EUROPEAN PHYSICAL SOCIETY
HEP2025
MARSEILLE

The CRESST experiment for Light Dark Matter Search

Stefano Di Lorenzo

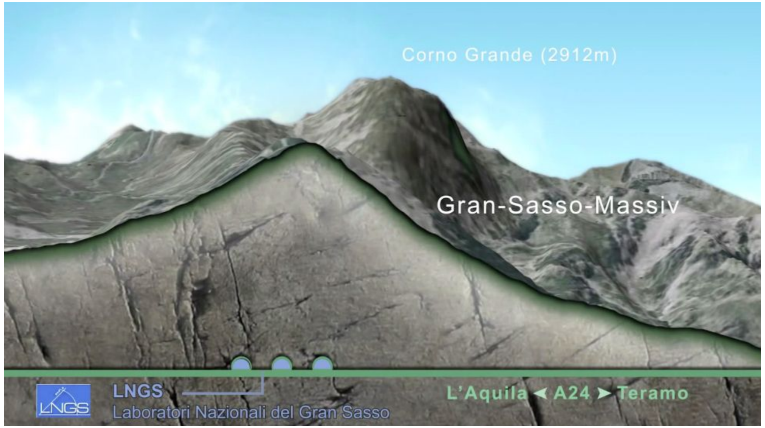
Max Planck Institute for Physics

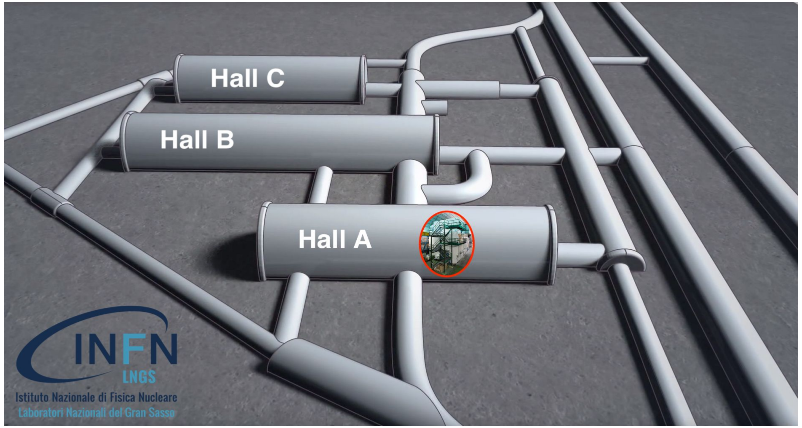
MAX-PLANCK-GESELLSCHAFT

CRESST

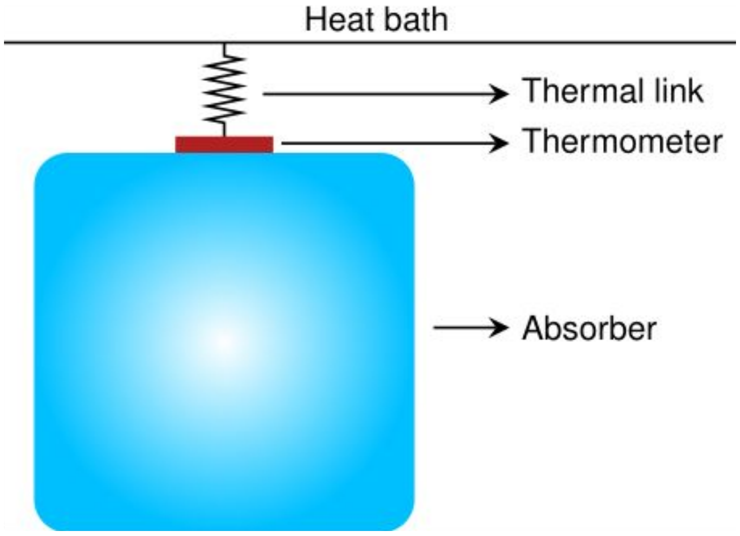
The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometersis located at the Laboratori Nazionali del Gran Sasso. Rock overburden ~1400m in all directions (3800 m.w.e)

