The CRESST experiment: Current status and future development

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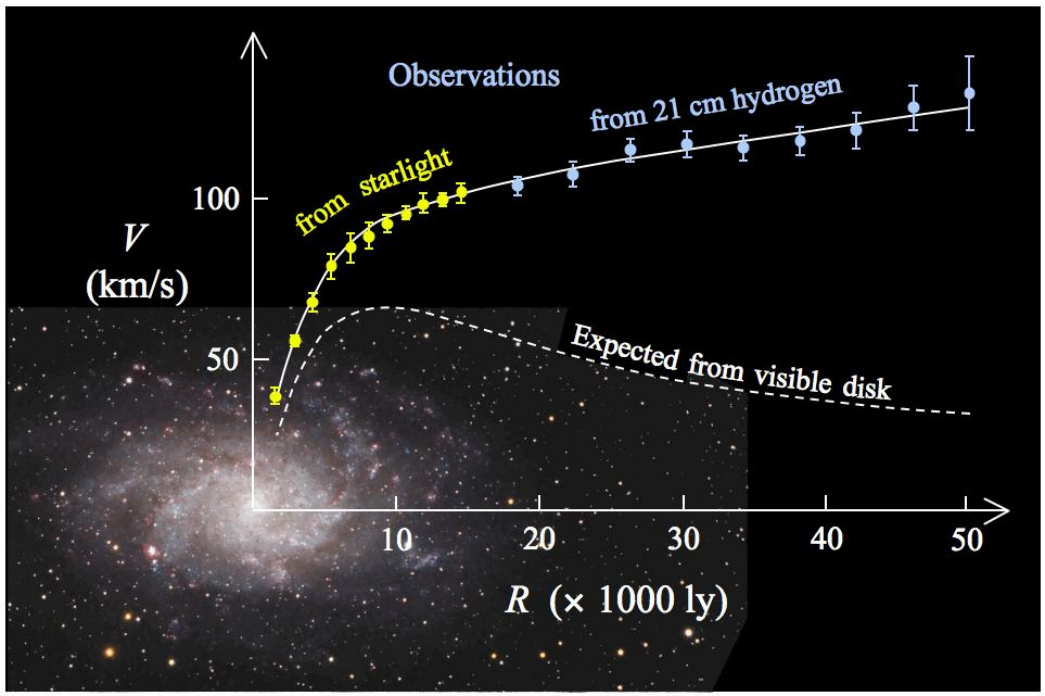
(Werner-Heisenberg-Institut)

Dark Matter in the Universe

- Numerous evidences for Dark Matter on all cosmic scales



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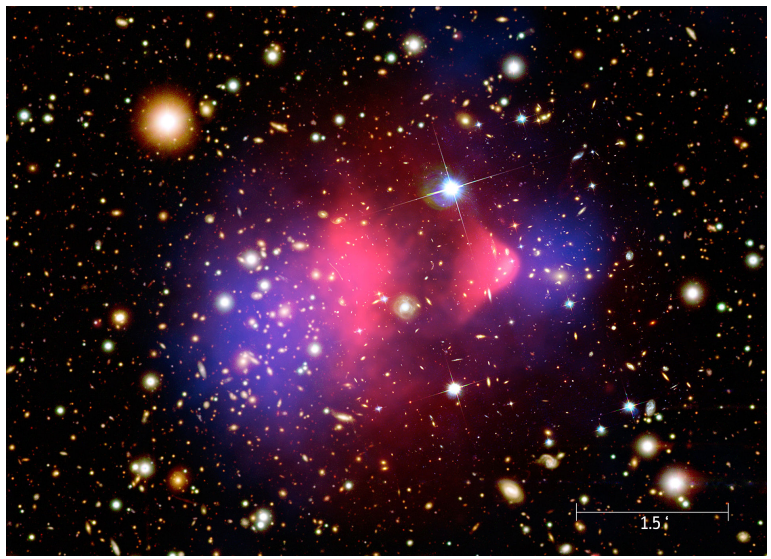

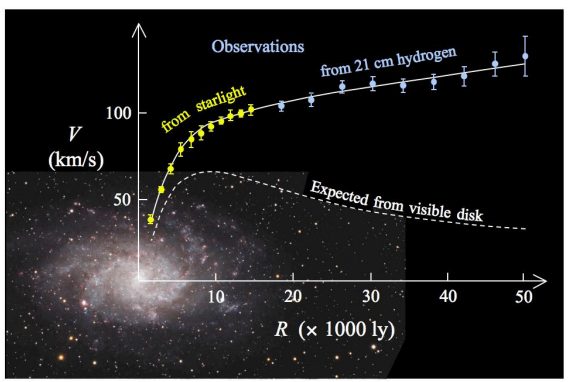

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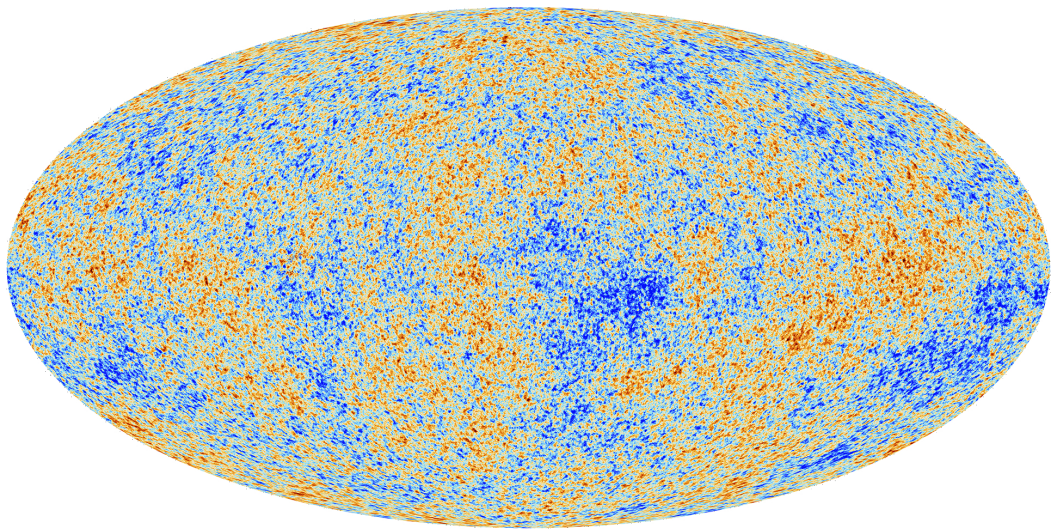
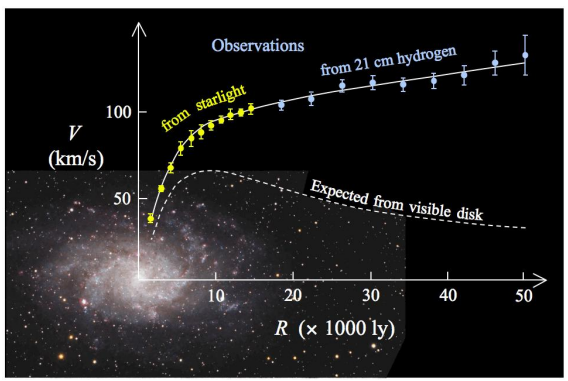
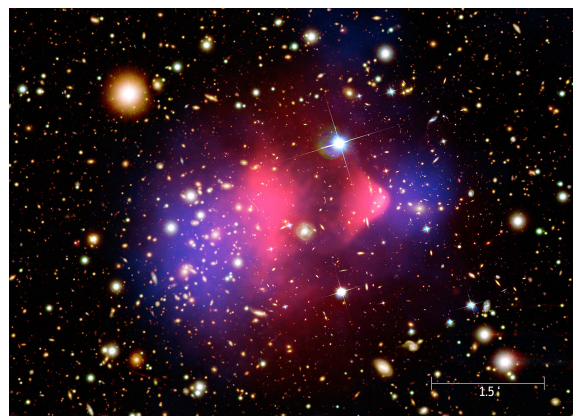
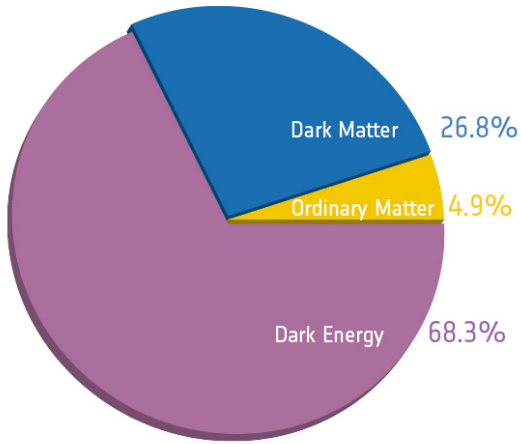


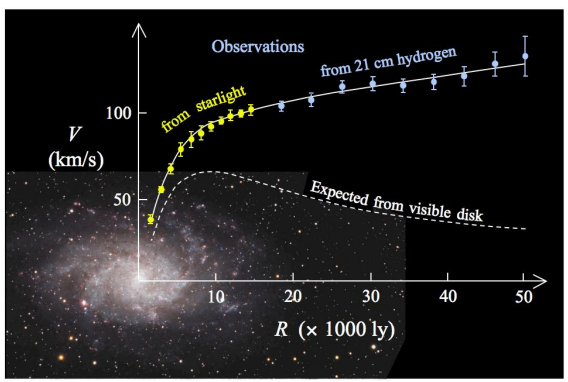


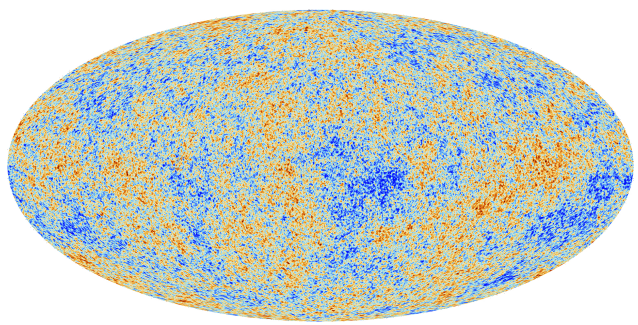


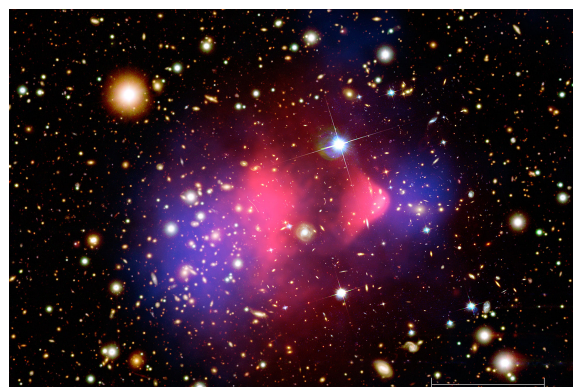
Dark Matter in the Universe

- Numerous evidences for dark matter on all cosmic scales
- Nature:
  - Cold/non-relativistic
  - Non-baryonic
  - Long living/stable





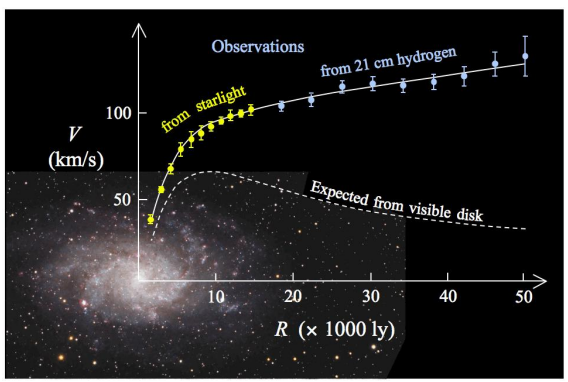


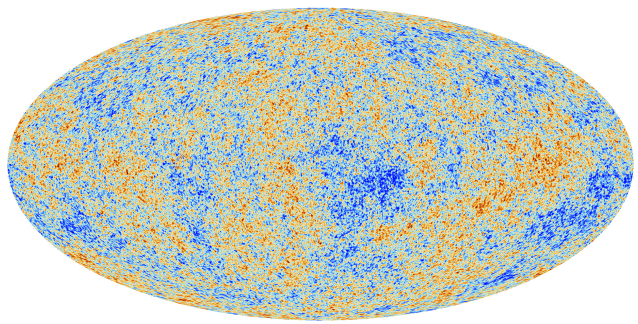


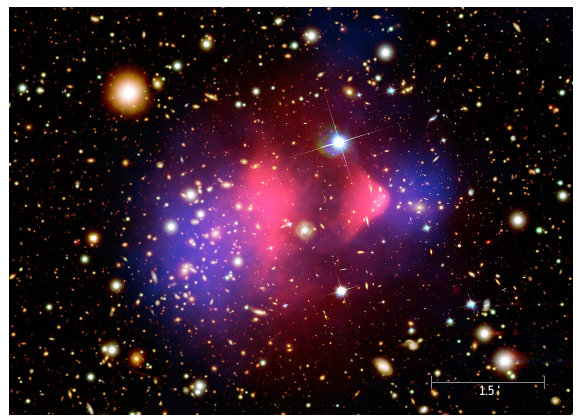
Dark Matter in the Universe

- Numerous evidences for dark matter on all cosmic scales
- Nature:
  - Cold/non-relativistic
  - Non-baryonic
  - 5 times more abundant than baryonic matter
  - Long living/stable

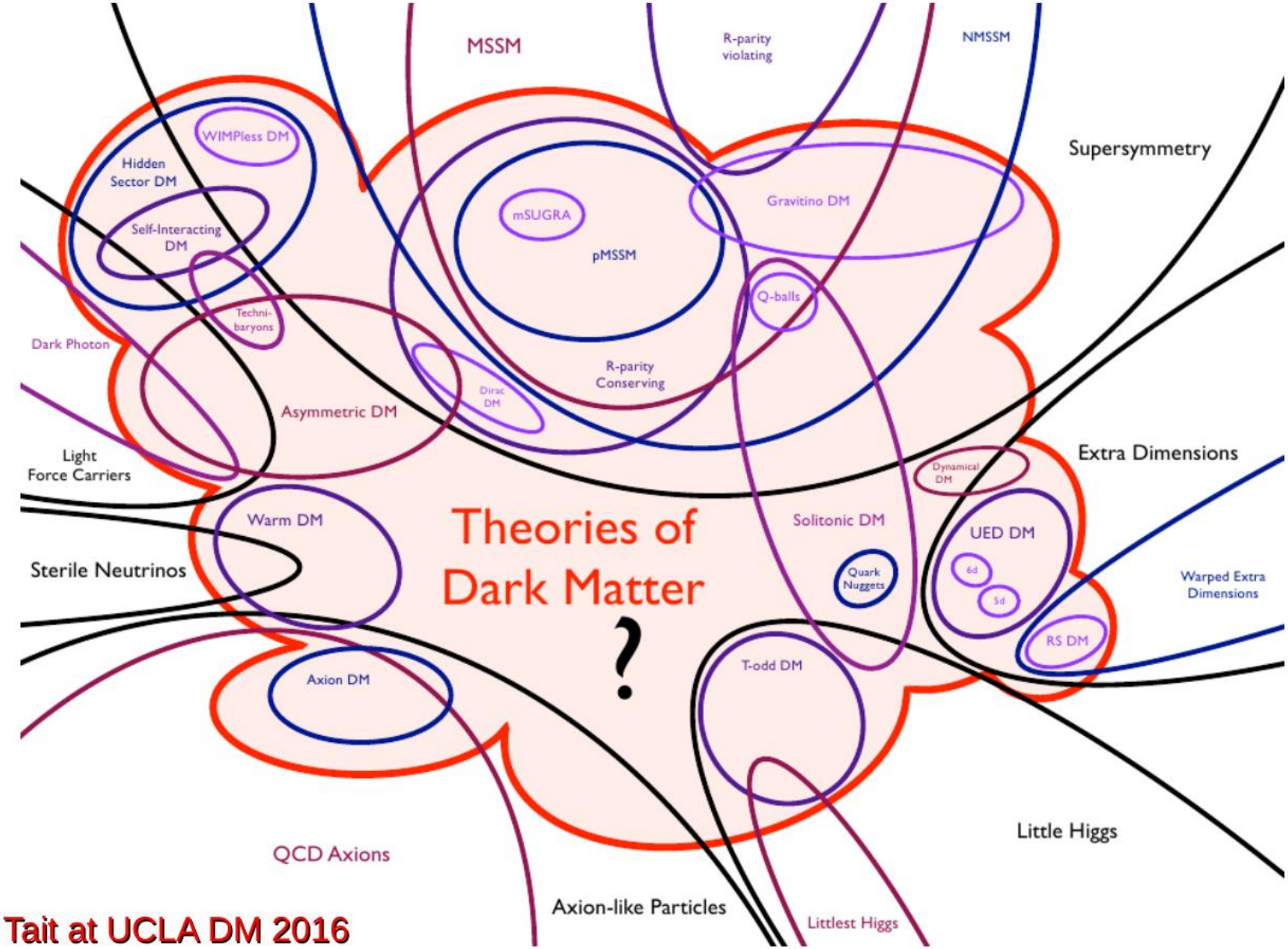
No direct proof achieved until today!





