Dark Matter search with the CRESST-III experiment

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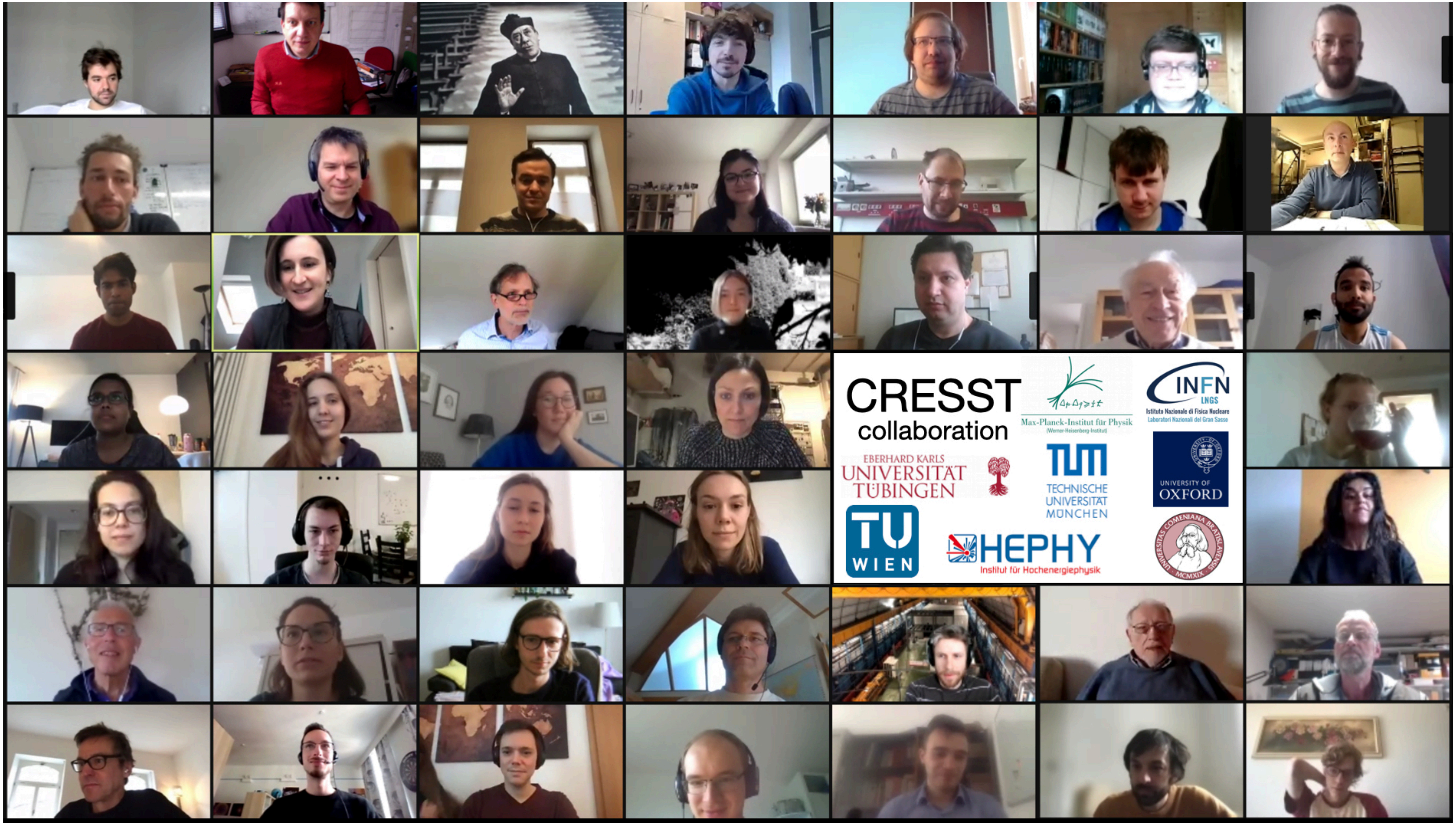
on behalf of the CRESST Collaboration


CRESST
collaboration
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INFN
LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso
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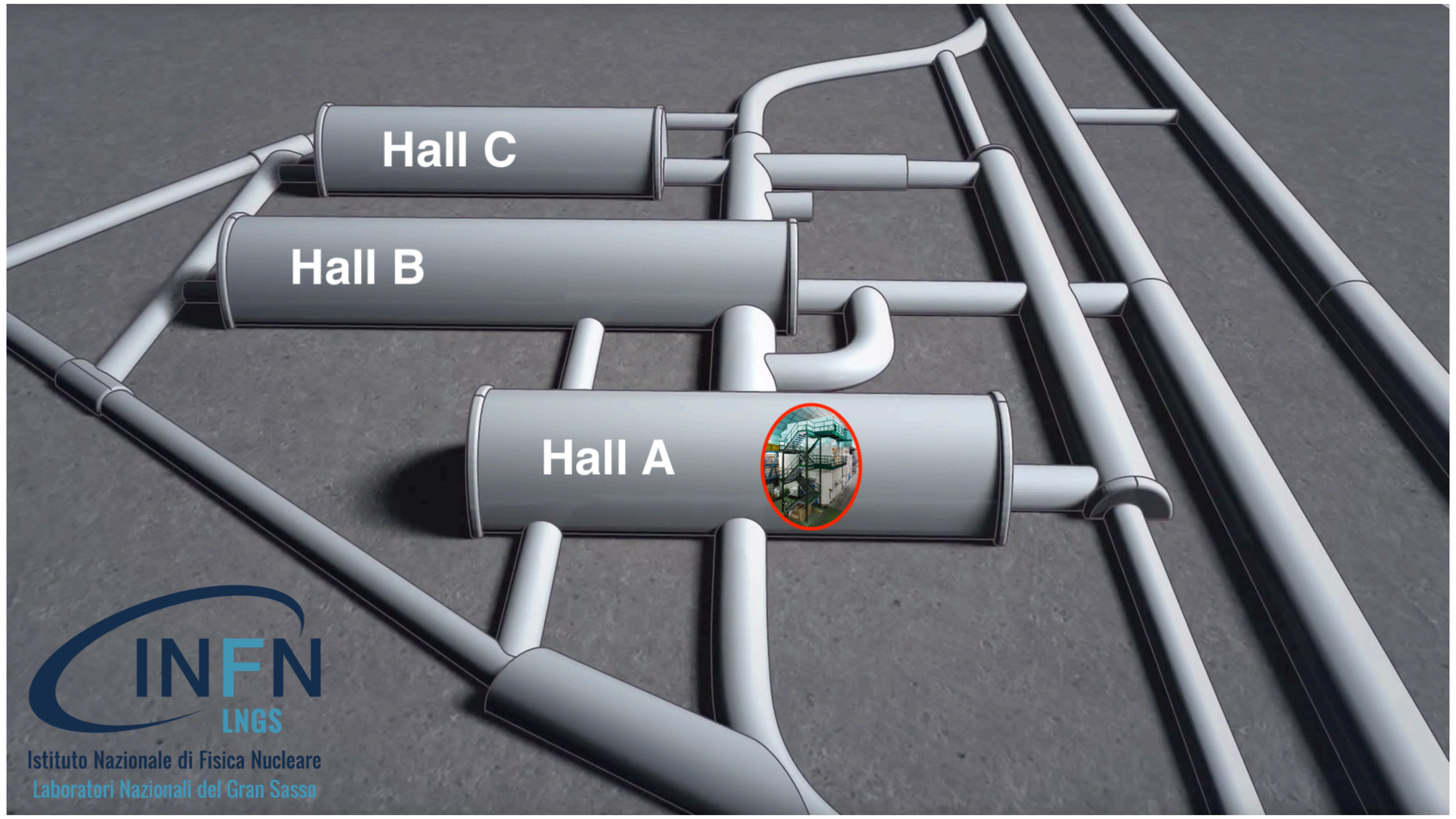
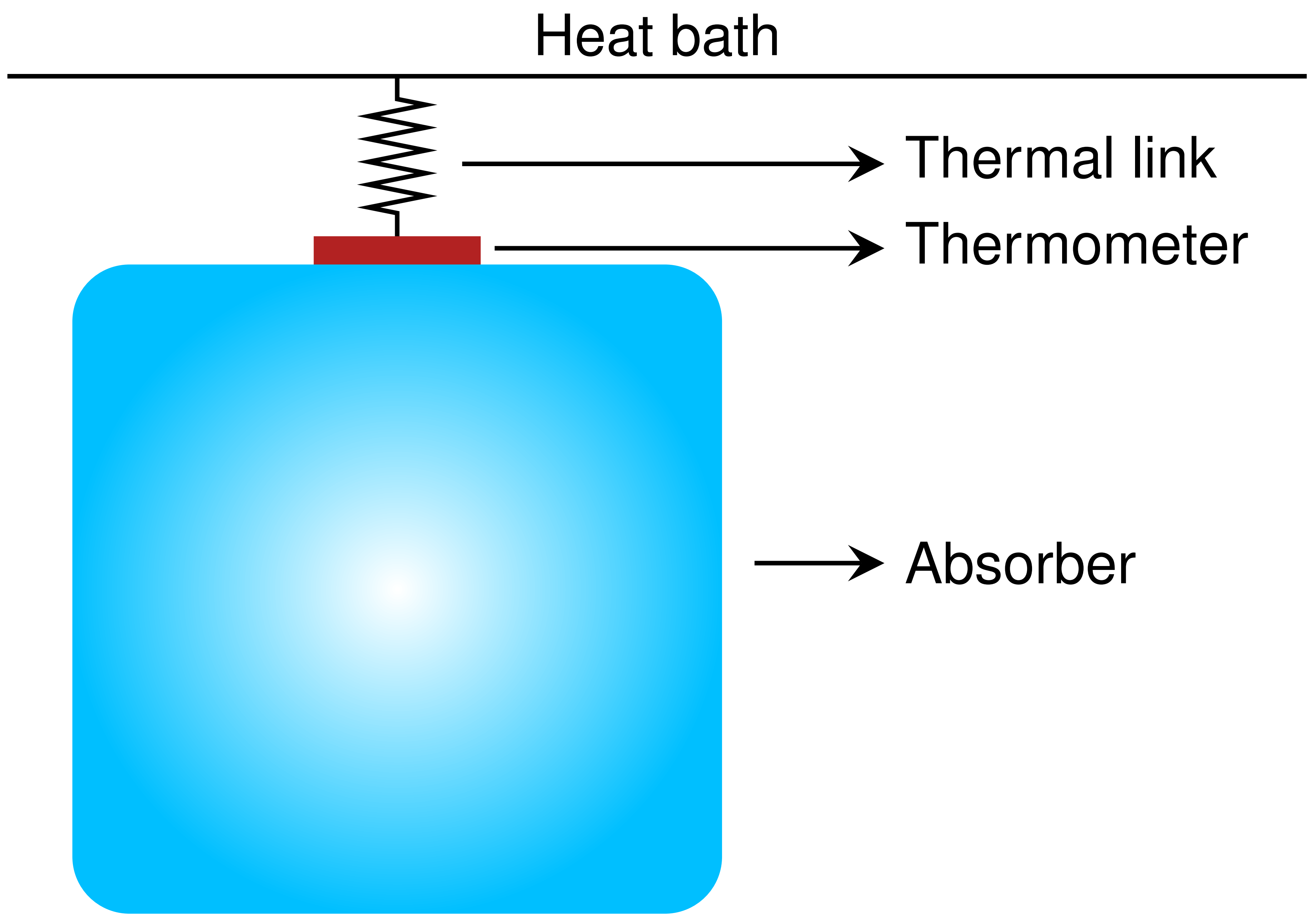
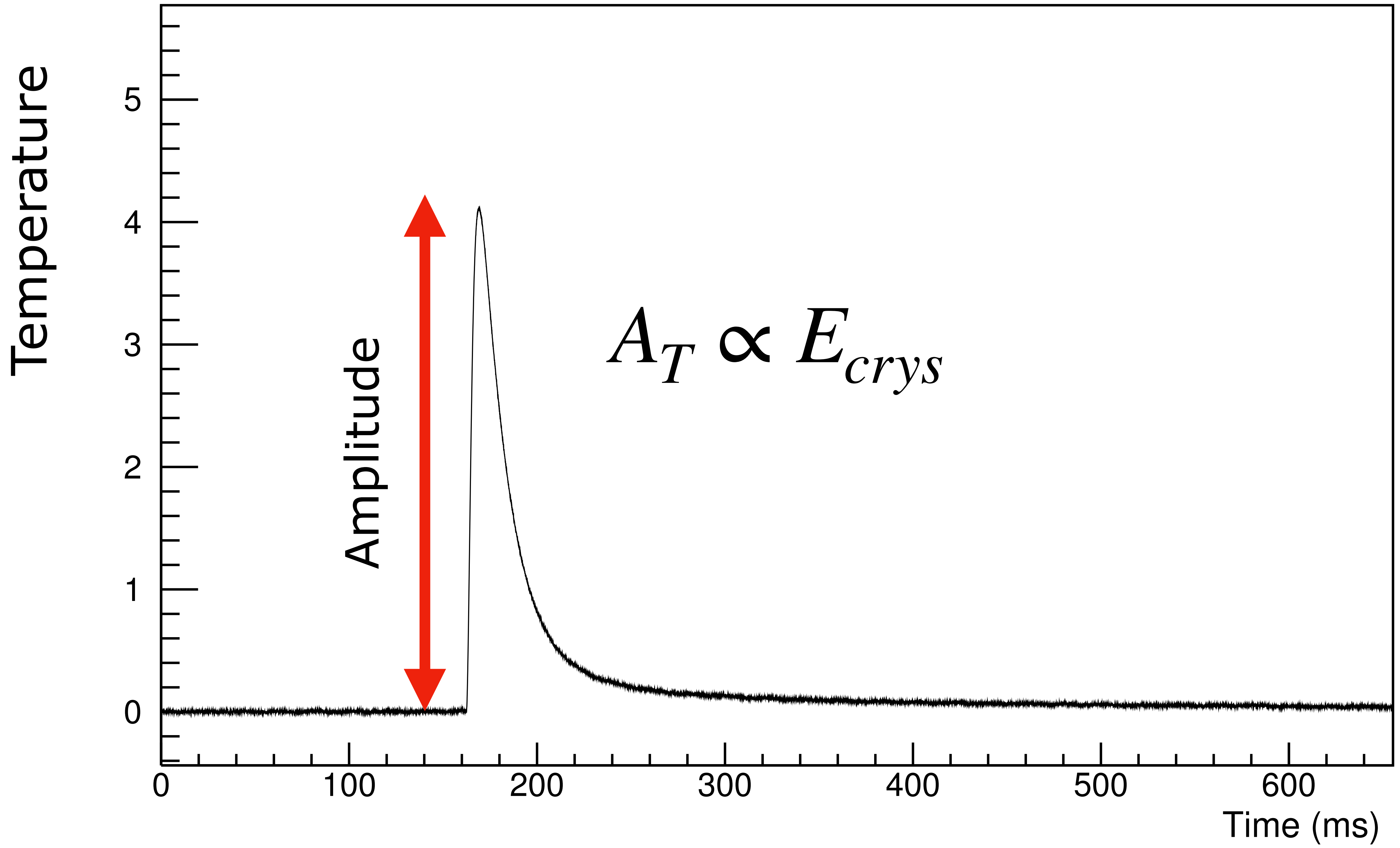
Cryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers is located at the Laboratori Nazionali del Gran Sasso. Rock overburden ~1400m in all directions (3800 m.w.e)

