# The CRESST dark matter search

**XLIV meeting of the Gran Sasso Scientific Committee**
**12 – 13 November 2015, LNGS**

Federica Petricca
Max-Planck-Institute for Physics Munich

on behalf of the CRESST collaboration

# The CRESST collaboration

HEPHY
Institut für Hochenergiephysik

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

TECHNISCHE UNIVERSITÄT MÜNCHEN

INFN
Laboratori Nazionali del Gran Sasso

UNIVERSITY OF OXFORD

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

# Outline

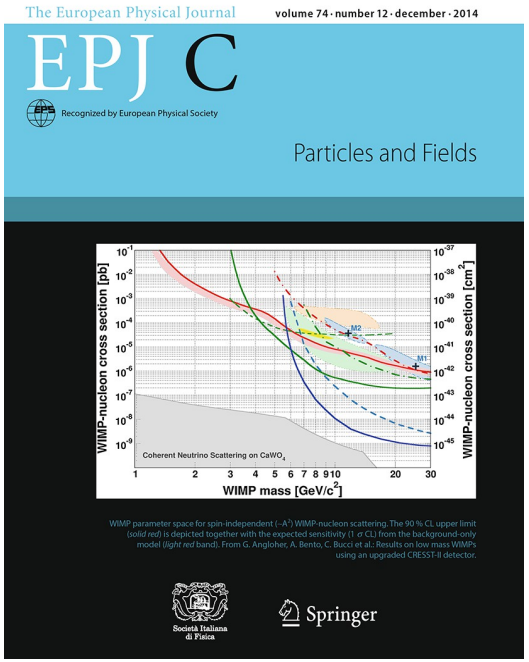
- Status of CRESST II – Phase 2
- First results
- Preparation for next data taking
- Schedule and Perspectives

# CRESST II Phase 2

Data taking: July 2013 – August 2015

First Phase 2 results on low mass dark matter particles:

- July 2014
- Single module TUM40
- Self grown crystal
- Best overall performance
- 29 kg days of exposure
- Non-blind 2013 dataset




Trigger thresholds of several modules lowered

Final Phase 2 results on low mass dark matter particles:

- September 2015
- Single module Lise
- External supplier
- Lowest threshold
- 52 kg days of exposure
- Full blind data set

arXiv:1509.01515

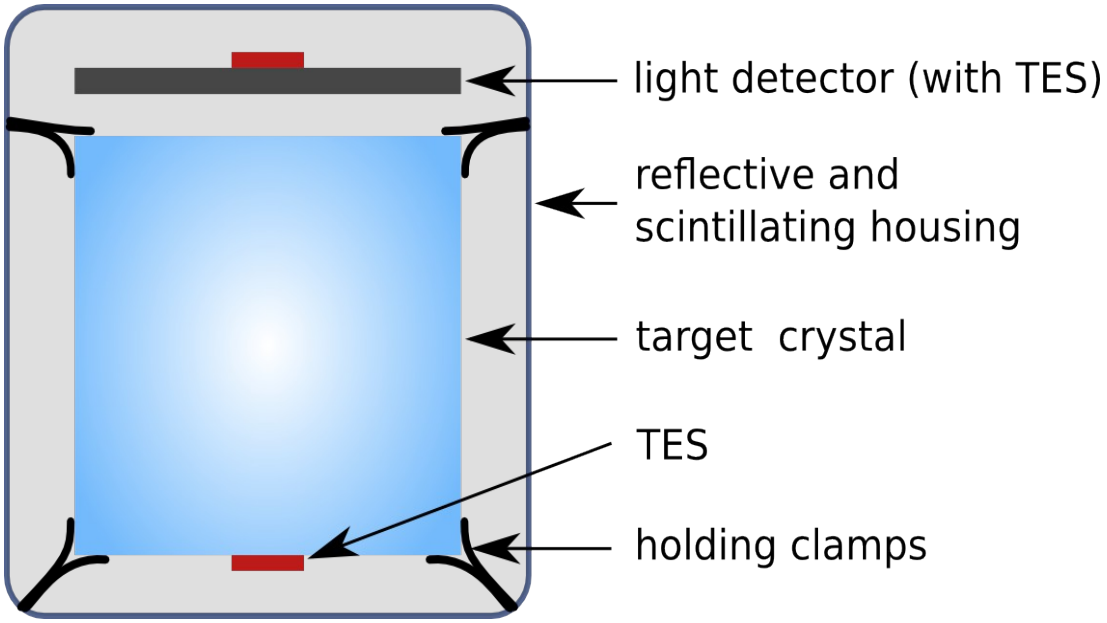
# Detector Lise

Detector design: Conventional
No veto for surface alpha decays

Crystal: Lise (external supplier)
Background level ~8.5 counts/keV kg day

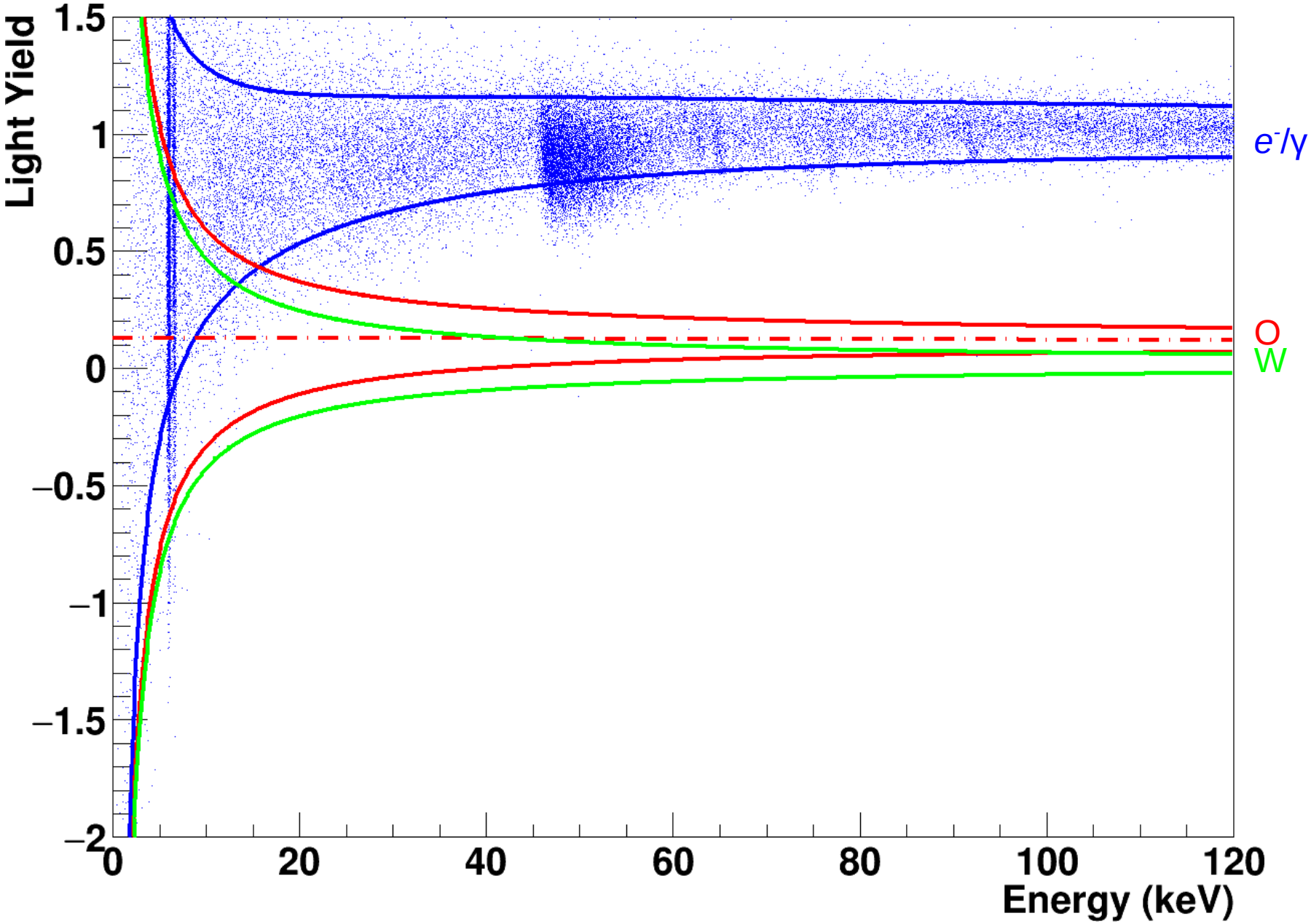
Threshold: 307eV

Resolution: 62eV at zero energy

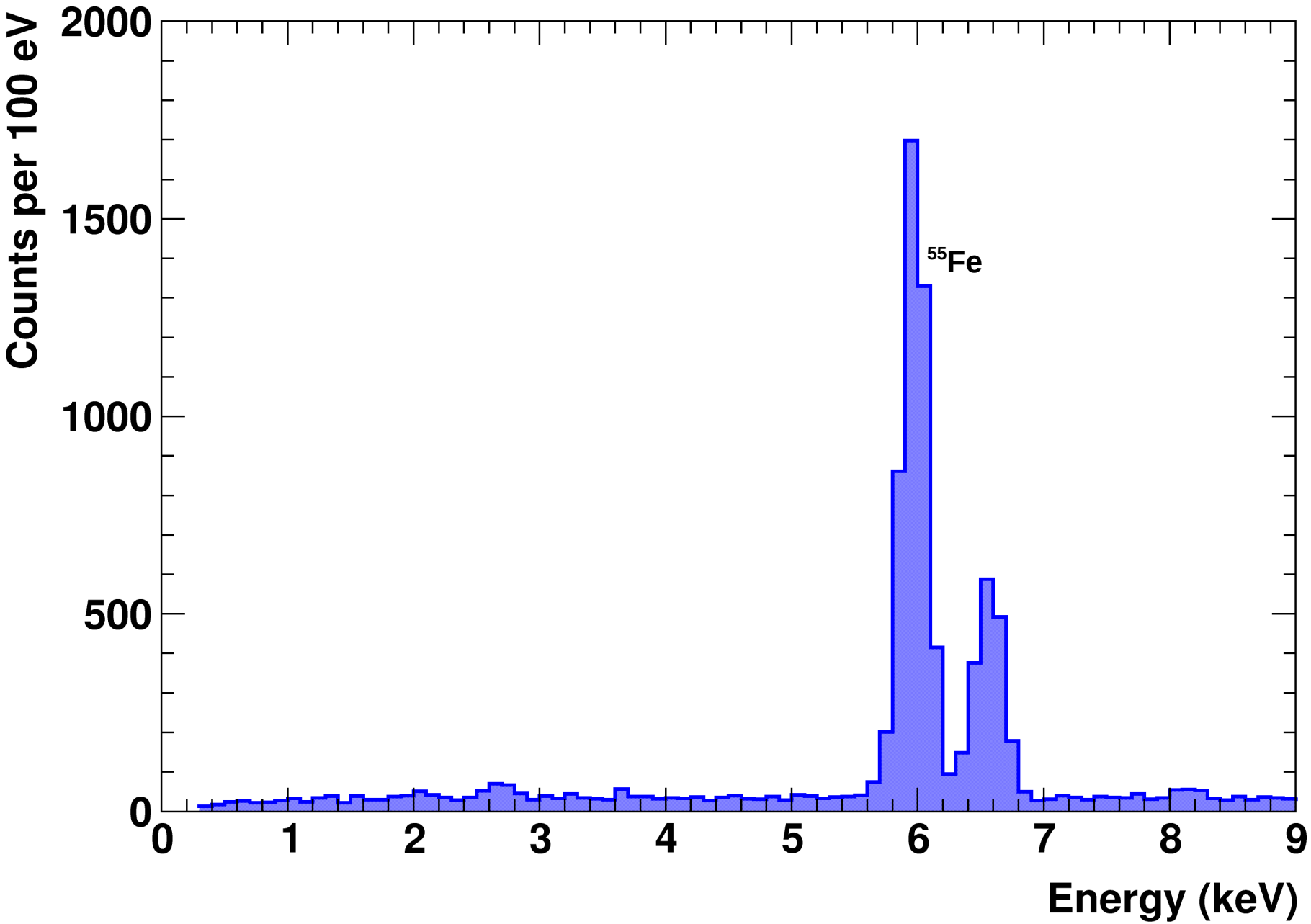



- **Average overall performance**
- **Lowest threshold**

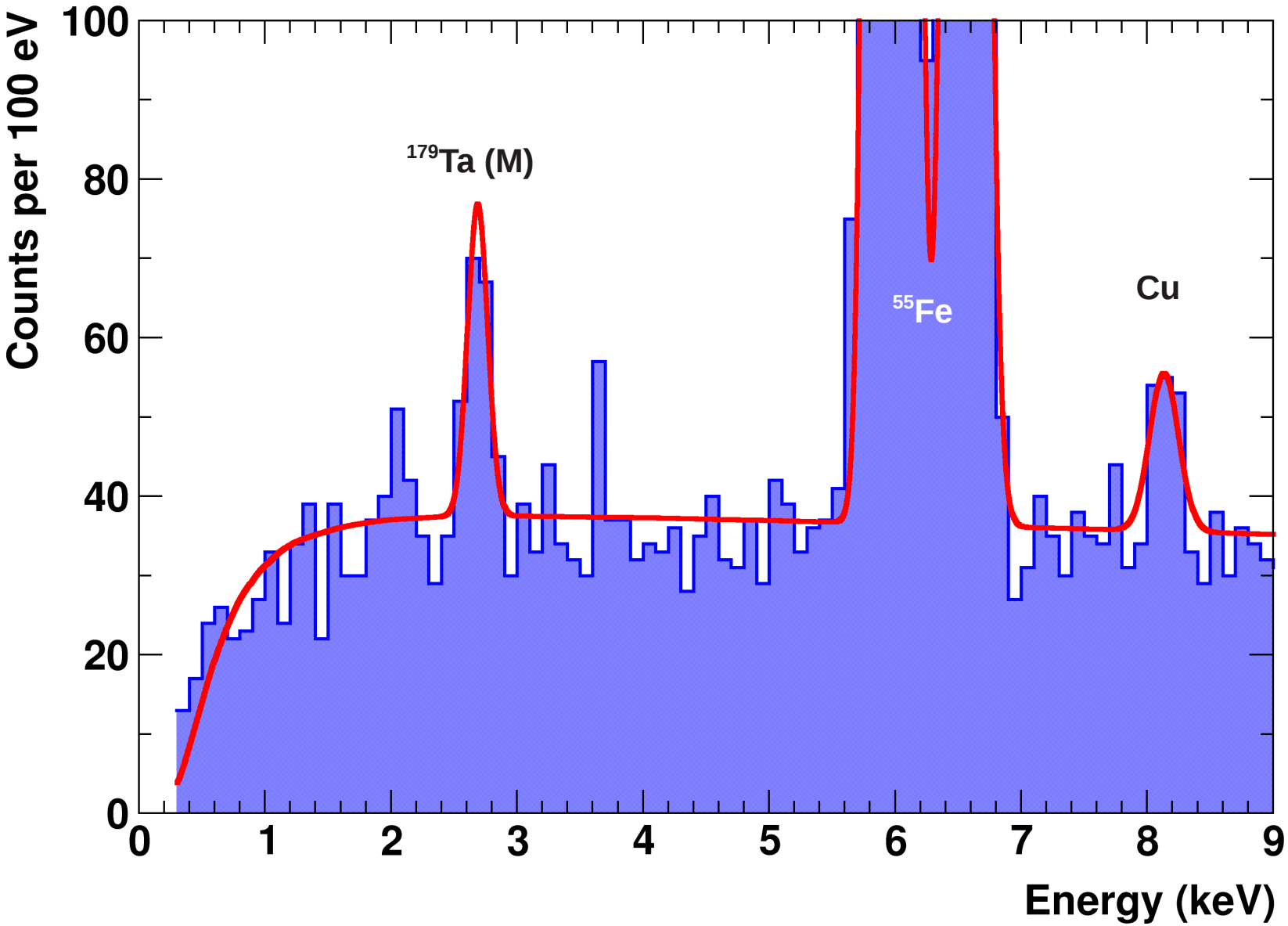
# Data


Light Yield
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0
20
40
60
80
100
120
Energy (keV)
e-/γ
O
W