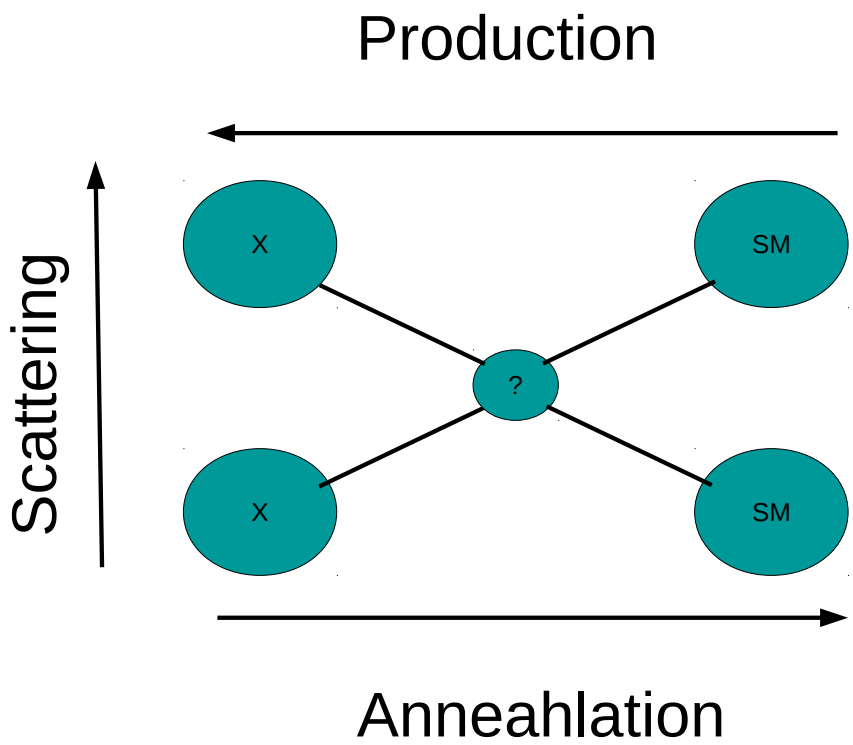


Dark Matter Candidates



Detection

- Necessary assumption: Weak coupling to standard model particles



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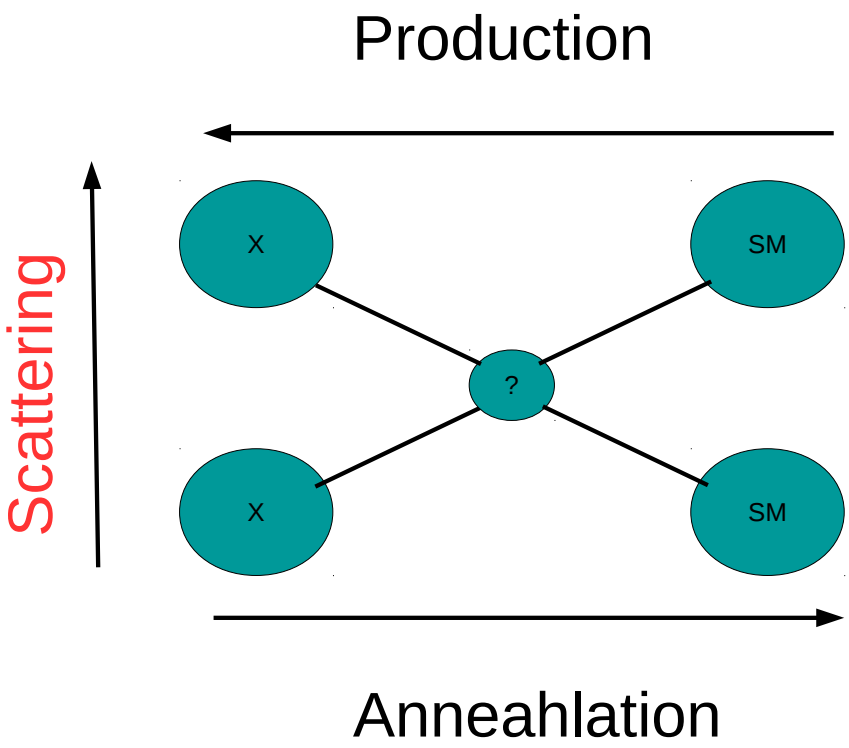
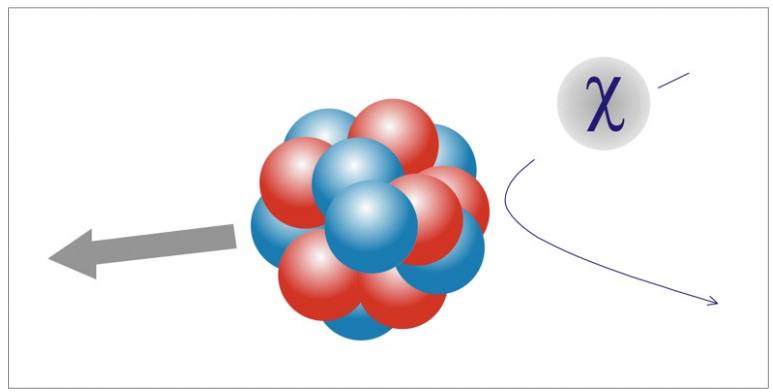




CRESST: Direct detection via elastic, coherent scattering off nuclei

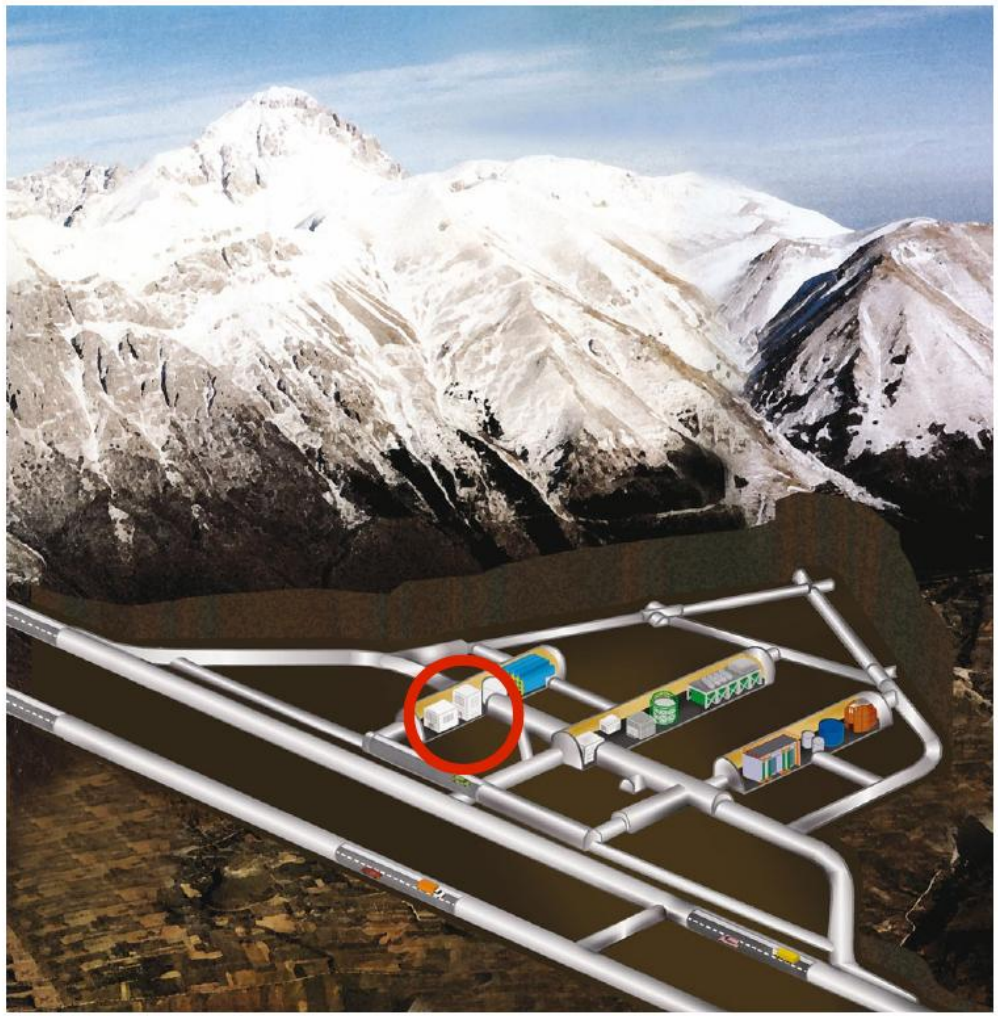
Crygenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers

Experimental Challenges

- Tiny signal rate (0.1-1 counts/(ton·year)
- Tiny energy depositions $\mathcal{O}$(0.1-10keV)
- Numerous background sources (internal & external)

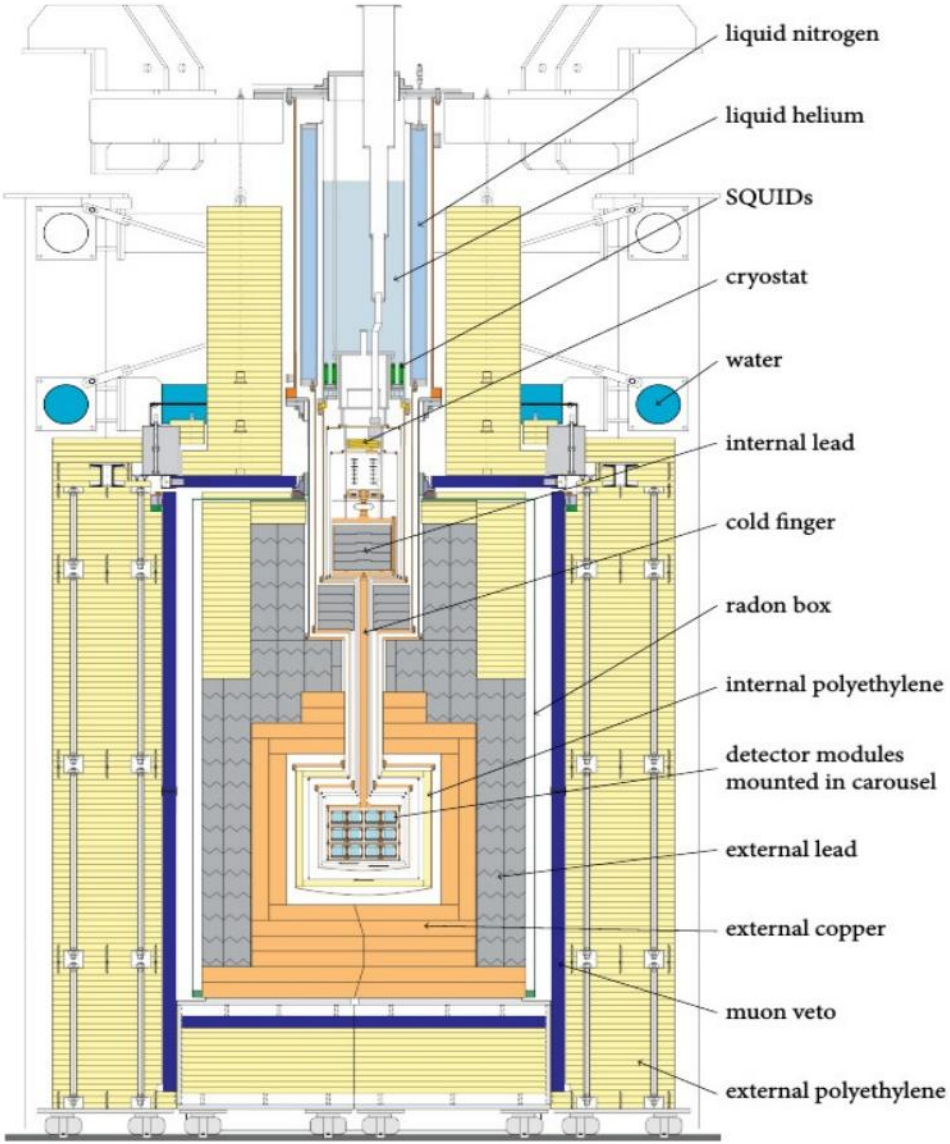
$\rightarrow$ Big detectors
$\rightarrow$ Low threshold
$\rightarrow$ Ultralow background environment
$\rightarrow$ Particle identification on event by event basis

CRESST: Location

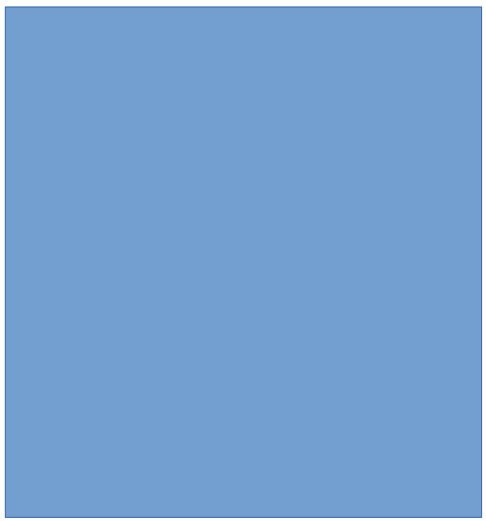


3600 m.w.e.

CRESST: Experimental Setup

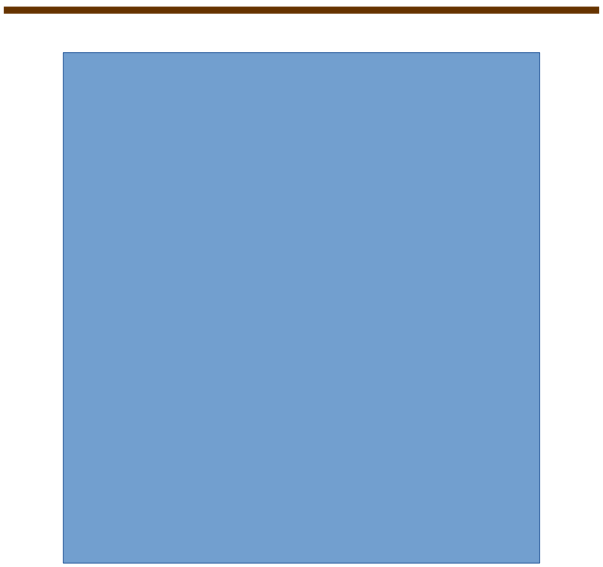


CRESST: Detector Module

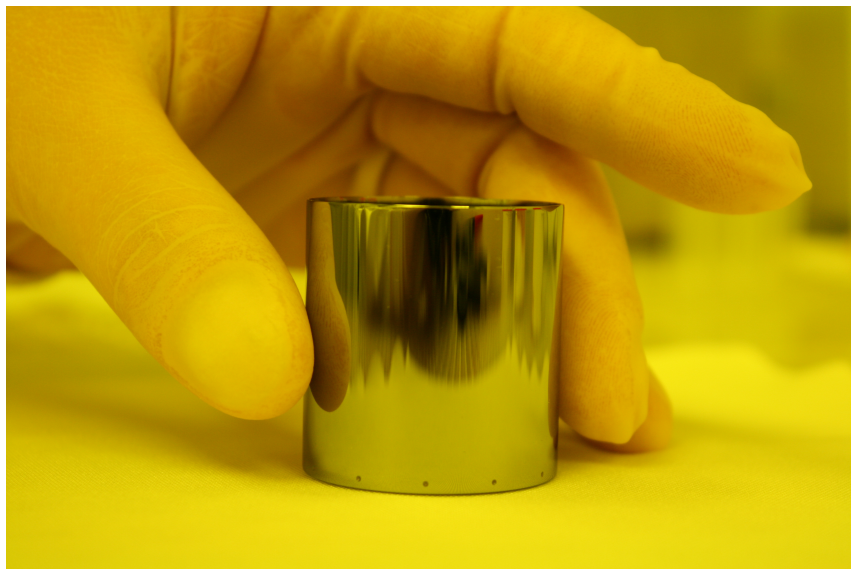


- Scintillating $CaWO_4$ main absorber
  - Multi element target (Ca, 0, W)
  - Inorganic scintillator (peak of emission at 420nm)
  - In-house production via Czochralski methode (control of internal backgrounds)

