The search for neutrinoless double beta decay with the CUORE experiment

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on behalf of the CUORE collaboration

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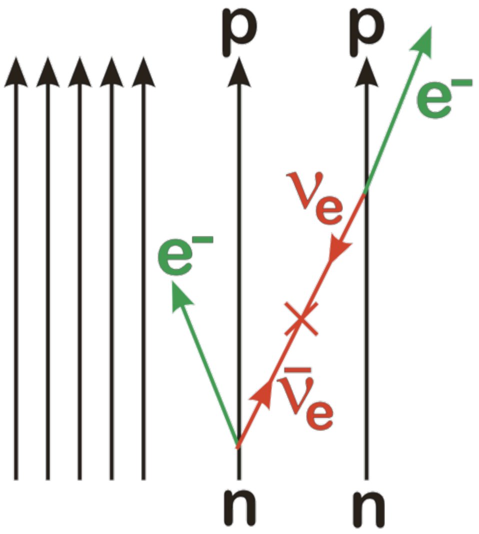
CUORE

ββ0ν decay for neutrino physics

- Neutrinos' open questions:
  - absolute neutrino mass scale
  - neutrino mass hierarchy
  - DIRAC $\nu_e \neq \bar{\nu}_e$ or MAJORANA $\nu_e = \bar{\nu}_e$ nature

- Neutrinoless double beta decay could address these questions



- ββ0ν observation would imply:
  - Lepton number non conservation
  - Majorana nature of the neutrinos

Where we stand

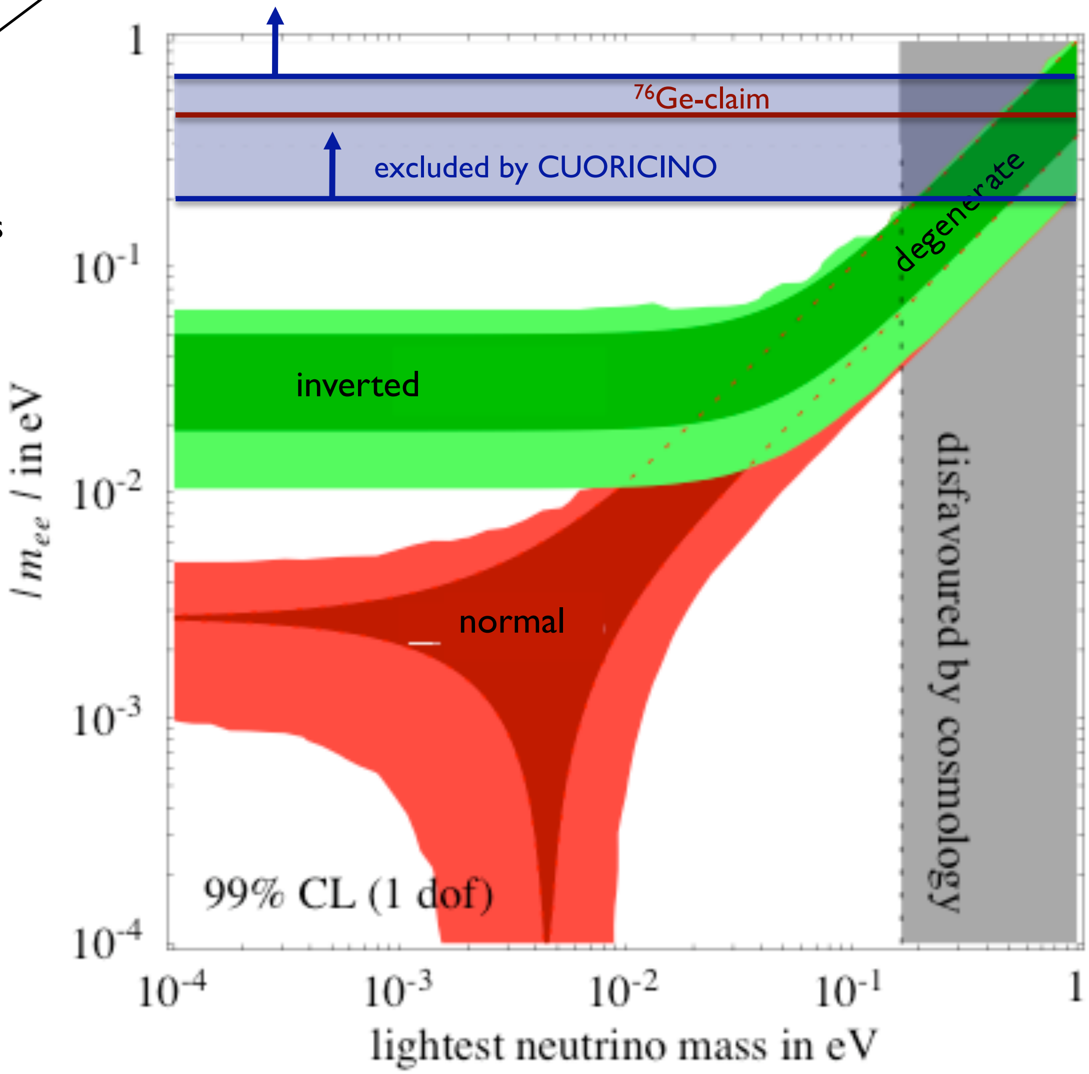
$$T^{0\nu}_{1/2} \sim \frac{1}{G^{0\nu}\left|M^{0\nu}\right|^2 \left\langle m_{ee} \right\rangle^2}$$

