# An innovative Neganov-Luke-assisted light detector for the sensitivity enhancement of CUORE experiment

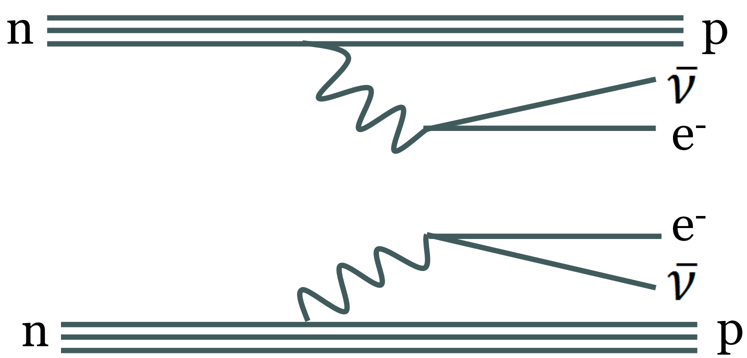
Valentina Novati

École Doctorale PHENIICS Doctoral School

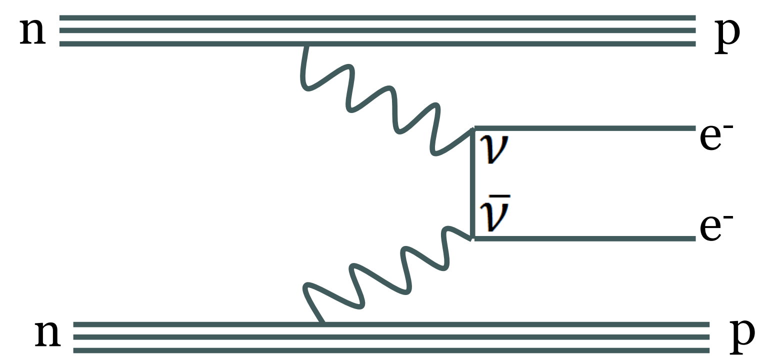
CSNSM Centre de Sciences Nucléaires et de Sciences de la Matière

# What is neutrinoless double beta decay?

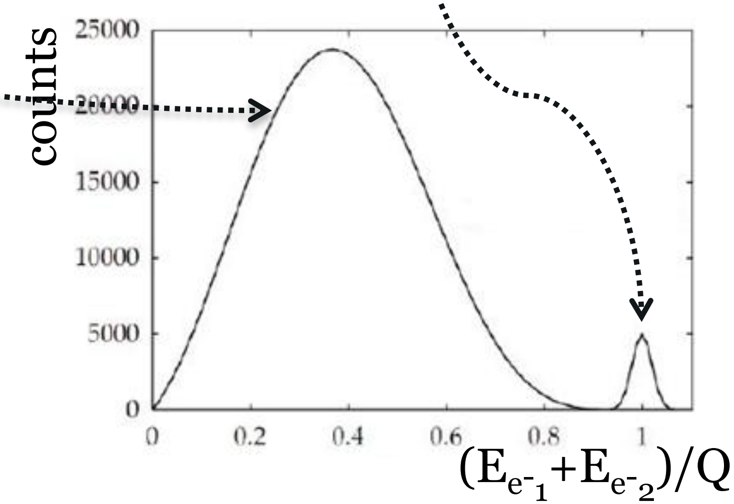
$$2n \rightarrow 2p + 2e^- + 2\bar{\nu}$$




$$2n \rightarrow 2p + 2e^-$$




Neutrinoless double beta decay is a hypothetical rare nuclear process: its mean life is longer than $10^{26}$ years, that corresponds to $10^{16}$ times the age of the Universe