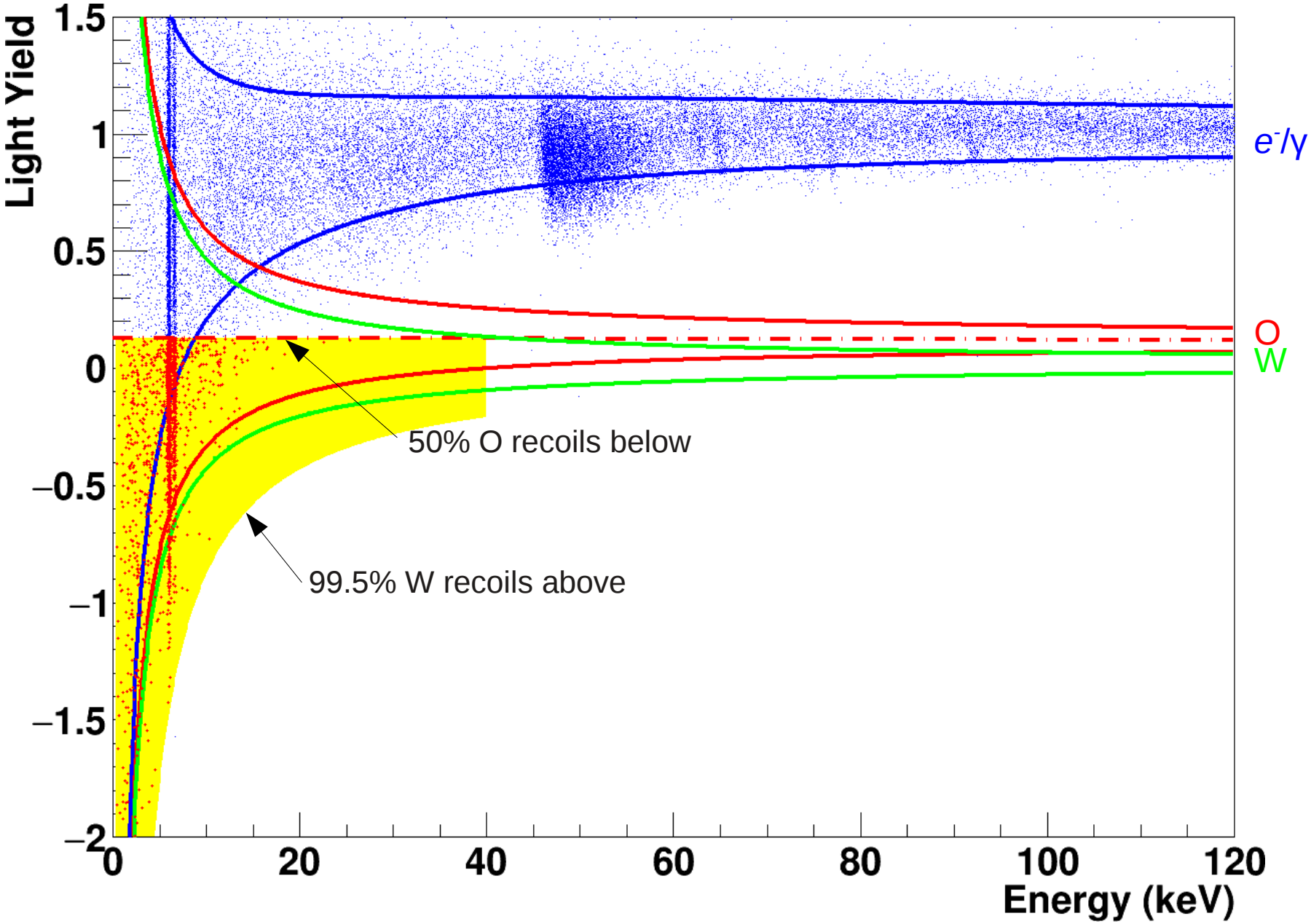
# Data


Counts per 100 eV
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
Energy (keV)
55Fe

# Data


Counts per 100 eV
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
Energy (keV)
179Ta (M)
55Fe
Cu

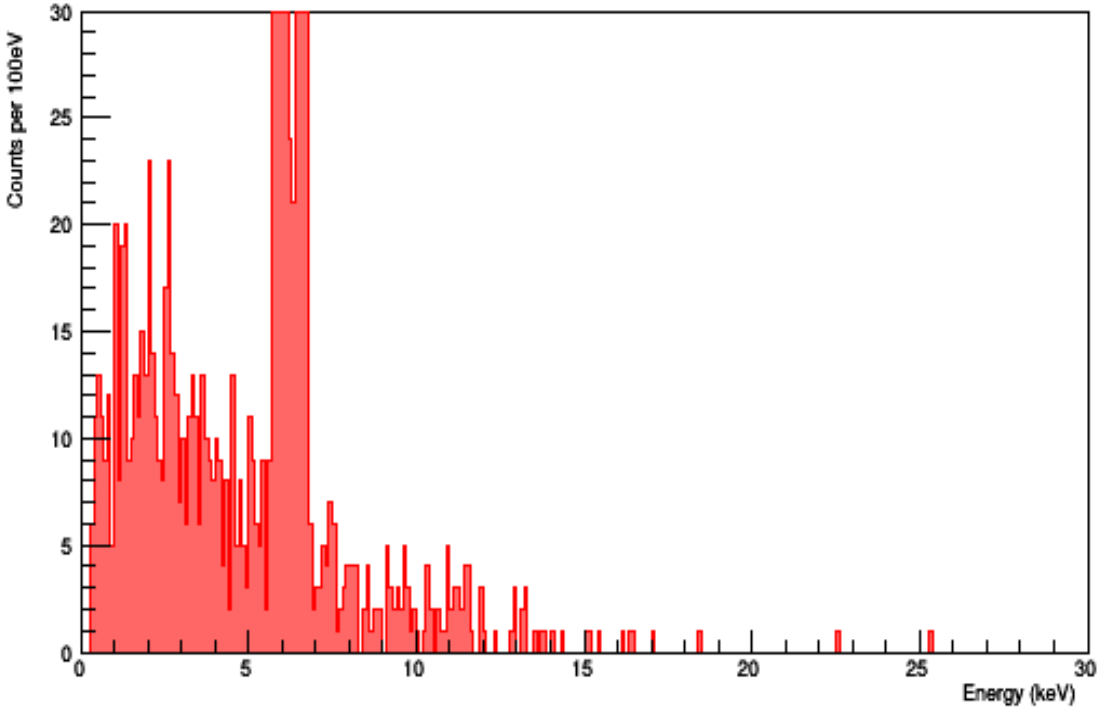
# Data


Light Yield
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0
20
40
60
80
100
120
Energy (keV)
e-/γ
O
W
50% O recoils below
99.5% W recoils above

# Data

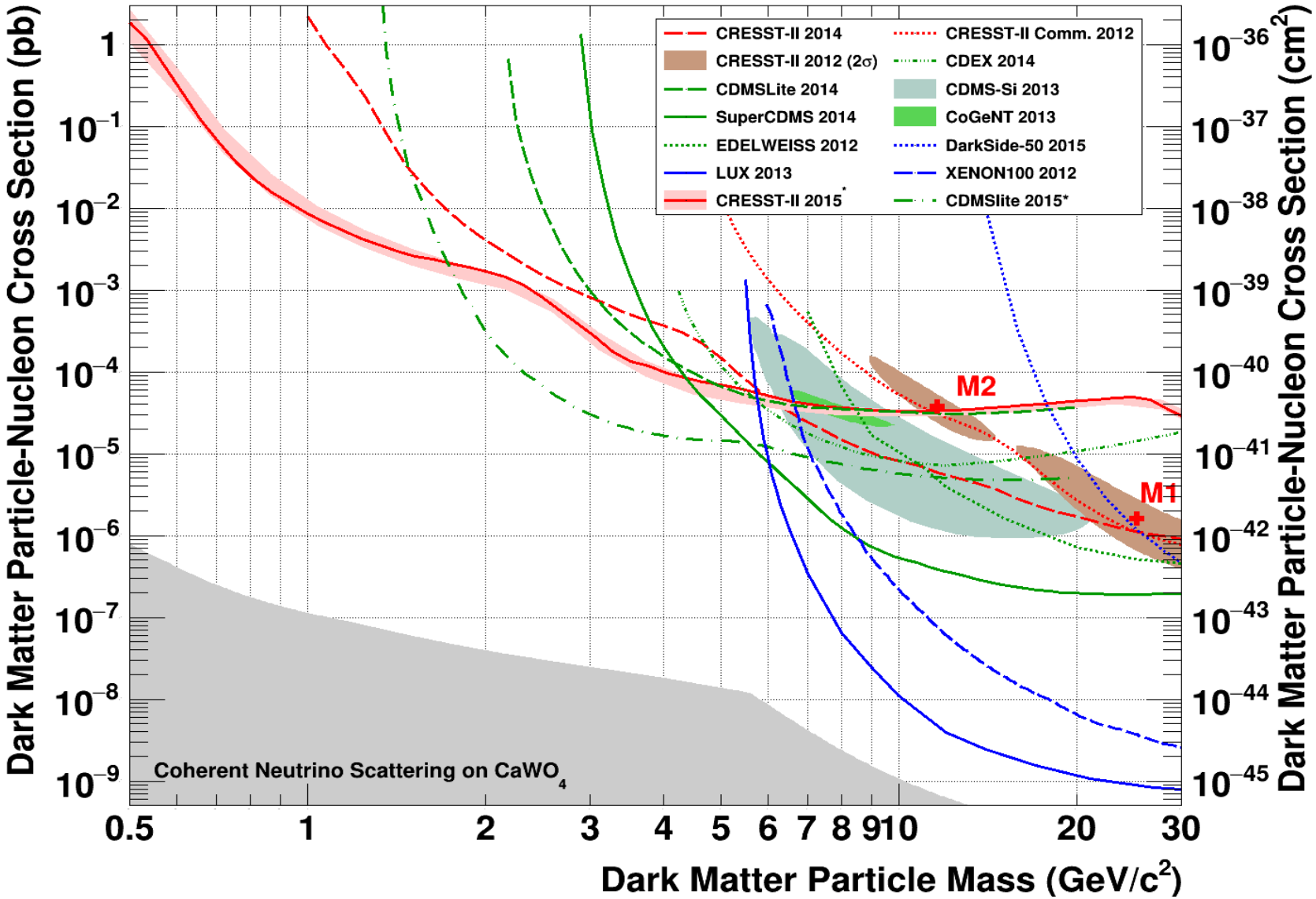
All accepted events considered as potential signal

- Standard assumptions on dark matter halo
- Helm form factors
- Yellin one-dimensional optimum interval method

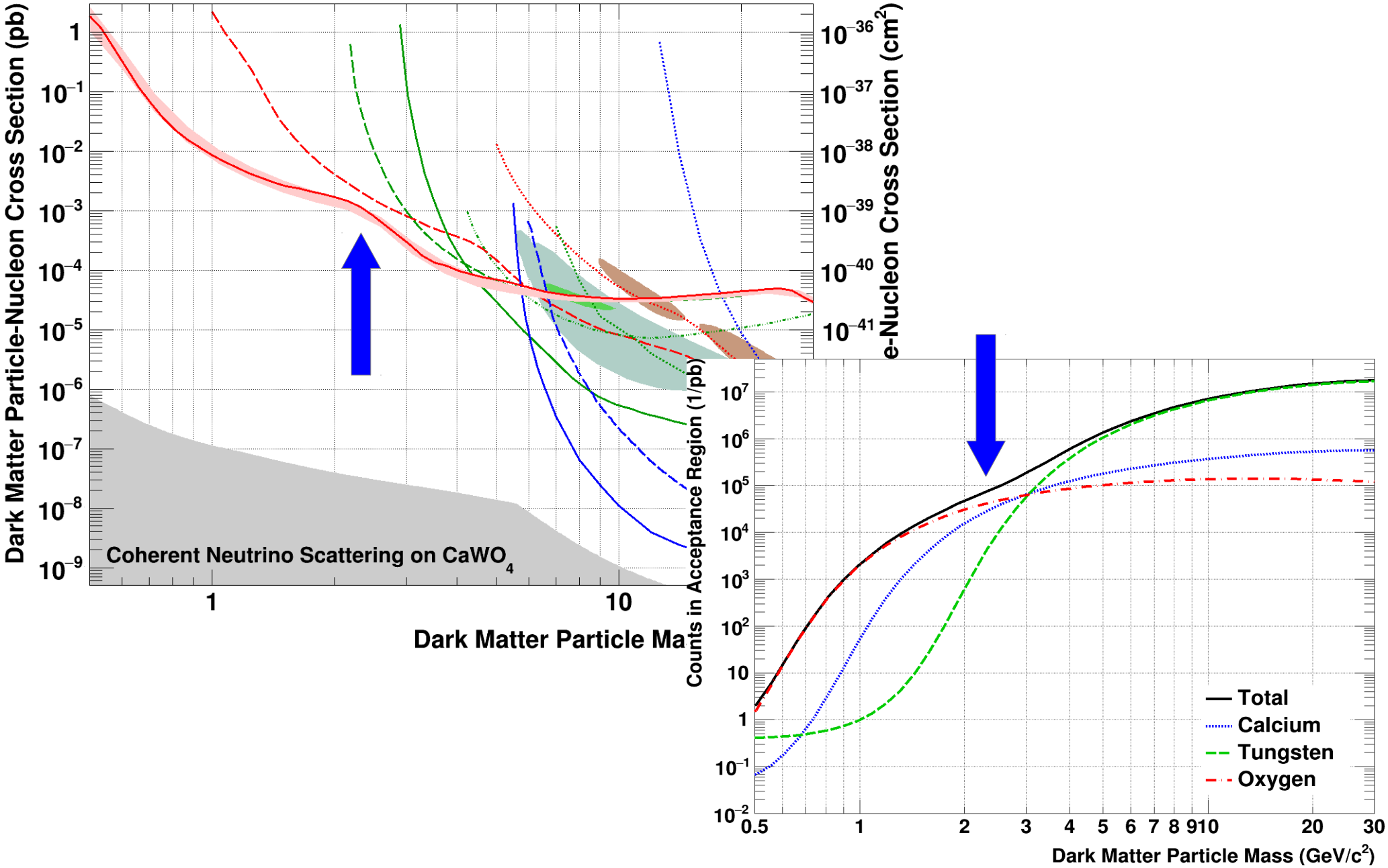


# Exclusion limit

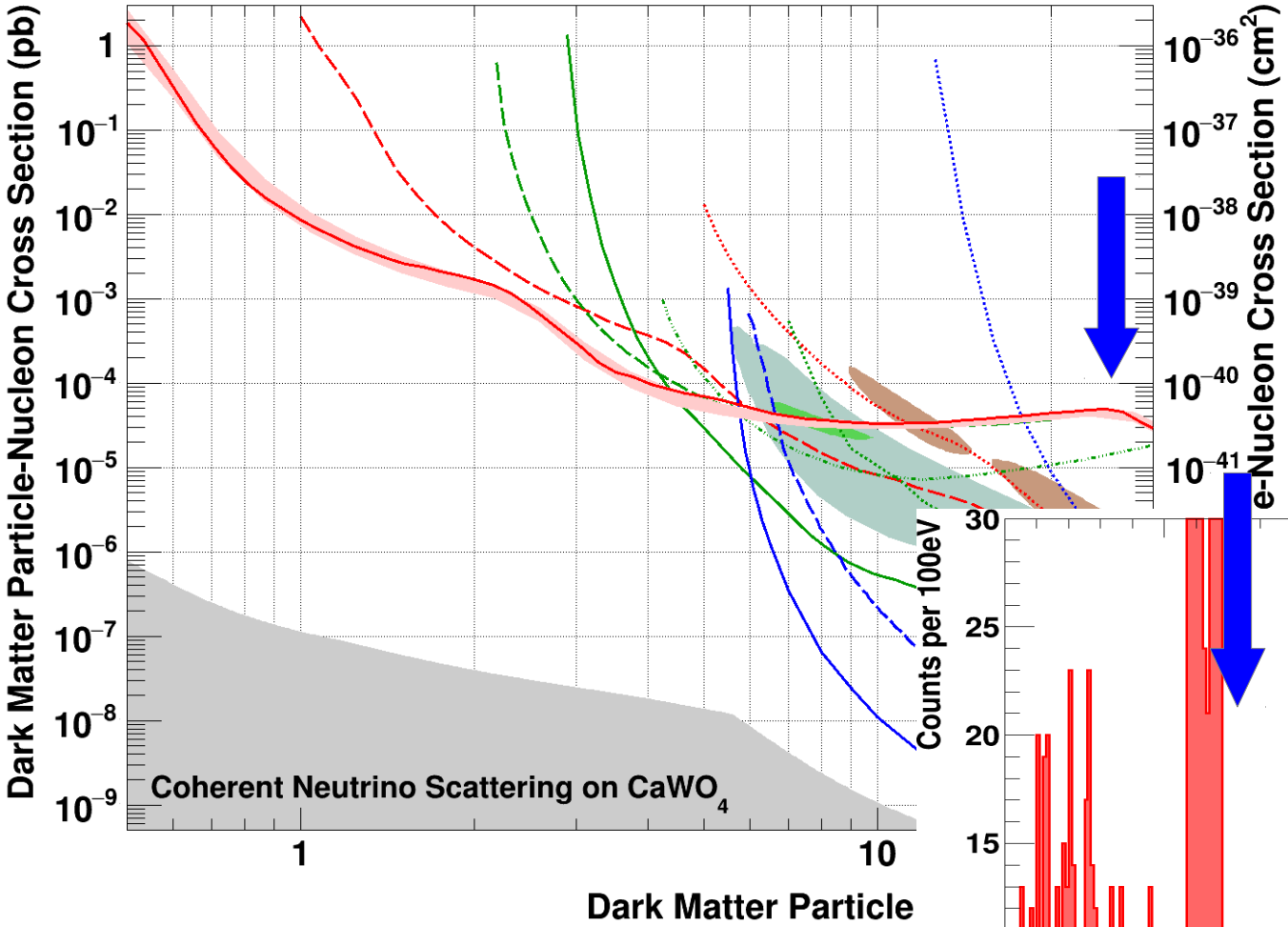
Explore masses in the sub-GeV/c$^2$ range

