TAUP 2017

Topics in Astroparticle and Underground Physics

COSINE-100

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Yale University

TAUP 2017
24 – 28 July 2017

Yale

Wright Laboratory

Current & Planned NaI(Tl) Experiments

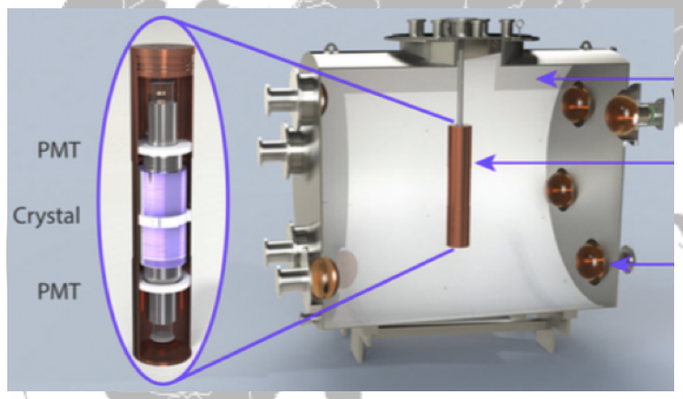
DM-Ice + KIMS

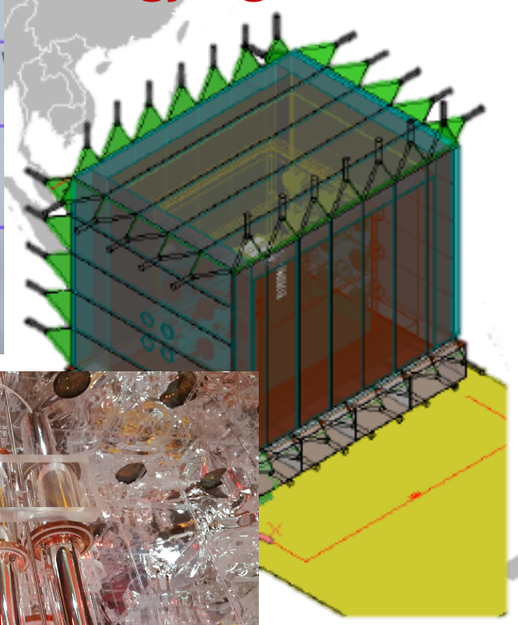
SABRE COSINUS

★ Gran Sasso + Australia

COSINE-100

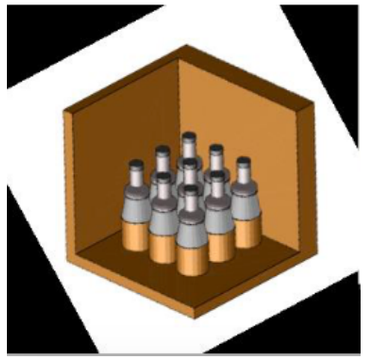
★ Yangyang ★ Kamioka





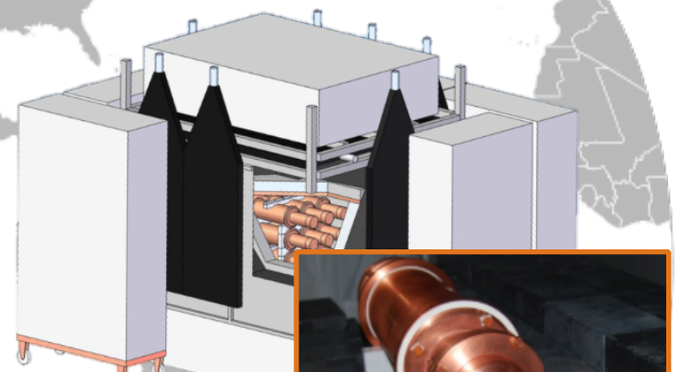
Eur.Phys.J. C **77** 437 (2017)
Phys.Rev. D **90** 052006 (2014) (CsI)

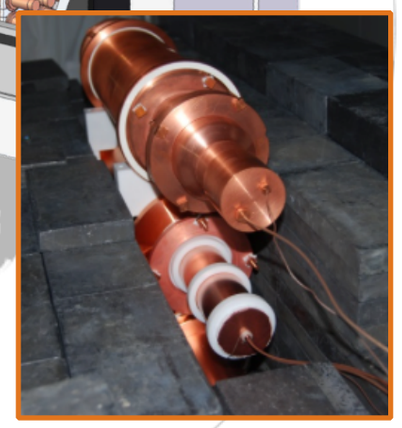
PICOLON



ANAIS

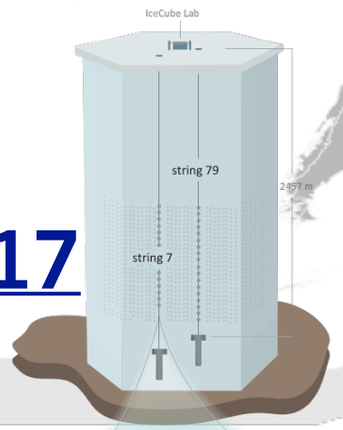
★ Boulby ★ Canfranc

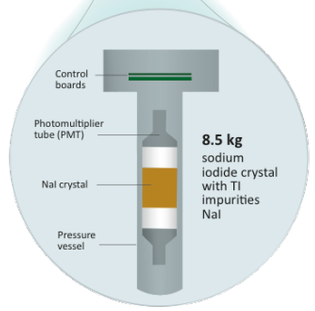


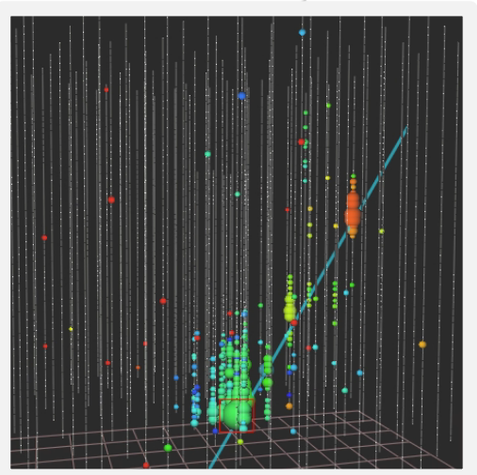


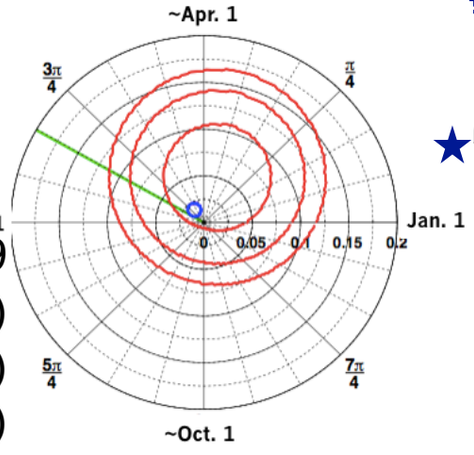
DM-Ice17

★ South Pole

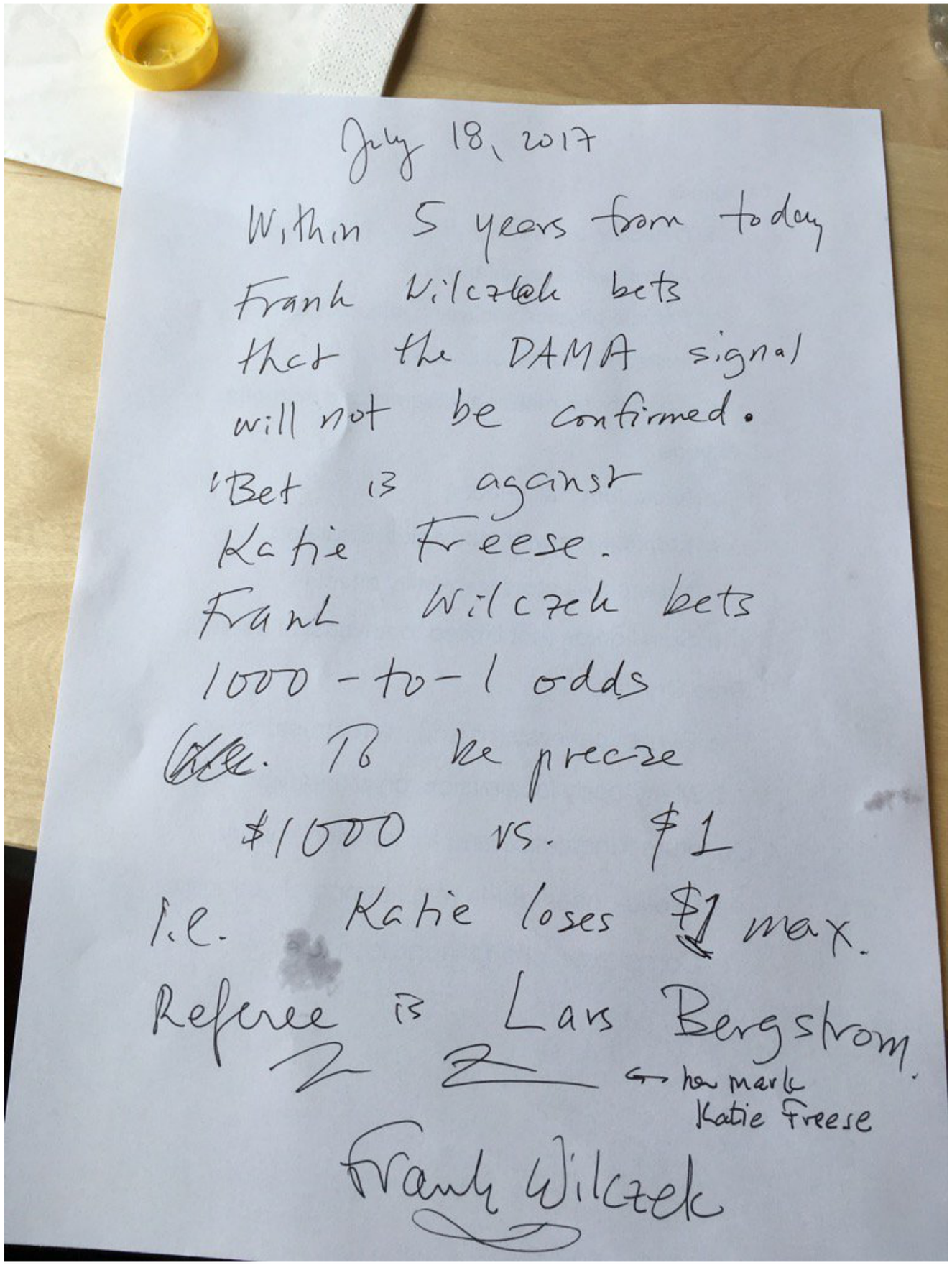








Astropart. Phys. **35** (2012) 749
Phys. Rev. D **90** 092005 (2014)
Phys. Rev. D **93** 042001 (2016)
Phys. Rev. D **95** 032006 (2017)

