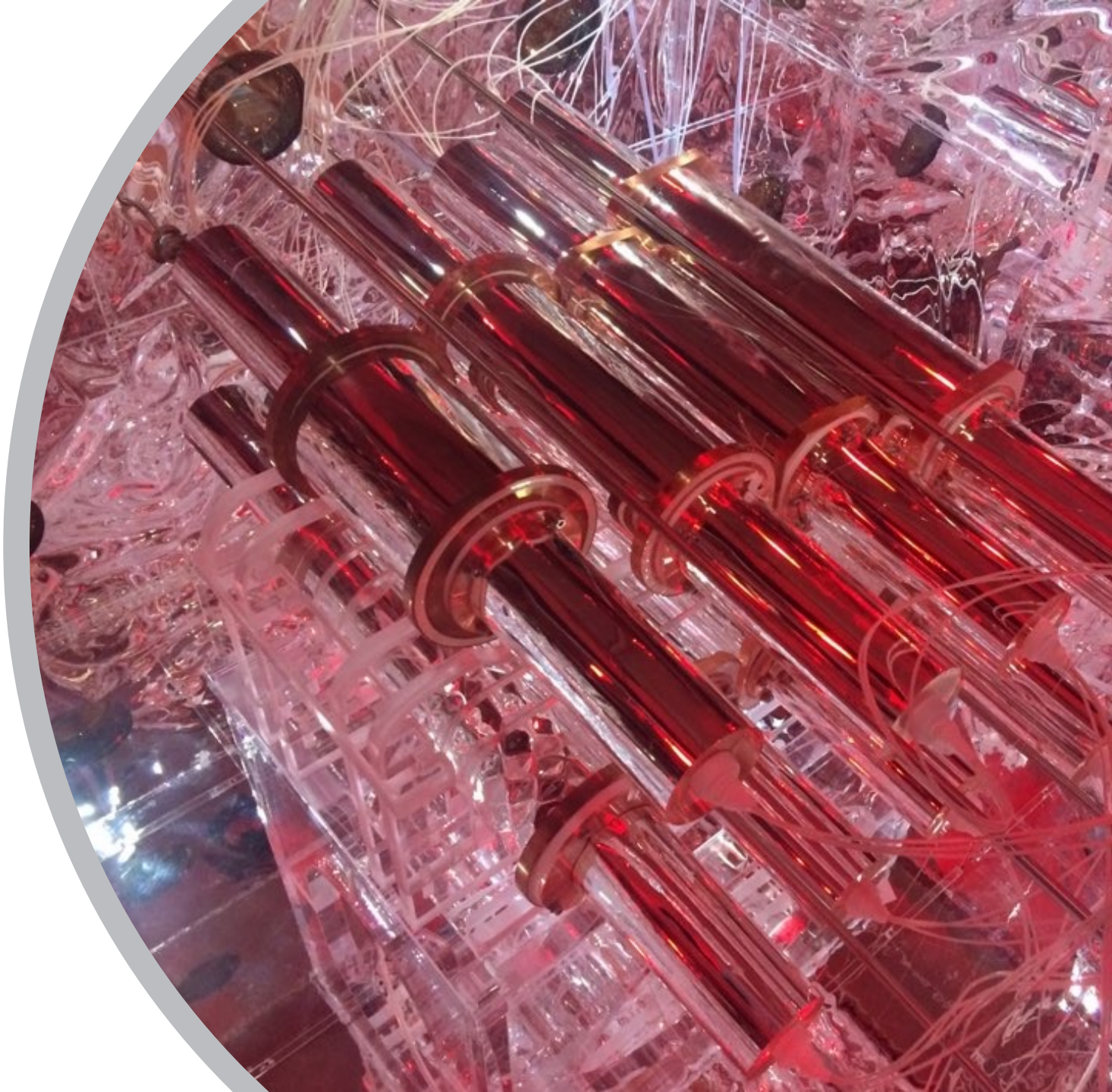
Testing DAMA with New Results from COSINE-100

Will Thompson
On Behalf of the COSINE-100 Collaboration
Lake Louise Winter Institute 2022
February 22nd, 2022



Yale

Wright Laboratory

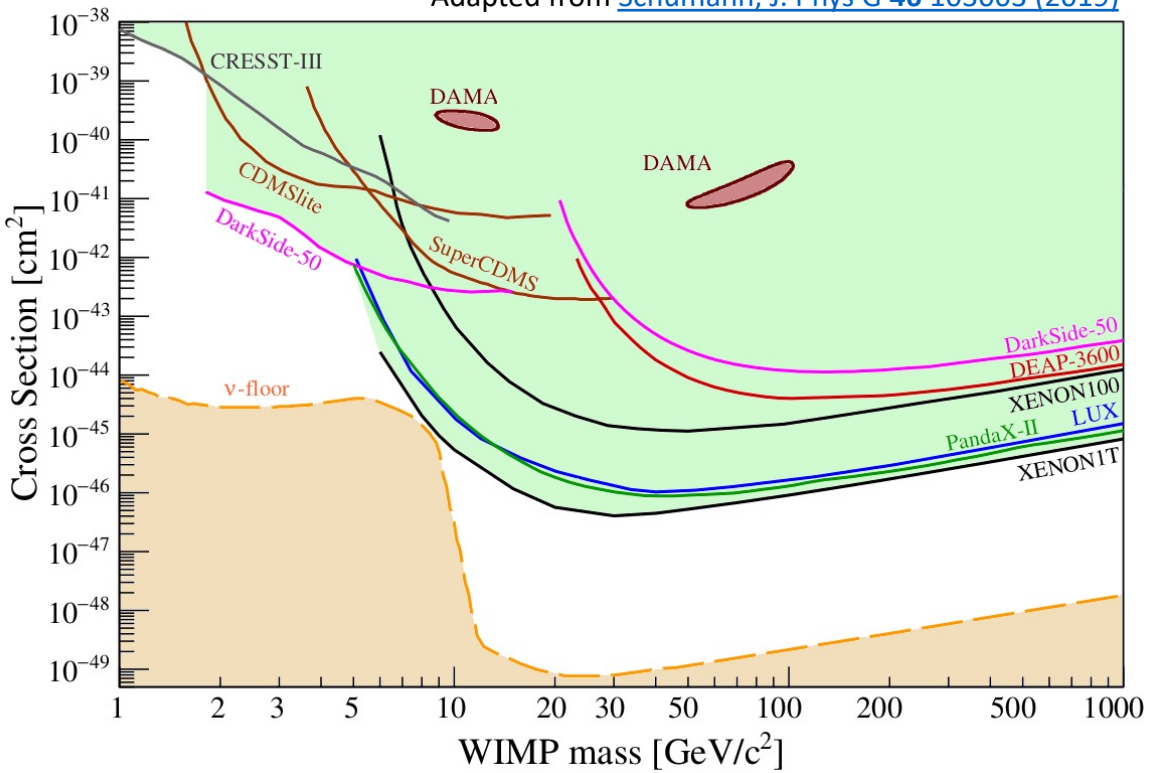
Motivation for COSINE-100

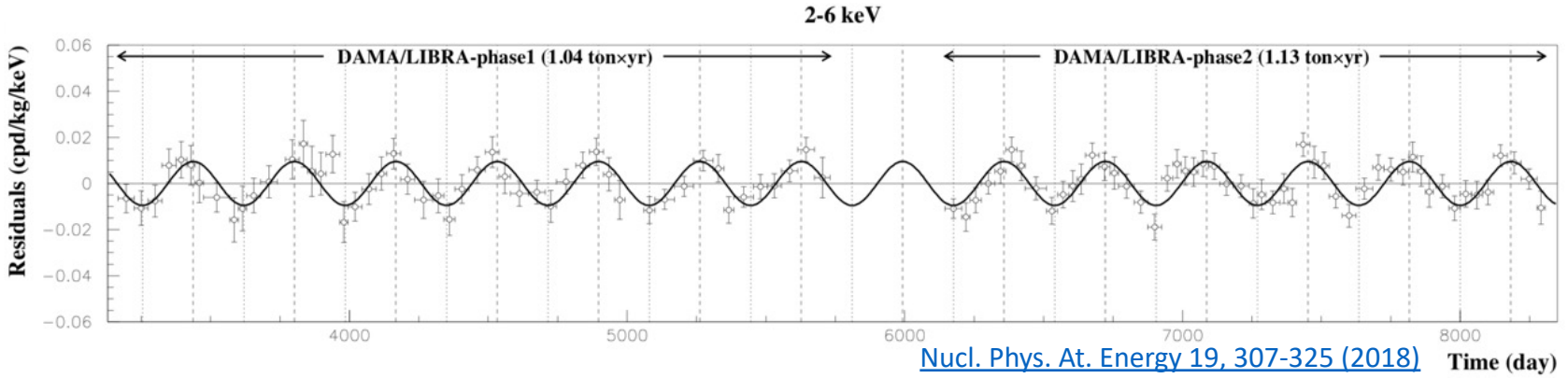
- DAMA observes annual modulation at 12.9σ C.L.
  - Phase & period consistent with dark matter origin
  - Observed over ~2 decades

- But result in conflict with direct detection searches using different target materials!

