Status and Prospects for the CRESST Experiment

Lucia Canonica
Max-Planck-Institut für Physik

MPP Project Review
Dec 16th, 2018

SFB 1258 Neutrinos Dark Matter Messengers

CRESST @ MPP

- **Staff:**
  - F. Petricca (PI)
  - D. Hauff
  - A. Bento (visiting)
- **PostDoc:**
  - L. Canonica
  - M. Mancuso
  - R. Strauss (up to 10.2018)
- **Ph.D student:**
  - A. Abdelhameed
  - P. Bauer
  - E. Bertoldo
  - N. Ferreiro*
  - J. Rothe
  - M. Wüstrich*

*thesis completed in 2018

The CRESST Collaboration

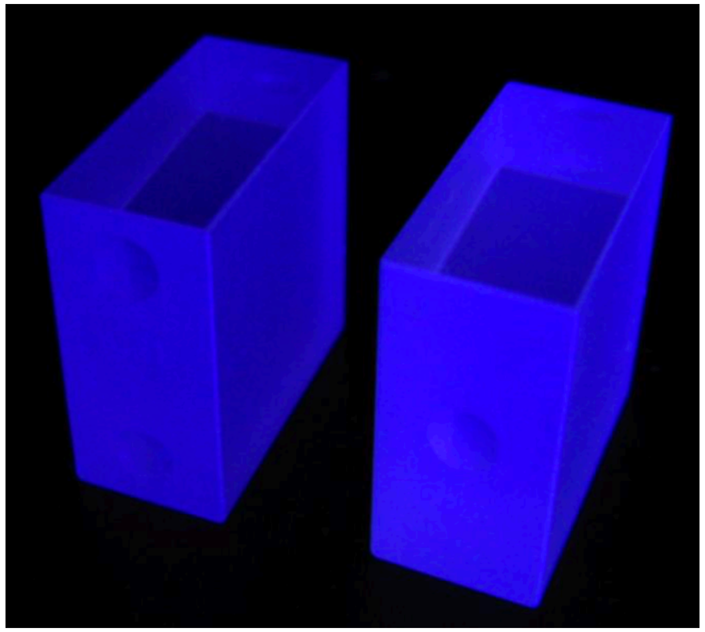
~45 Collaborators:

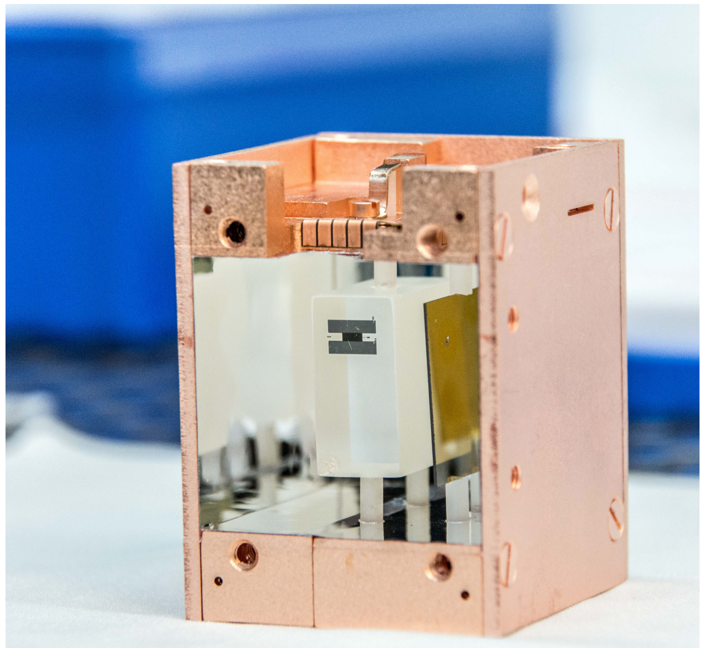
- 14 MPP, DE
- 10 TUM, DE
- 4 Tubingen, DE
- 8 HEPHY, AT
- 8 LNGS, IT
- 1 Oxford, UK

The CRESST experiment

Cryogenic Rare Event Search with Superconducting Thermometers

- Direct detection of Dark Matter particles via their scattering off target nuclei
  - Signal: low energy nuclear recoil
- Target: Scintillating $CaWO_4$ crystals
  - Composite detector CaWO4 + Light Detector
  - Efficient particle ID at low energy





Credit: MPP/T.Dettlaff

The CRESST experiment @ LNGS

Cryogenic Rare Event Search with Superconducting Thermometers

Laboratori Nazionali del Gran Sasso (Italy)

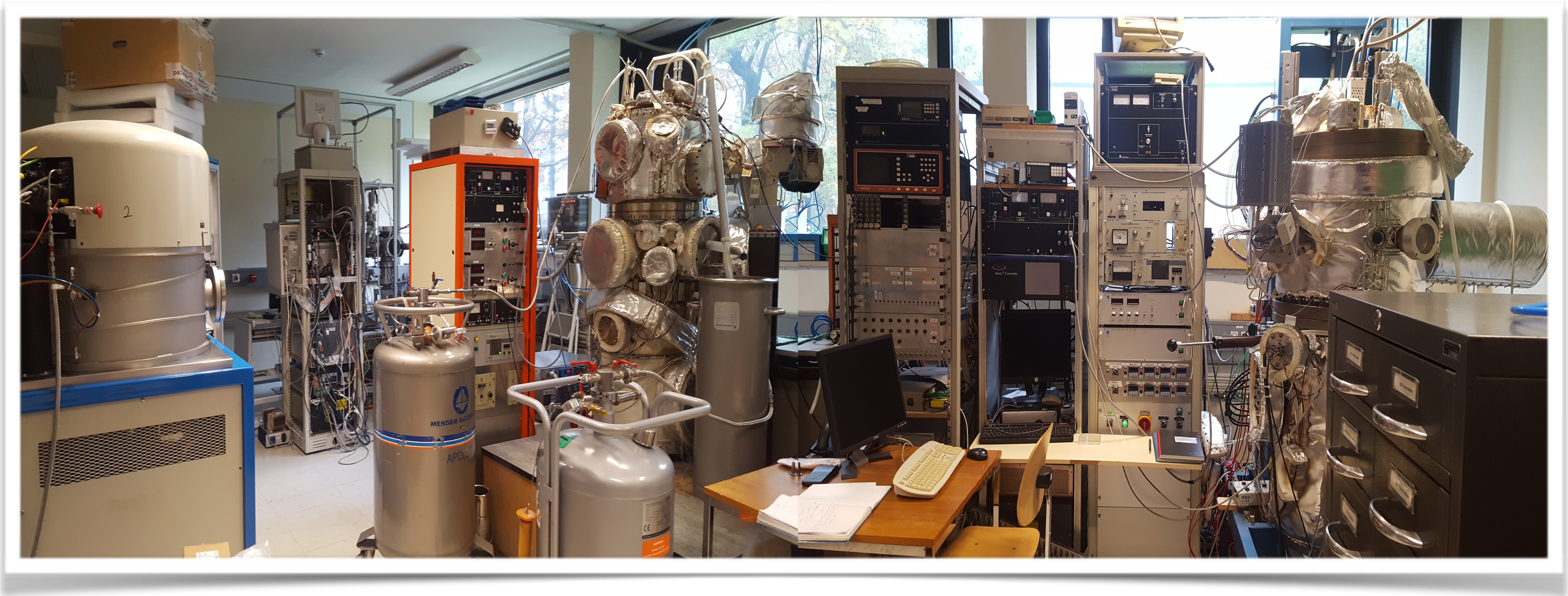
Experimental location:

Average depth ~ 3600 m w.e.

Muon flux ~ 2.6×10^{-8} μ/s/cm^2

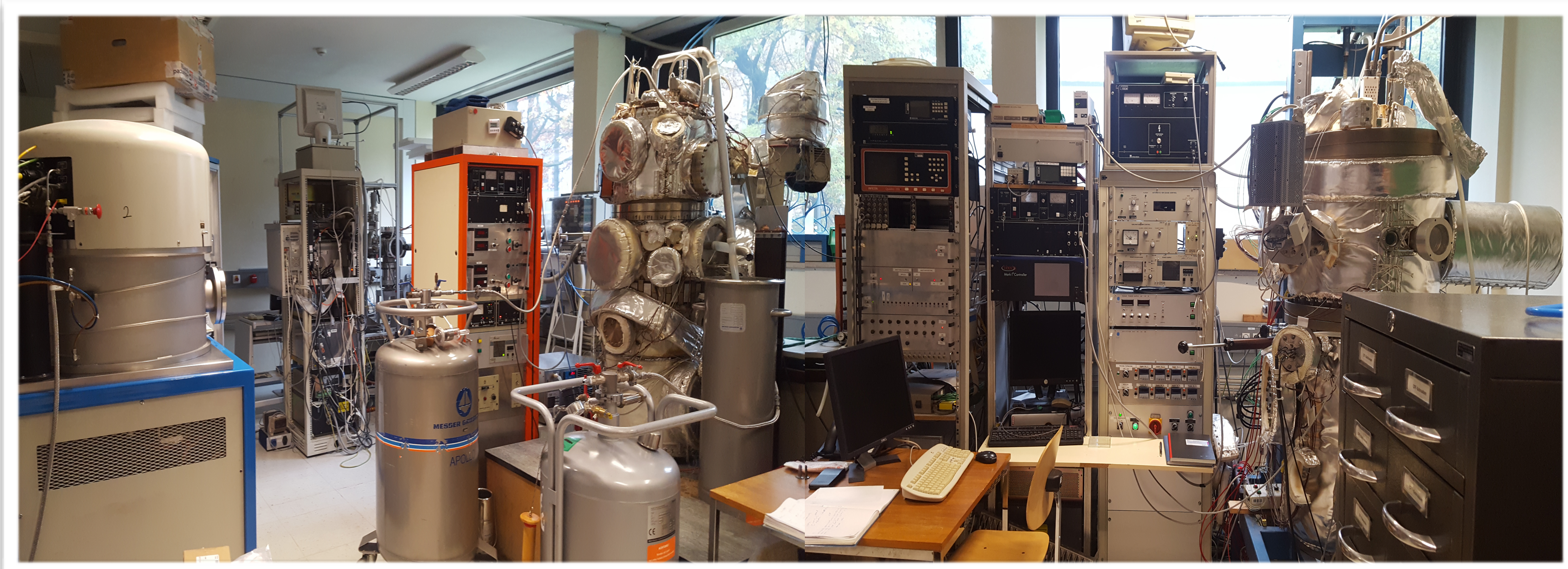
Neutrons (<10 MeV): $<10^{-6}$ n/s/cm^2

The CRESST experiment @ MPP



Sensor production

The CRESST experiment @ MPP



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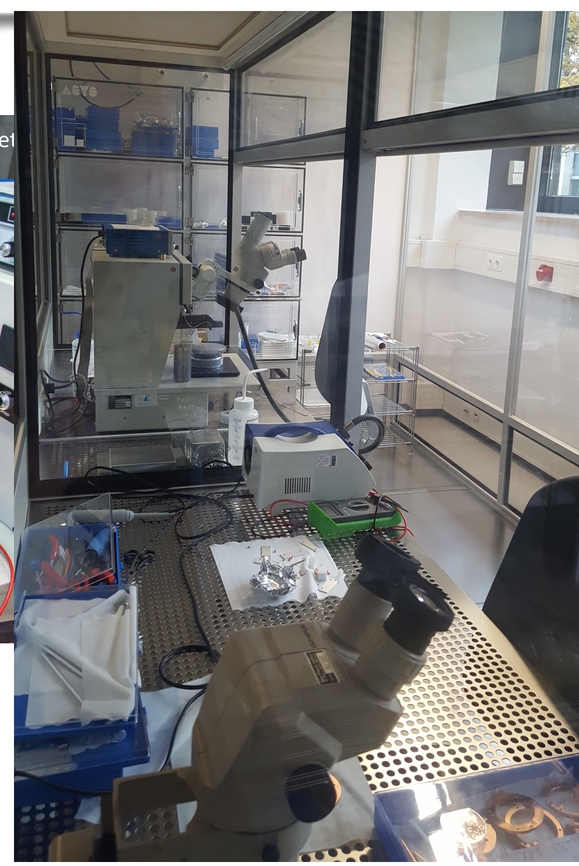
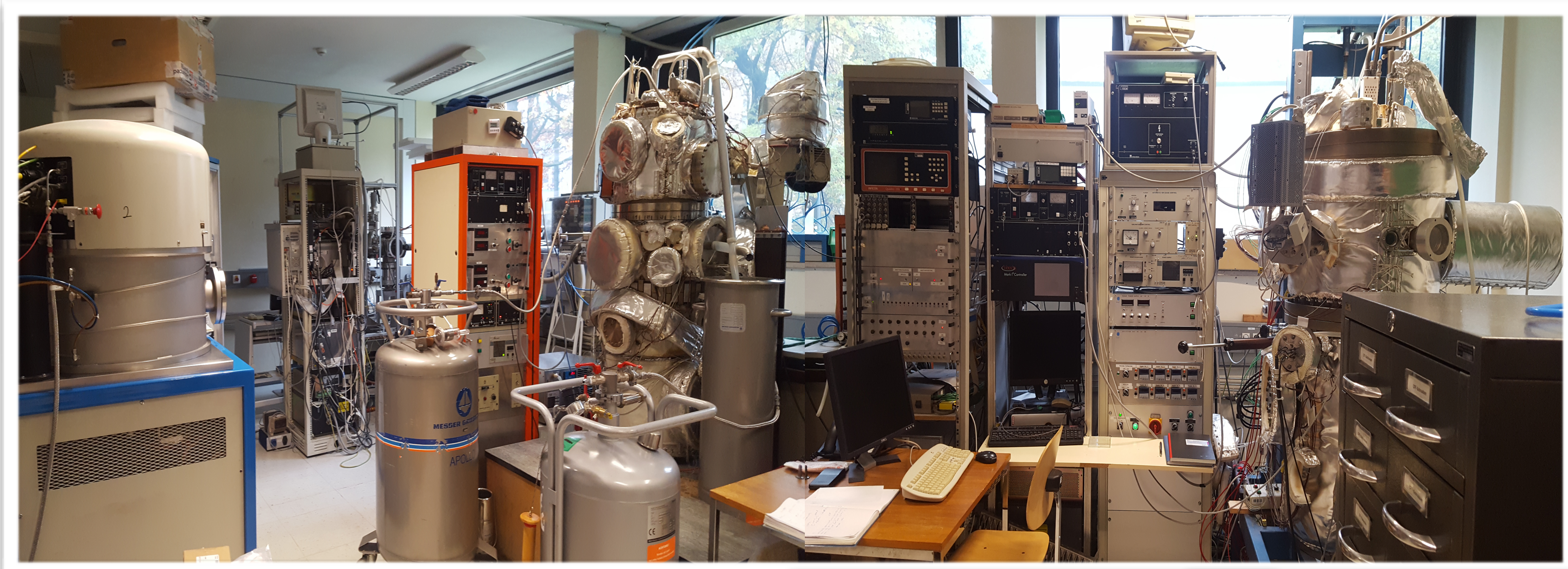


