

Update on the CUORICINO and CUORE experiments

Samuele Sangiorgio
on behalf of the CUORE collaboration



University of Insubria
Como - Italy



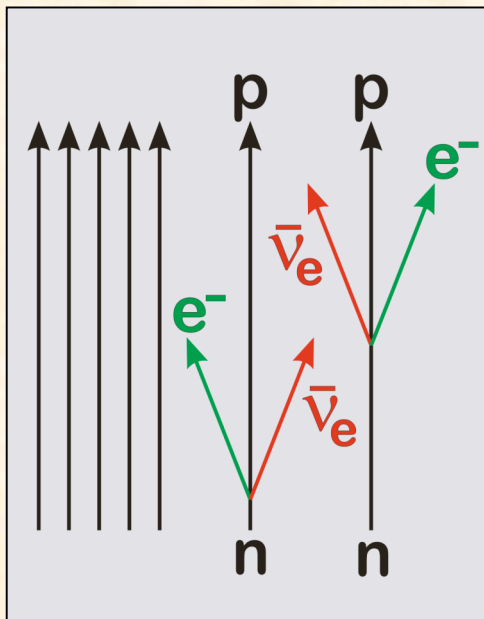
INFN
Milano - Italy

Neutrinoless Double Beta Decay ($0\nu\text{DBD}$)

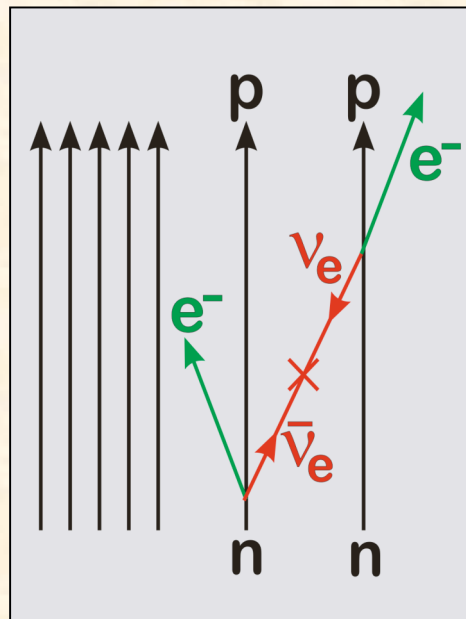
We recommend, as a high priority, a phased program of sensitive searches for **neutrinoless nuclear double beta decay**. In this rare process, one atomic nucleus turns into another by emitting two electrons. Searching for it is very challenging, but the question of whether the neutrino is its own antiparticle can only be addressed via this technique. The answer to this question is of central importance, not only to our understanding of neutrinos, but also to our understanding of the origin of mass.

The Neutrino Matrix, Prepared by the Members of the **APS Multidivisional Neutrino Study**, arXiv:physics/0411216

$\beta\beta 2\nu$ allowed
by Standard Model



$\beta\beta 0\nu$ possible only
with Majorana ν



» 0ν double beta decay

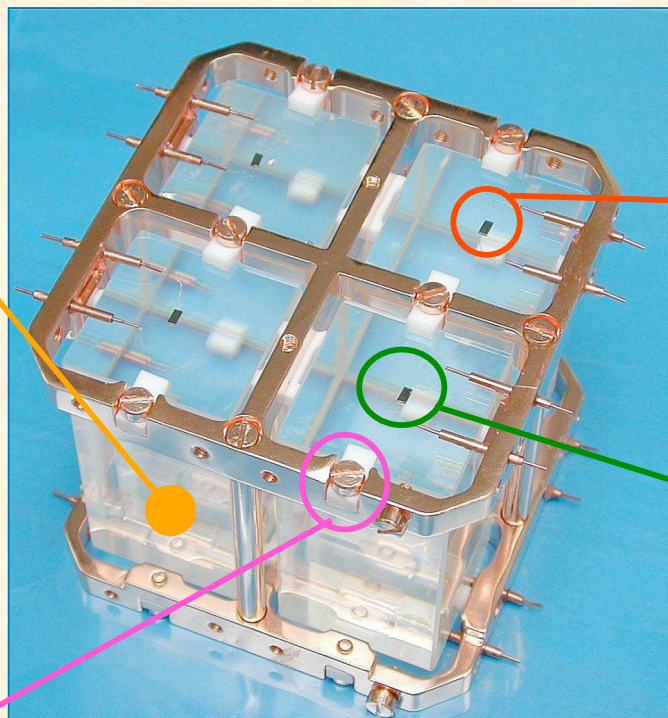
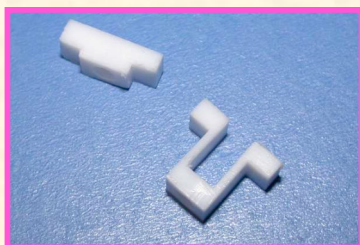
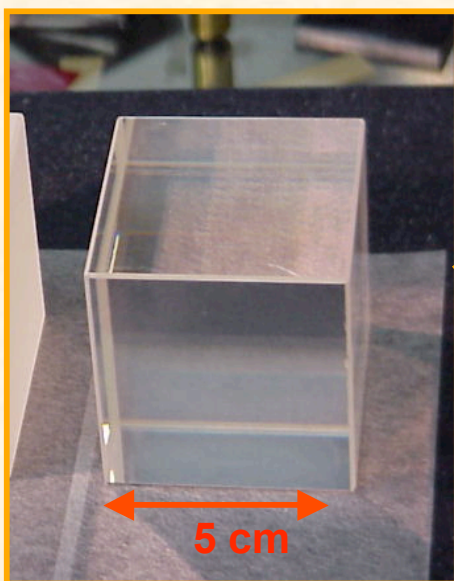
$$T_{1/2}^{0\nu} \sim \frac{1}{G^{0\nu} |M^{0\nu}|^2 \langle m_{ee} \rangle^2}$$

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

CUORICINO bolometers

Absorber crystal

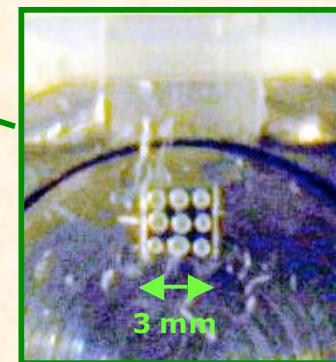
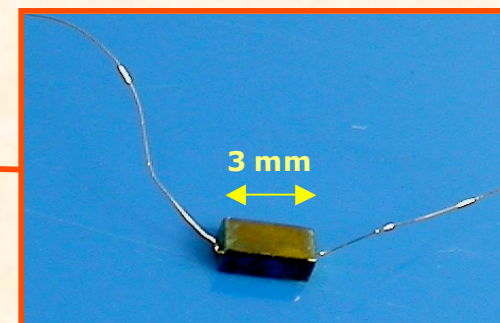
The absorber is a **5x5x5 cm³** crystal of **TeO₂** which contains the neutrinoless DBD candidate **¹³⁰Te**



Temperature sensor

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

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



CUORICINO setup

CUORICINO = tower of 11 modules, 4 detector (790 g) each
2 modules, 9 detector (330 g) each

Statistics:

M ~ 40.7 kg $\text{TeO}_2 \sim 5 \times 10^{25}$ ^{130}Te nuclides

Run I (Feb 2003 – Oct 2003):

Working detectors: 73%

Live Time: 23%

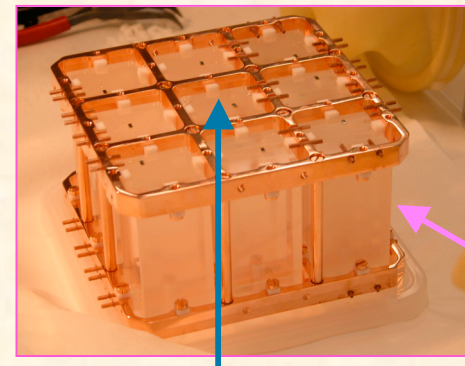
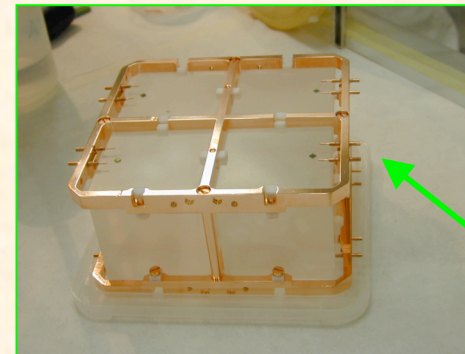
Run II (from May 2004):

Working detectors: 94%

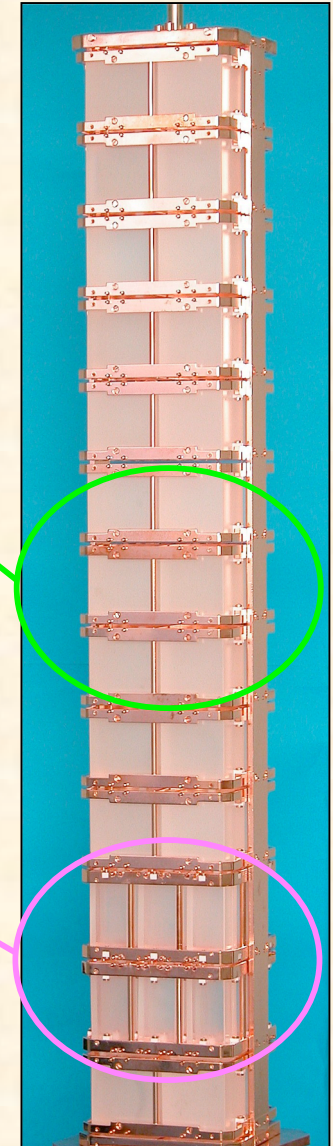
Live Time: $\sim 60\%$ (+ $\sim 10\%$ calib time)



LNGS - ~ 3500 m.w.e.