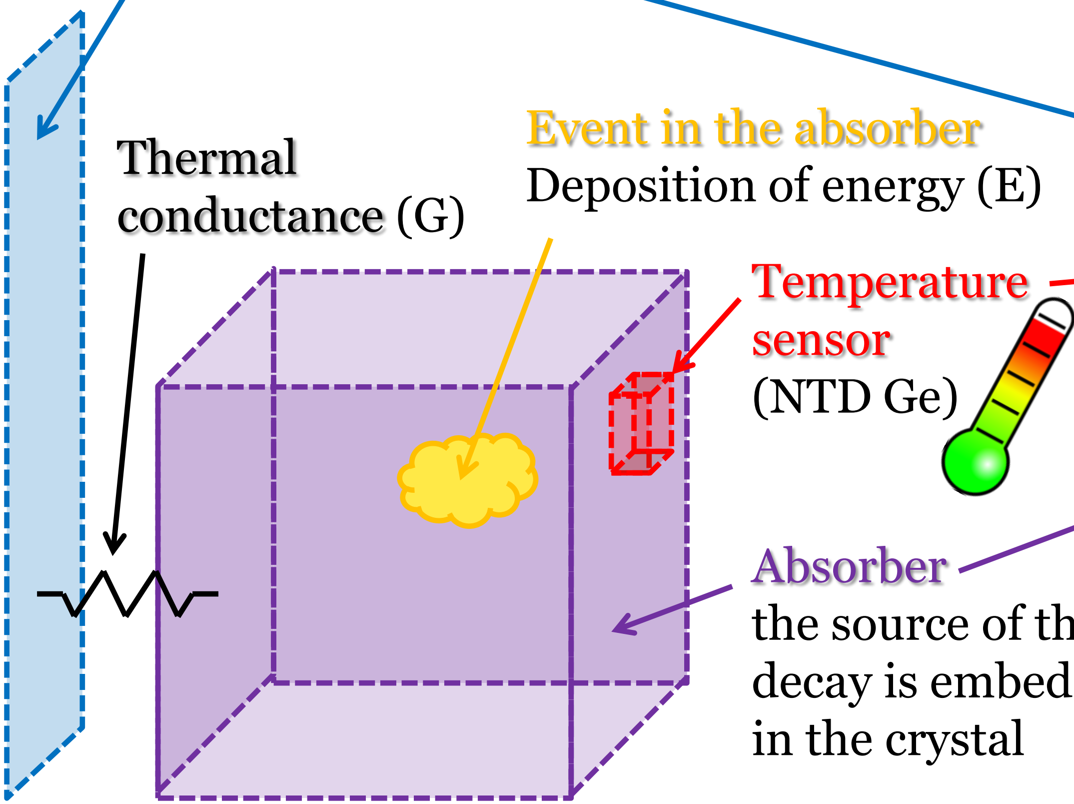


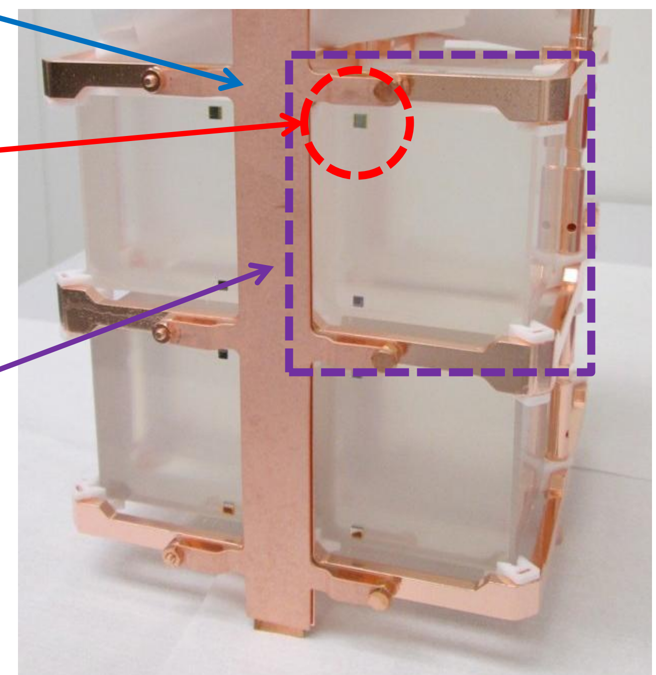
# And why do we search for it?

- Majorana nature of neutrino $$\nu = \bar{\nu}$$
- Neutrino mass $$T_{1/2} \propto \frac{1}{m_\nu^2}$$
- Lepton number violation $$\underbrace{2n}_{\text{no leptons}} \rightarrow \underbrace{2p + 2e^-}_{\text{2 leptons}}$$

# How do we search for it? Bolometers!!

Bolometers work at **cryogenic temperatures** to be sensitive to temperature variation of the order of **μK** induced by particles



# CUORE experiment

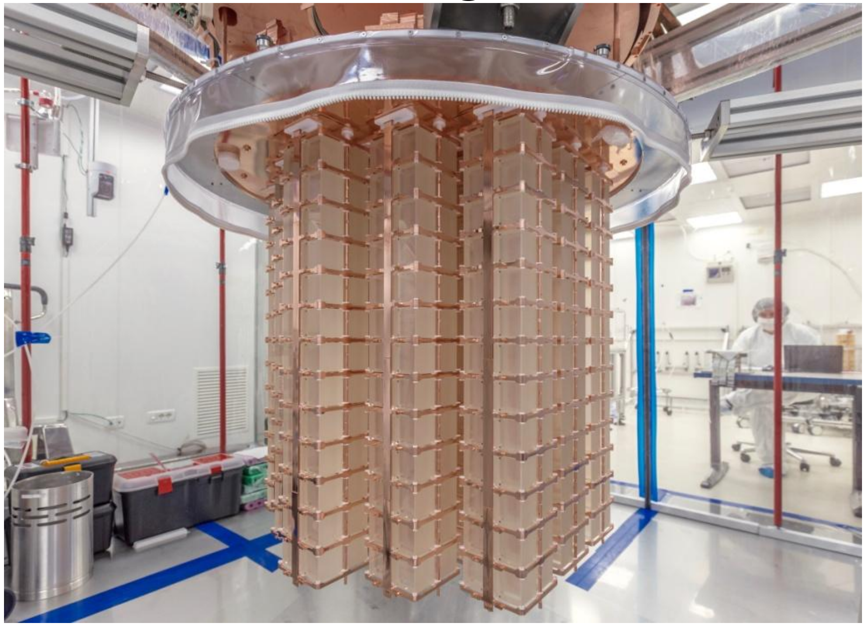
Gran Sasso
Underground laboratory
(LNGS, IT)

