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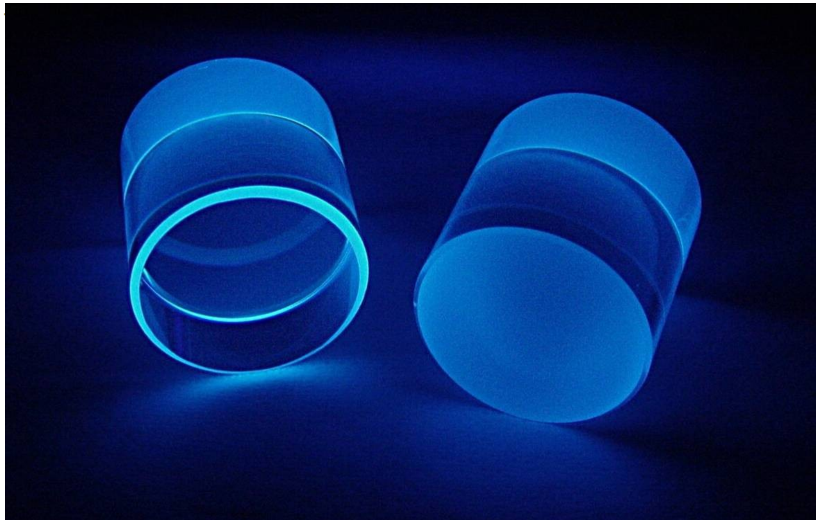
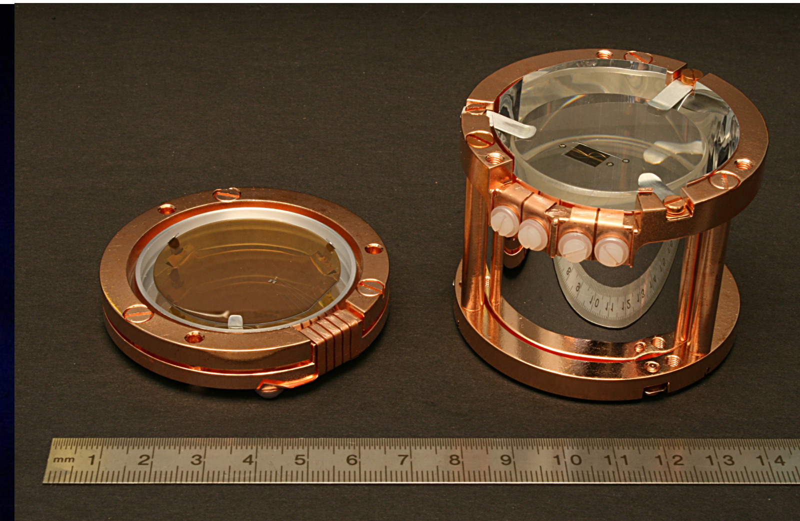
FACULTY OF SCIENCE

Kepler Center for Astro and Particle Physics





Temperature Dependent Light Output of Scintillating Crystals

18.09.13, Martin Uffinger

Outline

Dark Matter direct detection with CRESST

NaI: alternative scintillating material for CRESST?

Relative light output measurements

Conclusion and outlook

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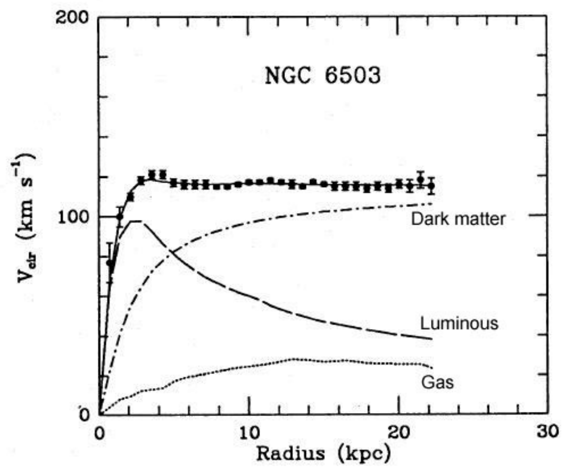
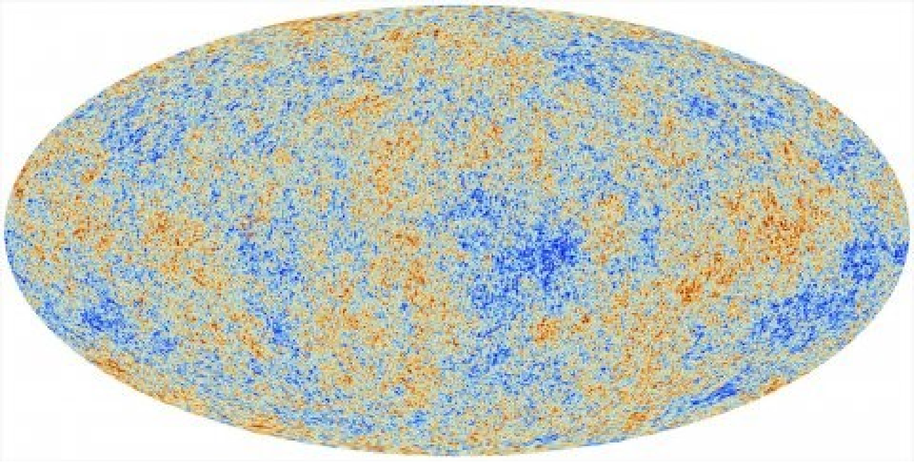
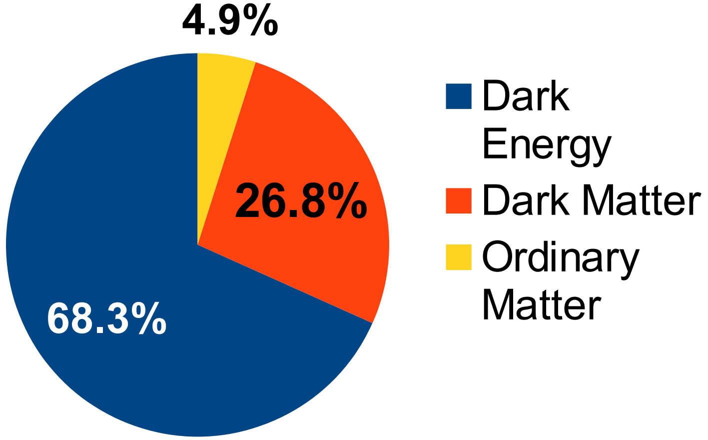
Dark Matter in the universe





