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# Probing the Mystery of Neutrino Mass with CUORE

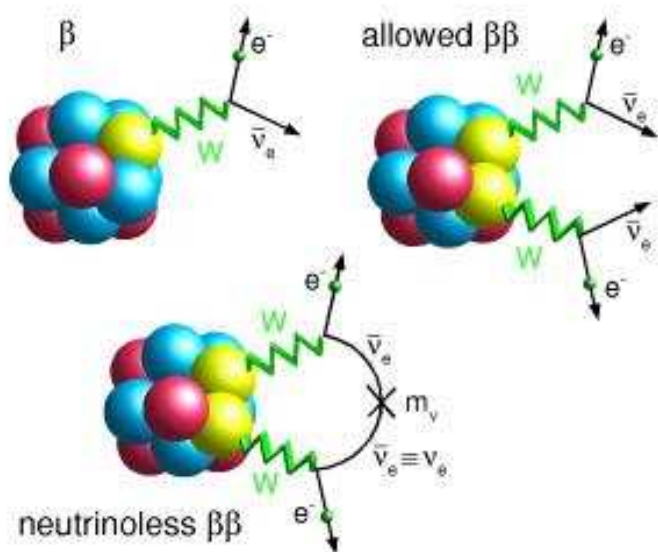
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Larissa Ejzak on behalf of the CUORE collaboration  
University of Wisconsin-Madison  
April 13, 2008





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



What CUORE hopes to discover:

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

$$\Gamma_{0\nu} \propto |M_{\text{nucl}}|^2 \langle m_\nu \rangle^2$$

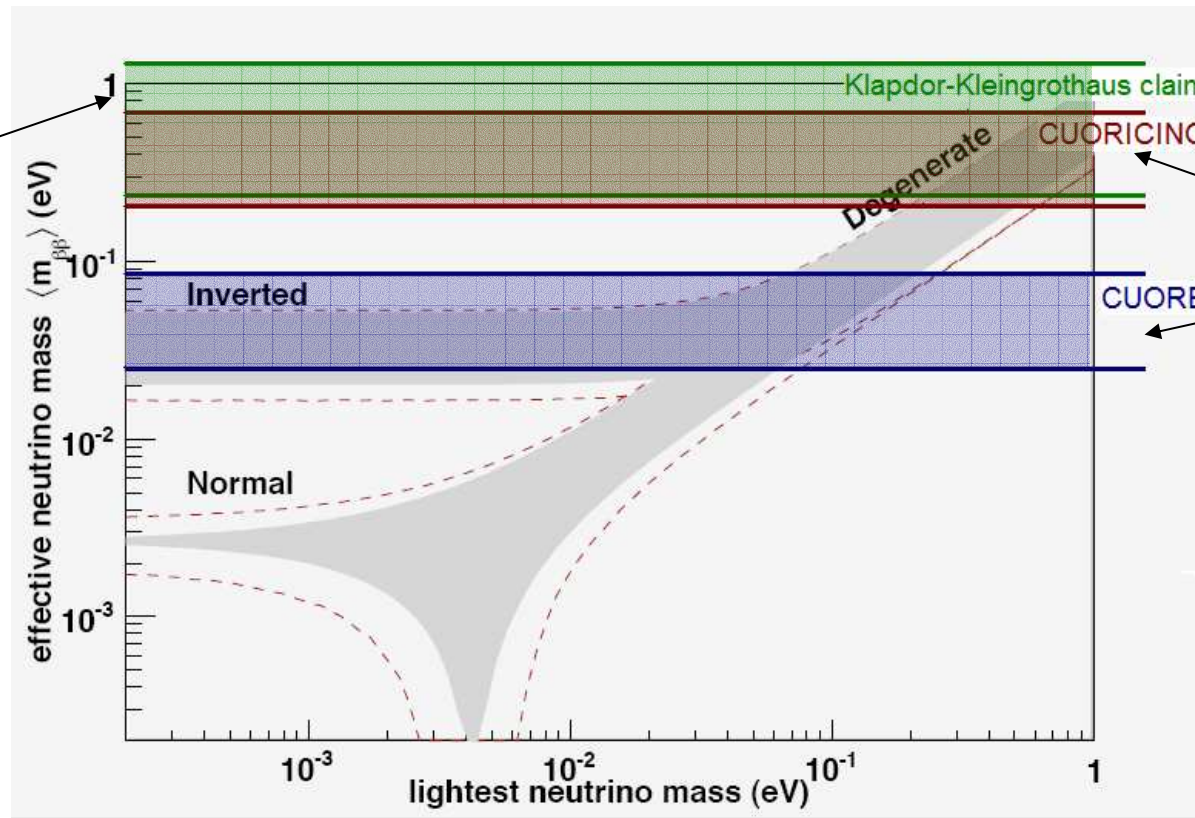
Decay rate  $\uparrow$   $\Gamma_{0\nu}$       Nuclear matrix elements (source of theoretical uncertainty)  $\uparrow$   $|M_{\text{nucl}}|^2$       Effective  $\beta\beta$  neutrino mass  $\uparrow$   $\langle m_\nu \rangle^2$



