

Detector Stability of COSINE-100

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IDM 2018

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Providence, RI



Yale

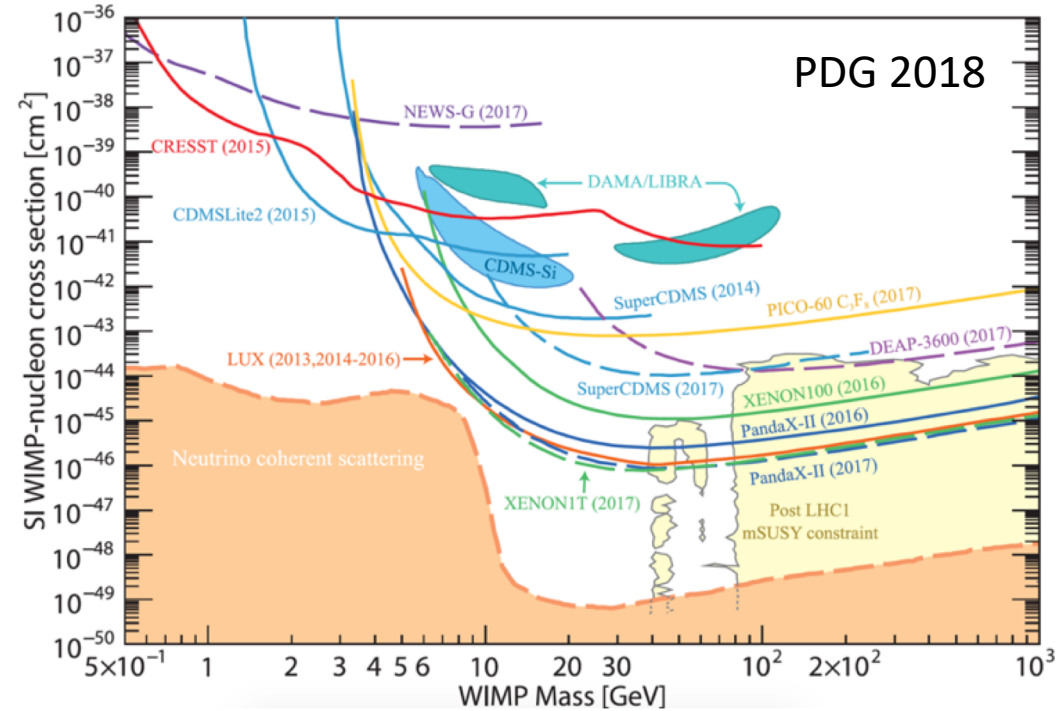
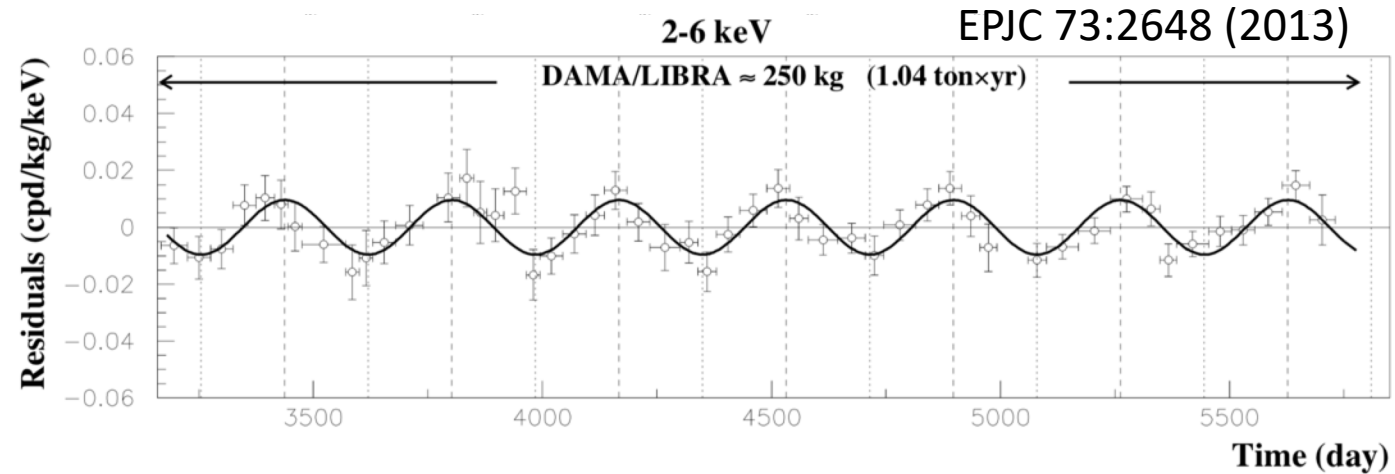


Wright
Laboratory

Motivation for COSINE-100

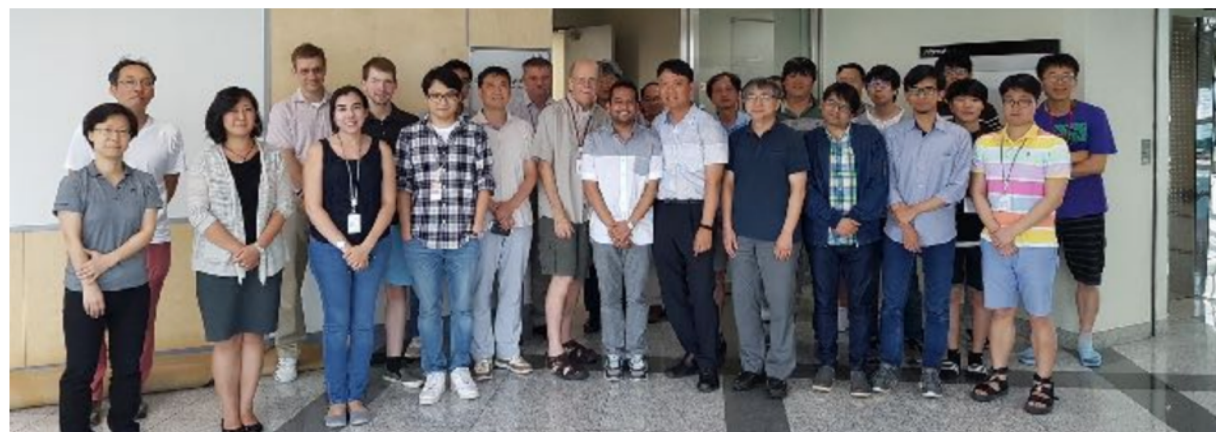
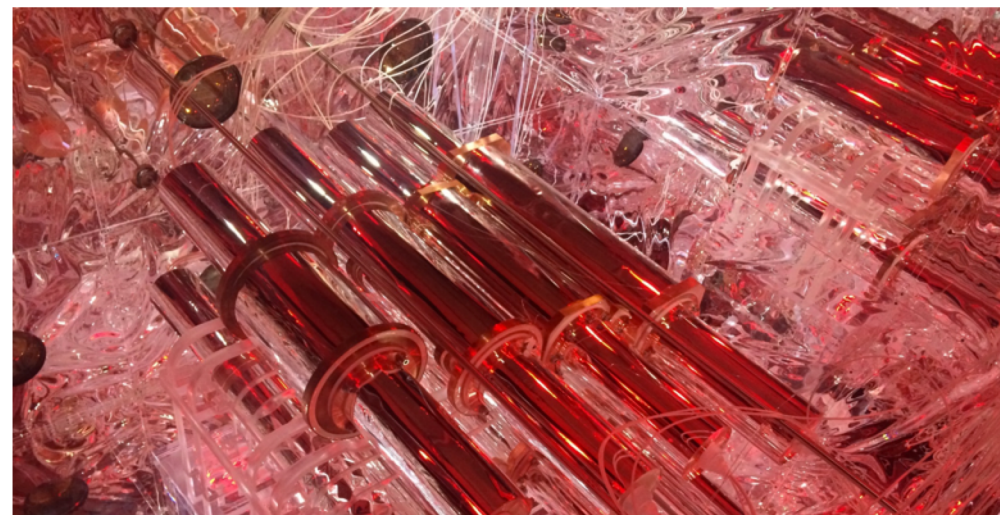


- **Goal: Test DAMA's claim of dark matter detection**
- DAMA observes annual modulation at 9.3σ C.L.
 - Phase & period consistent with dark matter origin
 - Total exposure: 1.33 ton·yr over 14 annual cycles
- But, result in conflict with direct detection searches using different target material