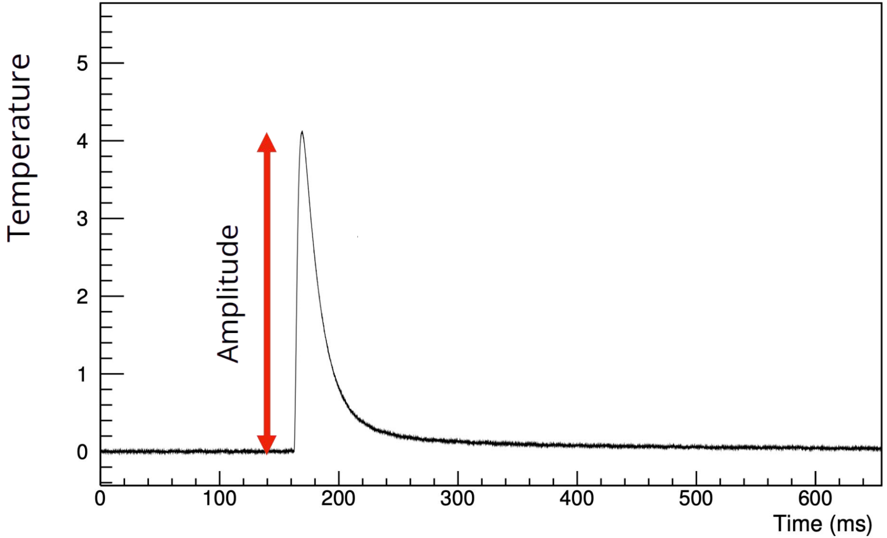




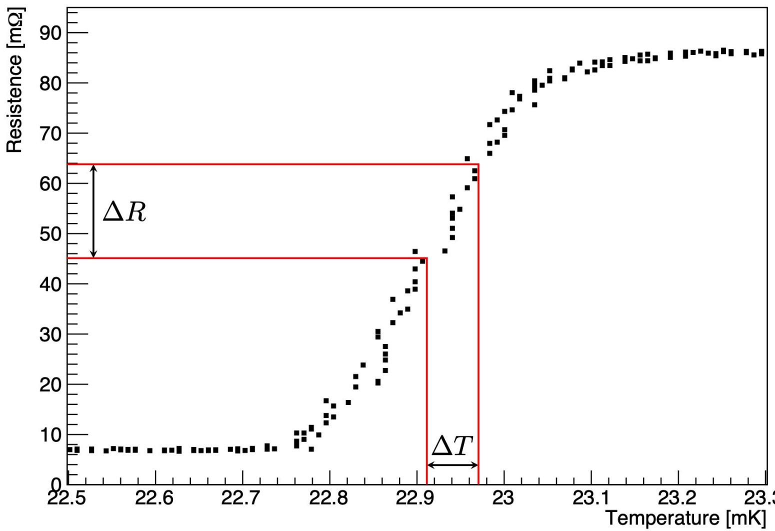
The CRESST experiment

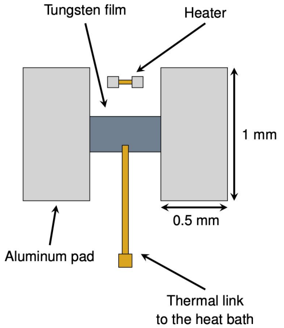


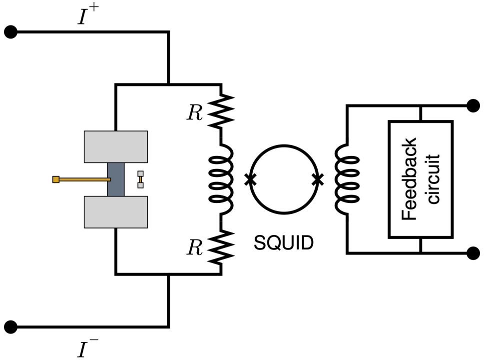
CRESST goal: direct detection of dark matter particles via their scattering off target nuclei in cryogenic detectors, operated at ~15 mK



Transition Edge Sensors







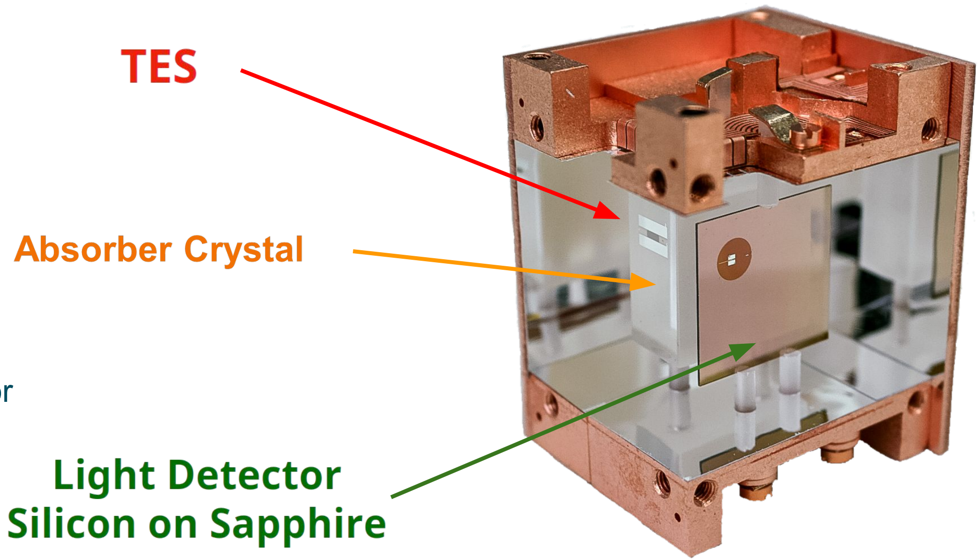
E~keV ⇒ T~μK ⇒ R~mΩ

CRESST Detector

CRESST standard detector are made by scintillating crystal as main absorber paired with a Silicon on Sapphire wafer as Light detector.

Advantages

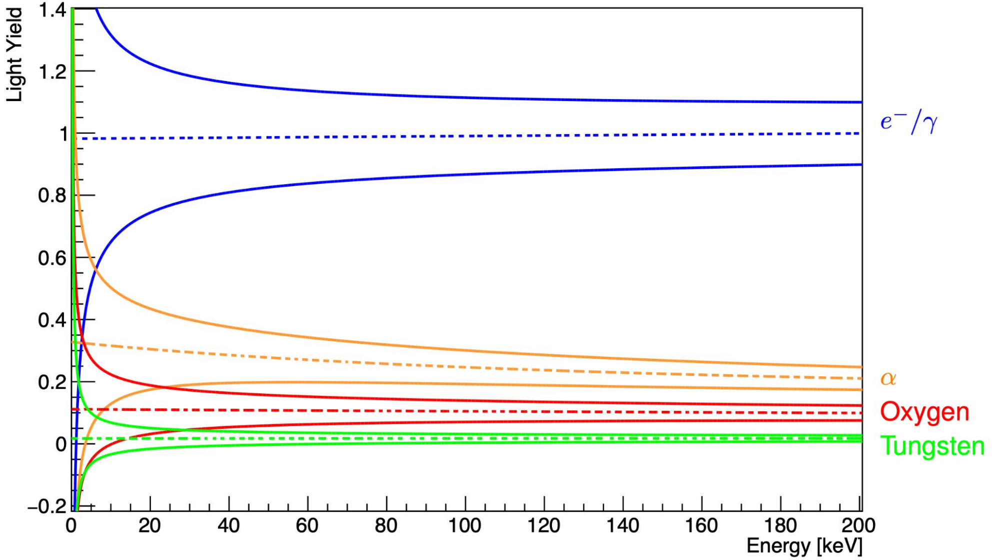
- Precise energy measurement
- Particle Identification thanks to the light detector
- Possibility to use different targets (Al_2O_3,$LiAlO_2$,$CaWO_4$)
- Low energy threshold



