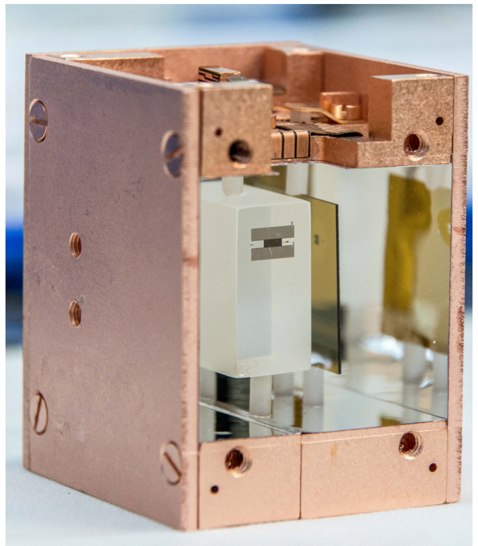


Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

CRESST Results

Lucia Canonica
Max Planck Institut für Physik, München

Mainz, September 18th 2018

The CRESST Collaboration

~50 Collaborators:

- 16 MPP, DE
- 14 TUM, DE
- 4 Tubingen, DE
- 8 HEPHY, AT
- 8 LNGS, IT
- 1 Oxford, UK

The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

Laboratori Nazionali del Gran Sasso (Italy)

Experimental location:

Average depth ~ 3600 m w.e.

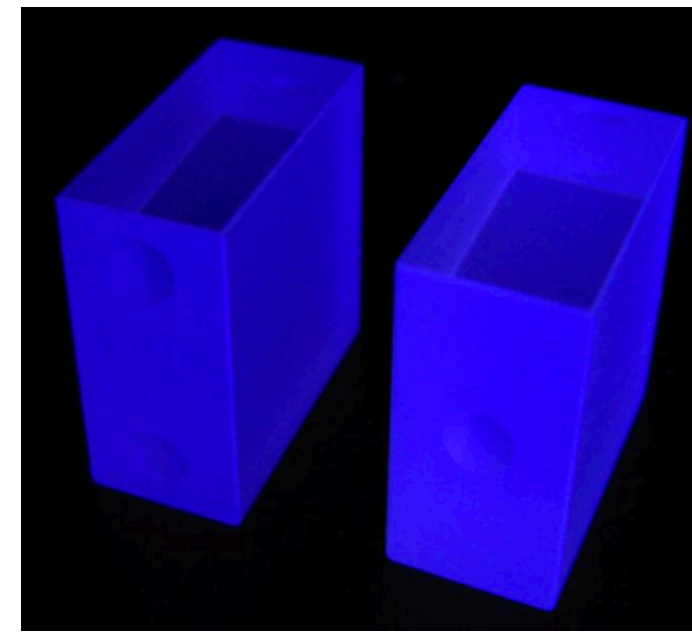
Muon flux ~ 2.6×10^{-8} μ/s/cm^2

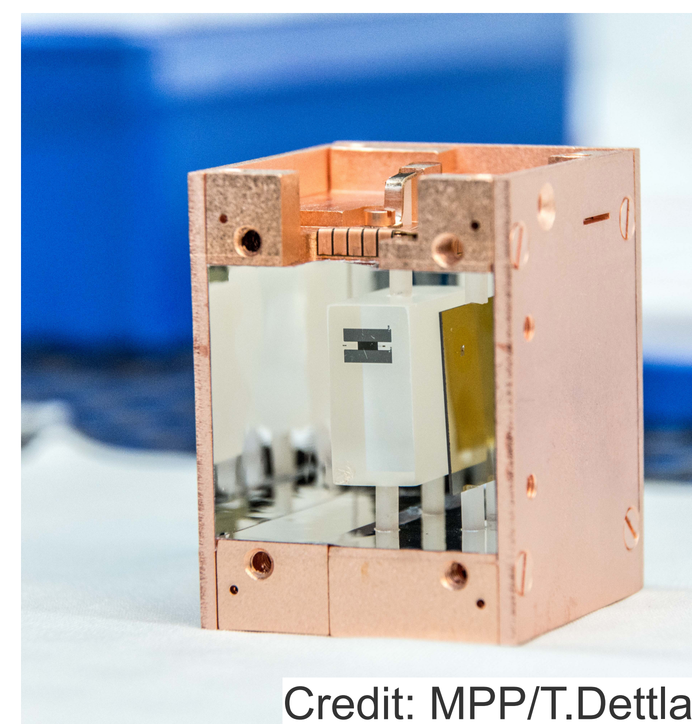
Neutrons < 10 MeV: <10^{-6} n/s/cm^2

The CRESST detector

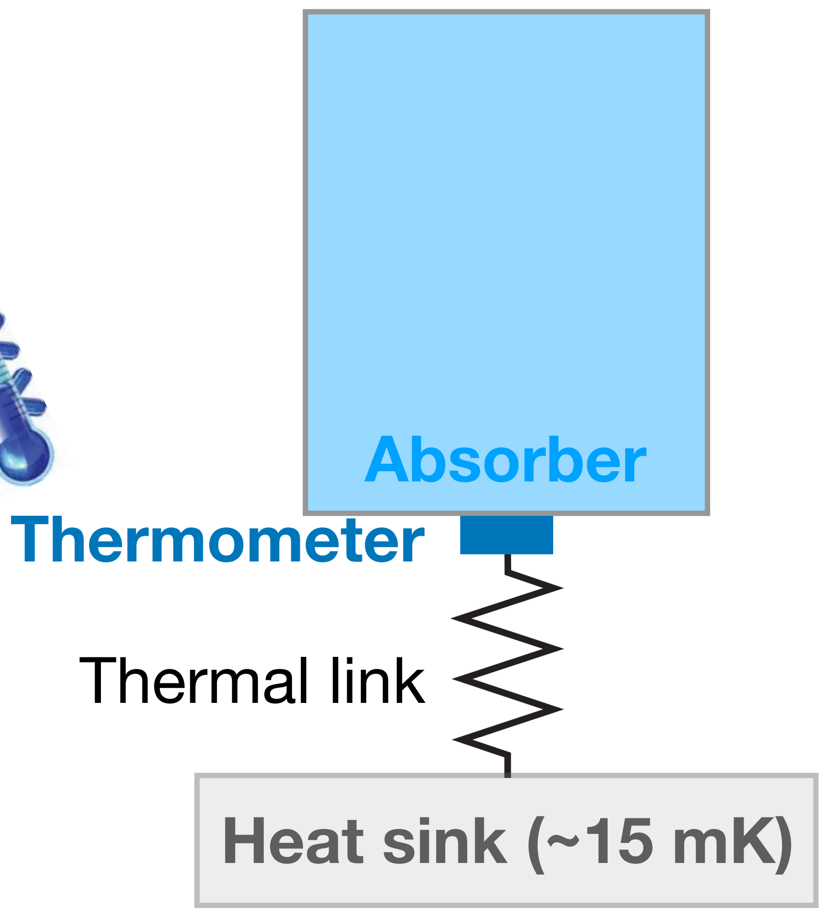
Cryogenic Rare Event Search with Superconducting Thermometers

- Direct detection of Dark Matter particles via their scattering off target nuclei
- Target: Scintillating $CaWO_4$ crystals
- Operated as cryogenic calorimeters (~15mK)
- Double read-out cryogenic detector: heat ($CaWO_4$) and light (Light detector)
- Transition Edge Sensor (TES) for read out





Cryogenic calorimeter



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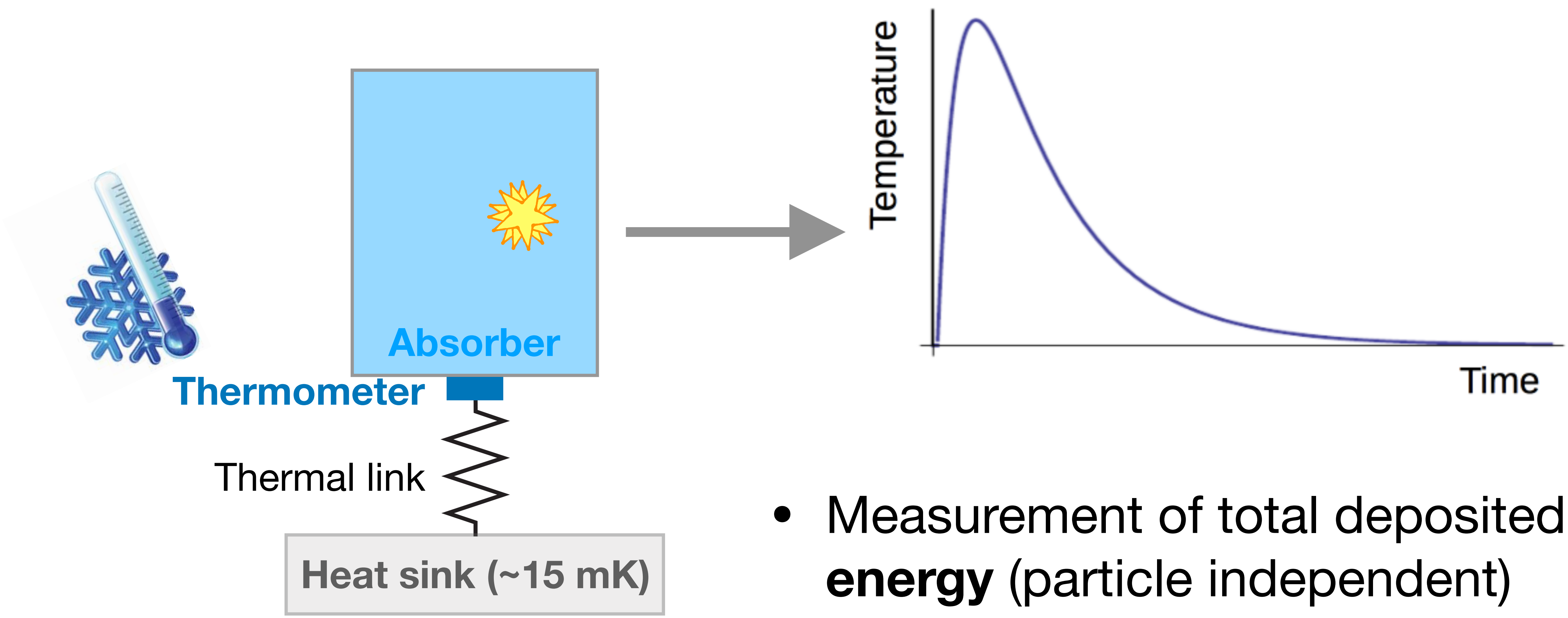
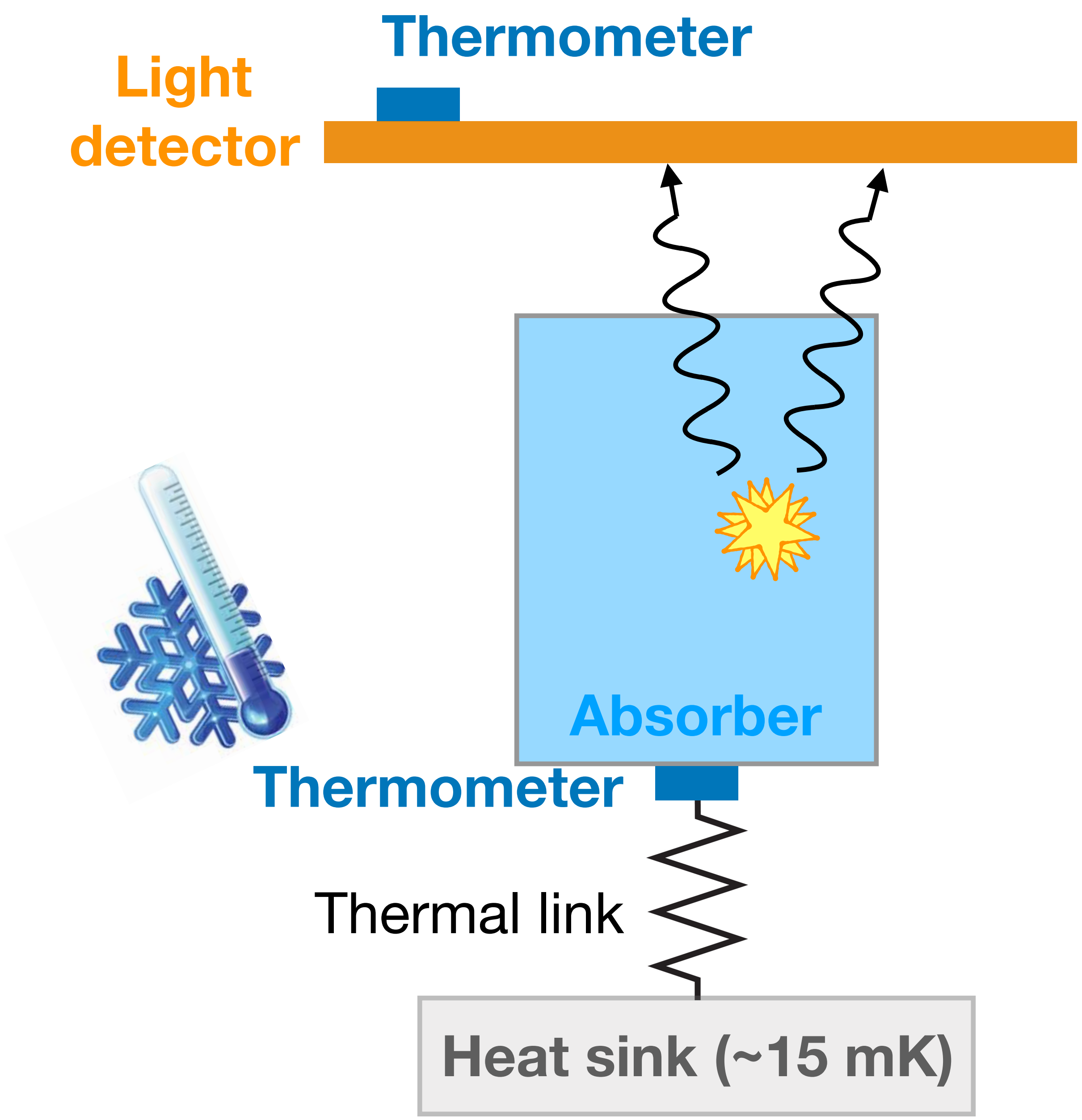


