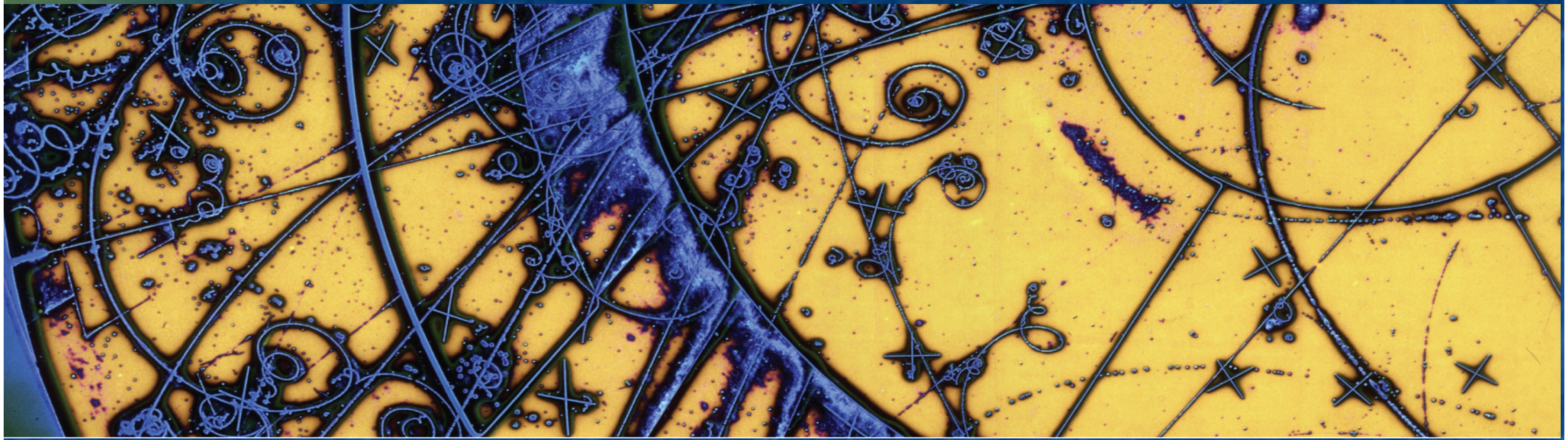
Status of CUORE Experiment and Latest Results from CUORE-0



Les Rencontres de Physique de la Vallée d'Aoste

6-12 March 2016 *La Thuile, Aosta Valley, Italy*

Carmine Elvezio Pagliarone

UNICLAM/DiCEM & LNGS/INFN, Italy

on the behalf of CUORE Collaboration

What we know about neutrinos

- neutrinos are massive fermions
- there are 3 active neutrino flavors (ν_α)
- neutrino flavor states are mixtures of mass states (ν_k)

$$|\nu_\alpha\rangle = \sum_k U_{\alpha k} |\nu_k\rangle$$

Pontecorvo–Maki–Nakagawa–Sakata matrix

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Atmospheric / Accelerator — Reactor / Accelerator — Solar / Reactor

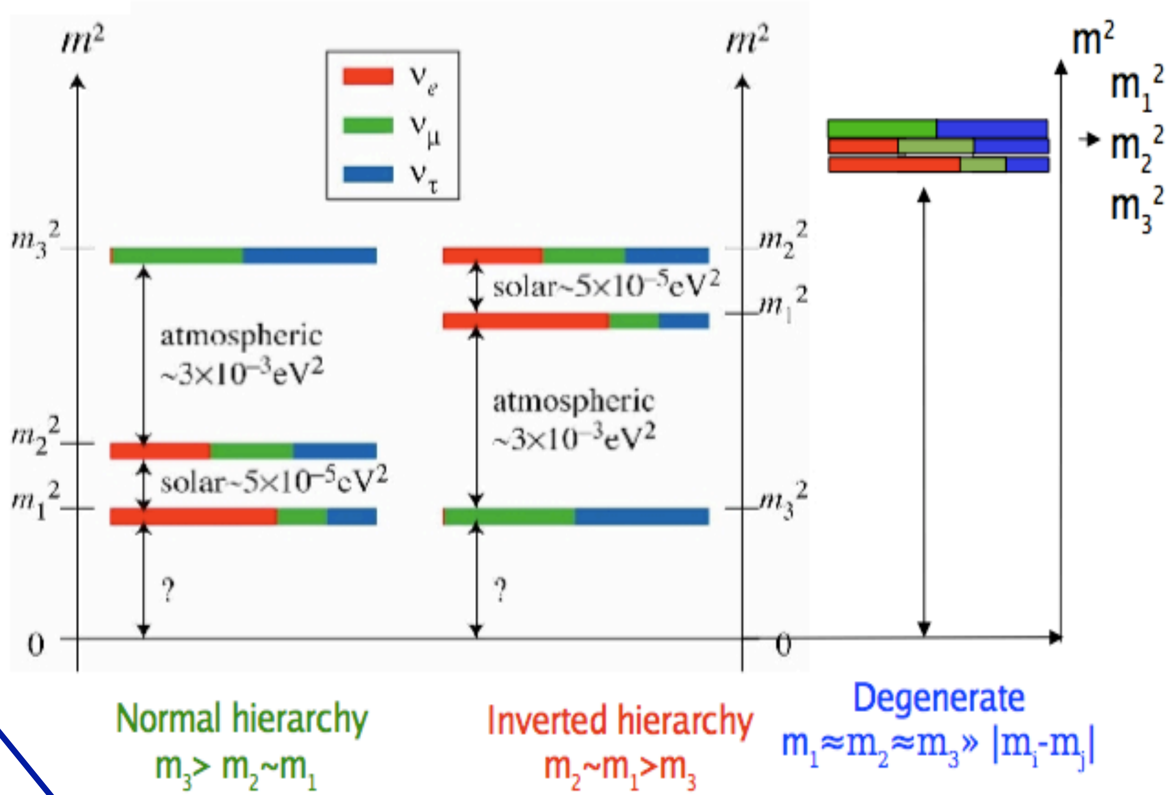
Measurements of neutrino parameters from:
- neutrino oscillations
- single beta decay
- cosmology
- neutrinoless double beta decay

Physics Motivations

Neutrino oscillation experiments proved that neutrinos are ***Mixed*** *and* ***Massive***

Open questions:

- Absolute mass scale and the hierarchy pattern
- Type of fermion: **Dirac** or a **Majorana** ?
- θ_{13} and values of the CP phases



Motivations for $0\nu2\beta$ searches

Double Beta Decays

- Double Beta Decay

$$(N,Z) \rightarrow (N-2, Z+2) + 2e^- + 2\overline{\nu}_e$$

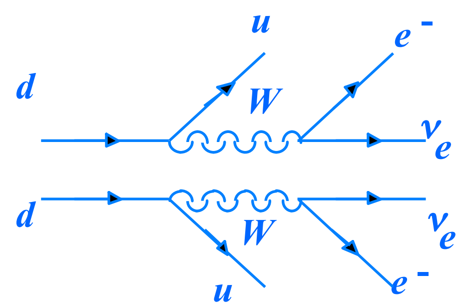
  - **2^{nd} order SM weak process**
  - already **observed** with lifetimes **$\tau \sim 10^{19}$-10^{21} y**

- **Neutrinoless** Double Beta Decay

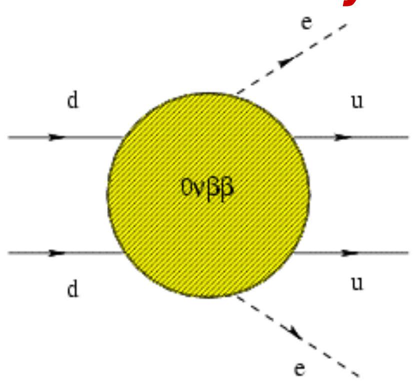
$$(N,Z) \rightarrow (N-2, Z+2) + 2e^-$$

  - **Not allowed by SM** (L-Violation)
  - **Claim** of observation in ^{76}Ge: t = 2.23 x 10^{25} y
    Mod.Phys.Lett.A21:1547-1566,2006
  - **Neglecting** the claim: **$\tau(^{76}$Ge)> 1.9 x 10^{25} y**
    Phys. Rev. D 63 073005
  - **Possible only if neutrinos are Majorana particles**
    Schetcher, Valle Phys. Rev. D25 2951 1982

2n2b Decay

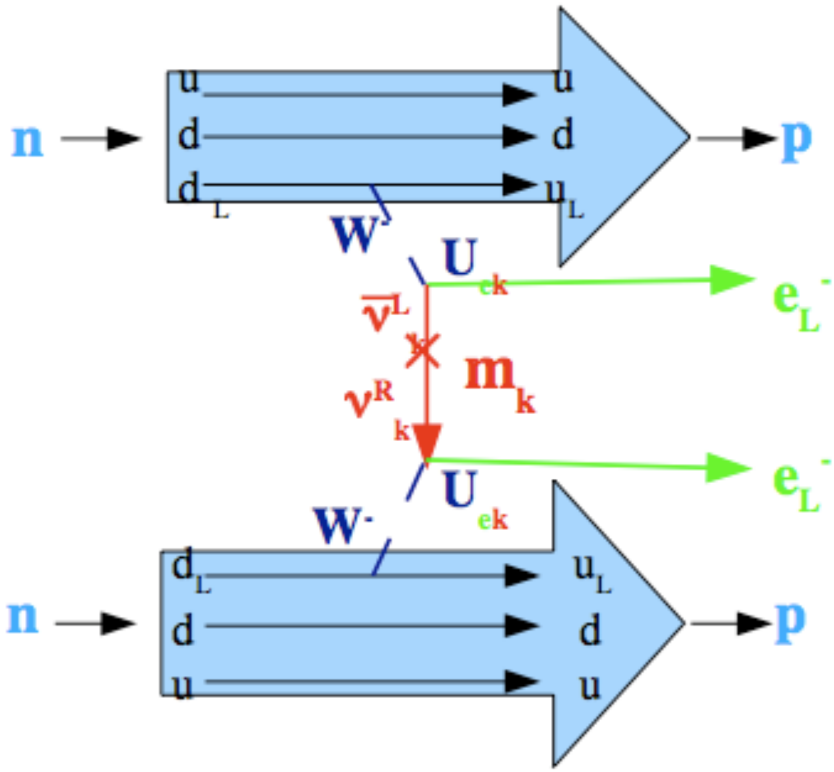


0n2b Decay



0ν2β Decay and the Effective Mass

In the (standard) hypothesis that the process is mediated by the ***exchange of a light Majorana*** *ν the* ***half-life*** *for 0ν2β is:*



$$\left(\tau_{1/2}^{0\nu\beta\beta}\right)^{-1} = G(Q,Z)\left|M_{nucl}\right|^2\left|m_{\beta\beta}\right|^2$$

Phase space factor, ~ Q^5, *can be computed exactly*

Effective neutrino mass

$$m_{\beta\beta} = \left|\sum_k m_{\nu_k} U_{ek}^2\right|$$

Nuclear matrix element, *main source of* ***uncertainty*** *when deriving $m_{\beta\beta}$ from τ*

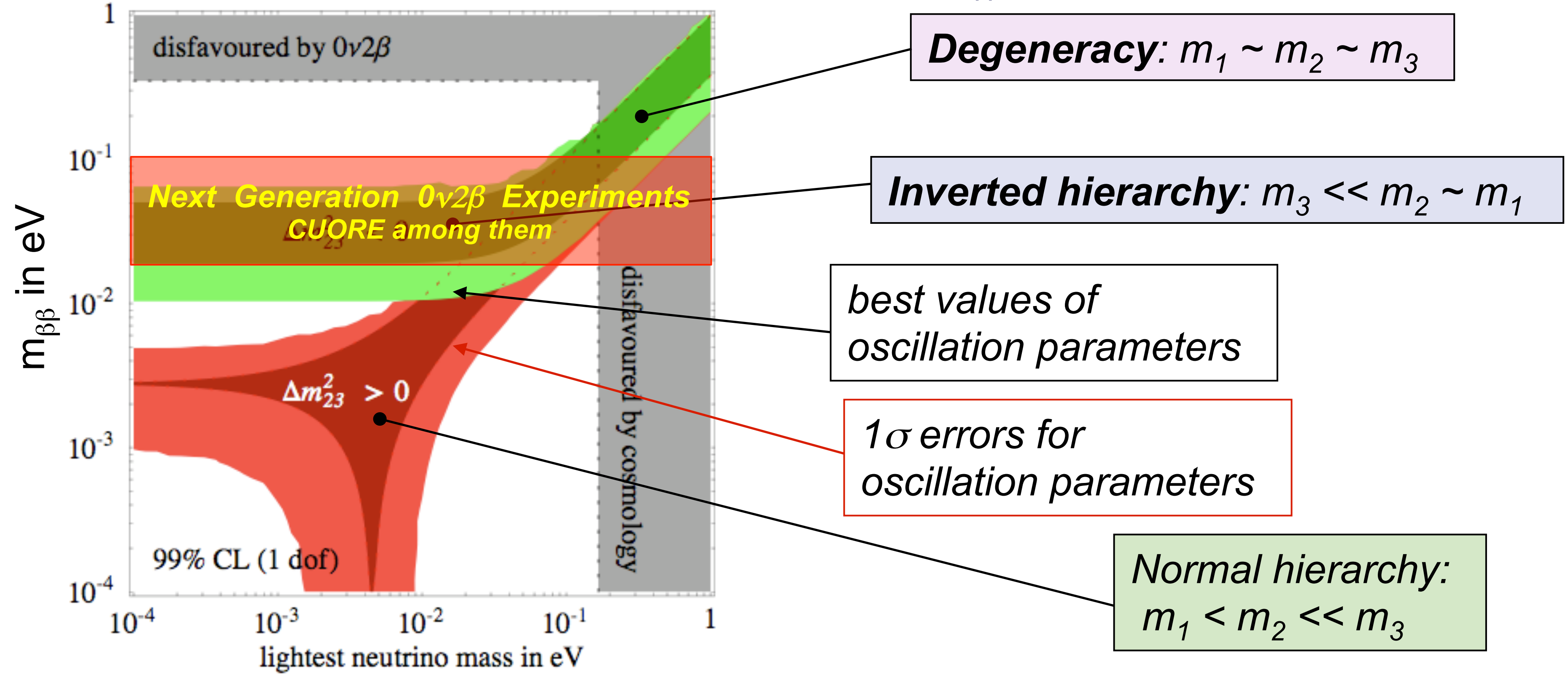
From the measurement of ***$m_{\beta\beta}$*** *costraints on the ν* ***Mass Hierarchy*** *can be set*

$0\nu2\beta$ and Mass Hierarchy Patterns

We can express the effective neutrino mass in terms of the measured oscillation parameters and of the unknown lightest neutrino mass:

$$m_{\beta\beta} = f\left(U_{ek}, m_{lightest}, \Delta m_{12}, \Delta m_{13}\right)$$

and therefore use the oscillation parameters to constraint $\mathbf{m}_{\beta\beta}$ *and* $\mathbf{m}_{min}$



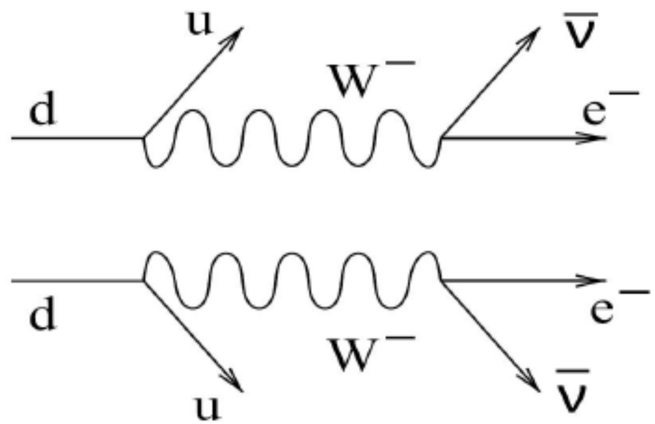
A. Strumia, F. Vissani, arXiv.org/abs/hep-ph/0606054

$2\nu2\beta$ vs $0\nu2\beta$ Decay

Double Beta Decay:

$$(N,Z) \rightarrow (N\text{-}2, Z+2) + 2e^- + 2\nu_e$$

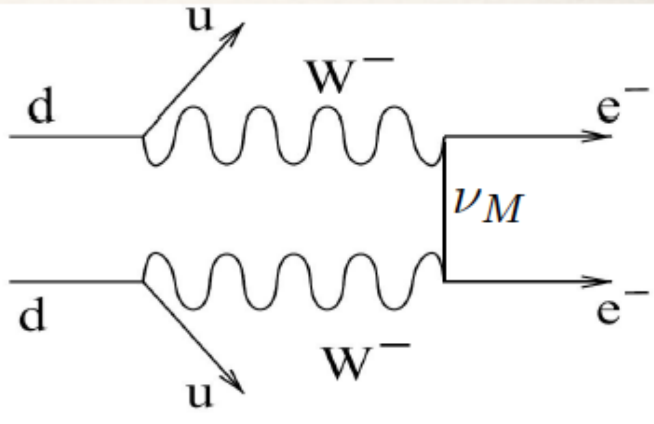
- Second order SM weak process
- Observed with lifetimes $T_{1/2} \sim 10^{19}\text{-}10^{21}$ y



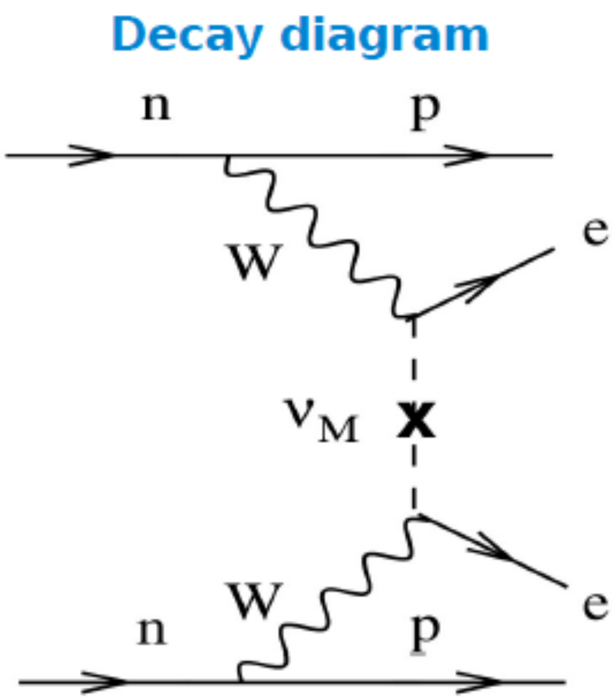
Neutrinoless Double Beta Decay:

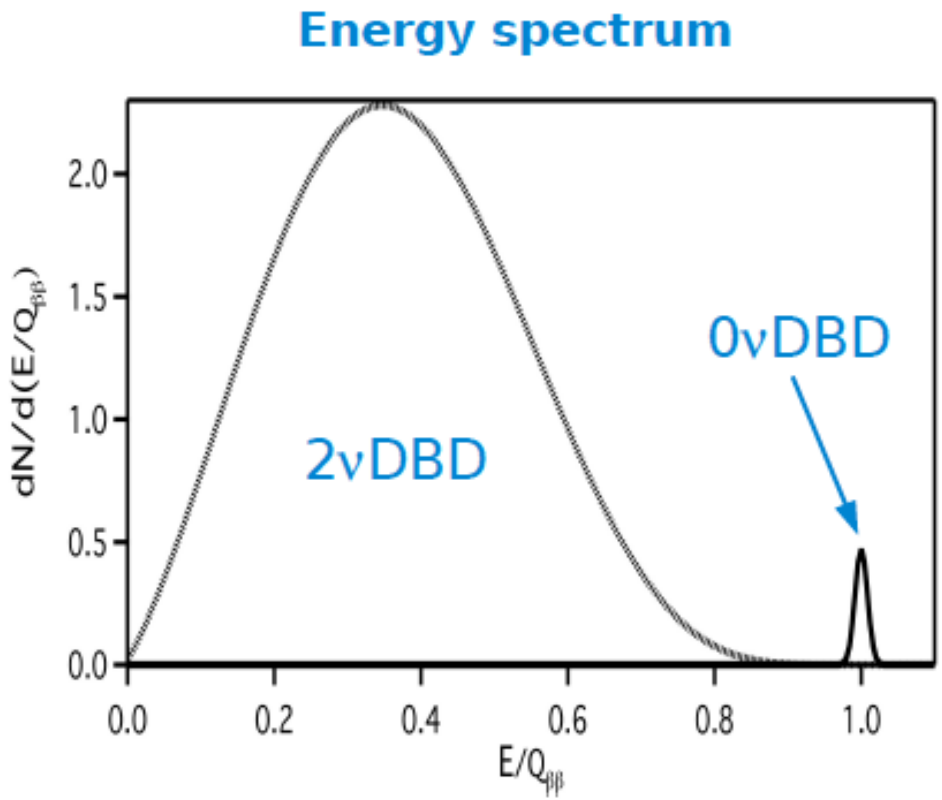
$$(N,Z) \rightarrow (N\text{-}2, Z+2) + 2e^-$$

- Not allowed by the Standard Model ($\Delta L=2$)
- Possible only if neutrinos are Majorana particles



$0\nu2\beta$ Decay Signature





Experimental Sensitivity ($0\nu2\beta$)

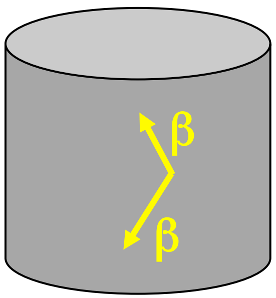
$$\langle m_\nu \rangle \propto M^{1/4}$$

$$\tau^{0\nu}_{1/2}(y) \propto \frac{\varepsilon}{A}\sqrt{\frac{M\ .\ t}{N_{Bckg}\ .\ \Delta E}}$$

M: mass (g)
ε : efficiency
$K_{C.L.}$: Confidence level
$\mathcal{N}$: Avogadro number

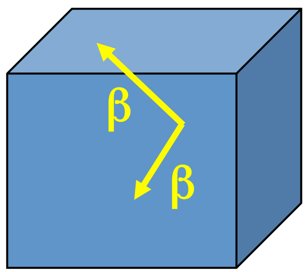
t: time (y)
N_{Bckg}: Background events ($keV^{-1}.g^{-1}.y^{-1}$)
ΔE: energy resolution (keV)

Calorimeter
Semi-conductors
Bolometers
Source = Detector



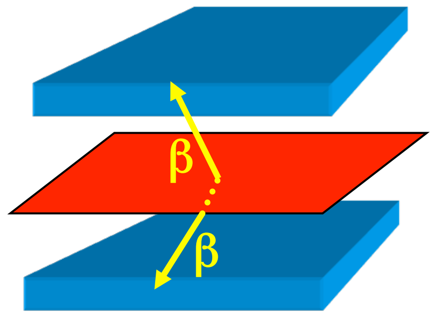
ε, ΔE

Calorimeter
(Loaded) Scintillator
Source = Detector



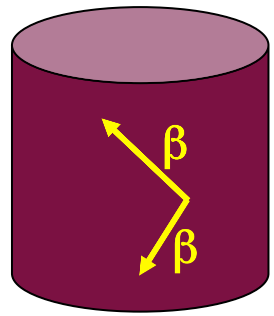
ε, M

Track-calorimeter
Source ≠ Detector



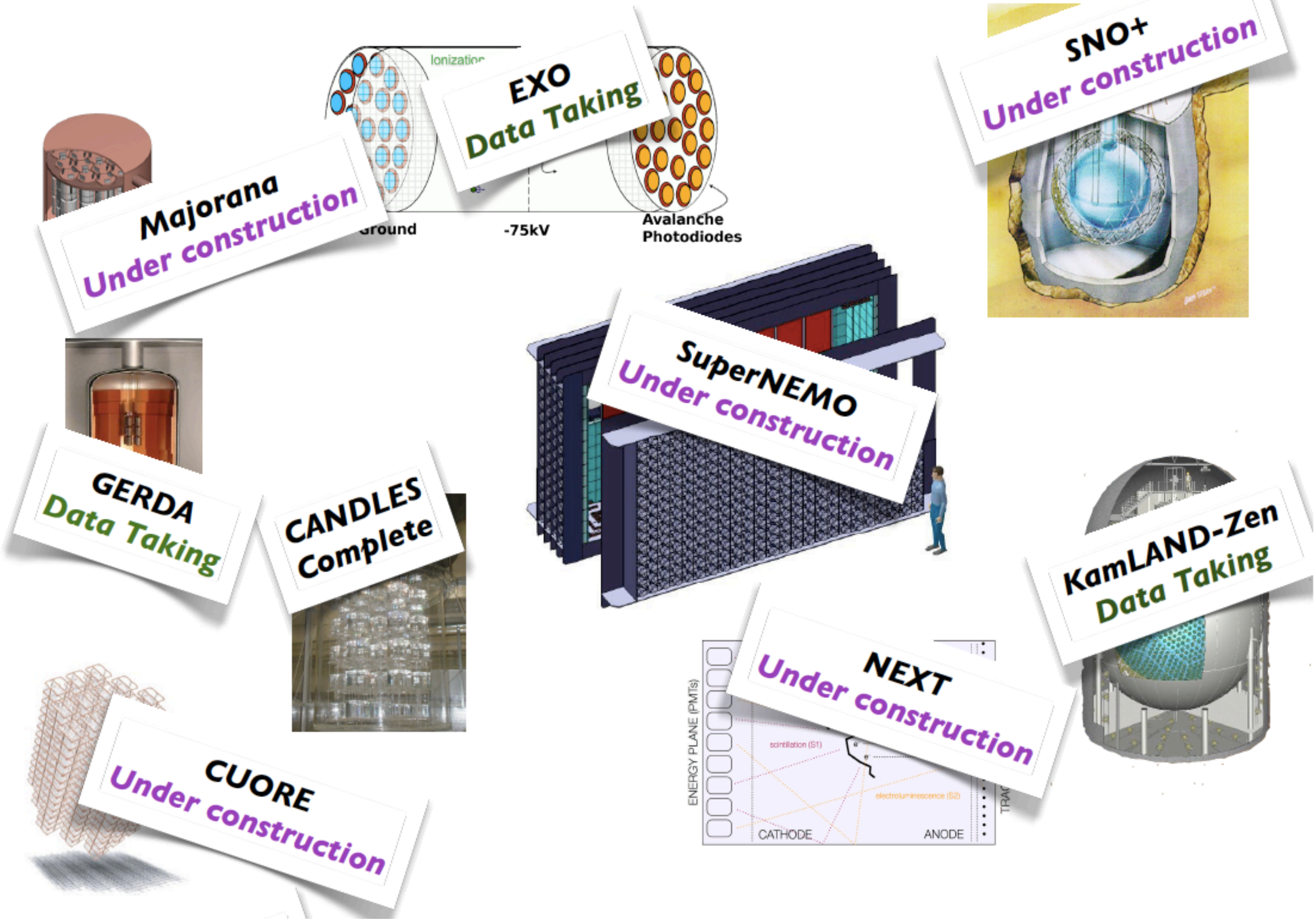
NBckg, isotope choice

Xe TPC
Source = Detector



ε,M, (N_{Bckg})

A lot of detector ideas!



