# Direct Dark Matter search with the CRESST-III experiment

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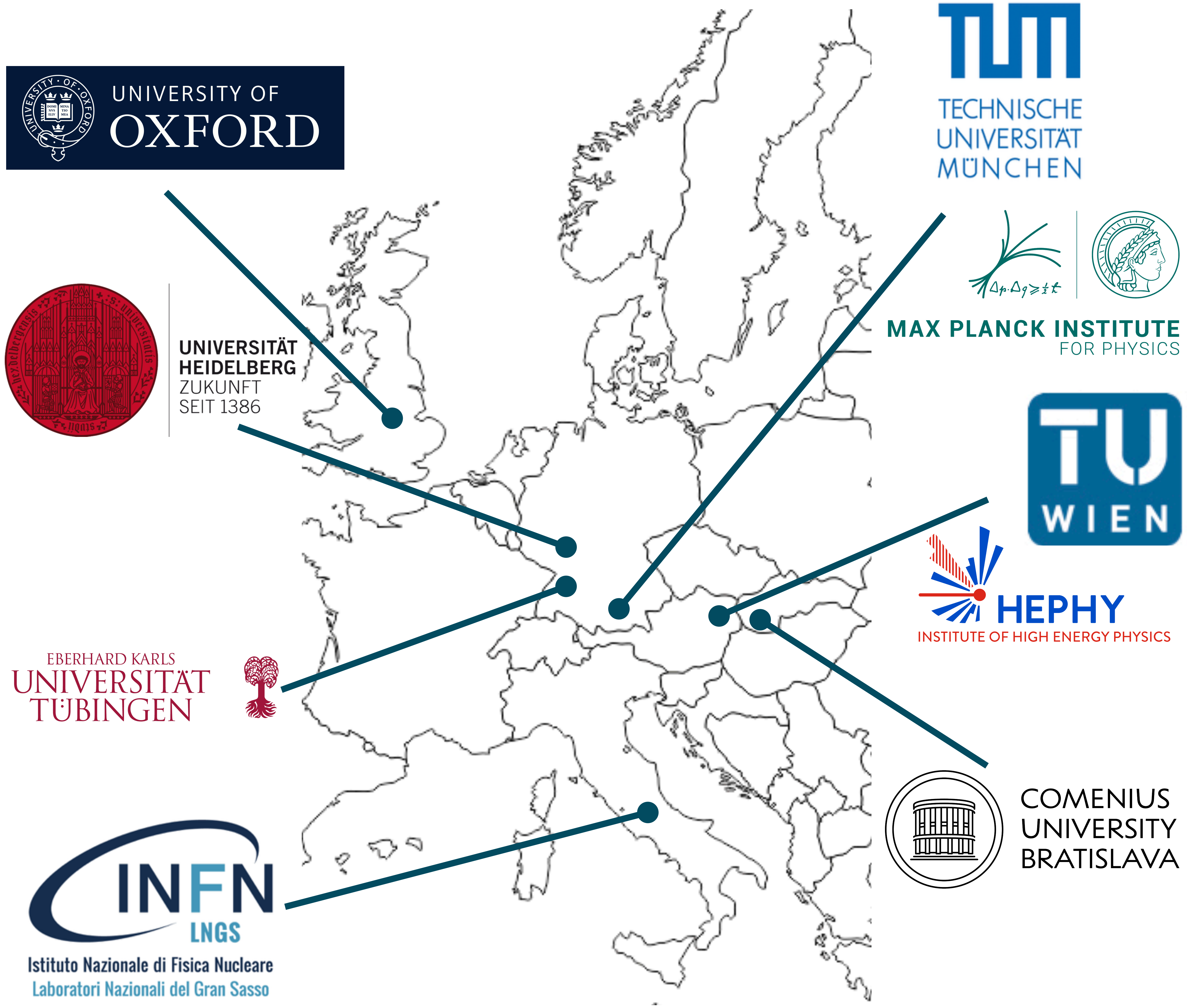
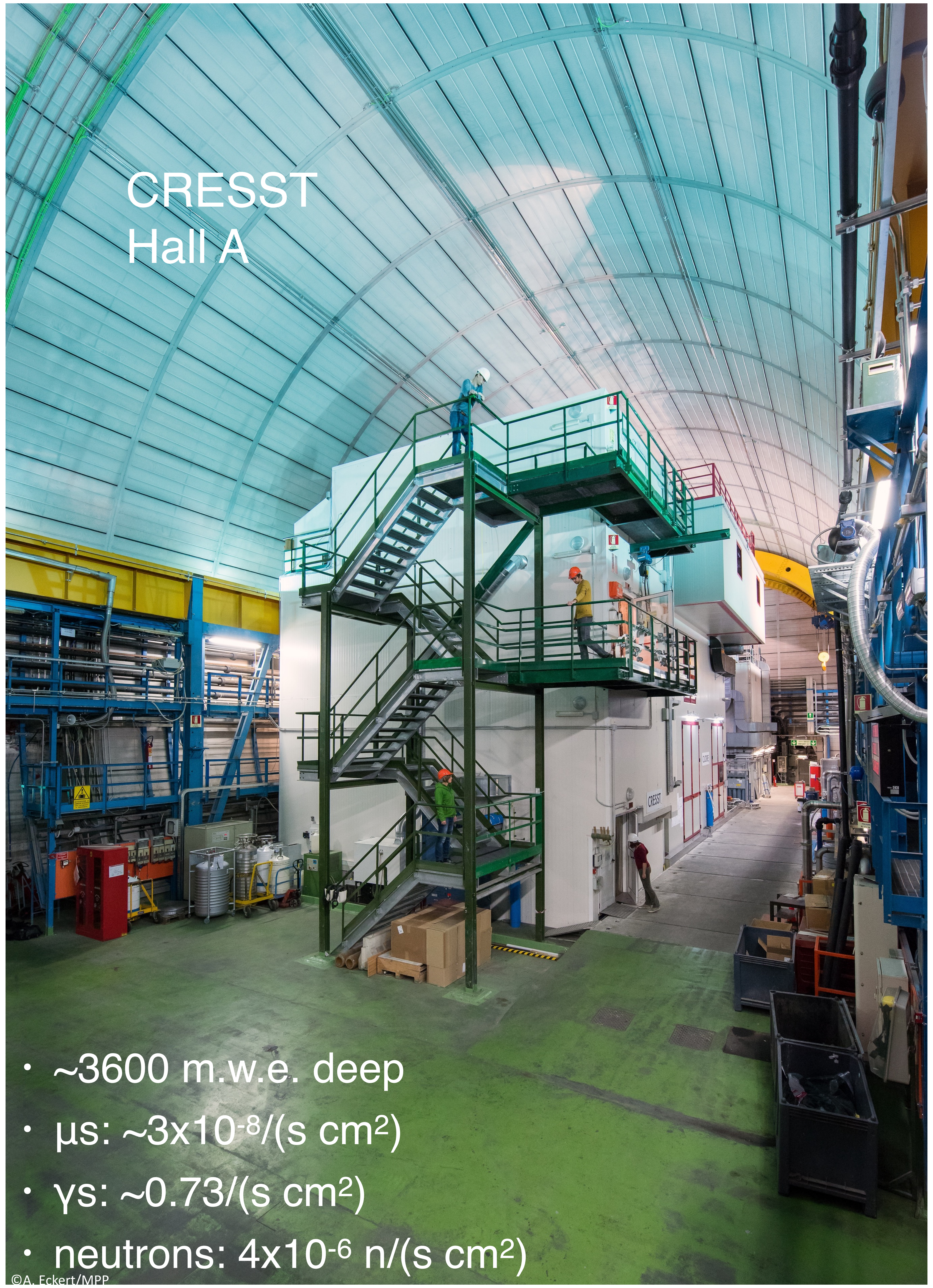
# The CRESST collaboration

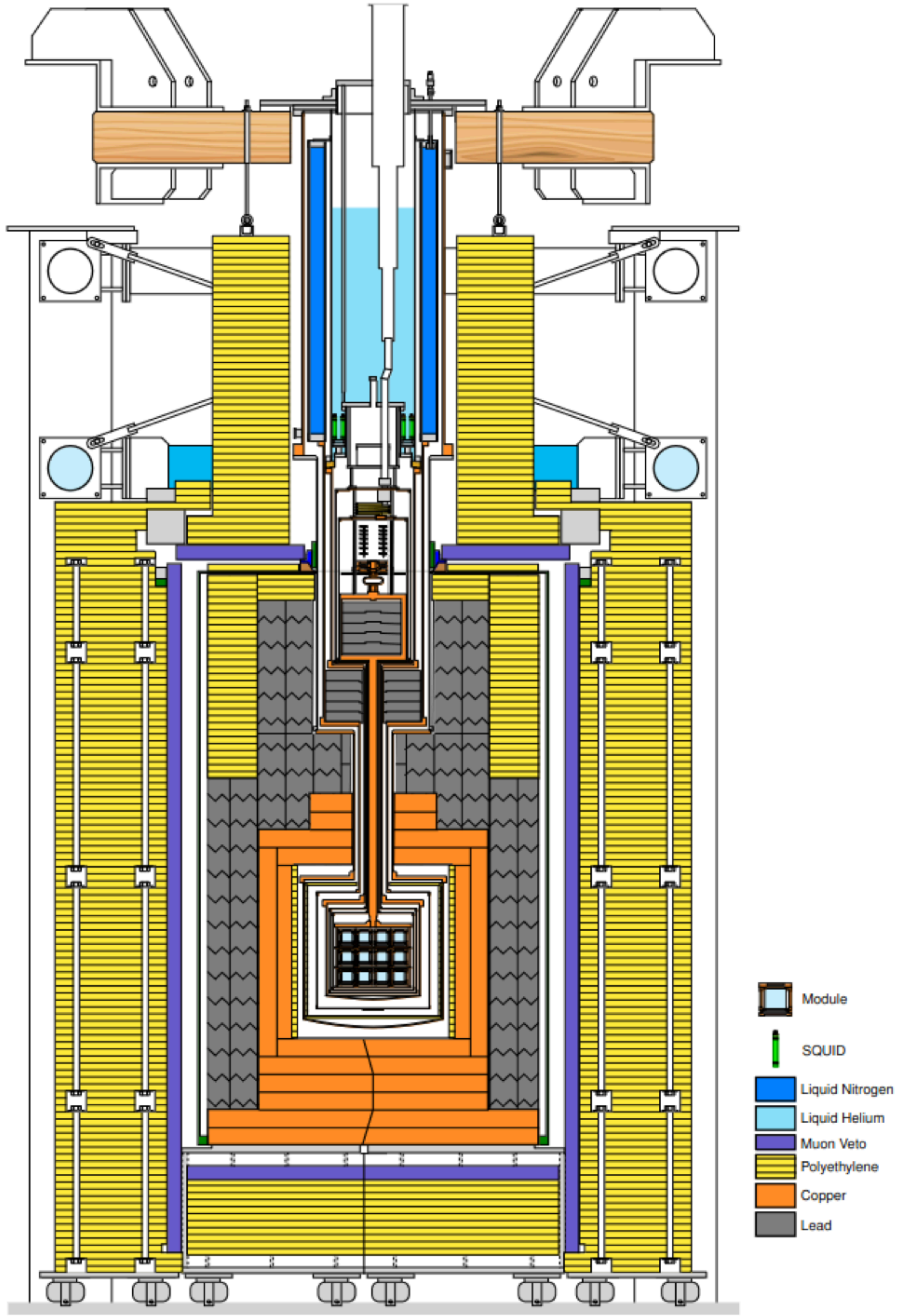
CRESST



# The CRESST experiment

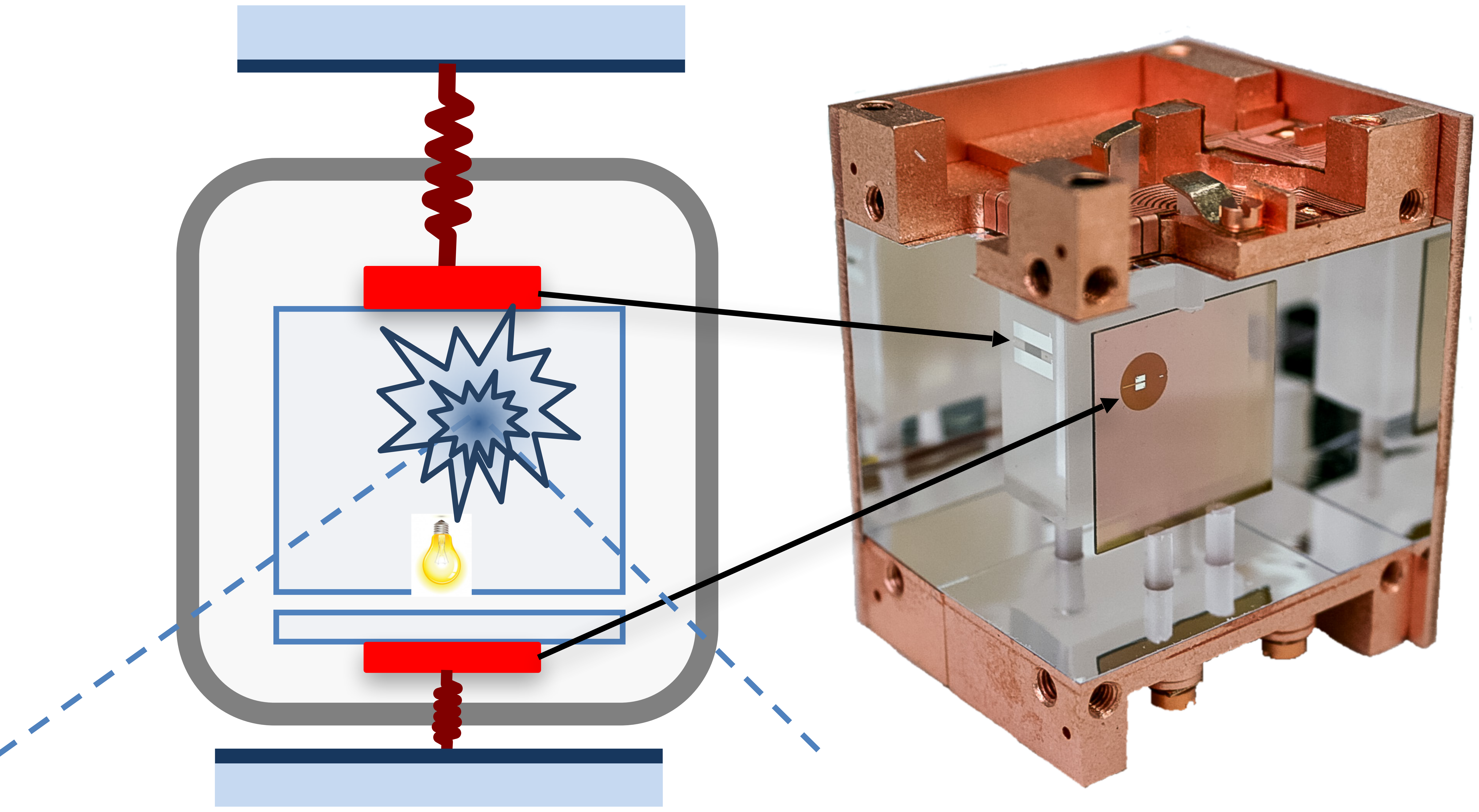
CRESST

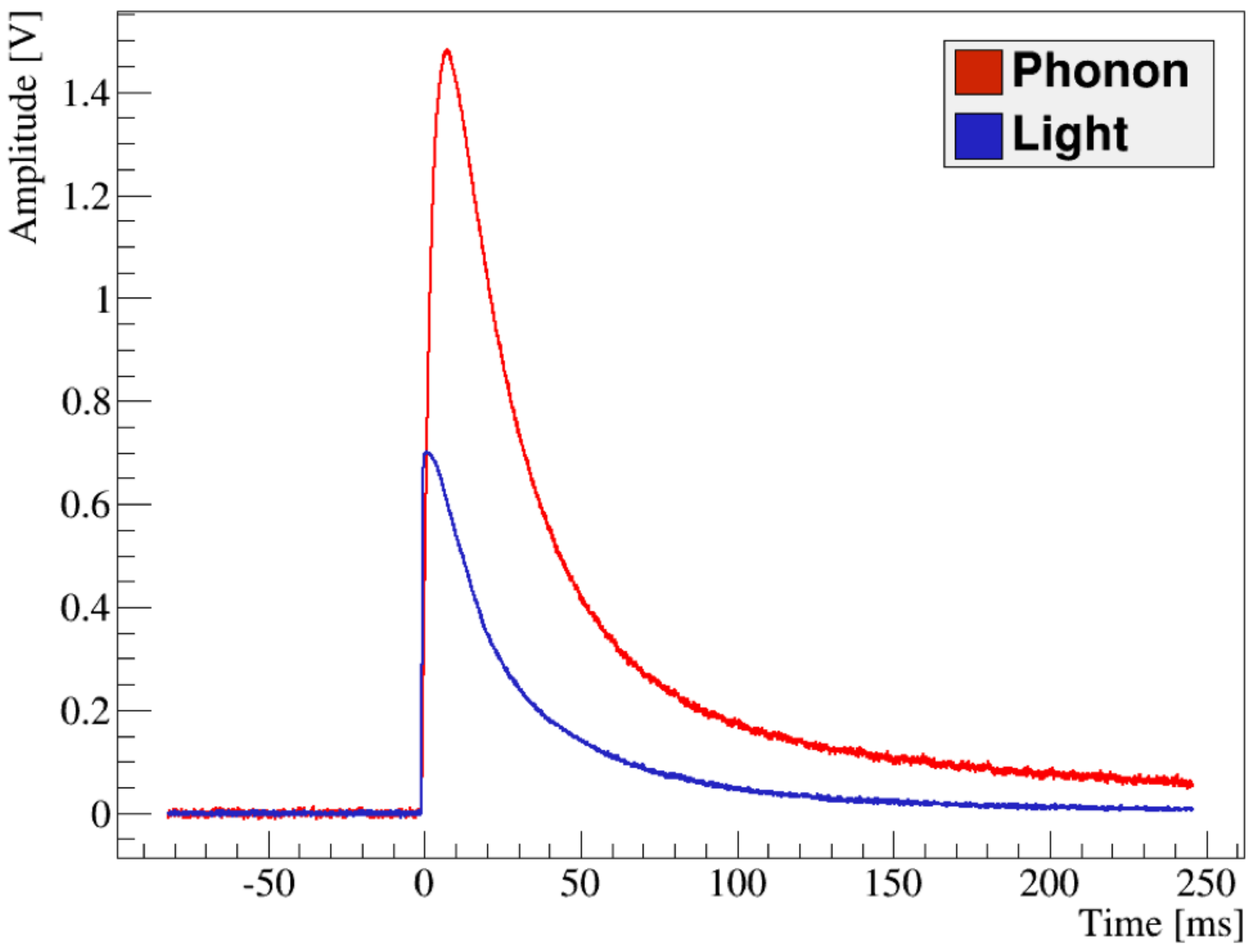



CRESST goal: direct detection of dark matter particles via their scattering off target nuclei in cryogenic detectors, operated at ~15 mK

# The CRESST-III detector module



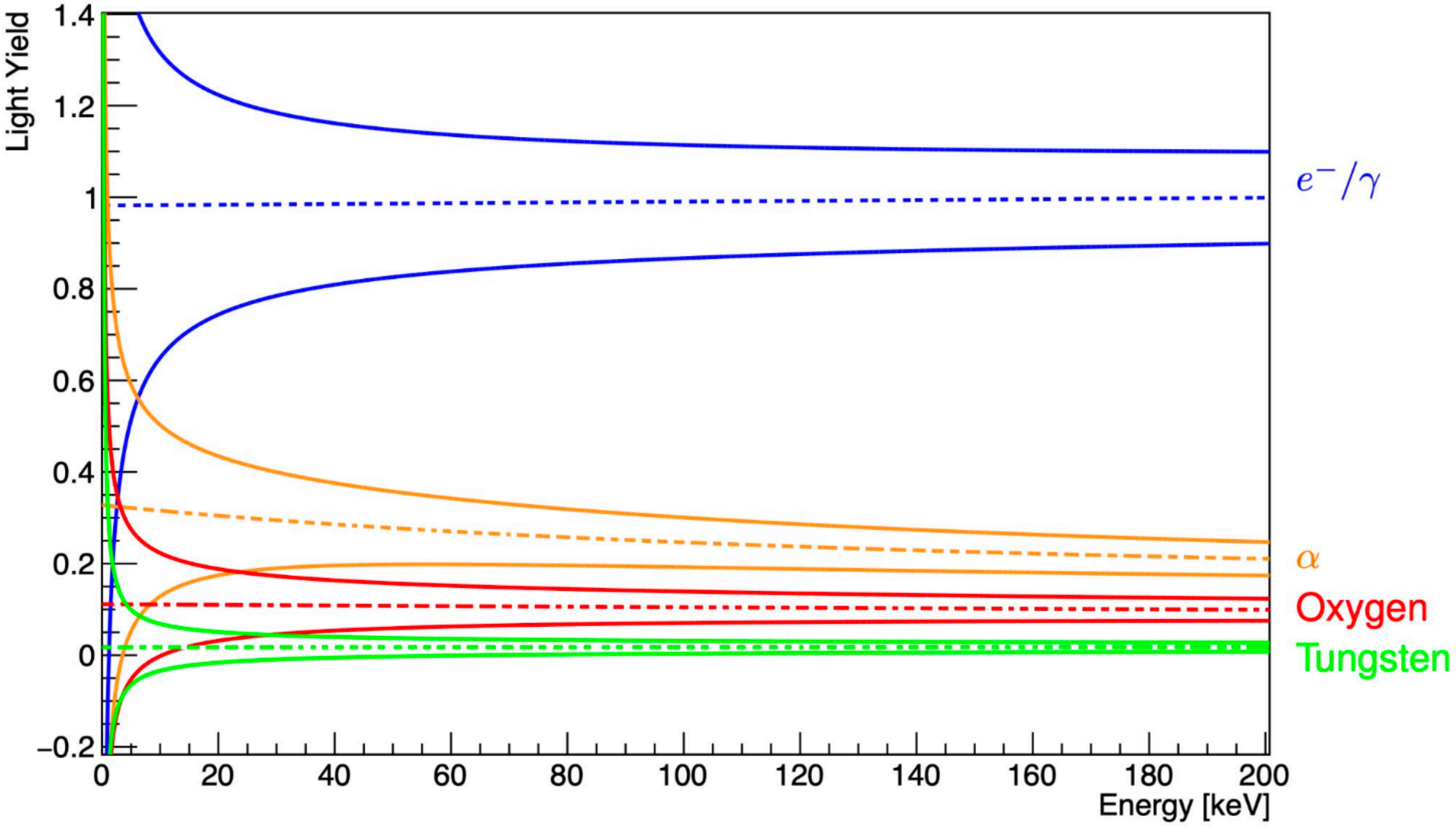



CRESST standard detectors are composed of a scintillating crystal as the main absorber, paired with a Silicon-on-Sapphire wafer as light detector.

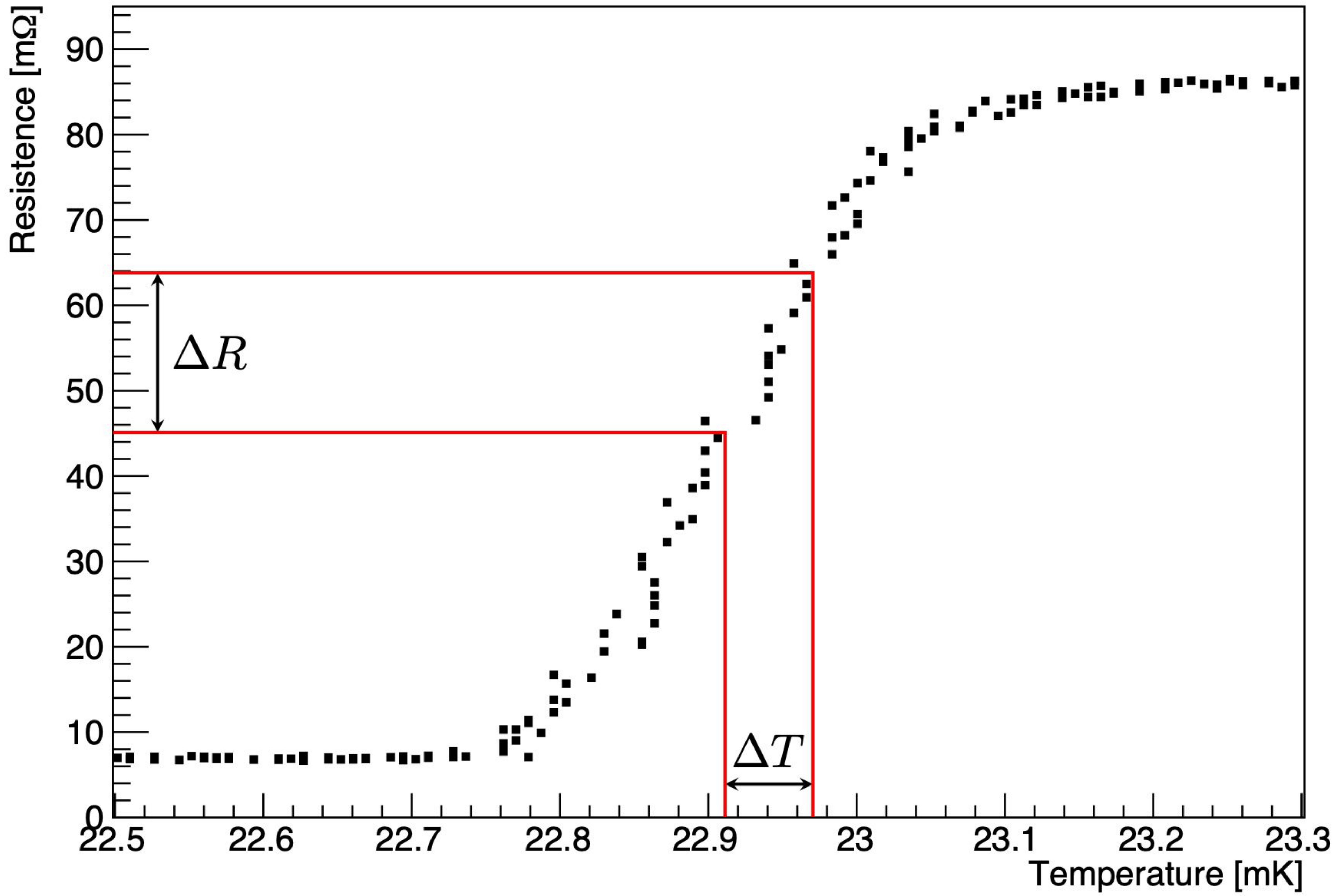
# Particle discrimnation

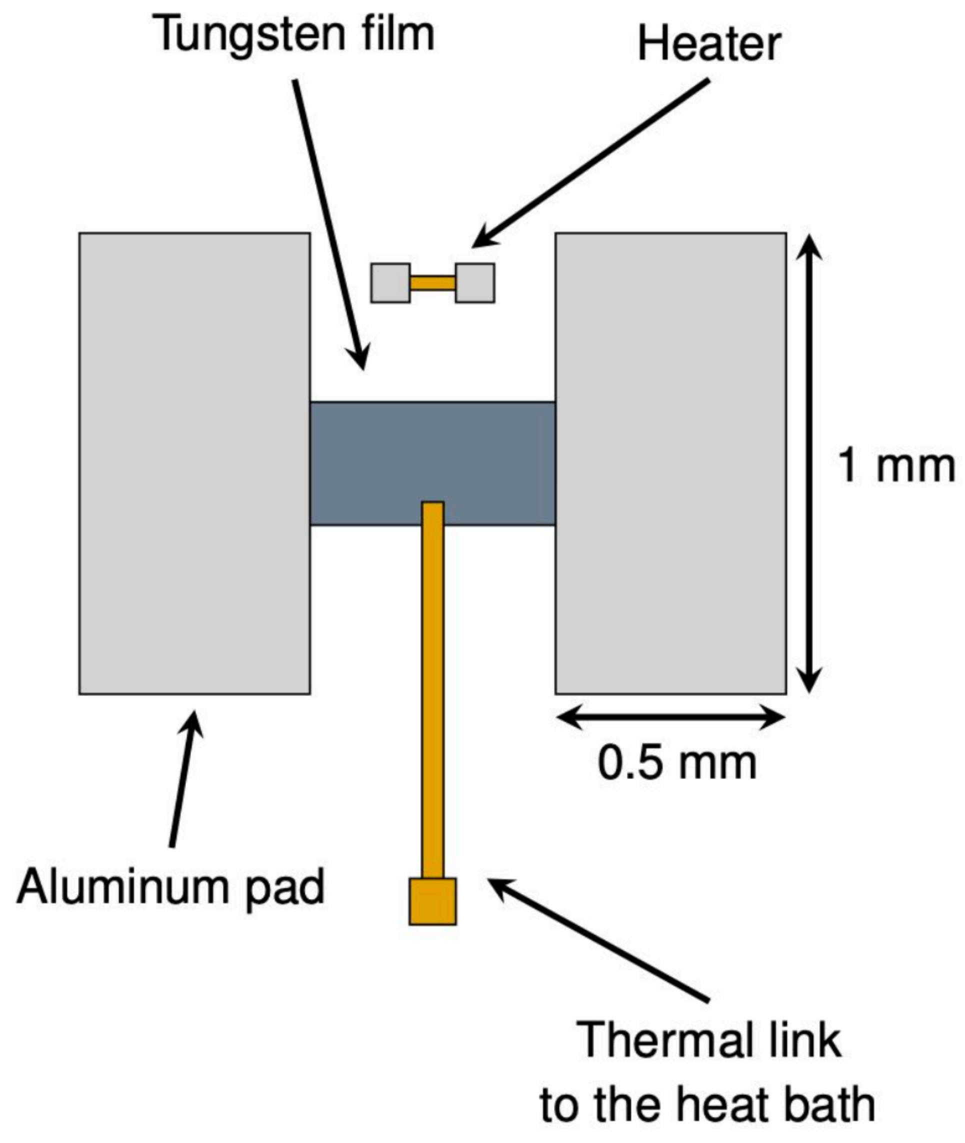
The double readout of light and phonon signals allows for separating potential signal events (**nuclear recoils**) and the dominant radioactive background (**electron recoils**) and defining different bands.