phase space factor
~ Q^5

nuclear matrix elements
» uncertainties

effective Majorana neutrino mass

$$\left\langle m_{ee} \right\rangle = \left| \sum_{i=1}^{N} \lambda_i \left|U_{ei}\right|^2 m_i \right|$$



Strumia, Vissani arXiv:hep-ph/0606054v2

CUORE and next generation experiments **goal**:

- probe the inverted hierarchy region
- check ^{76}Ge claim

The rules of the game

Sensitivity $F^{0\nu}$ **:** Lifetime corresponding to the minimum number of detectable events above background at a given C.L.

isotopic abundance

active mass

live time

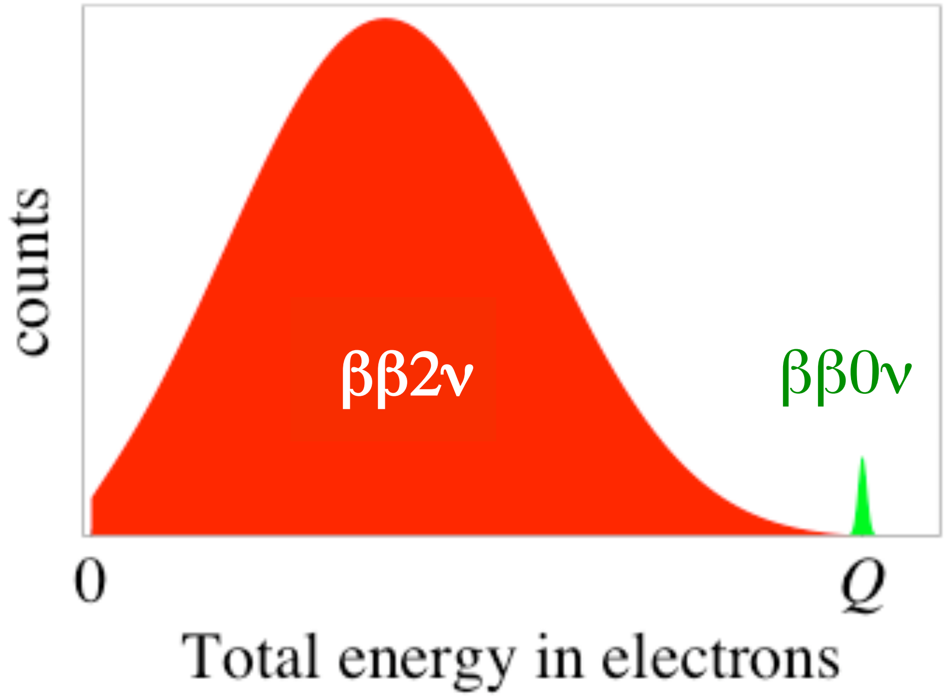
energy resolution

