Search of Light Dark matter with the CRESST-III experiment

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Marcel Grossmann Meeting
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CRESST
collaboration
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(Werner-Heisenberg-Institut)
INFN
LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso
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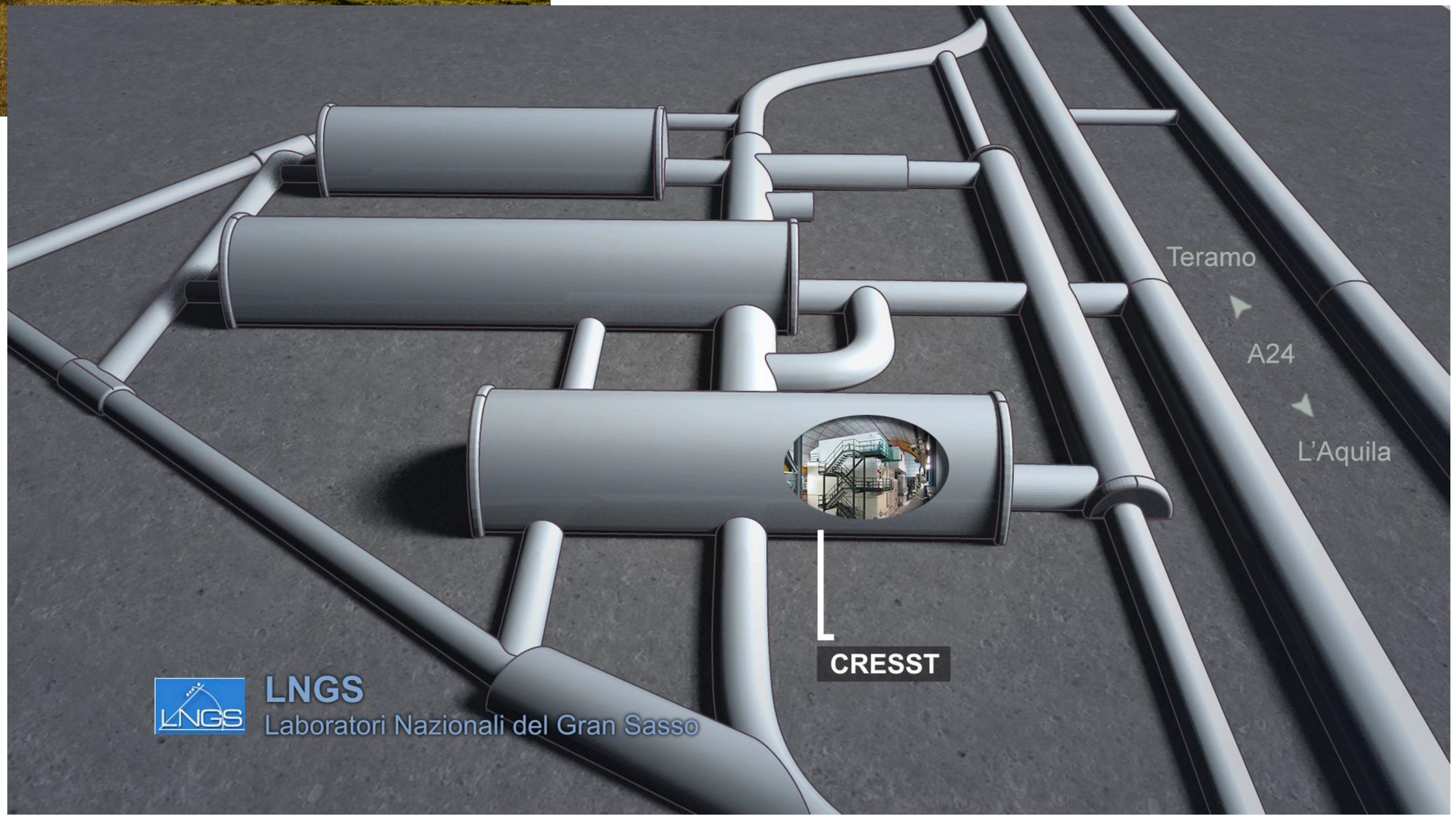
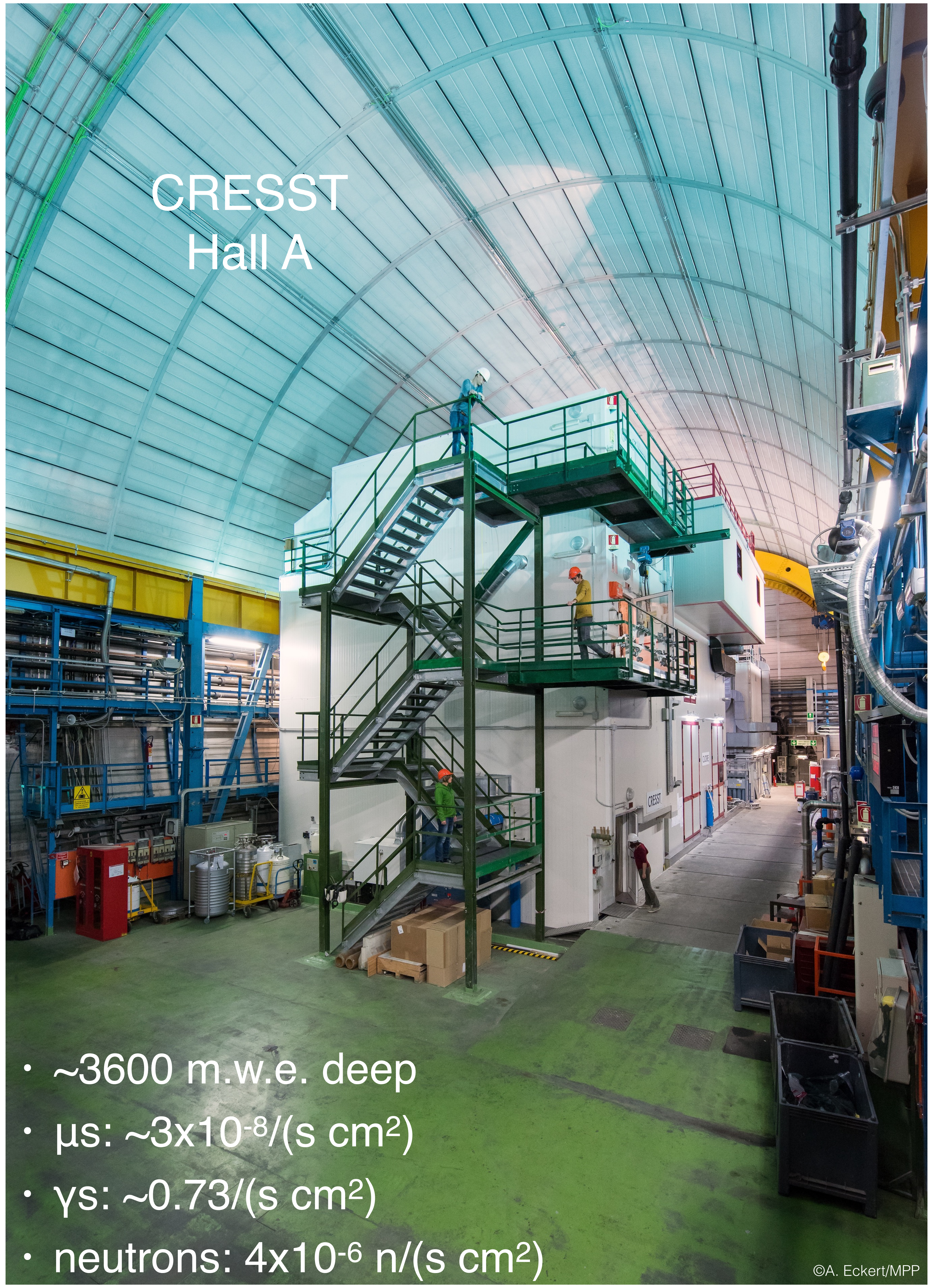
CRESST @ Laboratori Nazionali del Gran Sasso

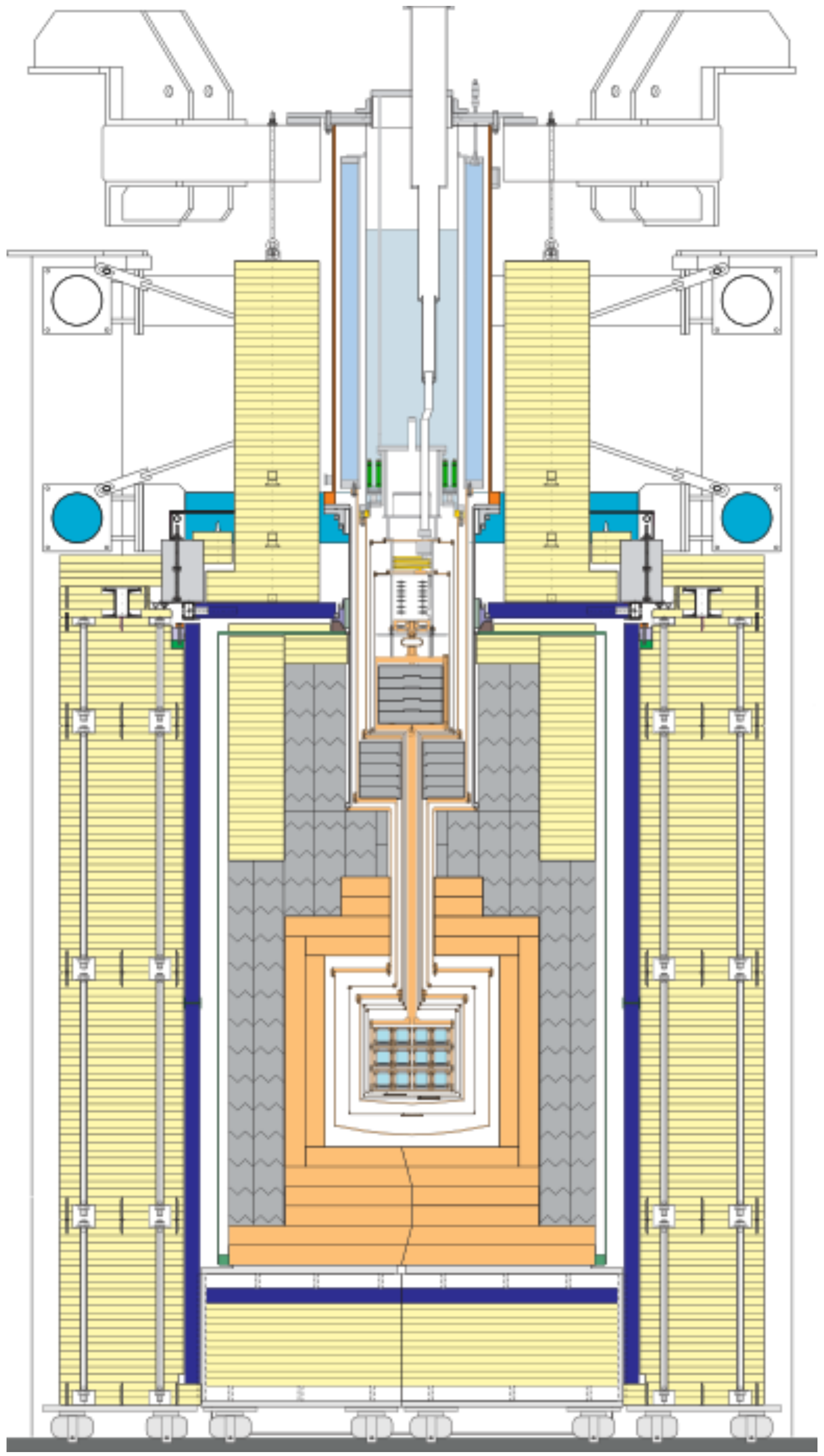


CRESST @ Laboratori Nazionali del Gran Sasso



The CRESST Experiment

Cryogenic Rare Event Search with Superconducting Thermometers



Dilution Refrigerator

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

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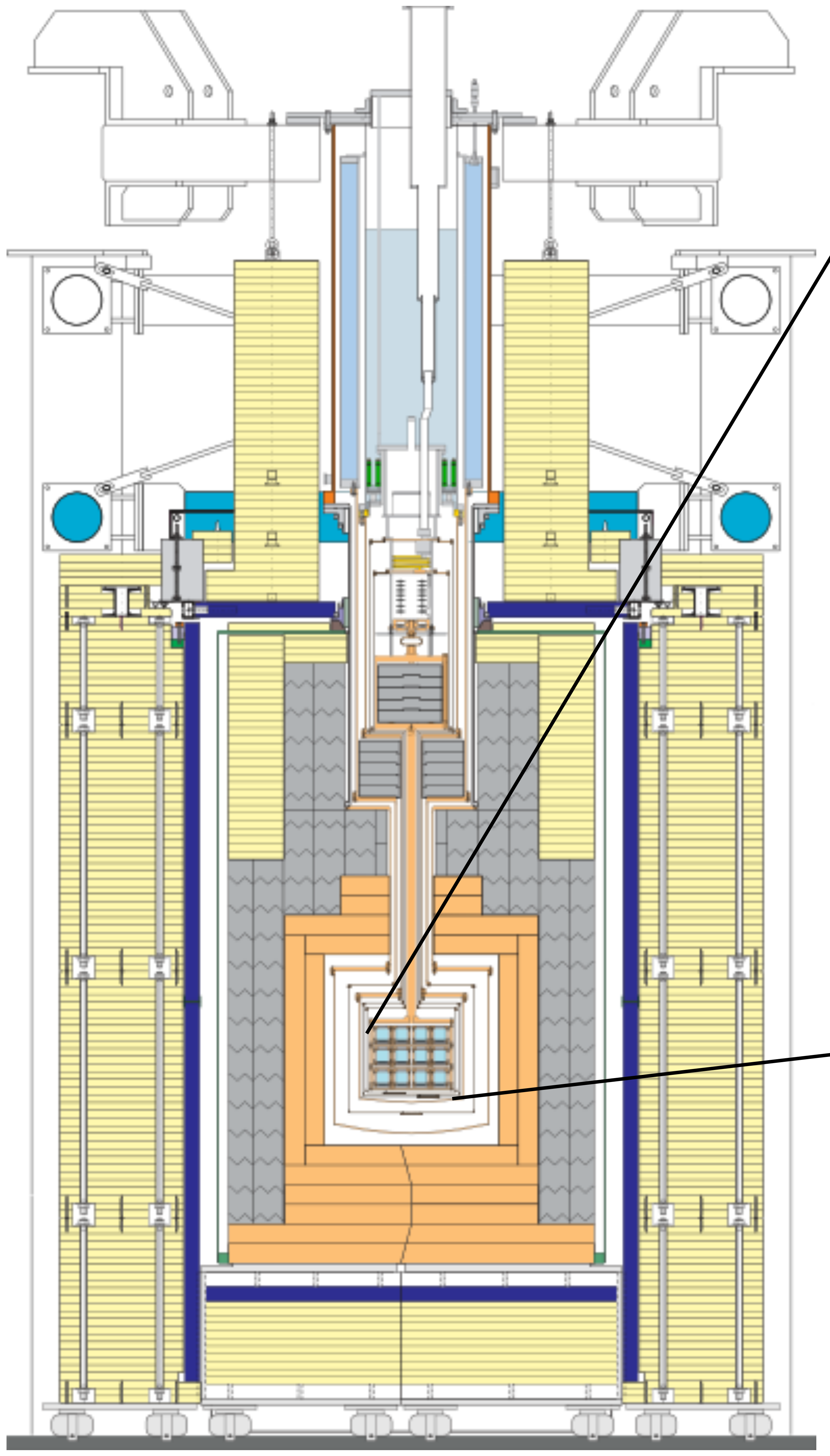