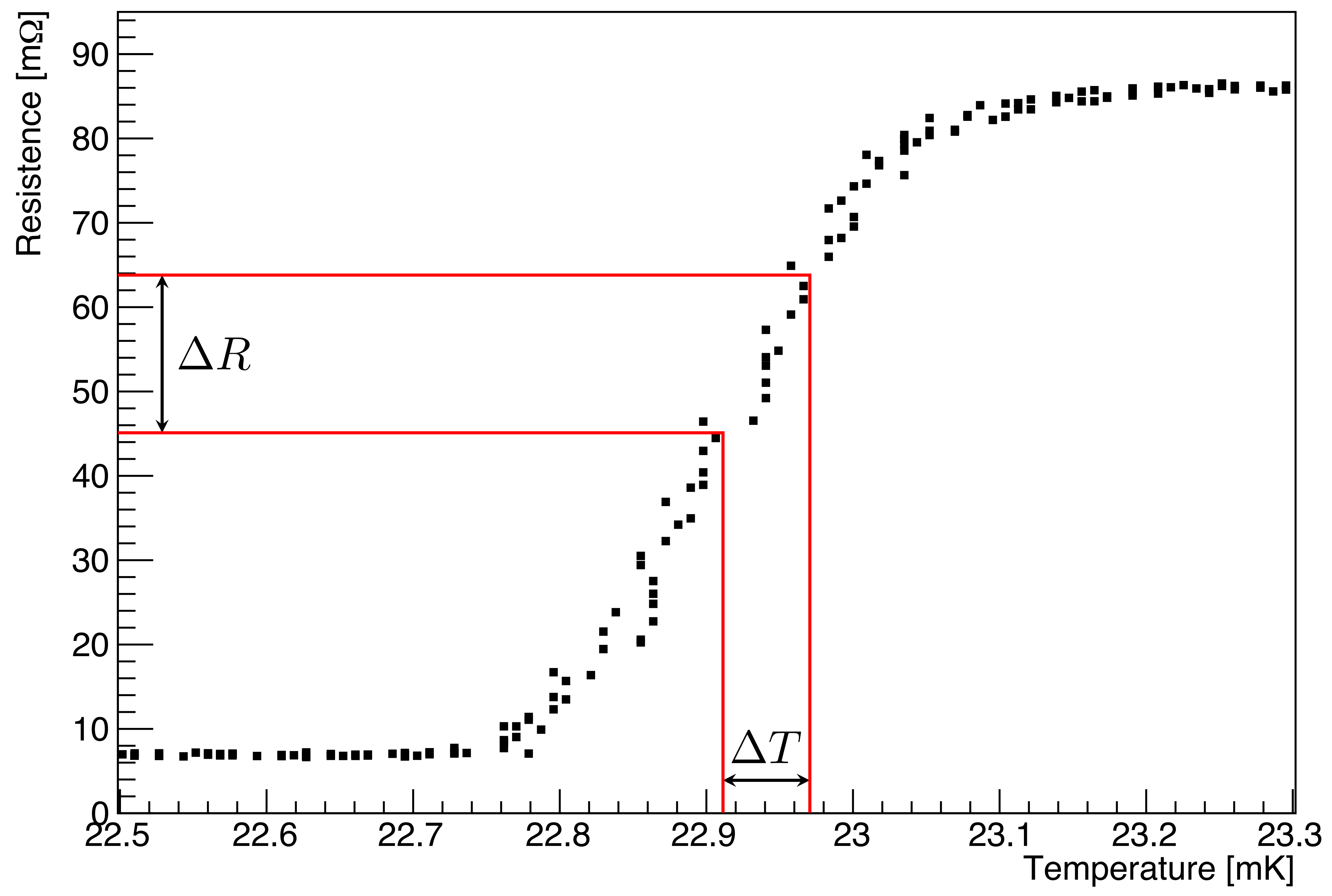


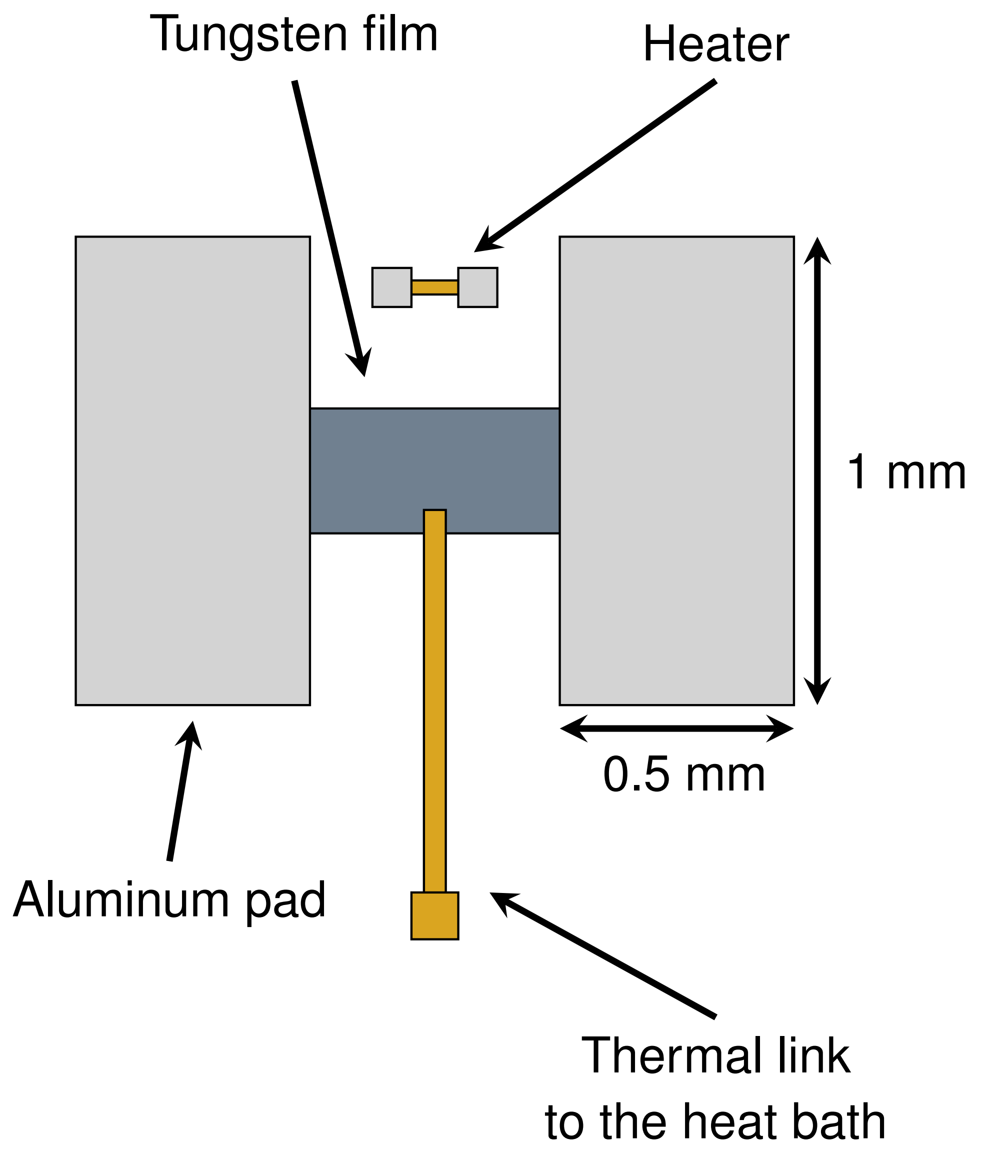
CRESST goal: direct detection of dark matter particles via their scattering off target nuclei in cryogenic detectors, operated at ~15 mK

