13th International Conference on Topics in Astroparticle and Underground Physics

Dark Matter search with CUORE-0 and CUORE

Matteo Biassoni on behalf of the CUORE Collaboration

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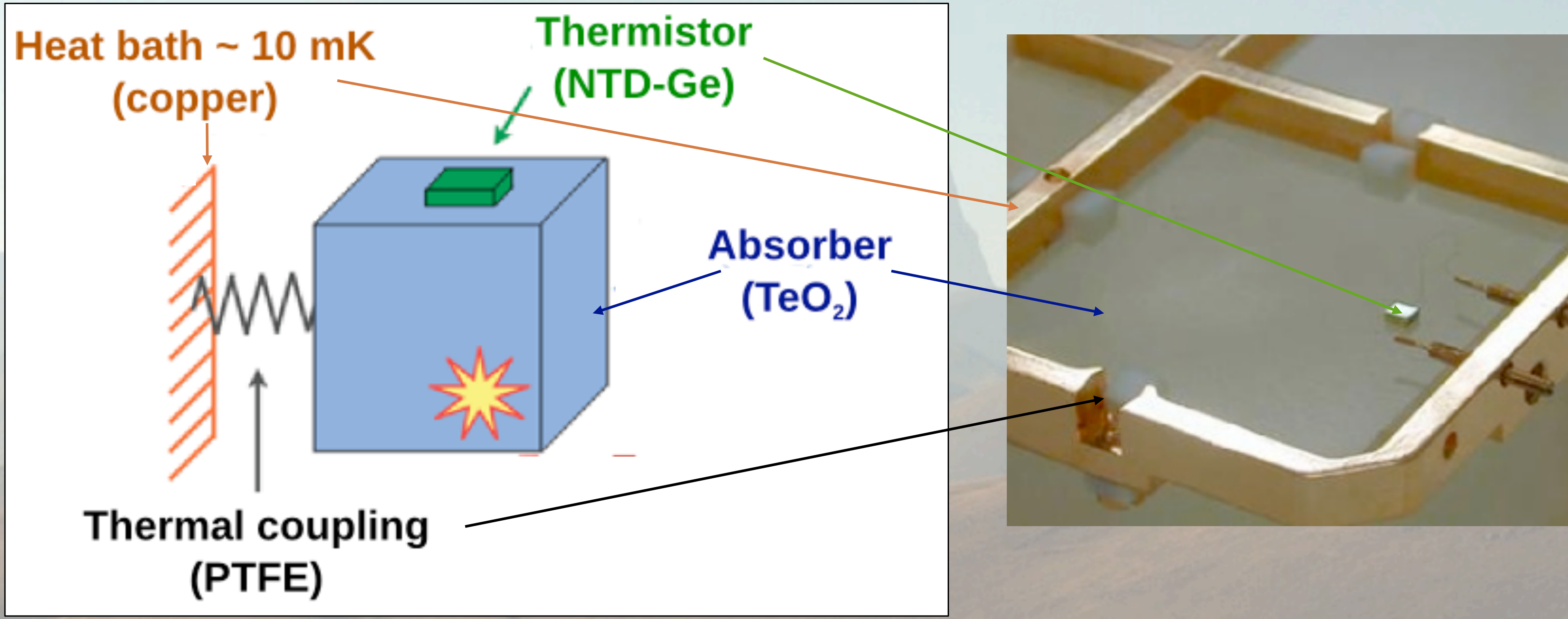
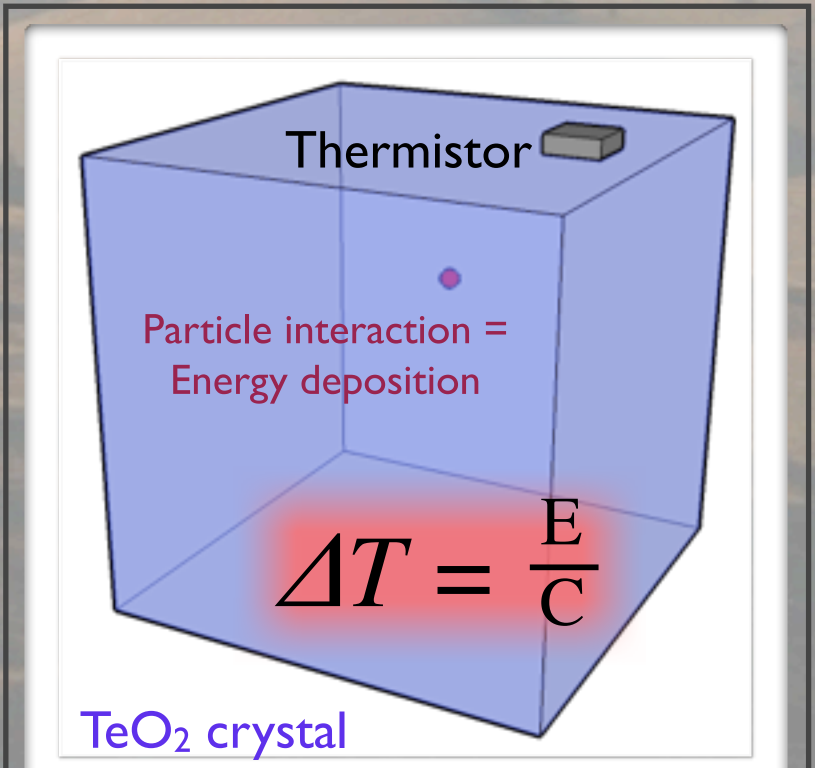
OUTLINE

- The bolometric technique and the search for rare events with TeO_2
- CUORE(-0) experiment: Double Beta Decay and rare events
- DM detection in bolometers
- The low energy bkg and CCVR2 test run
- CUORE DM sensitivity: spectrum modulation fit
- Results
- Conclusions

Bolometric technique





Particle energy is converted into phonons by dielectric and diamagnetic absorbers whose heat capacity ($C \propto T^3$) is very low at low T (~10mK)

- Crystal Absorber (TeO_2): $E \rightarrow \Delta T$
- Biased T sensor (NTD-Ge): $\Delta T \rightarrow \Delta V$
- Thermal link (PTFE+gold wires): $T_0 \sim 10$ mK

