Introduzione alle ricerche dirette di Dark Matter e il caso dell'esperimento CRESST

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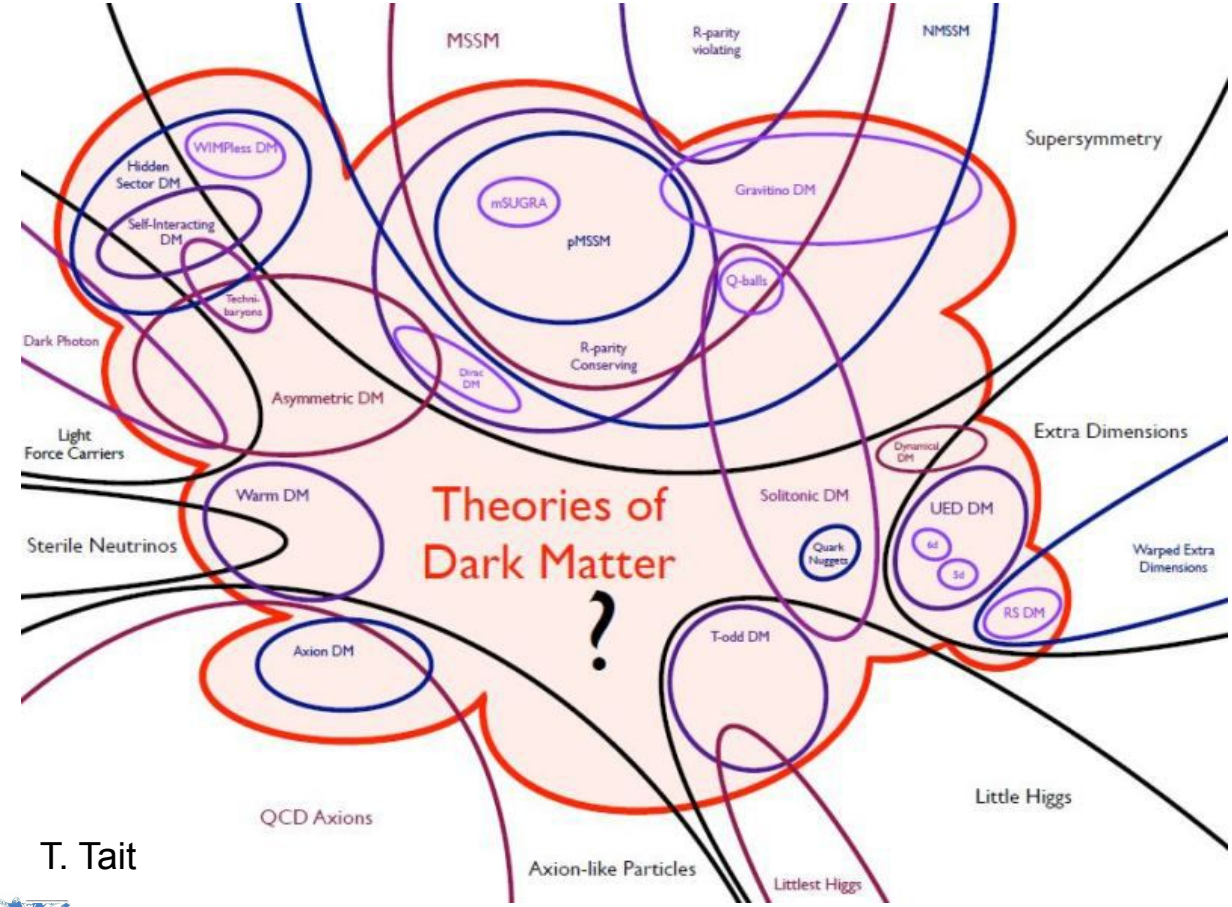
THE DARK MATTER PROBLEM



T. Tait

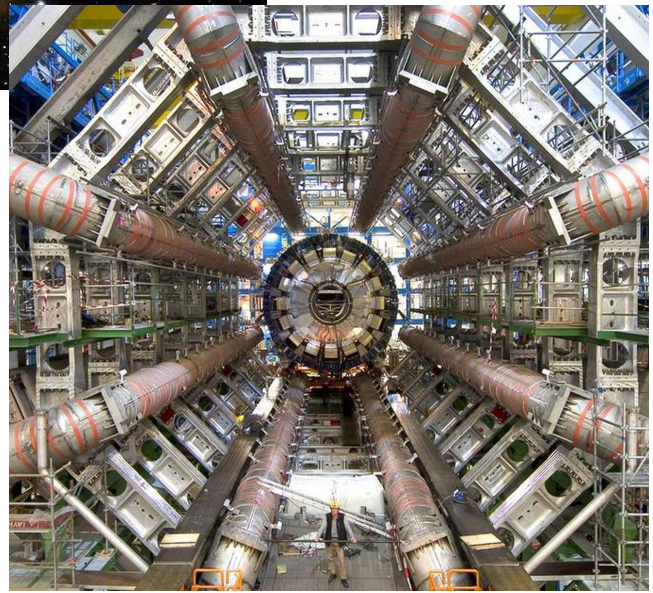
Standard scenario for DM:

- Cold (non-relativistic)
- Non baryonic
- Stable/Long lived
- Gravitationally interacting and maybe also at some subweak scale

