EBERHARD KARLS UNIVERSITÄT TÜBINGEN

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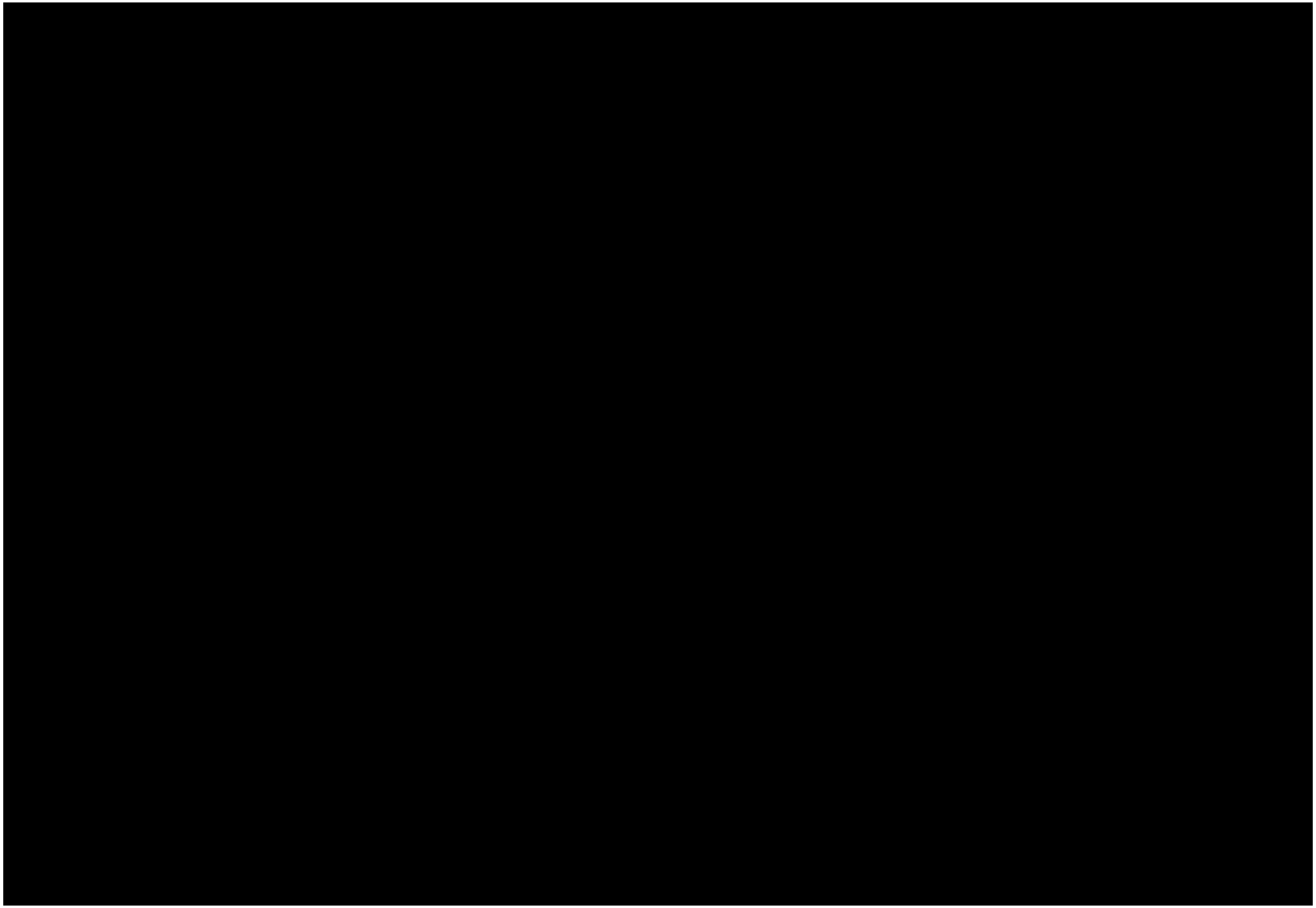
Effective Field Theory Analysis of CRESST-II Data

