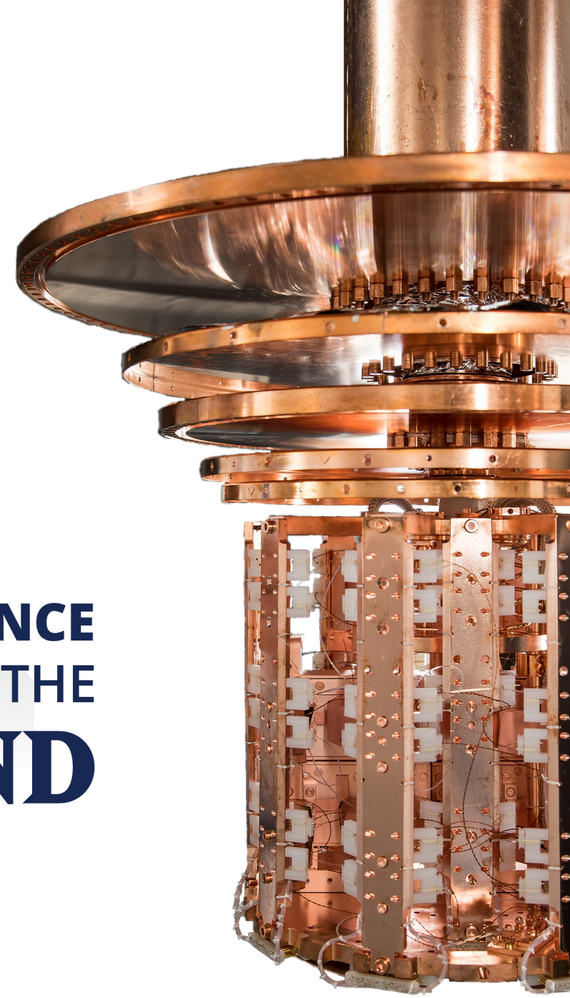
Dark Matter search with the CRESST-III experiment

Stefano Di Lorenzo
on behalf of the CRESST collaboration

CONFERENCE **ON SCIENCE** AT THE
SANFORD UNDERGROUND RESEARCH FACILITY

South Dakota Mines campus, May 11-13, 2022

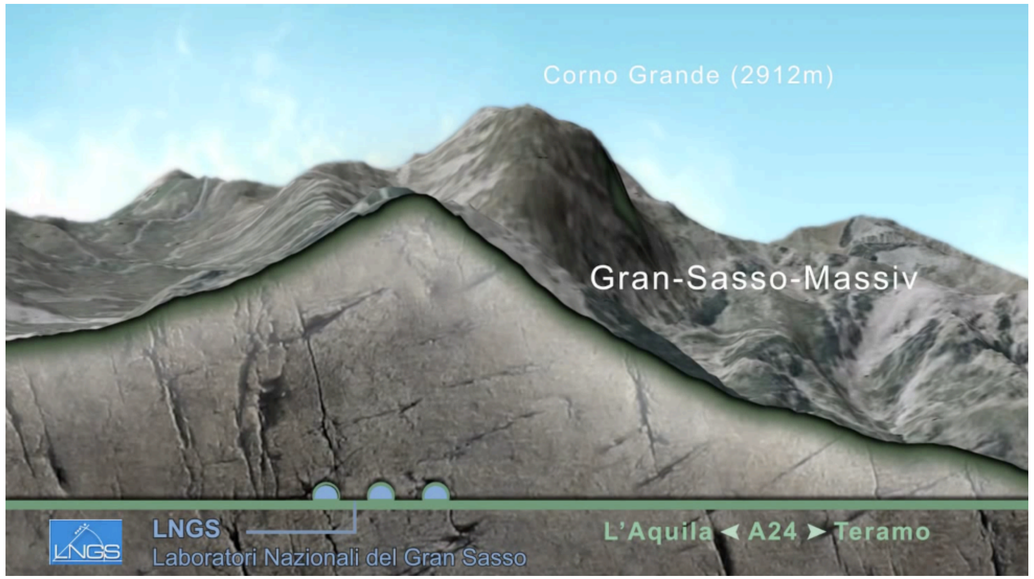


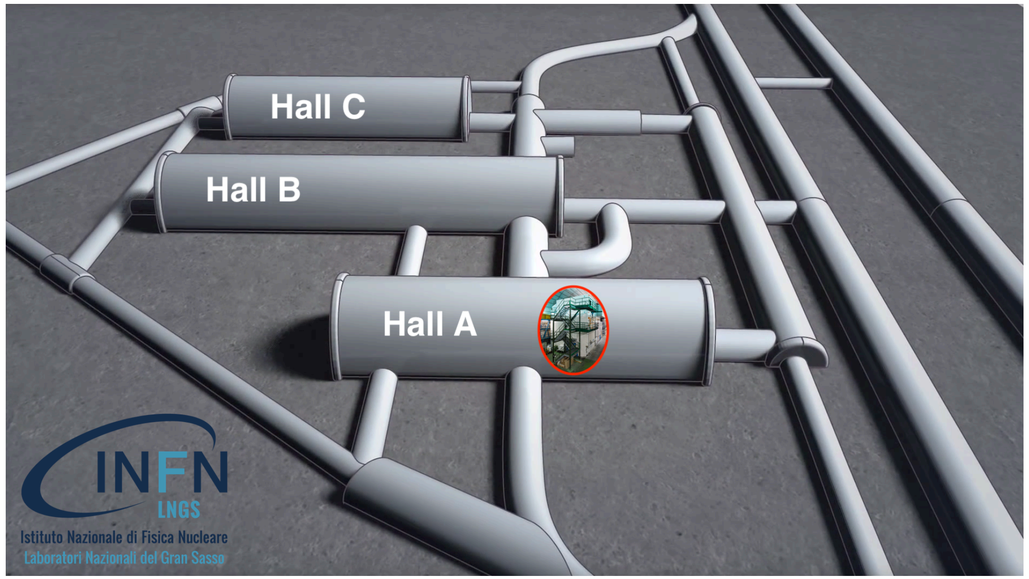
CRESST

CRESST experiment

Cryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers is located at the Laboratori Nazionali del Gran Sasso.

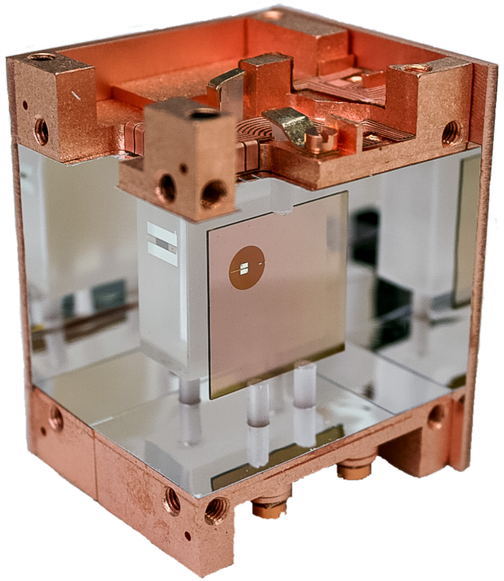
Rock overburden ~1400m in all directions (3800 m.w.e)

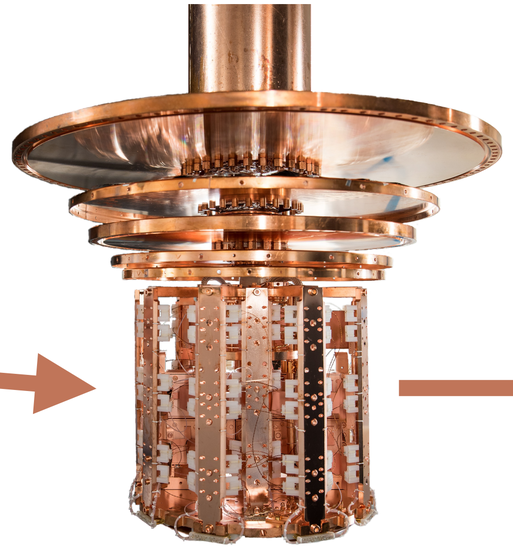


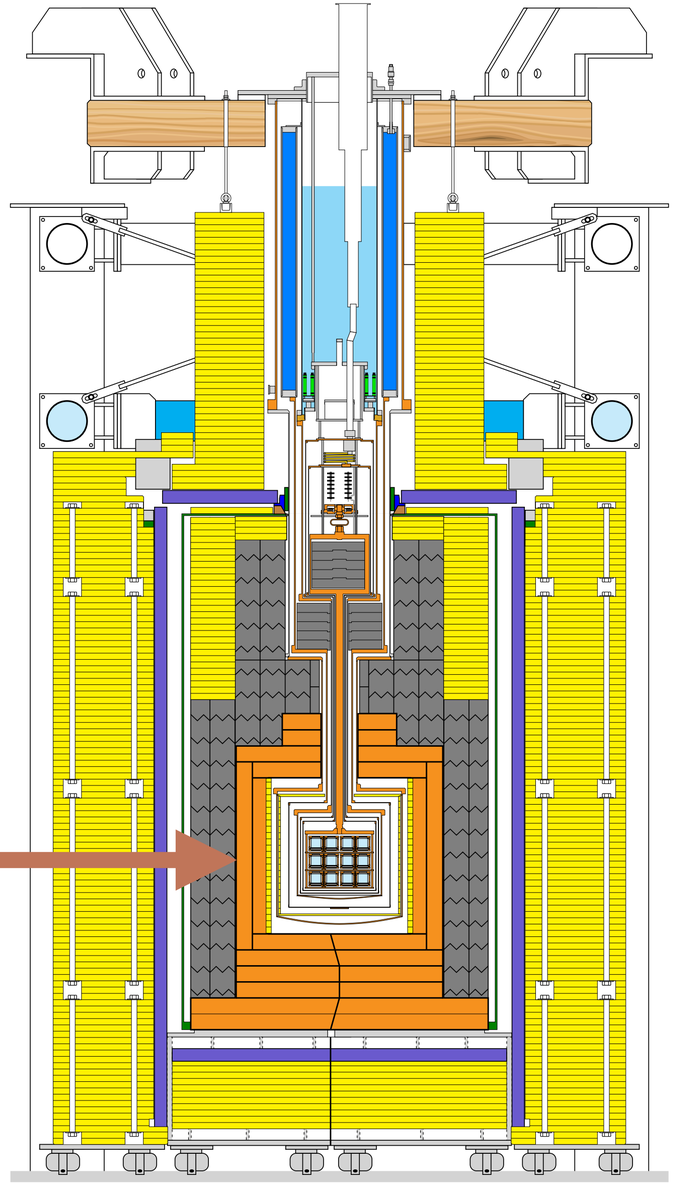


The CRESST experiment

CRESST goal: direct detection of dark matter particles via their scattering off target nuclei

