Investigating Neutrino Masses with CUORE

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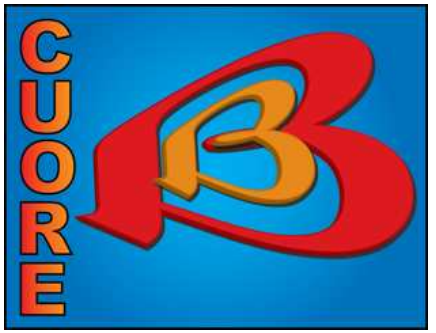
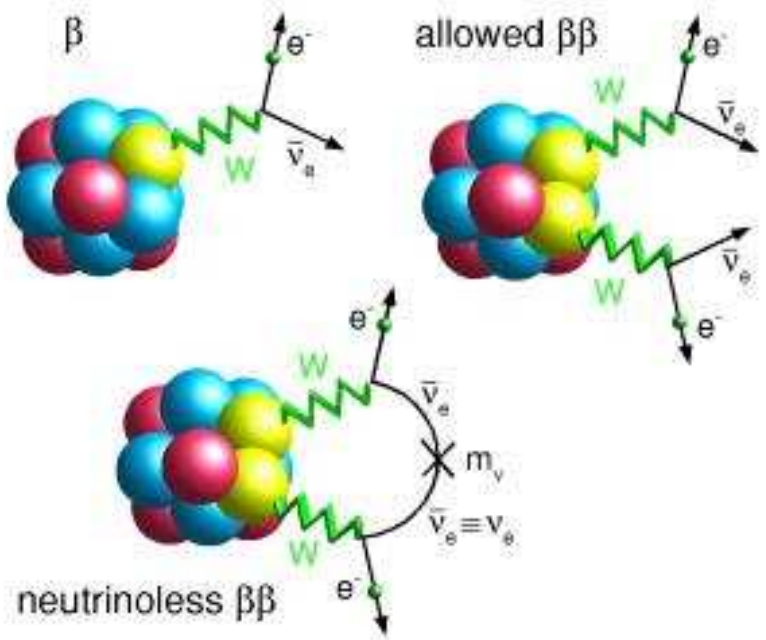
735 Particle Physics

December 4, 2008



Neutrinoless Double-Beta Decay ($0\nu\beta\beta$)



What CUORE hopes to discover:

- Majorana particles? ($\nu=\bar{\nu}$?)
  - → lepton number is not conserved
- Improved limits on absolute ν mass scale
- Mass hierarchy?

Why Majorana Neutrinos Are Interesting: Seesaw

A Dirac mass term couples a right-handed field to a left-handed field or vice versa.

A Majorana mass term couples a right-handed field to another right-handed field or vice versa.

Type I Seesaw introduces heavy right-handed singlet neutrinos as counterparts to the familiar light neutrinos in order to provide a 'natural' explanation for the small mass of the neutrino:

Mass matrix for (ν_L,ν_R) system

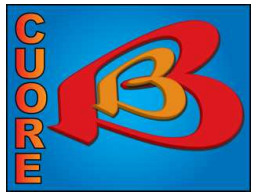
Dirac terms: similar scale to quark, charged lepton sectors

$$\begin{pmatrix} 0 & h_\nu v \\ h_\nu^T v & M_R \end{pmatrix}$$

Majorana term: much heavier, $M_R >> h_\nu v$

$$\Rightarrow m_\nu \approx -h_\nu^2 v^2 / M_R$$

Why Majorana Neutrinos Are Interesting: Leptogenesis



Where did the net baryon number in the Universe come from?
A possible explanation is leptogenesis:

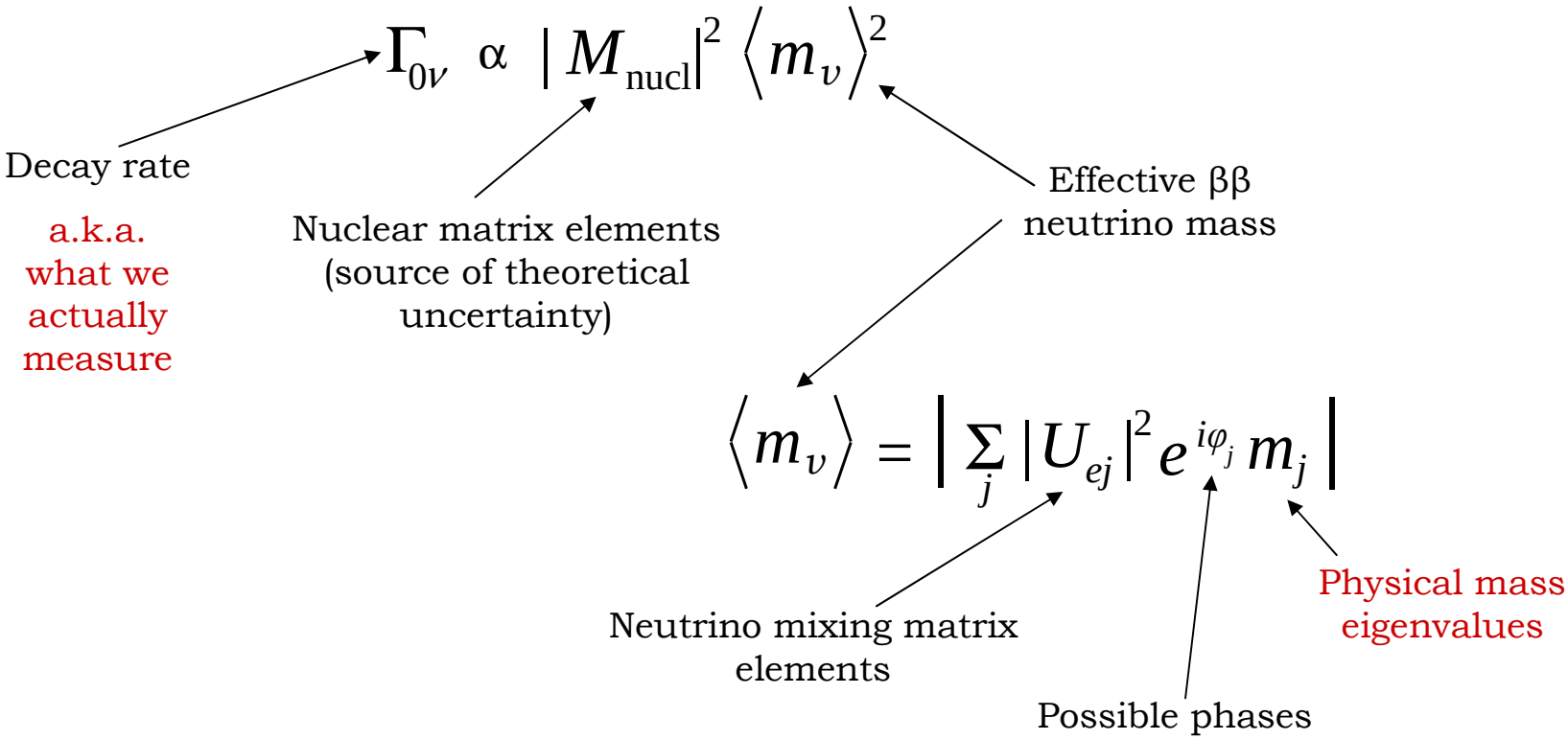
1) Lepton-number-violating processes produce net L

- Majorana neutrinos explicitly violate L
- In the early universe, temperatures were high enough for a significant population of heavy ν_R's to be around, and to undergo L-violating decays

2) (B–L)-conserving processes convert net L into net B

- Contained in the Standard Model ("sphaleron transitions")