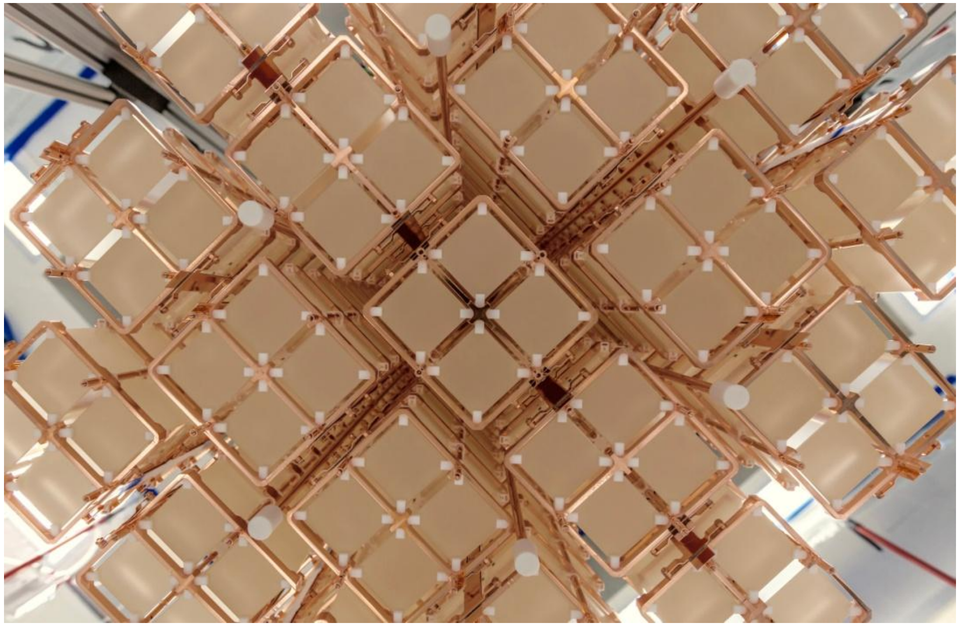
CUORE uses 988 $TeO_2$ bolometers, where $^{130}Te$ is the candidate isotope to the neutrinoless double beta decay (with 2527 keV energy)

Neutrinoless double beta decay is really **rare**

Huge mass:
206 kg of $^{130}Te$
and 742 kg of $TeO_2$

Radiopurity control
to minimize the background

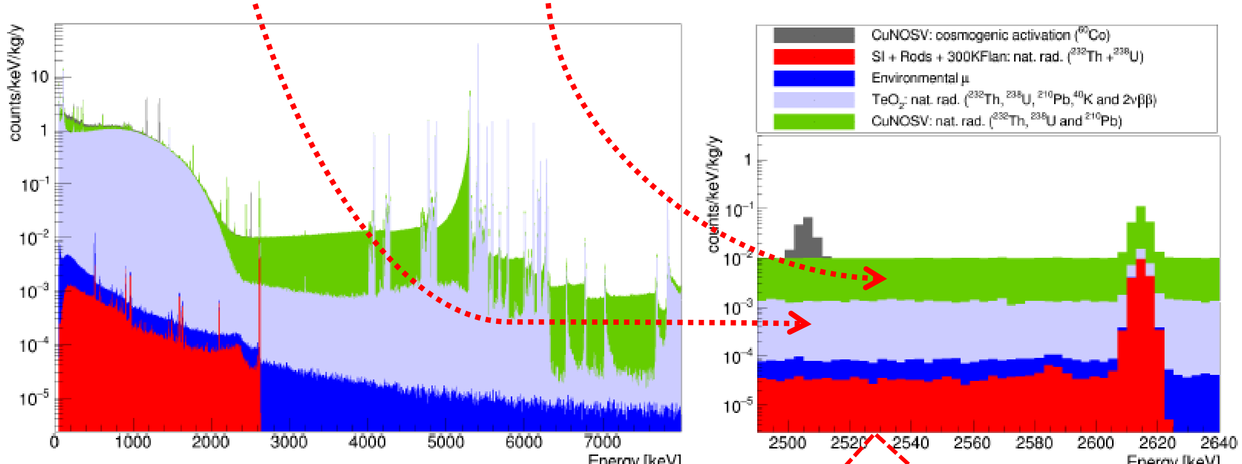




# The issue…

CUORE is not a zero-background experiment, the main background is due to α particles with degraded energy emitted from the surfaces near the detector.

Background budget of the CUORE experiment




32 α events are expected in the neutrinoless-double-beta-decay-energy region in 1 year.