Carmine Elvezio Pagliarone

Determining the Nature of Neutrino using Bolometric Techniques

La Thuile 2016

Carmine Elvezio Pagliarone

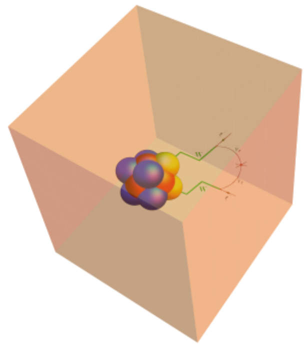
The Bolometric Technique

- Crystals, **cooled to ~10 mK** inside a **Dilution-Refrigerator Cryostat**, have small heat capacities: single particle interactions produce <u>measurable rises in temperature</u>.

Good Features:
- Excellent energy resolution
- Wide choice of detector materials
- Large source mass
- High Efficiency
- Real Calorimeter

Bad Features:
- Speed
- Very Low Operating Temperatures (5-10 mK)

Source = Detector

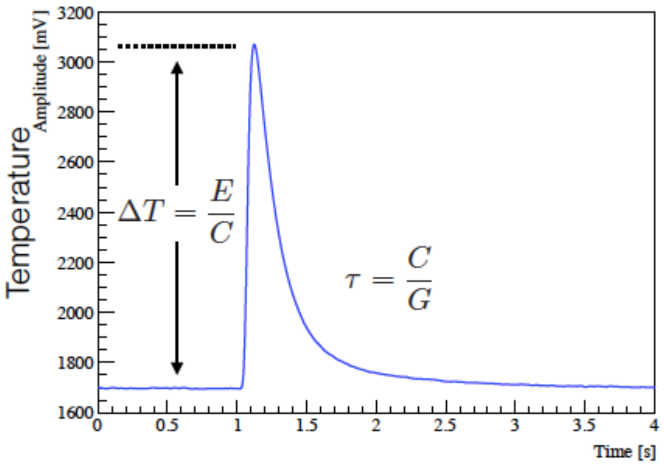


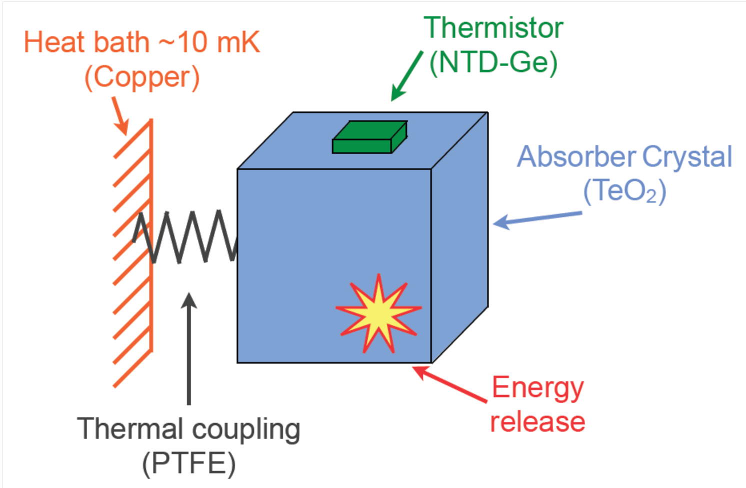
$$\Delta T(t) \approx \frac{\Delta E}{C} e^{-\frac{t}{\tau}}$$

$$\tau = C / G$$

C= Heat Capacity

G= Thermal conduct.



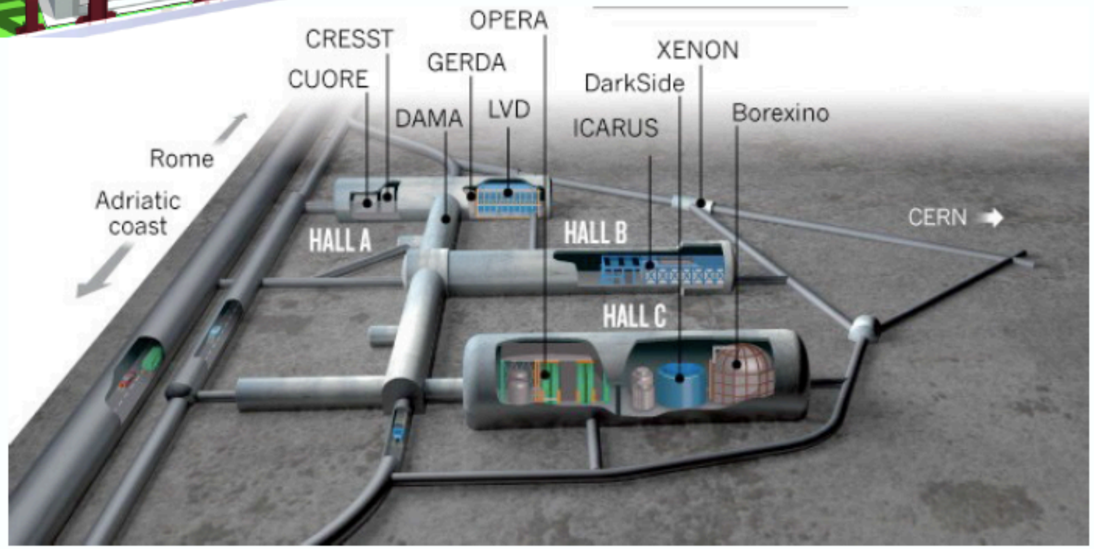


Carmine Elvezio Pagliarone

LNGS
Gran Sasso National Laboratories

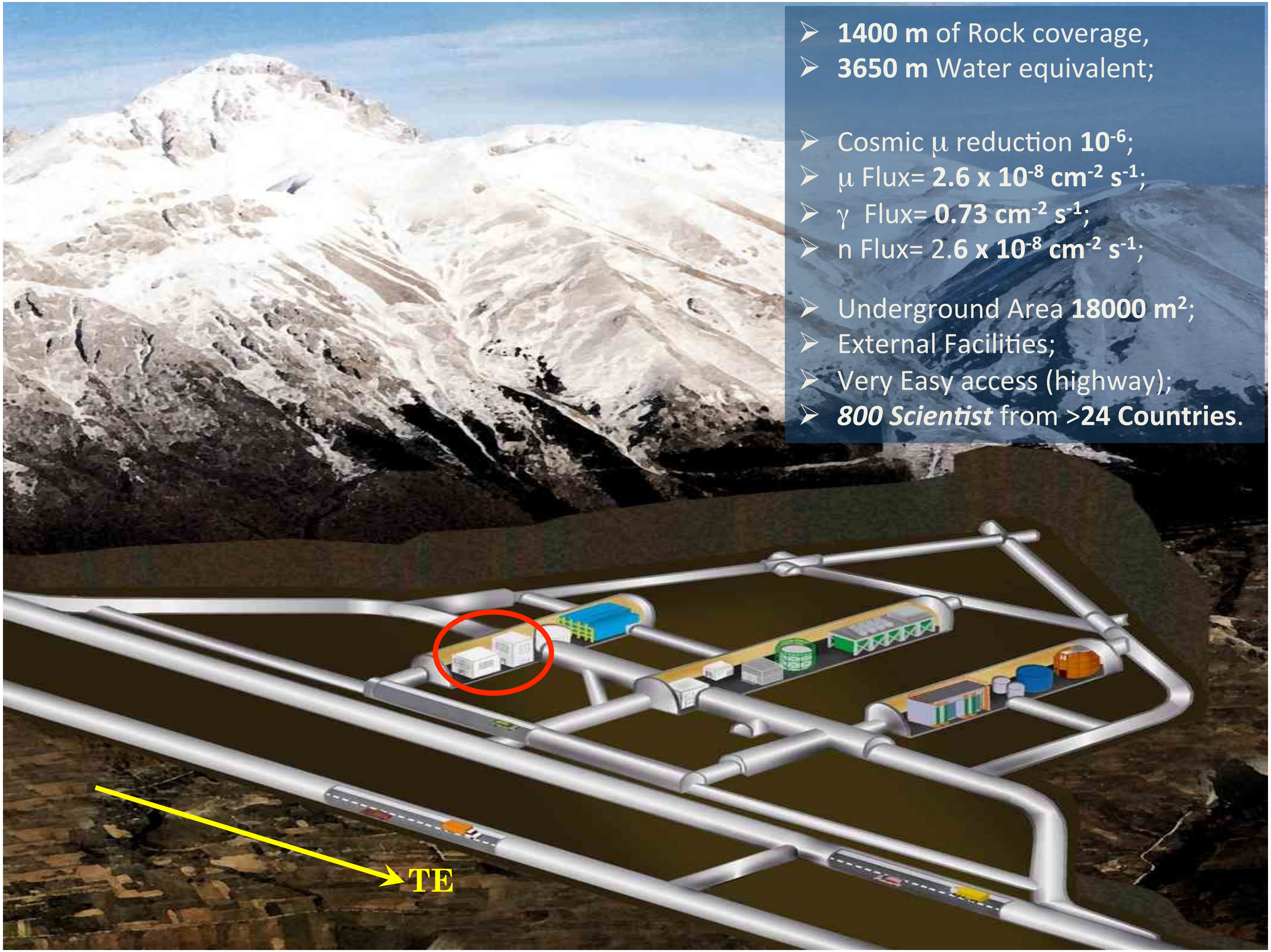
CUORE: Cryogenic Underground Observatory for Rare Events

- 1400 m of Rock coverage
- 3650 m Water equivalent deep
- Underground Area 18000 m^2
- Cosmic μ reduction 10^{-6}
- μ Flux= 2.6×10^{-8} cm^{-2} s^{-1}
- g Flux= 0.73 cm^{-2} s^{-1}
- n Flux= 2.6×10^{-8} cm^{-2} s^{-1}



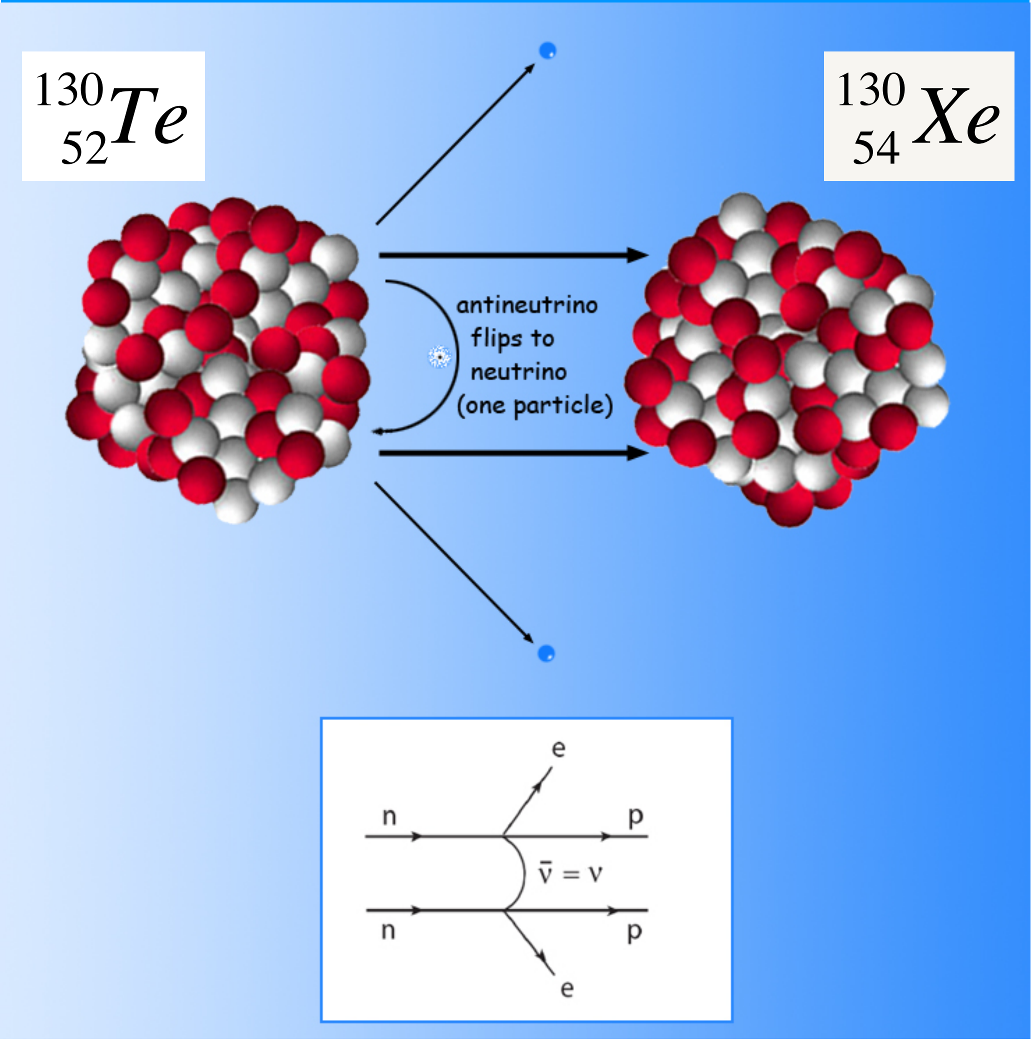
CUORE *in Italian stands for Hearth*

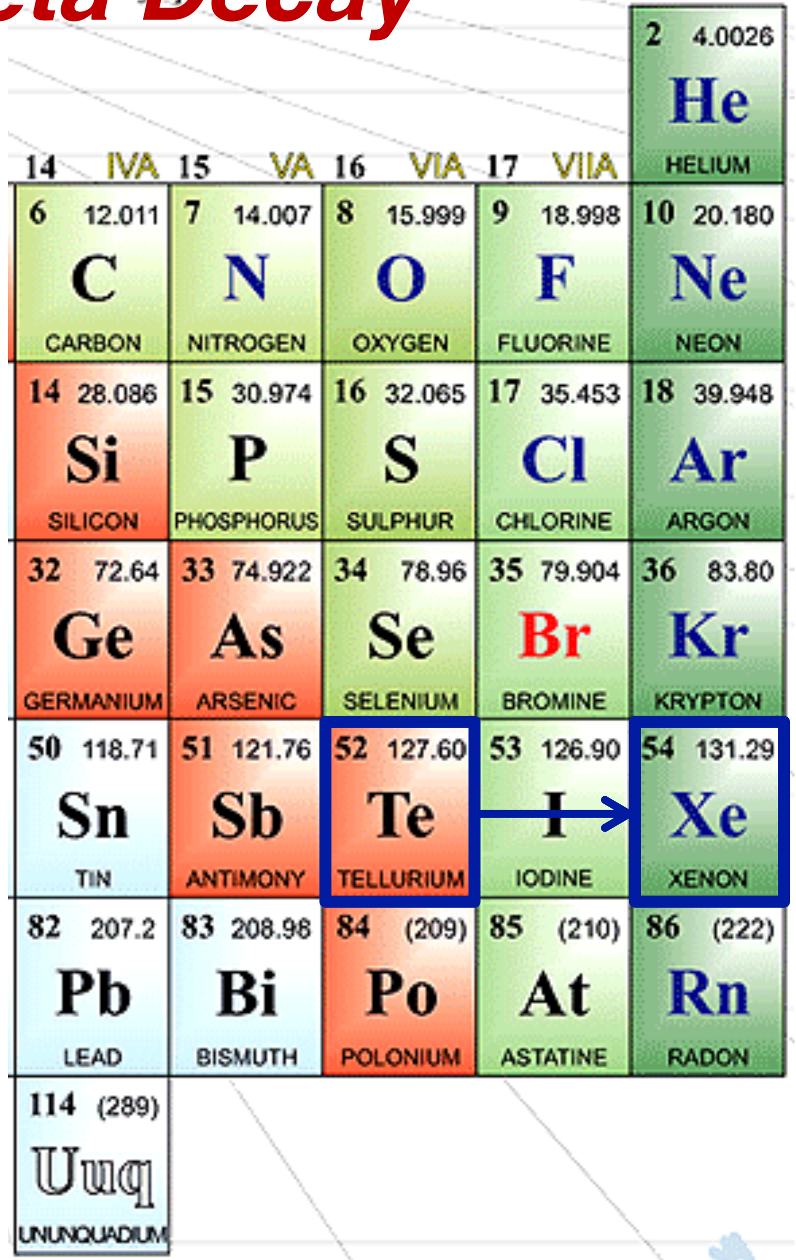
Carmine Elvezio Pagliarone


1400 m of Rock coverage,
3650 m Water equivalent;
Cosmic μ reduction **10^{-6}**;
μ Flux= **2.6×10^{-8} cm^{-2} s^{-1}**;
γ Flux= **0.73 cm^{-2} s^{-1}**;
n Flux= 2.6 **x 10^{-8} cm^{-2} s^{-1}**;
Underground Area **18000 m^2**;
External Facilities;
Very Easy access (highway);
800 Scientist from >**24 Countries**.
TE

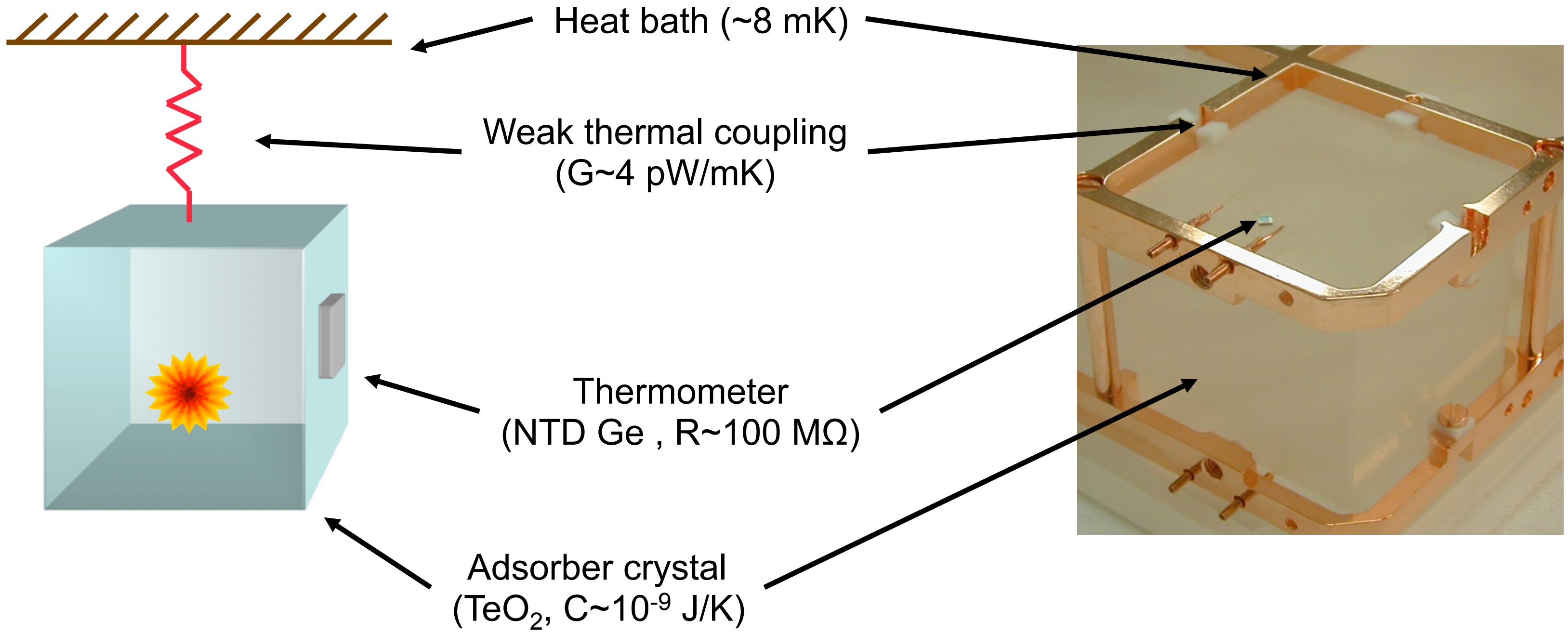
^{130}Te Double Beta Decay

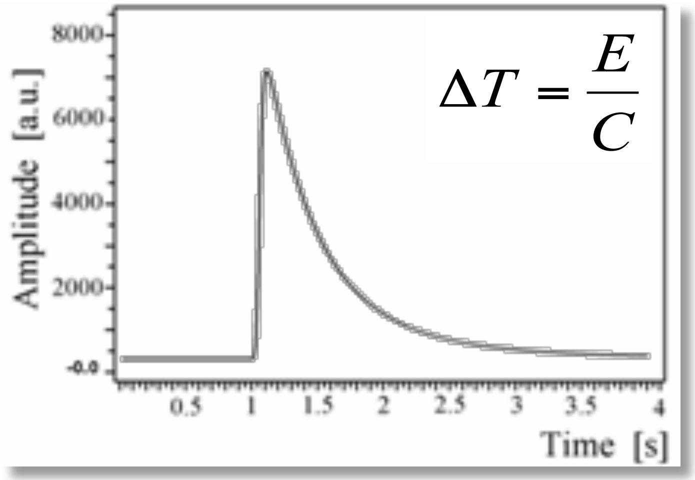
$$^{130}_{52}Te \longrightarrow \, ^{130}_{54}Xe + 2e^{-}$$





CUORE Bolometers





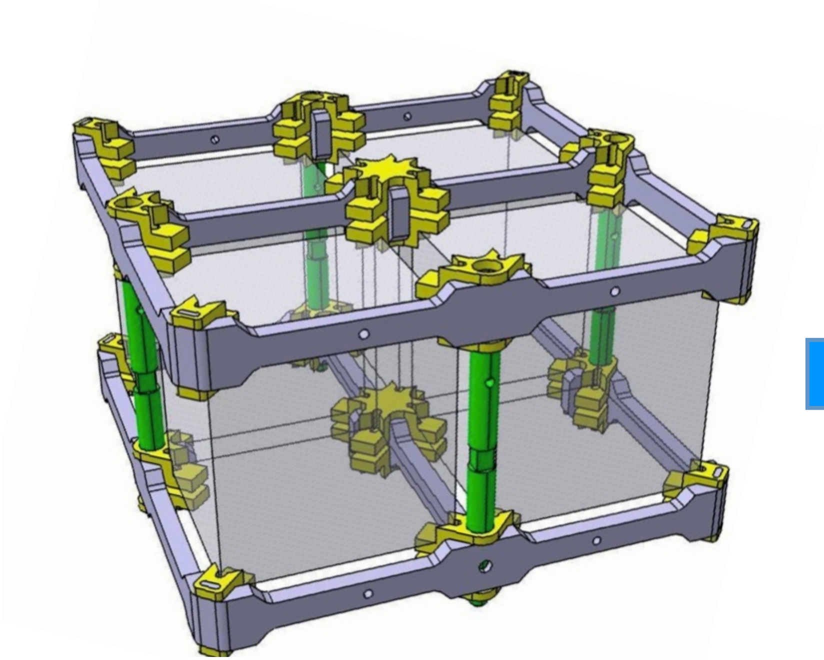
CRYSTAL

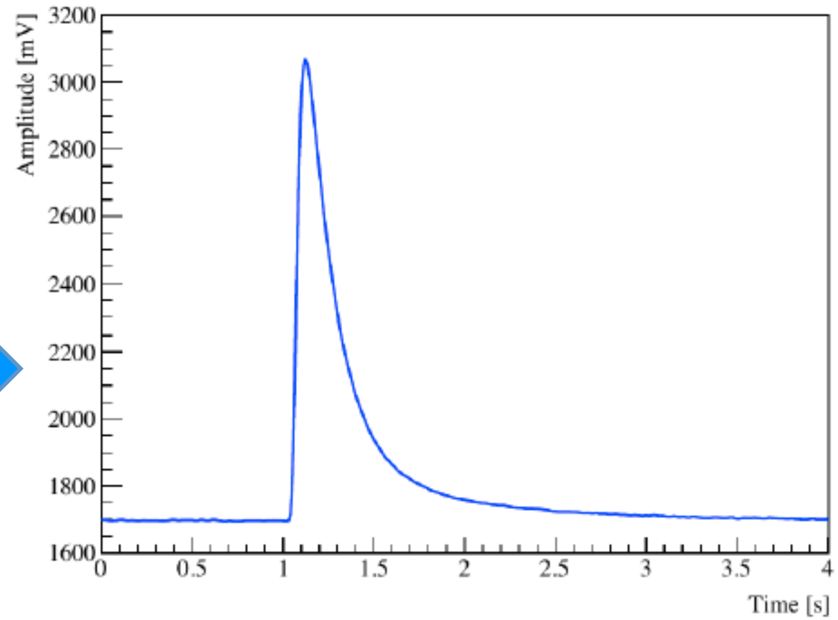
- TeO_2, Sizes: 5x5x5 cm^3; Mass= 0.75 kg
- Heat Capacity= 10^{-9} J/K
- ΔT/ΔE= 100 μK/MeV

SENSOR

- Joule heaters for calibration purposes
- Transmutation Doped (NTD) Ge thermistors
- R= 100 MΩ
- ΔR/ΔE= 3 MΩ/MeV

CUORE Cryogenic Bolometers





Absorber: E → ΔT ~ E/C(T)

TeO_2 crystals ~ 750 g

Low heat capacity

High radio-purity

Temperature sensor ΔT → ΔV

NTD Ge thermistor

$R = R_0 \exp(T/T_0)^\gamma$ → high sensitivity

At T=10 mK, energy deposited inside a TeO_2 crystal by radiation produces a measurable rise in its temperature

Amplitude of temperature pulse is proportional to deposited energy

$0\nu2\beta$ Sensitivity

Sensitivity: Lifetime corresponding to the minimum number of detectable events above background at a given C.L.

$$S^{0\nu} = \ln 2\, N_A \times \frac{a}{A}\left(\frac{M\,T}{b\,\Gamma}\right)^{1/2} \times \varepsilon$$

Isotopic abundance (a)

Atomic mass (A)

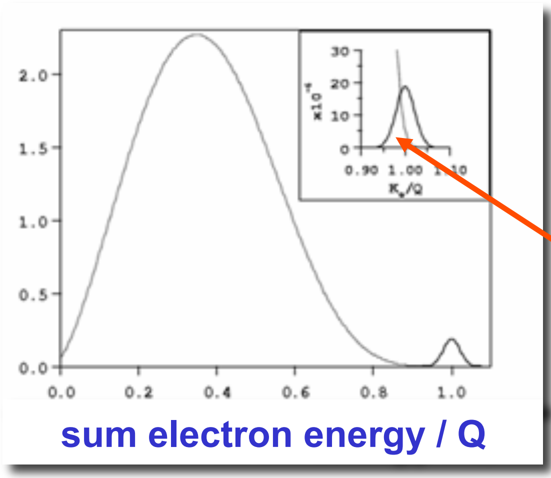
Detector mass (kg) (M)

Measurement Time (y) (T)

Background (counts/keV/kg/y) (b)

Energy resolution (keV) (Γ)

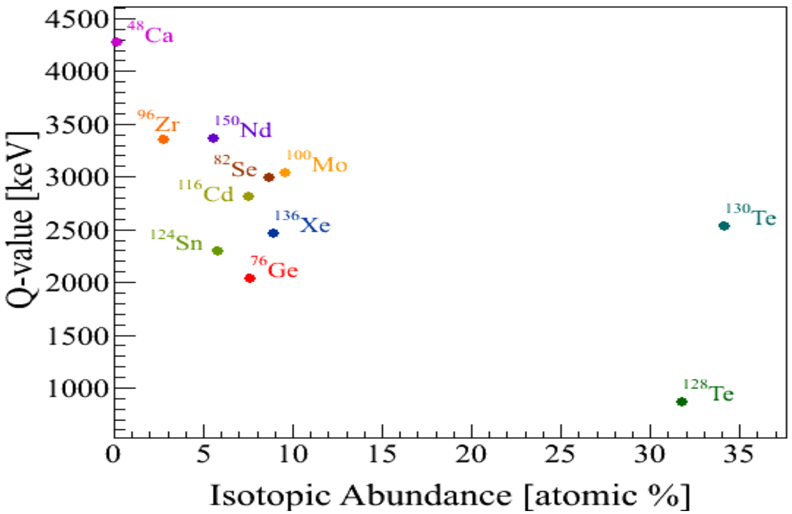
Efficiency (ε)

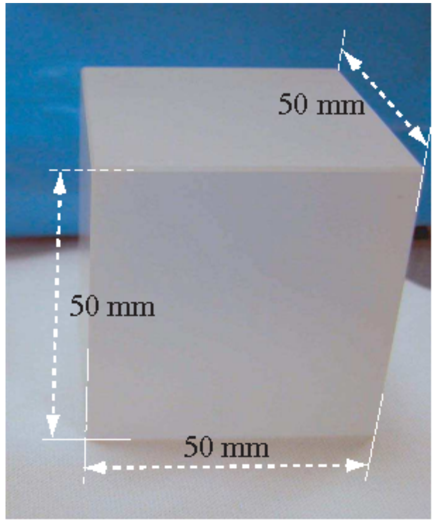


Unavoidable background

$\propto Q\Gamma^6$

Why $^{130}Te0_2$ Crystals ?