- Measurement of total deposited **energy** (particle independent)

Cryogenic calorimeter



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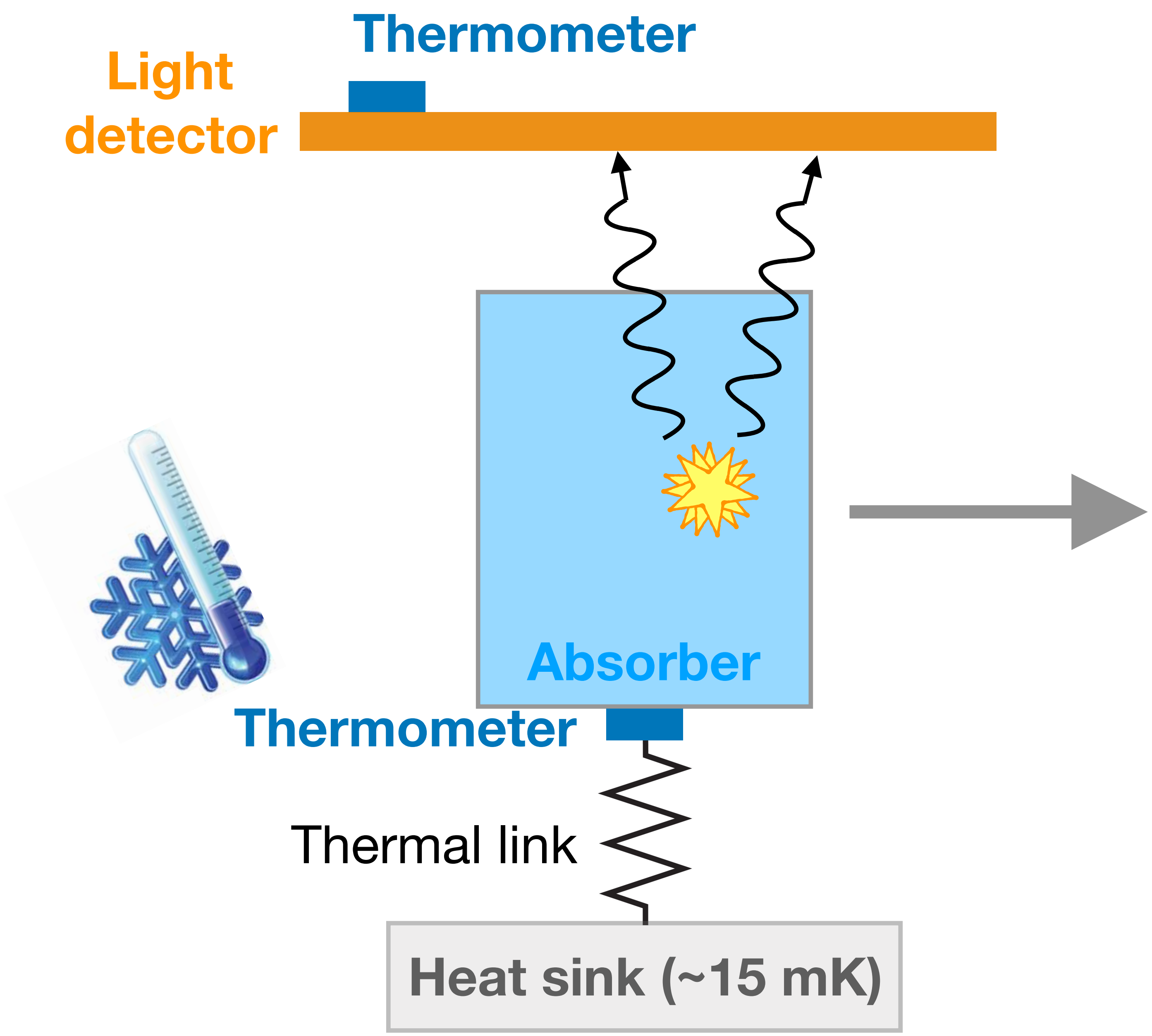
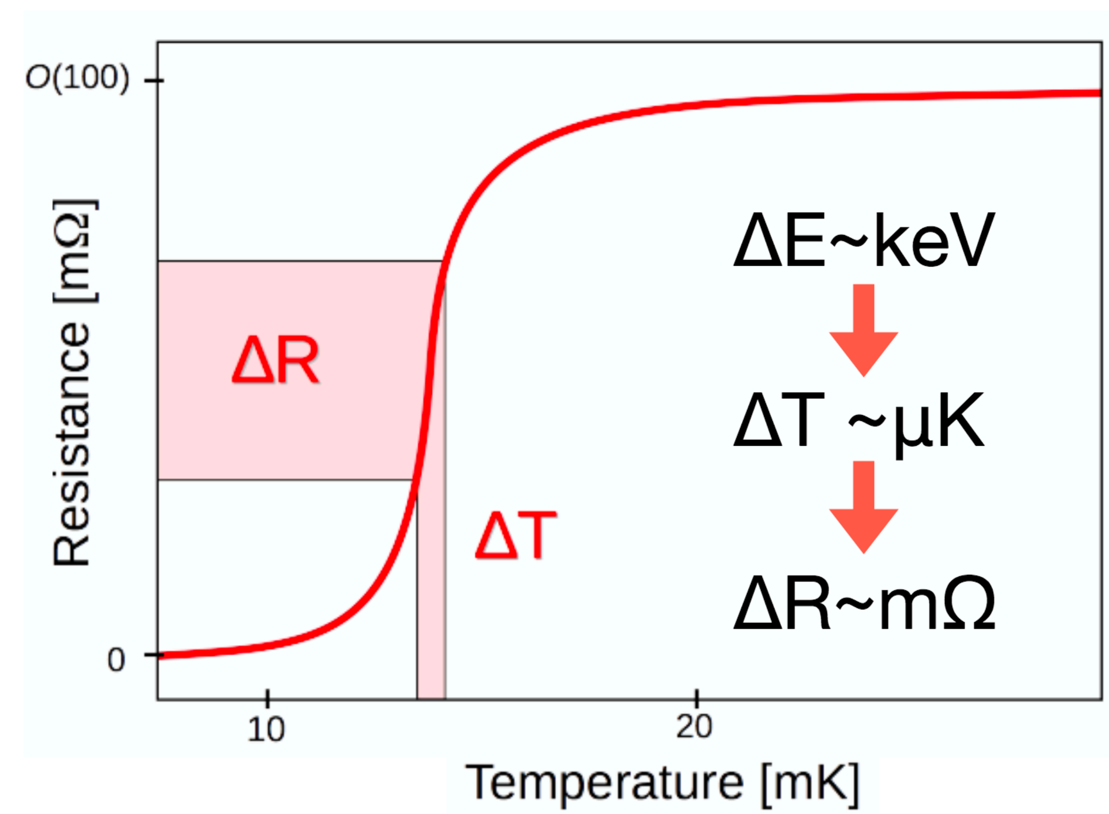
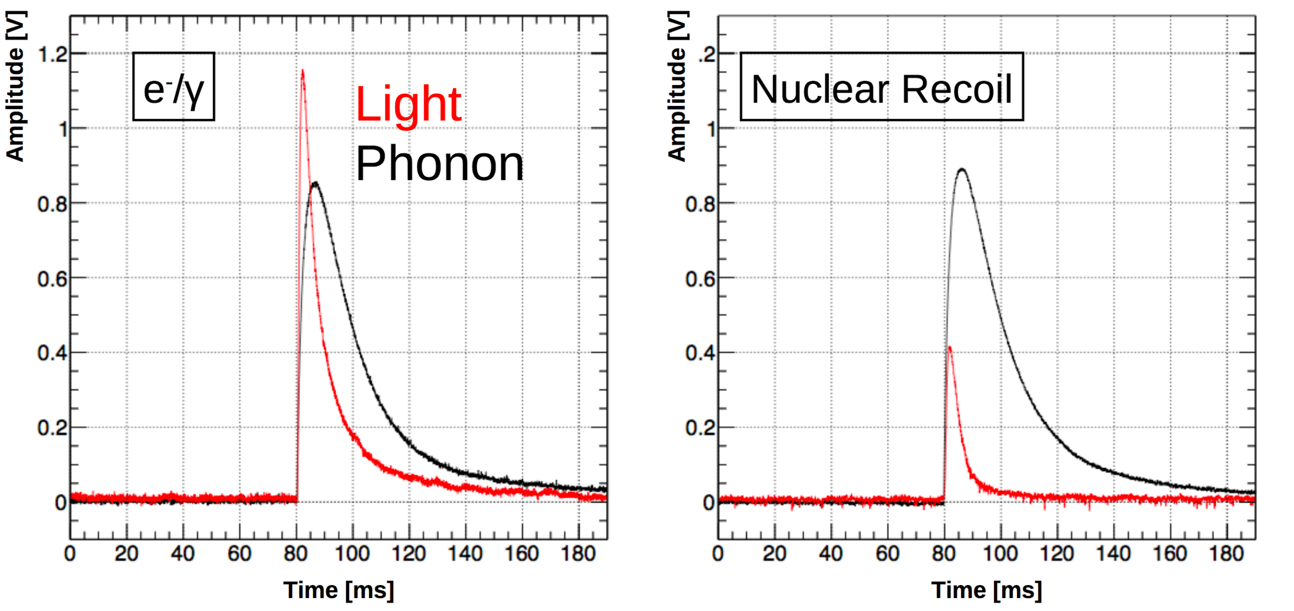




Detection of temperature rise with **TES** (Transition Edge Sensor) sensors operated at the phase transition from normal to superconducting.

Particle Identification

If the absorber is also an efficient scintillator the energy is converted into **heat** + **light**



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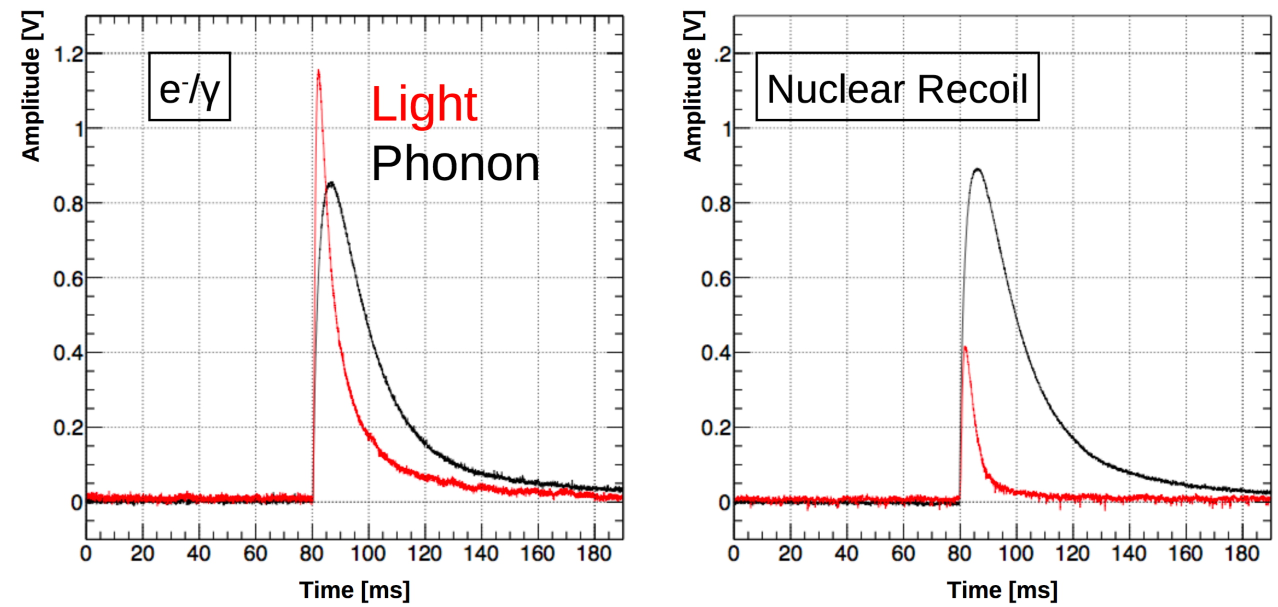

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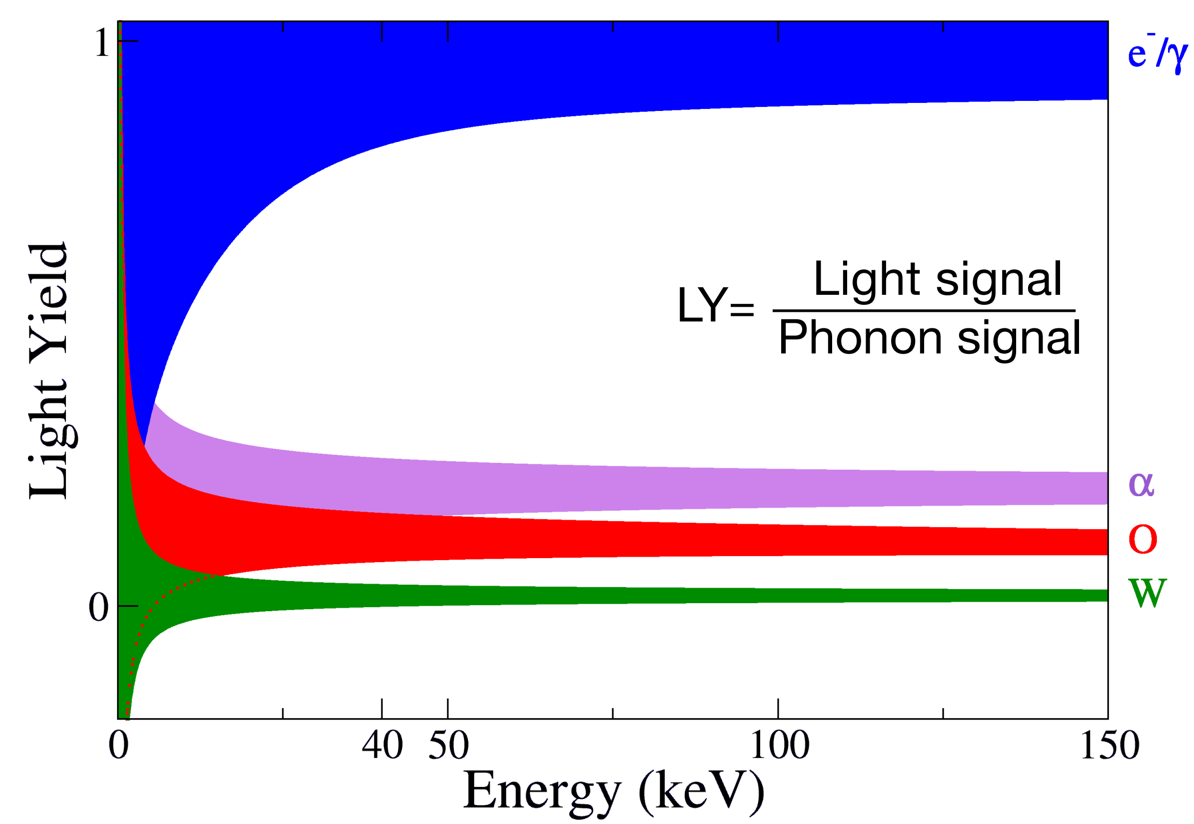

