Progress and Plans of CUORE

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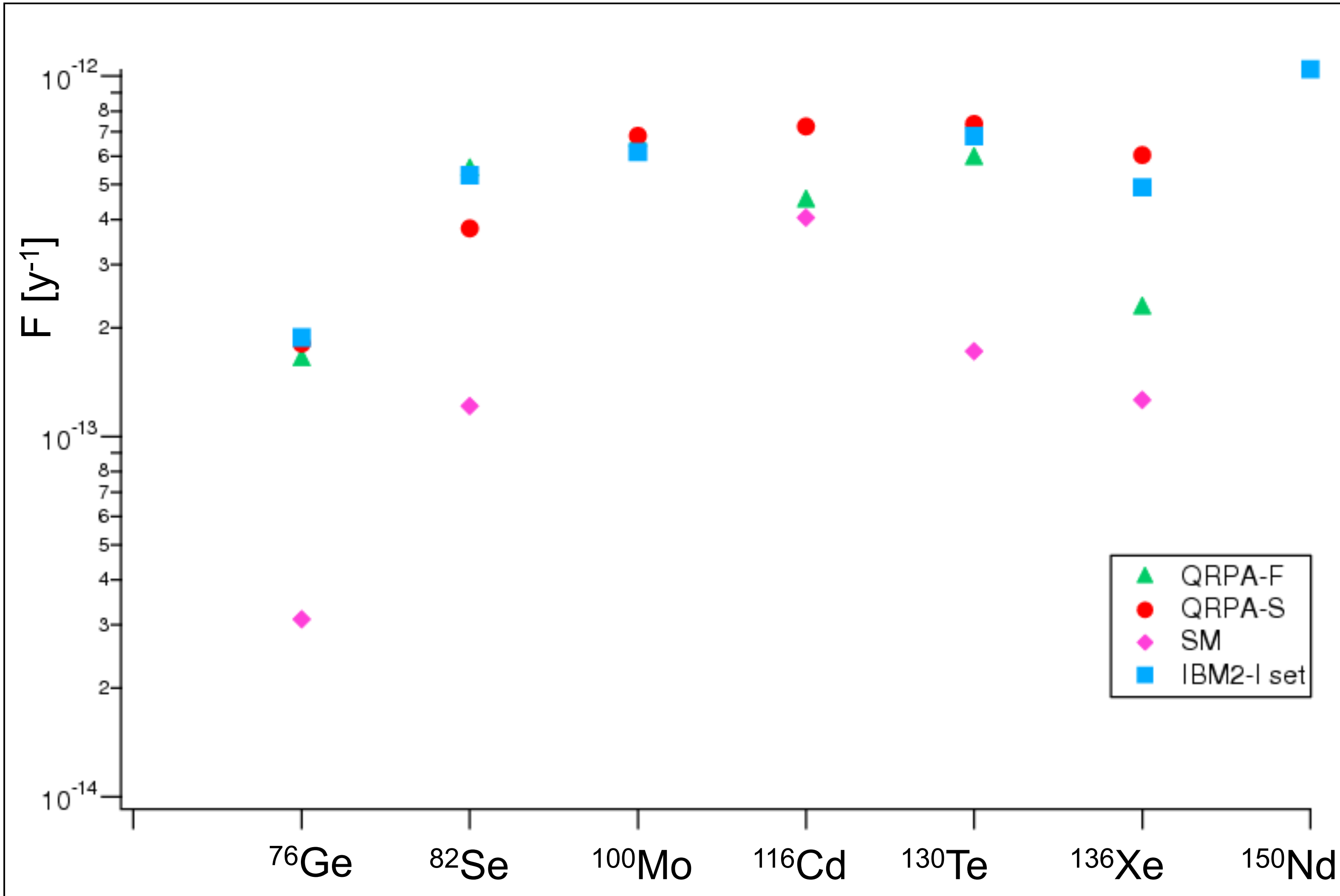
0νββ Isotopes: Figure of Merit

$F = G_F^2 \Phi(Q,Z) |M_{0\nu}|^2 m_e^2$ [y^{-1}] (Want as high as possible)



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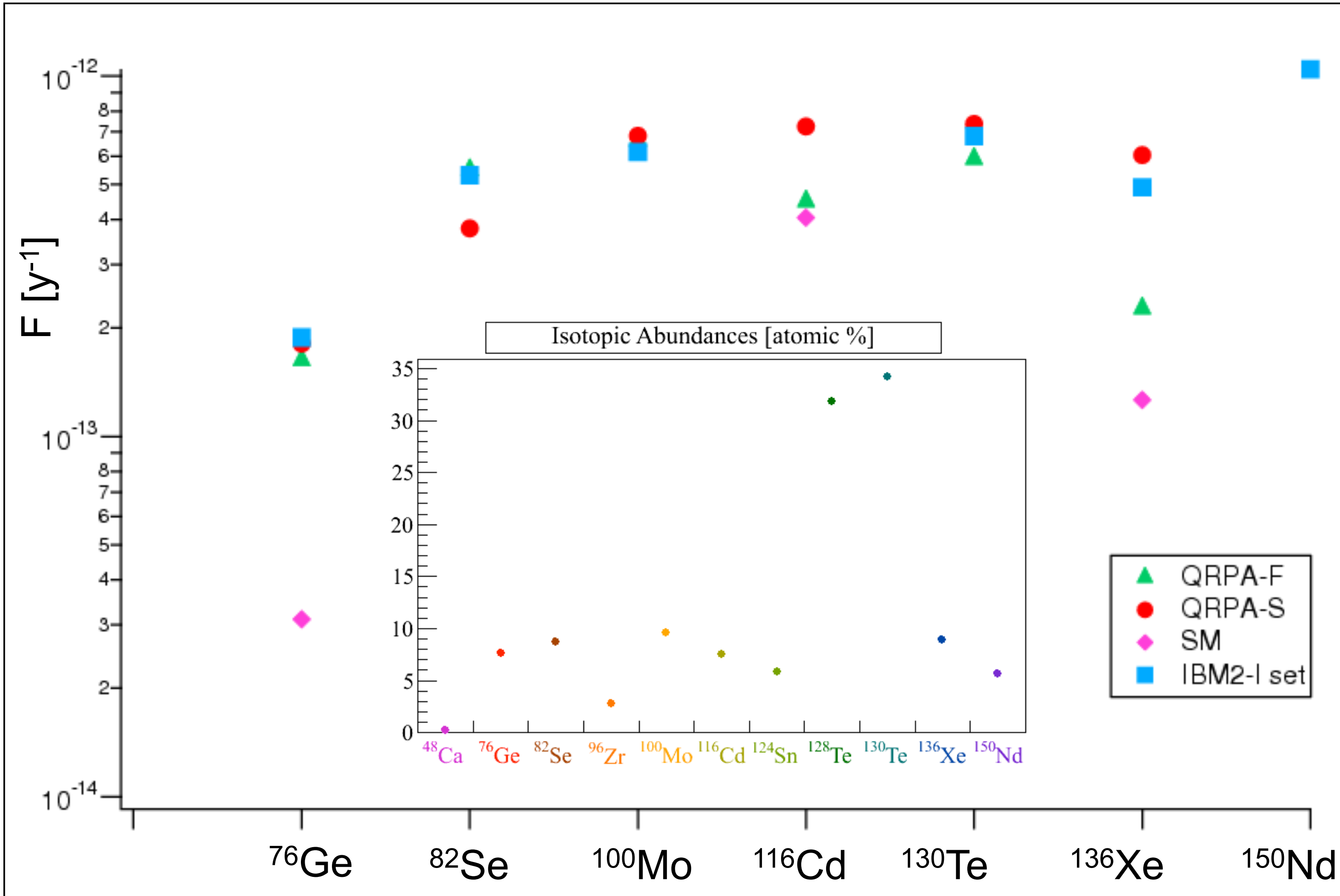


Experimental Sensitivity

Standard sensitivity for a counting analysis (nonzero background):

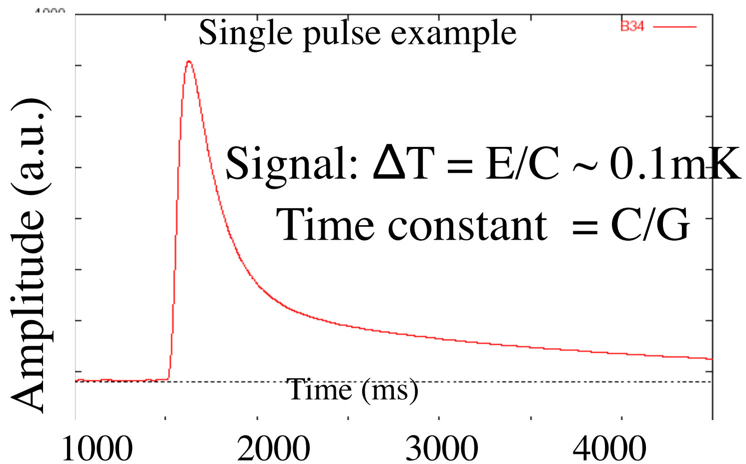
$$T^{0\nu}_{1/2}(n_\sigma) = \frac{4.17\times 10^{26}}{n_\sigma}\left(\frac{a\varepsilon}{W}\right)\sqrt{\frac{Mt}{(1+\zeta)b\delta(E)}}$$

Efficiency
Detector mass (kg)
Isotopic abundance
Exposure time (y)
Desired sensitivity in σ
ROI (keV)
Atomic weight
SNR (assume 0)
Background (c/kg/y/keV)

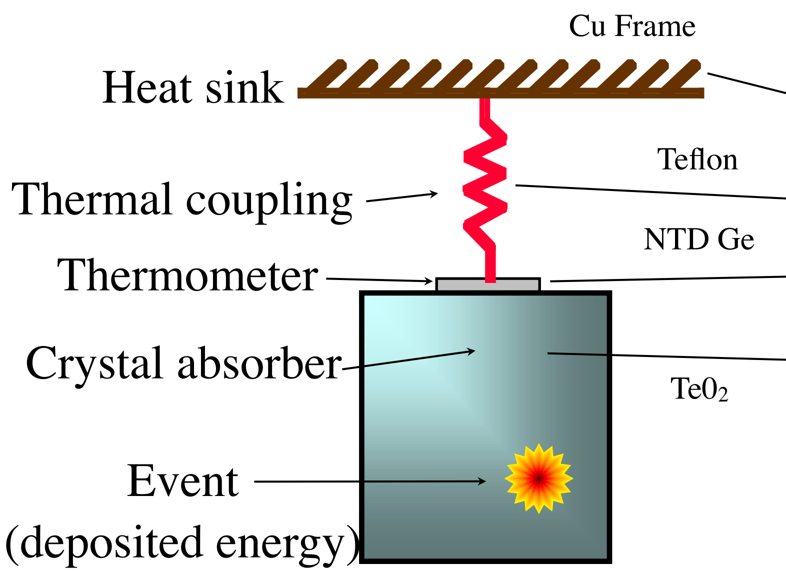
Experimental challenge:

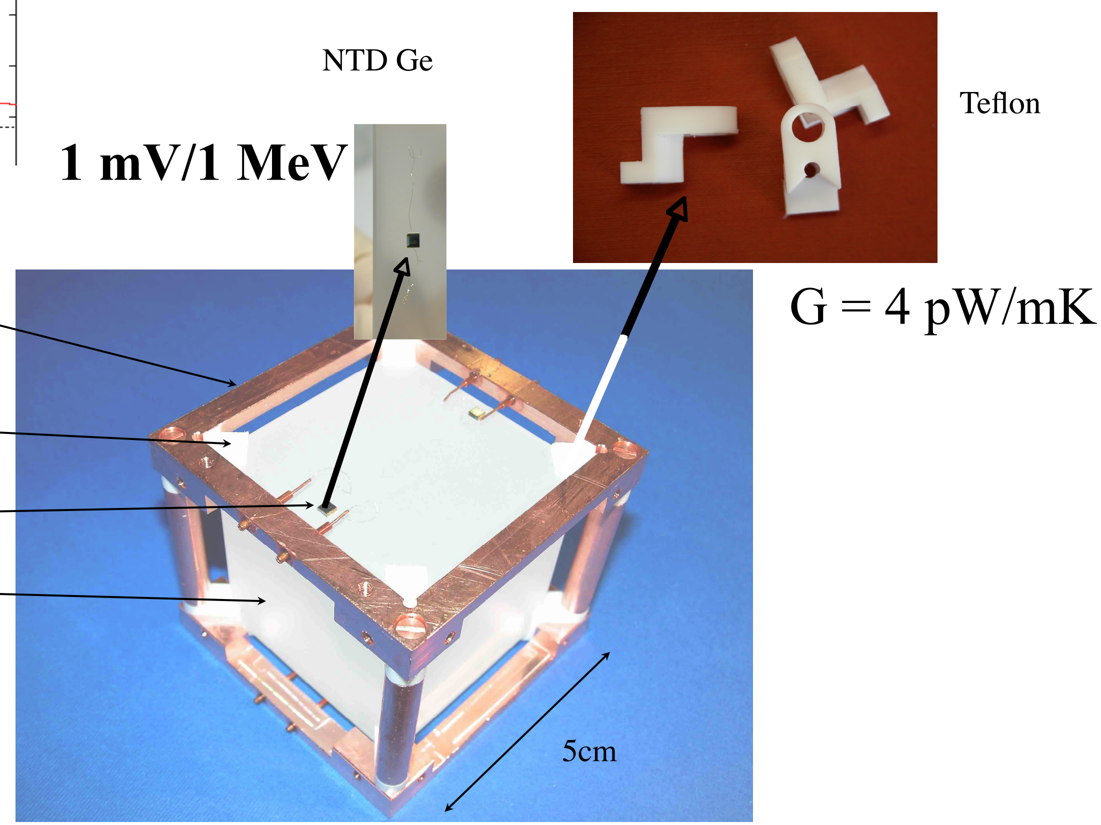
- ✓ Increase *M* as high as possible (200-1000 kg for current experiments): $$, R&D
- ✓ Increase *a*: $$
- ✓ Decrease *b* as much as possible (to 2νββ limit): radio purity, active rejection
- ✓ Decrease δ (highest resolution possible): technology choice

Cryogenic Bolometers

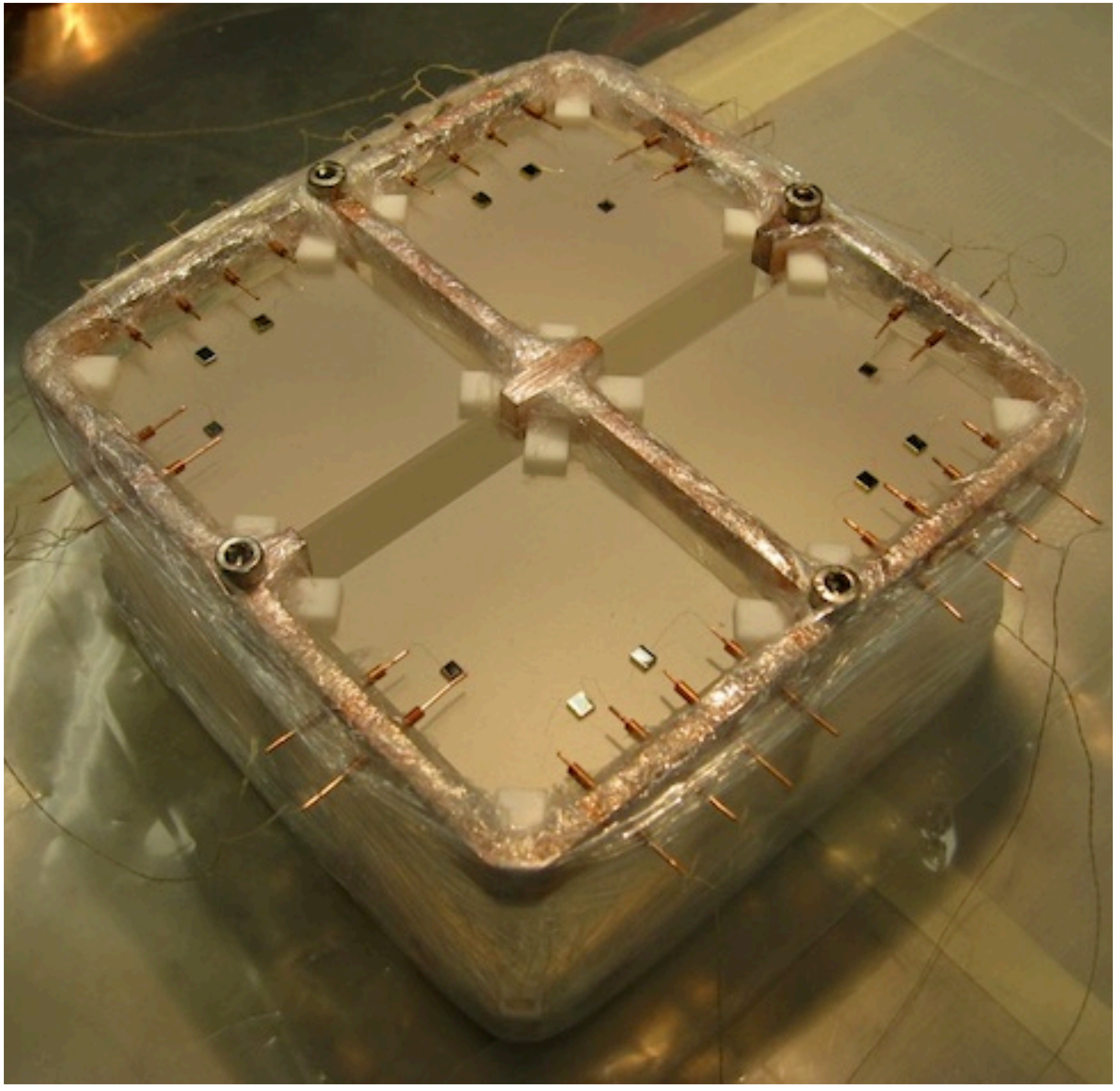


- Dielectric diamagnetic materials
- Low temperatures (~10mK)
- Low heat capacity
  - C~2 nJ/K = 1 MeV / 0.1 mK

