Center for Underground Physics

Status of the COSINE-100 experiment at Yangyang underground laboratory

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On behalf of the COSINE collaboration

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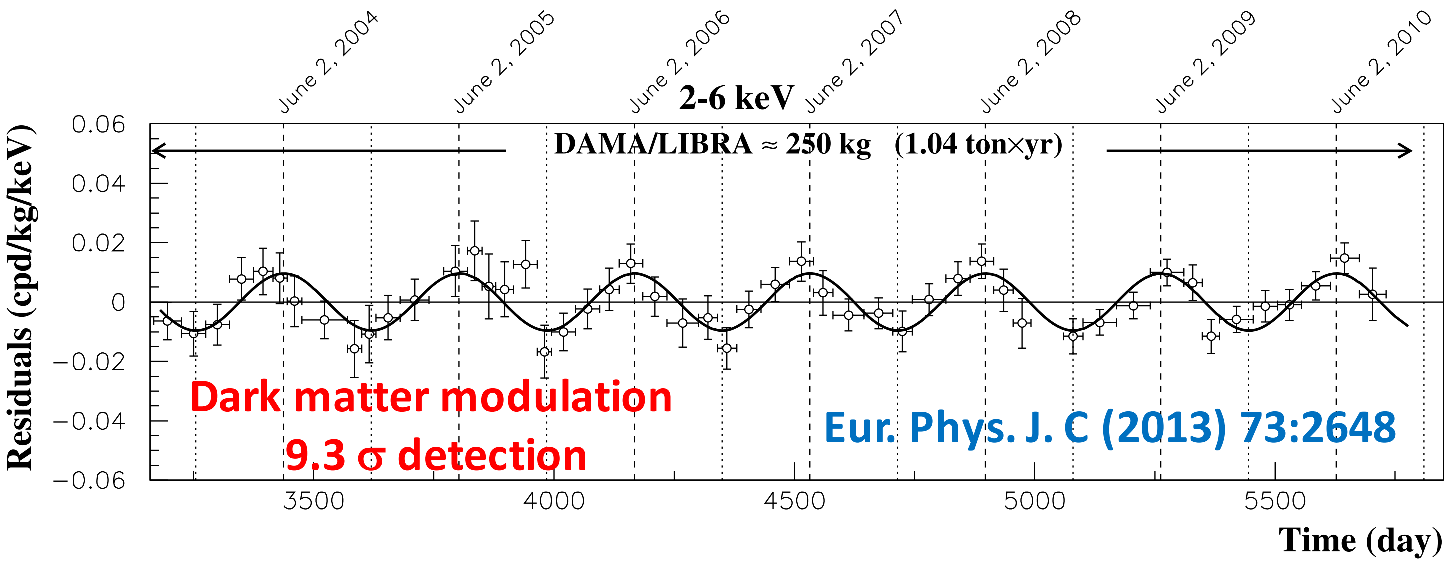
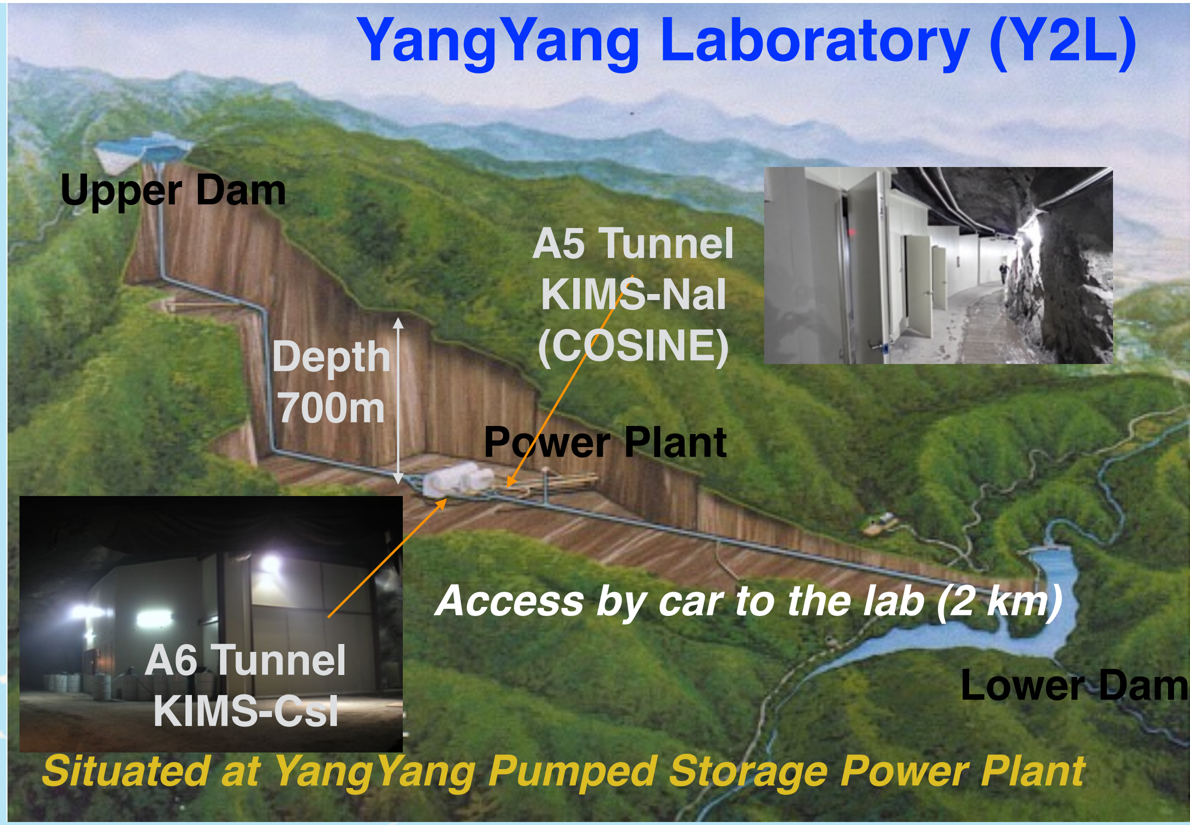
Contents

Motivation of the COSINE experiment

- **Direct comparison to confirm or rule out the DAMA/LIBRA claims using the same type of NaI(Tl) crystals**
- **Achieve lower background level and lower energy threshold then the DAMA with the same NaI(Tl) crystal detectors**
  - ✓ **background level < 1 counts/keV/kg/day (dru)**
  - ✓ **Energy threshold < 2 keV**



