A low-threshold diamond cryogenic detector for sub-GeV Dark Matter searches

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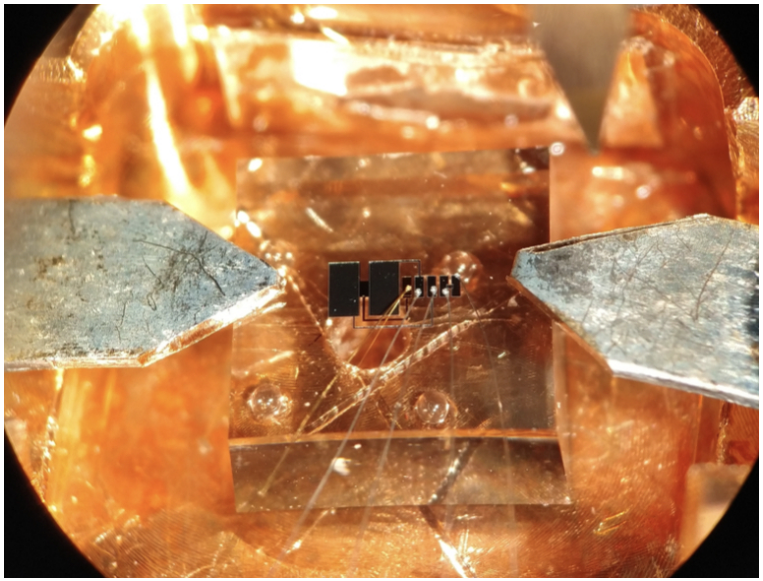
DM searches with cryogenic experiments

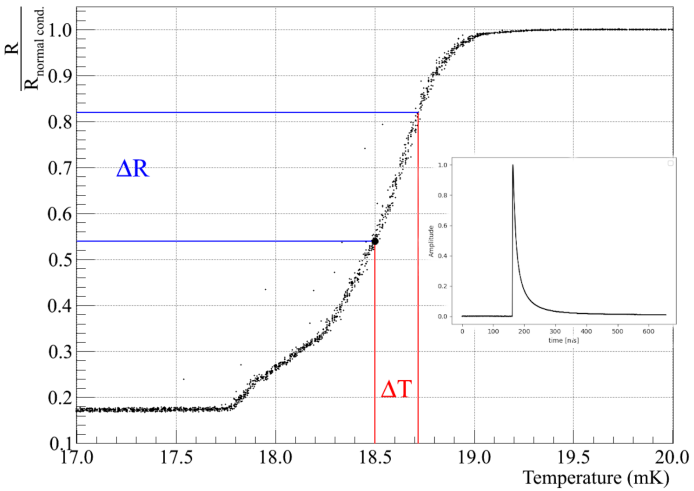


Detection principle

- Crystal equipped with a TES (Transition Edge Sensor)
- WIMP scattering off the target nuclei causes an energy deposition
- energy reconstruction via $\Delta T = \frac{\Delta E}{C}$

TES (Transition Edge Sensor)