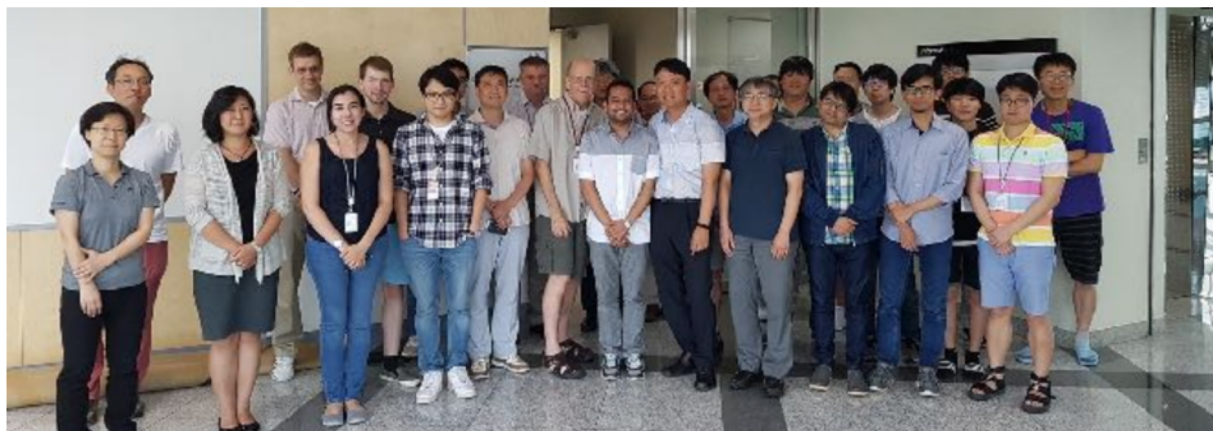
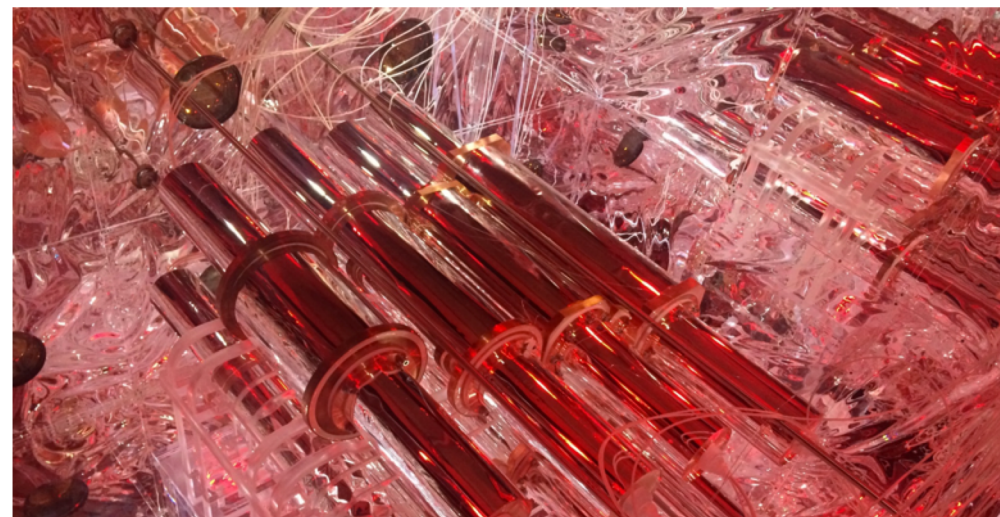
The COSINE-100 Experiment

- Model-independent test of DAMA's result
- 106 kg of same target material (NaI(Tl))
- Located 700 m underground at Yangyang Underground Lab in Korea
- Physics run began Sept. 2016



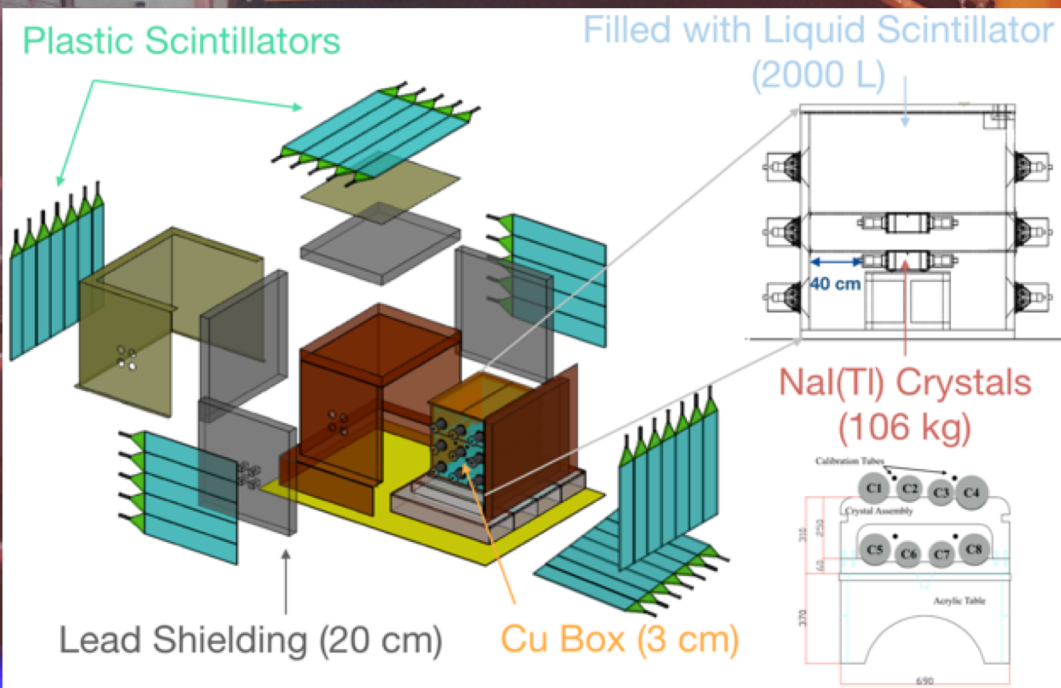
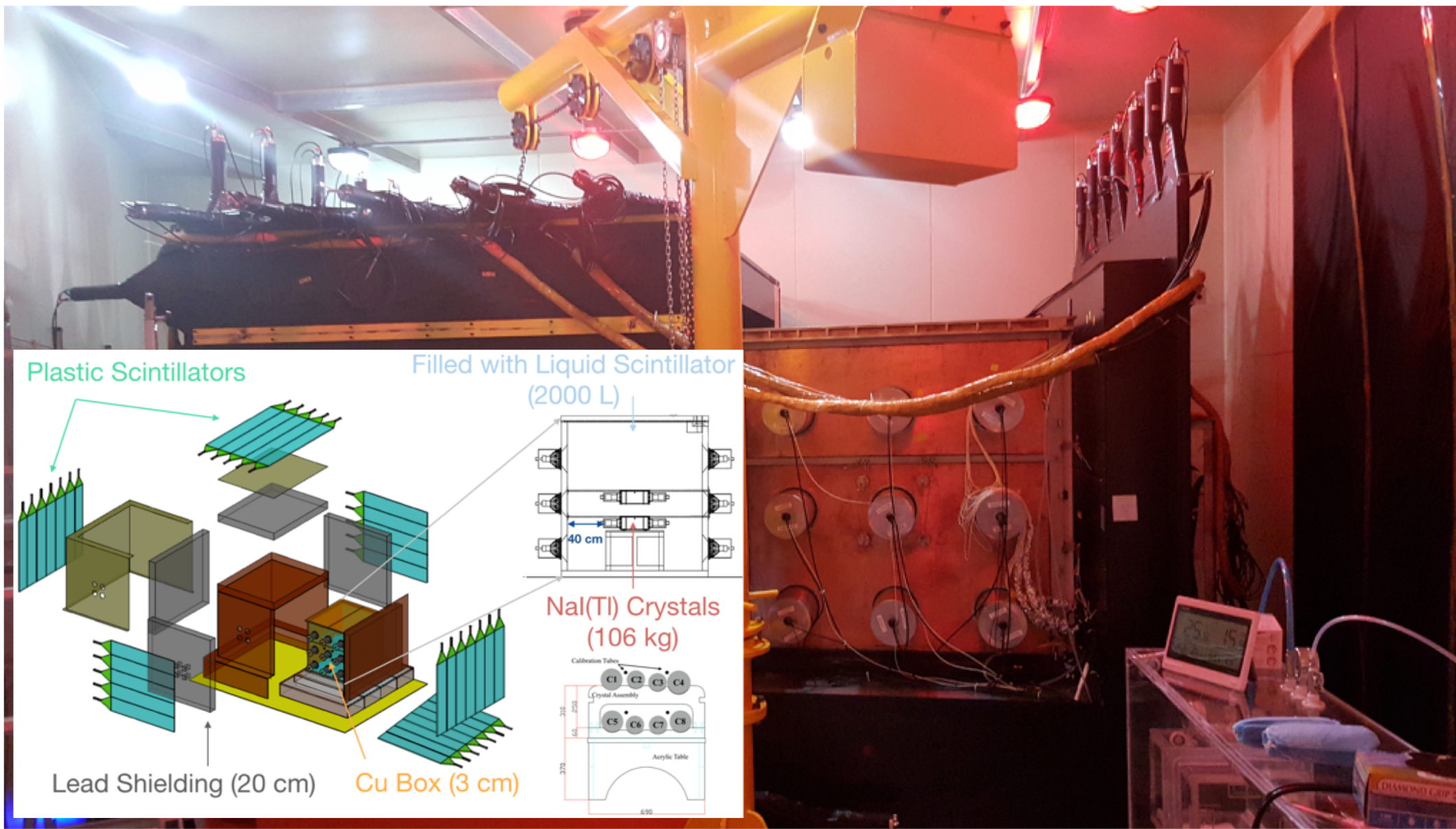
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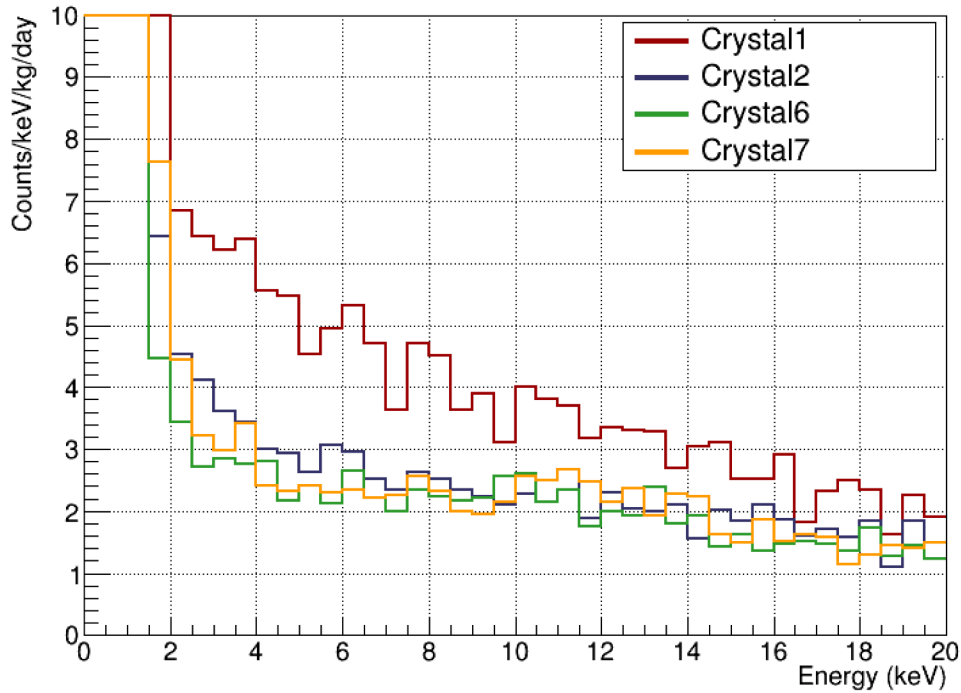


Also see Jay Hyun Jo and Estella Barbosa de Souza's talks on Friday!