56th International Winter Meeting on Nuclear Physics

January 25, 2018, Vincent Schipperges



CRESST

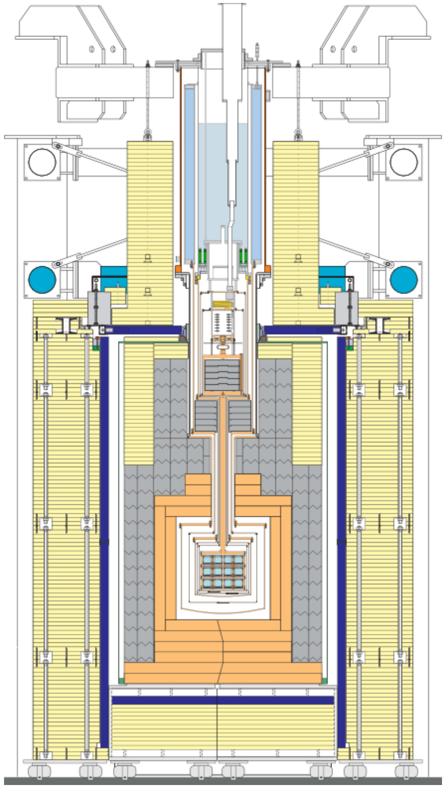
- direct Dark Matter detection experiment (model independent): nuclear recoils

- Cryogenic Rare Event Search with Superconducting Thermometers

- located at the LNGS underground lab in central Italy

CRESST

- additional shielding
- temperature $\sim$ 15 mK



CRESST-II detectors

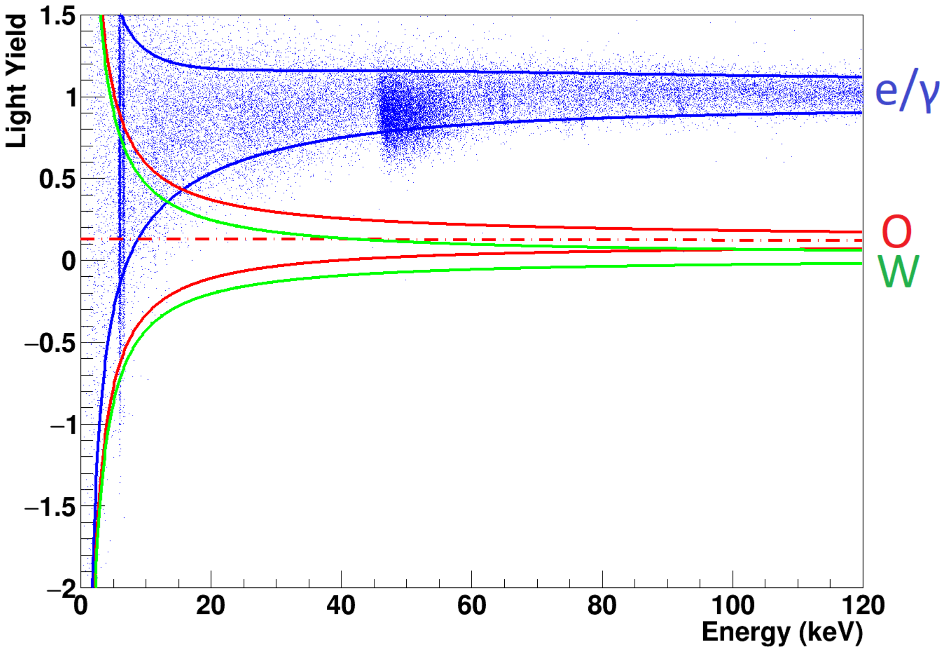
- scintillating target ($CaWO_4$)
- separate phonon detector and light detector (for scintillation light detection)