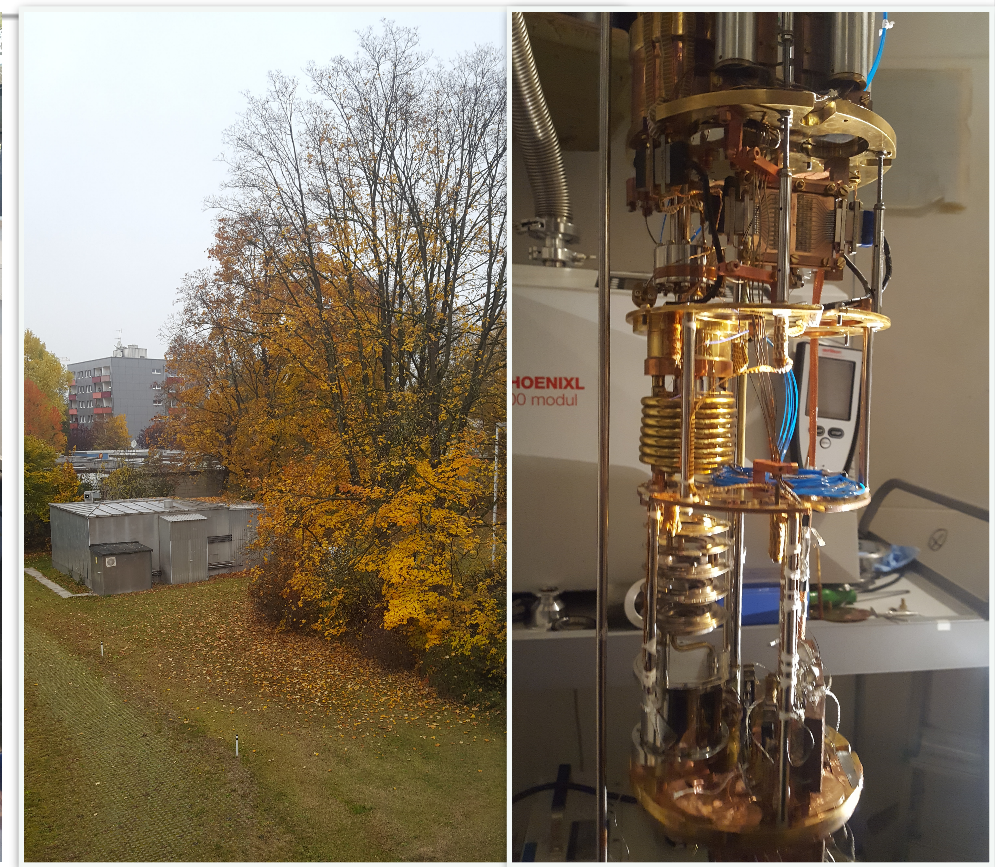
Detector assembly

The CRESST experiment @ MPP



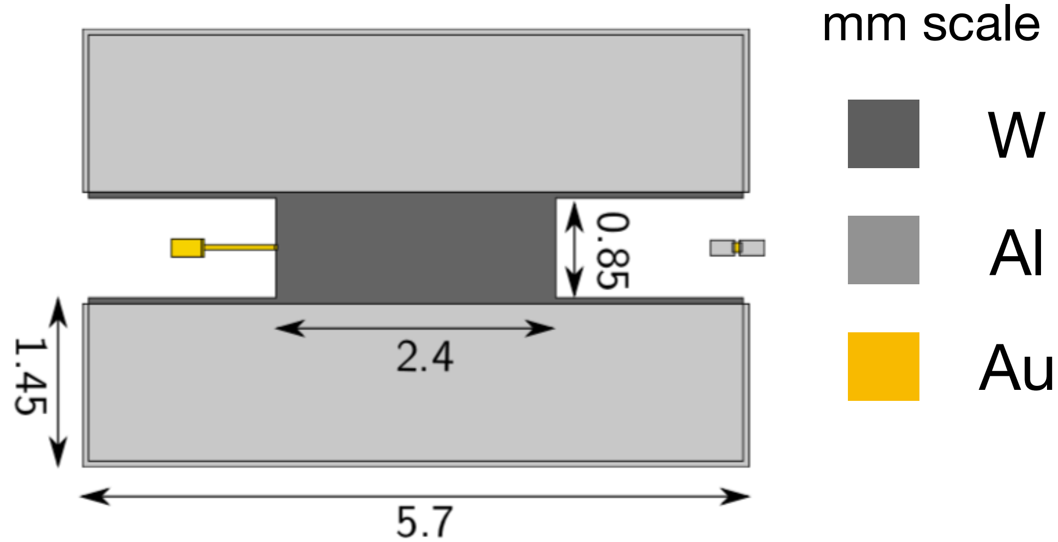
Sensor production

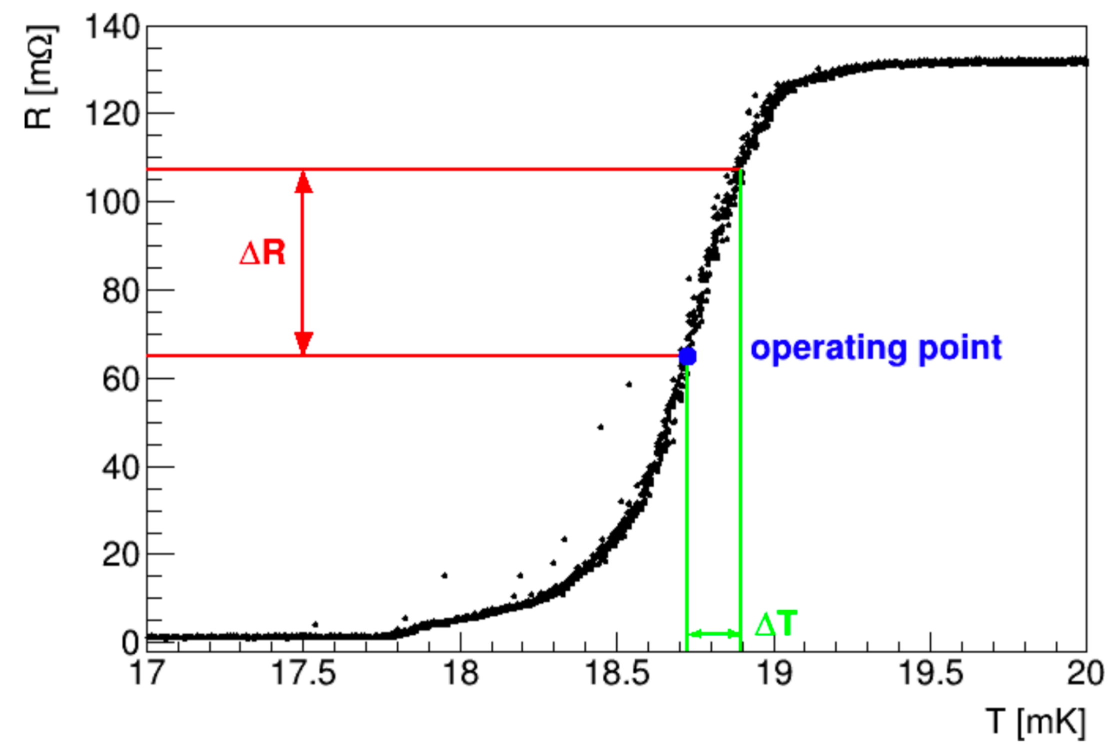
Detector assembly



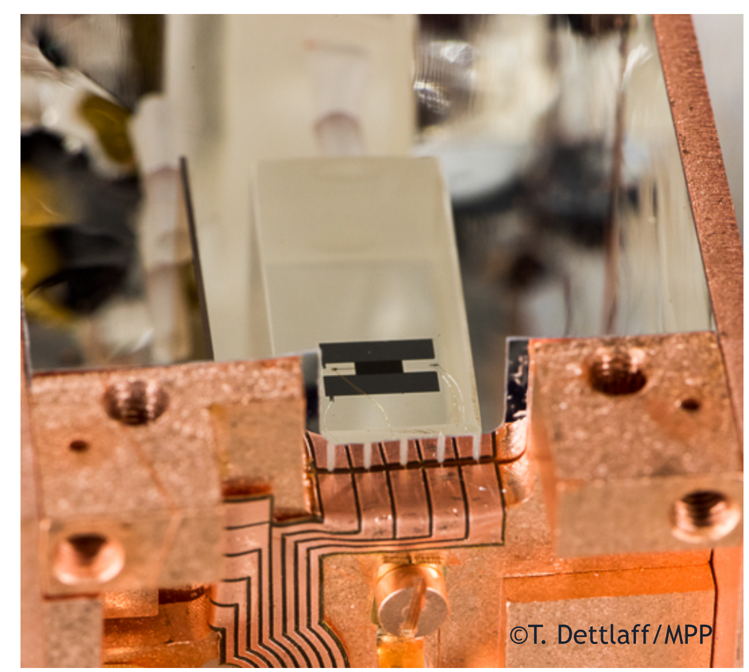
Detector Testing

Transition Edge Sensors



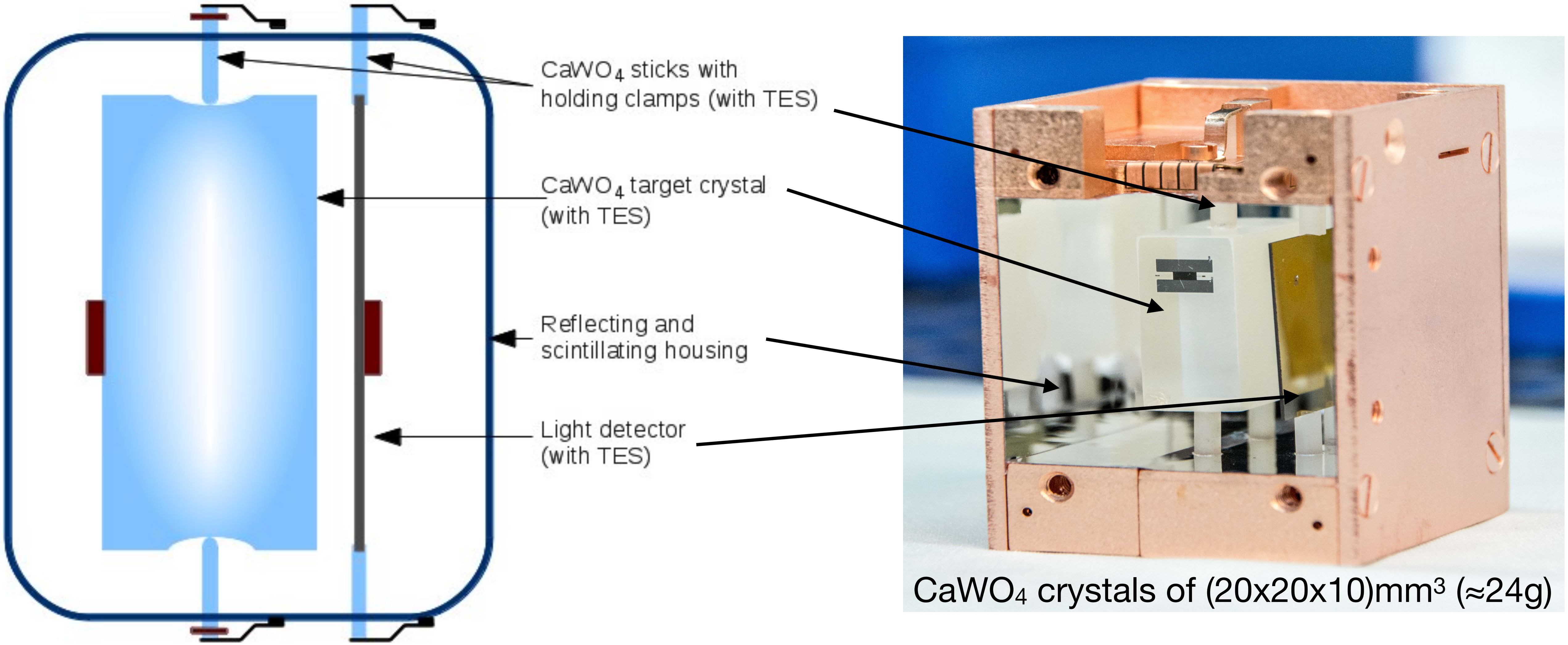


- Thin (200 nm) Tungsten film evaporated on the crystal.
- Transition temperature ~ [10 - 20] mK



- **Key technology for detecting very small recoiling energies.**
- **TES R&D and fabrication at MPP.**

