18th International Workshop on
Low Temperature Detectors

LTD18 — 22-26 JULY 2019 MILANO — LOW TEMPERATURE DETECTORS

Searches for low mass dark matter with the **CRESST-III** experiment

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The CRESST collaboration

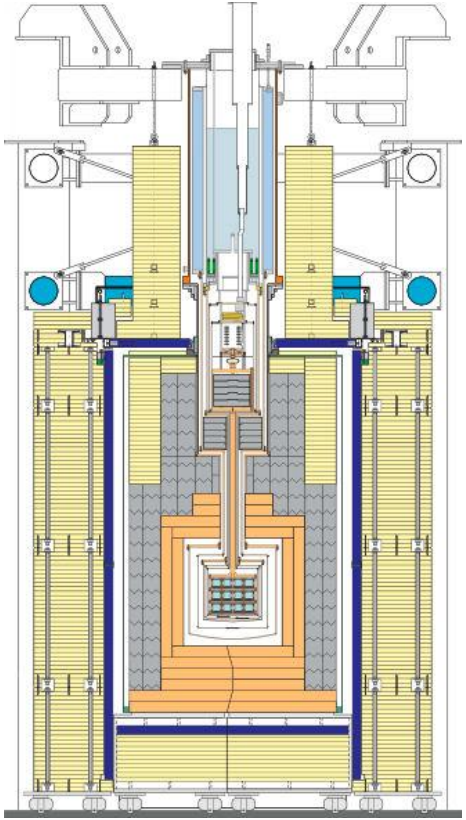
Cryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers

The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

CRESST located at LNGS (Laboratori Nazionali del Gran Sasso) in Italy

~3600 m.w.e. deep
μ: $3\times10^{-8}/(\mathrm{s\ cm}^2)$
γ: $0.73/(\mathrm{s\ cm}^2)$
neutrons: $4\times10^{-6}/(\mathrm{s\ cm}^2)$



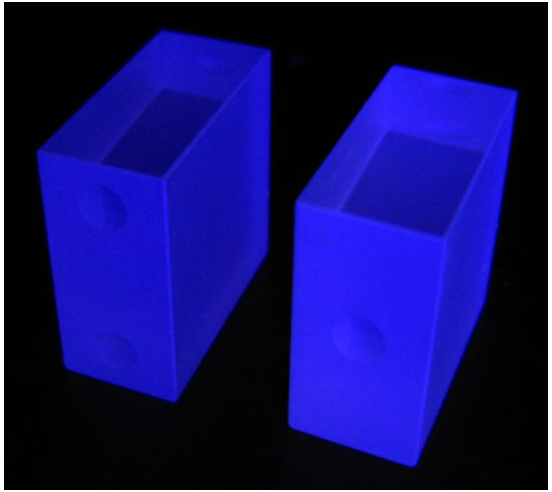
Shielding:
- polyethylene
- muon veto system
- lead
- copper
- polyethylene

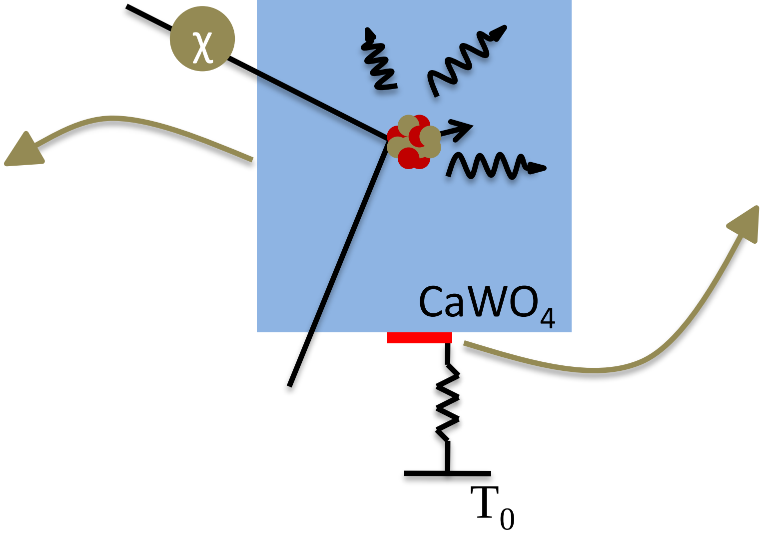
The CRESST detector

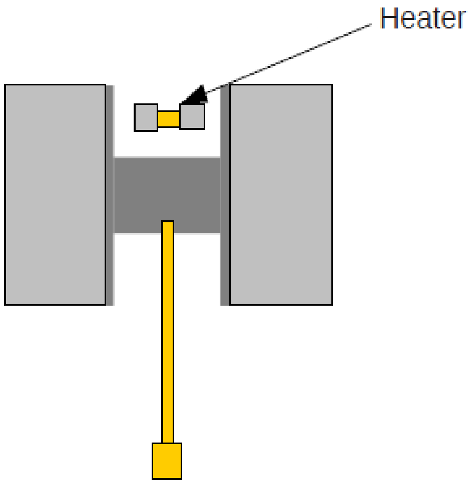
Target crystal

Scintillating 20x20x10 mm^3 ~24 g $CaWO_4$ crystals as target

- Cryogenic detector $T_0 \approx 10$mK
- W-TES sensor for T read-out 2.4x0.85 mm^2 and 200 µm thick







Au thermal link
(~100 pW/K at 10 mK.)

