CUORE

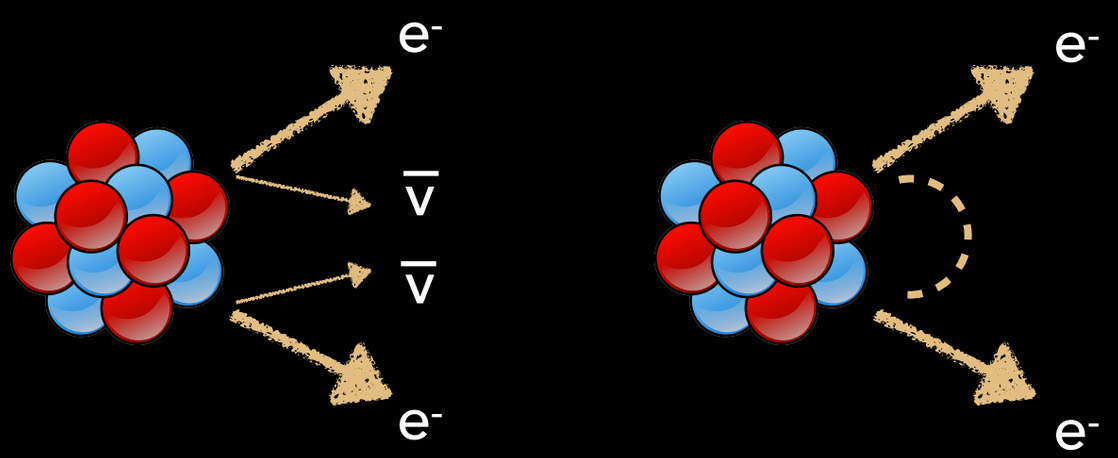
Scientific Committee - LNGS October 2019

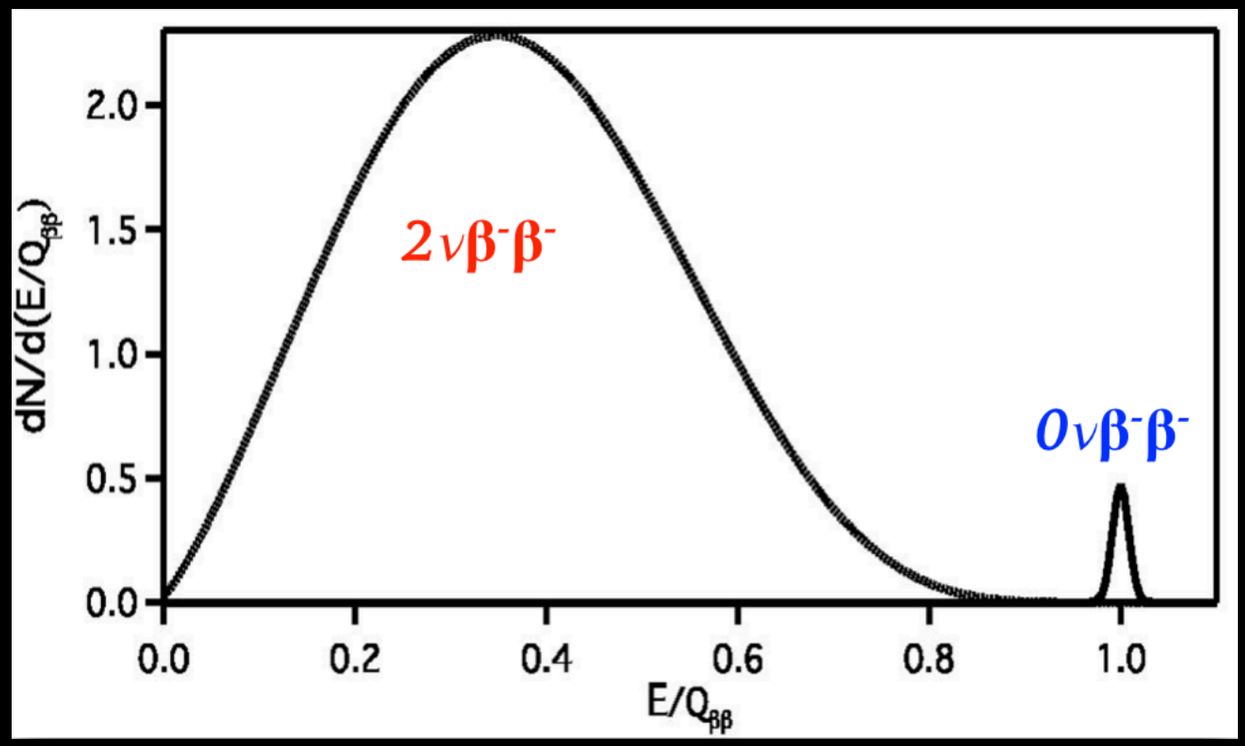
Overview

- The CUORE Experiment
- Data Taking
- Cryogenics Intervention
- Duty Cycle
- Trigger Optimization
- Latest Results
- To Dos

Physics goal

Double Beta Decay is a second order weak interaction, only directly observable for few nuclei, for which the standard Beta Decay is suppressed or forbidden (even - even nuclei)





Signature
peak at the Q-value of ^{130}Te ßß decay
(2527.515 ± 0.013)keV

Challenges: $$T^{0\nu}_{1/2}(n_\sigma) = \frac{ln2}{n_\sigma}\frac{N_A i\varepsilon}{A} f(\Delta E)\sqrt{\frac{Mt}{B\Delta E}}$$

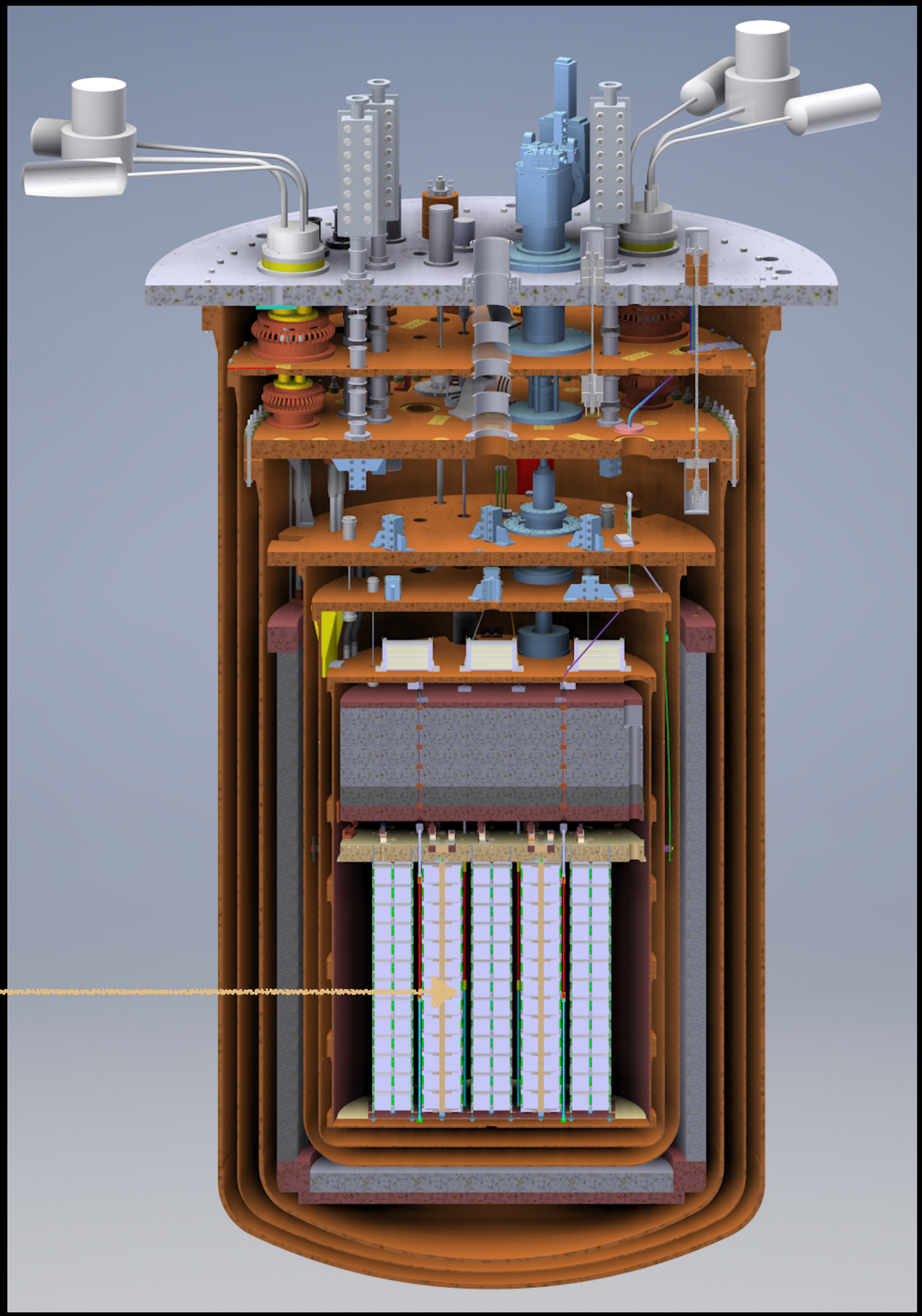
- **Exposure**
- **Background**
- **Energy resolution**

