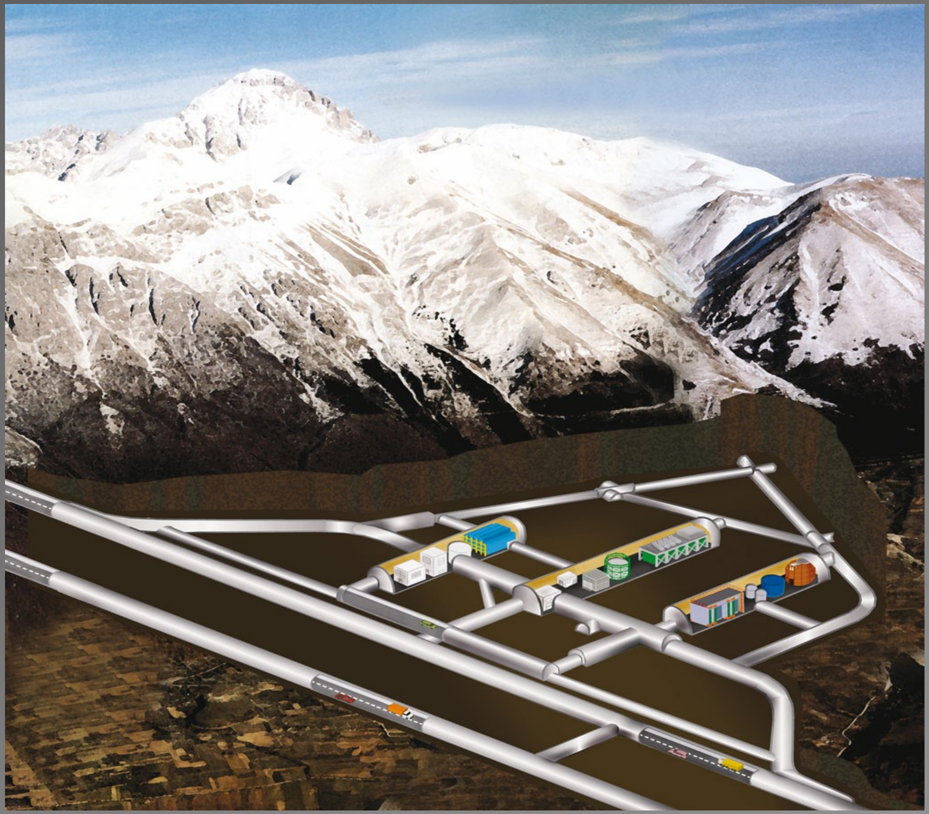
Direct Search for Light Dark Matter in CRESST-III



Nahuel Ferreiro
Max-Planck-Institut für Physik, München
Light Dark Matter 2017 – Isola d'Elba
25.5.2017

Outline

- Scintillating cryogenic detectors
  - Basic principles
  - Light Dark Matter sensitivity
- The CRESST technology
  - CRESST set up
  - CRESST-II results
- CRESST-III optimization for light dark matter

Cryogenic Detectors

- Main Absorber:

  Energy deposition causes temperature rise

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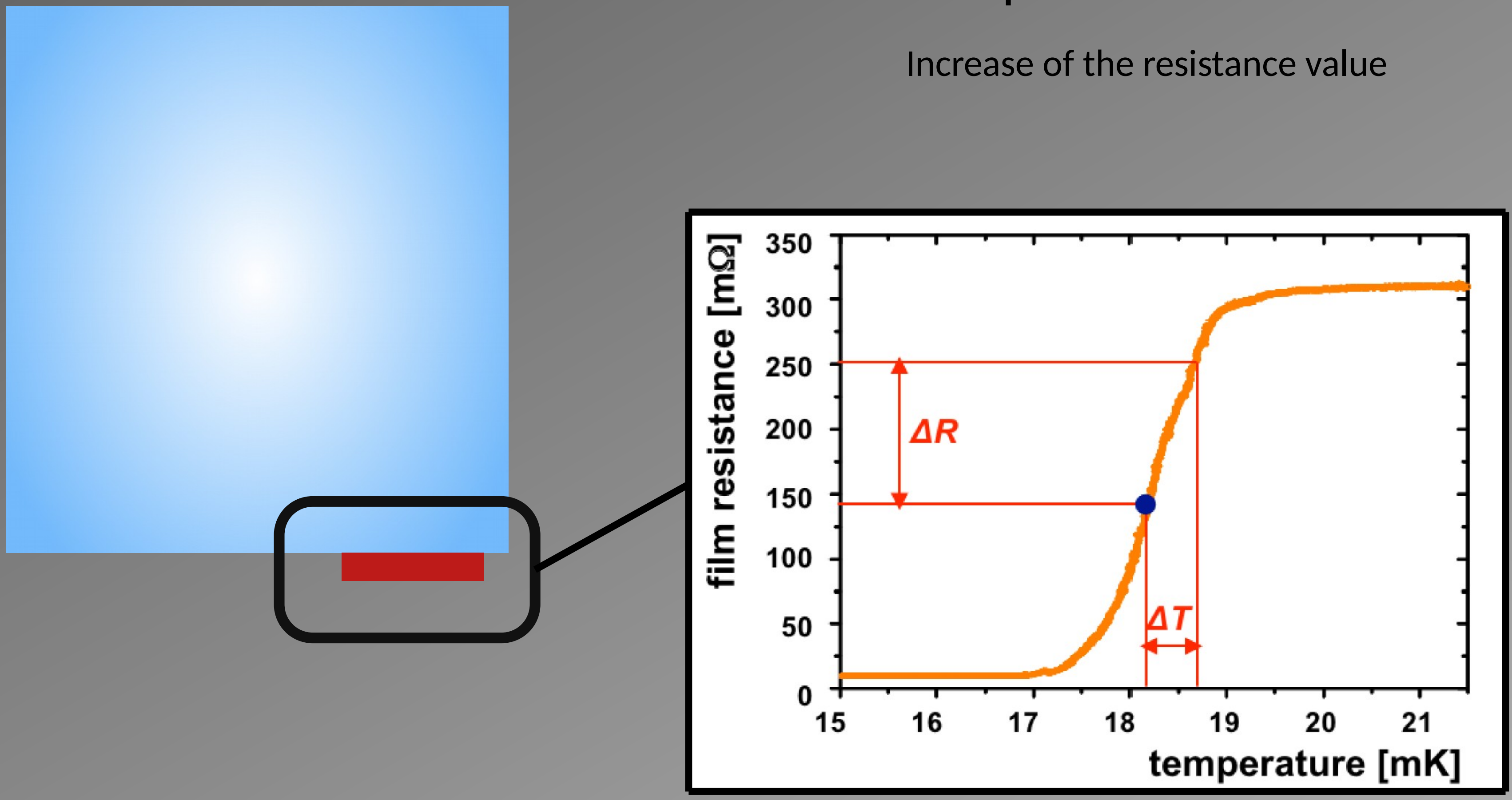
  Increase of the resistance value



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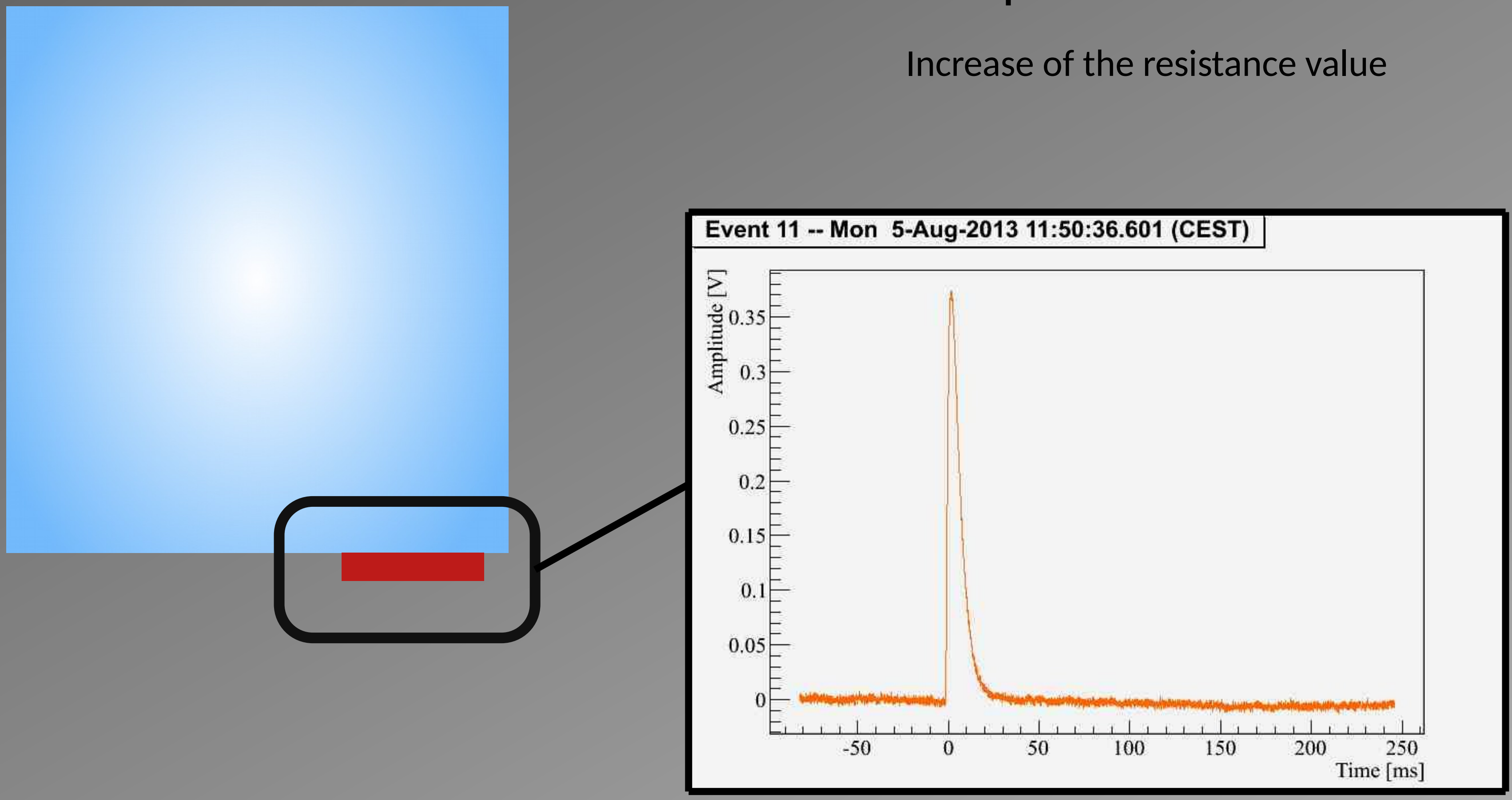
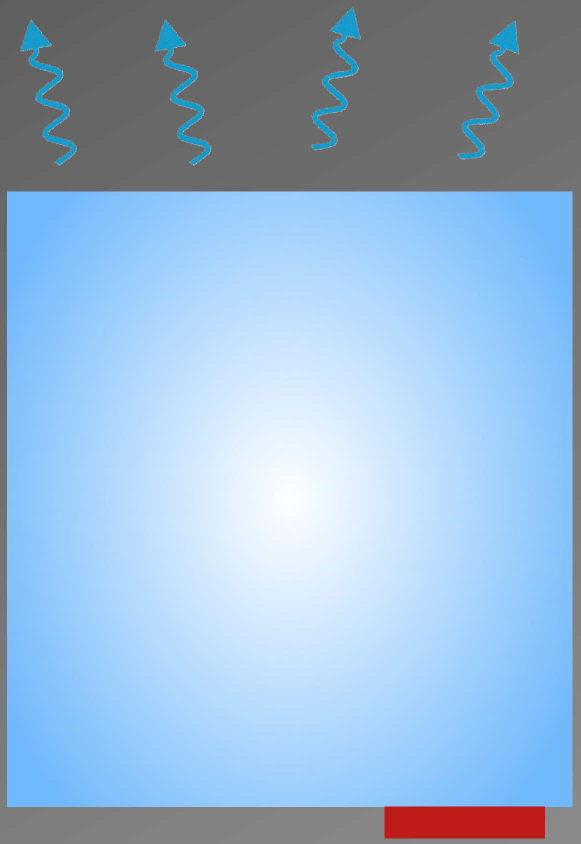