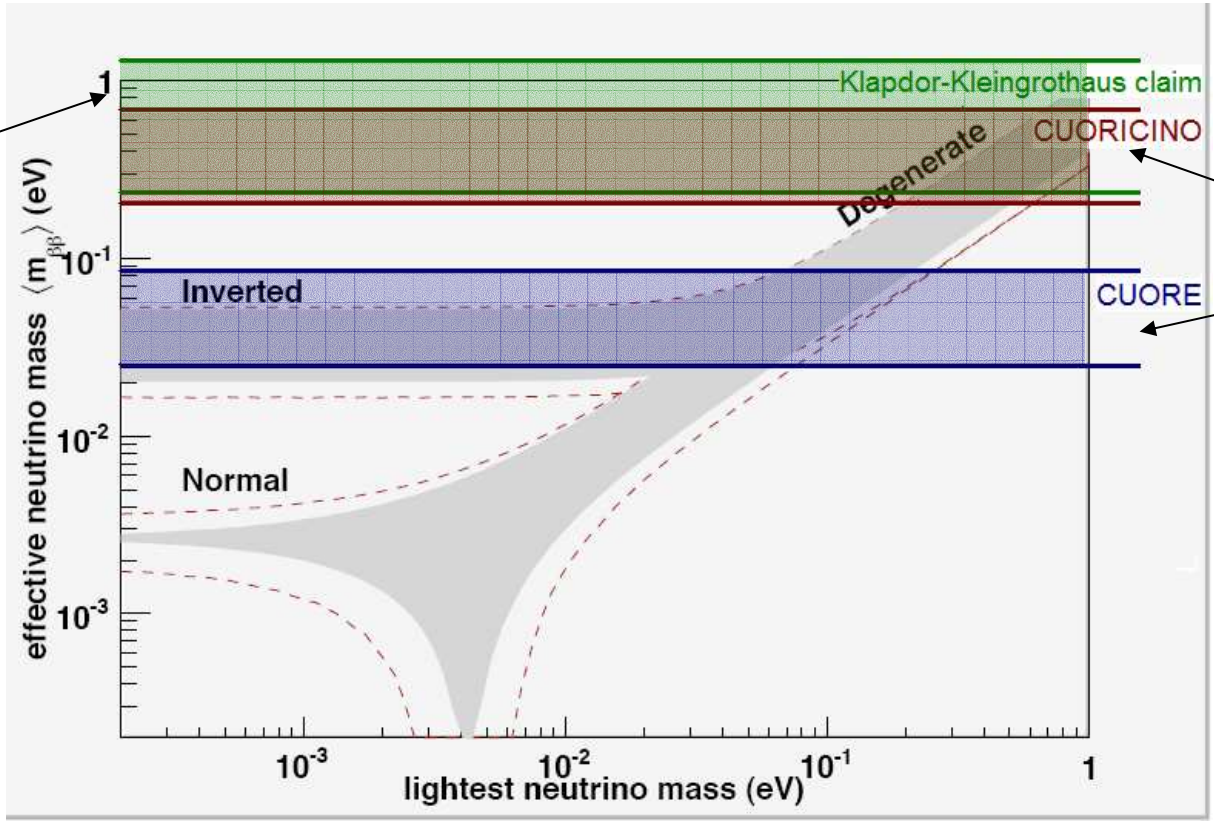
Absolute Mass Scale and Some Tricky Math



So what we can do is set a lower limit: **at least one $m_j \geq \langle m_\nu \rangle$**

