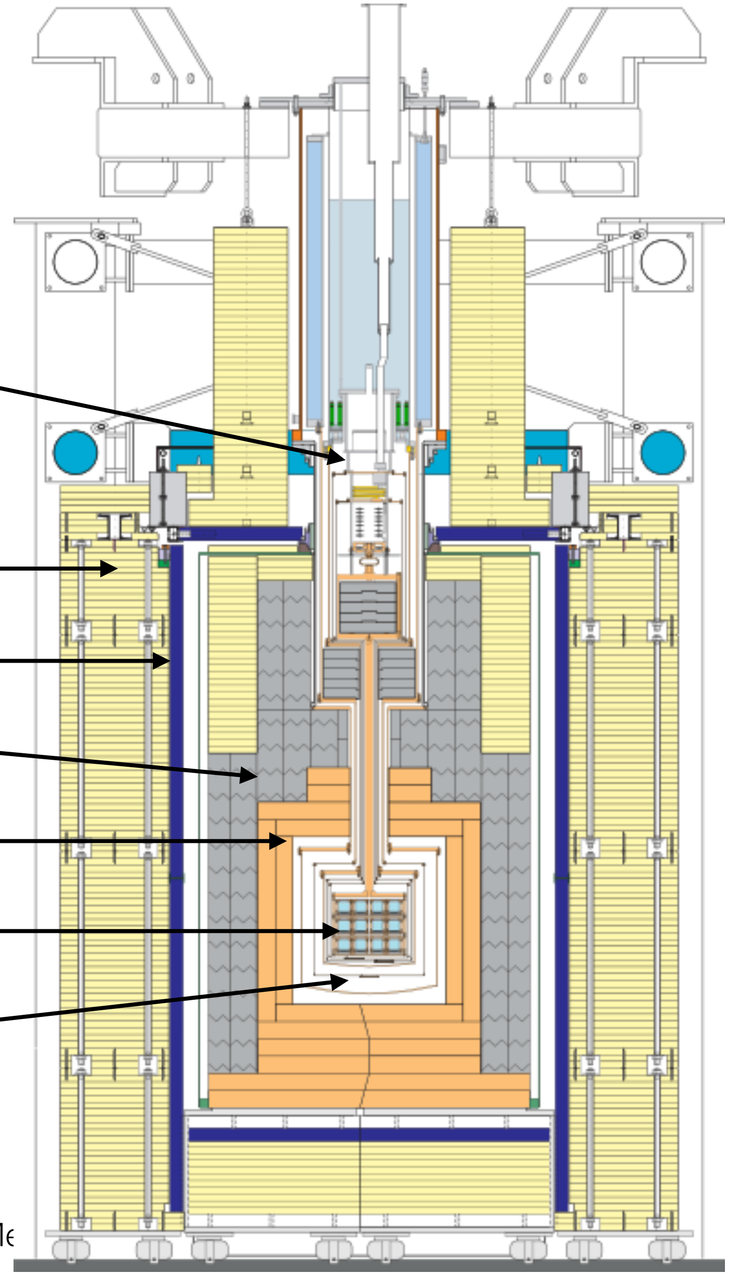
Hunt for light Dark Matter at LNGS with the CRESST experiment

Paolo Gorla
Laboratori Nazionali del Gran Sasso - INFN

The CRESST Experiment

Cryogenic Rare Event Search with Superconducting Thermometers



CRESST searches for DM with cryogenic scintillating detectors, operated at ~14 mK

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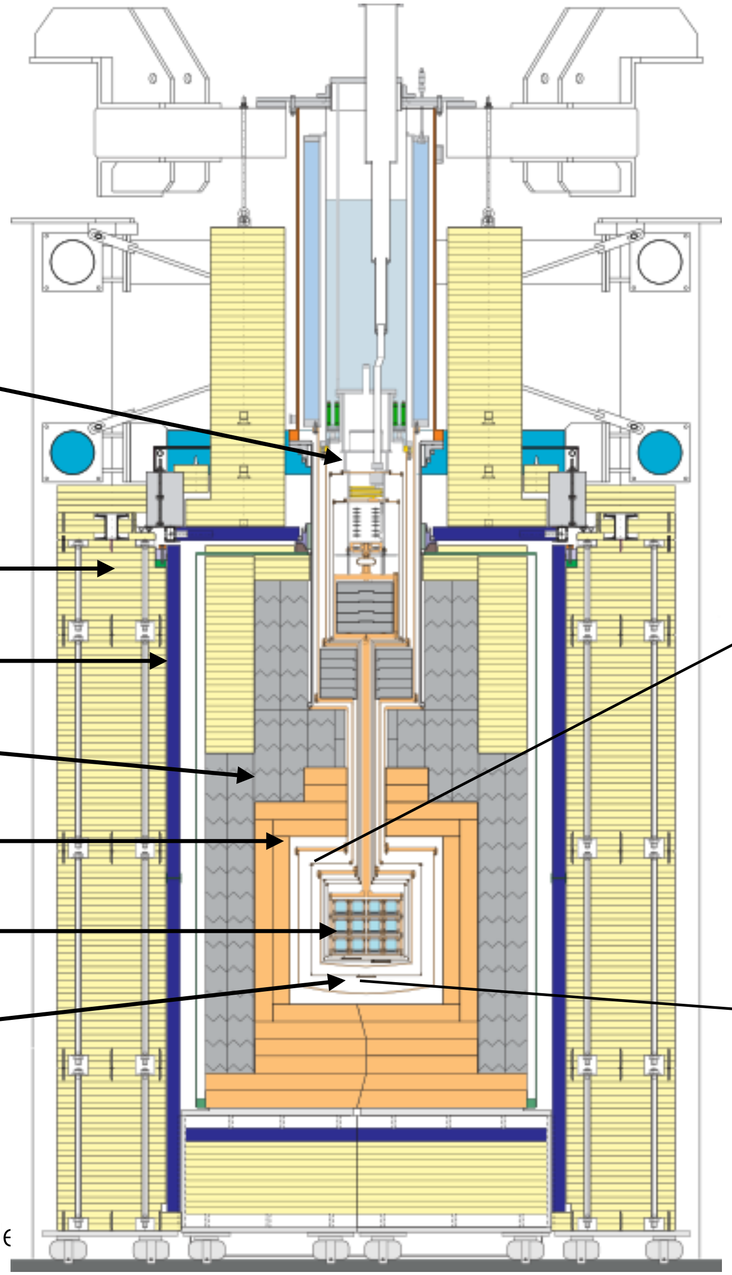

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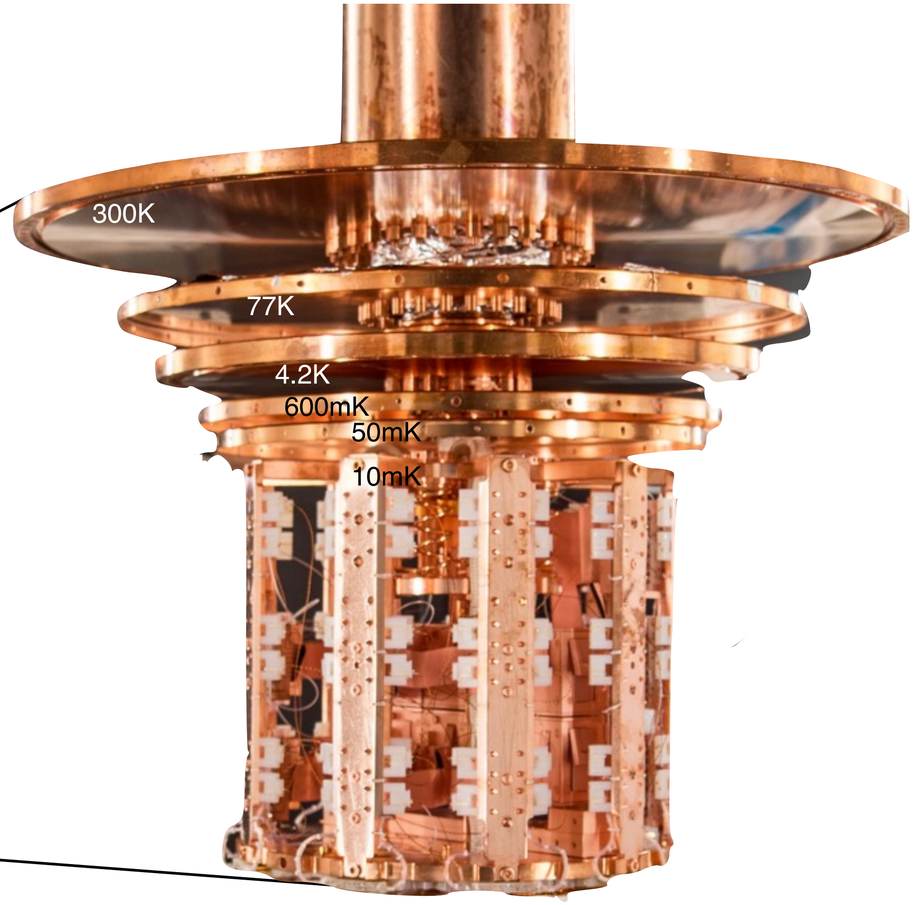

The CRESST Collaboration

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

INFN
Laboratori Nazionali del Gran Sasso

TECHNISCHE UNIVERSITÄT MÜNCHEN

UNIVERSITY OF OXFORD

EBERHARD KARLS
UNIVERSITÄT TÜBINGEN

HEPHY
Institut für Hochenergiephysik

CRESST @ Gran Sasso

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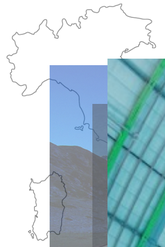
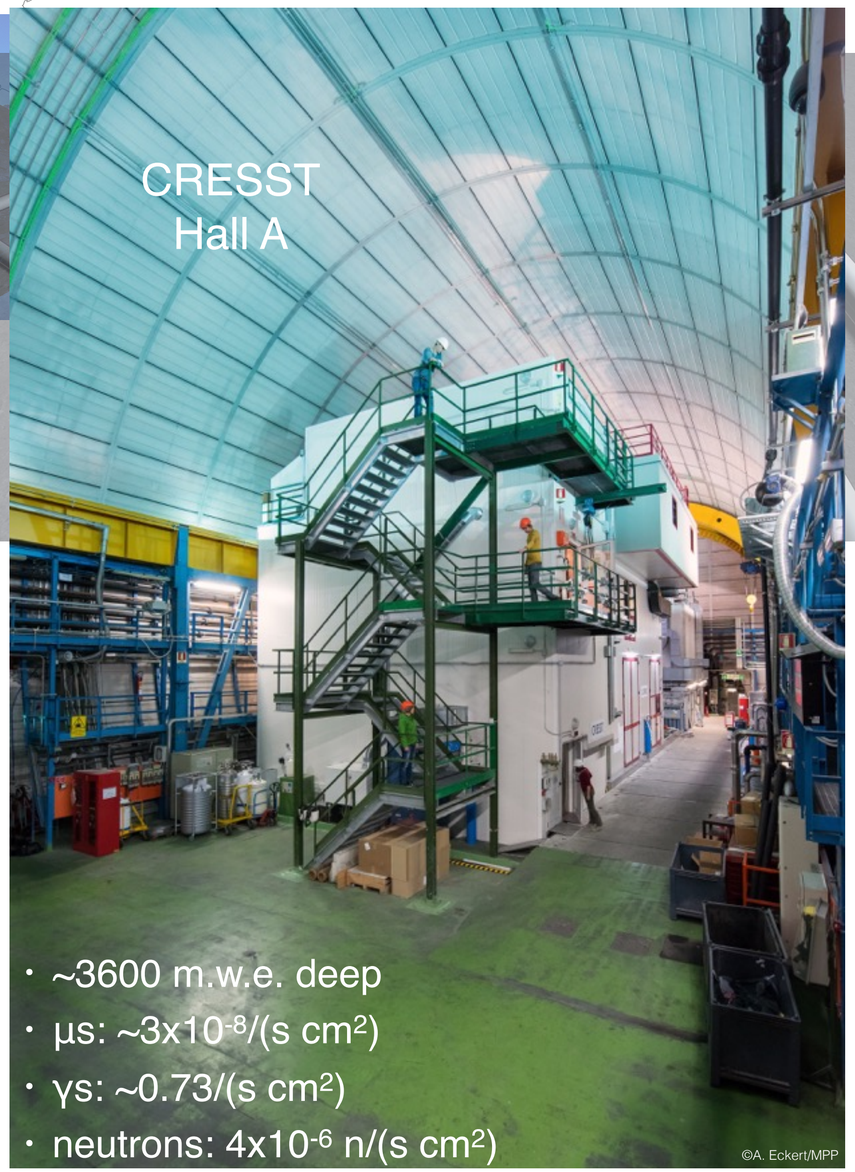
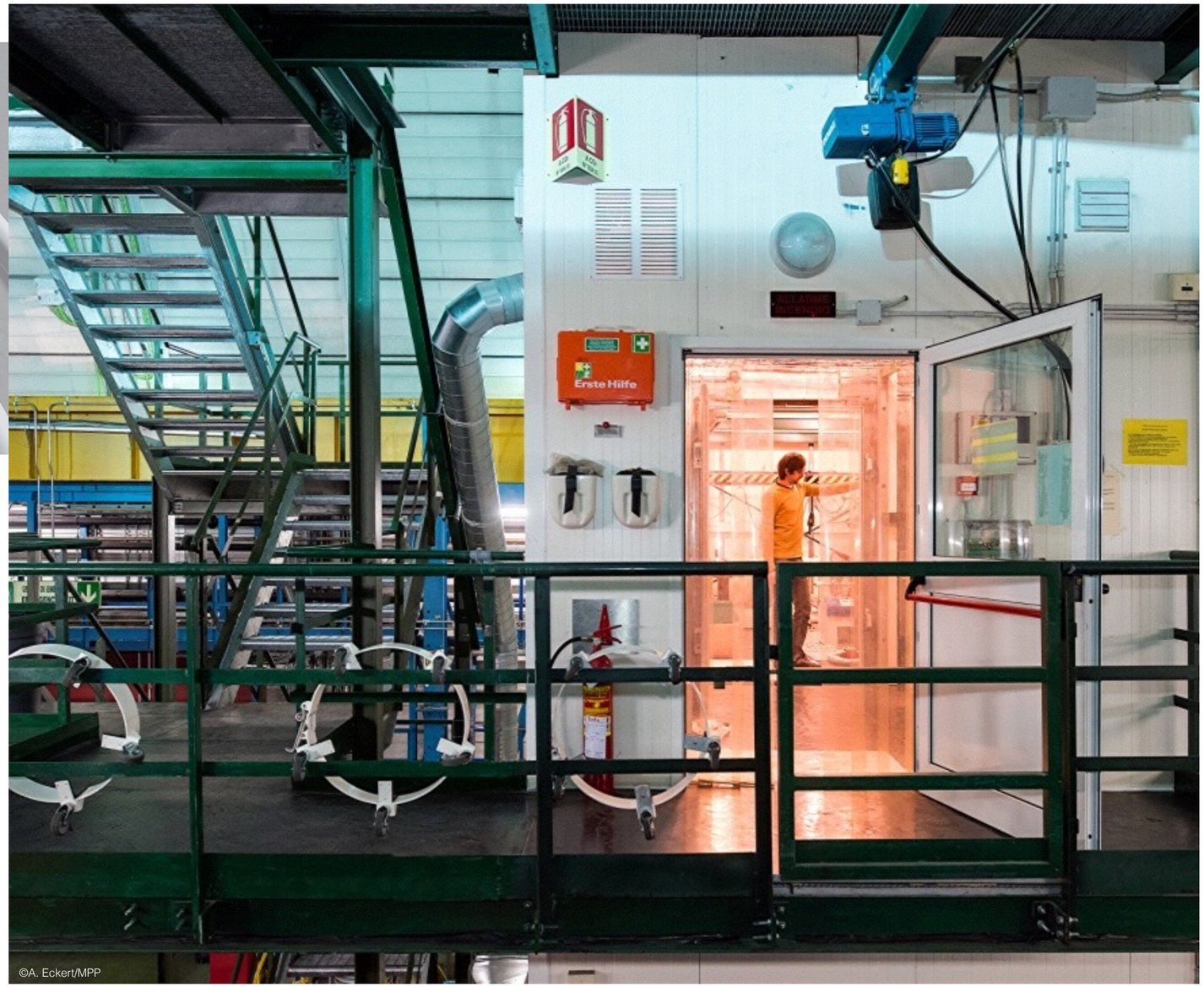
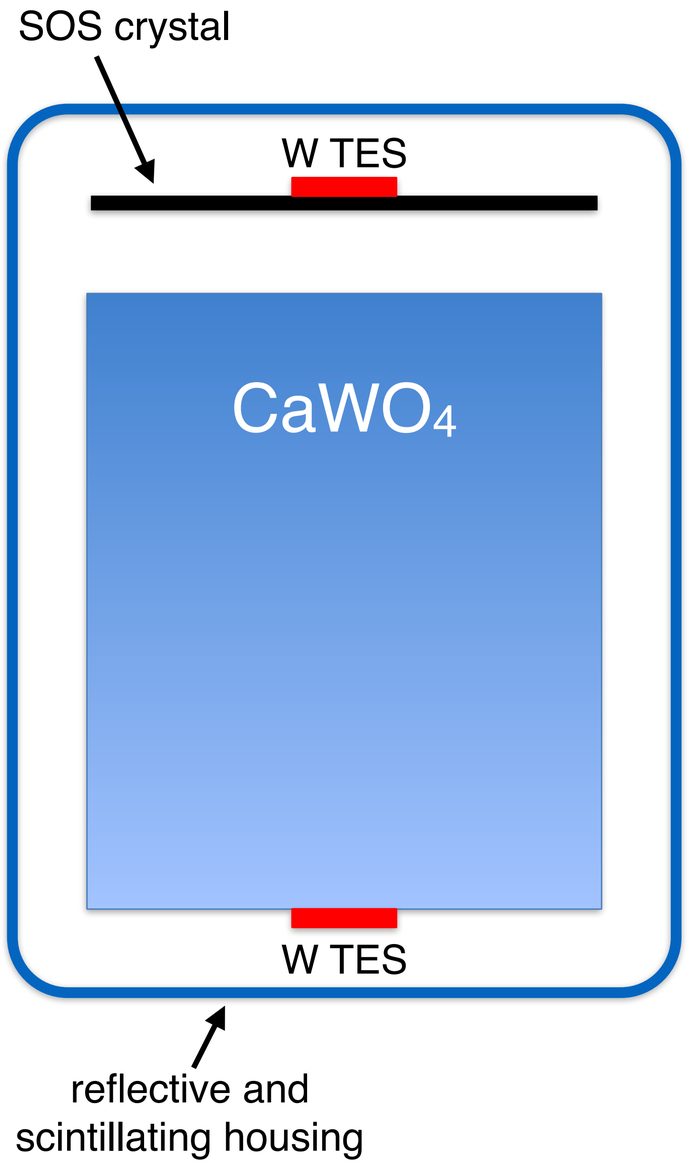






CRESST Detectors



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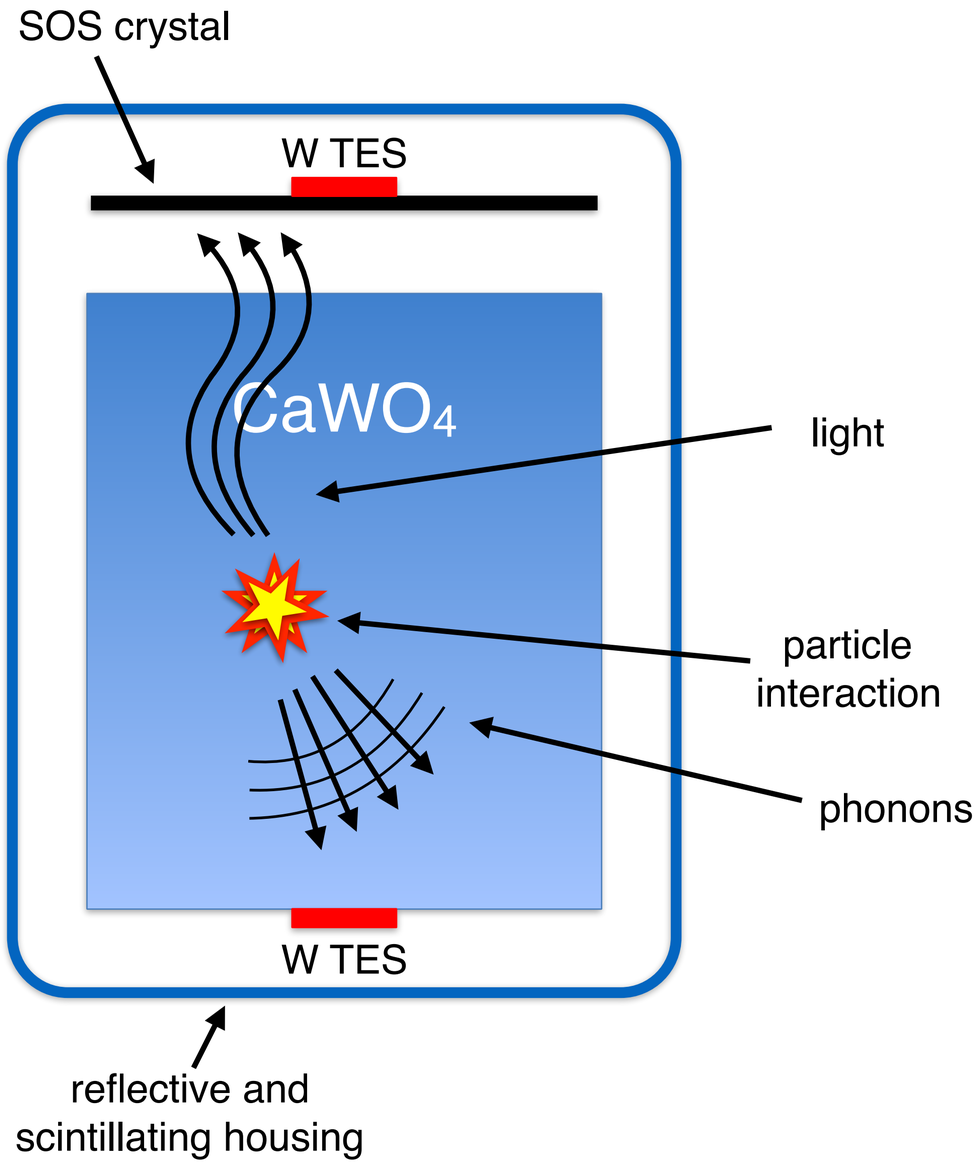

