EXCESS workshop 2021

Seeding a common effort to understand the observed excess signals in the sub-keV region

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On behalf of the EXCESS 2021 workshop organizers: *A. Fuss[1,2], M. Kaznacheeva[3], F. Reindl[1,2], F. Wagner[1]*

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Technische Universität München

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

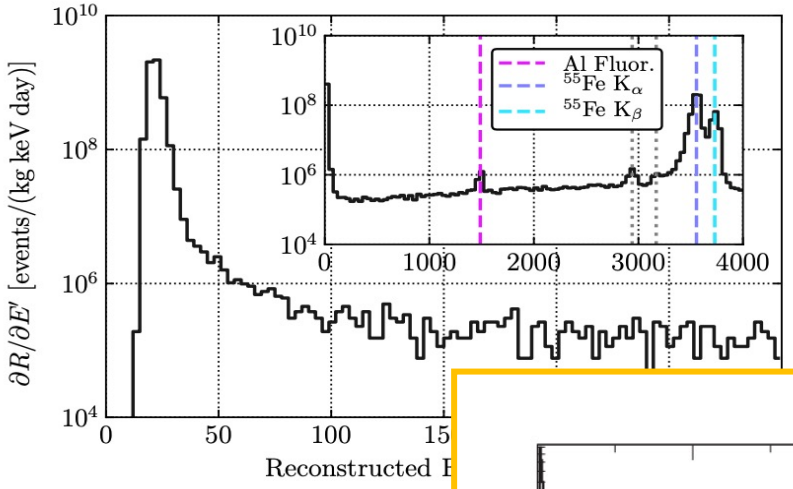
From idea to a white paper and beyond

- Motivation for the EXCESS initiative
- EXCESS 2021 workshop – main outcomes
- White paper
- What's next?

Previously…

SuperCDMS-CPD

In this search, we see an excess of events for recoil energies below about 100 eV, emerging above the roughly flat rate from Compton scattering of the gamma-ray back-



Phys. Rev. Lett. 127, 061801

CRESST

Phys. Rev. D 100, 102002

Below 200 eV, an excess of events above the flat back-
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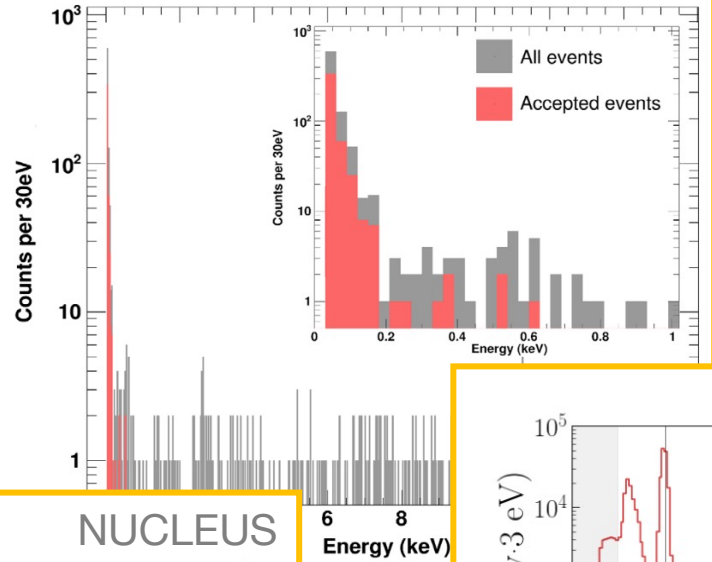
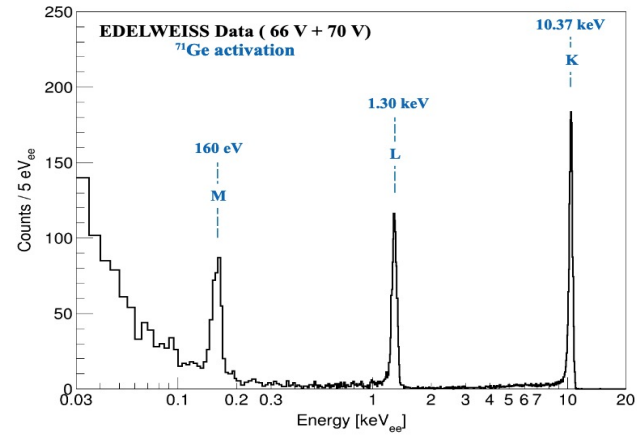
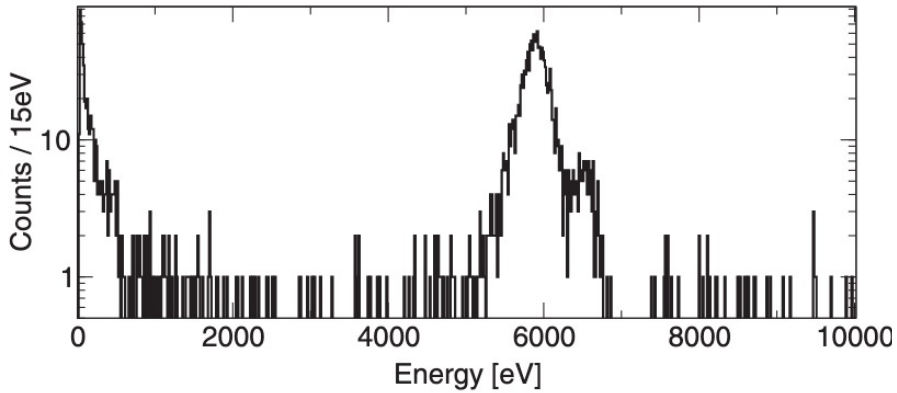