CRESST III detector module

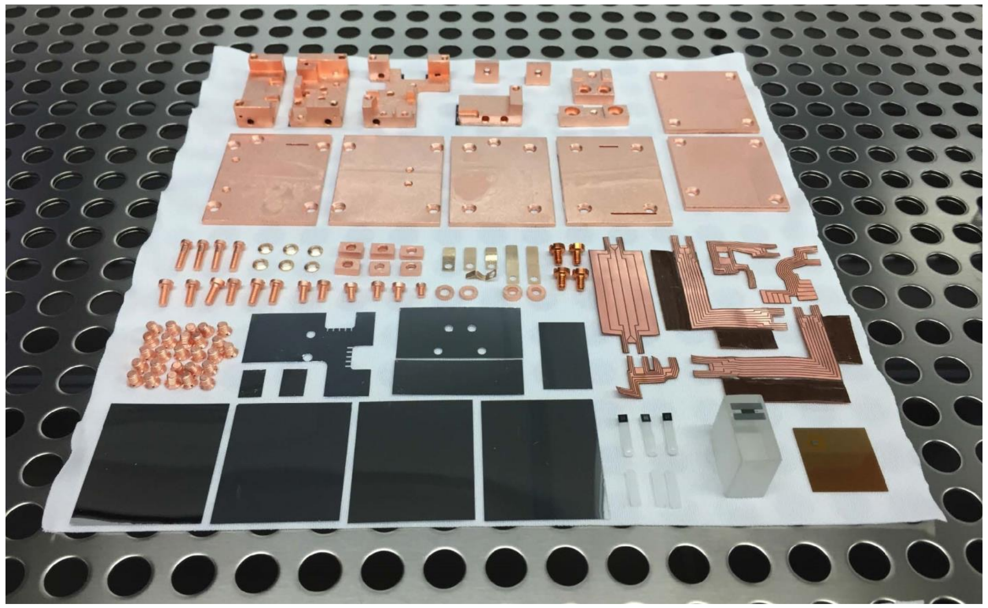


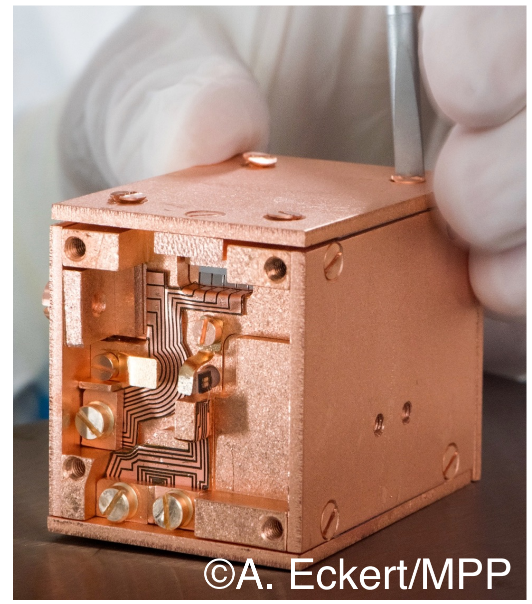
$CaWO_4$ crystals of $(20x20x10)mm^3$ (≈24g)

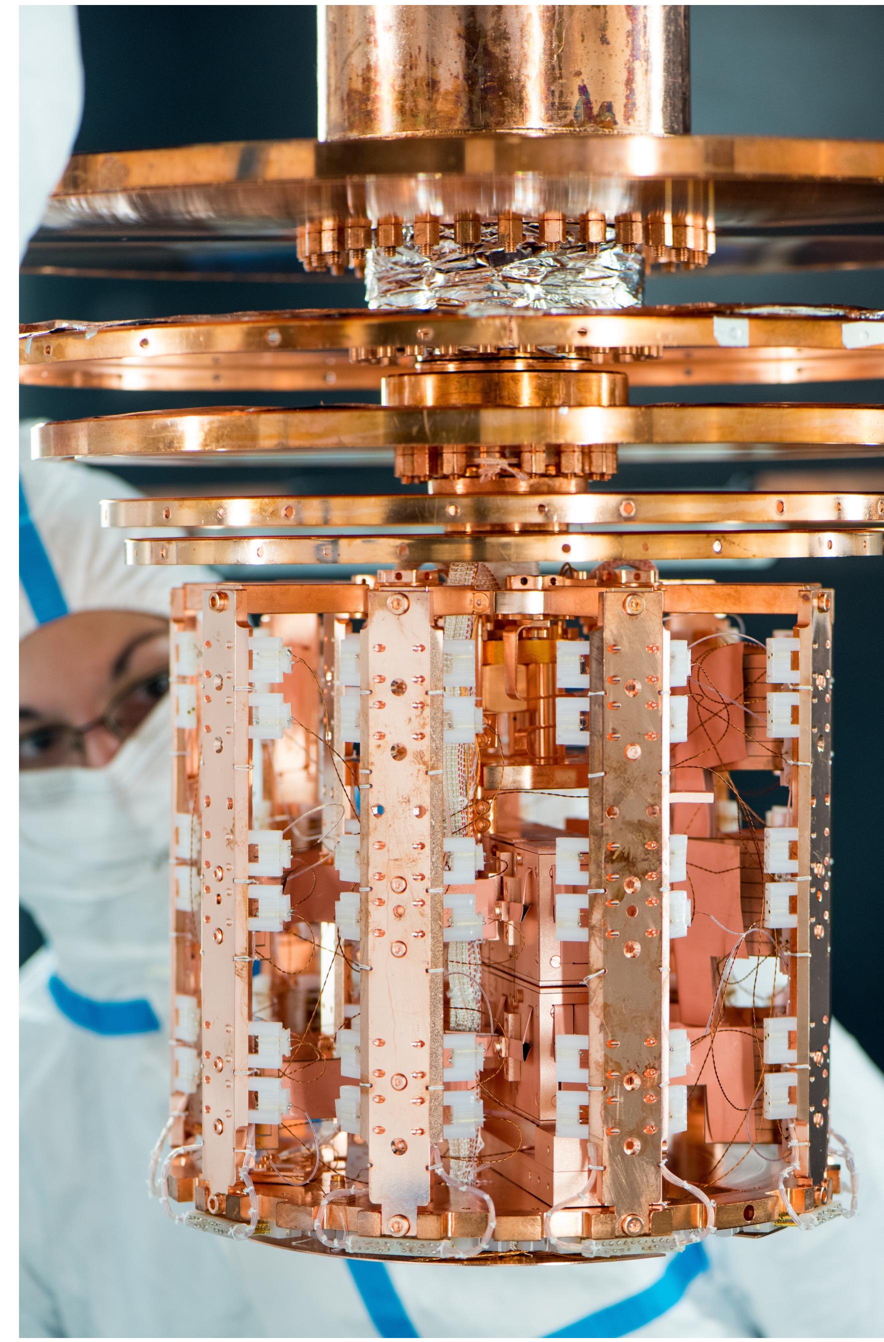
- Detector layout optimized for low-mass dark matter
- Fully scintillating housing
- Instrumented holders

