

# *The COSINE experiment at Yangyang*

**Chang Hyon Ha**

On behalf of the COSINE collaboration  
Center for Underground Physics, IBS, Korea





# The COSINE collaboration

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

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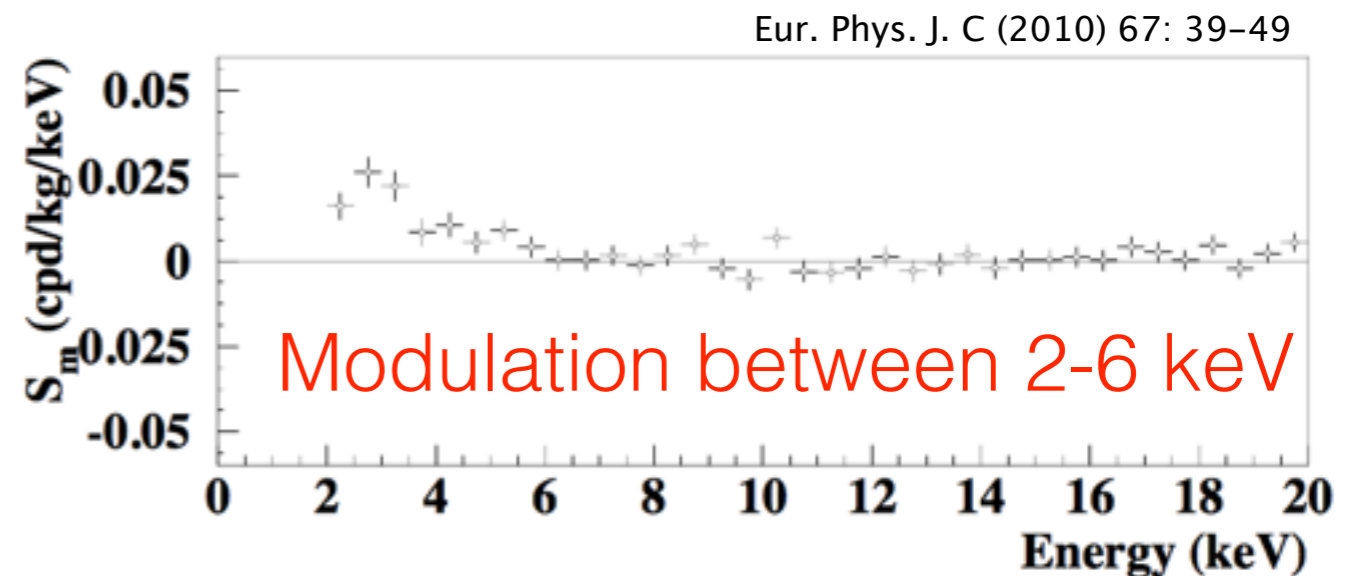
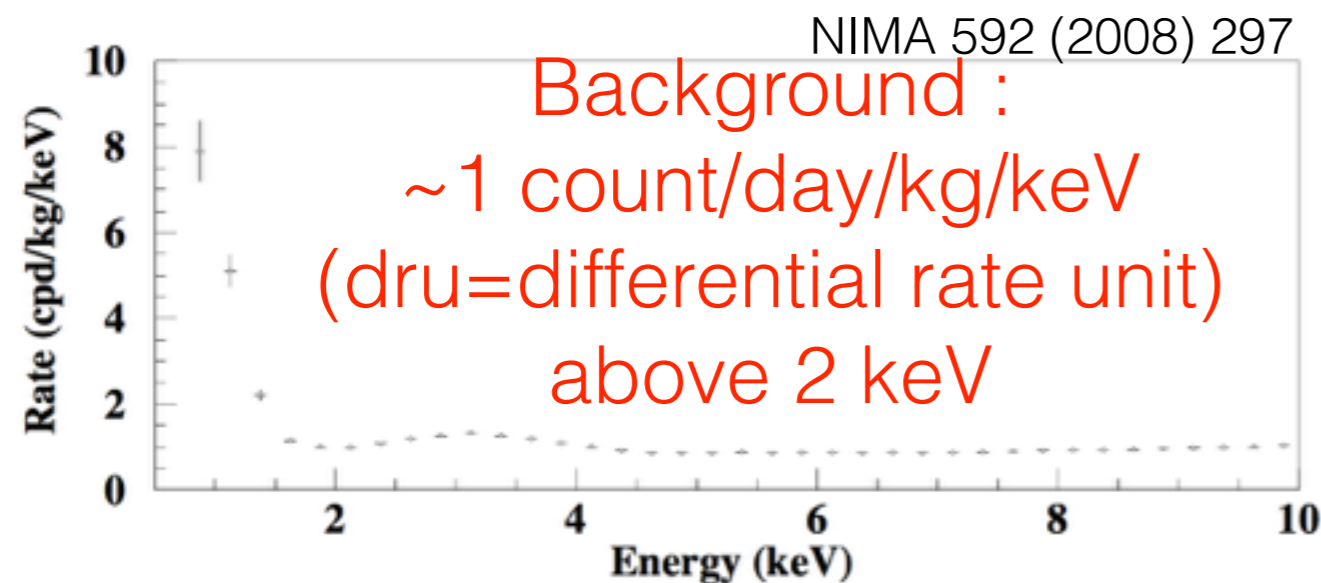
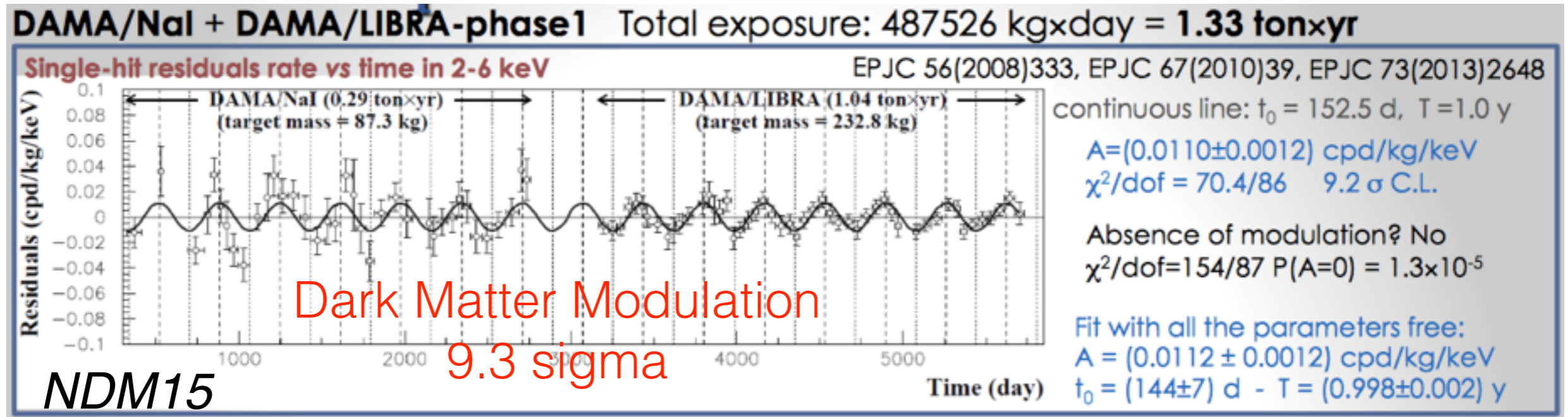
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15 institutes,  
~60 members



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





# YangYang Laboratory (Y2L)

**Upper Dam**

**KIMS-CsI  
at A6 tunnel**



**Depth  
700m**

**Power Plant**

**COSINE  
at A5 tunnel**



**Lower Dam**

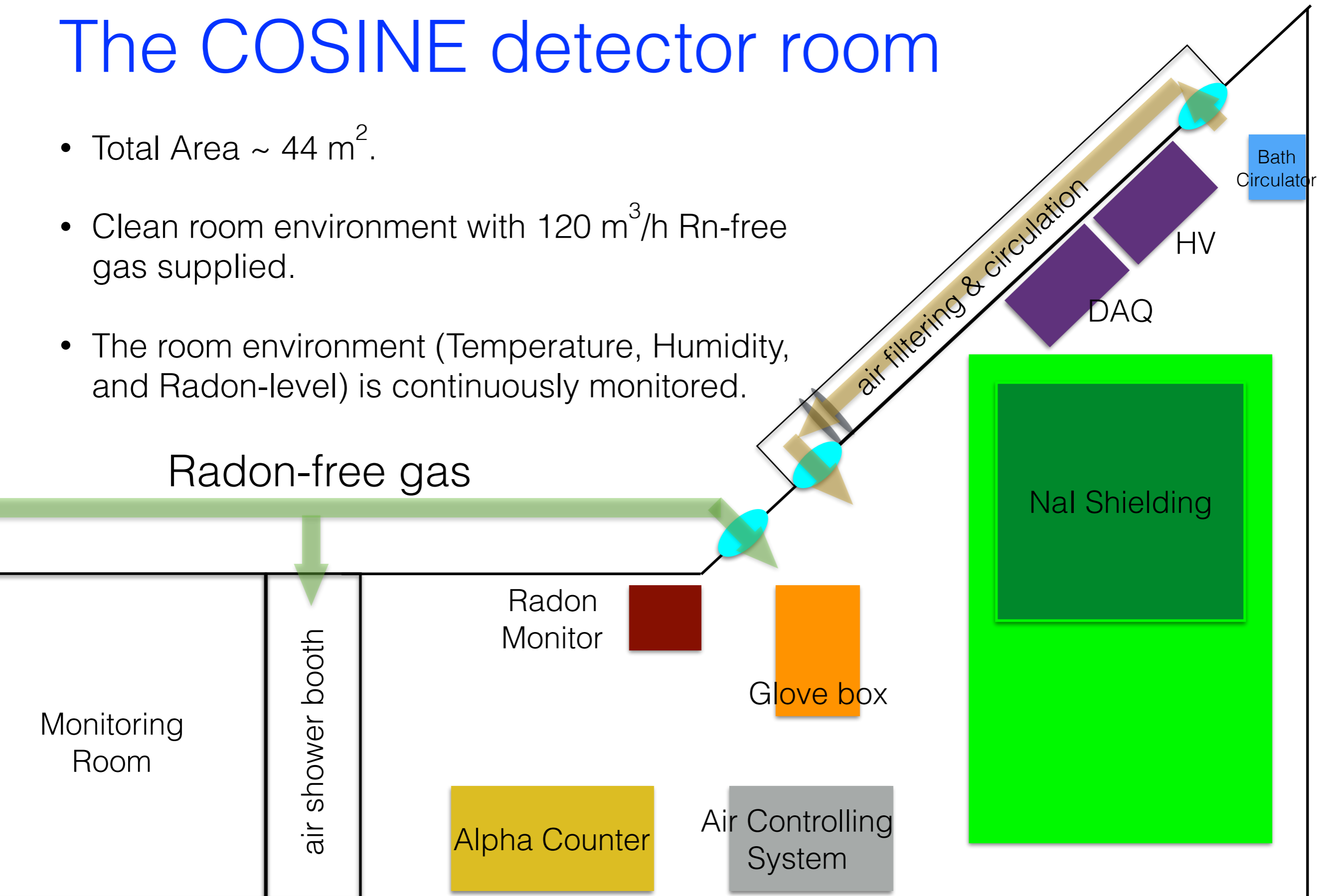
**Access by car to the lab (2 km)**

**Situated at YangYang Pumped Storage Power Plant**



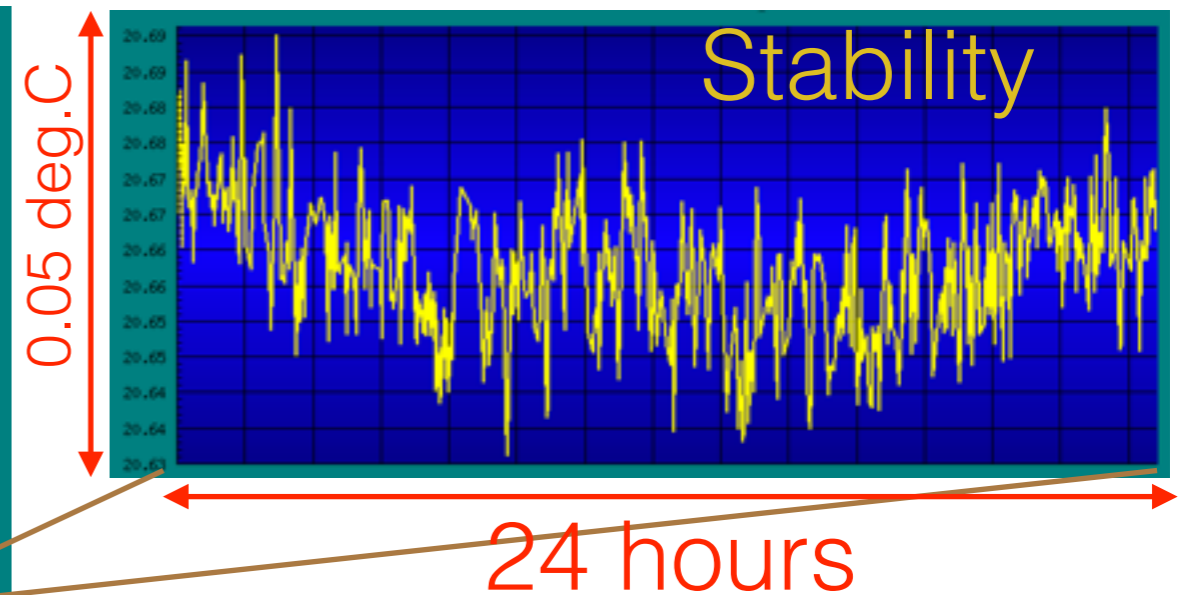
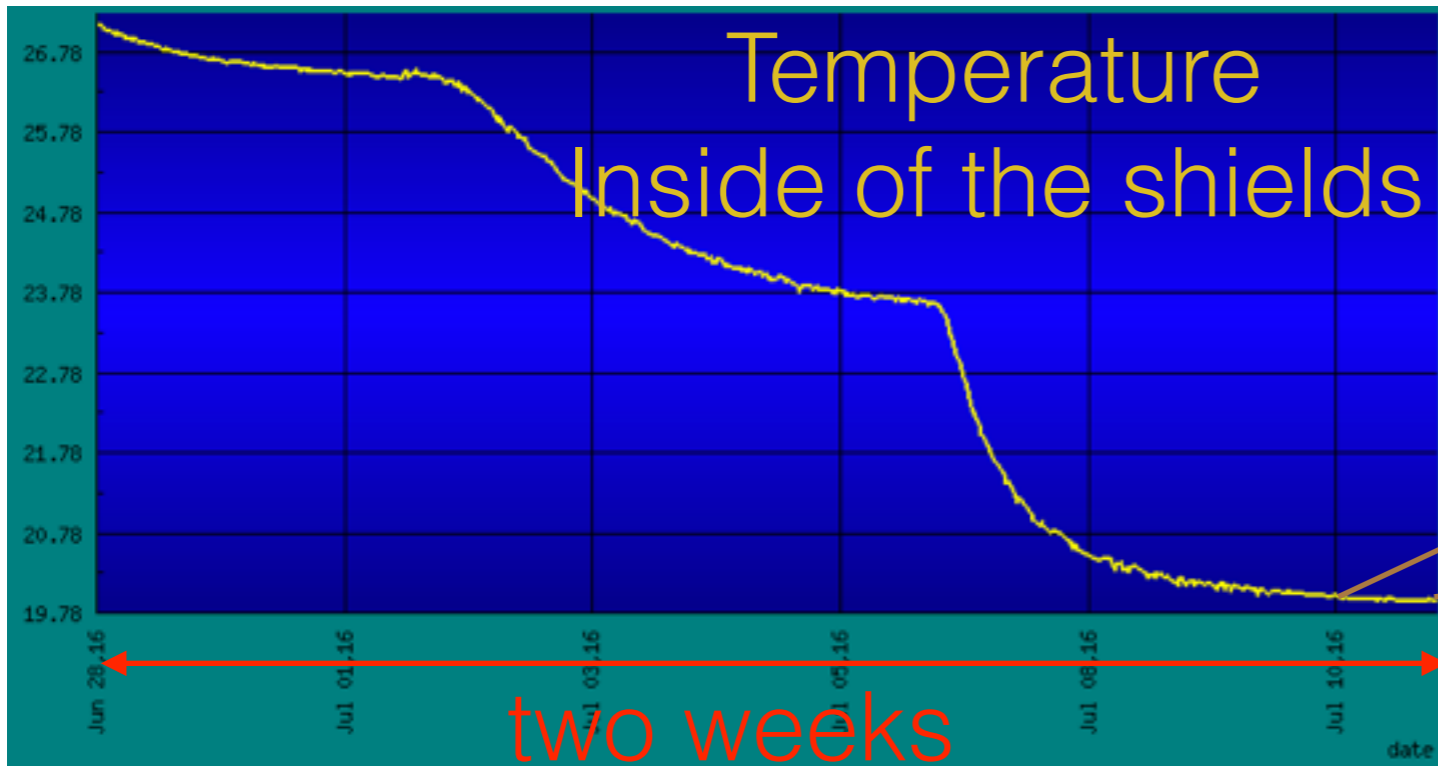
# The COSINE detector room

- Total Area  $\sim 44 \text{ m}^2$ .
- Clean room environment with  $120 \text{ m}^3/\text{h}$  Rn-free gas supplied.
- The room environment (Temperature, Humidity, and Radon-level) is continuously monitored.



