
Status of the dark matter search in the COSINE-100 experiment

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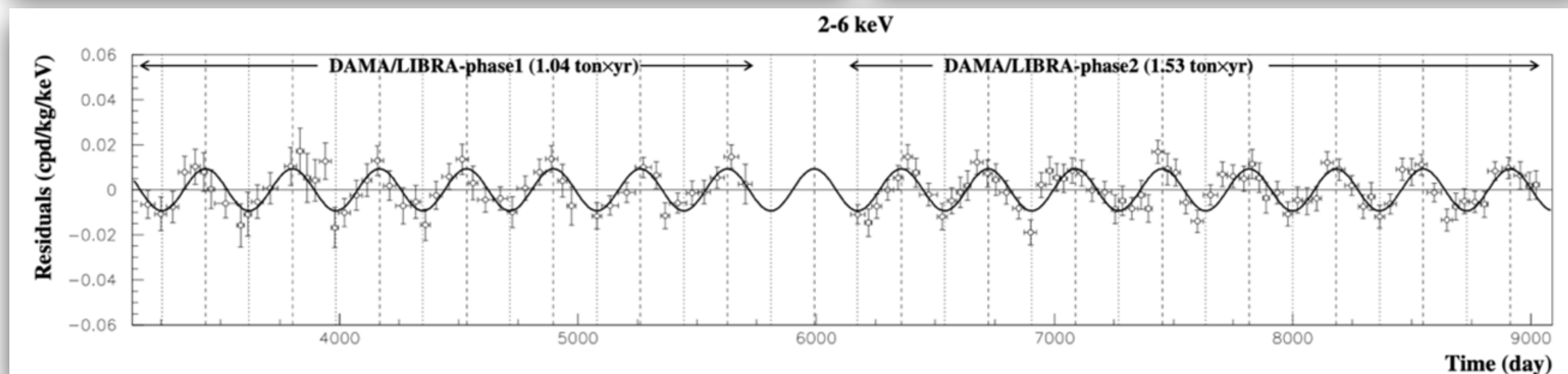
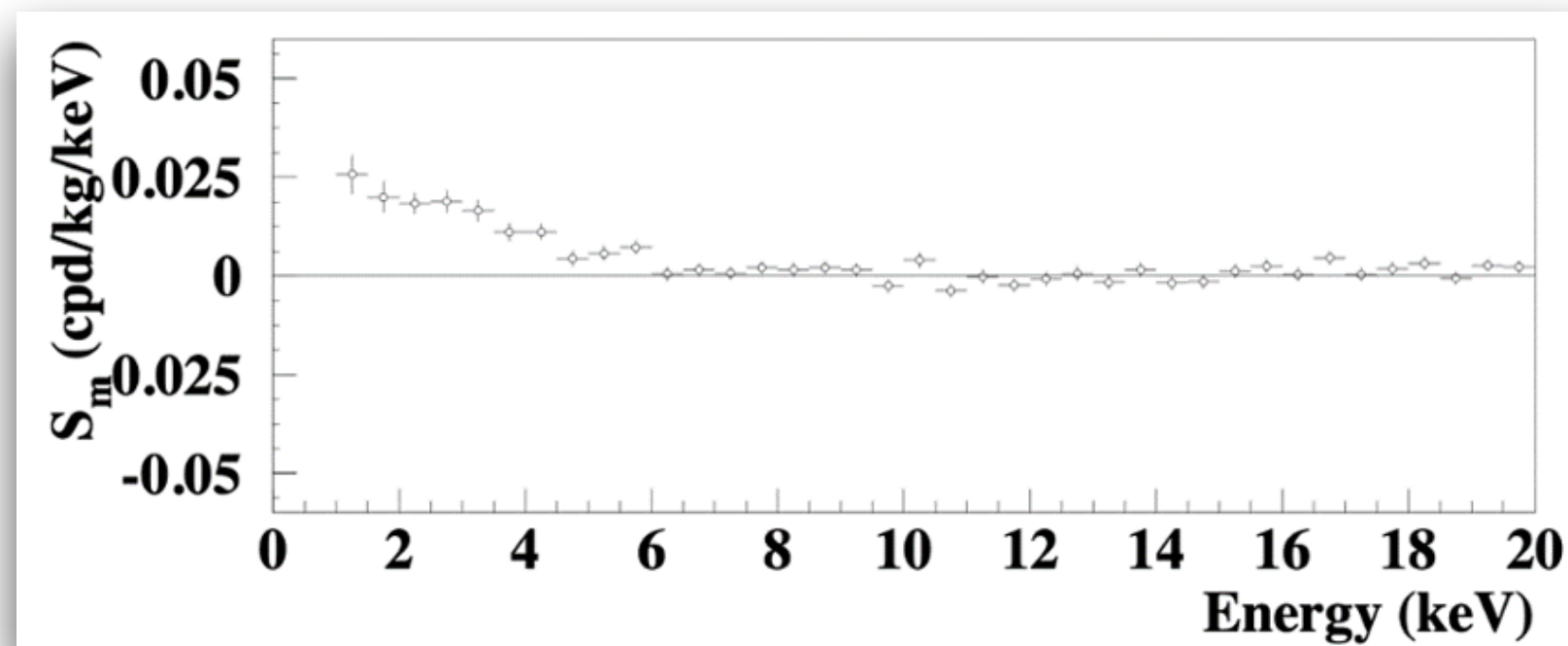
On behalf of the COSINE collaboration

IDM 2026 · International Conference on the Identification of Dark Matter
1 June 2026 · University of Zaragoza, Spain