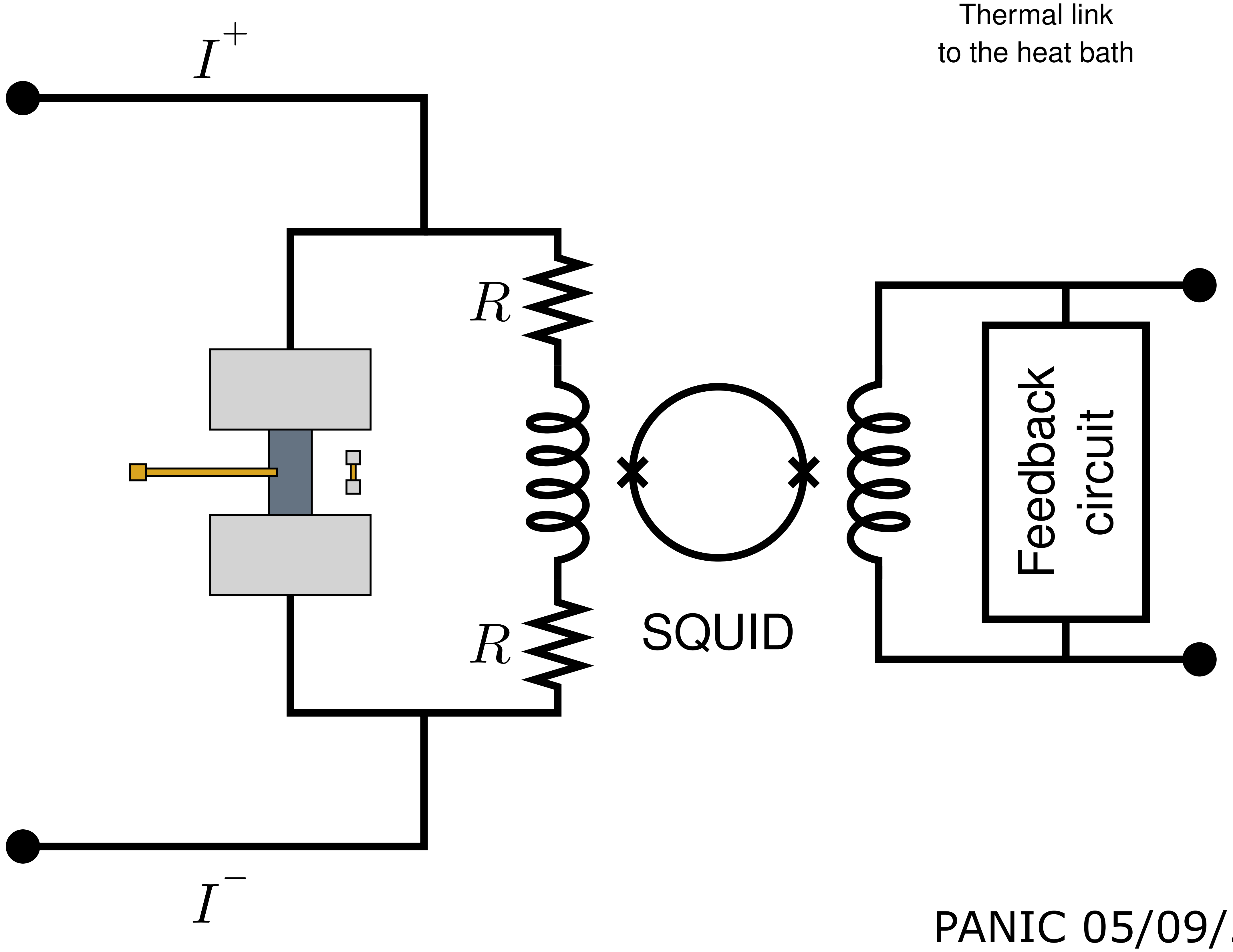




Transition Edge Sensor

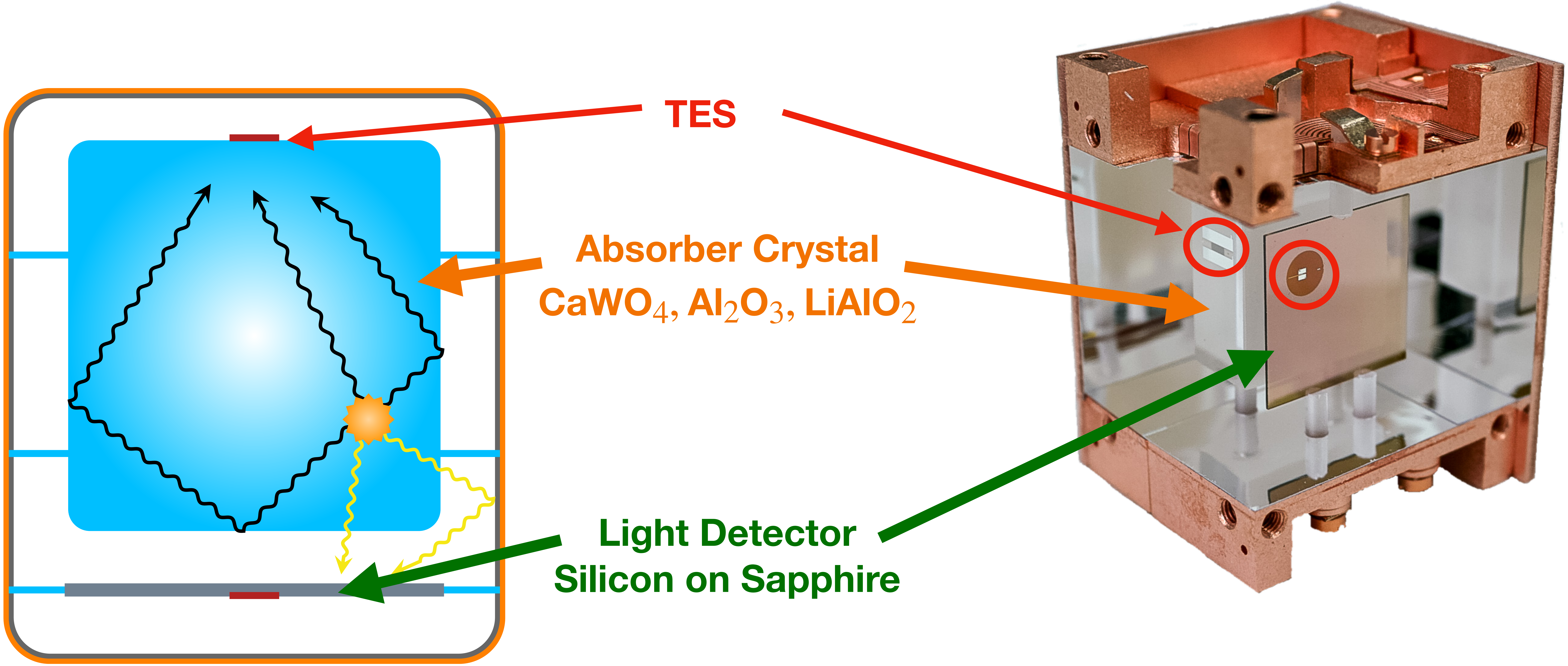




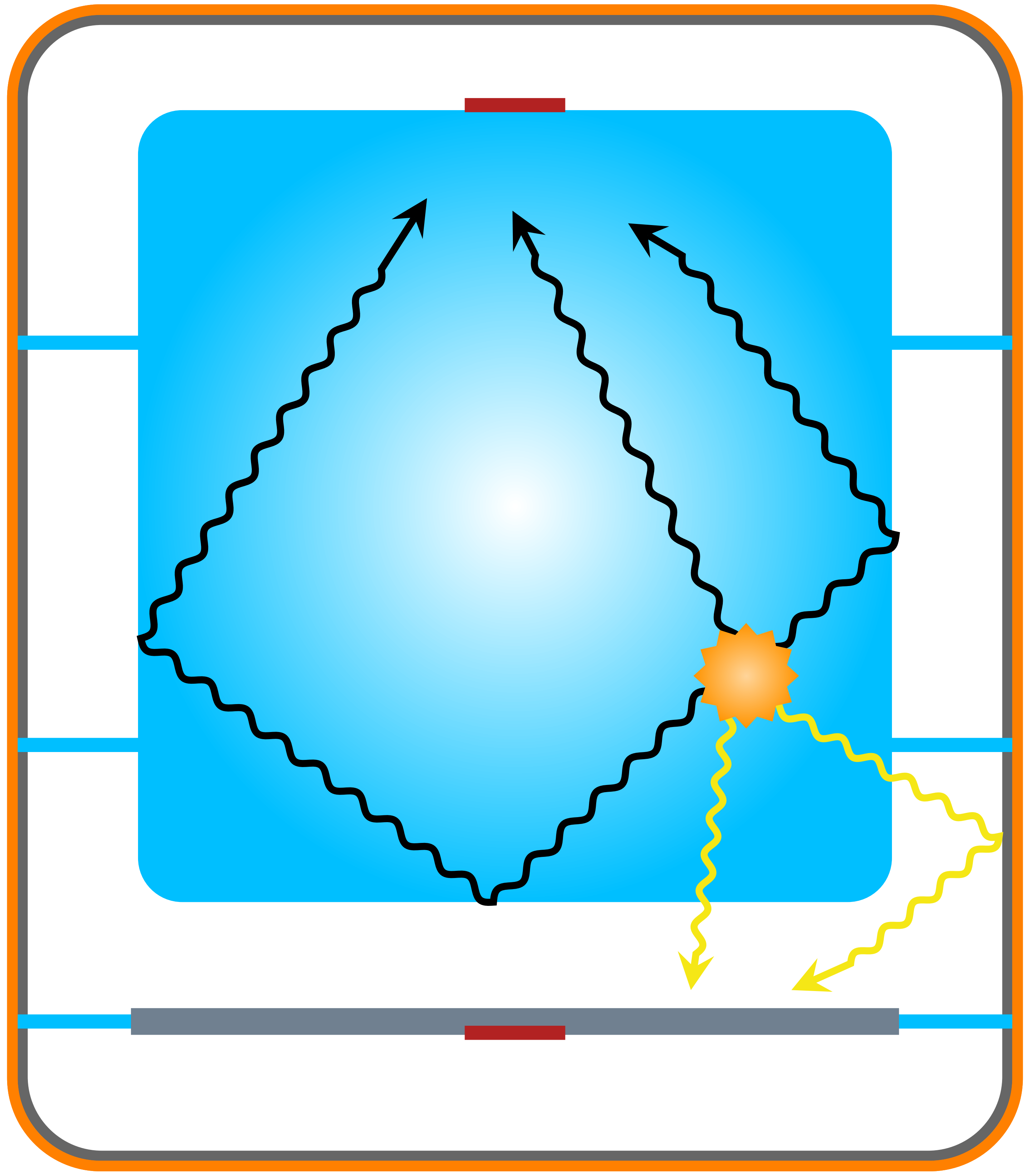


$$E \sim \text{keV} \Rightarrow T \sim \mu\text{K} \Rightarrow R \sim \text{m}\Omega$$