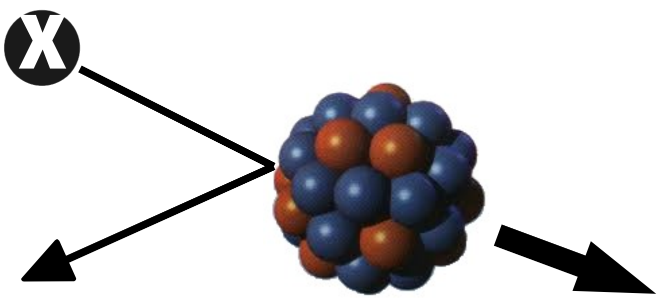


Martin Uffinger

Dark Matter Direct Detection

With the **C**ryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers (**CRESST**)

Measurement of deposited energy in a scintillating material via off scattering target nuclei.



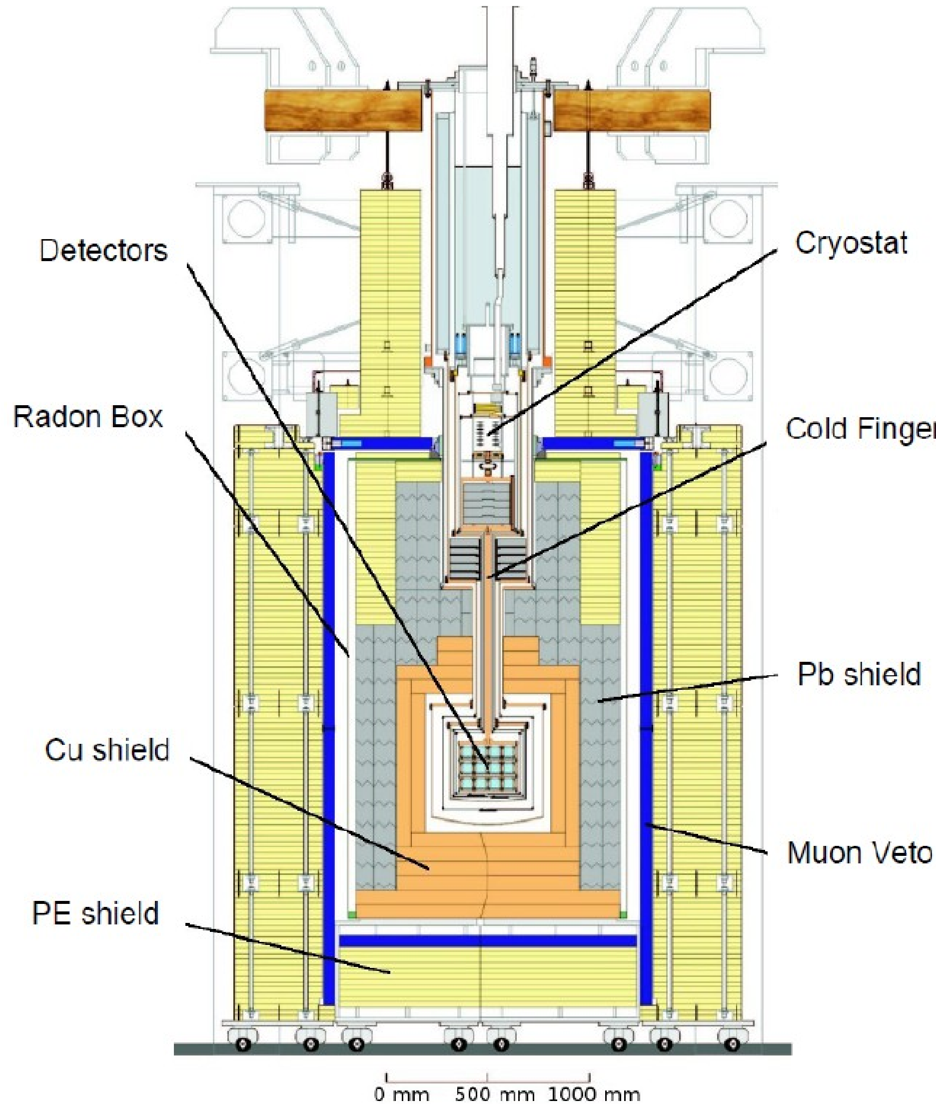
High background suppresion required!