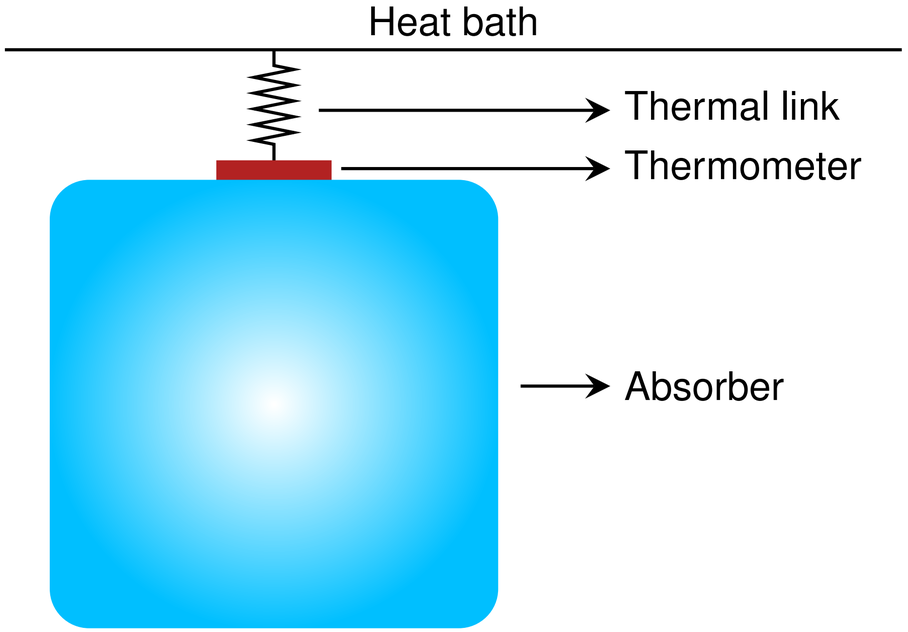


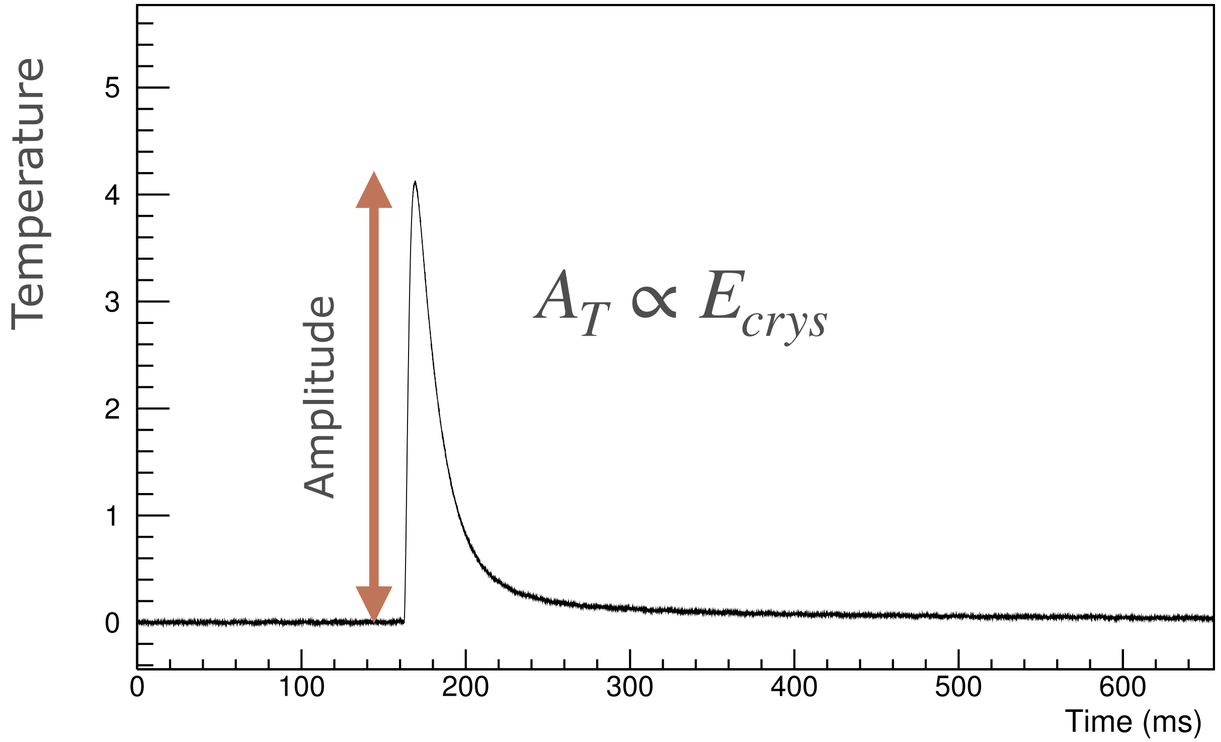




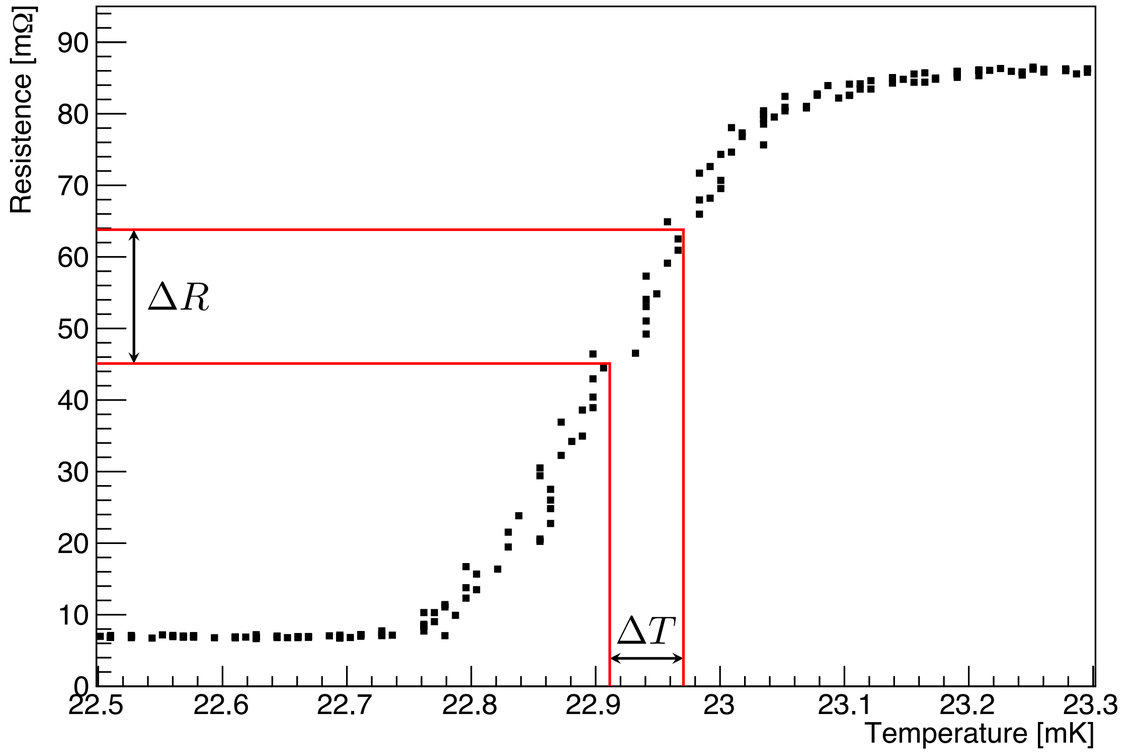
Working Principle

The CRESST detectors are cryogenic calorimeters operated ~15mK

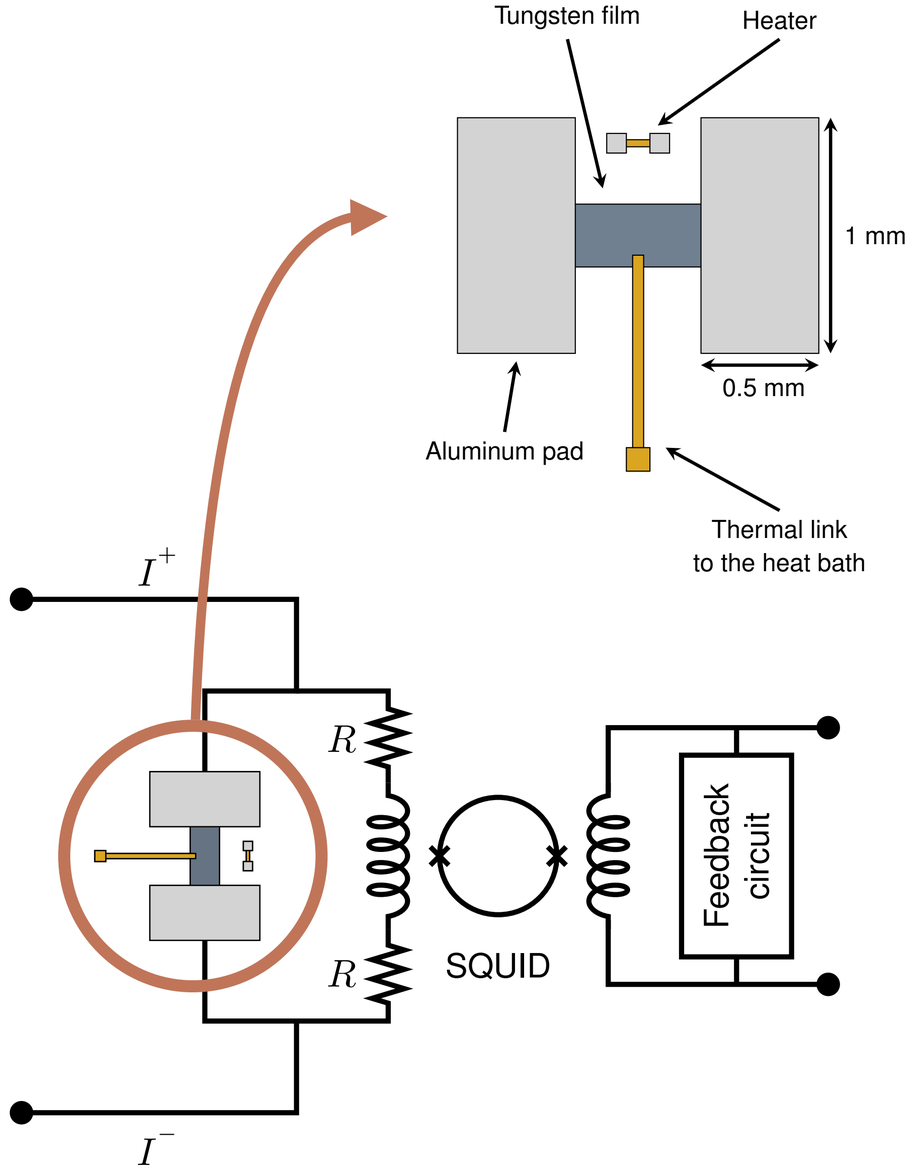




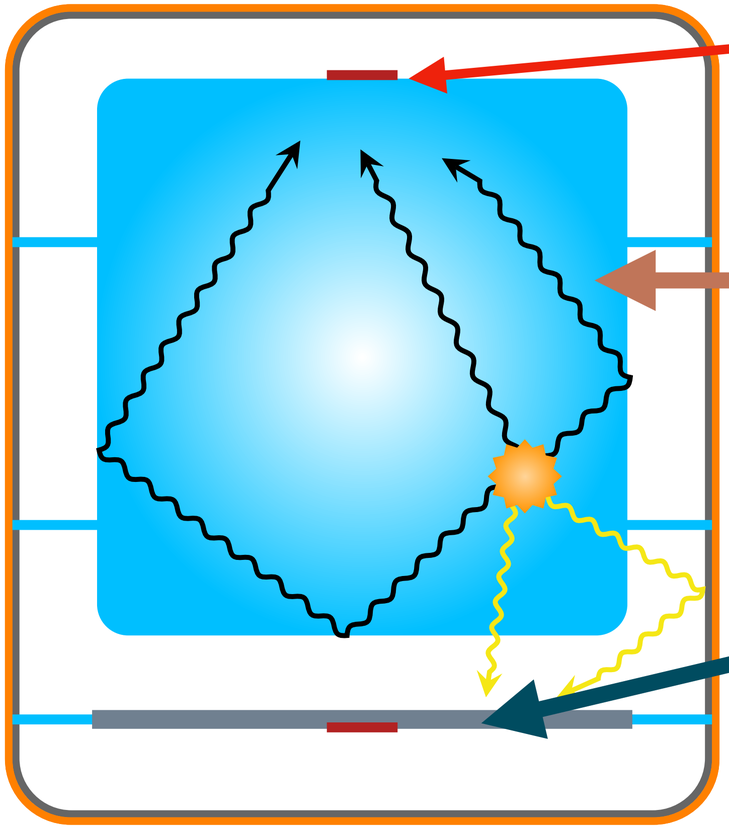
Transition Edge Sensor



$$E \sim \text{keV} \Rightarrow T \sim \mu\text{K} \Rightarrow R \sim \text{m}\Omega$$