CRESST: Detector Module



- Scintillating $CaWO_4$ main absorber
- Light detector/absorber
  - Silicon or Silicon on Sapphire (SOS) absorber
  - Absorber dimension easy to adjust to the detector geometry



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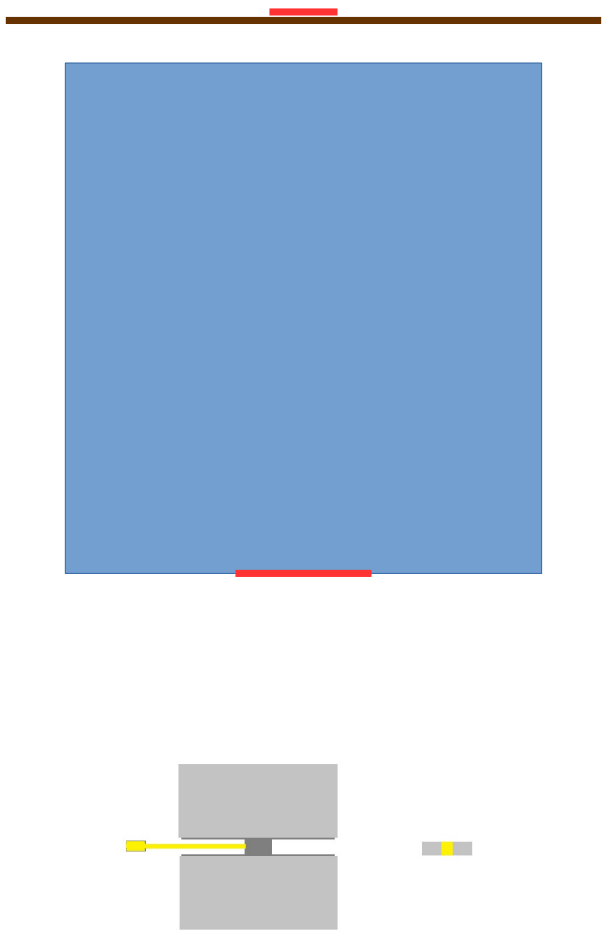
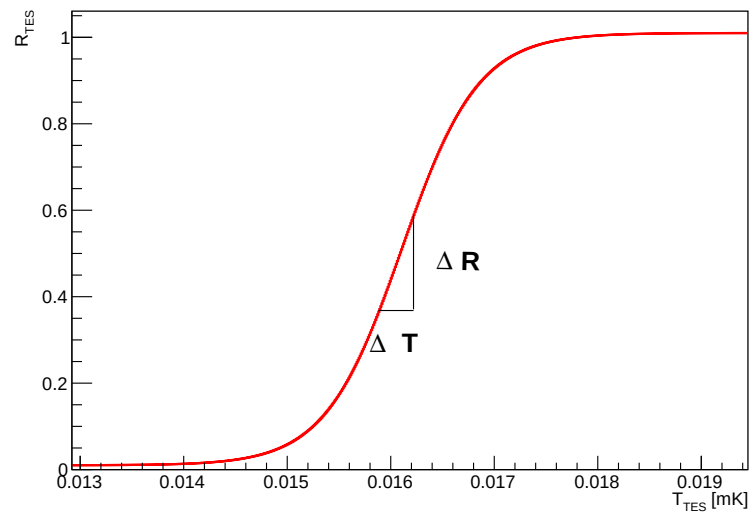


- Scintillating $CaWO_4$ main absorber
- Separated light detector (pure silicon/ silicon on sapphire (SOS))
- Thermometers: Tungsten Transition Edge Sensors (TES)
  - Bolometric/calorimetric mode possible
  - μK sensitivity
  - SQUID readout



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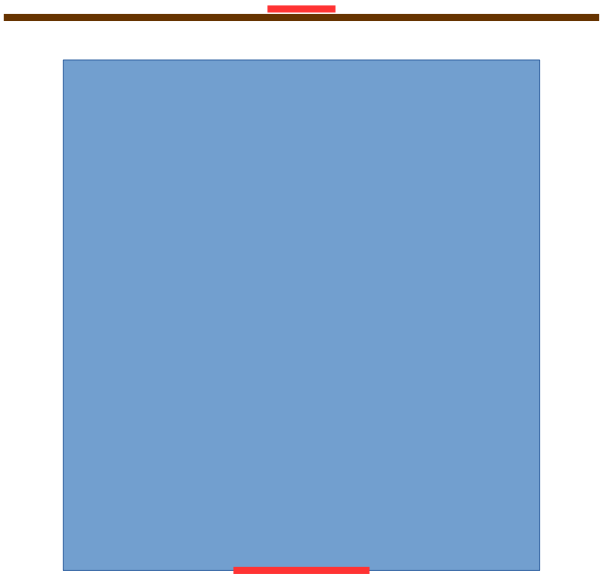

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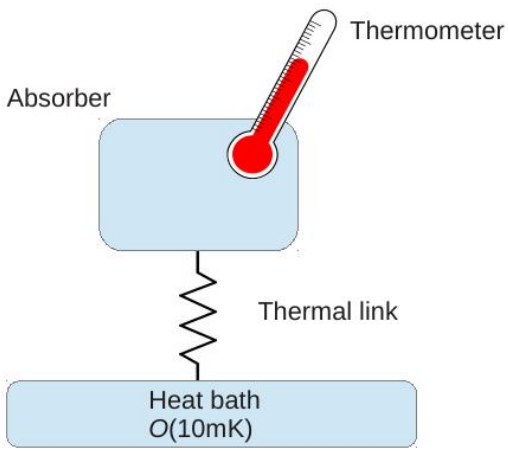
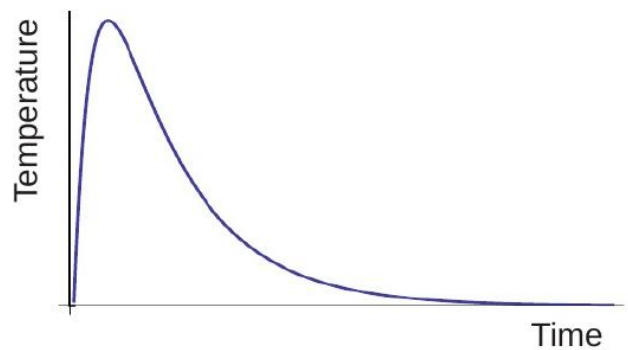




CRESST: Particle identification

Phonon Channel:

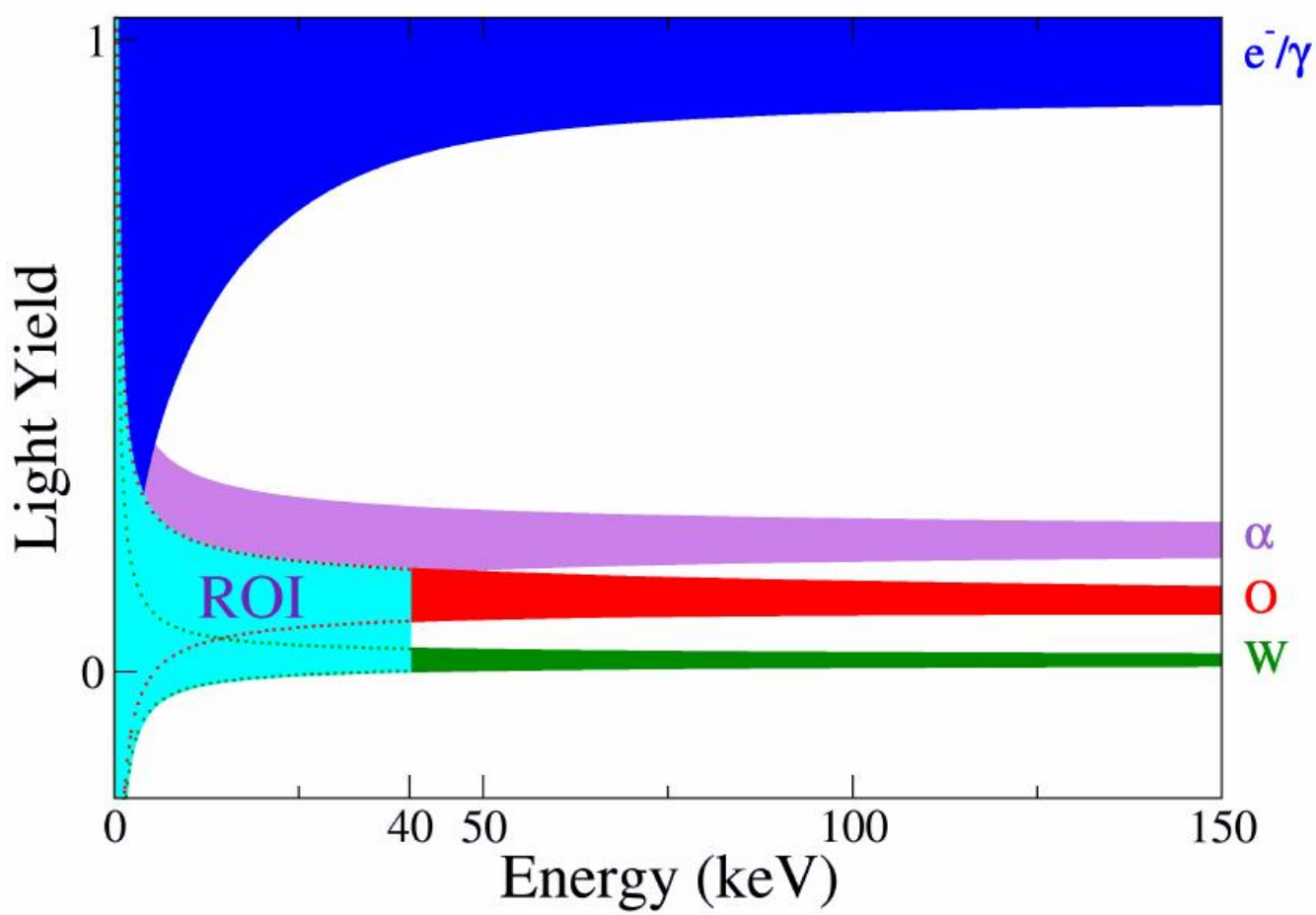
- Detects major part of the deposited energy
- Particle indepent detection channel
- Precise measurement of the recoil energy

Light Channel:

- Detects about $\approx 2\%$ of the deposited energy
- Particle dependent detection channel
- Provides information for particle identification

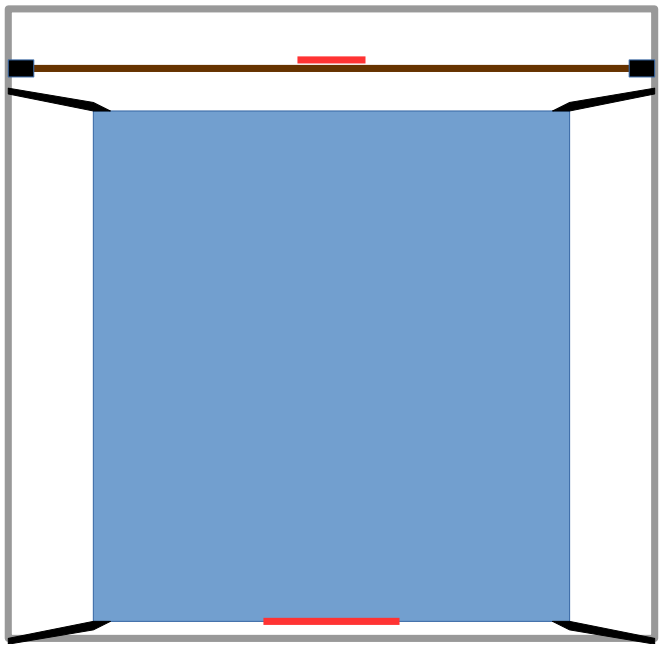
CRESST: Particle Identification

$$\text{light yield} = \frac{\text{energy detected in light detector}}{\text{total energy}}$$



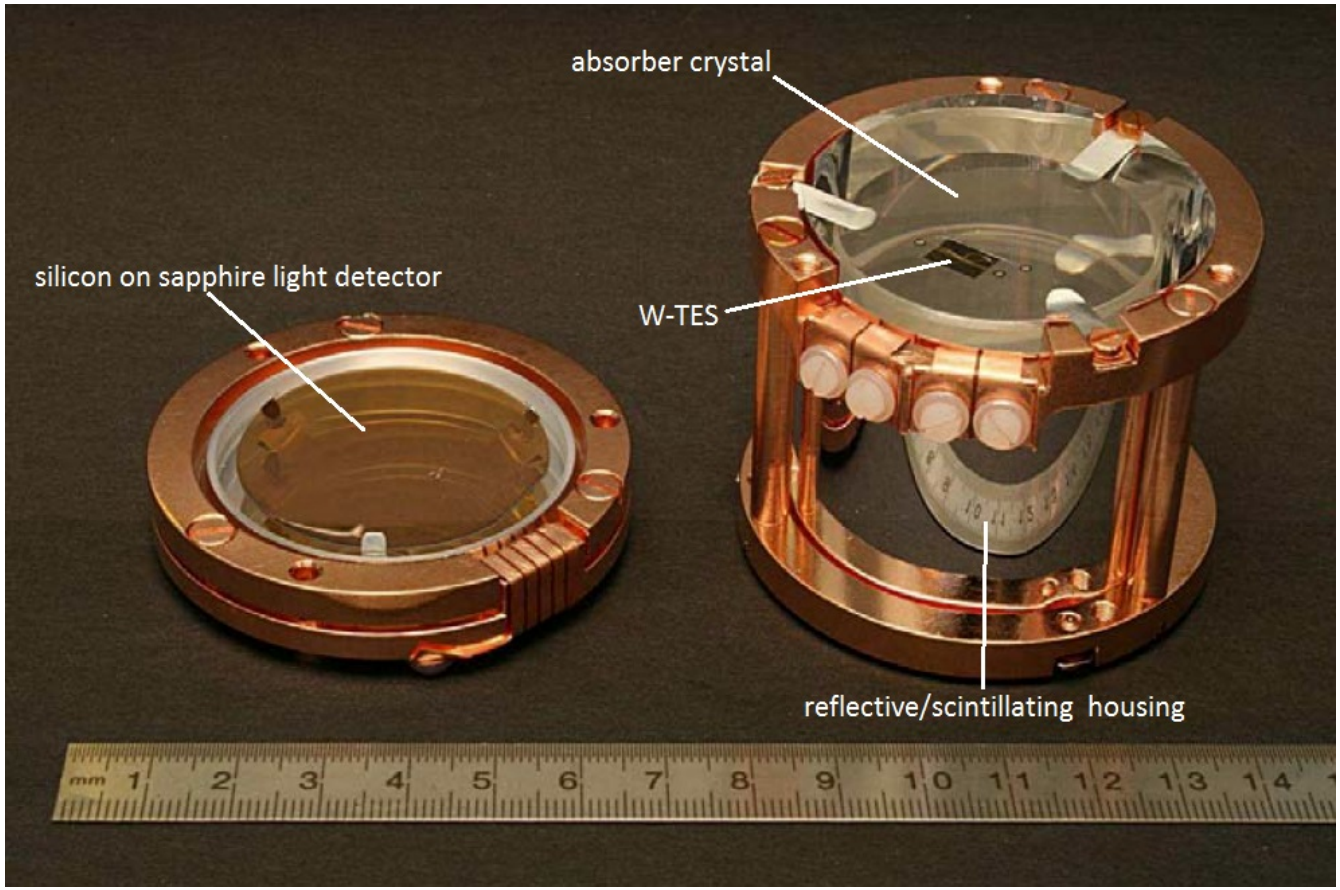
- Particle identification on event by event basis
- Dark matter events are expected to arise in the nuclear recoil bands below 40keV

