

# Exploring low mass WIMPs with CRESST

Paolo Gorla

for the CRESST collaboration

Laboratori Nazionali del Gran Sasso - INFN

# The CRESST Collaboration



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



Laboratori Nazionali del Gran Sasso



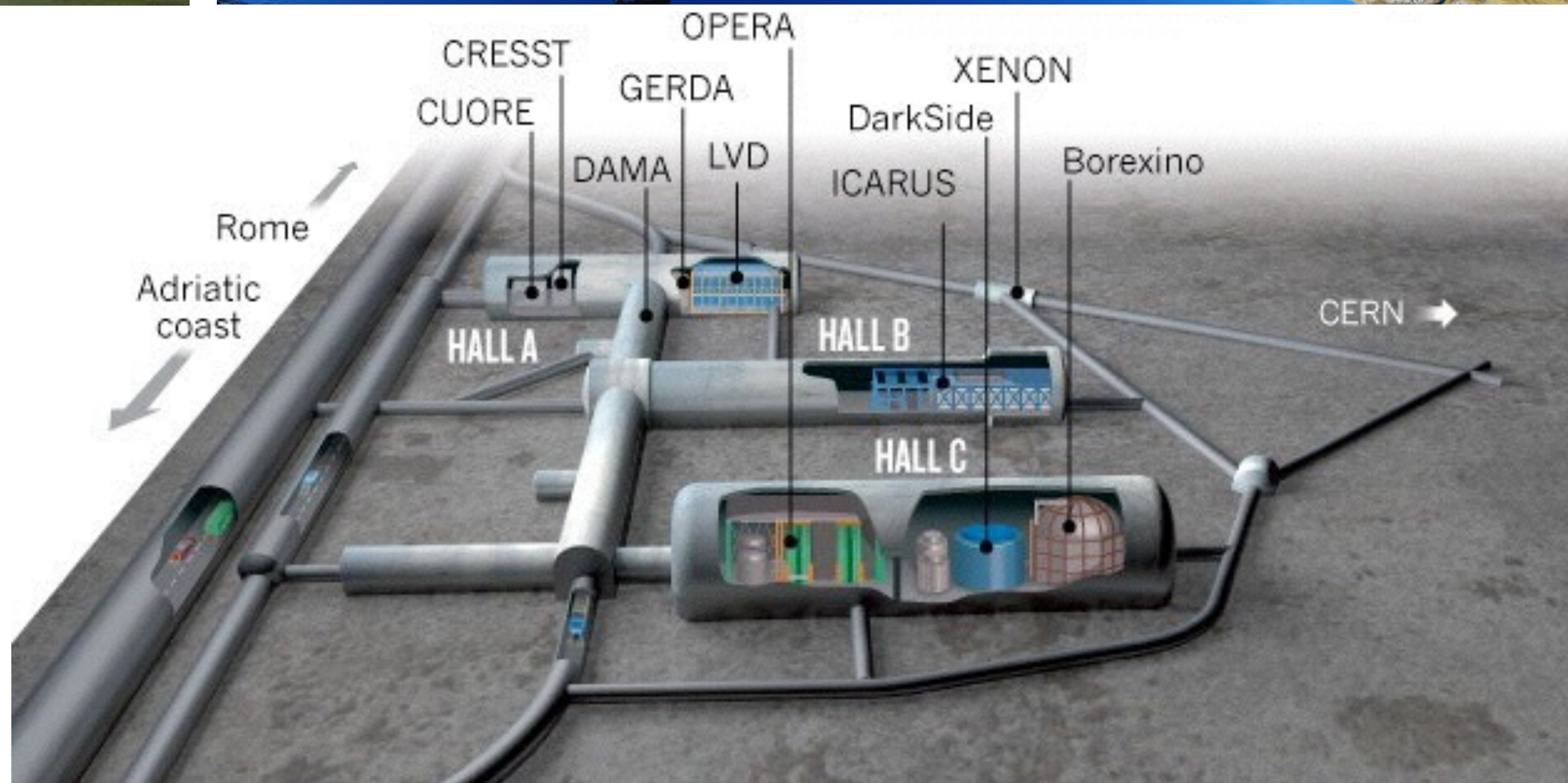
EBERHARD KARLS  
UNIVERSITÄT  
TÜBINGEN



# CRESST @ Gran Sasso

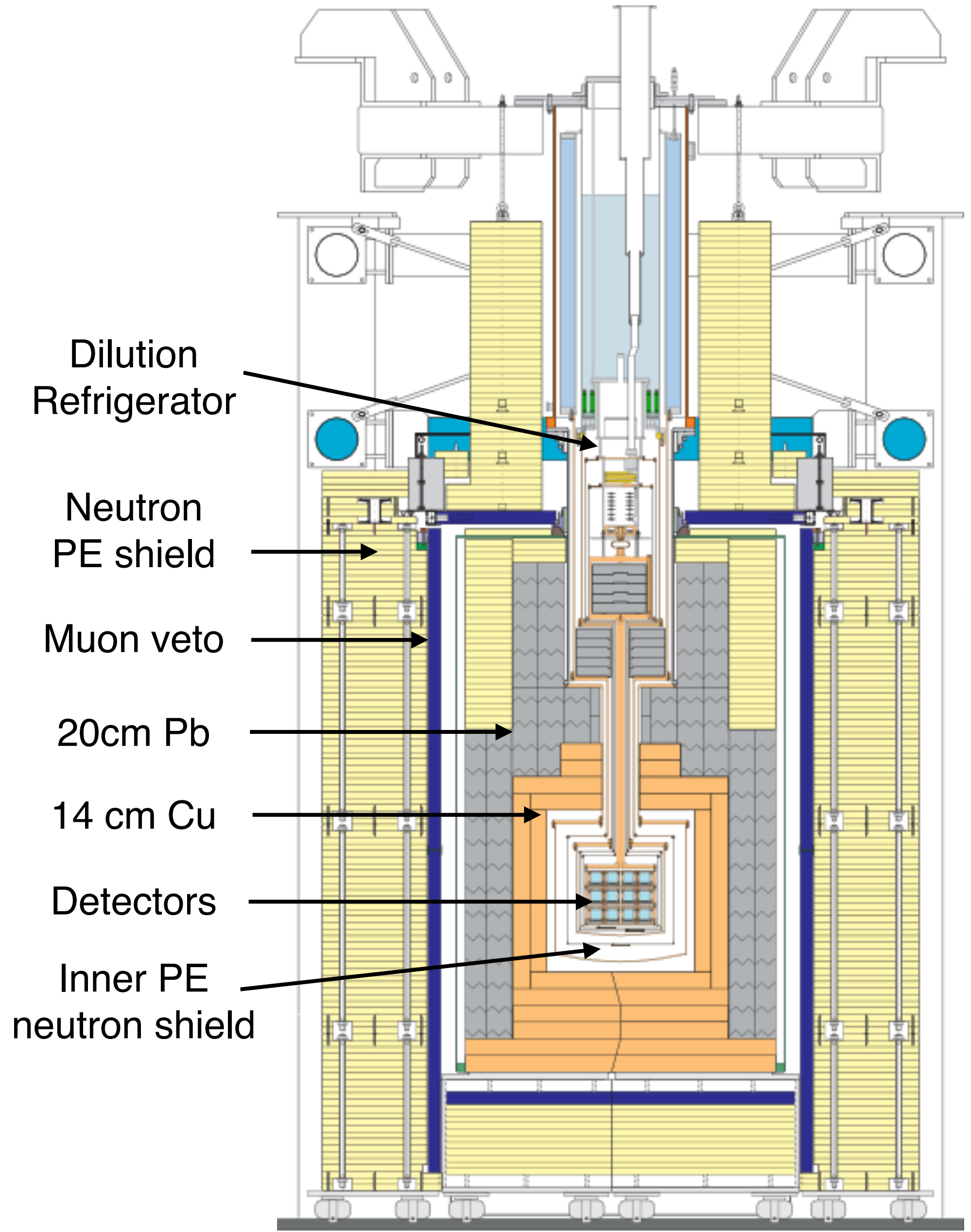


- $\sim 3800$  m.w.e. deep
- $\mu$ s:  $\sim 3 \times 10^{-8}/(\text{s cm}^2)$
- $\gamma$ s:  $\sim 0.73/(\text{s cm}^2)$
- neutrons:  $4 \times 10^{-6} \text{ n}/(\text{s cm}^2)$



# The CRESST Experiment

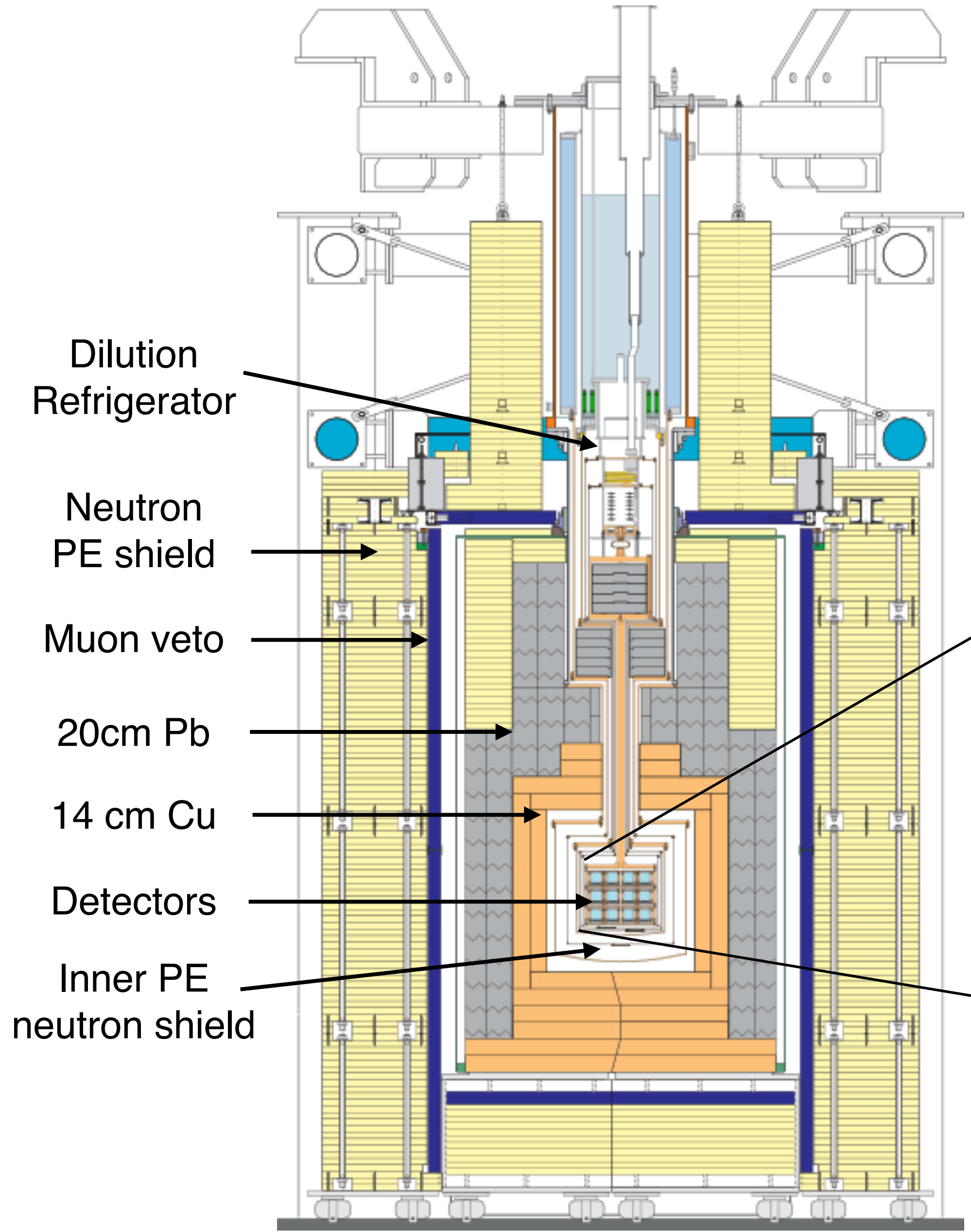
Cryogenic Rare Event Search with Superconducting Thermometers



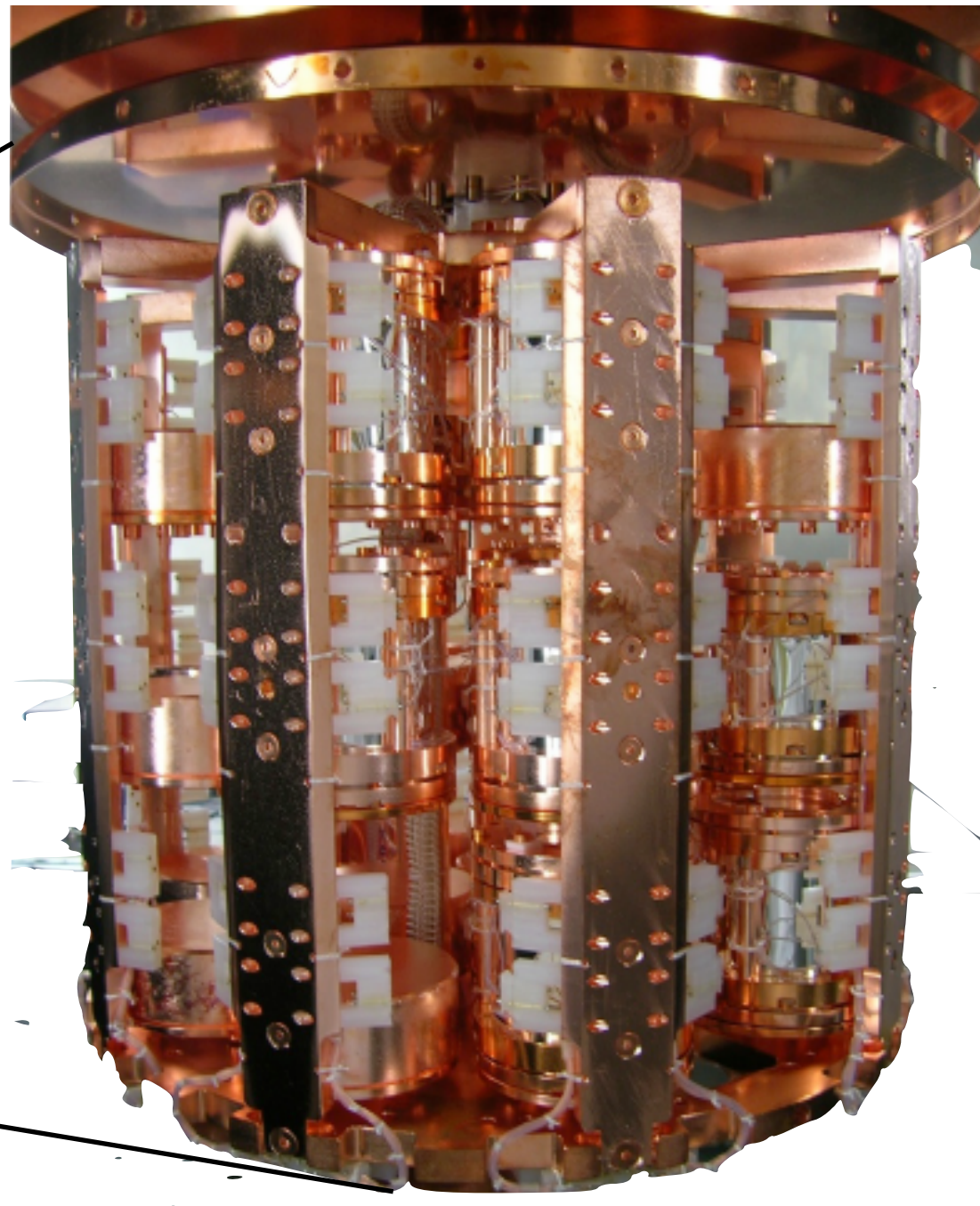
CRESST is designed to detect elastic WIMP-nucleus scattering using scintillating  $\text{CaWO}_4$  crystals as target

# The CRESST Experiment

Cryogenic Rare Event Search with Superconducting Thermometers



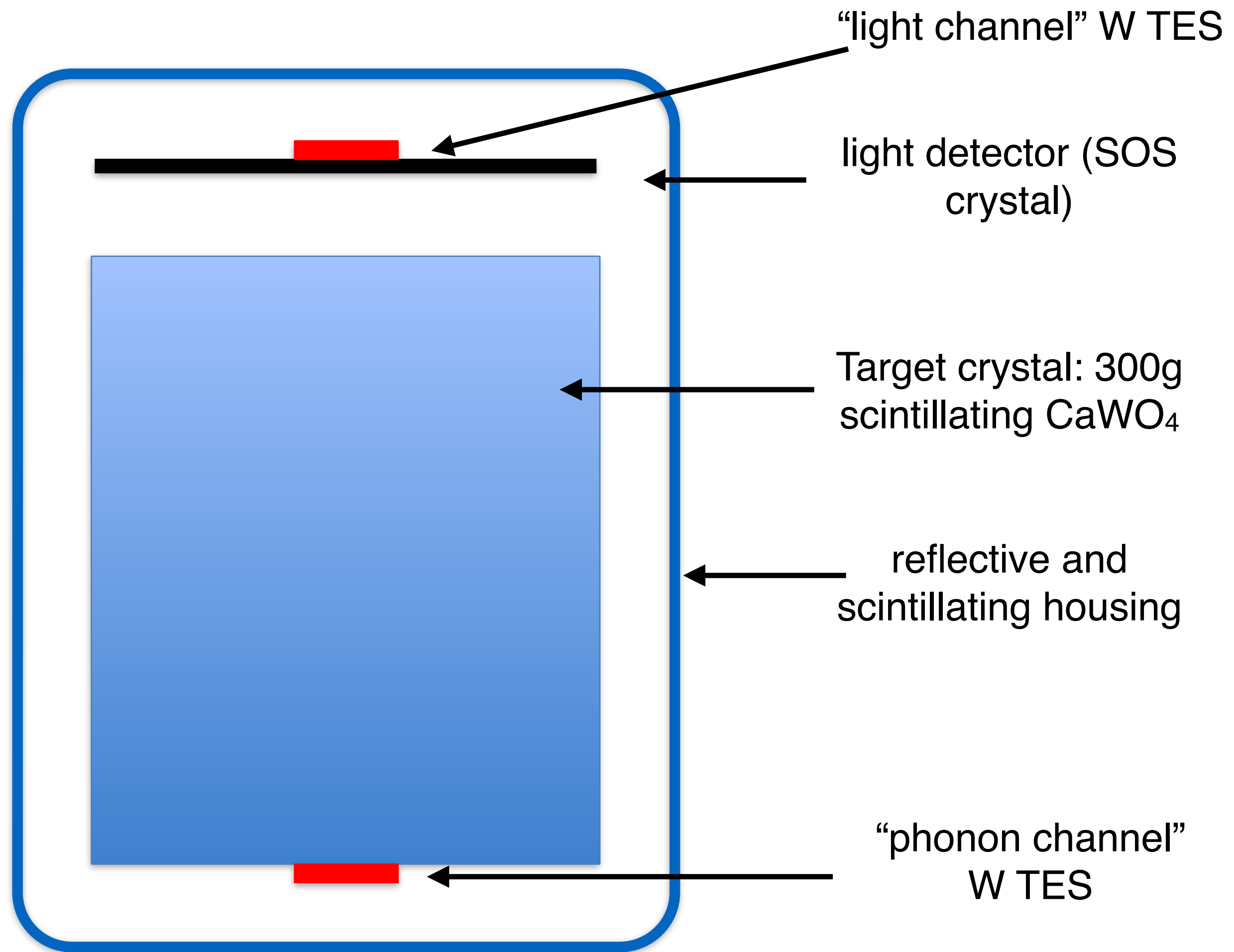
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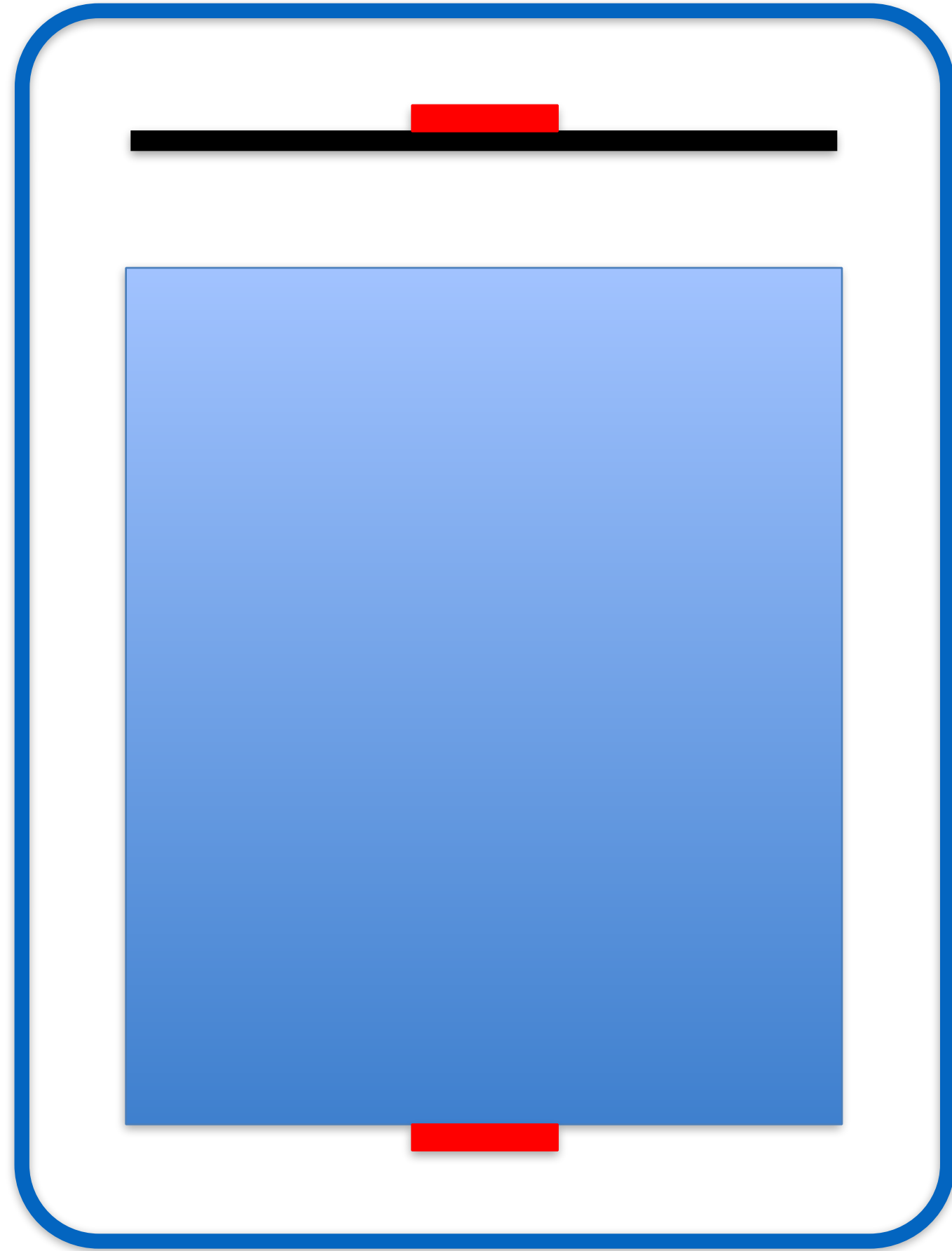
## Detector "Carousel"

- Tightly packed array of bolometric detectors (up to 33 CRESST modules, 10 kg of  $\text{CaWO}_4$ )
- Excellent energy resolution near threshold ( $<500$  eV) and threshold ( $<1$  keV)
- Suitable for a Phased research program
- Complex cryogenic set-up