CUORE

The CUORE detector is hosted in a cryogen-free cryostat:

- Mass to be cooled < 4K: ~15 tons (Pb, Cu and TeO_2)
- Operating temperature ~10 mK
- Designed to guarantee extremely low radioactivity and low vibrations environment

988 TeO_2 crystals (arranged in 19 towers with 13 floors each, 52 5x5x5 cm^3 TeO_2 crystals per tower)



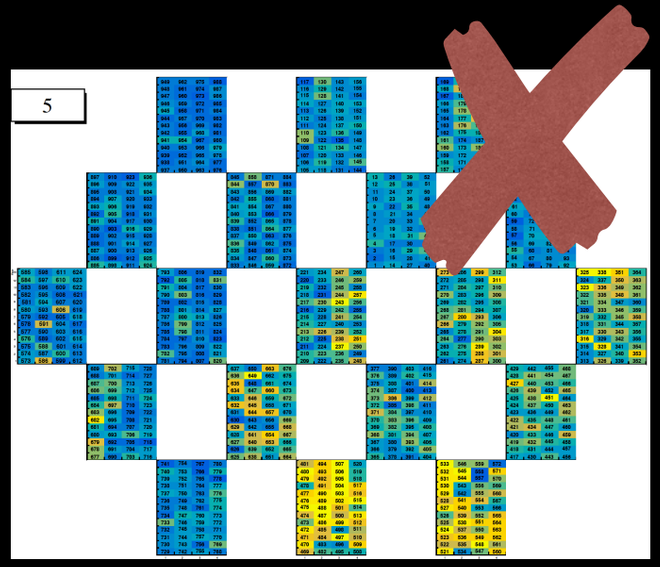
Data taking

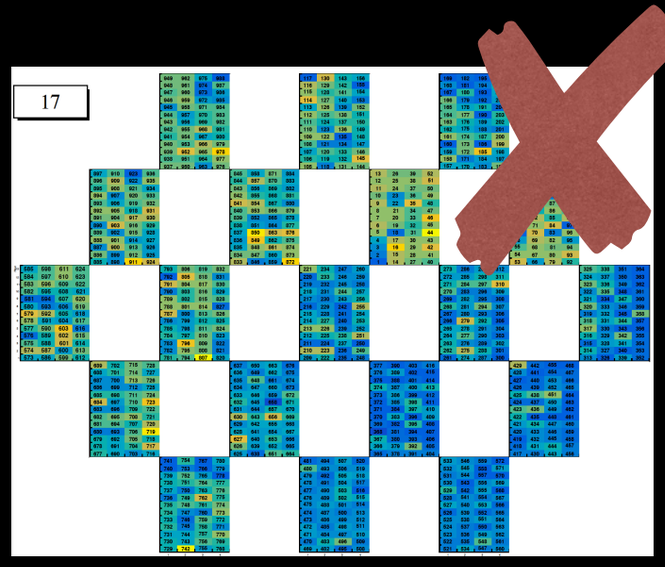
Data taking started in March 2017

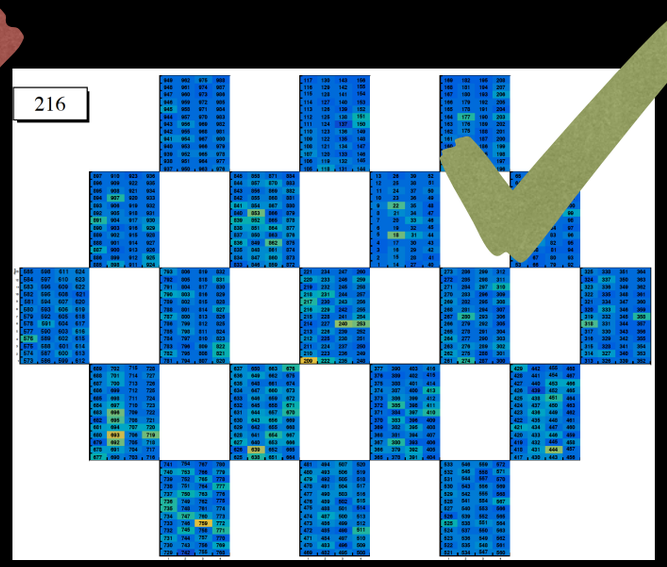
- **The data is divided in datasets (1-2 months of physics data)**
- **Datasets are bracketed by calibrations with Th or Th-Co sources**
- **Few technical operations are needed between datasets to ensure the stability of the data taking**
- **When any of the systems undergoes some interventions more time is needed to restore a stable data taking**

Technical runs

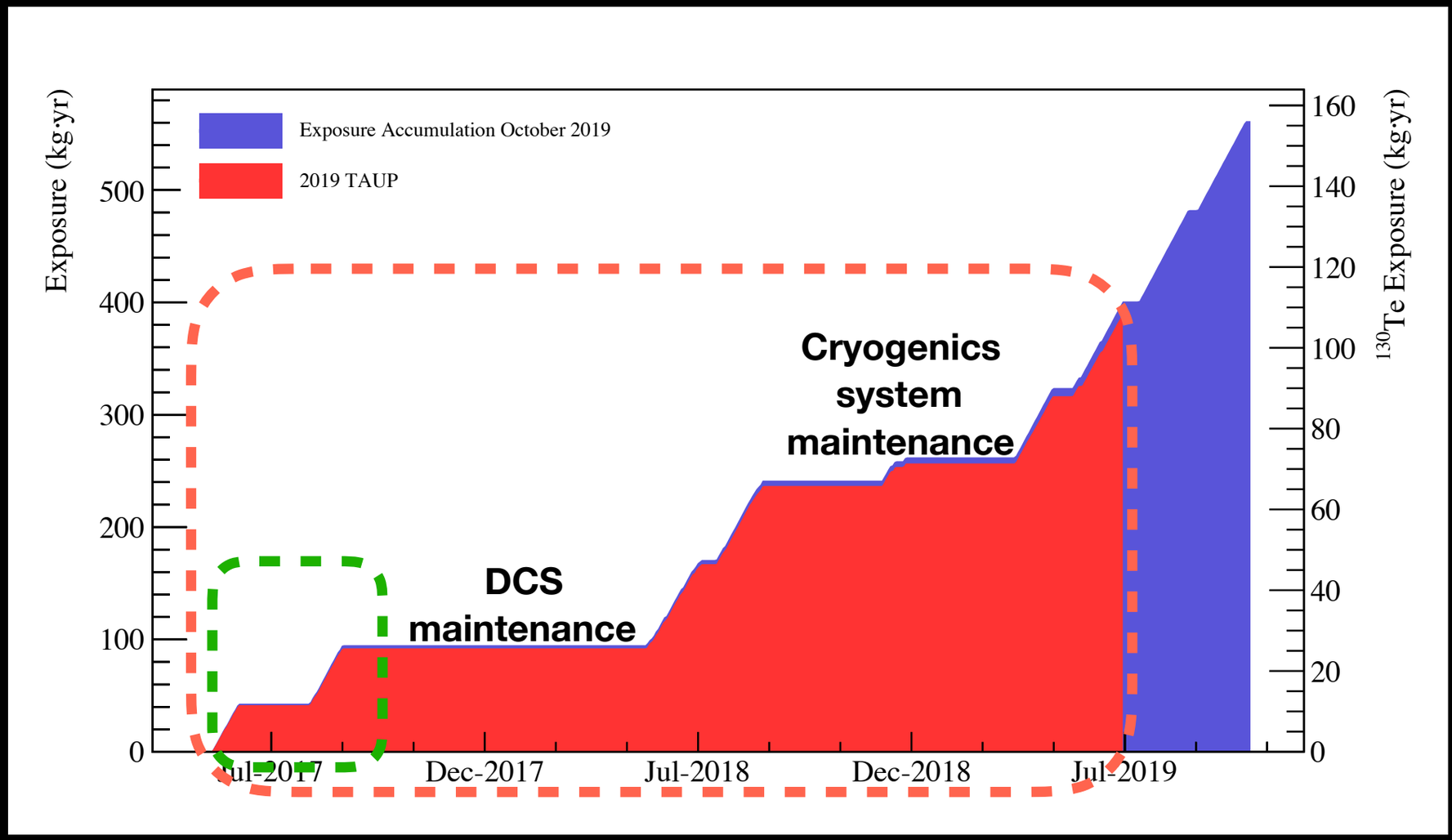
- Technical runs are needed to check the detector stability (measurement of the NTD resistance)
- NPulser runs for energy threshold determination
- Pulse Tubes phase scan in order to minimise the noise introduced by PT vibrations (Pulse Tube active noise cancellation)