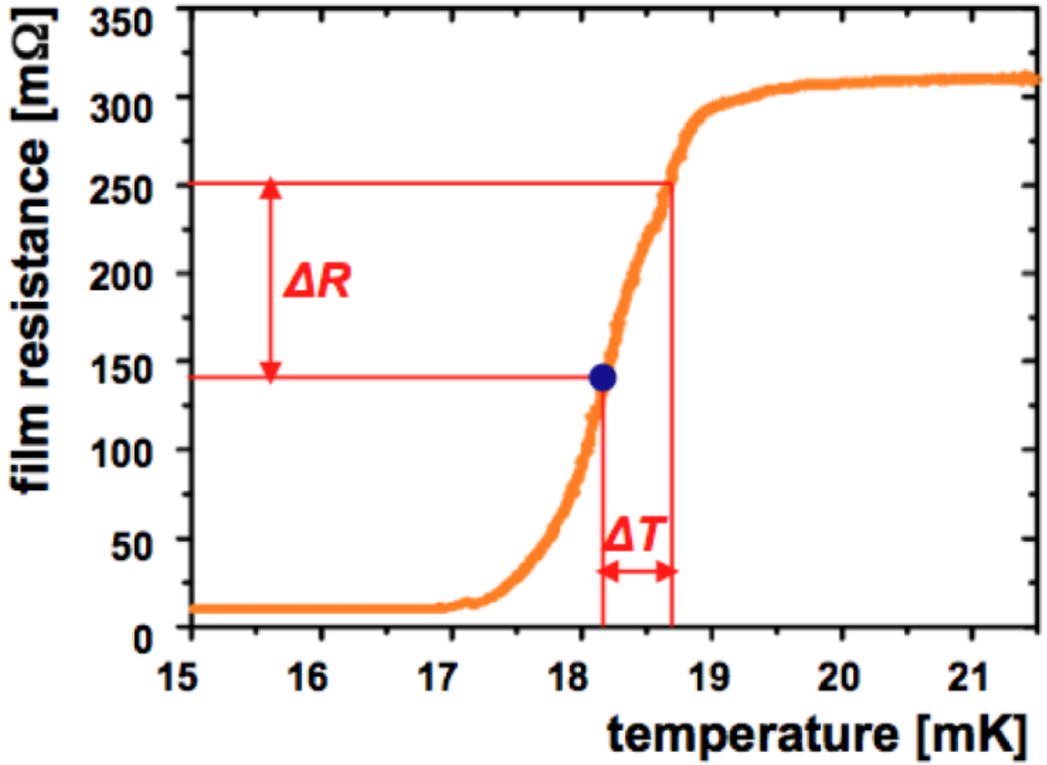

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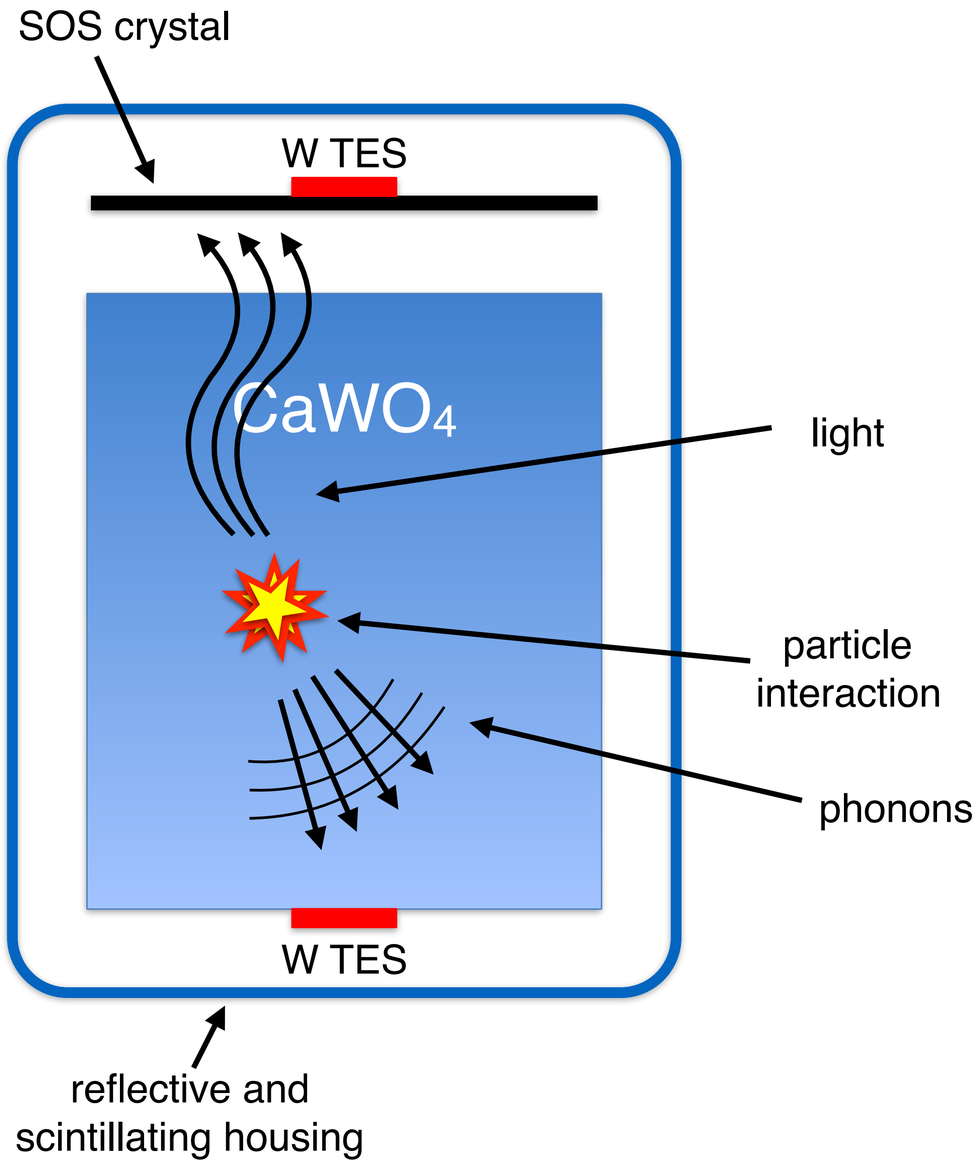

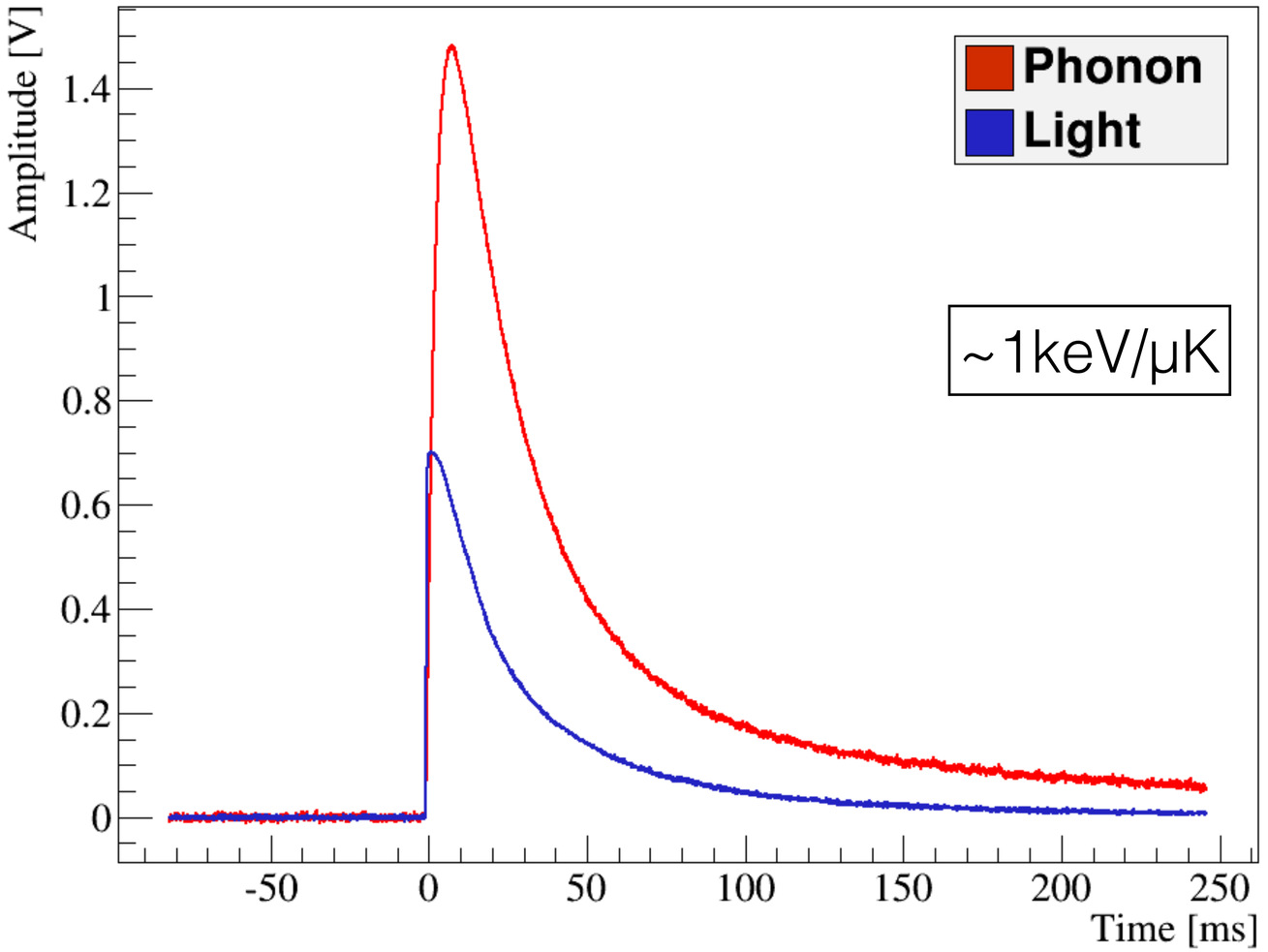

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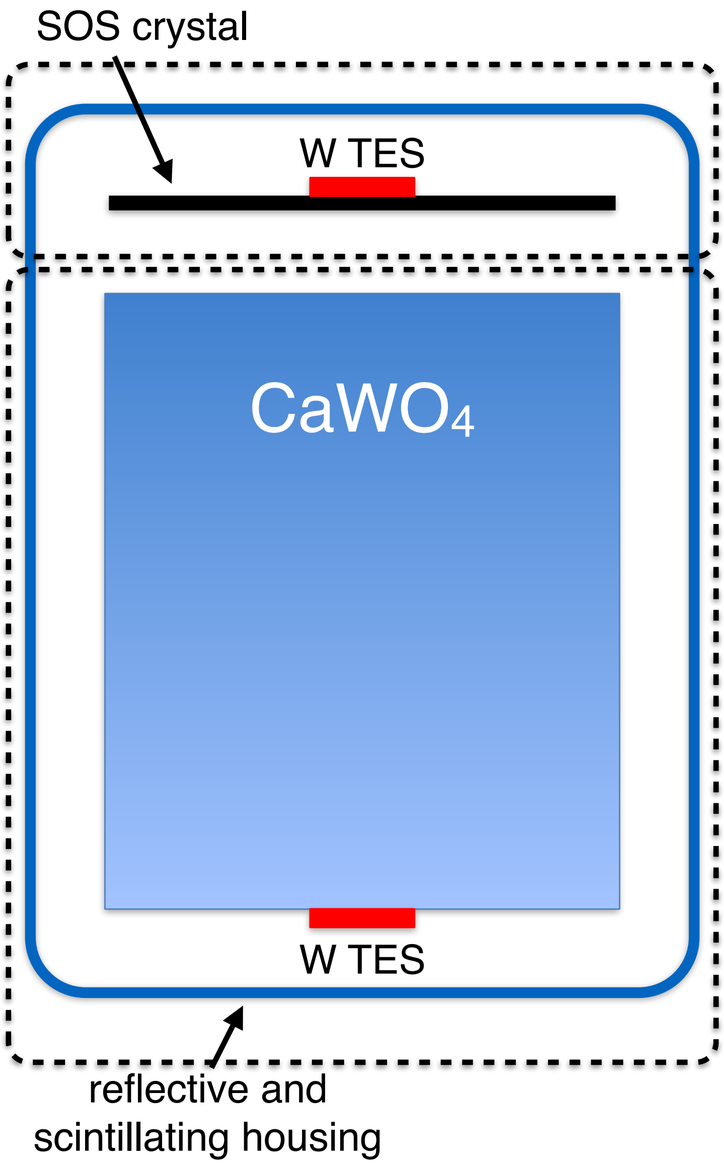
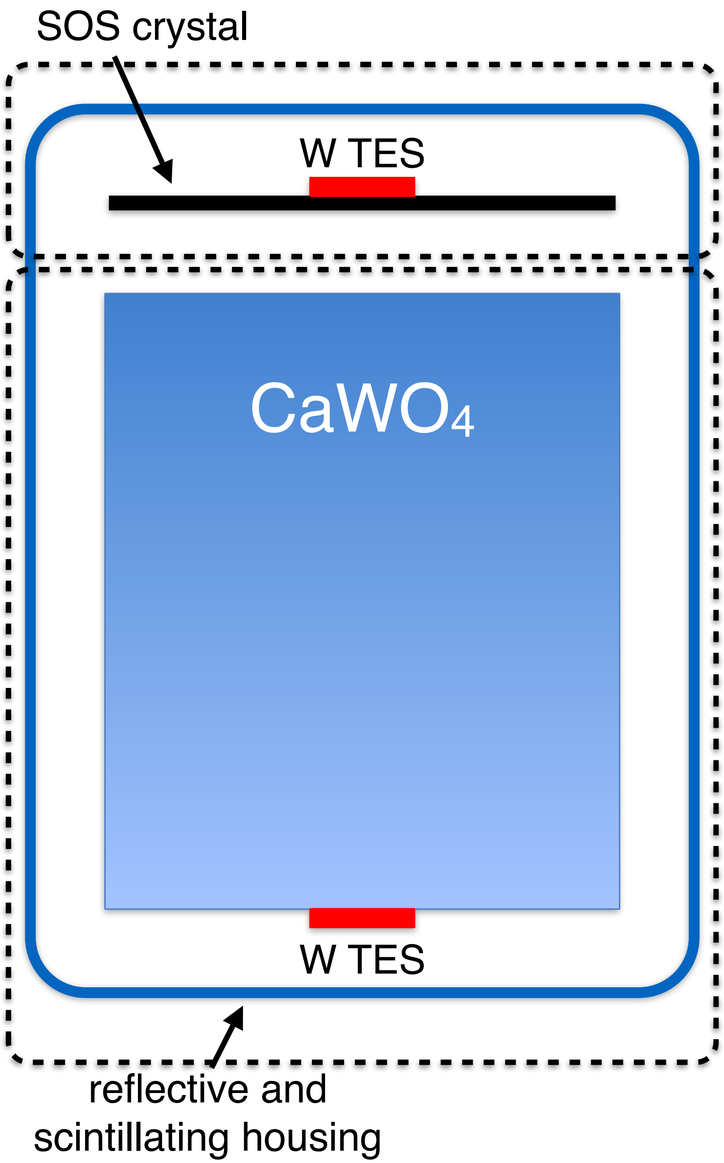


Scintillating light:
particle discrimination

Phonon signal:
deposited energy

CRESST Detectors



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$$\text{light yield} = \frac{\text{energy detected in light channel}}{\text{energy detected in the phonon channel}}$$

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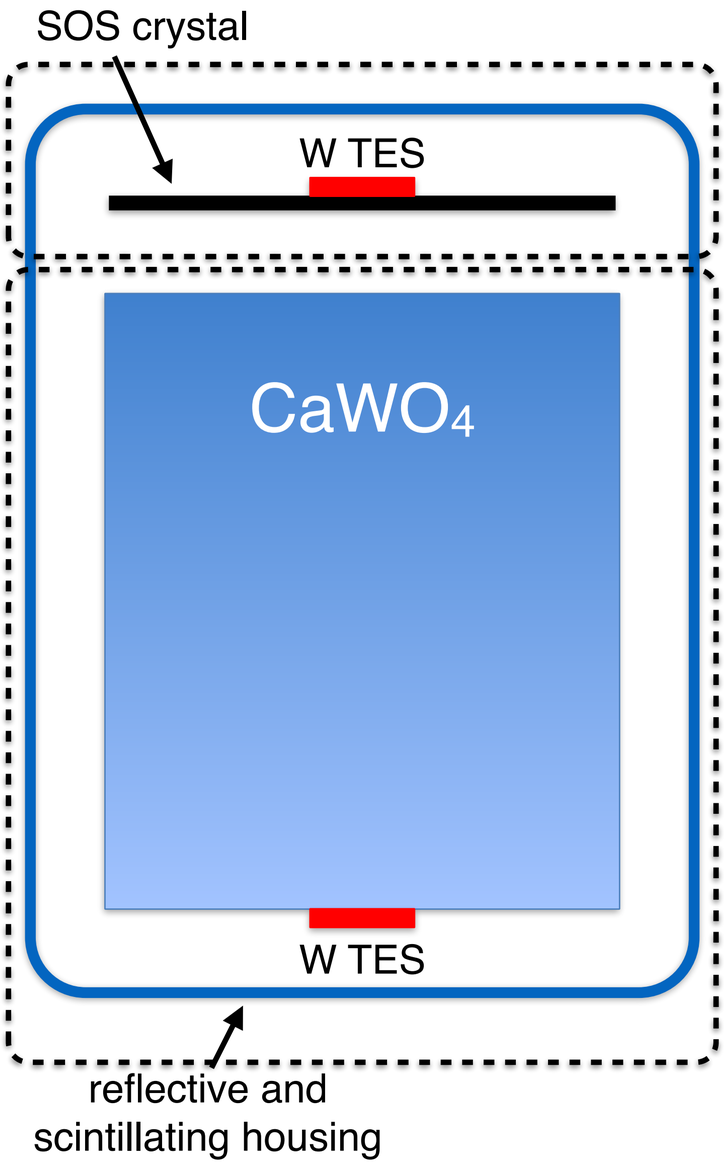

