

# Results of CUORE-0 and Prospects of the CUORE Experiment

#### Kyungeun E. Lim (on behalf of the CUORE collaboration)

Aug. 26, 2014, Particles and Nuclei Interactional Conference, Hamburg, Germany



# Neutrinoless Double-Beta Decay (0vββ)





#### Hypothetical lepton number violating process

## Observation of $0\nu\beta\beta$

- will establish that neutrinos are Majorana particles
- constrains on absolute V mass
- may provide info on mass hierarchy

#### **Experimental Signature**

summed energy spectrum of final state e-



#### **Rule of Thumb**



$$\sqrt{\frac{M \cdot t}{1 + \varepsilon t}}$$

a	isotopic abundance of source	
3	detection efficiency	
Μ	total detector mass	
b	background rate /mass/energy	
t	exposure time	
δΕ	energy resolution (spectral width)	

## TeO<sub>2</sub> Bolometers for 0vββ Search





- <sup>130</sup>Te is a good 0vββ source (high isotopic abundance, relatively high Q-value)
- TeO<sub>2</sub> bolometer provides excellent energy resolution (0.2% at Q-value)

K. E. Lim (Yale University)



# CUORE



Cryogenic Underground Observatory for Rare Events

- Search for  $0\nu\beta\beta$  in <sup>130</sup>Te
- 741 kg of <sup>nat</sup>Te, 206 kg of <sup>130</sup>Te
- 988 TeO<sub>2</sub> crystals (5x5x5 cm<sup>3</sup>) as an bolometric array, 19 Towers (13 floors x 4 crystals)
- I0 mK operation temperature
- Excellent energy resolution
- Located at LNGS (3650 m.w.e, 10<sup>6</sup> μ reduction)
- Radiopure materials, surface background suppression, and clean tower assembly
- Complex cryogenic setup
- Also suitable for direct dark matter search

## **CUORE** Collaboration





I9 groups
(Italy, USA,
China, France)
I48 people



## The CUORE 0vββ Search





 $\langle m_{\beta\beta} \rangle_{90\% \text{ C.L.}} = 300 - 710 \text{ meV}$ K. E. Lim (Yale University)

## Cuoricino to CUORE



- More bolometers (Self-shielding, more powerful single crystal hit requirement).
- Crystals with higher radiopurity.
- Improved copper surface treatment, less copper.
- Optimized tower assembly procedure.
- Radiopure materials + Roman lead shield ( < 4mBq/kg <sup>210</sup>Pb) for cryostat.
- Pulse tube refrigerator, cryogen free dilution unit (DU).
- Separated DU suspension from crystal tower suspension.

	Cuoricino	CUORE-0 (Phase I)	CUORE
130	11	11	206
Background [counts/(keV ·kg ·yr)] @ ROI	0.17	0.07*	0.01
E resolution (FWHM) [keV] @ 2615 keV	~ 6	5.7*	5

K. E. Lim (Yale University)

\* Phase II data analysis shows lower values 7

## CUORE-0





- The first CUORE-like tower hosted in old Cuoricino cryostat.
- 52 (13 x 4) crystals, 39 kg of TeO<sub>2</sub> (11 kg of <sup>130</sup>Te), 4 kg of copper structure.
- Validated new cleaning and assembly procedures for CUORE.
- Taking  $0\nu\beta\beta$  data since Mar. 2013.
- First results (Phase I data analysis) were released in Sep 2013.

Eur. Phys. J. C 74, 2956 (2014)

Phase II data w/ improved detector

operation condition ongoing.



Energy [keV]

June 2, 2014

K. E. Lim (Yale University)

## **CUORE-0: Background**



	Avg. flat bkg. [counts/(keV ·kg ·yr)]		
	$0\nu\beta\beta$ region (α + γ/β)	[2.7-3.1, 3.4-3.9] MeV (α)	
Cuoricino (ɛ=83%)	0.153 ± 0.006	0.110 ± 0.001	
CUORE-0 (ε=78 %)	0.063 ± 0.006	0.020 ± 0.002	
Reduction factor	2	6	
Due to	Better Radon control (	Better Cu/crystal surface treatment	

Consistent w/ Cuoricino background model

K. E. Lim (Yale University)

## **CUORE-0: Sensitivity**



Assumptions: ~ 5.2 keV FWHM ROI resolution (δE) and background rate (b) of 0.063±0.006 counts/(keV kg γr) from the measurements.

Expected to surpass Cuoricino limit w/ about a year of live time.

## **Projection to CUORE**



CUORE-0 demonstrated that the background mitigation was successful.
CUORE MC for Bkg prediction using the results of CUORE-0 along with other screening campaign results as input shows the CUORE Bkg goal is within reach.



K. E. Lim (Yale University)



- $I\sigma$  sensitivity  $T_{1/2}^{0\nu\beta\beta}=1.6 \times 10^{26}$  yr (9.5 x  $10^{25}$  yr @ 90% C.L.)
- Effective Majorana mass 47-100 meV (51 133 meV @ 90% C.L.)
- Assumptions: 5 keV FWHM ROI resolution ( $\delta E$ ), background rate (b) of 0.01 counts/(keV kg yr) arXiv:1109.0494
- **-** 5 years of live time.
- K. E. Lim (Yale University)





#### Assembly of all 19 towers is complete!





.ompleted.

1. 14

Top Lead

Lateral Lead



#### Phased commissioning - Adding complexity at each phase

- Phase I: 4K system check
  - Outer/Inner vacuum chamber test
  - Cryogenic verification of detector calibration system
  - Commissioning test of DU

#### Phase II: full cryostat vessel check

- Full assembly of cryostat
- Cool down of cryostat (ongoing)
- Integration of test tower, other subsystem

#### Completion is expected in 2015



17





18









# Beyond CUORE





Isotopic enrichment.

Particle discrimination by simultaneously measuring heat/light.



Particle discrimination by simultaneously measuring heat/light.

## Summary



- CUORE-0, the first CUORE-like tower is operated as a stand alone 0vββ search experiment at LNGS since March 2013.
- CUORE-0 demonstrates successful background mitigation and confirms the Cuoricino background model. It also demonstrates that 5 keV FWHM ROI energy resolution goal of CUORE is achievable.
- CUORE tower assembly is complete and cryogenic system commissioning is underway.
- Detector array deployment is expected in 2015.
- Low background and large mass of CUORE extend the physics reach of CUORE to other rare event searches such as direct dark matter and rare nuclear decays.
- Various R&D effort is ongoing for 0νββ search beyond CUORE.