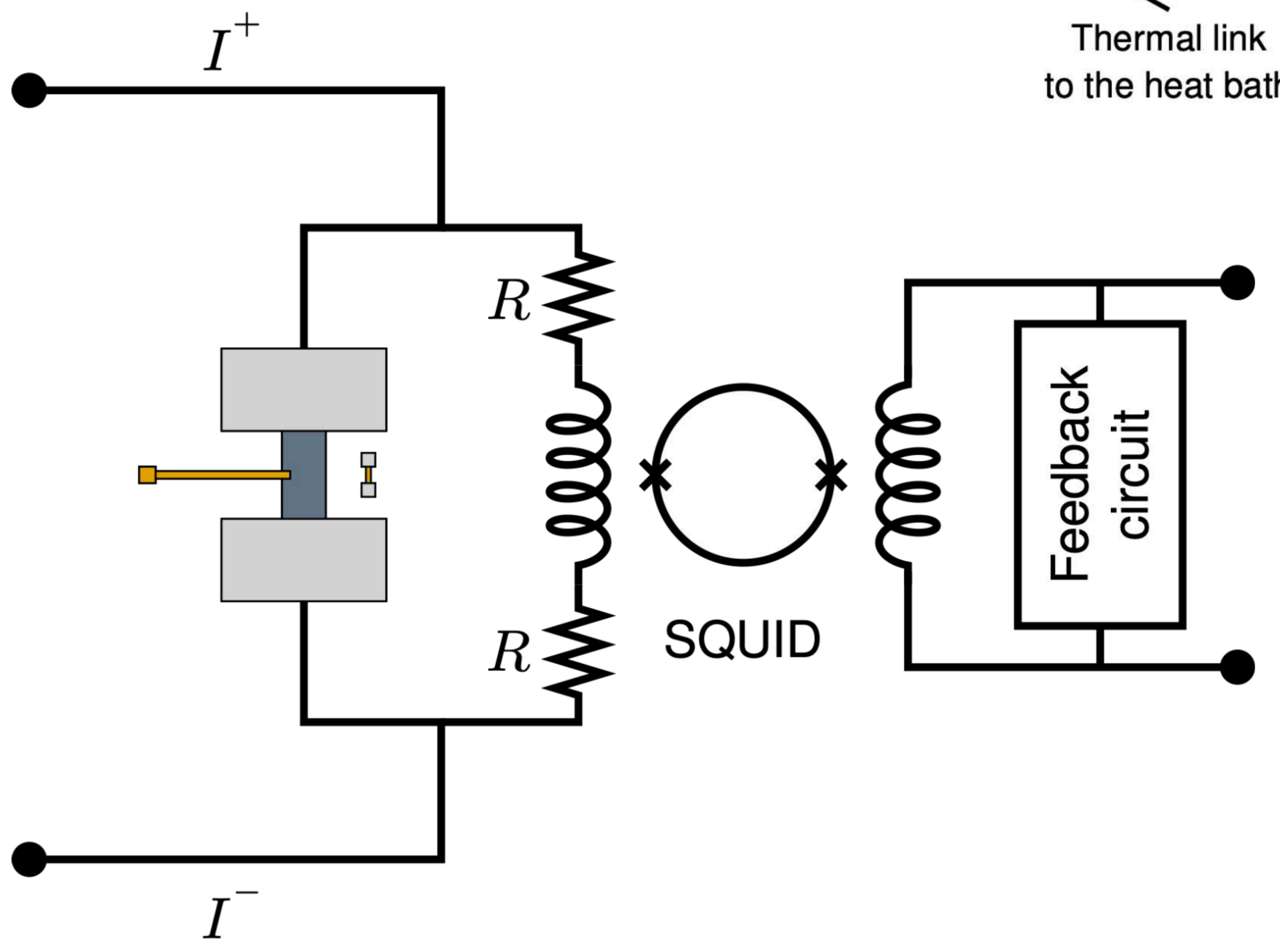
$$LY = \frac{\text{Light signal}}{\text{Phonon signal}}$$



# Transition Edge Sensor

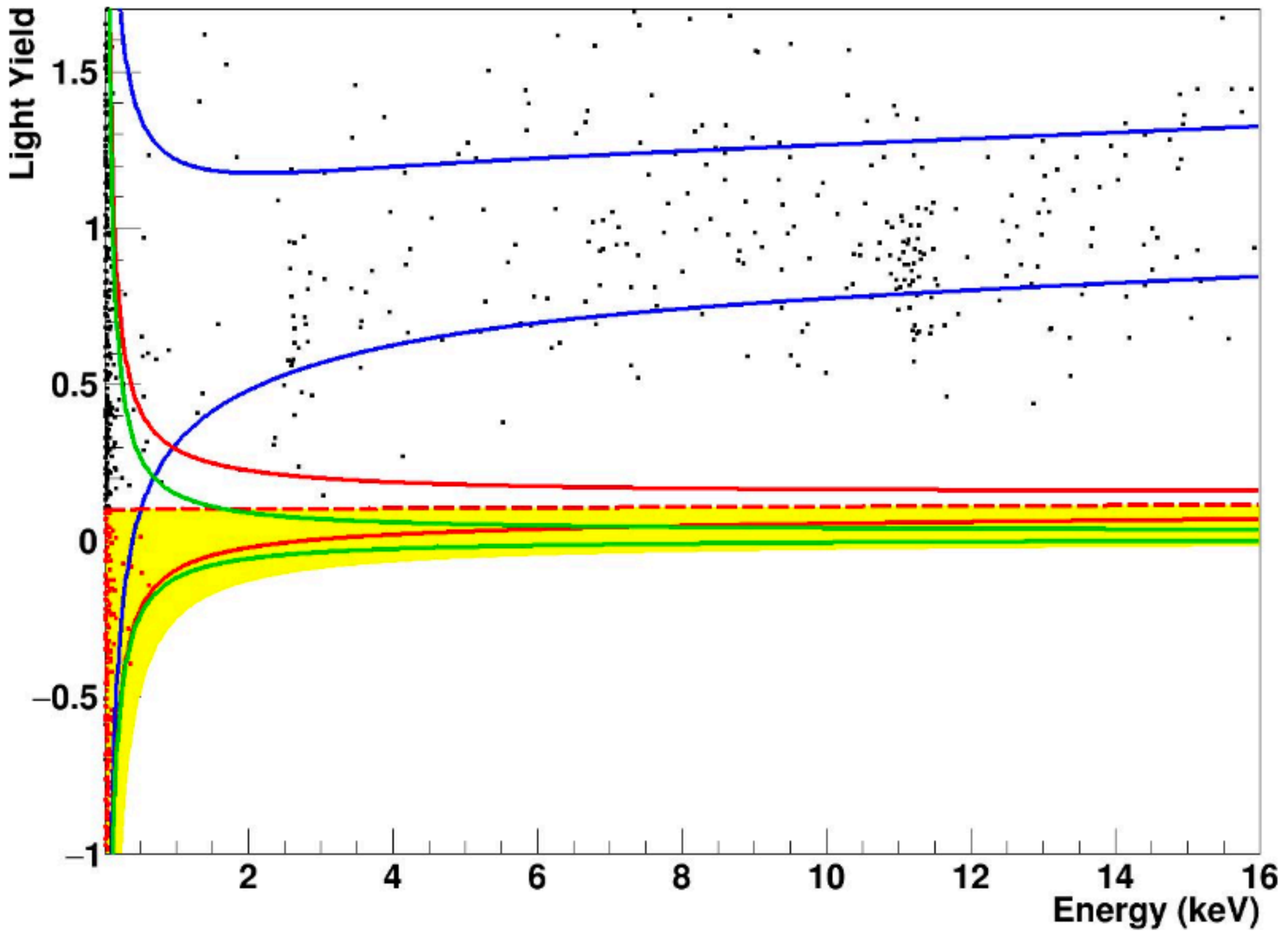


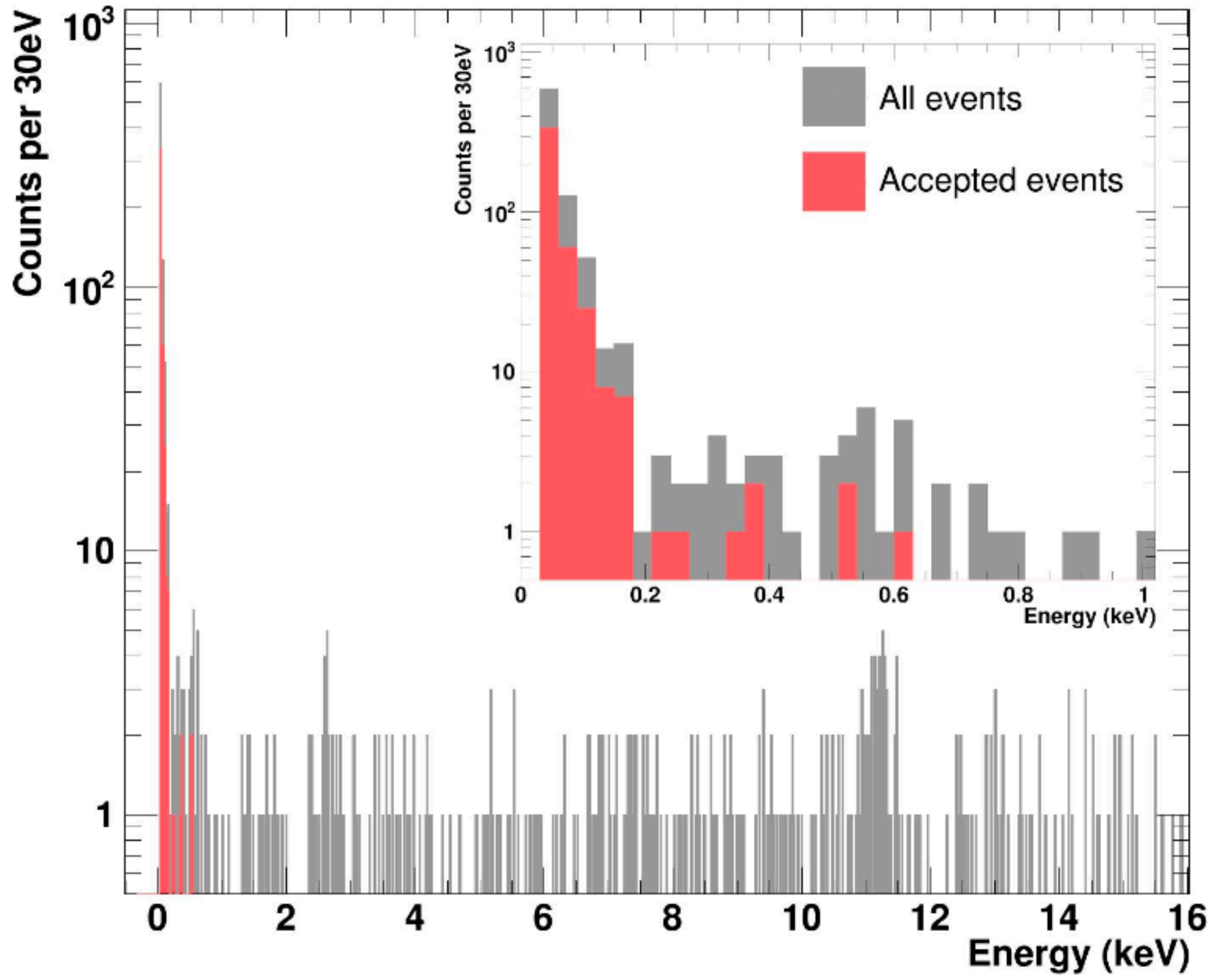



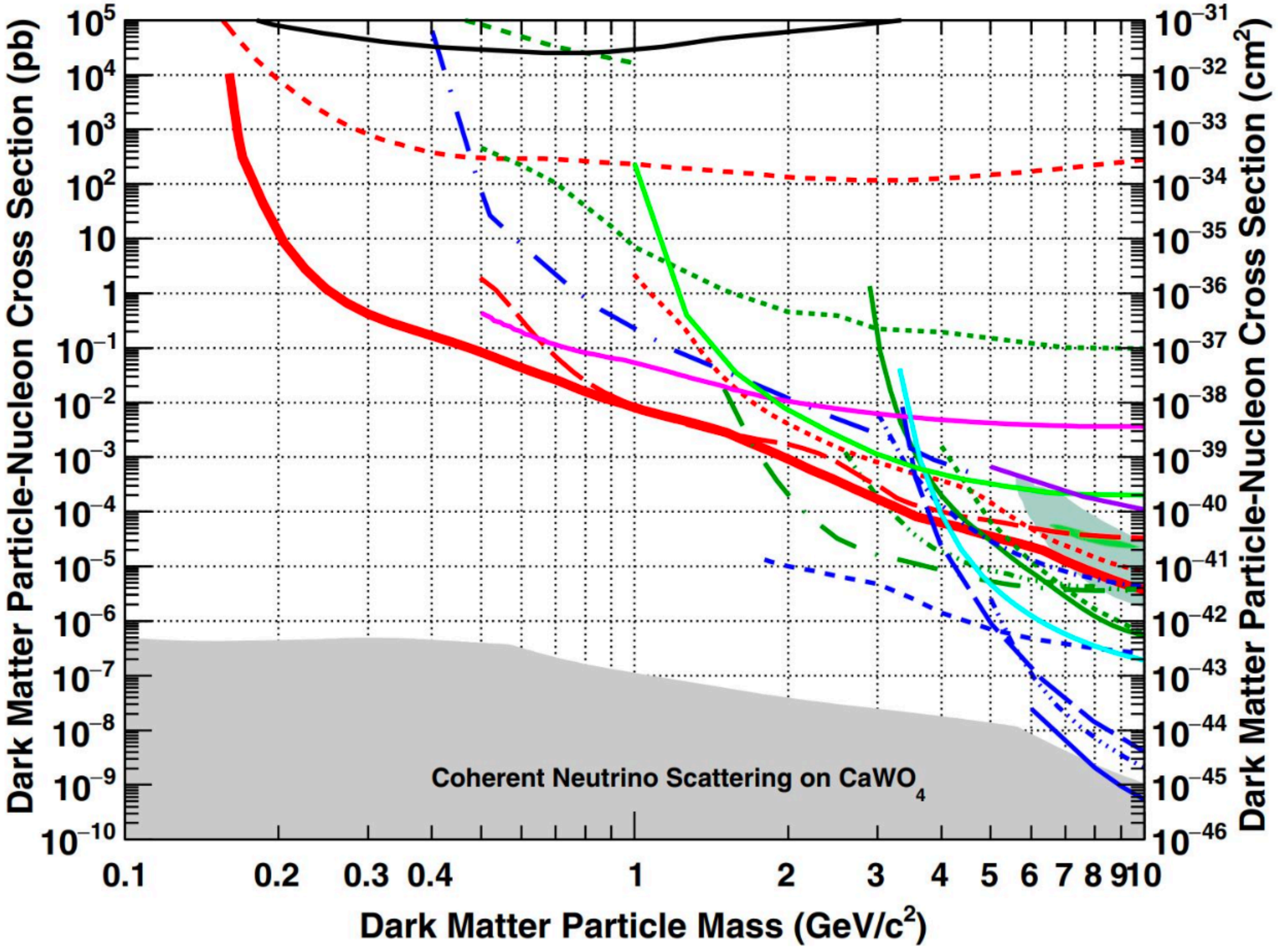




$E \sim keV \Rightarrow T \sim \mu K \Rightarrow R \sim m\Omega$

# CRESST-III first result

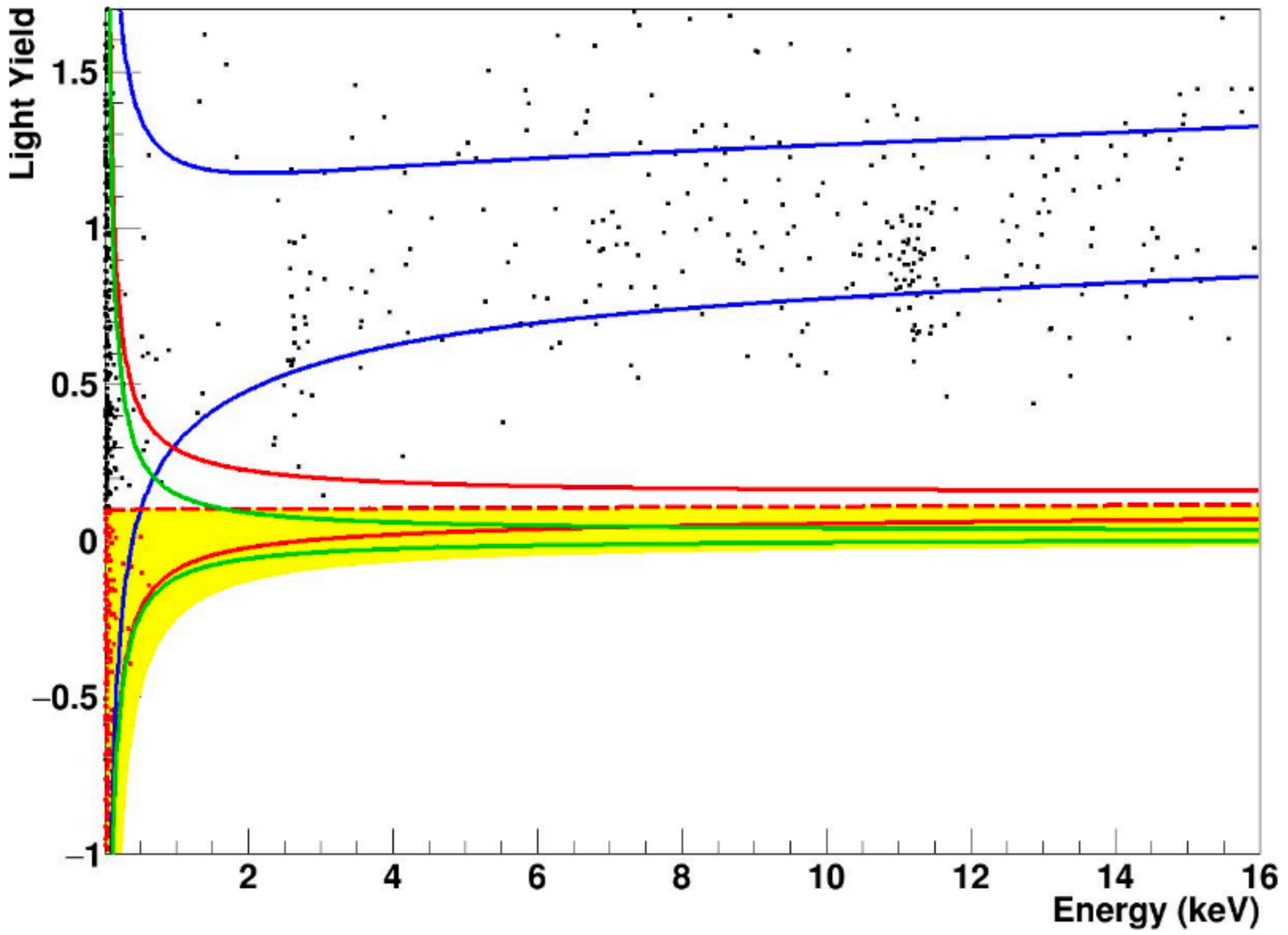


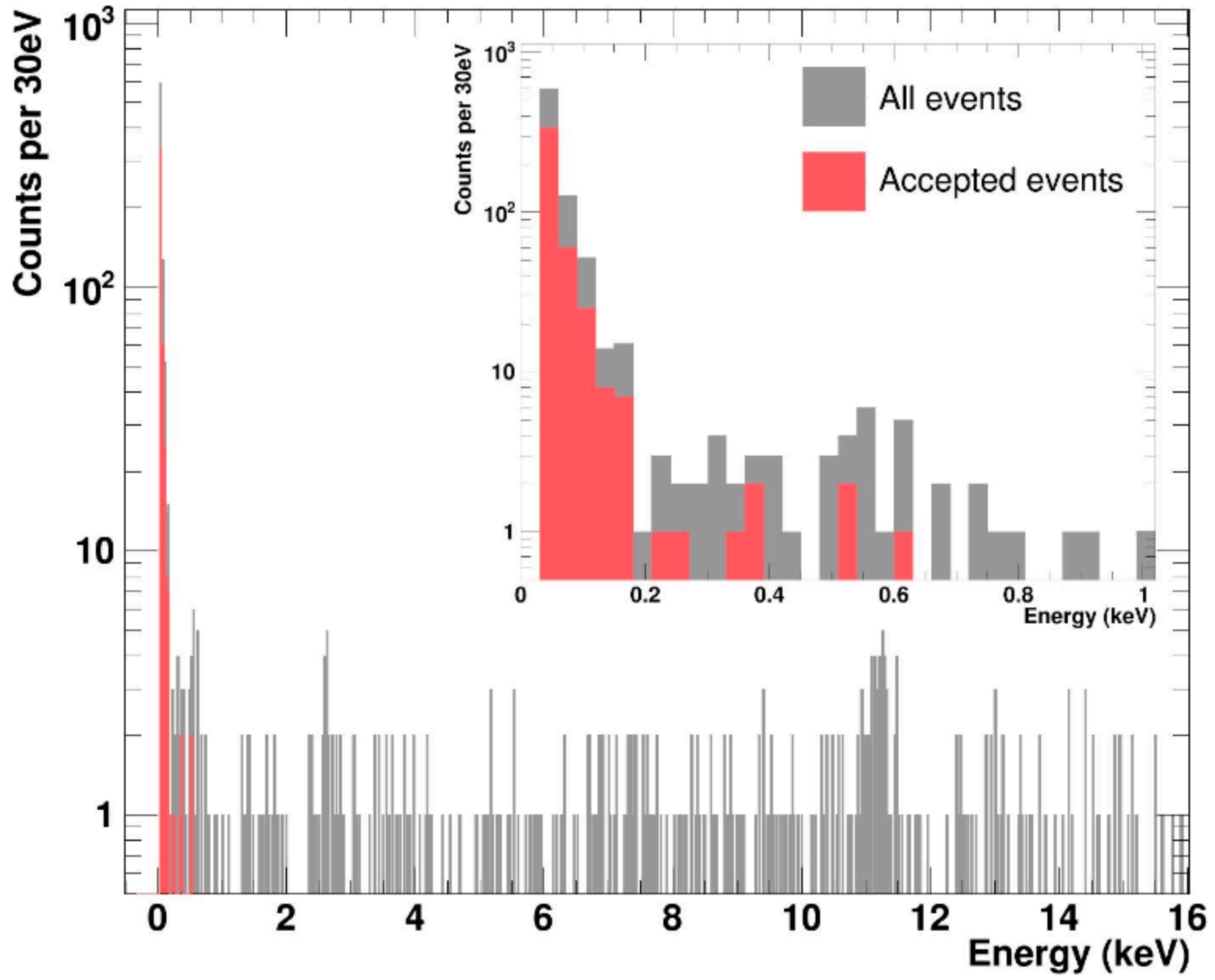



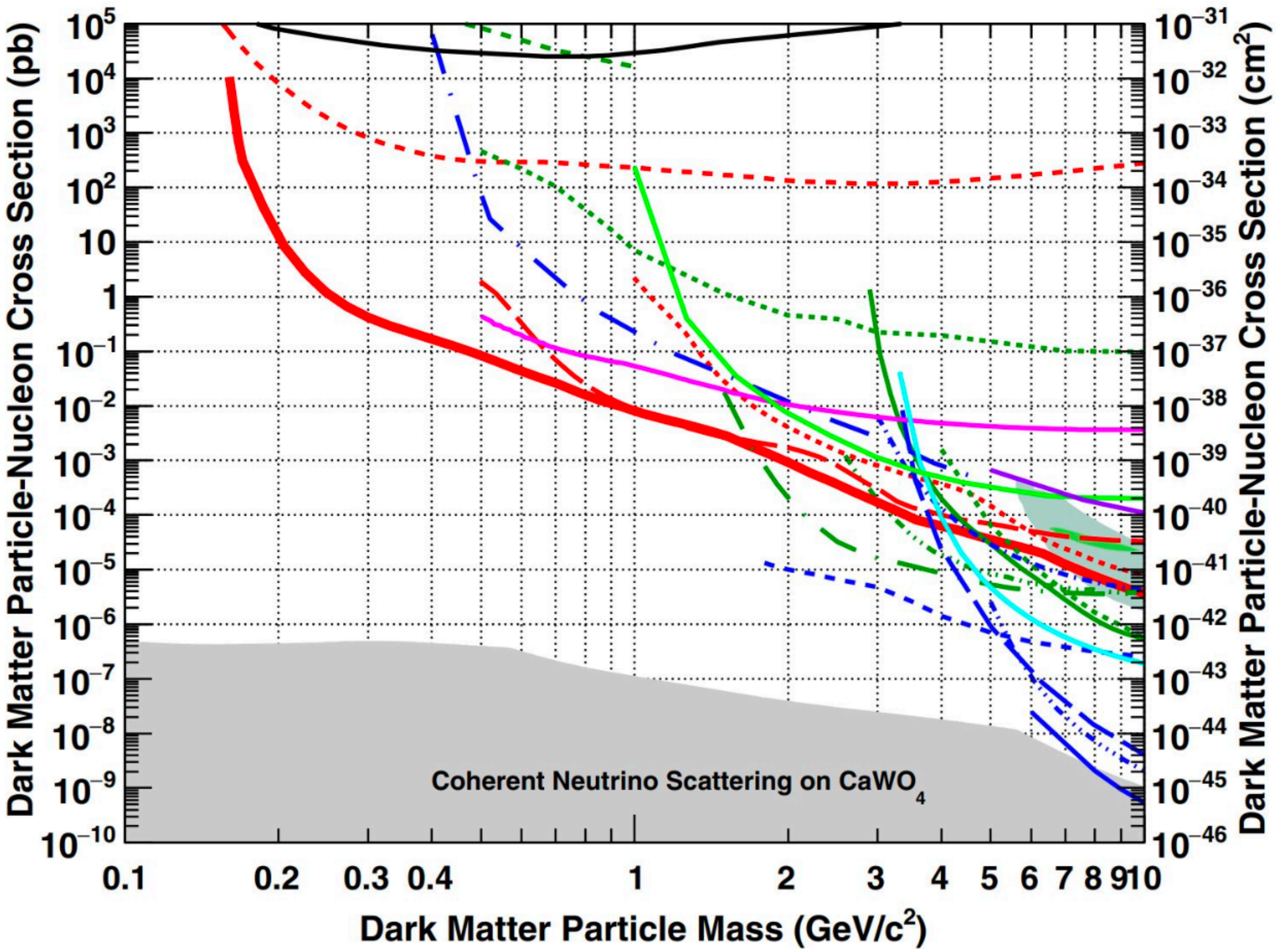




Phys. Rev. D 100, 102002

# CRESST-III first result



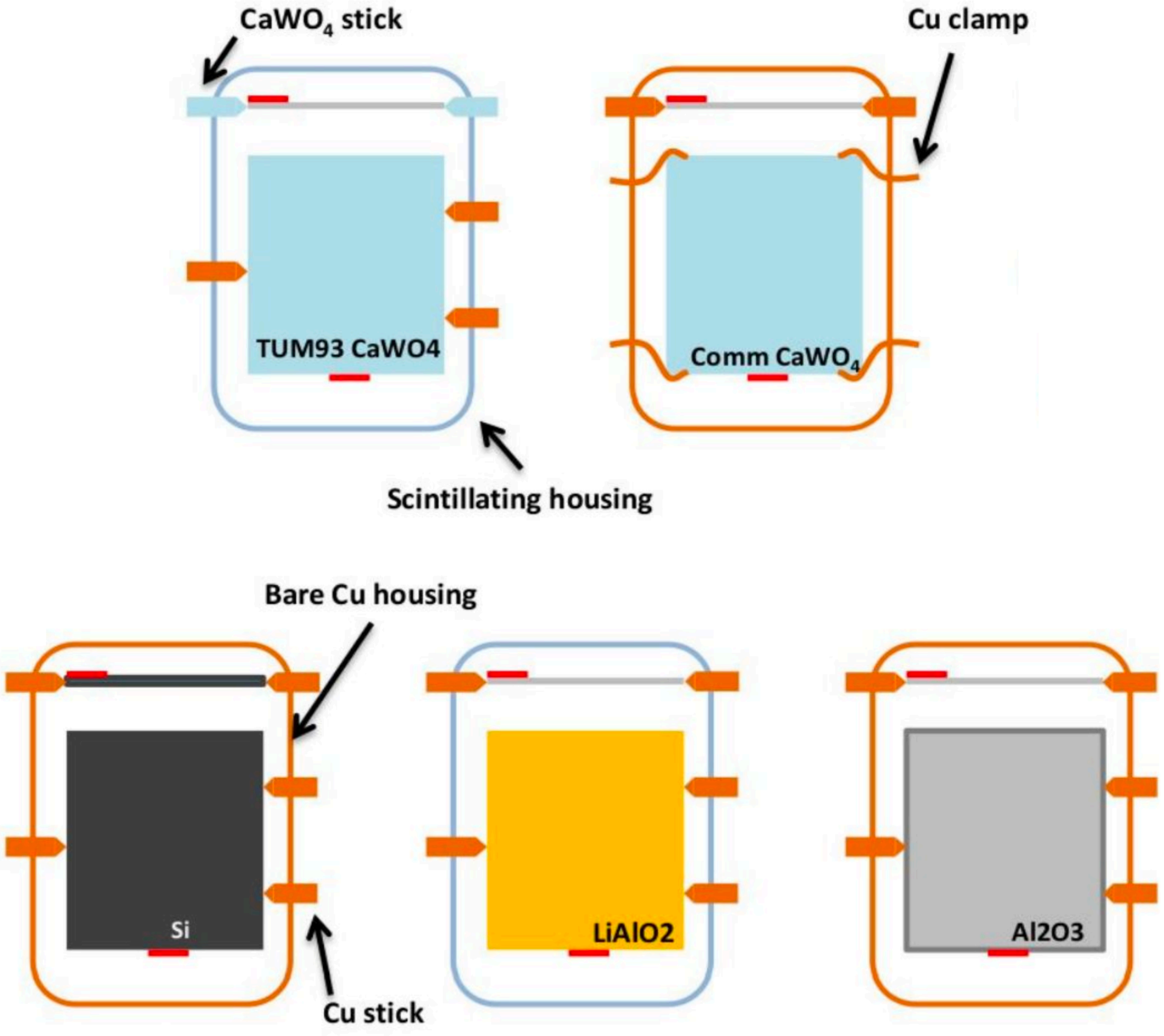

Phys. Rev. D 100, 102002

Breakthrough result + First observation of the unexpected rise of events below 200 eV, Low Energy Excess (LEE), limiting Dark Matter sensitivity

