Title: CRESST Detectors for Dark Matter and Neutrino Physics

Date: Jul 20, 2017 09:10 AM

URL: http://pirsa.org/17070004

Abstract:

CRESST detectors for dark matter and neutrino physics

Federica Petricca

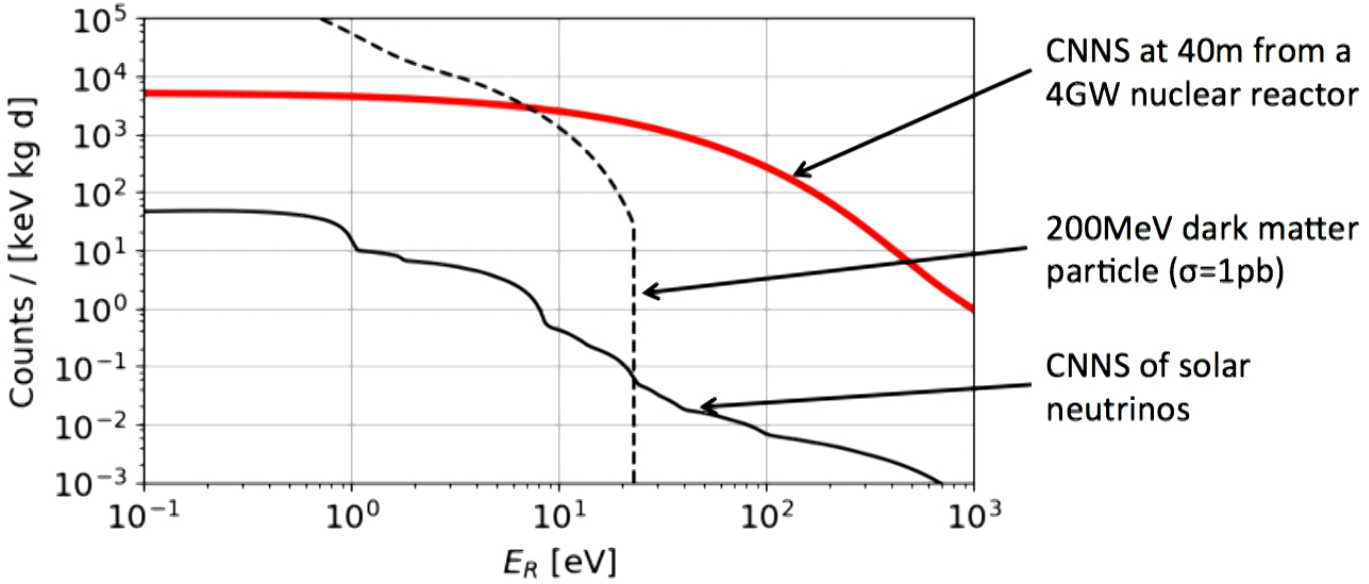
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

NEW DIRECTIONS IN DARK MATTER AND NEUTRINO PHYSICS
July 20-22, 2017

Low-mass dark matter direct detection vs. CNNS

Detector requirements

Nuclear recoil spectra on $CaWO_4$



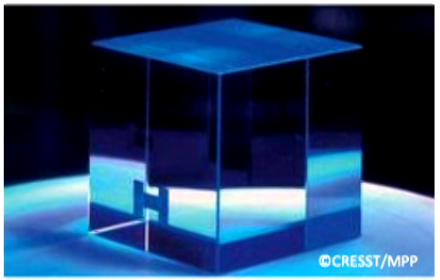
Extremely low thresholds and extremely small background levels

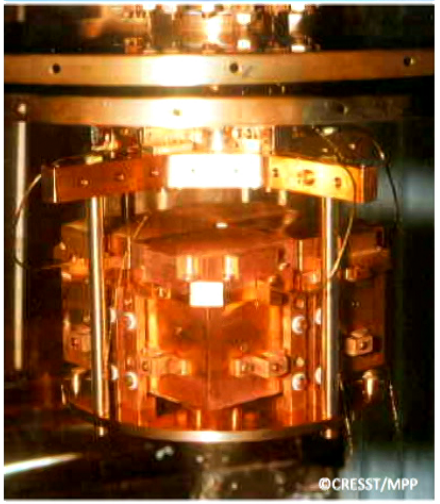

Reebok

CRESST detectors in the years

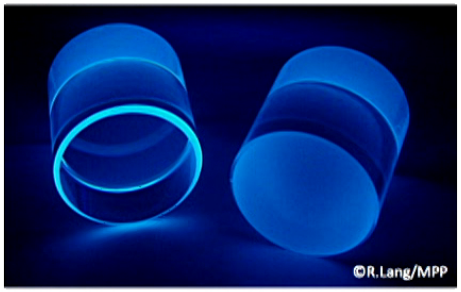
Cryogenic Rare Event Search with Superconducting Thermometers