- Another NaI(Tl) experiment required for definitive test

Adapted from Schumann, J. Phys G **46** 103003 (2019)





Nucl. Phys. At. Energy 19, 307-325 (2018)

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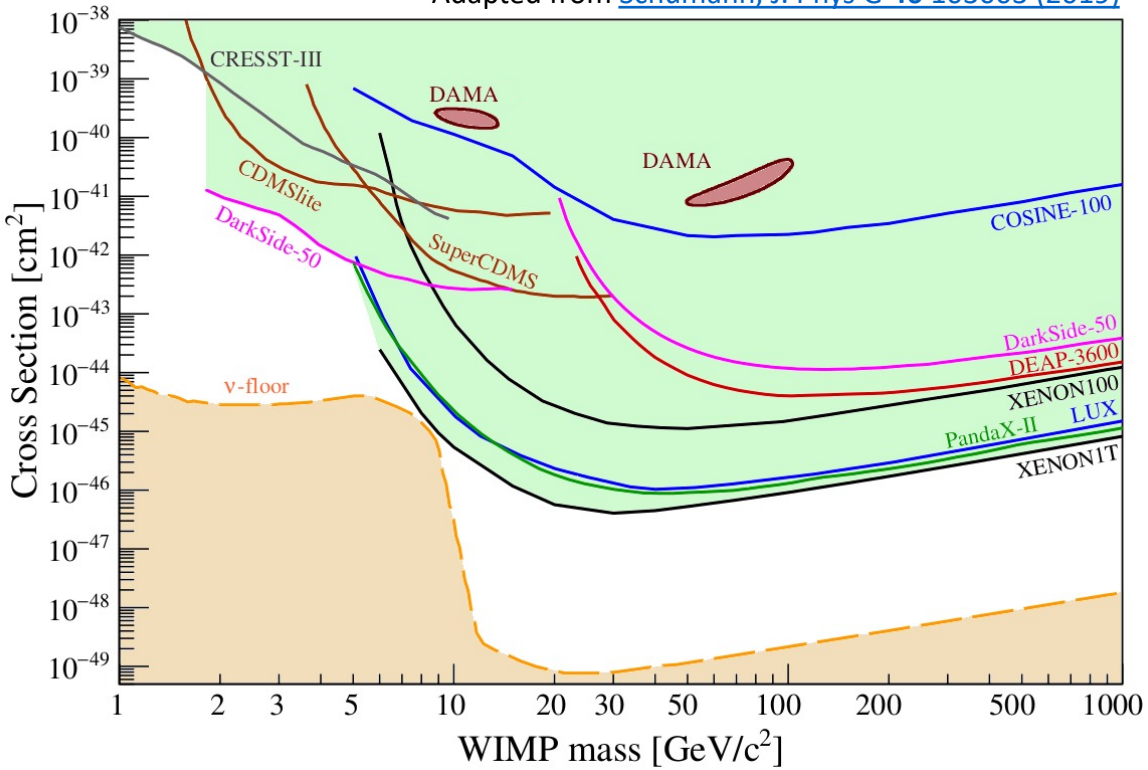

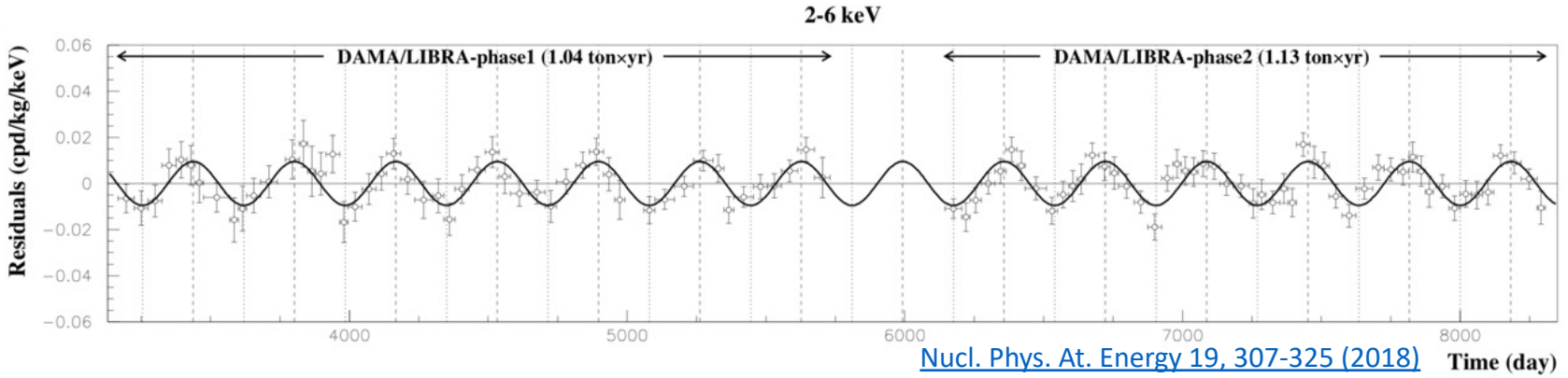

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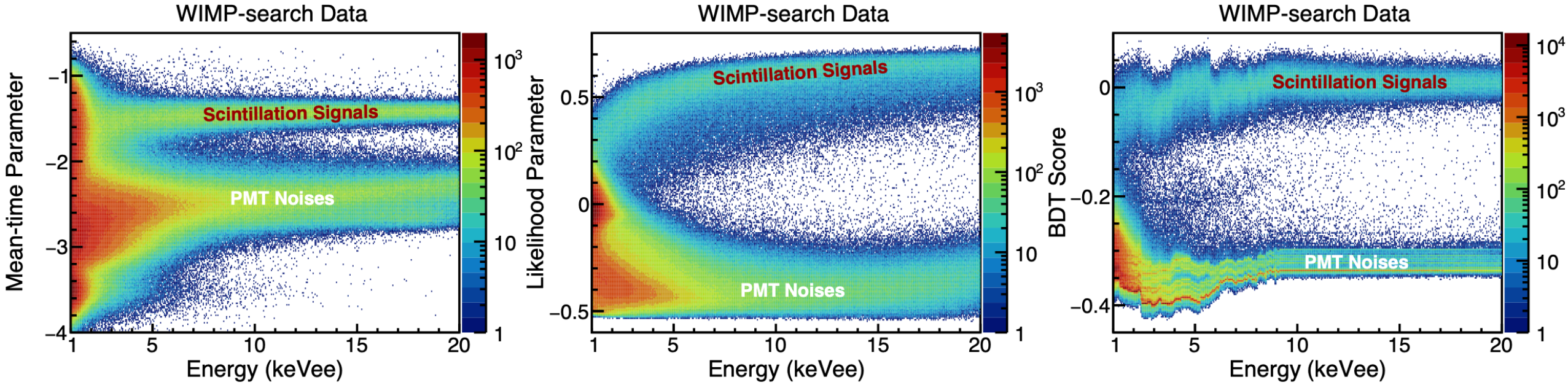
Lowering Analysis Threshold to 1 keV