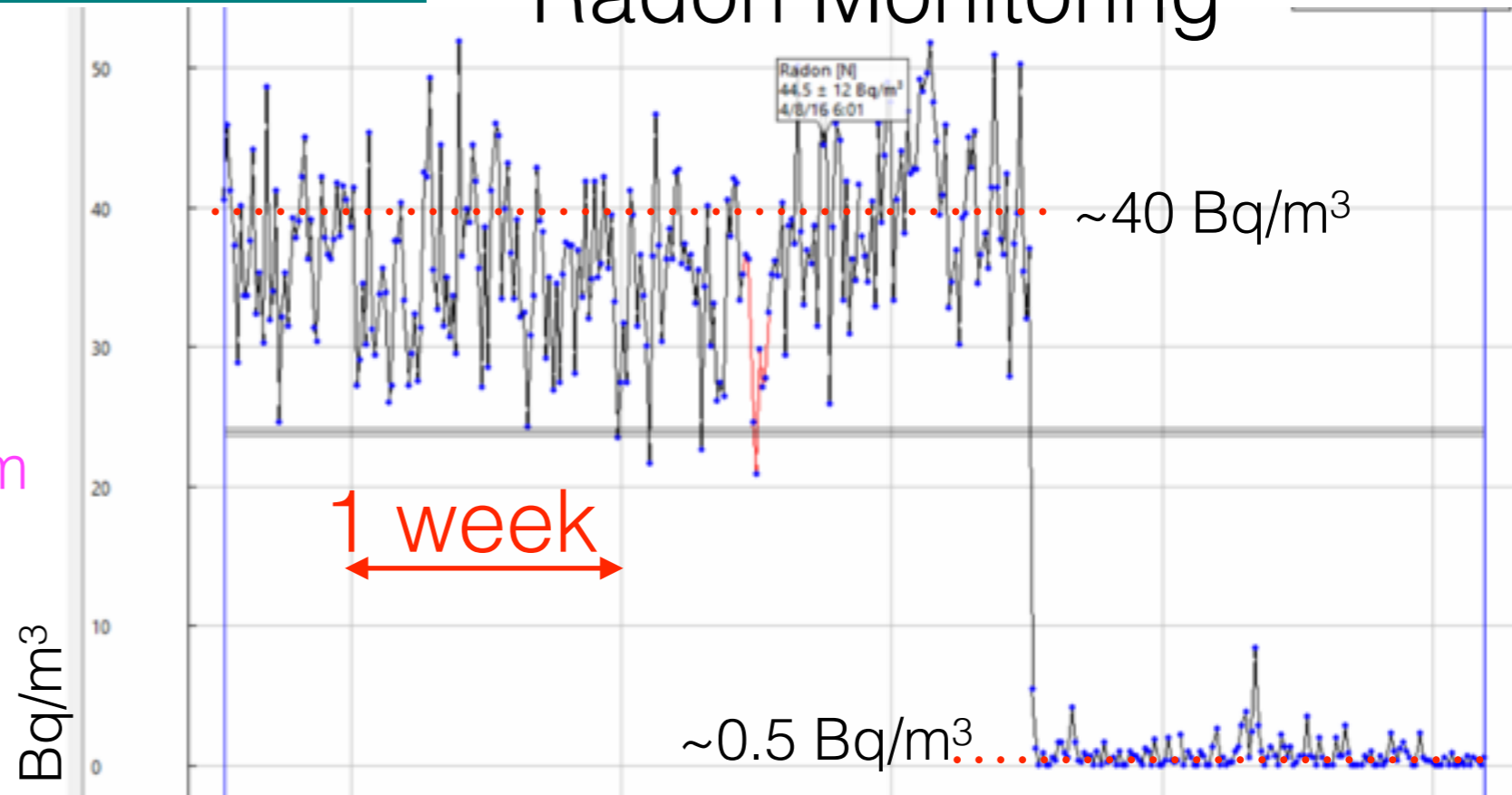


# Environmental Control



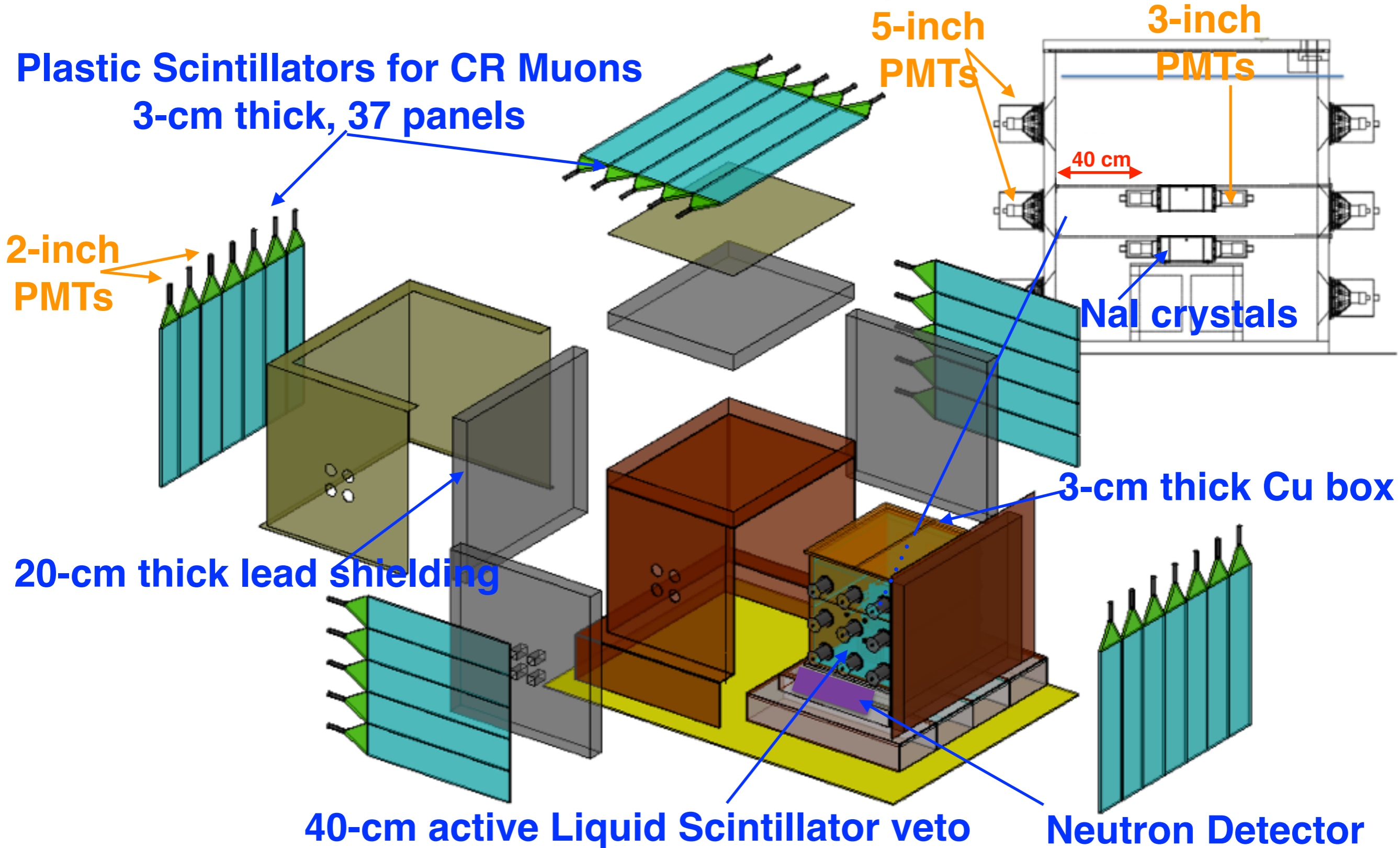
## Radon Monitoring

Radon level monitoring in the detector room. ( RAD7 )  
 ~40 Bq/m<sup>3</sup> (No Rn-free gas)  
 ~0.5 Bq/m<sup>3</sup> (Rn-free gas)  
 Radon emanation from the room limits the lowest possible level





# Shields, Vetoes, and $\mu$ -counters





# Shields, Vetoes, and $\mu$ -counters





# NaI(Tl) crystals evaluated at KIMS-CsI

*Astropart. Phys.* 62 (2015) 249 *Eur. Phys. J. C* (2016) 76: 185

Crystals	Powder	Mass (kg)	<sup>nat</sup> K( <sup>40</sup> K) (ppb)	<sup>238</sup> U (ppt)	<sup>232</sup> Th (ppt)	α rate (mBq/kg)	Light Yield (pe/keV)
NaI-001 (C1)	AS B	8.3	40.4 ± 2.9	< 0.02	< 3.2	3.29 ± 0.02	15.6 ± 1.4
NaI-002 (C2)	AS C	9.2	48.2 ± 2.3	< 0.12	0.5 ± 0.3	1.77 ± 0.01	15.5 ± 1.4
NaI-007 (C3)	AS WimpScint II	9.3	38.1 ± 5.5	< 0.04	0.20 ± 0.01	0.85 ± 0.06	15.2 ± 1.4
AS3 (C4)	AS WimpScint II	18.0					
AS1 (C5)	AS C	18.3					
NaI-011 (C6)	AS WimpScint III	12.5	18.5 ± 3.2	< 0.018	< 0.079	1.03 ± 0.13	16.8 ± 1.2
NaI-012 (C7)	AS WimpScint III	12.5					
AS2 (C8)	AS C	18.3					
DAMA			< 20	0.7 - 10	0.5 - 7.5		