CRESST @ LNGS

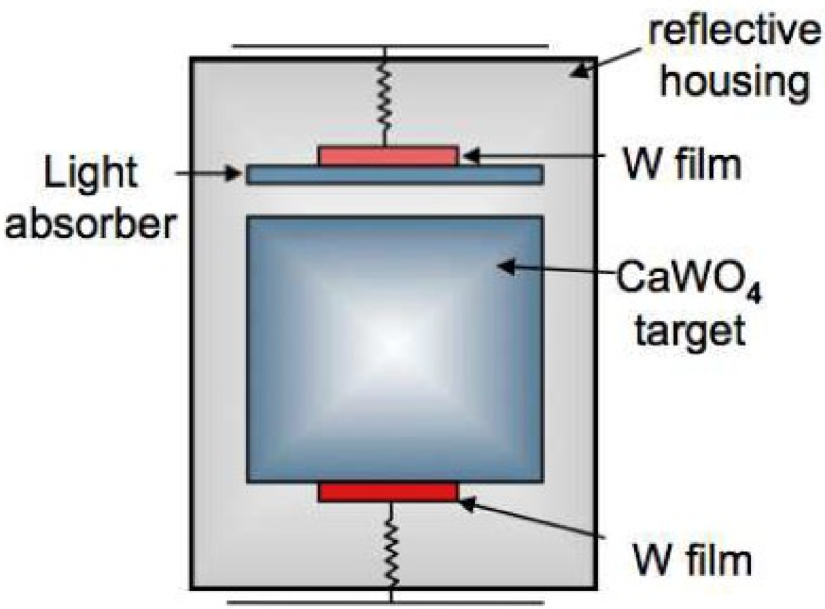
- 3500m w.e. rock overburden
- Passive shieldings against radioactivity

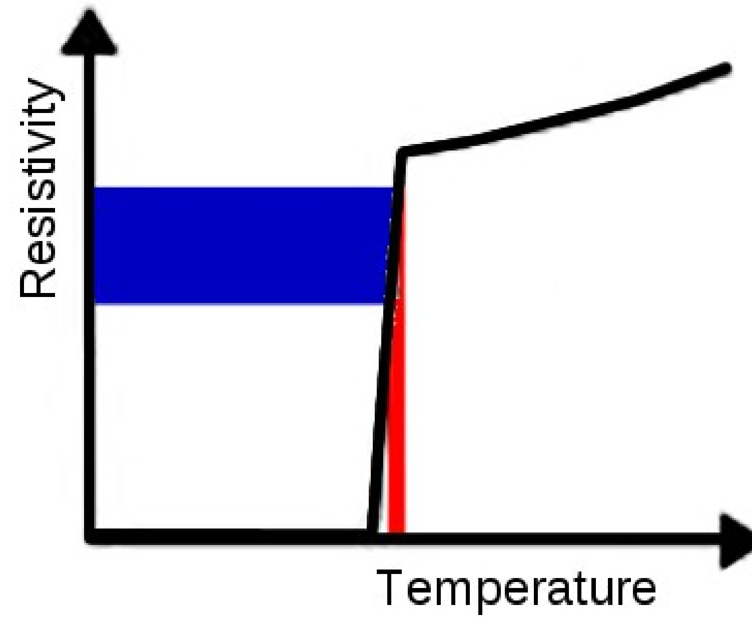
Passive background reduction not sufficient