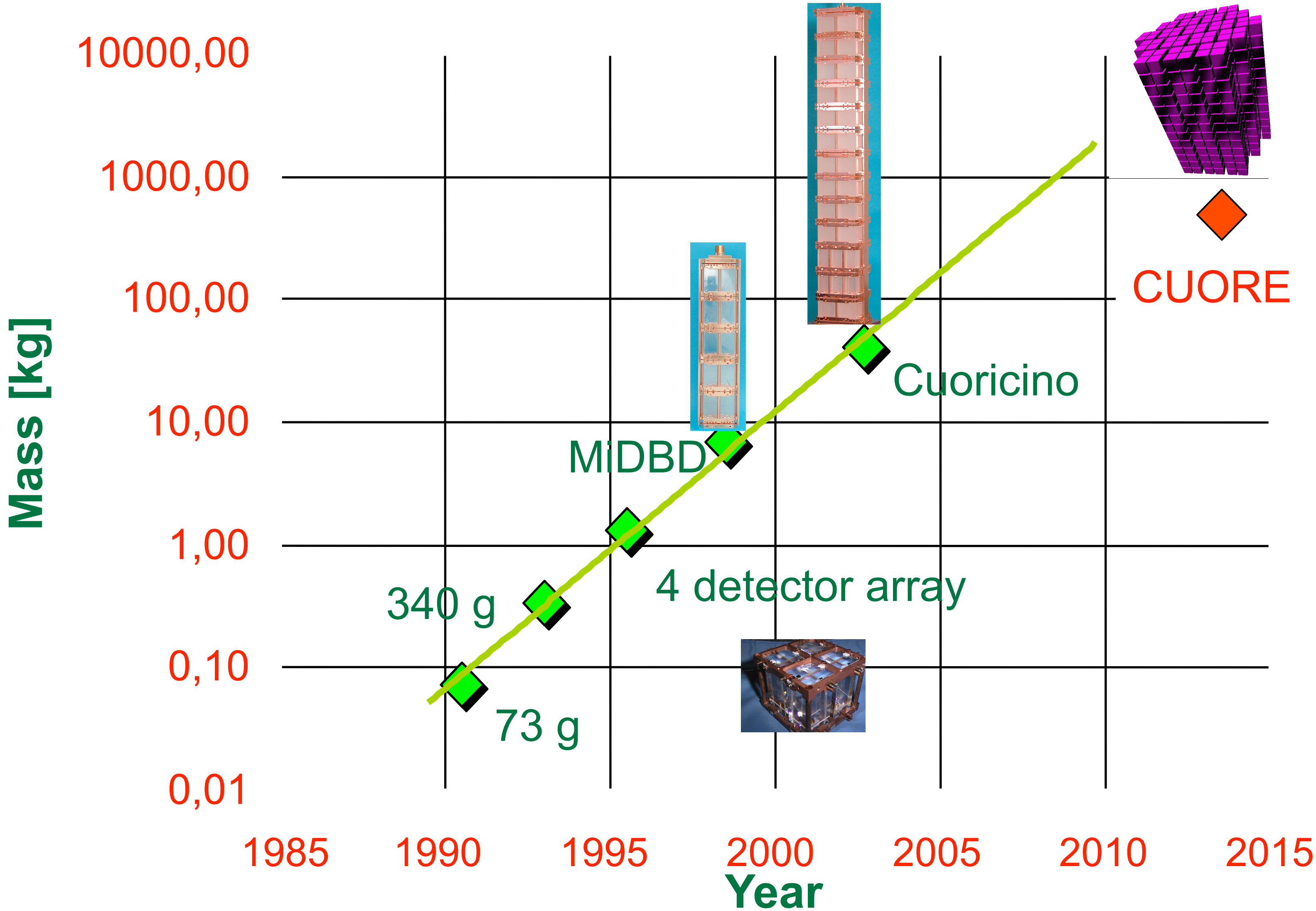




TeO_2 Bolometers



TeO_2 Experiments



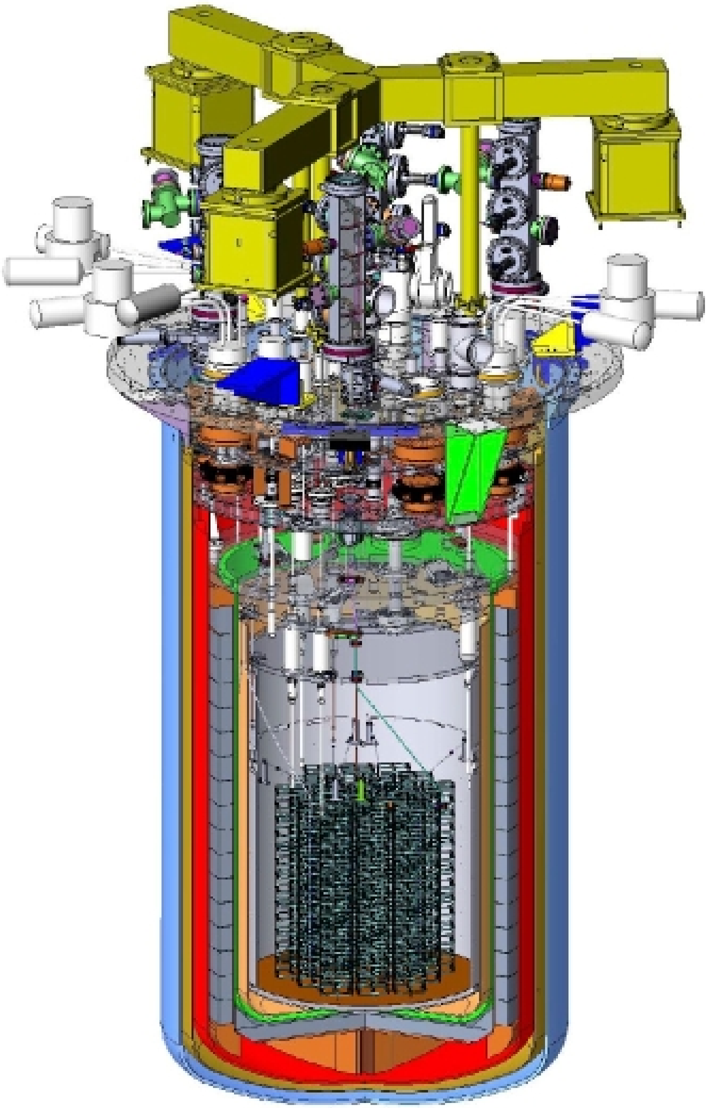
CUORE

Array of 988 TeO_2 crystals

- **19** towers suspended in a cylindrical structure
- **13** levels, **4** crystals each
- 5x5x5 cm^3 (750g each)
- ^{130}Te: 33.8% natural isotope abundance

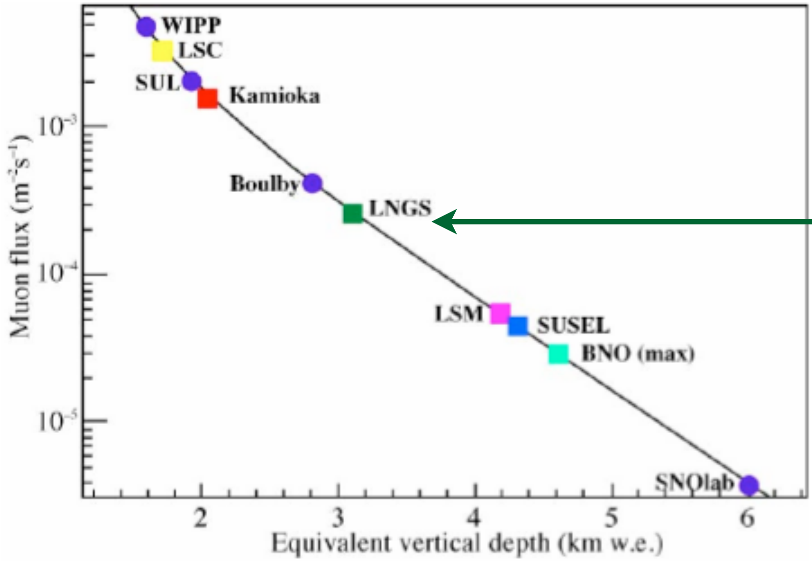
750 kg TeO_2 => 200 kg ^{130}Te

- New pulse tube refrigerator and cryostat
- Radio-purity techniques and high resolution achieve low backgrounds
- Joint venture between Italy (INFN) and US (DOE, NSF)
- Under construction (expected start of operations by end of 2014)
- Expect energy resolution of 5 keV FWHM and background of ~0.01 counts/(kg*keV*year) in ROI

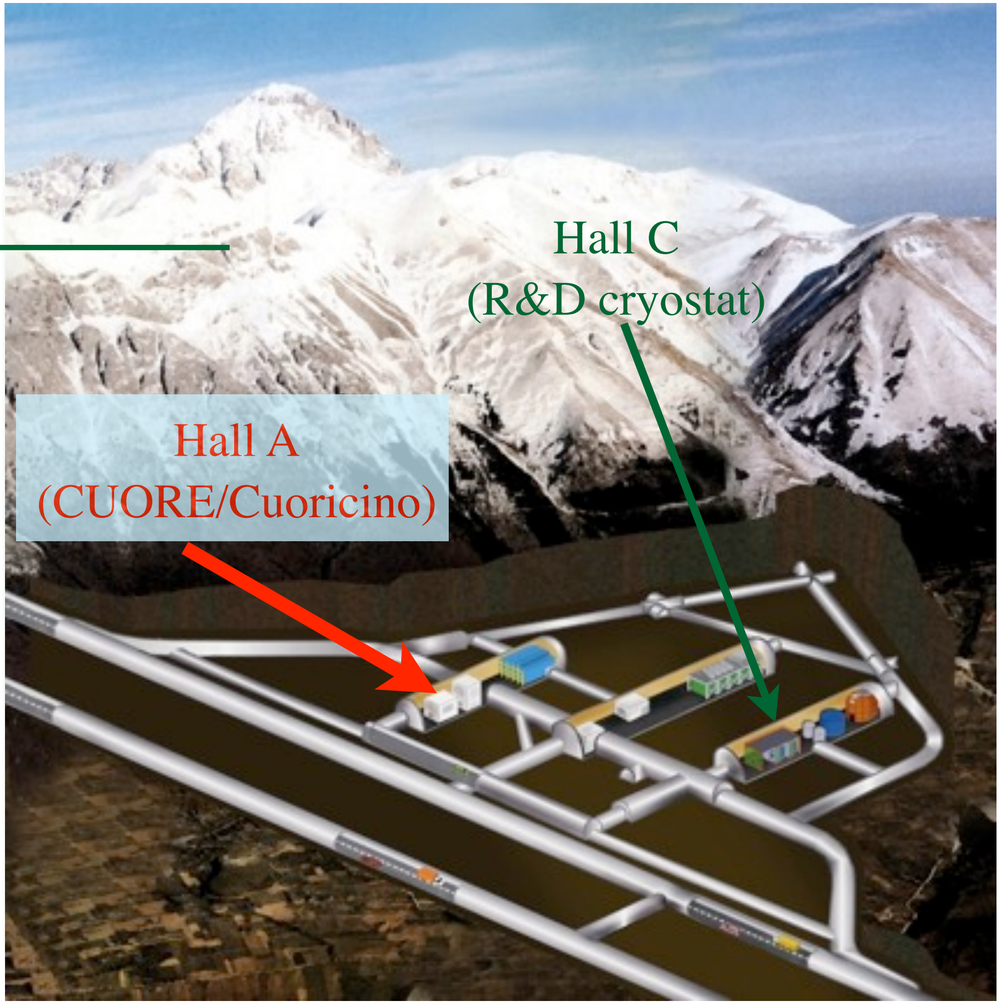


The CUORE Collaboration

Gran Sasso Laboratory

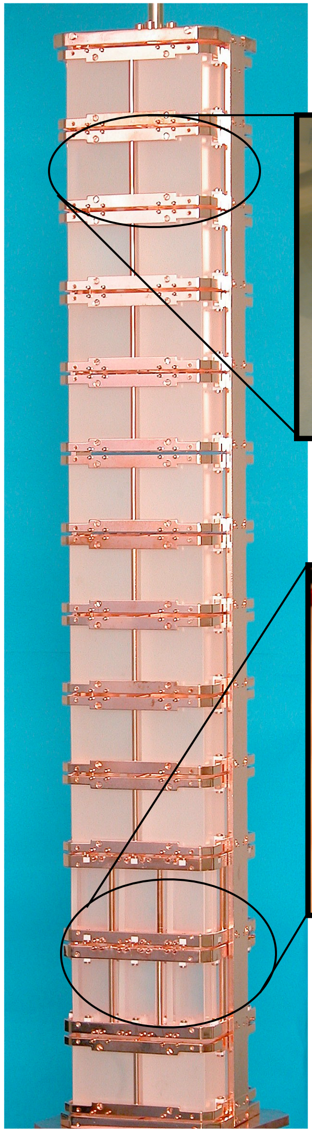


Shielding: ~3650 m.w.e.
Muons: ~2 x 10^{-8}/cm^2-s
Thermal neutrons: ~1 x 10^{-6}/cm^2-s
Epithermal neutrons: ~2 x 10^{-6}/cm^2-s
> 2.5 MeV Neutrons: 2 x 10^{-7}/cm^2-s



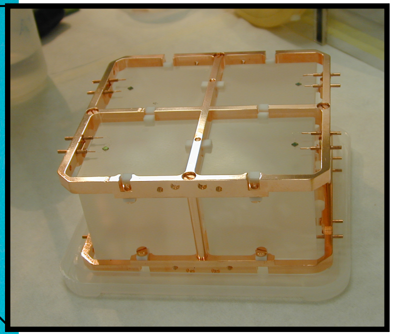
CUORE under construction in Hall A

Cuoricino, the prototype for CUORE



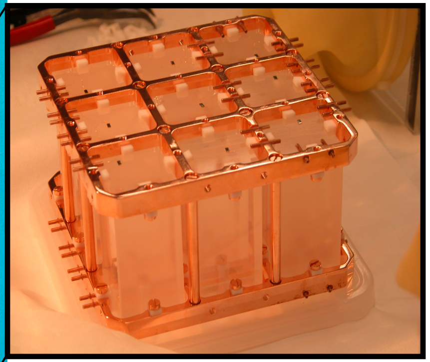
Gran Sasso National Lab (Italy)

Bolometer detectors
Cooled to 10mK



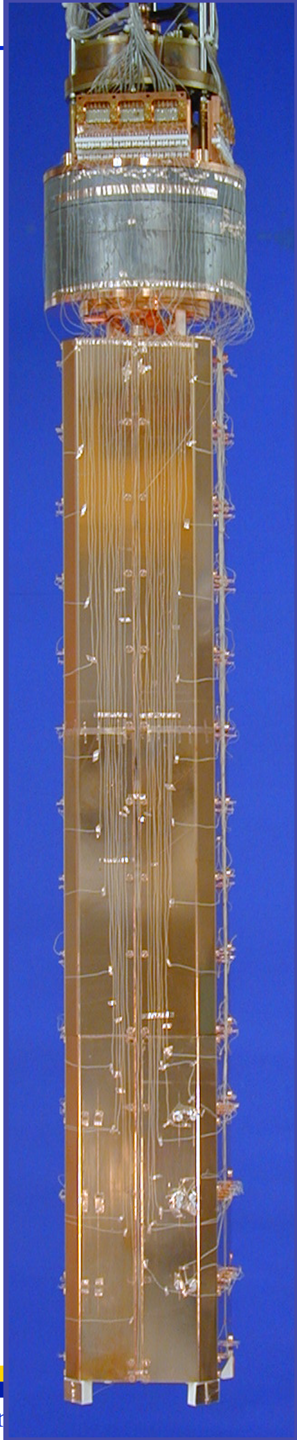
11 modules, 4 detector each,
crystal dimension: 5x5x5 cm^3
crystal mass: 790 g
44 x 0.79 = 34.76 kg of TeO_2

Encased in a cryostat, lead shield, nitrogen box, neutron shield, and Faraday cage



2 modules x 9 crystals each
crystal dimension: 3x3x6 cm^3
crystal mass: 330 g
18 x 0.33 = 5.94 kg of TeO_2

Total detector mass: 40.7 kg TeO_2 ⇒ **11.34 kg ^{130}Te**

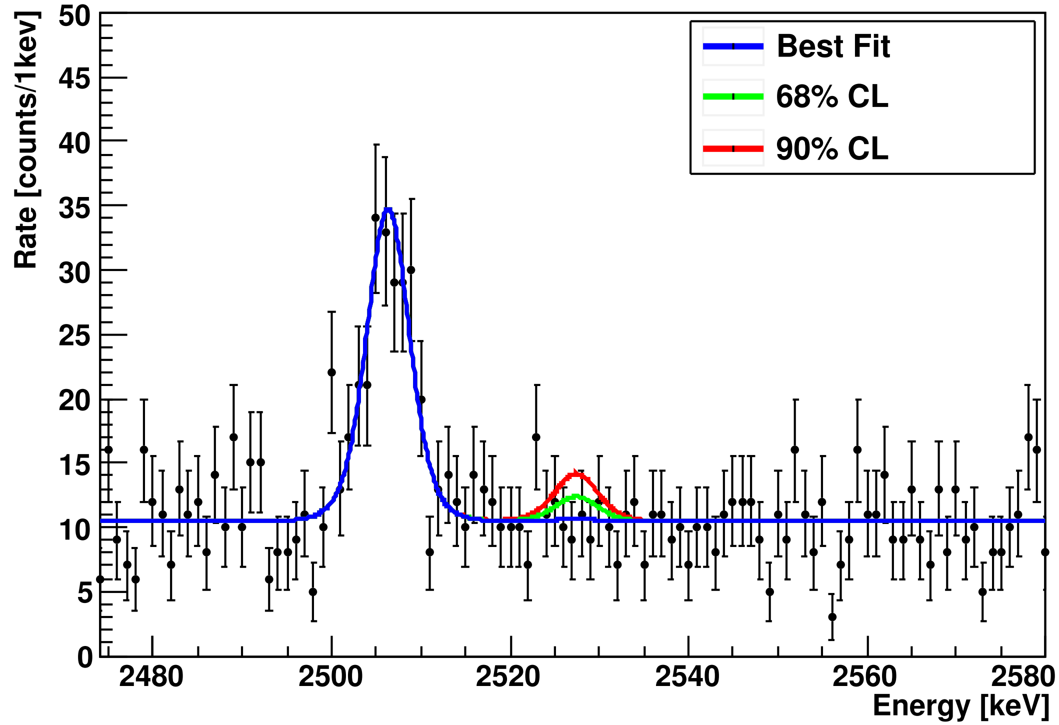


Cuoricino Results (2010)

Exposure
= 19.6 kg y

Resolution:
FWHM at 2615 keV ~7 keV

Background:
In the ββ0ν region (large crystals)
= 0.153 ± 0.006 counts /(keV kg y)



E. Andreotti et al., Astr. Phys. **34**, 822 (2011)

No peak found

$\tau^{0\nu}_{1/2} > 2.8\times10^{24}$ y at 90% C.L.