Crystals show high light yields. K-40 level is low enough

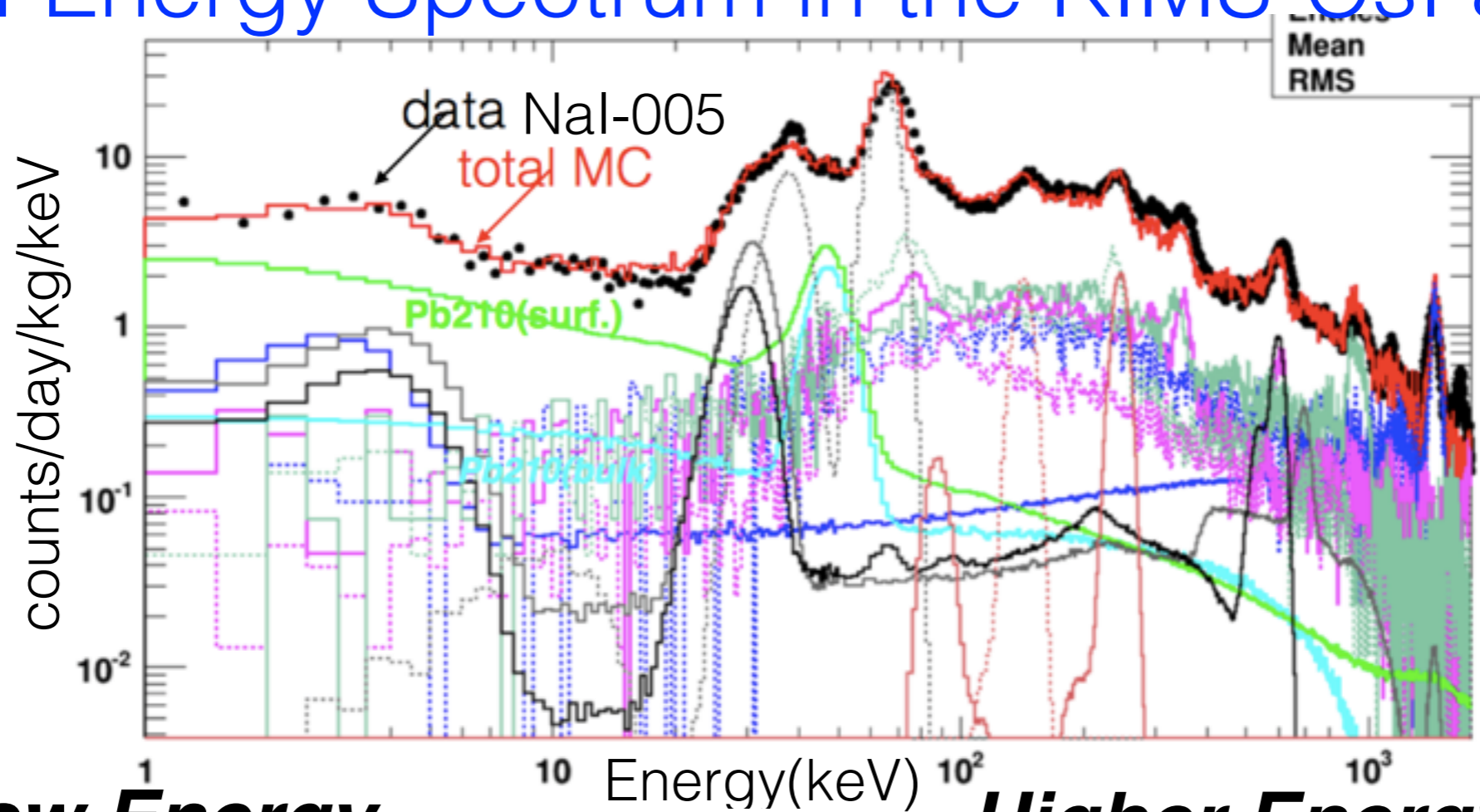
\* 25 ppb K-40 : ~0.4 dru at 2-4 keV

\* 0.5 mBq/kg with bulk Pb-210 : ~0.7 dru at 2 keV

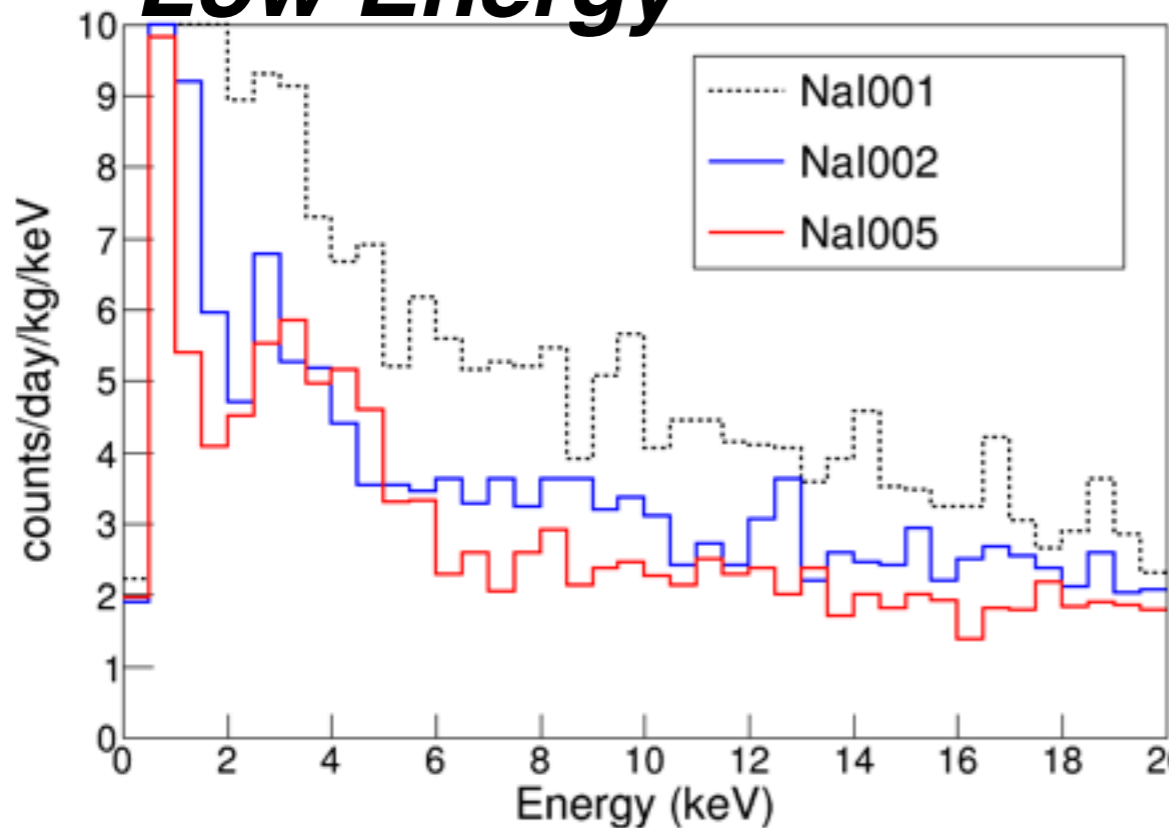
Crystal R&D results showed substantial progress in background reduction



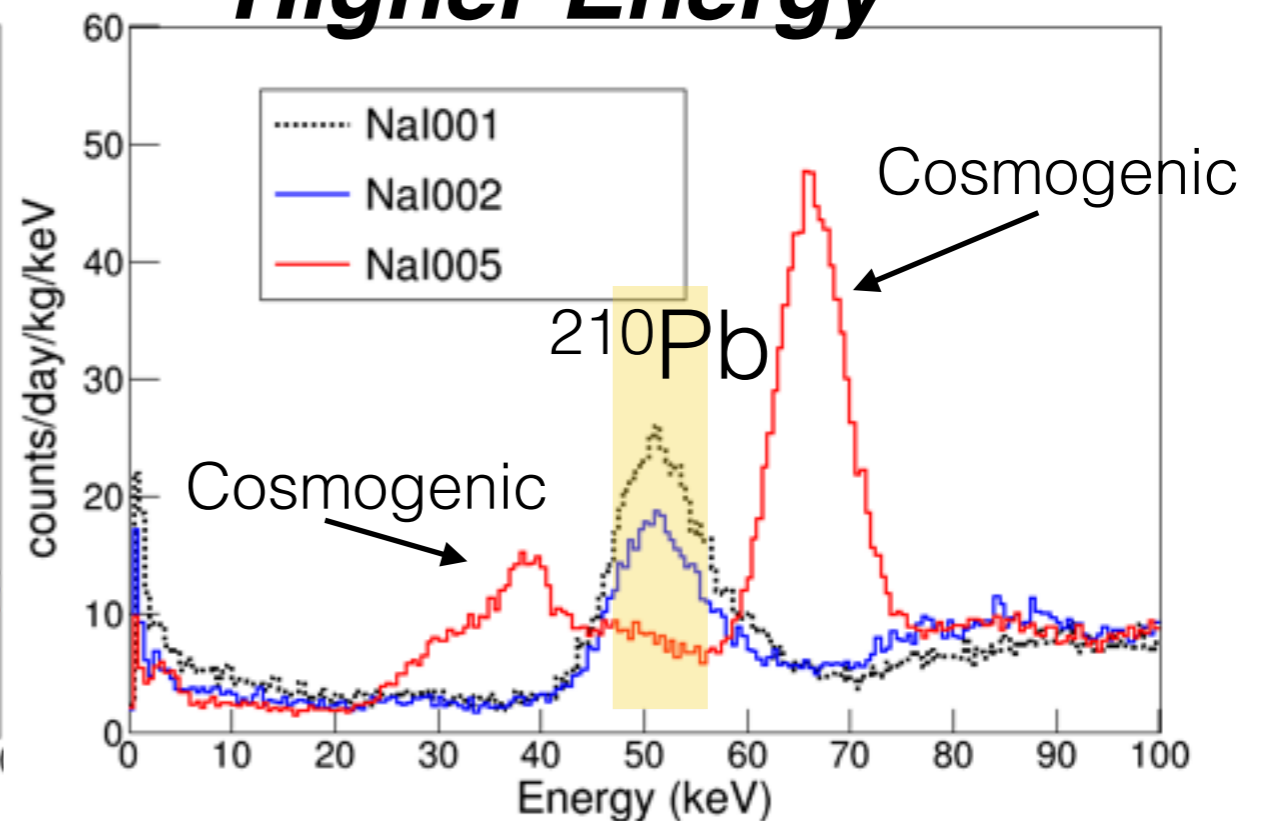
# NaI Energy Spectrum in the KIMS-CsI array



**Low Energy**

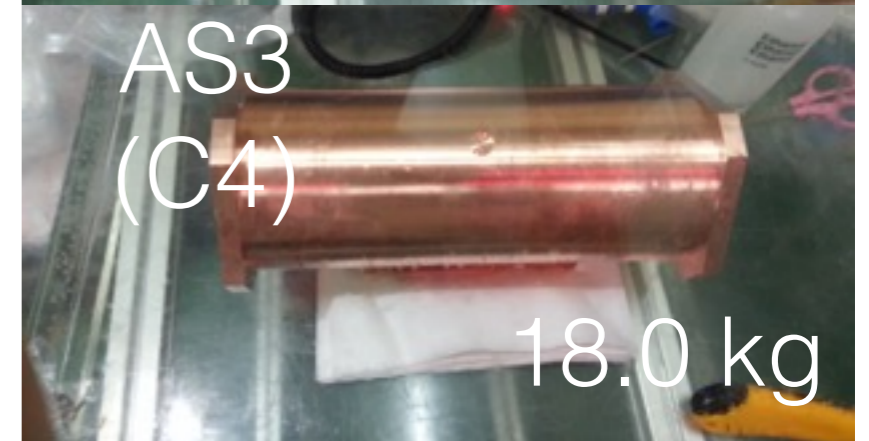
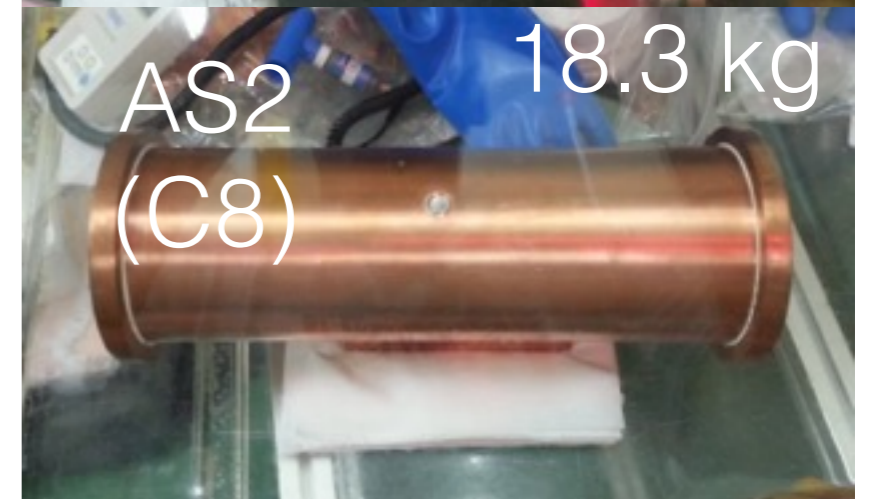
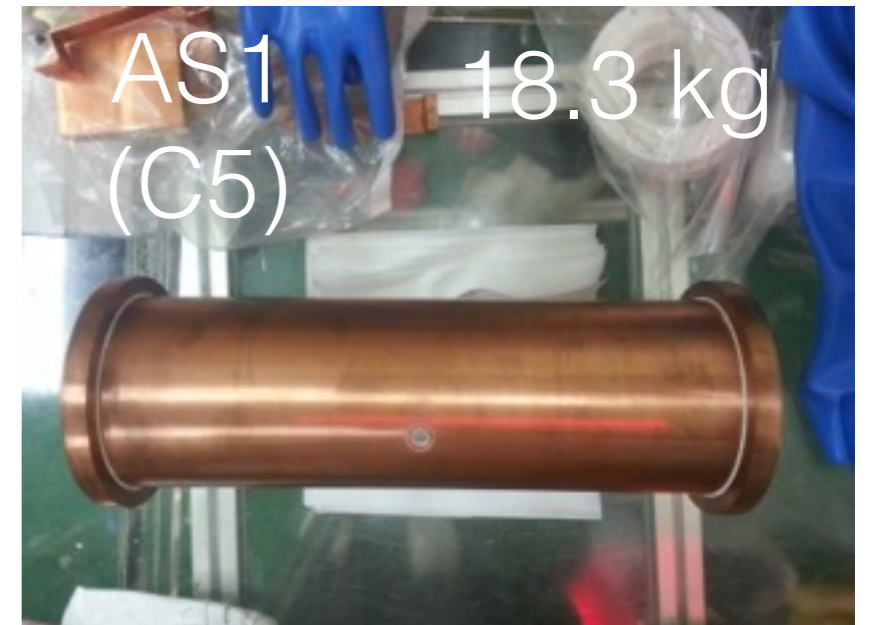
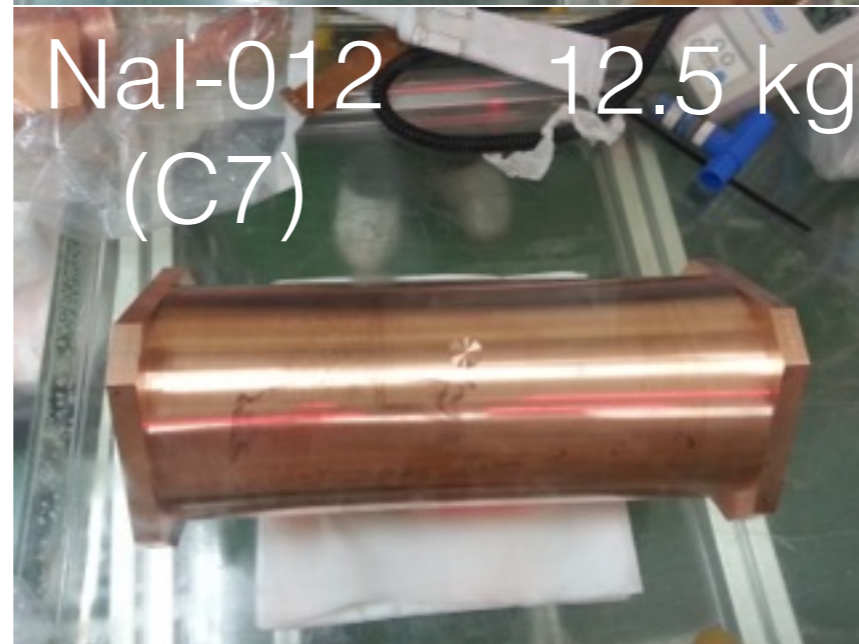
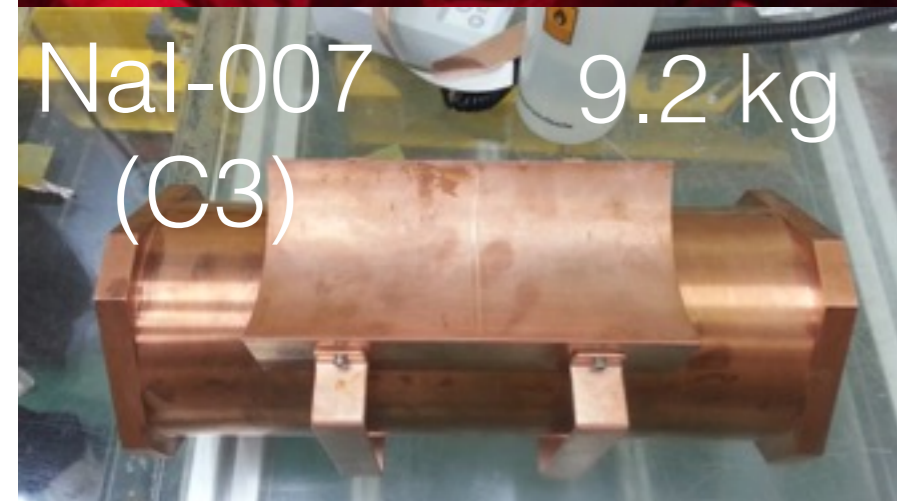