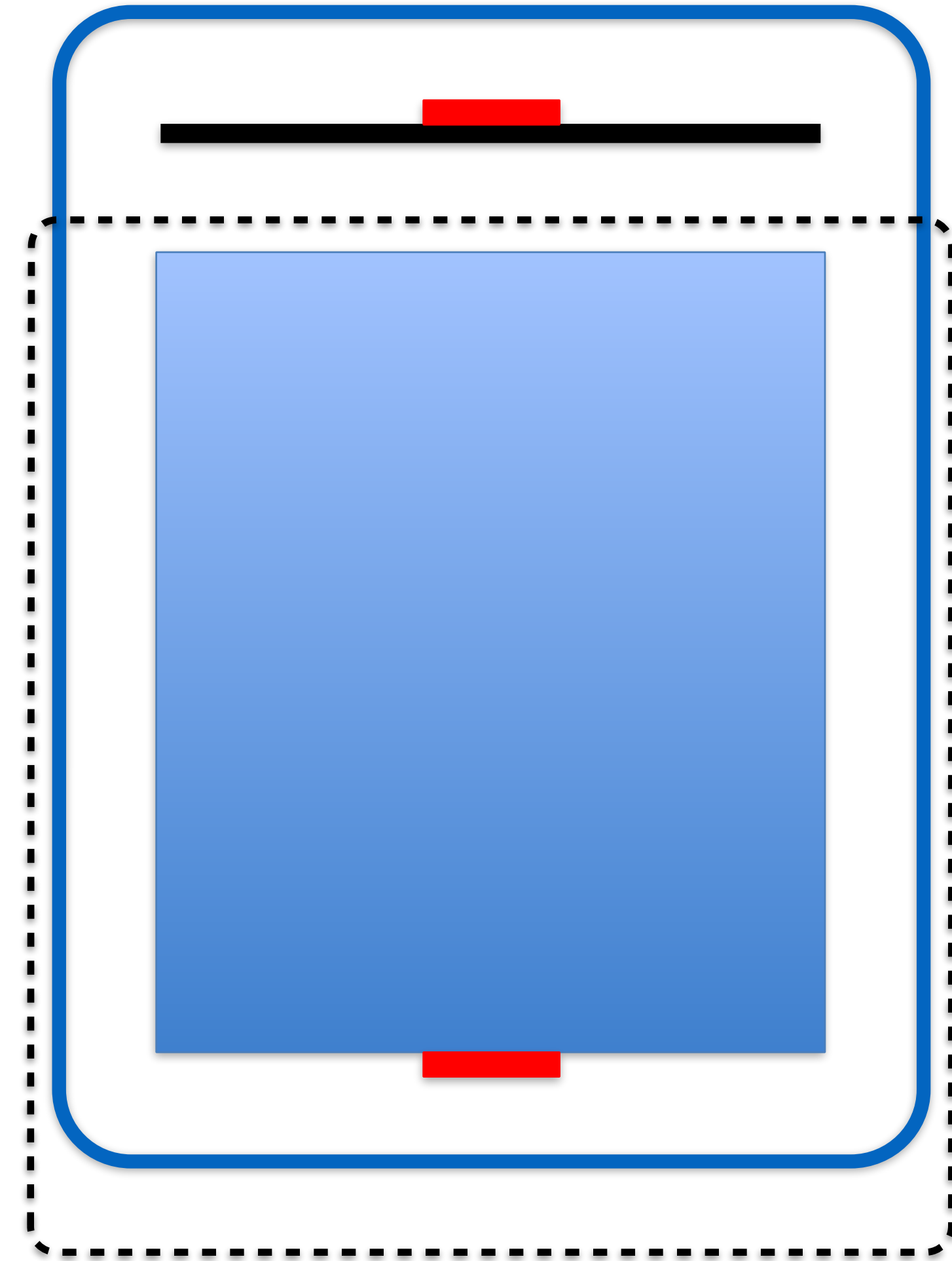
# CRESST Detectors



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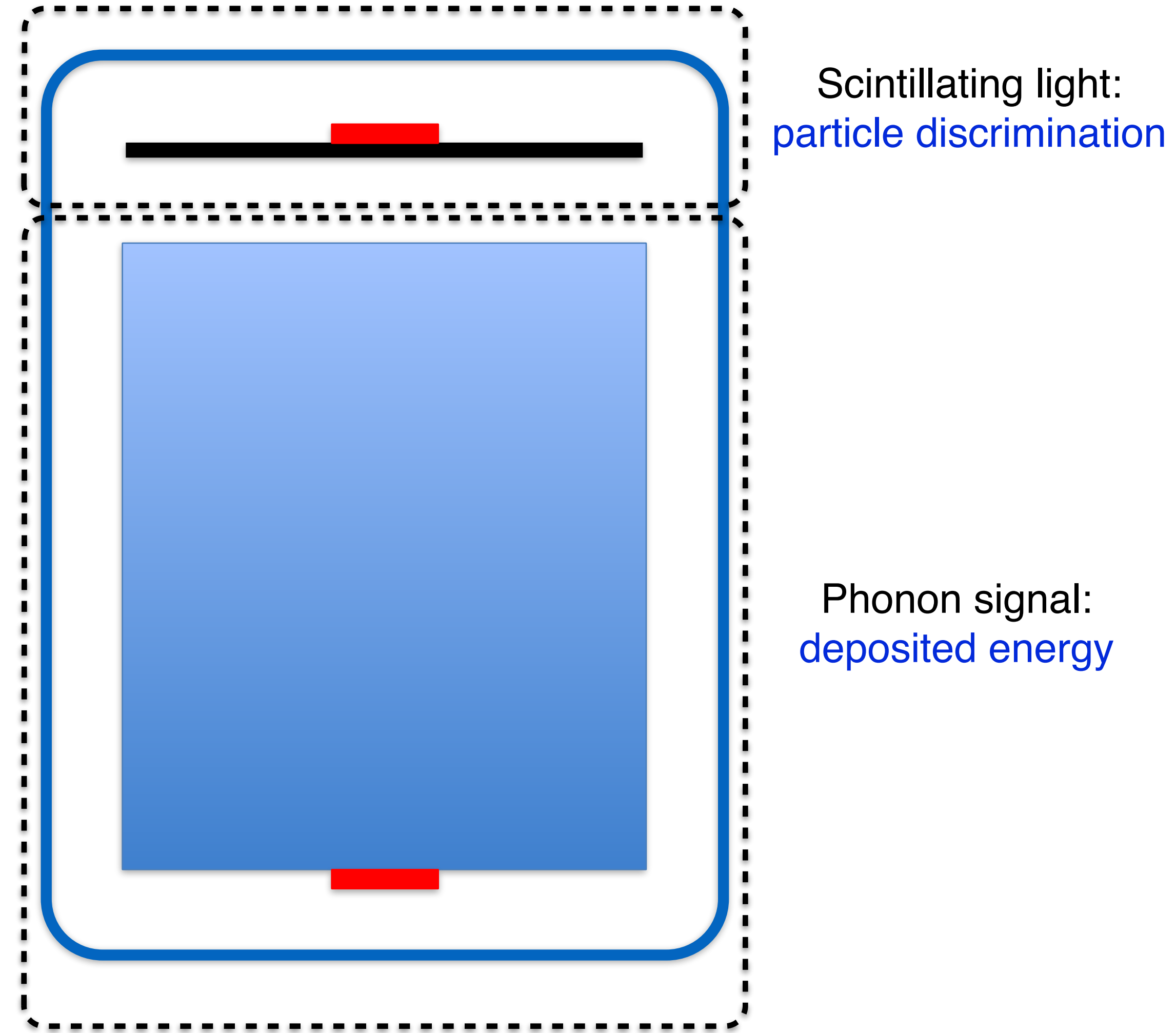
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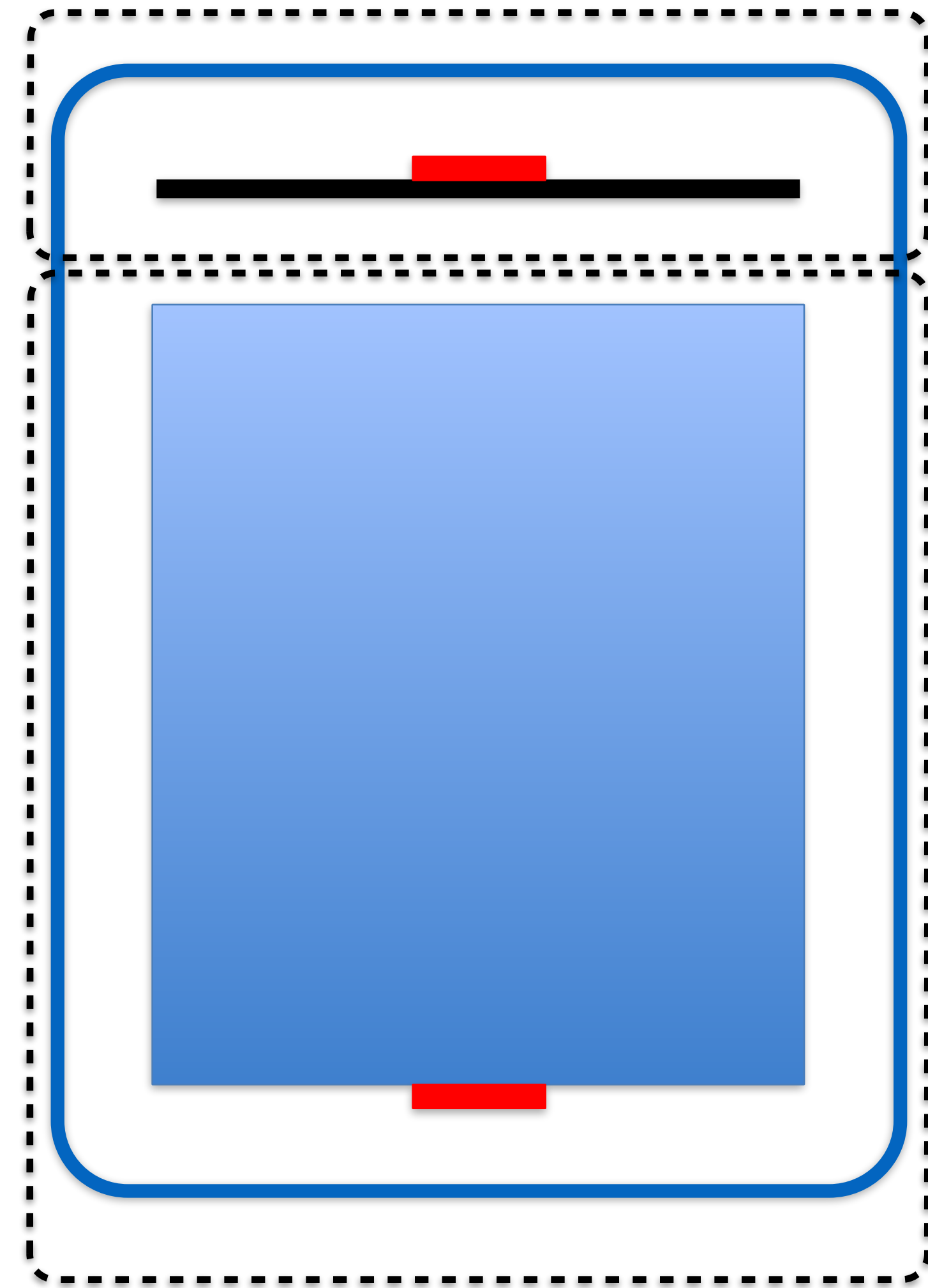
Phonon signal:  
deposited energy



# CRESST Detectors



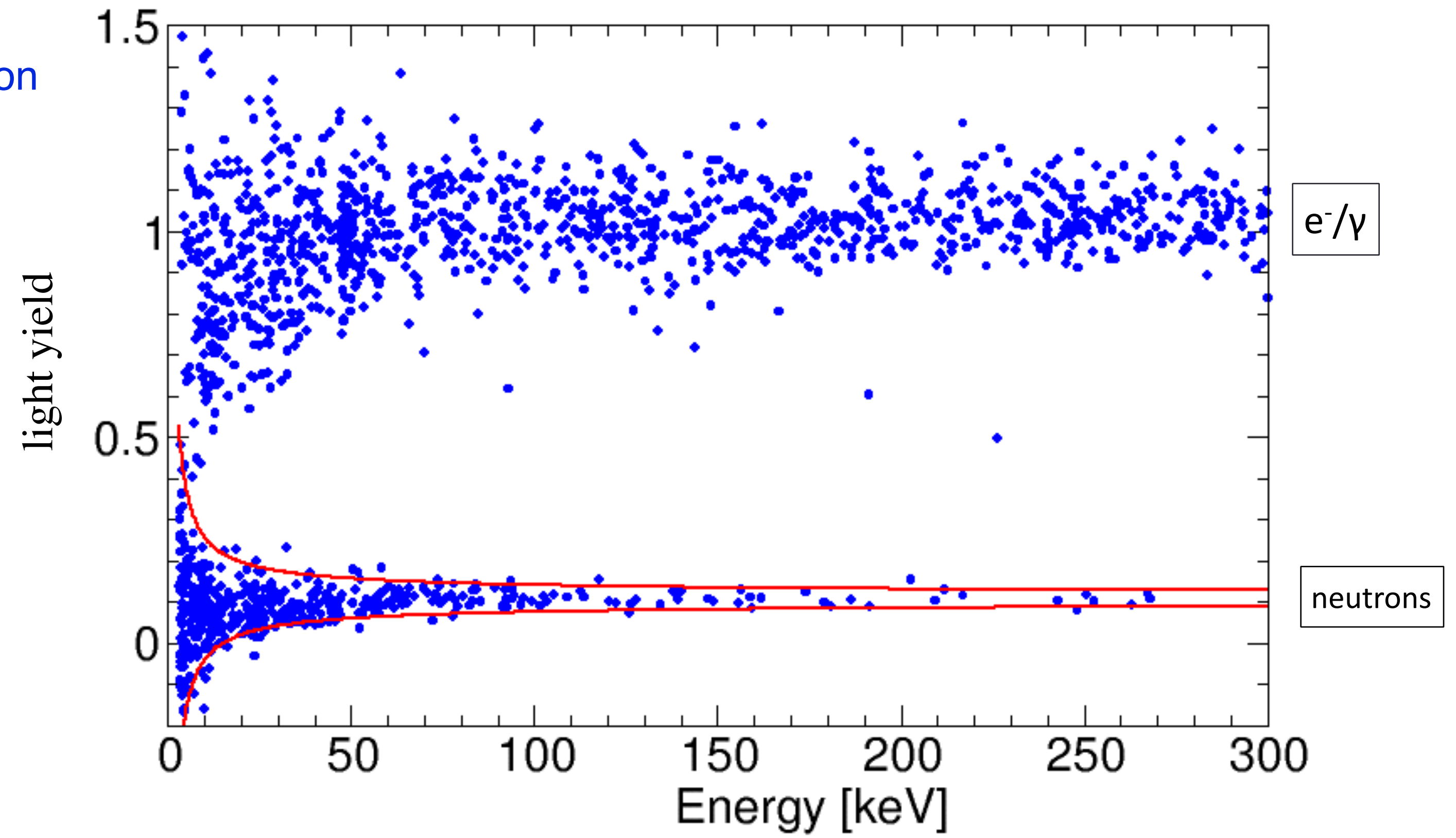
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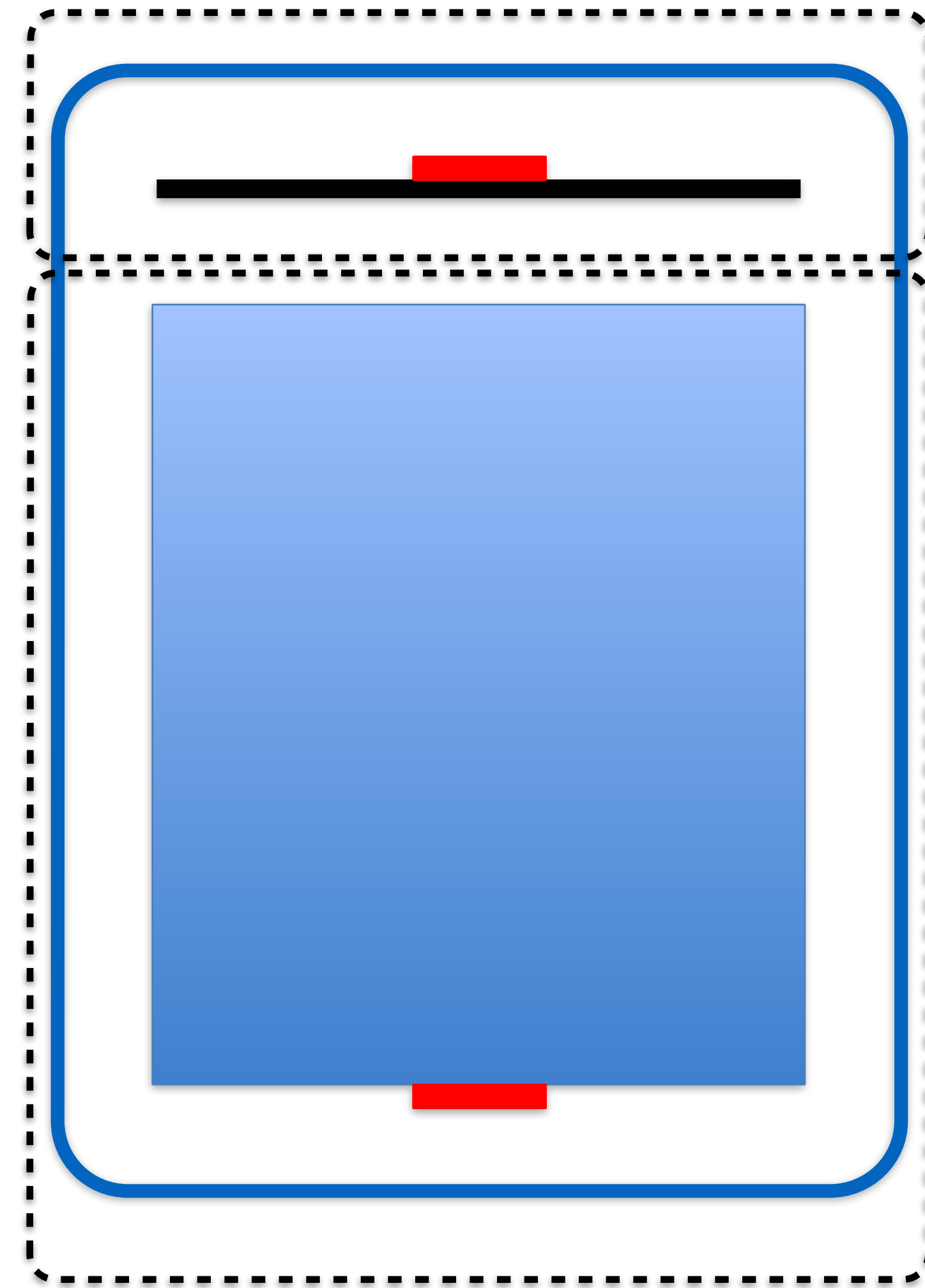
Scintillating light:  
particle discrimination

Phonon signal:  
deposited energy

## Neutron Calibration



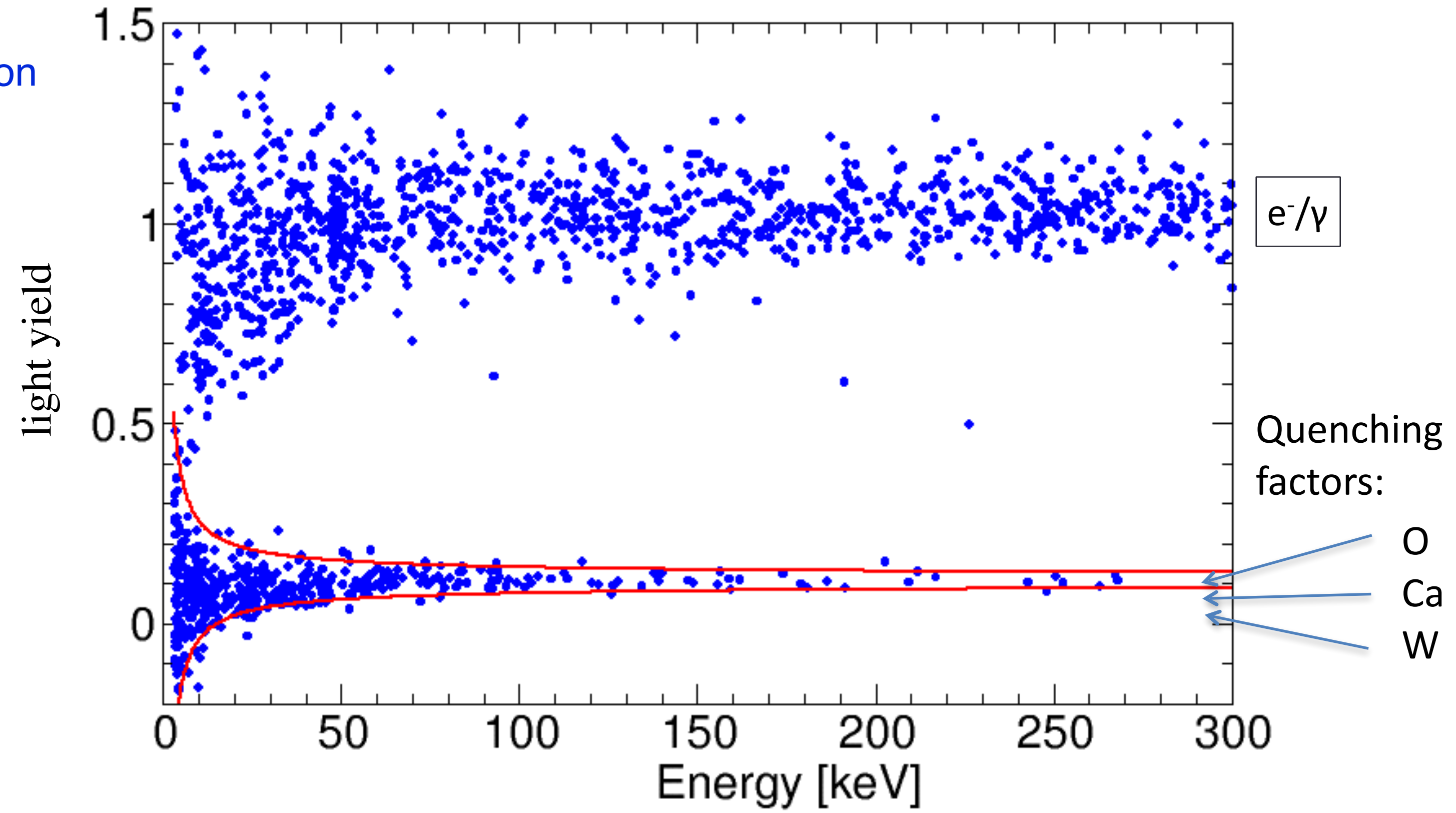
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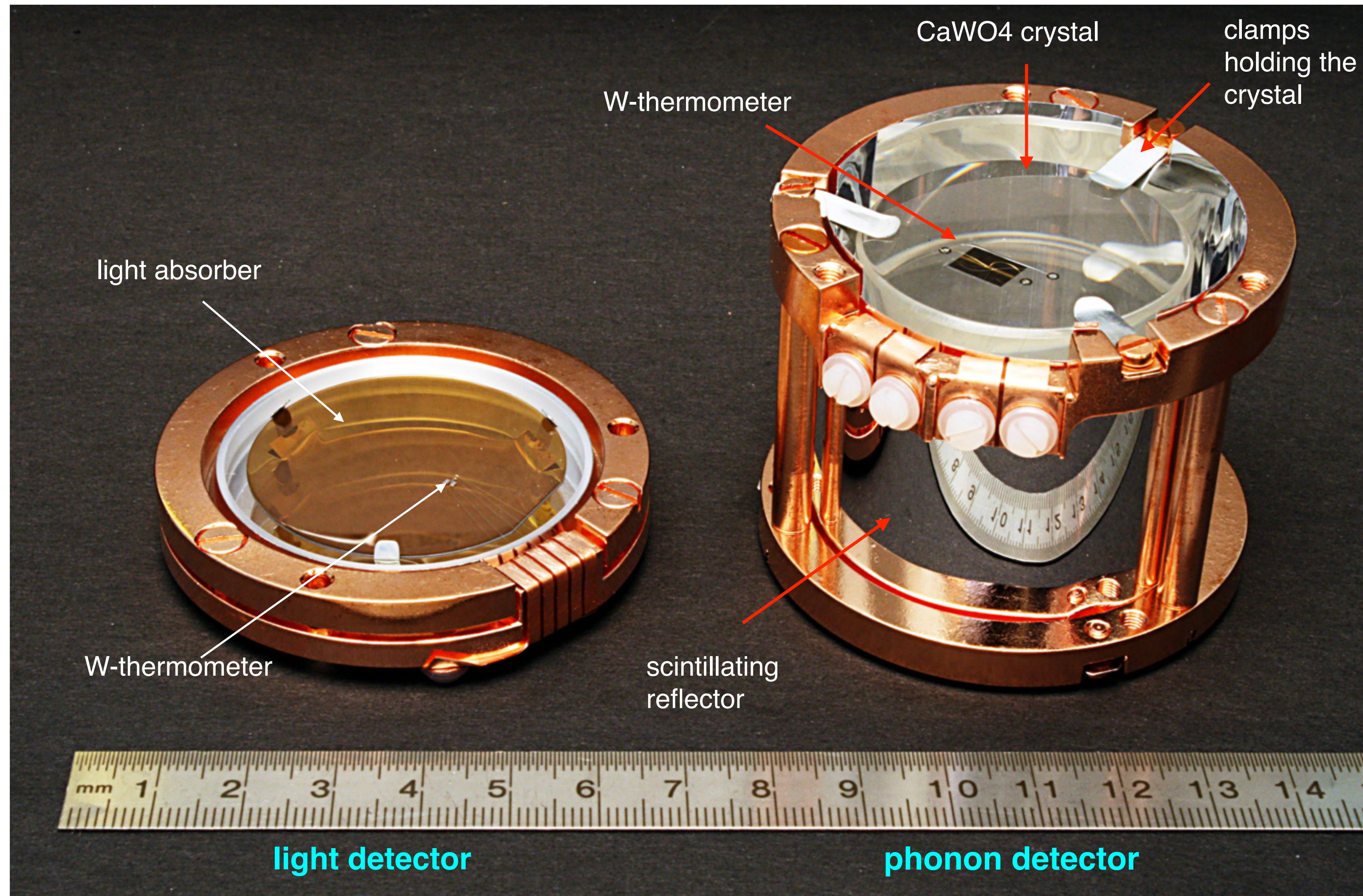
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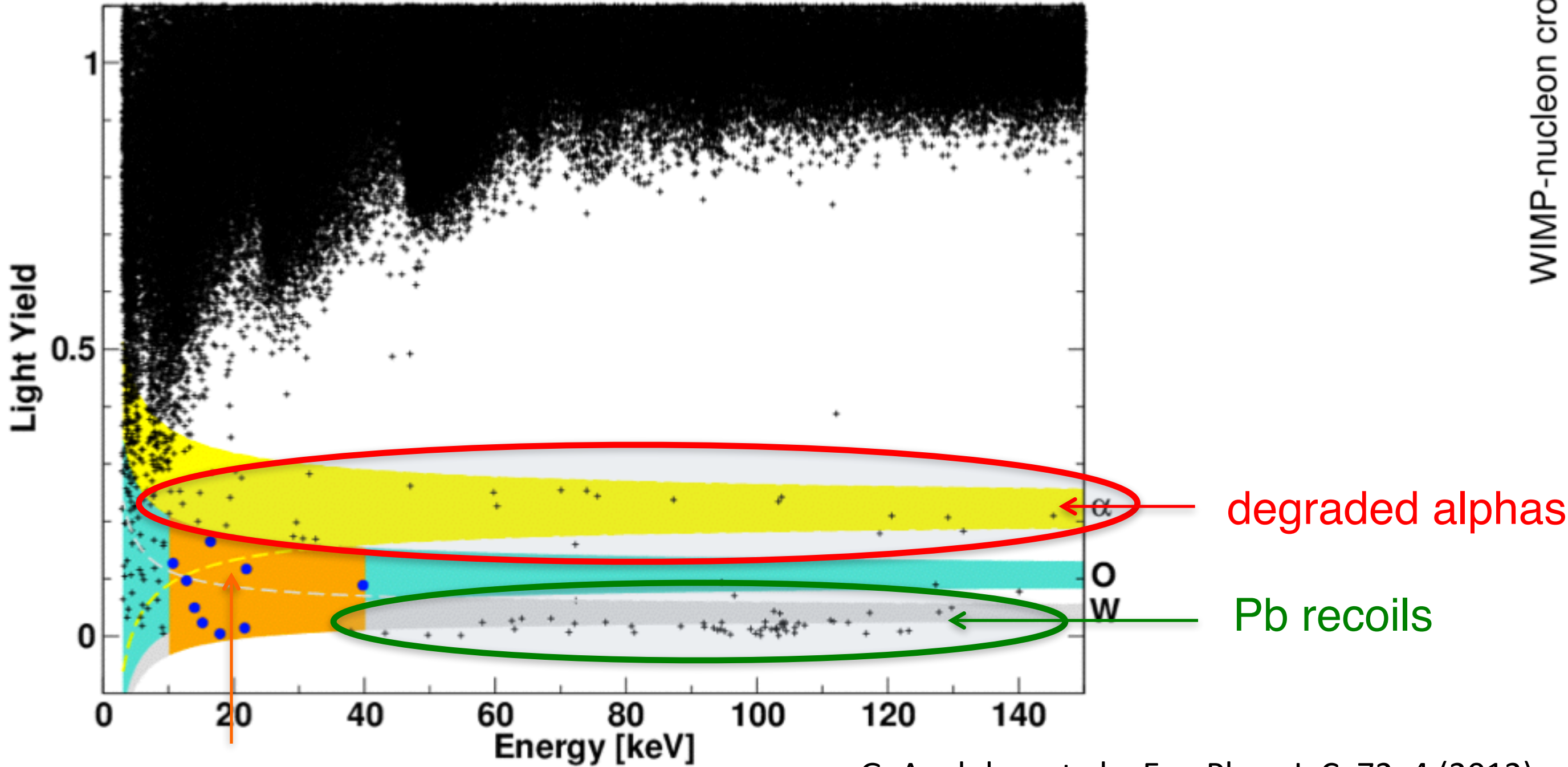
# 300 g Detector Module



