Results from the CRESST-III low-mass dark matter detector

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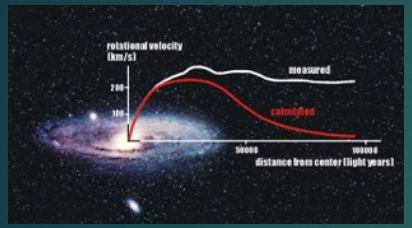
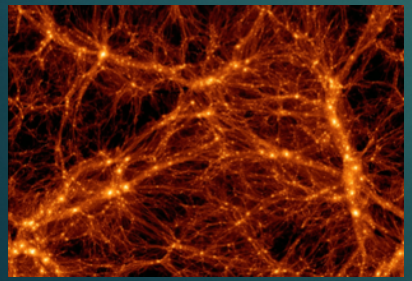
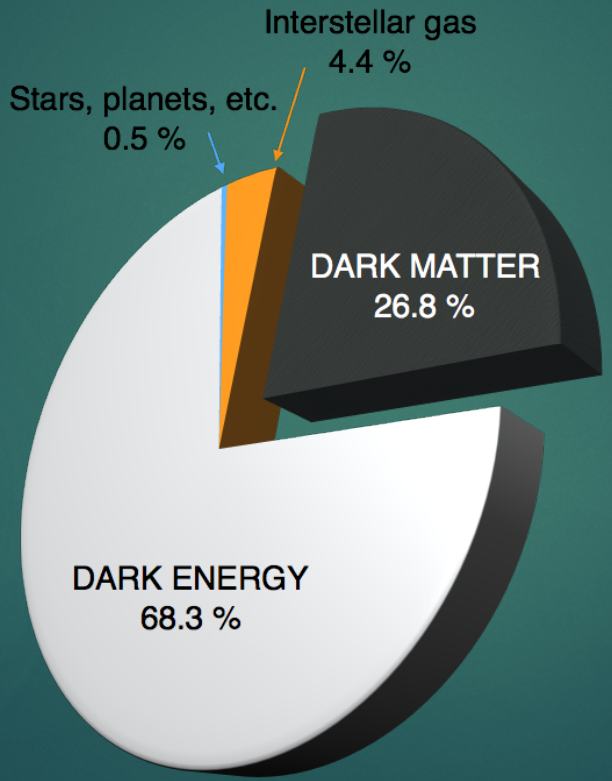
THE PARTICLE FRONTIER - ASPEN
27.03.2018

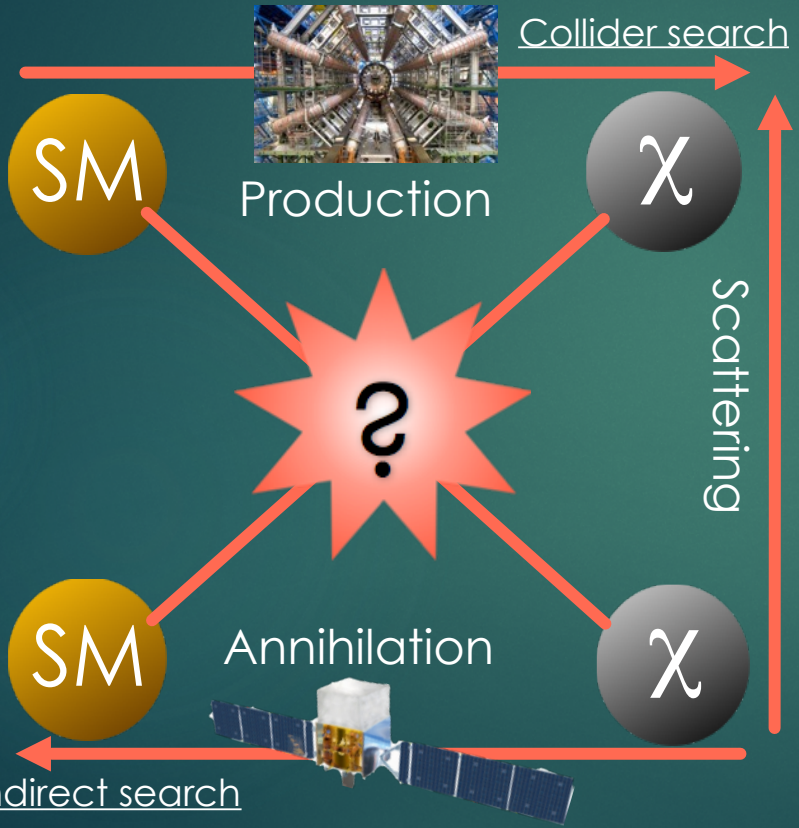
The dark matter problem



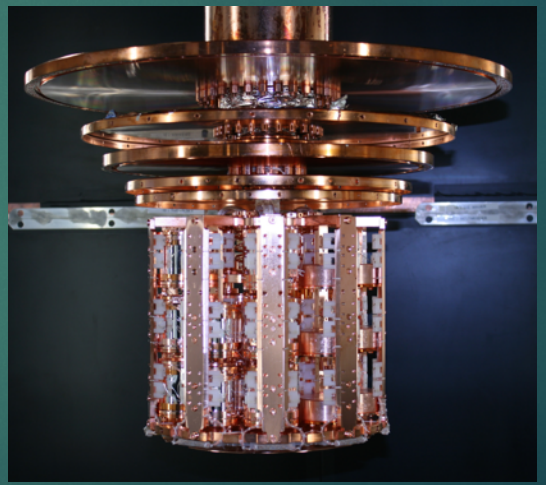




The hunt for dark matter



Direct search

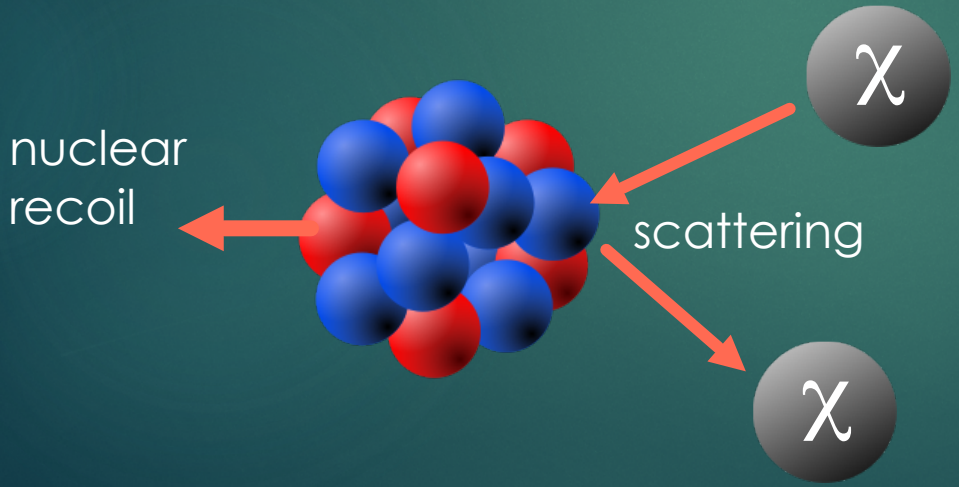


The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

What?

Direct detection of dark matter particles via their scattering off target nuclei



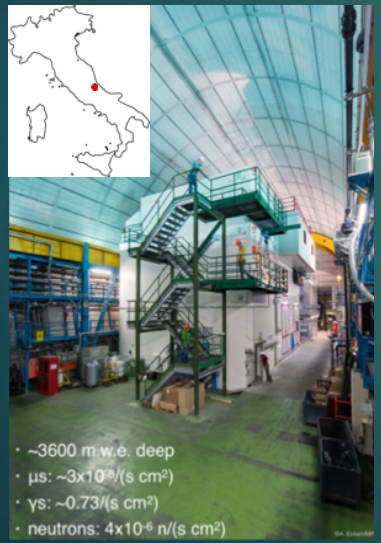
Dark matter particles scatter

- off nuclei
- elastically
- coherently: ~A^2

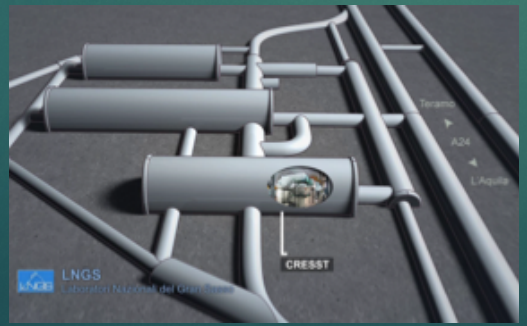
The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

Where? Laboratori Nazionali del Gran Sasso (LNGS) underground facility, Italy



Background suppression

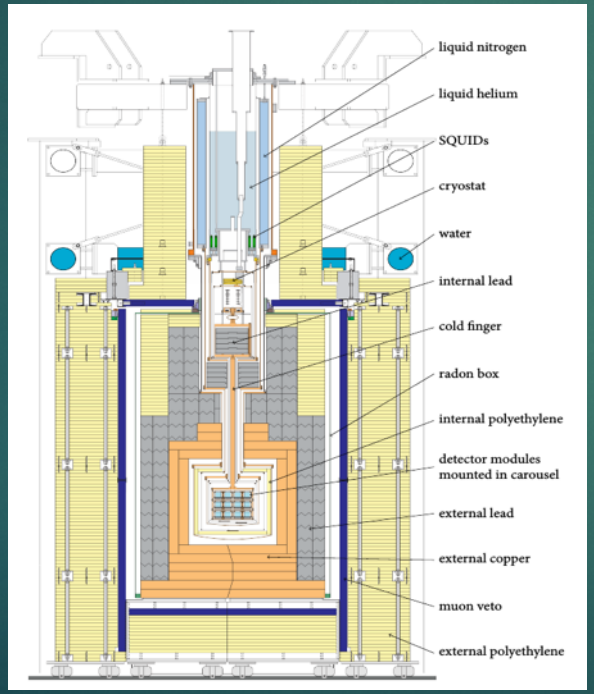


- Underground site
- Shielding/vetoing
- Radon mitigation
- Purity of materials
- Material handling
- Event discrimination