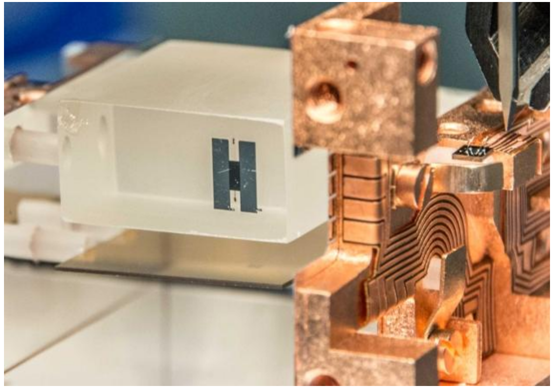
- CRESST is not bound to one target material

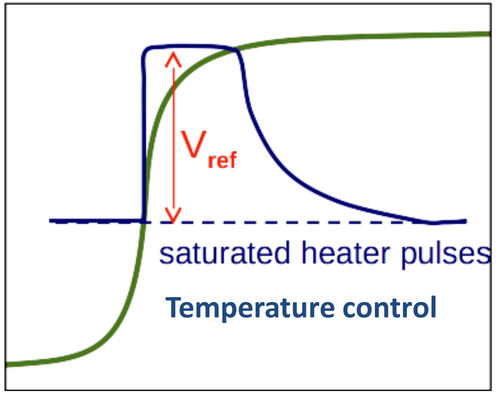
Poster id: P59 L. Canonica Diamond cryogenic detector for low-mass Dark Matter searches
P258 E. Bertoldo Lithium-containing crystals for light dark matter search experiments

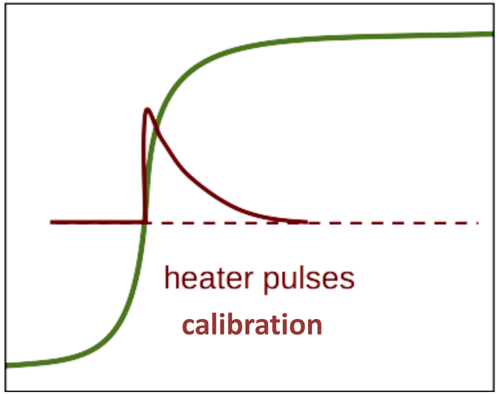
Poster id: P214 A. Abdelhameed
Innovative technique for large scale production of W-TES

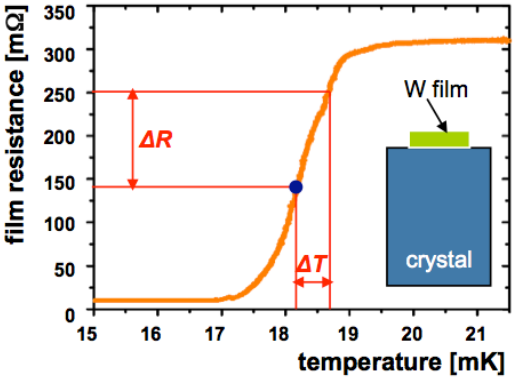
The CRESST detector

TES read-out control

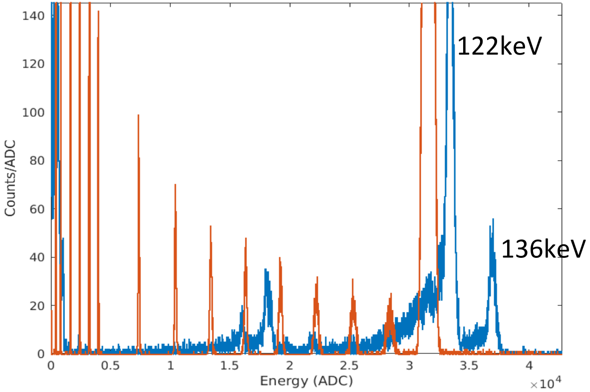








Calibration data ^{57}Co

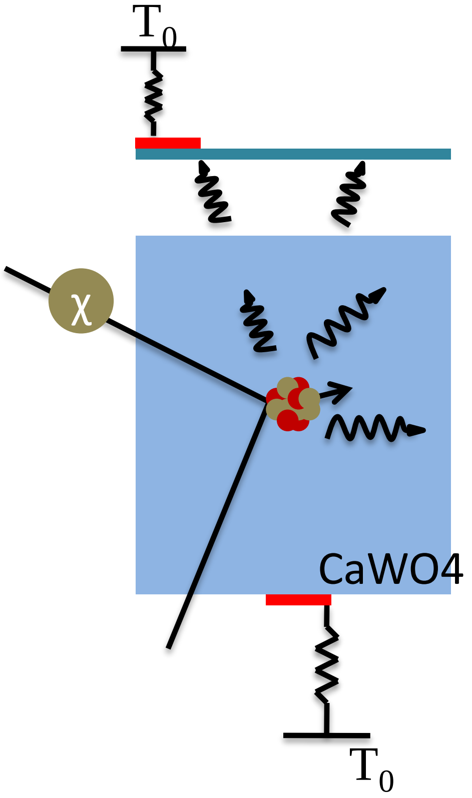


Particle interaction
External ^{57}Co source

Heater pulses
a pattern of heater pulses are periodically delivered to the heater element

