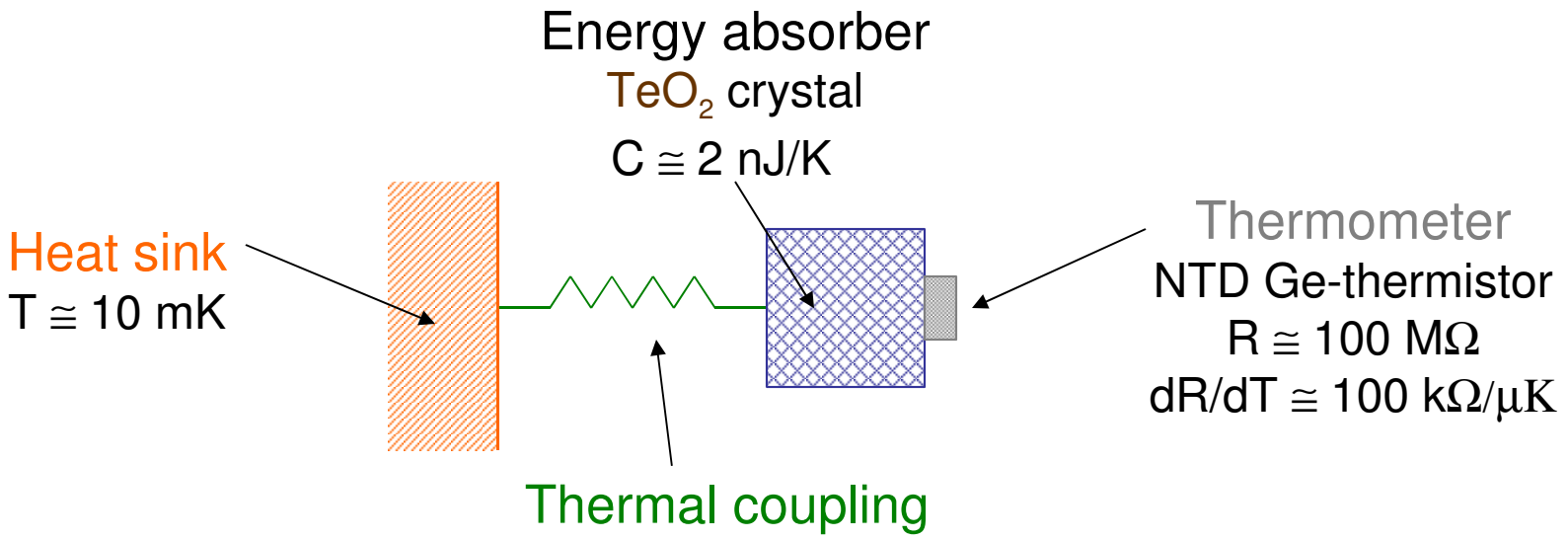
CUORE:

A bolometric search for neutrinoless double beta decay

Rick Norman
Lawrence Livermore National Laboratory

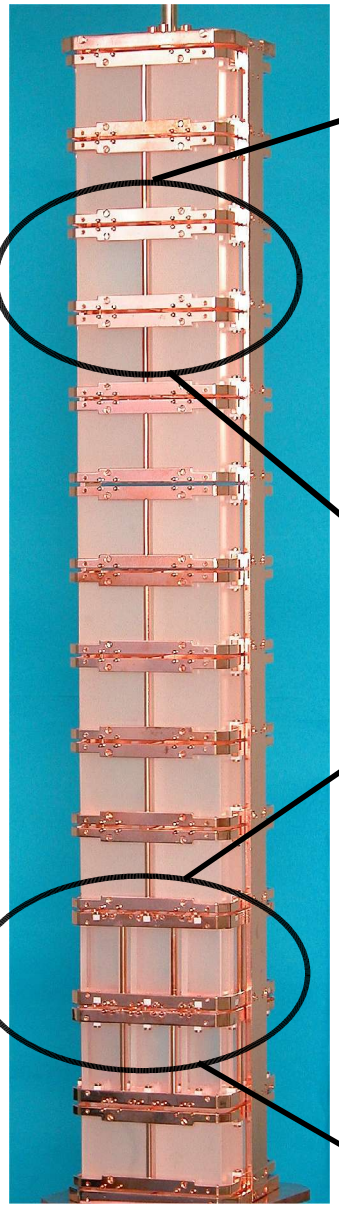
CUORE Detector concepts

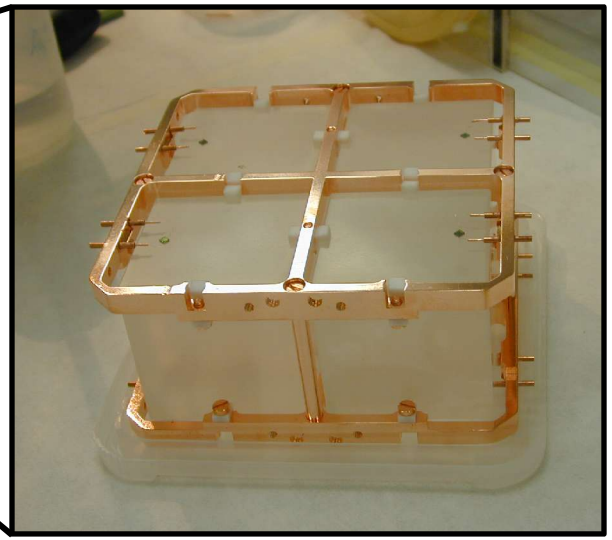


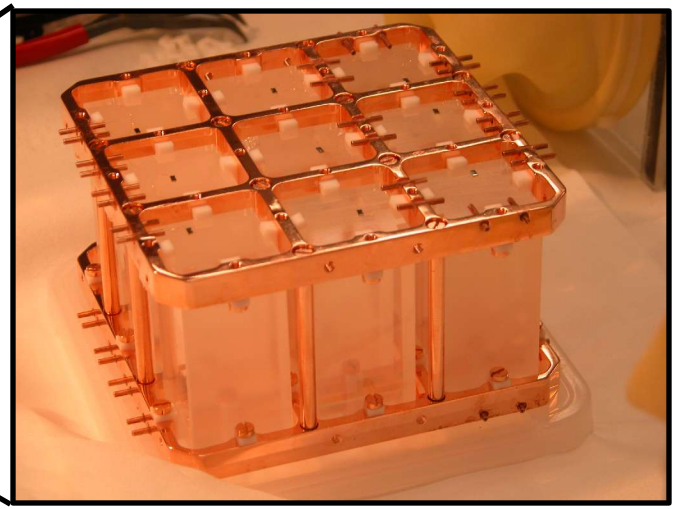
- Temperature signal: $\Delta T = E/C \cong 0.1$ mK for $E = 1$ MeV
- Voltage signal: $\Delta V = I \times dR/dT \times \Delta T \Rightarrow \Delta V = 1$ mV for $E = 1$ MeV
- Signal recovery time: $\tau = C/G \cong 0.5$ s

Energy resolution (FWHM): ≅ 5 keV at 2500 keV

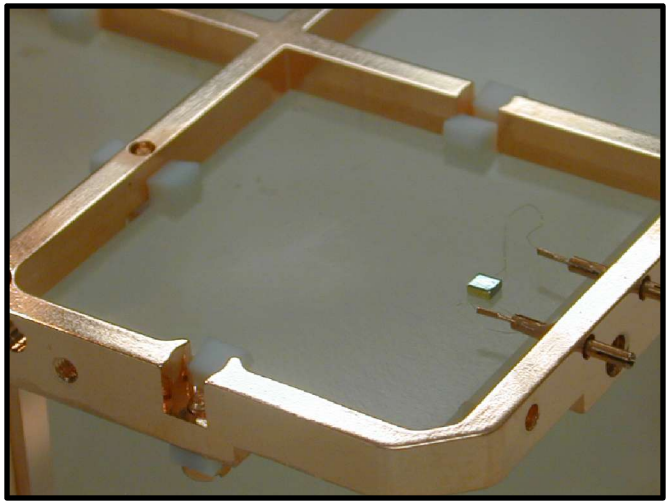
CUORICINO







A prototype for CUORE



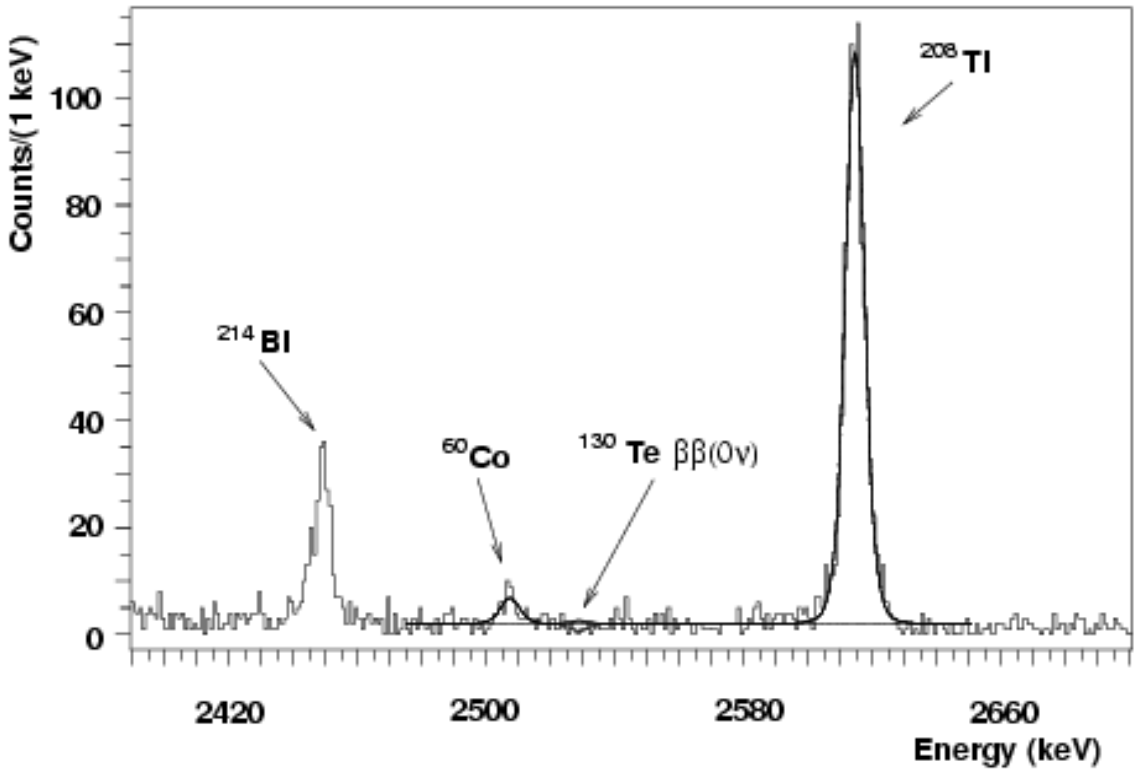
Active mass during first runs:

42 x 0.790 kg = 33.2 kg

17 x 0.330 kg = 5.6 kg

→ ***~ 11 kg ^{130}Te***

Results of CUORICINO Runs 1&2



C. Arnaboldi *et al.*
PRL 95, 142501
(2005)

exposure = 10.85 kg y (TeO_2)