CRESST Detector



CRESST Detector



Phonon signal

- Most energy released in this channel (~90%)
- Energy released is (almost) particle independent

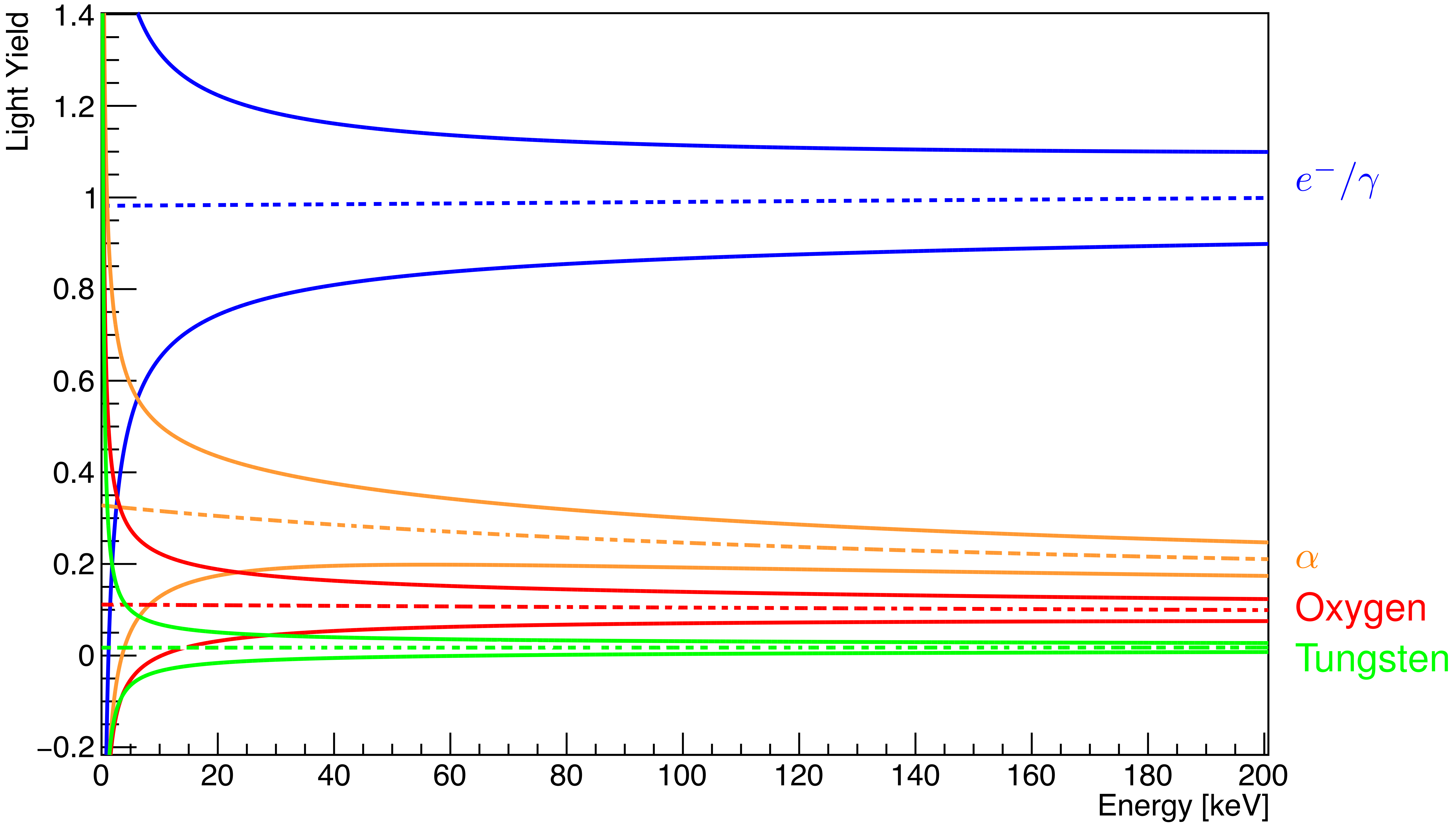
Light signal

- few % of the energy released as scintillation light
- particle dependent ⇒ event discrimination

Event Discrimination

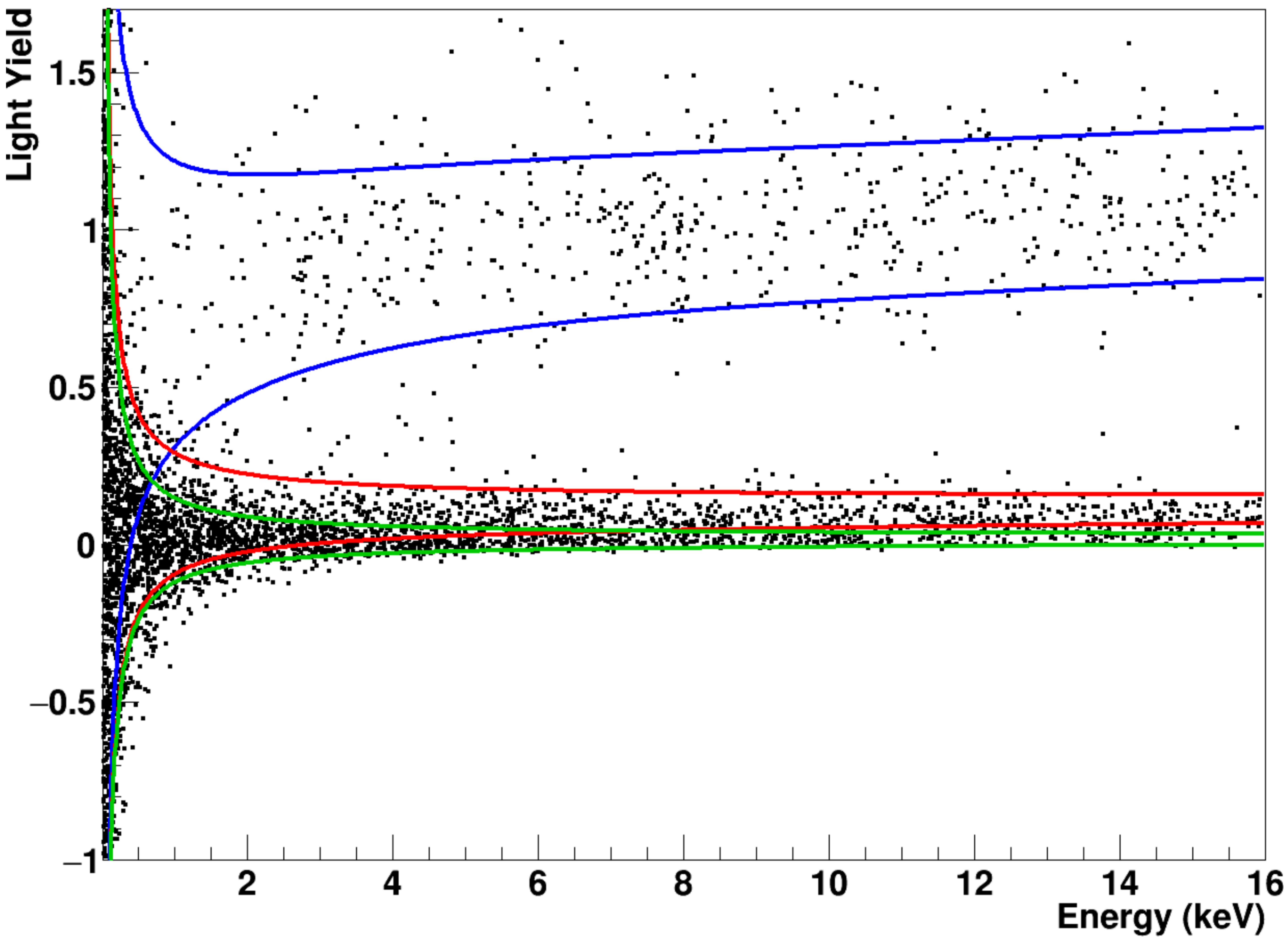
$$LY = \frac{\text{Light signal}}{\text{Phonon signal}}$$

Excellent discrimination between potential signal events and dominant radioactive background



Neutron Calibration

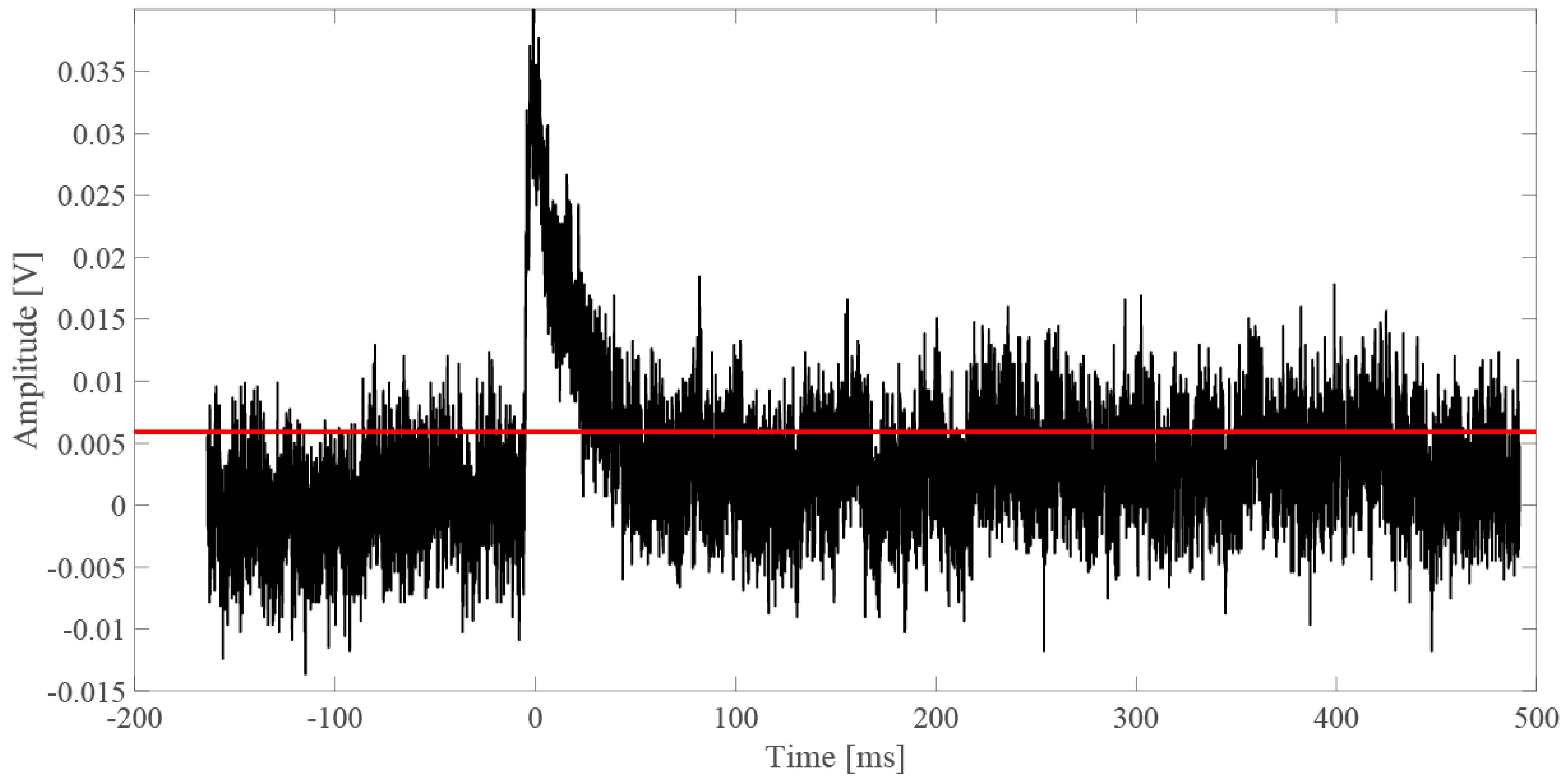
Dedicated neutron calibration campaign to precisely fit the electron and nuclear recoil bands.