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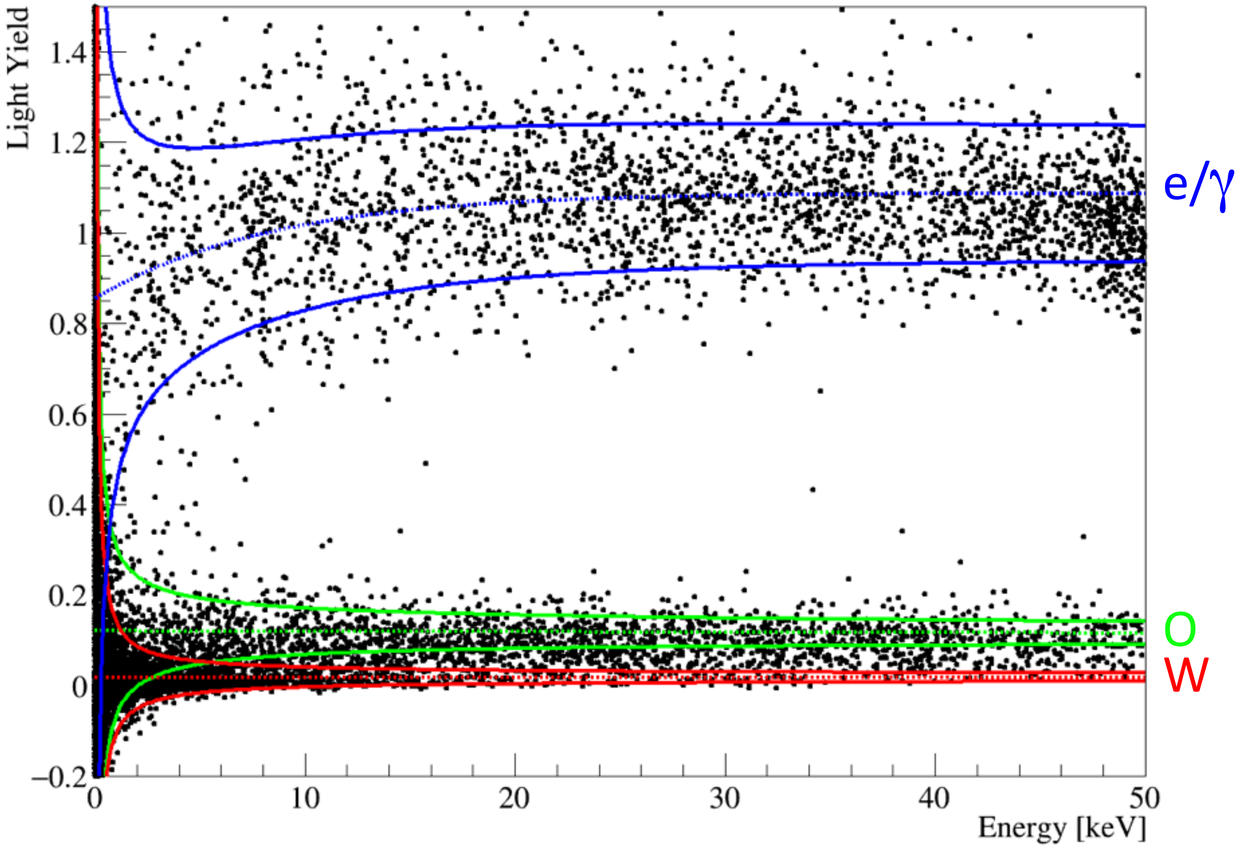
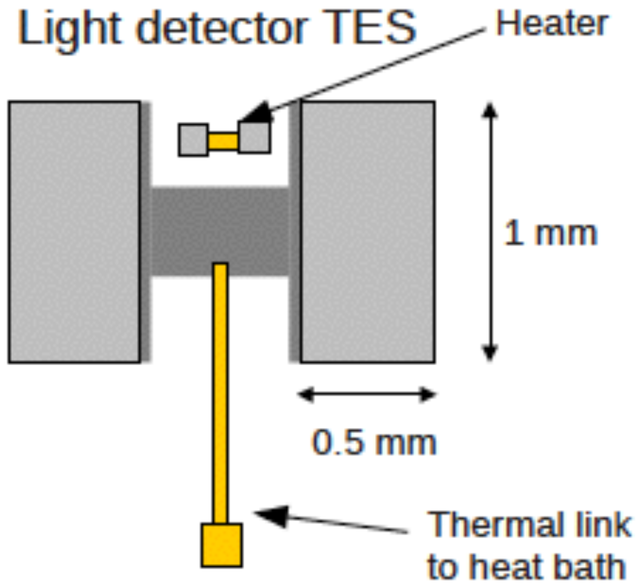


Detector heater

W-TES equipped with heaters

- Stabilization of detectors in the operating point
- Injection of heat pulses for calibration and determination of trigger threshold



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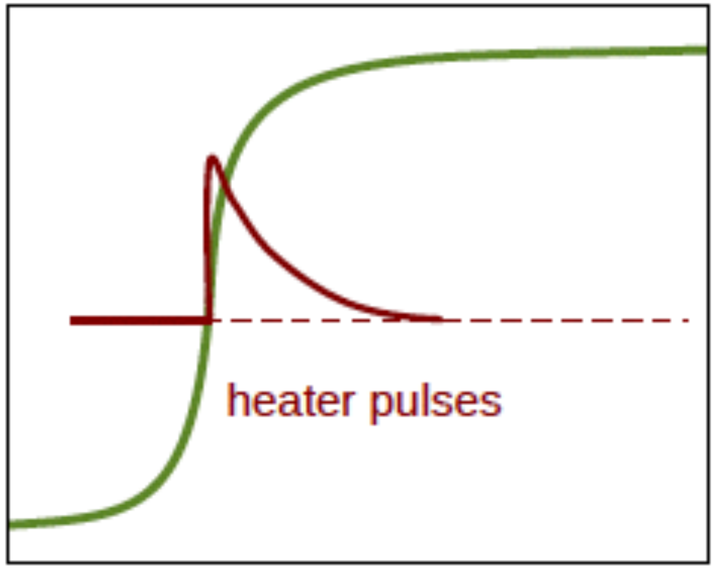

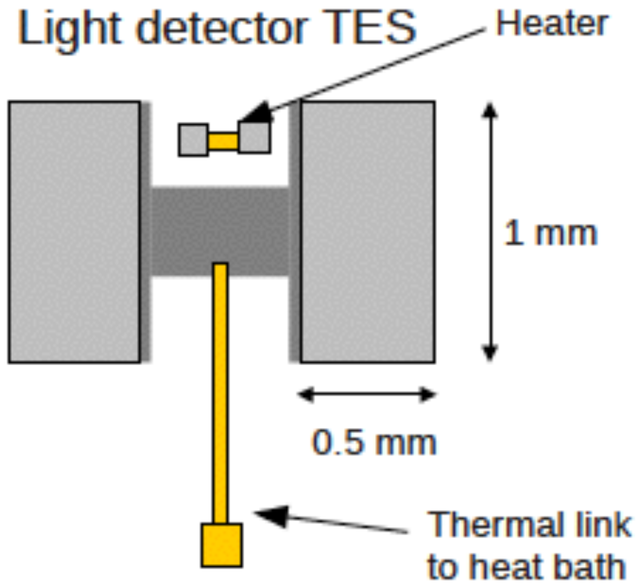

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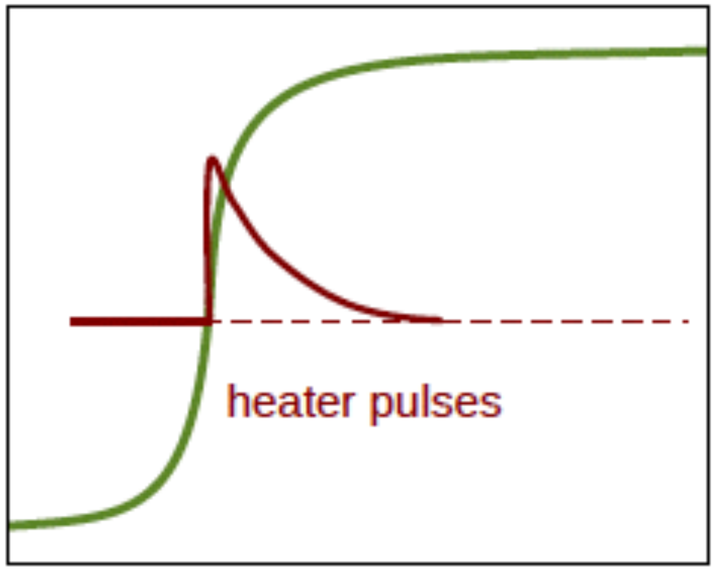

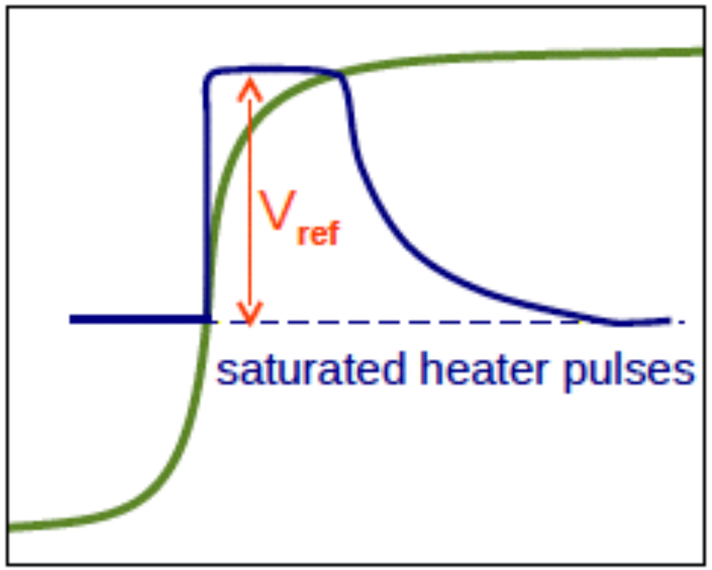

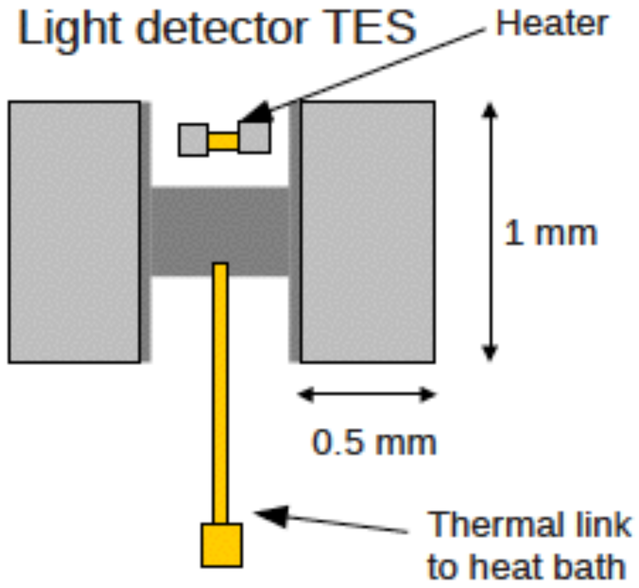

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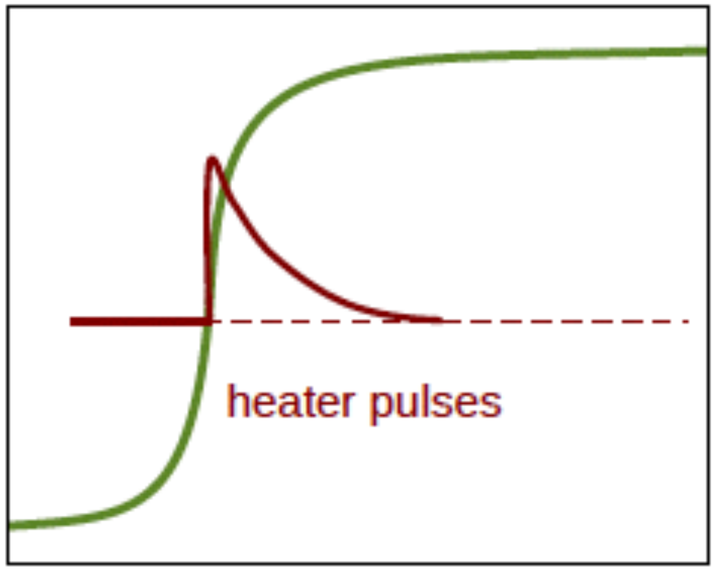
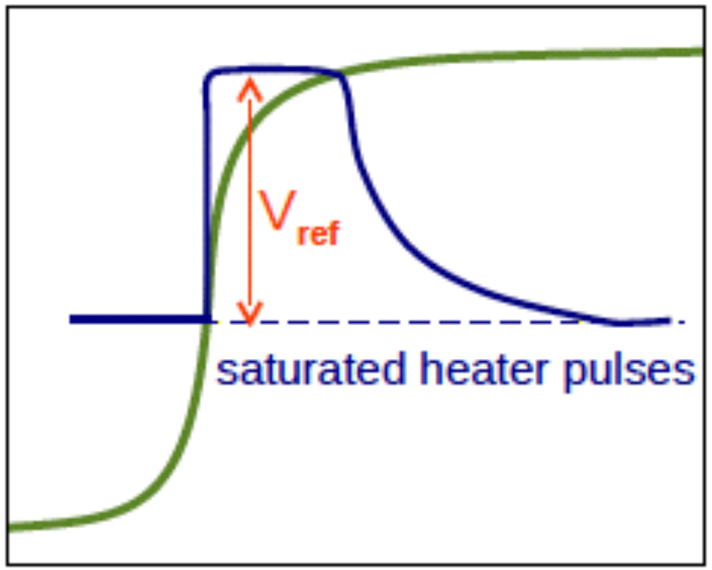
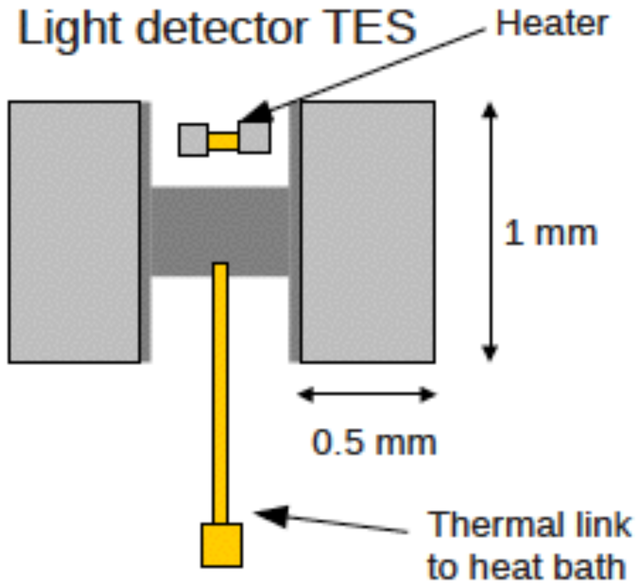
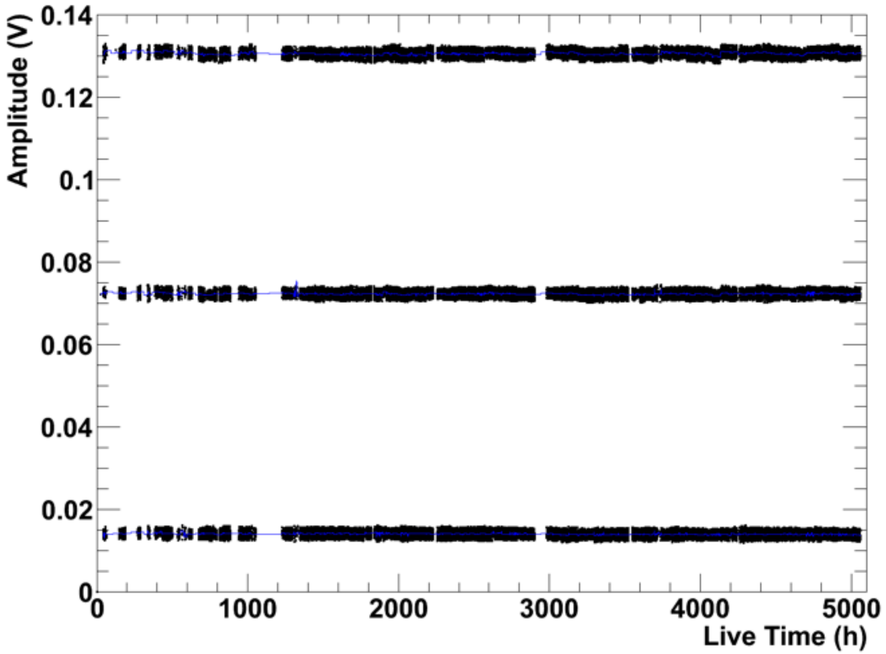


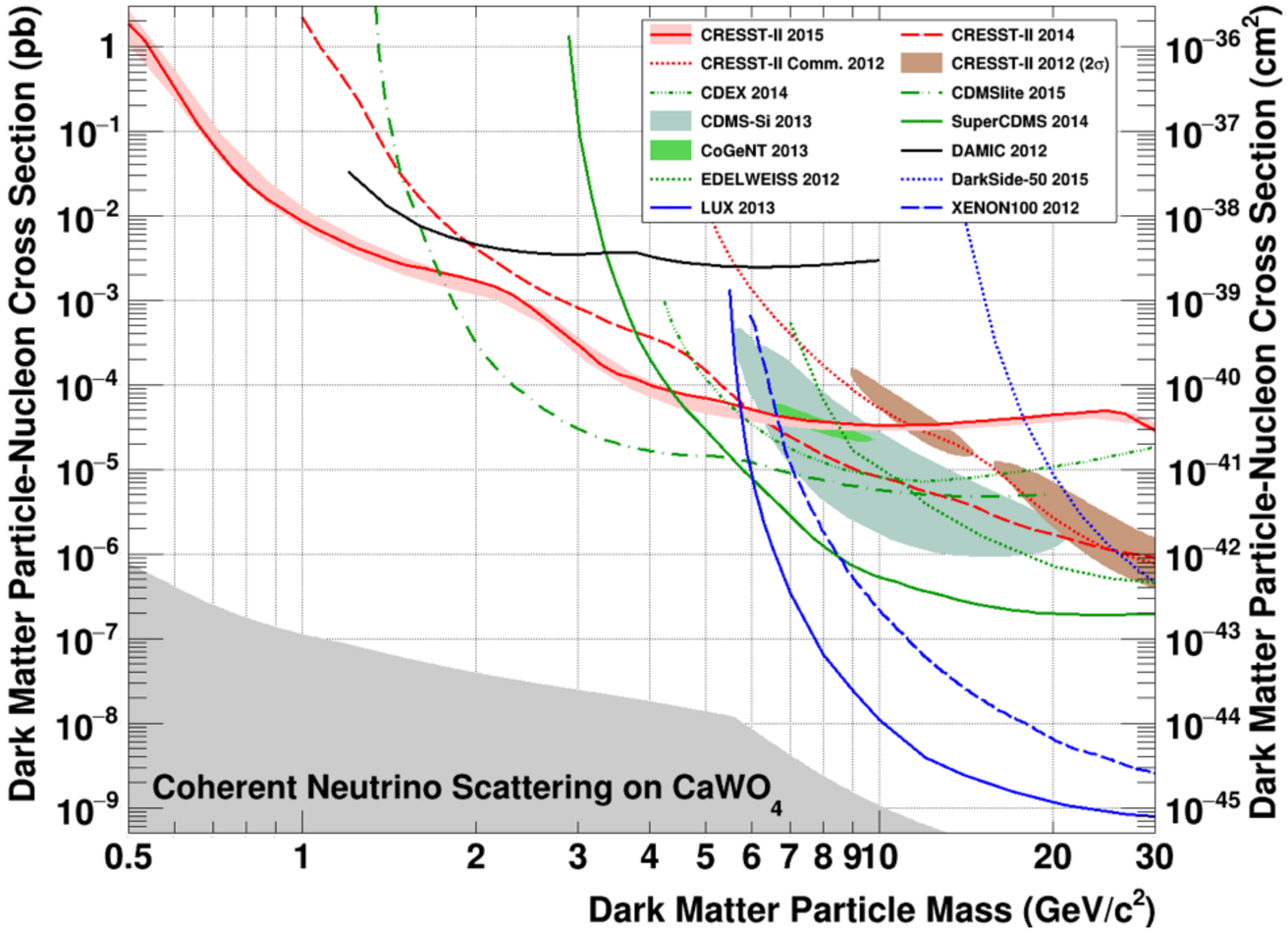


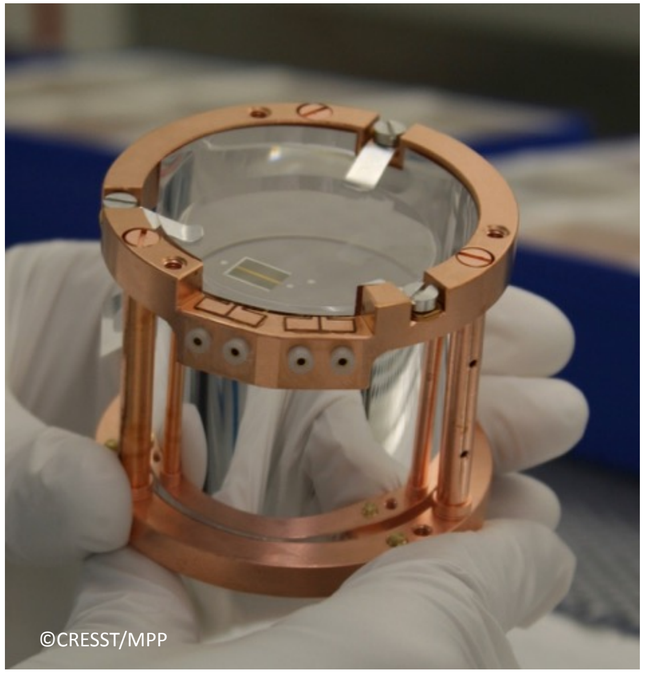




CRESST-II results

Crystal: Lise - background level ≈8.5 counts/(keV kg day)
Threshold: 307eV
Resolution: 62eV at zero energy