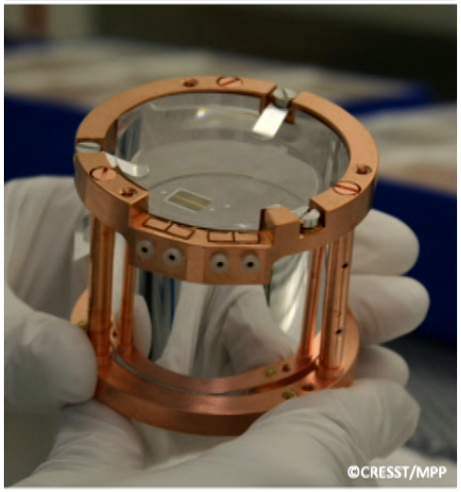
CRESST-I



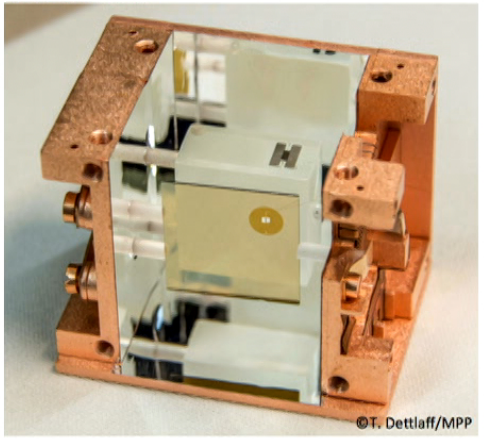


CRESST-II

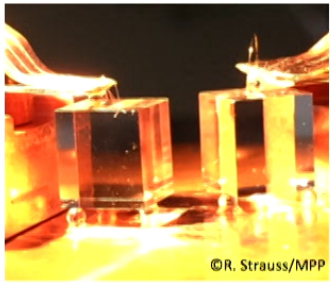




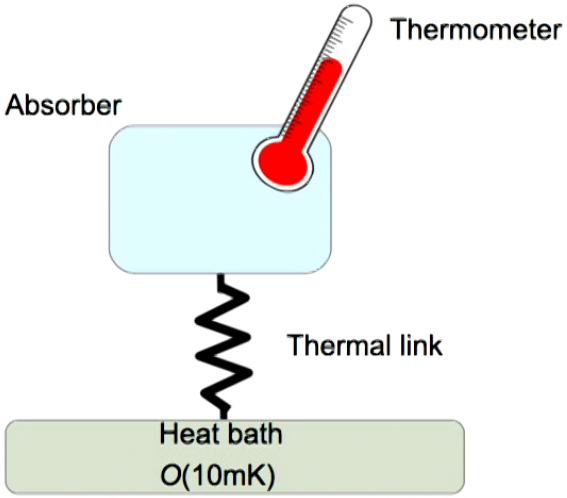
CRESST-III

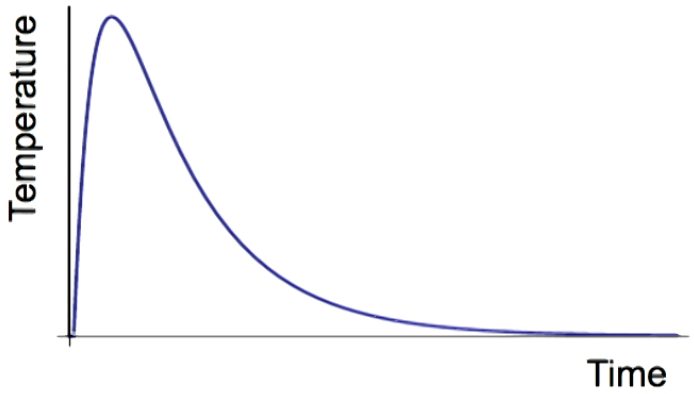


and also CRESST-for *ν*



Cryogenic calorimeters



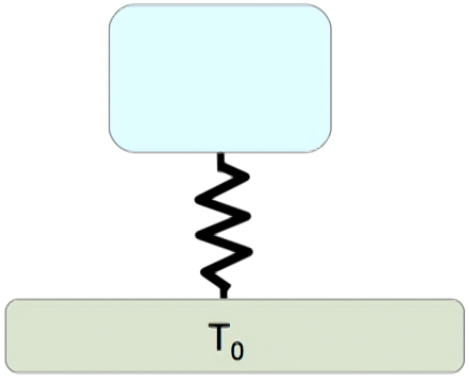


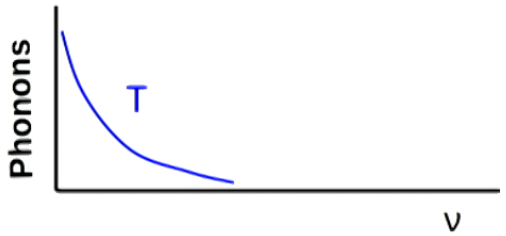
$\Delta T = \Delta E/C$

Valid for a system in thermal equilibrium
i.e. thermometer measuring absorber temperature