Hierarchy and the Current Experimental Situation

mass range corresponding to claim of discovery in Ge



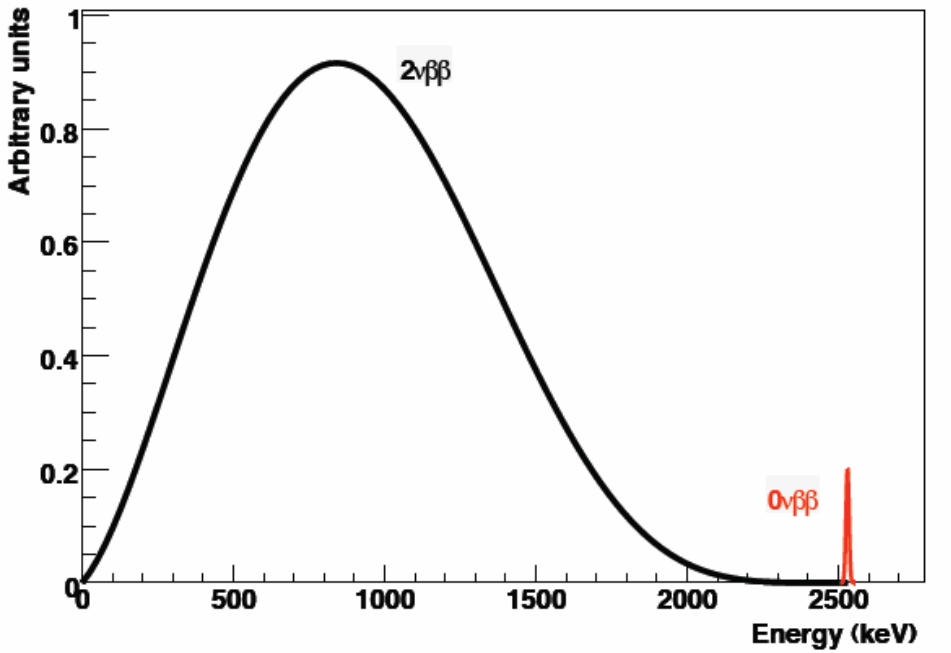
limits on mass to within theoretical uncertainty

Double-Beta Decay in Tellurium 130

What we are looking for is an energy signal:

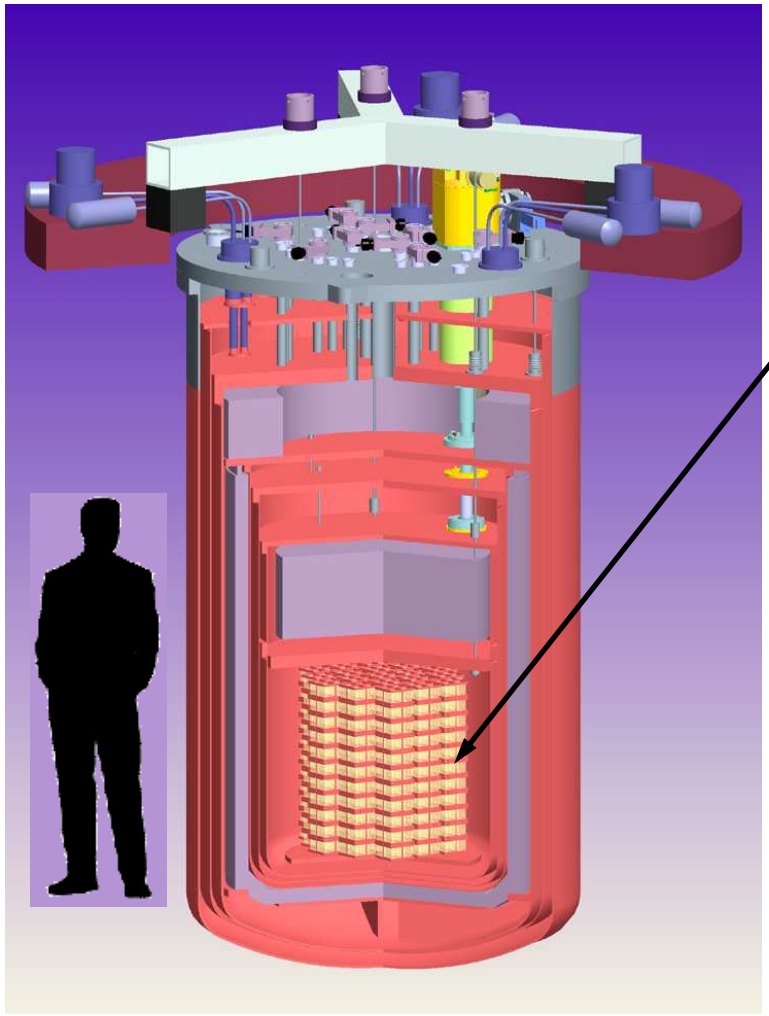
Q-value for $0\nu\beta\beta$ in ^{130}Te