CRESST Detector



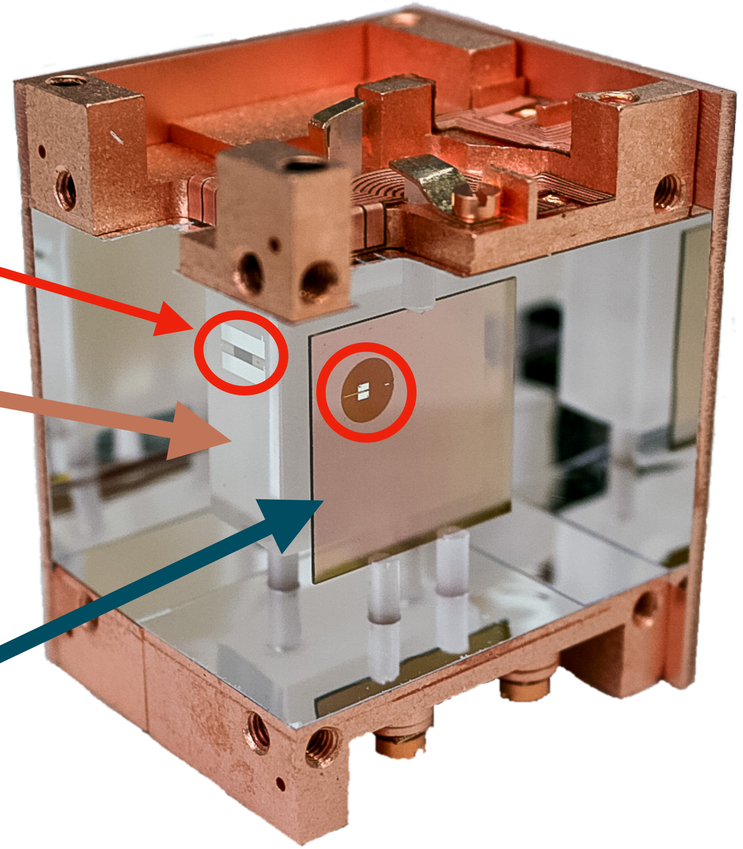
TES

Absorber Crystal

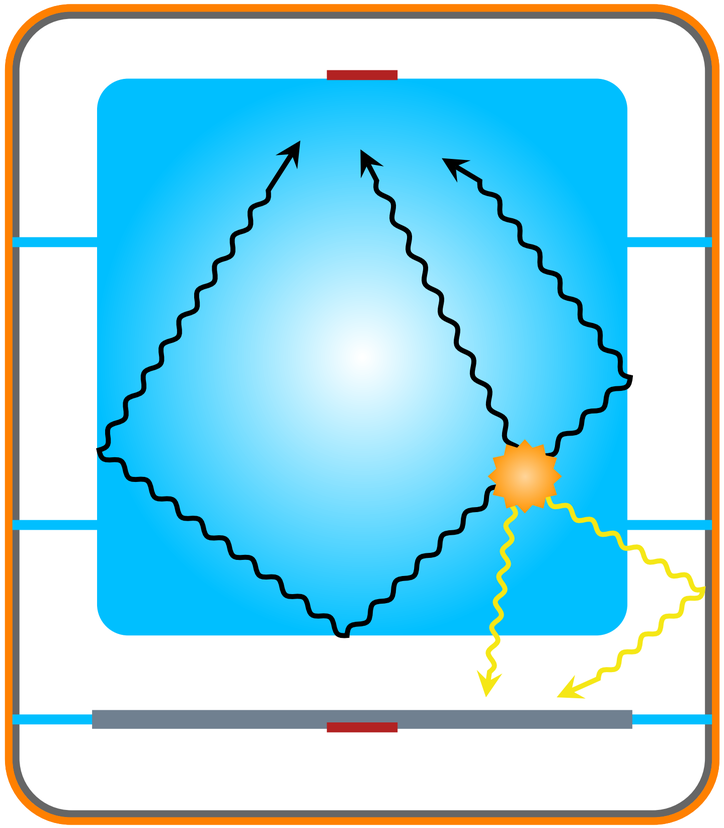
$CaWO_4$, Al_2O_3, $LiAlO_2$, (Si)

Light Detector

Silicon on Sapphire



CRESST Detector



Phonon signal

- Most energy released in this channel (~90%)
- Energy released is (almost) particle independent

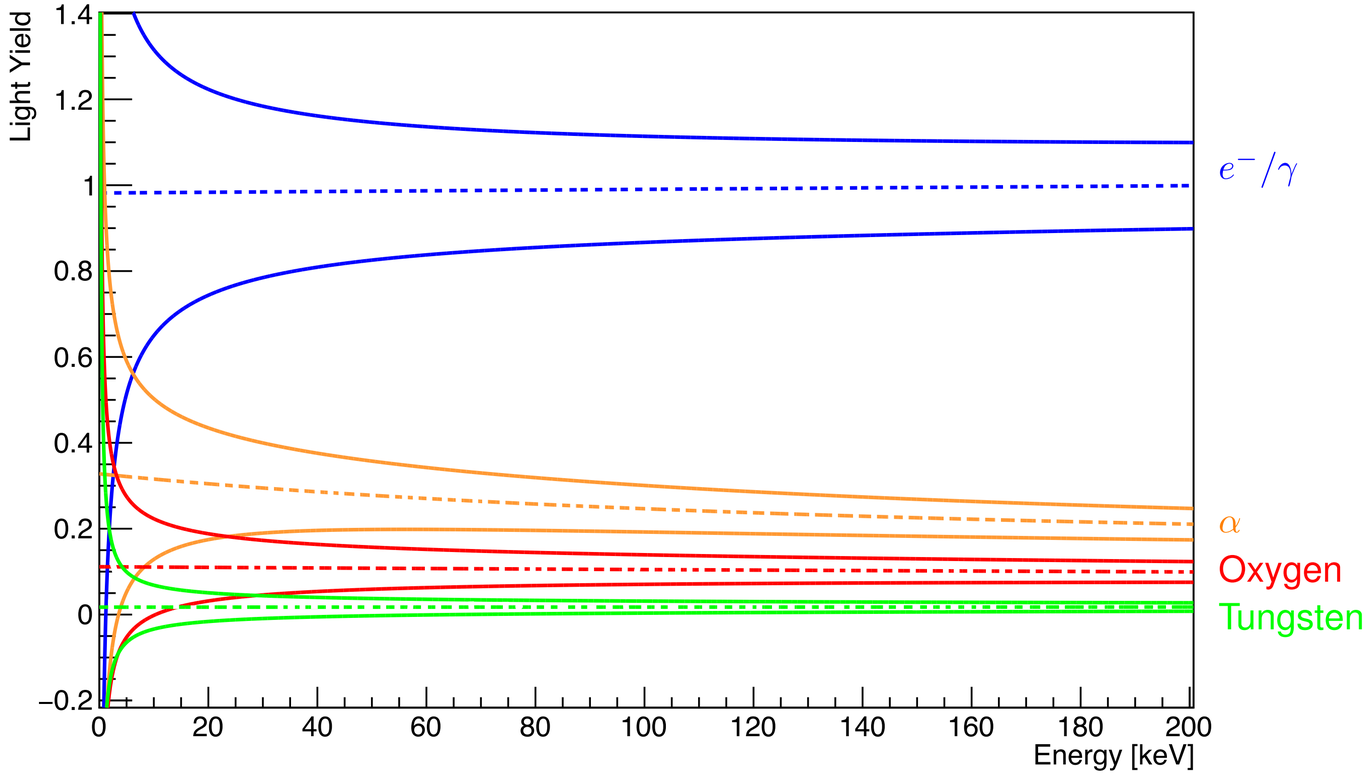
Light signal

- few % of the energy released as scintillation light
- particle dependent ⇒ event discrimination

Event Discrimination

$$LY = \frac{\text{Light signal}}{\text{Phonon signal}}$$

Excellent discrimination between potential signal events and dominant radioactive background



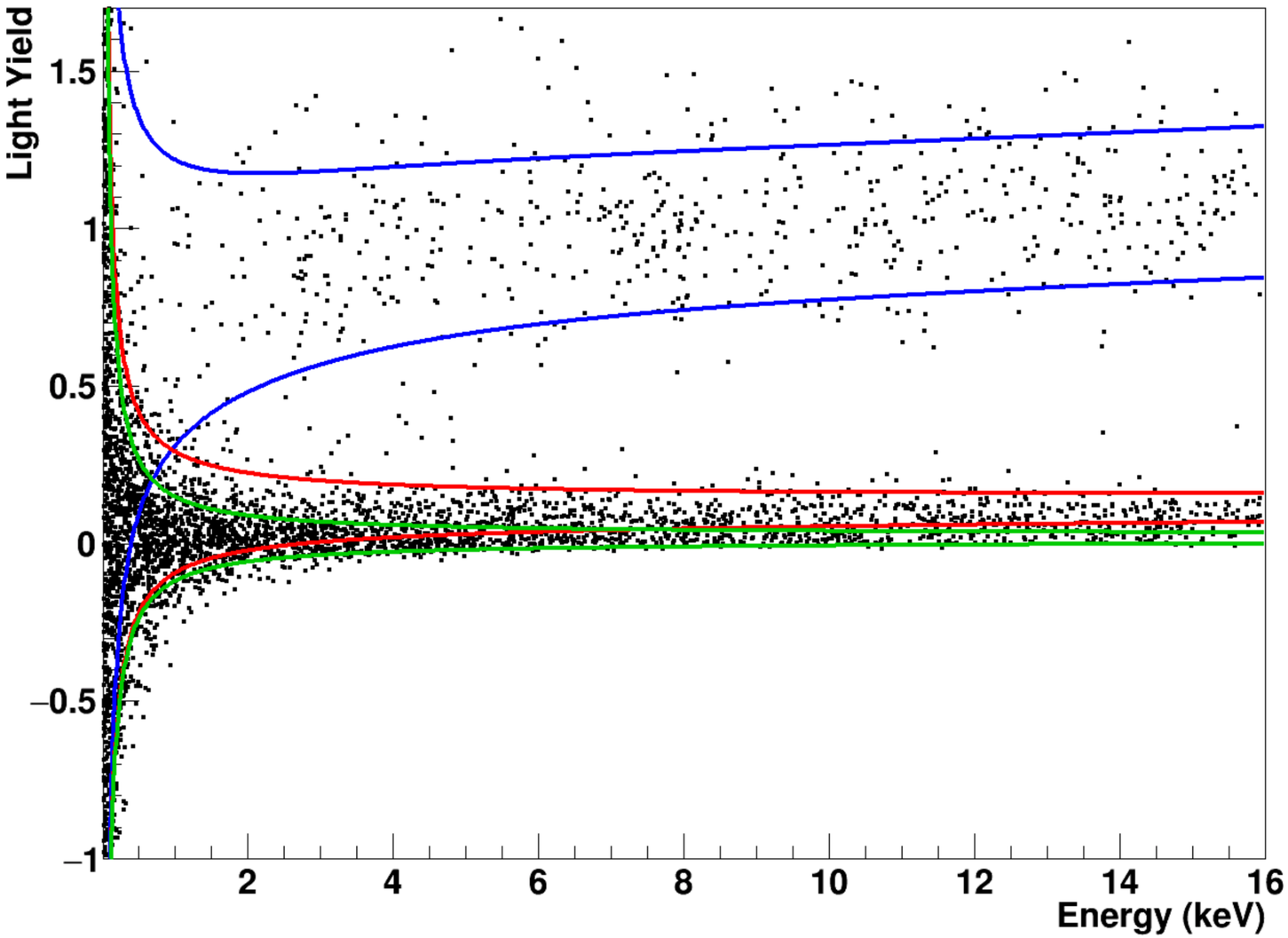
Neutron Calibration

Dedicated neutron calibration campaign to precisely fit the electron and nuclear recoil bands.