SEARCH FOR DARK MATTER

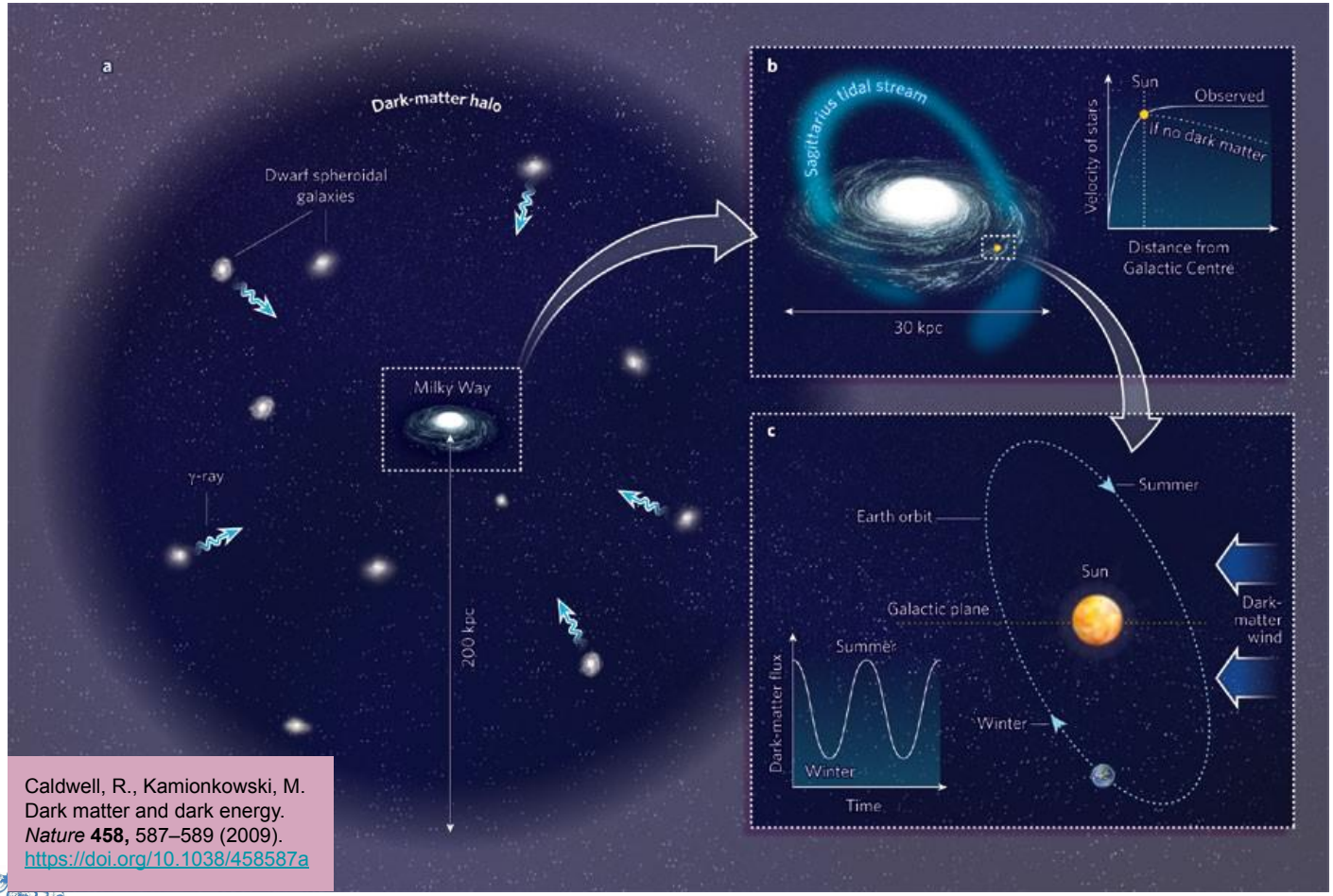
Indirect searches

Collider searches



Direct searches

DARK MATTER: DIRECT DETECTION IDEA



Caldwell, R., Kamionkowski, M. Dark matter and dark energy. *Nature* **458,** 587–589 (2009). https://doi.org/10.1038/458587a

Key point for **direct** DM searches

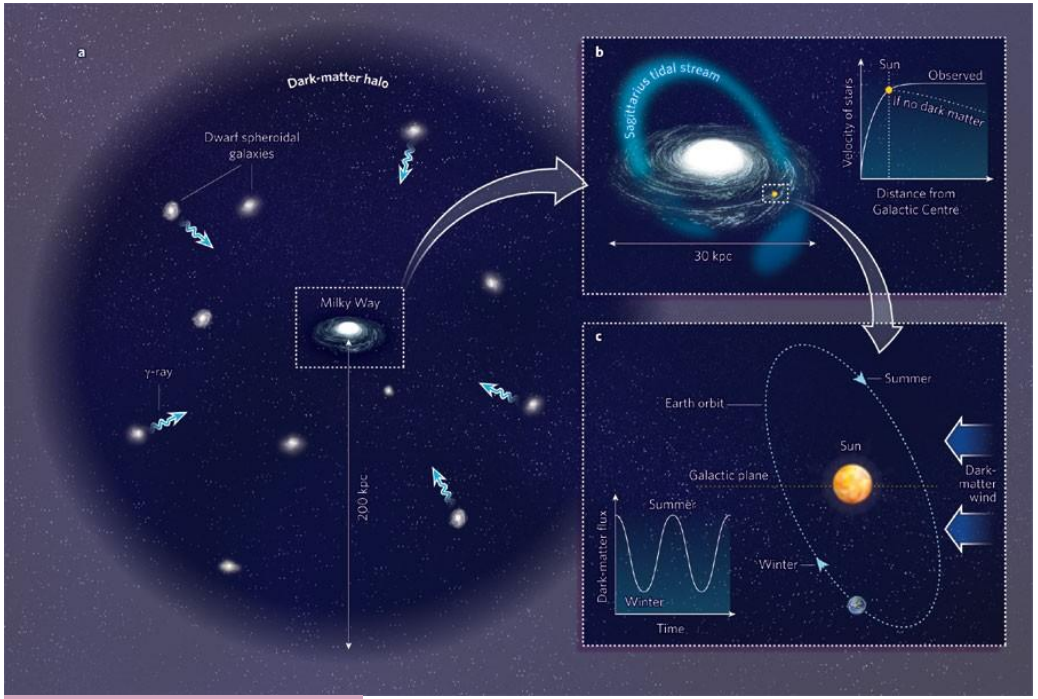
⇩

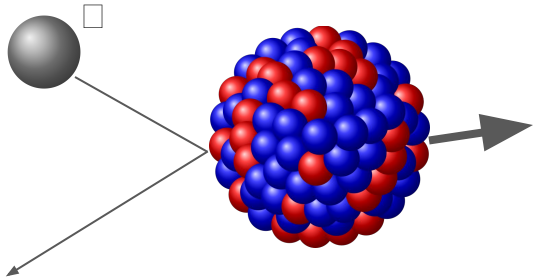
DM halo model

Standard assumptions:

- Maxwellian velocity distribution with most probable value v_0 220 km/s
- Galactic escape velocity 544 km/s
- Local DM density 0.3 GeV/cm^3

DARK MATTER: DIRECT DETECTION EVENT RATE





Astrophysical input

Nuclear physics input

$$\frac{dR}{dE_r} \propto \frac{\rho_\chi}{m_\chi} N_T \sigma_0 F^2(E_r) \underbrace{\int_{v_{min}(E_r)=\sqrt{\frac{E_r m_N}{2\,\mu^2}}}^{v_{esc}} \frac{f(\vec{v})}{v} d^3v}$$

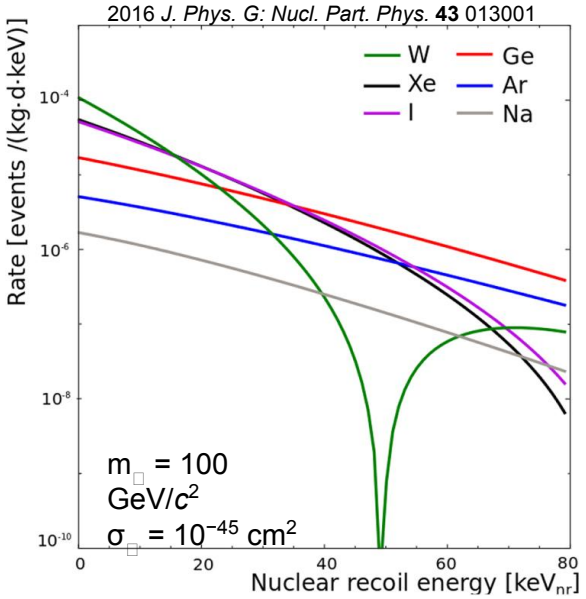
strongly affected by the DM halo model

Particle theory dependencies: goals of experiments

Caldwell, R., Kamionkowski, M. Dark matter and dark energy. *Nature* **458,** 587–589 (2009). https://doi.org/10.1038/458587a

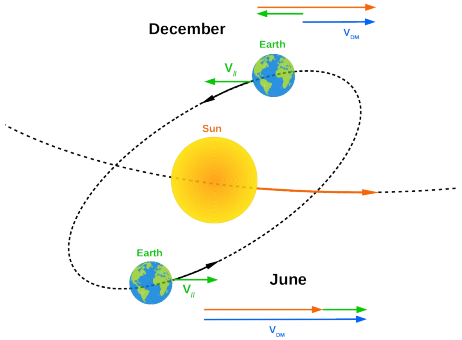
EXPERIMENTAL SIGNATURES

Spectral shape



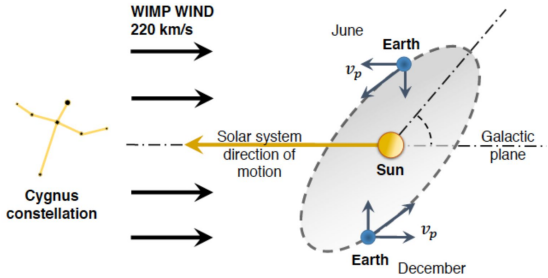
Shape of recoil spectra on different target material

Annual modulated rate



Periodic modulation of the signal due to motion of the Earth orbiting around the Sun