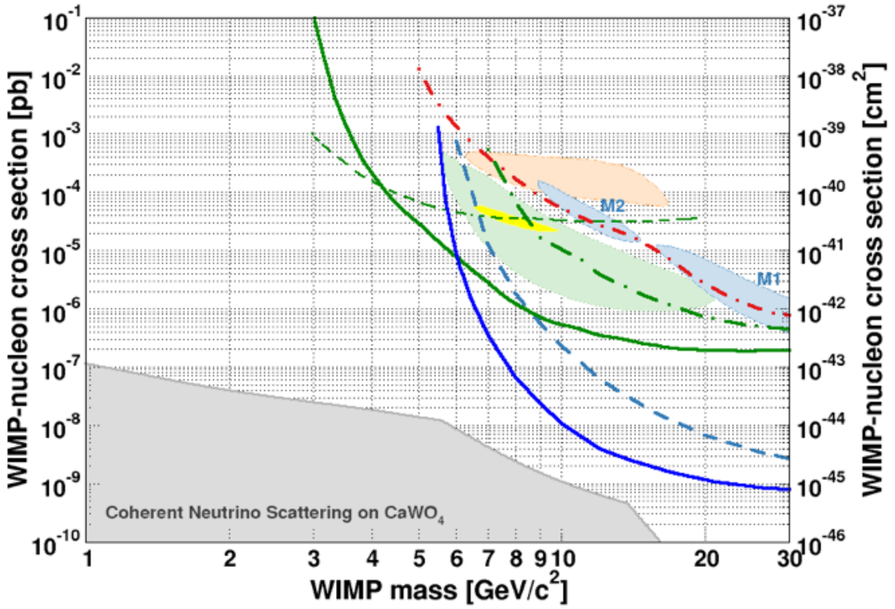


World-leading below 1.7GeV/c^2
Exploring new parameter space down to 0.5GeV/c^2

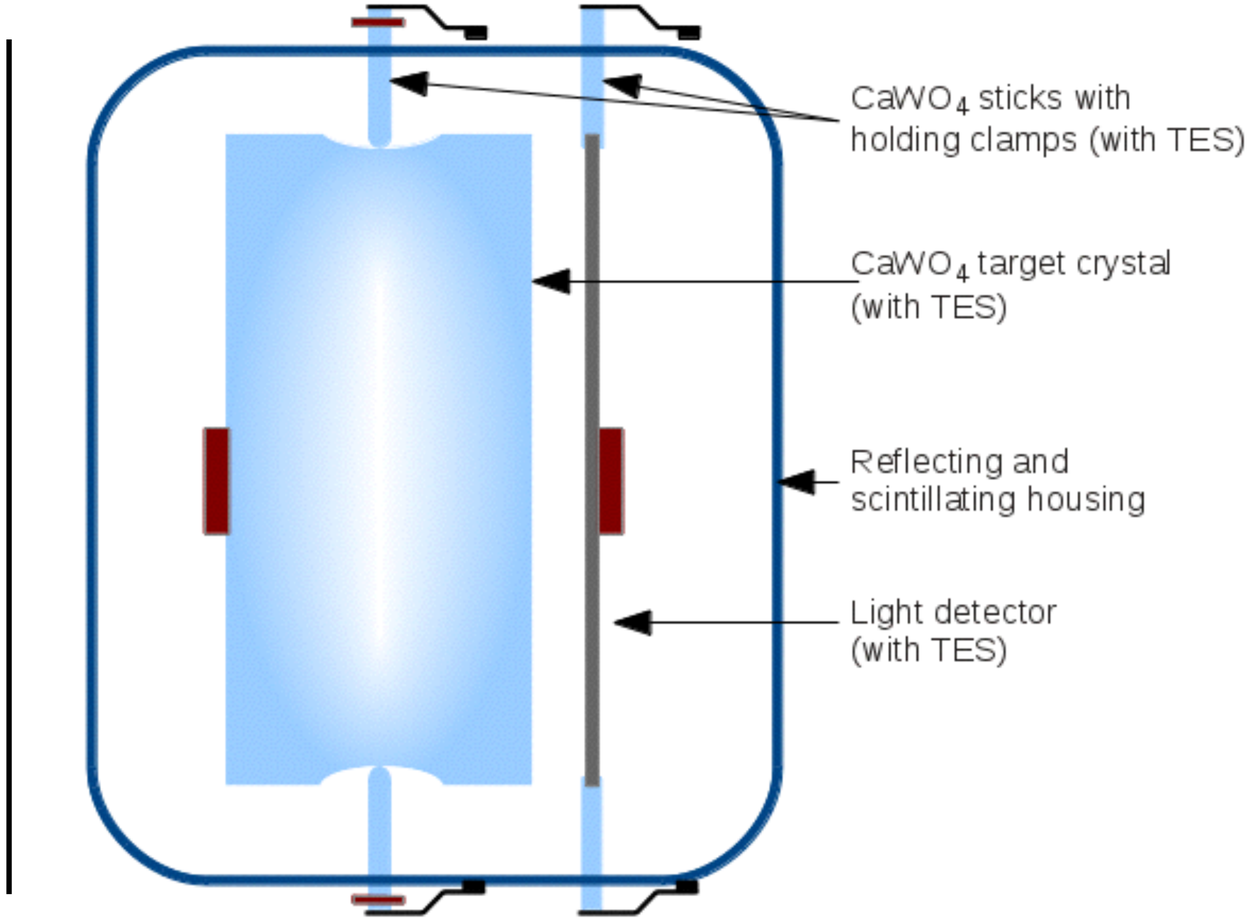
Hunting light dark matter requires a low threshold!

Eur.Phys.J. C76 (2016) 25

CRESST-III: go for the small



To improve sensitivity to low masses a radical change of strategy:



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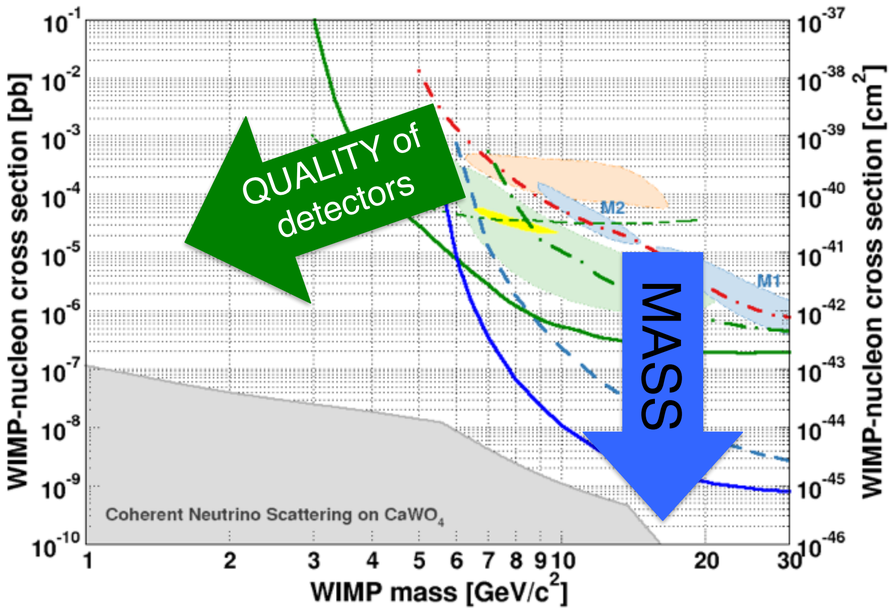

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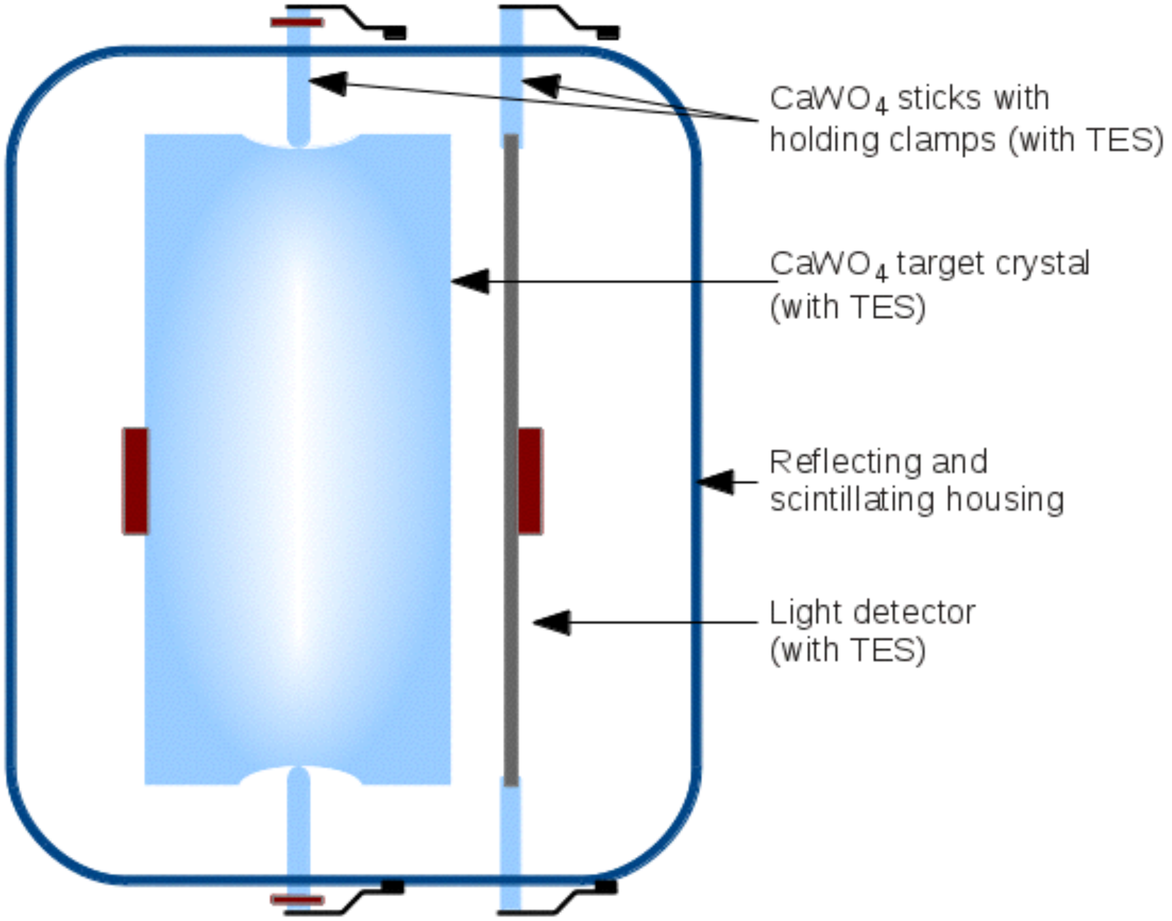

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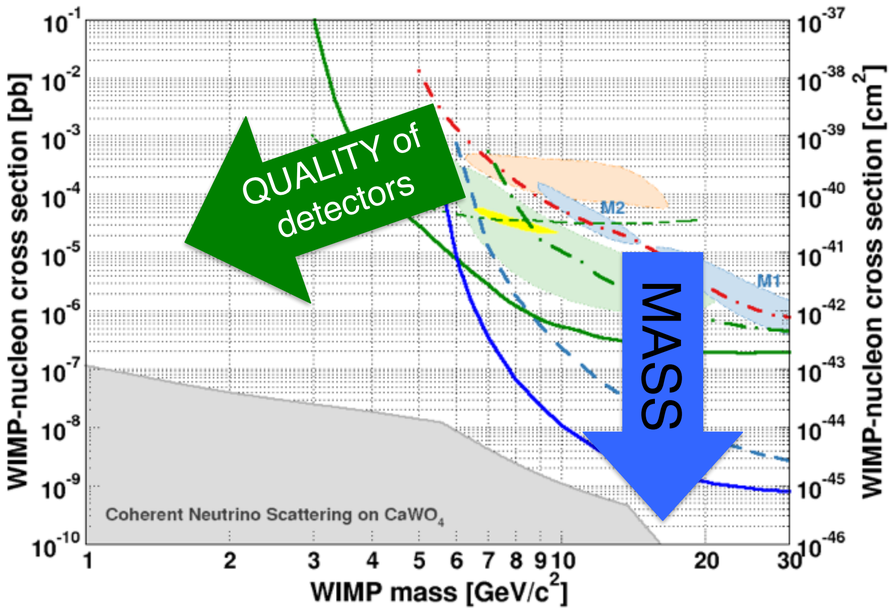
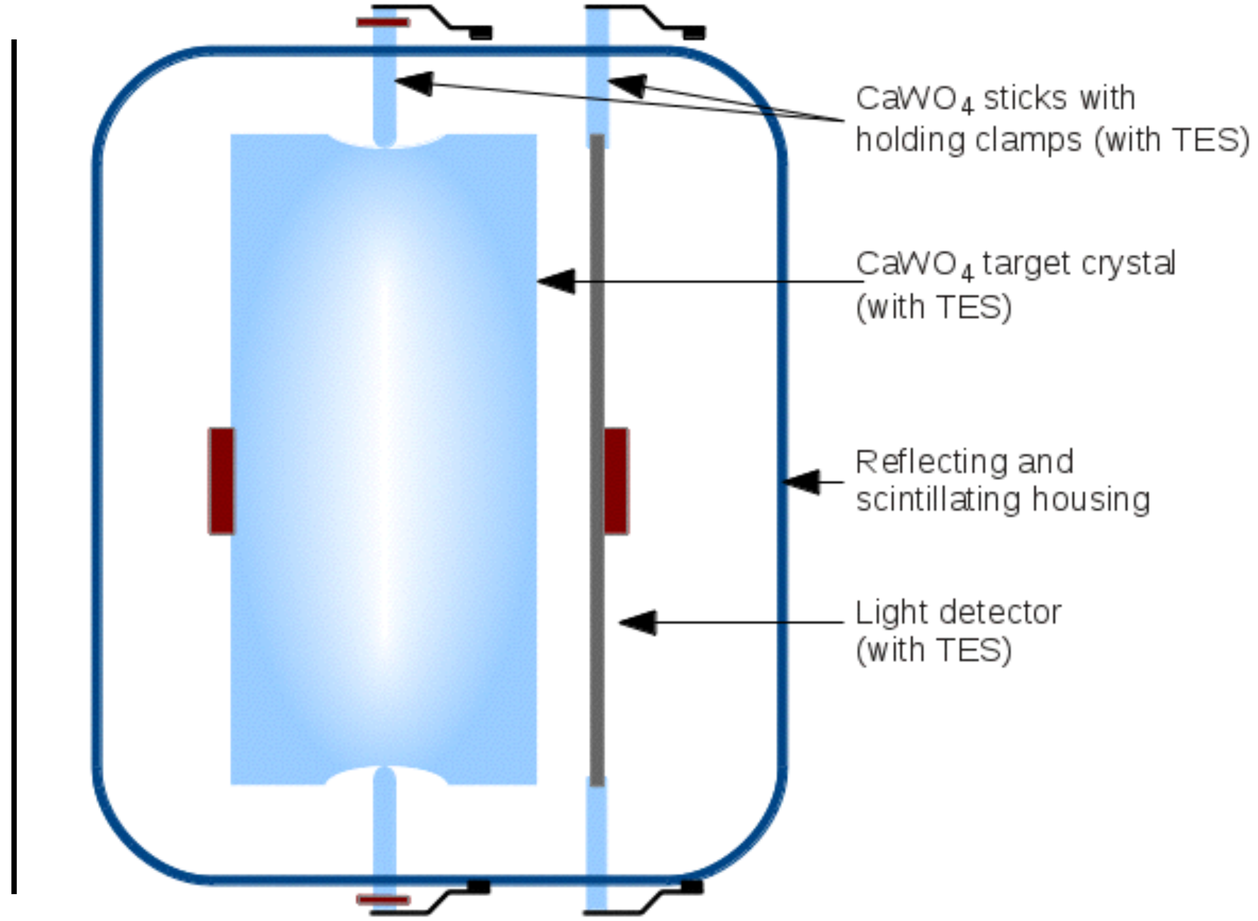


To improve sensitivity to low masses a radical change of strategy:

Smaller crystals: **250g → 24g**

Threshold: **300eV → 100eV**



CRESST-III low threshold detectors

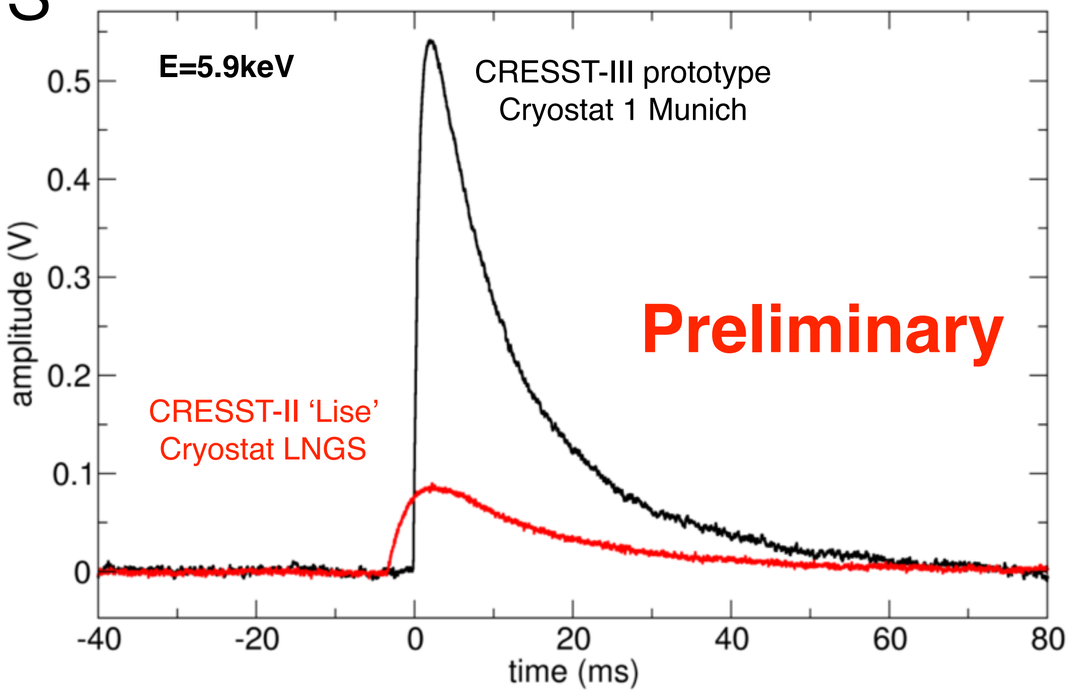
Detector layout optimized for low mass dark matter

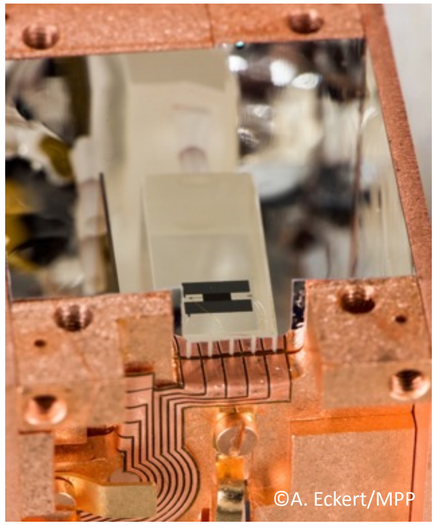
Radical reduction of dimension

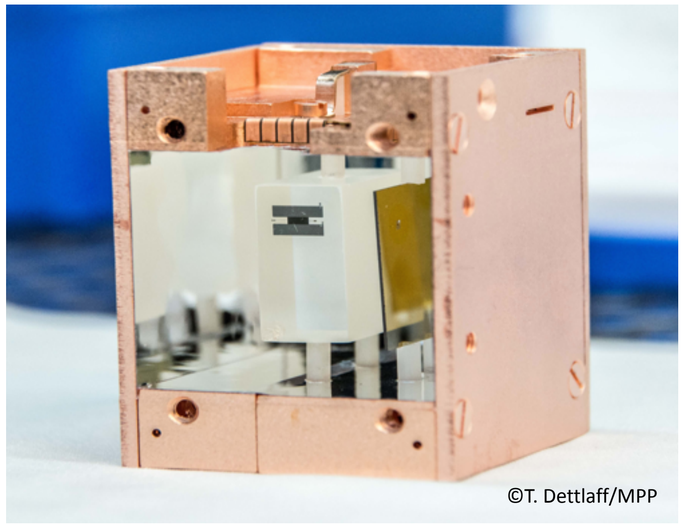
- Absorber volume reduced of a factor ~10

