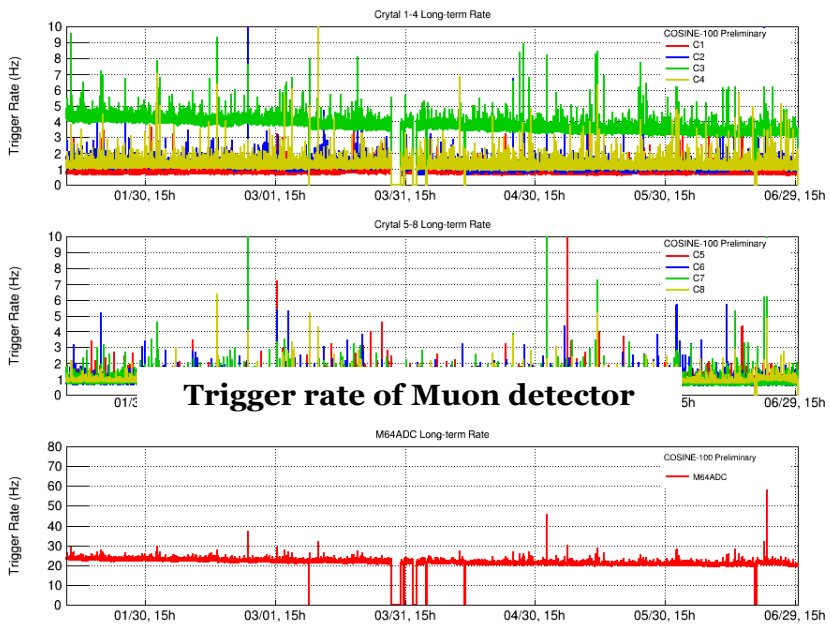
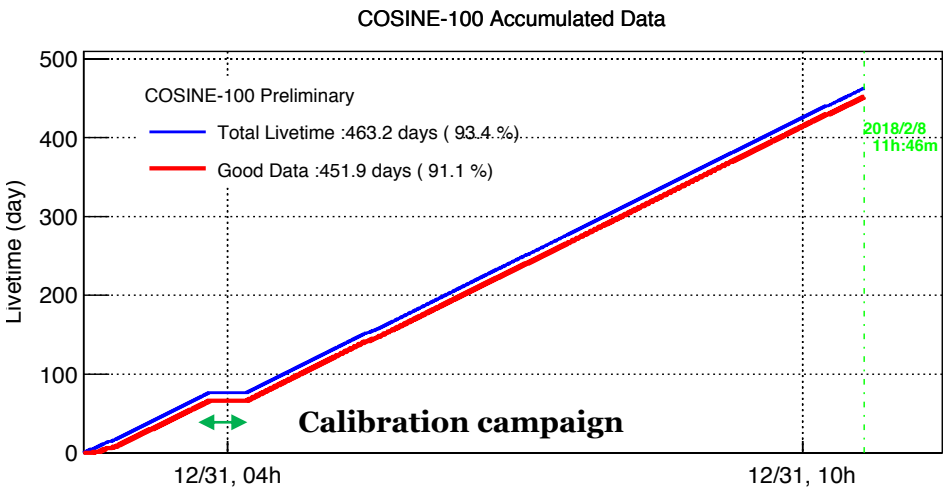
COSINE-100 operation