# LEE studies

## Physics campaign to pinpoint the LEE

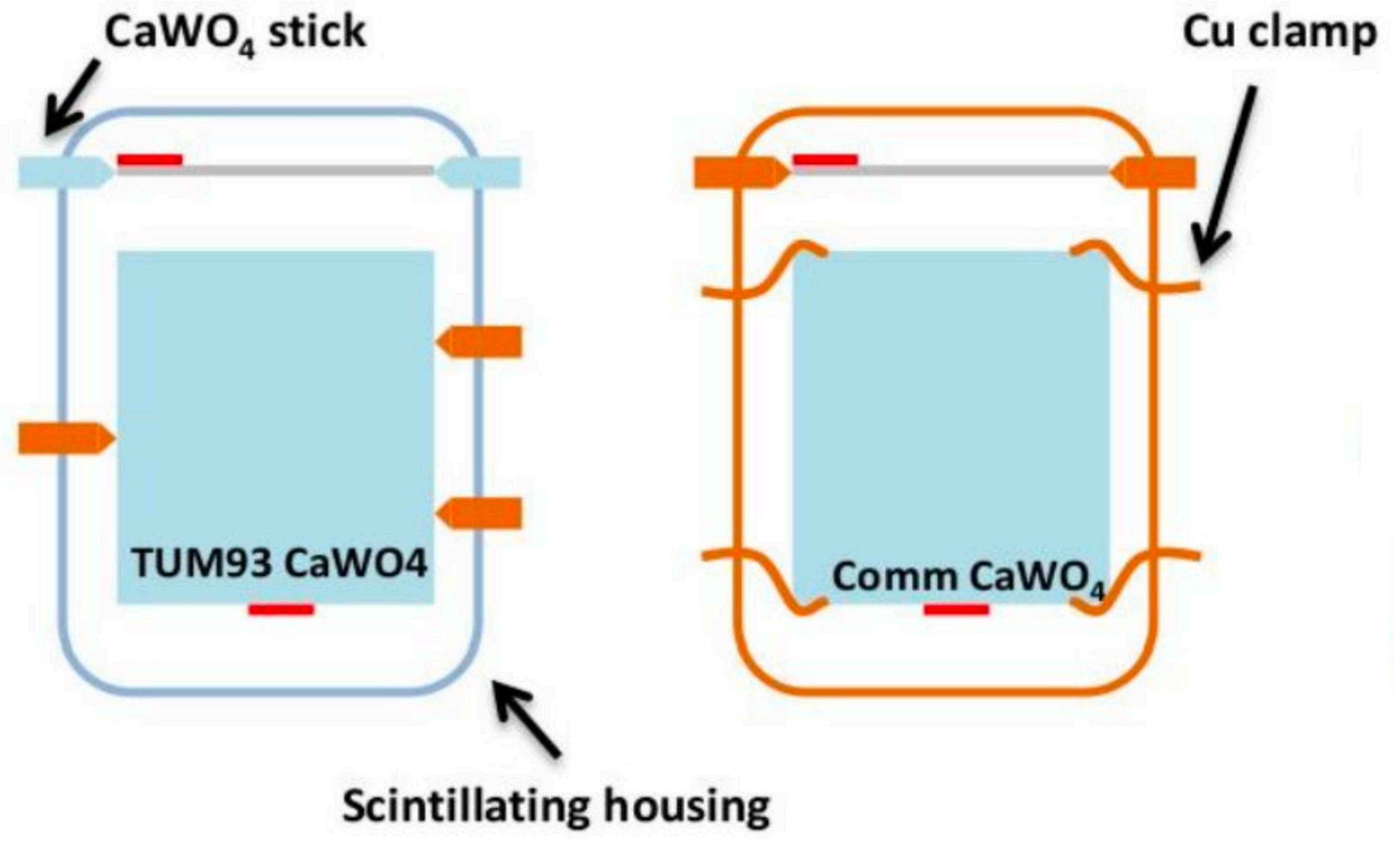
Target material?
Stress induced by holder?
Crystal growth parameters?
Scintillating material?
Geometry?



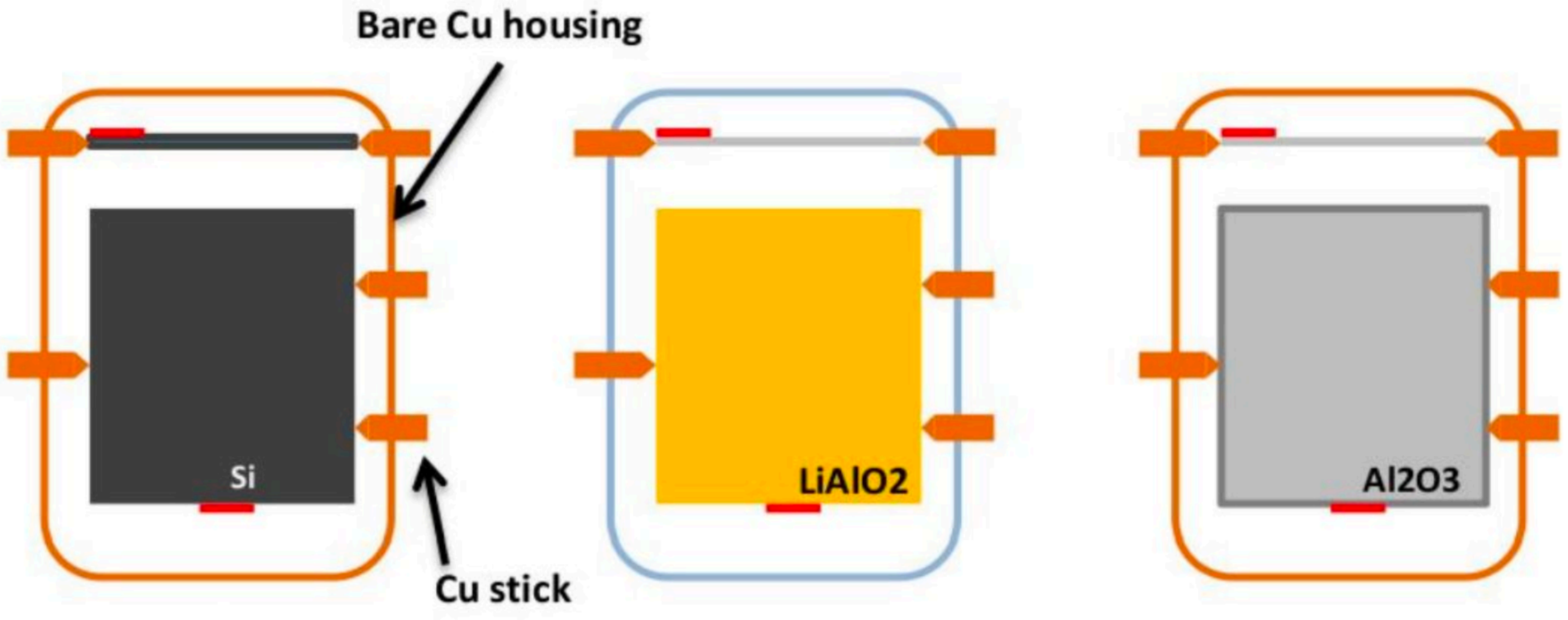
# LEE studies

## Physics campaign to pinpoint the LEE

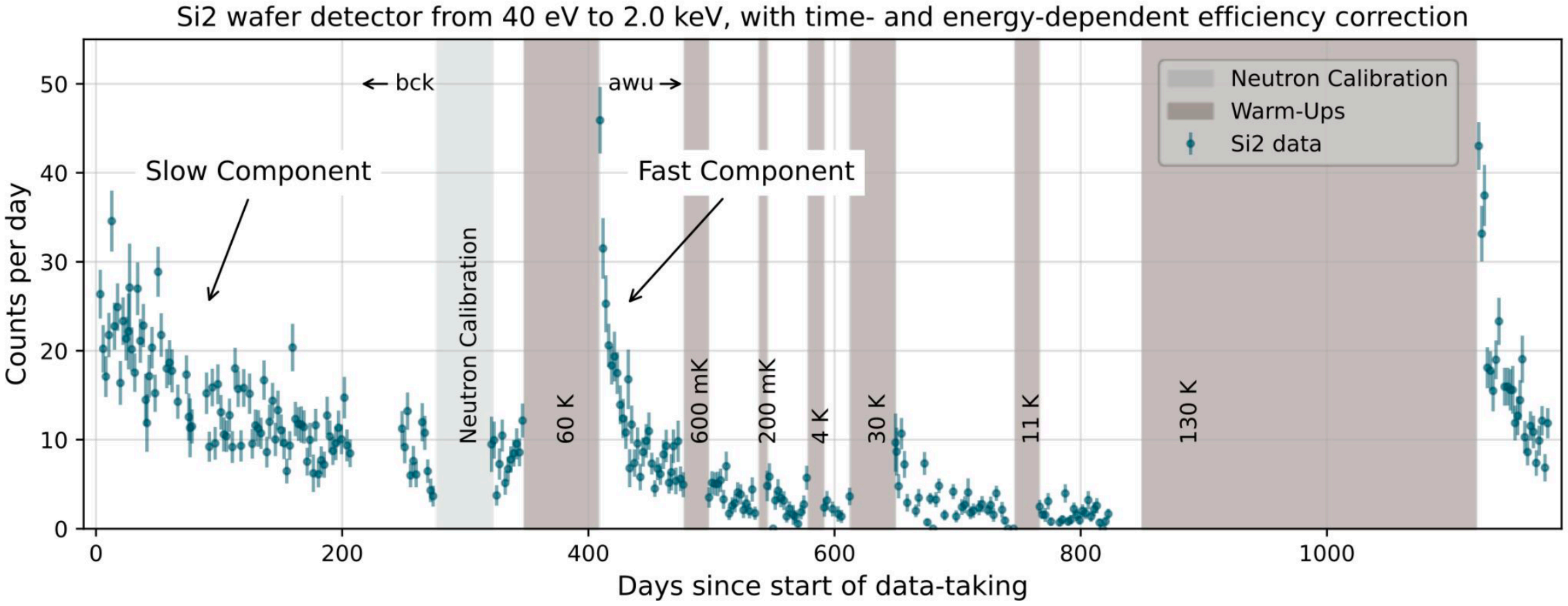
Target material? Different materials
Stress induced by holder? Different holder
Crystal growth parameters? Tested on slow grown crystal
Scintillating material? Removed scintillating material
Geometry? LEE studies also on wafer




None of the modification had a significant impact on the LEE

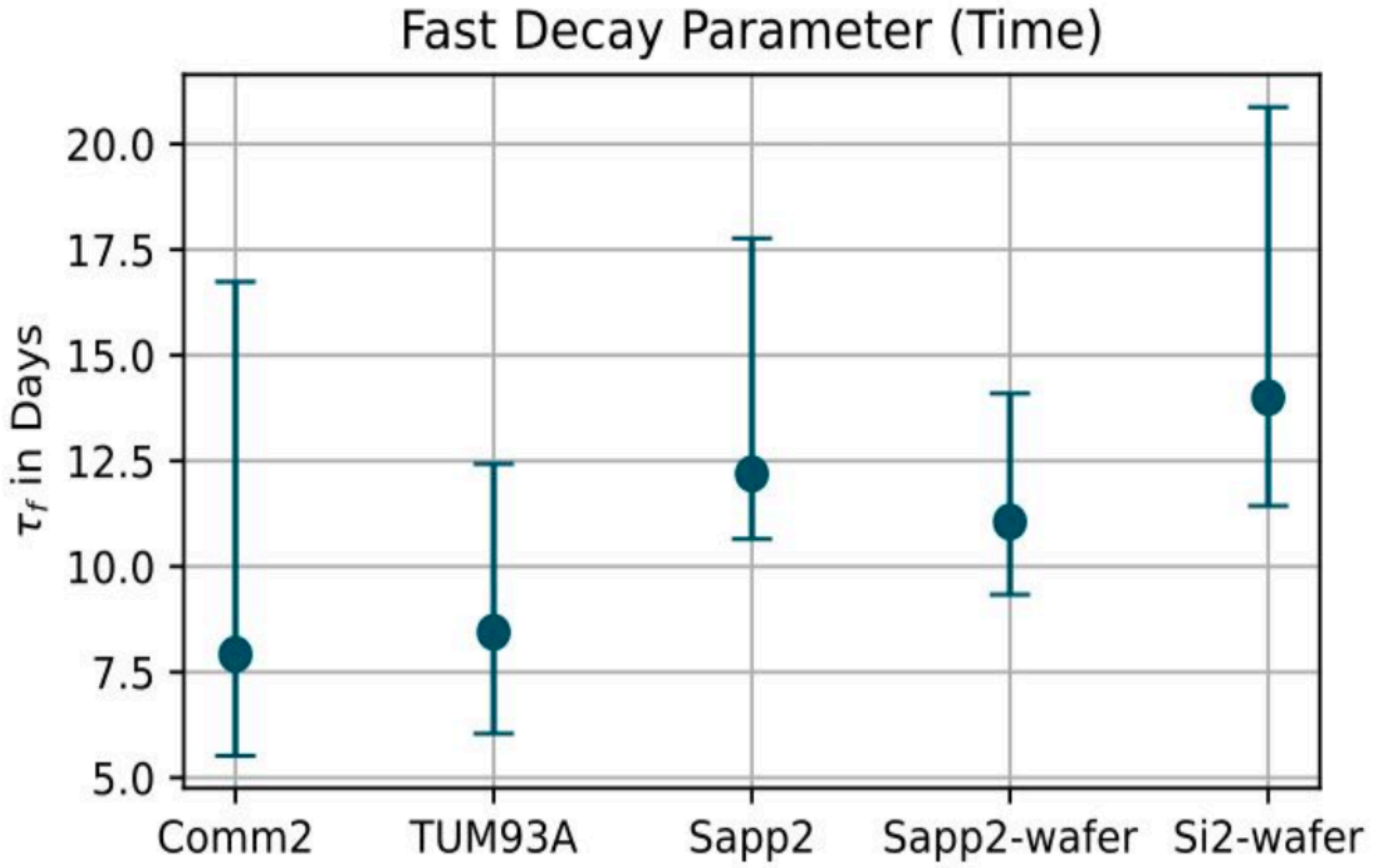


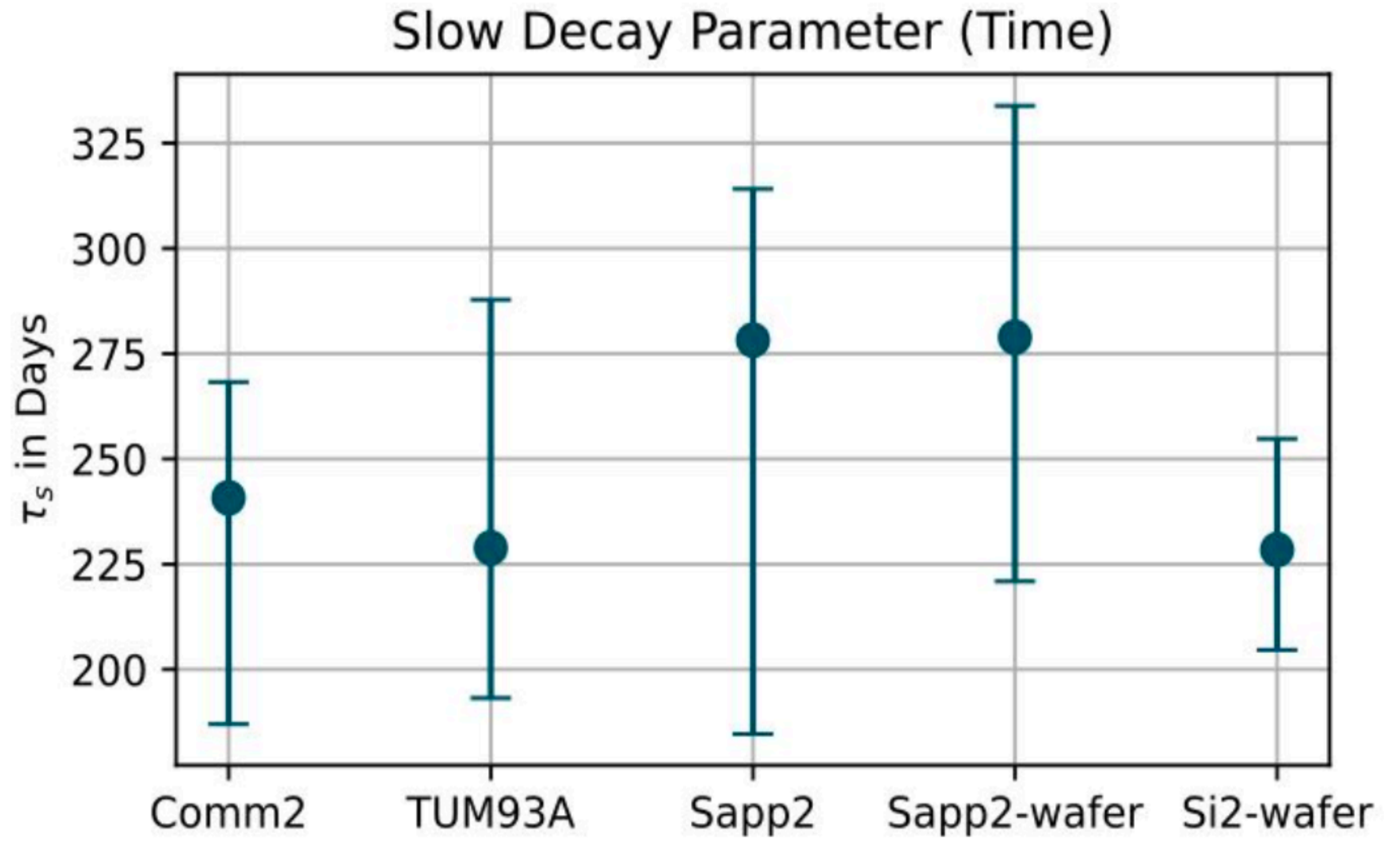
# LEE time variation



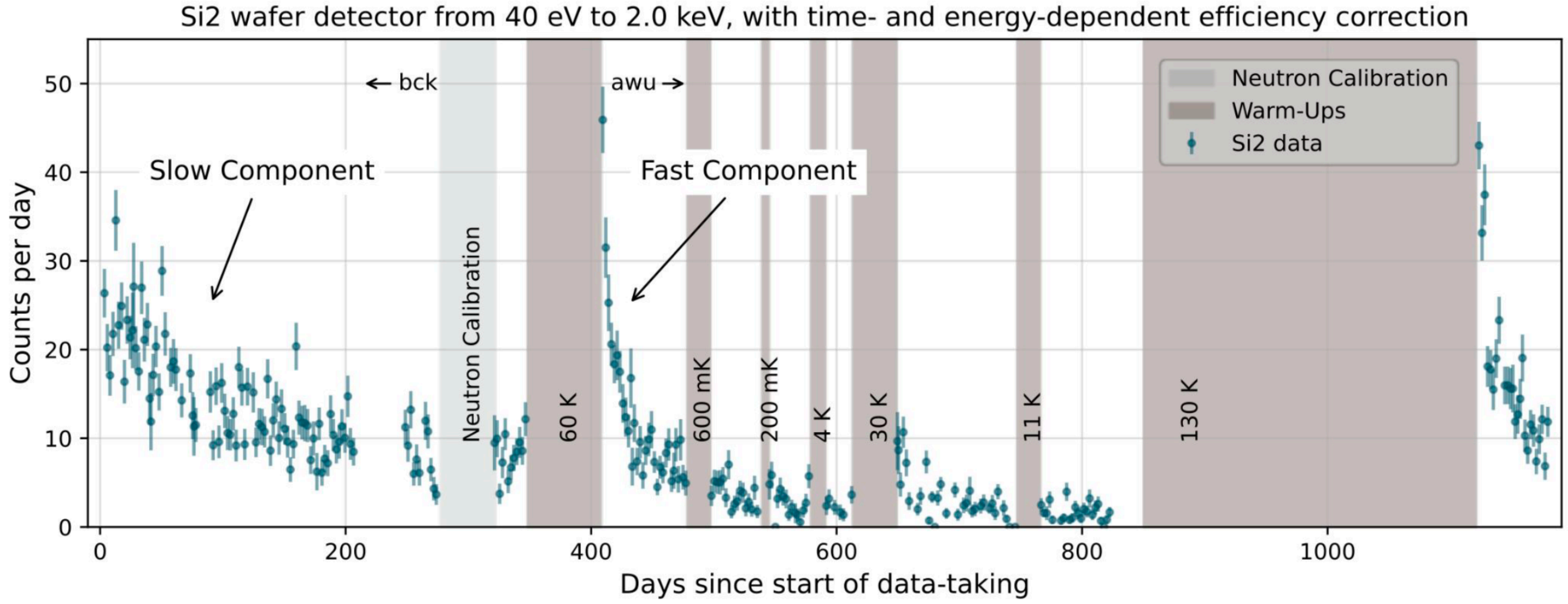

Rate monitoring over time:

- Rate decays exponentially in time
- Reset of the rate after warm-up cycles
- Two decay constants
  - Fast decay ~ 10 days
  - Slow decay ~ 250 days



# LEE time variation




Not caused by radioactivity

Rate monitoring over time:

- Rate decays exponentially in time
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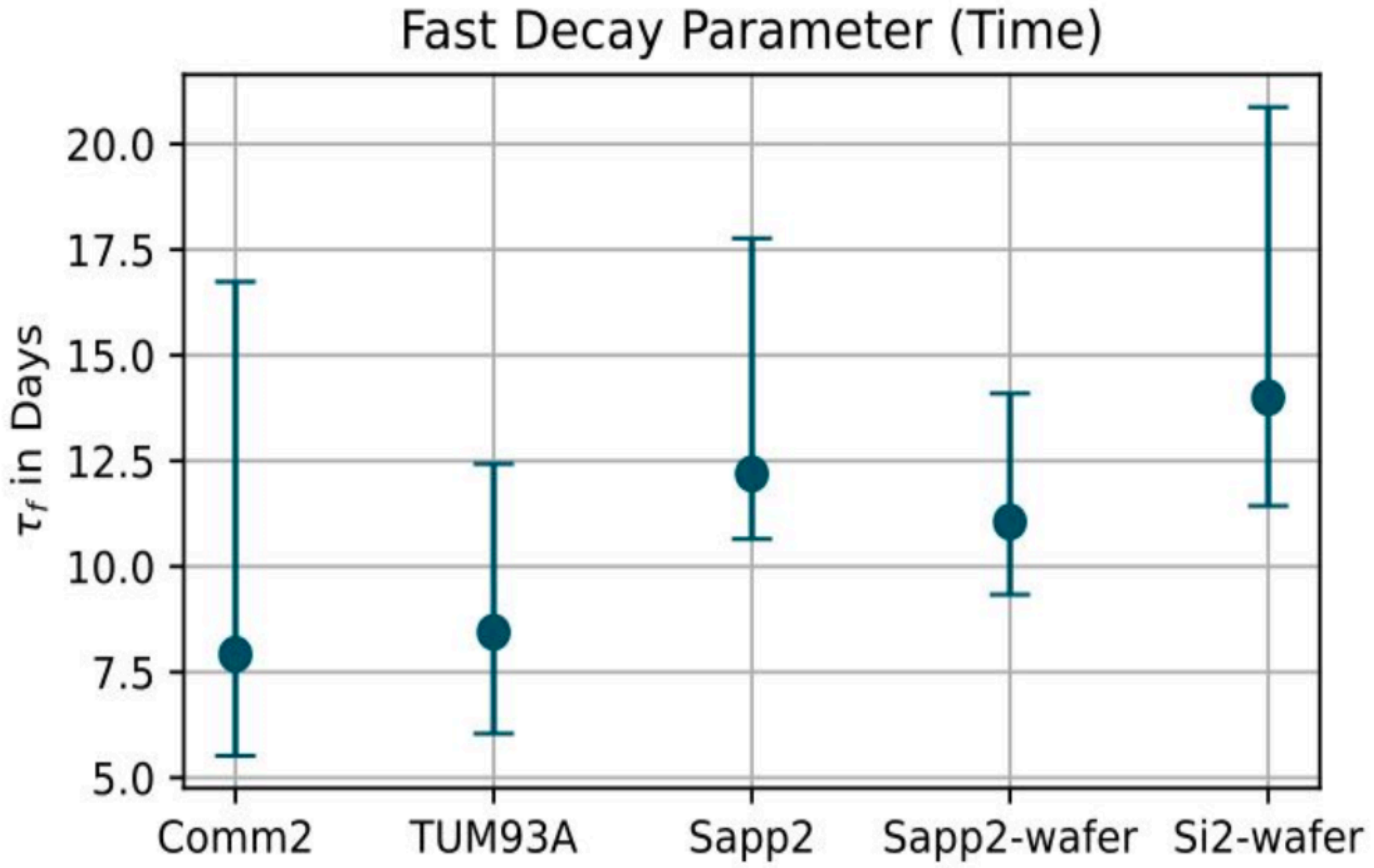
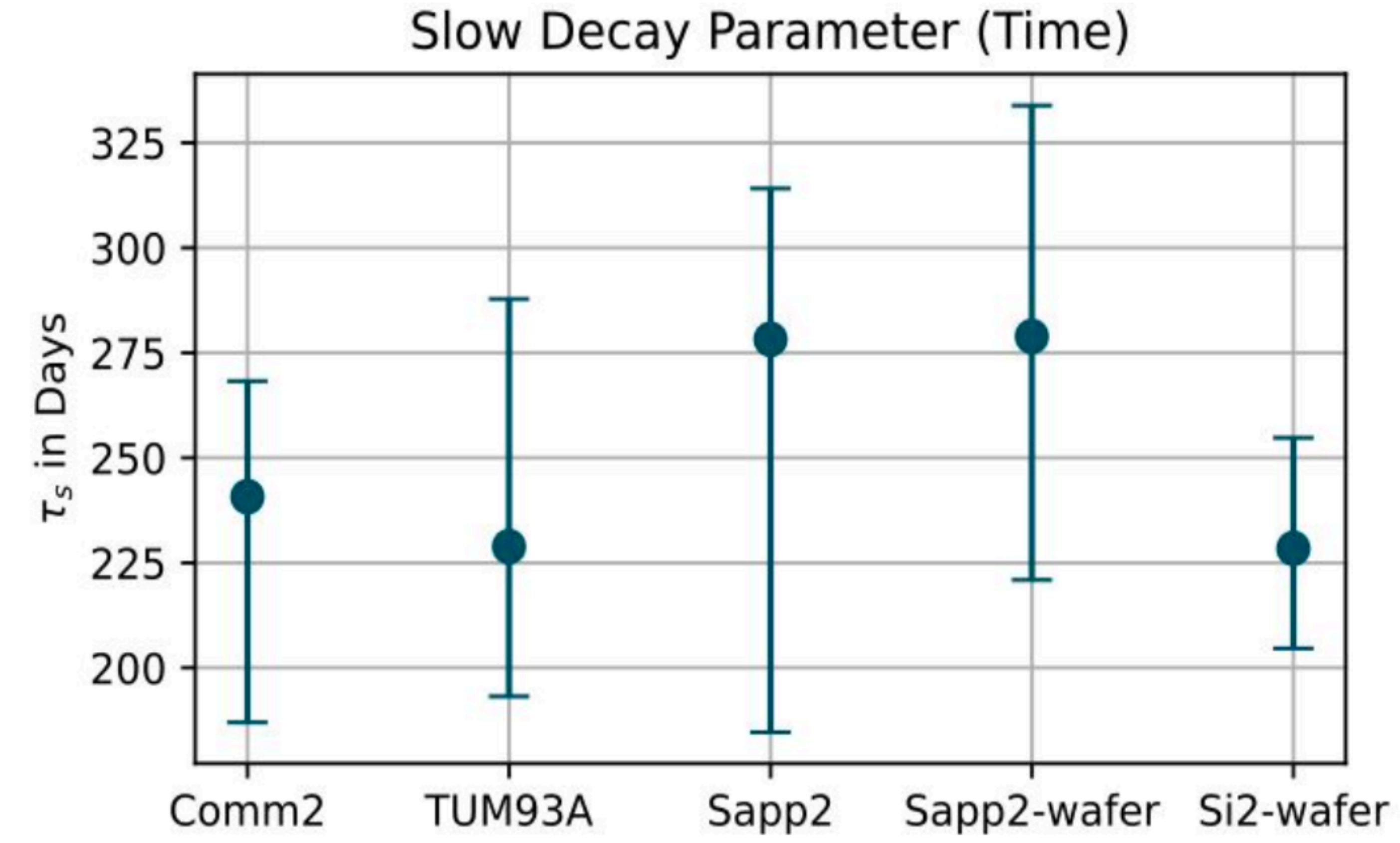


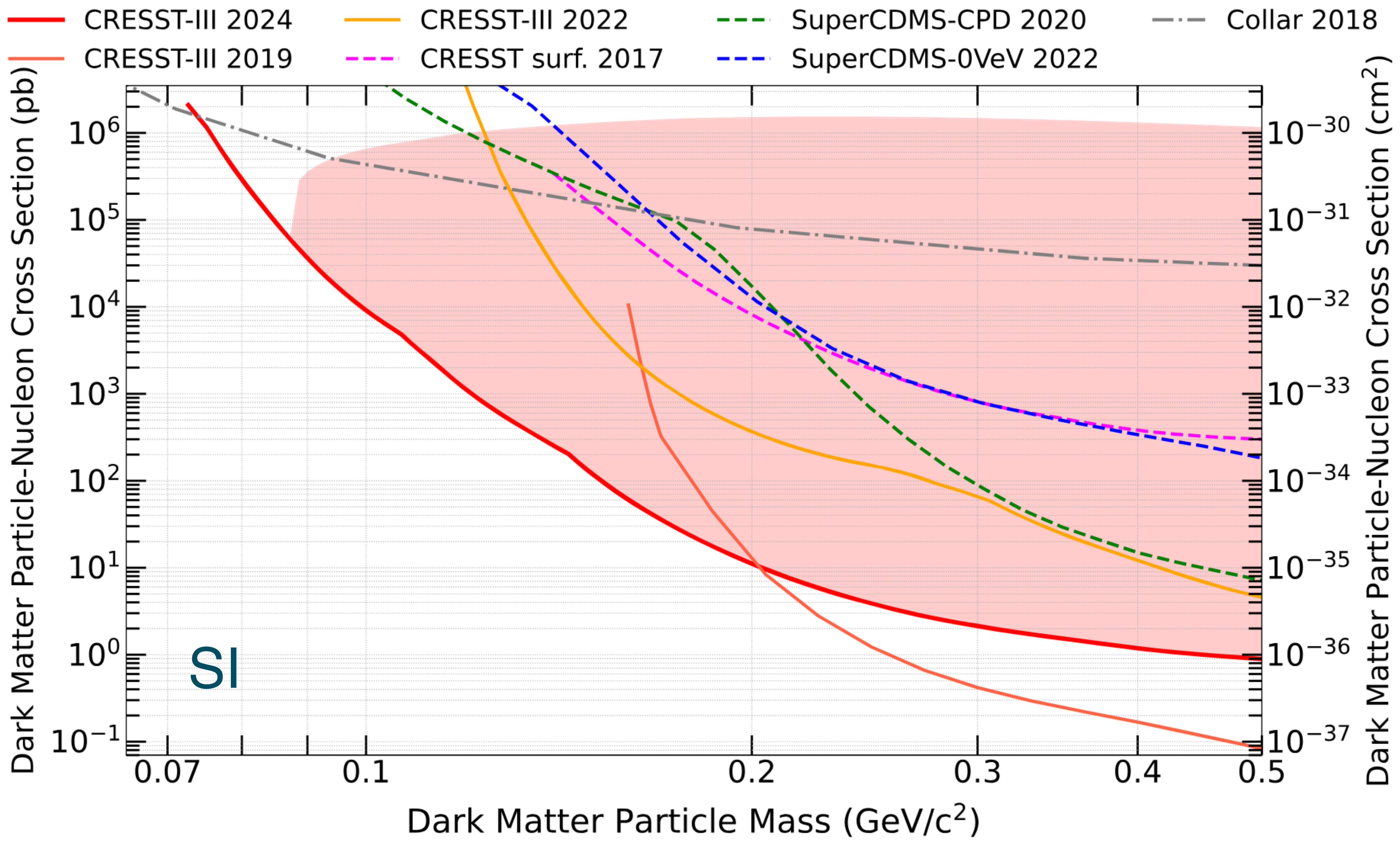



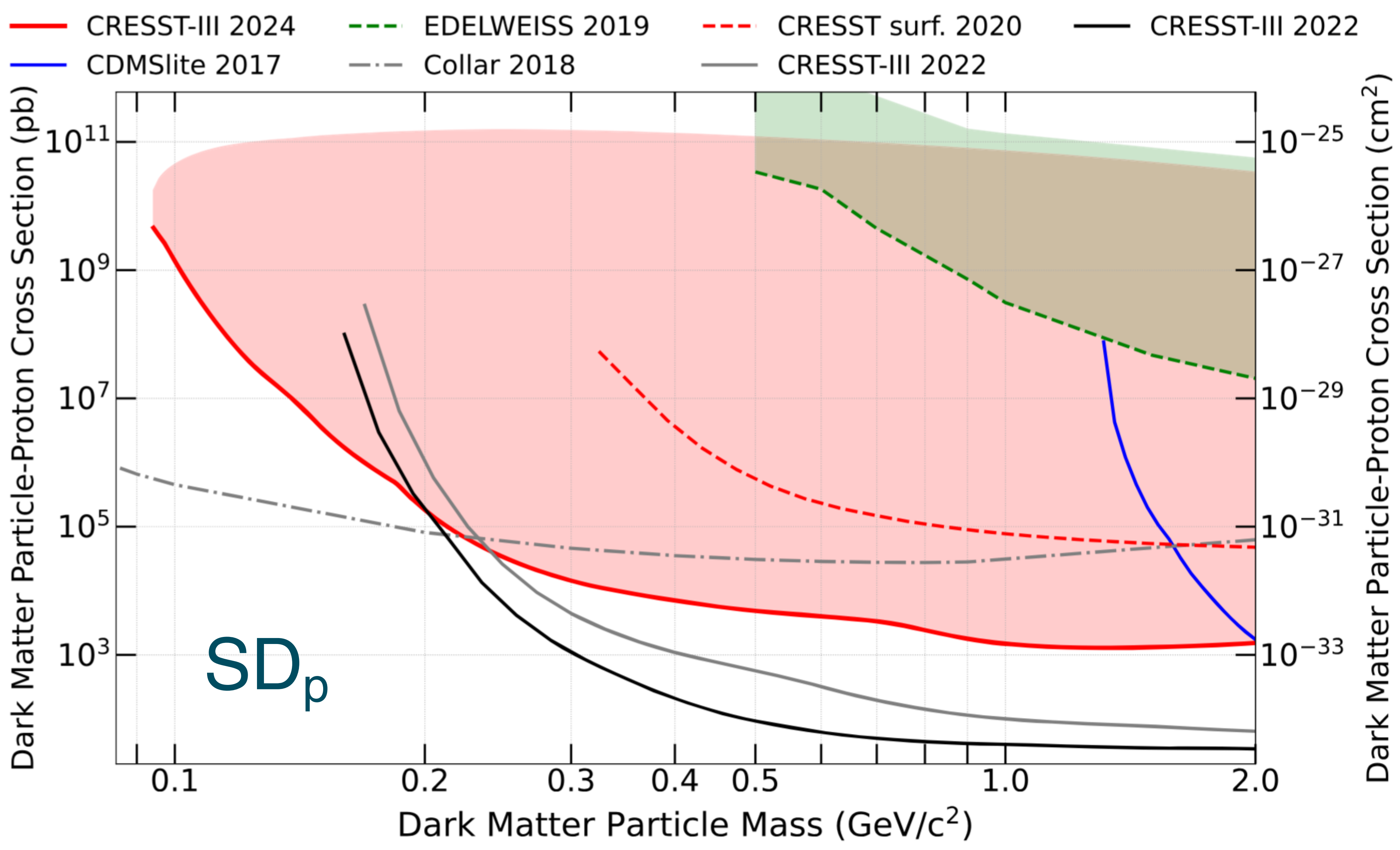
# Low-threshold Dark Matter results

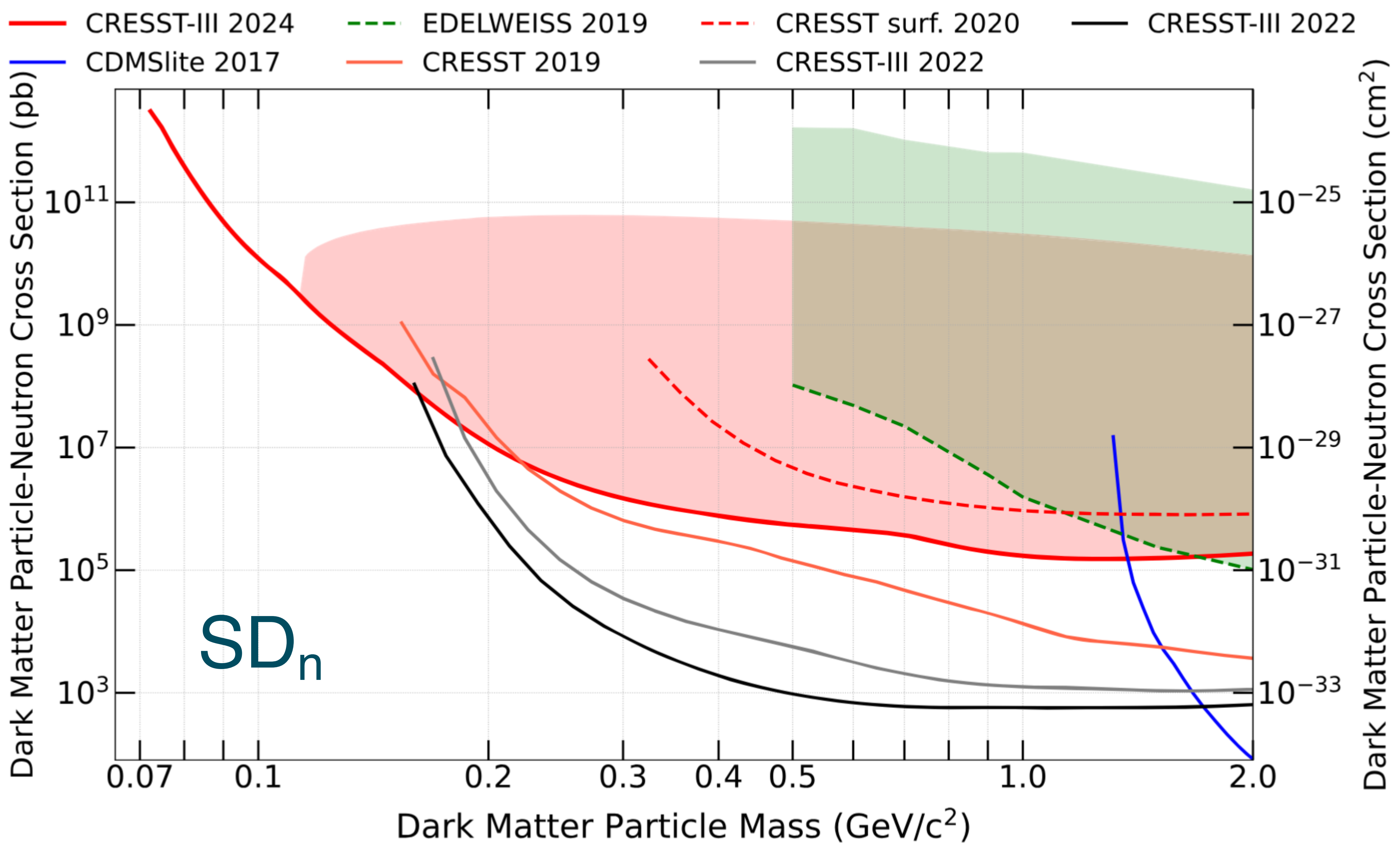
CRESST

## Light detector analyzed for dark matter limit:

**Material**: $Al_2O_3$
**Mass**: 0.6 g
**Exposure**: 138 g · days
**Resolution**: 1 eV
**Threshold**: 6.7 $eV_{nr}$



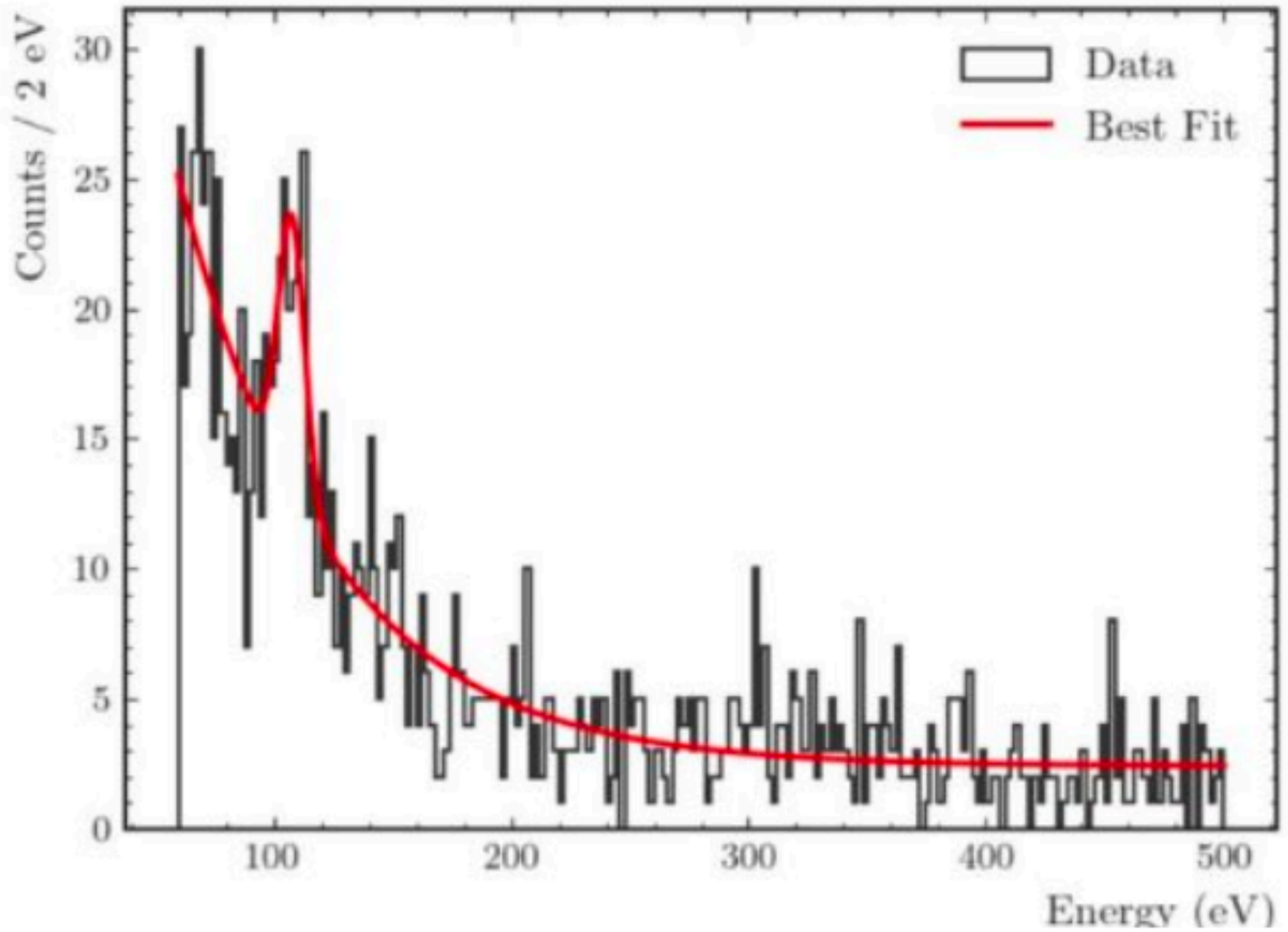




10.1103/PhysRevD.110.083038

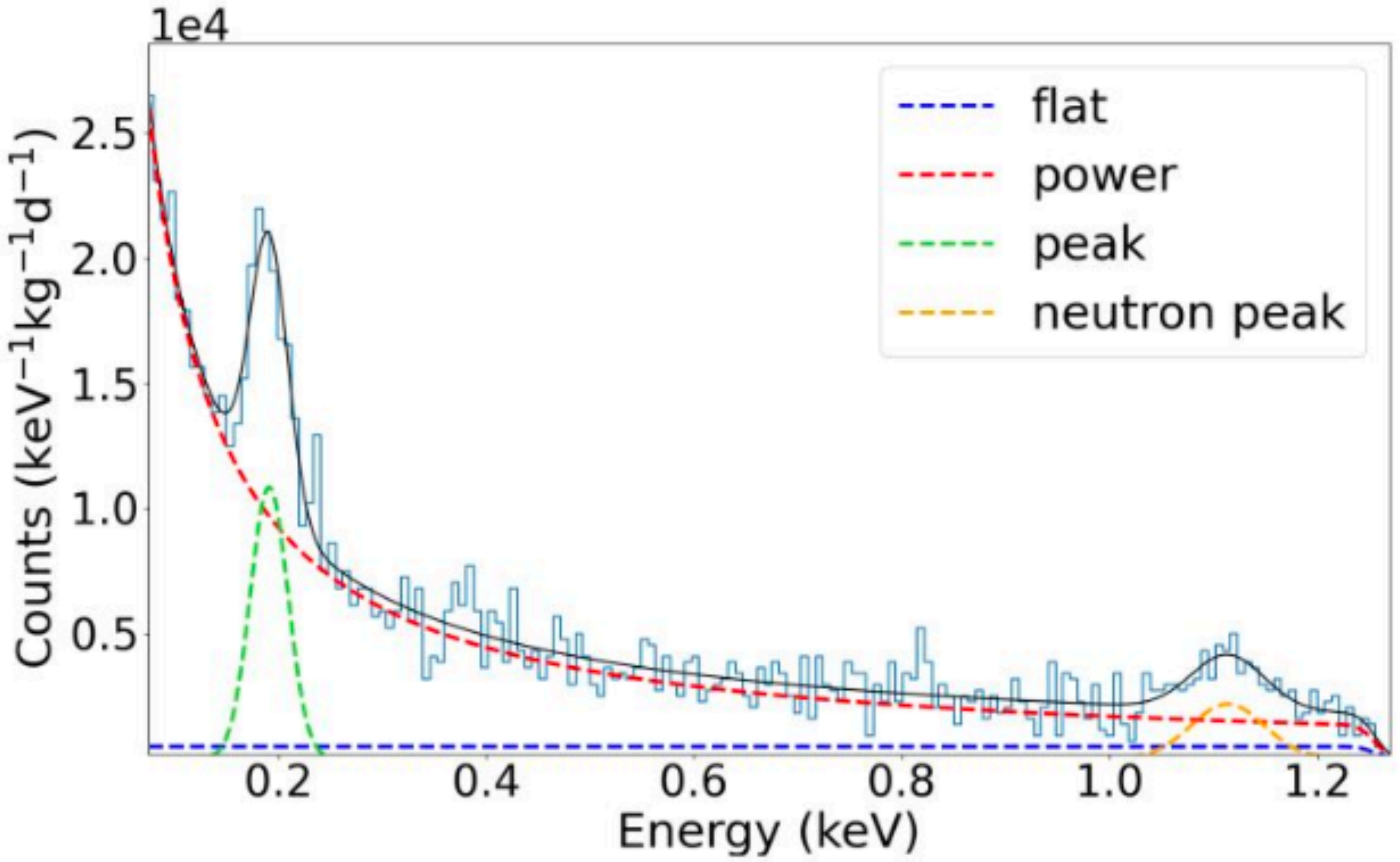
# New method for low energy calibration

CRESST

Phys. Rev. D 108, 022005




arxiv.org:2506.09059




New technique for low nuclear recoil energy calibration for $CaWO_4$ and $Al_2O_3$ crystals through (n,ɣ) reactions

$^{182}$W (n,ɣ) $^{183}$W

De-excitation gamma of 6.1 MeV and W nuclear recoil of 112eV

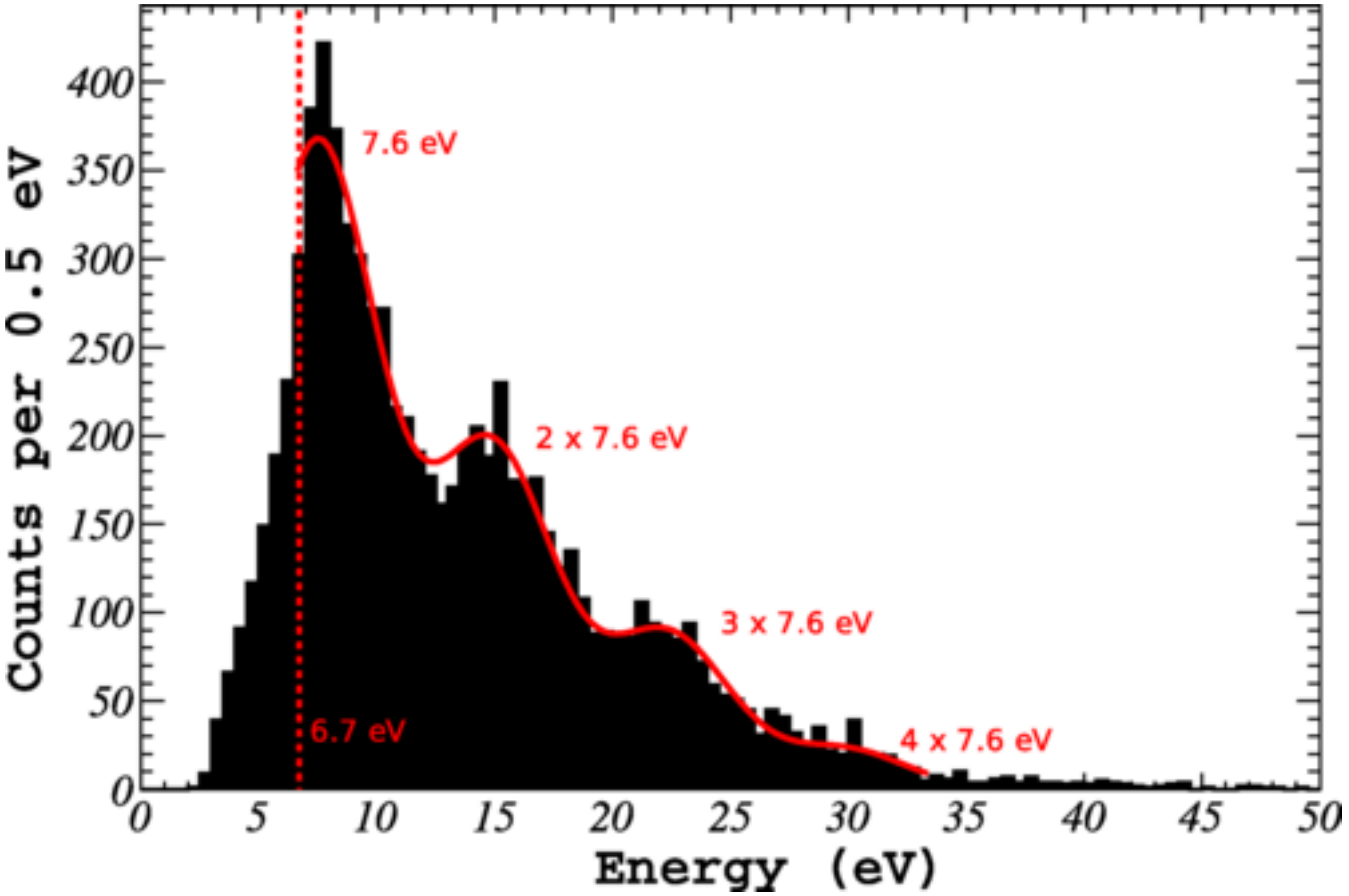
$^{27}$Al (n,ɣ) $^{28}$Al

De-excitation gamma of 7.7 MeV and Al nuclear recoil of 1144eV

# New method for low energy calibration

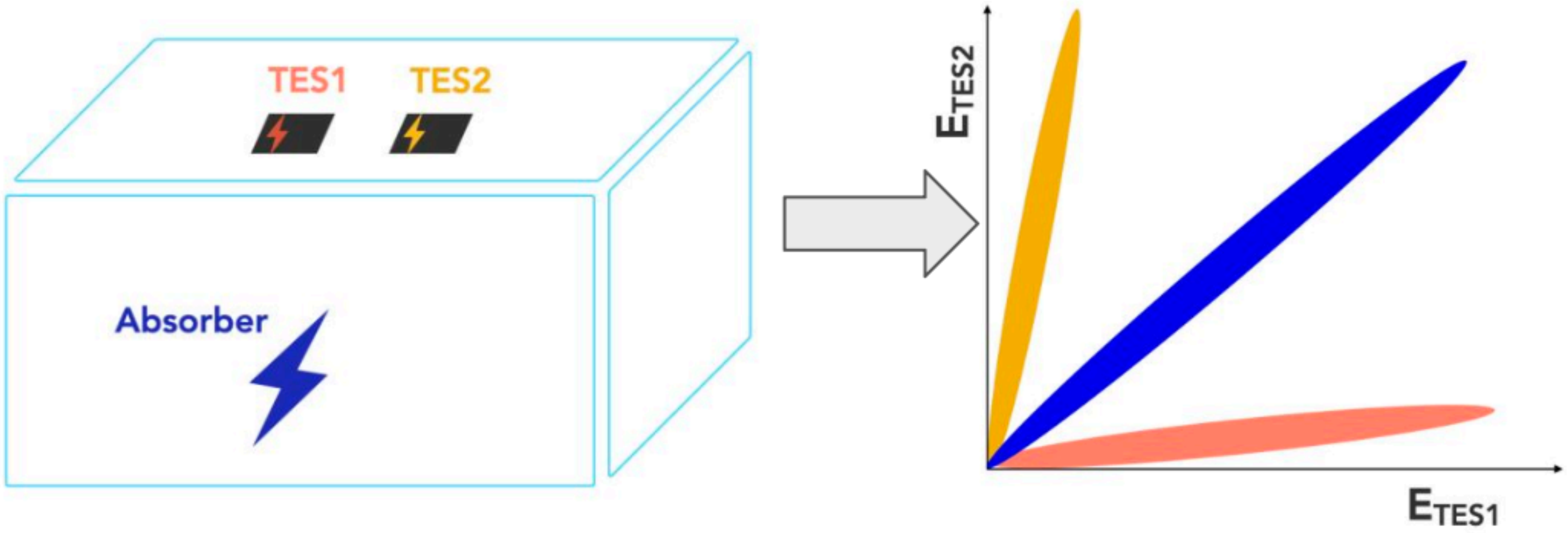
First measurement of single photon in CRESST from sapphire de-excitation