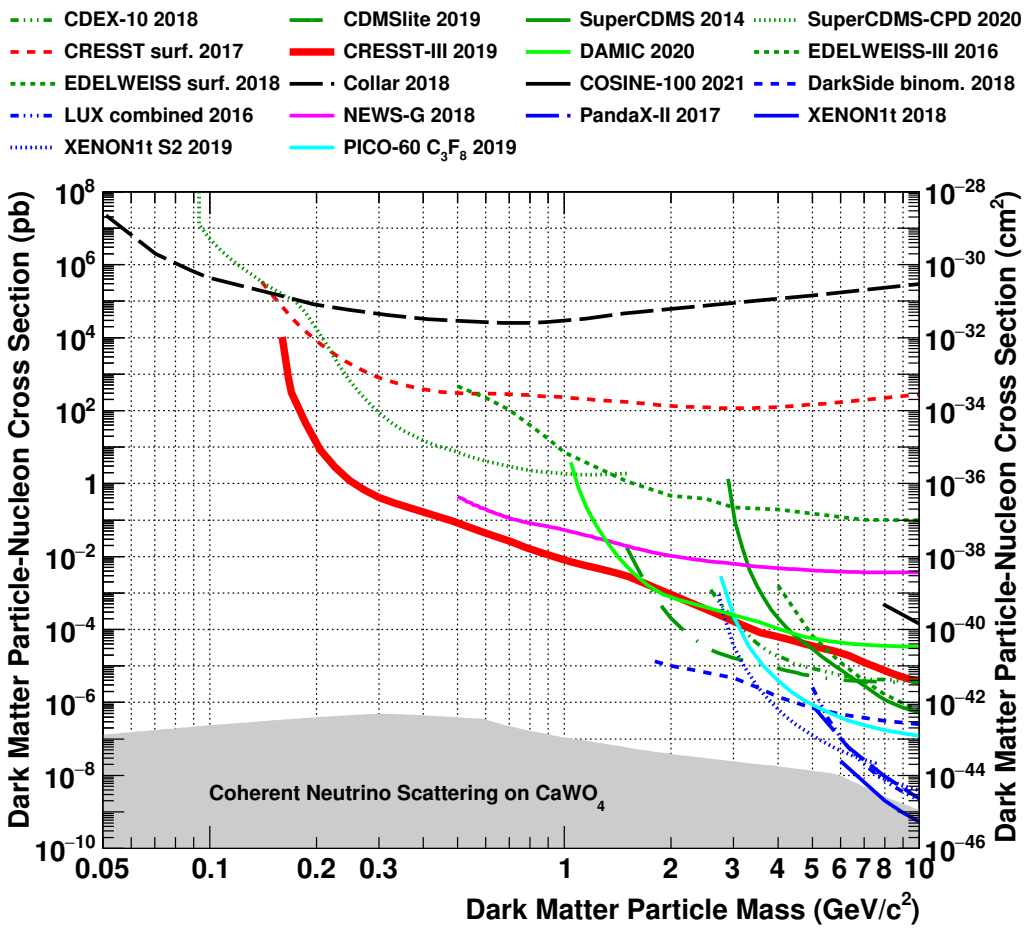
- Operating point is at transition from superconducting to normal conducting phase (15 mK)
- An event corresponds to a pulse



Current status of low mass dark matter searches

With the measured paritcle rate we can set exclusion limits following the formula

$$\frac{dR}{dE} \sim \frac{\sigma_0}{m_\chi} \cdot \frac{m_T}{\mu^2} \cdot I_{halo}$$



- the parameter space for dark matter masses below 1 GeV starts to be explored
- to be sensitive to low dark matter masses a low energy threshold is needed

Why diamond detectors?