FWHM at 2615 keV = 9.2 ± 0.5 keV

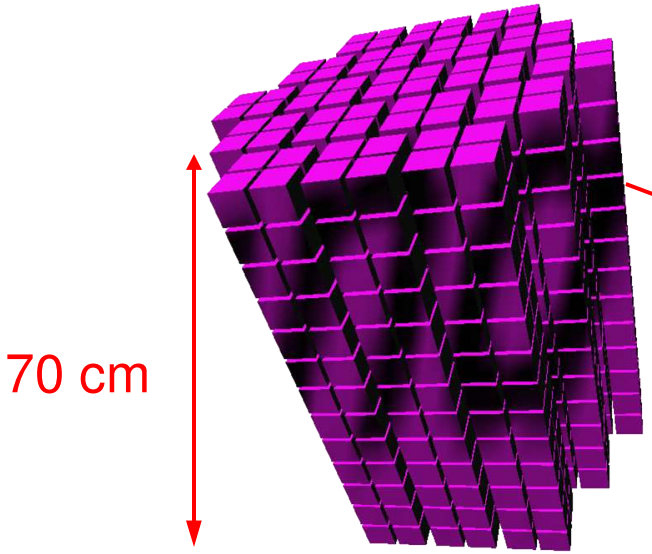
bkgd in the 0νββ region = 0.18±0.01 counts /(keV kg y)

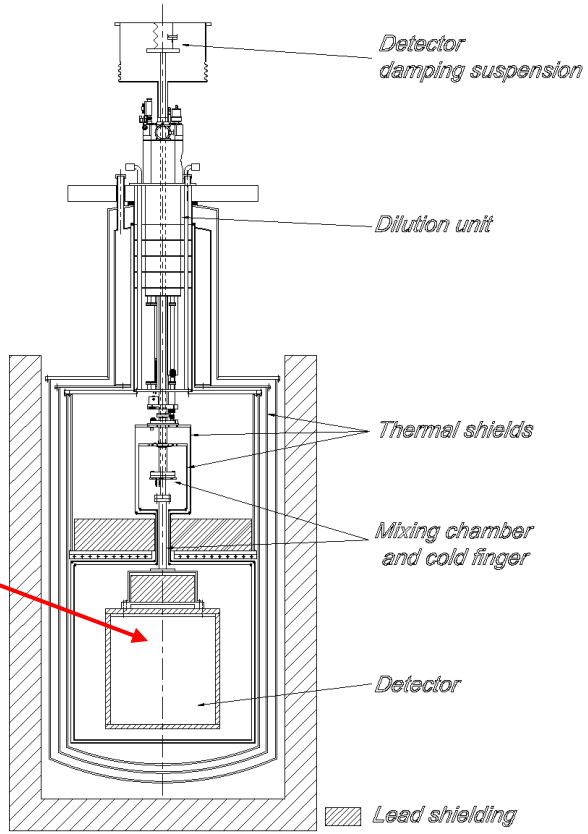
$$\tau^{0\nu}_{1/2} > 1.8 \times 10^{24}\ \text{y}\ \text{at}\ 90\%\ \text{C.L.}$$

$$m_\nu < 0.2 - 1.1\ \text{eV}$$

CUORE

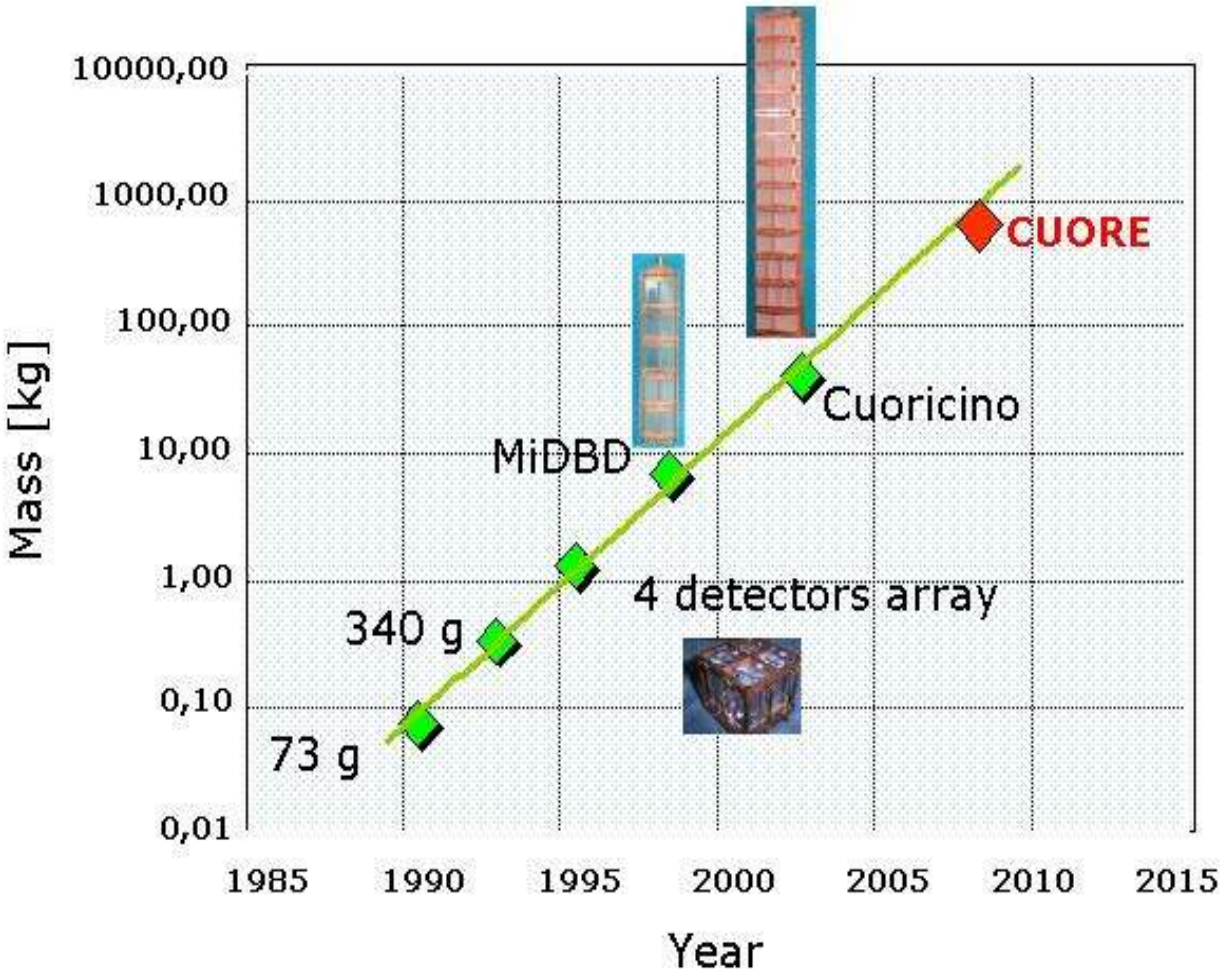
Array of 988 crystals:
19 towers of 52 crystals/tower.
M = 0.78 ton of TeO_2