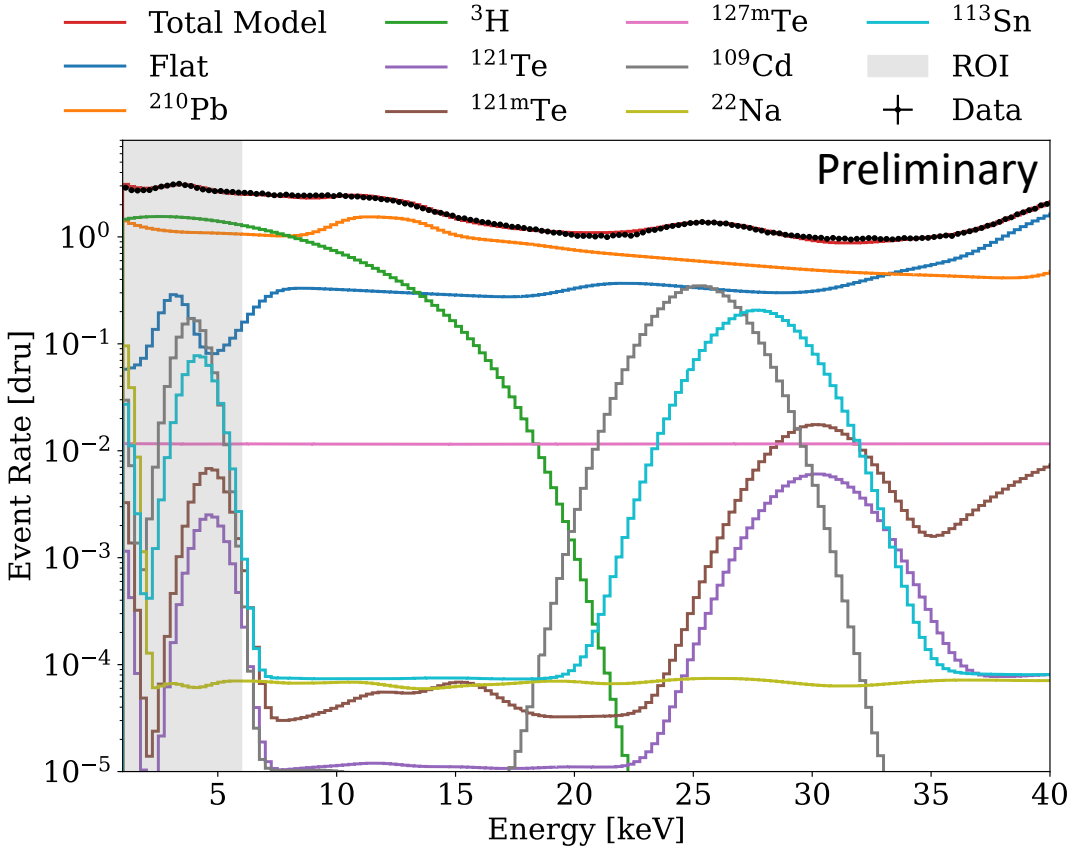
PRD Accepted, arXiv:2110.05806

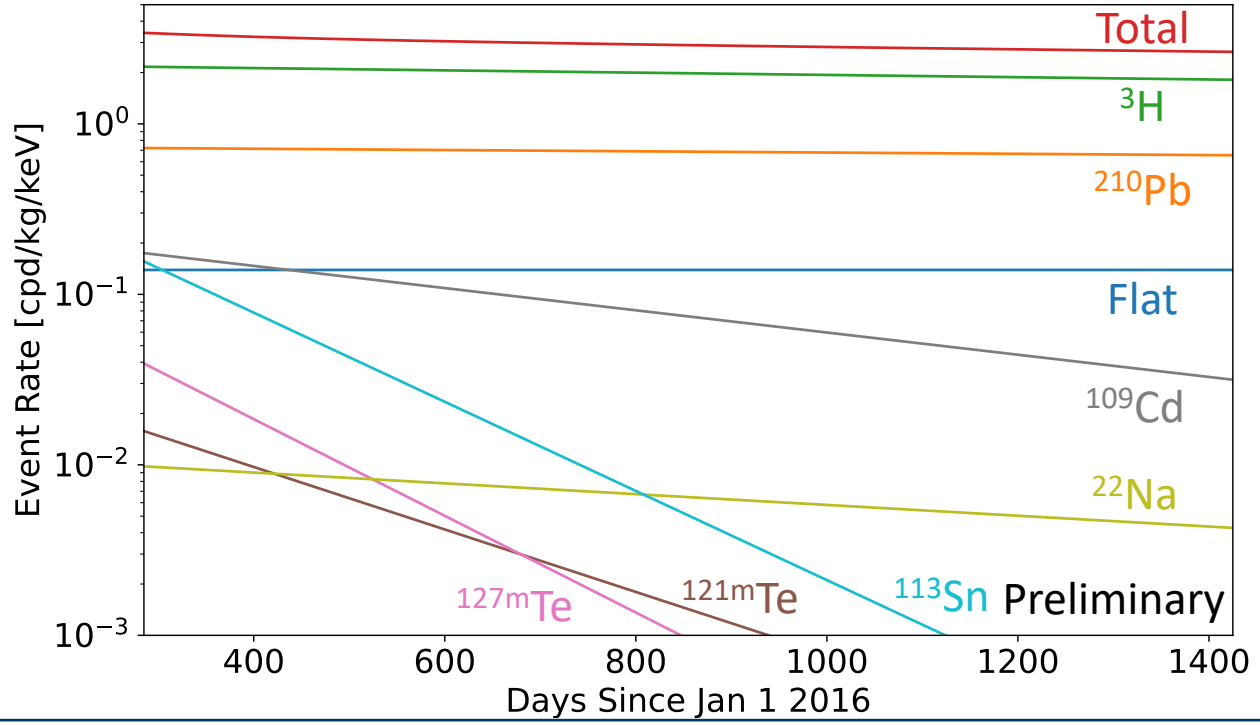


- Previous event selection effectively separated signal & noise down to 2 keV
- Developed new waveform template comparison-based discrimination method, enabling 1 keV threshold
  - Quantified by “likelihood parameter”

Time-Dependent Background Model

- New: Detailed study of short-lived cosmogenics
- Enables time-dependent modeling of each short-lived isotope
- Previous modulation search: flat + exponential background

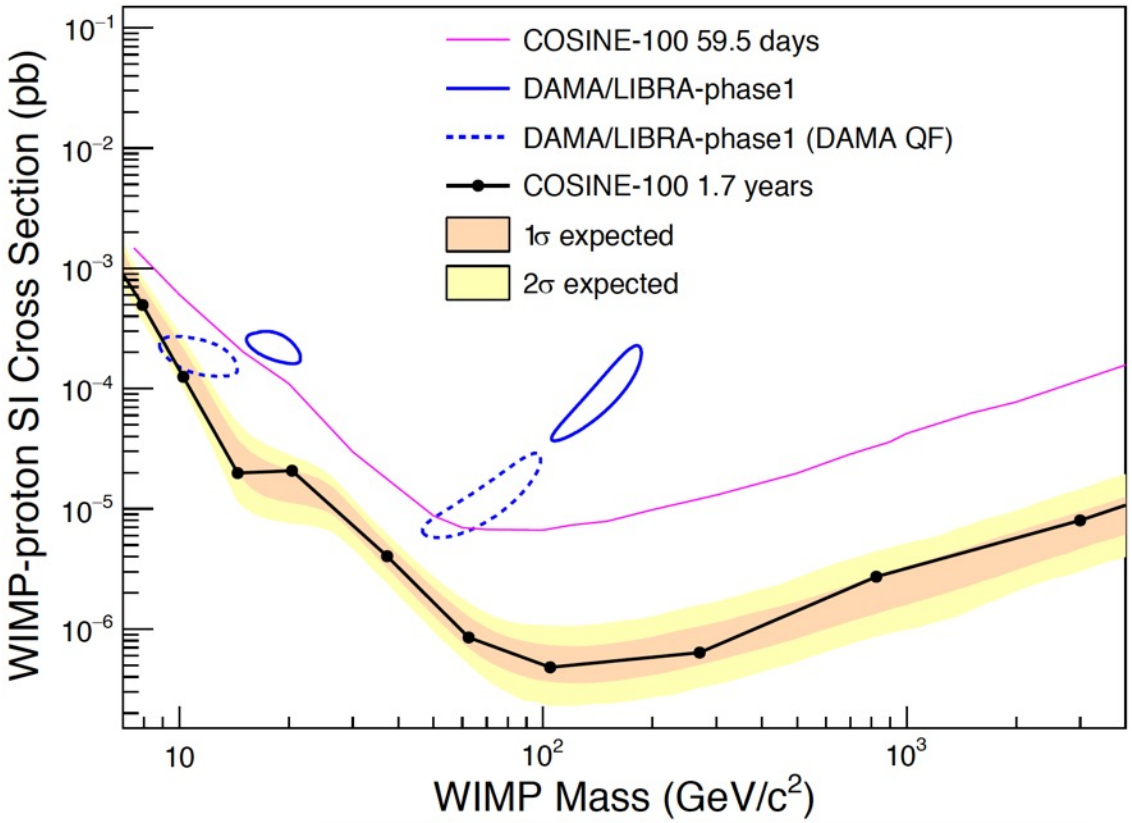




Model-Dependent WIMP Search

WIMP Search – Results

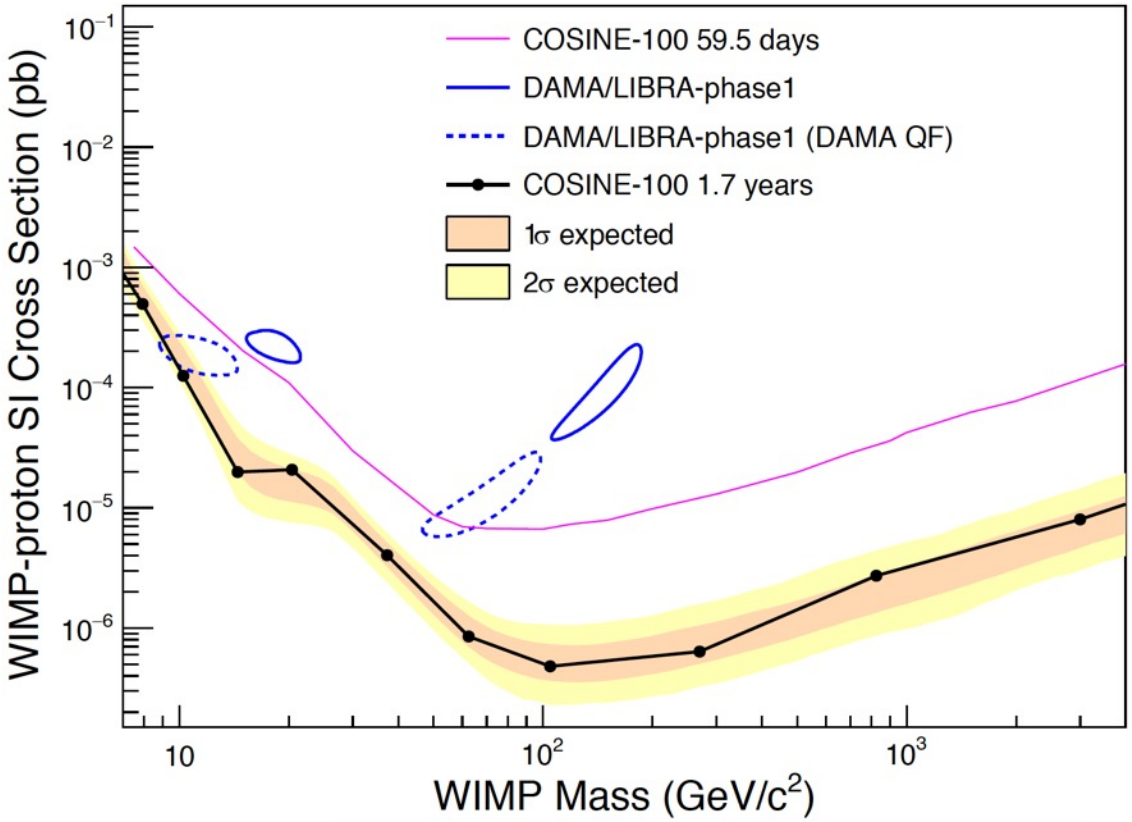
Sci. Adv. **7** 46 (2021)