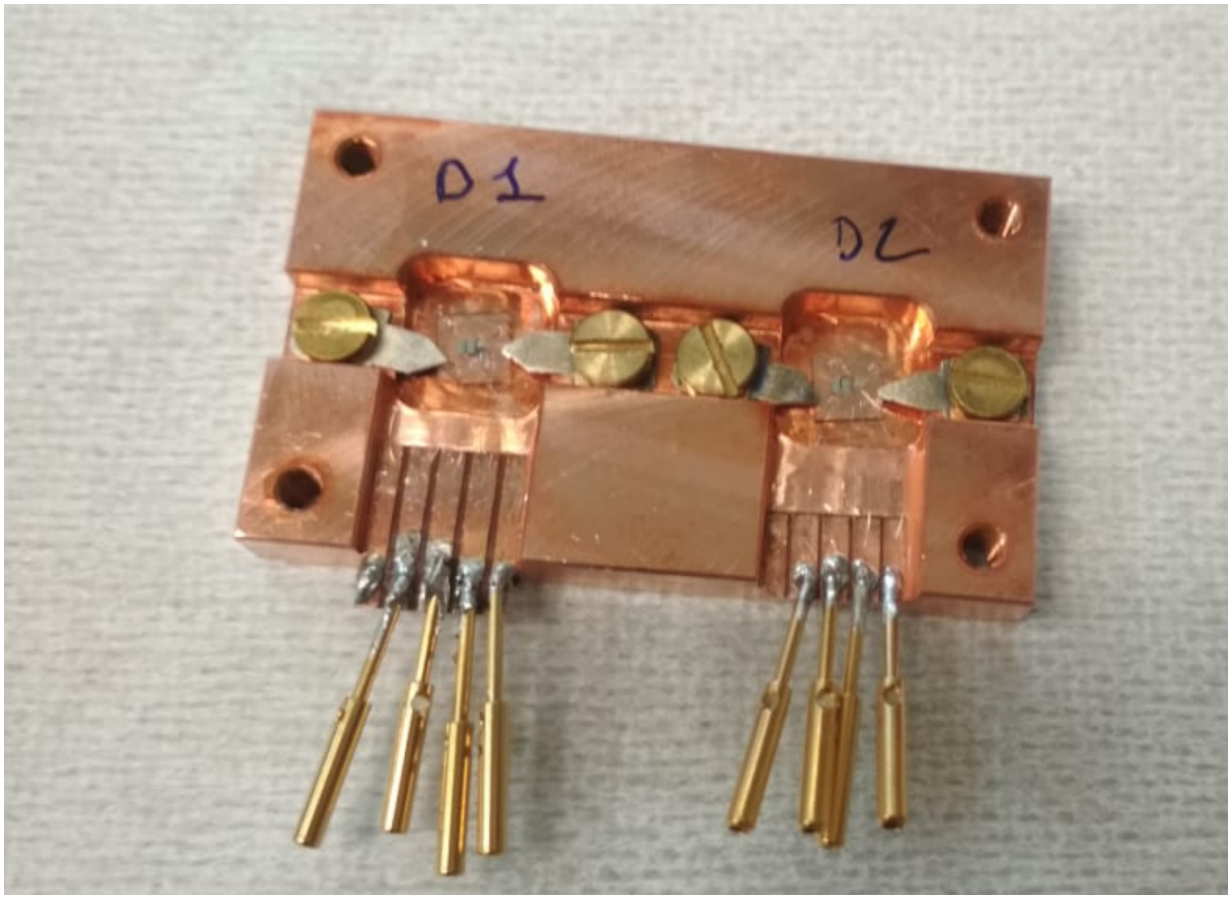
- Diamond has a high debye temperature (2220K) and high energy and long-lived phonon mode
  $\rightarrow$ perfect for cryogenic detectors
- light nucleus (Z=6)
- Diamond is a semiconductor with excellent isotopic purity
  $\rightarrow$ simultaneous readout of phonon and charge signals makes background discrimination possible

Diamond detectors could achieve a **very low threshold** and be an ideal tool for sub-GeV DM searches

Drawbacks:

- Cost
- Limited size

The two detectors



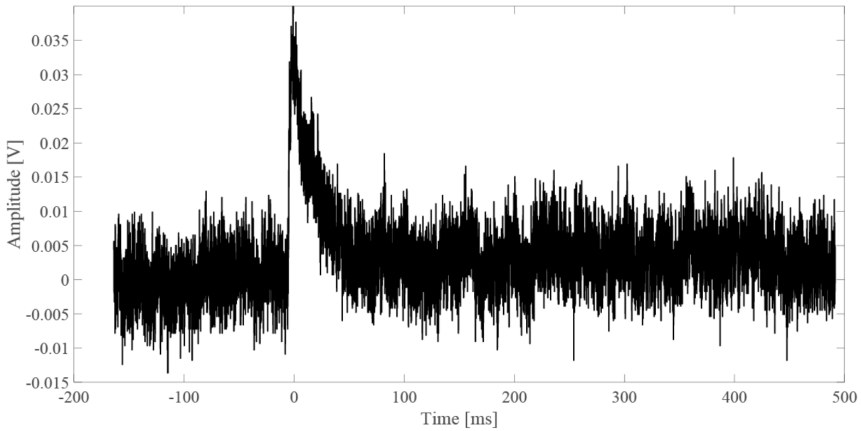
Two single crystals diamonds

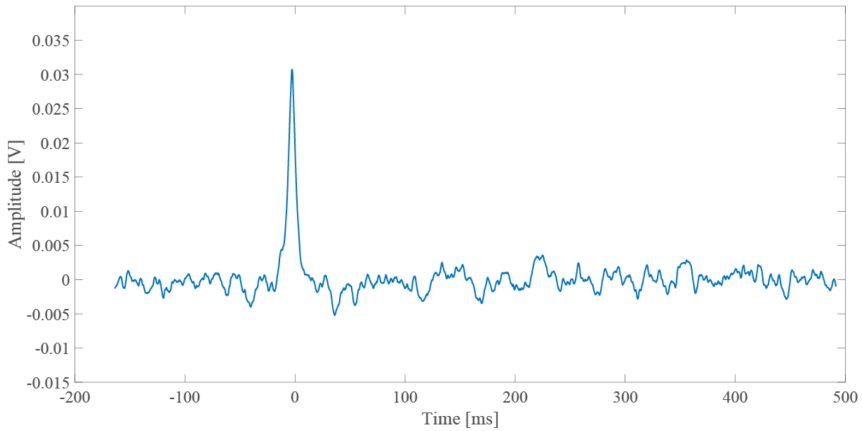
Dimensions:
5x5x2 mm^3
Mass:
0.176 g each
Purchased from
AuDiaTec
Seed money funds
Origins Cluster

- Operation above ground at Max-Planck-Institut für Physik
- Data has been taken for 58 hours for two modules

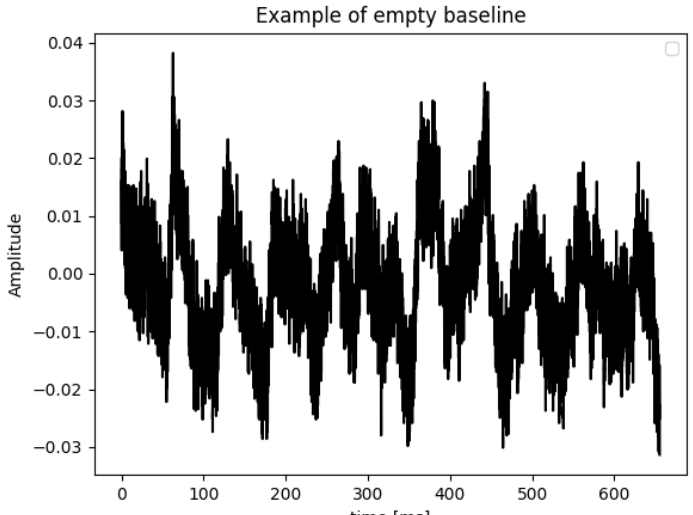
Data processing

- Continuous data taking + software triggering
- We maximize the signal-to-noise ratio using an optimum filter
- Very precise amplitude estimation due to efficient noise reduction