**Higher Energy**



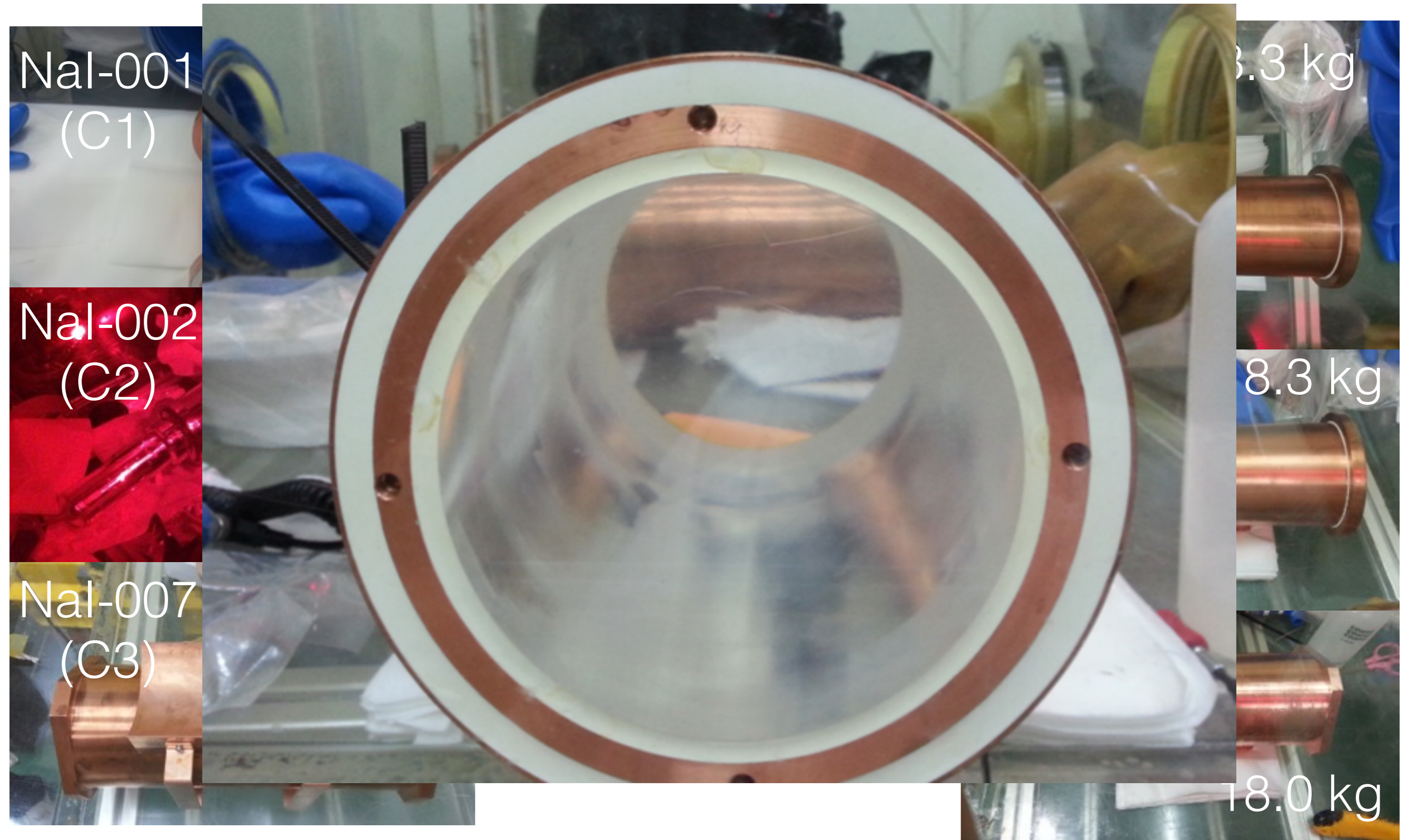


# NaI(Tl) Crystals for COSINE-100





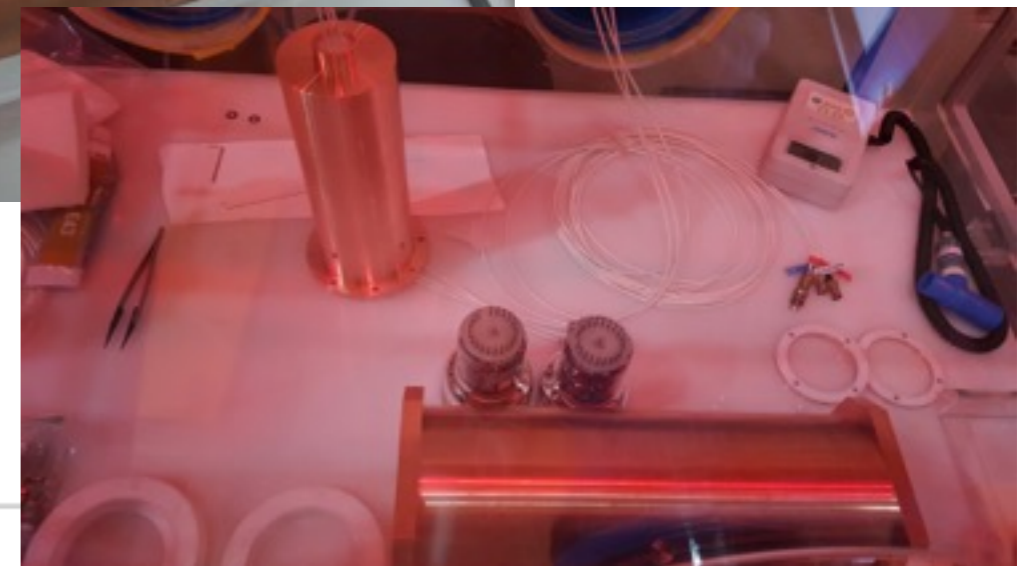
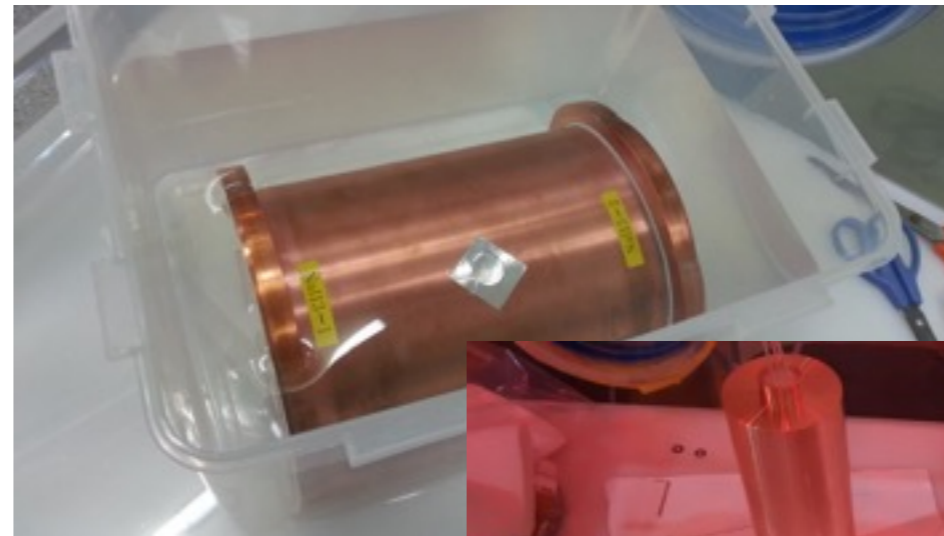
# NaI(Tl) Crystals for COSINE-100



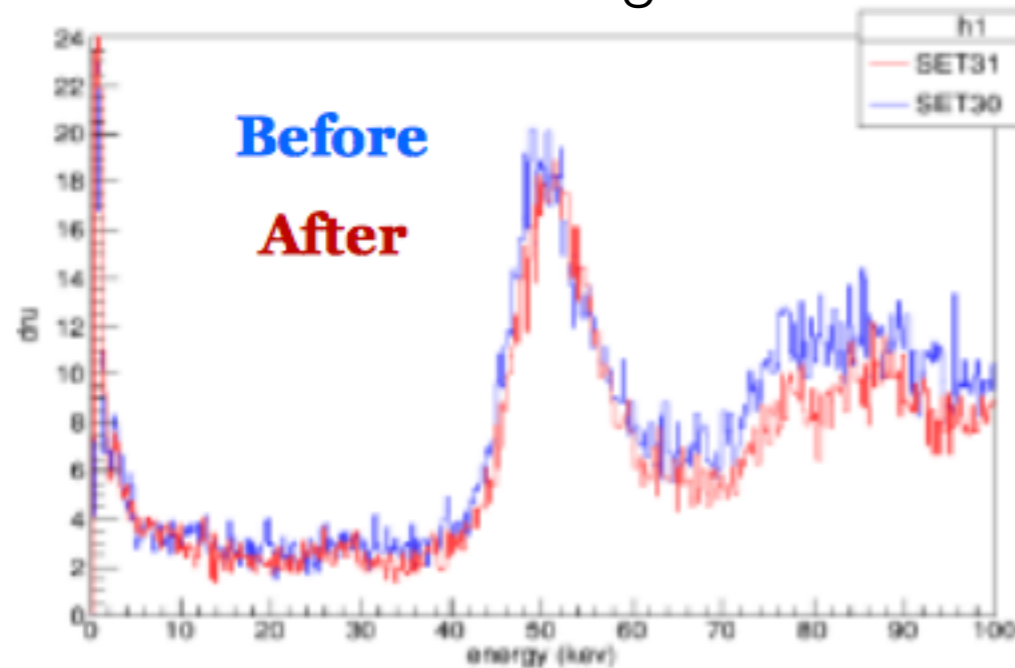


# Cleaning of crystals and assembly parts

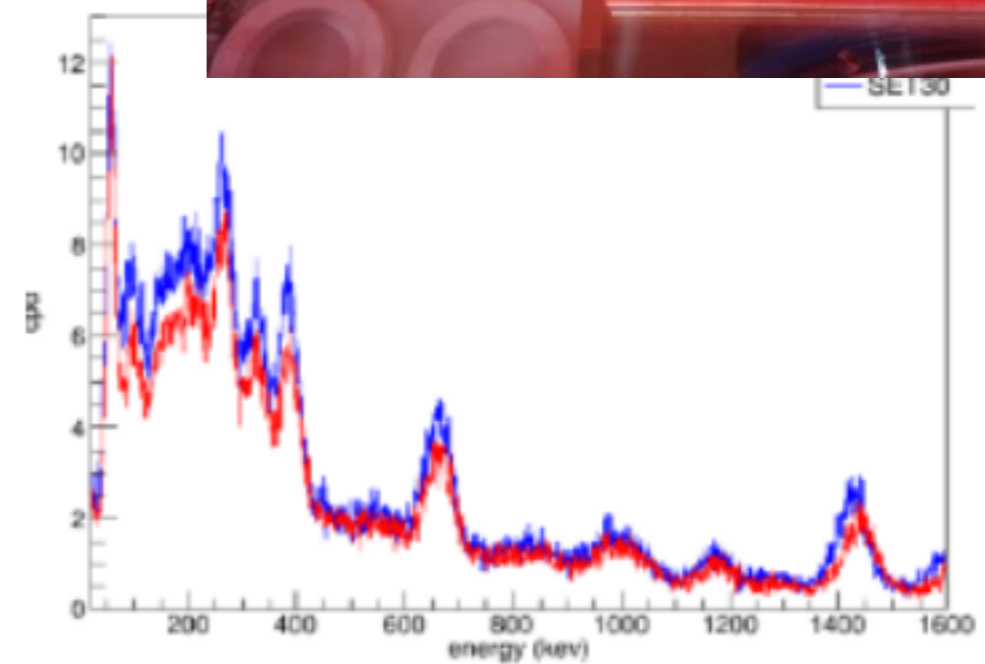
Cleaning in an ultrasonic bath with radiac wash and high grade ethanol.



Previously, 0.3 dru reduction at 6-20 keV  
Alcohol cleaning tests

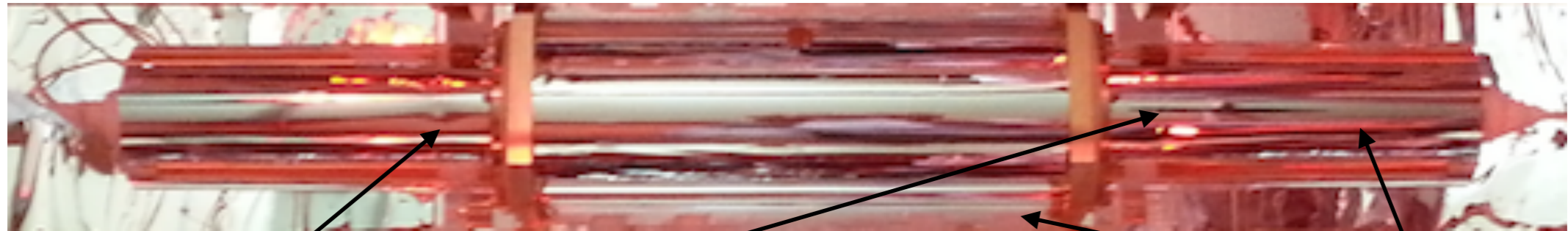


Low Energy

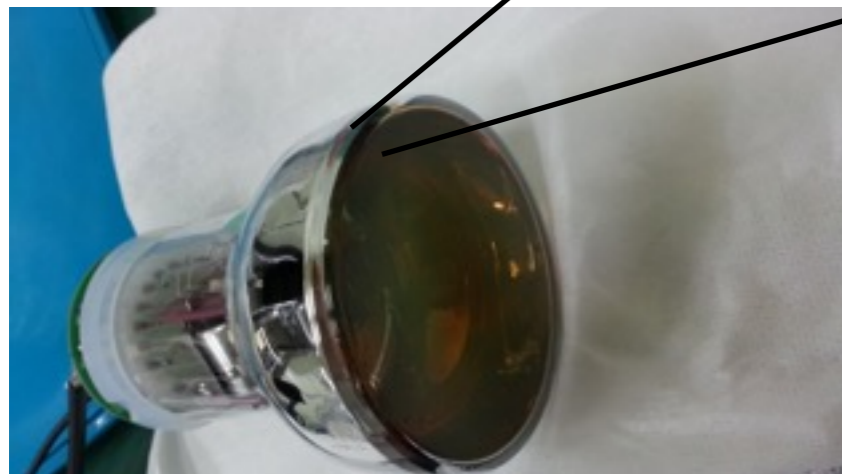


High Energy

# Crystal Assembly, PMT, and DAQ



Cu-encapsulated NaI crystal



## PMT :

3-inch R12669 Hamamatsu PMT  
35% Quantum Efficiency at 420nm  
High Light yield  $\sim 15$  p.e./keV

## Trigger :

2 photons per channel (low E)  
pulse width  $> 50$ ns (high E)