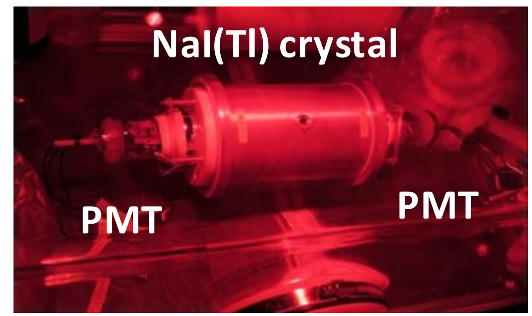
Direct Dark Matter search in Korea

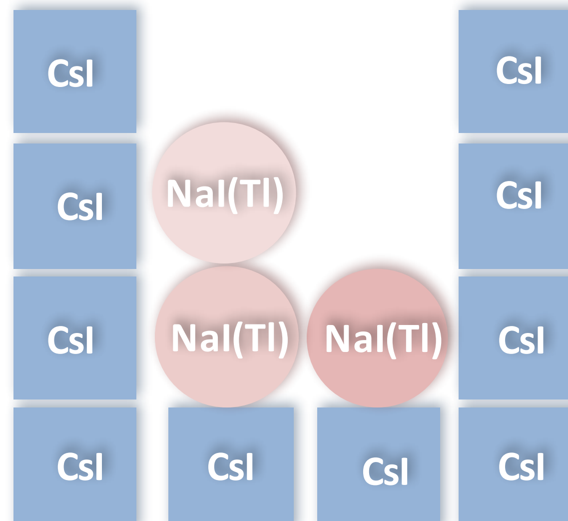


- The KIMS-CsI at the A6 tunnel
  - ✓ Being used as a screening test bench for NaI(Tl) crystals R&D after finishing a dark matter search with CsI(Tl) crystal detectors
- The COSINE experiment at the A5 tunnel
  - ✓ DM-ICE and KIMS-NaI with 100kg NaI(Tl)

Background reduction Effort

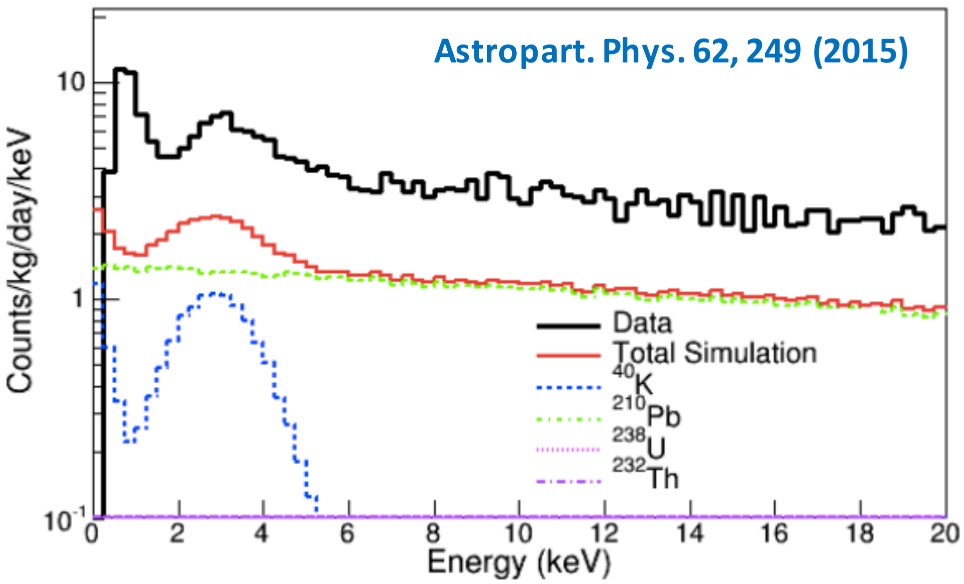
- **Measurements of internal-radioisotope contaminations in NaI(Tl) crystals**
  - ✓ **U, Th, K, Pb-210, and Cosmogenic isotopes**
  - ✓ **Screening measurement in the CsI (Tl) crystals array**
- **To understand the internal backgrounds and to learn how they can be reduced**

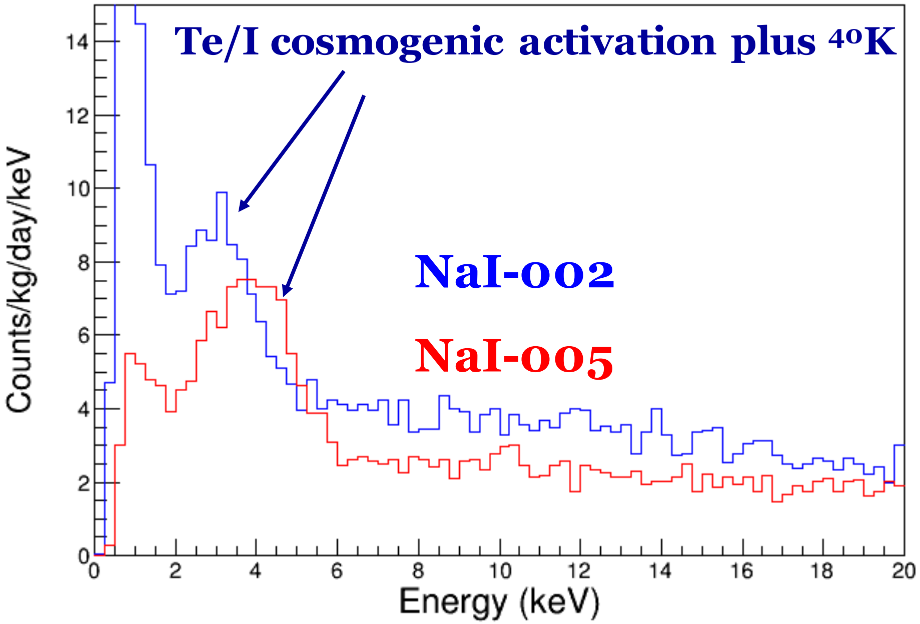




Internal background

- NaI-005 reduced to ~1.0 dru by reduction of Pb-210
  - ✓ To understand and reduce Pb-210 contamination R&D
- K-40 can be reduced by using 10 ppb NaI powder as raw material





NaI-002 : ~ 3 dru @ 6 keV

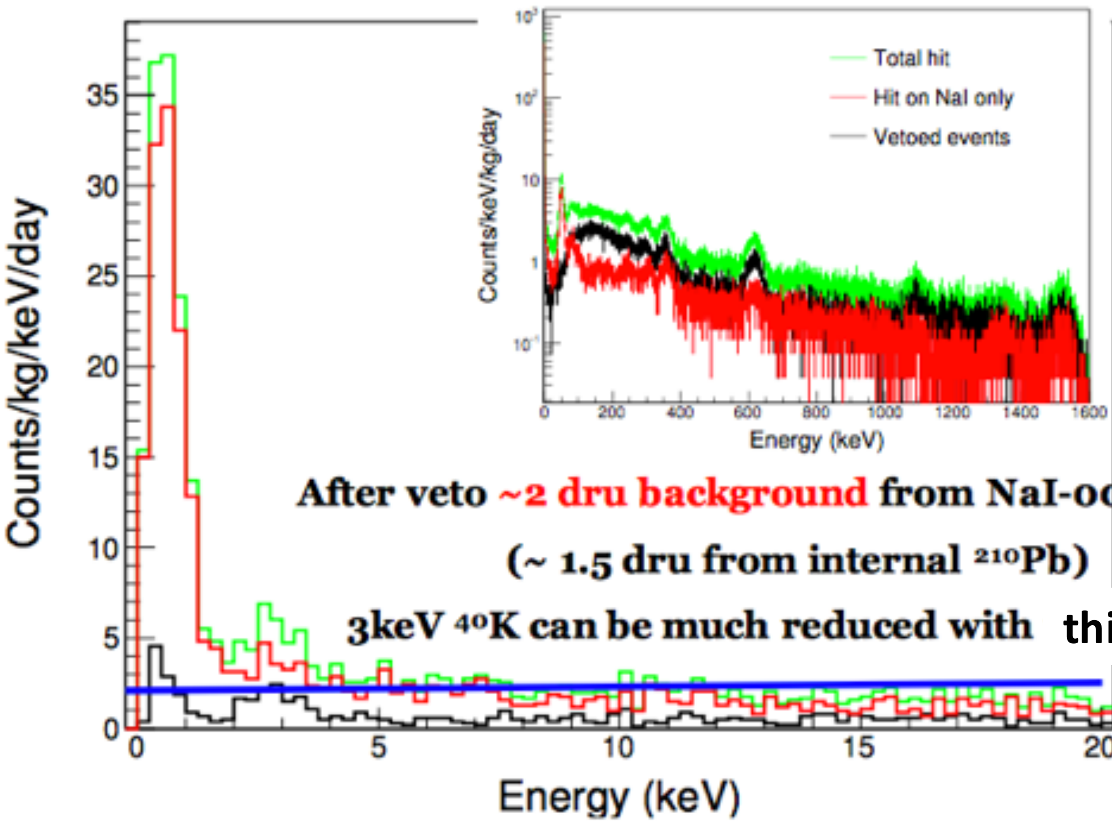
- ✓ Internal Pb-210 : 1.5 dru (overall)
- ✓ Internal K-40 : 0.7 dru (2-4 keV)
- ✓ External : 1.5 dru

