

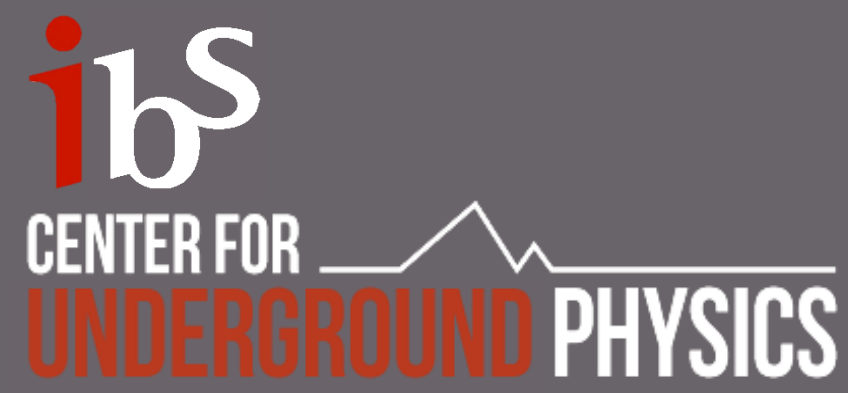
Resolving the DAMA/LIBRA Anomaly with the Full COSINE-100 Dataset

Dataset

Hyunsu Lee

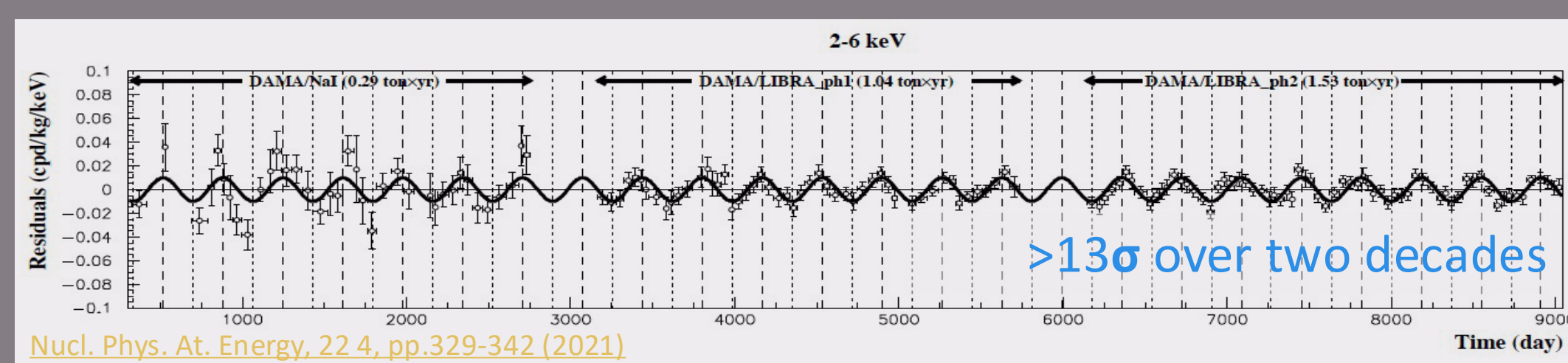
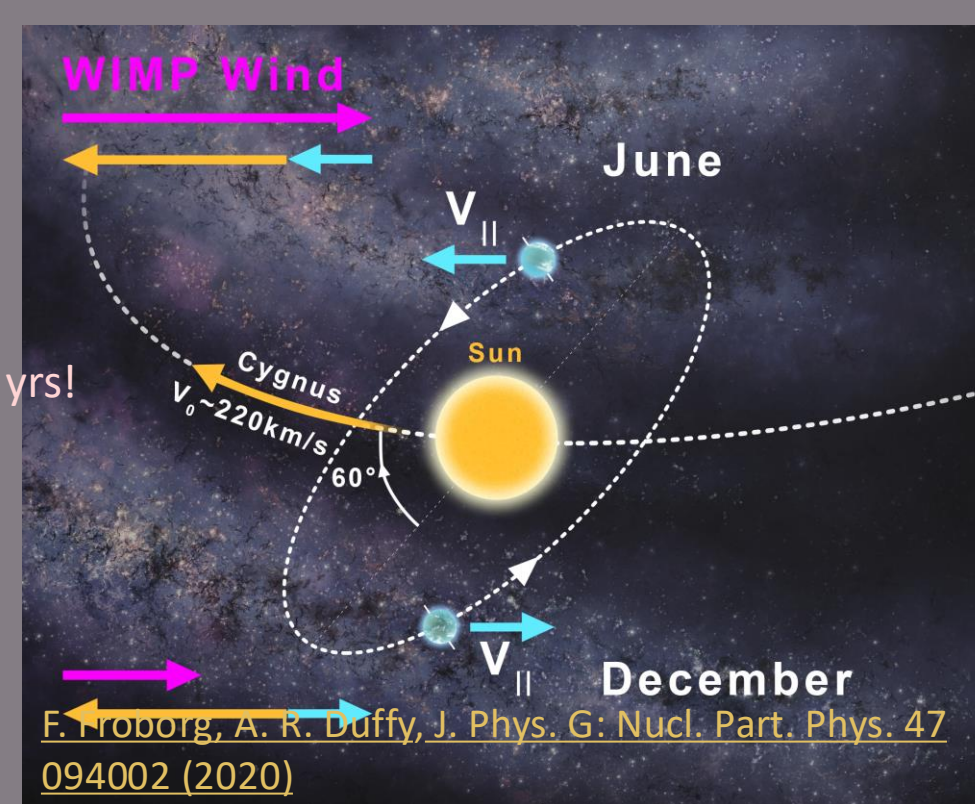
Center for Underground Physics, Institute for Basic Science
On behalf of the COSINE-100 Collaboration