The CRESST detector

Scintillating Calorimeter Detector



Scintillating 24 g $CaWO_4$ crystals as target

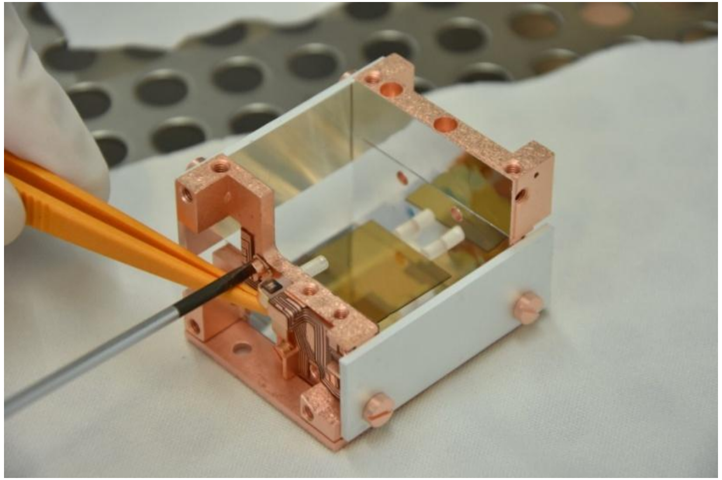
- Cryogenic detector $T_0 \approx 10mK$
- W-TES sensor for T read-out → True energy deposition

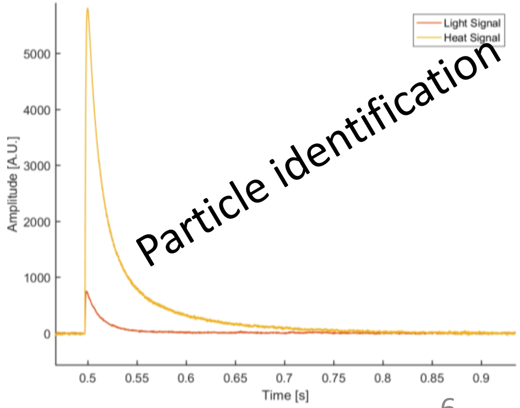
Light detector SOS (Silicon On Sapphire)

- Cryogenic detector $T_0 \approx 10mK$
- W-TES sensor for T read-out → Quenched for different kinds of particles

\+

Particle identification





The CRESST detector

The CRESST-III detector module

Energy resolution

Scintillating 24 g $CaWO_4$ crystals as target

- Cryogenic detector $T_0 \approx 10$mK
- W-TES sensor for T read-out
- $E_{threshold} \leq 100$ eV (nuclear recoils)

Particle discrimination

Light detector SOS

- Cryogenic detector $T_0 \approx 10$mK
- W-TES sensor for T read-out

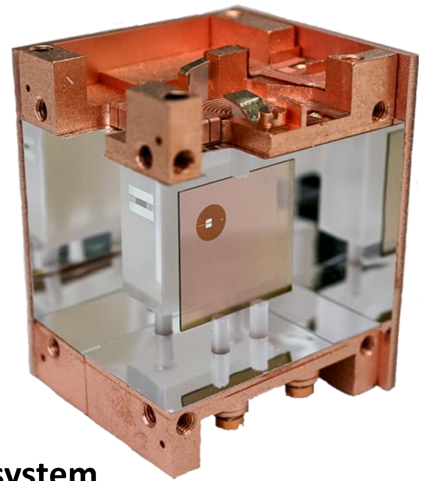
Light yield characteristic of the type of particle → **Particle discrimination**

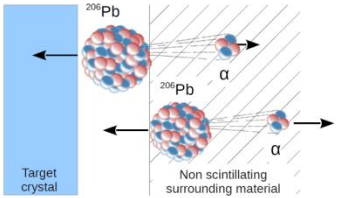
Background rejection

Veto surface related background

Housing

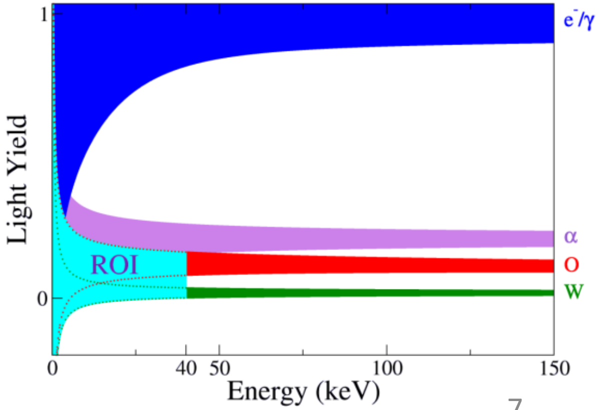
- Reflecting & scintillating foil
- Fully scintillating





