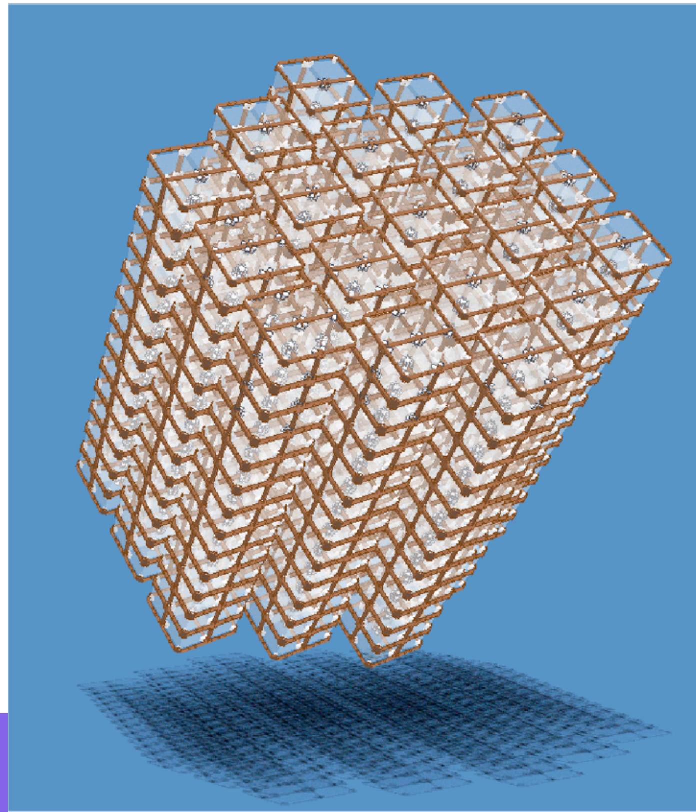


Status of the CUORE experiment

Claudia Tomei, on behalf of the CUORE collaboration
INFN, Sezione di Roma

The Physics Case

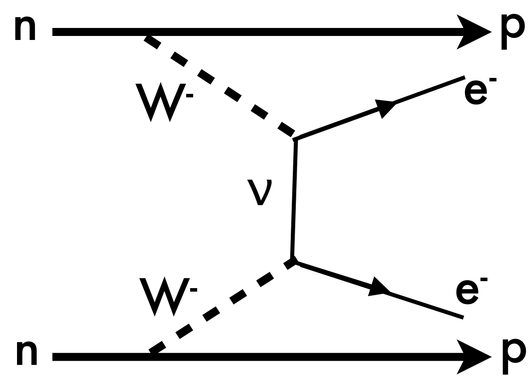
Neutrino oscillations experiments have convincingly shown that neutrinos have mass

But there are still open questions in Neutrino Physics:

- Is neutrino different from antineutrino?
- What is the absolute scale of the neutrino mass?
- What is the neutrino mass hierarchy?

The neutrinoless double beta decay (0vDBD) is a unique probe to test the neutrino nature, the neutrino mass scale and the mass hierarchy.

0νDBD in Theory



- Extremely rare process ($T_{1/2} > 10^{24}$ y), never observed
- Allowed only for massive Majorana neutrinos
- Violates lepton number conservation => Beyond SM physics

The decay amplitude depends on the effective Majorana mass:

$$m_{\beta\beta} = |\sum_k U_{ek}^2 m_k|$$

The measurable quantity is the half-life:

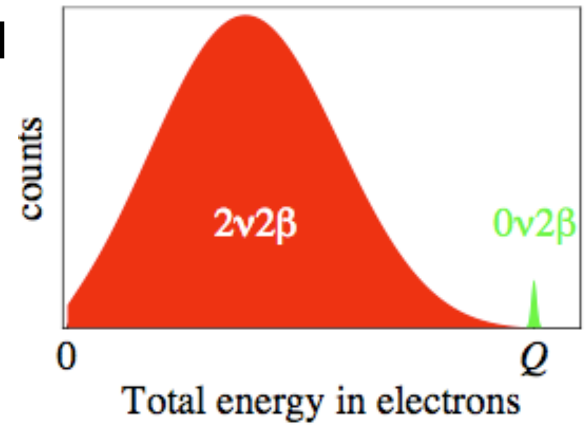
Phase space factor: ~ Q^5 **Nuclear Matrix element**

$$(T_{1/2}^{0\nu})^{-1} = G^{0\nu}(Q,Z) \; |M^{0\nu}|^2 \; \frac{|\langle m_{\beta\beta}\rangle|^2}{m_e^2} \Longleftrightarrow m_{\beta\beta} = \frac{m_e}{\sqrt{F_N T_{1/2}^{0\nu}}}$$

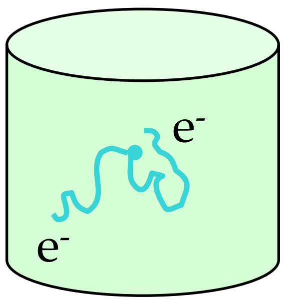
F_N (Nuclear Factor of Merit)

0νDBD in Experiments

- Signature: two simultaneous electrons with summed energy equal to the Q value of the ββ emitter
- Main issues: mass, background, energy resolution, detection efficiency