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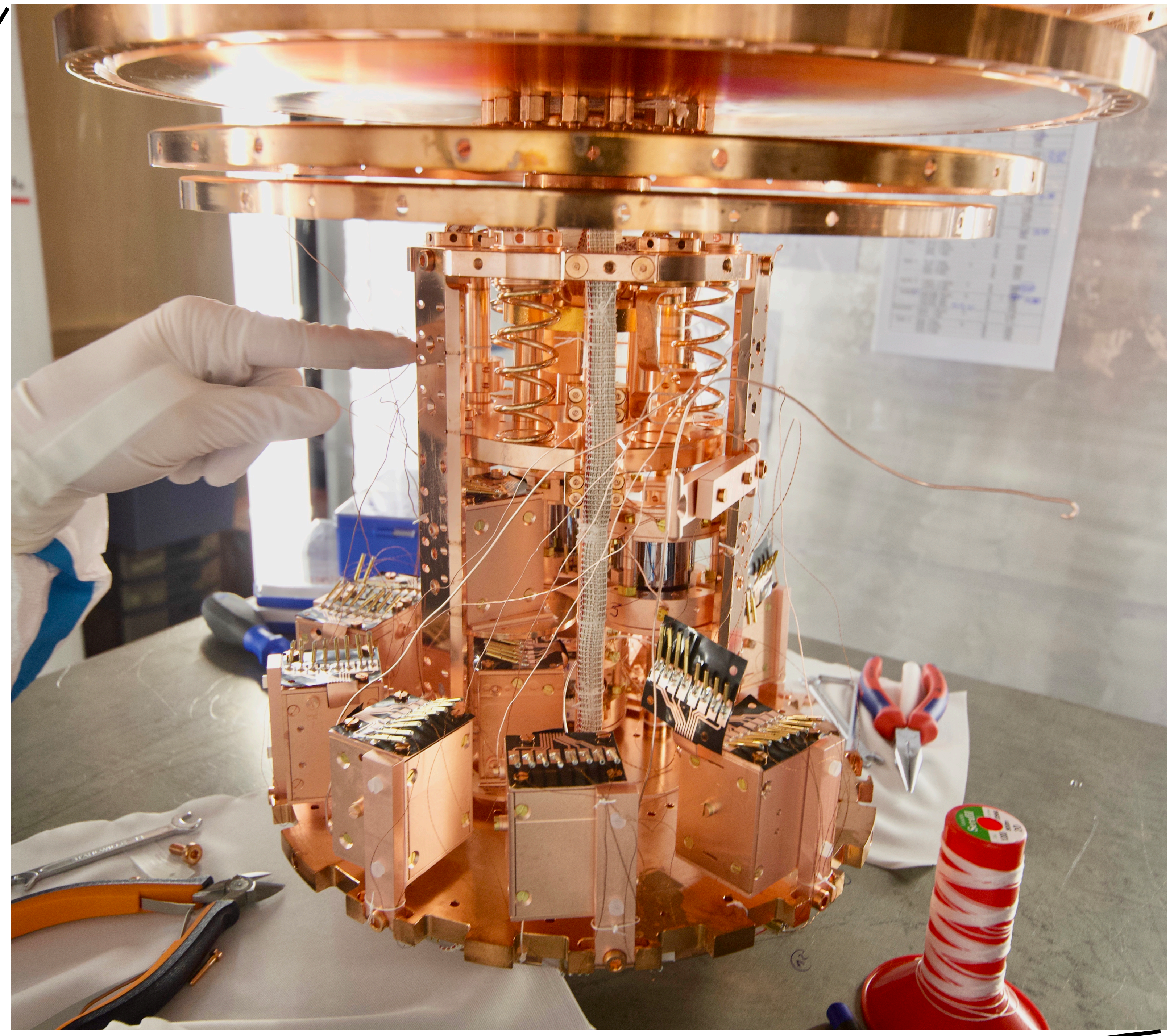

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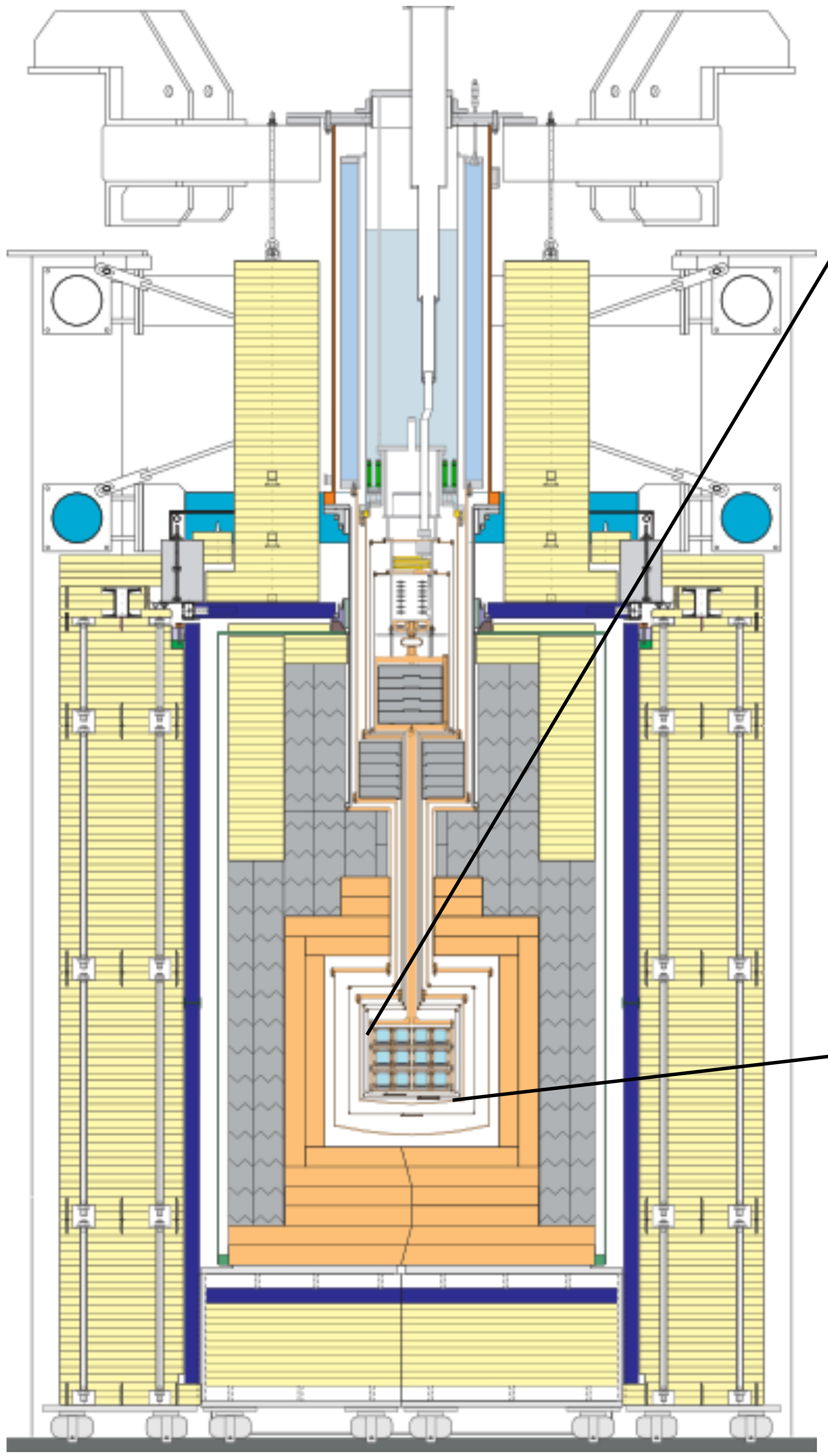

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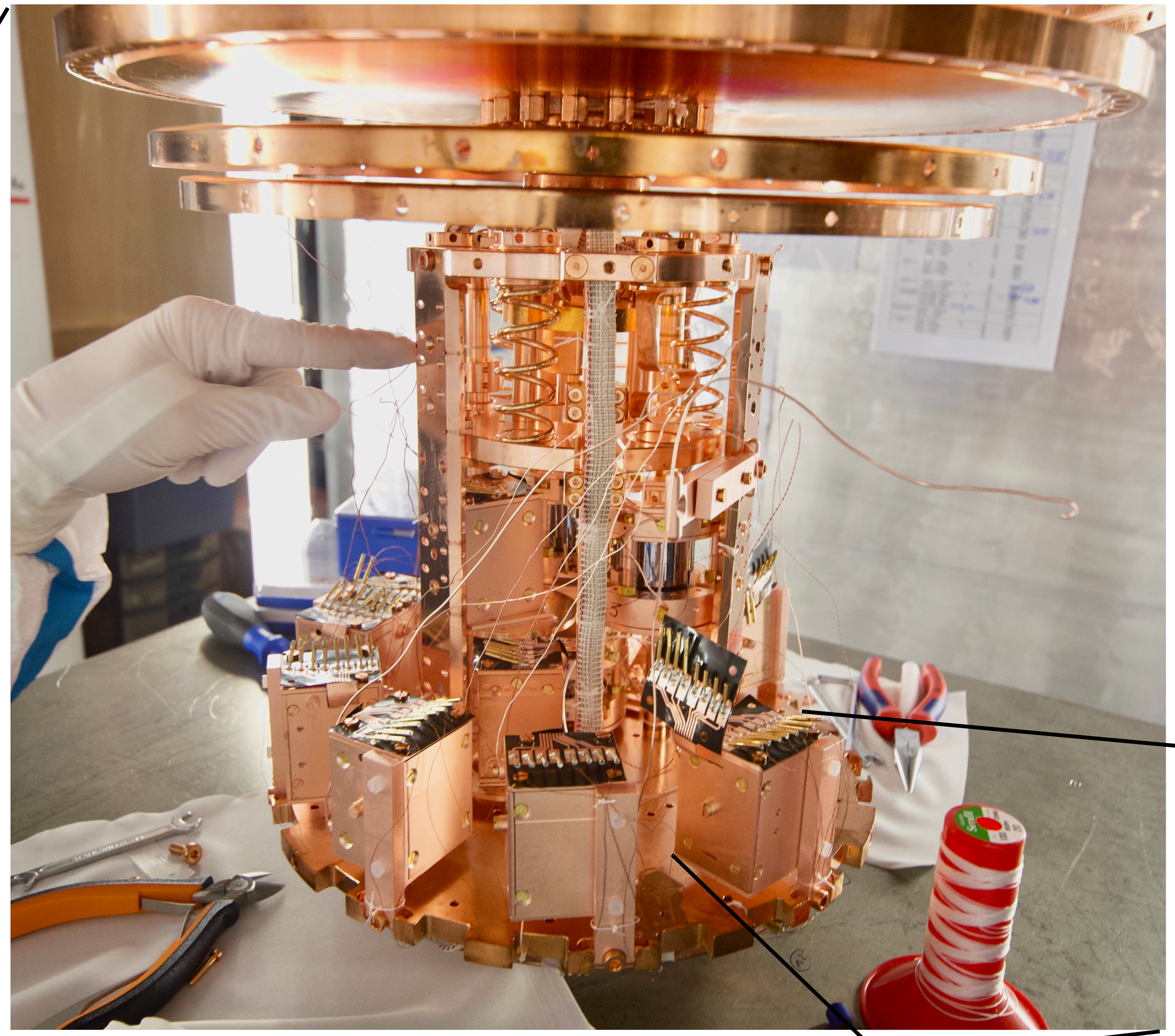
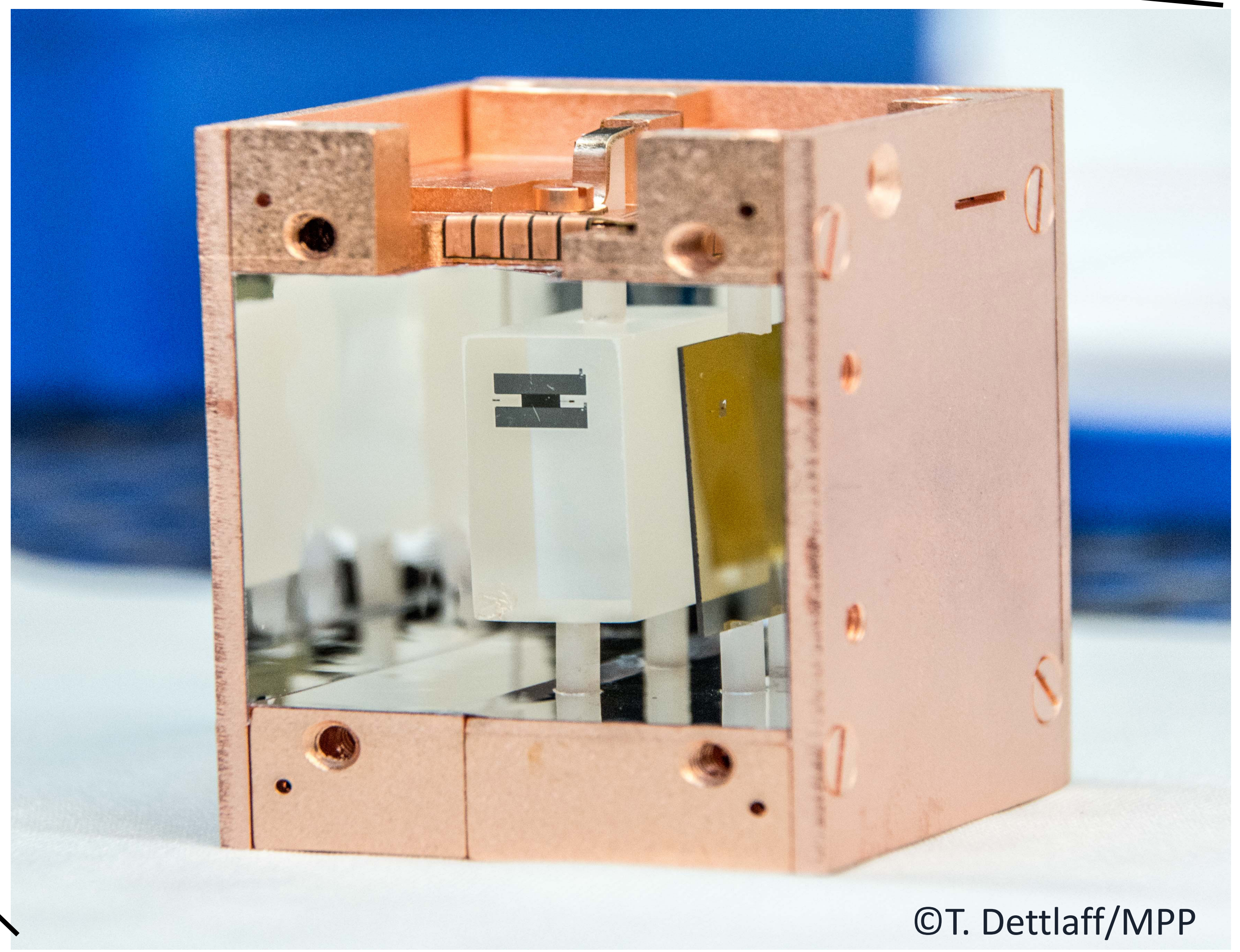


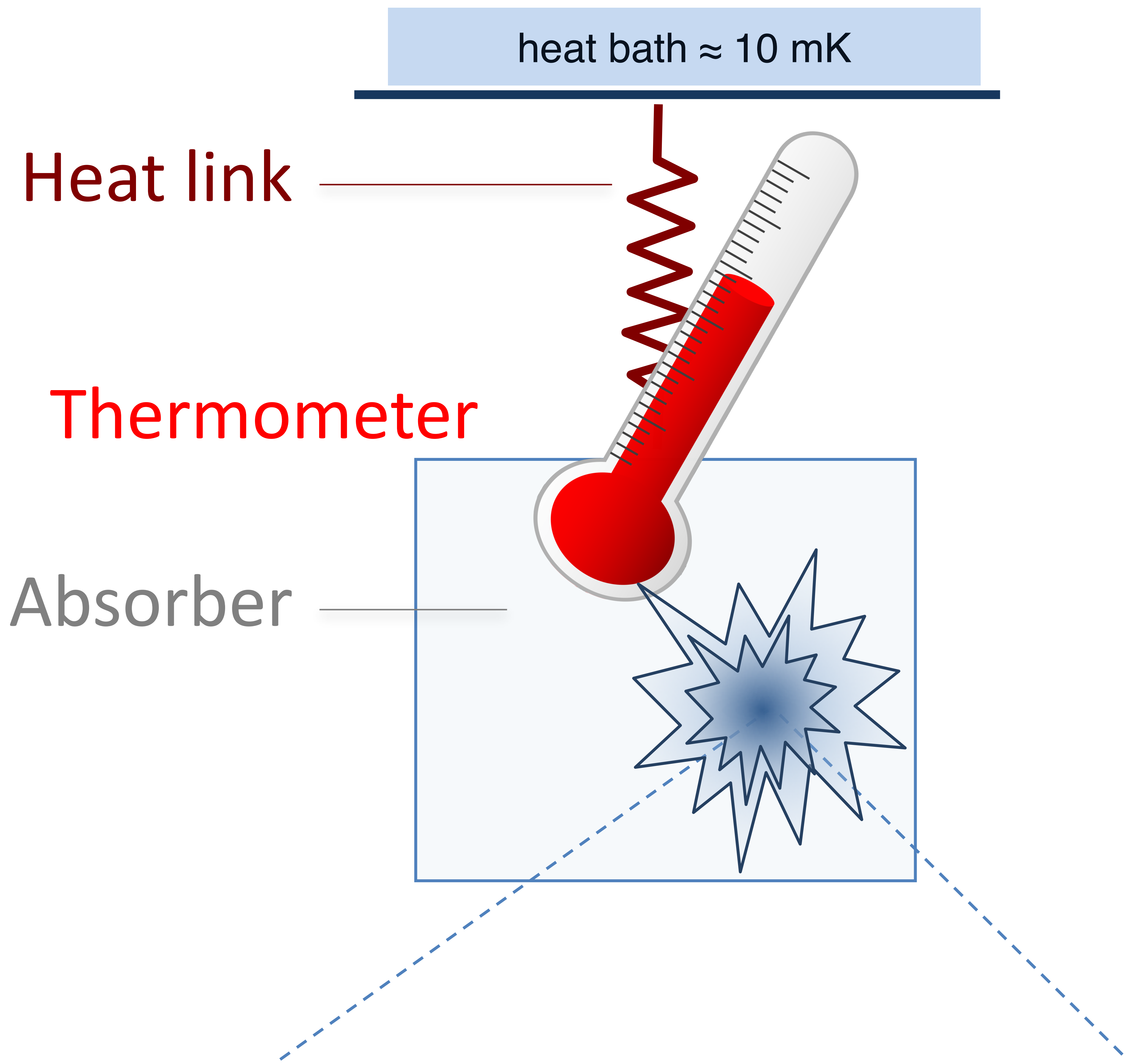
Scintillating $CaWO_4$ crystals as target