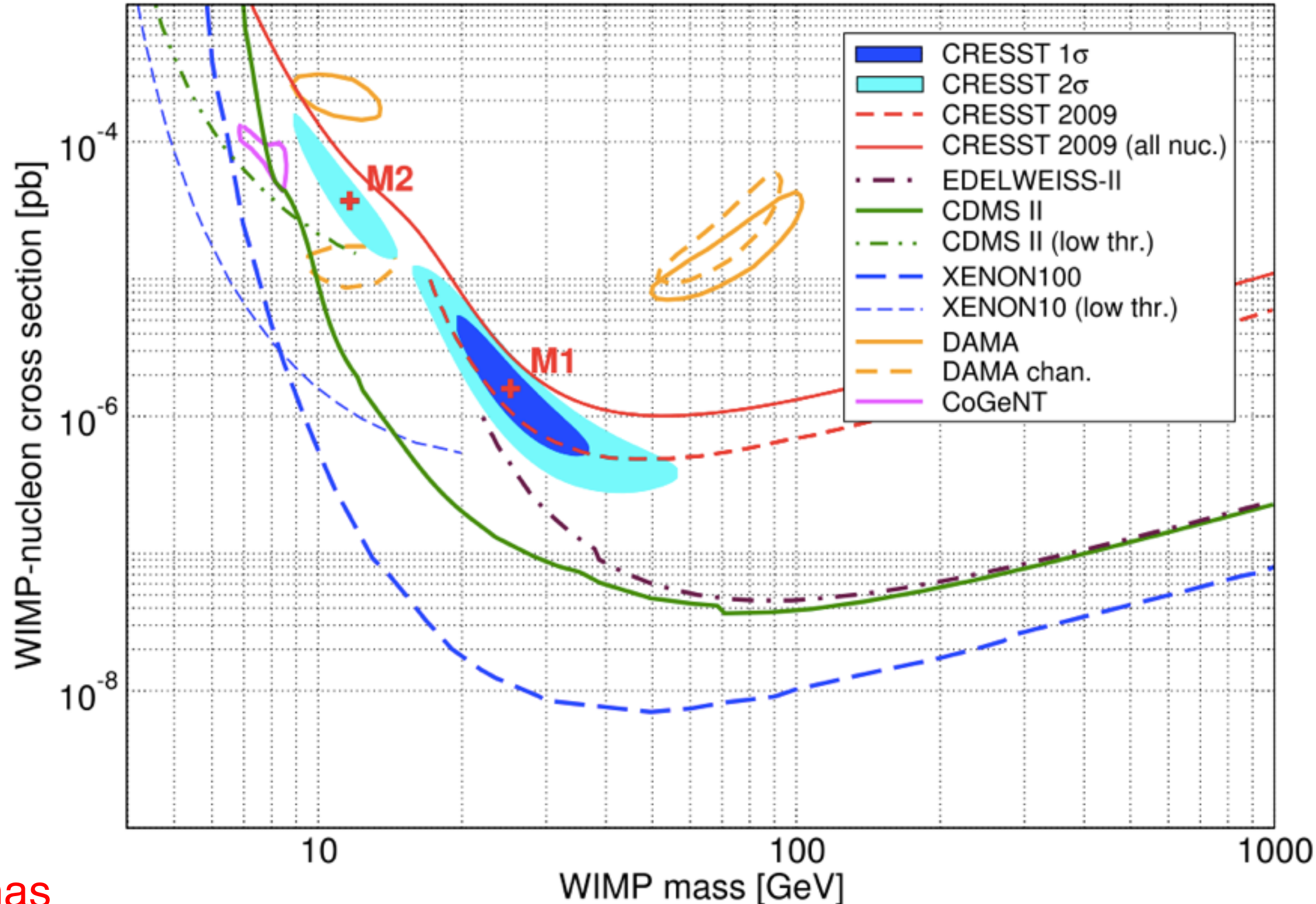
# CRESST-II Phase I (2009-2011)

Extended physics run from June 2009 to April 2011:

- 8 CaWO4 modules used for Dark Matter analysis: 730 kg days
- 67 events observed in WIMP search region
- If interpreted as bkg+WIMPs: likelihood with two maxima M1 & M2



G. Angloher et al., Eur. Phys. J. C, 72, 4 (2012)

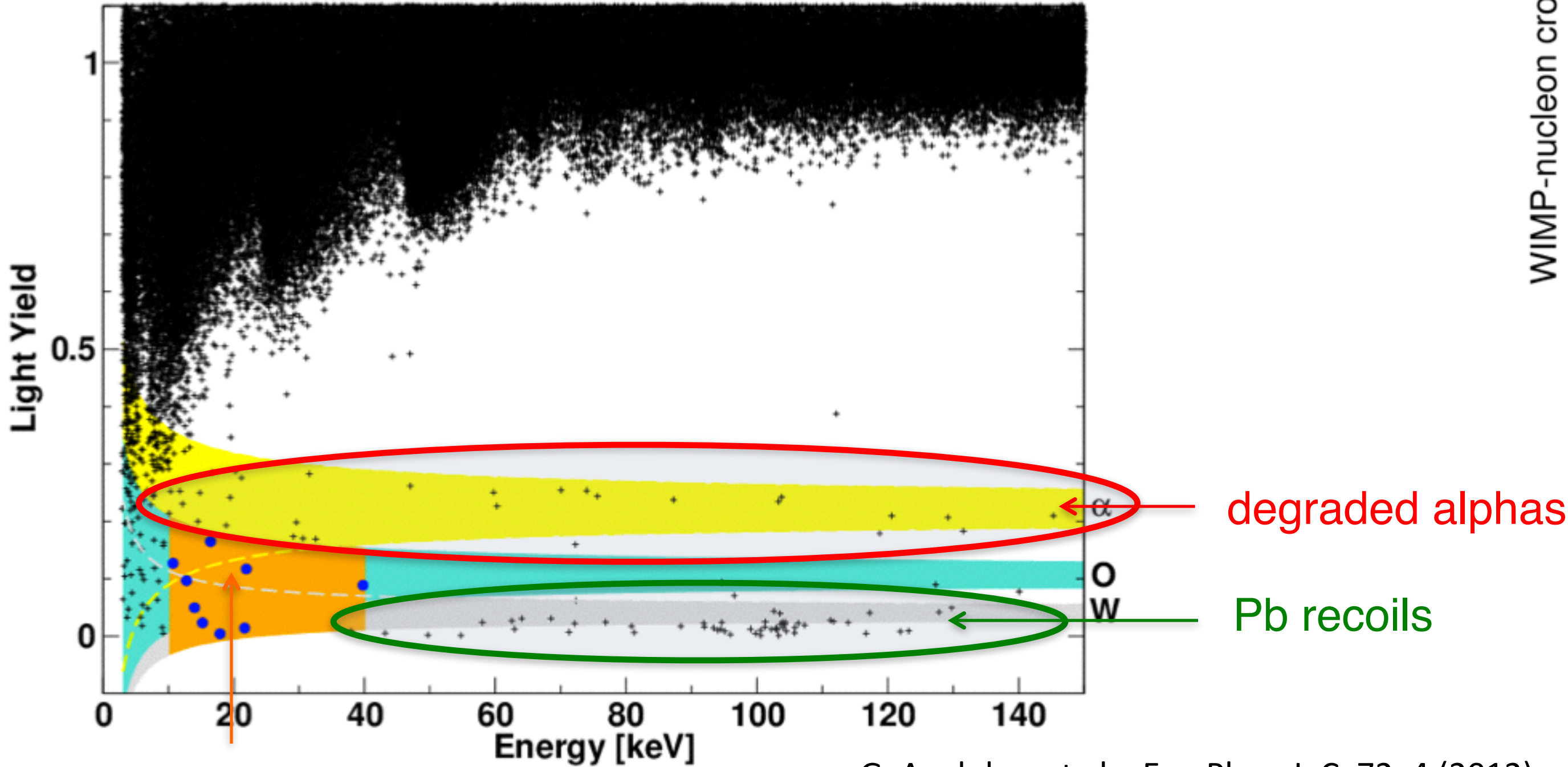


- Background only hypothesis rejected with rather high statistical significance ( $>4\sigma$ )
- Background contributions still relatively large

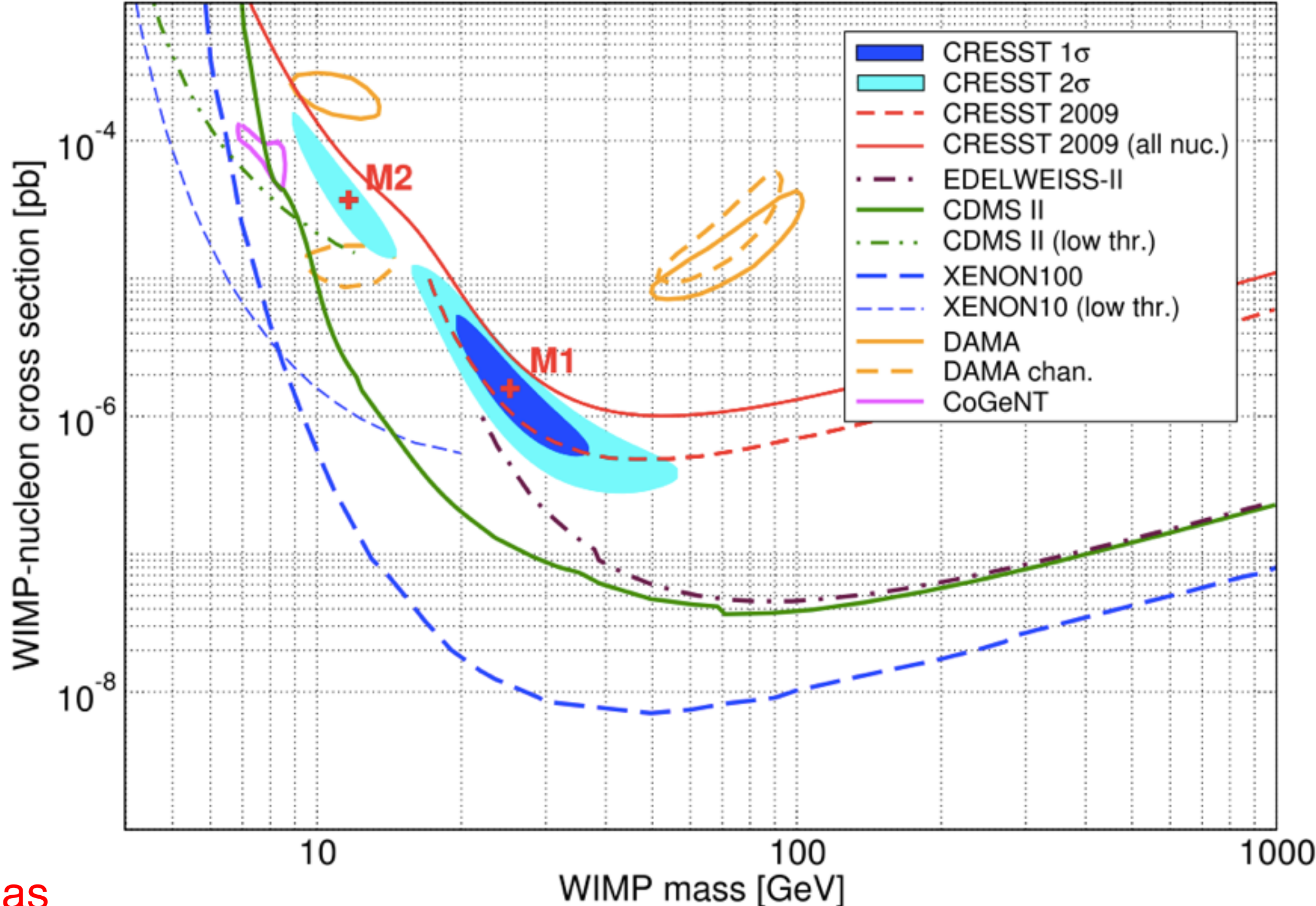
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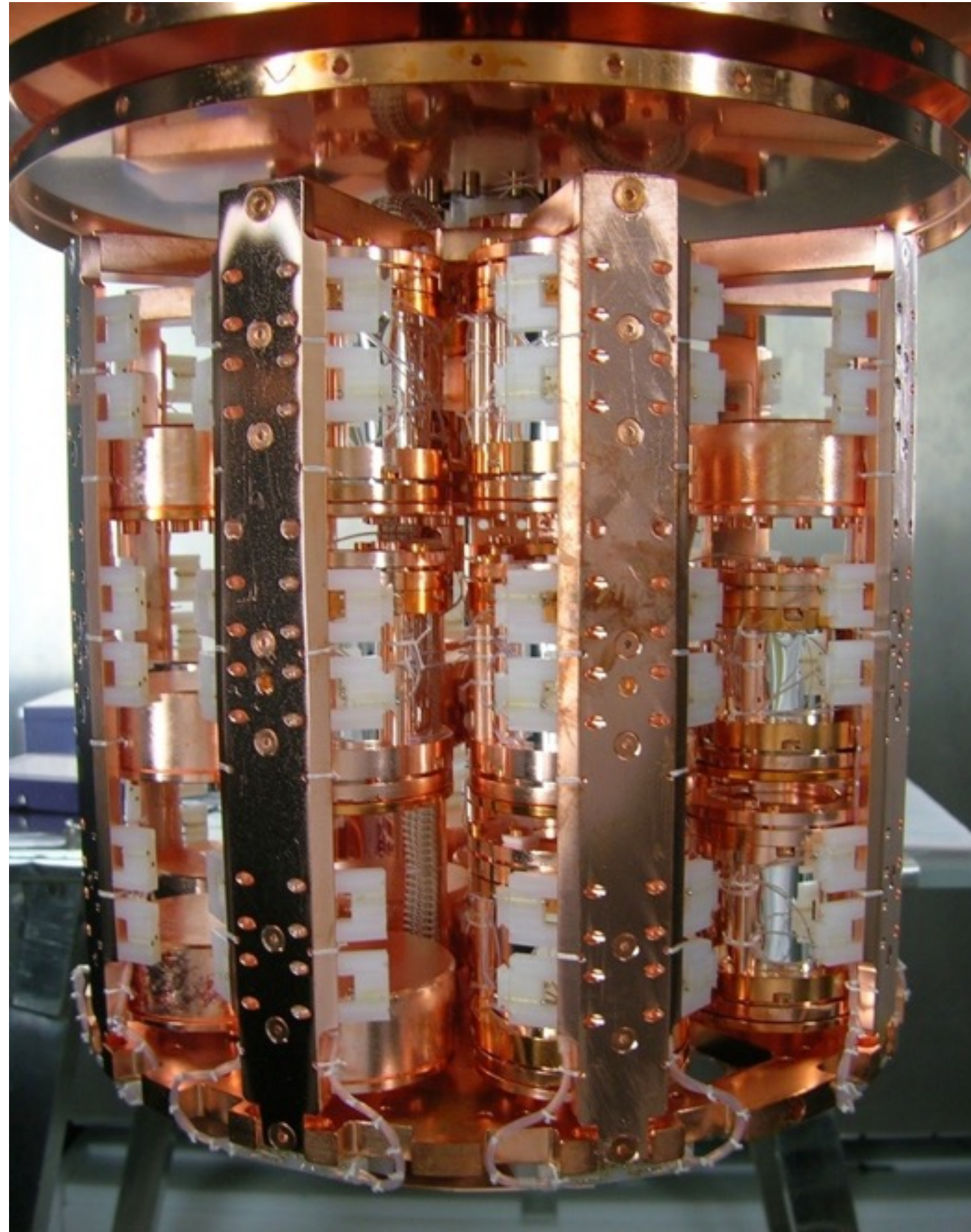


ROI 15-40keV

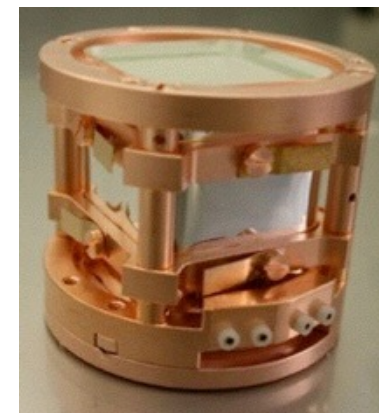
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→ BACKGROUND REDUCTION MANDATORY FOR CLARIFICATION

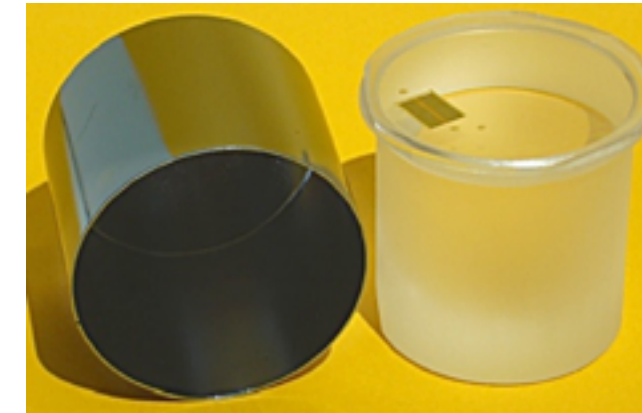
# CRESST-II Upgrade: Phase 2



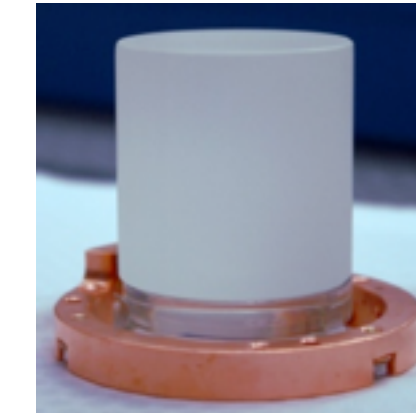
- Data-taking since July 2013
- 18 modules mounted (~ 5kg)  
→ 17 of 18 are fully operational
- ✓ 11 x conventional design (improved)
  - Use of radiopure clamps
  - Radon prevention
- ✓ 6 x fully-active new designs