→ Active event-by-event discrimination



CRESST Detector Modules





E = total deposited energy
L = scintillation light

Event Discrimination

- **Light Yield (LY) = L/E**

Characteristic of the event type

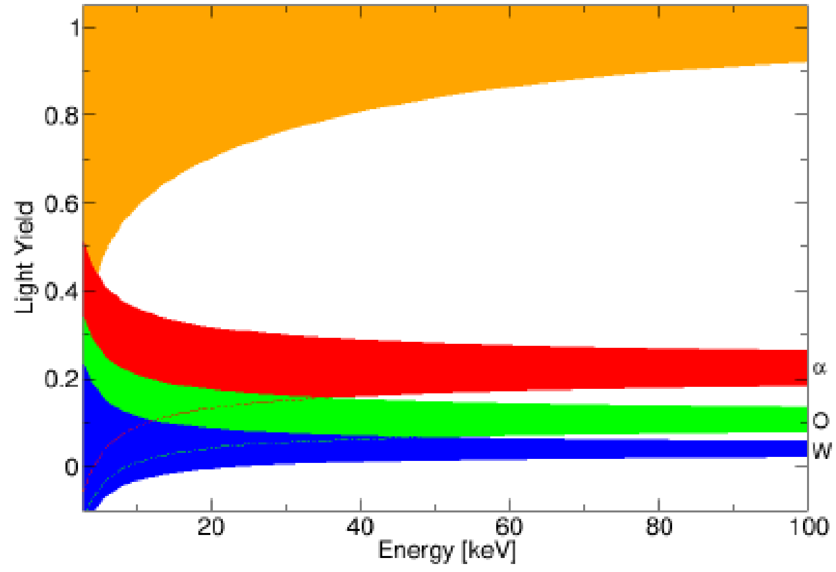
- LY(*e*-recoil):1 by definiton

- LY(alpha) ~ 0.22

- LY(O) ~ 0.1

- LY(Ca) ~ 0.06

- LY(W) ~ 0.04



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

Light/Energy vs Charge/Energy

- Only small variety of semiconductor materials for direct Dark Matter search (Si, Ge)
- Large variety of scintillating materials available
- Different target nuclei to investigate Dark Matter properties and interaction mechanism (e.g. scaling factors)

Investigation of
- temperature dependent relative light yield
- phonon properties

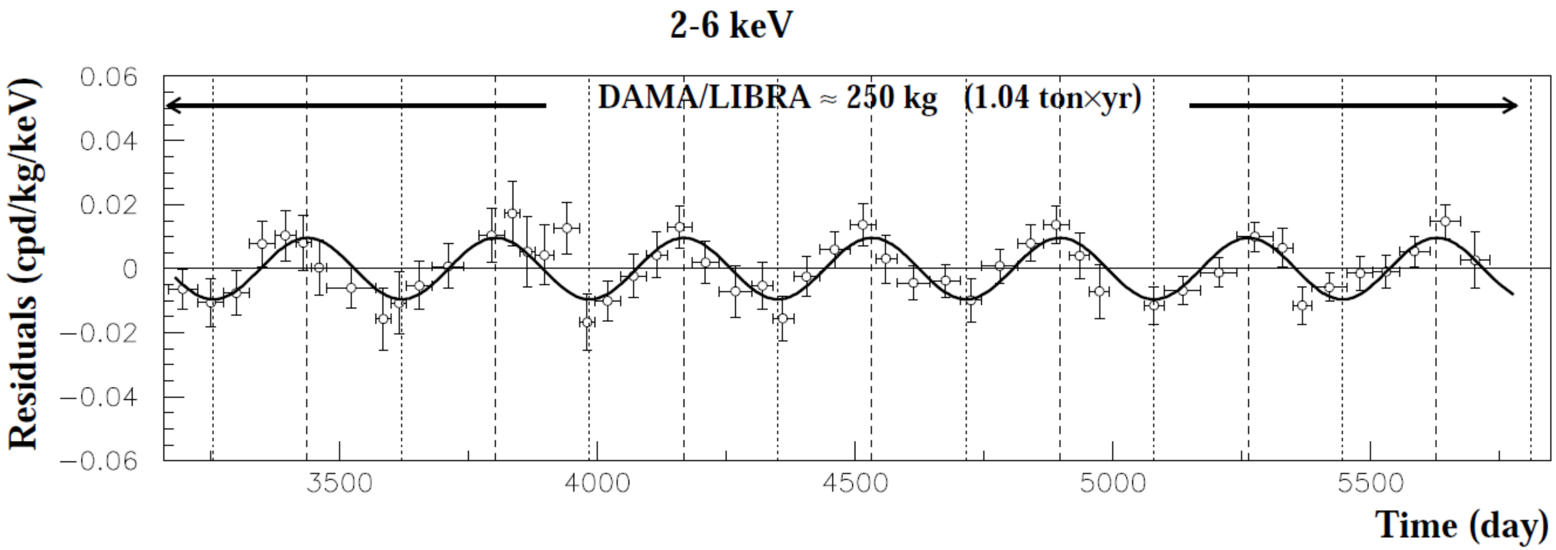
of alternative scintillating crystals at the University of Tübingen

DAMA annual modulation signal

- DAMA uses NaI(Tl) crystals to investigate rare processes, especially Dark Matter interactions (**model independent**)
- DAMA results show a modulation of 14 annual cycles (DAMA/NaI + DAMA/LIBRA)
- The observed modulation cannot be explained by any known background

The observed modulation signature is assigned to dark matter particle interactions in NaI(Tl) crystals

DAMA annual modulation signature



arXiv:1308.5109v1

Combined with 7 annual cycles of DAMA/NaI there is an evidence of dark matter particles in the galactic halo at 9.3σ C.L.