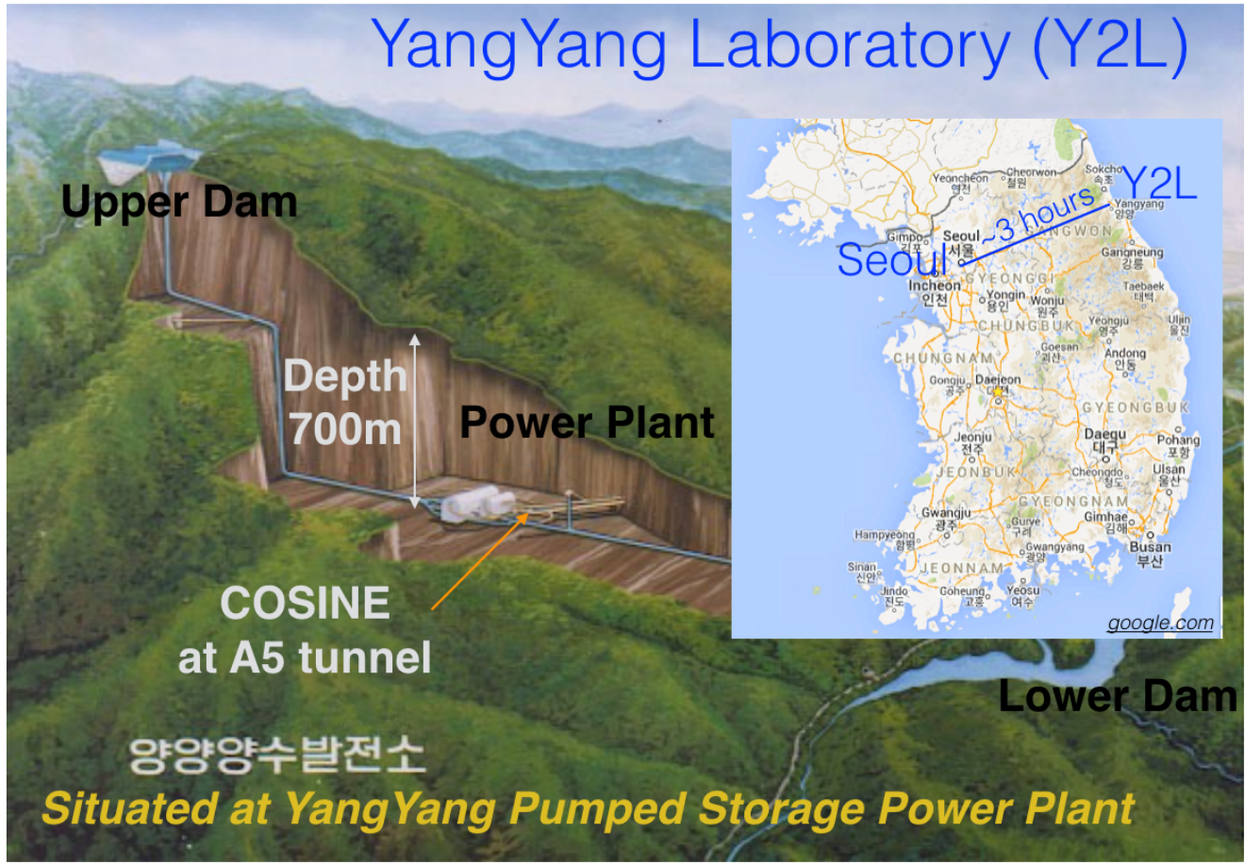


https://twitter.com/ktfreese/status/888730718477713408

COSINE-100 Collaboration

http://cosine.yale.edu

Joint collaboration between KIMS and DM-Ice. 106 kg of NaI(Tl) crystals.



KIMS + DM-ICE

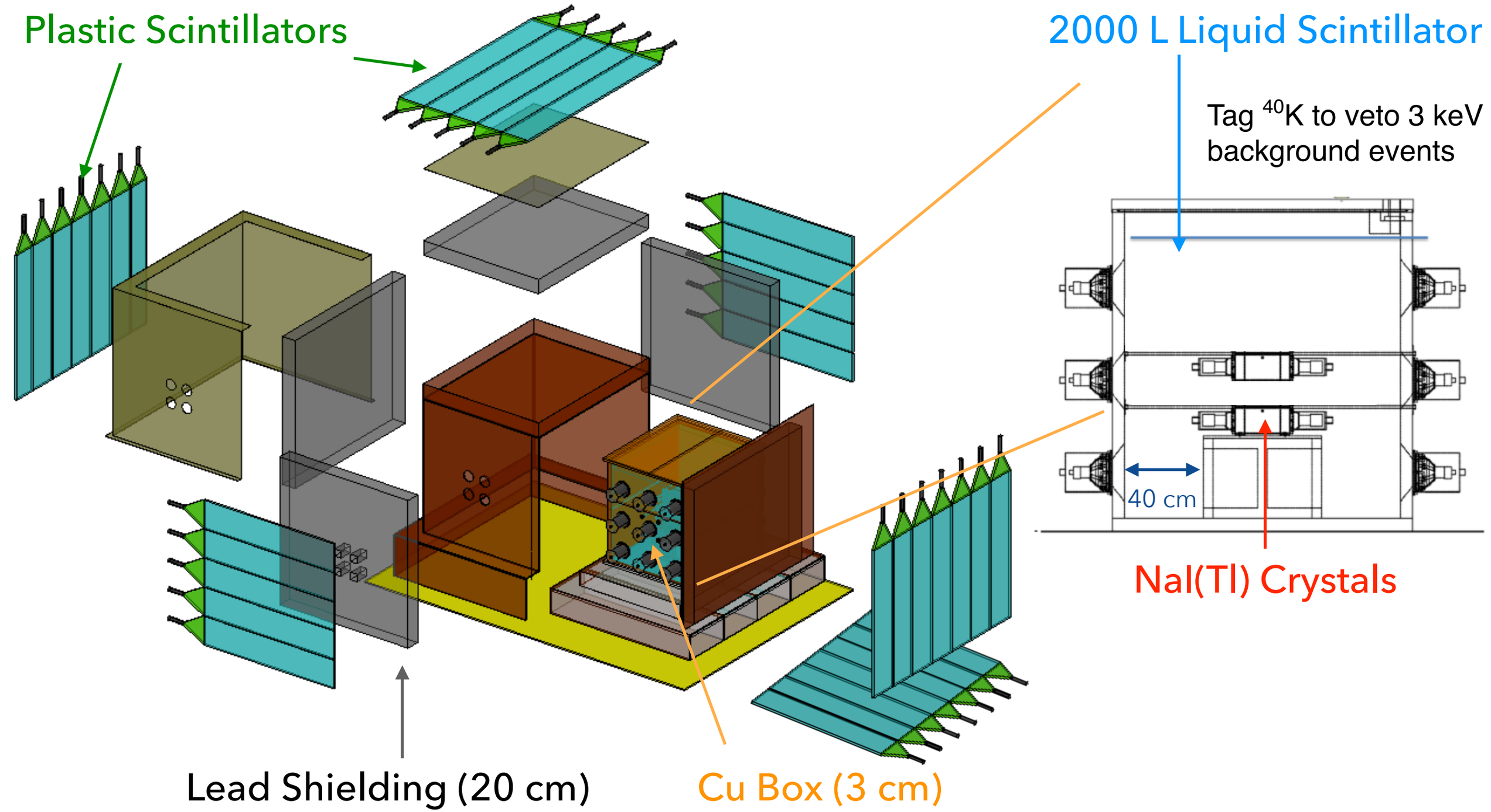
Korea Invisible Mass Search Experiment

The University Of Sheffield.

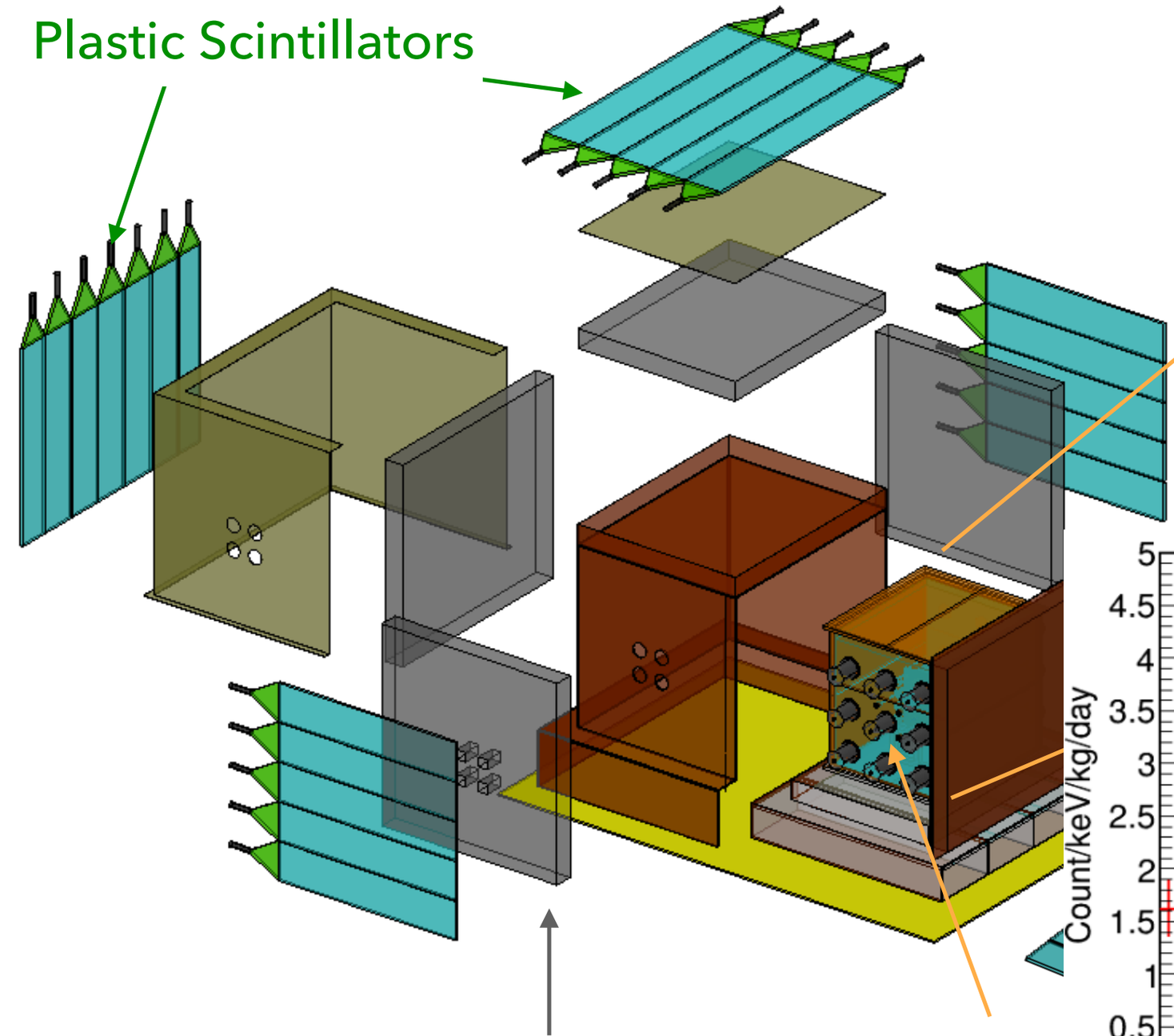
WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