CaWO<sub>4</sub> sticks

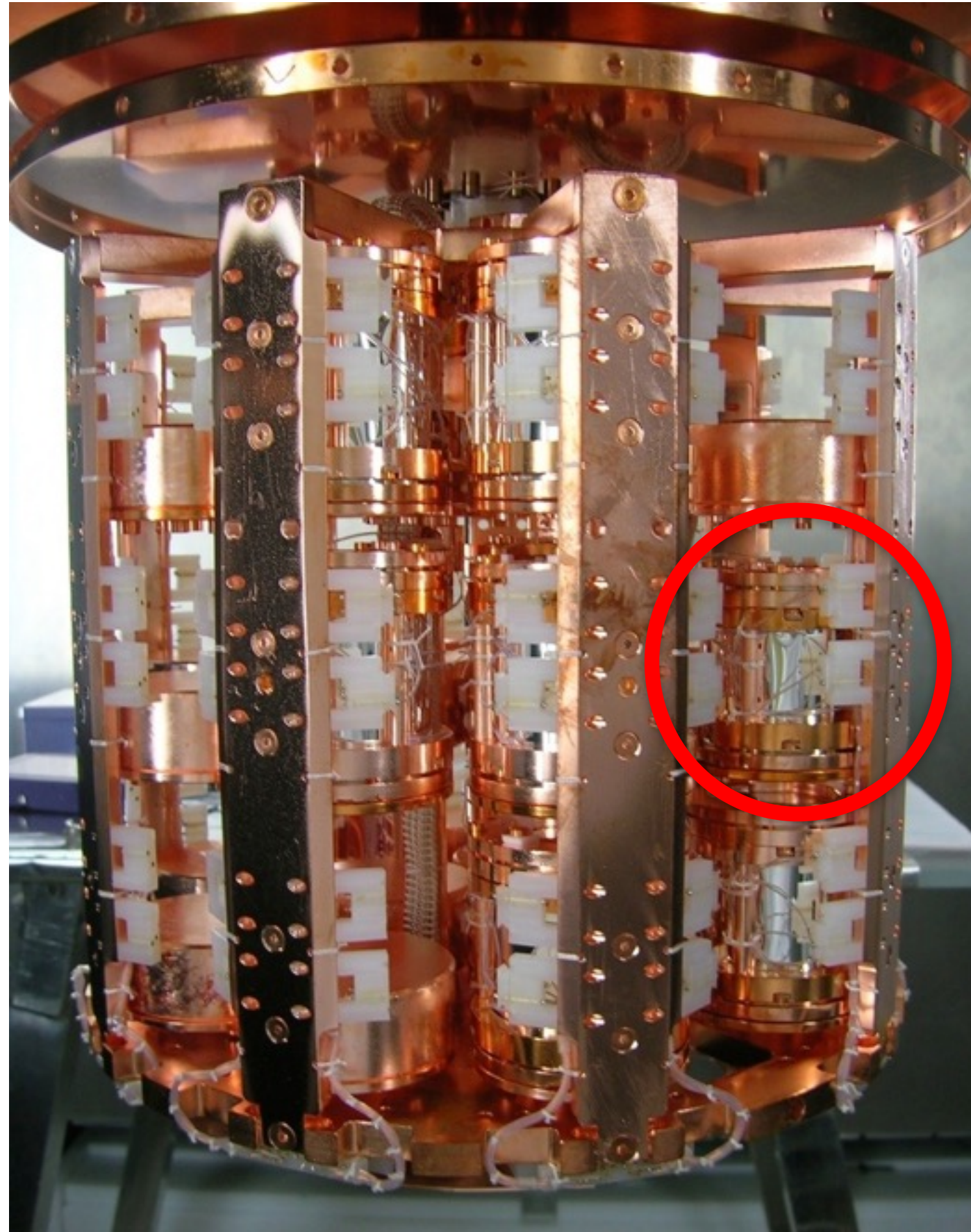


beaker

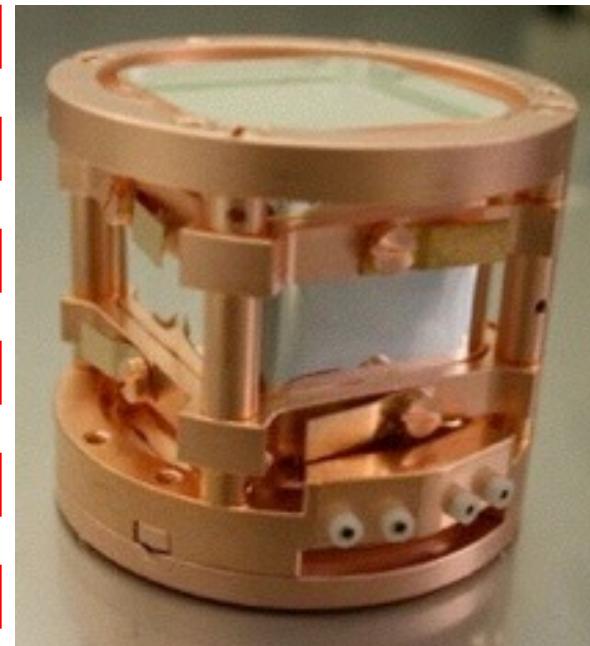


K-14

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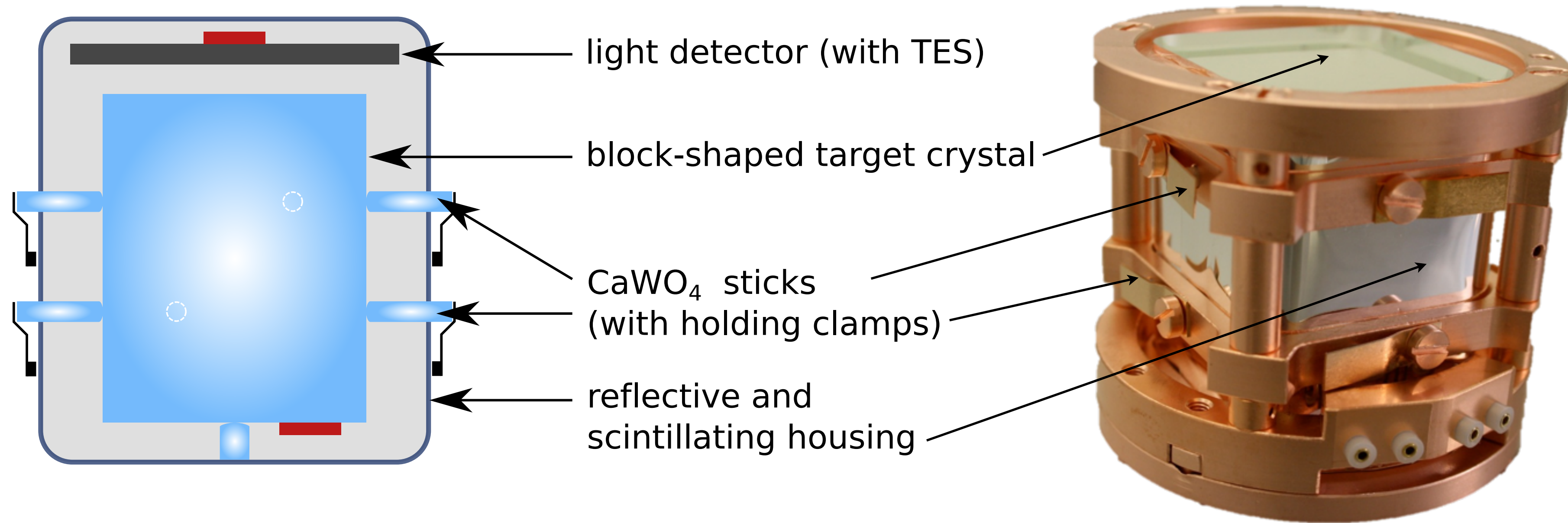
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these results:  
analysis of one  
detector module  
(TUM-40)  
mass: 250g  
exposure: 29 kg-days

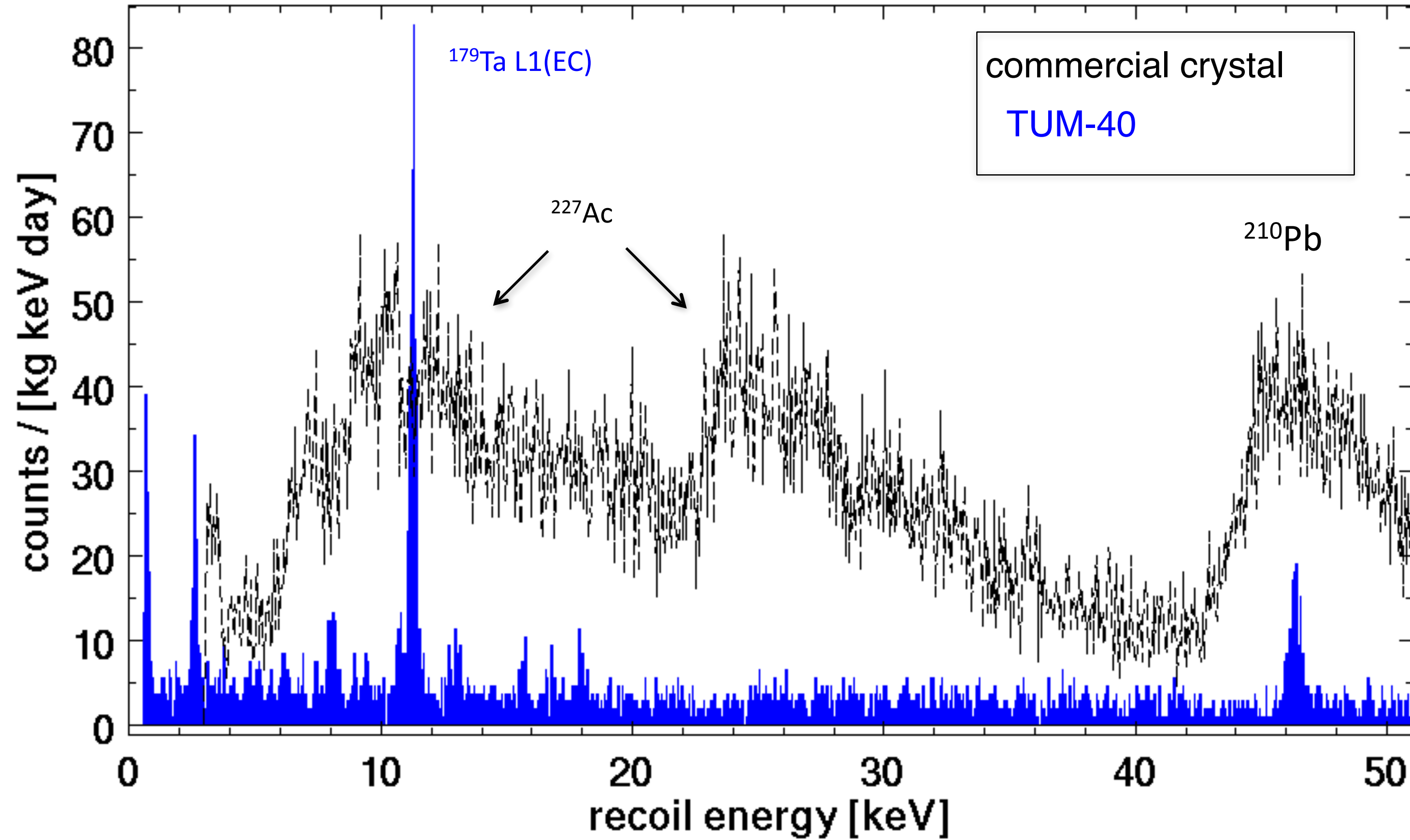


# Stick-Based Detector Holder



TUM 40

# TUM-40: Radiopurity & Performance



Average rate:

$\sim 3.5$  counts / [kg keV day]

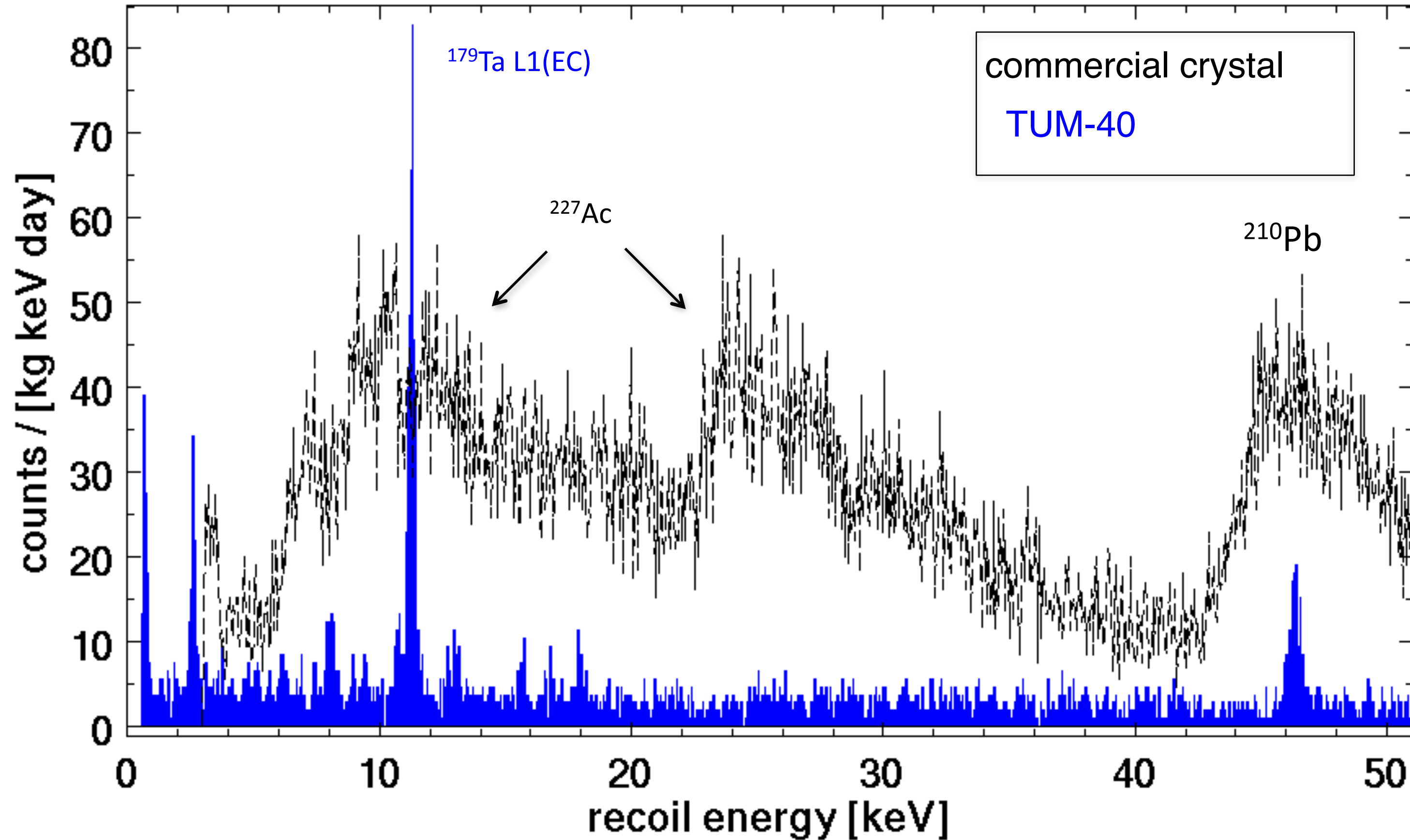
Gamma-lines from cosmogenic activation

Excellent resolution:  $\sigma \approx 100\text{eV}$

Low trigger threshold  $\approx 600\text{eV}$

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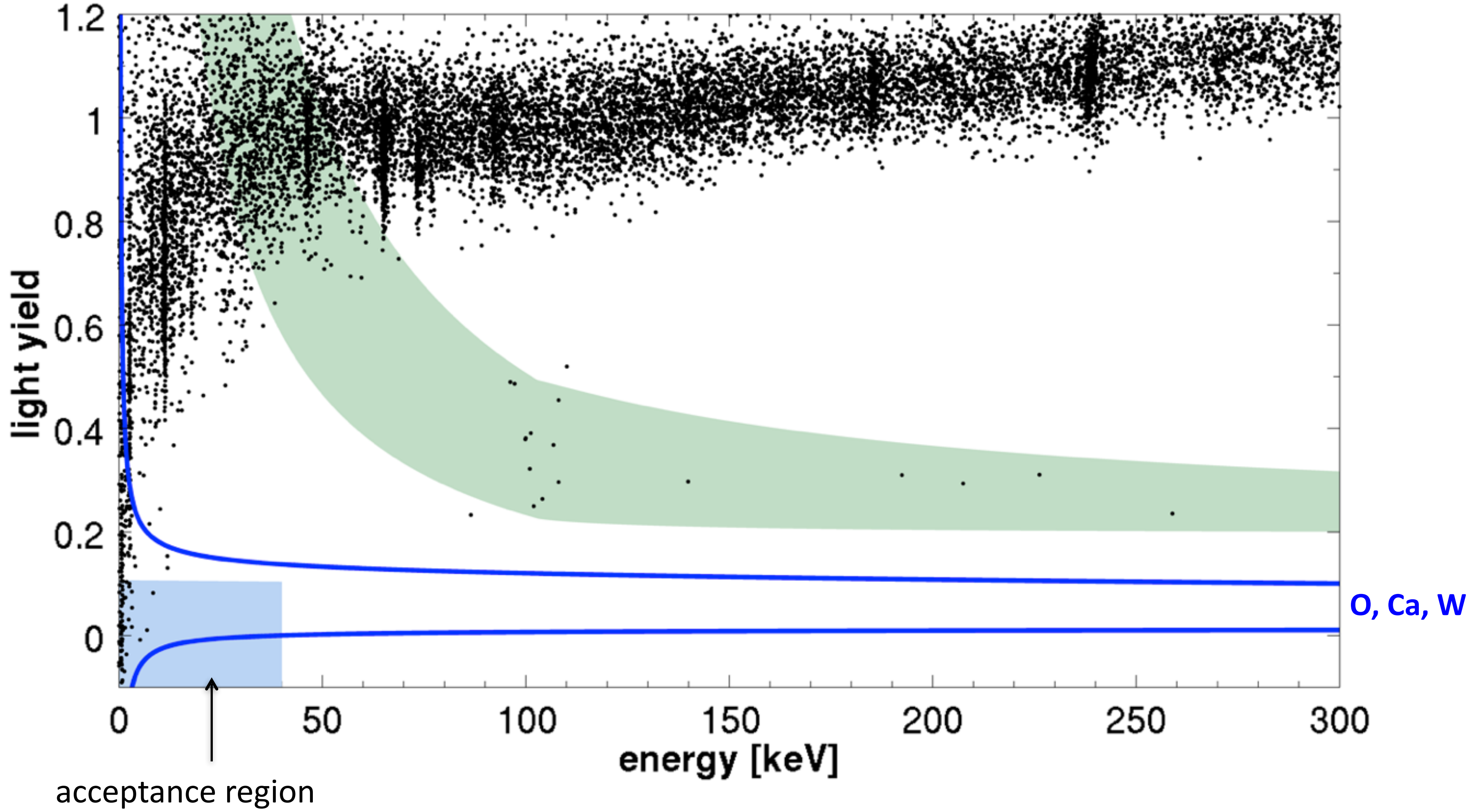
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→ Low-threshold Dark Matter analysis possible

→ Use non-blinded dataset of 29 kg\*days

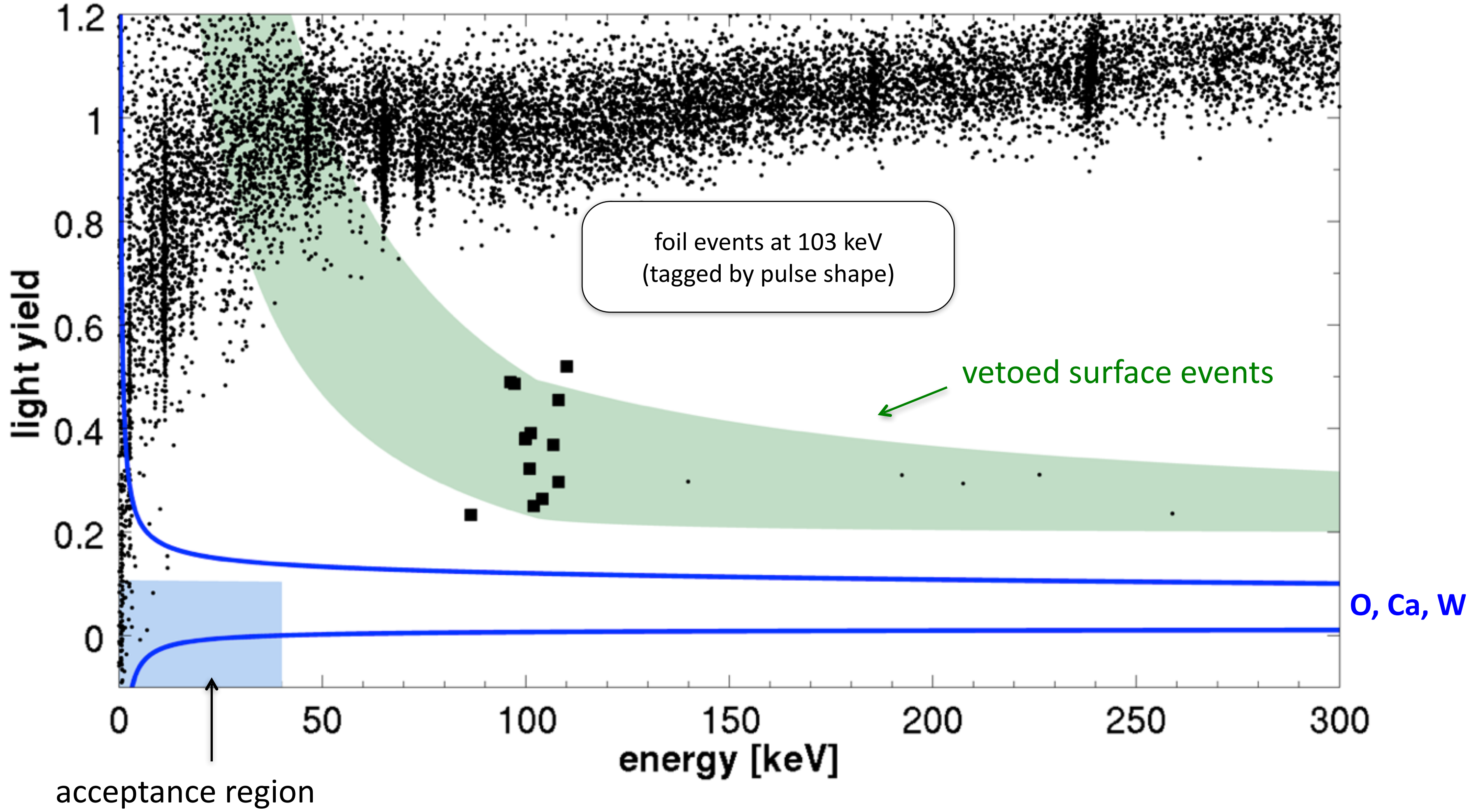
# TUM-40: Surface Backgrounds

exposure: 29 kg-days



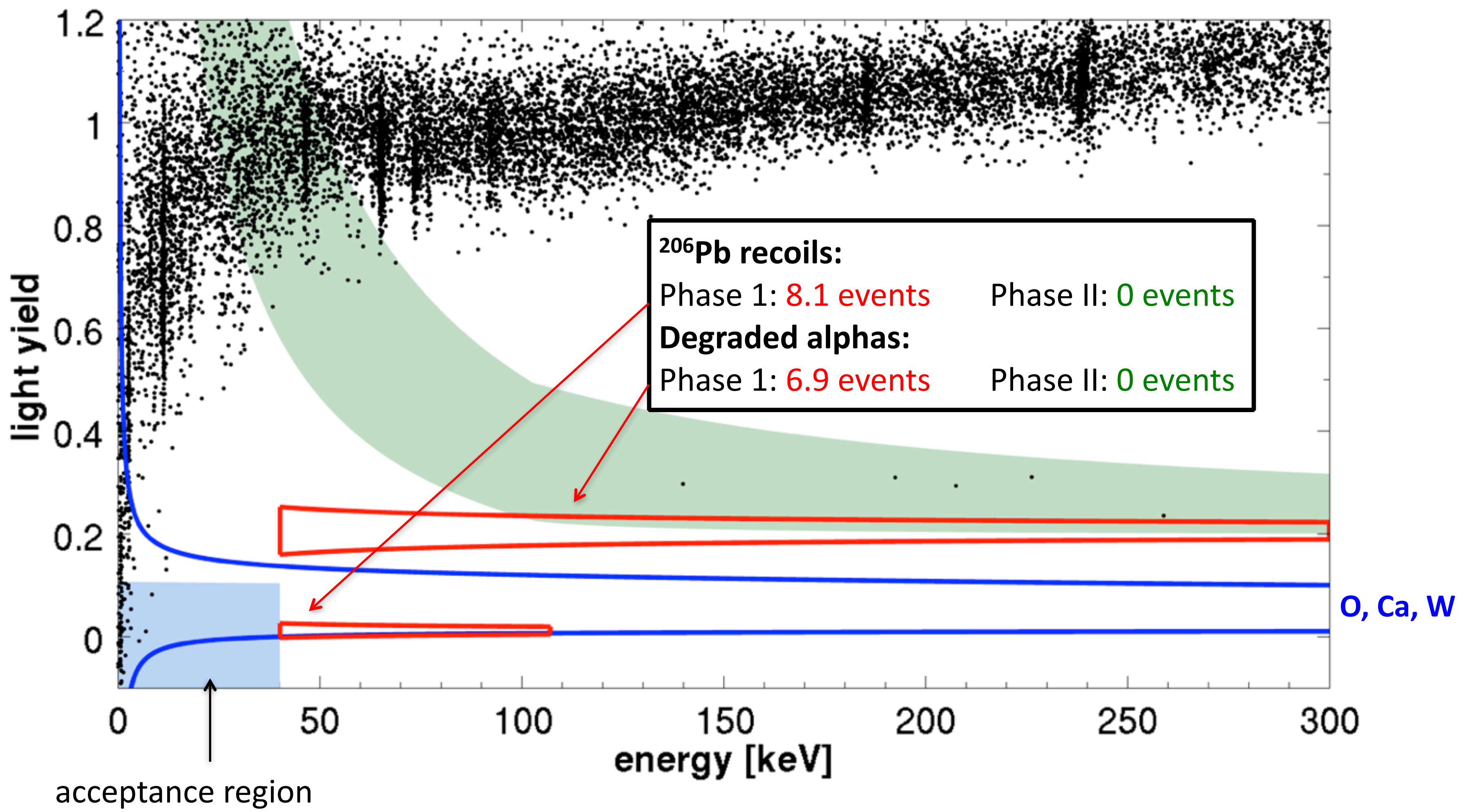
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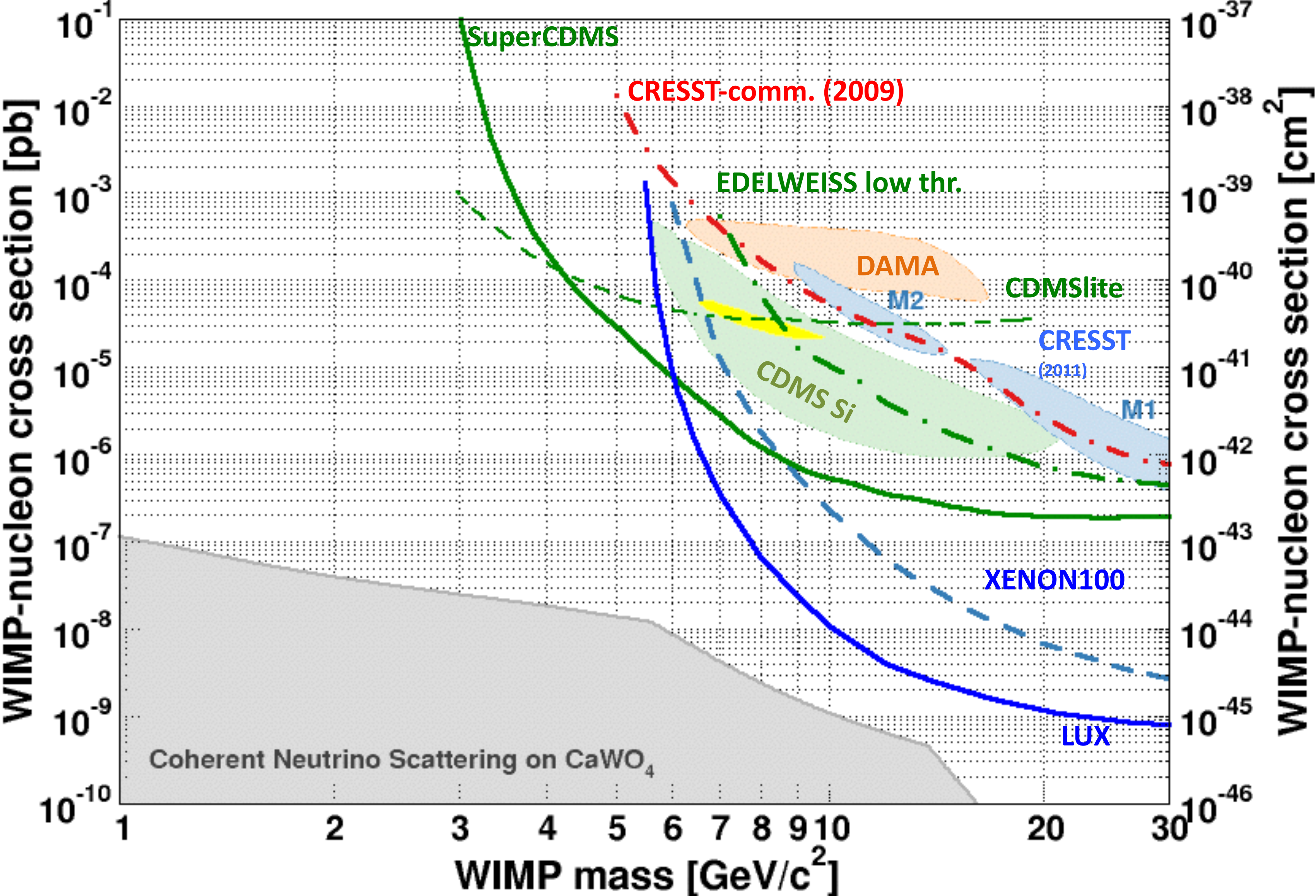