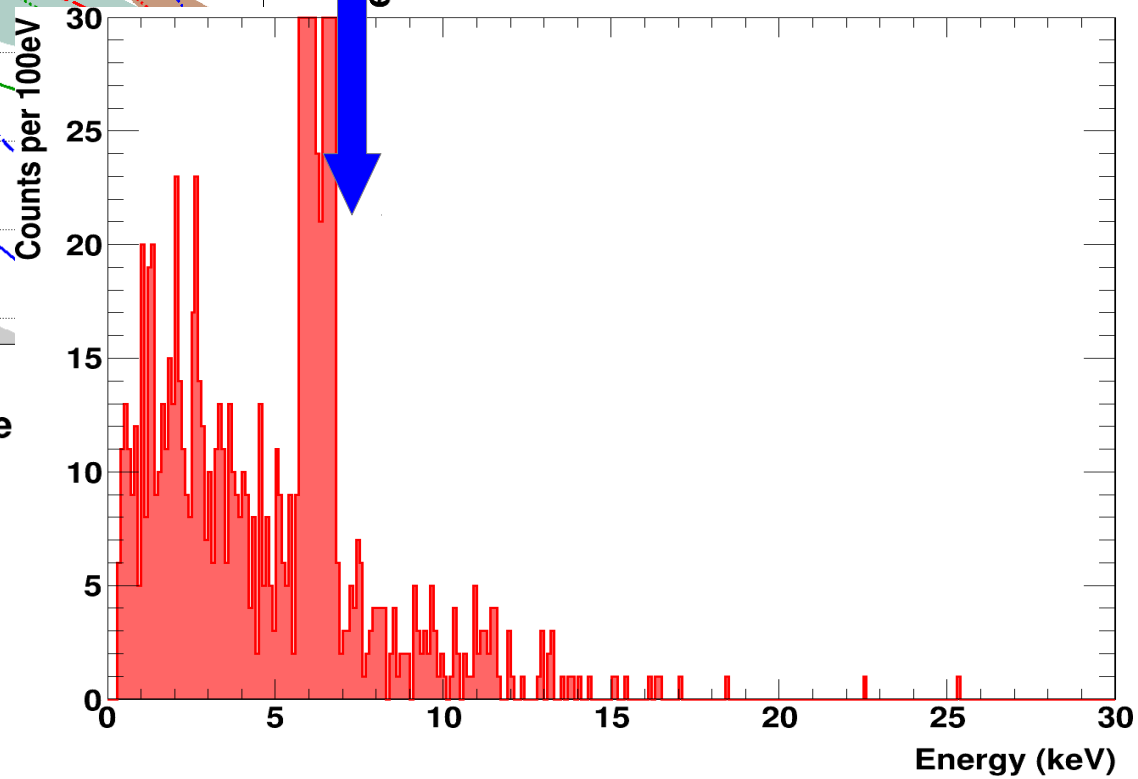


# Exclusion limit



# Exclusion limit



# Upcoming results

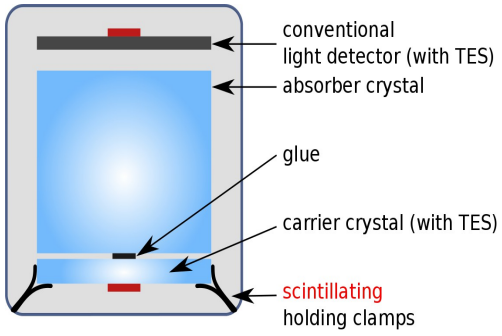
## Stated goal of Phase 2:

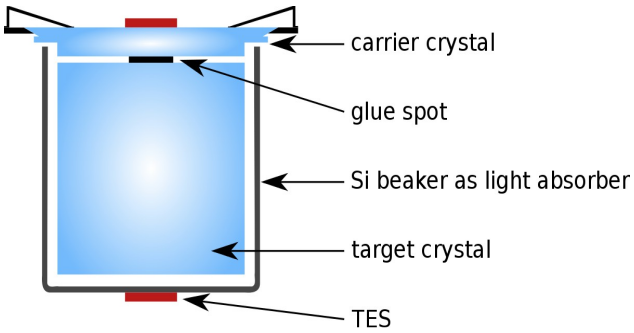
Lower background in the detectors to clarify the low mass dark matter scenario

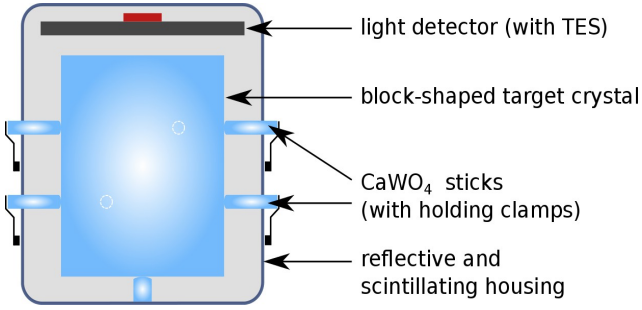
Actively discriminating detector modules used for the final analysis

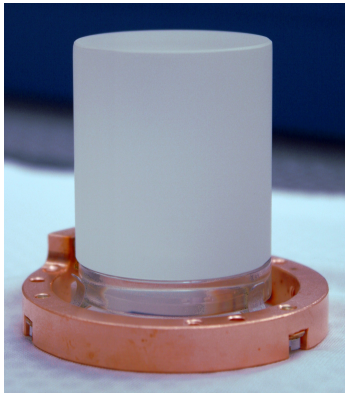
- Crystal Clamped on Carrier
- Silicon Beaker Light Detector
- Crystal Held by Sticks

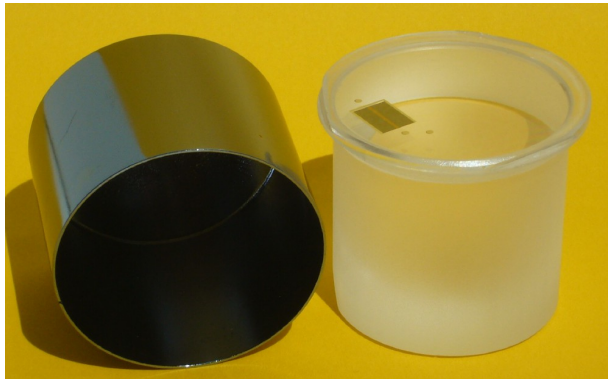
} Tag alpha decays originating from all inner surfaces of the detector module

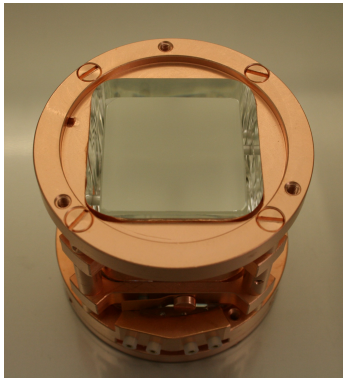






# Upcoming results

## Stated goal of Phase 2:

Lower background in the detectors to clarify the low mass dark matter scenario

Actively discriminating detector modules used for the final analysis

| Module | Design | Mass [kg] | Total exposure [kg days] | Exposure non-blind [kg days] |
|---|---|---|---|---|
| TUM40 | Sticks | 0.248 | 125.04 | 28.55 |
| TUM38 | Clamps on carrier | 0.299 | 153.76 | 34.35 |
| VK27 | Silicon beaker | 0.197 | 99.54 | 22.26 |
| VK28 | Silicon beaker | 0.194 | 98.05 | 21.95 |

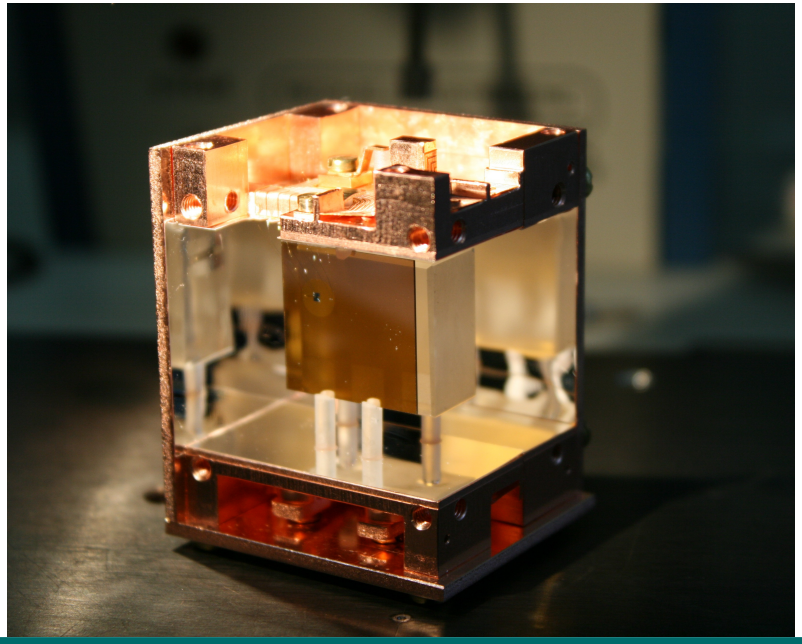
Combined analysis of the complete exposure before the end of the year

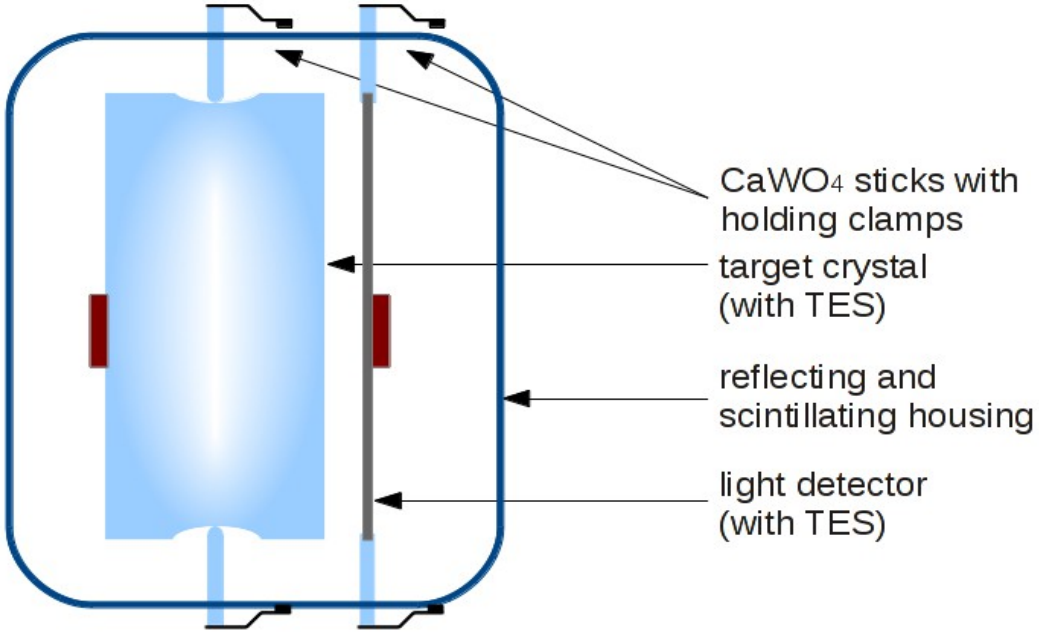
# Modules for CRESST III

## Detector layout optimized for low mass dark matter

### Phase 1

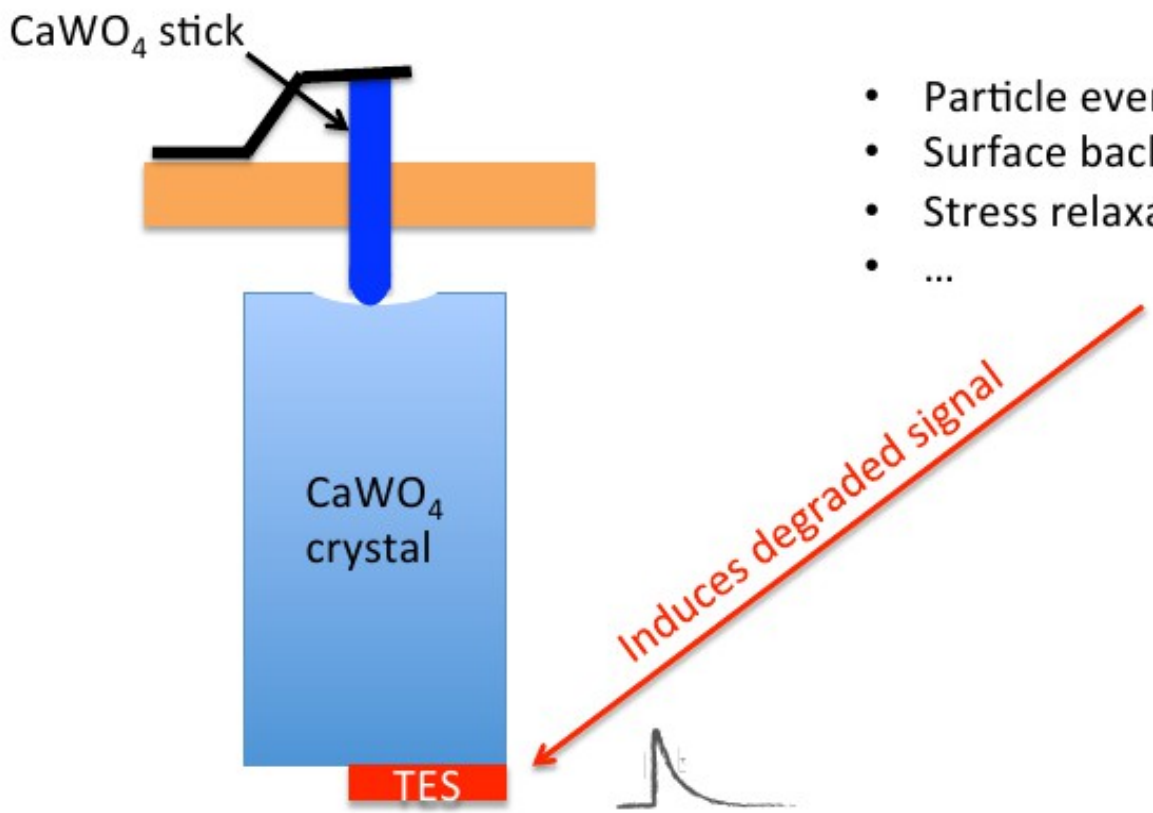
- Available self grown crystals (background level ~3 counts/keV kg day)
- 100 eV threshold
- Cuboid crystal of $(20\times20\times10)mm^3$ (~25g)
- Fully scintillating housing
- Light detector $(20\times20)mm^2$