Data taking

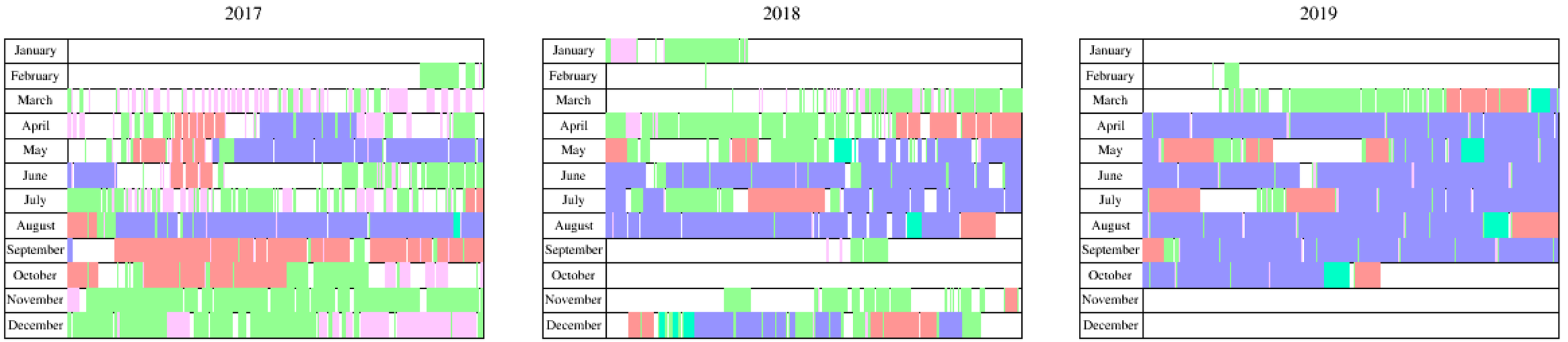


Data published in PRL 120.132501 (2018)

Data presented at TAUP 2019 (paper under preparation)

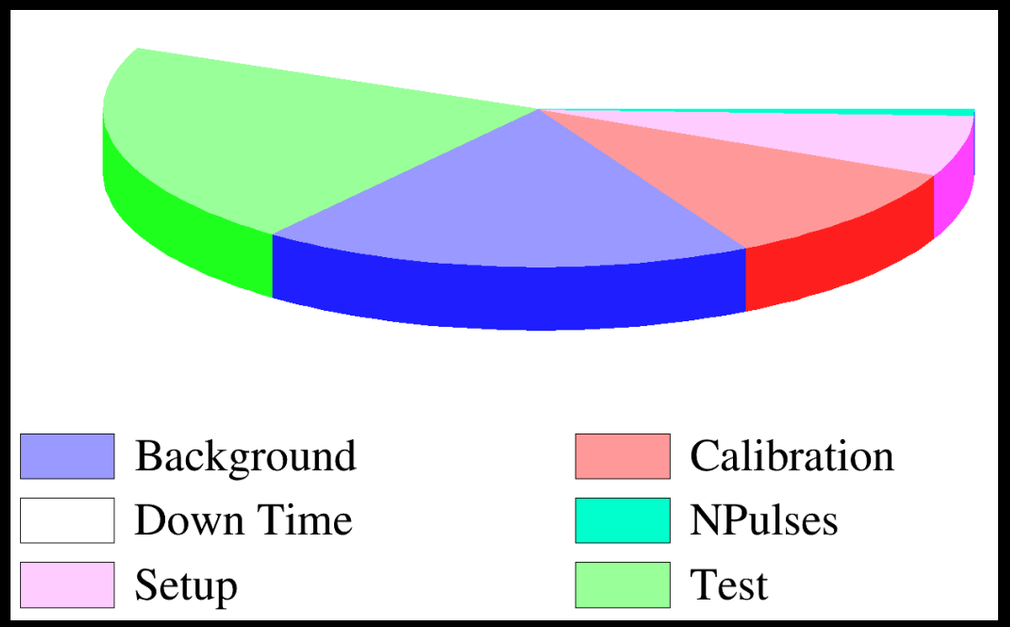
More than 550 kg yr of raw exposure acquired (analysis of the latests datasets ongoing)

Data taking



During the first 2 years of operation (2017 - 2018) the duty cycle of the system was poor, dominated by down-time (short warm-ups and cool-downs) and technical runs.

- **Performed an upgrade of the calibration system (2018)**
- **Performed a major maintenance of the cryogenic system (early 2019)**
- **Focussed on physics data-taking**



Cryogenics Intervention

We concentrated our efforts on understanding the causes of our down time and improving the reliability of the overall system and the stability of the data-taking.

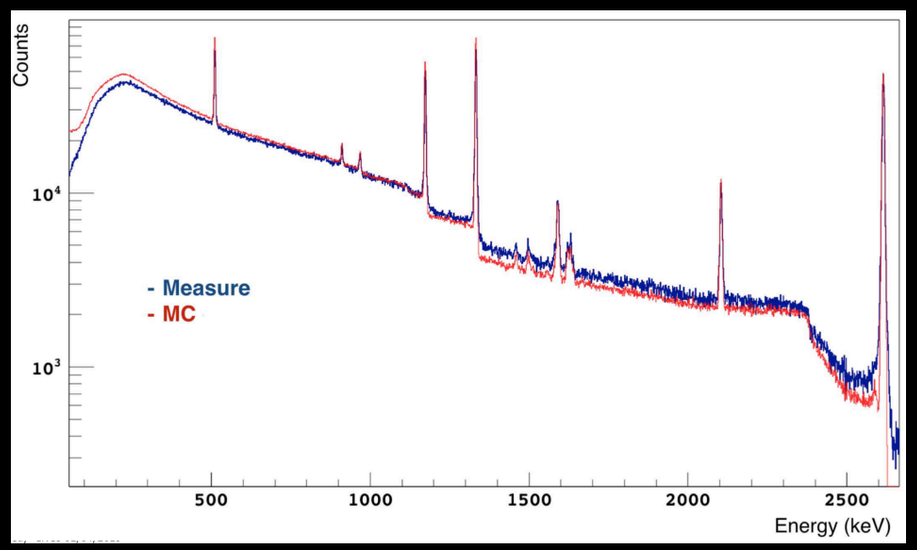
The DCS obliged us to repeatedly warmup the cryostat to 100-150 K

