

# Status of the COSINE Experiment

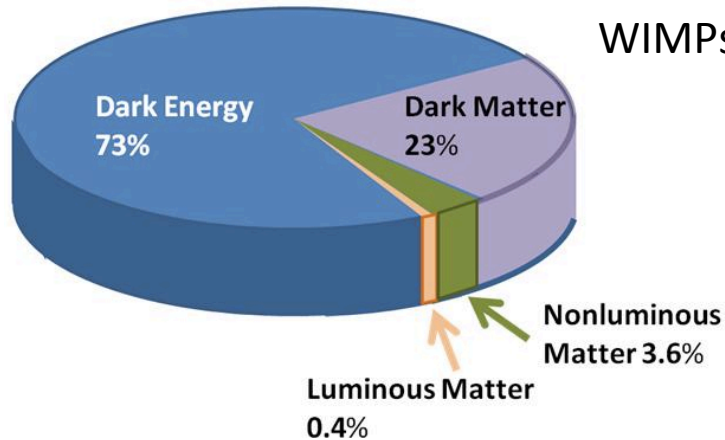
Jungsic Park  
Center for Underground Physics, IBS  
on behalf of COSINE  
PATRAS 2016 @ Jeju Island, South Korea

## Contents

- **COSINE-100 : DM-ICE + KIMS-NaI (100kg of NaI crystals)**
- **Efforts to reduce background.**
- **Construction of Main Detector.**
- **DAQ and Dry run**
- **Expected Sensitivity**
- **Summary**

# COSINE : Consortium between KIMS and DM-ICE Sodium Iodine Experiment

WIMPs (Weakly Interacting Massive Particles) ?



Goal : confirm or exclude the DAMA/LIBRA's modulation results.  
strategy : achieve ultra-low background and lower energy threshold.

# Development of crystals.

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

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

Alpha Spectra Inc. (AS)

Beijing Hamamatsu Inc (BH).

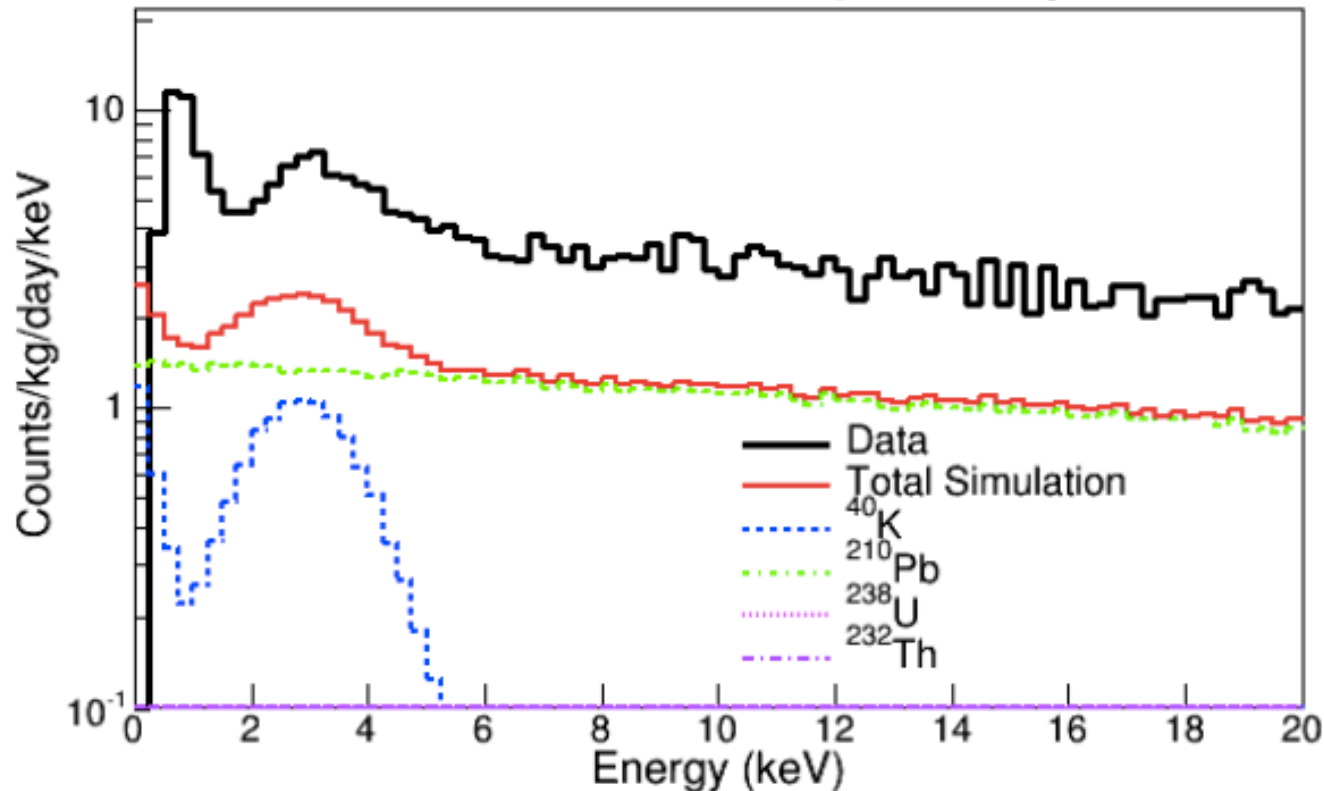
\*Measurement not finished for blank slots

AS crystals show high light yields.

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

Internal BKG :  $\sim 2$ dru (differential rate unit) @ 3keV

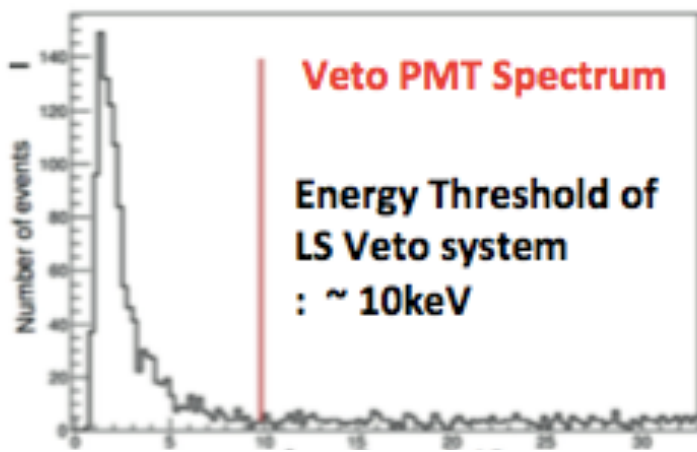
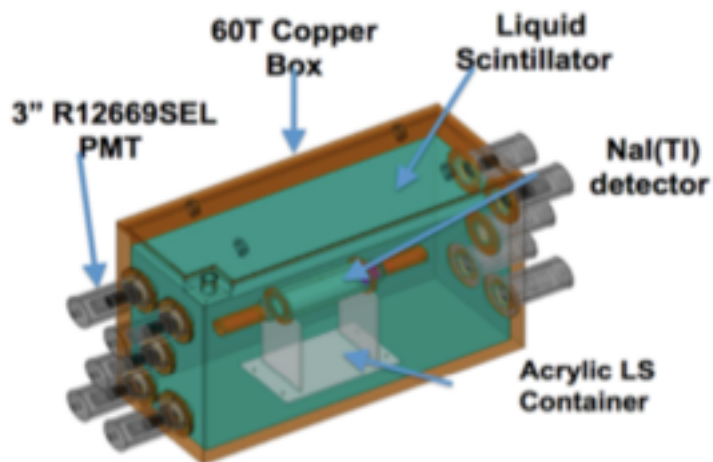
selected for COSINE-100



- ~2 dru @ 3keV (1.5 dru @ 6keV) from Pb210 and K40
  - ❖ Pb210 : Need about factor 5 reduction
  - ❖ K40 : Need more than factor 2 reduction
  - ☐ Can be reduced (tagged) with LSC veto