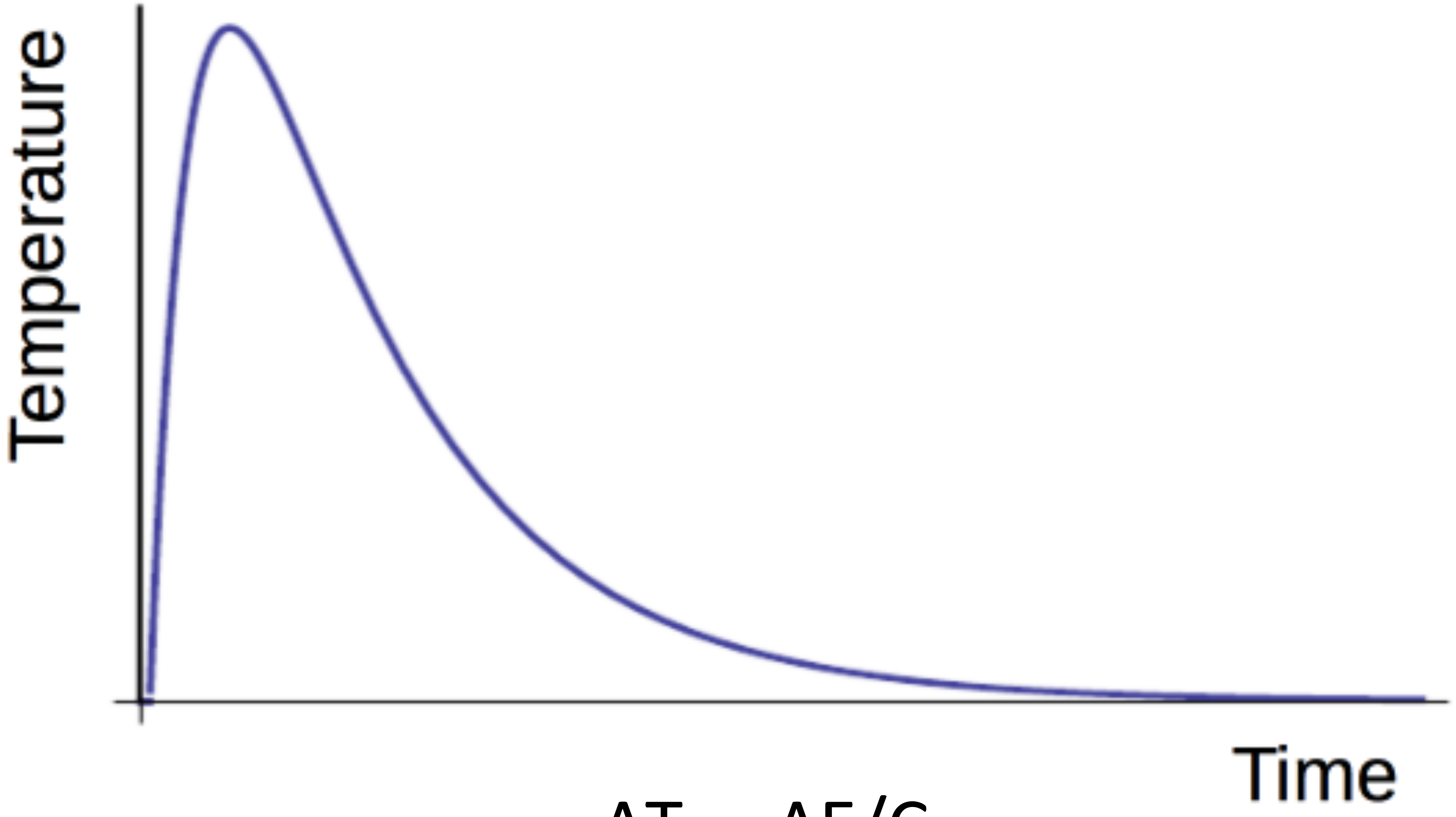
Separate **cryogenic light detector**



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

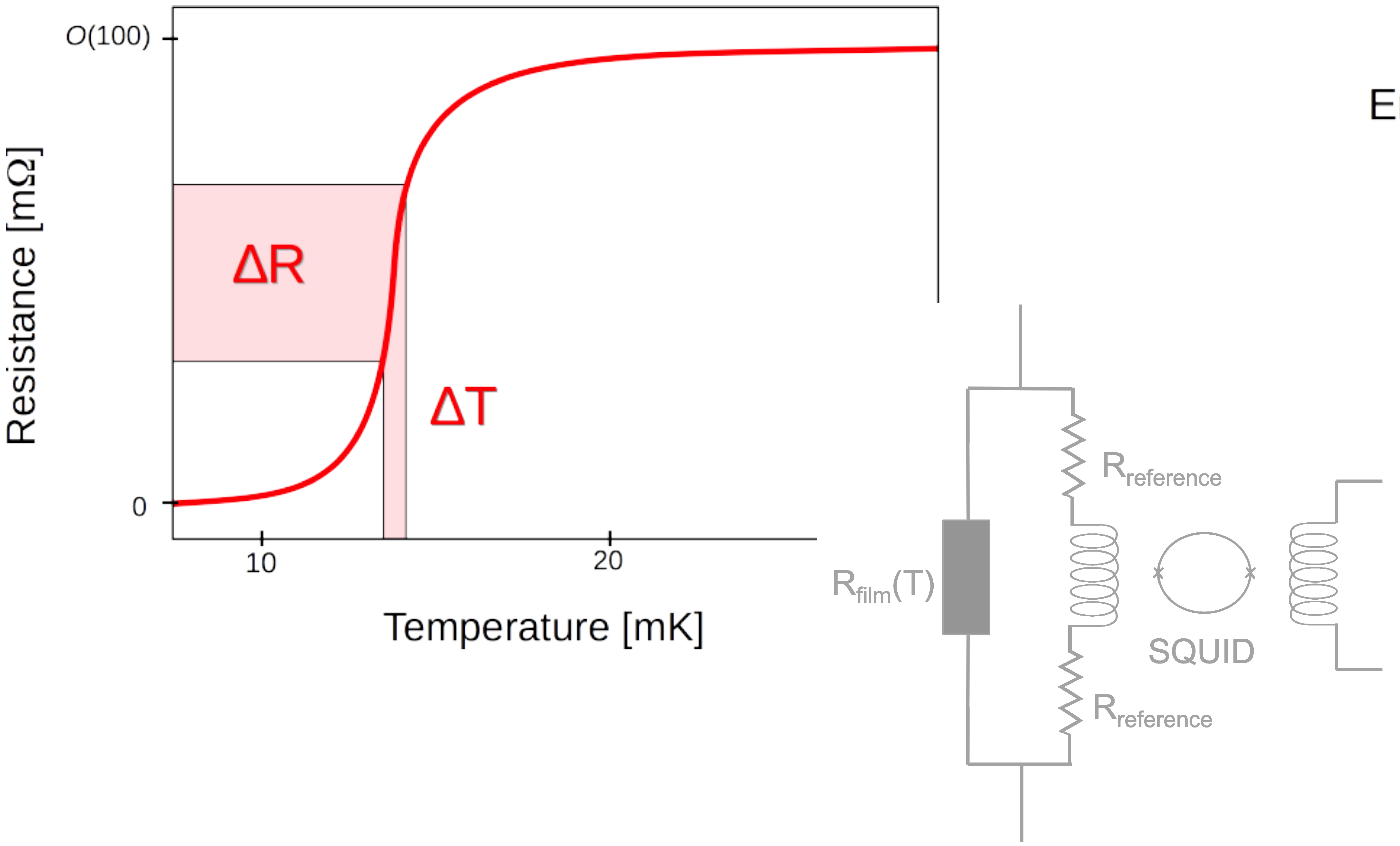
CRYOGENIC CALORIMETER





$\Delta T = \Delta E/C$

TRANSITION EDGE SENSOR

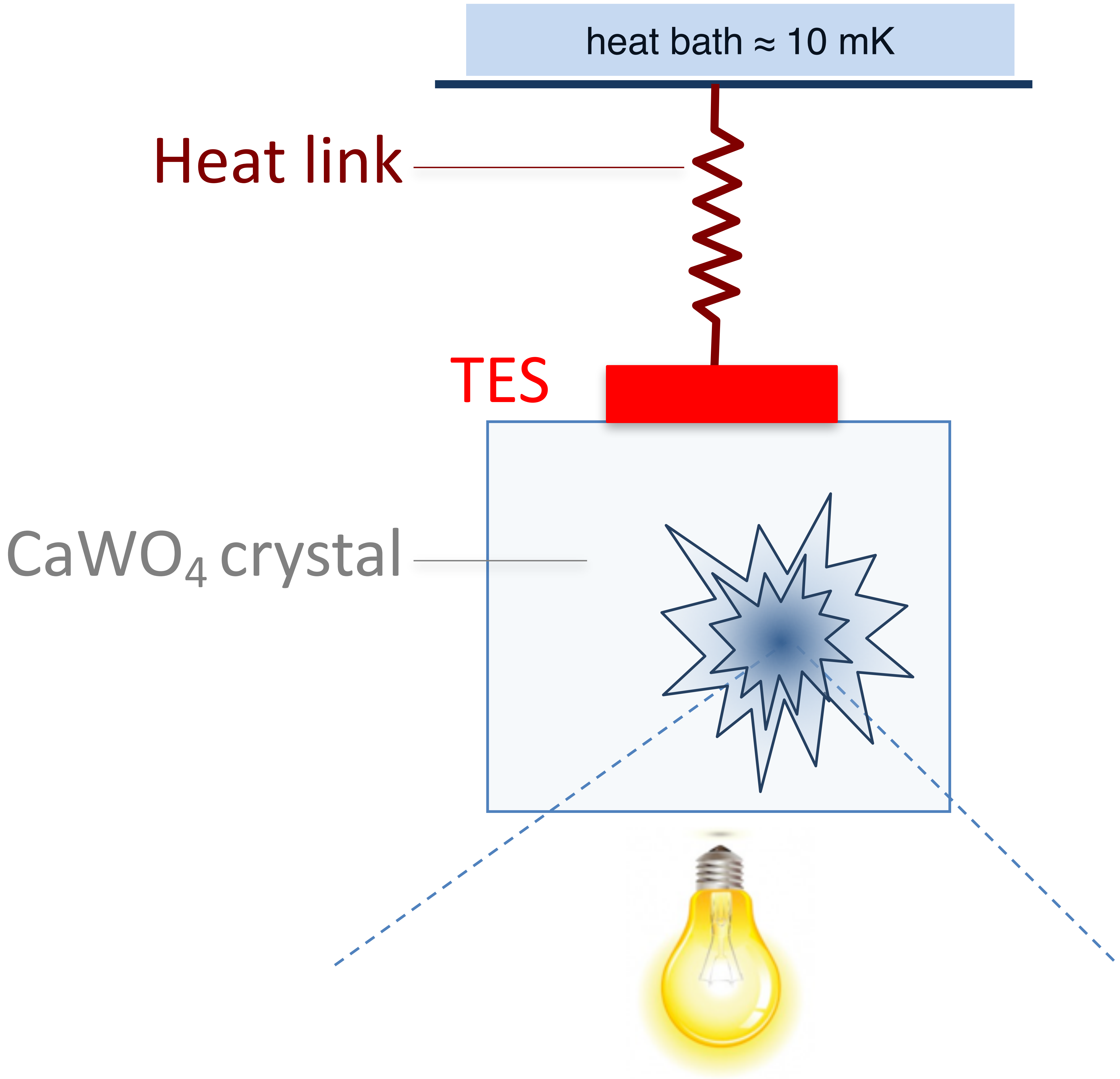


Energy deposition in absorber
~keV

Temperature rise in TES
~μK

Resistance change
~mΩ

CRYOGENIC DETECTOR

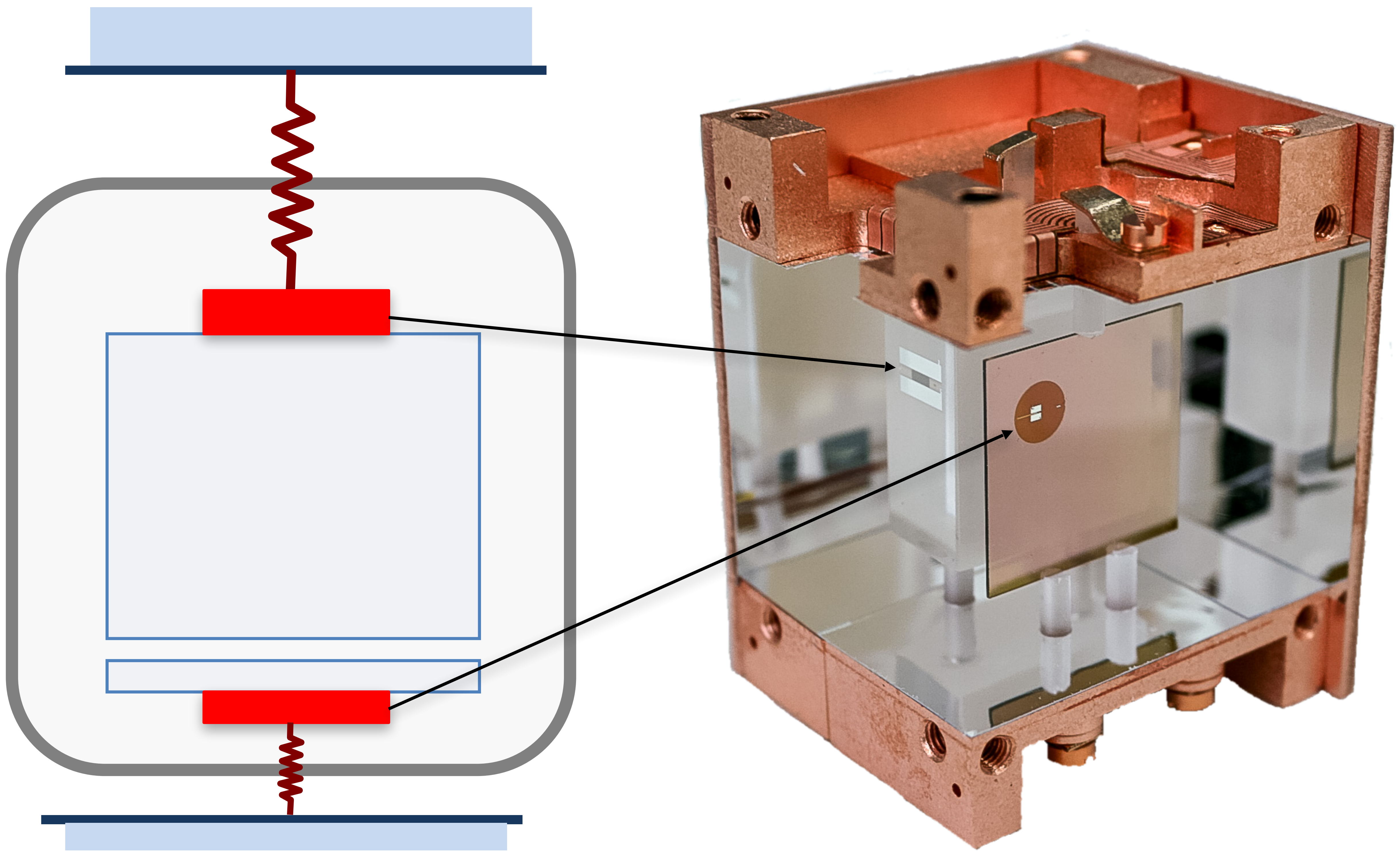


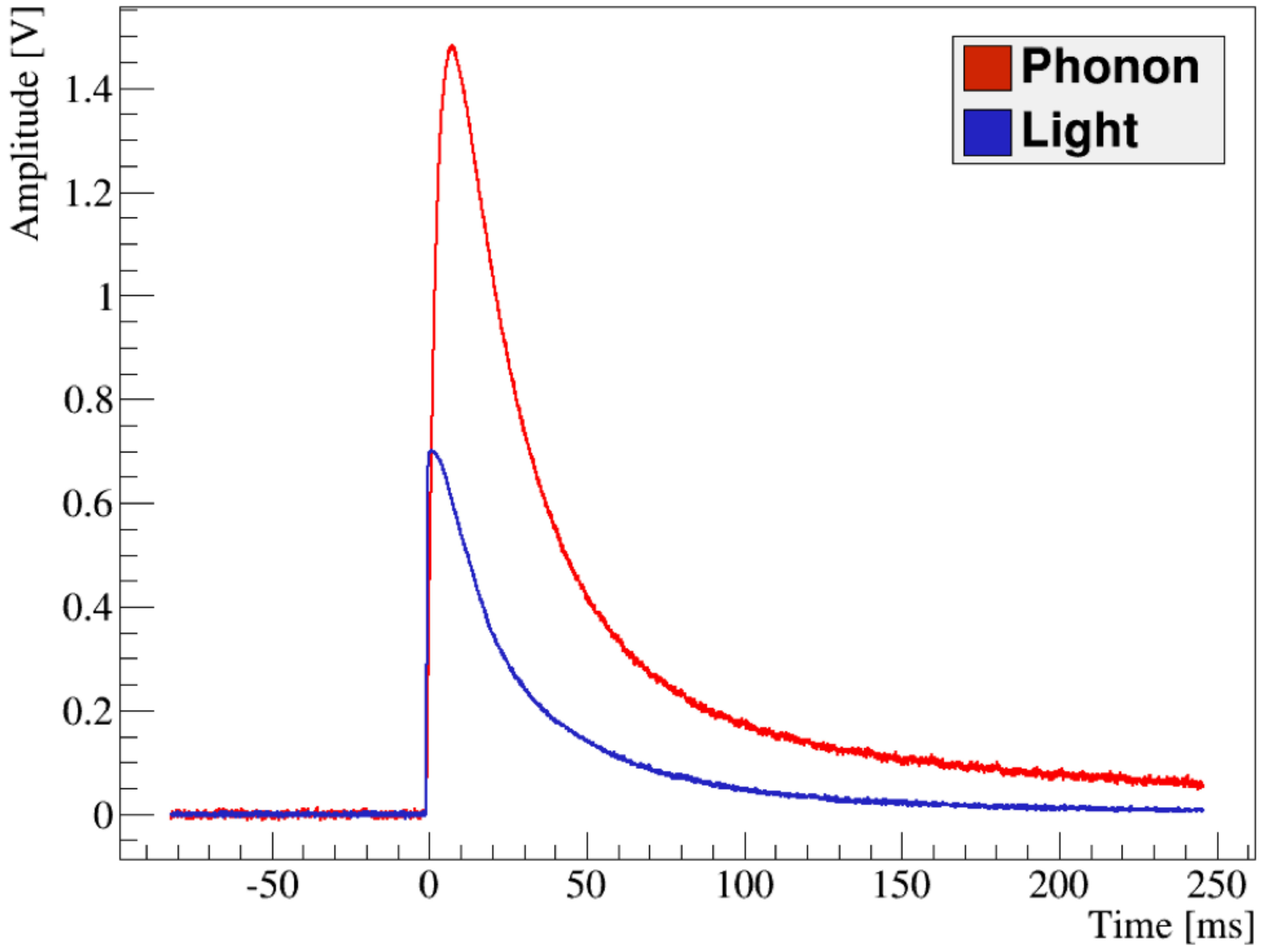
Phonon signal (≳90 %)
(almost) independent of particle type
precise measurement of the deposited energy