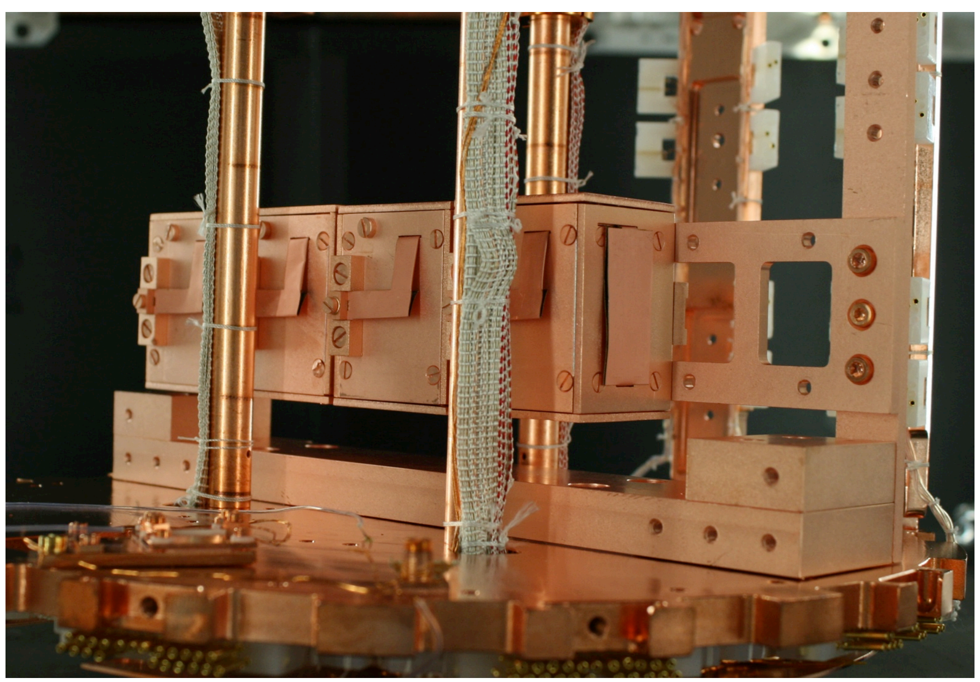
**Threshold design goal:
100 eV**

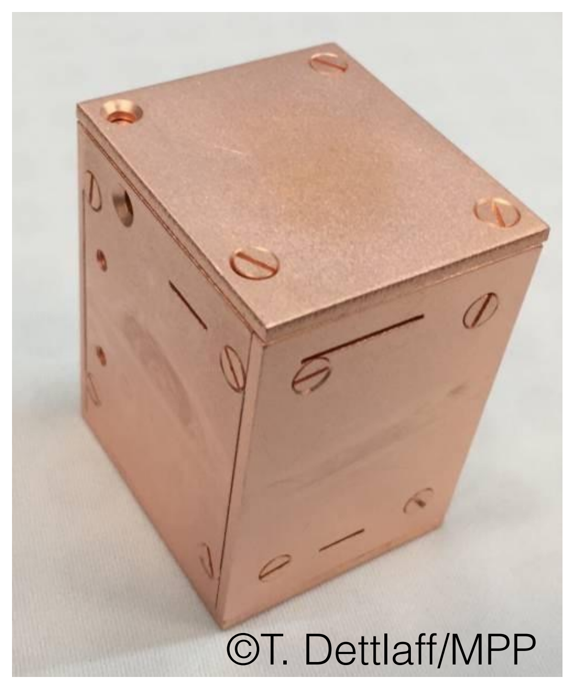
CRESST-III detectors





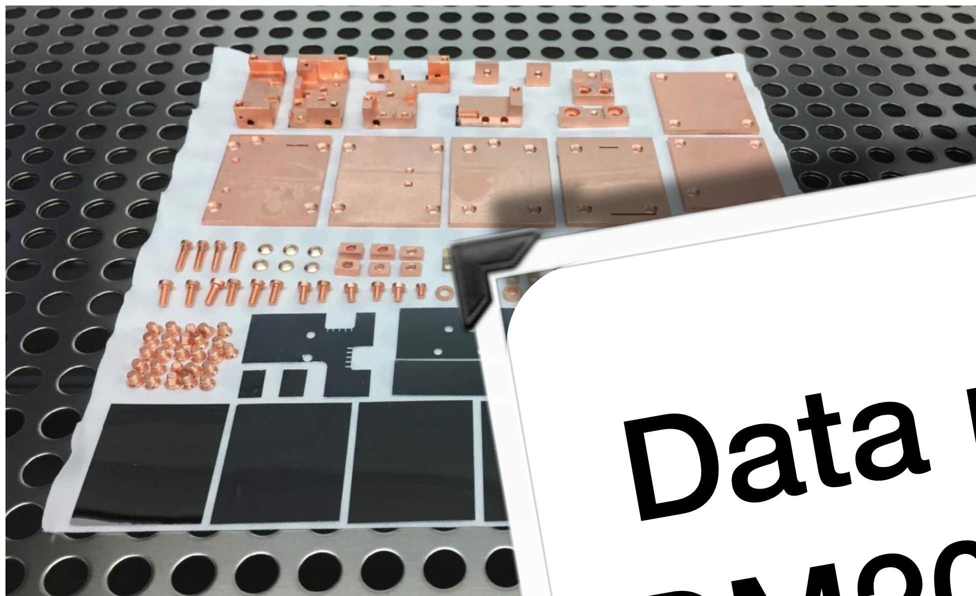


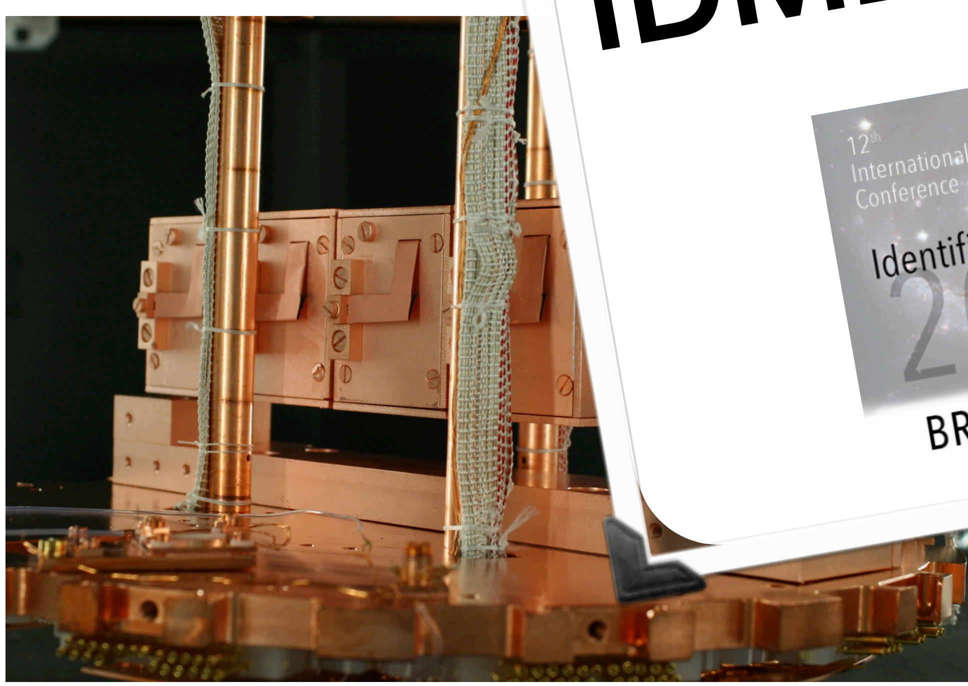


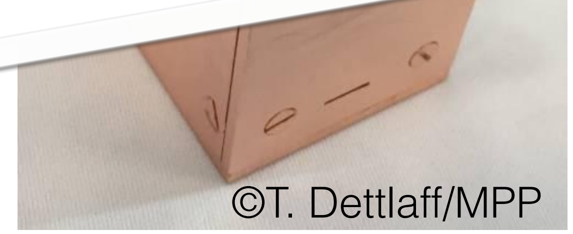


10 detectors operating in Gran Sasso from July 2016 to February 2018

CRESST-III detectors



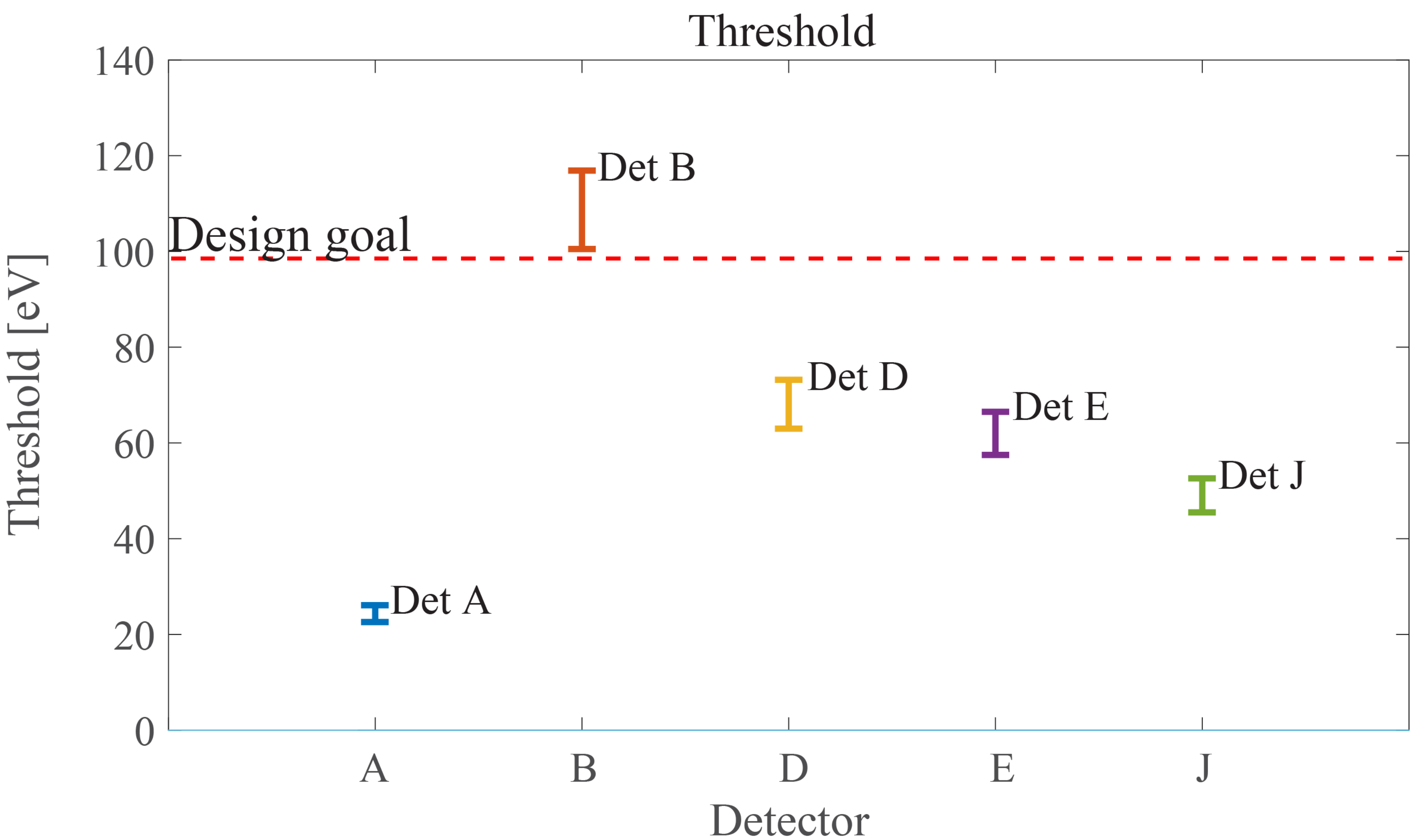




Data release at the IDM2018 conference

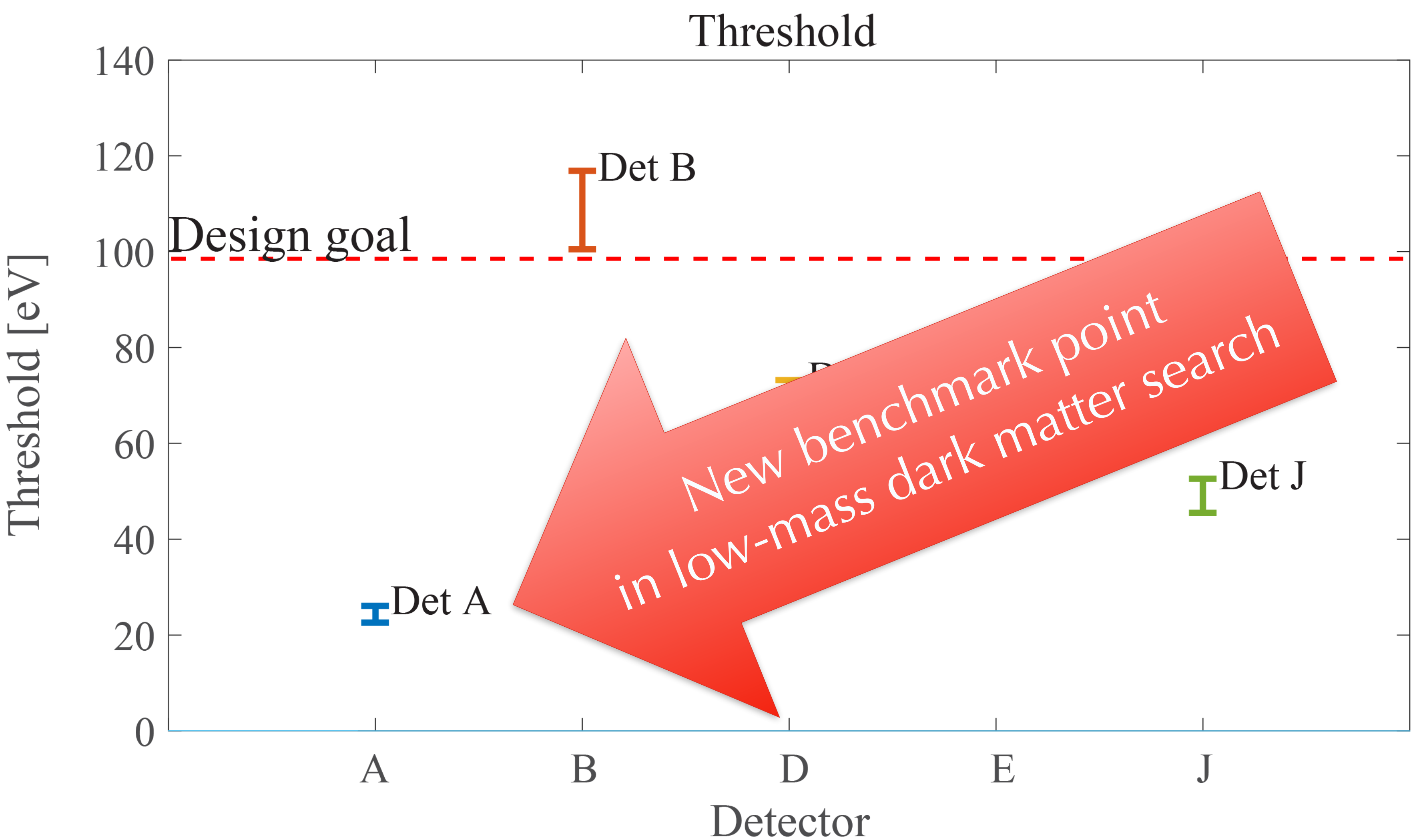
10 detectors operating in Gran Sasso from July 2016 to February 2018

Optimum thresholds



5 detectors reach/exceed the CRESST-III design goal

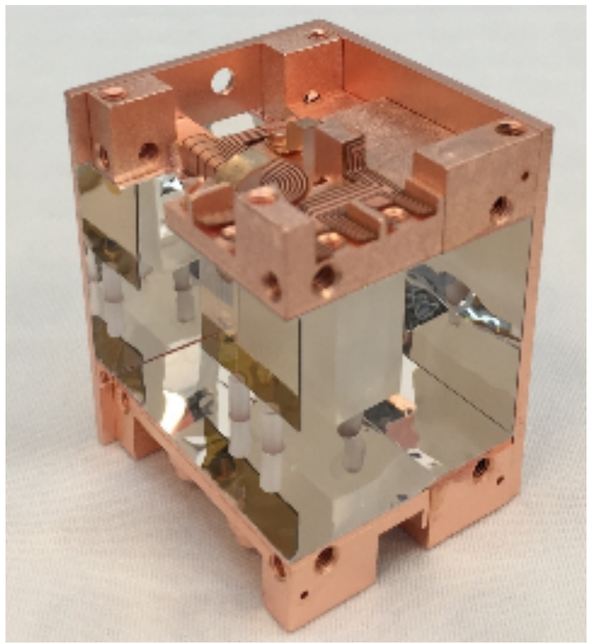
Optimum thresholds



5 detectors reach/ exceed the CRESST-III design goal

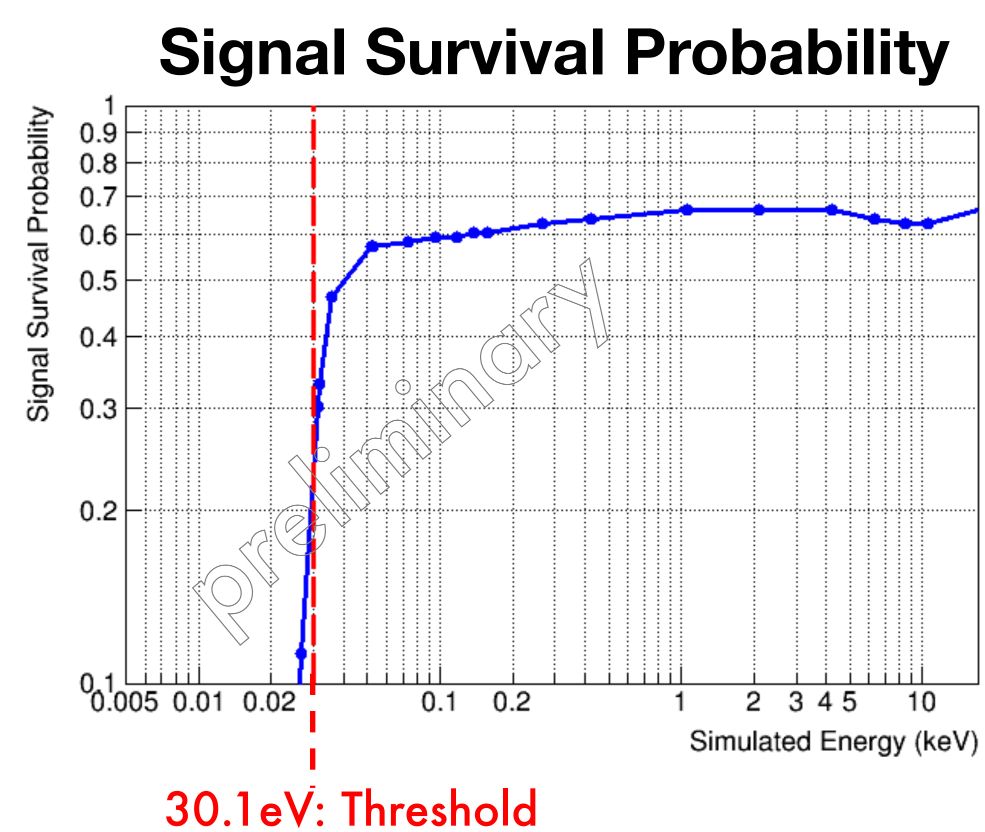
NEW FRONTIER IN DIRECT DM DETECTION

Detector A

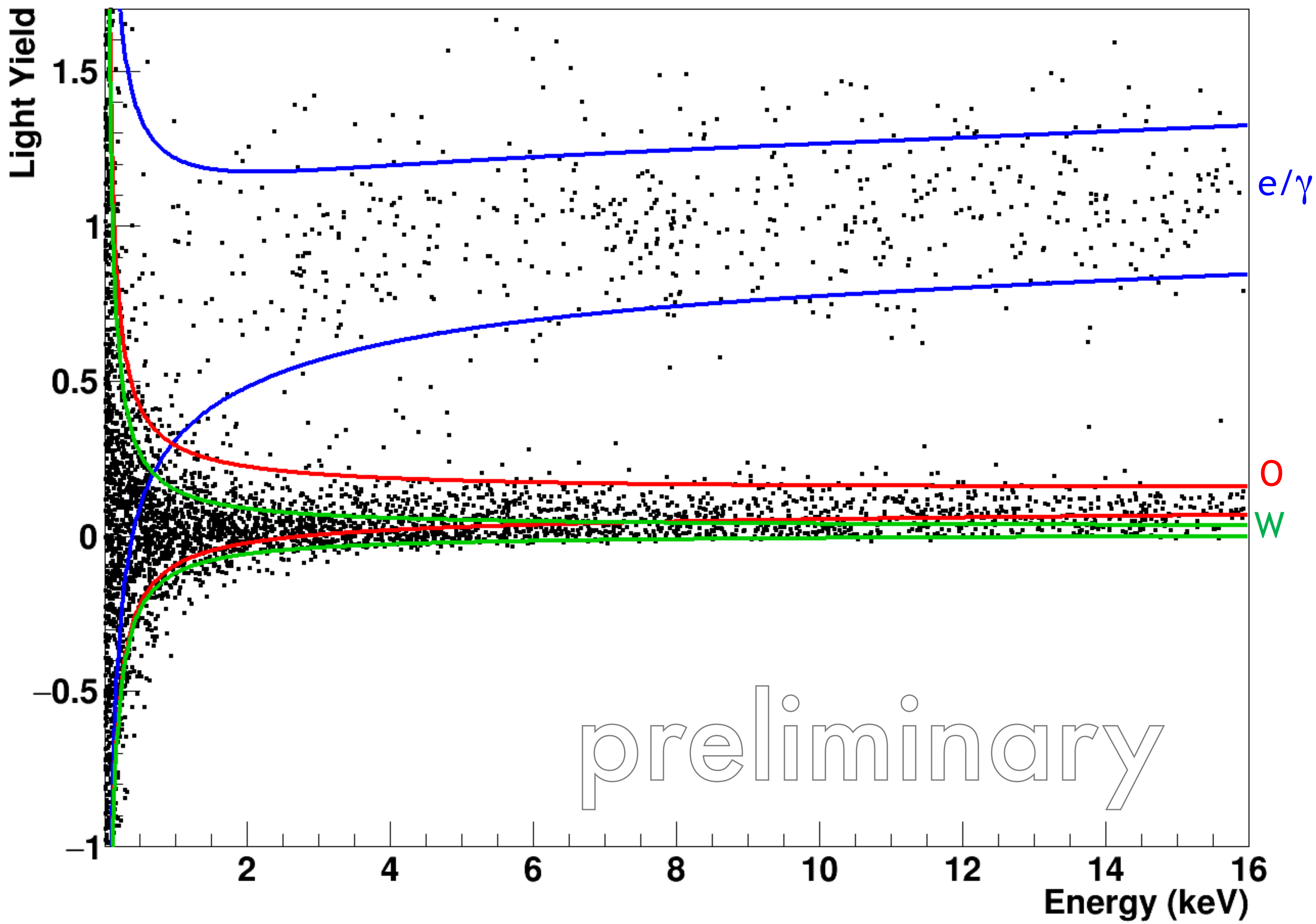


Data taking period: 10/2016 – 01/2018
Target crystal mass: 23.6 g
Gross exposure (before cuts): 5.7 kg days
Energy threshold: 30.1 eV

