

# *Direct dark matter search with ultra-low thresholds in the CRESST-III experiment*

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for The CRESST Collaboration

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- Direct searches for Dark Matter
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# Direct search for dark matter

- Hypothetical interaction of galaxy-bound dark matter particles with detector material
- Elastic scattering off nuclei
- Measured quantity for energy reconstruction:  
➔ ***Energy of recoiling nucleus***

Illustration by Sandbox Studio, Chicago;  
Courtesy of FermiLab

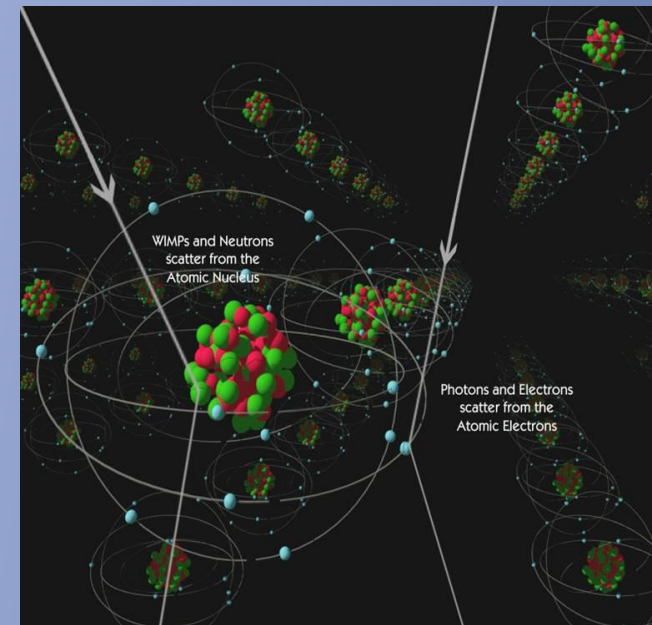
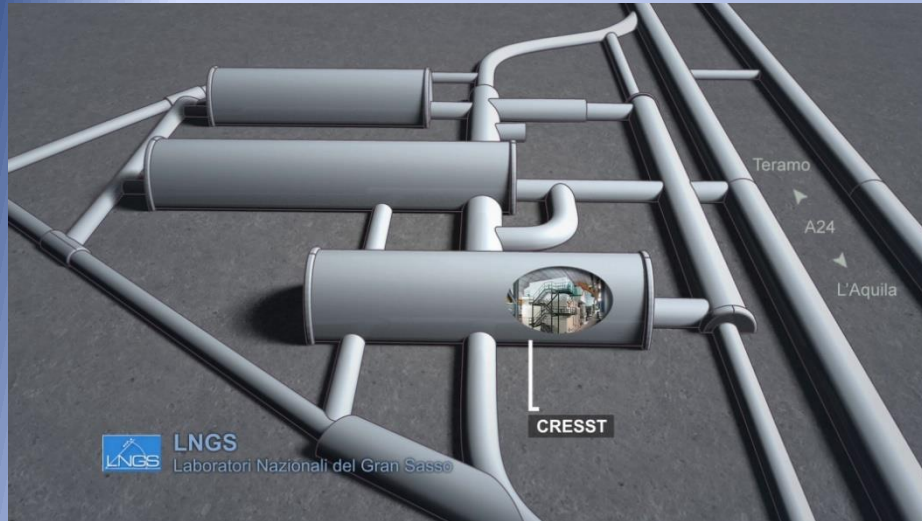


Image courtesy of University of California, Berkeley

# CRESST

(Cryogenic Rare Event Search with Superconducting Thermometers)



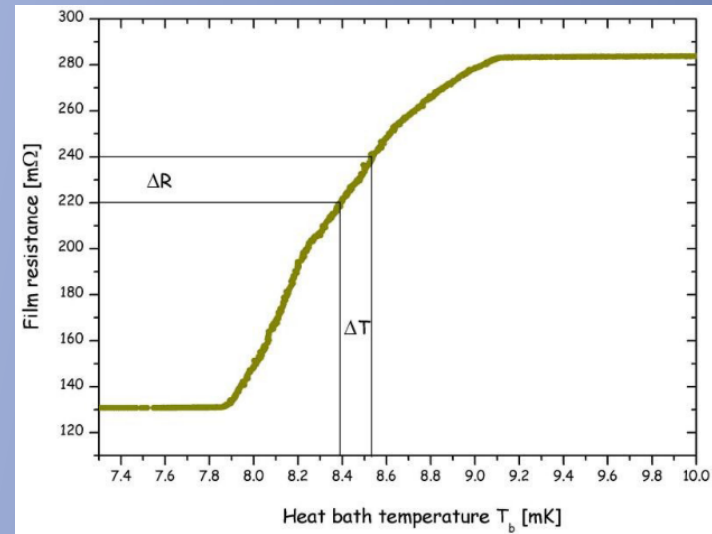
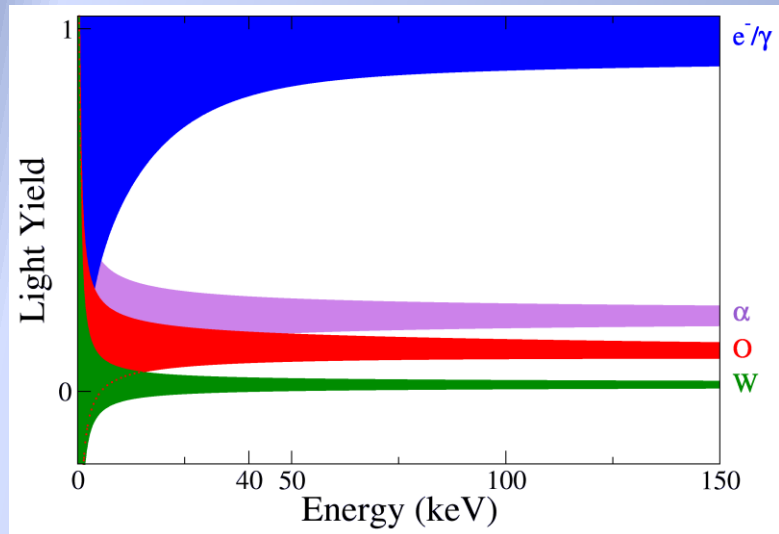
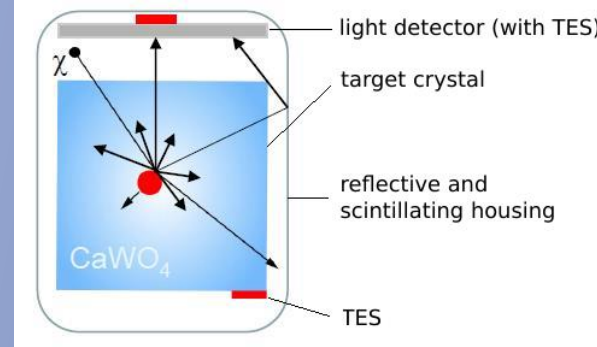
➤ **Target:**  
**CaWO<sub>4</sub> crystals**  
**(scintillating)**