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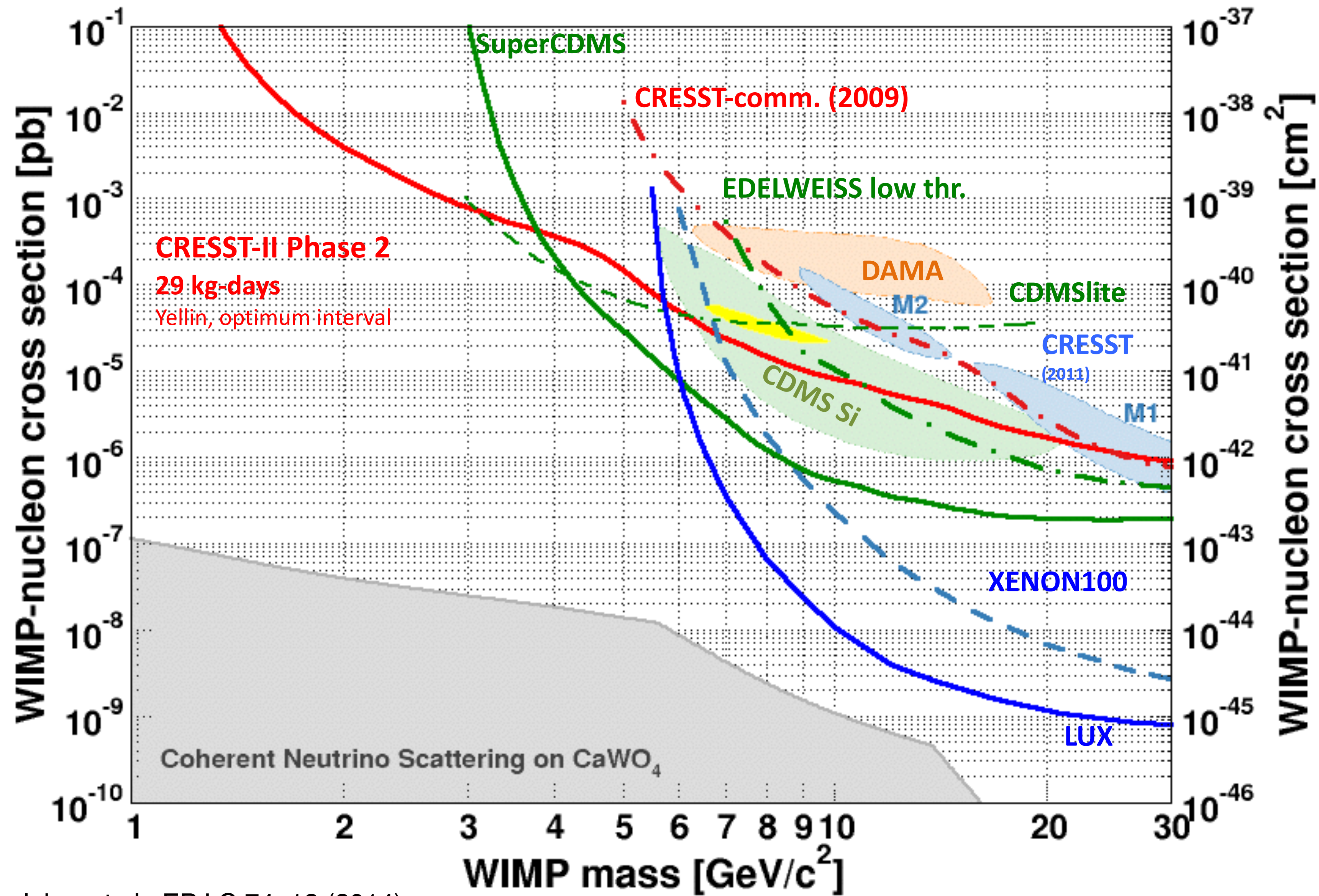
exposure: 29 kg-days



# Present WIMP Landscape

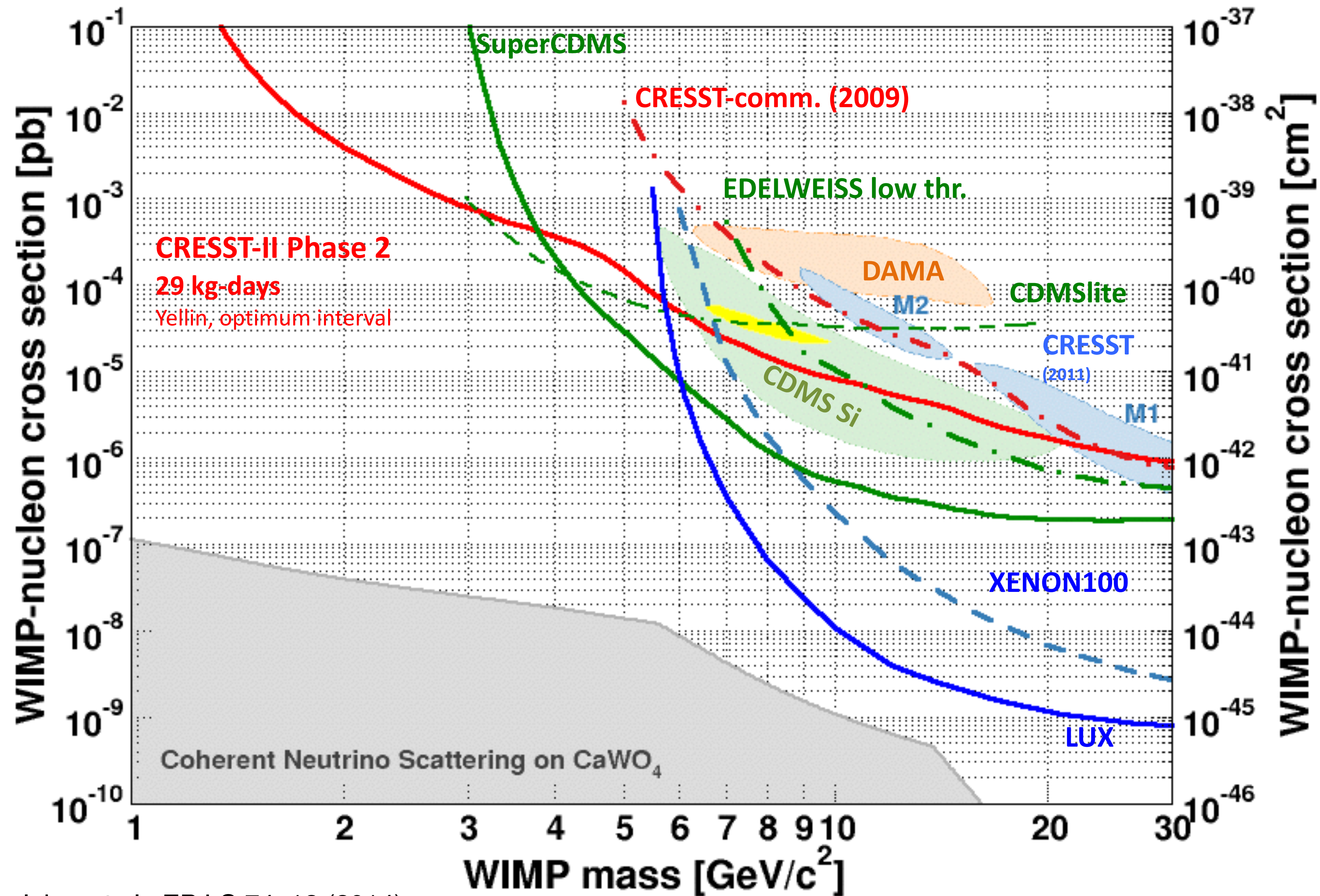


# Results from 29kg-days of TUM-40



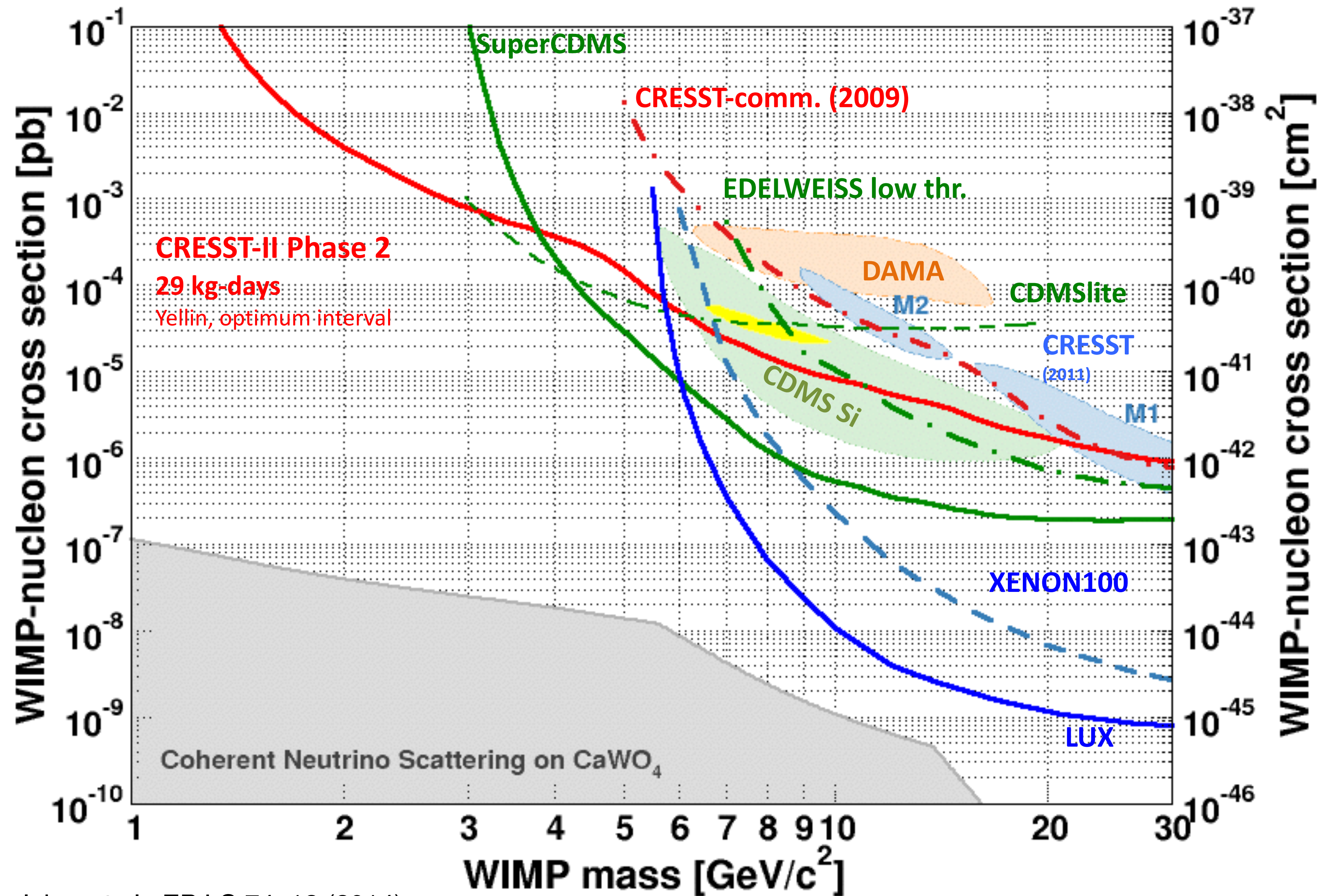


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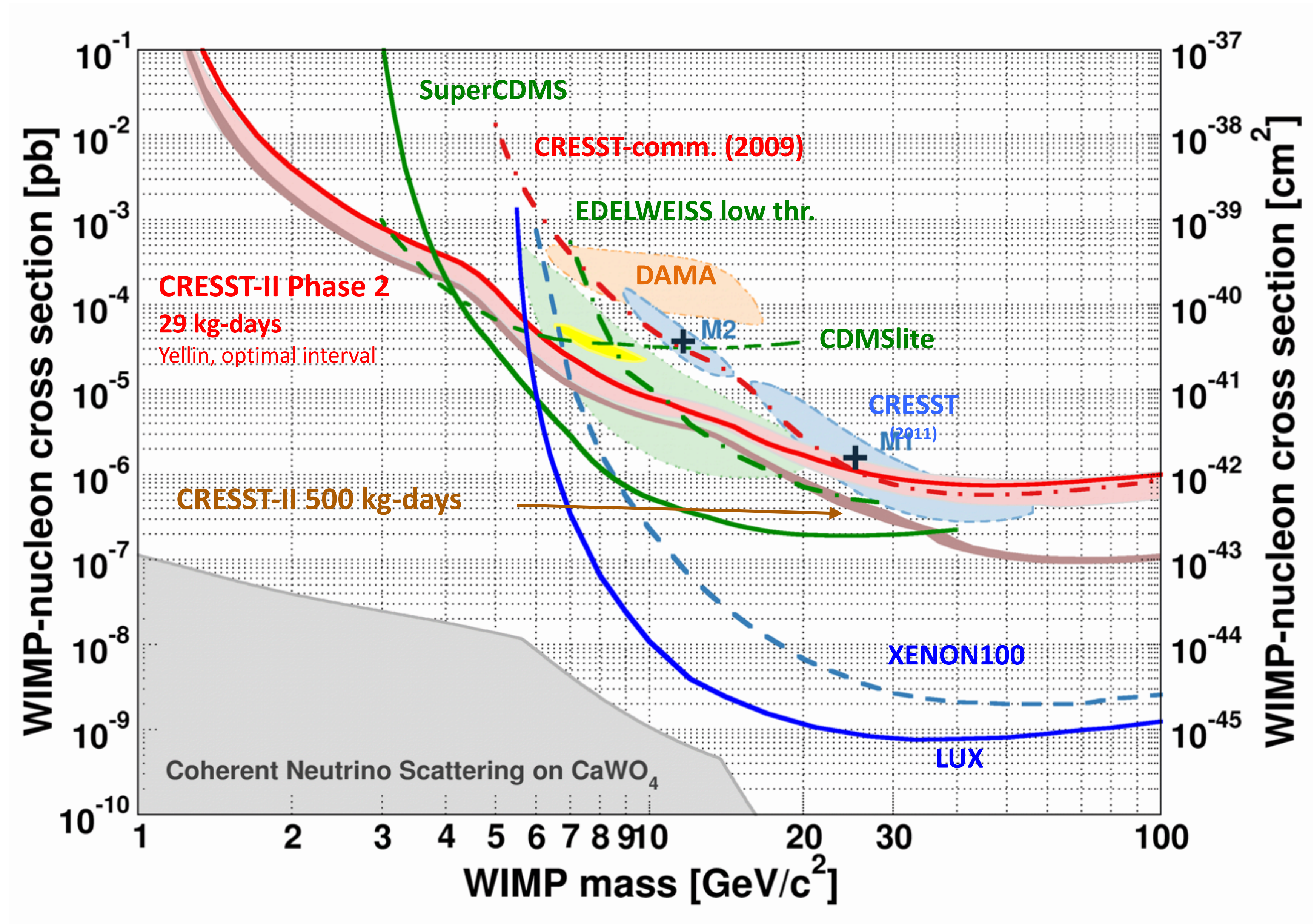
- explored new parameter space for WIMP masses  $< 3 \text{ GeV}/c^2$  with single detector module and  $29 \text{ kg} \cdot \text{days}$  of exposure

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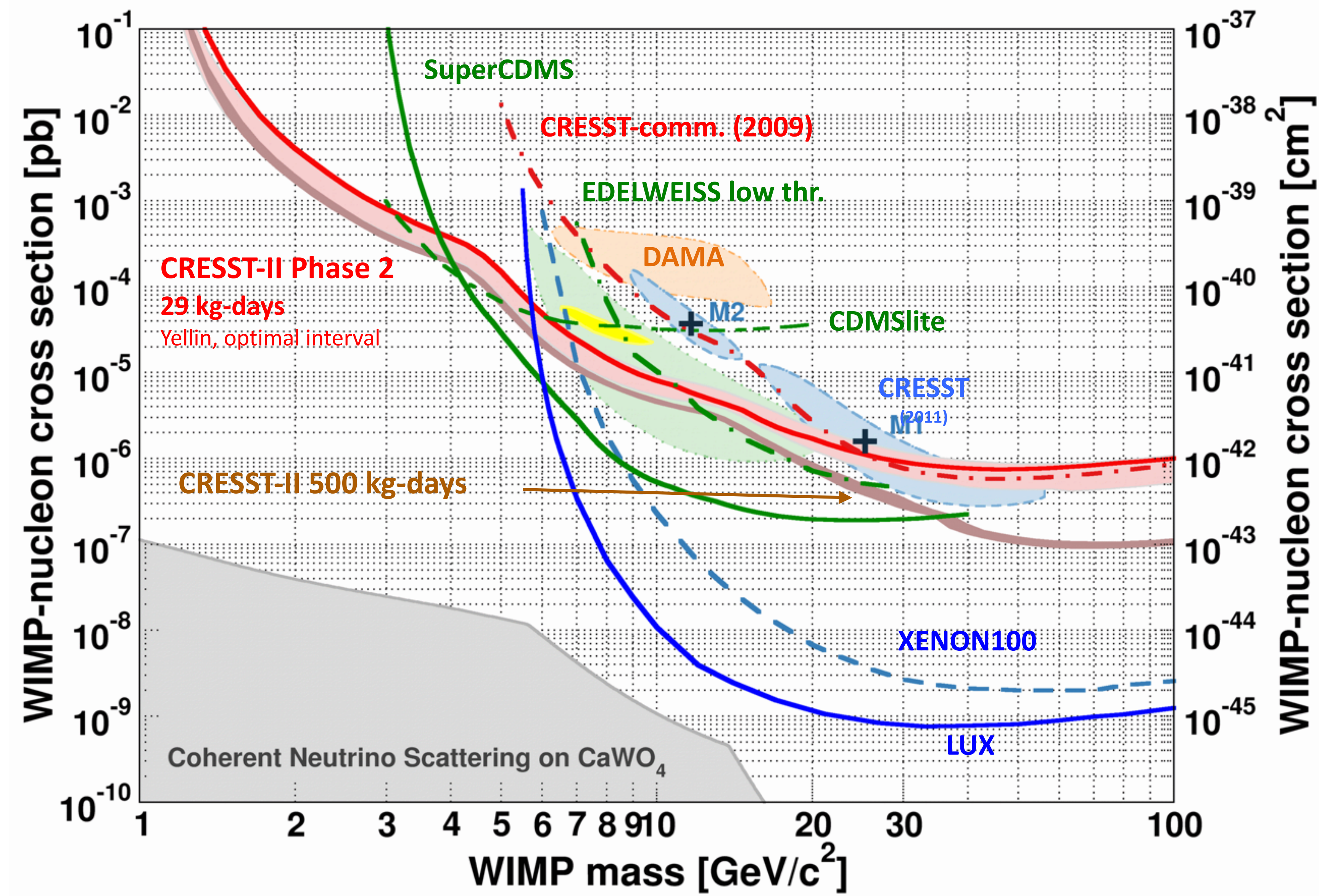
- explored new parameter space for WIMP masses  $< 3 \text{ GeV}/c^2$  with single detector module and  $29 \text{ kg} \cdot \text{days}$  of exposure
- excess not confirmed – lower mass solution (M2) already ruled out