Cryogenic Detectors



- Main Absorber $CaWO_4$:

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- Scintillating Crystal:

  Part of the energy is converted into scintillation light

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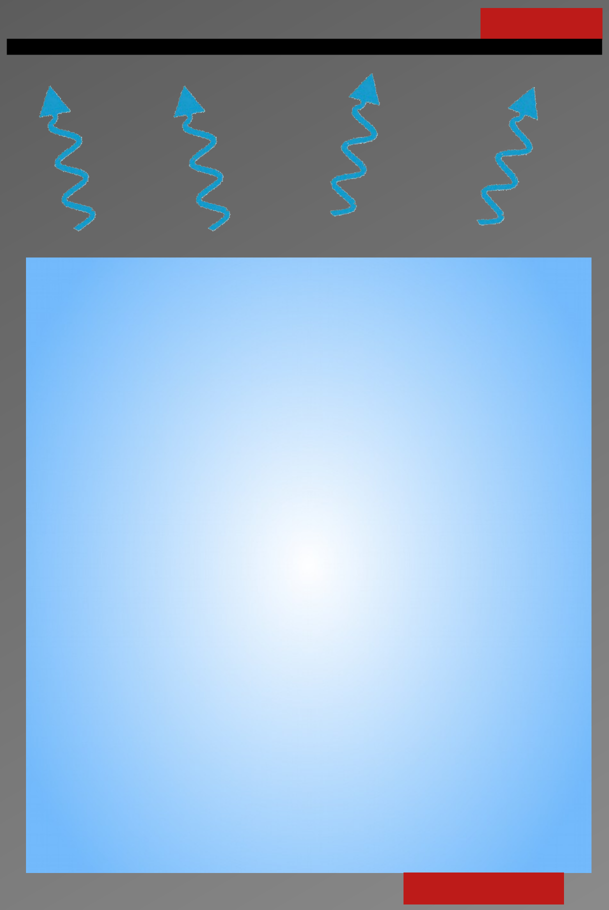

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  A light detector faced to the main absorber measures the amount of emitted light

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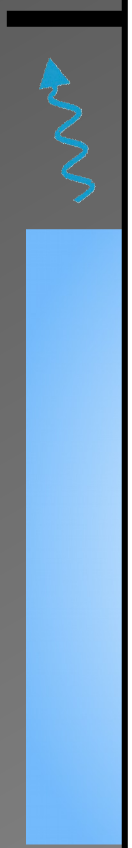

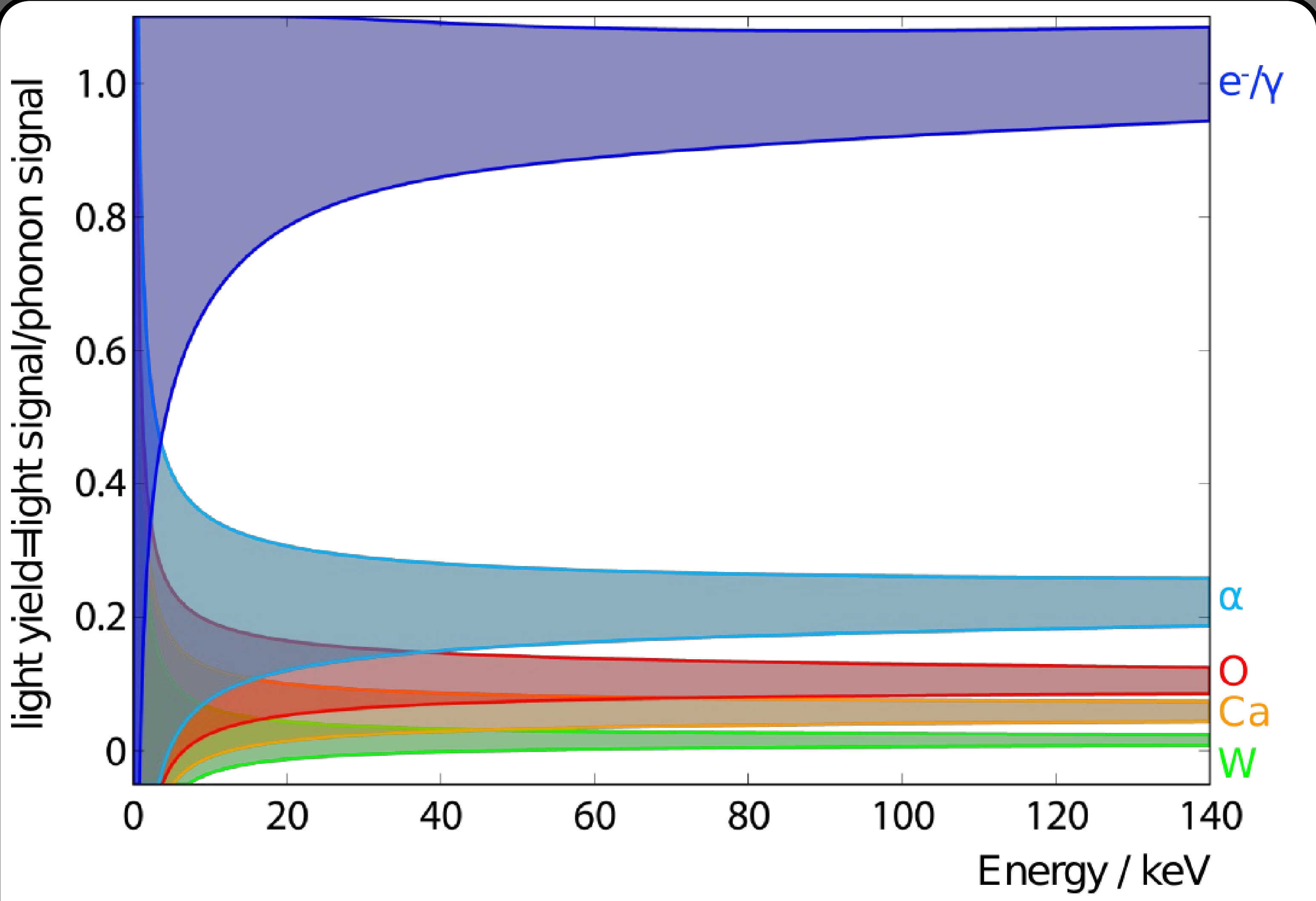

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$$Light\ Yield = \frac{Light\ Channel}{Phonon\ Channel}$$

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- Housing:

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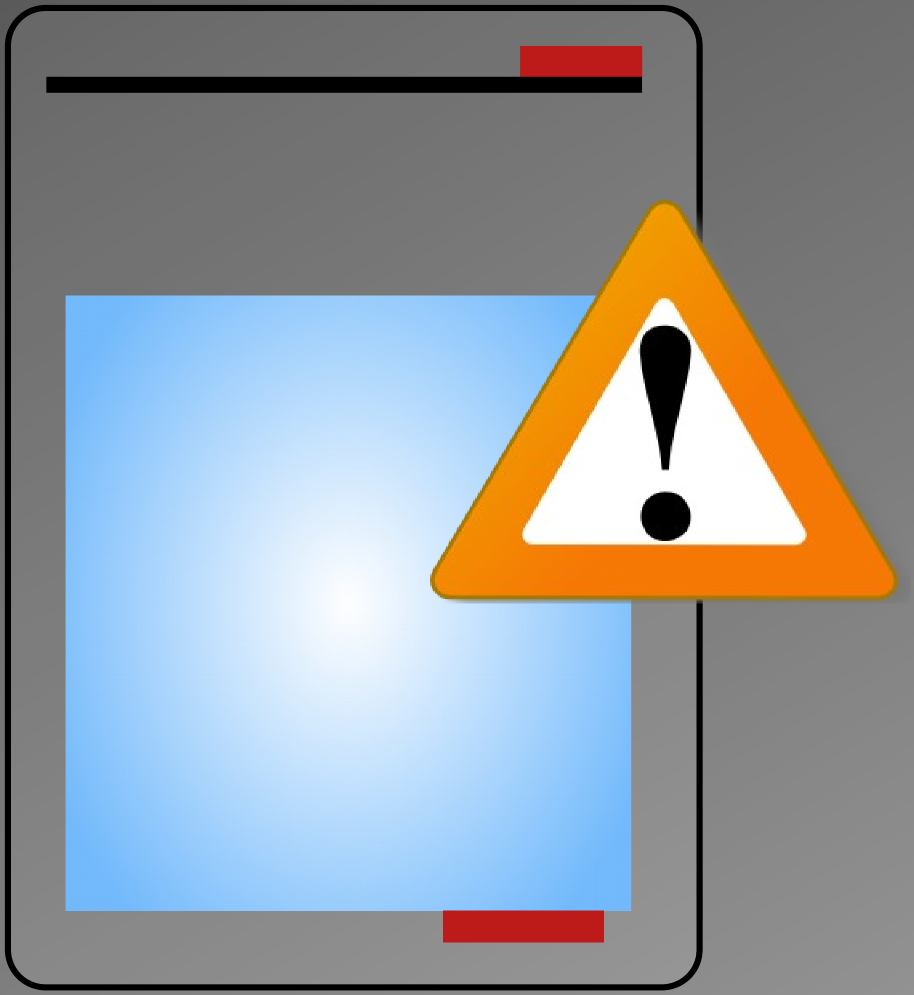

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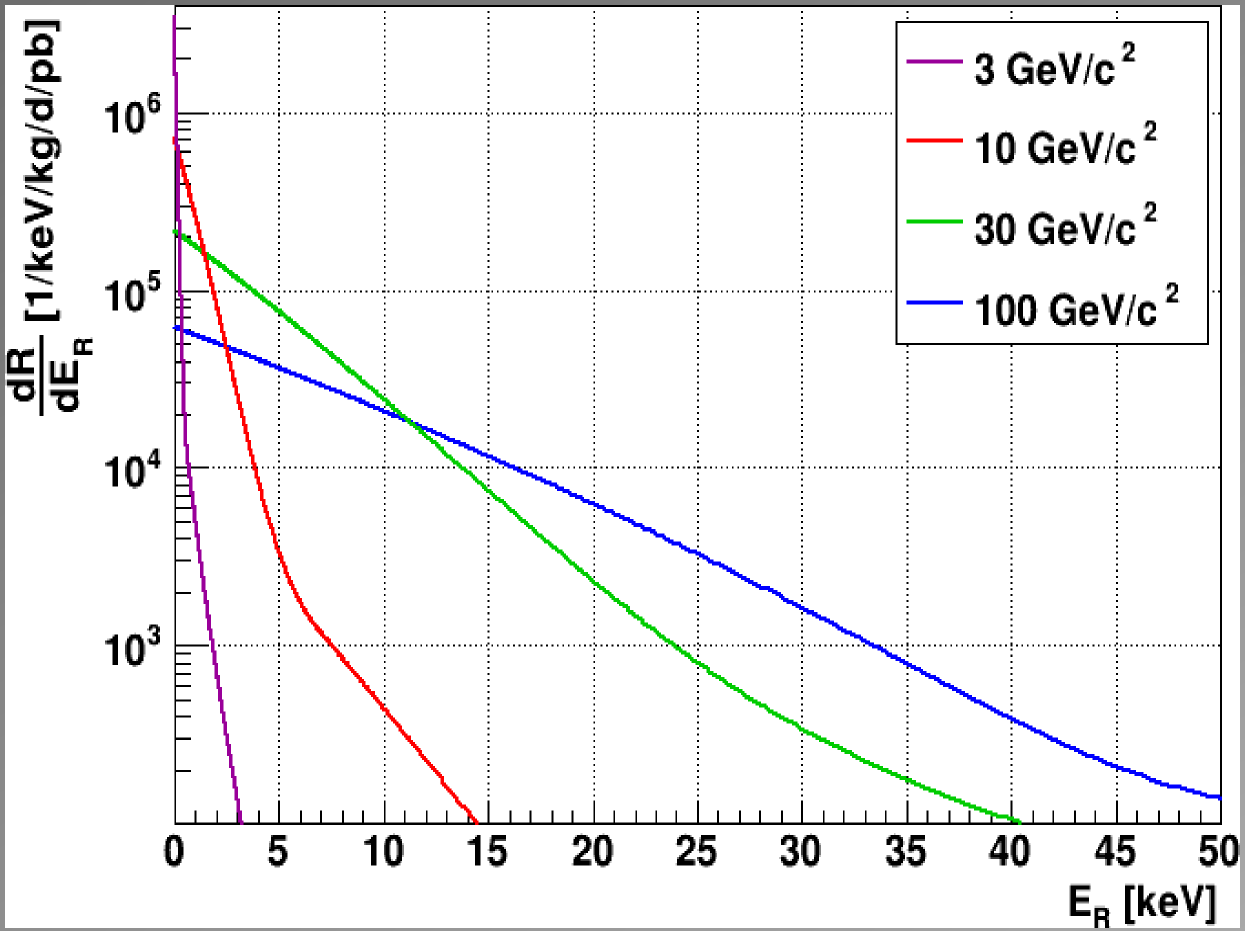
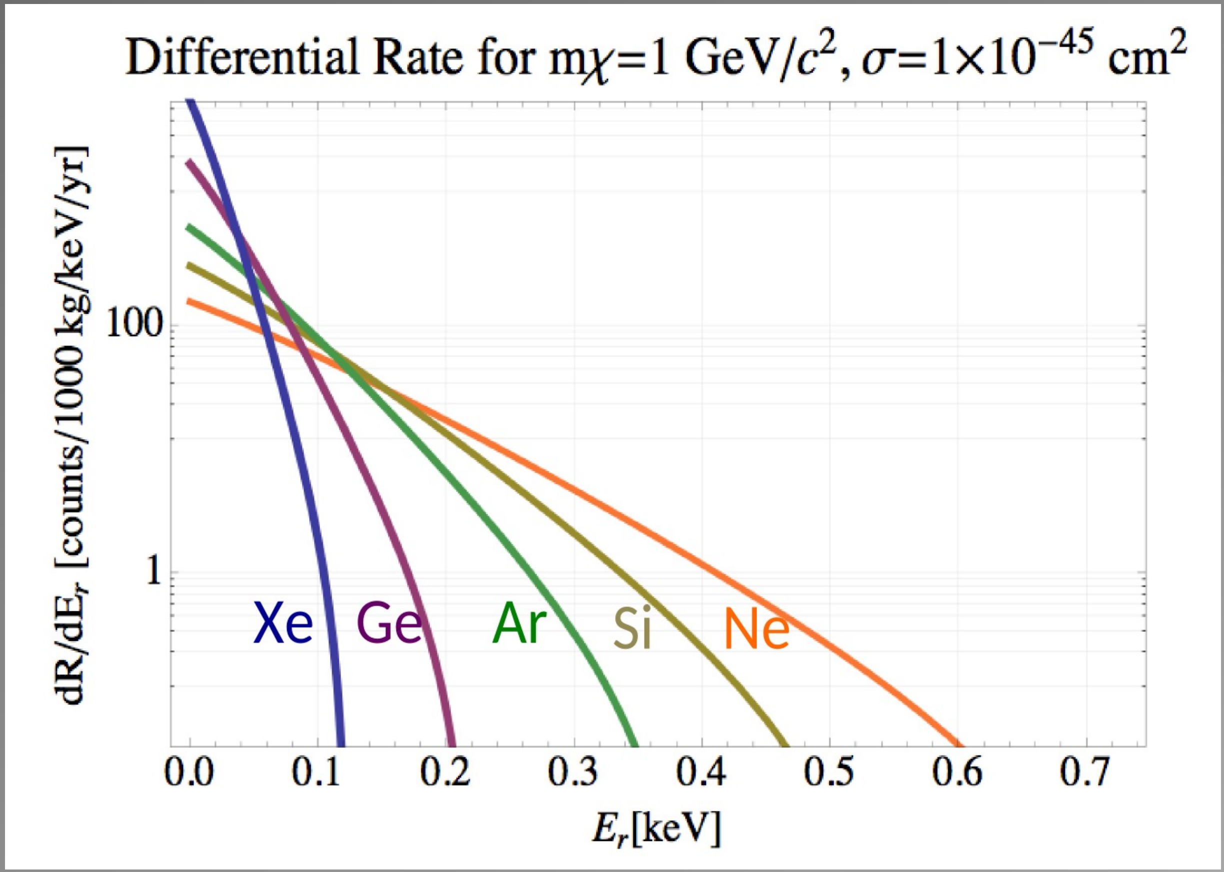
Light Dark Matter particles in cryogenic detectors

- Nuclear recoil spectrum shrinks towards low energies as Dark Matter particles get lighter