Confirm validity of our calibration method done with $^{55}Fe$ source (5.9 and 6.5 keV) is valid down to threshold



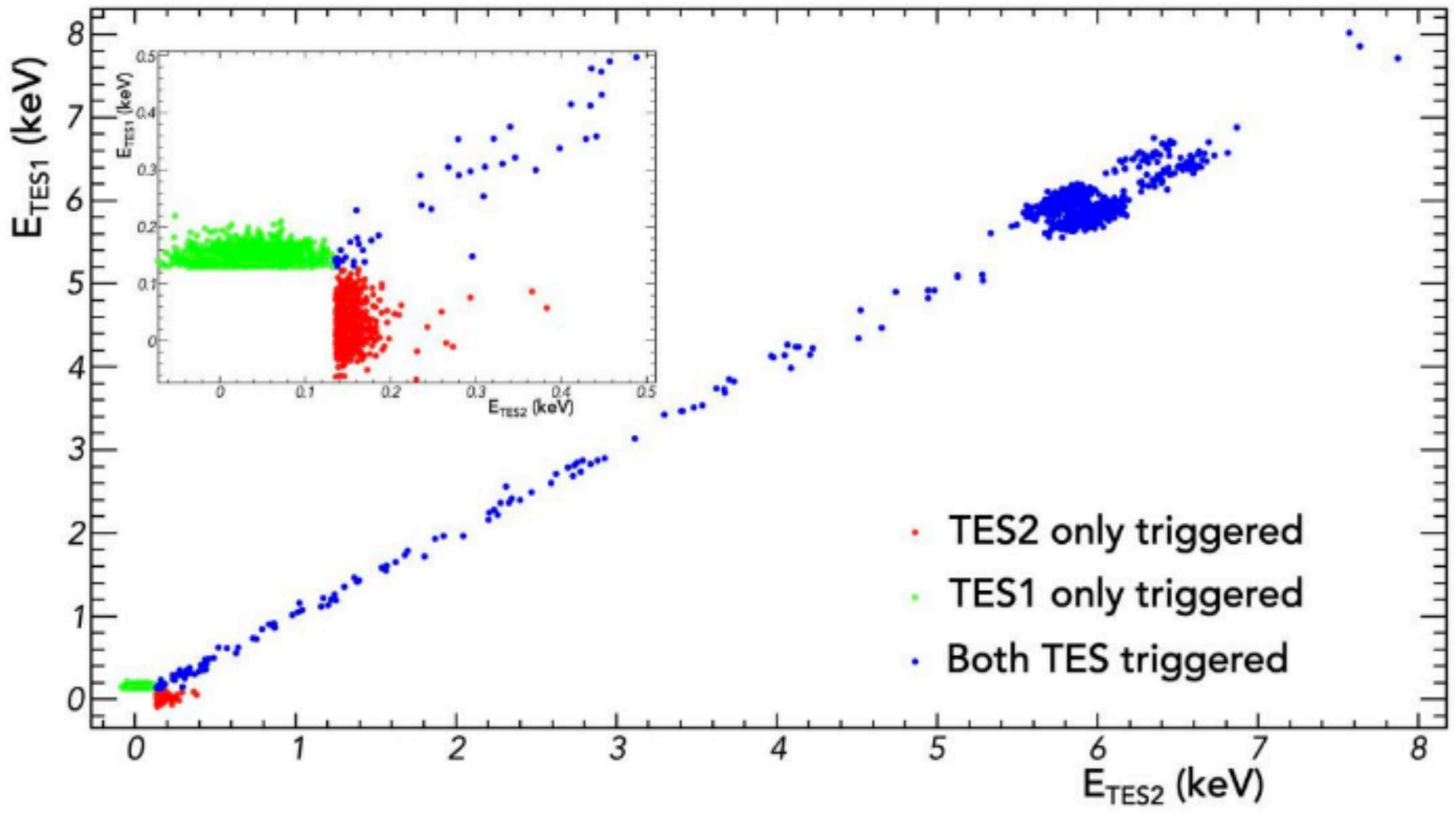

Phys. Rev. D 110, 083038

# Double TES approach




## Probe the LEE origin

from inside TES or from interface between TES and the crystal



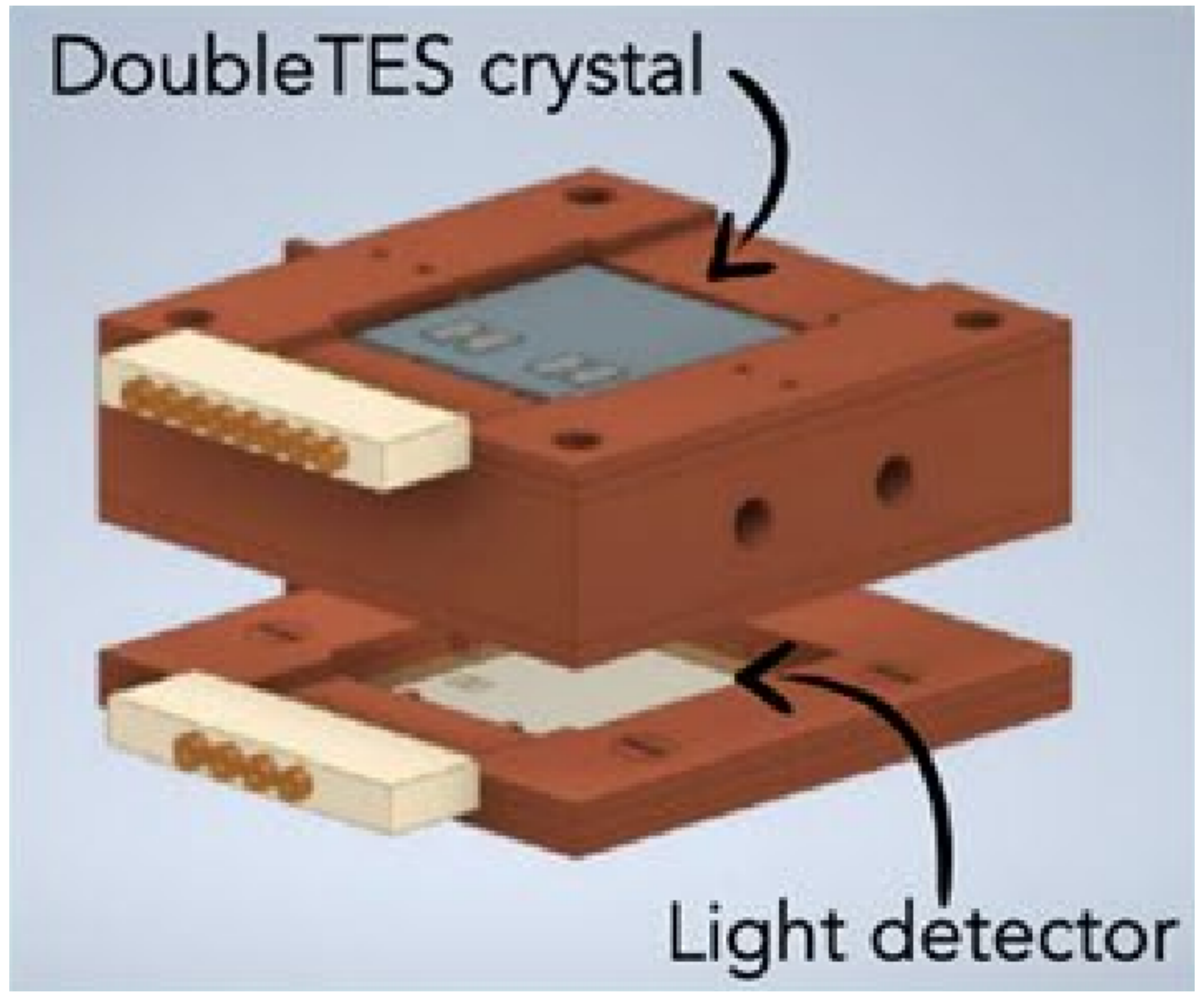

Eur. Phys. J. C 84, 1001

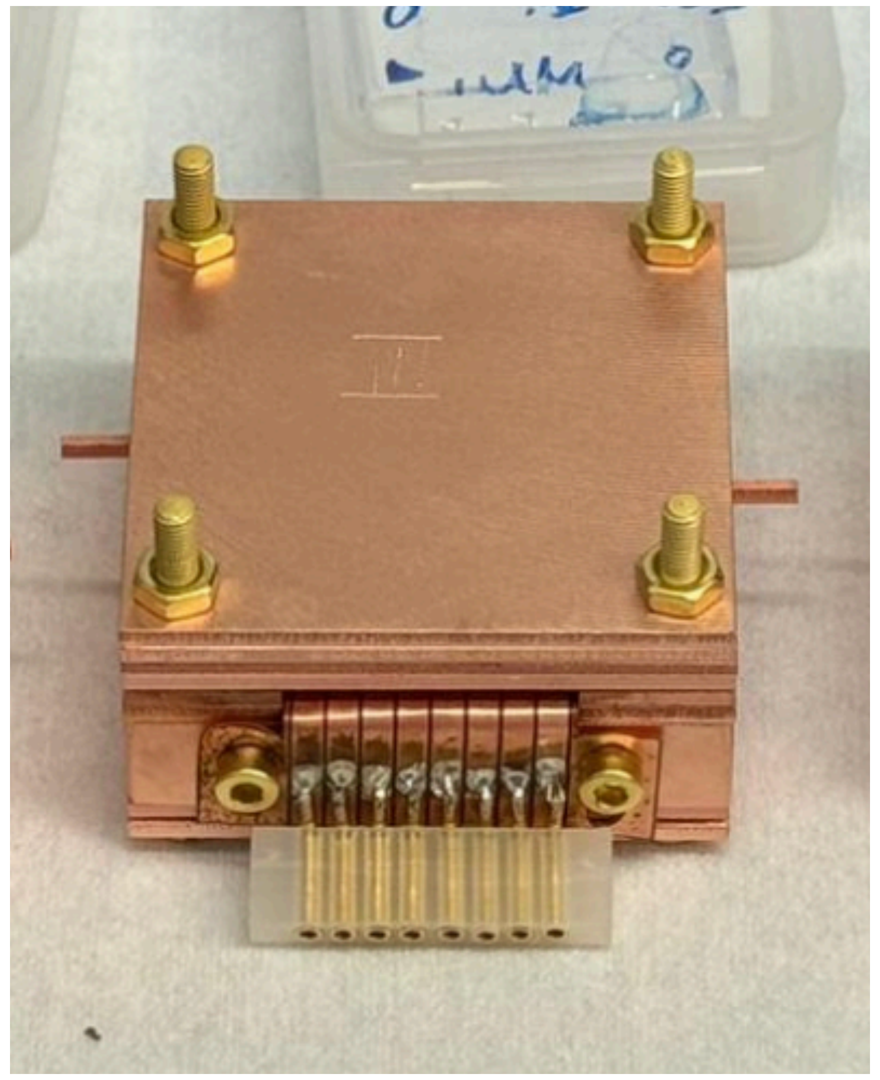
## Idea

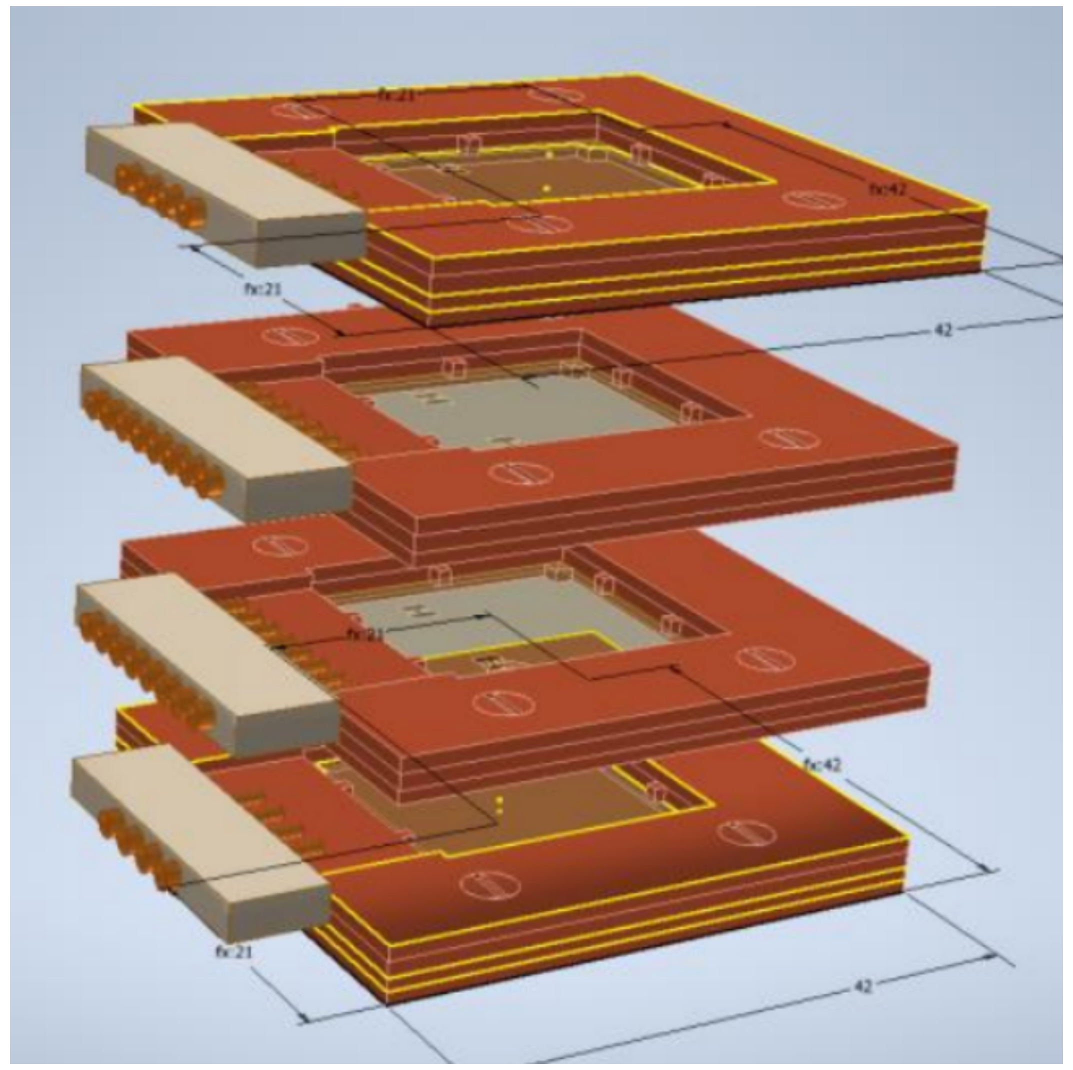
- Events from the absorber are shared between the 2 TES
- Events close to single TES are seen only by one TES

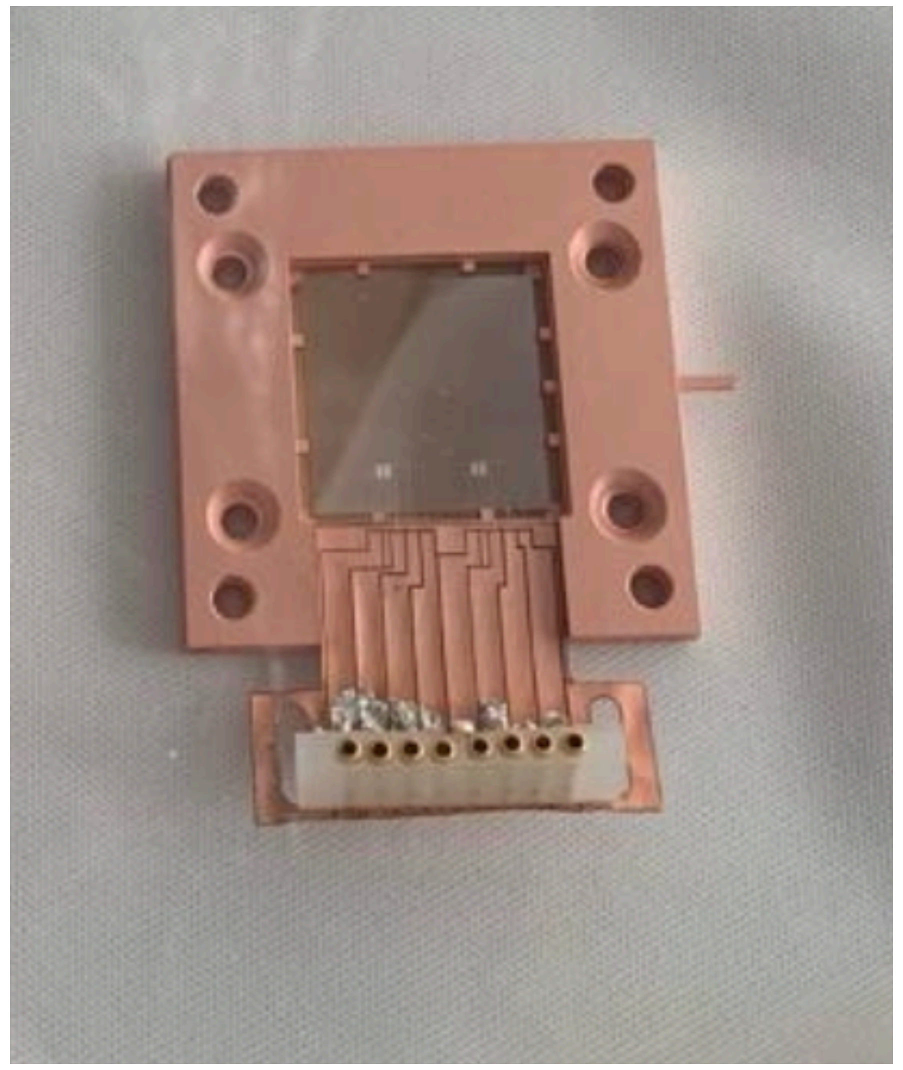
First results from above ground measurement

# New detector design







## 5x Double TES

- $CaWO_4$ crystal 20x20x10 mm$^3$
- Operated with two TESs
- Gravity-assisted holder
- Sapphire light detector

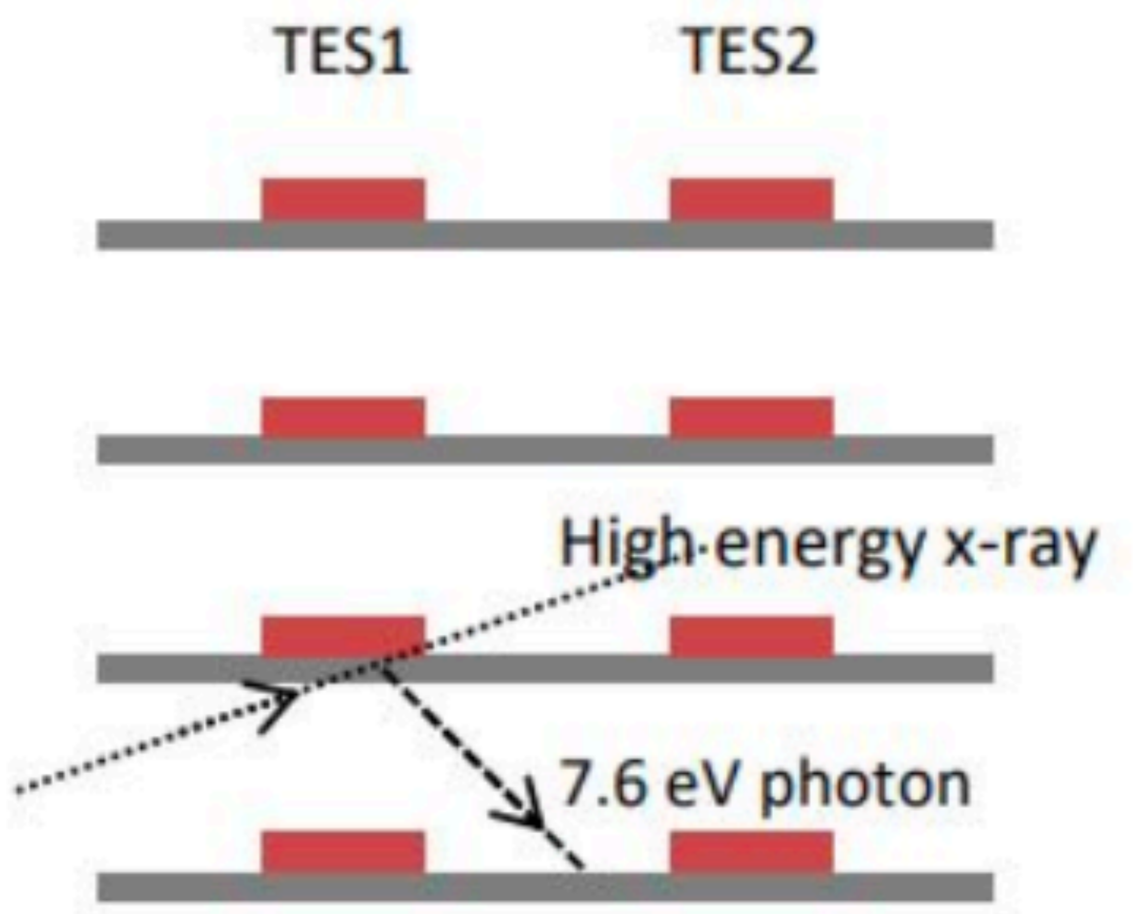
## Stack

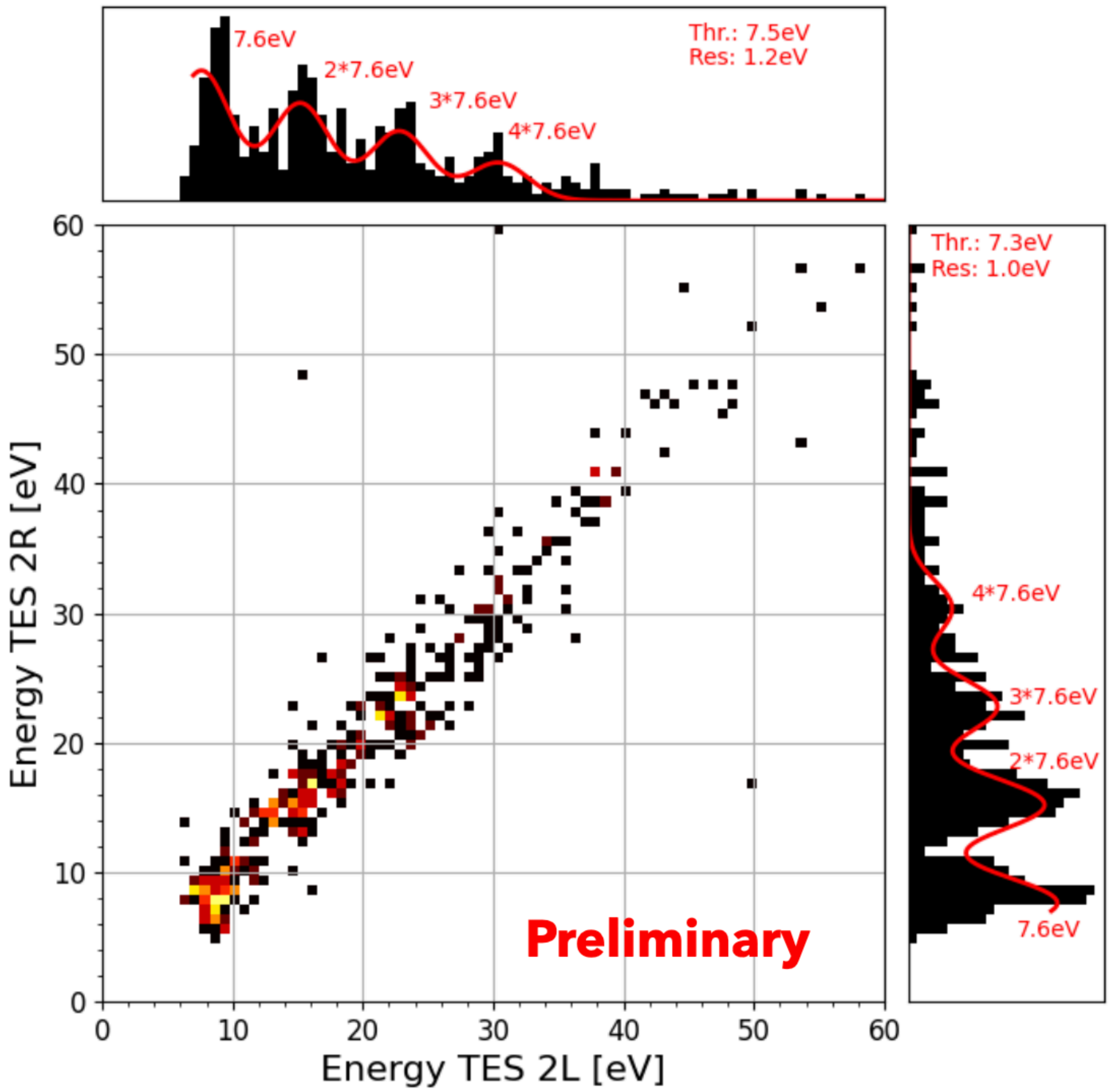
- 4x Silicon-On-Sapphire wafers 20x20x0.4 mm$^3$
- Operated with two TESs
- Gravity-assisted holder

# Stack detector results

- 8 TESs fully working
- Calibrated with an 55Fe source
- Low-energy thresholds optimized to light dark matter
- Baseline resolution: ~1 eV
- Analysis threshold: ~7.5 eV
- Single photon detection