arXiv:2409.13226

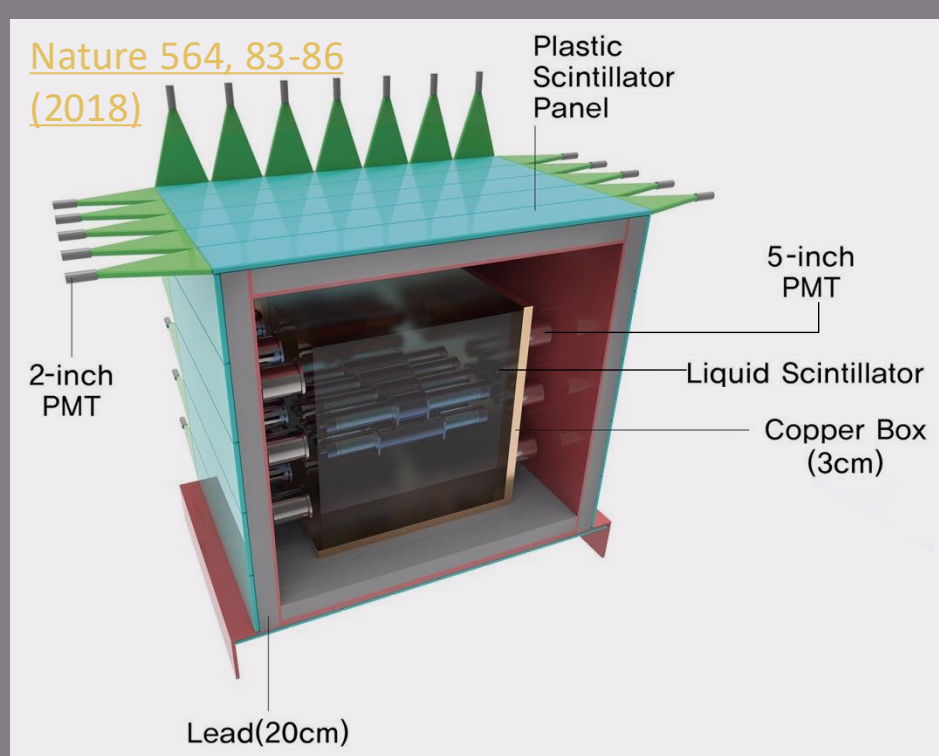


Annual Modulation by DAMA

- Dark matter signal rate is expected to show the annual modulation.
- DAMA has reported detecting the oscillation using NaI(Tl) detectors.
- No other experiments have reproduced the signal, but with other materials and analysis methods.