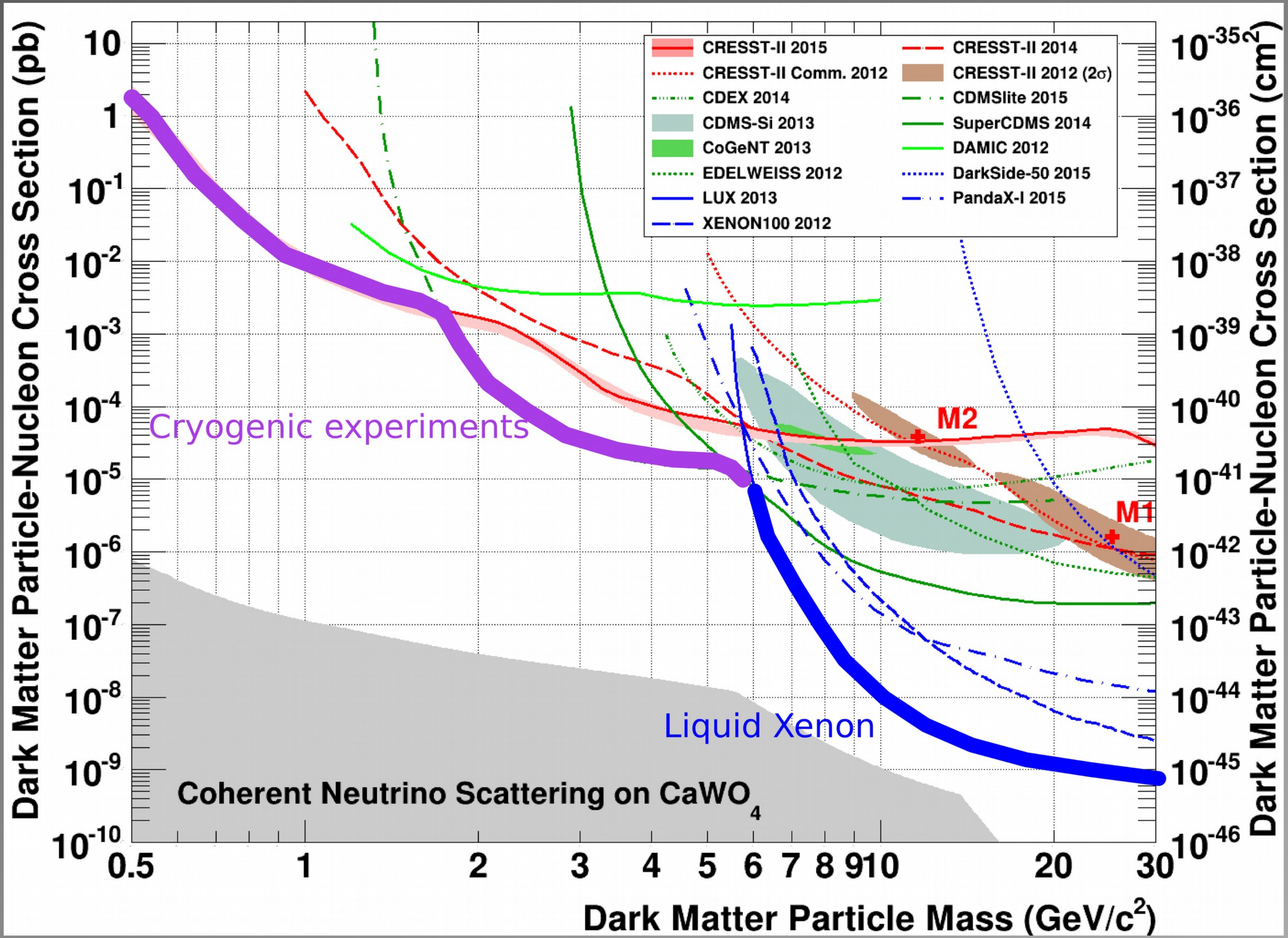


Light Dark Matter particles in cryogenic detectors

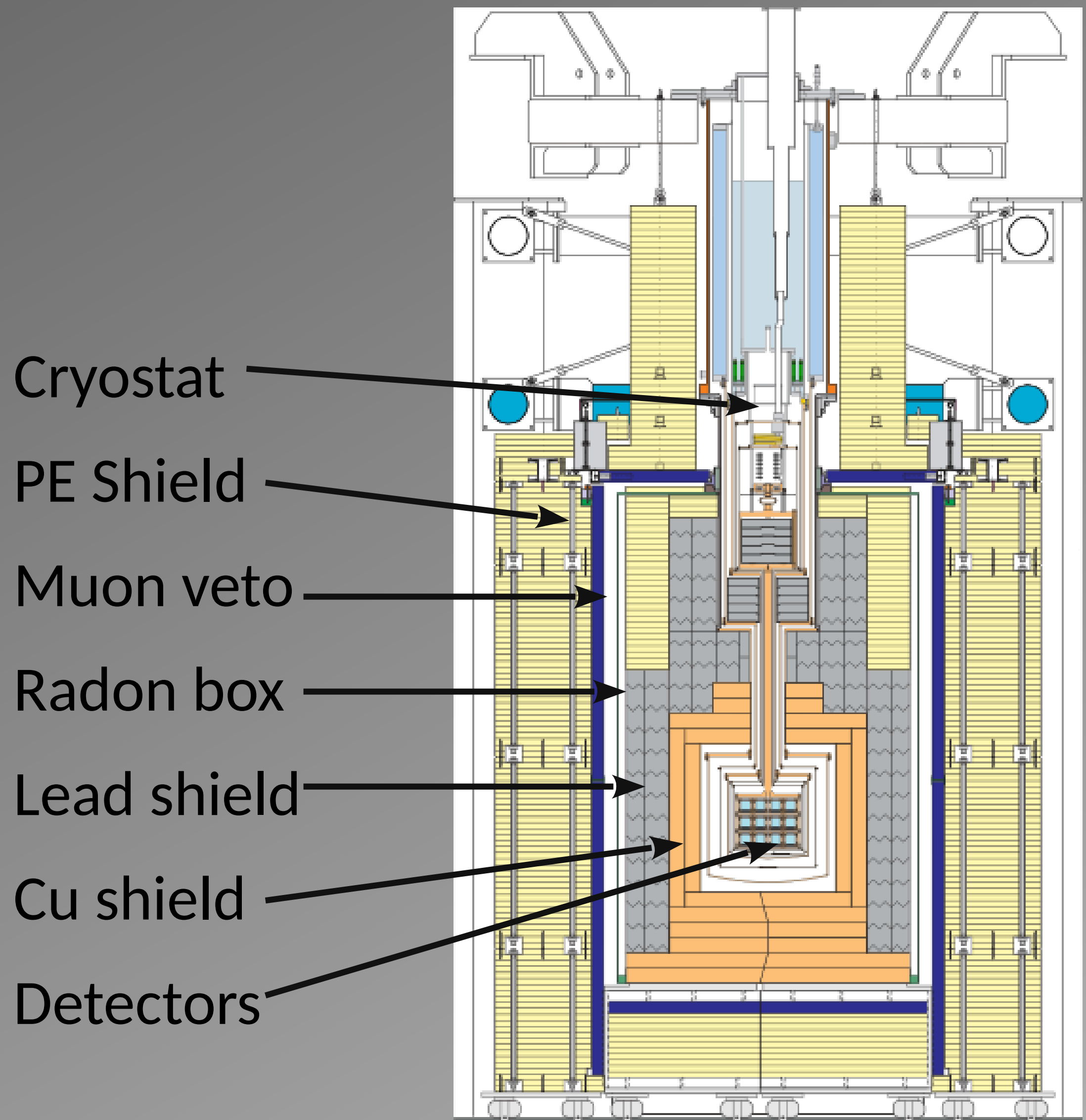
- Nuclear recoil spectrum shrinks towards low energies as Dark Matter particles get lighter
- Recoil energy is maximal when $M_{target} = M_{DM}$



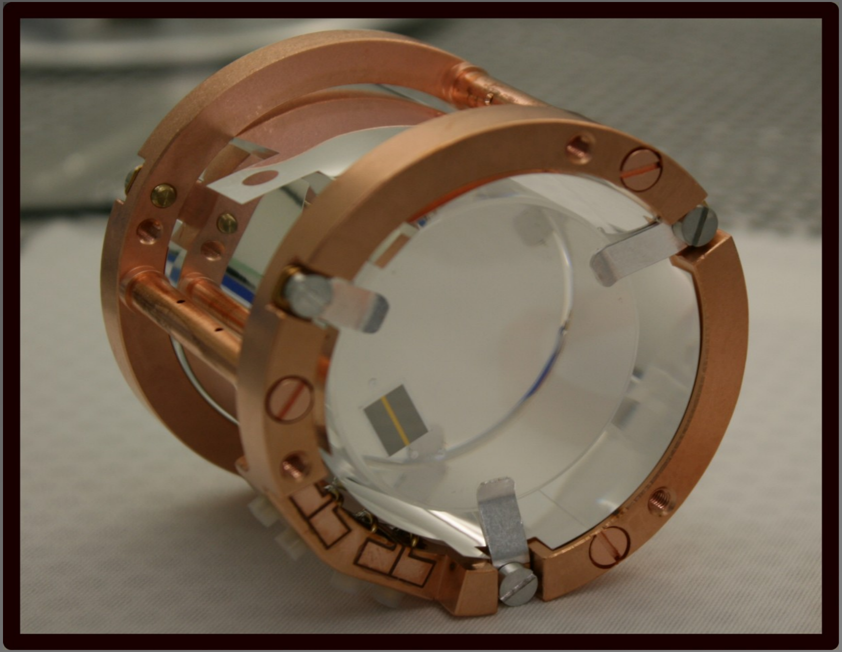
Light Dark Matter particles in cryogenic detectors