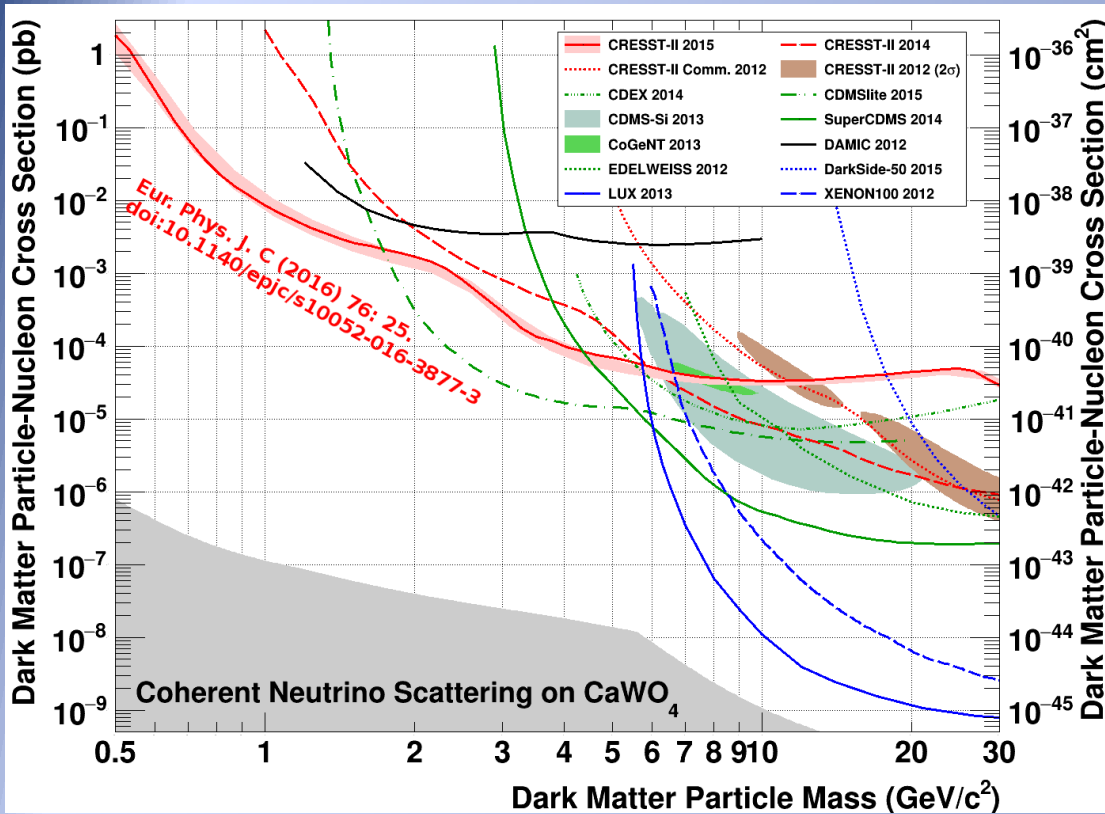
- **Located underground at Laboratori Nazionali del Gran Sasso (LNGS)**
- **Operational in different configurations since 1999**
- **CRESST-III Phase one started in July 2016**
- **Previous result: CRESST-II Phase 2 in 2015**

# CRESST working principle

- Readout based on two channels
  - **Phonon signal** (heat)  $\rightarrow$  recoil energy
  - **Scintillation light**  $\rightarrow$  particle separation
- Operation as cryogenic calorimeter
- Temperatures  $\sim 10$  mK

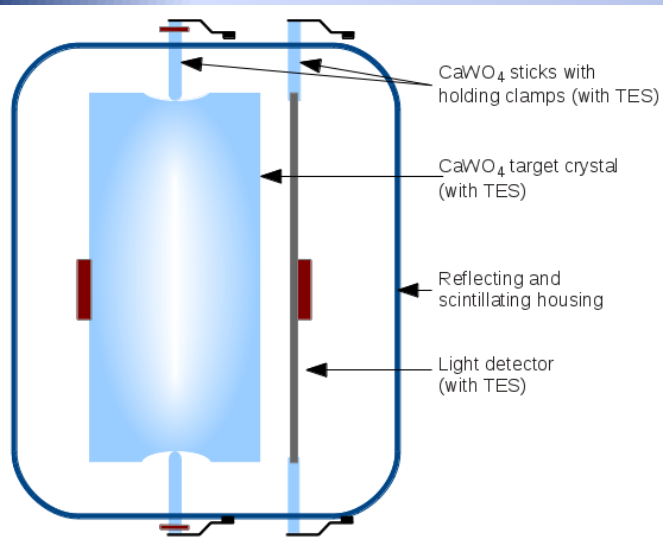


# Where we start off...



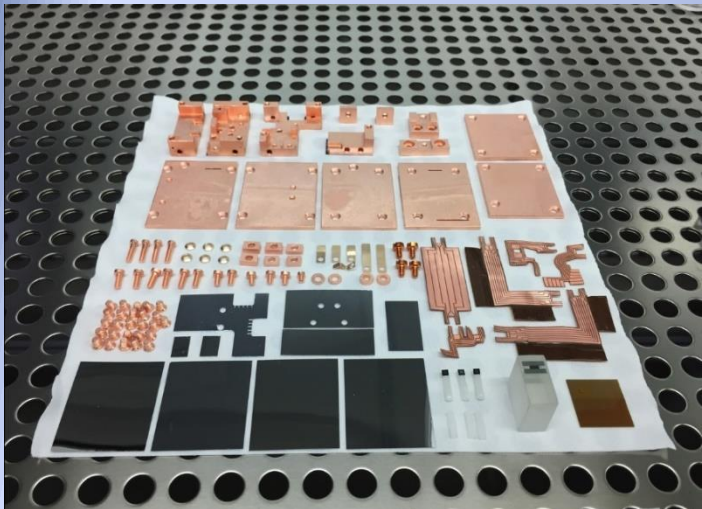
- Achieved with threshold of 307 eV
- (Flat) background at 8.5 counts / (keV kg day)
- World-leading below 1.7 GeV/c<sup>2</sup>

# The CRESST-III experiment



- Improved detector design
- In older designs:  
Background events due to metal holding clamps  
  
-> **Included instrumented sticks to measure background (already for some modules since 2014)**

- Fully scintillating housing
- Design goal: nuclear recoil thresholds of **100eV** and below
- Operating since July 2016
  - High-Statistics gamma calibration
  - High-Statistics neutron calibration



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# Data characteristics: Short overview

- **Hardware threshold (measured with test pulses): 48 eV**
- **Analyzed data period: 31.10.2016 - 05.07.2017**
- **Non-blind data (dynamically growing): 20% , randomly selected**
- **Detector mass: 24 g**
- **Total live-time: 2391 h**
- **Total exposure: 2.39 kg days**
- **Net exposure: 2.21 kg days**
- **Analysis threshold: 100 eV**