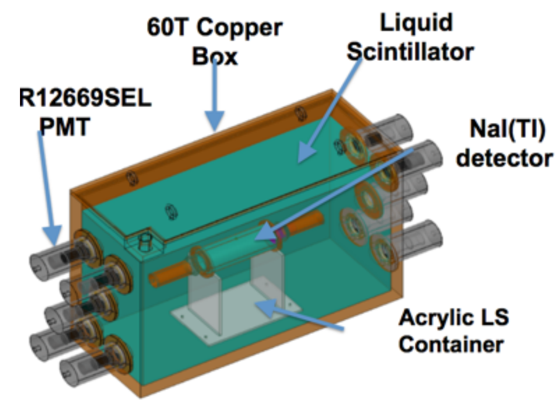
NaI-005 : ~ 2 dru @ 6keV

- ✓ Internal Pb-210 : 0.5 dru (overall)
- ✓ Internal K-40 : 0.7 dru (2-4 keV)
- ✓ External : 1.5 dru

LS Veto Prototype

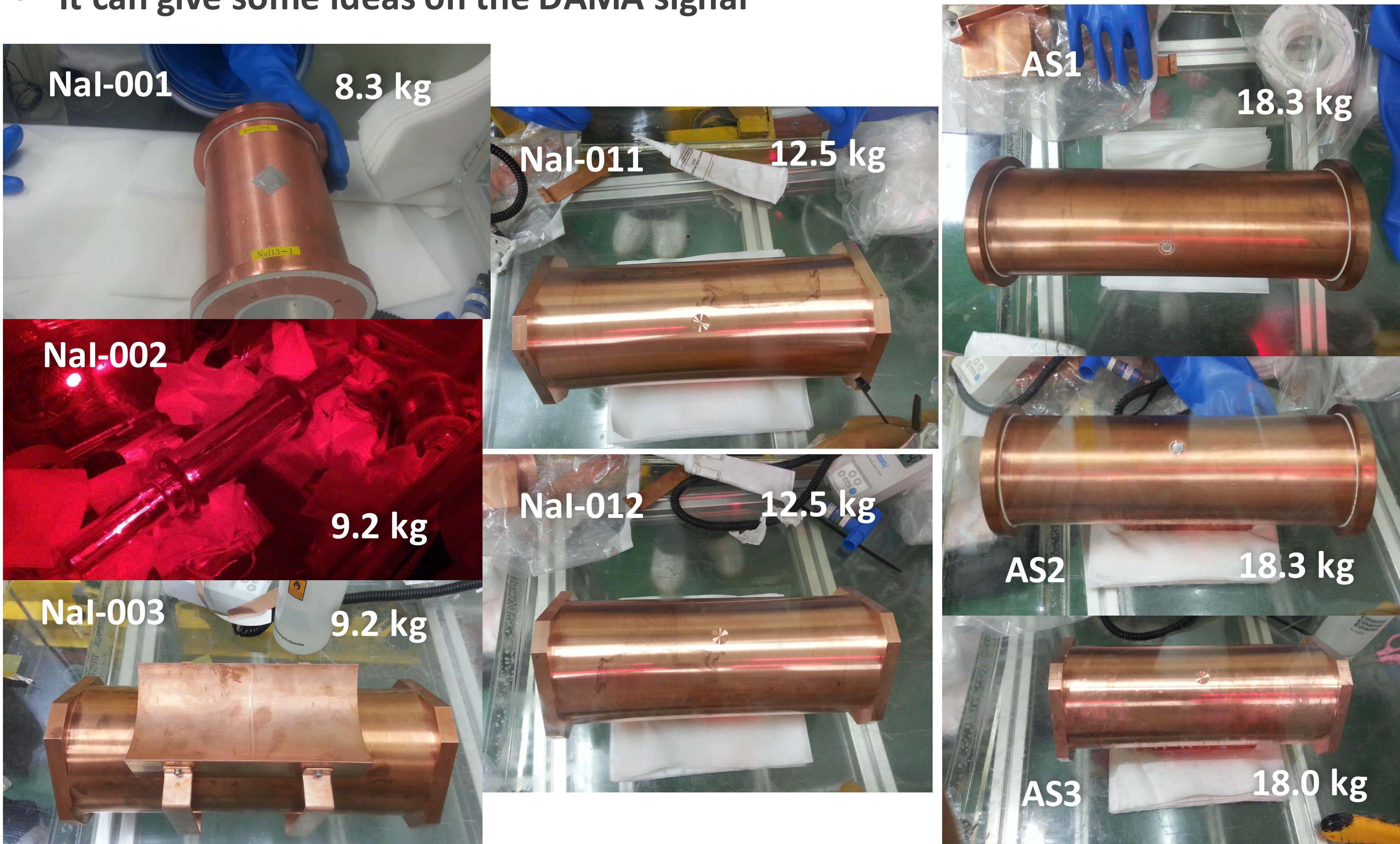
- Active Background Rejection
  - ✓ Backgrounds from crystal and surrounding components
  - ✓ External Backgrounds
- Multiple hit events are vetoed with 25% veto efficiency at 6-20 keV