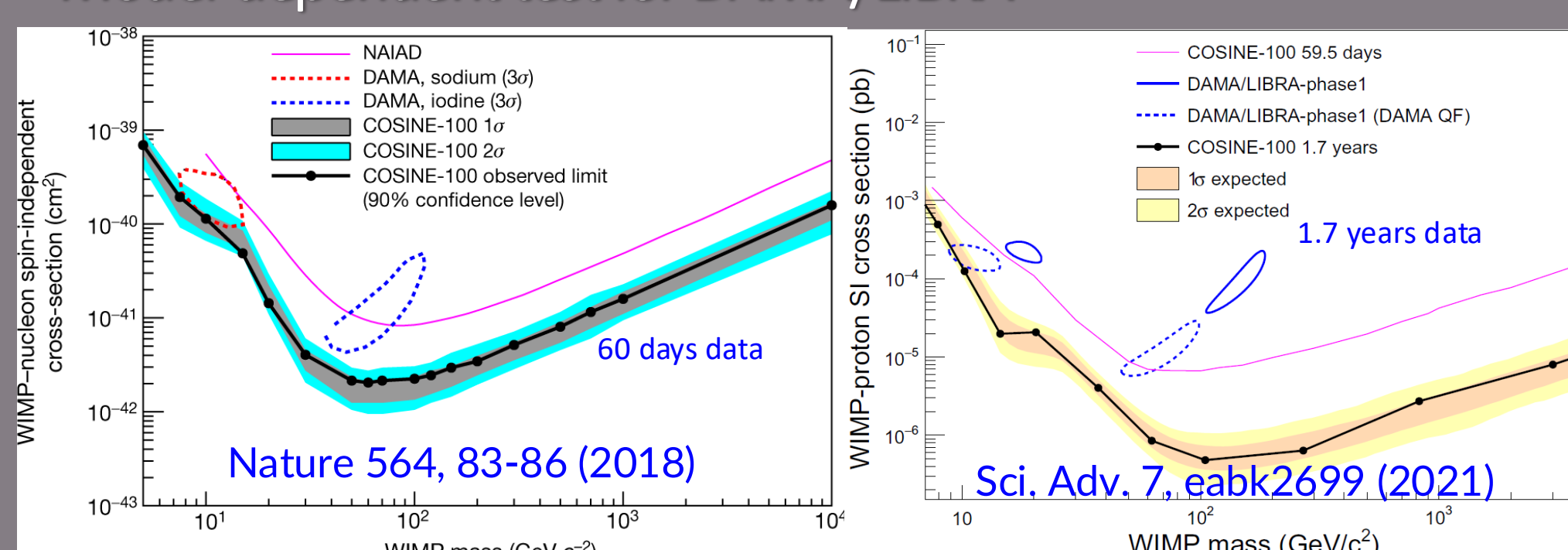


COSINE-100 Tests DAMA

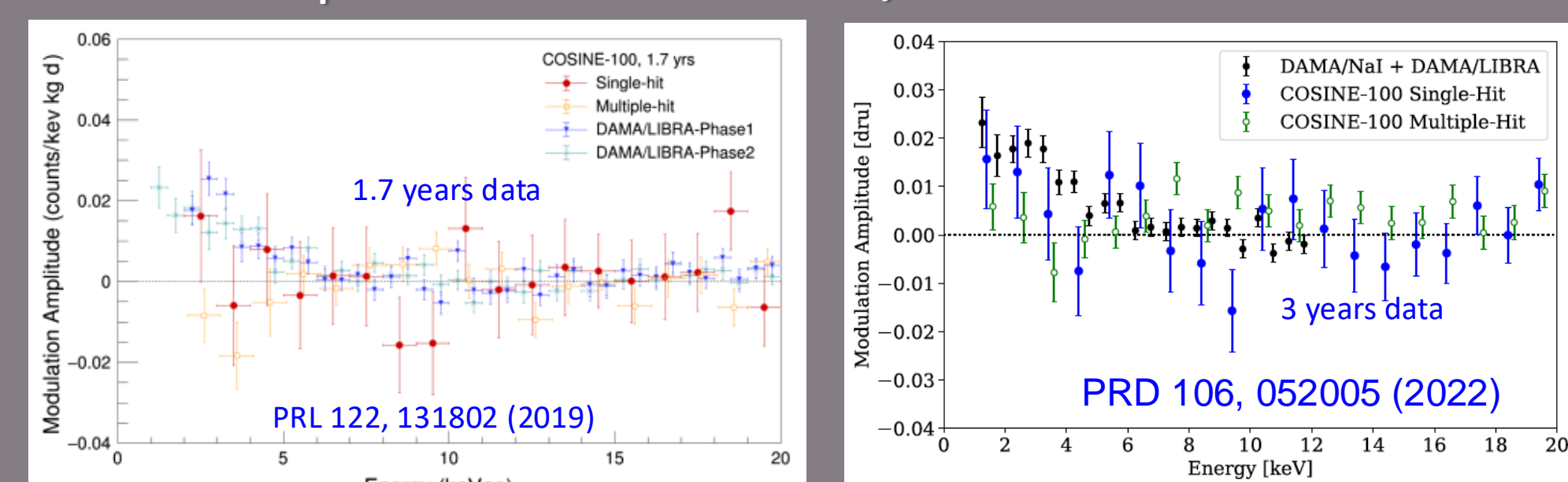


- 106 kg of NaI(Tl) crystals was installed at Y2L, Yangyang Underground Laboratory.
- Surrounded by the active and passive veto systems.
- 6.4 years operation (Oct 2016 ~ Mar 2023).
- Detector is upgraded for COSINE-100U at Yemilab.

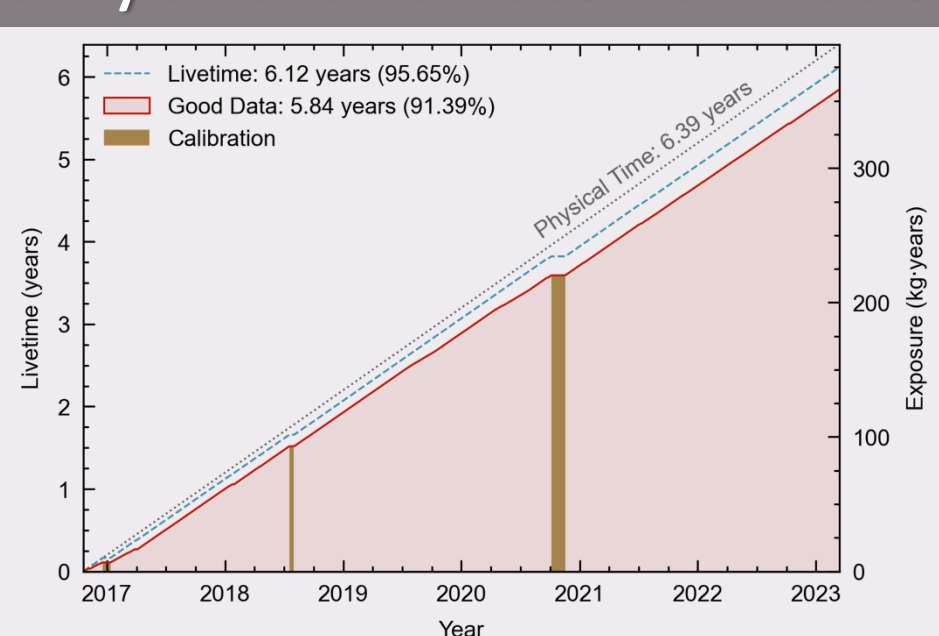
Model-dependent test for DAMA/LIBRA



Model-independent test for DAMA/LIBRA



6.4 years full dataset for model-independent test

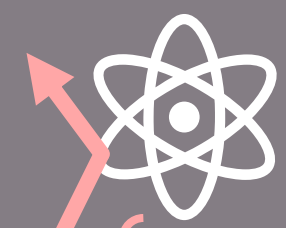


- Low energy threshold with a high efficiency. [arXiv:2408.14688](https://arxiv.org/abs/2408.14688)
- Crystal responses to photon and neutron were measured. [arXiv:2408.09806](https://arxiv.org/abs/2408.09806)
- Improved detector understanding [arXiv:2408.09806](https://arxiv.org/abs/2408.09806)

Time to Test DAMA's Claim!

