Limits on Inelastic Dark Matter from CRESST

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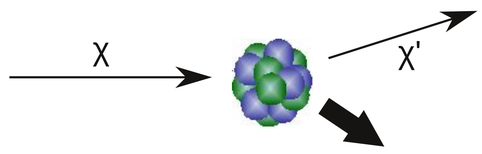
I. Inelastic Dark Matter: Basic Idea and Compatibility with DAMA/LIBRA

Inelastic Dark Matter (iDM) is an alternative model to standard elastic Dark Matter scattering [1]. In this scenario, a WIMP χ is assumed to undergo a transition to a slightly heavier state χ' when scattering off an atomic nucleus:



The mass difference between the two states shall be

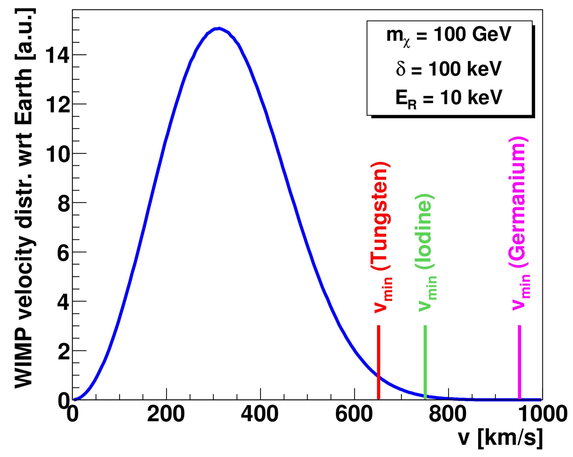
$$\delta := m_{\chi'} - m_{\chi} \approx \mathcal{O}(100\,\mathrm{keV}).$$

Kinematic consequence:
The minimum WIMP velocity in order to induce a recoiling nucleus with an energy E_R becomes

$$v_{min} = \sqrt{\frac{1}{2 m_N E_R}} \left(\frac{m_N E_R}{\mu_N} + \delta \right),$$

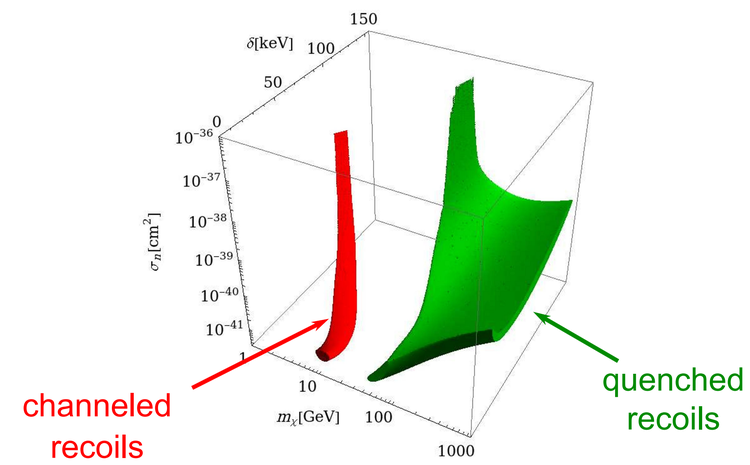
with the mass m_N of the target nucleus and the reduced mass μ_N of the WIMP-nucleus system.

This implies that experiments with heavier targets allow to probe a larger part of the WIMP velocity distribution. Experiments with light targets can thus be completely insensitive to iDM:



Motivation to consider iDM:
iDM might reconcile the signal observed by DAMA/LIBRA (heavy iodine target nuclei, $A \approx 127$) [2] with the null results of many other DM searches (often with lighter nuclei).