Search for 0ν DBD of ^{130}Te
$Q_{\beta\beta}$ = 2529 keV
Natural isotopic abundance [^{130}Te] = 34.08%
Therefore, isotopic enrichment is unnecessay

Temporal law for mass increase of TeO_2 detectors



What can CUORE do ?

CUORE Sensitivity

5 year sensitivity

Pessimistic

b = 0.01 – Γ = 5 keV

$F^{0\nu} = 2.1 \times 10^{26}$ y

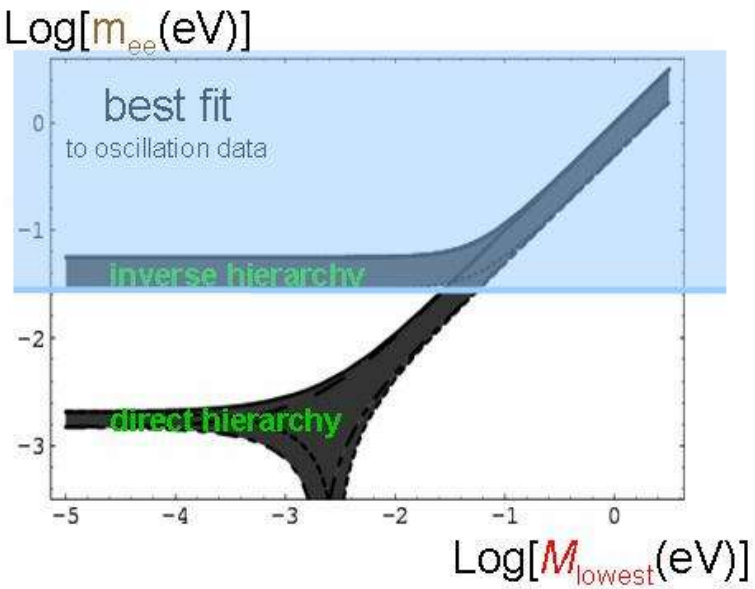
m_{ee} < **20 – 103** meV

Optimistic

b = 0.001 - Γ = 5 keV

$F^{0\nu} = 6.5 \times 10^{26}$ y

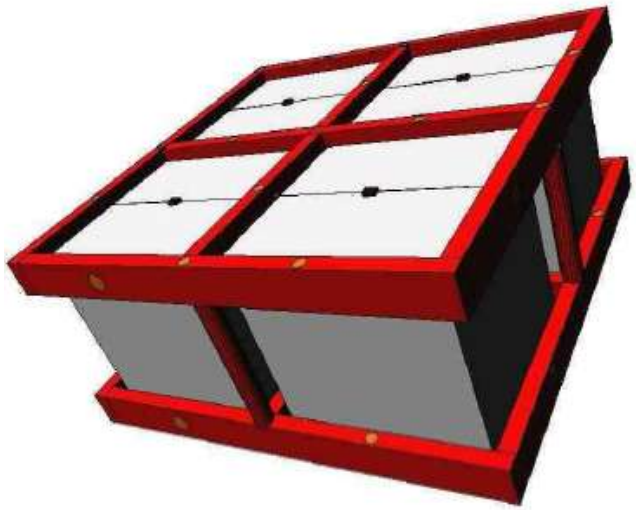
m_{ee} < **10 - 55** meV



MC simulation of CUORE background

Table 16: Bulk contamination levels (in picograms per gram) used in the simulation for TeO_2 , copper and lead.

Contaminant	^{232}Th	^{238}U	^{40}K	^{210}Pb	^{60}Co
TeO_2	0.5	0.1	1	10 μBq/kg	0.2 μBq/kg
copper	4	2	1	0	10 μBq/kg
Roman lead	2	1	1	4 mBq/kg	0
16 Bq/kg lead	2	1	1	16 Bq/kg	0



