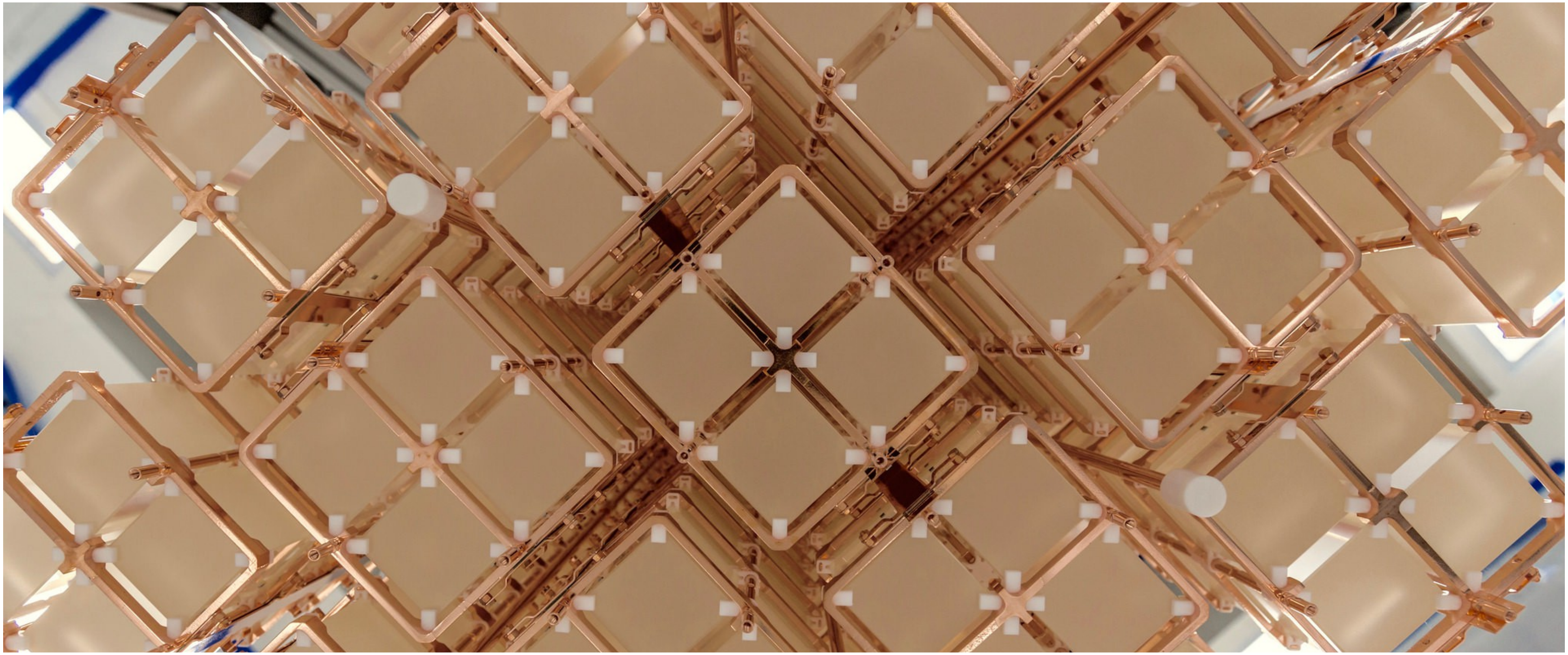

Results from the CUORE experiment

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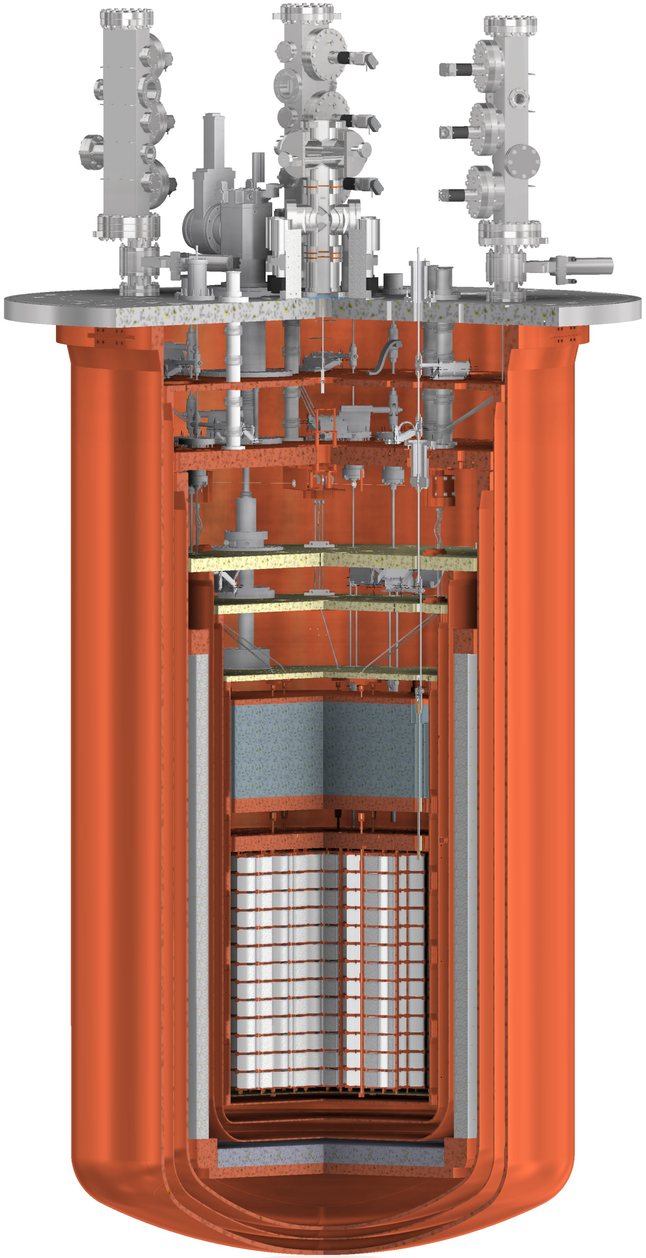
Università/INFN Milano-Bicocca

ICHEP 2018, 4-11 July 2018, Seoul (S. Korea)

CUORE



- **C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents
- Main objective: 0νββ in ^{130}Te
- 988 TeO_2 crystals, 5x5x5 cm^3 each
- Total mass: 742 kg TeO_2 (natural Te)
- ^{130}Te mass: 206 kg
- Crystals operated as bolometers in a cryostat capable of reaching T < 10mK