Trigger rate of NaI(Tl) crystals





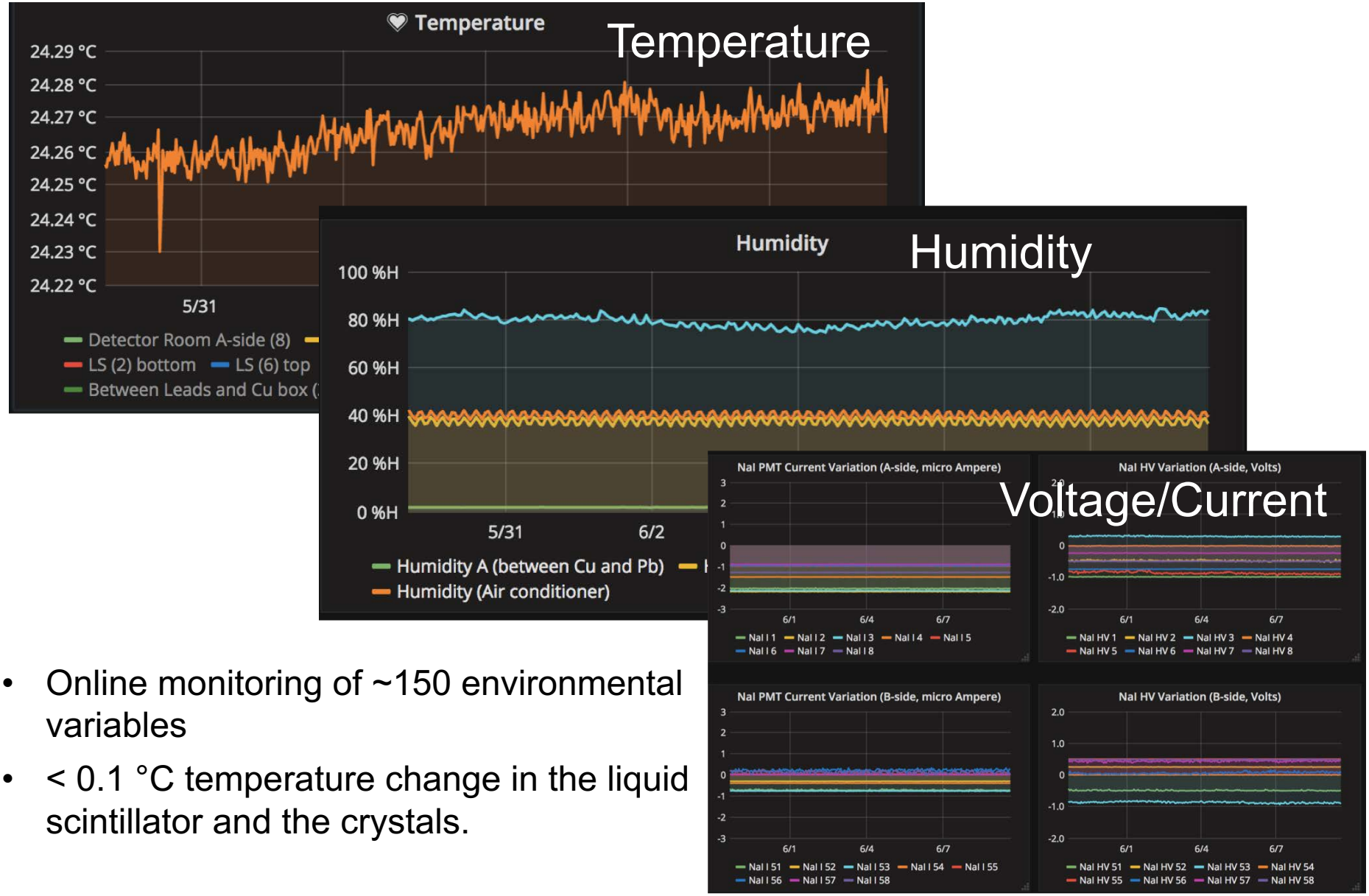
- Stable physic run

  ~ 95% lived time, near 100% uptime outside of calibration

- Taken more than 1.5 year of good physics data

  Physics analysis is ongoing

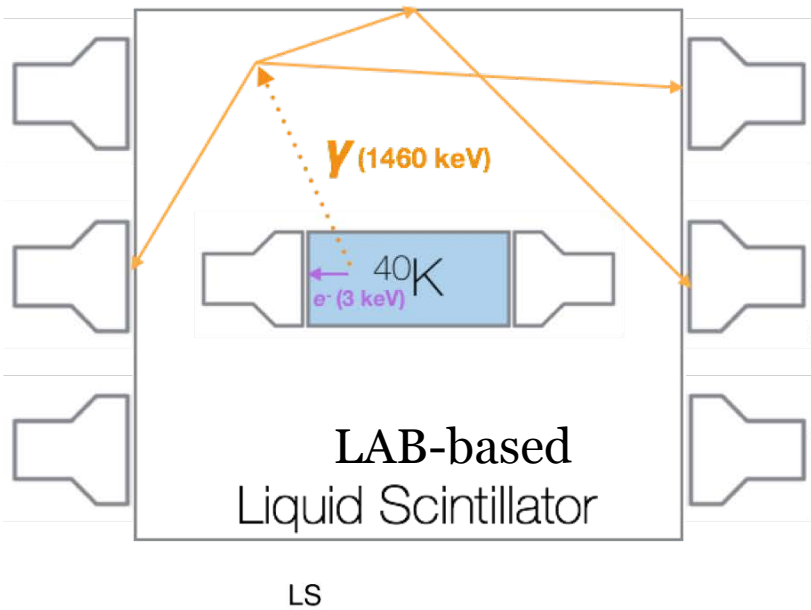