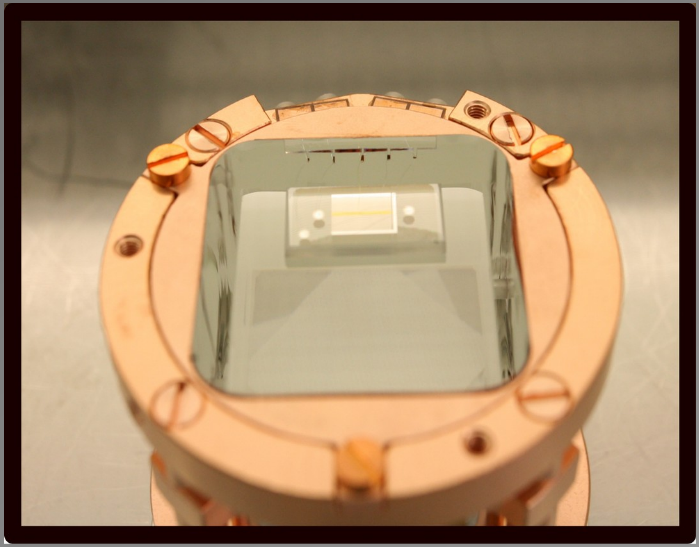


CRESST @ Gran Sasso



CRESST-II Detector Module





Detector Lise

Threshold: 307 eV

Incomplete surface background rejection

Commercial crystal

Best threshold

Detector TUM40

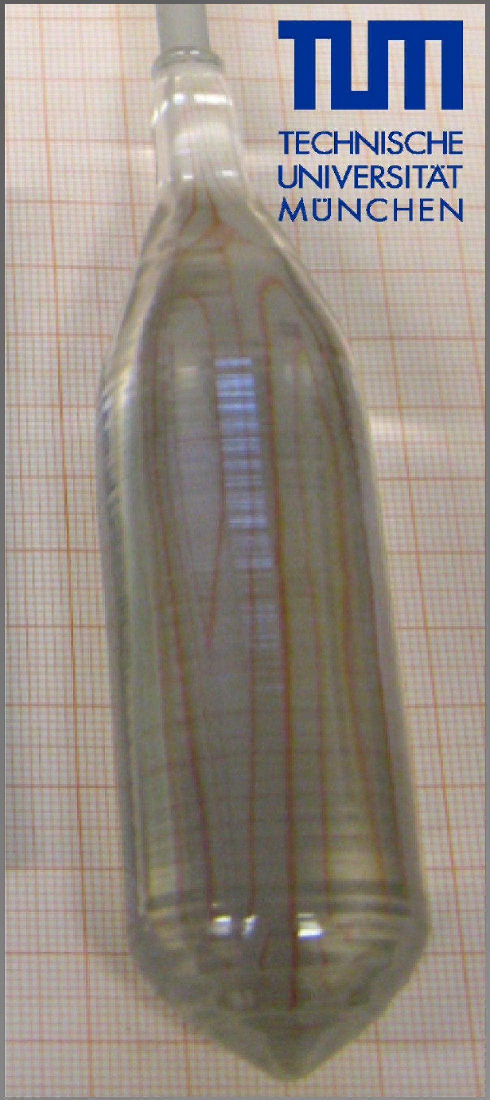
Threshold: 400 eV

Efficient surface background rejection

Improved radiopurity

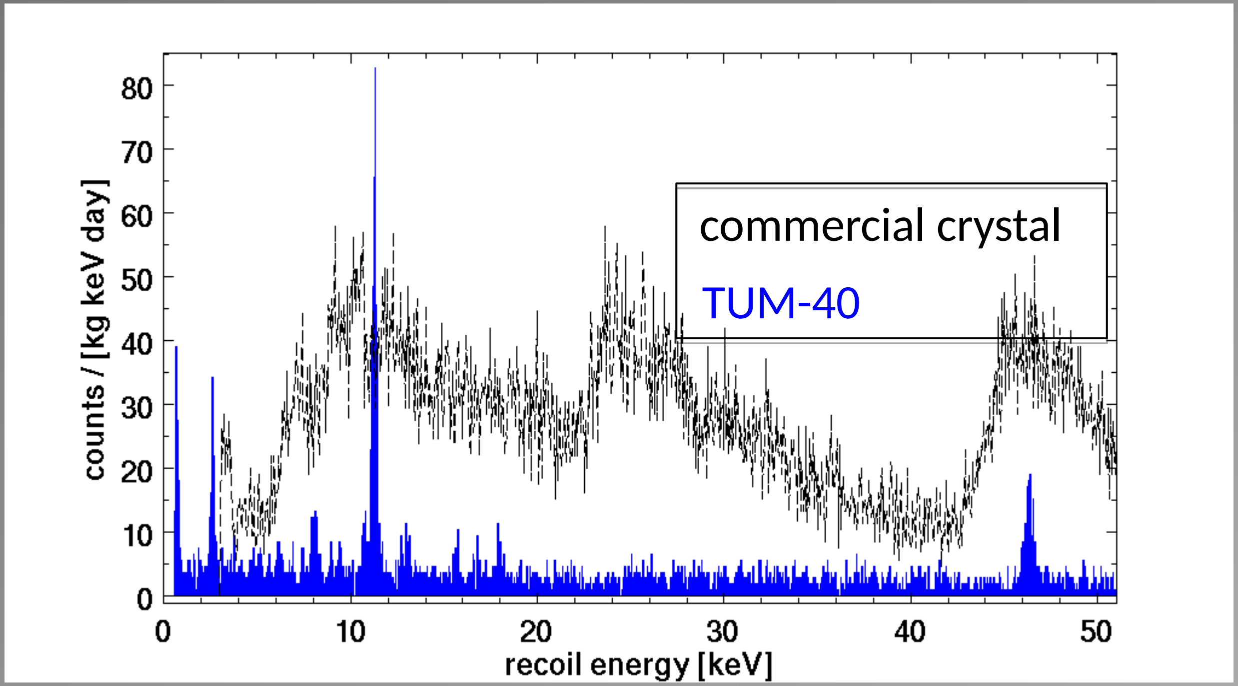
Best overall performance

$CaWO_4$ as target material

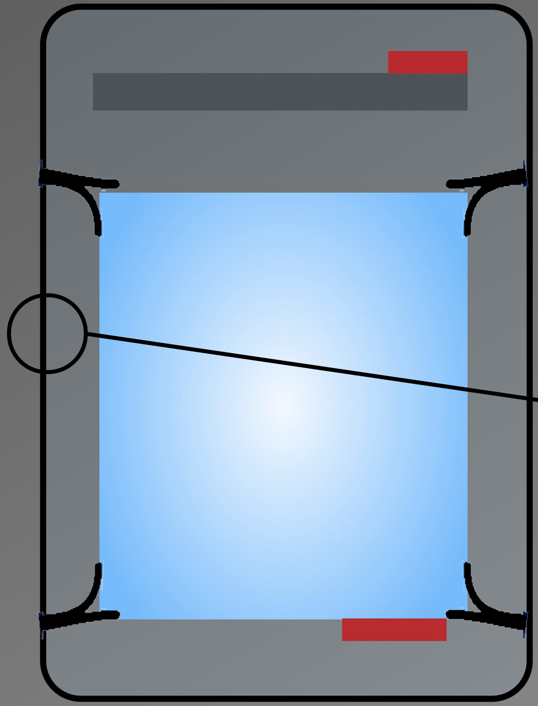


Crystal growth at TU Munich

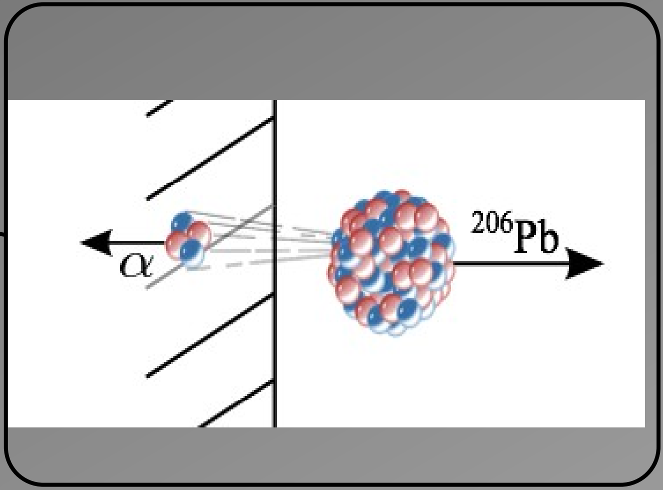
- Average countrate 3.5 counts/keV/kg/day
- Radiopurity improved 2-10 times compared to commercially available crystals



Holding of the crystal
Surface background



$^{210}Po \rightarrow {}^{206}Pb$ (103keV) + α (5.3 MeV)