Scintillation light (few %)
particle-type dependent
→ LIGHT QUENCHING

DETECTOR MODULE

Each component x 2





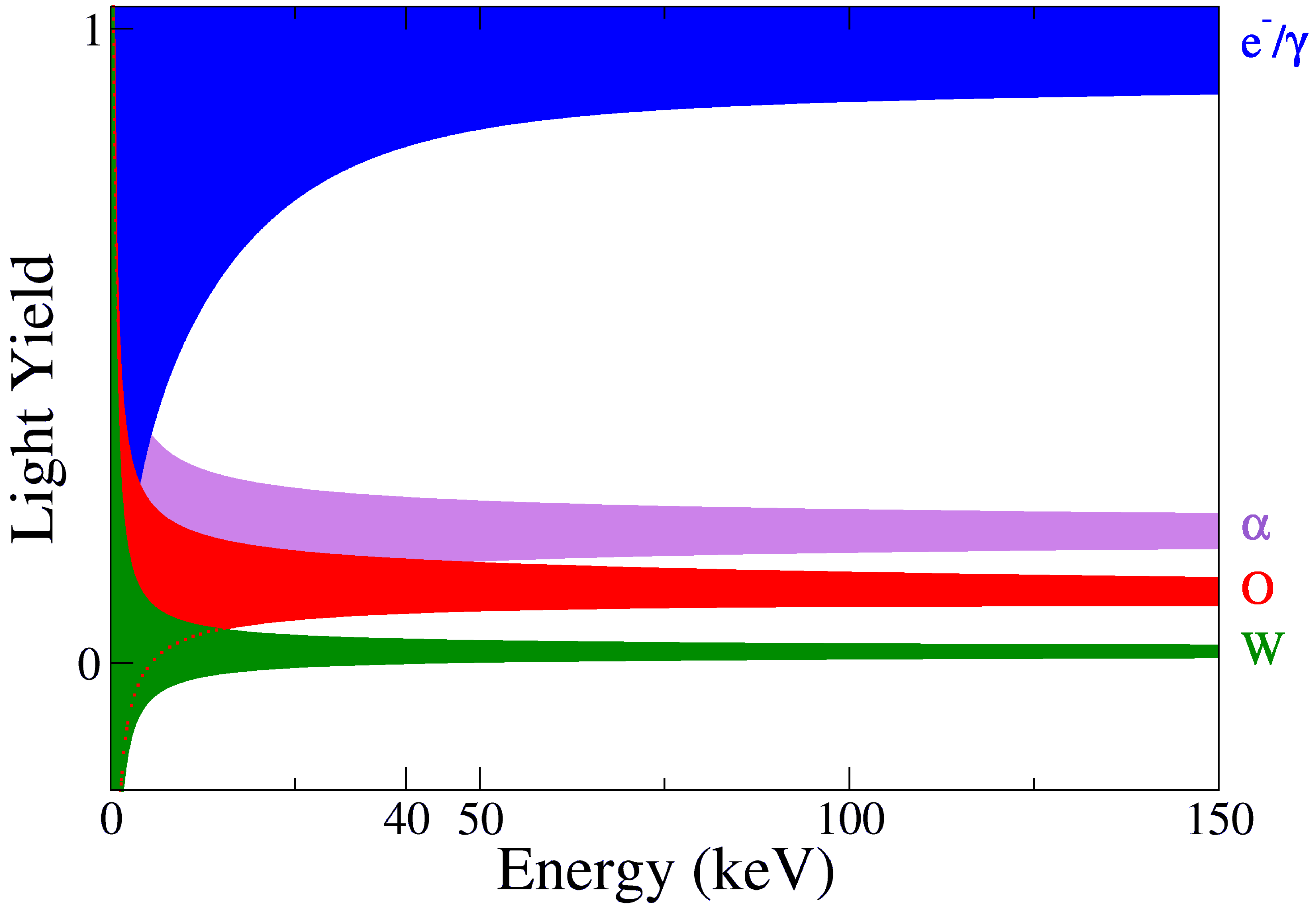
Simultaneous signals from the transition edge sensors (TESs)

EVENT DISCRIMINATION

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

Characteristic of the event type

Excellent discrimination between potential signal events (**nuclear recoils**) and dominant radioactive background (**electron recoils**)



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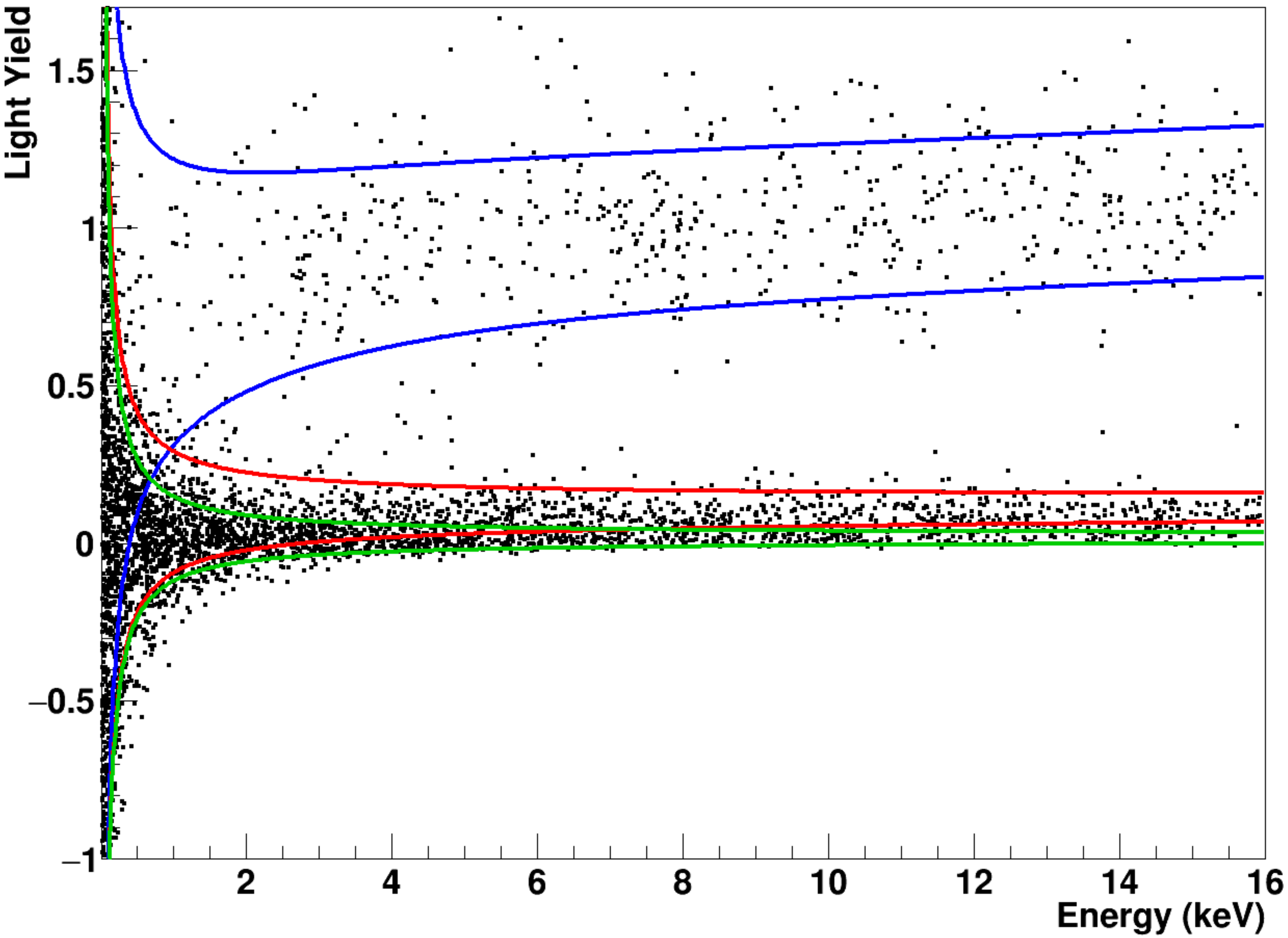
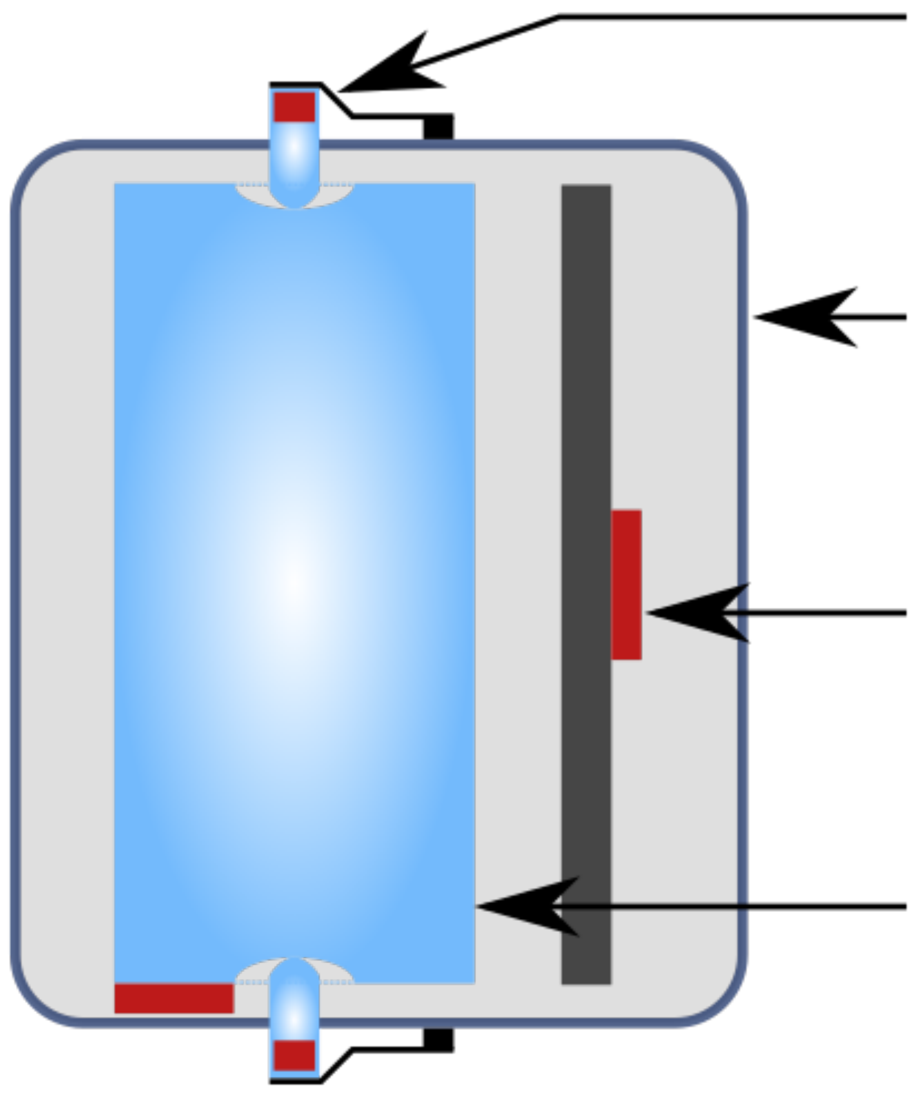