- 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

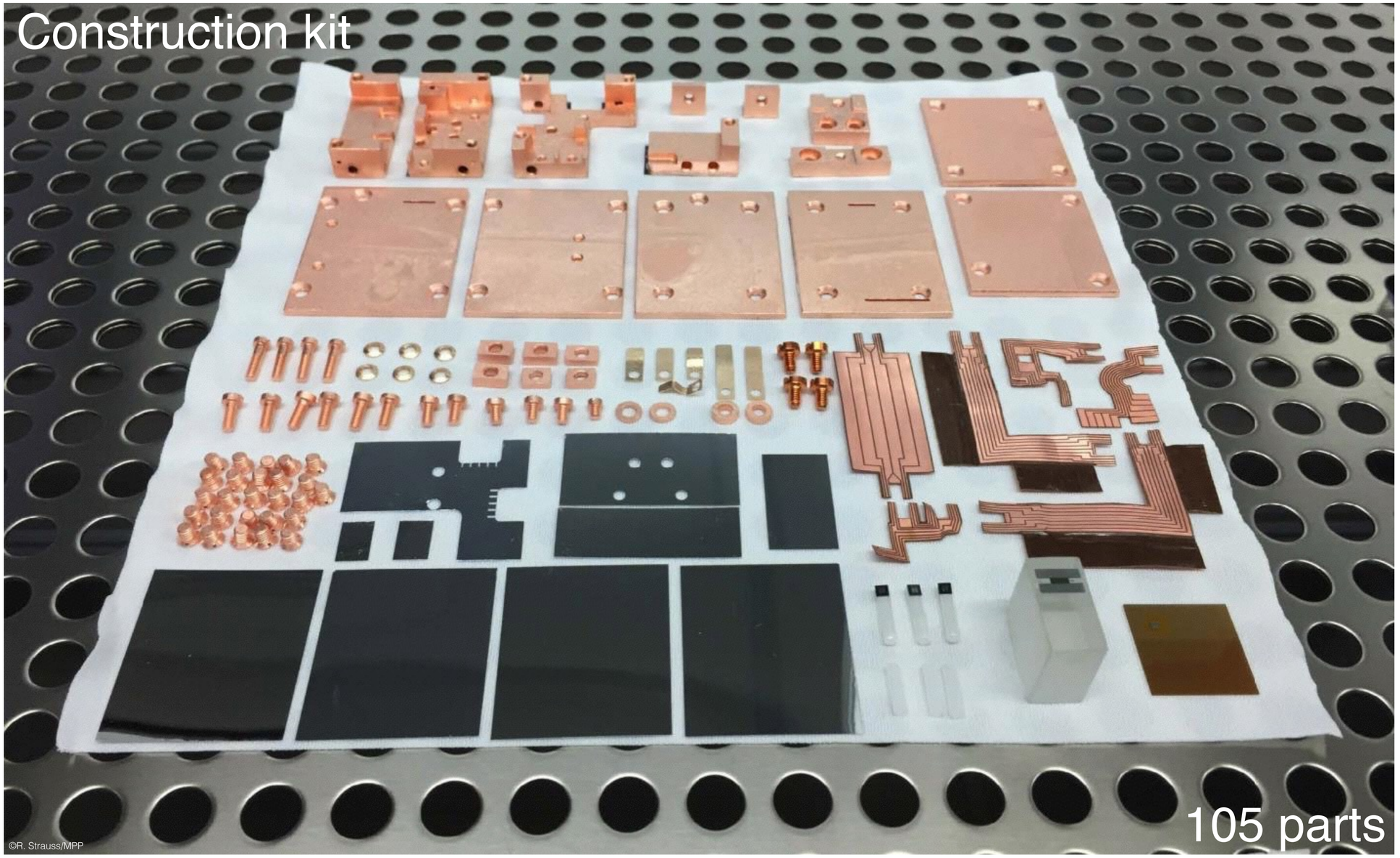
} **Veto surface related background**

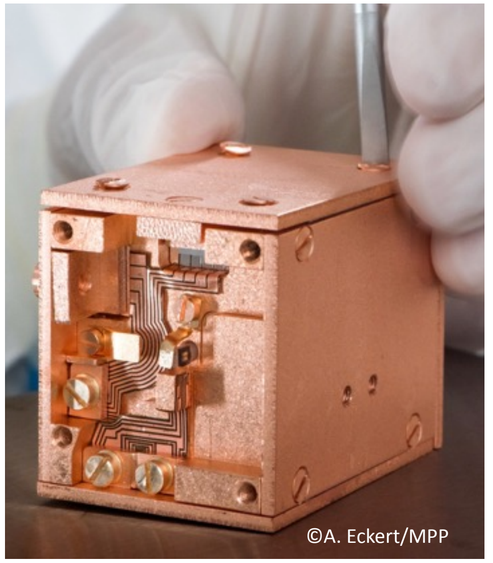


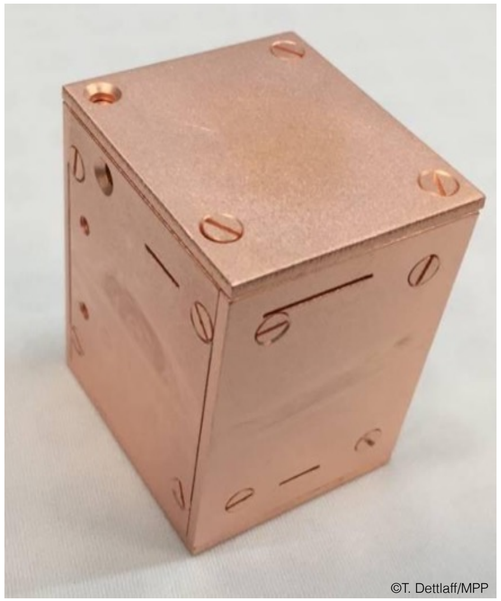




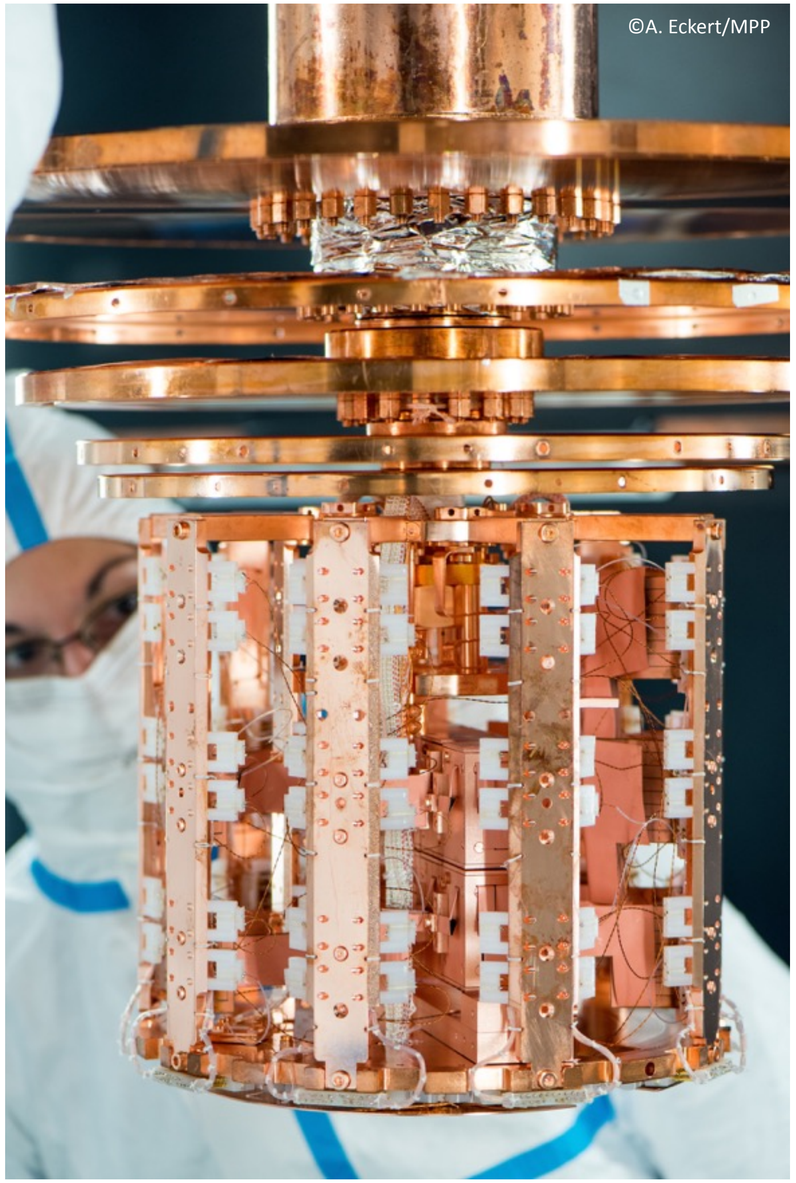
CRESST-III Phase I: Detector preparation

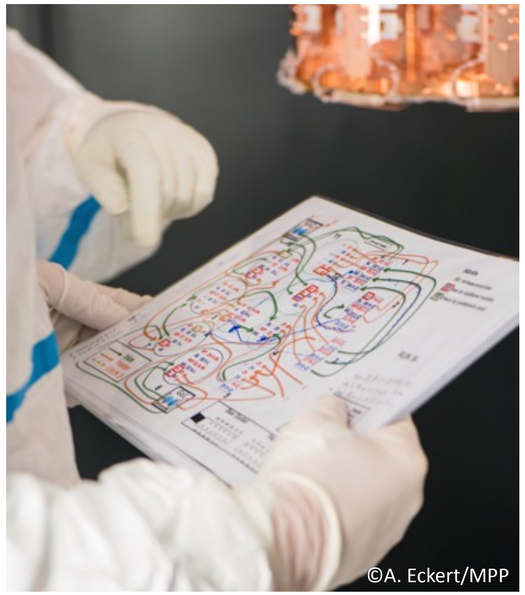






Status of CRESST-III Phase I





Data taking started July 2016

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

Optimum Filter

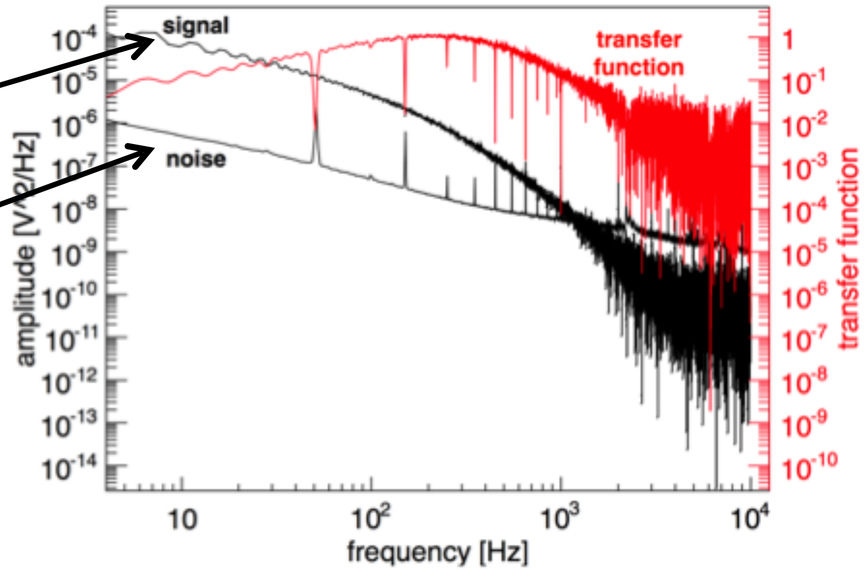
arXiv:1711.11459

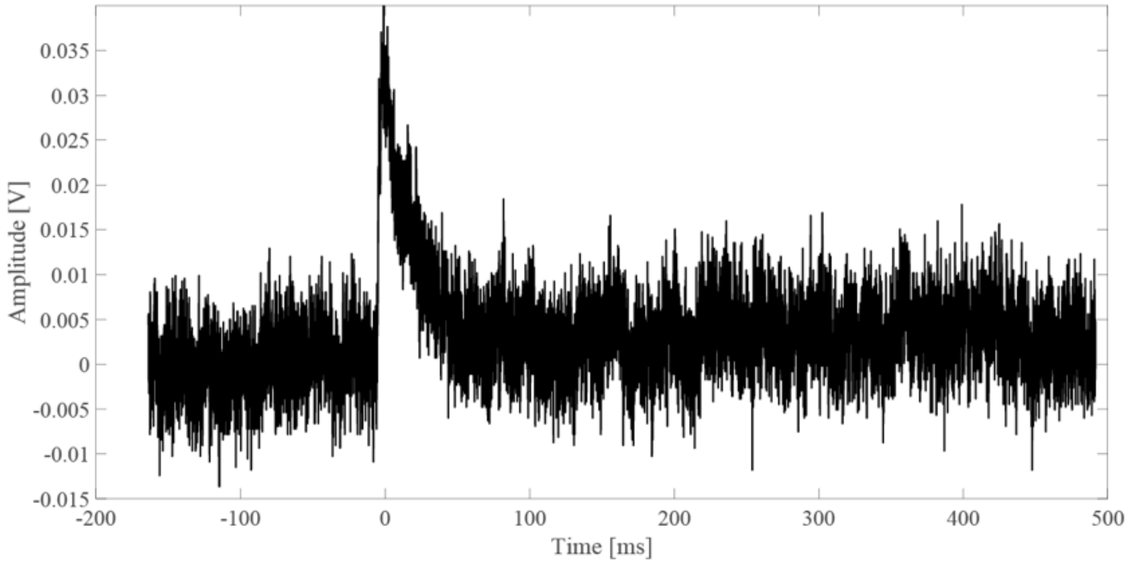
Pulse-height evaluation with optimum filter

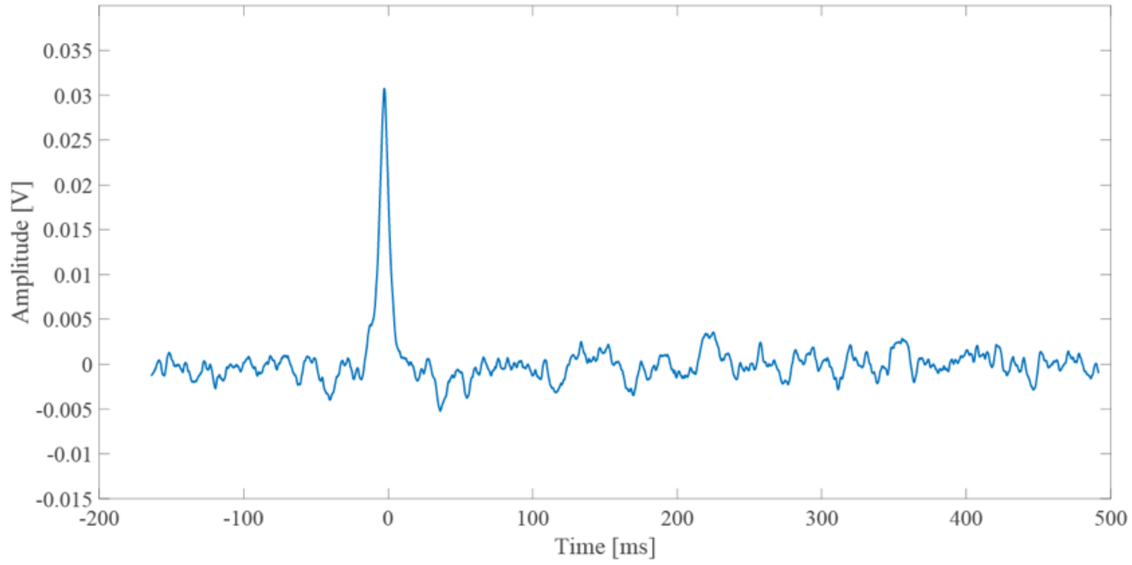
The **Gatti-Manfredi filter** is an optimum filter which maximize the ratio between the amplitude of the treated pulse and the noise RMS

Template pulse

Baselines





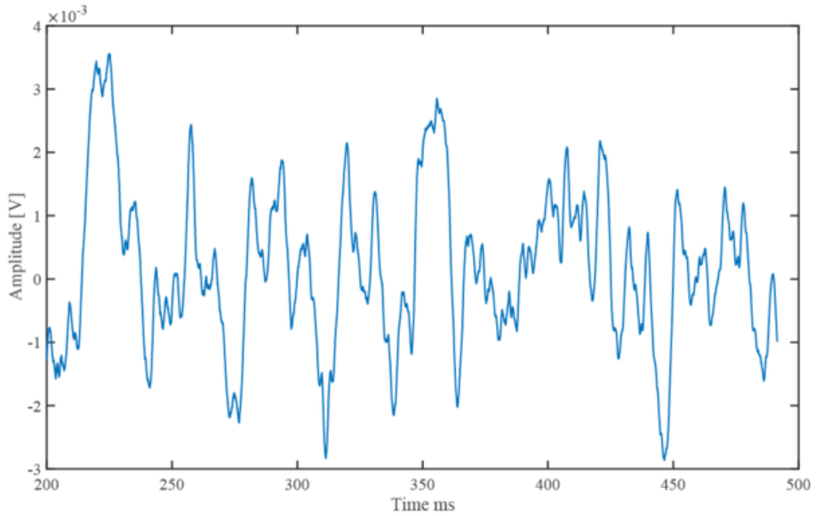


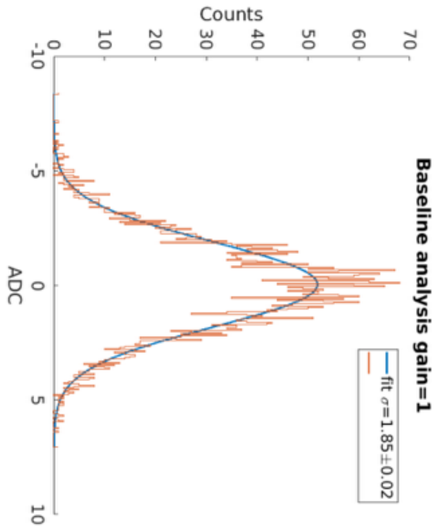
Typical improvement in resolution by using the optimum filter: factor 2-3

Optimum Filter for Threshold Analysis: the Optimum Trigger

Detector A

Typical base line trace

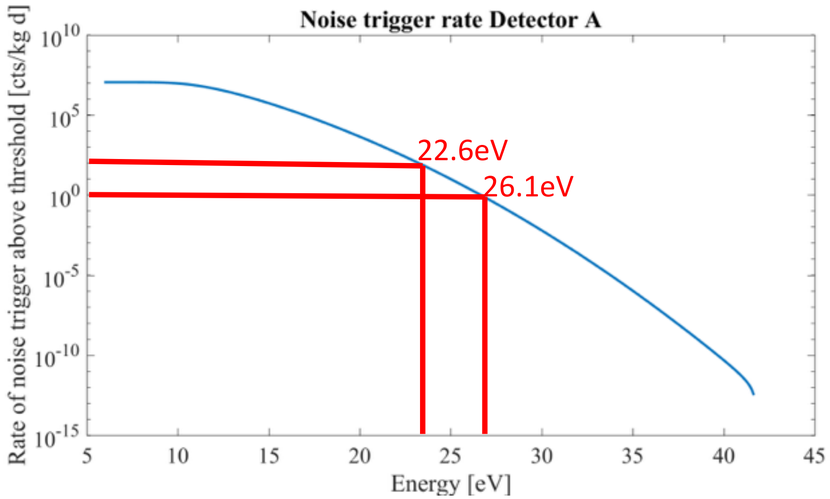


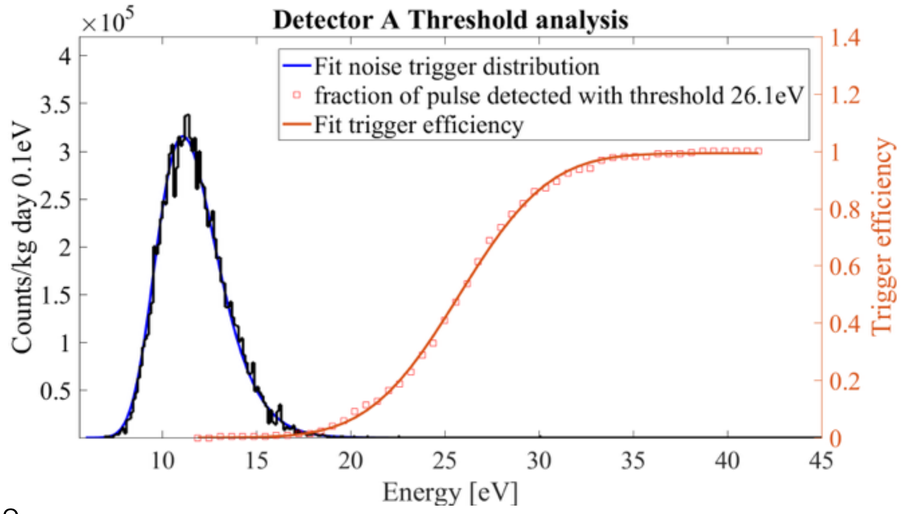


Histogram of a typical baseline trace

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

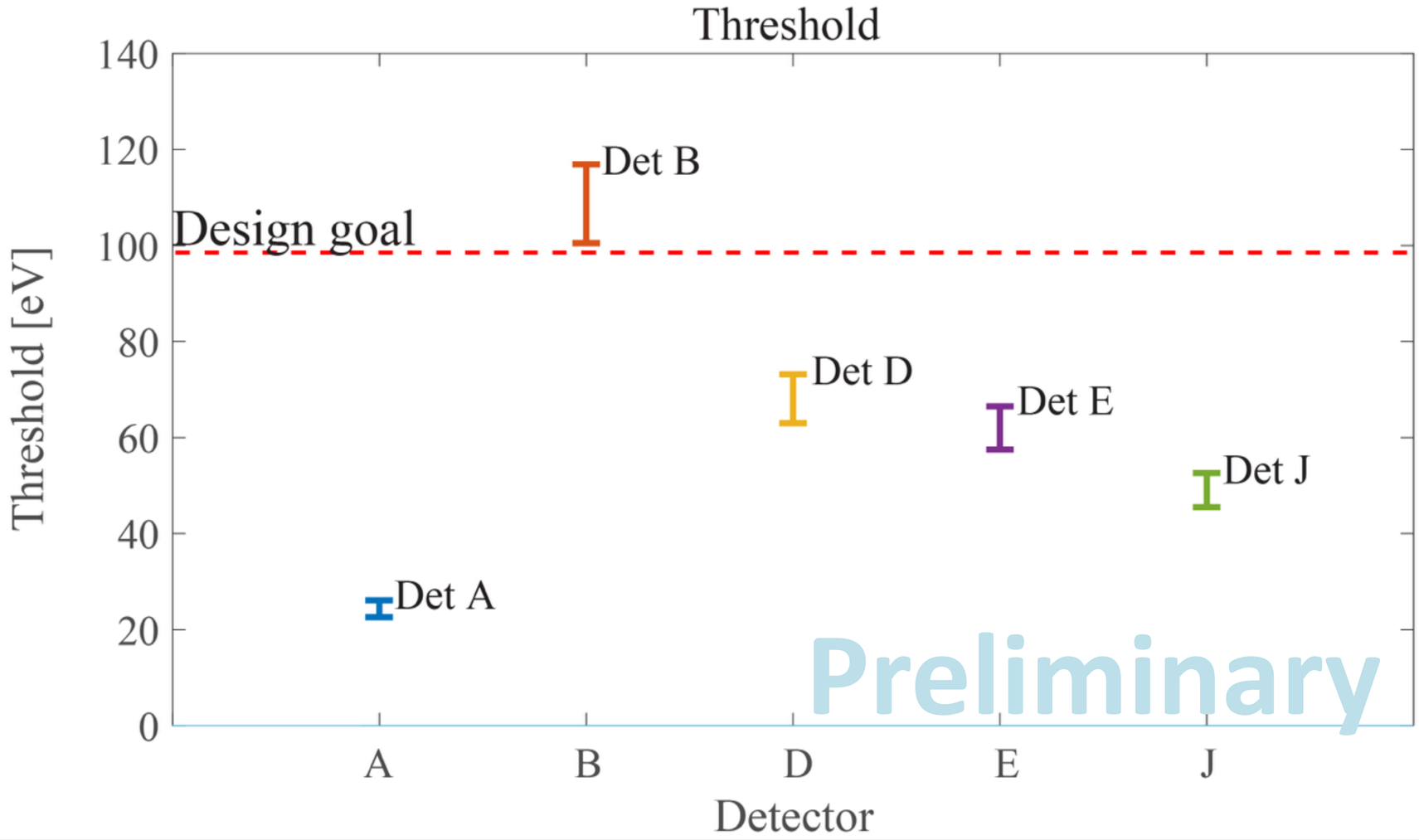
Analytical description of amplitude distribution in empty baselines