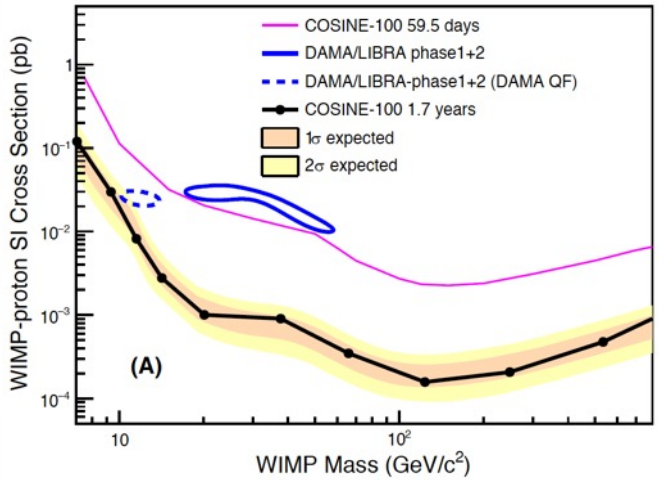


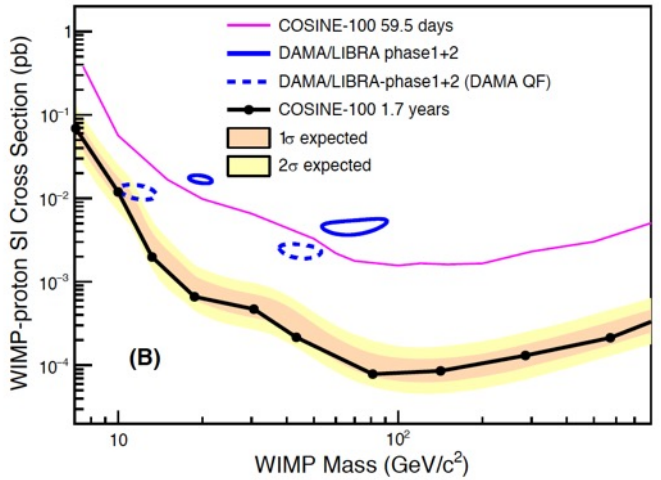
- Order of magnitude increase in exclusion limit compared with first result
- Fully exclude DAMA in alternative WIMP EFT operators, QFs
  - Difficult to reconcile DAMA result in standard WIMP picture

WIMP Search – Results

Sci. Adv. **7** 46 (2021)







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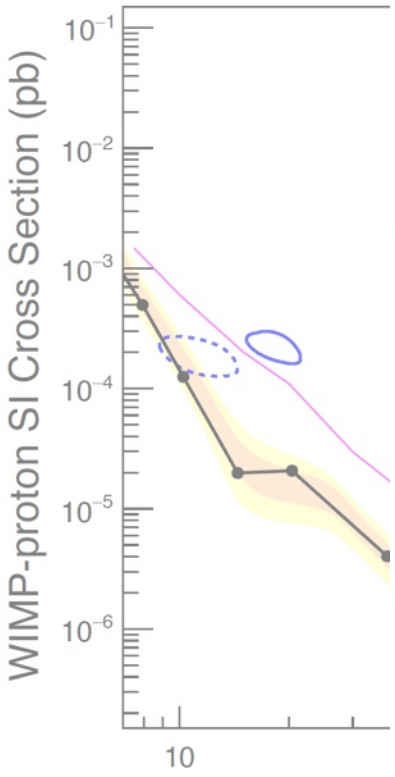
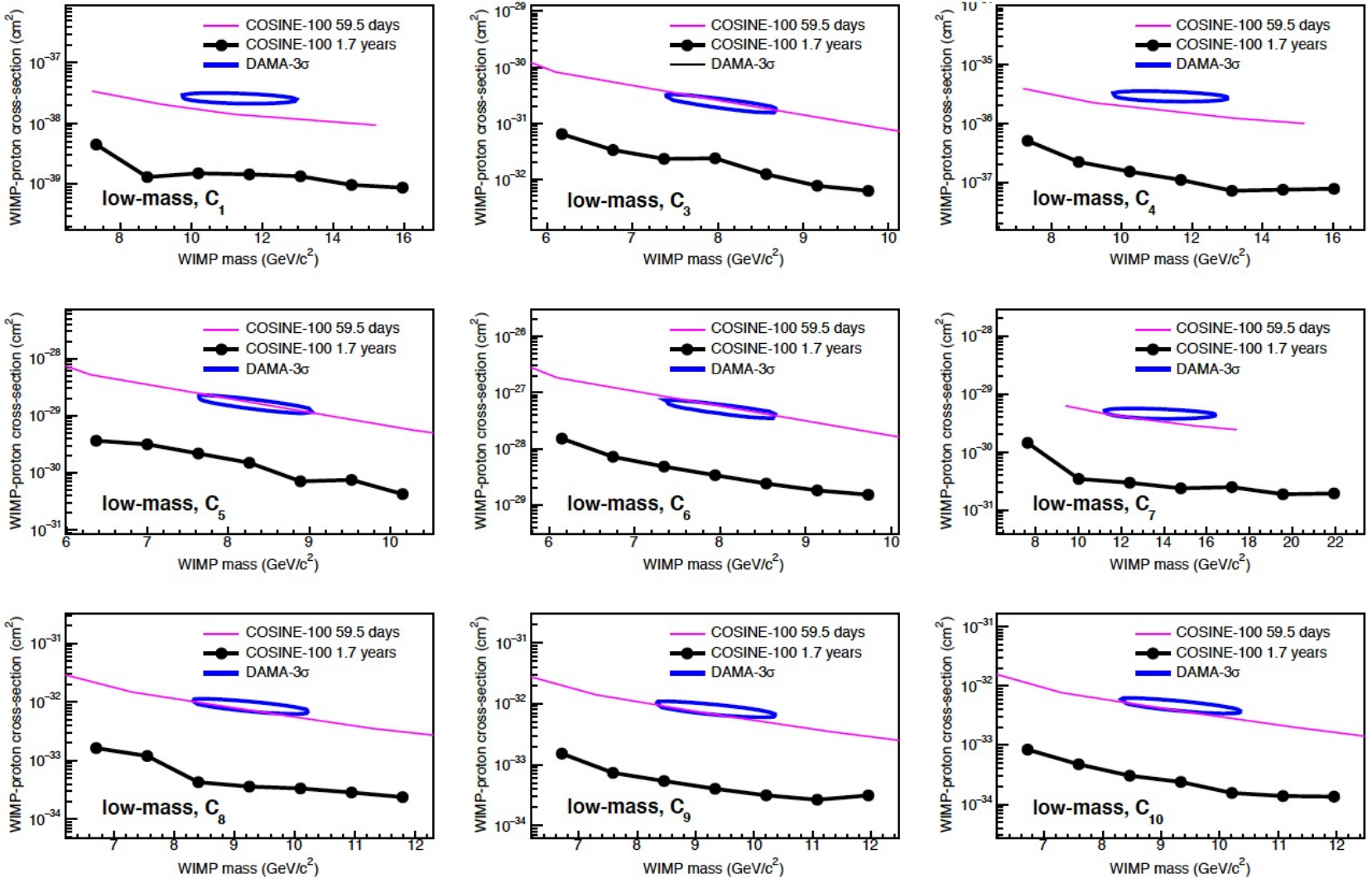
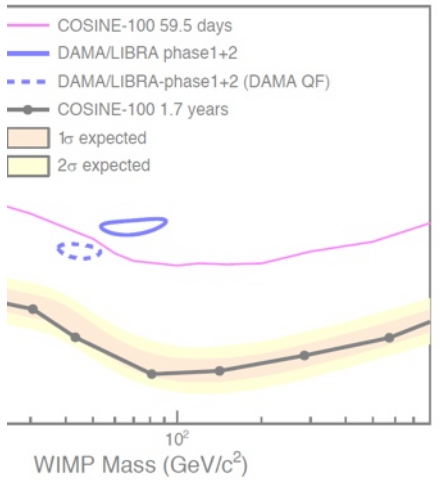
WIMP Sear

46 (2021)







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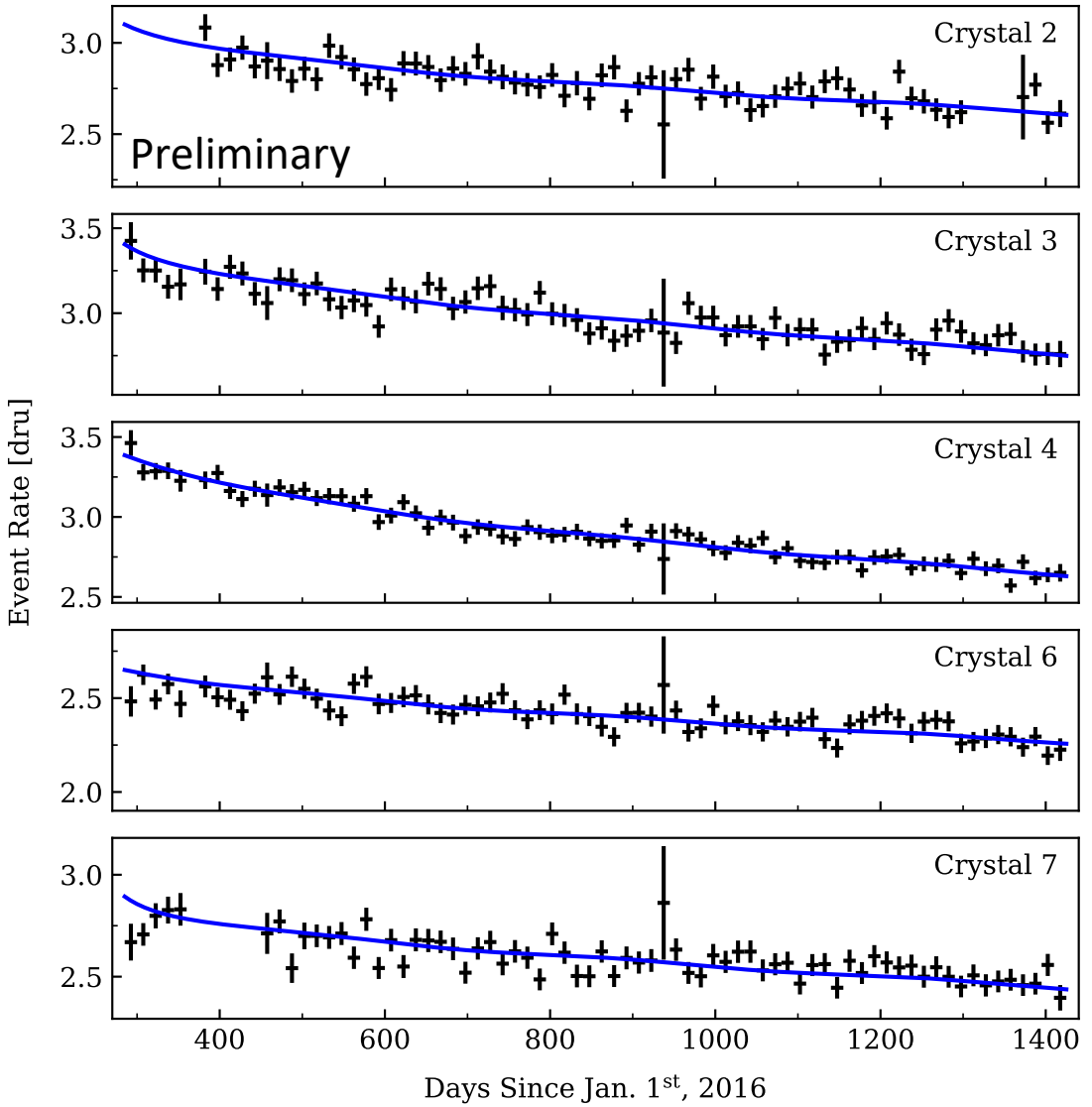
- Fully exclud
  - Difficult tc