The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

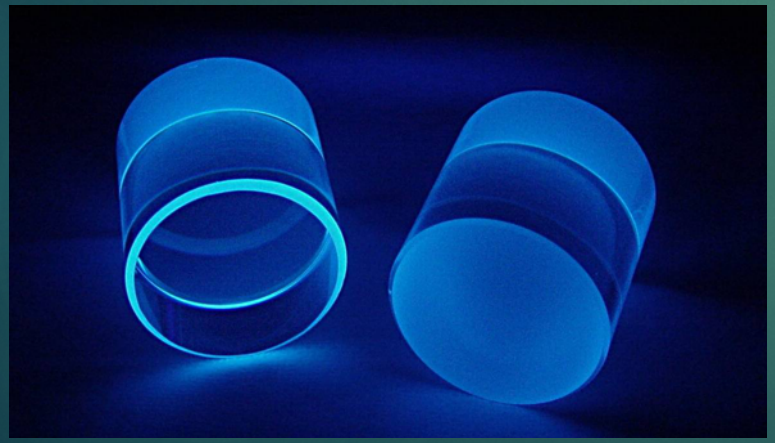
Setup?



The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

Target? **Scintillating $CaWO_4$** crystals



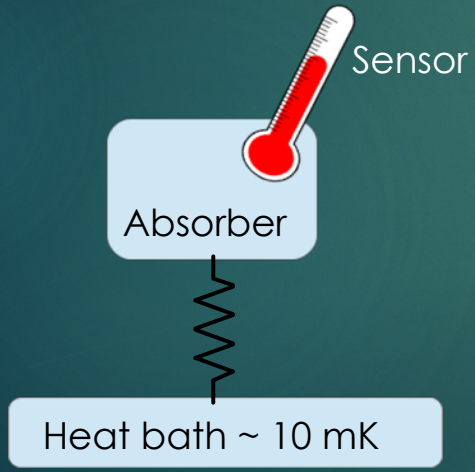
- 3 nuclei: O, Ca and W
- Light targets to maximize sensitivity for low mass dark matter
- Each particle interaction implies **phonon signal** + **light signal**

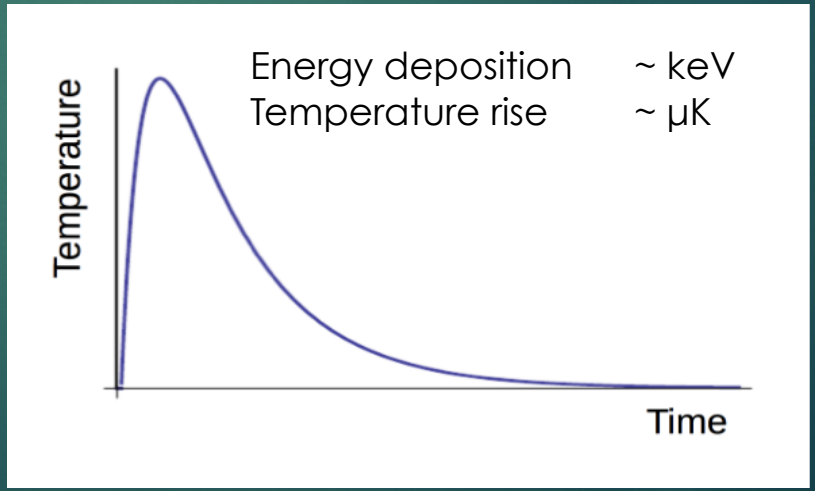
The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

How?

Crystals operated as
cryogenic calorimeters (~ 15 mK)



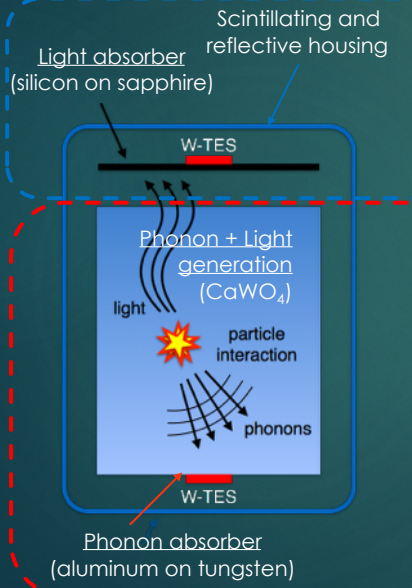


The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

Detector?

- Absorber:



SOS for **light channel**:

different responses depending on particle type

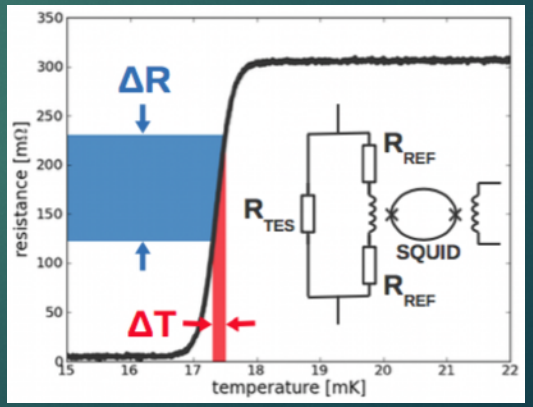
$CaWO_4$ for **phonon channel**:

measures deposited energy independently of particle type

- Sensor:

W-TES

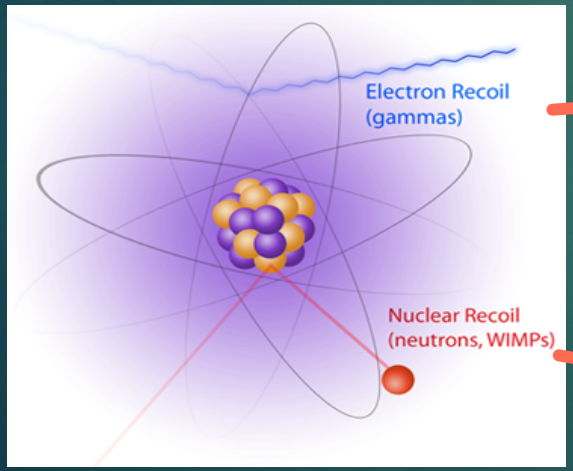
Transition Edge Sensors

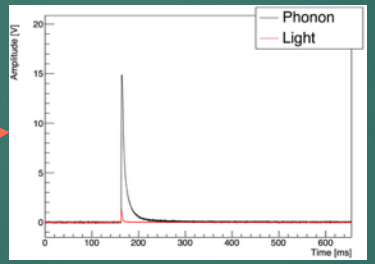


The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

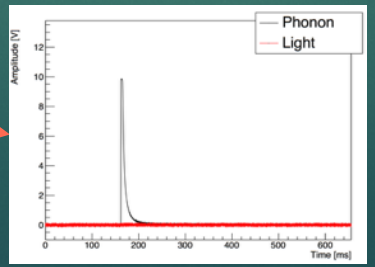
Discrimination? - **Phonon channel** for **heating** +
- **Light channel** for **scintillation light**





Phonon + light

(e/γ background)

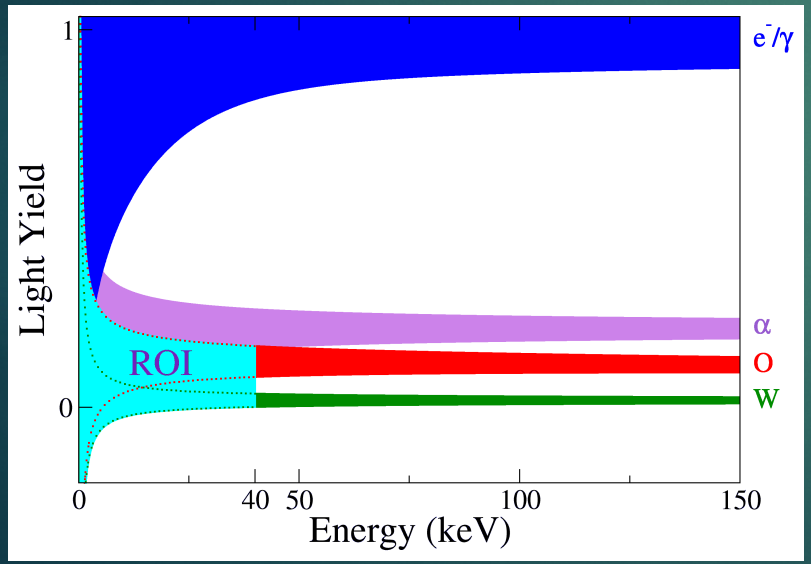


Phonon only

The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

Discrimination?