CUORE experiment

Cryogenic Underground Observatory for Rare Events

Necessary features for $\beta\beta 0\nu$ search:

- huge mass (741kg TeO_2 active mass)
- good energy resolution
- low background (underground, material selection)
- high efficiency

CUORE additional features:

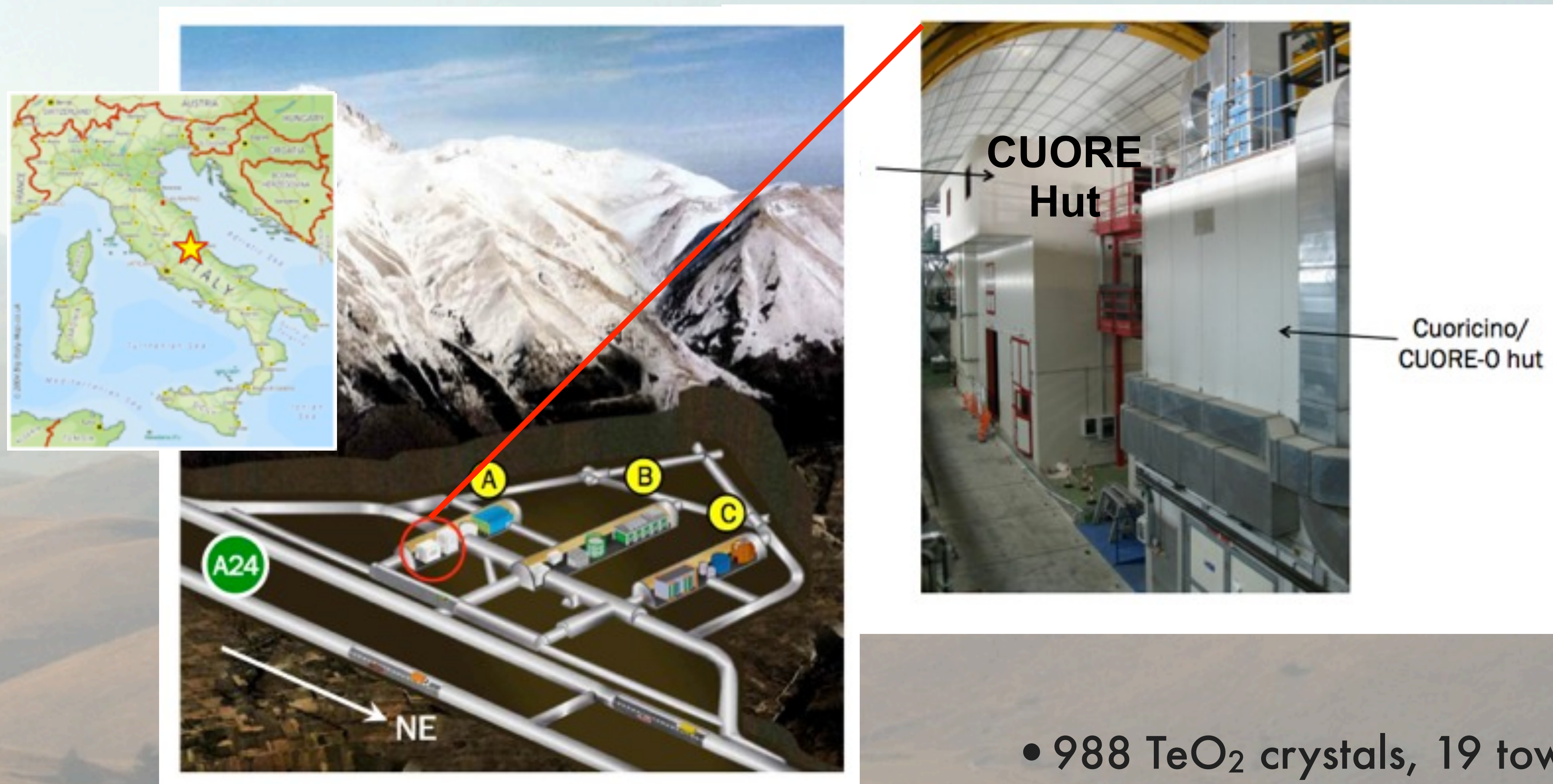
- modularity
- same yield for alpha particles, beta/gamma particles and nuclear recoils
- low threshold
- online pulse shape analysis at low energy

Thanks to these features CUORE is a powerful tool also for the study of phenomena other than DBD

OBSERVATORY for RARE EVENTS

rare nuclear decays
dark matter
solar axions
supernova neutrinos
artificial sources neutrinos (?)

CUORE status



CUORE-0, the first CUORE tower, already taking data at LNGS

See K. Han talk in double beta decay session

- 988 TeO_2 crystals, 19 towers
- 741kg of TeO_2 (592kg Te, 149kg O)
- Construction phase
- Start cool down: end 2014
- @ LNGS HallA