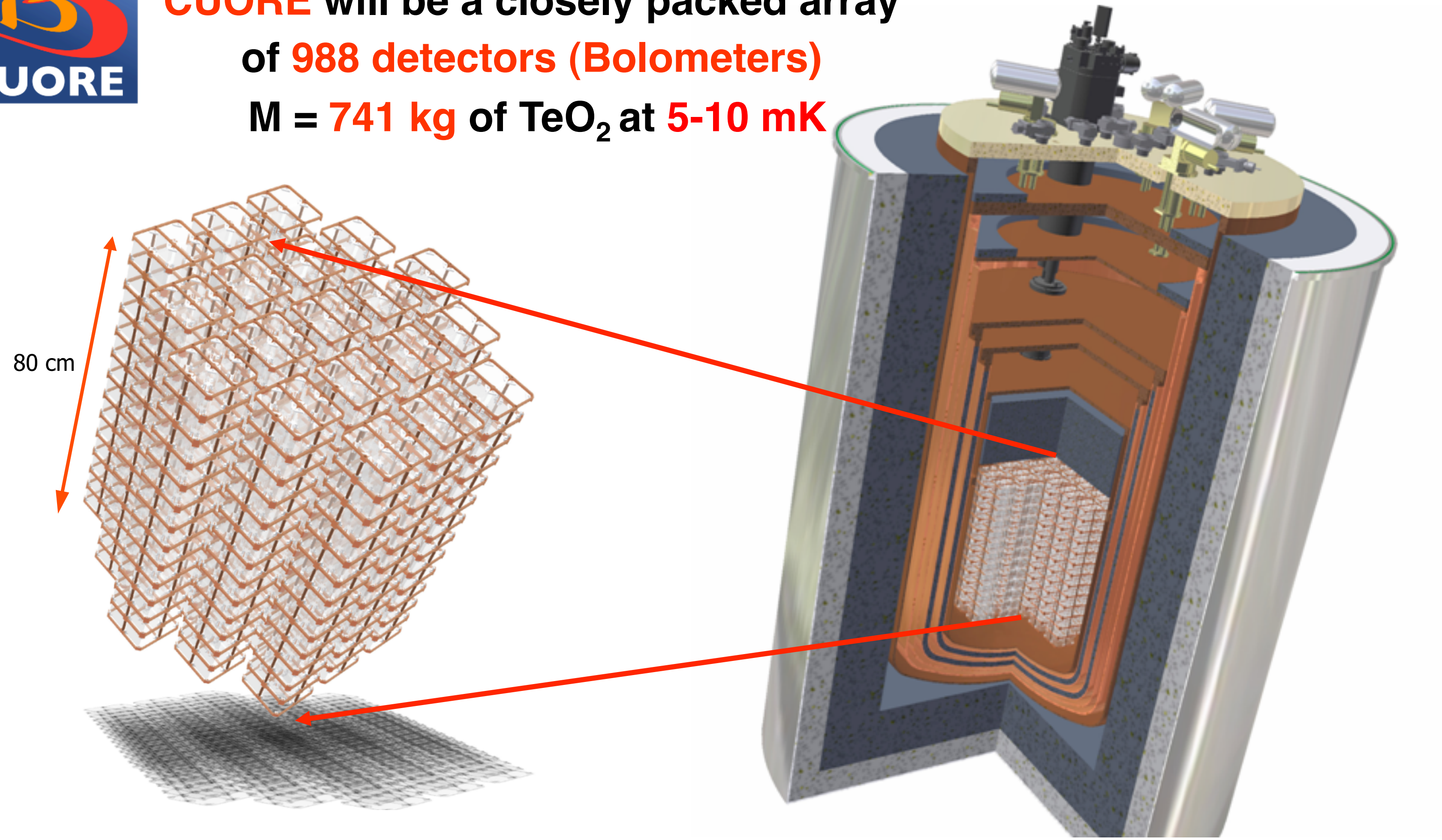
- There are 38 known nuclear isomers of tellurium ($_{52}$Te), with atomic masses that range from 105 to 142;
- Naturally occurring Tellurium has eight isotopes. Five of those isotopes, ^{122}Te, ^{123}Te, ^{124}Te, ^{125}Te and ^{126}Te, are stable. The other three, **^{120}Te**, **^{128}Te** and **^{130}Te**, have been observed to be radioactive;
- High natural abundance (i.a. **^{130}Te ~ 34%**): **no need for enrichment**;
- **Q-value ~2528 keV** is above the energy range of most naturally occurring γ rays.

Good Features:

- Favorable characteristics of these crystals if compared with Te.
- Higher Debye temperature;
- Rather **good mechanical properties** and it is **possible to grow large crystals**;
- **Good intrinsic radio-purity** (**< 1 pg/g in ^{232}Th and ^{238}U**).

CUORE will be a closely packed array of 988 detectors (Bolometers)

M = 741 kg of TeO_2 at 5-10 mK



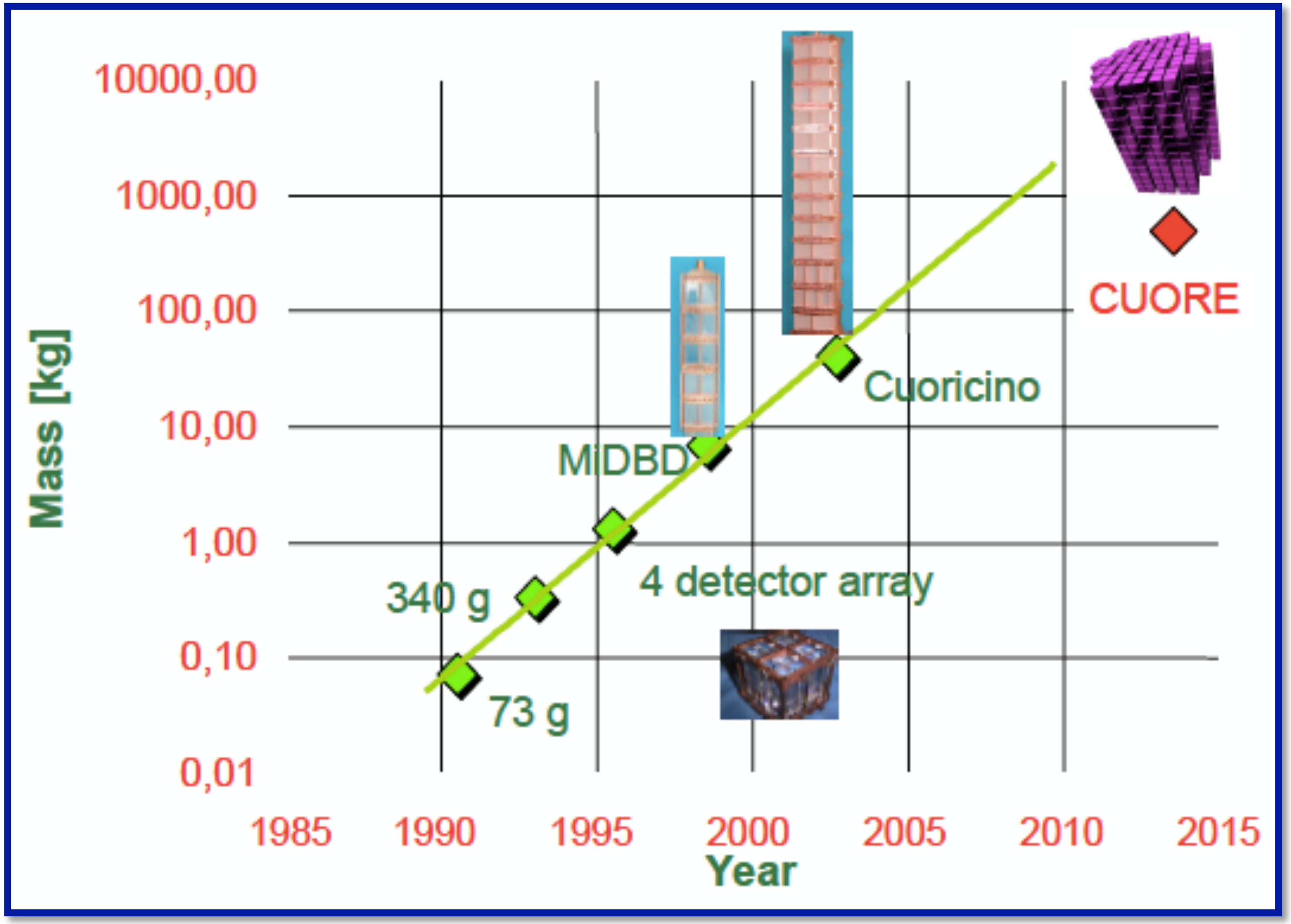
Detector

- ^{130}Te mass: 206 kg (~10^{27} nuclei)
- TeO_2 mass: 741 kg
- 988 TeO_2 bolometers arranged in 19 towers
- Single crystal: 5x5x5 cm³ (0.75 kg)

Goals

- Resolution: 5 keV FWHM at 2.5 MeV
- Bkg: 0.01 counts/(keV kg y)
- Half life sensitivity: 1.6 x 10^{26} y (1σ)
- Majorana mass sensitivity: 39 – 102 meV (1σ)

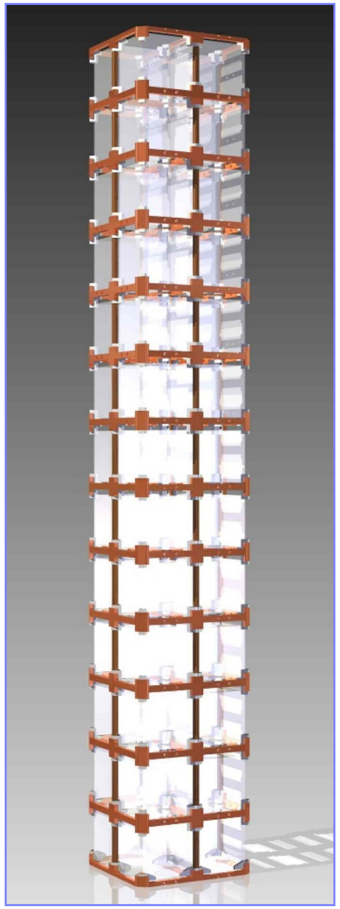
The long path to CUORE



The long path to CUORE

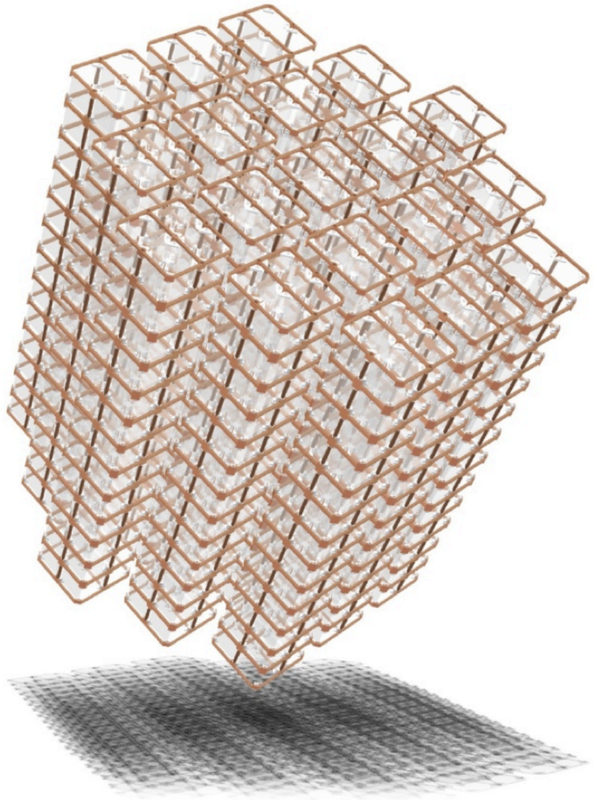
Cuoricino

2003 - 2008
11.3 kg ^{130}Te
(62 TeO_2 – 41 Kg)



CUORE0

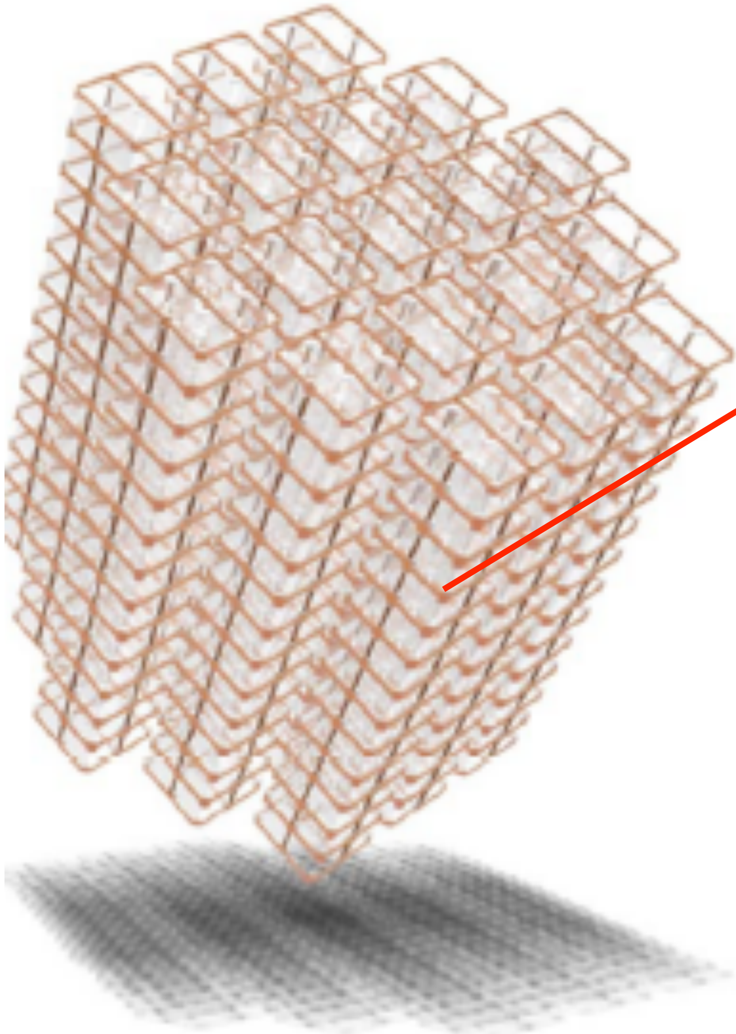
2013 - 2015
11.3 kg ^{130}Te
(59 TeO_2 – 39 Kg)

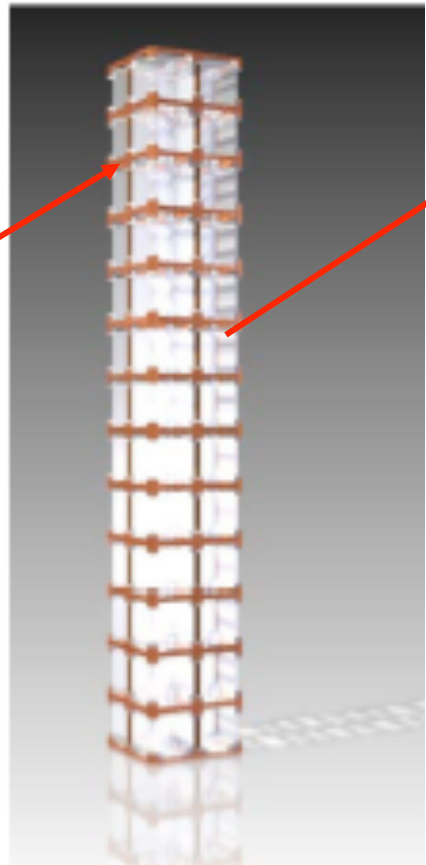


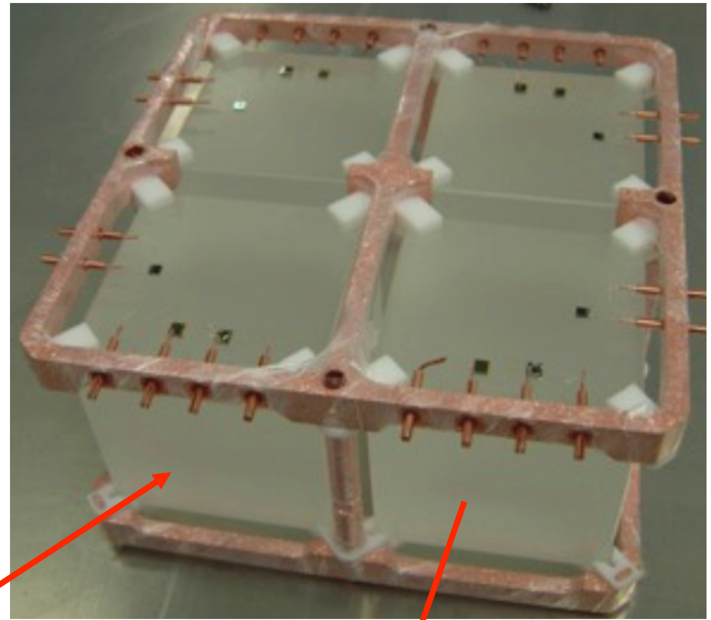
CUORE

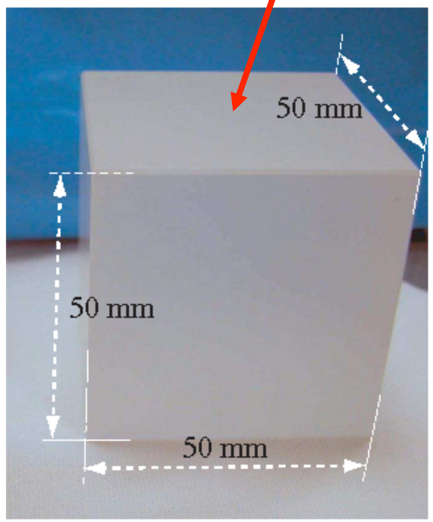
End 2016 – ?
206 kg ^{130}Te
(988 TeO_2 – 741 Kg)

CUORE

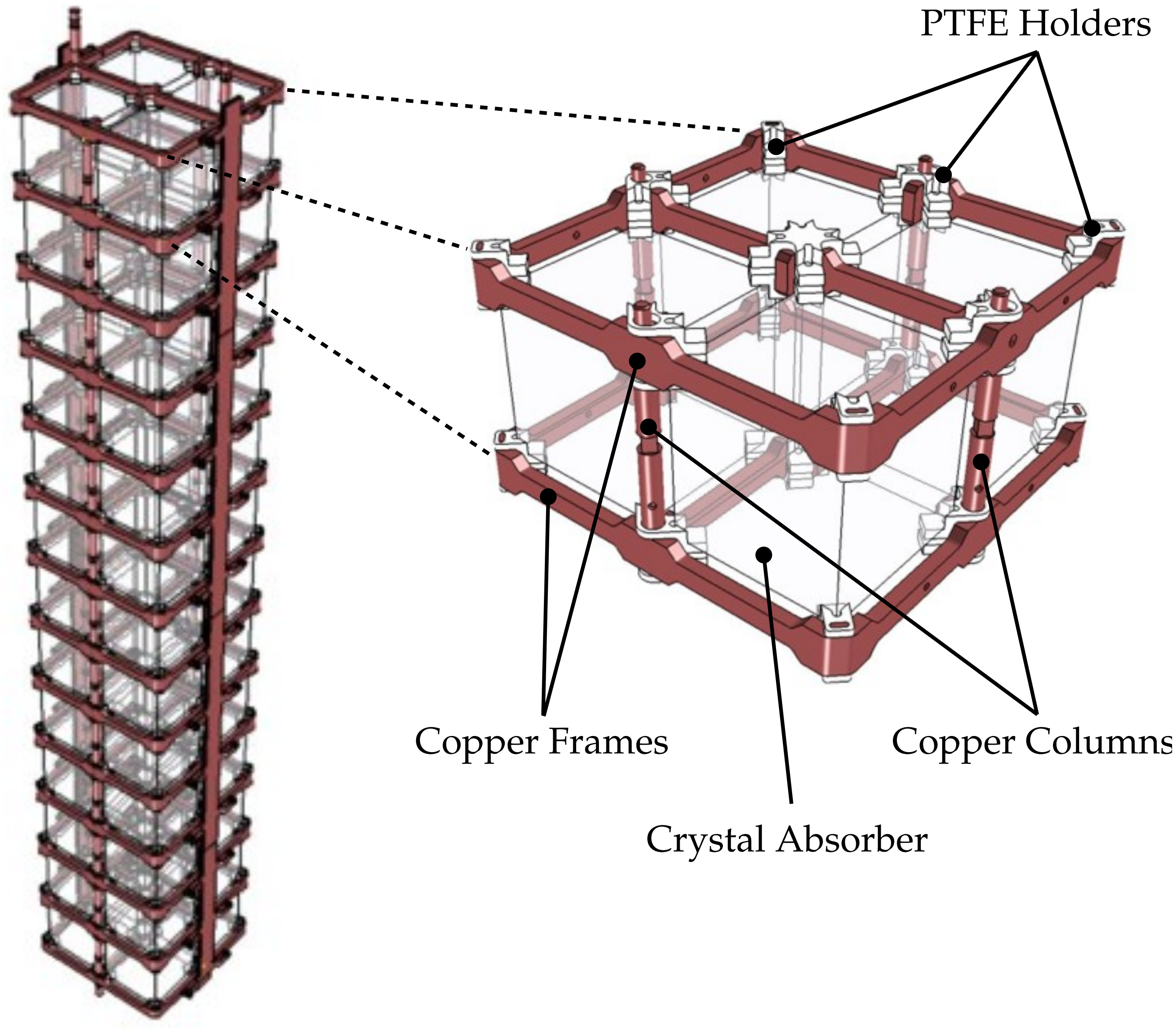






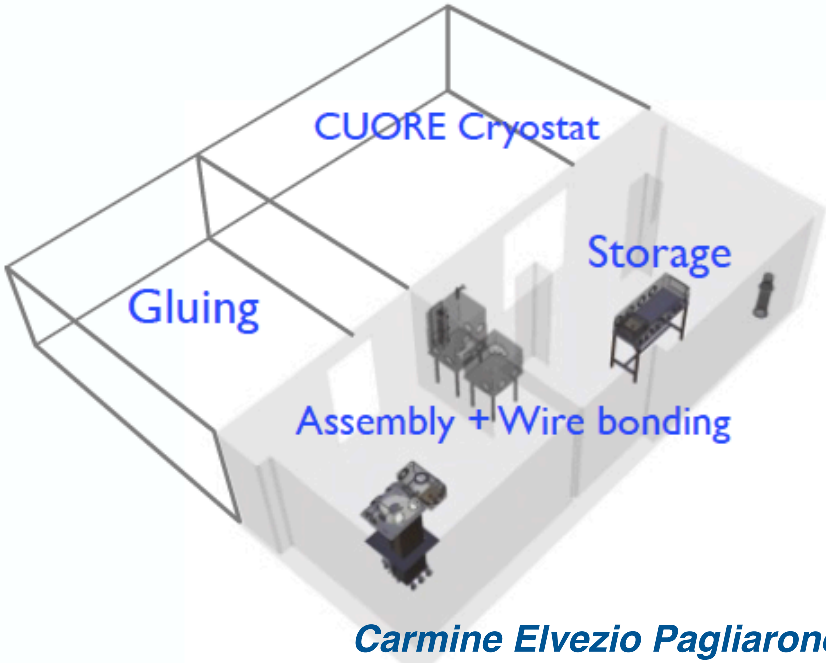


CUORE Bolometric Towers

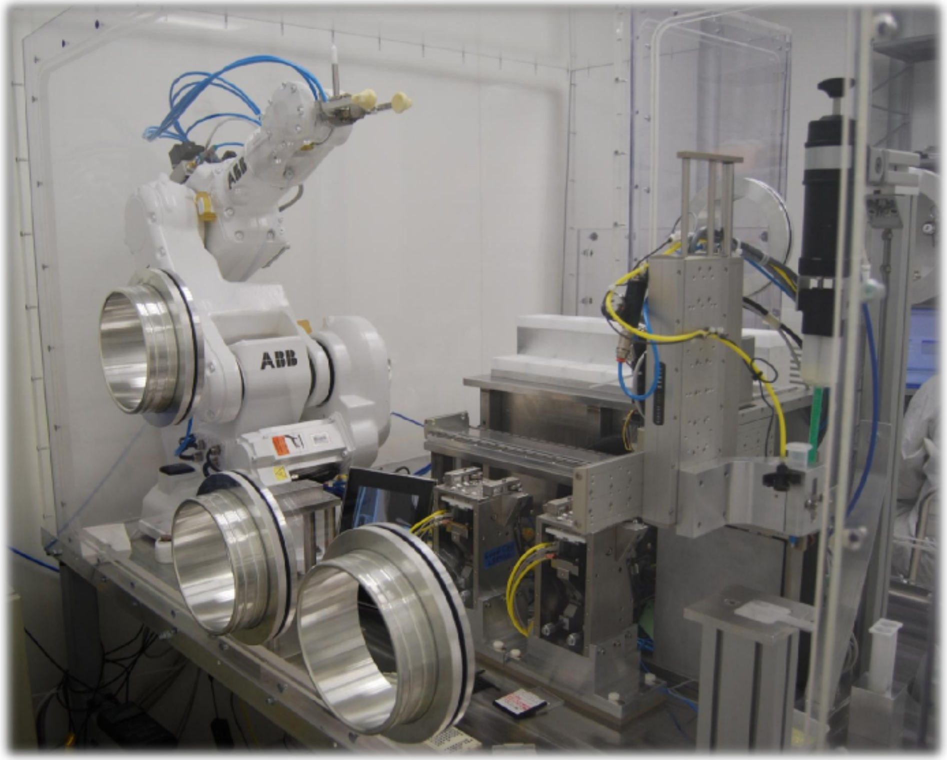


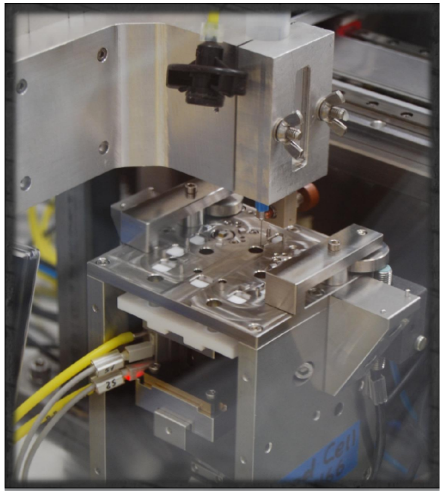
CUORE Assembling Line

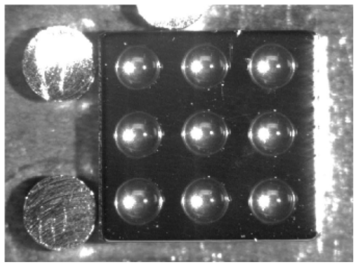
- All parts cleaned/screened according to CUORE protocol
- Stored underground at LNGS
- Assembly in underground clean room in N2 flushed glove boxes