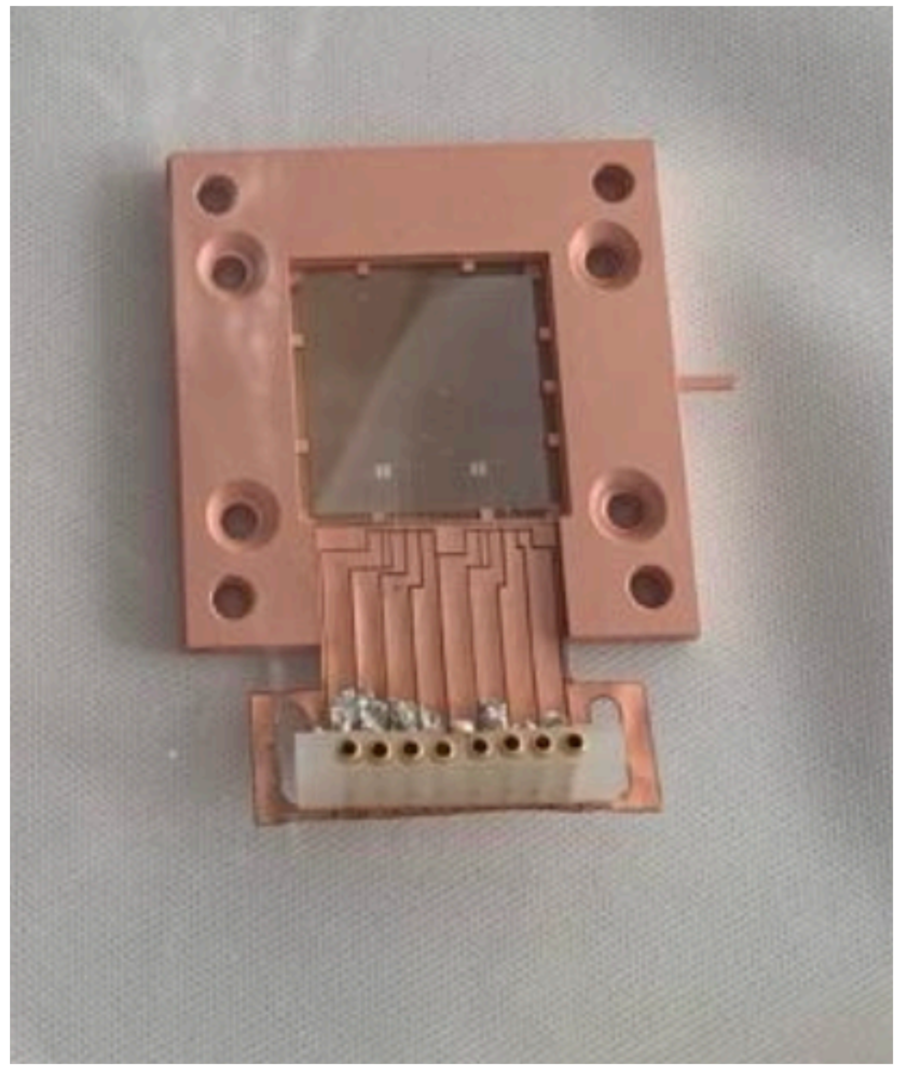
| # | Baseline resolution TES1 | Baseline resolution TES2 |
|---|---|---|
| 1 | 1.4 eV | 1.1 eV |
| 2 | 1.2 eV | 1.0 eV |
| 3 | 1.7 eV | 1.5 eV |
| 4 | 1.4 eV | 3.9 eV |

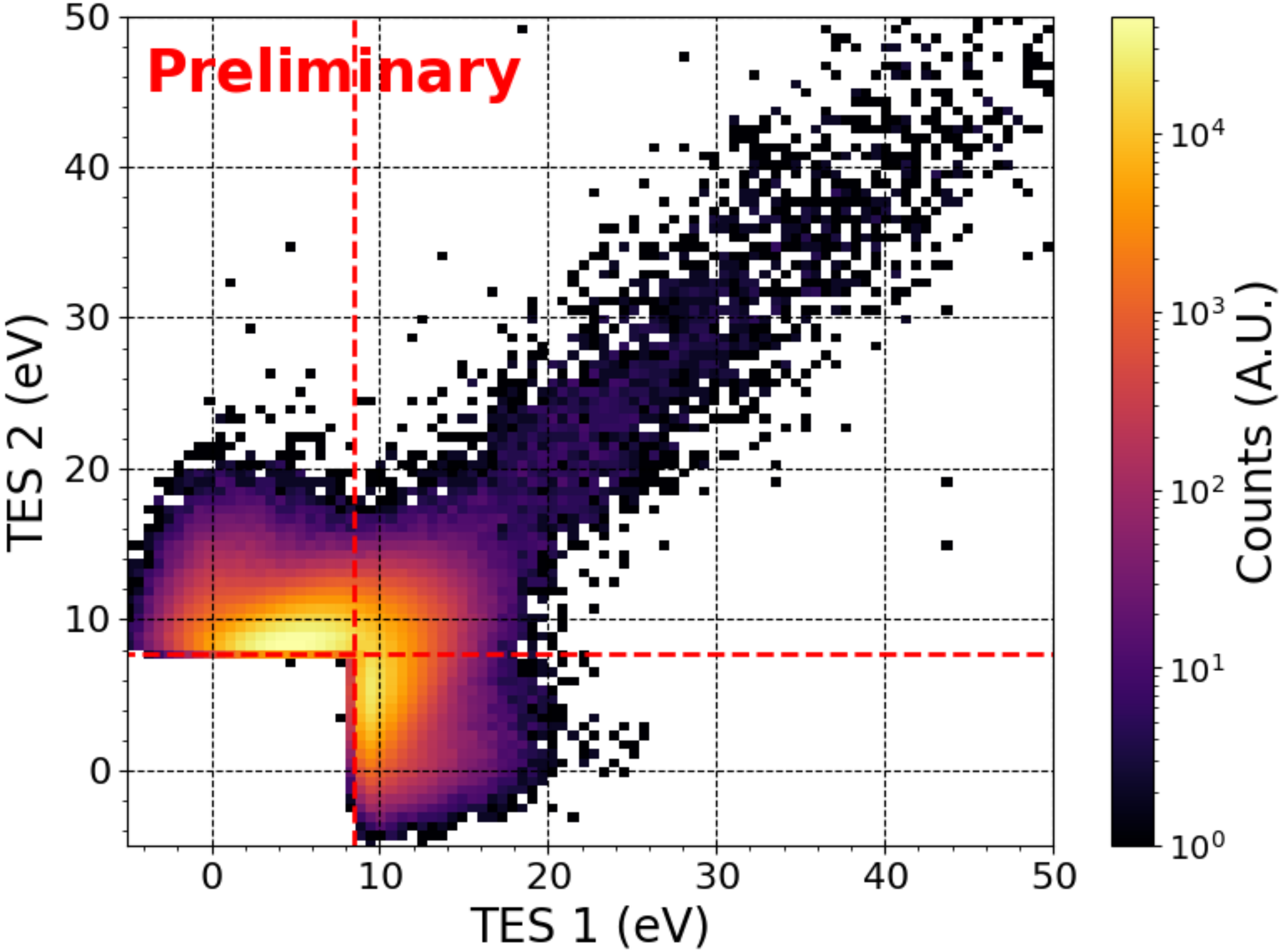


# Stack detector result

Stack 3
Analysis thresholds: 7.7 eV and 8.7 eV





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Stack 3
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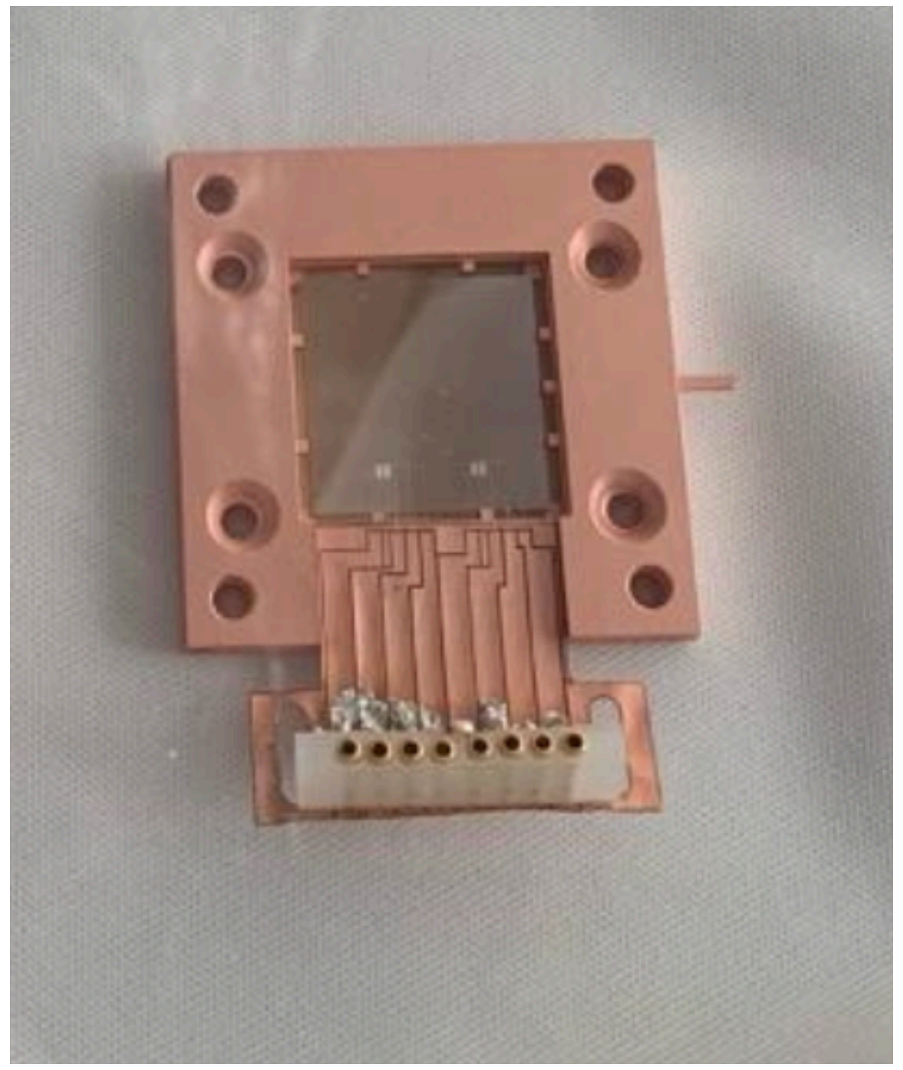
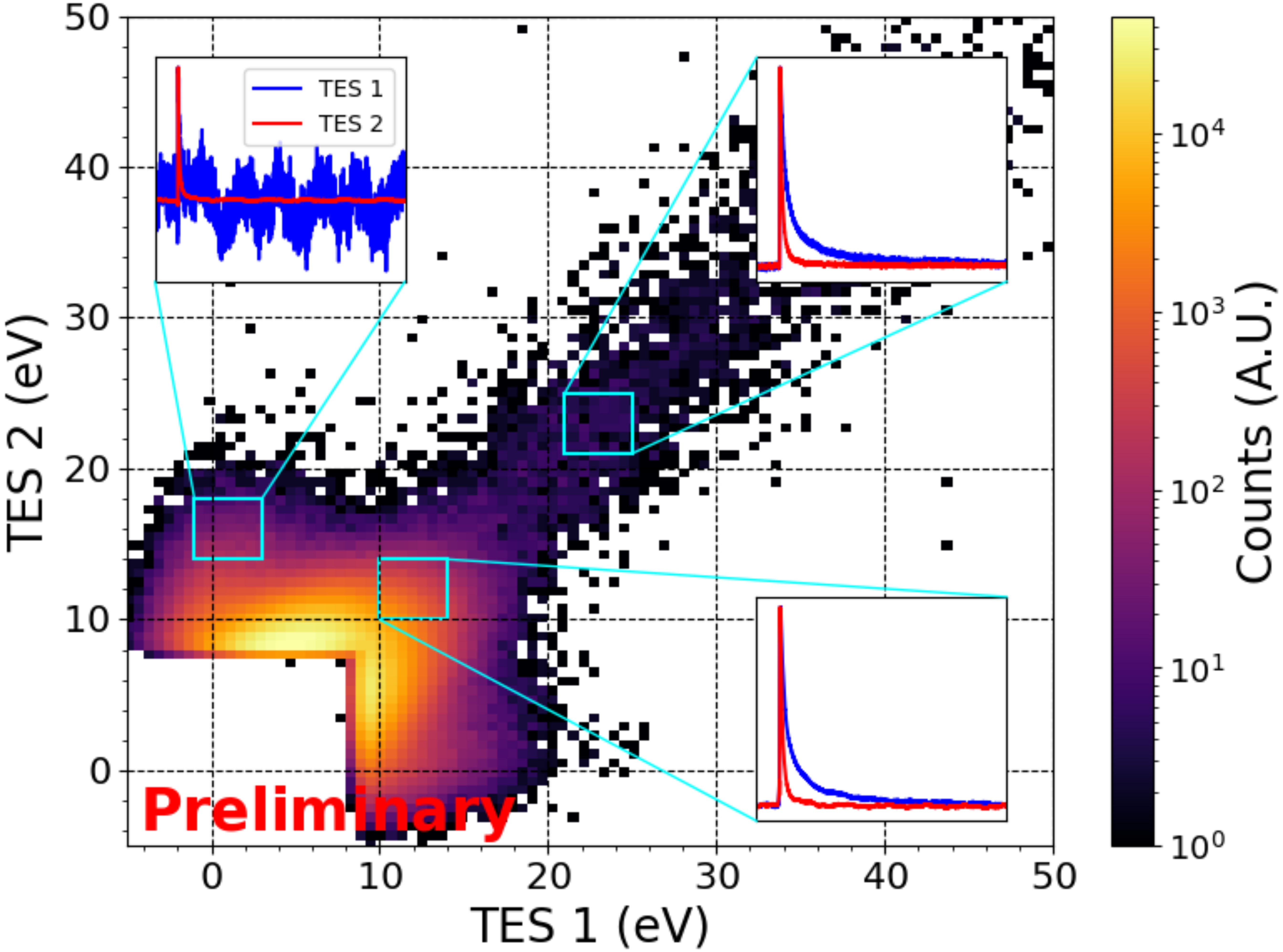
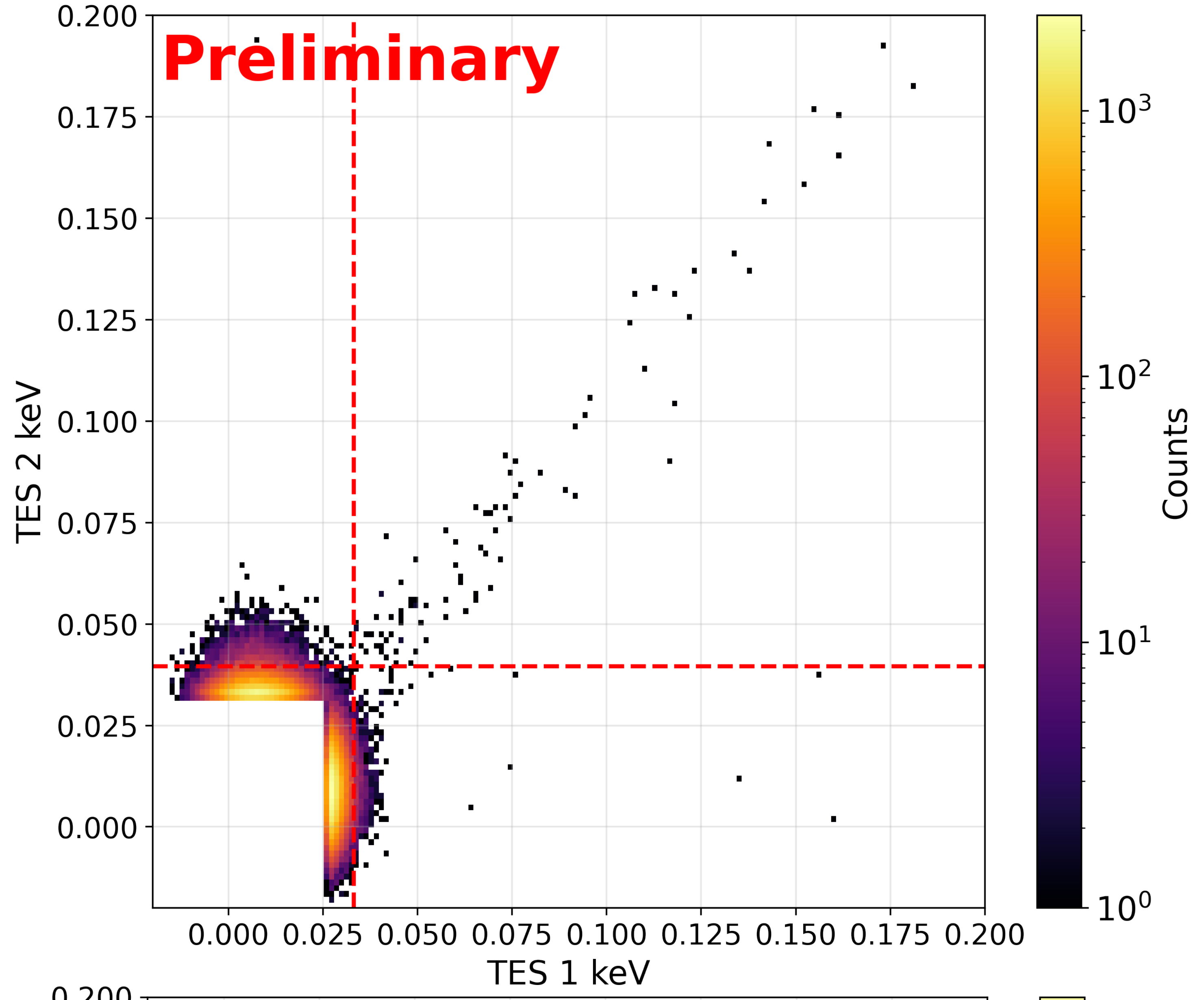


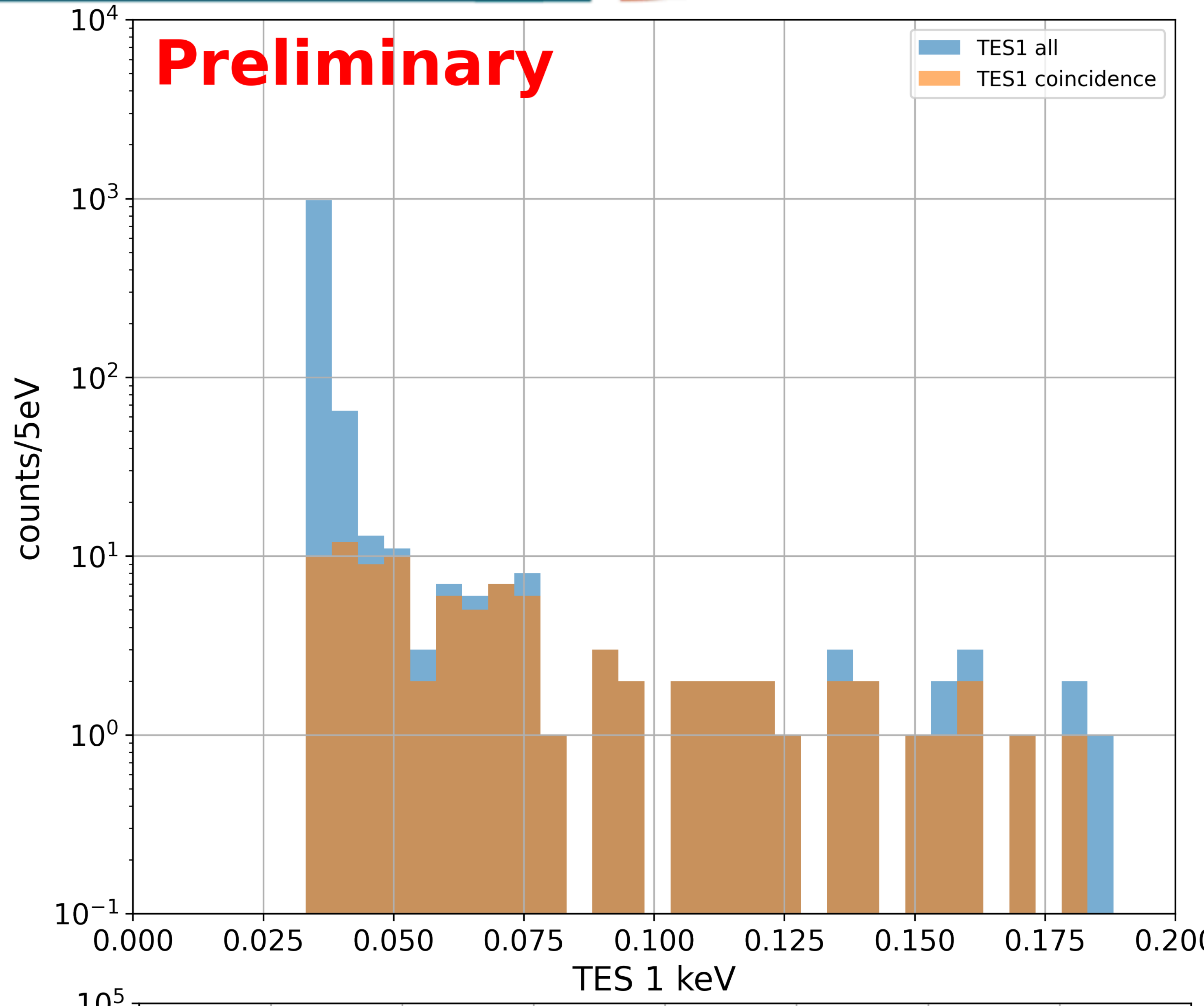


# Double TES results

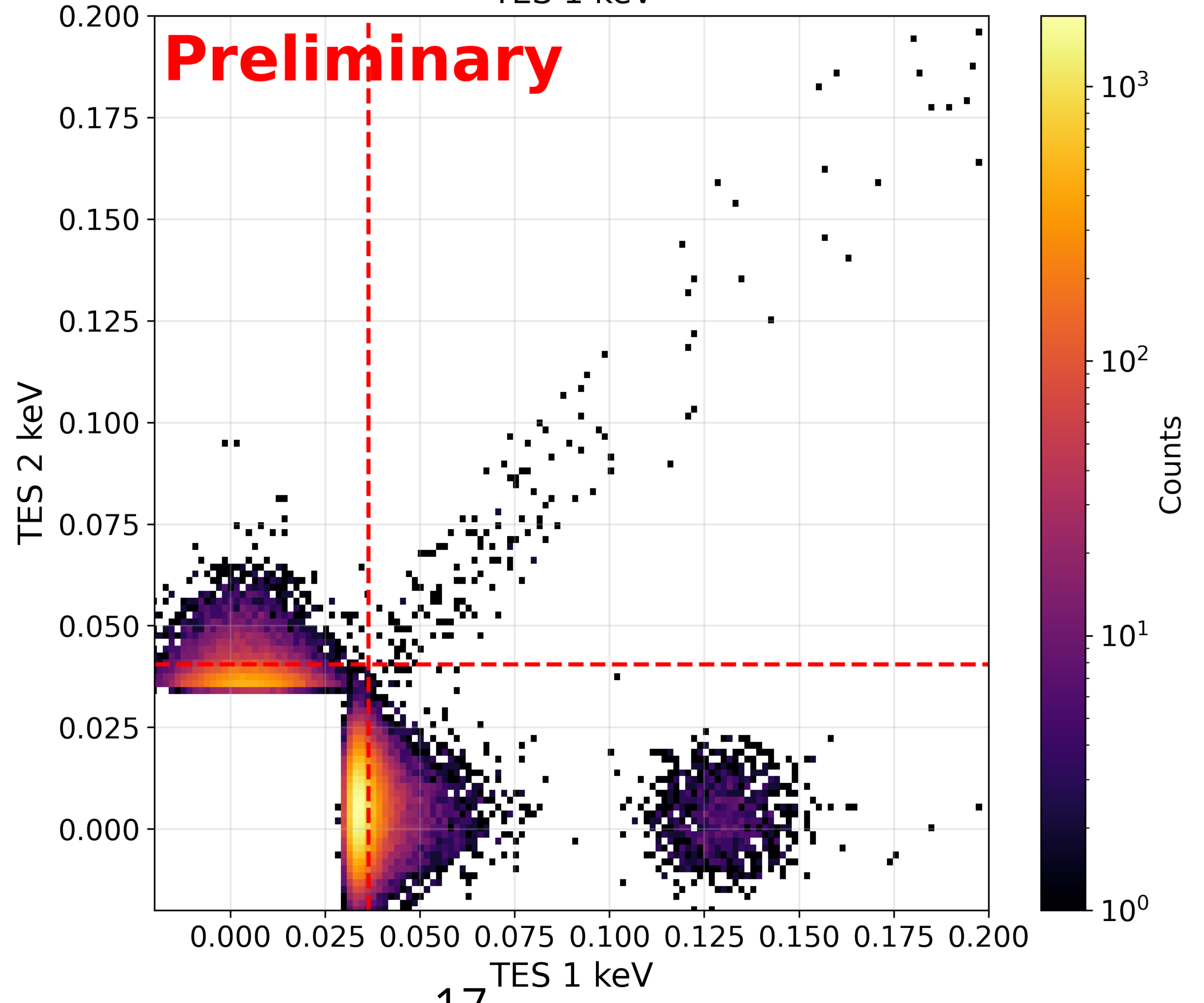
| # | Baseline resolution TES1 | Baseline resolution TES2 | LD |
|---|---|---|---|
| 2 | 6.6 eV | 7.9 eV | ✓ |
| 5 | 8.1 eV | 7.3 eV | ✓ |

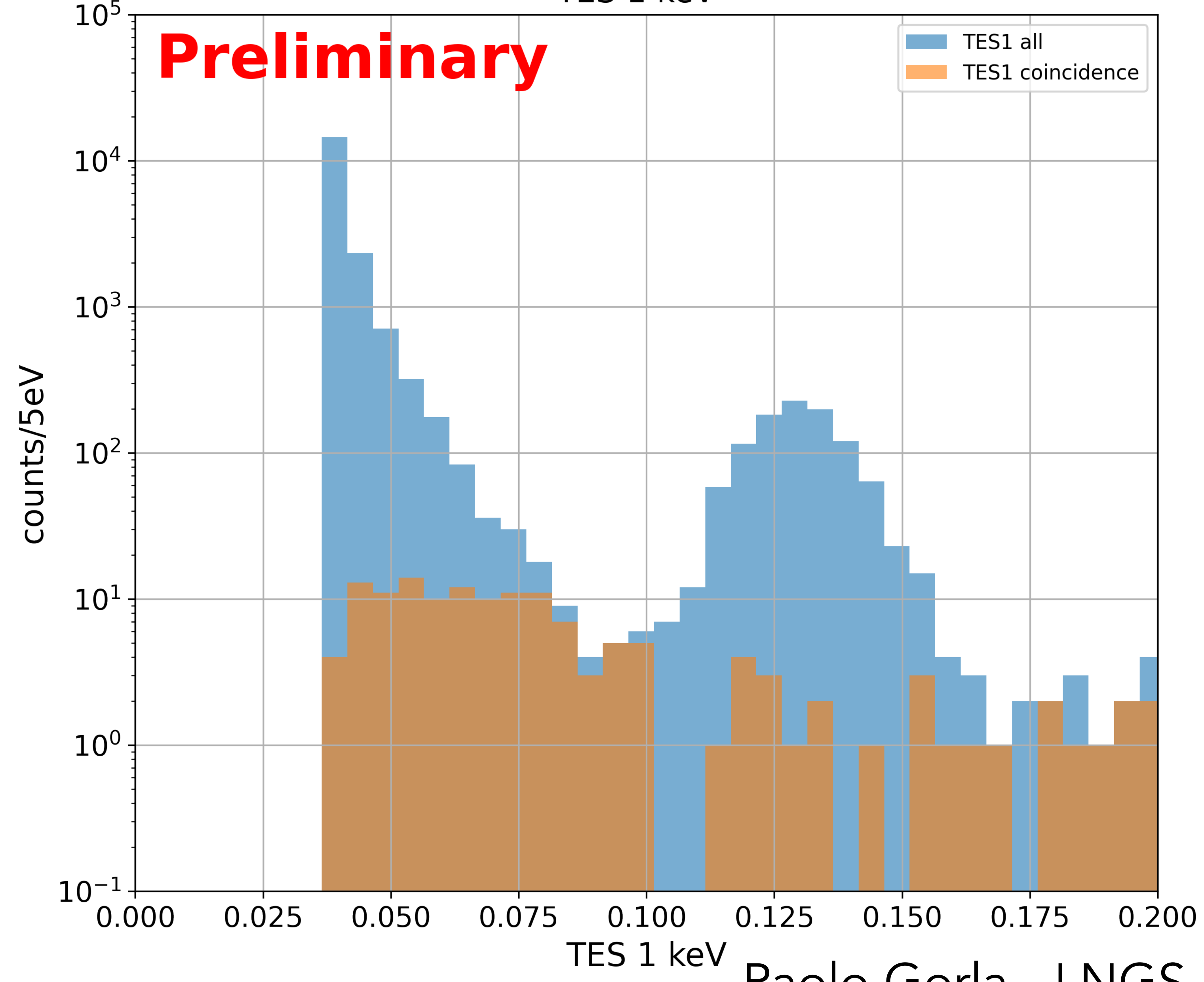
DoubleTES2



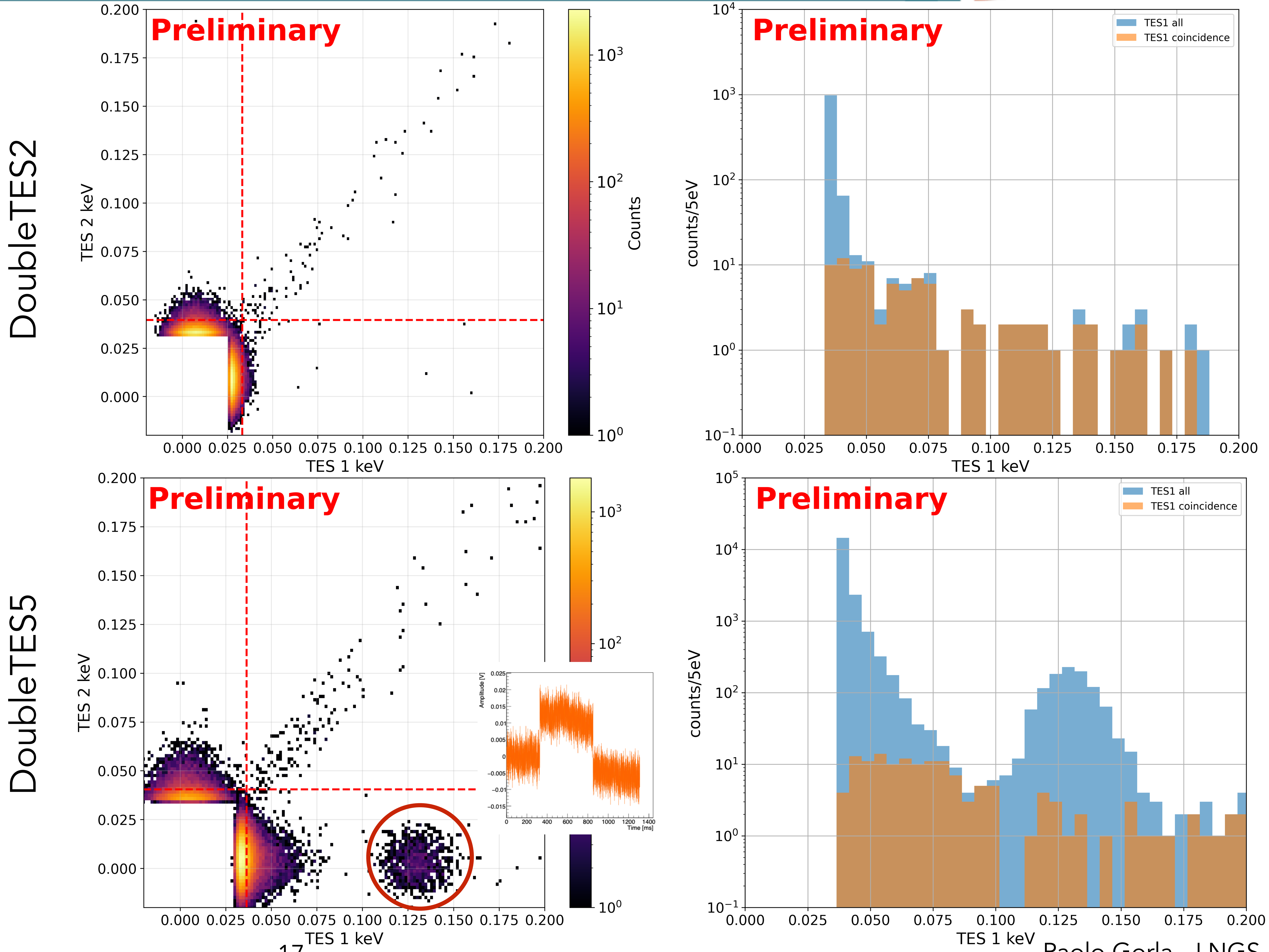

DoubleTES5



# Double TES results

| # | Baseline resolution TES1 | Baseline resolution TES2 | LD |
|---|---|---|---|
| 2 | 6.6 eV | 7.9 eV | ✓ |
| 5 | 8.1 eV | 7.3 eV | ✓ |