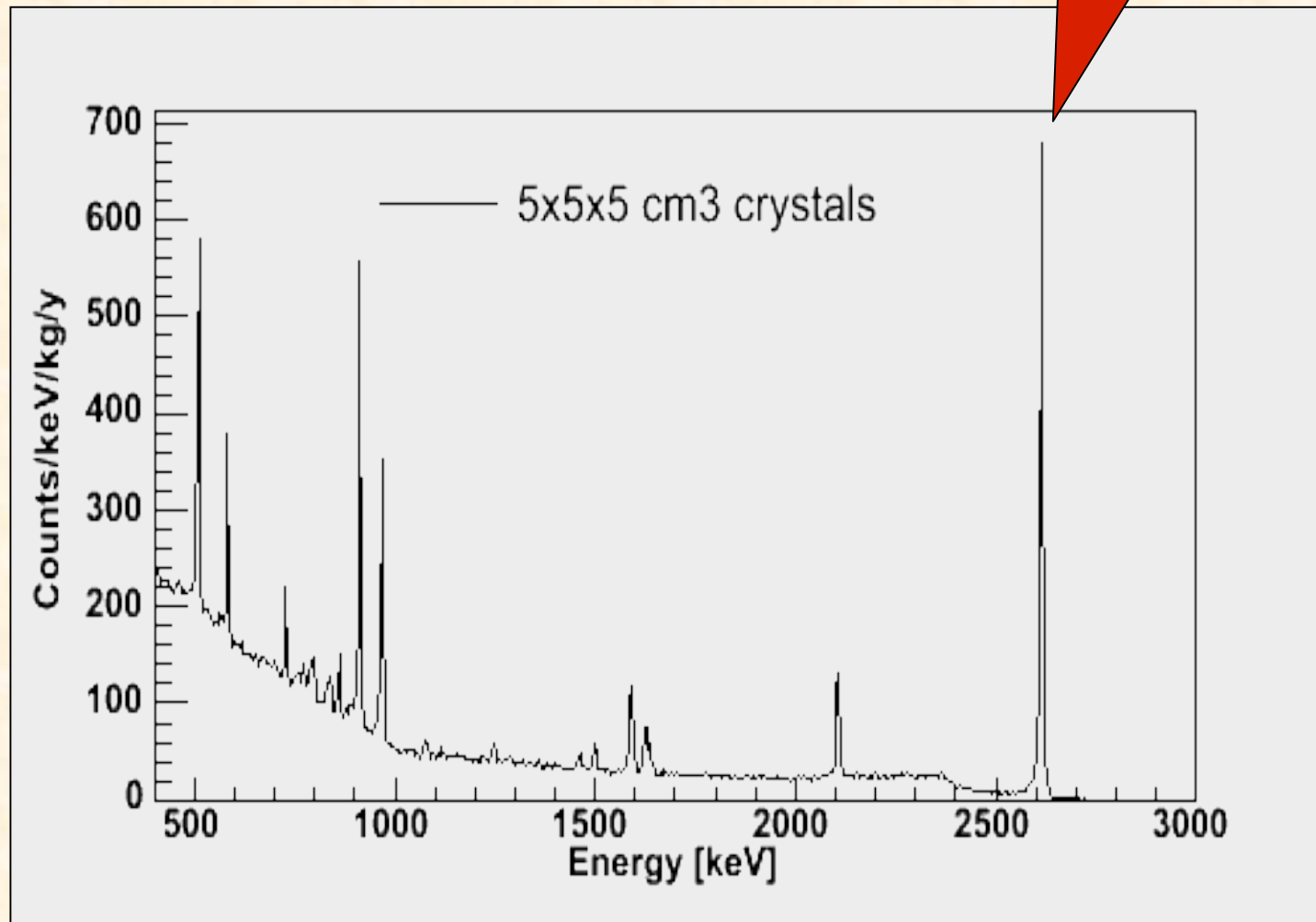


This detector is completely surrounded by active materials.
Useful for bkg origin models



CUORICINO performances

Sum calibration spectrum (U+Th)



**Mean energy
resolution
@ 2615 keV**

5x5x5 cm³
crystals
~ 7.8±2.4 keV

3x3x6 cm³
crystals
~ 11.0±4.7 keV

**Best energy
resolution (₇₉₀
g) @ 2615 keV
is 3.9 keV**

Resolution data for RUN II up to April 2005

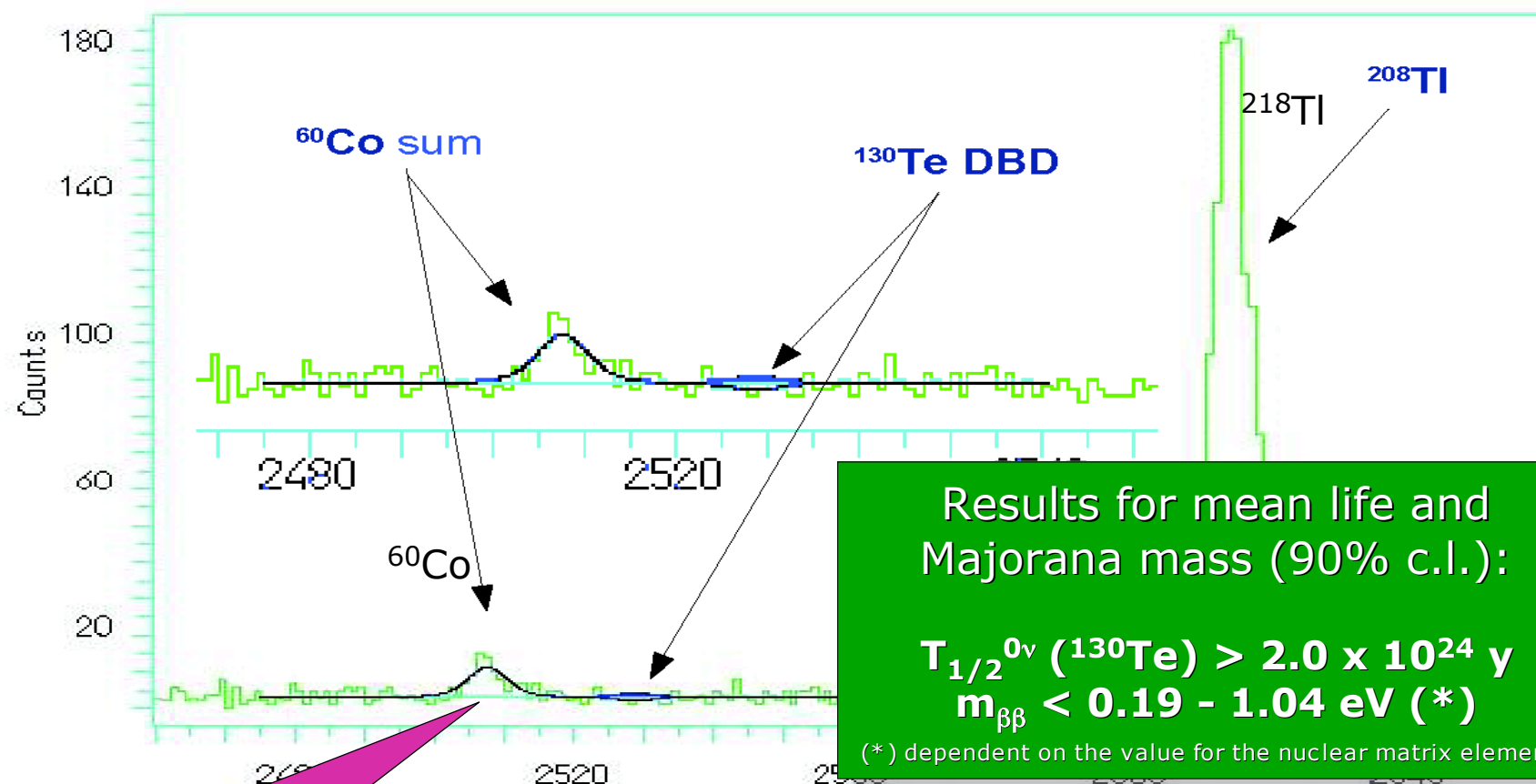
Samuele Sangiorgio, Università' dell'Insubria, Como, Italy

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Cryogenic Detector Meeting - 14 Nov 2005, IAP, Paris

CUORICINO results

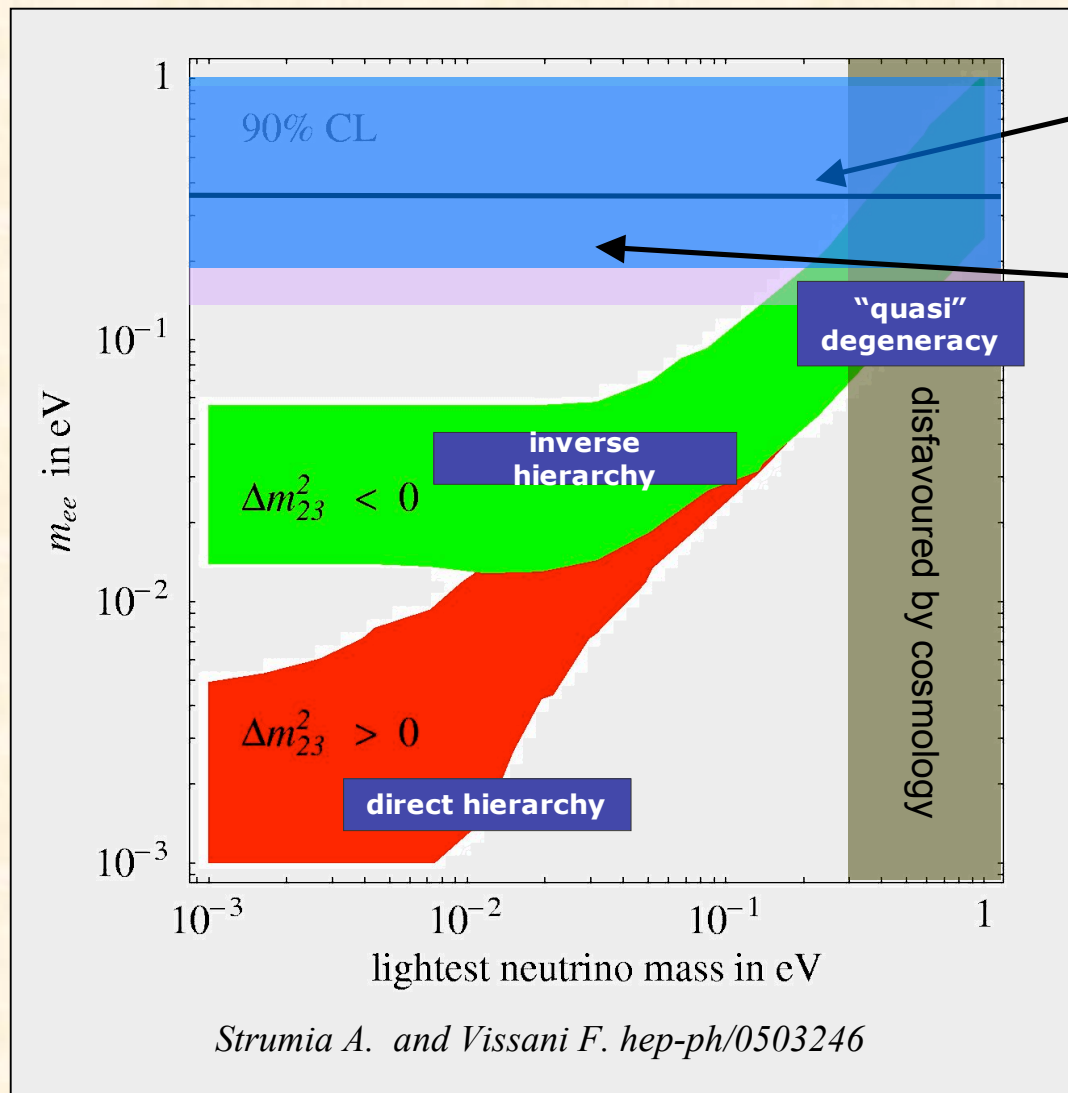
Cuoricino is successfully acquiring data from April 2003 (MT = 5.87 kg y ^{130}Te)
Background in $\beta\beta$ region (anticoincidence spectrum, only 5x5x5 cm³ crystals)
 0.18 ± 0.02 c/keV/kg/y



Appear only in the sum spectrum!