Gluing of Thermistors to TeO_2 crystals

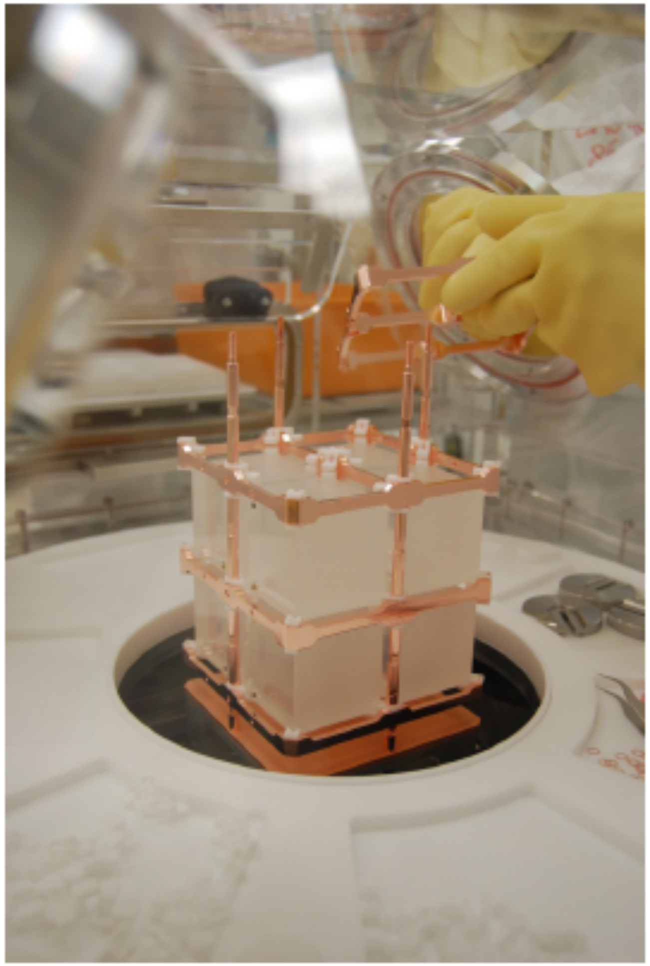


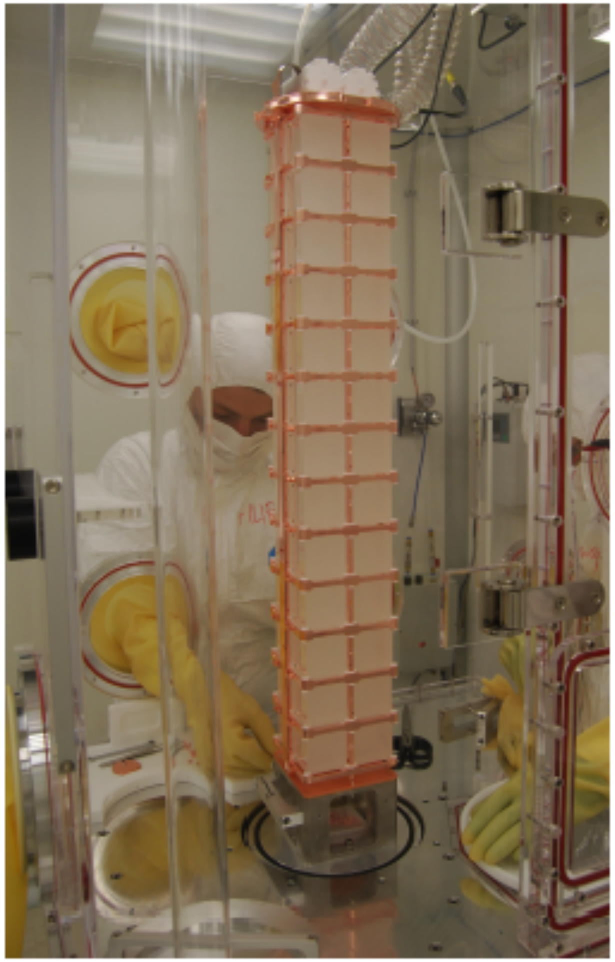


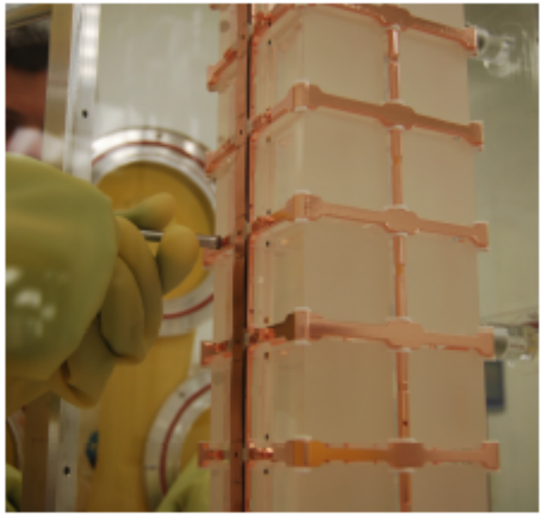


- Semiautomatic Gluing System (Clean Room @1° floor);
- Joule heaters for calibration purposes;
- Transmutation Doped (NTD) Germanium thermistor sensors.

Tower Assembling

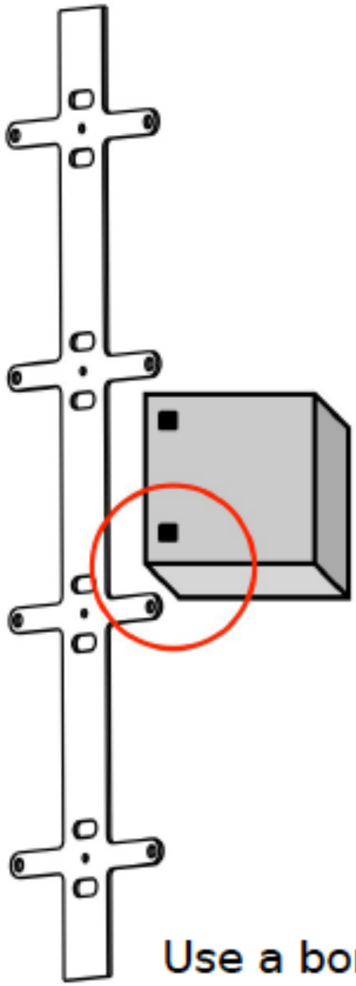


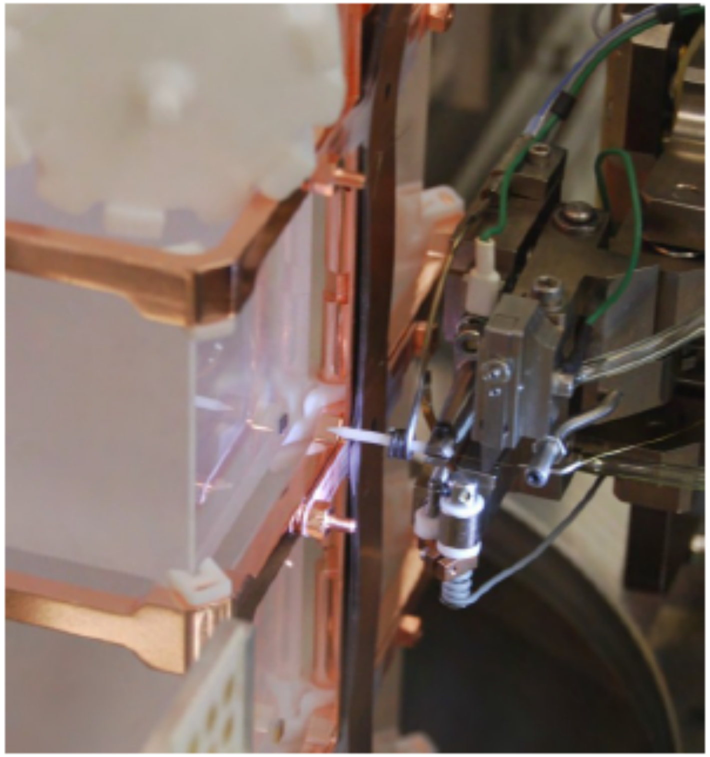


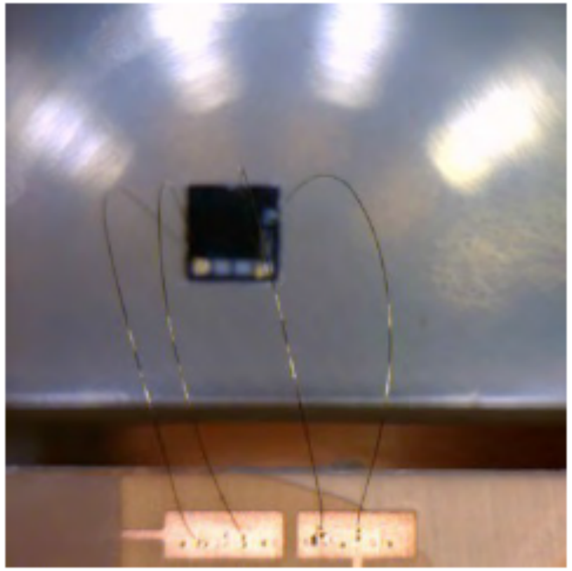


- Copper support structure
- Teflon supports
- Crystals
- Wire trays

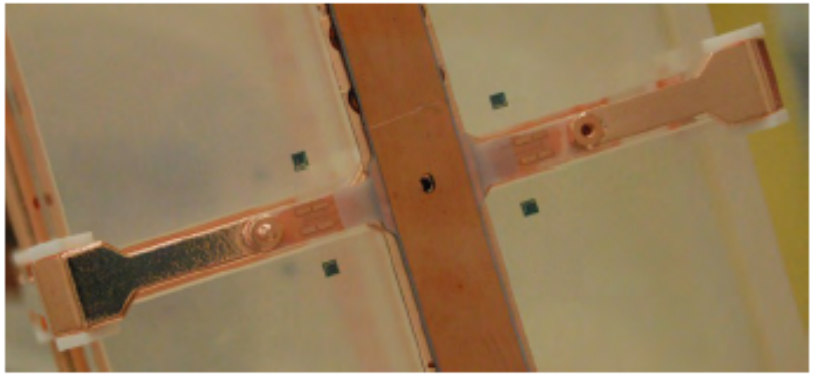
NTD Sensors Bonding



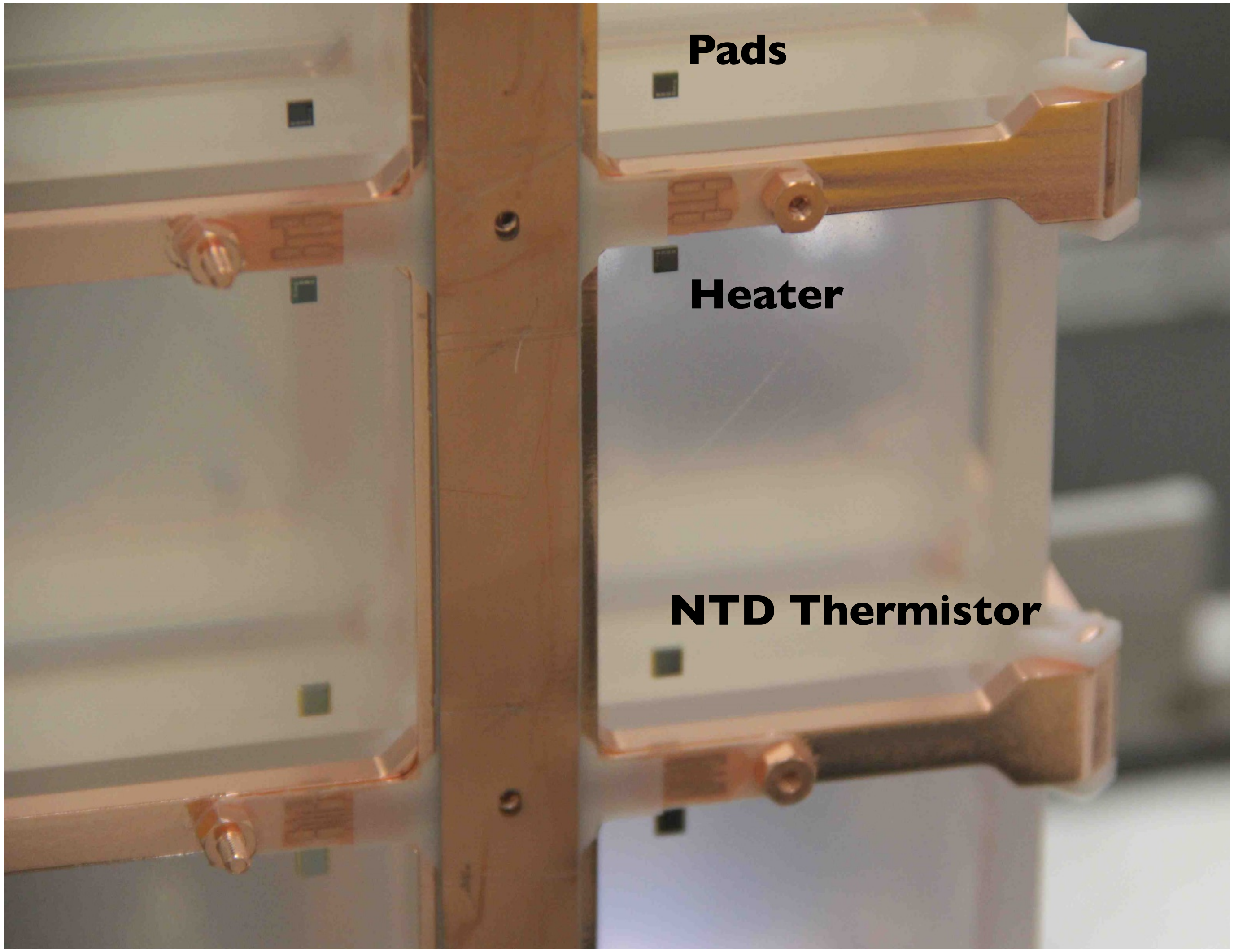




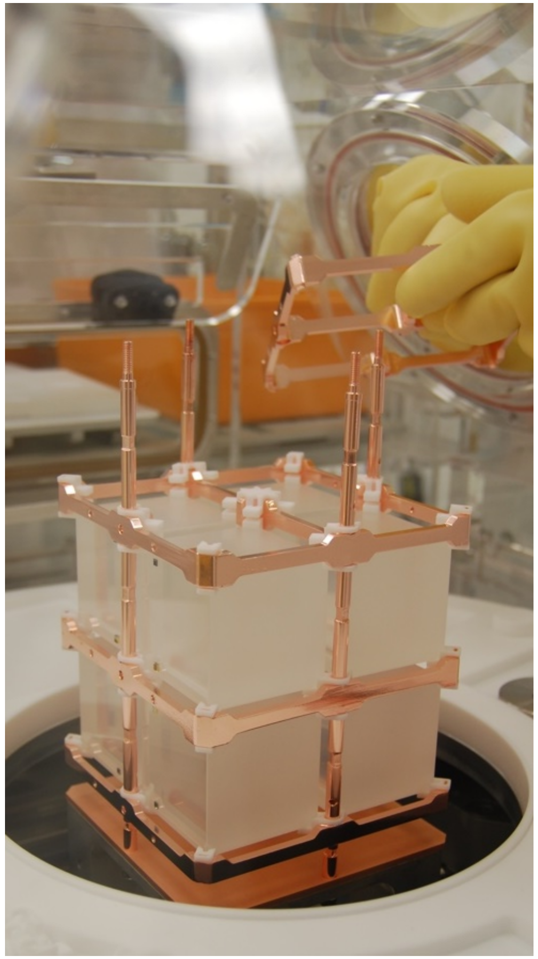
Use a bonding machine to connect the sensors and the heaters to the wire tray pads with gold wires



Close-up of Sensors and Readout traces

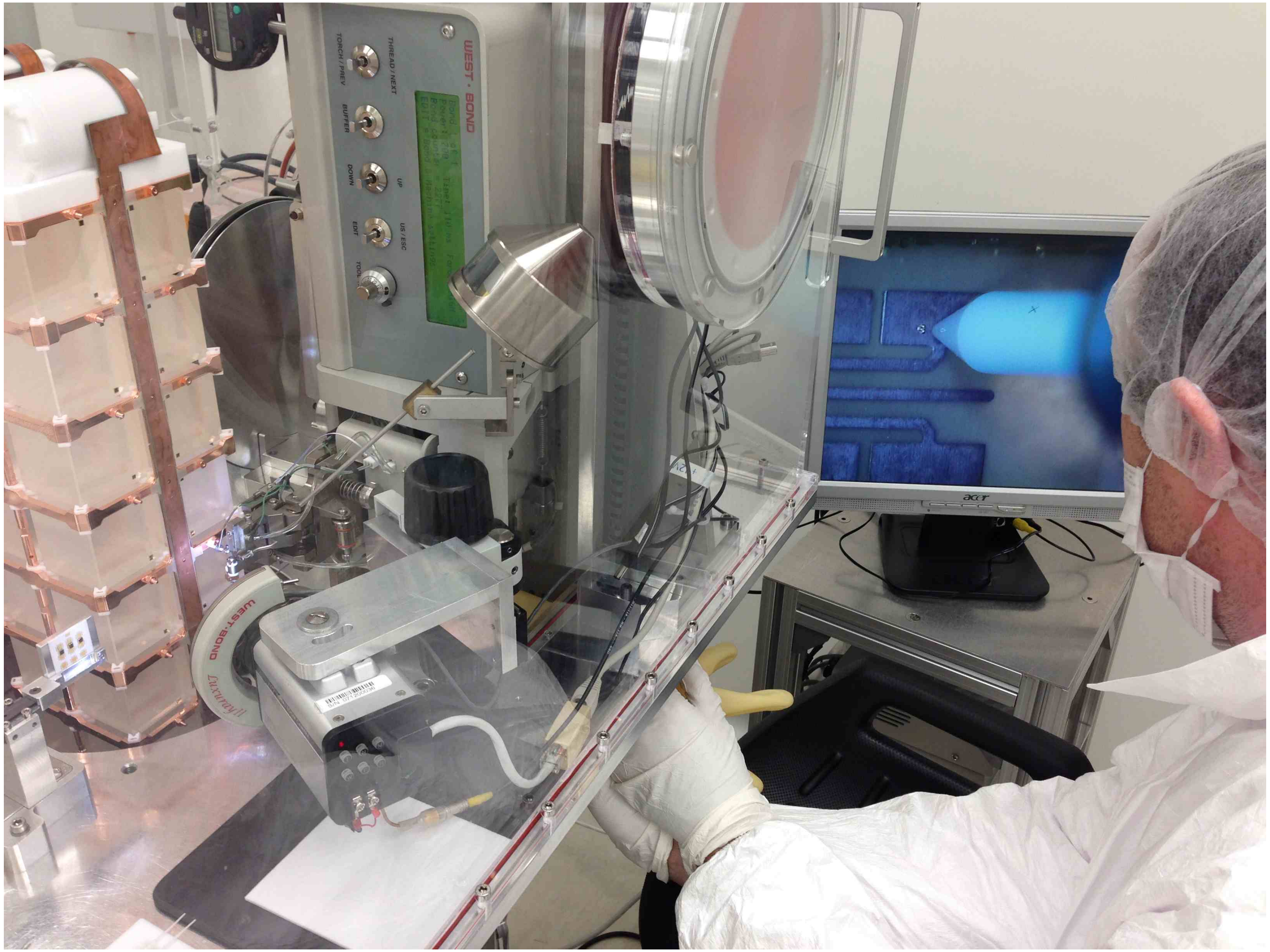


Tower Assembly Line



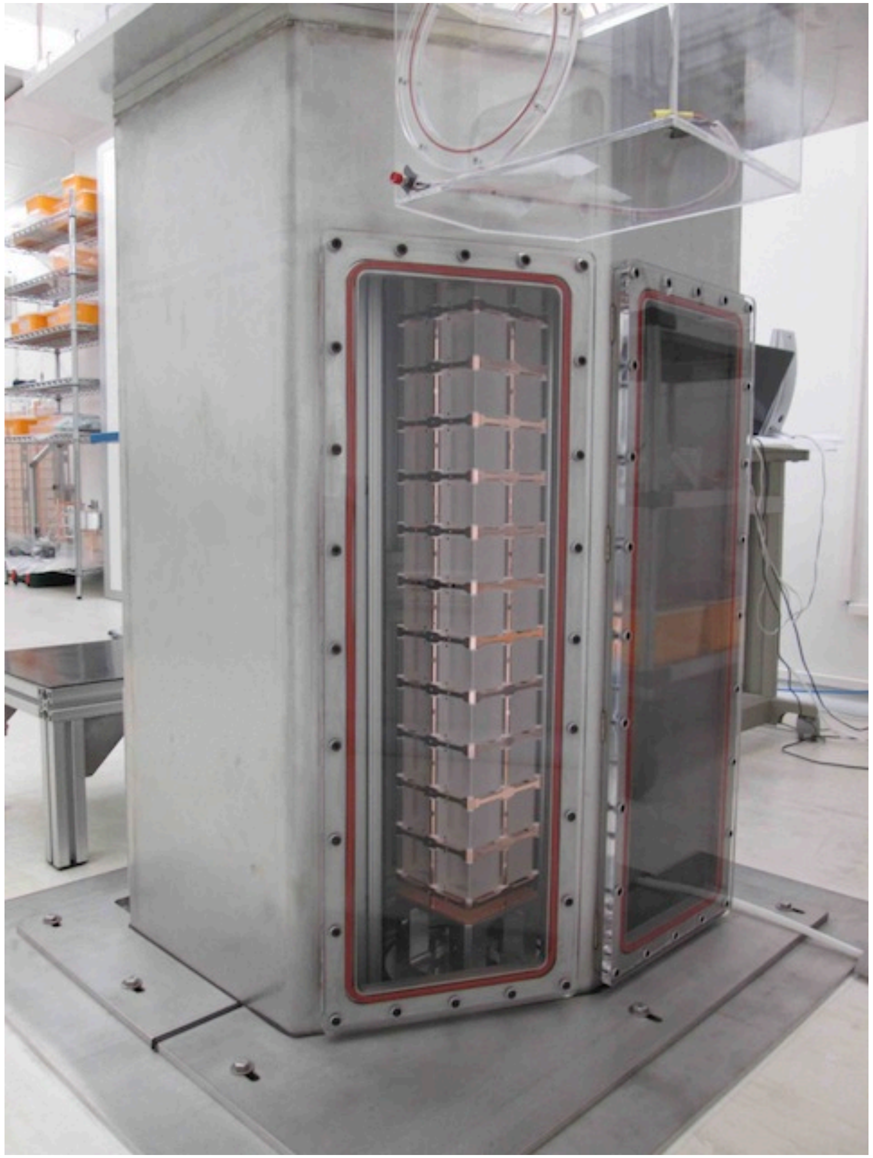
Step 1: **Physical Assembly of a Tower**