2530.3 ± 2.0 keV



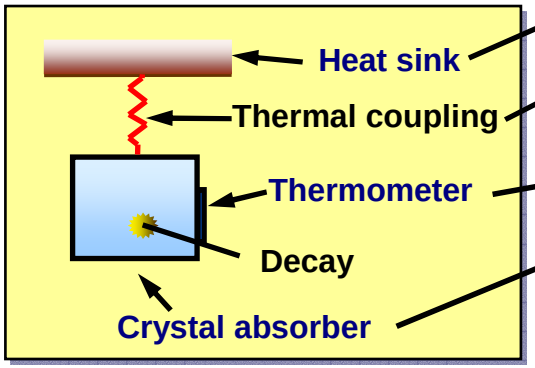
Cartoon of ββ in CUORE, neglecting backgrounds

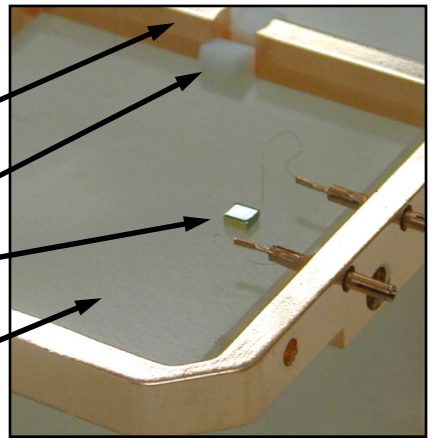
The CUORE Detector I



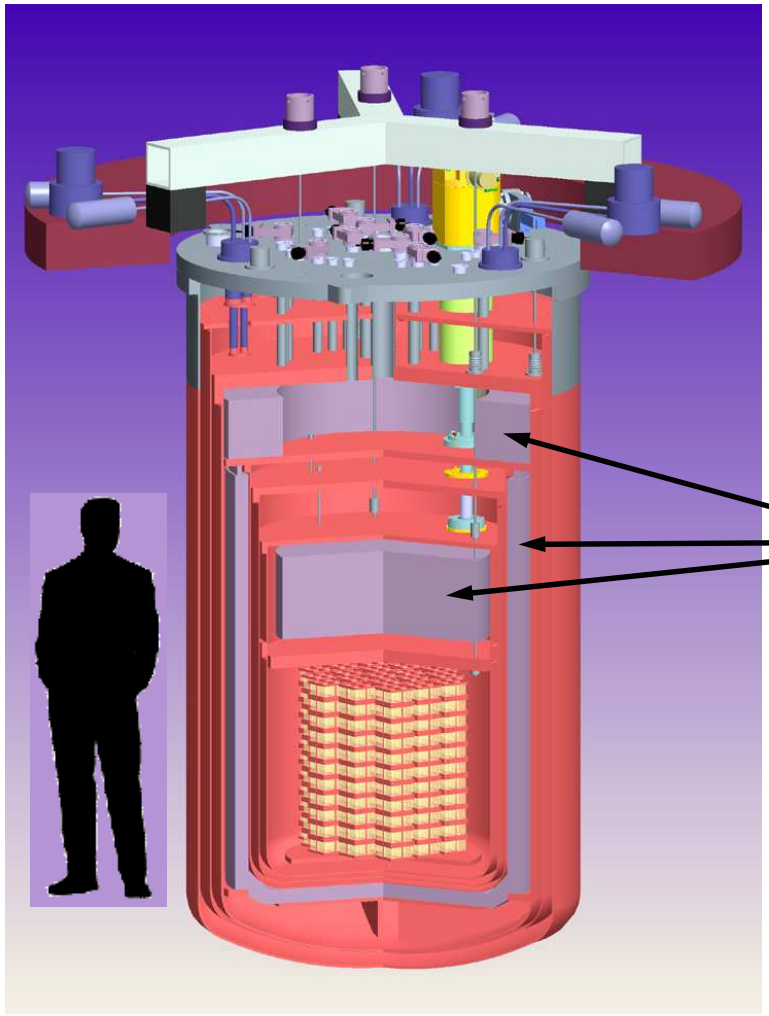
An array of bolometers

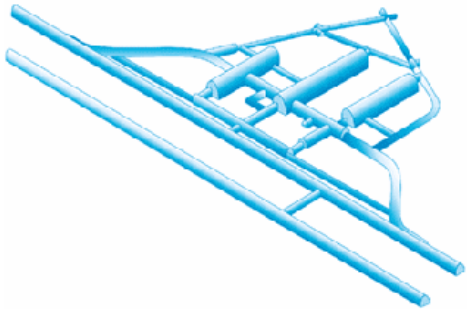
- 988 5x5x5 cm^3 TeO_2 crystals
  - detector mass ~750 kg; ^{130}Te mass ~200 kg
- 8-10 mK
- Temperature change caused by energy deposition read out by thermistors