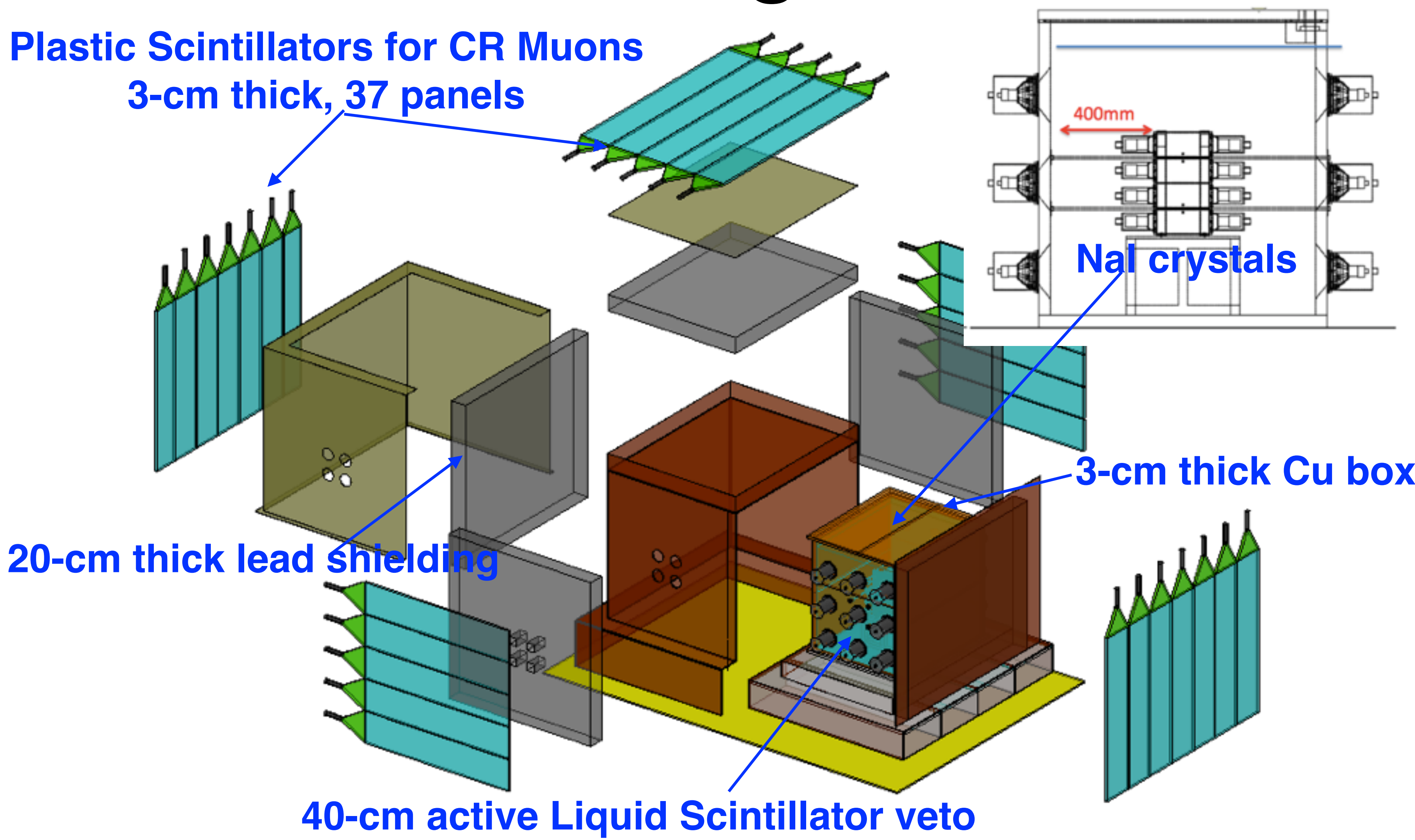


COSINE 100 : DM-ICE + KIMS-NaI

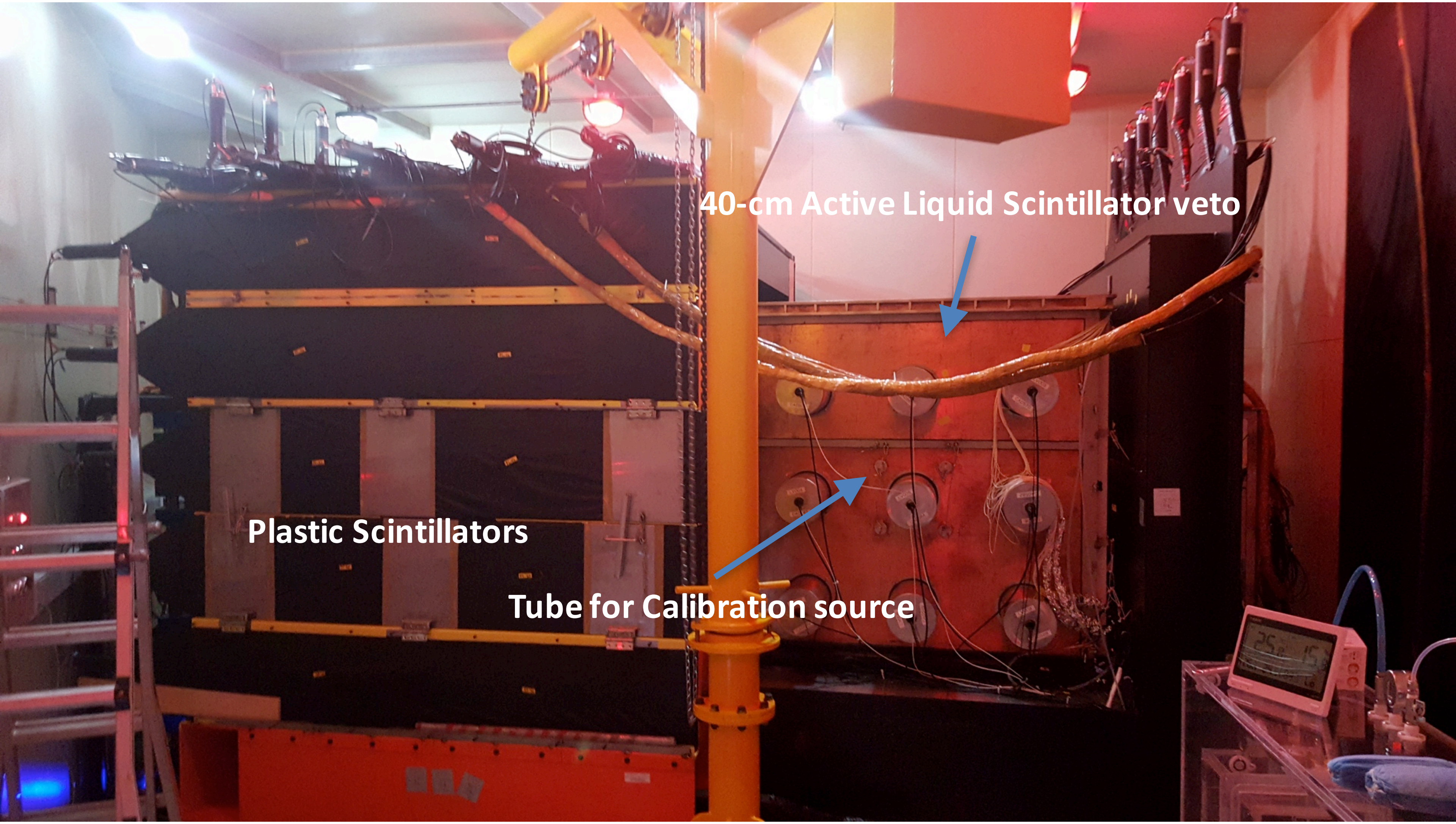
- Total of 8 crystals (~ 100 kg) have been ready for the phase-I run.
- It can give some ideas on the DAMA signal



New Shielding Structure



New Shielding Structure



Production of Liquid Scintillator (LS)

- **LAB-based LS**
  - ✓ Linear alkylbenzene (LAB), PPO (3 g/L) and bis-MSB (30 mg/L)
  - ✓ Total 3200 liter was produced and ready to be filled
  - ✓ Purification of the LS by water extraction and nitrogen gas purging
  - ✓ After an PSD analysis, U-238 < 7 ppt, Th-232 < 4 ppt are measured to be contaminated in the LS