EDELWEISS



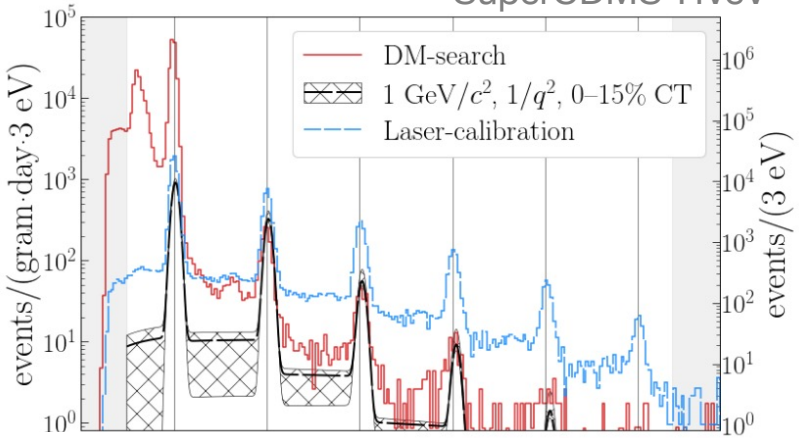
Phys. Rev. Lett. 125, 141301

NUCLEUS



Phys. Rev. D 96, 022009

SuperCDMS-HVeV



Phys. Rev. D 102, 091101(R)

adds to the growing narrative of unexplained, $\mathcal{O}$(Hz/kg) low-energy excesses measured in many sub-GeV DM searches (Refs. [64–66], and references therein). This result

Step 1: state the problem

- **Unexplained sharply rising event rates below a few hundred eV are observed in multiple experiments** with various technologies, different materials, above and below ground.

- This excess over the expected known backgrounds is the **main limitation for further sensitivity improvement of low-threshold experiments** (Dark Matter searches, CEvNS detection).

- The community has a **shared challenge**.