Outer surface is wrapped with  
Vikuiti reflective films

## DAQ :

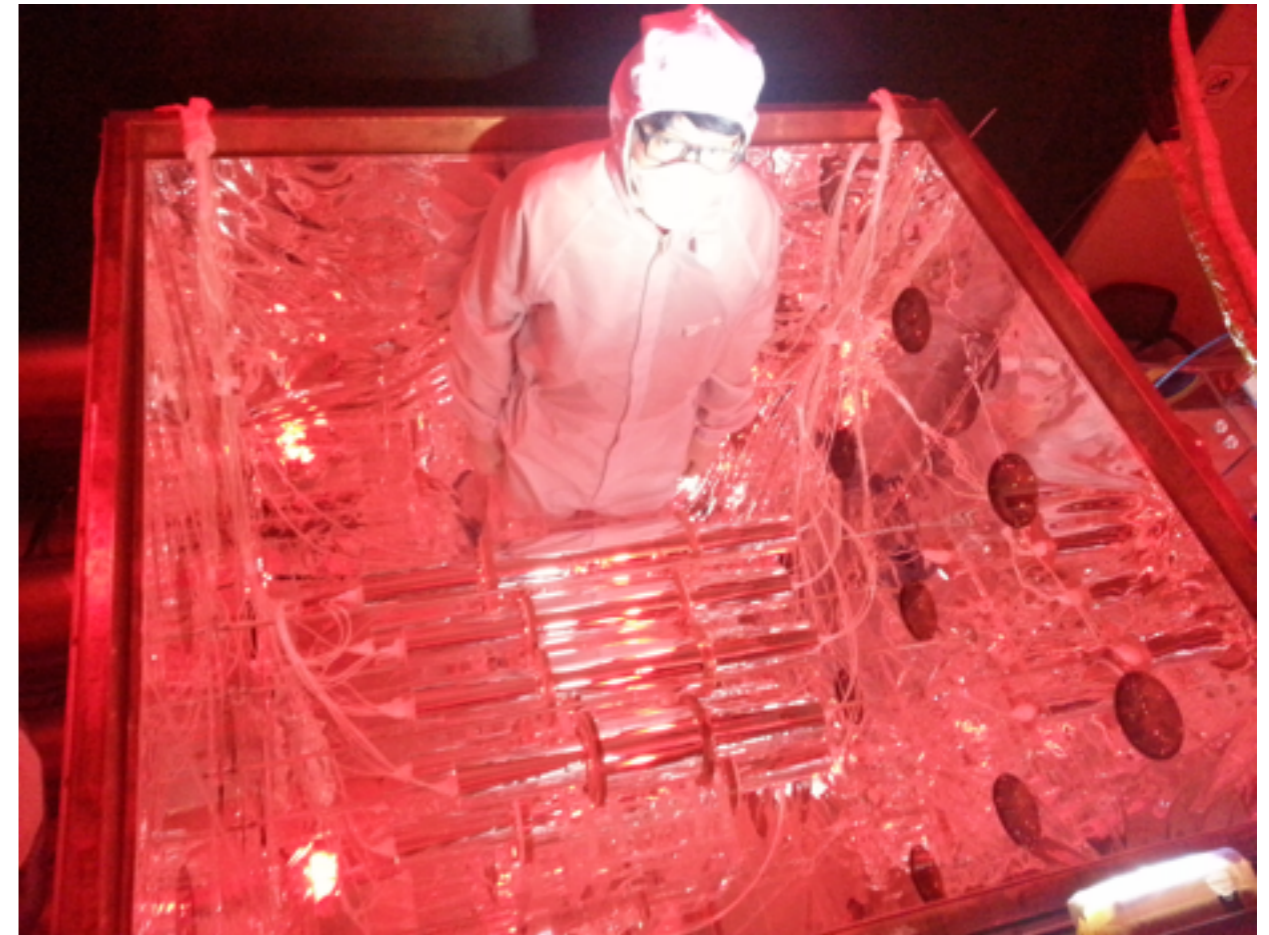
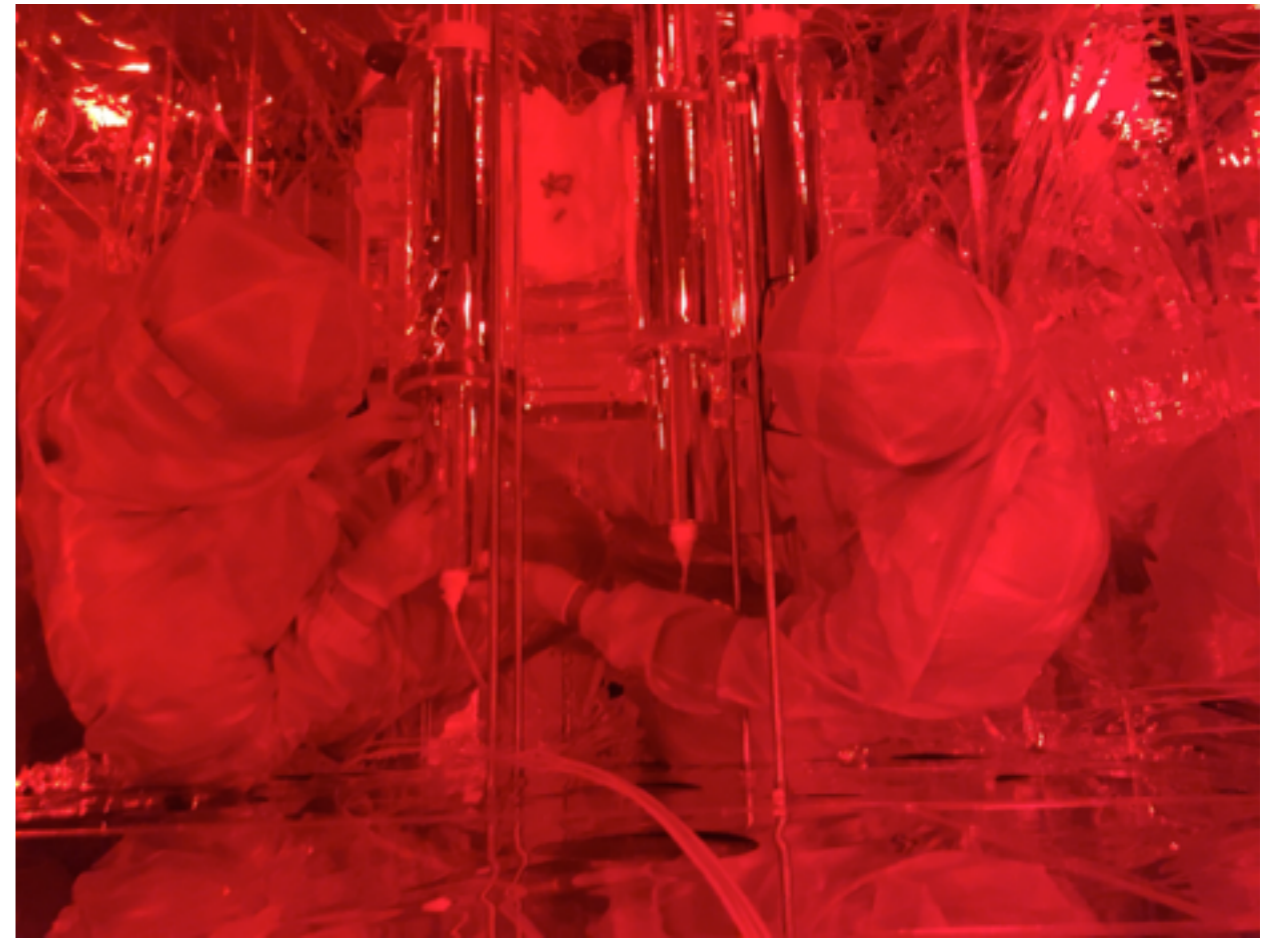
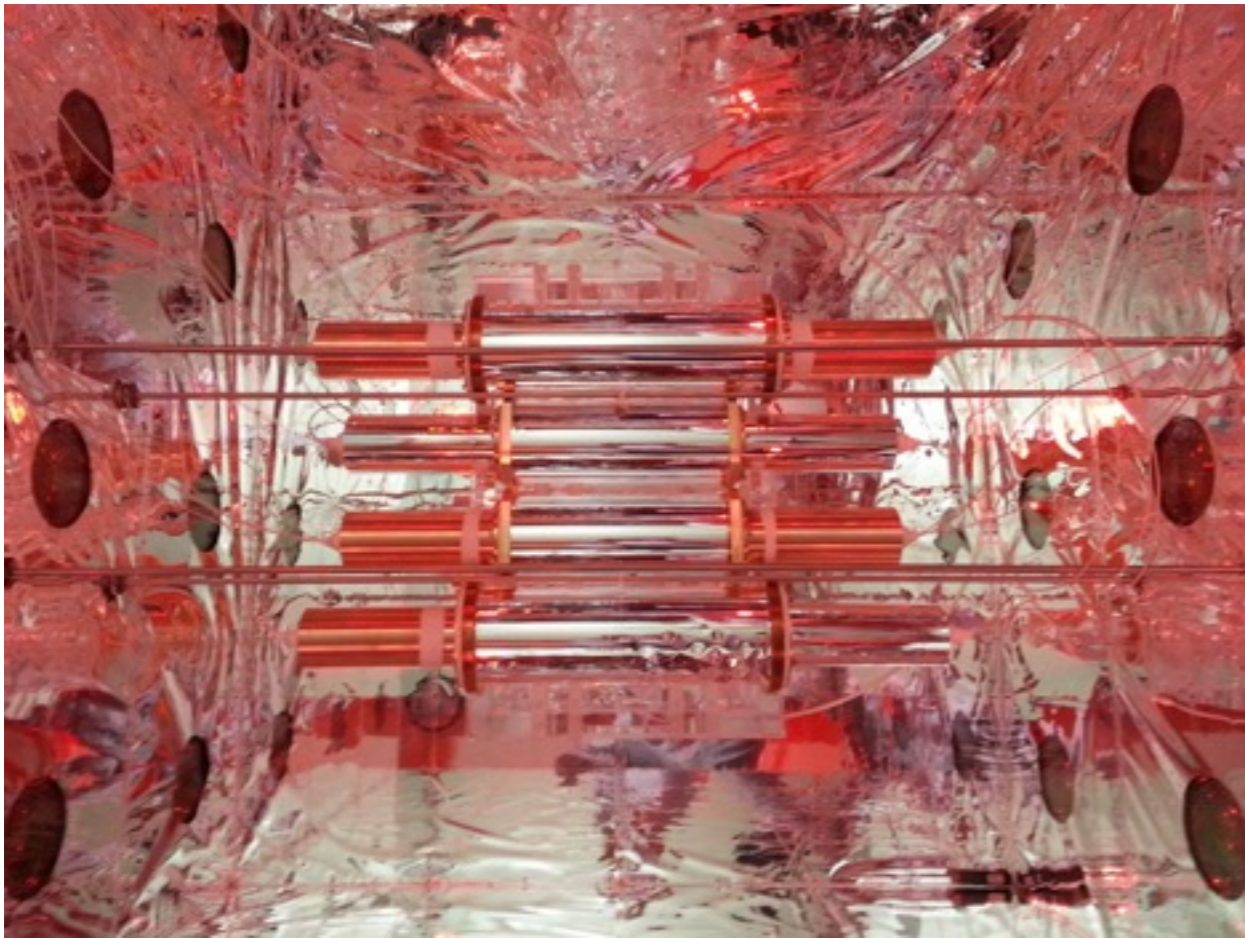
### *FADC500 readout*

- Flash ADC that stores waveforms.
- 500 MHz, 2.5V dynamic range, 12 bit resolution.
- Reads out 32 ch. from NaI(Tl) crystals & 4 ch. from neutron detectors.

### *ADC readout*

- 64 MHz and reads out signals from plastic and liquid scintillators.





**Chang Hyon Ha, Center for Underground Physics, IBS**

**ICHEP2016, Chicago, Aug. 3-10**



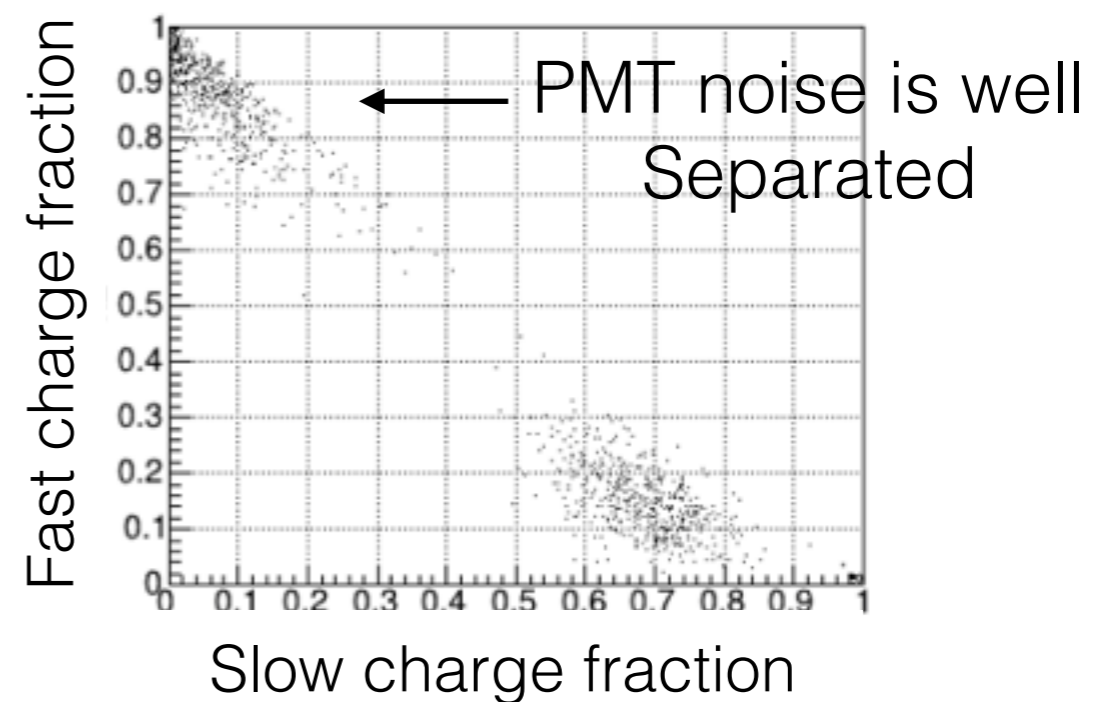
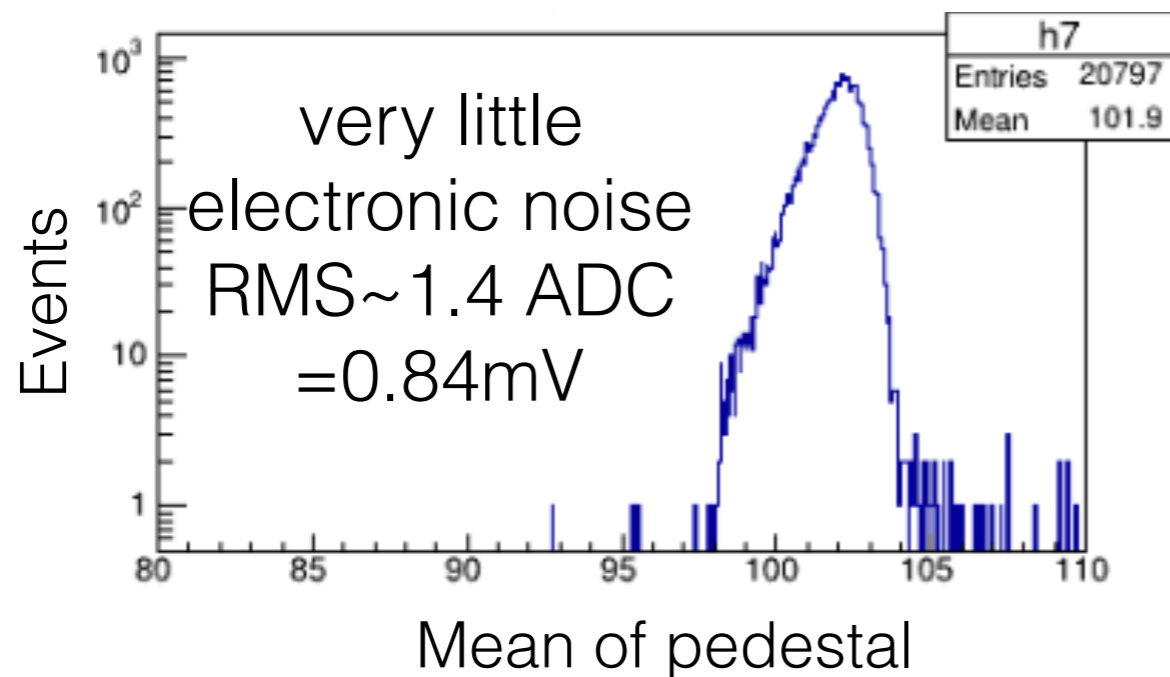
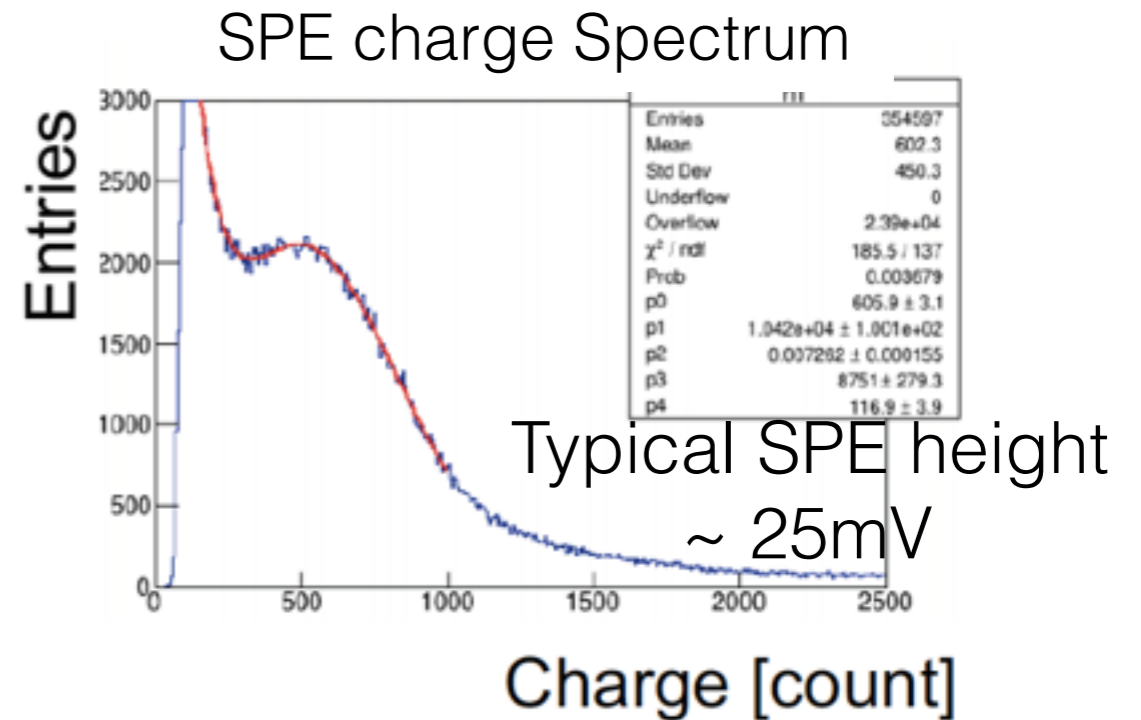
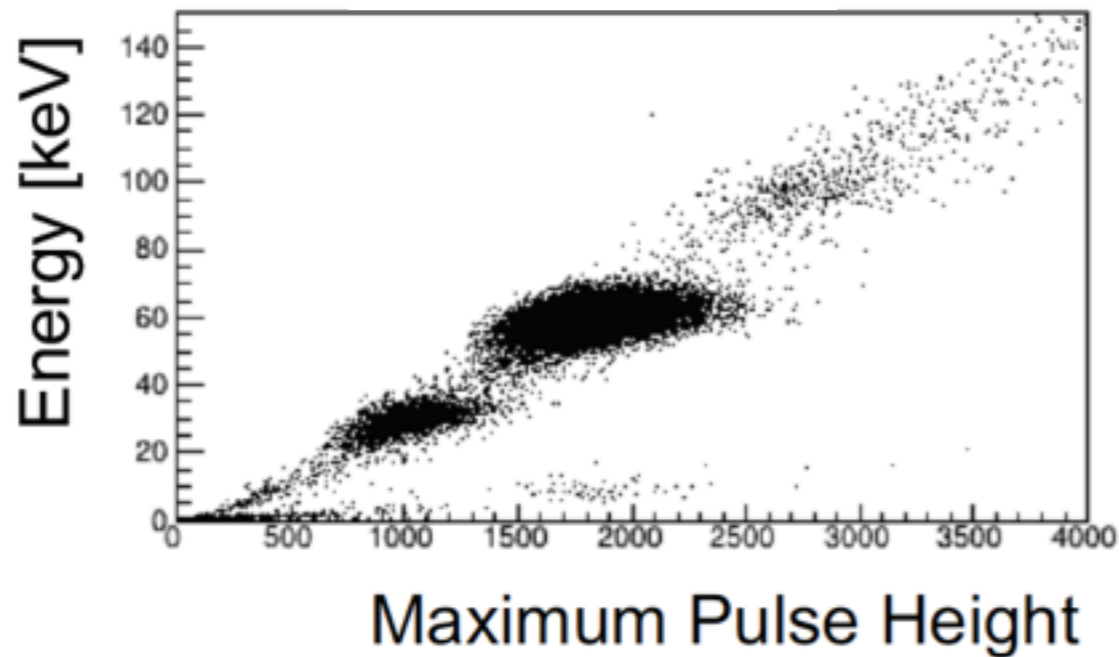
# Crystal installation for COSINE-100