Corollary investigations of the nature of dark matter particles needed with **model dependent** analyses

How to compare DAMA with model dependent analyses?

Exclusion limits are reported based on various assumptions

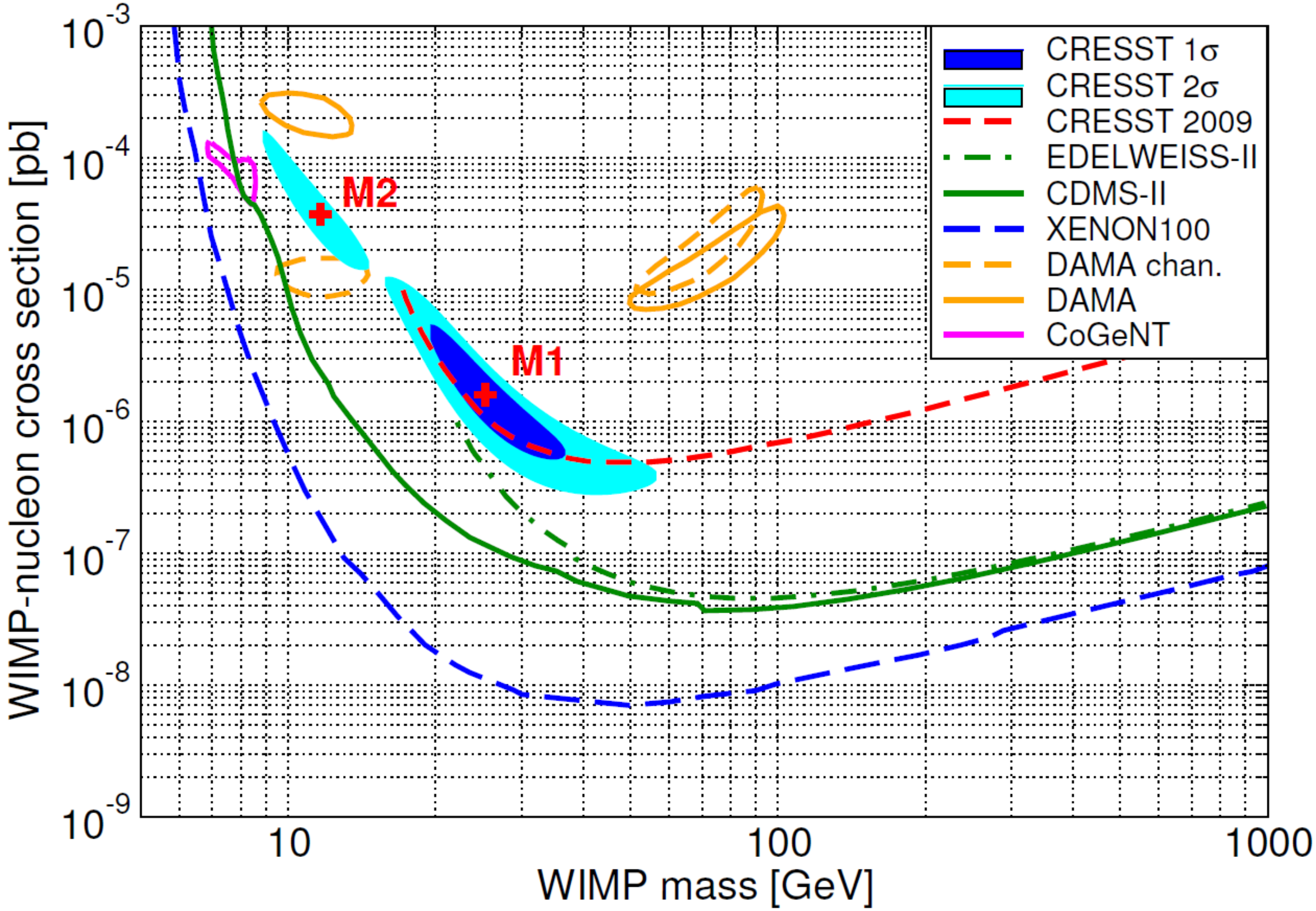
- 'standard' dark matter halo

- interaction of dark matter particles via elastic off scattering nuclei in target material

- A^2 dependence of DM-nucleus cross section

- often constant quenching factors are assumed

How to compare DAMA with model dependent analyses?



How to compare DAMA with model dependent analyses?