Signal formation

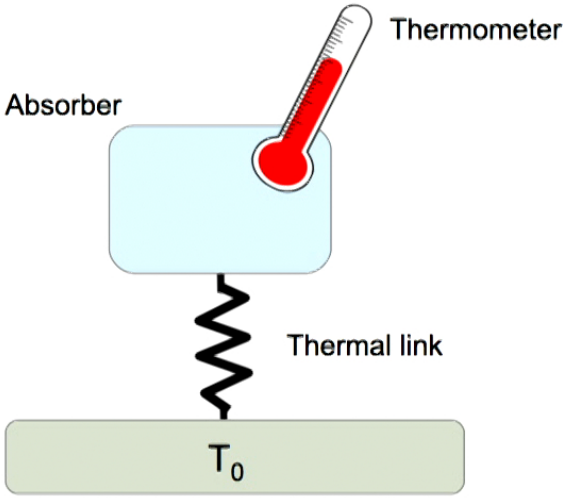
In thermal equilibrium $T=T_0$

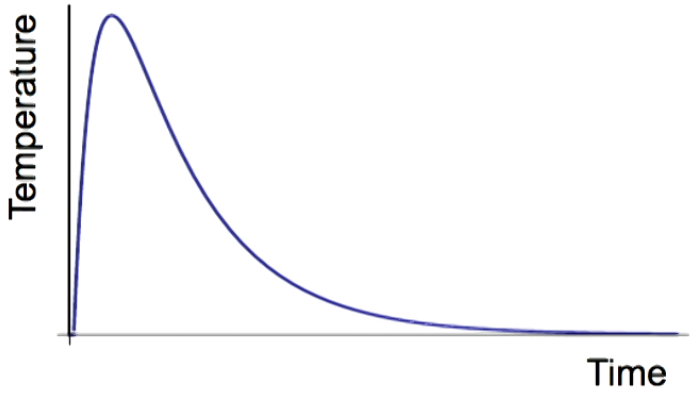




Cryogenic calorimeters

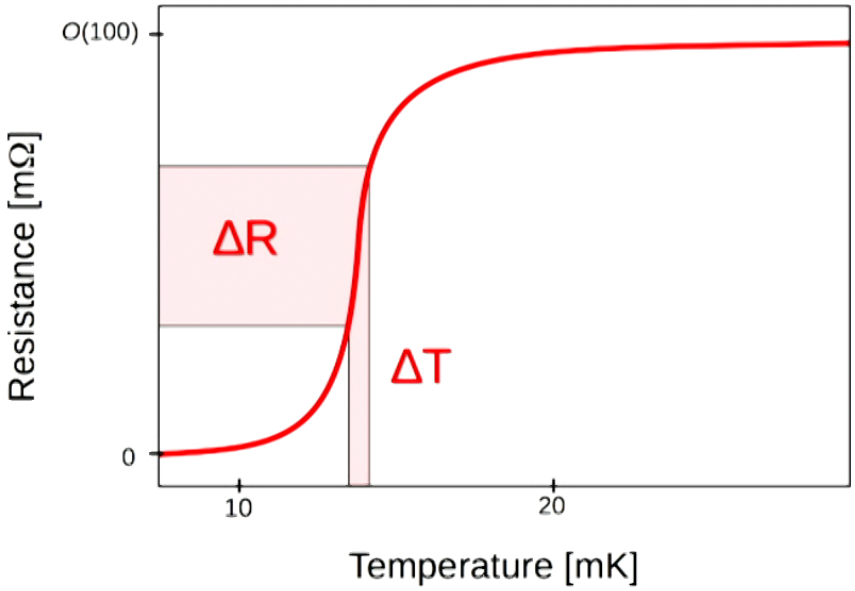
CRESST thermometers (TES) sensitive to non-equilibrium phonon population





Amplitude	$\propto \Delta E_{abs}/C_{ther}$
Rise	life time of non thermal population
Relaxation	$\propto C_{ther}/G_{link}$

Transition edge sensors



Energy deposition in absorber
~keV

↓

Temperature rise in TES
~μK

↓

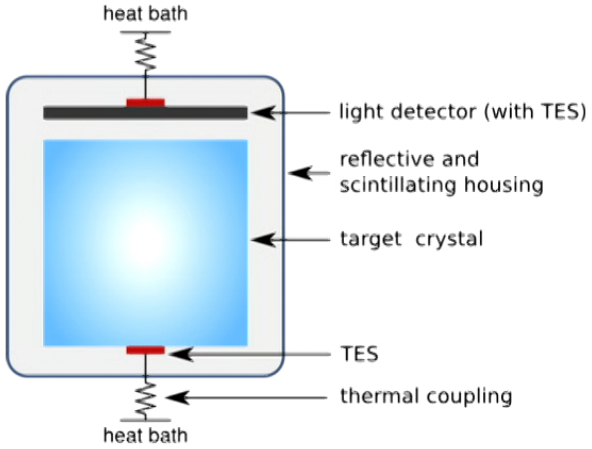
Resistance change
~mΩ

CRESST-II detectors

Scintillating $CaWO_4$ crystals as target

Target crystals operated as **cryogenic calorimeters** (~15mK)

Separate **cryogenic light detector** to detect the scintillation light signal



Energy deposition:

- mainly phonons

(almost independent of the type of particle)

Measurement of deposited energy

- small fraction into scintillation light

(characteristic of the type of particle)

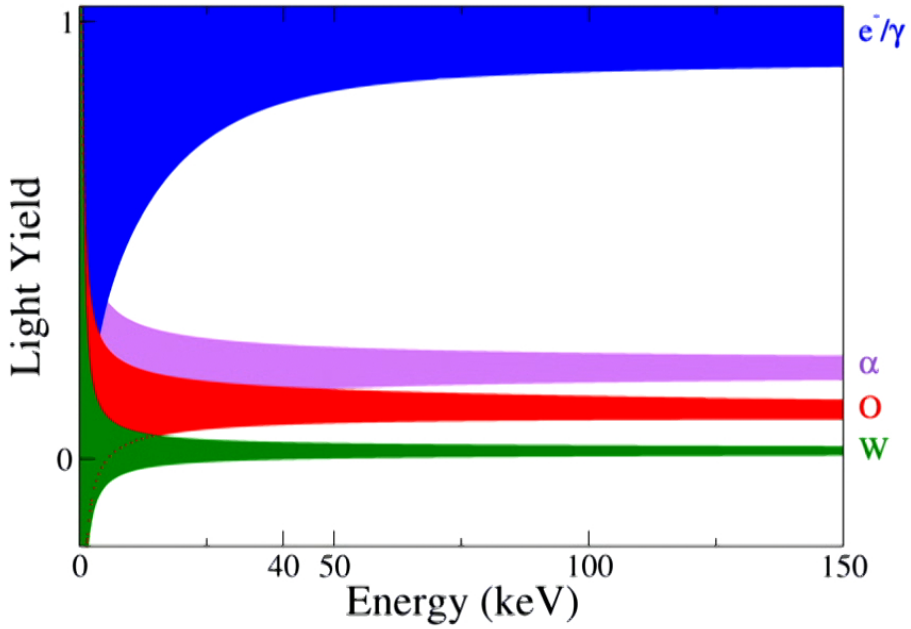
Particle discrimination

Two simultaneous signals from the two transition edge sensors (TES)