NCSR Demokritos, Athens, Greece

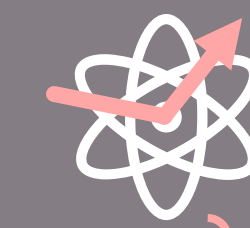
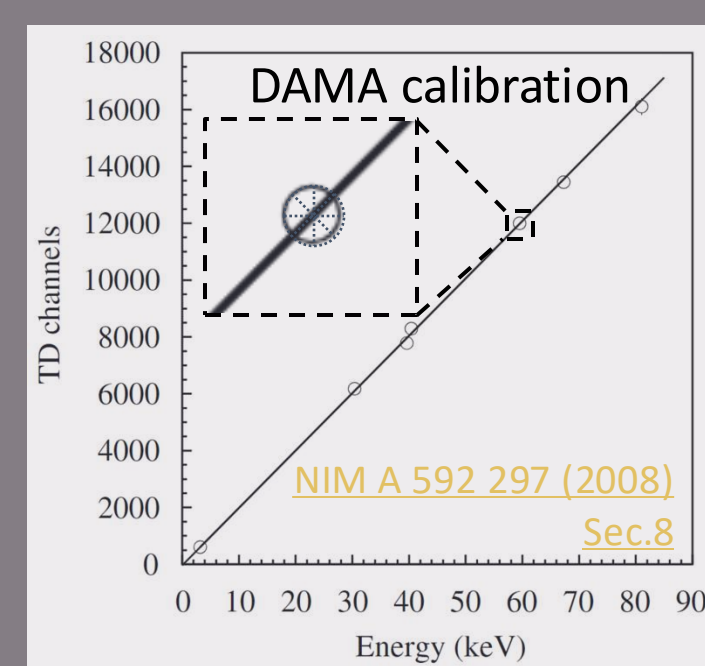
Compatible Calibration



DAMA signal can be...

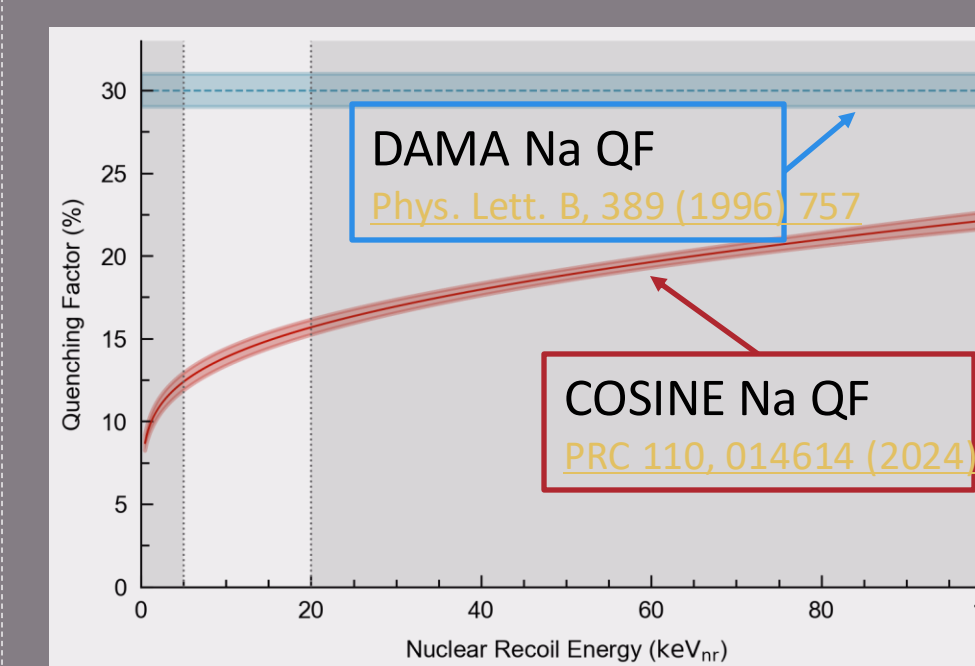
Electron Recoil keV_{ee}

- Applied linear calibration passing through 59.5 keV.
- Same method as DAMA.
- 1-3 keV_{ee}, 1-6 keV_{ee} and 2-6 keV_{ee} were studied.



