HVeV Run 5

The Latest Generation of High-Voltage, Electronvolt-Scale Cryogenic Silicon Calorimeters in the Search for Dark Matter

Mason Buchanan

University of Toronto

25 June 2026

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Overview

Background

SuperCDMS and HVeV

- SuperCDMS is a direct-detection low-mass dark matter experiment

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  - Uses Si and Ge HV (High Voltage, phonon) and iZIP (phonon + ionization) detectors

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  - Ideal for finely probing background

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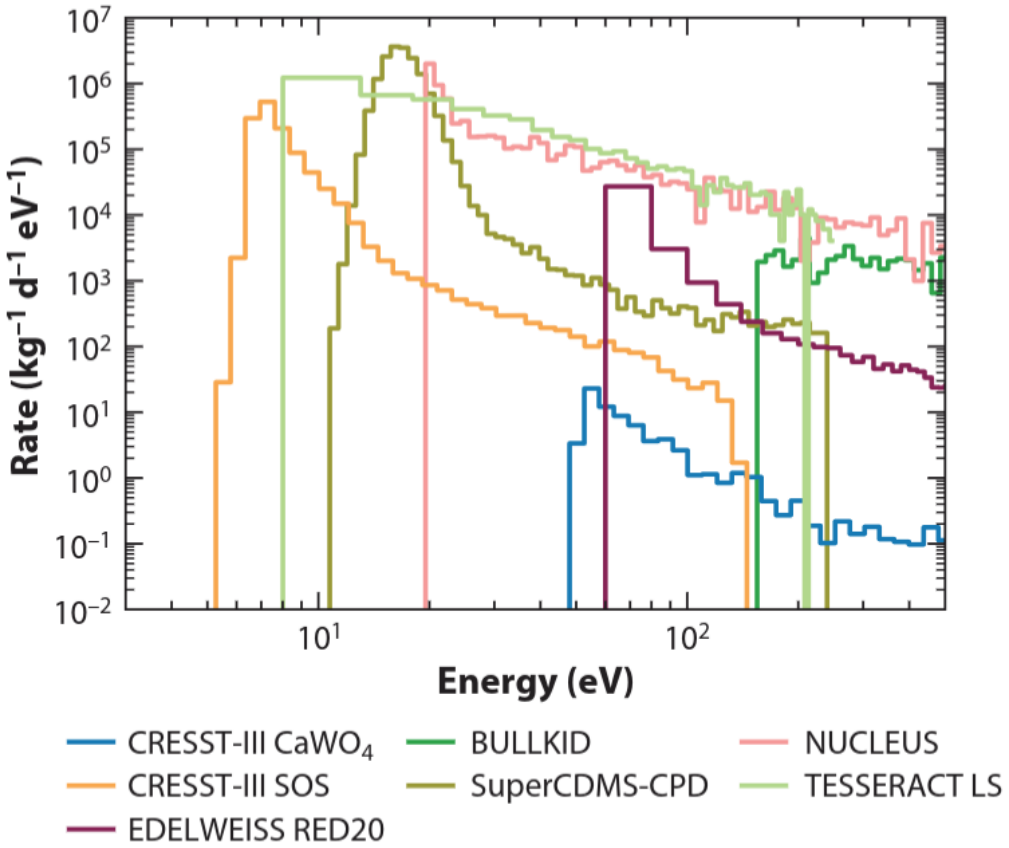
Unknown Backgrounds: The Low-Energy Excess

- Low-mass experiments are seeing unknown backgrounds



Baxter, Essig, et al. 2025

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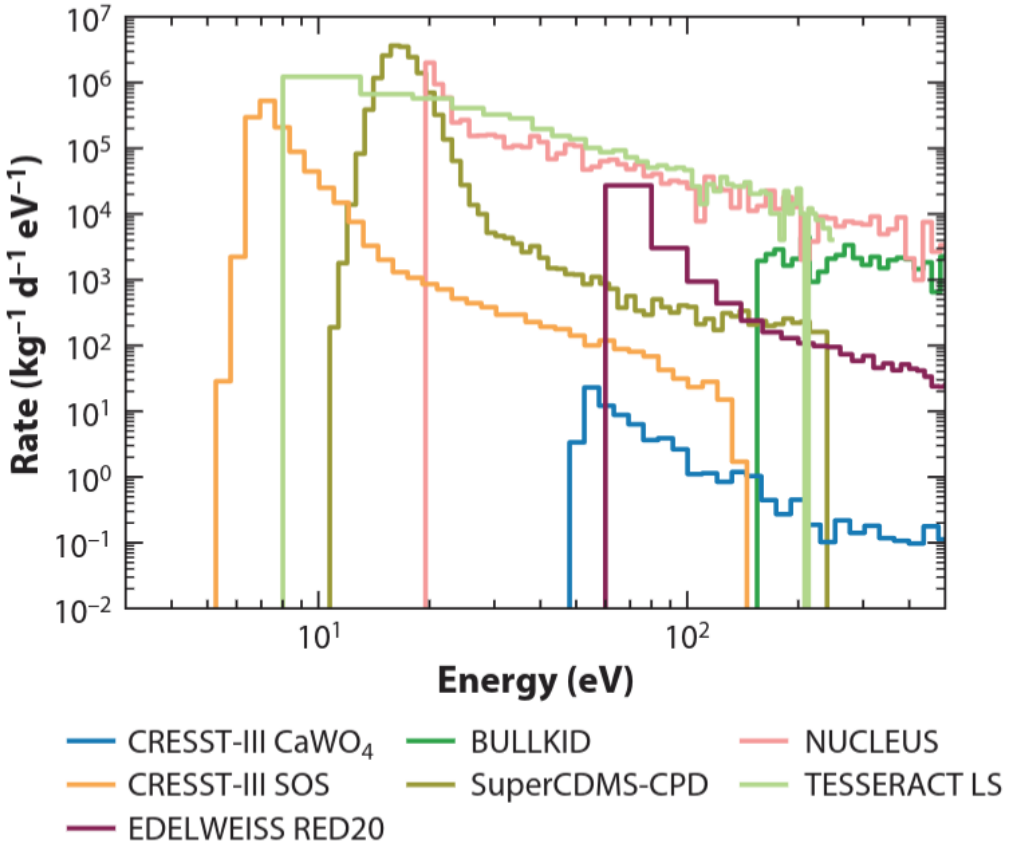

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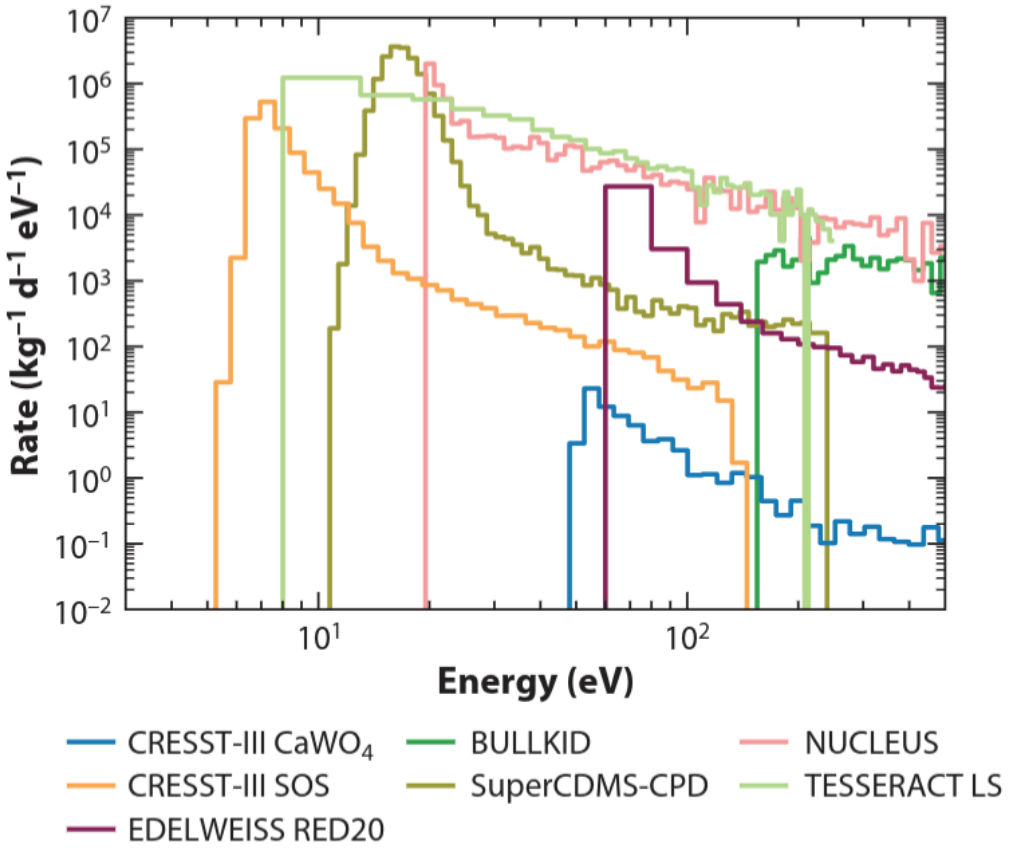

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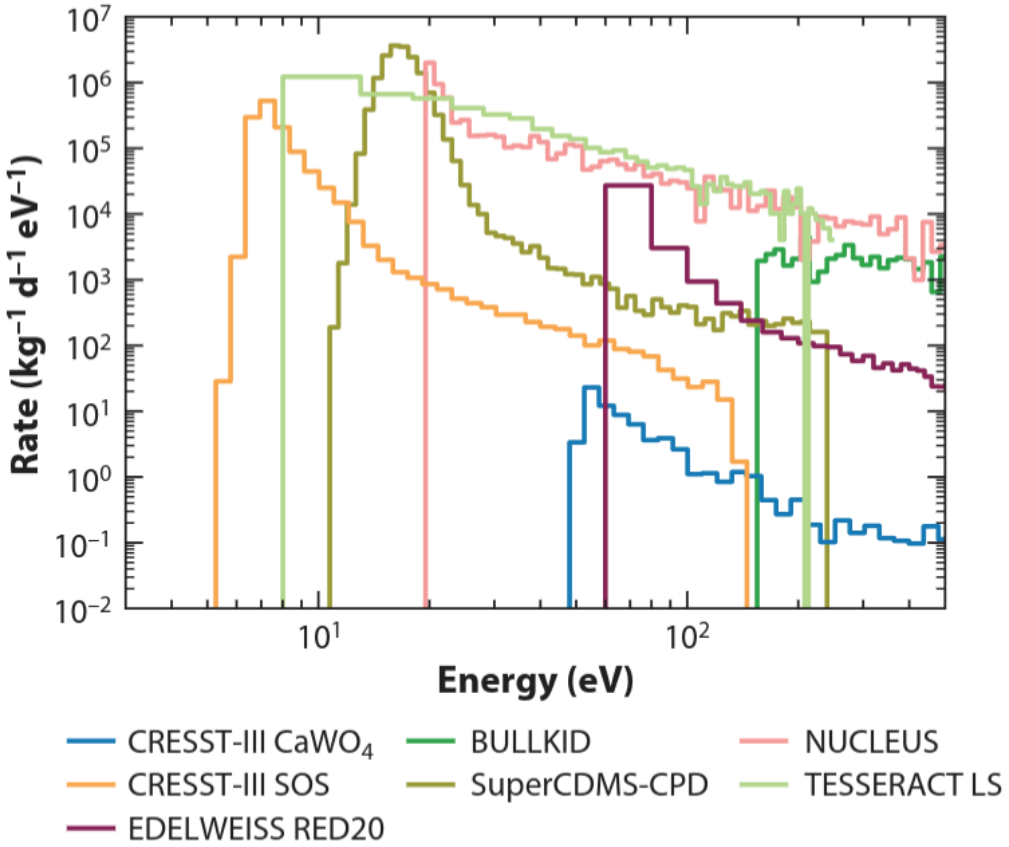