Step 2: collect the facts

Bring together the experts from the experiments where the excesses are observed

1. Share the observations together with details about the measurement conditions, detector setups, measured spectra

2. Start a scientific discussion within the community

EXCESS Workshop

EXCESS workshop 2021

15-16 June 2021

Participant List

139 participants

13 talks by 10 collaboration

CONNIE
CRESST
DAMIC
EDELWEISS
MINER
NEWS-G
NUCLEUS
RICOCHET
SENSEI
SuperCDMS

Chairs:
Alexander ss (CRESST)
Felix Wa CRESS
ESST)

Presentations tailored to the observed excess signals are available at https://indico.cern.ch/e/cryoexcess

ikolopoulos (NEWS-G)
PhyStat DM)
ah Kurinsky (SuperCDMS)
und Strauss (NUCLEUS)
Rouven Essig (SENSEI)
Rupak Mahapatra (MINER)
ile Ghete (NUCLEUS)

oroni
CONNI Kipper-CO
Jules Gascon (EDELWEISS)
Julien Billard (RICOCHET)

Data is publicly available!

launch binder **https://github.com/fewagner/excess**

Excess Workshop Data Repository

Multiple rare event search experiments ob… exponen… nt… phenomenon is yet unexplained and the com… …vations is the objective of the EXCESS workshop (https:// provided data for the workshop a…

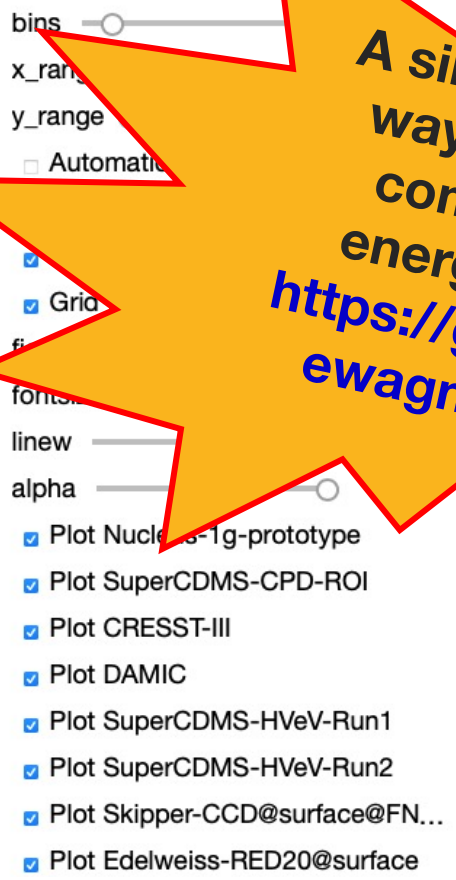
CONNIE/Skipper-CCD
CRESST
DAMIC
EDELWEISS
MINER
NEWS-G
NUCLEUS
PhyStat-DM
RICOCHET
SENSEI
SuperCDMS