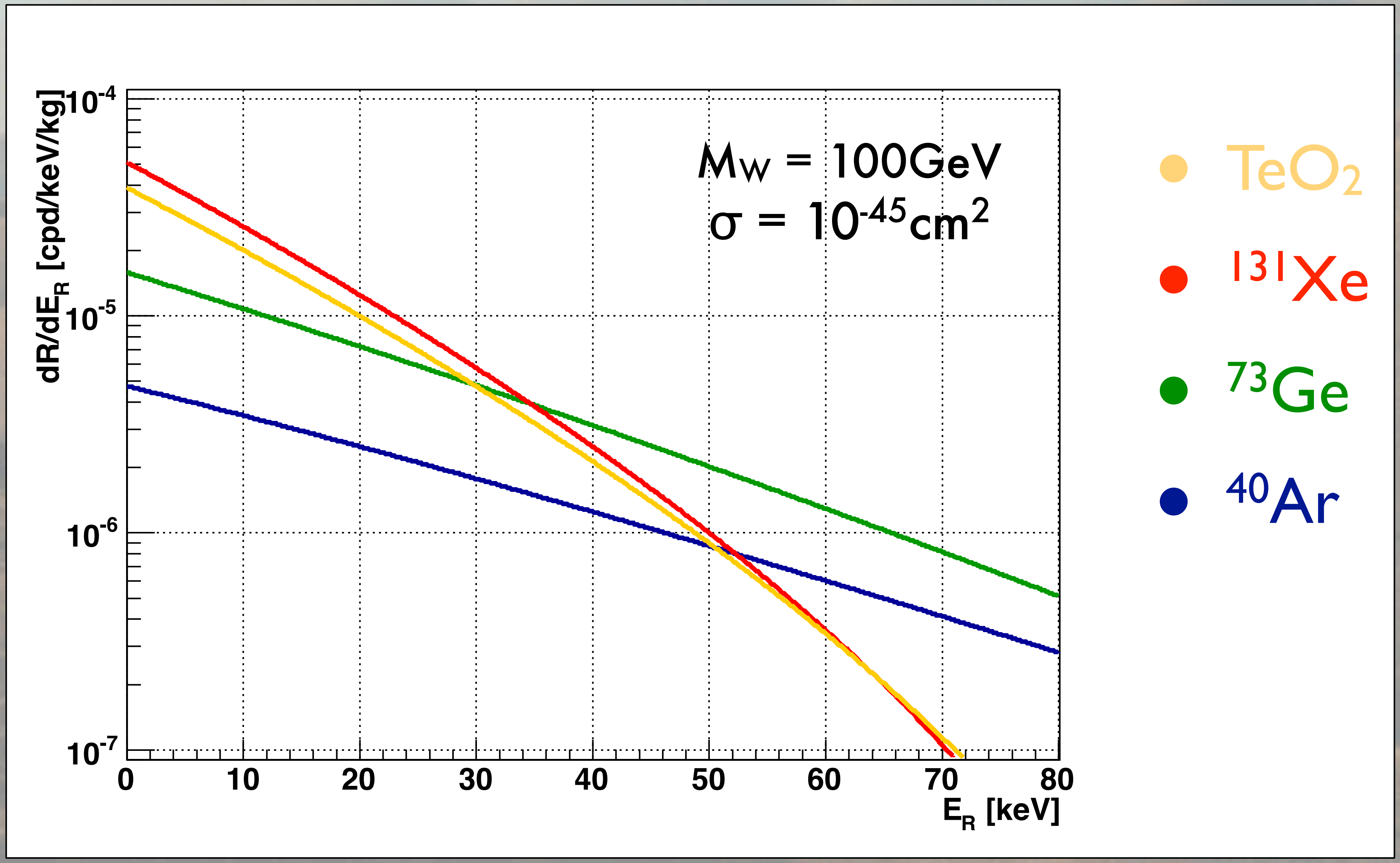
CUORE-0

- First CUORE-like tower
- Cold in CUORICINO cryostat
- Data taking since March 2013
- Until now: detector optimization for double beta decay search and high energy background study
- Background in the double beta decay region released in this conference
- Detector optimization for low energy region just started
- Low energy data will be released in the near future

See M. Vignati talk in double beta decay session

DM with TeO_2

- Detection mechanism: coherent scattering of WIMP on detector nuclei
- Spin-dependent cross section highly suppressed, almost only spin-independent interactions
- Both heavy (Te) and light (O) targets in the same detector
- Scattered nucleus recoils in the crystal lattice, energy converted into heat



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- PROS:

✓ large mass, long term stability ==> seasonal modulation of events number

✓ high energy resolution ==> seasonal modulation of spectral shape

✓quenching factor = 1, all recoils detected in the same way

✓ detection efficiency =1, basically all recoils are fully contained

- CONS:

✓ recoil energy is typically small (depending on nucleus and WIMP mass) ==> LOW THRESHOLD REQUIRED (<25keV)

✓ no particle identification (same signal for nuclear recoils, gammas, betas, alphas with the same energy)

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Great effort in lowering the threshold and reducing the background

Reducing the background

Background reduction efforts focused on Double Beta Decay region (2528keV):

- low radioactivity materials cryostat (CUORE only)
- heavy shielding with ultra-pure materials
- material selection
- rigorous cleaning procedures for all the detector parts
- assembly procedures carefully developed in order to minimize detectors recontamination probability

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Successfully applied and tested in CUORE-0

Mitigation of background sources is expected to positively affect also the background at low energy

Lowering the threshold

Standard "high energy" acquisition = THRESHOLD TRIGGER:

- threshold applied to raw data stream
- fast, reliable
- no discrimination between particle signals and baseline fluctuations/electronic noise
- not low enough (typically around 30keV)

Lowering the threshold

Standard "high energy" acquisition = THRESHOLD TRIGGER

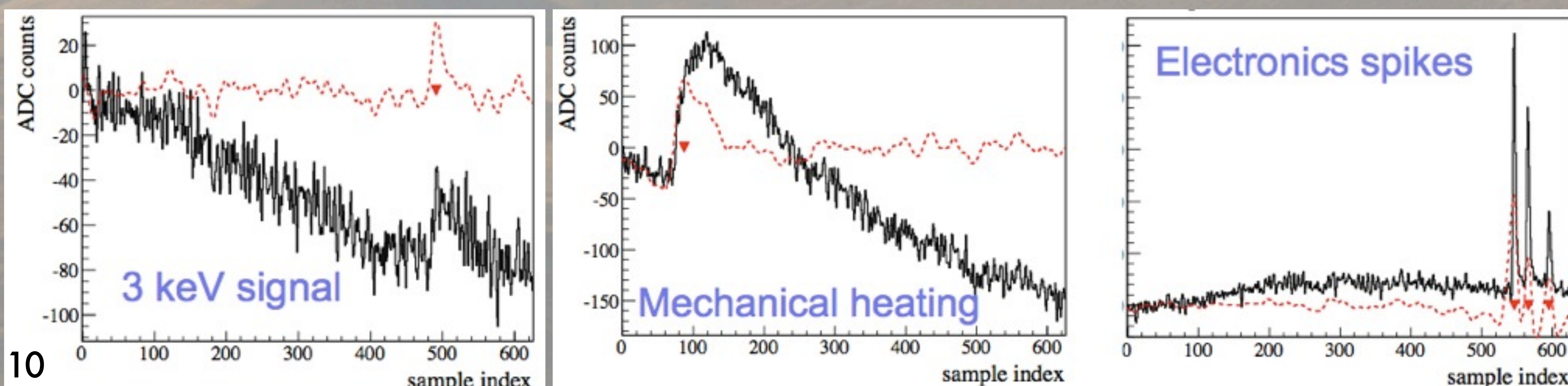
See G. Piperno poster

"Low energy" dedicated trigger = OPTIMUM TRIGGER:

- threshold applied to filtered data stream
- Matched Filter (Optimum Filter) based on expected signal shape and noise power spectrum (detector optimized)
- result:

  - filtered data stream has maximum signal-to-noise ratio

  - Optimum Trigger also returns a shape parameter based on how close is the signal shape to the expected one

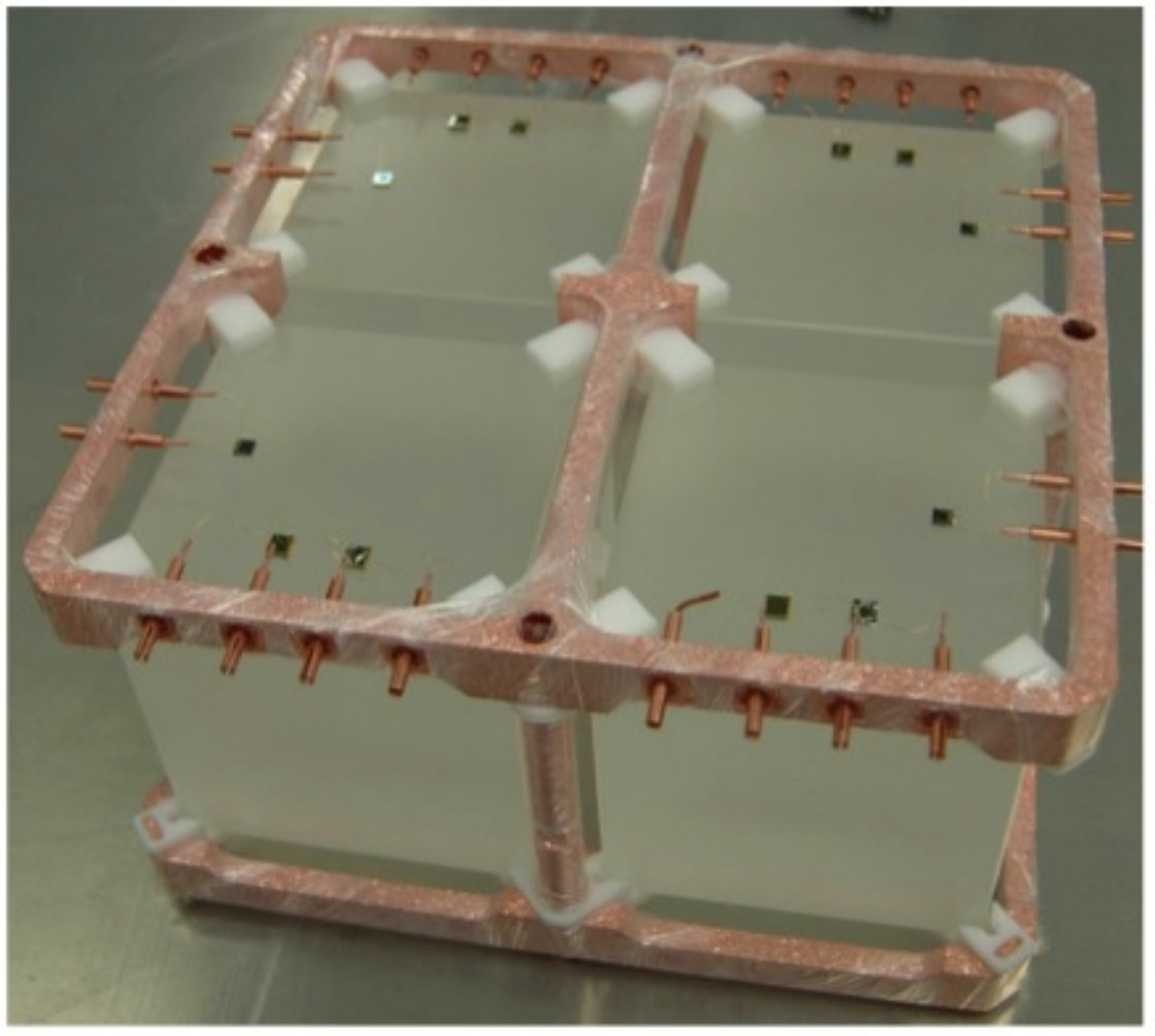


CCVR2: Low E demonstrator

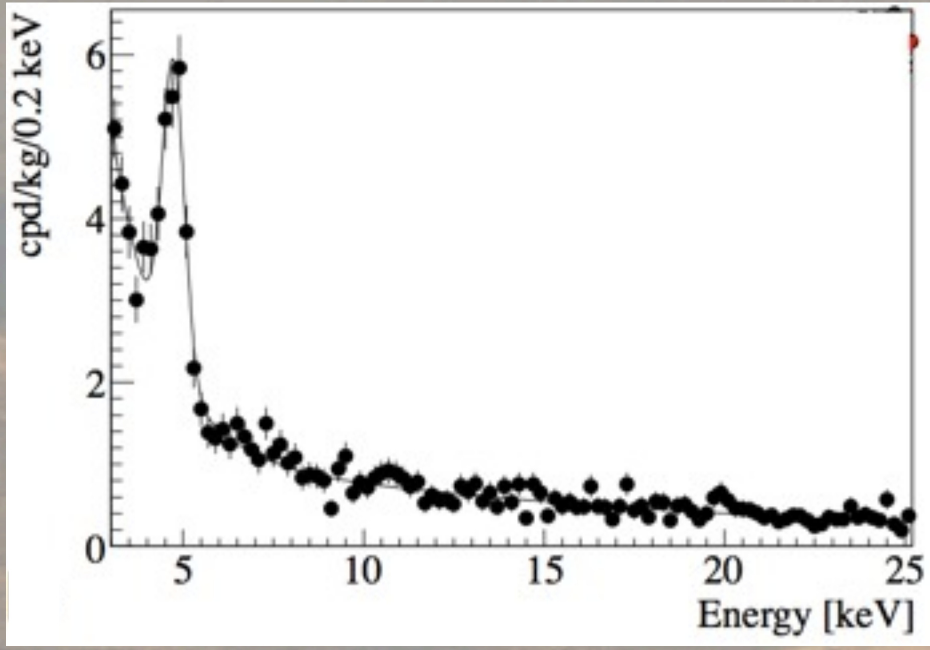
CCVRs were test runs of 4 crystal randomly chosen from each production batch of CUORE to test performance and purity.