- 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

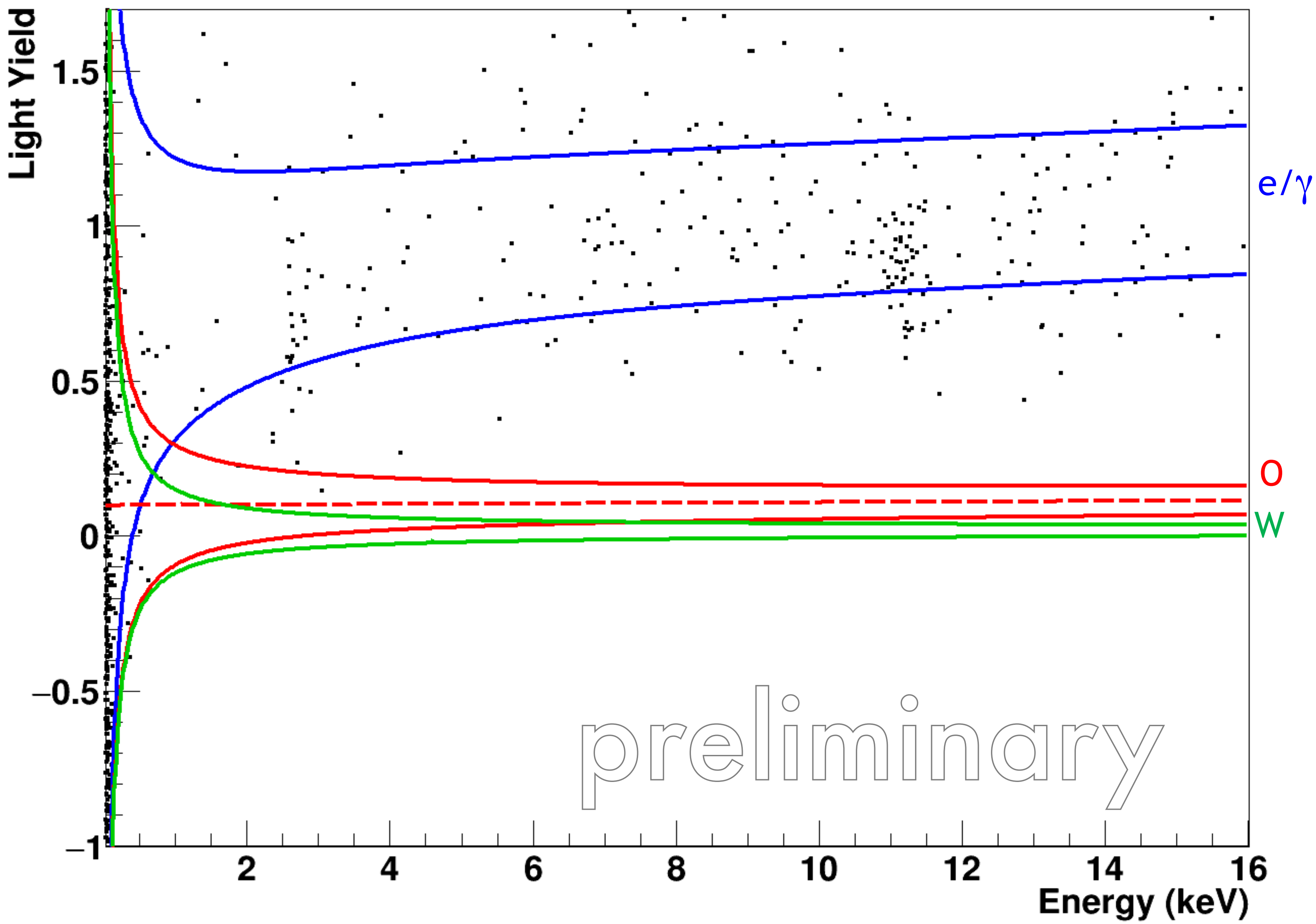


Neutron calibration data

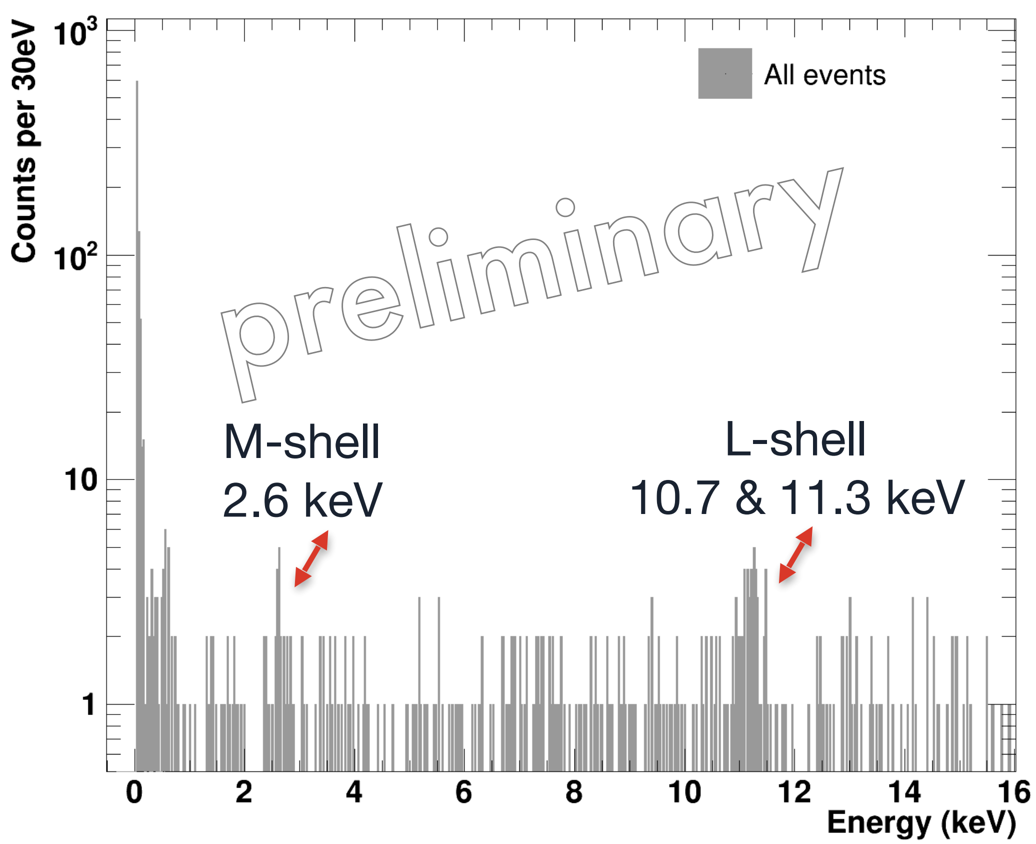


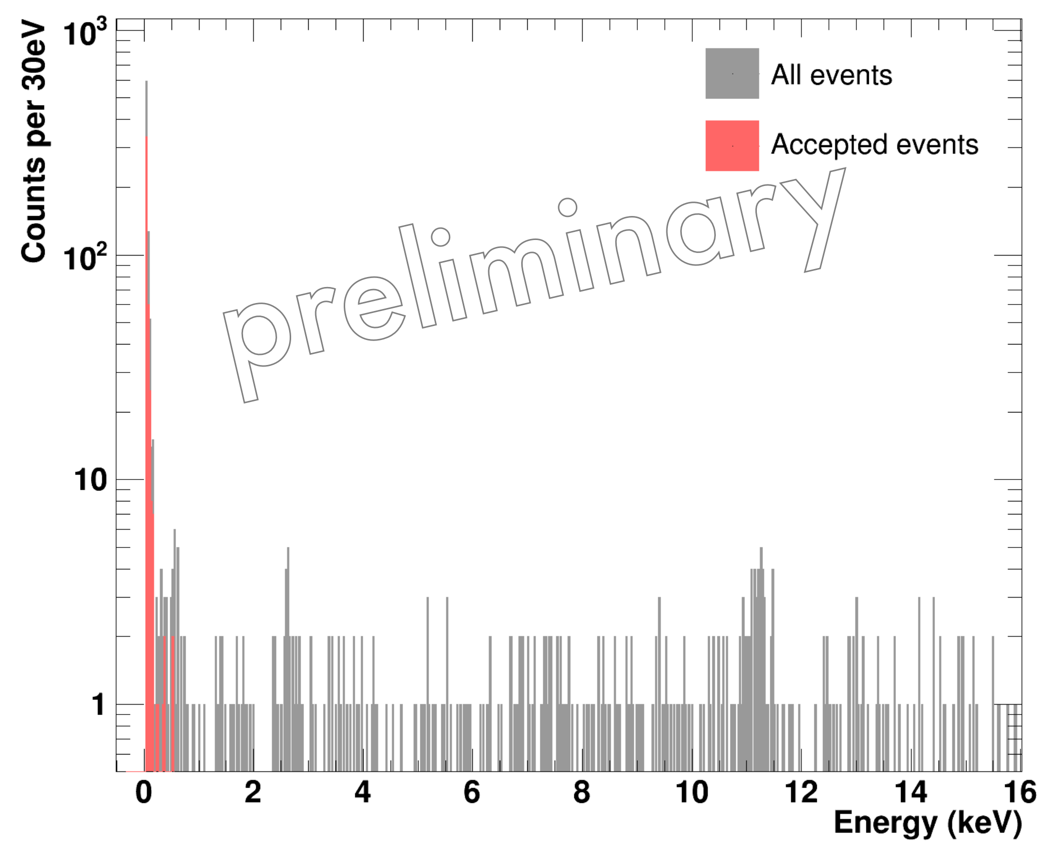
Quenching factors measured with neutron beam
Unbinned maximum likelihood fit