Environmental control and Monitoring

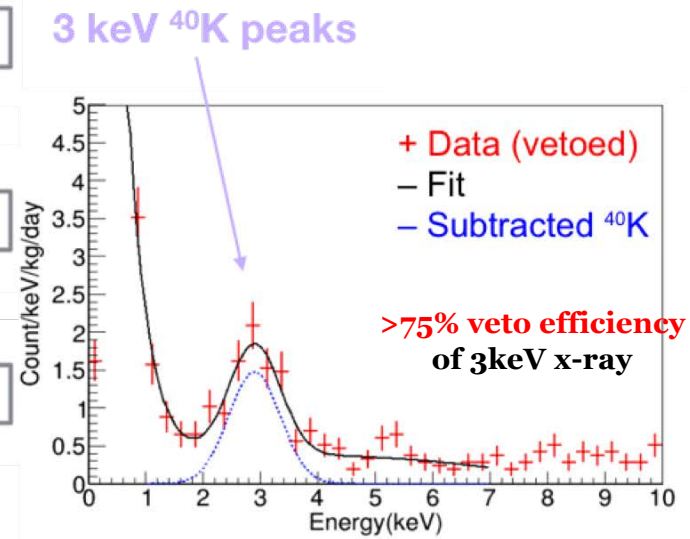


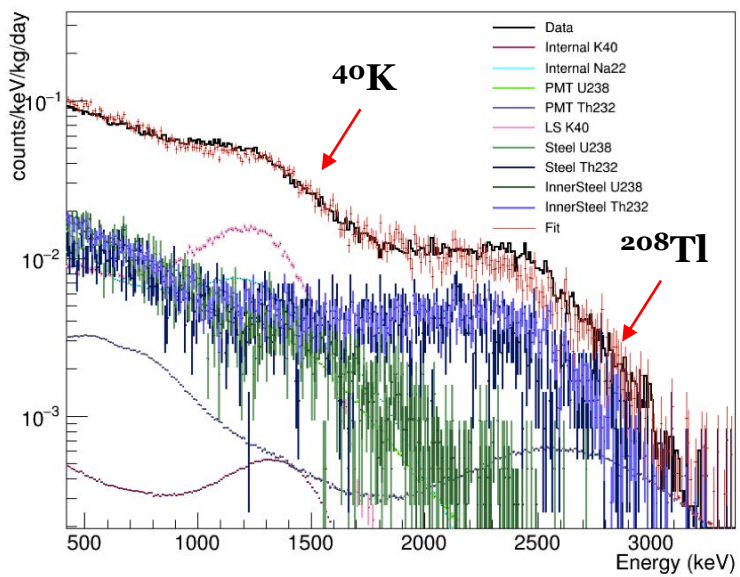
Voltage/Current

- Online monitoring of ~150 environmental variables
- < 0.1 °C temperature change in the liquid scintillator and the crystals.