CRESST: Detector Module

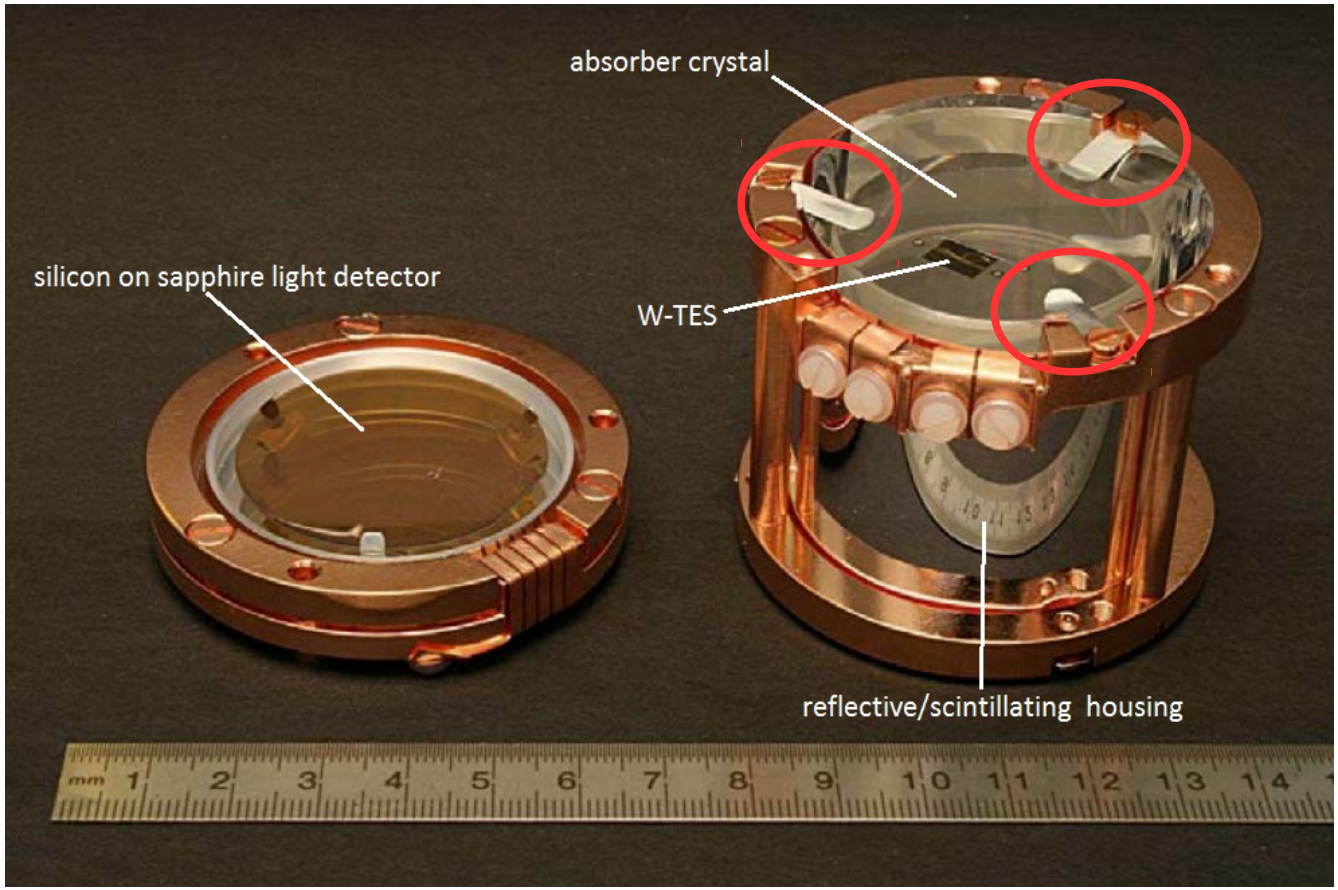


- Scintillating $CaWO_4$ main absorber
- Separated light detector (pure silicon/ silicon on sapphire (SOS))
- Thermometers: Tungsten Transition Edge Sensors (TES)
- Scintillating and vetoing detector housing
- Holding structure

CRESST-II Conventional Detector Module



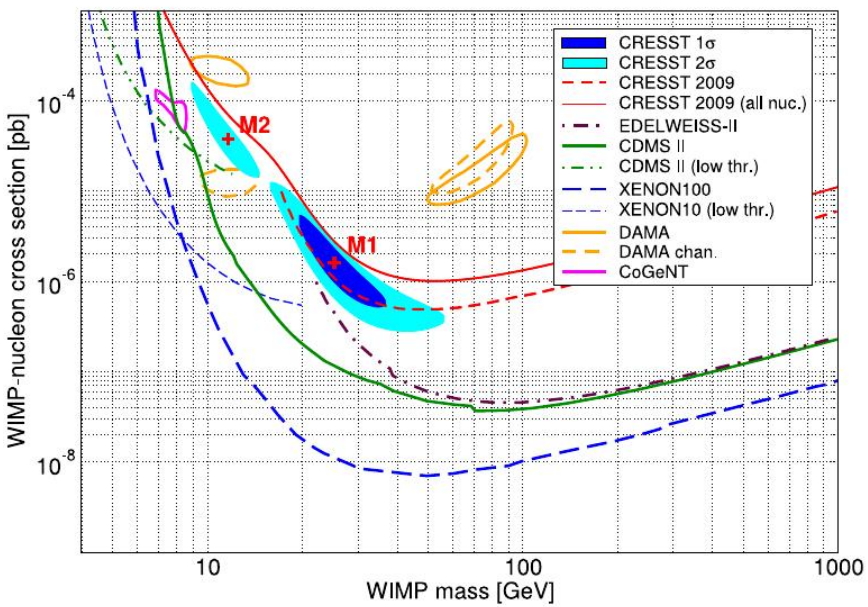
CRESST-II Conventional Detector Module

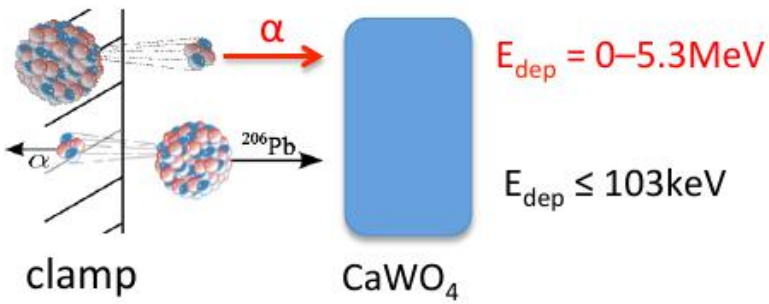


CRESST-II (Phase 1) Results

- Positive background signal
- Origin: Non-Scintillating bronze clamps

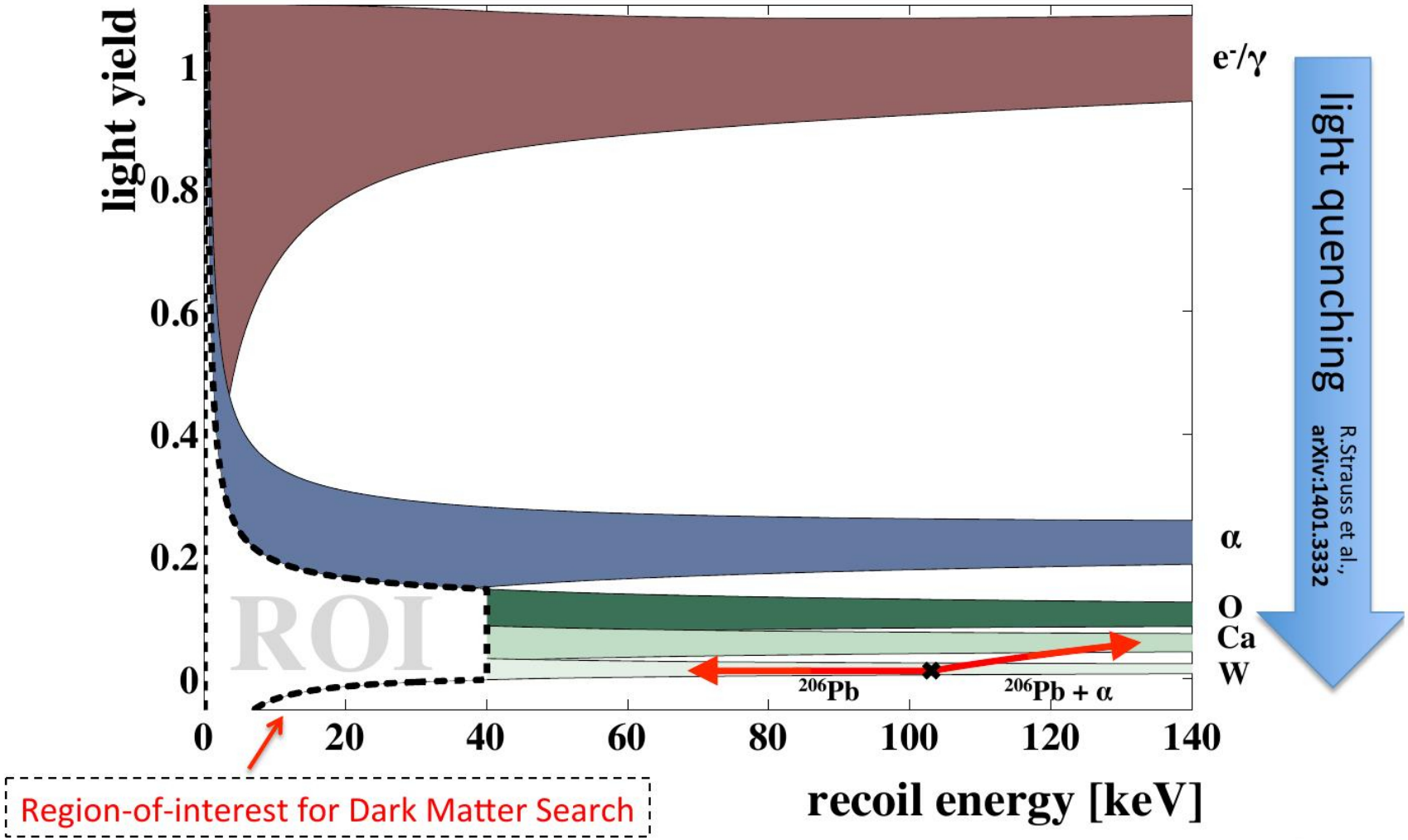
$^{210}\text{Pb} \rightarrow {}^{206}\text{Pb}$ (103keV)$+ \alpha$(5.3MeV)



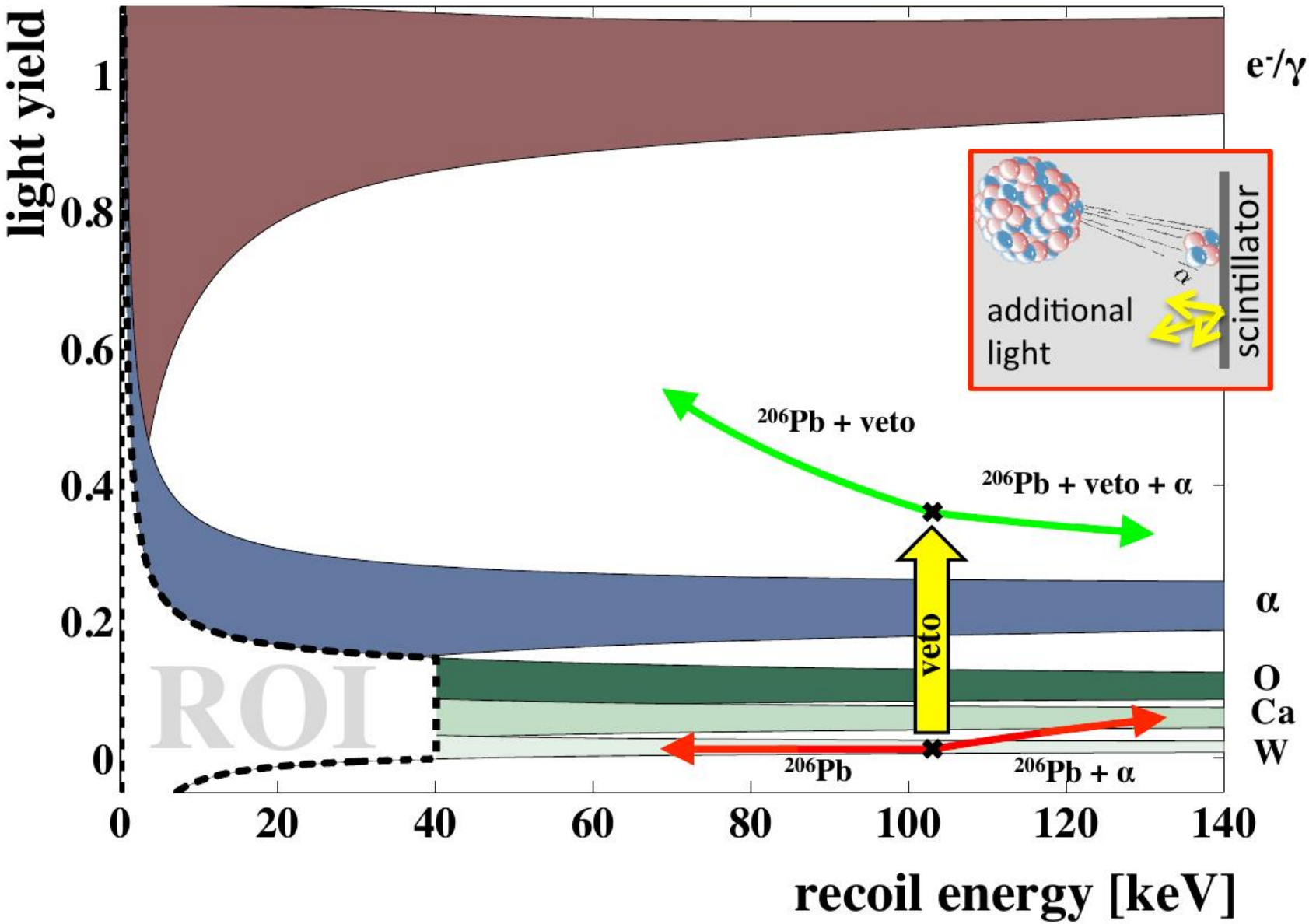


→ **avoid non-scintillating surfaces!**

CRESST: Surface Backgrounds



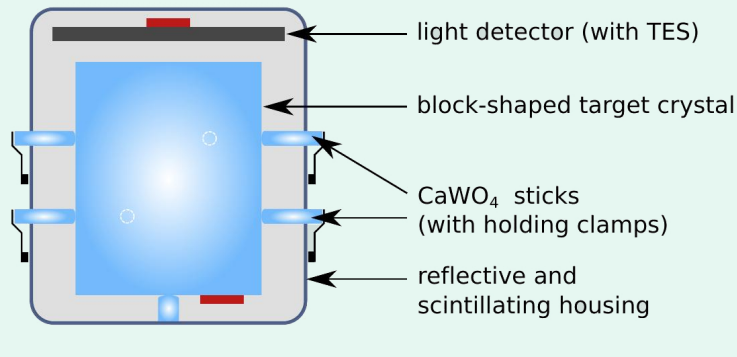
TUM 40 Module



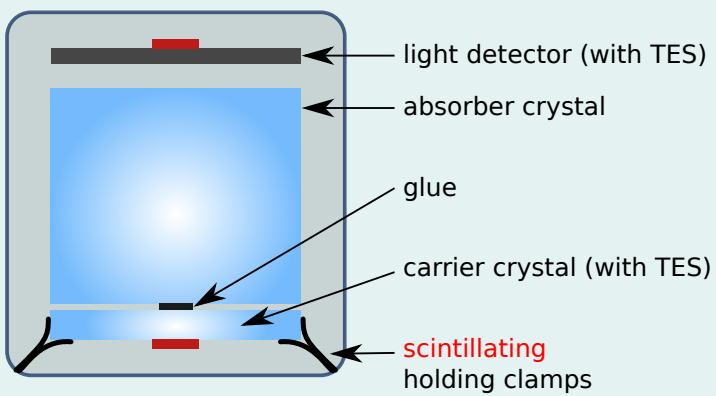
Next Generation of CRESST-II Modules (CRESST-II (Phase 2))

- Avoiding any line of sight to non-scintillating surfaces (glued carrier, $CaWO_4$ sticks, light detector as veto)