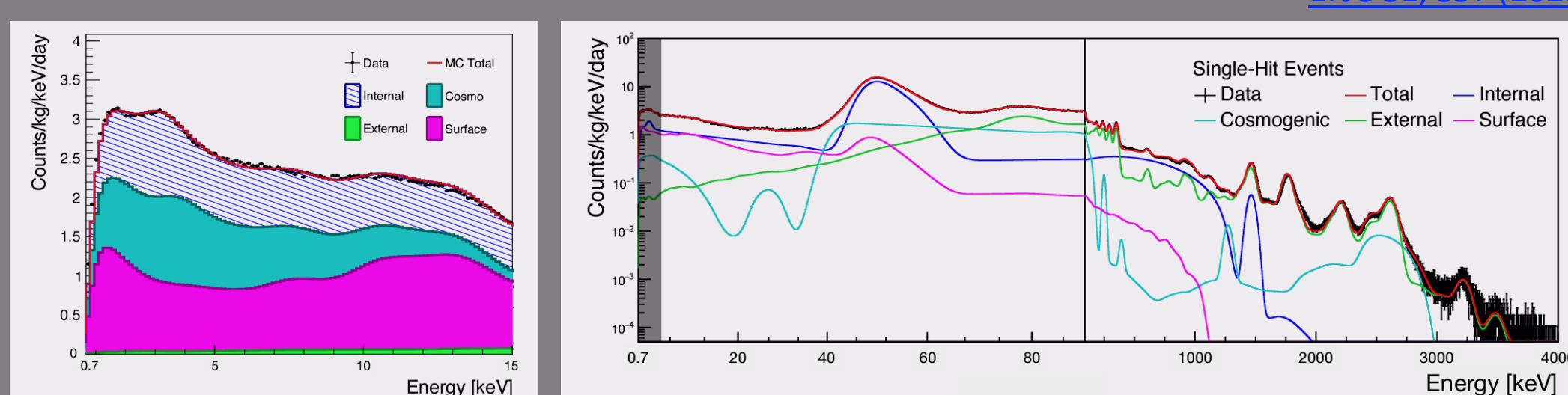
Nuclear Recoil keV_{nr}

- Correct using each quenching factor.
- Search in the NR energy.
- 6.7-20 keV_{nr} was studied which is 2-6 keV in DAMA.



Unbiased Statistical Model

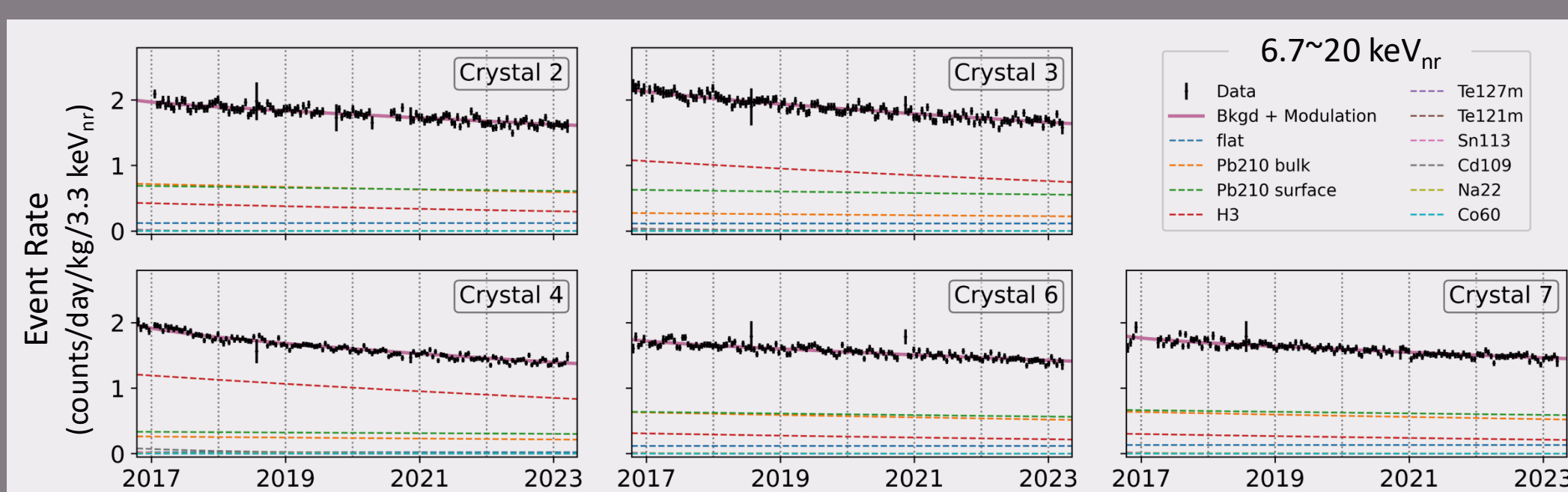
- COSINE-100 is the only NaI experiment understanding the radioactive isotope contamination in detail. [arXiv:2408.09806](https://arxiv.org/abs/2408.09806), [EPJ C 81, 837 \(2021\)](https://arxiv.org/abs/2408.09806)



- Every radioactive isotope was considered to avoid any statistical bias.

$$R_i(t) = A \cos\left(\frac{2\pi(t - \phi)}{T}\right) + \sum_j C_{ij} e^{-\lambda_{ij}t}$$

Annual Modulation Background Radioactive



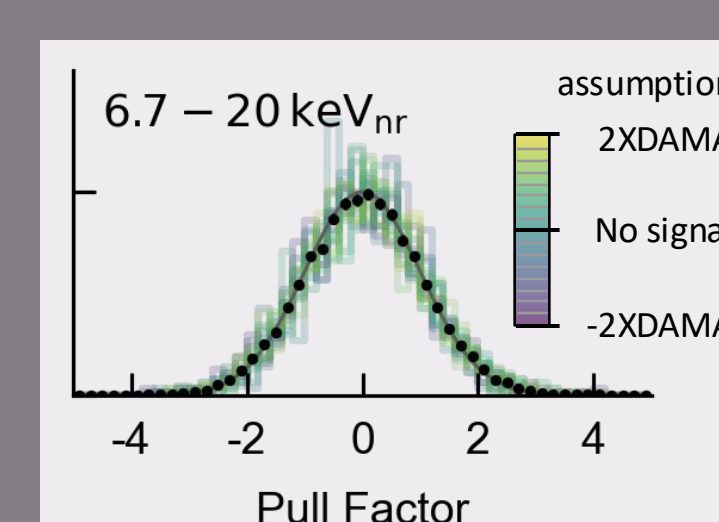
- Posterior distribution of the modulation amplitude A was extracted using the Markov chain Monte Carlo method.