DAQ System

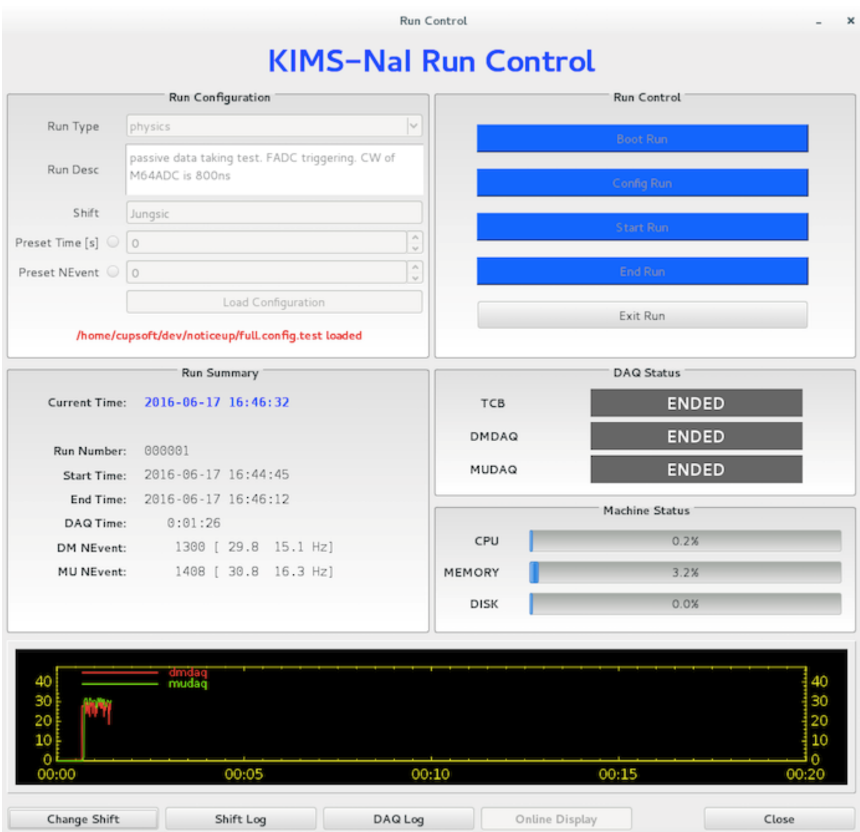
- Electronics

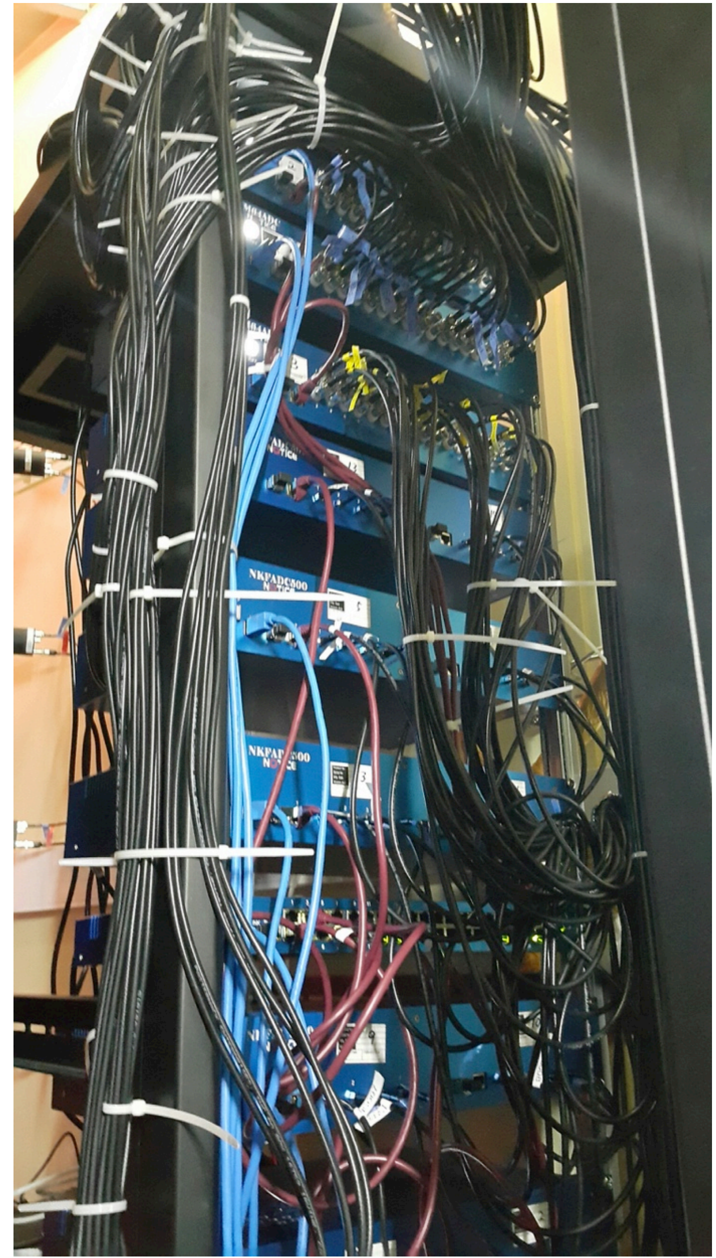
✓ 500 MHz FADC : NaI(Tl) and Neutron detector