Yale

COSINE-100 Shielding

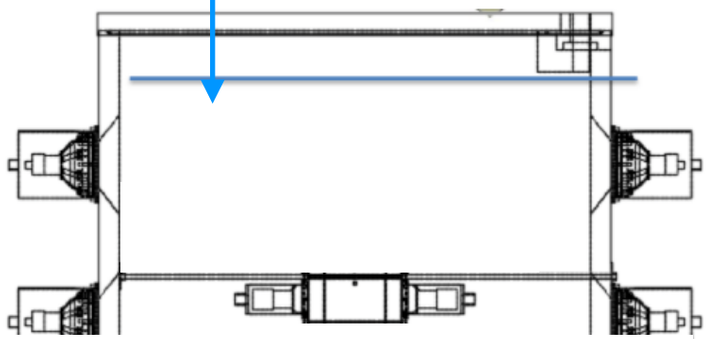


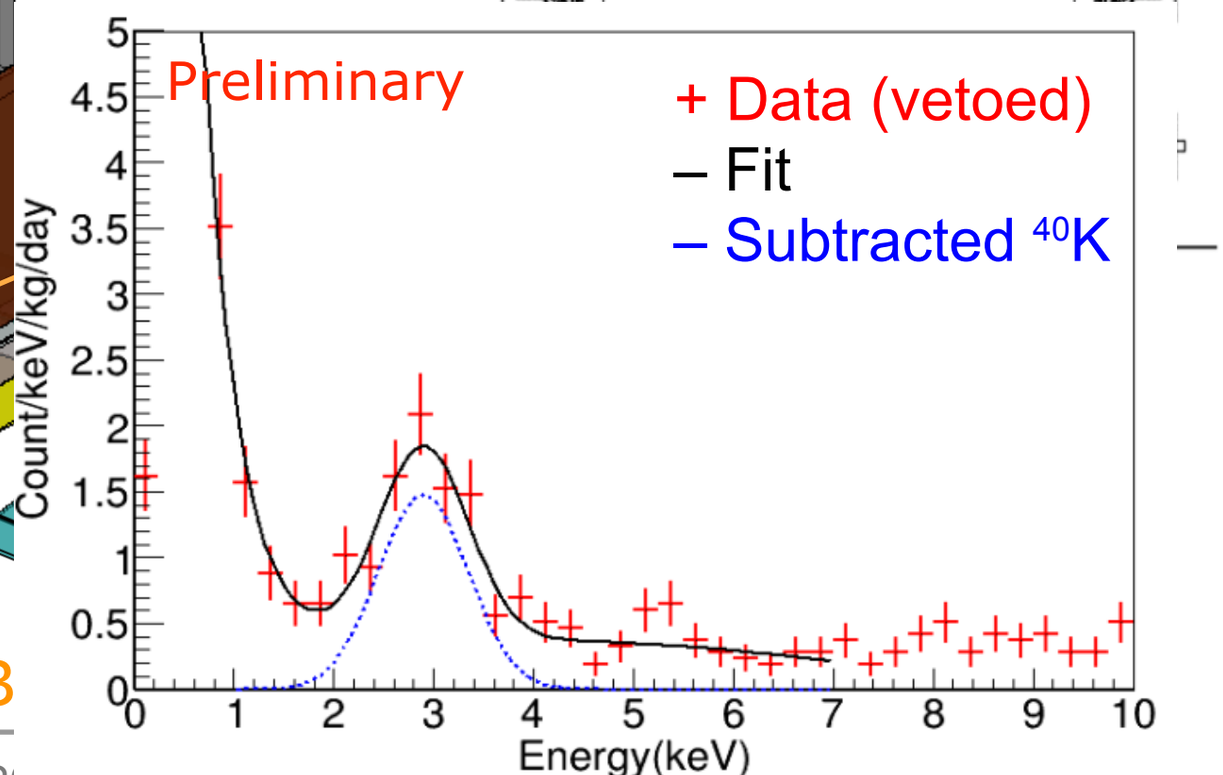
COSINE-100 Shielding



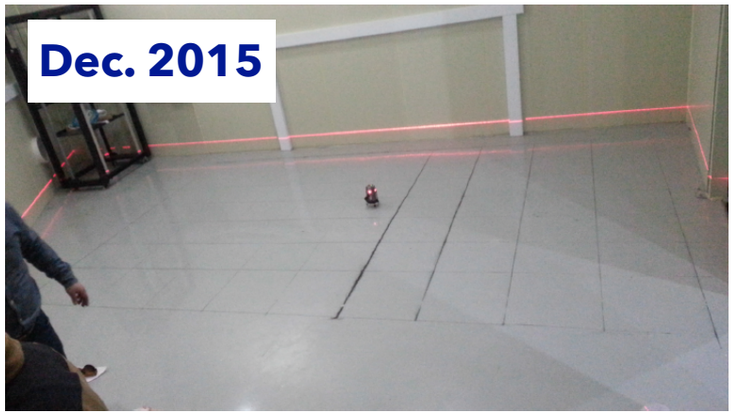
2000 L Liquid Scintillator

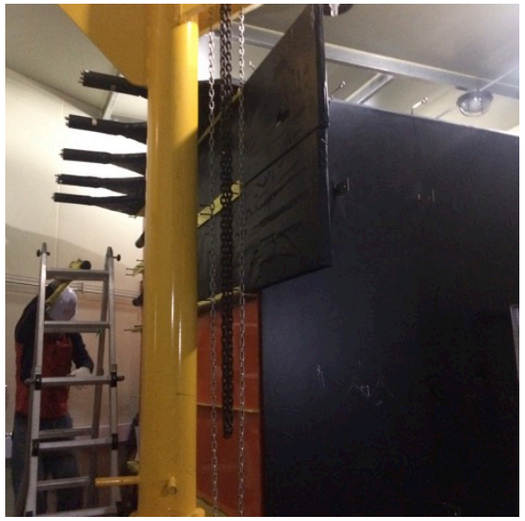
Tag ^{40}K to veto 3 keV background events