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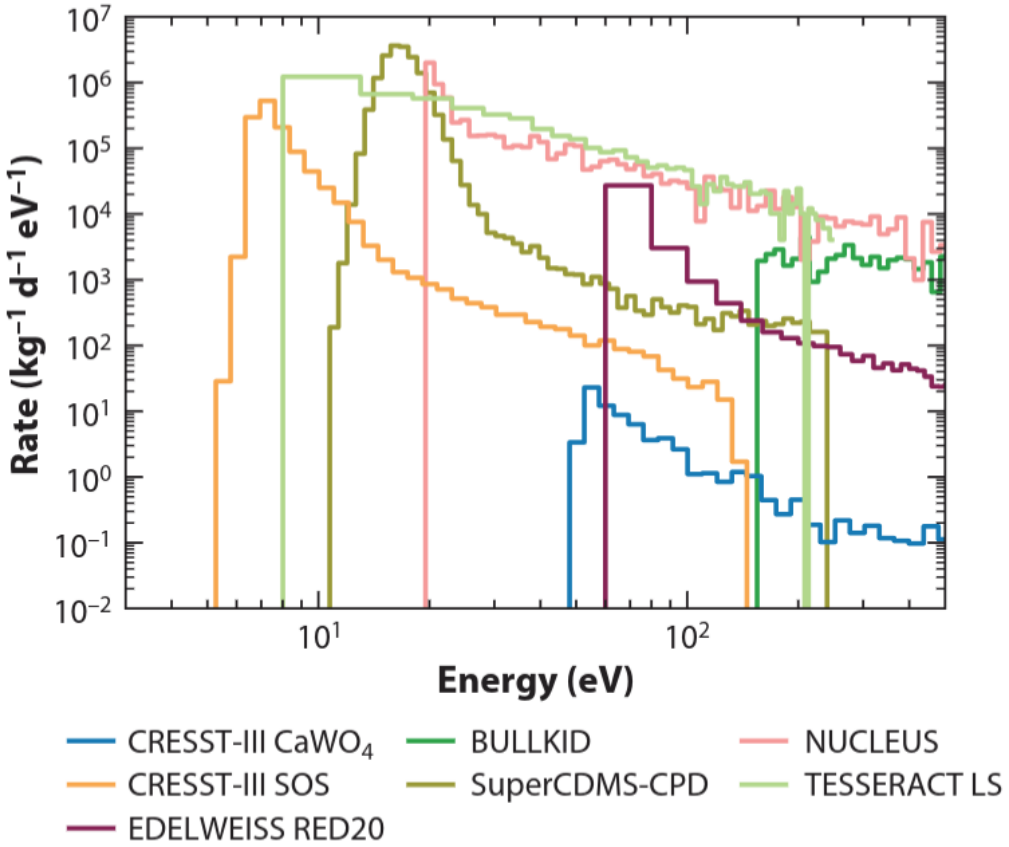
- Appears non-ionizing (EDELWEISS 2023)
- Decreases with time after cooldown; very unlikely dark matter



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HVeV Run 5

- New SiO_2 design aiming to lower leakage background (more on this in a moment)
- Moving from NEXUS at Fermilab (100 m underground) for Run 4 to SNOLAB's CUTE facility (2 km)

- Using resulting sensitivity for dark matter search that could also be used to probe LEE

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Experiment

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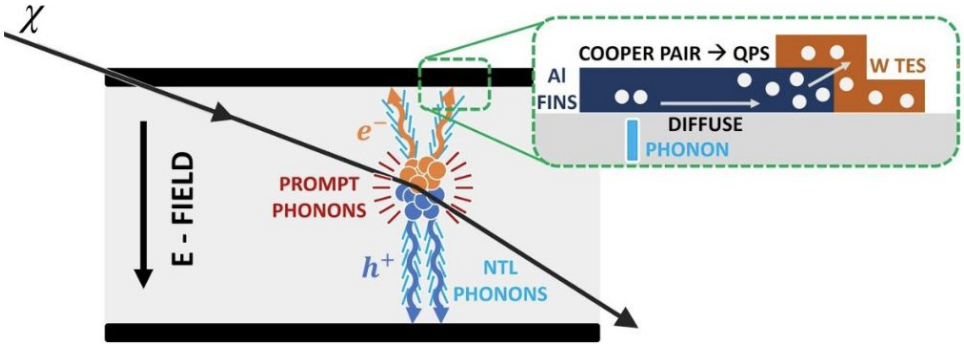
The SiO_2 HVeV Detector

- Interactions in crystal knock loose electron-hole pairs



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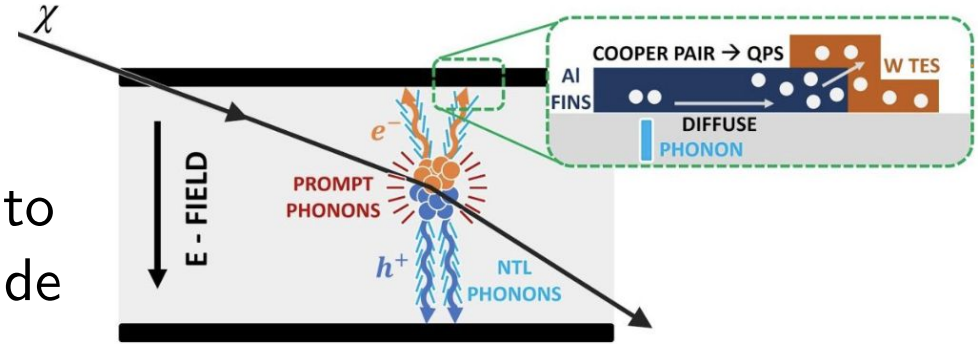

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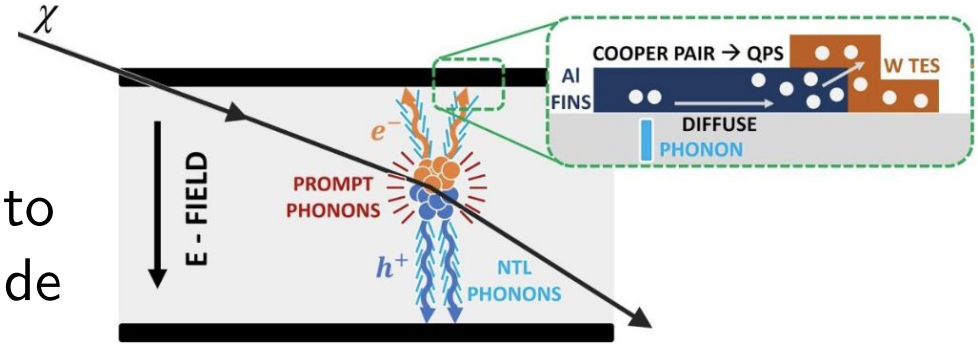

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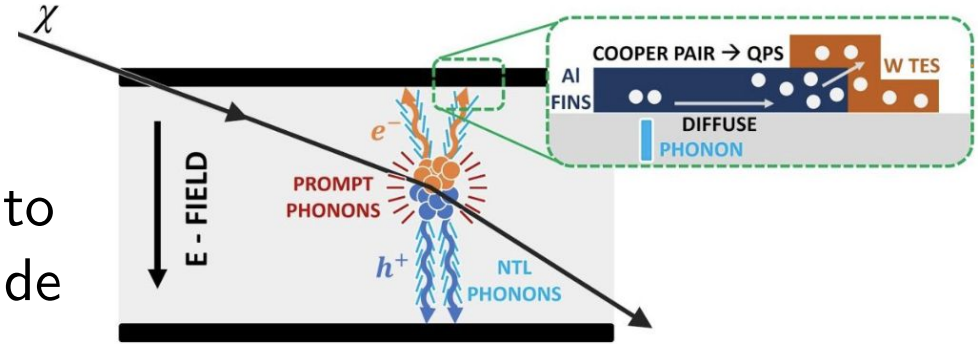

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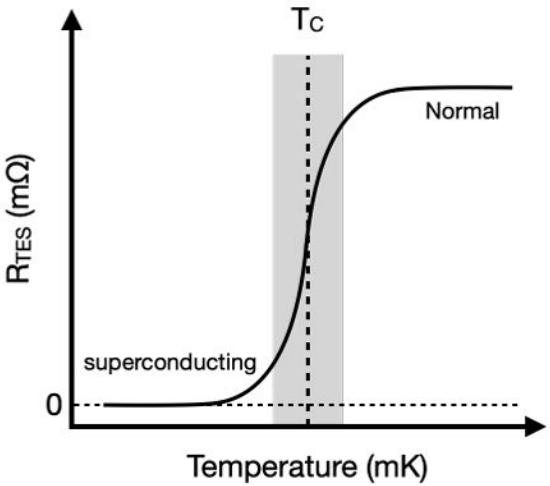

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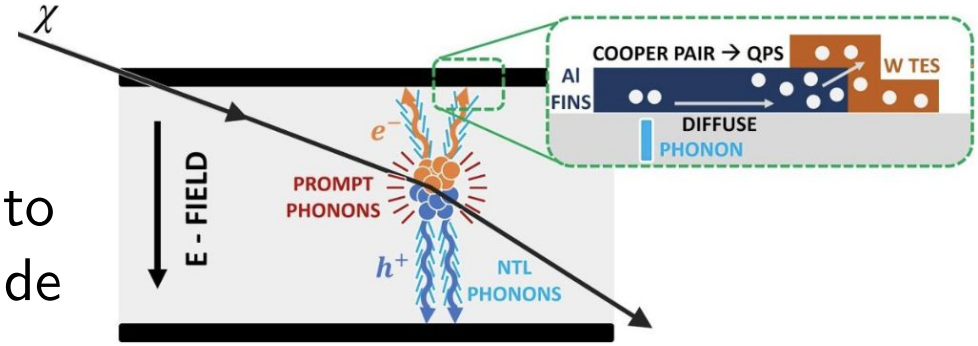

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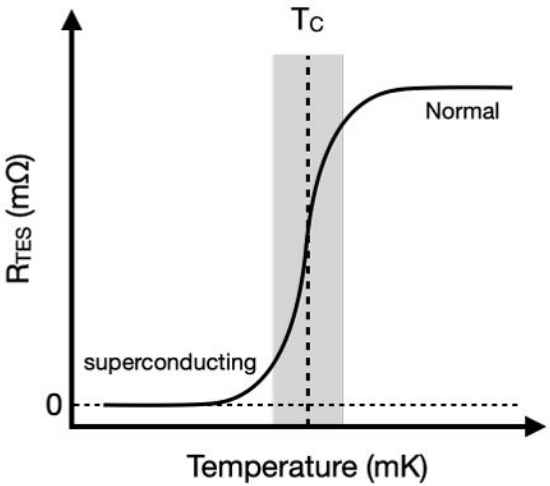

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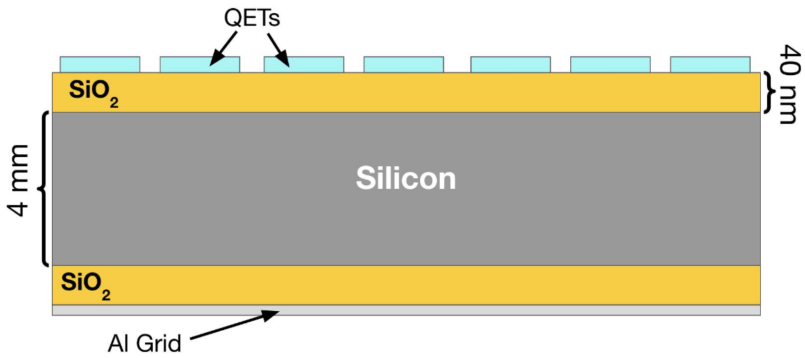
- New SiO_2 layer to reduce charges tunneling from Al into crystal ("leakage")