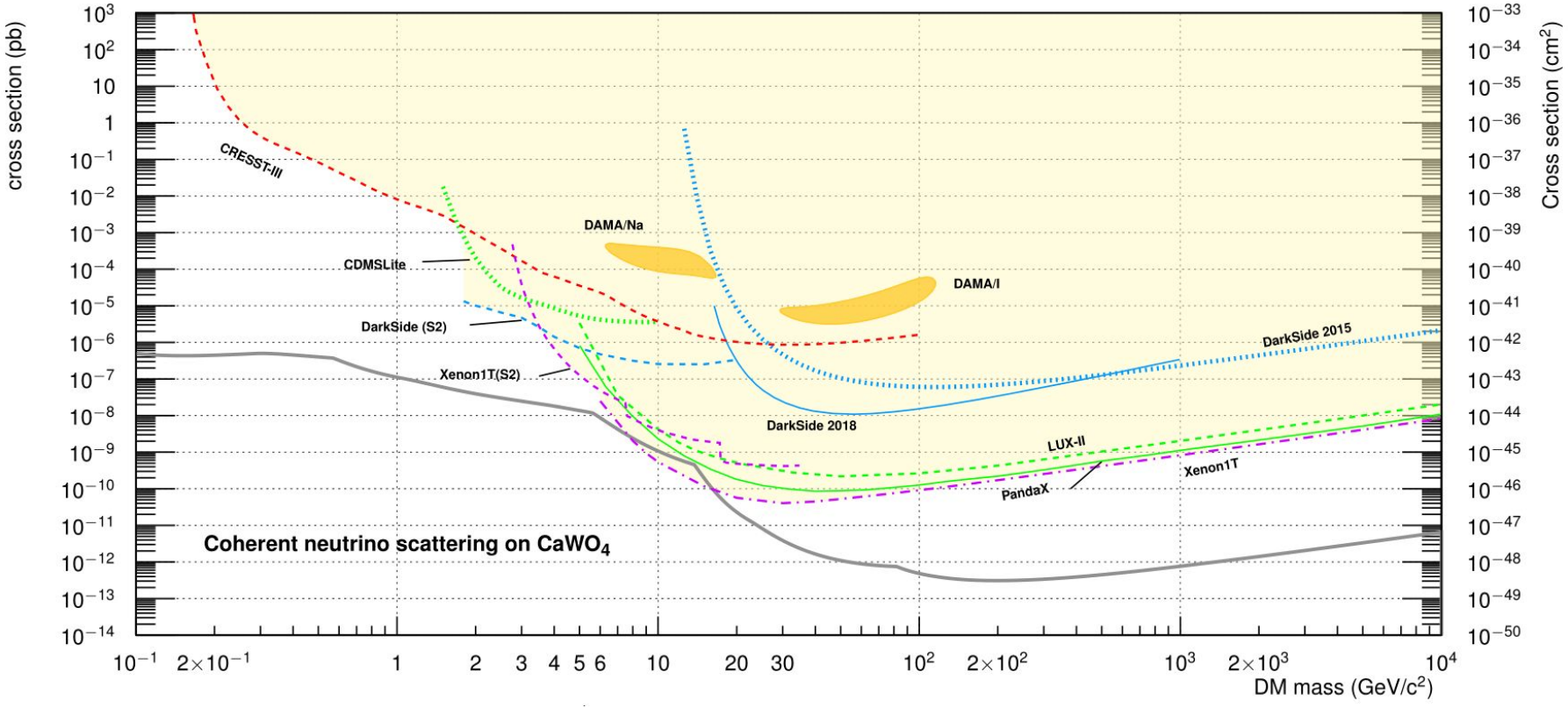
Directional dependence



Cesarano R., Esperimento ReD, B.T.AA2018/19, UniNa

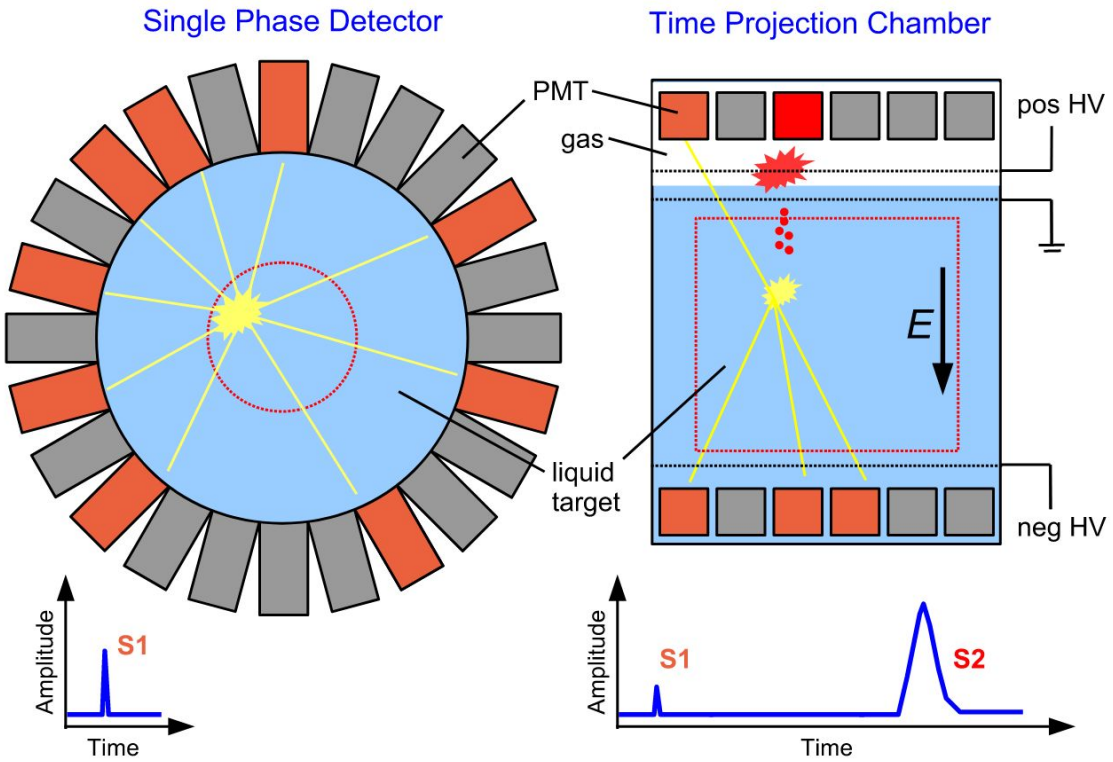
Motion of the Sun in the Galaxy leads to a directional dependence of nuclear recoils due to dark matter scattering