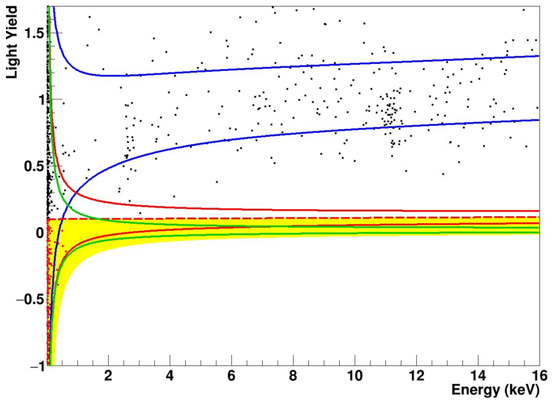
Particle Discrimination

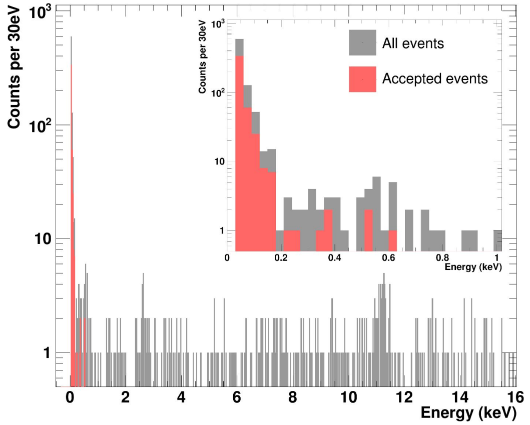
The double readout of the light and phonon signal allow to separate the dominant electron/gamma background from the nuclear recoil and define different bands.

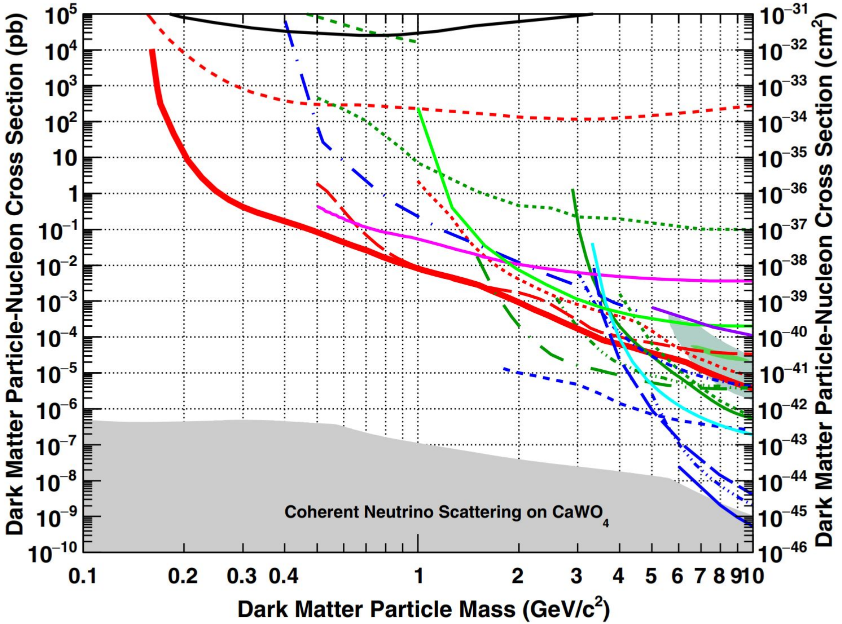
$$LY = \frac{\text{Light signal}}{\text{Phonon signal}}$$



CRESST III - First Results







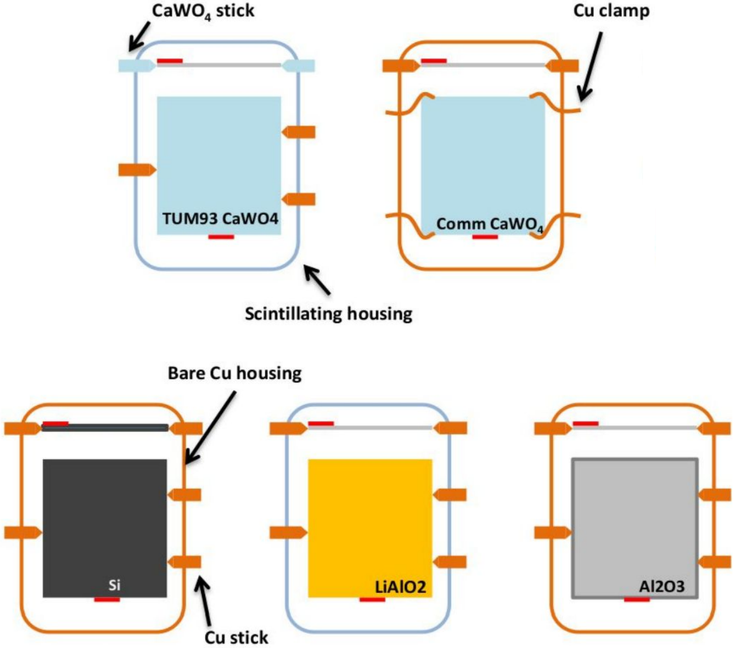
Phys. Rev. D 100, 102002

Unexpected rise of event below 200 eV
Low Energy Excess (LEE) limiting sensitivity for Dark Matter