The detectors have been cooled down in test cryostat in HallC at LNGS.

CCVR2 was triggered with OT and 3 out of 4 detectors reached a 3keV threshold



- 3 detectors
- About 40kg*day of exposure
- Threshold 3keV
- Integrated bkg = 15.3±1.5cpd/kg
- Bkg fitted with exp+exp+gaus p.d.f.



CUORE bkg/threshold demonstrator

Sensitivity evaluation

Bkg function

CCVR2*

Modulation function

$f(\sigma, M_w)$**

MC spectra generator based on ROOFIT tools

* JCAP01 (2013) 038 **Astropart.Phys.6,87,1996

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Fit with H_0 (no modulation) and $H_1(\sigma, M_w)$

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Sensitivity evaluation

Bkg function → CCVR2*

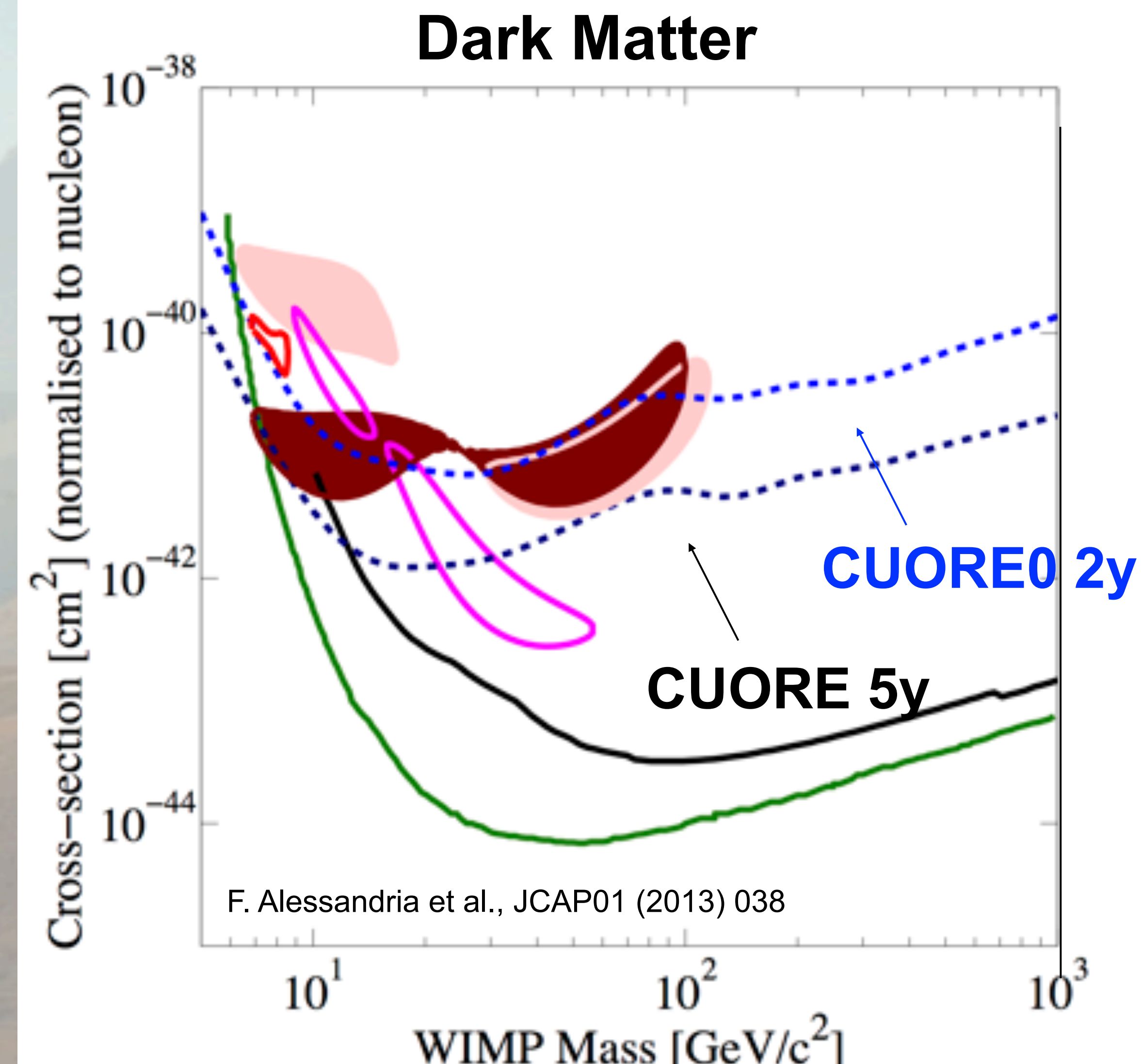
Modulation function → $f(\sigma, M_w)$**