Quenching factor measured with dedicated Runs at MLL in Garching

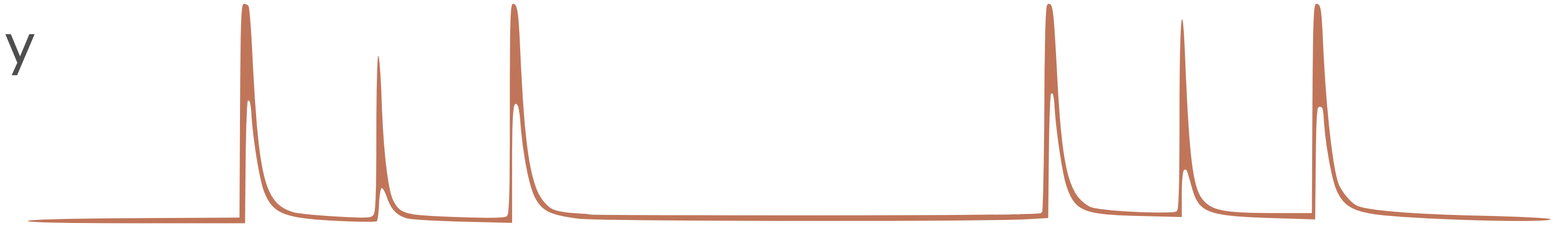
Event	QF^{-1}
e/γ	1.00
α	2.7
O	8.03 ± 0.32
Ca	15.2 ± 1.0
W	51.0 ± 5.7

Eur. Phys. J. C (2014) 74

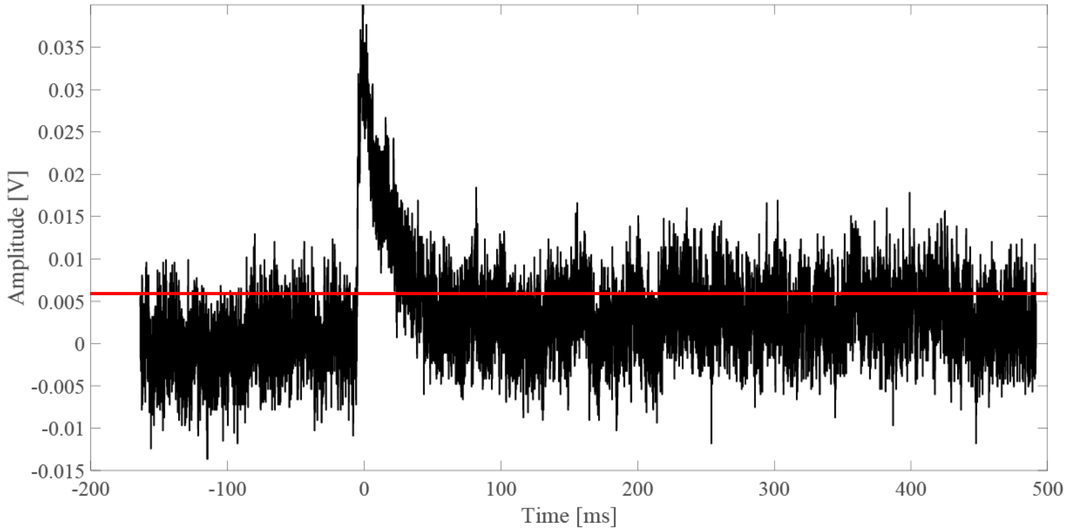


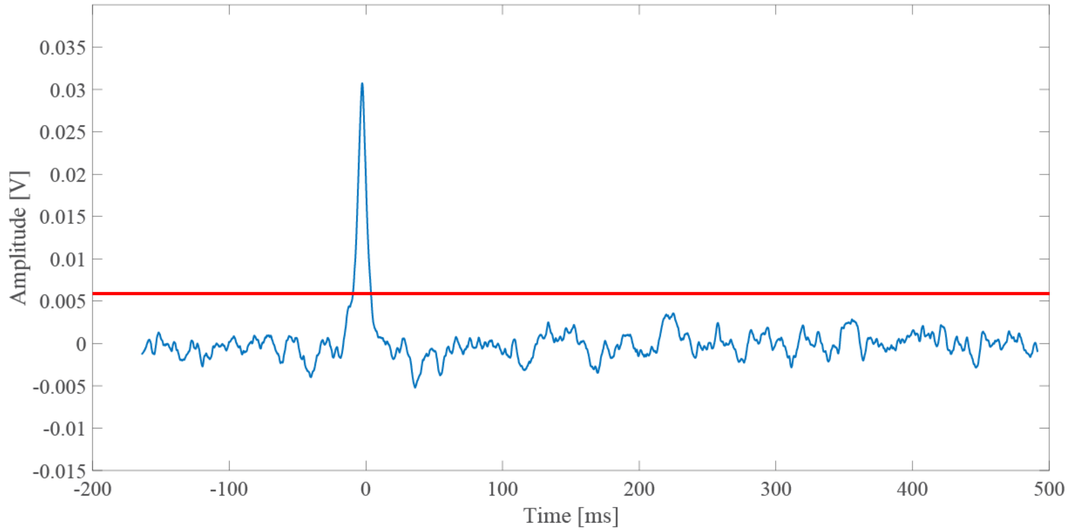
Data Acquisition

Data stream continuously stored on disk



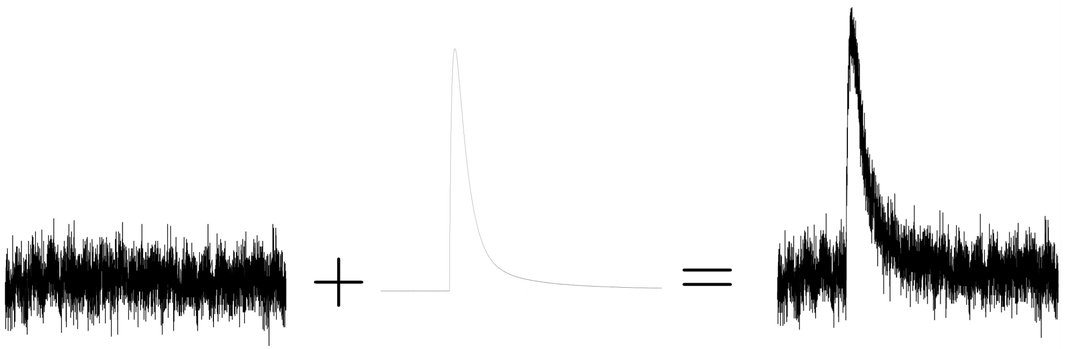
Optimum Filter trigger algorithm applied to the data-stream



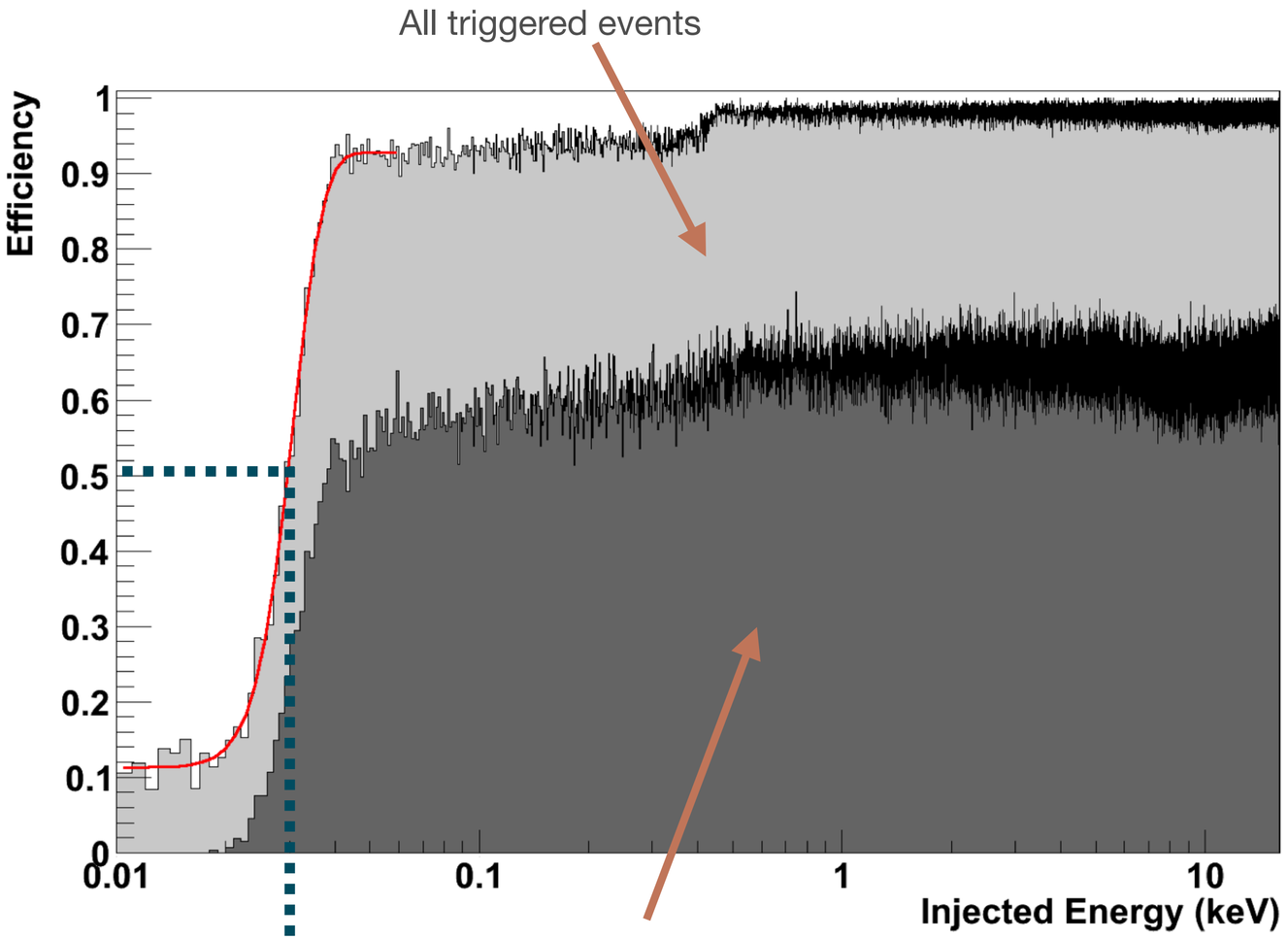


Efficiency & Threshold

To measure efficiency simulated events are created by superimposing the standard event onto the continuous data stream at randomly selected points in time.



Efficiency ≳ 60 % over a wide energy range



Best performing module Detector A
Energy Threshold = 30.1 eV

(= 1 noise event triggered 1 c/kg/day)

Phys.Rev.D 100 (2019) 10, 102002

Data Analysis

Blind analysis

- Cuts optimized on non-blind training data set (~20% of the data randomly selected)
- Applied without change to the **blind** dataset