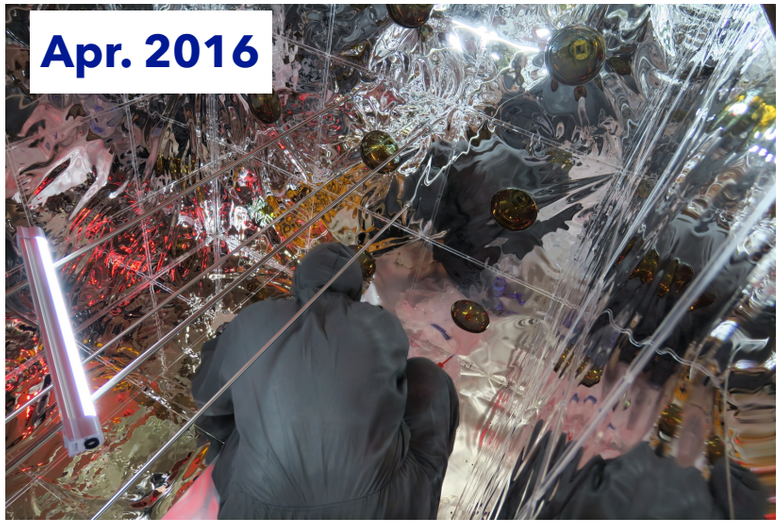


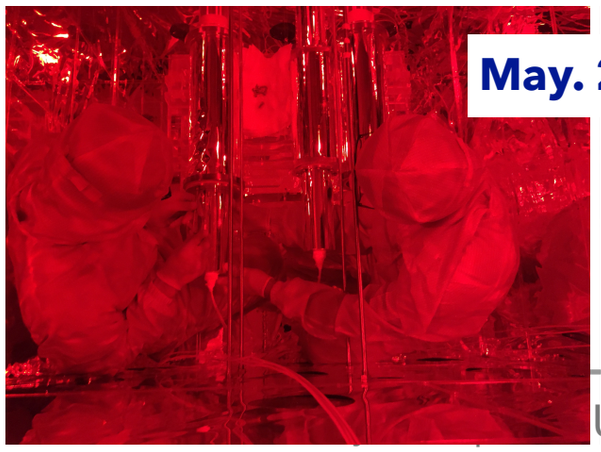


COSINE-100 Construction

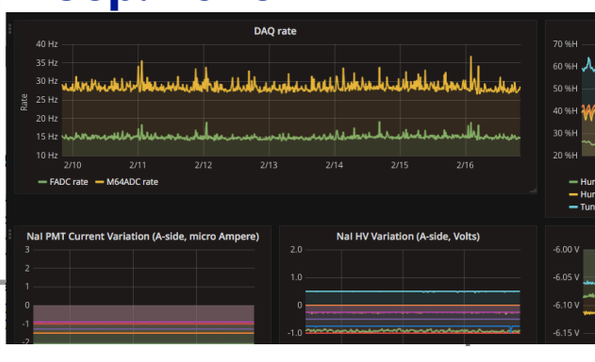




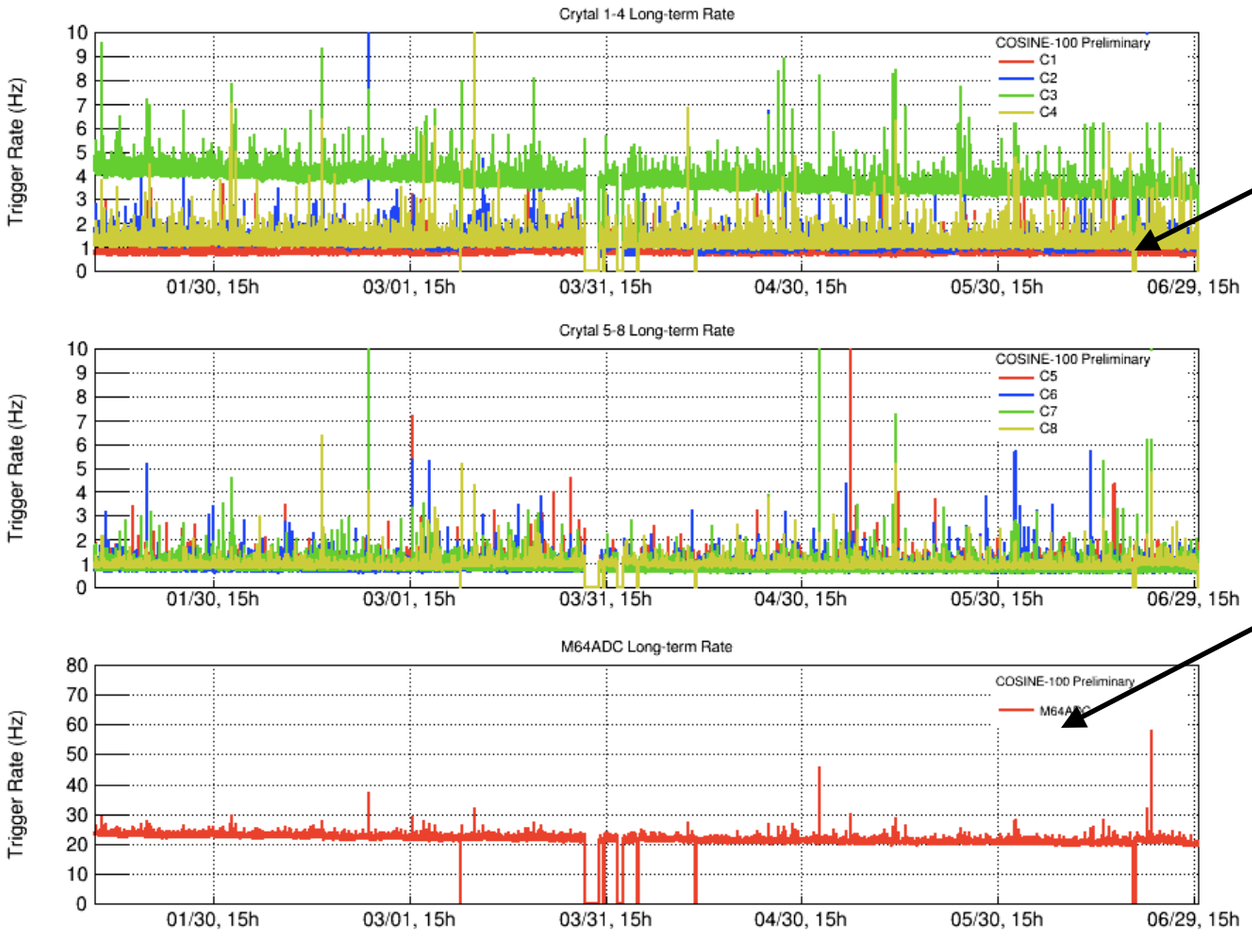




Sep. 2016



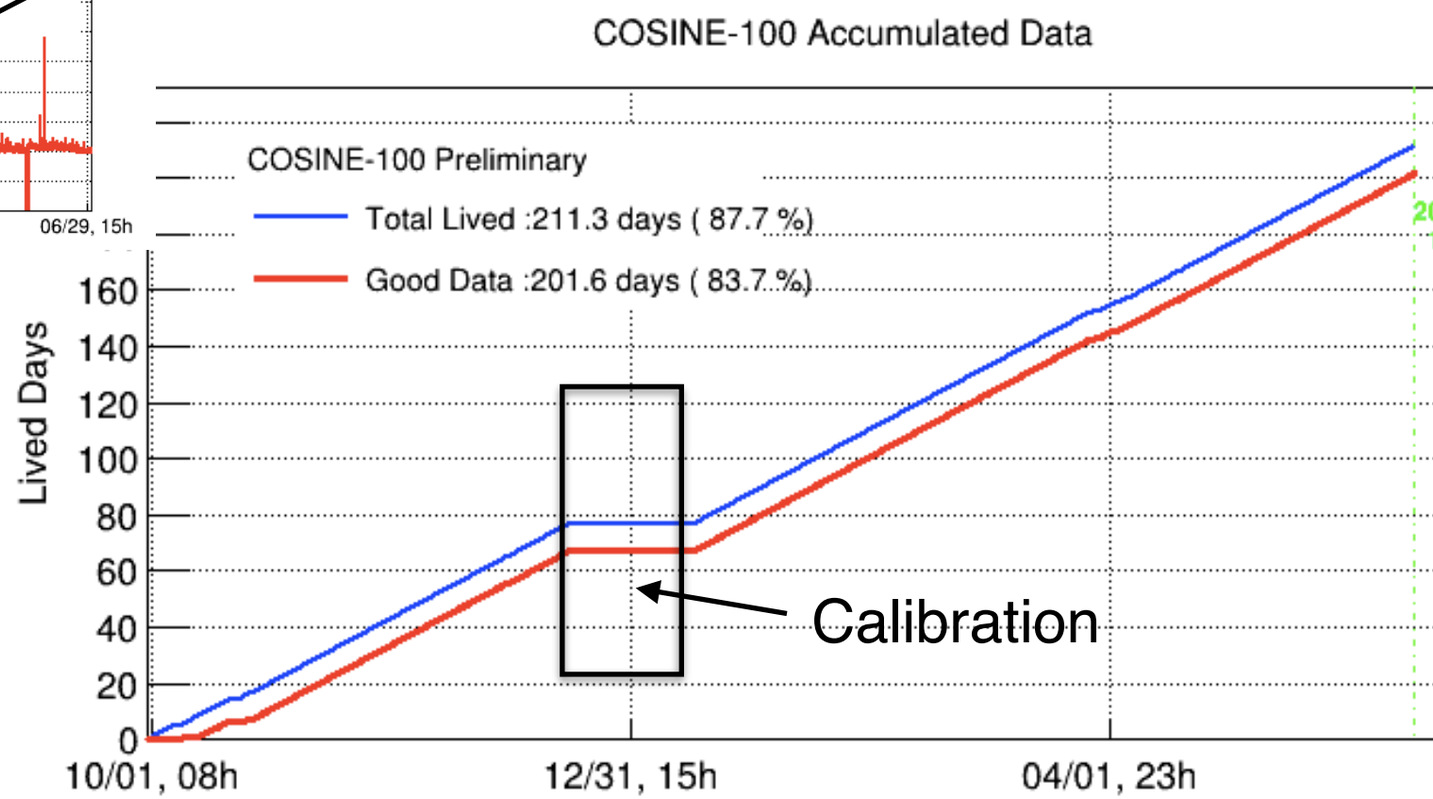
COSINE-100 Operation



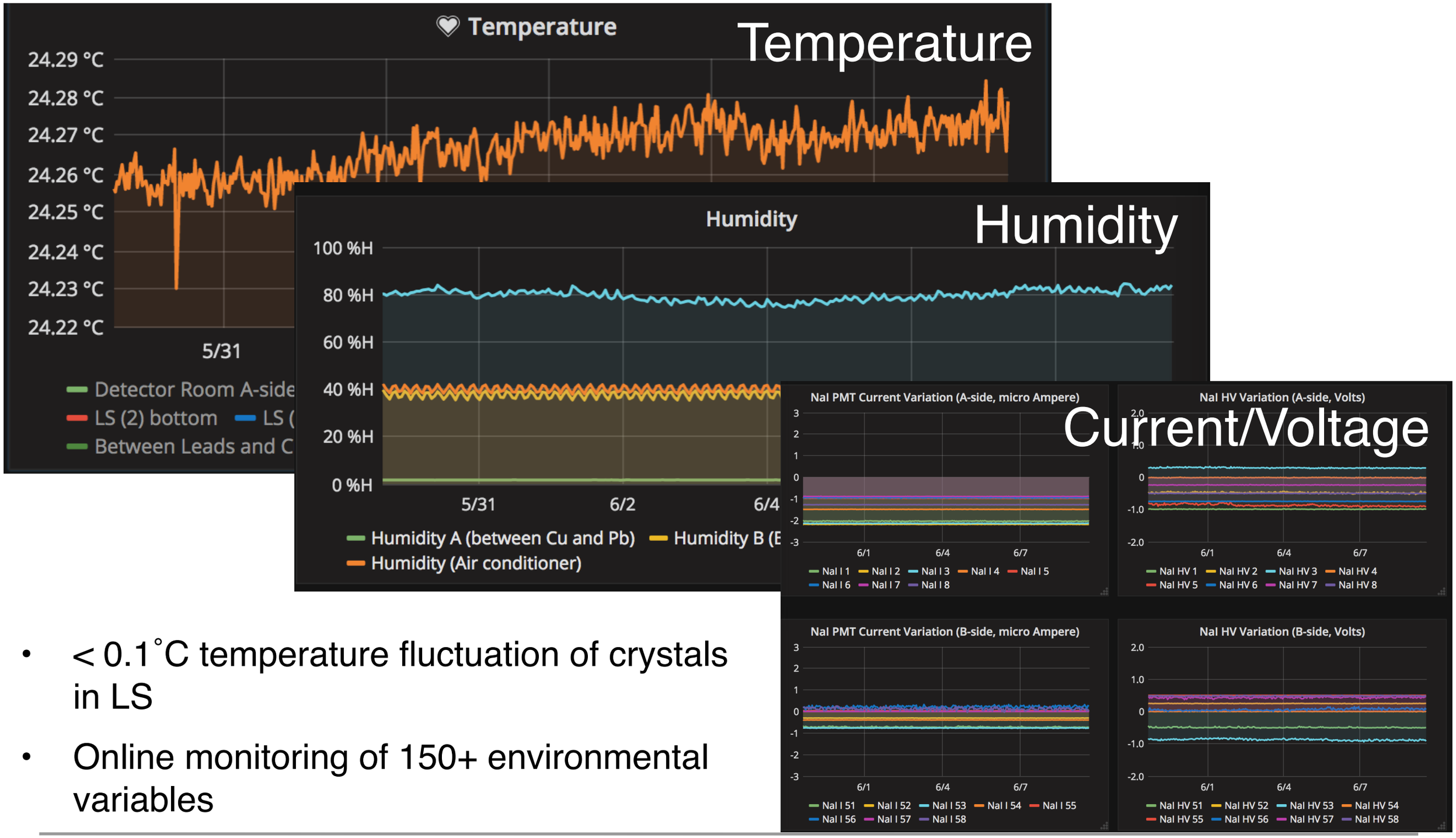
Crystal Trigger Rate: 13 Hz

Muon Detector Rate: 12 Hz

- Data taking since Sep. 2016
- Stable operation
- > 85% physics data
- 95% good runs



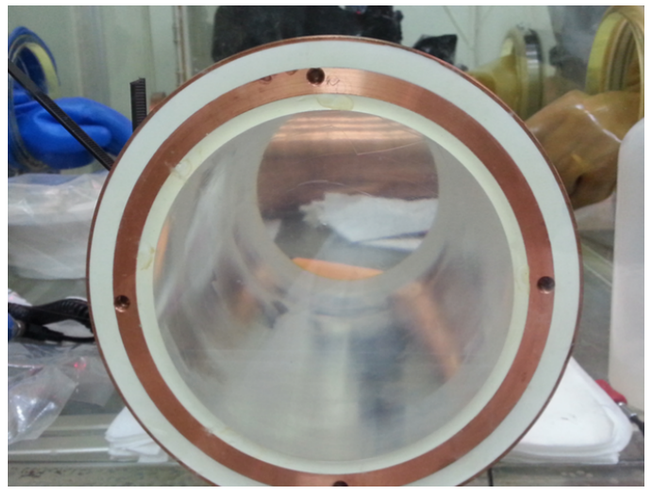
Environmental Control & Monitoring



- < 0.1˚C temperature fluctuation of crystals in LS
- Online monitoring of 150+ environmental variables

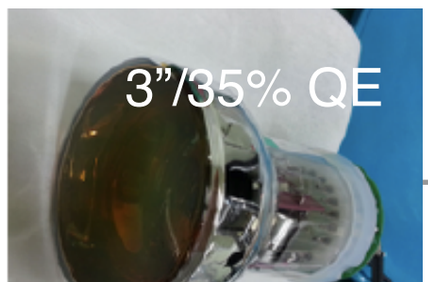
COSINE-100 NaI(Tl) Crystals

- 8 crystals, total 106 kg
- Culmination of R&D program with Alpha Spectra
- U/Th/K below DAMA, ^{210}Po very close
- Light yield ~15 p.e./keV
- Challenge: putting it all together
- Total Background: 2 - 4 x DAMA's avg.