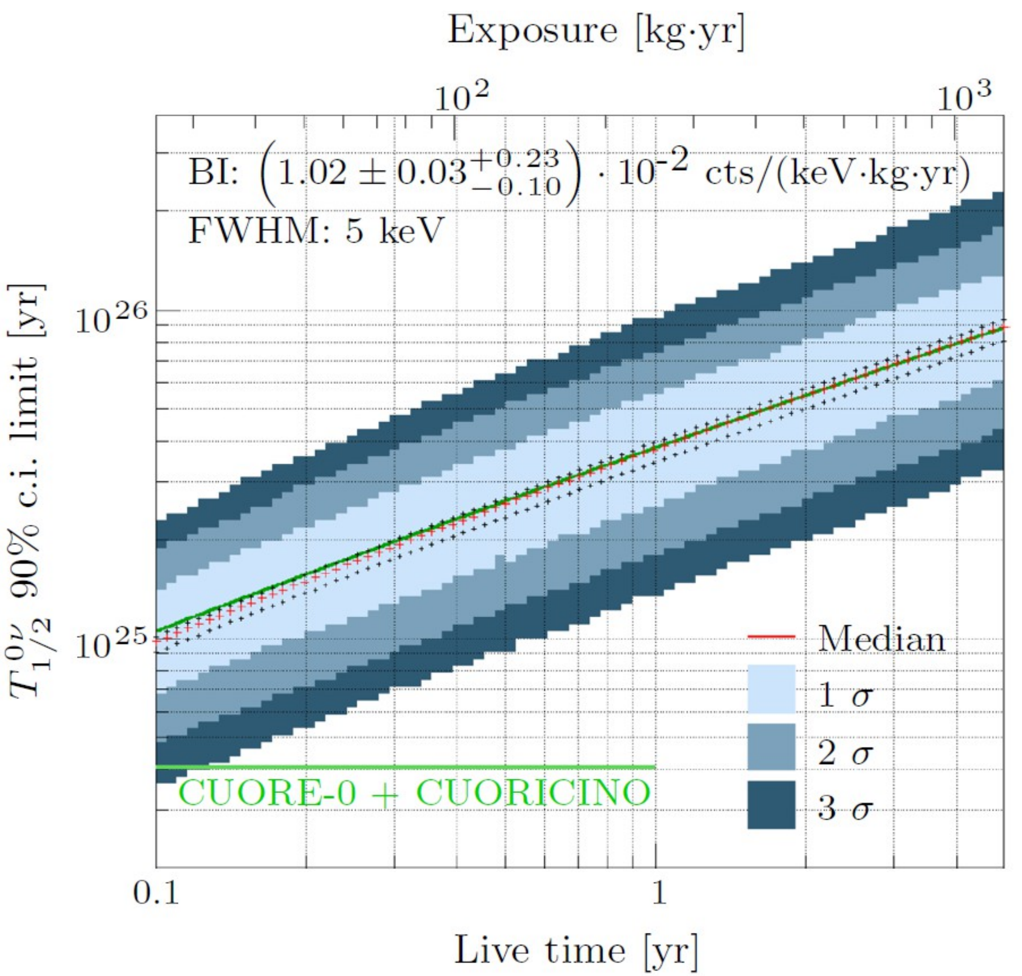
CUORE: sensitivity

CUORE

$$T^{0\nu}_{1/2}(n_\sigma) \propto \sqrt{\frac{M \cdot t}{b \cdot \Delta E}}$$

Goals

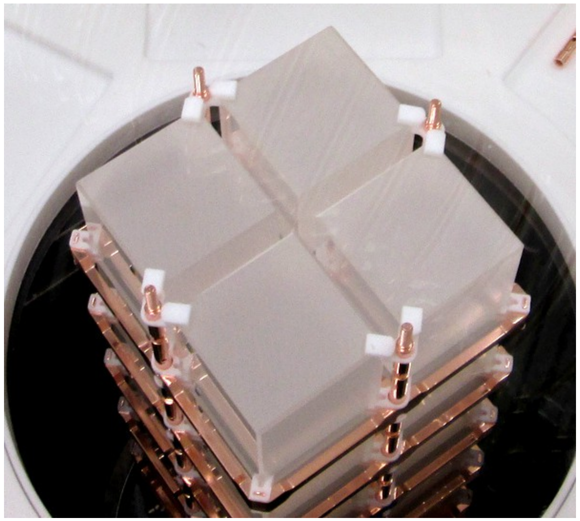
- ΔE : 5 keV FWHM @$Q_{\beta\beta}$
- b : 0.01 counts/(keV·kg·y)
- t : 5 years livetime

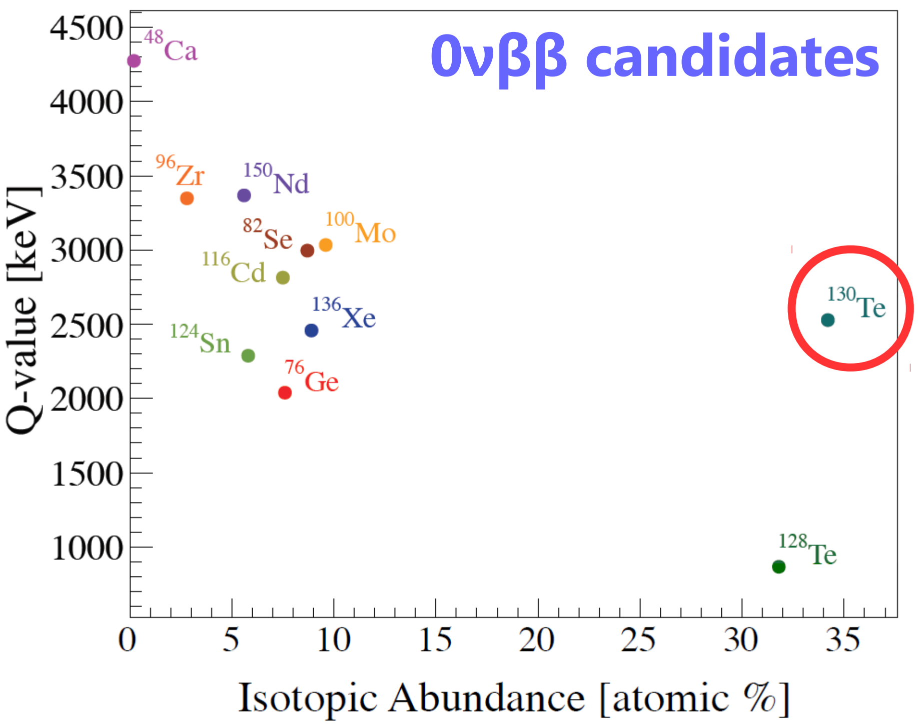


Median expected sensitivity:

$T^{0\nu}_{1/2}$ > 9 x 10^{25} yr (90% C.L.)

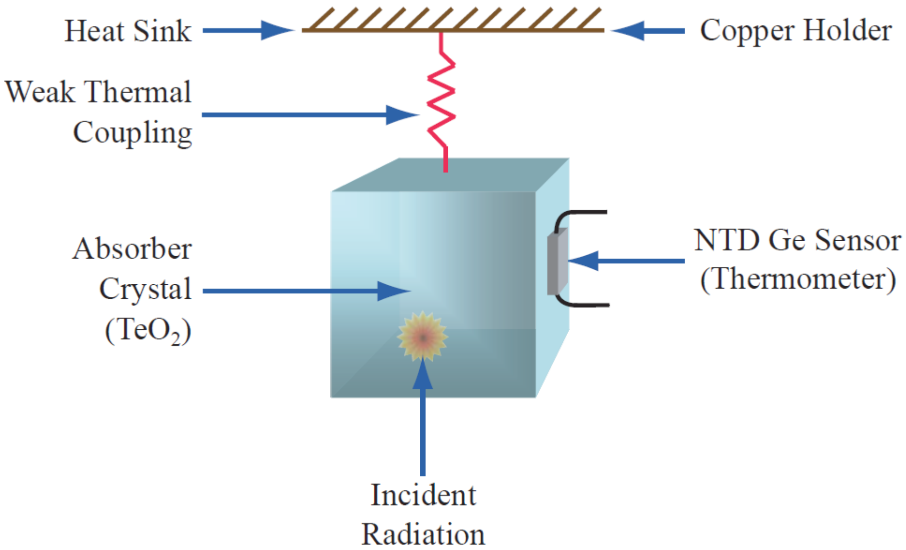
TeO_2

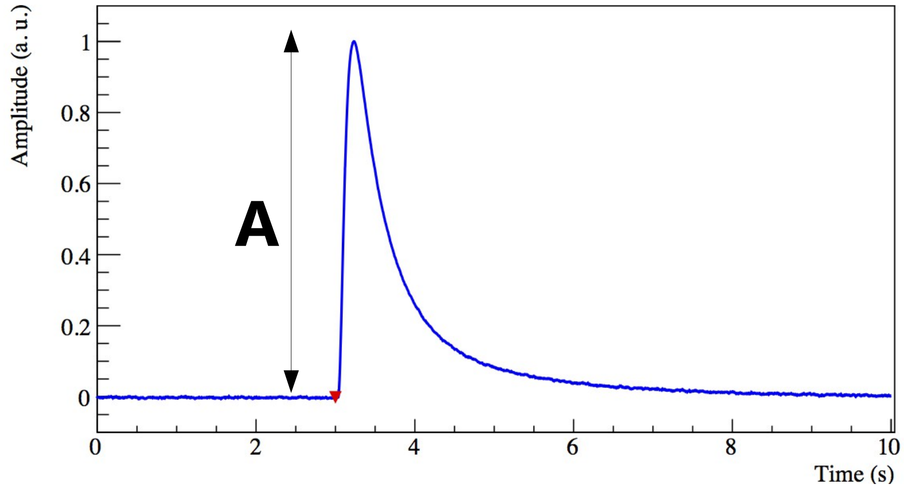




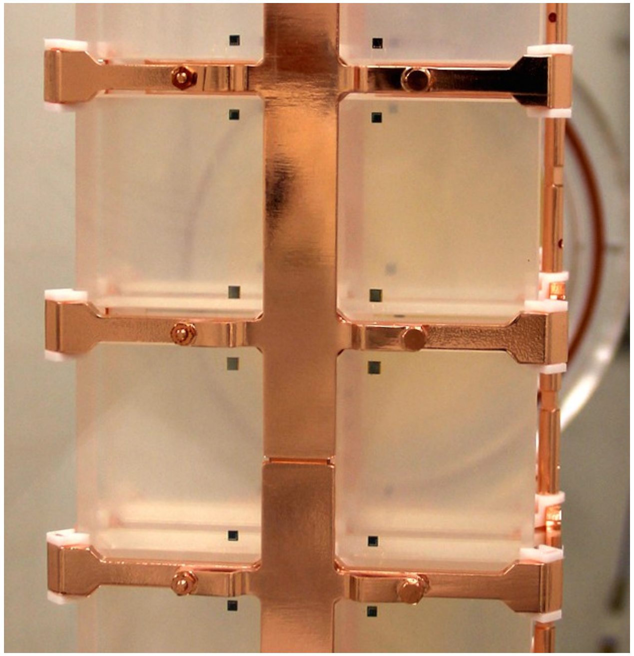
- High natural isotopic abundance of source isotope (^{130}Te)
- ^{130}Te included in the detector: high efficiency
- $Q_{\beta\beta}$ = 2527.5 keV, in a region with relatively low β/γ background
- Excellent energy resolution (5 keV FWHM @ $Q_{\beta\beta}$)
- Reproducible growth of high quality crystals