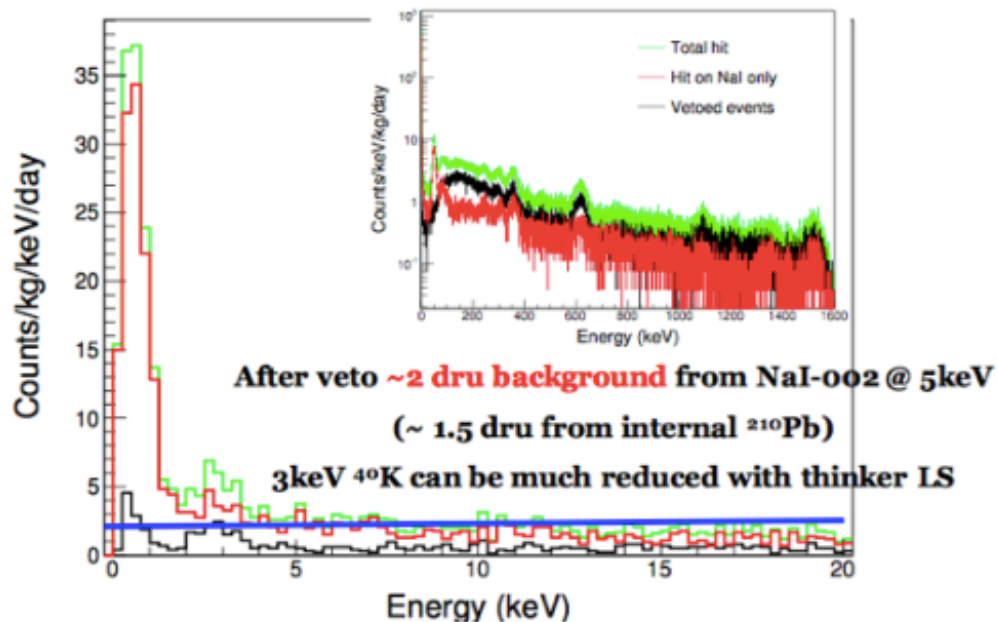


# LS Veto Prototype



Energy (keV)

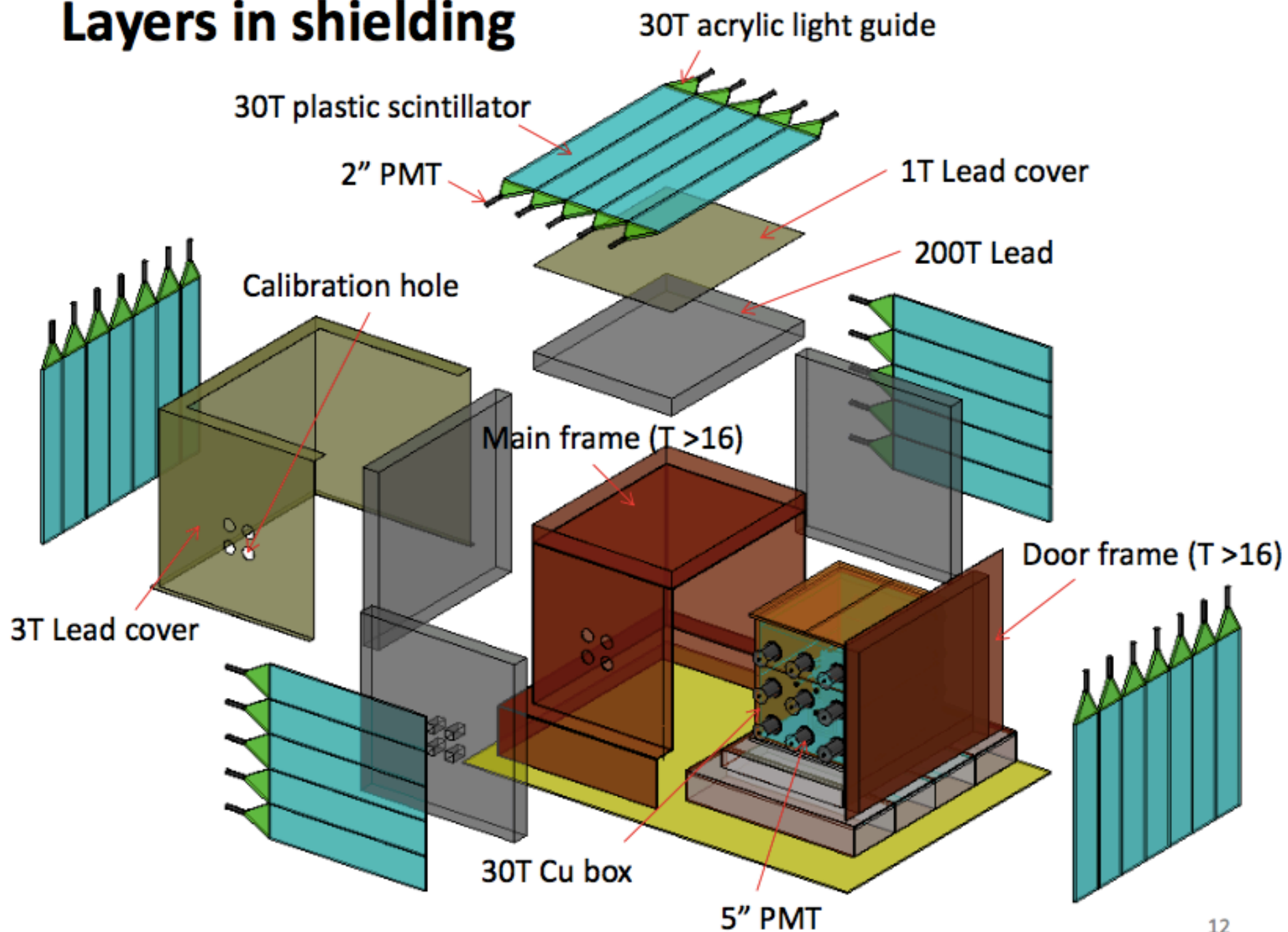
Take data with NaI-002



Multiple hit events are vetoed with 25% veto efficiency at 6-20keV.

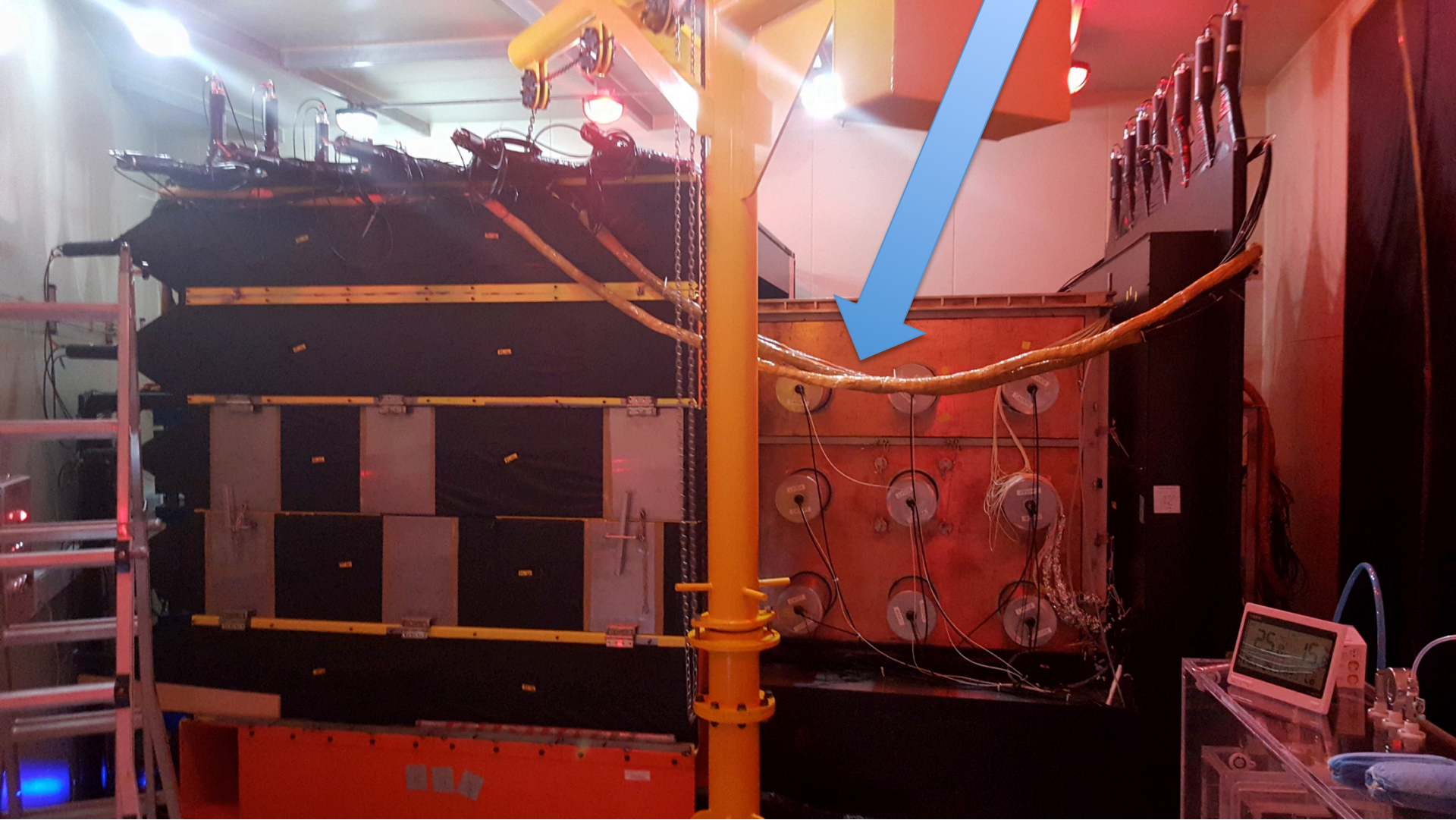
We expect additional reduction for backgrounds from U/Th/K with 40cm thickness veto system.