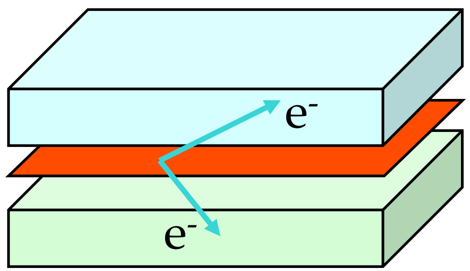


Experimental approaches



calorimeter

Good energy resolution
High source mass
High efficiency

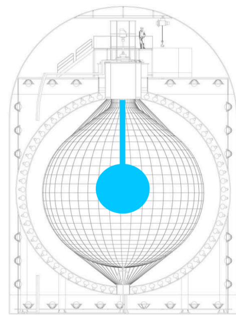


tracking

Event topology
Particle ID

Loaded Liquid Scintillator

Existing experiments
Large source mass



Xenon TPC

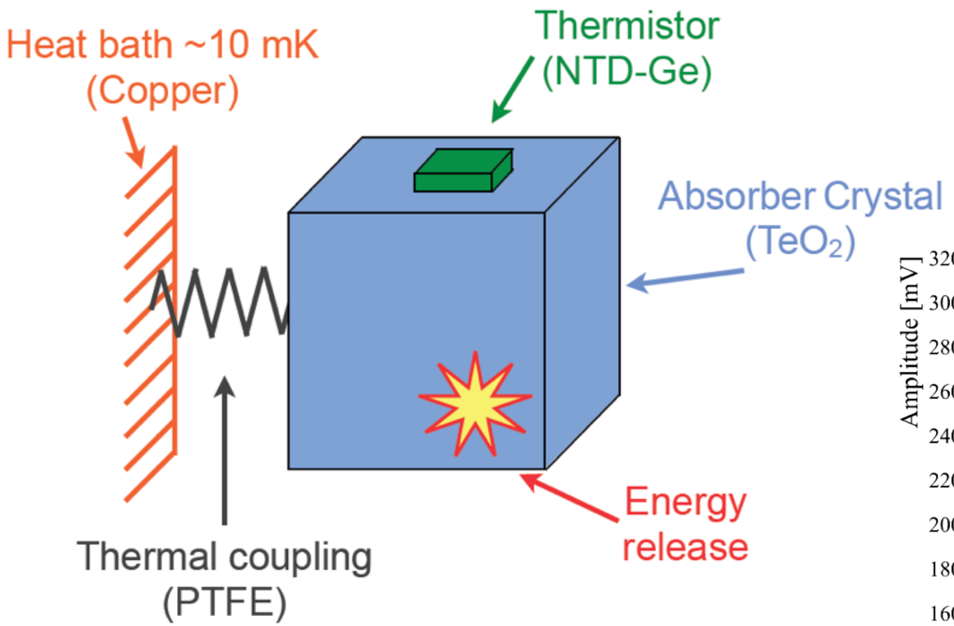
Particle ID

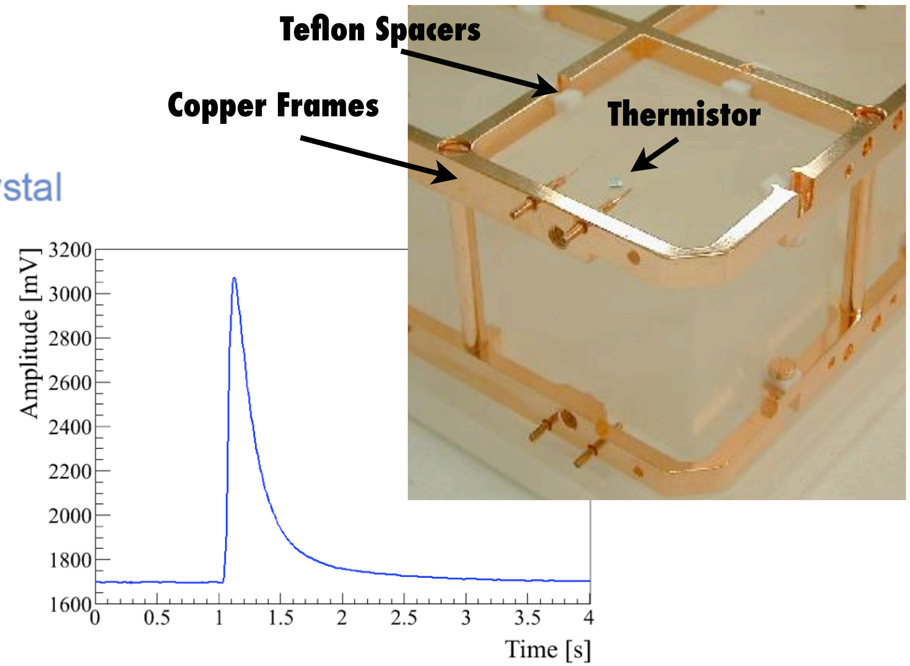
Bolometric technique

Particle energy converted into phonons → temperature variation (ΔT)

Low heat capacity and low base temperature to see small ΔT

Temperature rises are measured by thermistors glued to the crystals





- $\Delta V_{thermistor}$ ~ 0.3 mV/MeV
- $\Delta R_{thermistor}$ ~ 3 MΩ/MeV

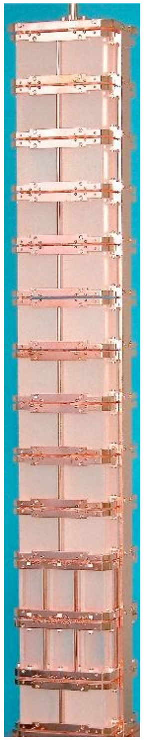
- $\Delta T_{thermistor}$ ~ 0.03 mK/MeV
- $\Delta T_{crystal}$ ~ 0.1 mK/MeV

0νDBD with Tellurium

- Active isotope: ^{130}Te ⟶ $^{130}Te \rightarrow {}^{130}Xe + 2\,e^-$
- Natural abundance: 34.2 % ⟶ no need for enrichment
- Q-value: 2528 keV ⟶ reasonably high: leads to high phase space and is almost above natural radioactivity background

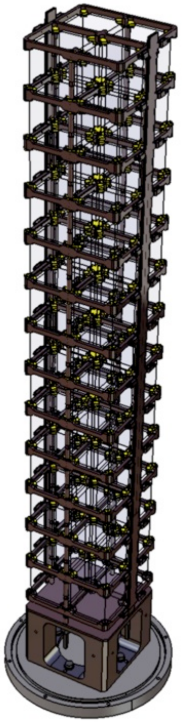
CUORICINO

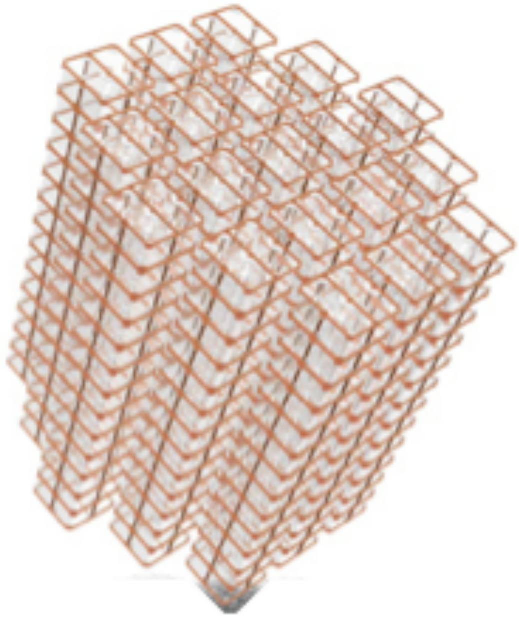
11 kg ^{130}Te



CUORE-0

11 kg ^{130}Te

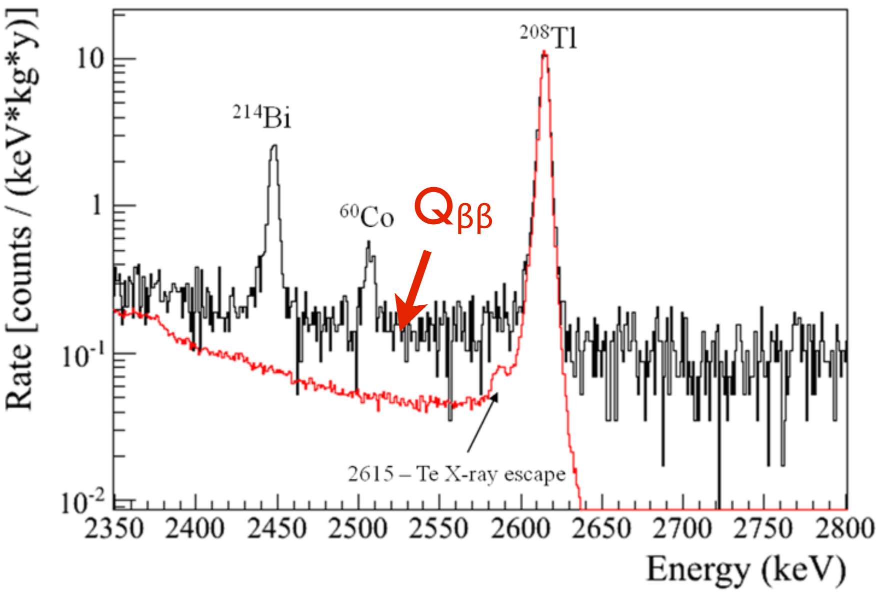


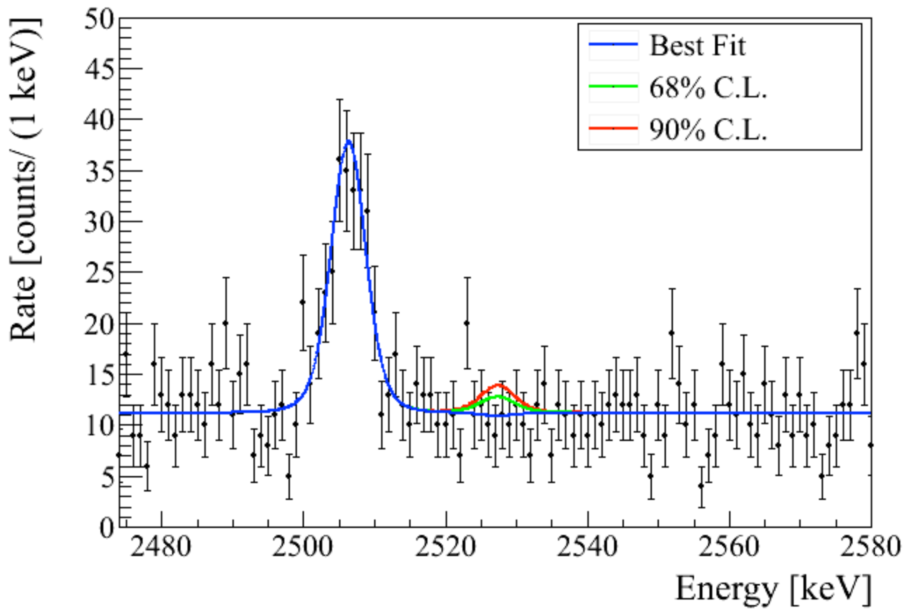


CUORE 206 kg ^{130}Te

CUORICINO final result

Crystal Type	Crystal Mass [g]	^{130}Te Mass [g]	Exposure Run I [kg(^{130}Te)·y]	Exposure Run II [kg(^{130}Te)·y]	Total Exposure [kg(^{130}Te)·y]	Total Exposure [10^{24} (^{130}Te Nuclei)· y]
big	790	217.3	0.94	15.80	16.74	77.50
small	330	90.8	0.09	2.02	2.11	9.78
^{130}Te-enriched	330	199.1	0.15	0.75	0.90	4.17
All			1.18	18.57	19.75	91.45