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

ROI

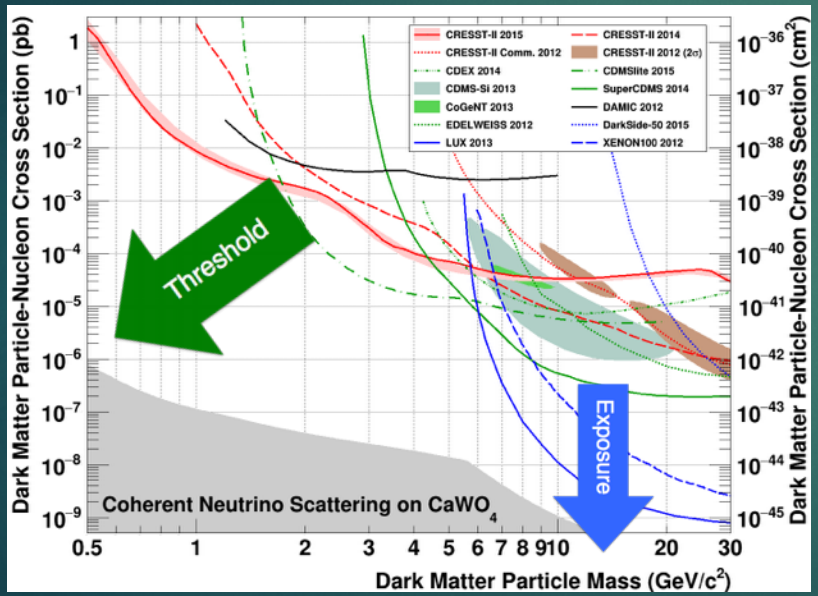
region of interest for DM search

Excellent background rejection

dominant radioactive background (electron recoils) from potential DM signals (nuclear recoils)

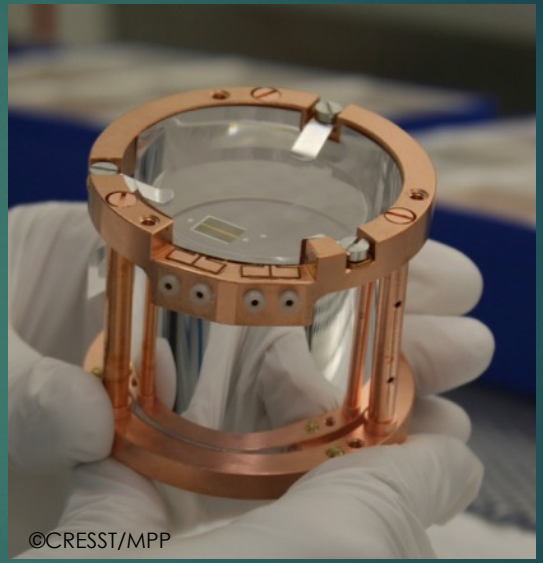
CRESST-II results

Crystal: Lise (mass 300 g)
Background level ~ 8.5 counts/(keV kg day)
Threshold: 307 eV, Resolution: σ = 62 eV @ 0 eV
Exposure: 52 kg day



EPJ C (2016) 76:25

World-leading below 1.7 GeV/c^2



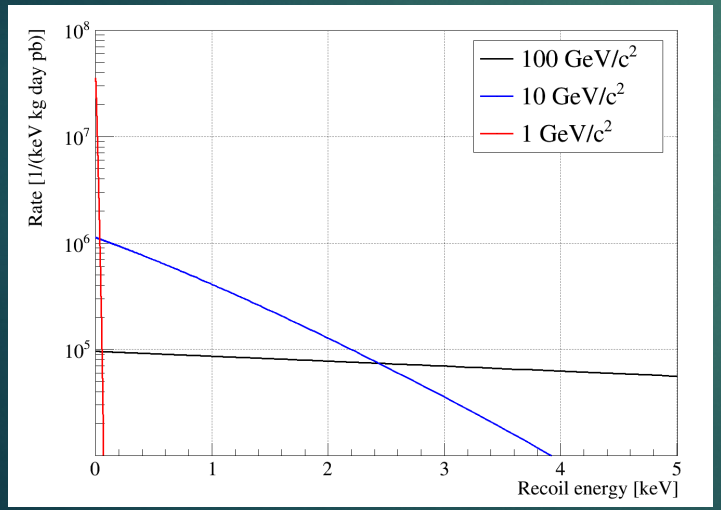
Hunting light dark matter requires a low threshold!

Low threshold detectors

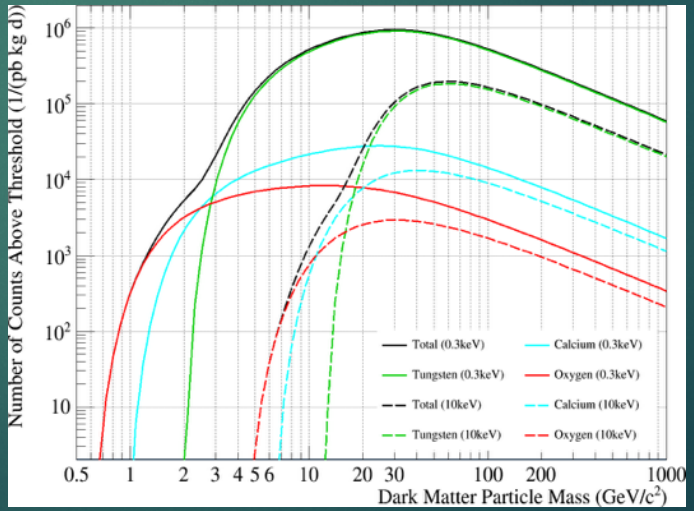
Exploring new parameter space below 0.5 GeV/c^2

Challenges:

low energy



low rates

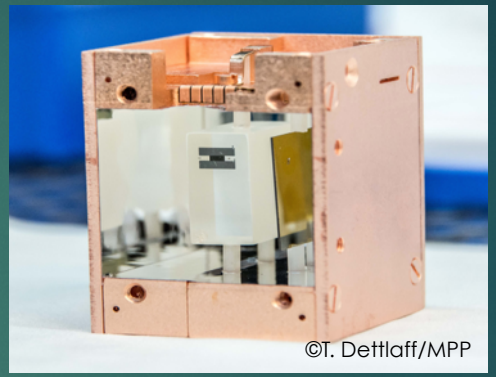


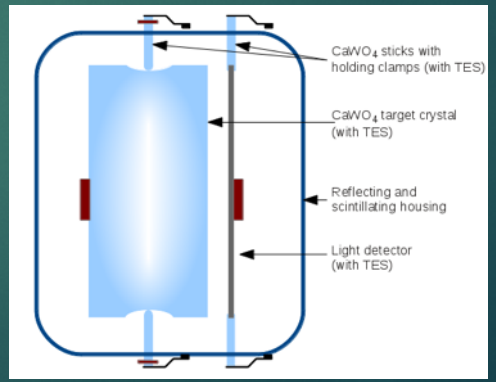
CRESST-III low-threshold detector

Exploring new parameter space below 0.5 GeV/c^2

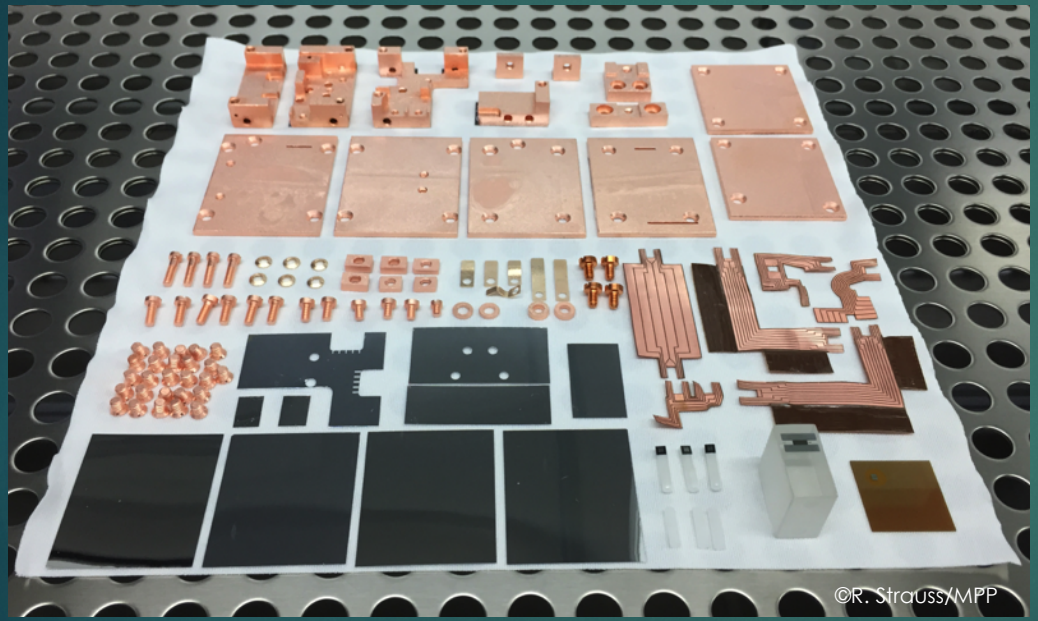
CRESST-III detector dimensions scaling down	**(CRESST-II)**
• (20×20×10) mm^3	(40×40×40)
• Mass ~ 24 g	(~300)
• Threshold goal ~ 100 eV	(~300)
• Self grown crystals ~ 3 counts/(keV kg day)	(~8.5)
• Fully scintillating housing	no
• Instrumented sticks	no