# Near future: goal for Phase 2

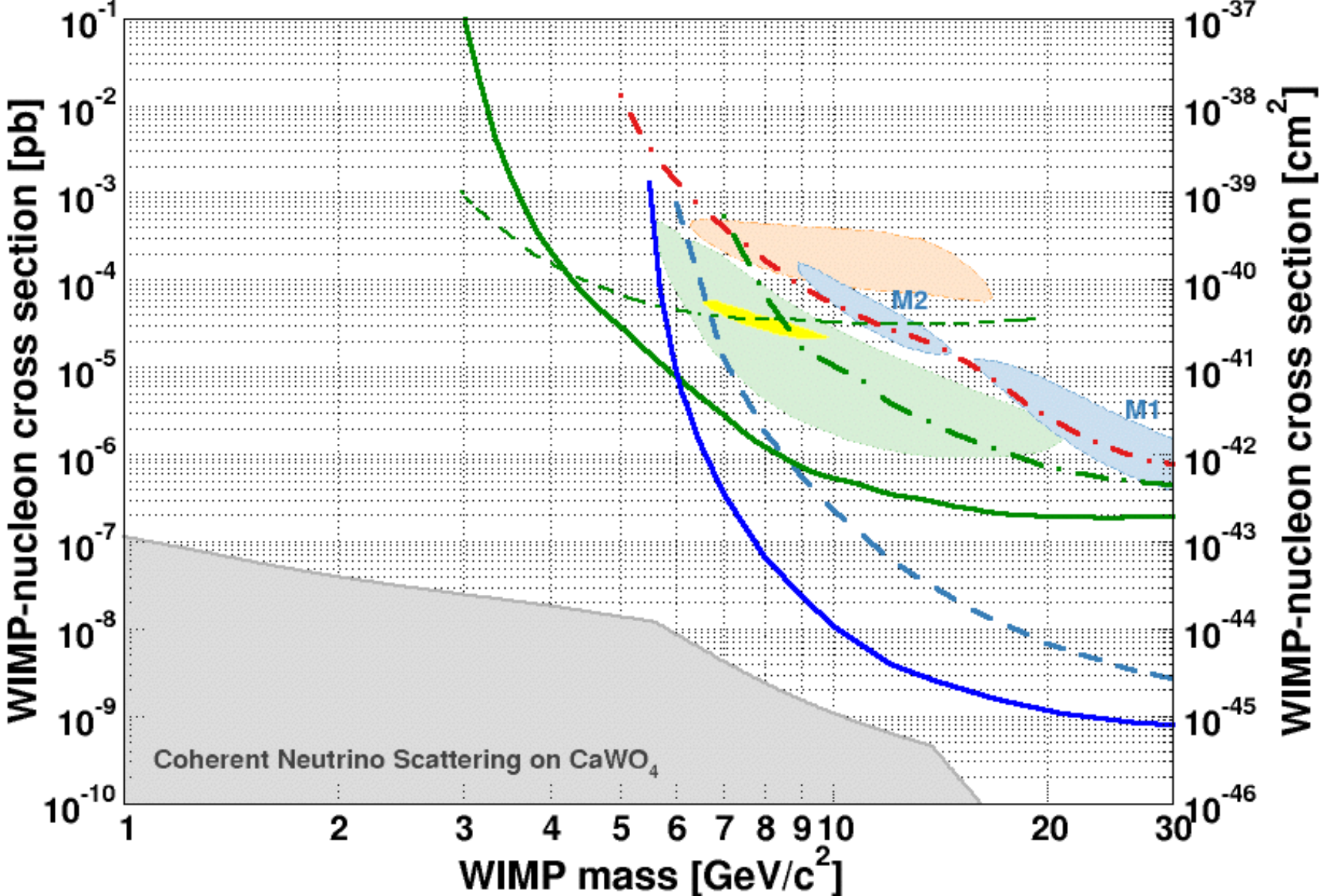


# Near future: goal for Phase 2

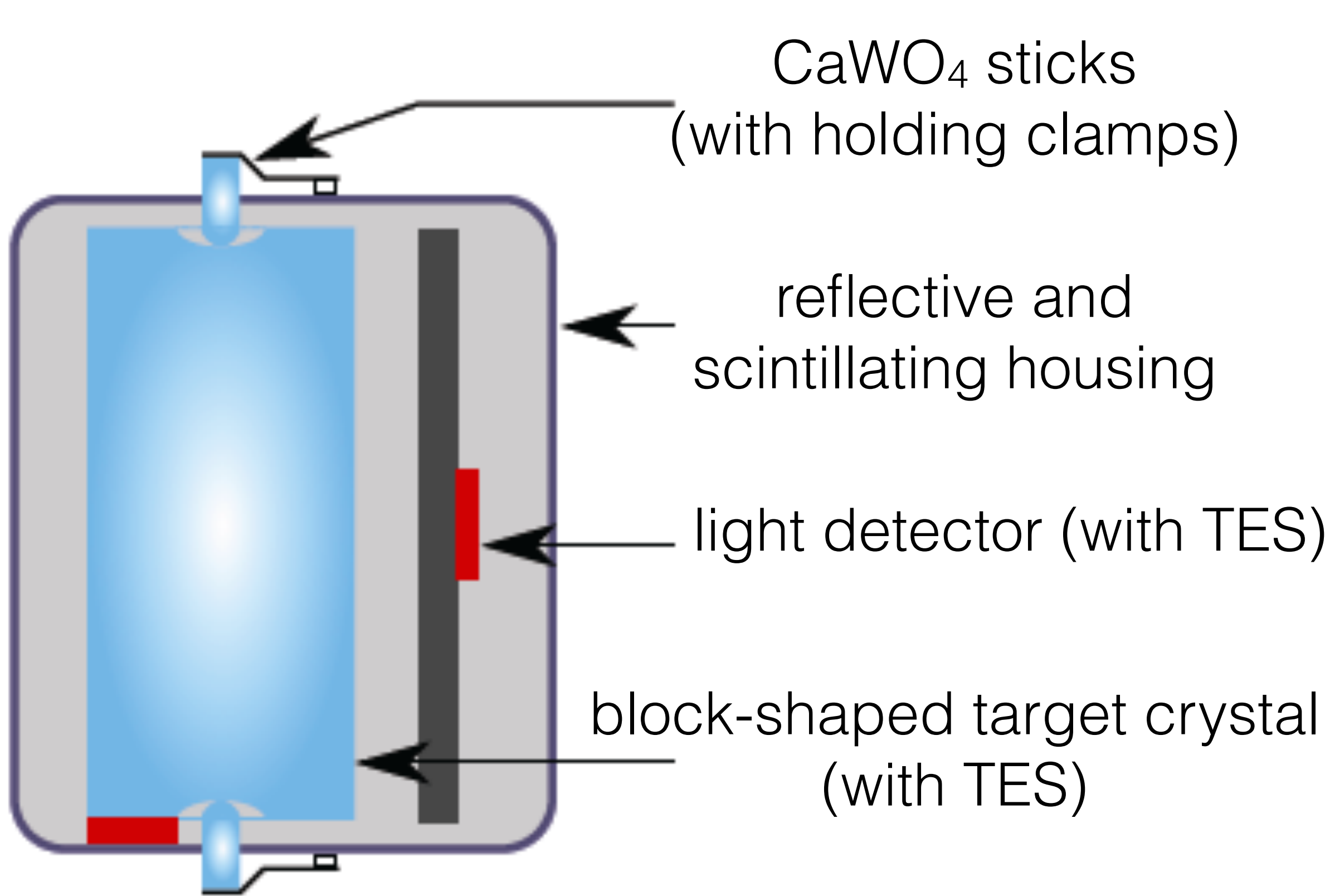
- 500 kg days reached at the end of May 2015
- Threshold of several modules lowered to < 400 eV: Further improvement in low-mass region?
- Unblinding: June 15, 2015



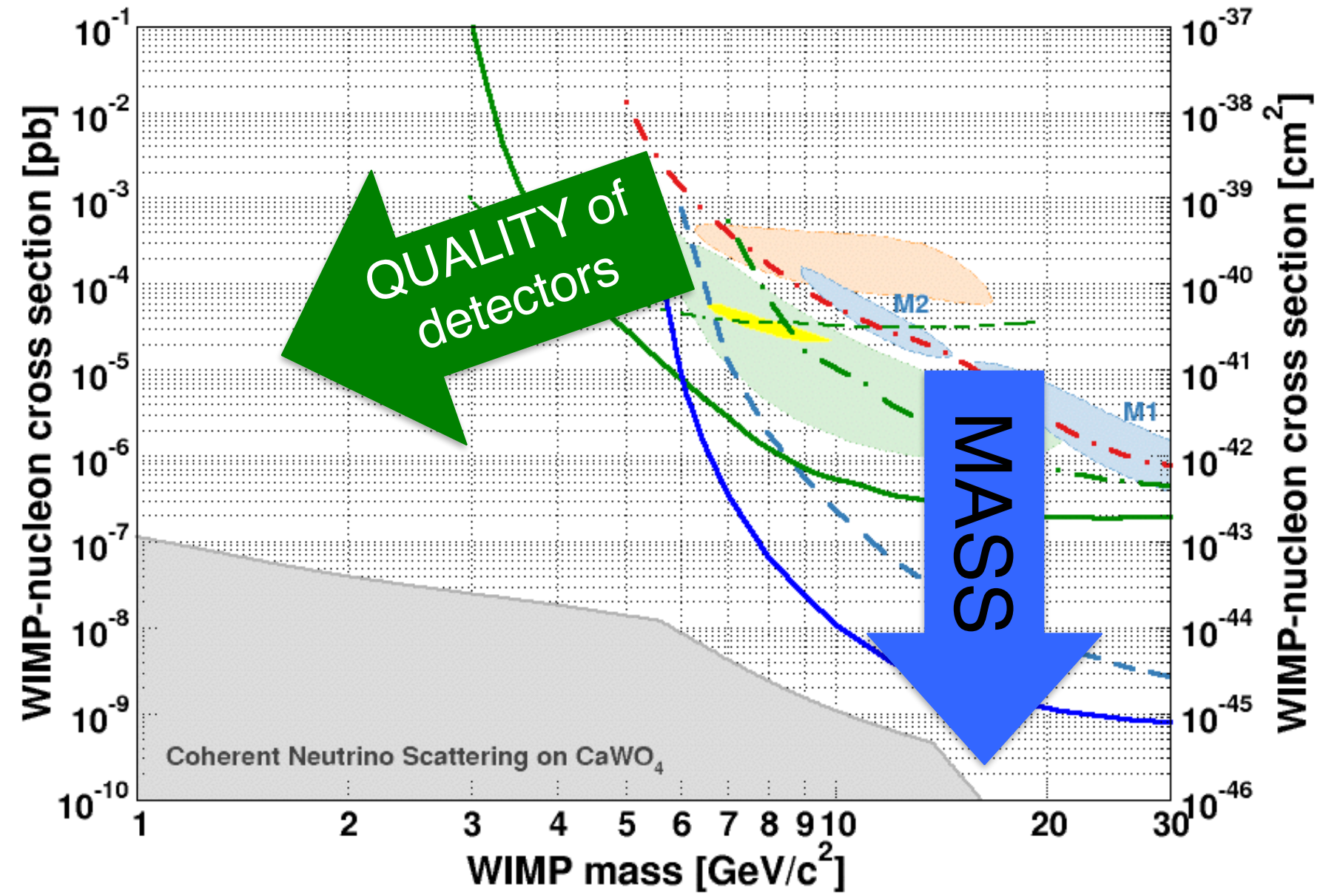
# CRESST-III: go for the small



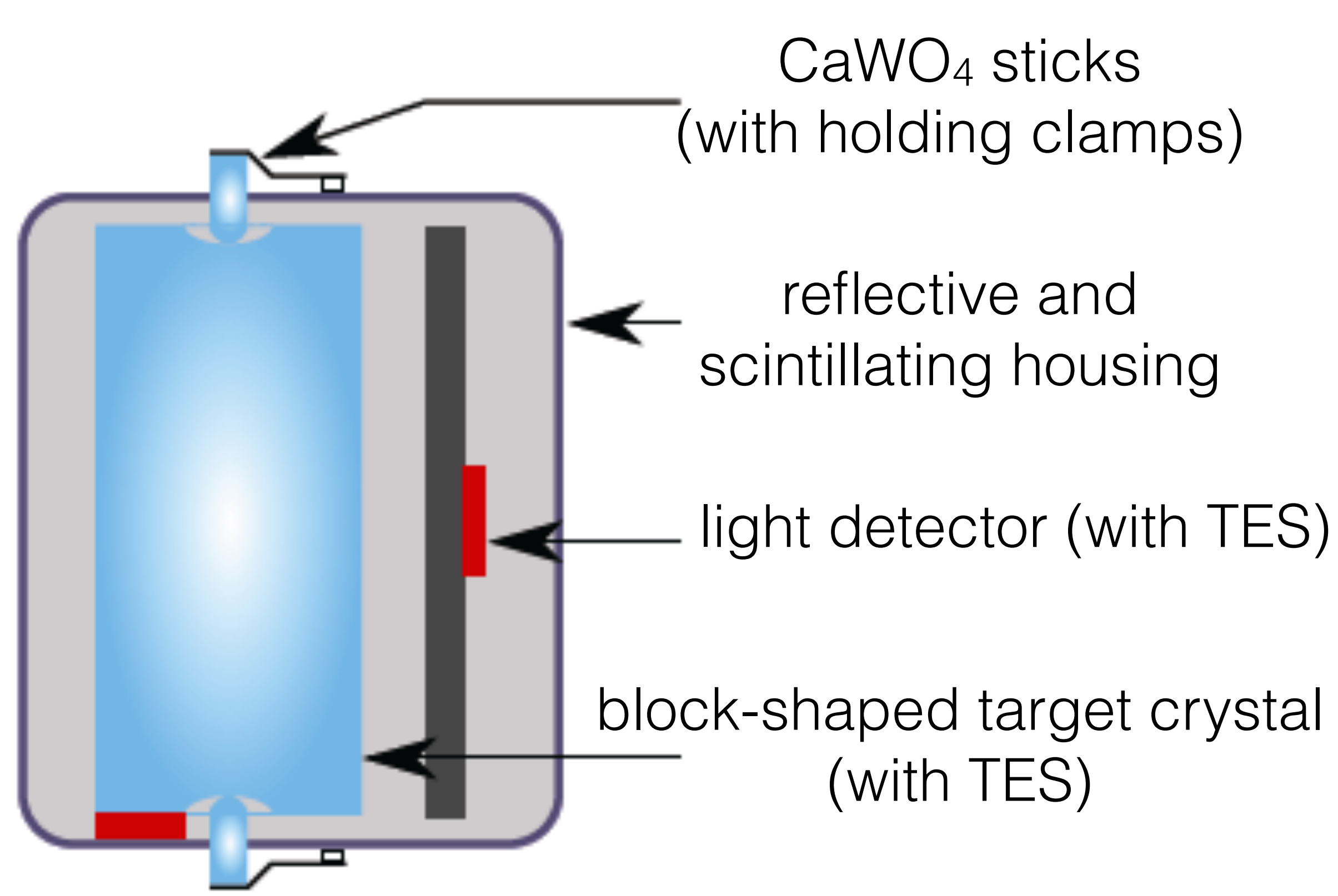
To improve sensitivity to low masses a radical change of strategy:



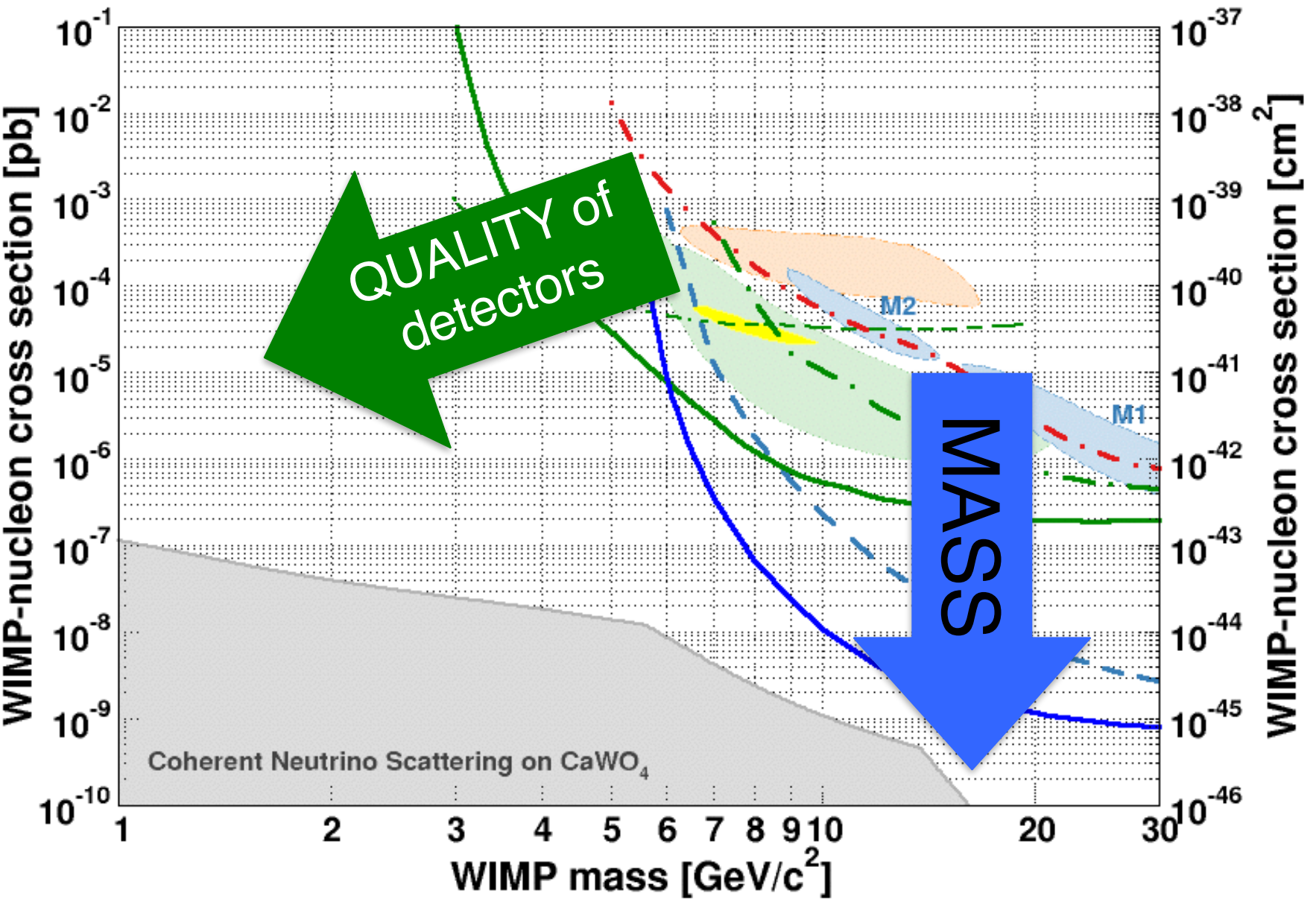
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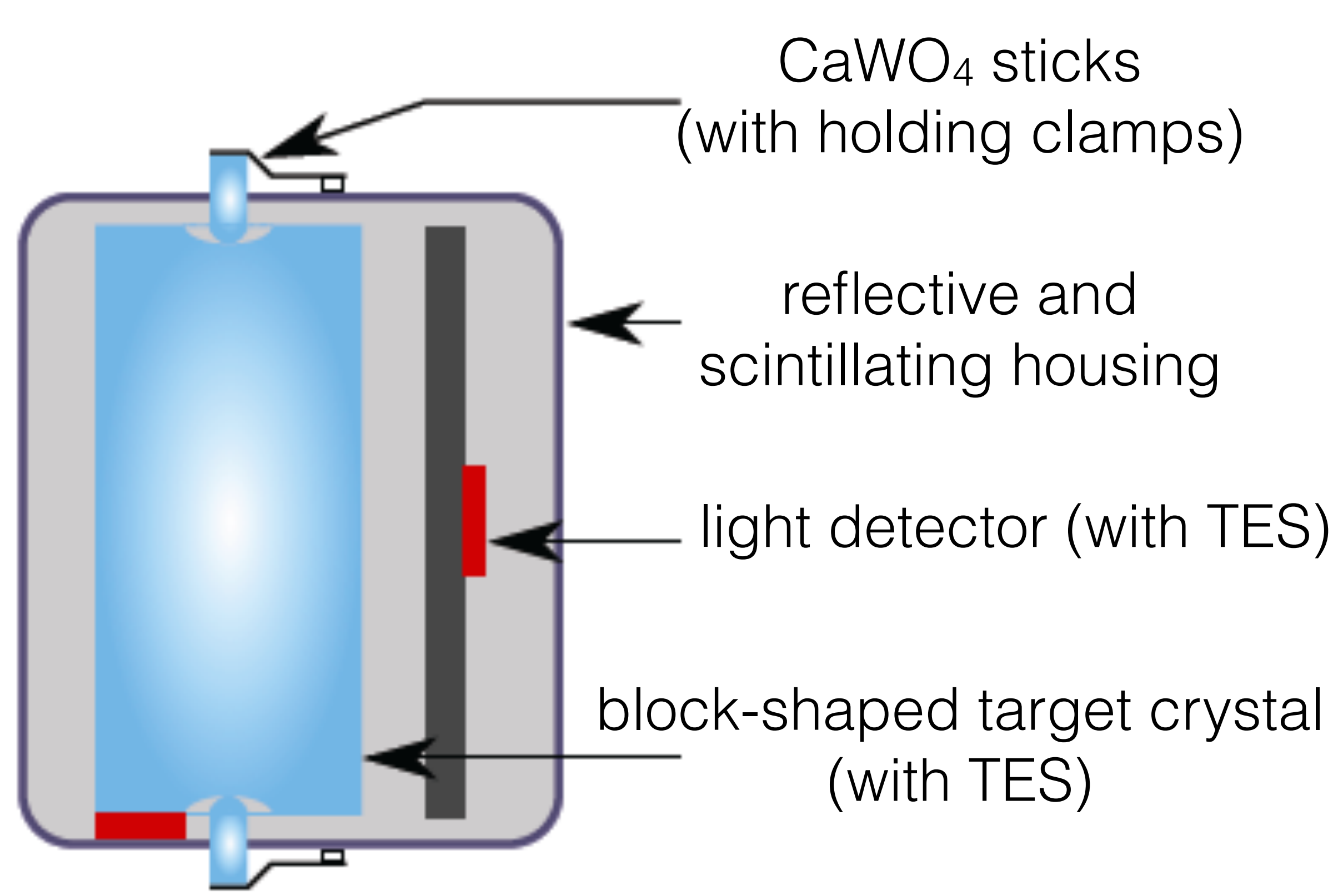
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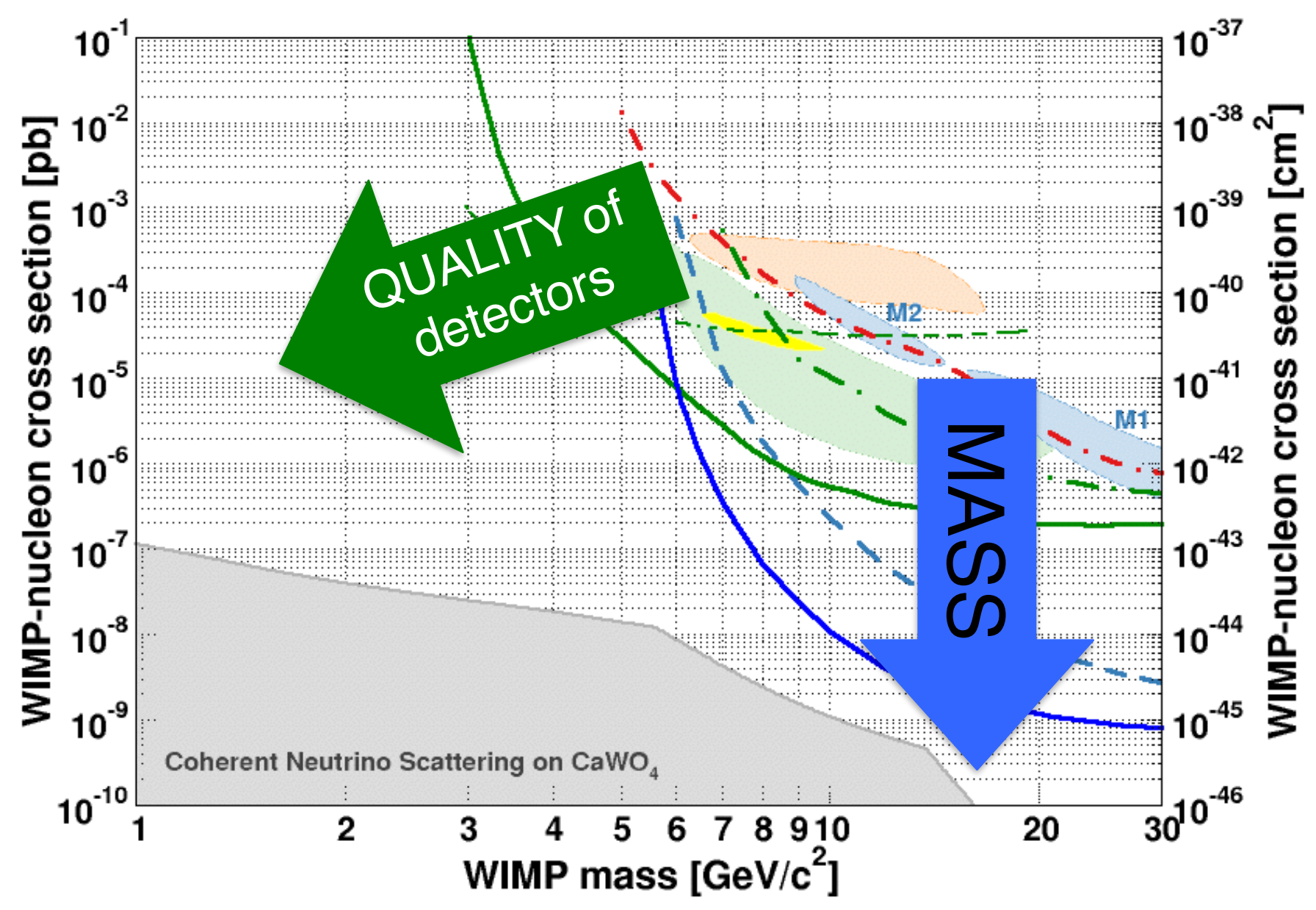
To improve sensitivity to low masses a radical change of strategy:

Smaller crystals of TUM40 quality: 250g → 24g

Threshold: 600eV → 100eV



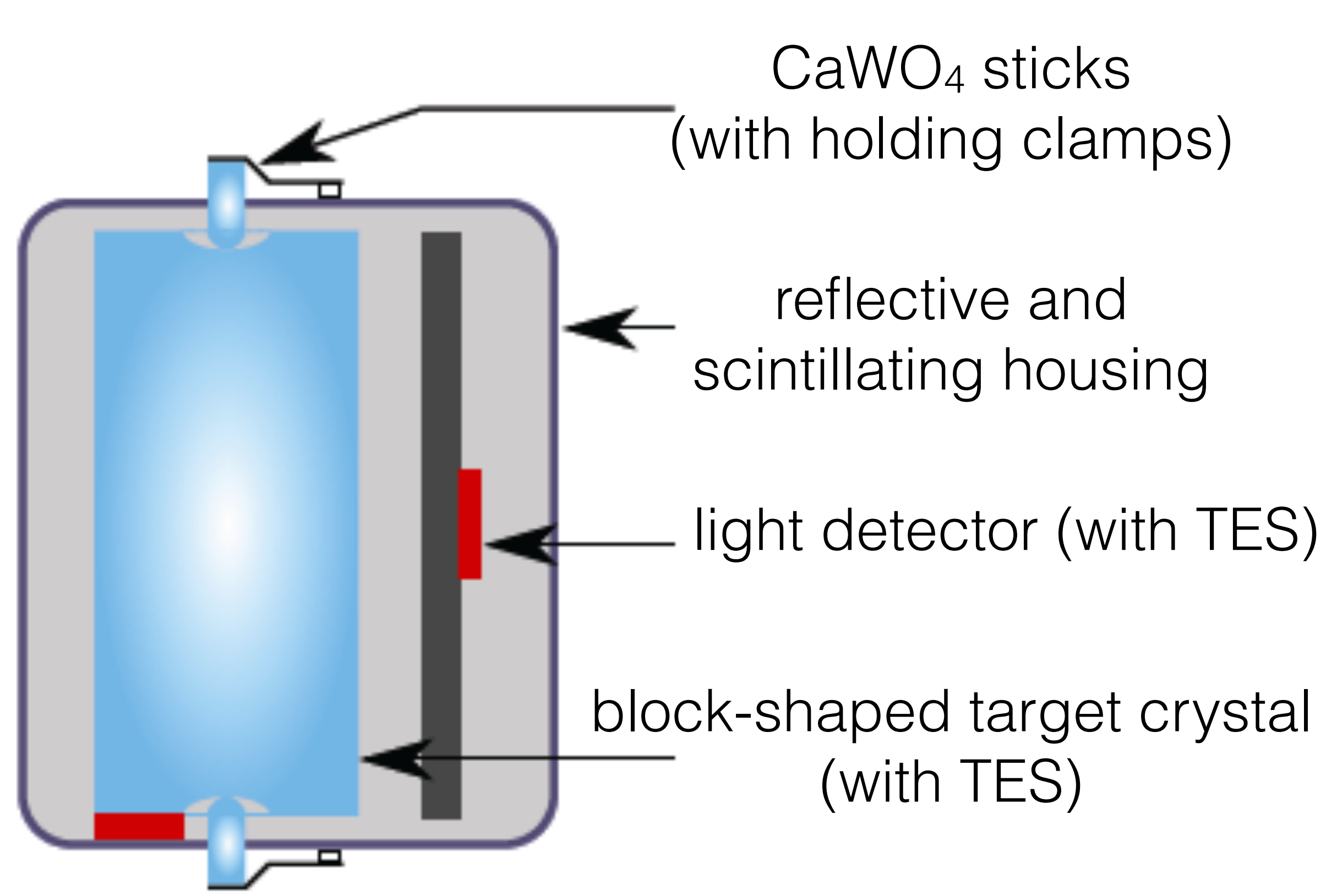
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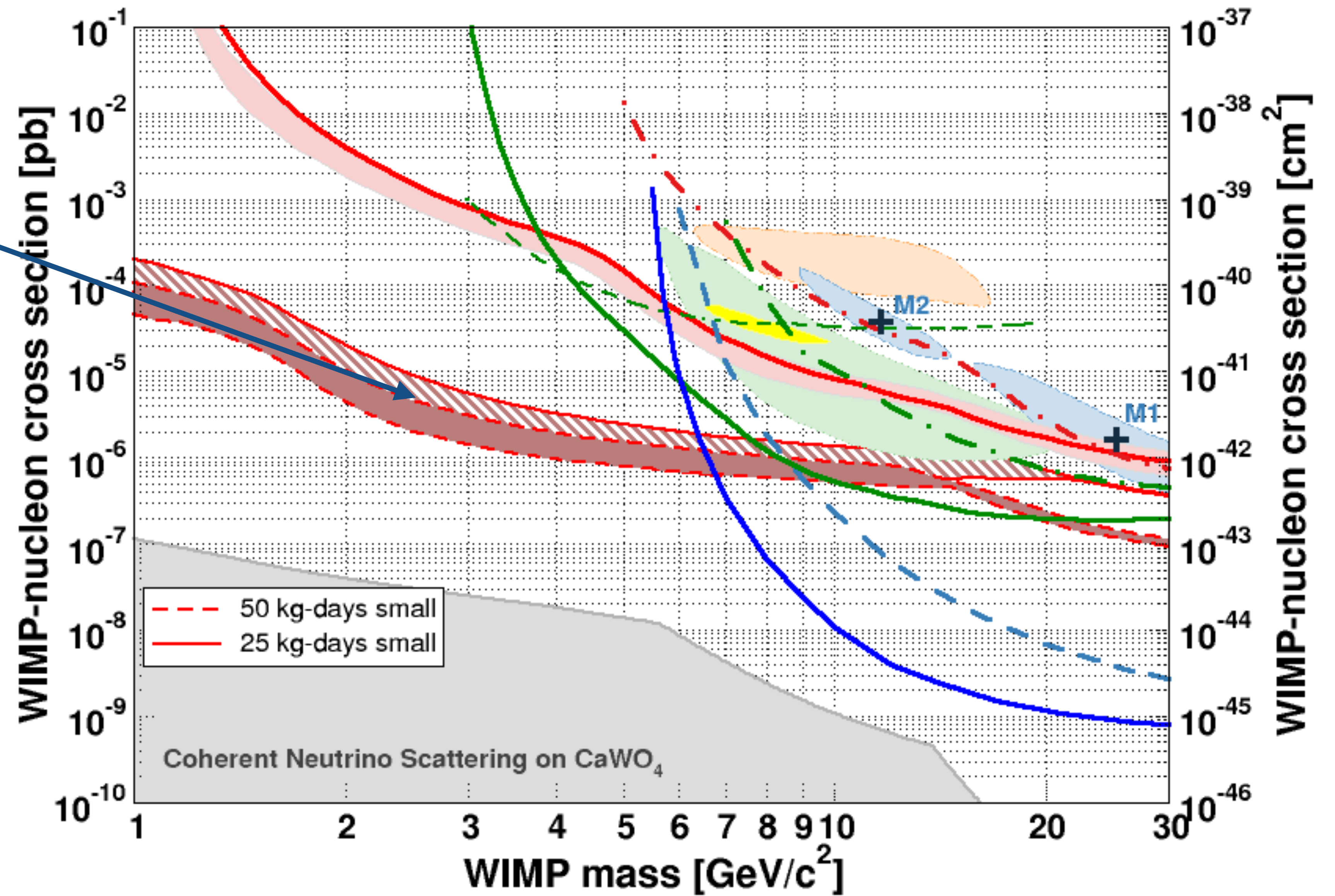
May 2015: Positive indications from prototype testing +  
Detector production ongoing



# CRESST-III

## Phase 1:

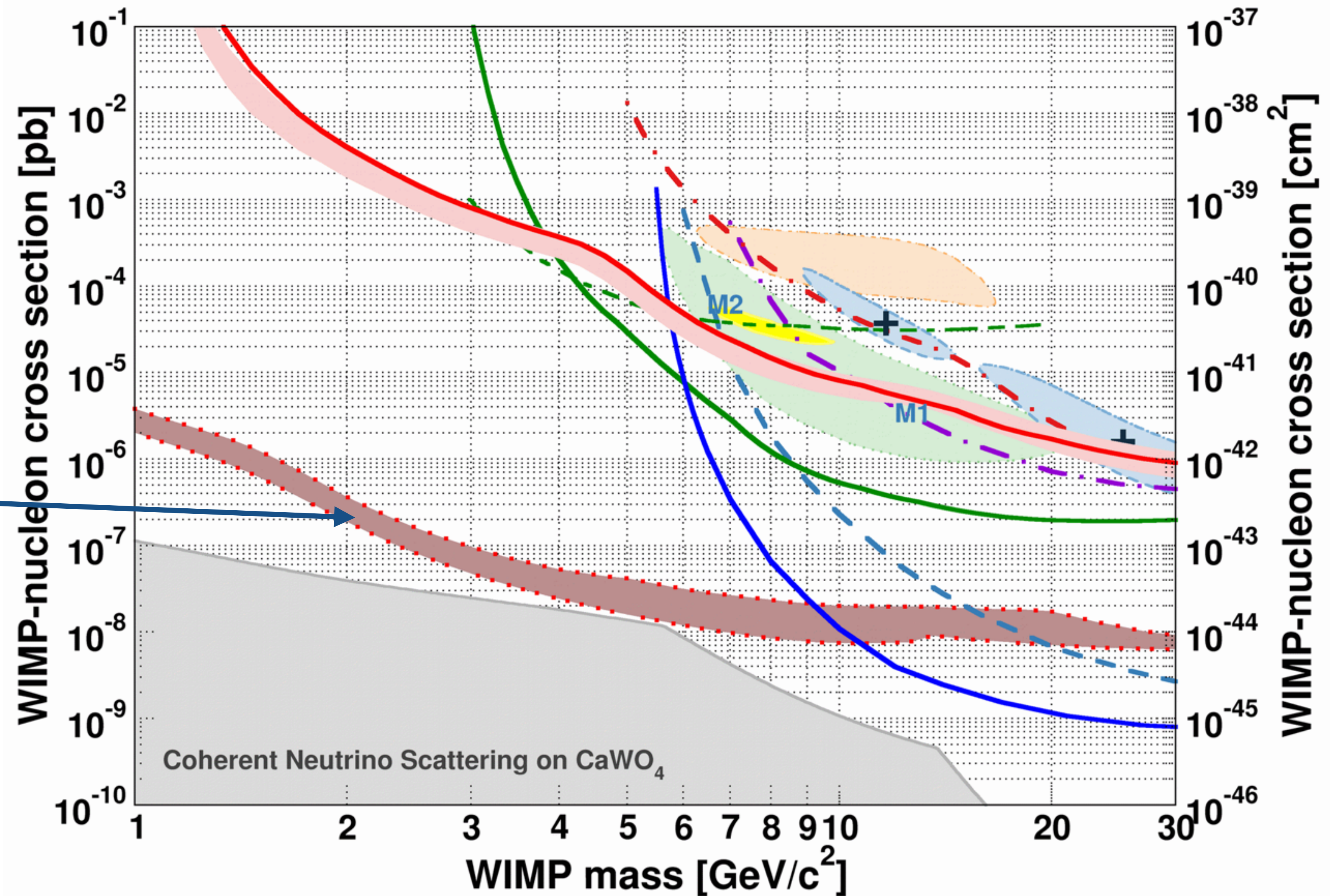
- 50kg days: 10 modules, 1 year



# CRESST-III

## Phase 2:

- 1 tonne days:  
100 modules, 2  
years
- crystal radiopurity  
improved by  $\sim 100$

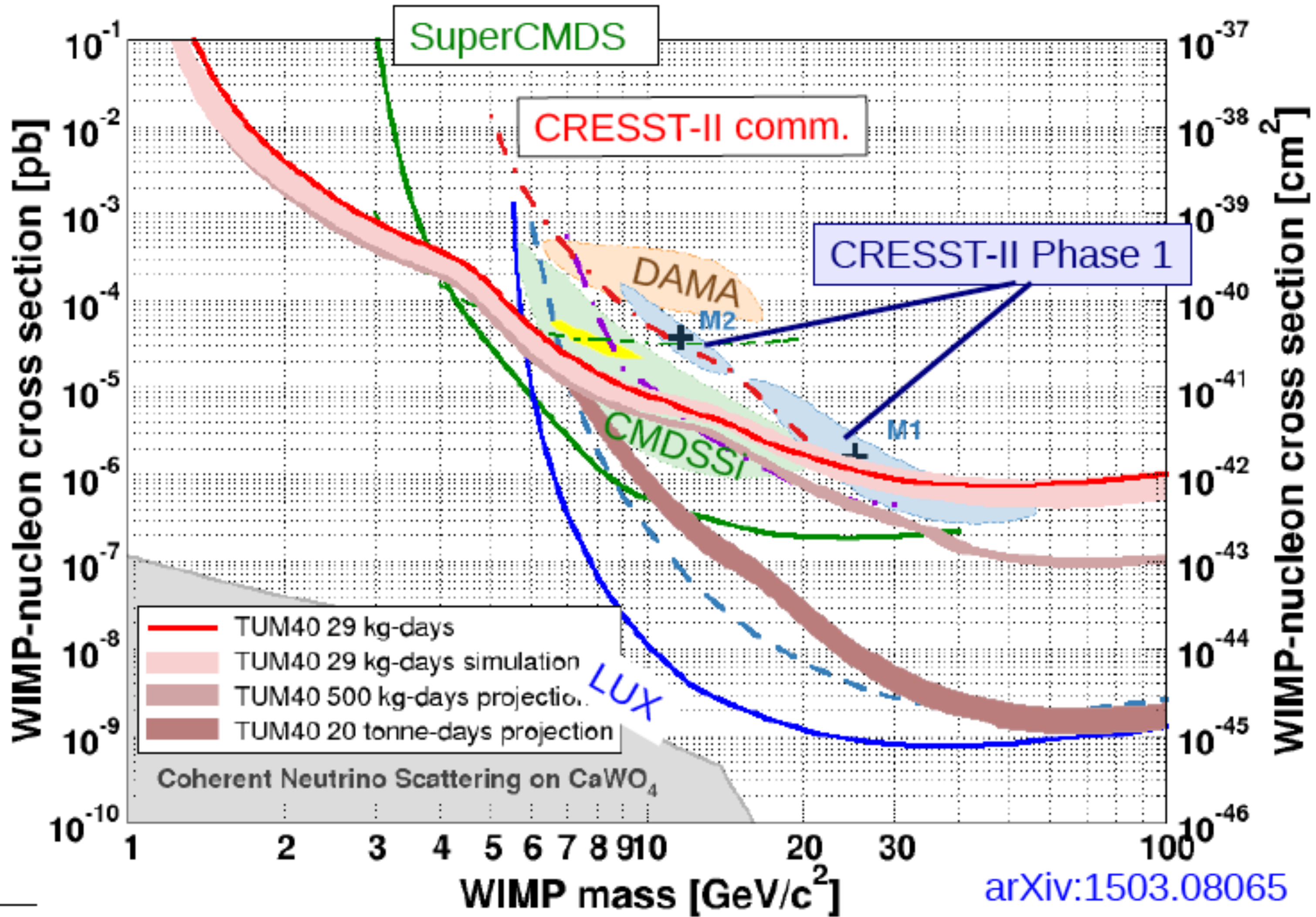


# Conclusion

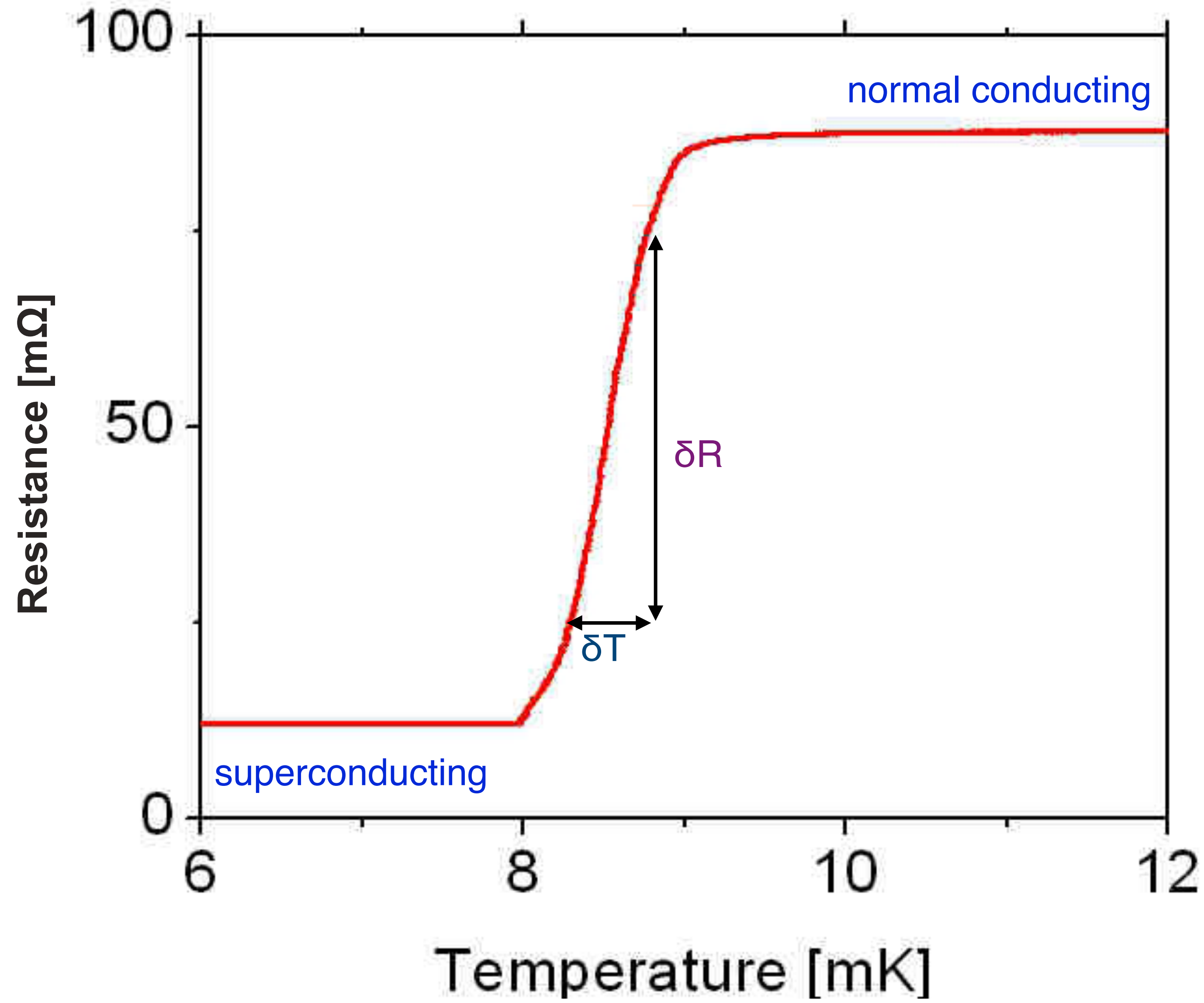
- CRESST have set a new state of the art for the low mass WIMPs search
- The unblinding of the 500 kg\*days of the full CRESST-II Phase 2 will probe the M1 region and possibly improve the low mass limit
- The new strategy developed for the low mass region exploration (“go for the small”) will lead to CRESST-III Phase 1 in late 2015
- Improving radiopurity will allow further improvements in the next few years