THE EXPERIMENTAL LANDSCAPE



LIQUID NOBLE GASSES

XENON 1T/nT LUX/LZ Panda-X ArDM DarkSide
DEAP XMASS

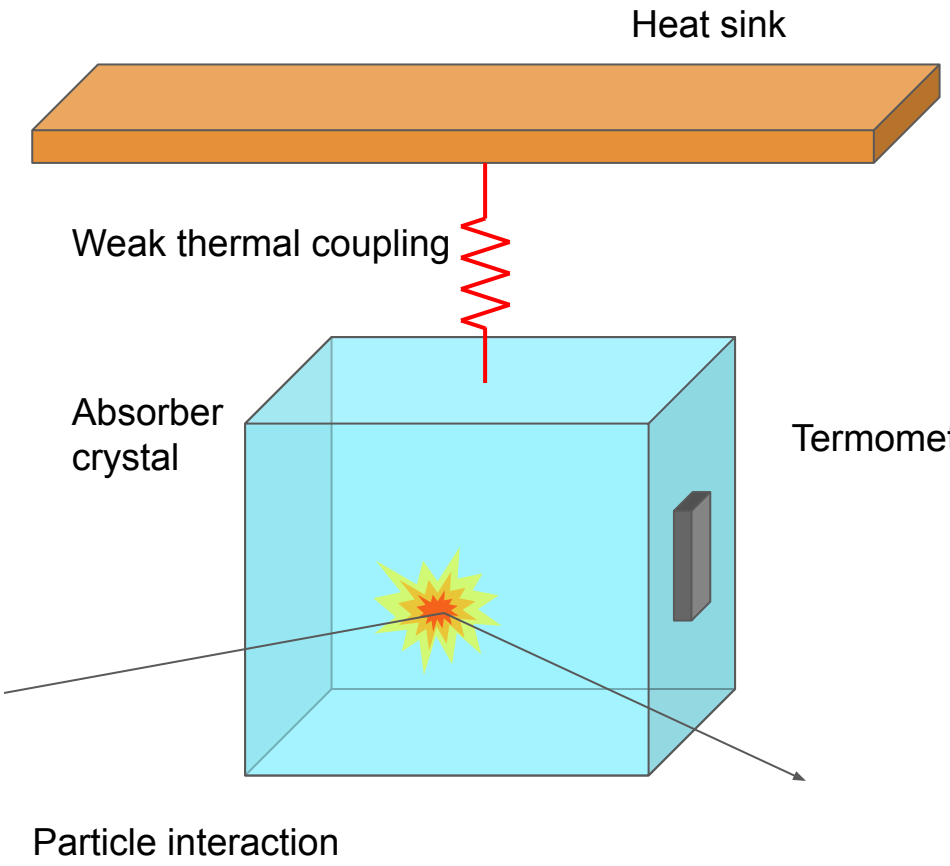


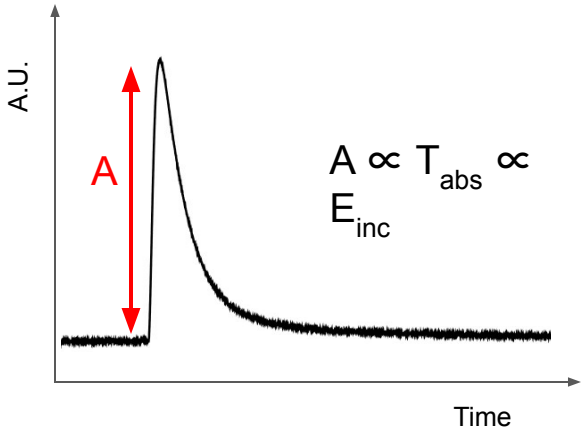
arXiv:1206.2169

★ Easily scalable to very large masses (multi-tonne)
★ Fiducialisation (self-shielding)
★ Very effective in the WIMP-like scenario and for heavy dark matter

More details: September the 16th

CALORIMETERS





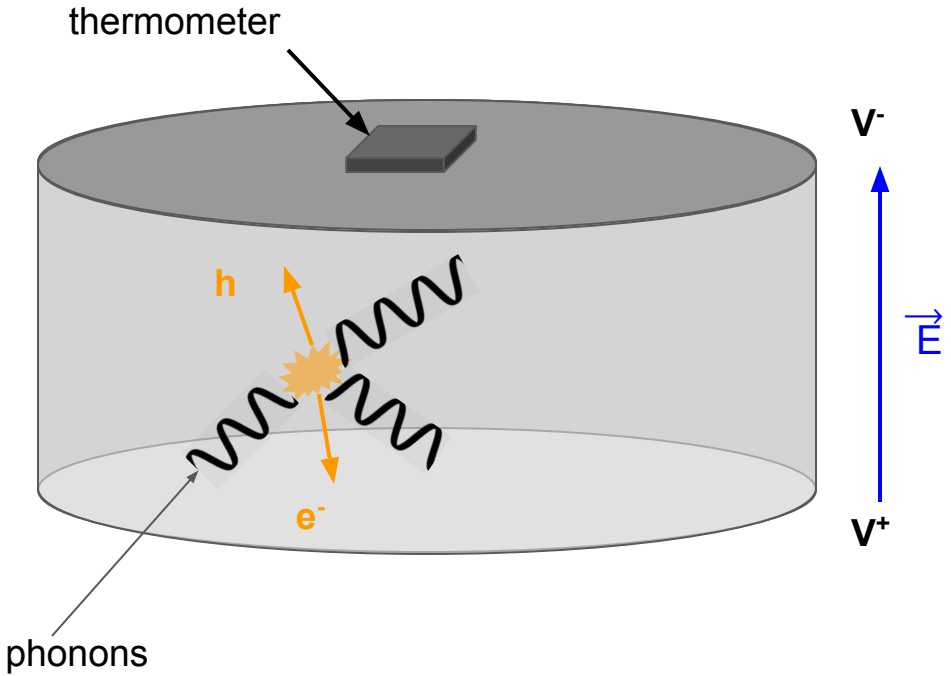
$\Delta T = \Delta E / C$

- Direct measurement of the (almost) full energy deposition
- Low (< 100eV) nuclear recoil energy thresholds
- Background rejection down to low energy
- mK operating temperature

SEMICONDUCTING CALORIMETERS

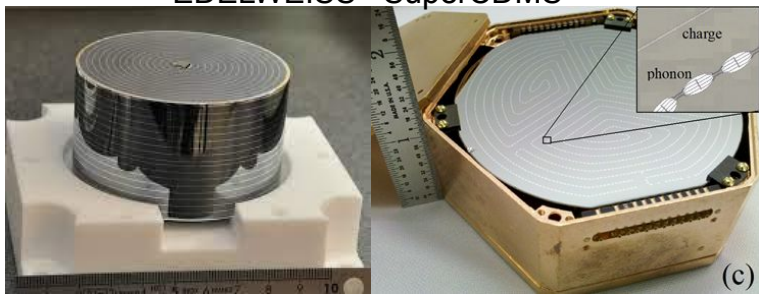
Phonon + Ionization

SuperCDMS EDELWEISS



- Phonon and charge sensors on the target crystal
- Particle identification via ratio of ionization and primary phonon
- Surface events identified thanks to ID electrodes