Prototype successfully tested

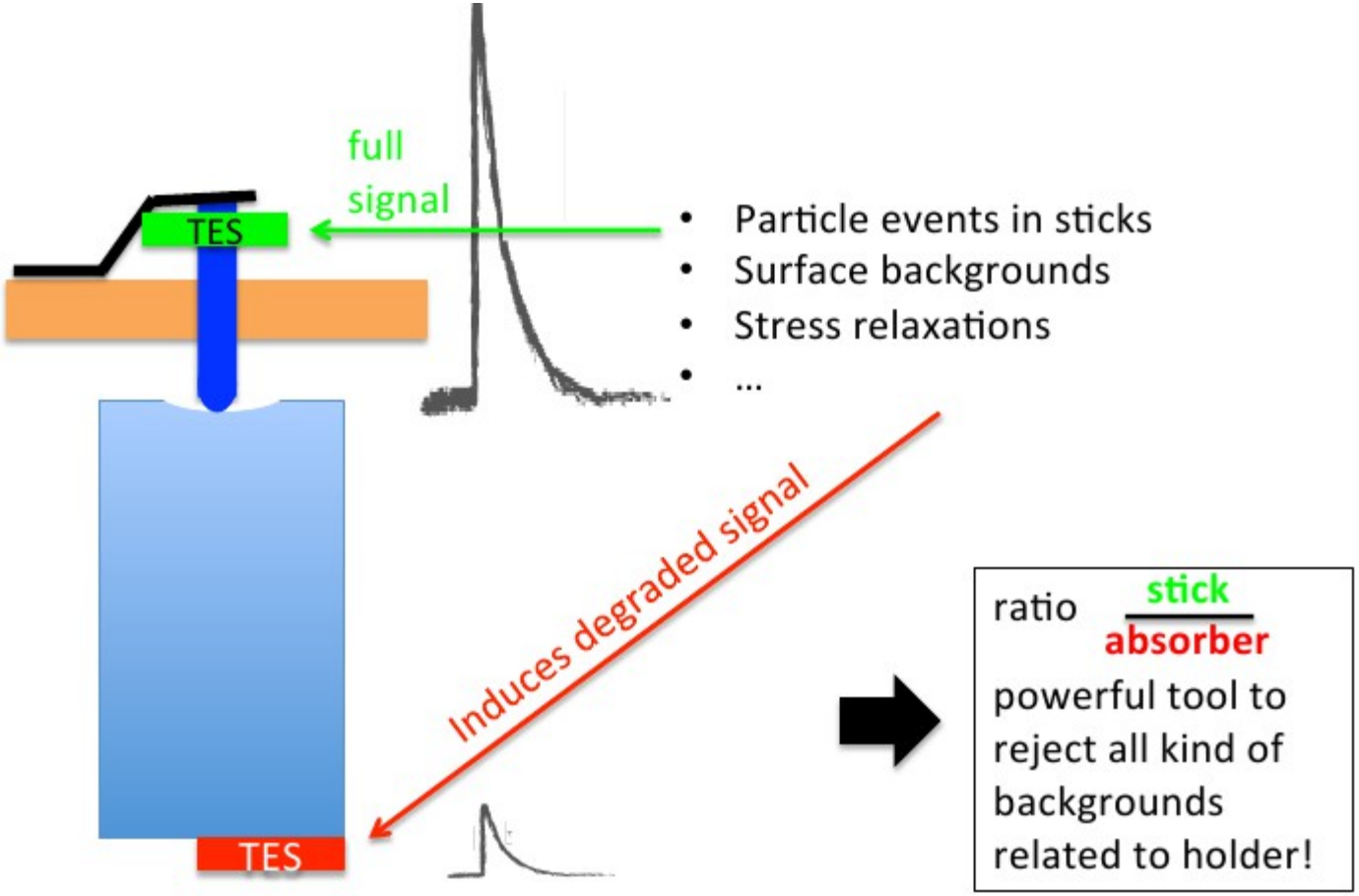
# Modules for CRESST III




- Particle events in sticks
- Surface backgrounds
- Stress relaxations
- …

Slide from R. Strauss

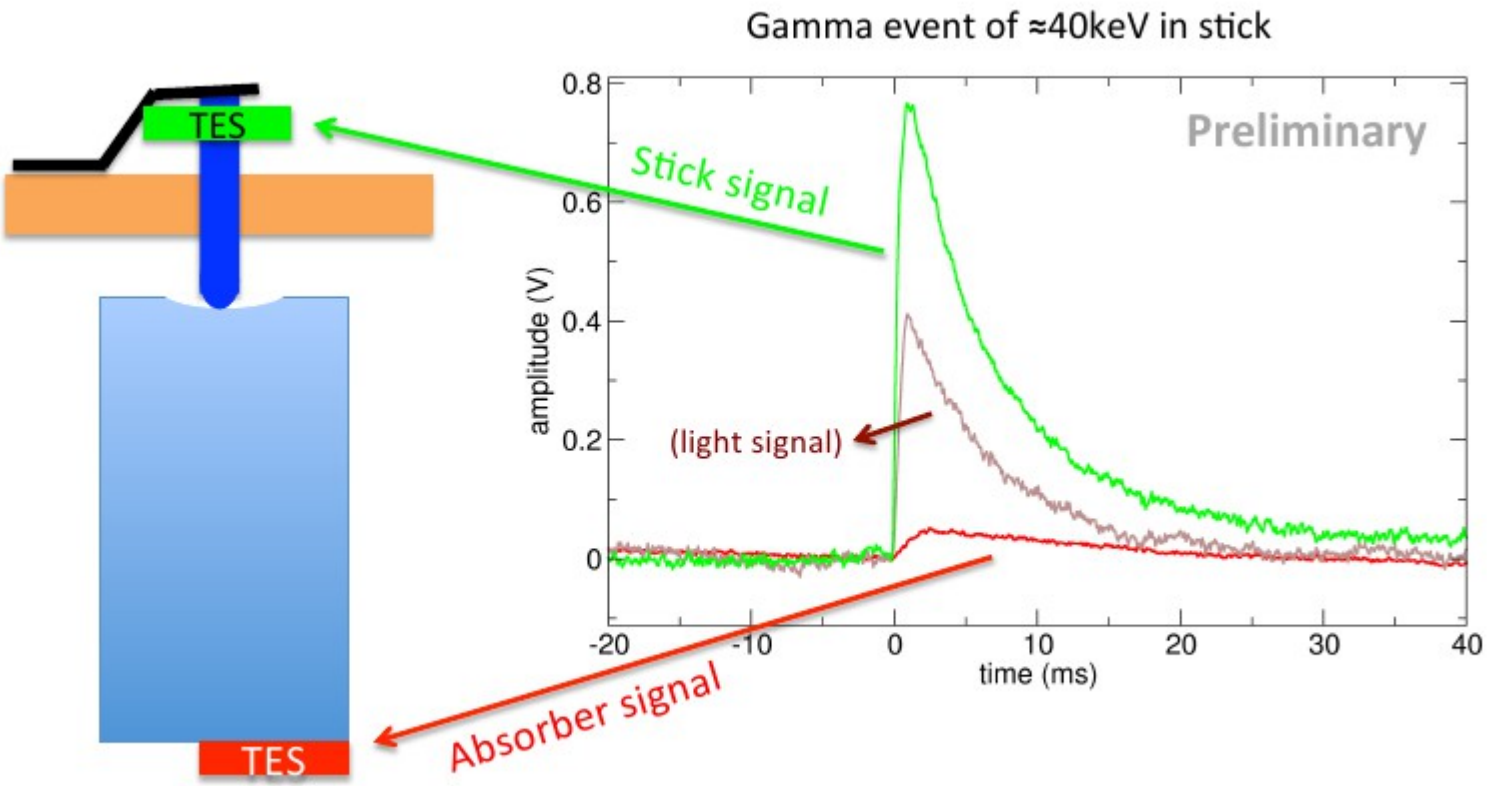
# Modules for CRESST III




- Particle events in sticks
- Surface backgrounds
- Stress relaxations
- ...

Slide from R. Strauss

# Modules for CRESST III




Slide from R. Strauss

# Schedule for CRESST III – Phase 1

Phase 1

- Production of ~15 modules ongoing
- All parts ready by November 2015
- Assembly MPP Munich by the end of the year
- Mounting at LNGS January 2016
- Start of data taking until spring

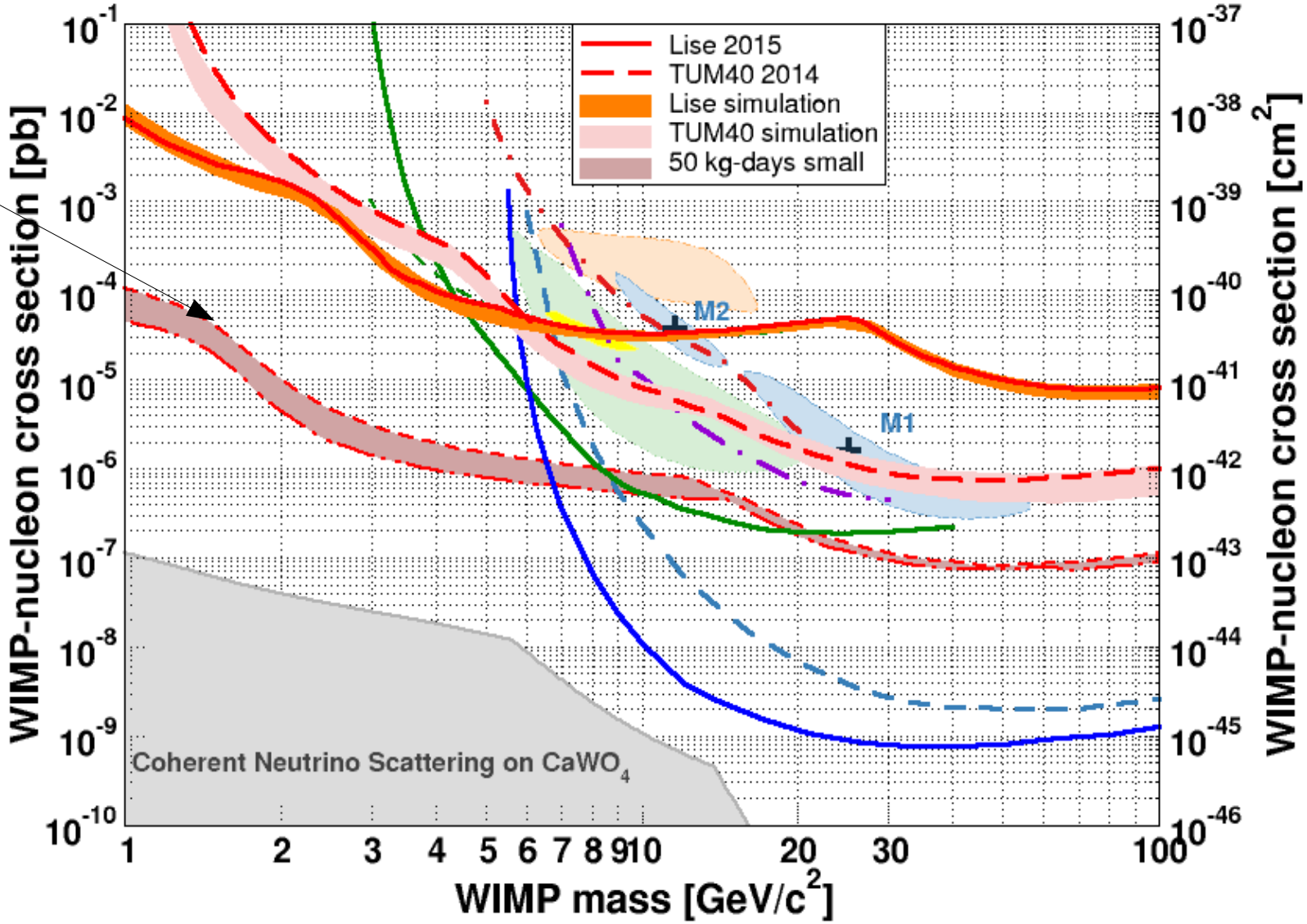
# CRESST III – Phase 1 projections

arXiv:1503.08065 [astro-ph.IM]

Phase 1

- 50 kg-days

1 year of running with
10 small modules



# Schedule for CRESST III – Phase 2

Phase 2

Factor 100 reduction in background

- Reduction of the background originated from the surrounding of the detectors

- Improved crystal radiopurity

  In house growth of crystals (TUM)

  All production steps under control

  Cleaning procedure by recrystallization and purification of raw materials

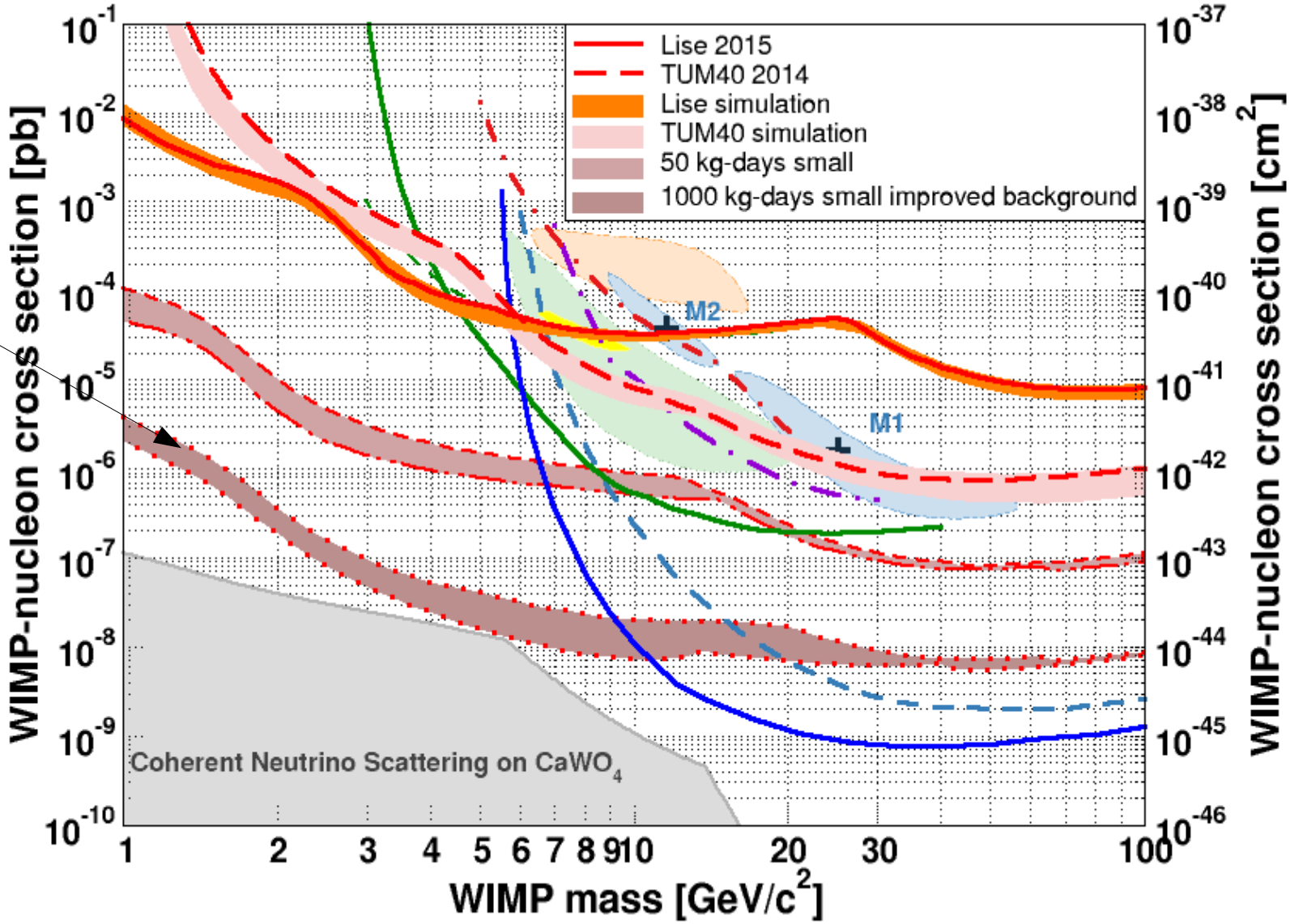
# CRESST III – Phase 2 projections

arXiv:1503.08065 [astro-ph.IM]