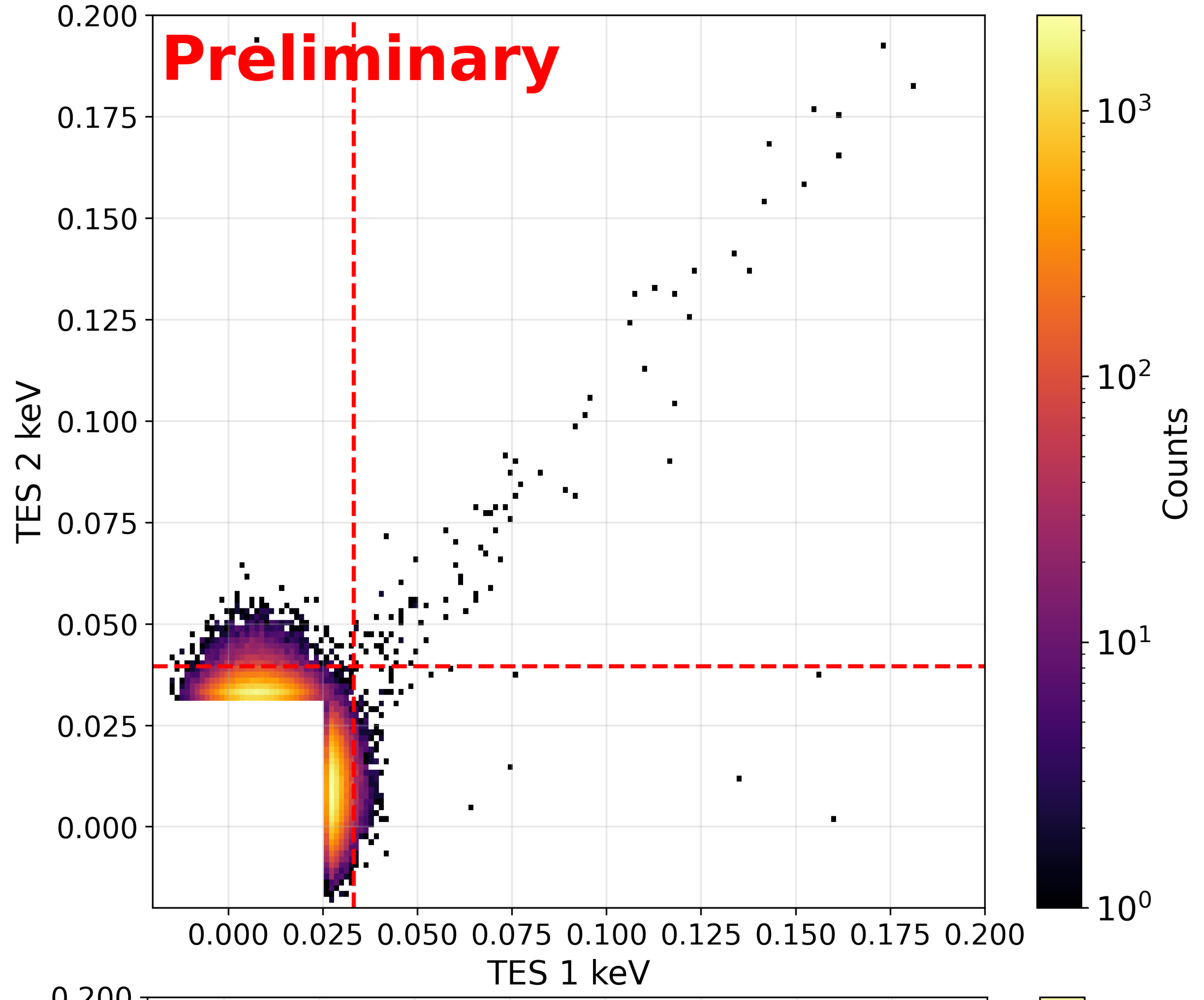


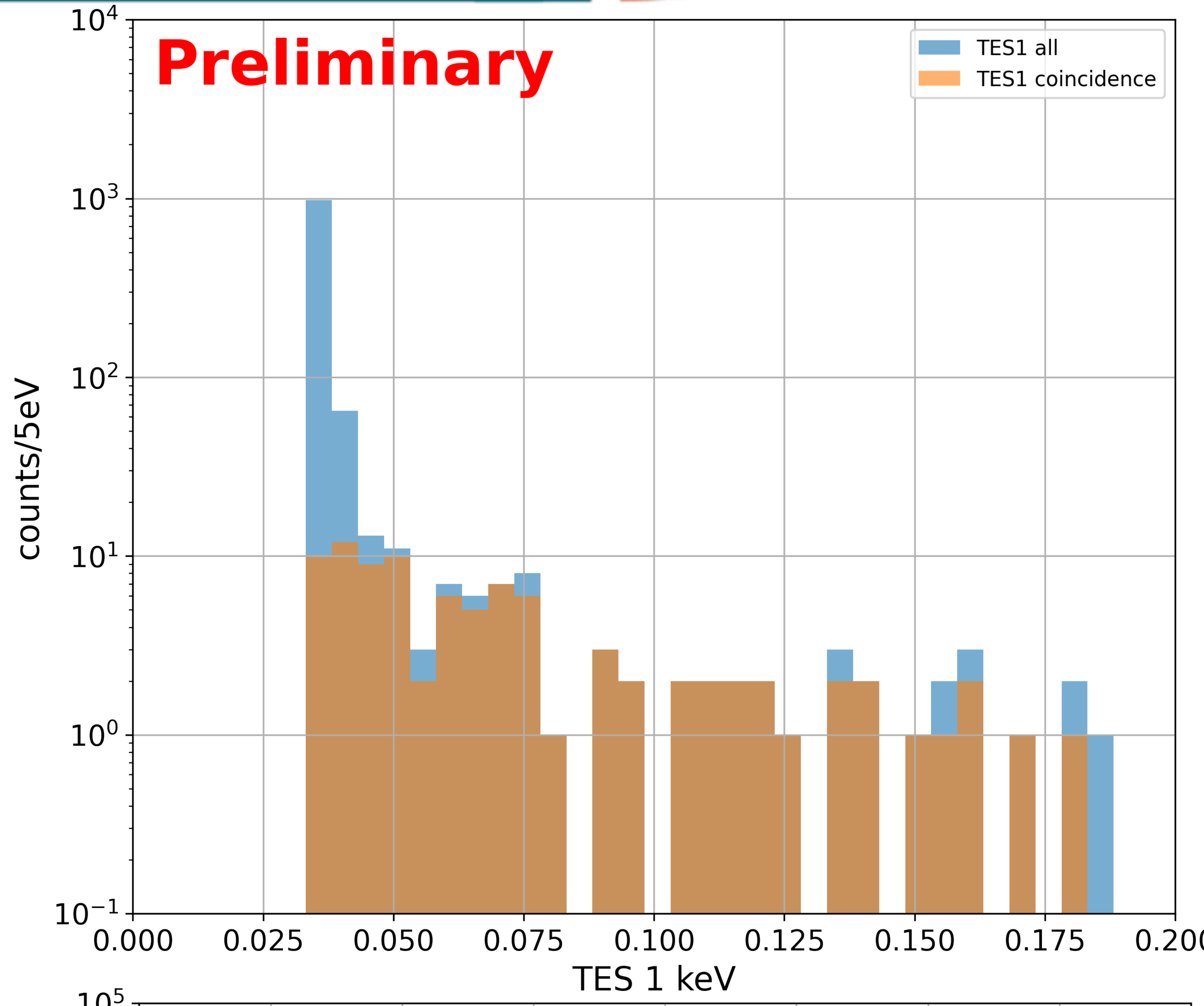
# Double TES results

| # | Baseline resolution TES1 | Baseline resolution TES2 | LD |
|---|---|---|---|
| 2 | 6.6 eV | 7.9 eV | ✓ |
| 5 | 8.1 eV | 7.3 eV | ✓ |

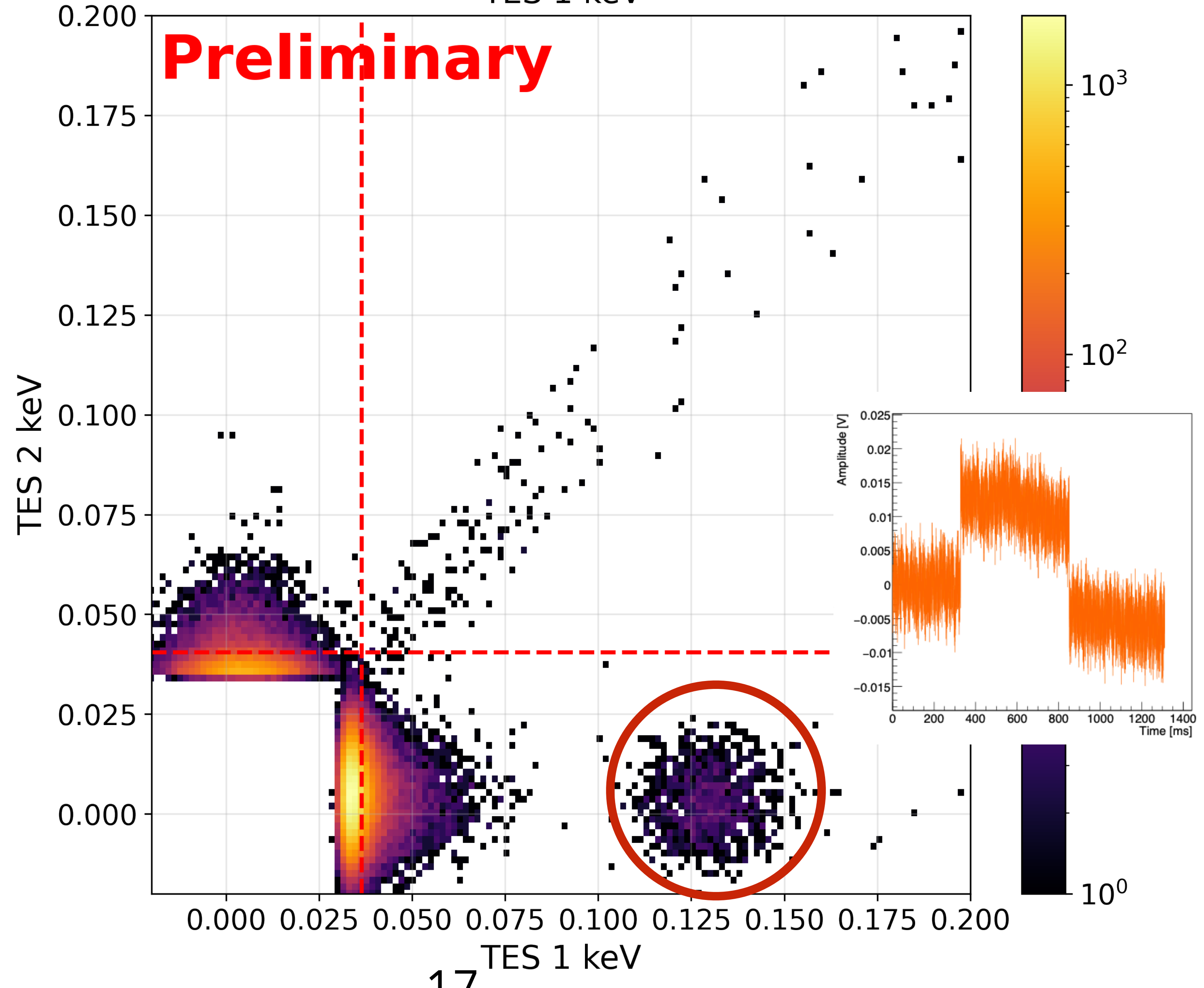
**Strong indication of LEE reduction**

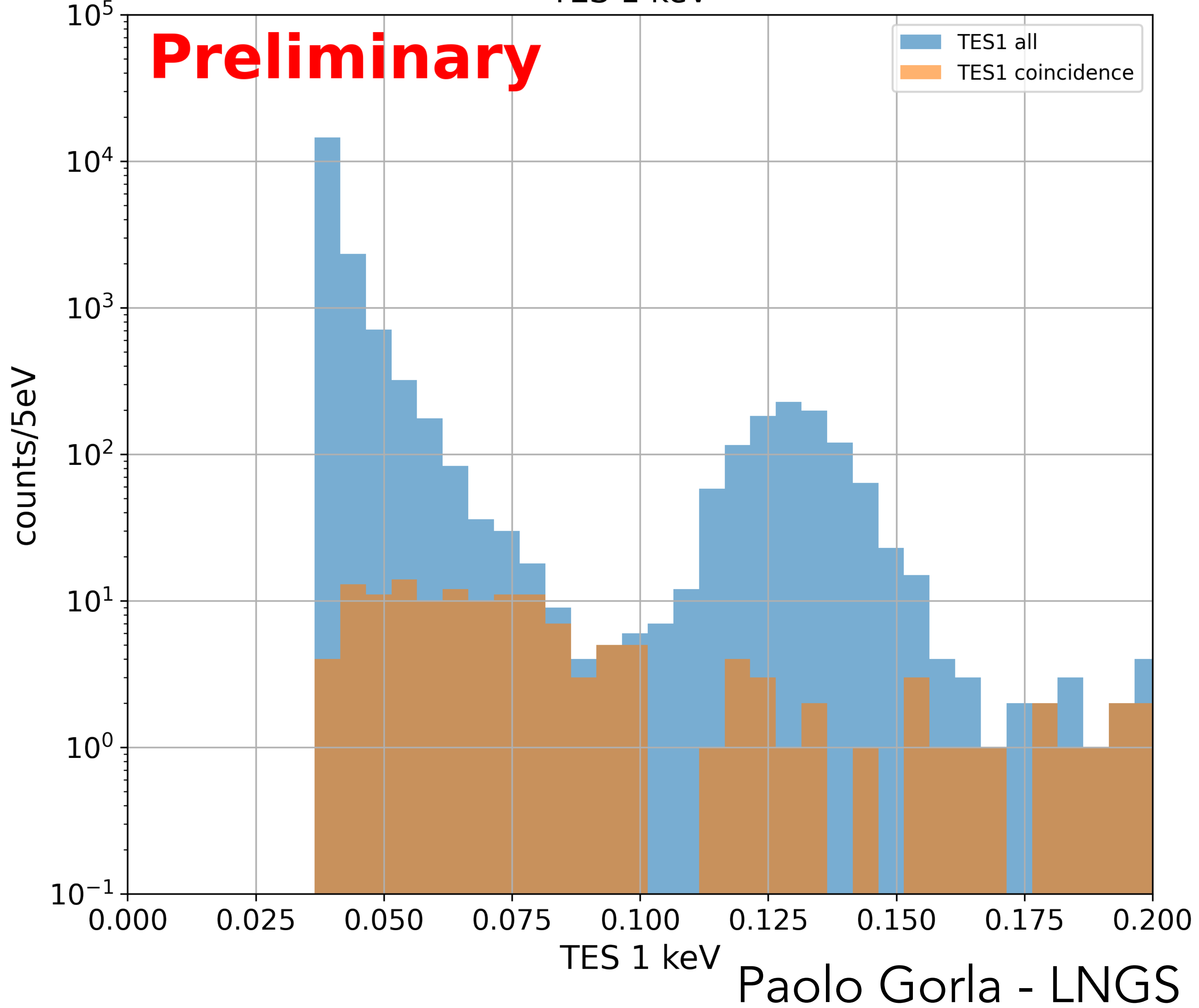
DoubleTES2




DoubleTES5

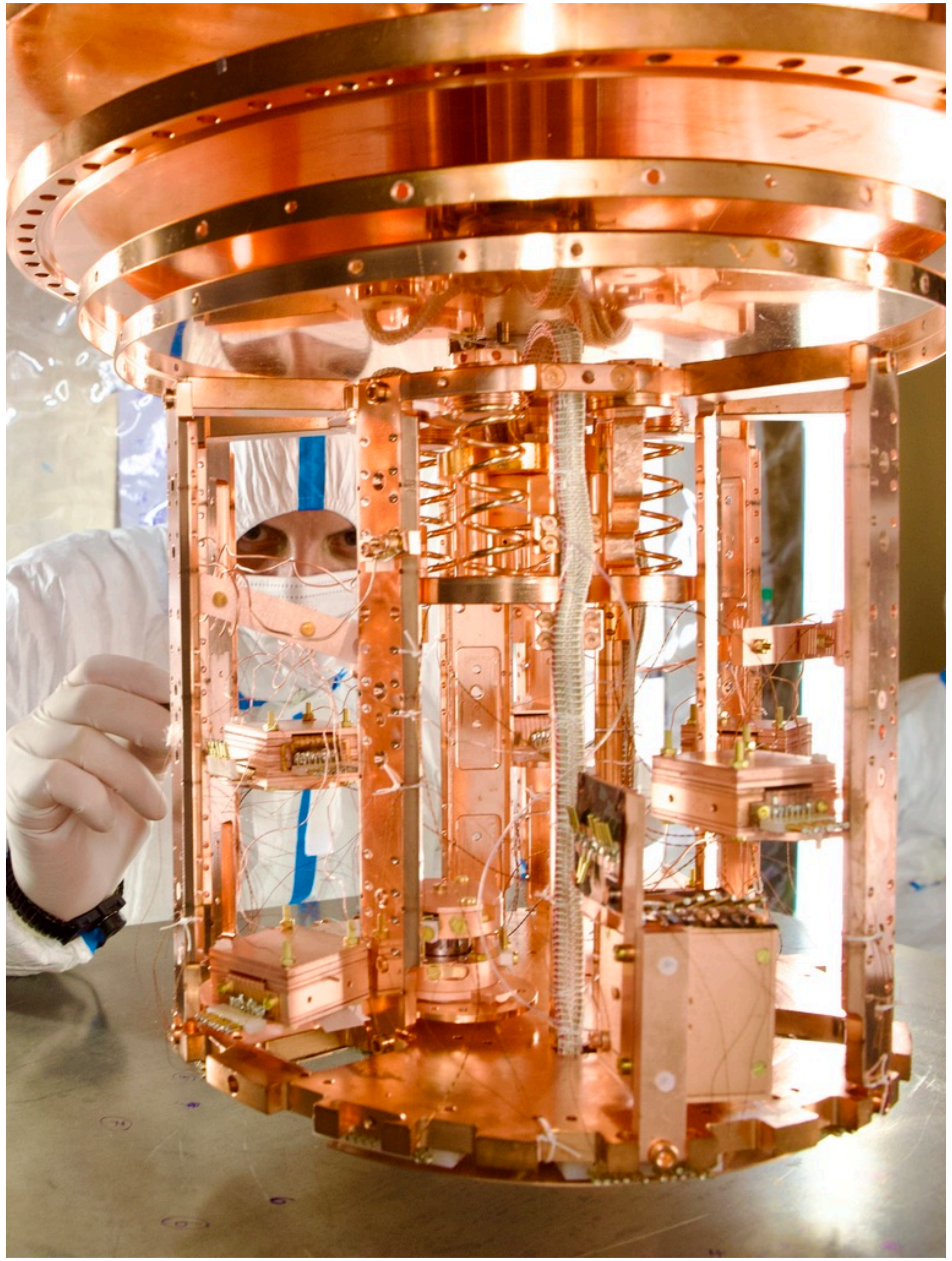


# Conclusion

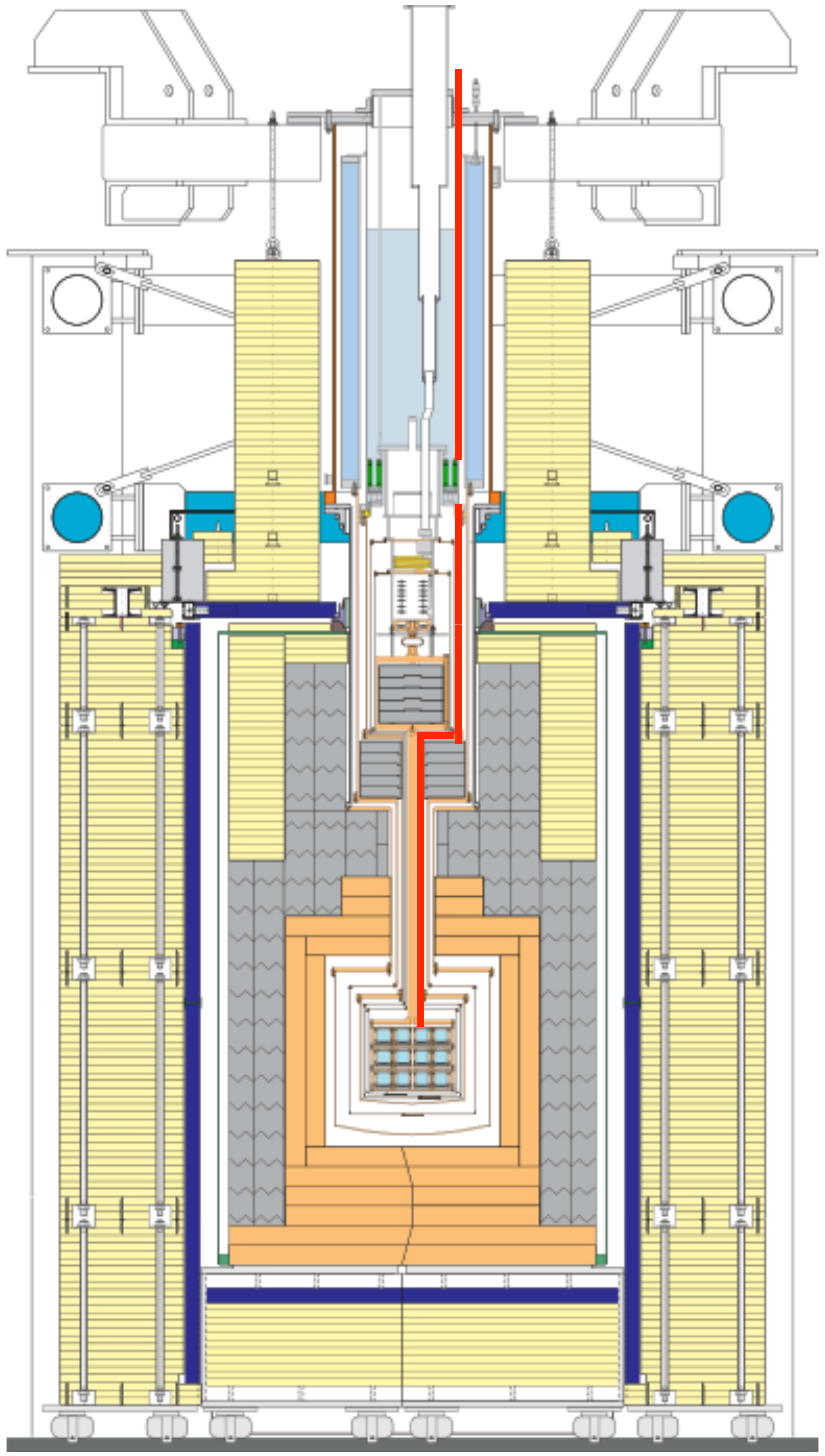
CRESST

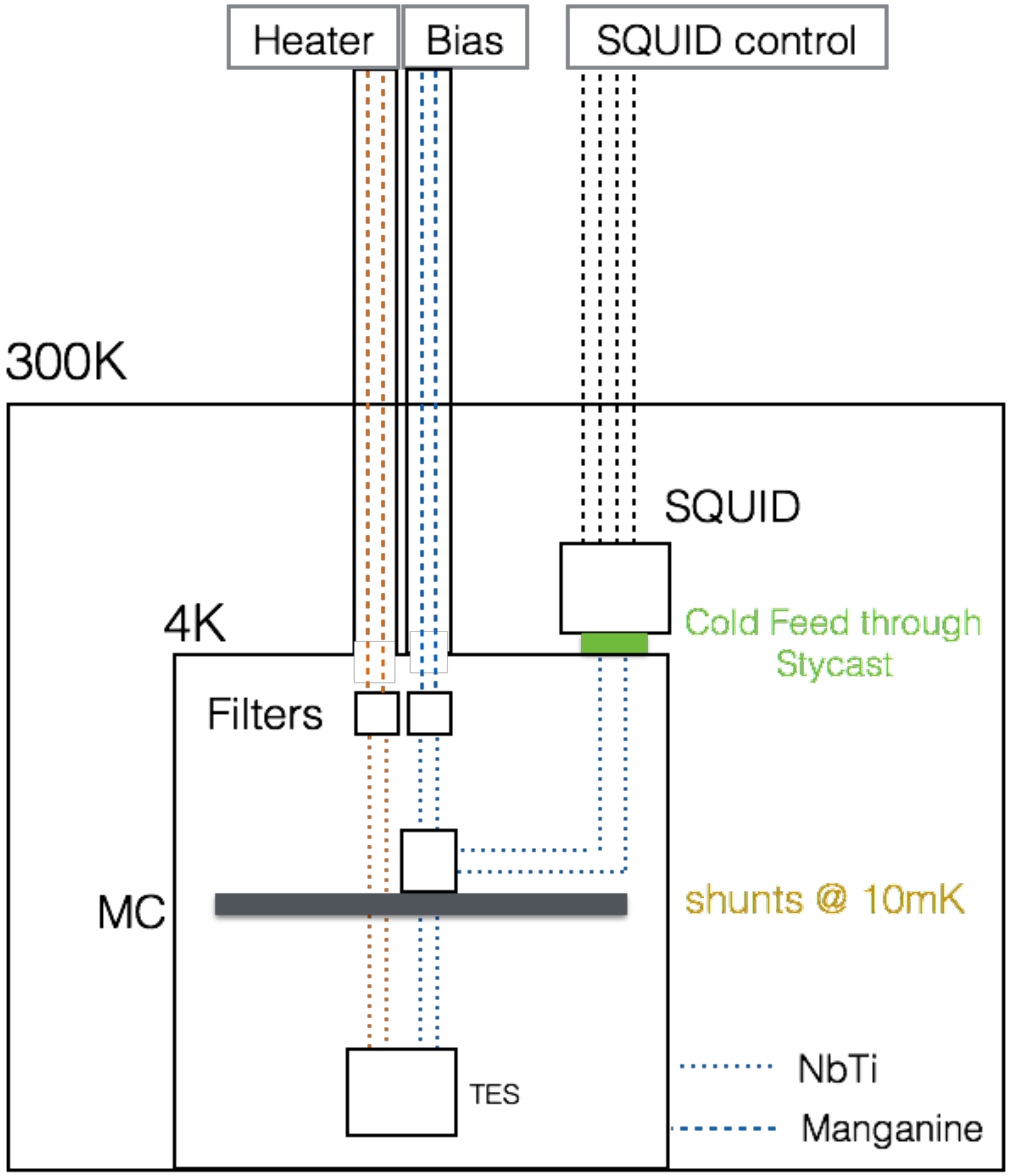
- CRESST energy thresholds O(30-10eV) allow for deep exploration of light DM mass region, extending sensitivity in the ~100 MeV range for the DM mass
- CRESST's capability of using different target crystals allows investigation of both SI (Si, $CaWO_4$) and SD ($LiAlO_2$, $Al_2O_3$) interactions
- Calibration from recoils induced by radiative capture of thermal neutrons allows calibration of $CaWO_4$ detectors without introducing contaminants in the CRESST setup
- **Double TES preliminary results** show, for the first time, a relevant reduction of LEE events. An analysis is ongoing to understand the behaviour of the different populations.
- **Stay tuned for upcoming DM results!**