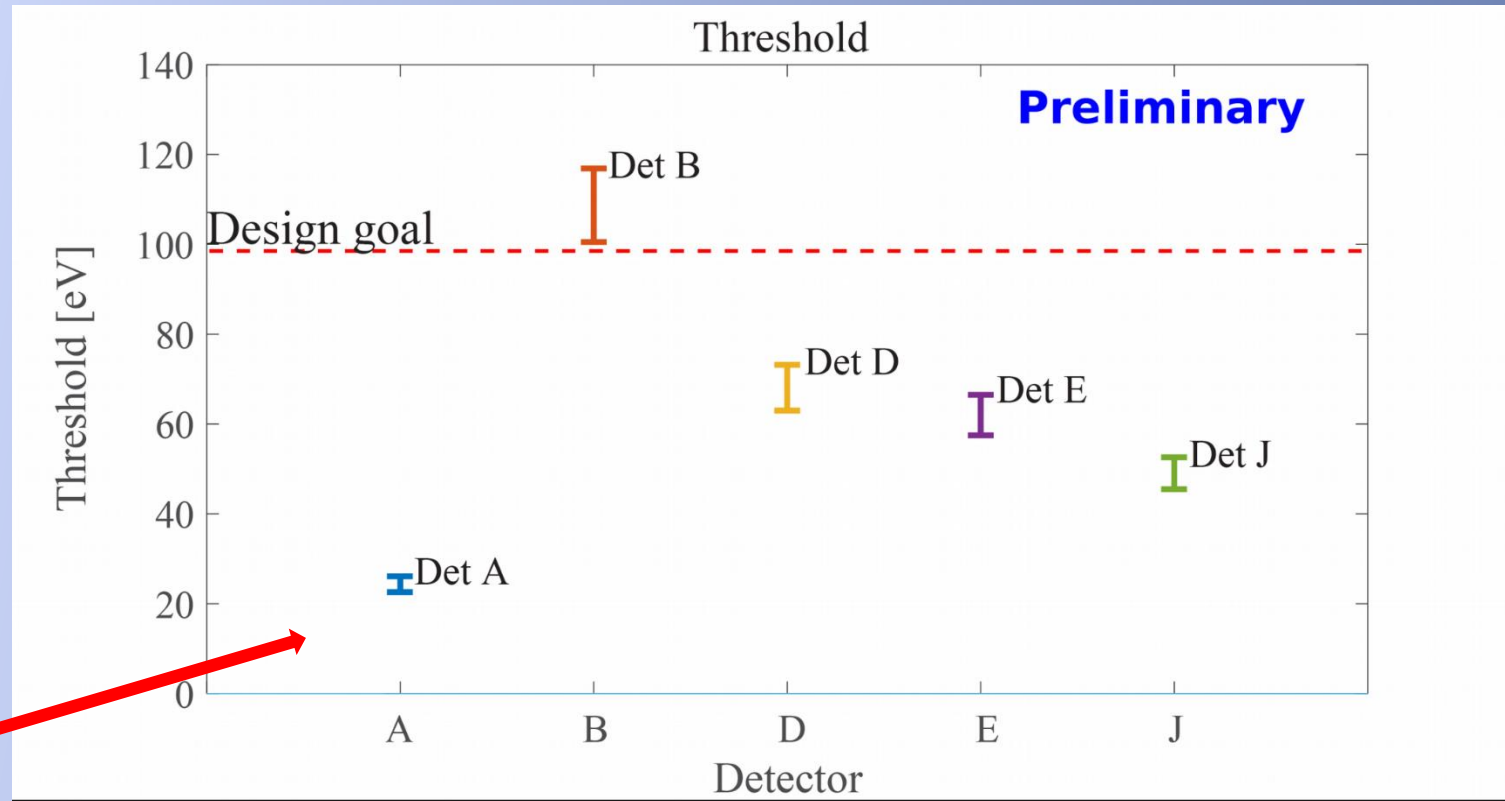
# Preliminary Thresholds

## Strategies:

- Smaller crystals (Det. A: 24g)
- Improved radiopurity
- ...

## Challenges:

- TES sensors
- Find optimal working point

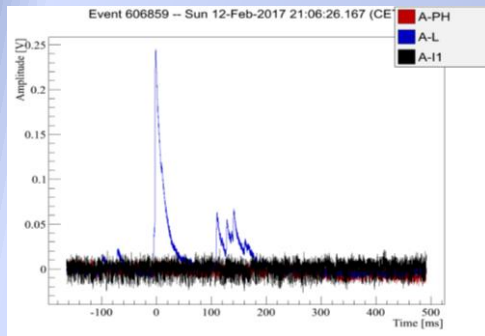
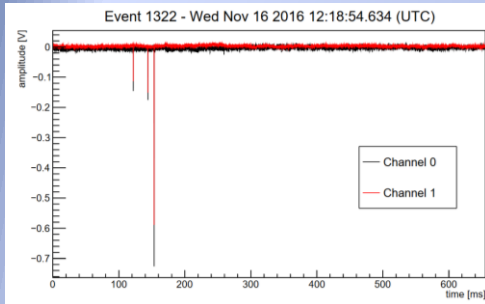


This analysis

(Measurement from continuous DAQ)

# Event Selection

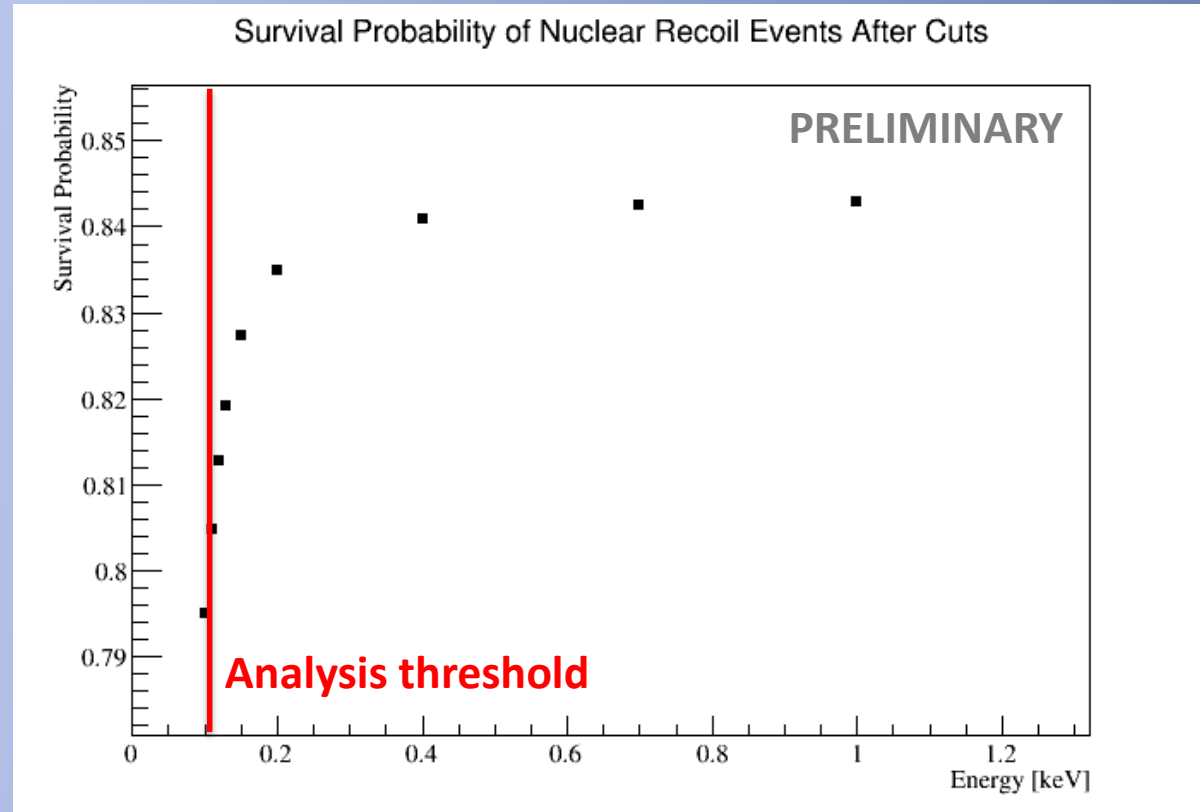
Apply cuts to remove pulses for which correct amplitude determination is not guaranteed



- General data quality:  
Events which cannot be properly analyzed (e.g. Electronic features, external disturbance)
- Pulse shape quality:  
events in iSticks, pileup
- Coincidences:  
Events coincident with muon veto and iSticks