Details of CUORE module used in MC simulations

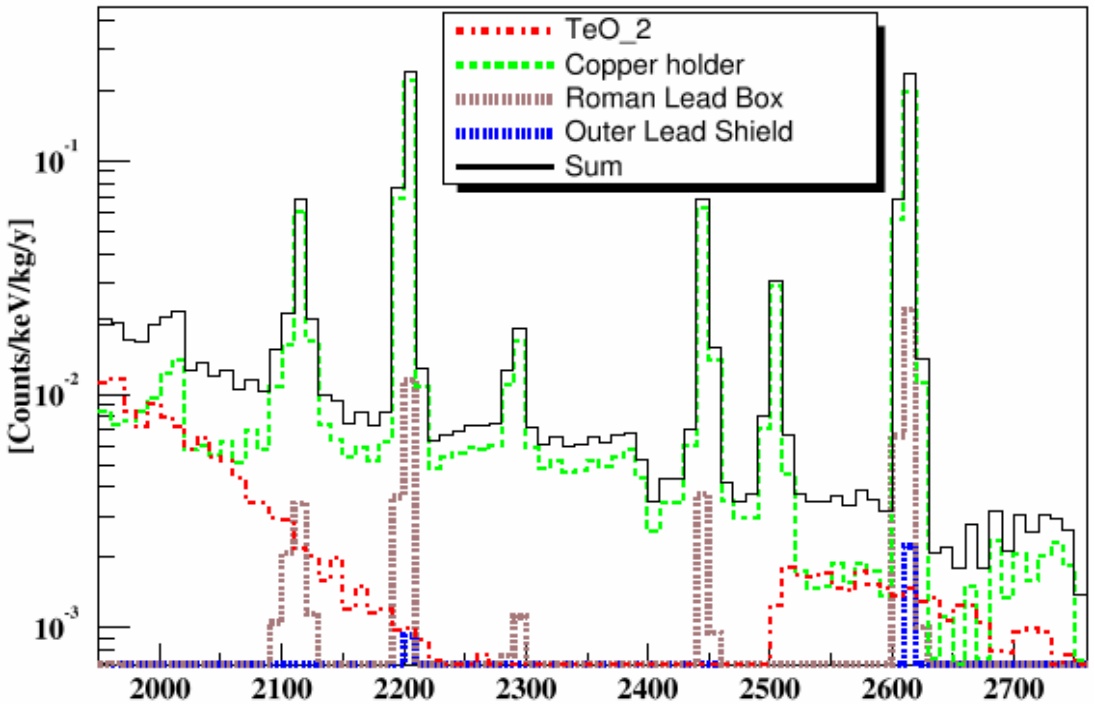


Figure 53: Double beta decay region of the simulated spectra for bulk contaminations of the TeO_2 crystals, the Copper structure, the Roman Lead shield and the outer Lead shield. Each spectrum is obtained by summing the simulated anticoincidence spectra of all the CUORE detectors.

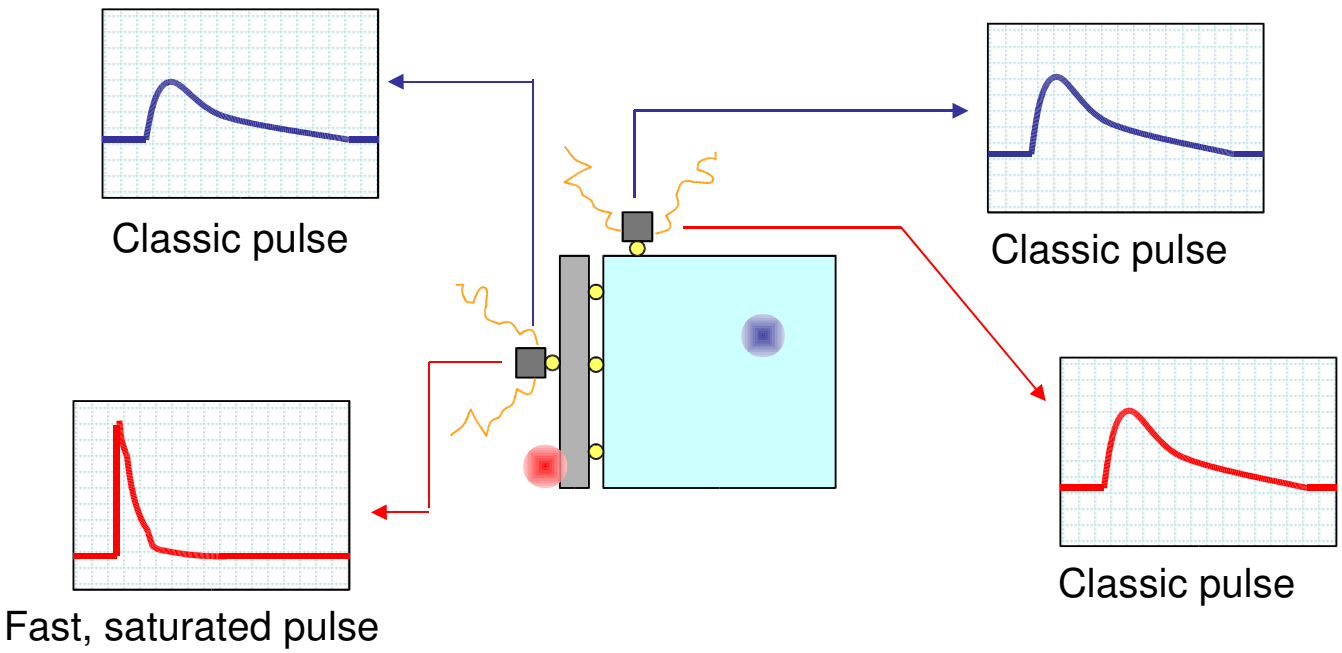
R&D efforts on background reduction

- **Plasma cleaning of copper surfaces**
  - **Indications that U,Th can be reduced by factor of 10**
- **Doping TeO_2 to produce scintillating crystals**
  - **Detection of both light and heat would distinguish α's from β's and γ's**
- **Surface sensitive bolometers**
  - **Provides anticoincidence shield for surface contamination**