Example: detector *Lise*

- E_{th} = 307 ± 4 eV for nuclear recoils

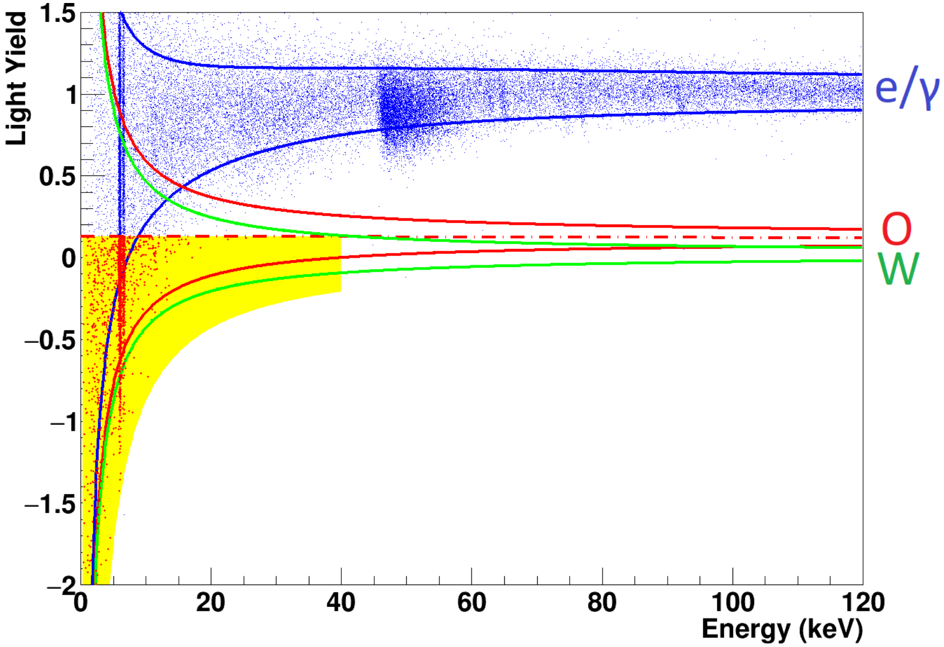
CRESST Data Analysis

- signal: nuclear recoils, most background: electron recoils
- particle discrimination by fraction of light and heat (phonon) signal: light yield



CRESST Data Analysis

- signal: nuclear recoils, most background: electron recoils
- particle discrimination by fraction of heat (phonon) and light signal: light yield
- assuming all events in ROI as signal
- using Yellin optimum interval method for limit calculation



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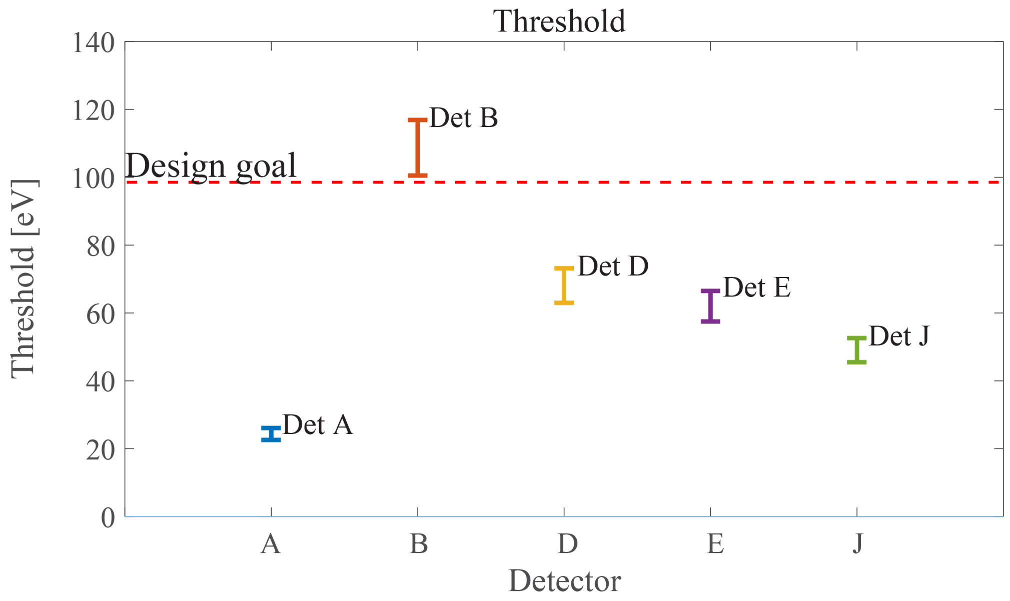
CRESST-III