PRELIMINARY – Update 30 July 05

CUORICINO discovery potential



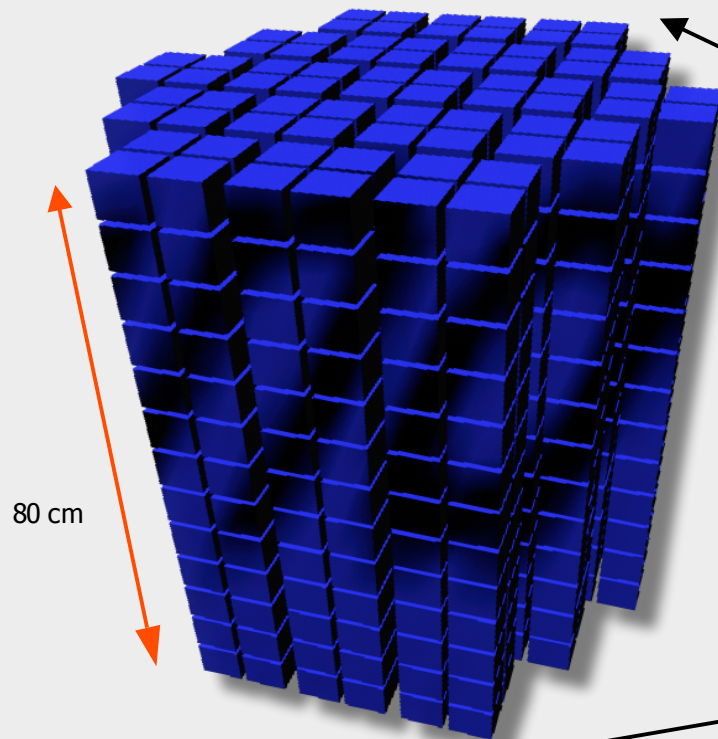
KK-HM possible evidence
hep-ph/0201231

Present CUORICINO limit
Arnaboldi et al, **Phys.Rev.Lett.**,
hep-ex/0501034 (2005)

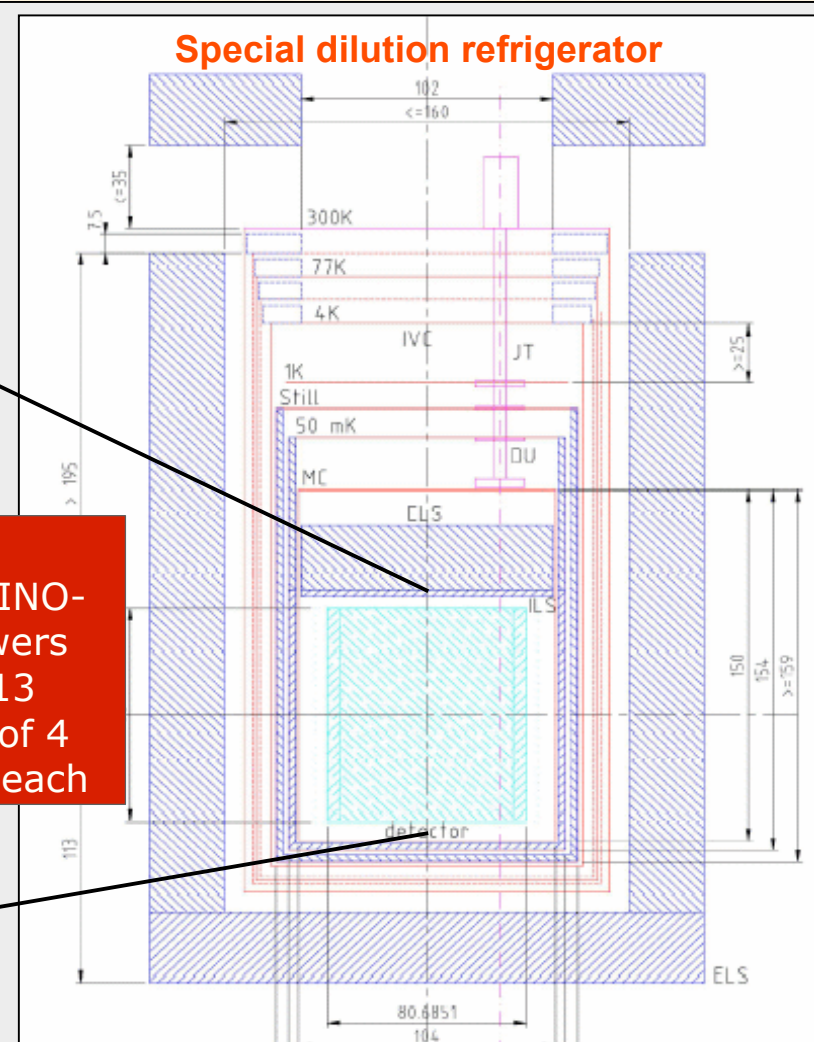
good chance to have a
positive indication in a short
time (3 y) but cannot falsify
KK if no signal is seen

CUORE: Cryogenic Underground Observatory for Rare Events

CUORE will be a closely packed array of **988 detectors** - $M \sim 741 \text{ kg}$ of TeO_2



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



Next-generation experiment – Already approved and funded

0ν DBD sensitivity

Sensitivity: Lifetime corresponding to the minimum number of detectable events above background at a given C.L.

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

M: active mass [kg]

b: background [c/keV/kg/y]

T: live time [y]

Γ : energy resolution [keV]

a: isotopic abundance

A: atomic mass

ε : efficiency

**CUORE
GOAL:
 ~ 50 meV**

Prospect ("straightforward") for CUORE:

T = 10 years **Γ** = 10 keV

b = **0.01** c/(keV·kg·y)

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

$$m_{ee} < 24 - 133 \text{ meV}$$

» background must be reduced by one or two order of magnitude from present Cuoricino one.

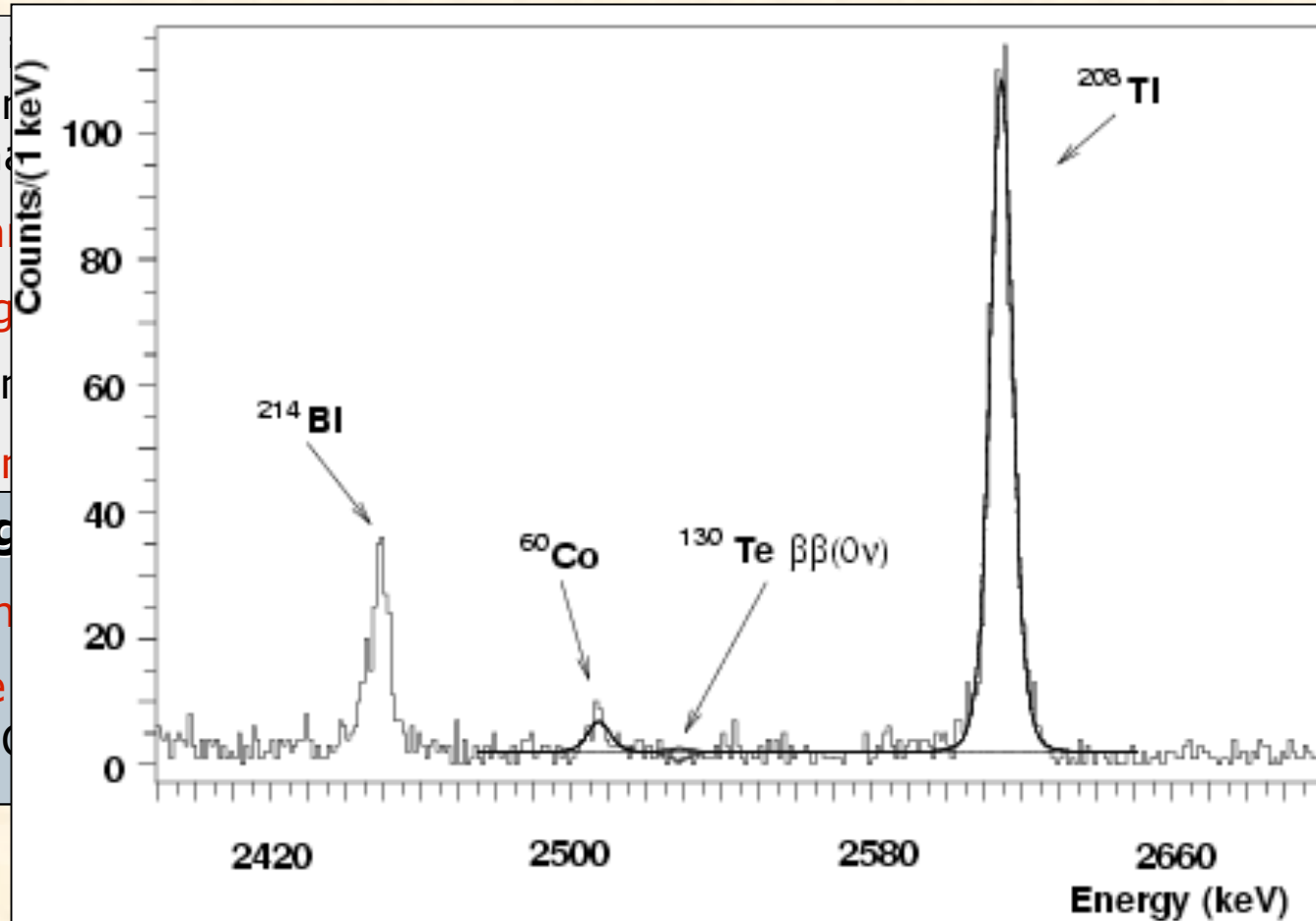
The background reduction

We have
evaluation
contamin

- Environ
- Cosmog
- $\beta\beta 2\nu \gg$
- Bulk cor

Flat bkg

- Neutron
- Surface
granular



**Possible
solutions**

» Review detector holder structure to minimize surfaces facing directly the absorber