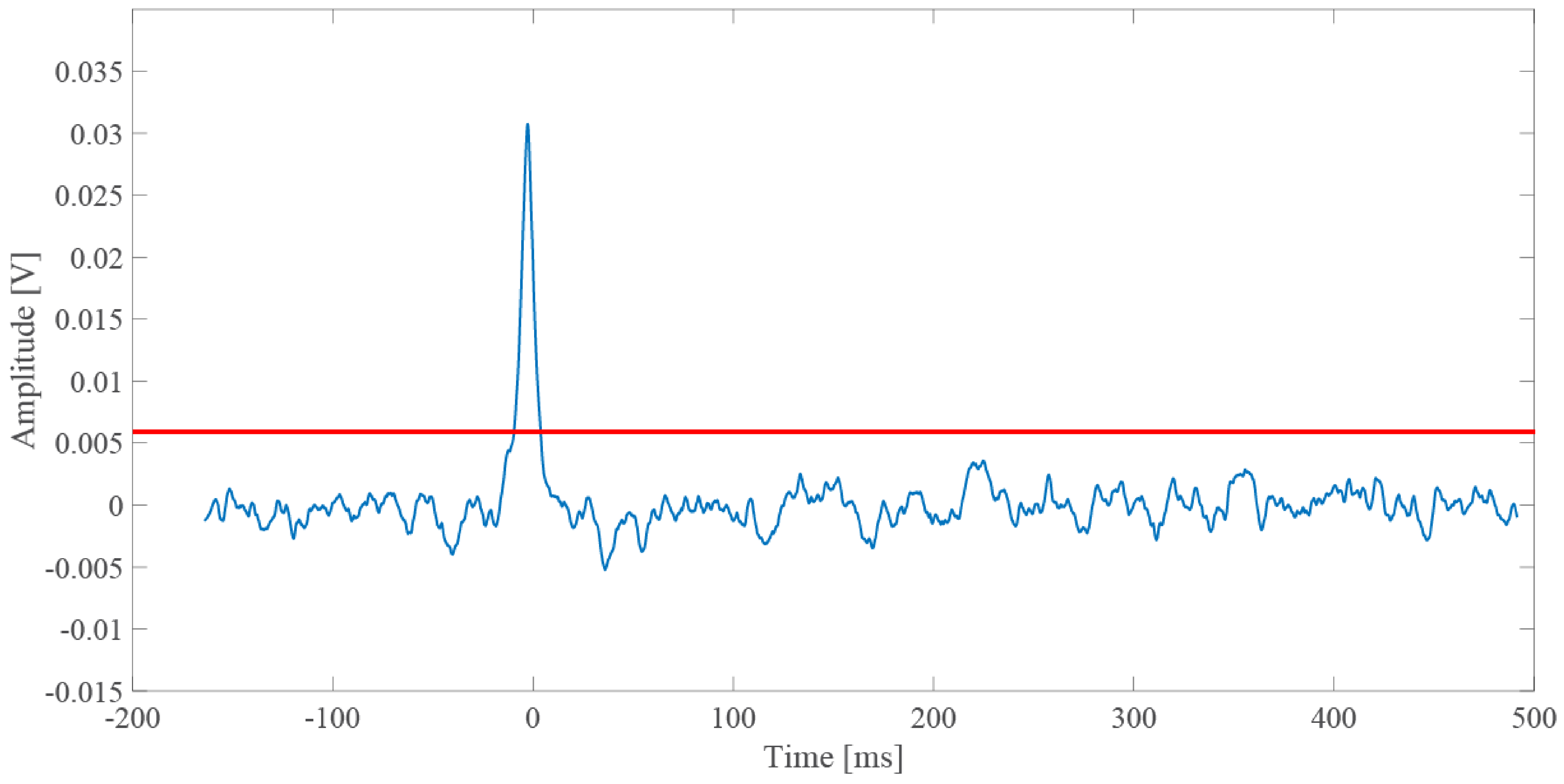


Data Acquisition

Data stream continuously stored on disk

Optimum Filter trigger algorithm applied to the data-stream





Mancuso, M. et al, J Low Temp Phys **199,** 547–555 (2020).

Data analysis

Blind analysis

- Cuts optimized on non-blind training data set (~20% of the data randomly selected)
- Applied without change to the **blind** dataset

Stability: detector in the correct operating point

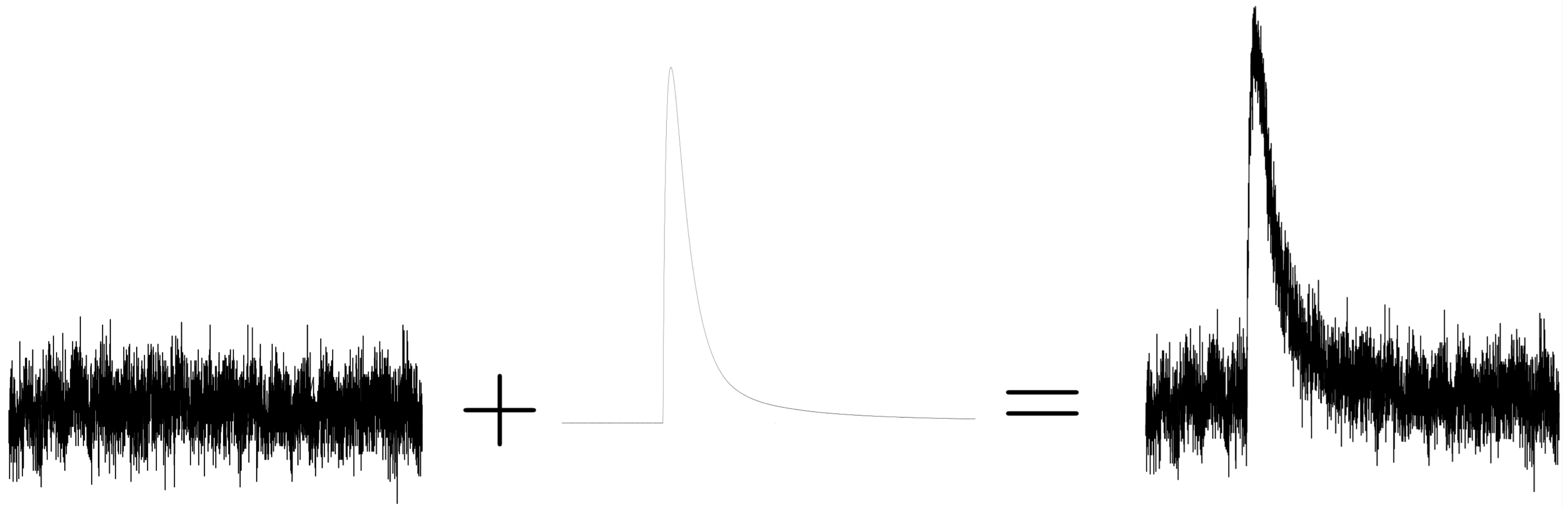
Rate: noise condition

Coincidences : μ-veto, events in other detectors

Data Quality: non standard event (pile up, quantum flux loss…)

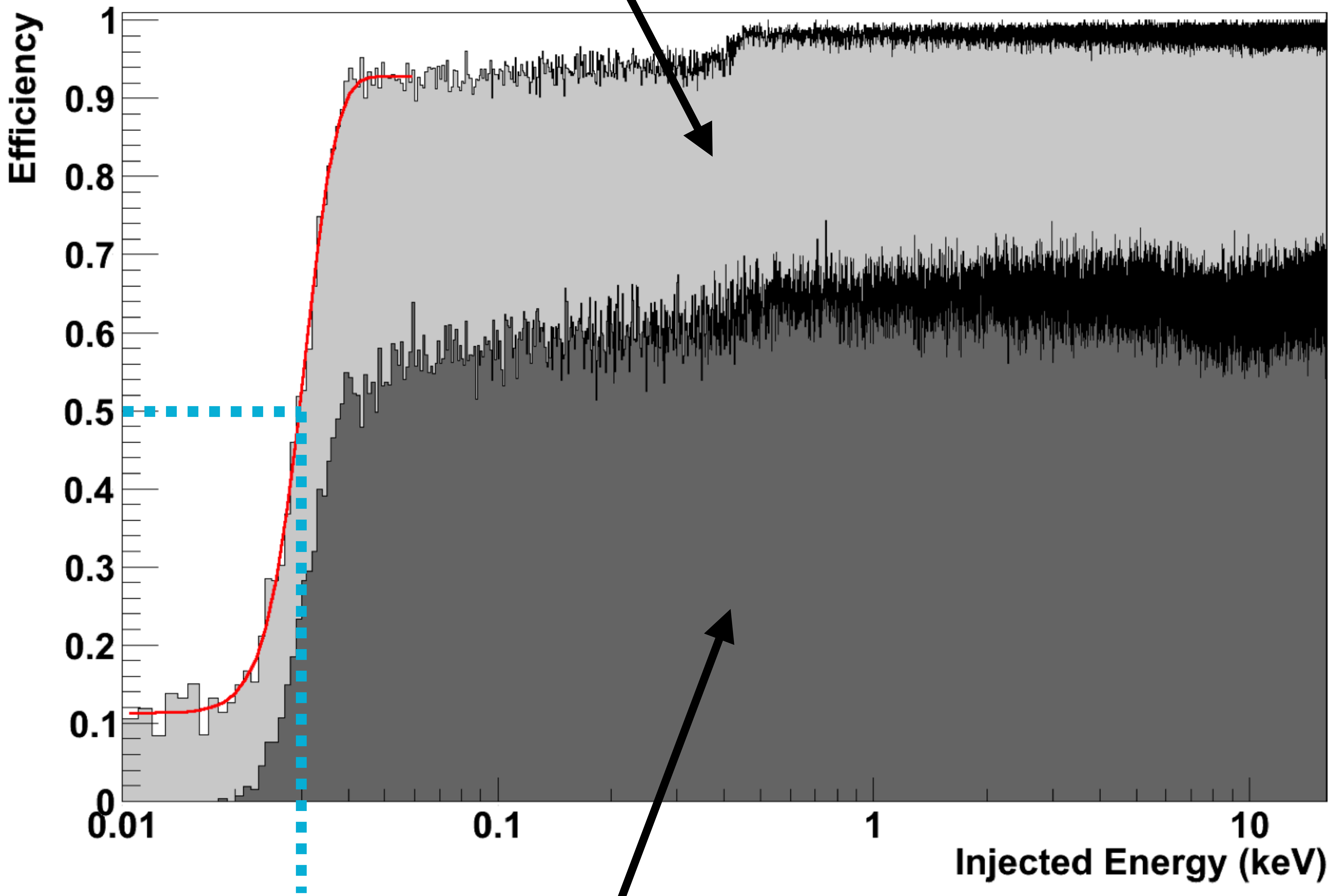
Efficiency & Threshold

To measure efficiency simulated events are created by superimposing the standard event onto the continuous data stream at randomly selected points in time.