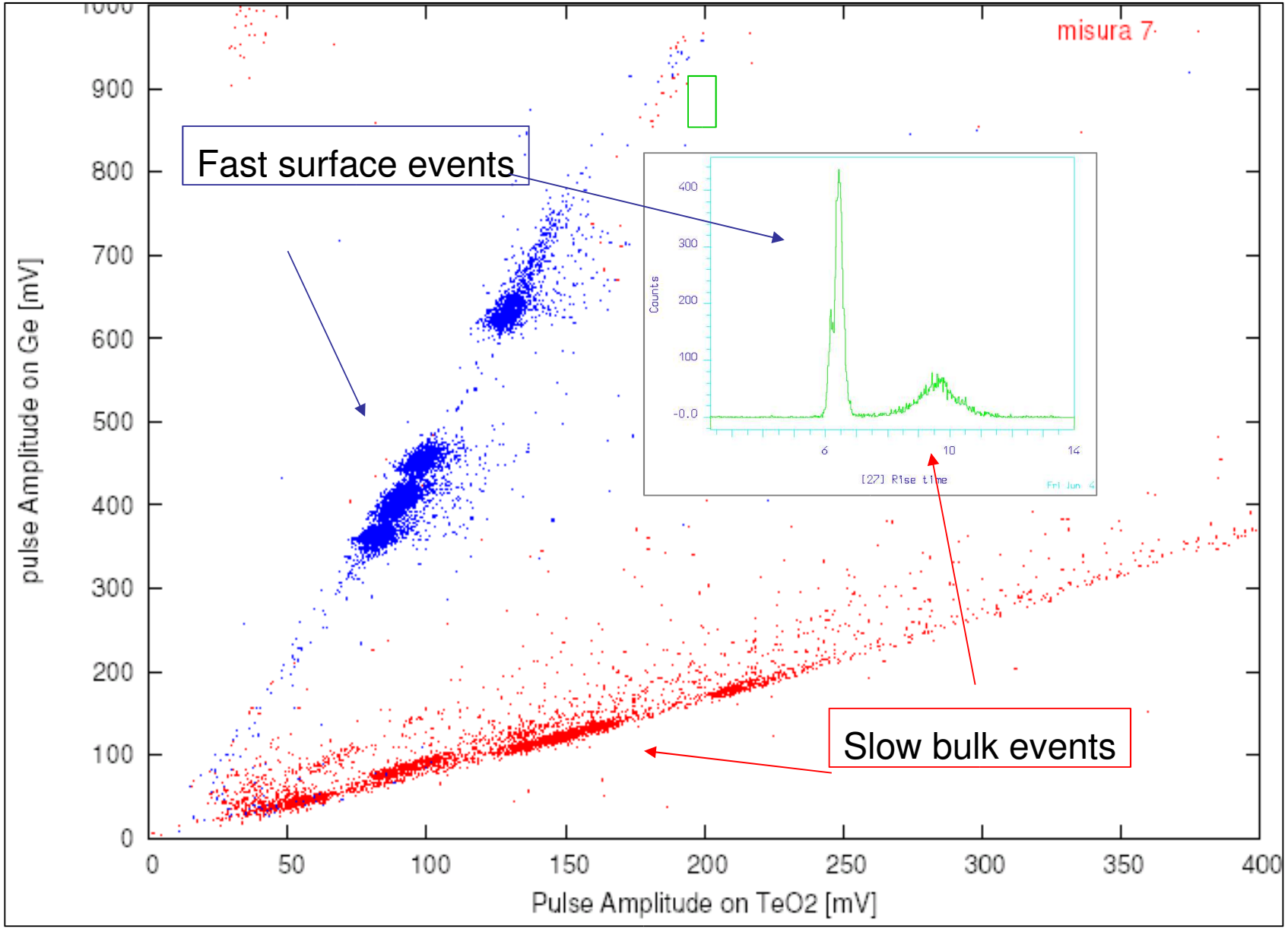
Surface sensitive bolometers

A composite bolometer with a thin crystal of Ge, Si or TeO_2

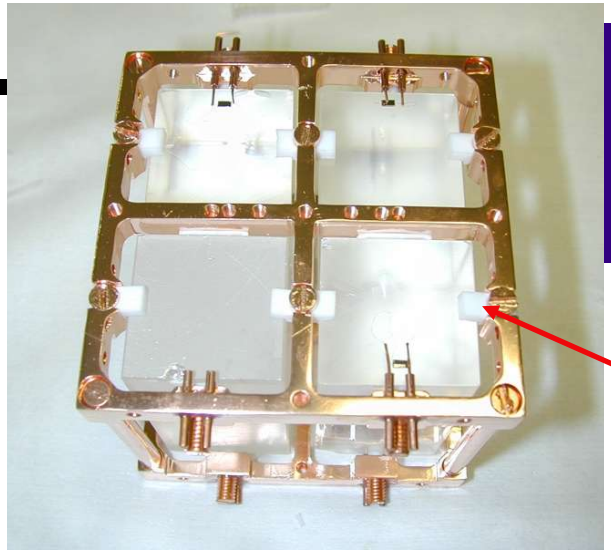
" ββ" event



Degraded α event

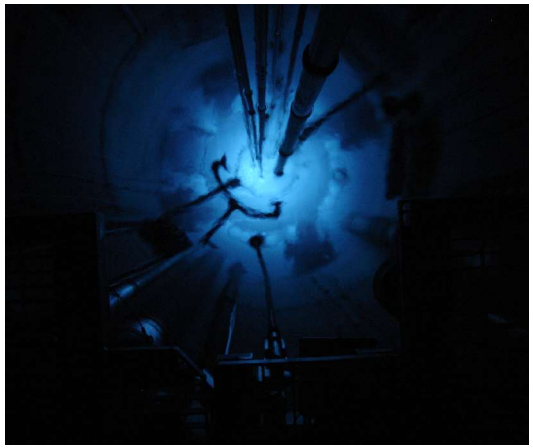

misura 7
Fast surface events
Slow bulk events
pulse Amplitude on Ge [mV]
Pulse Amplitude on TeO2 [mV]
0
50
100
150
200
250
300
350
400
100
200
300
400
500
600
700
800
900
Counts
400
300
200
100
-0.0
6
10
14
[27] Rise time
Fri Jun 4

Teflon NAA



There is a total of < 200 g of Teflon in Cuoricino.
There will be an estimated 1-2 kg of Teflon in CUORE.