Tower Assembly Line



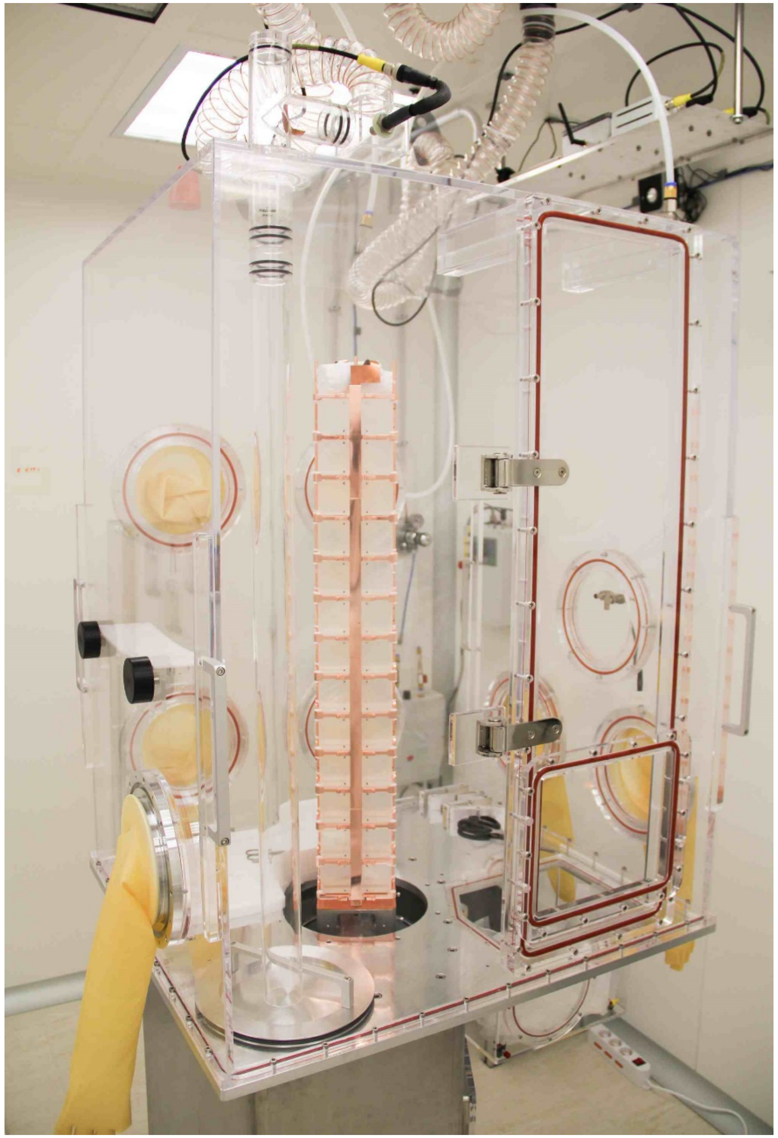
Step 2: **Tower Wire Bonding**

Tower Assembly Line



Assembled tower in the garage

Tower Assembly Line



Final steps

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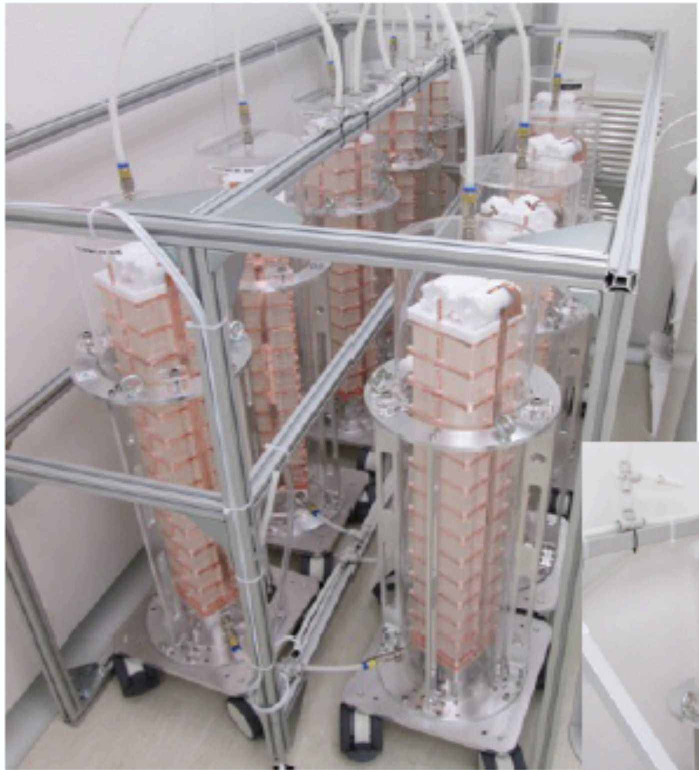
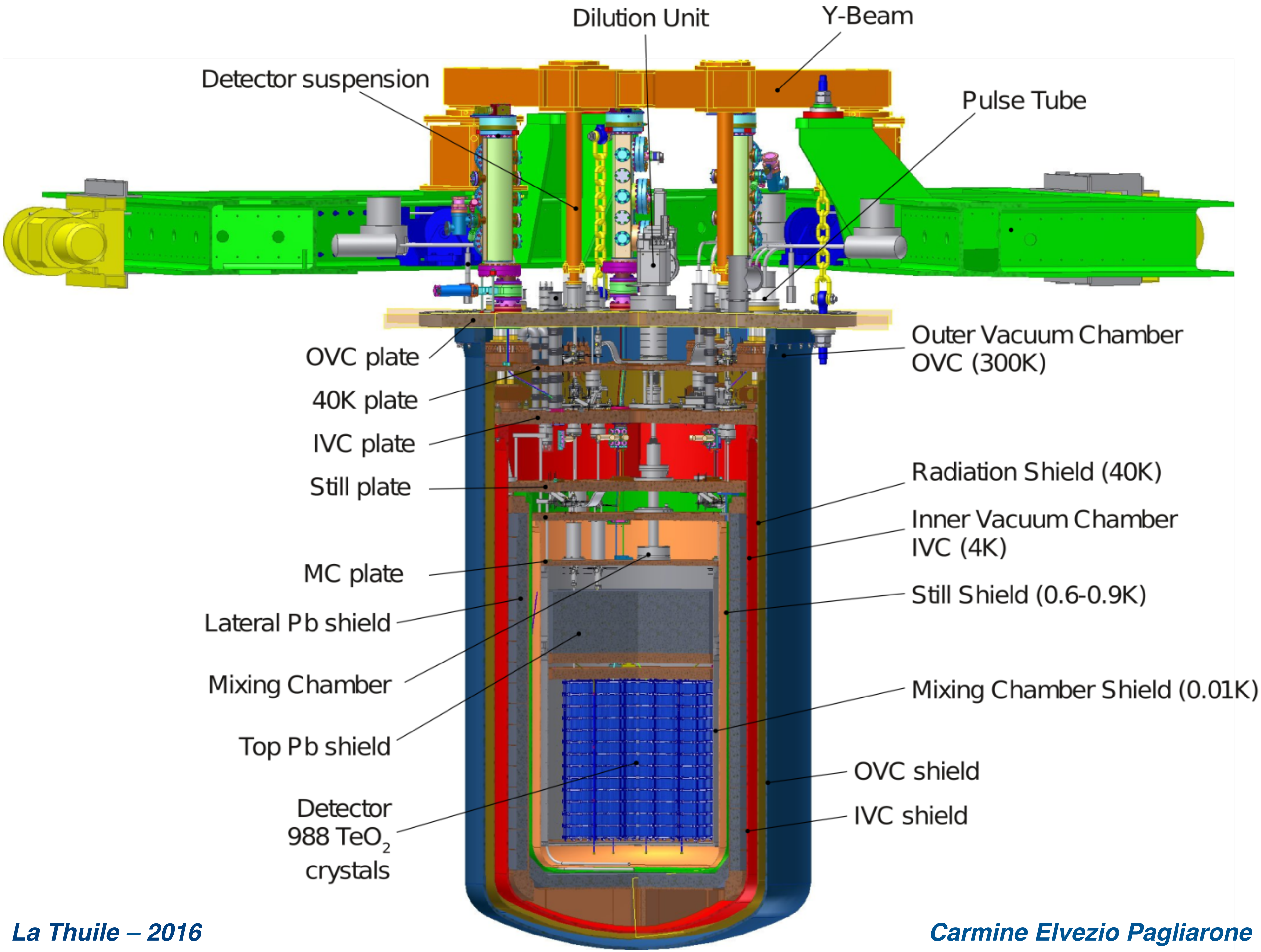
All the 19 assembled CUORE Towers



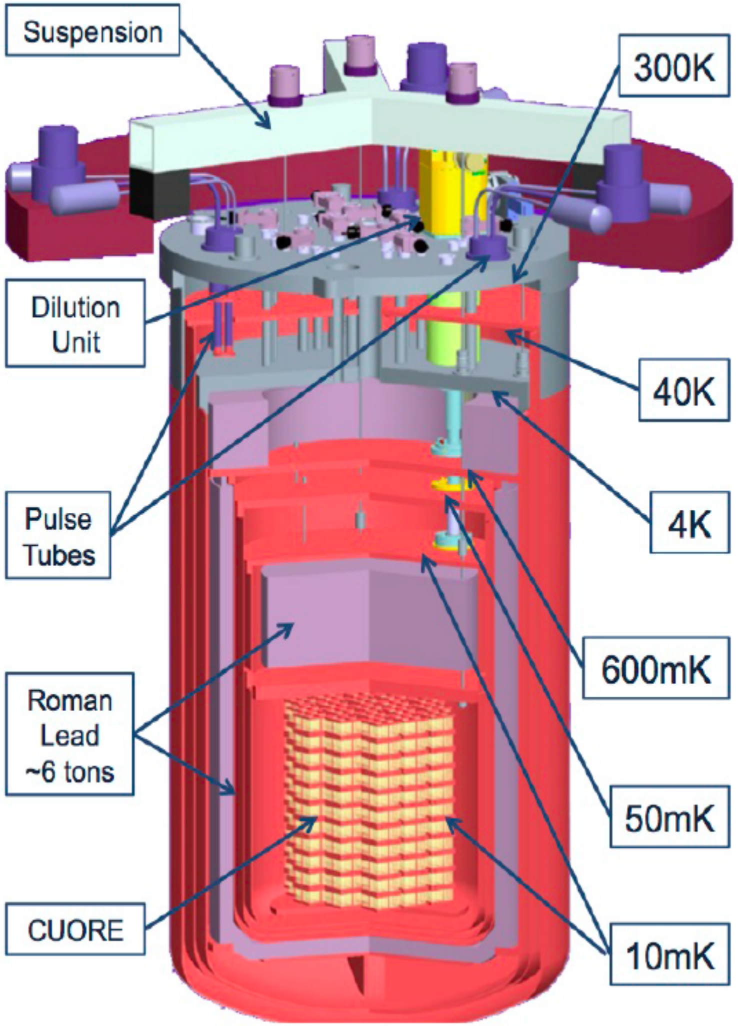
Sitting in N_2-fluxed storage
Ready to be installed

CUORE Cryostat
& Cryogenic Systems

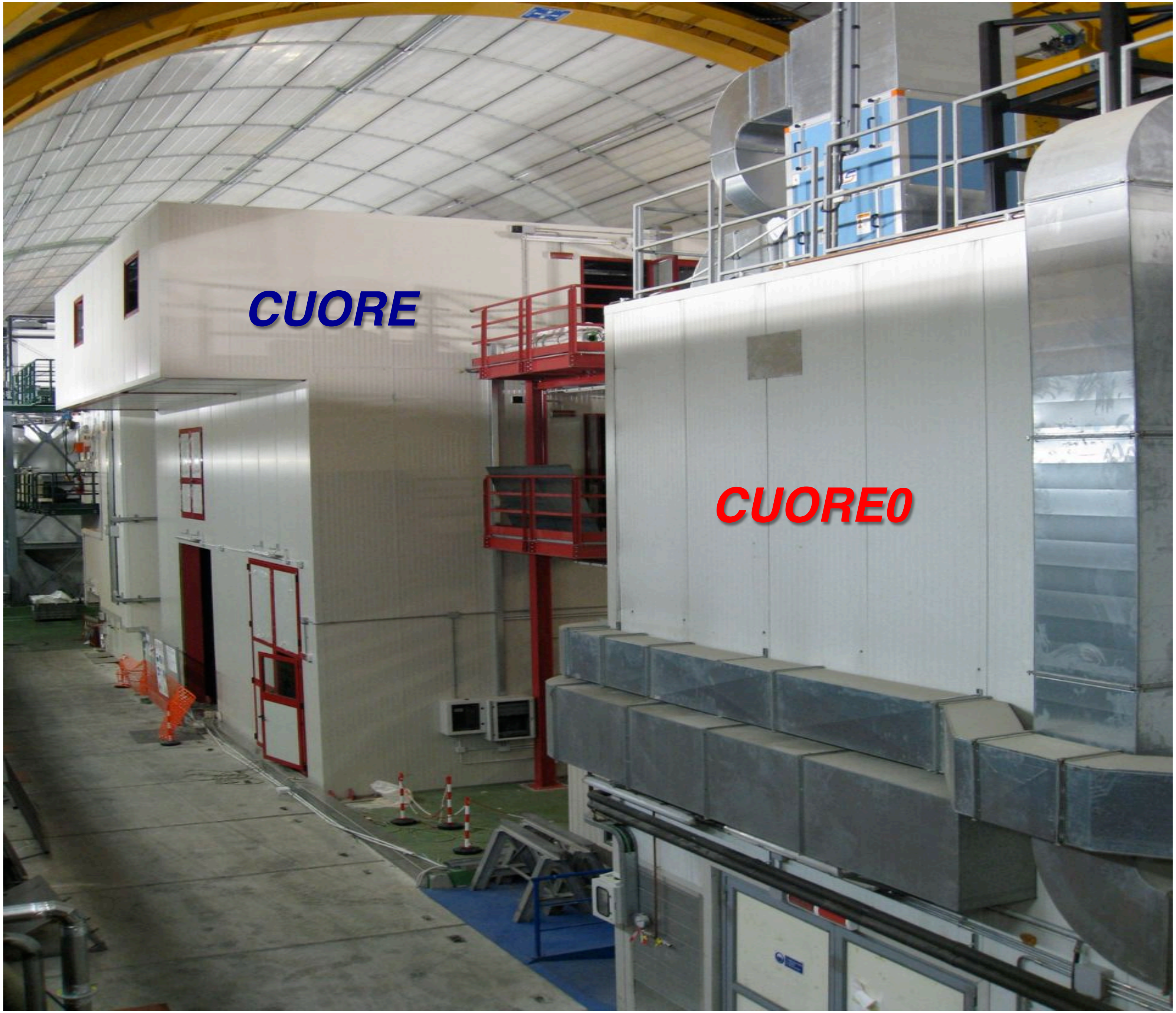
Carmine Elvezio Pagliarone

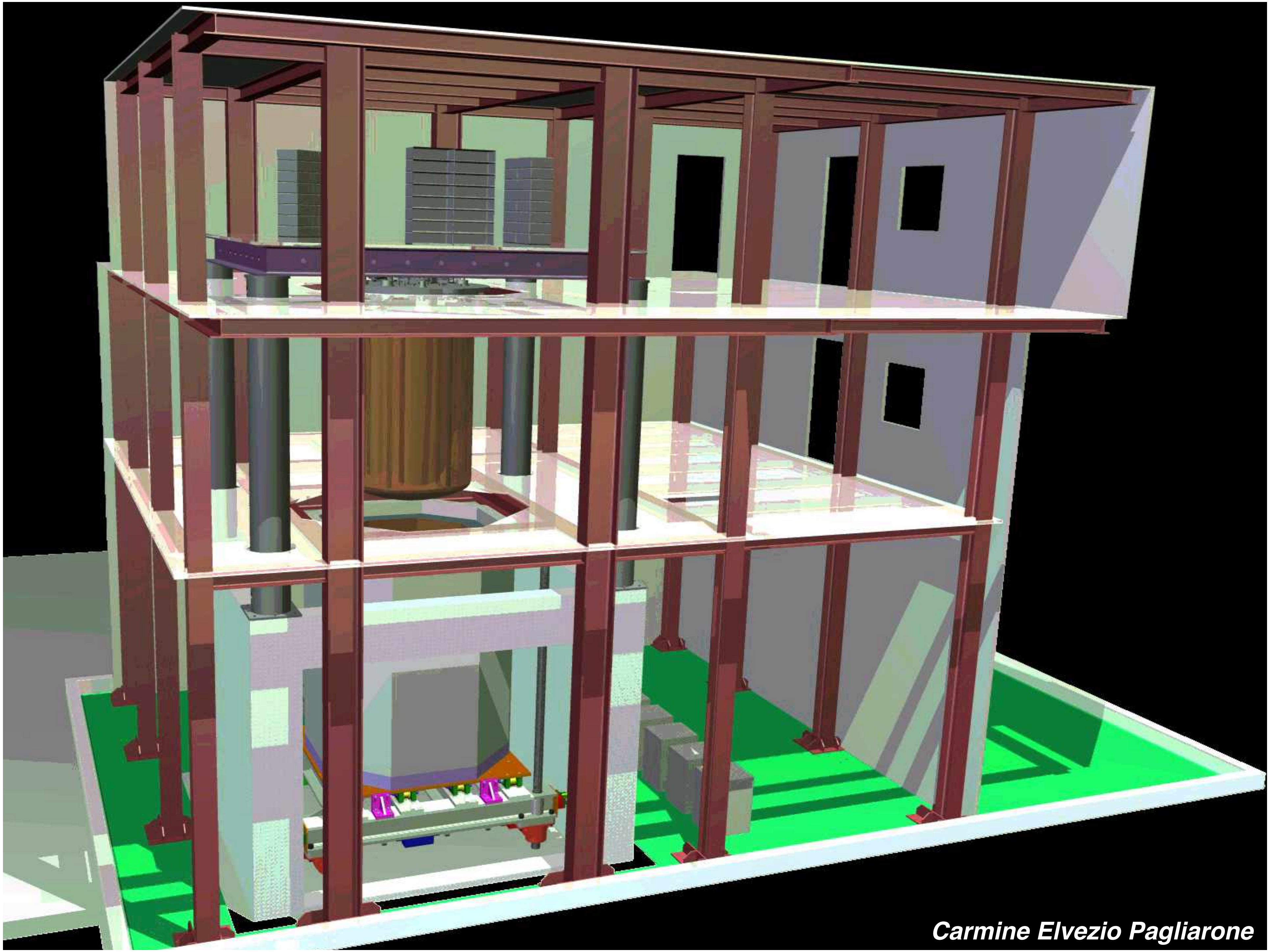

Dilution Unit
Y-Beam
Detector suspension
Pulse Tube
OVC plate
40K plate
IVC plate
Still plate
MC plate
Lateral Pb shield
Mixing Chamber
Top Pb shield
Detector
988 TeO_2
crystals
Outer Vacuum Chamber
OVC (300K)
Radiation Shield (40K)
Inner Vacuum Chamber
IVC (4K)
Still Shield (0.6-0.9K)
Mixing Chamber Shield (0.01K)
OVC shield
IVC shield

CUORE Cryostat Complex



- The Cryostat consists of **Six Nested Vessels**.
- **Two** of them are **Vacuum Chambers**:
  - the Outer Vacuum Chamber (**OVC**), at room temperature,
  - the Inner Vacuum Chamber (**IVC**), at ~4 K.
- Between them there is a ther-mal radiation shield at 40 – 50 K covered with 30 layers of Multilayer Insulation (MLI).
- **5 Pulse Tubes** (PT) mounted on the OVC top flange provide the cooling for the 40 K radiation shield (PT first stages) and the IVC (PT second stages)
- Cooling to mK range is achieved by a high-power **Dilution Unit** (DU).
- Inside the IVC, three radiation shields are ther- mally linked to the DU: the Still shield (600 – 900 mK), the Cold Plate shield (50 – 100 mK), and the Mixing Chamber (MC) shield (< 10 mK) that surrounds the experimental space.


CUORE
CUORE0



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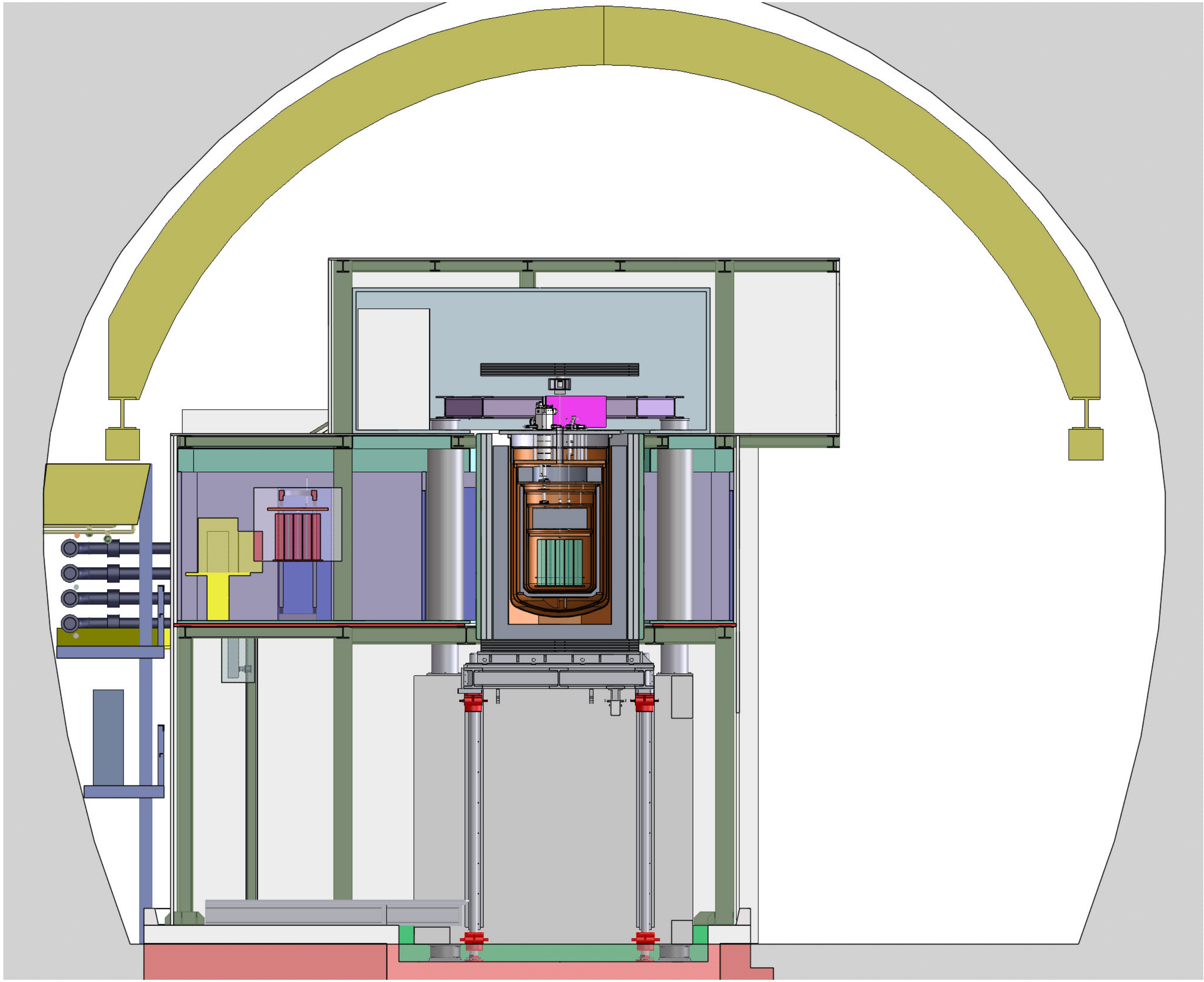
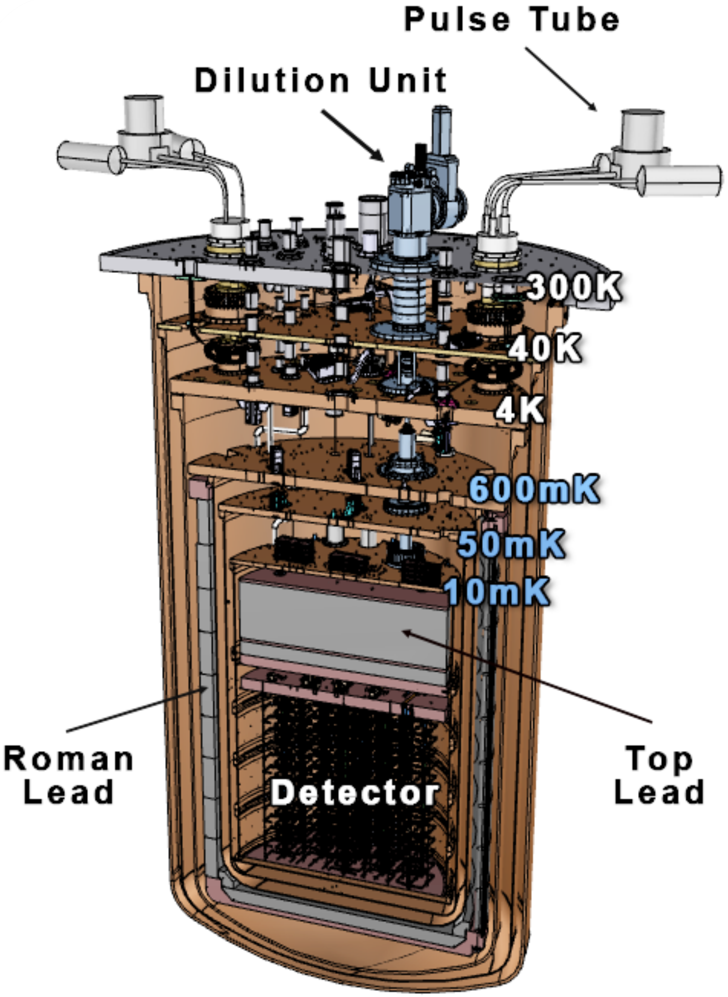


CUORE Cryogenic Systems

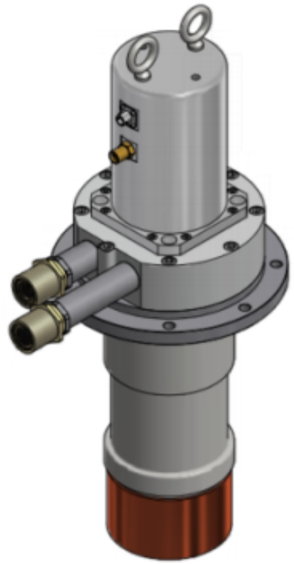


OVC – Outer Vacuum Chamber
IVC – Inner Vacuum Chamber

4 K

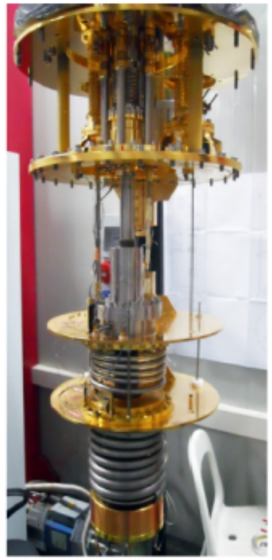
Pulse Tubes
Cryomech PT415

25 K



Fast Cooling System
Cryomech GM AL600

5 mK



Dilution Unit
Leiden Cryogenics

CUORE Cryogenic Systems

PULSE TUBES (PTs)

- The commercial PT cryocoolers that will be used are **5** two-stage **Cryomech PT415**, chosen for their high cooling power.
- To reduce vibrations transmitted to the cryostat the rotatory valve is detached from the cold head.
- The pulsed He flow is transmitted by a ~ 35 cm long tube from the valve to the cold head and by two 20 m long flexible lines to the compressor.

DILUTION UNIT (DU)

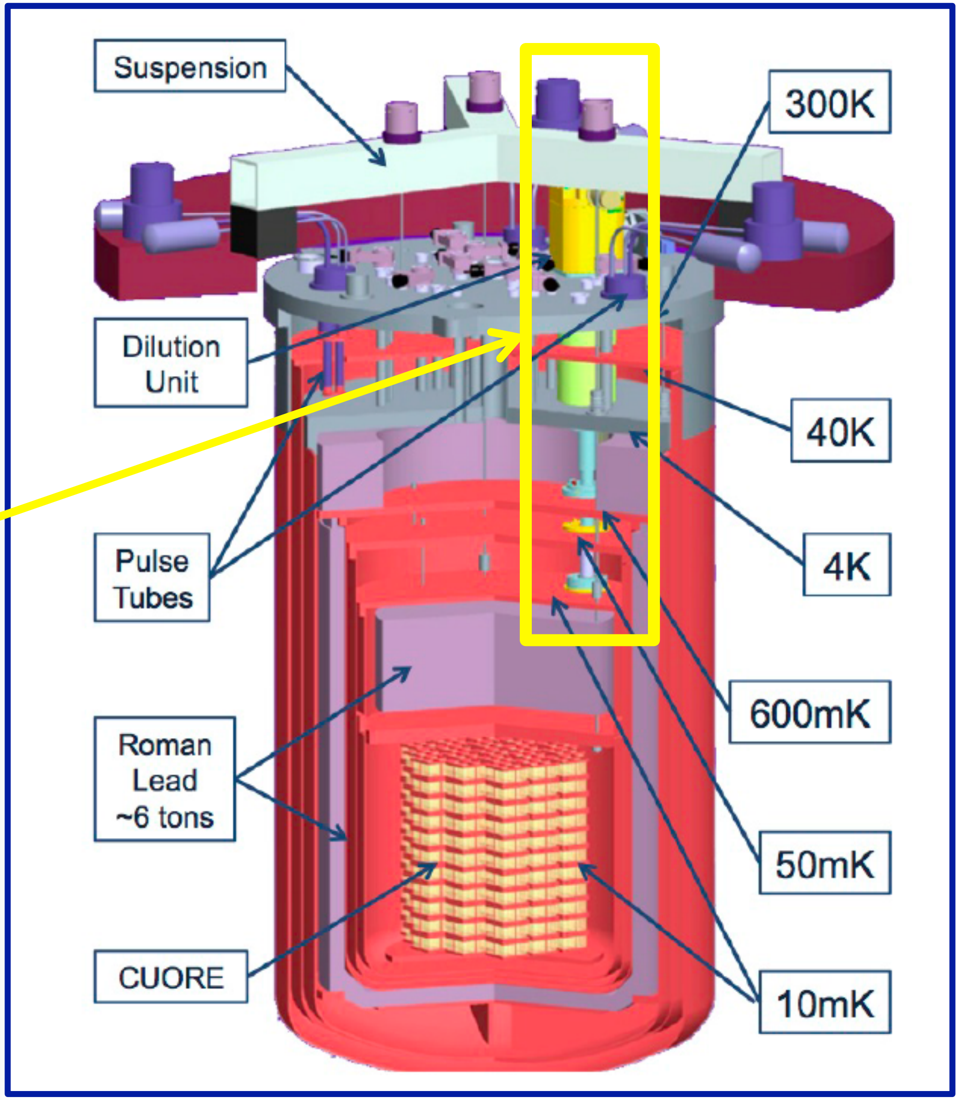
- The inner thermal shields will be cooled by the thermal stages of a $^3He/^4He$ Dilution Cryorefrigerator as well as the detector.