Excellent discrimination between potential signal events (**nuclear recoils**) and dominant radioactive background (**electron recoils**)

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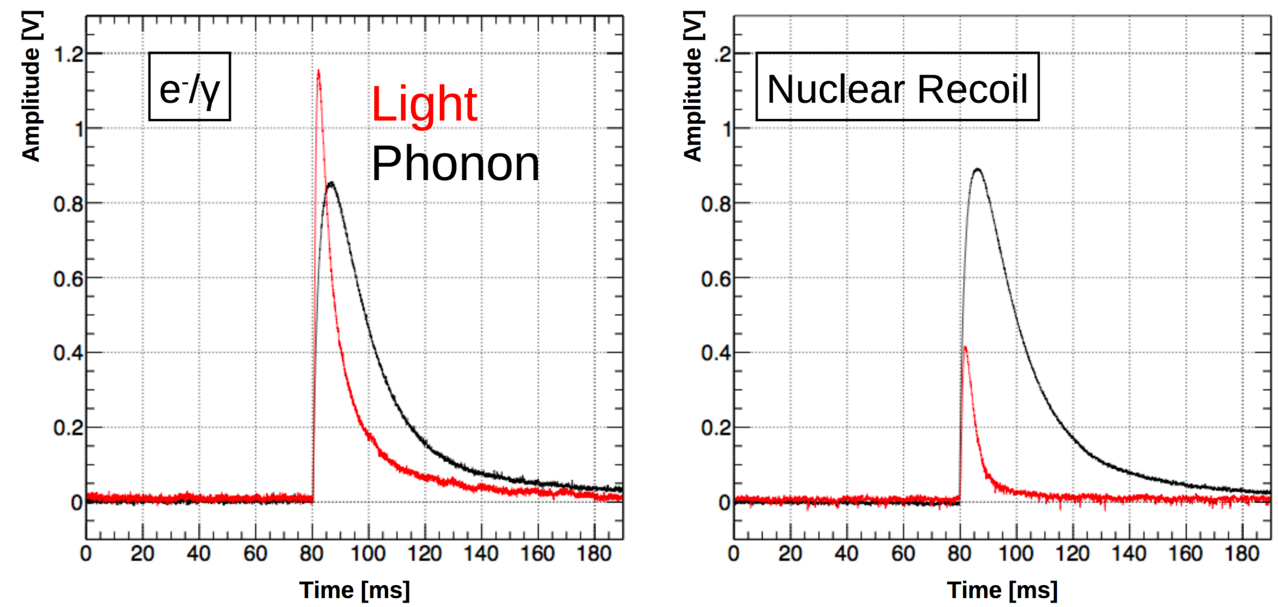

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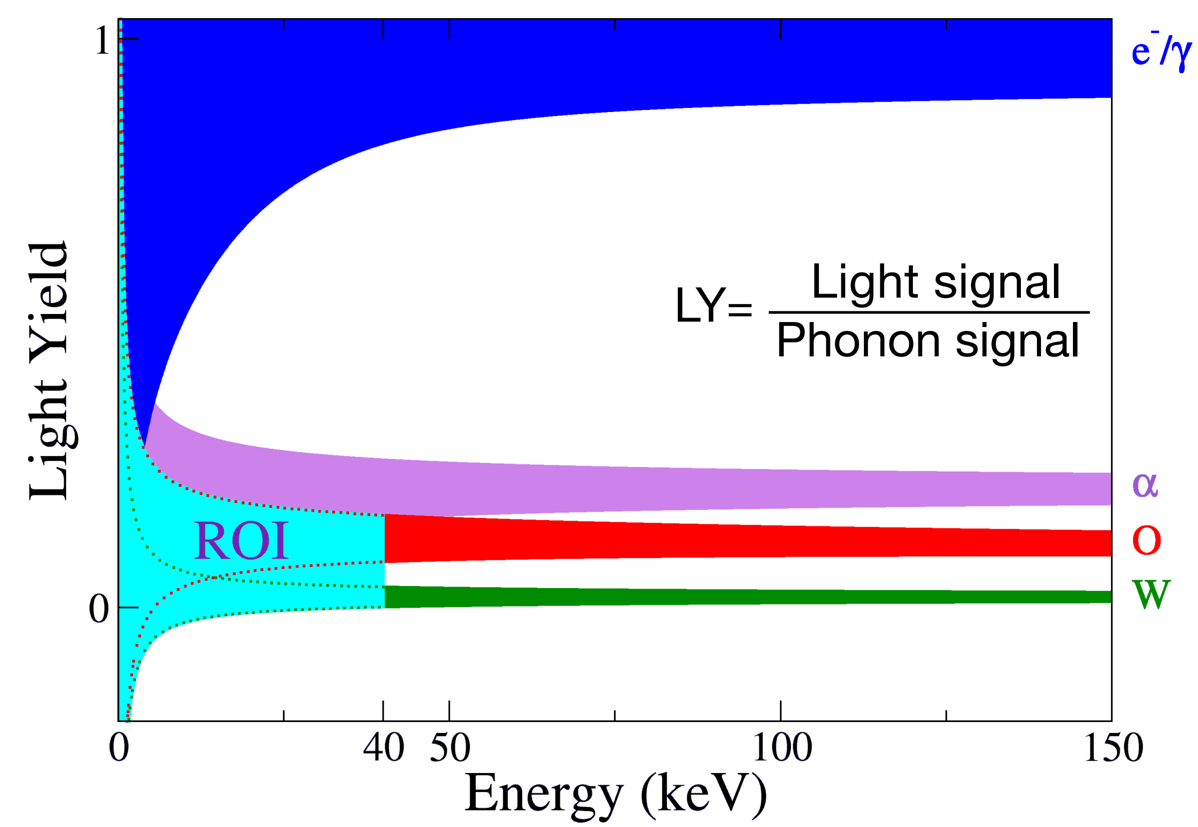


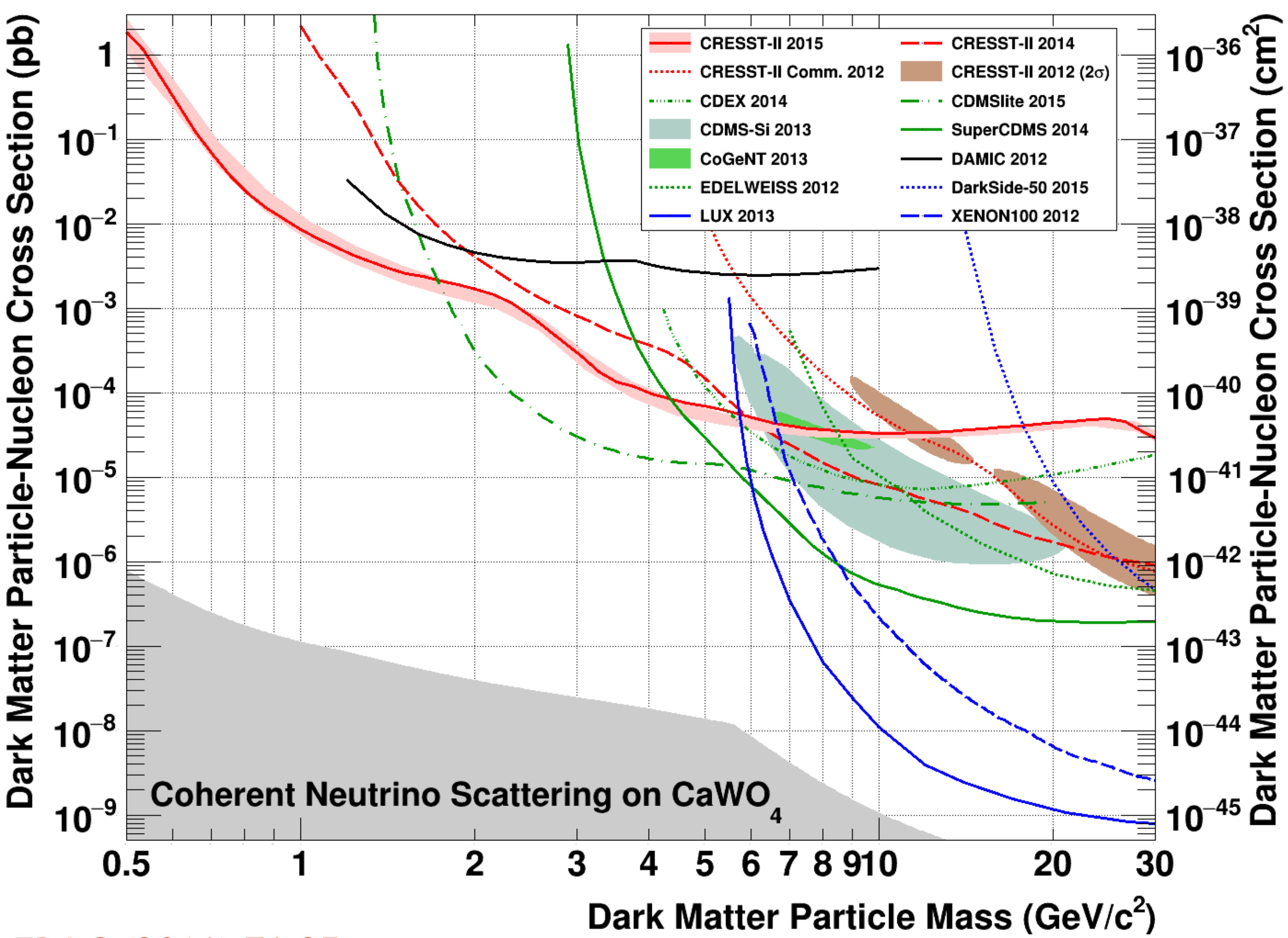
CRESST-II results - 2015

Crystal: Lise (mass ~300 g)

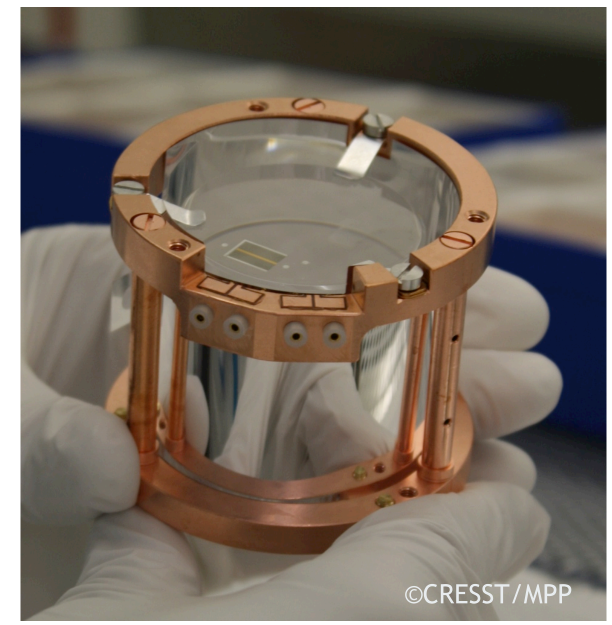
Exposure: 52 kg day

Background level ≈ 8.5 counts/(keV kg day)

Threshold: 307eV



EPJ C (2016) 76:25



Until 2017 world-leading below 1.7GeV/c²

Opened up sub-GeV/c² regime

Hunting light dark matter requires low threshold and low background!