LEE studies

Physics campaign to pinpoint the LEE

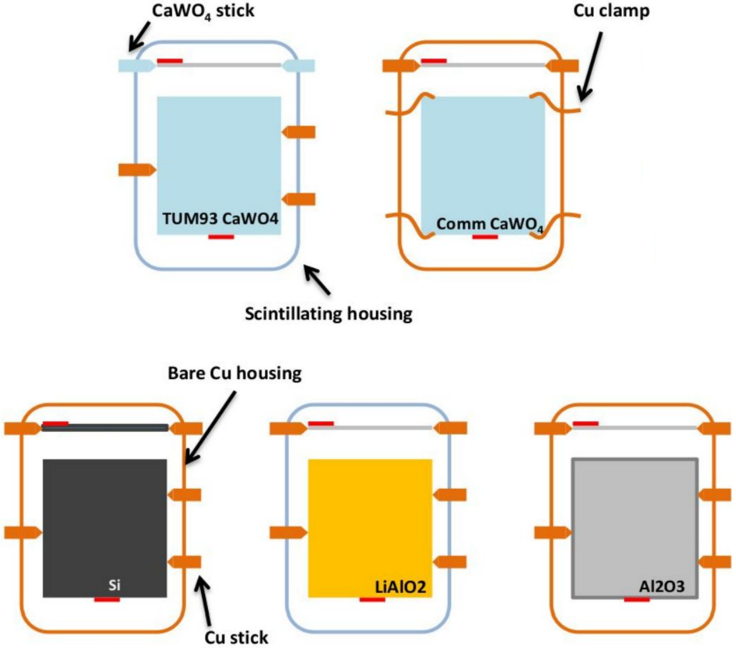
Target material?
Stress induced by holder?
Crystal growth parameters?
Scintillating material?
Geometry?



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



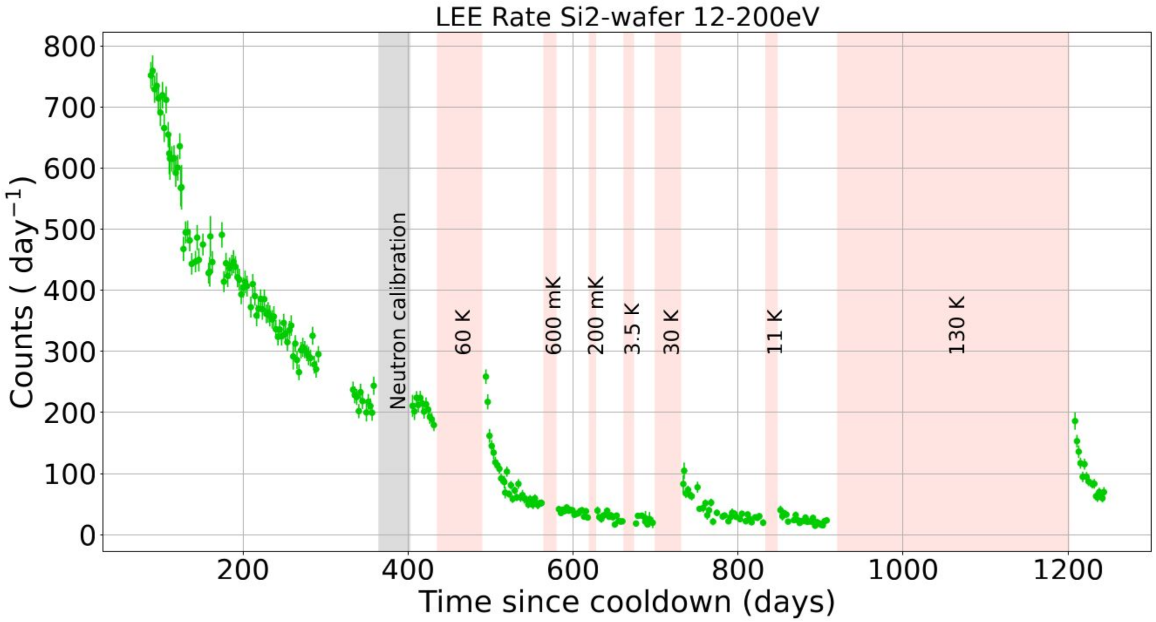
None of the modification had a significant impact on the LEE

LEE time studies

Physics campaign to pinpoint the LEE

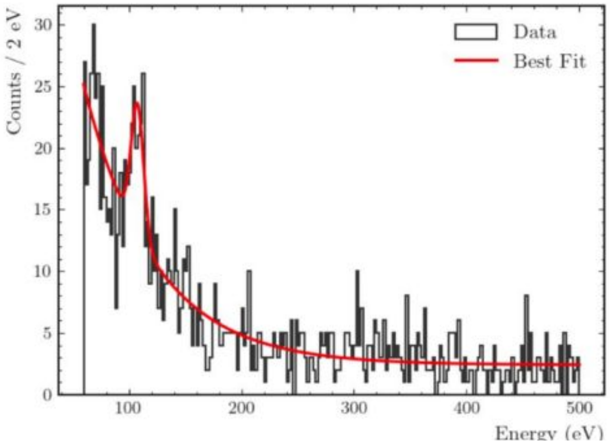
- LEE decay with time with 2 components
  - fast component ~10 days
  - slow component ~250 days
- Reset of fast component after thermal cycle
- No reset after neutron calibration