Event discrimination

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

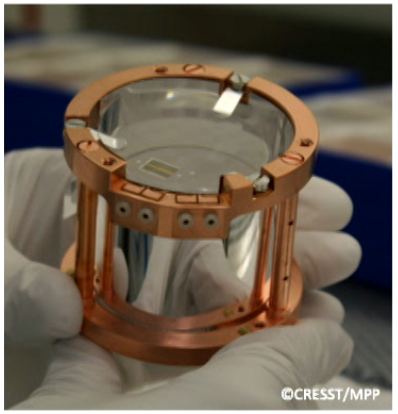
Characteristic of the event type

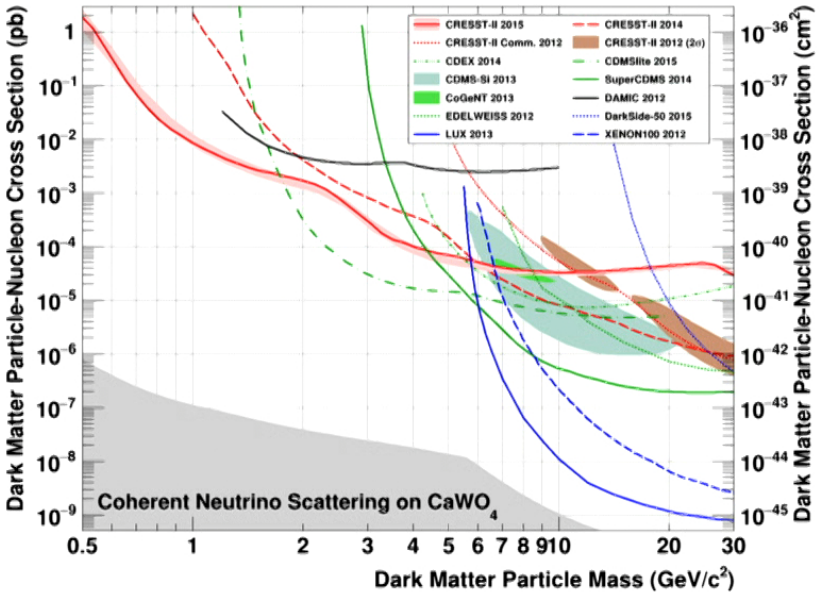


Discrimination between potential signal events (**nuclear recoils**) and dominant radioactive background (**electron recoils**)

CRESST-II results

Detector design: 300g $CaWO_4$ conventional holder
Crystal: Lise - background level ≈8.5 counts/(keV kg day)
Threshold: 307eV
Resolution: 62eV at zero energy





June 15th
Until today world-leading below 1.7GeV/c^2
Exploring new parameter space down to 0.5GeV/c^2

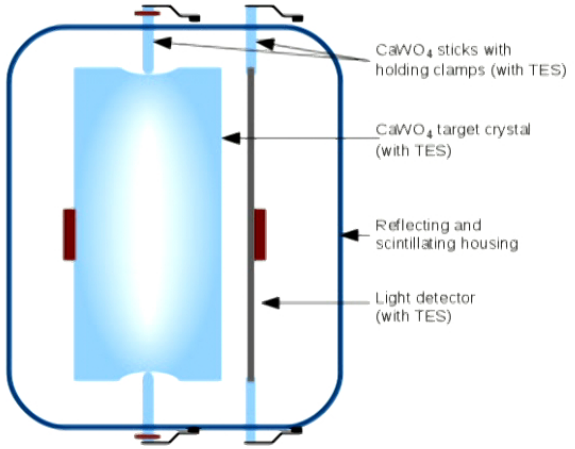
Hunting light dark matter requires a low threshold!

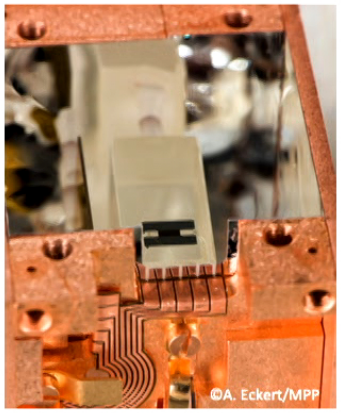
CRESST-III low threshold detectors

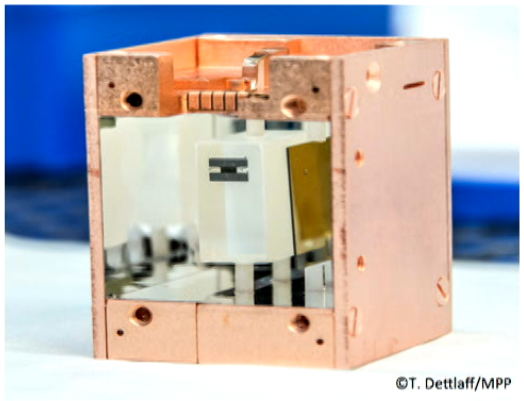
Detector layout optimized for low mass dark matter
Radical reduction of dimension

- Absorber volume reduced of a factor ~10
- Cuboid crystals of (20×20×10)mm^3 (**≈24g**)
- Self grown crystals - background level **≈3 counts/(keV kg day)**
- **100 eV threshold**
- Light detector (20×20)mm^2
- Fully scintillating housing
- Instrumented sticks

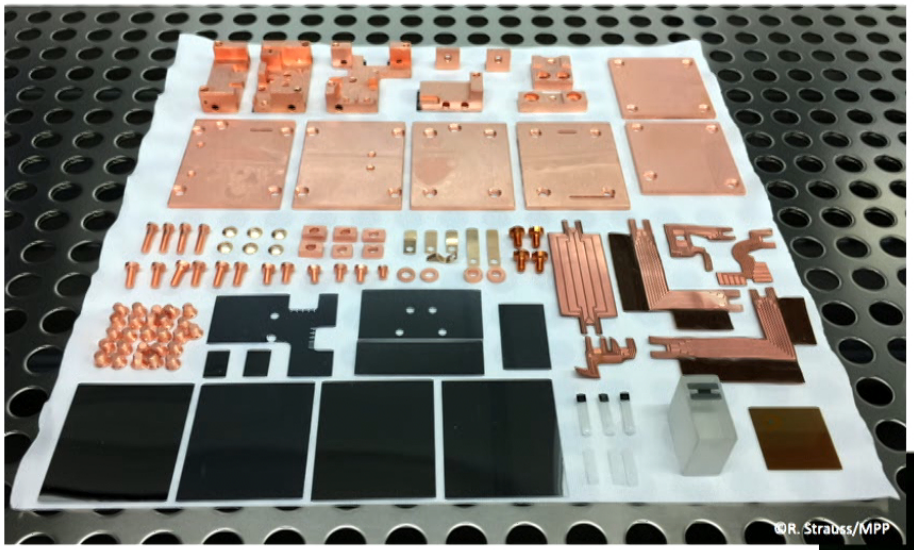
} **Veto for surface related backgrounds**