$$T^{0\nu}_{1/2} > 2.8 \cdot 10^{24} \text{ y } (90\% \text{ C.L.})$$

$$m_{\beta\beta} < (300 \div 710) \text{ meV}$$

NME spread

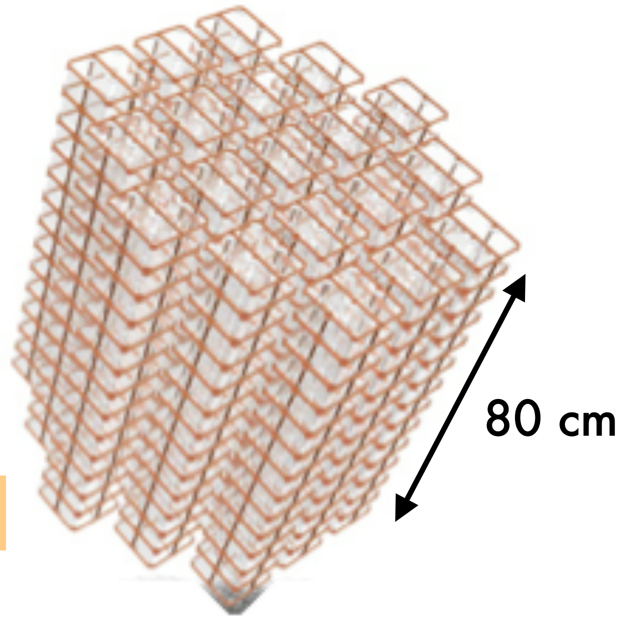
From CUORICINO to CUORE

988 TeO_2 crystals – 5x5x5 cm^3 (750 g)
Total detector mass: 741 kg
Total ^{130}Te mass (nat. abundance): 206 kg

Crystal mounting: 19 towers, each with 13 modules of 4 crystals each

M×20 – T×2 – B/20 – ΔE/1.5

CUORE sensitivity ~ 35 CUORICINO sensitivity

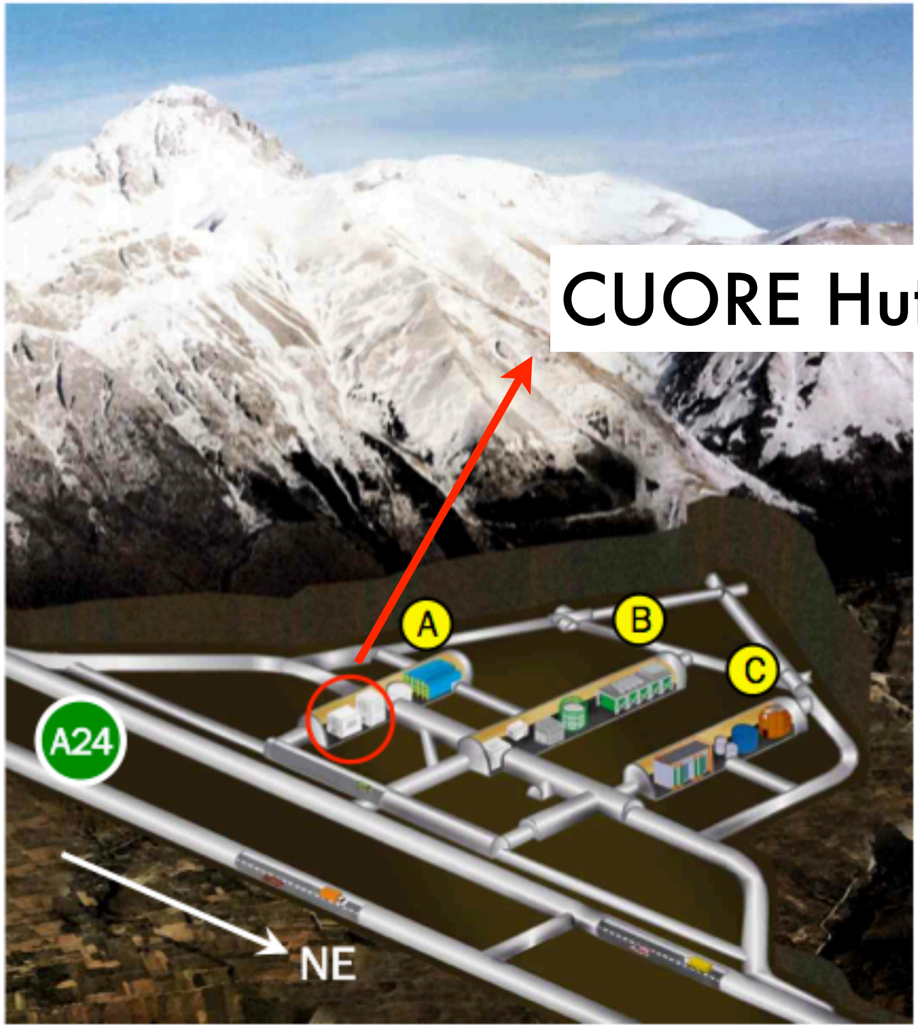


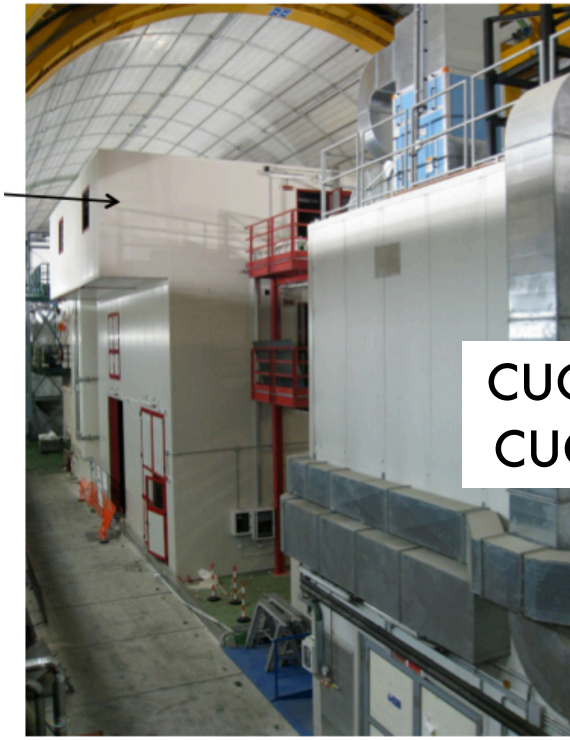
$$S^{0\nu}(1\sigma) = \ln 2 N_A \cdot \frac{a\,\eta}{W}\left(\frac{MT}{B\Delta E}\right)^{1/2} \cdot \epsilon$$

Stoichiometric coefficient of the DBD emitter
Isotopic abundance
Molecular weight of active mass
Detector mass [kg]
Measurement time [y]
Background [counts/keV/kg/y]
Energy Resolution [keV]
Efficiency