# Layers in shielding



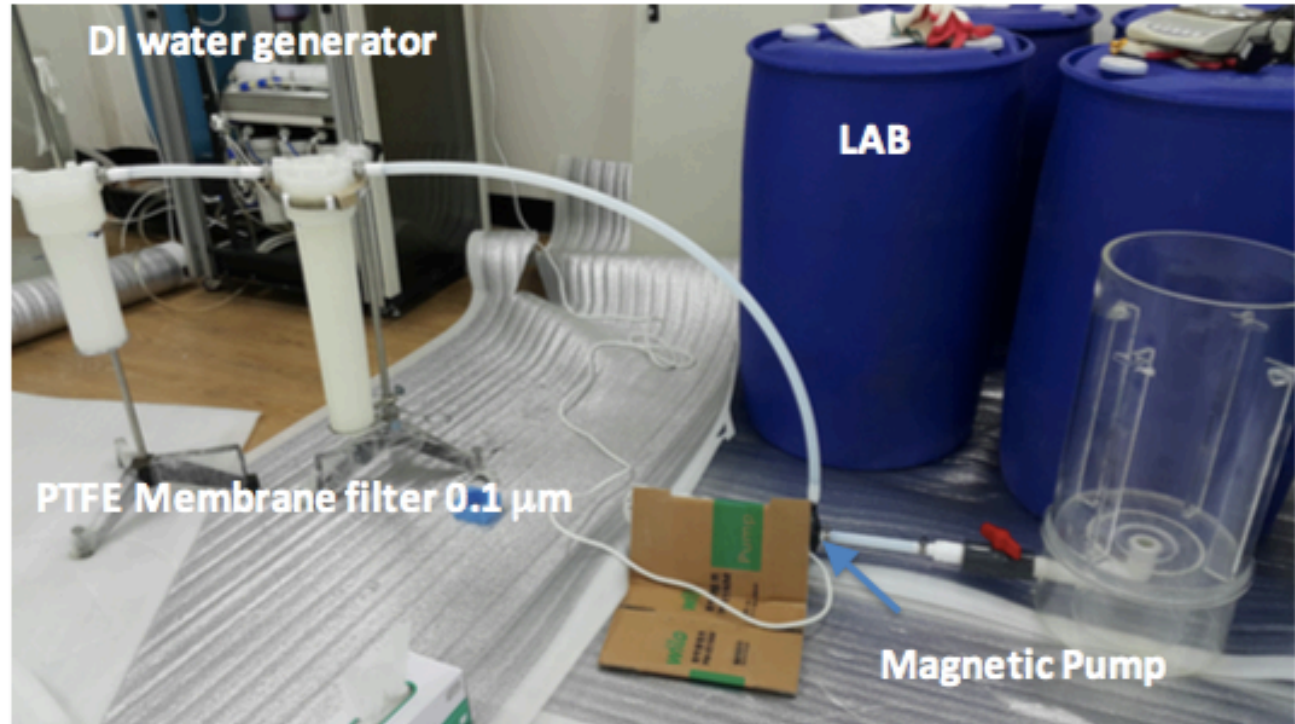
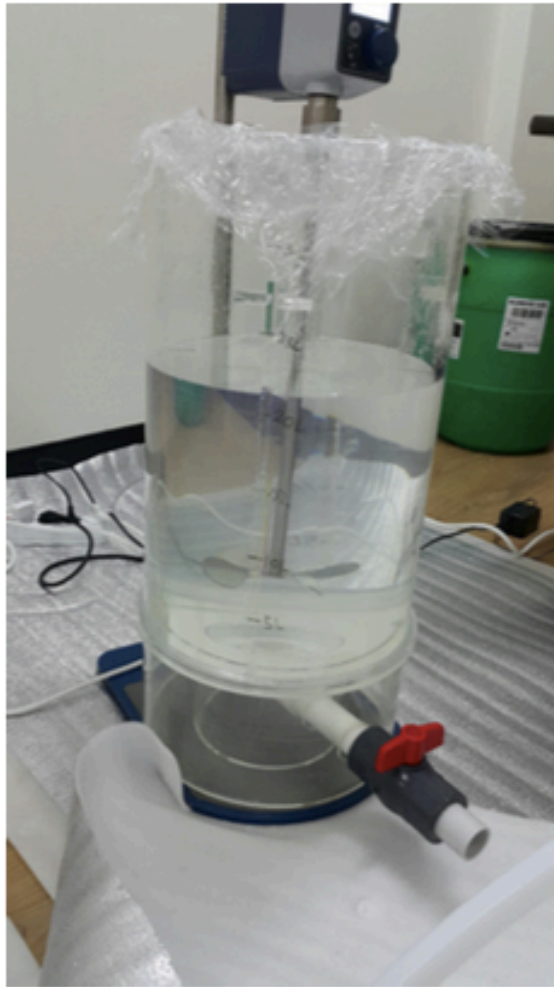


**40cm thickness of LS Active Veto System**





# Production of LAB-Based Liquid Scintillator (LS)



- **LAB-based LS**
  - **Linear alkyibenzene (LAB)**
  - **PPO (3 g/L)**
  - **bis-MSB (3 mg/L)**

# Purification of LS

- U, Th, and K are dissolved in the water
  - Water and LS is separated by themselves
- Nitrogen purging
  - To reduce remained water and other isotopes in the LS

Water extraction

DI water + LS

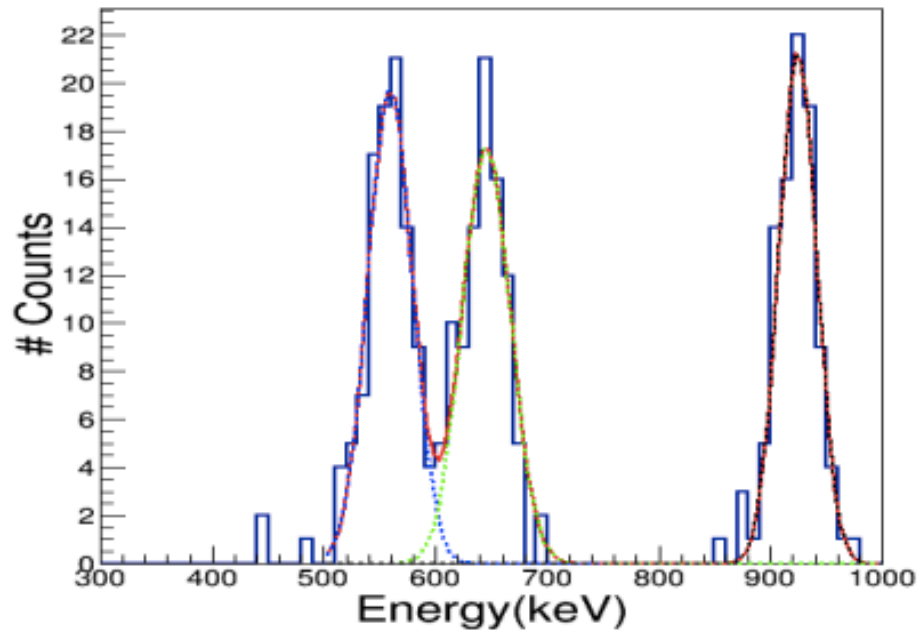
Nitrogen Gas Purging

# Amount of Background inside LS

We took data with 70mL sample of LS.