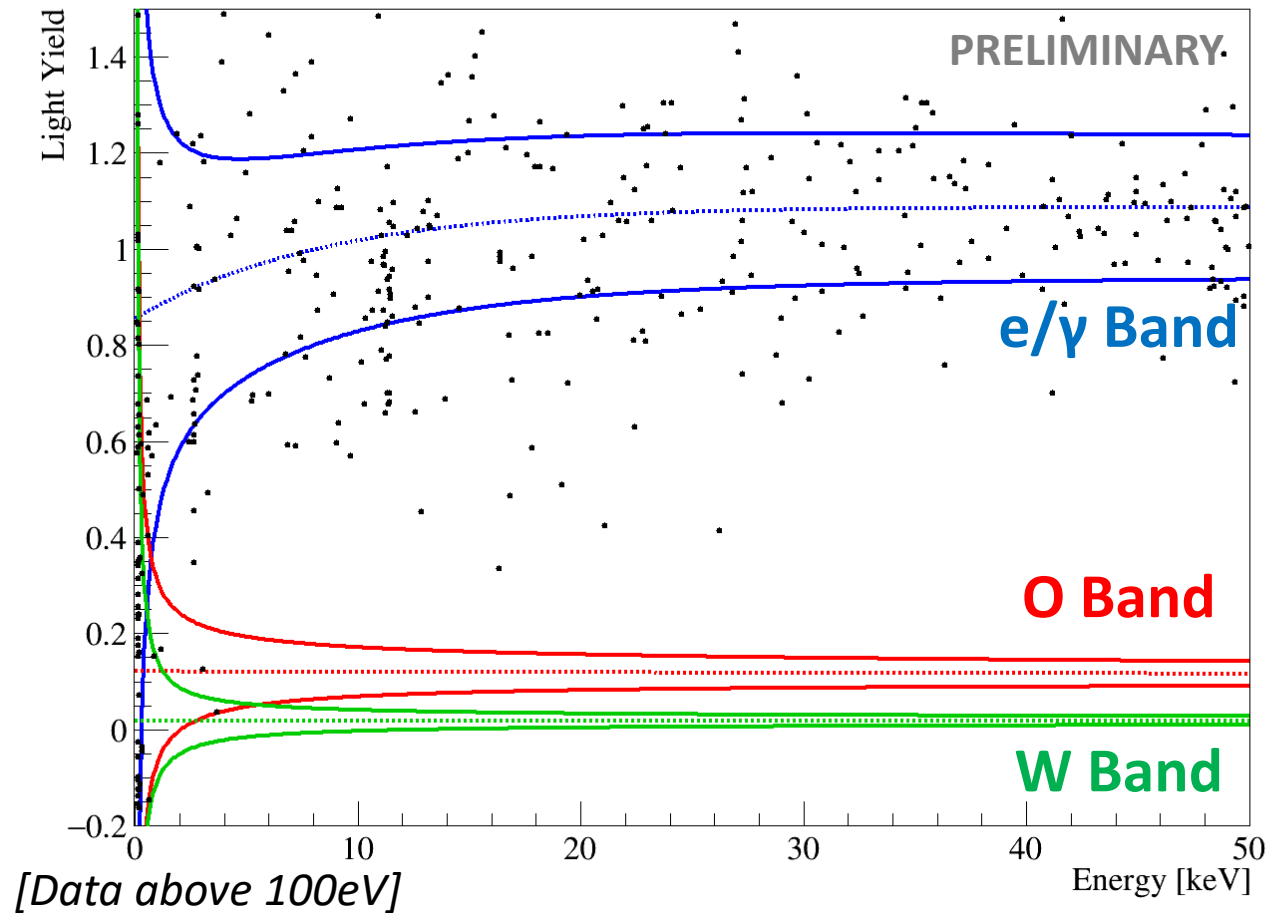
# Cut efficiency in 100 eV analysis

- Reduced efficiency due to cuts
- Simulate signal pulses
- Determine survival probability as function of energy



➔ Incorporated into limit calculation

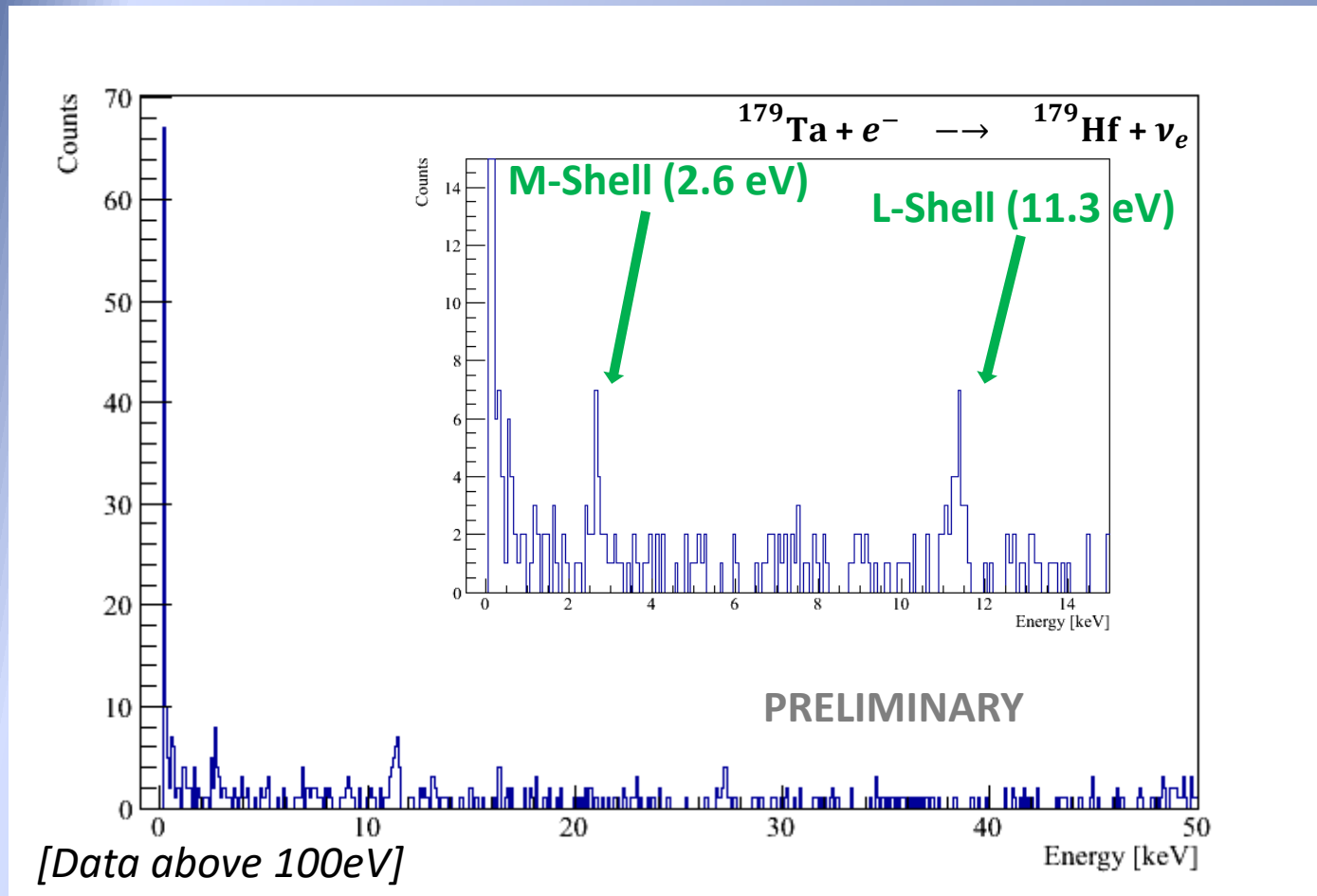
# Results of unblinded 100 eV analysis



- Bands obtained from neutron calibration and quenching factors from previous run