$$\hat{E}_{ik} = R_i(t_k) \Delta t m_i \Delta E \varepsilon_{ik}^{(\text{livetime})} \varepsilon_i^{(\text{selection})}, \quad n_{ik} \stackrel{\text{iid}}{\sim} \text{Pois}(\hat{E}_{ik})$$

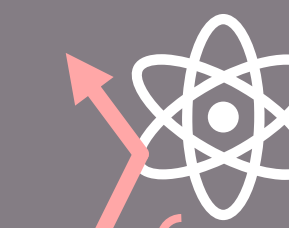
- Radioactive terms were constrained by the background model. [arXiv:2408.09806](https://arxiv.org/abs/2408.09806)

- Pseudo-experiments show no bias. total 17,000 simulations

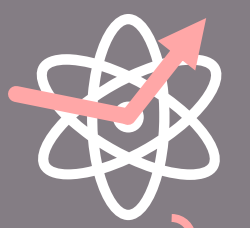
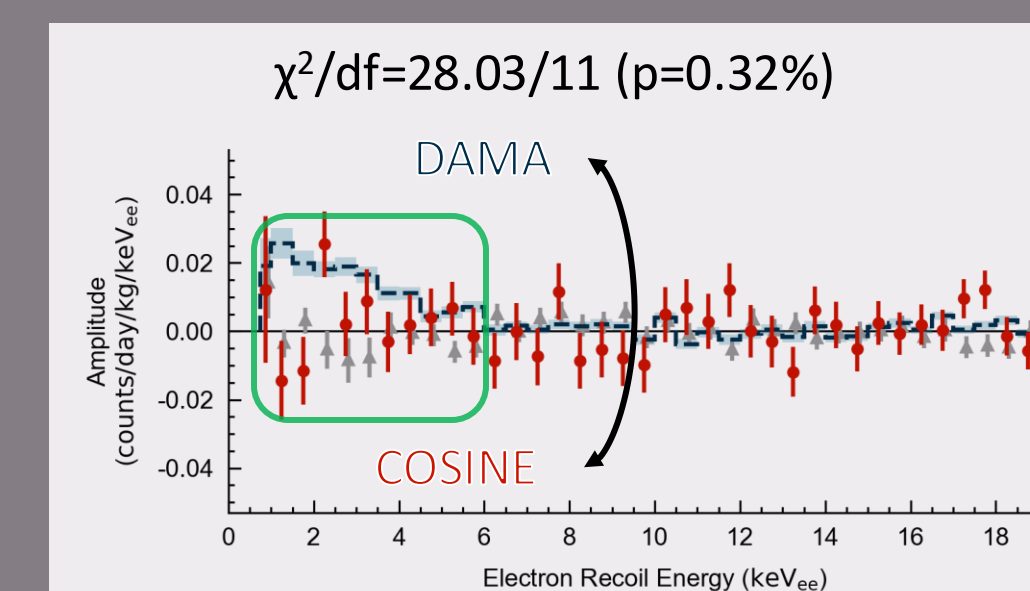
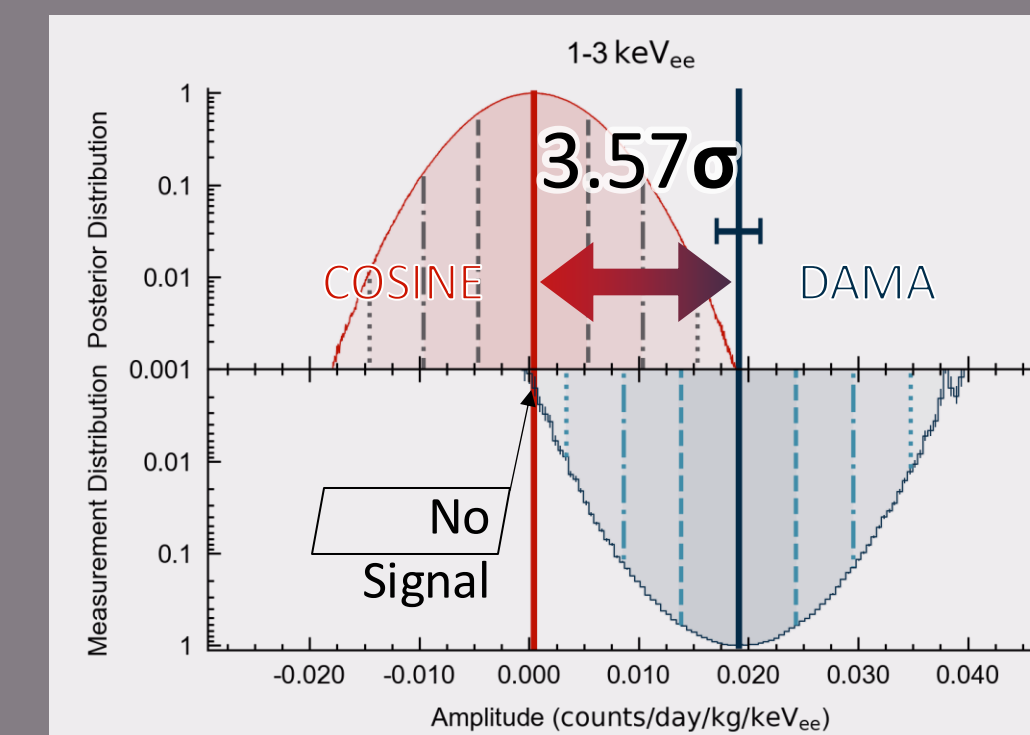
- Blind analysis was performed.