- After PSD, we found that almost all alphas come from Rn and goes away according to time.

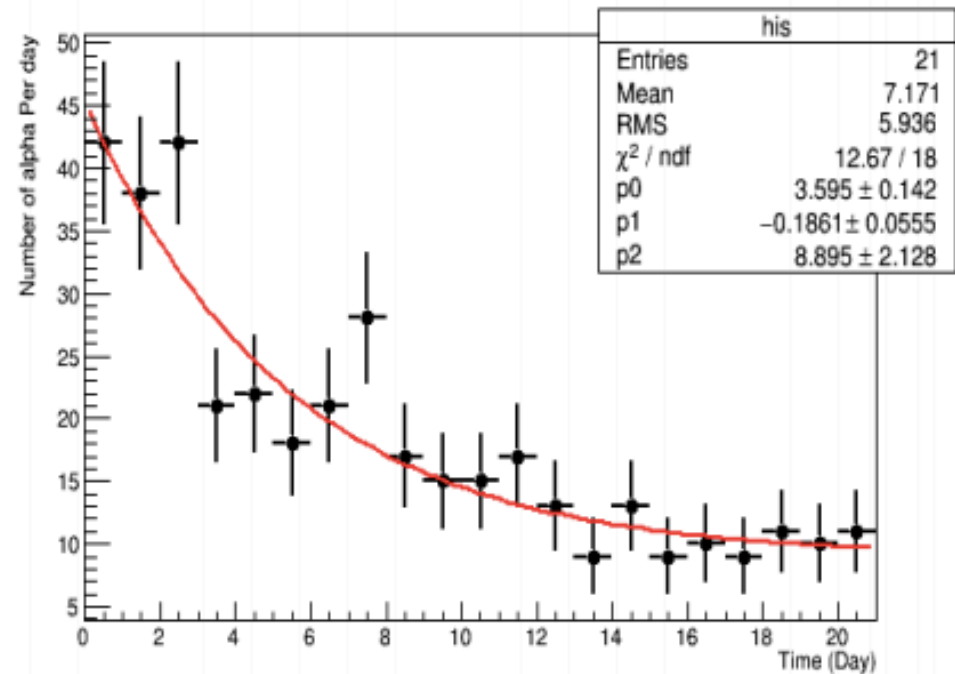
Alpha Energy distribution(Radon Effect)



Initial  $^{222}\text{Rn}$  activity :  $3.47 \pm 0.18$  mBq/Kg

$^{238}\text{U}$  upper limit :  $< 7$  ppt

$^{232}\text{Th}$  upper limit :  $< 4$  ppt

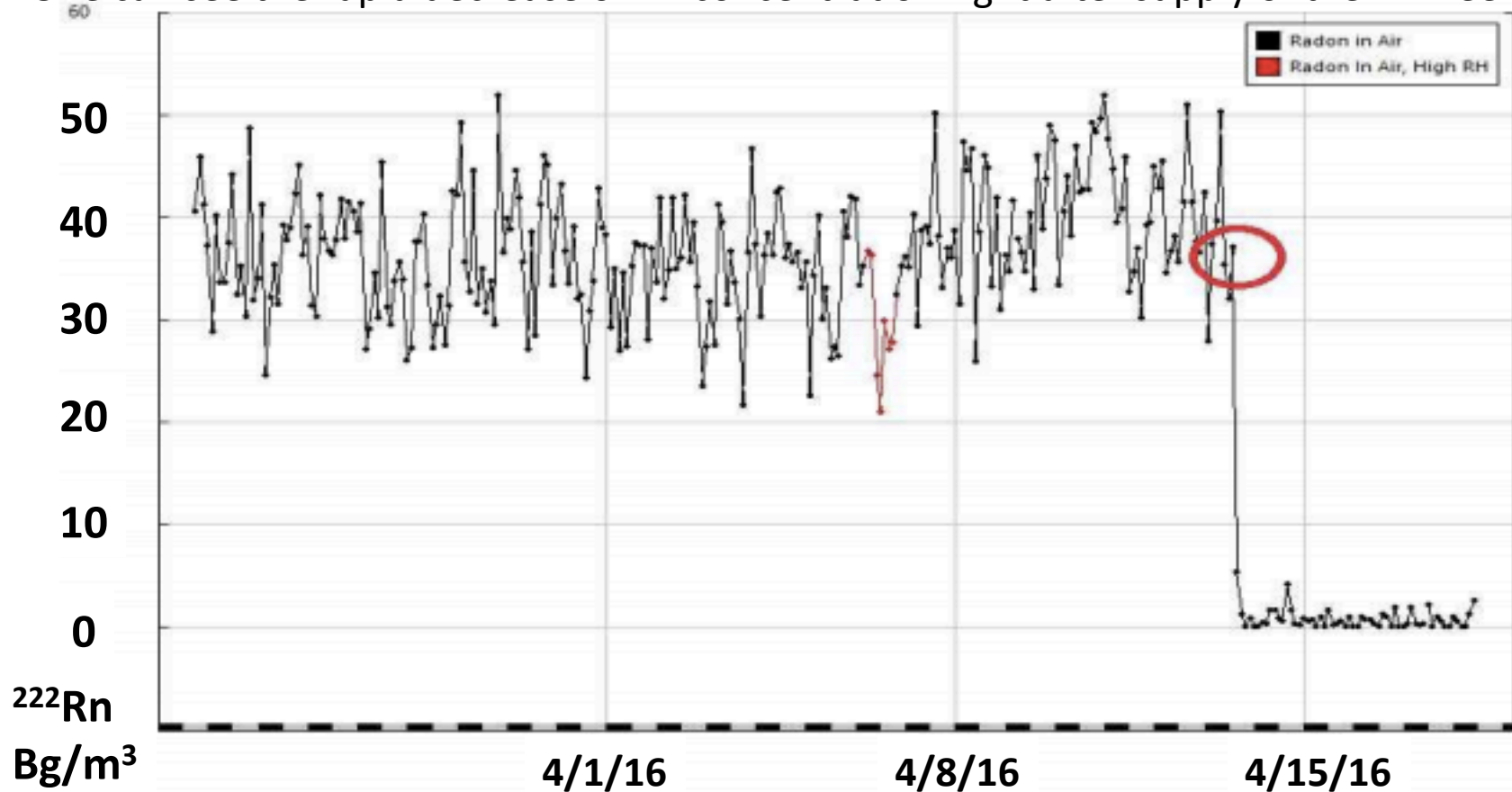


Background contribution from LS is negligible amount.



# Rn Reduction System

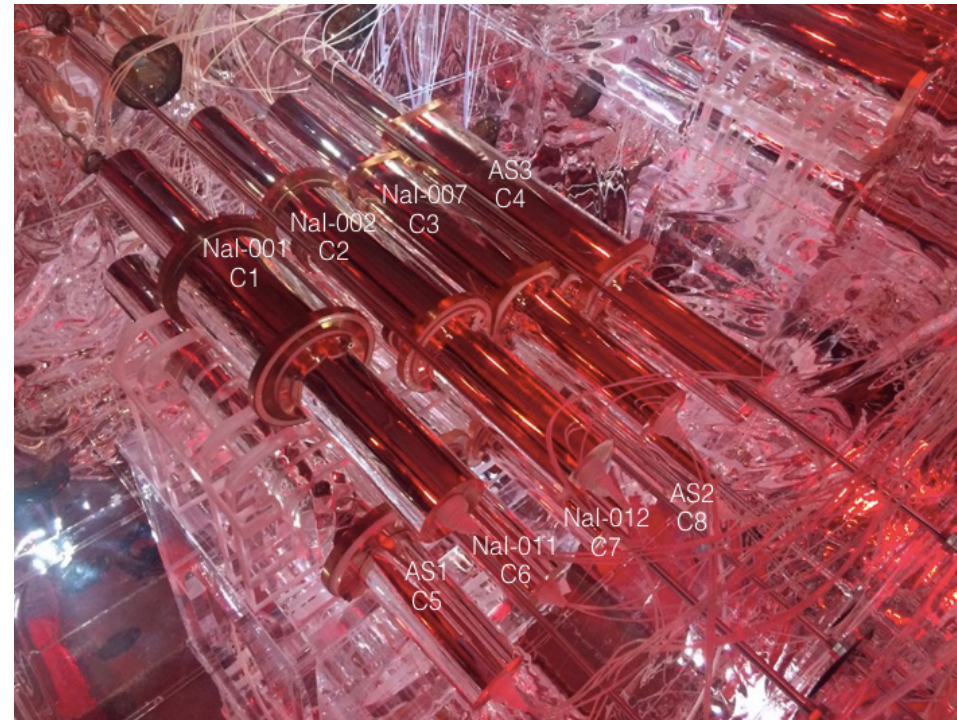
- We installed Rn reduction system and measured with with RAD7 detector.
- One can see the rapid decrease of Rn concentration right after supply of the Rn free air.