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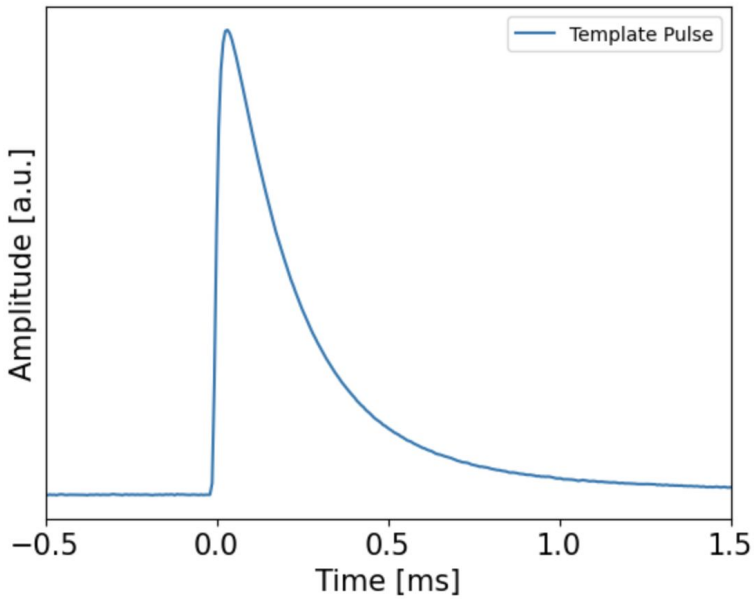
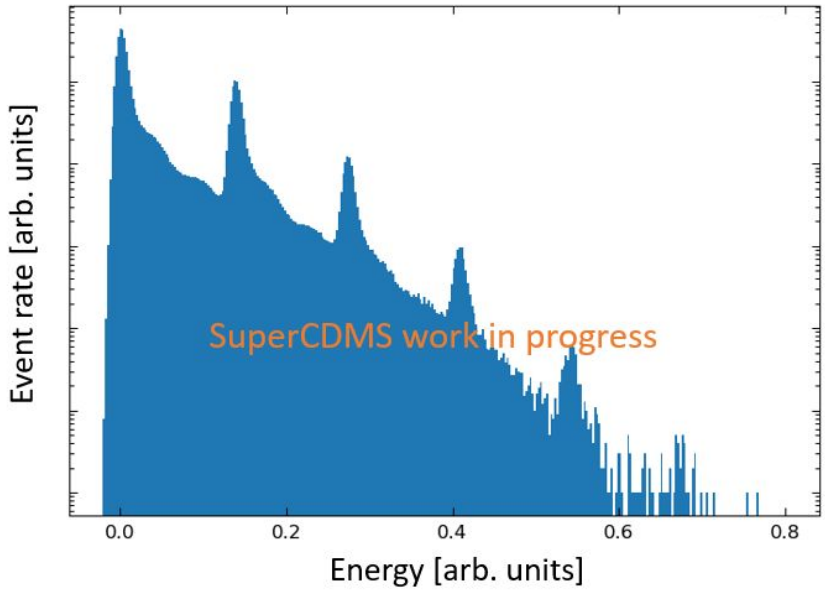
Data from an HVeV Experiment





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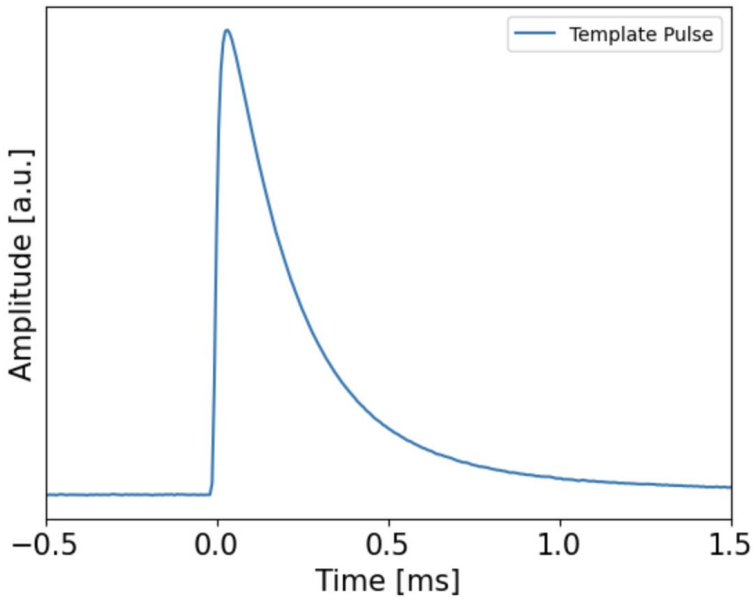

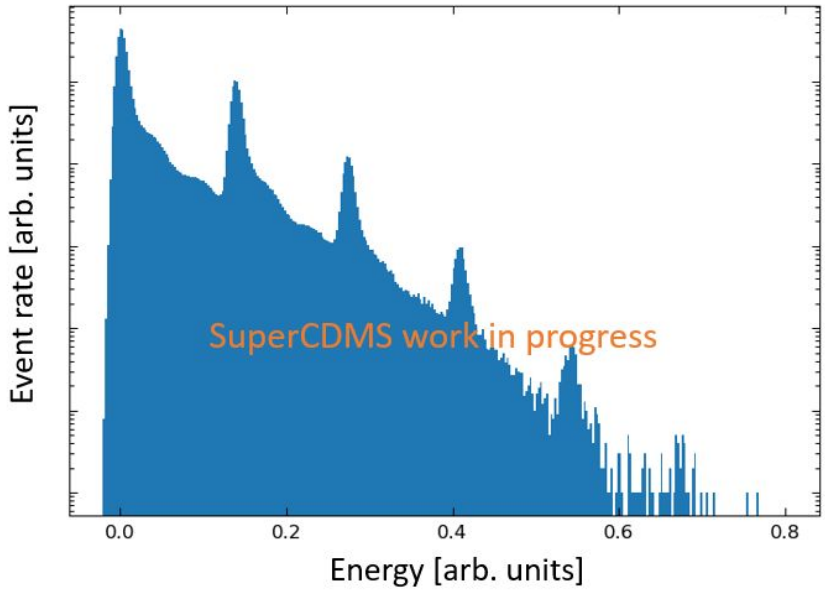

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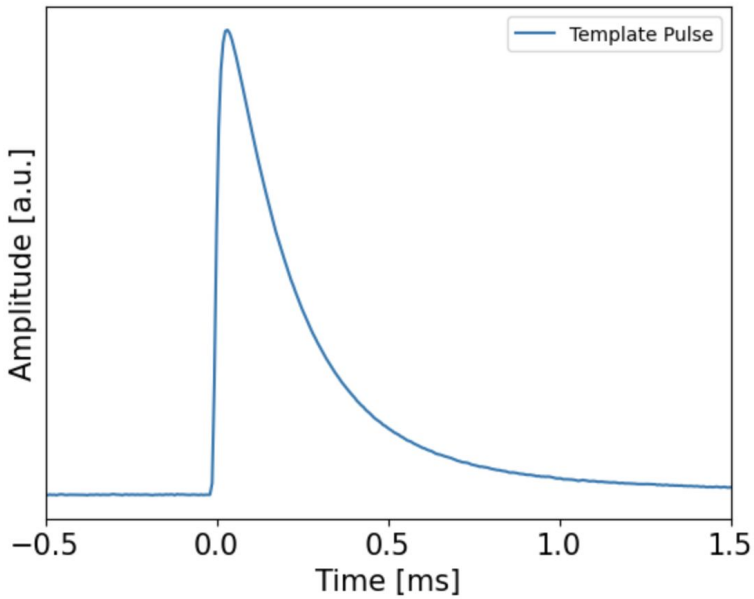

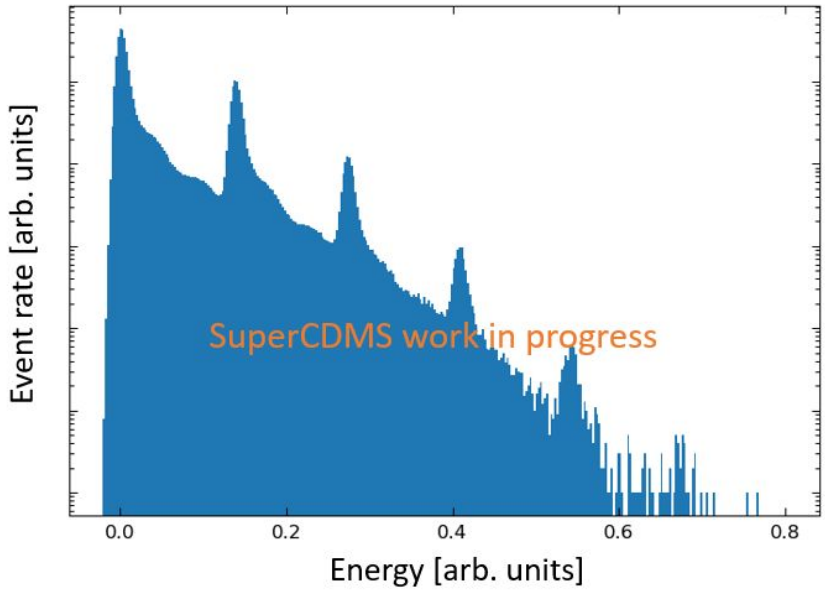

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  - Height corresponds to energy
- Energies are distributed in peaks per number of e-h pairs created

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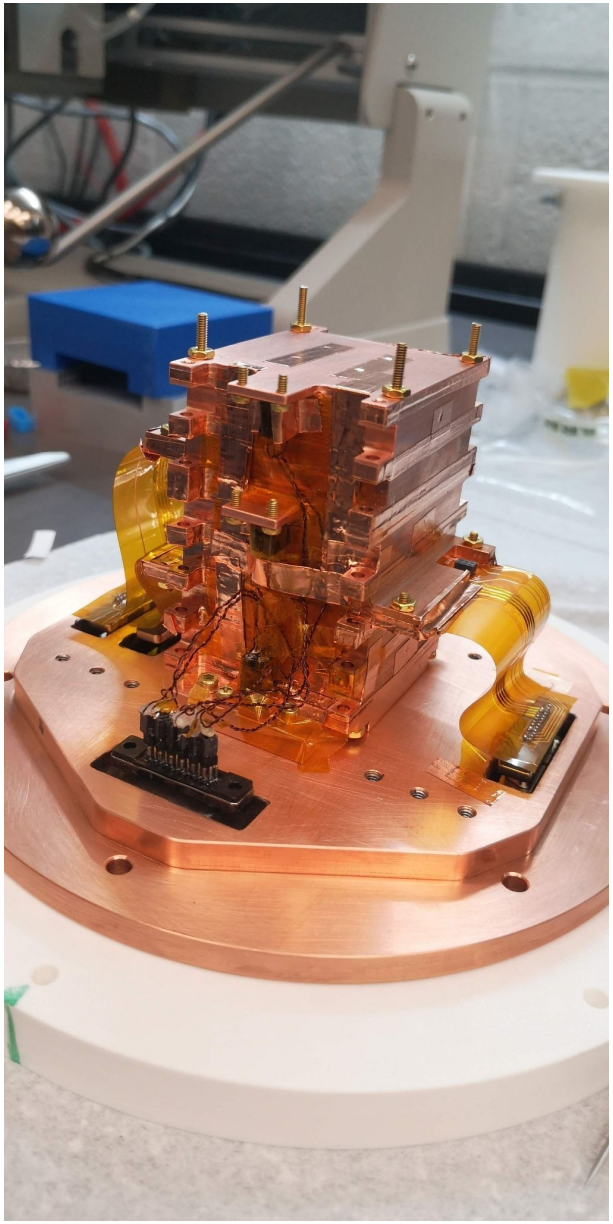
Data Collection



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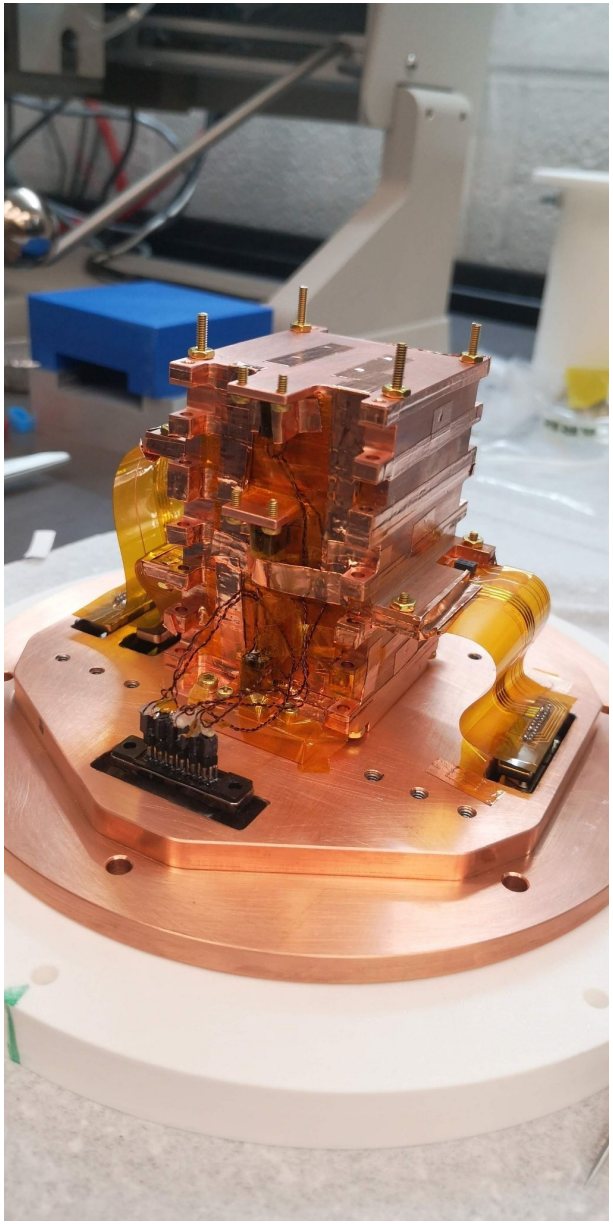