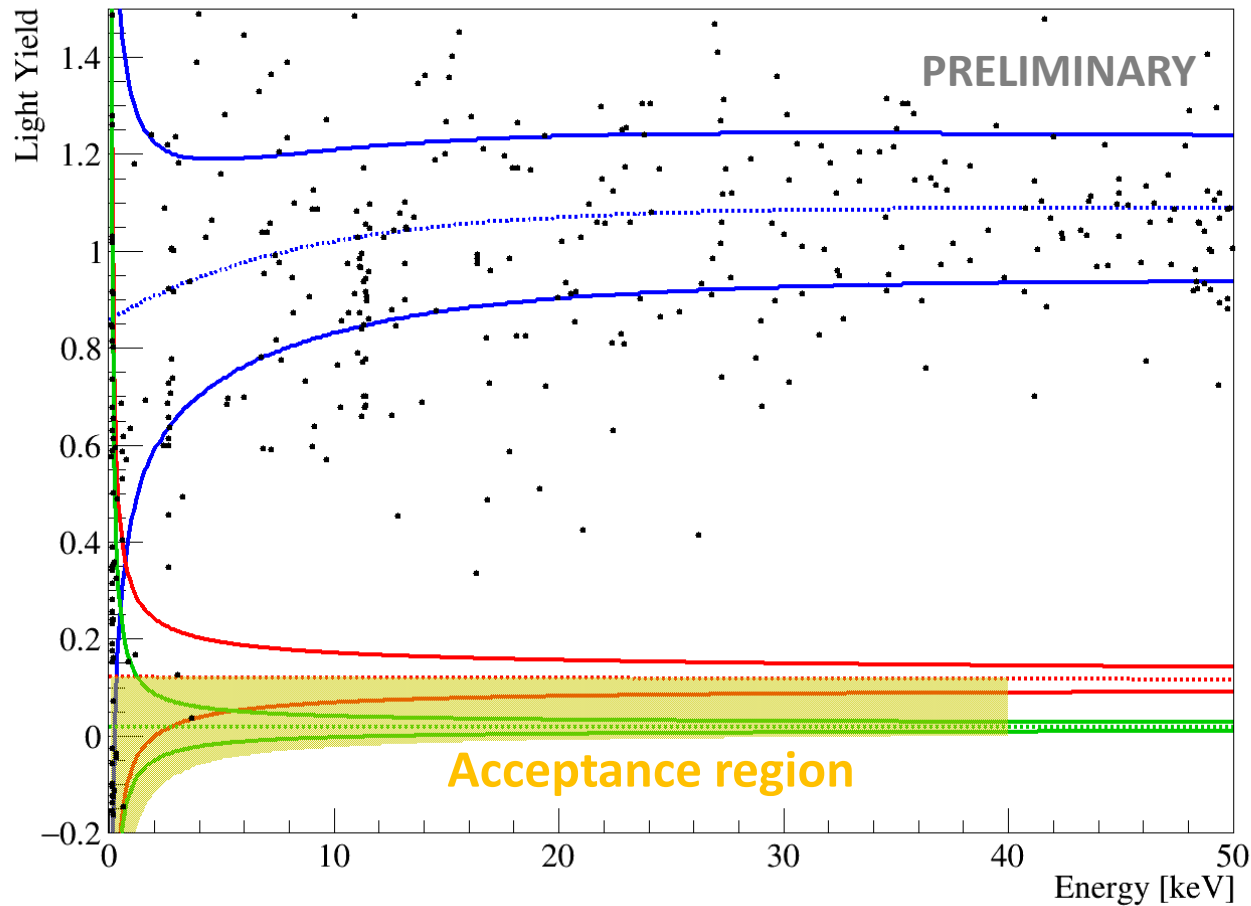
# Results of unblinded 100 eV analysis

## ➤ Projection on phonon energy (no LightYield cut):



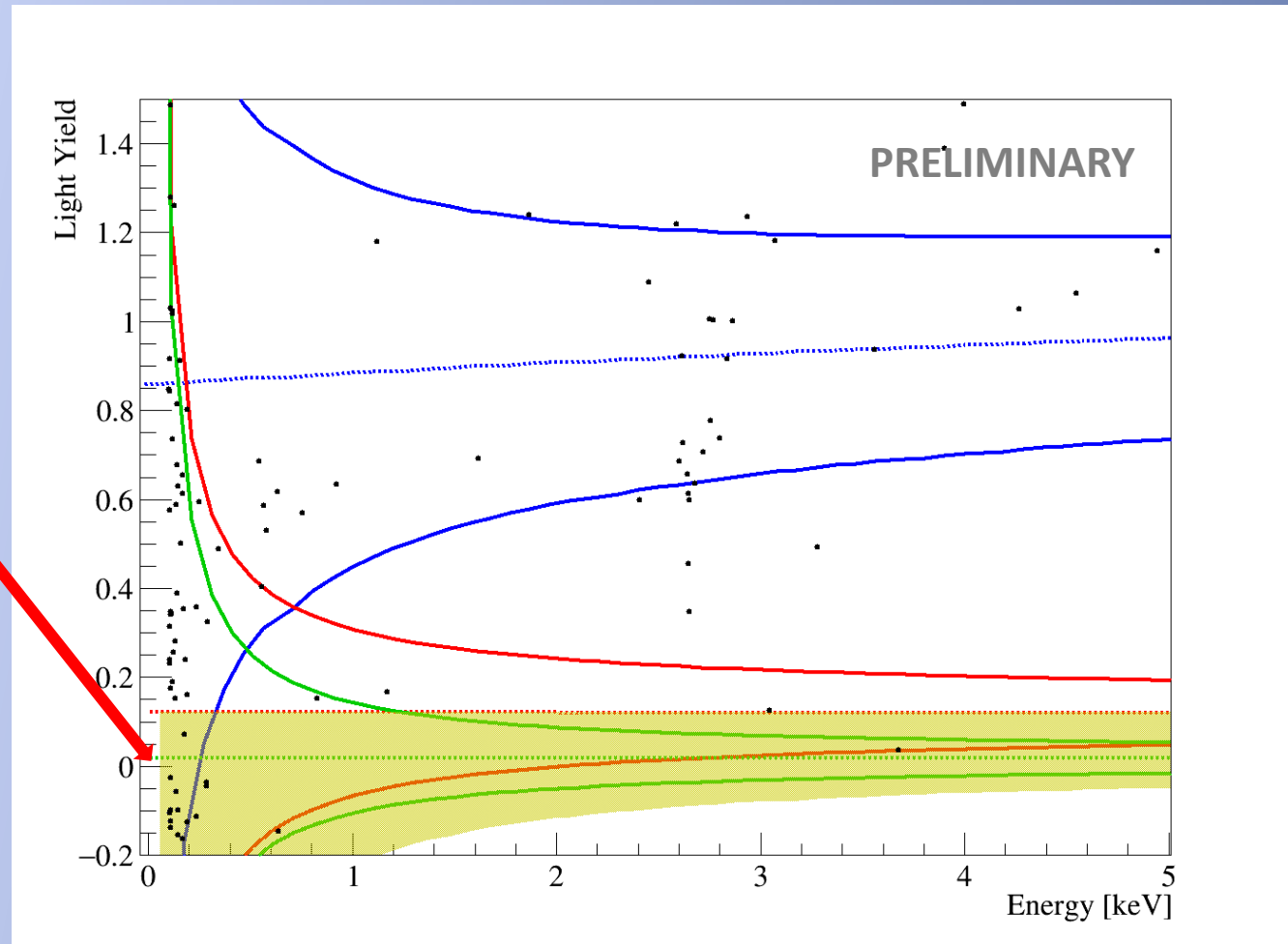
- Spectrum shows lines from intrinsic contaminations
- Flat background at 3 counts / (keV kg day)