Detector principle

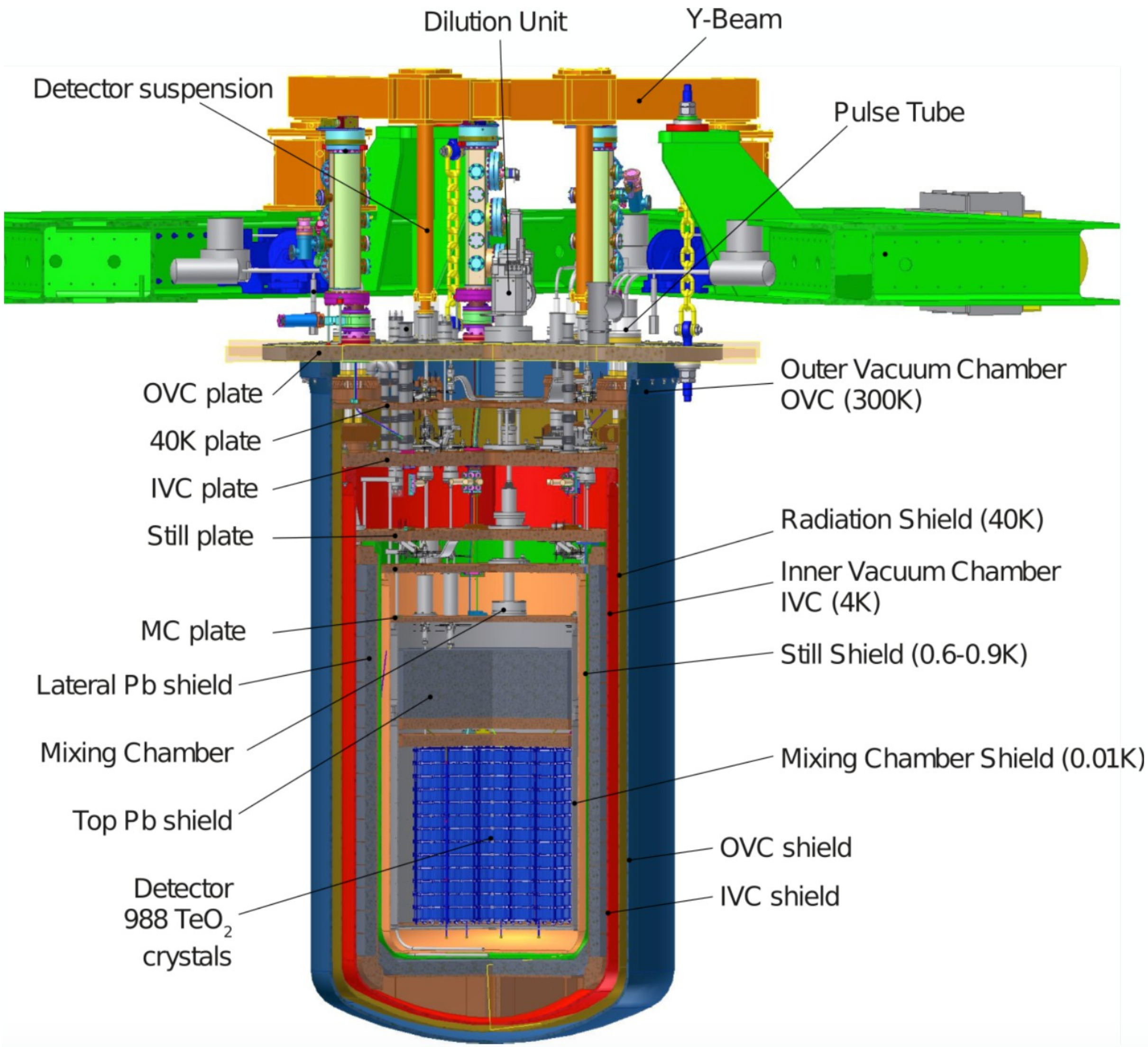




- Energy deposition converted into a temperature rise: **$A \propto E/C(T)$**
- Need to work at extremely low temperature, as **$C(T) \propto T^3$**
- Signal readout with an NTD Ge sensor
  $R_{NTD} \propto \exp(1/T^{1/2})$
- Heat dissipated to the Cu holder; base temperature restored in a few seconds