Stability: detector in the correct operating point

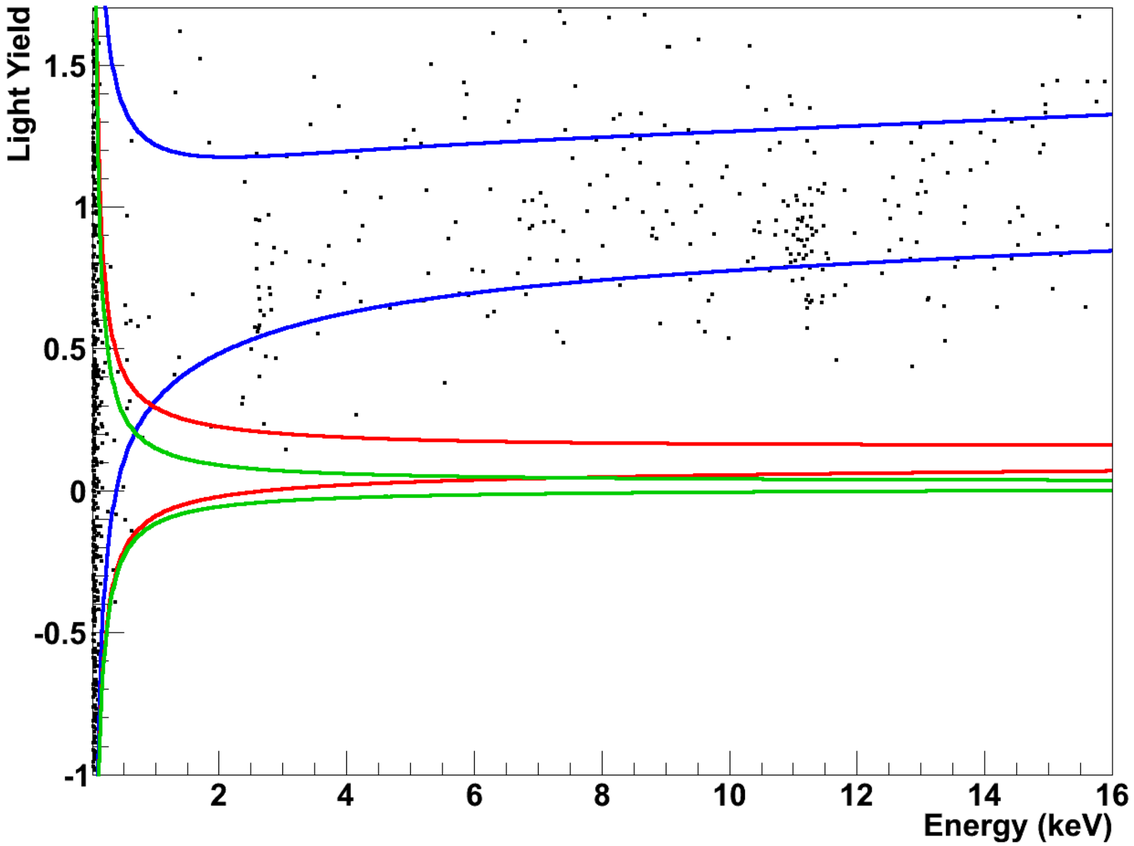
Rate: noise condition

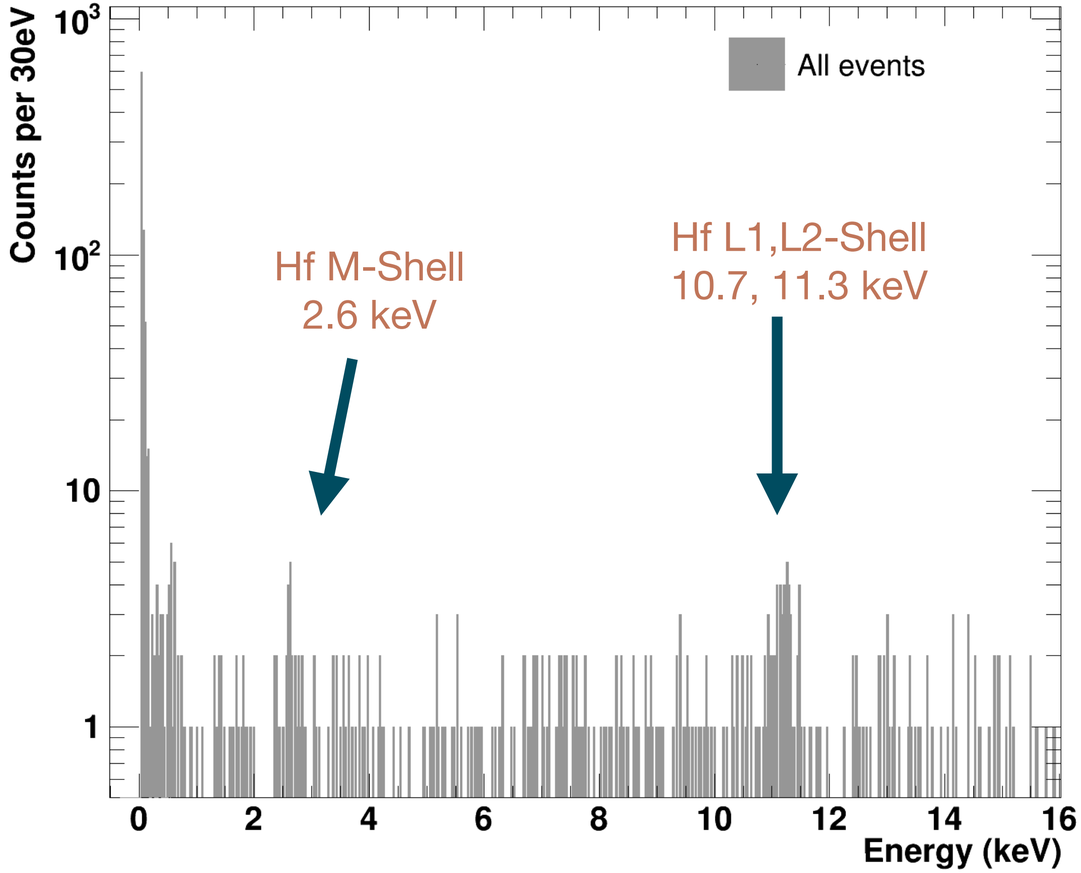
Coincidences : μ-veto, events in other detectors

Data Quality: non standard event (pile up, quantum flux loss...)

Run34 - Detector A

Data taking 05/2016 – 02/2018





Analysis optimized for very low energy: 30 eV ⇒16 keV

Unexpected rise at low energies

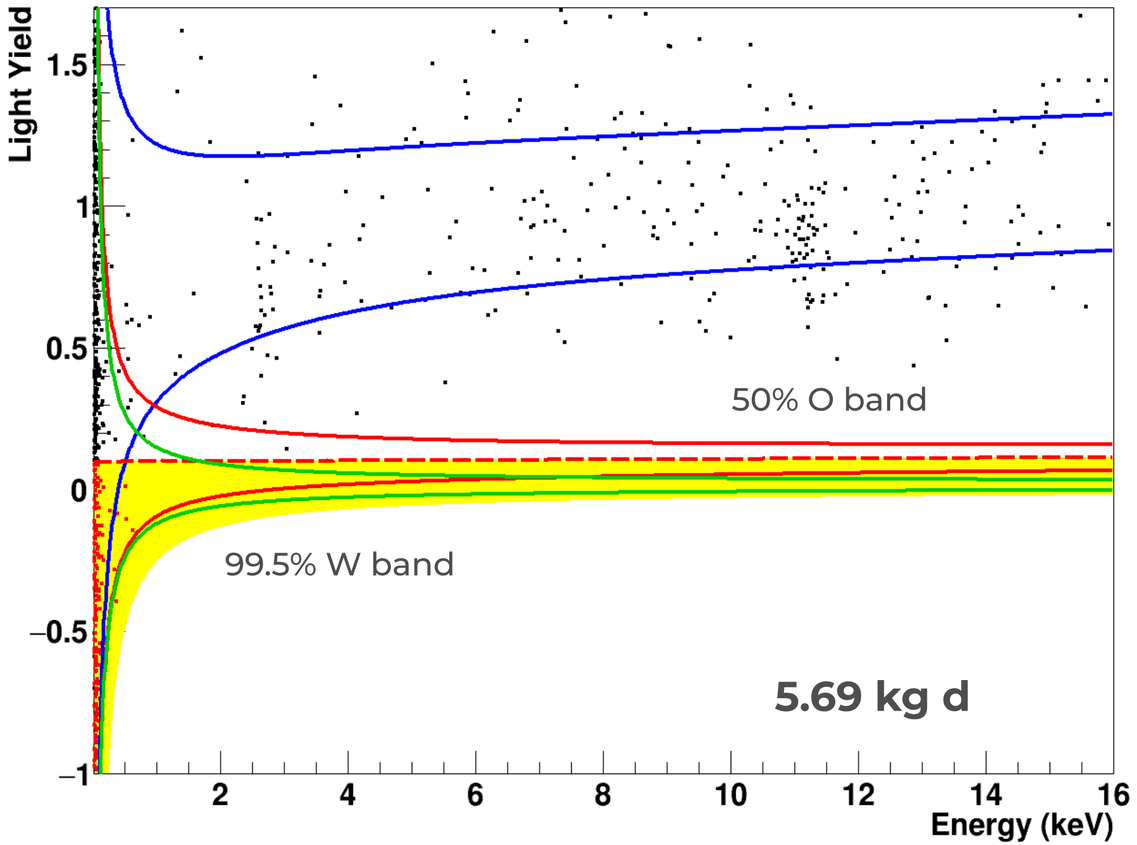
$^{182}\mathrm{W}(p,\alpha)^{179}\mathrm{Ta}$

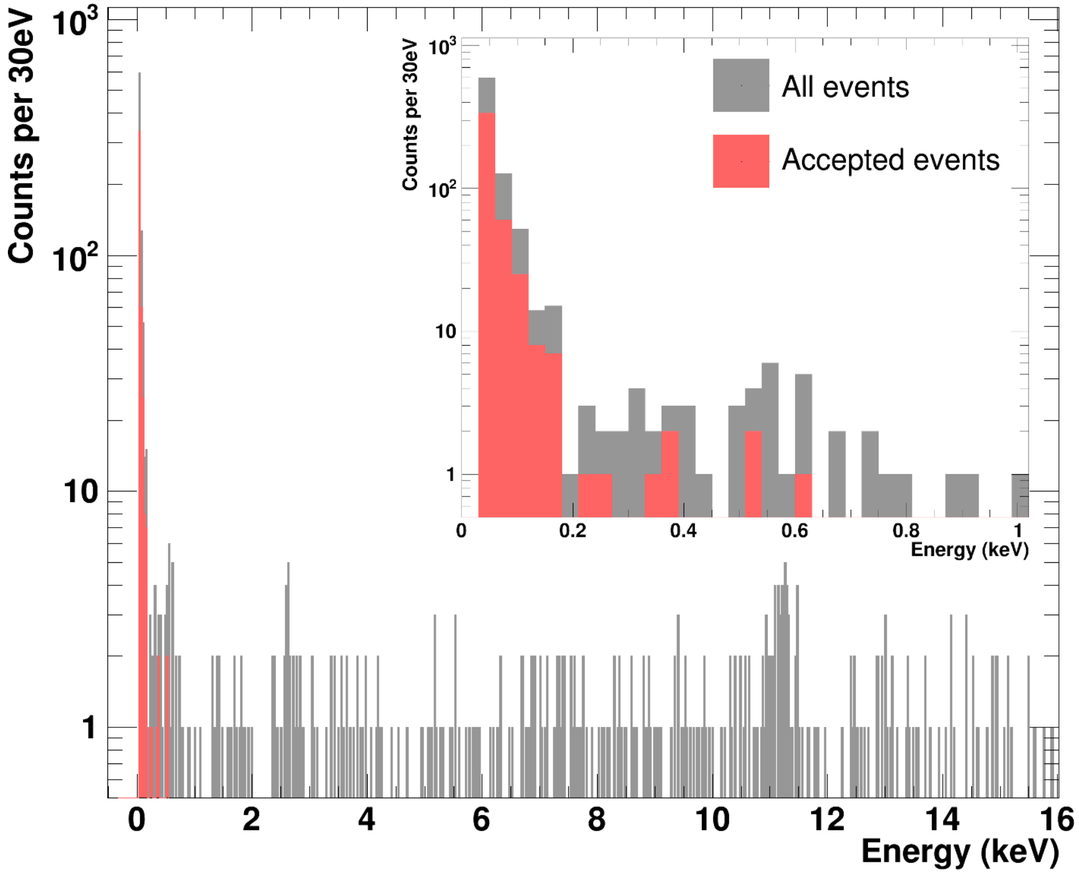
$^{179}\mathrm{Ta} + e^- \xrightarrow{1.82\mathrm{y}} {}^{179}\mathrm{Hf} + \nu_e$