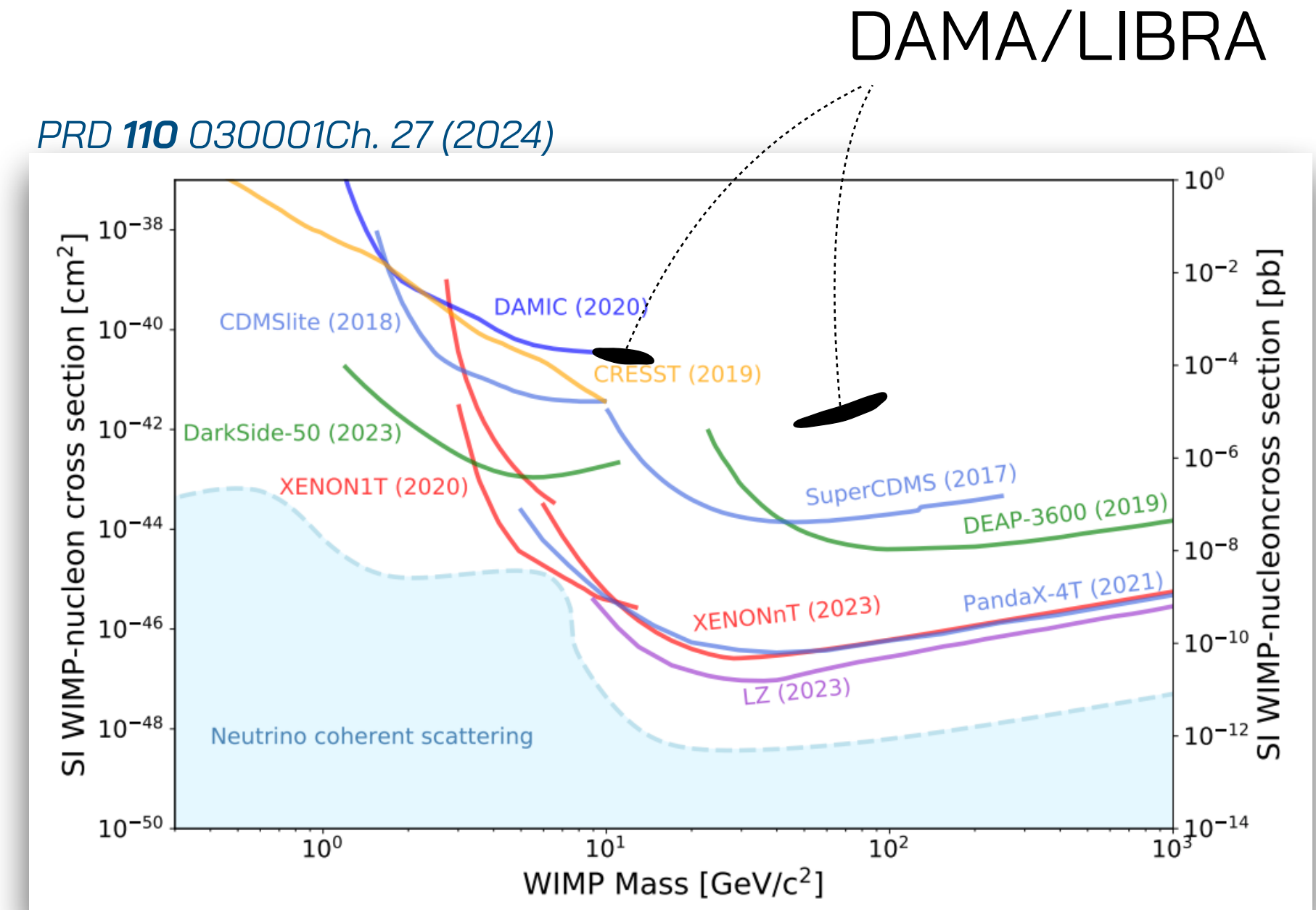
The DAMA/LIBRA puzzle

Annual modulation observed in NaI(Tl) crystals at LNGS

DAMA/LIBRA observation : significance $> 13\sigma$ over 20+ years of running



Nucl.Phys.At.Energy **22** (2021) 329



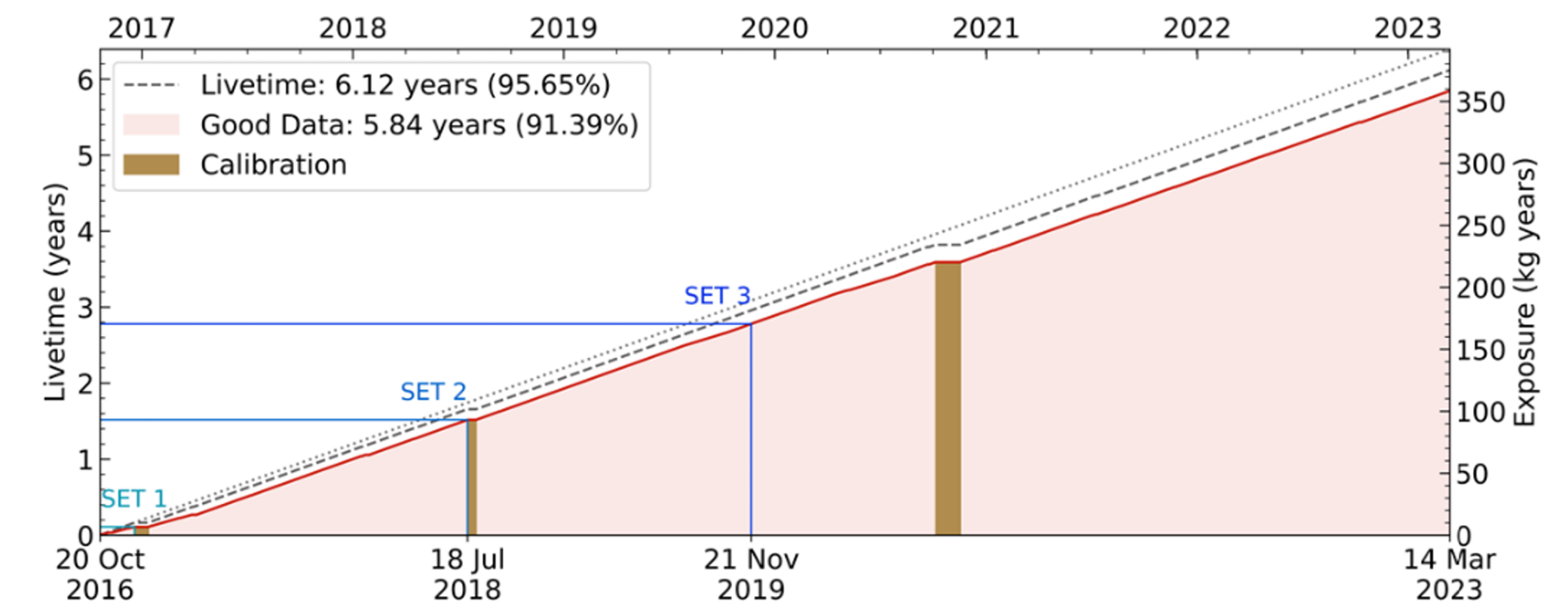
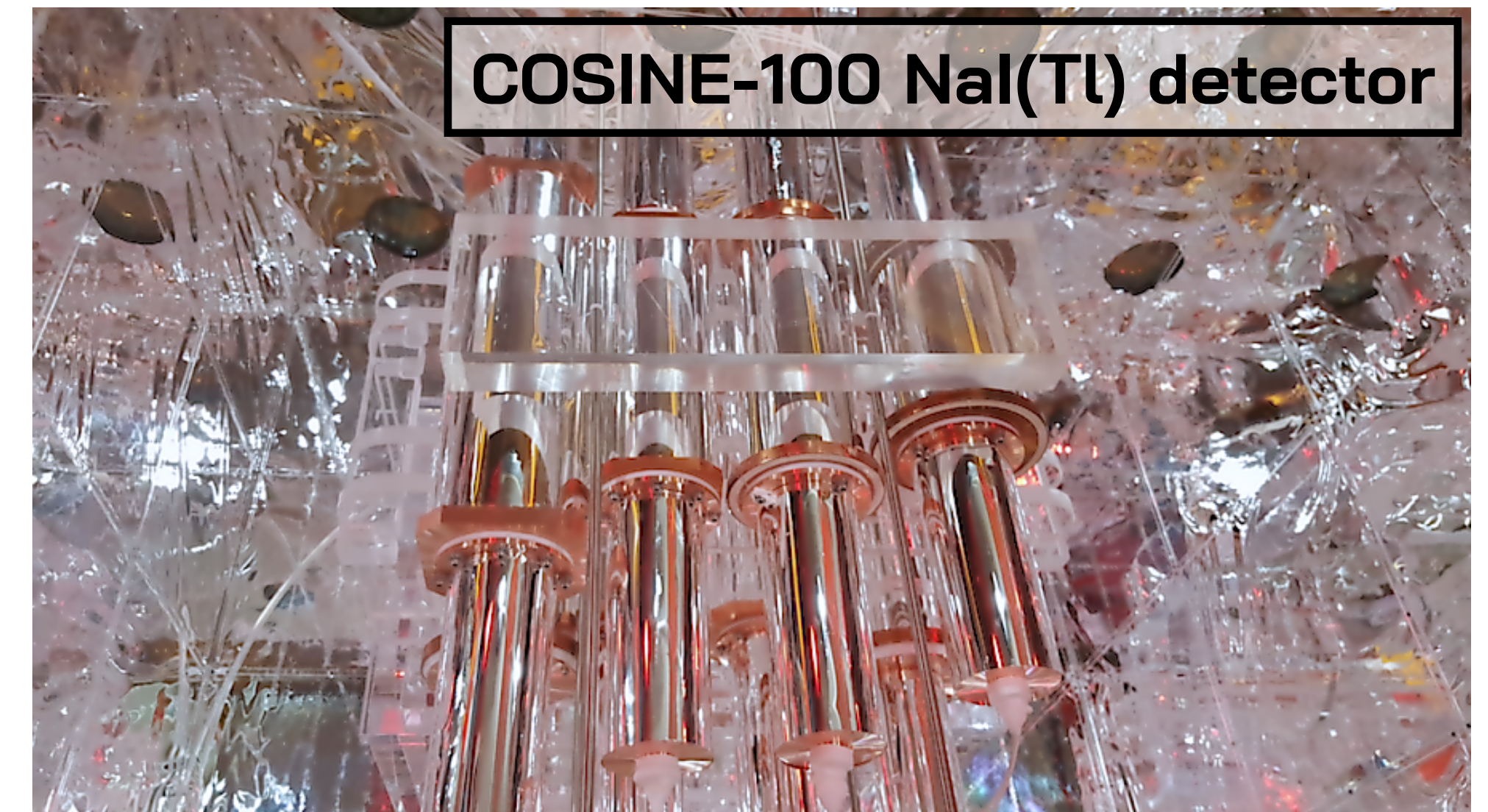
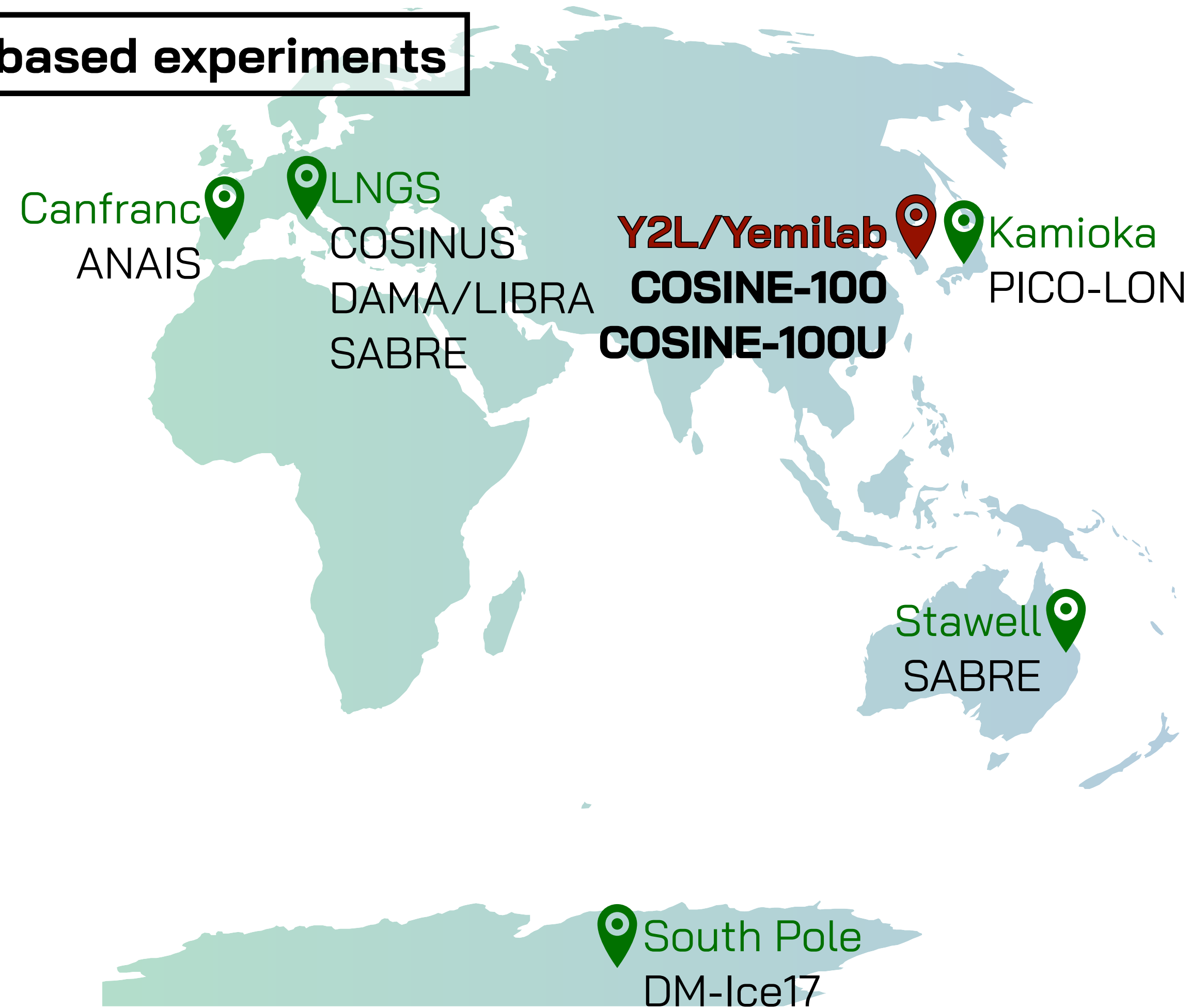
DAMA's claim contradicts findings from other experiments

Is the NaI(Tl) target itself the key to the DAMA/LIBRA signal?

COSINE-100 Experiment

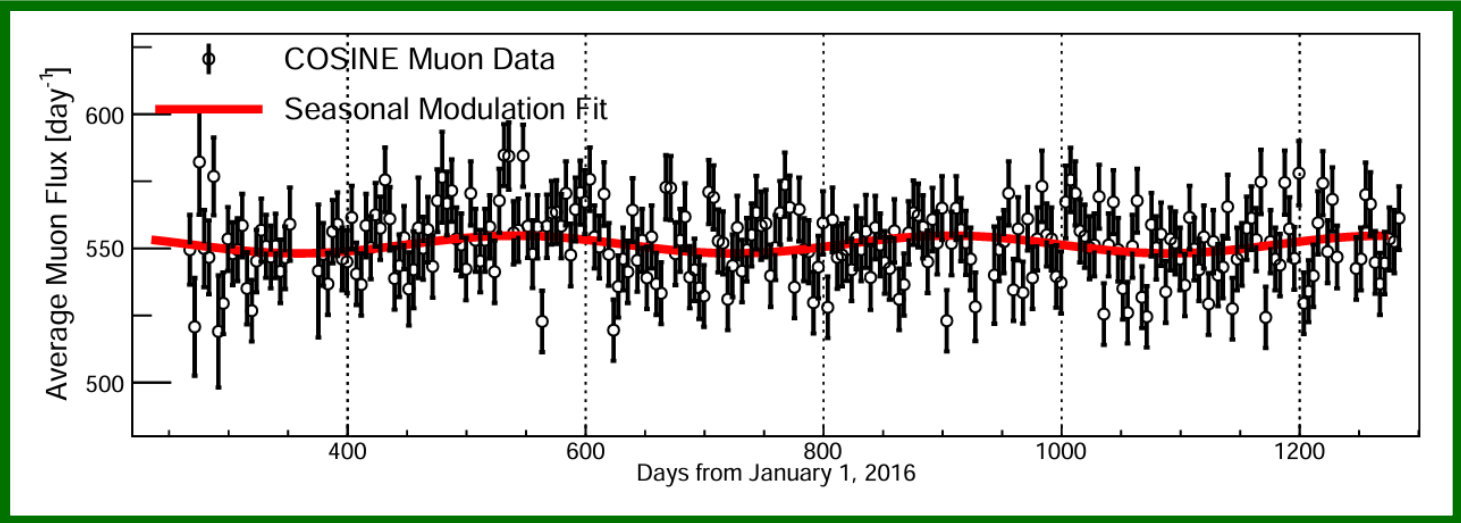
Nal(Tl) dark matter experiment

Nal-based experiments



COSINE-100 Detector Understanding

Modulation of cosmic-ray muon



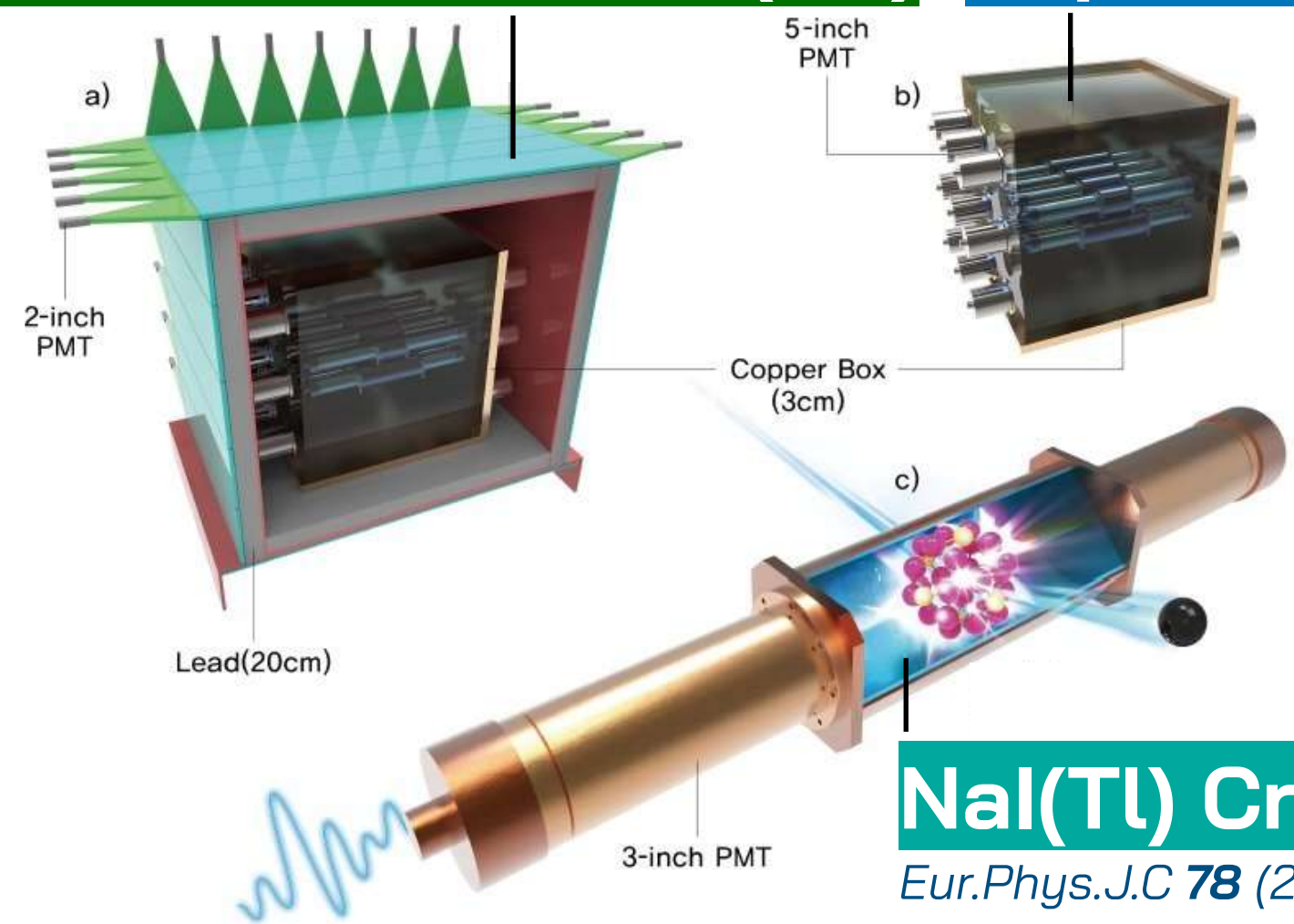
JCAP **02** (2021) 013

JINST **13** (2018) T02007

Plastic Scintillator (PS)