Two regions of the iDM parameter space were found to be compatible with the DAMA/LIBRA signal [3]:

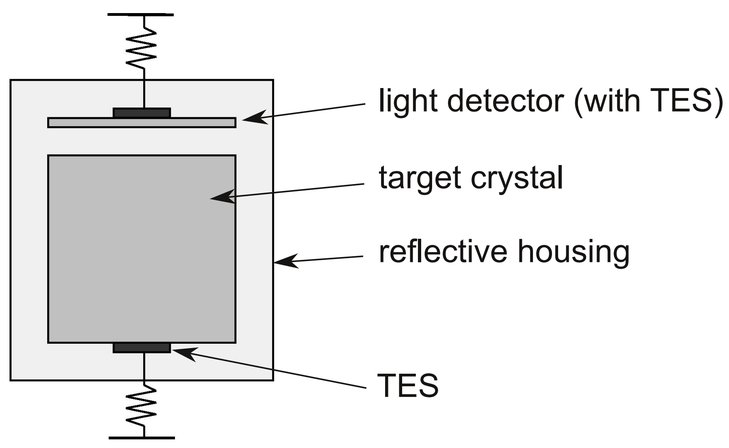


In the green region, the signal could arise from normal "quenched" recoils of iodine nuclei. A second region (red) opens up if non-standard "channeled" recoils exist. However, this channeling effect is still under debate.

II. The CRESST Dark Matter Search

CRESST is a direct DM search using scintillating $CaWO_4$ crystals as a target. The heavy tungsten nuclei ($A \approx 184$) make CRESST highly sensitive to iDM.

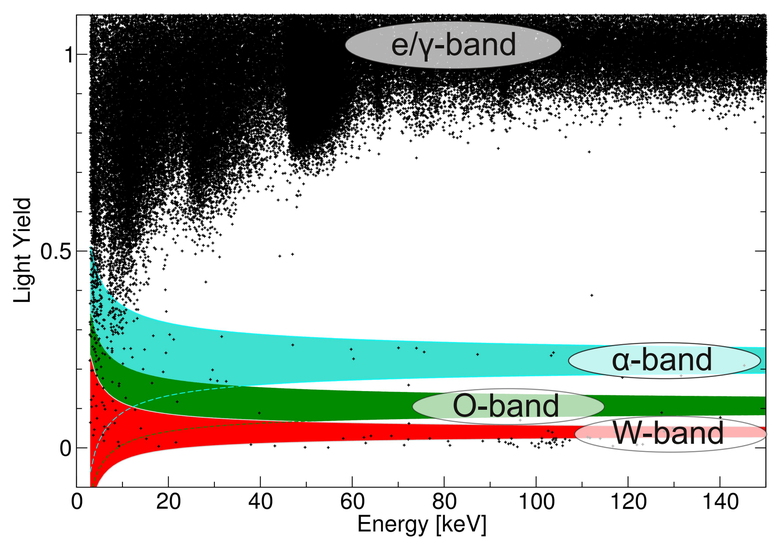
CRESST Detector Modules:



A transition edge sensor (TES) allows to detect tiny energy depositions in the crystal. An independent light detector measures the amount of scintillation light produced by the interaction.

Active Discrimination:
The simultaneous measurement of energy deposition and scintillation output allows for a discrimination between different types of interacting particles by the *light yield*, defined as the ratio of detected light to energy measured in the crystal:

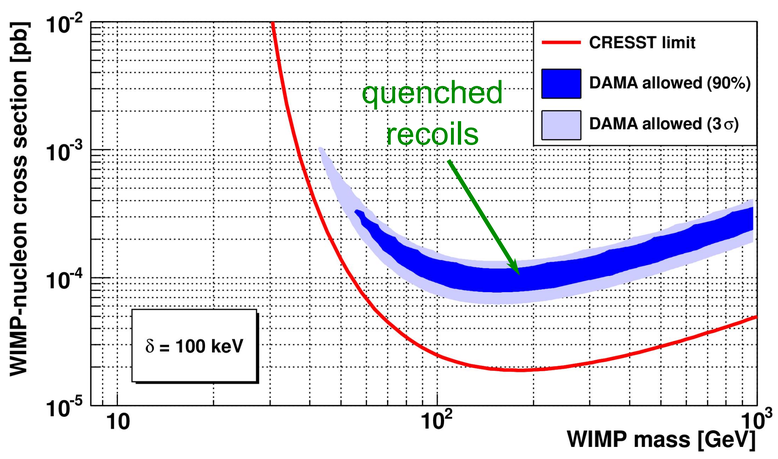
- Ordinary electron and gamma interactions have a light yield of 1 (by definition).
- Nuclear recoils give less light. They can thus be discriminated from electron recoils induced by the dominant radioactive backgrounds.
- Even a partial identification of the recoiling nucleus is possible within the resolution.