✓ M64ADC : Muon veto and LS veto detector

✓ Trigger control box

- Run Control Panel



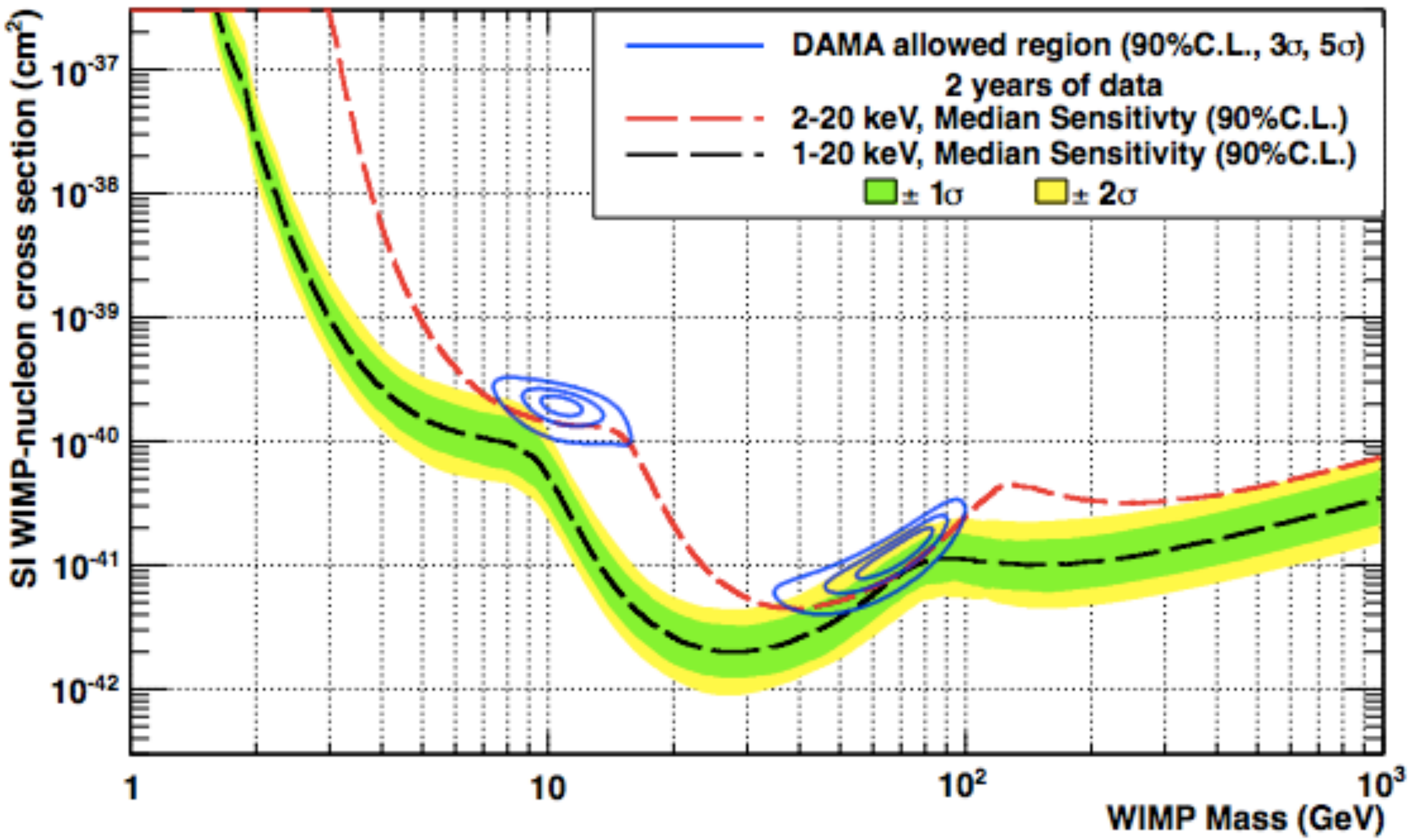


COSINE-100

- ✓ We installed total 8 of selected KIMS-NaI and DM-ICE crystals.
- ✓ Total amount of mass is about 106 kg.
- ✓ A dry run has started before filling the LS.

Crystals	Nickname	Powder	Mass
NaI-001	C1	Sample B	8.3 kg
NaI-002	C2	Sample C	9.2 kg
NaI-007	C3	WimpScint 2	9.2 kg
AS-3	C4	WimpScint 2	18.0 kg
AS-1	C5	Sample C	18.3 kg
NaI-011	C6	WimpScint 3	12.5 kg
NaI-012	C7	WimpScint 3	12.5 kg
AS-2	C8	Sample C	18.3 kg

Expected Sensitivity



- **COSINE-100 at Yangyang, with 1 keV and 2 keV energy thresholds.**
- **Assumed flat background with 2 dru for several crystals and 4 dru for other crystals.**
- **Assumed 2 years of data taking.**

Conclusion

- **COSINE is poised to confirm or to rule out the DAMA's modulation result.**
- **Various R&D programs have identified background reductions for ultra-pure crystal production.**
- **Construction of the main detector has been completed except liquid scintillator filling.**
- **A dry run for the COSINE phase 1 (~ 100 kg) has started for several weeks before filling the LS.**

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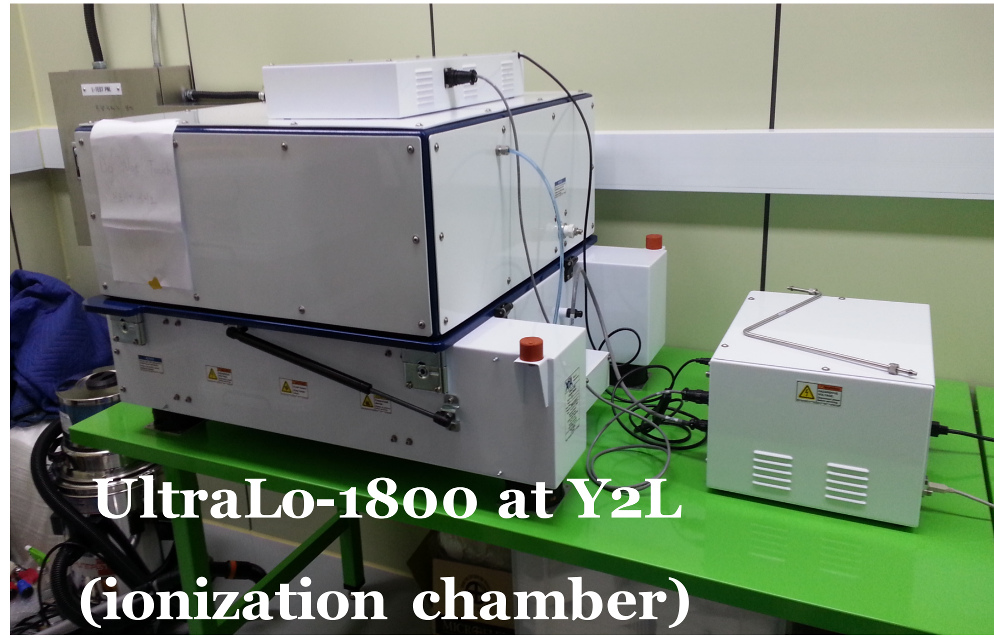
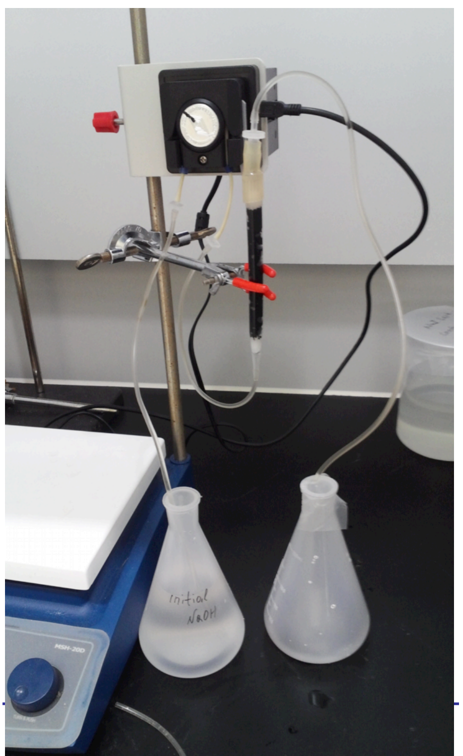
Thank you

Backup

Background Reduction
– To understand and reduce Pb-210 contamination

- Alpha counter
  - ✓ Po-210 in NaI powder
- Well-type HPGe detector
  - ✓ Pb-210 in NaI powder





- Purification of NaI powder with ion-exchange resin
  - ✓ ~ 300 reduction of Pb with dirty NaI powder
  - ✓ ~ 10 reduction of Pb with normal NaI powder
  - ✓ Will grow crystals with and without resin purification

Evaluation of NaI(Tl) crystals at KIMS-CsI

- Astropart. Phys. 62, 249 (2015)
- EJPC, 76, 185 (2016)