Nucl.Instrum.Meth.A **1006** (2021) 165431

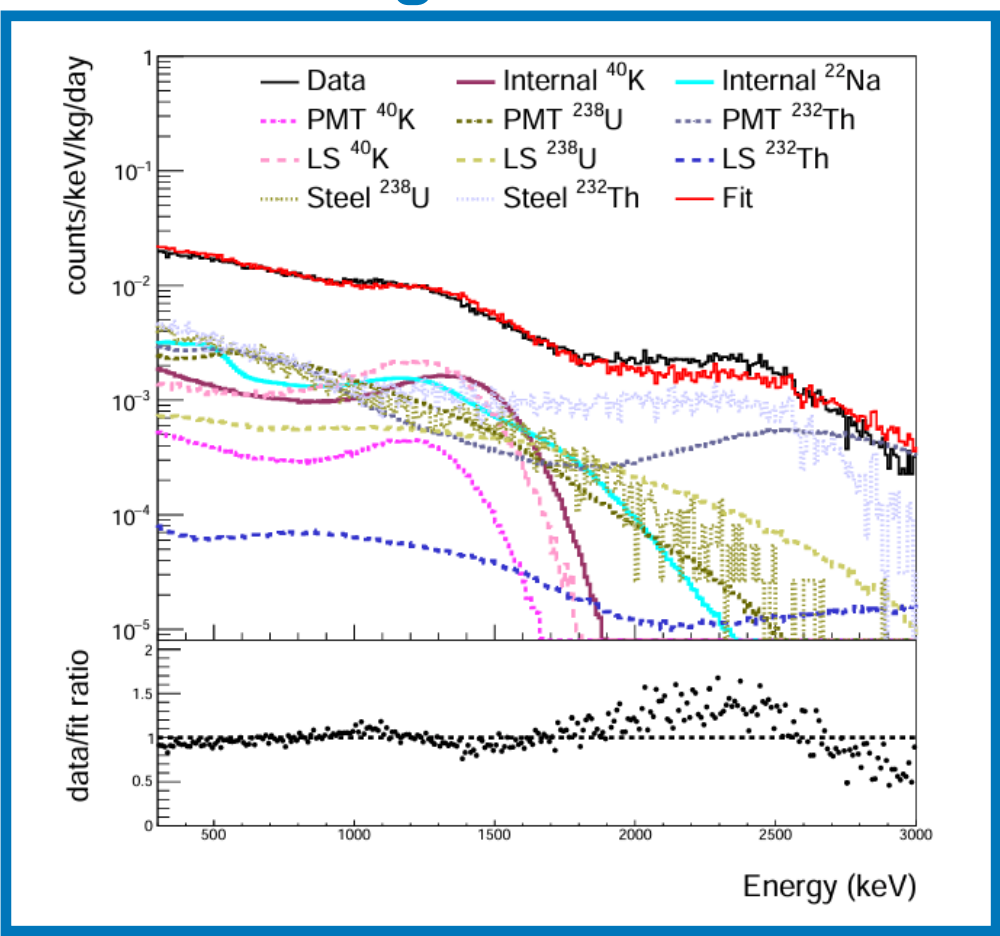
Liquid Scintillator (LS)



Nal(Tl) Crystal

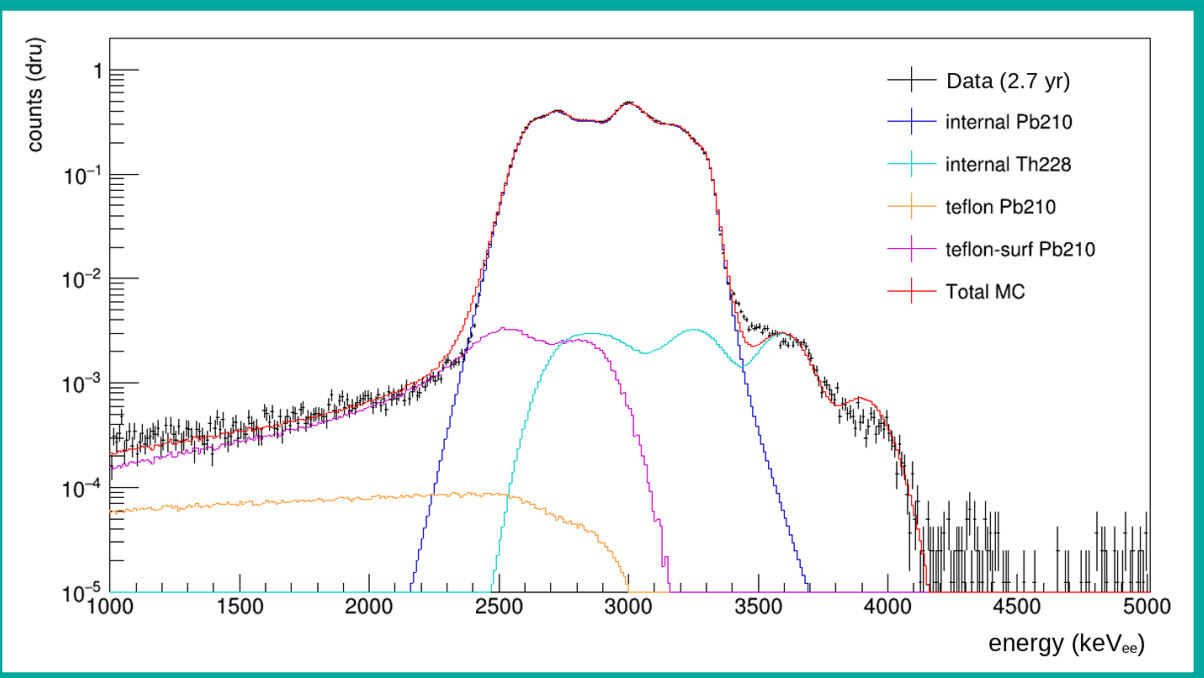
Eur.Phys.J.C **78** (2018) 107

LS Background Model



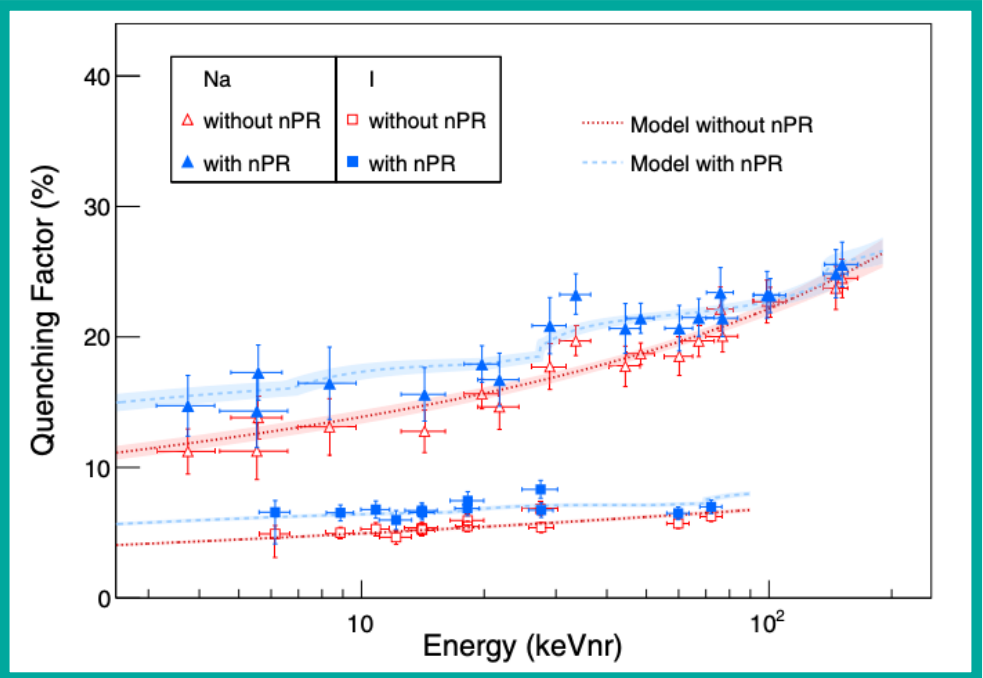
Nucl.Instrum.Meth.A **1006** (2021) 165431

α background in Nal(Tl)