Phys.Rev.D 100 (2019) 10, 102002

Run34 - Detector A

Data taking 05/2016 – 02/2018





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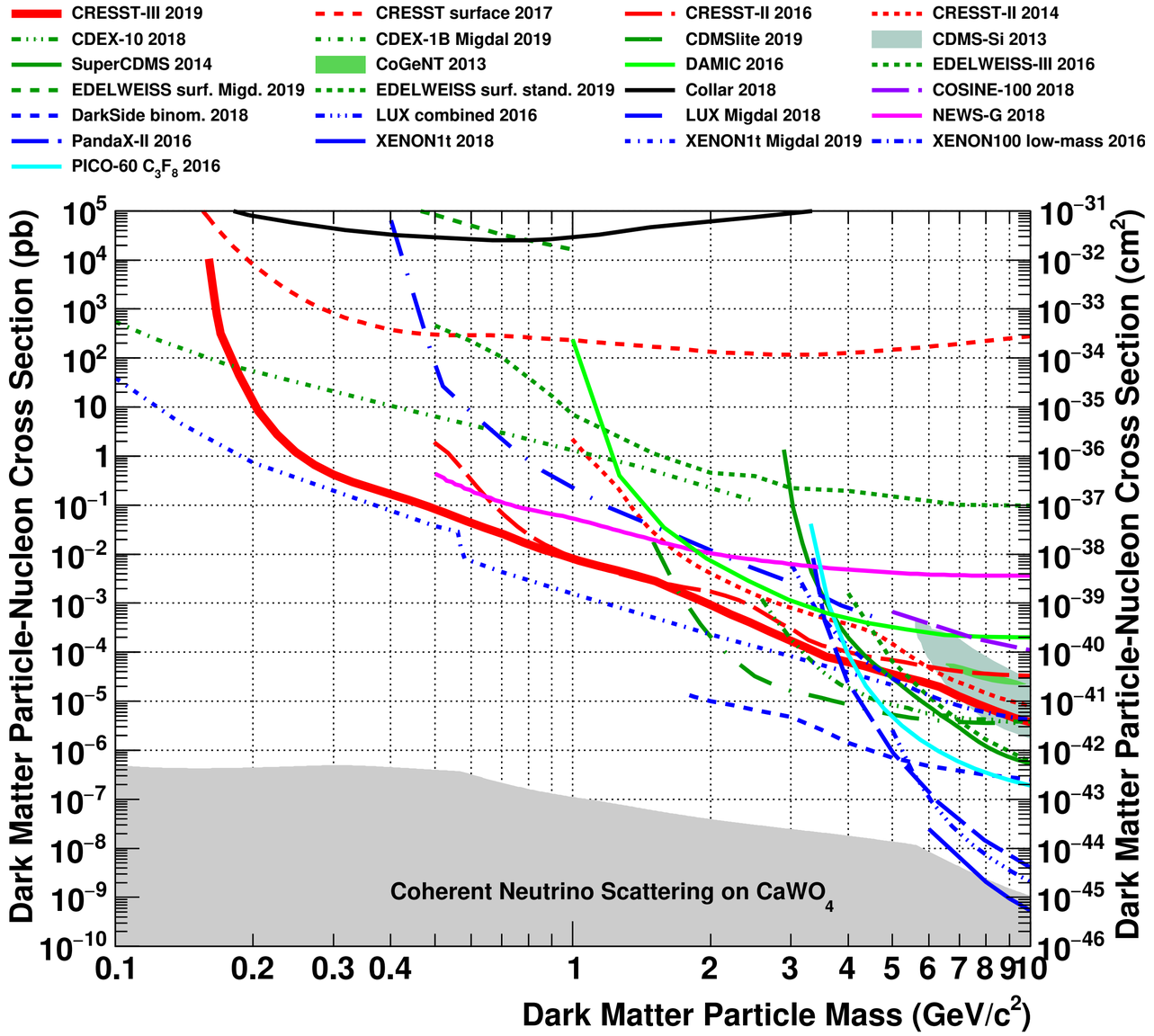
Exclusion Limit

Comparing the DM expected energy spectrum and the events in the ROI, we use 1D Yellin optimum interval method to compute the exclusion limit:

- Improved limit a 0.5 GeV/c²
- Extended reach from 0.5 to 0.16 GeV/c²
- Best Limit for mass below 1.7 GeV/c²*

*Not based on Migdal Effect



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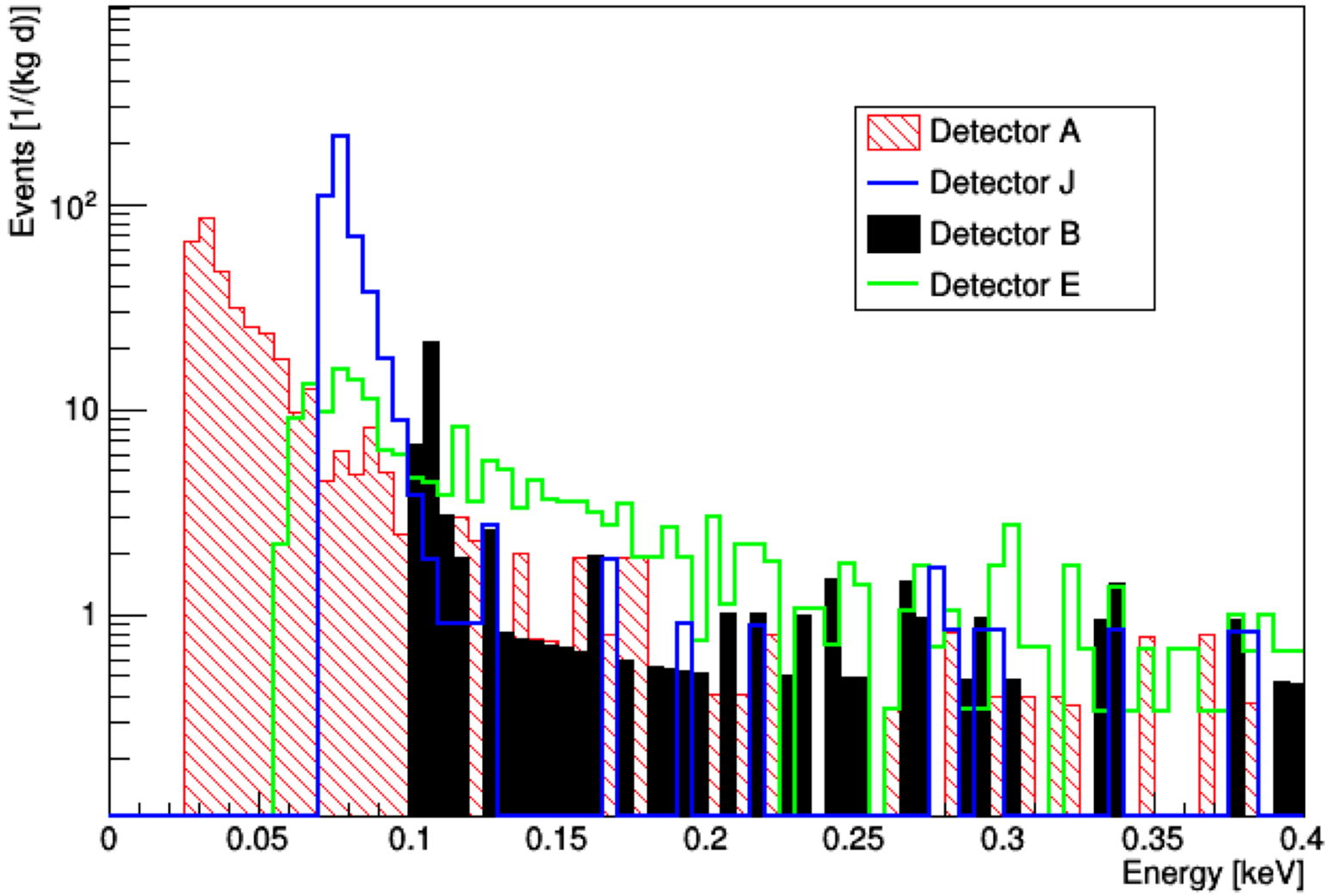
Run34 other $CaWO_4$ absorbers



PhD Thesis, M. Stahlberg, TU Wien (2020)

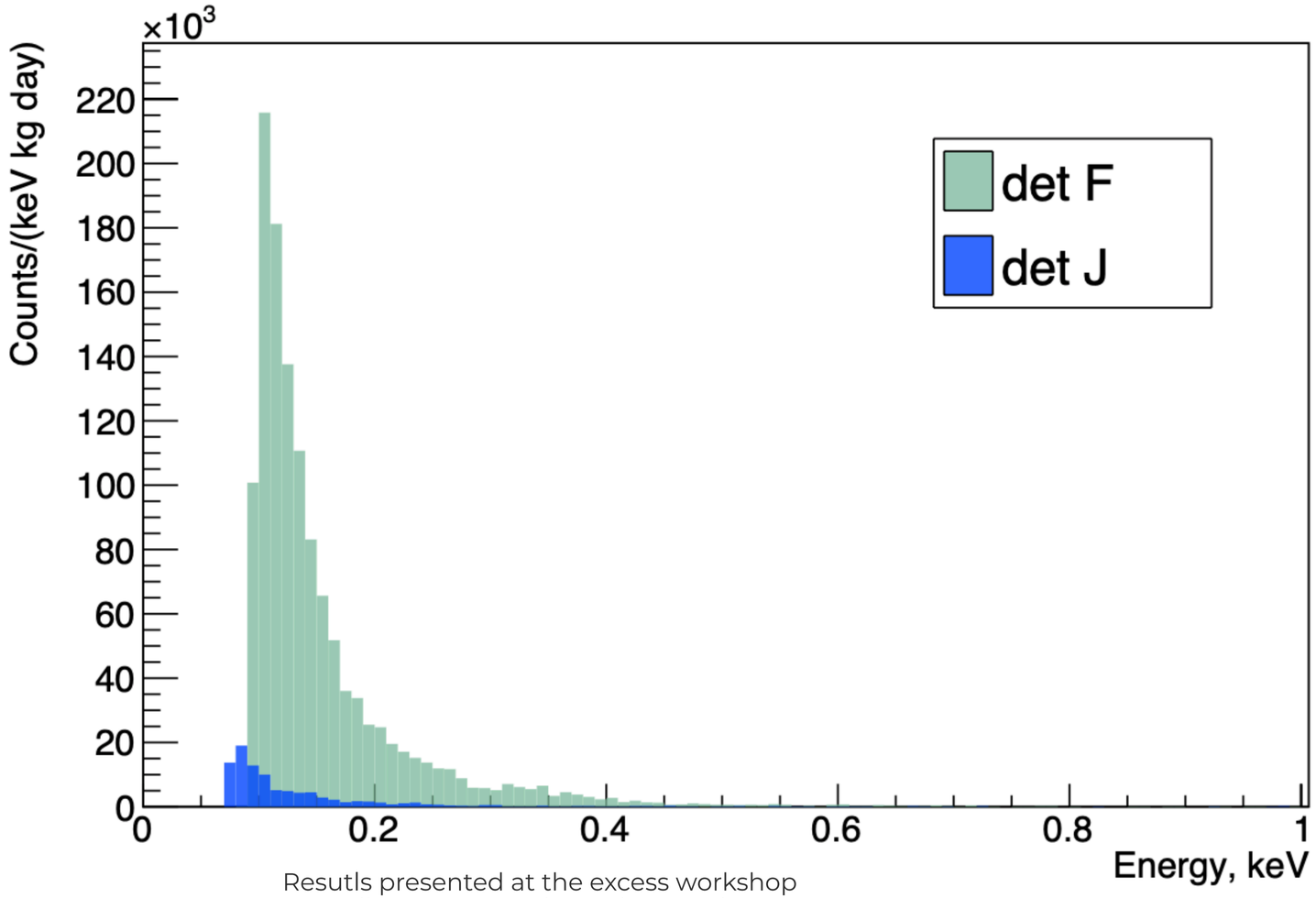
Detector	Threshold (eV)
Det A	30.1
Det B	120
Det E	64.8
Det J	83.4

Low energy excess in similar detectors but with different shape

Not single external common origin

Run 35 - Sapphire absorbers

Data taking 11/2018 – 10/2019



Resutls presented at the excess workshop
https://indico.cern.ch/event/1013203/

Both crystals cut from same sapphire crystal used in CRESST-I

Same detector configuration, but detector F has a much higher rate.