# Installation of Crystals.

- We installed total 8, selected crystals.
- Total amount of mass is 106 kg.

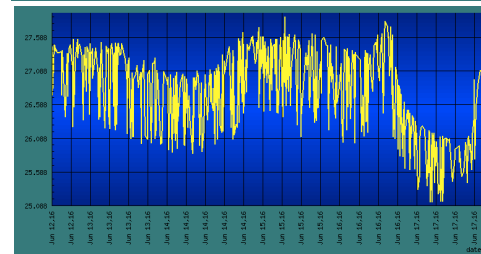
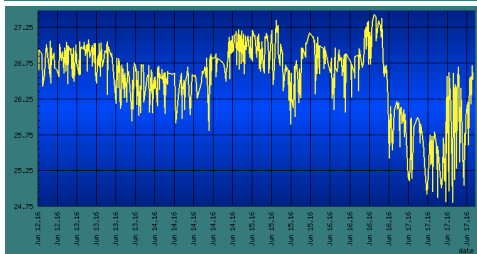
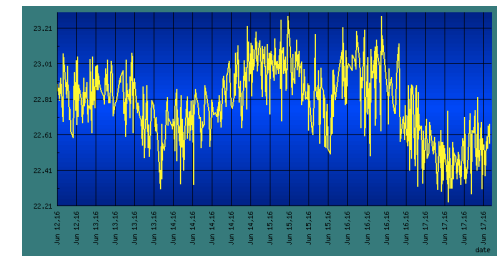
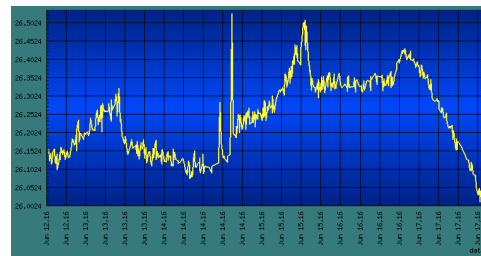
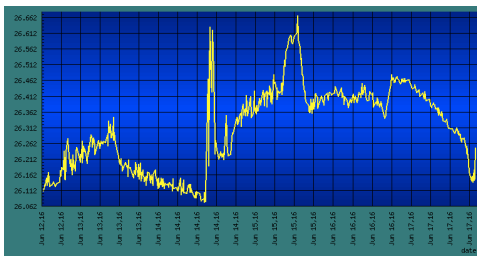
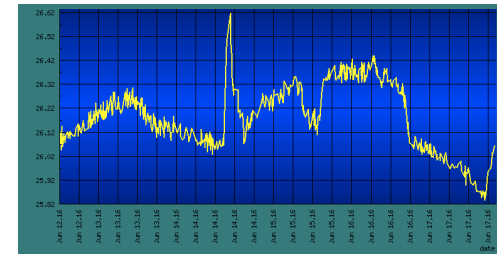
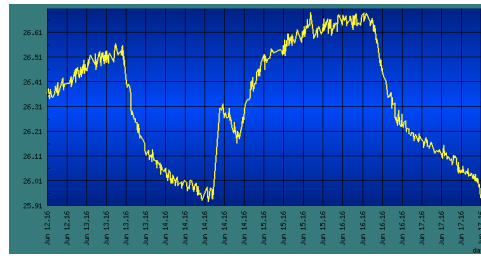
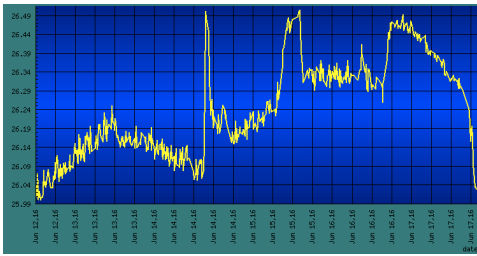
Crystals	Nickname	Powder	Mass
Nal-001	C1	Sample B	8.3 kg
Nal-002	C2	Sample C	9.2 kg
Nal-007	C3	WimpScint 2	9.2 kg
AS-3	C4	WimpScint 2	18.0 kg
AS-1	C5	Sample C	18.3 kg
Nal-011	C6	WimpScint 3	12.5 kg
Nal-012	C7	WimpScint 3	12.5 kg
AS-2	C8	Sample C	18.3 kg



# Environmental monitoring

we attached 8 temperature sensors.

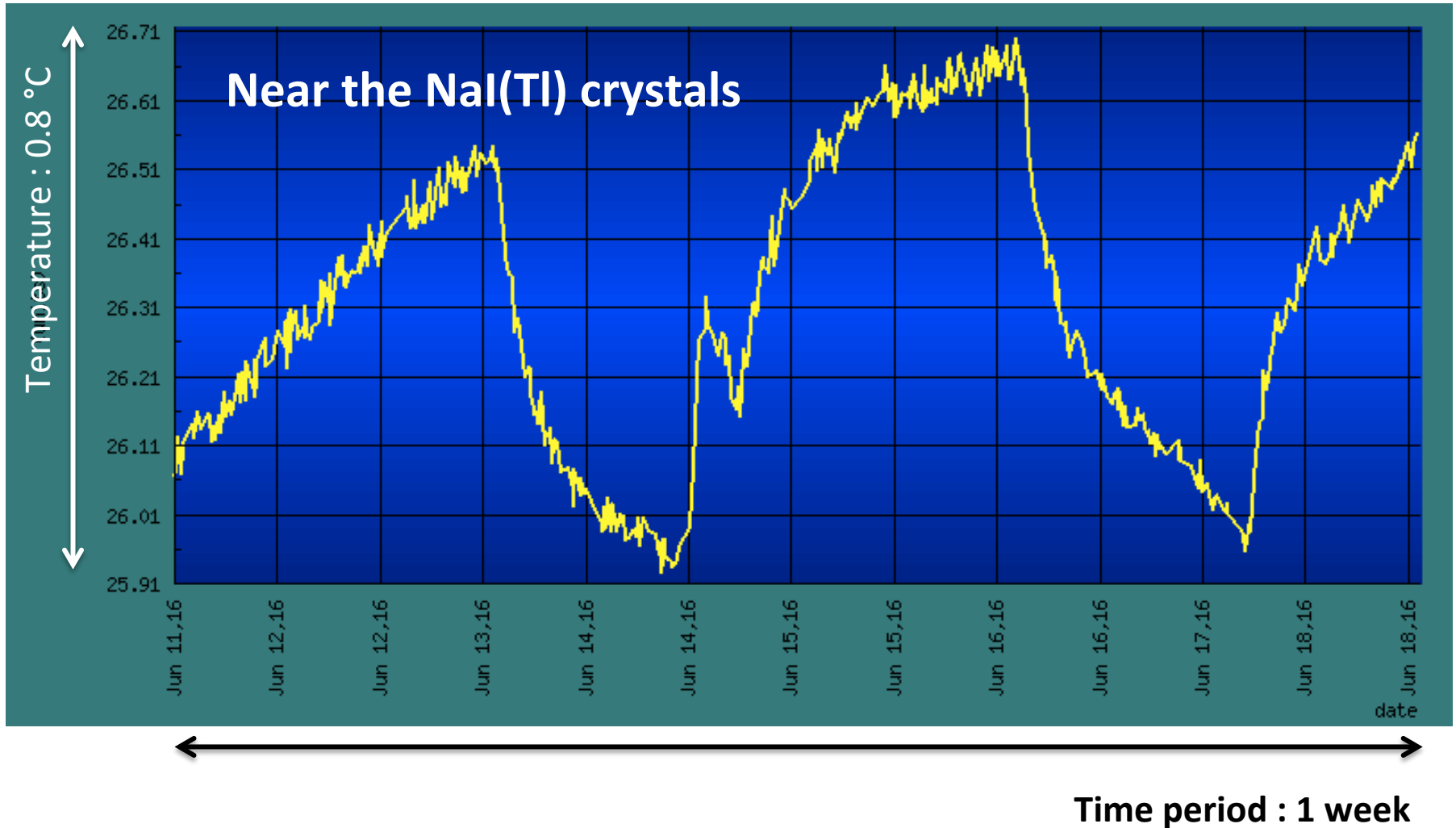
- Three : Inside inner most copper box. (Top / Middle / Bottom)
- Two : near the outside copper box. (Front / Side)
- One : Inside of COSINE-100 detector room.
- One : Tunnel that just outside of COSINE-100 detector room.
- One : Near the temperature sensor machine
- Default : Temperature of sensor machine