Dark matter data



Energy spectra





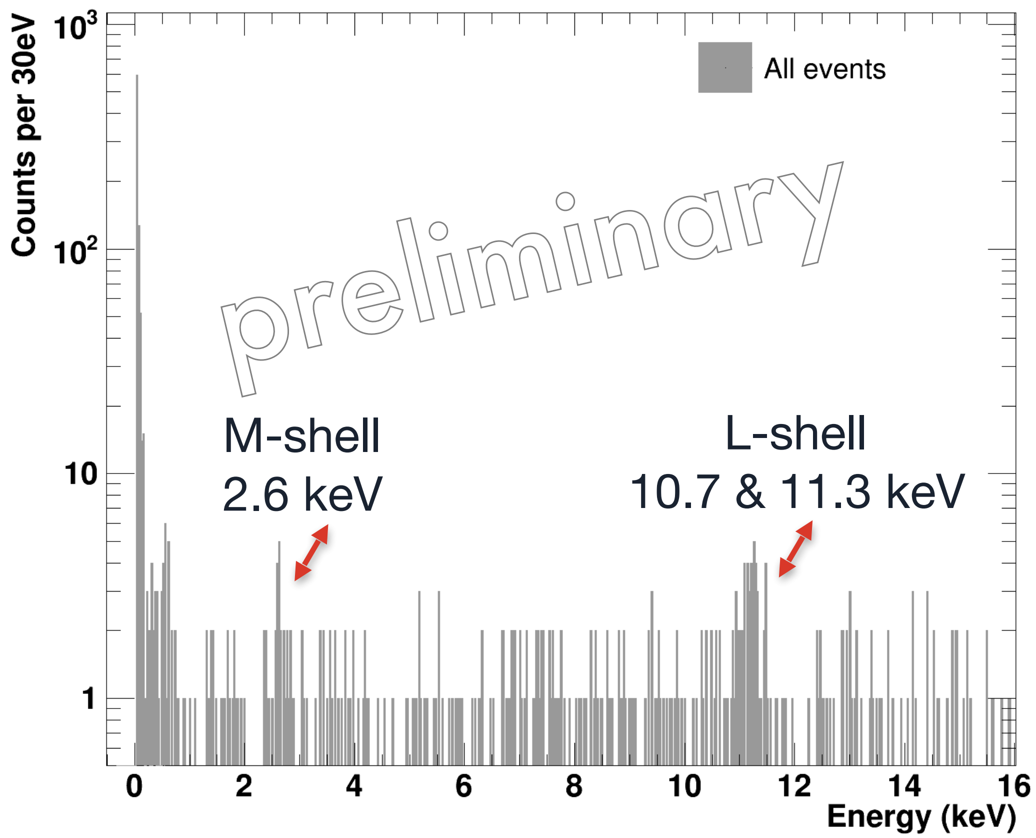
Cosmogenic activation

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

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

- 445 events in the acceptance region

Energy spectra

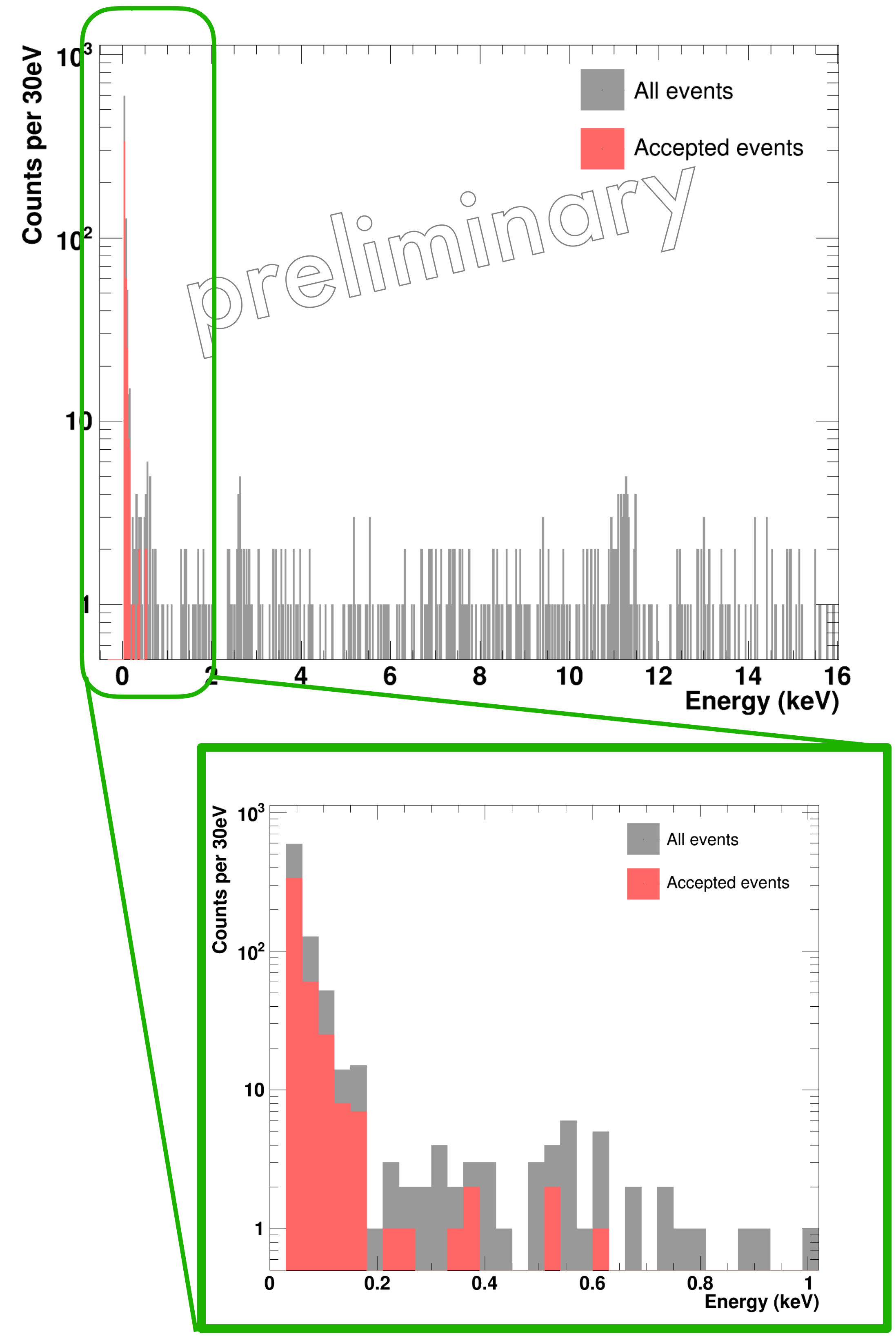


Cosmogenic activation

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

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

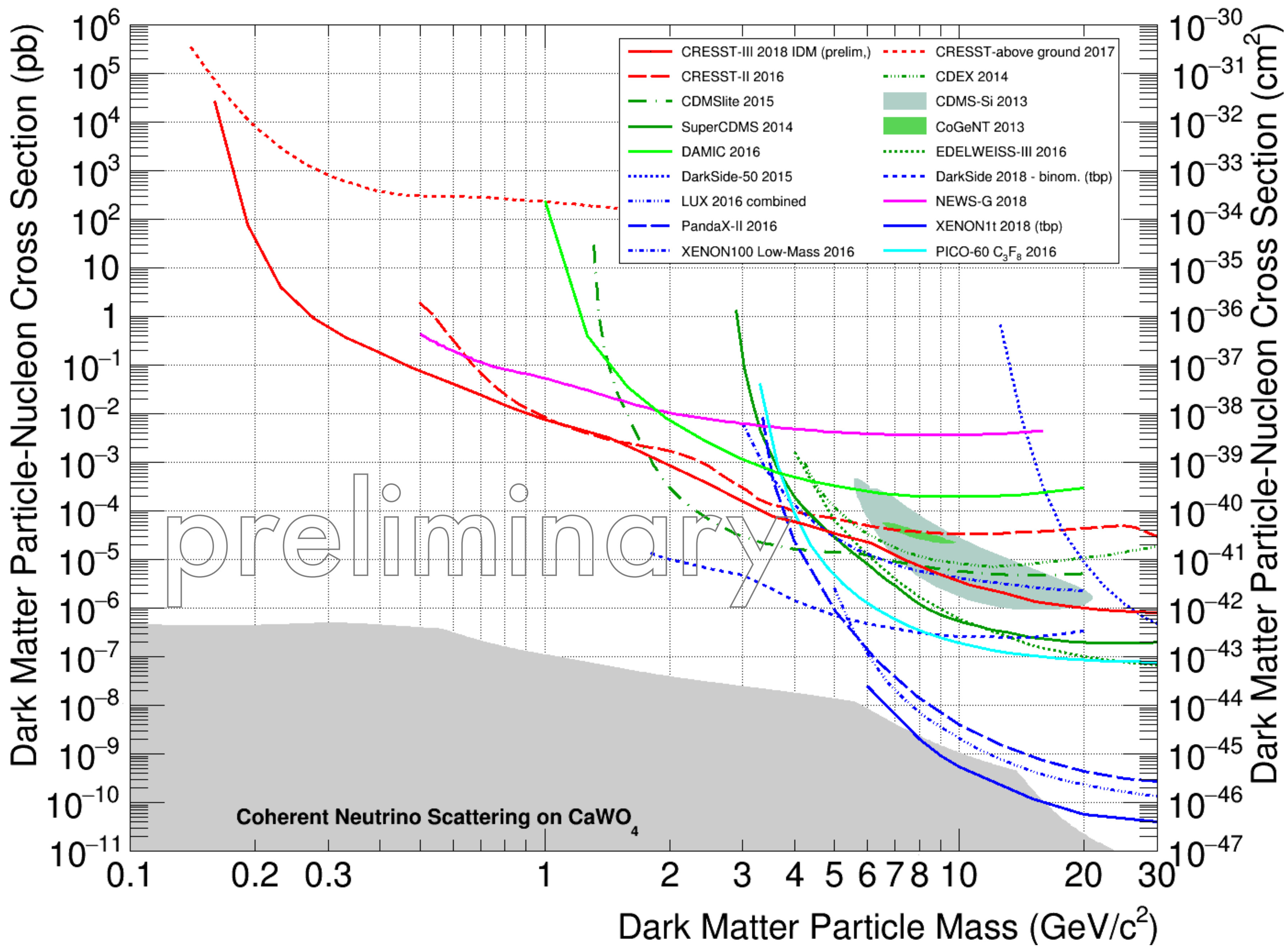
- 445 events in the acceptance region
- Unexpected rise of event rate <200 eV



Result

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

Energy spectrum of accepted events
+
Expected DM energy spectrum



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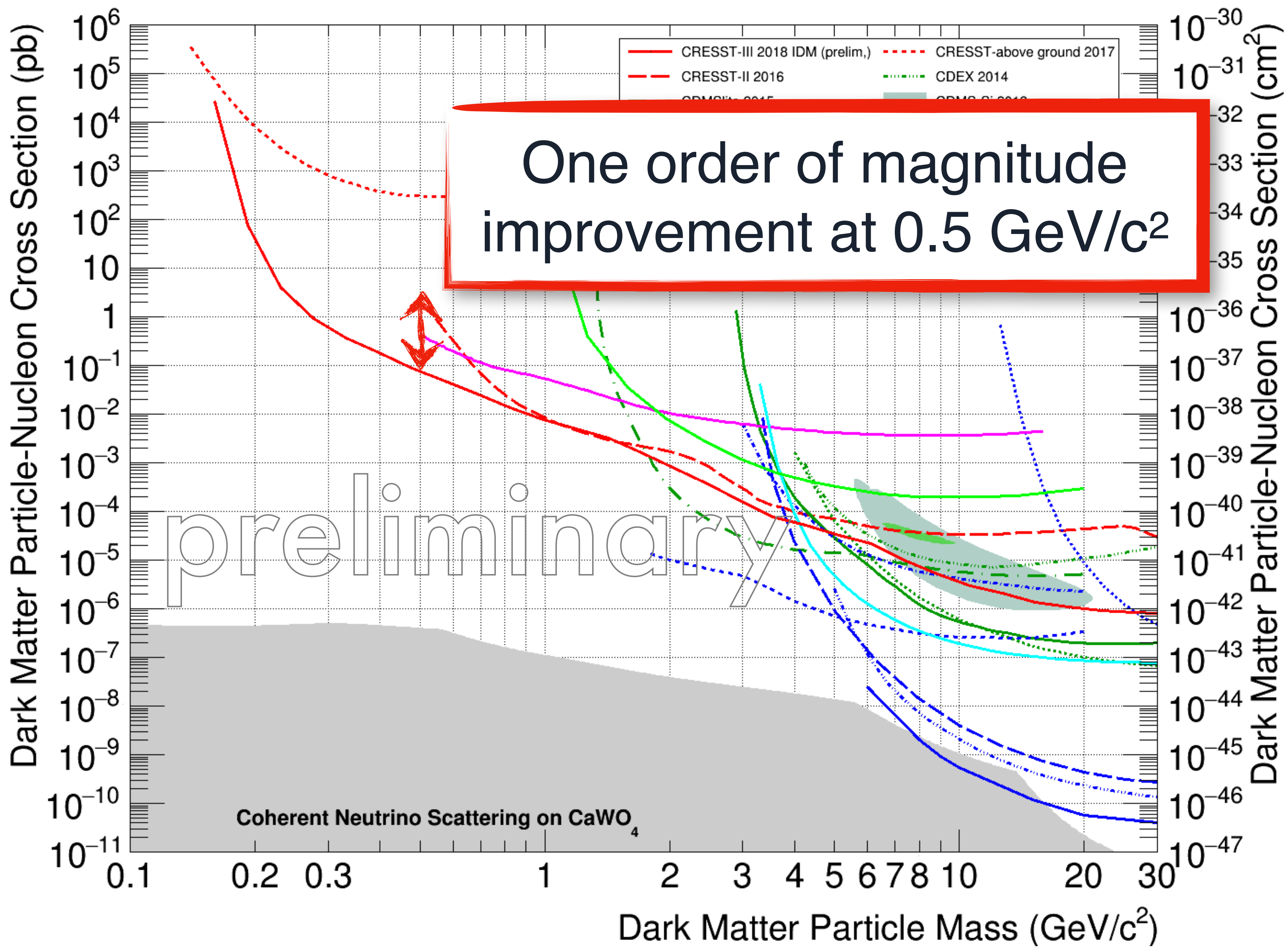

World leading limit at low-mass <1.7 GeV/c²

↳ Background limited

Result

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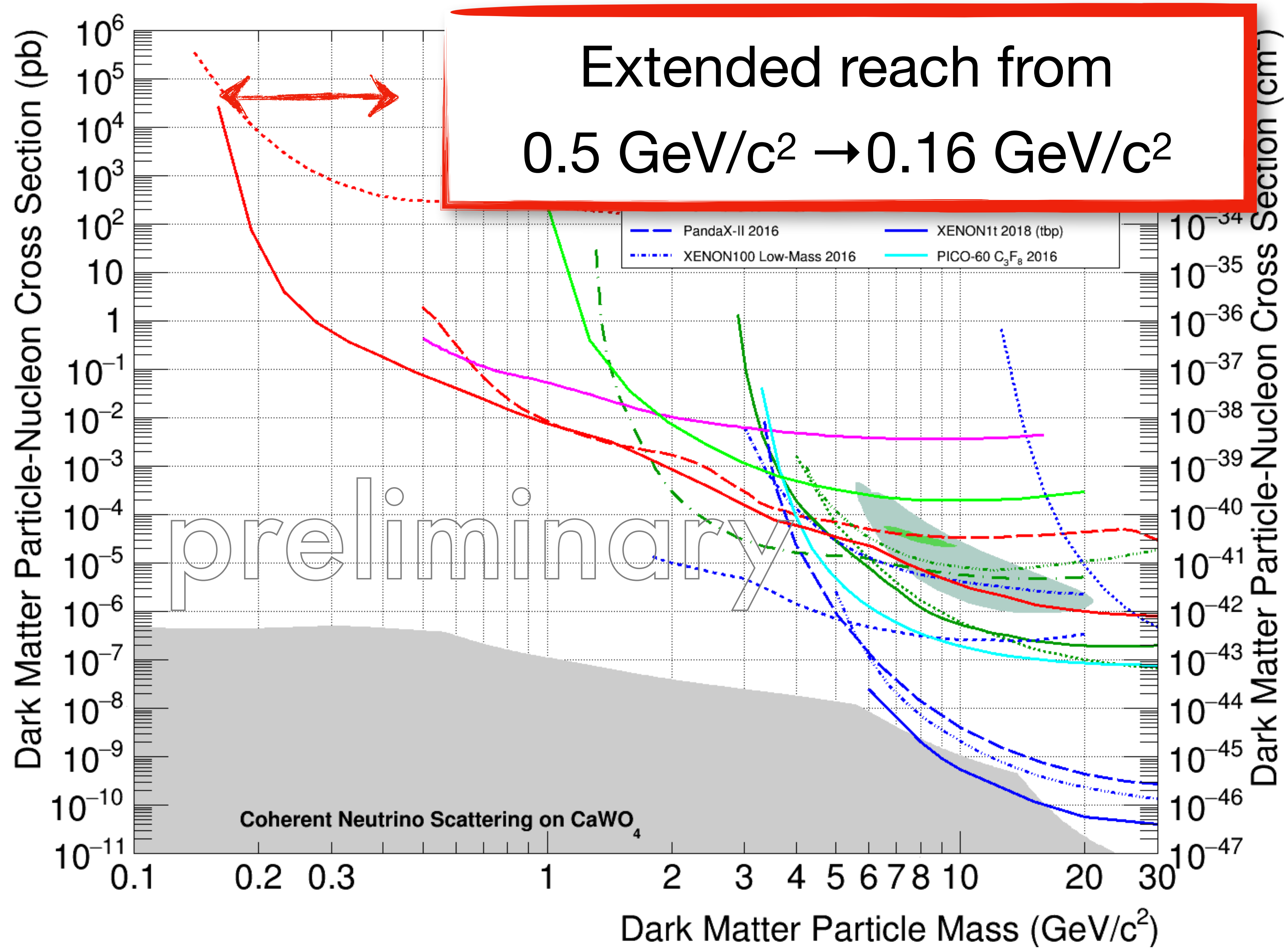