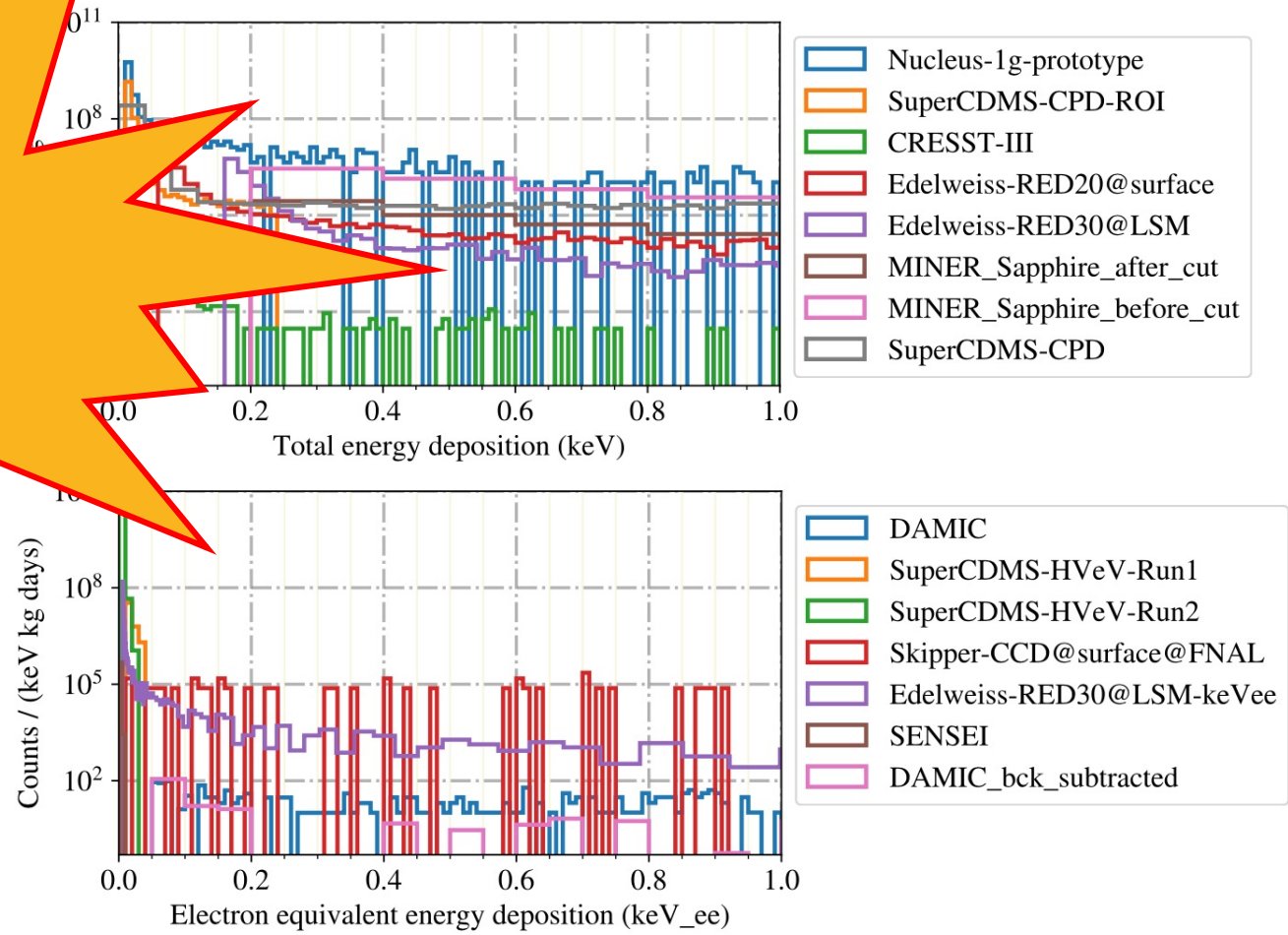
Data required to reproduce the energy spectra measured by various experiments is publicly accessible.

Online visualization tool

Instruction how to use the online visualization tool:
https://indico.cern.ch/event/1013203/attachments/2264385/3847018/how_to_plot_excess.pdf

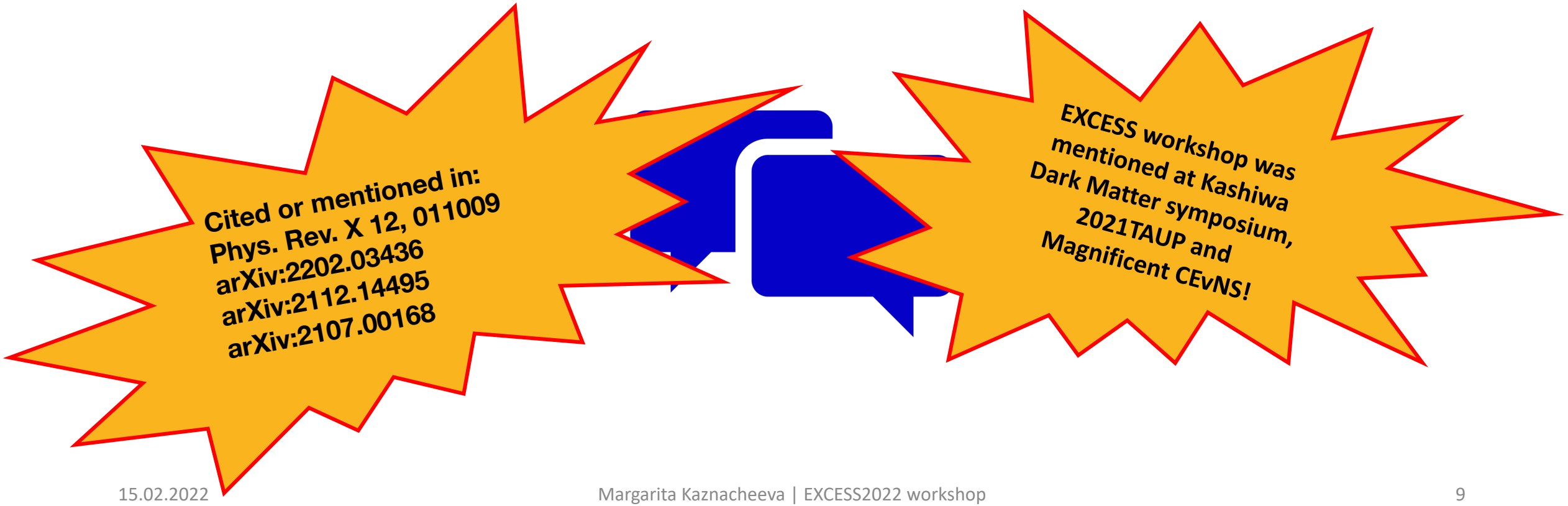
A simple and fast way to plot and compare low-energy spectra: https://github.com/fewagner/excess