$$F^{0\nu} \sim \frac{a}{A}\sqrt{\frac{M\cdot T}{b\cdot \Delta E}}$$

atomic mass

background level

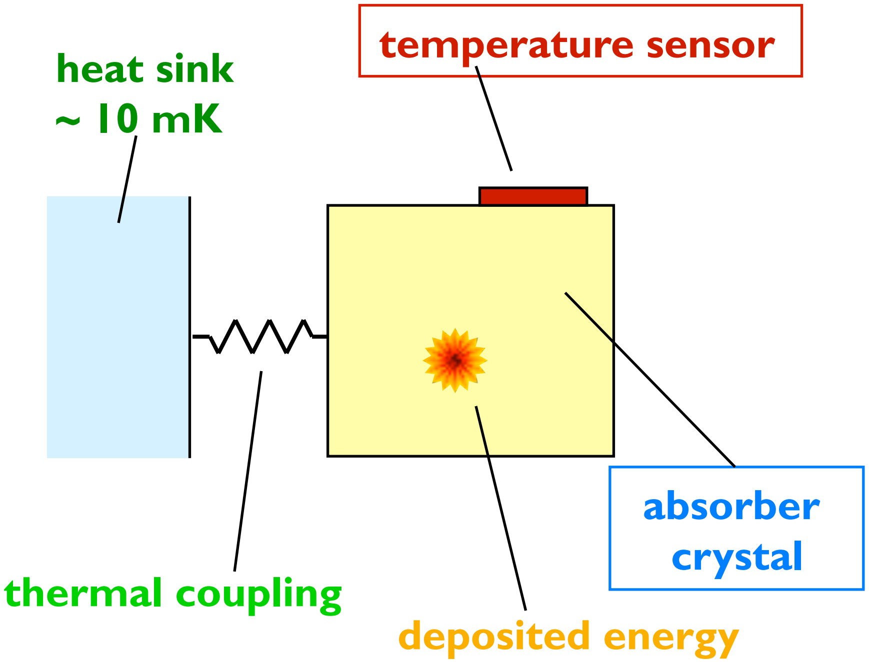
Experimental signature: peak at the transition Q value, enlarged by detector resolution, over the unavoidable background due to ββ2ν



CUORE:

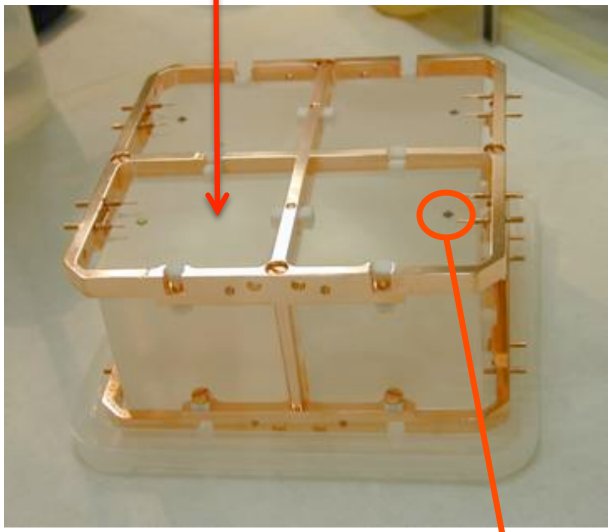
$Q_{\beta\beta0\nu}(^{130}\mathrm{Te})$ = 2530.3 ± 2.0 keV

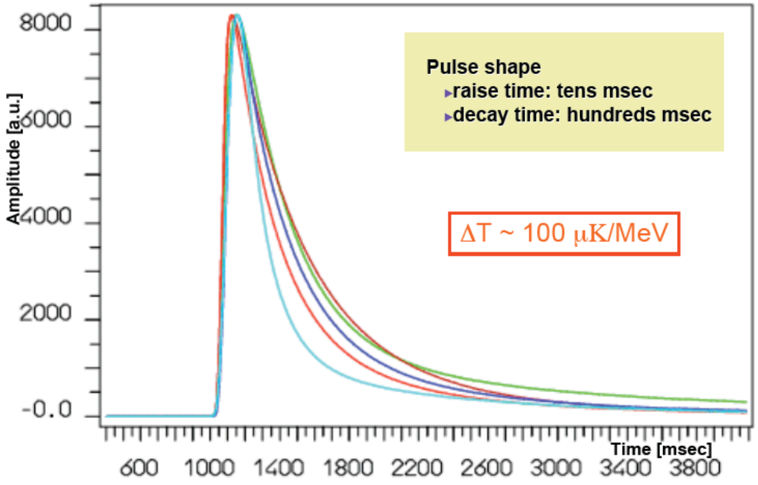
TeO_2 bolometers



Absorber crystal

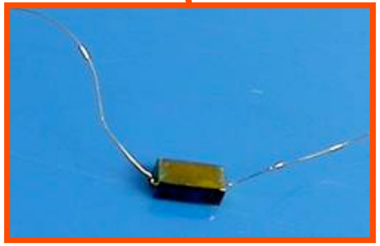
The absorber is a $5x5x5\ cm^3$ (790 g) crystal of TeO_2 which contains the ββ0ν candidate ^{130}Te