arXiv:1704.08970

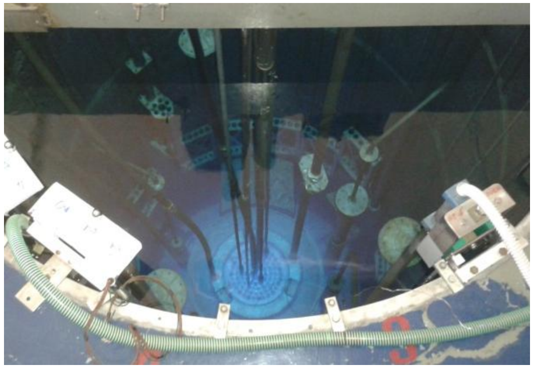
Signal

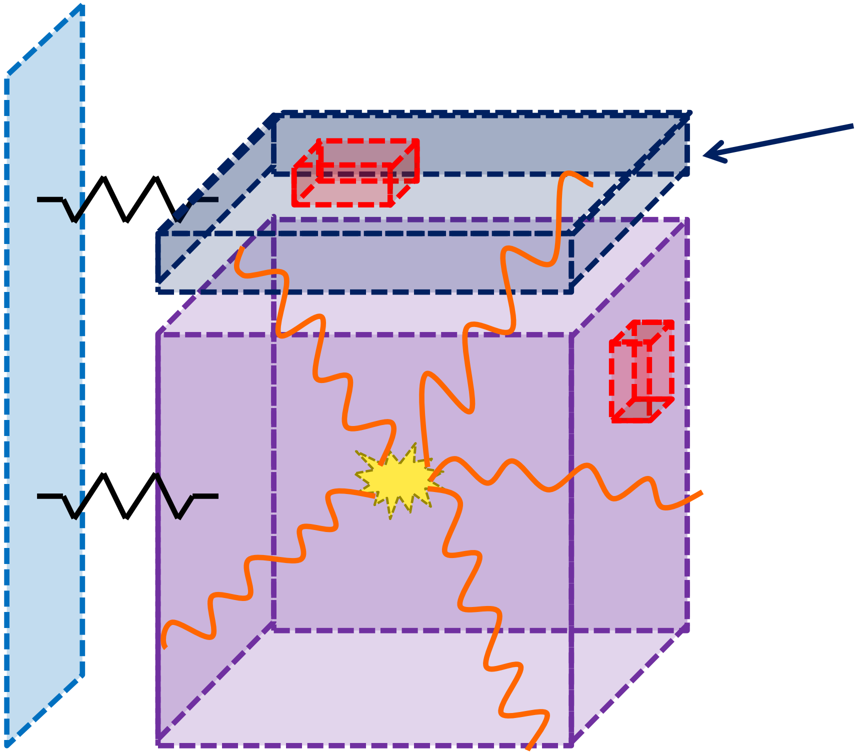
# Our solution: the Cherenkov light tagging

The $TeO_2$ Cherenkov emission threshold:

- 50 keV for the electrons;
- 400 MeV for αs.

Electrons, produced by neutrinoless-double-beta decay in $^{130}Te$, have an energy higher (2527 keV) than the threshold, while surface αs do not.

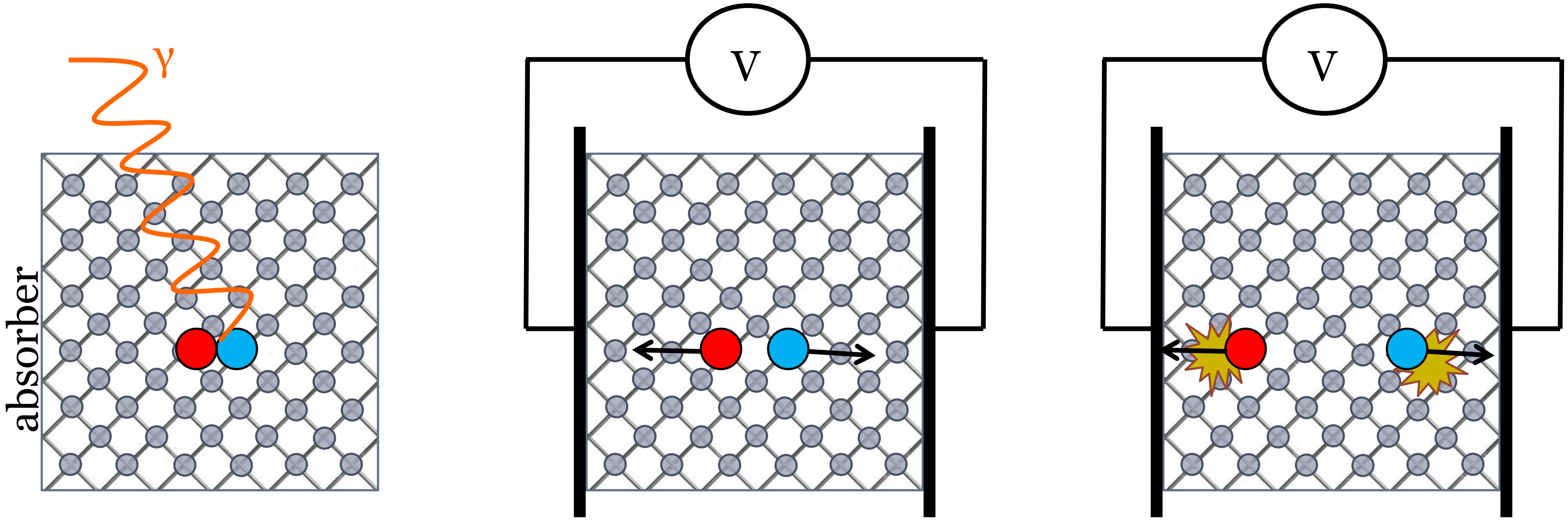




If the detector is coupled to a bolometric light detector, it is possible to measure the Cherenkov light produced by electrons and distinguish their signal from the α background.

Cherenkov light collected by a light detector corresponds to an energy of around 100 eV, that would be hidden in the baseline noise of a standard light detector (~50-100 eV).

# Neganov-Luke effect




The absorption of photons produces *electron-hole pairs*

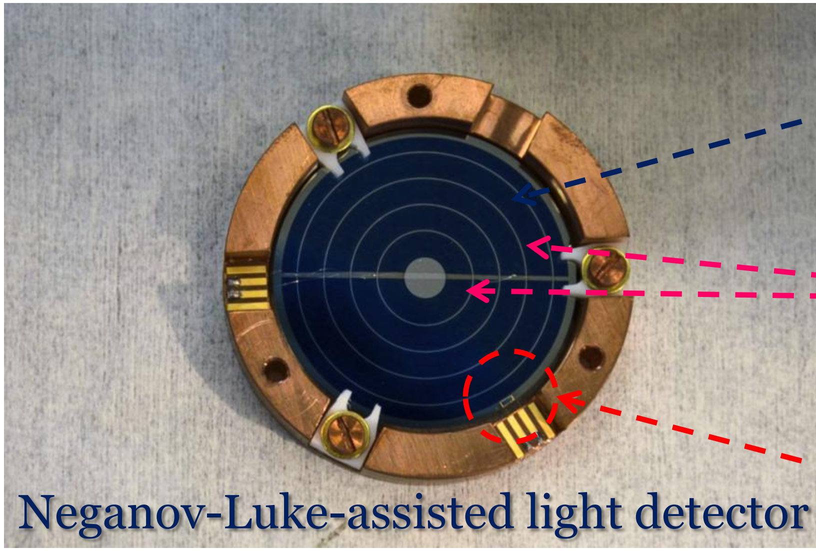
The electric field *drifts the charges and it prevents their recombination*