Efficiency ≳ 60 % over a wide energy range

All triggered events



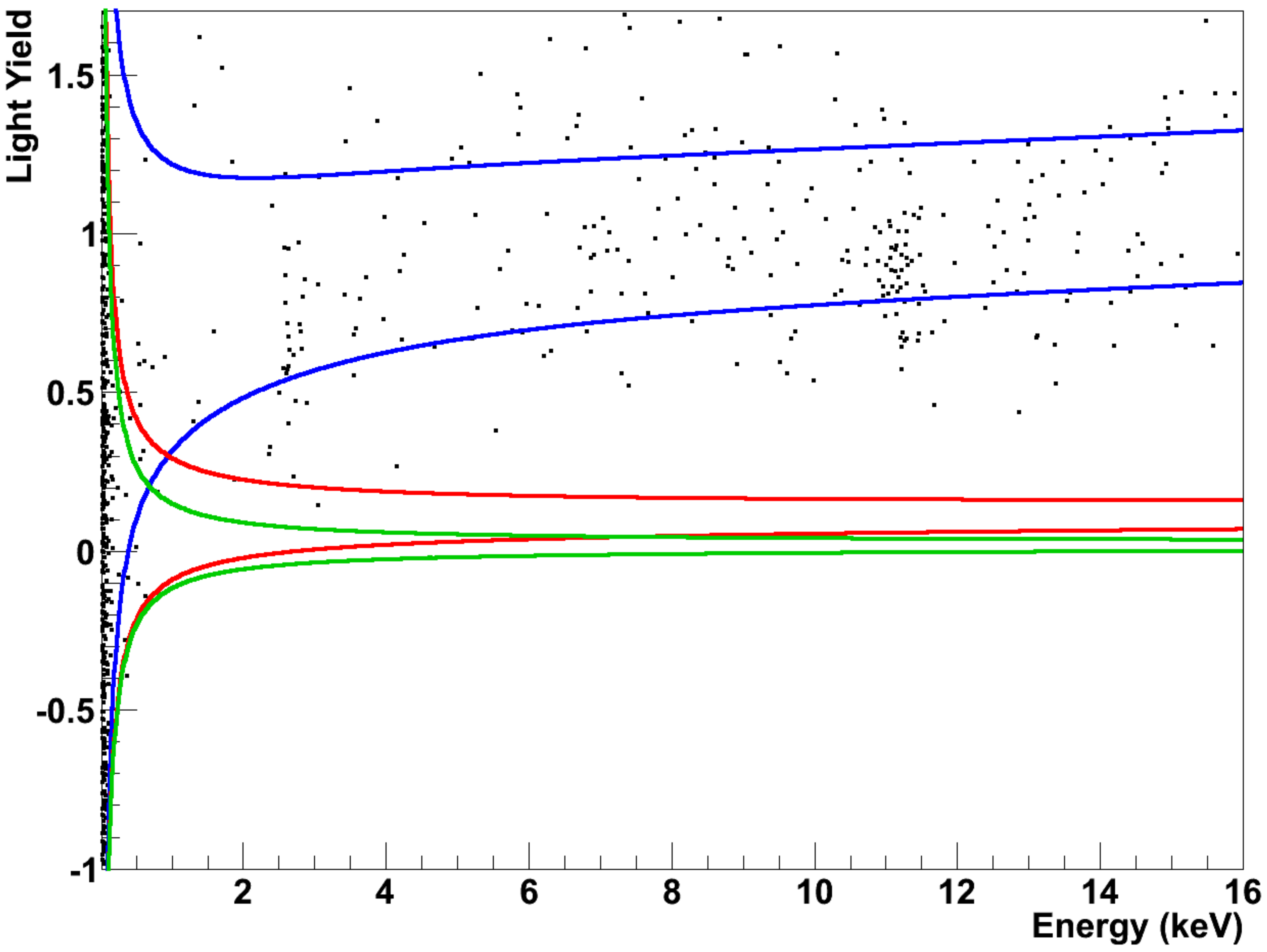
Best performing module Detector A
Energy Threshold = 30.1 eV

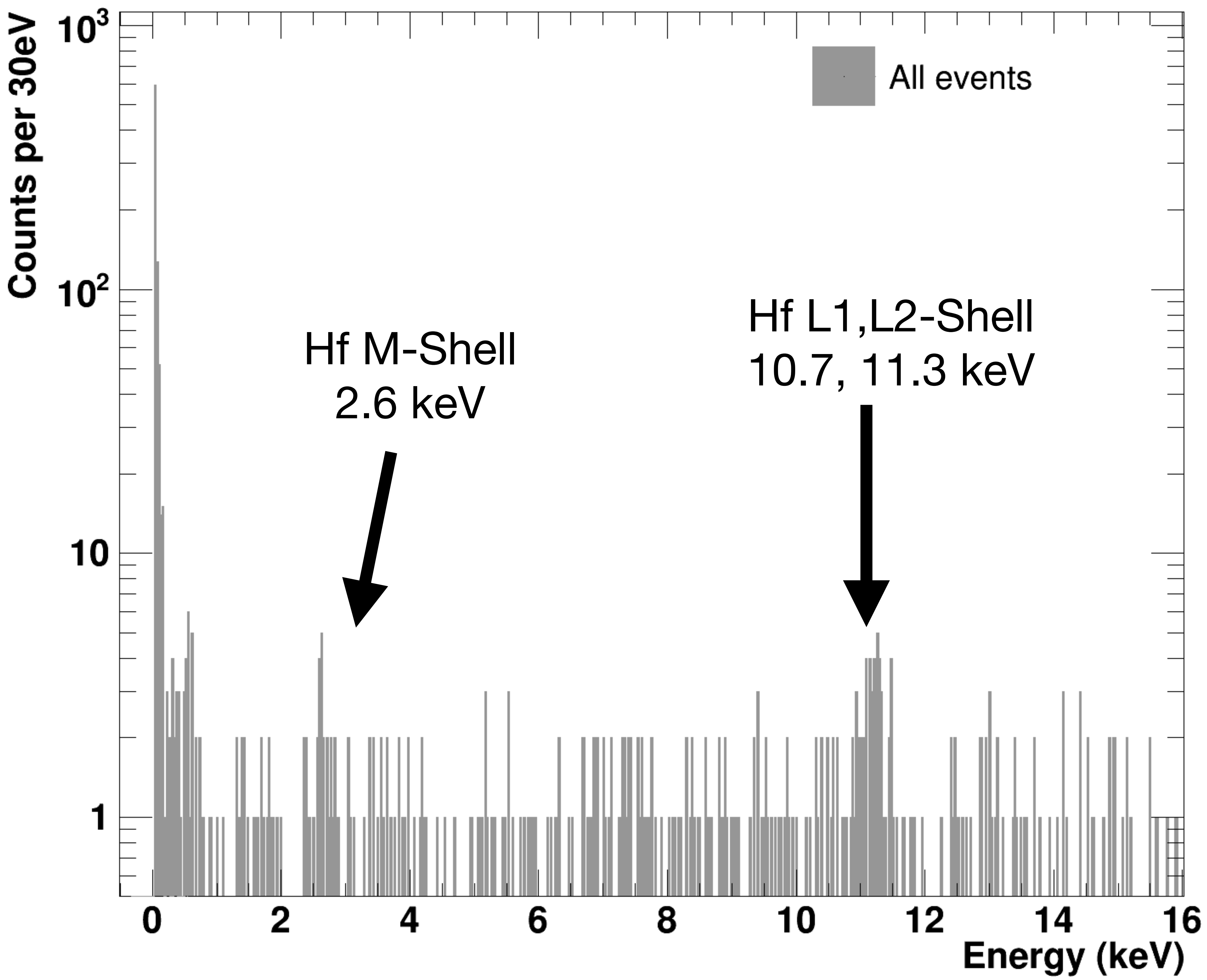
Events after selection

(= 1 noise event triggered 1 c/kg/day)