Temperature sensor

The thermal signal is measured by means of an NTD Ge Thermistor



$$R(T) = R_0 e^{\sqrt{\frac{T_0}{T}}}$$

The Cuoricino experiment

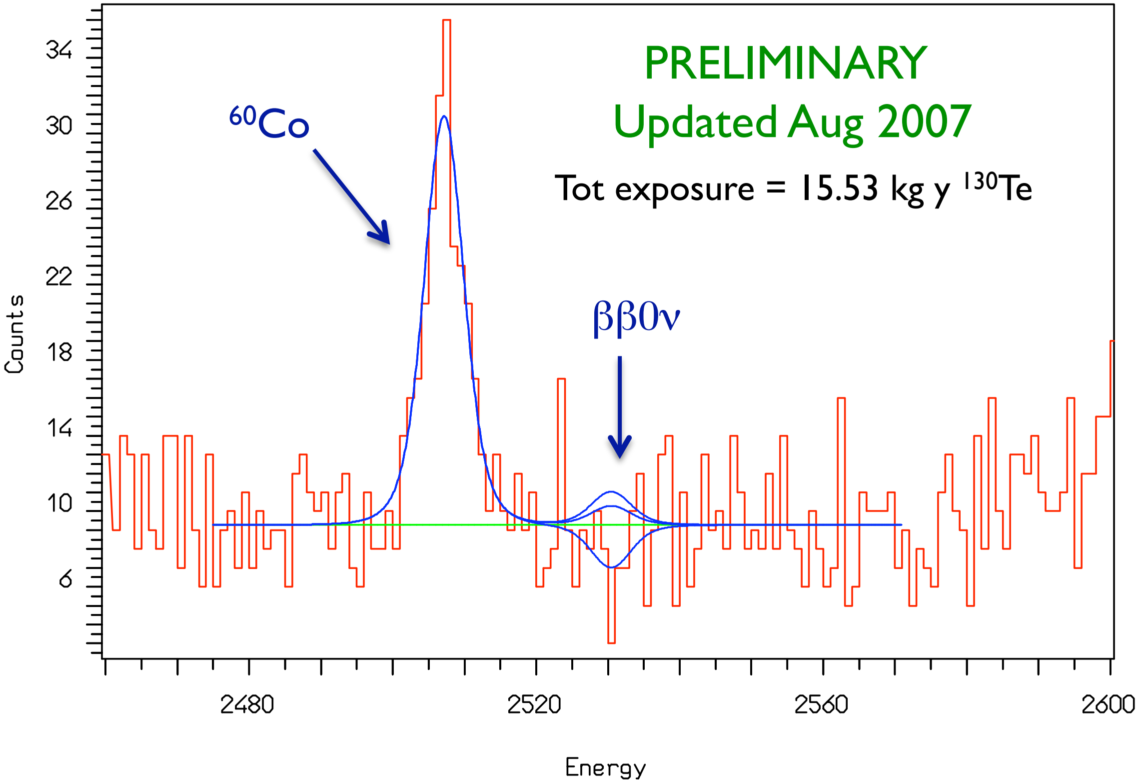
- 62 TeO_2 bolometers
- Total detector mass:

  M ~ 11 kg ^{130}Te ~ 5x10^{25} ^{130}Te nuclides

- Deep underground in the Gran Sasso Laboratory (Italy) (3500 m.w.e.)

- Started in 2003, currently the largest operated bolometric experiment

Cuoricino results



Background in ββ region

0.18 ± 0.01 c/keV/kg/y

anticoincidence spectrum, only 5x5x5 cm^3 crystals

Average resolution @ 2615keV

~ 8keV

during calibrations, only 5x5x5 cm^3 crystals

Results for 0νββ half life and Majorana mass (90% c.l.):

$T_{1/2}^{0\nu}$ (^{130}Te) > 3.1 x 10^{24} y

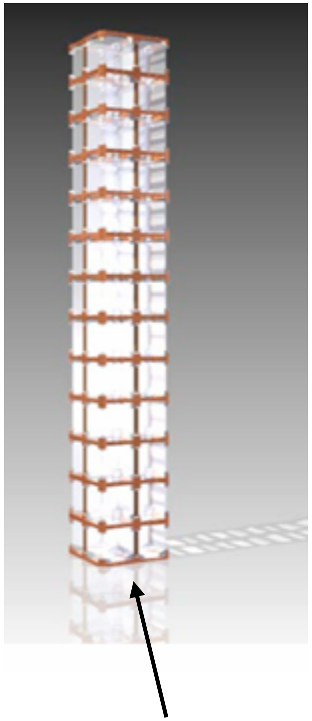
$m_{\beta\beta}$ < 200 - 680 meV (*)

(*) using NME from Rodin et al, Nucl. Phys. A 776 (2006) and erratum arXiv::nucl-th/0706.4304