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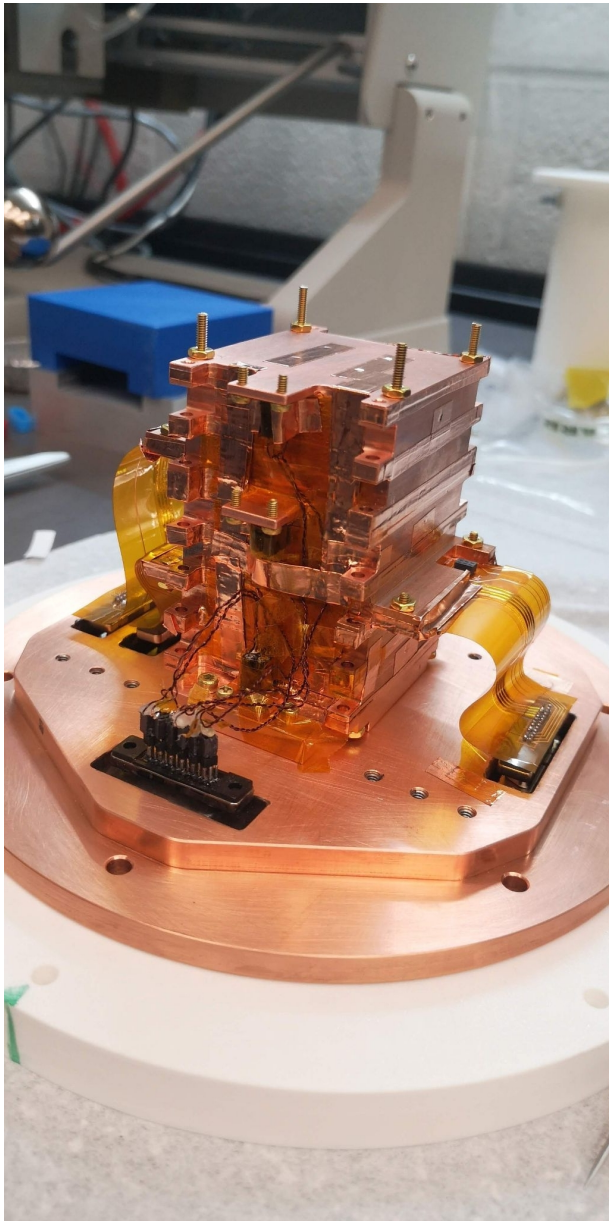

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- About 13 days of blinded dark matter search data, broken into 12-hour series

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Analysis

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  - Template produced by averaging pulses in 1 e-h peak

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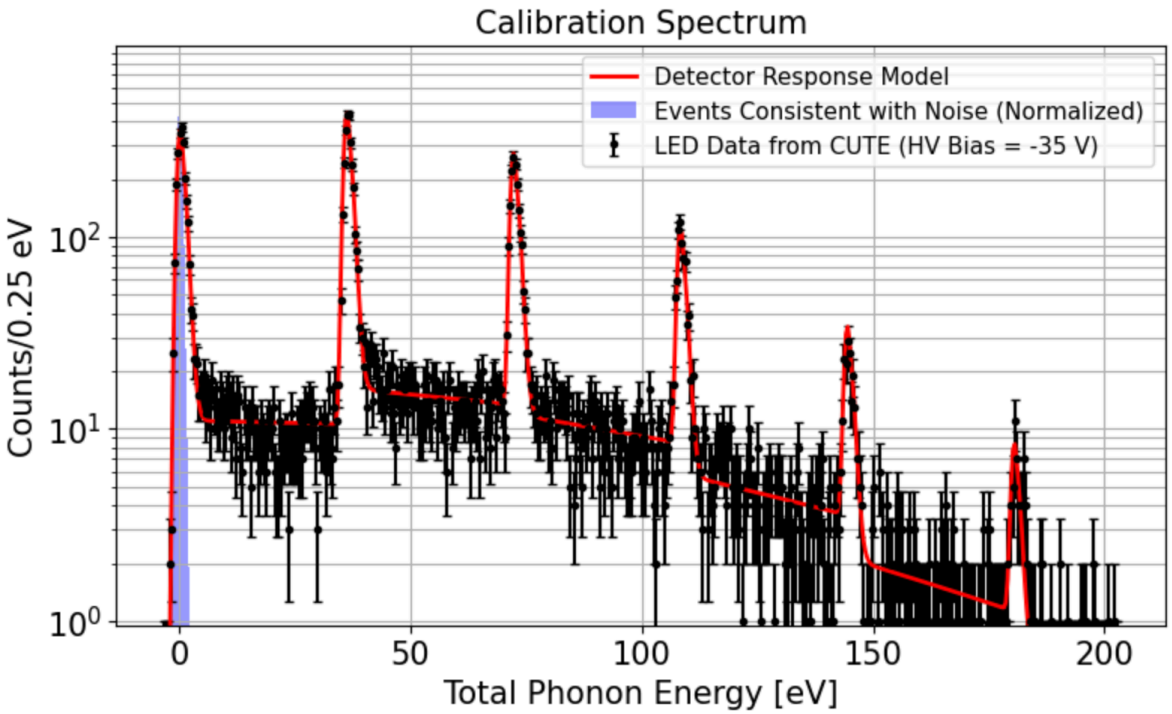
Calibration



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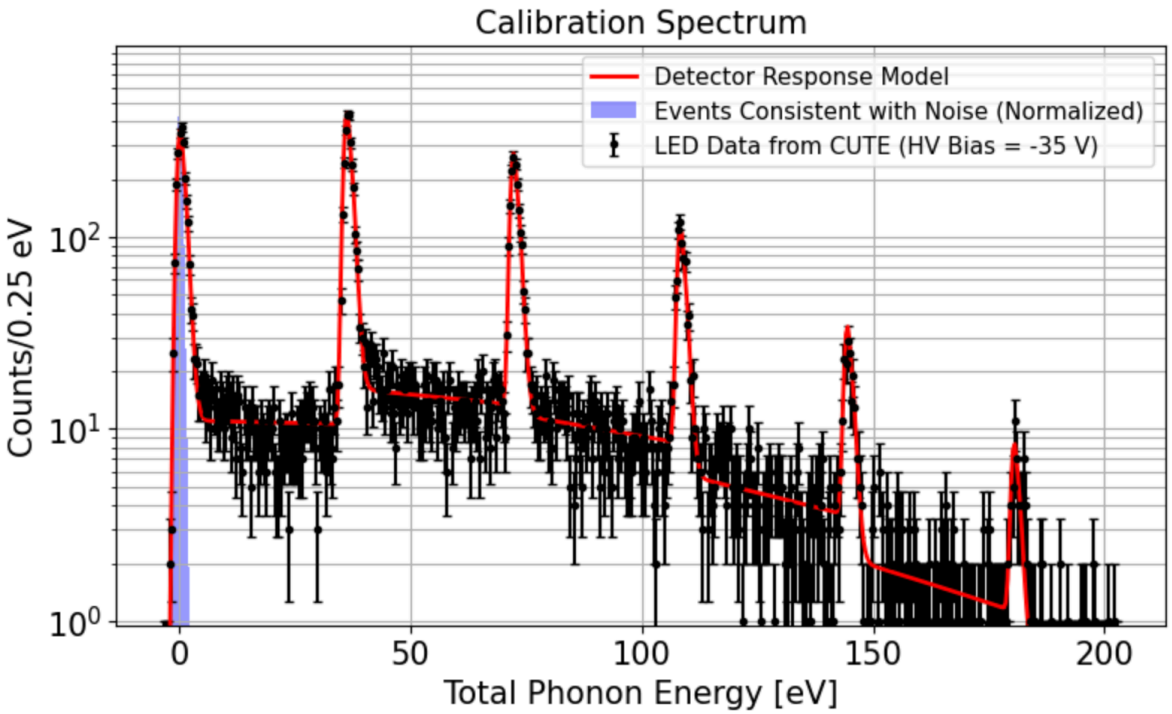

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- Also measured width of energy distribution random triggers to calculate resolution of **0.589 ± 0.005 eV**

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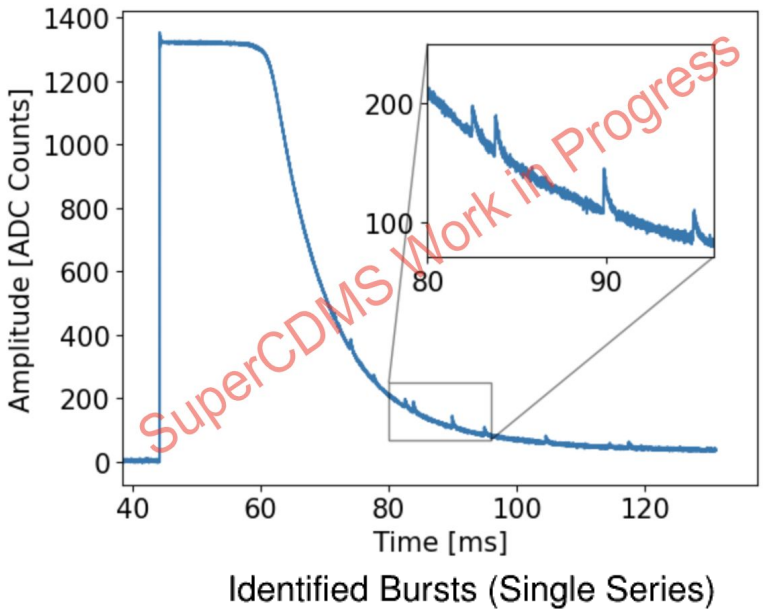
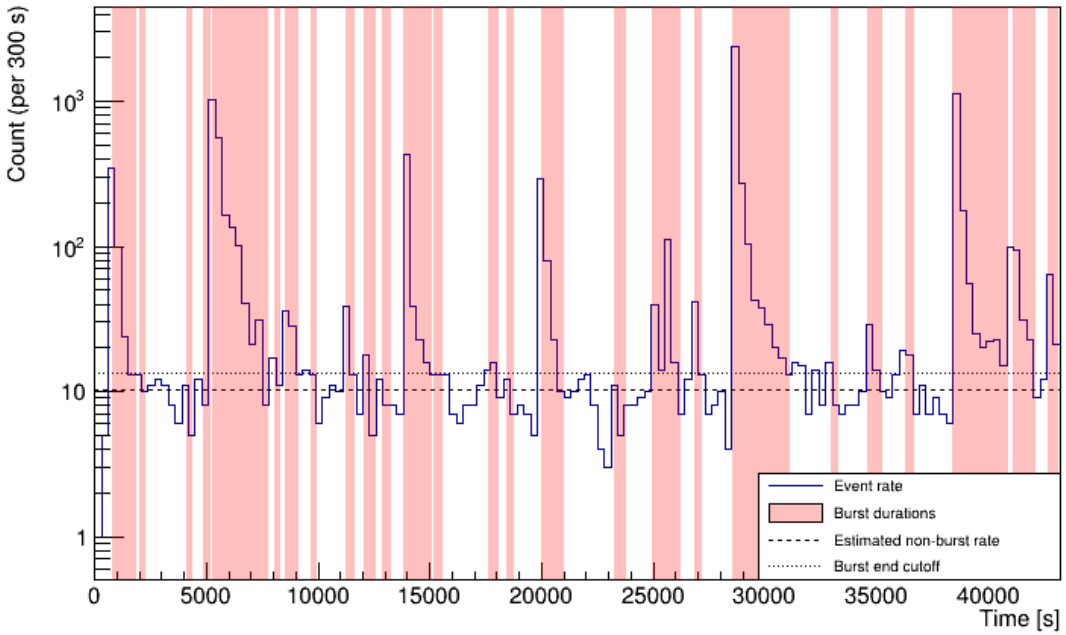
“Bursts”