MC spectra generator based on ROOFIT tools

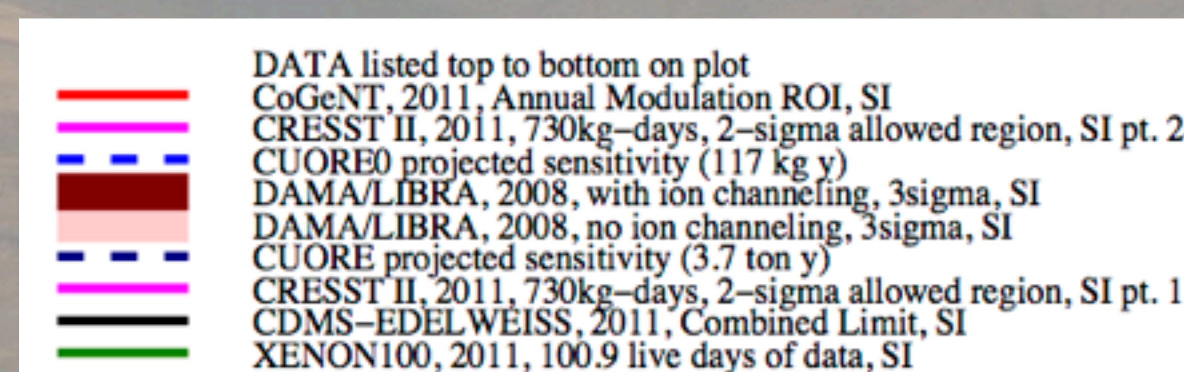
N spectra for each (σ, M_w)

Fit with H_0 (no modulation) and $H_1(\sigma, M_w)$

$P(\sigma, M_w) = N_{H1>H0}/N$



90% C.L. sensitivity to the cross-section for spin independent interactions normalized to nucleon



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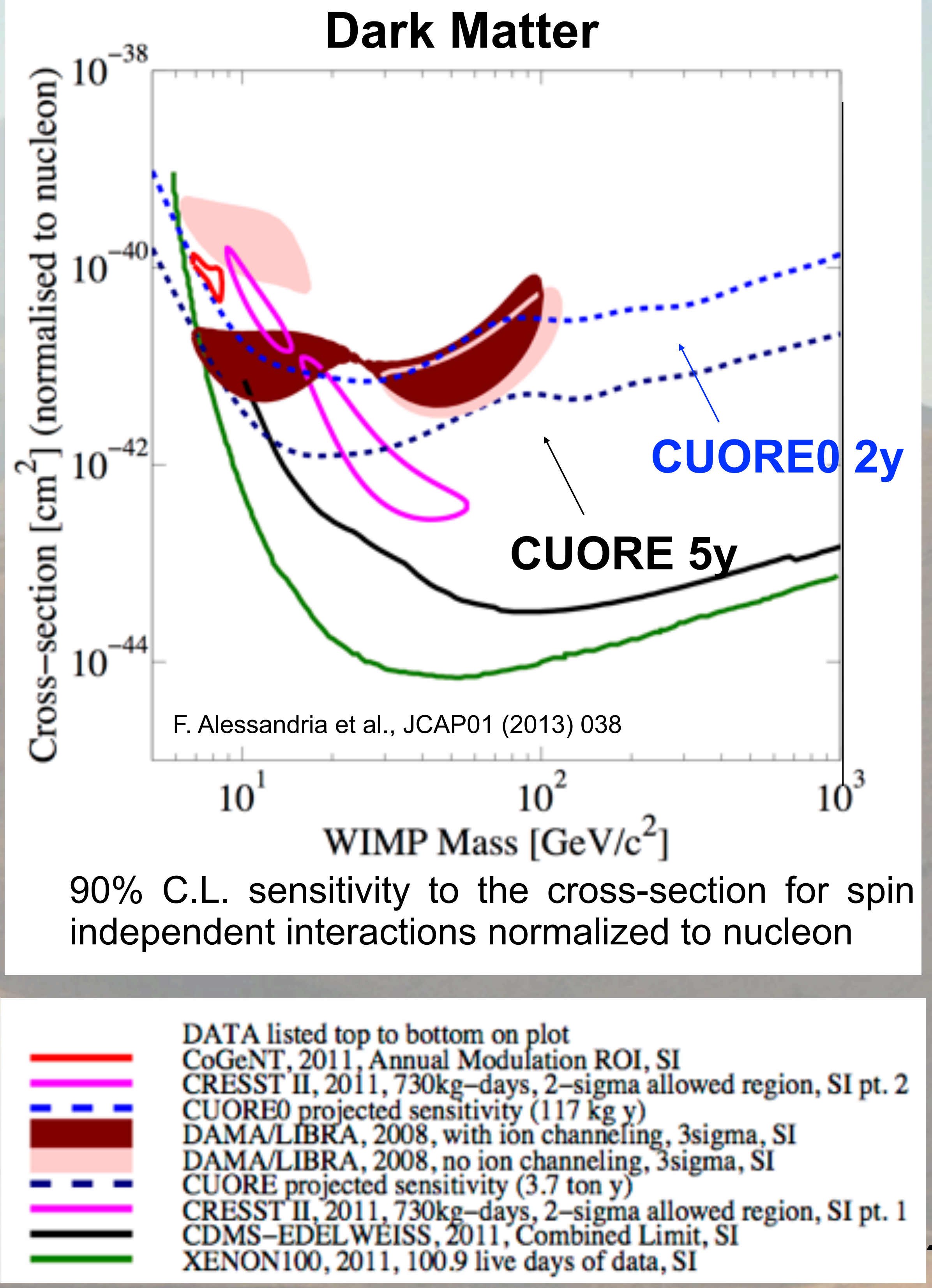
Sensitivity evaluation

CUORE contribution to DM search:

- upcoming 1ton scale, low background experiment
- large scale **solid state** detector (most competing experiments are liquid gas detectors)
- sensitive to spin independent annual modulation signal
- same location of many other DM experiments (LNGS)