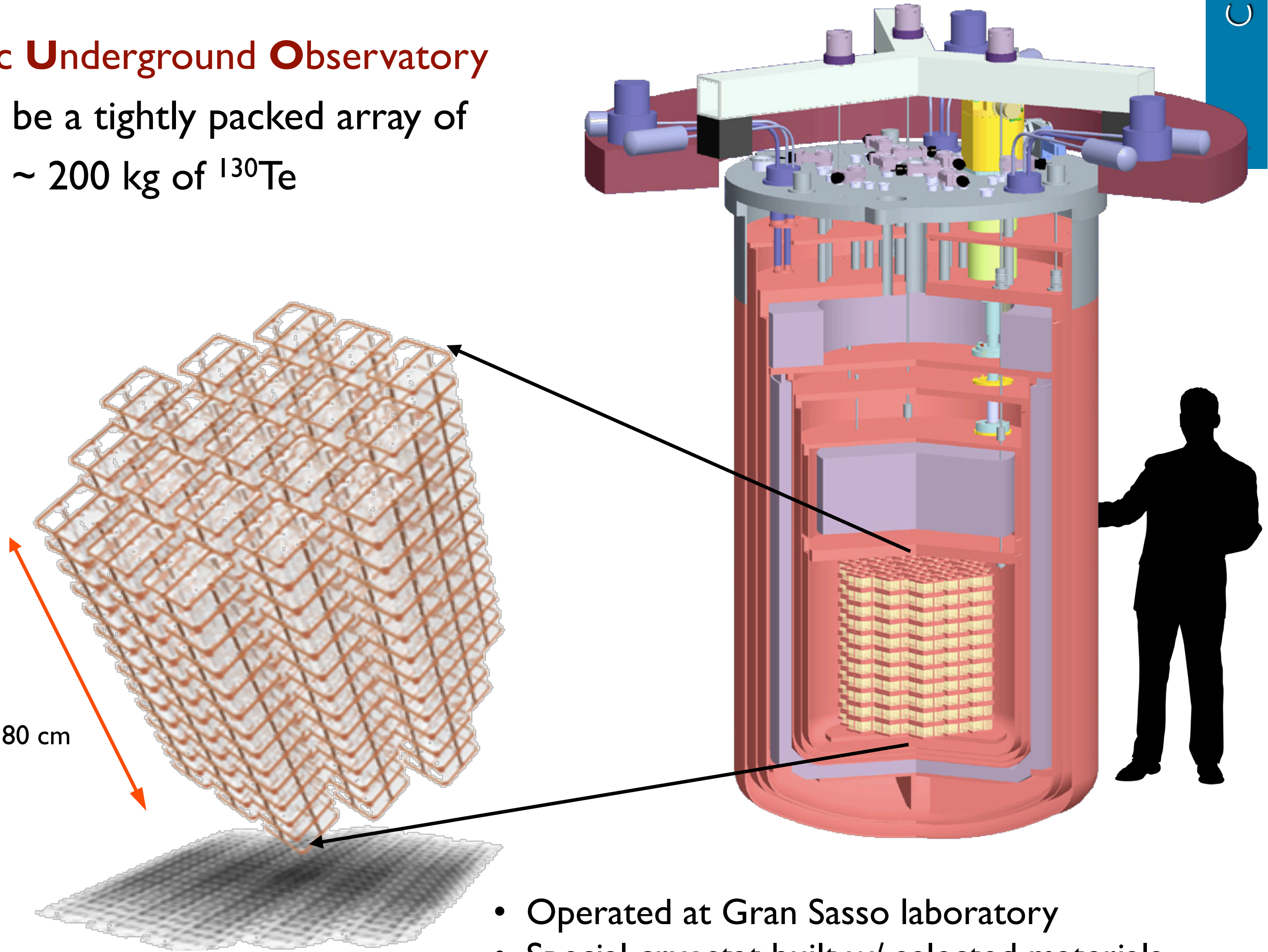
- Cuoricino demonstrates the feasibility of a large scale bolometric detector with good energy resolution and background

CUORE

CUORE: **C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents will be a tightly packed array of 988 bolometers - M ~ 200 kg of ^{130}Te