Identified Bursts (Single Series)



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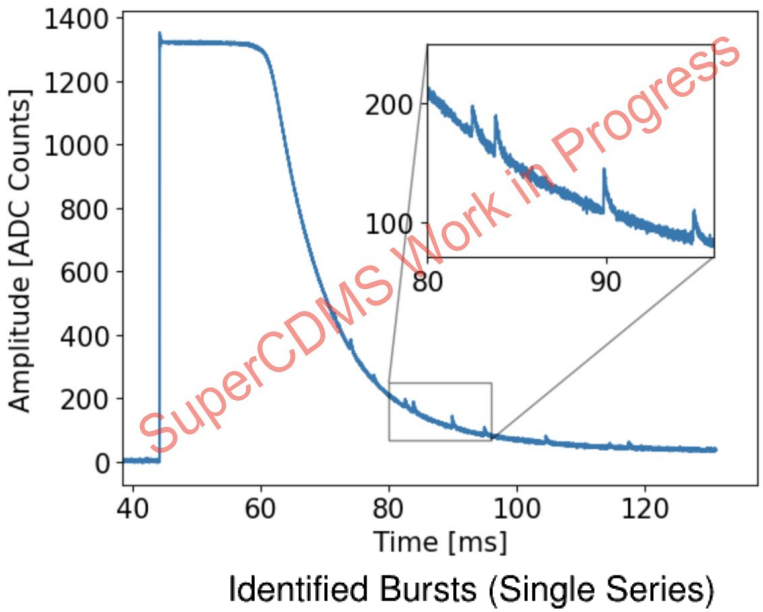

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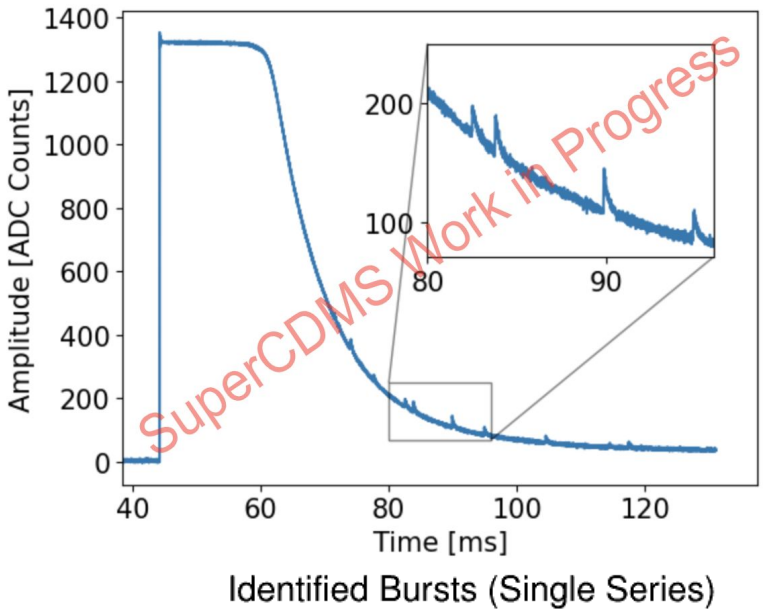

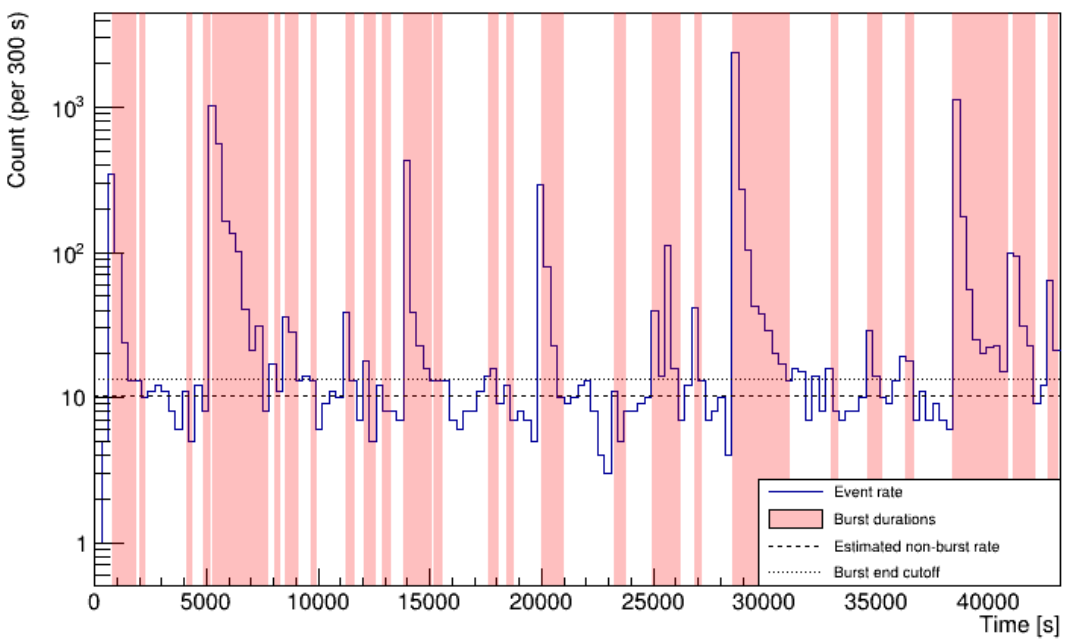

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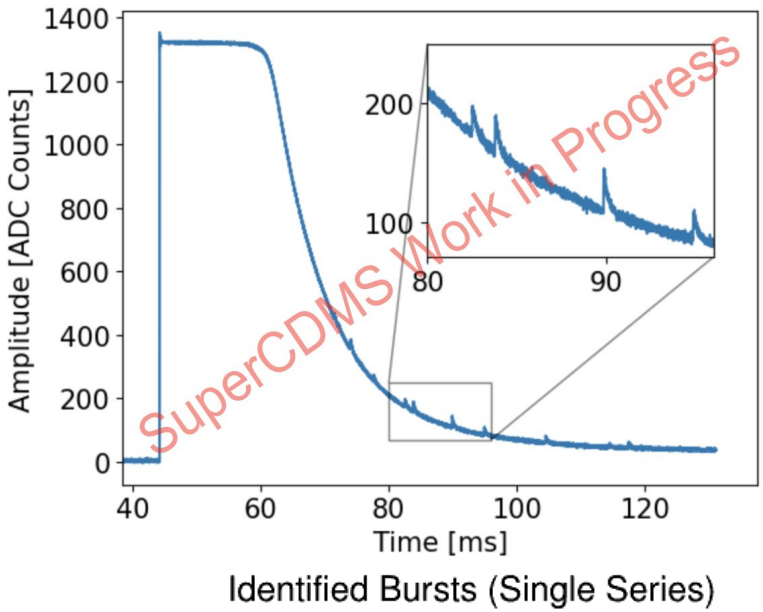

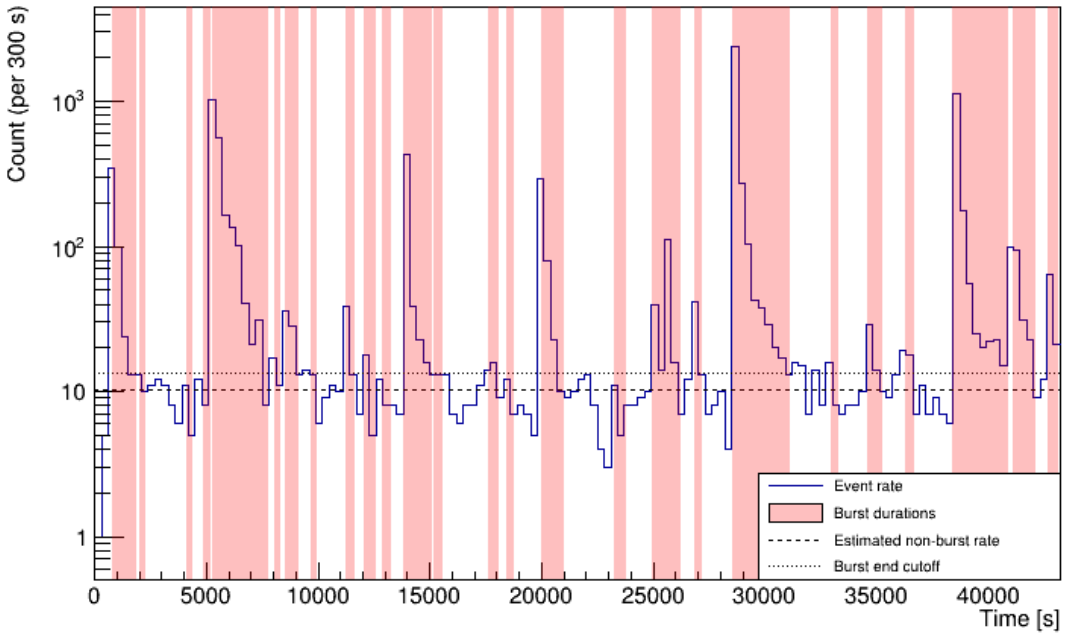

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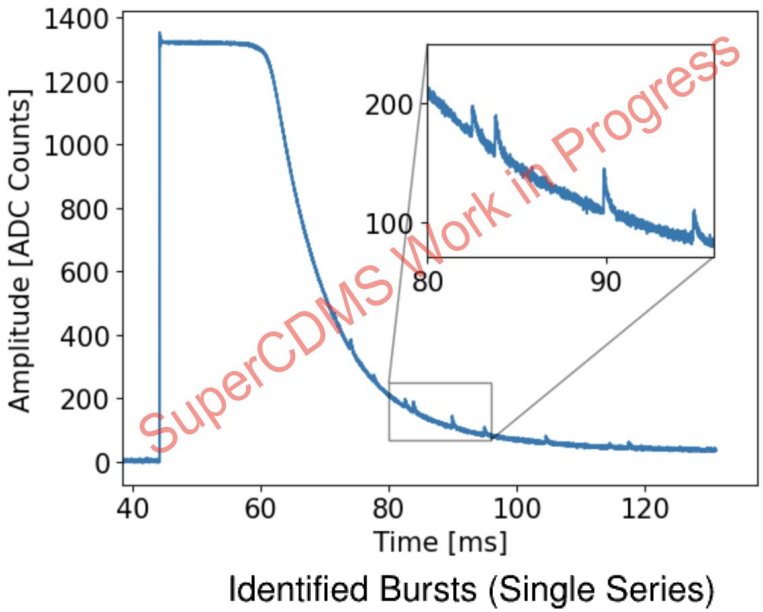

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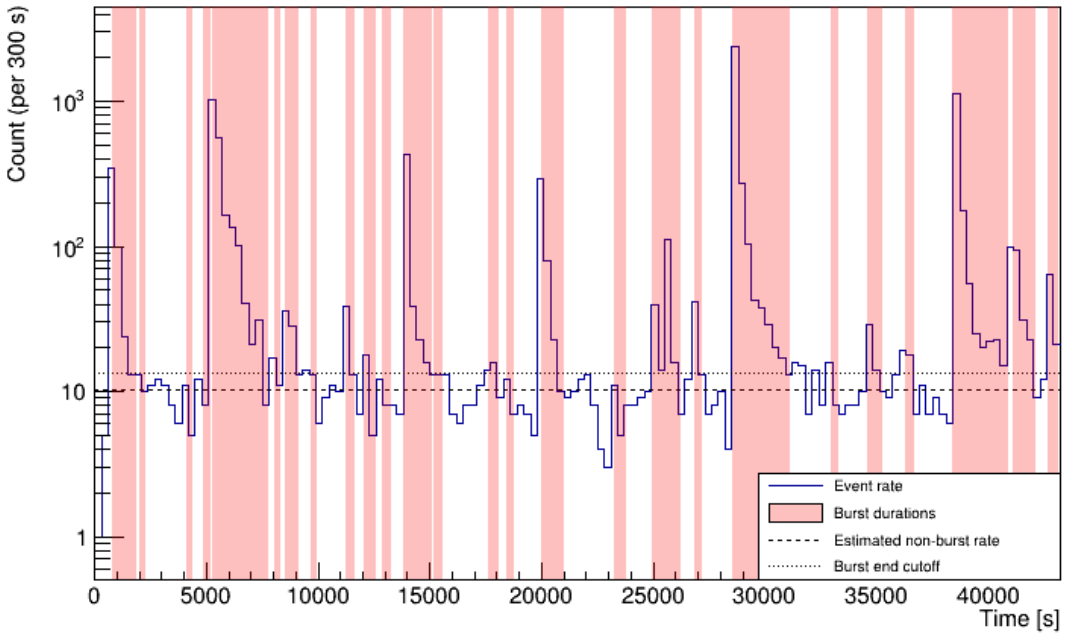