Carriers *collide with the lattice during the drift, increasing the temperature*

$$E = E_0 \cdot \left(1 + \frac{q \cdot V}{\varepsilon}\right)$$

q electron charge
V voltage applied
ε energy used to produce an electron-hole pair

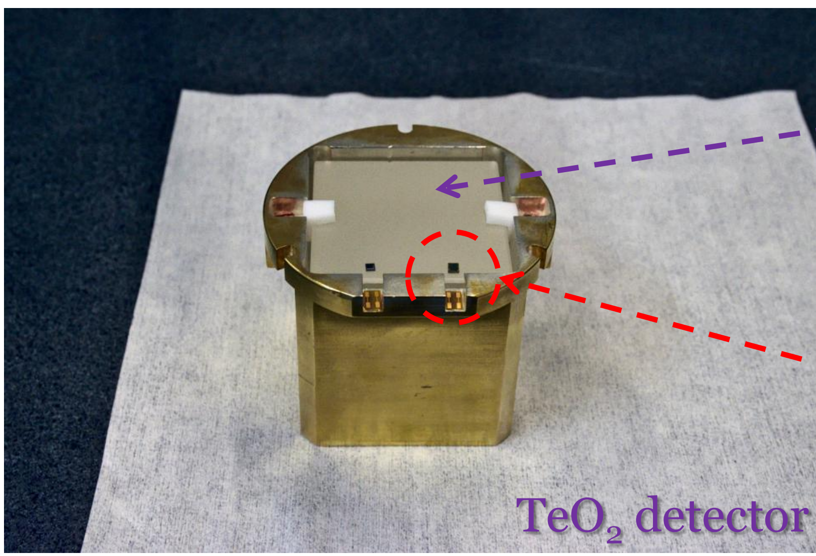
# Our hero: Neganov-Luke light detector




Ge wafer
Ø=44 mm, h=0.17 mm

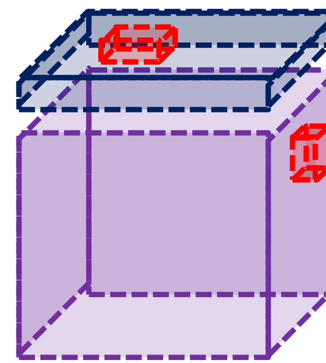
Concentric grids (made of Al) to apply the electric field for the Neganov-Luke effect