Run34 - Detector A, Light Yield and Energy Spectrum

Data taking 05/2016 – 02/2018





Analysis optimized for very low energy: 30 eV ⇒16 keV

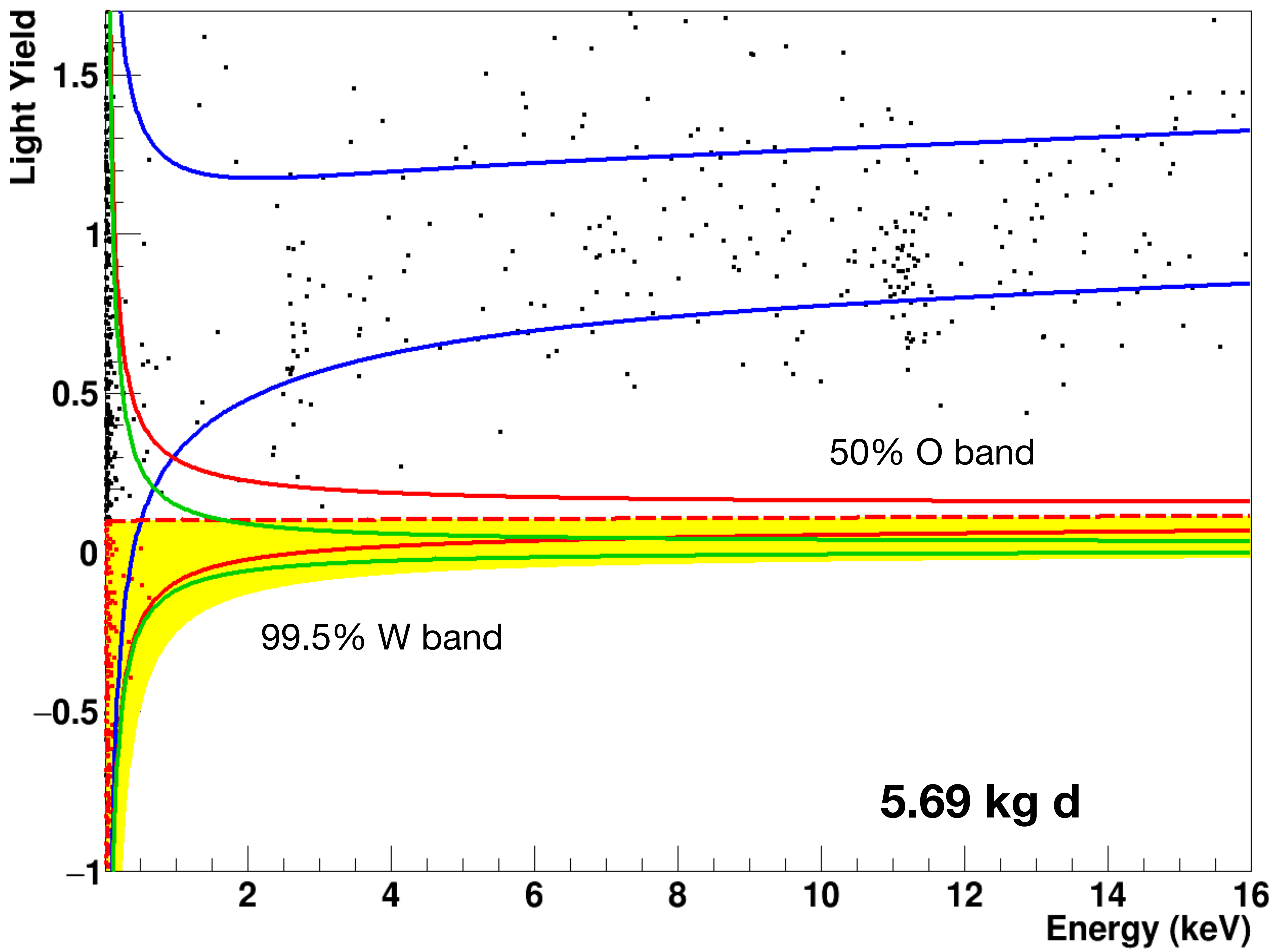
Unexpected rise at low energies

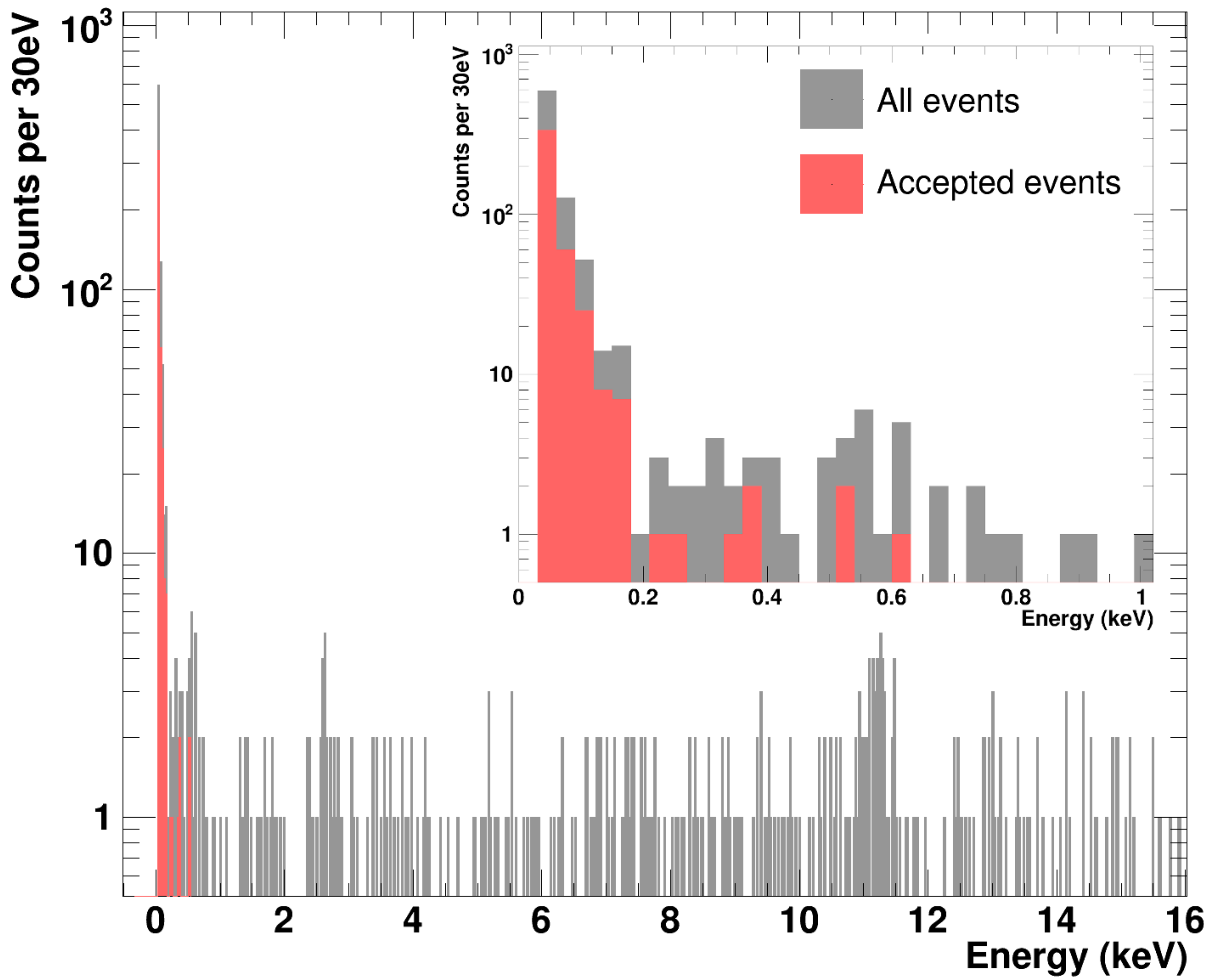
$^{182}\mathrm{W}(p,\alpha)^{179}\mathrm{Ta}$

$^{179}\mathrm{Ta} + e^{-} \xrightarrow{1.82\mathrm{y}} {}^{179}\mathrm{Hf} + \nu_e$