# Environmental monitoring

we attached 8 temperature sensors.



# DAQ Modules

## FADC

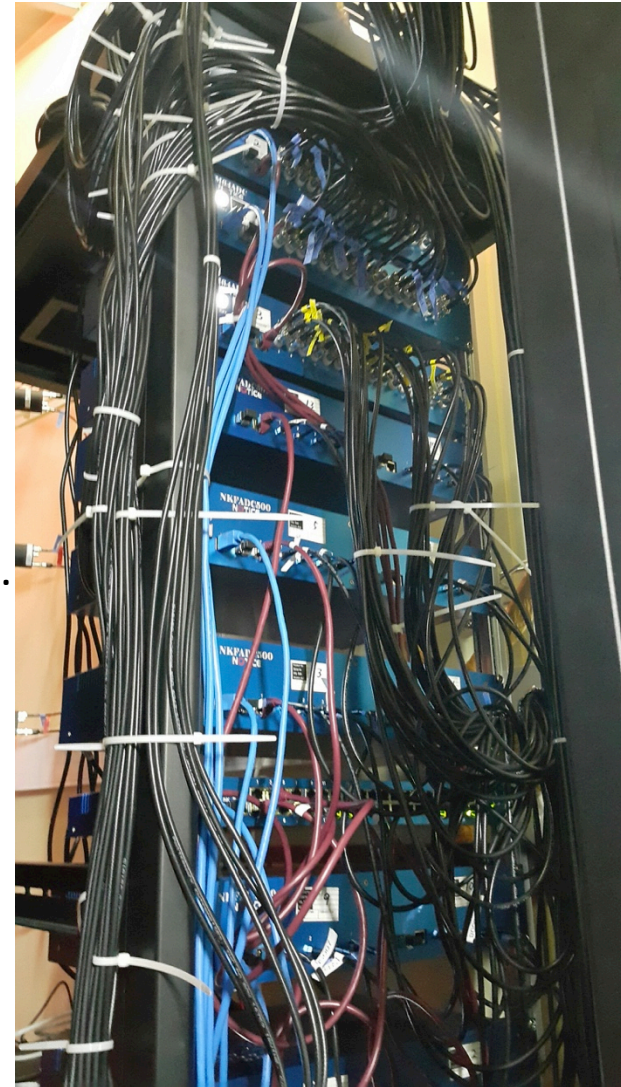
- Flash ADC that stores event shape.
- 500 MHz
- 2.5V dynamic range
- 12 bit resolution
- Takes NaI(Tl) crystal signal / Neutron detector signal

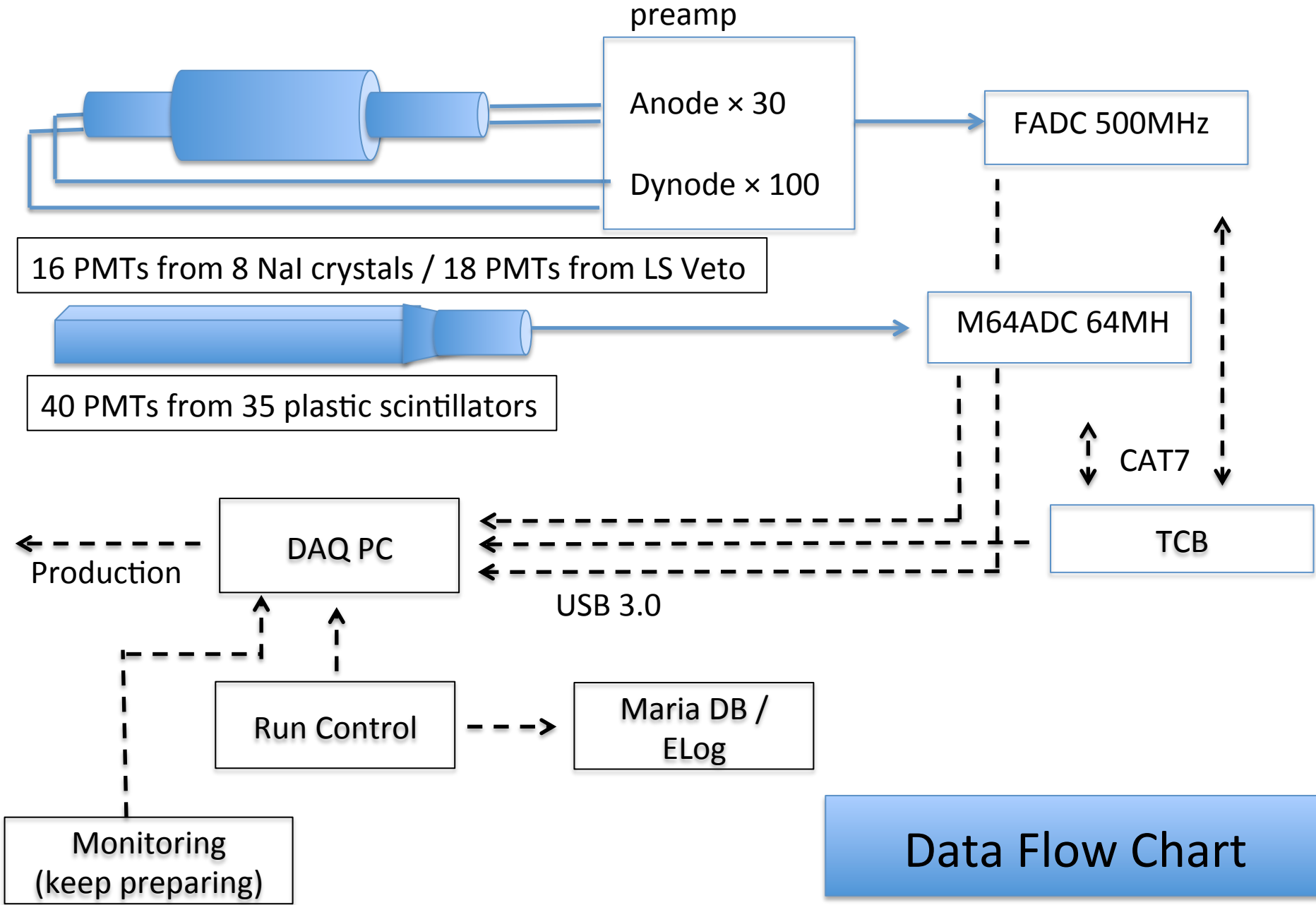
## M64ADC

- Integrated charge at the FPGA and stores only charge info.
- 64 MHz
- 2.5V dynamic range
- 12 bit resolution
- Takes plastic scintillator (Muon Veto) / LS active veto.

## TCB

- Trigger control box for FADC and M64ADC
- Give triggered time information also.