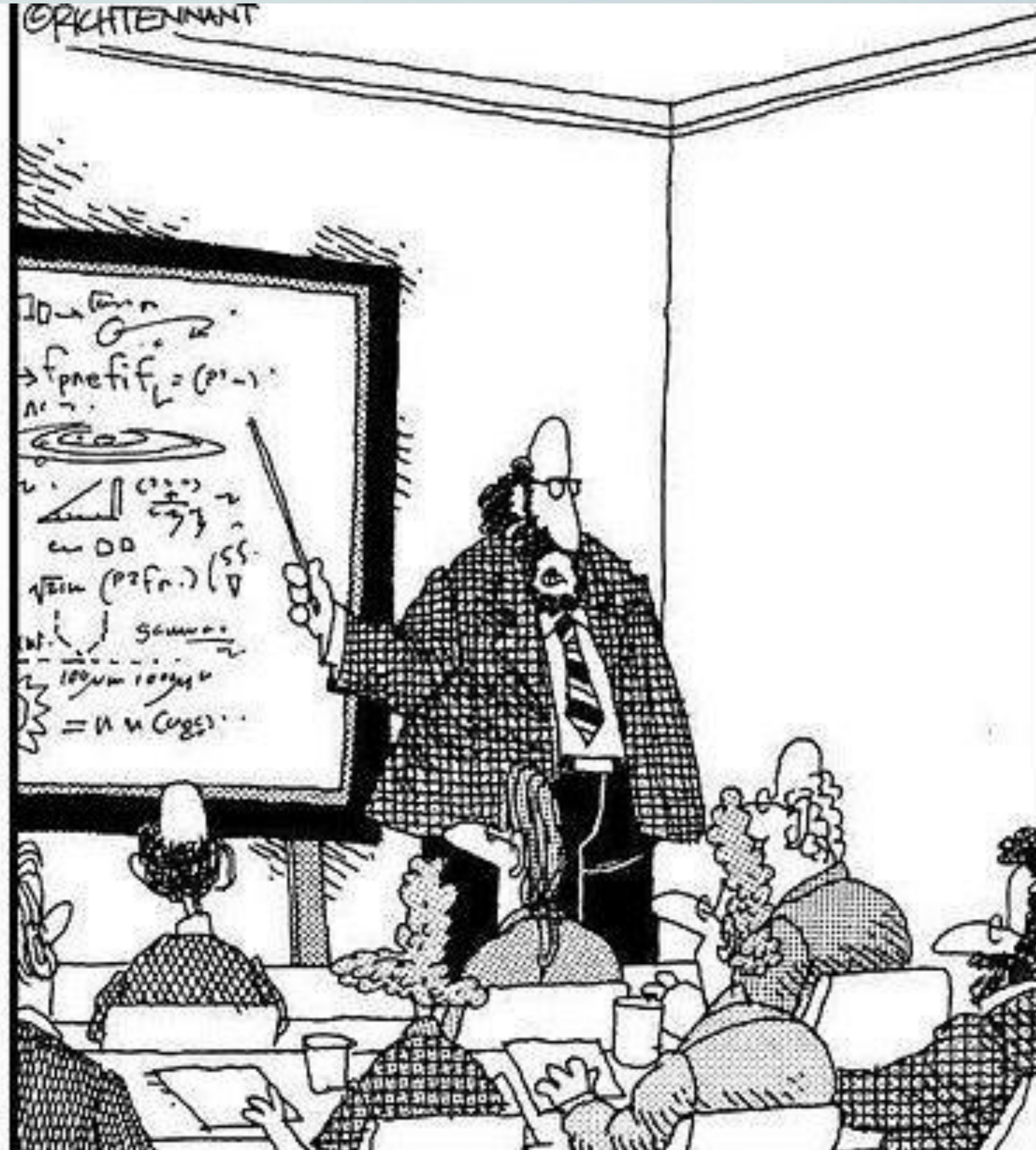
In the next years CUORE can help disentangling the DM puzzle



90% C.L. sensitivity to the cross-section for spin independent interactions normalized to nucleon

Conclusions

- CUORE is an upcoming 1ton scale experiment (cool down in 2014)
- CUORE potential for DM annual modulation detection proved with CCVR2 low energy performance
- Spin independent cross section can be investigated with solid state detectors and unique technique
- Both low and high mass wimps can be detected (depending on background level)
- CUORE-0 is also in the DM game, low energy optimization already begun



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."

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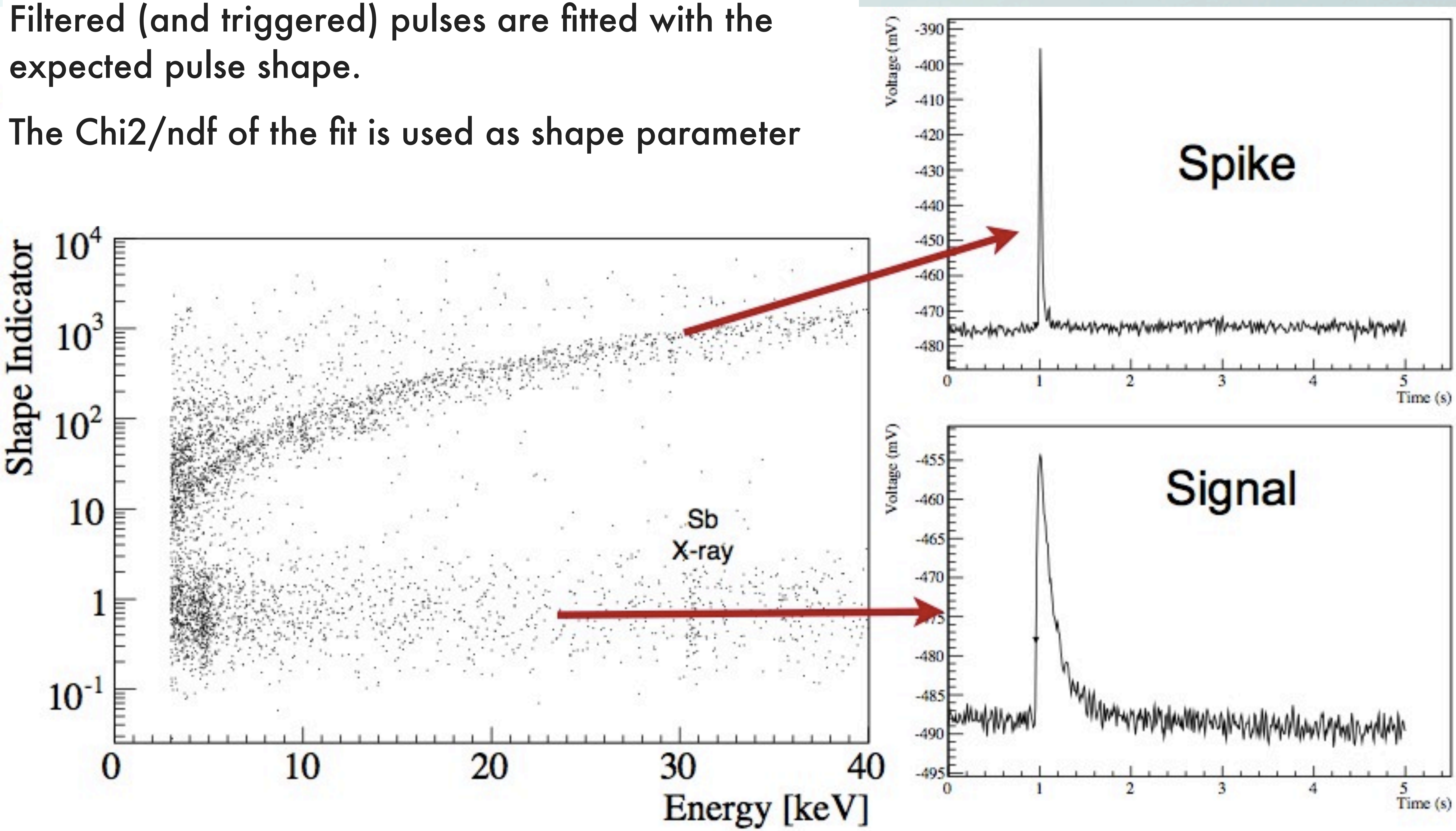
Backup slides