FAST COOLING Systen (FCS)

- As the **5 PTs alone cannot cool down the IVC to 4 K in an acceptable time**, in addition to the 5 PTs, a **Fast Cooling System** (FCS) is being designed for a quick pre-cooling of the IVC from **300 K to less than 30-50 K in about a week**.
- A root pump will circulate the He gas cooled by **3 Gifford McMahon AL600 Cryomech** Cryocooler (600 W @ 77 K) inside the IVC vessel.

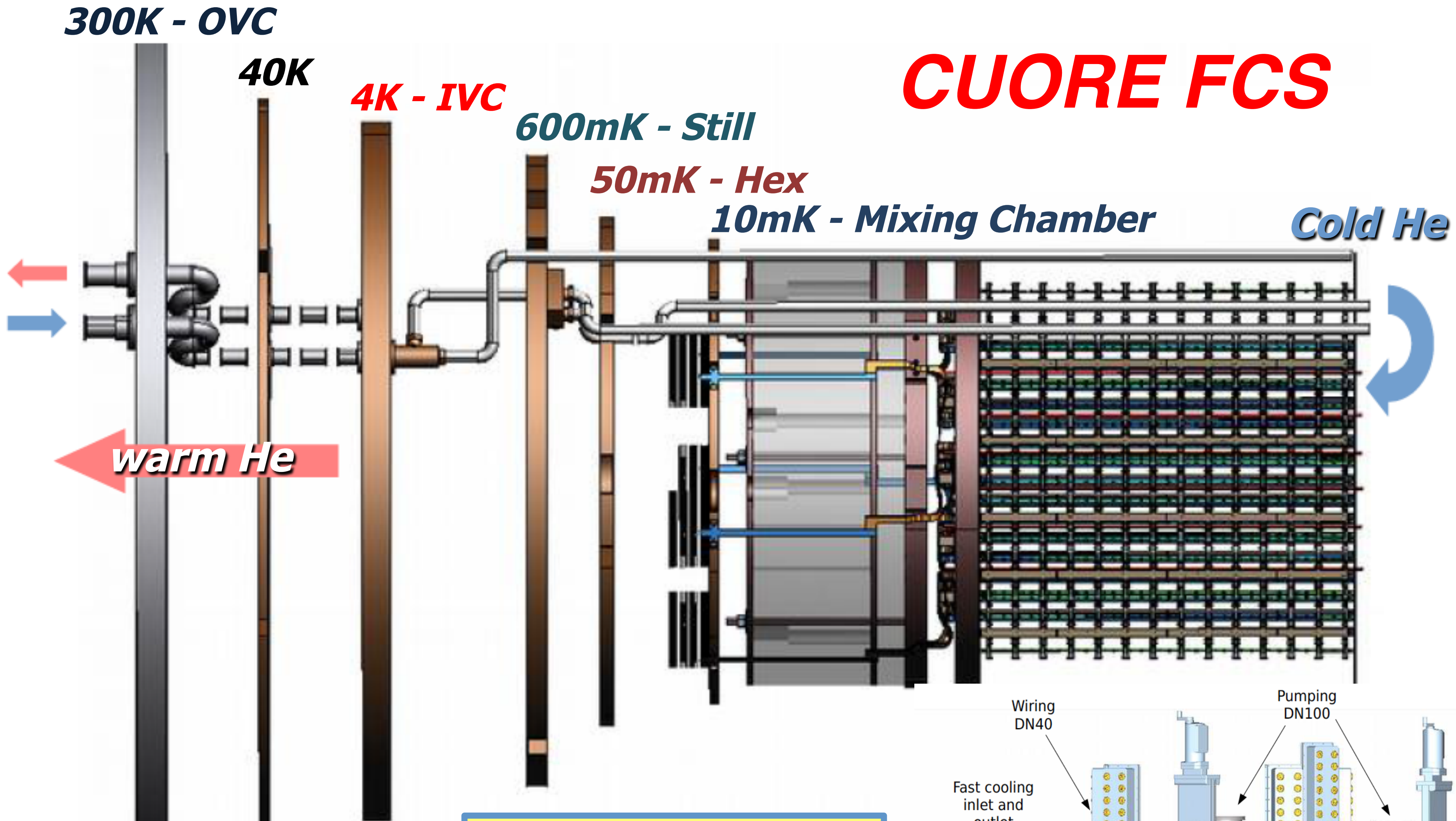
- **Below 4 K it takes several hours to cool down CUORE to the baseline temperature.**

CUORE DU



Suspension
300K
Dilution Unit
40K
4K
Pulse Tubes
600mK
Roman Lead ~6 tons
50mK
CUORE
10mK

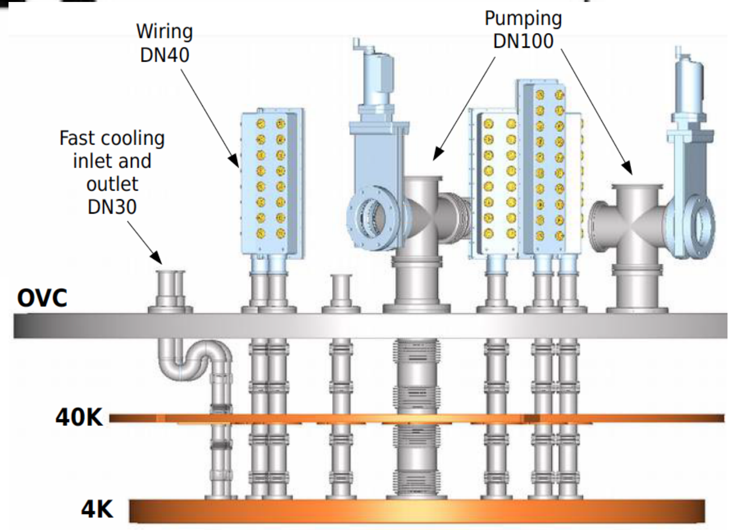
CUORE FCS



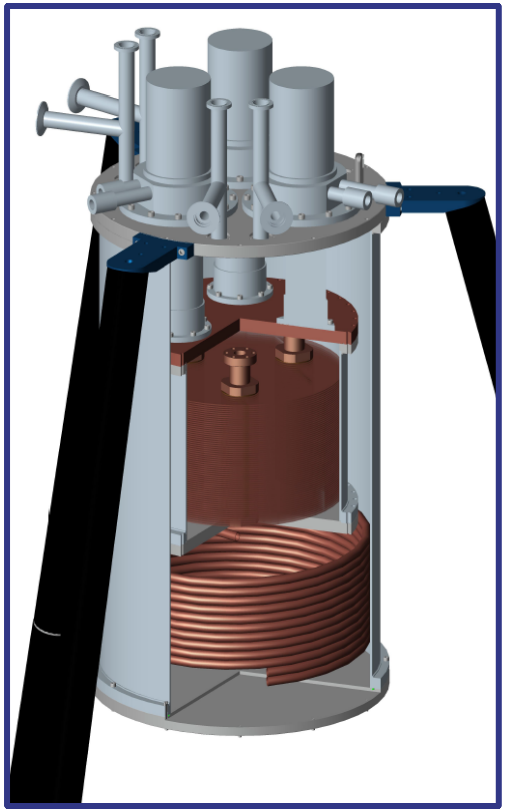
$P_{IVC} < 1.36$ bar

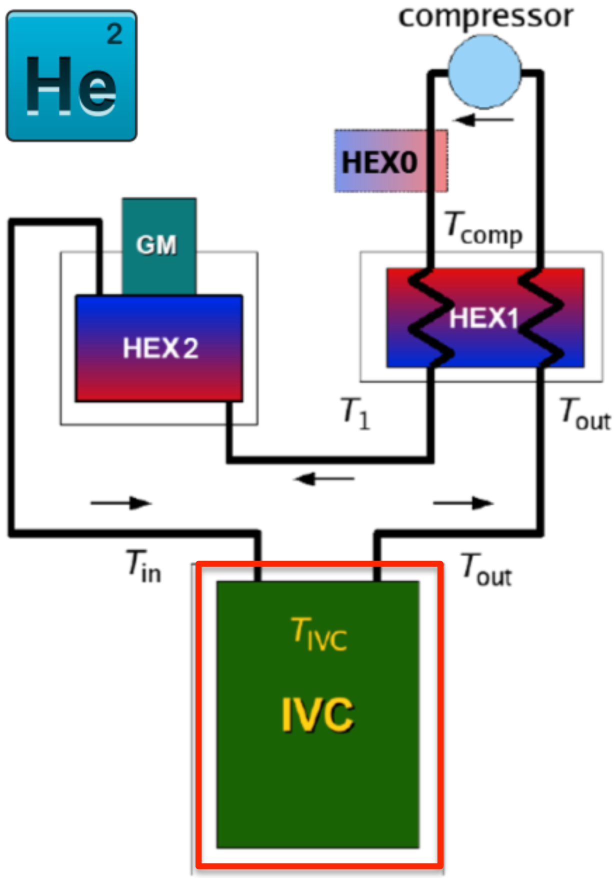
$\Delta T < 40$ K

$\Phi_{FM} = -7.6 + 3.96$ V

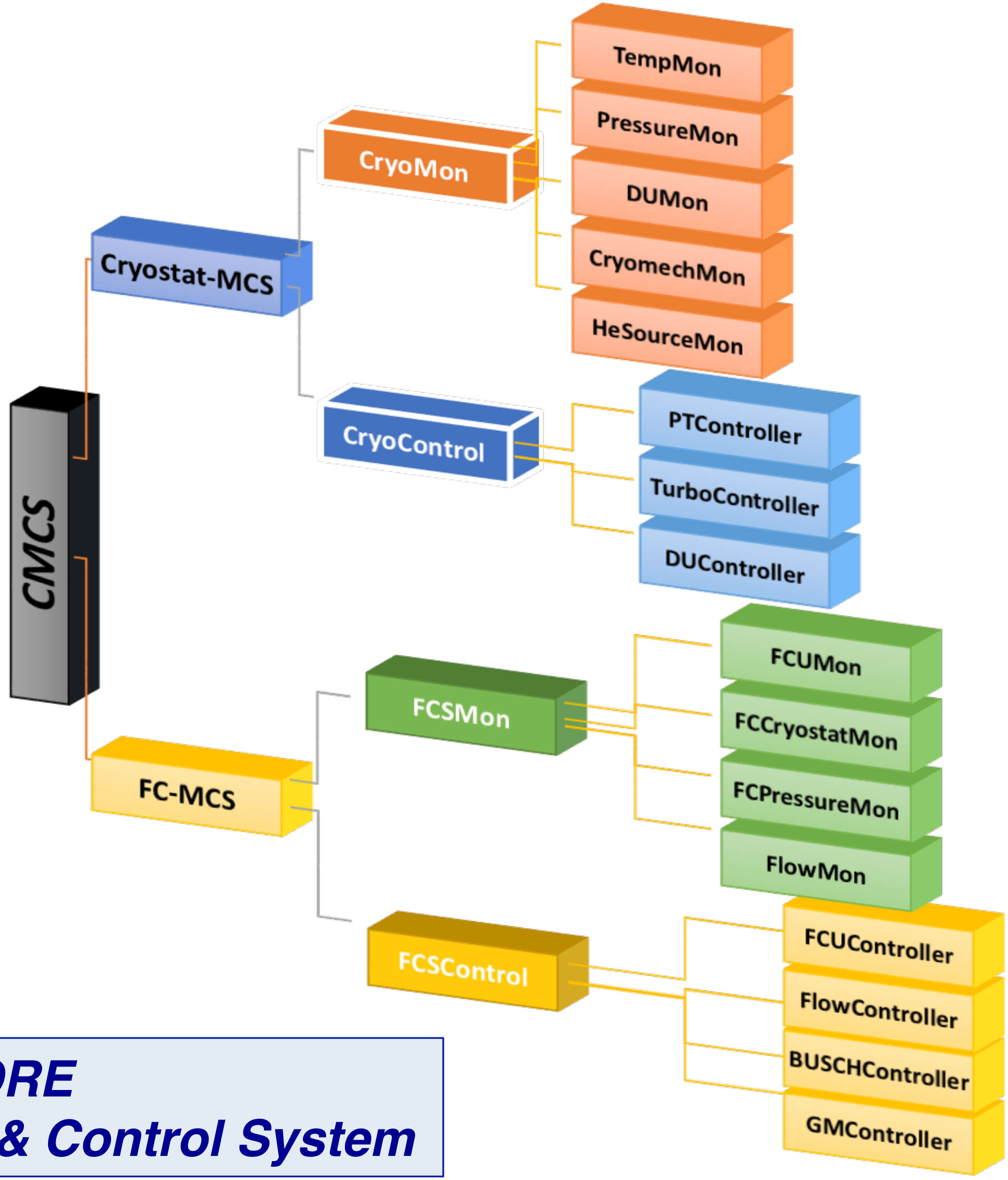


CUORE Fast Cooling System





- **Speeds up the cooling procedure flowing He into CUORE;**
- **3 Heat Exchangers: 2 Counter flow bellows + 1 Copper HEX;**
- **3 Cryomech Gifford-McMahon (GM) Cryocoolers;**
- **Cooling power: 600 W @ 77K (each);**



CUORE
Cryogeny Monitor & Control System

La Thuile 2016

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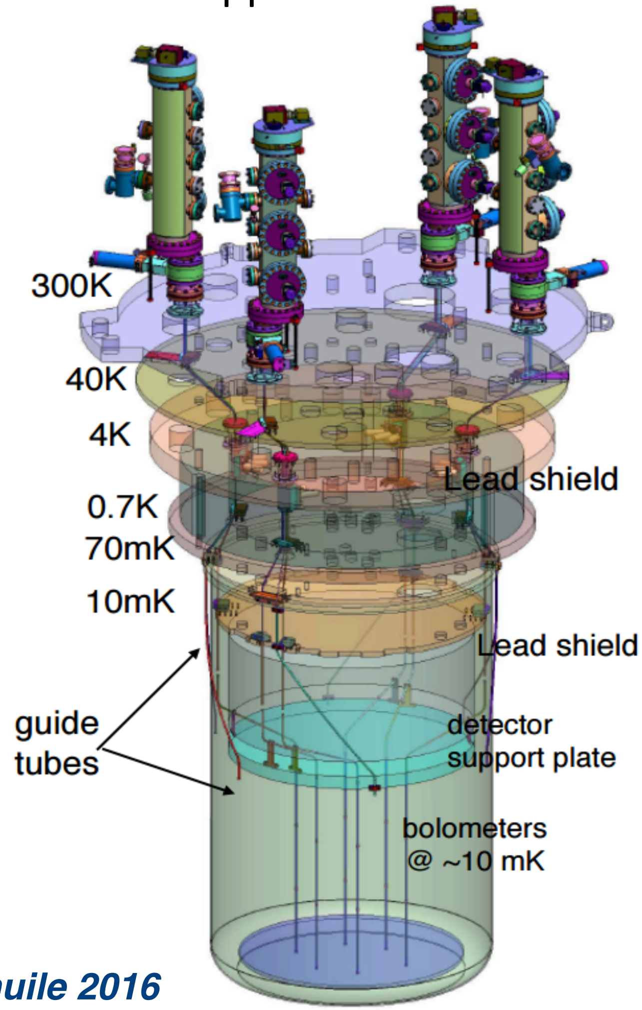
CUORE Detector Calibration System

- DCS is needed to lower and raise, to known positions under independent control, 12 strings of 29 weakly radioactive calibration sources through bent guide tubes;
- The strings are Kevlar or Vectran thread just 0.35mm (0.014") in diameter, on which 1.8mm diameter copper tubes and extend up to 4 meters in overall length;



I. Gain Stabilization

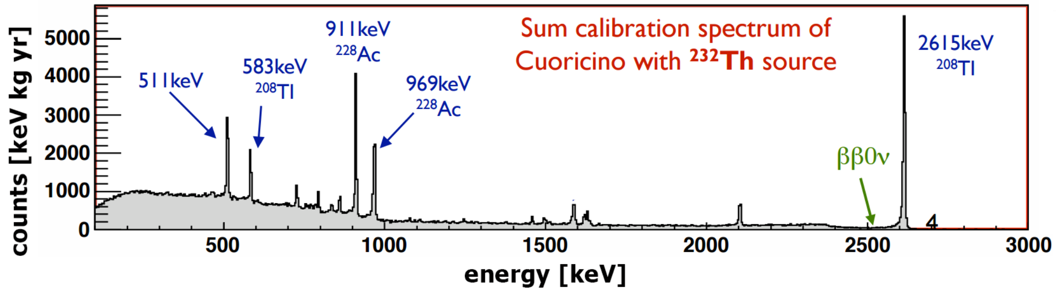
For each bolometer an energy pulse generated by a Si resistor is used to correct pulse amplitudes for gain instabilities (→ every 5 min).

II. Calibration of individual bolometer

- calibrate with γ-sources
- need 5+ lines visible in calibration spectrum
- energy accuracy goal: < 0.05 keV

III. Voltage-Energy Conversion

Fit of a calibration measurement with a gamma source (e.g. 232Th) of known energy. Energy calibration performed regularly. (~ monthly).



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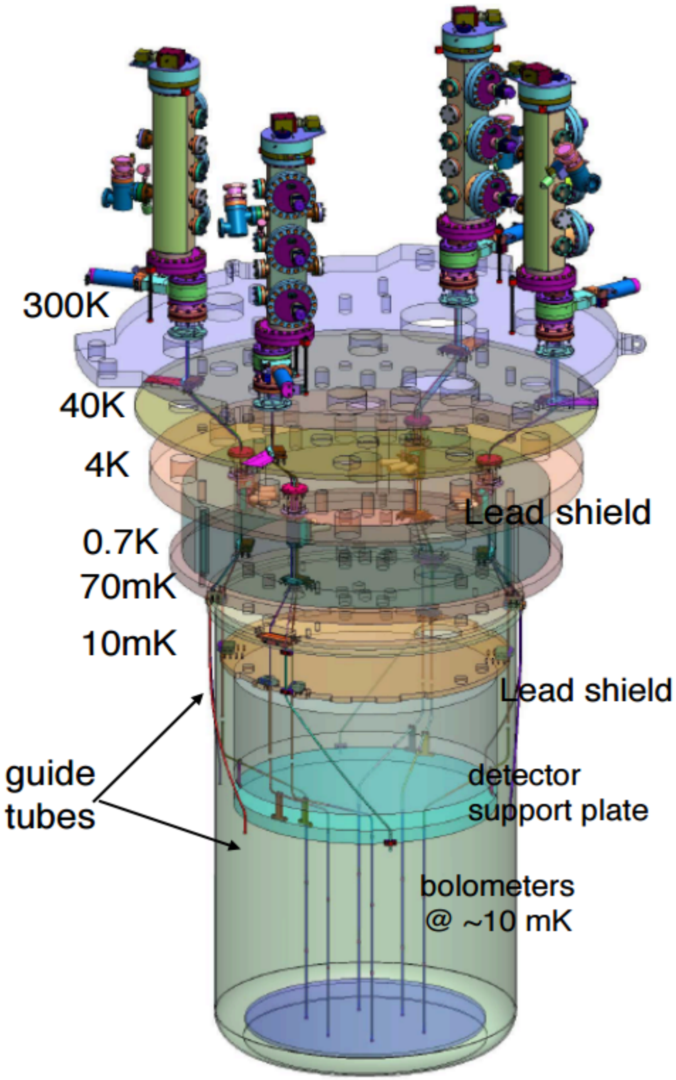
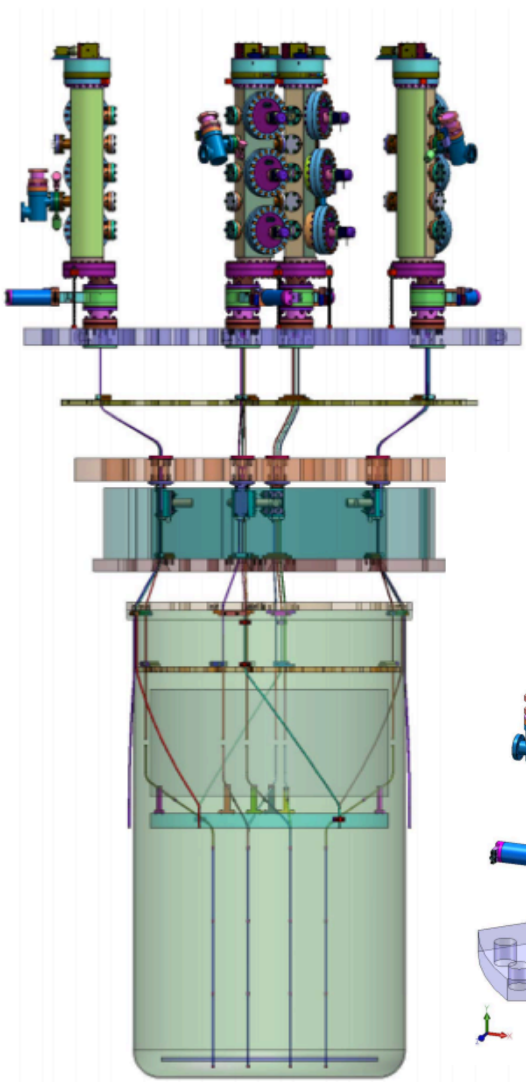
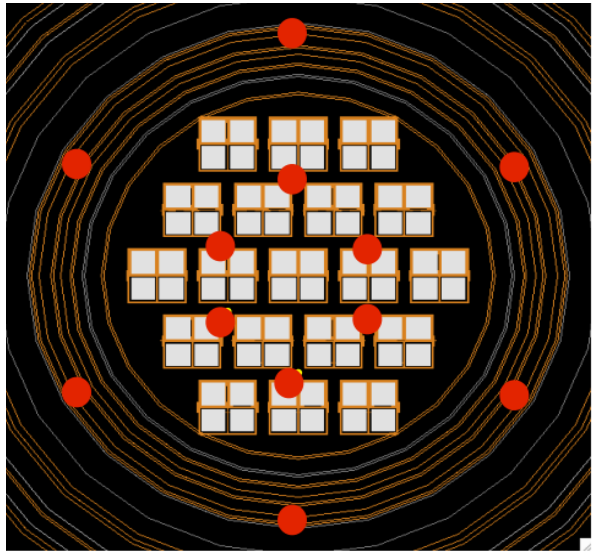
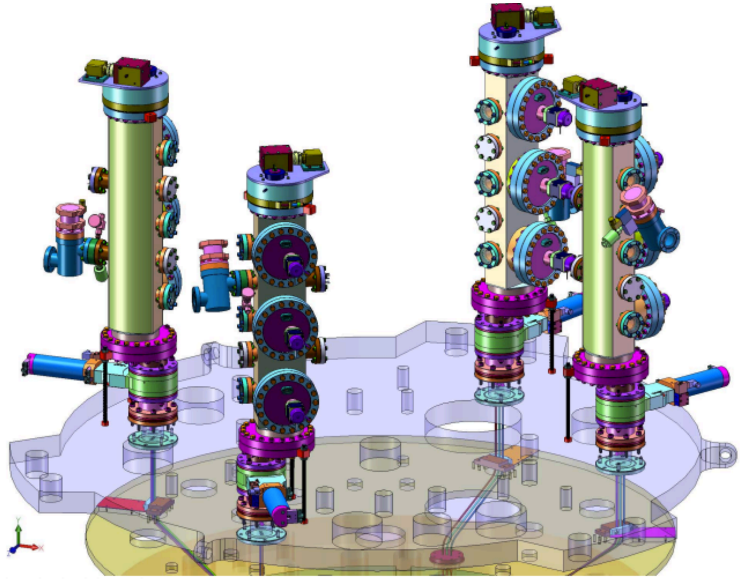
CUORE Detector Calibration System