Liquid scintillator veto system



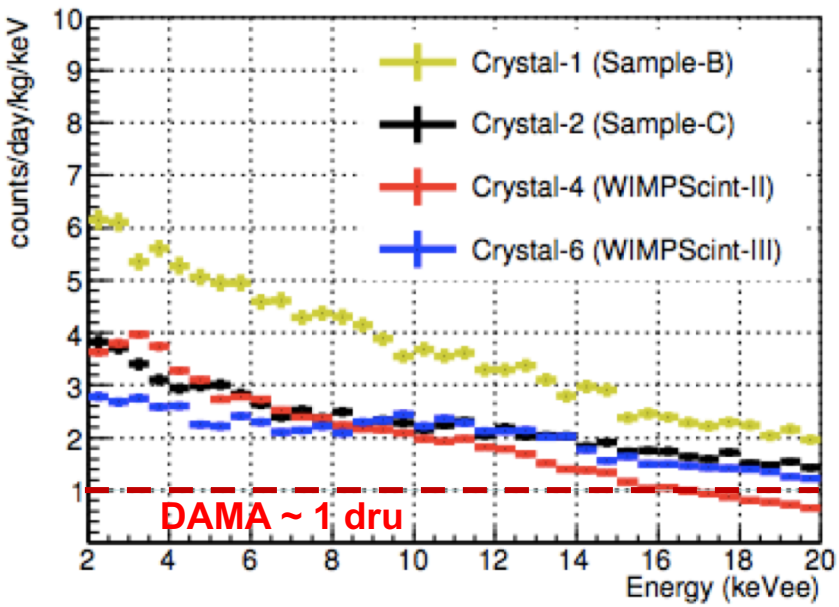




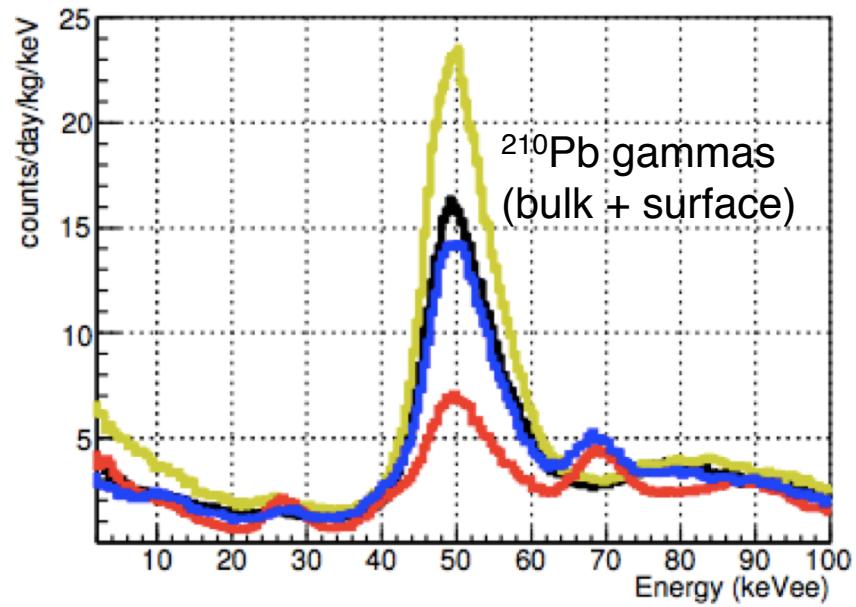
- Tagging rate of ^{40}K modelled with Geant4-based simulation
- Low internal background of LS
  - ^{40}K ~300 ppb
  - ^{238}U < 7 ppt
  - ^{232}Th < 4 ppt

Low Energy Spectrum

2 – 20 keV



2 – 100 keV



- 2 to 4 cnts/keV/kg/day in region of interest depending on the crystal
- ^{210}Pb, U/Th in Internal components (crystal growing/raw material)
- ^{210}Pb on crystal & PTFE surface