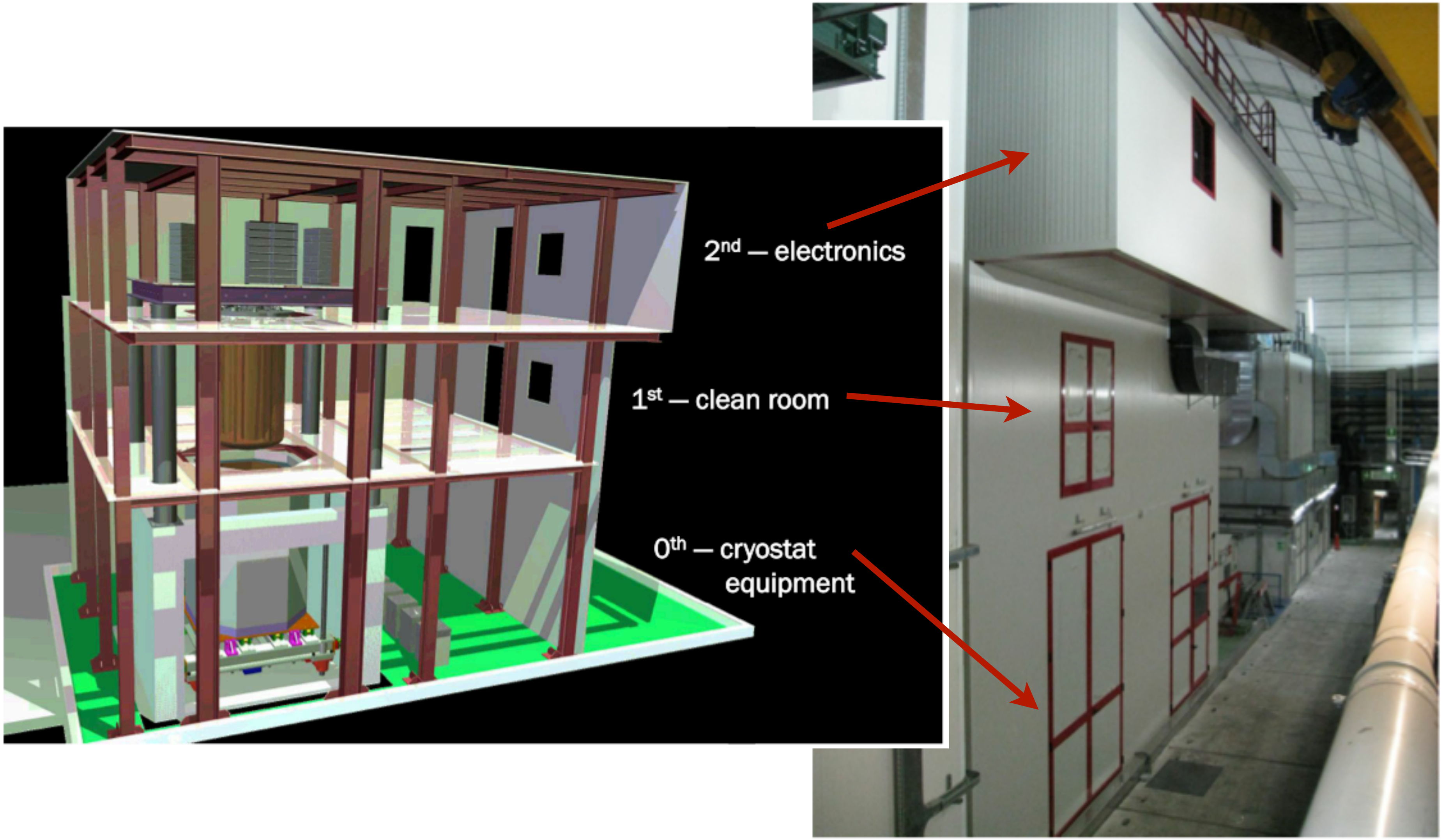
CUORE Location

LNGS Underground Laboratory (INFN)