- upgrade to CRESST-III, data taking since 2016 with 10 new detectors
- focus on low mass dark matter, detector design improvements
- design goal: energy threshold below 100 eV



Dark Matter Search

- model-independent? in general assuming scalar (or spin-dependent) DM-nucleon interaction to be dominant

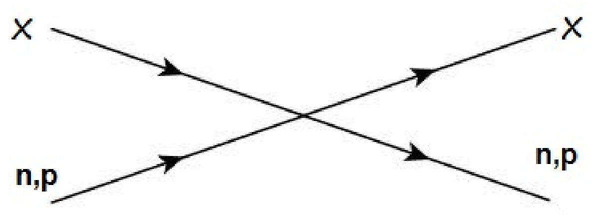
- dark matter nature unknown

- structure might be more complicated than assumed

$\rightarrow$ set limits in a more general way

Effective Field Theory of Dark Matter Detection

low momentum transfer (keV)



non-relativistic

Effective Field Theory of Dark Matter Detection

possible relevant Galilean invariant quantities:

$$\vec{S}_\chi, \quad \vec{S}_N, \quad \vec{q}, \quad \vec{v}$$

Hermitian and orthogonal:

$$\vec{S}_\chi, \quad \vec{S}_N, \quad i\vec{q}, \quad \vec{v}^\perp = \vec{v} + \vec{q}/(2\mu_N)$$

Dark-Matter-Nucleon Interaction

possible combinations:

$$\mathcal{O}_1 = \mathbb{I}$$
$$\mathcal{O}_3 = i\vec{S}_N \cdot (\vec{q} \times \vec{v}^\perp)$$
$$\mathcal{O}_4 = \vec{S}_\chi \cdot \vec{S}_N$$
$$\mathcal{O}_5 = i\vec{S}_\chi \cdot (\vec{q} \times \vec{v}^\perp)$$
$$\mathcal{O}_6 = (\vec{S}_\chi \cdot \vec{q})(\vec{S}_N \cdot \vec{q})$$
$$\mathcal{O}_7 = \vec{S}_N \cdot \vec{v}^\perp$$
$$\mathcal{O}_8 = \vec{S}_\chi \cdot \vec{v}^\perp$$
$$\mathcal{O}_9 = i\vec{S}_\chi \cdot (\vec{S}_N \times \vec{q})$$
$$\mathcal{O}_{10} = i\vec{S}_N \cdot \vec{q}$$
$$\mathcal{O}_{11} = i\vec{S}_\chi \cdot \vec{q}$$
$$\mathcal{O}_{12} = \vec{S}_\chi \cdot (\vec{S}_N \times \vec{v}^\perp)$$
$$\mathcal{O}_{13} = i(\vec{S}_\chi \cdot \vec{v}^\perp)(\vec{S}_N \cdot \vec{q})$$
$$\mathcal{O}_{14} = i(\vec{S}_\chi \cdot \vec{q})(\vec{S}_N \cdot \vec{v}^\perp)$$
$$\mathcal{O}_{15} = -(\vec{S}_\chi \cdot \vec{q})((\vec{S}_N \times \vec{v}^\perp) \cdot \vec{q})$$

interaction with nucleon described by $\sum_{\tau=0,1} \sum_{k=1}^{15} c_k^\tau \mathcal{O}_k t^\tau$