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



mass range corresponding to claim of discovery in Ge



limits on mass to within theoretical uncertainty



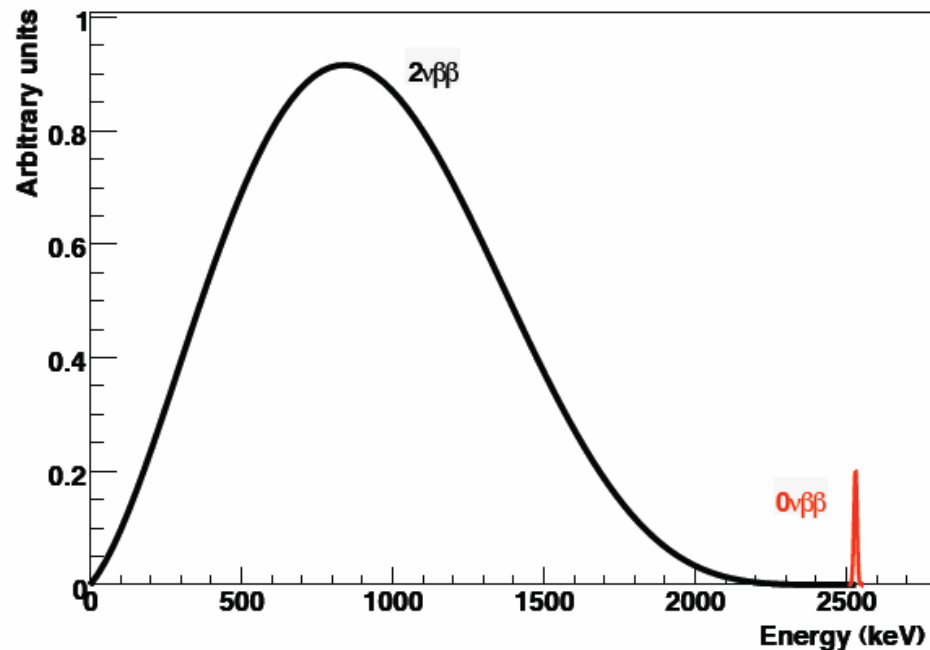
# Double-Beta Decay in Tellurium 130



What we are looking for is an energy signal:

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

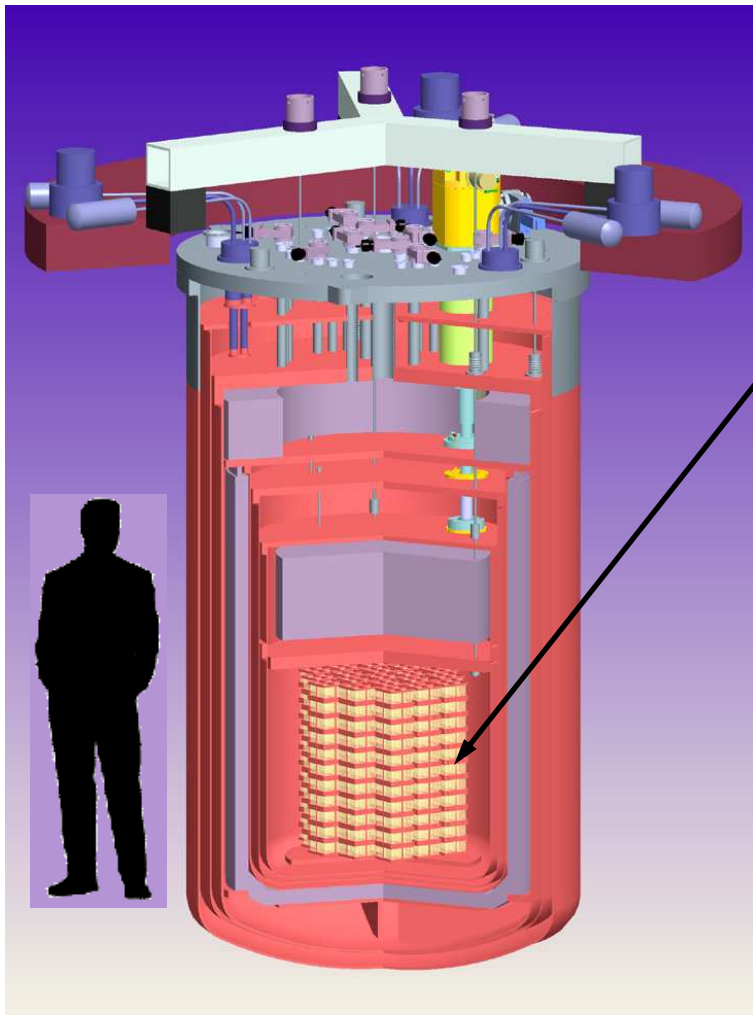
$2530.3 \pm 2.0$  keV



*Cartoon of  $\beta\beta$  in CUORE, neglecting backgrounds*

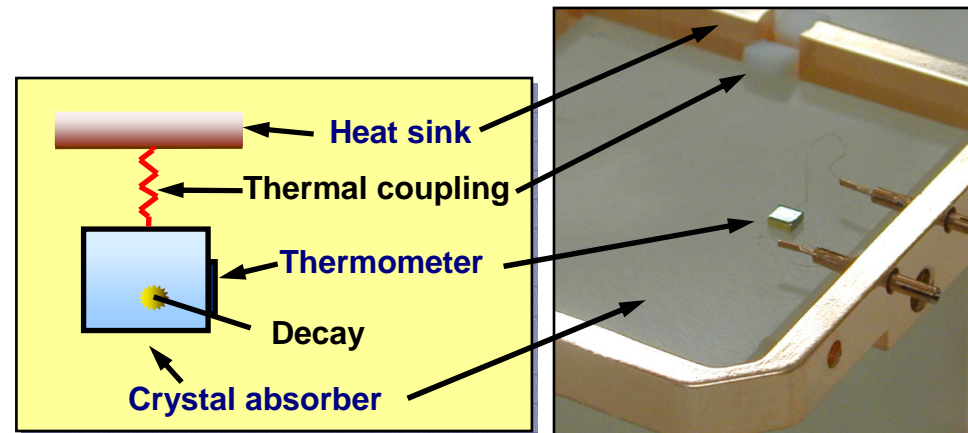


# The CUORE Detector I



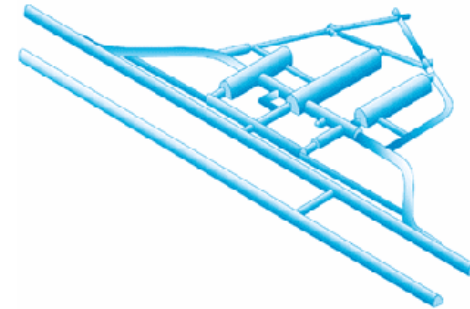
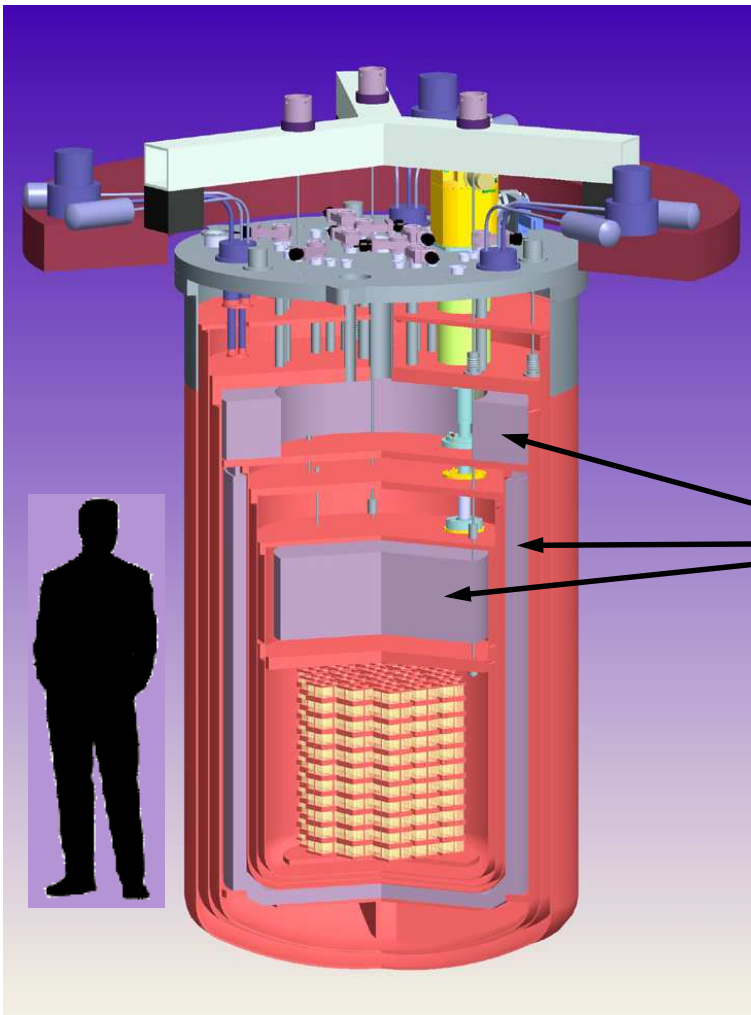
## An array of bolometers

- 988  $5 \times 5 \times 5 \text{ cm}^3$   $\text{TeO}_2$  crystals