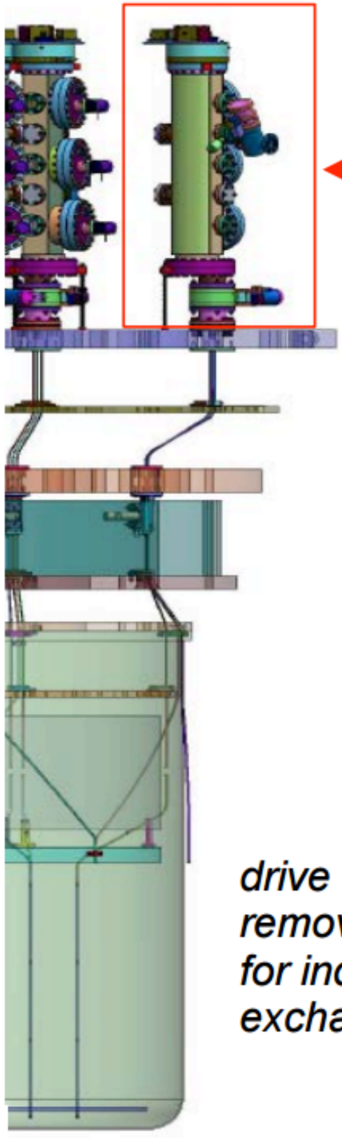


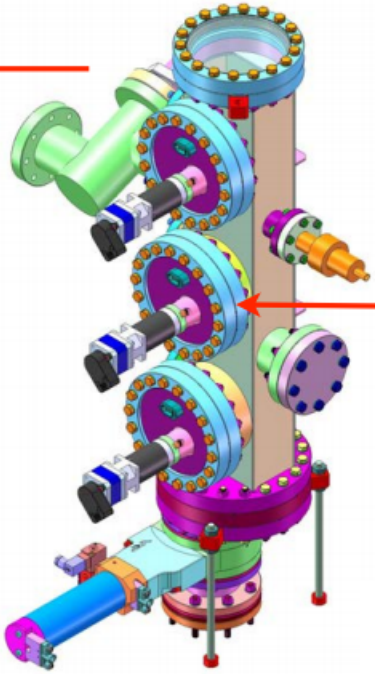


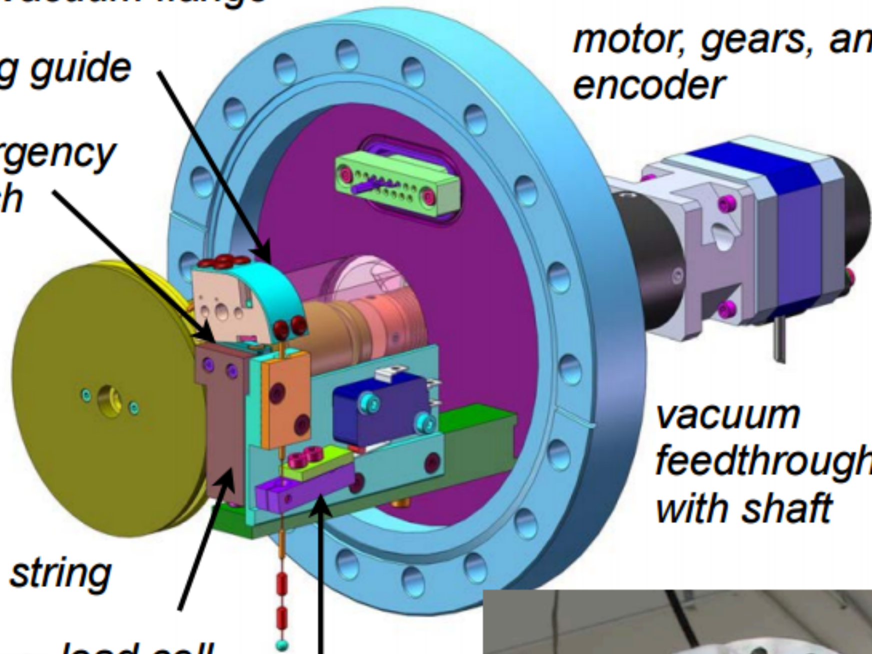


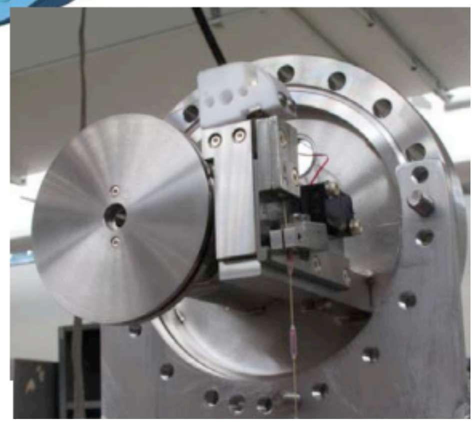


Calibration Motion System



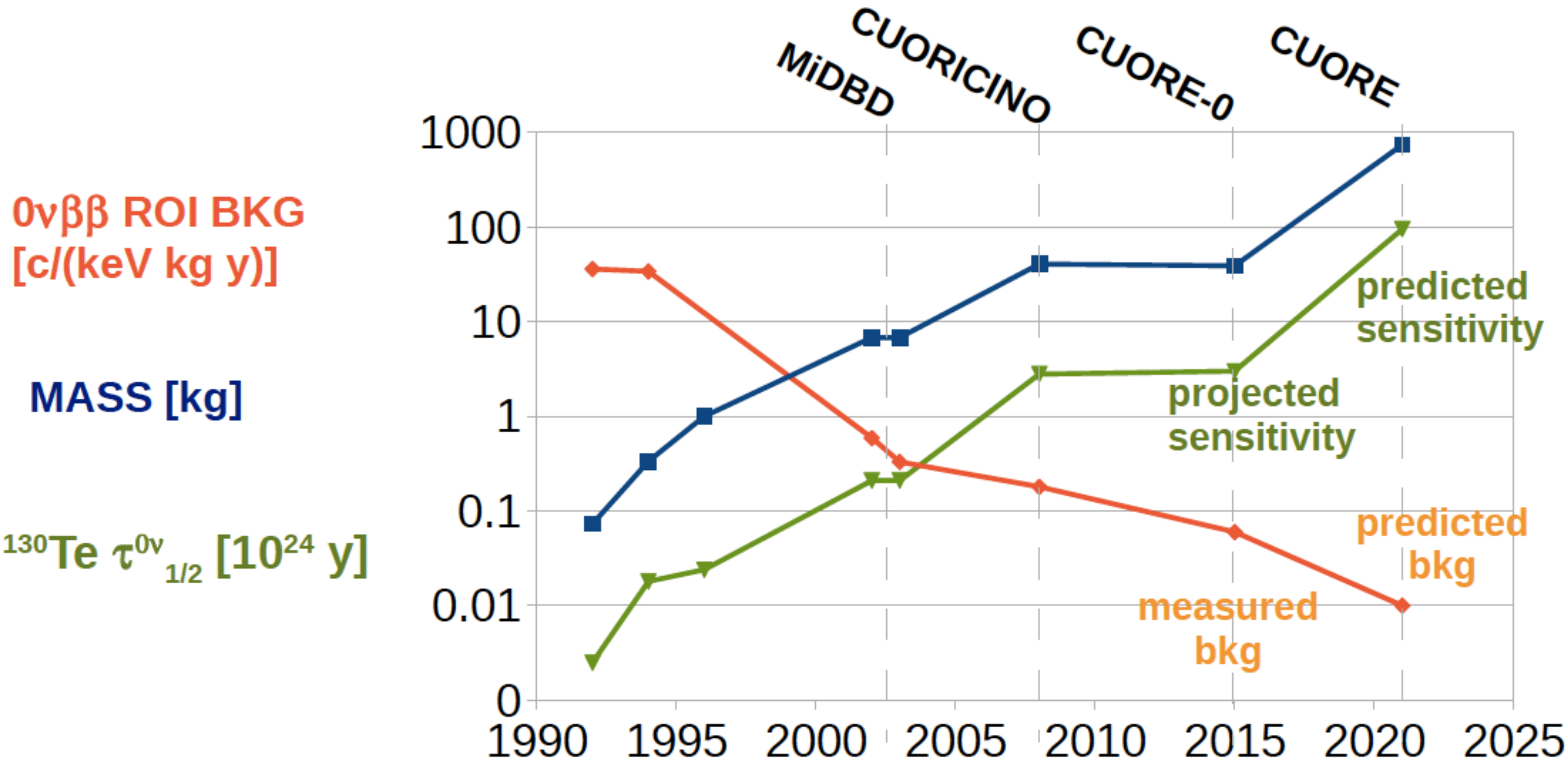






drive spools can be removed with clean bag for individual source exchange

CUORE Expected Sensitivity



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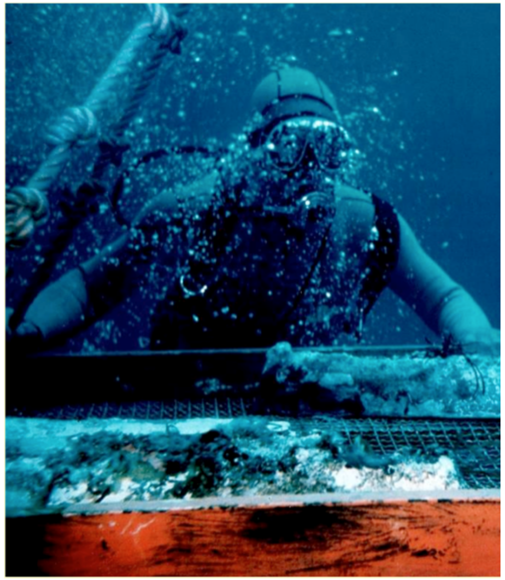
CUORE Run 4
Status & Preliminary Results

- Installation of the Roman Lead;
- Performances of the Cryogenic Systems;
- Tests with a first Tower of 8 TeO_2 Crystals (MiniTower);

CUORE Roman Lead Shield

- Ancient Roman lead bricks for low-activity shielding;
- Recovered in late ‘80s from shipwreck off Sardinian Coast;
- Obtained through an agreement between INFN and Sopraintenza ai beni archeologici (Italian Historical Society);
- 270 bricks, 33 kg each = 7 tons (after inscriptions removed)

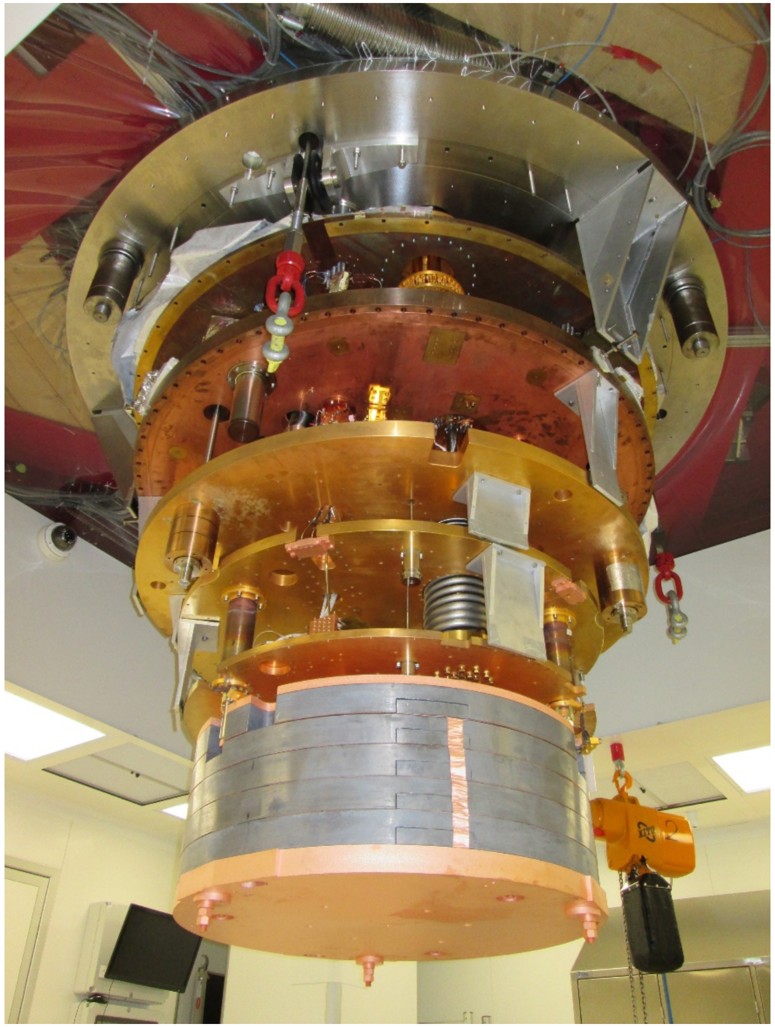


Construction and Installation of the Roman Pb Shield

~ 5 tonnes of Pb shielding was added for Run 4. This is in addition to **2 tonnes of top Pb** that was already installed previously.

CUORE Roman Lead Shield

Top Pb ~ 2 tonnes



Side Pb ~ 5 tonnes

Performances of CUORE Cryogenic Systems

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The Coldest m^3 "in the Universe"

INTERACTIONS.ORG

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Interactions NewsWire #71-14
21 October 2014 http://www.interactions.org
****

Source: INFN
Content: Press Release
Date Issued: 21 October 2014
****

21/10/2014

5.9 mK

2 Più... Login AddThis

CUORE: The Coldest Heart in the Known Universe

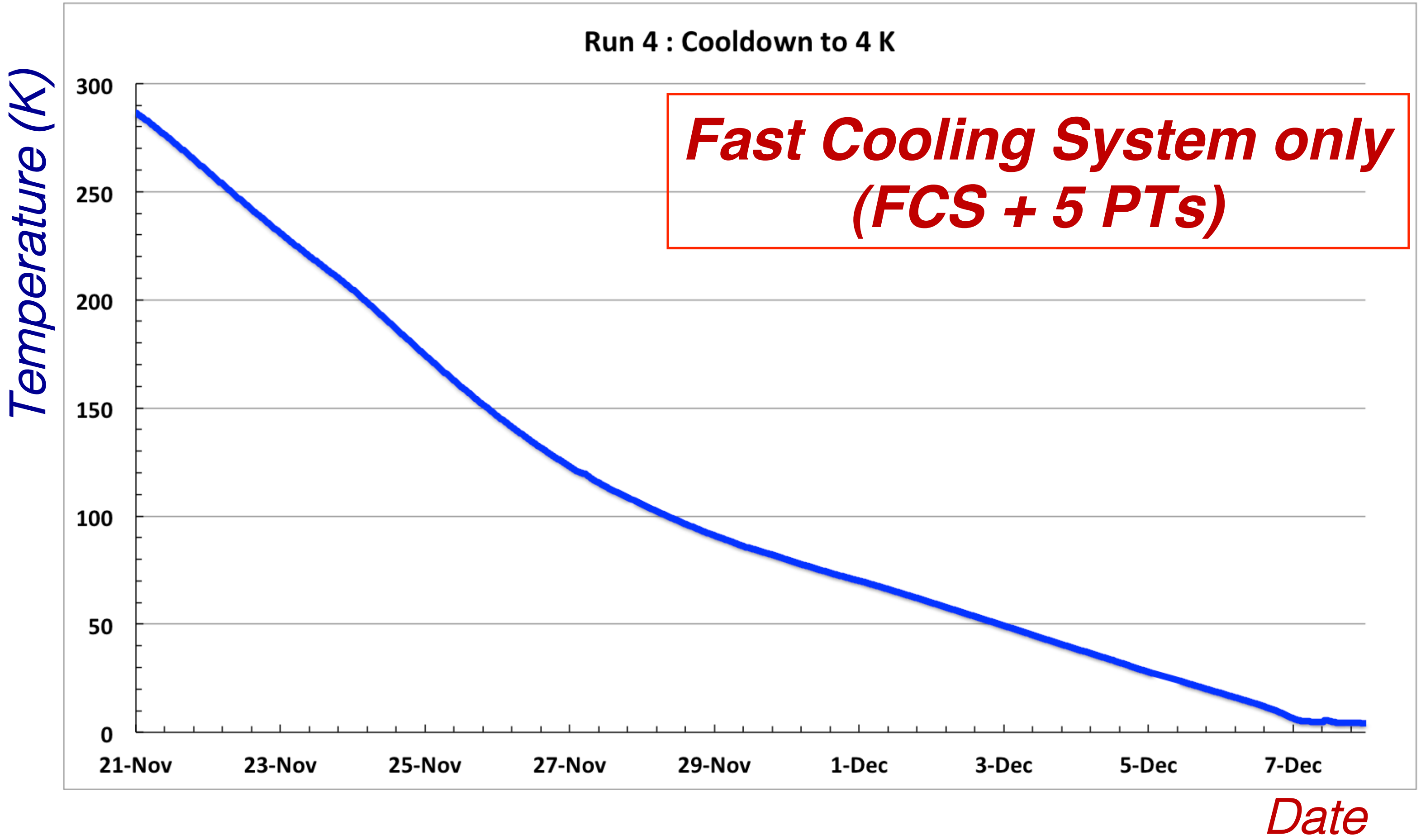
The CUORE collaboration at the INFN Gran Sasso National Laboratory has set a world record by cooling a copper vessel with the volume of a cubic meter to a temperature of 6 milliKelvins: it is the first experiment ever to cool a mass and a volume of this size to a temperature this close to absolute zero (0 Kelvin). The cooled copper mass, weighing approx. 400 kg, was the coldest cubic meter in the universe for over 15 days.

CUORE is an international collaboration involving some 130 scientists mainly from Italy, USA, China, Spain, and France. CUORE is supported by the Istituto Nazionale di Fisica Nucleare (INFN) in Italy; the Department of Energy Office of Science (Office of Nuclear Physics), the National Science Foundation, and Alfred P. Sloan Foundation in the United States.

No Top-Pb and Roman-Pb Shields at that time

Performances of CUORE Cryogenic Systems

CUORE Run 4 Preliminary



We cooled down **~ 14 tonnes** (Pb shielding + Cryostat copper flanges and vessels) to **4K in ~16 days**

Performances of CUORE Cryogenic Systems

(CUORE Run 4 Preliminary)

- ✓ *From 4 K to Base Temperature in* ***~ 1 day****;*
- ✓ *The I Base Temperature reached have been:* ***~11 mK****;*
- ✓ *After some adjustment we reached the II Base Temperature of* ***~ 6.3 mK****;*
- ✓ *The II Base Temperature of 6.3 mK has been kept stably along all Run 4 Tests for* ***more than 2 months****.*

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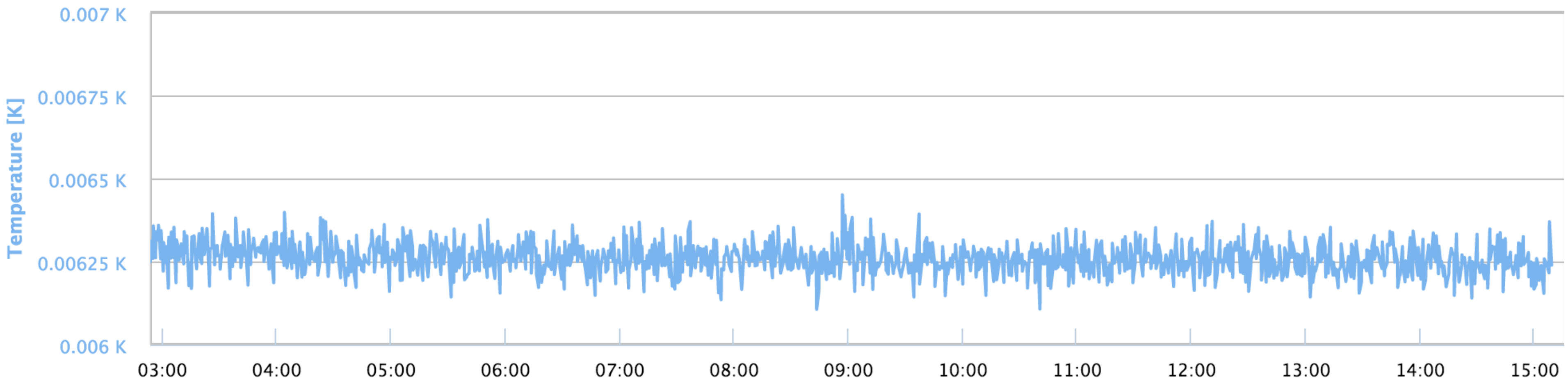
Performances of CUORE Cryogenic Systems

(CUORE Run 4 Preliminary)

Minimum Temperature reached: **(6.3 ± 0.2) mK** - **($M_T \approx$ 410 kg)**



We have proved that:

- ✓ *We are able to reach the Base Temperature with Roman-Pb Shields;*
- ✓ *The base temperature is Reproducible and Stable;*
- ✓ *The operating conditions can be sustained over a long period of time.*

Mini-Tower
Installation & Tests

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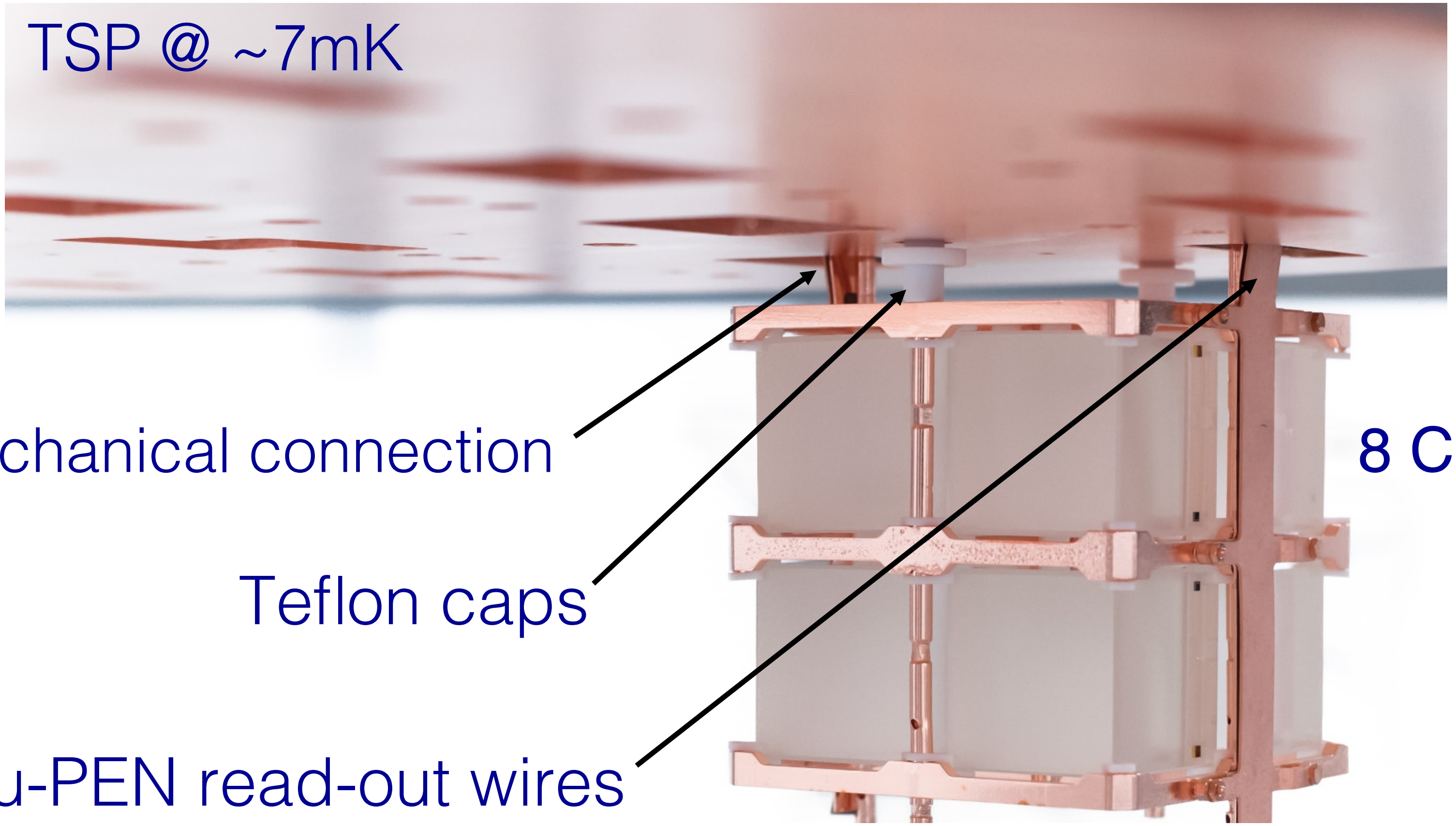
Run 4 Mini-Tower Setup

Goals:

- demonstrate detector performance
- study vibrational and thermal noise
- check detectors base temperature
- check background

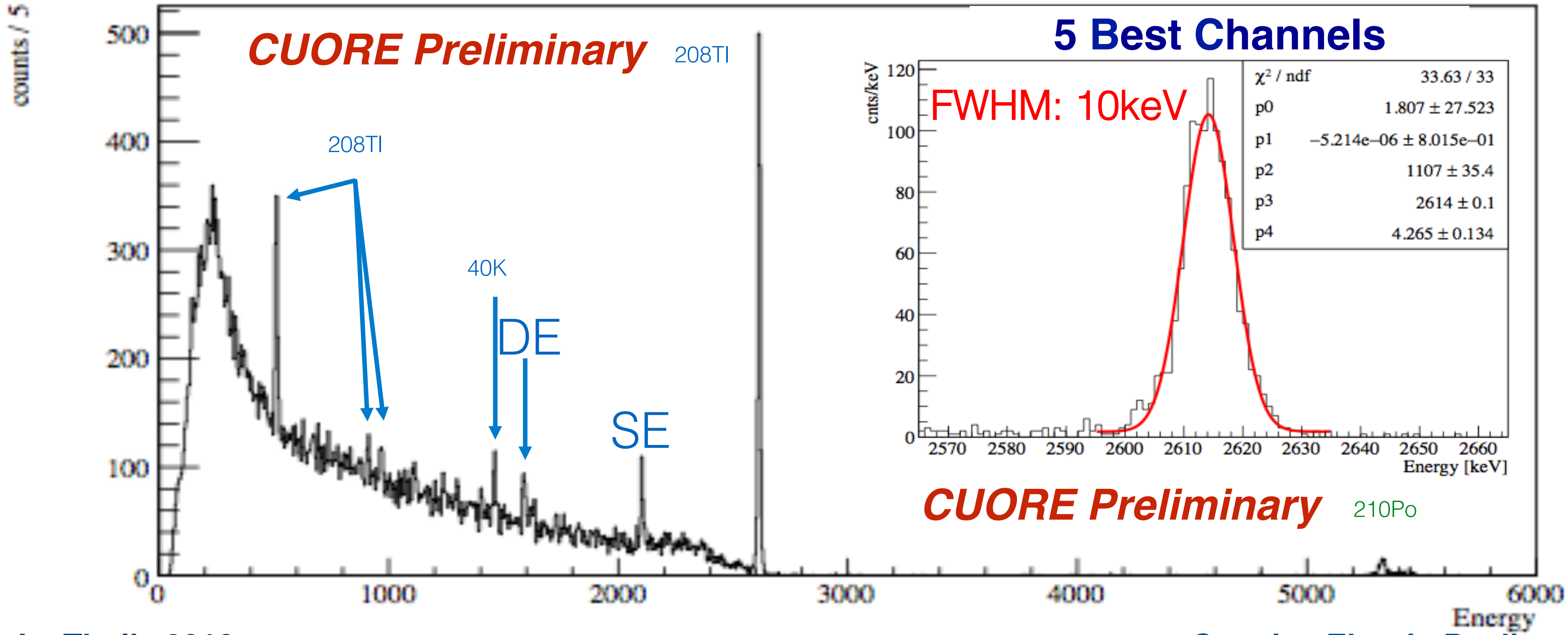
Need a detector as similar as possible to CUORE



Run 4 Mini-Tower Results

Total calibration spectrum with pulse shape cuts:

- Cryostat at Base Temperature;
- Minus-K suspensions active;
- Th source outside 300 K Vessel;
- ~ 45 h livetime;
- 8 out of 8 channels operational;
- 5 out of 8 channels have ***~10 keV*** *FWHM Resolution*.