The CUORE Detector II



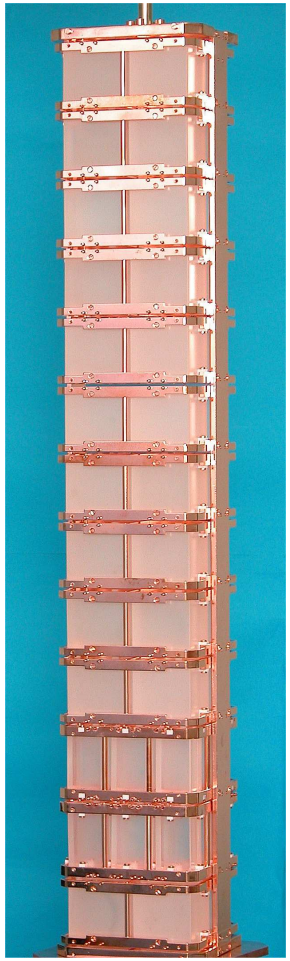


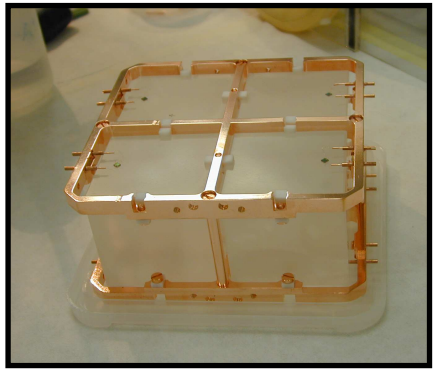
The underground lab at LNGS

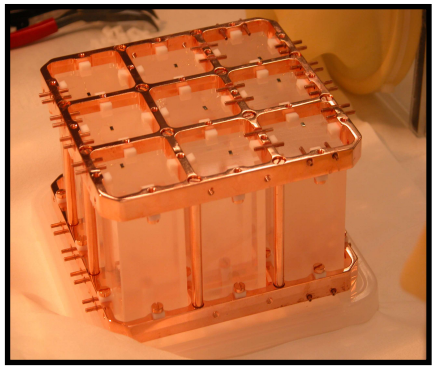
A low-background environment

- Several lead shields
- All materials close to/part of detector array (e.g. copper structure) cleaned, and handled in clean-room
- Run underground at the Laboratori Nazionali del Gran Sasso

CUORICINO







- 44 5x5x5 cm^3 and 18 3x3x6 cm^3 TeO_2 crystals
  - detector mass 40.7 kg; ^{130}Te mass 11 kg
- Pilot experiment to test the technologies to be used in CUORE
- Running at LNGS from 2003 to 2008