- Uncertanties concerning dark matter interactions

  - velocity distribution
  - density profile of dark matter particles
  - scaling factor of cross section
  - quenching factors, especially energy dependence
  - crystal effects (e.g. channeling)
  - interaction type (only nuclear recoils)

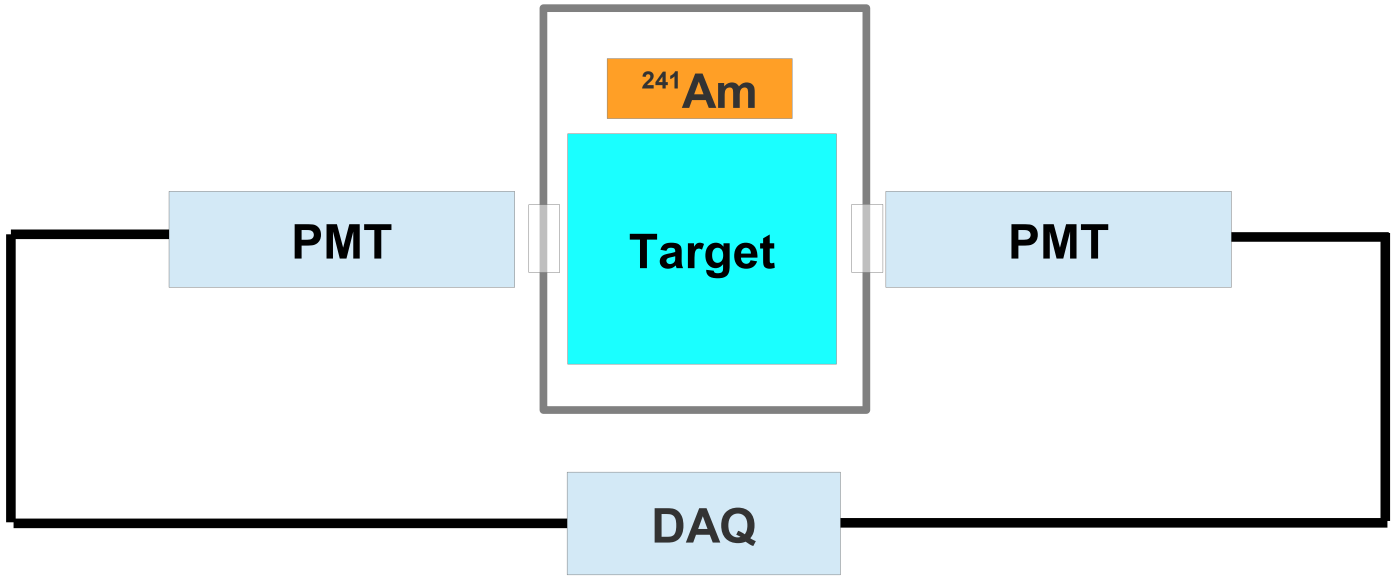
NaI: An alternative CRESST detector material?

- Two different target nuclei for light and heavy dark matter candidates (A_{Na}=23 and A_I=127)
- High purity material available
- Well known scintillator at room temperature with high light output

but: sufficient light output at mK temperatures is necessary for application in CRESST like detector modules

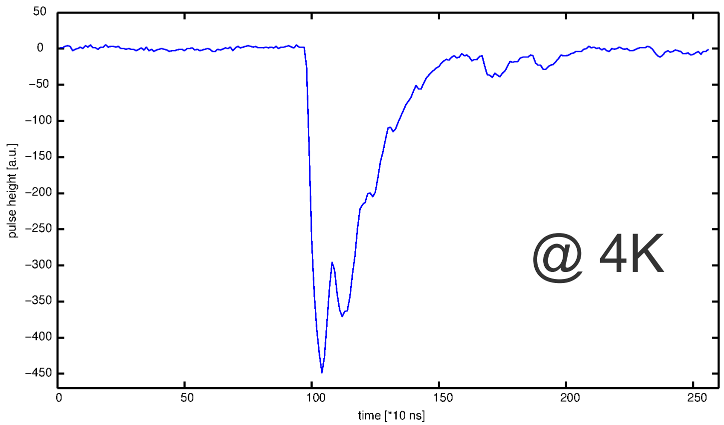
Temperature dependent light output of NaI and NaI(Tl)