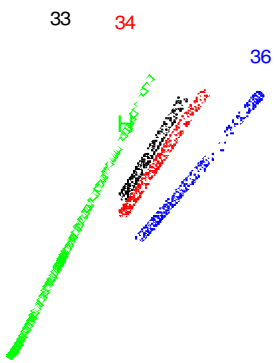
- Neutron activation analysis of 40 g of Cuoricino Teflon
- Irradiated at the McClellan Nuclear Radiation Center
- Gamma ray spectroscopy at the LBNL Low Background Facility



Uranium: 150 ppt (= 10-20%)
Thorium: 250 ppt (< 10%)
→ 0.003 cts/keV/kg/yr
Worst case: 0.03 cts/keV/kg/yr

NTD Ge Thermistors

^{70}Ge (21%) + n → ^{71}Ge	($\sigma_T = 3.43 \pm 0.17$ b, $\sigma_R = 1.5$ b)	
^{71}Ge → (EC) ^{71}Ga	($t_{1/2} = 11.4$ d)	Acceptor
^{74}Ge (36%) + n → ^{75}Ge	($\sigma_T = 0.51 \pm 0.08$ b, $\sigma_R = 1.0 \pm 0.2$ b)	
^{75}Ge → $^{75}As + \beta^-$	($t_{1/2} = 83$ min)	Donor
^{76}Ge (7.4%) + n → ^{77}Ge	($\sigma_T = 0.16 \pm 0.014$ b, $\sigma_R = 2.0 \pm 0.35$ b)	
^{77}Ge → $^{77}As + \beta^-$	($t_{1/2} = 53$ s + 11.3 h)	
^{77}As → $^{77}Se + \beta^-$	($t_{1/2} = 38.8$ h)	Double Donor



- First irradiation at the MIT NRL by the end of 2005
- Characterization of NTD Ge using NAA, SIMS
- Delivery by January 2008

Status of CUORE in Italy

CUORE was approved by LNGS Science Policy Committee

CUORE has been assigned space at LNGS

→former location of GALLEX/GNO

CUORE was approved by INFN

6.5 M Euros ($8.45M)

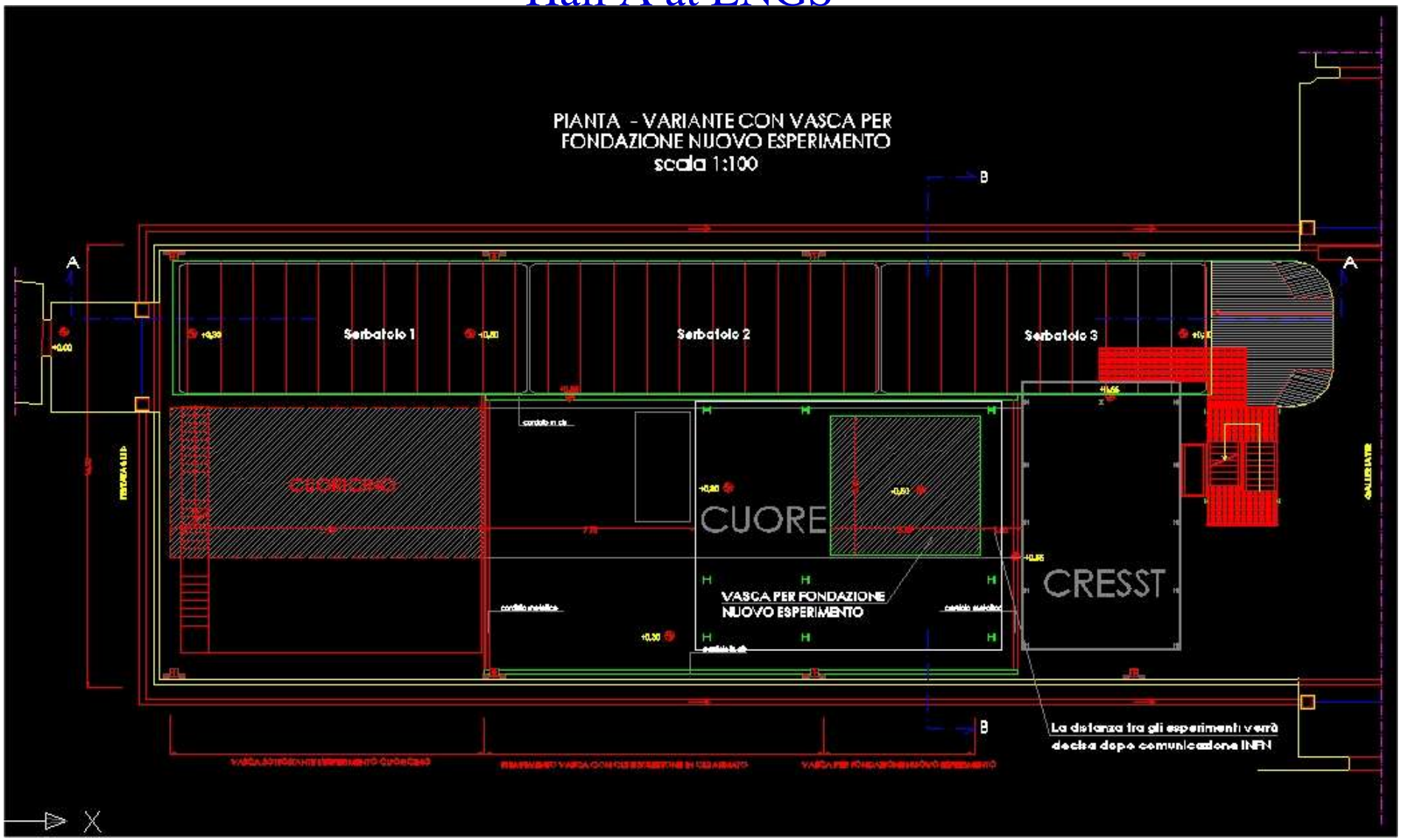
1.5 M Euros already allocated for procurement of dilution refrigerator