Annual Modulation Search

Three-Year Modulation Search – Results

$$R(t) = \sum_i \left[C^i + \sum_{j=1}^{8} A_j^i e^{-\lambda_j t} \right] + S_m \cos\left(\frac{2\pi(t-t_0)}{T}\right)$$

- Five detectors fit with:
  - Constant from long-lived backgrounds
  - Exponential decays from short-lived cosmogenics
  - Modulation signal – fixed period and phase



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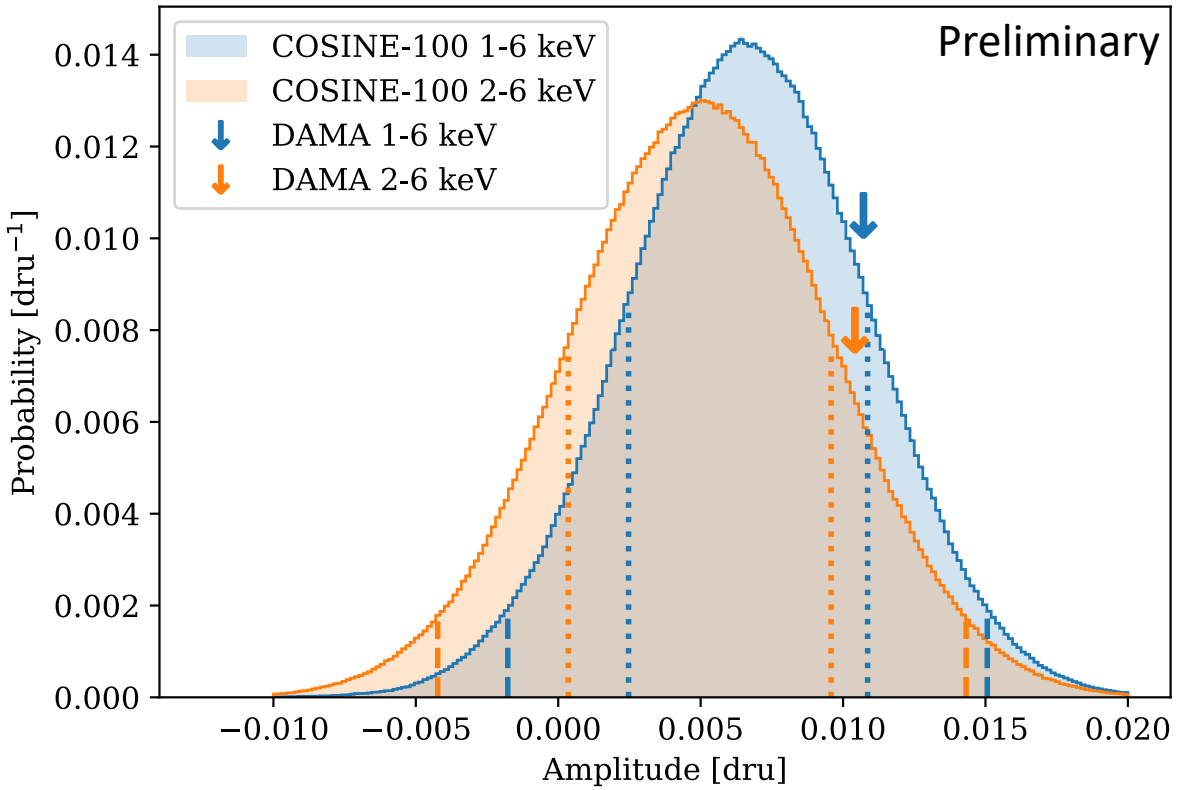
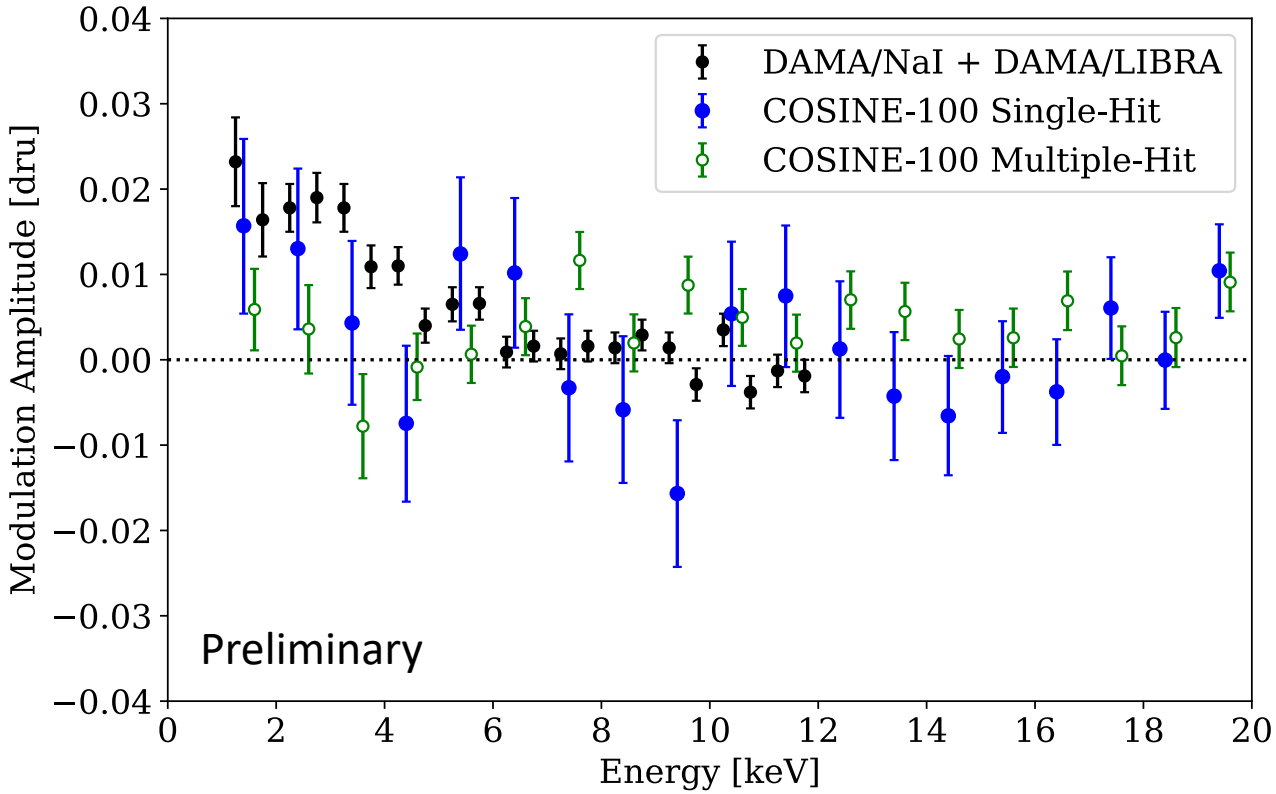
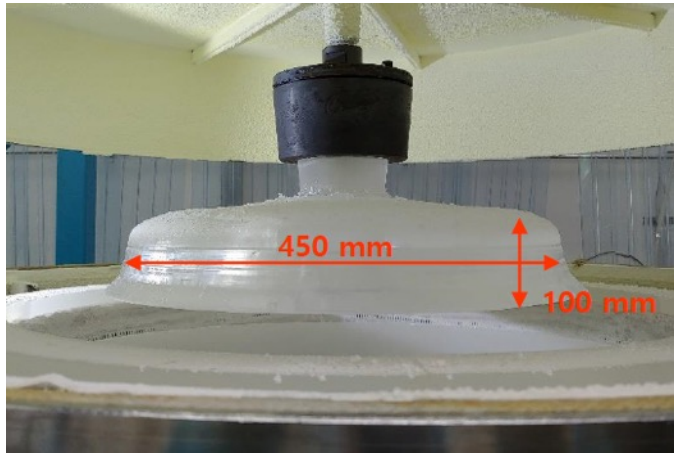