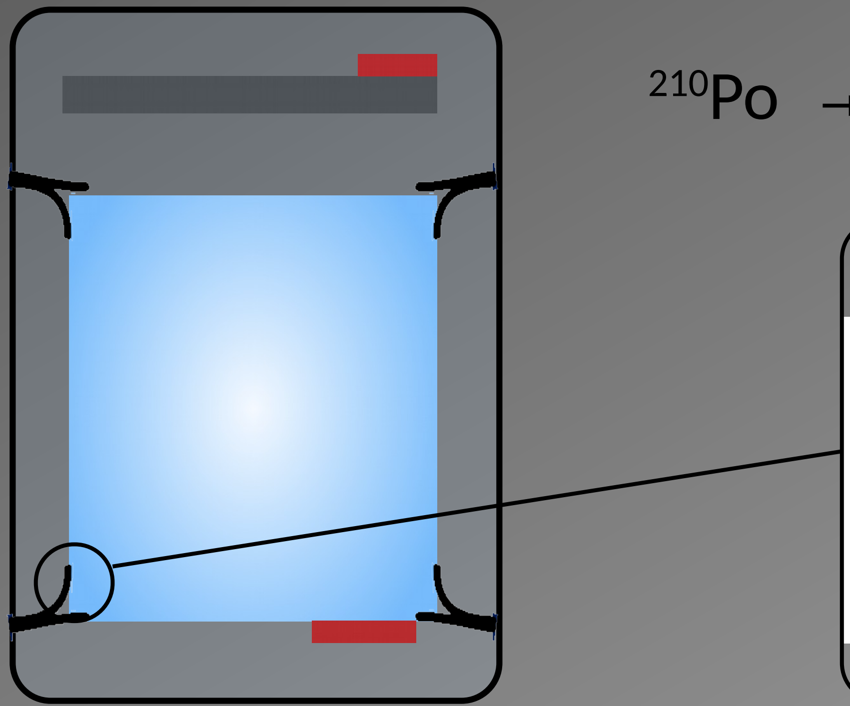


^{206}Pb → Nuclear recoil in the crystal

α → Light from the scintillating housing

Low energy vetoed recoil

Holding of the crystal
Surface background



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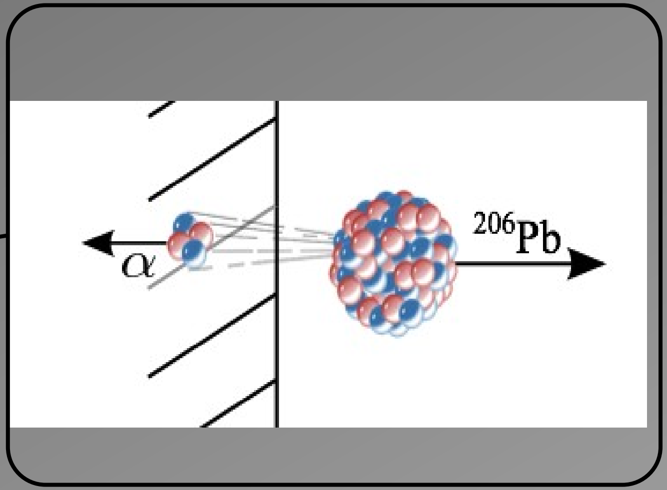


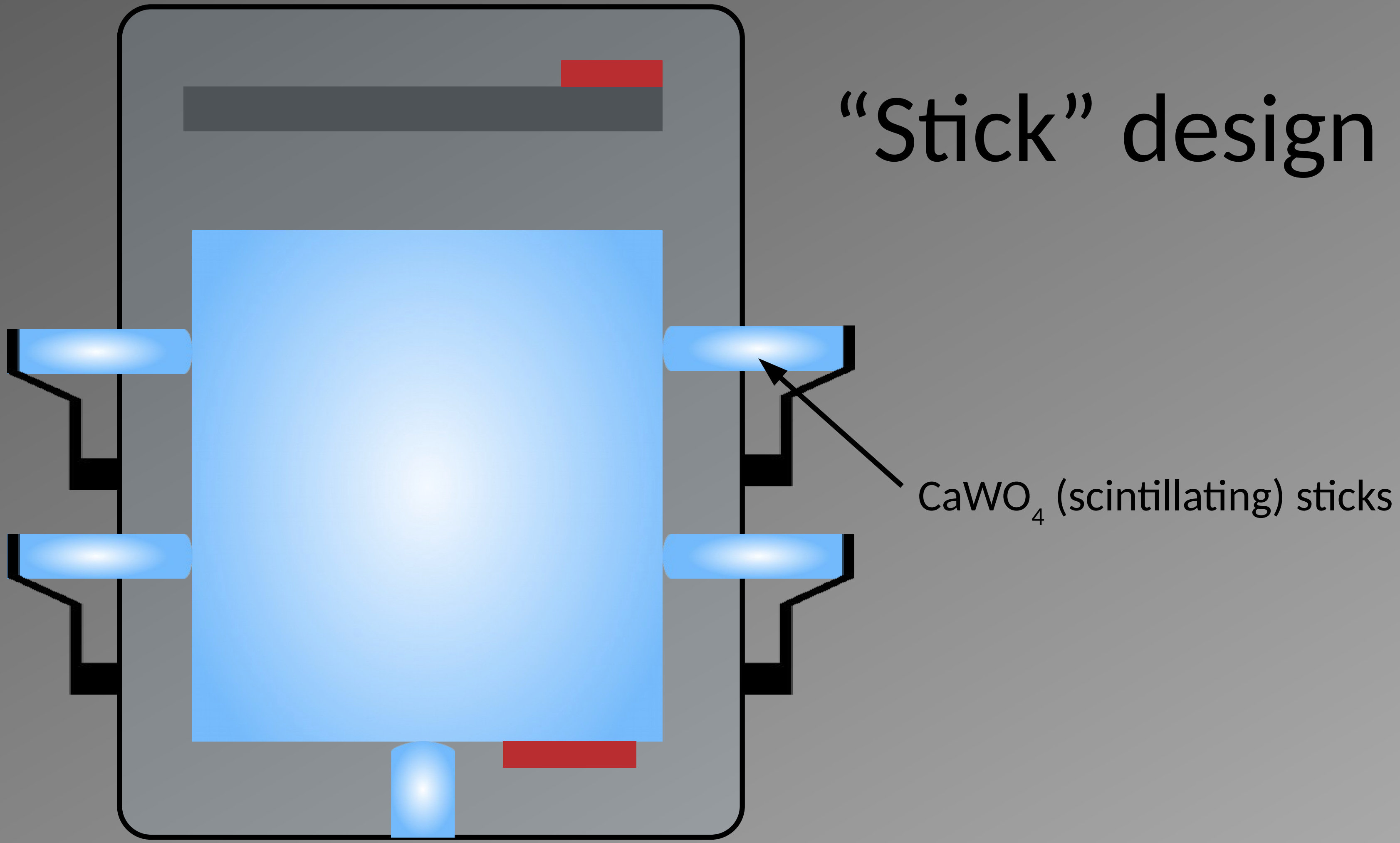
$^{206}Pb \rightarrow$ Nuclear recoil in the crystal