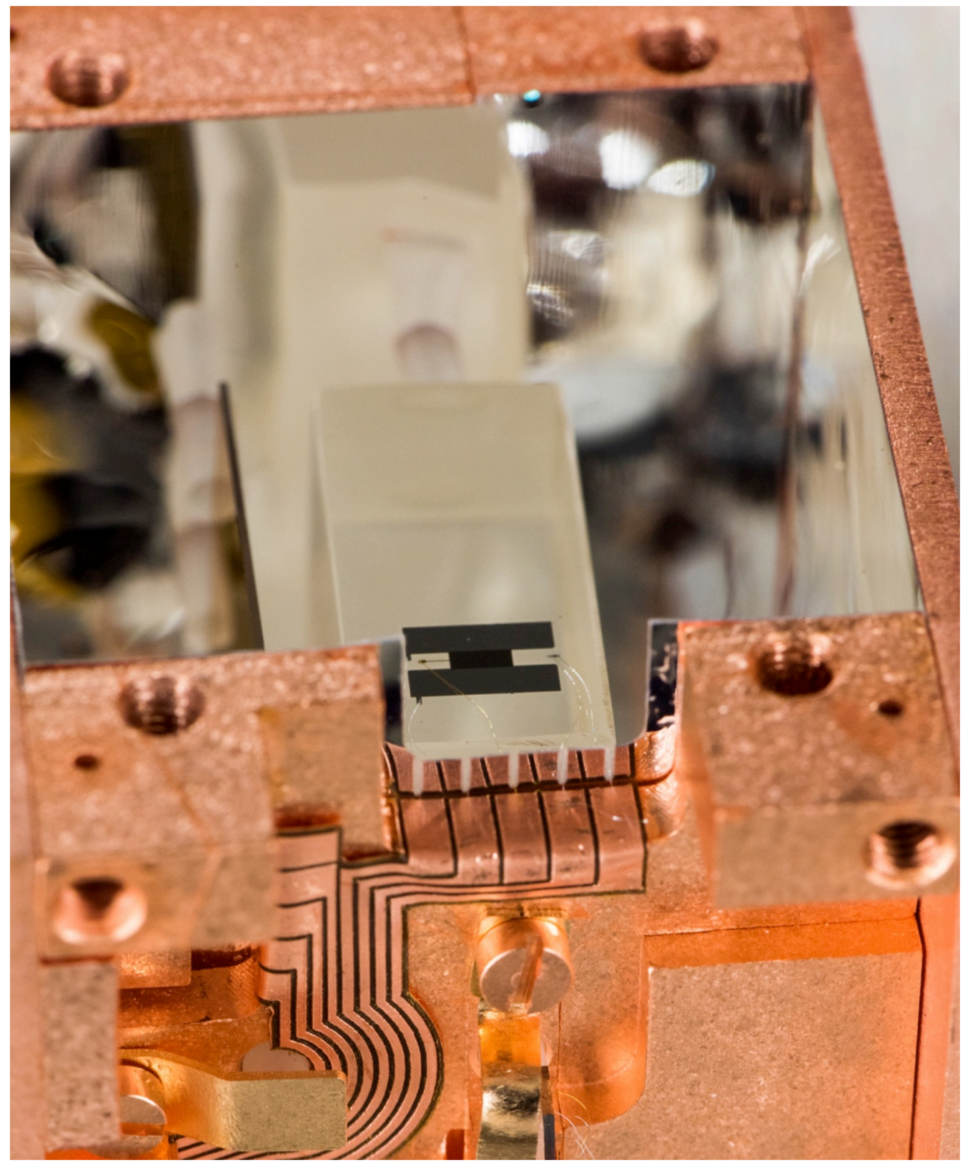
CRESST-III: LOW-THRESHOLD DETECTORS

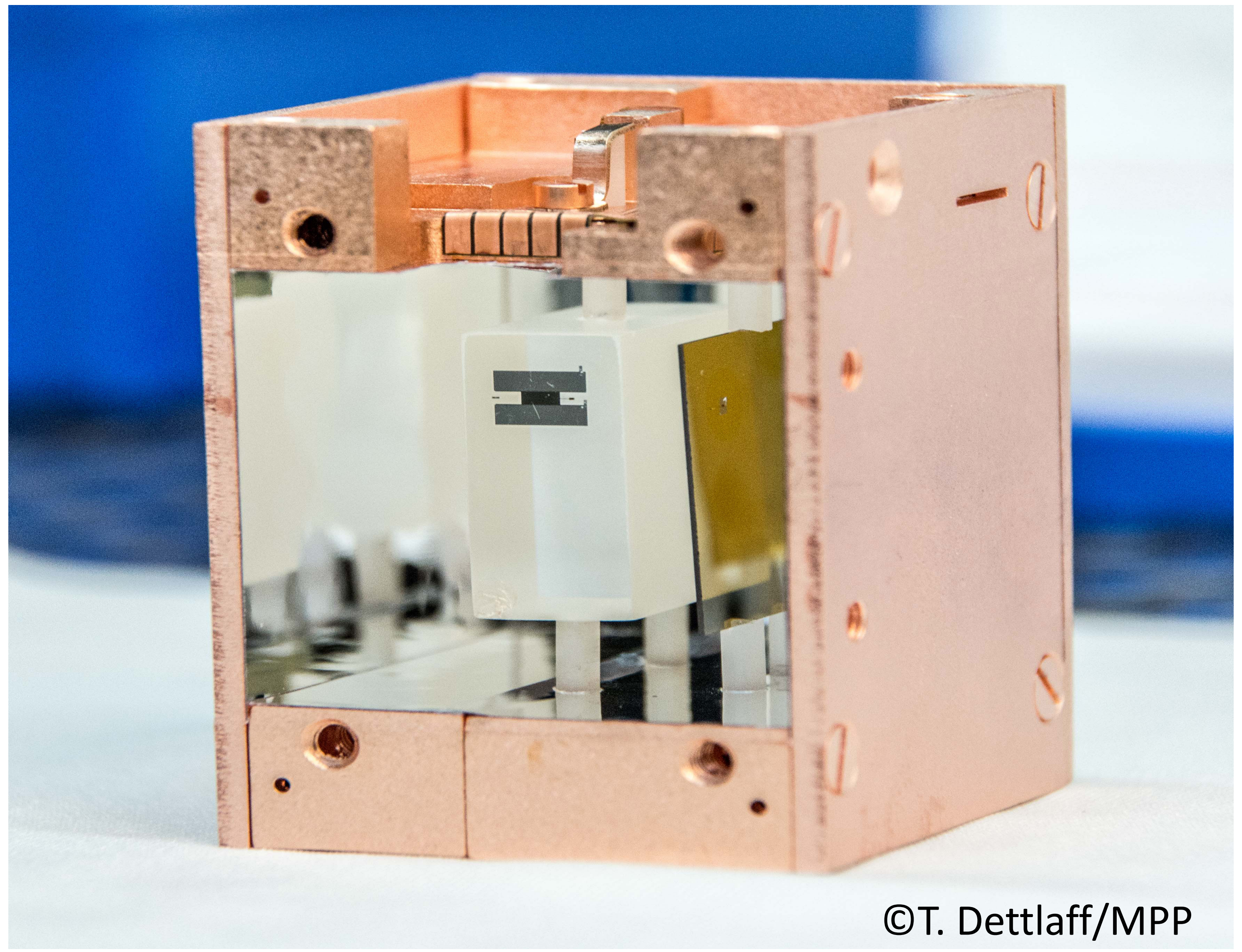
Detector layout optimised for low-mass dark matter

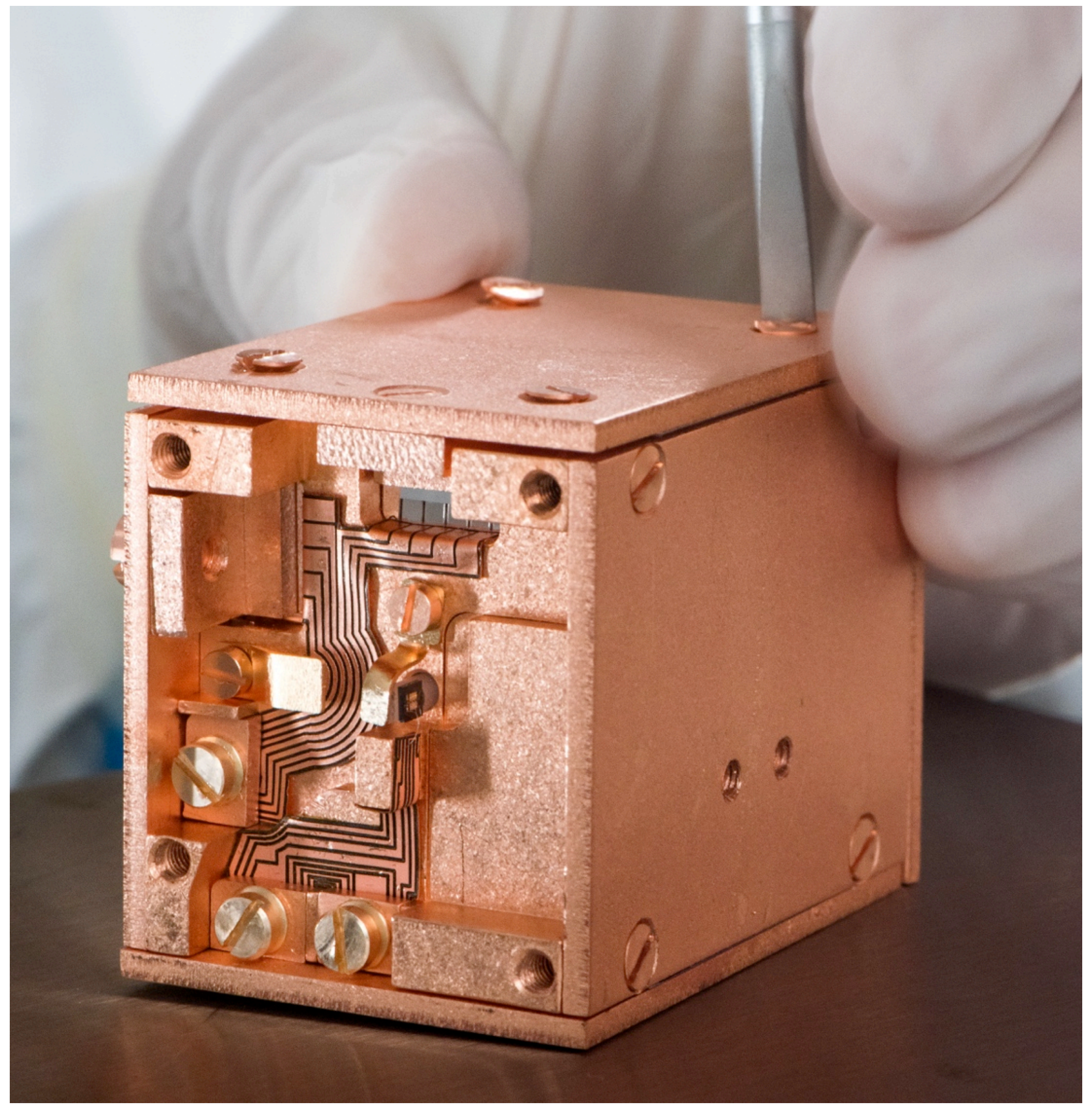
Radical reduction of dimension

- Cuboid crystals of (20×20×10)mm³ (**≈24g**)
- With self grown crystals **≈4 counts/(keV kg day)**
- Veto of surface-related background