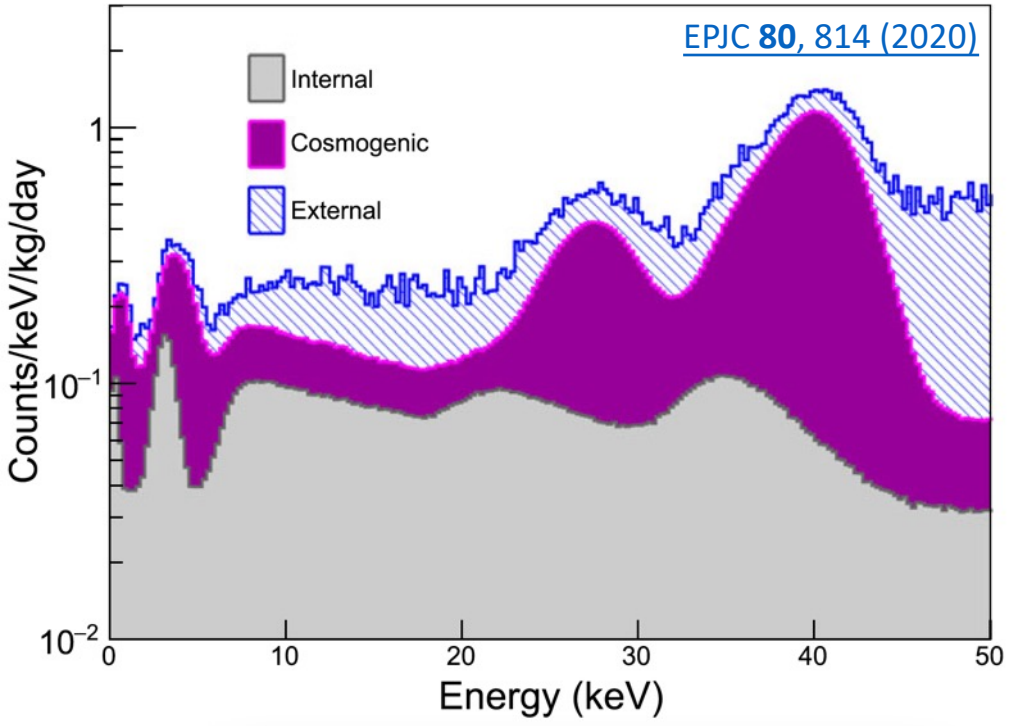


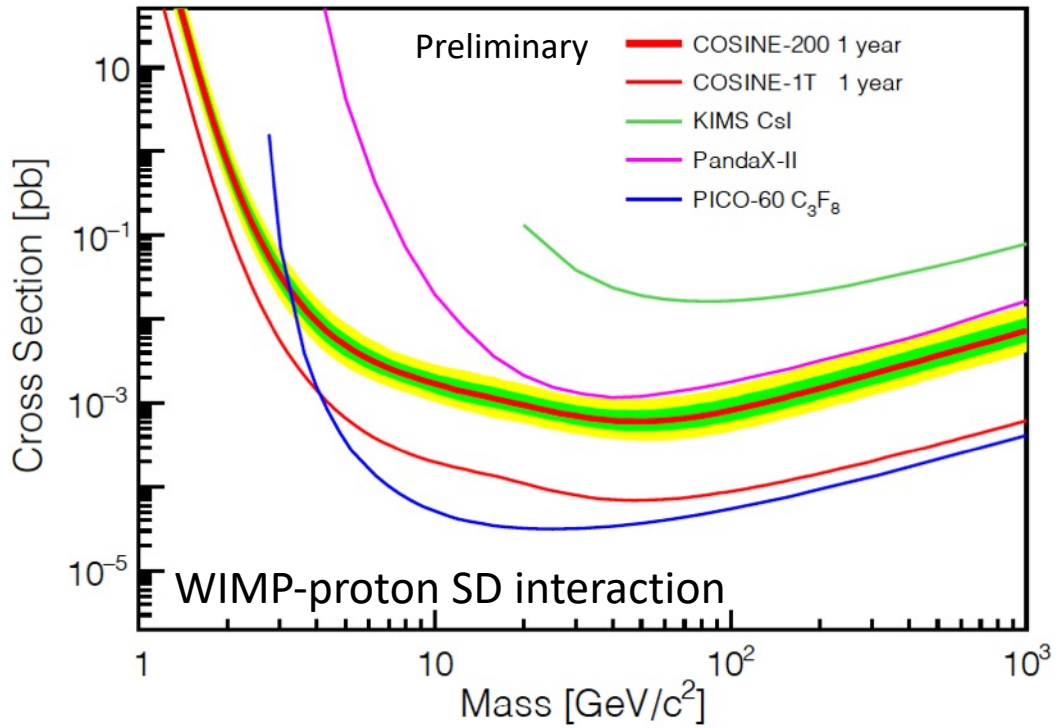
- Best-fit modulation amplitude of 0.0067 ± 0.0042 cpd/kg/keV at 1-6 keV
- COSINE-100 consistent with both DAMA and no modulation with 3 years of data
- Lack of modulation in sidebands certifies analysis procedure

Next Phase: COSINE-200

- COSINE-100 will continue data-taking until late 2022
- COSINE-200 will use same shielding structure and feature:
  - <1 cpd/kg/keV background with detectors developed in-house
  - 50% increase in light yield with new encapsulation design







Summary

- COSINE-100 strongly rules out DAMA result as originating from WIMPs in various interaction models

- Annual modulation search currently statistics limited; not able to distinguish DAMA- and no-modulation cases

- COSINE-100 will continue to take data until late 2022, when COSINE-200 begins commissioning

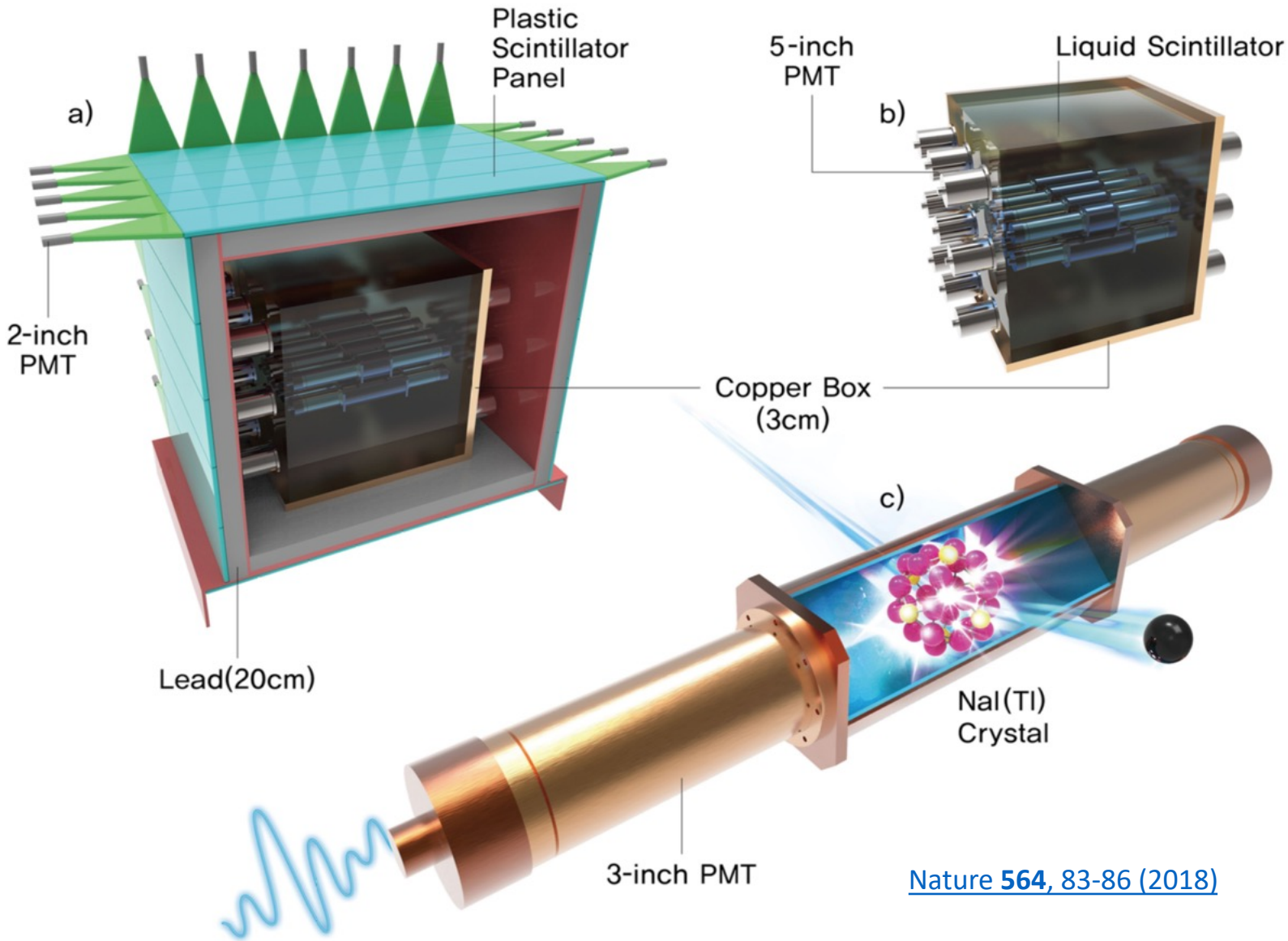
Thank You!

http://cosine.yale.edu/

COSINE-100 from 30,000 ft.