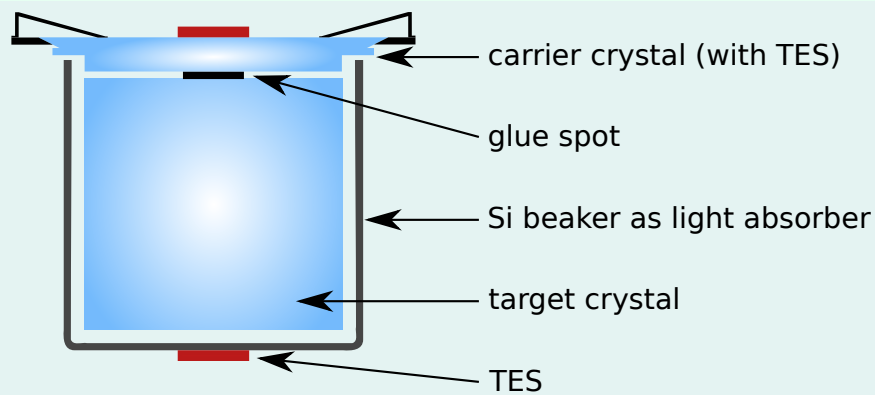
Stick/TUM 40 Module



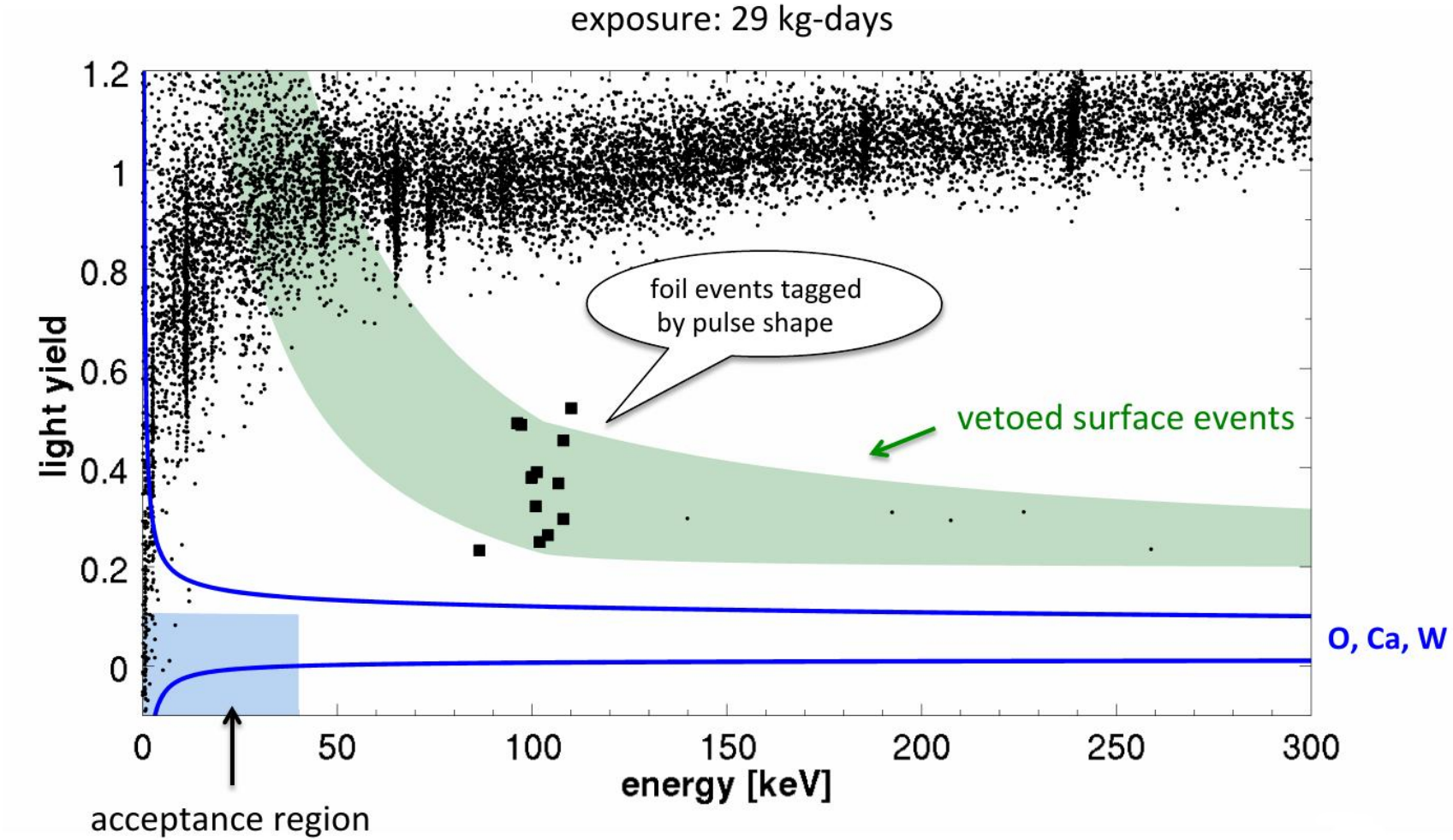
Glued Carrier Disk



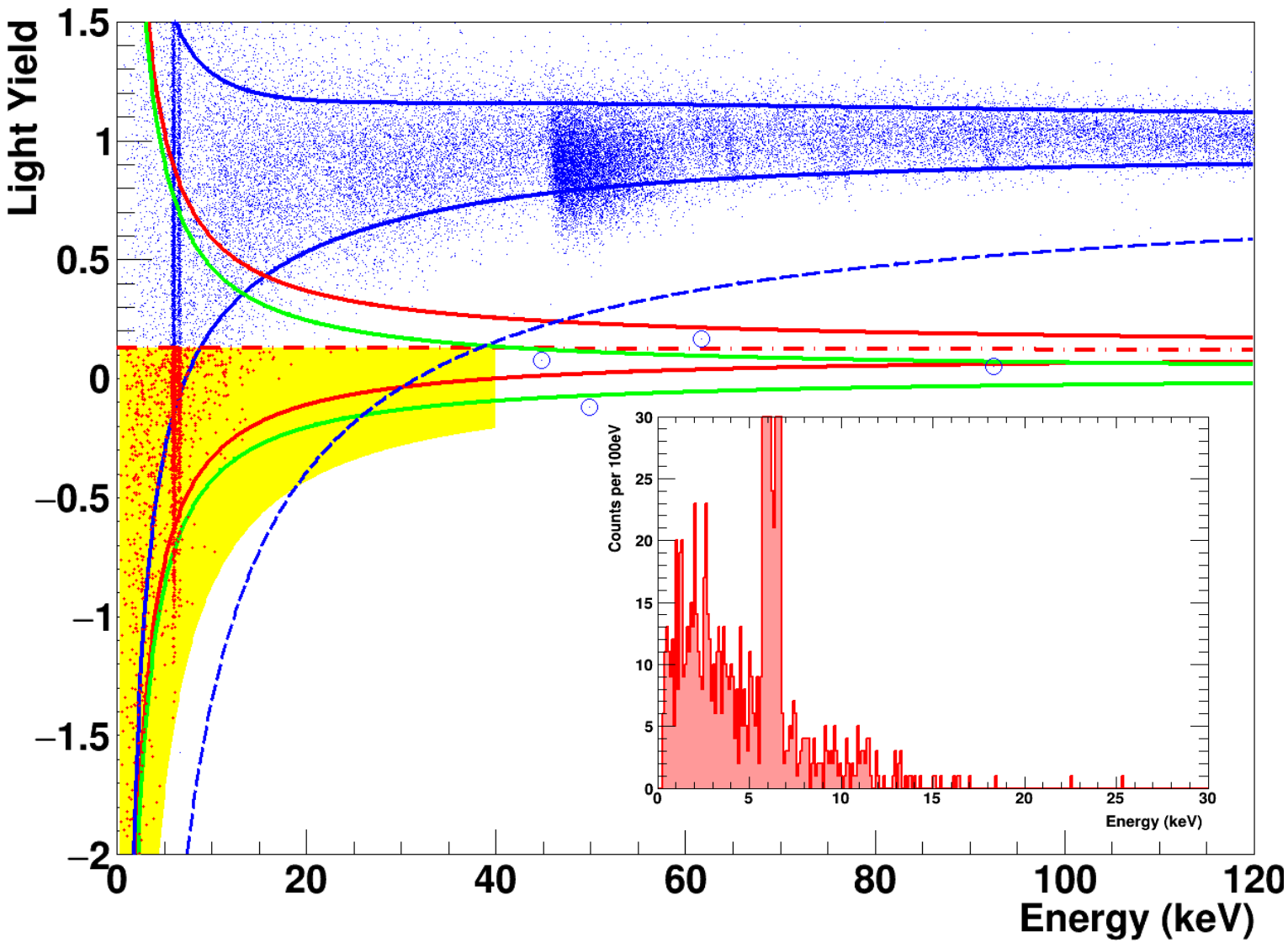
Beaker Module



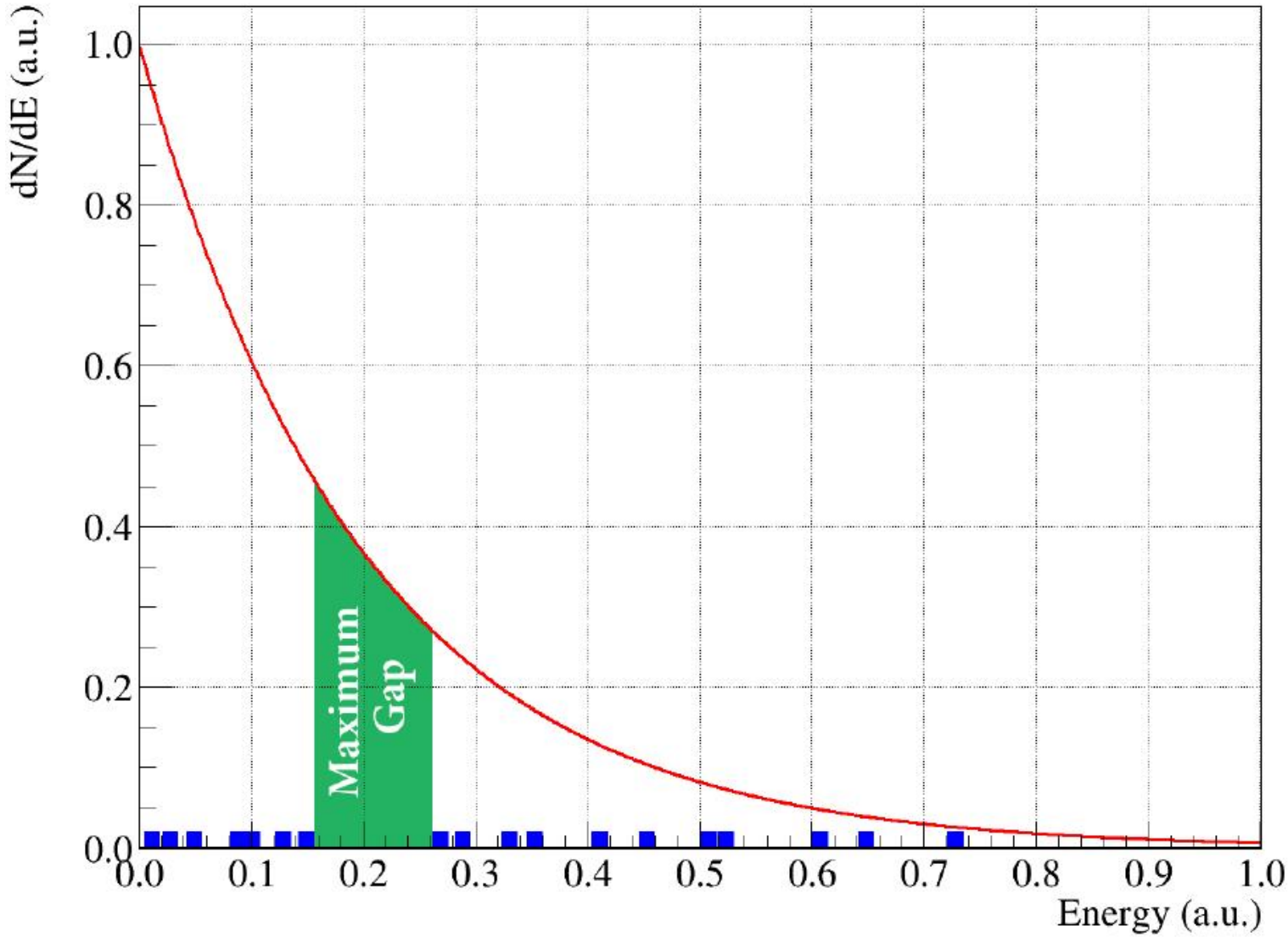
CRESST: Veto for surface events



Accepted Data



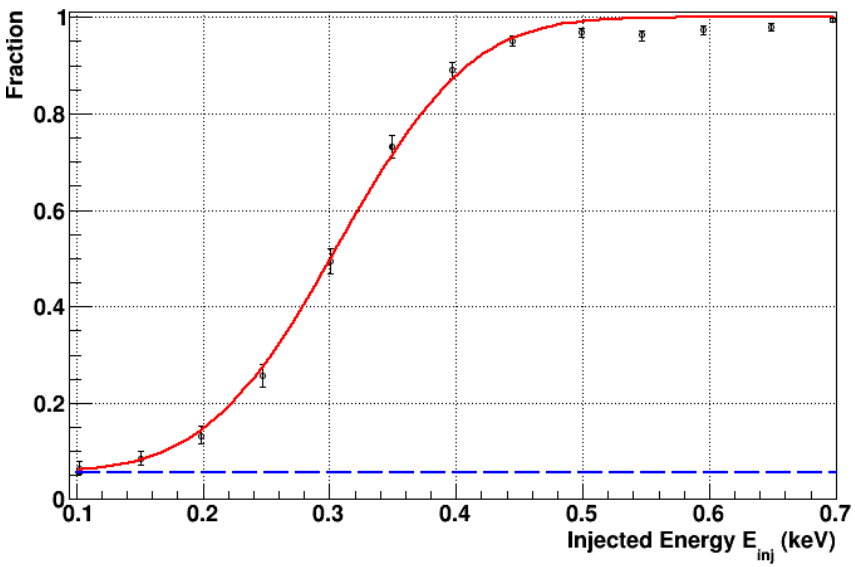
CRESST: Dark Matter Analysis

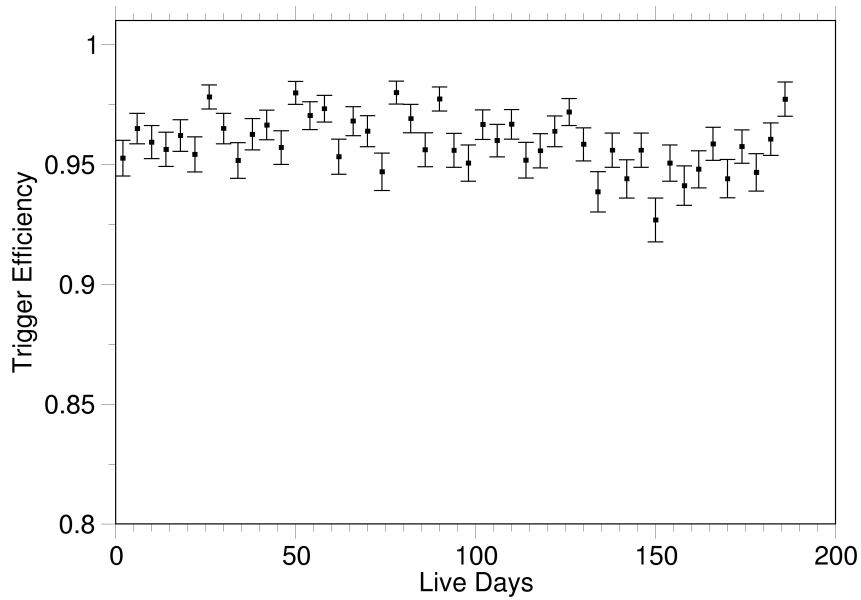


CRESST: Dark Matter Analysis

Crucial for setting good limits for small dark matter masses:

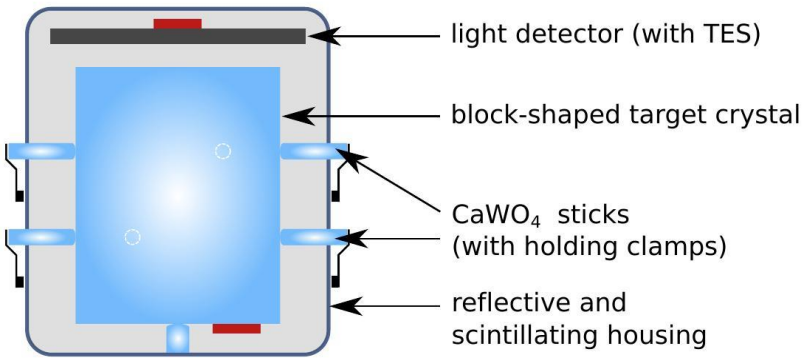
- Longtime stability of the detector working point
- Well defined and determined trigger threshold