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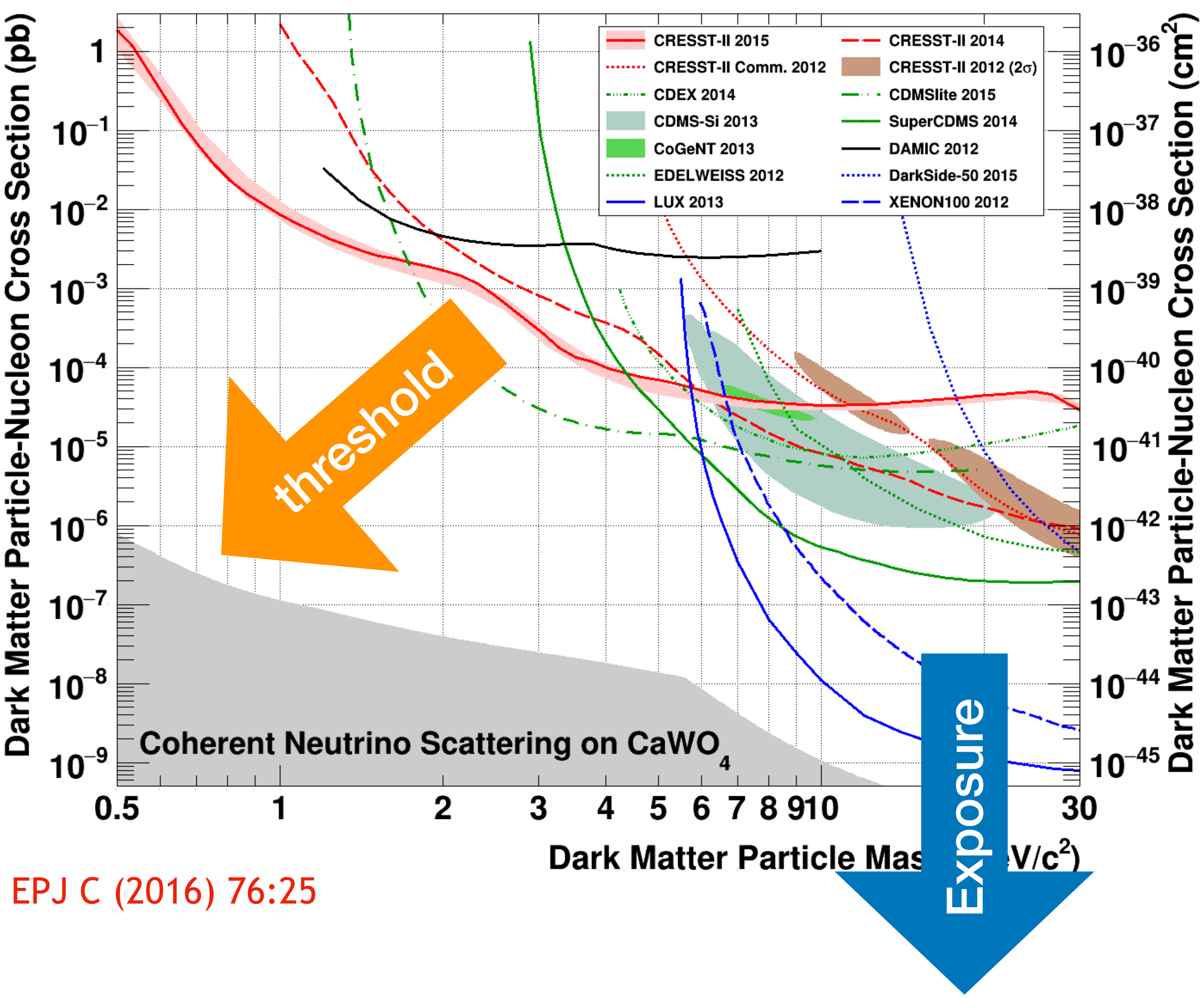

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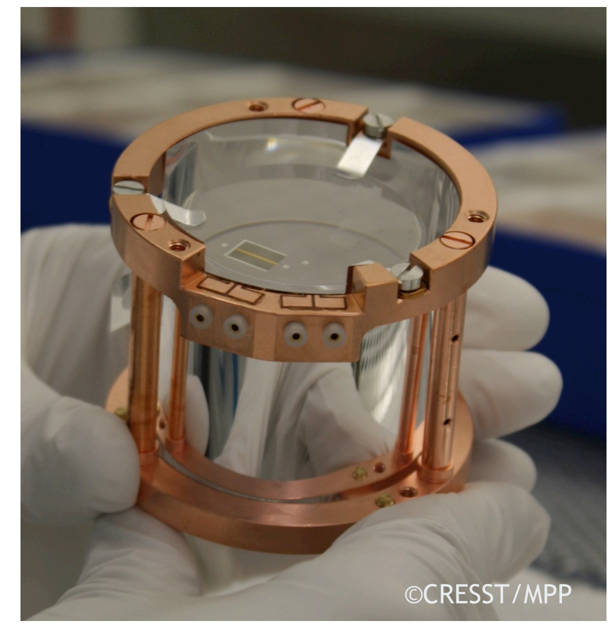

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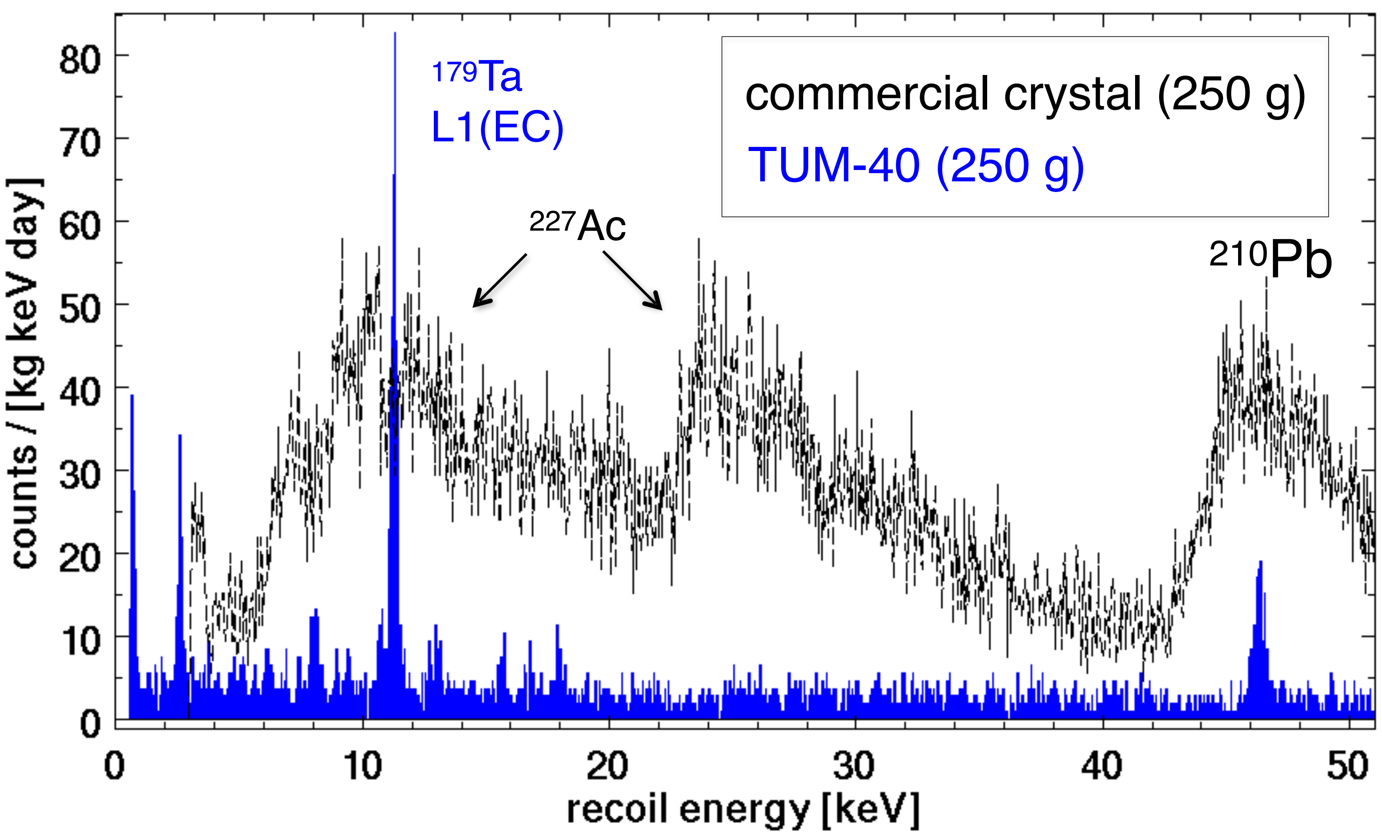
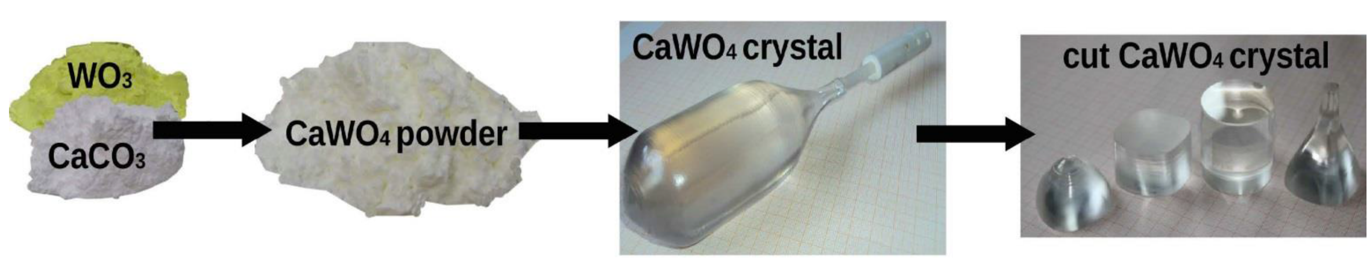
CaWO$_4$ crystals at TUM



- CRESST Crystal grown in the facility at Technische Universität München (TUM)
- Average rate achieved: ~3.5 counts /[kg keV day]
- Gamma-lines from cosmogenic activation
- All gamma lines agree within < 5eV with tabulated values

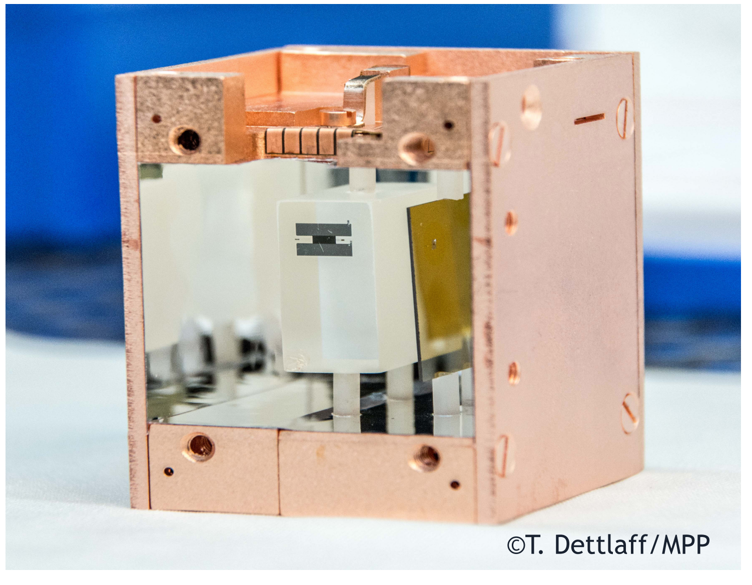


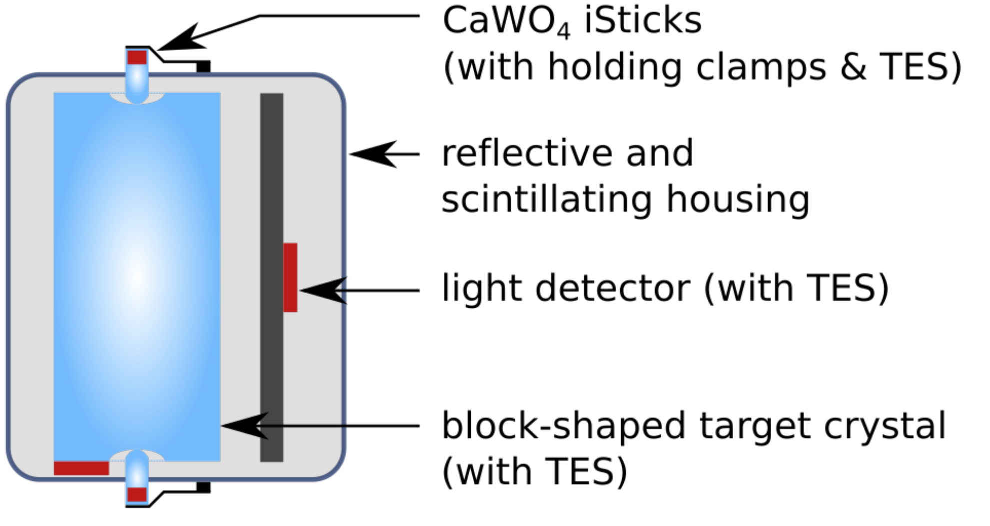
- Contamination reduction program
  - Raw materials selection
  - Re-crystallisation
  - Chemical purification of raw materials

Towards low thresholds

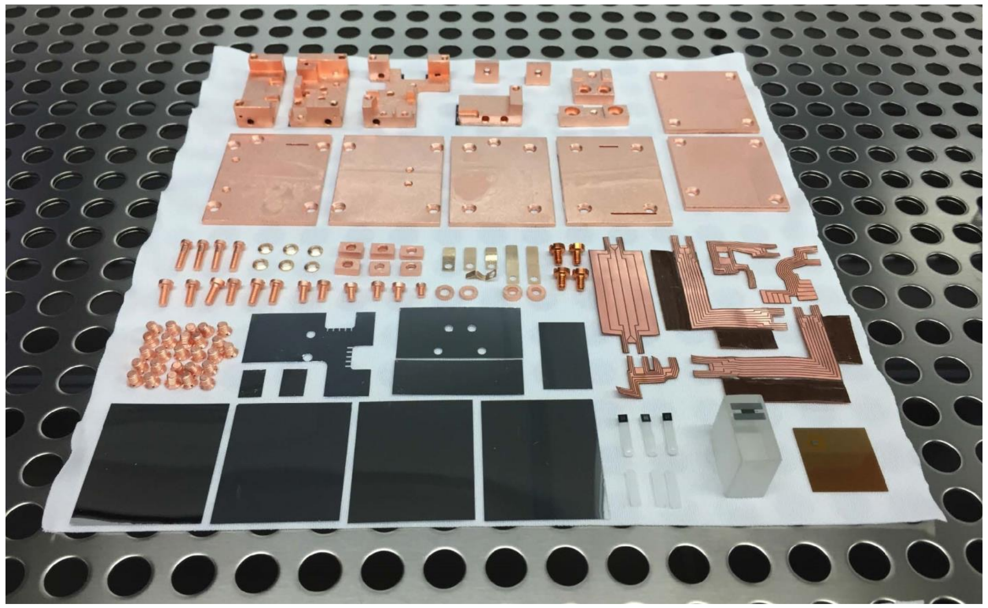
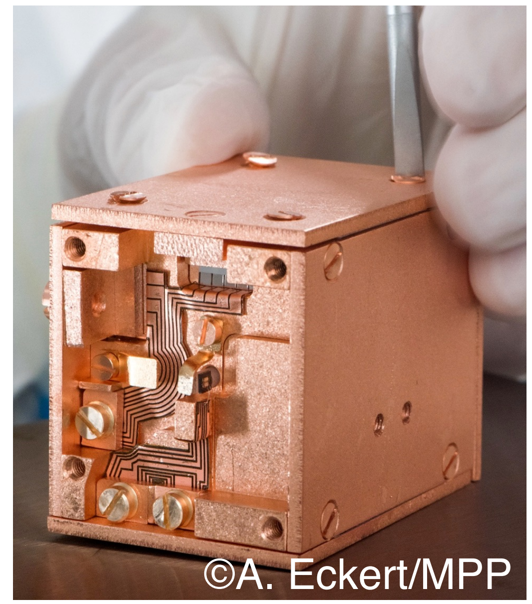
- Detector layout optimized for low-mass dark matter: reduction of crystal dimension (from 300g to 24g)
- Cuboid fully scintillating housing
- Instrumented holders