Instrumented holding system

- $CaWO_4$ stick instrumented with W-TES



The CRESST-III experiment

CRESST-III Phase 1 Run commissioning

May 2016 ➢10 detector modules mounted

June 2016 ➢Cool down to mK temperature

Sept 2016 ➢Start physics run

Oct 2016 ➢Gamma calibration (energy calibration)

April 2017 ➢Neutron calibration (Light Yield calibration)

Feb 2018 ➢ End of run

10 X CRESST-III detector module

Today

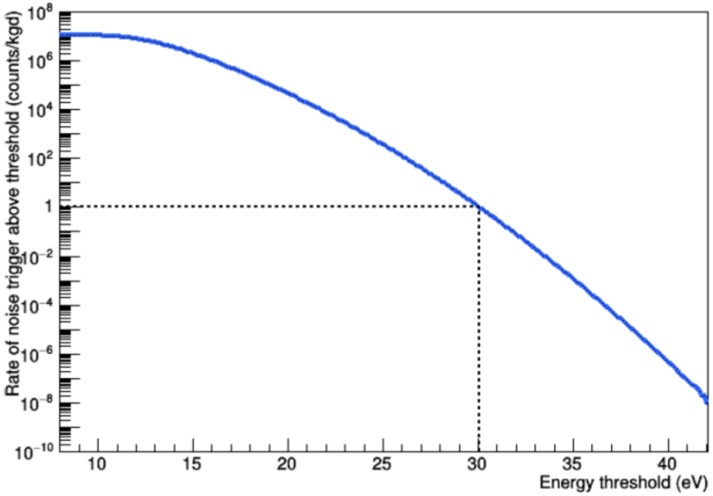
- ➢Total raw exposure collected as of 02.2018 : ~30 kg · day
- ➢**Results from 1 detector module: 5.689 kg · day**

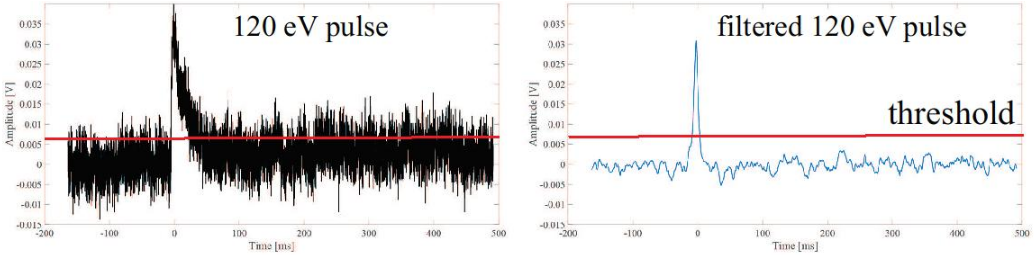
CRESST collaboration submitted to PRD
arXiv:1904.00498v1

Results

Data acquisition and processing

- Data acquisition (DAQ) is a dead-time free transient digitizer, the detector output is continuously recorded with a sampling rate of 25 kHz
- Optimum filter of the entire data stream for triggering and energy reconstruction (maximization of the signal-to-noise ratio)
- In-depth study of energy calibration at low energy (< 1keV)





- Rigorous threshold analysis: threshold determined by accepted noise trigger rate
- Detectors outperformed the design goal of 100 eV threshold

[Mancuso, M. et al. J Low Temp Phys (2018). https://doi.org/10.1007/s10909-018-1948-6]
[Mancuso, M. et al. NIM A (2019). https://doi.org/10.1016/j.nima.2019.06.030]

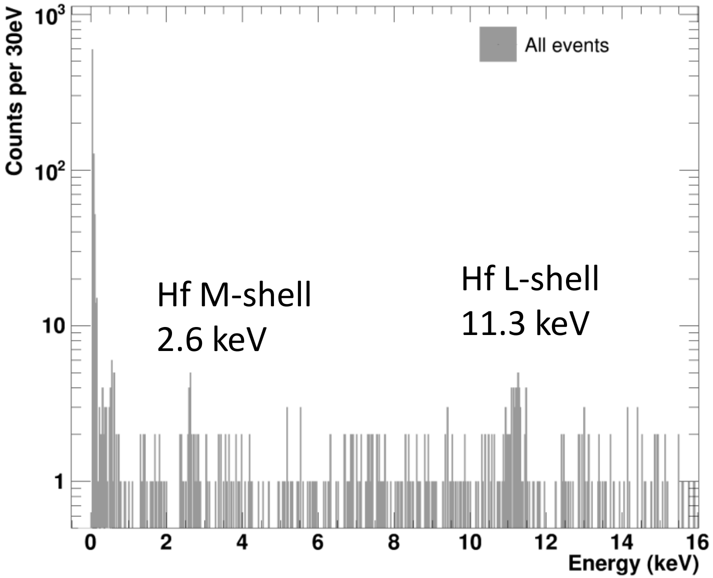
Results

Physics data Detector A – **energy calibration & efficiency**

- **Data taking period:** 11/2016 to 02/2018
- **Detector mass:** 23.6 g
- **Total exposure:** 5.689 kg day
- **Analysis Threshold:** 30.1 eV