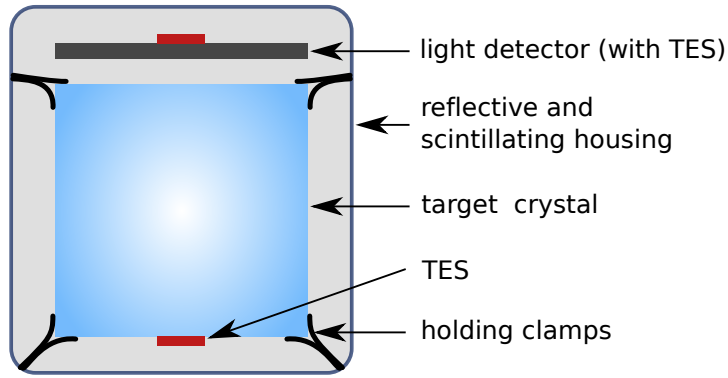
CRESST: Modules used for Analysis

TUM 40



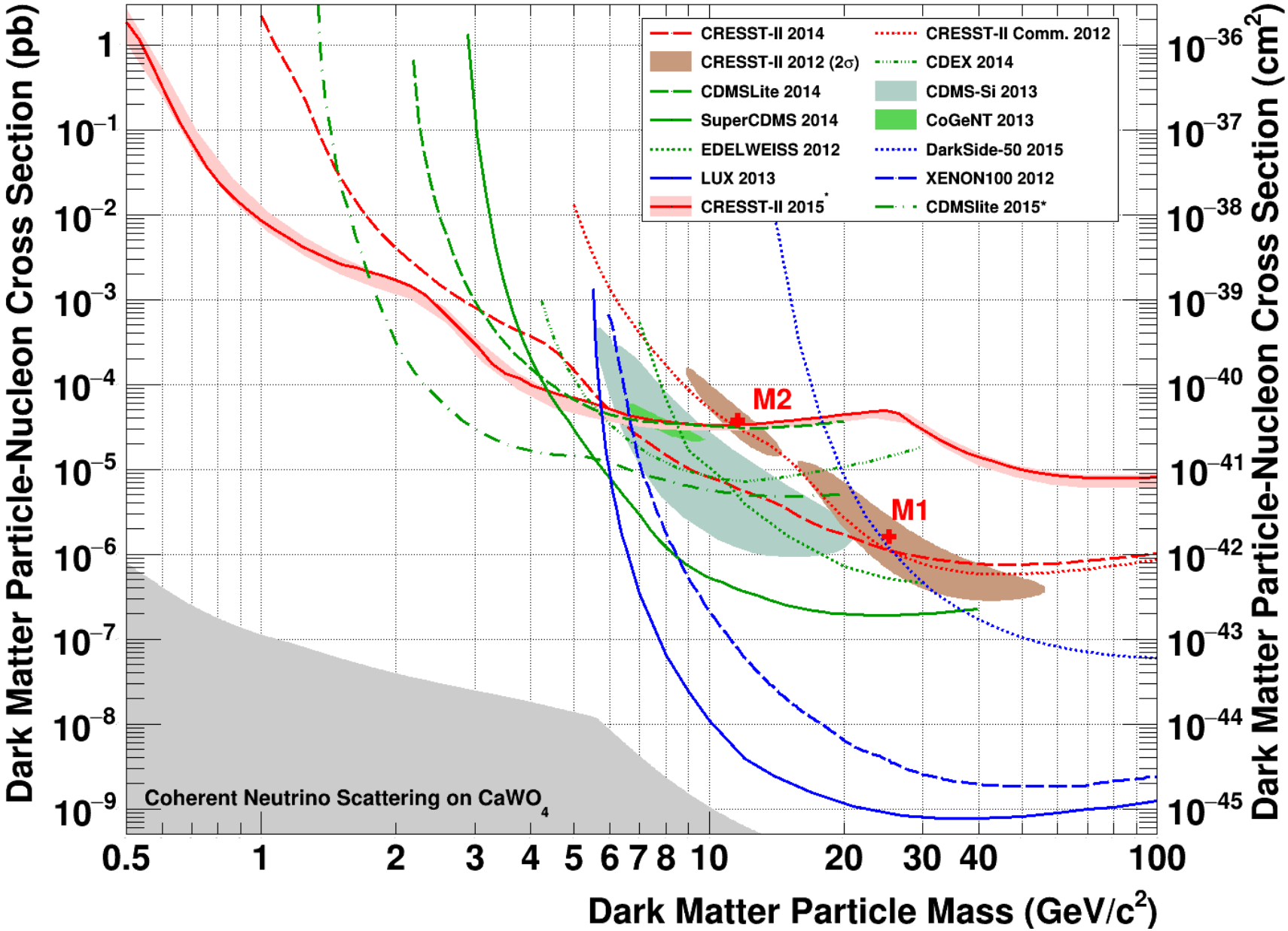
- Crystal held by $CaWO_4$ sticks
- Surface background rejection
- Clean, selfgrown crystal
- Detection threshold: E_{thres} ≈600eV

Lise

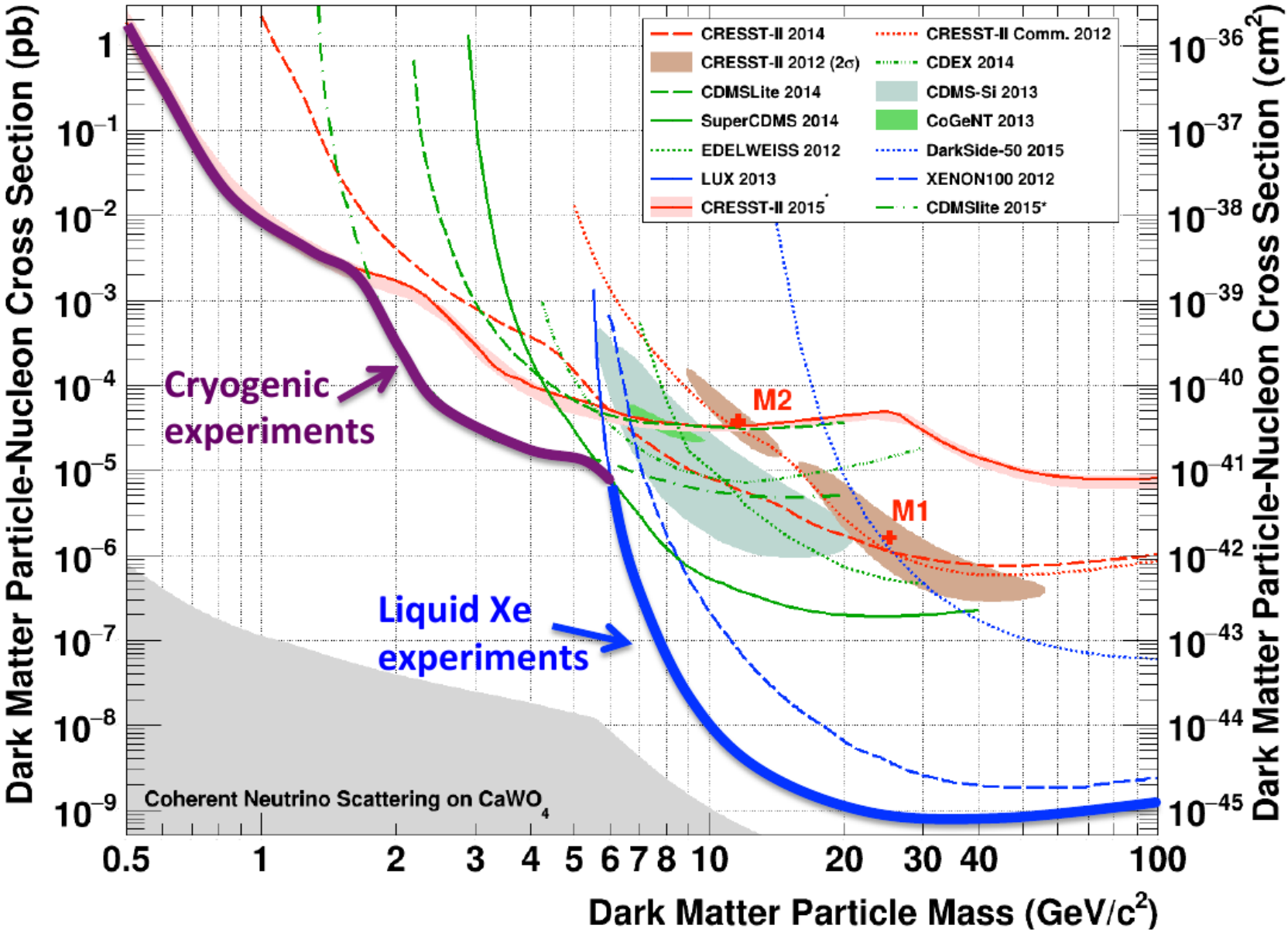


- Conventional detector module
- Surface background problem
- Crystal with high internal contamination
- But: Best detection threshold:
  E_{thres} ≈300eV

CRESST-II (Phase 2)

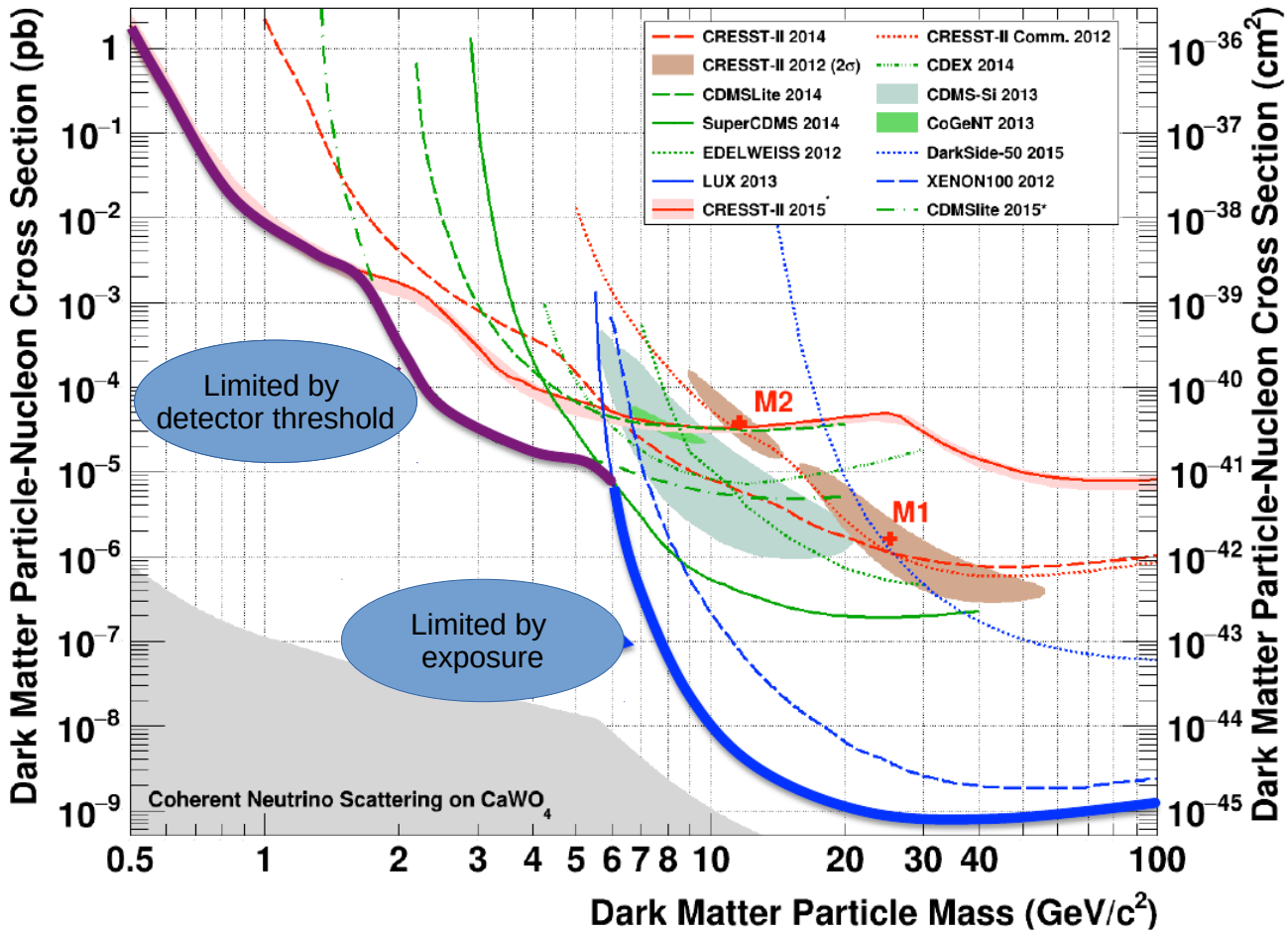


Limitation of Sensitivity

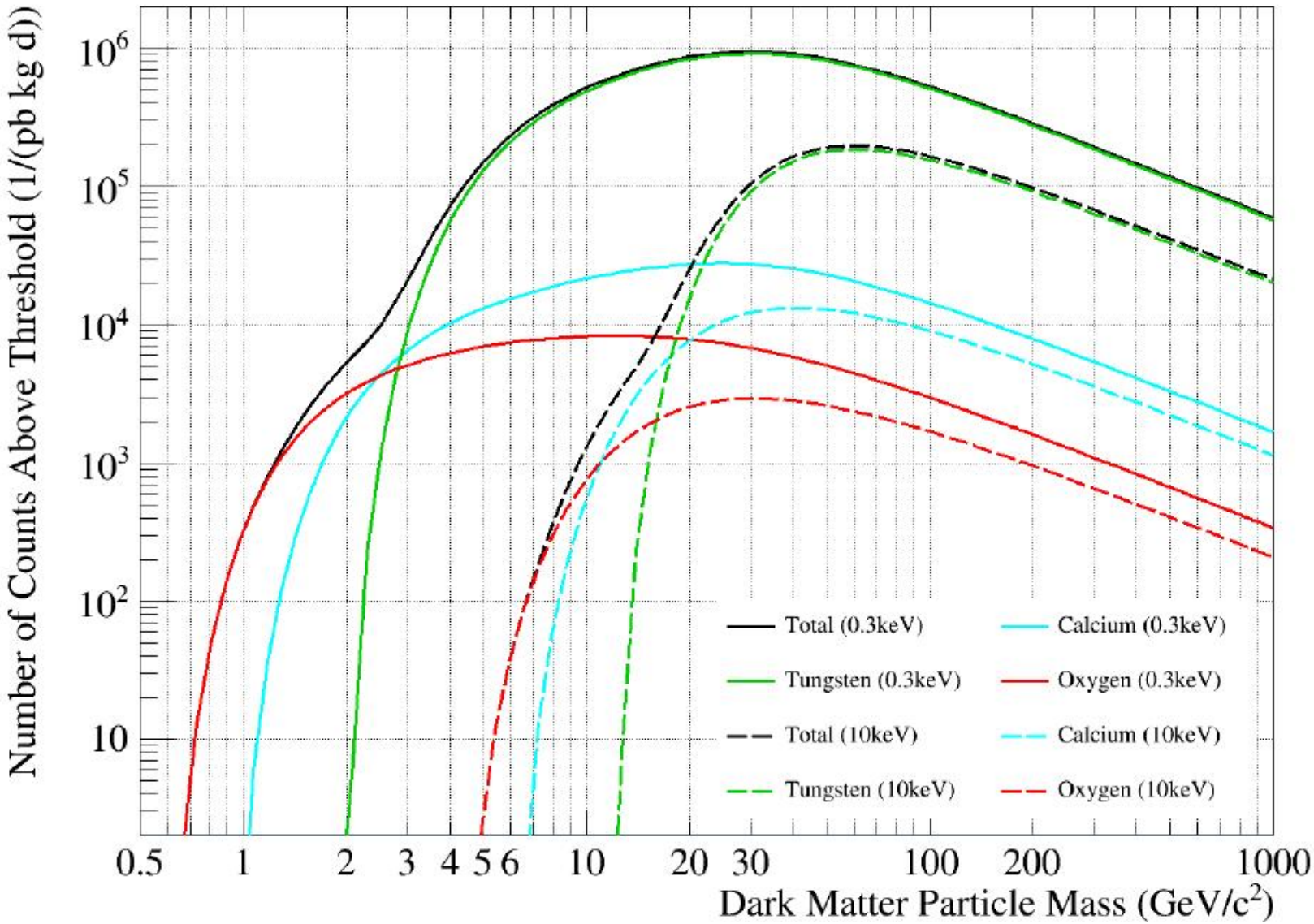


Conclusions from CRESST-II (Phase 2)