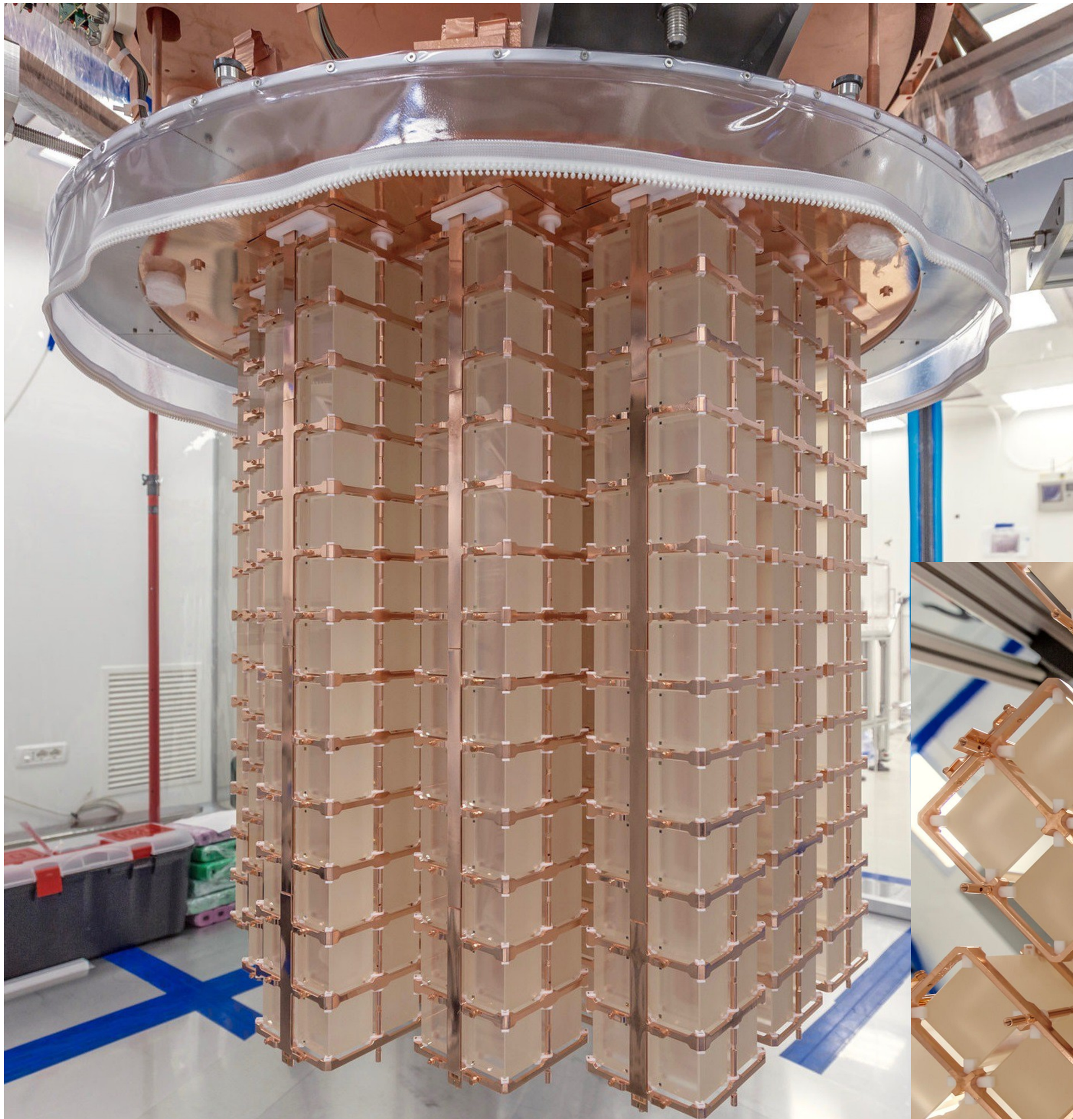


CUORE Cryostat

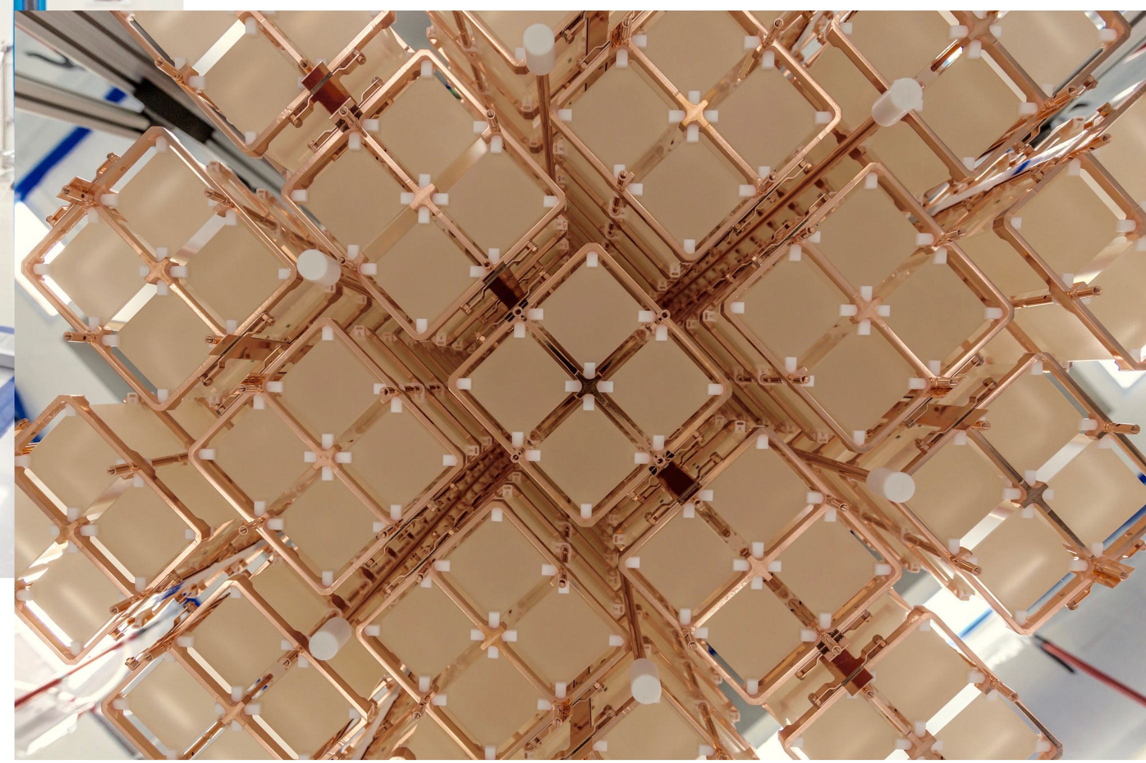


- Material selection driven by thermal/mechanical properties and radio-purity
- Special surface cleaning procedures for elements close to the detector
- Shielding: 25 cm Pb @300K + 6 cm roman Pb @4K
- Extremely low vibrations (suspensions)
- Stable, ultra-low temperature

Detector installation

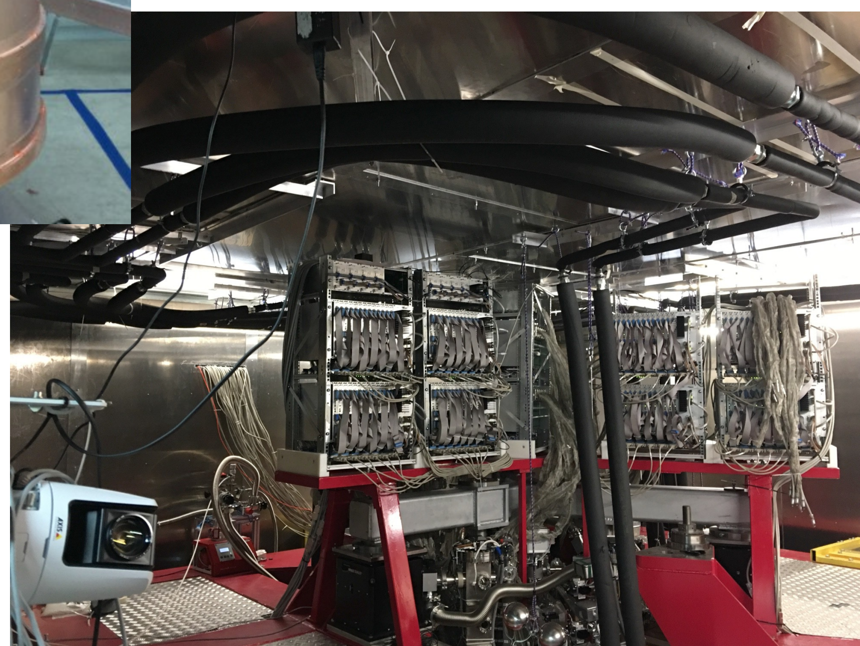


The 19 towers were completely installed in August 2016 in a specially constructed, radon-free clean room

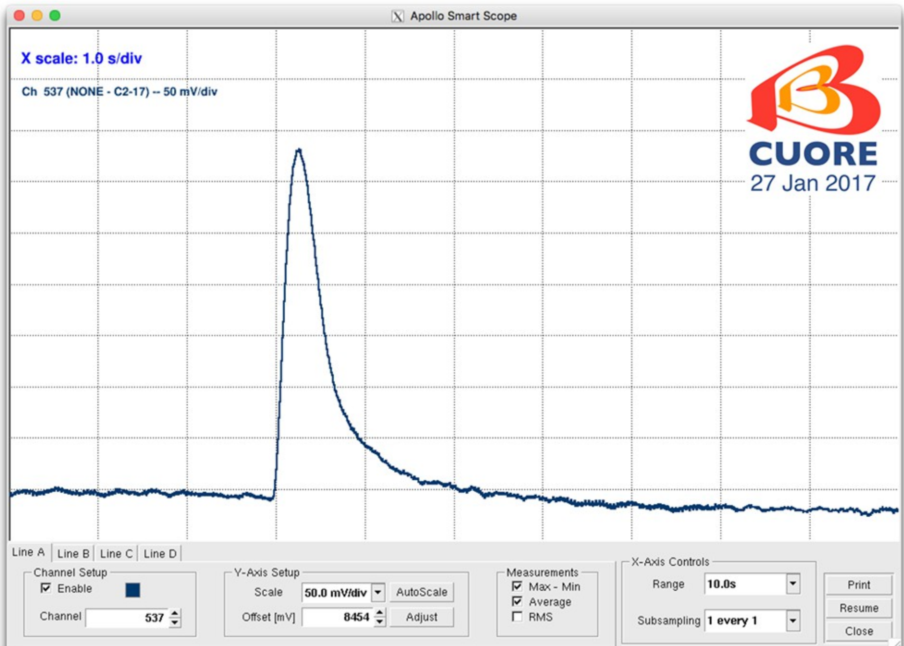


Detector installation

Installation of thermal and radiation shields, electronics and DAQ completed between Sep. and Nov. 2016



Pre-operation



First pulses recorded on Jan. 2017

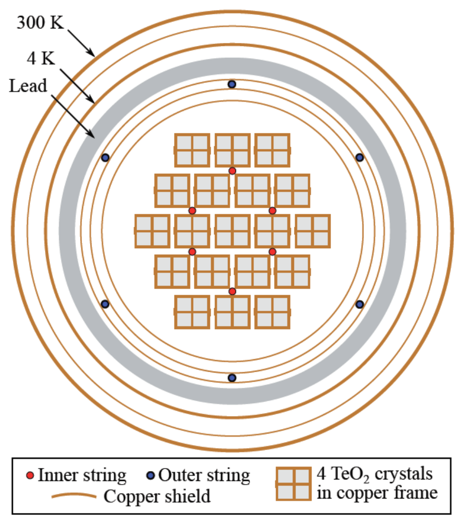
- Gradually turned on all the 988 channels
- Optimization of the DAQ and data analysis software
- Improvement of noise, both from electronics and from vibrations (pulse tubes)
- Determination of the optimal working point for each crystal