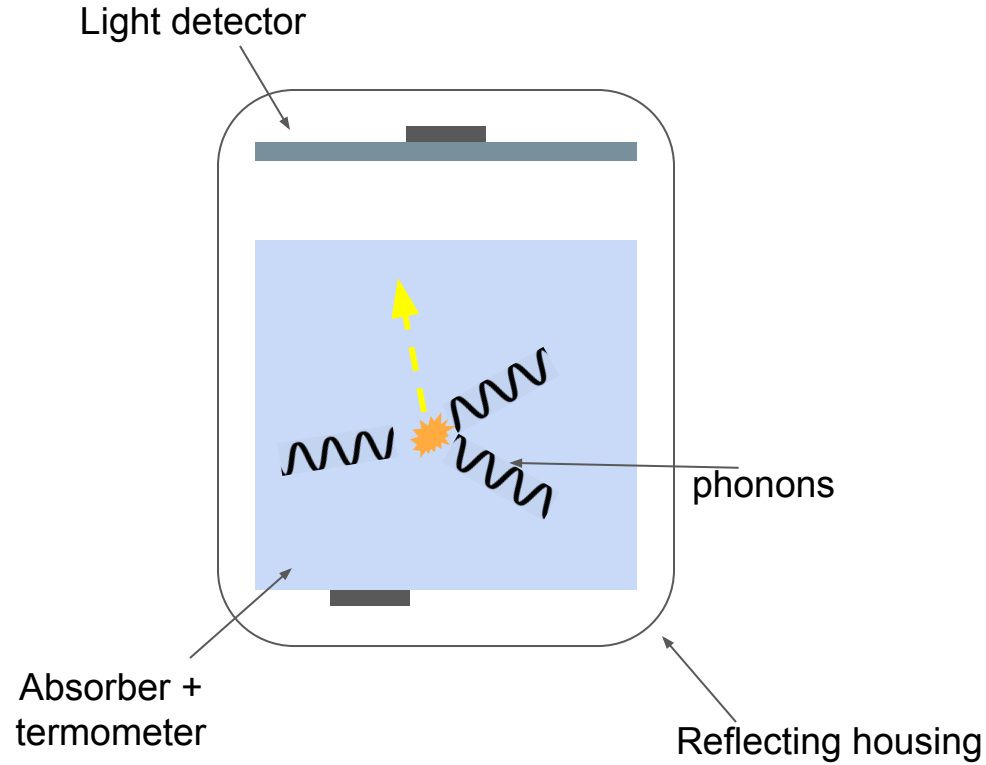
EDELWEISS SuperCDMS



SCINTILLATING CALORIMETERS

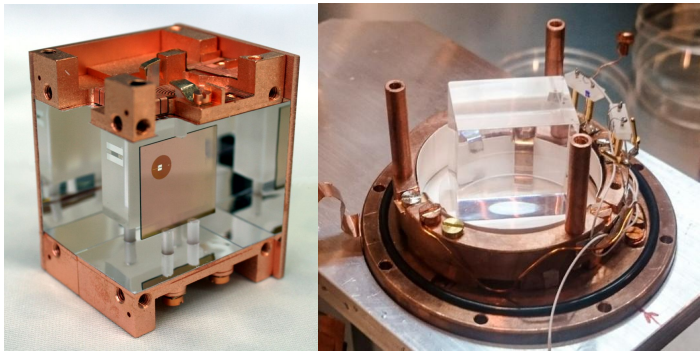
Phonon + Light

CRESST COSINUS



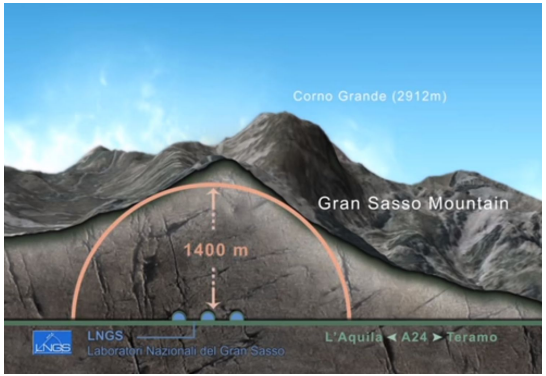
- Phonon sensor on the target crystal, separate cryogenic detector for light signal
- Particle identification via ratio of light to primary phonon