Threshold

76.9 eV (Det-F)

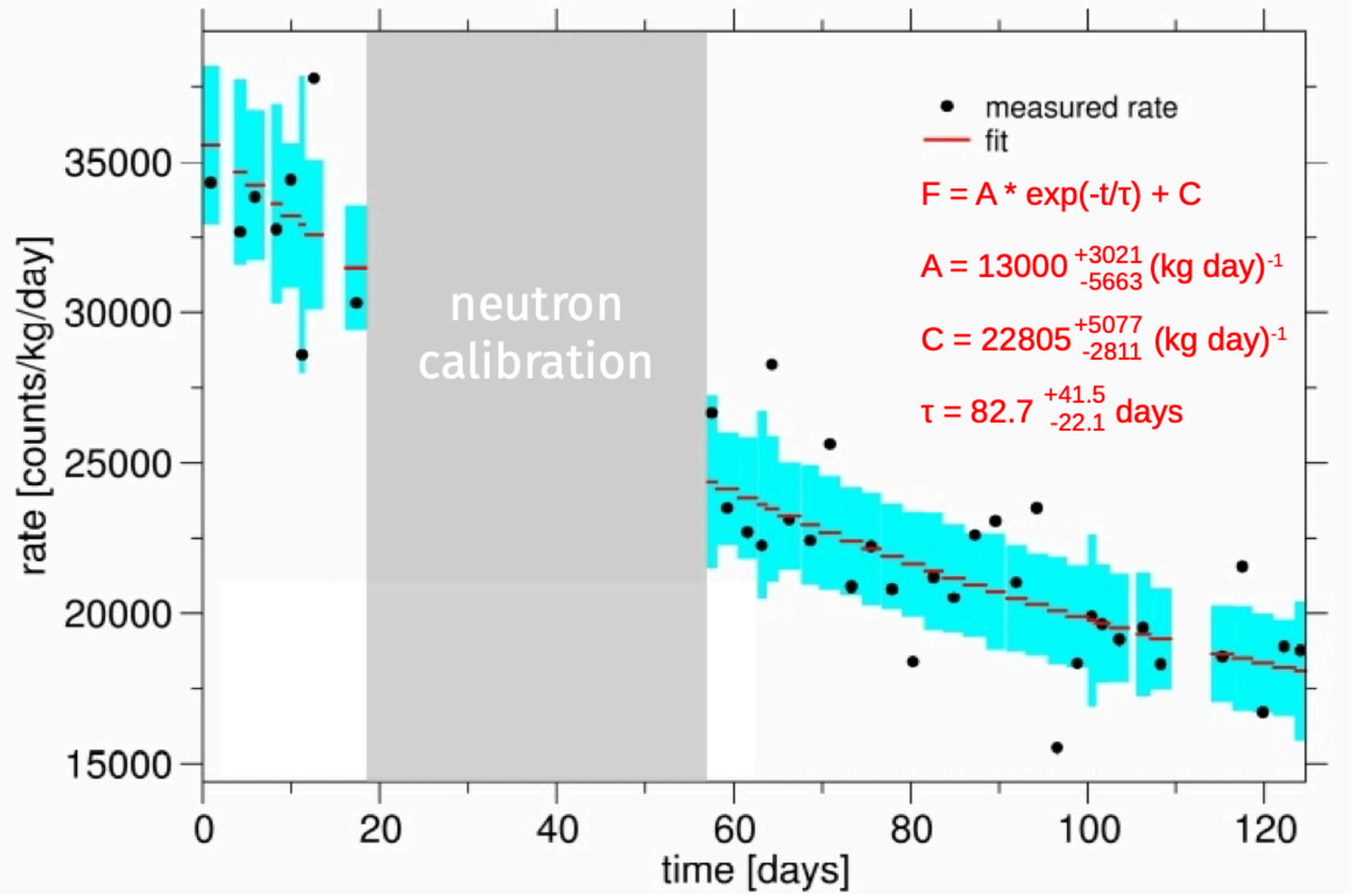
66.5 eV (Det-J)

Exposure

0.995 kg days (Det-F)

0.970 kg days (Det-J)

LEE Time Dependance



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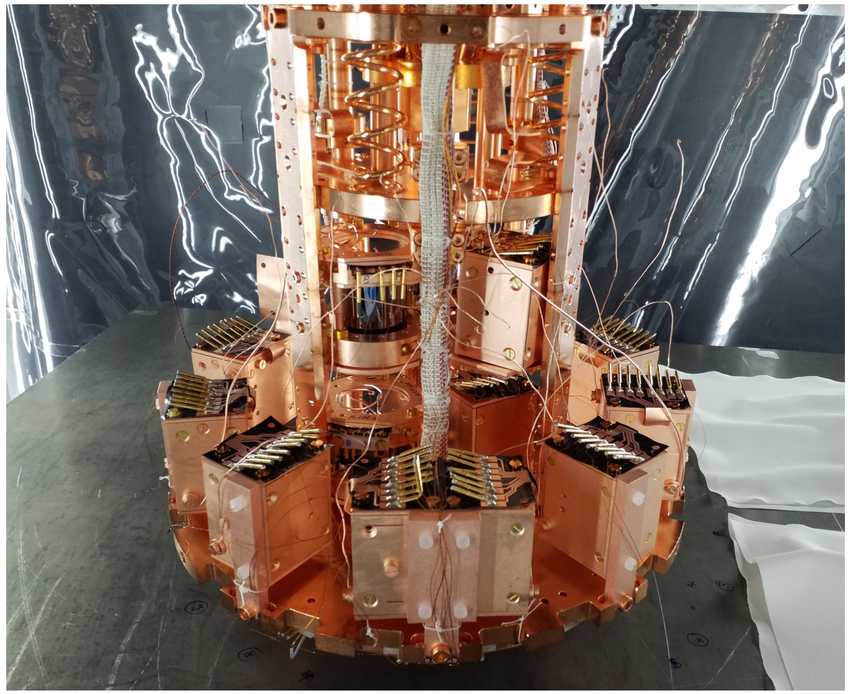
https://indico.cern.ch/event/1013203/

- Decreasing rate observed in sapphire detectors in Run 35.
- Here the rate of Det-J below 200 eV is shown.
- Similar behavior for Det-F.
- The same effect is also visibile in Detector A from Run34.
- Rate of calibration lines remains constant.

Understanding the Low Energy Excess

Dedicated setups with hardware modifications to disentangle the different contributions are currently installed in the CRESST cryostat

- Crystal material
- Crystal surface
- Holding
- Facing surfaces
- Thermal Cycle Effect



Future plans

Upgrade of CRESST-III to 288 channels

Final planning, prototyping and testing:

- SQUID
- wiring
- DAQ

Detector R&D

- lower threshold
- complementary target materials

- Upgrade of the setup at LNGS
- Detectors production and testing

Restart data taking

Summary and Conclusion

The CRESST cryogenic approach enables to obtain

- Leading results for the low mass DM search
- Unprecedented low energy threshold
- Possibility to use different target materials

Ongoing studies on the low energy excess

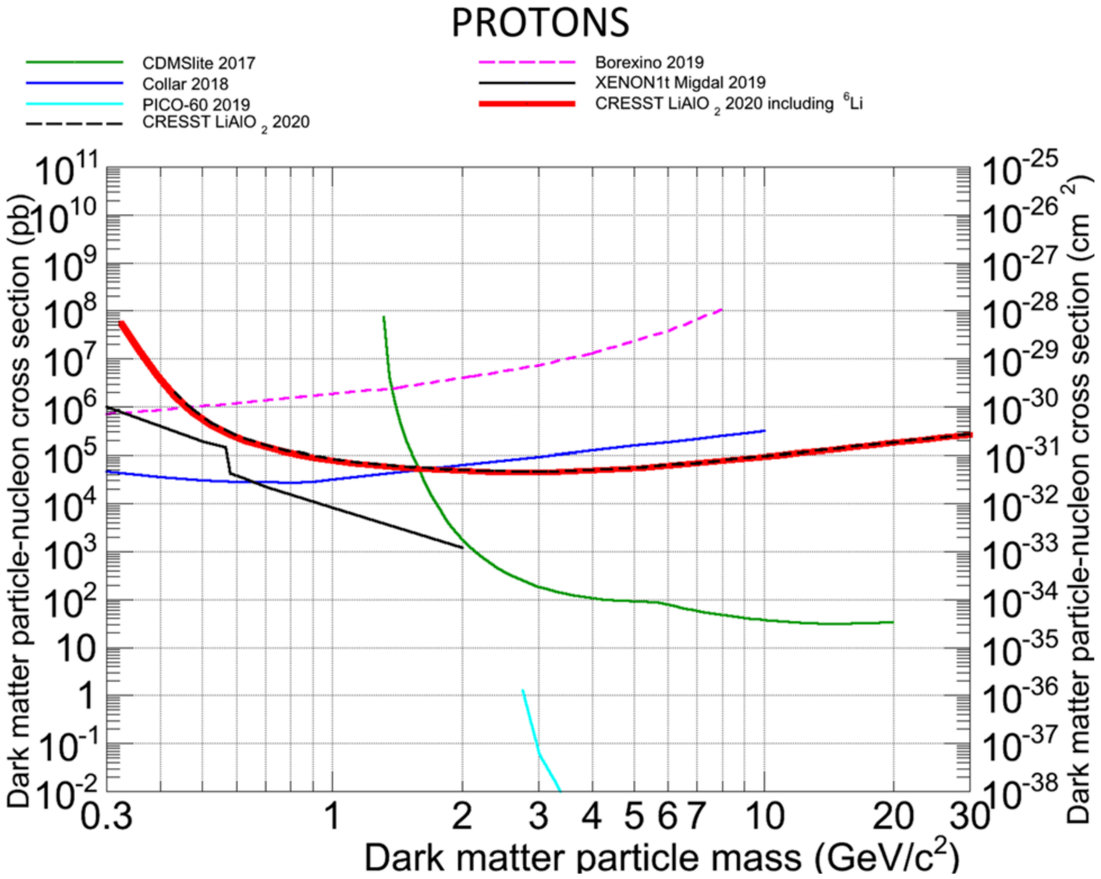
With the future upgrade we will have new **challenges** to face and new physics to explore