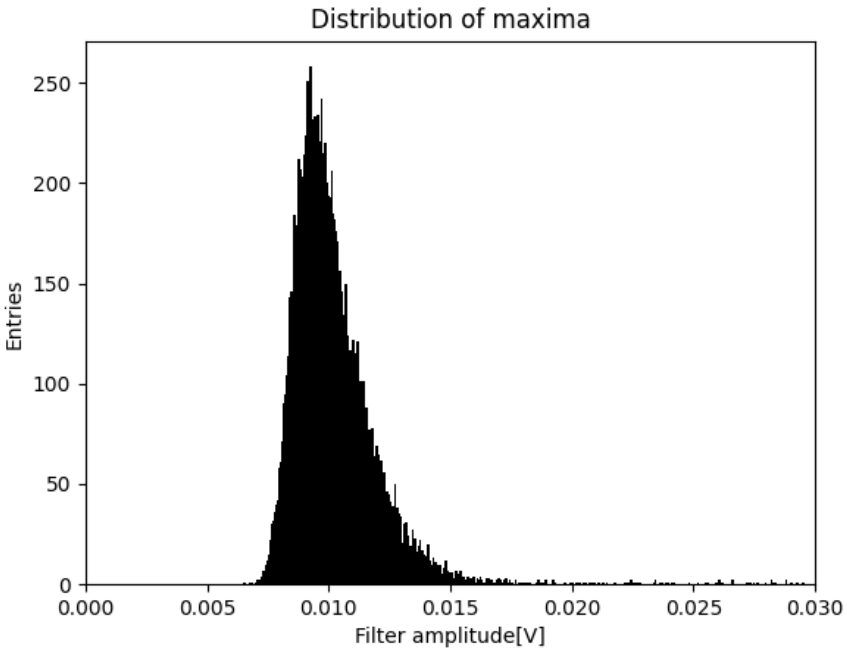


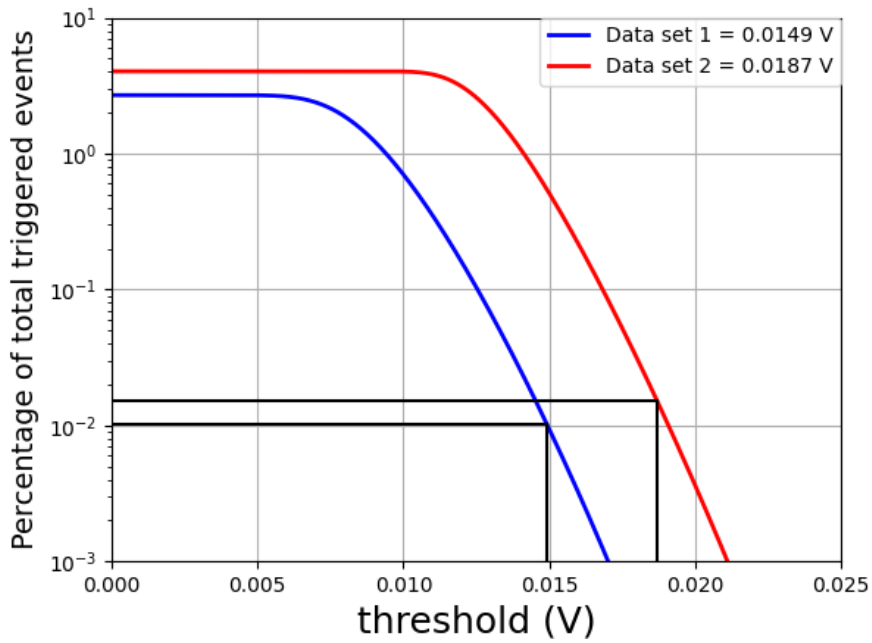


- We also record parts of the stream with no triggers for noise studies



Threshold determination

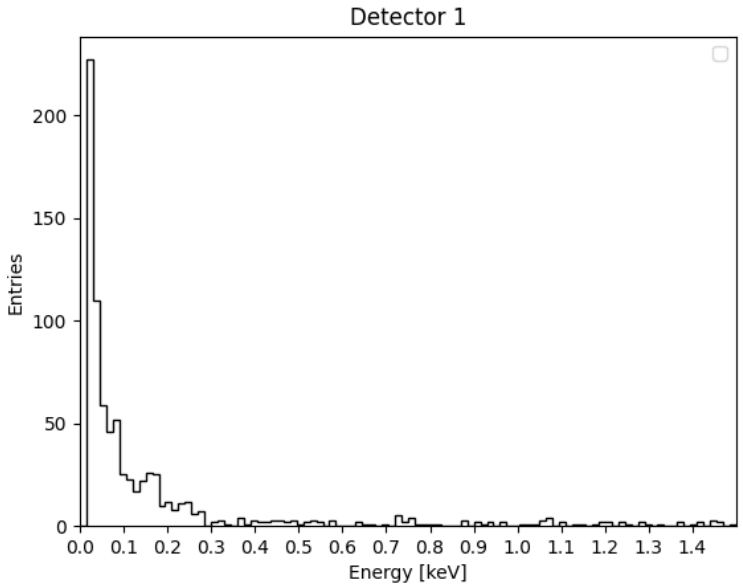


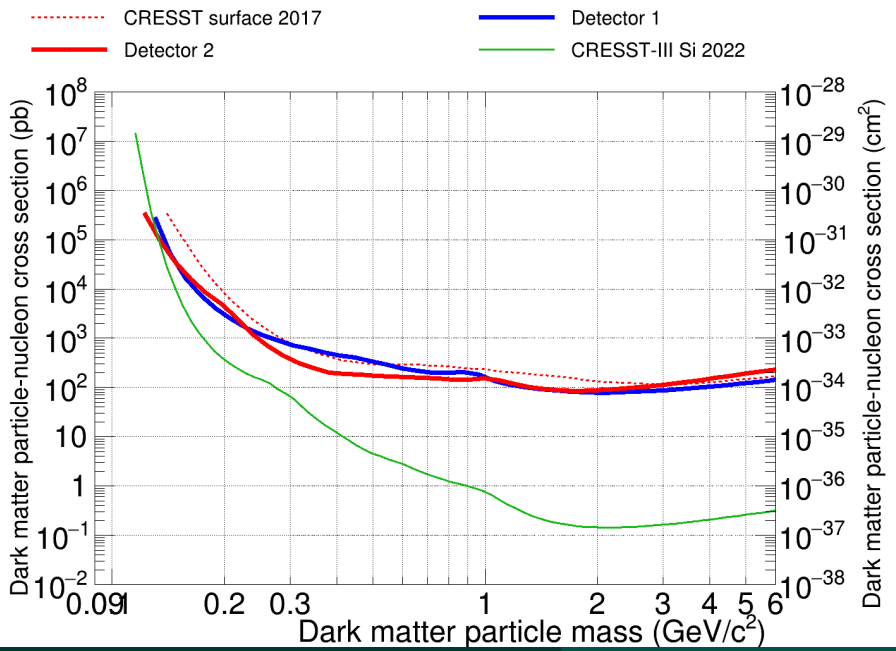


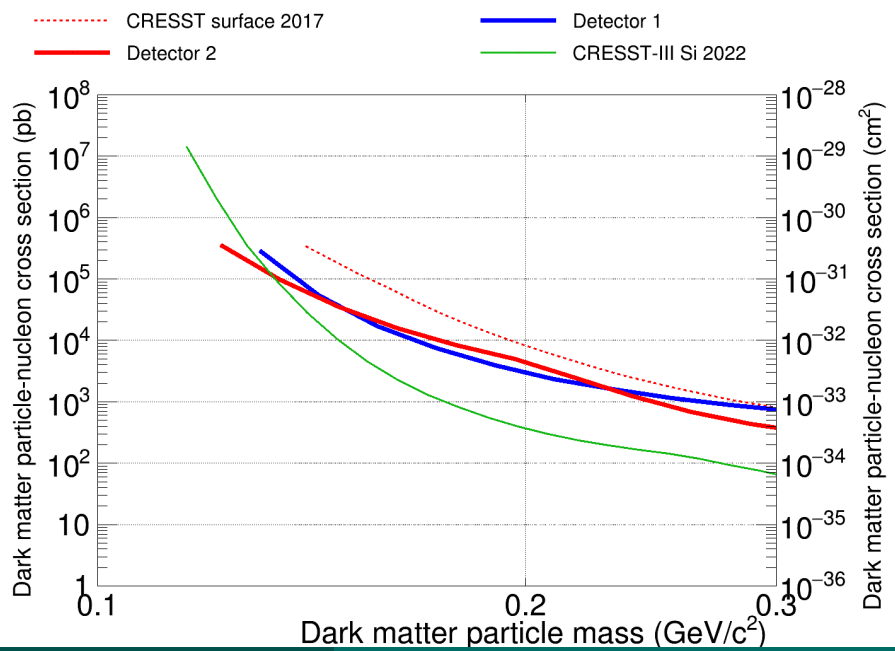
- the trigger threshold is chosen accepting a certain number of noise triggers
- detector 1 has a threshold of 14.9mV which corresponds to **19.7 eV**
- detector 2 has a threshold of 18.7mV which corresponds to **16.8 eV**
- Energy resolutions: 3.54 eV (Det1) and 3.42 eV (Det2)

Calculation of exclusion limits

- With the final calibrated spectrum we can then calculate exclusion limits
- Very good results for a proof of principle measurement







Summary

- Diamonds have characteristics that are very promising for sub-GeV dark matter searches
- With a very basic setup we could reach the extremely low energy threshold of 16.8 eV
- With this first tmeasuremtn we coul already improve our previous best above ground limits
- For the future we plan another improved measurement

Ways of improvement

Our electronic readout was limited from the fast risetime of the diamond's pulses

- Try to use a TES with a reduced size
- Get a faster readout

Thank you for your attention!

BACKUP

Calibrationmethod

- the reconstructed voltage values were converted to the corresponding injected voltage of the heater pulses
- events coming from the calibration source were fitted to determine the conversion from injected voltage to incoming energy