Not caused by radioactivity

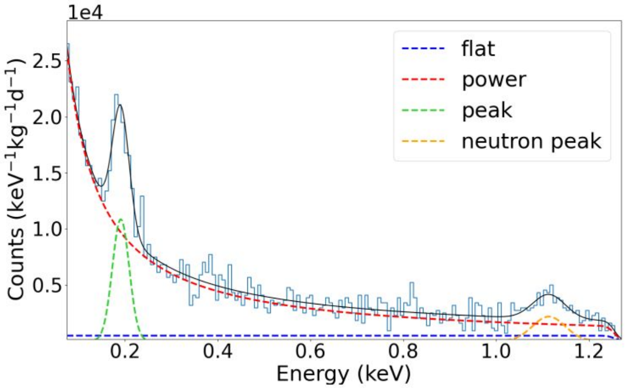


New method for low energy calibrations

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

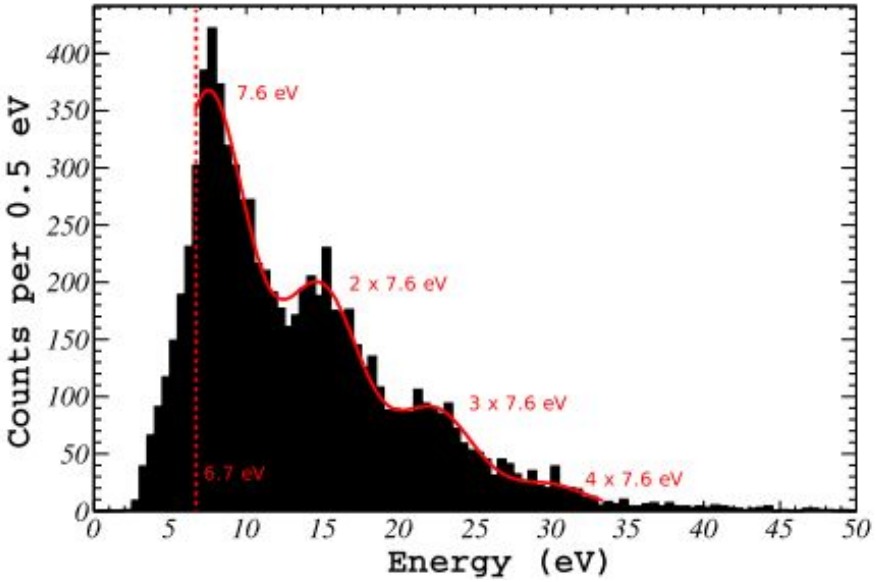
^{27}Al (n,ɣ) ^{28}Al

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

New method for low energy calibrations

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

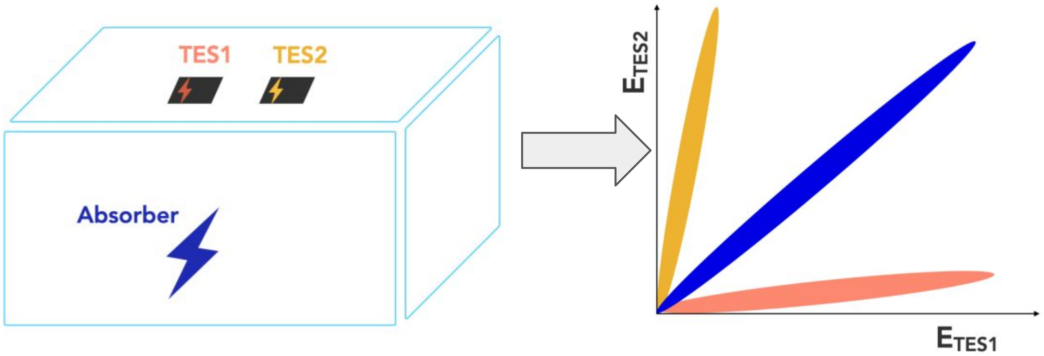


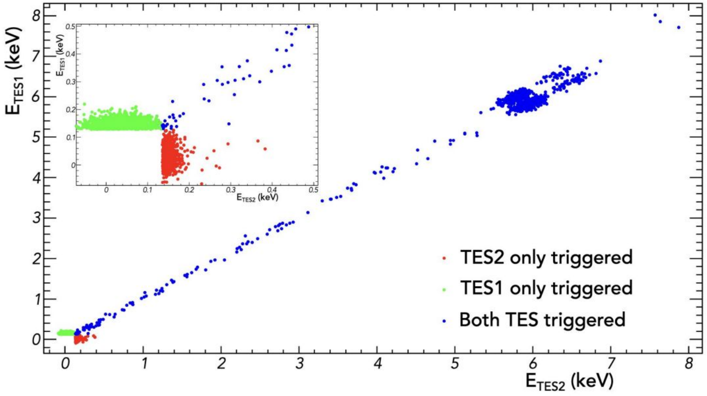
Phys. Rev. D 110, 083038

Double TES approach

Probe the LEE origin
from inside TES or from interface between TES and the crystal

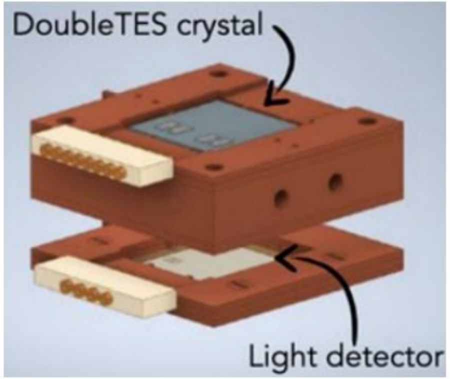
Idea
- event from the absorber are shared between the 2 TES
- event close to single TES are see only by one of the TES
- First results from above ground measurement





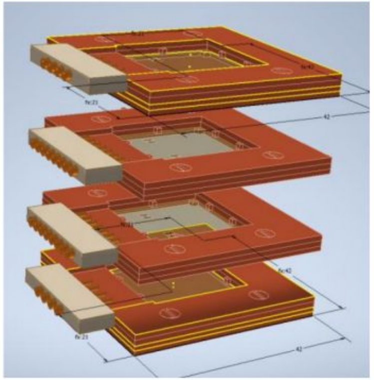
Eur. Phys. J. C 84, 1001

New detector design



5x Double TES

- $CaWO_4$ crystal 20x20x10 mm3
- Operated with two TESs
- Gravity assisted holder
- Light detector