CUORE Future Plans

- ✓ ***Assembling of Faraday Cage**: ~ March-April 2016*
- ✓ ***DAQ & Electronics**: ~ March-May 2016*
- ✓ ***CR6 (CUORE Tower Assembling Clean Room)**: ~ May 2016*
- ✓ ***New FCS** (Cleaning and Assembling): ~ March-May 2016*
- ✓ ***Detector Installation**: ~ May-June 2016*
- ✓ ***Run I Cool-down**: ~ July-August 2016*
- ✓ ***Tests & Optimization**: ~ September 2016*
- ✓ ***Data Taking (1th CUORE Physics Run)**: by the end of 2016*

Latest Results from CUORE-0

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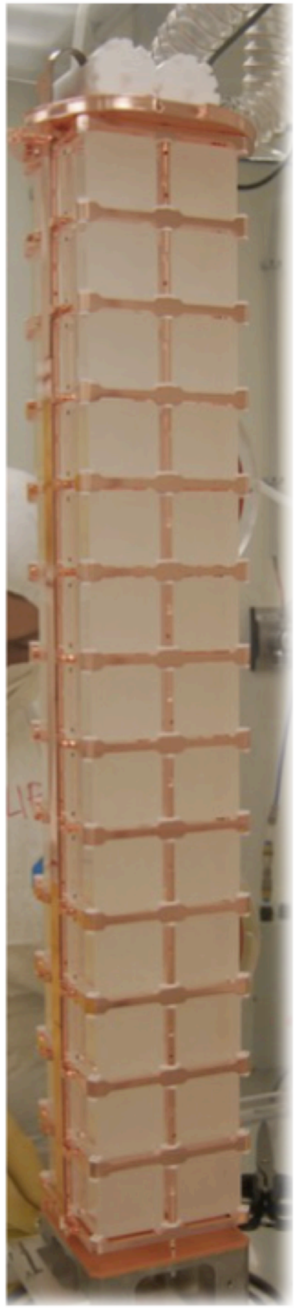
CUORE-0

CUORE-0 is the first tower produced out of the CUORE assembly line.

- 52 TeO_2 5x5x5 cm^3 crystals (~750 g each)
- 13 floors of 4 crystals each
- total detector mass: 39 kg TeO_2 (10.9 kg of ^{130}Te)

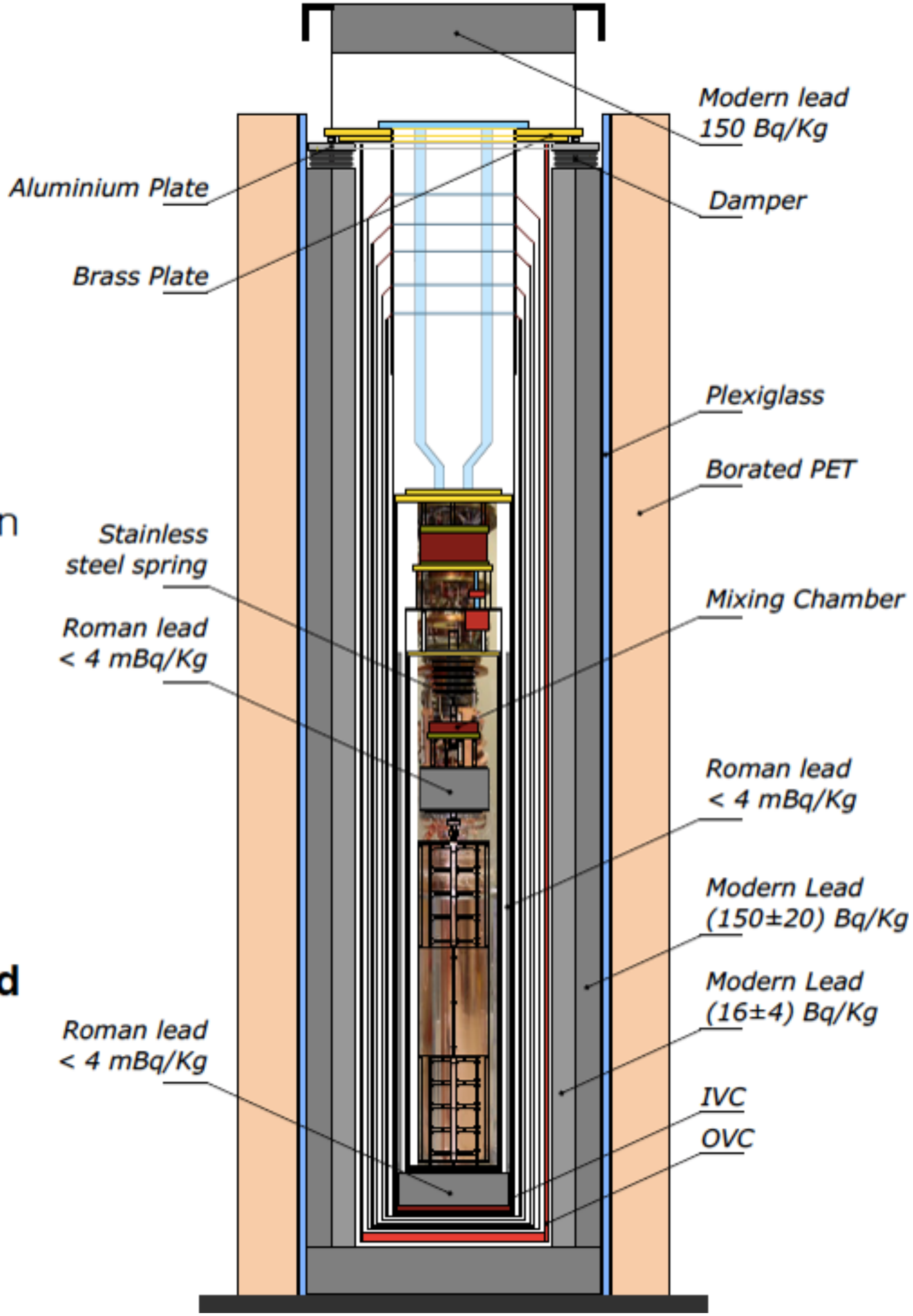
CUORE-0 has been taking data since March 2013 in the 25 year old Cuoricino cryostat.

- Proof of concept of CUORE detector in all stages
- Test and debug of the CUORE tower assembly line
- Test of the CUORE DAQ and analysis framework
- Extend the physics reach beyond Cuoricino while CUORE is being assembled

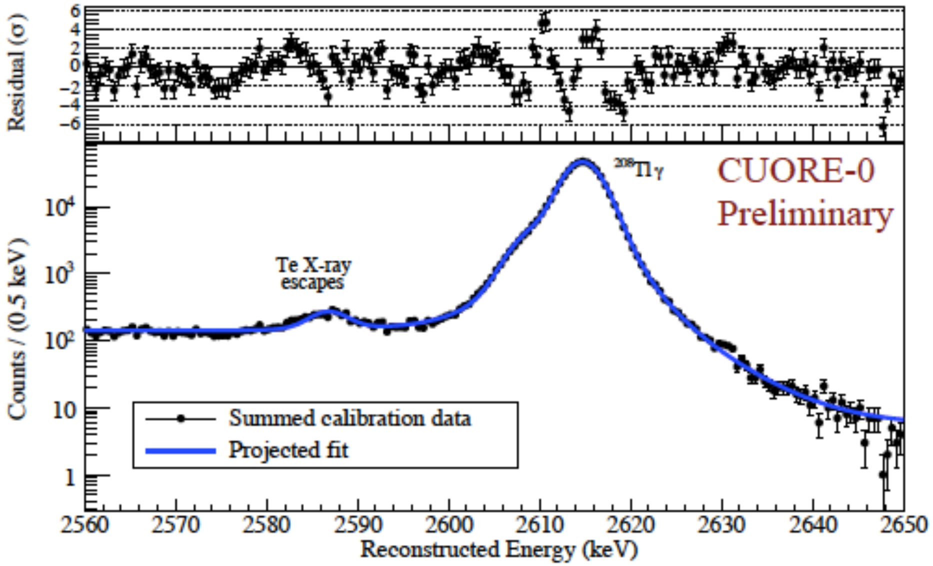


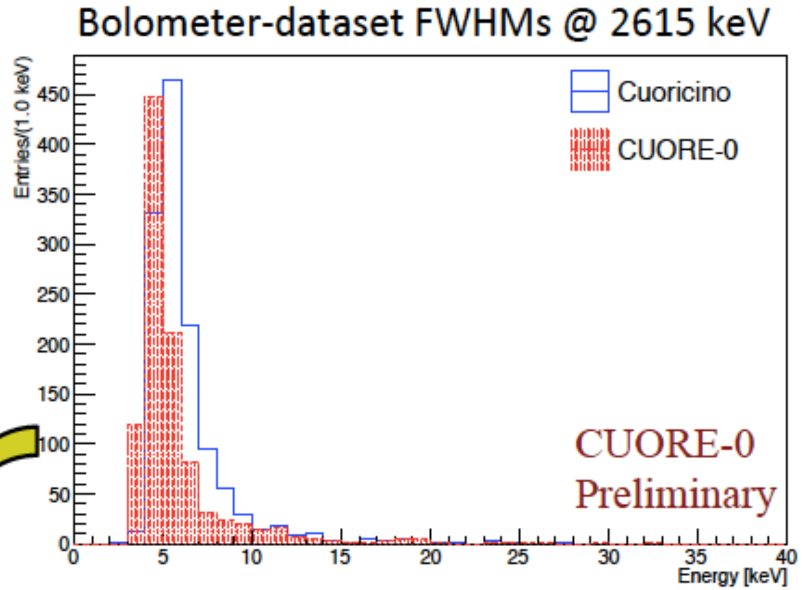
Experimental Setup

- Same cryostat as Cuoricino:
  - inner shield: 1 cm of Roman Lead (A < 4 mBq/kg).
  - External shield: 20 cm of Modern Lead.
  - nitrogen flushing
- **gamma background from cryostat shields not expected to change** (test of alpha background)



Energy Resolution



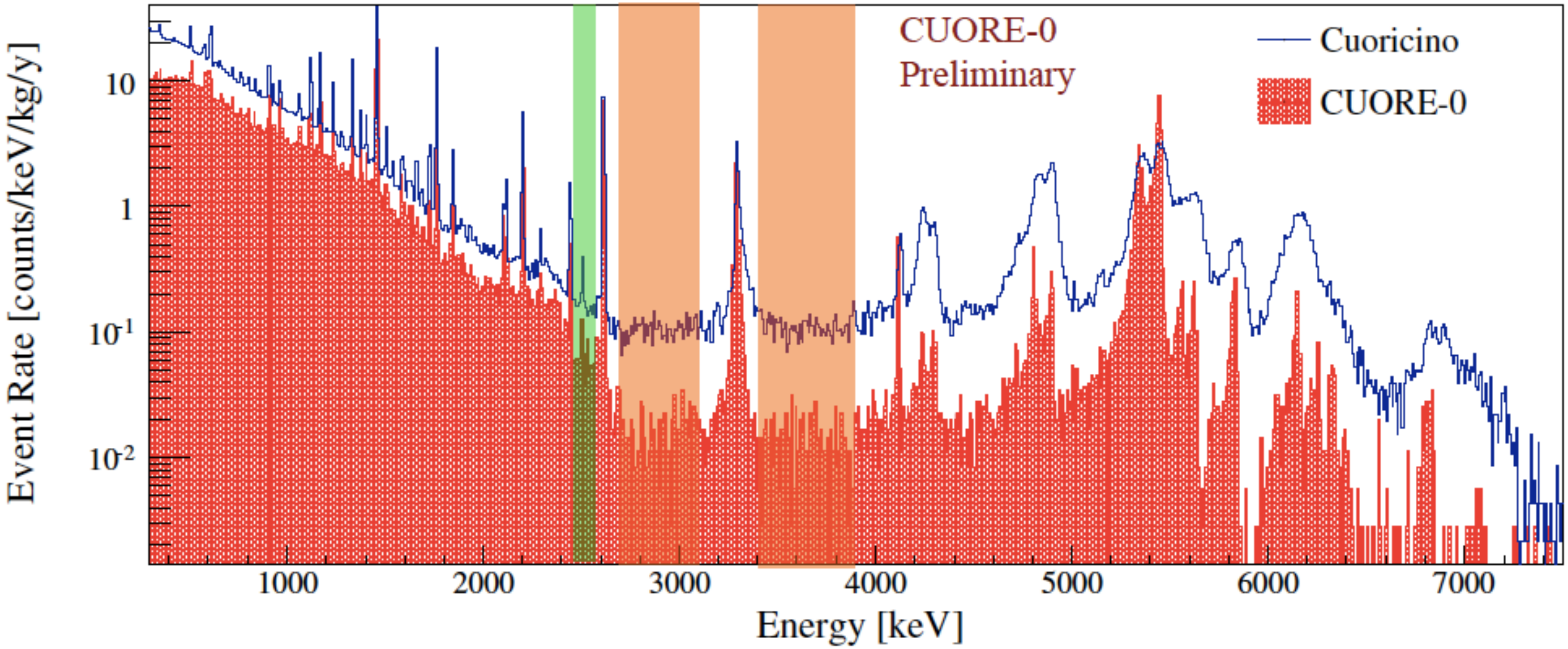


Weight FWHMs by corresponding physics exposure

	FWHM harmonic mean (keV)	FWHM dist RMS (keV)
Cuoricino	5.8	2.1
CUORE-0	4.9	2.9

- We evaluate the energy resolution for each bolometer and dataset by fitting the ^{208}Tl photopeak in the calibration data
- We achieved the 5 keV resolution goal of CUORE!

Background Reduction

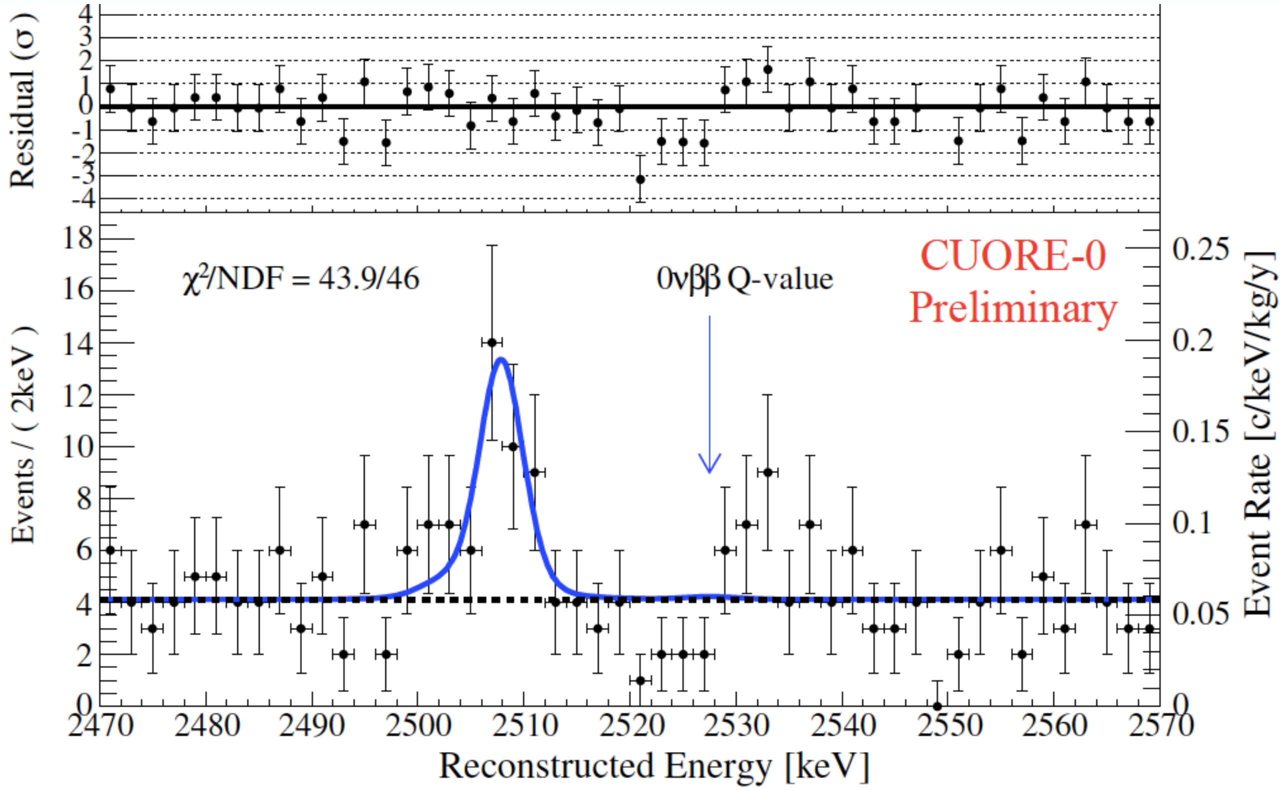


Experiment	Background rate (counts/keV/kg/y)	
	$0\nu\beta\beta$ decay region	Alpha region (excl. peak)
Cuoricino	0.169 ± 0.006	0.110 ± 0.001
CUORE-0	0.058 ± 0.004	0.016 ± 0.001

Results from CUORE-0

Fitted background: 0.058 ± 0.004 (stat.) ± 0.002 (syst.) counts/keV/kg/yr

Best-fit decay rate: $\Gamma^{0\nu\beta\beta}(^{130}Te) = 0.007 \pm 0.123$ (stat.) ± 0.012 (syst.) $\times 10^{-24}$ yr^{-1}



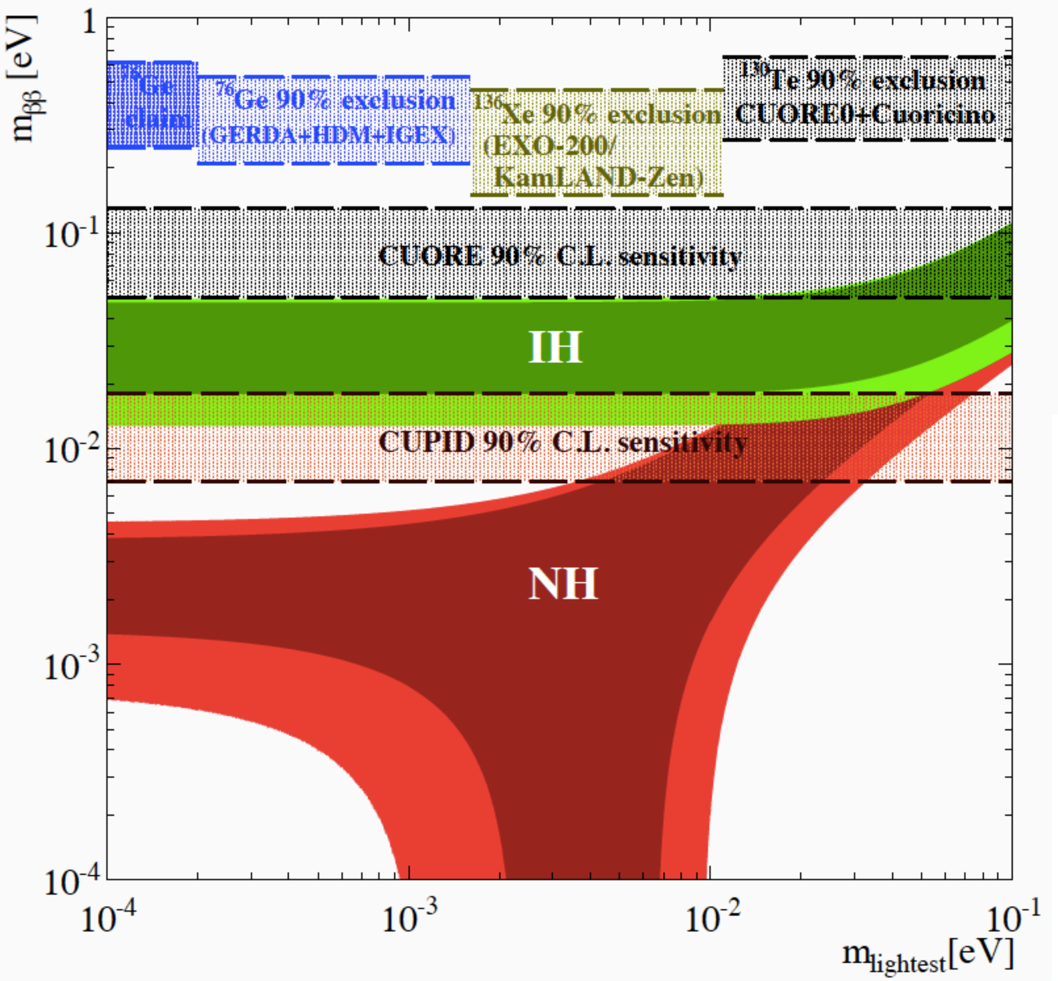
CUORE-0 90% C.L. lower limit from profile likelihood:

$$T^{0\nu}_{1/2} > 2.7 \cdot 10^{24}\, yr$$

CUORE-0 results combined with the existing 19.75 kg· yr of ^{130}Te exposure from Cuoricino

$$T^{0\nu}_{1/2} > 4.0 \cdot 10^{24}\, yr$$

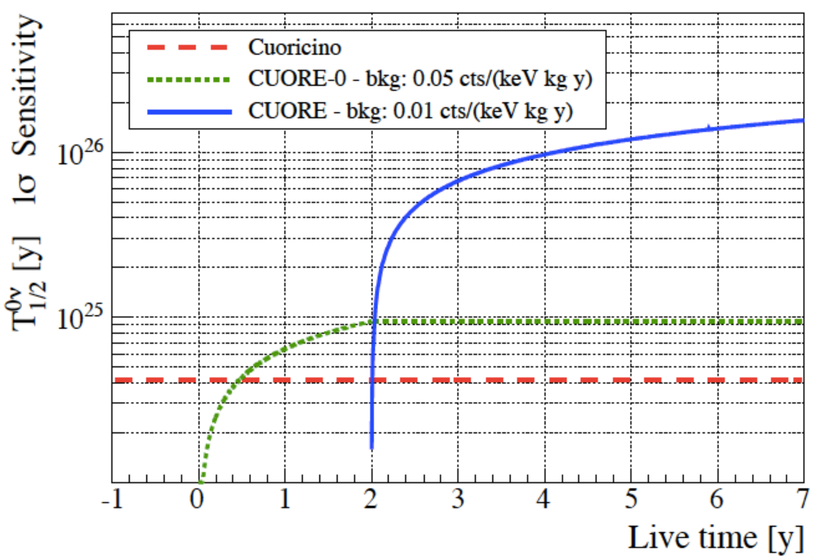
CUORE Expected Sensitivity



5-year Sensitivity:

$T_{1/2}(^{130}Te) > 9.5 \times 10^{25}$ years;

$M_{\beta\beta} < 52\text{-}120$ MeV



Carmine Elvezio Pagliarone

Status of CUORE Experiment and Latest Results from CUORE-0

- ✓ We released the first CUORE-0 results, which are very encouraging in view of CUORE:
  - Characteristic energy resolution: 4.9 keV
  - α background 7 times smaller than CUORICINO

- ✓ CUORE-0 provides the best word limit on neutrino-less double beta decay in ^{130}Te
  - $T_{0\nu} > 2.7 \times 10^{24}$ y (standalone)
  - $T_{0\nu} > 4.0 \times 10^{24}$ y (combined CUORE-0+CUORICINO)

- ✓ The construction of CUORE is close to the end:
  - All 19 detector towers built and ready to be installed
  - Cryostat reached 6 mK in commissioning runs
  - Full integration runs are ongoing

✓ **1^{th} CUORE Data Taking (Physics) Run by the end of 2016**

UCLA

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Massachusetts Institute of Technology

UNIVERSITY OF SOUTH CAROLINA

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THE UNIVERSITY OF CALIFORNIA 1868 LET THERE BE LIGHT

BERKELEY LAB

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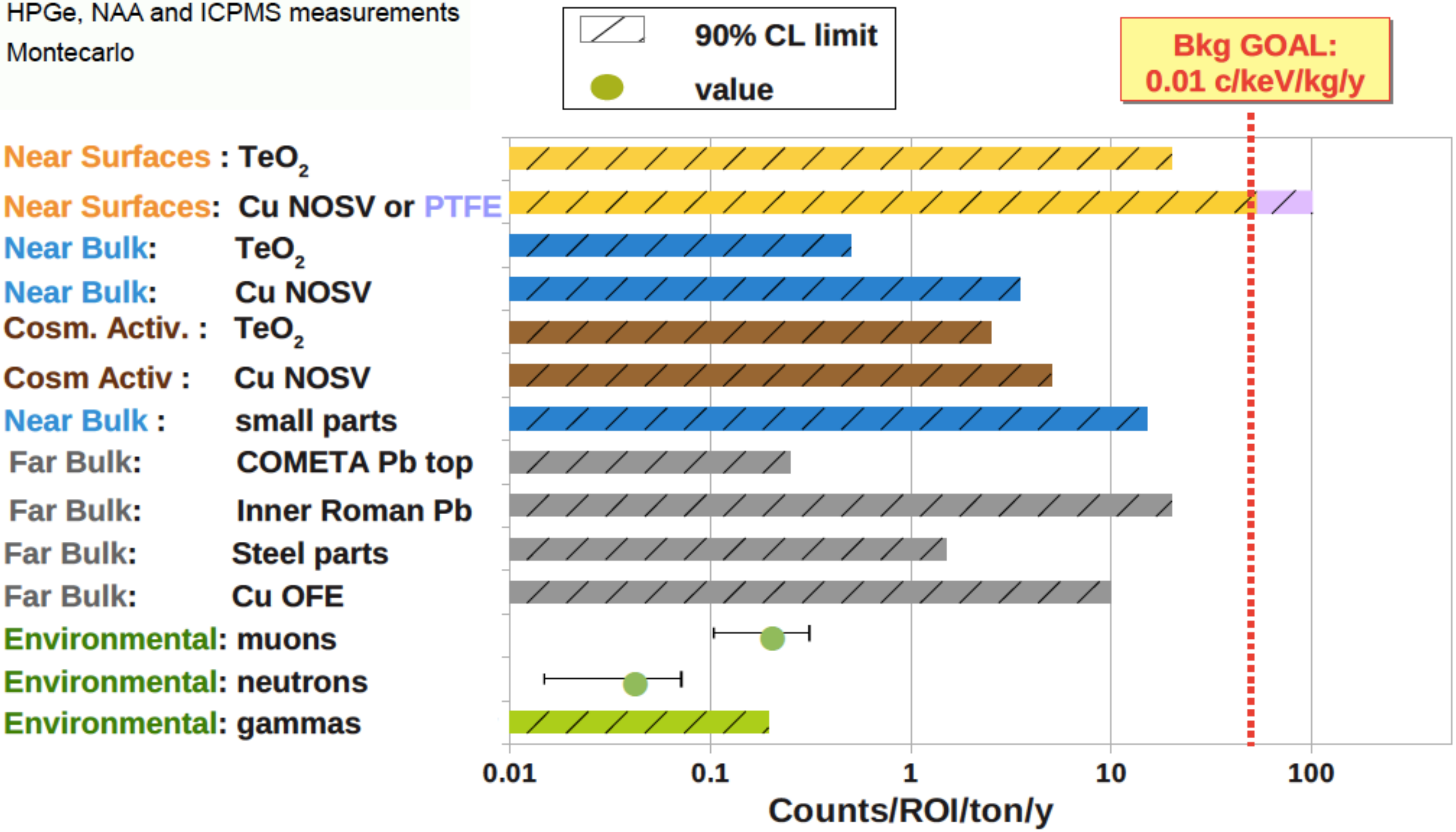
CUORE

THANK YOU !

CUORE background budget

Based on

- Cuoricino & CUORE-0 data
- HPGe, NAA and ICPMS measurements
- Montecarlo

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