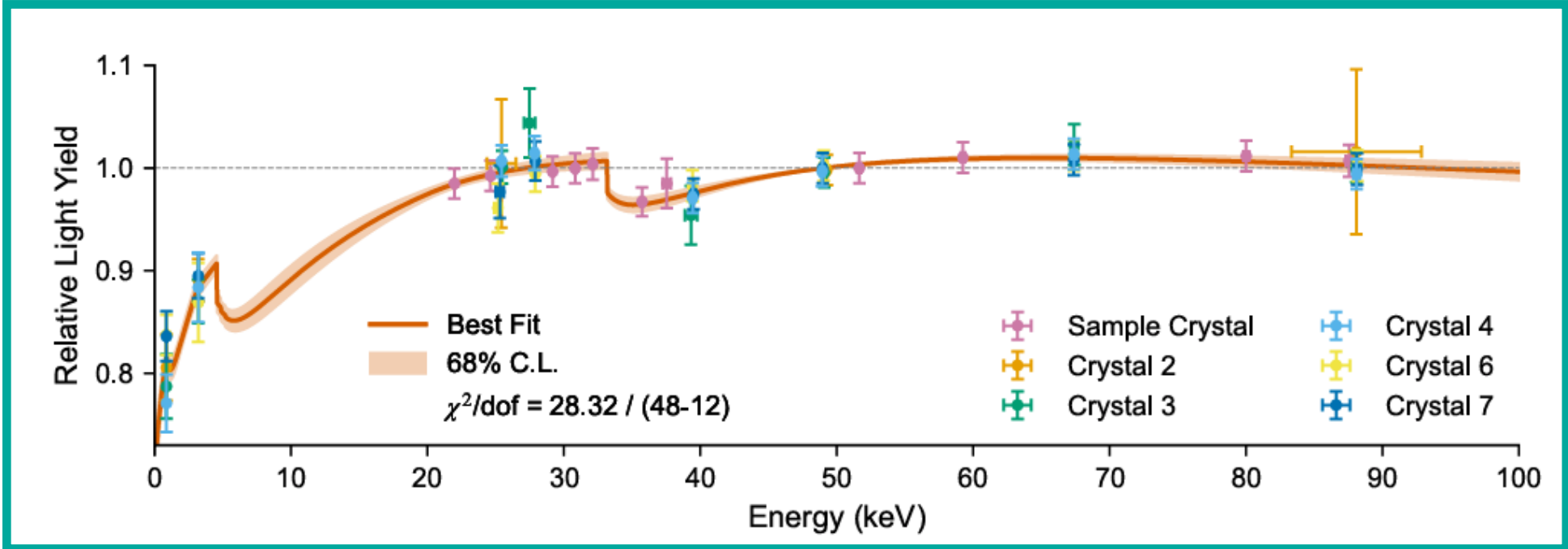
Astropart.Phys. **158** (2024) 102945

Quenching factor



Phys.Rev.C **110** (2024) 014614

Non-proportionality



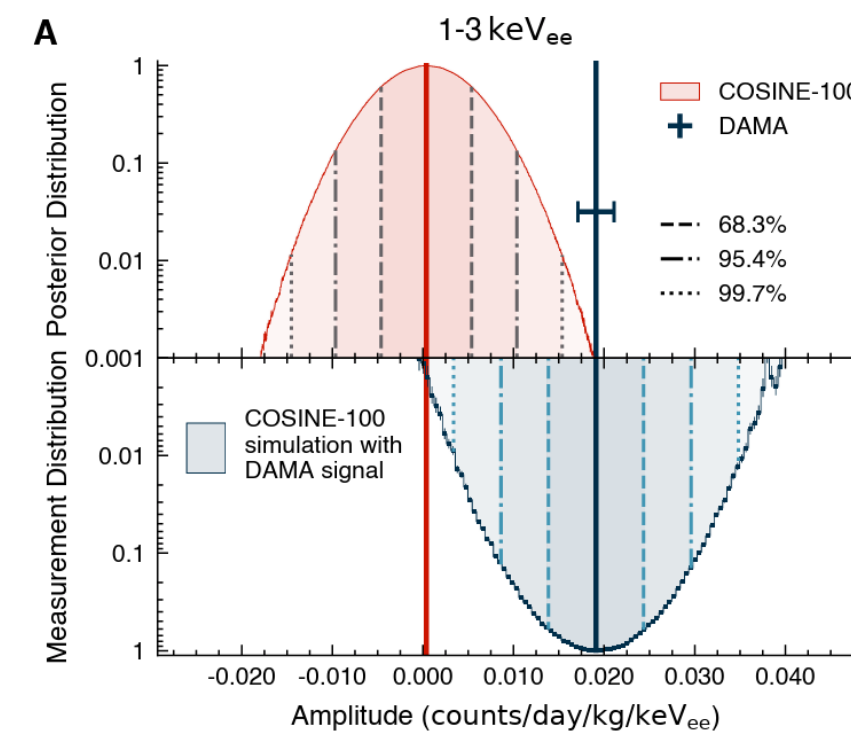
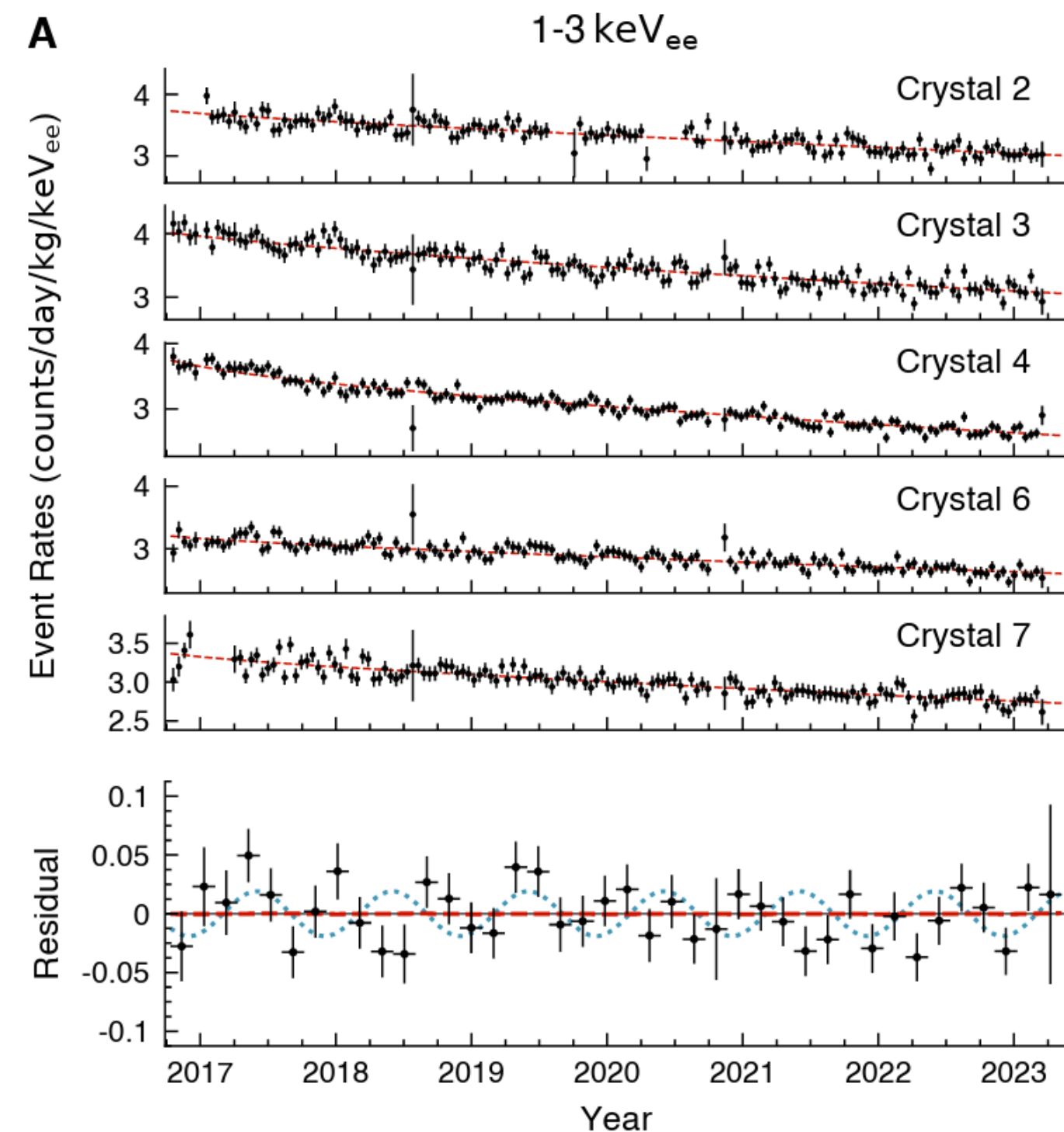
Eur.Phys.J.C **84** (2024) 484

Annual Modulation Search with 6-year Data

Model-independent analysis

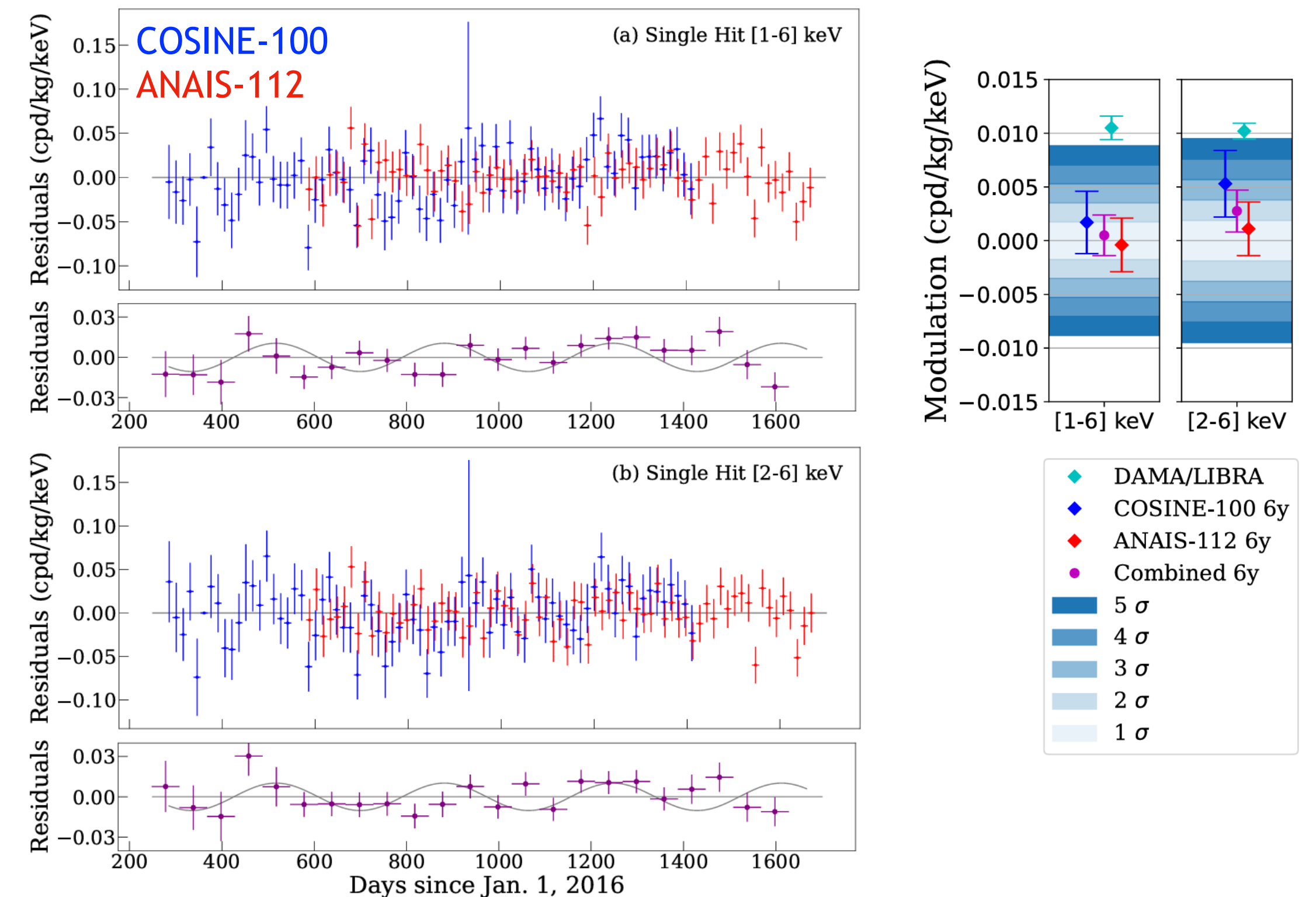
Sci. Adv. 11 eadv6503 (2025)

No modulation in COSINE-100 6-year data



Phys. Rev. Lett. 135 (2025) 121002

No modulation in the combined data (984 kg . yr)



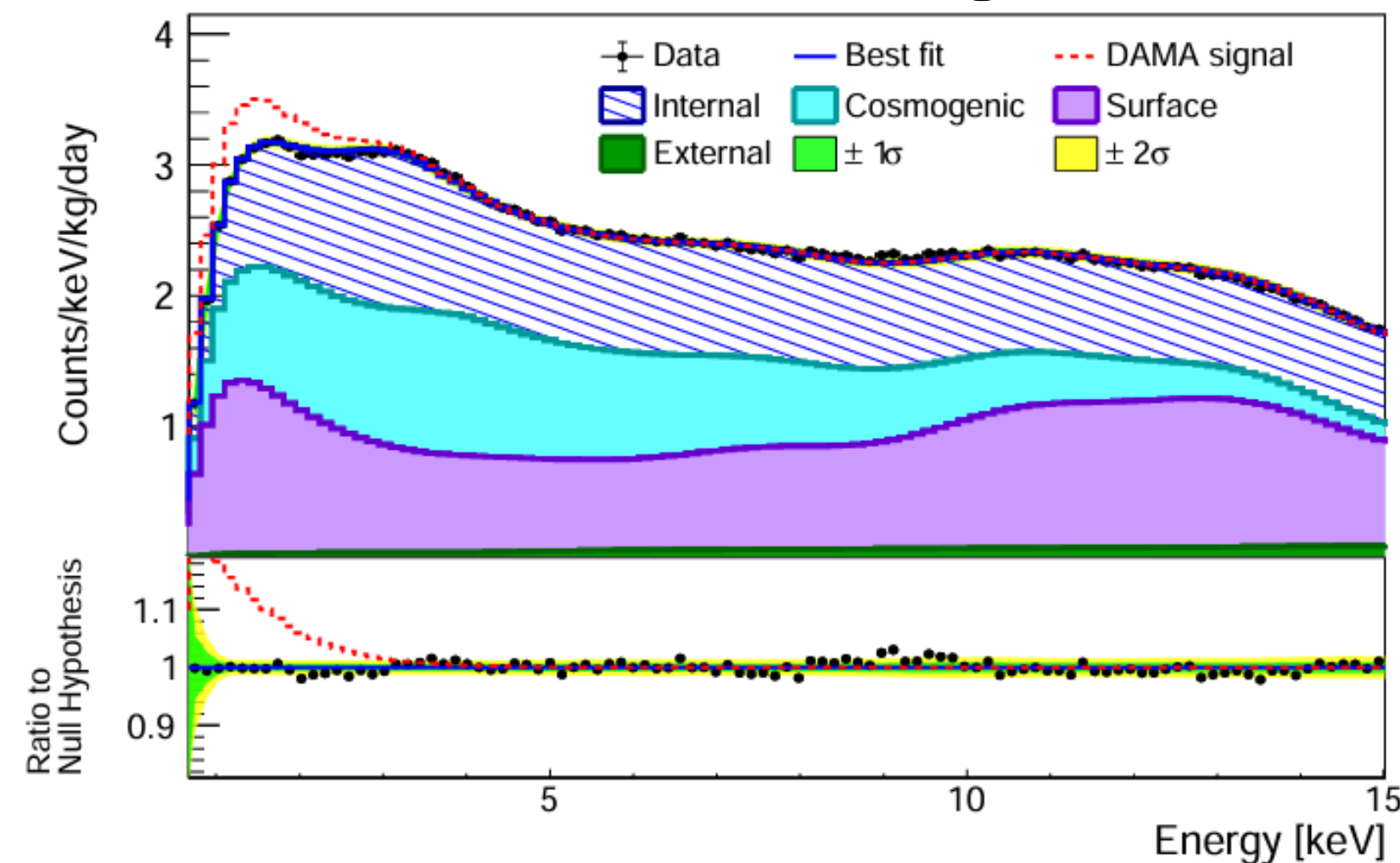
We ruled out DAMA with **3.57σ** (COSINE-100 6-year data), **4.57σ** (COSINE & ANAIS combined data)