AS3  
NaI-007 C4  
NaI-002 C3  
NaI-001 C2  
C1  
AS1 C5  
NaI-011 C6  
AS2 C8  
NaI-012 C7



# Calibration Campaign

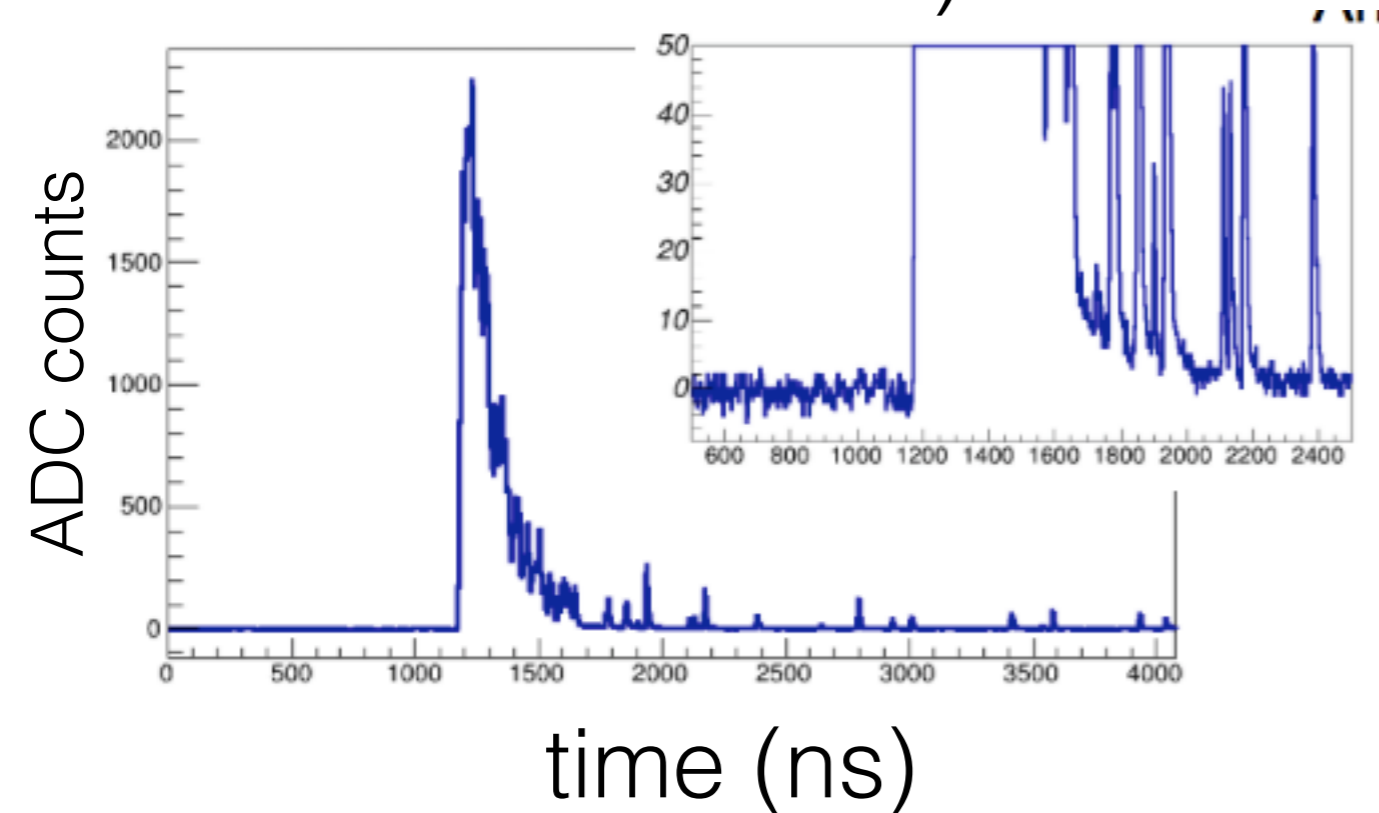
- Am-241 source (60 keV gamma) data to calibrate all PMTs
- Average light yield per crystal is  $\sim 15$  p.e./keV



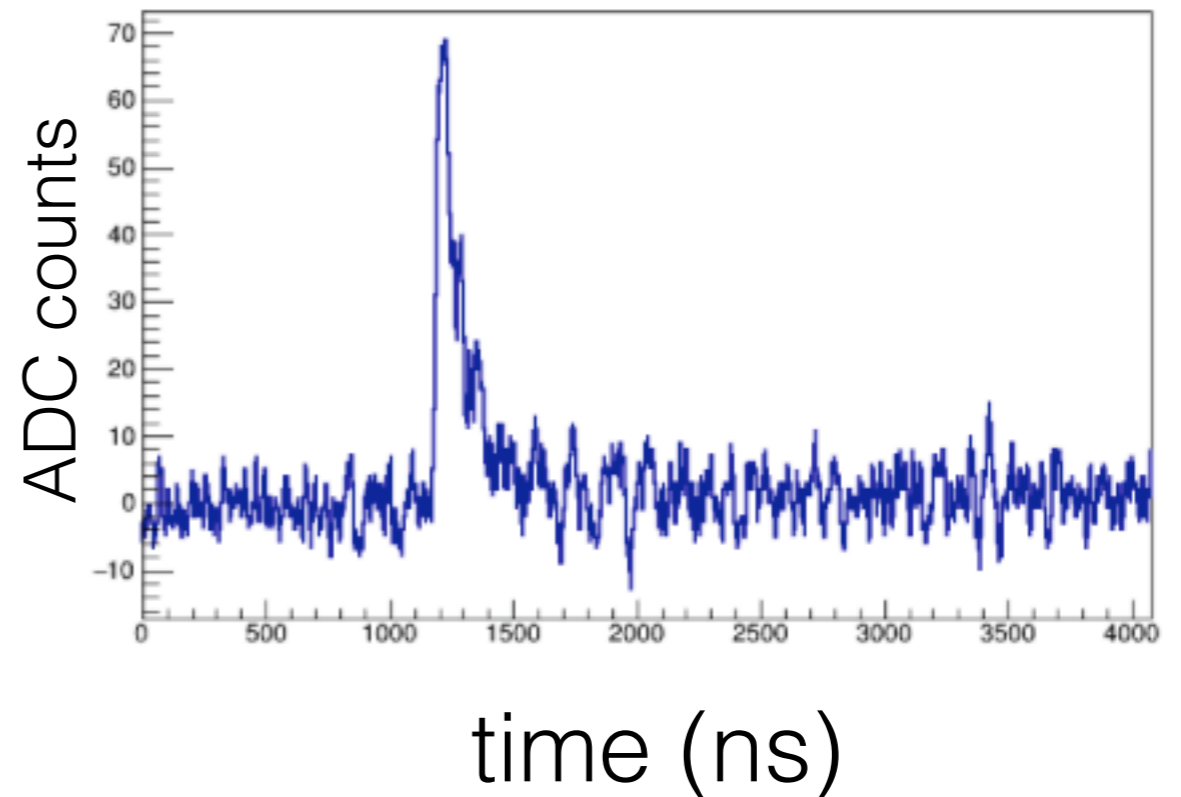


# PMT Waveforms

Anode Waveform (Low E  
0-120 keV)



Dynode Waveform (High E  
50-10000 keV)



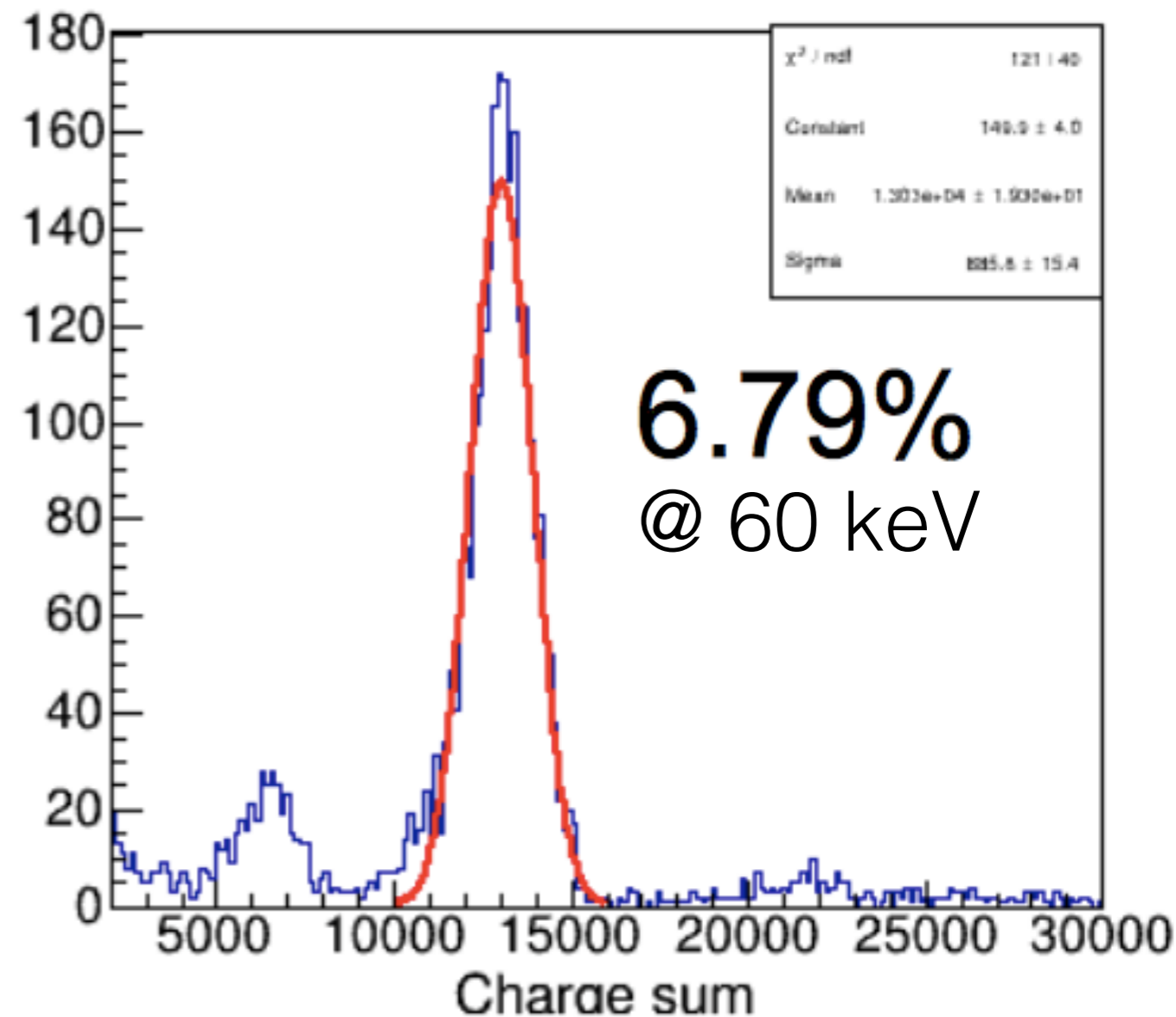
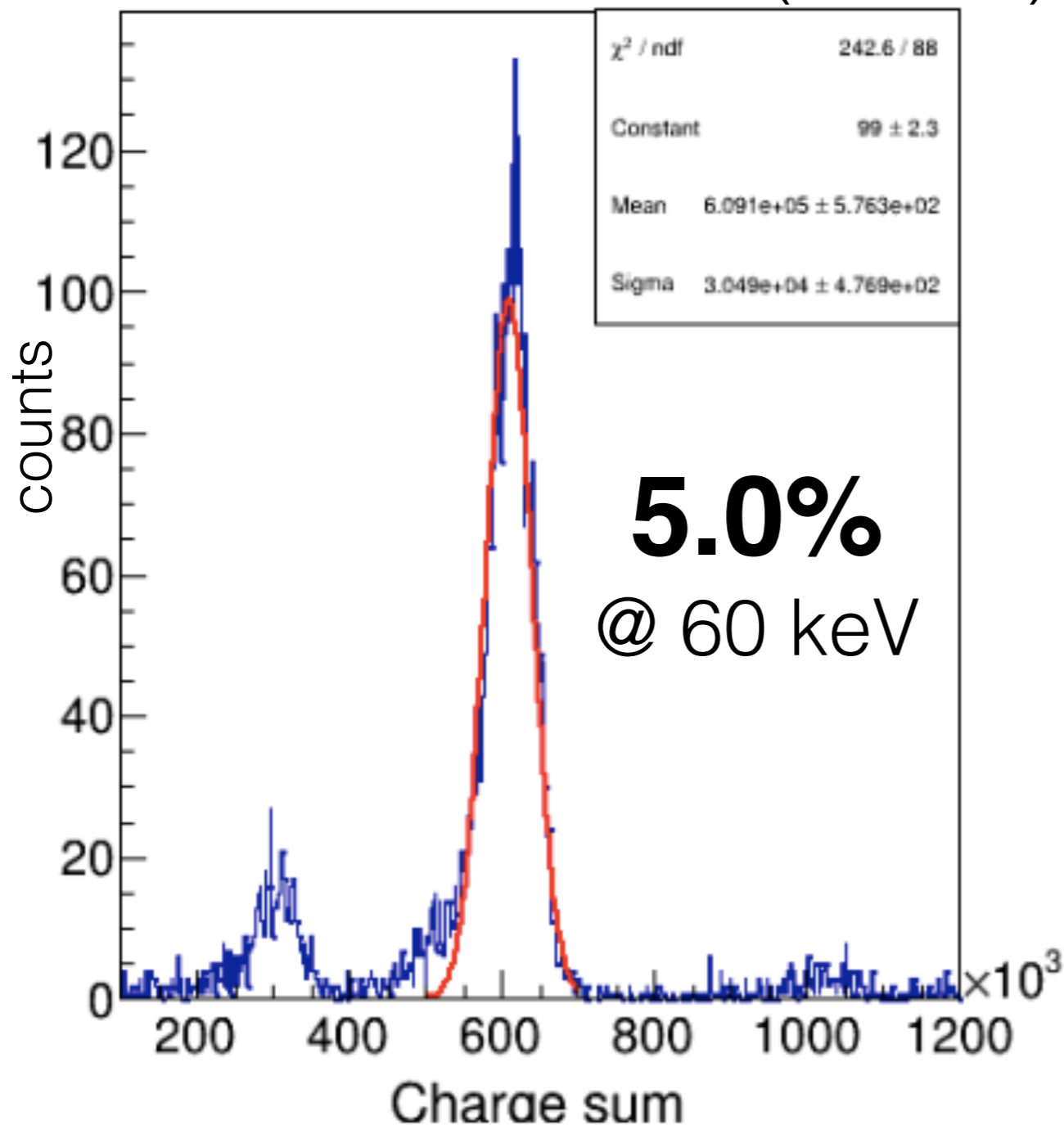
The same signal read out from Anode and Dynode.  
For 60 keV gammas from Am-241, 1.2 V height signal is recorded in Anode while 40 mV height signal in Dynode.