Status of CUORE in US

- APS neutrino study ranked ββ decay as highest priority for new experiments (Nov. 2004)
- CUORE presentation to DOE in Gaithersburg (Nov. 2004)
- CUORE “whitepaper” submitted to DOE (Jan. 2005)
- NUSAG recommended support for two or more of following experiments: CUORE, EXO, Majorana (Sept. 2005)

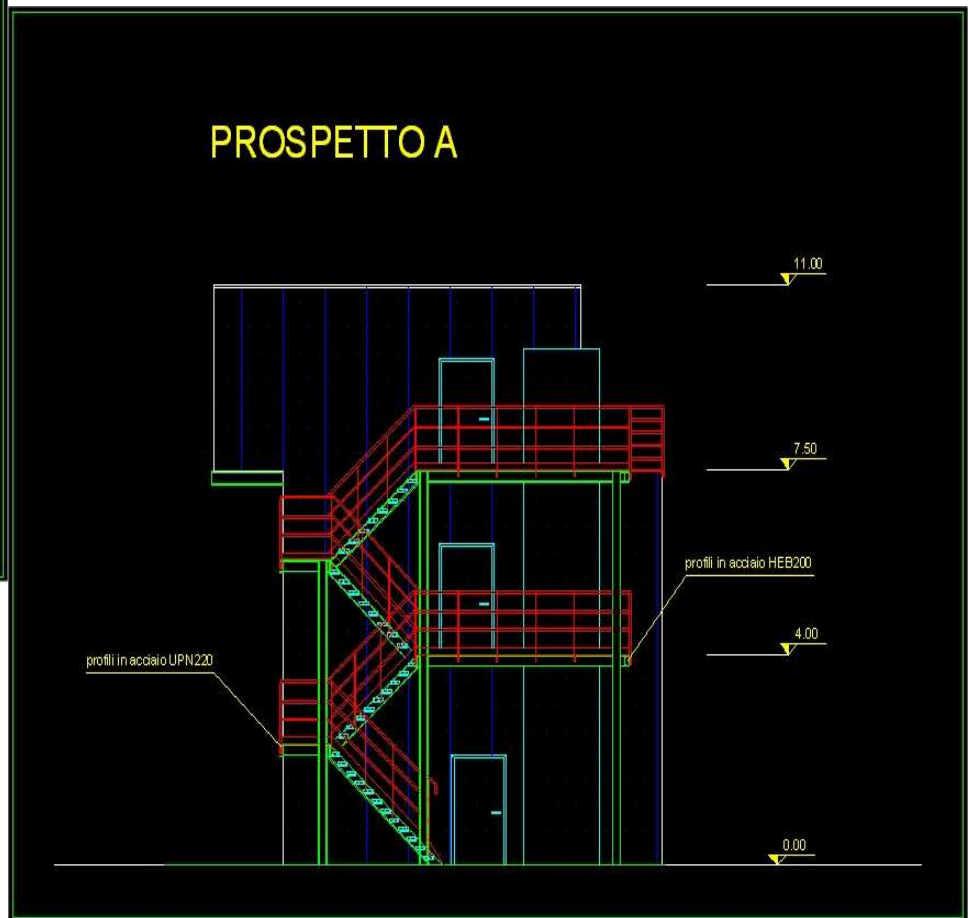
CUORE lab design

Hall A at LNGS



CUORE layout

← Front inside view



Right side view →

CUORE Collaboration

E. B. Norman, M. Dolinski,

Lawrence Livermore National Laboratory

J. W. Beeman, T. D. Gutierrez, K. M. Heeger, A. R. Smith, N. Xu

Lawrence Berkeley National Laboratory

S. J. Freedman, E. E. Haller, R. Maruyama

University of California at Berkeley

D. R. Artusa, F. T. Avignone III, I. Bandac, R. J. Creswick, H. A. Farach, C. Rosenfeld

University of South Carolina

C. Arnaboldi, C. Brofferio, S. Capelli, F. Capozzi, L. Carbone, O. Cremonesi, E. Fiorini,
A. Nucciotti, M. Pavan, G. Pessina, S. Pirro, E. Previtali, M. Sisti, L. Torres, L. Zanotti

Universita' di Milano-Bicocca

R. Ardito, G. Maier

Politecnico de Milano

A. Giuliani, S. M. Pedretti, S. Sangiorgio

Universita degli Studi dell'Insubria

M. Barucci, E. Olivieri,, E. Pasca, L. Risegari, G. Ventura

Universita' di Firenze

F. Bellini, C. Cosmelli, I. Dafinei, M. Diemoz, F. Ferroni, C. Gargiulo, E. Longo, S. Morganti

Universita di Roma

E. Guardincerri, P. Ottonell, M. Pallavicini

Universita di Genova

M. Balata, C. Bucci, S. Nisi

Laboratori Nazionali del Gran Sasso

V. Palmieri, S. Toffanin

Laboratori Nazionali di Legnaro

A. de Waard, G. Frossati

Leiden University