WIMP Extraction in 3-year Data

Model-dependent analysis

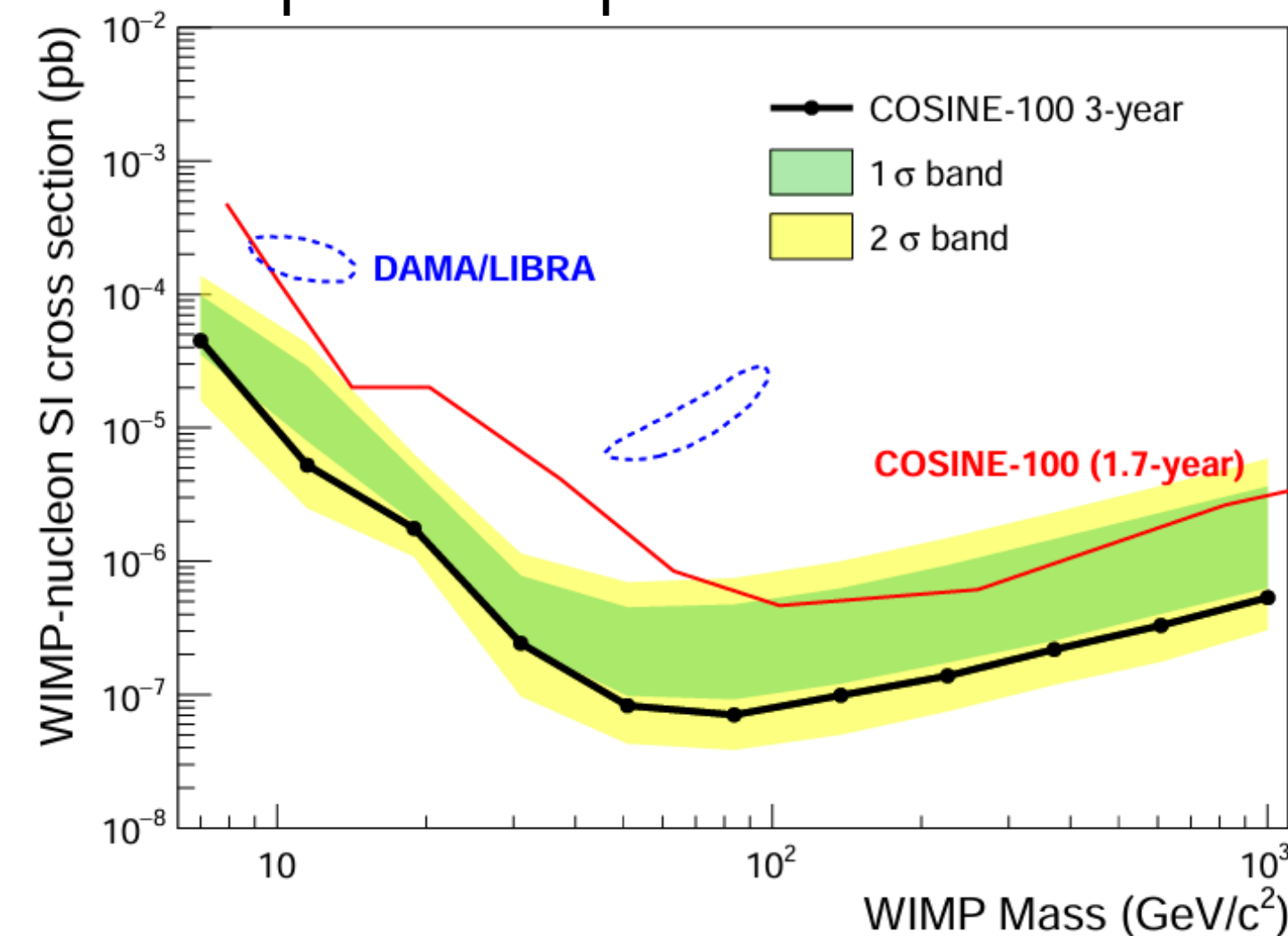
Phys. Rev. Lett. **135** (2025) 231001

Data Fitting



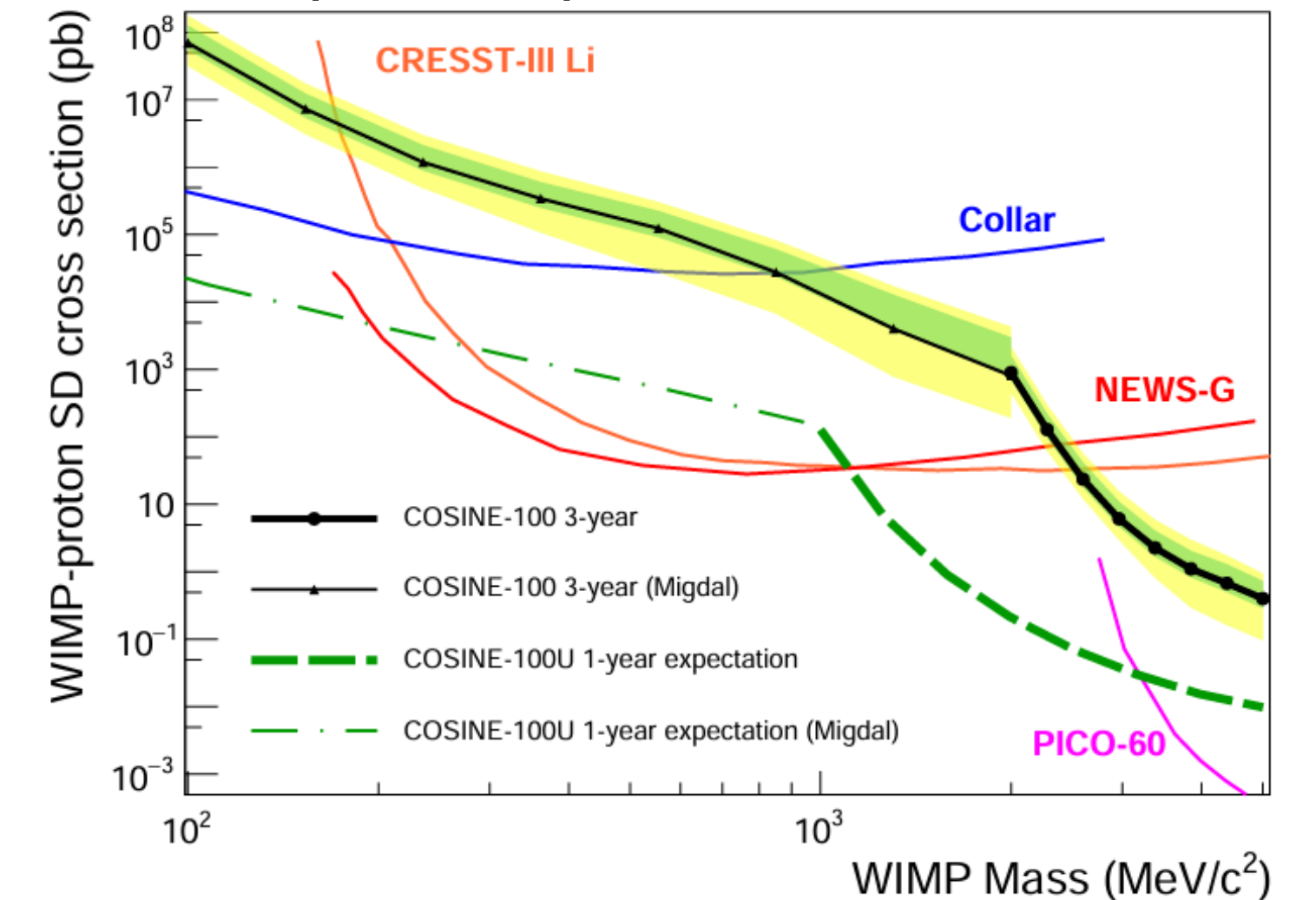
No WIMP signal observed

Spin-Independent channel



SI limit perfectly excludes the DAMA/LIBRA contour

Spin-Dependent channel

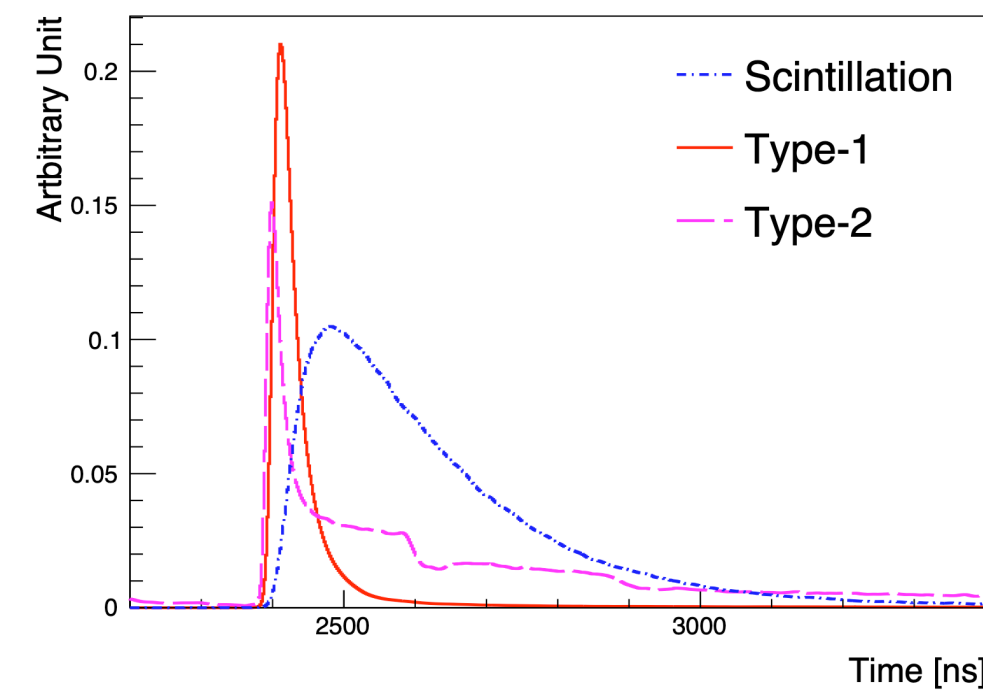


It seems to have potentially competitive in the GeV region

Event Selection

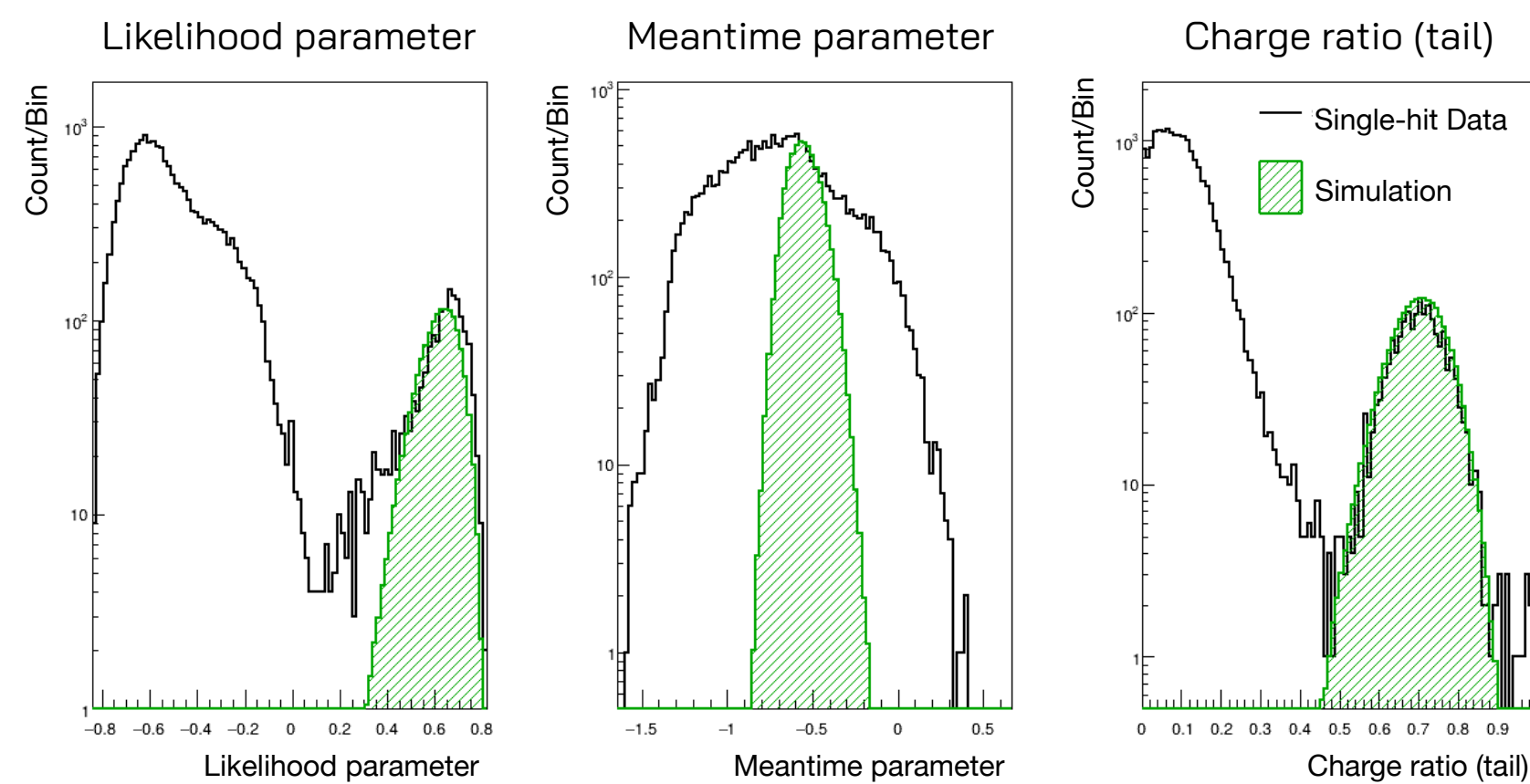
PMT noise reduction

Accumulated waveform