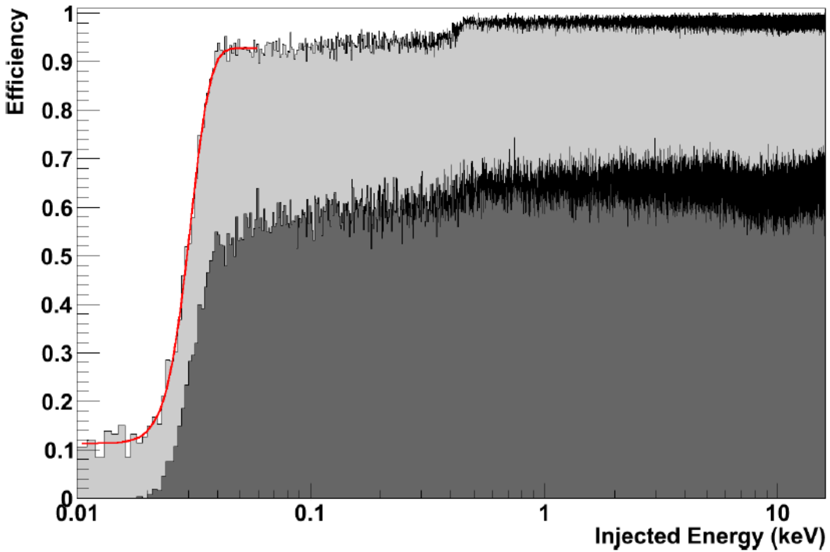
Simulated spectrum injected on real data

Light gray: trigger efficiency
Dark gray: after selection criteria



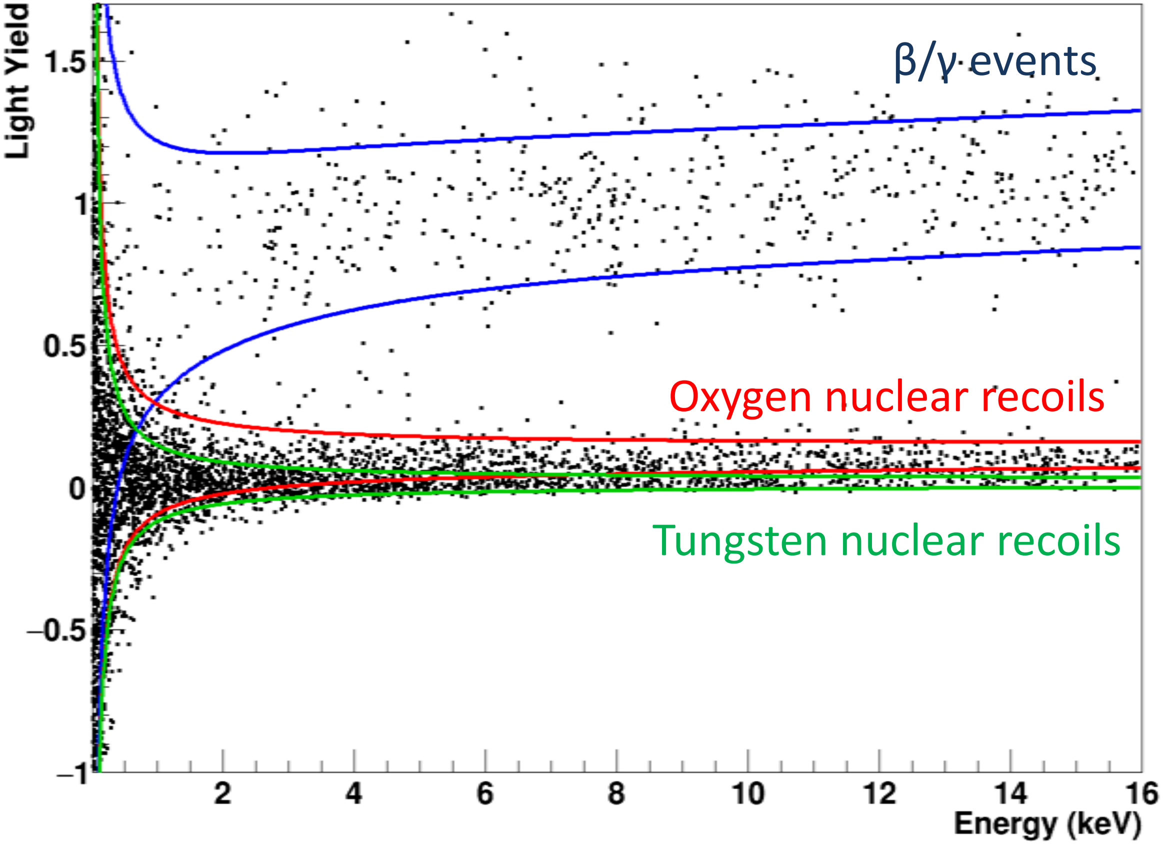
$$^{182}W + p \rightarrow {}^{179}Ta + \alpha$$