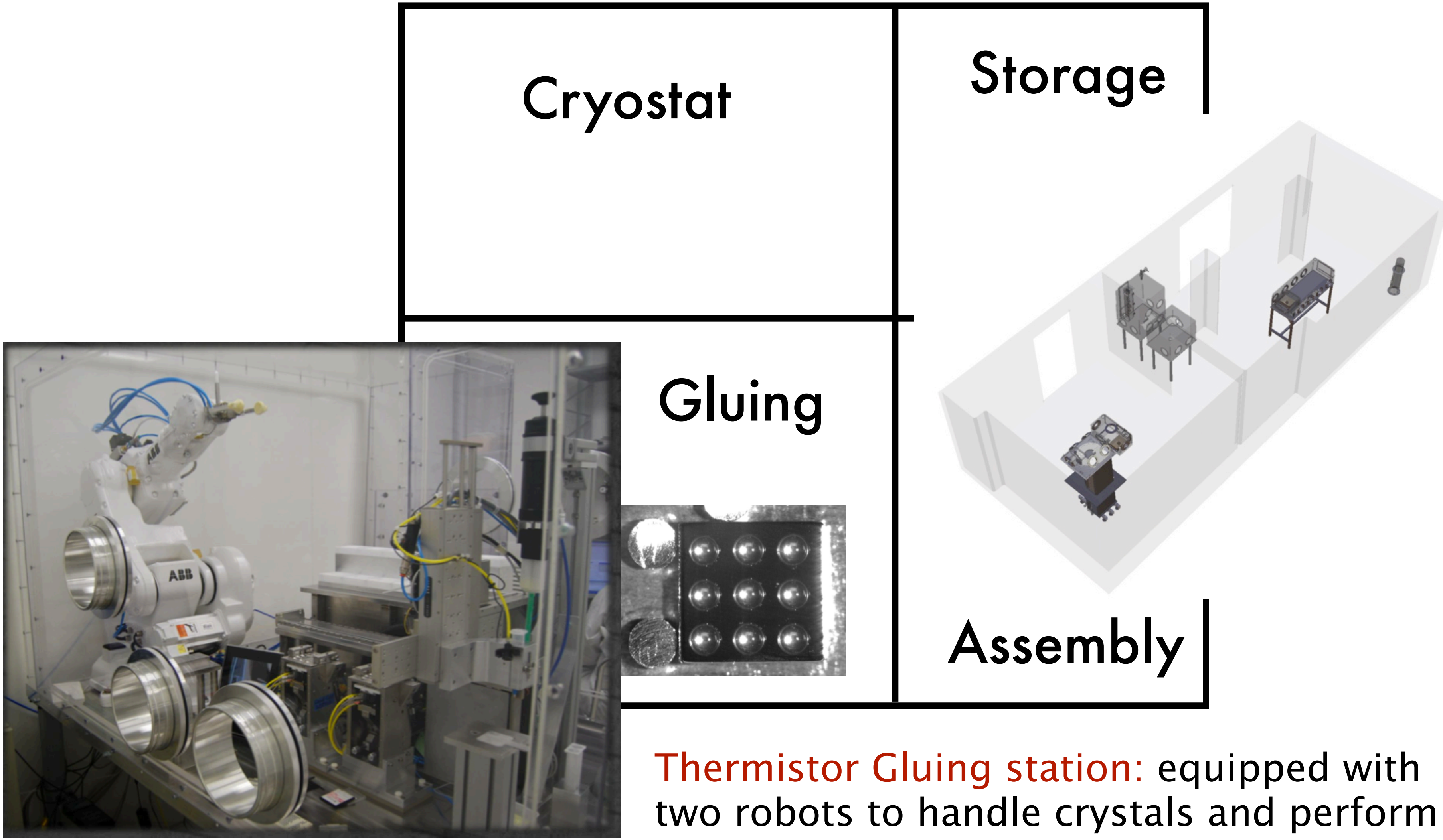




CUORE HUT @ LNGS

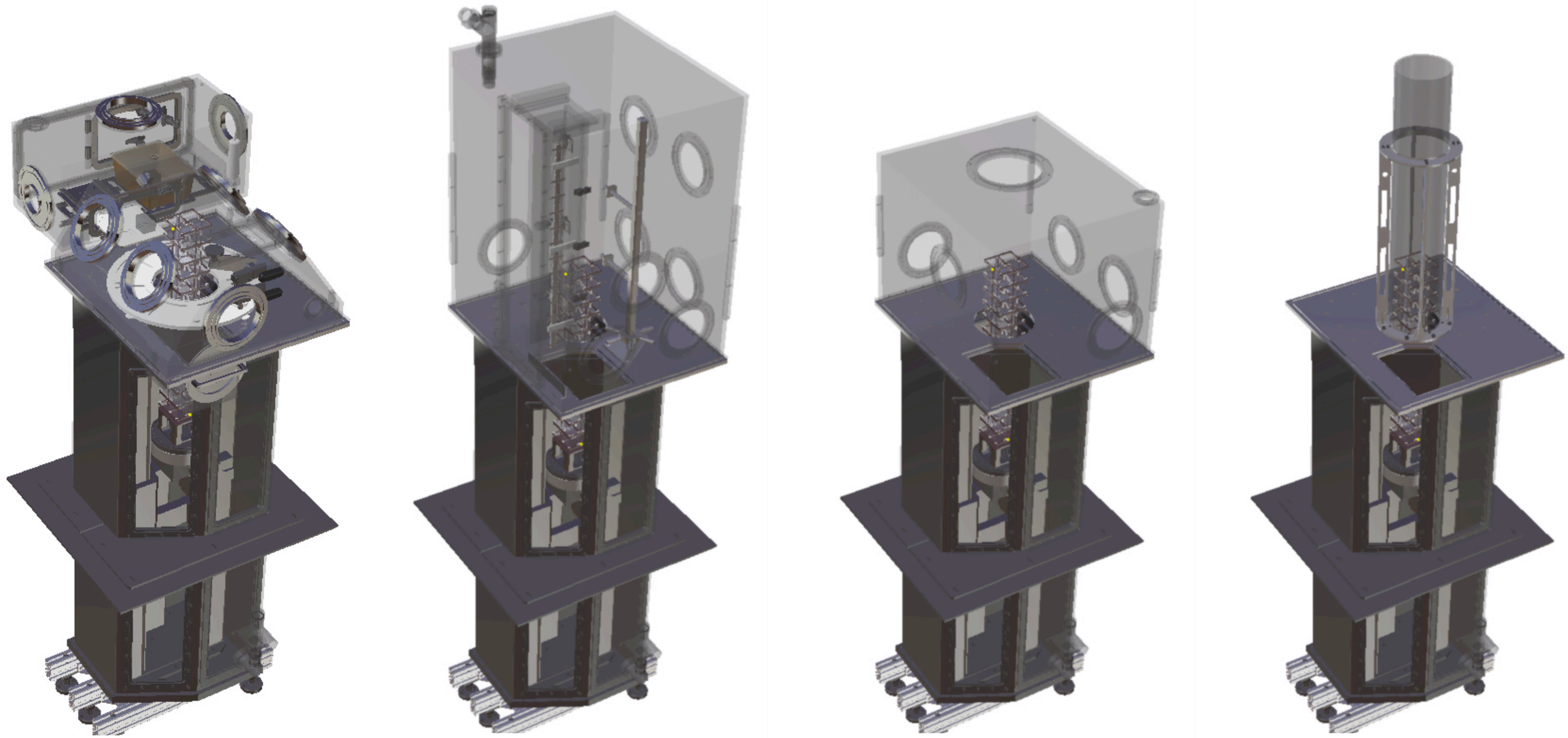


CUORE Clean Room



Thermistor Gluing station: equipped with two robots to handle crystals and perform a more precise and uniform gluing

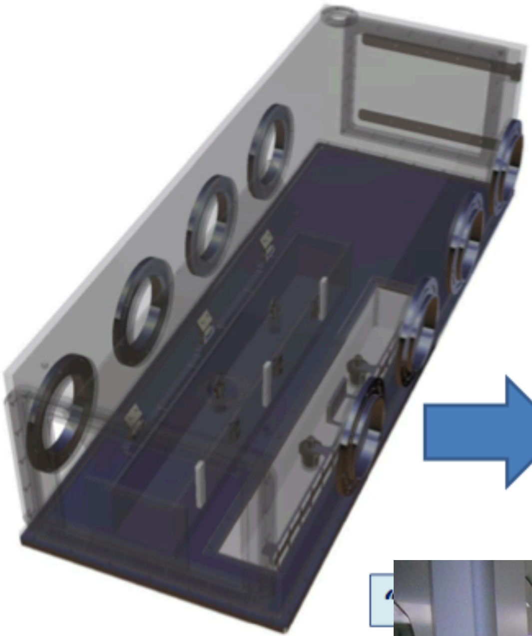
CTAL: Cuore Tower Assembly Line



Mounting Box | Cabling Box | Bonding Box | Storage Box

Towers Assembly Line: a sealed and flushed stainless steel chamber (Garage) supports a common working plane (UWP), where 4 PMMA chambers (Glove Boxes) will switch, each one with features able to allow specific operations, until tower completion.

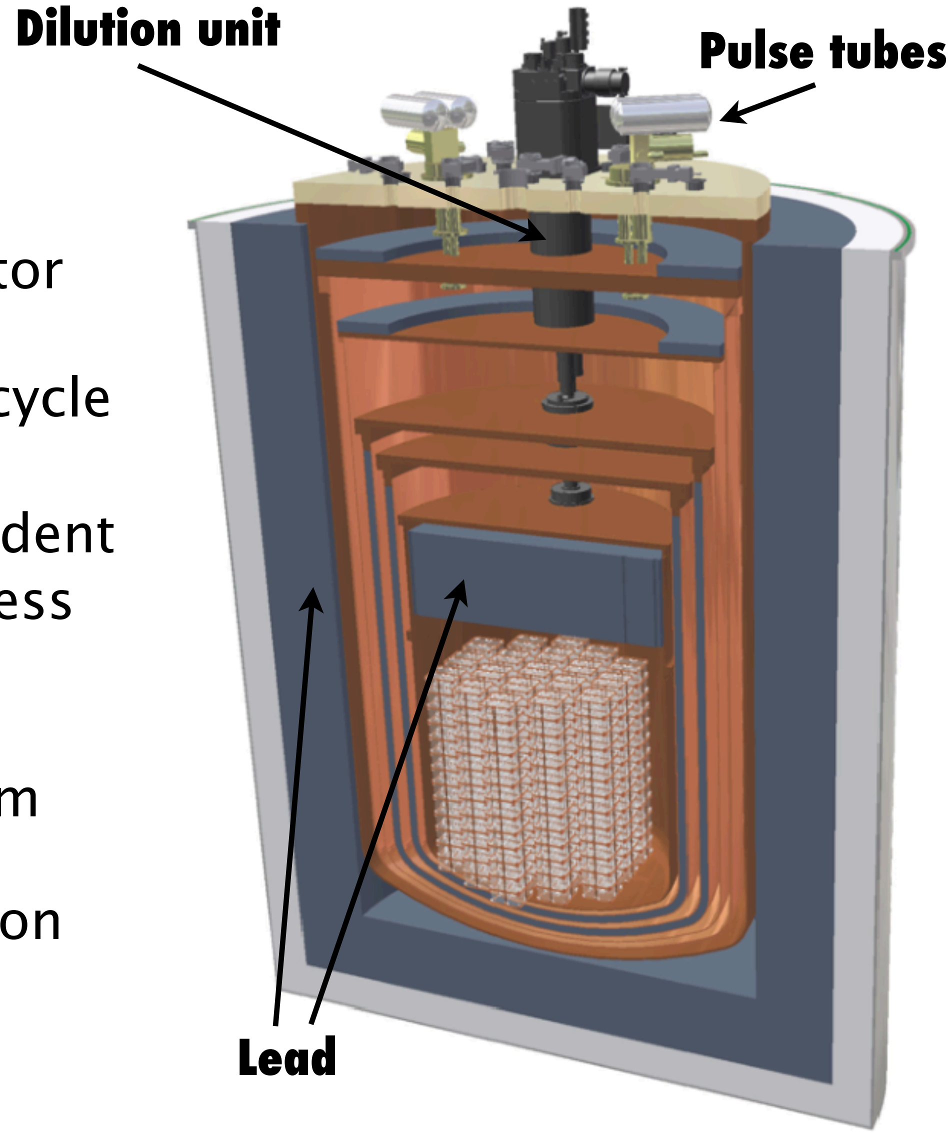
CTAL: Cuore Tower Assembly Line



Towers Assembly Line: a fifth Glove Box will be used to manage several components, coming sealed from PSA (for example the Wire Trays, using specific PTFE tools).