$m_{\beta\beta} < 0.3 - 0.7$ eV

Spread is due to a range of published matrix elements

From Cuoricino to CUORE

Standard sensitivity for a counting analysis:

Efficiency Detector mass (kg)

Isotopic abundance

Exposure time (y)

$$T_{1/2}^{0\nu}(n_\sigma) = \frac{4.17\times 10^{26}}{n_\sigma}\left(\frac{a\varepsilon}{W}\right)\sqrt{\frac{Mt}{(1+\zeta)b\delta(E)}}$$

Desired sensitivity

ROI (keV)

Atomic weight SNR Background (c/kg/y/keV)

Cuoricino to CUORE:

- ✓ Increase *M* by a factor of 19
- ✓ Decrease *b* by a factor of 18
- ✓ Decrease δ by 40%
- ✓ Improve livetime (increase *t*)

Background Reduction

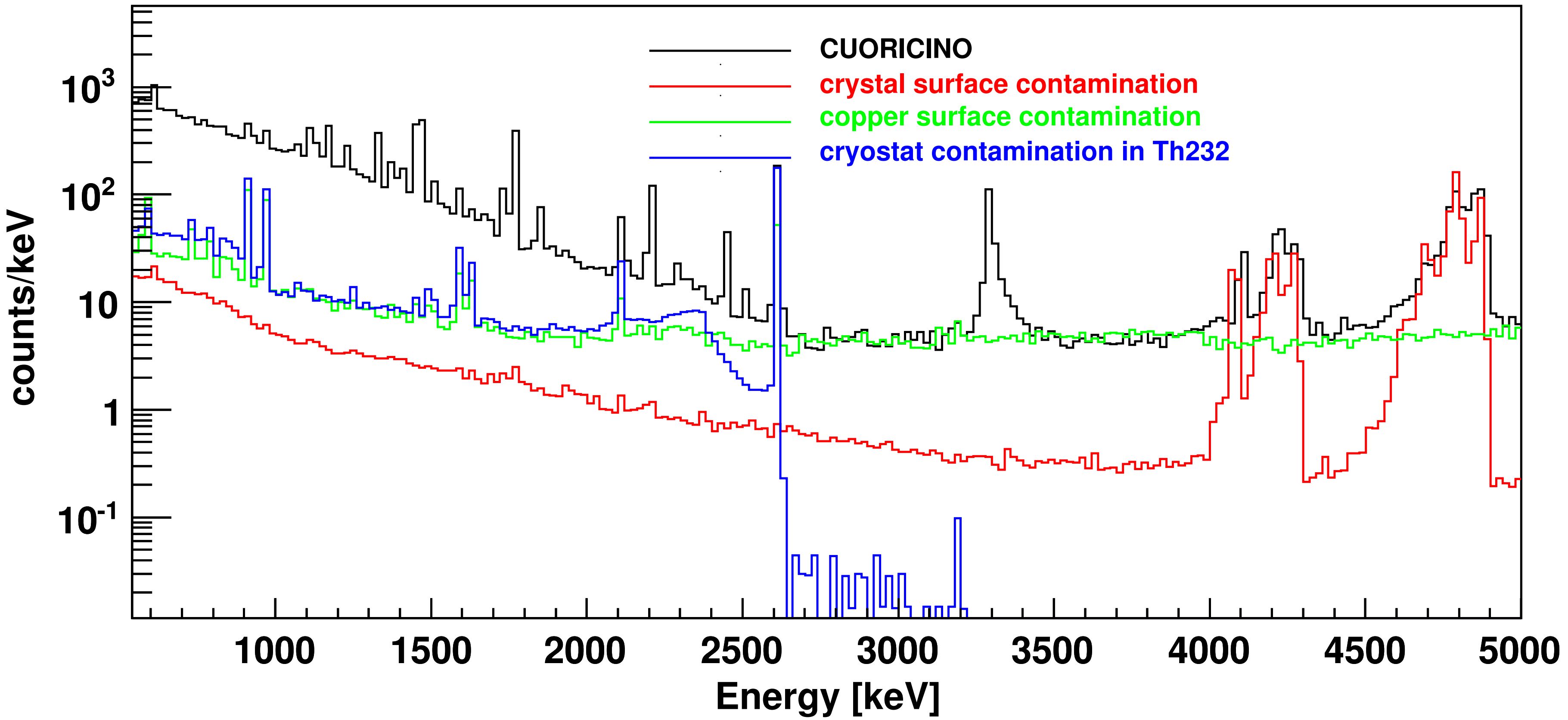
Background model: CUORICINO

- (40±10)% in ββ0ν region from ^{208}Tl at 2615 keV
- α and β from inert material facing detector (e.g. Cu): (50±20)%
- α and β from surface contamination of crystals: (10±5)%
- Negligible contributions from neutrons and ^{60}Co at 2505 keV

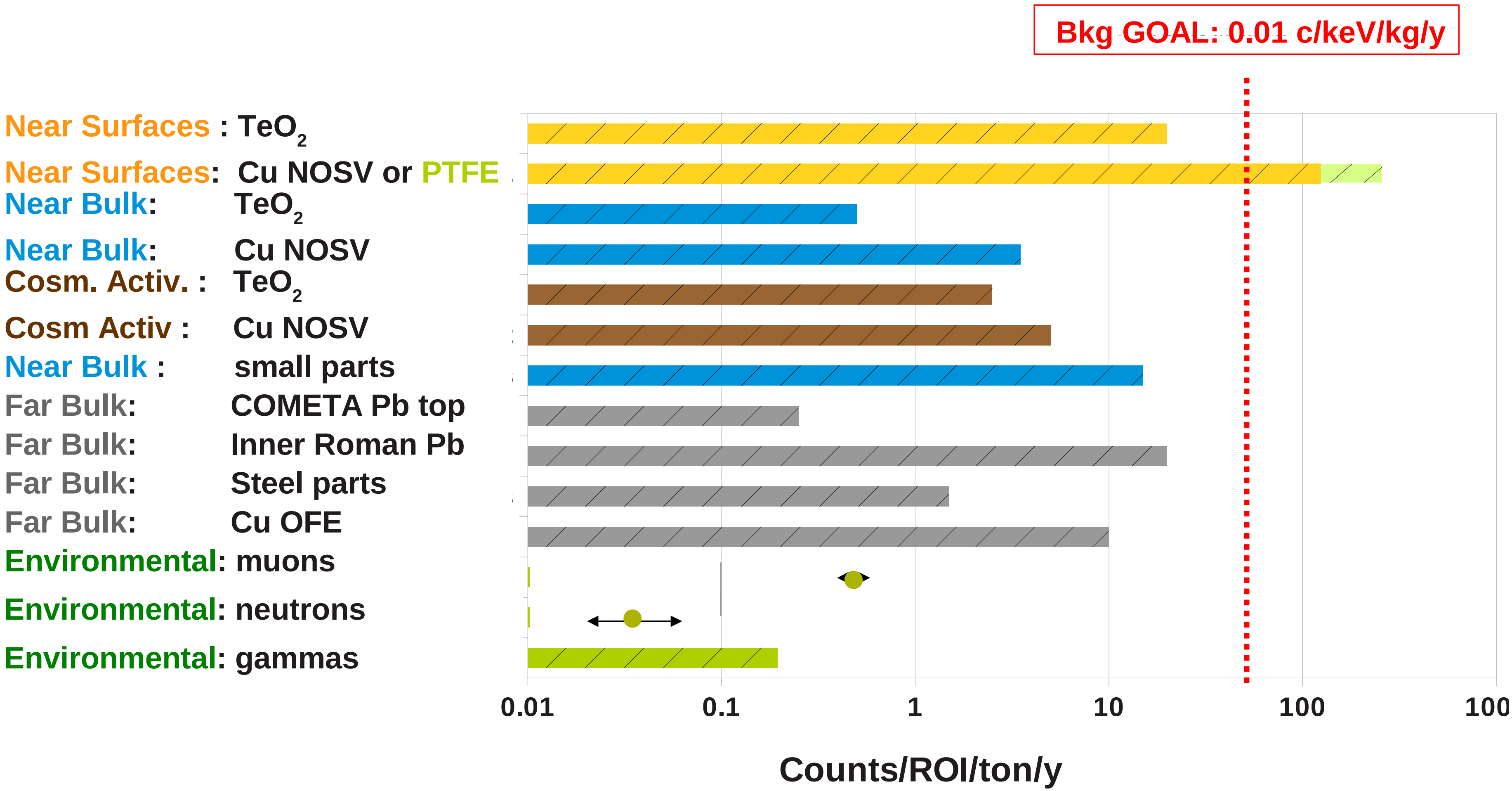
CUORE strategy:

- improve shields & material quality
- improve bulk contamination in TeO_2 (SICCAS)
- reduce surface contribution from
  - TeO_2 crystals
  - components facing TeO_2 crystals (mainly copper)
- Ultra-clean assembly
- increased coincidence efficiency to reject surface background events
- Overall goal: 0.01 c/y/kg/keV
- Demonstrated <0.02-0.03 c/y/kg/keV (90% C.L. upper limit)

Cuoricino Backgrounds



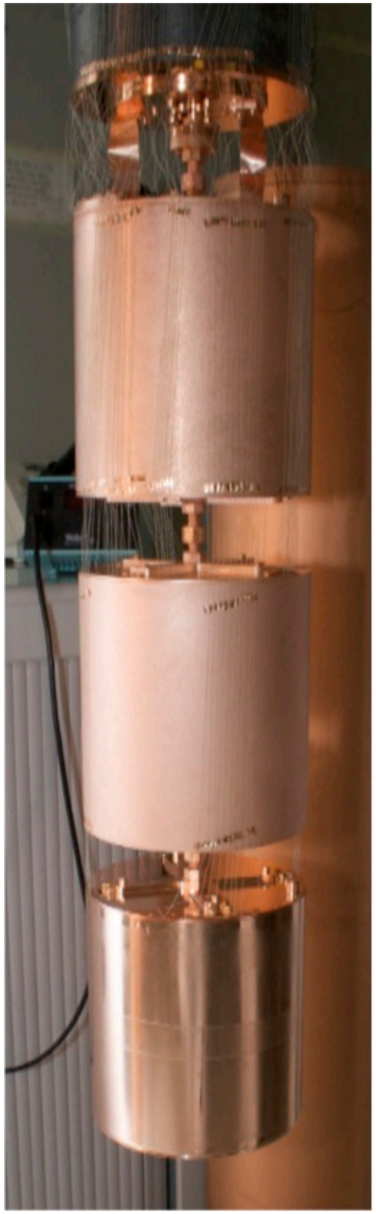
CUORE Background Budget

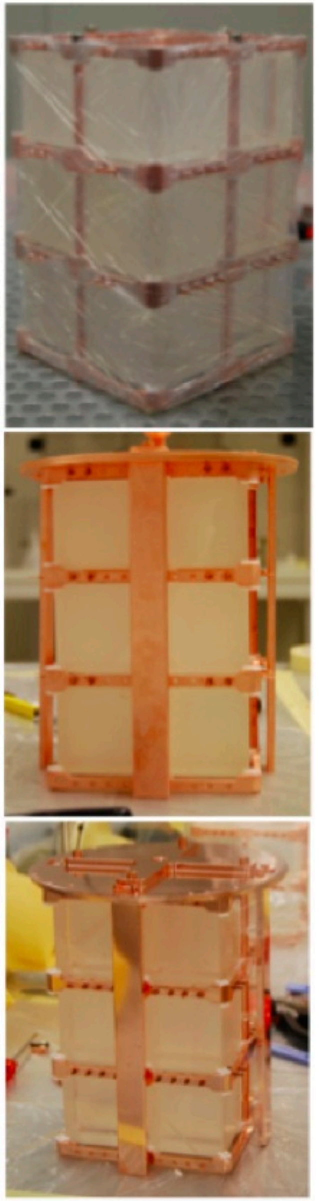


Most values are upper limits

Test Facilities

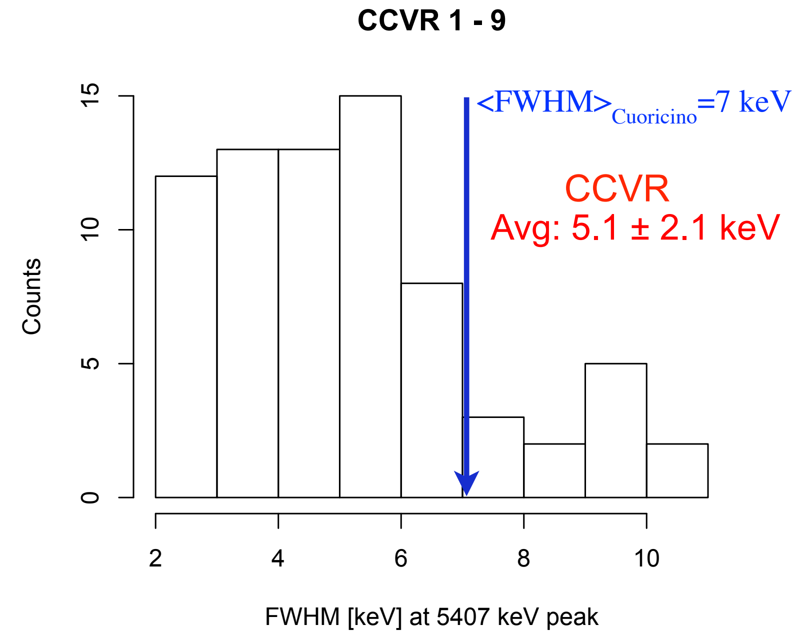
- Dedicated test facility in Hall C
  - Extensive R&D on material characterization (bulk, surface contaminations) during Cuoricino
- Cuoricino cryostat in Hall A
  - Final high-statistics tests of surface cleaning technologies
- Low-counting facilities @ LNGS and LBNL
- All results cross-checked against Cuoricino data and scaled to CUORE with MC
  - E.g. benefits of increased coverage for multi-site event veto (anti-coincidence)

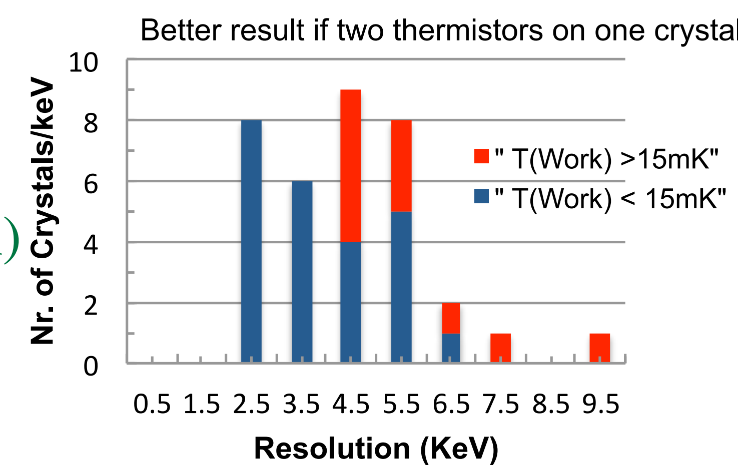




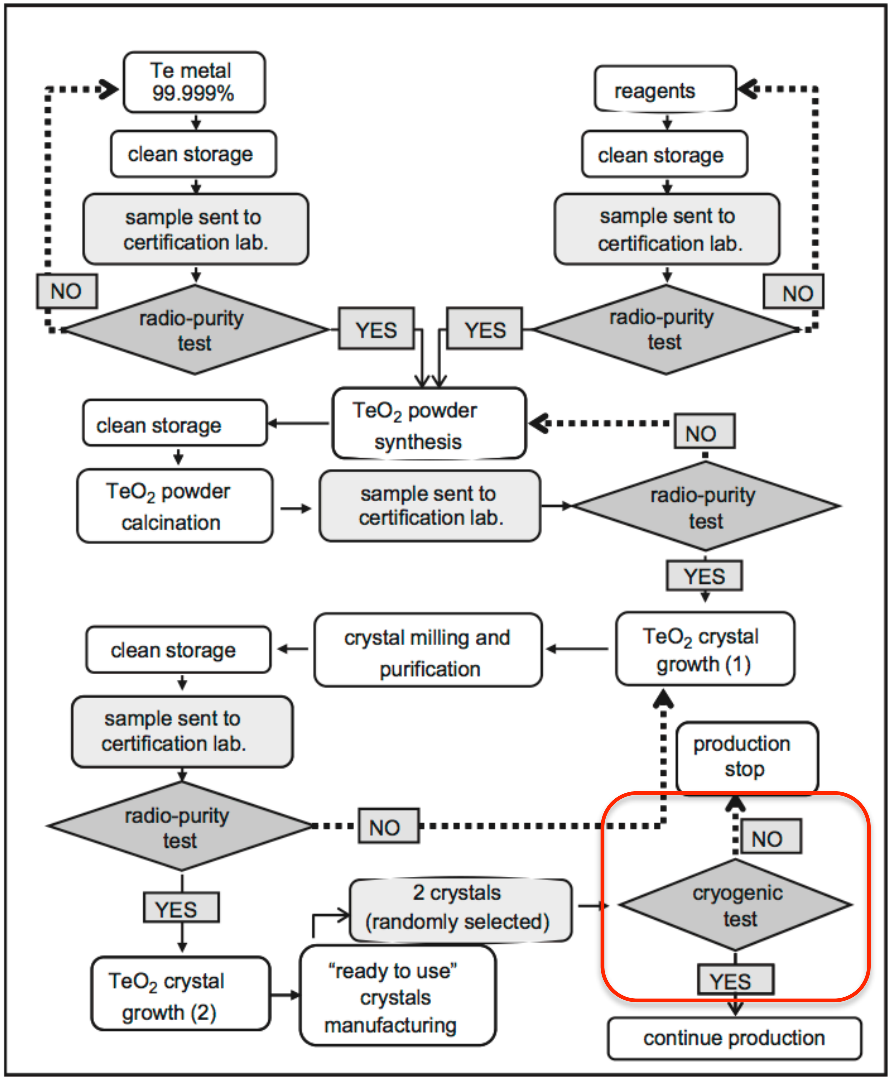
Crystals: Resolution Improvements

- CUORE crystals
  - Raw material carefully screened
  - Produced and cleaned at CICCAS (Shanghai, China)
  - All delivered
- Shipped by boat to Italy, then stored underground
  - Decrease cosmogenic activation
- Visually inspected on arrival
- Test ~4% of all crystals bolometrically in Hall C
  - CUORE Crystal Validation Runs (CCVR)
  - All crystals conform to specs
  - Demonstrate target resolution (5 keV FWHM)

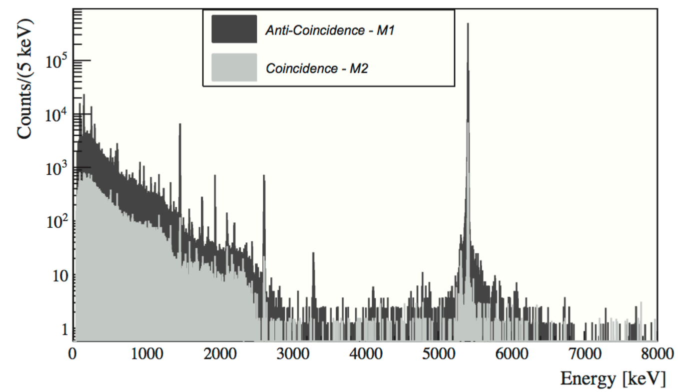




Crystals: Radiopurity

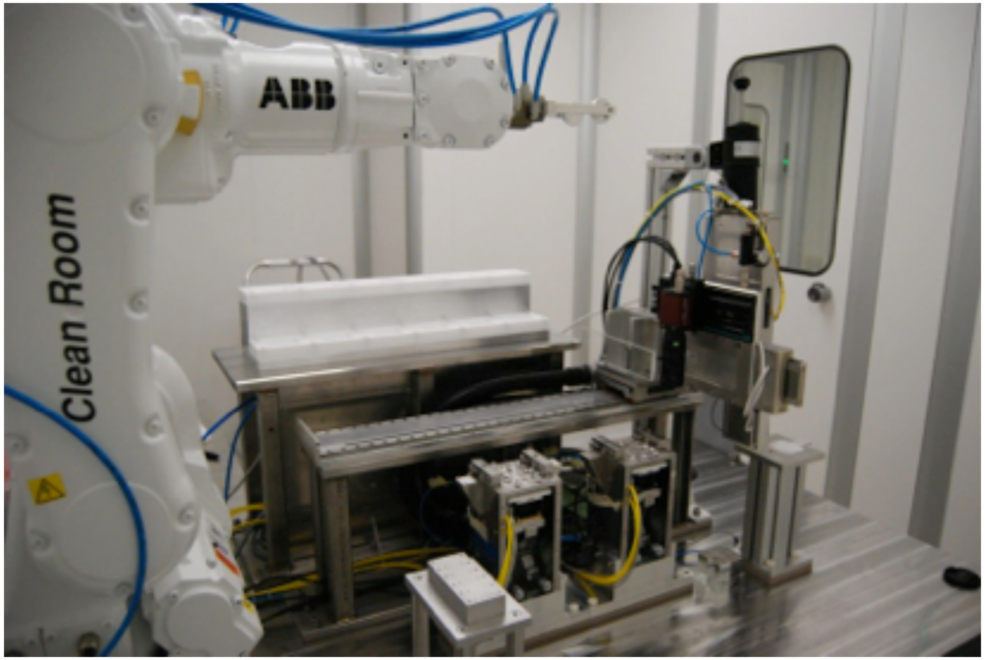


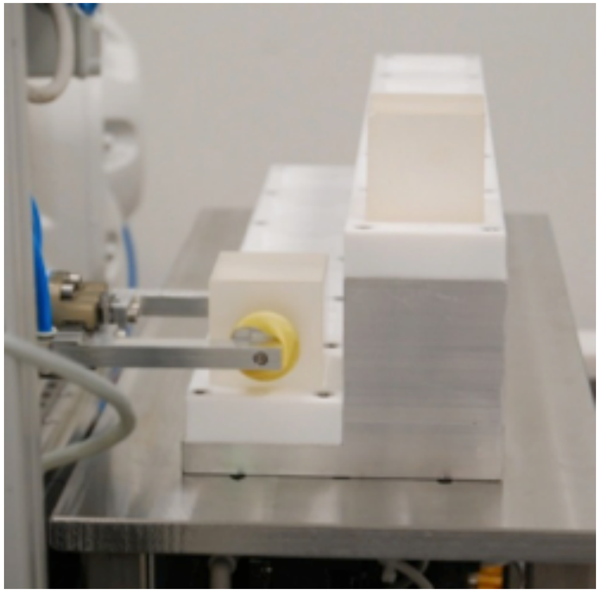
- CCVR to check crystal's
  - Bolometer performance
  - Surface and bulk contaminations

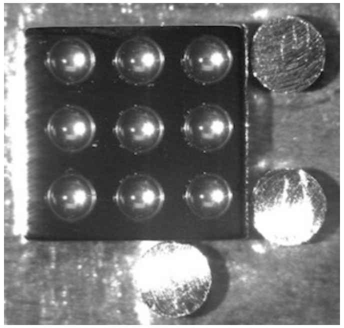


90% CL upper limit	^{232}Th	^{238}U	^{210}Po
Bulk Contaminations (Bq/kg)	< 8.4E-7	< 6.7 E-7	< 3.3 E-6
Surface Contaminations (Bq/cm^2)	< 2E-9	< 1E-8	< 1E-6