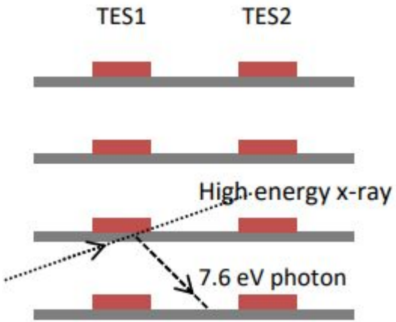


Stack

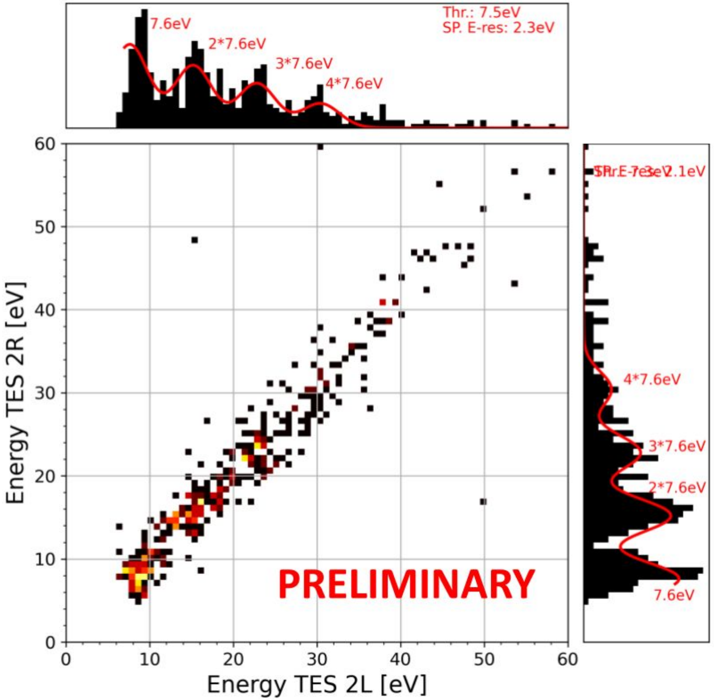
- 4x Silicon-On-Sapphire wafers 20x20x0.4 mm3
- Operated with two TESs
- Gravity assisted holder

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

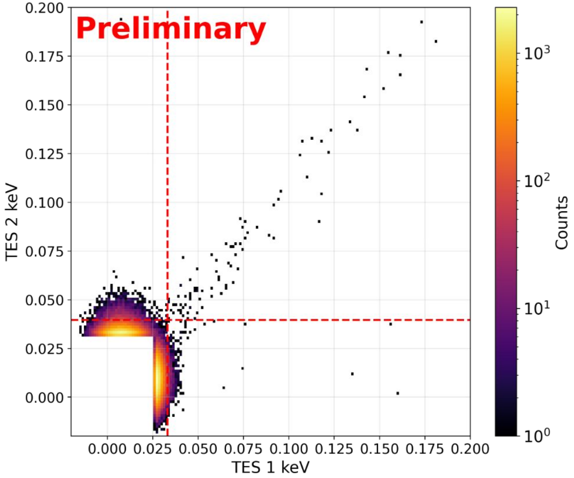


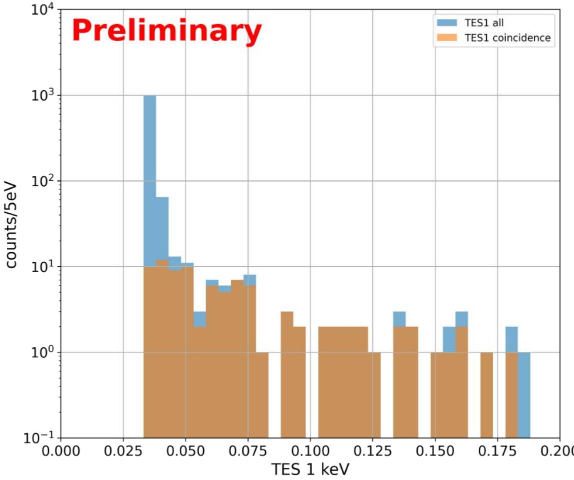
Baseline resolution TES1	Baseline resolution TES2
1.4 eV	1.14 eV
1.2 eV	1.0 eV
2.6 eV	1.7 eV
1.45 eV	3.9 eV



CRESST III - First Double TES results

#	Baseline resolution TES1	Baseline resolution TES2	LD
1	15.7 eV	-	✓
2	5.3 eV	4.9 eV	✓
3	9.7 eV	-	✓
4	-	9.4 eV	✓
5	8.1 eV	7.3 eV	✓





Reduction of the LEE

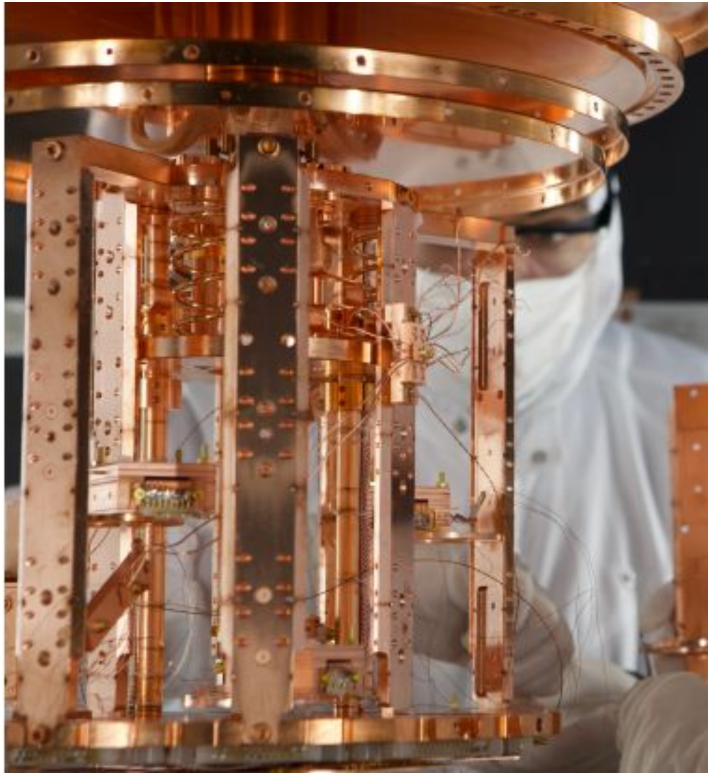
Conclusion and Outlook

CRESST status

- CRESST-III has world leading limit for DM mass below 1.2 GeV/c²
- State of the art detectors with threshold below 100eV
- Analysis of the current modules are promising