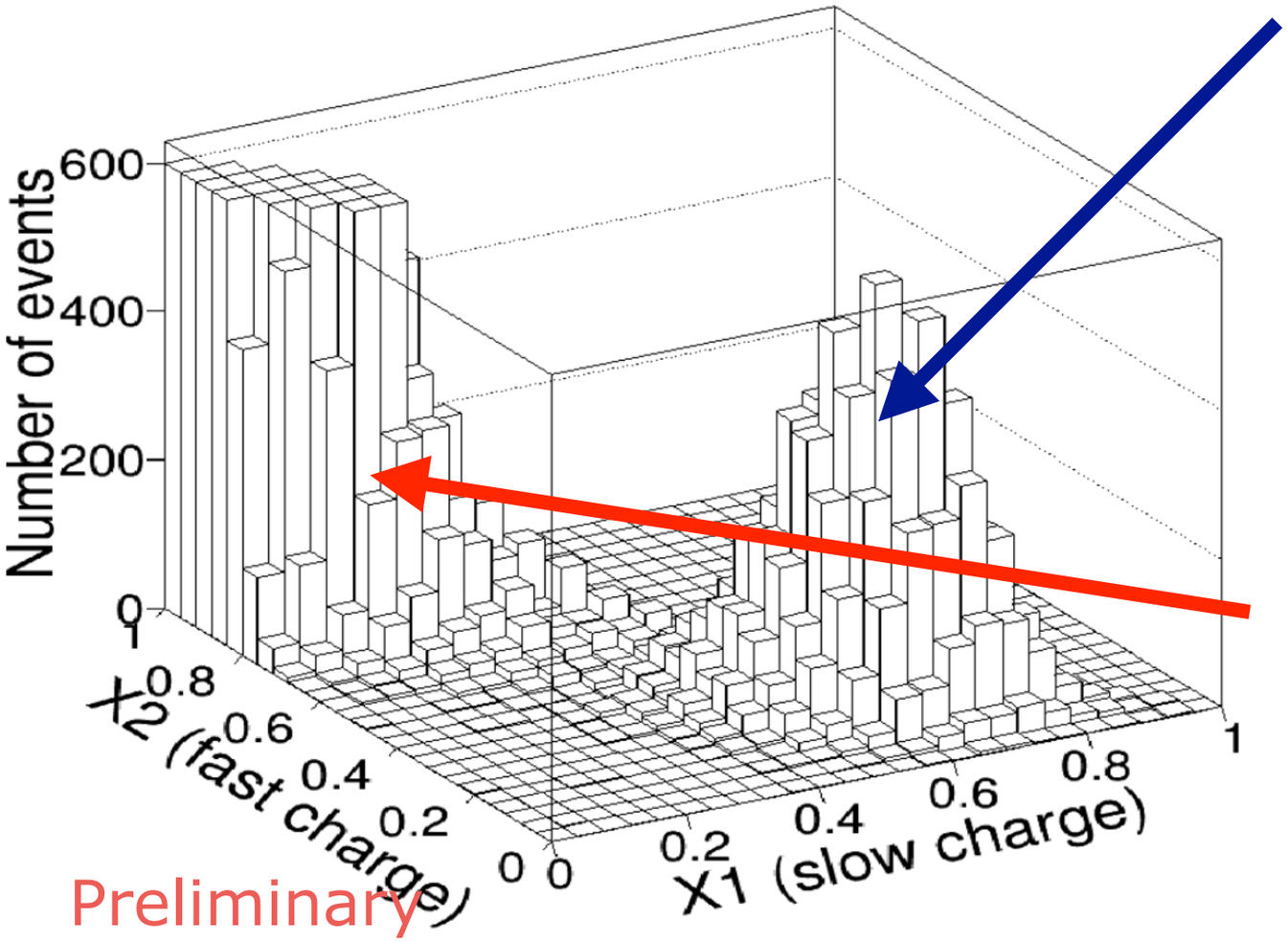
Preliminary

	Mass (kg)	Powder Type	^{40}K (ppb)	^{238}U (ppt)	^{232}Th (ppt)	^{210}Po (mBq/kg)	Light Yield (npe/keV)
Crystal 1	8.26	Powder B	34.74±4.74	<0.02	1.31±0.35	3.20±0.04	14.67±0.62
Crystal 2	9.15	Powder C	60.64±4.64	<0.12	<0.63	2.06±0.03	14.56±0.54
Crystal 3	9.16	WIMPScint-II	34.34±3.10	<0.04	0.44±0.19	0.76±0.02	15.75±0.76
Crystal 4	18.01	WIMPScint-II	33.32±3.50		<0.3	0.74±0.02	14.69±0.46
Crystal 5	18.28	Powder C	82.33±5.49		2.35±0.31	2.06±0.03	6.26 ±0.34
Crystal 6	12.5	WIMPScint-III	16.79±2.46	<0.018	0.56±0.19	1.52±0.02	14.52±0.51
Crystal 7	12.5	WIMPScint-III	18.69±2.79		<0.6	1.54±0.02	14.41±0.50
Crystal 8	18.28	Powder C	54.25±3.82		<0.9	2.05±0.02	3.27 ±0.20
DAMA			<20	0.7 - 10	0.5 - 7.5	<0.5	5.5 - 7.5

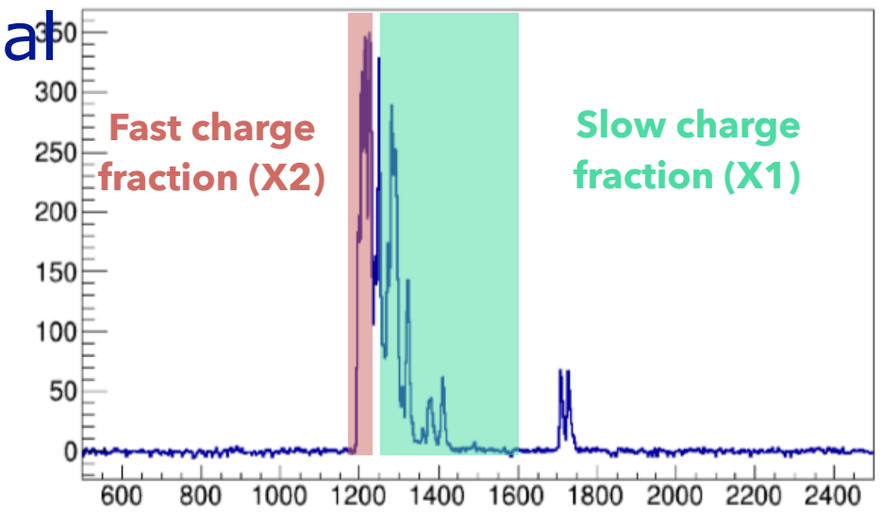


Event Selection: Fast Event Rejection

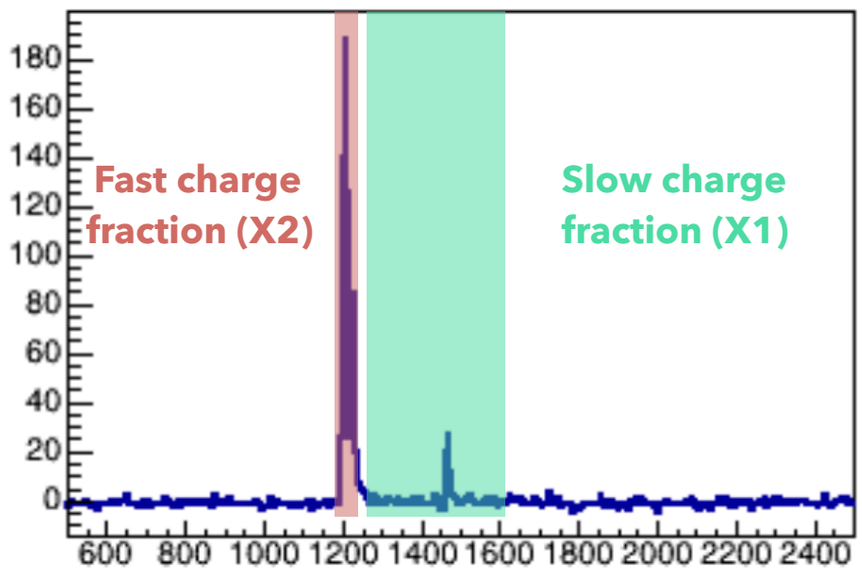
- Separate noise via charge ratio of rising edge vs. falling edge