# Resolution

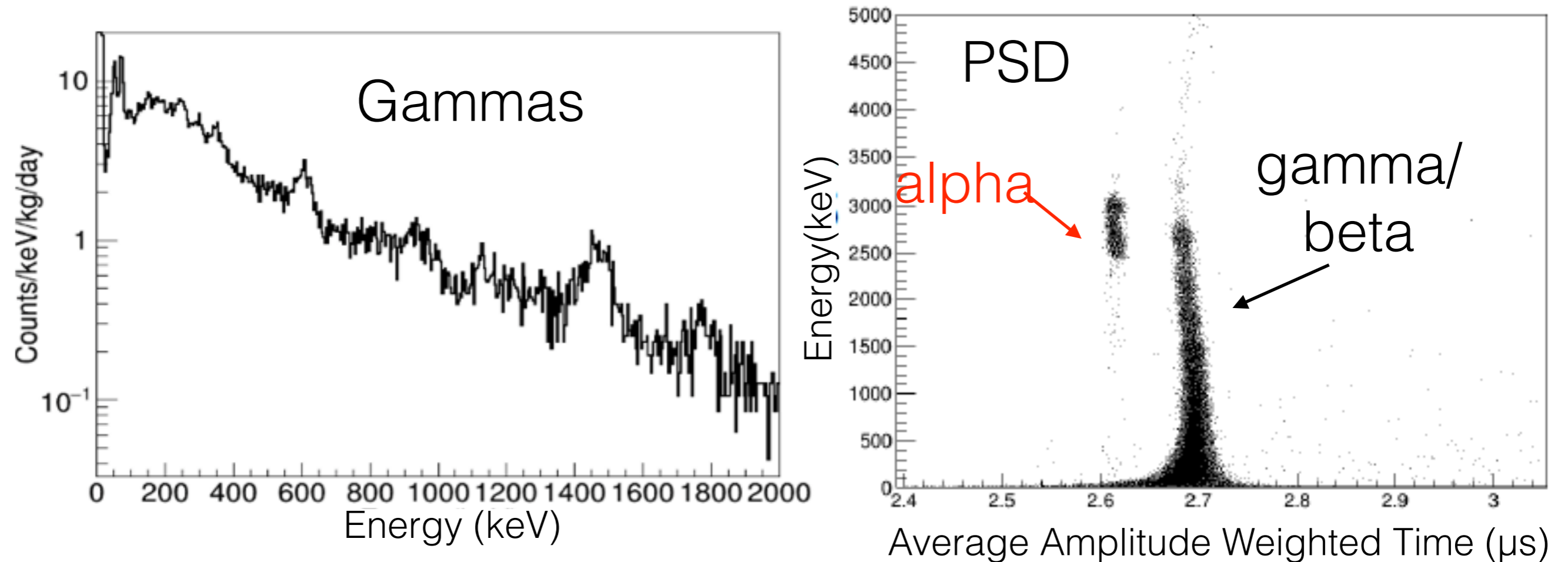
Am-241 ADC sum (Anode)

Am-241 ADC sum (Dynode)





# Initial Performance (High Energies)

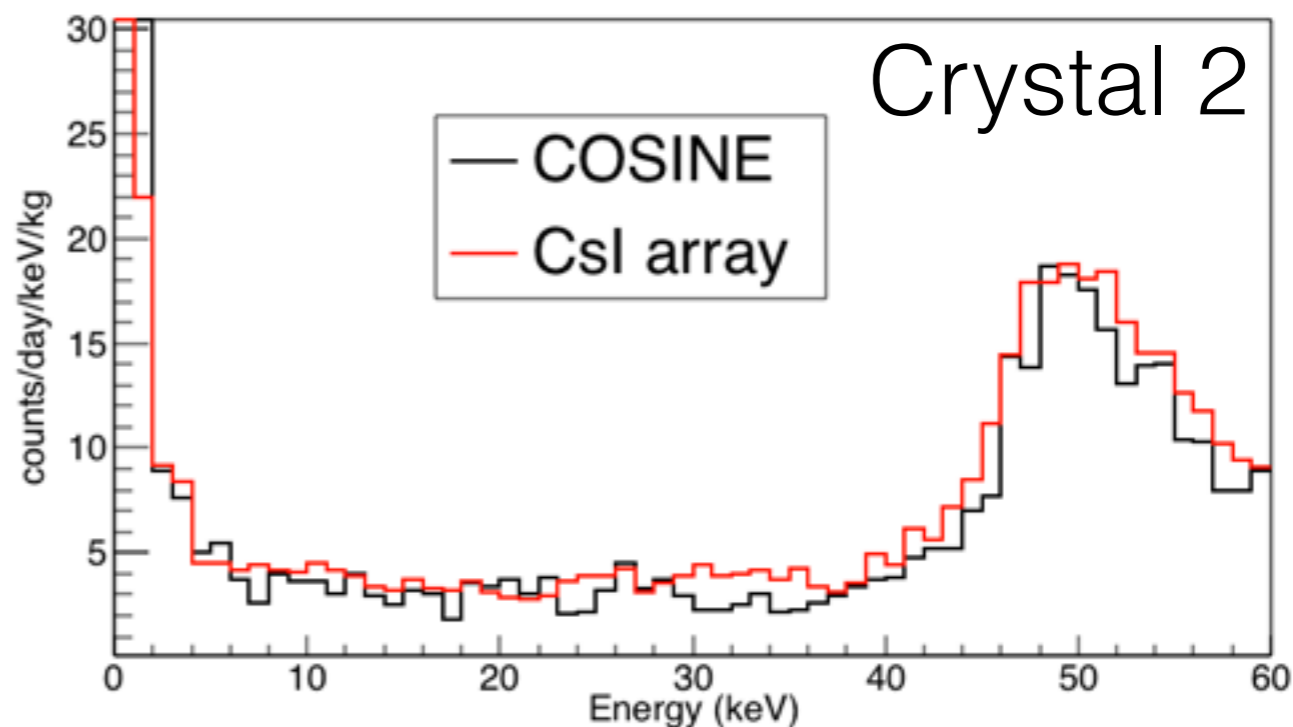
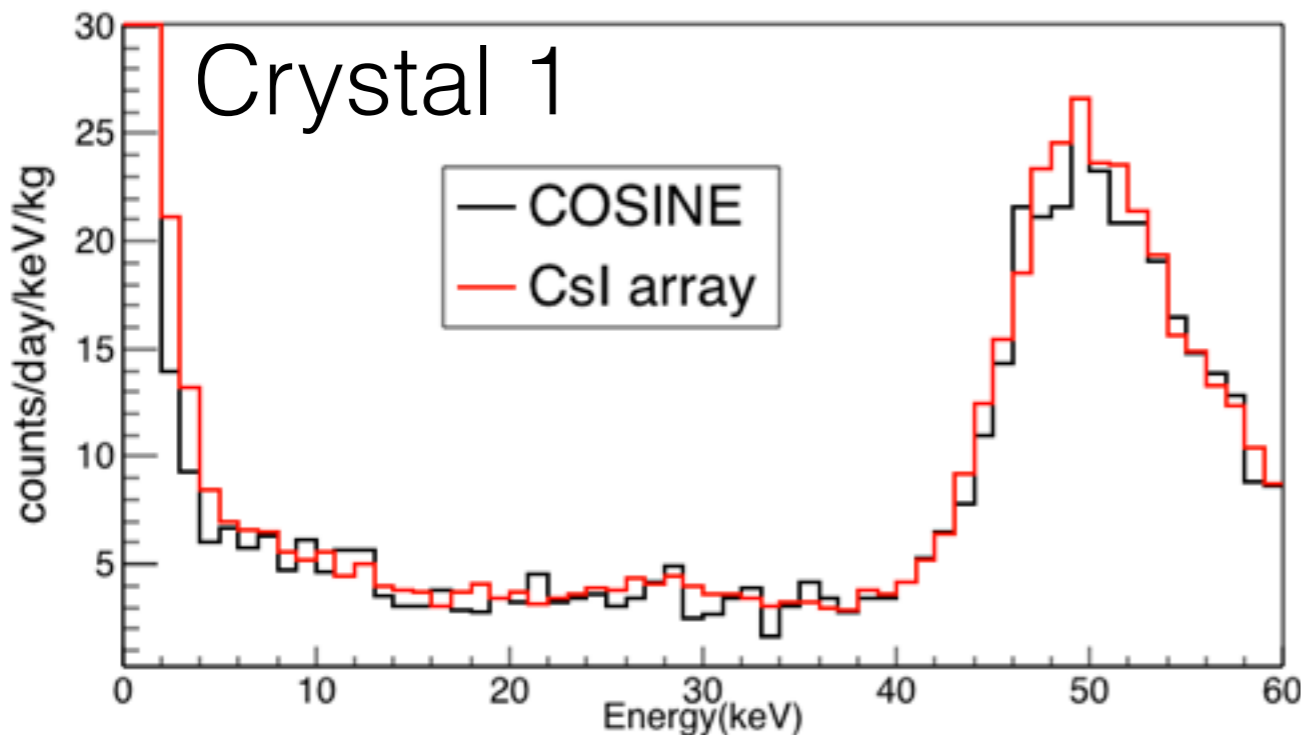


PSD for gamma and alpha performs very well.  
Dynamic range for high energy signals more than 5 MeV



# Initial Performance (Low Energies)

Spectrum comparison between at COSINE-100 and at KIMS-CsI



These are all events with no selection

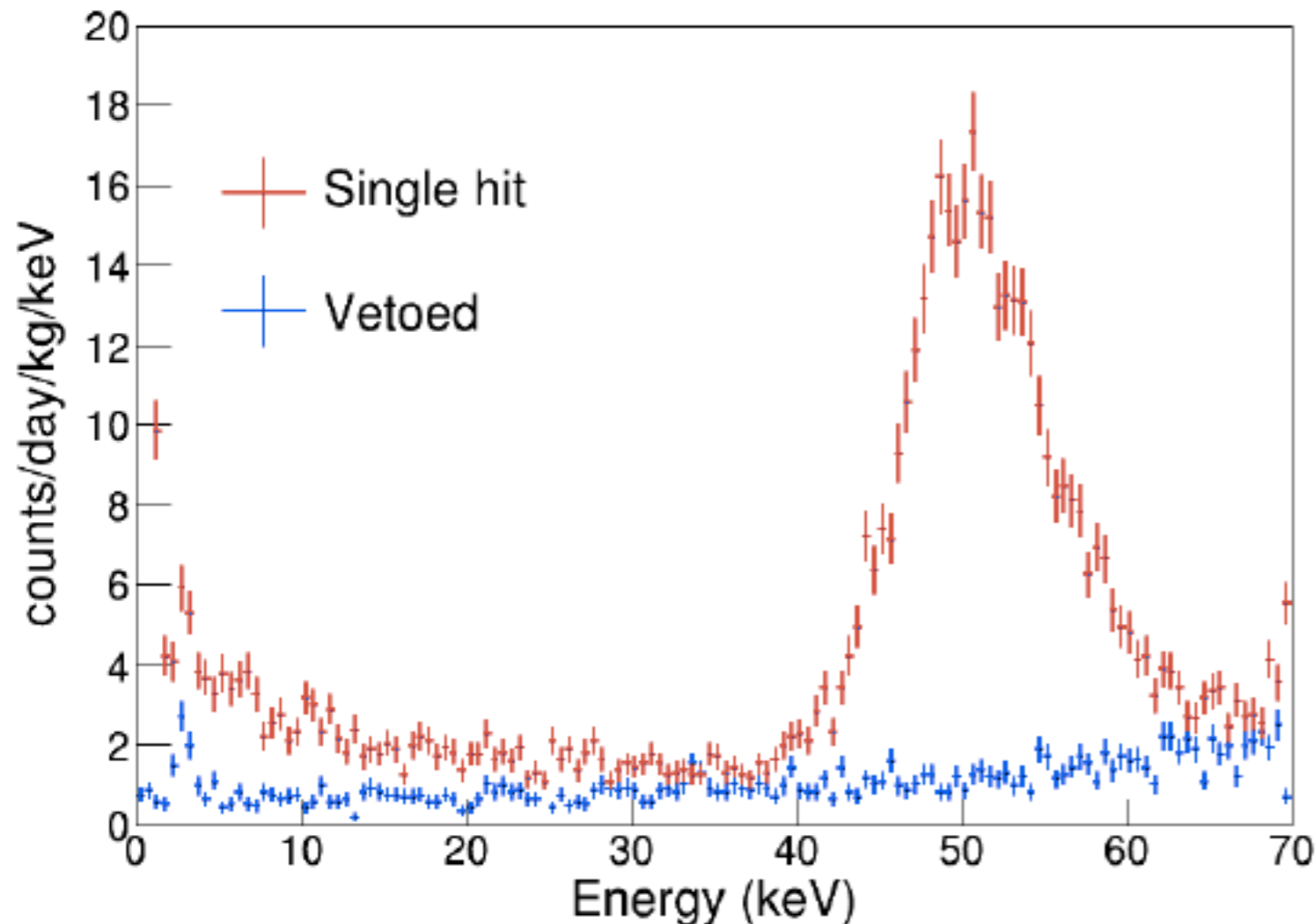
Low energy background level is as expected.