$$^{179}Ta + e^- \rightarrow {}^{179}Hf + \nu_e$$



Results

Physics data Detector A – Neutrons calibration



•The neutron source is used to calibrate light yields

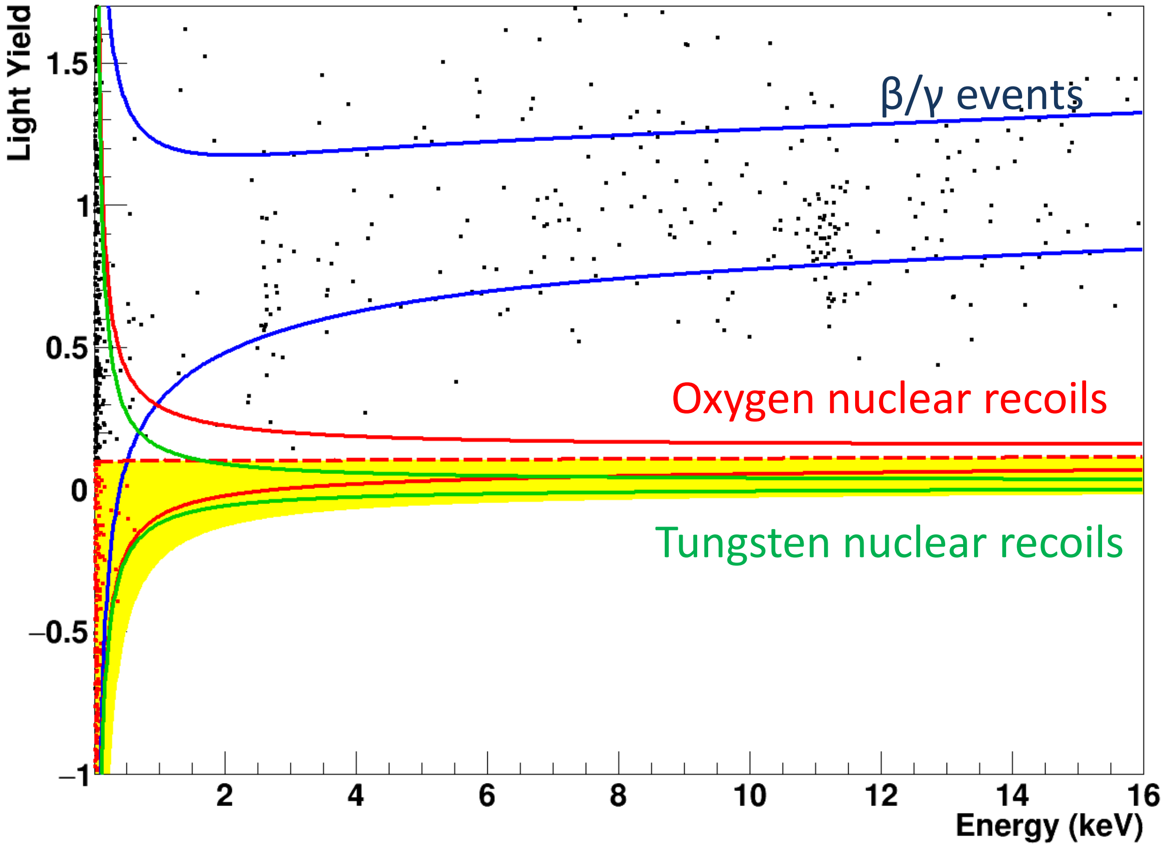
$$LY=E_L/E_{Ph}$$

•E_L is the energy estimator of the light detector response

•E_{Ph} is the energy estimator of the phonon channel which is considered to be the total deposited energy of an interaction.