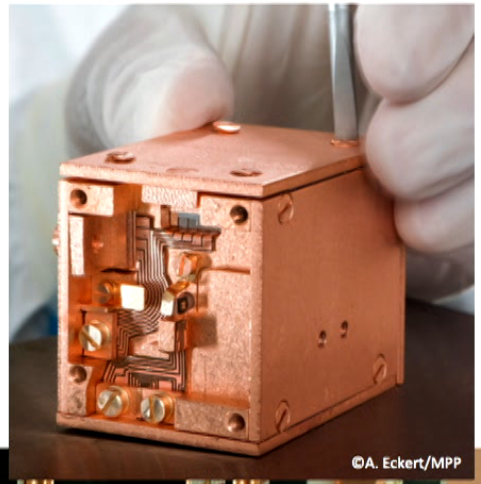


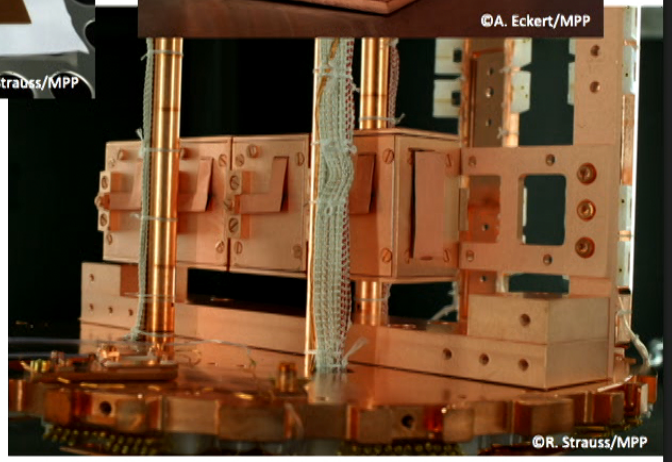




CRESST-III Phase 1







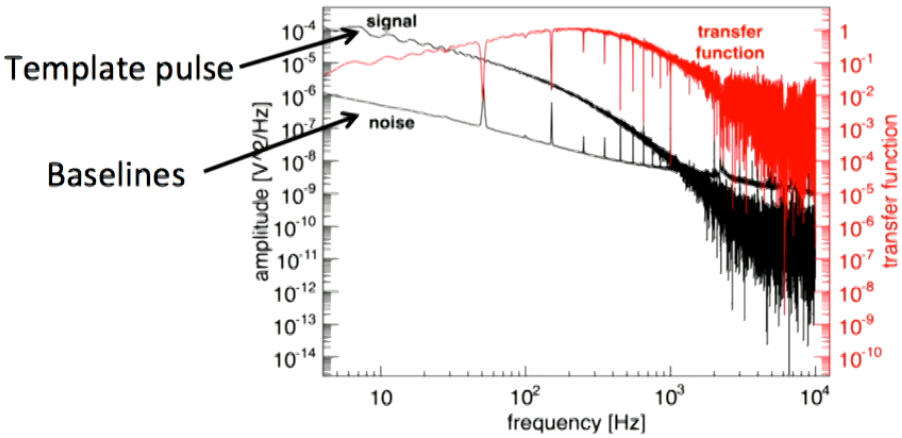
Data taking started July 2016

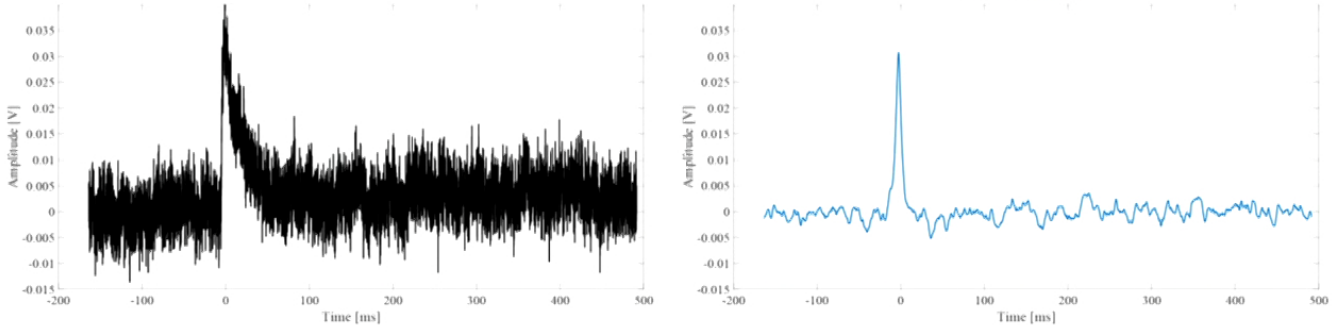
- High statistics gamma calibration
- High statistics neutron calibration
- 20% of DM data as training set

Optimum filter

Pulse-height evaluation with optimum filter

The **Gatti-Manfredi filter** is an optimum filter which maximize the ratio between the amplitude of the treated pulse and the noise RMS



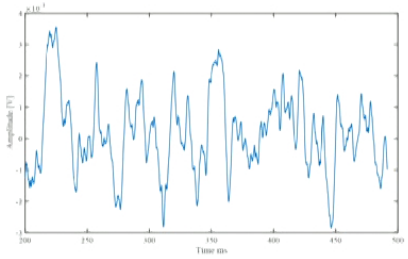


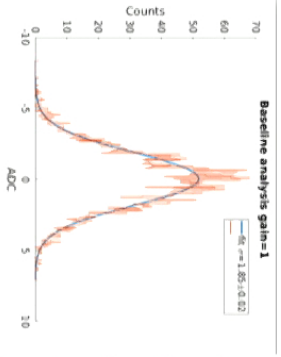
Typical improvement in resolution by using the optimum filter: factor 2-3