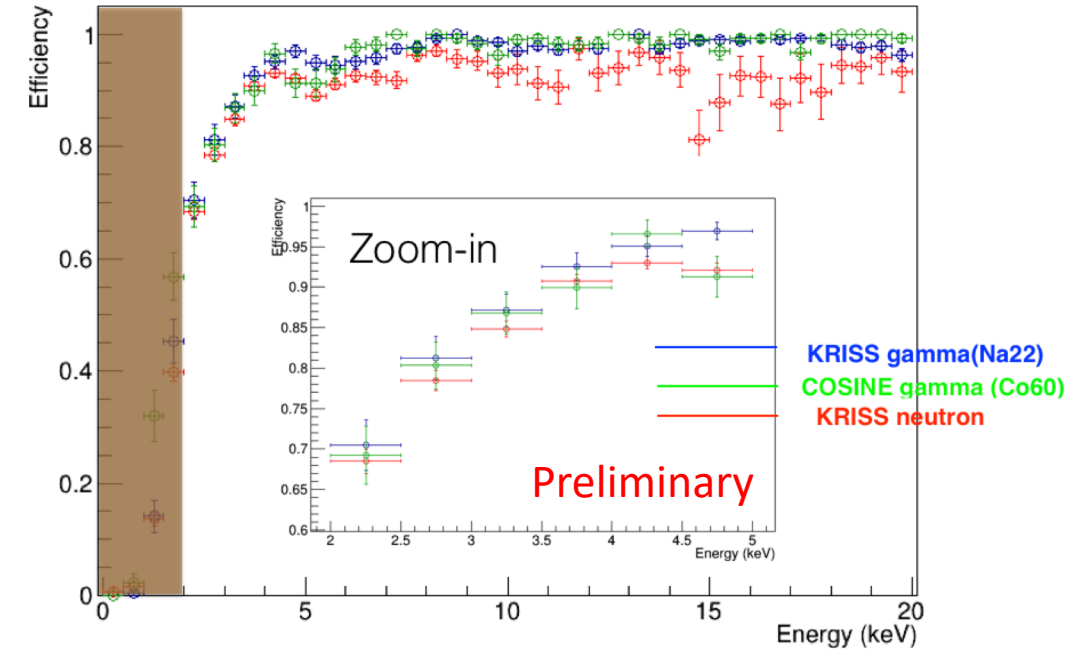
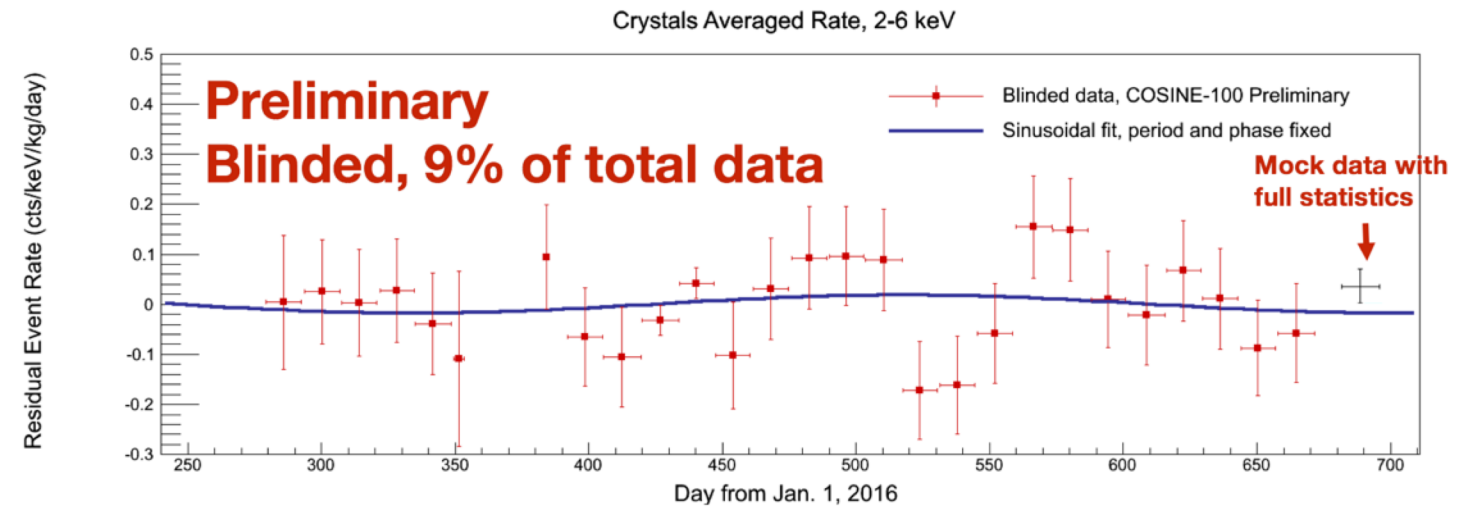
The COSINE-100 Detector



Preview COSINE-100 Analysis



- 2-4 counts/keV/kg/day in region of interest
- Data in 2-6 keV region blinded; 9% of total data



Other Modulation Sources?

- Alternative sources of modulation have been proposed
 - DAMA has addressed some of these

Source	Main comment	Cautious upper limit (90%C.L.)
RADON	Sealed Cu box in HP Nitrogen atmosphere, 3-level of sealing, etc.	$<2.5 \times 10^{-6}$ cpd/kg/keV
TEMPERATURE	Installation is air conditioned+ detectors in Cu housings directly in contact with multi-ton shield → huge heat capacity + T continuously recorded	$<10^{-4}$ cpd/kg/keV
NOISE	Effective full noise rejection near threshold	$<10^{-4}$ cpd/kg/keV
ENERGY SCALE	Routine + intrinsic calibrations	$<1-2 \times 10^{-4}$ cpd/kg/keV
EFFICIENCIES	Regularly measured by dedicated calibrations	$<10^{-4}$ cpd/kg/keV
BACKGROUND	No modulation above 6 keV; no modulation in the (2-6) keV <i>multiple-hits</i> events; this limit includes all possible sources of background	$<10^{-4}$ cpd/kg/keV
SIDE REACTIONS	Muon flux variation measured at LNGS	$<3 \times 10^{-5}$ cpd/kg/keV

Slide taken from DAMA/LIBRA

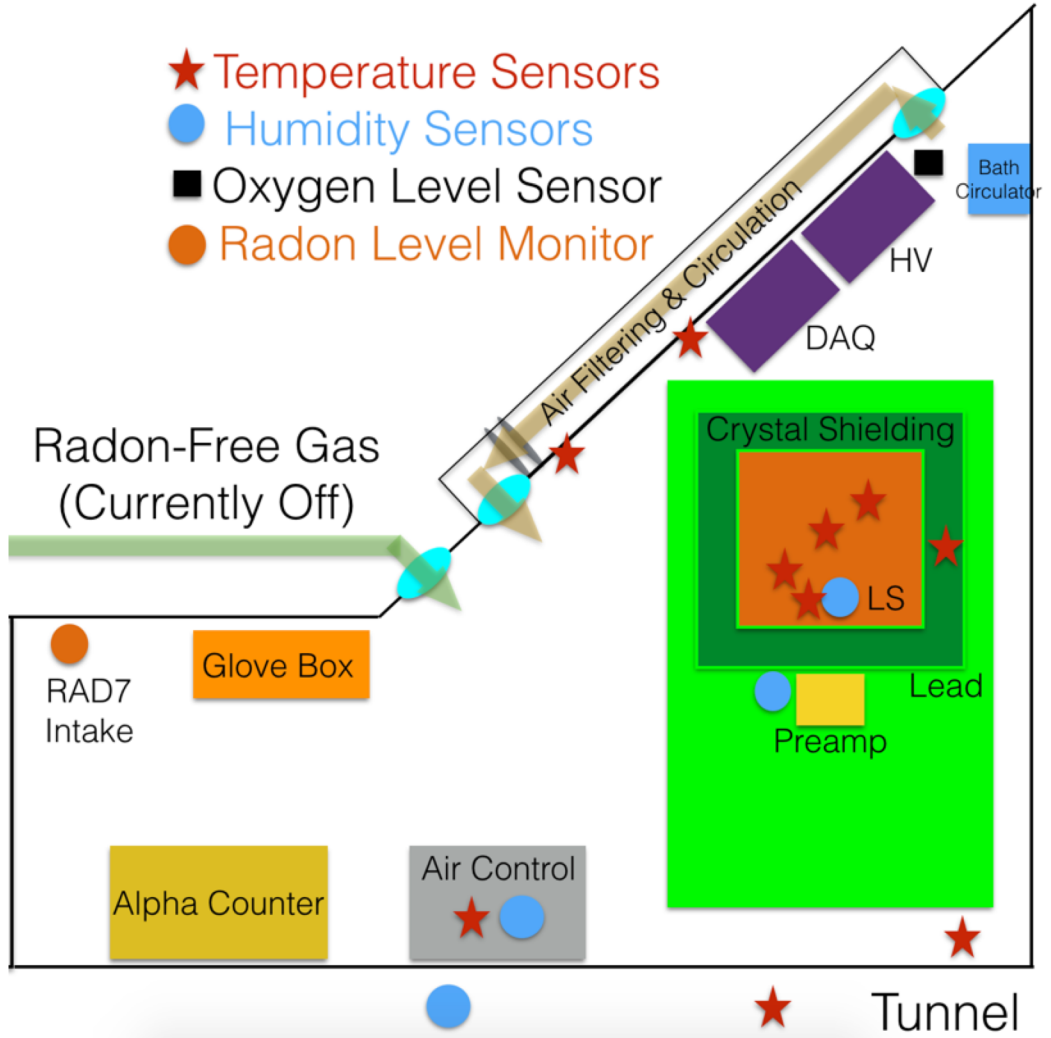
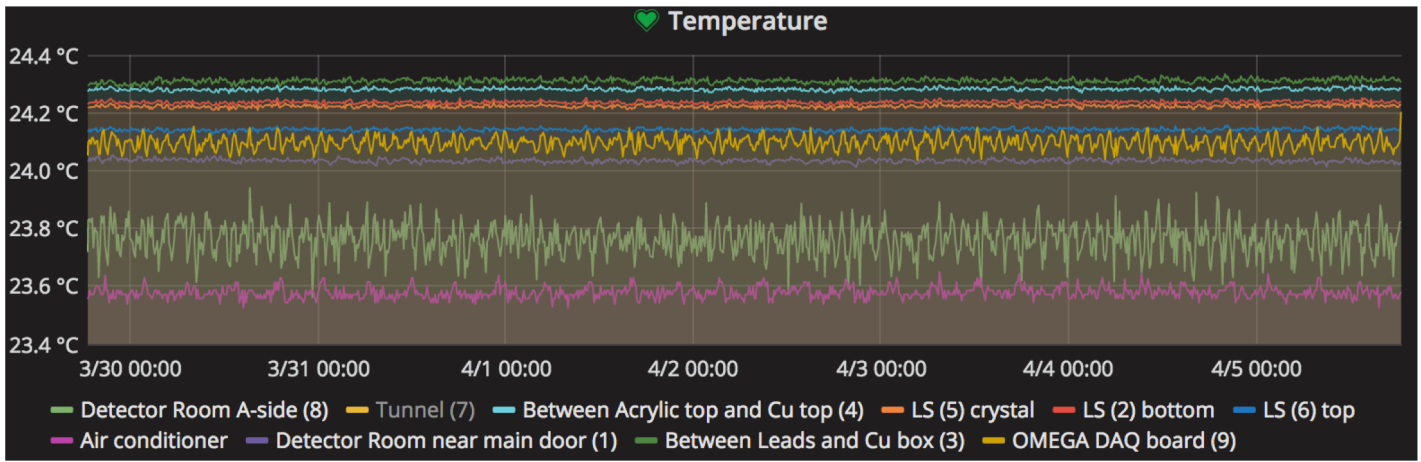
Further discussed in: EPJC 56:333 (2008), EPJC 72:2064 (2012), EPJC 74:3196 (2014)