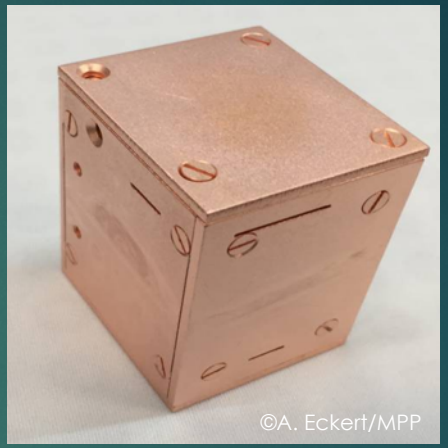
Surface related background vetoing

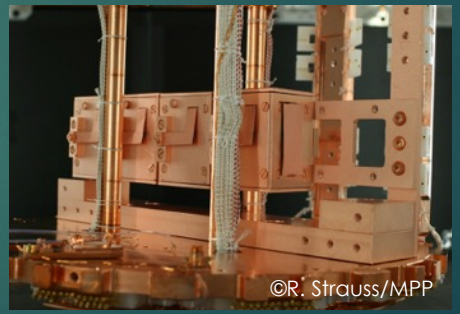




CRESST-III Phase 1





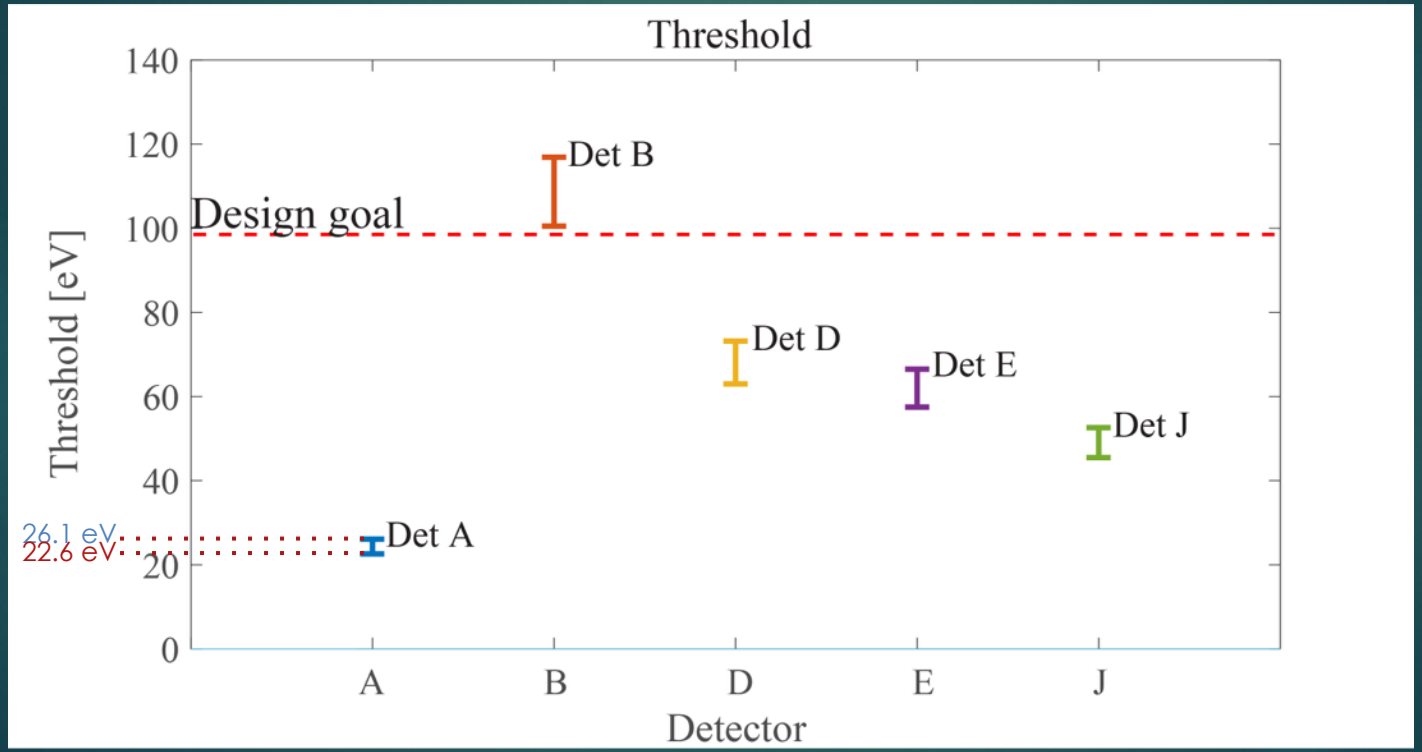


Data taking started July 2016

Optimum thresholds

New frontier in direct dark matter search

5 detectors met CRESST-III design goal



Det A – 100 eV threshold analysis

Selection criteria

Detector A

Data taking:	10/2016 – 05/2017
Non-blind data:	20% randomly selected
Target crystal mass:	24 g
Gross exposure (before cuts):	2.39 kg days
Analysis threshold:	100 eV

Objective

Accept events where a correct determination of the amplitude (→energy) is guaranteed

Unbiased (blind) analysis

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

Cut efficiency ~85%
79.5% at threshold of 100 eV

Rate: noise conditions

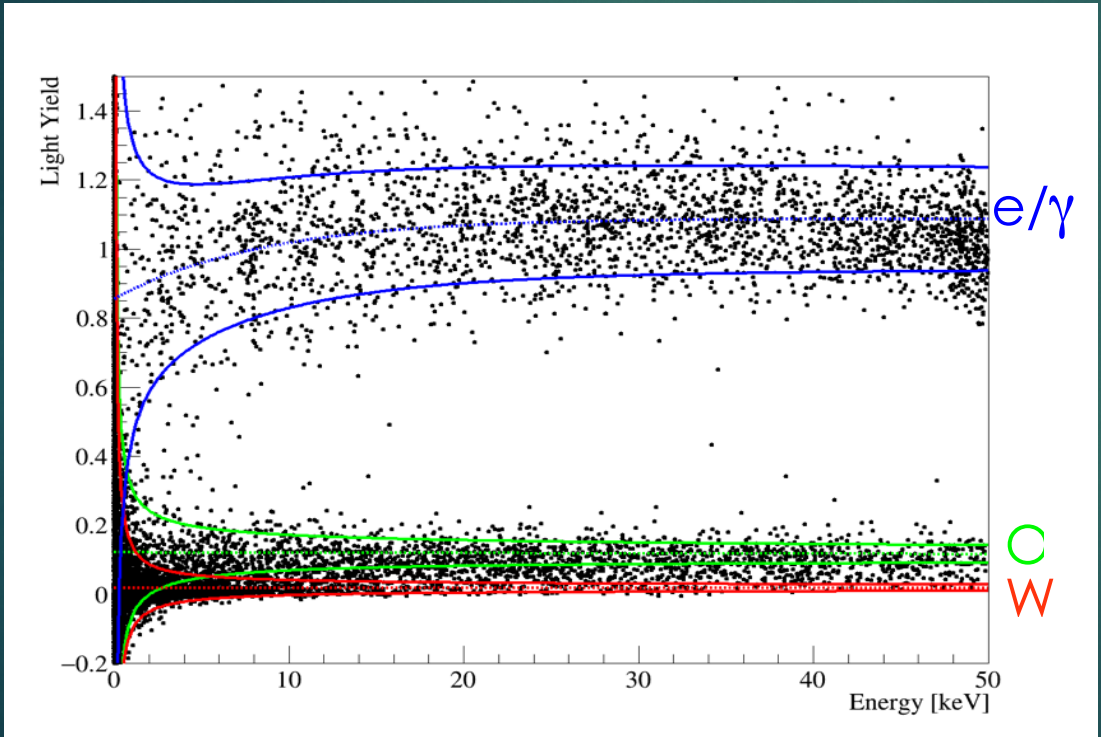
Stability: Detector(s) in operating point

Data quality: Non-standard pulse shapes (e.g. i-Stick events and pileup)

Coincidences: with μ-veto and i-Sticks only (to be expanded to "with other detector modules")