- Joint effort between KIMS and DM-Ice
- 8 NaI(Tl) detectors totaling 106 kg
- Located 700 m underground at Yangyang Underground Lab in Korea
- Physics run began Sept. 2016

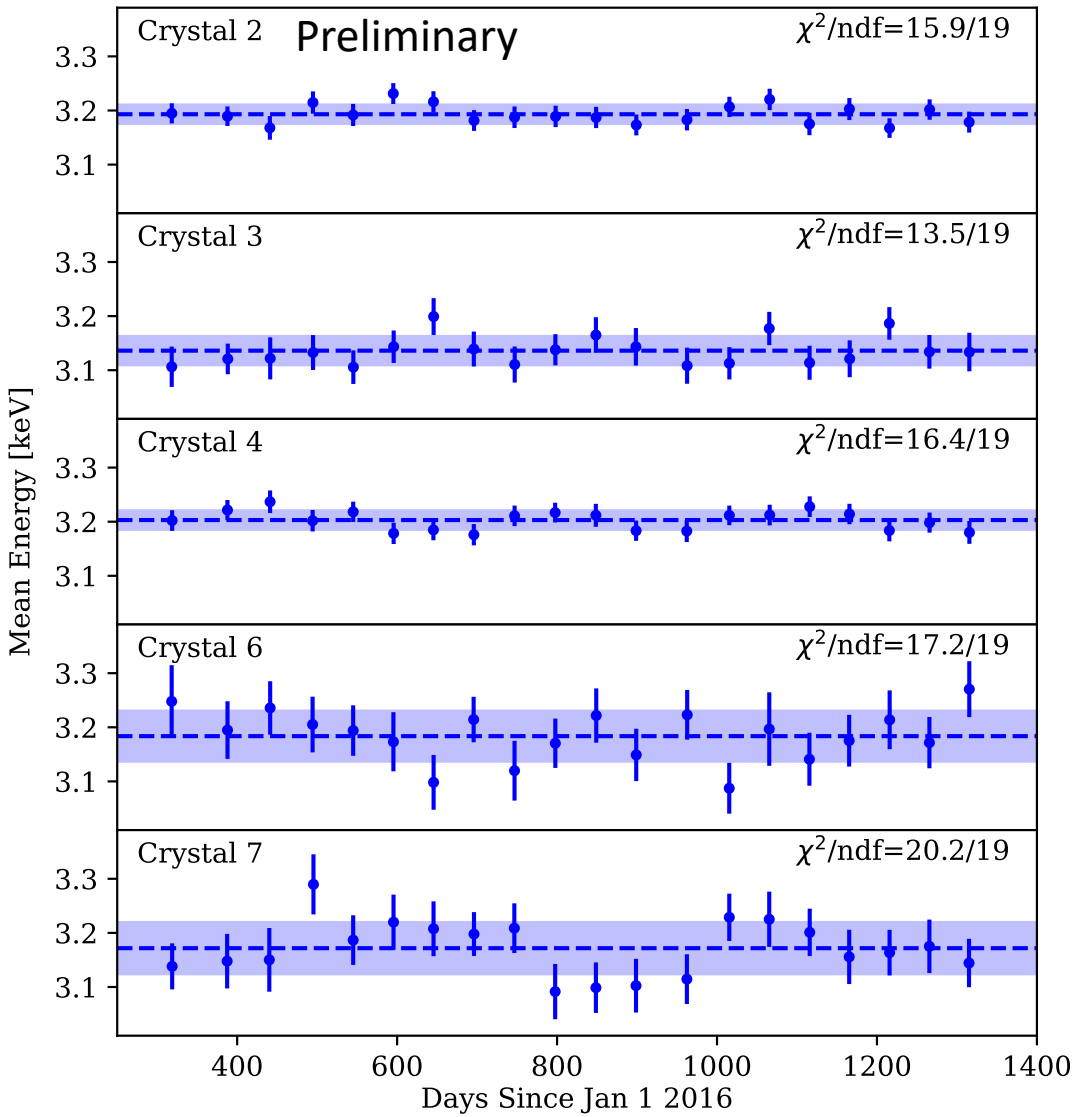
COSINE-100 Detector Design



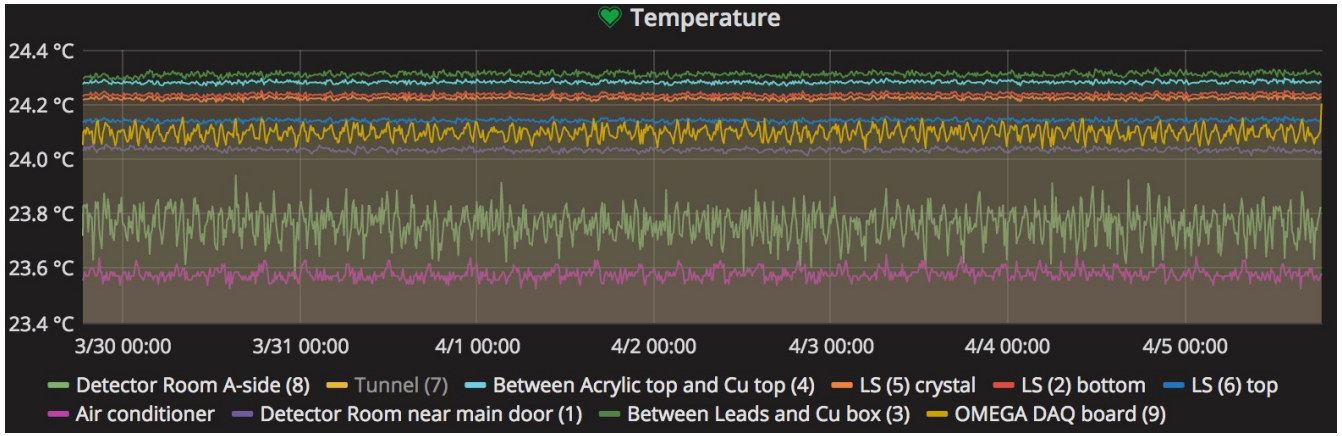
Nature **564**, 83-86 (2018)

- 8 low-background NaI(Tl) detectors
- 2200 L liquid scintillator veto
- 3 cm-thick copper box and 20 cm-thick lead shielding
- 37 plastic scintillator panels for 4π muon detection

Detector Stability

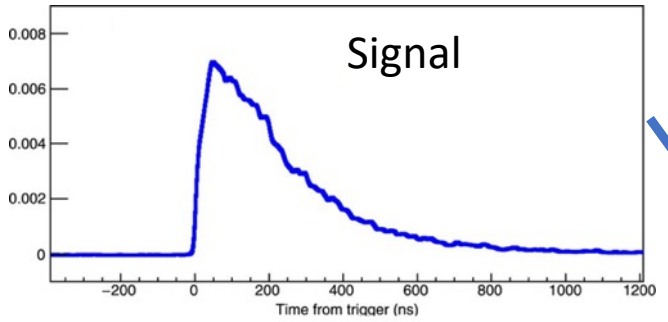


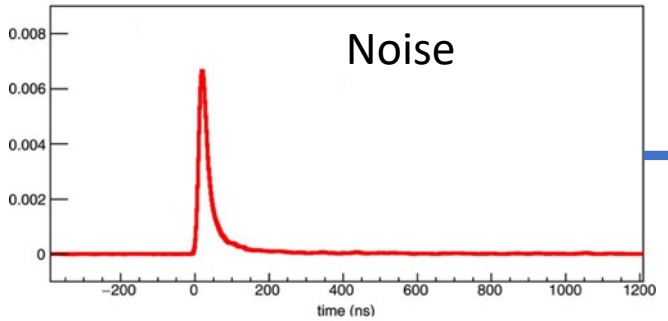
- Detector stability crucial for annual modulation search
- Environmental conditions continually monitored
- Energy scale stability verified by tracking measured energy of 3.2 keV decay from ^{40}K over time