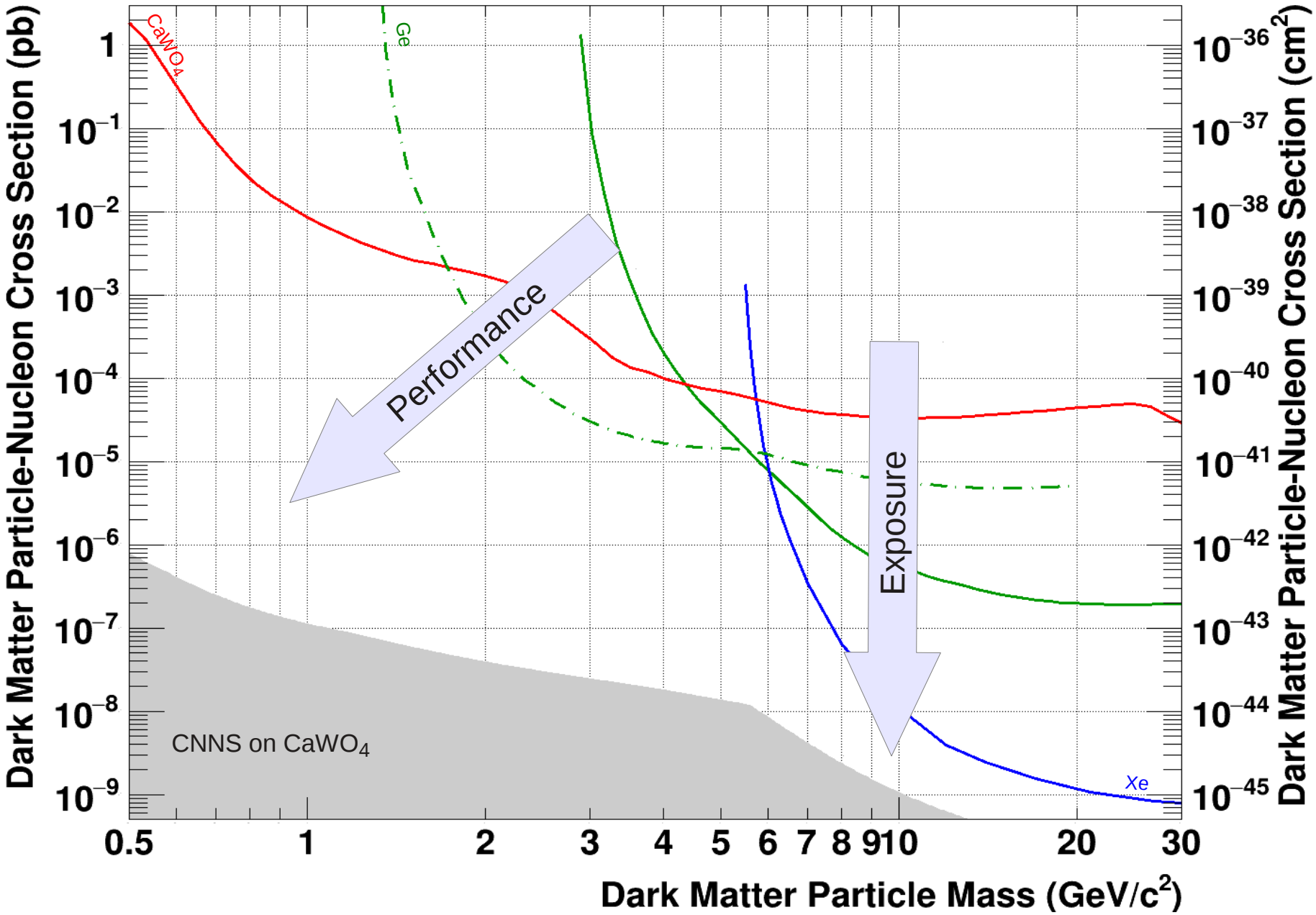
Phase 2

- 1000 kg-days

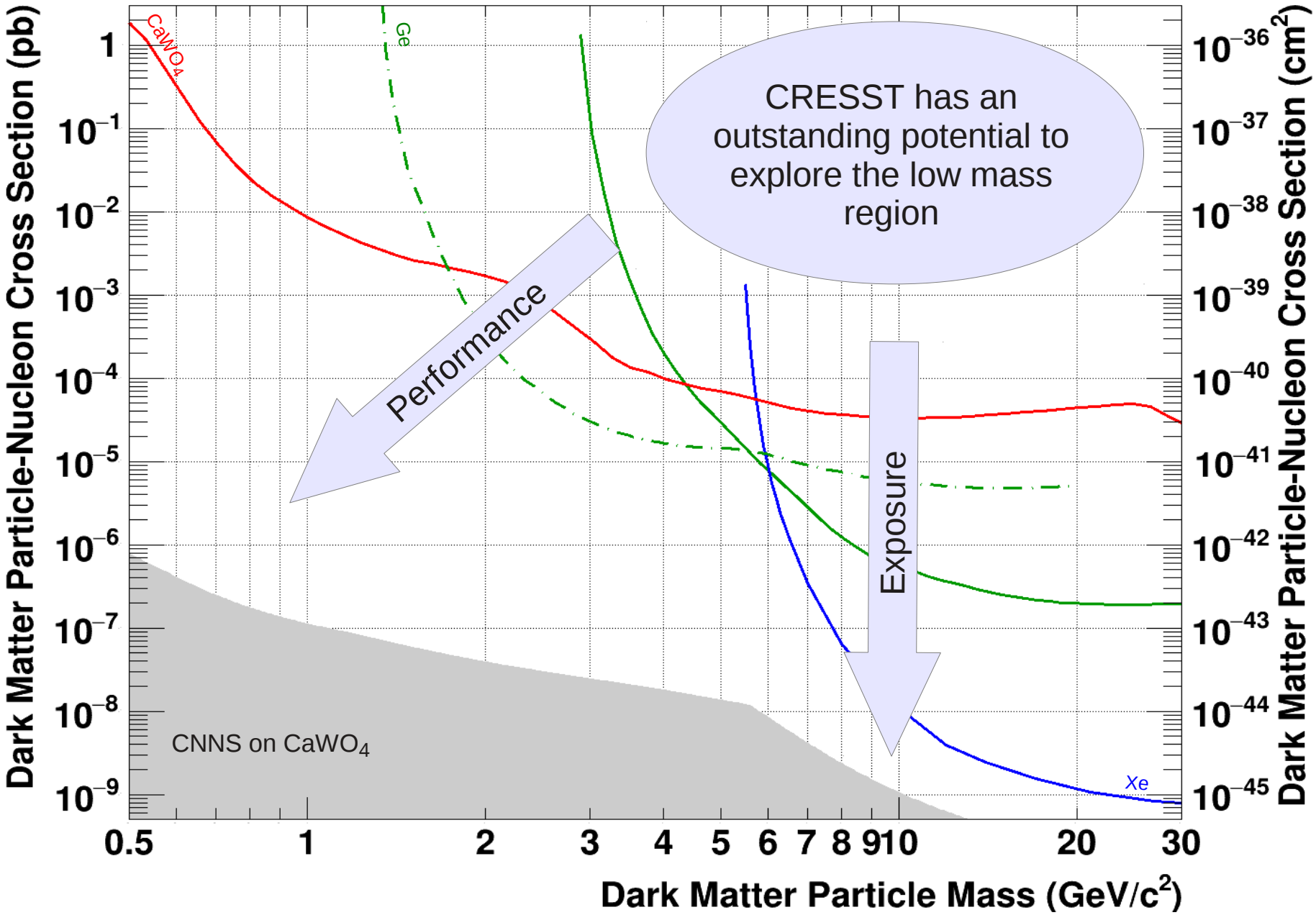
2 years of running with
100 small modules



# Take home message



# Take home message



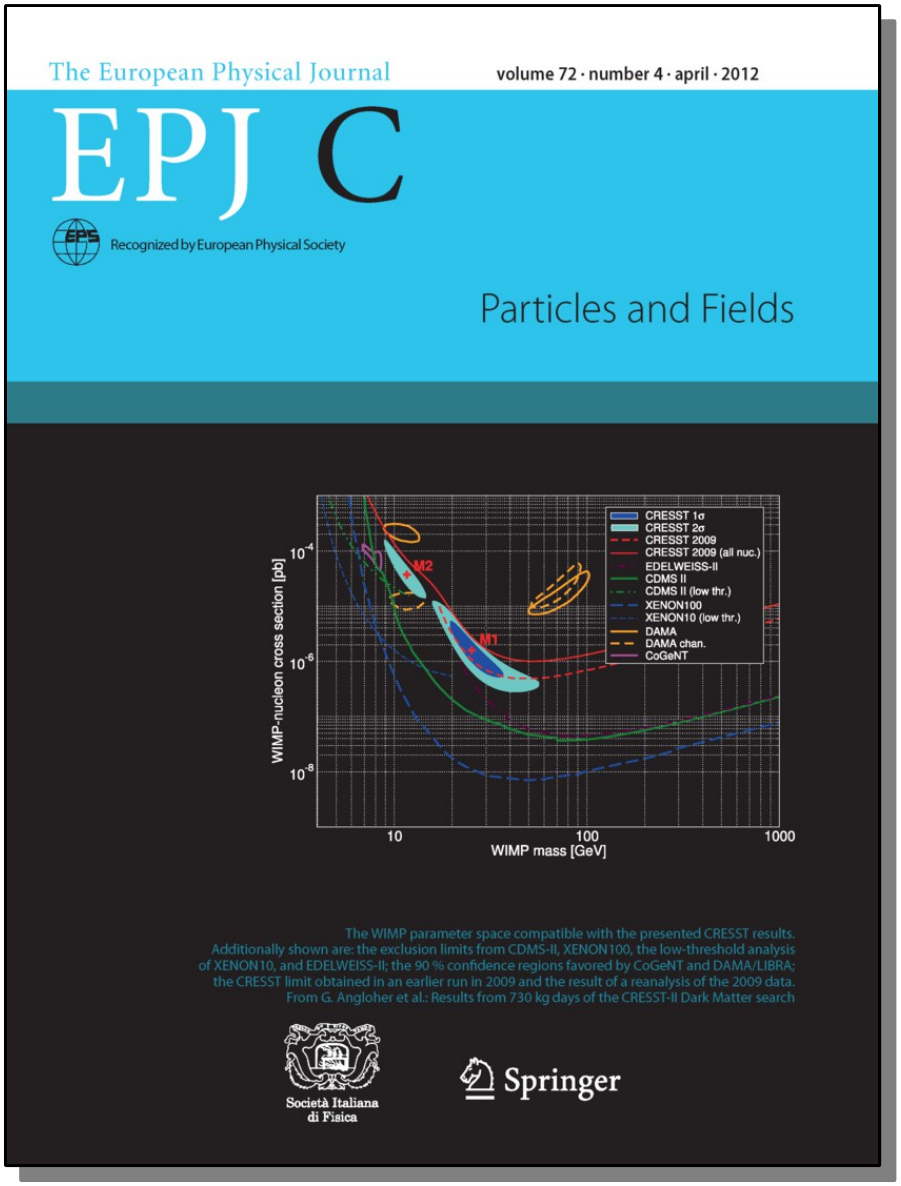
# Additional material

# CRESST II – Phase 1

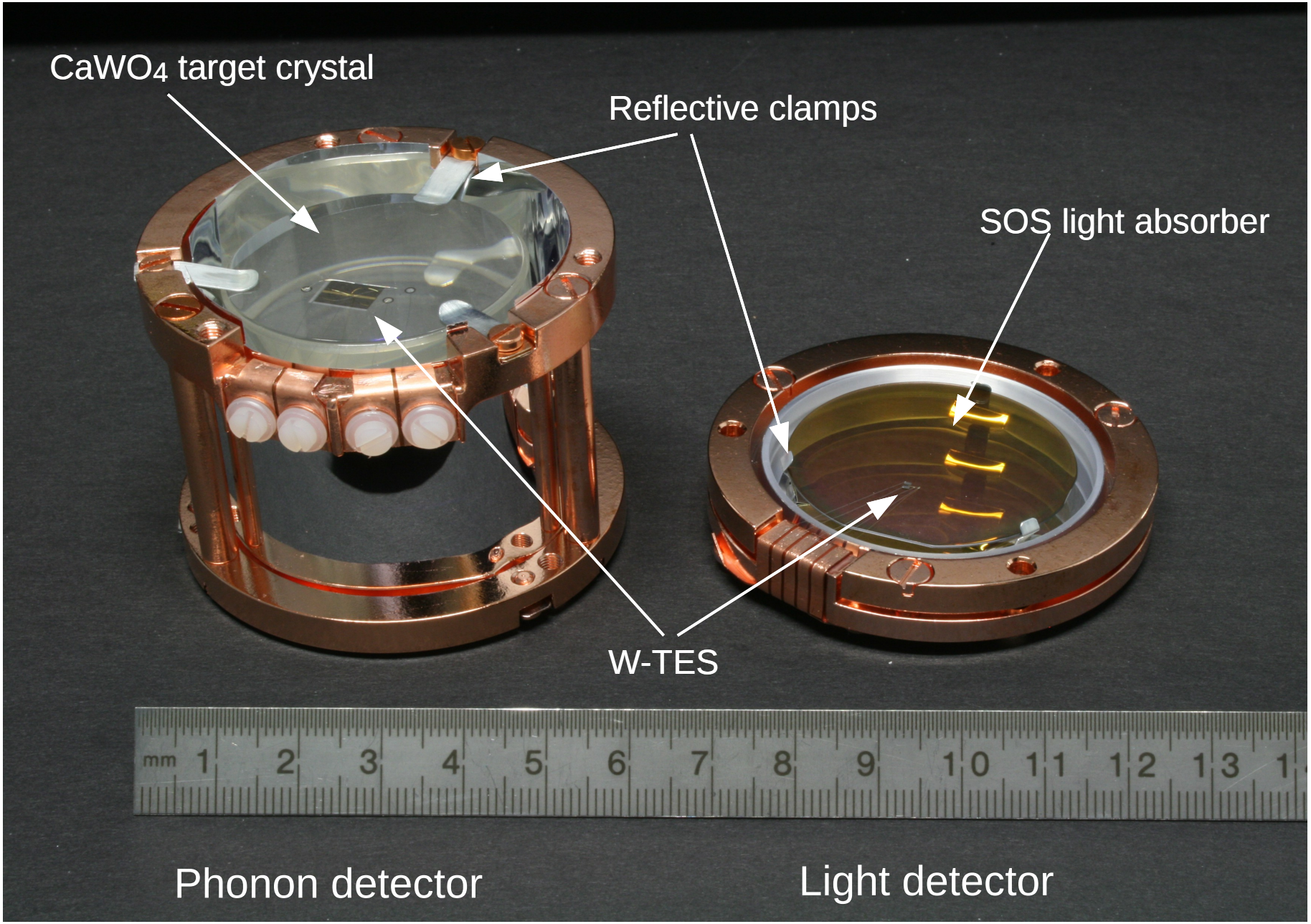
- Extended physics run from June 2009 to April 2011
- 8 $CaWO_4$ modules used for dark matter analysis
- Net exposure after cuts: 730 kg days
- 67 events observed in WIMP search region

| | M1 | M2 |
|---|---|---|
| $e/\gamma$-events | $8.00 \pm 0.05$ | $8.00 \pm 0.05$ |
| $\alpha$-events | $11.5\,^{+2.6}_{-2.3}$ | $11.2\,^{+2.5}_{-2.3}$ |
| neutron events | $7.5\,^{+6.3}_{-5.5}$ | $9.7\,^{+6.1}_{-5.1}$ |
| Pb recoils | $15.0^{+5.2}_{-5.1}$ | $18.7\,^{+4.9}_{-4.7}$ |
| signal events | $29.4\,^{+8.6}_{-7.7}$ | $24.2\,^{+8.1}_{-7.2}$ |
| $m_\chi$ [GeV] | 25.3 | 11.6 |
| $\sigma_{WN}$ [pb] | $1.6 \cdot 10^{-6}$ | $3.7 \cdot 10^{-5}$ |

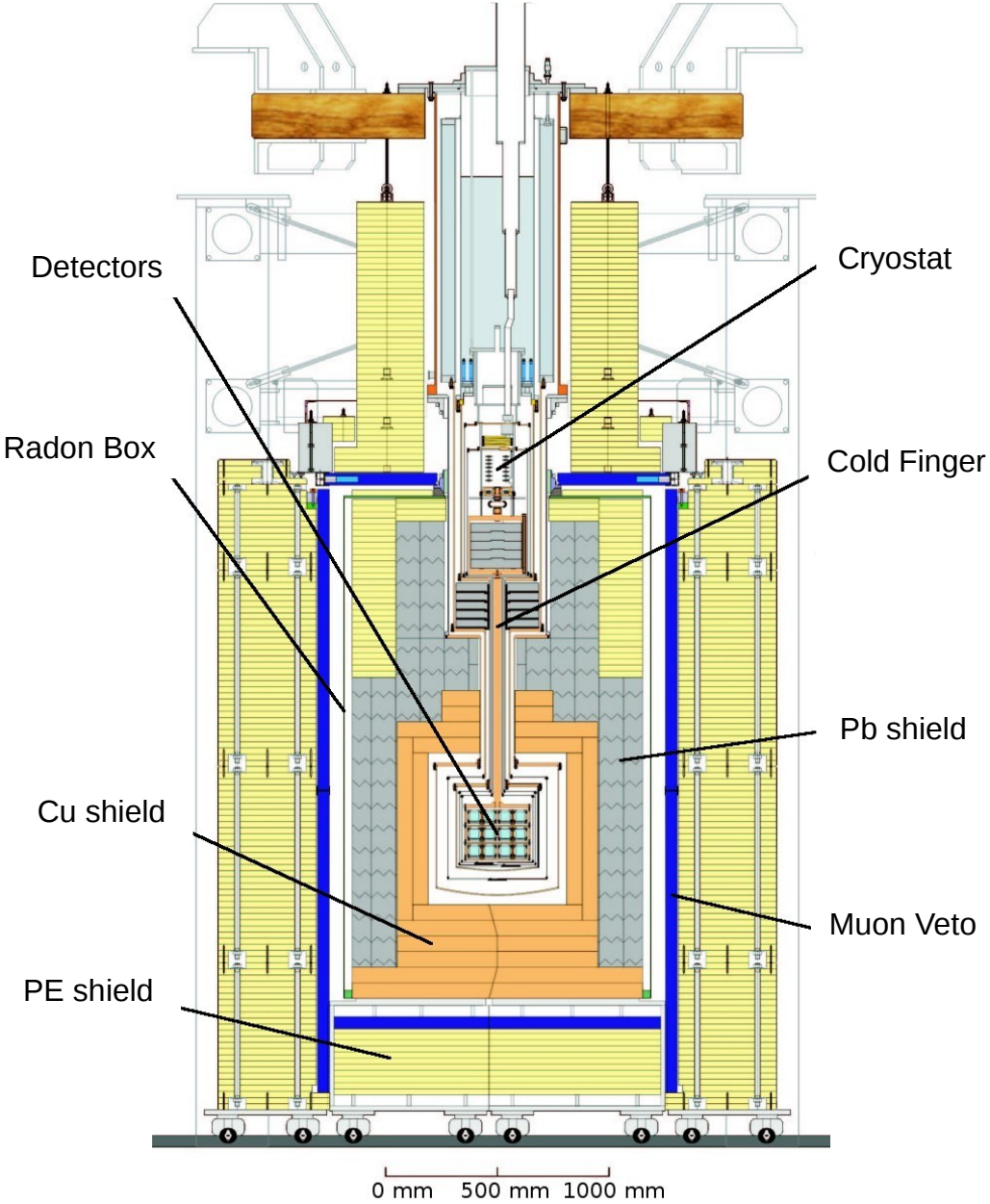
- High contribution of backgrounds
- Lower background mandatory to clarify the low mass WIMP scenario