Optimum trigger – Detector A

Optimum filter for threshold analysis

Typical base line trace

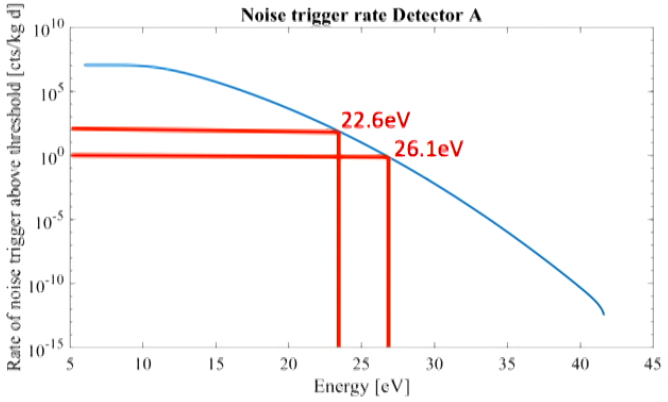


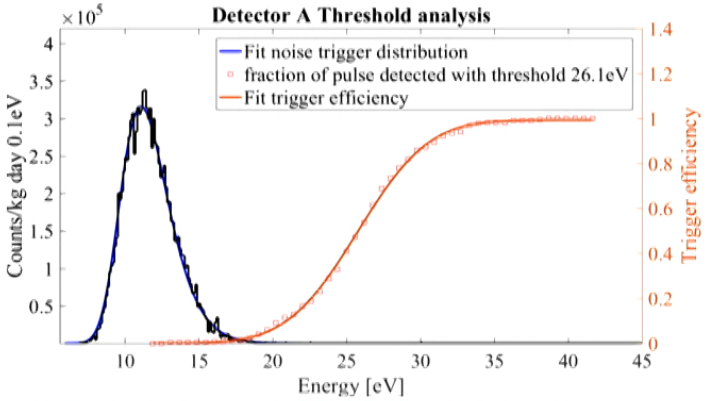


Histogram of a typical baseline trace

- Continuous sampling of raw data (new DAQ for CRESST-III)
- Study the noise distribution after optimum filter in order to set the threshold

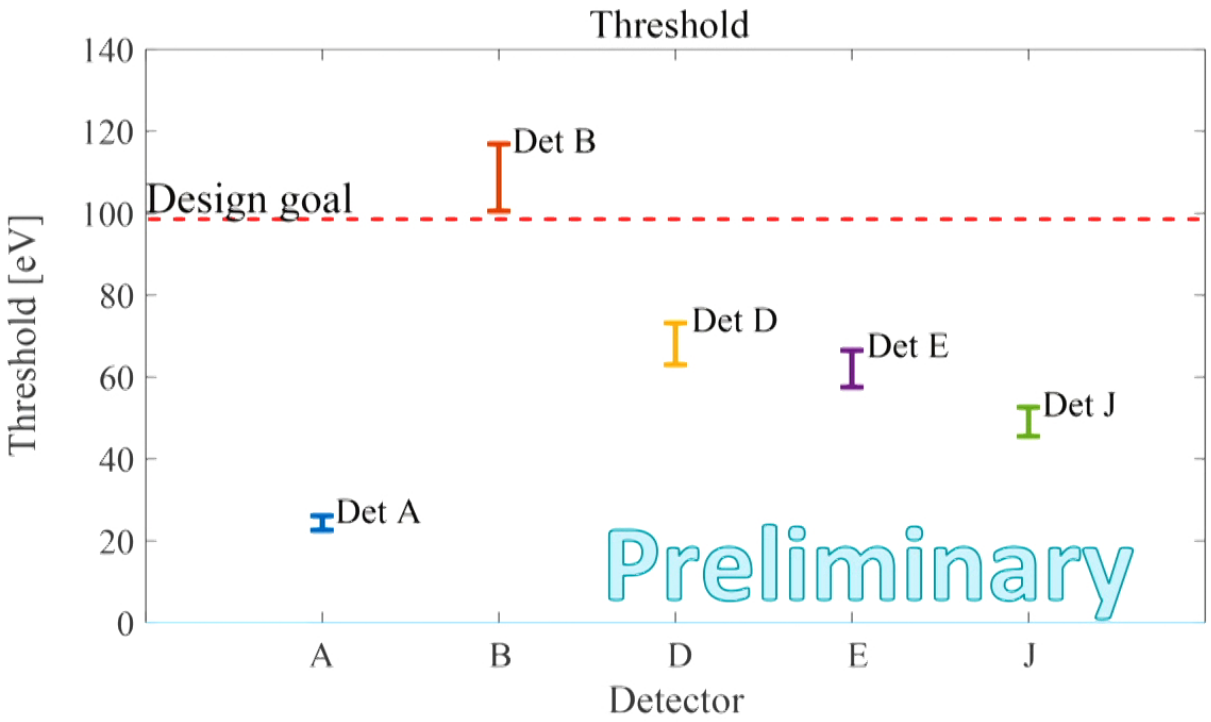
Analytical description of amplitude distribution in empty baselines





New frontier in direct dark matter detection

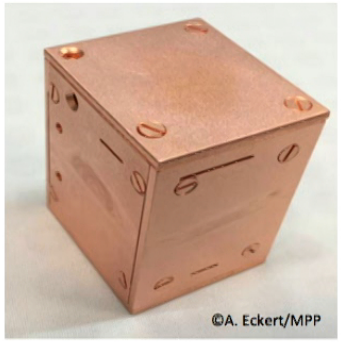
Optimum thresholds



5 detectors reach/exceed CRESST-III design goal

Detector A – high threshold analysis

Analysis started from detector A



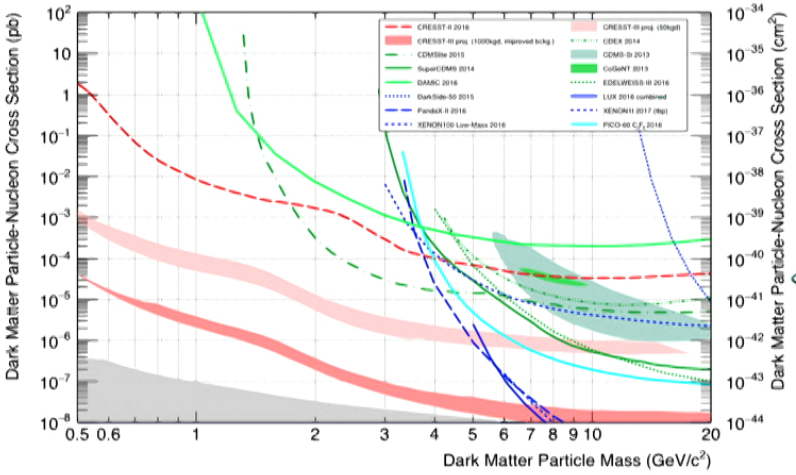
Data taking period: 31.10.16 - 05.07.17
Analysis threshold (high-threshold analysis): 100 eV

Preliminary results of this single module will be presented at

TAUP 2017

Beyond dark matter

CRESST-III detectors for CNNS - Atmospheric and solar neutrinos



Probability to observe a data-set which allows a detection of CNNS at the desired CL