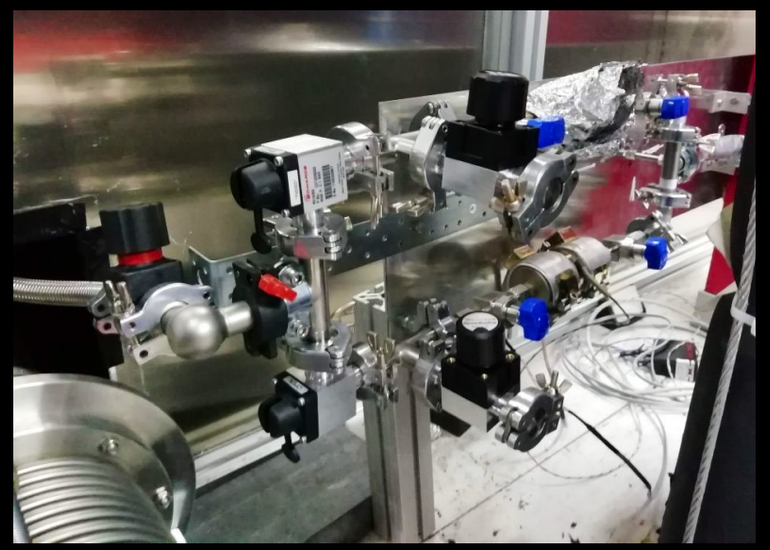
The warm-ups and cool-downs created additional problems and were very time consuming

✓ **Implemented an external calibration system (does not perturb the cryogenic apparatus)**

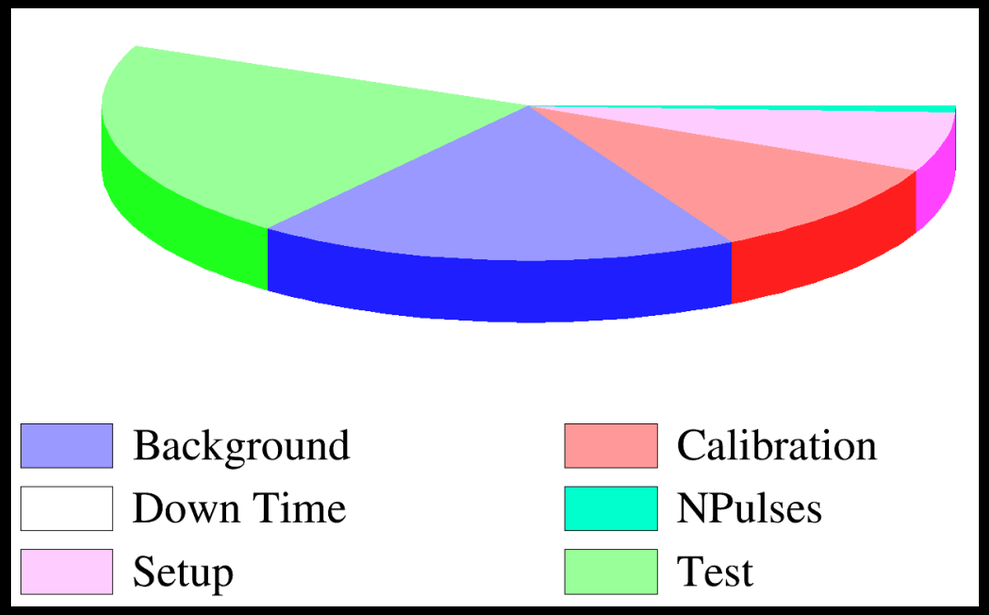
✓ **Performed maintenance and improvements of the cryogenics apparatus**

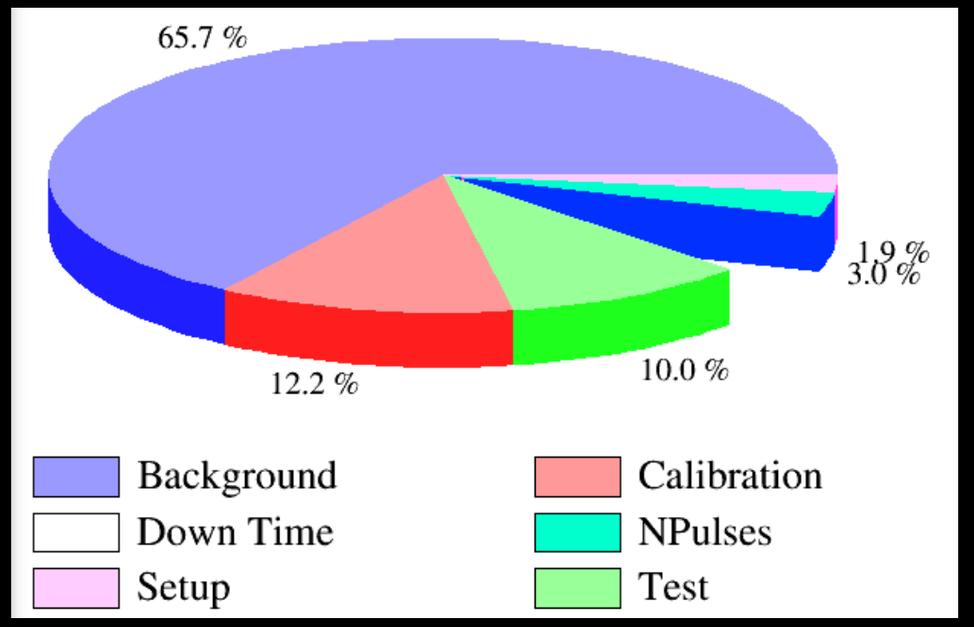
Now we know better our system and we know how to prevent/minimise future problems!