EXCESS workshop 2021

Launch of a discussion withing the community



Step 3: raise further awareness

https://arxiv.org/abs/2202.05097

arXiv.org > astro-ph > arXiv:2202.05097

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 10 Feb 2022]

EXCESS workshop: Descriptions of rising low-energy spectra

- Detailed description of the observed low energy spectra together with the spectra comparison are presented in the collaborative white paper – **available on arXiv now.**

EXCESS 2021: White paper's structure

Contents

- Introduction to the problem
- Brief description of the common experimental techniques and global terminology
- Detailed descriptions of the measurements, detector setups, and observed low-energy spectra
- Short discussions on the considered origins and planned tests
- Comparison of the presented energy spectra
- Summary and further plans

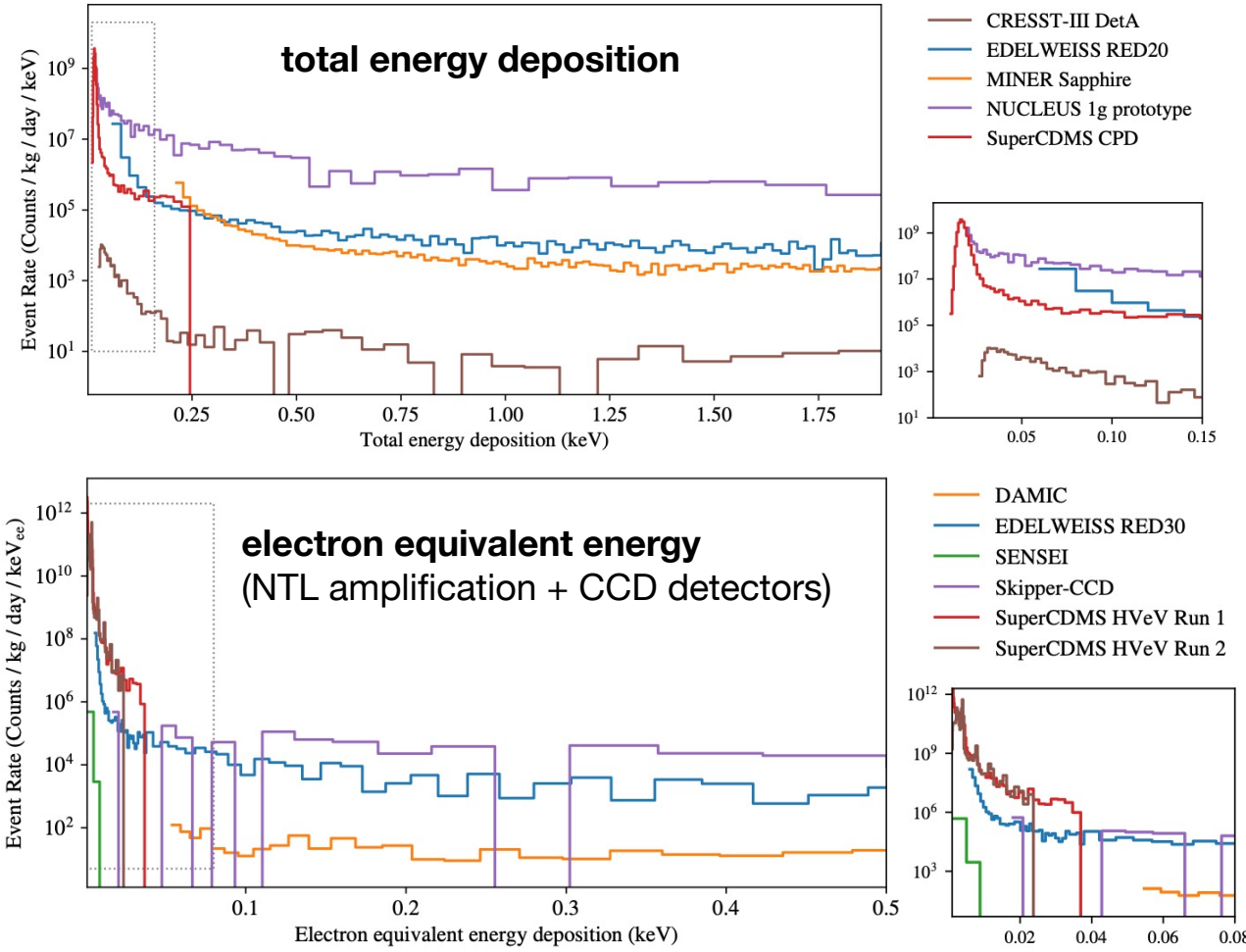
Comparison of the measured energy spectra