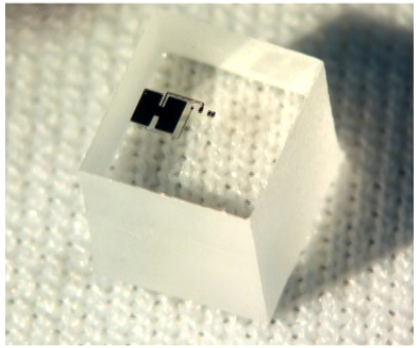
	Detection potential		
Exposure	99.9 % CL	99.99 % CL	99.9999 % CL
10 kg-years	12.8 %	7.6 %	3.3 %
20 kg-years	28.9 %	19.7 %	9.3 %
30 kg-years	44.6 %	29.9 %	16.5 %
40 kg-years	61.1 %	45.2 %	23.7 %
50 kg-years	73.4 %	57.9 %	34.0 %
60 kg-years	80.8 %	68.0 %	42.1 %
70 kg-years	89 %	79.4 %	55.1 %
80 kg-years	91.7 %	83.2 %	64.9 %
90 kg-years	96.1 %	90.6 %	70.5 %
100 kg-years	97.4 %	92.7 %	77.2 %

2 years of running with ~1000 CRESST-III modules

Gram-scale detectors

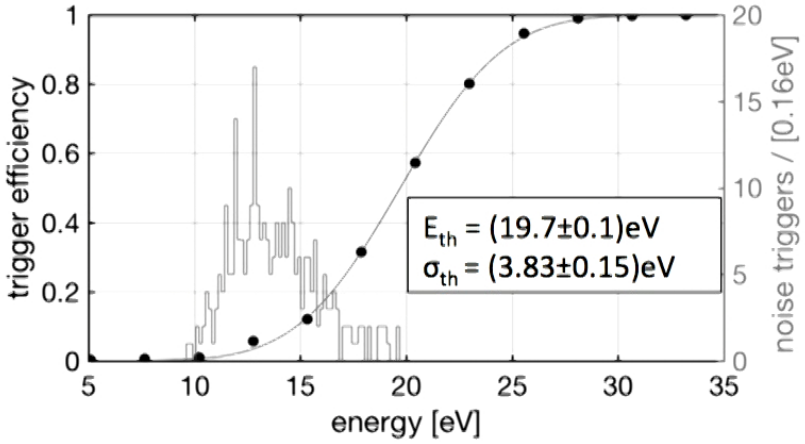
Even smaller

Al_2O_3 crystal 0.5g



First prototype detector successfully tested:

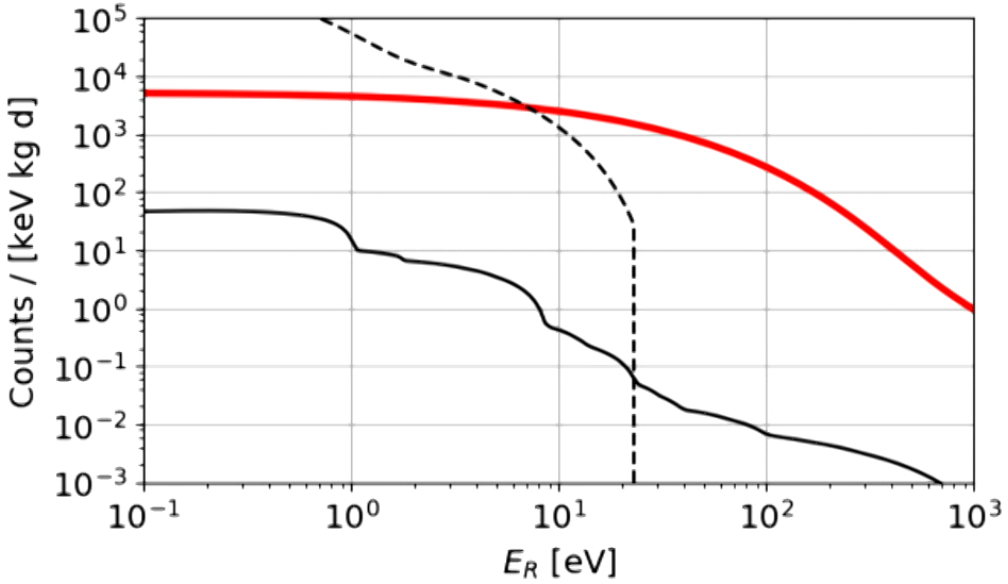
- operated above ground
- setup without shielding