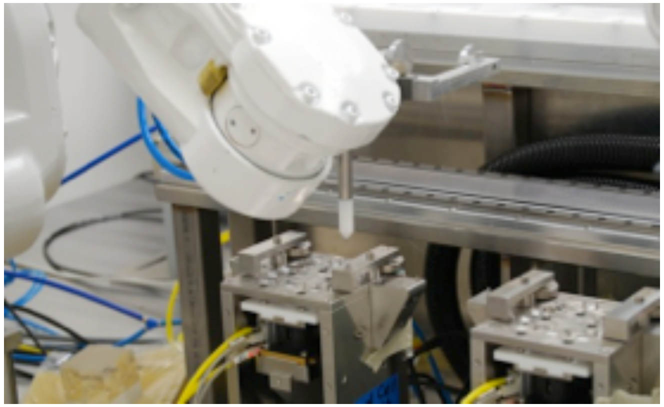
Sensor Gluing





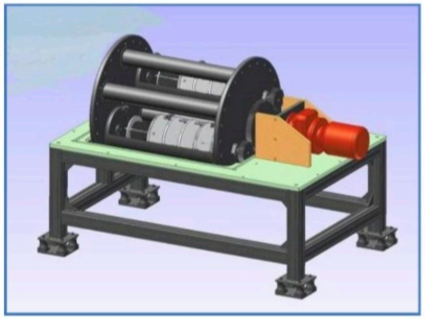


Production line, robotic operations
Emphasis on reproducibility, well-defined thermal coupling
All cleanroom operation

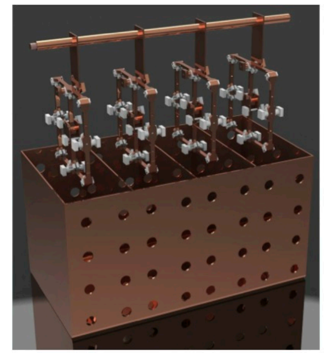
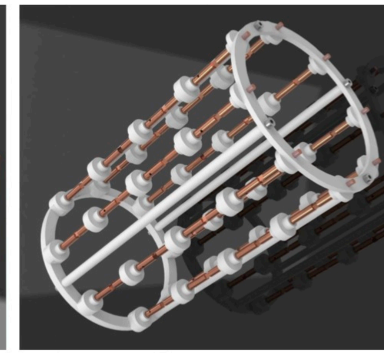


Copper Cleaning: TECM

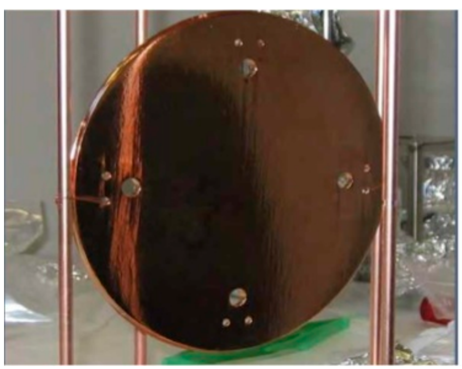
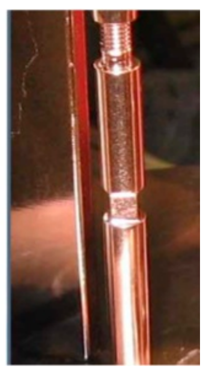
1. Tumbling



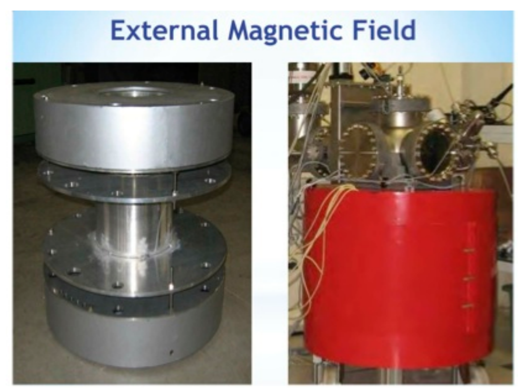

2. Electropolishing

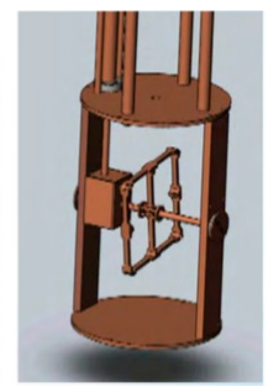



3. Chemical etching

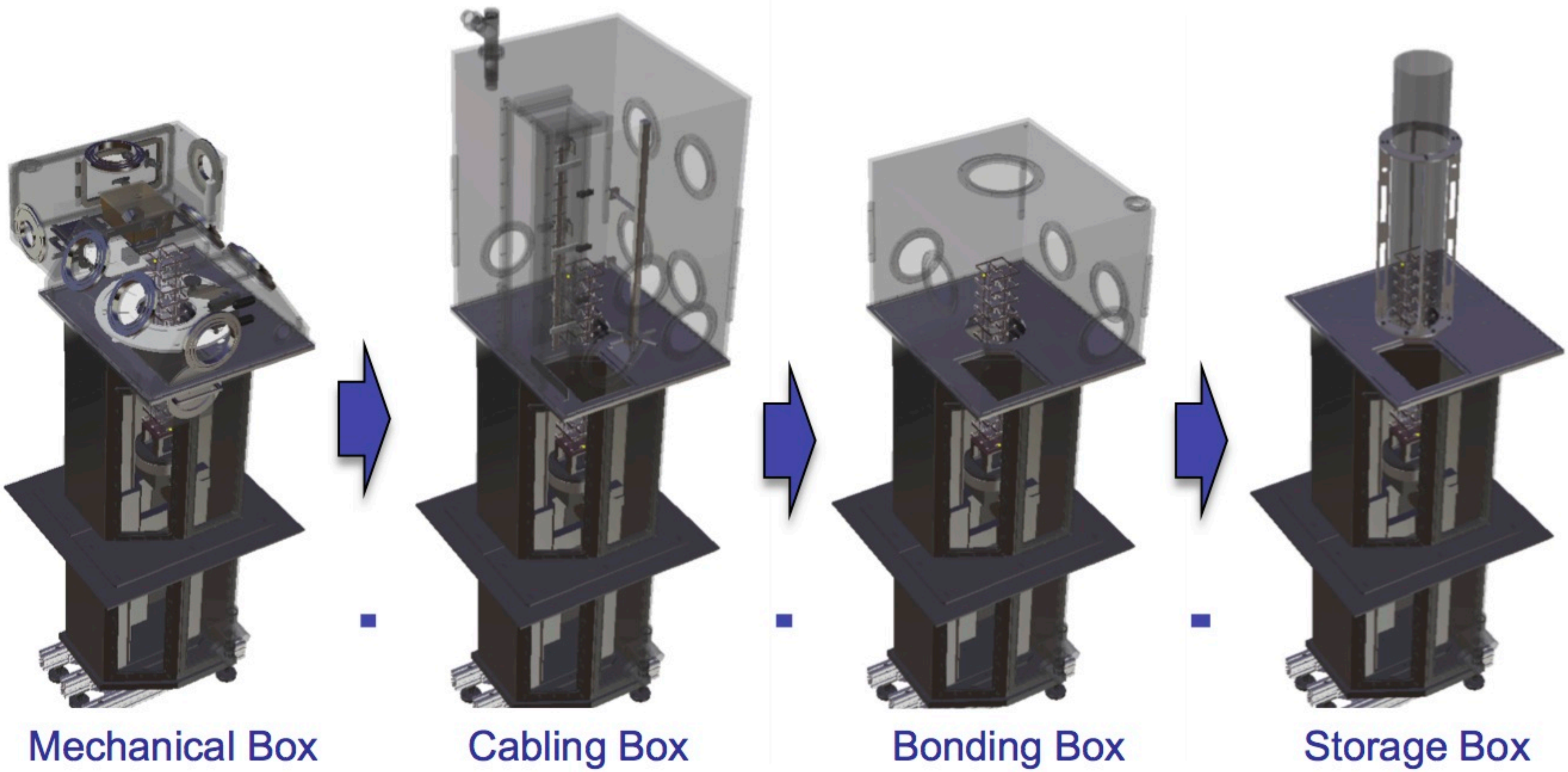
4. Magnetoplasma



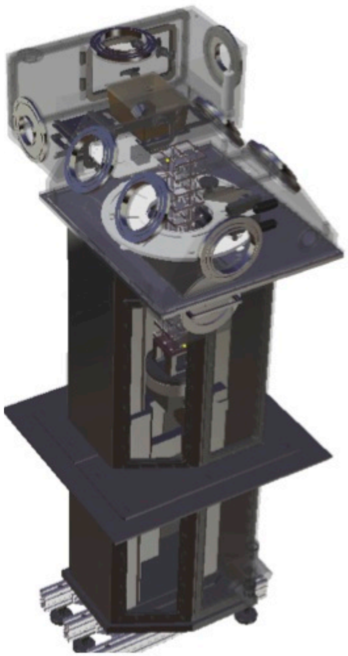


Validated in dedicated test in Hall C; reduced background by at least x3 compared to Cuoricino

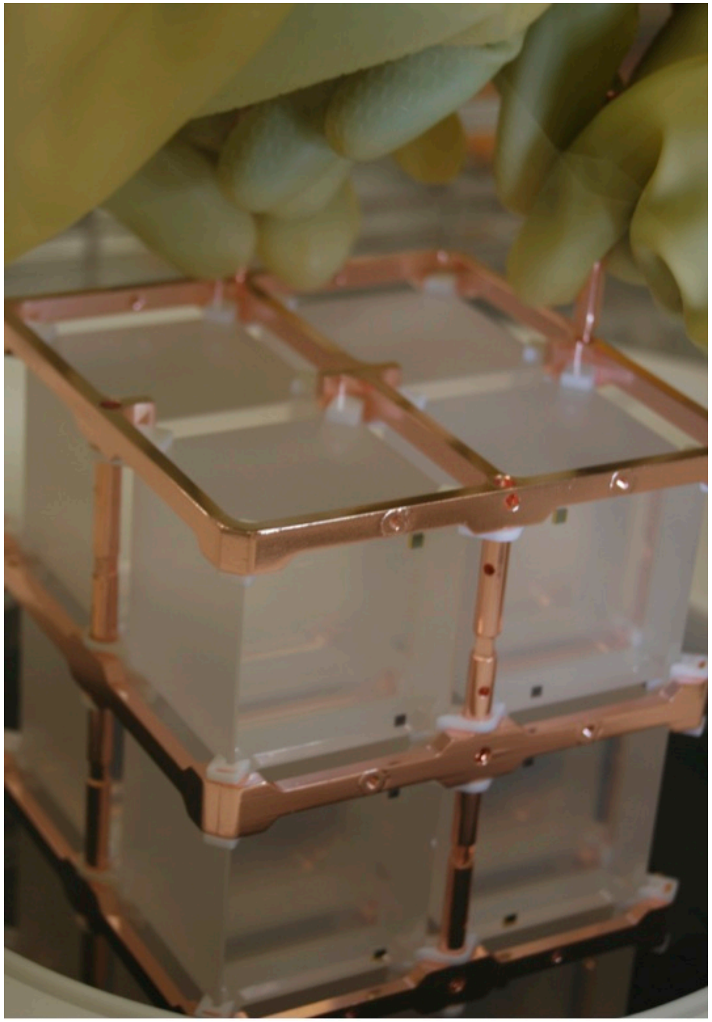
Assembly Line



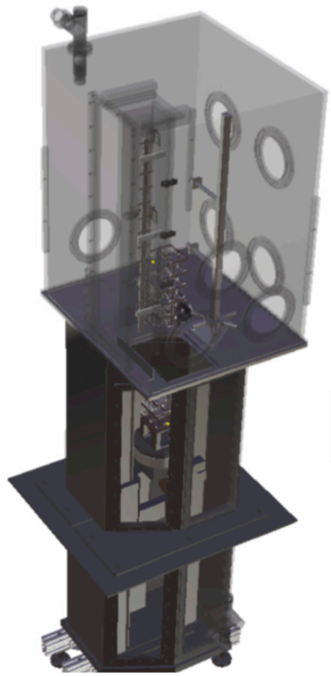
Tower Assembly



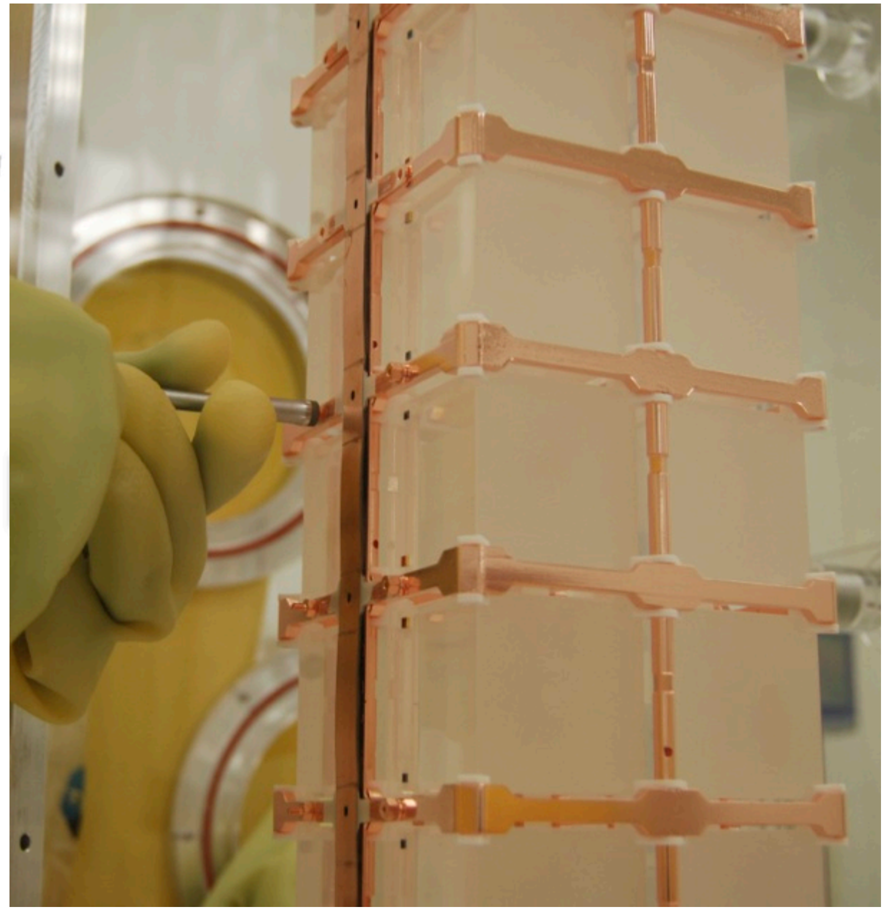
Mechanical Box



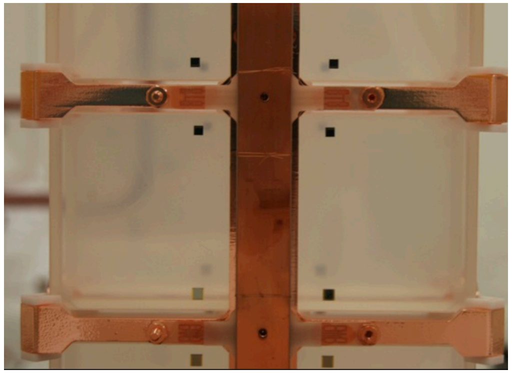
Sensor Cabling

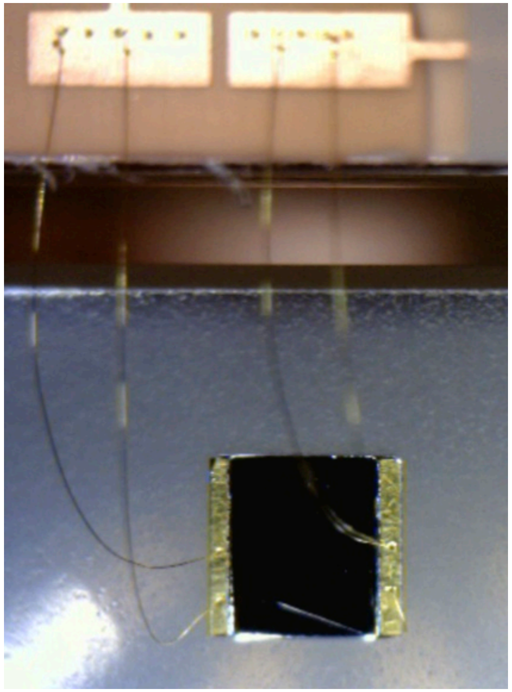


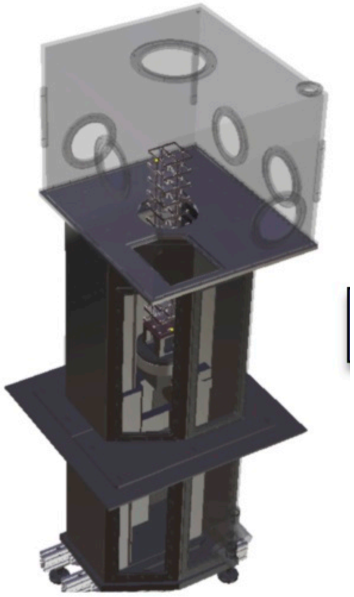
Cabling Box



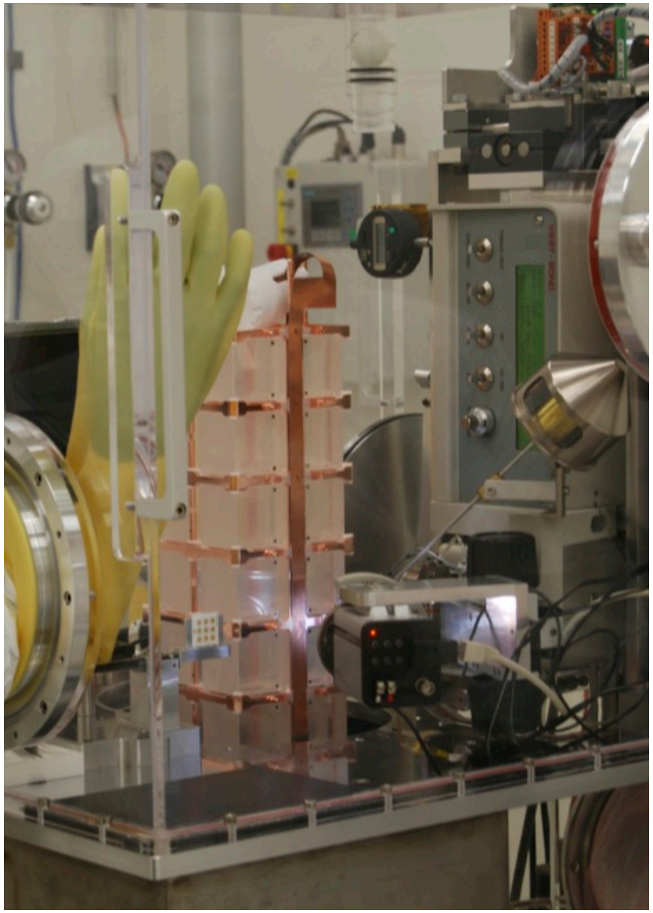
Sensor Wire Bonding



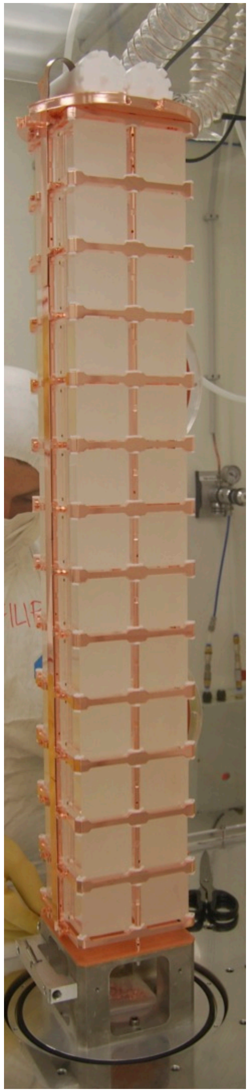


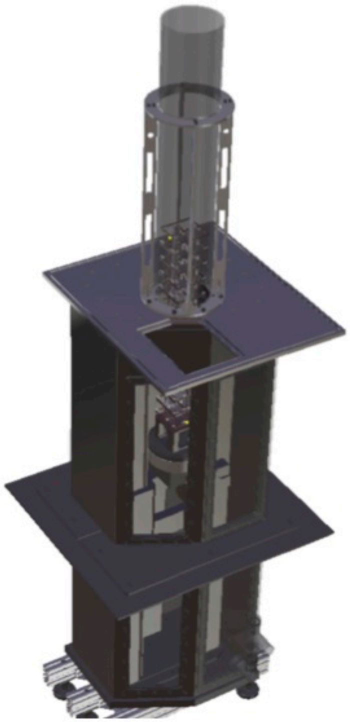


Bonding Box



Tower Storage and Transfer





Storage Box

Additional Challenges

Cryogenics

- 10 mK base temperature
- >1600 kg total mass @ 10 mK
- 5 μW power @ 10 mK
- 20 t total mass inside cryostat