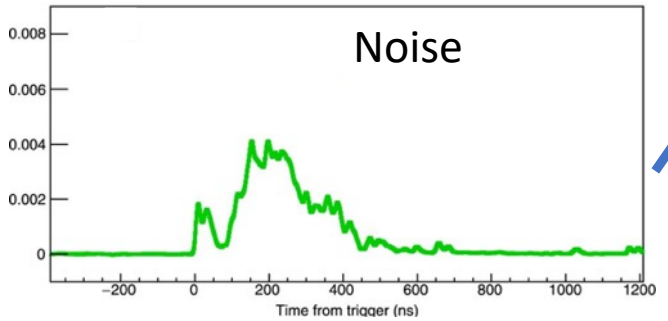


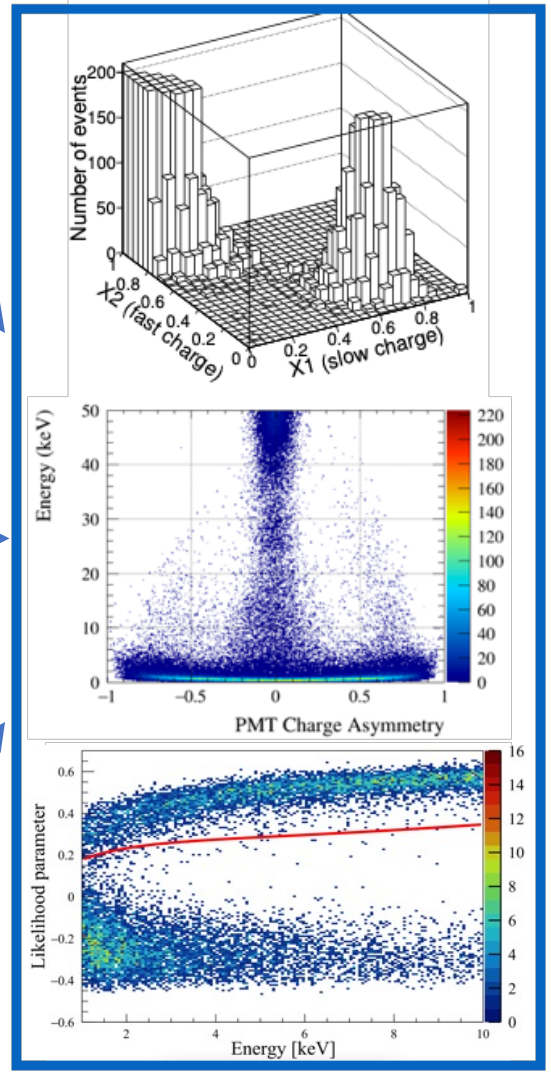
Lowering Analysis Threshold to 1 keV

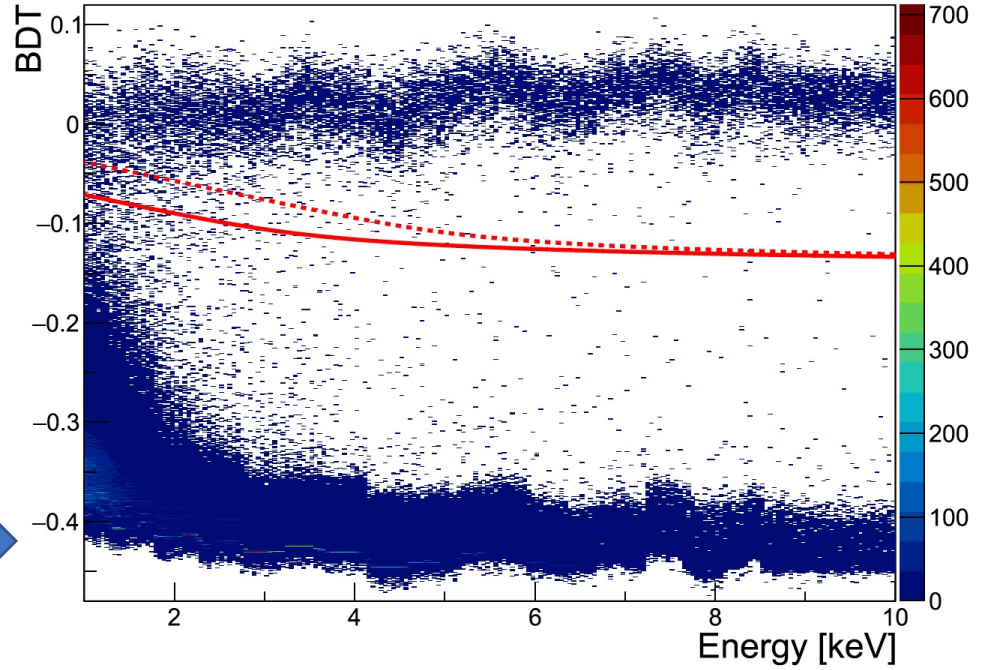
Astropart. Phys. **130** 102581 (2021)

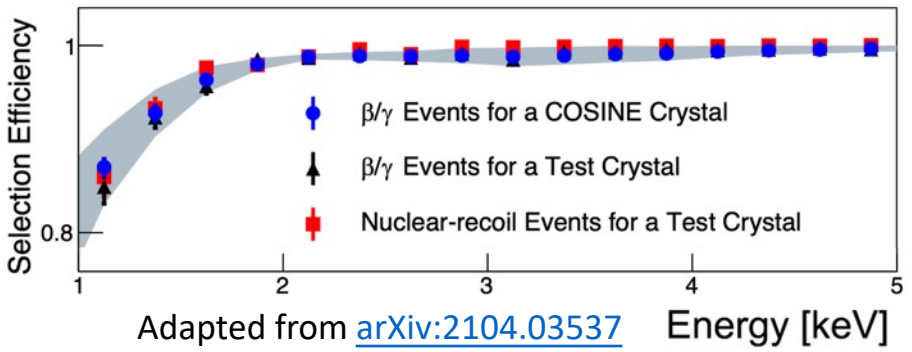








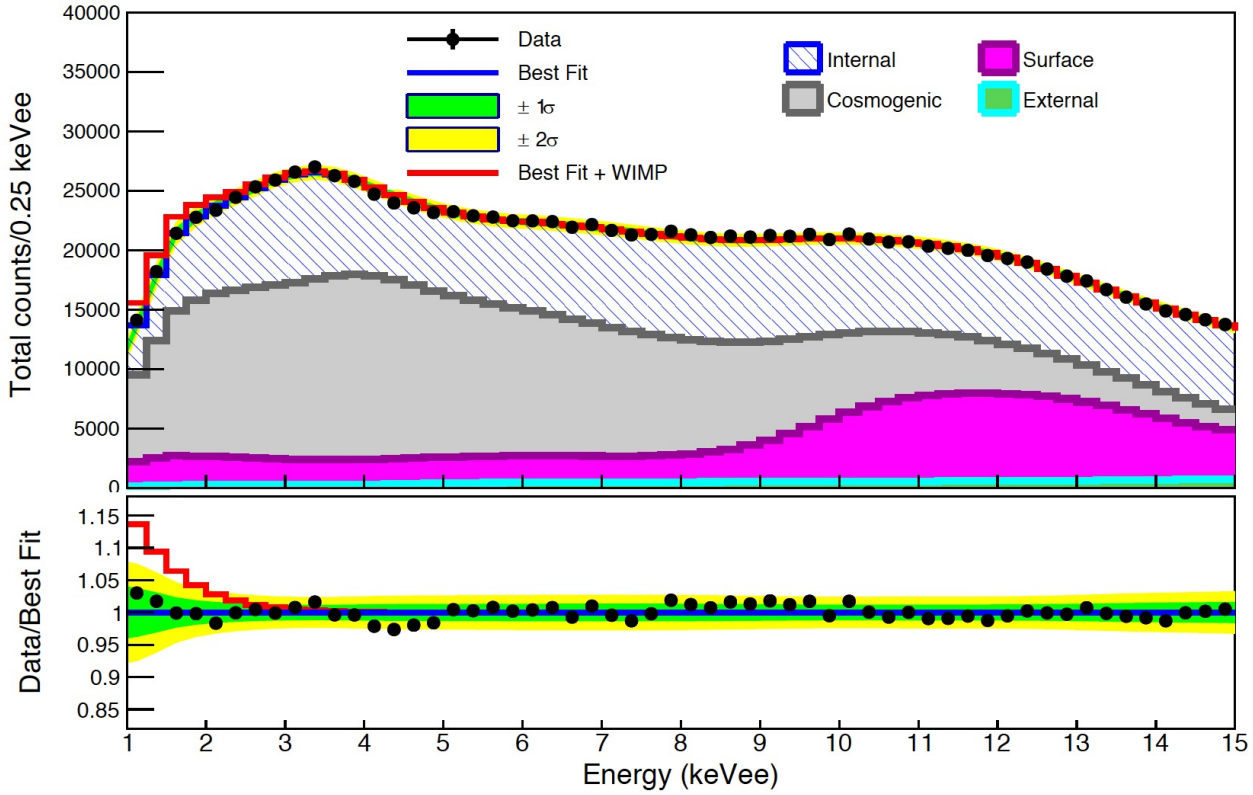


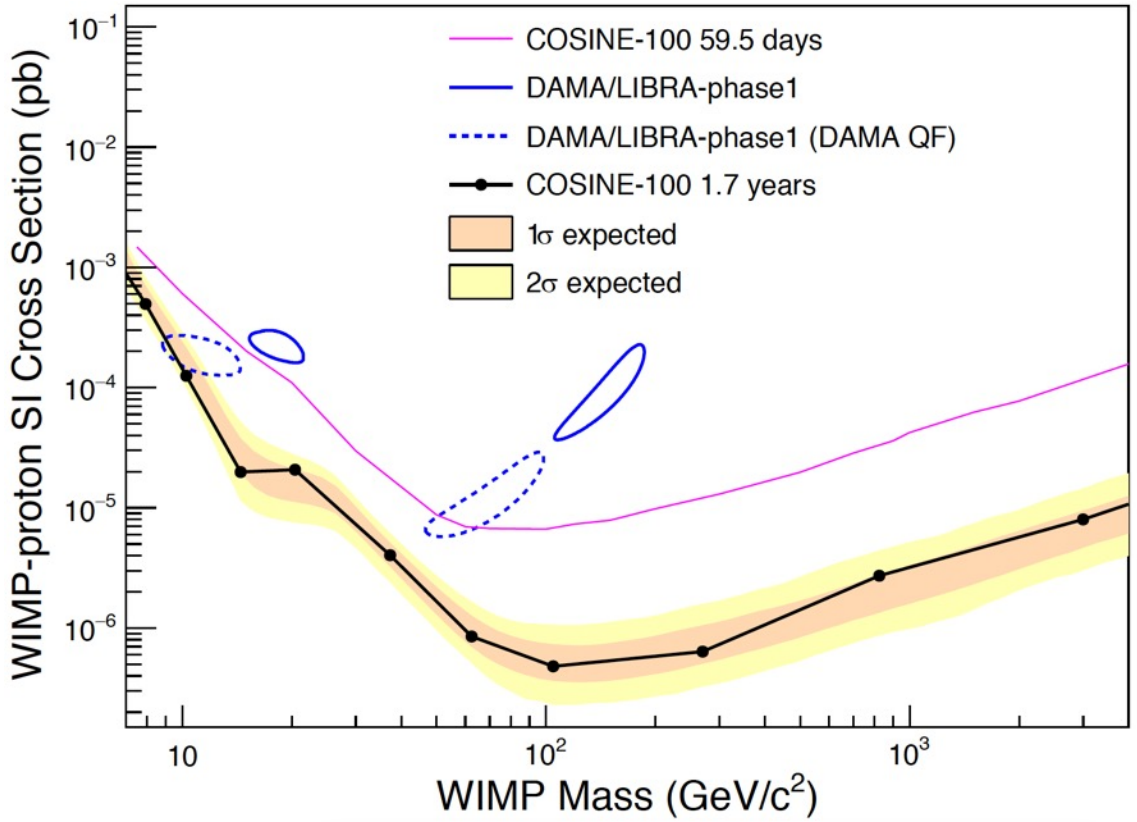


Adapted from arXiv:2104.03537

WIMP Search – Results

arXiv:2104:03537





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Modulation Search – Fitting Strategy & Bias Assessment

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- Five detectors fit with:
  - Constant from long-lived backgrounds
  - Exponential decays from short-lived cosmogenics
  - Modulation signal – fixed period and phase
- Utilize Bayesian fitting approach
- Pseudo-experiment study shows new model significantly reduces bias