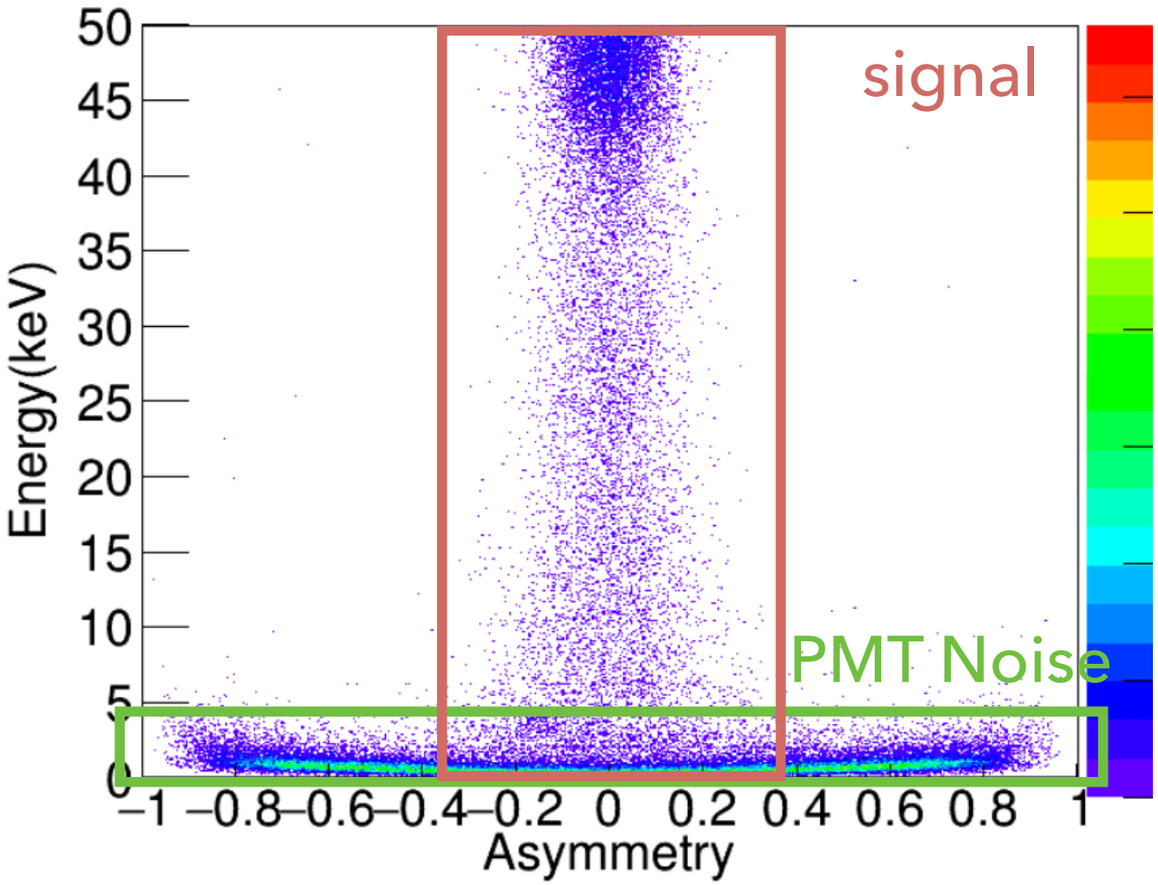
Signal

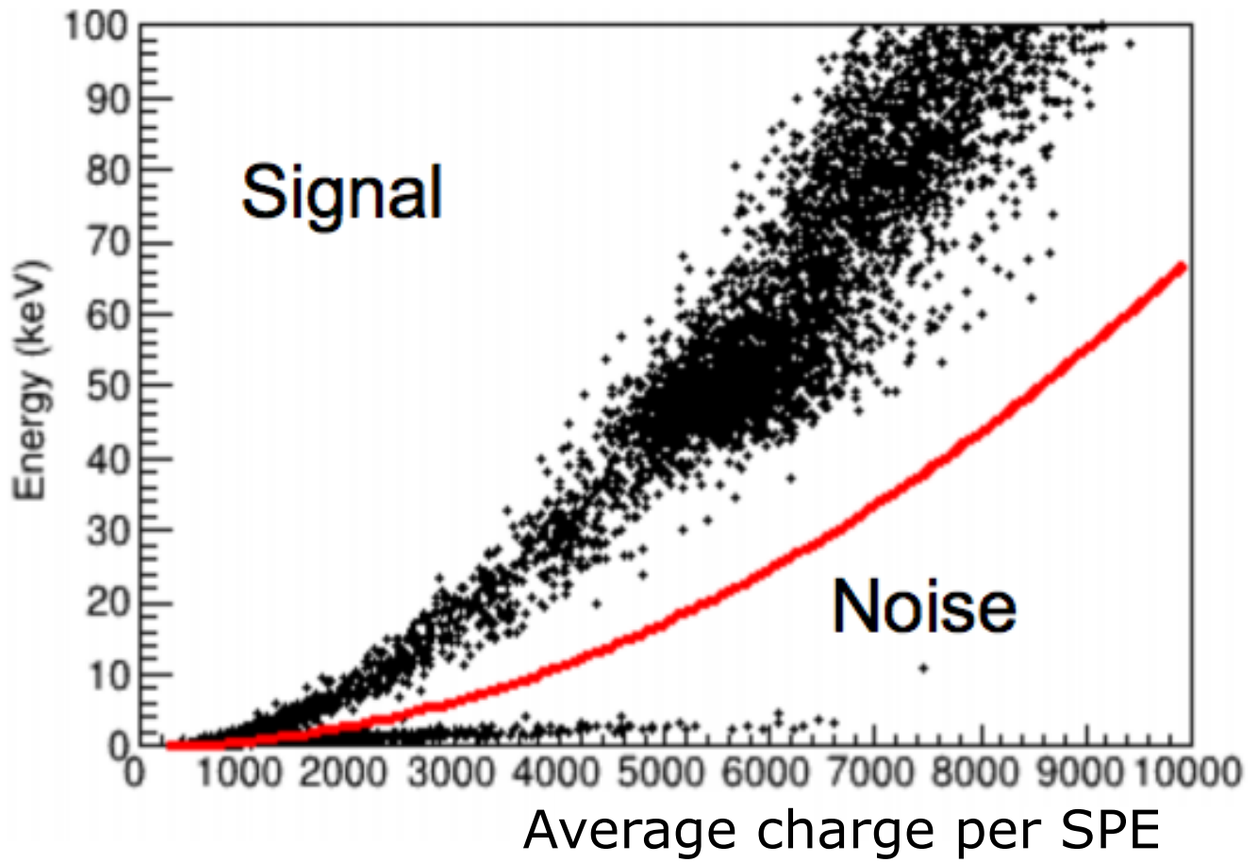


Noise



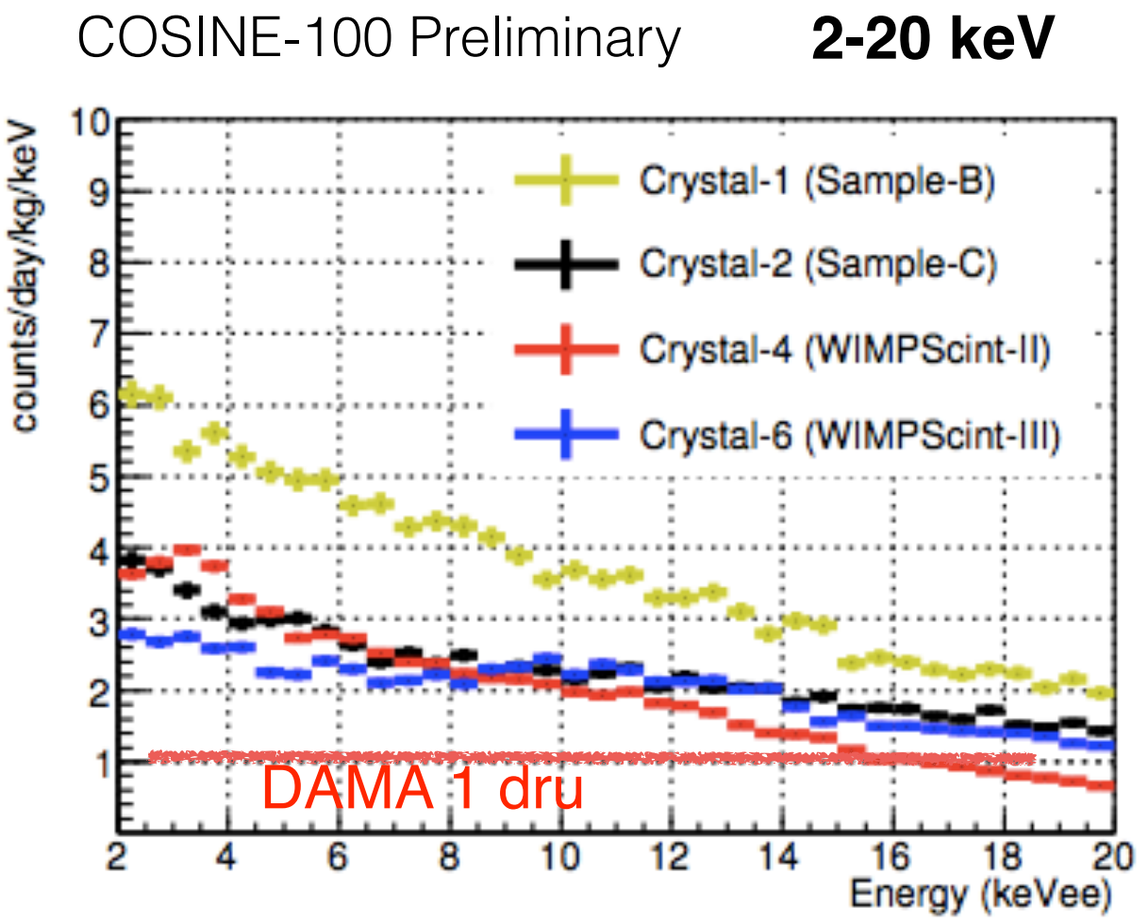
Event Selection: Asymmetry & Charge/Peak

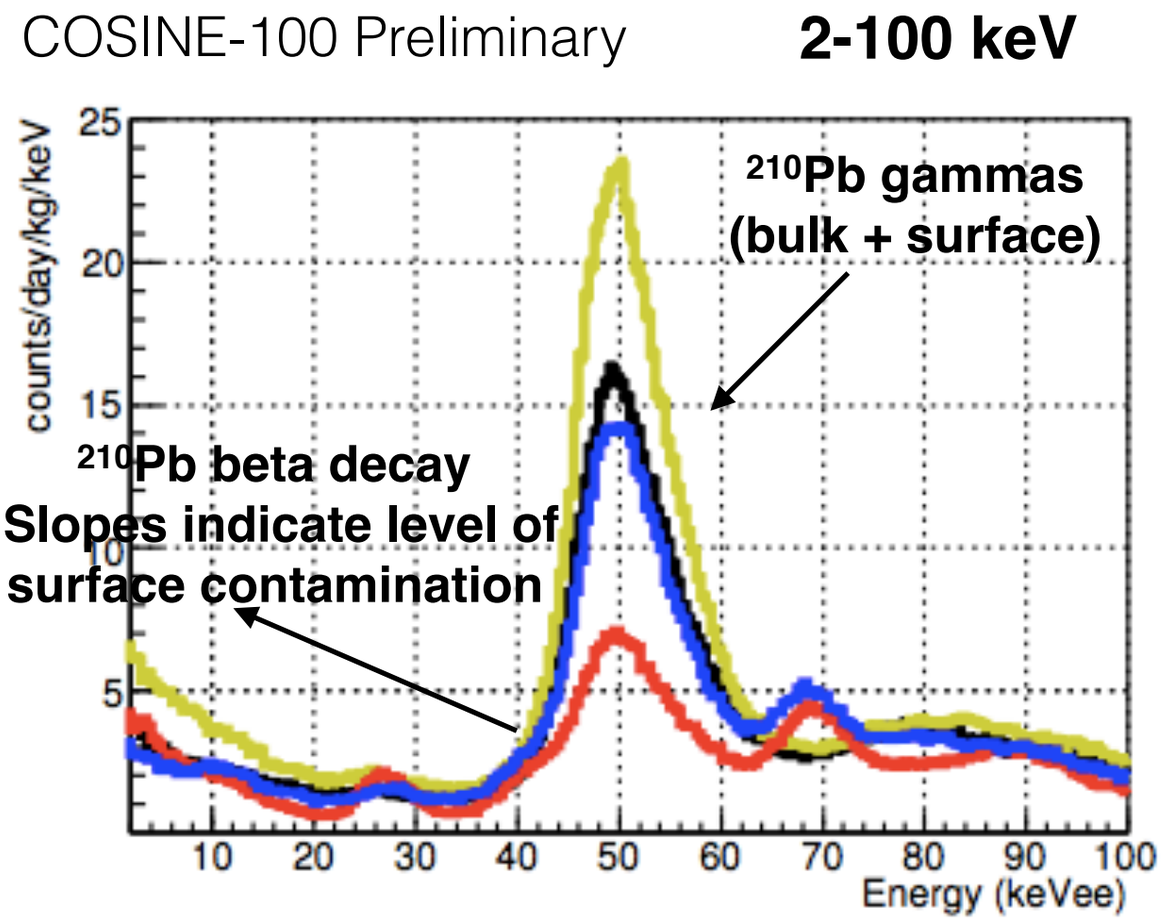




- Additional noise reduction cuts have been developed:
  - Charge asymmetry between 2 PMTs in each crystal
  - Charge/peak: Average charge per SPE
  - BDT