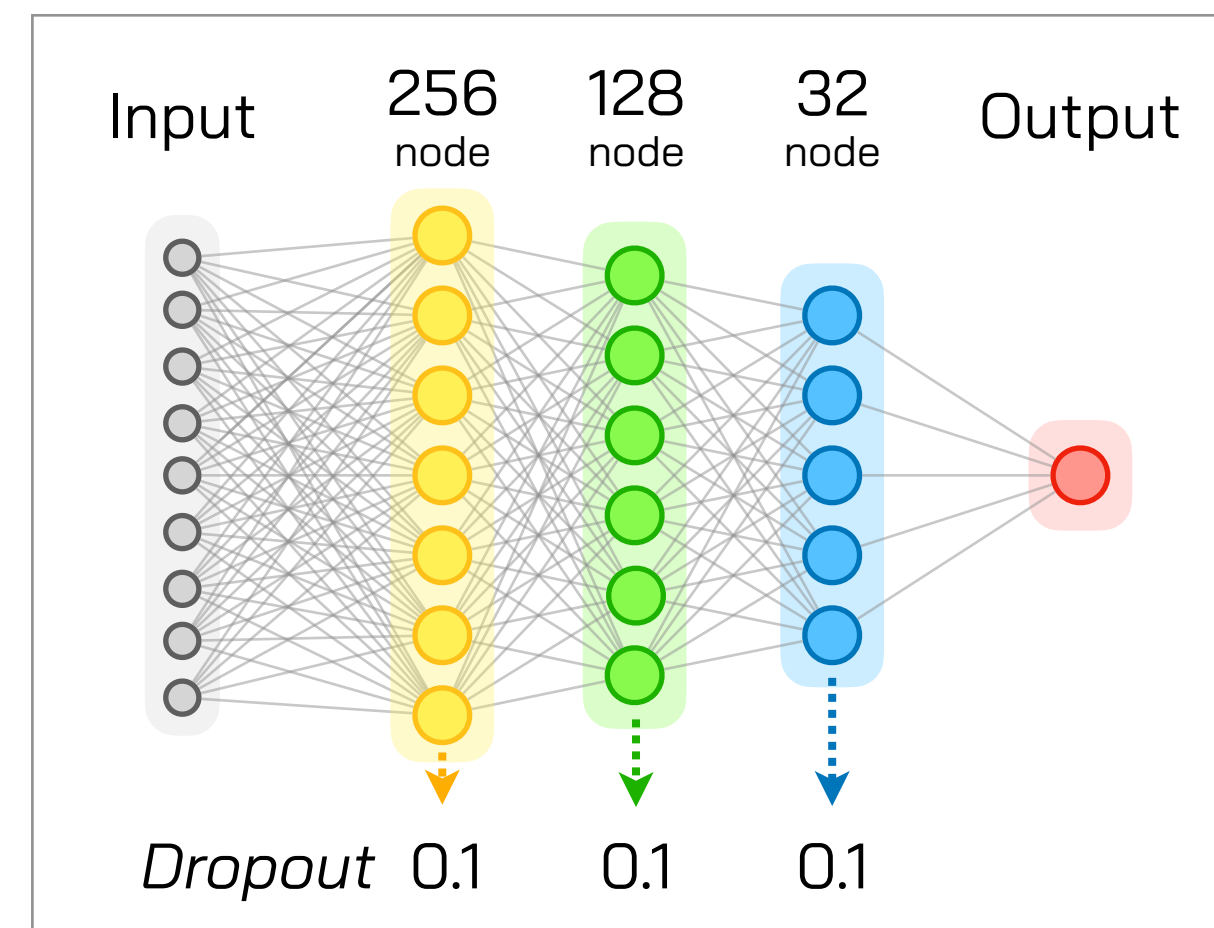


- Type-1 noise can be separated simply by charge-weighted mean time
 - Type-2 noise makes it challenging to distinguish
- ➡ Develop PSD parameters (ex. Likelihood parameter)
- ➡ Machine learning used for scintillation/noise classification

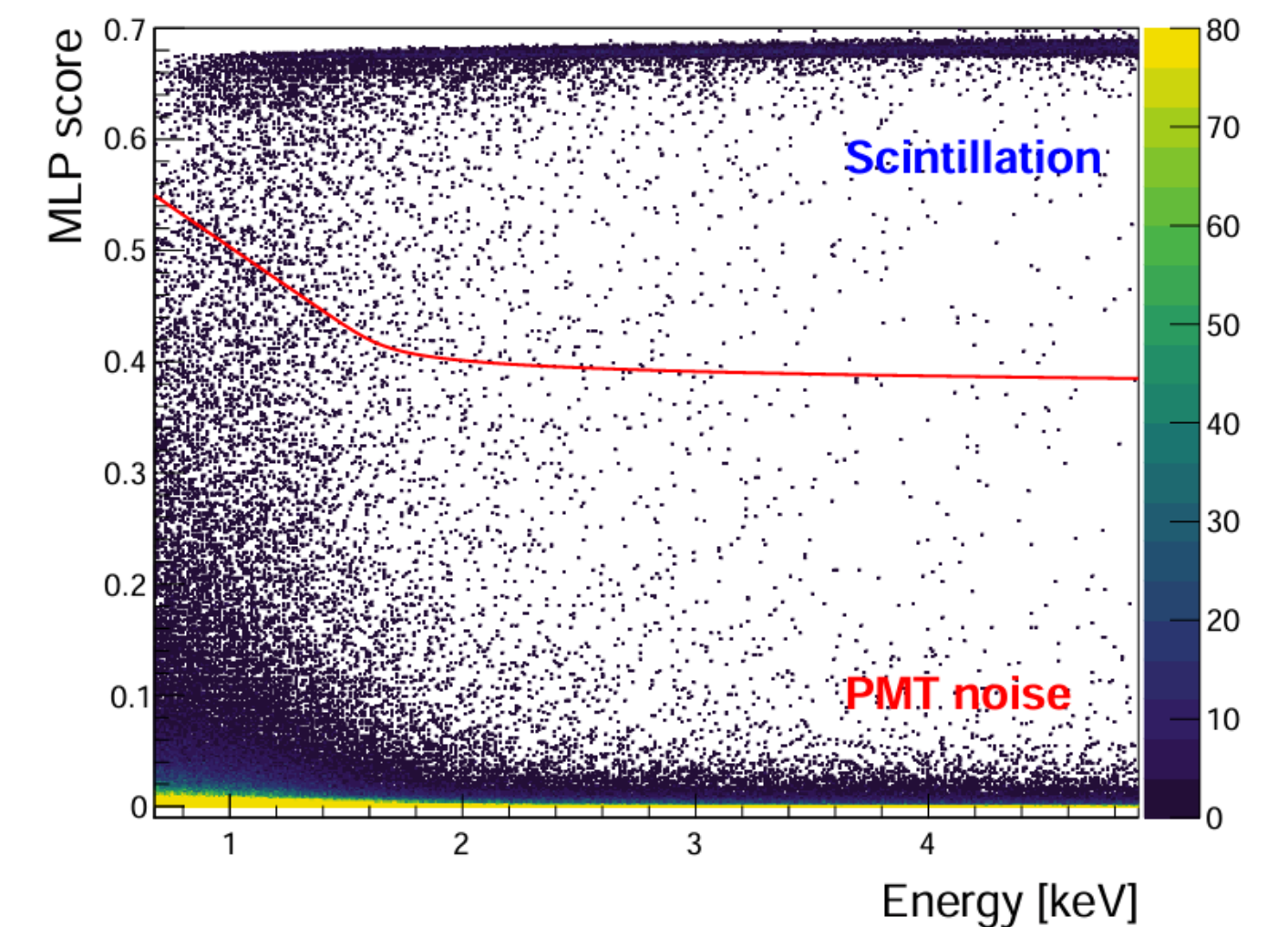
PSD parameter distribution



Multi-layer perceptron (MLP)



MLP score cut effectively suppresses noise while preserving high signal acceptance

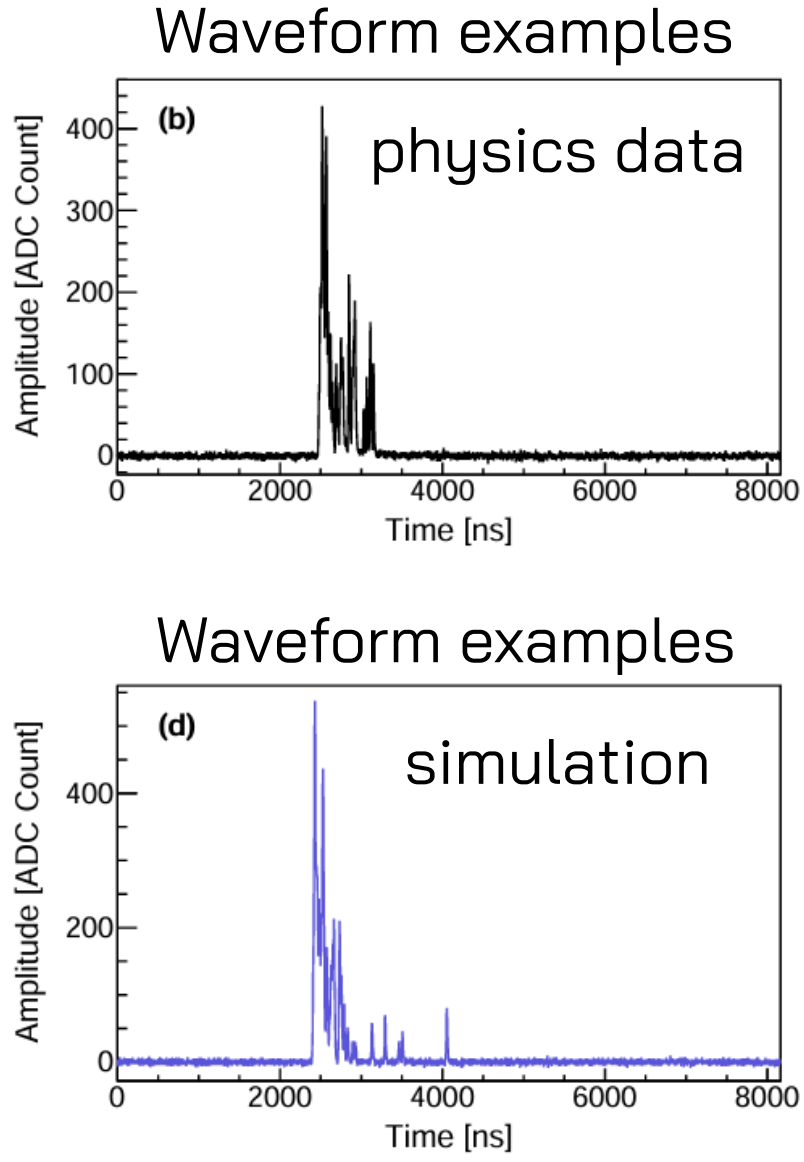


Lowering threshold to 0.49keV

How is it possible?