» Reduce material contamination increasing quality of surface treatment

» Develop "clever" calorimeters to discriminate the origin of an event

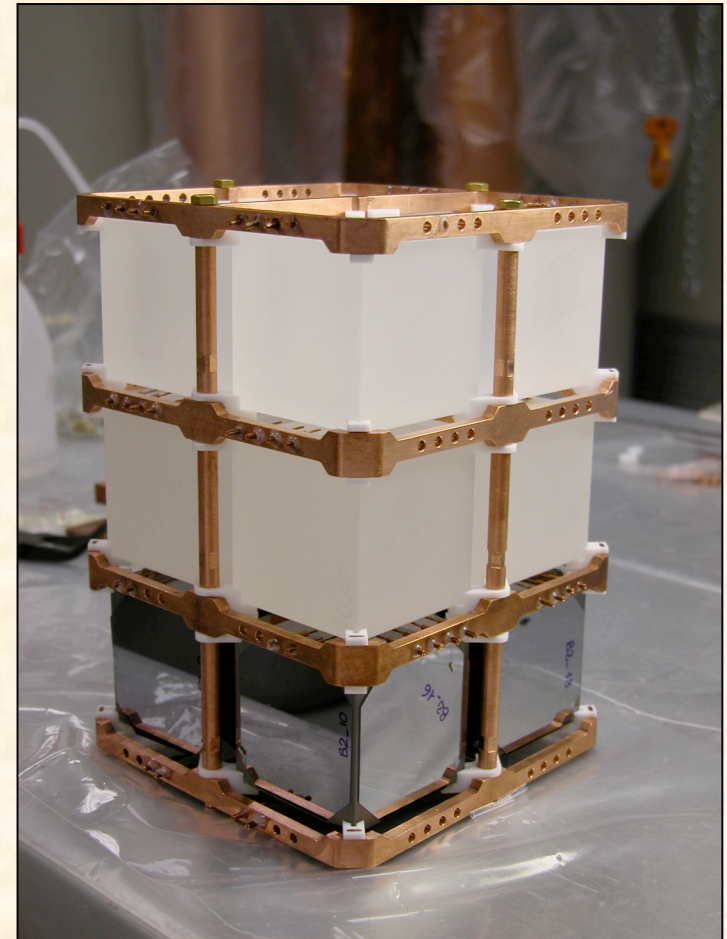
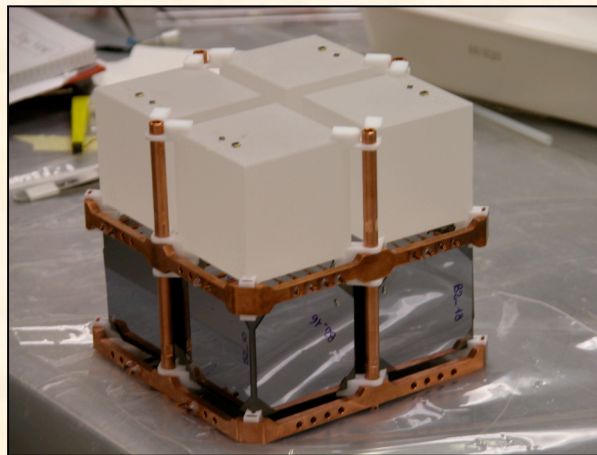
New mounting structure

Goals:

- Contribute to bkg reduction
- Improve resolution
- Improve reproducibility
- Improve the detector standardization
- Fast and standard assembling procedure

Results:

- resolution comparable with Cuoricino (5.5 ± 0.9 keV @ 2615keV)
- vibration analysis under way

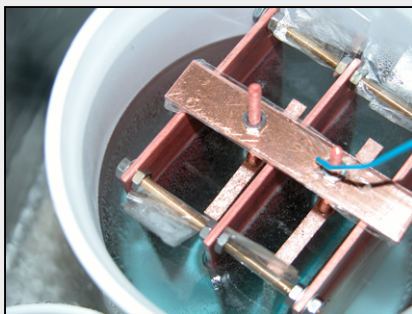


RAD tests

An array of **8 detectors** cleaned with **ultrapure materials** and **procedures**

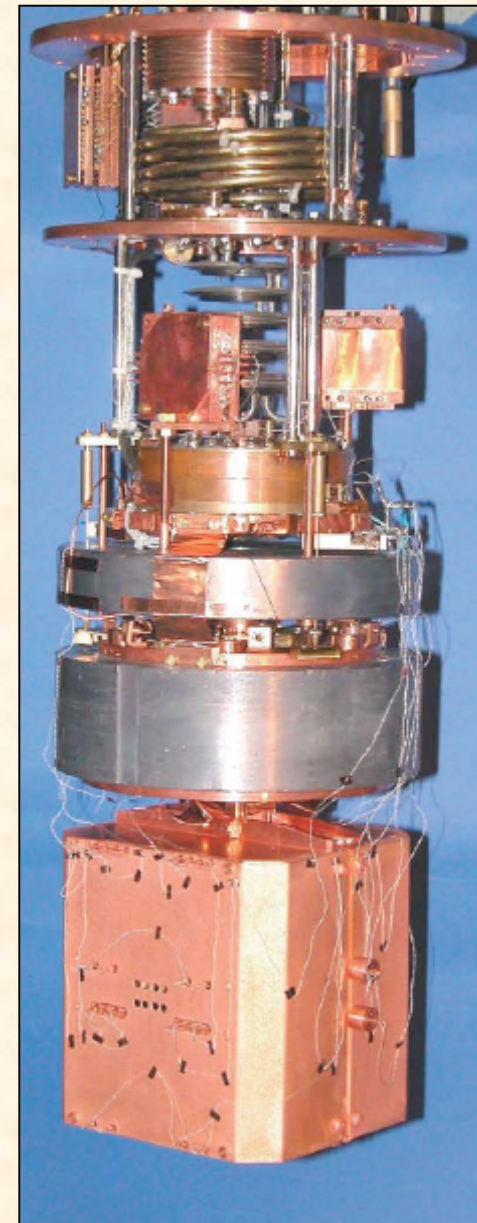
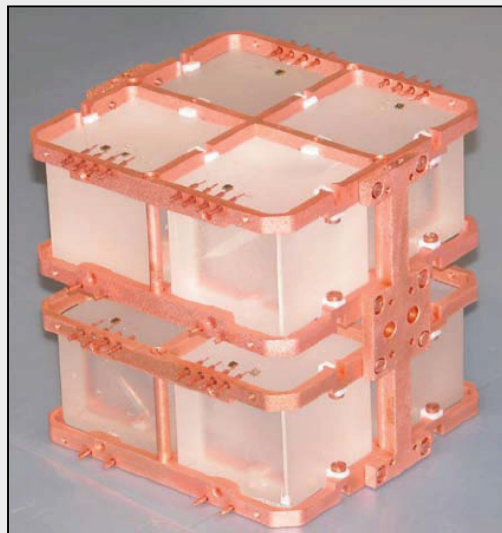
Copper

- Etching
- Electro polishing
- Passivation procedure

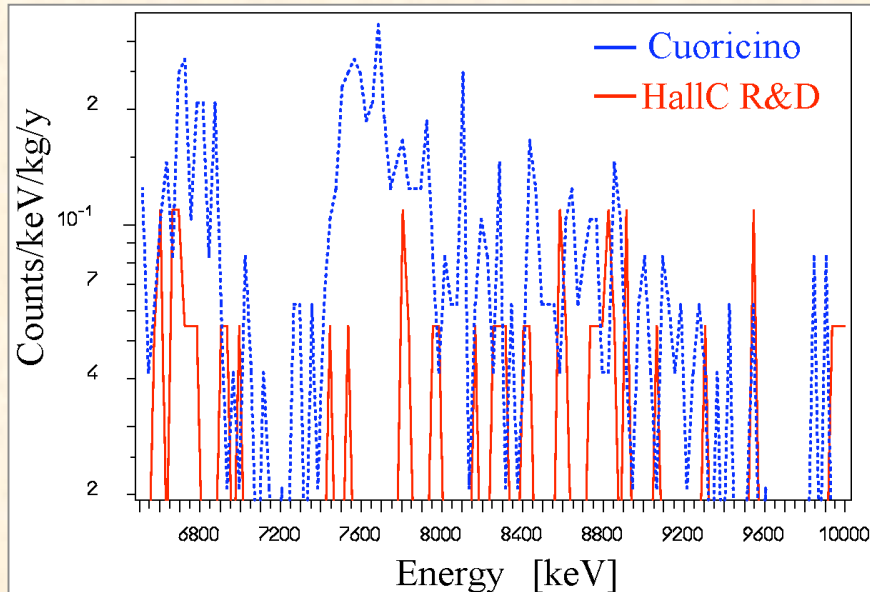
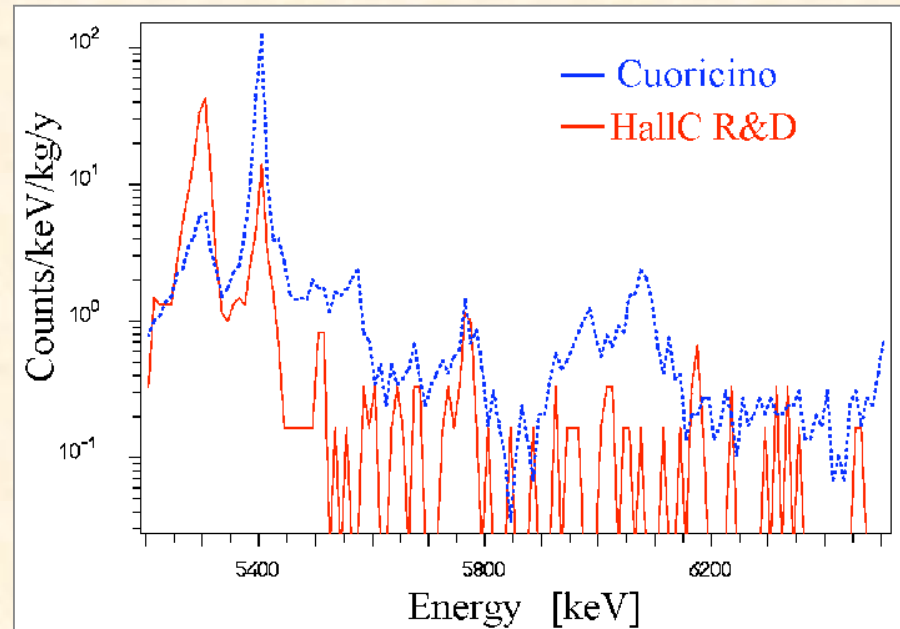
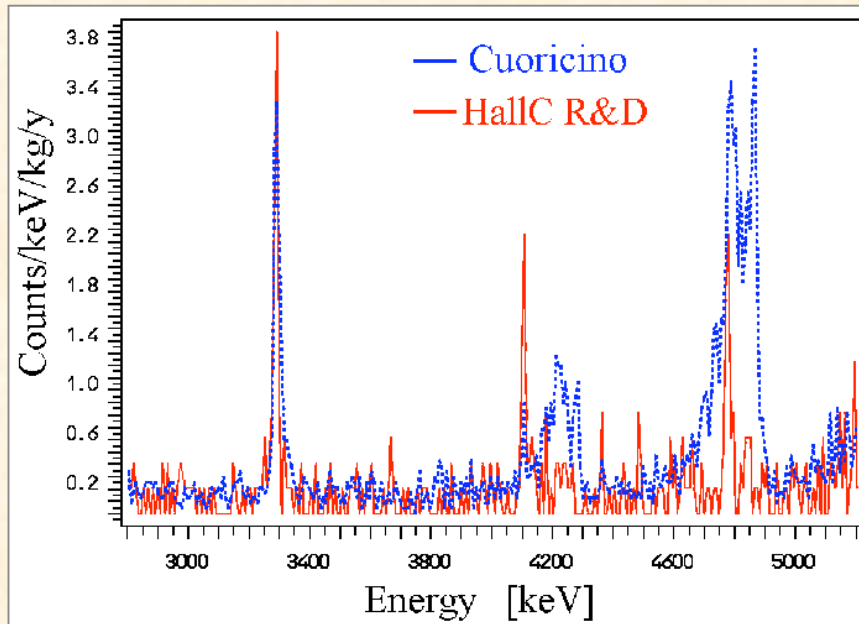