# Backup slides

# CRESST upgrade



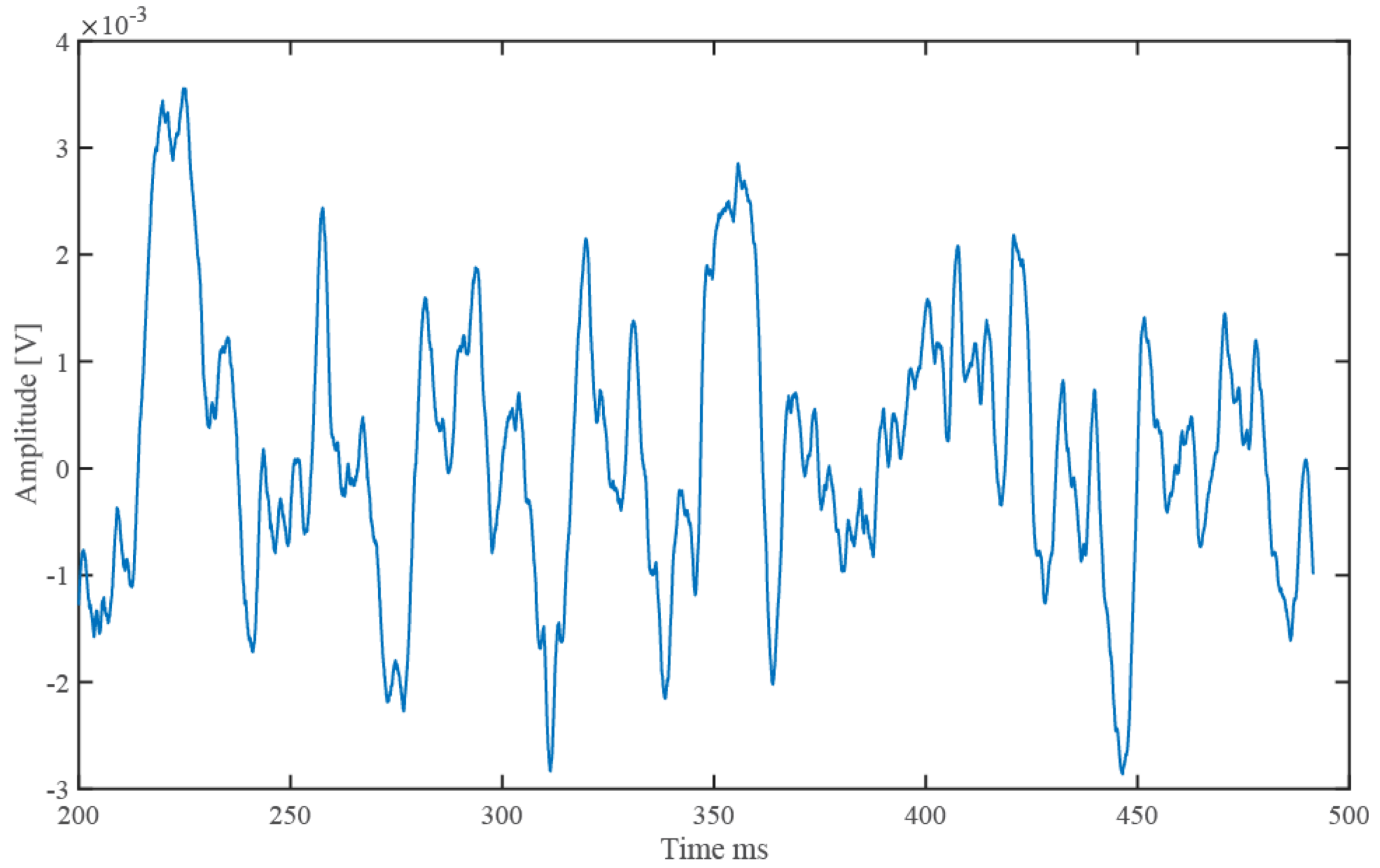


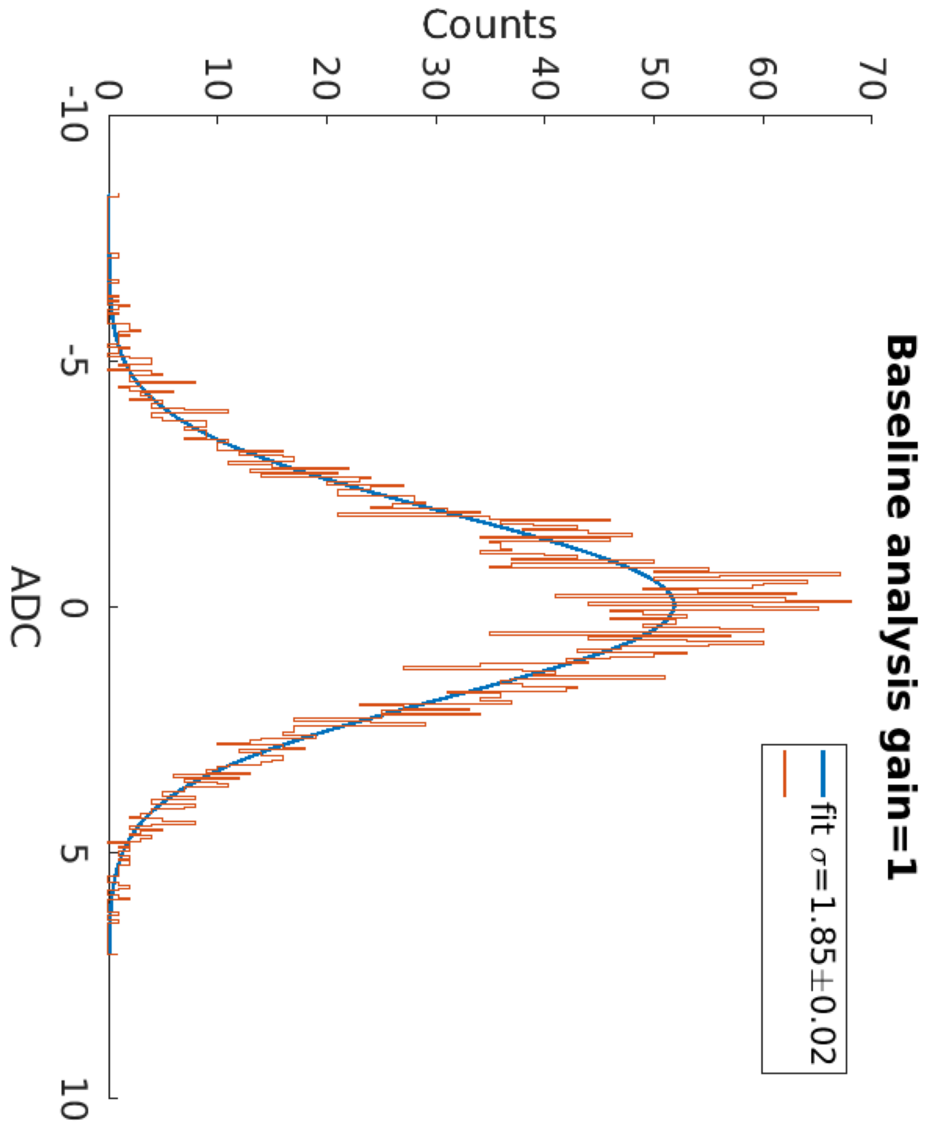

CRESST upgrade to 100 modules (288 readout channels) already in the procurement phase.
Cryogenic infrastructure will remain mostly the same while readout chain is upgraded.

# OPTIMUM TRIGGER THRESHOLD

## Optimum filter for threshold analysis

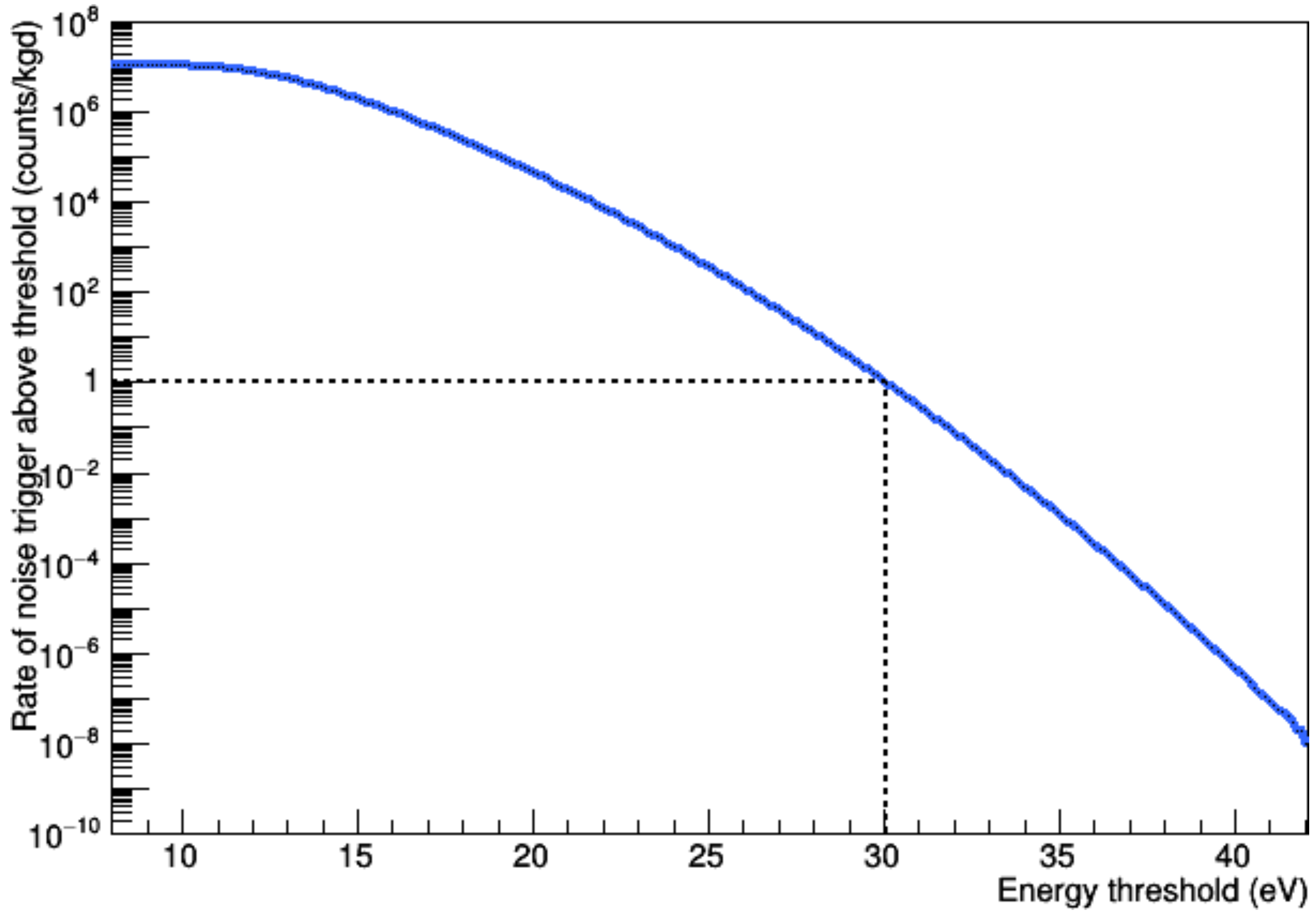
Empty base line trace




Histogram of a typical baseline trace

- Study the noise distribution after optimum filter in order to set the threshold
- Threshold optimised based on noise triggers in a given exposure



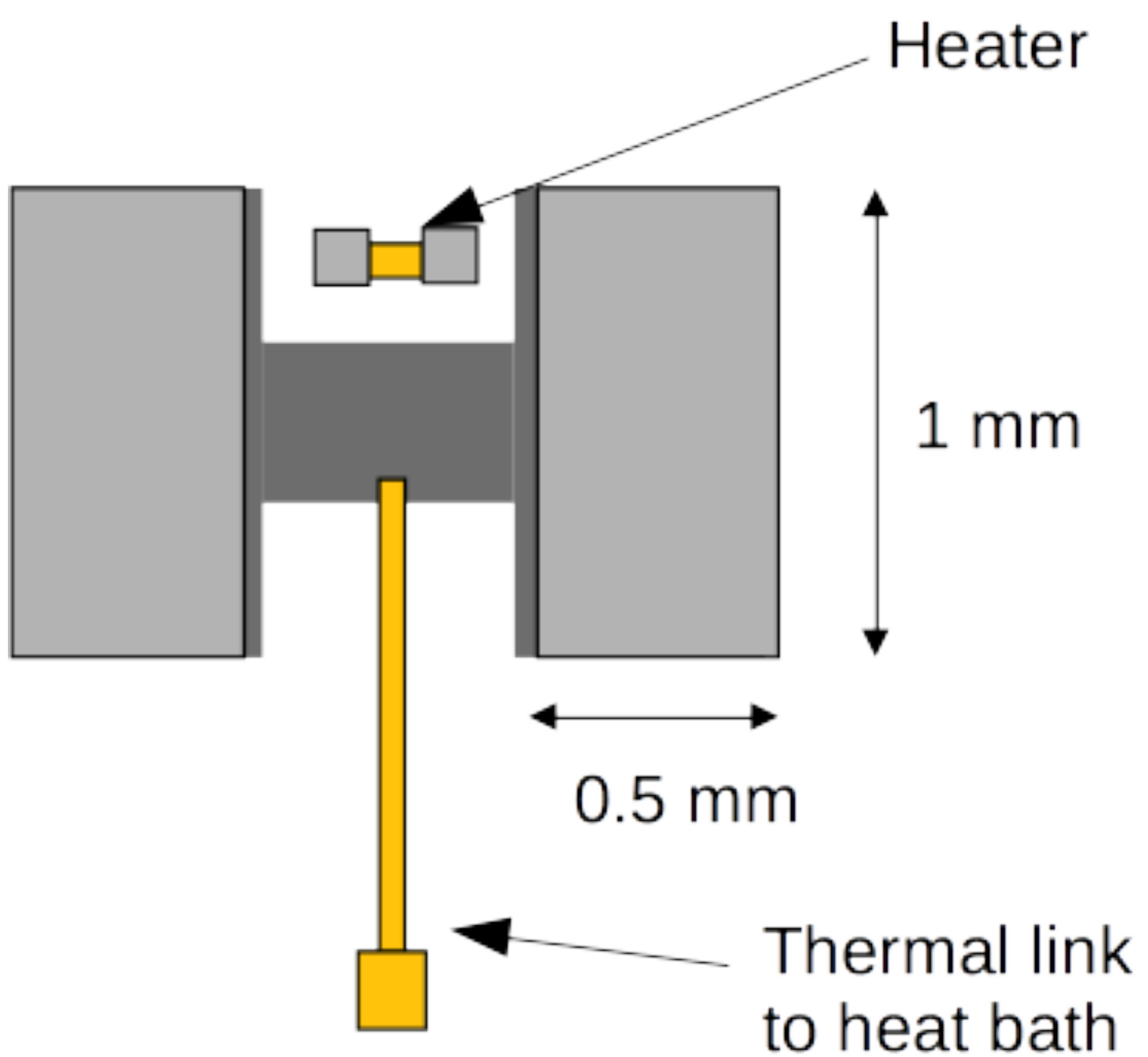

## Analytical description of amplitude distribution in empty baselines

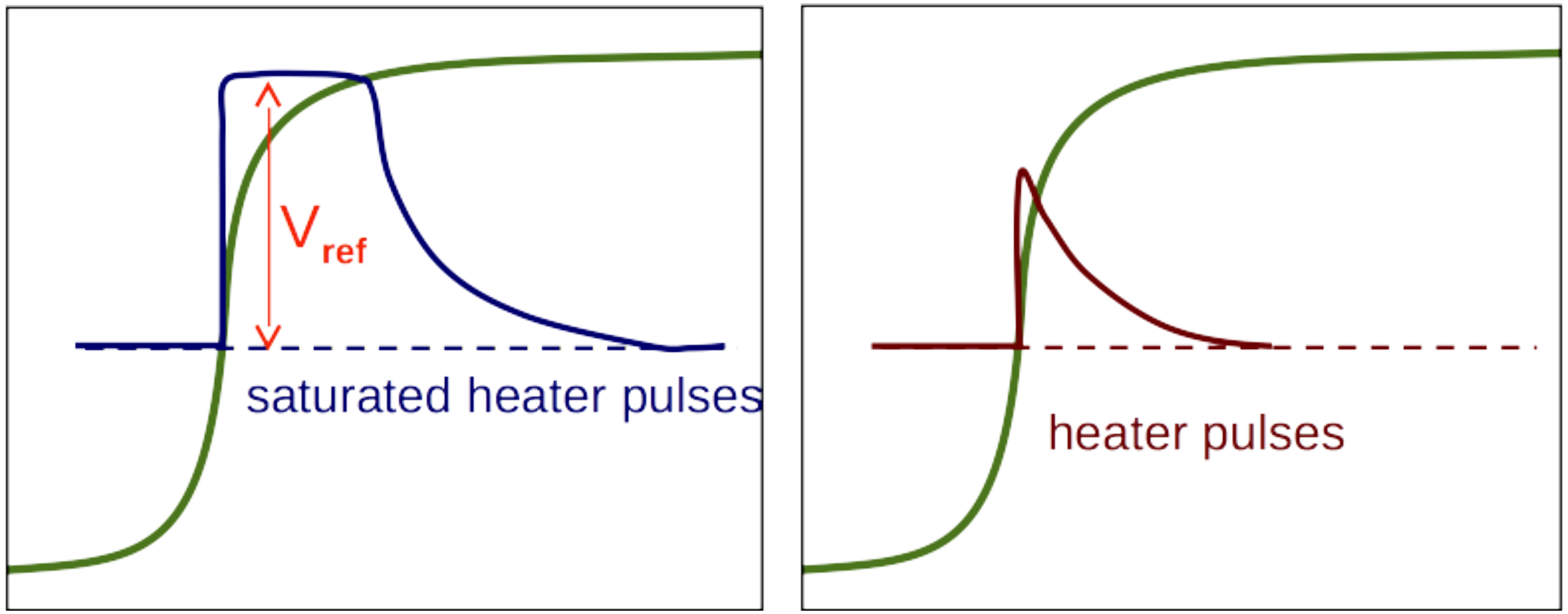
J Low Temp Phys (2019)
doi.org/10.1007/s10909-018-1948-6

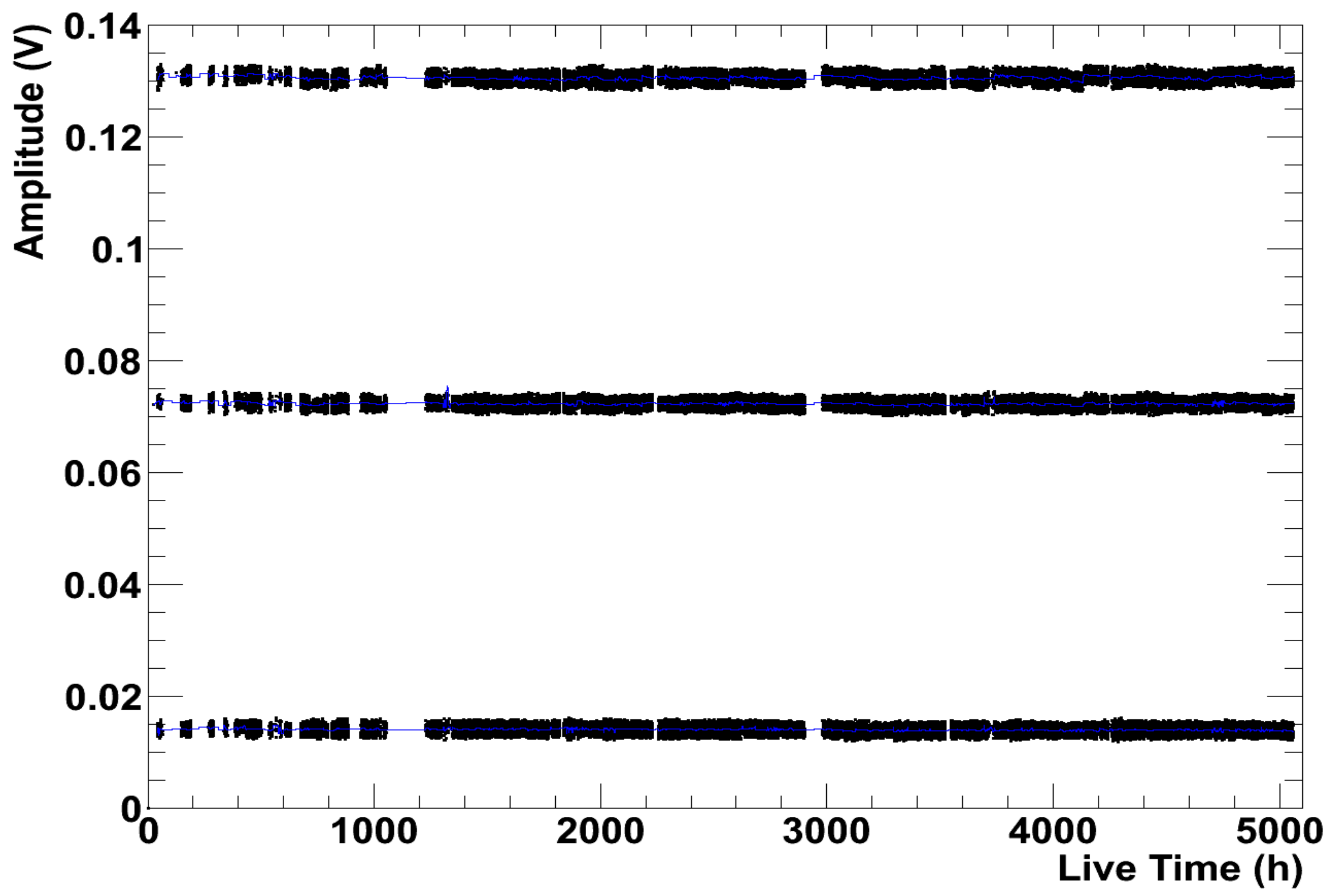
# DETECTOR STABILITY

W-TES equipped with heaters

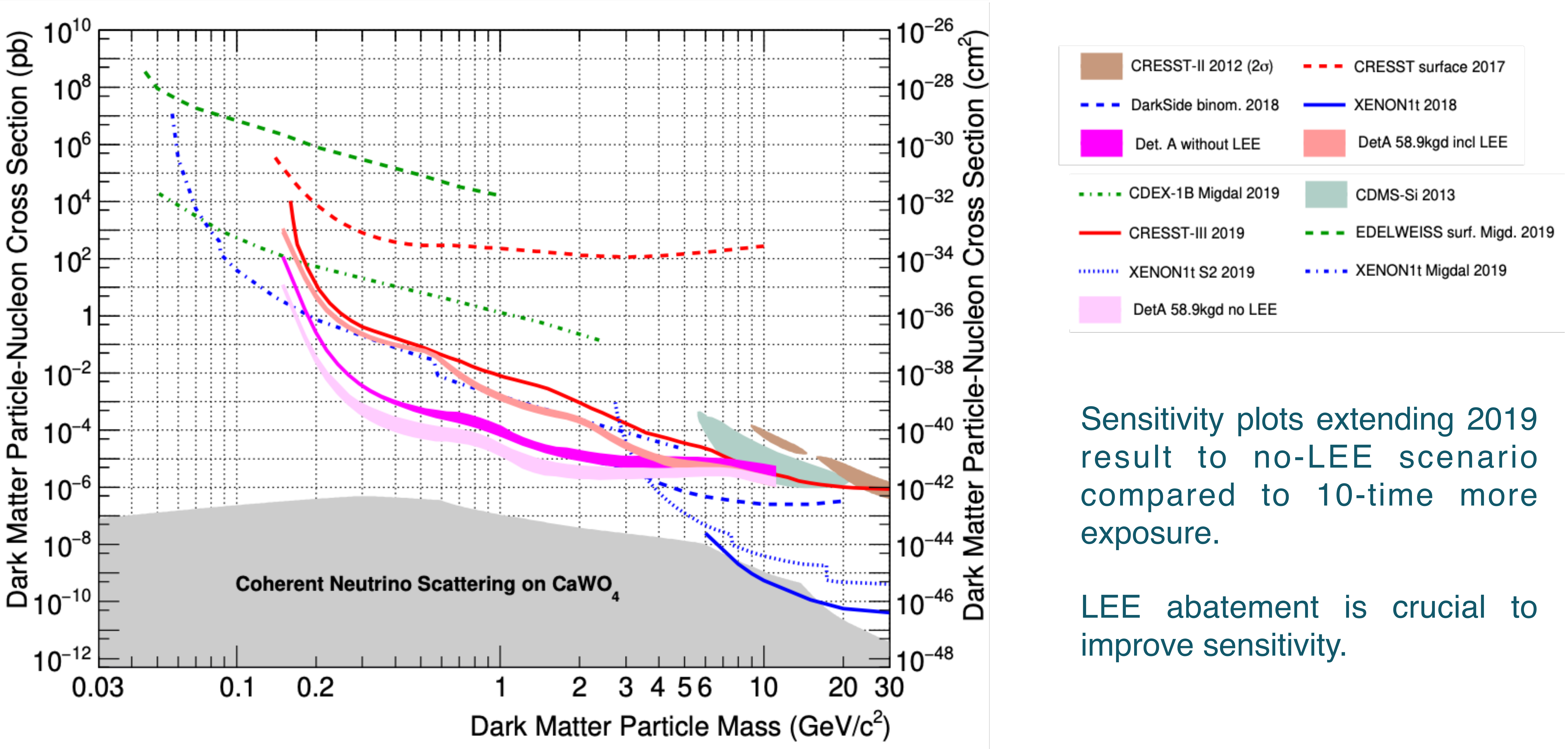
- Stabilization of detectors in the operating point
- Injection of heat pulses for calibration and determination of trigger threshold



# LEE impact




Sensitivity plots extending 2019 result to no-LEE scenario compared to 10-time more exposure.

LEE abatement is crucial to improve sensitivity.