NTD Ge
mass ~5.5 mg



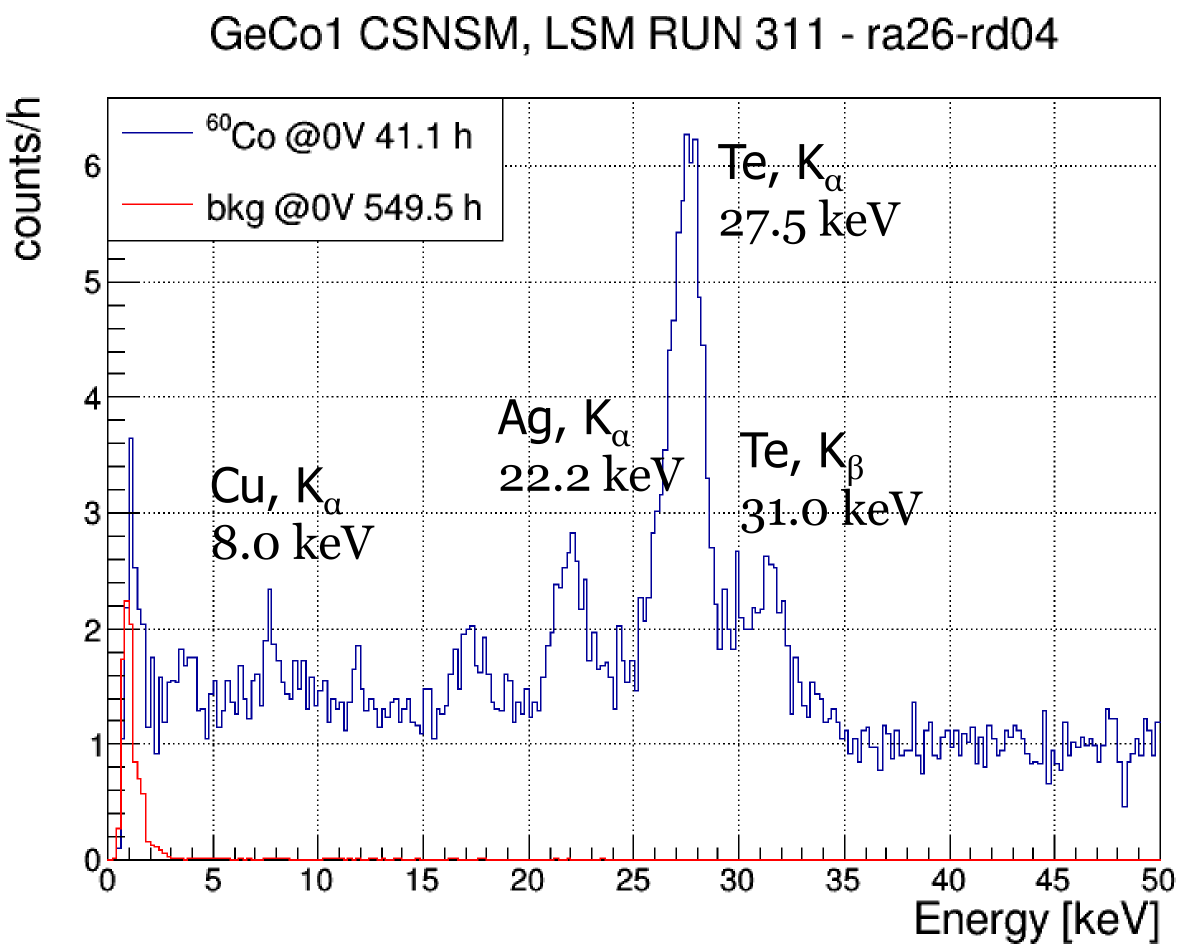

$TeO_2$ crystal
volume 5x5x5 cm$^3$

NTD Ge
mass ~48 mg



Smeared alpha source of $^{210}Po$

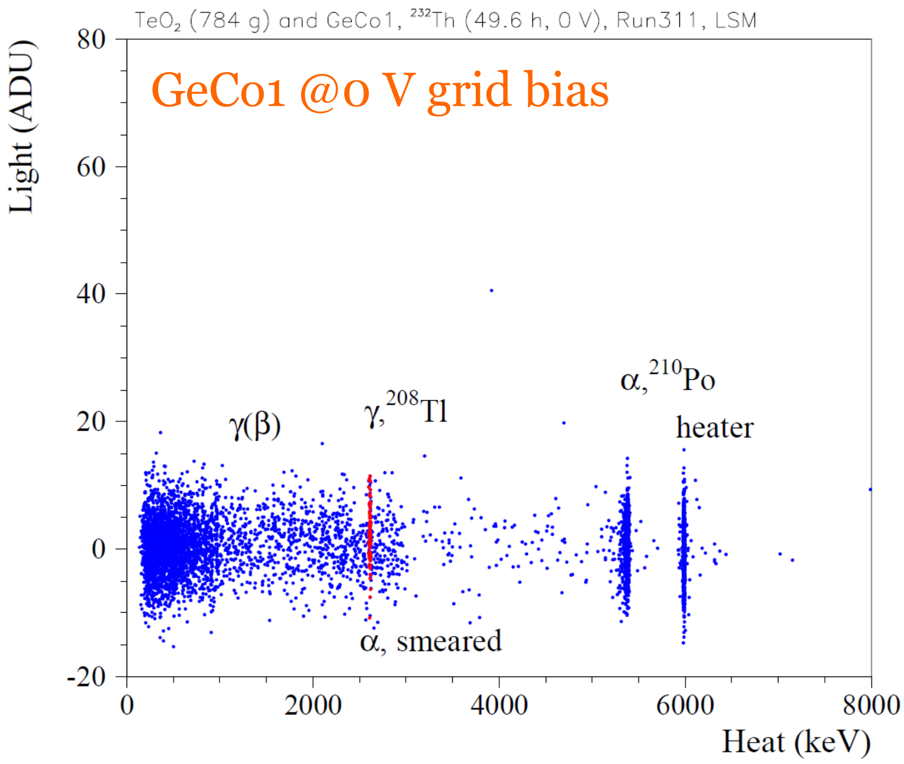
# Light detector calibration




GeCo1 41.1 h (@17 mK) with $^{60}$Co source

549.5 h (@17 mK) of background

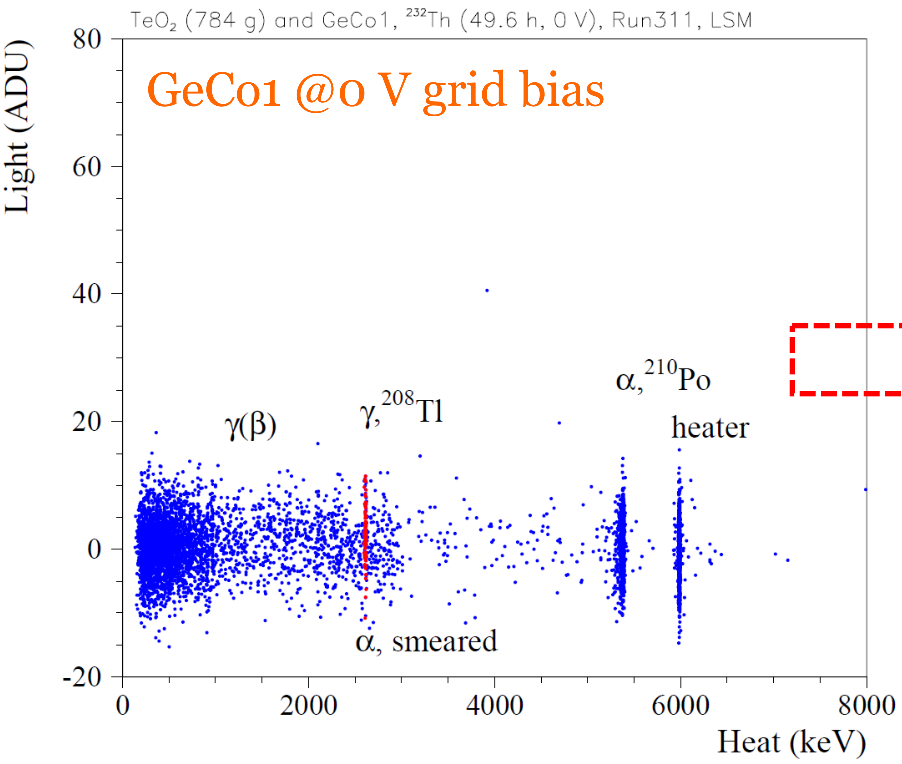
# What do we see with a standard light detector