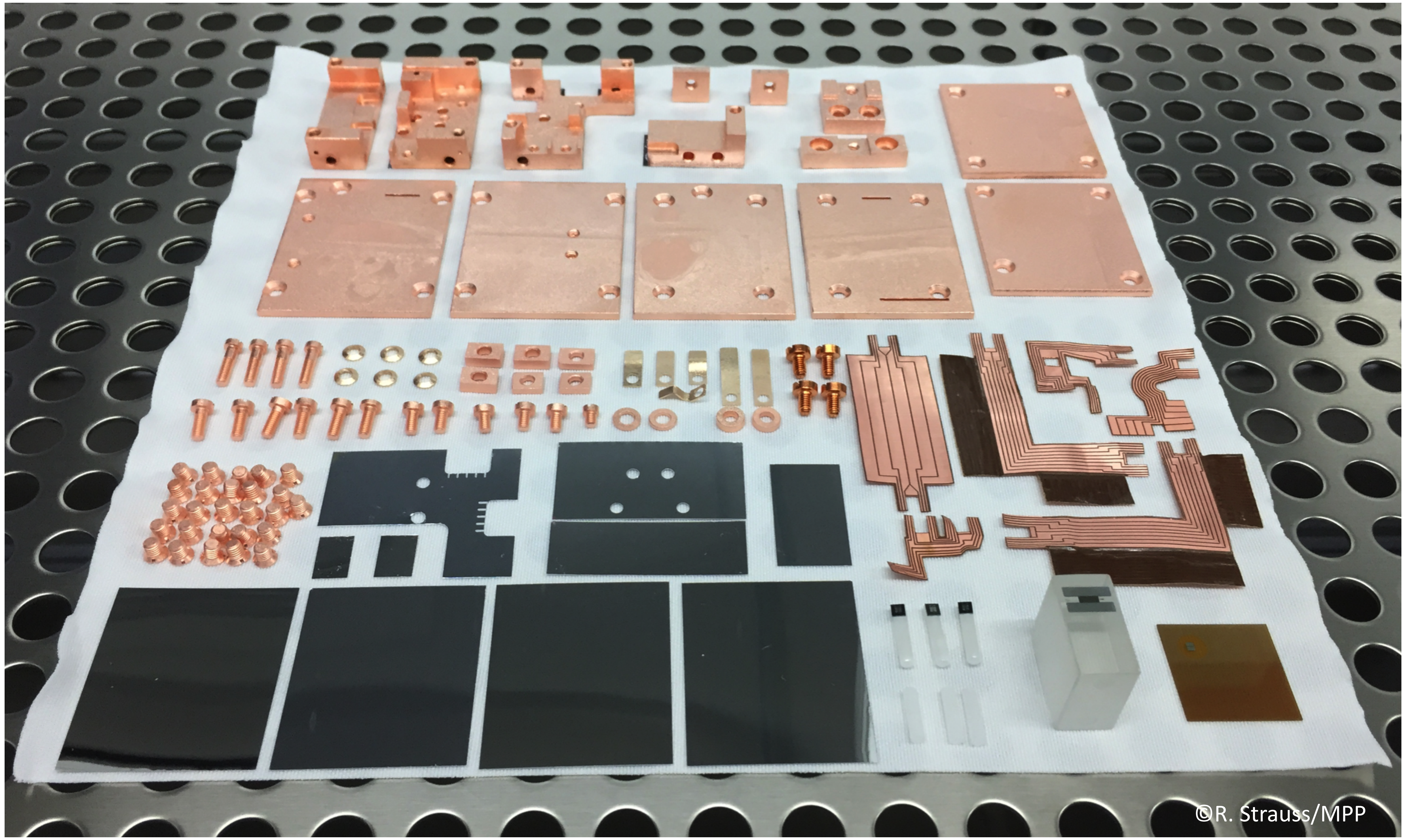


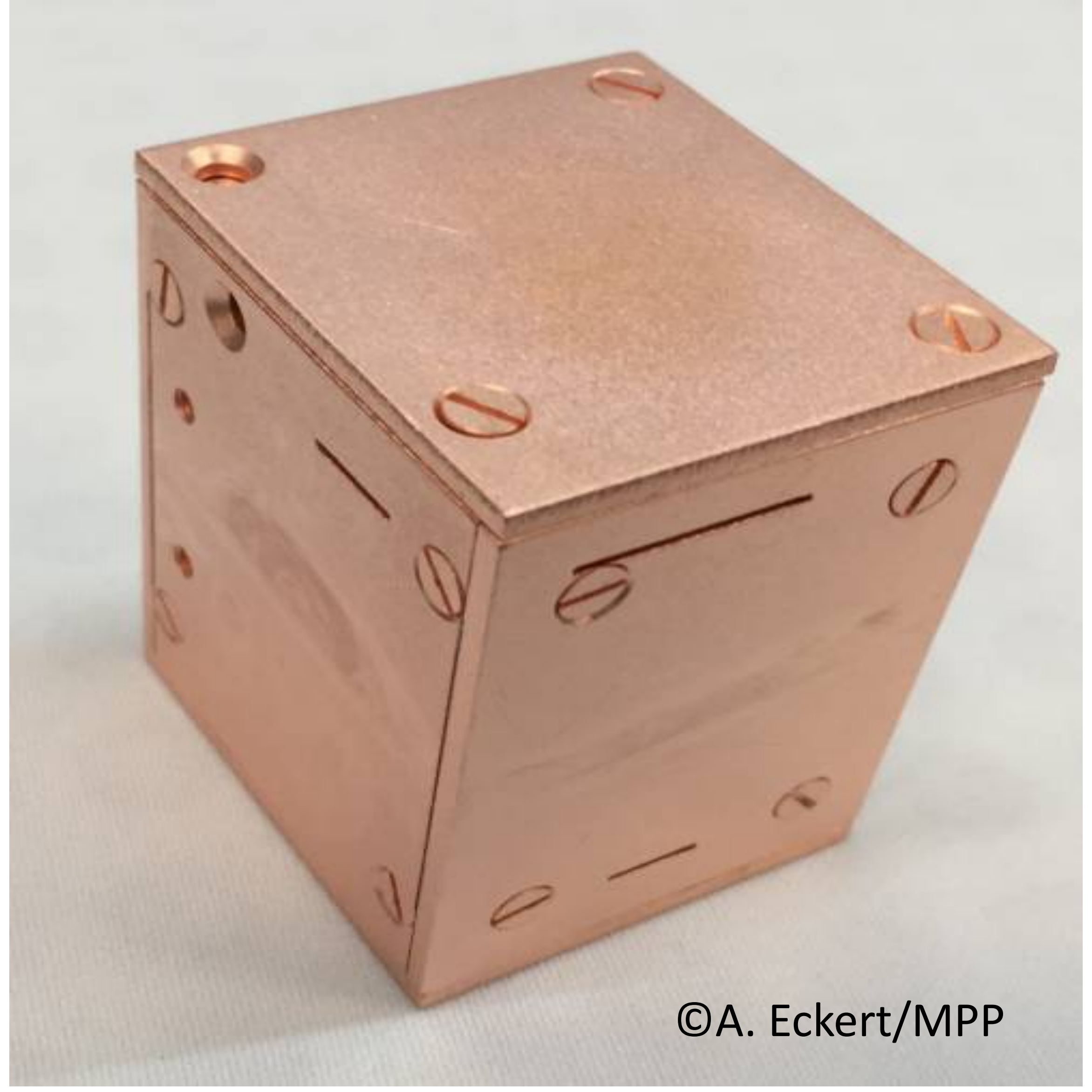


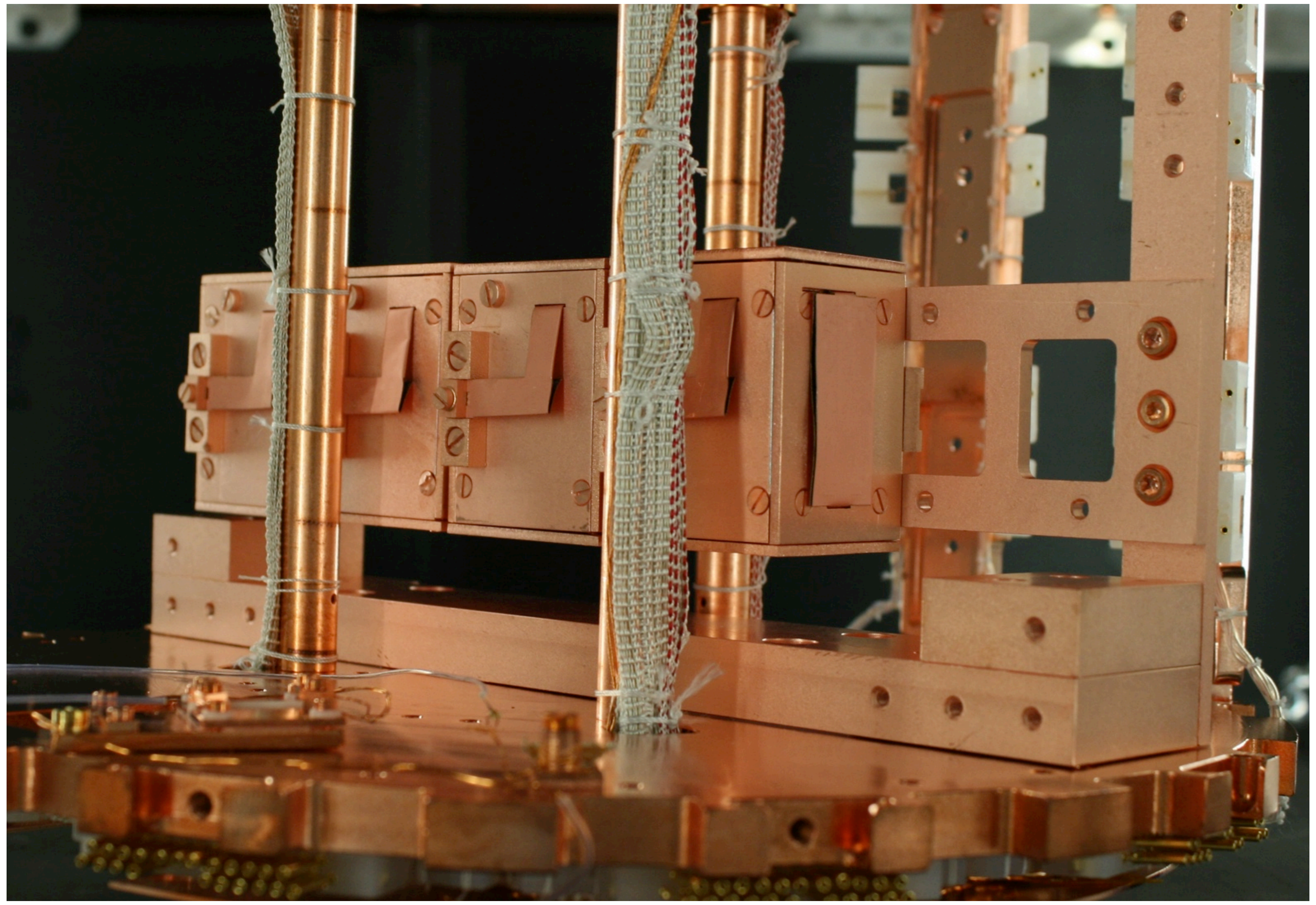




CRESST-III FIRST RUN





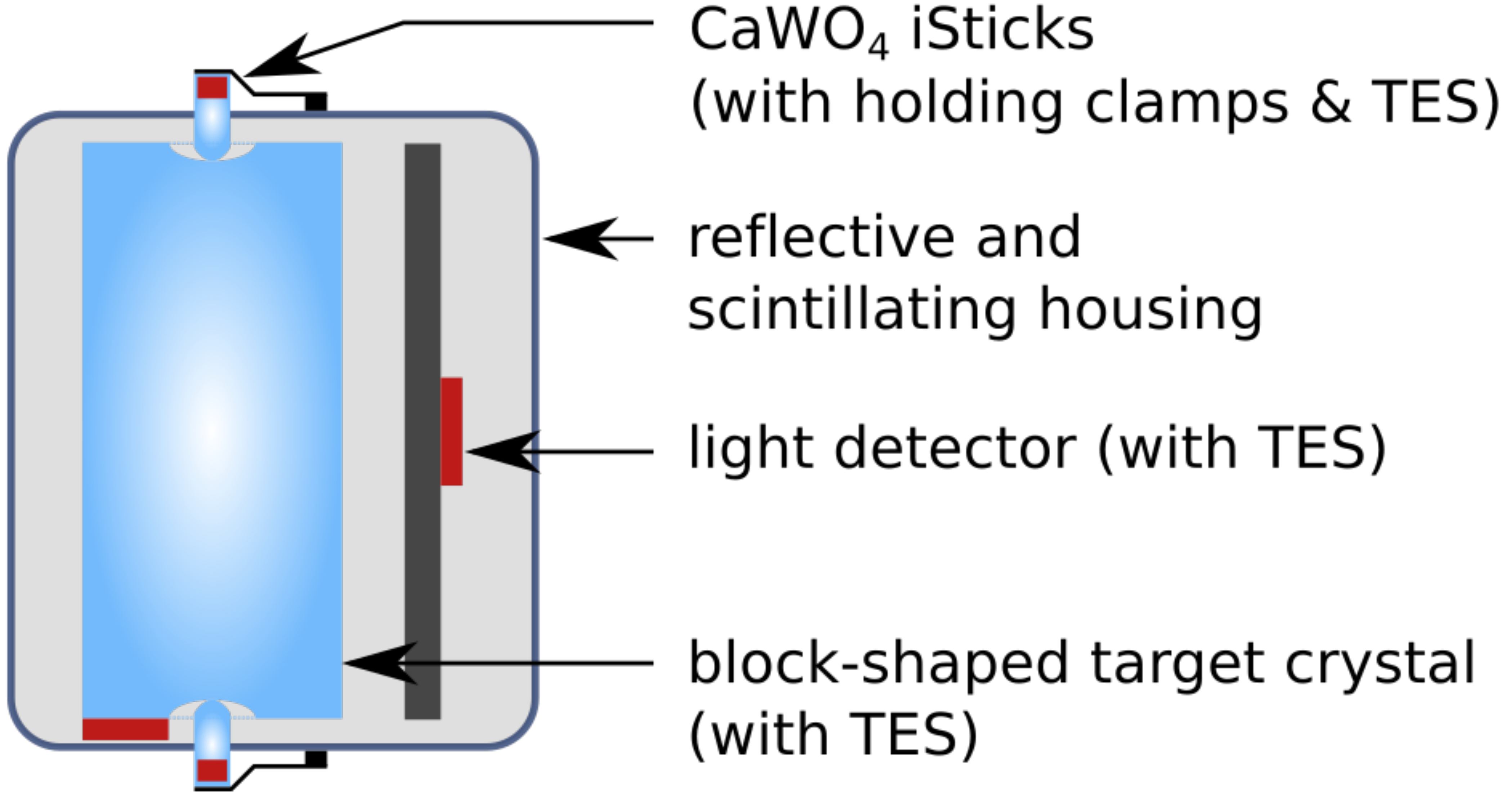


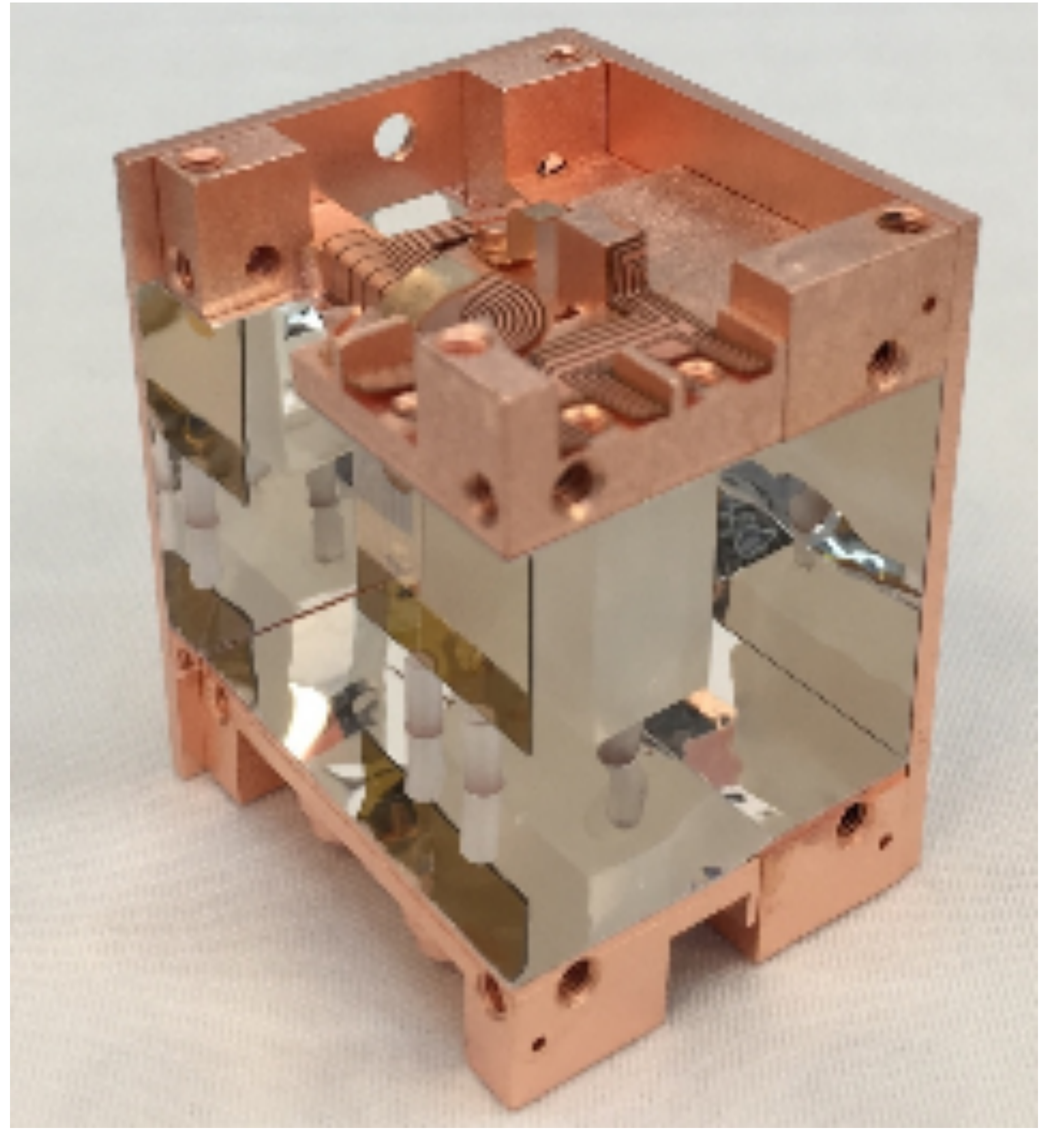
Data taking from May 2016 to February 2018

Phys. Rev.D100(2019) 10 102002

DETECTOR A

Lowest threshold in the first run of CRESST-III





Data taking period:	10/2016 – 01/2018
Non-blind data (dynamically growing):	20% randomly selected
Target crystal mass:	23.6g
Gross exposure (before cuts):	5.689 kg days
Nuclear recoil threshold:	**30.1 eV**

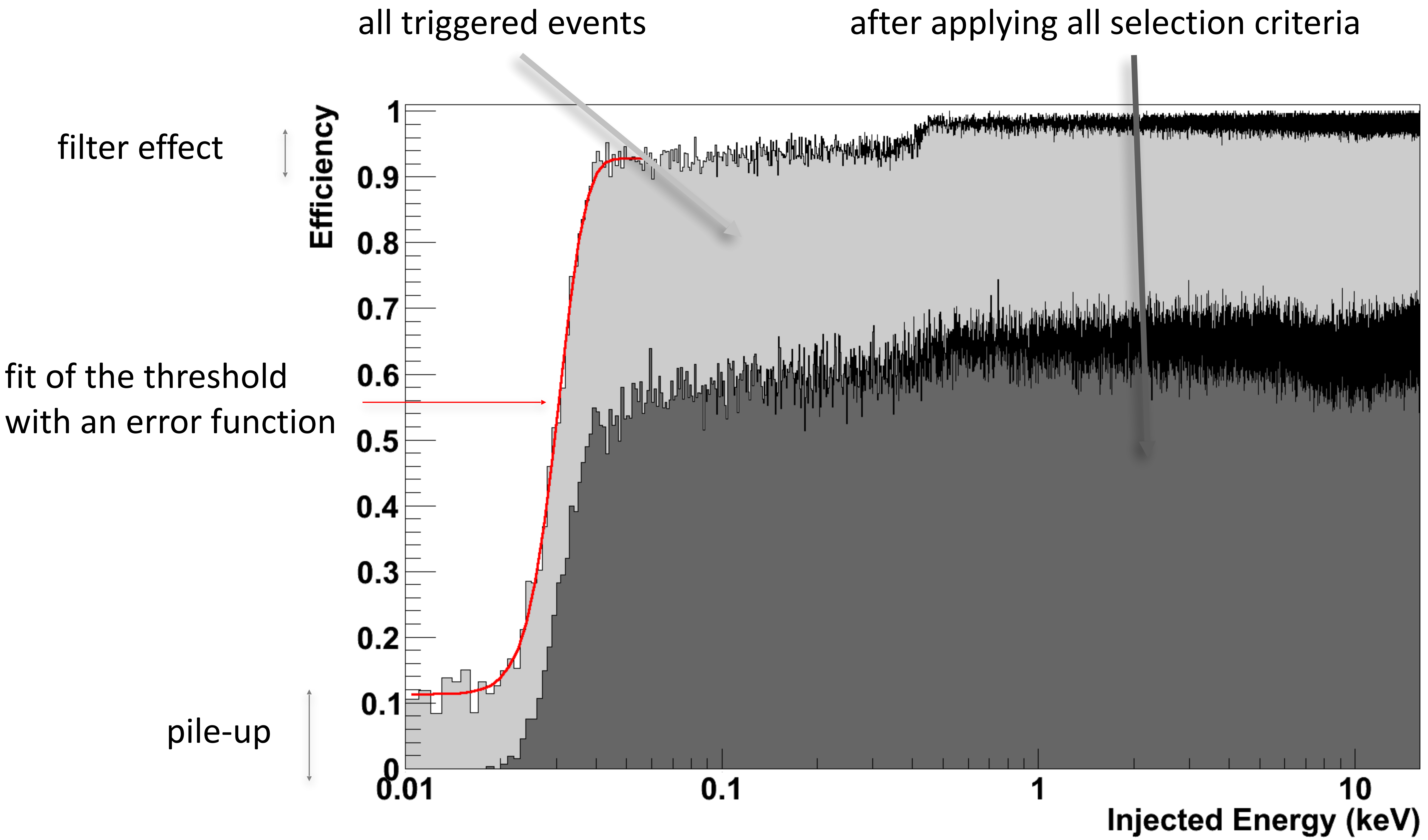
SELECTION CRITERIA

Objective
Keep only events where a correct determination of the amplitude (→energy) is guaranteed
Unbiased (blind) analysis

1. Design cuts on non-blind training set (≦20%, excluded from DM data set)
2. Apply without change to blind DM data set

Rate: noise conditions (14% of measuring time)
Stability: Detector(s) in operating point (3% of measuring time)
Data quality: Non-standard pulse shapes (e.g. i-Stick events and pileup)
Coincidences: with μ-veto (7.6% of measuring time), i-Sticks, other detector modules