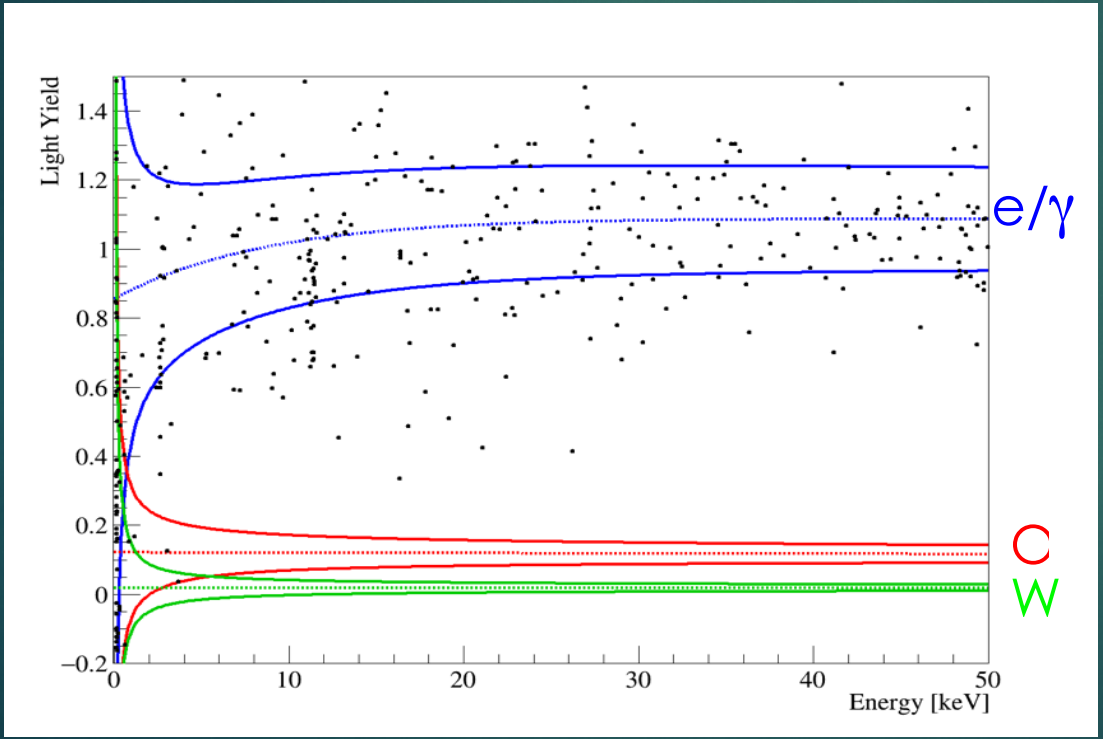
Det A – 100 eV threshold analysis

Neutron calibration



Det A – 100 eV threshold analysis

Dark matter data

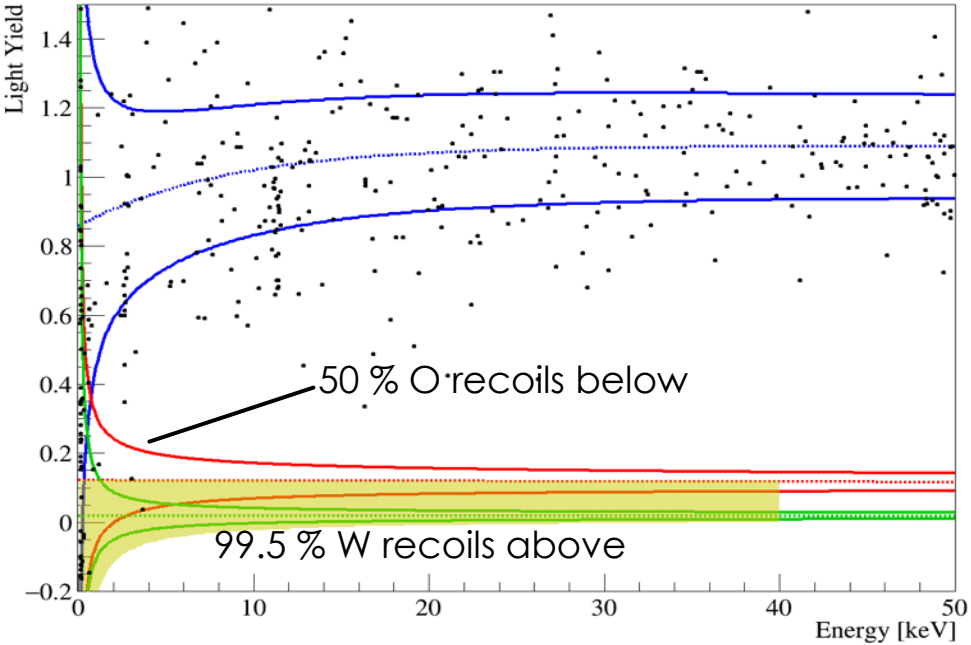


Unblinded:
Det A
E>100eV

Still blinded:
Det ≠ A
E<100eV

Det A – 100 eV threshold analysis

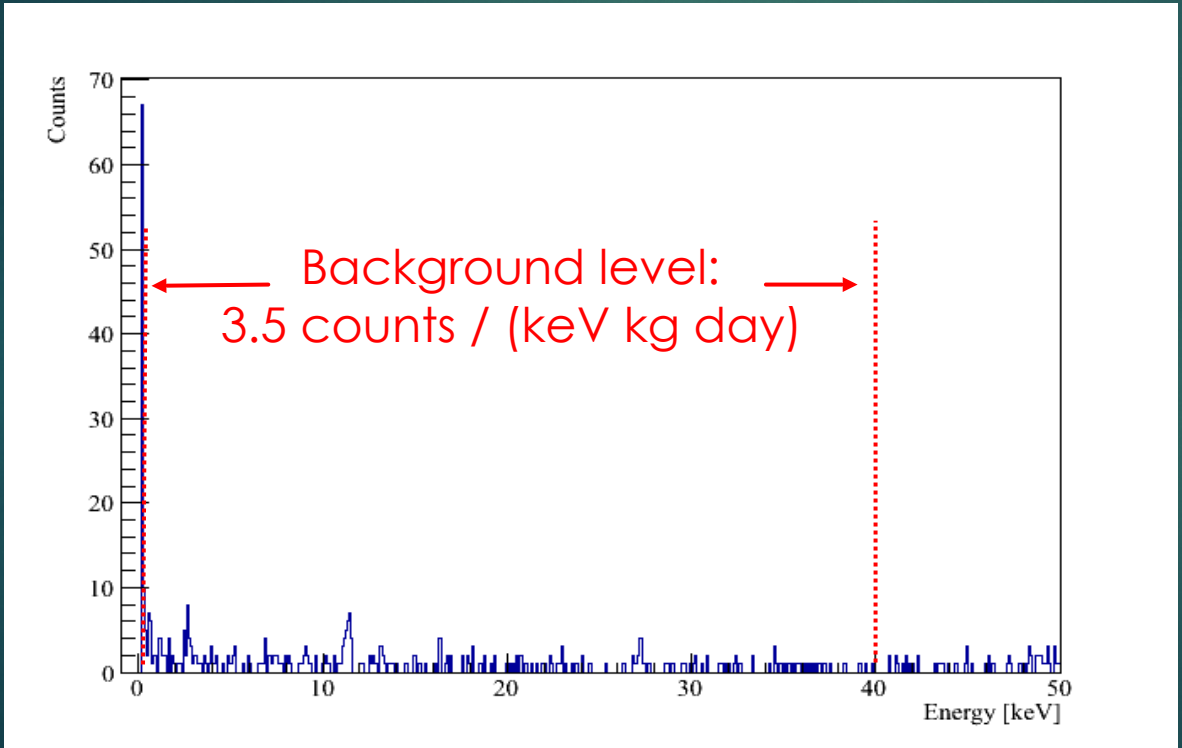
Dark matter data – Acceptance region



Acceptance region fixed before unblinding

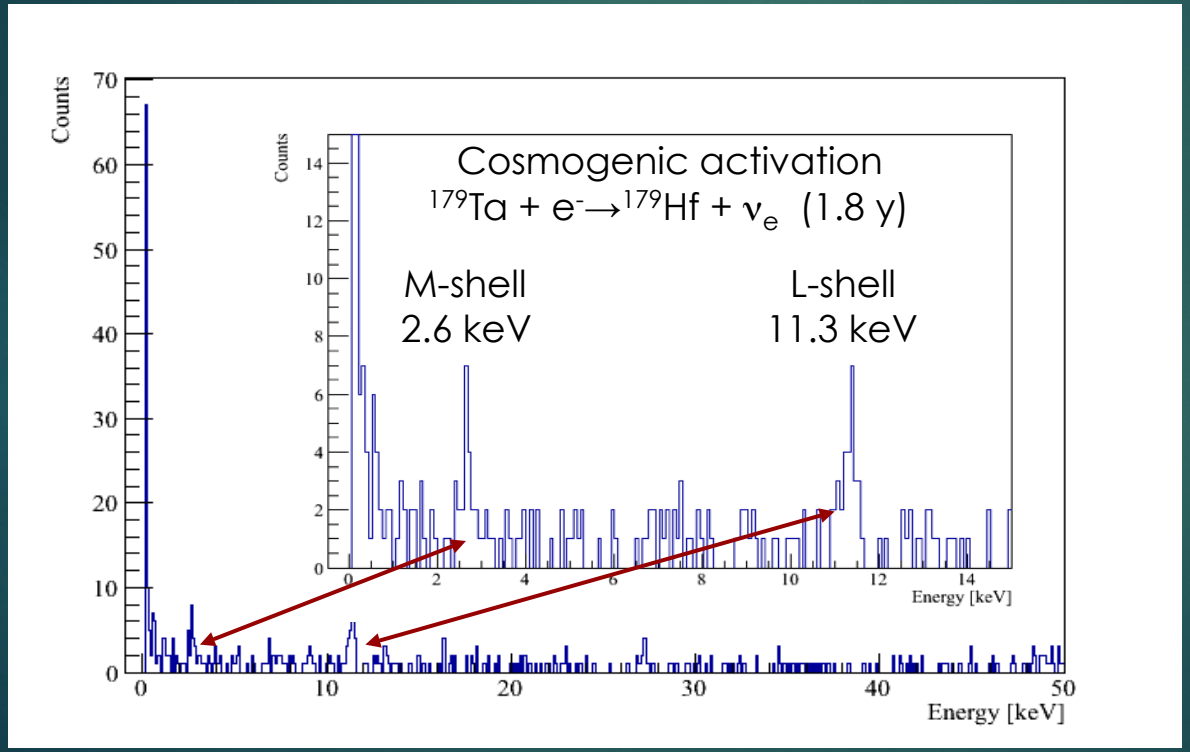