The measurements are separated into two groups according to their energy units:

1. Total energy deposition (no assumption on the interaction type - NR or ER)
   - phonon detectors

2. Electron equivalent energy deposition (assuming all incoming particles scattered off electrons in the detector material)
   - Phonon detectors with NTL amplification
   - CCD detectors

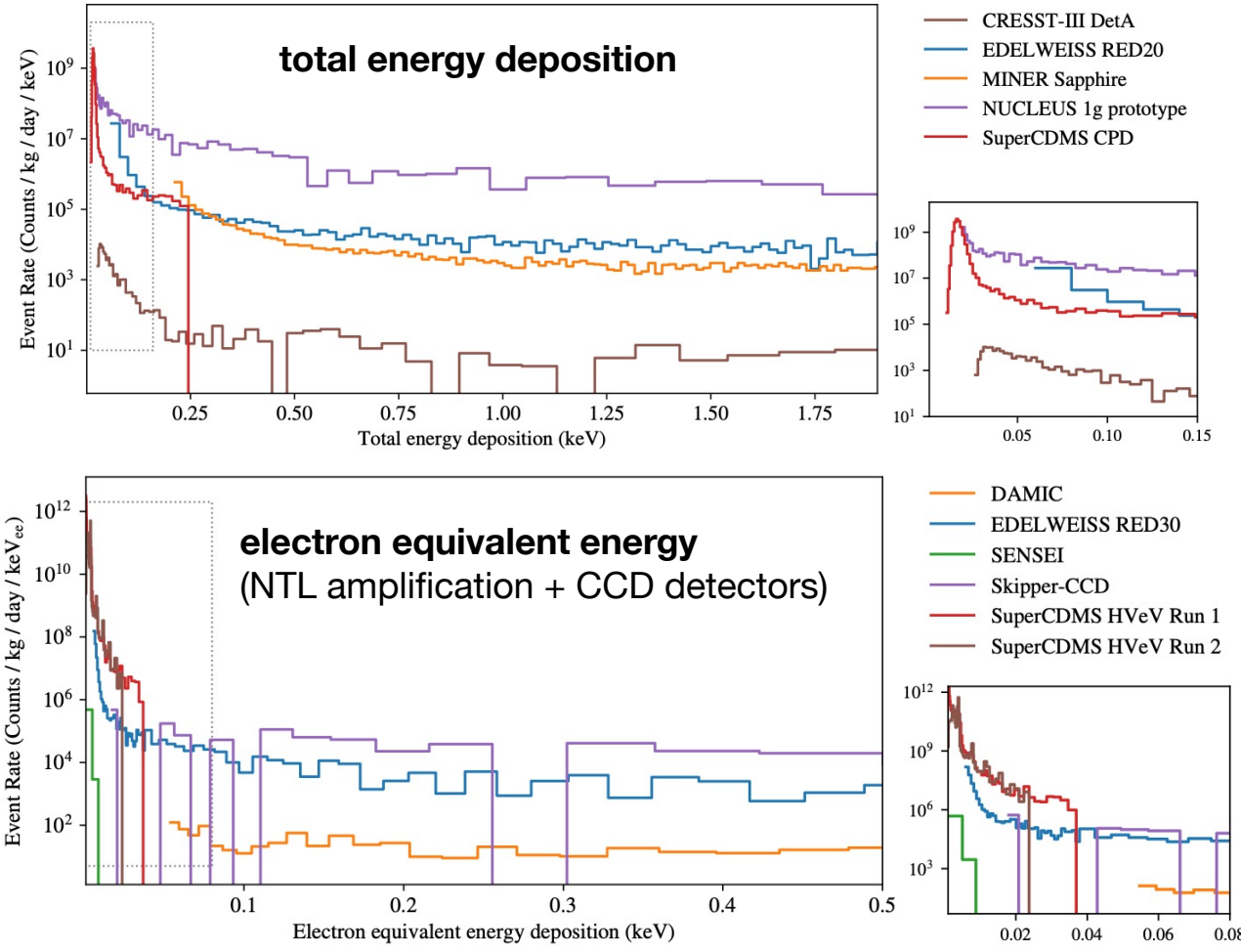
All spectra are scaled to count/keV/kg/day