Future

- Planned upgrade with O(100) detector after the current physics campaign



Thanks for the attention

MAX PLANCK INSTITUTE FOR PHYSICS

TU WIEN

HEPHY
INSTITUTE OF HIGH ENERGY PHYSICS

COMENIUS UNIVERSITY BRATISLAVA

UNIVERSITY OF OXFORD

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

TUM

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

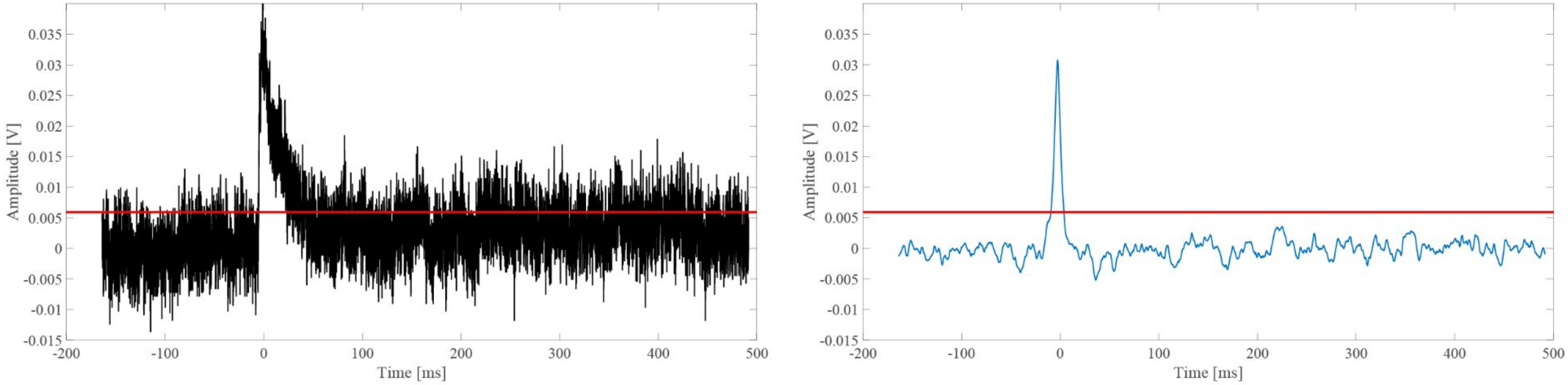
UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

BACK UP SLIDES

Optimum filter trigger

Data stream continuously stored on disk

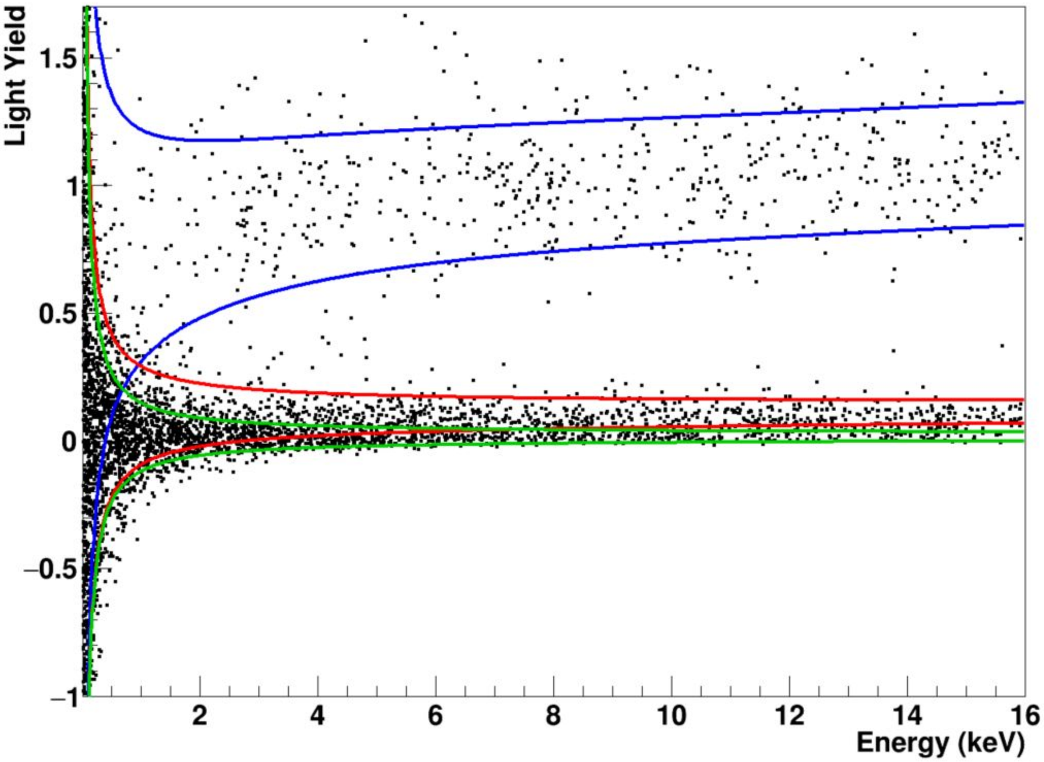
Optimum Filter trigger algorithm applied to the data-stream