  - detector mass  $\sim 750 \text{ kg}$ ;  $^{130}\text{Te}$  mass  $\sim 200 \text{ kg}$
- 8-10 mK
- Temperature change caused by energy deposition read out by thermistors





# The CUORE Detector II



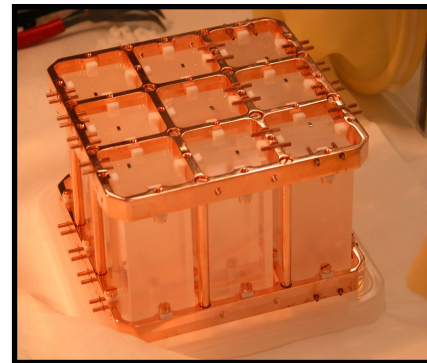
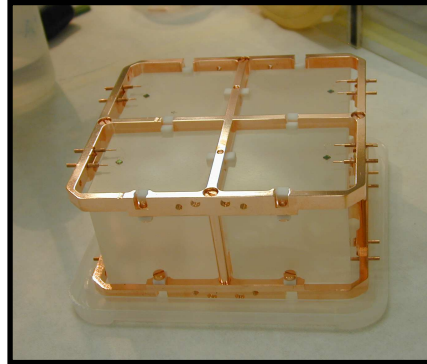
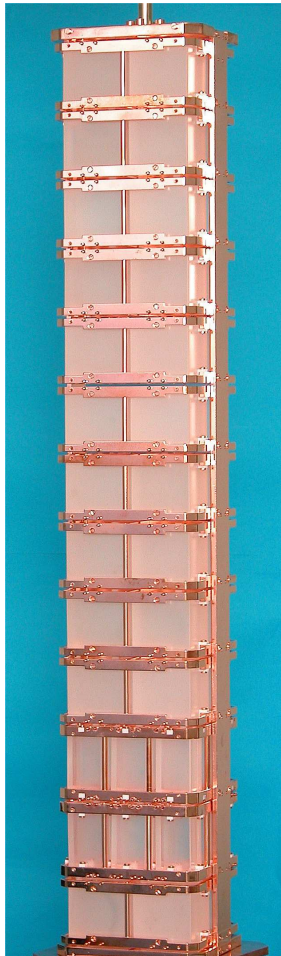
*The underground lab at LNGS*