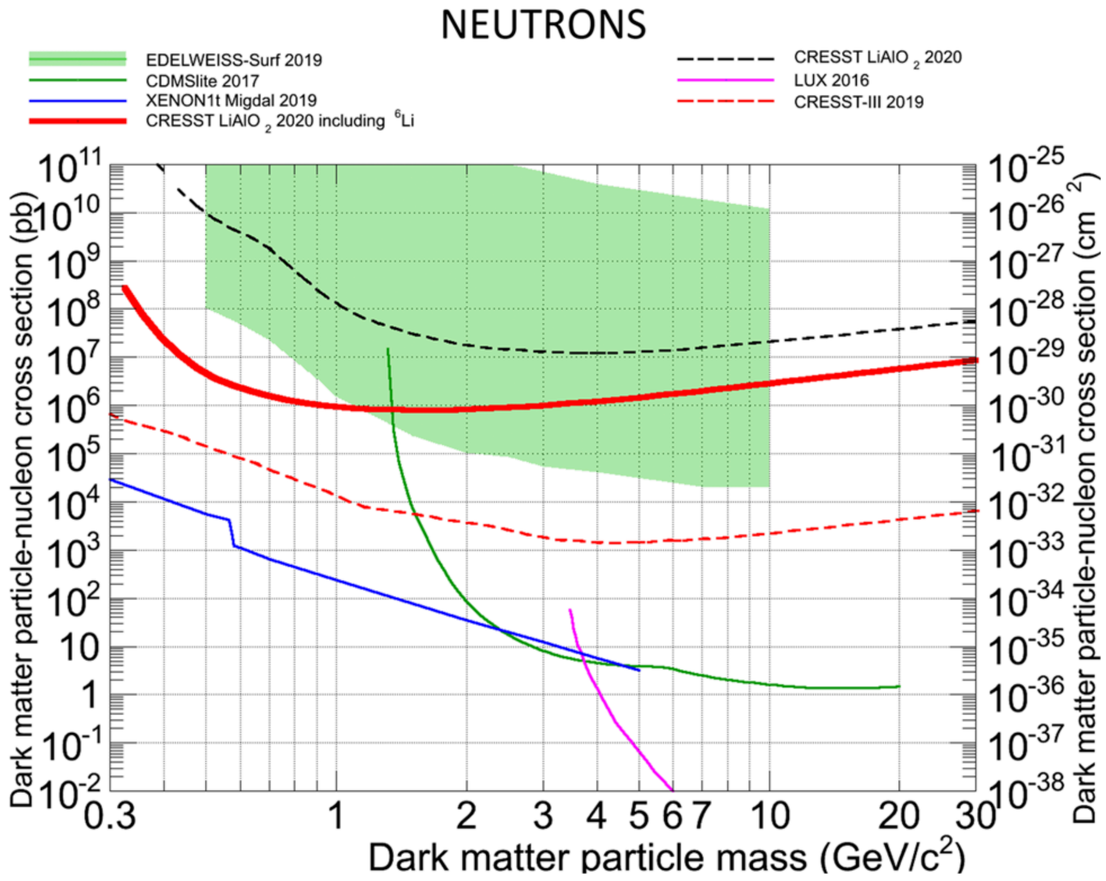
Thank you for the attention

Back Up

Spin Dependent Limit

Above ground constraint for spin dependent Dark Matter interaction



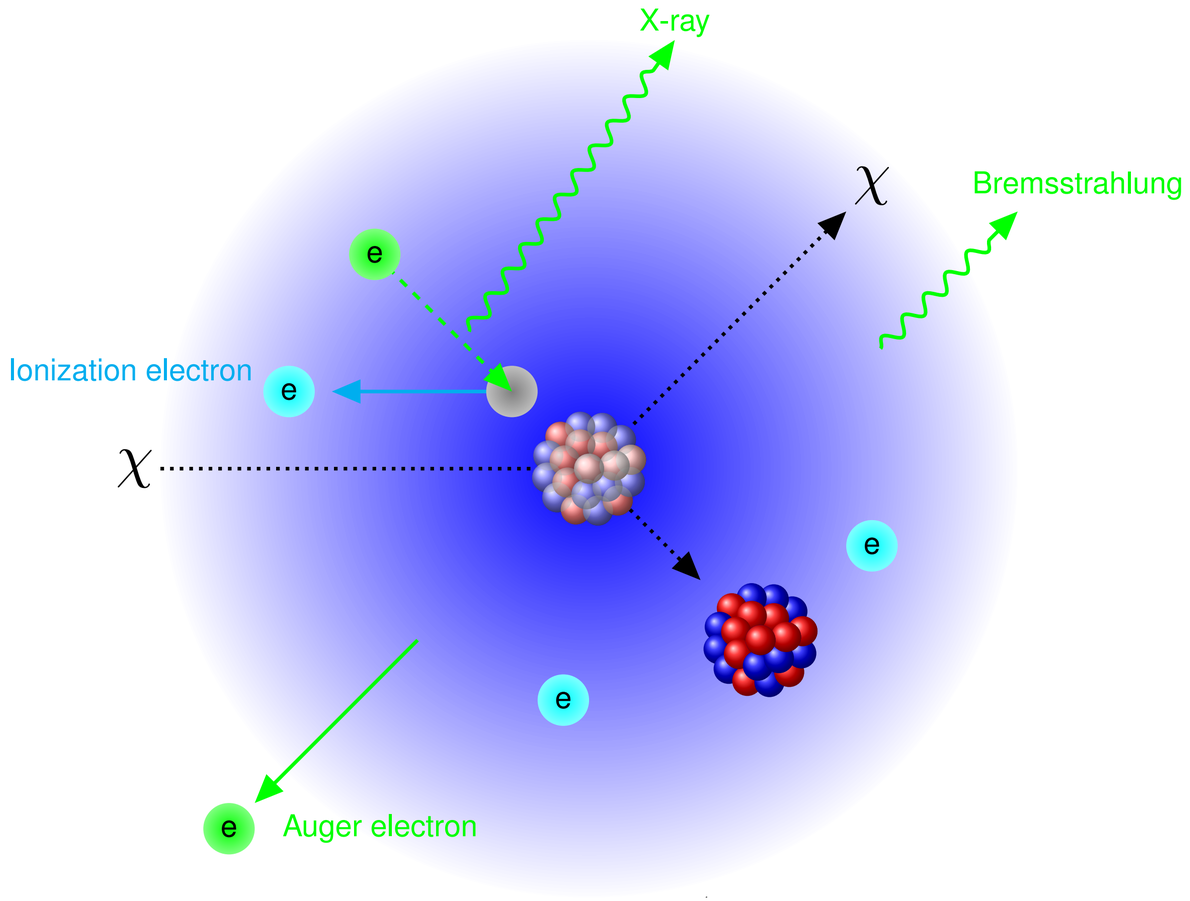


Eur.Phys.J.C 82 (2022) 3, 207

Migdal Effect

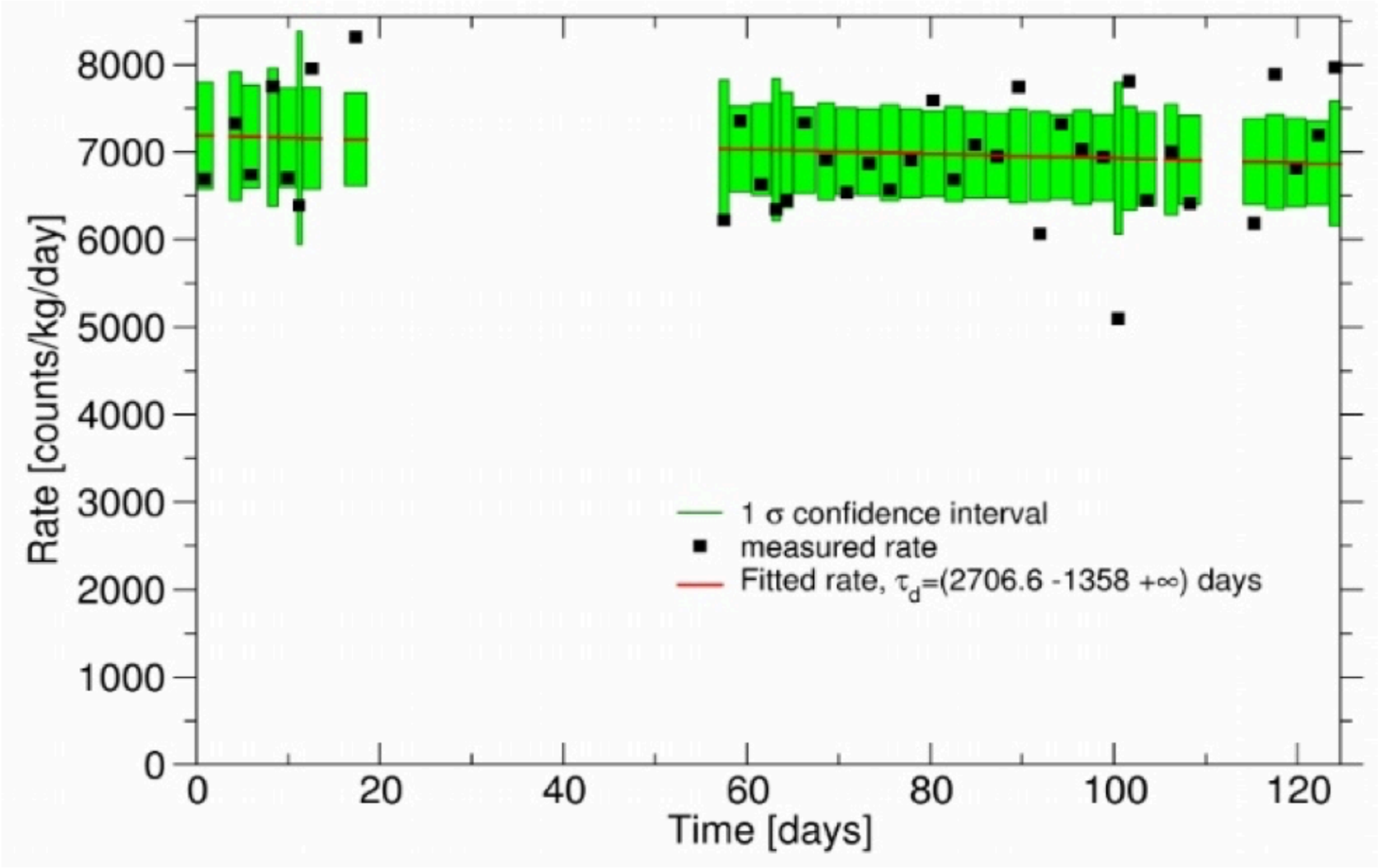
When a Dark Matter particle recoils off a target nucleus, the nucleus moves. The recoil produces a change in the electrons orbital function $\Psi \rightarrow \Psi'$.

The rearrangement of the electrons can result in different radiations produced .



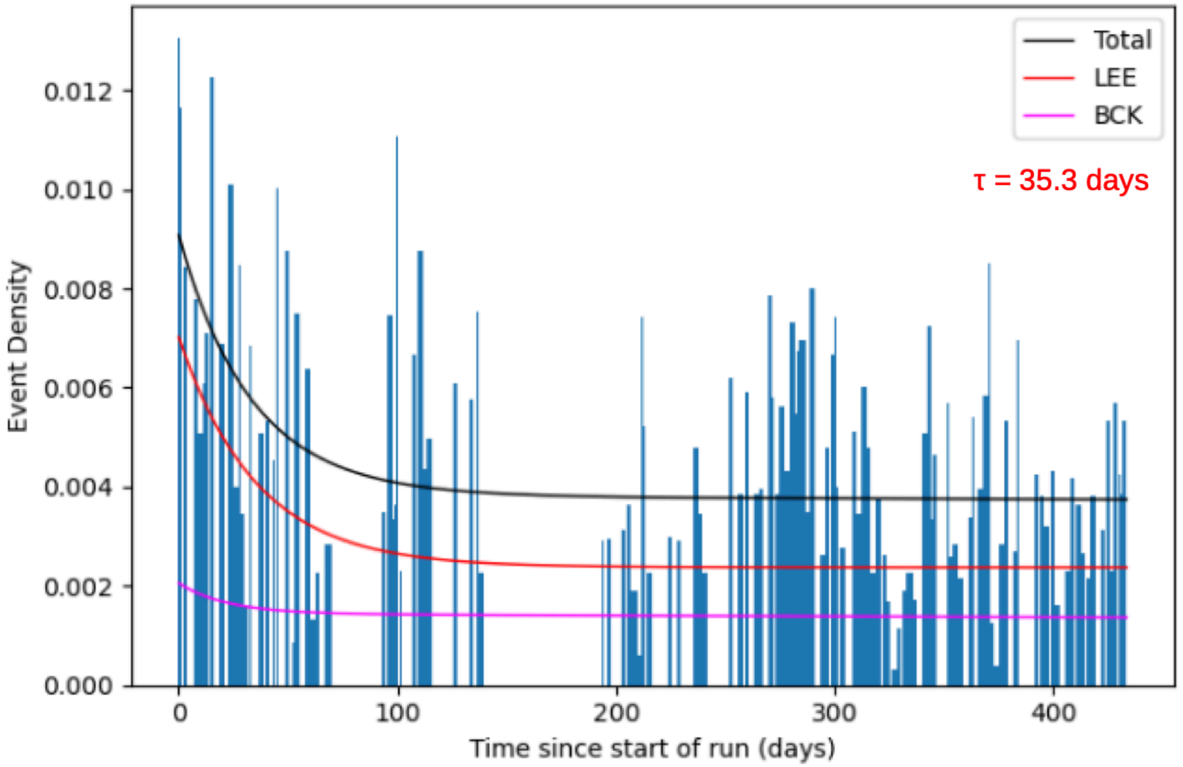
Time dependence Calibration Lines

No strong effect for energy range around lines from built-in 55Fe calibration source.



Resutls presented at the excess workshop
https://indico.cern.ch/event/1013203/

Time dependence LEE Run34



Excess rate in Det-A (Run 34) decreases over time

Background rate remains (almost) constant

Resutls presented at the excess workshop
https://indico.cern.ch/event/1013203/