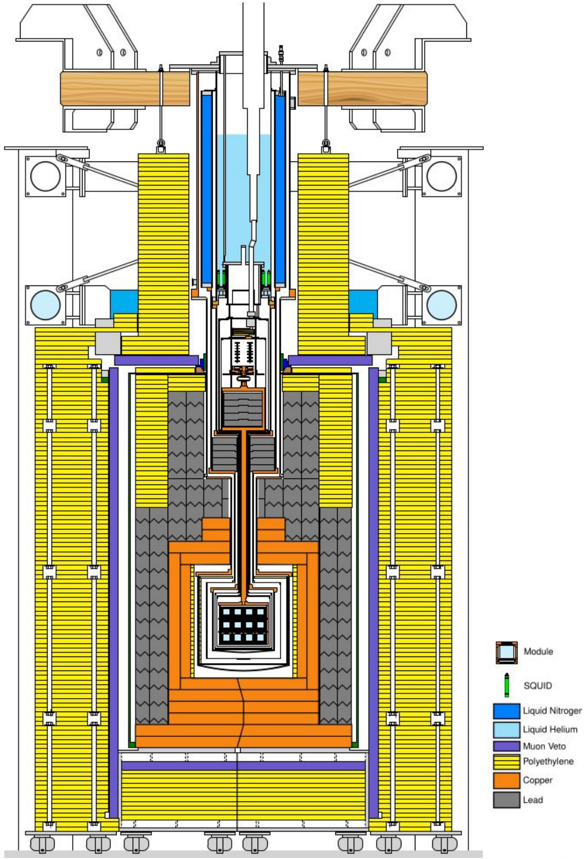
J Low Temp Phys 193, 441–448

Neutron Calibration

Neutron calibration to determine precisely the nuclear recoil bands



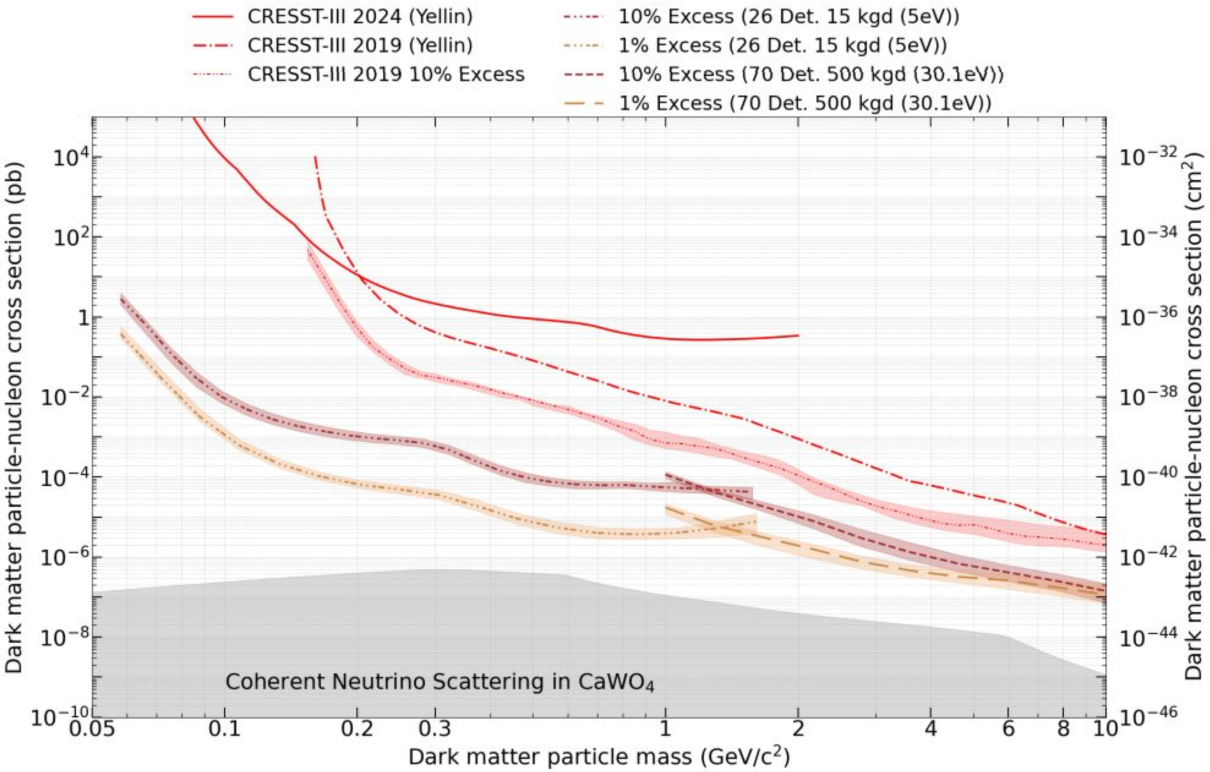
Cryostat shieldings



Different shield for different background

- Polyethylene shield (2 layer) for neutrons
- Lead shield for r β/γ radiation
- Radio pure copper shield for βs and γs from lead shield
- Muon veto
- Radon Box

CRESST prospective



Differential rate

$$\frac{dR}{dE_R dM} = n_\chi N_T \int_{v > v_{min}} v\, f(\vec{v}, \vec{v}_\oplus)\, \frac{d\sigma}{dE_R}\, d^3v$$

Experimental Setup
N_t = number of target
A = Nucleus atomic mass
E_{th} = Energy threshold

$$n_\chi = \frac{\rho_\chi}{m_\chi} \qquad v_{min} = \sqrt{\frac{E_{th} m_N}{2\mu^2}} \qquad \frac{d\sigma}{dE_R} = \frac{\sigma_n}{v^2}\frac{m_N}{2\mu_n^2}\frac{[Zf_p + (A-Z)f_n]^2}{f_n^2}F^2(E_R)$$

$$\Downarrow f_n = f_p$$

$$\frac{d\sigma}{dE_R} = \frac{\sigma_n}{v^2}\frac{m_N}{2\mu_n^2}A^2 F^2(E_R)$$

Astro physics input
Nuclear physics input