New frontier in direct dark Matter Detection

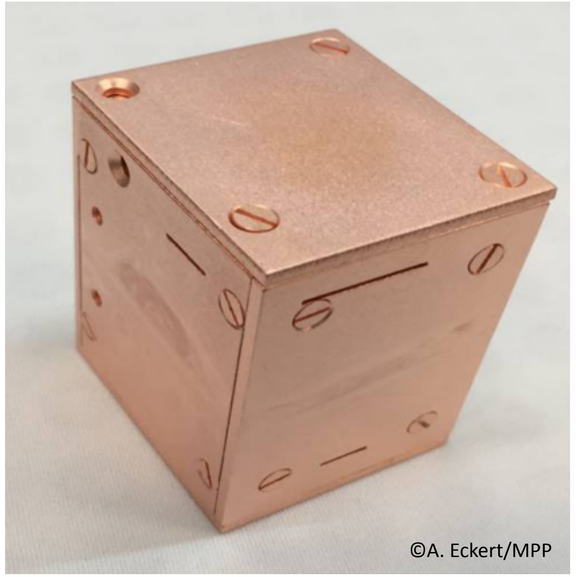
Optimum Threshold



5 detectors reach/exceed CRESST-III design goal

Detector A

Analysis started from detector A



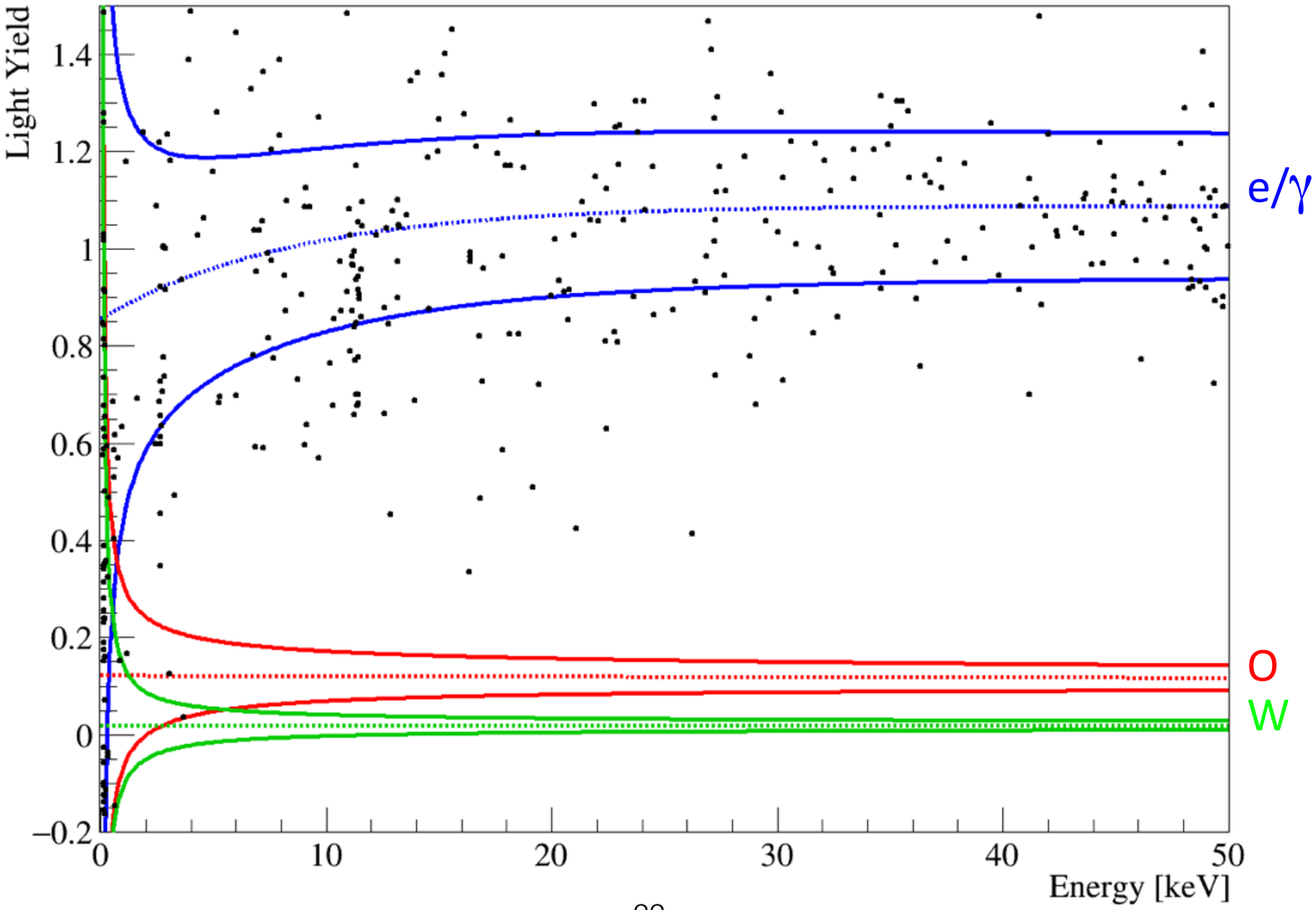
Hardware threshold (measured with test pulses):	48 eV
Data taking period:	31.10.16 - 05.07.17
Non blind data (dynamically growing):	20% randomly selected
Measuring time (blind):	2540 h
Detector mass:	24g
Total exposure:	2.39 kg days
Analysis threshold (high-threshold analysis):	100 eV

July 2017

Detector A: 100 eV threshold analysis

Blind data - LY vs. Energy

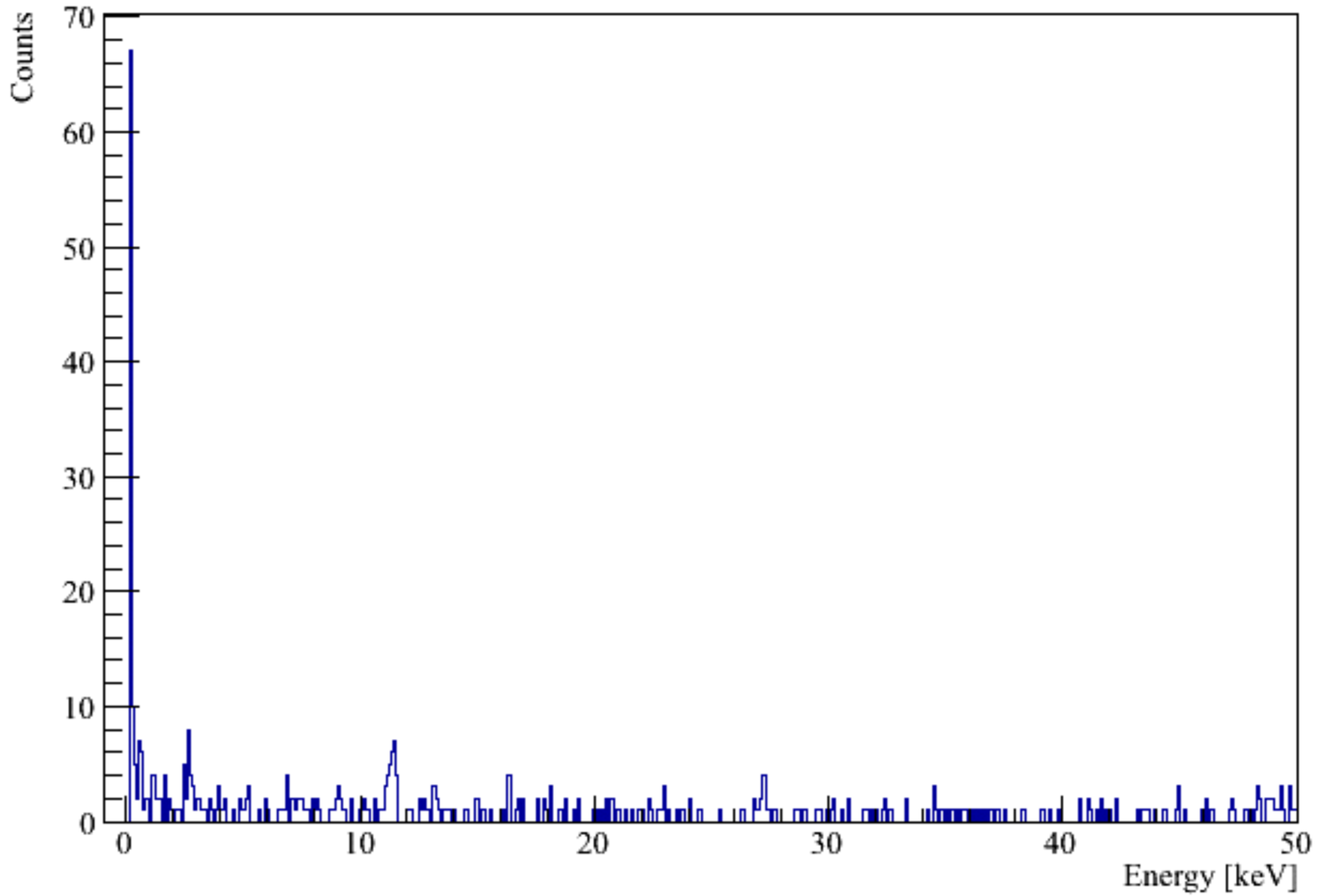
Unblinding for energies >100eV on July 10th



Detector A: 100 eV threshold analysis

The blind data – Energy spectrum

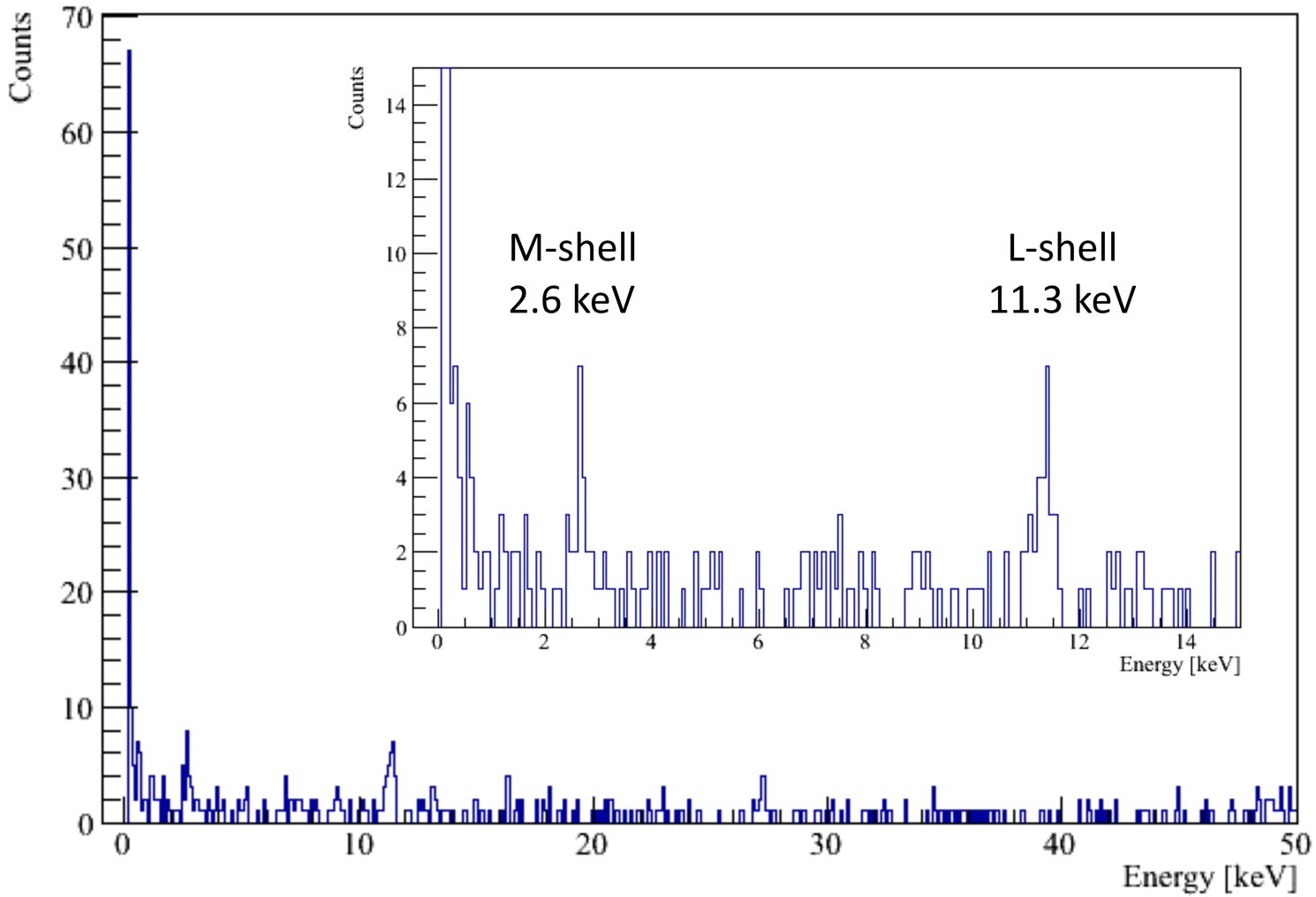
Background in energy range 1-40keV ≈3.5 counts per (kg keV day)



Detector A: 100 eV threshold analysis

The blind data – Energy spectrum zoom

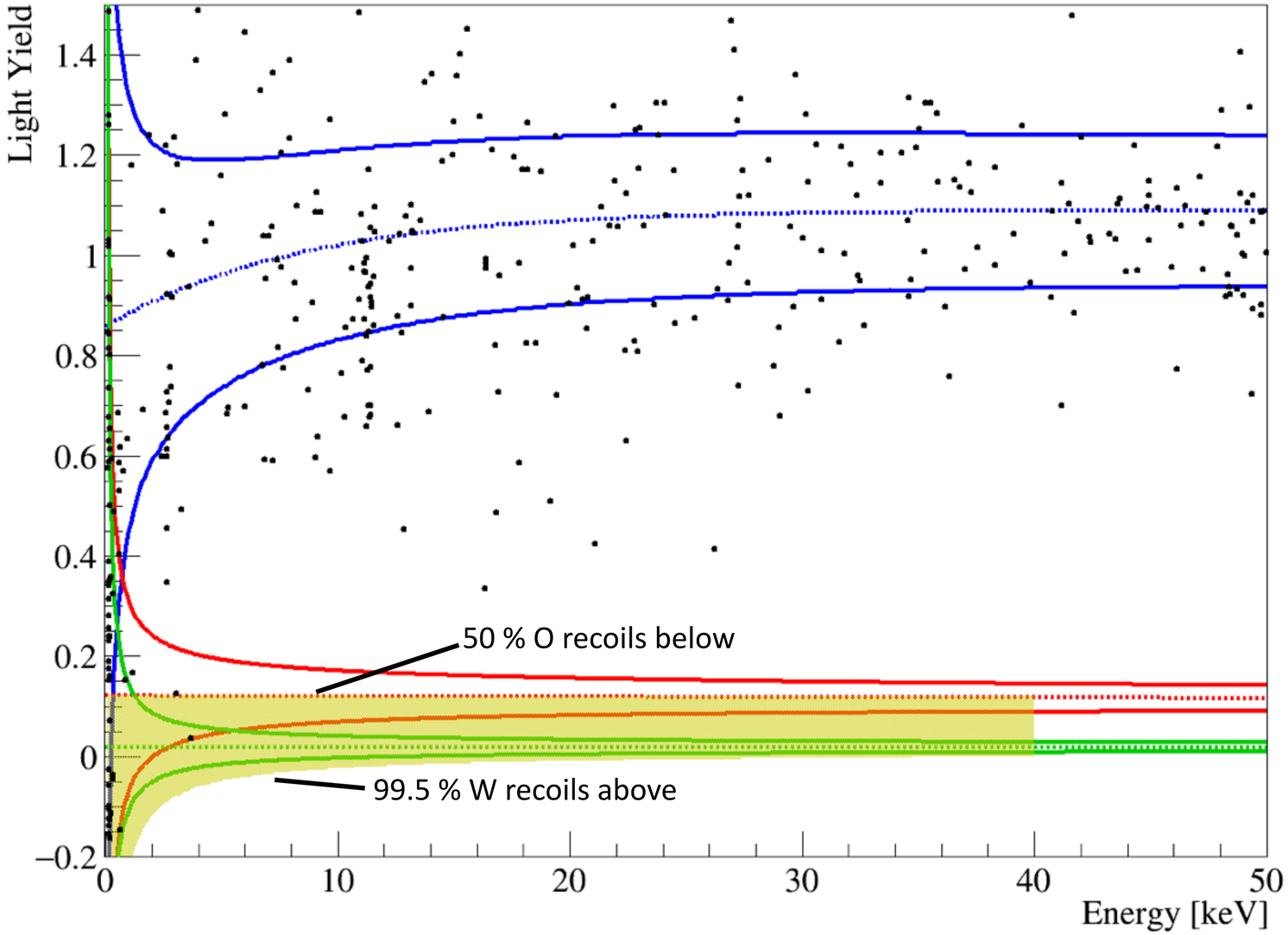
$^{179}Ta + e^{-} \rightarrow {}^{179}Hf + \nu_e$ (1.8y)