CUORE cryostat

- 6 nested copper shields
- New custom dilution refrigerator
- Cryogen-free $\Longrightarrow$ better duty cycle
- Detector suspensions independent of refrigerator apparatus $\Longrightarrow$ less vibrational noise
- Minimum lead thickness: 36 cm
- Stringent radiopurity controls on materials and assembly



CUORE Status

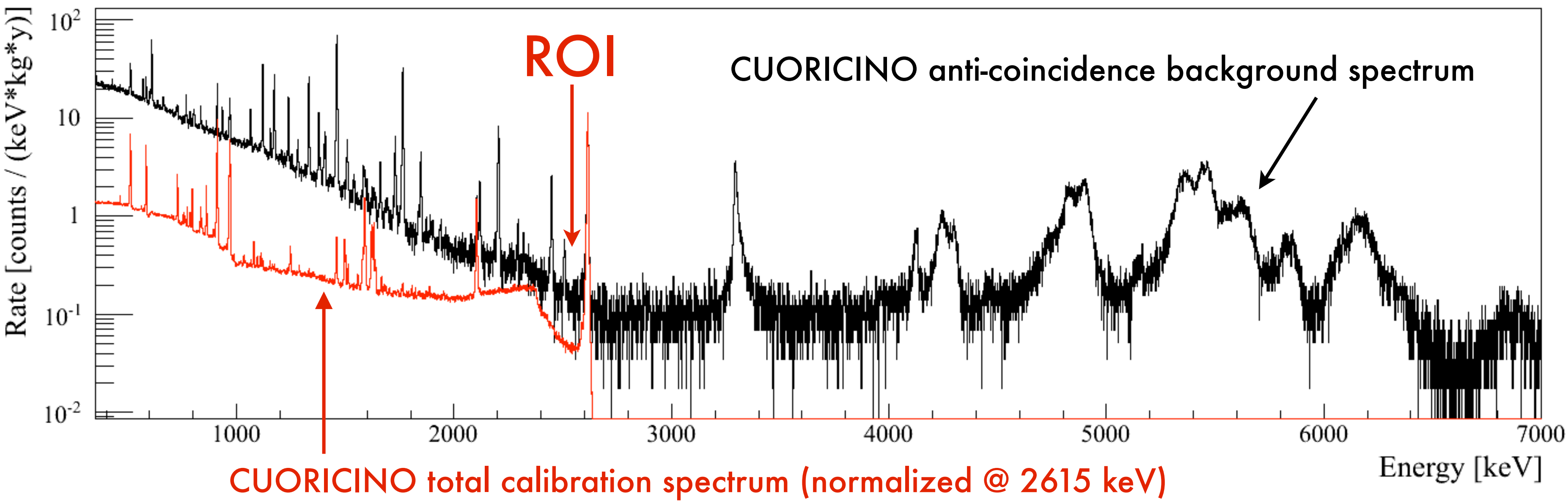
- CUORE experimental hut and clean room fully equipped for tower assembly
- Cryostat commissiong @ LNGS started april 2012
- 80% of CUORE crystals ready and stored underground @ LNGS
- Calibration system under construction
- Copper cleaning @ LNL started

CUORE background reduction

- Material selection
- Self-shielding
- Granularity

Starting point: the CUORICINO background

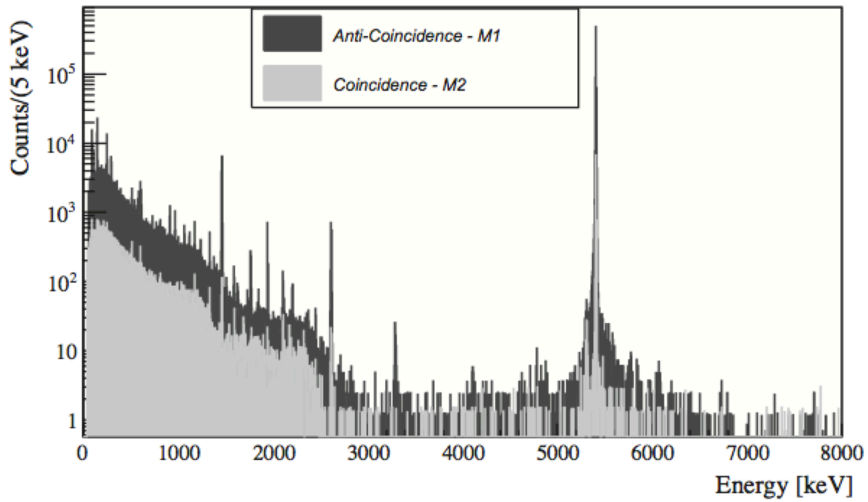
DBD (ROI) background: (0.169 ± 0.006) c/(keV kg y)



The main issues are degraded alphas from U/Th on copper and crystal surfaces

CCVR: Cuore Crystals Validation Runs

CUORE crystals production at SICCAS



CCVR 1-5

CUORE crystal validation runs: Results on radioactive contamination and extrapolation to CUORE background Astroparticle Physics 35 (2012)

Carried out since 2008 (8 runs so far)

- CCVR background rate shows a reduction with respect to CUORICINO
- No indication of bulk/surface contaminations from U/Th
- Bulk activities (^{210}Po and U/Th limits) within contact specifications
- Energy resolution improved

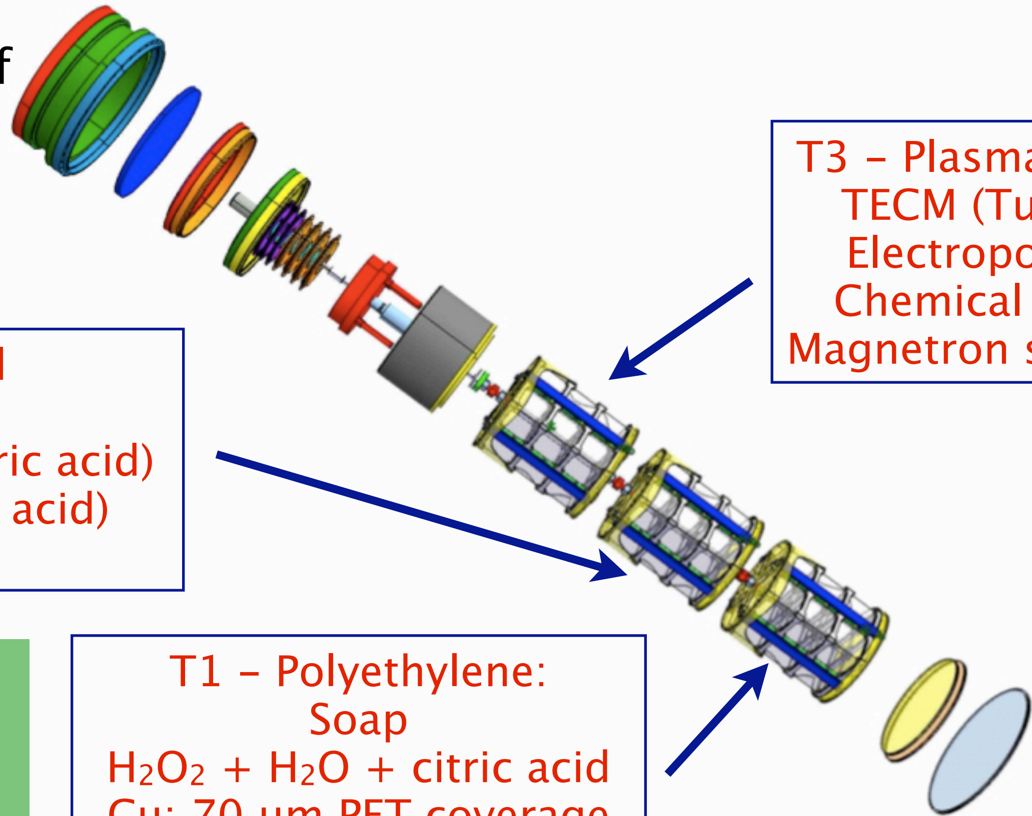
Extrapolation to CUORE background in ROI (upper limits):
$1.1 \cdot 10^{-4}$ counts/keV kg y (bulk) – $4.2 \cdot 10^{-3}$ counts/ keV kg y (surface)

Crystals OK - Cu surface treatment is the crucial issue

The Three Towers test

Large mass detector to test the Cu contaminations in 3 different configurations inside the CUORICINO cryostat (same background and operation conditions)

Complete reprocessing of all CUORICINO crystals according to CUORE standards



T3 – Plasma Cleaning
TECM (Tumbling, Electropolishing, Chemical etching, Magnetron sputtering)

T2 – New Chemical
Soap
Electro-erosion (phosphoric acid)
Chemical Etching (nitric acid)
Passivation

T1 – Polyethylene:
Soap
$H_2O_2 + H_2O$ + citric acid
Cu: 70 μm PET coverage

Best results for towers T1 and T3 (CUORE baseline)