EFFICIENCY/SIGNAL SURVIVAL PROBABILITY



Simulated by artificial pulses placed at random positions in the data stream

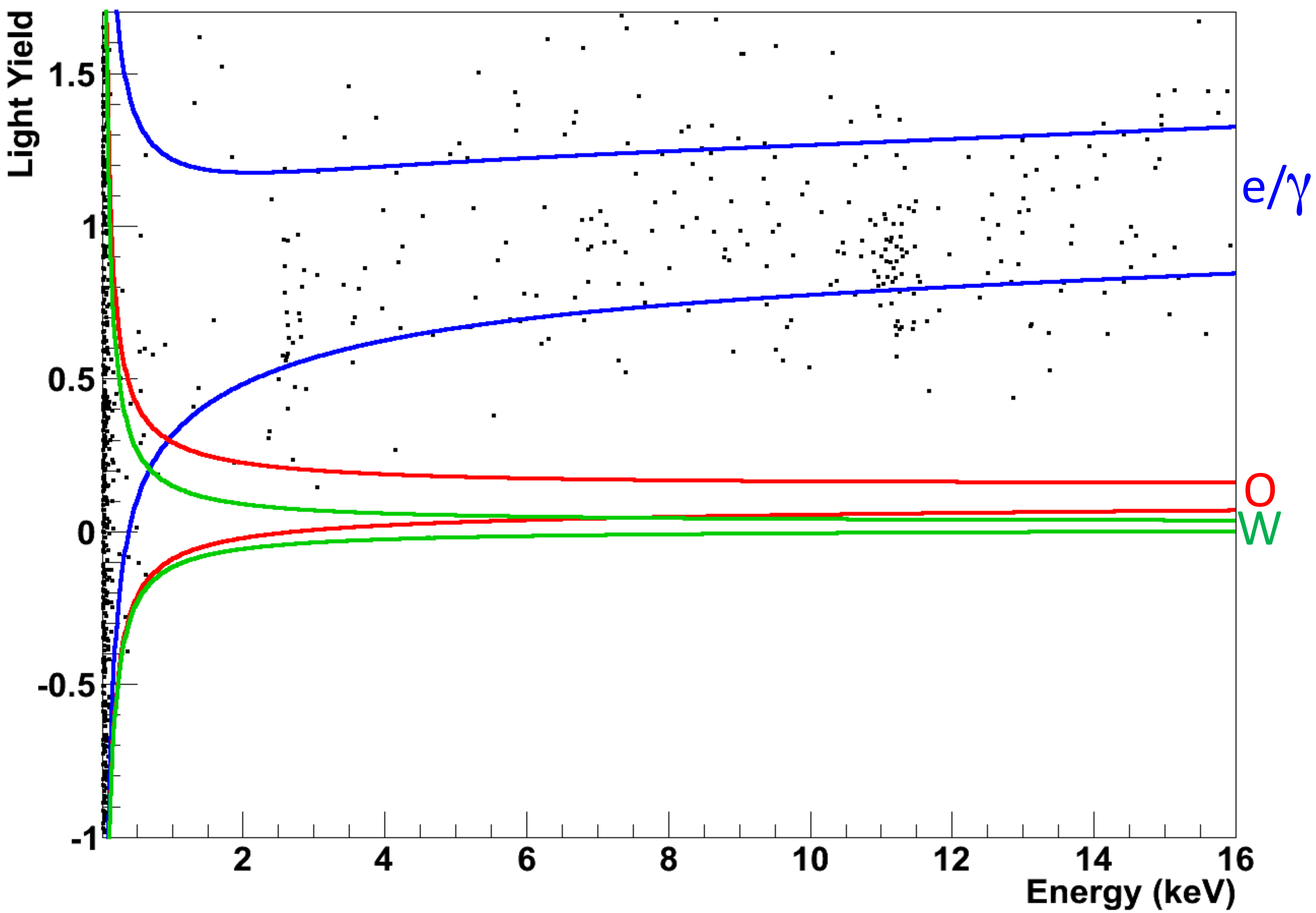
Includes trigger and cuts

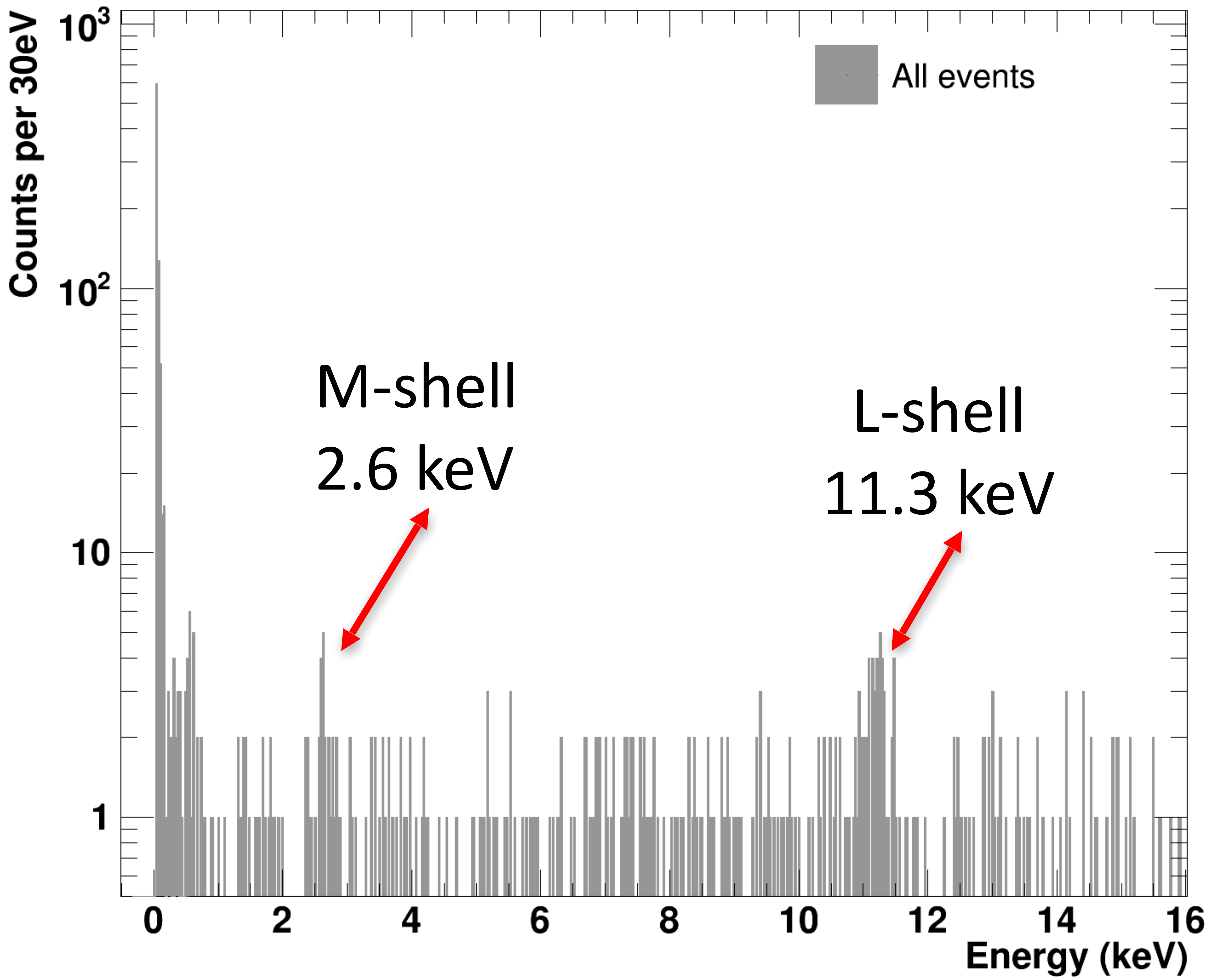
≳60% efficiency over broad energy range

DARK MATTER DATA

Analysis optimized for very low energies: 30eV → 16keV

Cosmogenic activation → ^{179}Ta + e^{-} → ^{179}Hf + ν_e (1.8y)





DARK MATTER DATA

Analysis optimized for very low energies: 30eV → 16keV

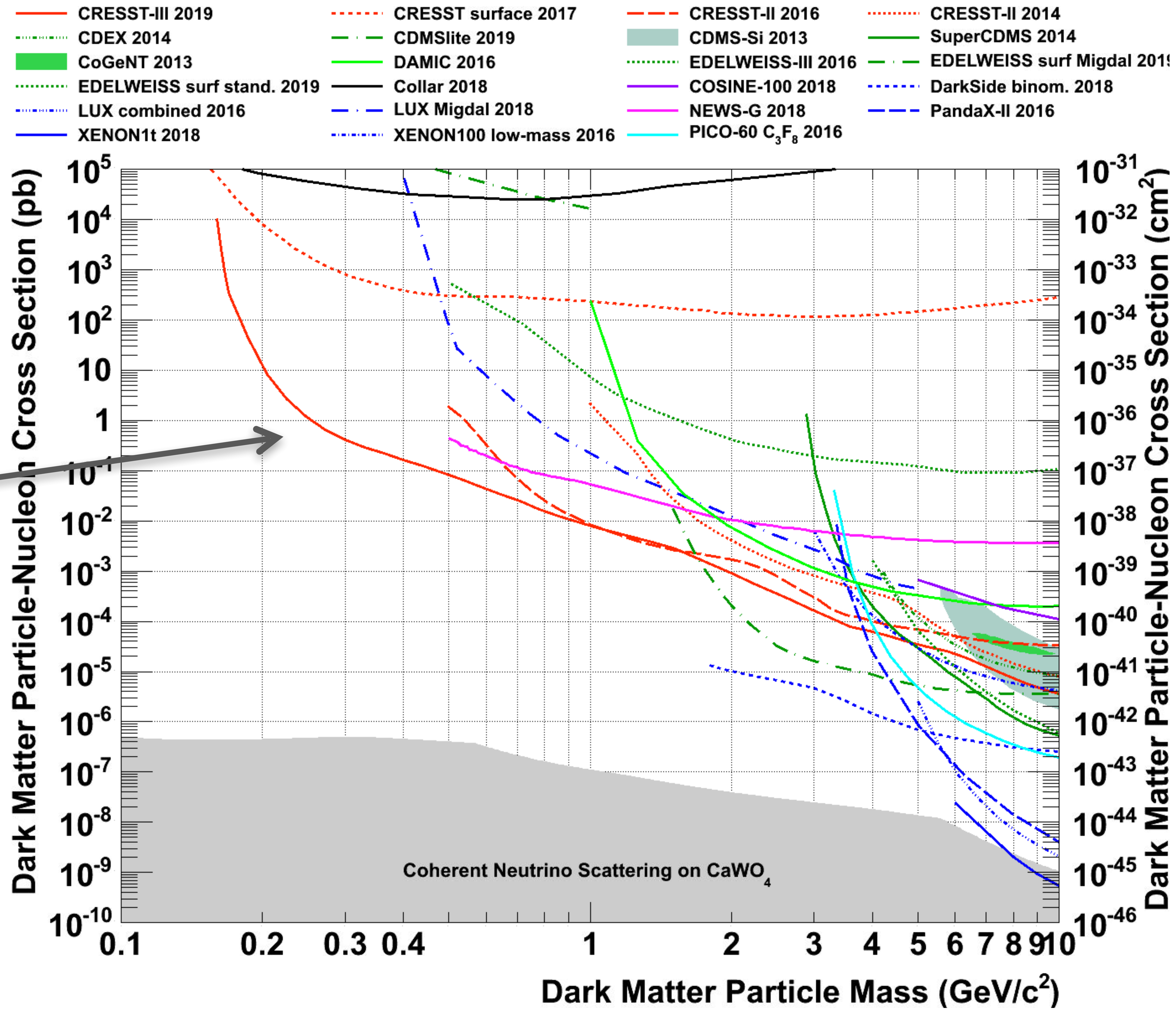
Acceptance region fixed before unblinding

FROM ACCEPTED EVENTS TO DARK MATTER LIMITS

Energy spectrum of accepted events

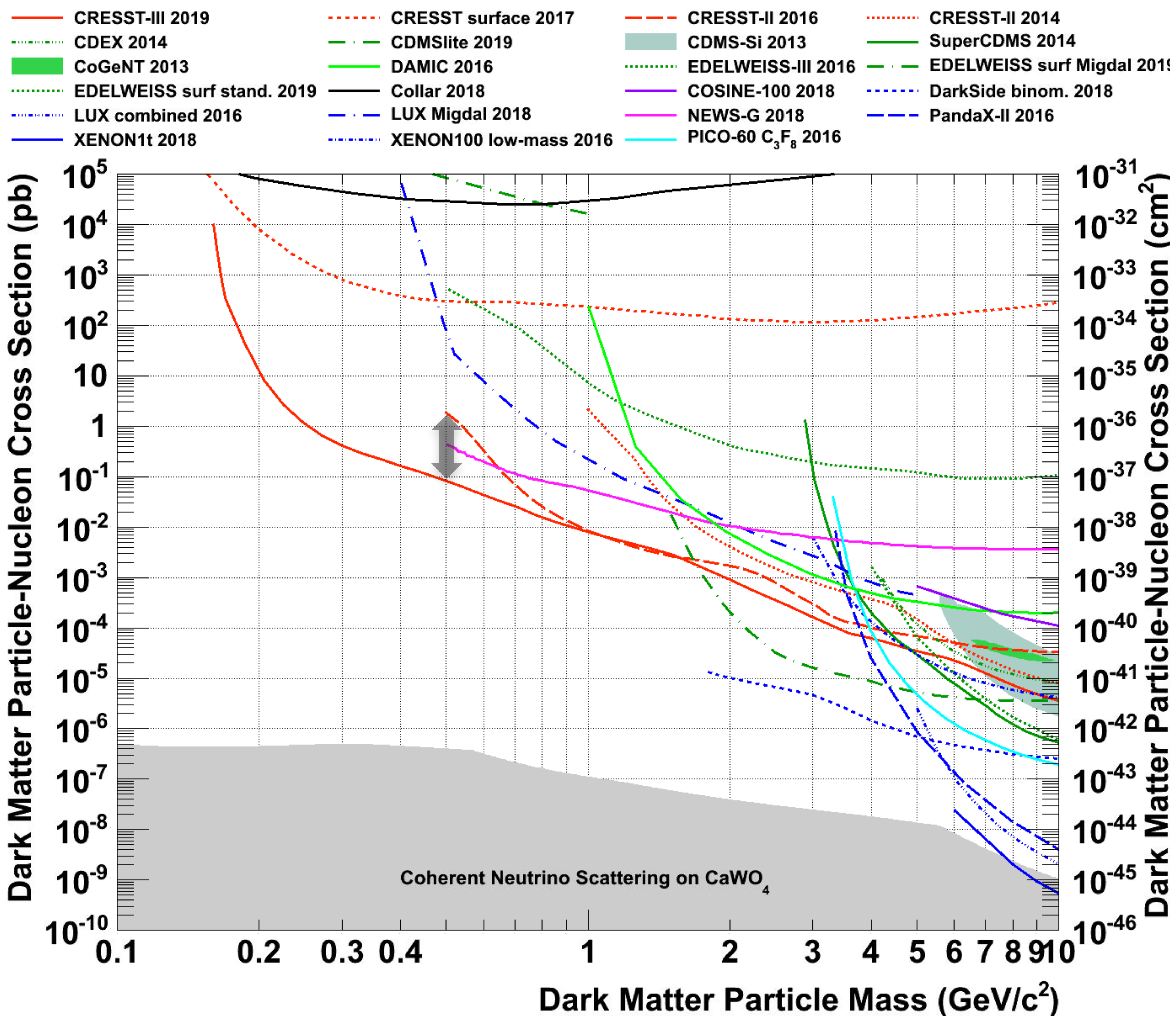
Yellin one dimensional optimum interval method