19 Cuoricino-like towers with 13 planes of 4 crystals each

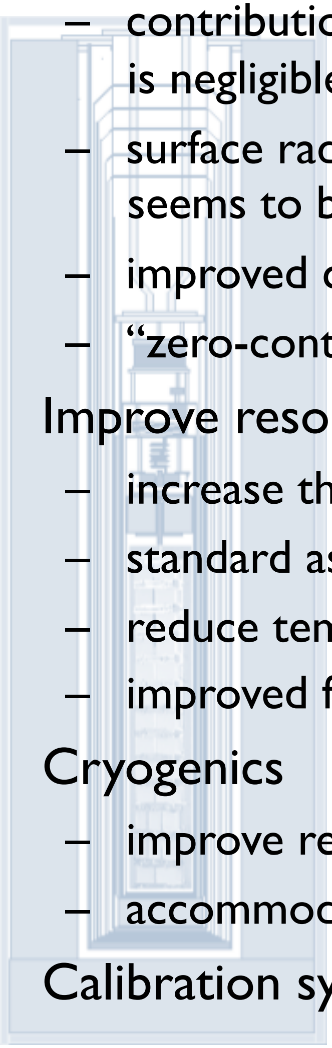


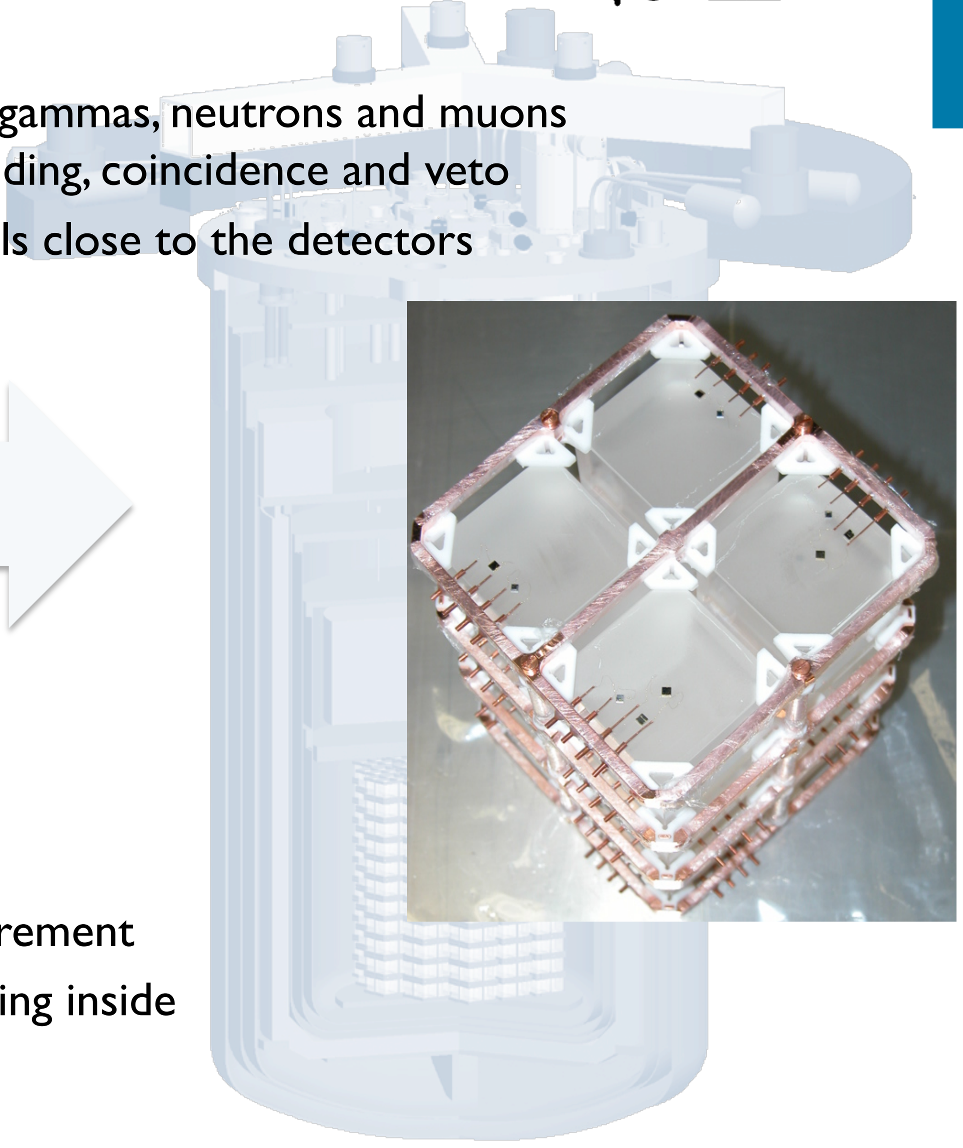
- Operated at Gran Sasso laboratory
- Special cryostat built w/ selected materials
- Cryogen-free dilution refrigerator
- Shielded by several lead shields

CUORE challenges

$$F^{0\nu} \sim \sqrt{\frac{M \cdot T}{b \cdot \Delta E}}$$

- Background reduction
  - contribution from environmental gammas, neutrons and muons is negligible due to improved shielding, coincidence and veto
  - surface radioactivity from materials close to the detectors seems to be the limiting factor
  - improved cleaning procedure
  - "zero-contact" assembly
- Improve resolution
  - increase thermistors uniformity
  - standard assembly procedure
  - reduce temperature instabilities
  - improved frame design
- Cryogenics
  - improve reliability for long measurement
  - accommodate the required shielding inside
- Calibration system