# Results of unblinded 100 eV analysis

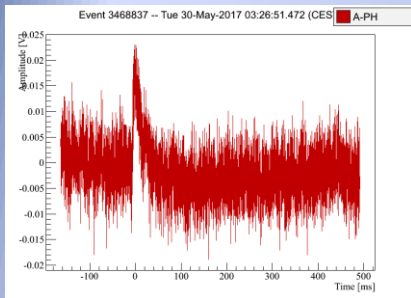


- Consider every event in acceptance region to be of DM origin
- Conservative approach for exclusion limit

# Results of unblinded 100 eV analysis



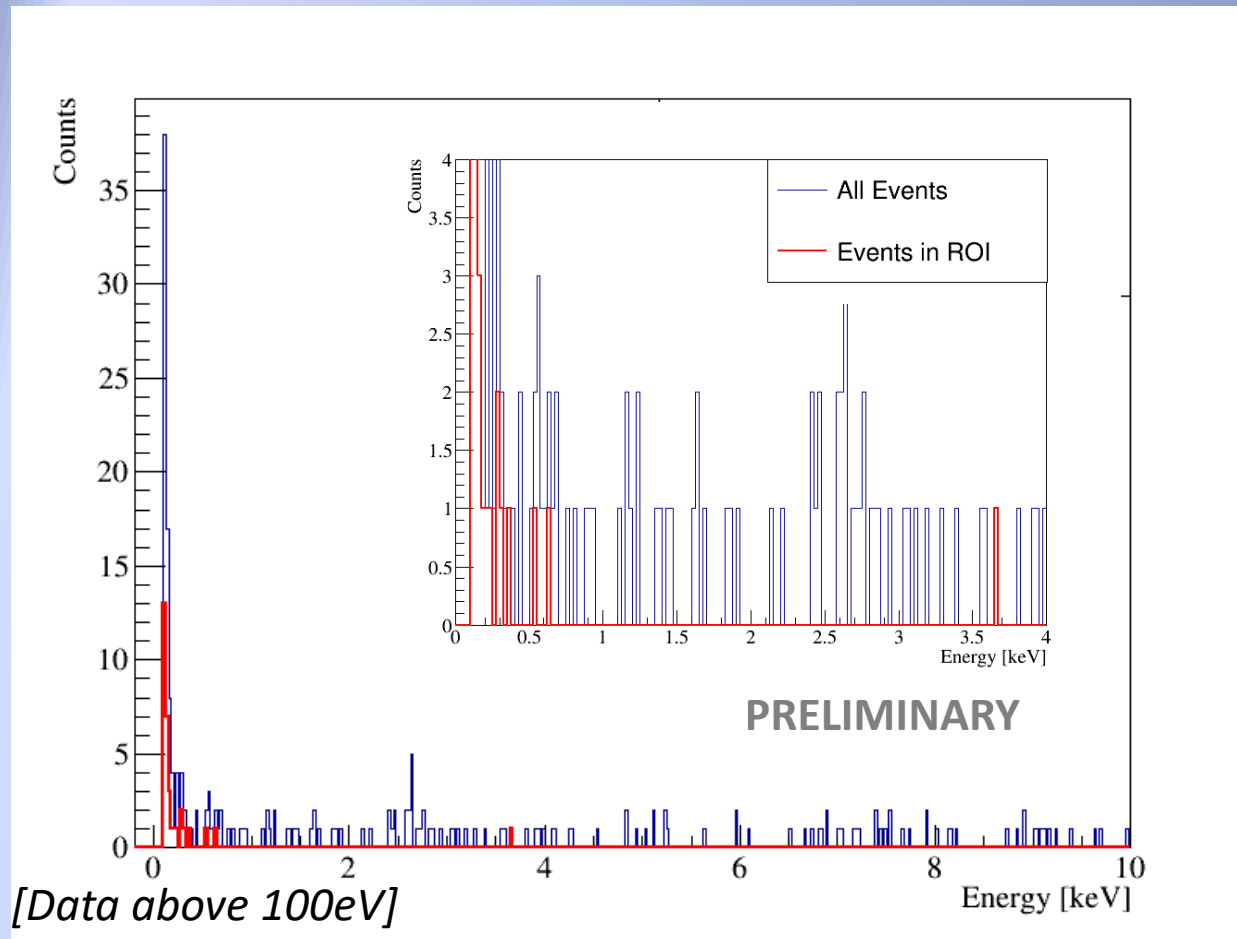
*New background  
appears around 100 eV*



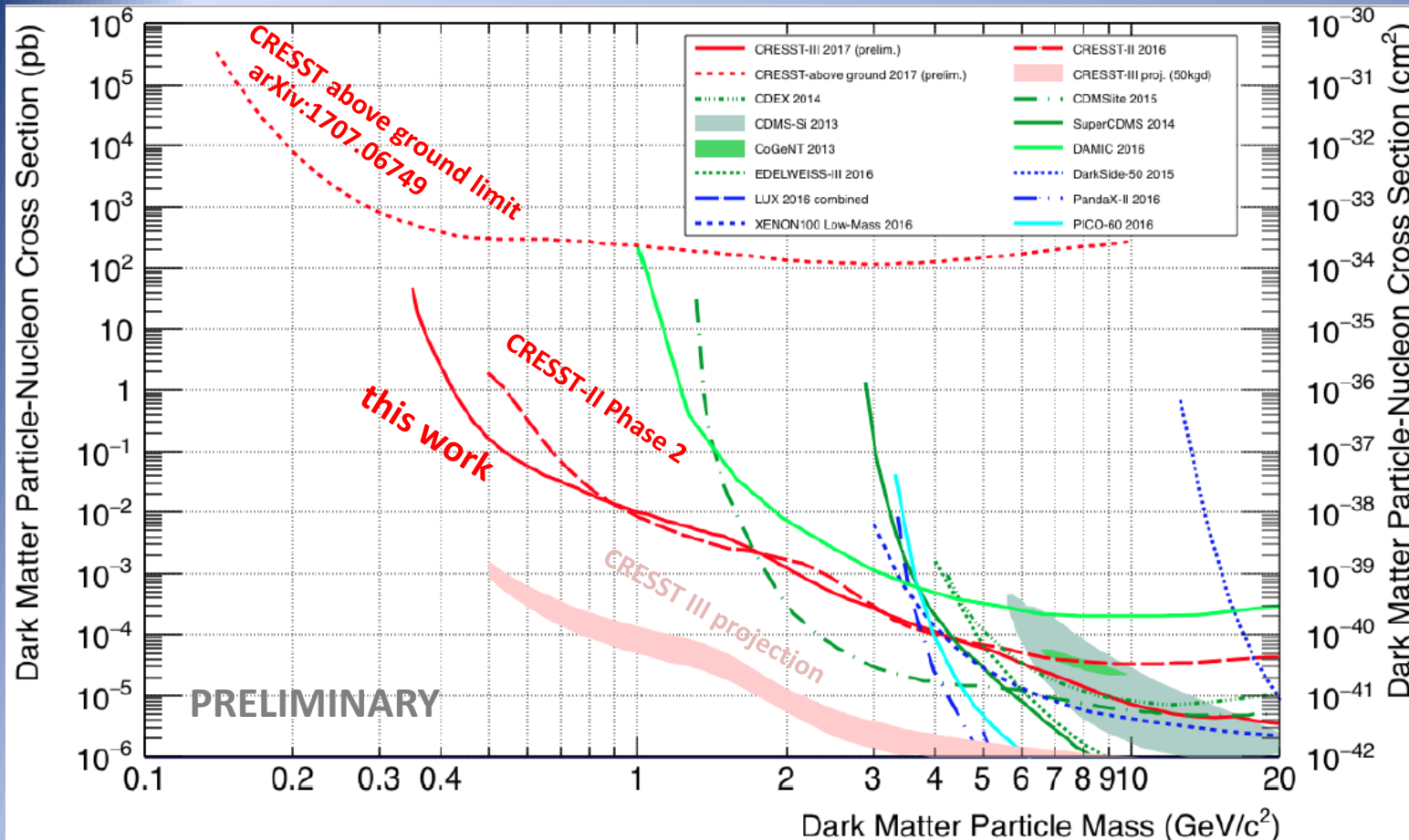
➤ **Origin (yet) unknown**

# Results of unblinded 100 eV analysis

- Projection on phonon energy (with region of interest)