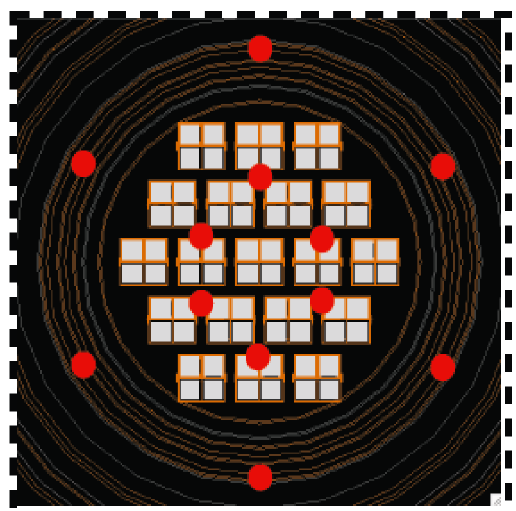
Detector Calibration System

- Internal to cryostat
- Minimize heat load
- Calibration time < 1 week while avoiding event pileup
- Energy scale uncertainty goal < 0.05 keV in 0νββ region

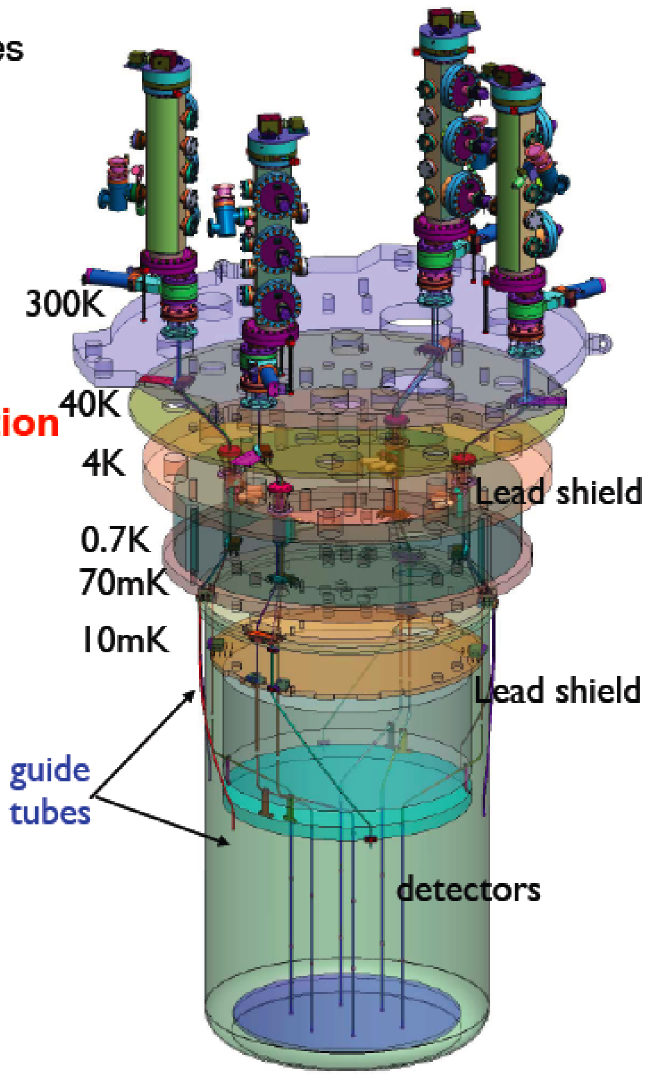
motion system:
insertion and extraction of sources in and out of cryostat

guide tubes:
no straight vertical access

source strings:
move under own weight in guide tubes



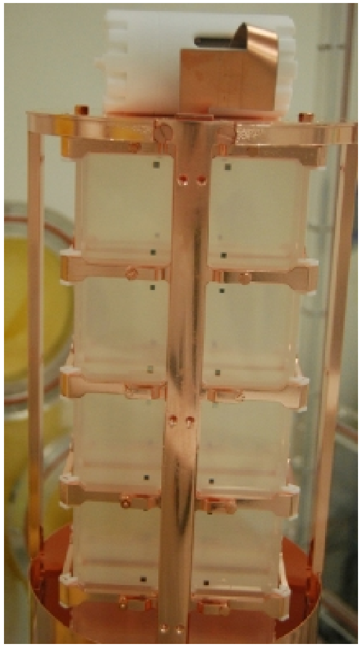
top view of detector array with source positions



CUORE-0

1 CUORE-like tower of 13 planes - 4 crystals each
52 TeO_2 5x5x5 cm^3 crystals (750 g each)
Detector Mass: 39 kg TeO_2
^{130}Te mass (natural i.a.): 11 kg of ^{130}Te

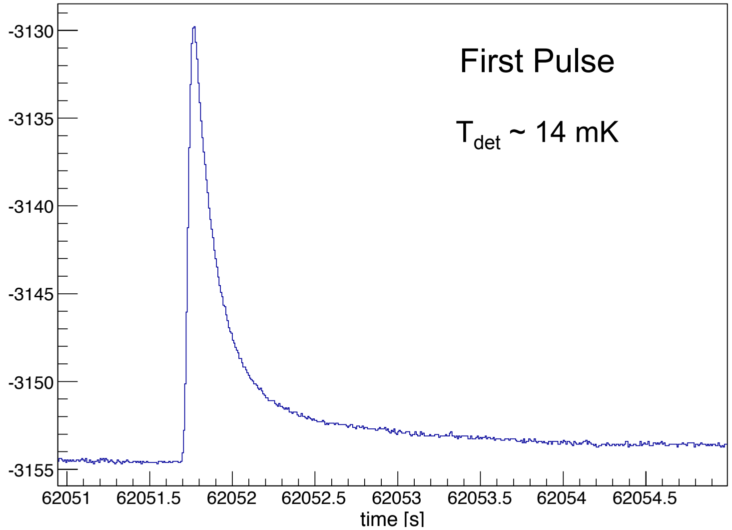
- All detector components manufactured, cleaned and stored with protocols defined for CUORE
- Assembled with the same procedures foreseen for CUORE
- In the 25 years-old CUORICINO cryostat

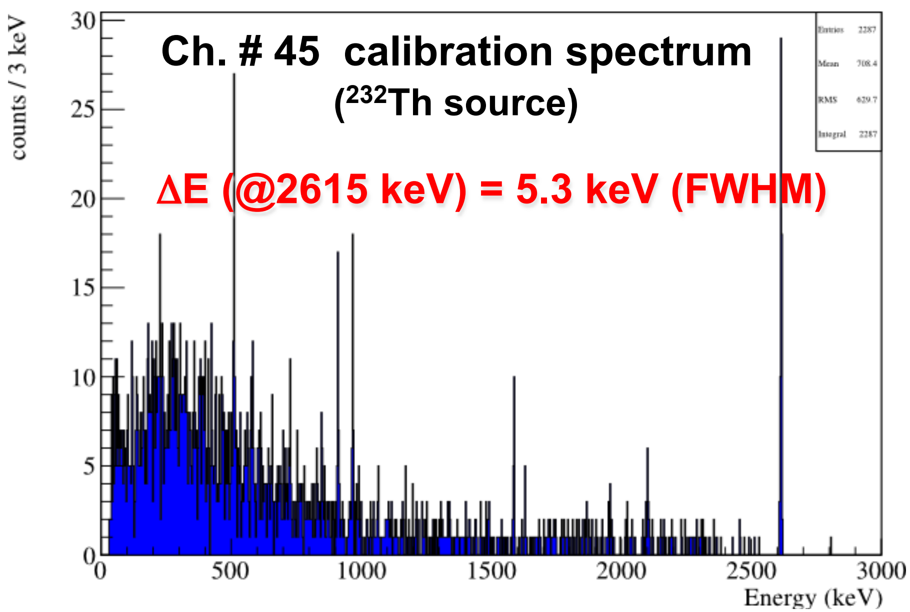


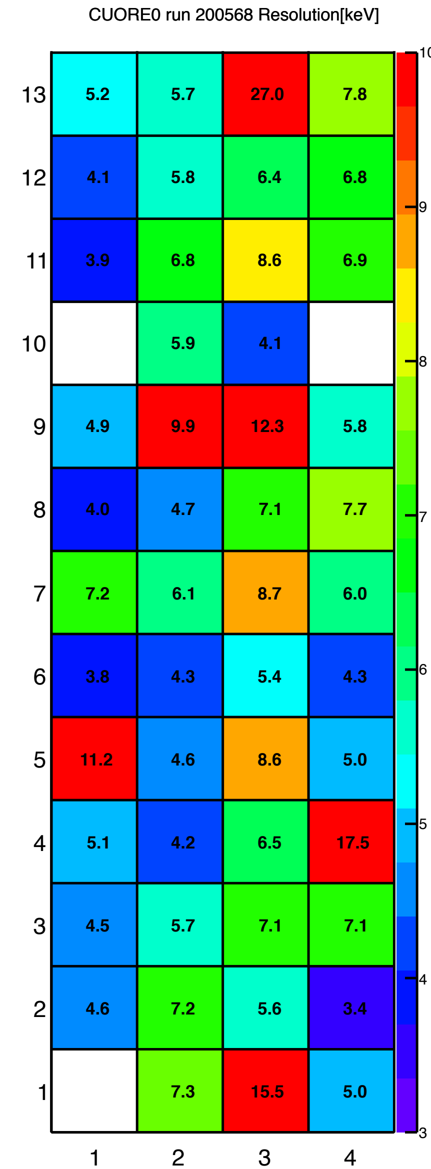
GOALS:

- Proof of Concept for CUORE in all stages
- Test and debug the CUORE assembly line (thermistor gluing, signal wires bonding, tower assembly)
- Test of the CUORE DAQ and analysis framework
- Extend the physics reach beyond CUORICINO while CUORE is being assembled
- Demonstrate potential for DM and Axion detection