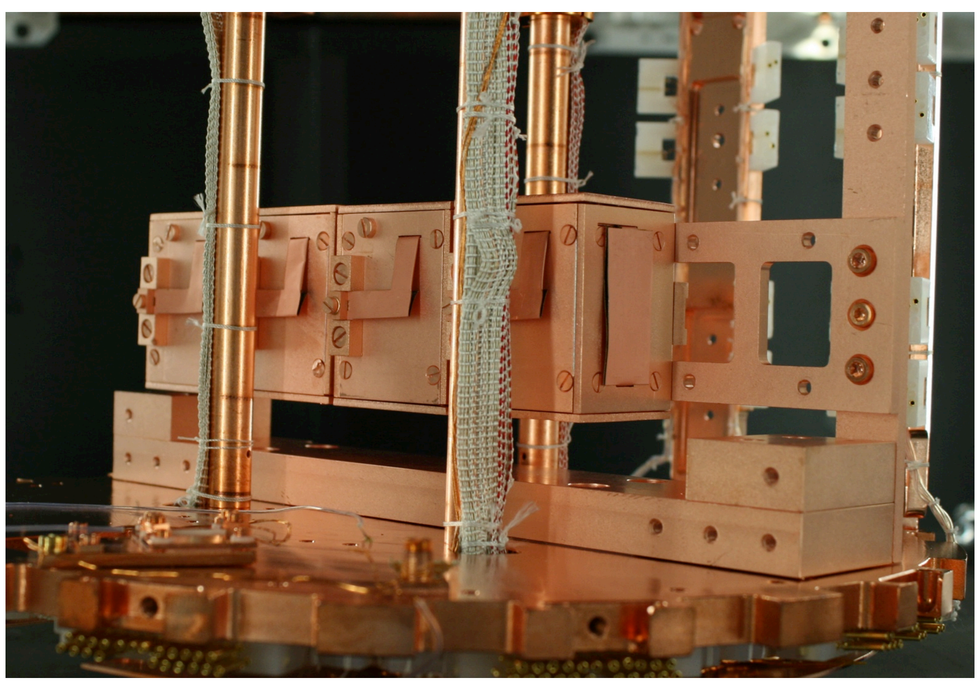
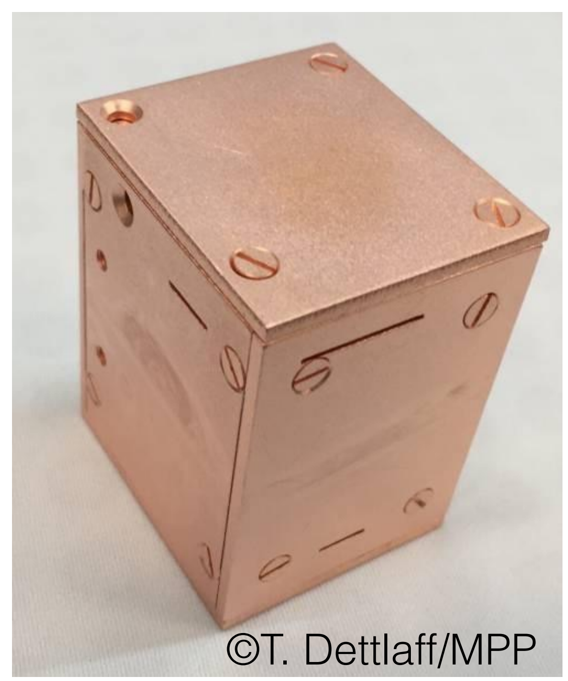
Threshold design goal: 100 eV threshold





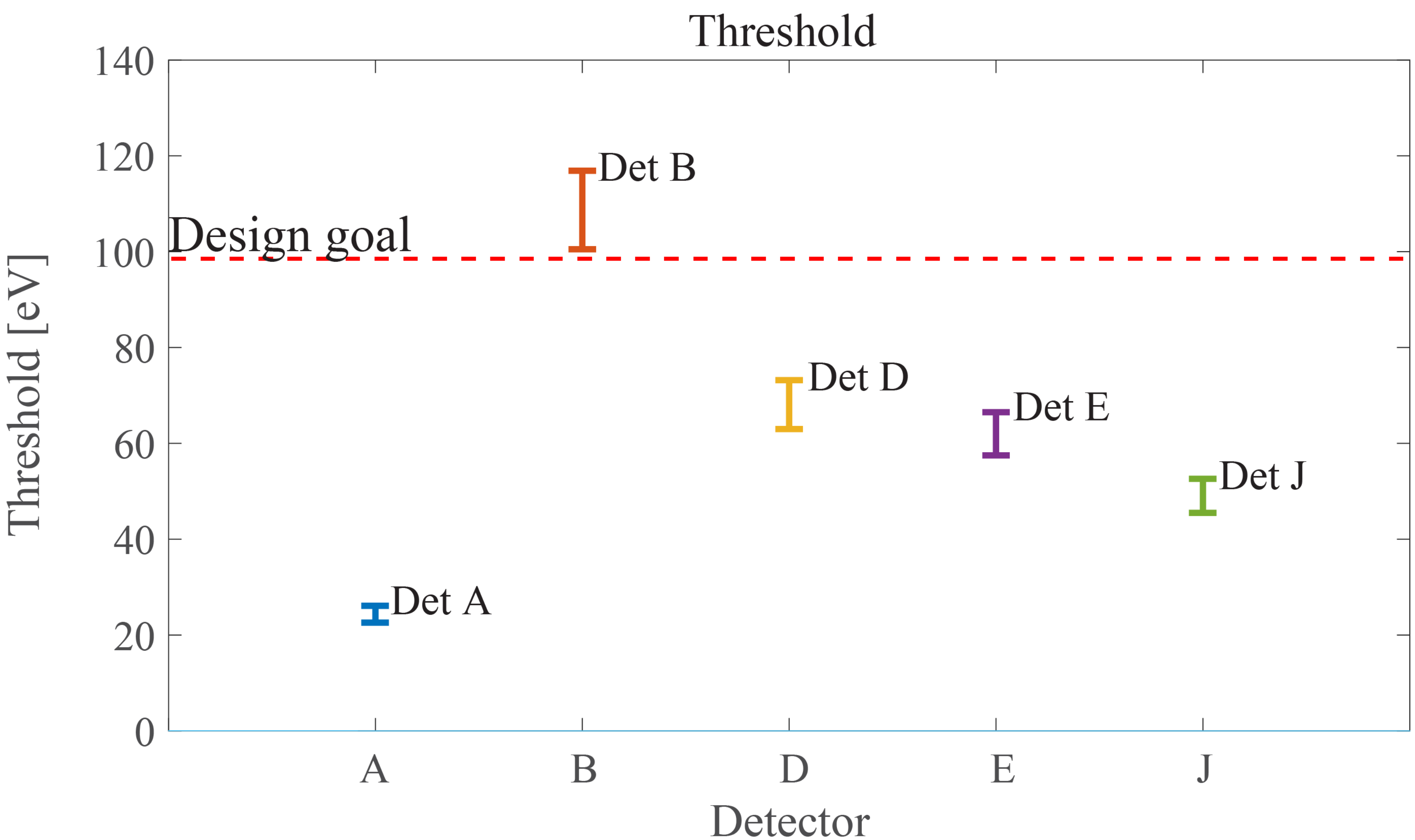
CRESST-III detectors

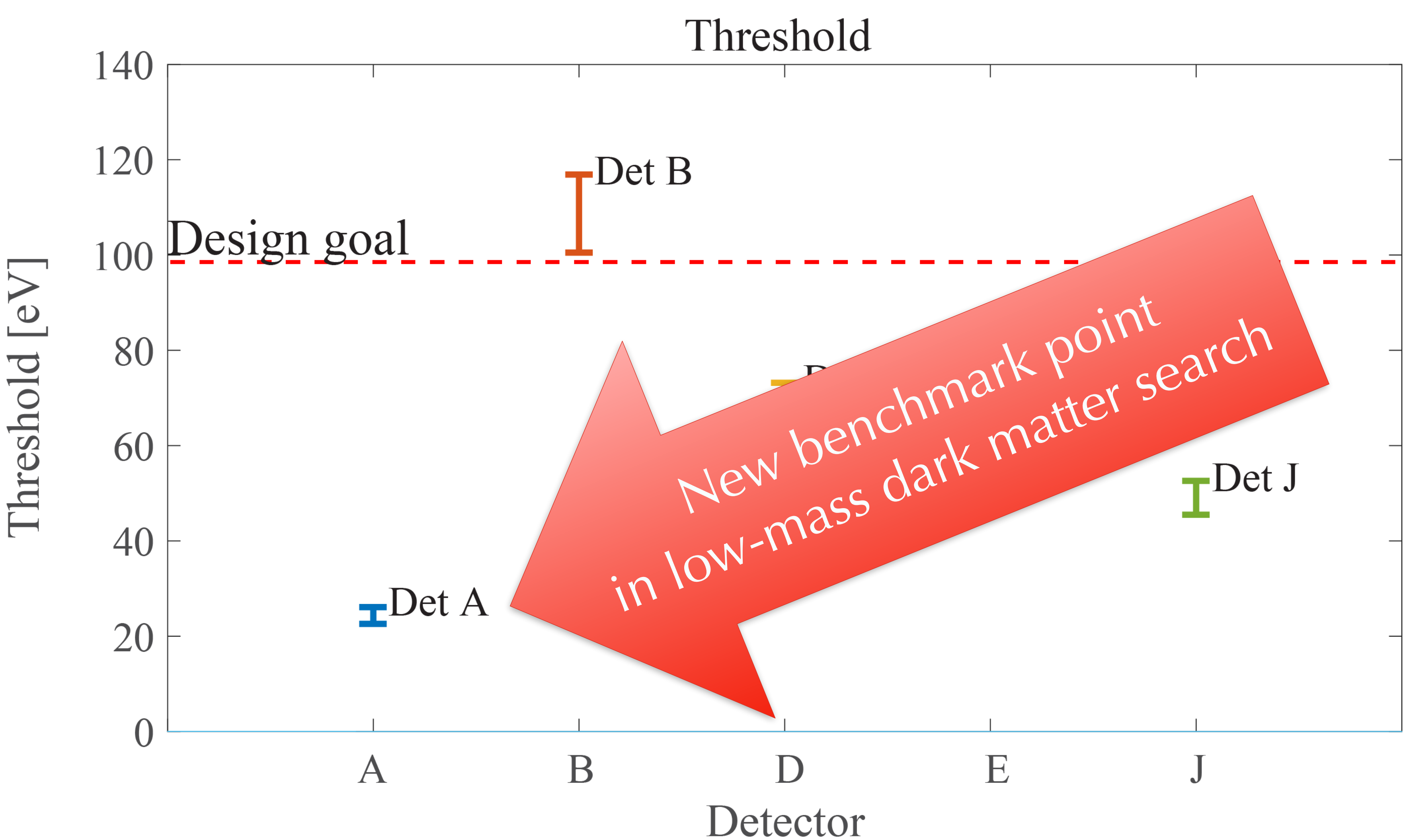
10 detectors operating in Gran Sasso from July 2016 to February 2018