Bkg @ (2.7 ÷ 3.9) MeV: 0.052 ± 0.08 counts/kg keV y

Paper in preparation

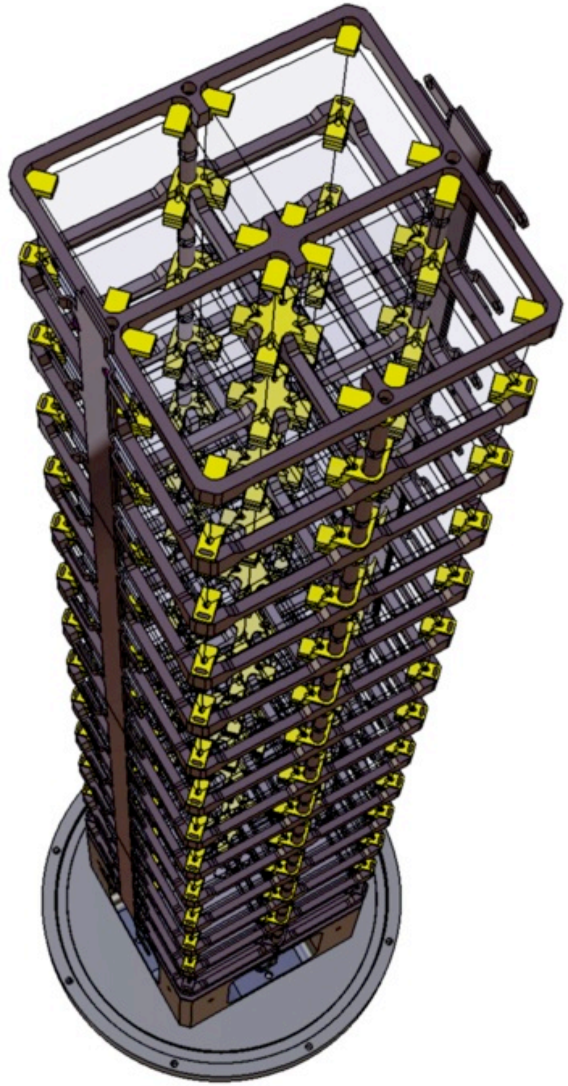
Background Budget

Source	Background [counts / kg keV y]	From
External (μ+n+γ)	$< 2 \cdot 10^{-3}$	Measured fluxes + MC
γ from cryostat + shields	$< 1 \cdot 10^{-3}$	Material selection + CUORICINO
Cu detector holder (bulk)	$< 2 \cdot 10^{-3}$	HPGe + NAA + MC
Cu detector holder (surface)	$< 2.5 \cdot 10^{-2}$ Preliminary	TTT + MC
TeO_2 (bulk)	$< 1 \cdot 10^{-4}$	CCVR + MC
TeO_2 (surface)	$< 5.5 \cdot 10^{-3}$	CCVR + MC

the only evidence of a measurable background

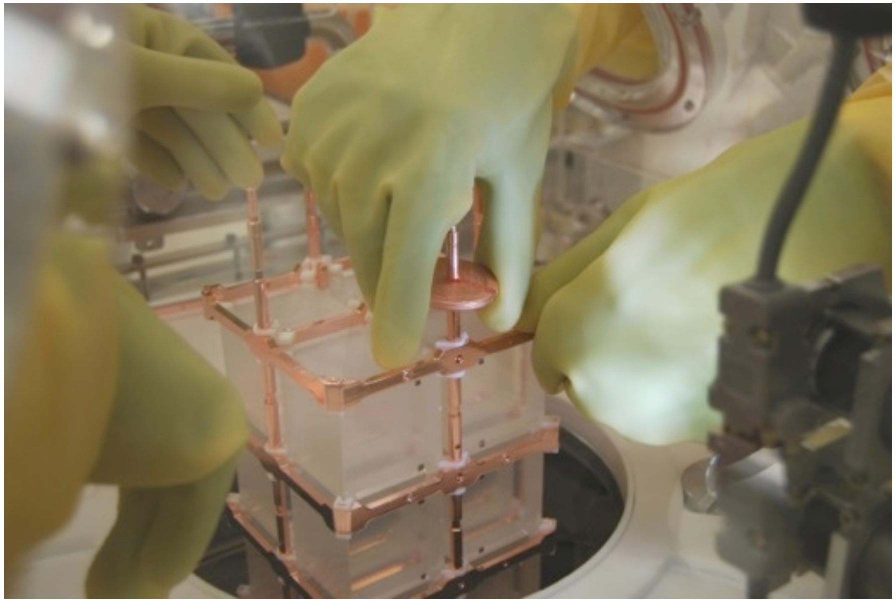
CUORE-0

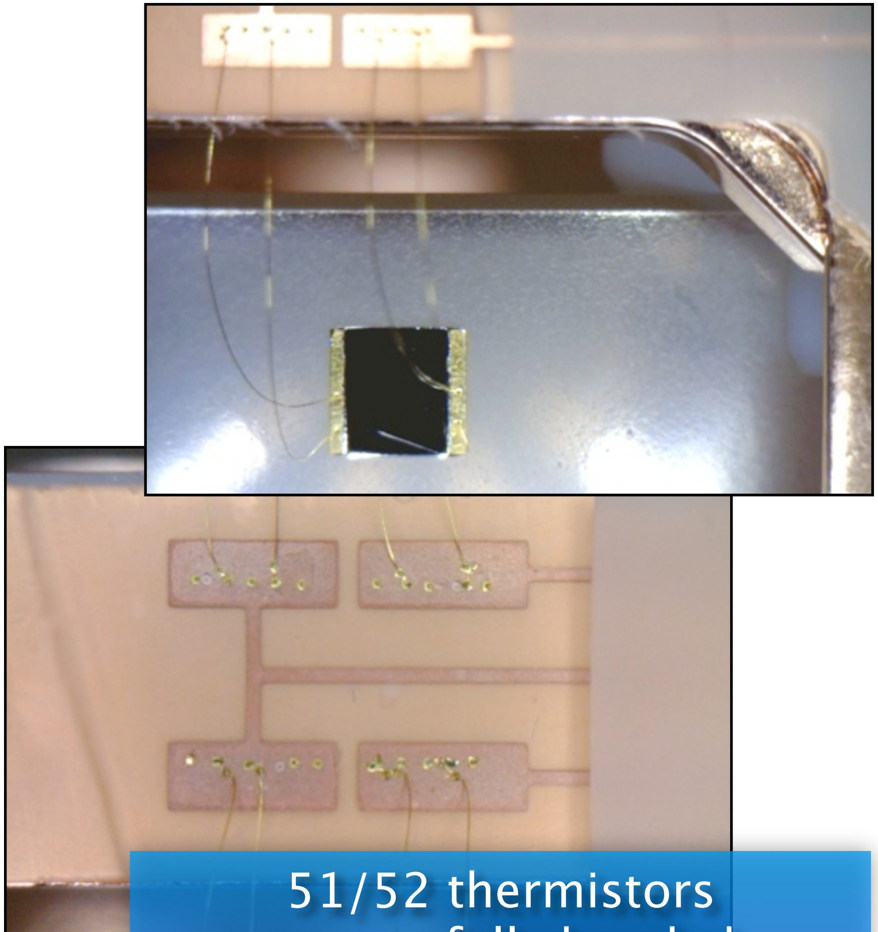
- 52 CUORE crystals mounted in CUORE-style frames as a single tower with a total TeO_2 mass of 39 kg
- Assembled from detector components manufactured, cleaned and stored following the same stringent protocols defined for CUORE
- Operated in CUORICINO cryostat at LNGS



CUORE-0: Assembly

The tower was built inside the Mounting Box, monitored by two microscopes to ensure right floor heights