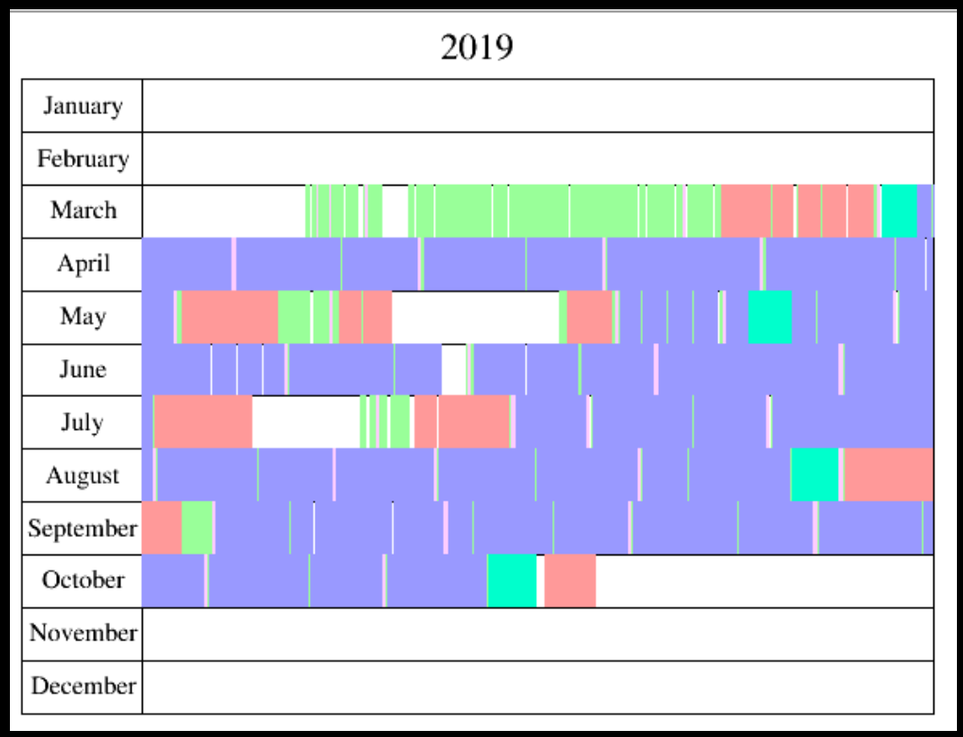


Duty Cycle

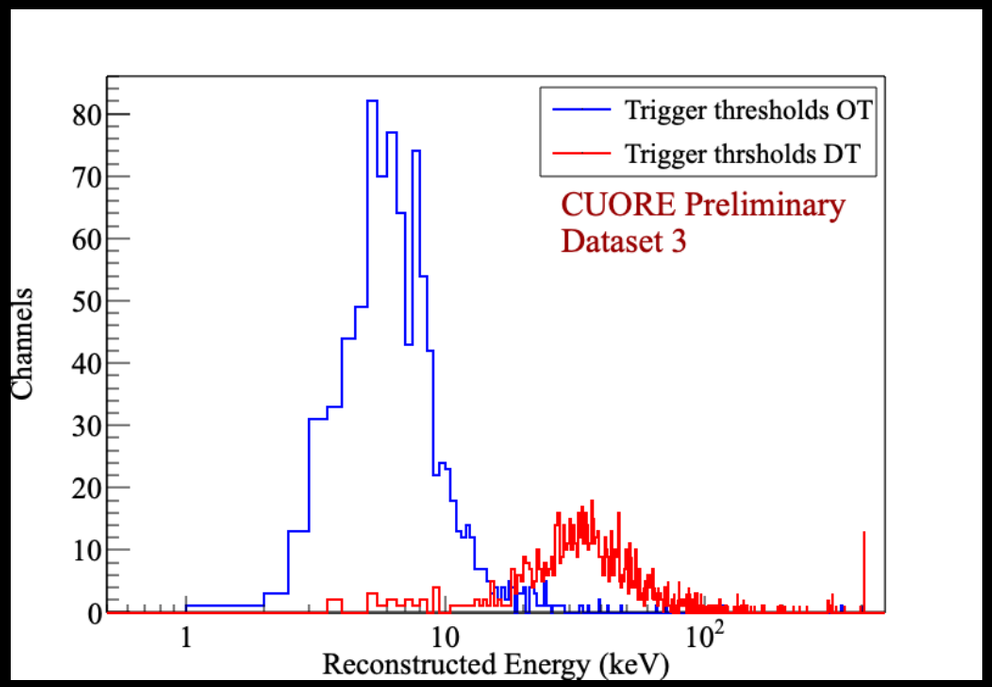




After the latests cryogenics interventions our duty cycle improved from 56.0% (18.4% physics data) to 92.8% (65.7% physics data)



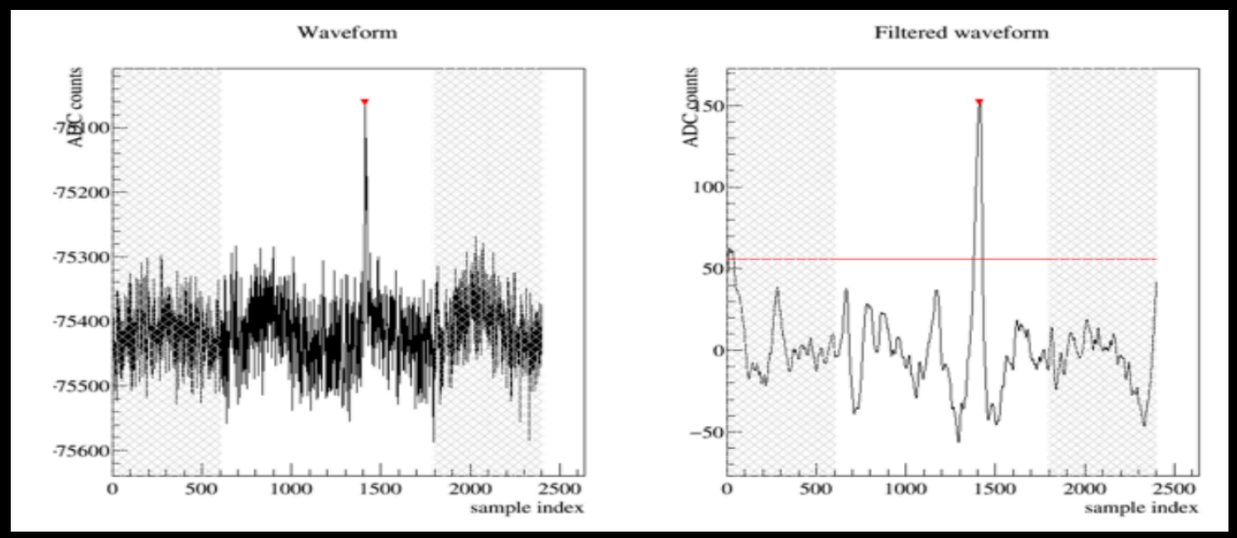
Trigger optimisation



OT trigger

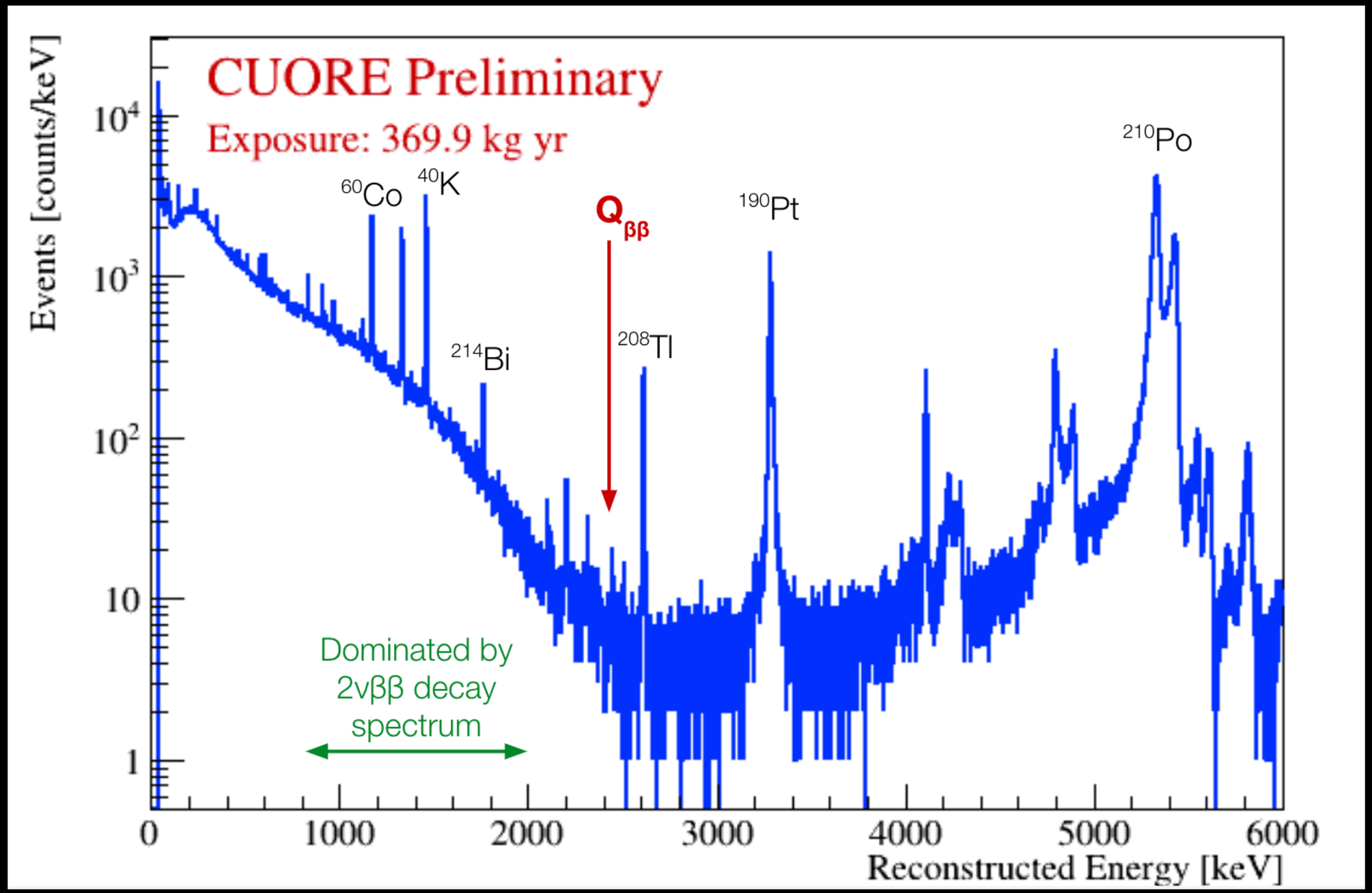
Disentangle low energy signals from fake signals produced by noise, lower the detectors trigger thresholds