## 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<sup>3</sup> and 18 3x3x6 cm<sup>3</sup> TeO<sub>2</sub> crystals
  - detector mass 40.7 kg; <sup>130</sup>Te mass 11 kg
  - the largest  $\beta\beta$  experiment currently in operation
- Pilot experiment to test the technologies to be used in CUORE
- Running at LNGS from 2003 to present



# What We See in CUORICINO

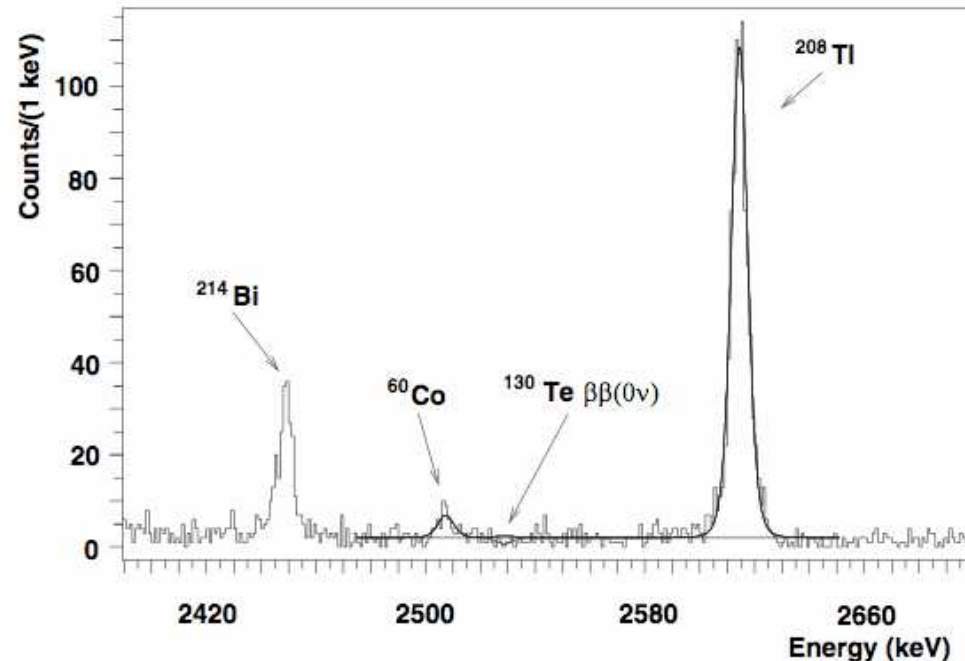


Most relevant backgrounds –  
U and Th contamination

- Flat  $\alpha$  background
  - Copper surfaces
  - Crystal surfaces
- 2615 keV  $\gamma$  line
  - Decay chain of Th in cryostat shields

...And additional concerns for CUORE

- $^{60}\text{Co}$  from cosmogenic activation of copper supports
- Environmental n's and  $\mu$ 's