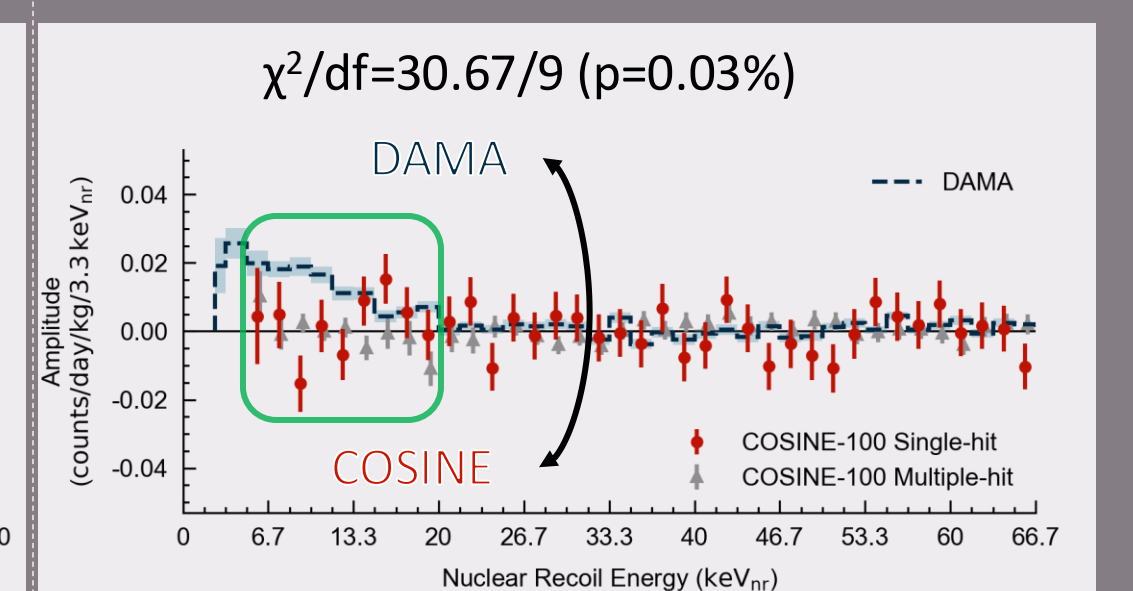
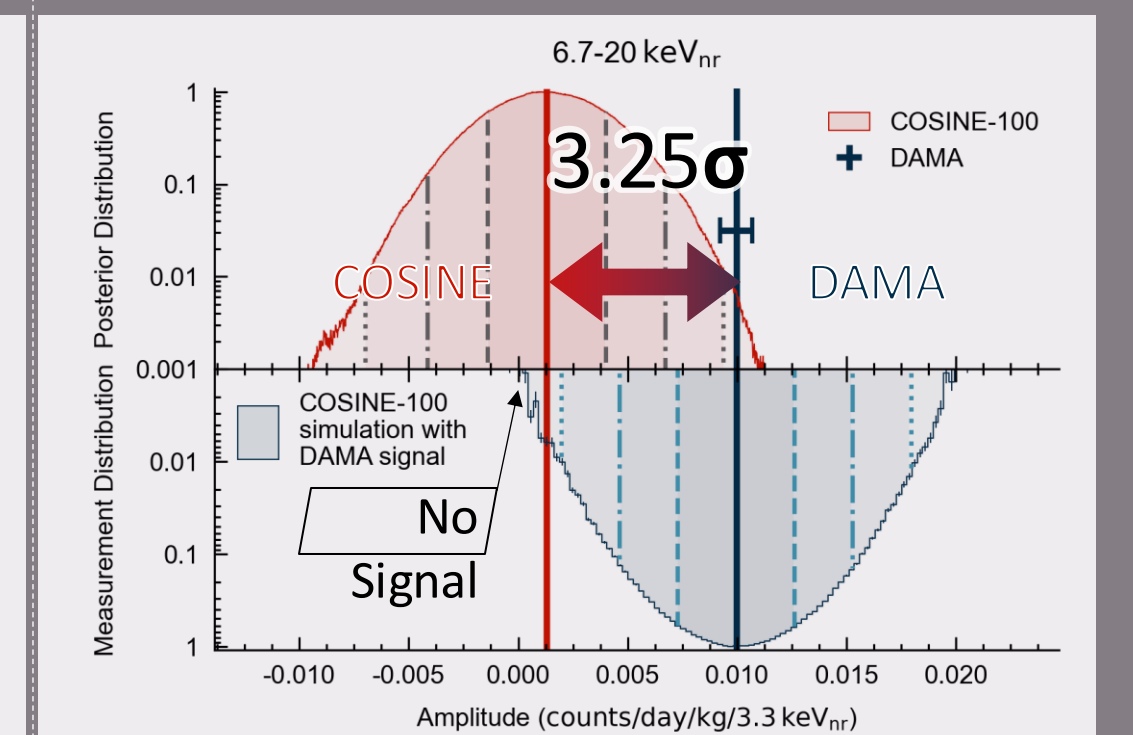
No Modulation Detected