Optimum Trigger (OT) algorithm: identifies a signal when the amplitude of the filtered signal waveform exceeds a configurable threshold



OT trigger applied for offline re-triggering of the continuous recorded stream of data

Spectrum after selection



Latest results: efficiencies

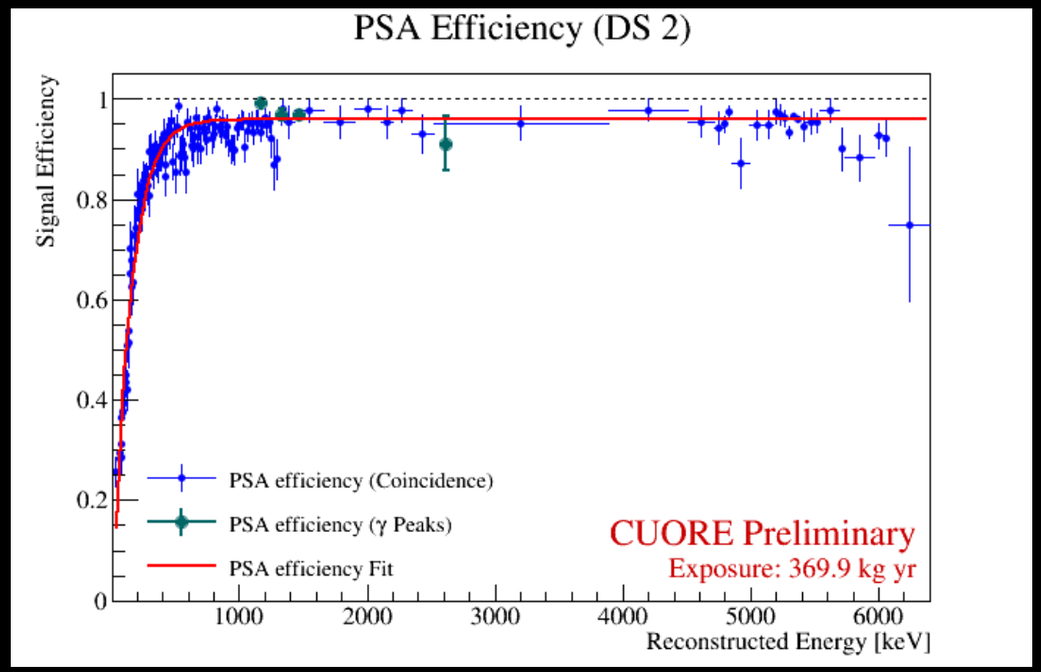
Reconstruction Efficiency →
- **Trigger**
- **Event reconstruction**
- **Pile-up identification**

Anti-coincidence efficiency → **Quantifies the probability of properly identifying a single-site event**

Pulse Shape analysis efficiency

↓

Fraction of events passing a multi-dimensional cut on 6 pulse-shape variables



Latest results: some numbers…

Parameter	Value
Number of datasets	7
Number of channels	842-948 (depending on dataset)
TeO_2 exposure	369.94 kg·yr
FWHM at 2615 keV in calibration data	8.1 keV
FWHM at $Q_{\beta\beta}$ in physics data	8.7 keV
Reconstruction efficiency	(95.9578 ± 0.0033)%
Anti-coincidence efficiency	$(98.95^{+0.15}_{-0.16})$%
PSA efficiency	(92.04 ± 0.11)%
Tot. analysis efficiency	(87.41 ± 0.18)%
Syst. on analysis efficiency	±1.9%
Containment efficiency	(88.350 ± 0.090)%

Latest results: ROI fit

Method:

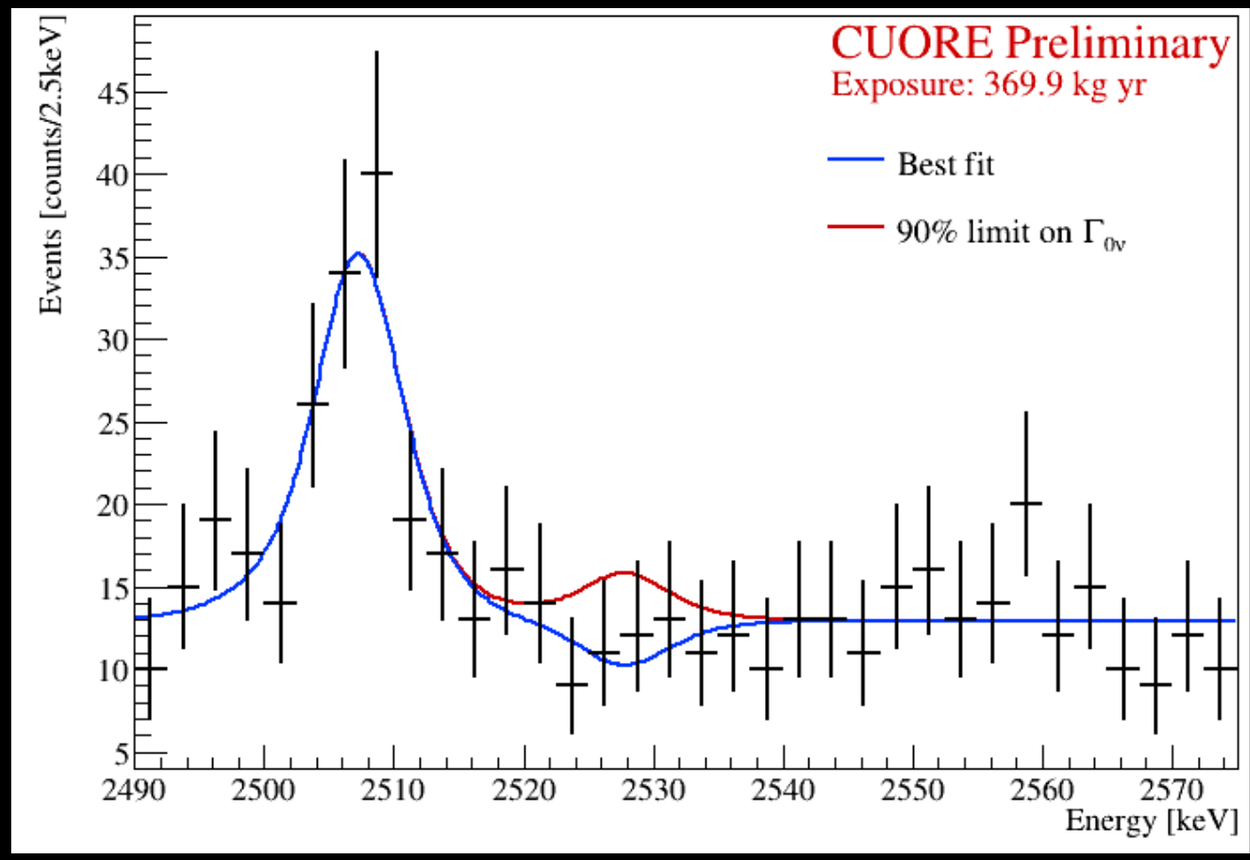
Bayesian analysis based on MCMC method (BAT)

Allow negative non-physical range for $\Gamma_{0\nu}$ to evaluate the amplitude of possible background under-fluctuations