Results

Physics data Detector A - ROI

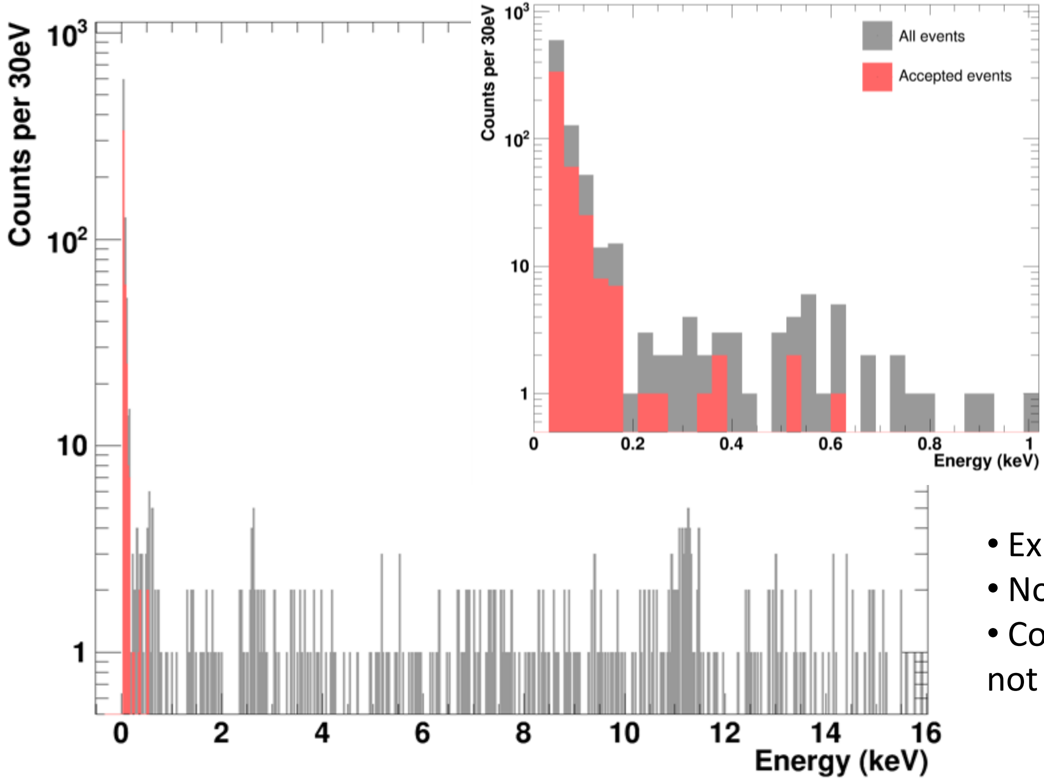


gammas have a slightly lower LY than betas

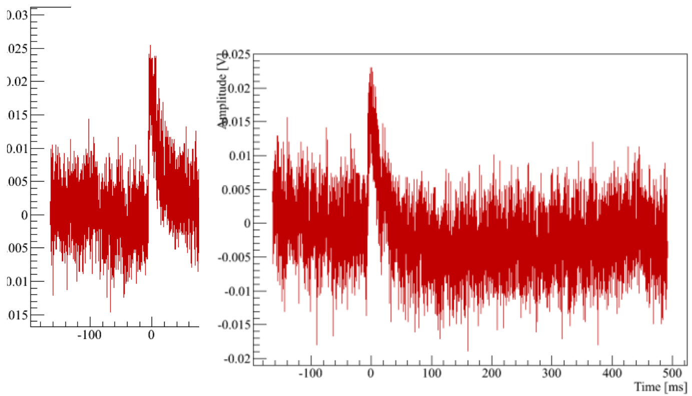
Region Of Interest (ROI)
from the mean of the oxygen band (red dashed line) down to the 99.5% lower boundary of the tungsten band.

Results

Physics data Detector A



Typical 100 eV pulses



- Exponential towards the low energy
- Not a trigger pedestal
- Common for all detector with Eth below 100 eV but not compatible

Results

Dark matter result

Yellin 1D optimum interval method

Replicated and improved result from CRESST-II

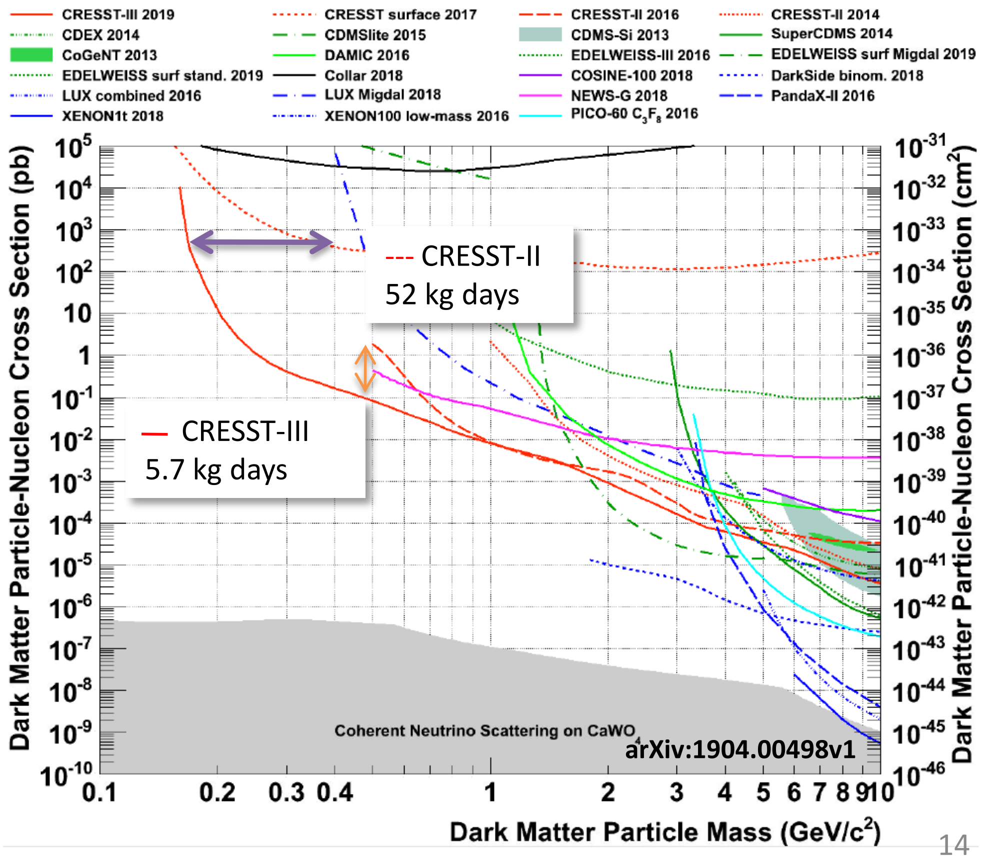
Extend reach from 0.5 GeV/c² to 0.16 GeV/c²