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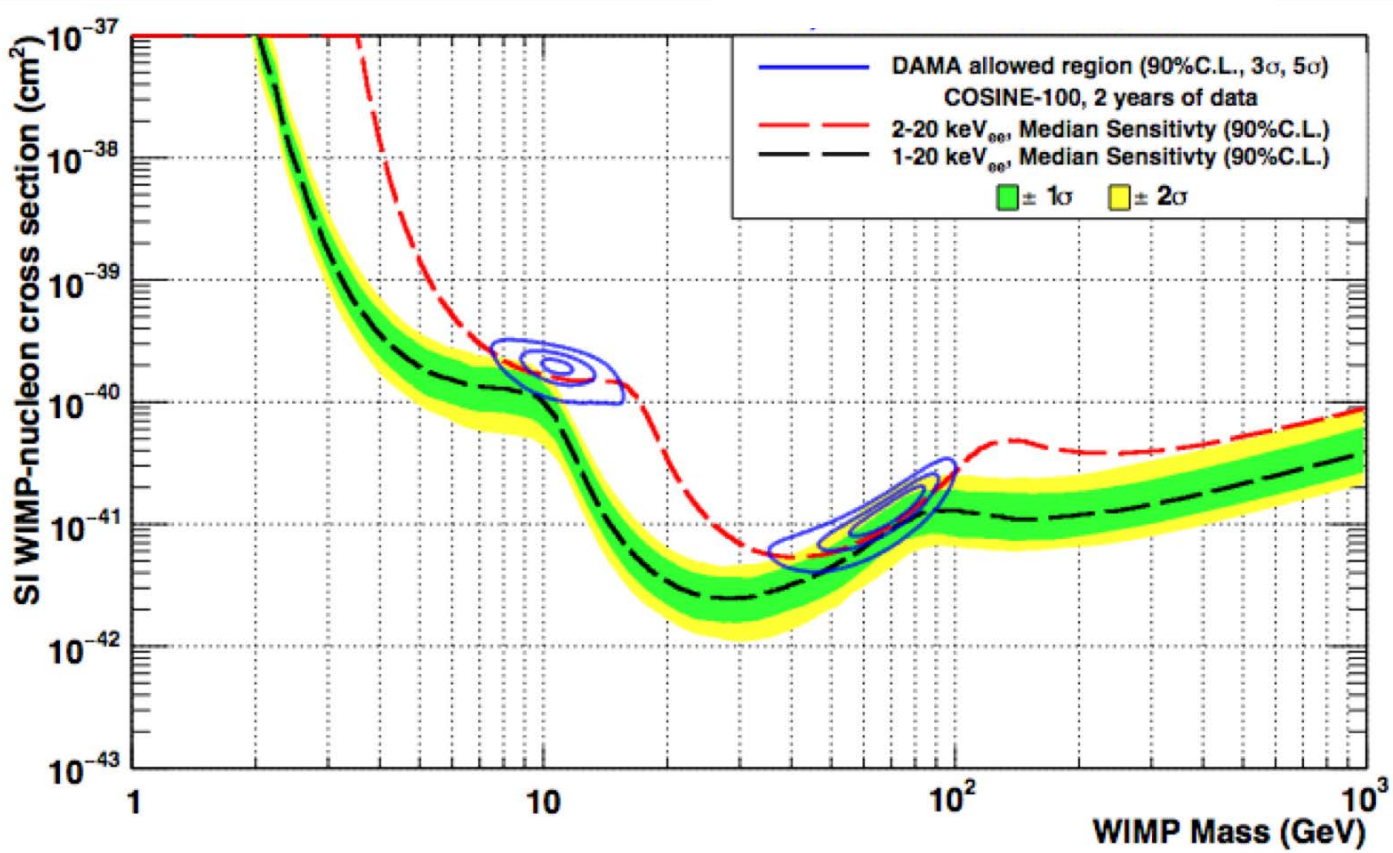
COSINE-100 Projected Sensitivity



- Assuming **2 - 4 dru flat background** depending on the crystal
- Sensitivity comparable to DAMA
- First dark matter search result expected in 2018.

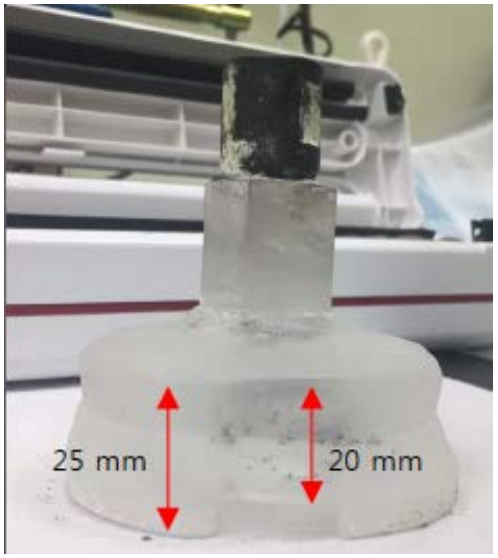
Next phase of COSINE (COSINE-200)

Goal : Reach background < DAMA (1 dru)