Detector A: 100 eV threshold analysis

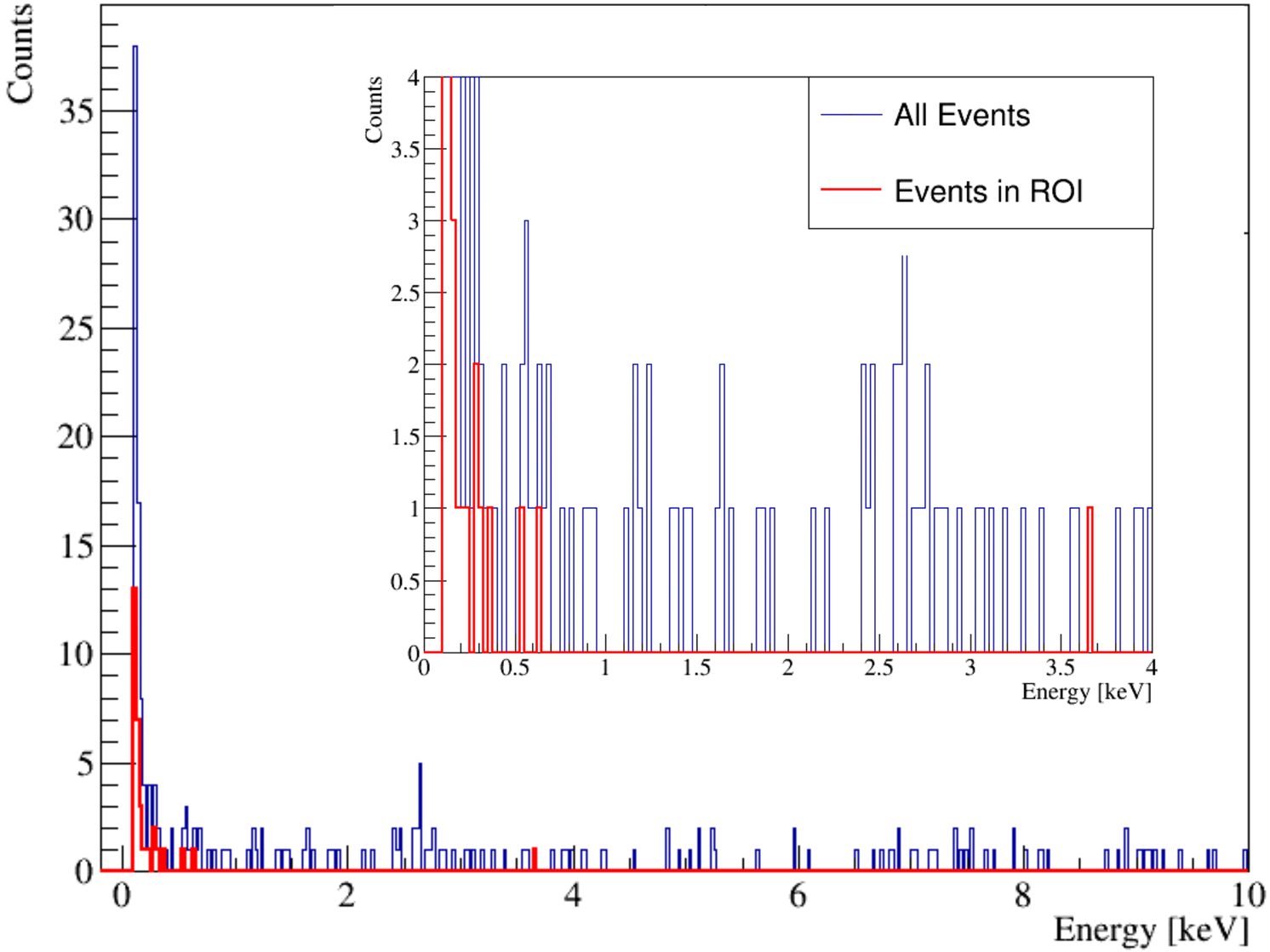
The blind data – Acceptance region

Acceptance region chosen before unblinding



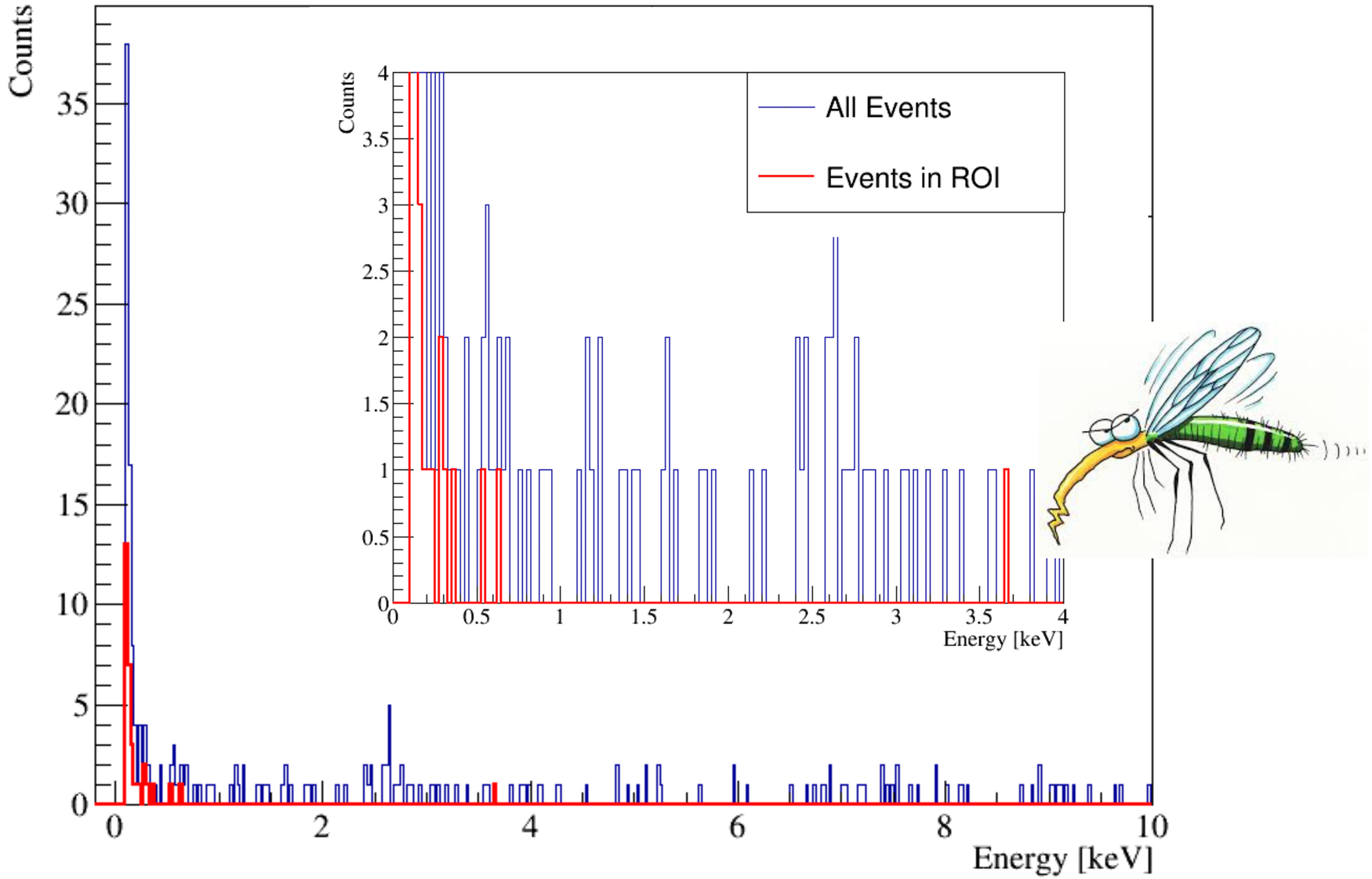
Detector A: 100 eV threshold analysis

The blind data – Energy spectrum accepted events



Detector A: 100 eV threshold analysis

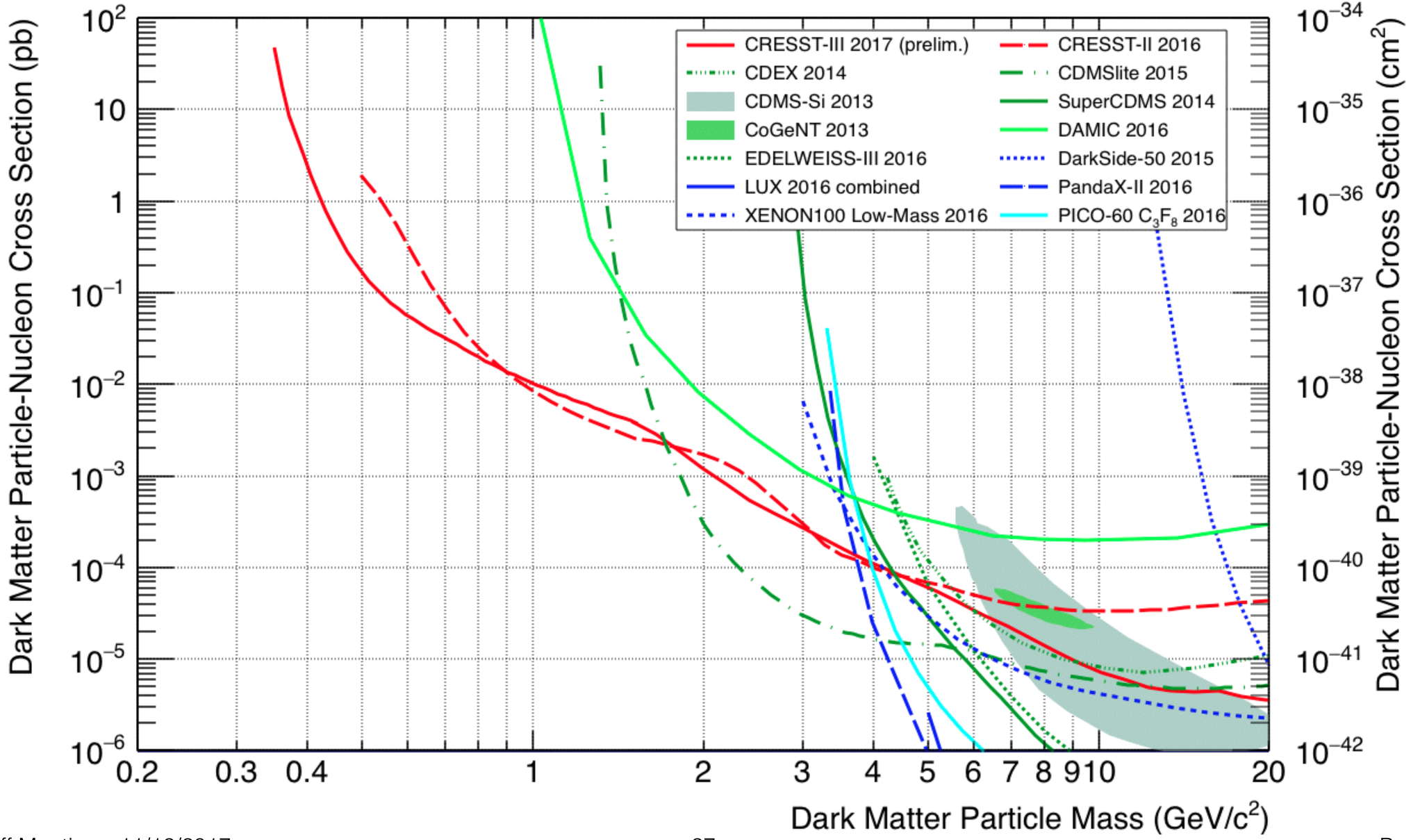
The blind data – Energy spectrum accepted events