Dark-Matter-Nucleus Interaction

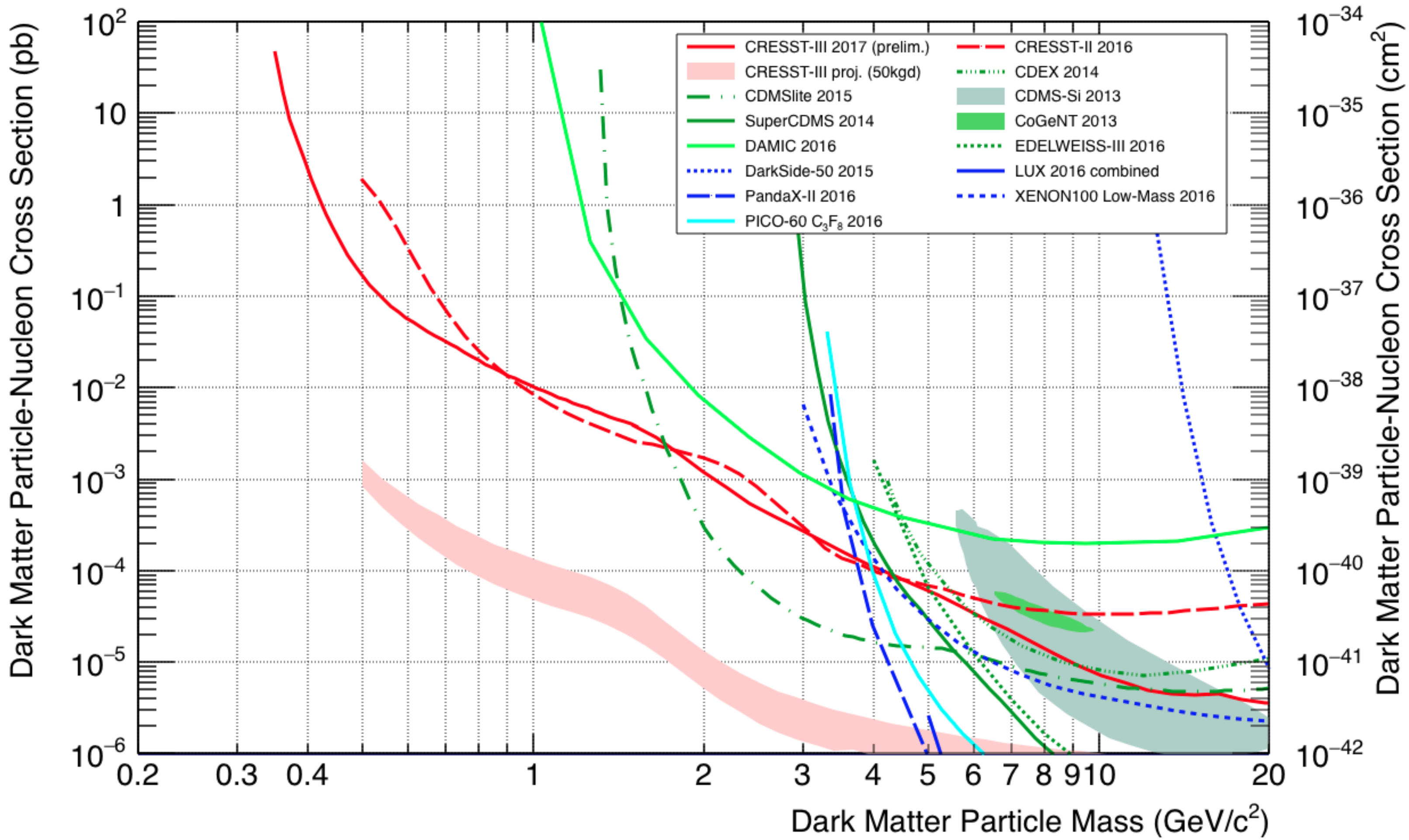
$$\hat{\mathcal{L}}(\vec{r}) = \sum_{i=1}^{A} \sum_{\tau=0,1} \sum_{k=1}^{15} c_k^\tau \mathcal{O}_k^{(i)} t_{(i)}^\tau$$

goal: set limits on c, for each one separately (setting all the other $c = 0$)

for movement inside nucleus: input from nuclear physics (shell model)