Compared to the measurement in the KIMS-CsI array, external background seems to be slightly reduced.

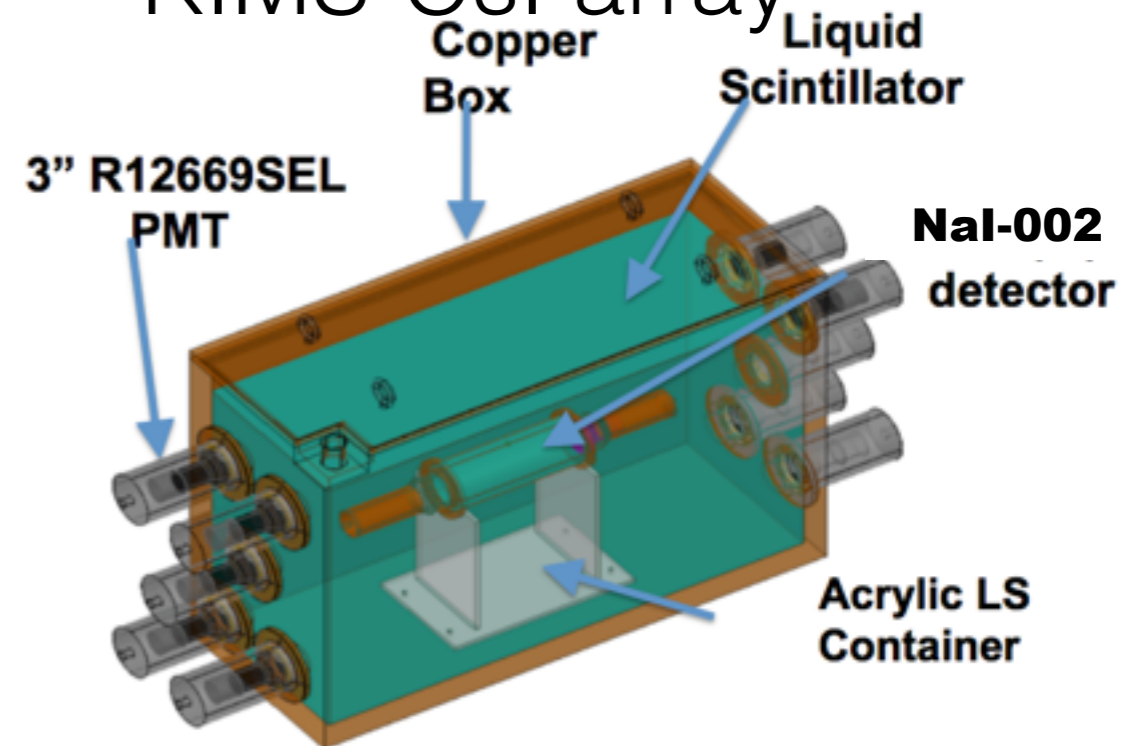
With liquid scintillator filled and analysis cuts, additional background reduction is expected.



# More Background Reduction -Liquid Scintillator Veto test setup



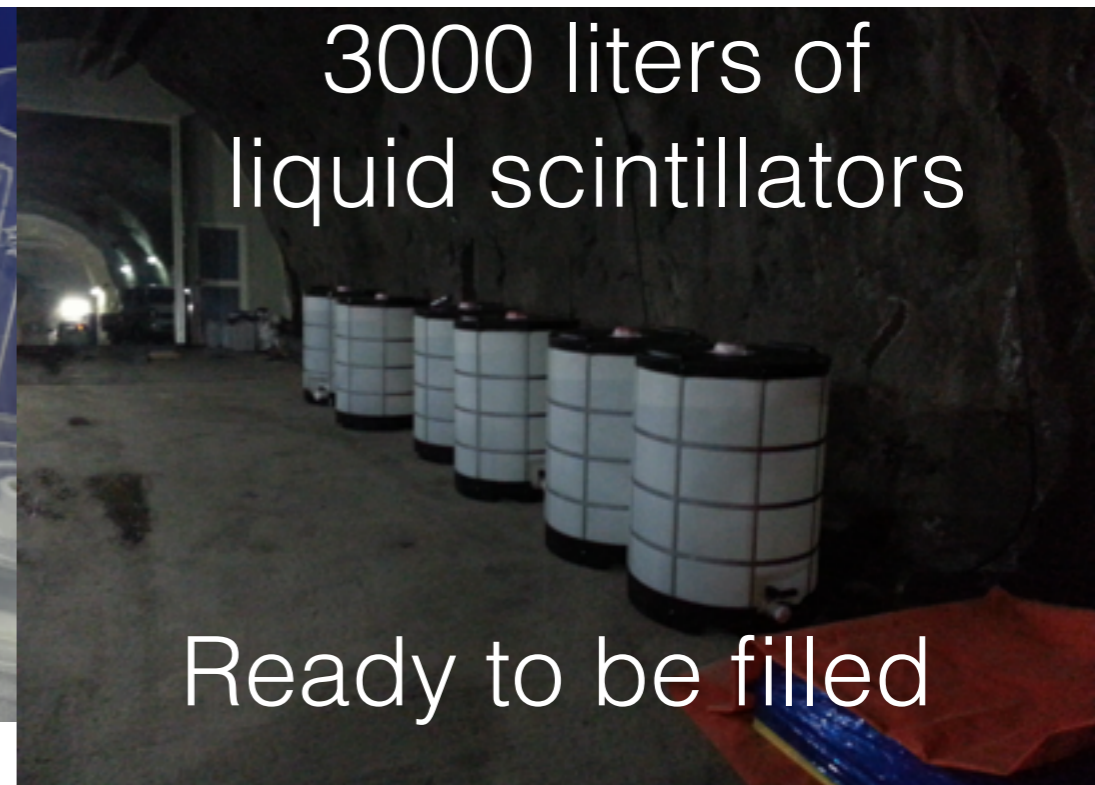
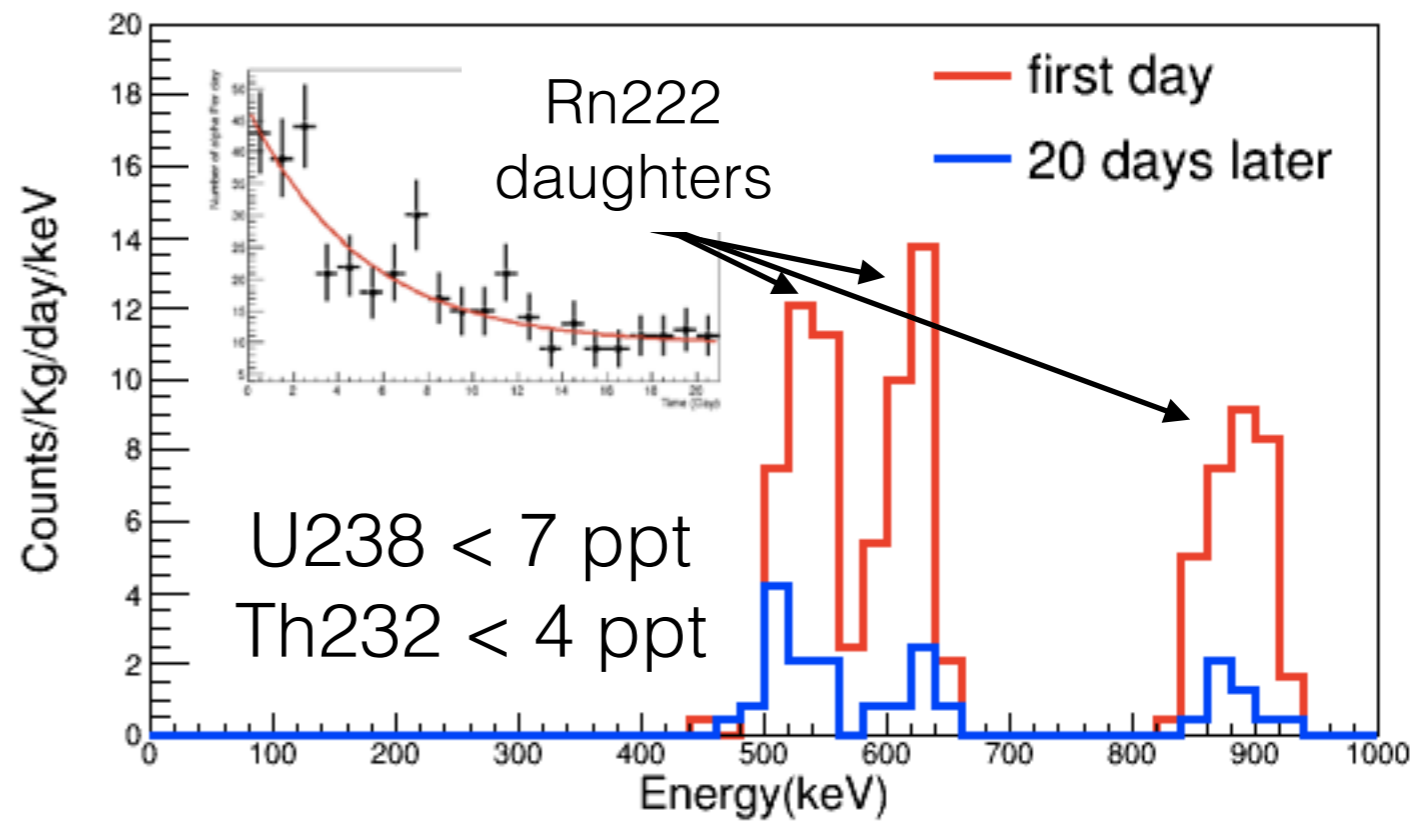
Prototype next to the  
KIMS-CsI array



With the Prototype LS system, 27% of low energy events at 2-4 keV are tagged.  
In the COSINE-100 LS system, the LS thickness is 40-50cm.  
Additional tagging for U/Th/K is expected.

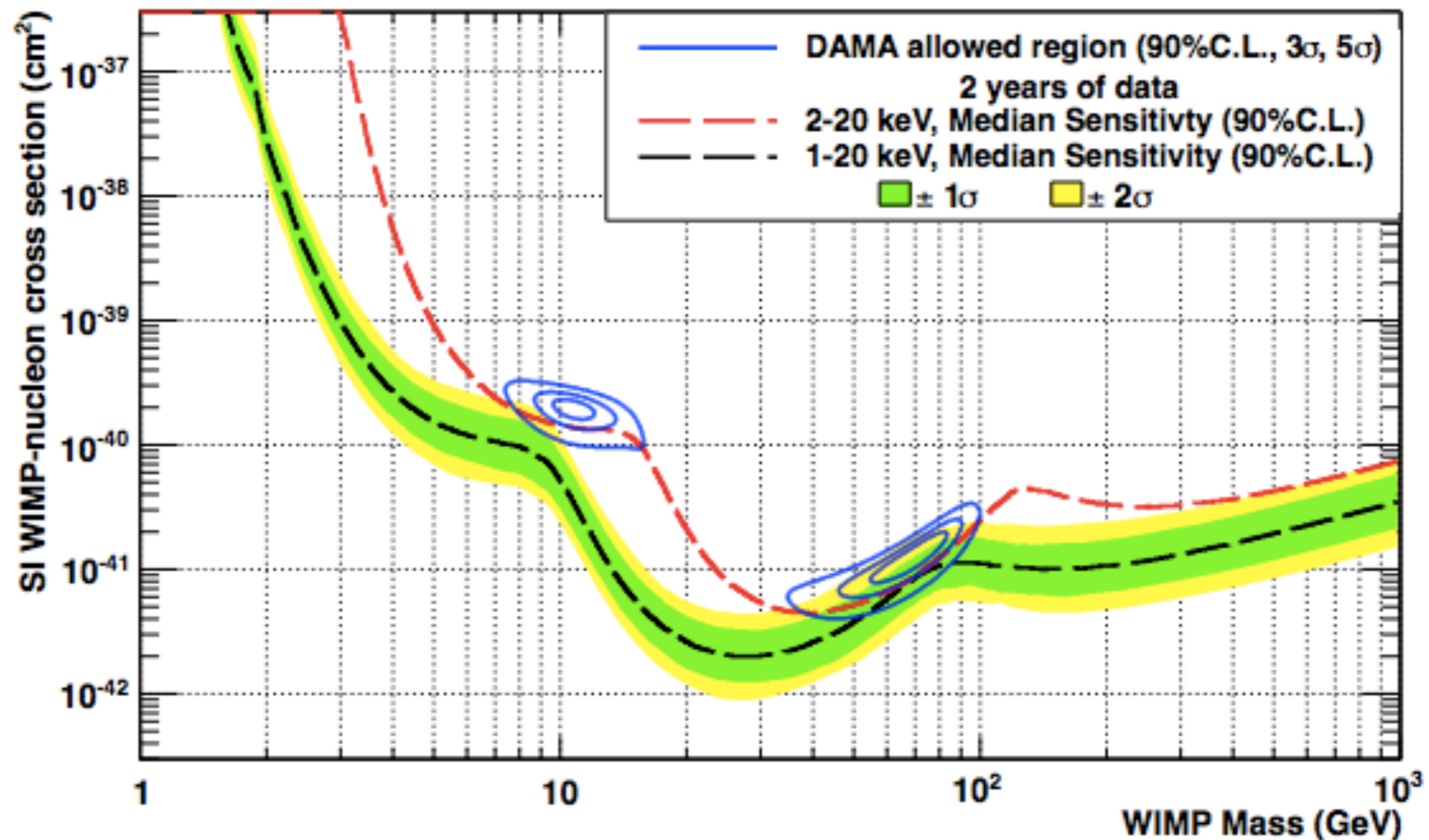
# Liquid Scintillator for COSINE-100 is ready

Linear alkylbenzene (LAB) :  
Good optical/radioactive properties  
2,5-Diphenyloxazole (PPO) :  
fluor, scintillator/wavelength shifter  
p-bis-(o-methylstyryl)-benzene (bis-MSB) : wavelength shifter





# Expected Sensitivity for COSINE-100



*\*Assumed 2 dru or 4 dru flat backgrounds depending on crystals.*

The sensitivity should be comparable with the DAMA allowed region.

# Conclusion & Outlook

- KIMS and DM-Ice under the name of the **COSINE** collaboration work together to search for nuclear recoils by Weakly Interacting Massive Particle in the NaI(Tl) crystals.
- At the Yangyang underground laboratory in Korea, COSINE is poised to confirm or dispute the DAMA's modulation signal.
- NaI(Tl) crystals are evaluated at Y2L and installed for COSINE-100
- Various R&D programs identified background reduction methods for ultra-pure crystal production.
- The background level is expected to reach better than 2 dru at around 6 keV.
- We will fill LS in a couple of weeks and COSINE-100 will start the physics run soon.
- Posters : #522 (Quenching, H. Ju), #1525 (DM-Ice, J. Jo)