# Data Flow Chart



# Run Control Panel

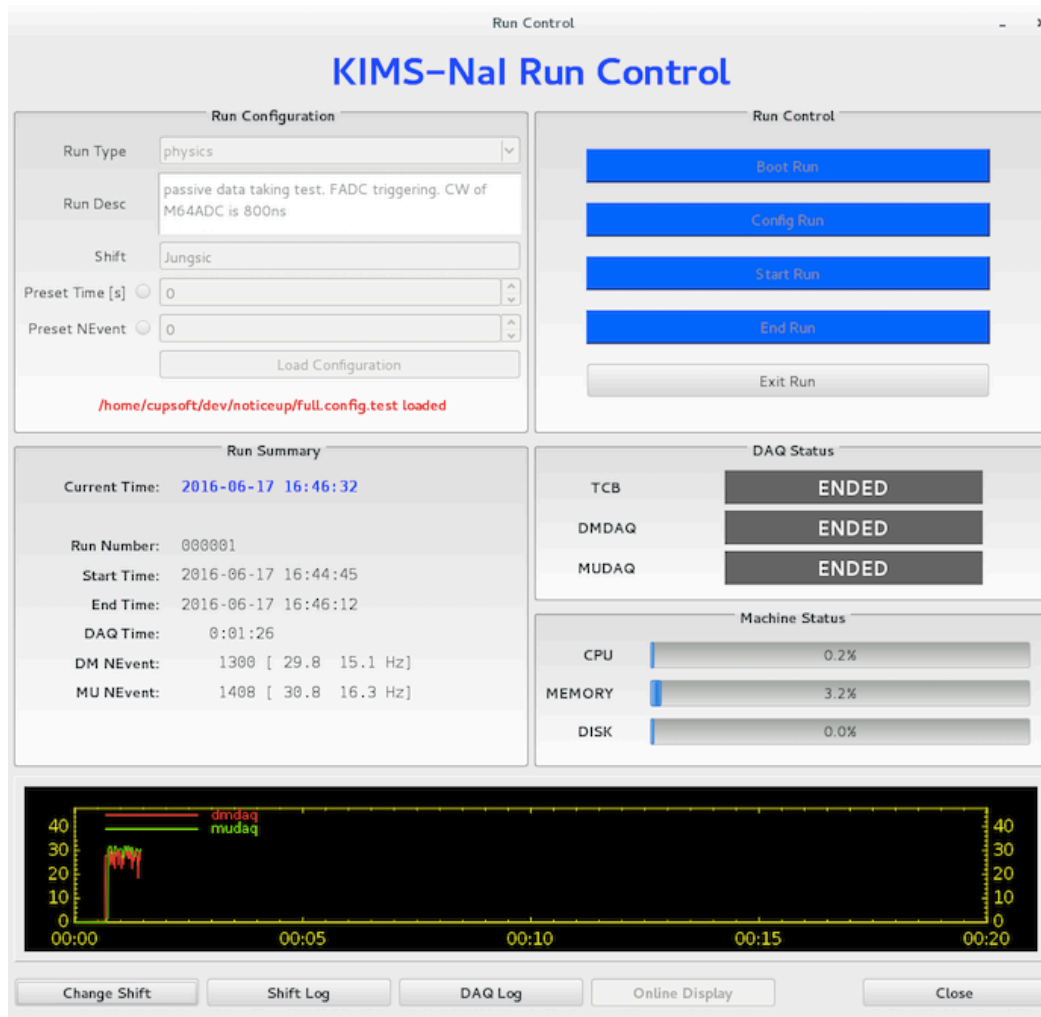
- Start and stop of data taking is controlled via run control GUI.
- Several information of each run is automatically recorded to the database.

Run Type  
Run Description  
Shifter

Real Time  
Run number

Event rate

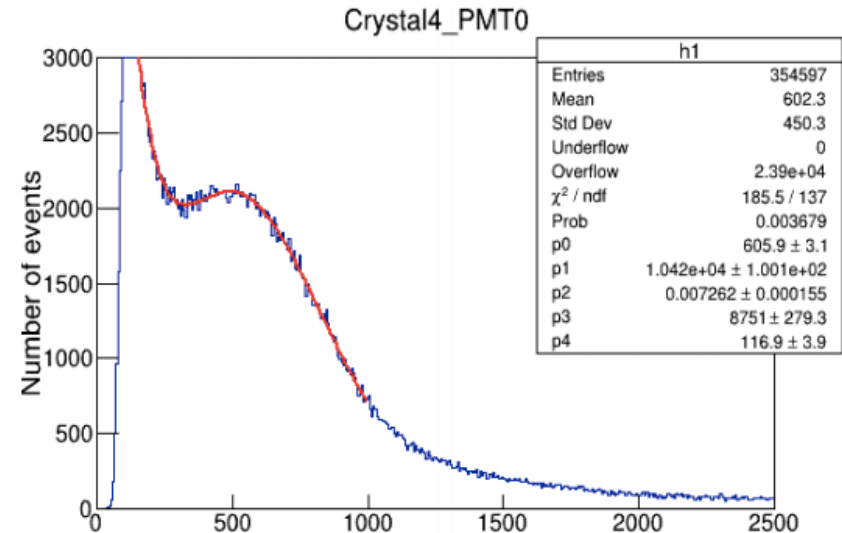
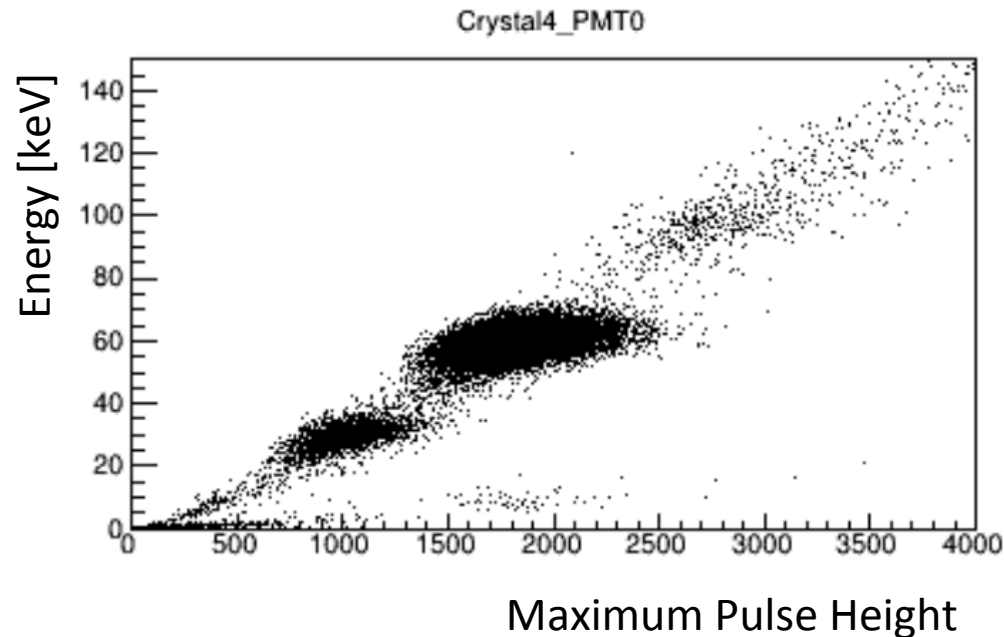
Event rate (graph)



CPU info  
Memory info  
Hdd info

# Calibration of NaI(Tl) PMTs.

- $^{241}\text{Am}$  source data to calibrate each PMTs.
- We matched 60keV from Am source to middle of dynamic range of FADC.