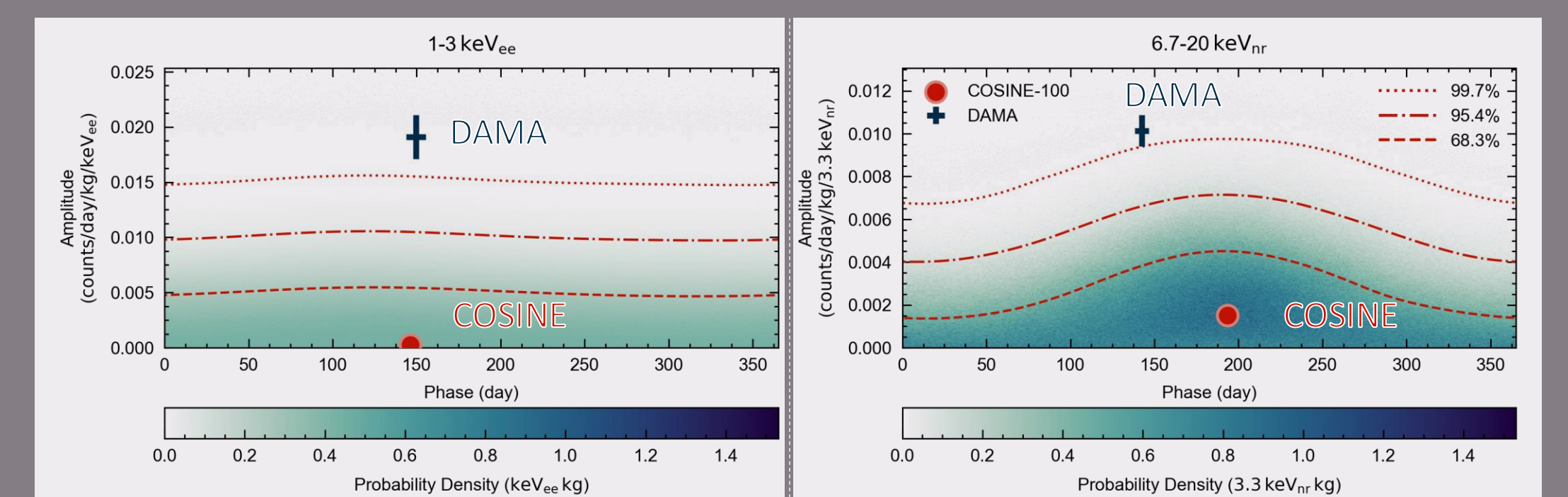
Electron Recoil Test



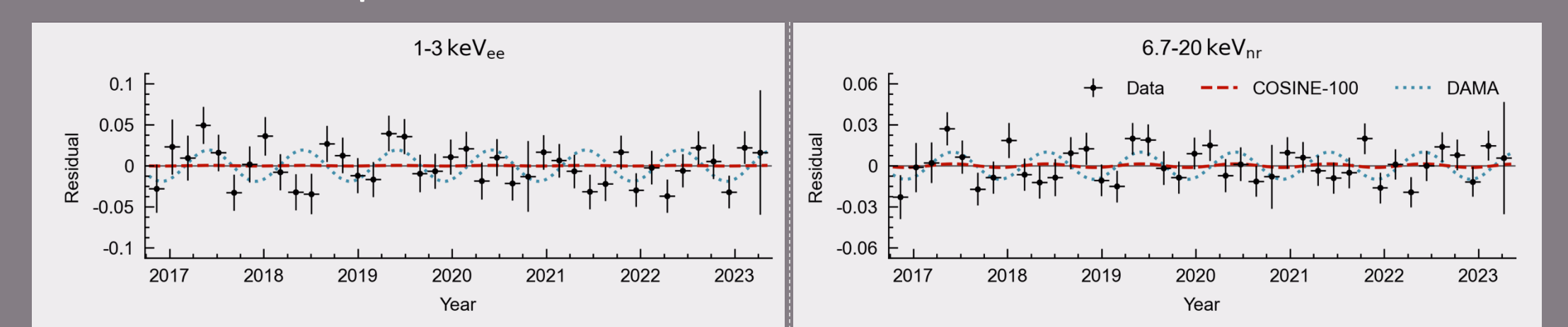
Nuclear Recoil Test



Even with an arbitrary phase...



No periodic behavior in the residual event rate!



The DAMA signal was not reproduced in the COSINE-100 full dataset, showing a **>3 sigma discrepancy**

(same target and same analysis)

E (keV _{ee})	A (counts/day/kg/keV _{ee})	
	COSINE-100	DAMA/LIBRA
1-3	0.0004±0.0050	0.0191±0.0020
1-6	0.0017±0.0029	0.01048±0.00090
2-6	0.0053±0.0031	0.00996±0.00074

E (keV _{nr})	A (counts/day/kg/3.3 keV _{nr})	
	COSINE-100	DAMA/LIBRA
6.7-20	0.0013±0.0027	0.00996±0.00074