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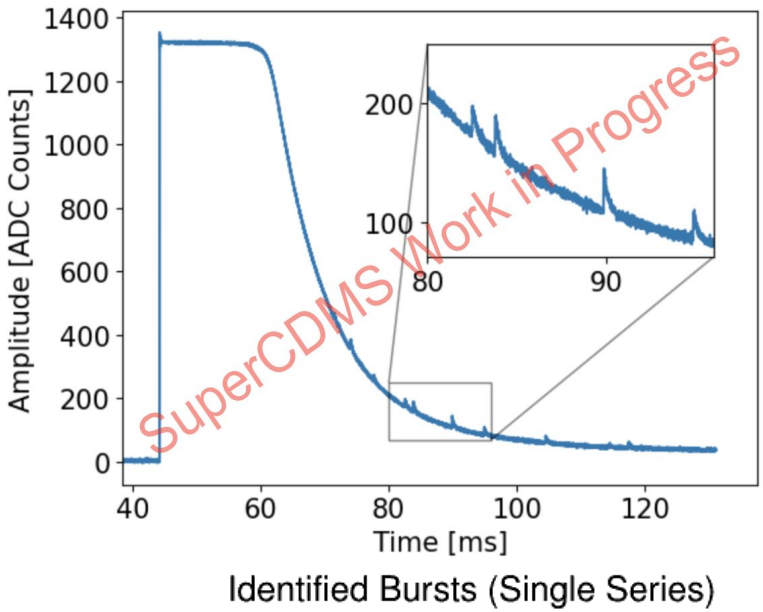

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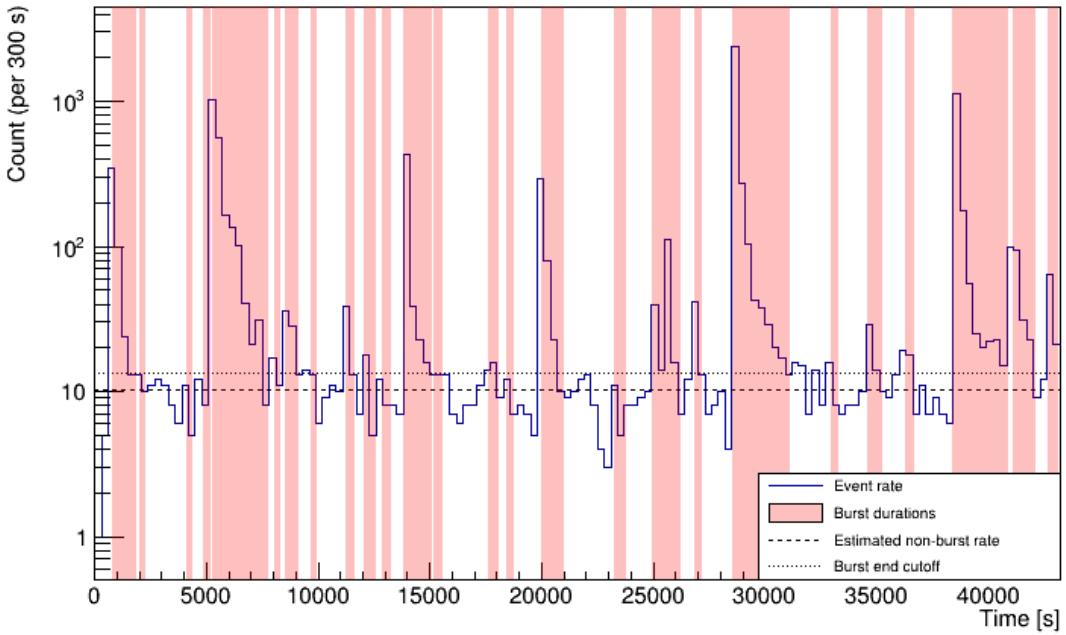

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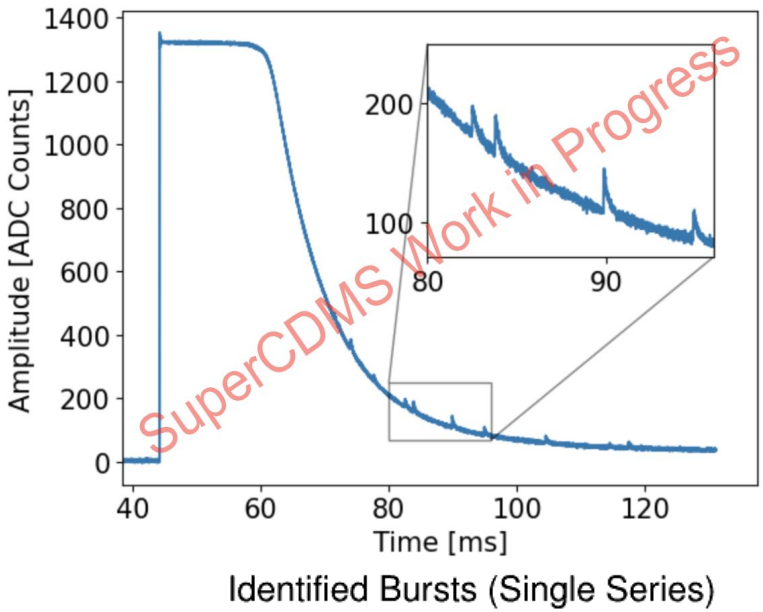

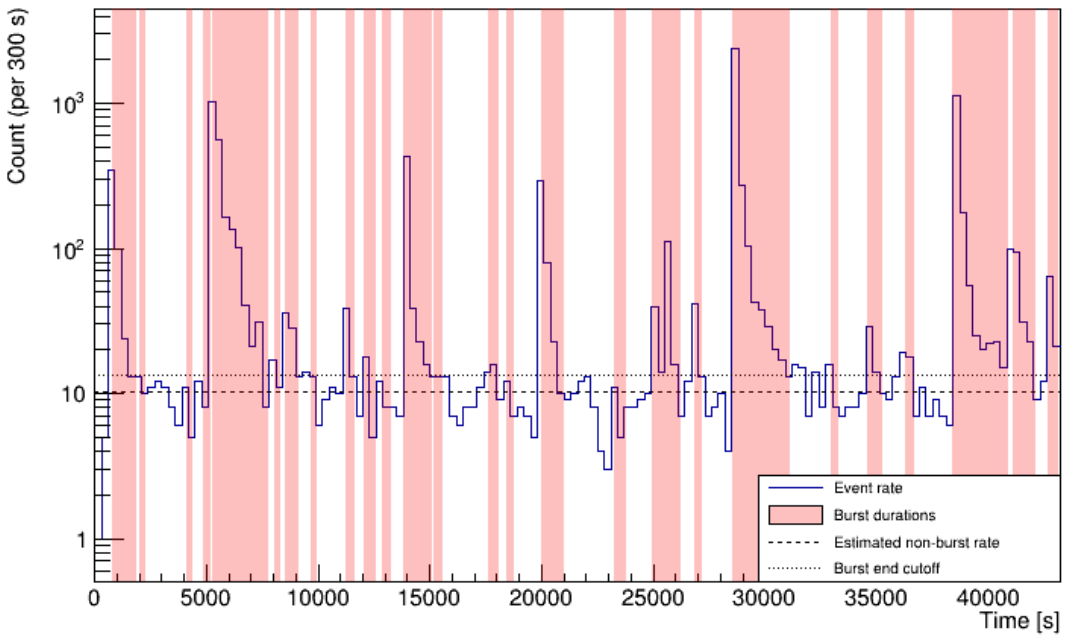

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- Cause is subject of ongoing investigation

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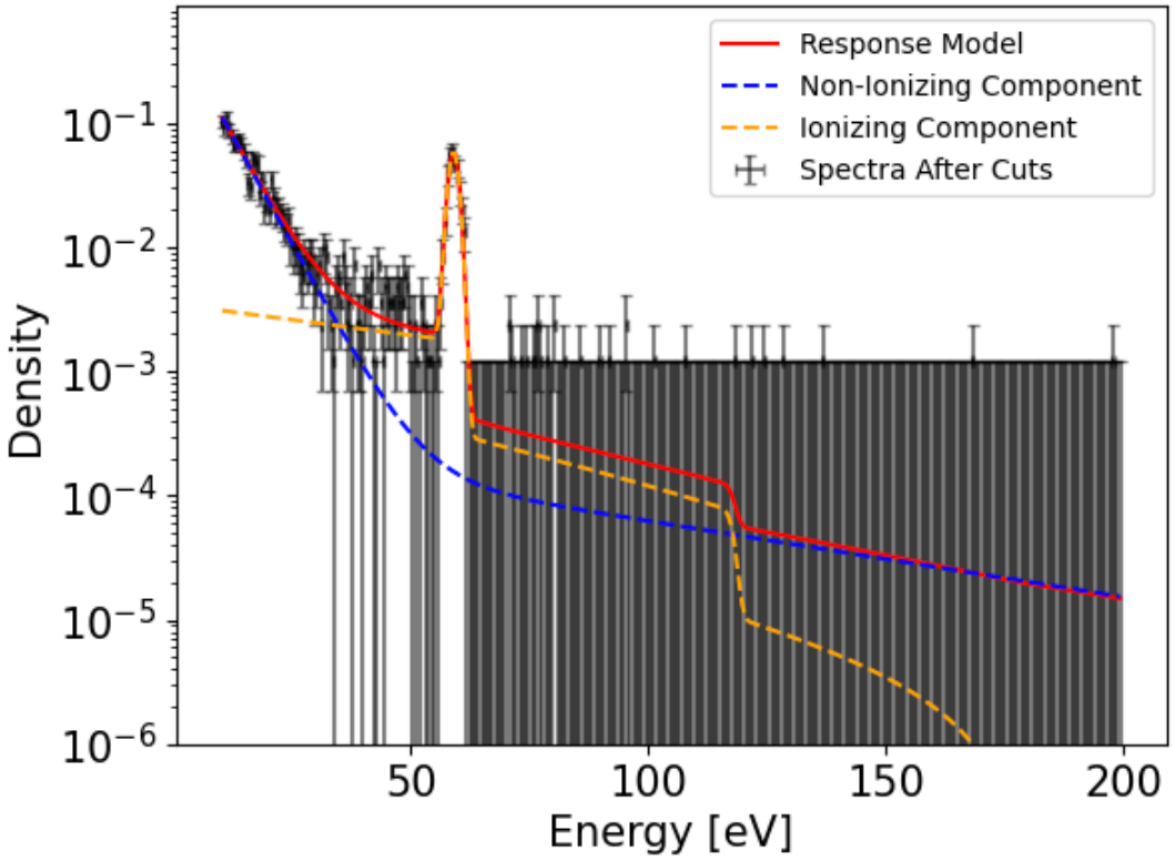
Background Model