One order of magnitude improvement at 0.5 GeV/c²

Background rising towards low energies limits the sensitivity at low DM masses

CRESST-III Phase 1 RUN2 *in data taking*

- ➢Upgraded detector modules with dedicated hardware changes to understand low energy spectrum



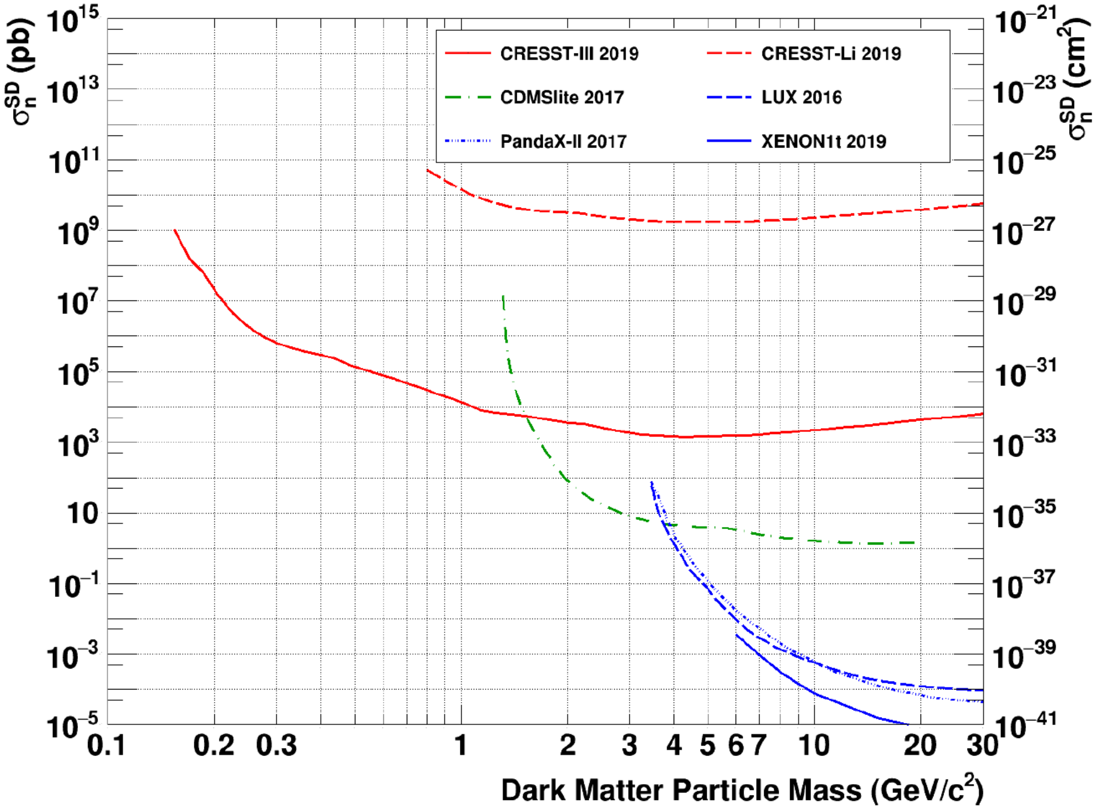
Results

Dark matter result – spin-dependent

The **spin-dependent** exclusion limit with natural isotope ^{17}O which is sensitive to spin-dependent neutron-only interactions

Total exposure 0.46 g days

➢R&D ongoing on new target materials sensitive to spin dependent.



Outlook

Detecting dark matter is one of the ultimate challenges in fundamental physics.

- Cryogenic detector are suited for precise measurement for low energy nuclear recoils

CRESST has an outstanding potential to explore the low mass region of the parameter space for DM nucleus scattering with unprecedented sensitivity

CRESST-III Phase 1 RUN1 *07/2016 – 02/2018*

- 40% of the detector modules with a threshold below 100 eV
- Leading sensitivity below 1.6 GeV/c^2 DM mass for spin-independent and spin-dependent interaction
- Background limited
- Similar background observed on all detector with E_{th} below 100eV

CRESST-III Phase 1 RUN2 *11/2018*

- mainly devoted to hardware-tests with upgraded detector modules to study the origins of low energy events