- Must also be studied by COSINE!
 - Need thorough understanding of environmental conditions and detector stability over time

<https://agenda.infn.it/getFile.py/access?contribId=34&sessionId=1&resId=0&materialId=slides&confId=15474>

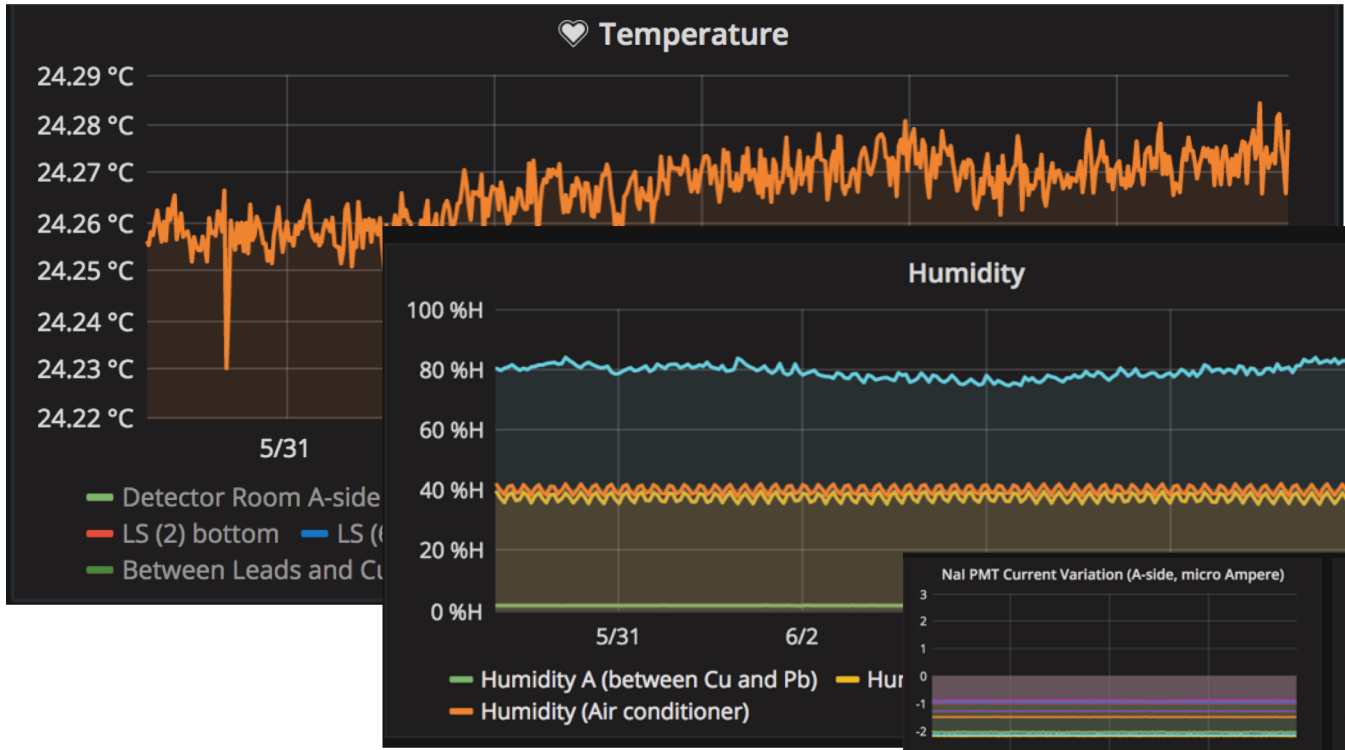
Environmental Monitoring System

- System monitors temperature, humidity, radon level, electronics, etc.
- Allows identification of correlations between event rates and environmental conditions
- Also used for real-time monitoring



Real-Time Monitoring

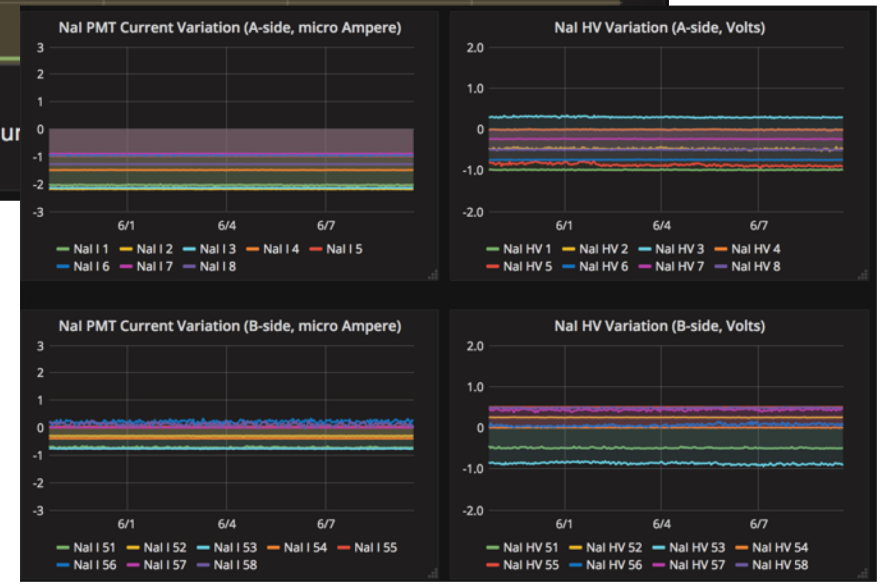
- Monitoring stability of temperature, humidity, current, voltage, etc.



Temperature

Humidity

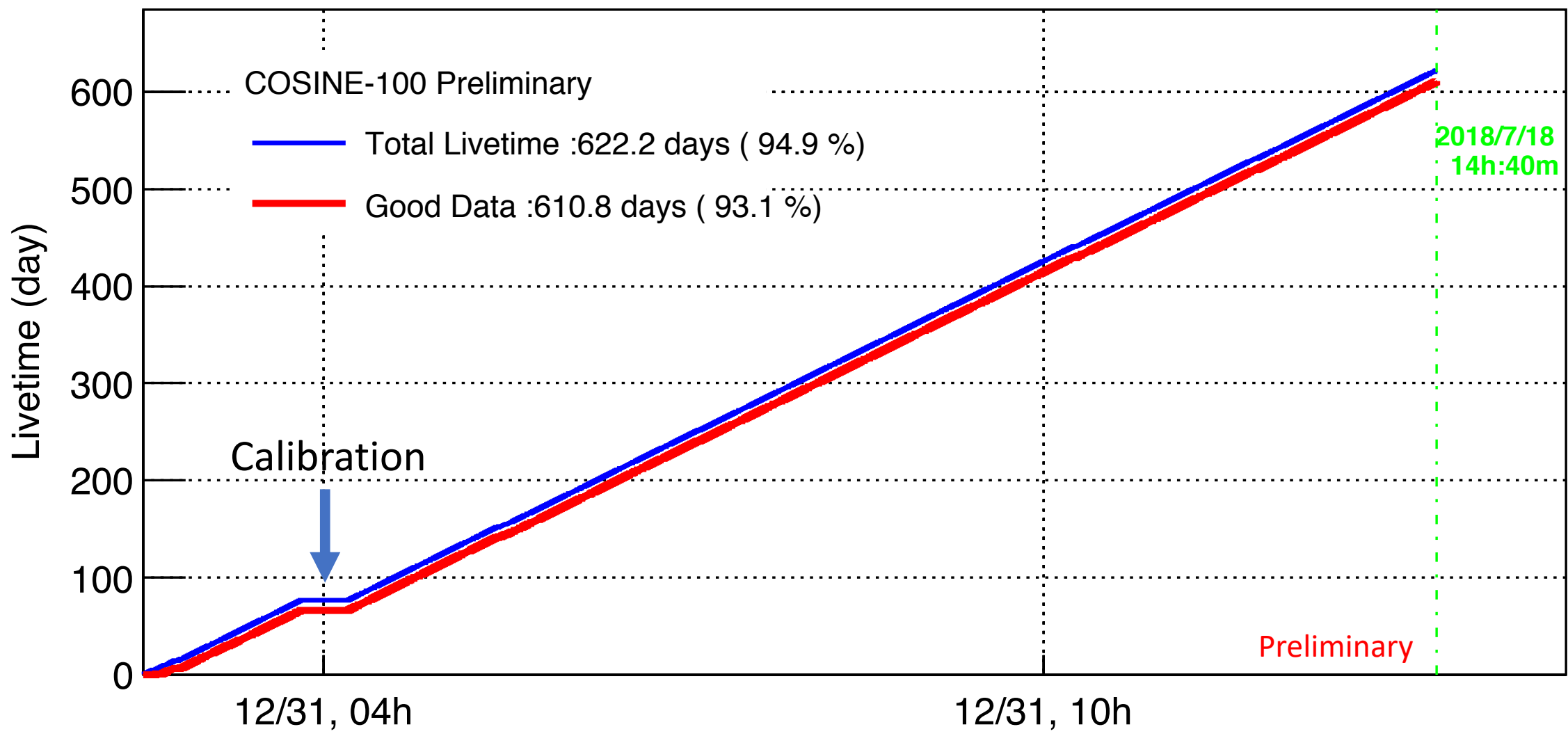
- < 0.5 °C temperature and $< 2\%$ humidity fluctuation inside the shielding structure
- Current and voltage of detectors very stable