*CUORICINO spectrum in region-of-interest*



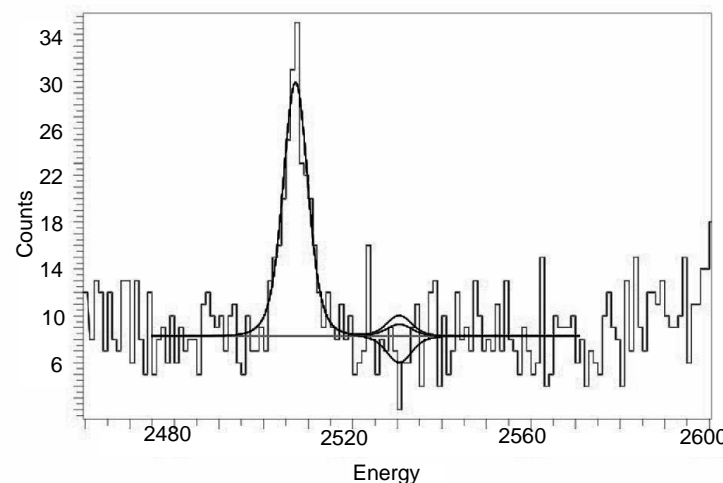
# Results and Goals



## CUORICINO Performance and Results

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

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



## CUORE Goals

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

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

*\*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>*



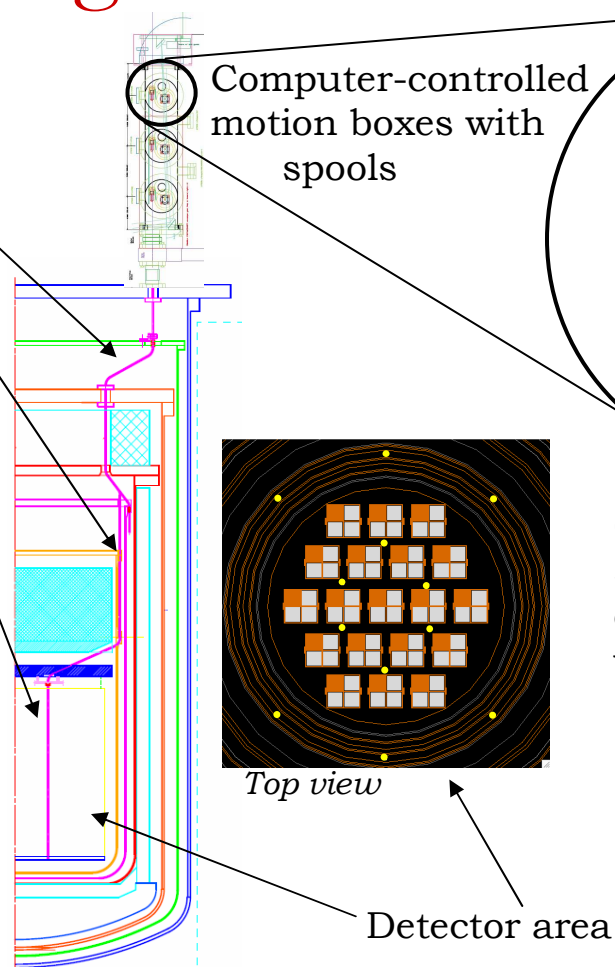
# Detector Calibration System Design R&D



Source routing (purple):  
We need to get some calibration sources in BETWEEN the detector towers for even illumination

## Other issues

- Choice of isotope:  $^{56}\text{Co}$  vs.  $^{228}\text{Th}$
- Thermal load on cryostat: source carrier moves between 300 K and detector region
  - Thermalization
  - Friction
- Low-background
  - Materials
  - Source parking position
  - Failsafe against detector contamination





# Current Status: Schedule Overview



## Spring 2008 (now)

- CUORICINO is running; plans to decommission in summer/fall 2008
- Crystal production for CUORE begun
- Continuing R&D on calibration system

## Fall 2008

- Assembly of first CUORE tower

## Spring 2009

- First CUORE tower installed in cryostat; will take data independently (engineering run to verify new procedures)

## 2009-2010

- Assembly of cryostat and integration of calibration system

## Late 2010

- Final commissioning of CUORE

## Early 2011

- Start of data-taking

## CUORE collaborators



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