Crystal (unit)	Mass (kg)	^{nat}K (^{40}K) (ppb)	^{238}U (ppt)	^{232}Th (ppt)	α Rate (mBq/kg)	Light Yield (p.e./keV)	Arrival (year-month)
NaI-001	8.3	40.4 ± 2.9	< 0.02	< 3.2	3.29 ± 0.01	15.6 ± 1.4	2013.9
NaI-002	9.2	48.1 ± 2.3	< 0.12	0.5 ± 0.3	1.77 ± 0.01	15.5 ± 1.4	2014.1
NaI-003	3.4	25.3 ± 3.6	< 0.14	0.5 ± 0.1	2.43 ± 0.01	13.3 ± 1.3	2014.8
NaI-004	3.4	> 116.7	–	–	–	3.9 ± 0.4	2014.8
NaI-005	9.2	40.1 ± 4.2	< 0.04	0.2 ± 0.1	0.48 ± 0.01	12.1 ± 1.1	2014.11
NaI-006	11.4	> 127.1	< 0.05	8.9 ± 0.1	1.53 ± 0.01	4.4 ± 0.4	2014.12
NaI-007	9.2	45.3 ± 6.6	< 0.04	0.2 ± 0.1	0.68 ± 0.01	14.4 ± 1.4	2015.9
NaI-008	1.8	< 15	–	–	30.3 ± 1.1	7.2 ± 0.8	2015.12
NaI-009	3.3	639 ± 51	–	–	7.2 ± 0.9	6.1 ± 1.1	2015.12
NaI-010	1.3	20.5 ± 11.7	–	–	0.6 ± 0.1	20.9 ± 1.1	2015.12
NaI-011	12.5	~ 25	–	–	1.06 ± 0.02	16.8 ± 1.2	2016.2

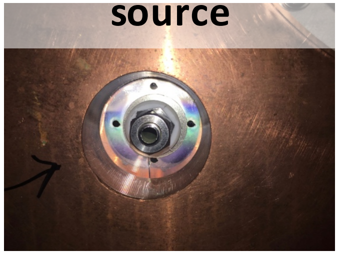
Alpha Spectra Inc. (AS)
Beijing Hamamatsu Inc (BH).

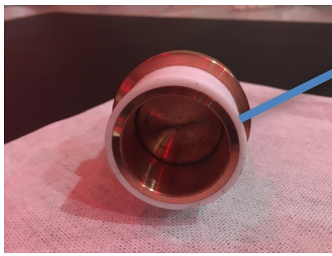
*Measurement not finished for blank slots

✓ **AS crystals show high light-yields**

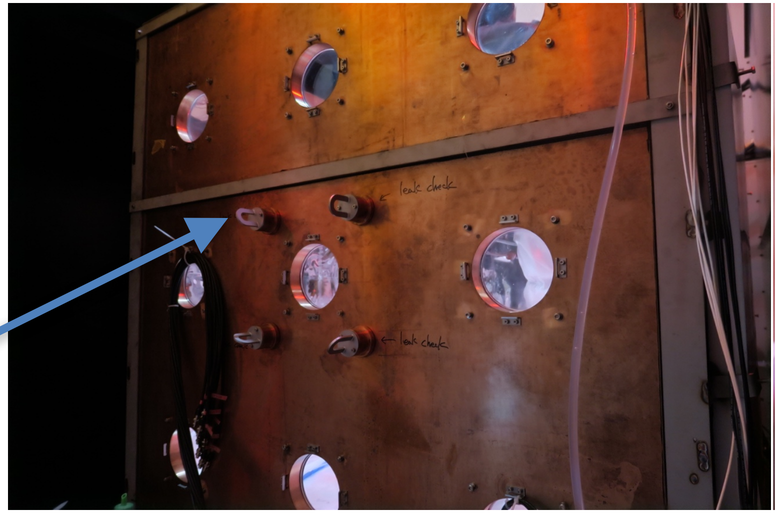
✓ **Astrograde powder-made crystals show low K-40 levels, e.g NaI-003, NaI-008.**