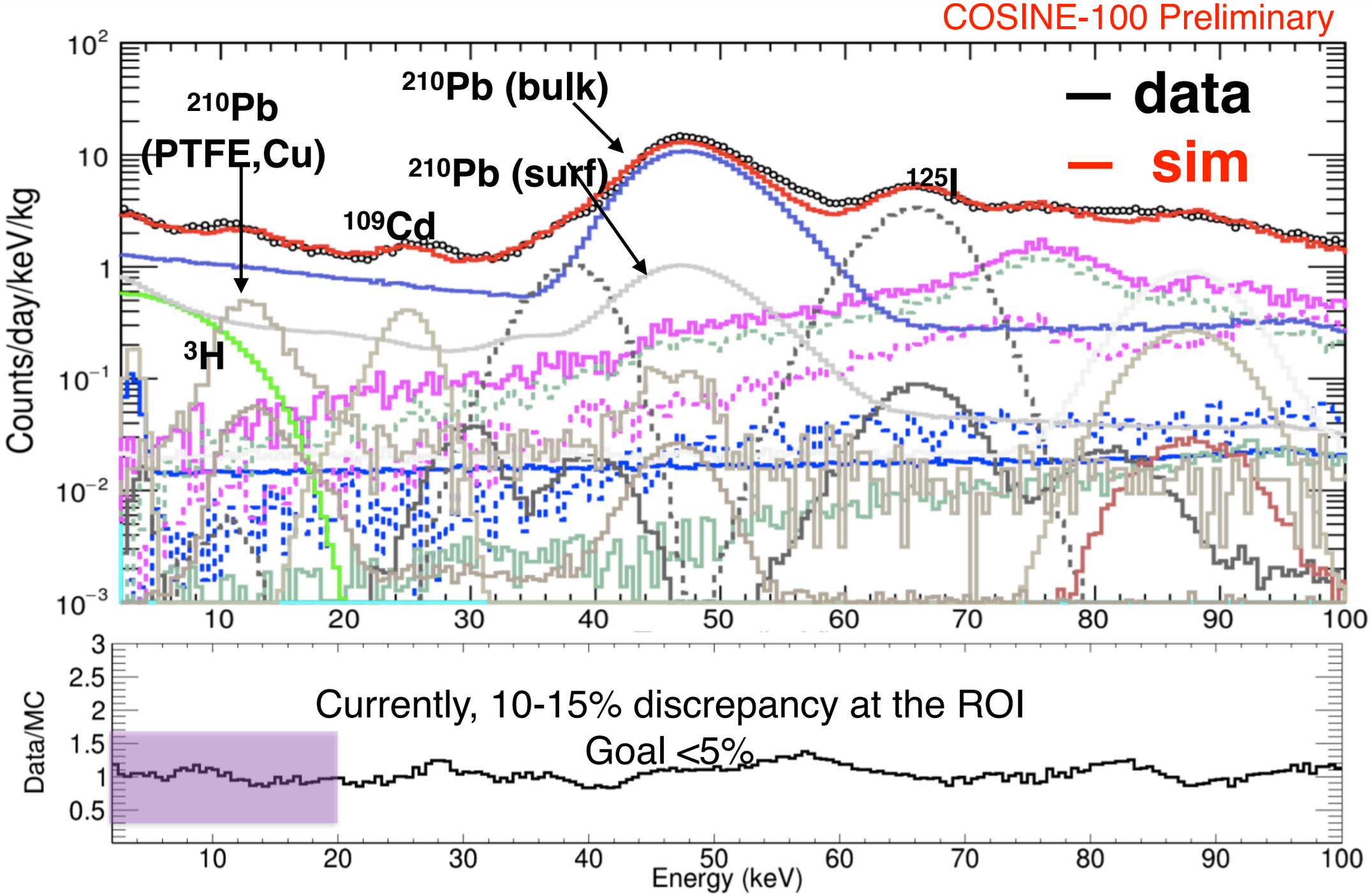
Low Energy Spectrum



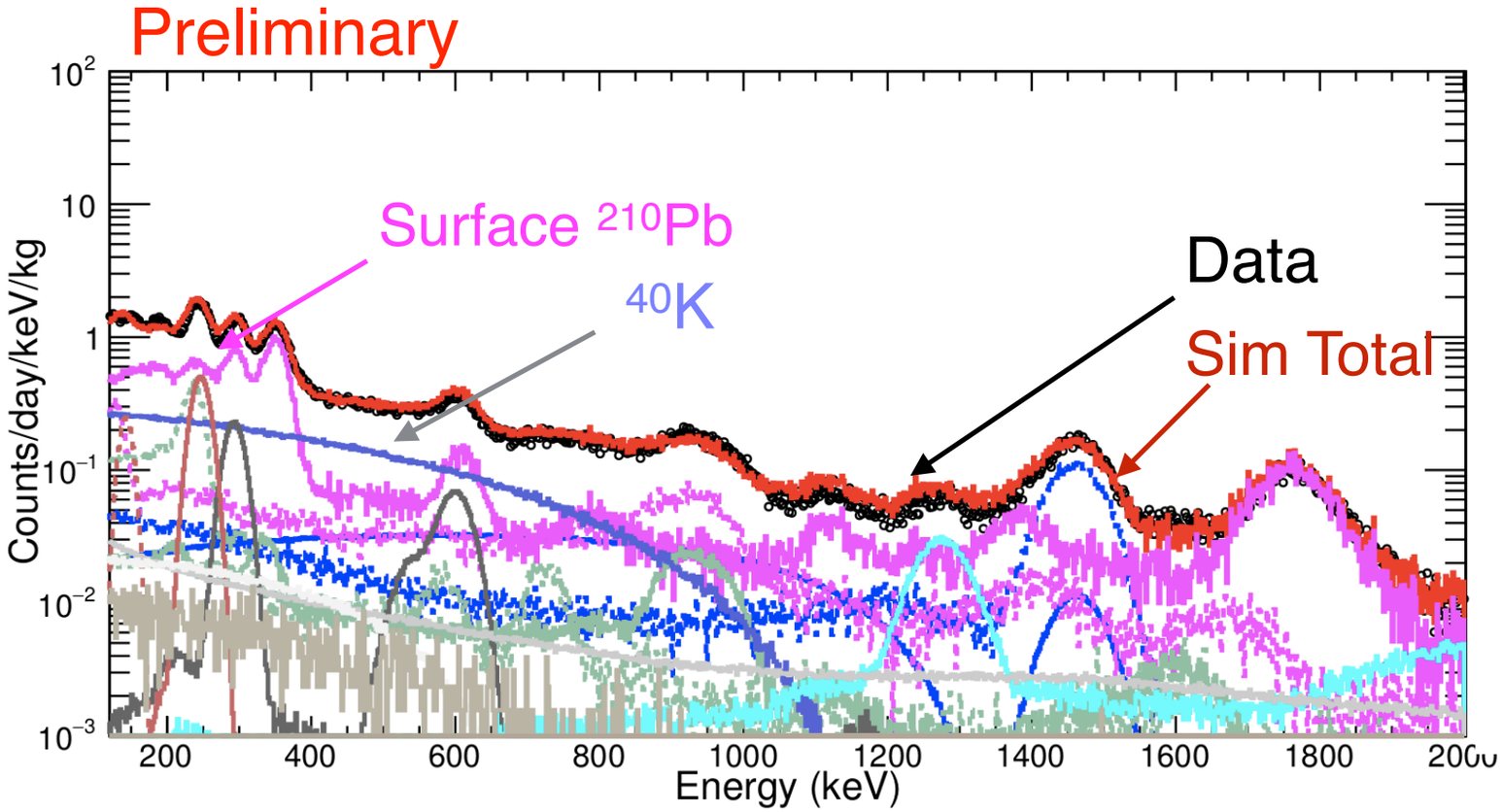


- **2 to 4 cnts/keV/kg/day** in region of interest depending on the crystal
- ^{210}Pb ($t_{1/2}$ = 22 yr), U/Th in Internal components (crystal growing/raw material)
- ^{210}Pb on crystal & PTFE surface
- Cosmogenic components: ^{125}I (59 d), ^{109}Cd (460 d), ^{3}H (12 yr)