The CUORE detector calibration system

- Goal: uniform energy calibration of the γ region of the energy spectrum for all the 988 CUORE bolometers

- CUORICINO: monthly calibration with γs from ^{232}Th sources placed outside the cryostat

- CUORE:
  - need to move a γ emitter in between the towers and then remove it
  - avoid radioactive contamination of the detector
  - minimize thermal load on the cryostat
  - minimize calibration (loss in detector live time)

The CUORE detector calibration system

R&D ongoing at University of Wisconsin - Current conceptual design

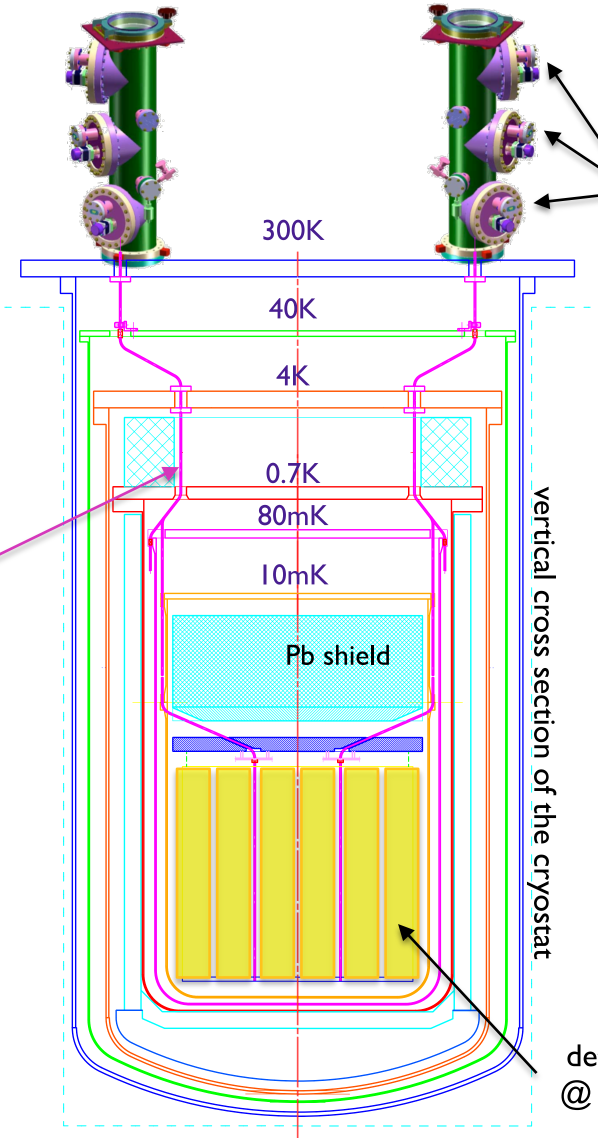
Source in the form of proton activated iron (**^{56}Co**) or thoriated tungsten (**^{232}Th**) could be carried in very small sealed cylinders crimped on a Kevlar string

Source carriers will be deployed from spools and guided into the detector area by means of guide tubes

- friction issues
- thermal connections
- source carrier cool-down

All materials must comply with the cryostat radiopurity requirements

(<1.0E-12 g/g in U & Th for copper)



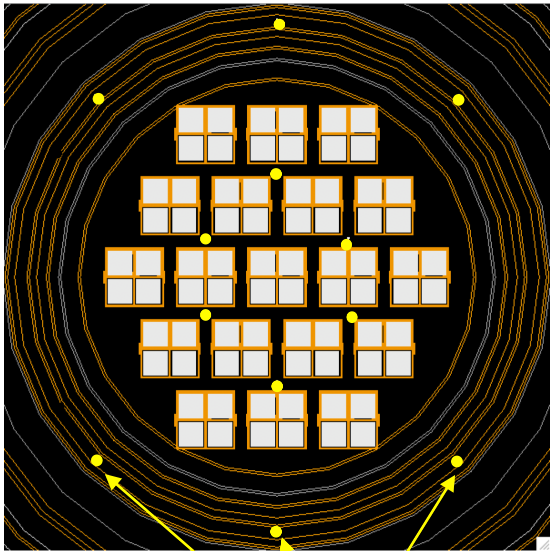
computer controlled motion box (x4)