Crystals

- Crystal etching (Nitric acid)
- Lapping with clean powder ($2\mu \text{SiO}_2$)



RAD tests results



- Reduction of a factor ~ 4 on **crystal** surface contaminations
- Reduction of a factor ~ 2 on **copper** surface contaminations

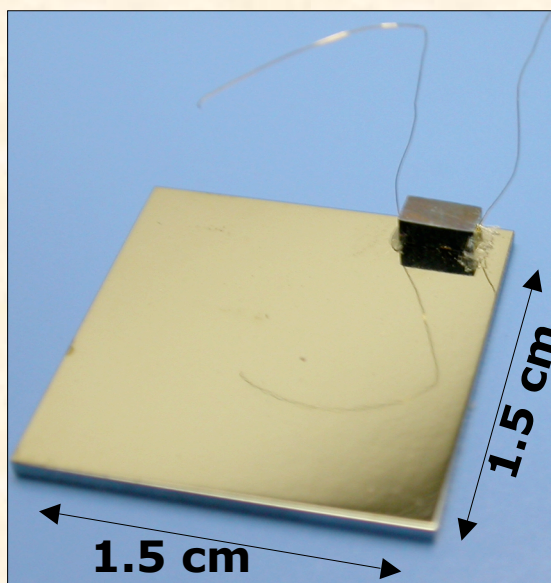
» new tests are on going in GranSasso

Surface Sensitive Bolometers (SSB)

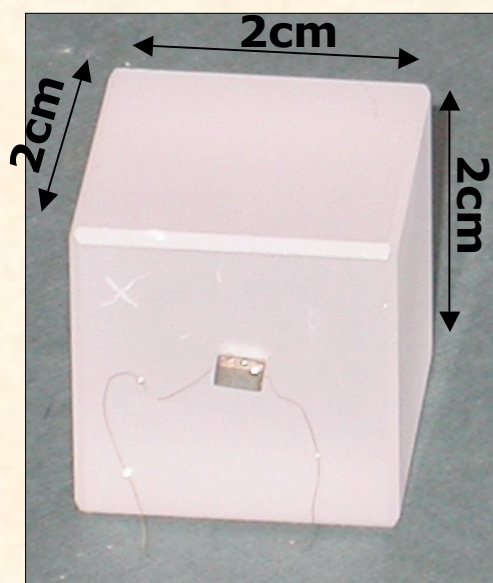
Active shielding of the main bolometer by means of thin foils of other absorber materials that provide full coverage.

New idea: the shields are thermally coupled with glue to the main absorber to form a single *composite bolometer*

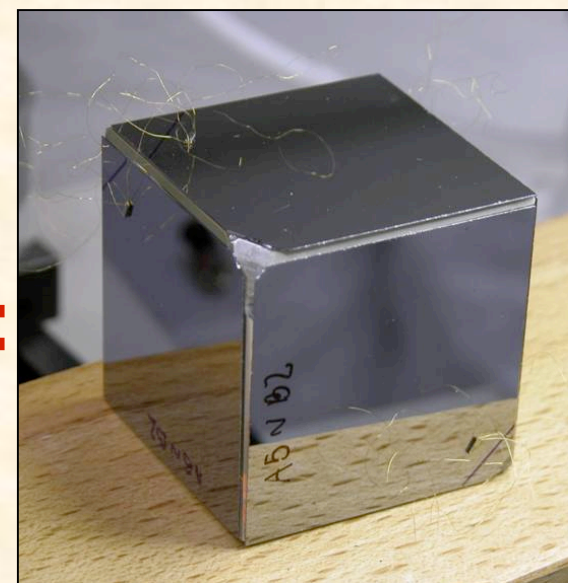
Shield bolometer



TeO₂ bolometer



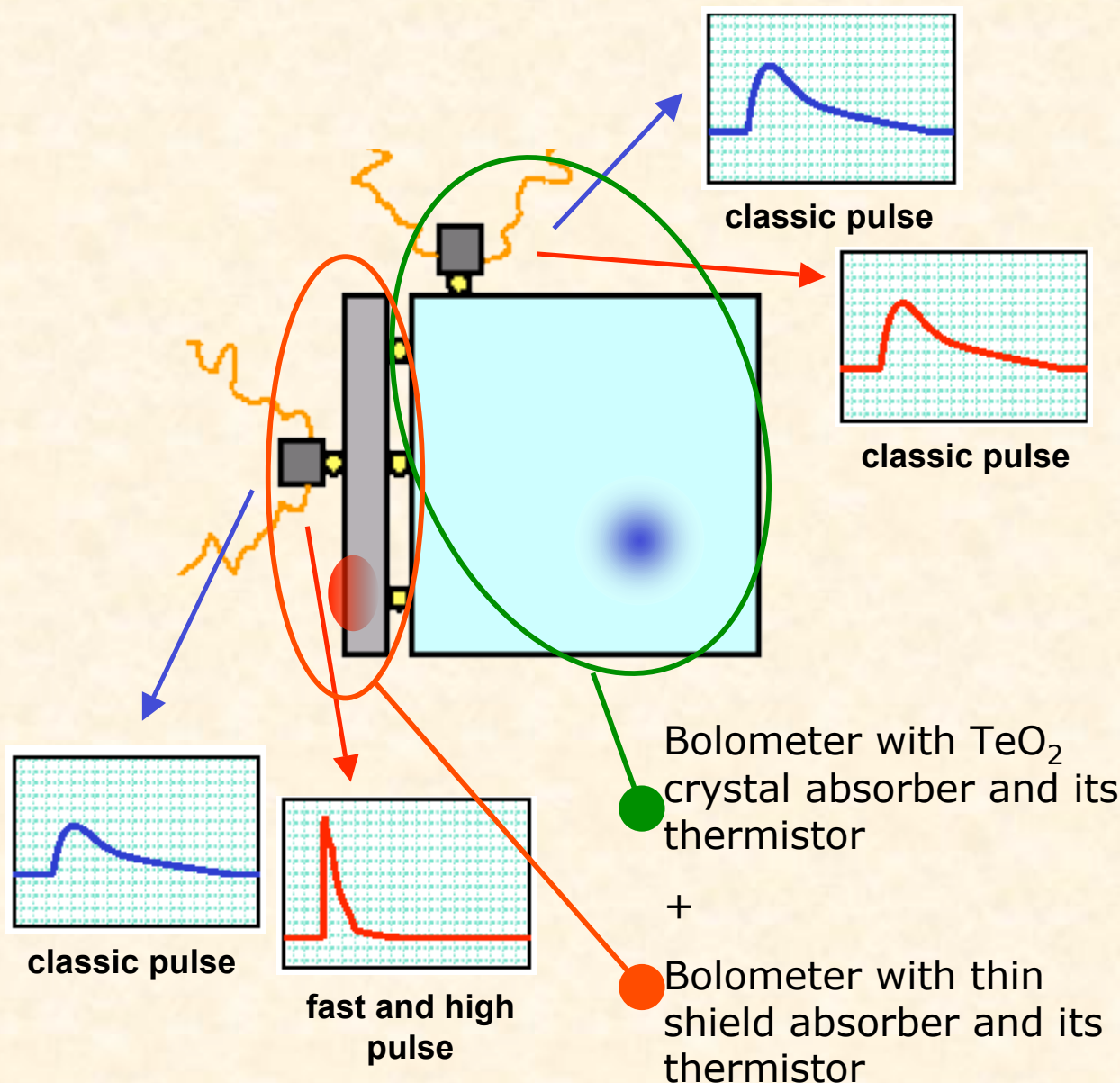
Composite bolometer



In this way the conventional anticoincidence technique is not very useful because particles releasing energy in the detector heat up each element of this composite bolometer.

How does it work?