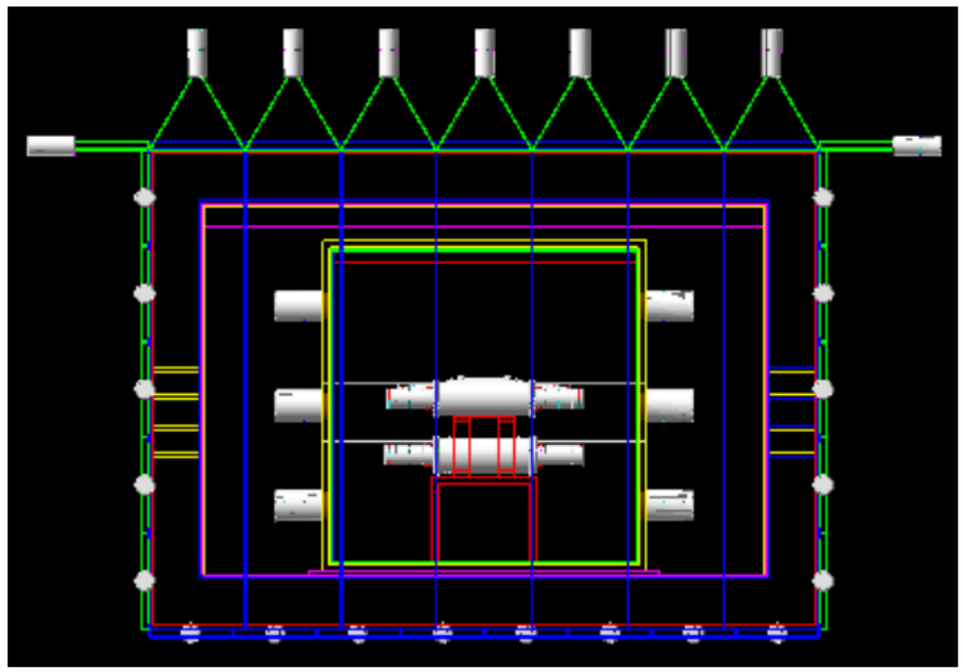
Single-site spectrum



Background in Data vs. Simulations



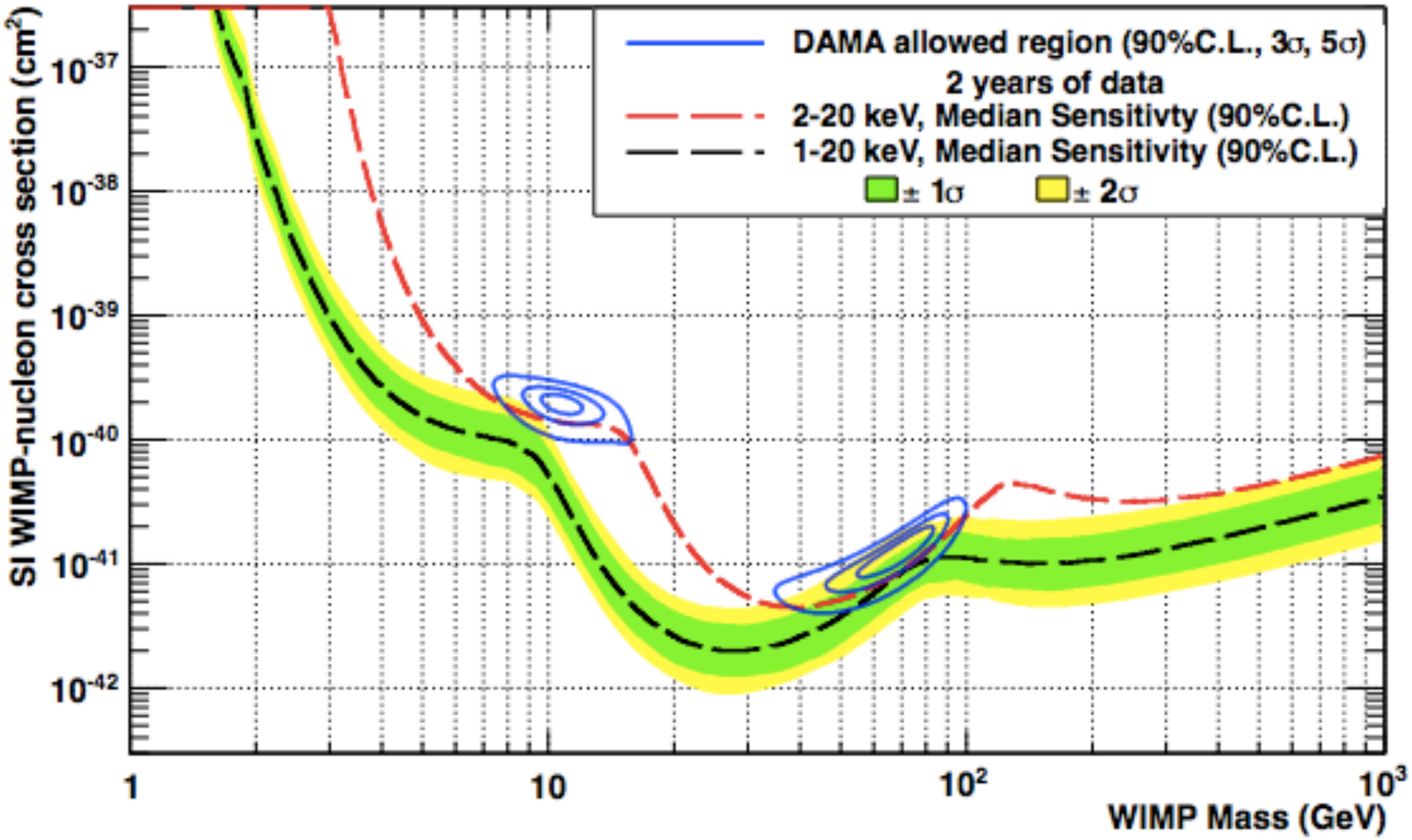
Simulation within R&D array (C3)



Detector Geometry at COSINE-100

- Geant4 simulation
- Reproduces data well, cosmogenic activation depends on crystal
- Surface ^{210}Pb is dominant background, followed by ^{40}K internal to crystal

Expected Sensitivity of COSINE-100



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

Sensitivity comparable with DAMA's allowed region.

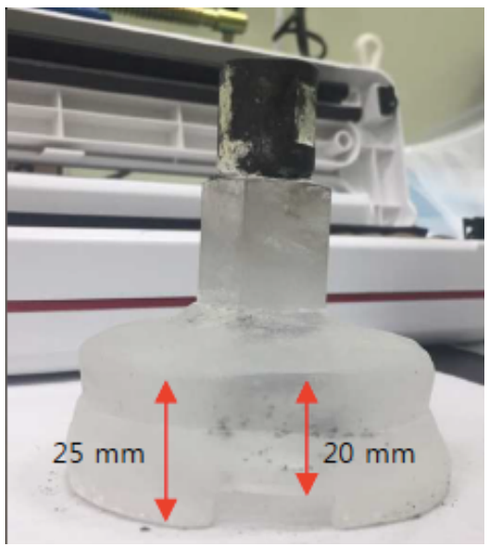
COSINE-200 (Phase-II)

Goal : Reach background < DAMA (1 dru)

Needs a factor two or more improvement

R&D at IBS in Korea

Powder	^{39}K (ppb)		^{208}Pb (ppb)	
	Initial	After	Initial	After
Astro grade	4.5	<1.0	0.9	<0.4
Crystal grade	45.1	6.0	3.3	0.8
Cian (99.5%)	180000	1305	5.7	<0.4

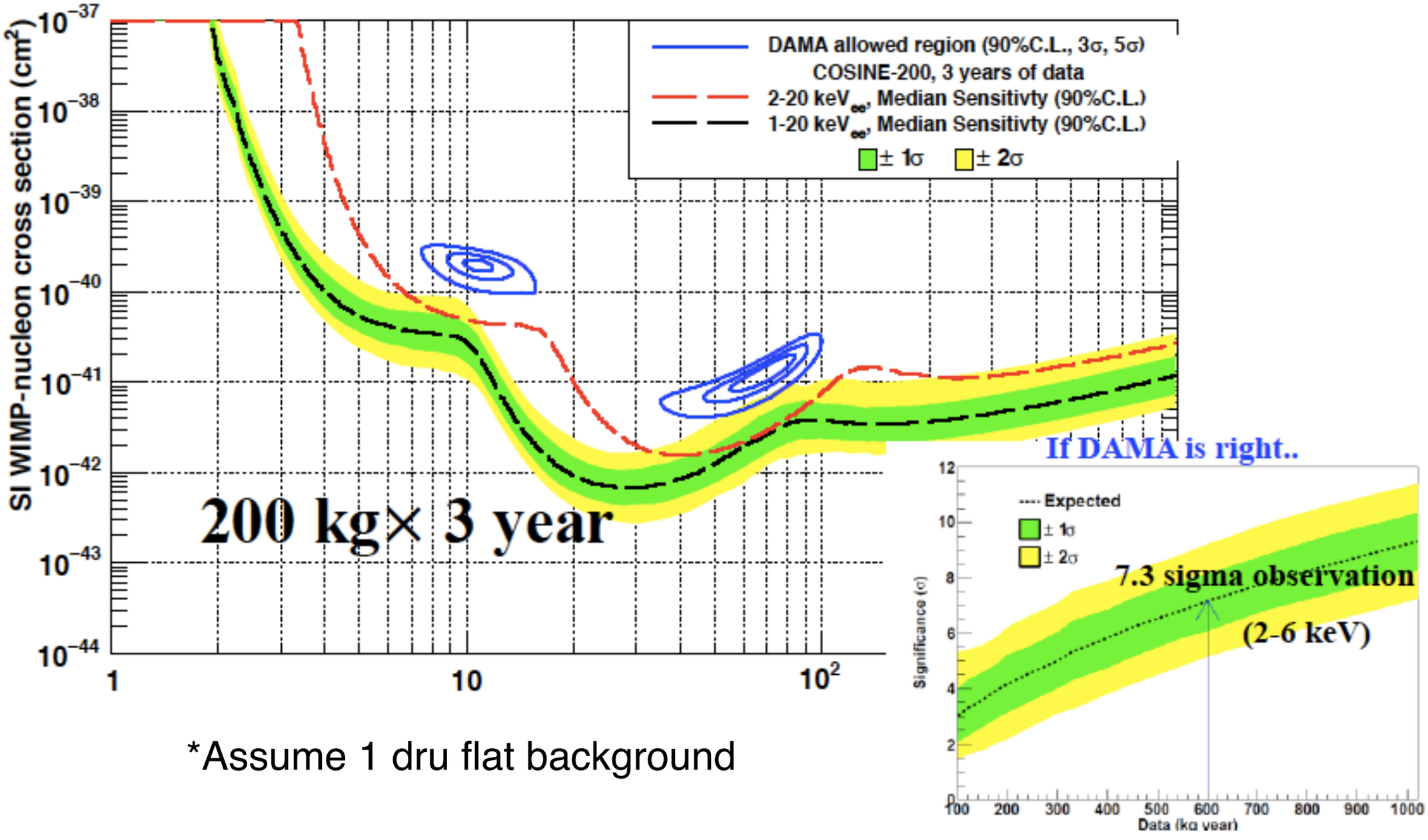


Powder purification (Recrystallization)

Crystal growing & Handling
Established a facility at our center

Powder purification
(mass production facility for purification under construction)

Expected sensitivity for COSINE-200 (Phase-II)



*Assume 1 dru flat background

Summary

see also Poster 253: William Thompson

- COSINE-100= DM-Ice + KIMS w/ goal to test DAMA's claim for dark matter observation
- COSINE-100 Physics run has started on September 2016
- COSINE-100 = 8 crystals, 106 kg + 2000 liters of LAB-based liquid scintillator veto + muon tagging panels
- Initial performance of COSINE-100 is promising. 2 keV threshold, 2-4 dru at ROI
- Expect to have DAMA-comparable sensitivity in ~2 years
- Continued R&D for higher purity crystals for COSINE-200 (Phase-II)