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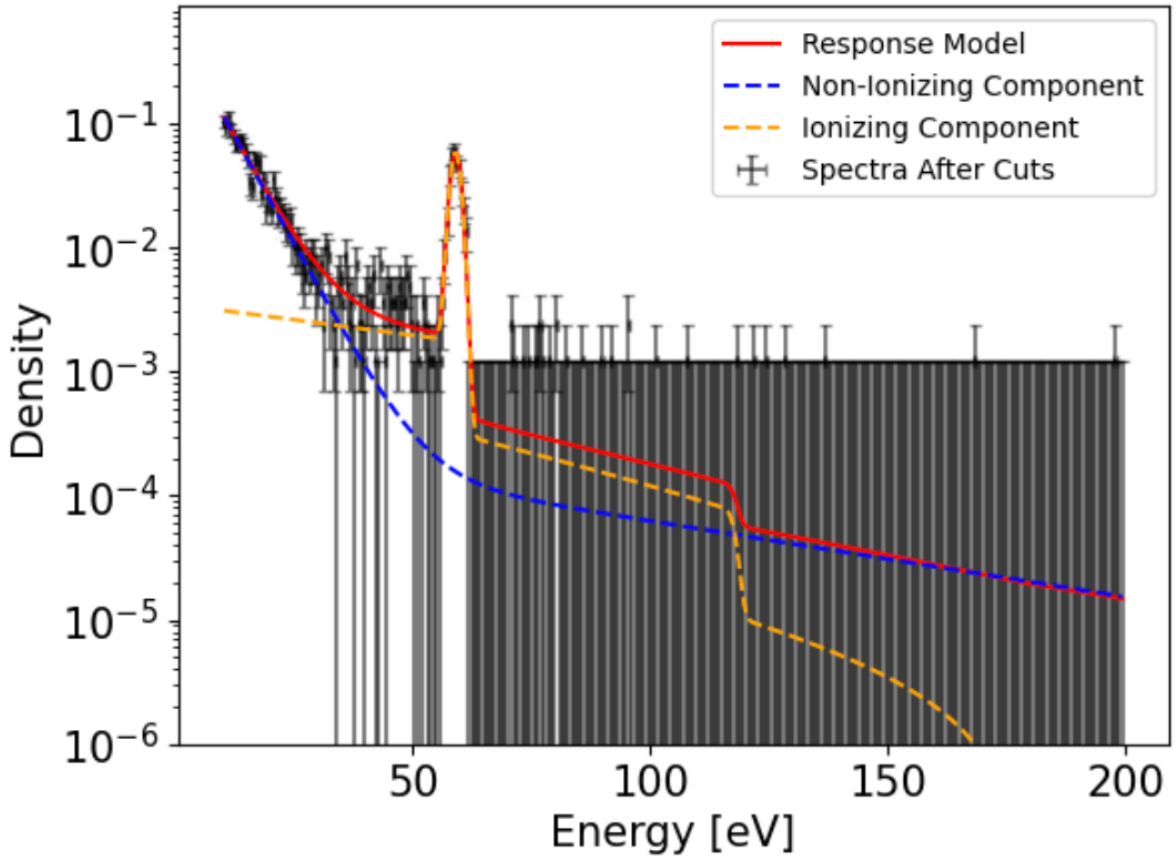

- Non-ionizing component (incl. LEE) is modelled by double-Poisson function constrained by 0 V data
- Ionizing component (leakage and bursts) is modelled by crystal response with bulk and surface trapping and impact ionization (Wilson, Zaytsev et al. 2024)

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Limit Setting

- Utilizes profile likelihood ratio
  - Scans possible DM cross section values, producing test statistic that compares likelihood for each cross section to the likelihood of most likely cross section

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  - Scans possible DM cross section values, producing test statistic that compares likelihood for each cross section to the likelihood of most likely cross section
- 90% confidence limit is calculated for each mass for each of four signal models
  - DM-e scattering with light mediator
  - DM-e scattering with heavy mediator
  - Dark photon
  - Axion-like particle (ALP)

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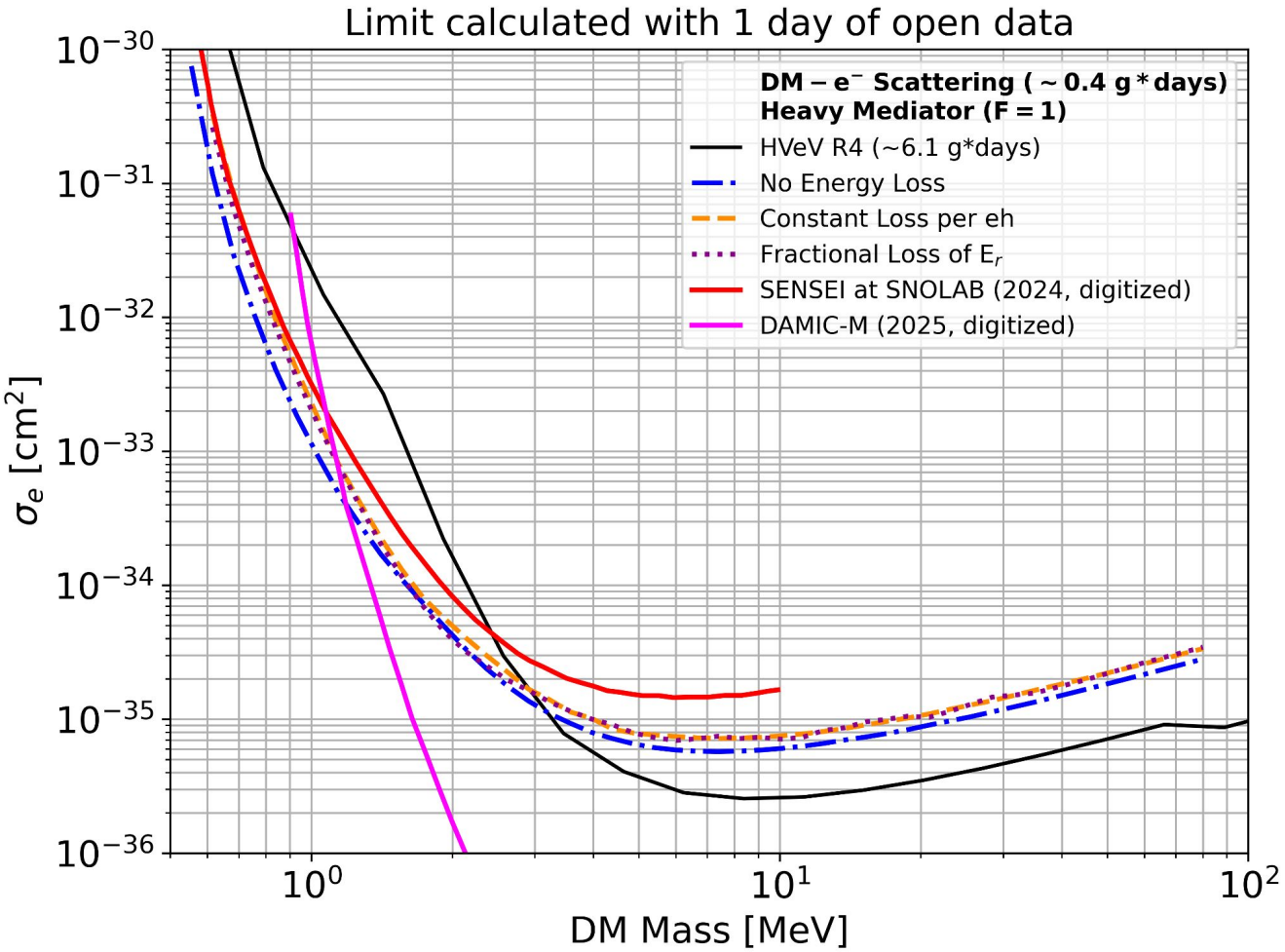
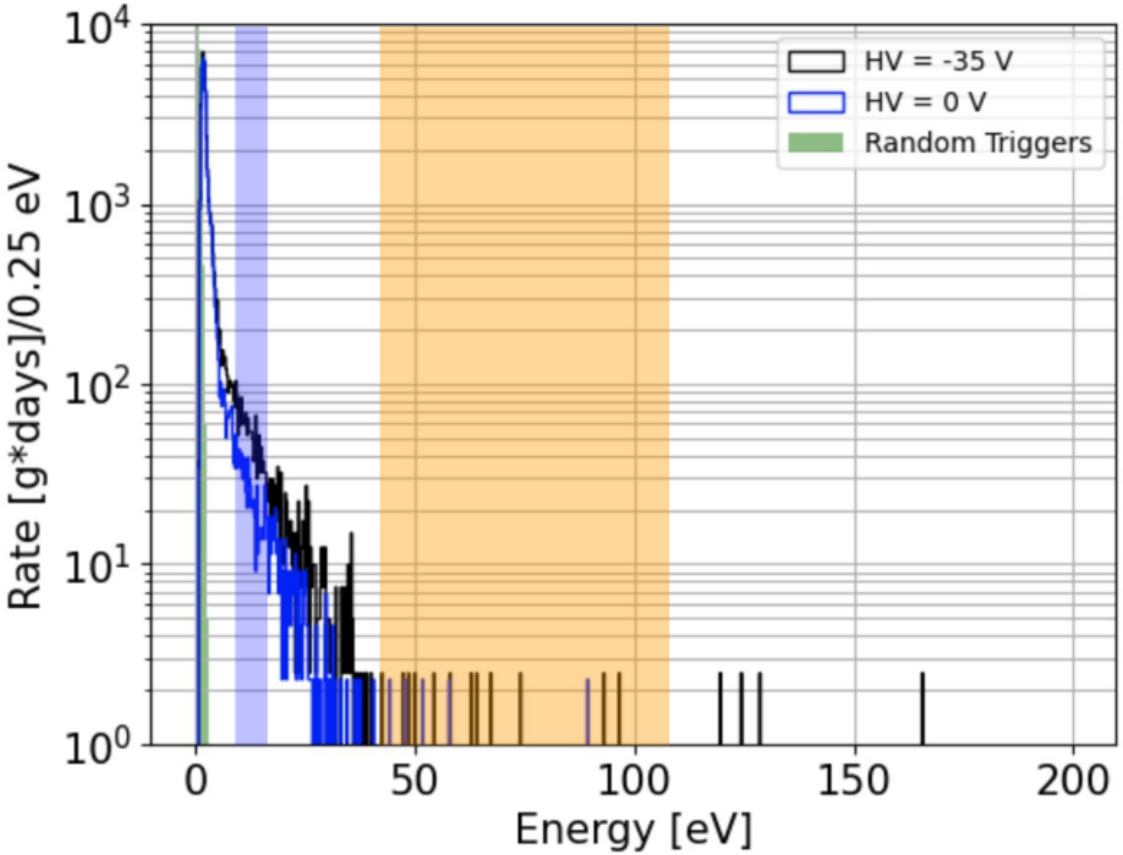
One Limit from One Day of Data



- Our most conservative limit:
  World leading below ∼1.2 MeV

What About the LEE? — Ionization



- Ionizing background would show up as **both** blue events in blue region and black events in orange region

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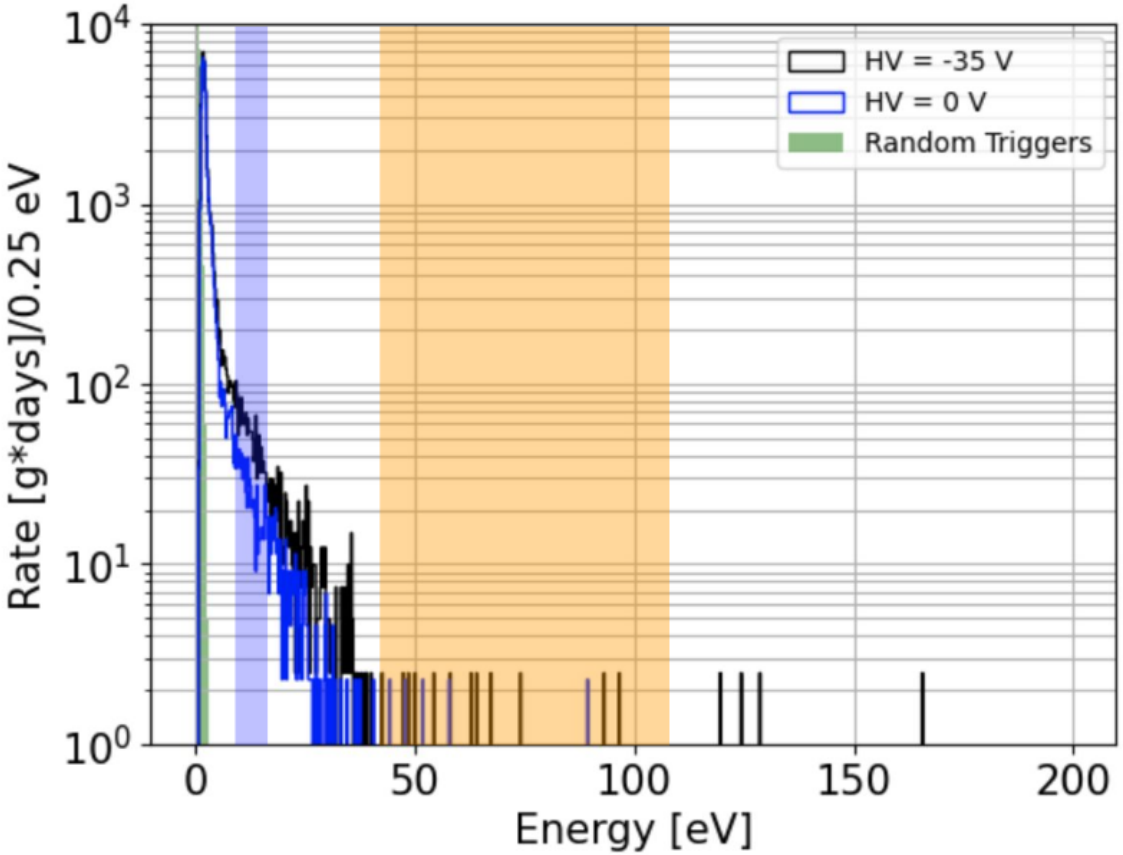