- The phonon-light technique is perfectly suited for exploring the low mass dark matter parameter space
- Lowering the detection threshold is key
- Exposure/statistic has a minor impact
- Performance of the light detector is sufficient/has a minor impact

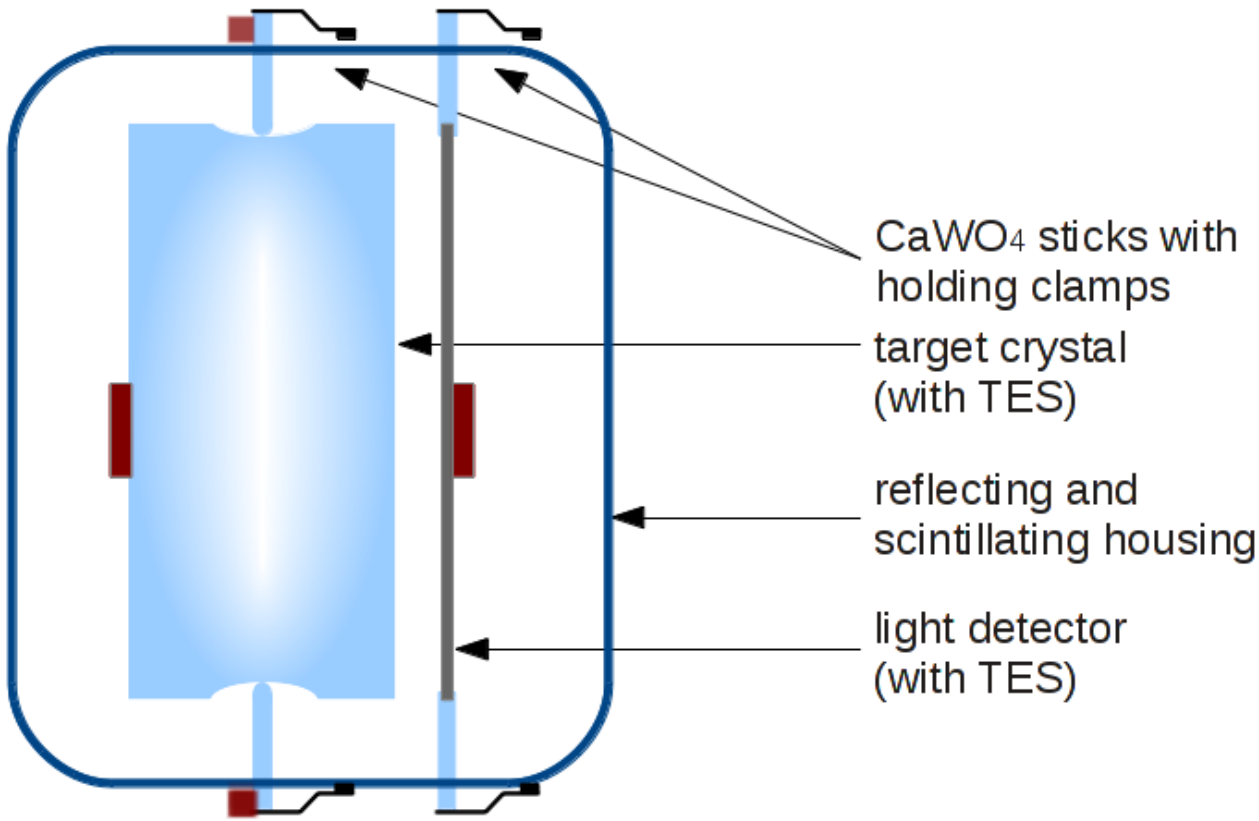


Limitation of Sensitivity

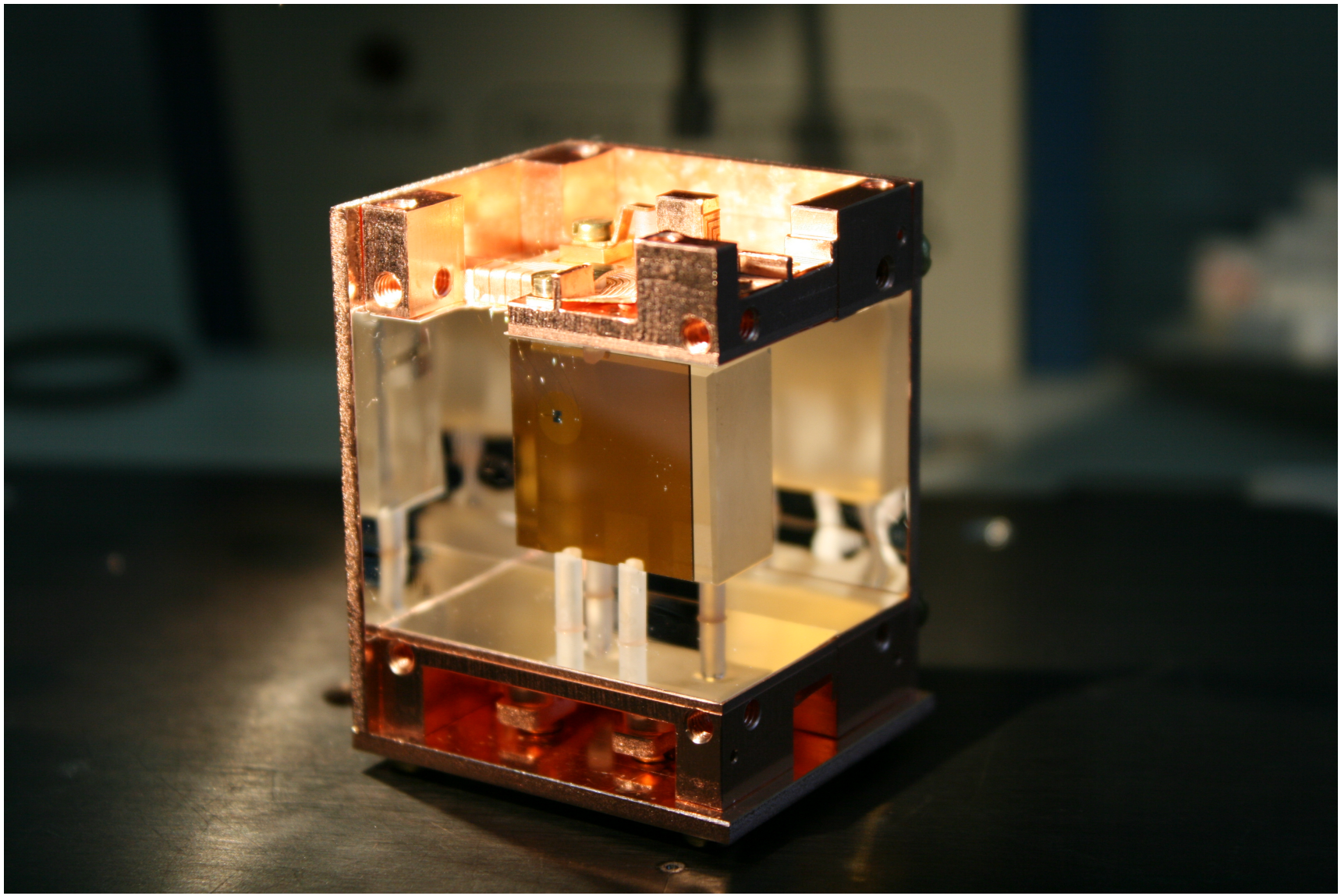


CRESST-III R&D goals for probing light dark matter

- Self-grown crystals for best radiopurity
- Lowering the detection threshold E_{thres} <100eV
  - Reduction of the absorber mass by a factor of 15 (300g→24g)
  - Improved TES structure
- Performance of the light detector sufficient (5eV) (minor impact on the limit)
- Fully scintillating detector housing using $CaWO_4$ sticks (with TES)



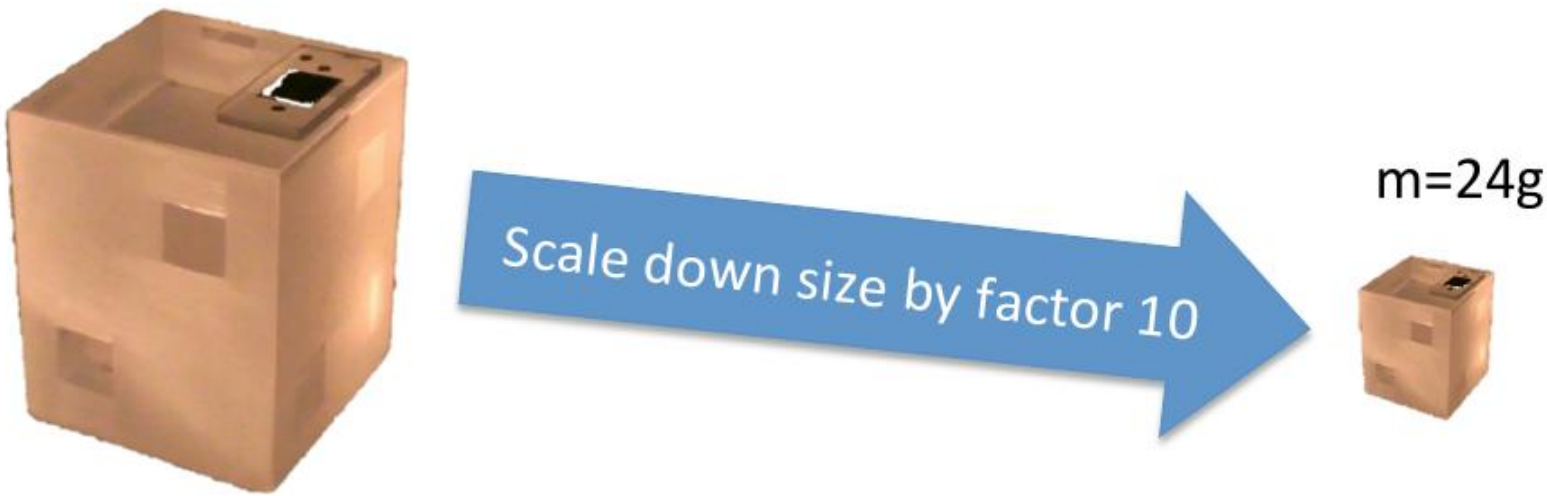
CRESST-III Module



CRESST-III: Improved phonon detector performance

Reduction of main absorber mass

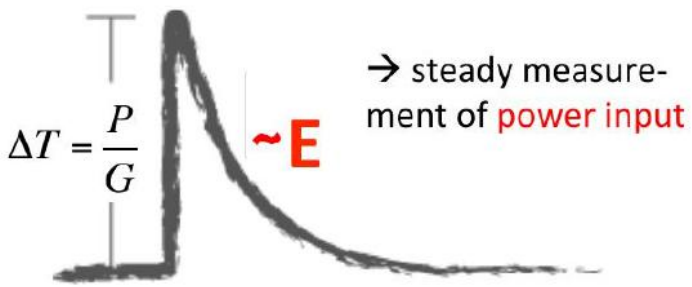
- Smaller heat capacity
- Higher energy density in the crystal per deposited energy
- Changed phonon life times in the crystal
  $\rightarrow$ Adjustment of the TES structure



CRESST-III: TES changes

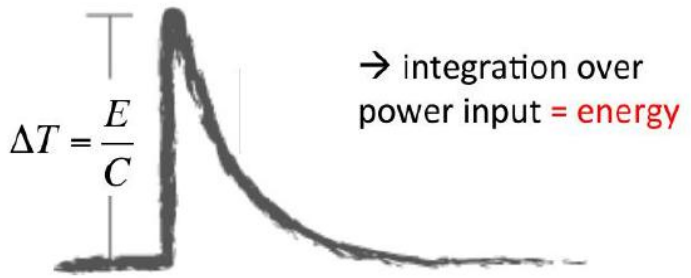
CRESST-II phonon detector TES for big crystals

- Bolometric mode → heat flux measurement
- Slow natural phonon decay due to the big crystal
- Large TES area for fast phonon thermalization in TES
- Strong thermal link
  → Reduction of pulse length and amplitude
  → Less dead time for the cost of sensitivity



CRESST-III phonon detector TES for small crystals

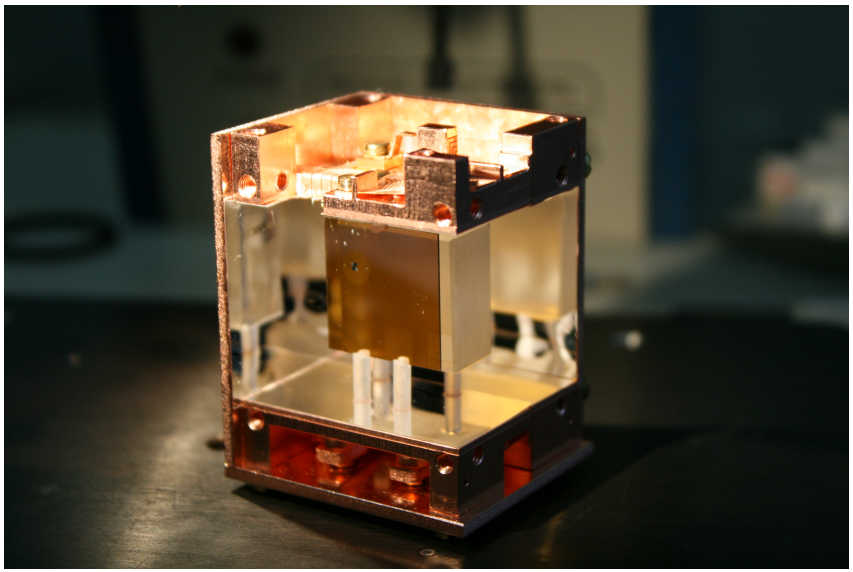
- Calorimetric mode → total temperature measurement
- Small TES area → phonon thermalization is dominated by the crystal
- Faster phonon decay due to smaller crystal dimensions
- Weak thermal link
  → Measurement of the complete energy depositions

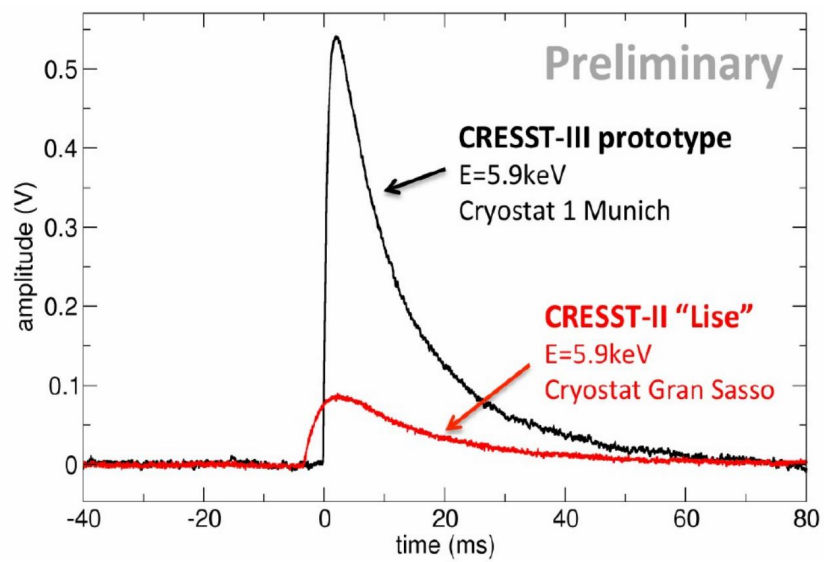


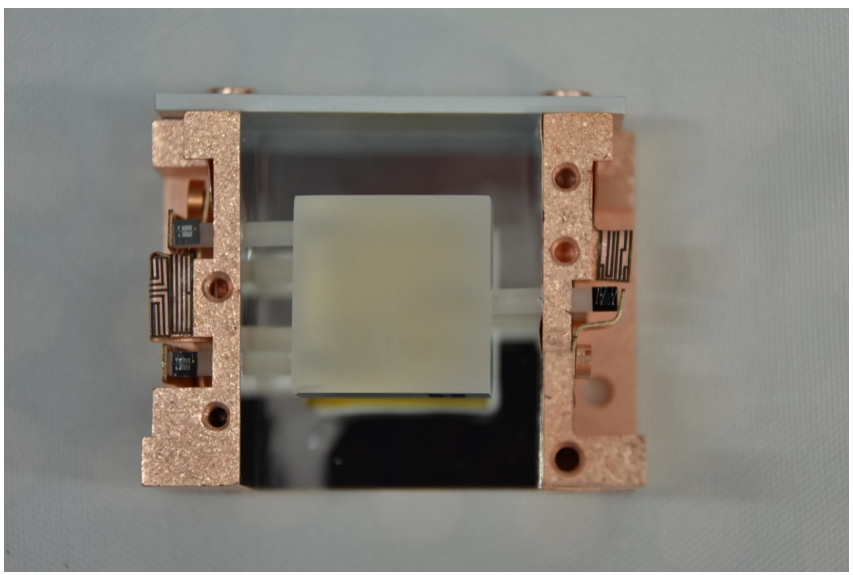
CRESST-III: Prototype Measurement

Overground measurement in Munich

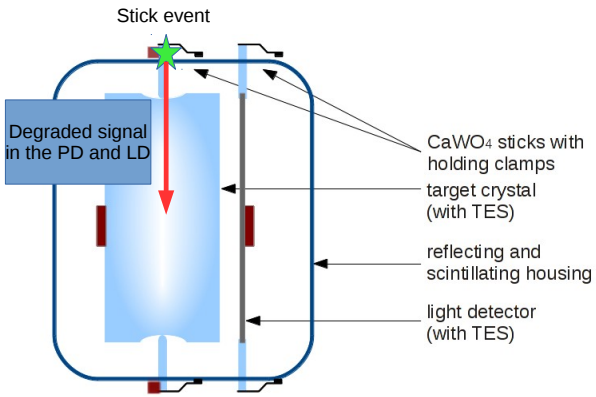
- Phonon detector threshold $\approx$ 80eV
- Good light detector performance (light yield 2.5%)
- iStick system successfully tested
- complete understanding of all event classes