CUORE-0 Operations

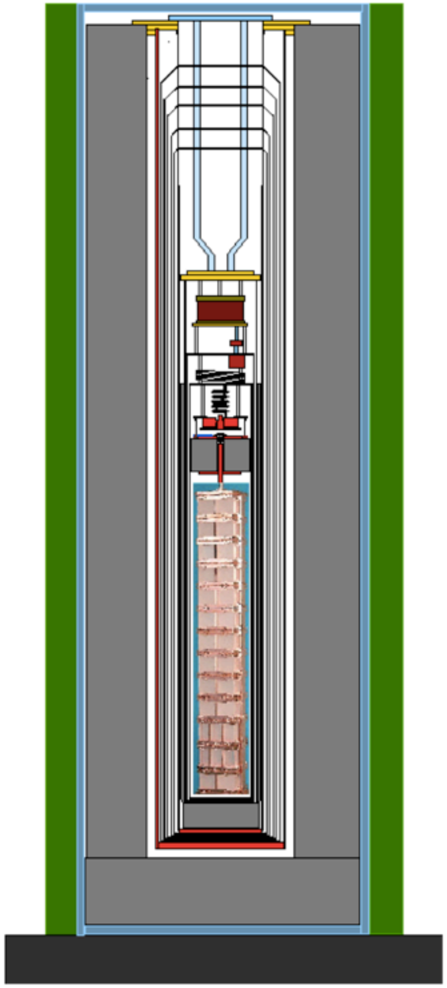


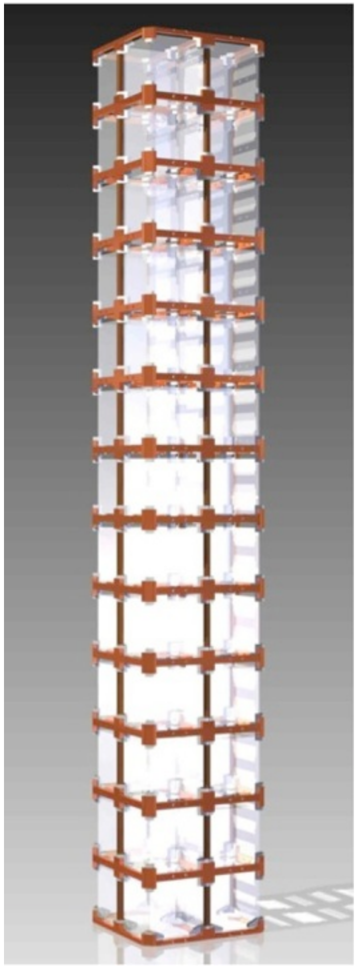




CUORE-0 to CUORE

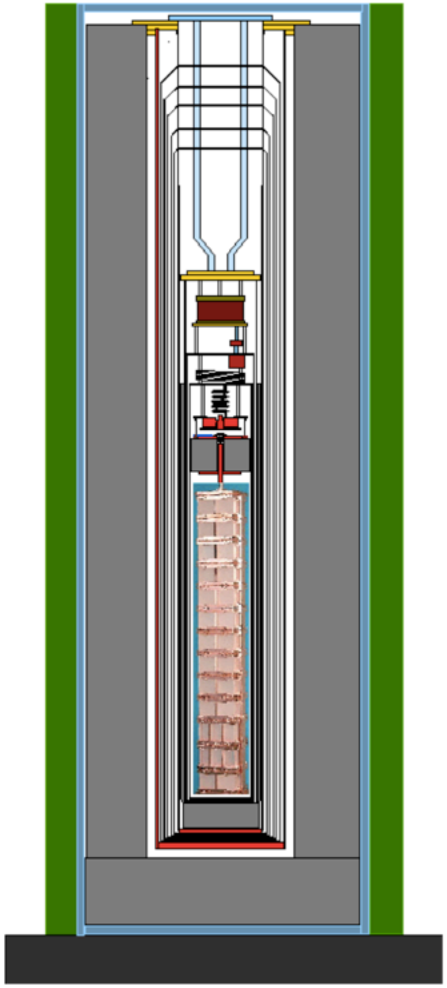
CUORE-0





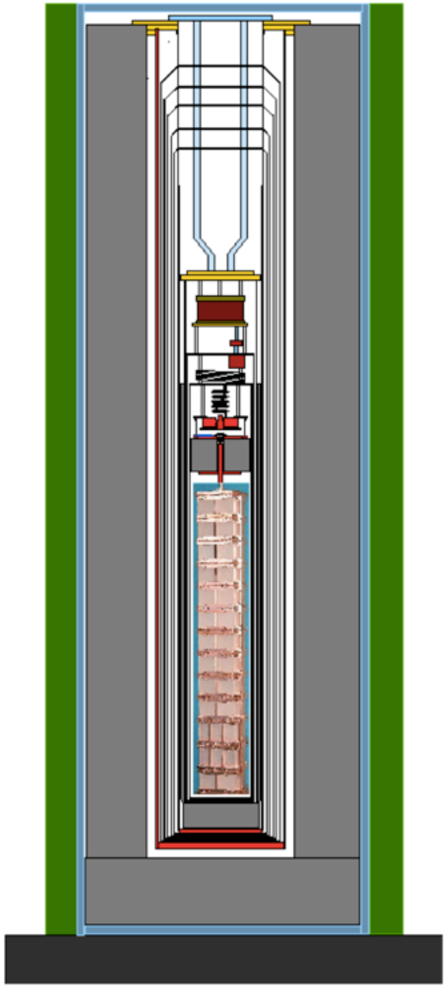
CUORE-0 to CUORE

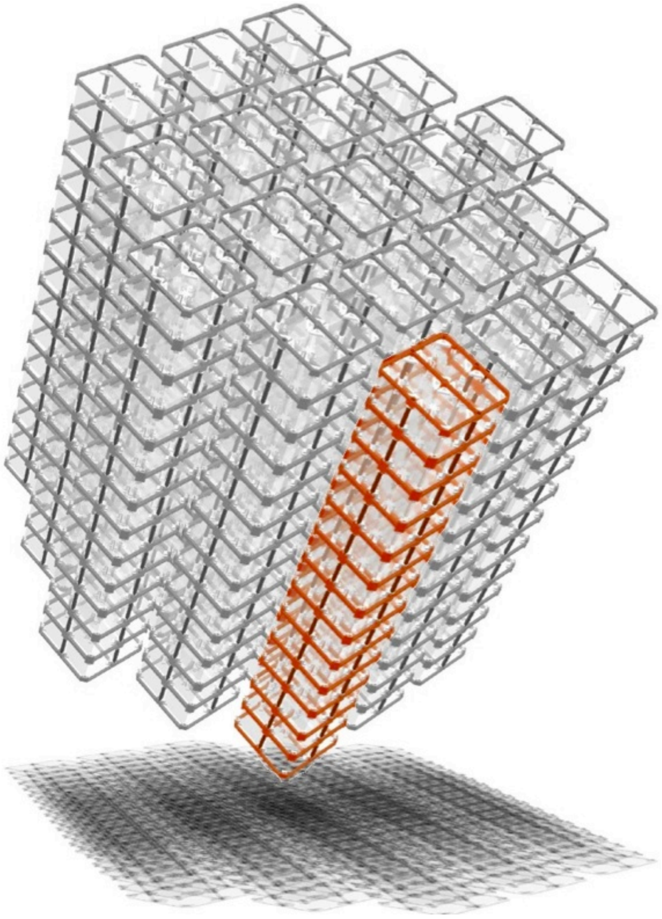
CUORE-0



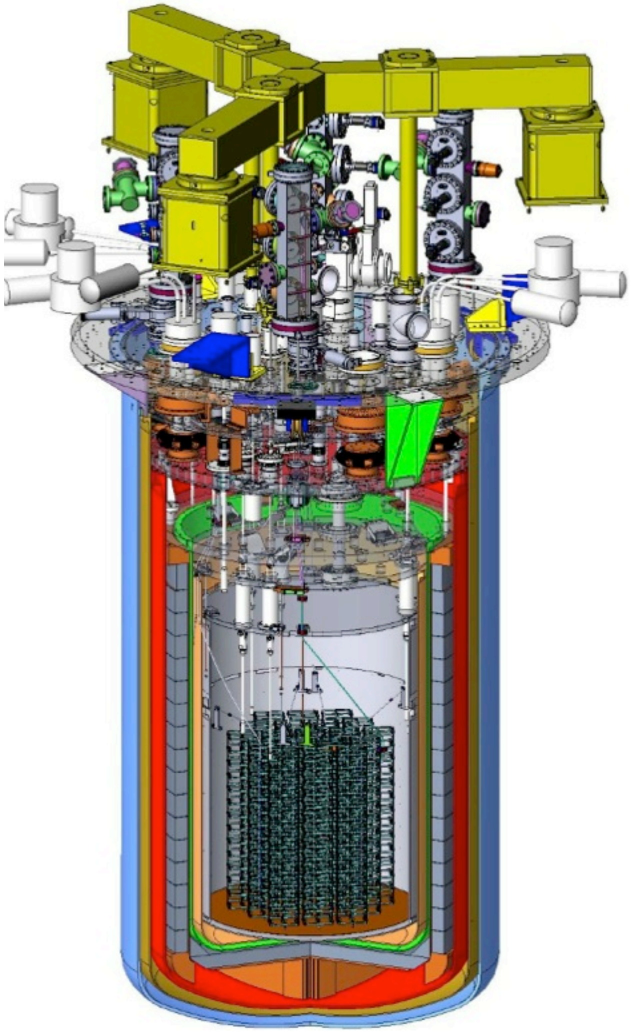
CUORE-0 to CUORE

CUORE-0



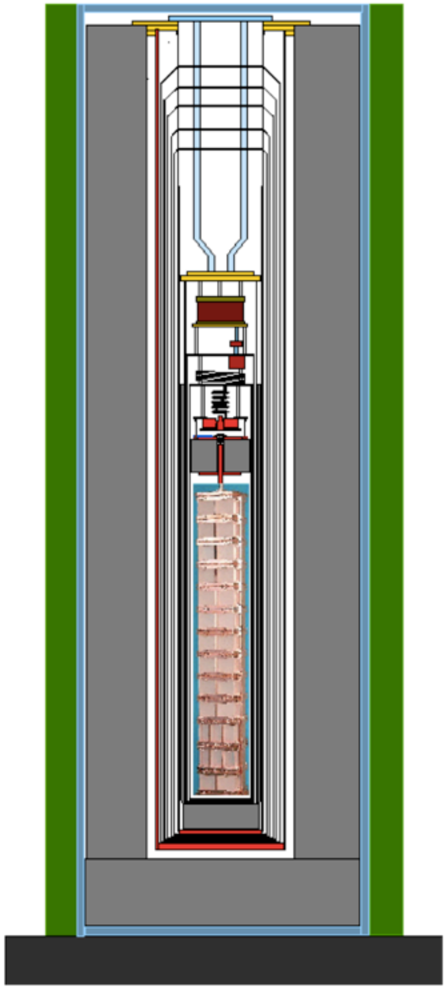


CUORE

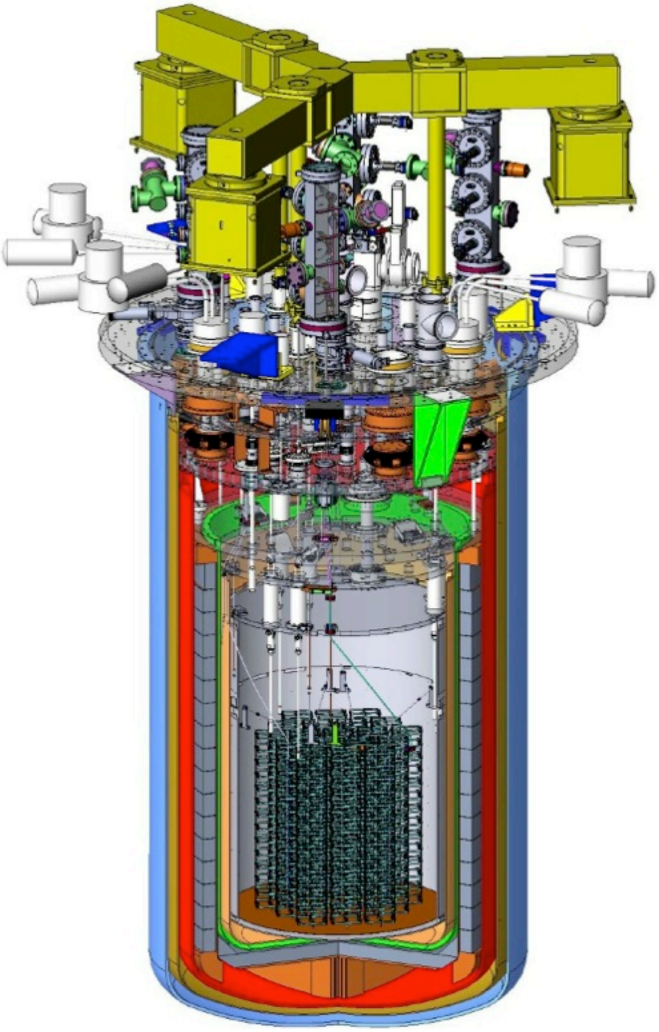


CUORE-0 to CUORE

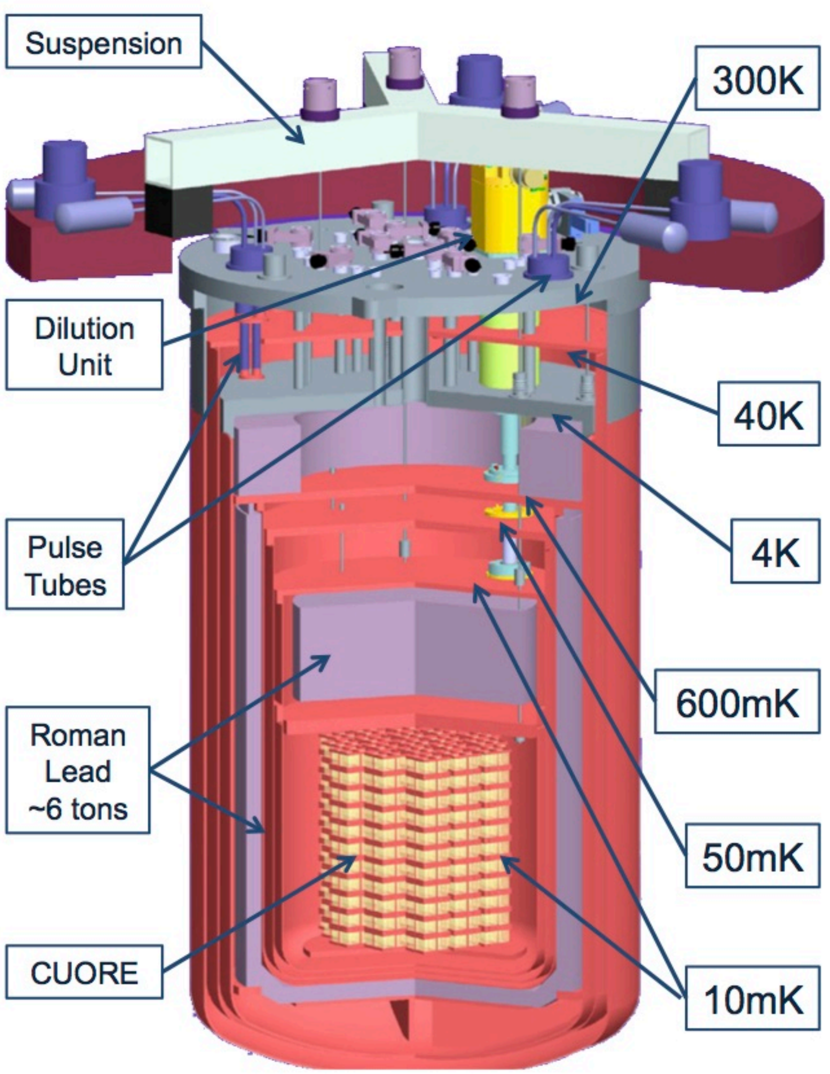
CUORE-0



CUORE

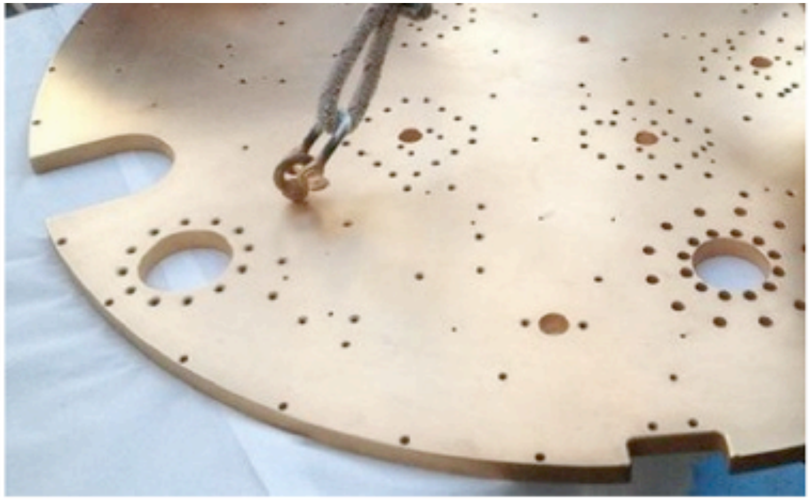


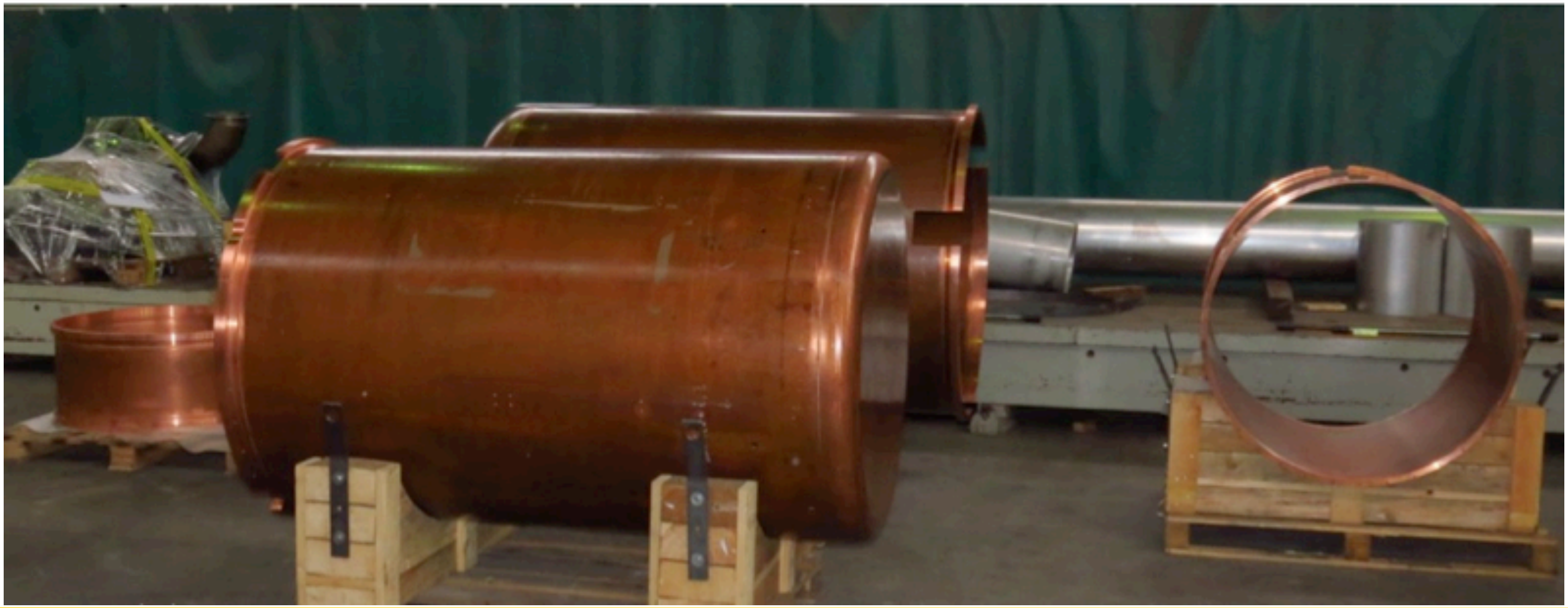
CUORE Cryostat



- 10 mK baseline temperature
  - 750 kg of crystals
  - Copper supporting structure
- ~20 tons at various low temperature
- Low background
  - Built with radio-pure materials
  - Roman lead shield from ancient shipwreck, <4mBq/kg ^{210}Pb
- Low vibrations
  - Separated suspension for the crystal tower and DR
- Minimal maintenance and dead time
  - Cryogen free DR

CUORE Cryostat





Cryostat Commissioning

- commissioning @LNGS in progress
- 3 outer vessels assembled
- cooled to 4K in April 2013

Dilution Unit

Lowest base temperature: 4.95 mK
Cooling power: 10 μW @ 12 mK

Dilution Unit

CUORE Status

Clean room & assembly line

Underground storage

Dilution Unit

300K vessel

- Hut and clean room: fully equipped
- Radon abatement system: operating
- Cryostat: in commissioning, successful 4K test
- Dilution unit: delivered, <5 mK reached
- Copper parts: cleaning proceeding, to be delivered by end of 2013
- Crystals: all (1063) delivered to LNGS underground storage
- NTD thermistors: all (1250) delivered
- Detector assembly line: operational, first four towers assembled
- CUORE-0 (single tower in Cuoricino cryostat): in operations

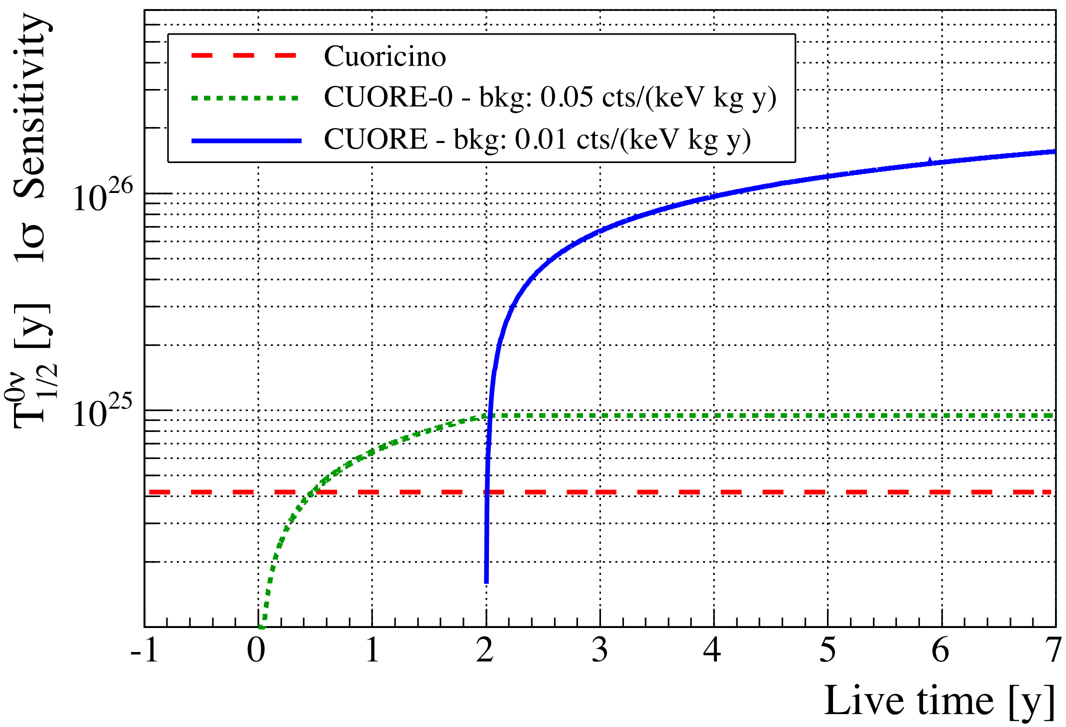
CUORE Sensitivity

5 year sensitivity

Setup	t (y)	b (cts/(keV kg y))	$\widehat{T^{0\nu}_{1/2}}(1\sigma)$ (y)	$m_{\beta\beta}$ (meV) QRPA-F	QRPA-S	ISM	IBM
CUORE-0	2	0.05	9.4×10^{24}	170–310	190–320	310–390	200
	zero-bkg. case at 68% C.L.:		5.3×10^{25}	*70–130*	*81–130*	*130–160*	*85*
CUORE baseline	5	0.01	1.6×10^{26}	41–77	48–78	76–95	50
	zero-bkg. case at 68% C.L.:		2.5×10^{27}	*10–19*	*12–19*	*19–24*	*12*

Five year sensitivity based on detector resolution (5 keV FWHM), background, and matrix element spread

First tower (CUORE-0) to be assembled in Cuoricino cryostat in Spring 2012 and operated until the start of CUORE.



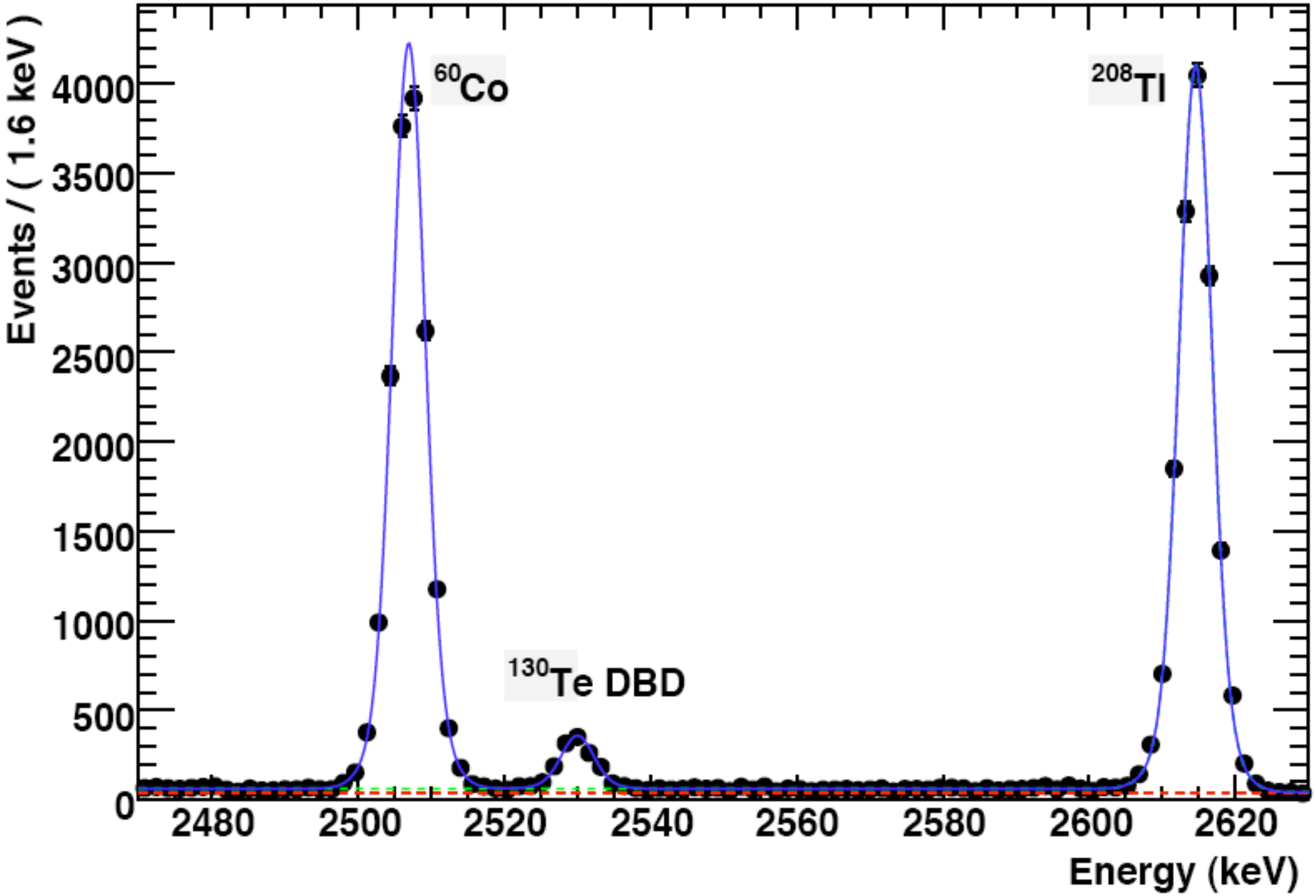
CUORE Sensitivity

Assume KKDC result: $T_{1/2}$=25x10^{23} y (also near Cuoricino limit)

Background 0.01 c/keV/kg/year, 5 keV FWHM resolution, 5 years of running

Assume conservative scaling of Co and Tl peaks

Outcome of one possible experiment:



Beyond CUORE

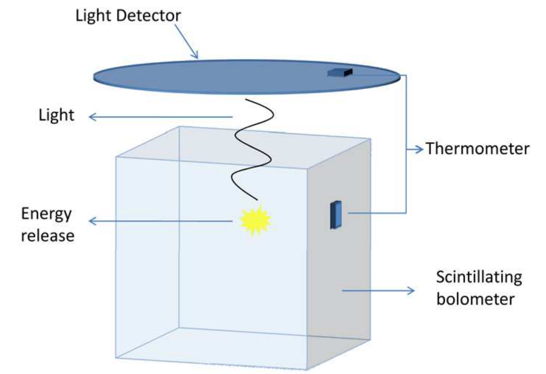
$$T_{1/2}^{0\nu}(n_\sigma) = \frac{4.17\times 10^{26}}{n_\sigma}\left(\frac{a\varepsilon}{W}\right)\sqrt{\frac{Mt}{(1+\xi)b\delta(E)}}$$

- CUORE design is scalable to O(1 ton) detector
  - Relatively inexpensive isotopic enrichment of ^{130}Te
    - ☞ > 500 kg of ^{130}Te
    - ☞ A factor of 3 increase in *a*
  - Other DBD isotopes can also be used bolometrically
- Additional background suppression
  - Scintillating bolometers
  - Ionization measurements
  - Surface-sensitive bolometers
  - Pulse shape discrimination through non-equilibrium phonons
- Important direction for future R&D

Beyond CUORE

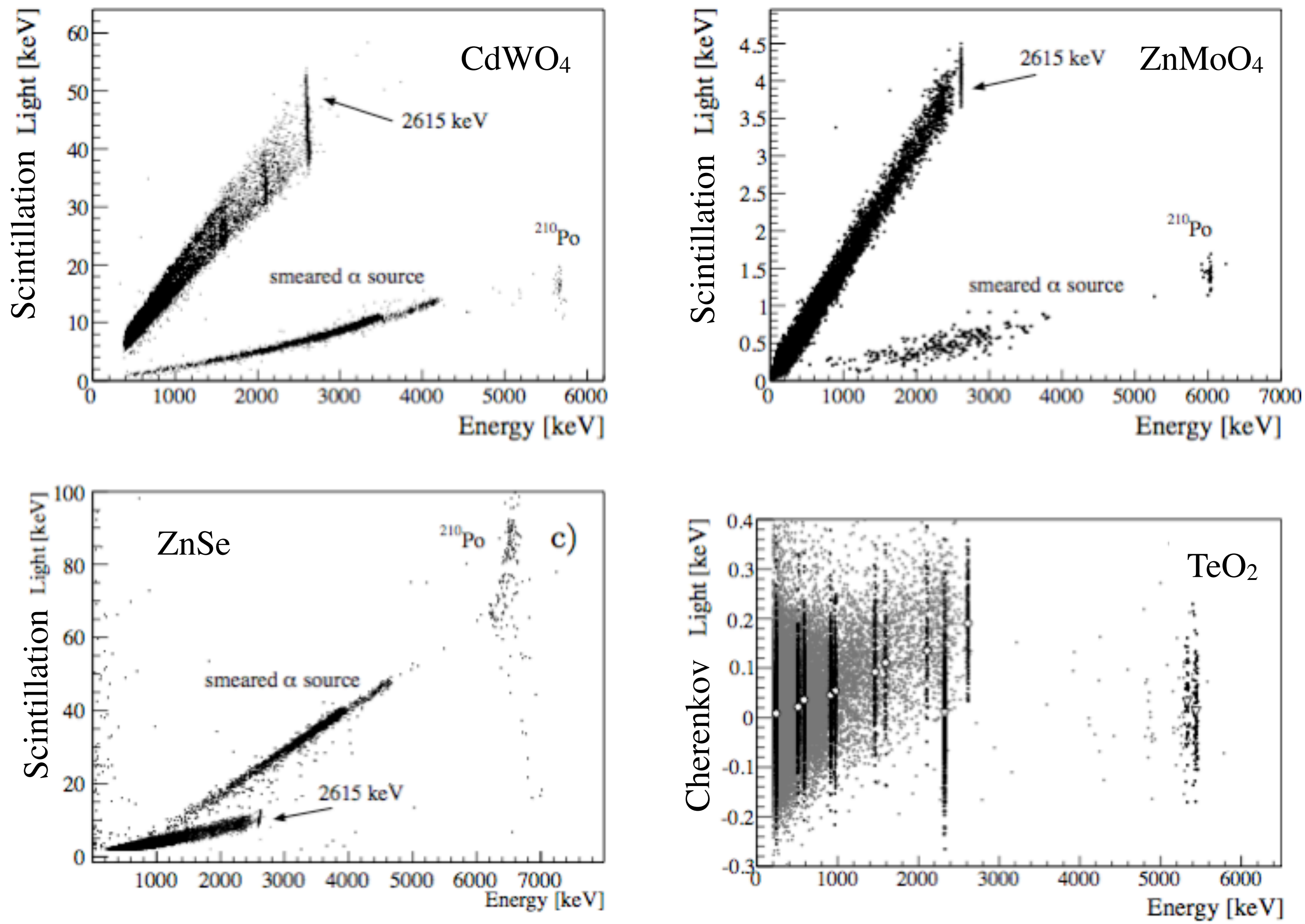
$$T^{0\nu}_{1/2}(n_\sigma) = \frac{4.17\times10^{26}}{n_\sigma}\left(\frac{a\varepsilon}{W}\right)\sqrt{\frac{Mt}{(1+\xi)b\delta(E)}}$$

- CUORE design is scalable to O(1 ton) detector
  - Relatively inexpensive isotopic enrichment of ^{130}Te
    - 740 kg of ^{130}Te
    - A factor of 3 increase in isotope mass
  - Other DBD isotopes can also be used bolometrically
    - E.g. ZnSe with isotopically enriched ^{82}Se, $ZnMoO_4$ with enriched ^{100}Mo
- Active background suppression to reduce background in ROI to ~zero
  - Energy resolution improvements (TES sensors)
  - Scintillating/Cherenkov bolometers or ionization
  - Surface-sensitive bolometers
  - Pulse shape discrimination through non-equilibrium phonons

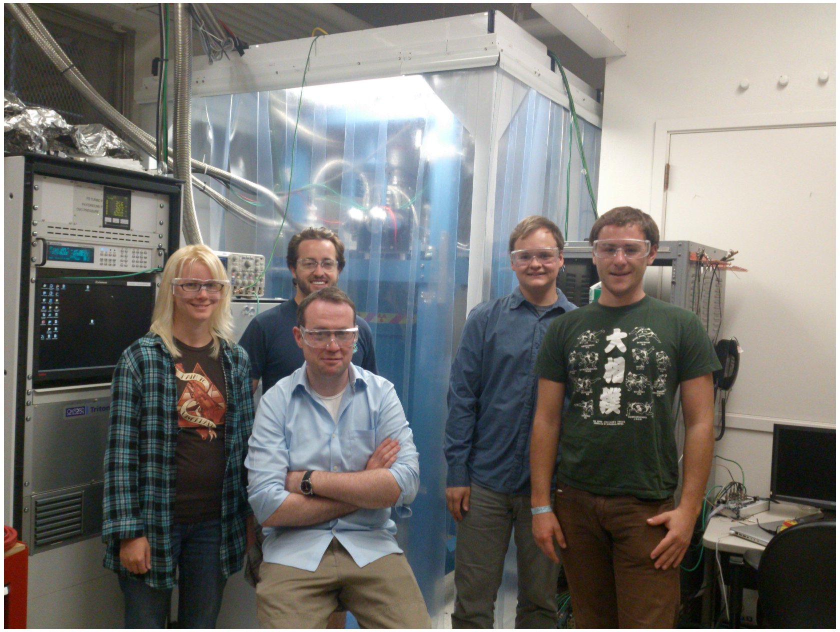


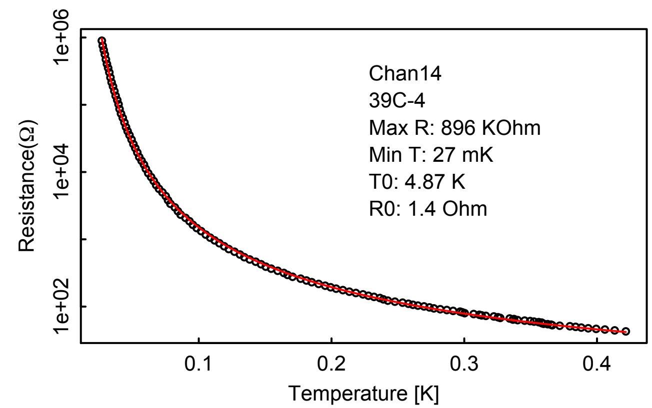
- Important direction for future R&D
  - Efforts in the US and Italy underway; several techniques already demonstrated
  - Technology demonstration by 2015-2016: background rejection + CUORE ops

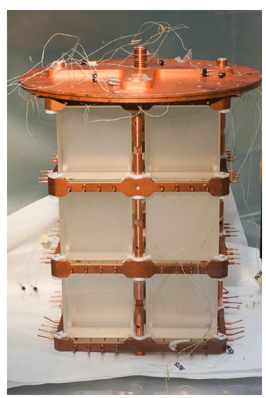
α/β Discrimination

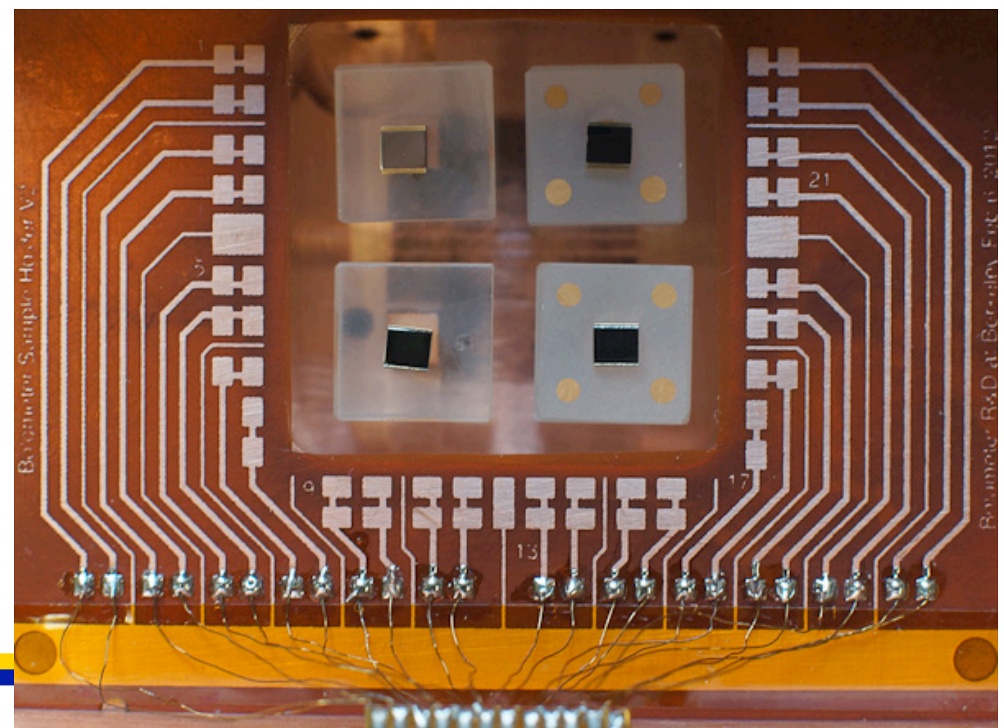


Bolometric R&D @ Berkeley

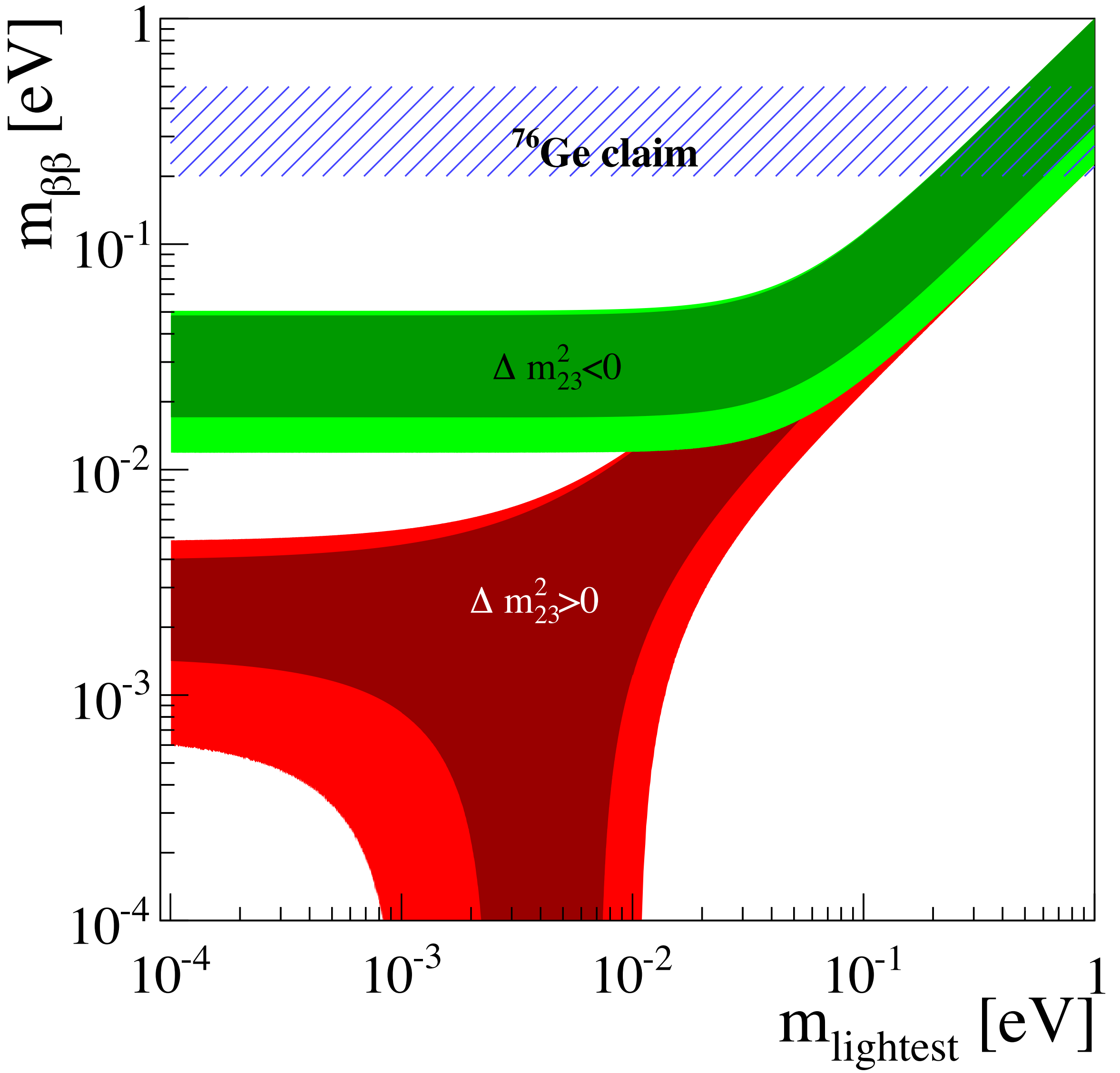






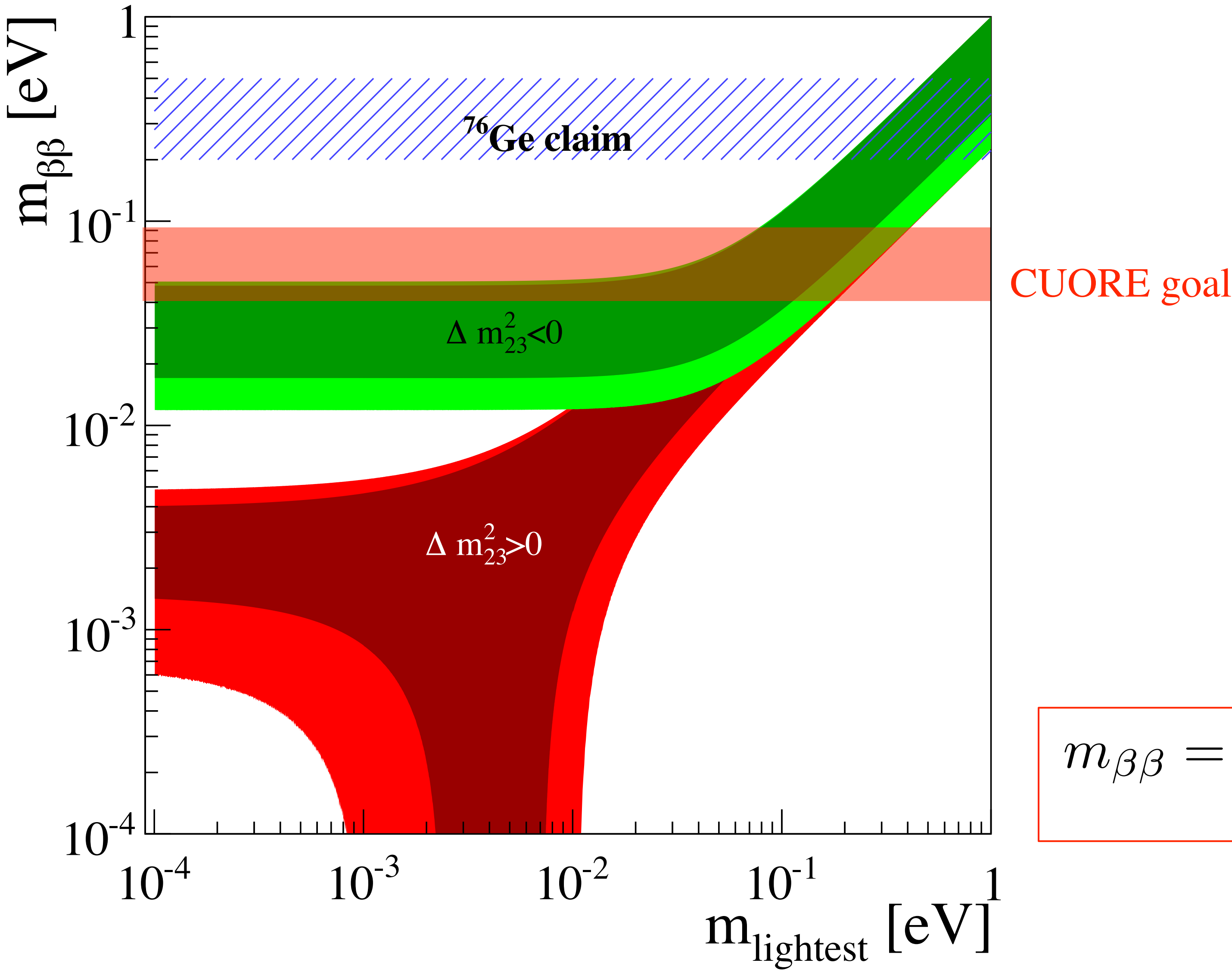


DBD and Neutrino Mass



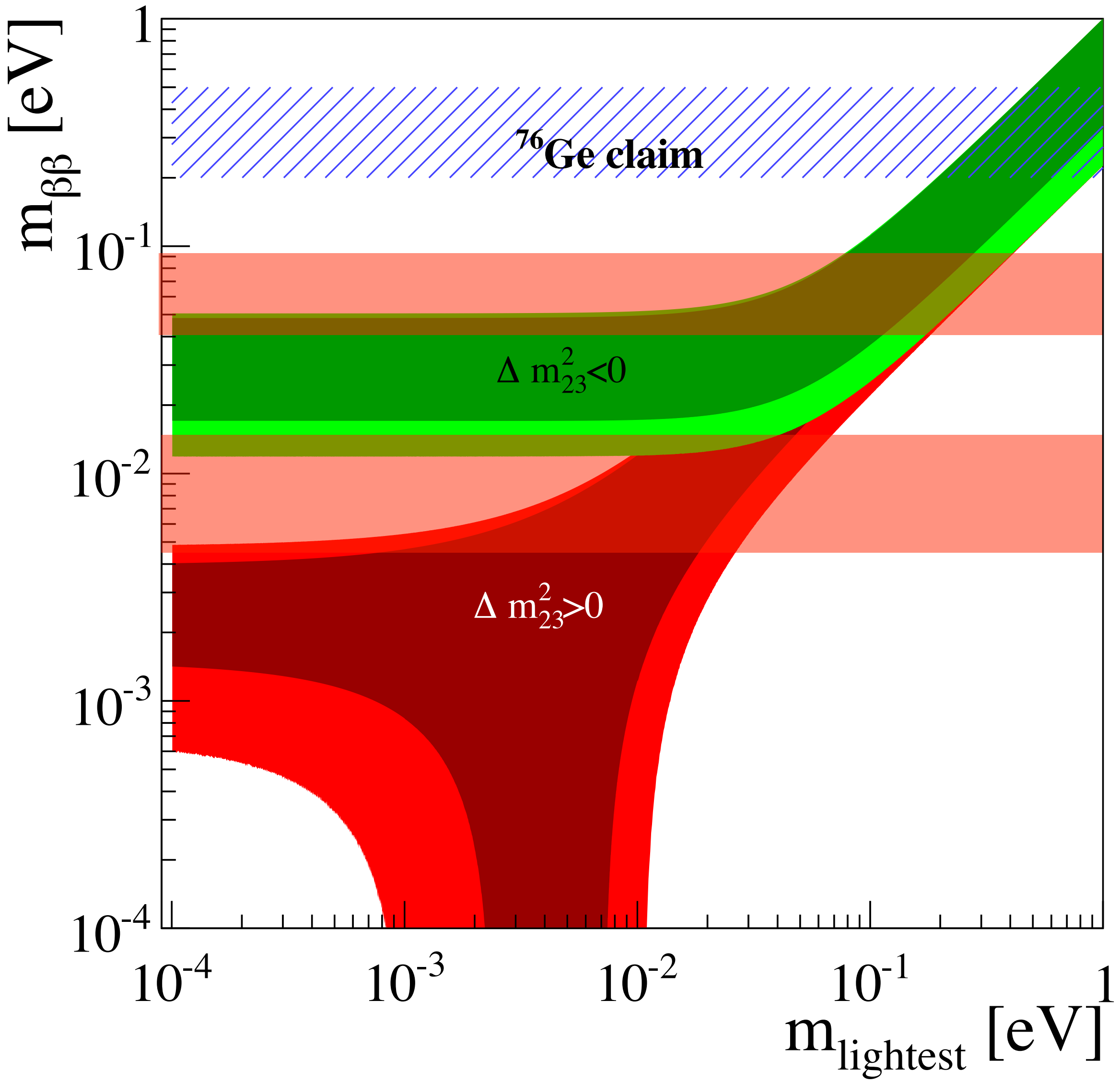
$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