# Detector module

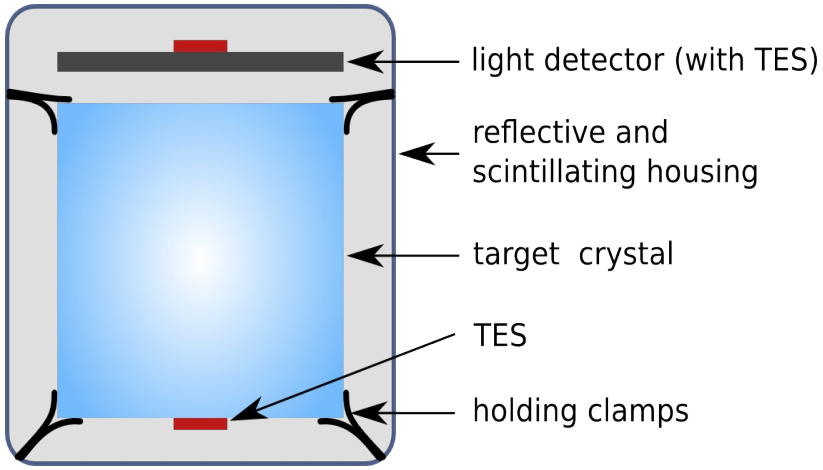


# The experimental setup

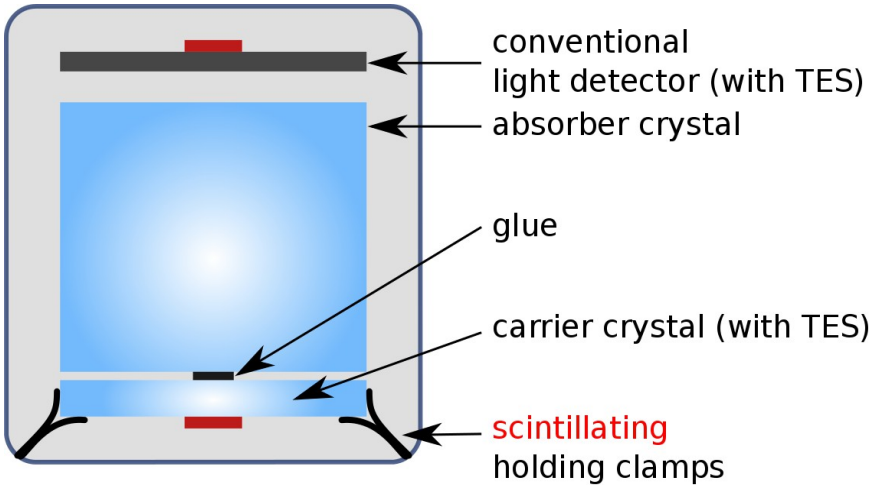


# Detector designs

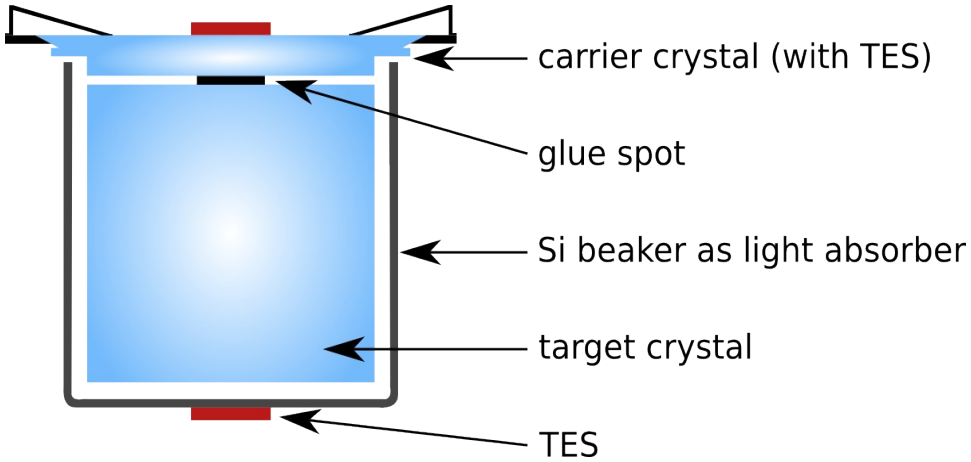
## Conventional



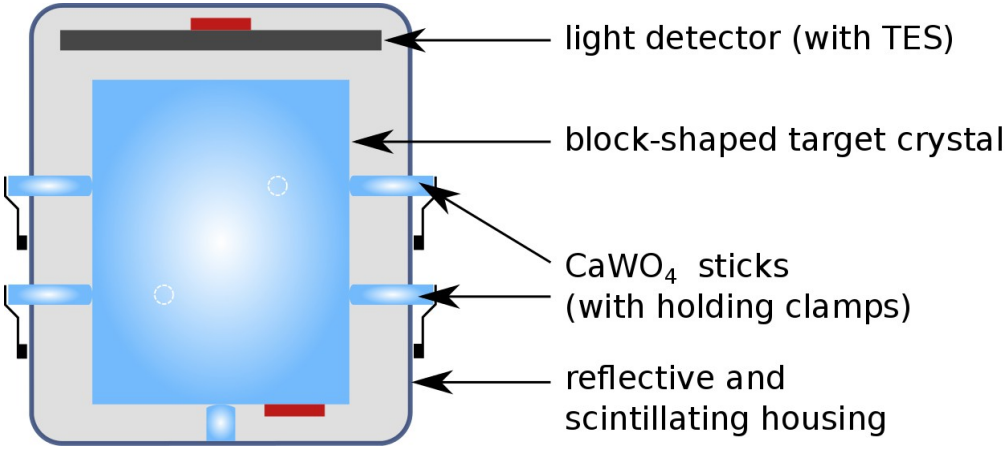

## Crystal Clamped on Carrier



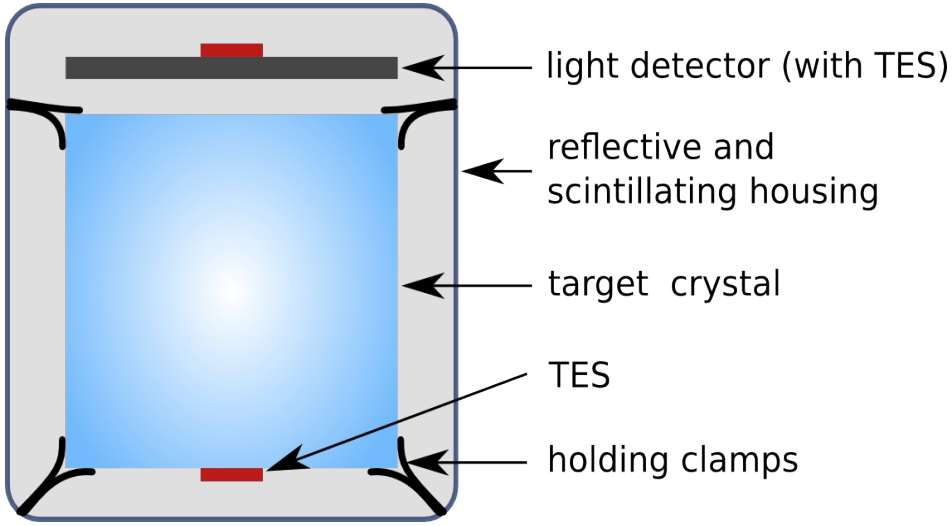

## Silicon Beaker Light Detector

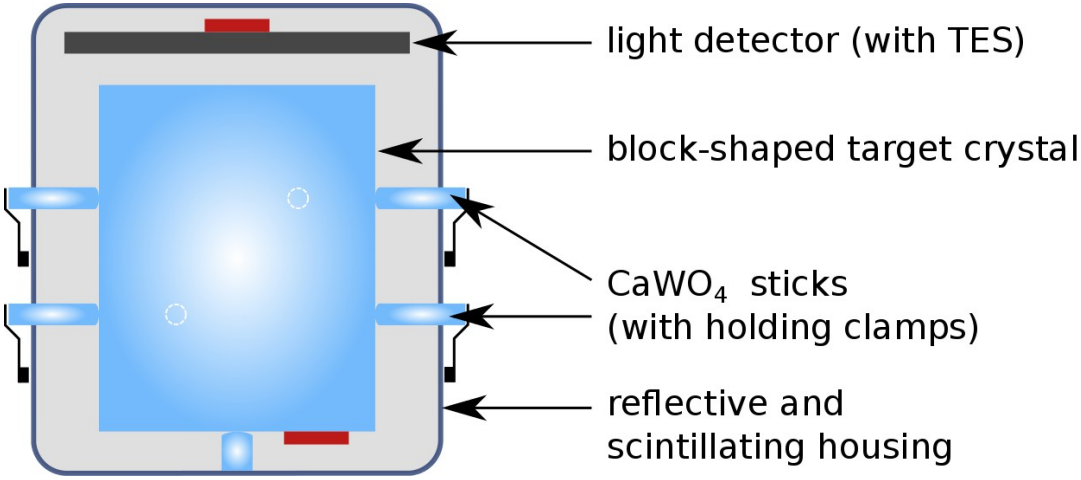



## Crystal Held by Sticks



# Lise vs. TUM40

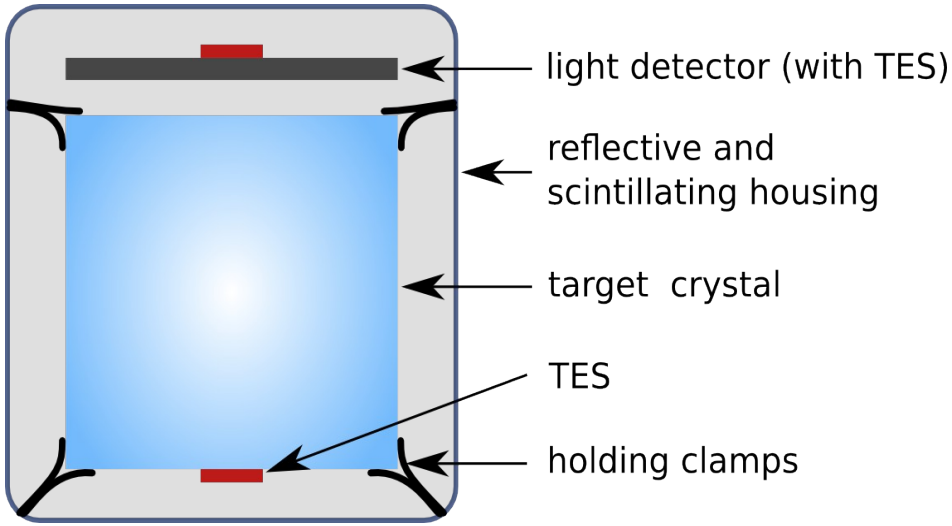


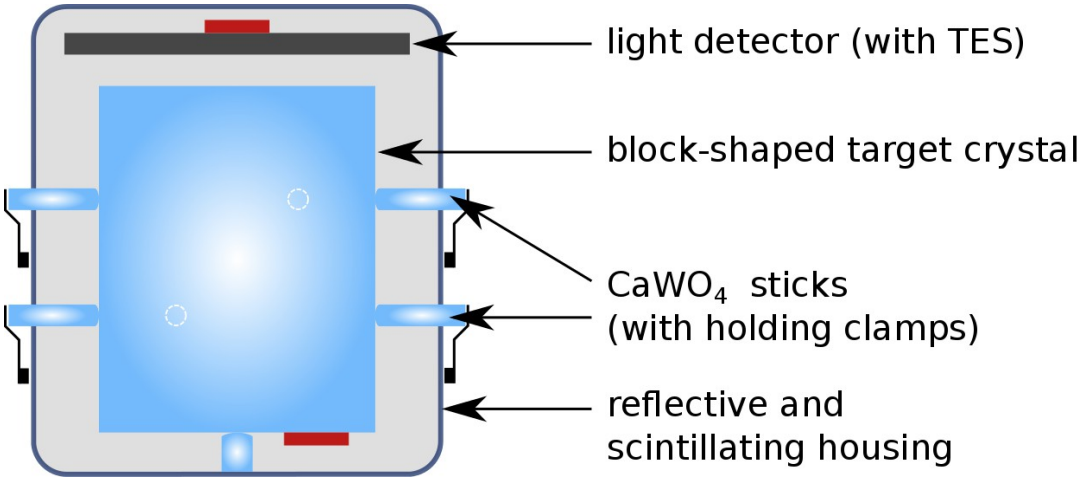



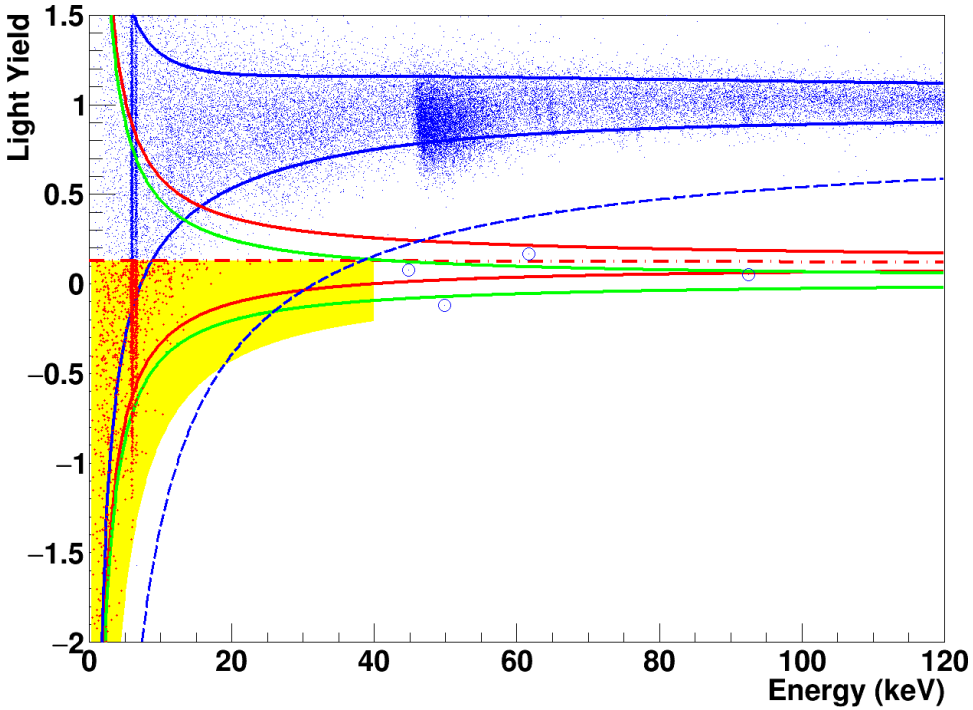

- Detector design: Conventional
  No veto for surface alpha decays
- Crystal: Lise (commercial)
  Background level ~8.5 counts/keV kg day
- Threshold: 307eV
- Resolution at zero energy: 62eV

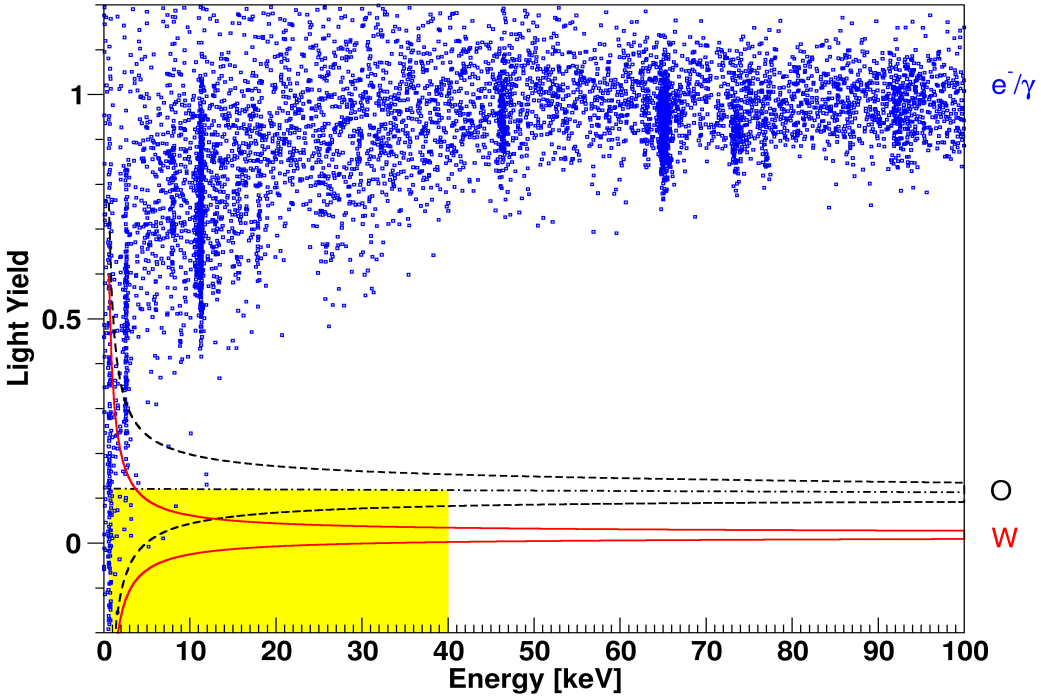
- Detector design: Sticks
  Fully scintillating housing
  Veto for surface alpha decays
- Crystal: TUM40 (self grown)
  Background level ~3.5 counts/keV kg day
- Threshold: 600eV
- Resolution at zero energy: 100eV