# Preliminary analysis results



- Extended exclusion limit down to DM particle masses of 0.35 GeV/c<sup>2</sup>
- Improved previous result above 10 GeV/c<sup>2</sup> and below 1 GeV/c<sup>2</sup> by one order of magnitude
- Currently background limited in the 1-10 GeV/c<sup>2</sup> range

# Outlook

- Understand new background  
(More statistics, distinct separation criterion, ...)
- High-threshold analysis above 100 eV to be performed for other detectors
- Low-threshold analysis will exploit full potential of detectors



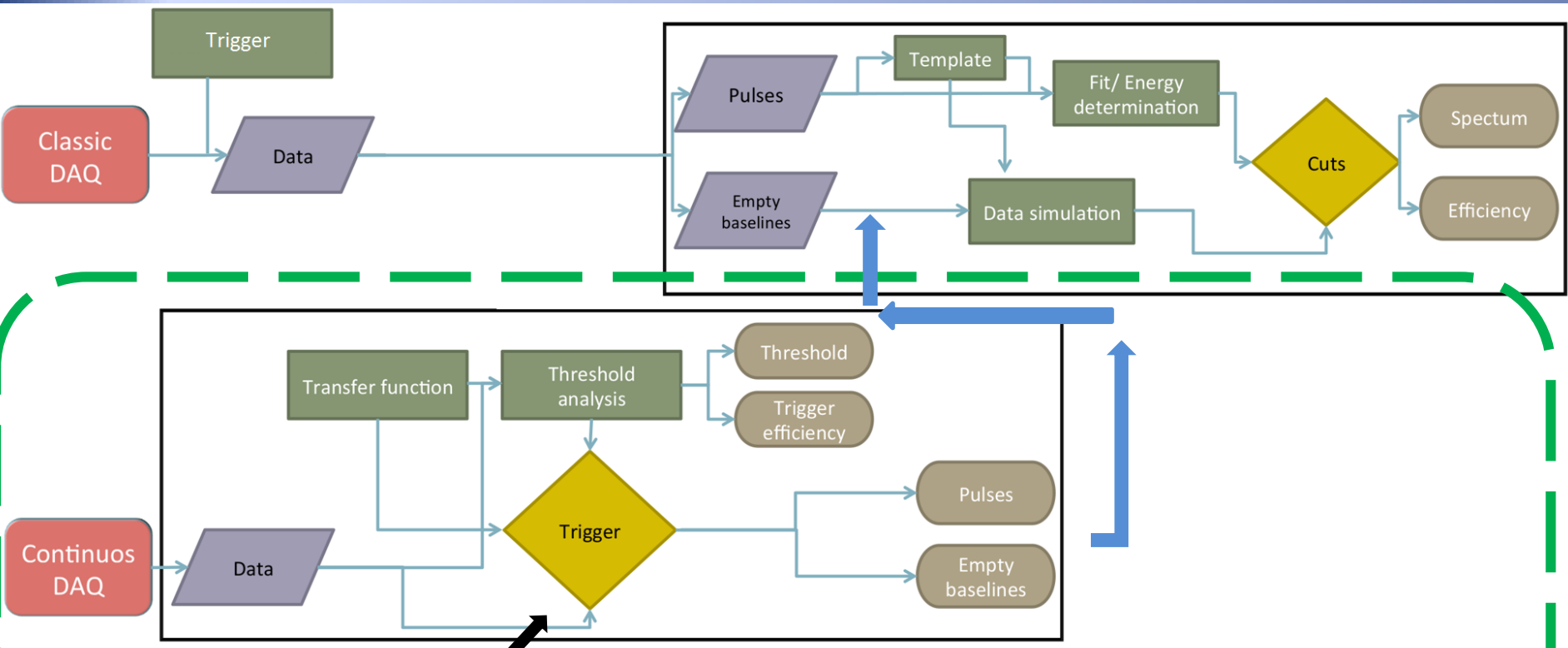
**More results to come!**

**Thank you!**

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# Analysis Workflow

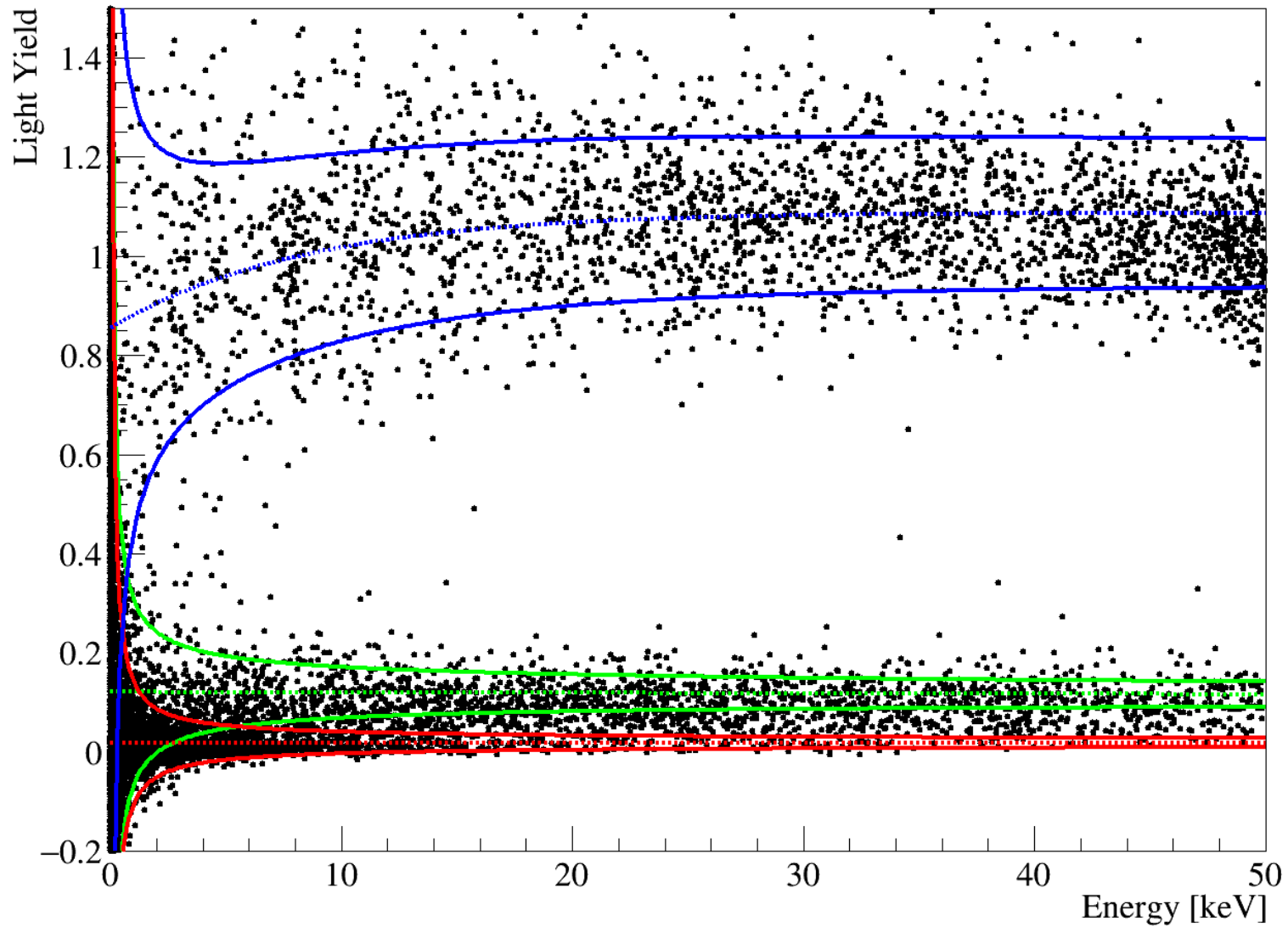
➤ Introduced continuous DAQ in addition to classical one