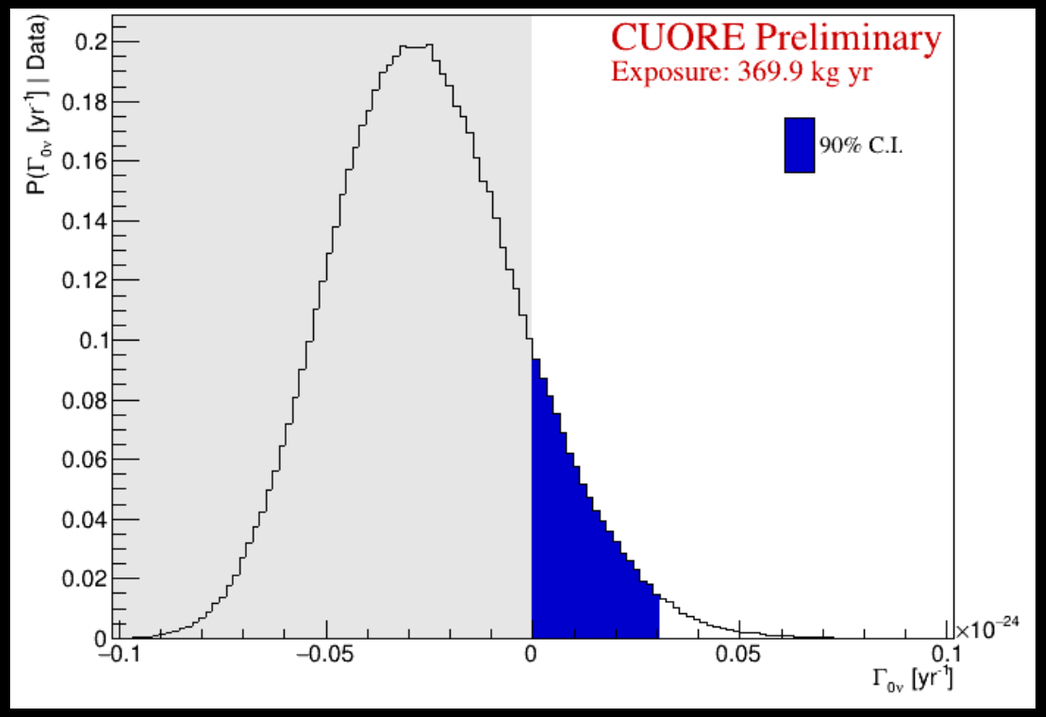
Repeat fit on physical range only
→ Results on $\Gamma_{0\nu}$ obtained from this!

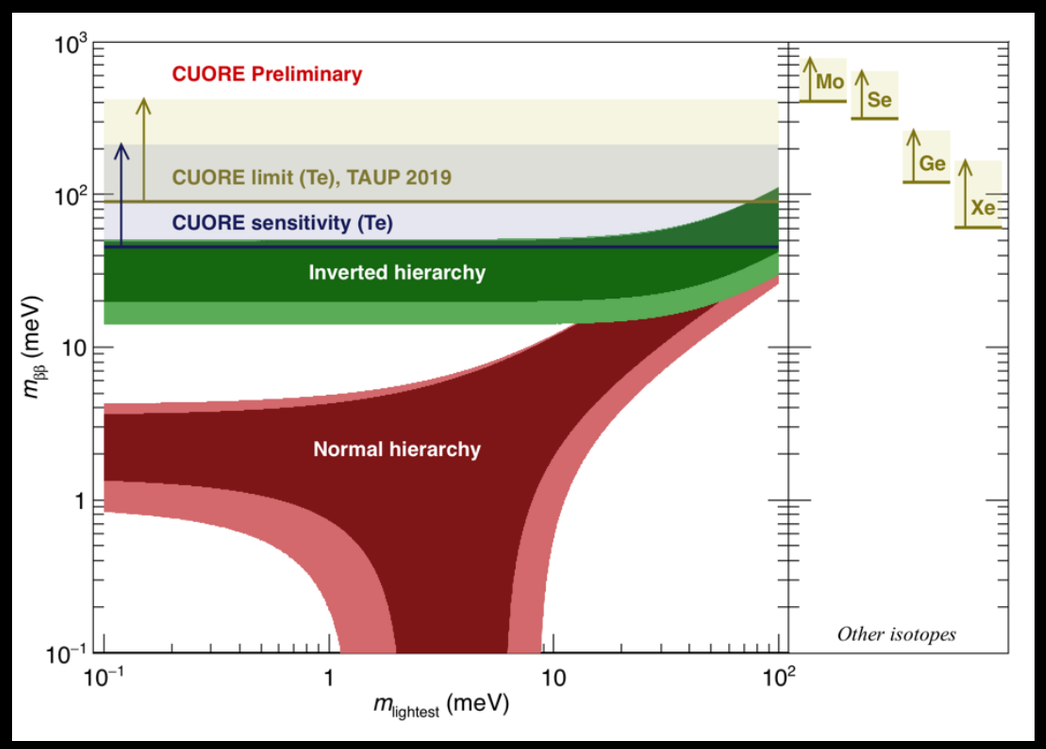
Free params: 60Co peak rate & position, $\Gamma_{0\nu}$ rate, background

Repeat fit with additional nuisance parameters to account for systematics



Latest results: limits





- Background under-fluctuation yields a best-fit value of: $\Gamma_{0\nu}=-3.0^{+2.8}\cdot10^{-26}\ yr^{-1}$
- Marginalized limit computed on physical range: $\Gamma_{0\nu}< 3.0\cdot10^{-26}\ yr^{-1}$

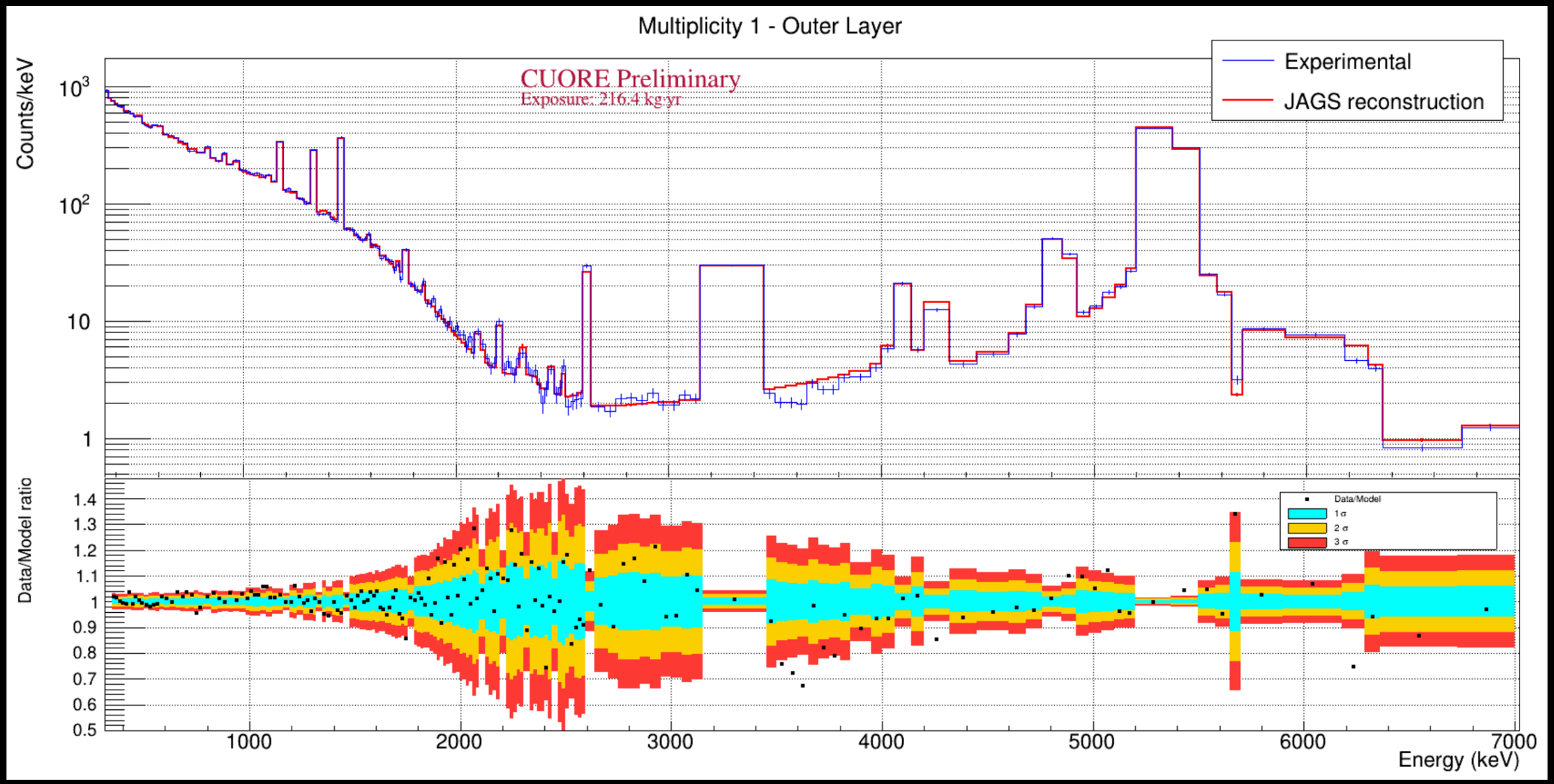
  $T_{1/2} > 2.3\cdot10^{25}$ yr at 90% C.I.