# Lise vs. TUM40



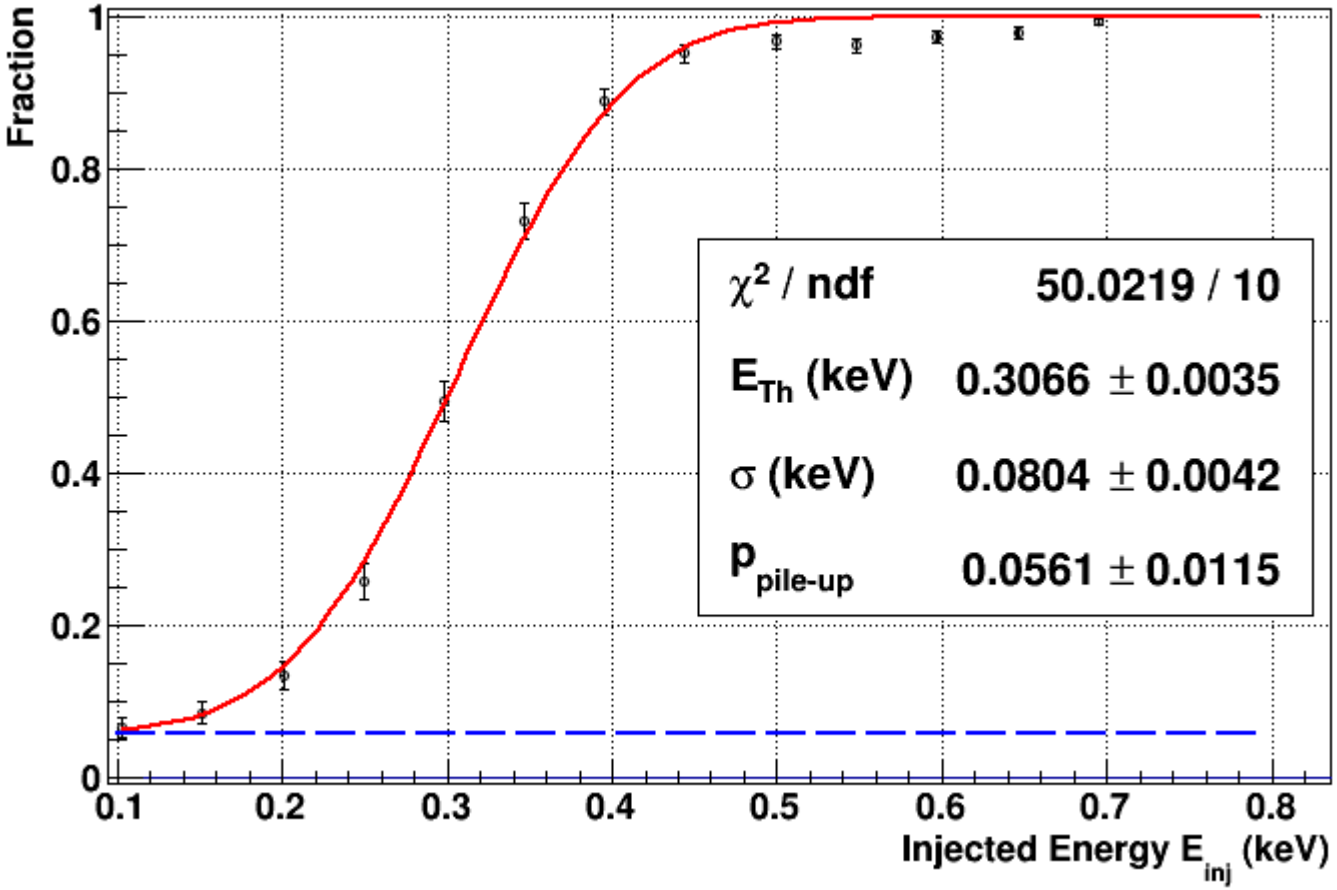



# Trigger efficiency

Trigger efficiency directly measured by injecting low energy heater pulses



# Data analysis

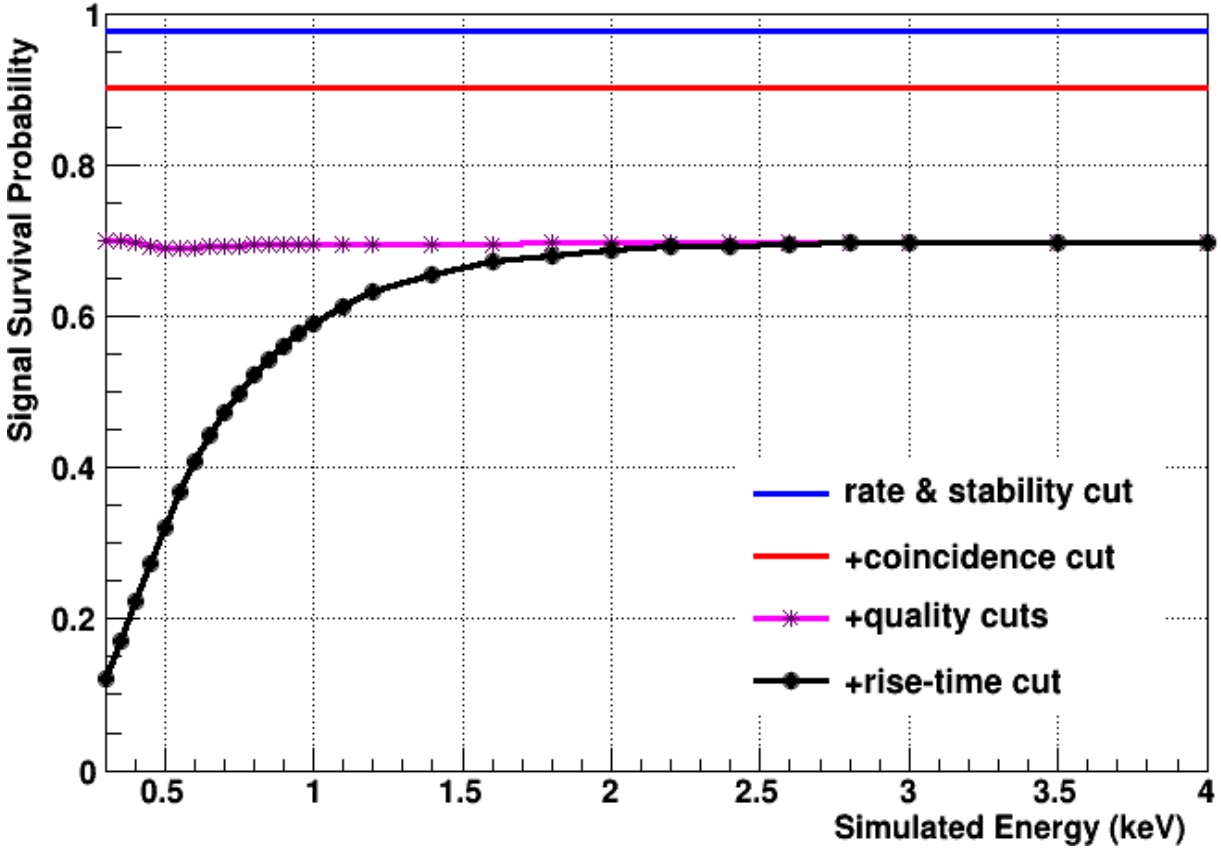
Data selection:

- Rate cut – removes period of abnormally high trigger rate (increased noise contribution)
- Stability cut – both detectors in the operating point
- Cut events coincident with other detector or muon veto
- Quality cut – remove pulses where a correct determination of the amplitude is not guaranteed
- Cut on carrier event (simple rise time cut)

Cuts designed on a non-blind data set not included in the final exposure

Signal survival probability determined by applying the cuts on a set of artificial nuclear recoil pulses

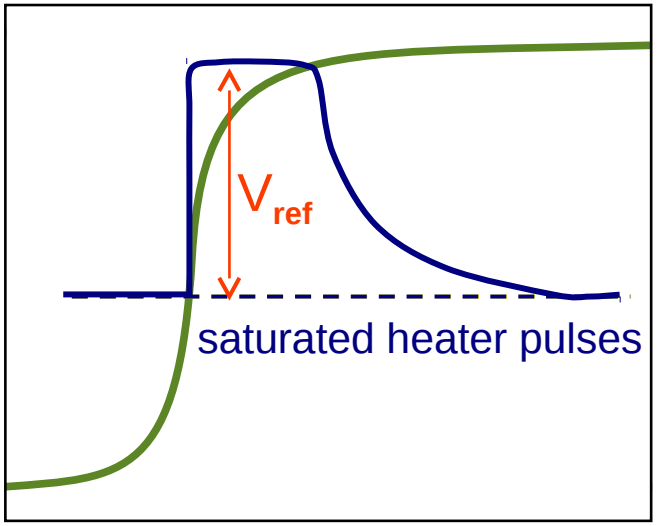
**12% survival probability at threshold**

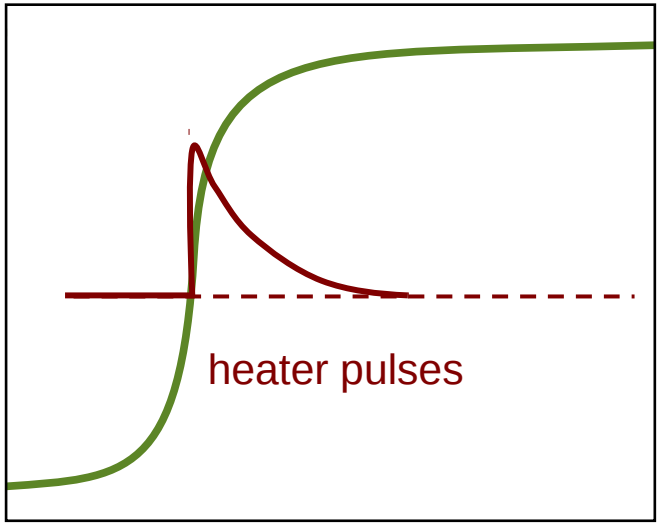


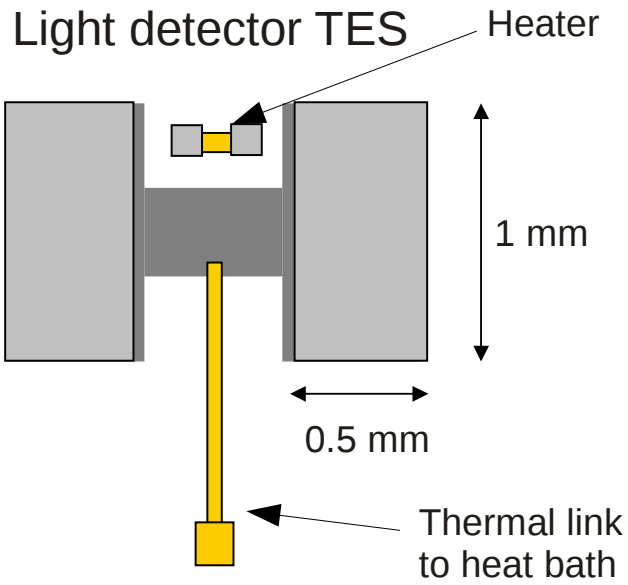
# Detector heater

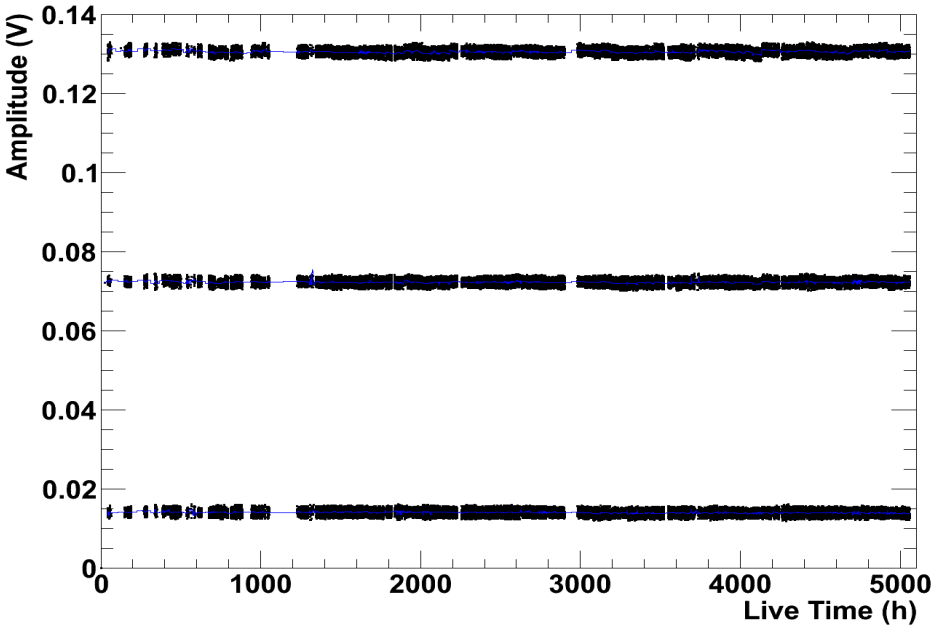
W-TES equipped with heaters

- Stabilization of detectors in the operating point
- Injection of heat pulses for calibration and determination of trigger threshold