# Backup slides

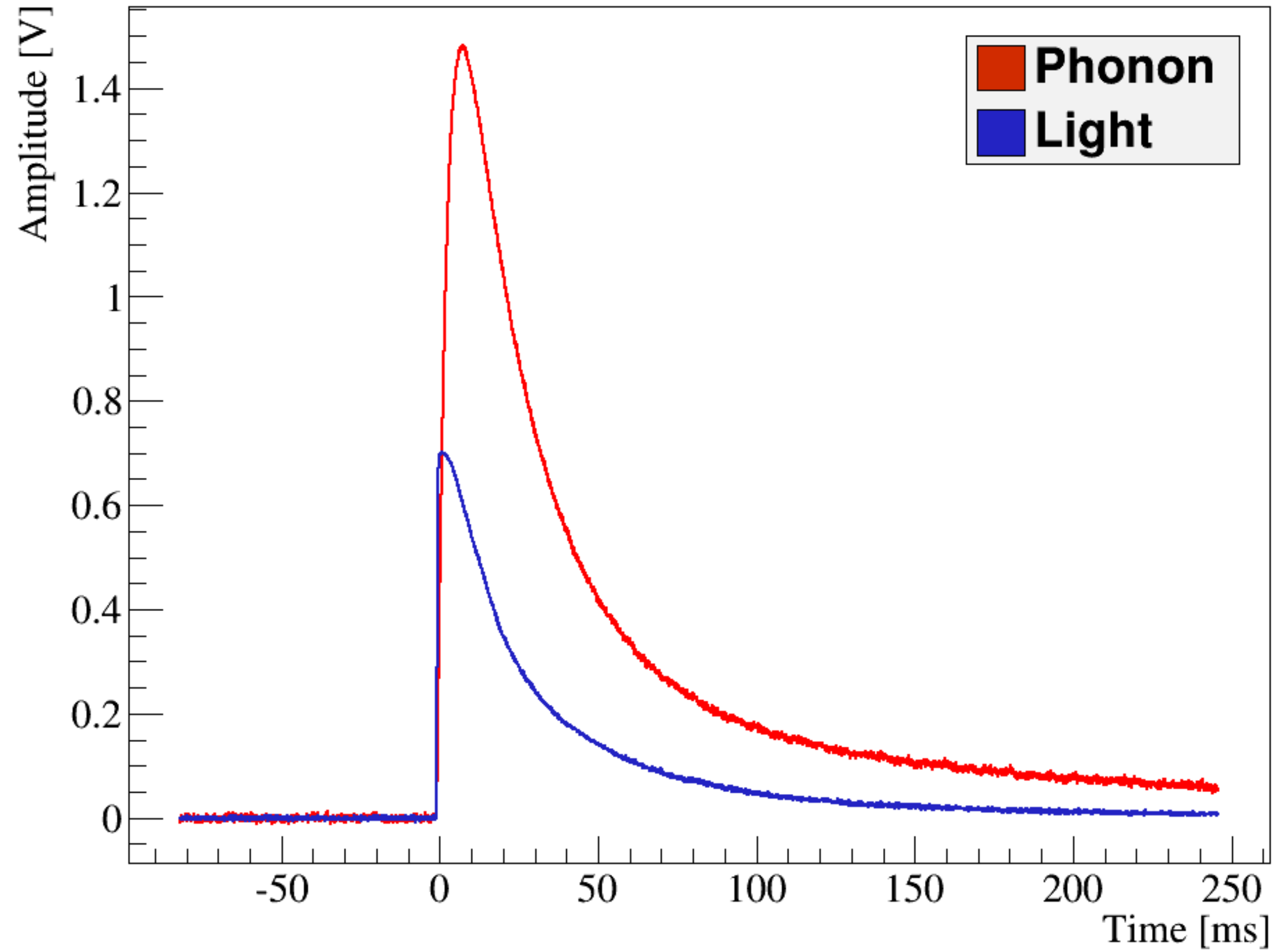
# Sensitivity at “high-mass” wimps



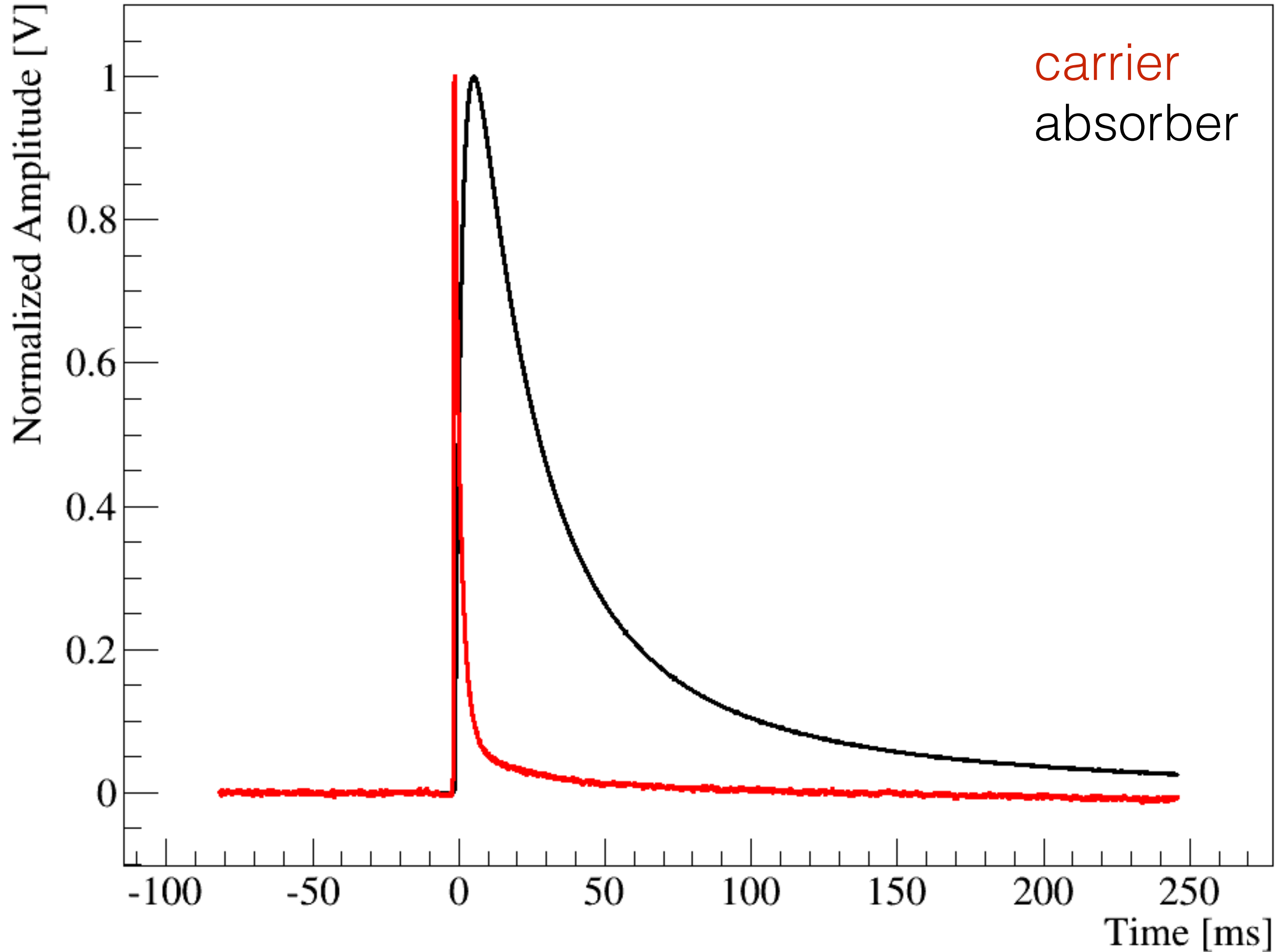
# Transition Edge Sensor



# Phonons vs. light

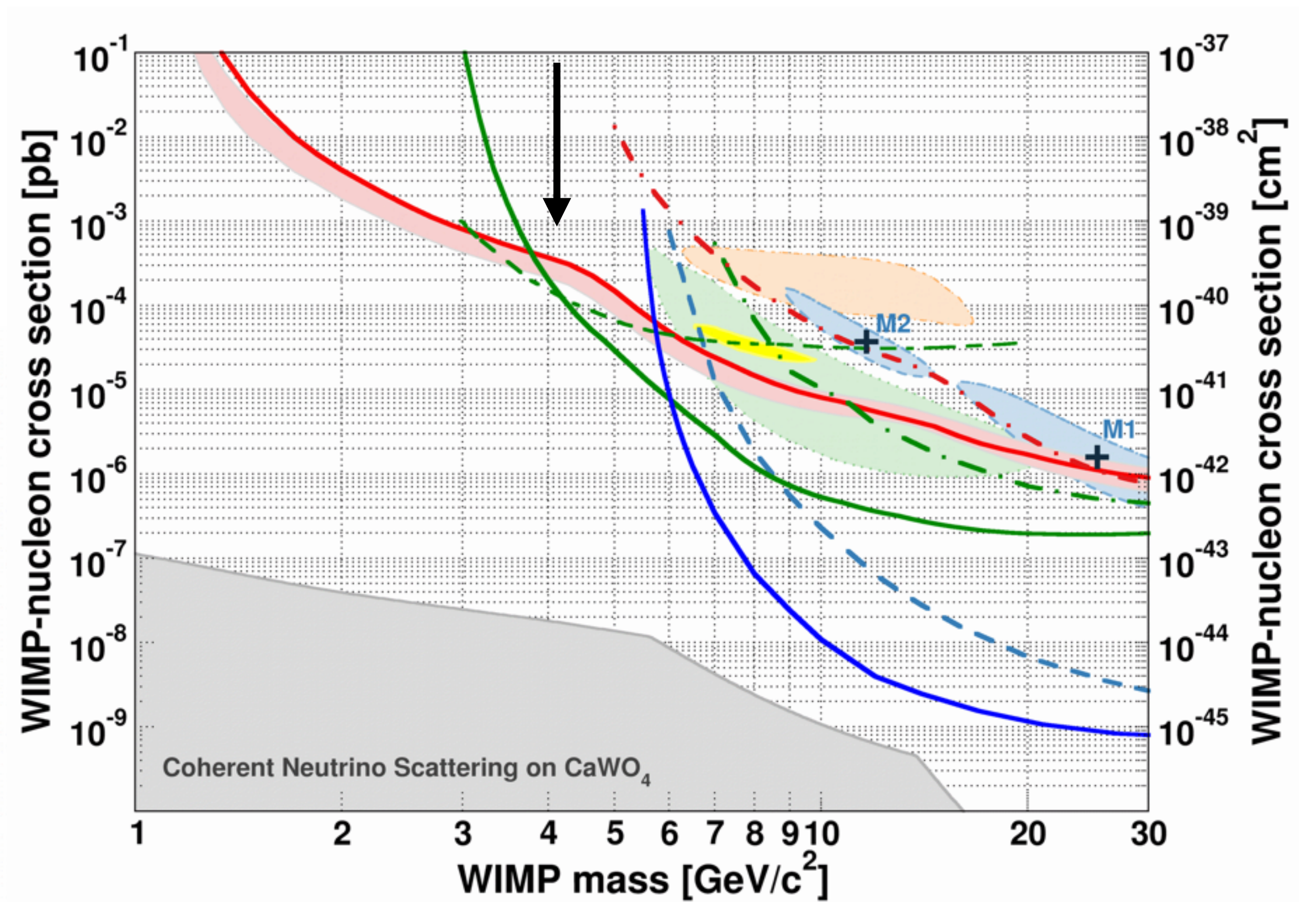
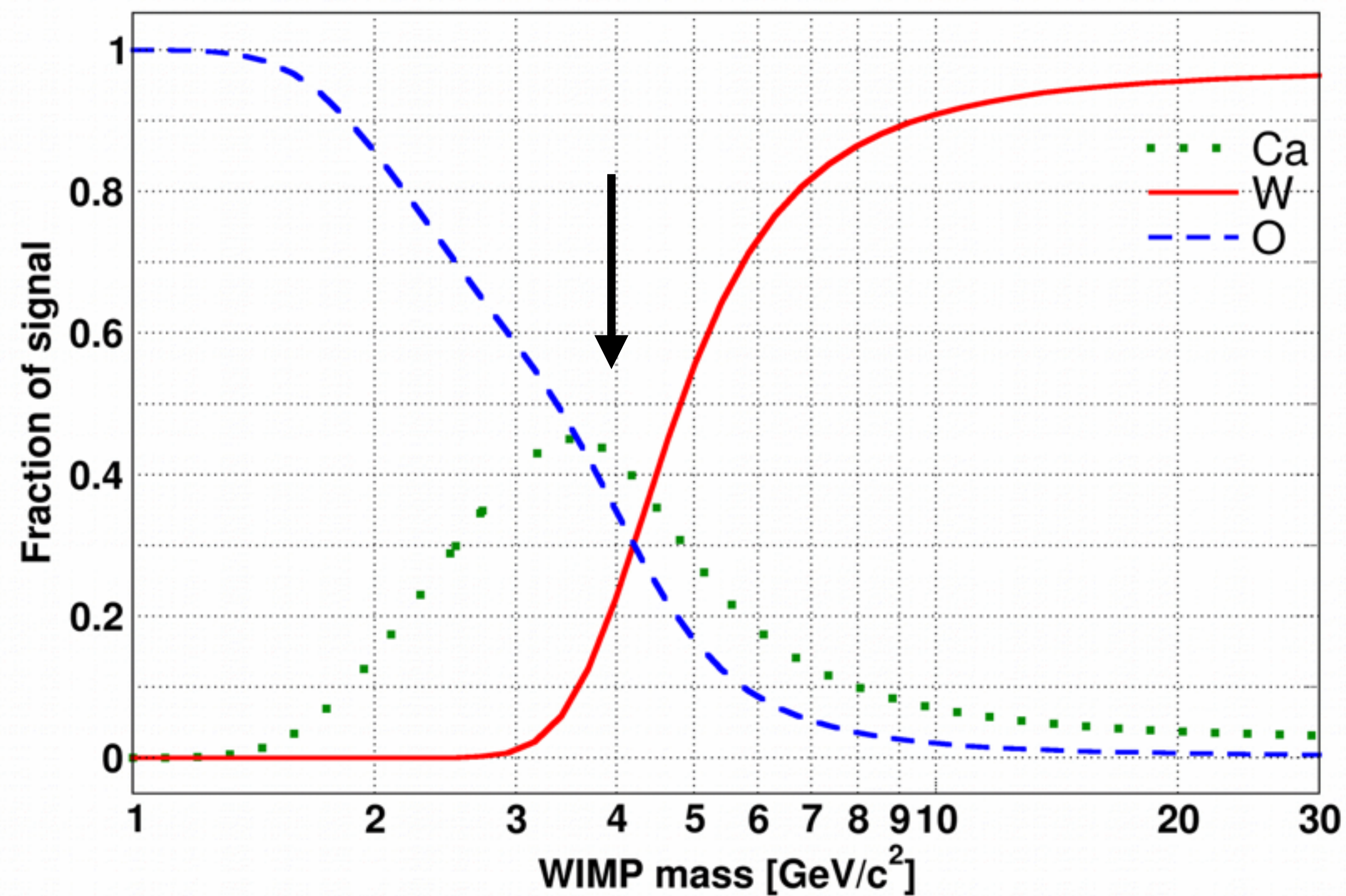


# TUM40: Carrier vs. Absorber



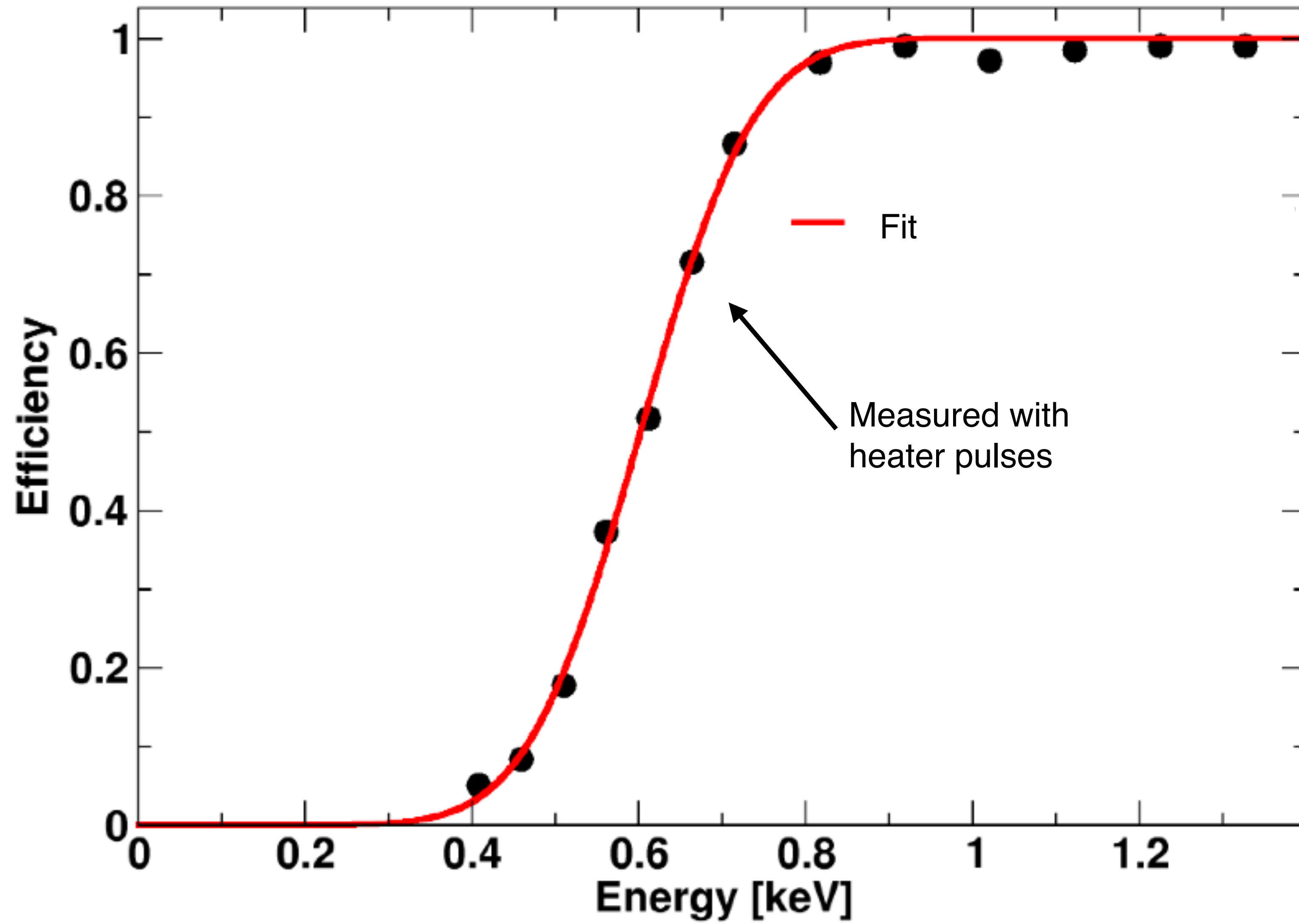


# Multielement targets



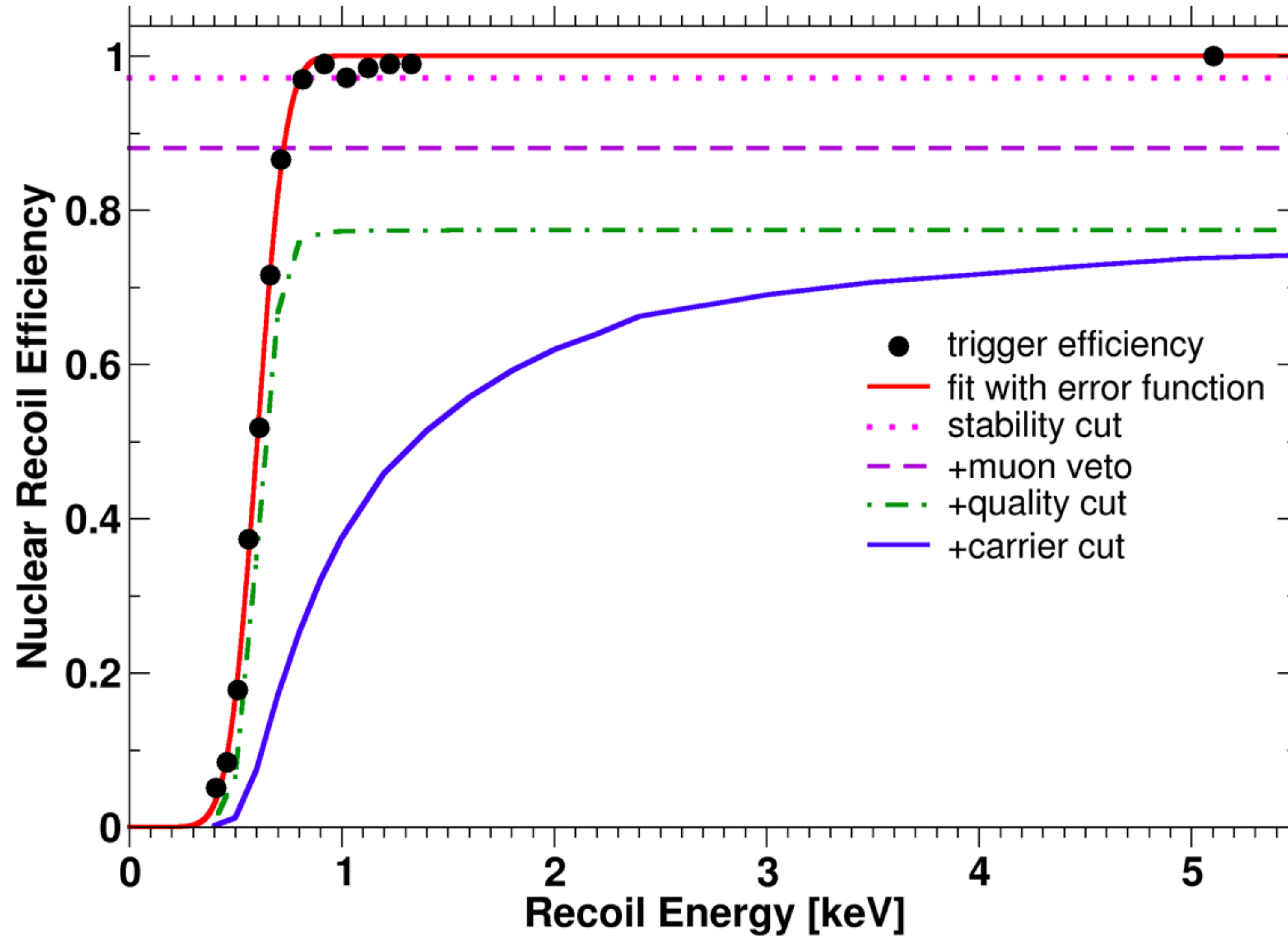
above  $5\text{GeV}/c^2$ : W dominates  
 below  $5\text{GeV}/c^2$ : O dominates

# TUM-40: Trigger threshold

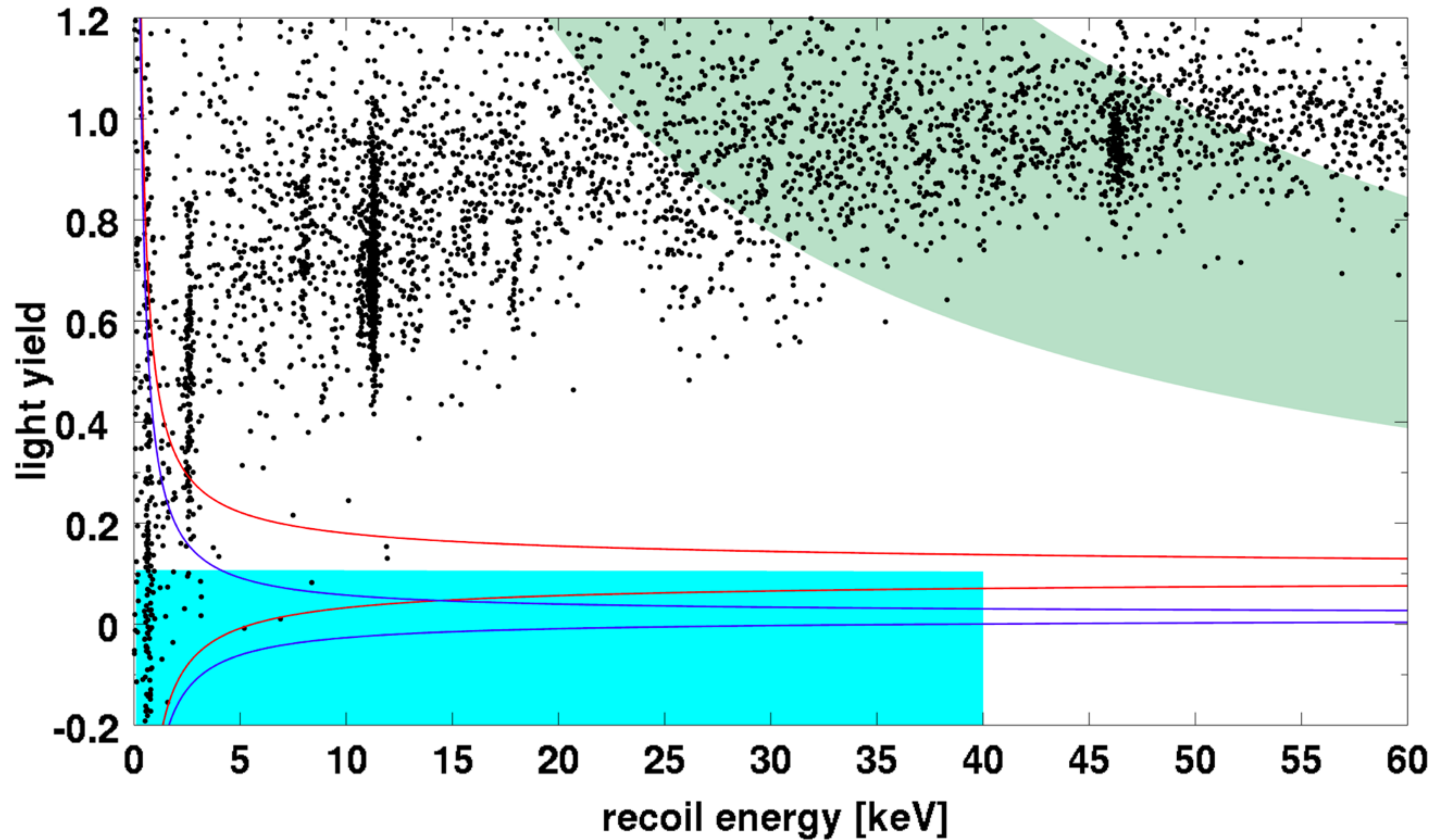


Extremely low trigger threshold of  $E_{th} \approx 603 \text{ eV}$

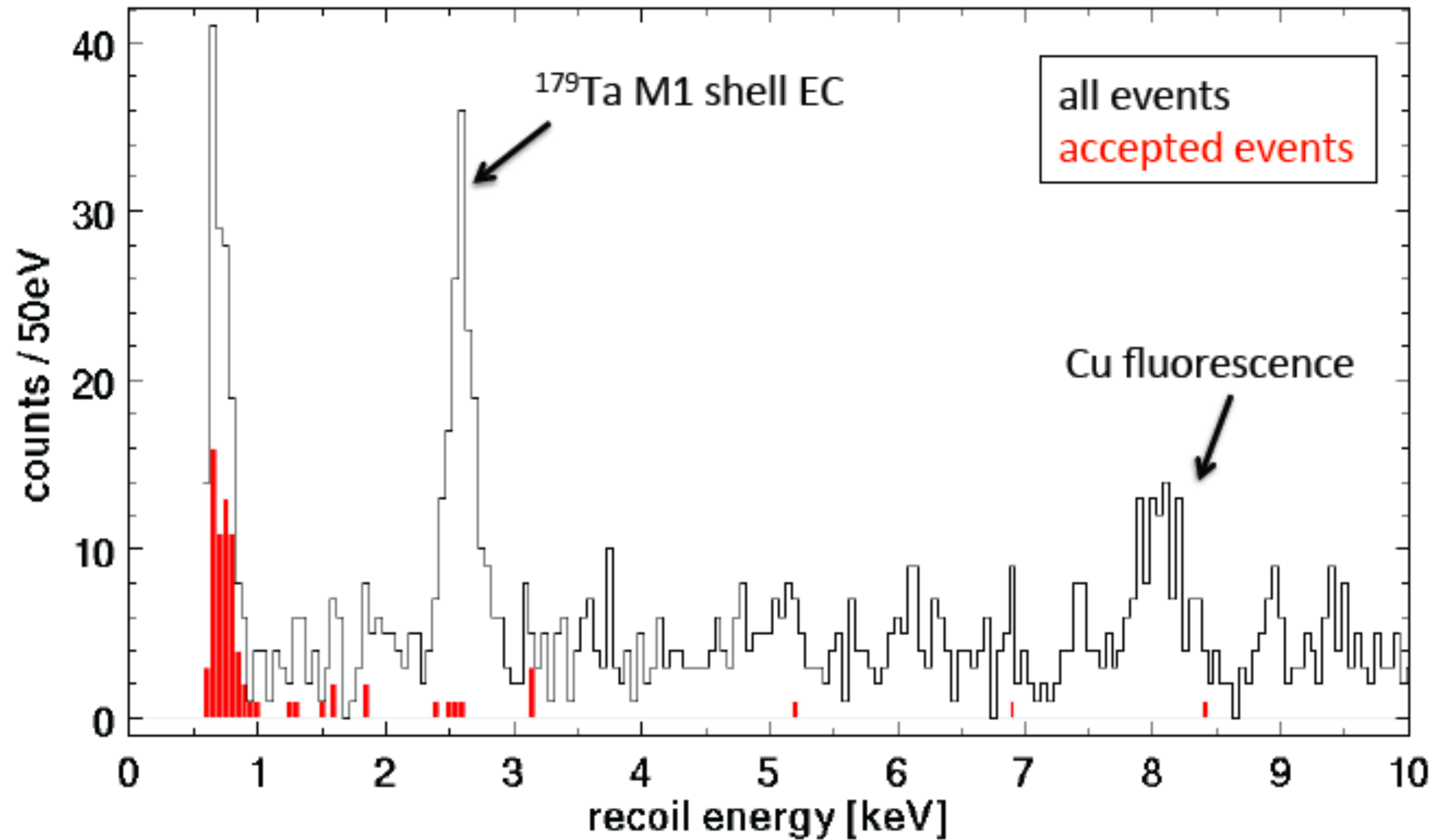
# TUM-40: Acceptance at Lowest Energies



# WIMPs Acceptance region



# TUM-40: Acceptance at Lowest Energies



All 79 events accepted are conservatively considered as WIMPs

# TUM-40: Low Energy Lines