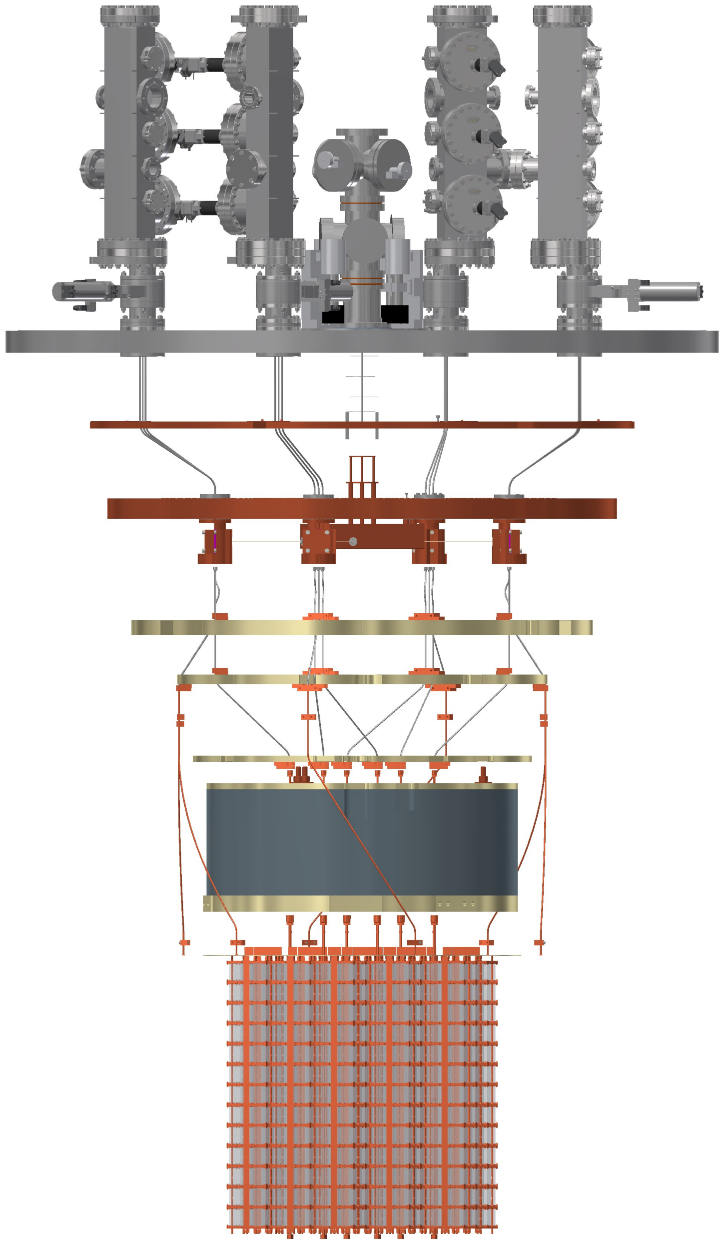
End of commissioning in April 2017

Physics data taking started in May 2017

Calibration system

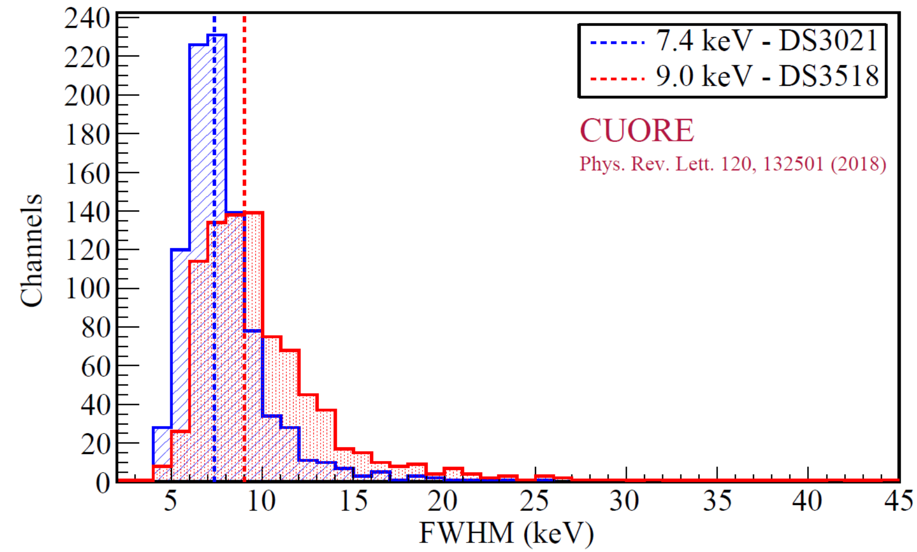
- The detector calibration system (DCS) consists of 12 strings, loaded in ^{232}Th, that can be lowered to detector level
- The strings are guided through tubes and positioned as to illuminate evenly all 19 towers
- Calibrations are run at the beginning and end of each dataset

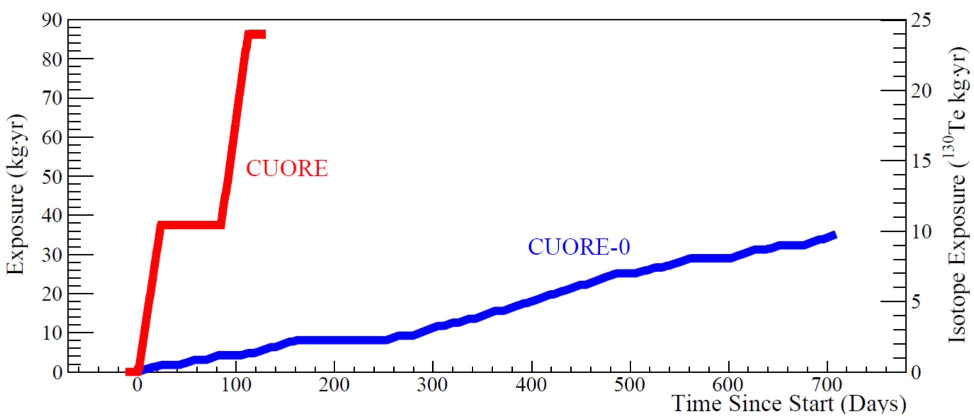


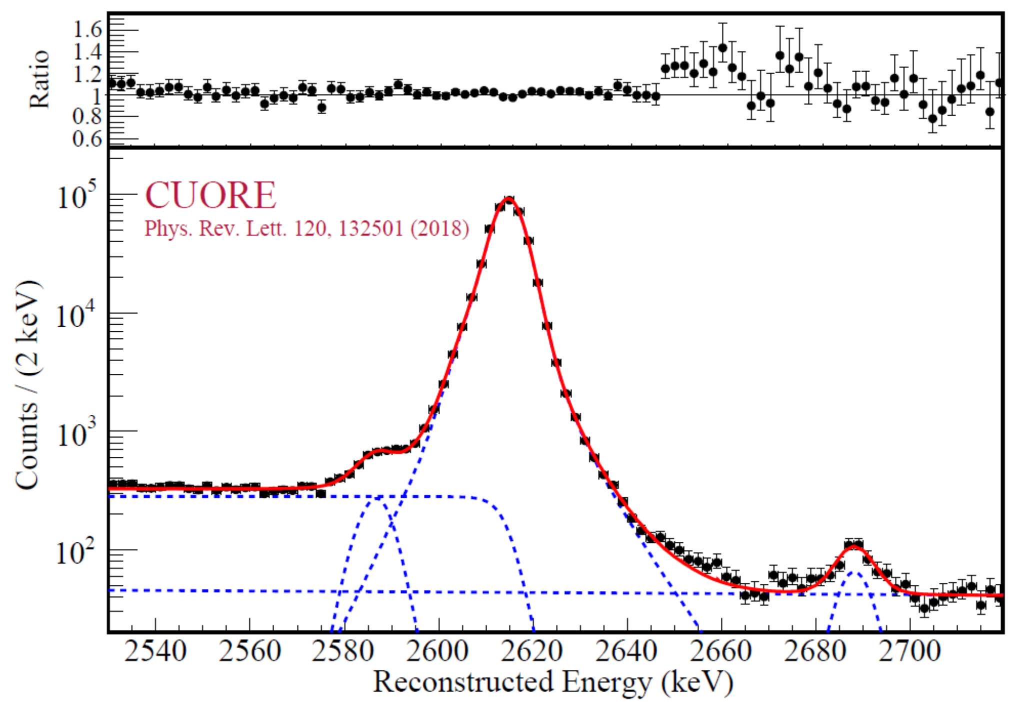


CUORE data taking

- **86.3 kg·y** exposure accumulated in summer 2017
- **99.6%** active channels (994/988)
- **92%** of channels pass analysis cuts
- **7.7 keV** FWHM @Q-value
- **80%** signal efficiency