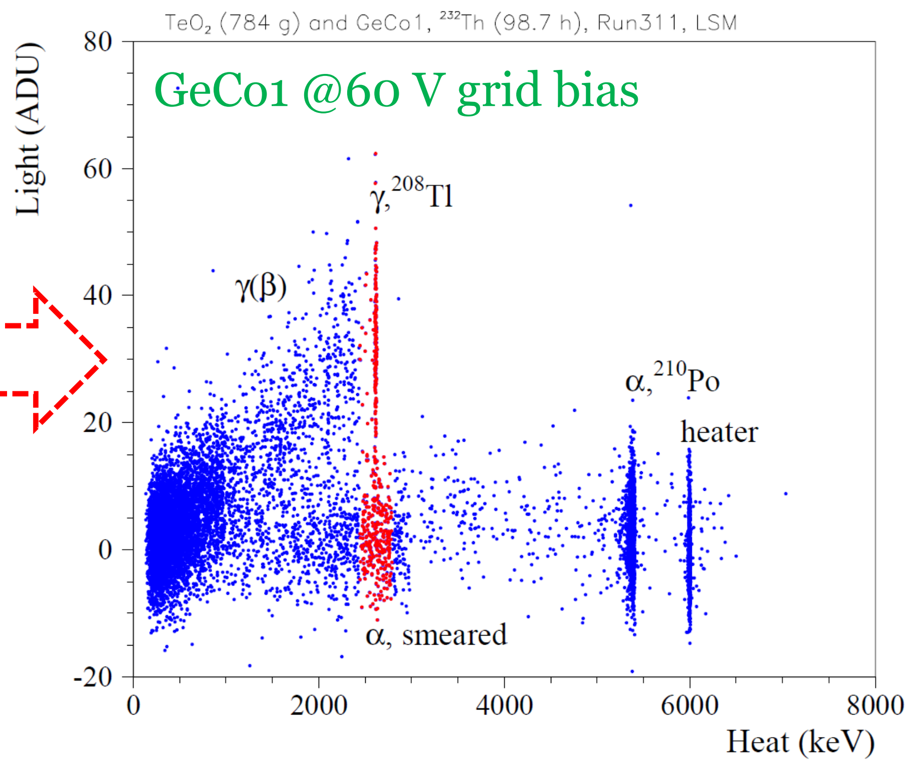



We acquired data without bias on the grids.