Operation in high-background environment demonstrated

CNNS

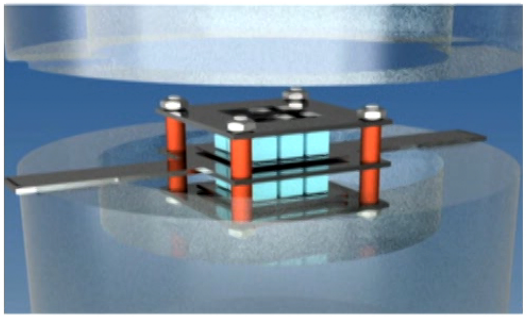
Threshold for CNNS reached above ground



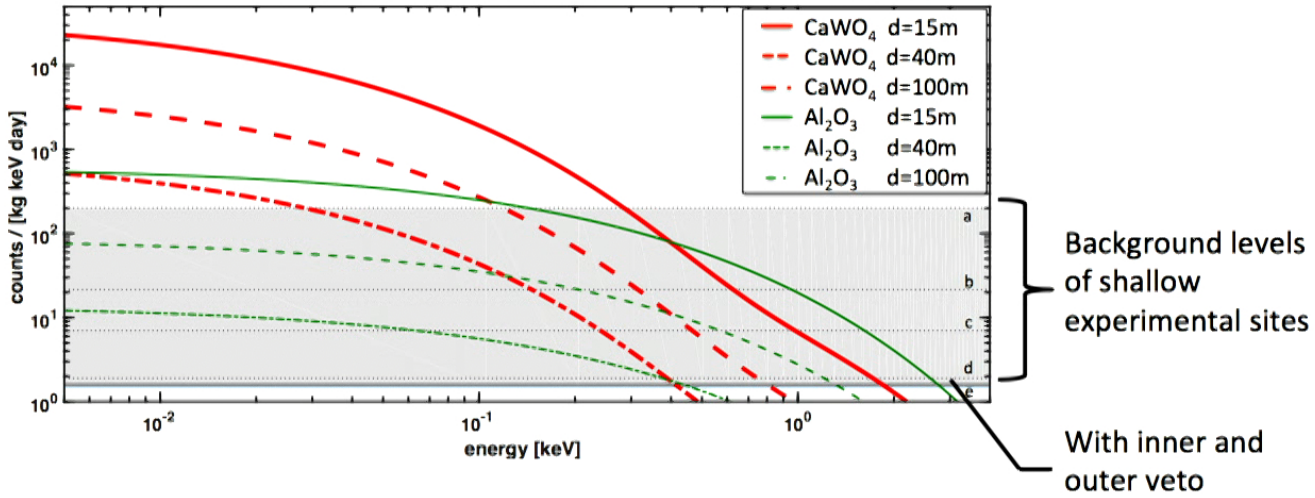
The *ν*-cleus experiment

Low-threshold $CaWO_4$ and Al_2O_3 calorimeter arrays
- total mass about 10g
- active veto

Strong material dependence of CNNS rate to discriminate signal from background



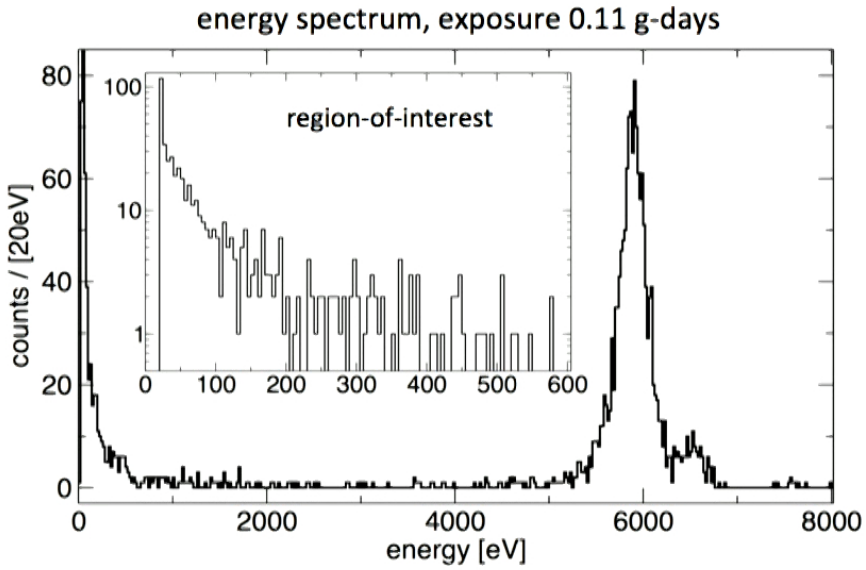
Count rates on $CaWO_4$ and Al_2O_3 at distance d from a 4GW nuclear power plant



MeV- scale dark matter

Dark matter search with a prototype detector

Calibration measurement in high background environment

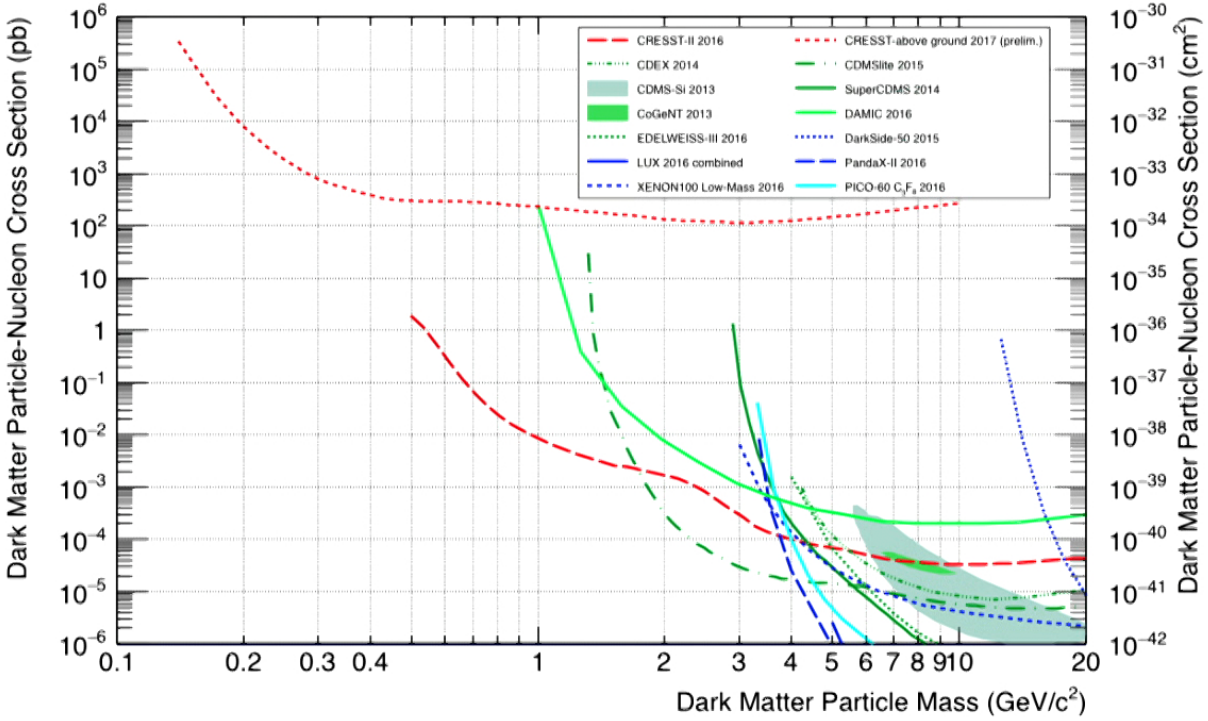


- No data-quality cuts applied
- Use Yellin optimum interval method

to appear on the arXiv this week

MeV- scale dark matter

The exclusion limit



to appear on the arXiv this week

New frontiers...
... new potentials...
... new challenges!