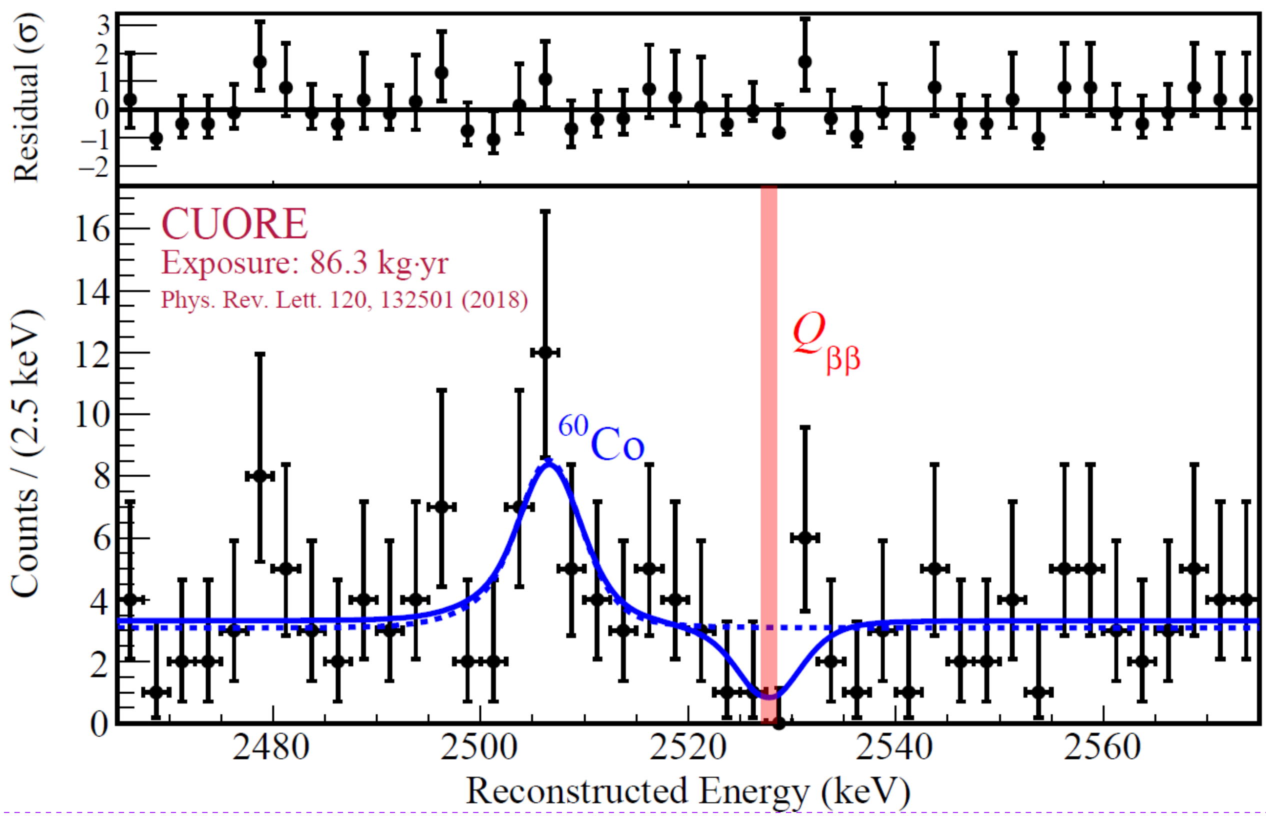




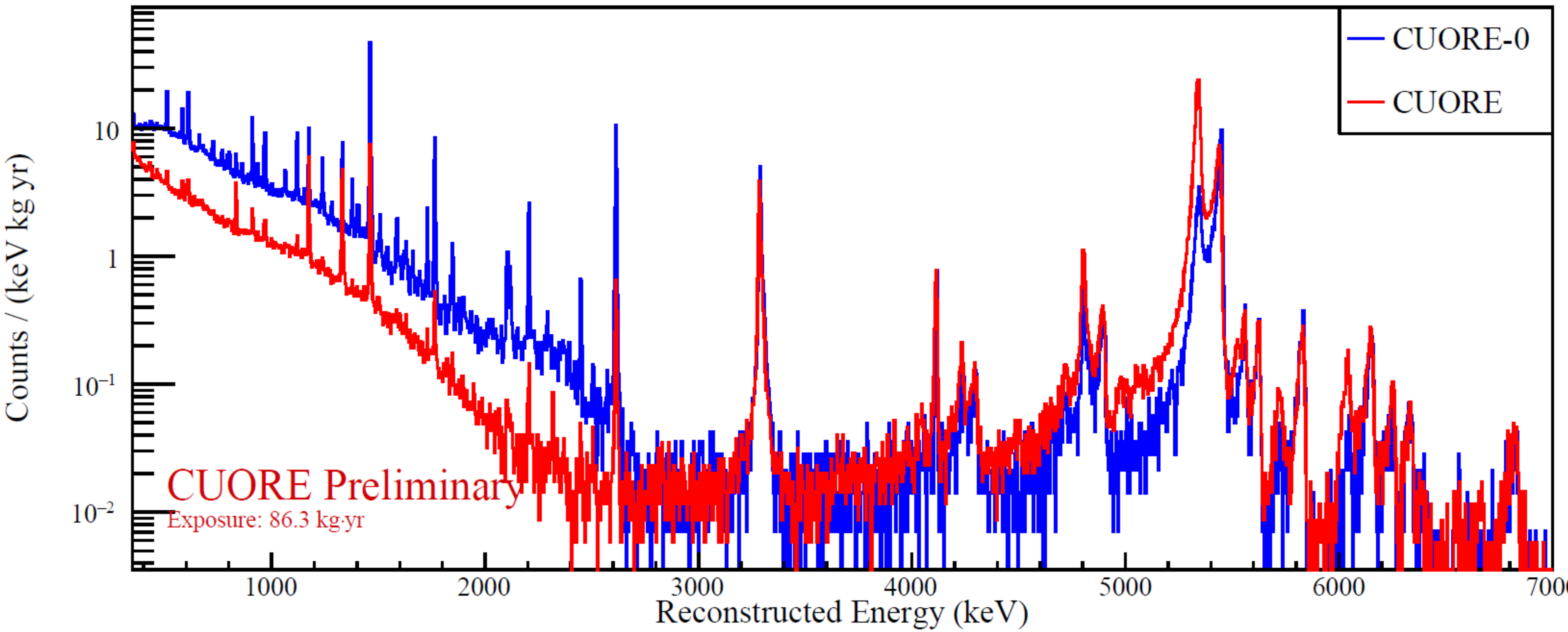
0νββ Results

- Background index: $(1.4 \pm 0.2) \times 10^{-2}$ counts/(keV·kg·y)
- Median expected sensitivity: $T^{0\nu}_{1/2} = 7.0 \times 10^{24}$ y
- Combined limit with CUORE-0 and CUORICINO:

$T^{0\nu}_{1/2} > 1.5 \times 10^{25}$ y (90% C.L.)



CUORE background

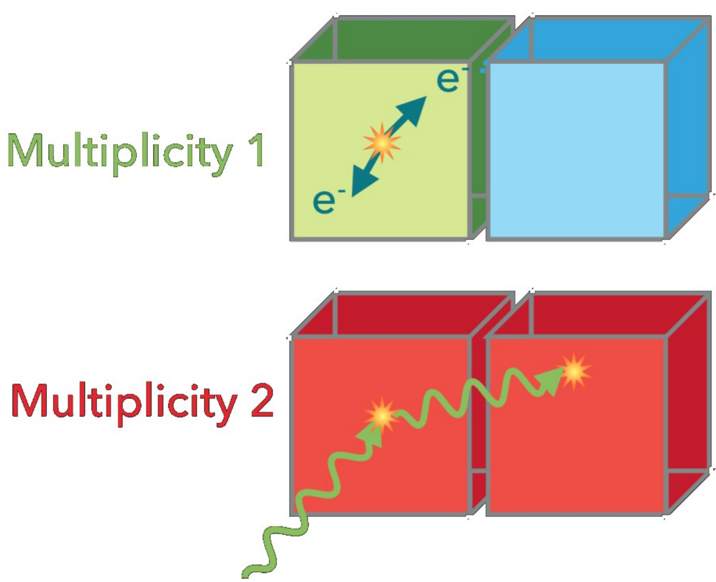


- Background generally consistent with expectation
- γ strongly reduced, α region consistent
- ^{210}Po excess under investigation, irrelevant in ROI (<1%)

CUORE background model

- Full background reconstruction with a Bayesian fit
- Fit components: 60 contaminations spread across the cryostat
- Each component is simulated with a detailed Geant4 MC simulation