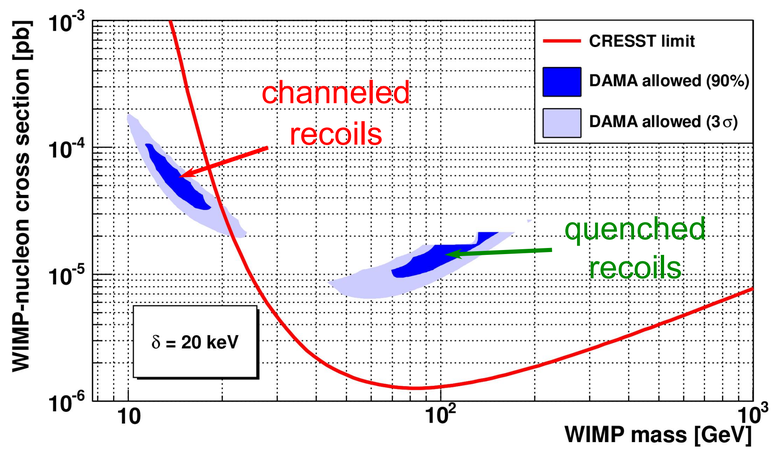


Search for iDM:
For iDM scatterings in the interesting parameter range, only tungsten nuclei are a possible target. The region of interest for iDM is hence the tungsten band in the light yield-energy-plane.

III. CRESST Limits on Inelastic Dark Matter

We calculate iDM exclusion limits from the latest CRESST data obtained by eight detector modules between 2009 and 2011 [4]. They comprise a total net exposure of 730 kg d.
As acceptance region, we select the tungsten band and impose a module-dependent lower energy threshold, such that the e/γ-background is limited to one event per module. The resulting thresholds are between 10 keV and 17 keV. We set a common upper energy threshold at 40 keV, since only a small fraction of an iDM signal is expected above.
We find a number of events in the acceptance region of each module and calculate exclusion limits with Yellin's optimum interval method [5]. We thereby assume the standard DM halo model [6]. The result is shown here for two exemplary values of the mass splitting δ, together with the DAMA/LIBRA-compatible region (based on data from [7]).





Results:

- **CRESST excludes the complete parameter region compatible with DAMA/LIBRA, if standard "quenched" recoils are assumed. This holds for all values of δ, for which this region exists.**
- **The region of channeled iodine recoils in DAMA/LIBRA is still compatible with the CRESST results. It has, however, been excluded by other experiments [8].**

In summary, inelastic Dark Matter cannot be the explanation for the apparent signal in DAMA/LIBRA under standard assumptions.

References

[1] D. Smith and N. Weiner, *Phys. Rev. D* **64** (2001)
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[3] K. Schmidt-Hoberg and M.W. Winkler, *JCAP* **0909** (2009)
[4] G. Angloher et al., "Results from 730 kg days of the CRESST-II Dark Matter Search" (see arXiv)
[5] S. Yellin, *Phys. Rev. D* **66** (2002)
[6] F. Donato et al., *Astropart. Phys.* **9** (1998)
[7] J. Kopp et al., *JCAP* **1002** (2010)
[8] The CDMS Collaboration, *Science* **327** (2010)

Acknowledgements

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