1

Waveform simulation
→ signal sample



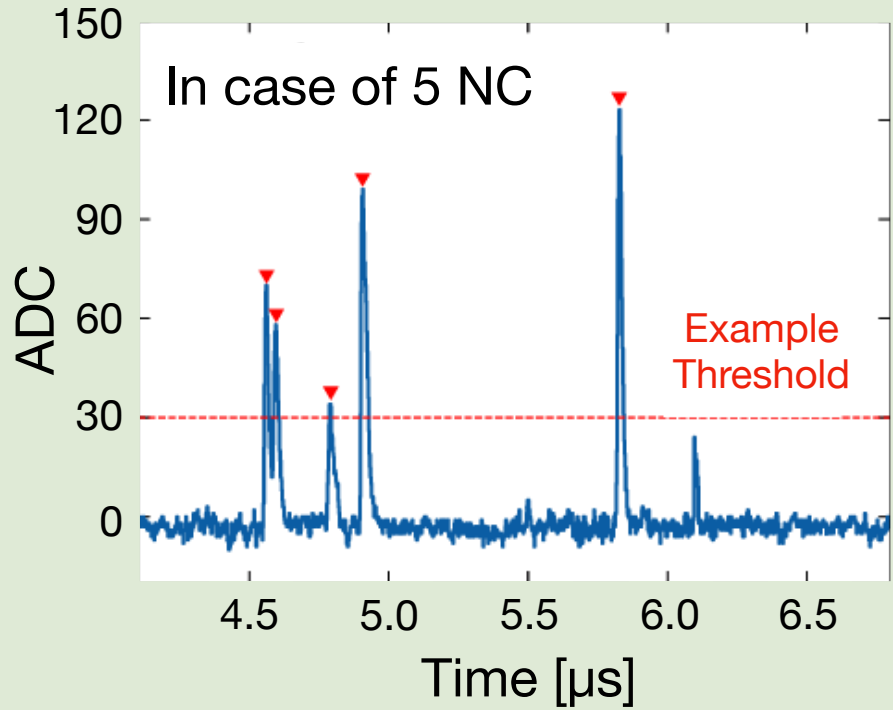
Nucl.Instrum.Meth.A **1065** 169489 (2024)

2

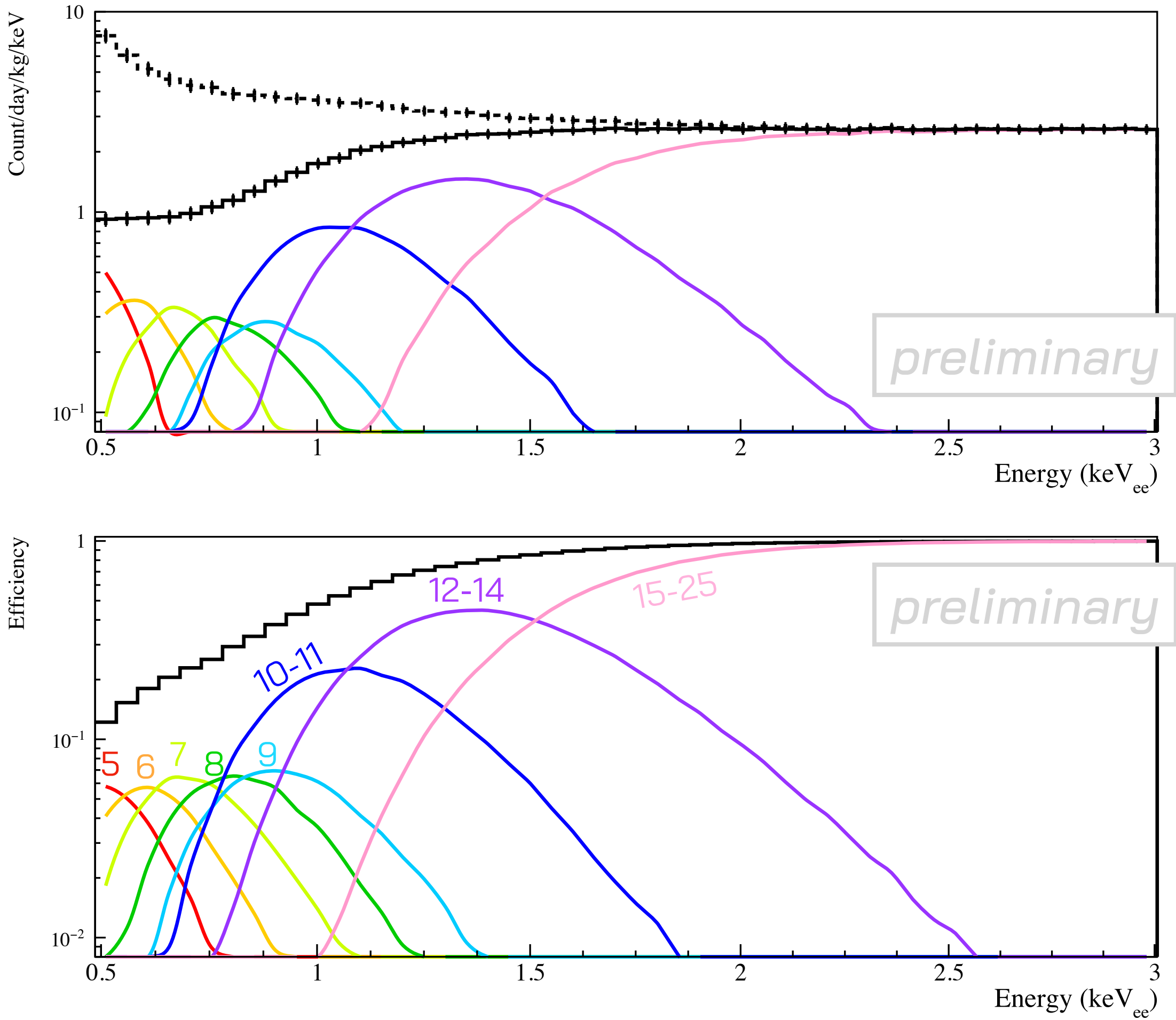
Individual training per
number of cluster (NC)