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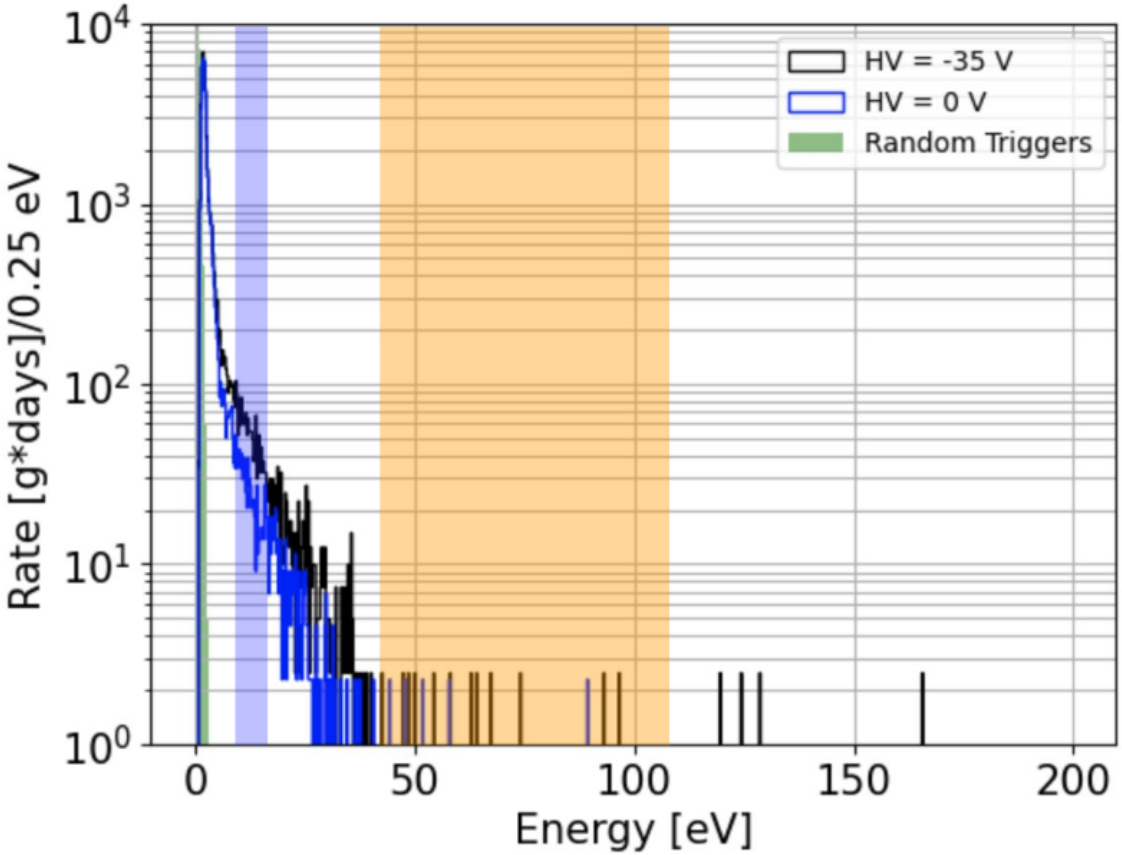

- Ionizing background would show up as **both** blue events in blue region and black events in orange region
- -35 V event rate in orange is $\sim$1/30 that of 0 V rate in blue
- Corroboration of the LEE being non-ionizing

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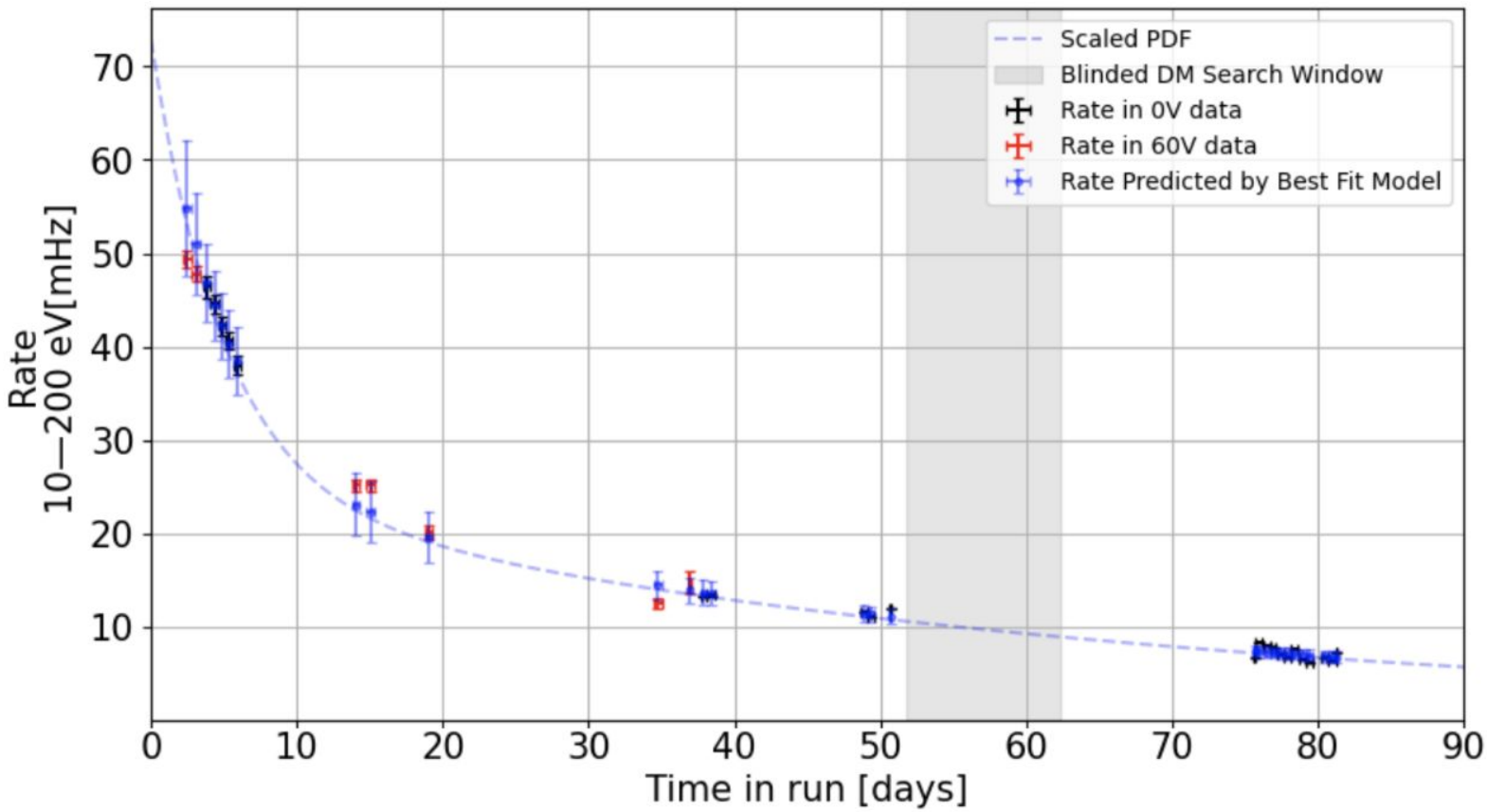
What About the LEE? — Rate Over Time



- Observed double exponential decay with time

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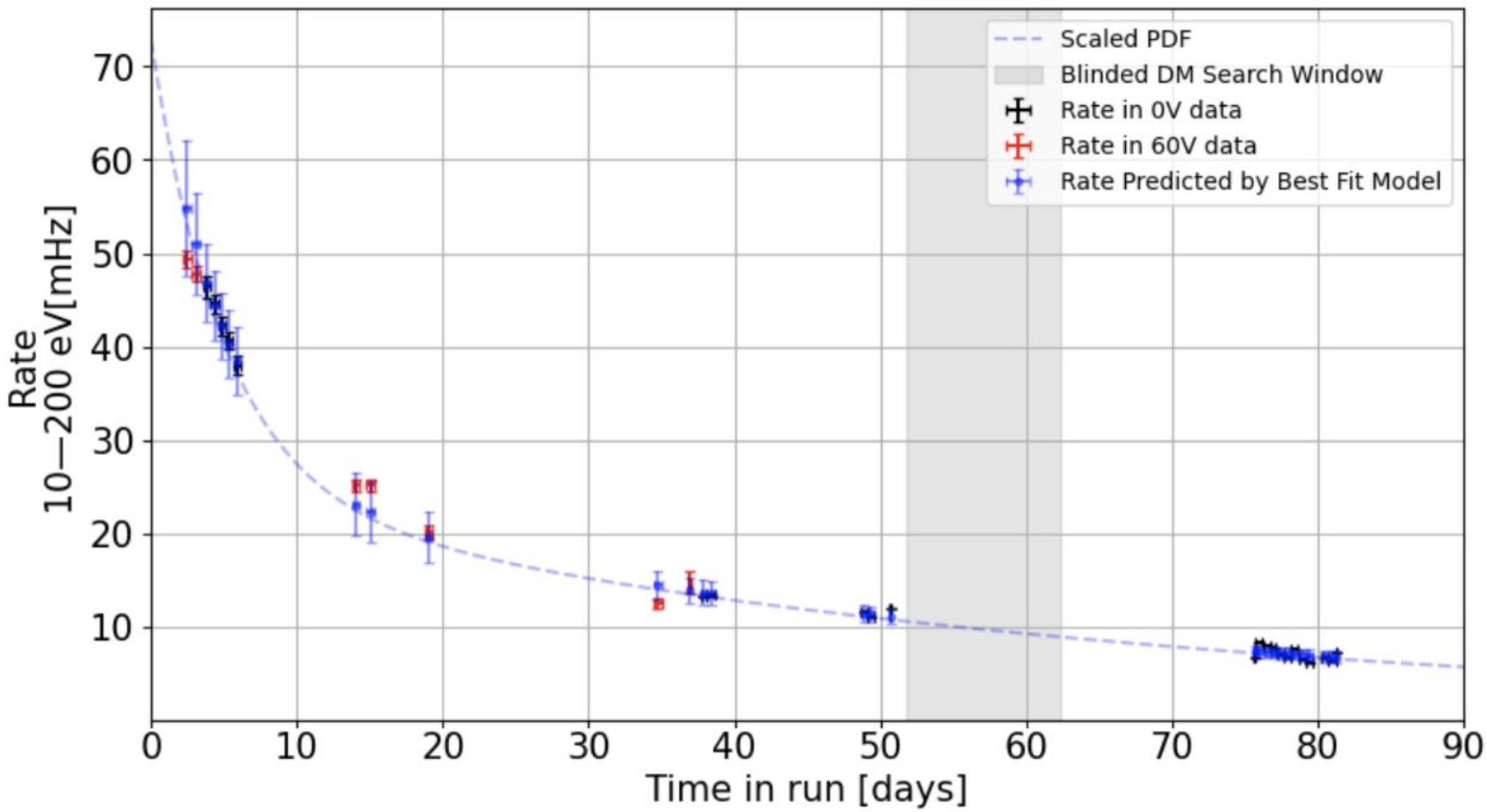
What About the LEE? — Rate Over Time



- Observed double exponential decay with time
- 0 V data and non-ionizing part of 60 V data both found same rate and time dependence

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Where We Go from Here

- Final limits are being readied for release! Paper coming soon

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- Closer examination of LEE to follow

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