Det A – 100 eV threshold analysis

Dark matter data – energy spectrum



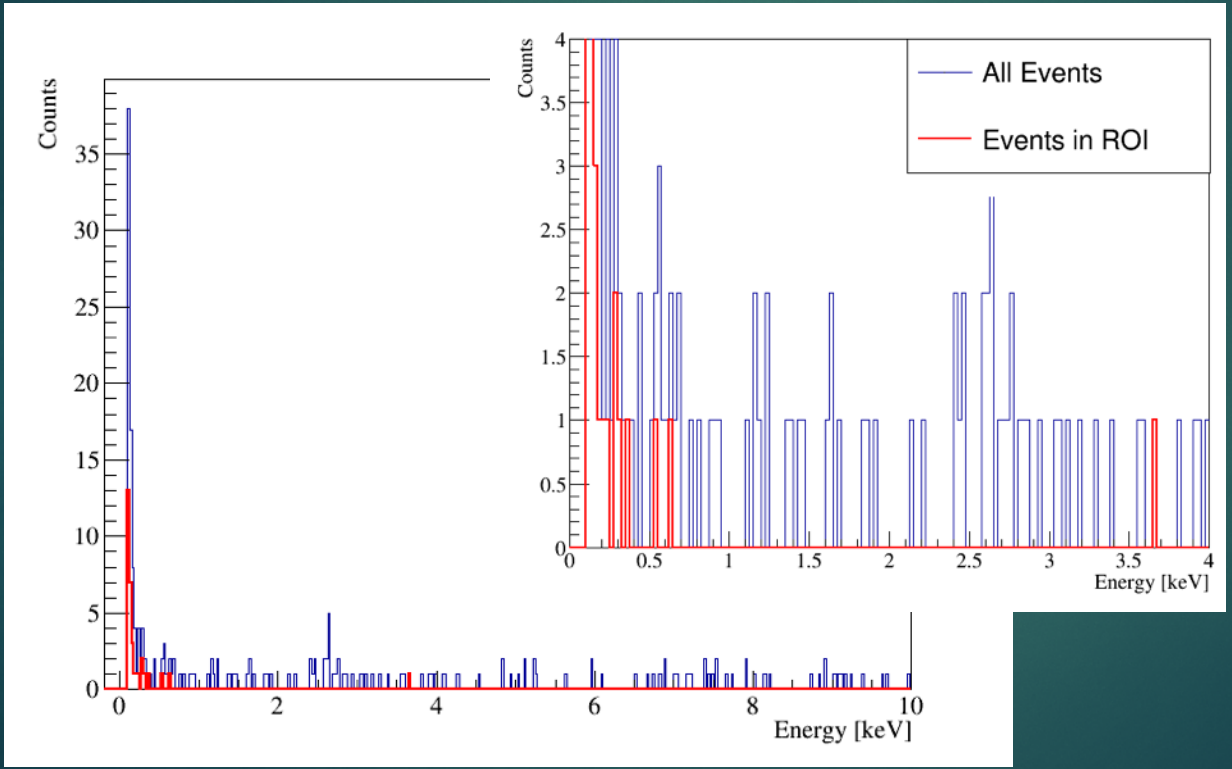
Det A – 100 eV threshold analysis

Dark matter data – energy spectrum



Det A – 100 eV threshold analysis

Dark matter data – Accepted events



Det A – 100 eV threshold analysis

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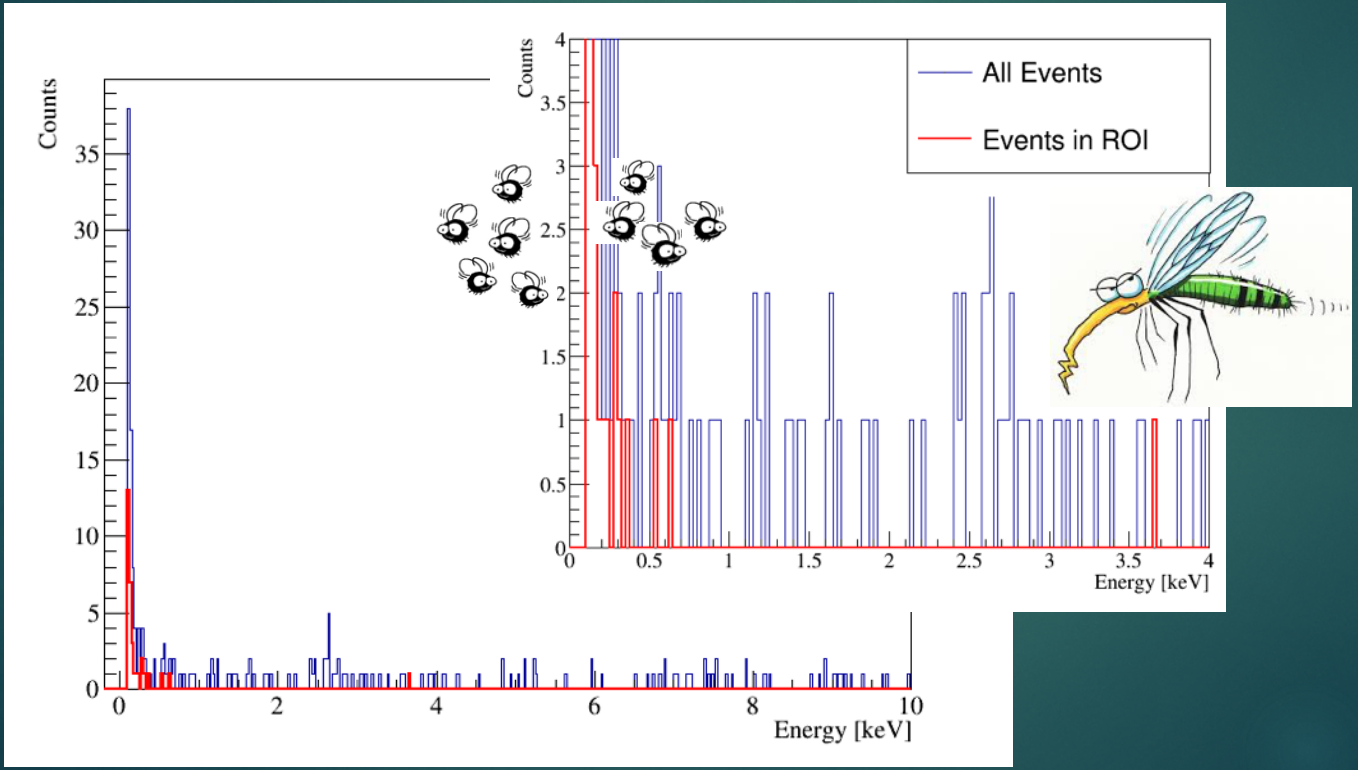
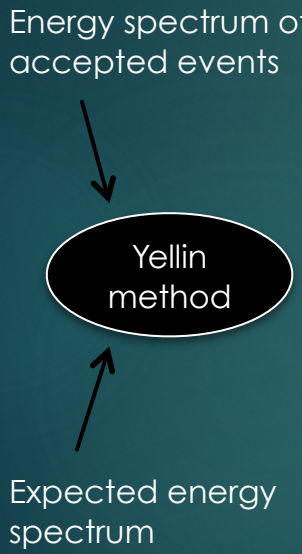