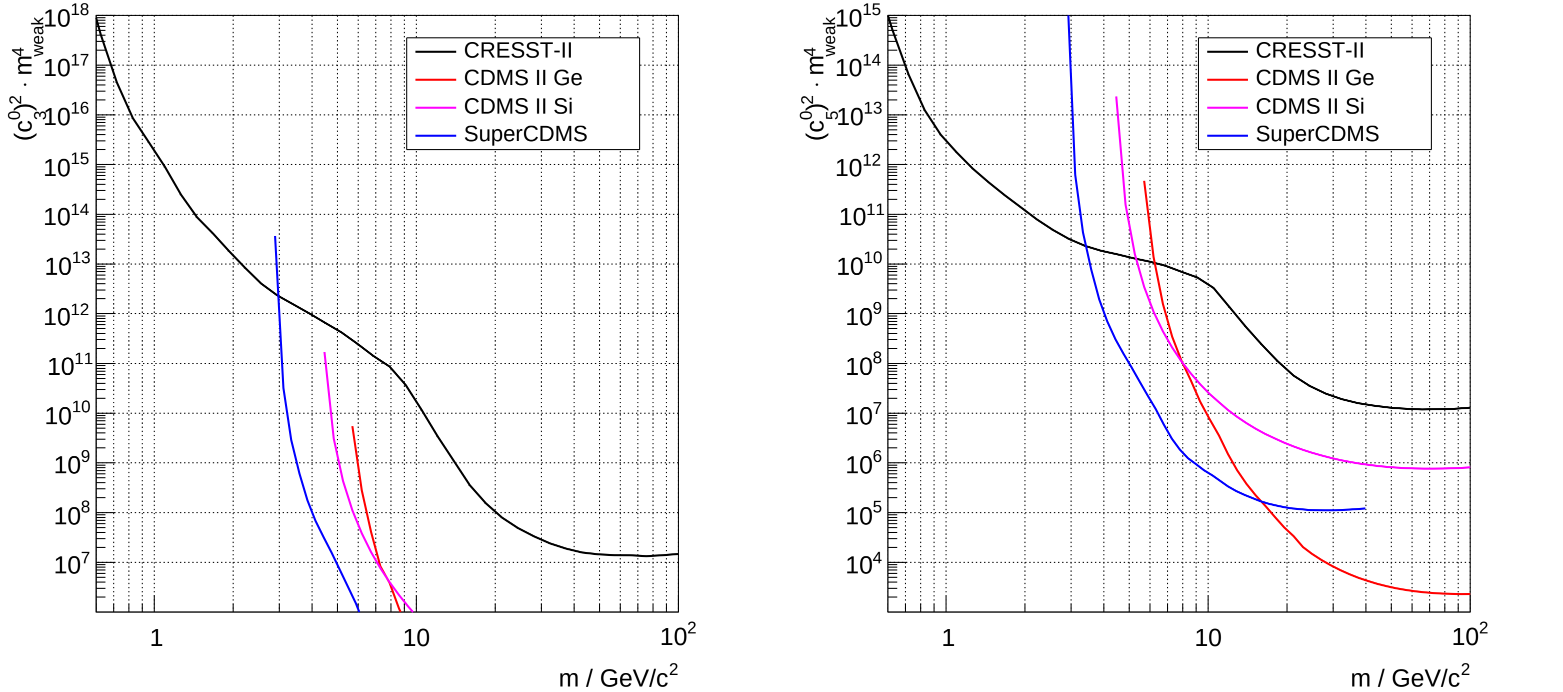
$\Rightarrow$ set limits (isoscalar operators not depending on nuclear spin)

Results



Dark Matter Particle-Nucleon Cross Section (pb)
Dark Matter Particle-Nucleon Cross Section (cm^2)
Dark Matter Particle Mass (GeV/c^2)
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-34}
10^{-35}
10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
0.2
0.3
0.4
1
2
3
4
5
6
7
8
9
10
20
CRESST-III 2017 (prelim.)
CRESST-III proj. (50kgd)
CDMSlite 2015
SuperCDMS 2014
DAMIC 2016
DarkSide-50 2015
PandaX-II 2016
PICO-60 C_3F_8 2016
CRESST-II 2016
CDEX 2014
CDMS-Si 2013
CoGeNT 2013
EDELWEISS-III 2016
LUX 2016 combined
XENON100 Low-Mass 2016

Limits for Wilson coefficients c_3^0 and c_5^0



Summary

- set limits for more general Effective Field Theory
- CRESST-II: best DM limit for SI interaction below 1.7 GeV/c^2
- leading limits for masses below $\sim$ 3-4 GeV/c^2 for coefficients c_1^0, c_3^0, c_5^0, c_8^0, c_{11}^0, c_{12}^0 and c_{15}^0
- upgrade to CRESST-III: improved threshold, precision, design and radiopurity