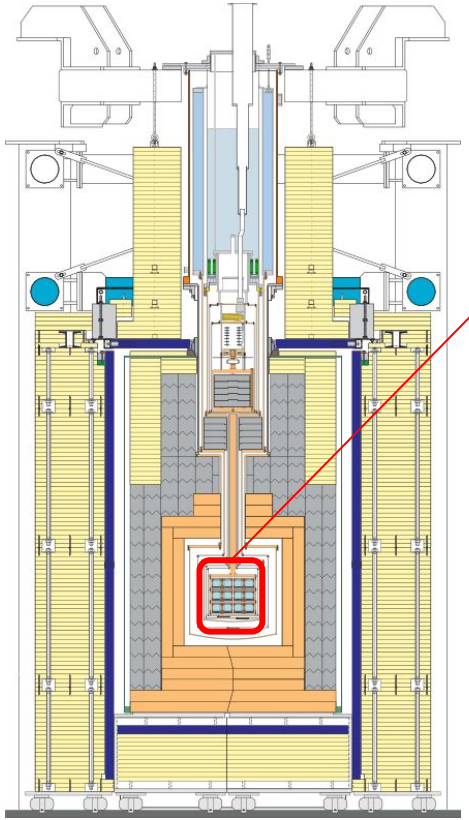
CRESST COSINUS

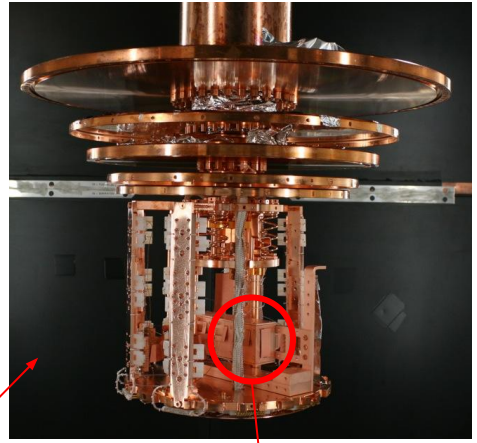


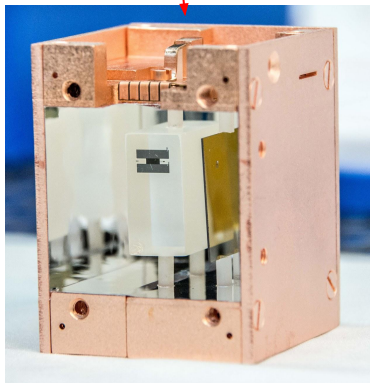
The CRESST experiment

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





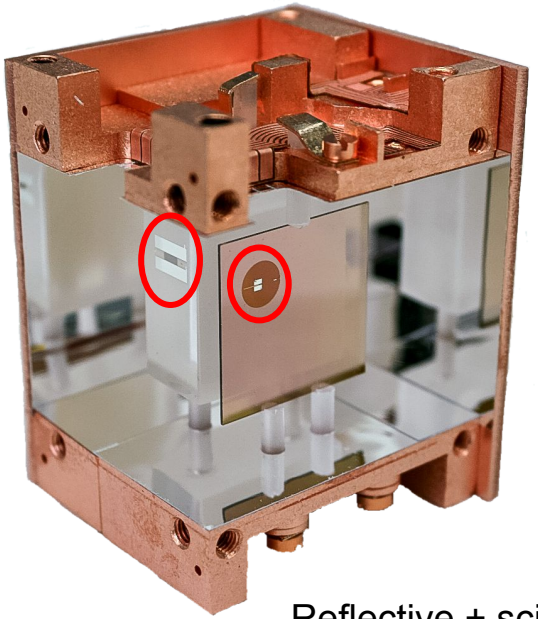




Target = $CaWO_4$ crystals
operated at ~15 mK

The CRESST detector

➡ Optimized for low mass dark matter particle

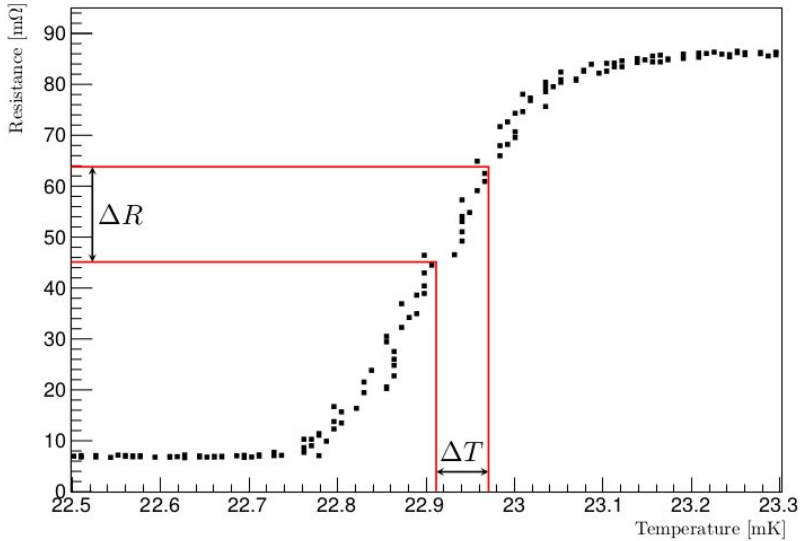


Phonon detector
~24g of $CaWO_4$
scintillating
crystal+TES

Light detector
Silicon On
Sapphire+TES

Reflective + scintillating
housing

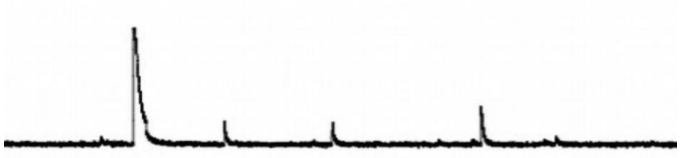
Transition **E**dge **S**ensor allows to be sensitive to extremely small changes in temperature

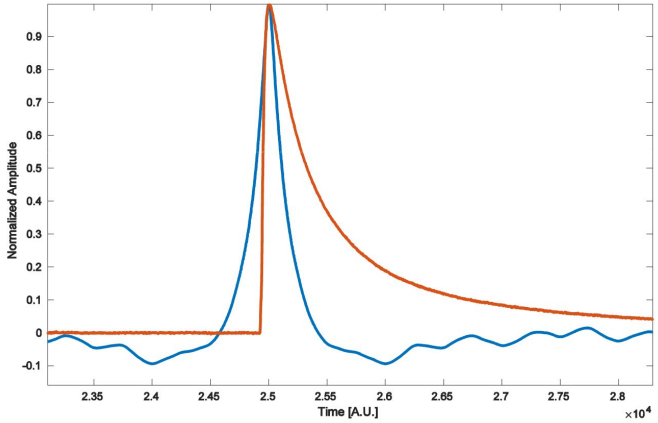


Energy ~keV ⇒ Temperature ~μK ⇒ Resistence ~mΩ

Data processing and selection

- Continuous stream of data
- Optimum Filter/Trigger algorithm
- Data selection training done on a subset of data
- Applied without change to the blind dataset





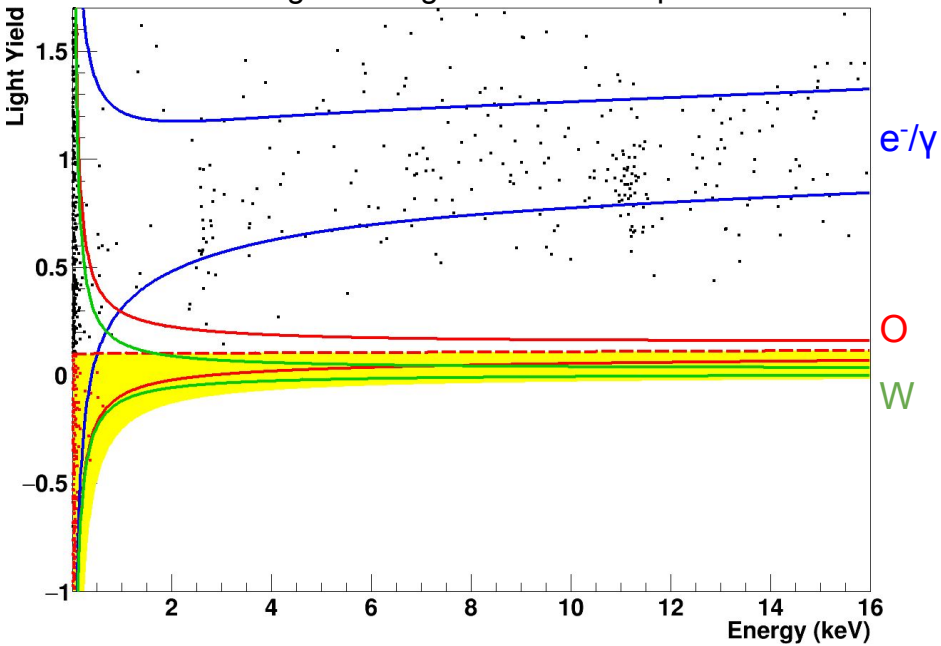
Rate: noise conditions
Stability: Detector(s) in operating point
Data quality: Non-standard pulse shapes (e.g. pileup)
Coincidences: with μ-veto, i-Sticks, other detectors