OT: pulse shape

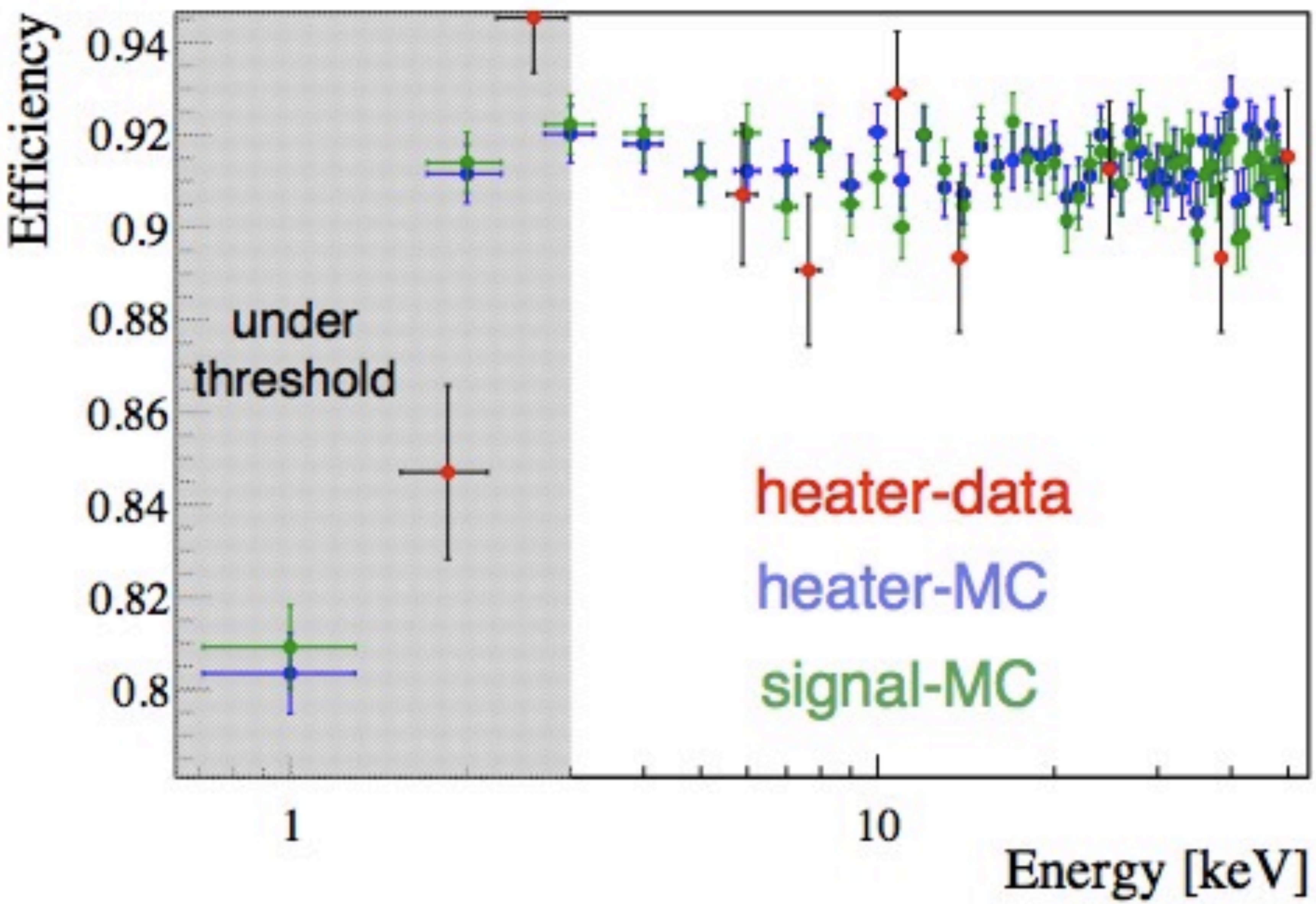
Filtered (and triggered) pulses are fitted with the expected pulse shape.

The Chi2/ndf of the fit is used as shape parameter



OT: efficiency

Detection efficiency near the threshold is evaluated with heaters glued to the crystals to inject power and emulate particle interactions



Efficiency above threshold: > 90 %

Energy threshold: ~3 keV

OT: energy calibration

Working at low energy poses a problem of calibration. Standard "high energy" calibration is performed with calibration (Th) sources: lowest peak = 511keV.

To calibrate at lower energies: Te metastable isotopes in bkg runs @ [30,150]keV

To check the calibration: γ-X coincidences from ^{121}Te (507 or 573.1 + 4.7 or 30.49keV) and ^{40}K (1461 + 3.21keV) and ^{55}Fe source (dedicated run)