- Measured with a coincidence technique

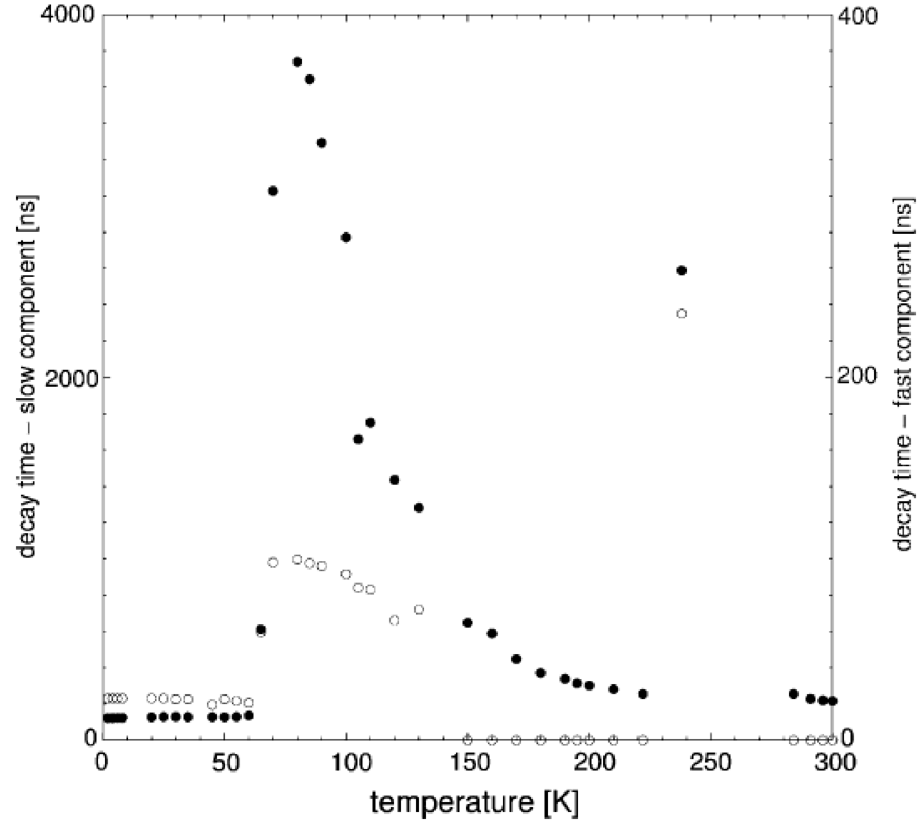


Temperature of target crystal can be varied down to ~1.7 K, while PMTs are operated at room temperature.

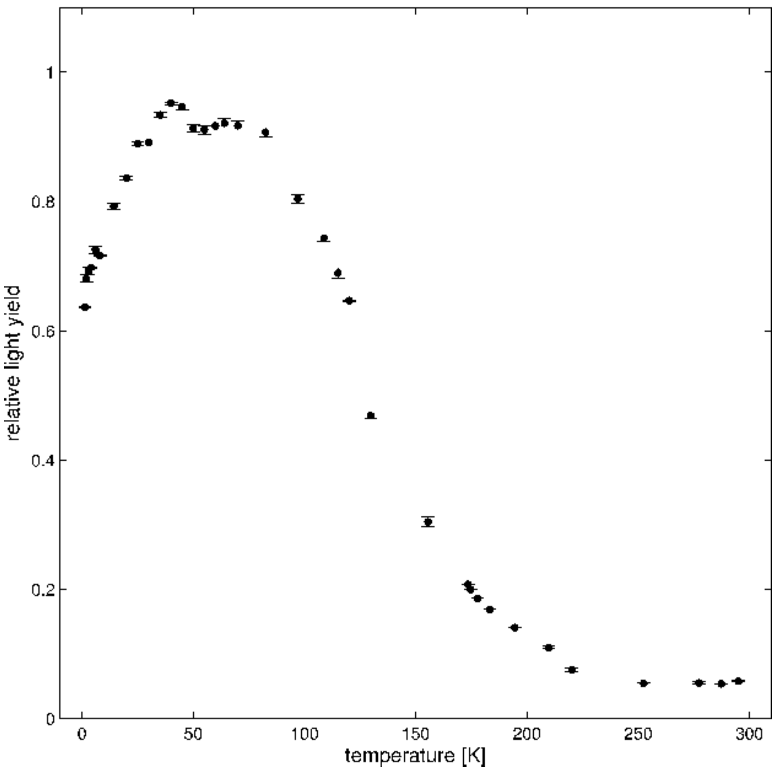
Example pulse of NaI scintillation event