Current/Voltage

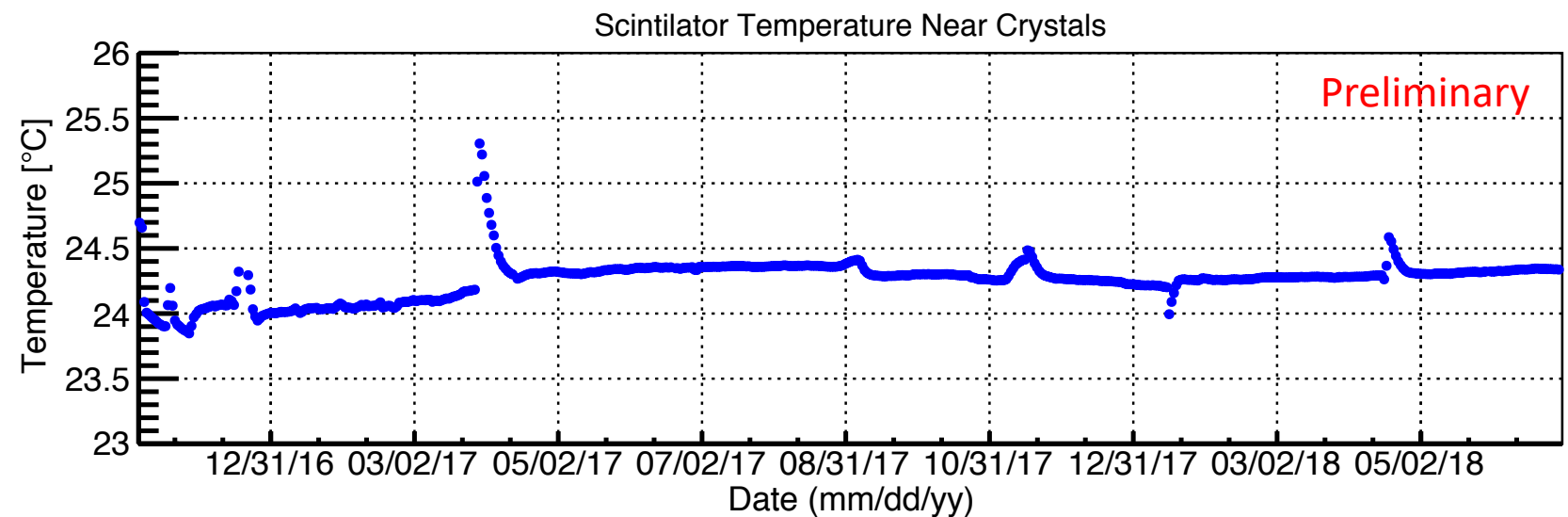
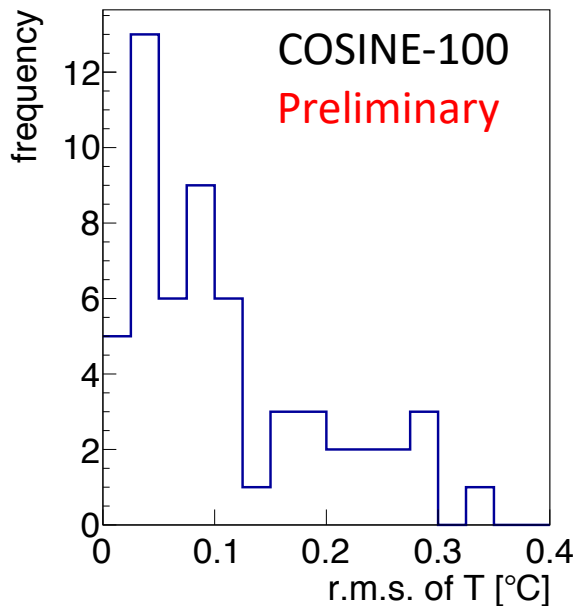
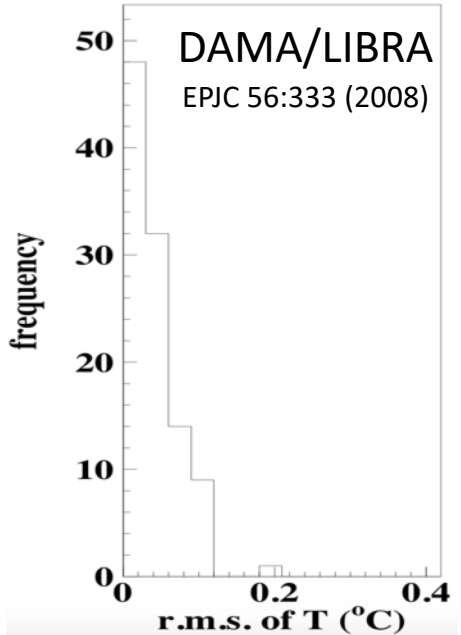
Detector Livetime

COSINE-100 Accumulated Data



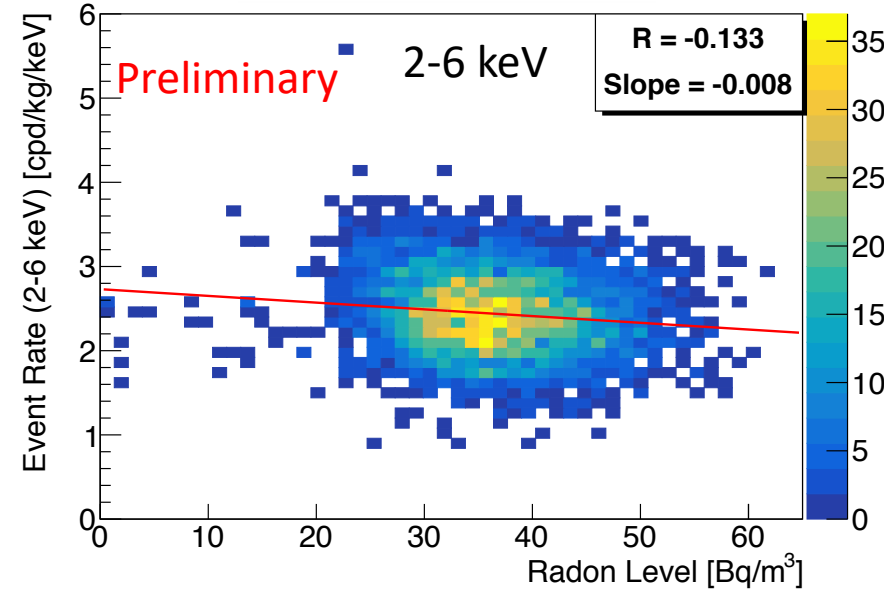
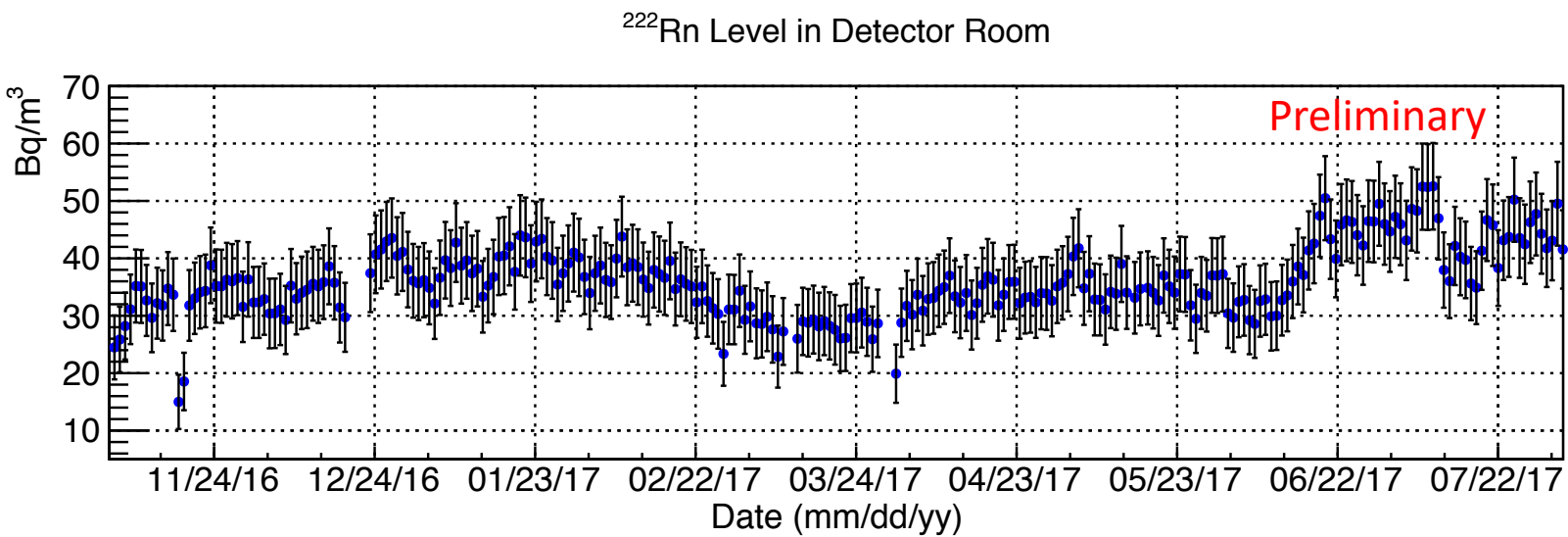
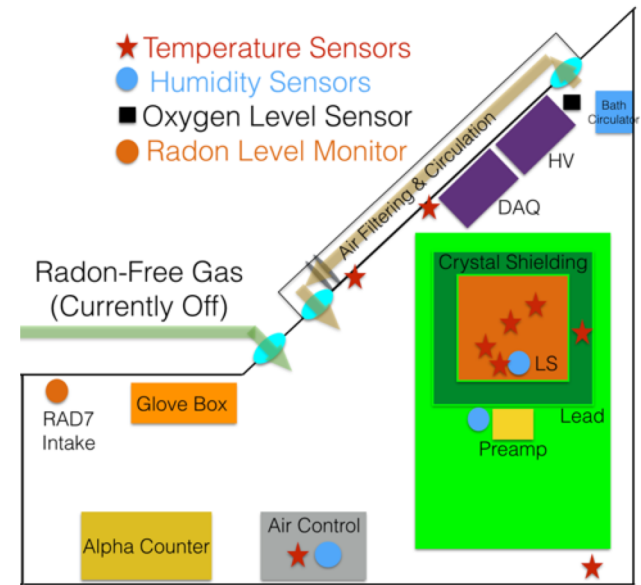
Temperature and Event Rate