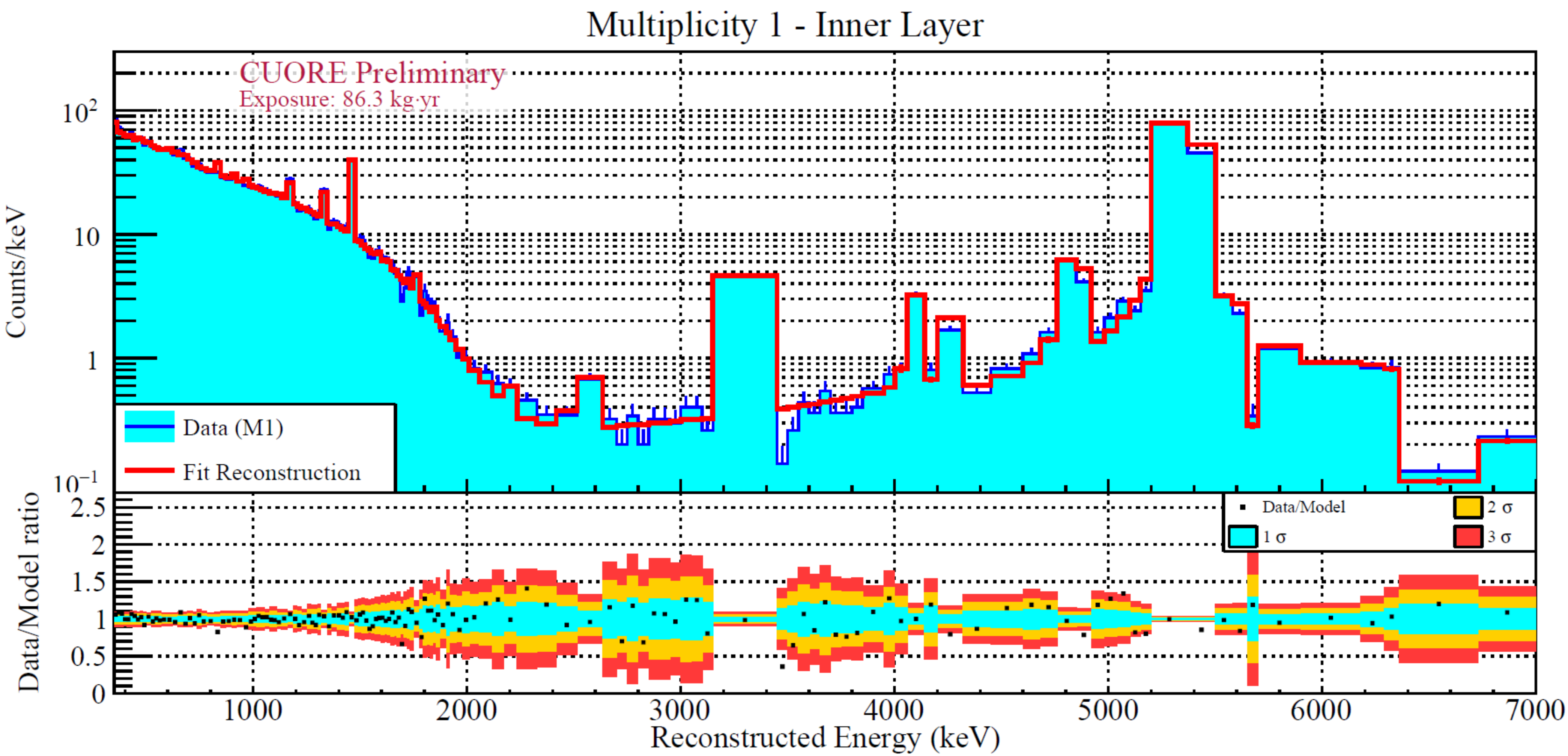
Volume	Type	Components
TeO_2	Bulk	$2\nu\beta\beta$, ^{210}Pb, ^{232}Th, ^{228}Ra-^{208}Pb, ^{238}U-^{230}Th, ^{230}Th ^{226}Ra-^{210}Pb, ^{40}K, ^{60}Co, ^{125}Sb, ^{190}Pt
TeO_2	Surface (0.01 μm)	^{232}Th, ^{228}Ra-^{208}Pb, ^{238}U-^{230}Th, ^{226}Ra-^{210}Pb, ^{210}Pb
TeO_2	Surface (1 μm)	^{210}Pb
TeO_2	Surface (10 μm)	^{210}Pb, ^{232}Th, ^{238}U
CuNOSV	Bulk	^{232}Th, ^{238}U, ^{40}K, ^{60}Co, ^{54}Mn
CuNOSV	Surface (0.01 μm)	^{210}Pb, ^{232}Th, ^{238}U
CuNOSV	Surface (1 μm)	^{210}Pb, ^{232}Th, ^{238}U
CuNOSV	Surface (10 μm)	^{210}Pb, ^{232}Th, ^{238}U
Roman lead	Bulk	^{232}Th, ^{238}U, ^{108m}Ag
Top lead	Bulk	^{232}Th, ^{238}U, ^{210}Bi
Ext. lead	Bulk	^{210}Bi
CuOFE	Bulk	^{232}Th, ^{238}U, ^{60}Co
External	-	Cosmic muons



- Split the data according to event multiplicity
- Split the detector in two layers, outer (sensitive to cryostat contaminants) and inner (sensitive to towers)

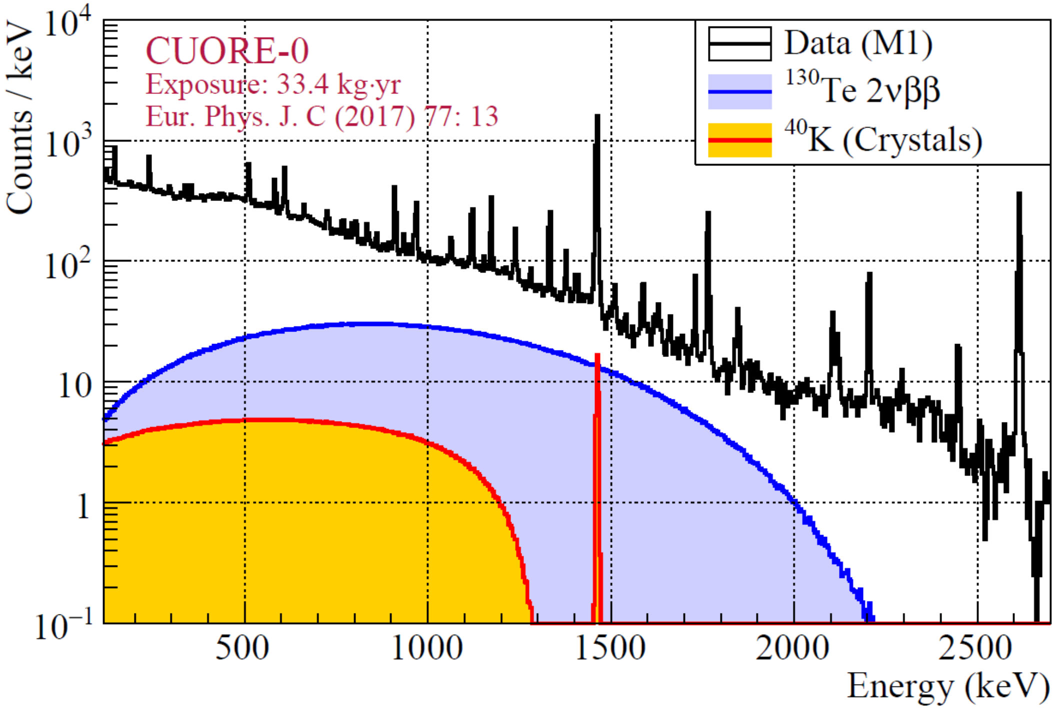
CUORE background model

CUORE



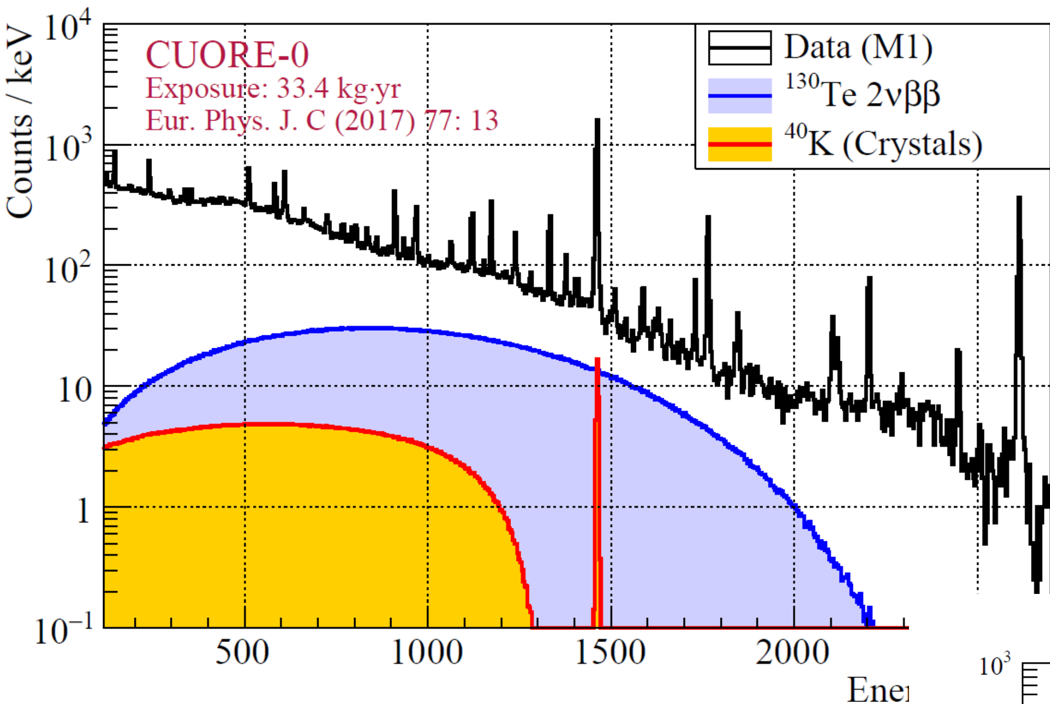
We're able to reconstruct the main features of the observed spectra