Detector A: energy spectrum

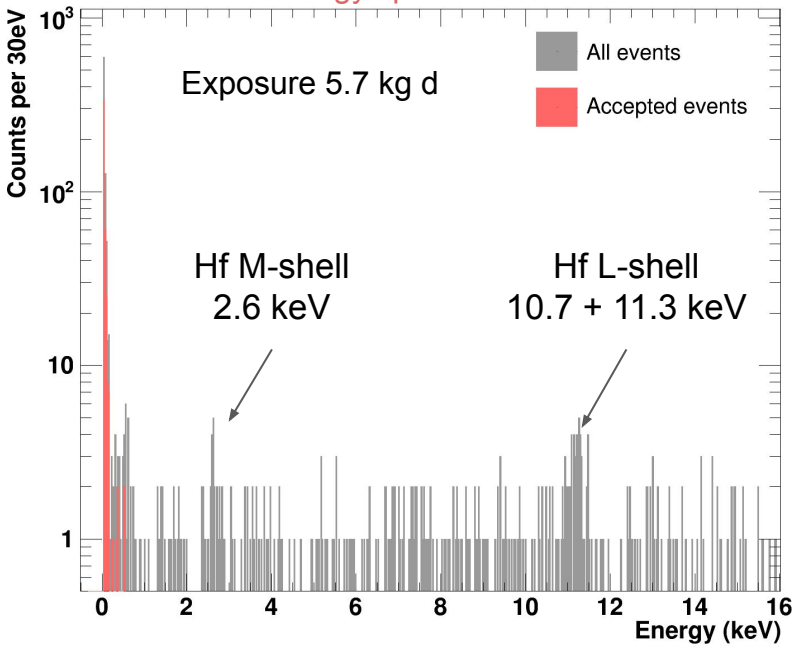
Phys. Rev. D 100, 102002 (2019)

Run 34 (05/2016 – 02/2018)

Background Light Yield scatter plot



Total energy spectrum in the ROI

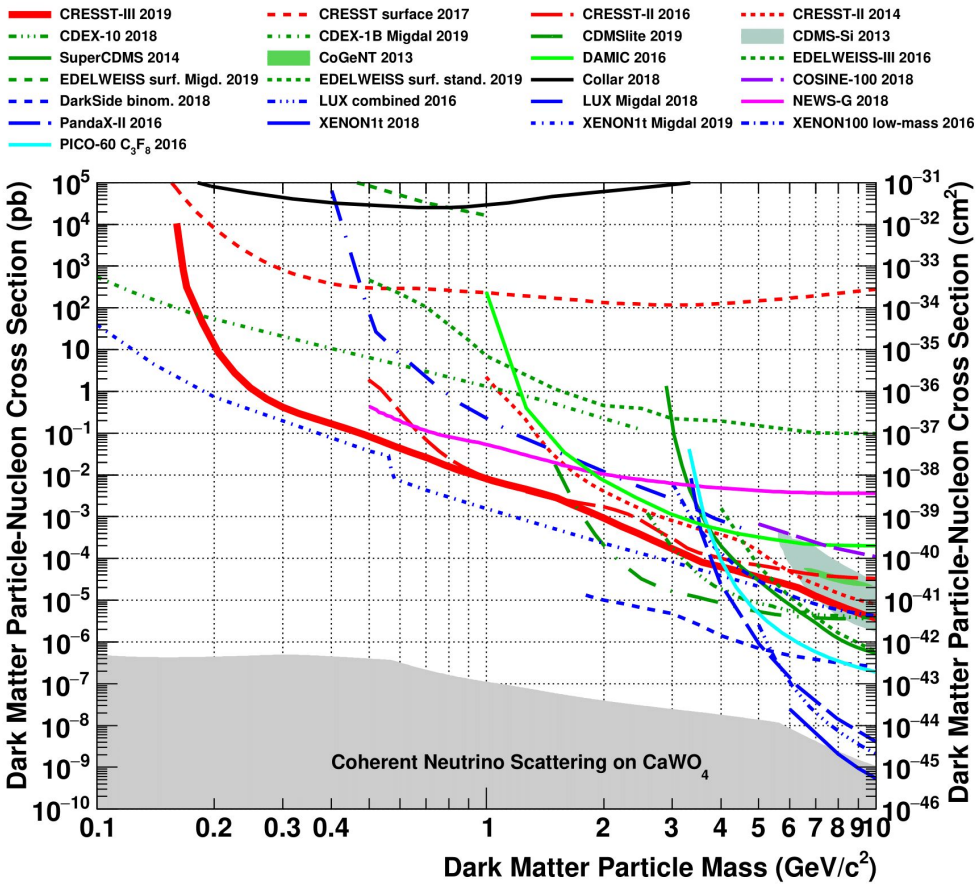


ROI
- upper limit 50 % O recoils
- lower limit 99.5 % W recoils

Cosmogenic activation
- $^{182}W + p \rightarrow {}^{179}Ta + \alpha$
- $^{179}Ta + e^- \rightarrow {}^{179}Hf + \nu_e$

CRESST results

* until the existence of the Midgal effect is confirmed



Adapted from: Phys. Rev. D 100, 102002 (2019)

*Leading limit at low-mass <1.7 GeV/c^2

Excess also present in other detectors but with different shapes
⇒ no common origin

Run 35 (11/2018 – 10/2019)
⇒ excess present with different shapes also in 2 sapphire crystals

Run 36 (03/2020 – ongoing)
⇒ detectors with different target materials and dedicated modifications to the housing to learn more about the origin of the low-energy excess

Thank you for the attention