Dynamic behaviour of SSBs



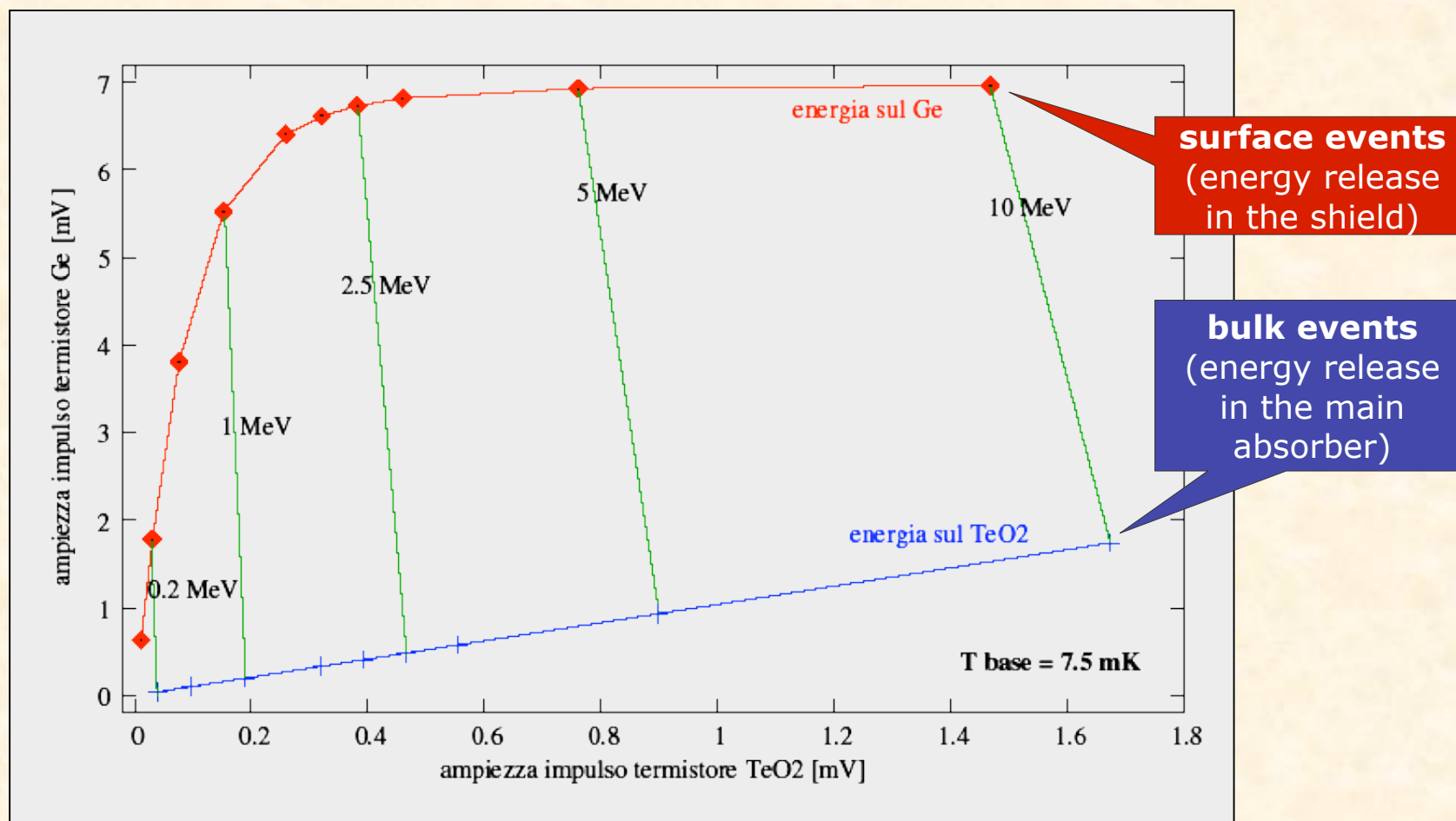
The presence of the shield changes the thermal dynamic behavior of the detector giving rise to pulses with different amplitudes and shapes.

Different impact points means different pulses on thermistors

Identification of surface events - 1: amplitude

Surface events may be identified comparing **pulse amplitudes** read **simultaneously** by the thermistor on the main absorber and on the active shield

» scatter plot



SSB Prototypes @ Como

Various **materials** for active shields were tested on small size detectors (main absorbers $2 \times 2 \times 2$ - $2 \times 2 \times 0.5$ cm³)

Ultrapure Ge

Pros:

- excellent results
- high purity

Cons:

- high cost

Ultrapure Si (PL – IRST)

Pros:

- affordable cost

Cons:

- lower purity

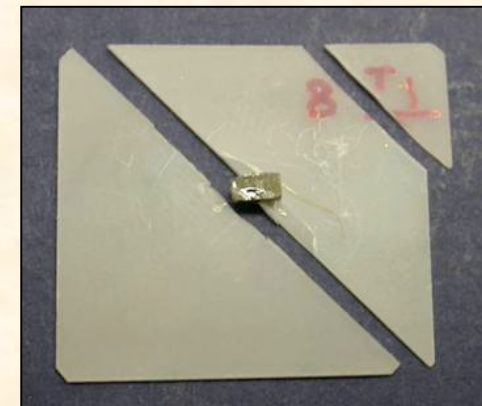
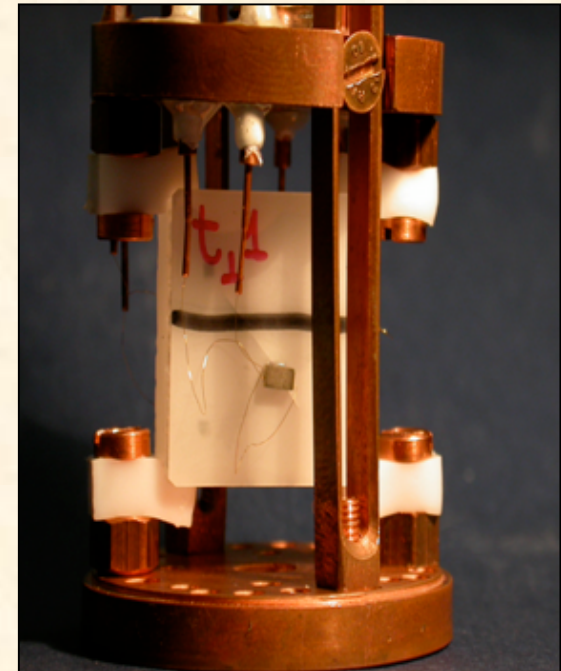
TeO₂

Pros:

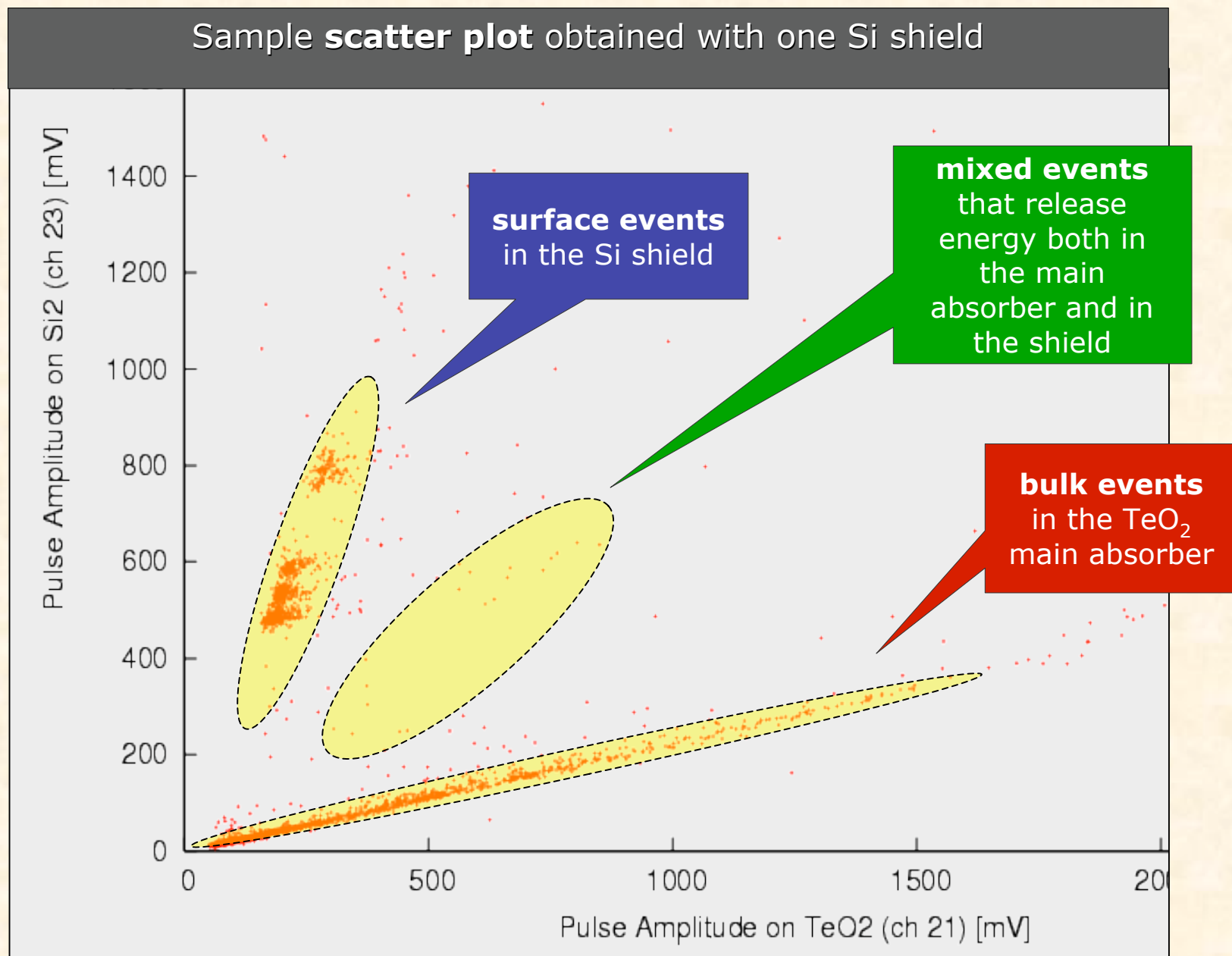
- known material
- differential thermal contractions

Cons:

- frailty ($h=500$ μ m)
- thermistor thermal coupling



Identification of surface events - 1: amplitude



Identification of surface events - 2: rise time

Rise time distribution of the pulses read by the thermistor on the shield:

Two

APPLIED PHYSICS LETTERS 86, 134106 (2005)