Optimum thresholds



5 detectors reach/exceed the CRESST-III design goal

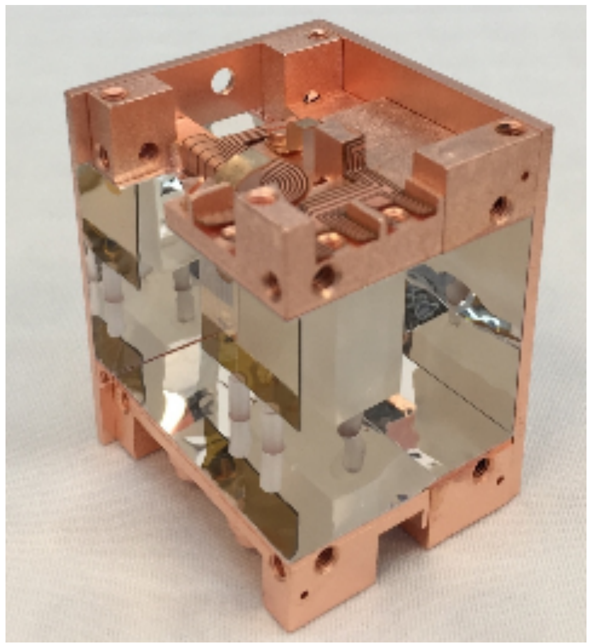
Optimum thresholds



5 detectors reach/ exceed the CRESST-III design goal

NEW FRONTIER IN DIRECT DM DETECTION

Detector A



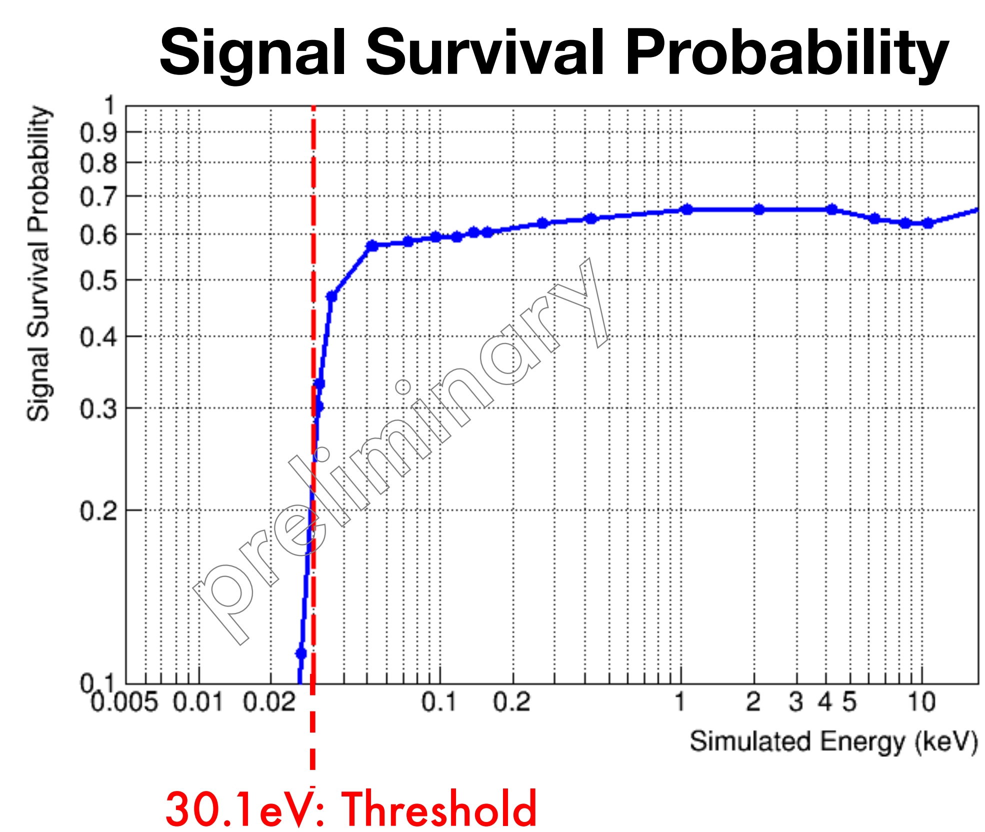
Data taking period: 10/2016 – 01/2018

Target crystal mass: 23.6 g

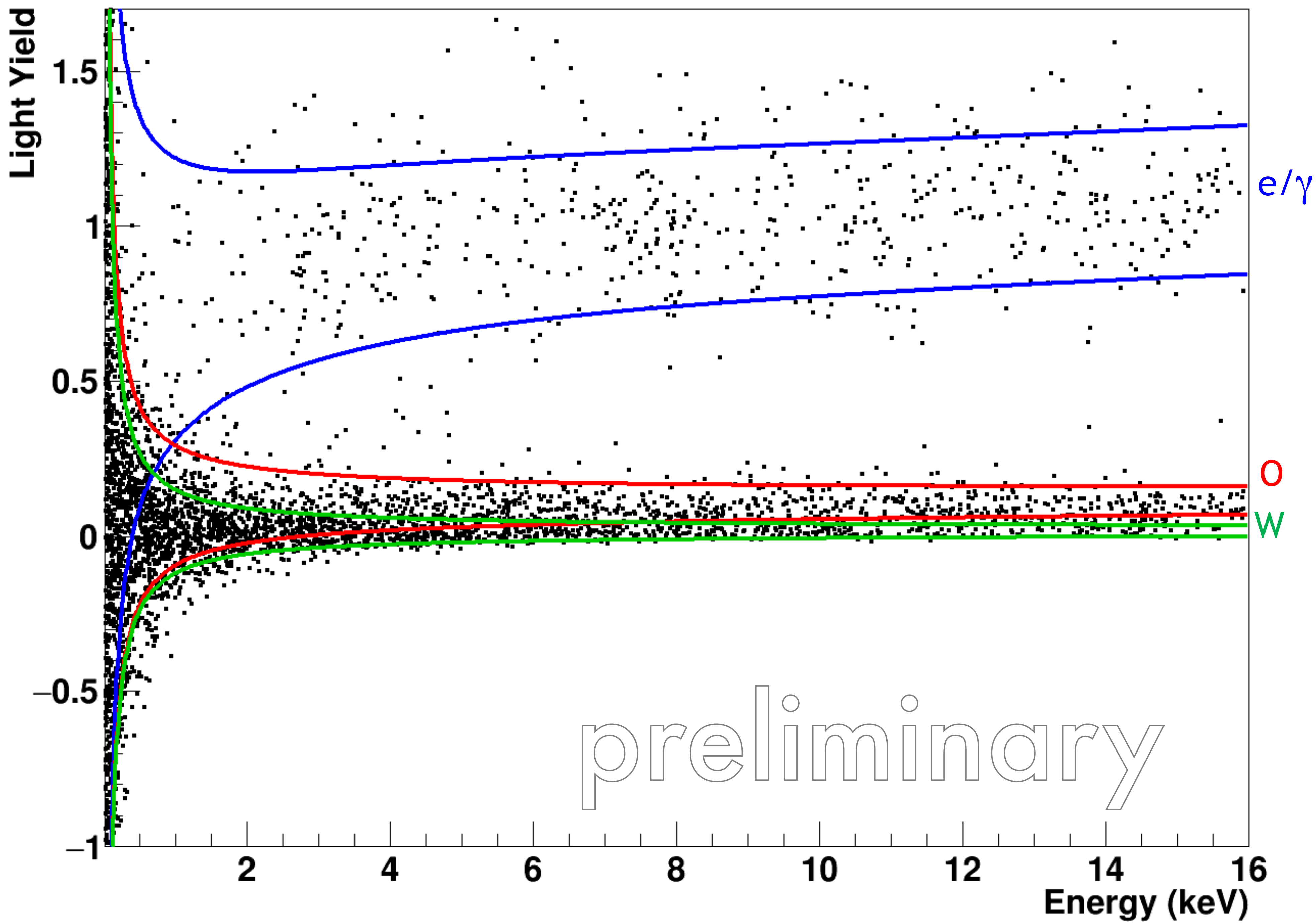
Gross exposure (before cuts): 5.7 kg days

Energy threshold: 30.1 eV

- Analysis chain includes selections on:
  - *Rate*: to select stable noise conditions
  - *Stability*: to select detector(s) in operating point
  - *Data quality*: Non-standard pulse shapes are discarded
  - *Coincidences*: rejected events in coincidence with iSticks, with other detectors and with muon veto