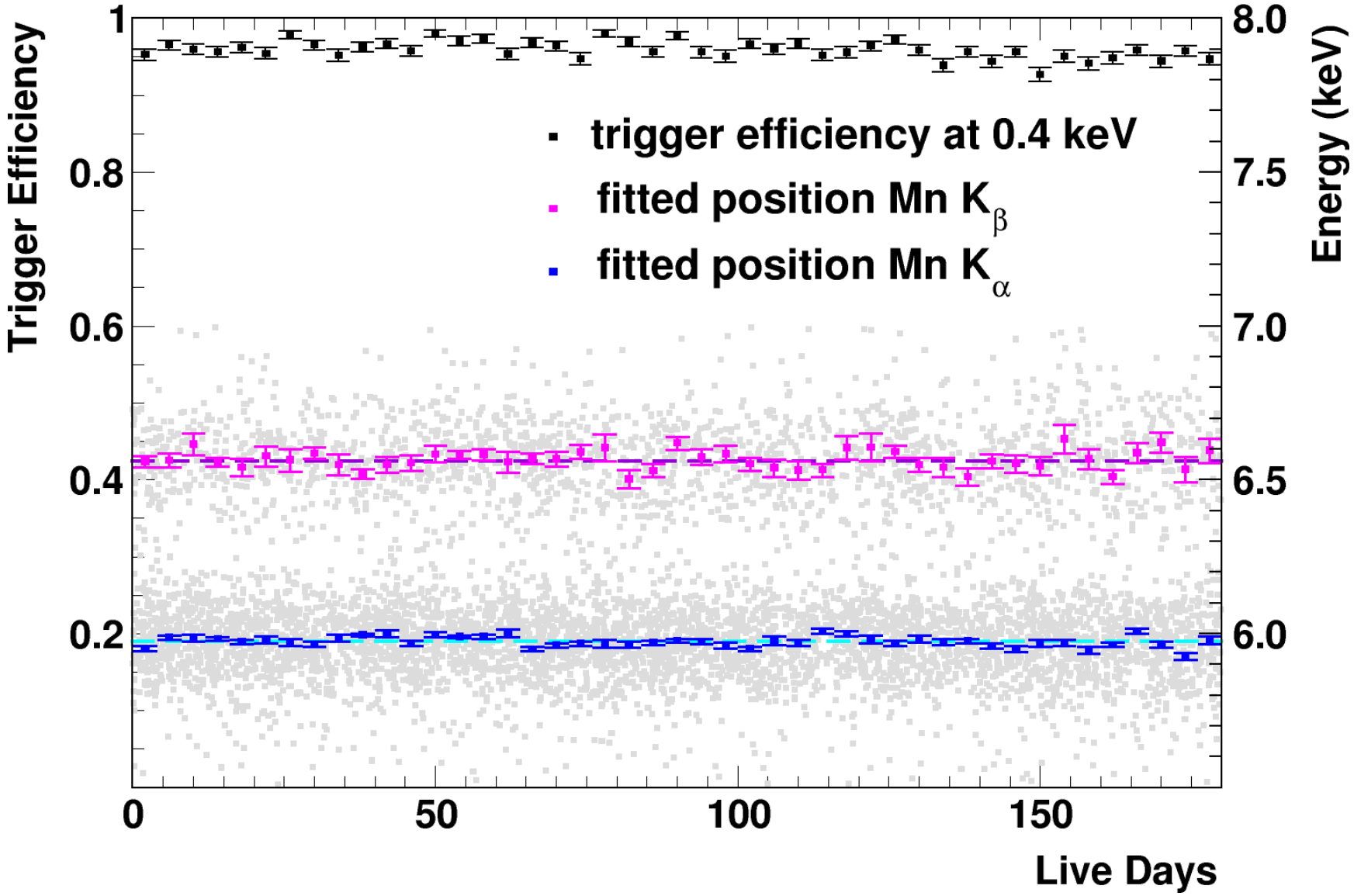


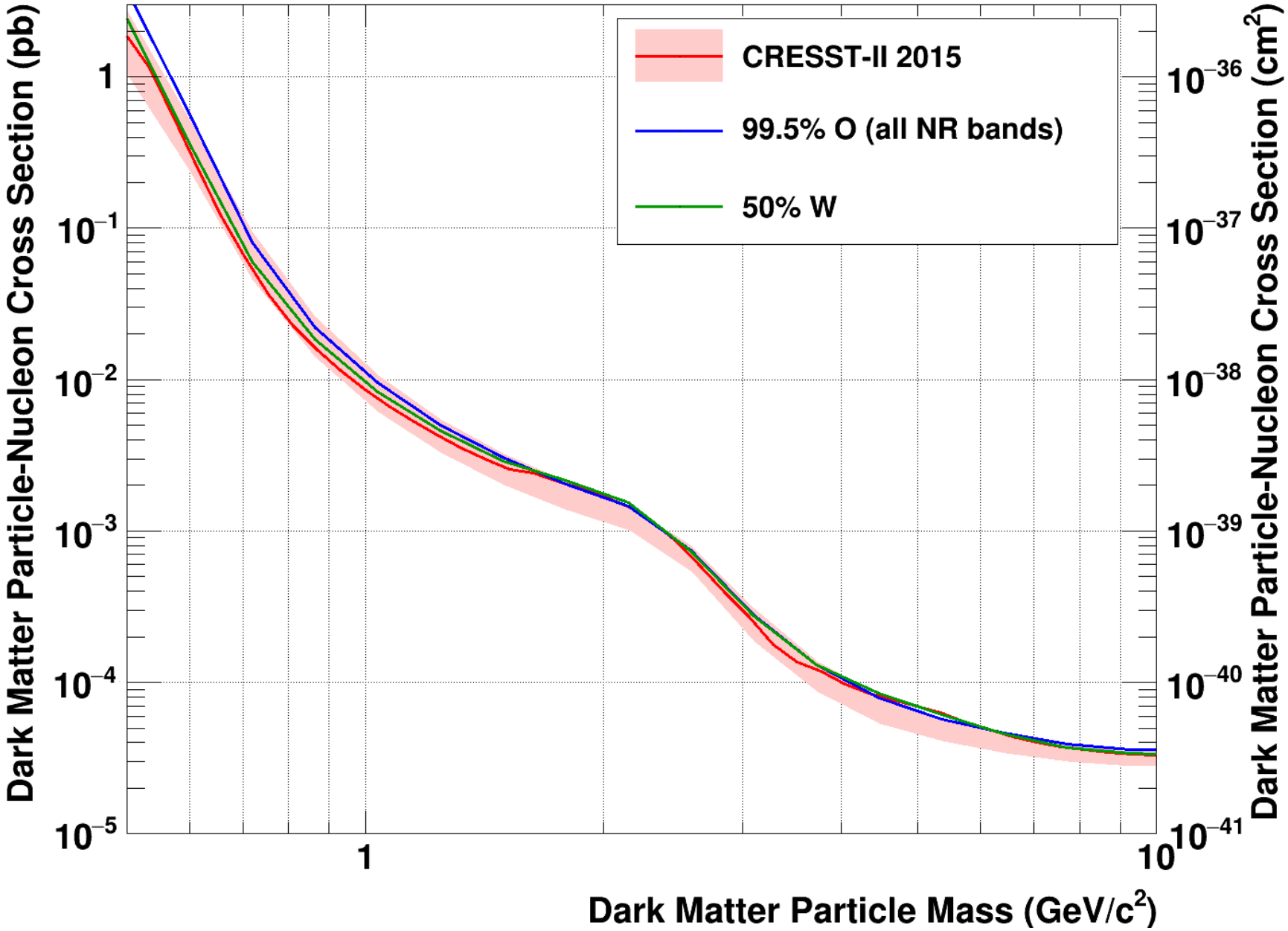



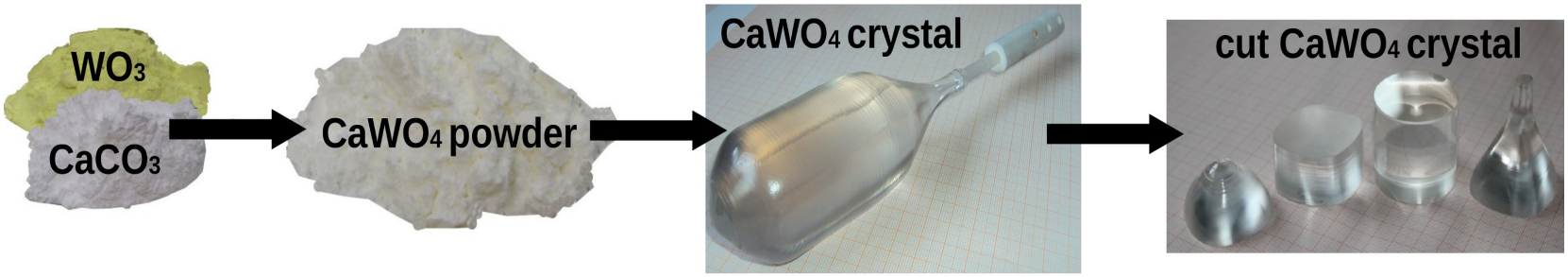
# Long term stability

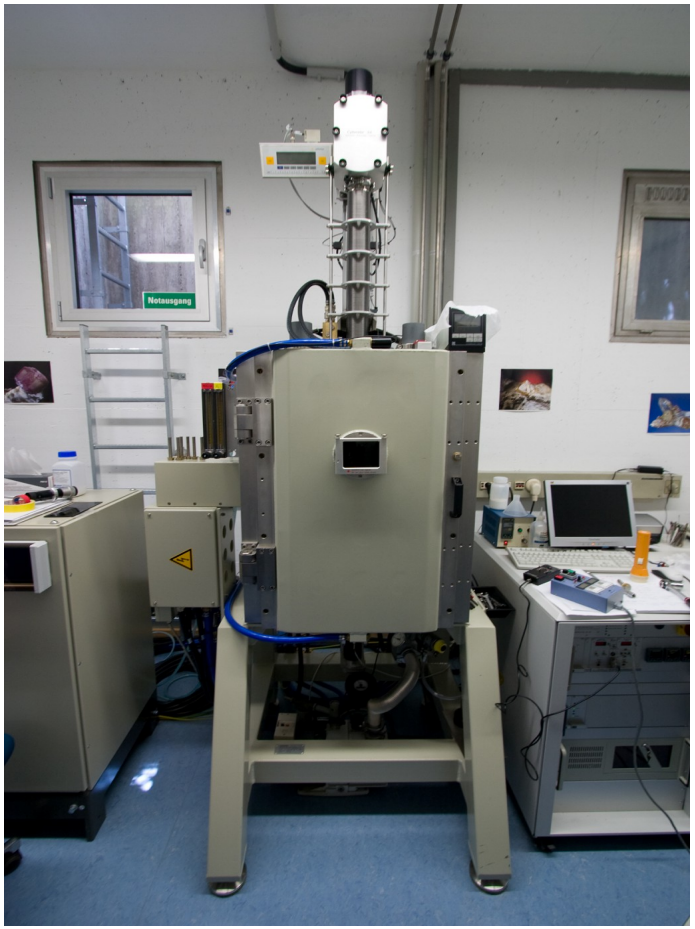


# Lise - Different LY boundaries



# Crystal growing



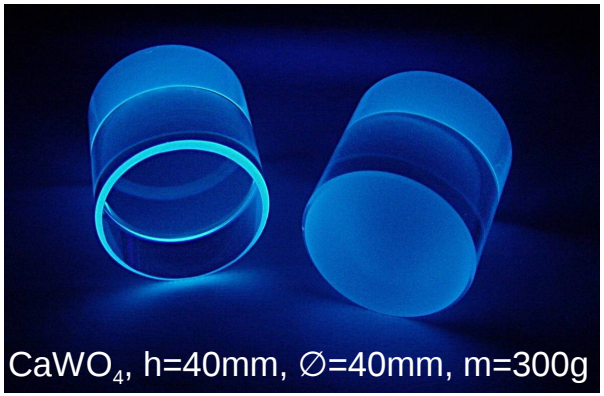



# The CRESST experiment

## Cryogenic Rare Event Search with Superconducting Thermometers

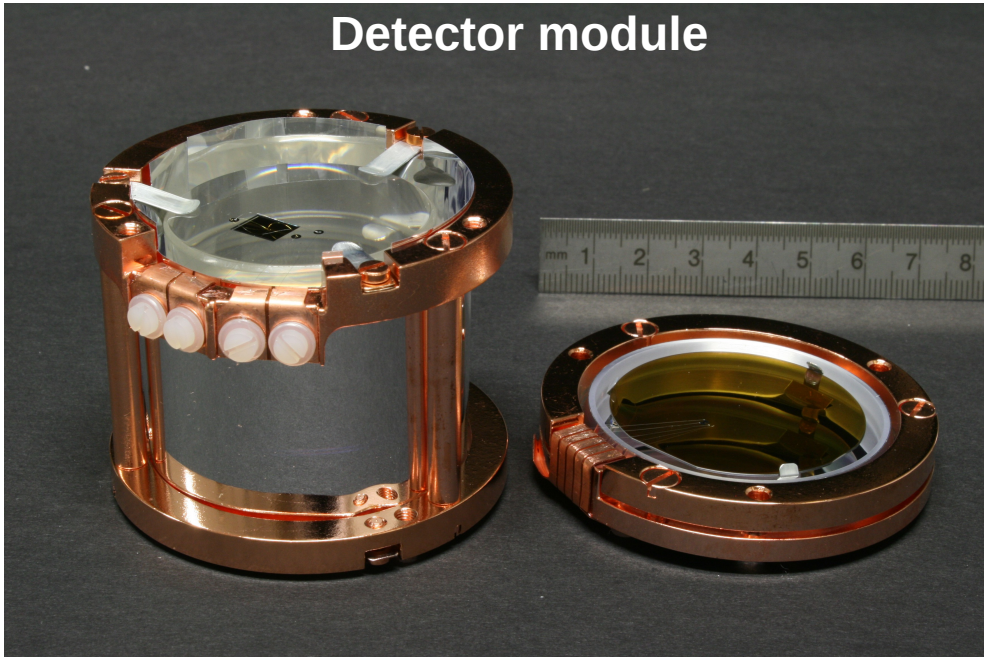
Direct detection of dark matter particles via their scattering off target nuclei

**Scintillating $CaWO_4$** crystals as target




Target crystals operated as **cryogenic calorimeters** (~15mK)

Separate **cryogenic light detector** to detect the scintillation light signal



# Detector module

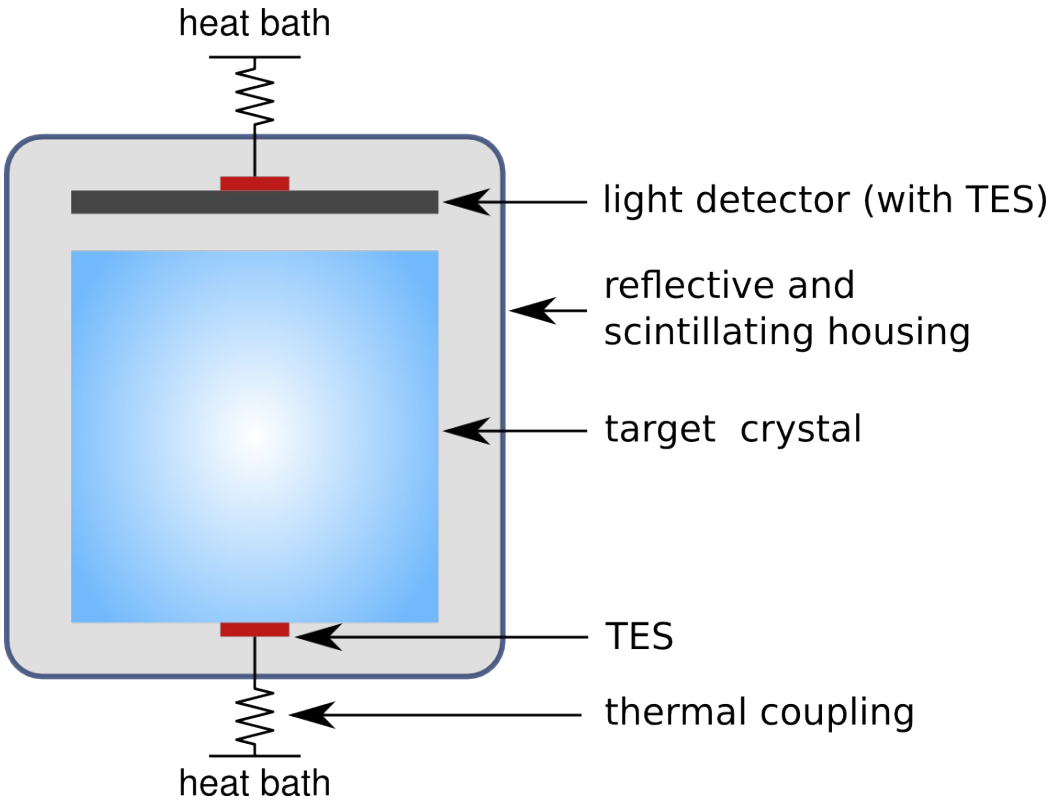
Energy deposition in the crystal:

- mainly phonons

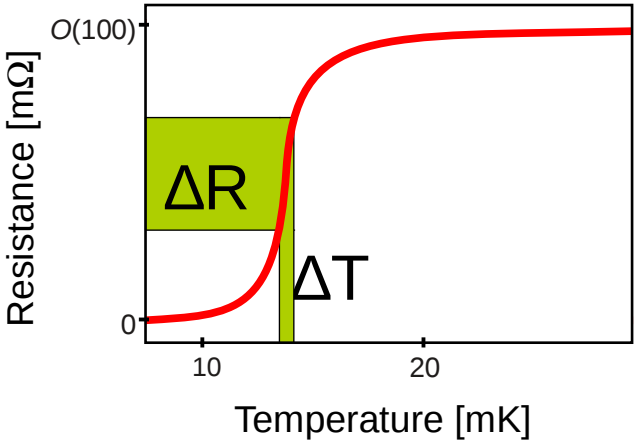
(independent of the type of particle)
**Measurement of deposited energy**

- small fraction into scintillation light

(characteristic of the type of particle)
**Particle discrimination**



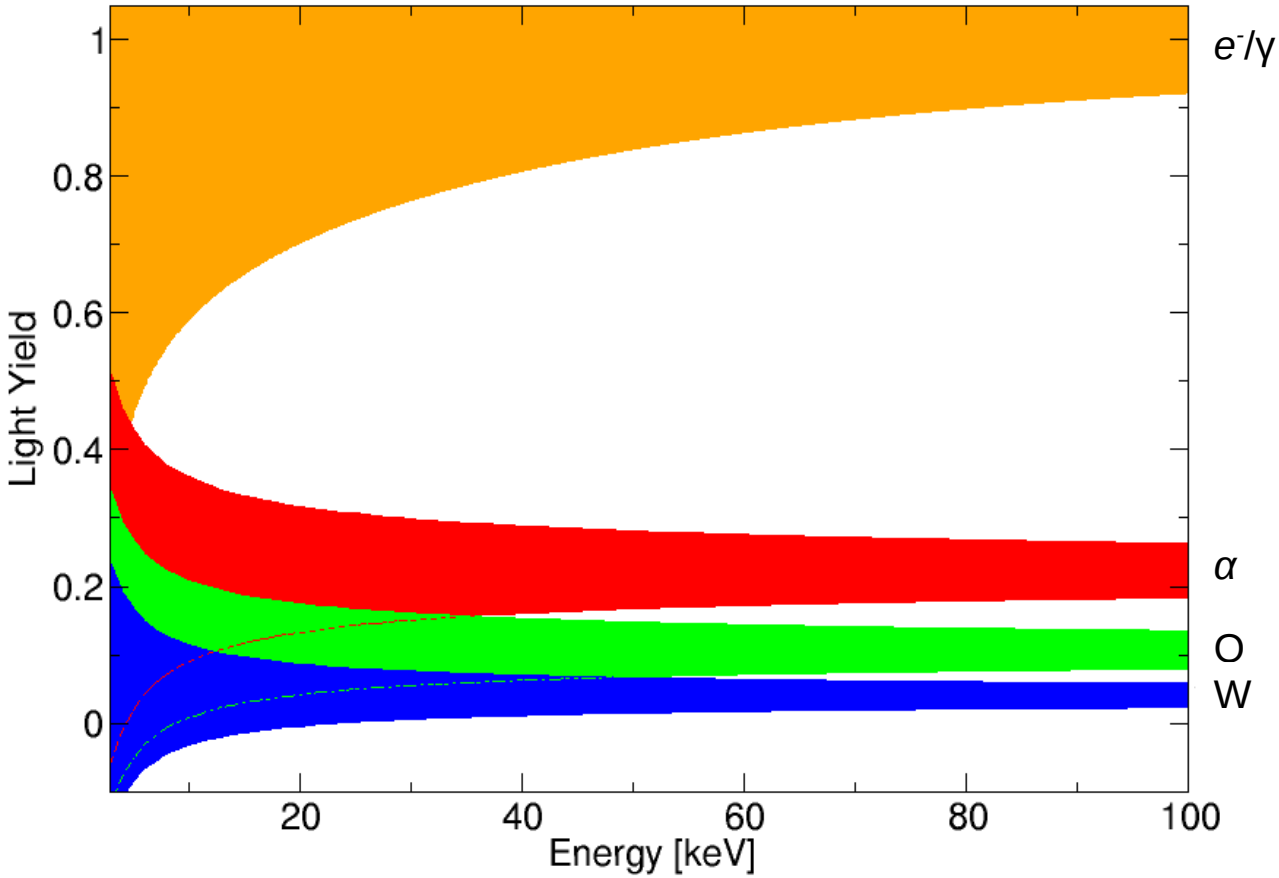

**Two simultaneous signals** from the two transition edge sensors (**TES**)



# Event discrimination

$$\text{Light Yield} = \frac{\text{Light signal}}{\text{Phonon signal}}$$

Characteristic of the event type




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