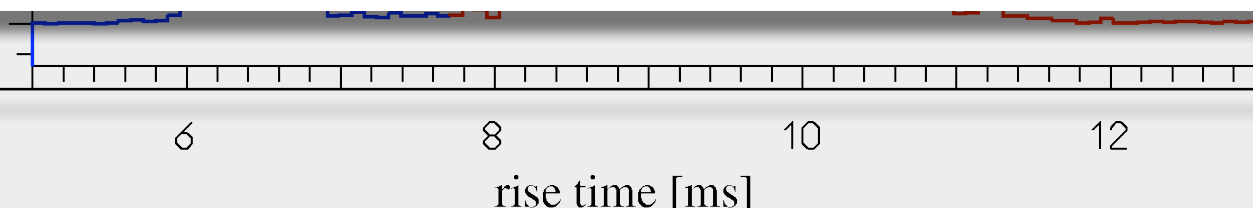
Surface-sensitive macrobolometers for the identification of external charged particles

Luca Foggetta, Andrea Giuliani,^{a)} Claudia Nones, Marisa Pedretti, and Samuele Sangiorgio

Department of Physics and Mathematics, University of Insubria, and INFN-Milano, Via Valleggio 11, 22100 Como, Italy

(Received 2 August 2004; accepted 22 February 2005; published online 22 March 2005)

We report the performance of two prototype TeO_2 macrobolometers, operated at ~ 25 mK, able to identify events due to energy deposited at the detector surface. This capability is obtained by thermally coupling thin Ge active layers to the main energy absorber of the bolometer, and is demonstrated by irradiating the detectors with α particles. The temperature variations of the main absorber and of the active layer are measured independently with doped Ge thermistors. These results show clearly that an intrinsic limitation of monolithic low temperature calorimeters, e.g., the impossibility to give information about event position, can be efficiently overcome using composite structures. © 2005 American Institute of Physics. [DOI: 10.1063/1.1894608]



pulse shape
discrimination

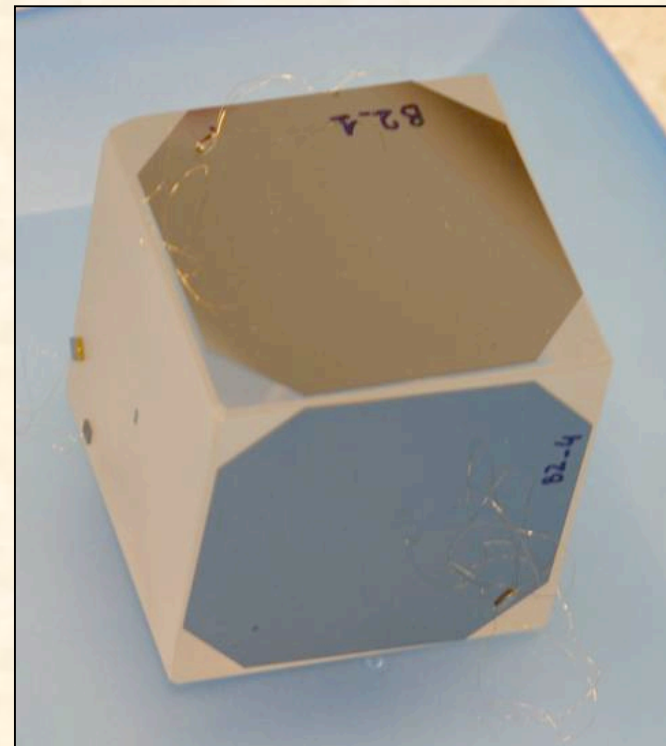
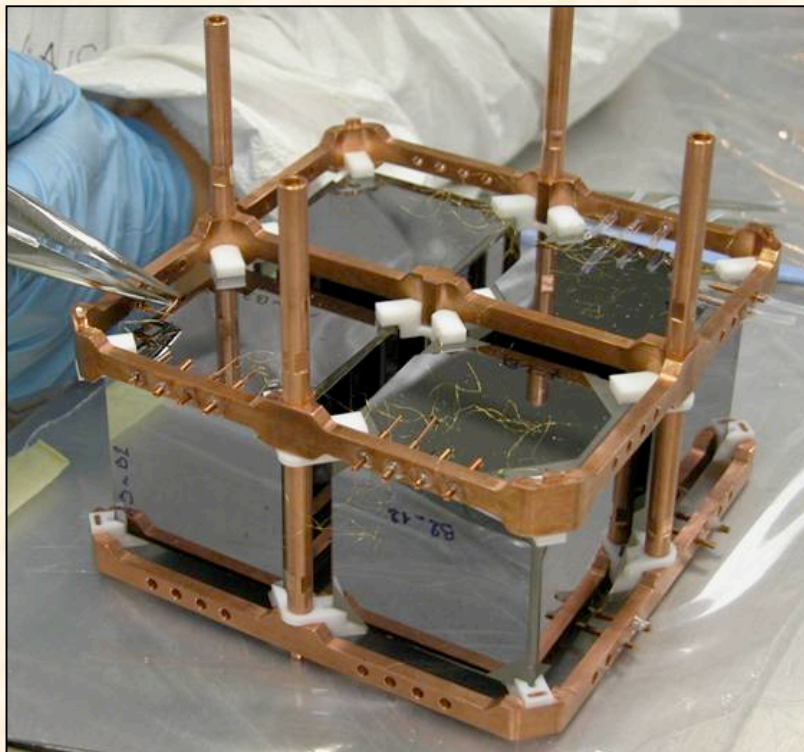
Large mass SSB @ LNGS

GOAL:

- real CUORICINO size bolometers ($5 \times 5 \times 5 \text{ cm}^3$)
- measure without pile-up from cosmic rays

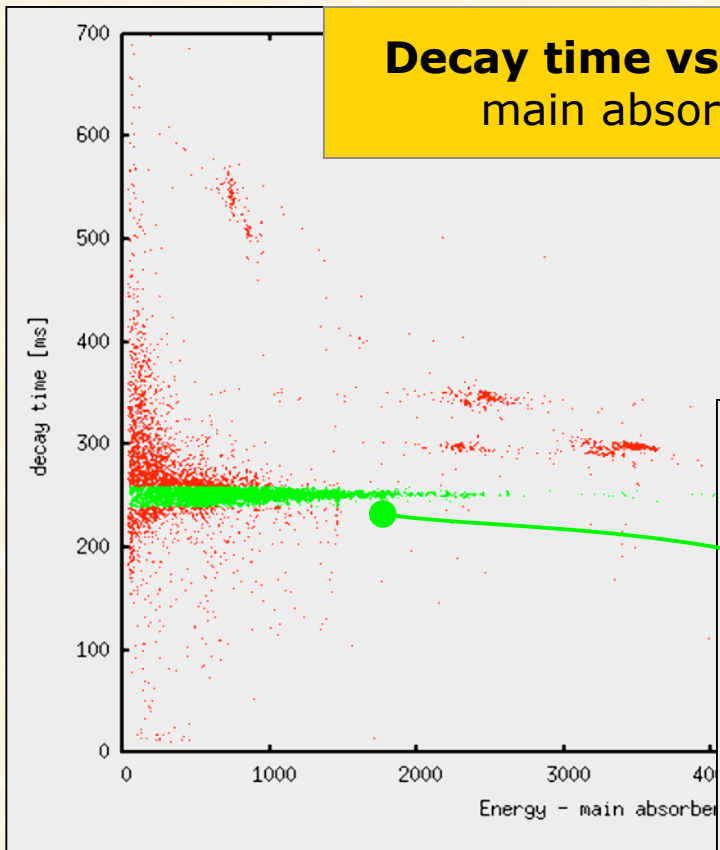
NB 1: No special surface treatment or radioactivity control » feasibility test to confirm behavior

NB 2: Parallel read-out for slabs to reduce channel proliferation

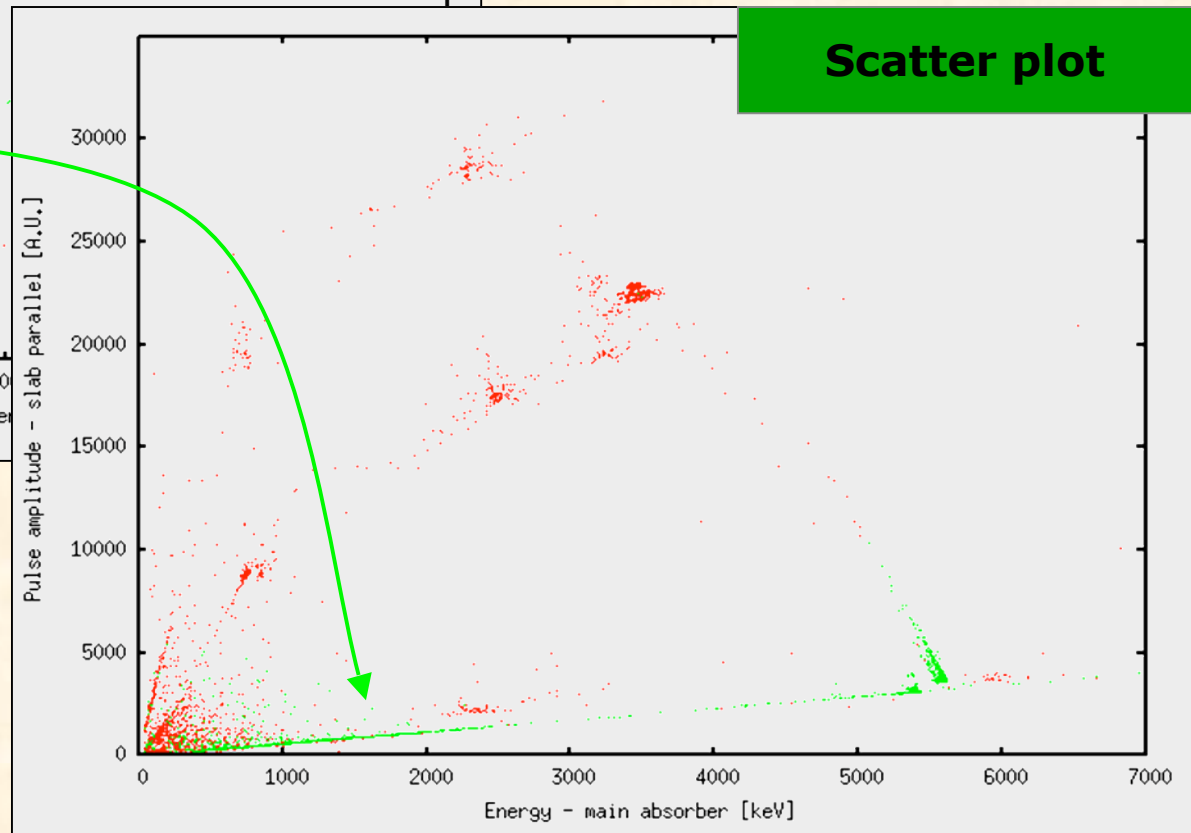


Identification of surface events - 3: decay time

Decay time vs amplitude on the main absorber thermistor



Scatter plot



Bulk events are well isolated by a cut in the decay time vs amplitude plot for the main sensor
» get rid of shields thermistors ?