Extended reach from
0.5 GeV/c² → 0.16 GeV/c²

Lowest limit
>0.16 GeV/c²

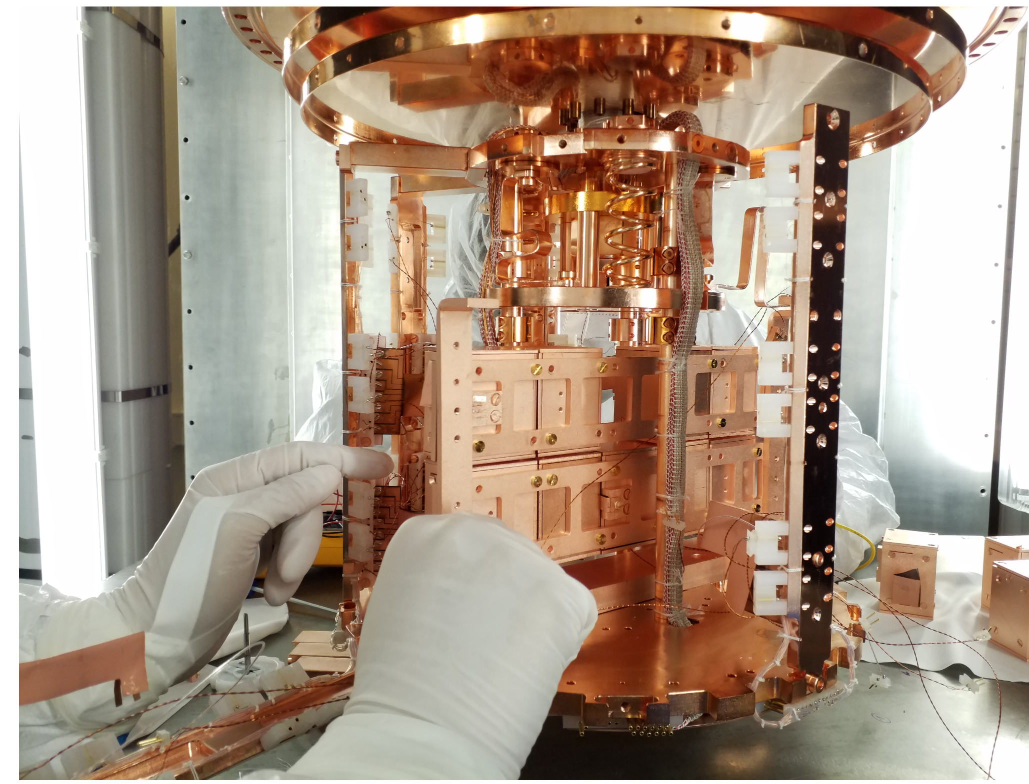
↳ Performance "limited"

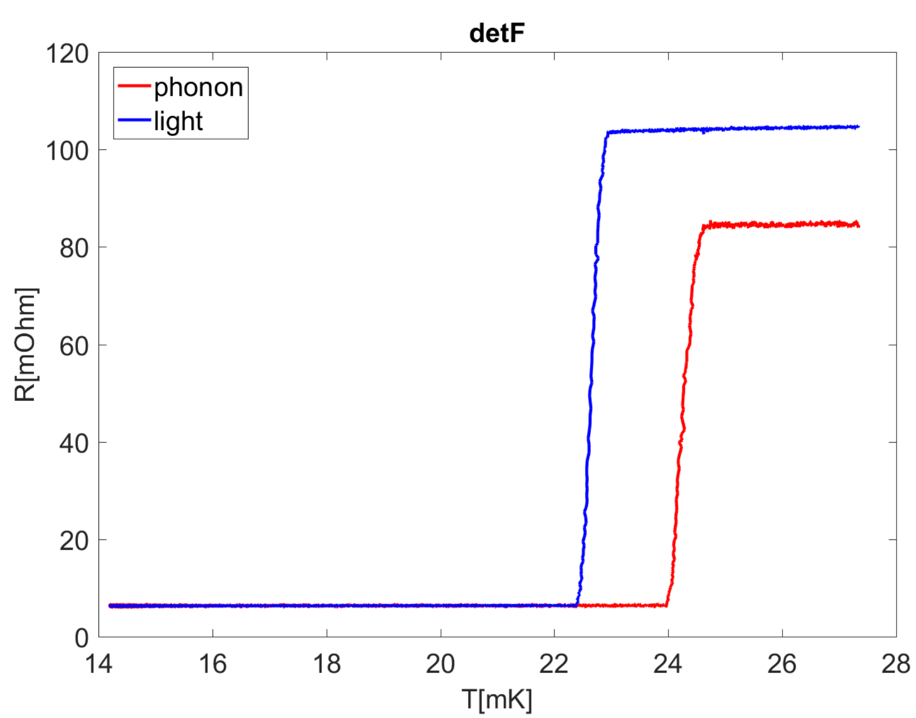
Current status

April-May 2018:

“Upgraded" detector modules have been prepared at MPP (crucial contribution from MPP Mechanical Workshop) and installed in Gran Sasso.

Dedicated hardware changes to understand source of excess events (different crystal absorbers, different detector holders, etc..)



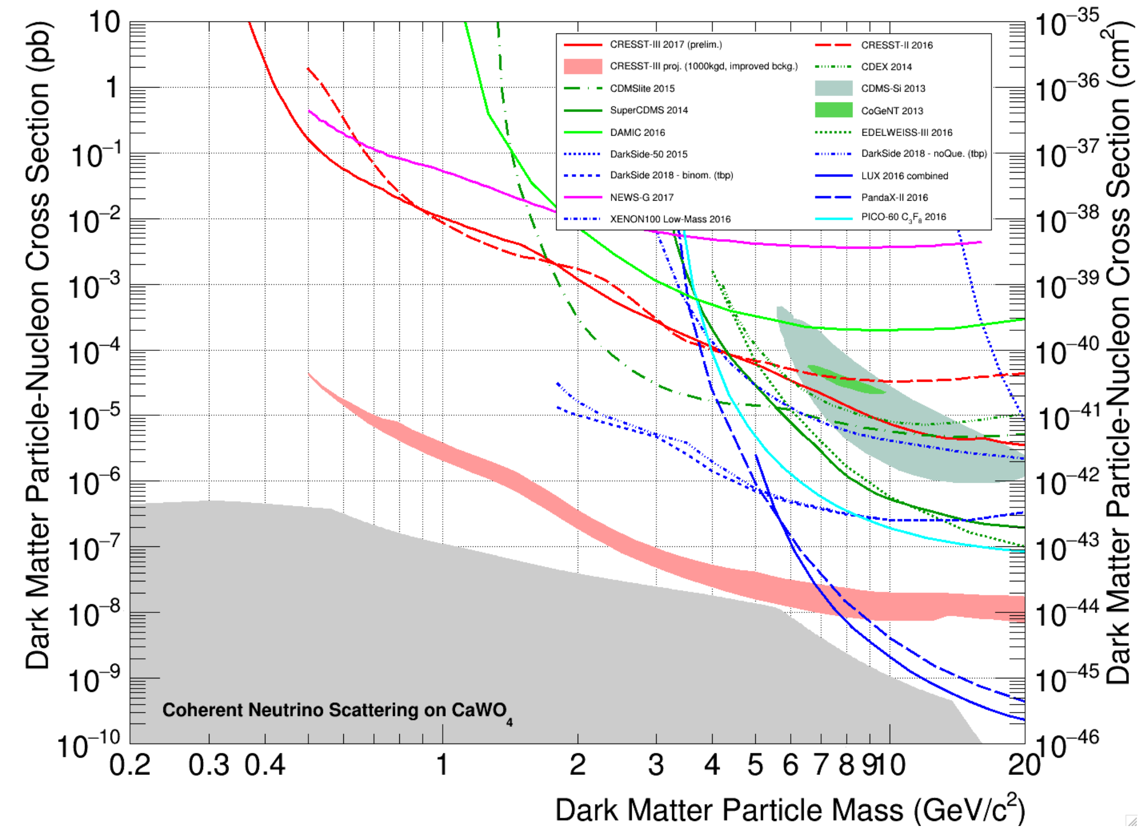


First data from Gran Sasso in these days.

What’s next? (2)

Long term: Major upgrade of the experiment is foreseen to start next year.

Goals: increase the number of channels in the LNGS setup to 100 and further improve threshold and background.



Final planning, prototyping and testing of wiring and read out electronics
Detectors R&D:
Further threshold reduction
Improved reproducibility
Increased production rate
Reduced background
Different materials

2019

Upgrade of the setup at LNGS
Production of detectors

2020

Restart data taking

2021

MPP activities (non exhaustive list…)

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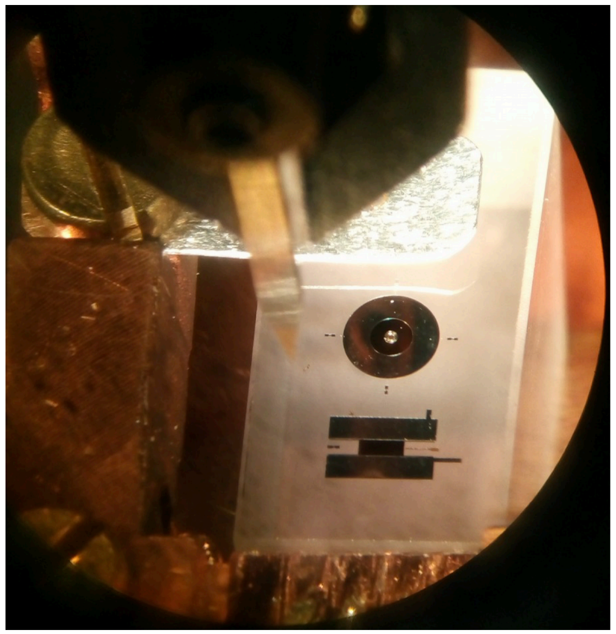
Sensor optimisation



MPP activities (non exhaustive list...)

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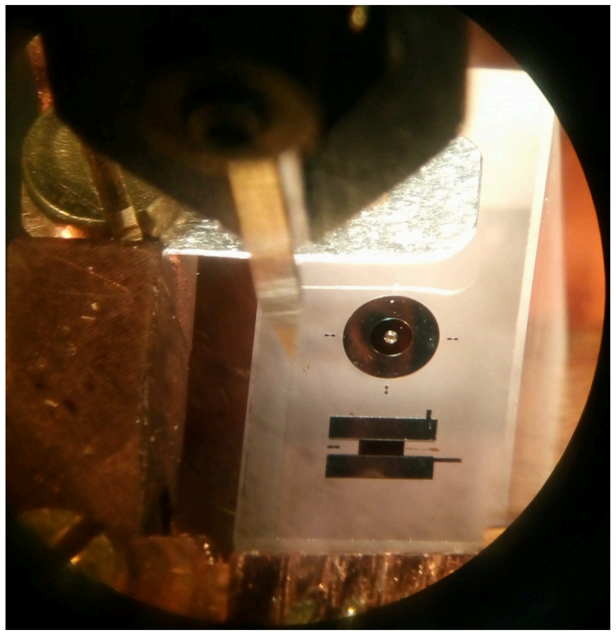
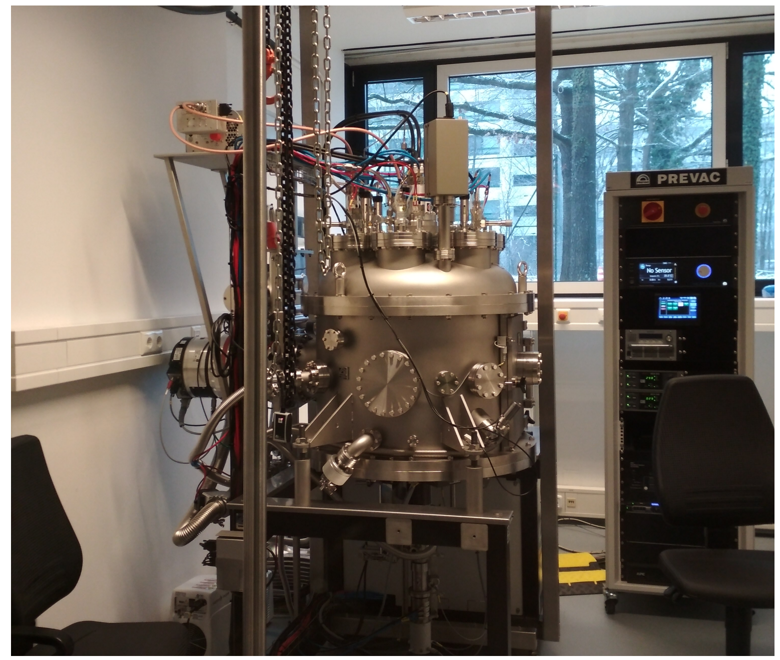