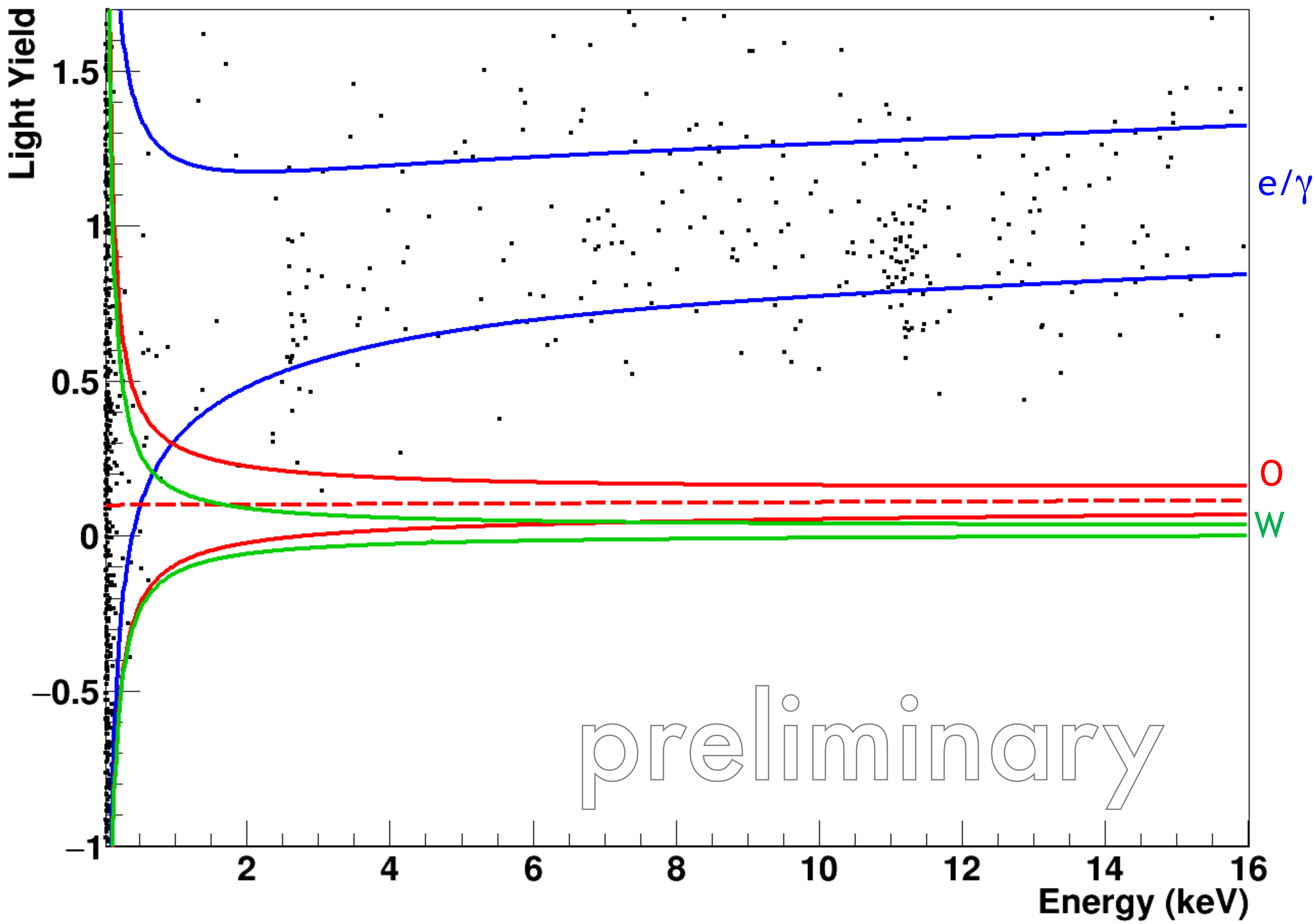


Neutron calibration data

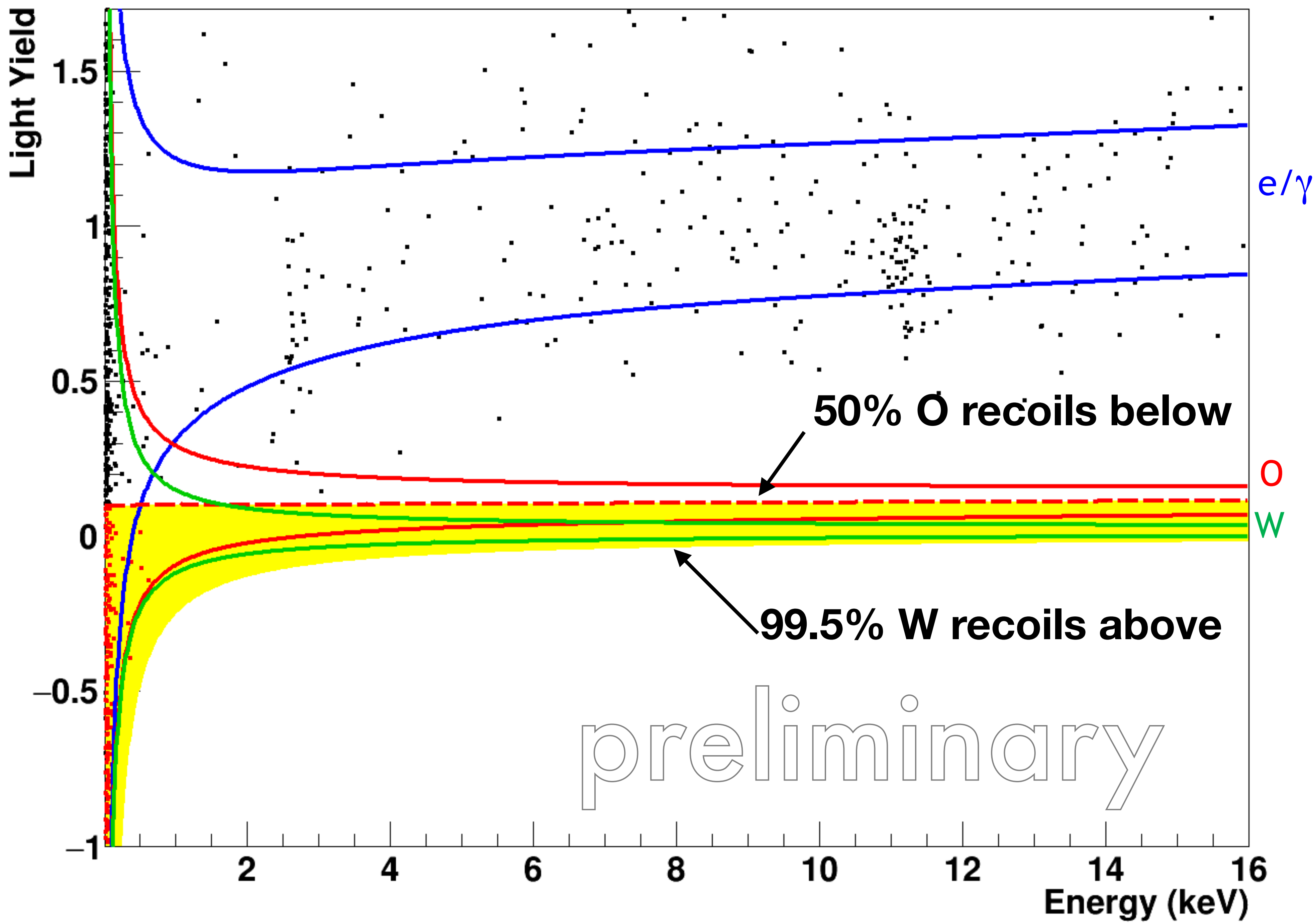


Quenching factors measured with neutron beam
Unbinned maximum likelihood fit

Dark matter data

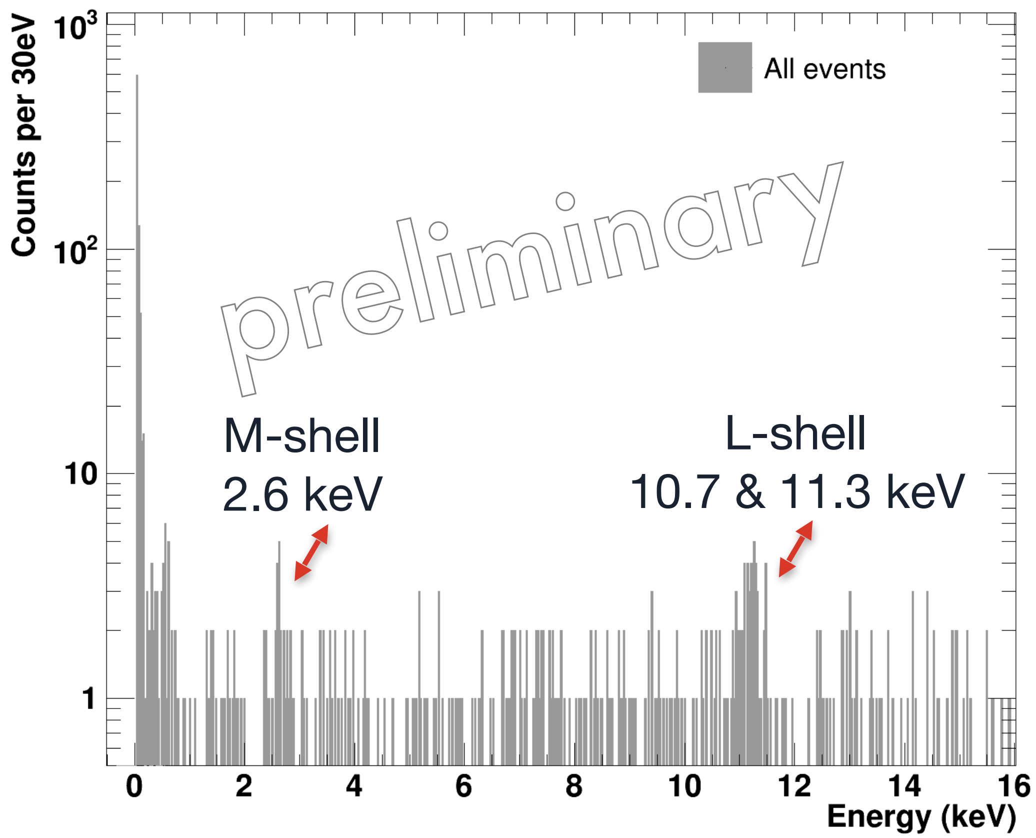


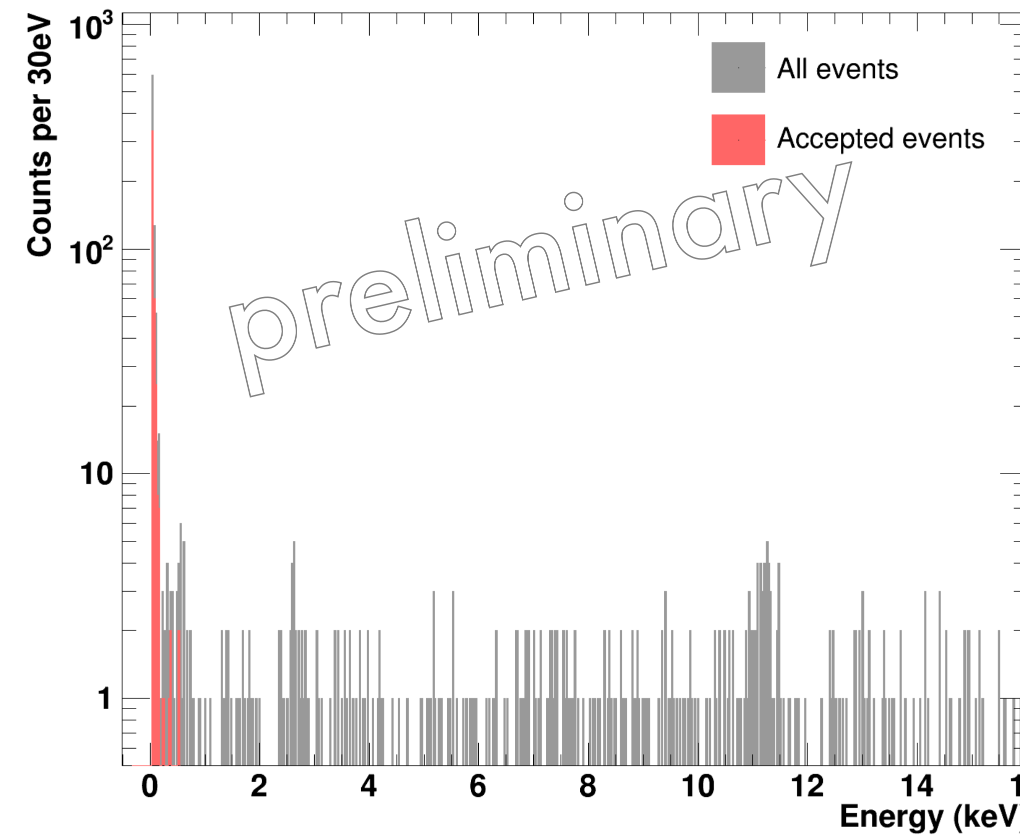
Dark matter acceptance region



Acceptance region defined before unblinding

Energy spectra





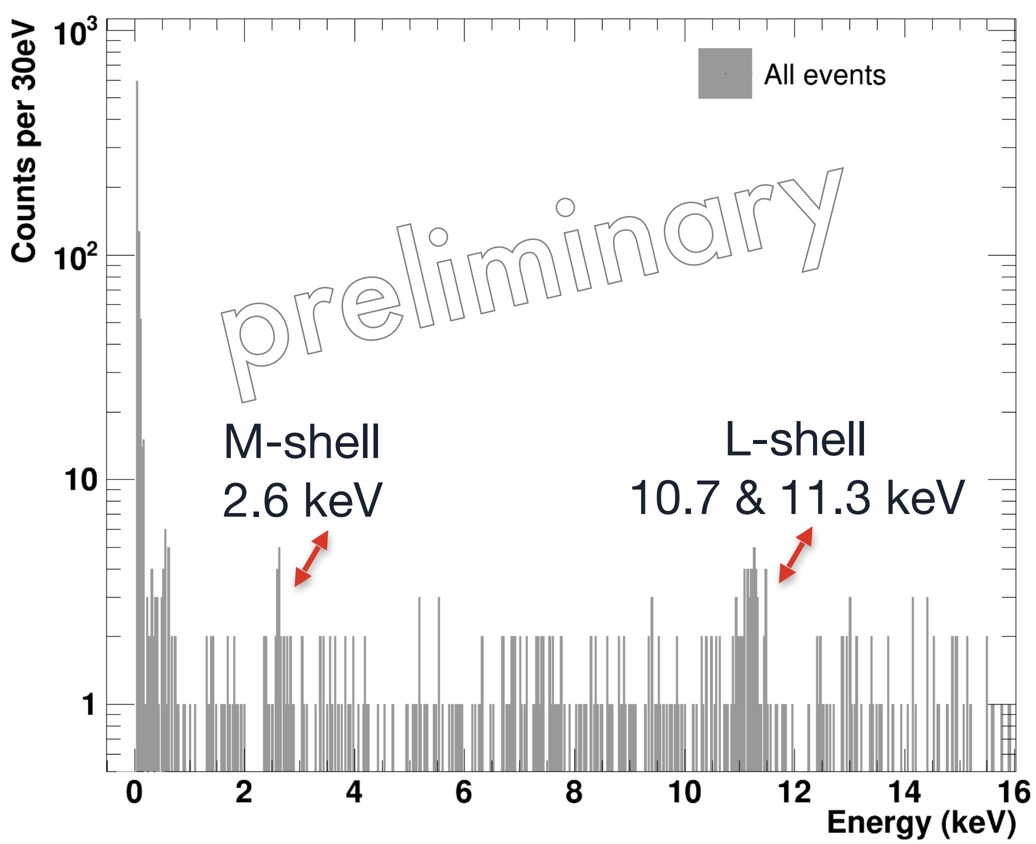
Cosmogenic activation

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

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

- 445 events in the acceptance region

Energy spectra



Cosmogenic activation

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

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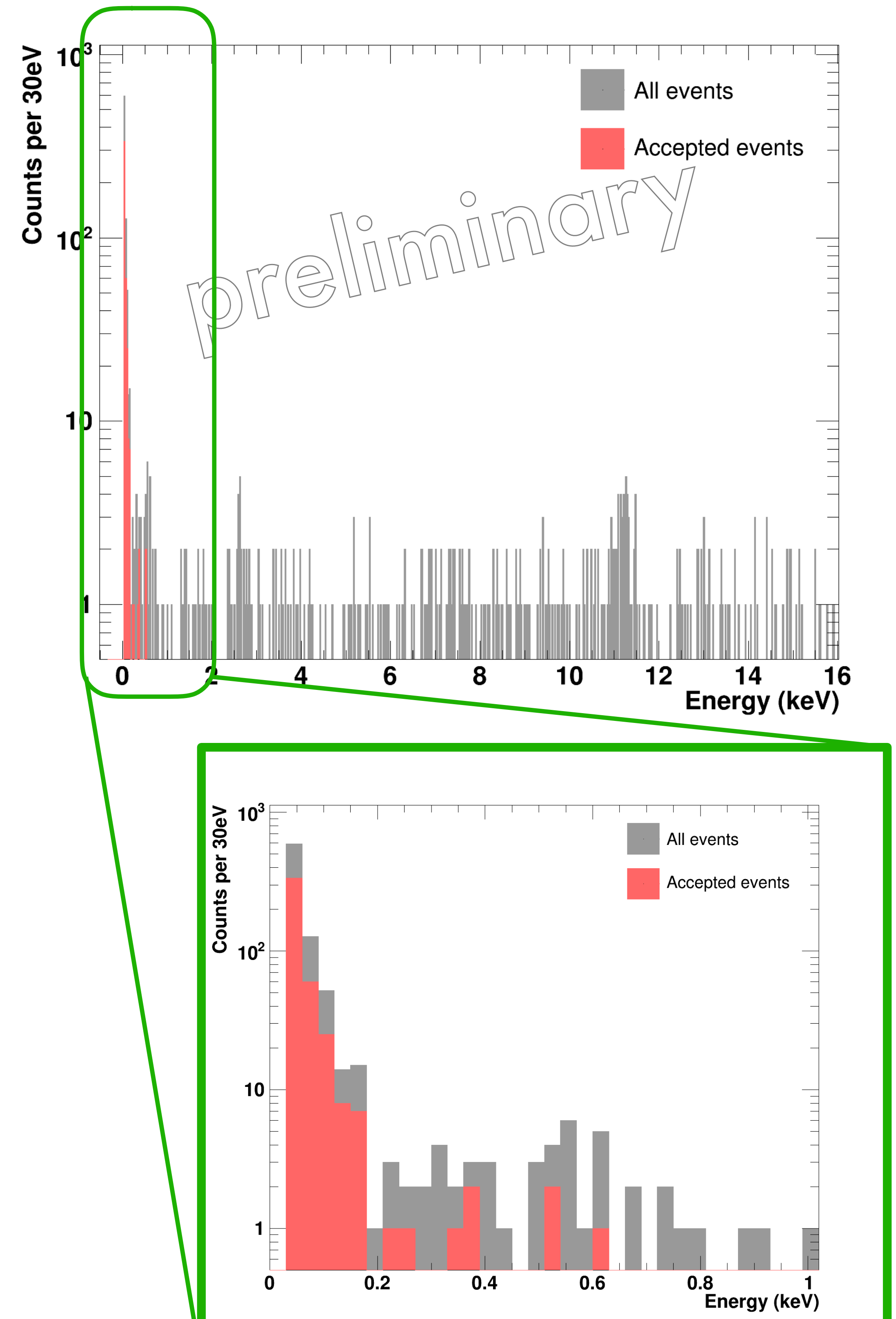
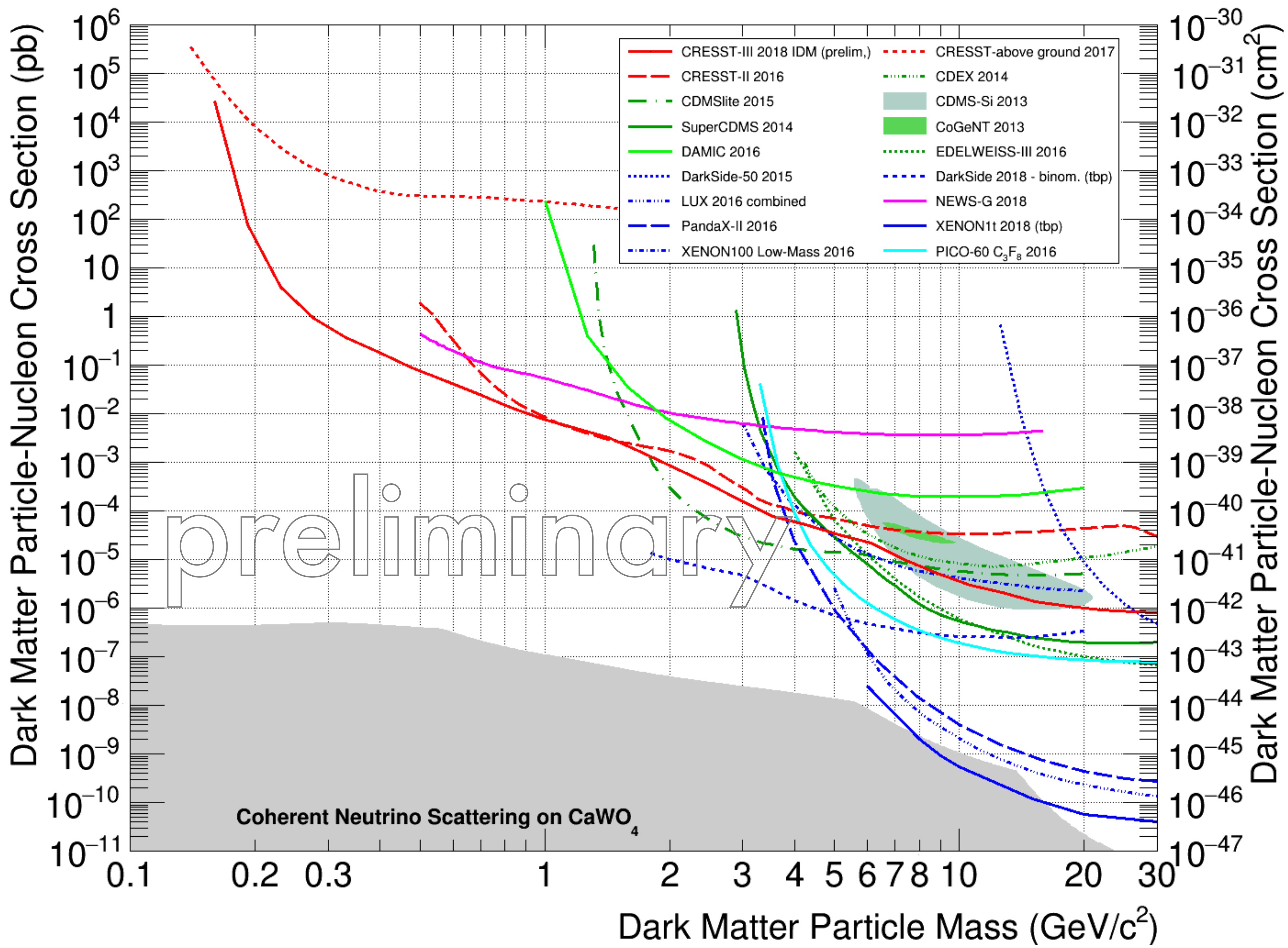
- 445 events in the acceptance region
- Unexpected rise of event rate <200 eV