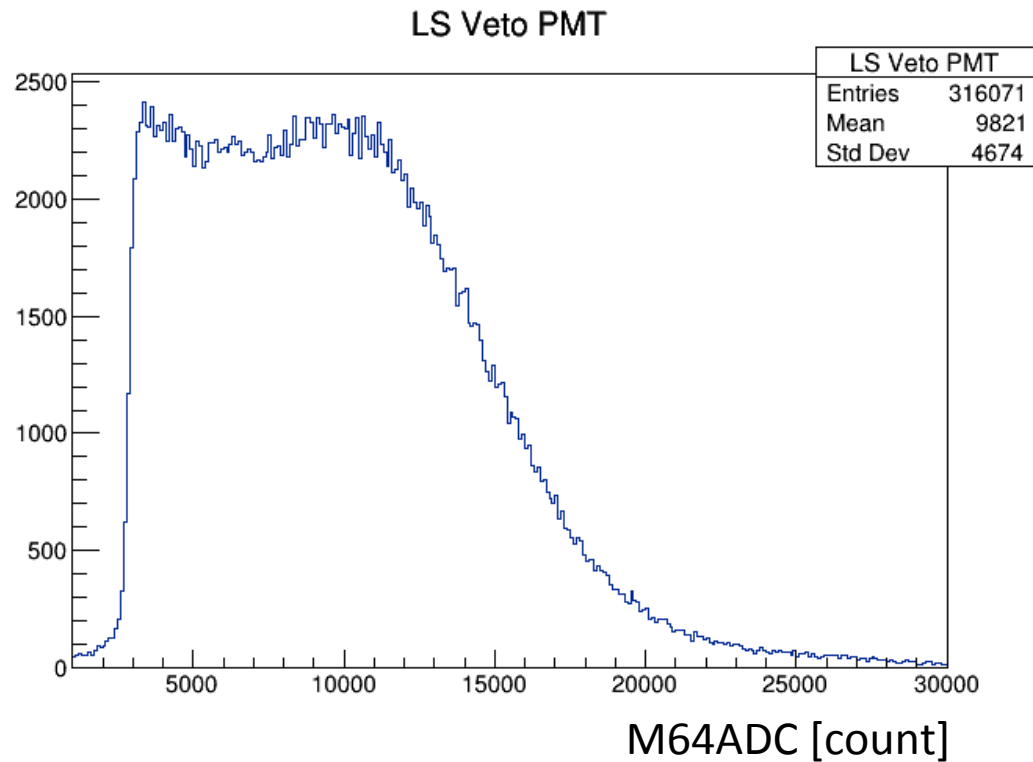
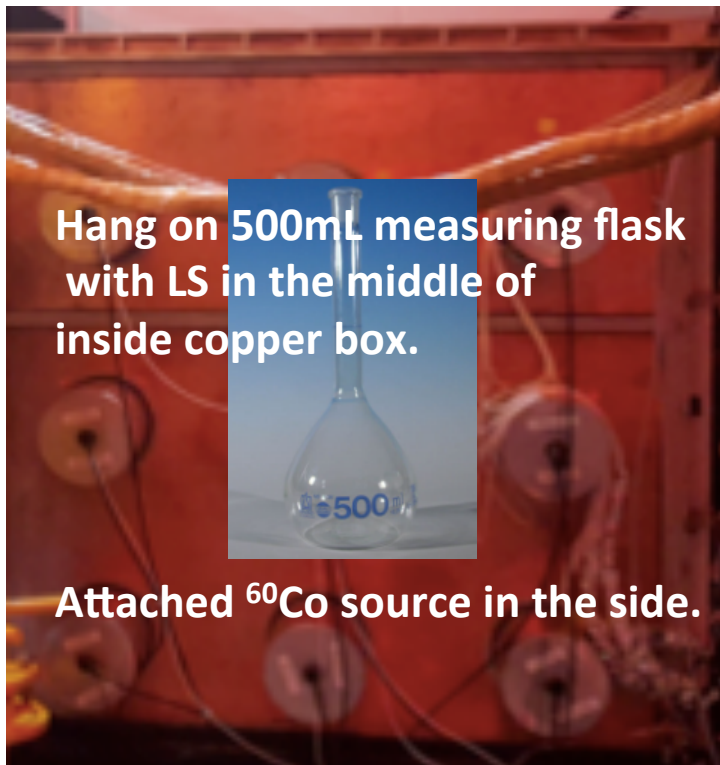


- We gathered single photon information 2us after from the triggered time.
- Spectrum was fitted to get the Light Yield of each NaI(Tl) crystals

Average light yield is  $\sim 15 \text{p.e./keV}$

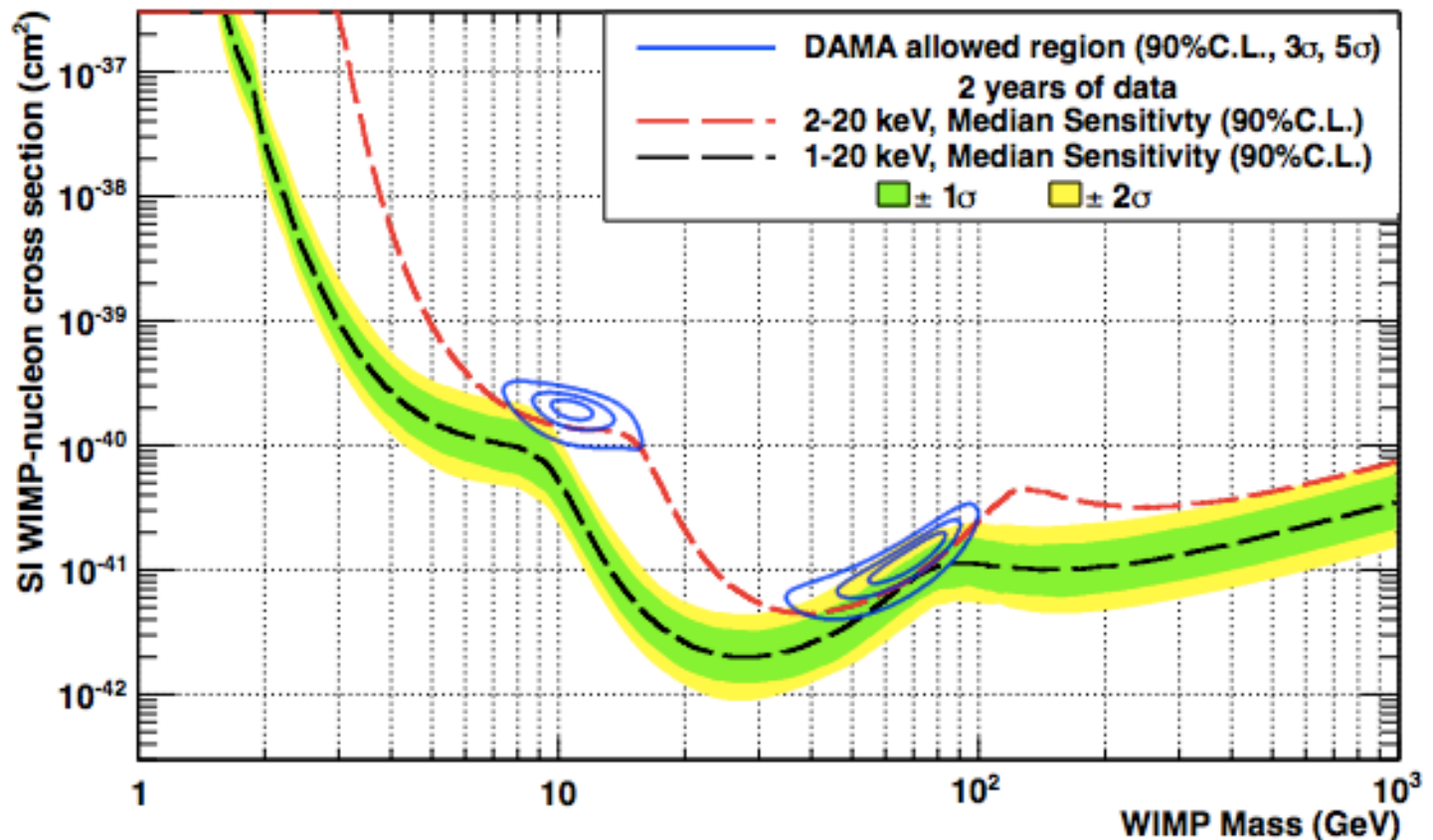
# Performance of LS Veto PMTs.

- Data taken with  $^{60}\text{Co}$  source and 500 mL of LS.
- calibration will be done after filling the LS.



# Expected Sensitivity

- COSINE-100 at YangYang, with 1 keV and 2 keV energy threshold.
- Assumed flat background with 2cpd for several crystals and 4 cpd for other crystals.
- Assumed 2 years of data taking.





## Summary

- COSINE is working together to confirm or to rule out DAMA/LIBRA modulation result.
- Construction of the main detector is completed except scintillation liquid fill.
- We started dry-run with 8 NaI(Tl) crystals and will take data for several weeks before filling the LS.
- Temperature, humidity, and  $^{222}\text{Rn}$ -level in the detector room is continuously monitored.
- Let's see the data !!