baseline-noise RMS = 108 eV
signal/noise = 0.65

# Let's turn on amplification

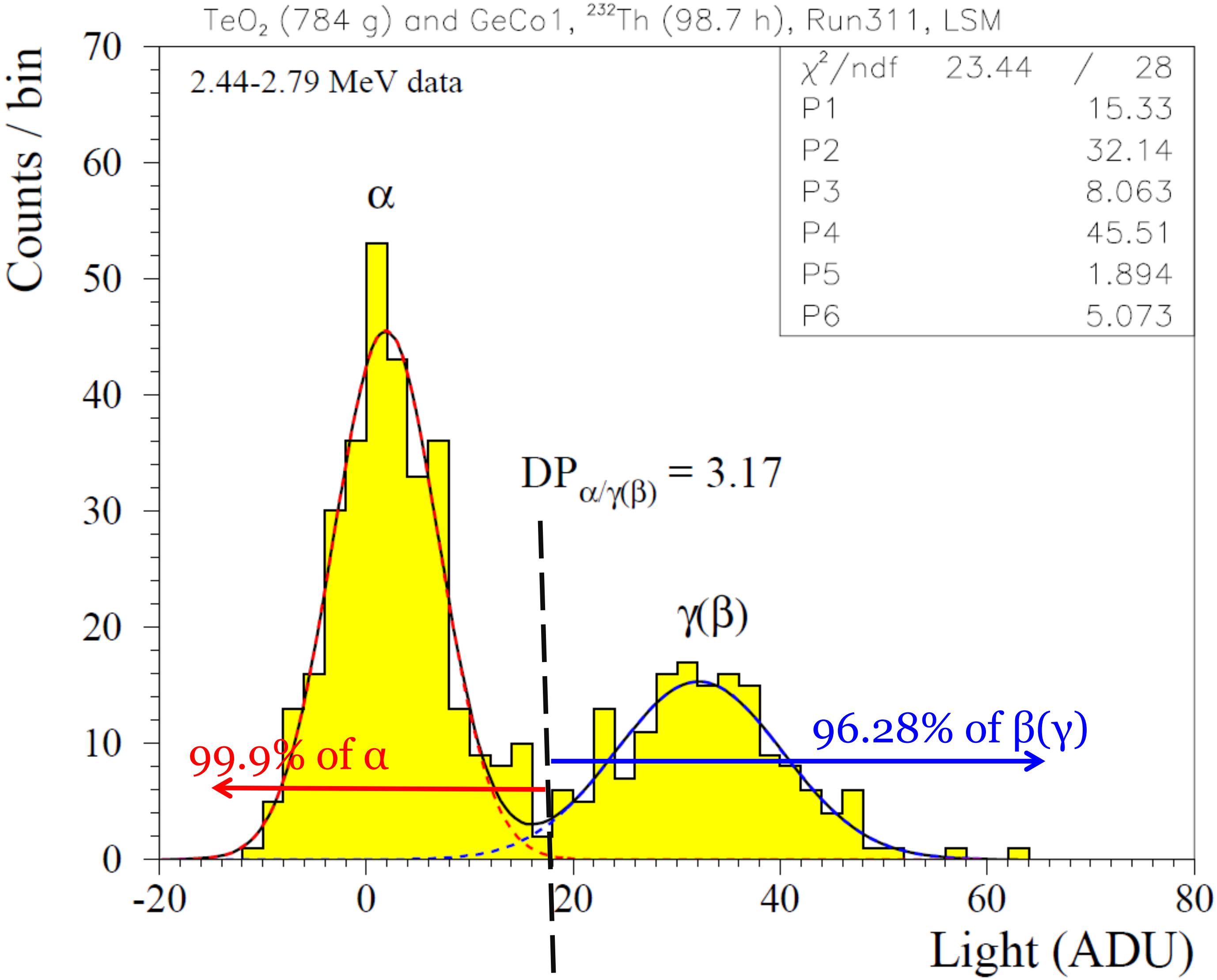



baseline-noise RMS = 108 eV
signal/noise = 0.65

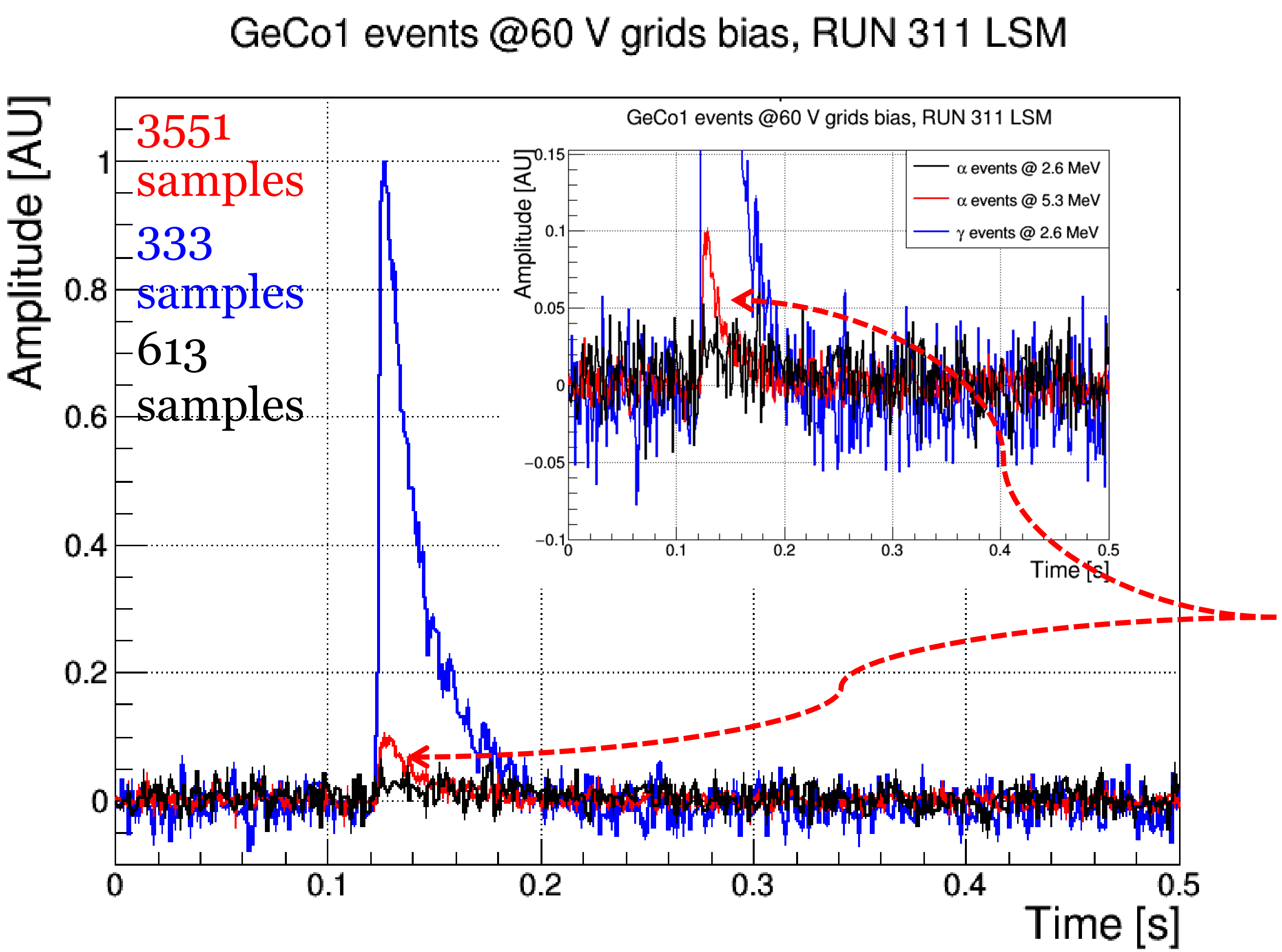
baseline-noise RMS = 9.9 eV
signal/noise=7.1

# α/β(γ) separation




We obtained an acceptance of 96.28% of β(γ) events with a rejection of 99.9% of α particles.

# Not only Cherenkov light…




Averaging many events to reduce the baseline noise…

Scintillation light of αs emitted by $^{210}Po$

# Conclusions

- We have been capable of distinguish the β signal from the α background: 96.28% of β events is accepted, rejecting 99.9% of αs.

- The light emitted by $TeO_2$ crystal is both Cherenkov and scintillation light.