DBD and Neutrino Mass



$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

DBD and Neutrino Mass



CUORE goal

Upgraded CUORE for 10 years
$m_{\beta\beta} < 5\text{-}15$ meV

$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

Other Measurements with CUORE

- Reduction in the background levels, especially at low energy, make other physics measurements possible
  - Dark matter search a la DAMA
    - Quenching factor of O(1) for bolometers
    - Look for annual modulation of detector rates
    - Requires low energy threshold (10 keV) and energy resolution of 1 keV at low energy
  - Solar axions through Bragg conversion
  - Supernova watch
  - Rare nuclear transitions

0νββ: one of the top priorities in neutrino physics

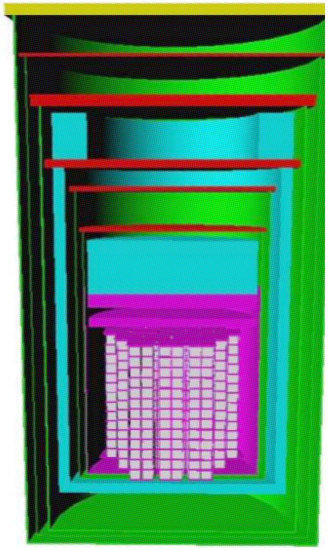
- Probe Majorana nature of neutrinos and the absolute scale of neutrino mass
- Next generation experiments: probe inverted hierarchy
- Multiple experiments and isotopes: complementary approaches and cross-checks
- CUORE: one of the leading DBD experiments in near future; to start operations in 2015

→ Stay tuned !

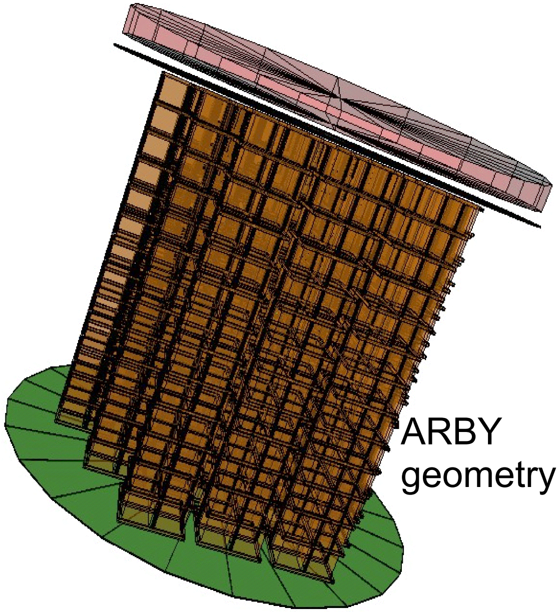
Backup

Background Analysis

- Detailed analysis of expected background contributions
  - Geant4-based Monte Carlo: QSHIELDS & ARBY
  - Inputs based on background measurements
    - ☞ Copper surface: TTT run
    - ☞ Internal contamination in TeO_2: CCVR runs
    - ☞ Heaters and bonding wires: RAD test in Hall C
    - ☞ Small parts: HPGe spectroscopy and NAA



QSHIELDS geometry



ARBY geometry

Bulk Contaminations

Material	Sample	^{232}Th [Bq/kg]	^{238}U [Bq/kg]	Technique
TeO_2 crystals	CUORE	$<8.4\cdot10^{-7}$	$<6.7\cdot10^{-7}$	bolometric (CCVR)
glue (Araldit Rapid)	CUORICINO	$<2.7\cdot10^{-3}$	$<8.2\cdot10^{-3}$	HPGe
PTFE spacers	CUORE	$<6.1\cdot10^{-6}$	$<2.2\cdot10^{-5}$	NAA
Au wires	CUORICINO	$<1.2\cdot10^{-1}$	$<9.8\cdot10^{-2}$	bolometric (RAD)
Si heaters	CUORE	$<3.3\cdot10^{-4}$	$<2.1\cdot10^{-3}$	bolometric (RAD)
NTD Ge thermistors	test sample	$<4.1\cdot10^{-3}$	$<1.2\cdot10^{-2}$	producer spec.
PEN cables	CUORE	$<1.0\cdot10^{-3}$	$<1.3\cdot10^{-3}$	NAA(Th)+HPGe(U)
polyethylene film	test sample	$<1.2\cdot10^{-3}$	$<1.4\cdot10^{-3}$	HPGe
wrapped polyethylene film	test sample	$<2.1\cdot10^{-1}$	$<1.6\cdot10^{-1}$	bolometric (T1)
NOSV Cu	CUORE	$<2.0\cdot10^{-6}$	$<6.5\cdot10^{-5}$	NAA(Th)+HPGe(U)
Roman Pb	CUORE	$<4.3\cdot10^{-5}$	$<4.6\cdot10^{-5}$	HPGe
OFE Cu	CUORE	$<6.4\cdot10^{-5}$	$<5.4\cdot10^{-5}$	HPGe
COMETA Pb	CUORE	$<1.2\cdot10^{-4}$	$<1.4\cdot10^{-4}$	HPGe
Stainless steel 300 K plate	CUORE	$<1.0\cdot10^{-2}$	$<5.0\cdot10^{-3}$	HPGe

All values are upper limits

Bulk Contaminations in ROI

Element	ROI rate from ^{232}Th [cnts/(keV·kg·y)]	ROI rate from ^{238}U [cnts/(keV·kg·y)]
TeO_2 crystal bulk	$<1\cdot10^{-4}$	$<2\cdot10^{-6}$
glue (Araldit Rapid)*	$<2\cdot10^{-7}$	$<8\cdot10^{-7}$
PTFE*	$<4\cdot10^{-5}$	$<9\cdot10^{-5}$
Au wires*	$<1\cdot10^{-3}$	$<1\cdot10^{-3}$
Si heater*	$<5\cdot10^{-6}$	$<3\cdot10^{-5}$
Ge NTD thermistors	$<1\cdot10^{-4}$	$<8\cdot10^{-4}$
PEN cables	$<1\cdot10^{-7}$	$<9\cdot10^{-8}$
Cu columns and frames	$<2\cdot10^{-5}$	$<5\cdot10^{-4}$
Cu upper and lower plates	$<3\cdot10^{-6}$	$<4\cdot10^{-5}$
Cu wire-trays	$<2\cdot10^{-6}$	$<3\cdot10^{-5}$
Cu 10 mK shield	$<2\cdot10^{-5}$	$<1\cdot10^{-4}$

All values are upper limits

(*) Anti-coincidence cuts not included

Additionally, cosmogenic activation of TeO_2 ($^{110m}Ag+^{110}Ag$) < 10^{-3} c/(keV kg y)

Cryostat Backgrounds

CUORE ROI - BULK CONTRIBUTIONS IN THE FAR REGION

Element	Material	ROI rate [cnts/(keV·kg·y)]
Cu TSP	NOSV Cu	$<4\cdot10^{-5}$
Cu 50 mK shield	OFE Cu	$<6\cdot10^{-4}$
Cu 600 mK shield	OFE Cu	$<6\cdot10^{-4}$
Cu 4 K shield	OFE Cu	$<1\cdot10^{-4}$
Cu 40 K shield	OFE Cu	$<4\cdot10^{-5}$
Cu 300 K shield	OFE Cu	$<1\cdot10^{-4}$
Cu plates from 10 mK to 40 K	OFE Cu	$<2\cdot10^{-5}$
inner Pb vessel	Roman Pb	$<4\cdot10^{-3}$
Pb top disk	Cometa Pb	$<5\cdot10^{-5}$
Fe 300 K plate	stainless Steel	$<3\cdot10^{-4}$

Only ^{208}Tl simulated: conservative upper limit

Environmental Backgrounds

Source	Total	Anti-coincidence (global)	Anti-coincidence (near neighbors)
gamma	$<0.4\times10^{-3}$ (stats limited)	$<0.4\times10^{-3}$ (stats limited)	$<0.4\times10^{-3}$ (stats limited)
muon	$(17.3\pm0.3)\times10^{-3}$	$(0.104\pm0.022)\times10^{-3}$	$(1.9\pm0.5)\times10^{-3}$
neutron	$(0.270\pm0.022)\times10^{-3}$	negligible	negligible

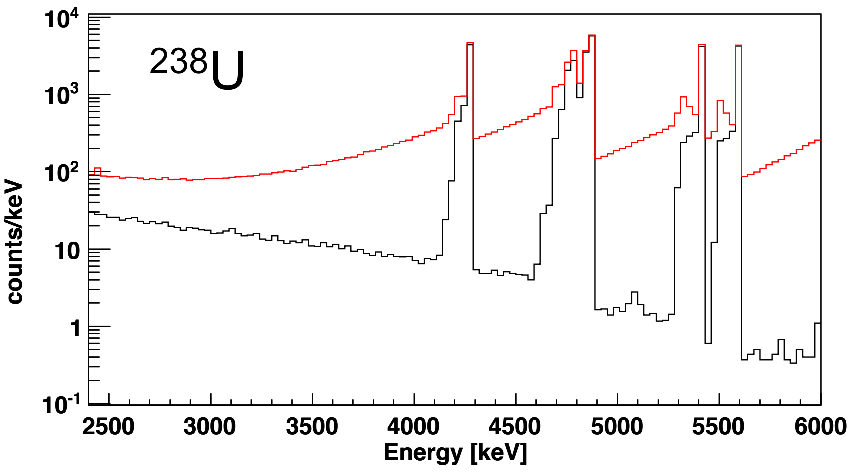
Neutron and muon backgrounds are cosmogenic, gamma backgrounds are from rock radioactivity. Upper limits are limited by MC statistics

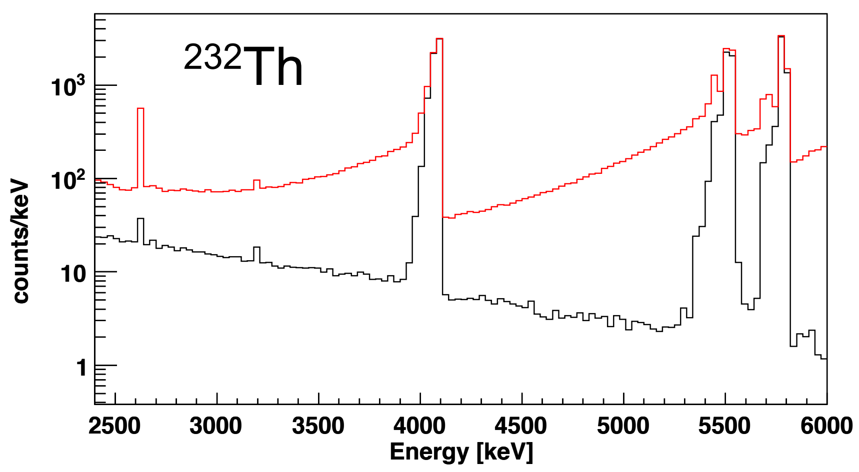
Surface Backgrounds

Material	Sample	Depth [μm]	^{232}Th [Bq/cm^2]	^{238}U [Bq/cm^2]	^{210}Pb [Bq/cm^2]	Tecnique
TeO_2 crystals	CUORE	0.01	$<1.6 \cdot 10^{-9}$	$<6.3 \cdot 10^{-9}$	$<9.8 \cdot 10^{-7}$	bolometric (CCVR)
		0.2	$<2 \cdot 10^{-9}$	$<7.6 \cdot 10^{-9}$	$<2.2 \cdot 10^{-8}$	”
		1	$<1.9 \cdot 10^{-9}$	$<8.9 \cdot 10^{-9}$	$<9.2 \cdot 10^{-9}$	”
		5	$<1.0 \cdot 10^{-9}$	$<5.4 \cdot 10^{-9}$	$<5.6 \cdot 10^{-9}$	”
		10	$<8.3 \cdot 10^{-10}$	$<4.4 \cdot 10^{-9}$	$<4.9 \cdot 10^{-9}$	”
Copper	TECM	0.1-10	$<7 \cdot 10^{-8}$	$<7 \cdot 10^{-8}$	$<9 \cdot 10^{-7}$	bolometric (T3)
PEN cables	CUORE	0.1-30	$<4 \cdot 10^{-6}$	$<5 \cdot 10^{-6}$	$<3 \cdot 10^{-5}$	Si diode
PTFE spacers	CUORE	0.1-30	$<6 \cdot 10^{-7}$	$<5 \cdot 10^{-7}$	$<7 \cdot 10^{-6}$	bolometric (T1)
NTD Ge thermistors	test sample	0.1-10	$<8 \cdot 10^{-6}$	$<5 \cdot 10^{-6}$	$<4 \cdot 10^{-5}$	Si diode

Anti-Coincidence Cut

Effect of anti-coincidence cut on TeO_2 surface backgrounds



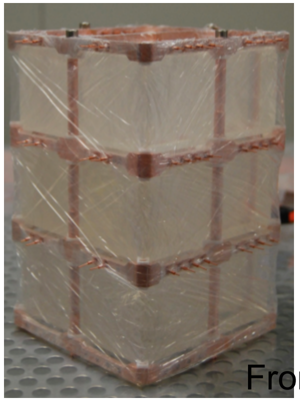
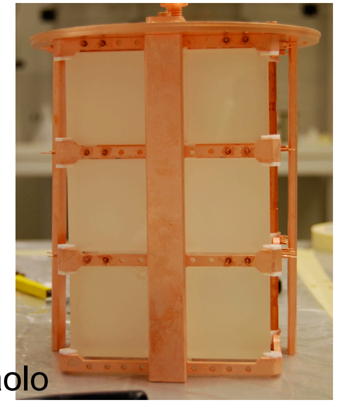
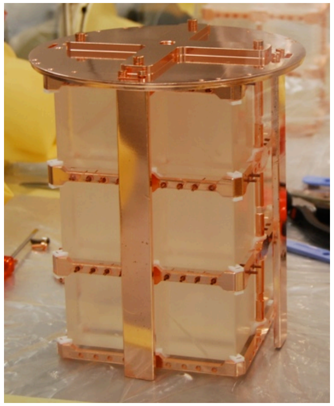


Surface Background: TTT Run

Dedicated run in Hall A: 9/2009-1/2010

3 towers with copper processed by different techniques

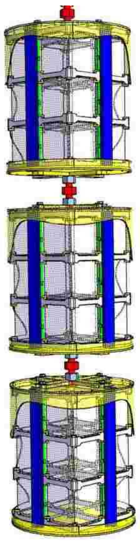
T1- Polyethylene	T2 - Gran Sasso	T3 - Legnaro
Cleaning: • Soap • H_2O_2 + H_2O + Citric acid Polyethylene: 7 layers	Chemical New Cleaning: • Soap • Electroerosion: 85% phosphoric acid, 5% butanol, 10% H_2O • Etching: Nitric acid •Passivation: H_2O_2 + H_2O + Citric acid	Complete Legnaro procedure - TECM Cleaning: • Tumbling • Electropolishing • Chemical Etching • Magnetron (plasma)

From Paolo

TTT Results

TTT



Detector	**3-4 MeV rate cnts / (keV kg y)**	**Sources**
T1 - copper wrapped with polyehtylene film	0.052 +/- 0.008 with single-hit cut	TeO_2 crystals (partially subtracted) PTFE spacers polyehtylene film
T2 - copper treated with an etching procedure	0.120 +/- 0.012 no coincidence cut	TeO_2 crystals PTFE spacers copper
T3 - copper treated with TECM procedure	0.072 +/- 0.008 no coincidence cut	TeO_2 crystals PTFE spacers copper

Scaling to CUORE:

TECM process: rate < 0.017-0.035 c/(keV kg y) in ROI
Poly wrapping: rate < 0.013-0.025 c/(keV kg y) in ROI

Surface Contamination Summary

Element	ROI rate [cnts/(keV·kg·y)]	Notes
TeO_2 crystal surface	$<4\cdot10^{-3}$	upper limit due to poor statistics
Cu - TECM cleaning	$<3\cdot10^{-2}$	no crystal background subtraction (T3 data)
Cu - polyethylene wrapping	$<2\cdot10^{-2}$	partial crystal background subtraction (T1 data)
PTFE	$<6\cdot10^{-2}$	new measurement in progress
PEN cables	$<1\cdot10^{-3}$	new measurement in progress

CUORE Background Budget

Region	Source	ROI rate cnts/(keV·kg·y)
Near	^{110m}Ag+^{110}Ag (half-life = 250 days) in TeO_2 crystals	$\sim 1 \cdot 10^{-3}$
Near	^{232}Th or ^{238}U in the Au bonding wires	$< 1 \cdot 10^{-3}$
Near	^{238}U in the NOSV Cu elements	$< 0.7 \cdot 10^{-3}$
Far	^{232}Th in the OFE Cu elements	$< 1.5 \cdot 10^{-3}$
Far	^{232}Th in the Roman lead shield	$< 4 \cdot 10^{-3}$
External	muon interaction	$\sim 1.8 \cdot 10^{-3}$
Near	TeO_2 crystals surface activity	$< 4 \cdot 10^{-3}$
Near	copper and/or PTFE surface activity	$<$(2-6)$\cdot 10^{-2}$

Scaling to CUORE-0

- Assume:
  - Similar surface contaminations as CUORE (Cu processed with LNL TECM technique)
  - Similar bulk TeO_2 and Cu contamination
  - Additional bulk contribution from Hall A cryostat shields from Cuoricino of 0.05 c/(keV kg y)
  - Resolution 5 keV FWHM
- Best case: bkg of 0.05 c/(keV kg y)
- Worst case: 0.11 c/(keV kg y)