- Systematics affect the limit by ~1%
- Probability of getting a stronger limit: 13%
- Assuming the light neutrino exchange:

  $m_{\beta\beta} < 0.09\text{-}0.42$ eV at 90% C.I.

Foreseen publication of this limit very soon!

Background model



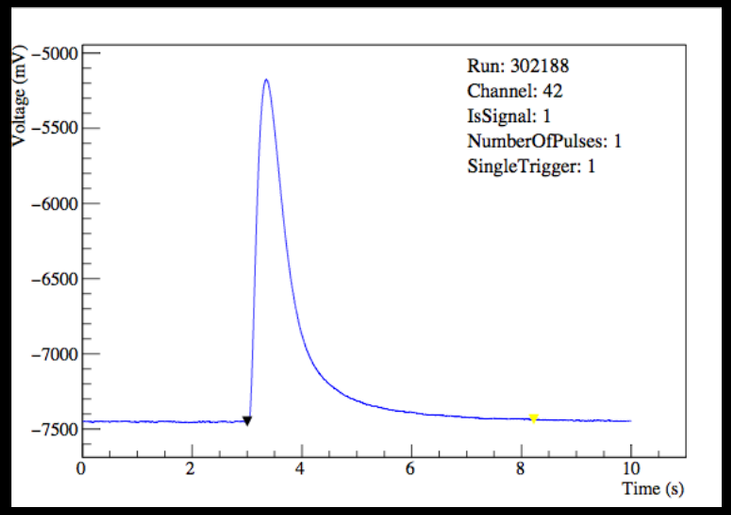
We're able to reconstruct the main features of the observed spectra

Foreseen publication of the background model in the near future

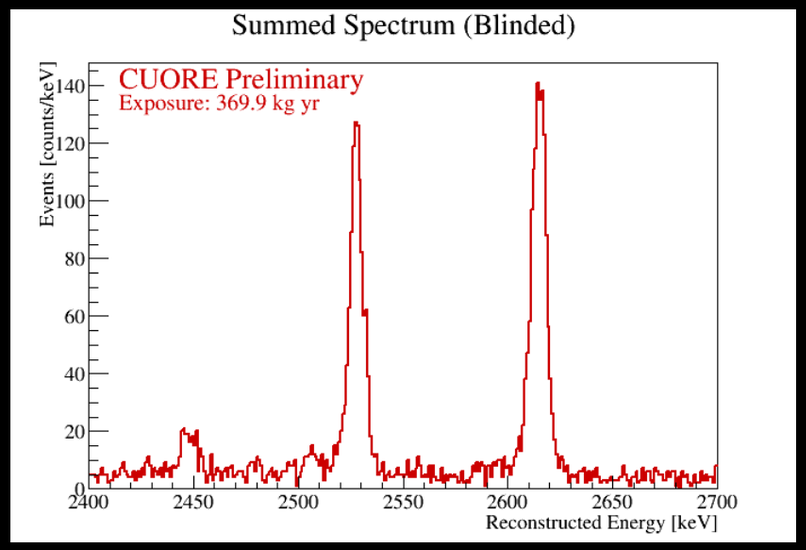
Keep running in a stable condition is our priority!

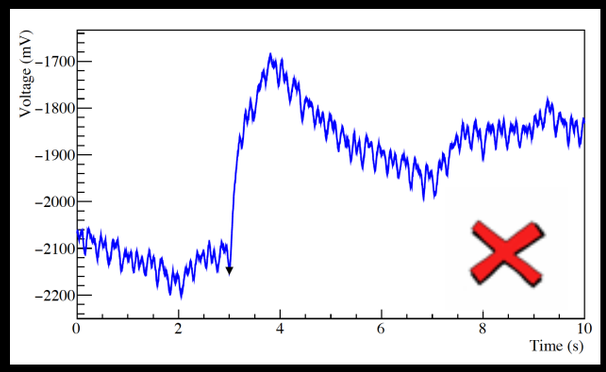
Back-up

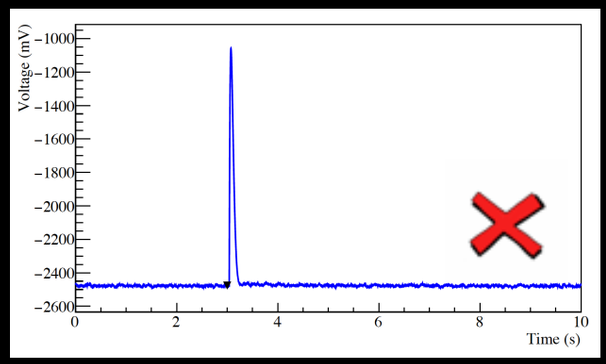
Latest results : data reconstruction

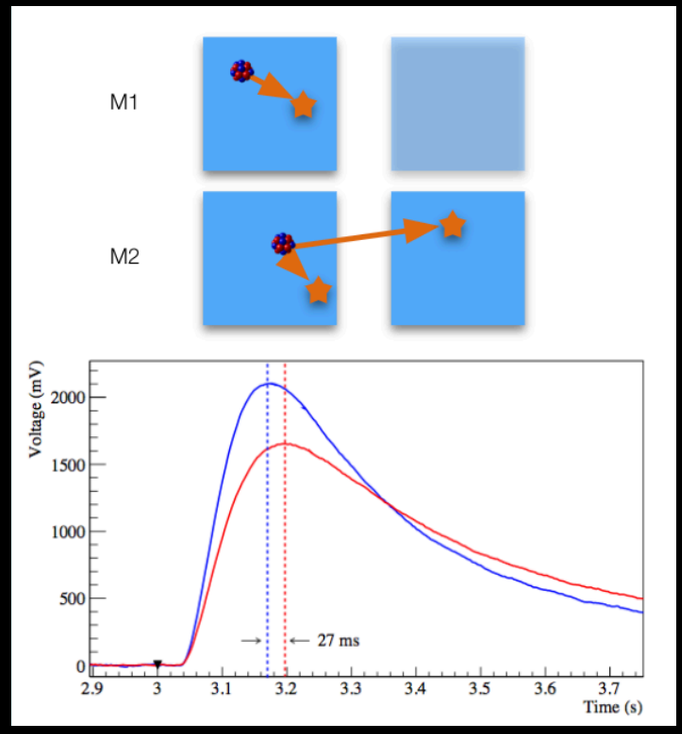


Optimum Filter → Gain Correction → Energy Calibration → Coincidences → Pulse Shape Analysis → Blinding of the ROI → Data quality selections → Unblinding









Background in the ROI

α region

Fit flat background in [2650,3100] keV region

Average α background: **$1.210(28)\cdot10^{-2}$ cts/keV/kg/yr**

$Q_{\beta\beta}$ region

Fit with flat background + ^{60}Co peak in [2490,2575] keV region

Average BI: **$1.369(69)\cdot10^{-2}$ cts/keV/kg/yr**

More than 88% of the background in the ROI is given by alpha interactions