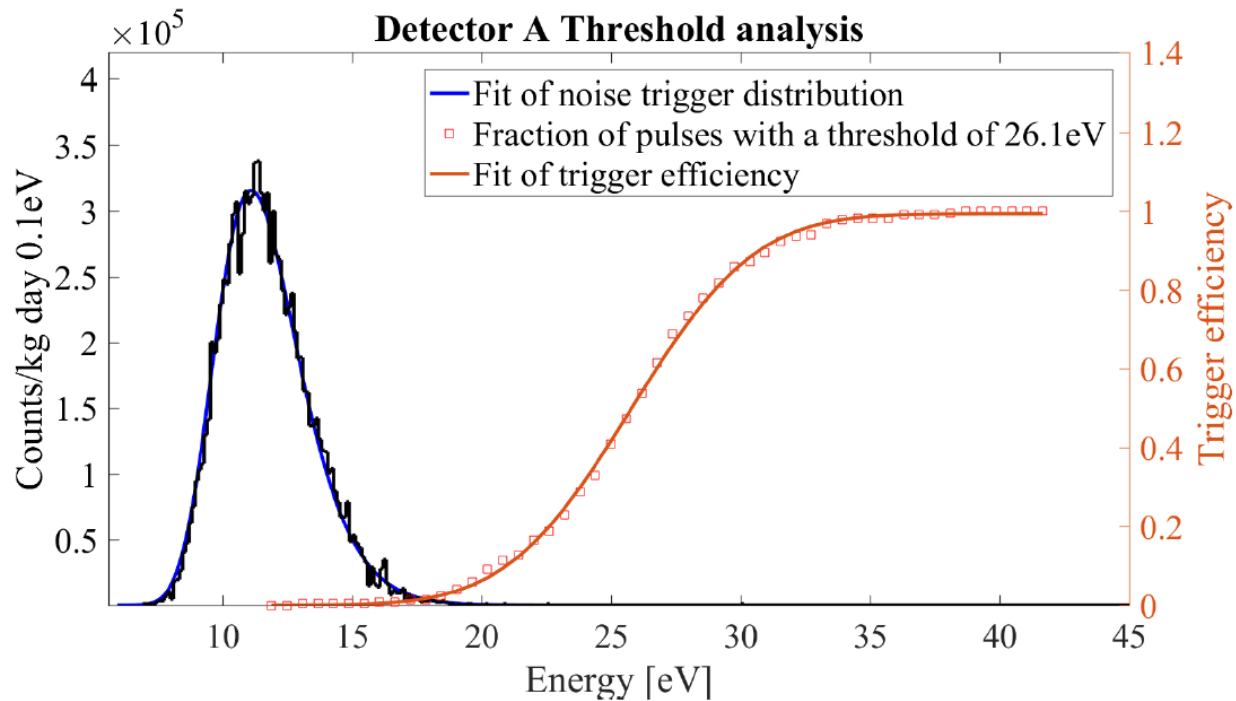
*Can now be optimized after data taking*

**NEW**

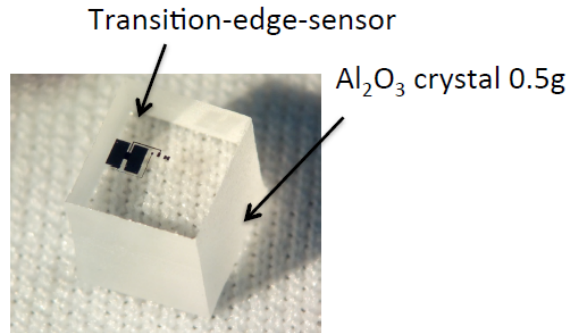
## Neutron calibration



# Trigger-threshold as determined with the optimum trigger



## Gram-Scale Calorimeters



### First prototype detector successfully tested:

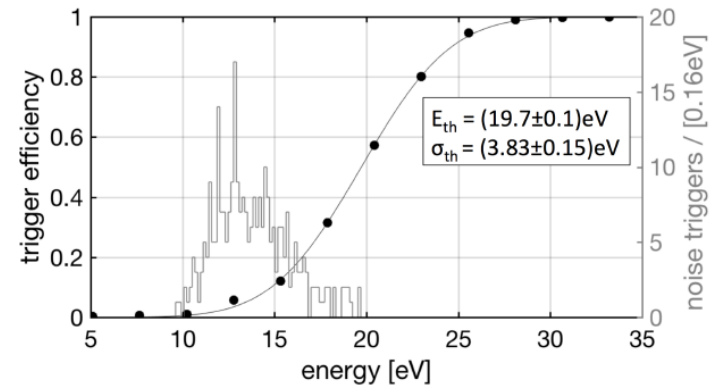
- operated above ground
- setup without shielding

→ Operation in high-background environment demonstrated

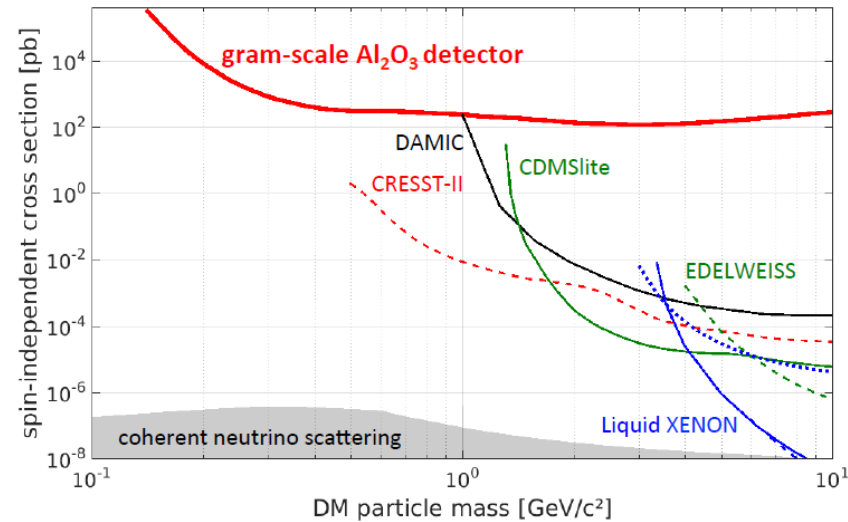
### Ultra-low threshold reached:

- $E_{th} = 19.7\text{eV}$  for nuclear recoils

- Threshold goal for CNNS achieved above ground
- Sensitivity to a new range of MeV-scale dark matter



## Results from a Gram-Scale Calorimeter



Extending dark matter searches to masses below 500MeV/c<sup>2</sup>

- Robust analysis, no data-quality cuts applied
- Use Yellin optimum interval method