α → No light

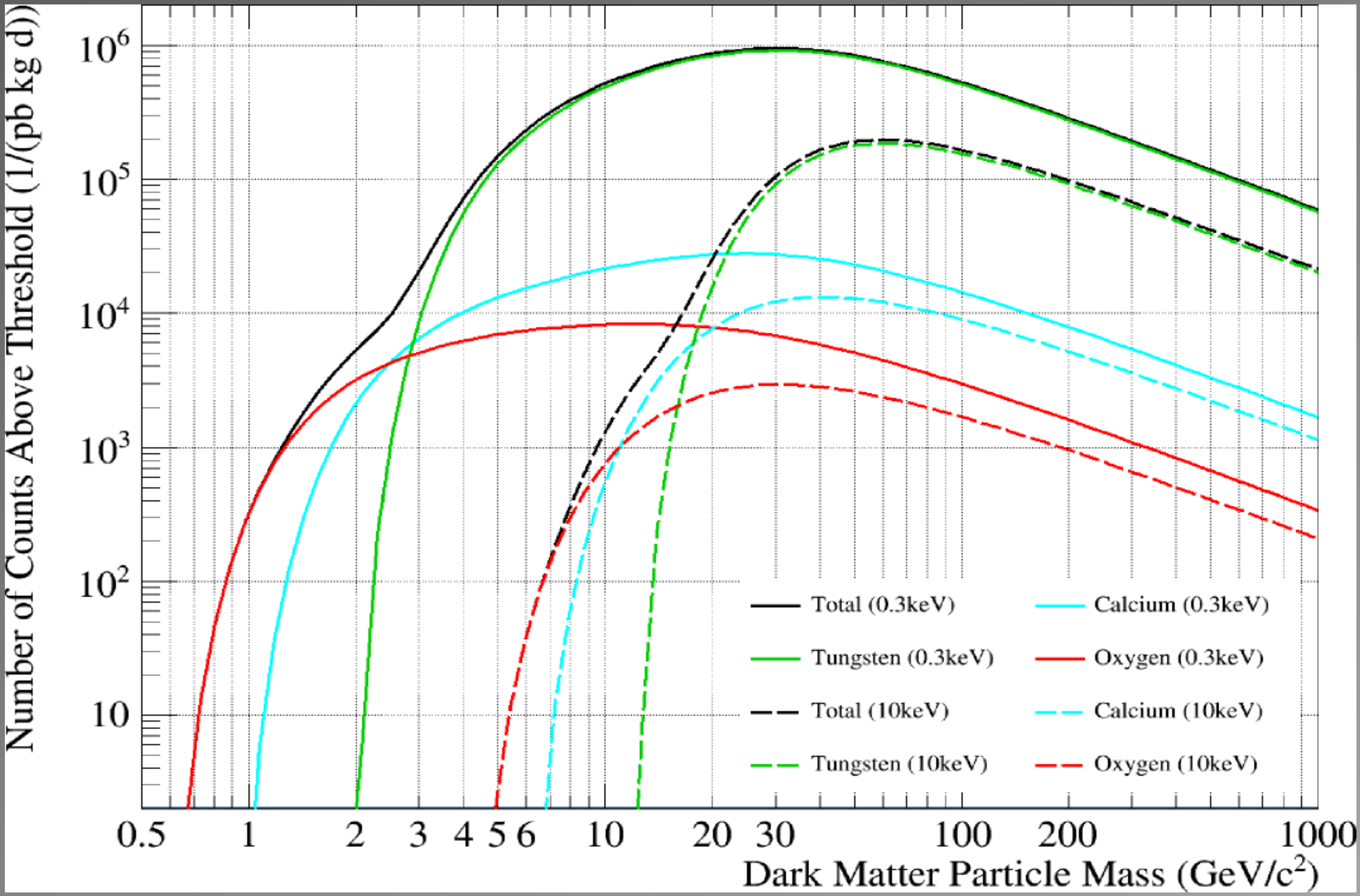
Low energy unvetoed recoil

Holding of the crystal
Surface background

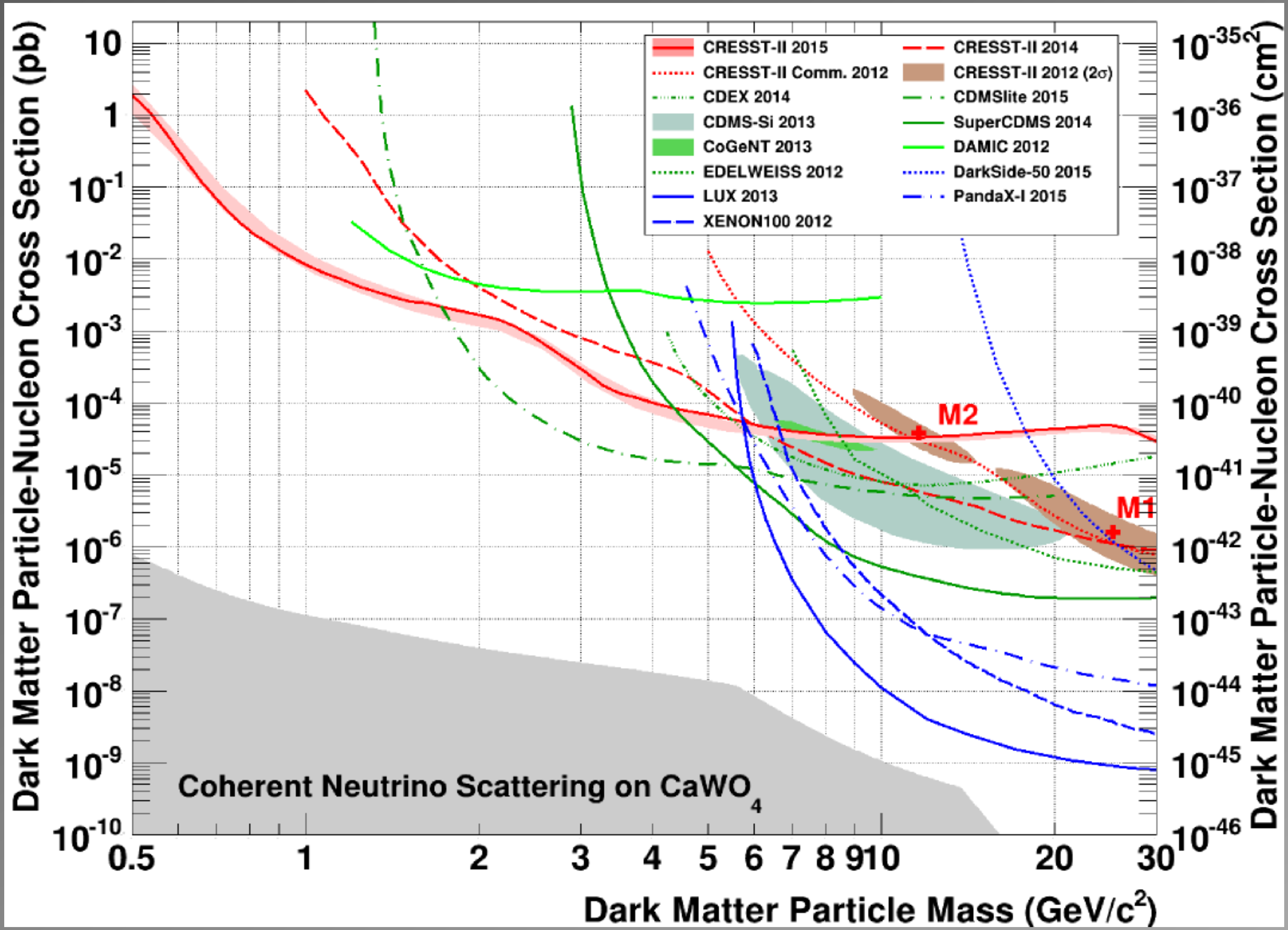
“Stick” design



$CaWO_4$ as target material



Last CRESST-II result



Eur. Phys. J C76 (2016) 25, arXiv:1509:01515

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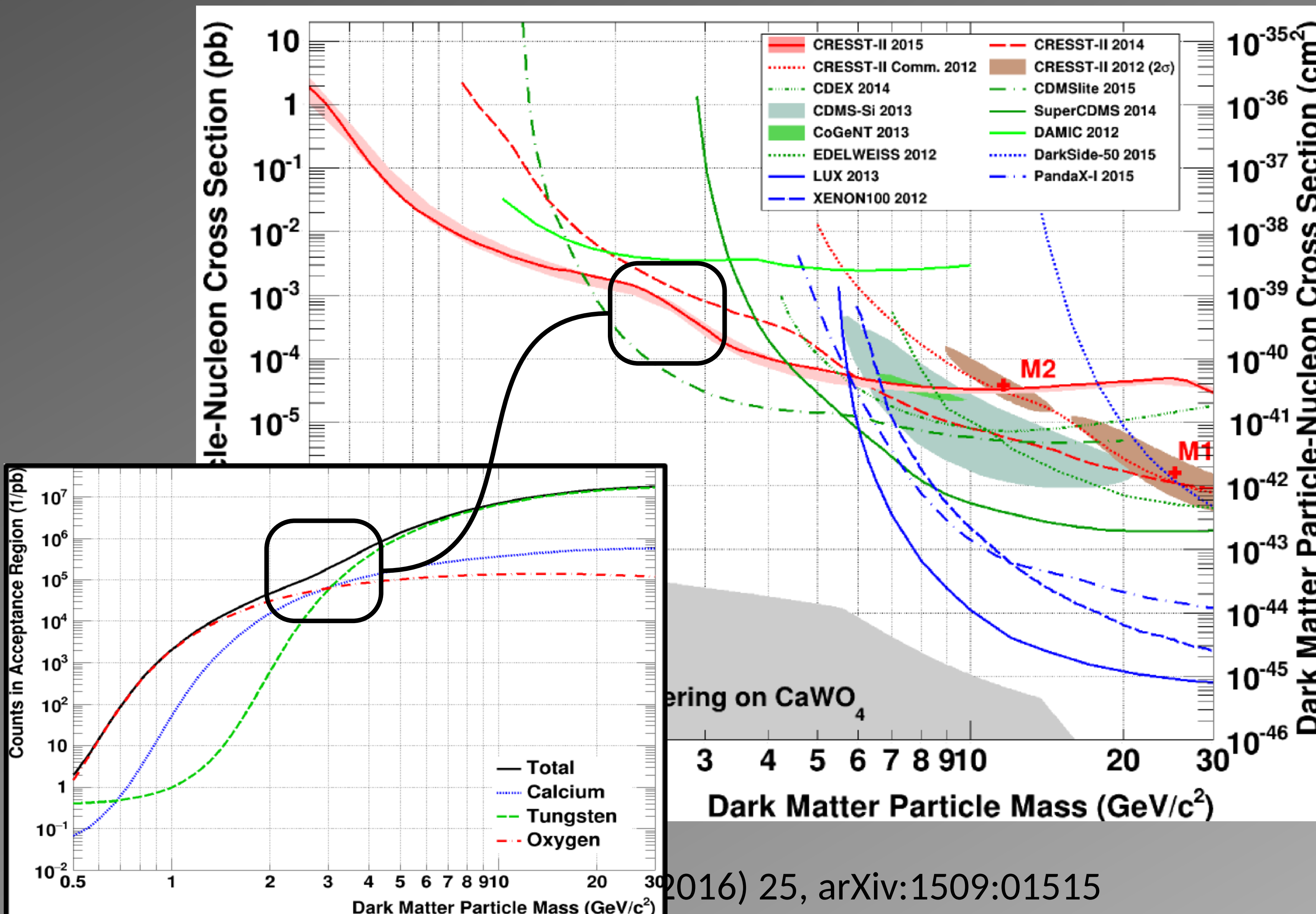
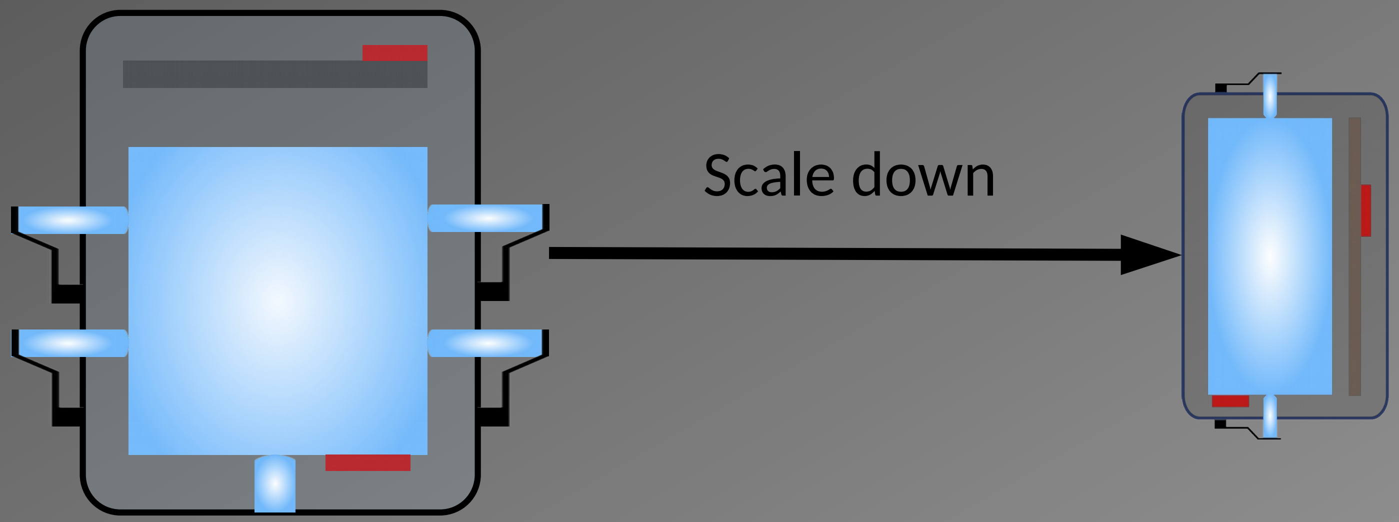