From accepted events to dark matter limits

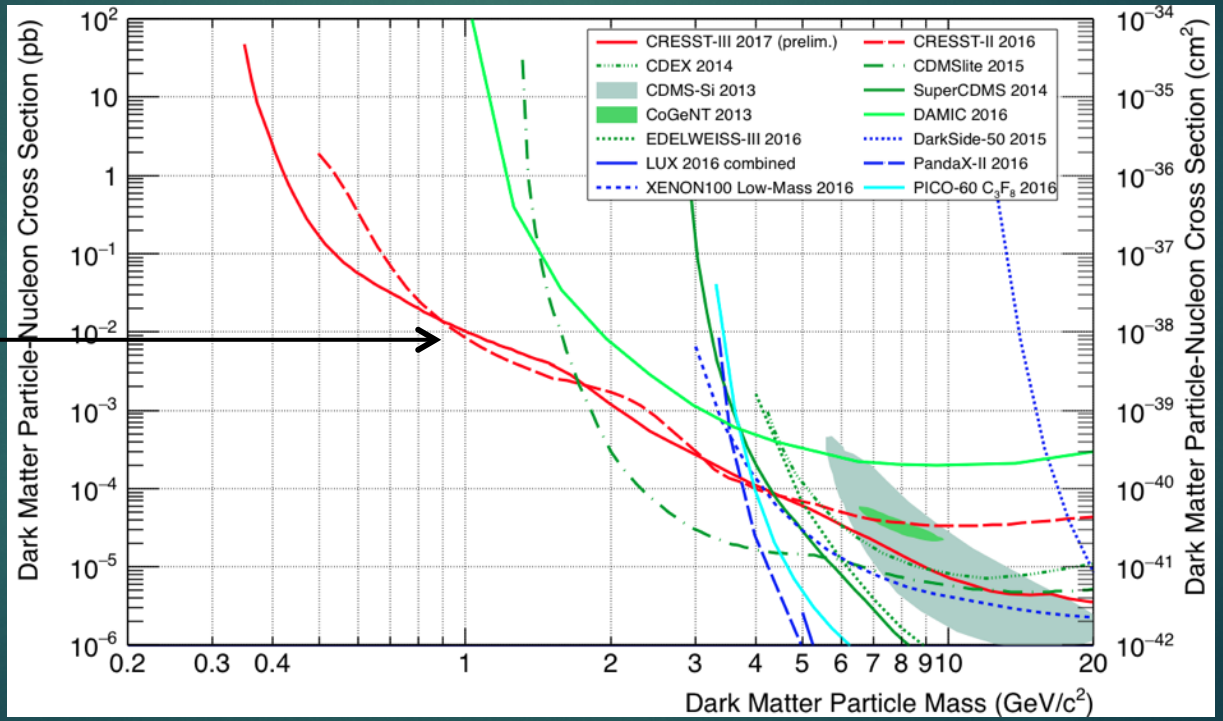


From accepted events to dark matter limits

Energy spectrum of accepted events

Yellin method

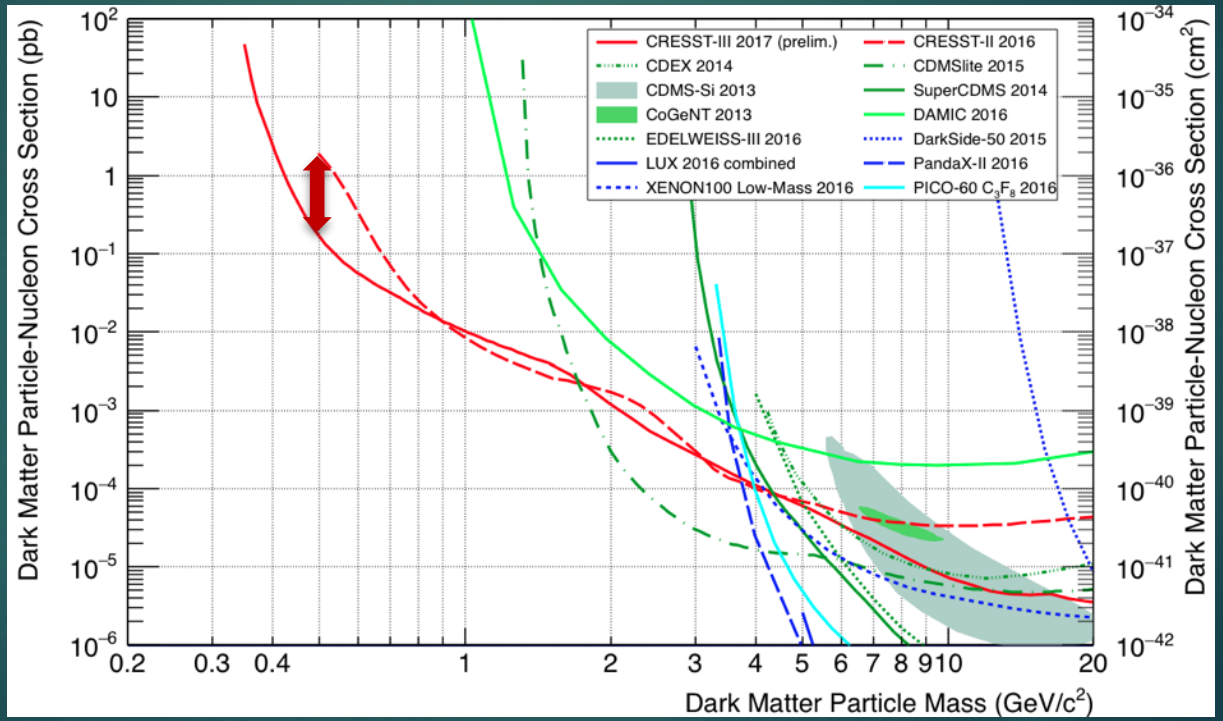
Expected energy spectrum



Det A – 100eV threshold analysis

Results

One order of magnitude improvement at 0.5 GeV/c^2



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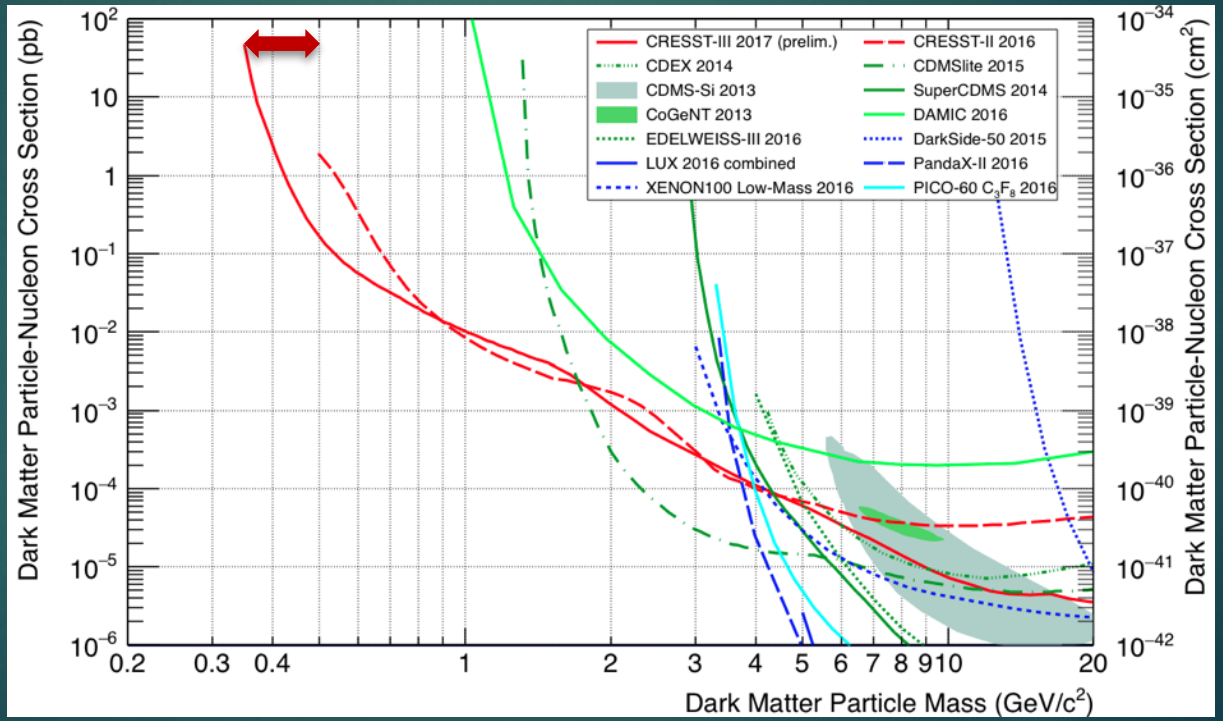
Reach of direct dark matter experiments extended to 0.35 GeV/c^2



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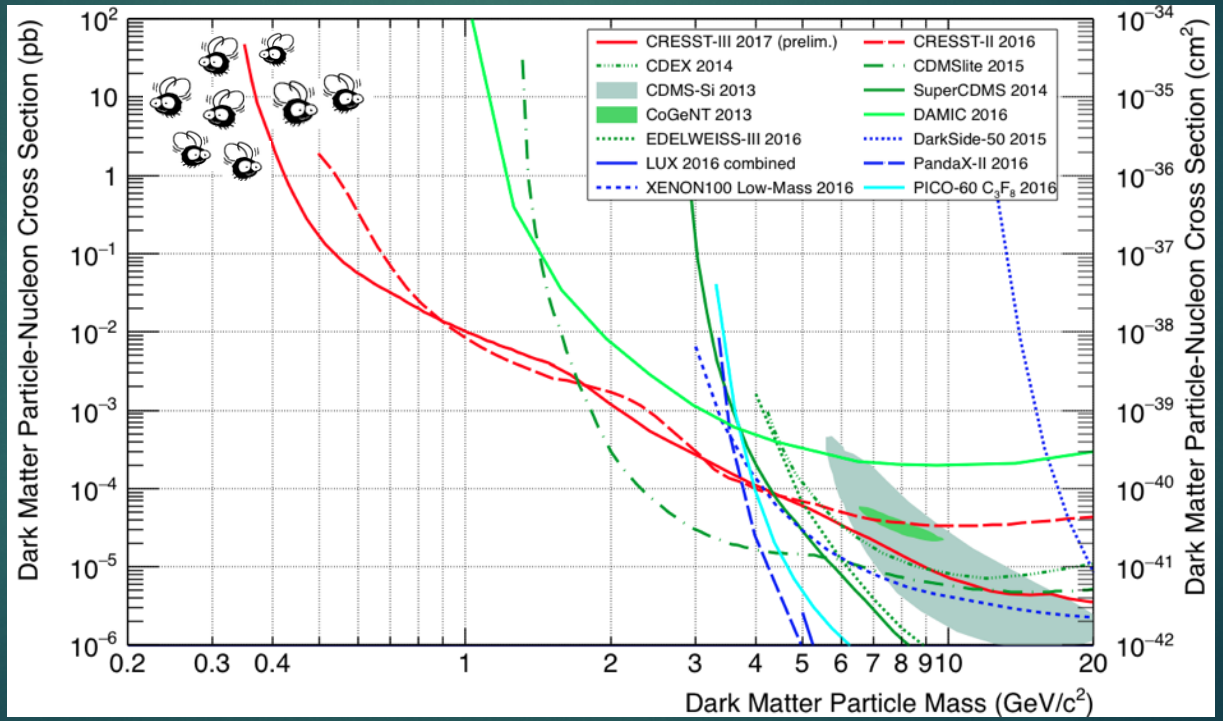
Reach of direct dark matter experiments extended to 0.35 GeV/c^2