SSB background reduction

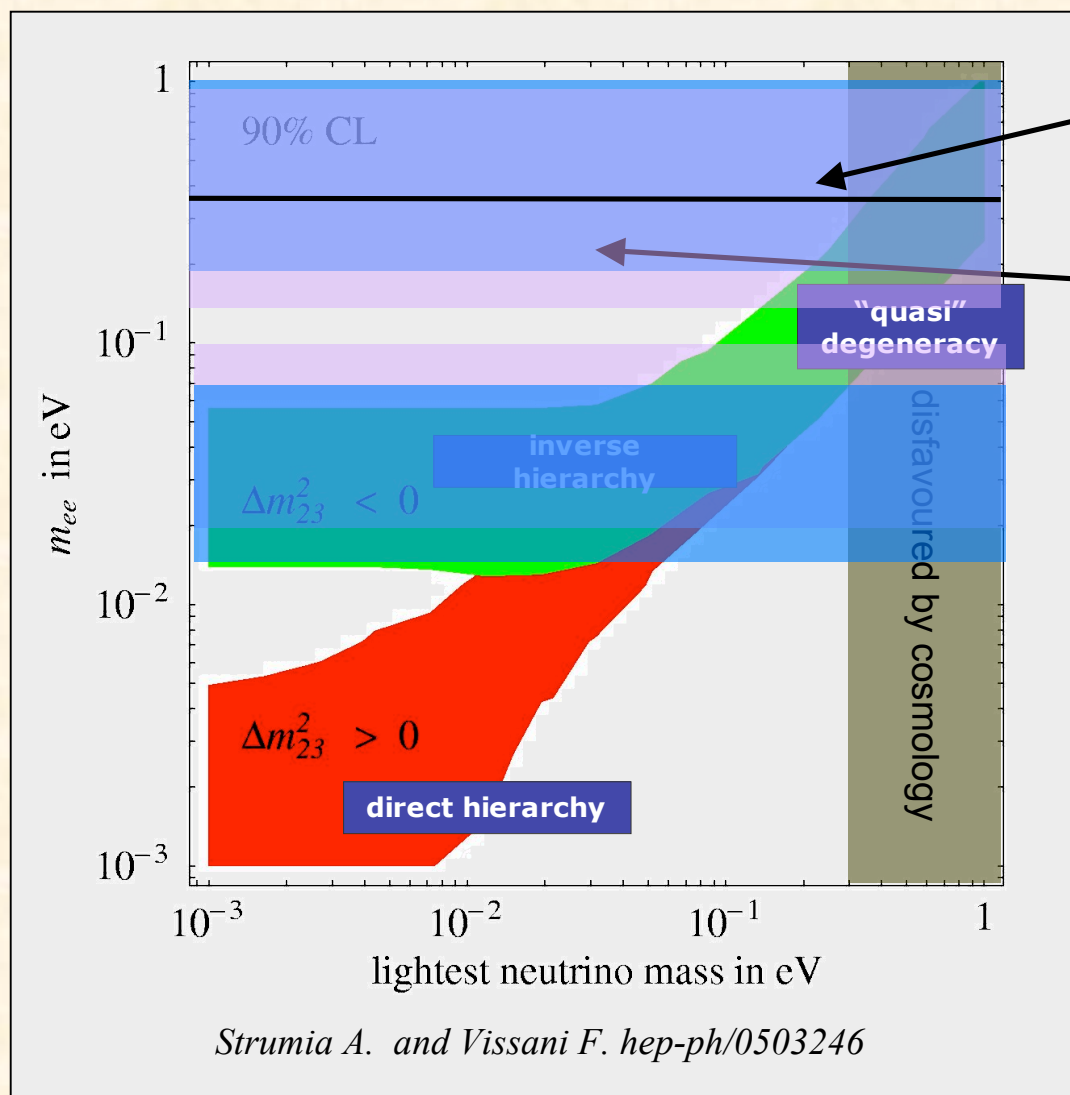
BACKGROUND MEASUREMENTS (α region)

measurements	2.7 – 3.2 MeV [c/keV/kg/y]	3.2 – 3.4 MeV [c/keV/kg/y]
CUORICINO (anticoinc, crystals btb)	0.14 ± 0.02	0.70 ± 0.07
RAD 1 TEST (anticoinc, 6 crystals)	0.14 ± 0.02	0.49 ± 0.06
LNGS SSB TEST (2 crystals, DT cuts)	0.18 ± 0.08 [2.9 – 3.2 MeV]	0.51 ± 0.16

Summary on the background issue:

- very good results from SSBs (even without any accurate cleaning procedure)
- DT selection could be an important feature to simplify SSBs
- more tests are on the way to clarify some aspects of the background (RAD 2-3 tests) and SSBs could be useful to investigate background origin
- also for SSBs a new run with TeO₂ slabs and clean condition is planned

CUORE expected sensitivity



KK-HM possible evidence
hep-ph/0201231

Present CUORICINO limit
Arnaboldi et al, **Phys.Rev.Lett.**,
hep-ex/0501034 (2005)

In 5 years:

b (counts/keV/kg/y)	Γ [keV]	$T_{1/2}$ [y]	$\langle m_\nu \rangle$ [meV]
10^{-2}	5	$2.1 \cdot 10^{26}$	19-100
10^{-3}	5	$6.5 \cdot 10^{26}$	11-57

Conclusions

- CUORICINO is presently the most sensitive $0\nu\text{DBD}$ running experiment (together with NEMO3)
- CUORICINO demonstrate the feasibility of a large scale bolometric detector with good energy resolution and background.
- An intense R&D work is going on to reduce the BKG, in order to permit to CUORE experiment to investigate the inverse hierarchy region of the neutrino mass pattern
- The construction of CUORE, a second generation detector, is started and we will start taking data in 5 years from now.

Cuoricino discovery potential

			Staudt et al.		
Ref.: (20)	(80)	(81)	(82)	(24, 83)	(84)

Expected event number in 3 y in a 13 keV energy window (1.5xFWHM: 92% of signal)

115	30	204	47	36	43
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$$1 \sigma \text{ BKG fluctuation} = (0.17 * 13 * 40 * 3)^{0.5} = 16$$

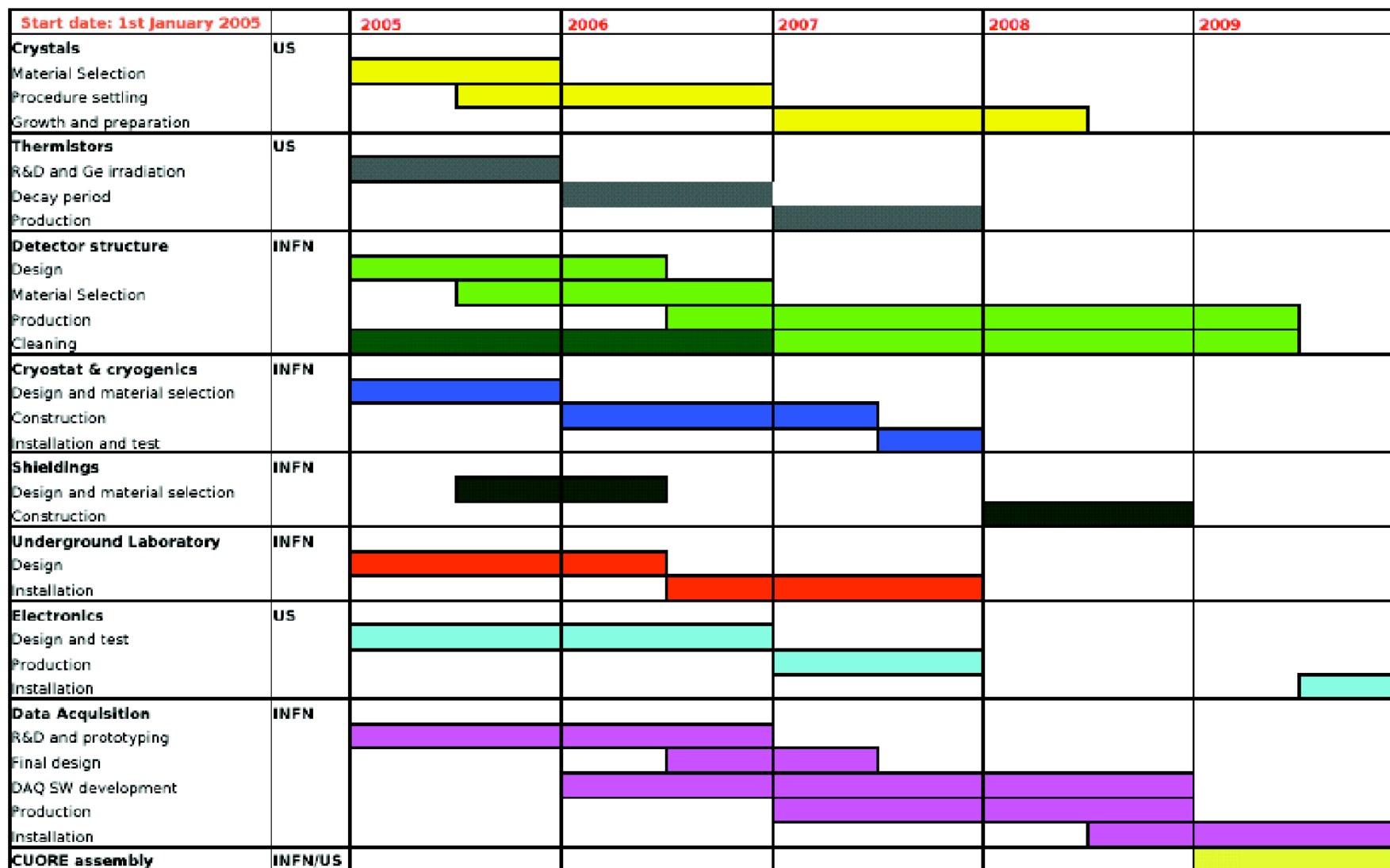
S/N ratio (σ)

7.2	1.9	13	2.9	2.3	2.7
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(to be compared with **28.75** events of the HM claim,
with a **BKG** level which is $0.11 / 0.17 = 0.65$ lower in HM
and with an energy **resolution** which is **3x better** in HM)

good chance to have a positive indication
cannot falsify HM if no signal is seen

CUORE time schedule



CUORE COLLABORATION

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