- Mean RMS variation: 0.120 °C
- Induces fluctuations of $\lesssim 10^{-4}$ cpd/kg/keV using DAMA-assumed change in light yield of $\lesssim -0.2\%/^{\circ}\text{C}$



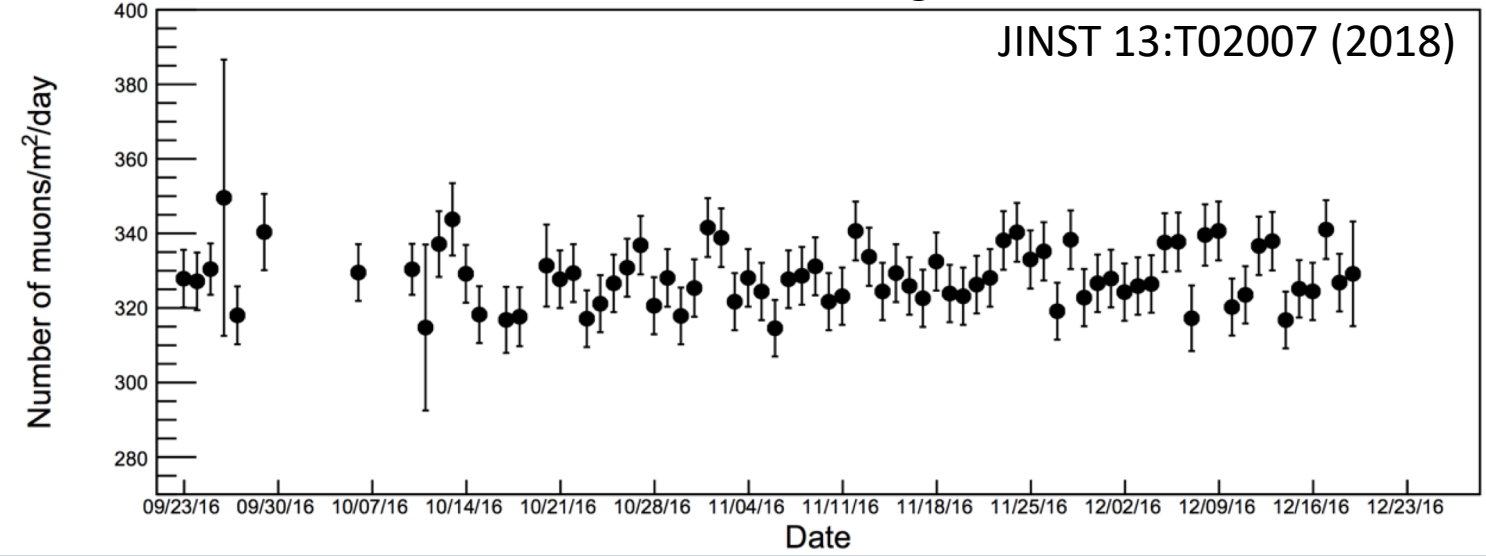
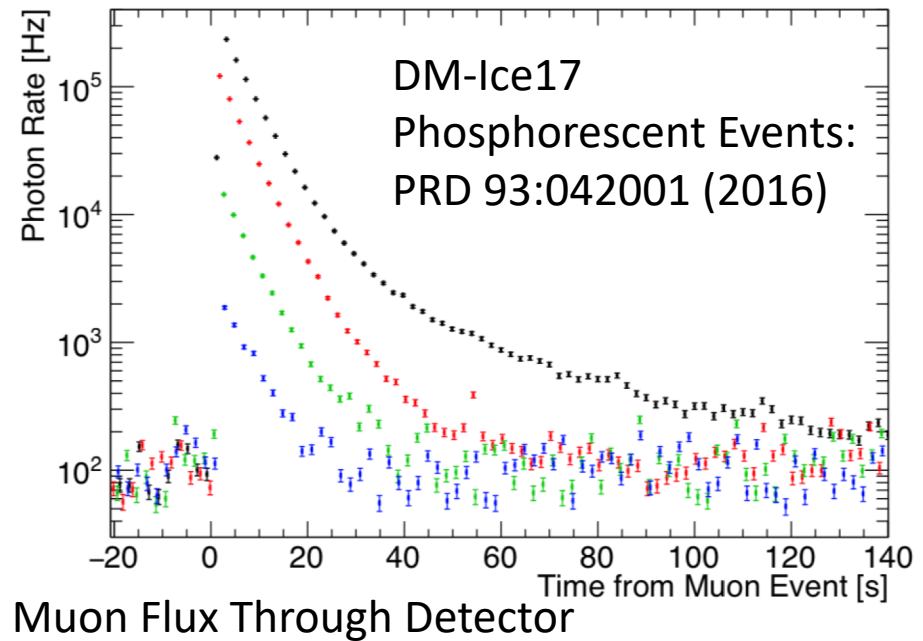
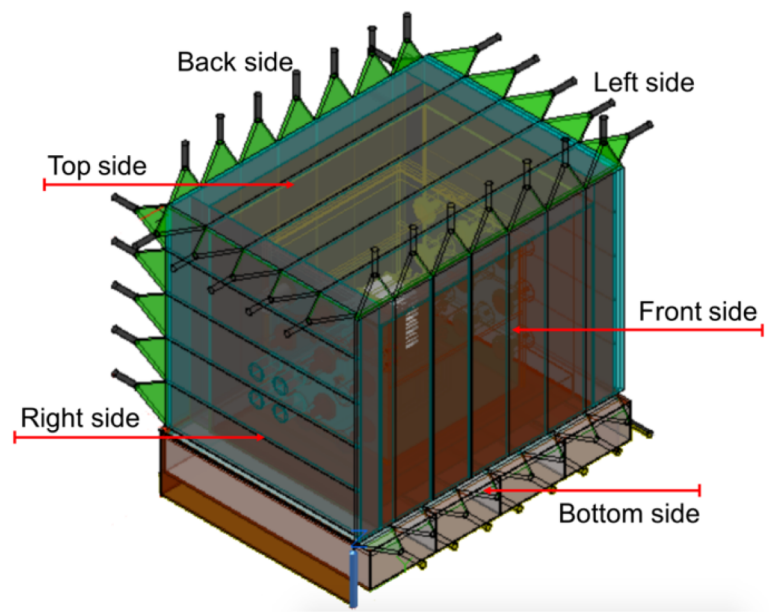
^{222}Rn and Event Rate

- Radon levels modulate in underground labs with period and phase similar to dark matter prediction
- Nitrogen cover gas significantly reduces radon in detector