Simulated dark matter energy spectrum



RESULTS

- More than one order of magnitude improvement at 0.5 GeV/c²



RESULTS

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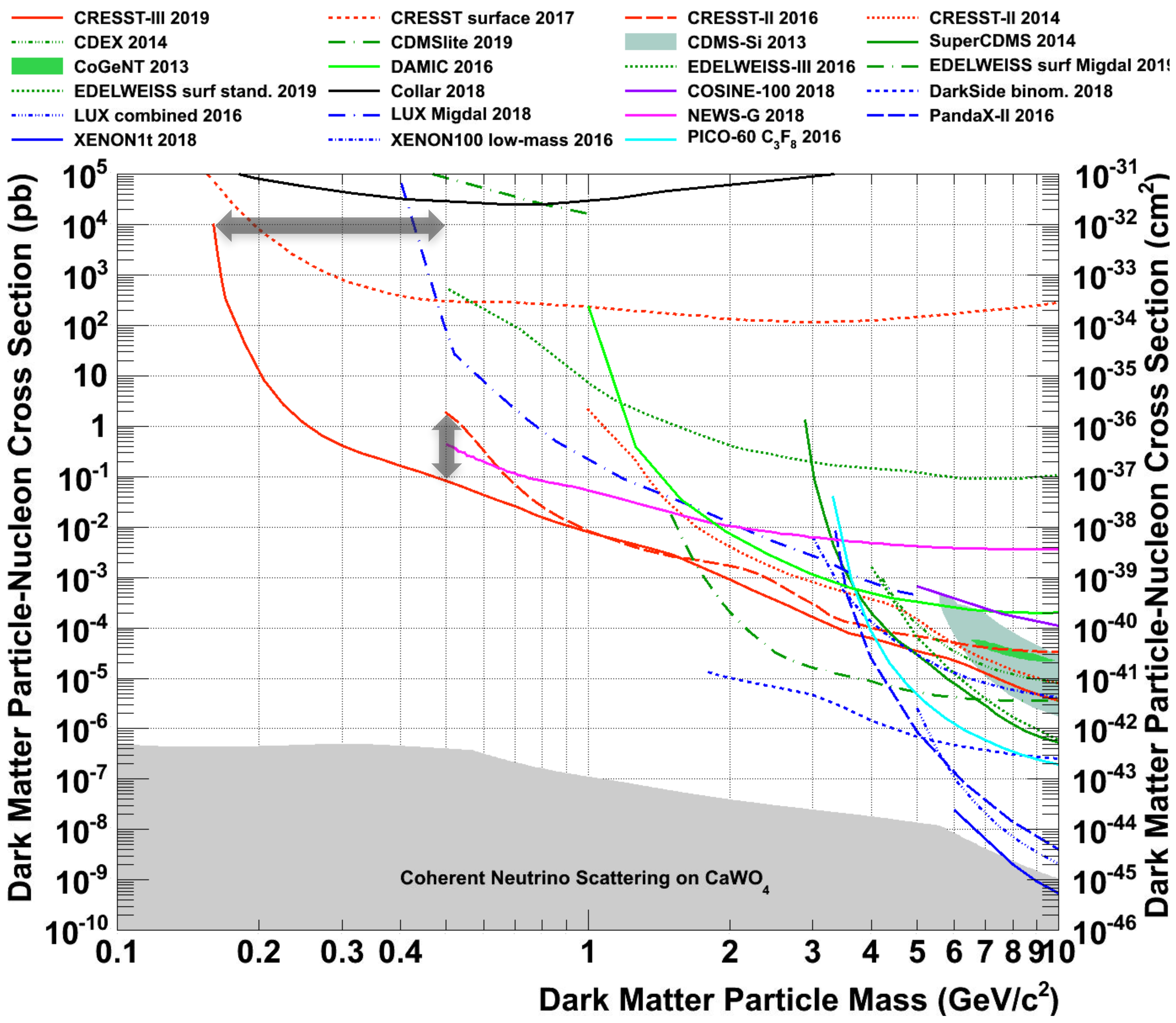
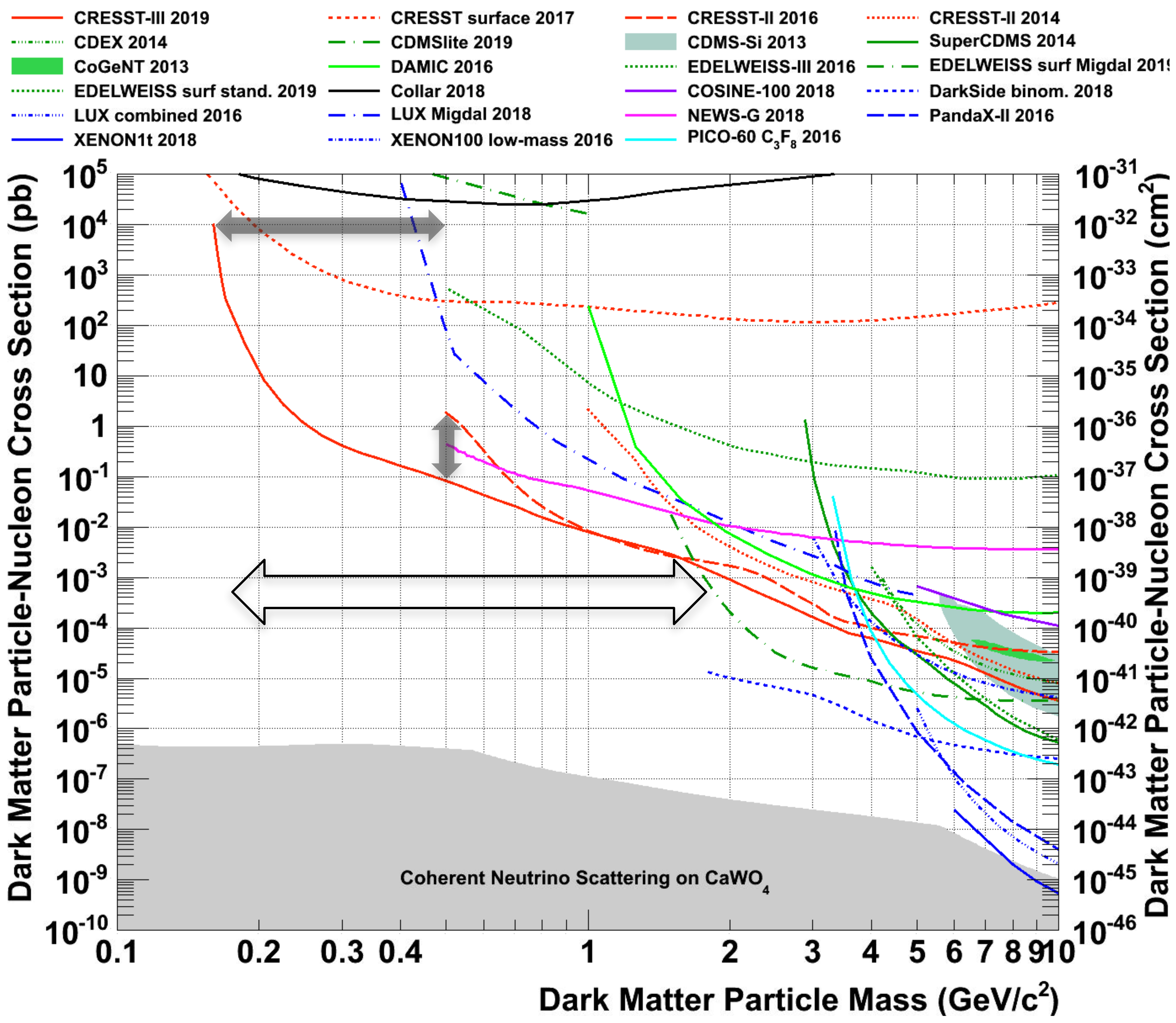
- Extended reach from 0.5GeV/c² to 0.16GeV/c²



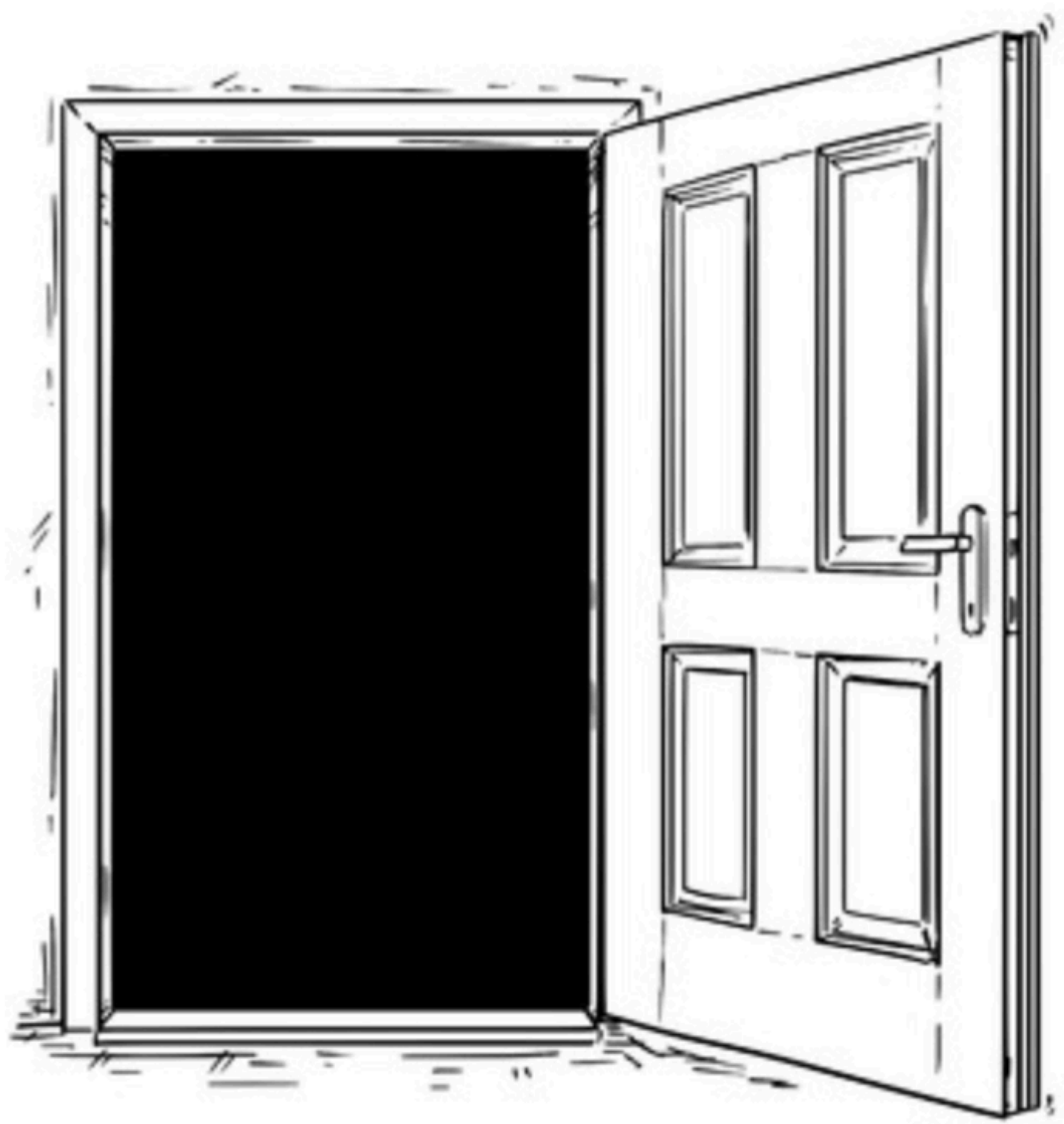
RESULTS

- More than one order of magnitude improvement at 0.5 GeV/c²
- Extended reach from 0.5GeV/c² to 0.16GeV/c²
- Unexpected rise of event rate < 200eV

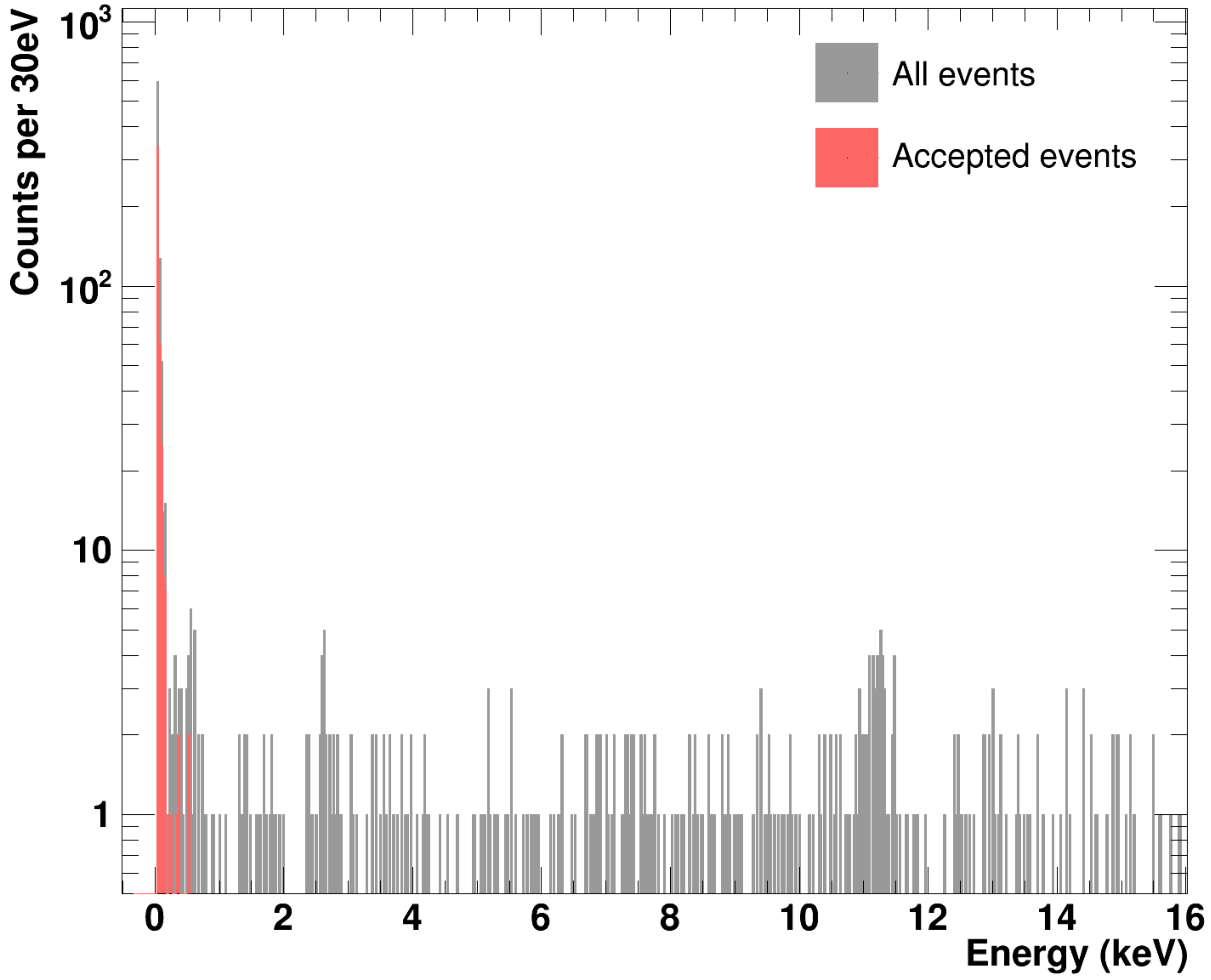


Unexplained low energy background:

- we explore regions never probed before
- we see a background never observed before



THE EVENT RISE



Present in different detectors, but spectral shape not compatible with one single common origin

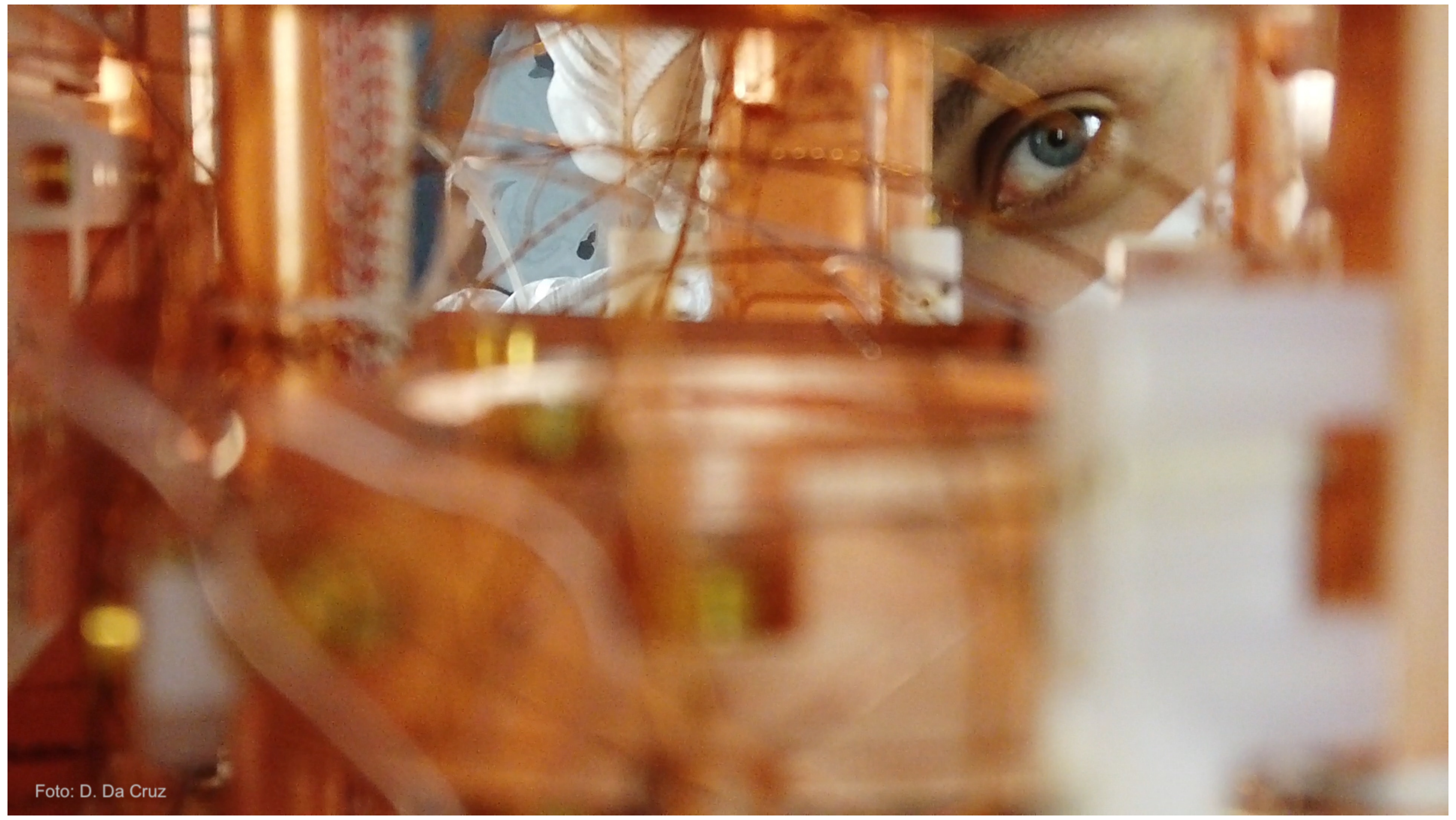
To pinpoint its origin we prepared dedicated setups with hardware modifications to disentangle the different contributions to be installed in the CRESST cryostat

- Crystal material
- Crystal surface
- Holding
- Facing surfaces
- ...

What happens below 100eV?
Cross checks with other low threshold experiments will be very interesting.

Understanding the rise

New CRESST-III runs ongoing to look into the origin of the background



- Assembly @ LNGS concluded mid February 2020
- Cooldown started February 17th with detectors operational on the fourth week of February – Terrible timing
- March 12th 2020 we had to stop the run and put the apparatus in safe conditions
- July new cooldown started
- From August detectors commissioned and calibrated
- Since November 5th 2020 collecting dark matter data!
  - First preliminary analysis of calibration data → very promising
  - Collecting (blind) exposure

THE CRESST III PROGRAM

Upgrade of CRESST-III to read-out 288 channels

2021

- Final planning, prototyping and testing of :
  - SQUID read-out electronics
  - wiring
  - biasing system and DAQ
- Detector R&D:
  - lower threshold
  - complementary materials
  - high production rate

2022

- Upgrade of the setup at LNGS
- Production and testing of detectors

2023

- Restart data taking

Proceeding a little slower than planned….

New frontiers. New potential.
New challenges…