Sensor reproducibility



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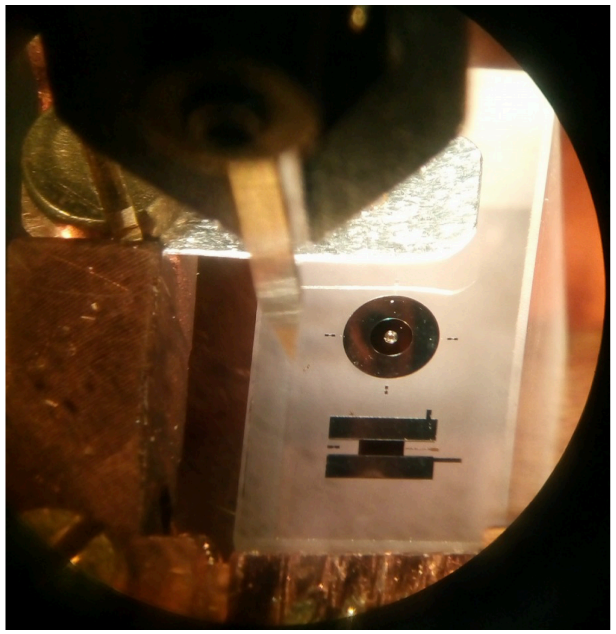

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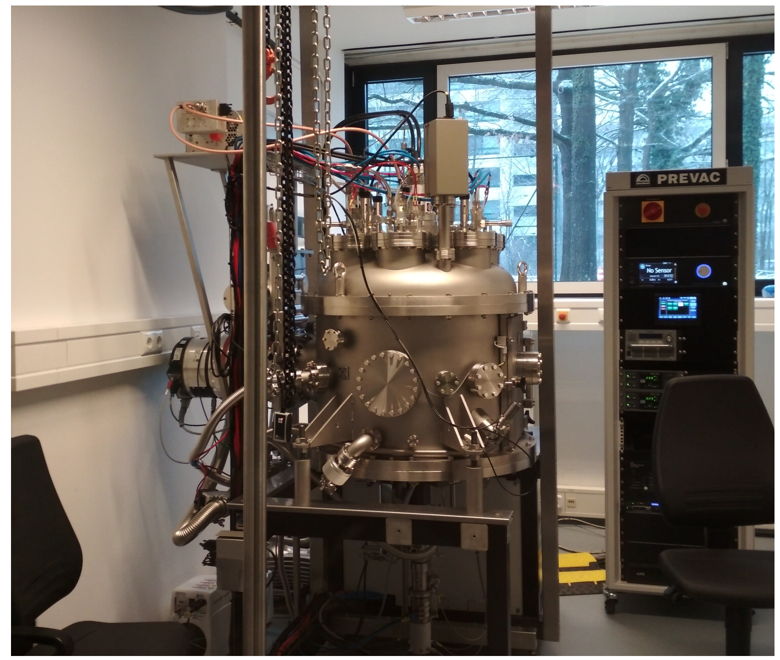
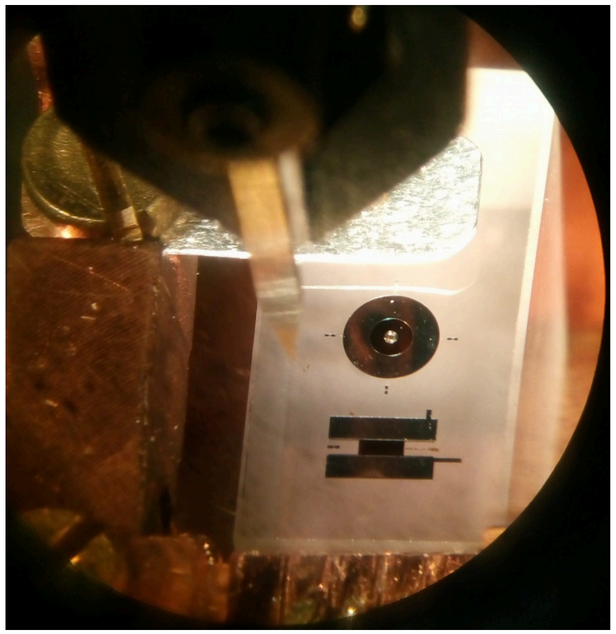


New materials

MPP activities (non exhaustive list…)

Sensor optimisation



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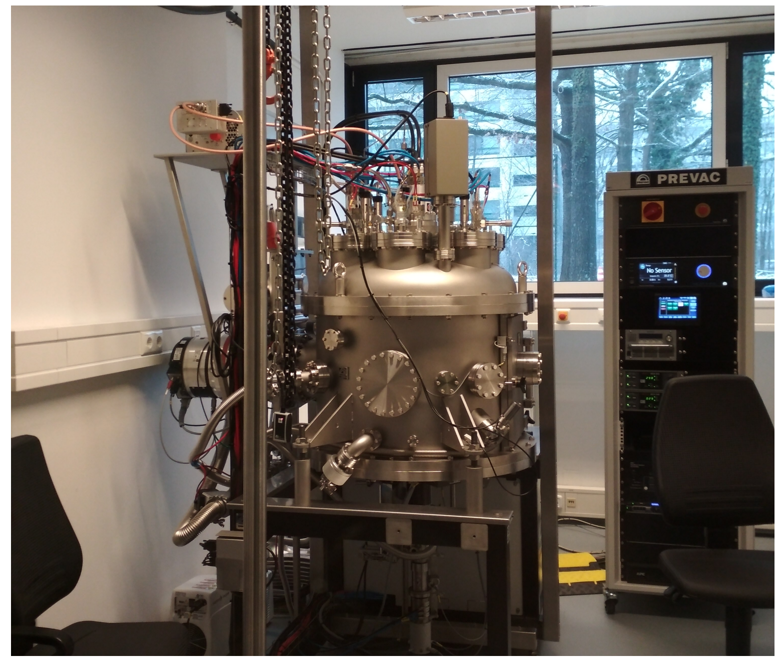
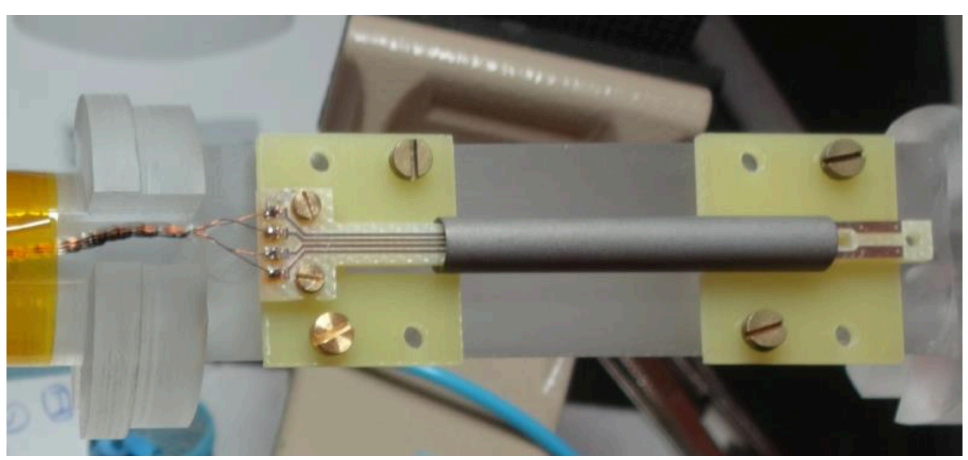


New materials

SQUID



MPP activities (non exhaustive list…)

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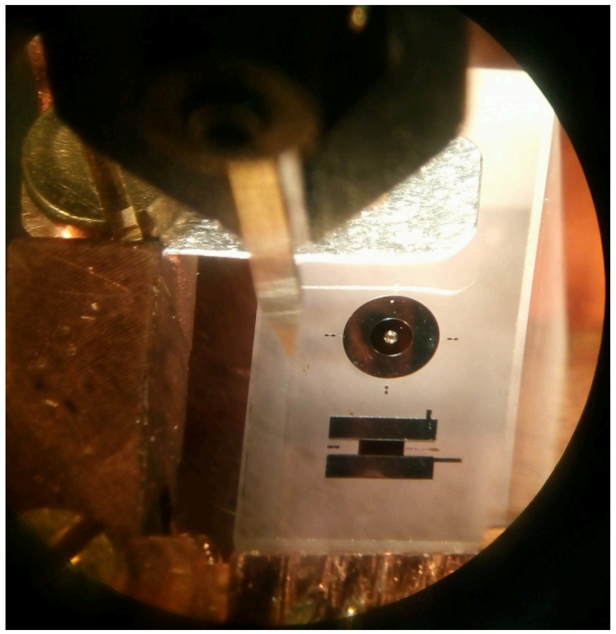

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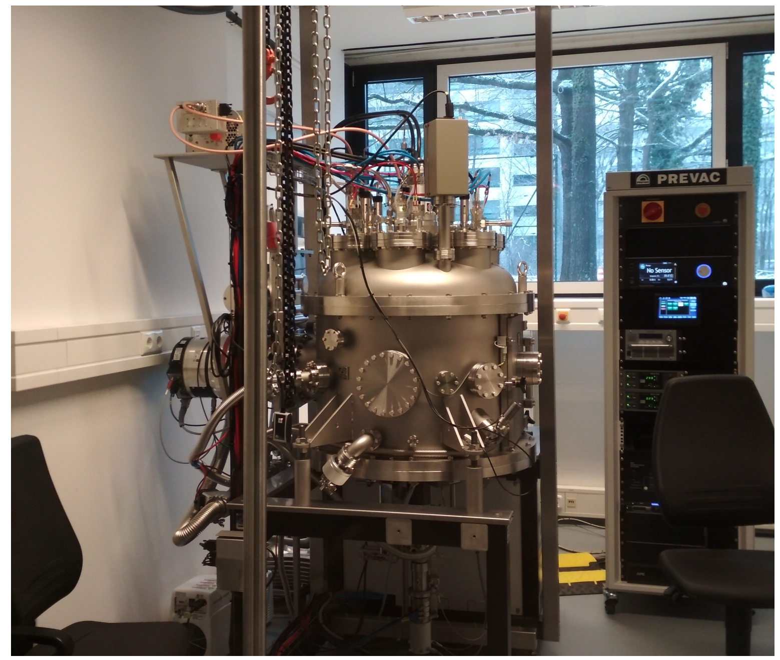

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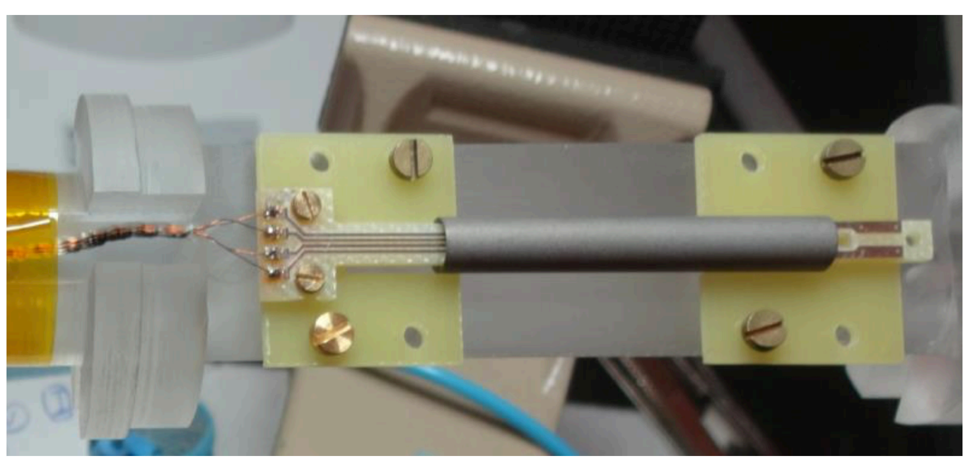
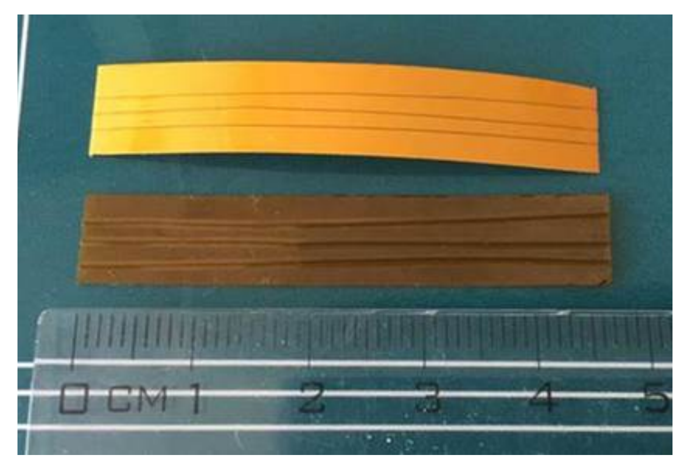


Read-Out



CRESST “Spin-offs”

Spin-offs of the CRESST-MPP technology successfully funded in 2018
→ **from R&D to experiments**

COSINUS

MPRG @ MPP, K. Shaeffner

CRESST-like cryogenic detectors made of NaI to study the DAMA signal.

NU-CLEUS
Exploring coherent neutrino scattering

ERC Starting Grant 2018, 804228, R. Strauss

Miniaturized CRESST-like detectors for studying CNNS at reactors.

Conclusions

- Cryogenic calorimeters represent a well established technology for the investigation of dark matter and other rare event searches.
- **CRESST** has reached an unprecedented low nuclear recoil threshold of 30 eV and is leading sensitivity for light DM searches at 160 MeV/c^2.
- **CRESST - MPP** is the leading institution in the experiment, developing highly sensitive cryogenic particle detectors.
- A new explorative run is ongoing at LNGS to investigate the source of excess events.
- Preparation for the major upgrade of the LNGS experiment.