2016) 25, arXiv:1509:01515

CRESST-III strategy



CRESST-II

Mass ~ 250g

Threshold ~ 500eV

Light detector resolution ~ 5eV

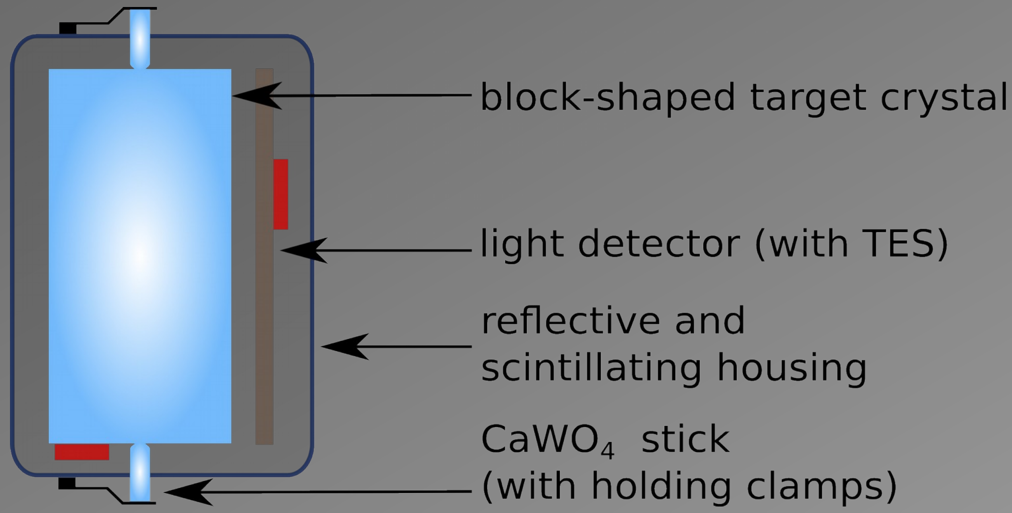
CRESST-III

Mass ~ 24g

Threshold reduced by 5-10

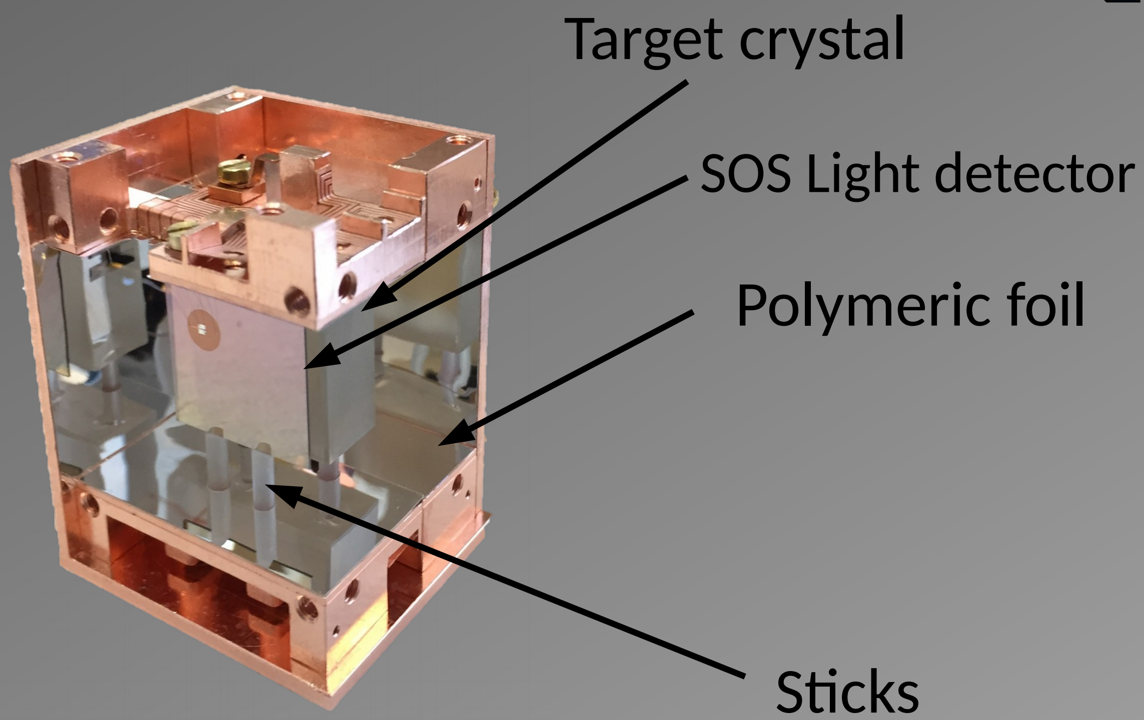
Light detector resolution improved by 2

CRESST-III



Our goals:

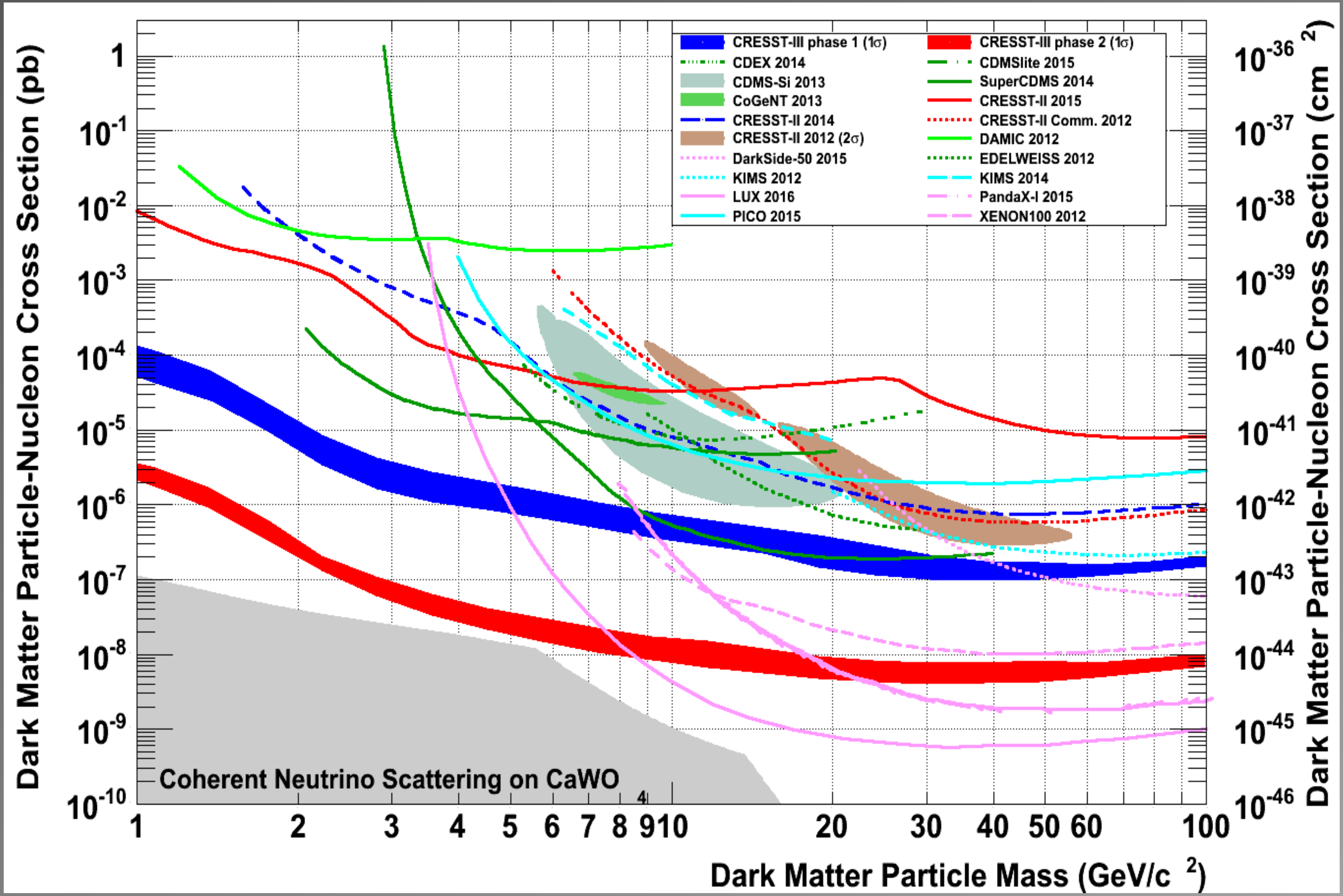
- Exposure of 50 kg days
- Self-grown crystals of high radiopurity
- Energy threshold ~100eV



Prototype

- Main absorber of 24g
- Fully scintillating housing
- Energy threshold: 60 eV!

CRESST-III Projection



Phase 1: 50 kg*days

Phase 2: 1000 kg*day + reduced background by a factor of 100

Summary

- CRESST technology allows for precise measurement of nuclear recoils at small energies
- The CRESST experiment has proven its competitiveness for the (yet) mostly uncharted low-mass Dark Matter region
- A new detector design has been developed to achieve a low energy threshold
- 10 of such detectors are currently taking data
- First release of new data this summer!

Stay tuned!

Thanks for your attention