3 independent source carriers drives

vertical cross section of the cryostat

detectors @ ~10mK

top view w/ source position



sources

Projected sensitivity for CUORE

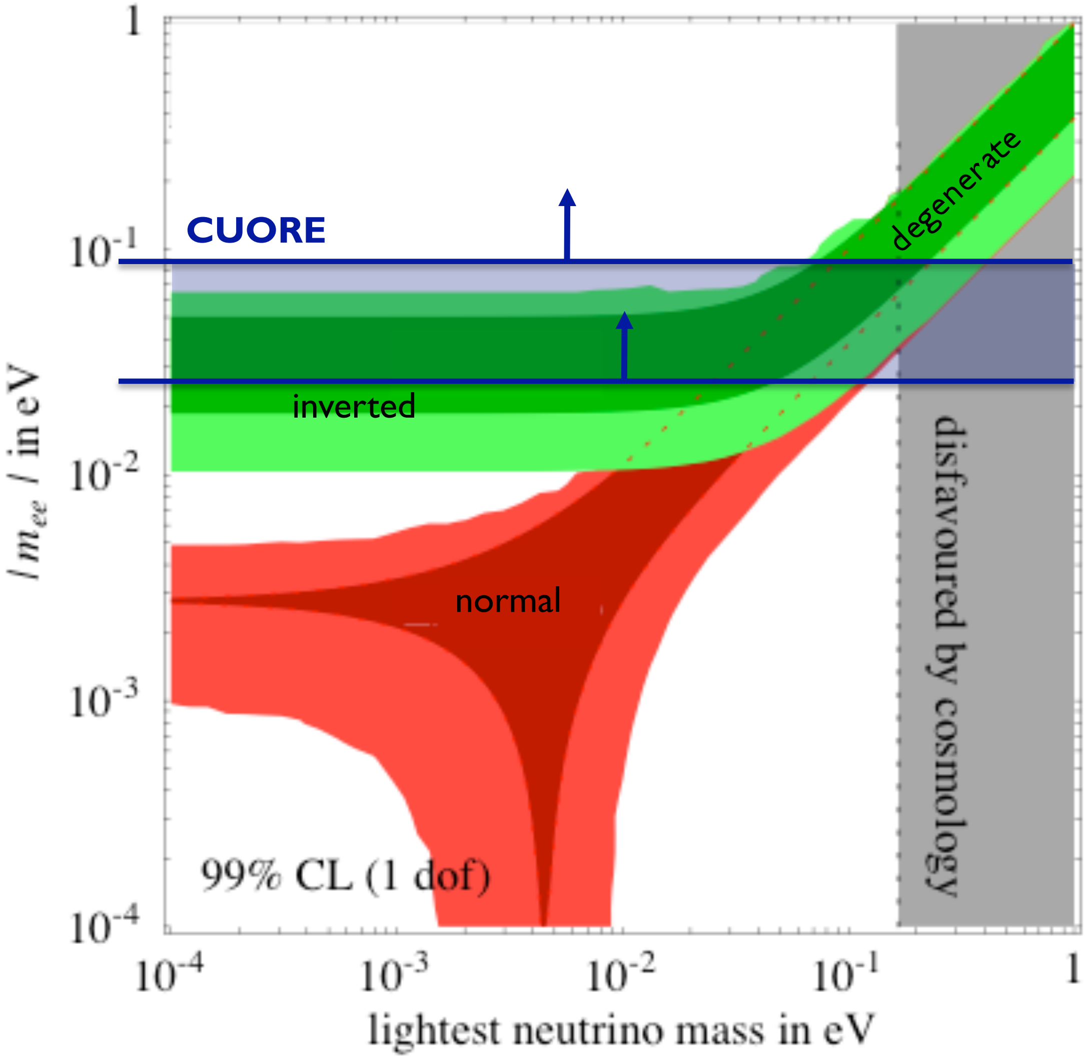
Projected

Background in ββ region
0.01 c/keV/kg/y

Average resolution
~ 5 keV

Live time
5 years

$T_{1/2}^{0\nu}$ (^{130}Te) > 2 x 10^{26} y
$m_{\beta\beta}$ < 24 - 83 meV



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CUORE Status and schedule

- Hut construction started at LNGS
- Copper procured
- Crystals production started
- Dilution refrigerator is being built


Status of the hut construction as of March 2008

- CUORE Schedule
  - summer 2008: Cuoricino decommissioning
  - fall 2008: start construction of the first CUORE tower
  - spring 2009: start data-taking of the first CUORE tower
  - 2009-2010: CUORE assembly and commissioning
  - early 2011: CUORE data taking

Conclusions

- CUORE searches for $0\nu\beta\beta$ to investigate the Majorana nature of neutrinos and to probe the inverted hierarchy region of neutrino masses.

- CUORE detector technology is based on the outstanding experience and knowledge gained with the Cuoricino experiment.

- To achieve its goal, CUORE has to face some challenges, especially in the reduction of the background.

- CUORE is not simply a larger version of Cuoricino and developing the calibration system is extremely challenging.

- The solution to these challenges is almost at hand and the construction of CUORE is already started.

CUORE collaboration

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