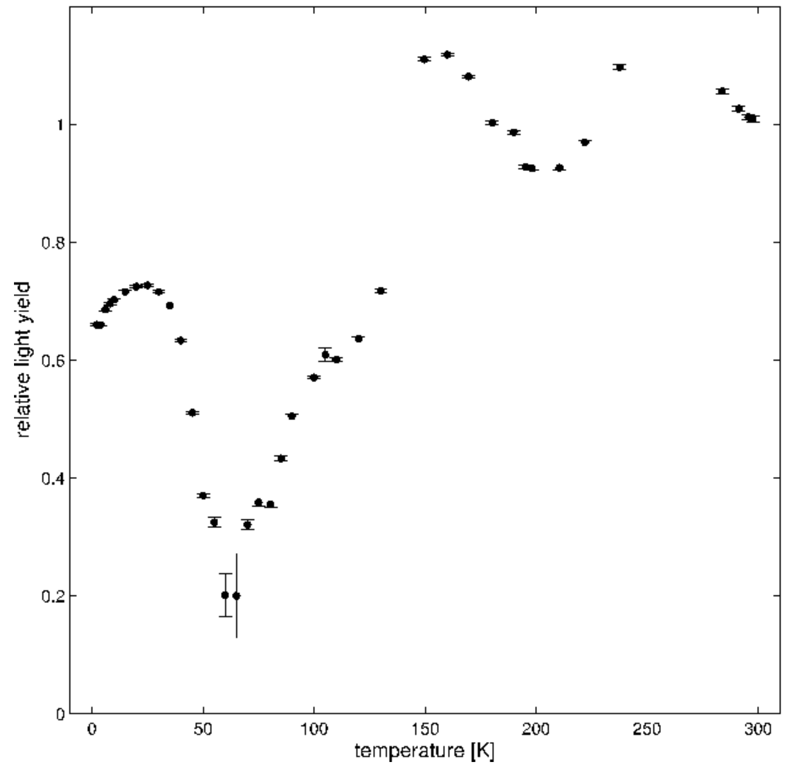


NaI pure			
T	290 K	156 K	6 K
τ_1	98 ns	112 ns	149 ns
τ_2	–	644 ns	–
NaI(Tl)			
T	300 K	150 K	6 K
τ_1	–	–	23 ns
τ_2	216 ns	646 ns	122 ns



Relative light output of NaI and NaI(Tl)





Sailer *et al.* Eur. Phys. J. C (2012)

NaI as alternative CRESST target

- Down to 1.7K the light output of NaI is sufficient for application as a CRESST modules
- Phonon properties not investigated yet
- Precise determination of quenching factors of Na and I
- New design will be needed for CRESST modules with NaI as target material due to surface properties of the crystal (hygroscopic)

Conclusion and Outlook

- CRESST experiment is able to use a large variety of scintillating materials for direct detection of WIMPs via off scattering target nuclei
- NaI as interesting alternative target material
- Measurements of relative light output of pure NaI and NaI(Tl)
- Investigation of phonon properties of pure NaI and NaI(Tl) at low temperatures
- Determination of quenching factors of Na and I
- CRESST like module design for NaI crystals

Conclusion and Outlook

- CRESST experiment is able to use a large variety of scintillating materials for direct detection of WIMPs via off scattering target nuclei

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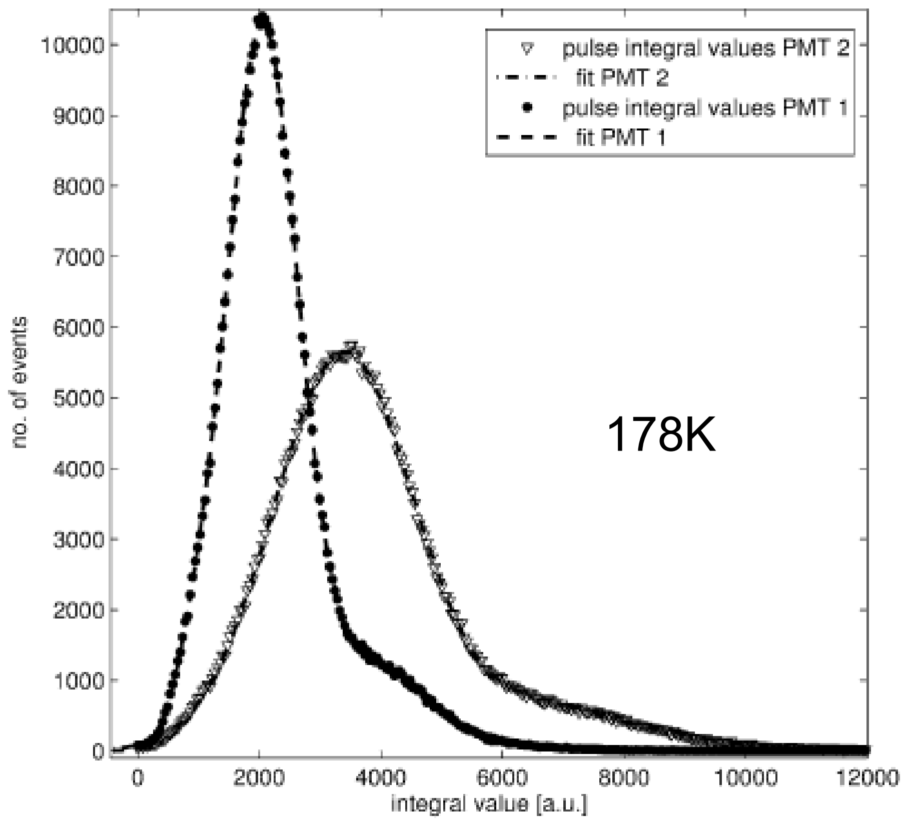
Backup – Histogram of integral values



Backup – Decay times derived by double exponential fit

NaI pure			
T	290 K	156 K	6 K
τ_1	98 ns	112 ns	149 ns
τ_2	–	644 ns	–
NaI(Tl)			
T	300 K	150 K	6 K
τ_1	–	–	23 ns
τ_2	216 ns	646 ns	122 ns

Fit results for the sum of single hit events at three different temperatures

Backup – Decay behavior of NaI(Tl)