Tube and cap for calibration source

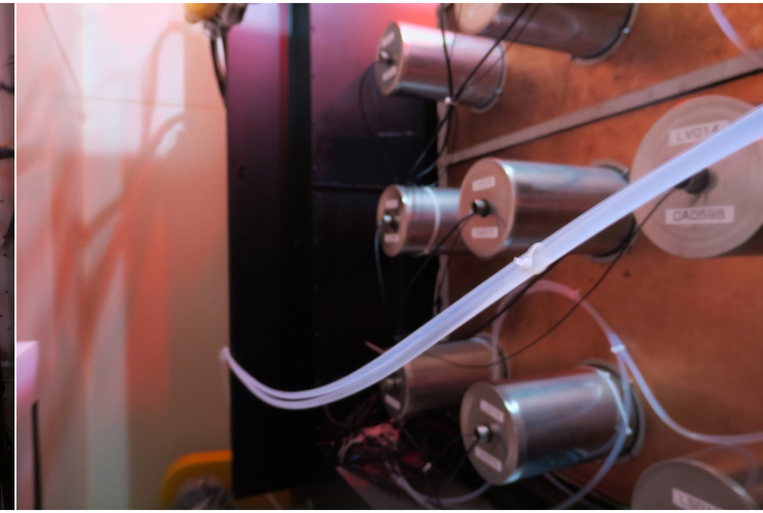




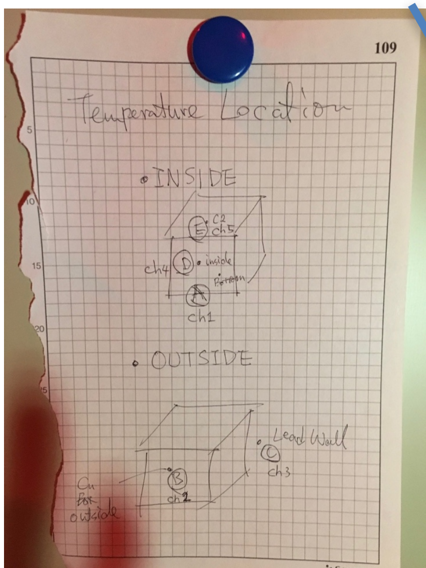
Before installation 5” PMT

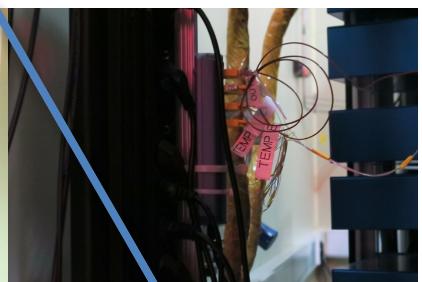


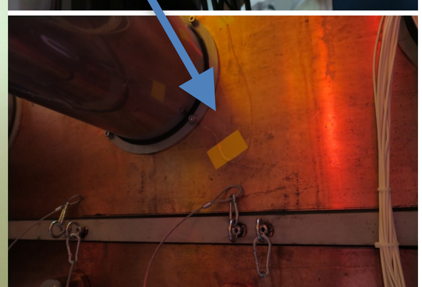
After installation 5” PMT



Temperature sensor

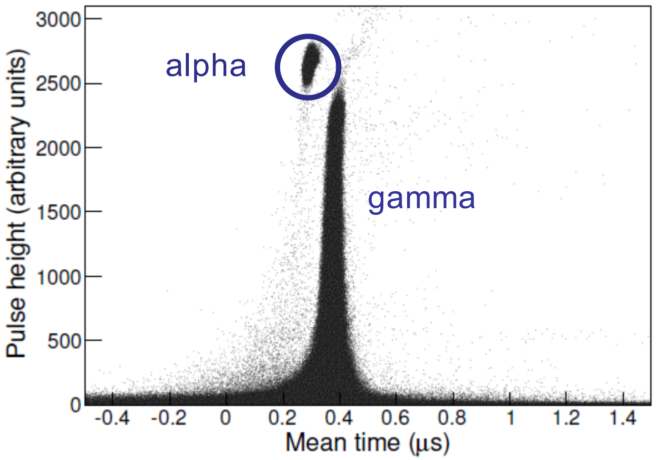






Reflector inside acrylic box for LS

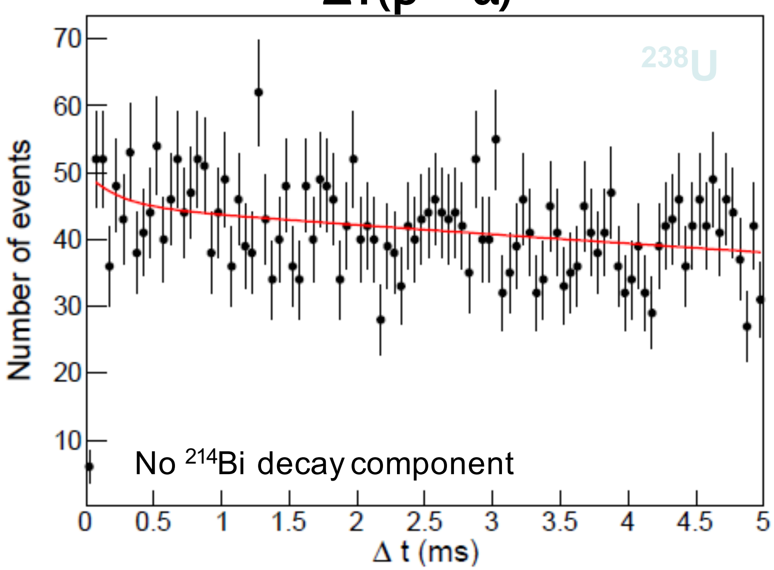
Internal background – ^{238}U, ^{232}Th



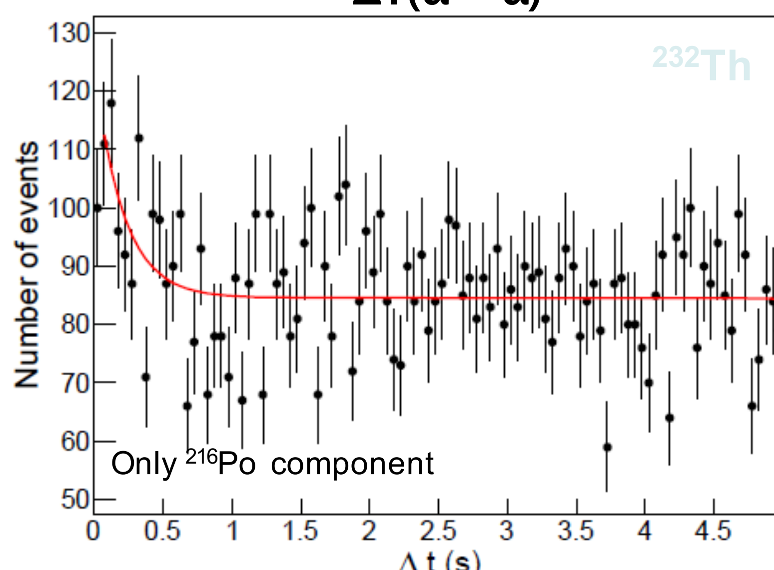
	NaI-001 (mBq/kg)	NaI-002 (mBq/kg)
^{238}U (^{214}Bi)	<0.0003	<0.0015
^{228}Th (^{216}Po)	<0.013	0.002±0.001
^{210}Pb	3.28±0.01	1.76±0.01
Total alphas	3.29±0.01	1.77±0.01

DAMA, ^{238}U: 0.009-0.13 (mBq/kg)
^{232}Th: 0.002-0.03
^{210}Pb: 0.005-0.03

ΔT(β – α)



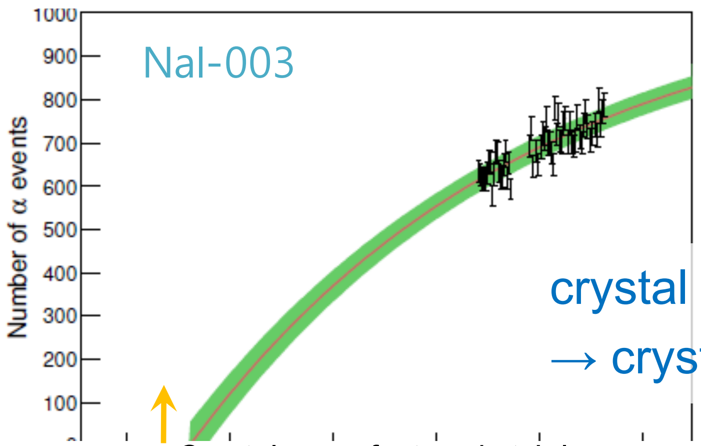
ΔT(α – α)



The contamination levels of U and Th are small.

Internal background – ^{210}Pb

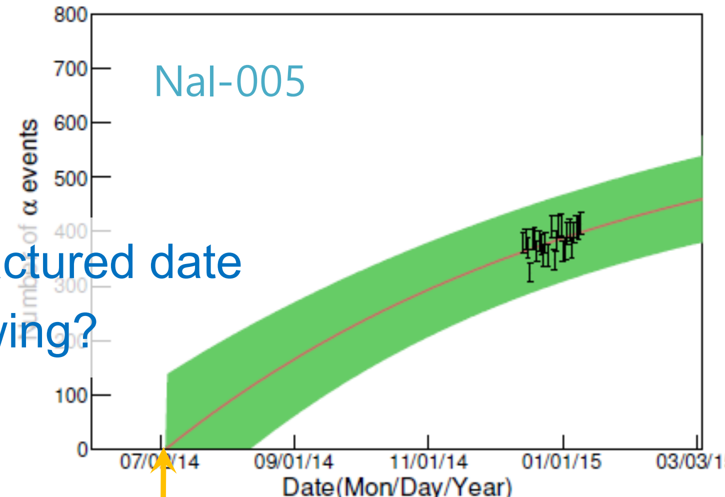
- Most of alphas are coming from ^{210}Pb
- We can estimate crystal manufactured date using alpha rate change.



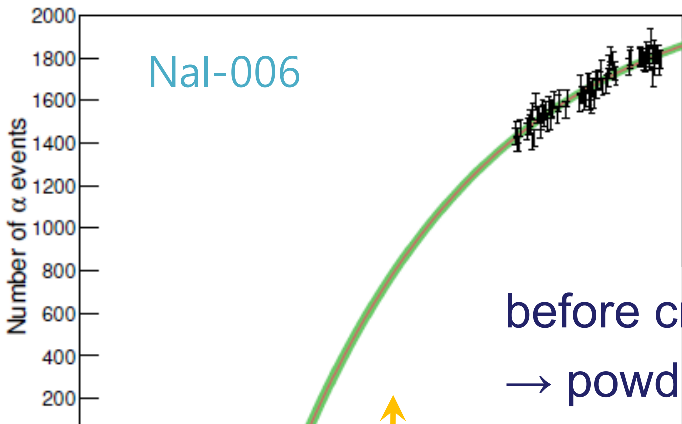
Crystal manufactured at Jul.

crystal manufactured date

→ crystal growing?



Crystal manufactured at Jul.



before crystal growing

→ powder?

Crystal manufactured at Oct.

$$R_\alpha(t) = A\left(1 - e^{-(t-t_0)/\tau_{Po}}\right)$$