Comparison of the measured energy spectra

Key properties of the measurements

Measurement	Target	Sensor	Exposure (kg days)	Operation Temperature	Depth (m.w.e.)
CRESST III DetA	23.6 g $CaWO_4$	Tungsten TES	5.594	15 mK	3600 (LNGS)
EDELWEISS RED20	33.4 g Ge	NTD	0.033	17 mK	above ground
MINER Sapphire	100 g Al_2O_3	QET	2.72	7 mK	above ground
NUCLEUS 1g prototype	0.49 g Al_2O_3	Tungsten TES	0.0001	15-20 mK	above ground
SuperCDMS CPD	10.6 Si	QET	0.0099	41.5 mK	above ground
DAMIC	40 g Si	CCDs	10.927	140 K	6000 (SNOLAB)
EDELWEISS RED30	33.4 g Ge	NTD, NTL amplification	0.081	20.7 mK	4800 (LSM)
SENSEI	1.926 g Si	Skipper CCD	0.0955	135 K	225 (Fermilab)
Skipper CCD	0.675 g Si	Skipper CCD	0.0022	140 K	above ground
SuperCDMS HVeV Run 1	0.93 g Si	QET, NTL amplification	0.00049	33-36 mK	above ground
SuperCDMS HVeV Run 2	0.93 g Si	QET, NTL amplification	0.0012	50-52 mK	above ground
NEWS-G	114 g CH_4	SPC	0.0156	Room temperature	4800 (LSM)



Considered origins of the excess

Group 1: particle origin

- Cherenkov interactions
- transition radiation
- luminescence
- surface backgrounds
- neutrons

Group 2: detector origin

- intrinsic stress of the target crystals
- stress induced by detector holders
- microfractures
- cracks in the glue attached to the target

Given the strongly varying rates and shapes of the excess signals, having a **single common origin for all observed signals is unlikely.**

EXCESS way forward

- Step 1: State the problem ✅
- Step 2: Collect the facts ✅
- Step 3: Raise awareness ✅
- Step 4: Collect more ideas about the origin
- Step 5: Test ideas

EXCESS 2021 workshop

White paper

EXCESS 2022 workshop

NEW

Satellite EXCESS workshop at IDM 2022 conference