Non-flat background at 100 eV



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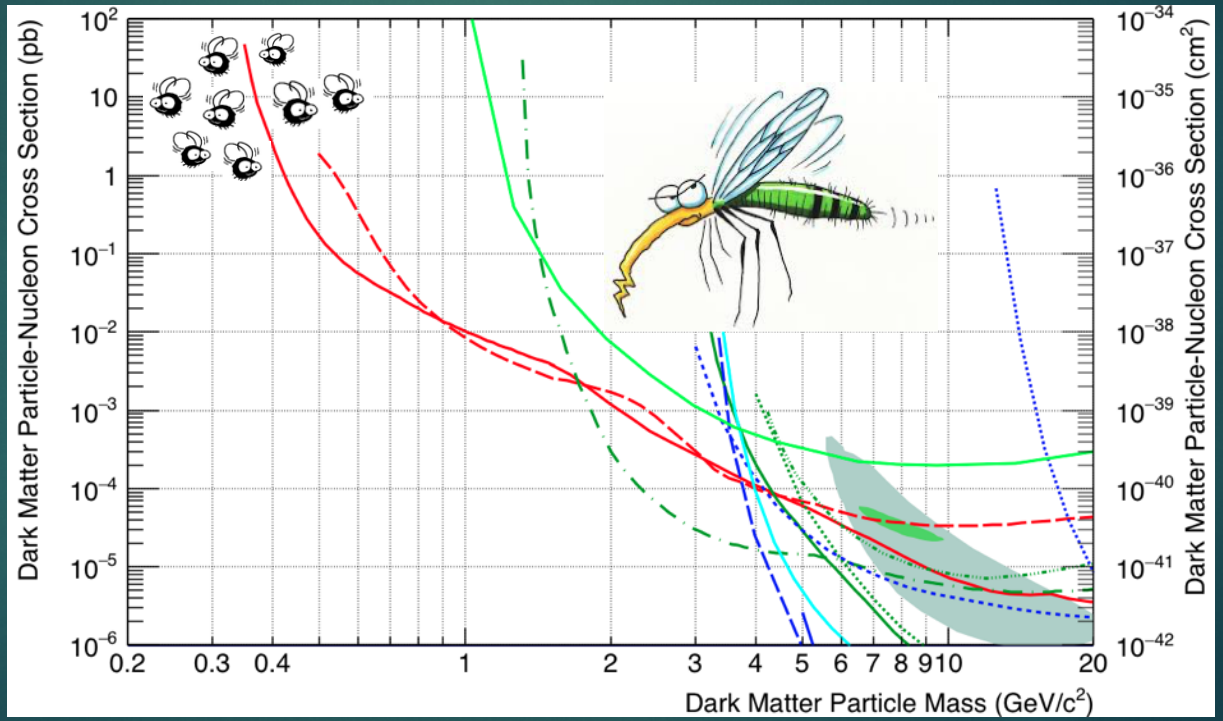

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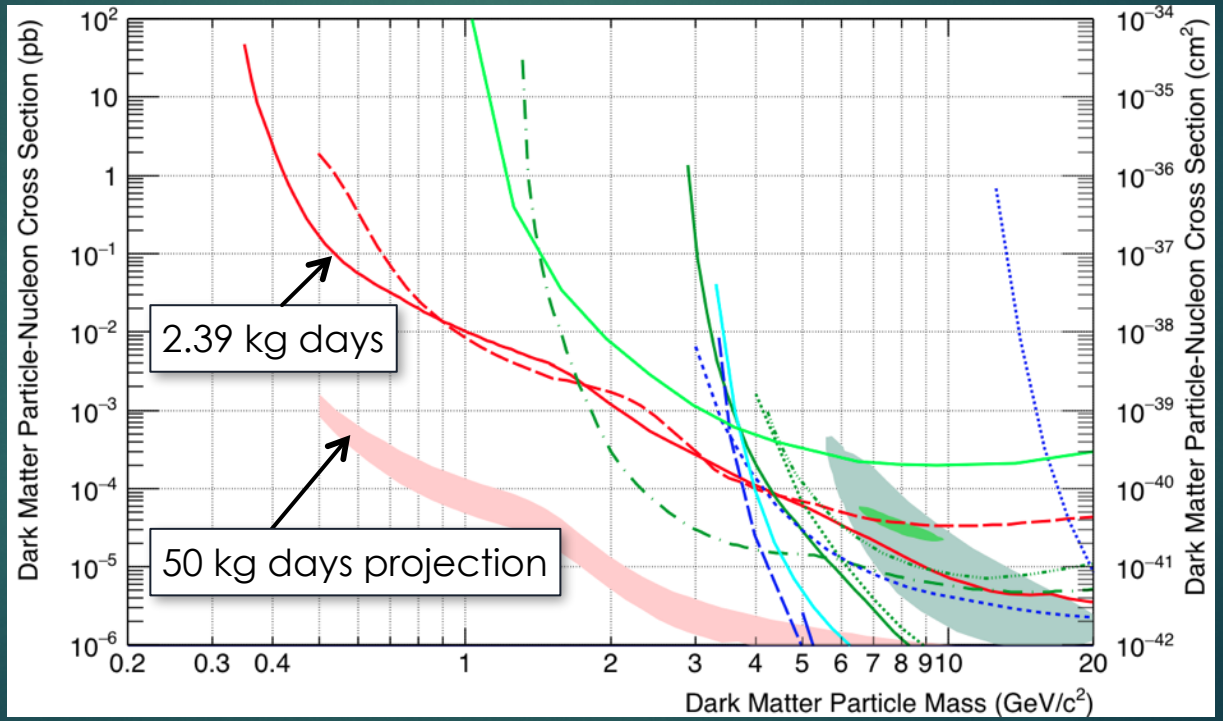
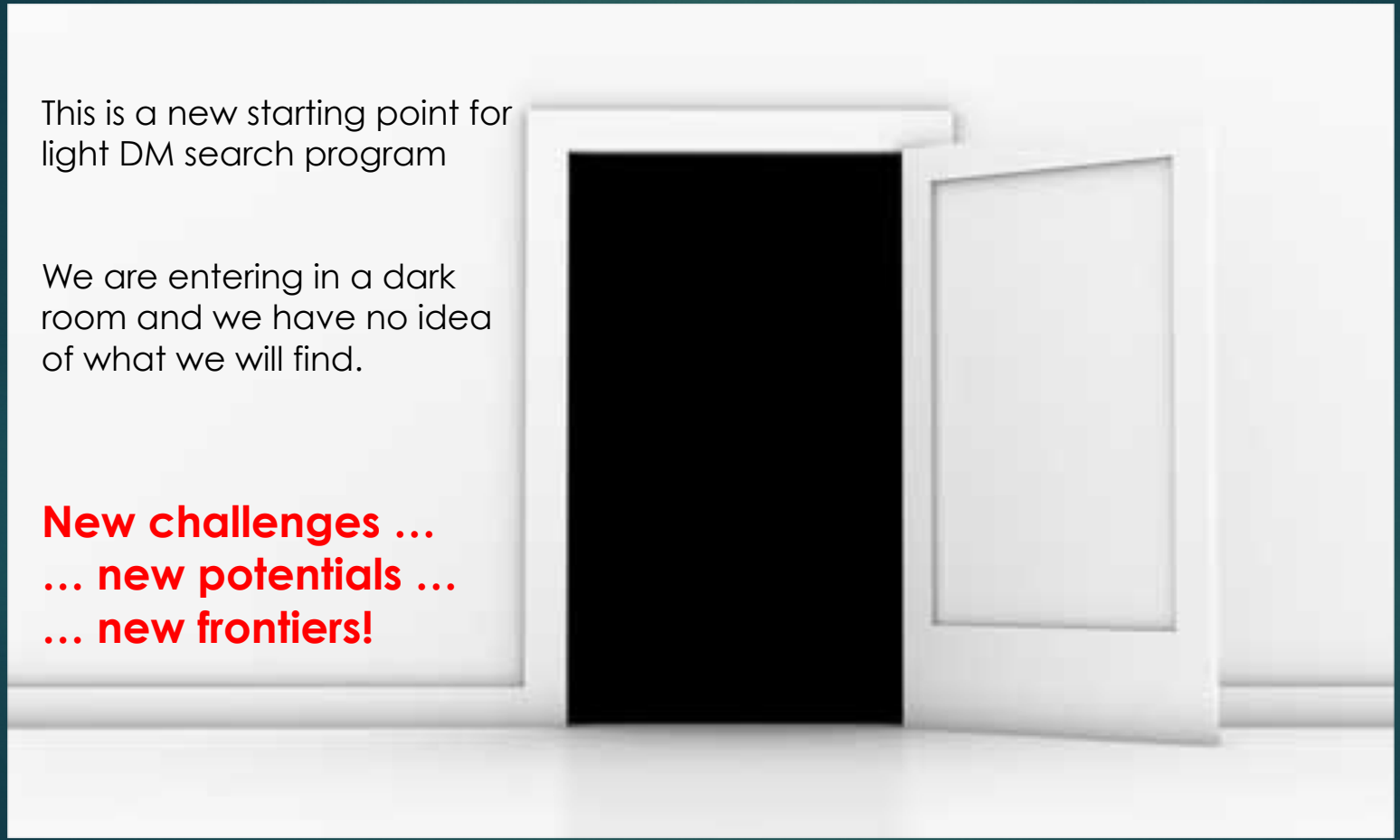


This is a new starting point for light DM search program

We are entering in a dark room and we have no idea of what we will find.

New challenges …
… new potentials …
… new frontiers!



The CRESST collaboration

Thanks for your attention!