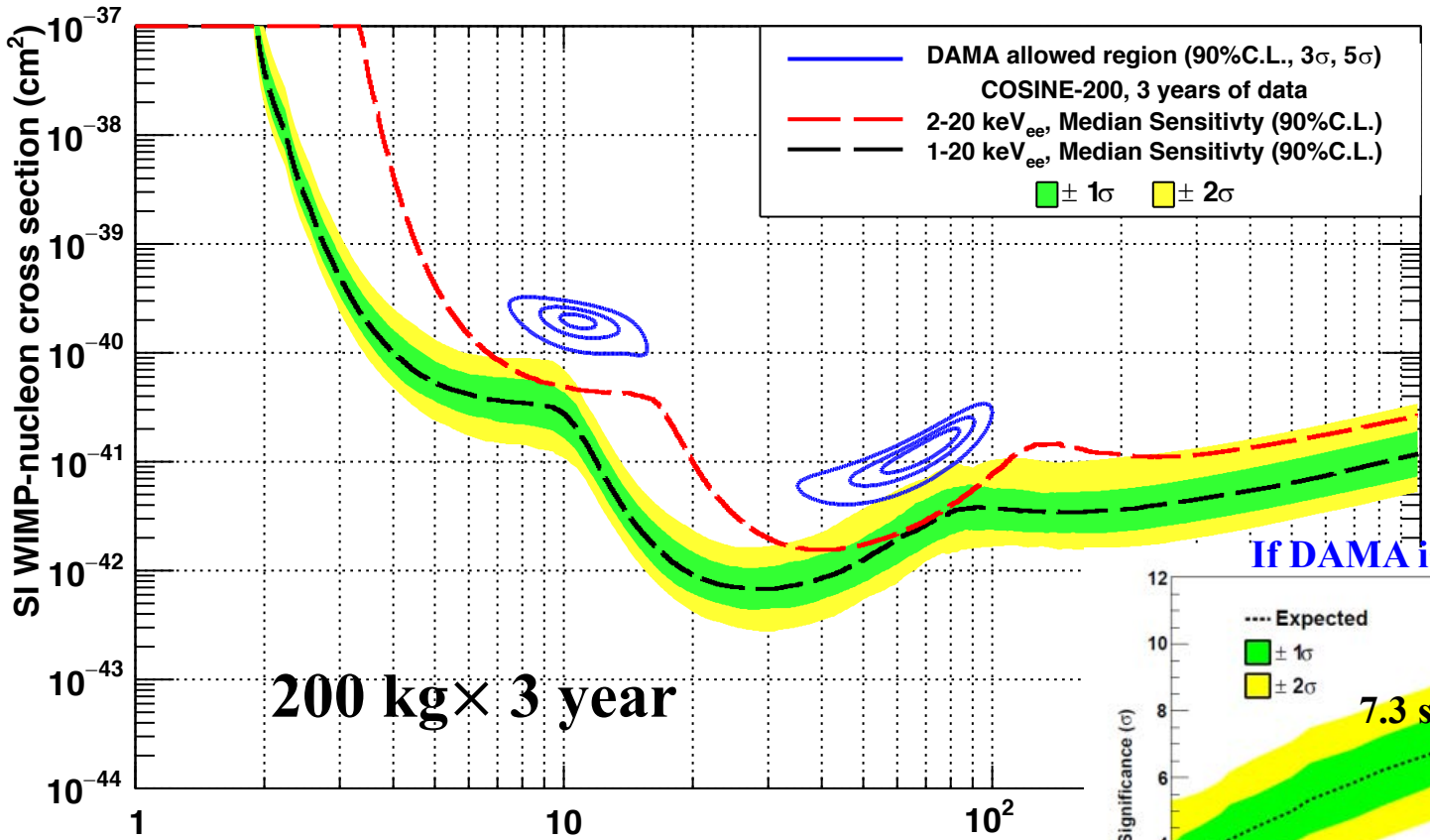
Needs a factor two or more improvement

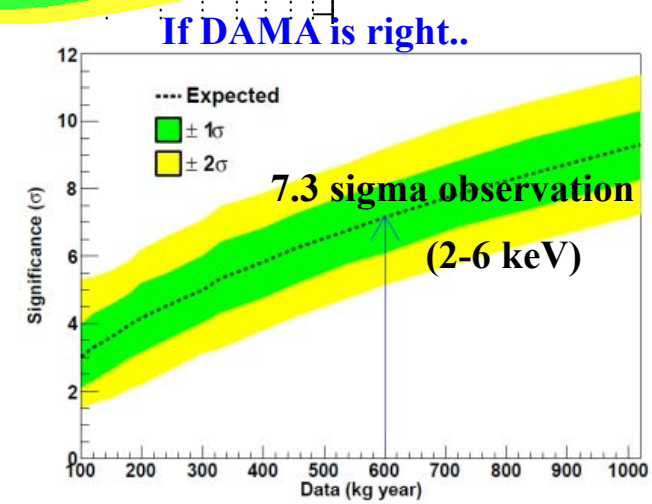
Crystal R&D at IBS in South Korea

- Powder purification (Recrystallization)
- Crystal growing & Handling
- Established a facility at the IBS center
- Mass production facility for purification under construction
- Can establish strict control for surface and bulk contaminations, in particular ^{210}Pb



COSINE-200 Sensitivity





1 dru background (same as DAMA/LIBRA)

Summary

- A global effort to test the DAMA result is underway.
- COSINE-100 data taking started in Sept. 2016.
- Crystal background is about twice as high as DAMA in 2-6 keV energy region.
- First dark matter search result expected in 2018
- R&D for COSINE-200 aims to further reduce the crystal background.

Stay Tuned !