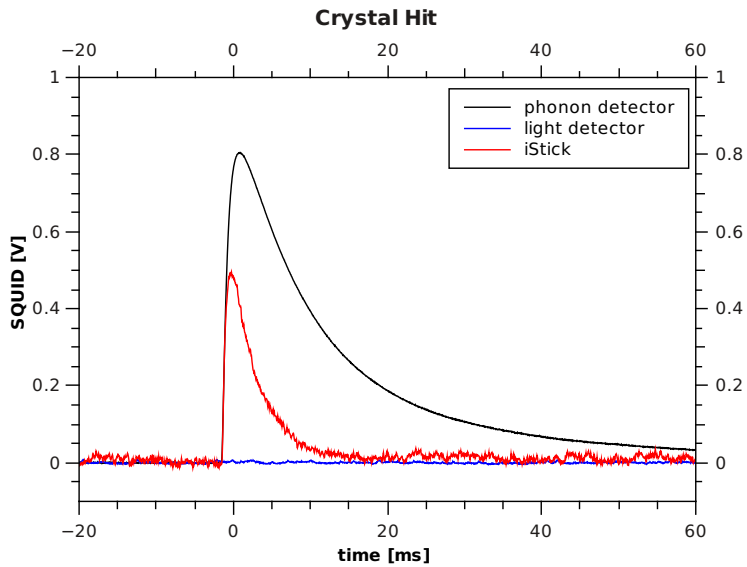


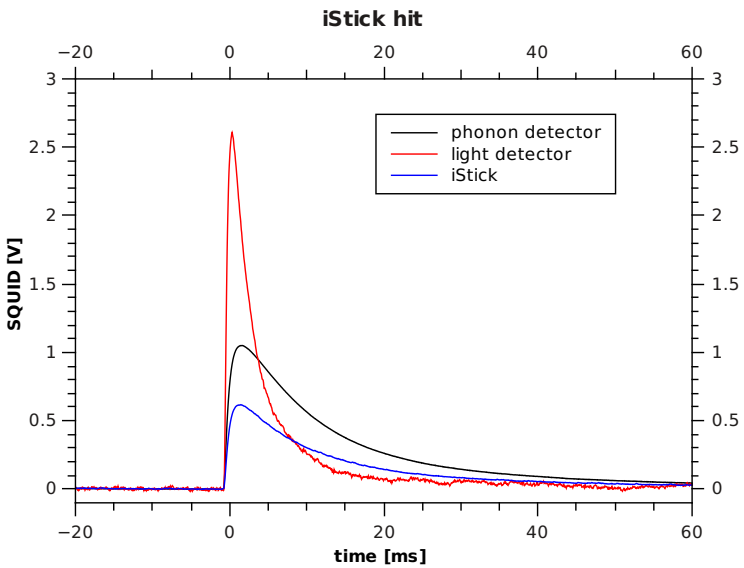




CRESST-III: iStick system



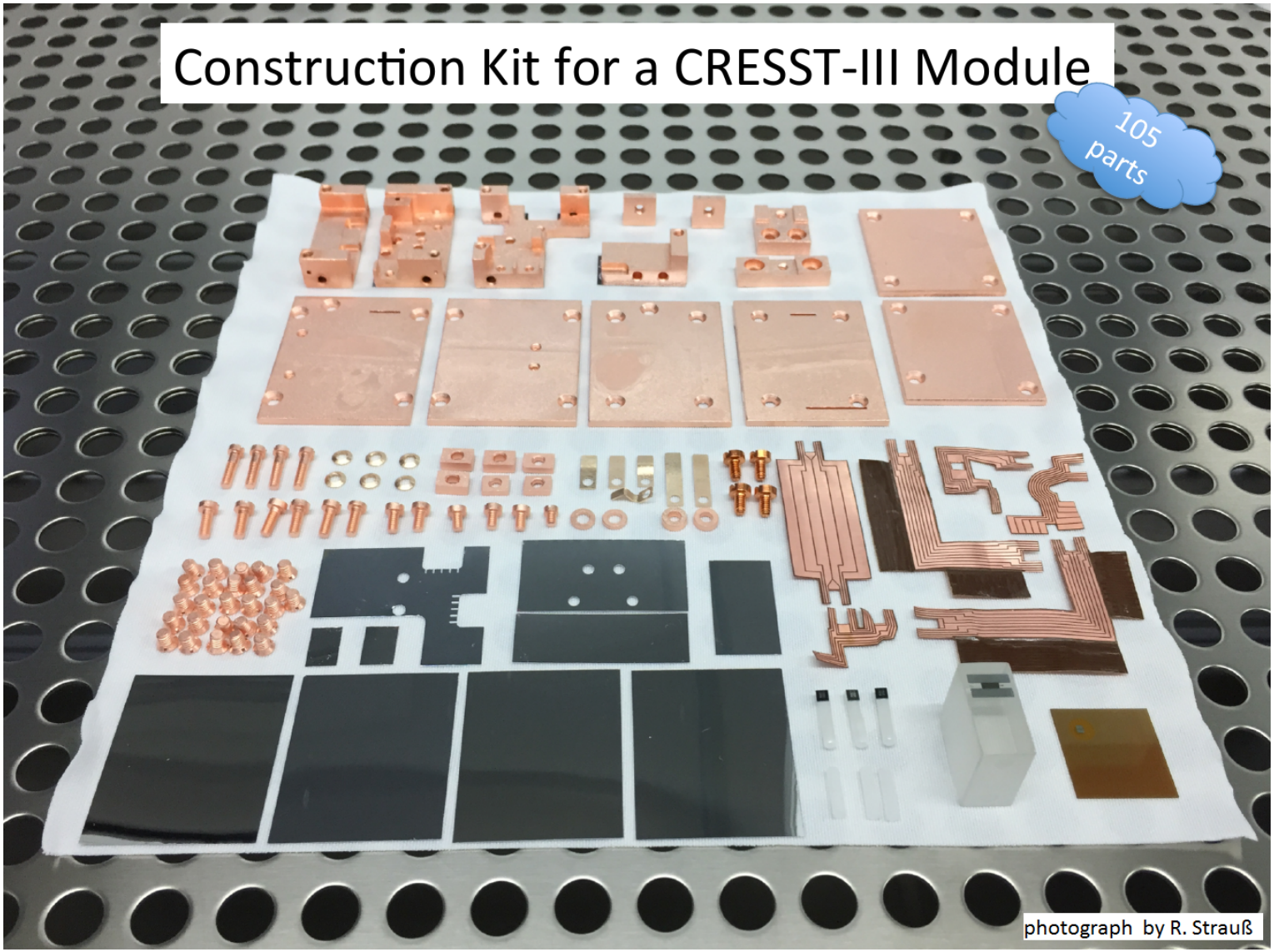




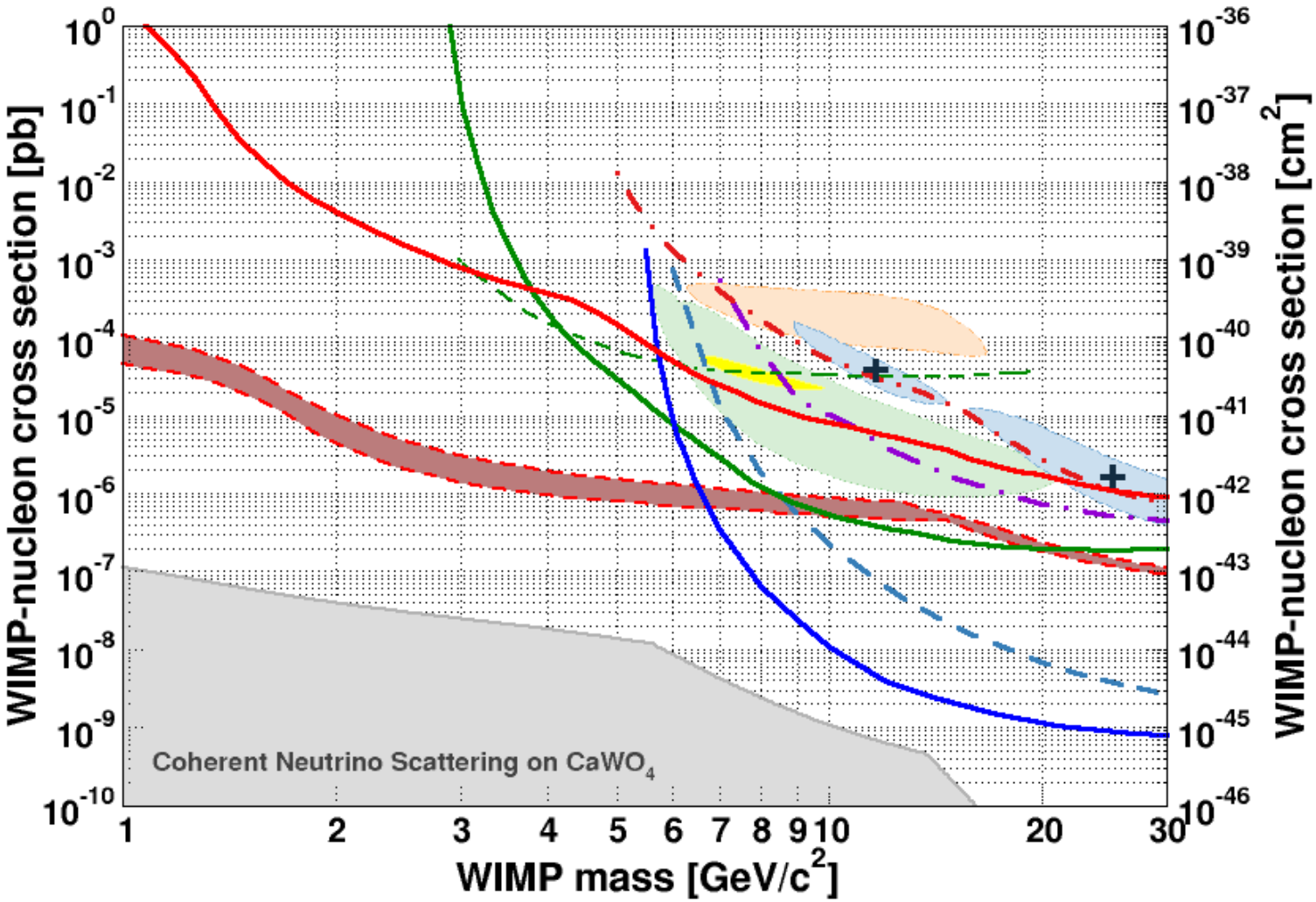
iStick system

- tagging of stick events to lowest energies
- prevention of degraded signals (phonon and light channel)
- 3 TES readout with a single SQUID readout

CRESST-III: 10 Modules

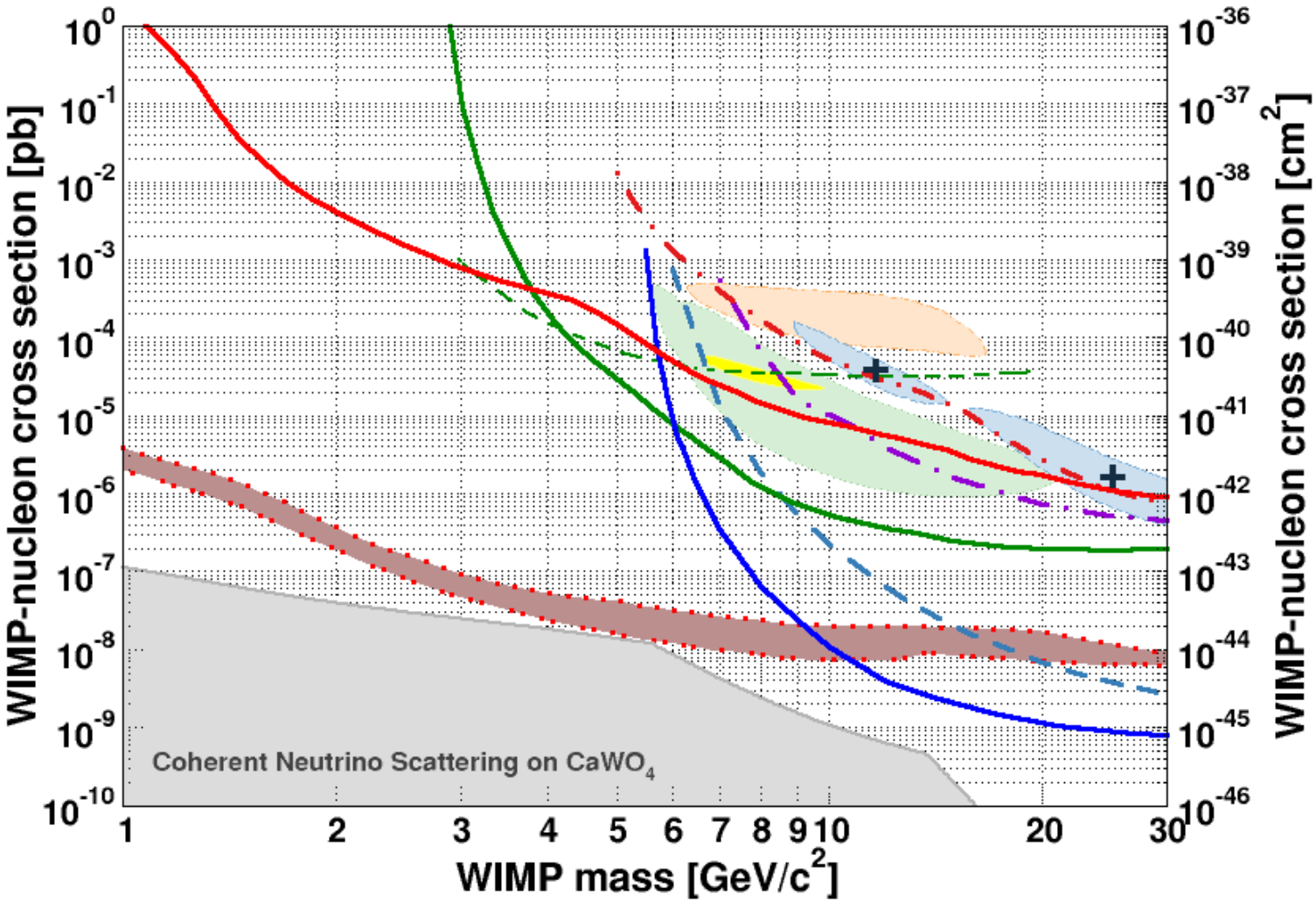


CRESST-III: Perspectives



CRESST-III (Phase 1): 100 kg*days

CRESST-III: Perspectives



CRESST-III (Phase 2): background improved by a factor 100, 1000 kg*days

Thank you!