Detector A: 100 eV threshold analysis

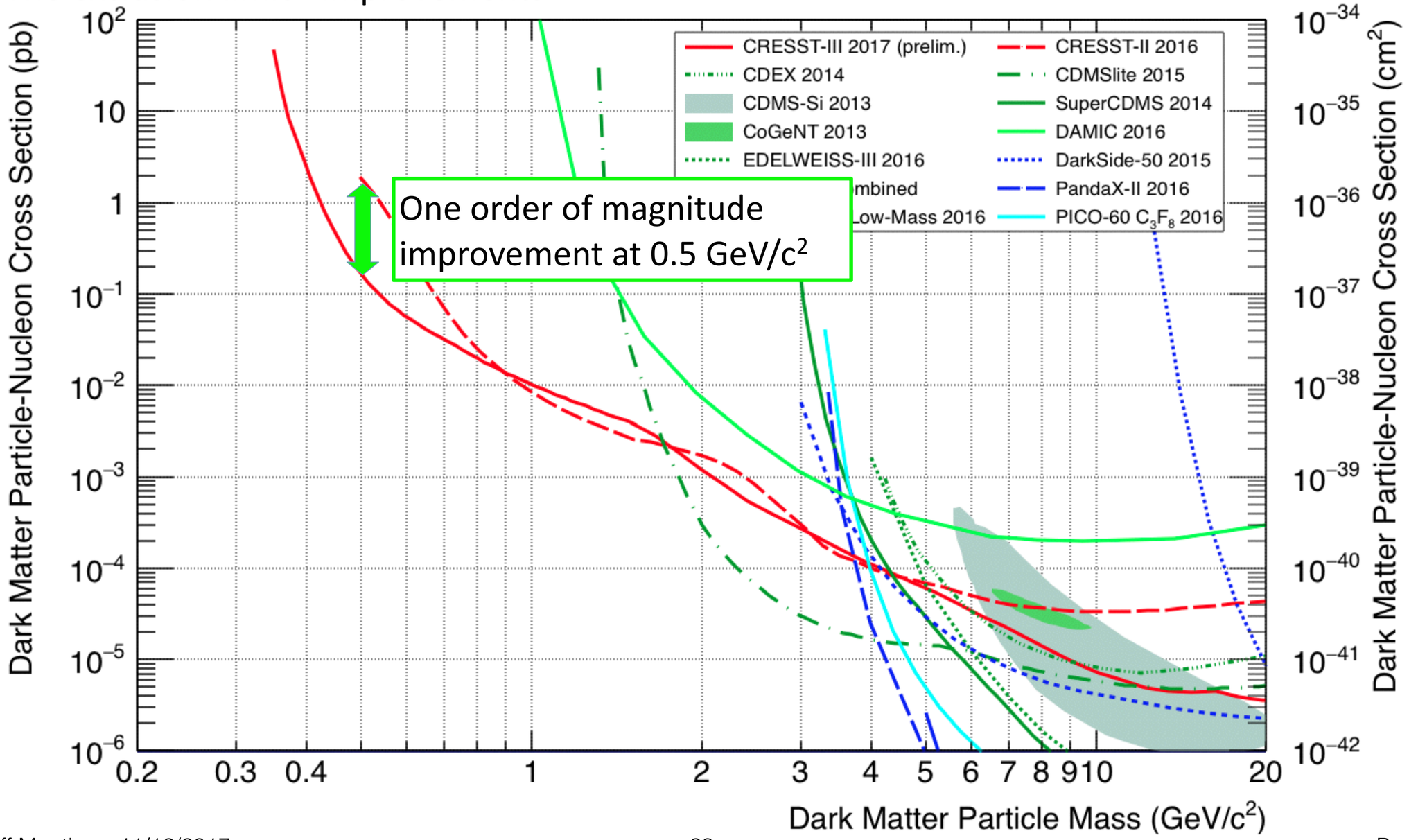
TAUP2017

The exclusion limit



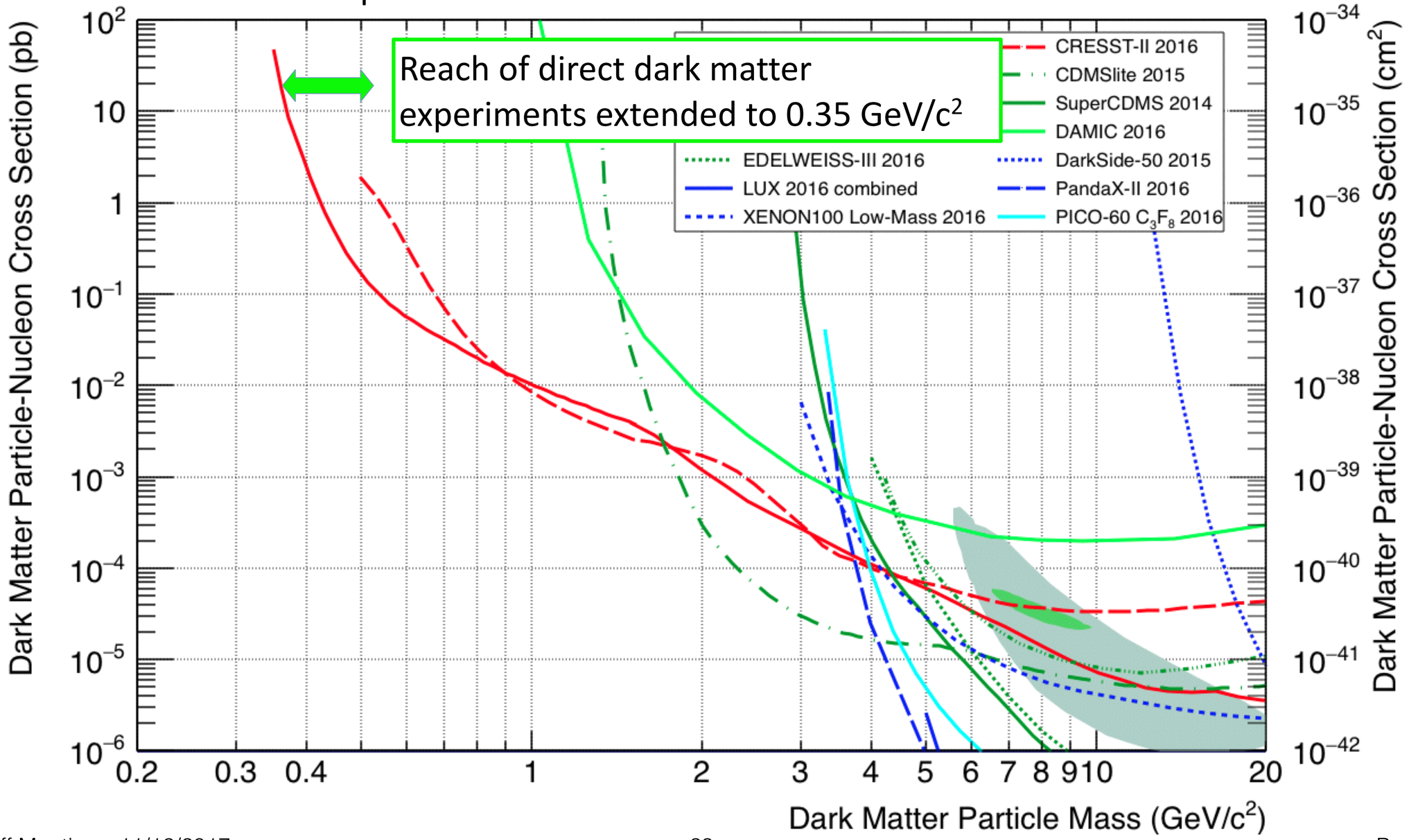
Detector A: 100 eV threshold analysis

The exclusion limit - improvements



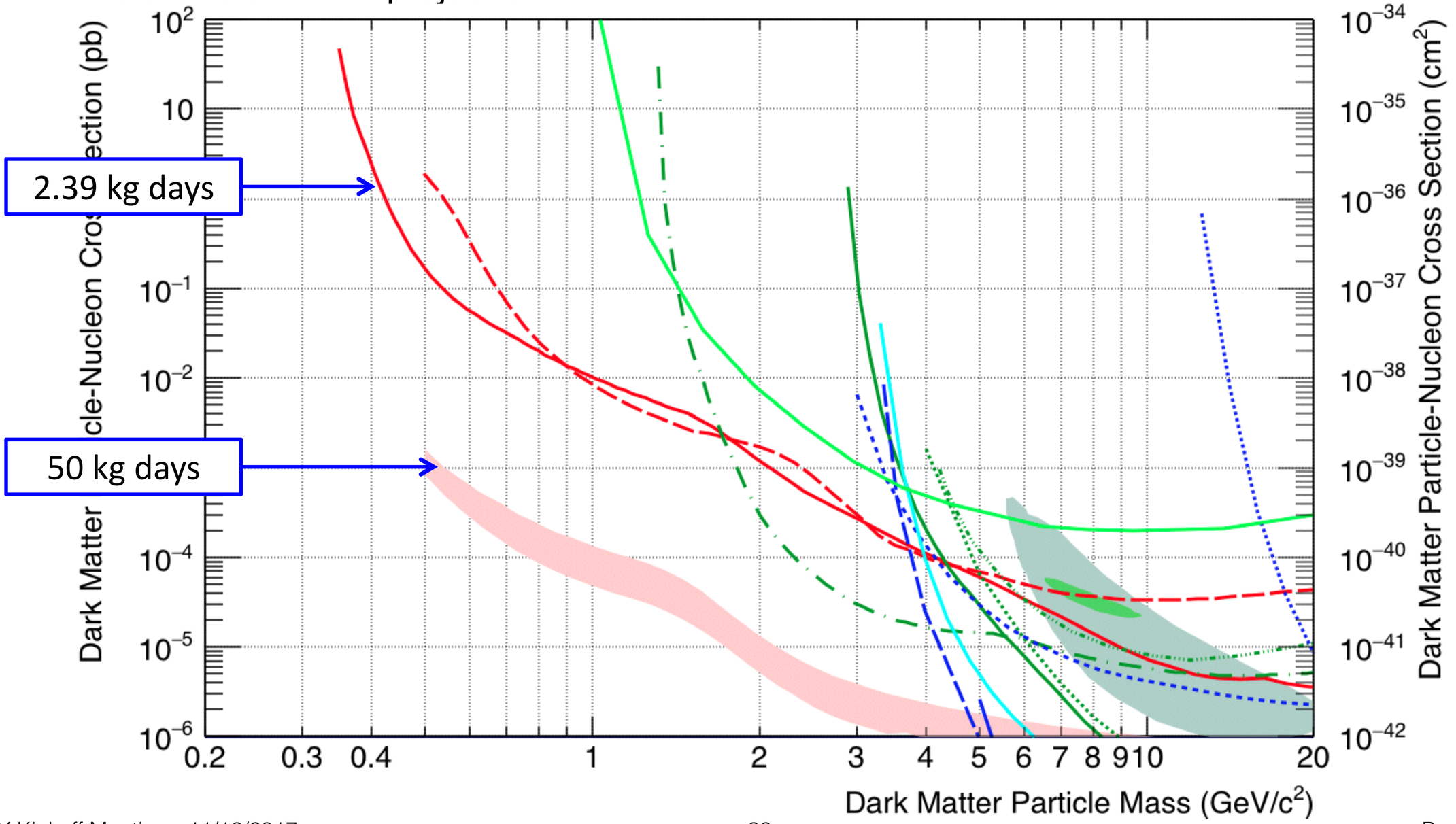
Detector A: 100 eV threshold analysis

The exclusion limit - improvements



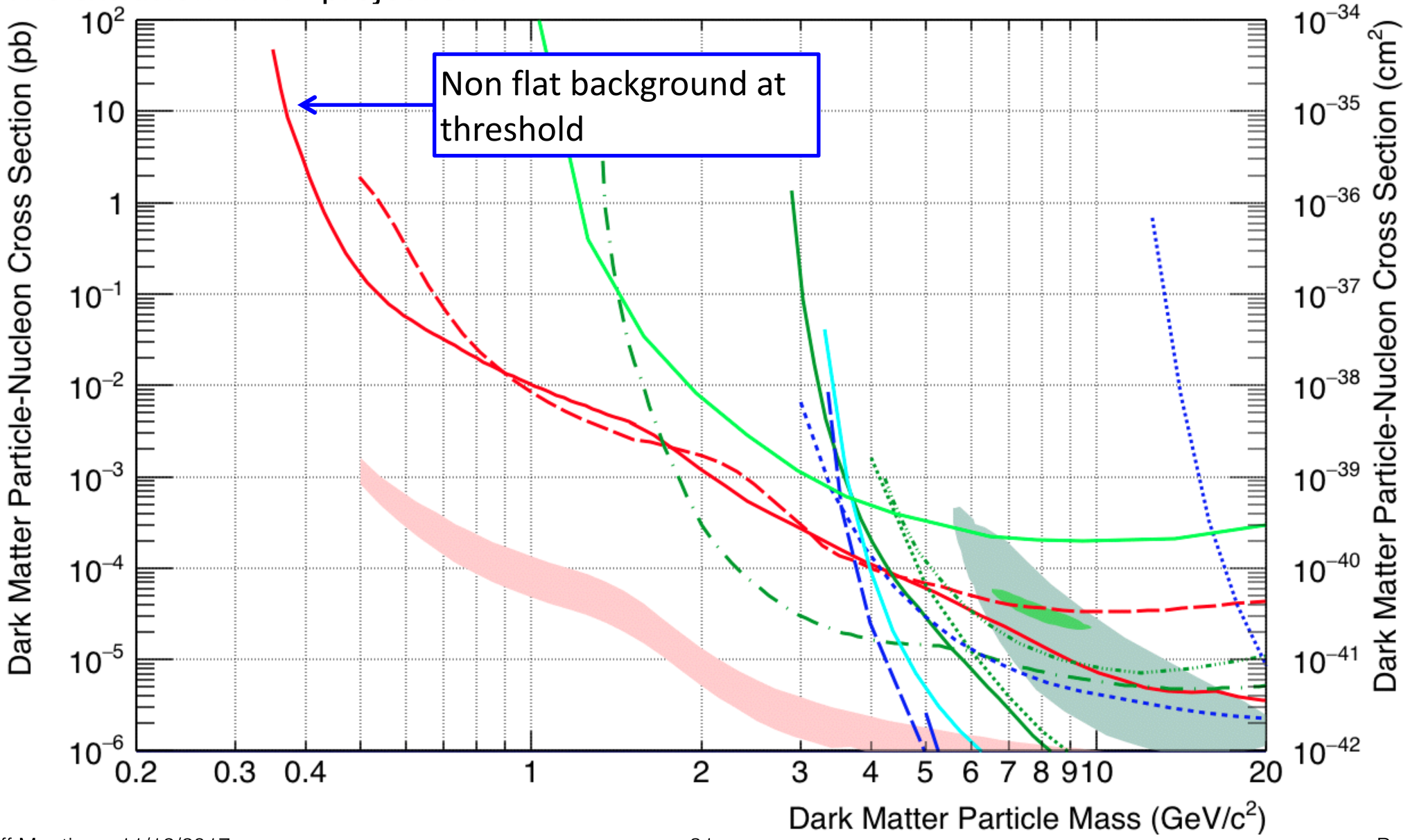
Detector A: 100 eV threshold analysis

The exclusion limit - projection



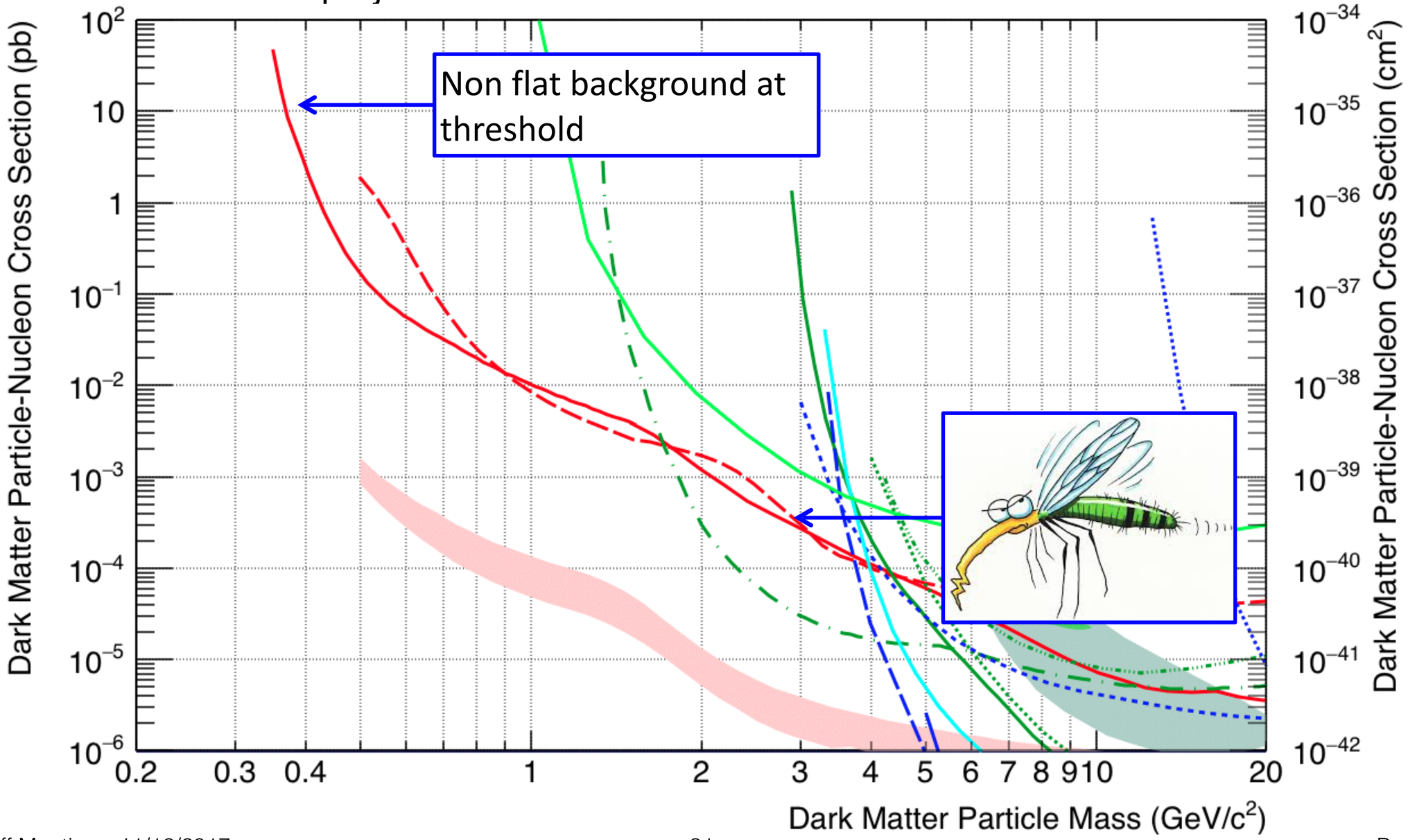
Detector A: 100 eV threshold analysis

The exclusion limit - projection

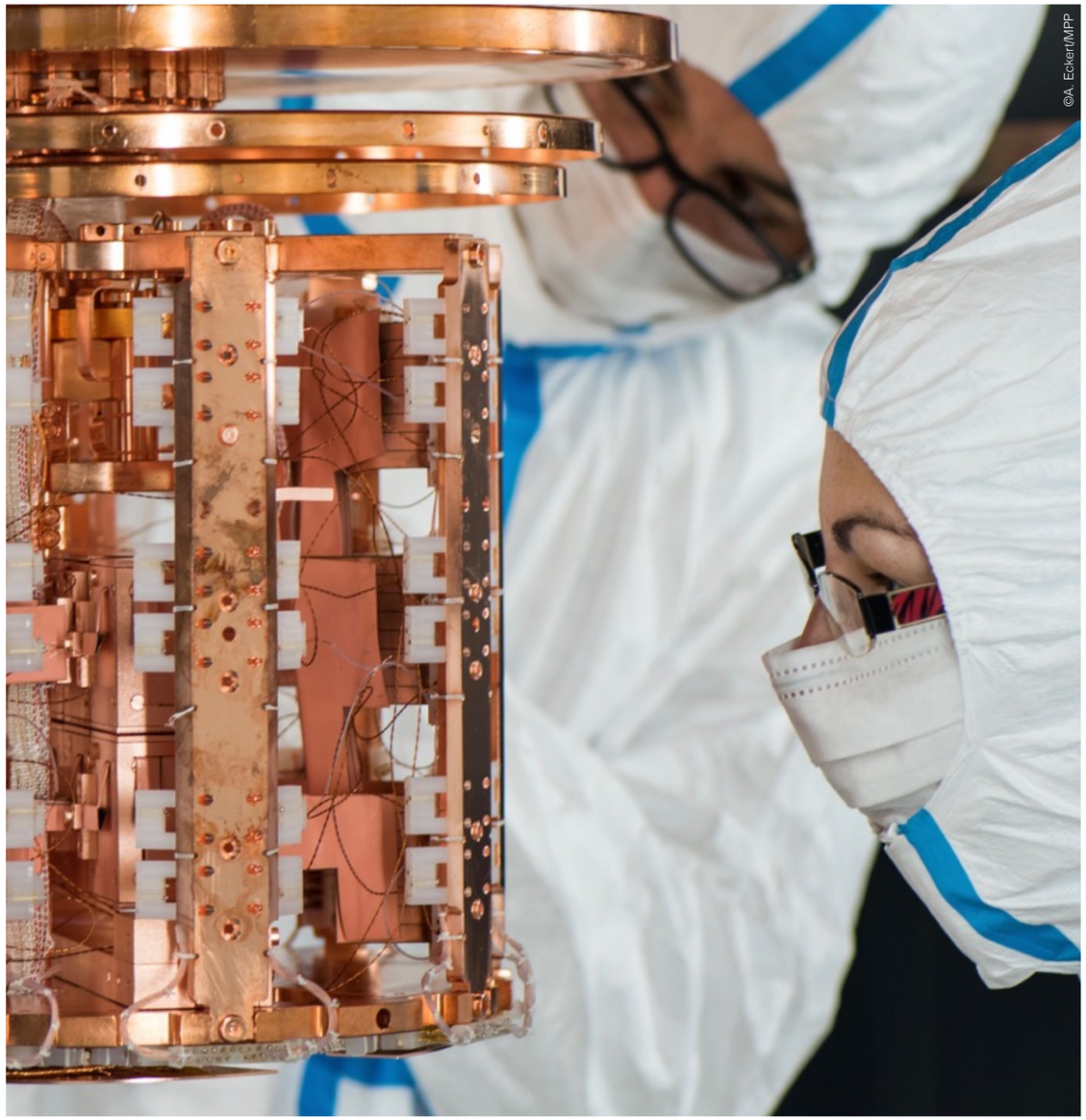


Detector A: 100 eV threshold analysis

The exclusion limit - projection



And is just the beginning…



Multiple detectors with Threshold lower than 100 eV

Kept acquiring statistic for deeper understanding of the background

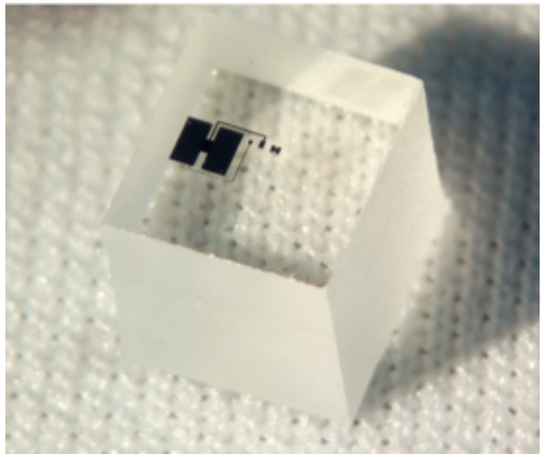
Opened a new era for low mass DM search

Still many ideas to develop

…stay tuned!

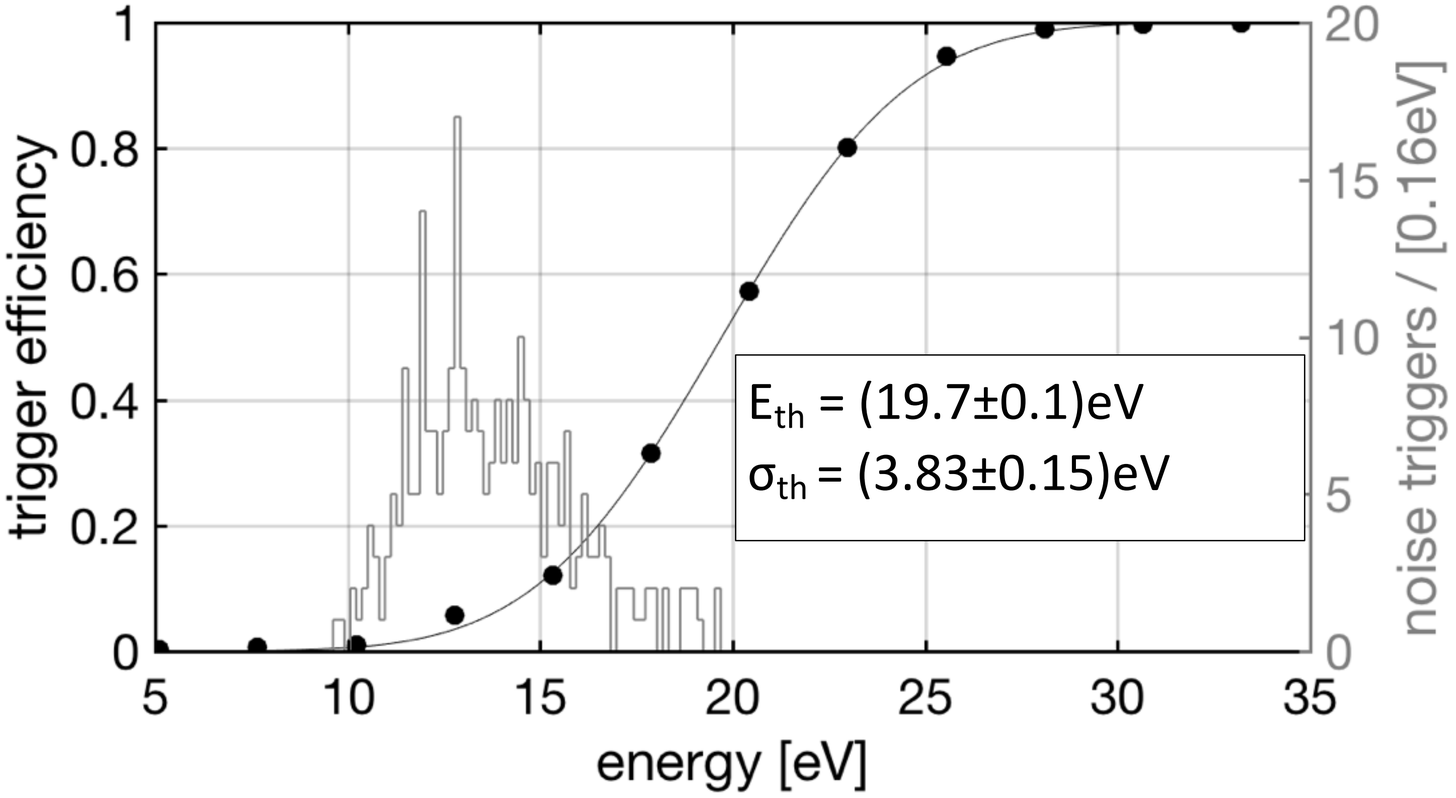
Gram scale detector

Al_2O_3 crystal 0.5g



First prototype detector successfully tested:

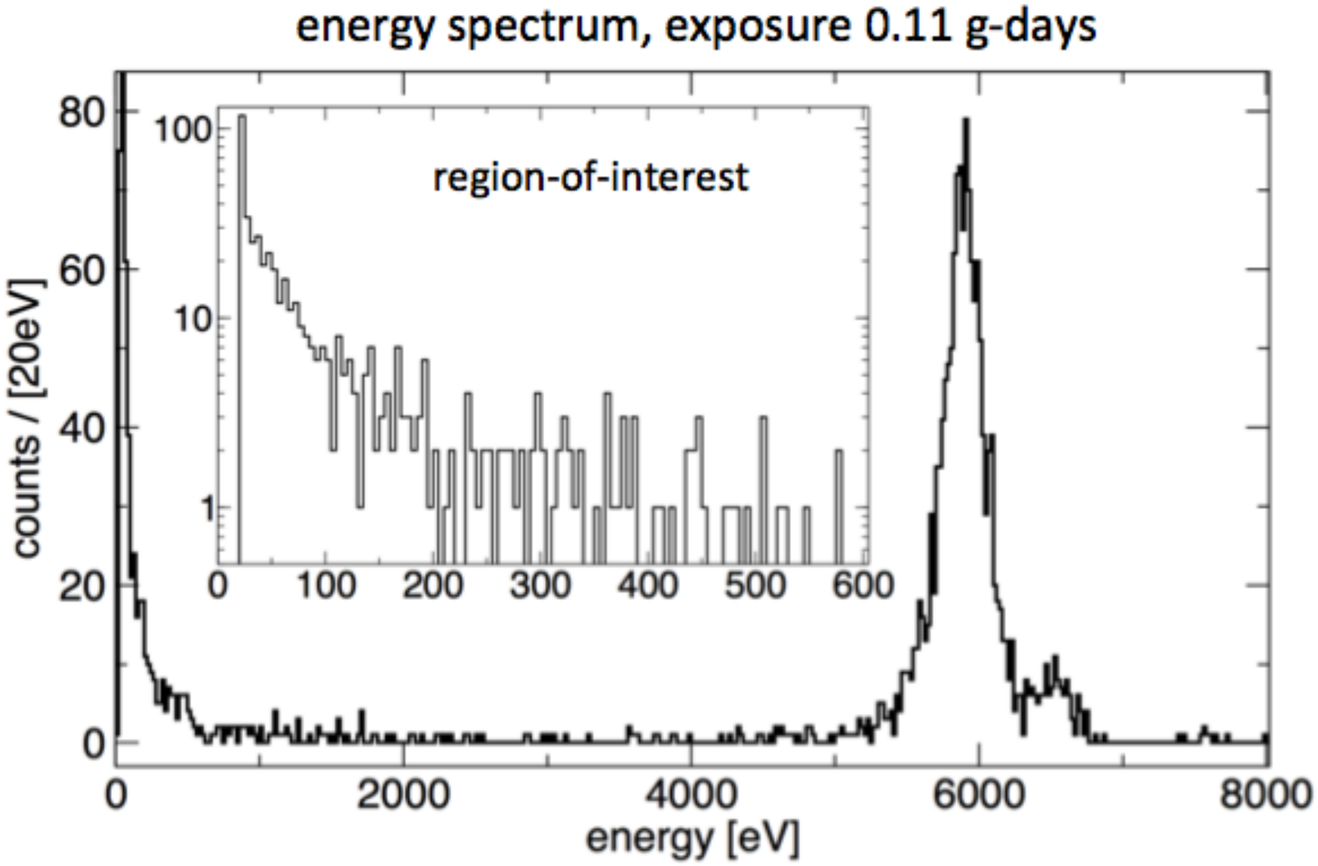
- operated above ground
- setup without shielding



Operation in high-background environment demonstrated

MeV scale Dark Matter

Calibration measurement in high background environment



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

MeV scale Dark Matter

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The exclusion limit