Run34 - Detector A, Light Yield and Energy Spectrum

Data taking 05/2016 – 02/2018





Analysis optimized for very low energy: 30 eV ⇒16 keV

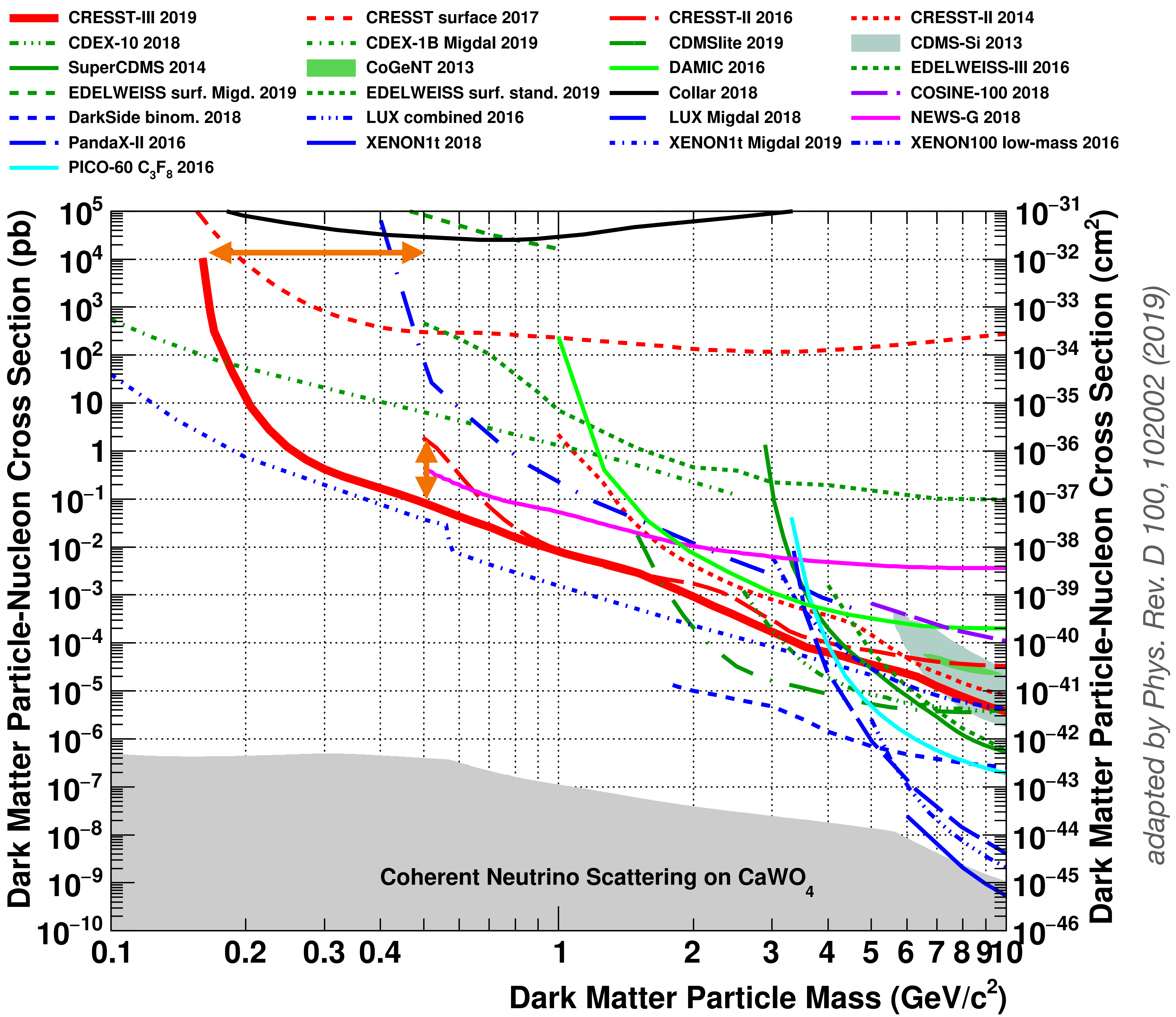
Unexpected rise at low energies

Exclusion Limit

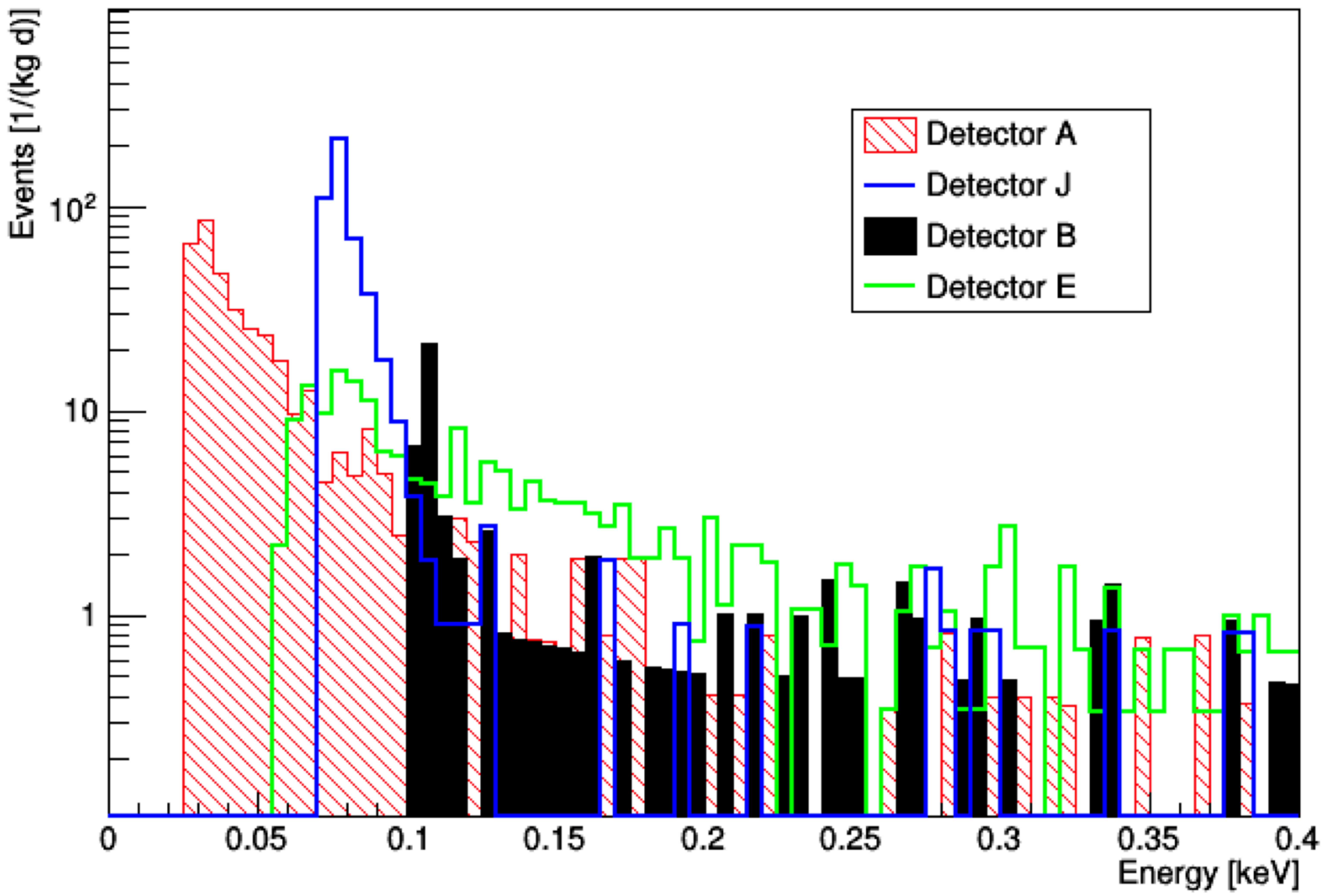
Using the DM expected energy spectrum and the events in the ROI, we use 1D Yellin optimum interval method to compute the exclusion limit:

- Improved limit a 0.5 GeV/c²
- Extended reach from 0.5 to 0.16 GeV/c²
- Best Limit for mass below 1.7 GeV/c²*

*Not based on Migdal Effect



Run34 - other $CaWO_4$ absorbers



PhD Thesis, M. Stahlberg, TU Wien (2020)

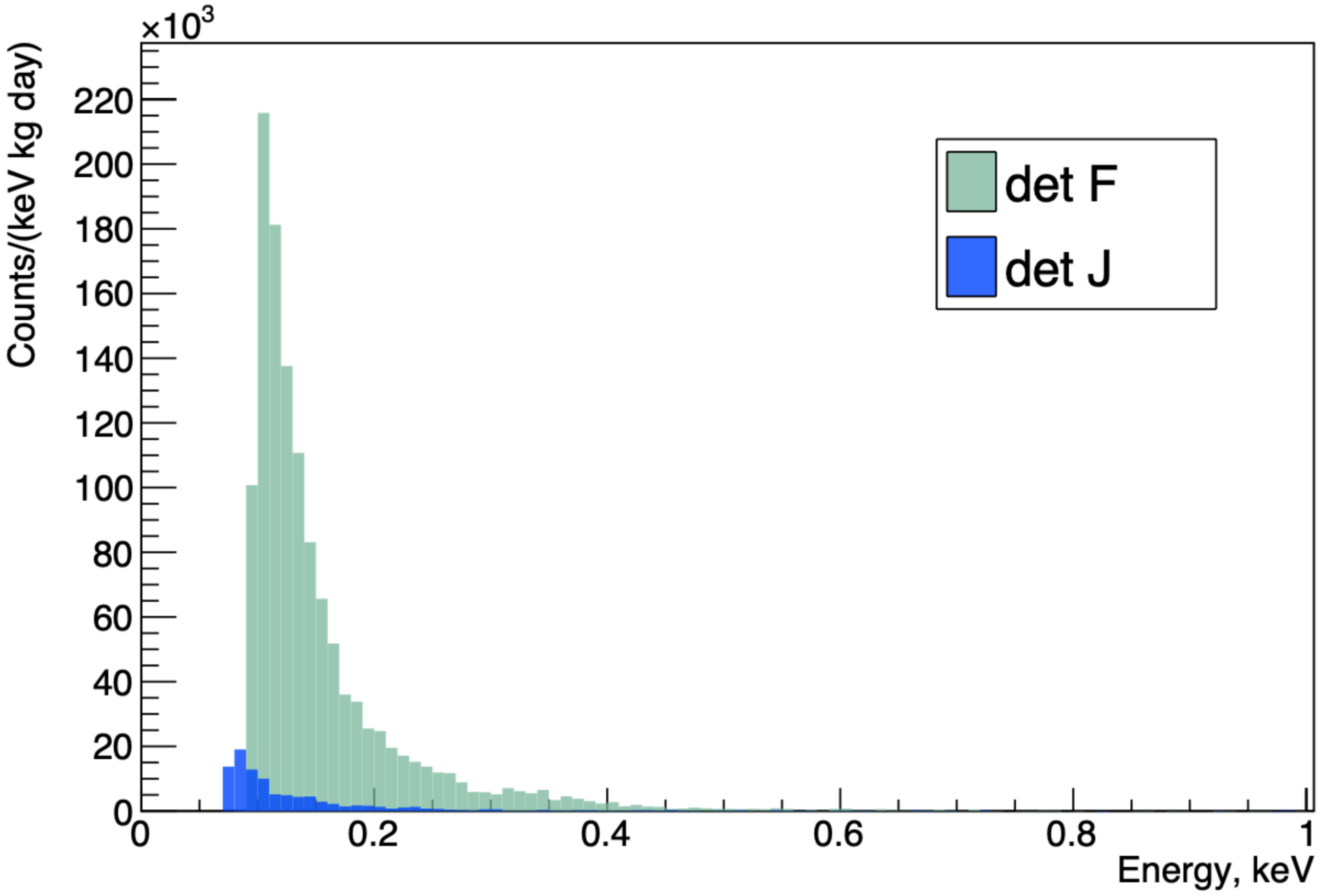
Detector	Threshold (eV)
Det A	30.1
Det B	120
Det E	64.8
Det J	83.4

Low energy excess in similar detectors but with different shape

Not single common origin

Run35 - Sapphire absorbers

Data taking 11/2018 – 10/2019



Both crystals cut from same sapphire crystal used in CRESST-I

Same detector configuration, but detector F has a much higher rate.

Threshold

76.9 eV (Det-F)

66.5 eV (Det-J)

Exposure

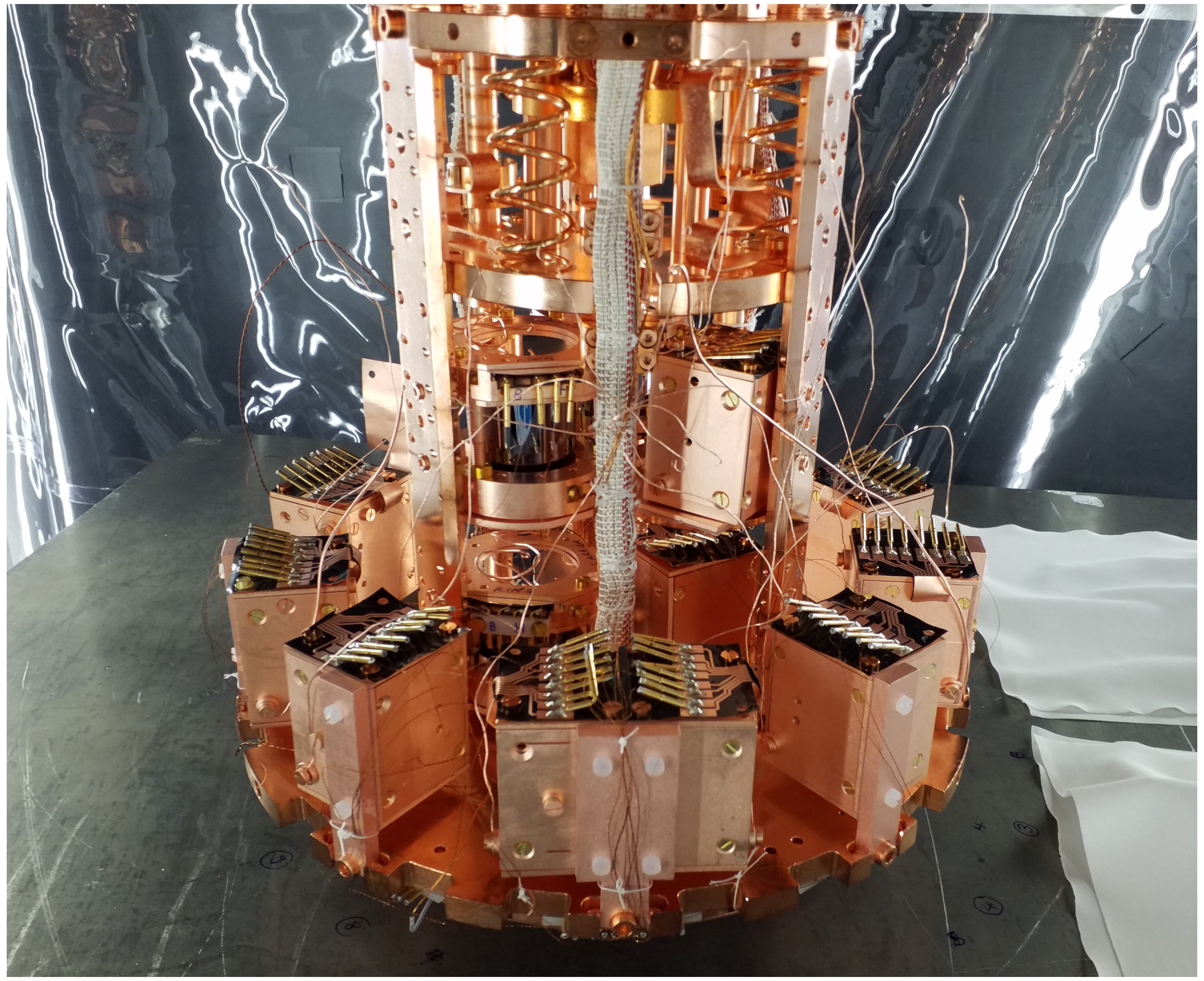
0.995 kg days (Det-F)

0.970 kg days (Det-J)

Understanding the low energy excess

Dedicated setups with hardware modifications to disentangle the different contributions are currently installed in the CRESST cryostat

- Crystal material
- Crystal surface
- Holding
- Facing surfaces



Collecting DM data since November 2020

Future plans

Upgrade of CRESST-III to 288 channels

Final planning, prototyping and testing:

- SQUID
- wiring
- DAQ

Detector R&D

- lower threshold
- complementary target materials

- Upgrade of the setup at LNGS
- Detectors production and testing

Restart data taking

Summary and conclusion

The CRESST cryogenic approach enables to obtain

- Leading results for the low mass DM search
- Unprecedented low energy threshold
- Possibility to use different target materials

Ongoing studies on the low energy excess

Community effort to understand the rise observed in other DM experiments

https://indico.cern.ch/event/1013203/

With the future upgrade we will have new challenges to face and new physics to explore

Thank you for your attention