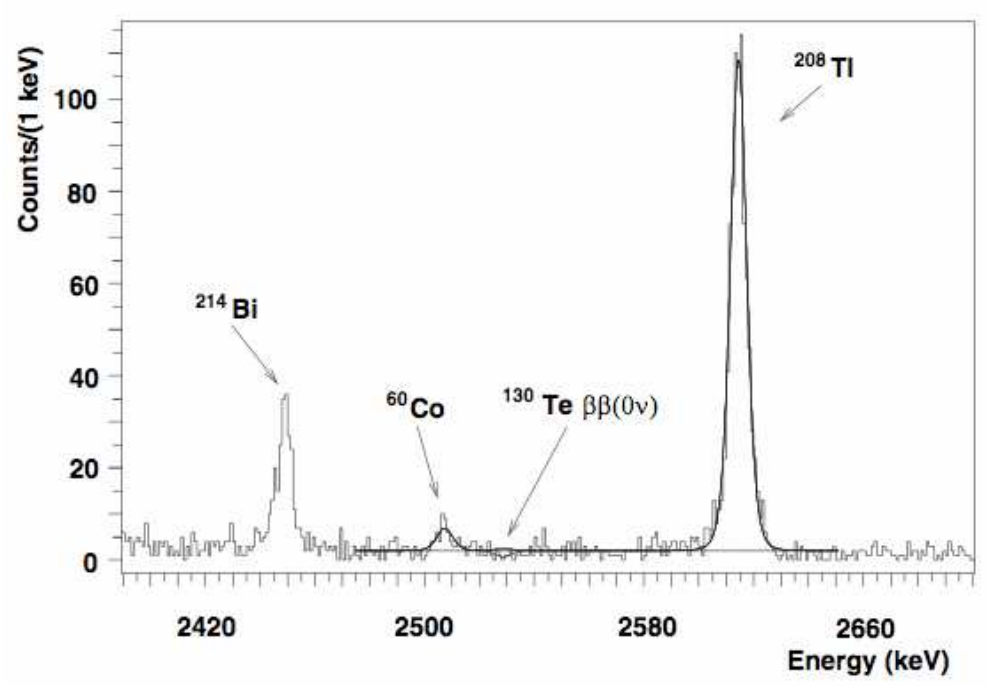
What We See in CUORICINO

Most relevant backgrounds – U and Th contamination

- Flat α background
  - Copper surfaces
  - Crystal surfaces
- 2615 keV γ line
  - Decay chain of Th in cryostat shields

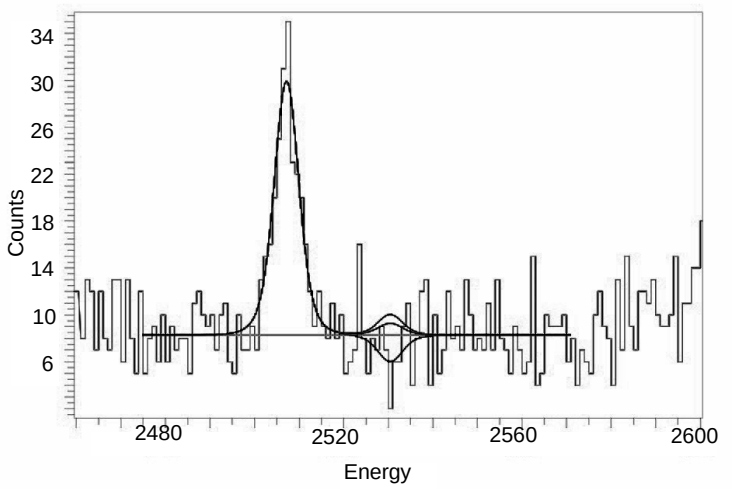
…And additional concerns for CUORE

- ^{60}Co from cosmogenic activation of copper supports
- Environmental n's and μ's



CUORICINO spectrum in region-of-interest

Results and Goals



CUORICINO Performance and Results

- Average background in region-of-interest:
  0.18 ± 0.01 counts*keV^{-1}*kg^{-1}*yr^{-1}
- Average FWHM resolution at 2615 keV:
  8 keV
- Statistics through Aug. 10, 2007
  (total exposure 15.53 yr*kg ^{130}Te):

$T_{1/2}(90\%\ C.L.) \geq 3.1 \times 10^{24}$ yr → $\langle m_\nu \rangle \leq (200 - 680)$ meV *

CUORE Goals

- Average background in region-of-interest: 0.01 counts*keV^{-1}*kg^{-1}*yr^{-1}
- Average FWHM resolution: 5 keV
- Predicted limit after ~5 years of running:

$T_{1/2} \sim 2.1 \times 10^{26}$ yr → $\langle m_\nu \rangle \leq (24 - 83)$ meV *

**NME from review table of QRPA calculations in Rodin et al Nucl. Phys. A 766,107 (2006) + Erratum nucl-th:0706.4304v1*

Image from http://crio.mib.infn.it/wigmi/pages/cuoricino.php

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