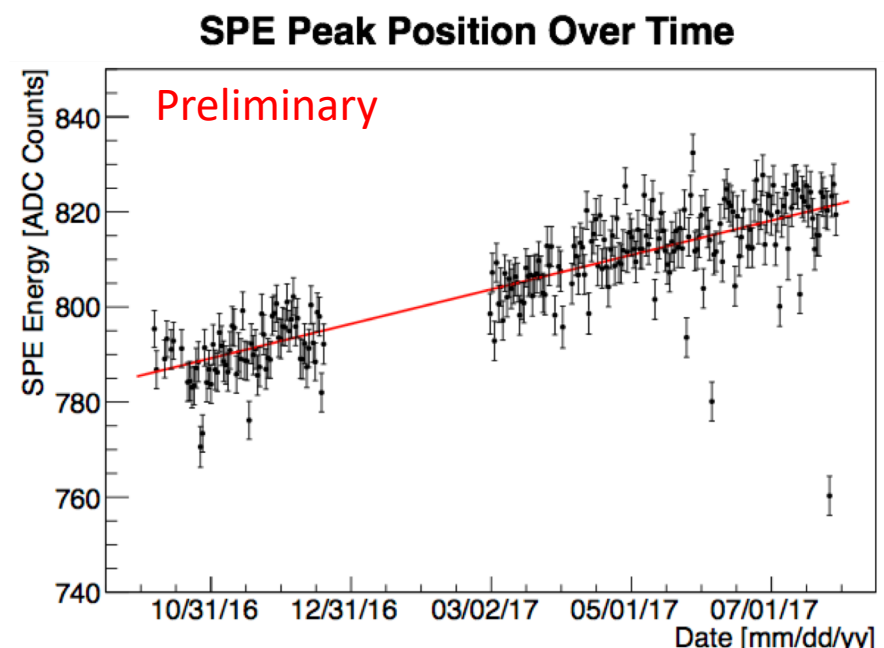
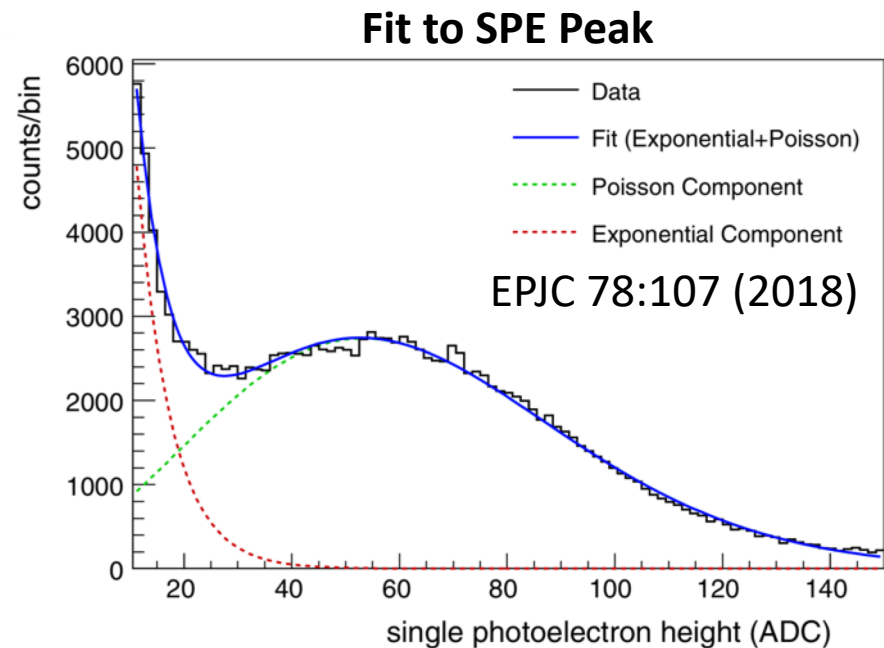
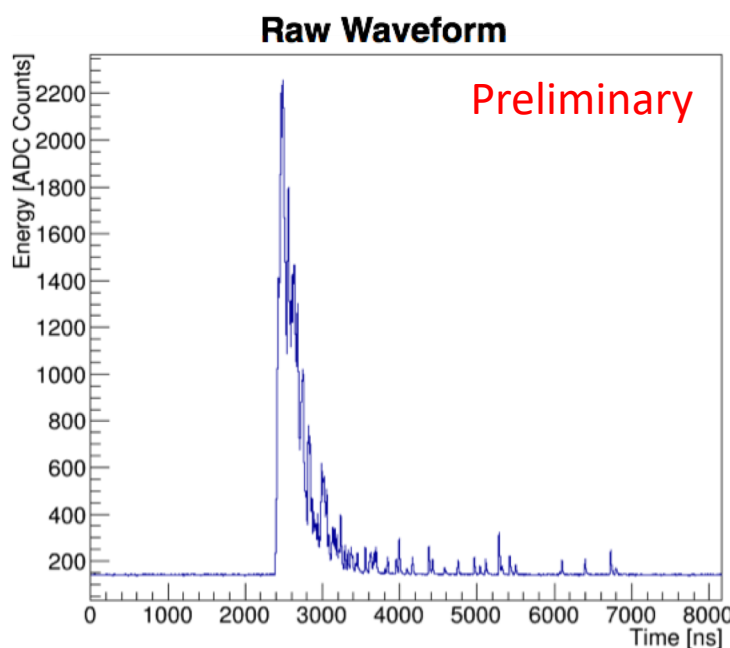
Muon Veto System

- Muon veto provides 4π coverage
- Muons induce long-lived phosphorescence
- Phase and amplitude not consistent with DAMA-observed modulation



Monitoring Single Photoelectrons

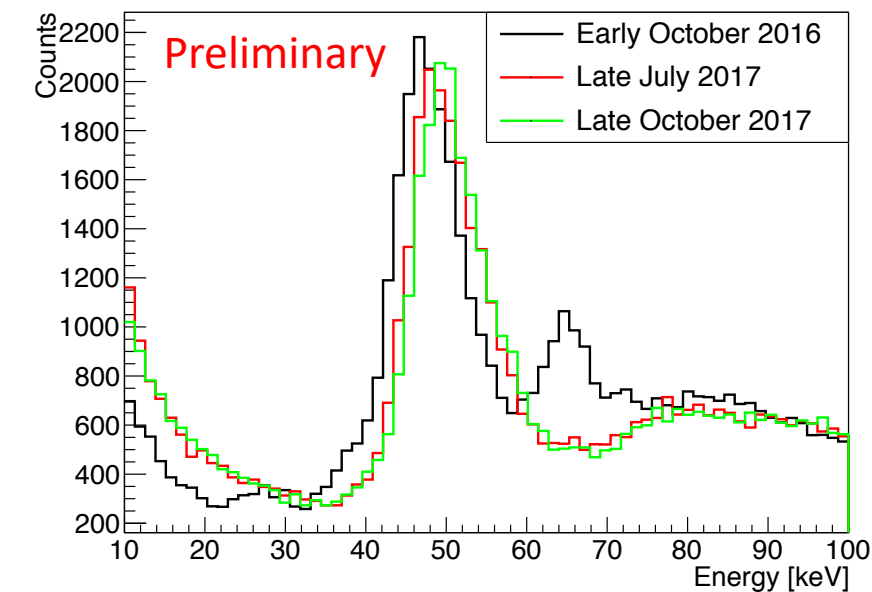
- Single photoelectrons extracted from tail of event pulse. Position monitored over time
- Gives information on stability of each PMT



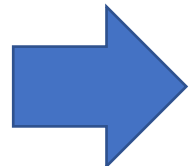
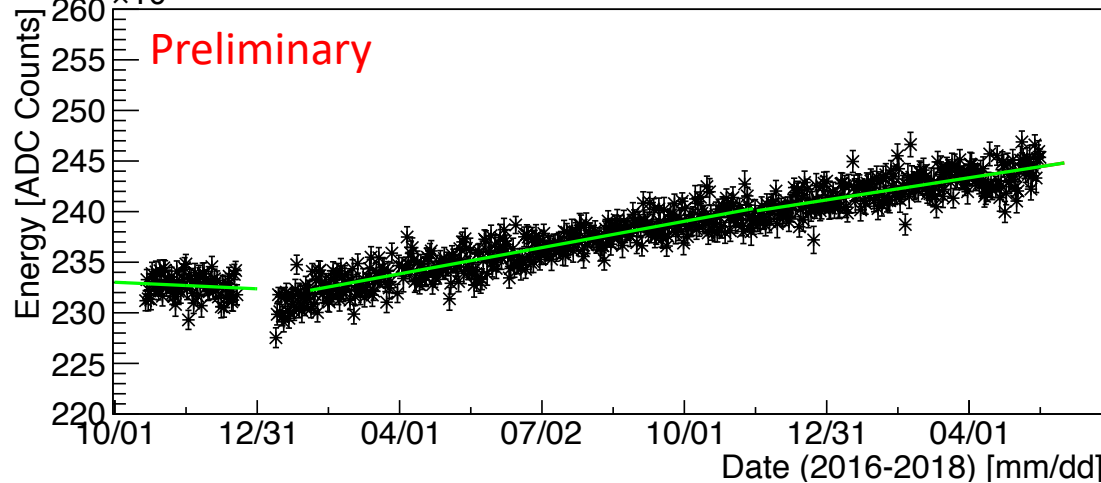
Correcting for Gain Shifts

- Position of internal ^{210}Pb decays also monitored over time
- Gain shift corrected for by dividing out linear behavior