✓ **Cluster**

Isolated pulse that overs threshold

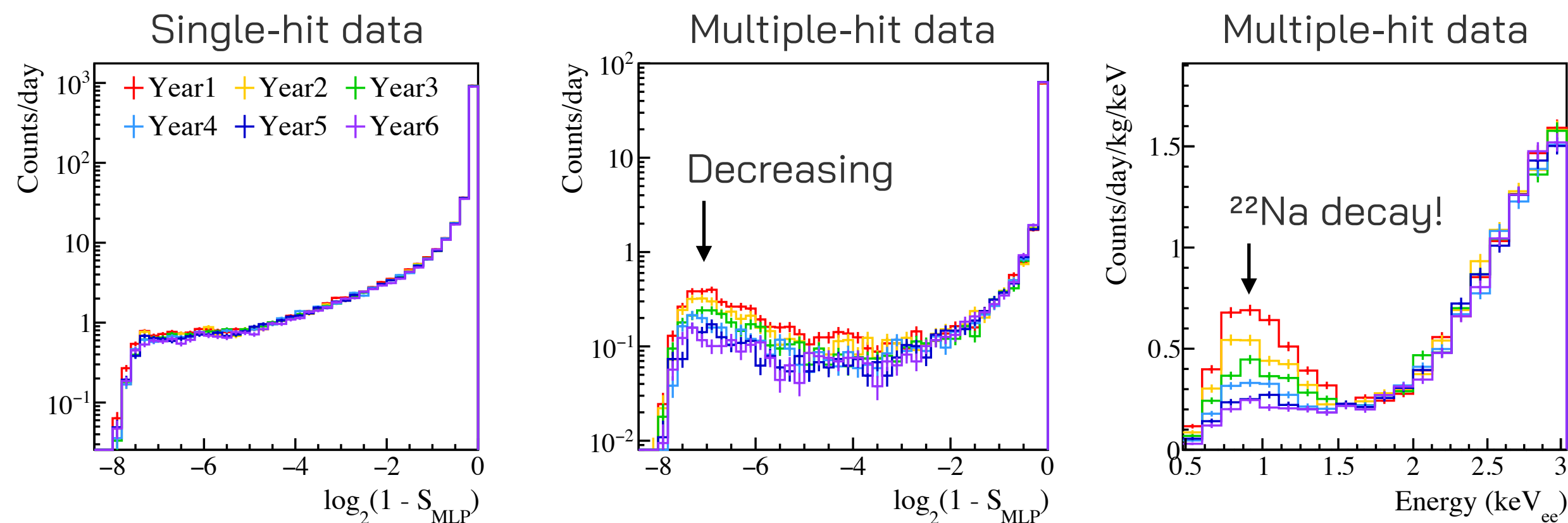


NC 5 NC 6 NC 7 NC 8
NC 9 NC 10-11 NC 12-14 NC 15-25

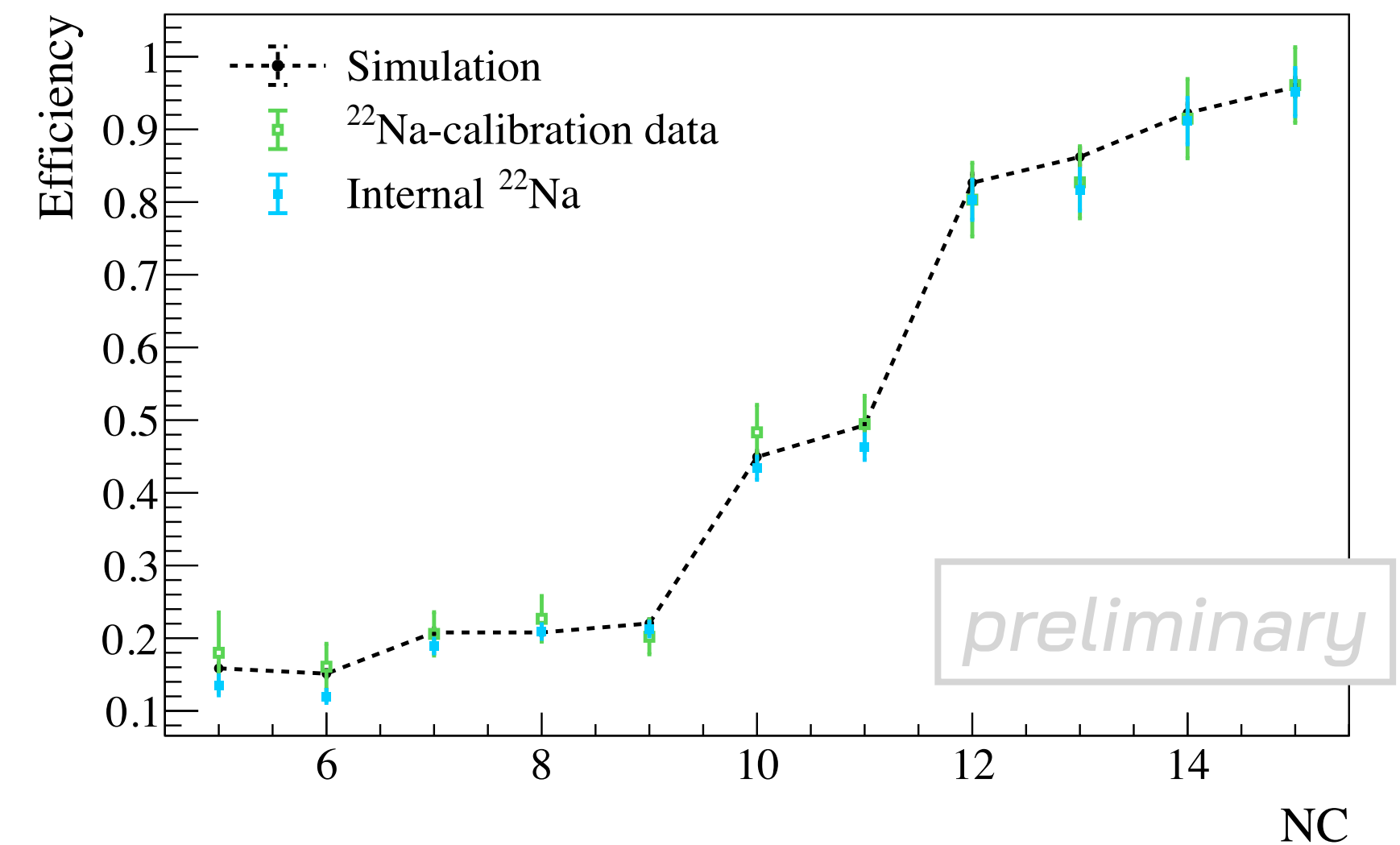


Validation for the New Event Selection

1 Time stability + recovery of a known isotope (^{22}Na decay)



2 Efficiency consistency



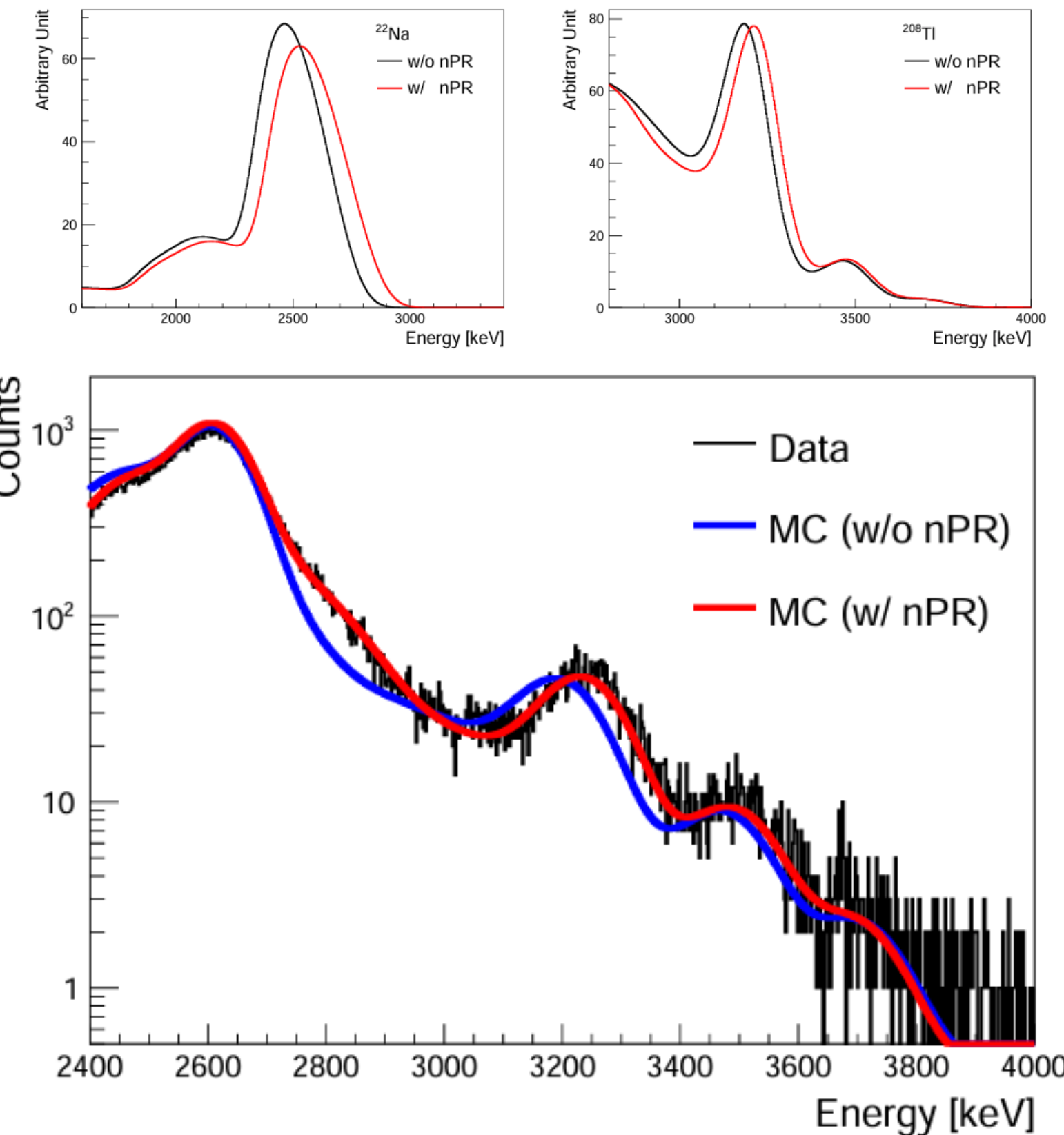
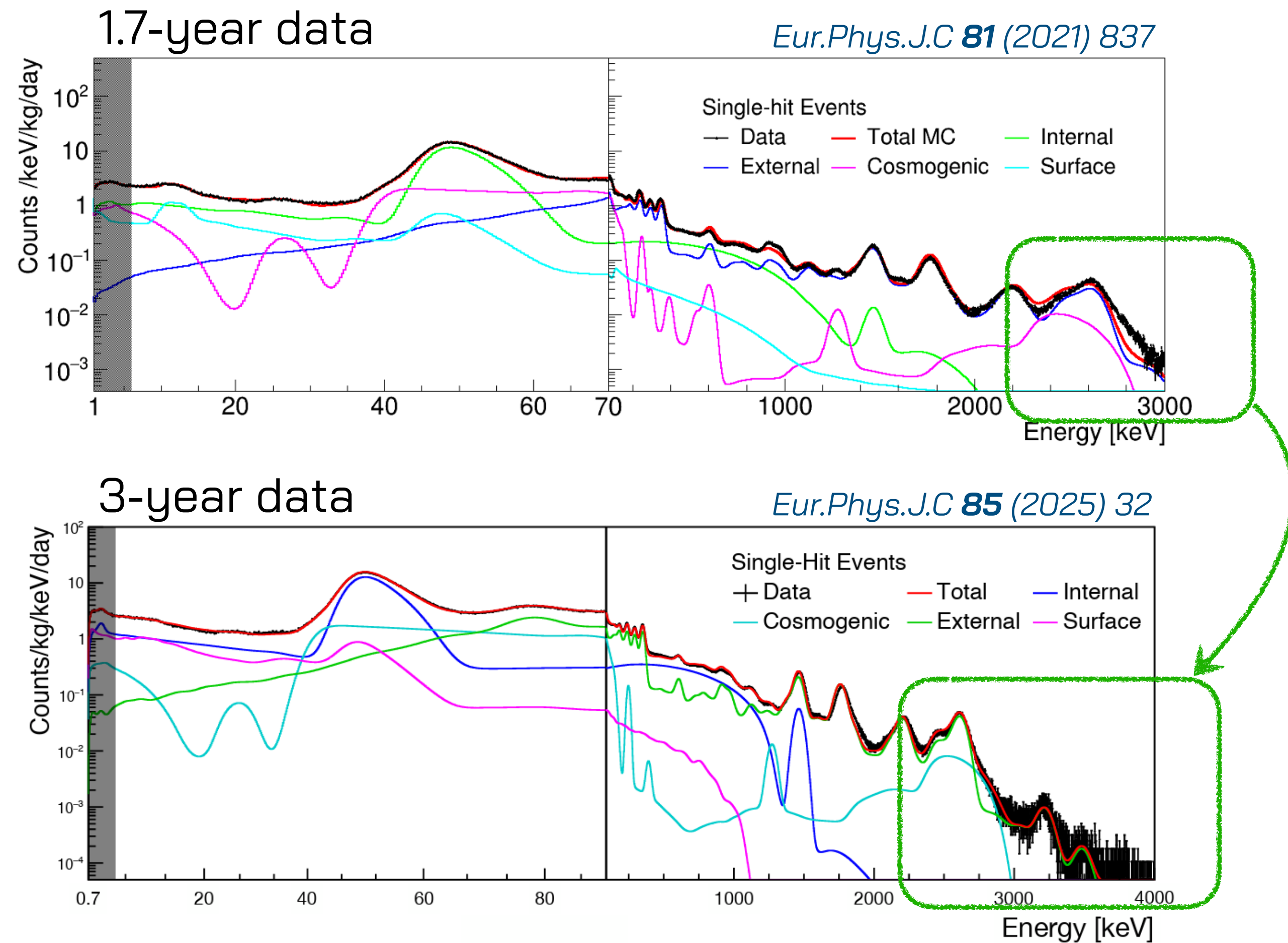
- Single-hit: $\text{MLP-score}(S_{MLP})$ is time-independent (stable selection).
- Multiple-hit: the signal-like region drops year by year.
 - tracking ^{22}Na decay at 0.87 keV ($T_{1/2} \approx 2.6$ yr) — seen in both score and energy.
- A known isotope is recovered with the correct lifetime.
 - genuine scintillation events are preserved.

three independent estimates agree

- Waveform Simulation
- Internal ^{22}Na — events from the 0.87 keV ^{22}Na -dominant region
- ^{22}Na -calibration data (dedicated source runs)

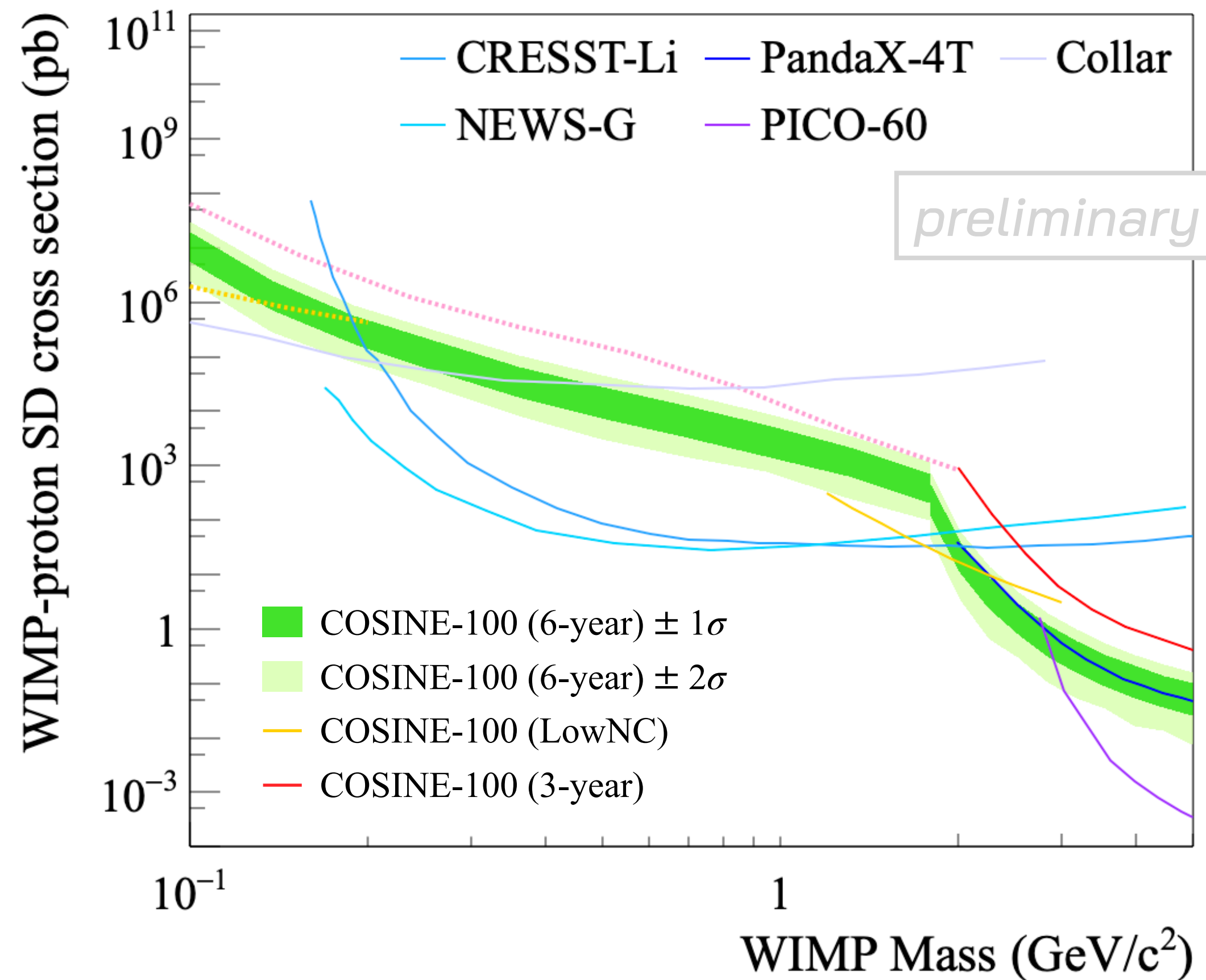
Improved Background Understanding

Overall data is well described



- High energy region modeling is improved with non-proportionality implementation

WIMP Extraction Sensitivity for 6-year Data



full six-year dataset analyses down to 0.49keV
→ best COSINE-100 sensitivity to low-mass WIMPs

potentially competitive in the GeV region

Now, we are also preparing for the modulation search with the new threshold

Summary

- COSINE-100 was designed to test the DAMA/LIBRA signal via the same target material, NaI(Tl).
- 6-year data modulation analysis ruled out the DAMA/LIBRA's claim with 3.25σ .
- Combined data with ANAIS-112 also disfavors the DAMA/LIBRA signal with 4.7σ .
- 3-year data event selection lowered threshold to 0.7 keV, and the SI limit perfectly excludes the DAMA/LIBRA contour.

- Now we lowered threshold to 0.49 keV as a result of 6-year event selection.
- We expect to cover un-explored region in SD channel.