2νββ Results



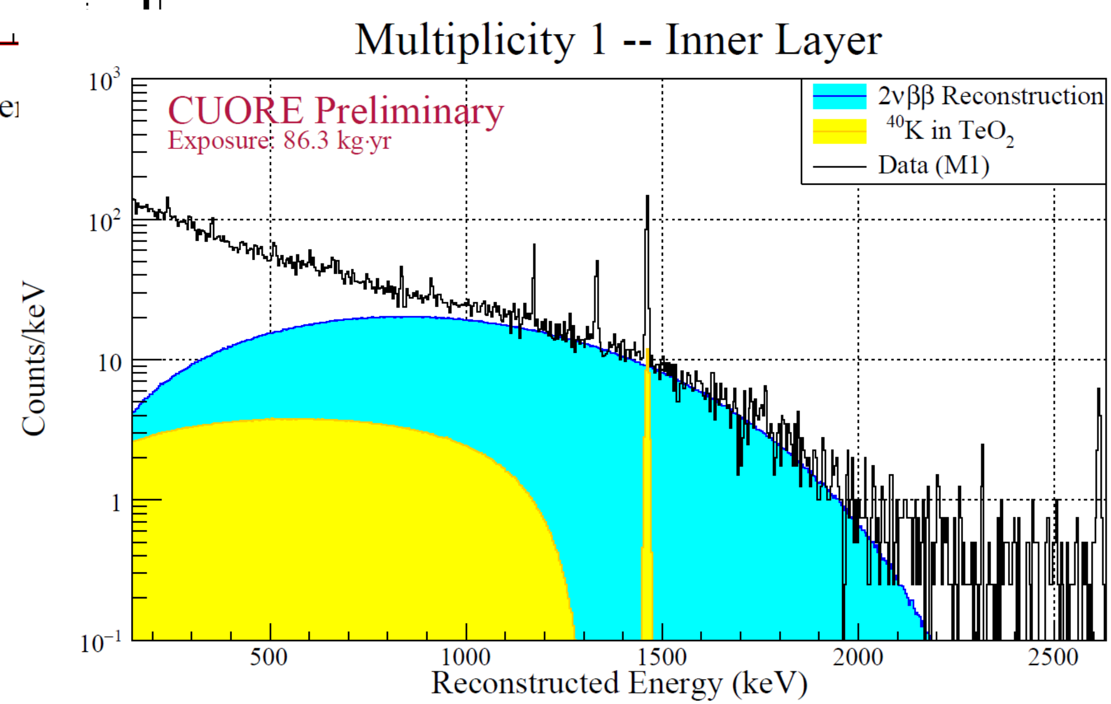
In CUORE0, 2νββ accounted for about 10% of the events in the 1-2 MeV region…

2νββ Results



In CUORE0, 2νββ accounted for about 10% of the events in the 1-2 MeV region...

...but now, thanks to the improved background, it accounts for almost 100% of events



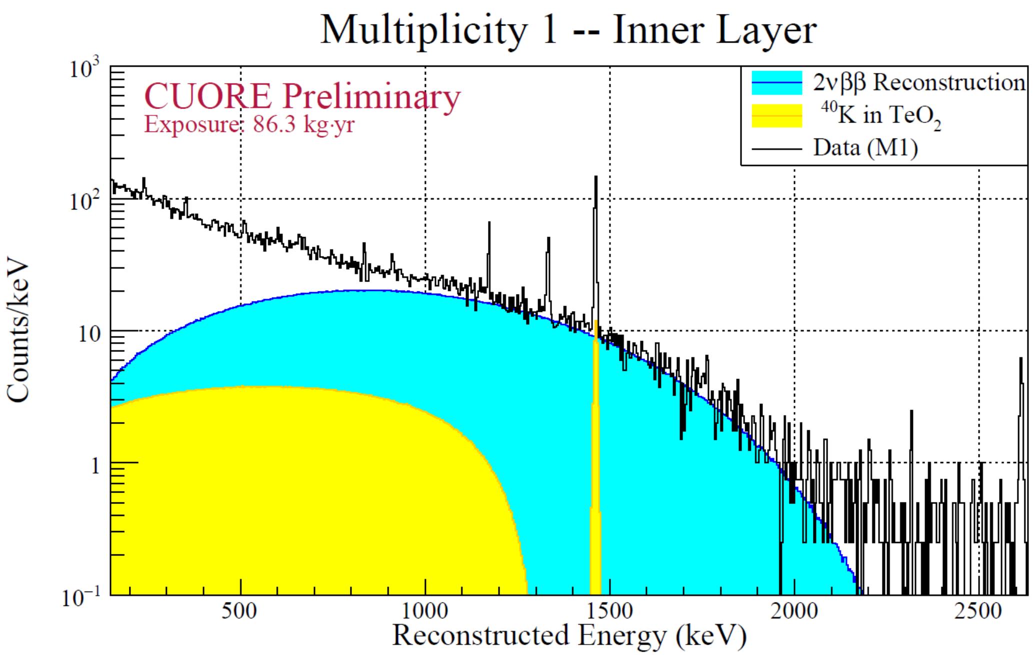
2νββ Results

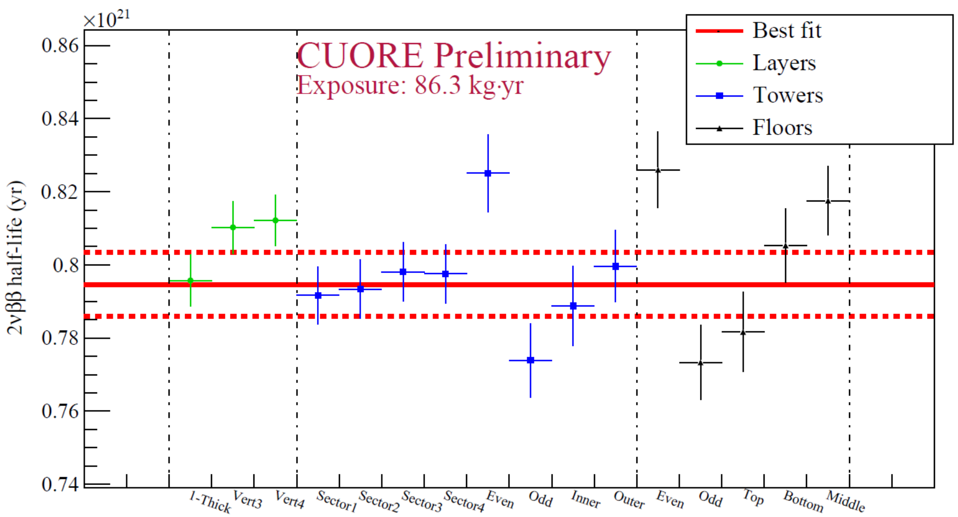
$T^{2\nu}_{1/2}$ = (7.9 ± 0.1 (stat.) ± 0.2 (syst.))x 10^{20} y

(Preliminary)

$T^{2\nu}_{1/2}$ = (8.2 ± 0.2 (stat.) ± 0.6 (syst.))x 10^{20} y (CUORE-0)

$T^{2\nu}_{1/2}$ = (7.0 ± 0.9 (stat.) ± 1.1 (syst.))x 10^{20} y (NEMO-3)





Summary

- With 7 weeks of data CUORE:
  - Set the most stringent limit on 0νββ half-life of ^{130}Te to date
  - Made the most precise measurement of 2νββ half-life of ^{130}Te
- After a period of detector optimization, we restarted data taking in May 2017
- CUORE will continue taking data in the coming years, with an ultimate sensitivity to 0νββ half-life in ^{130}Te of $T^{0\nu}_{1/2} > 9 \times 10^{25}$ yr