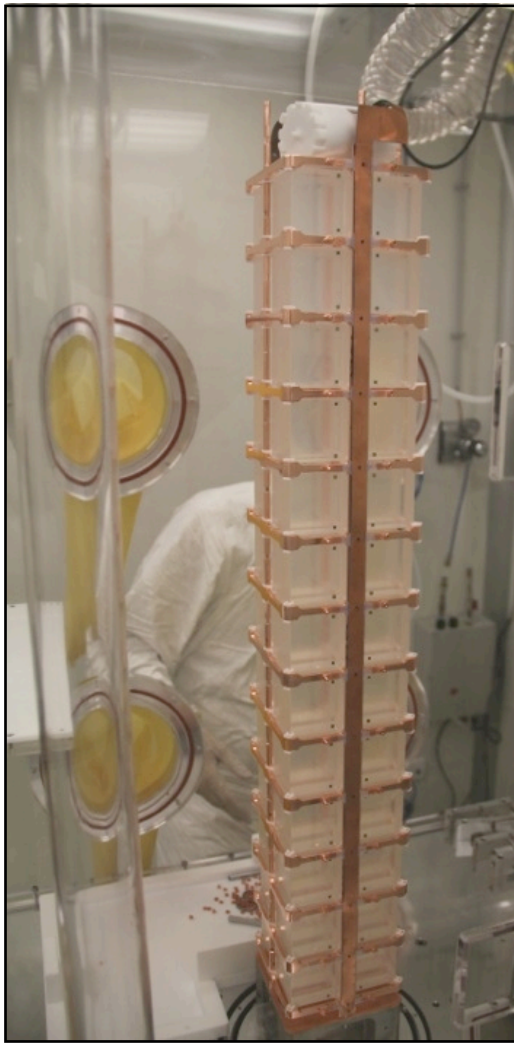




51/52 thermistors successfully bonded

- Readout ribbons were glued on the two wire trays
- The wire trays were fixed on the tower
- NTD thermistors were connected with 25μm gold wire to the Cu pads on the ribbons

CUORE-0 Present Status

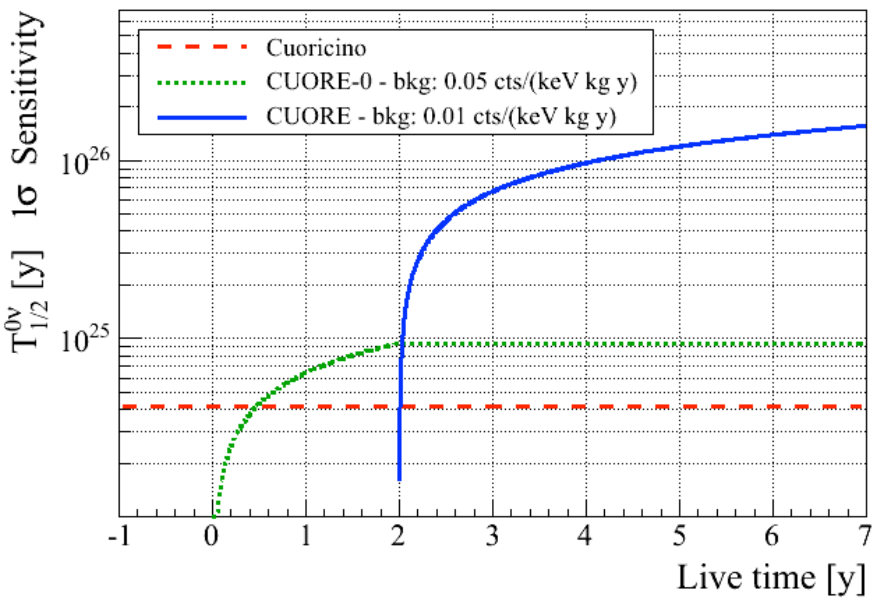


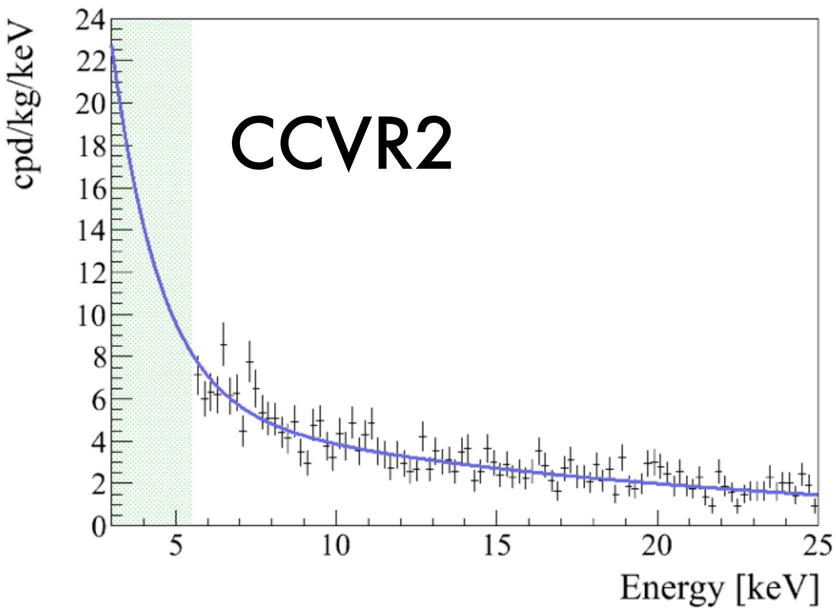
- The tower was finished in April 2012 and then connected to the cryostat
- A leak was discovered in the cryostat dilution unit, determining a delay of 2 months for fixing
- CUORE-0 will be cooled down in the next weeks

First data soon

CUORE-0: Physics Objectives

- Surpass CUORICINO in physics reach while CUORE is being assembled
- Demonstrate low threshold and potential for Dark Matter and Axion detection



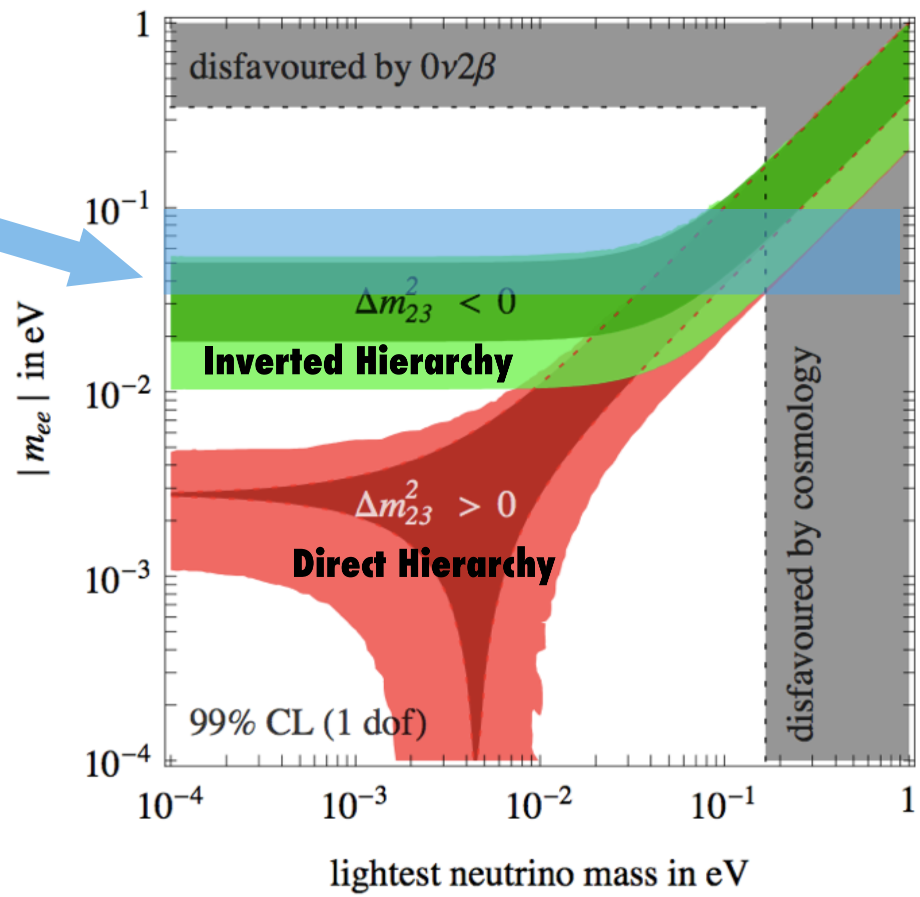


CUORE sensitivity

Time = 5 y and Background =0.01 c/kev/kg/y

$$T^{0\nu}_{1/2} > 1.6 \cdot 10^{26}\,\mathrm{y}\ @68\%CL$$

$$T^{0\nu}_{1/2} > 9.5 \cdot 10^{25}\,\mathrm{y}\ @90\%CL$$



A. Strumia, F. Vissani, arXiv.org/abs/hep-ph/0606054

CUORE Collaboration

Thank You