Result

1D Yellin optimum interval method to compute the exclusion limit:

Energy spectrum of accepted events
+
Expected DM energy spectrum



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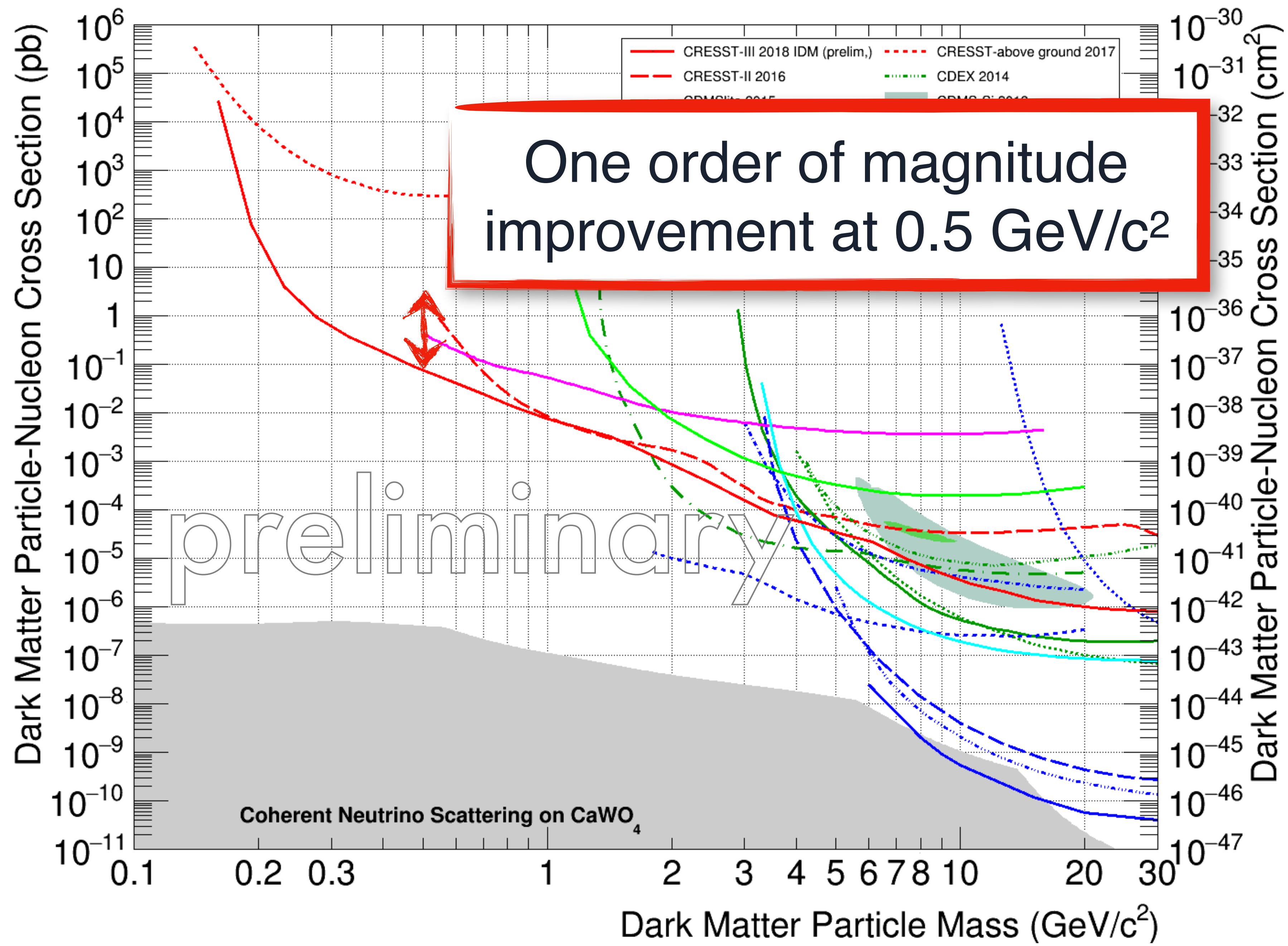


One order of magnitude improvement at 0.5 GeV/c²

World leading limit at low-mass <1.7 GeV/c²

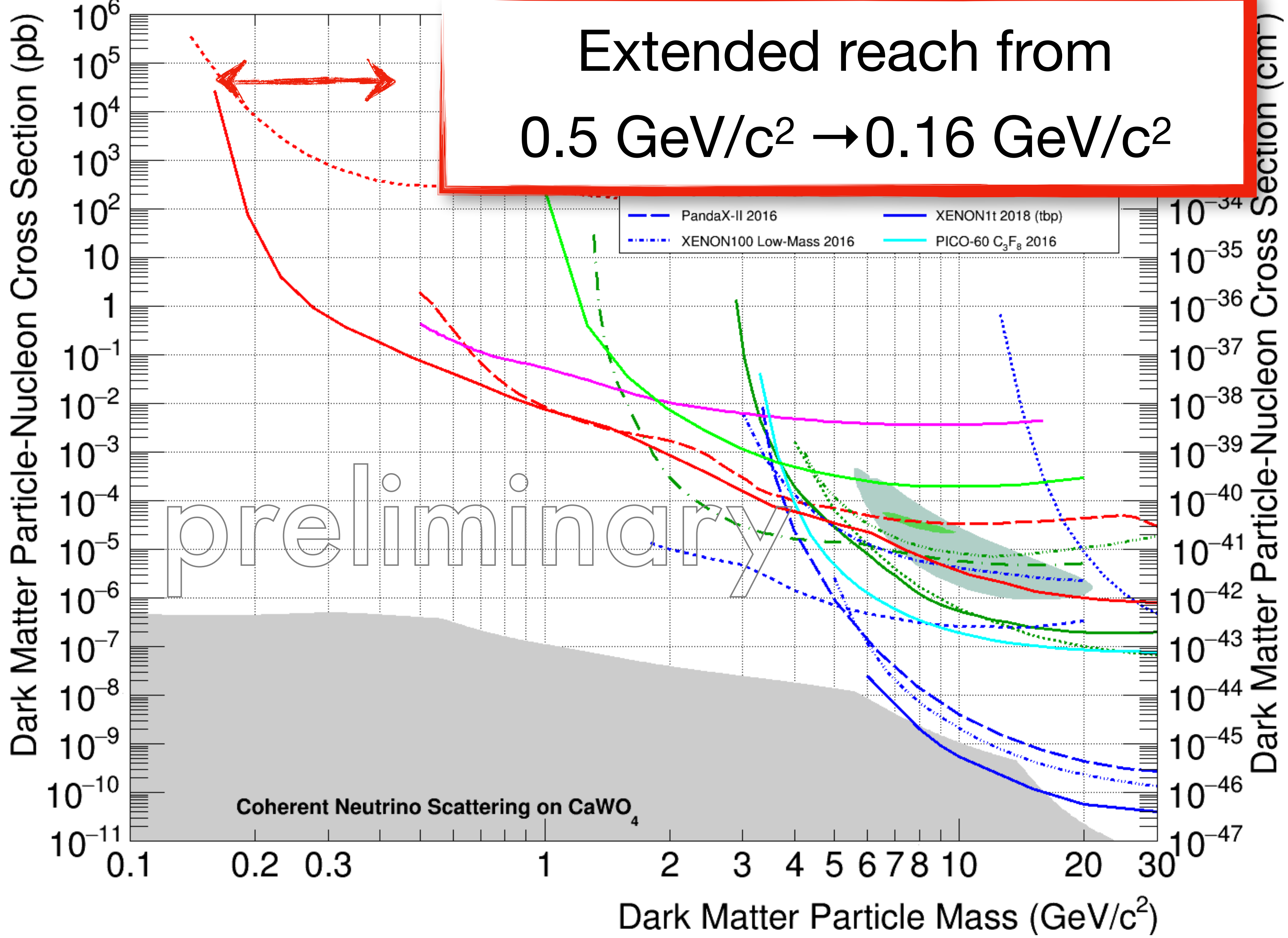
↳ Background limited

Result

Extended reach from
0.5 GeV/c² →0.16 GeV/c²

1D Yellin optimum interval method to compute the exclusion limit:

Energy spectrum of accepted events
+
Expected DM energy spectrum

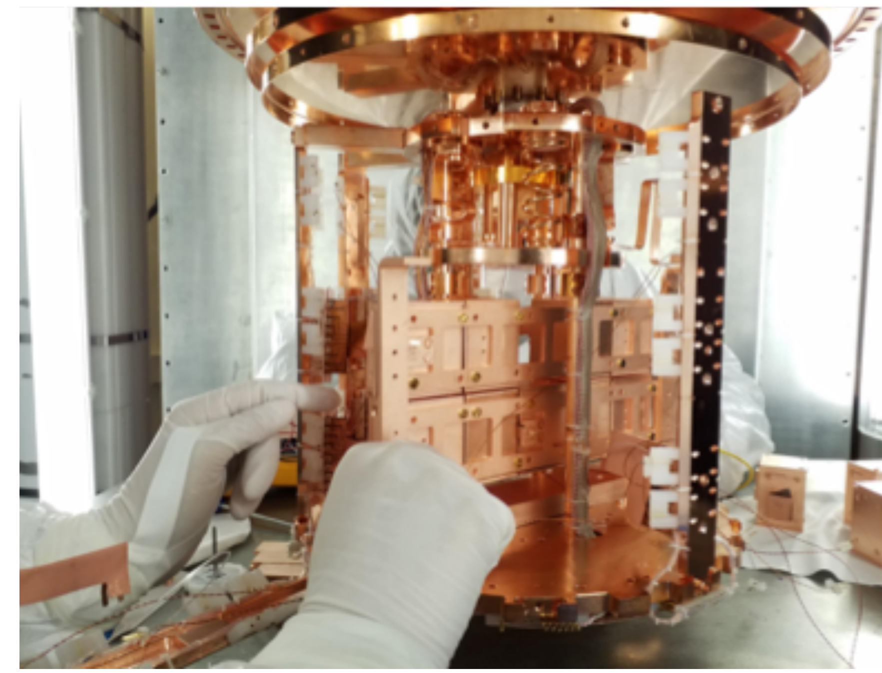


Lowest limit
>0.16 GeV/c²

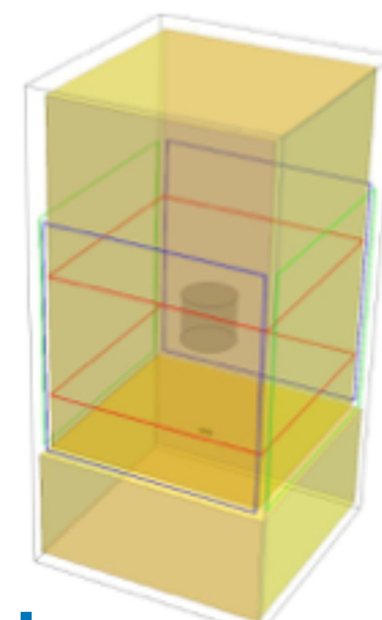
↳ Performance "limited"

Second CRESST-III run

- Upgraded detector modules with dedicated hardware changes to understand source of excess events (different crystal absorbers, different detector holders)



- Implemented a new active magnetic field compensation with three air coils for x,y,z-axes



The run is going to start soon, new results to come!

Conclusions

- Cryogenic calorimeters represent a well established technology for the investigation of dark matter.
- **CRESST** has reached an unprecedented low nuclear recoil thresholds of 30eV, and is leading sensitivity over one order of magnitude in the region at 160MeV/c^2.
- Cryogenic calorimeters are complementary to noble liquids for the investigation of dark matter properties.
- New explorative run is ongoing to investigate the source of excess events.

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New challenges,
new potentials,
new discoveries….