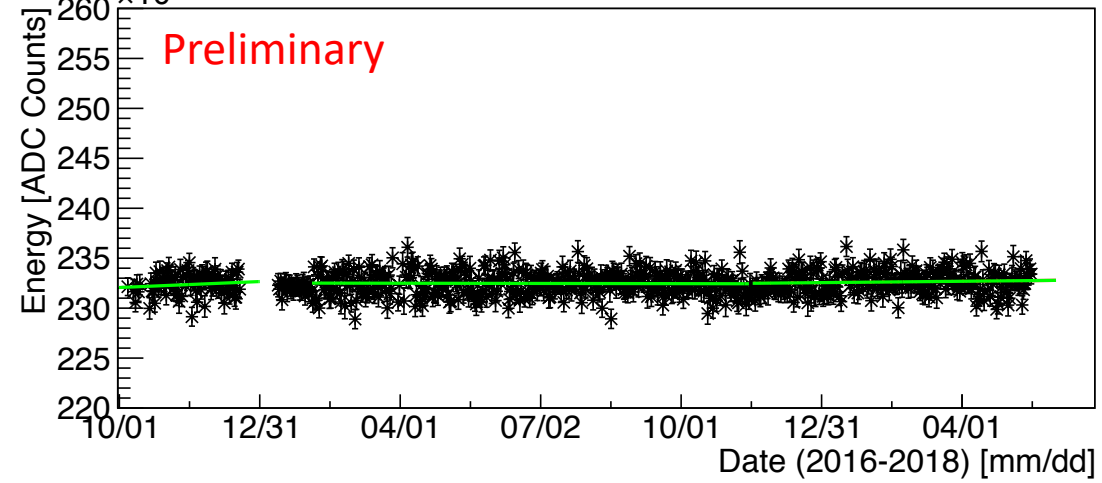
^{210}Pb Peak Position



^{210}Pb Peak Position Over Time

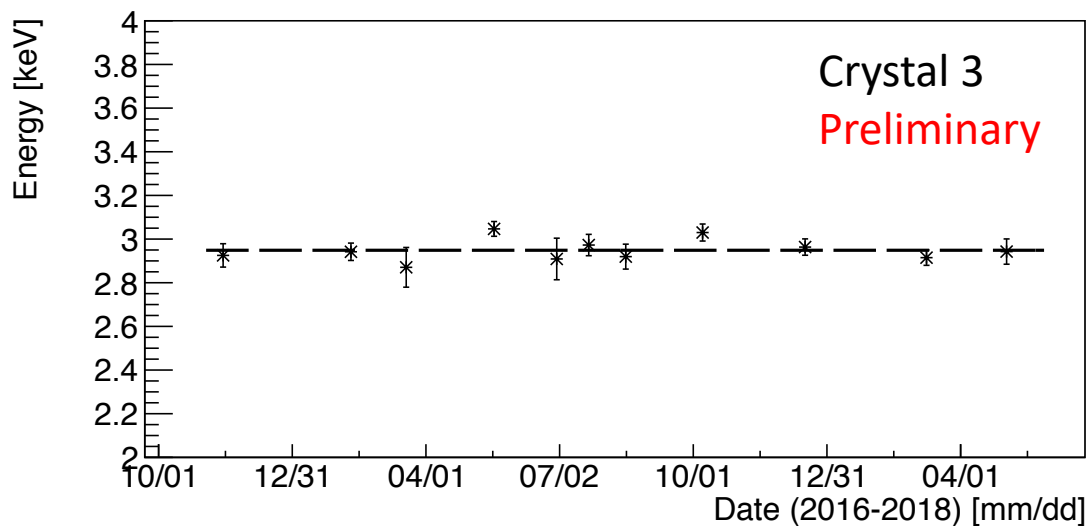
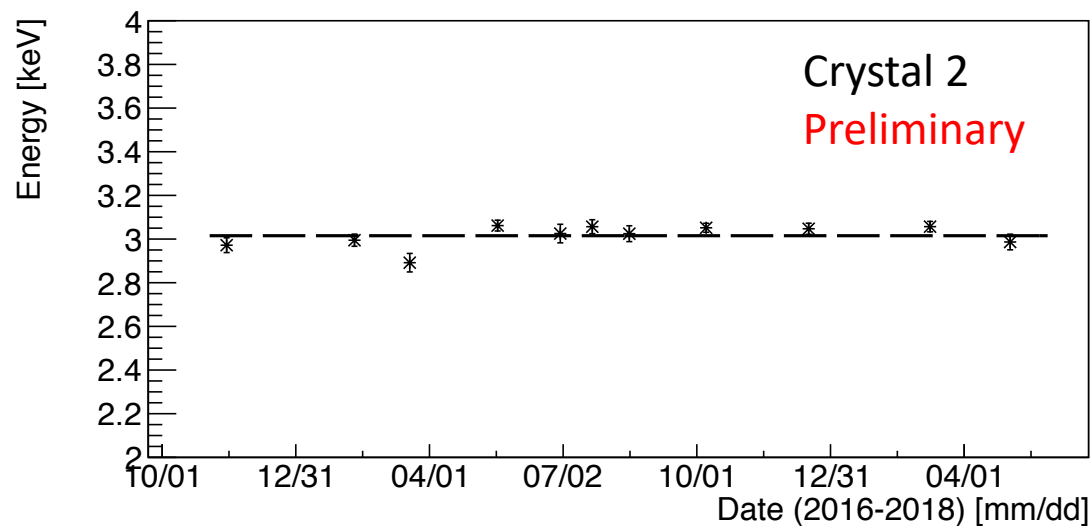
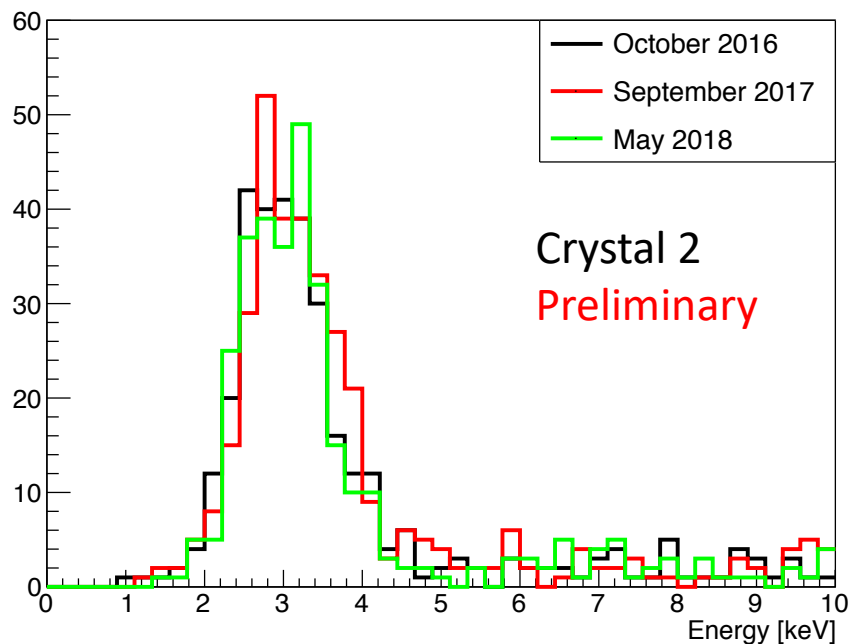


^{210}Pb Peak Position Over Time



Verifying Gain Correction

- Gain stability must be verified in 2-6 keV region of interest
 - Use 3 keV peak from ^{40}K contamination in crystal
- Gain steady over time within region of interest



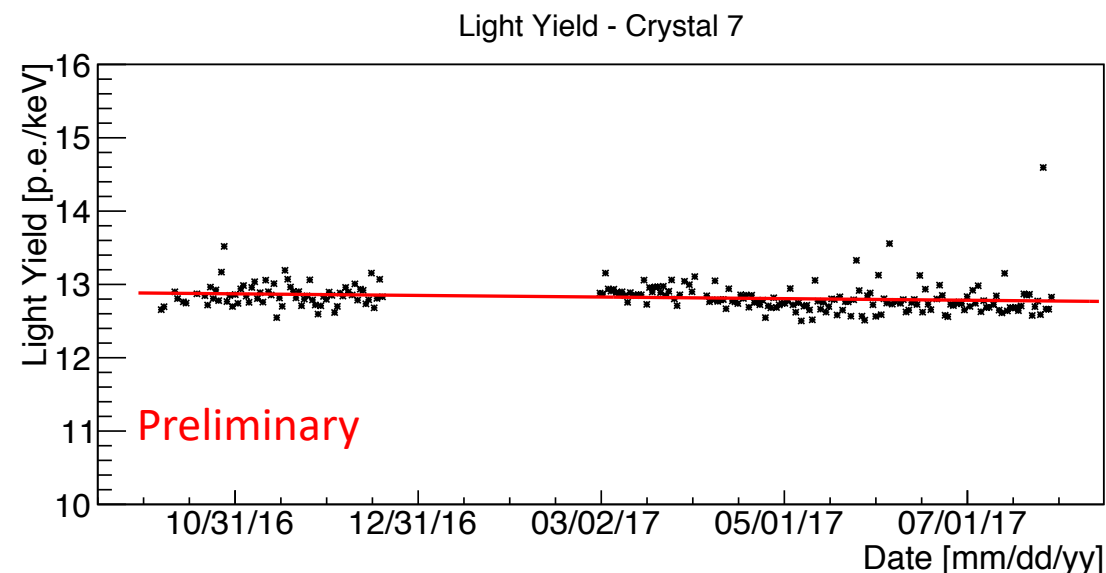
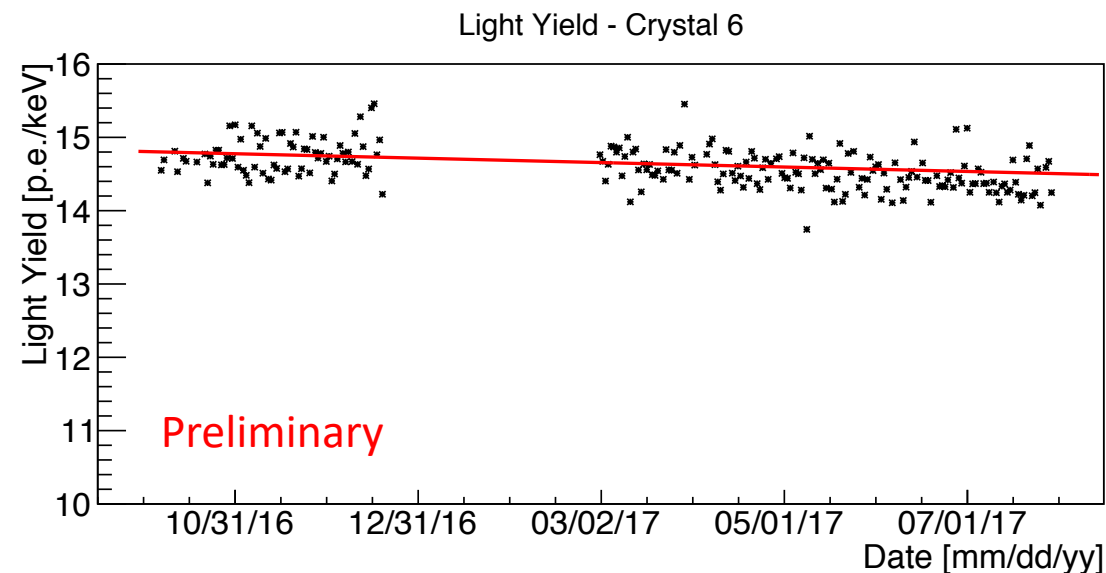
Observed Light Yields

- Measurement of SPE and ^{210}Pb peaks allow determination of crystal light yields

- Light yield: $\frac{E_{50\text{ keV}}}{E_{\text{SPE}} \times 50\text{ keV}}$

- Change of $\lesssim 1 \frac{\text{p.e.}}{\text{keV}}$ per year in modulation analysis crystals

- Verified by calibration with ^{241}Am



- COSINE-100 is conducting a model-independent test of DAMA by using the same target material, NaI(Tl)
- COSINE-100's environmental conditions are well monitored
- Change in detector gain tracked over time and corrected for over time
 - Crystal light yields successfully tracked over time
- If COSINE-100 observes modulation, monitoring system will enable us to identify potential correlations with environmental and detector conditions

Thank You!

<http://cosine.yale.edu/>



+ DM-ICE



The University of Sheffield.



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