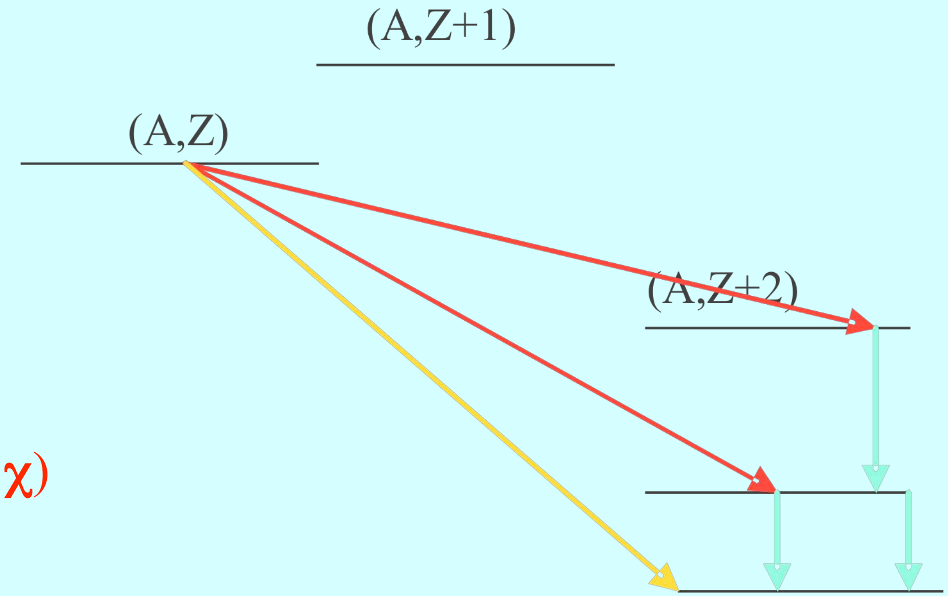
Results of CUORICINO and R&D of CUORE

Ettore Fiorini, Erice, September 22, 2005



1. $(A,Z) \Rightarrow (A,Z+2) + 2\,e^- + \mathbf{2}\ \bar{\nu}_e$
2. $(A,Z) \Rightarrow (A,Z+2) + 2\,e^- + (..\ 2,3\ \chi)$
3. $(A,Z) \Rightarrow (A,Z+2) + 2\,e^-$

Process 2. And 3. imply lepton violation
Process 3. Is normally called "neutrinoless $\beta\beta$ decay"
Crucial for the determination of the absolute value of the Majorana neutrino mass $<m_{\nu}>$

IS THE NEUTRINO A MAJORANA OR A DIRAC PARTICLE ?

$\nu = \bar{\nu}$ or $\nu \neq \bar{\nu}$

Lepton number

conservation or violation

Has neutrino a finite mass

100 % chirality

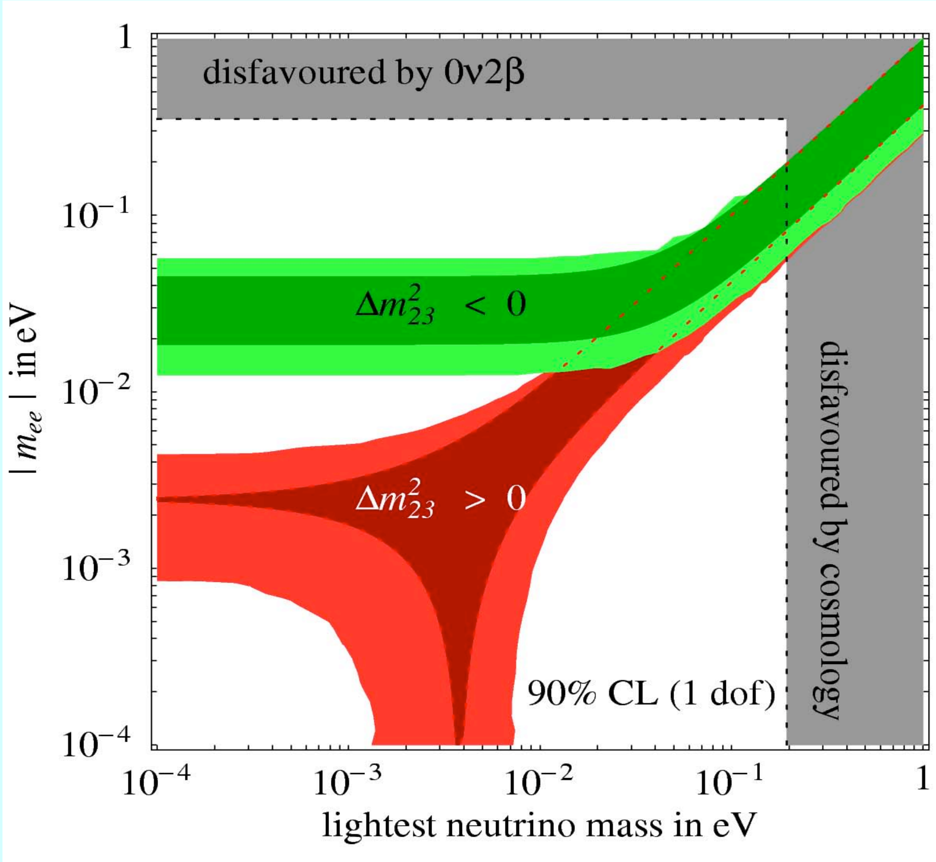
ν	$\bar{\nu}$
$\rightarrow$	$\rightarrow$
$\Leftarrow$	$\Rightarrow$

Double Beta –Disintegration

M.Goeppert-Mayer, *The John Hopkins University*
(Received May, 20 , 1935)

From the Fermi theory of $\beta-$ disintegration the probability of simultameous emission of two electrons (and two neutrinos) has been calculated. The result is that this process occurs sufficiently rarely to allow an half-life of over 10^{17} years for a nucleus, even if its isobar of atomic number different by 2 were more stable by 20 times the electron mass

Since the very beginning double beta decay was considered as a powerful tool to test lepton number conservation. Many experiments were carried out sometimes with later disproved evidences. First evidences in geochemical experiments and for the first time with a direct experiment on ^{82}Se by M.Moe



rate of DDB-0ν Phase space Nuclear matrix elements EffectiveMajorana neutrino mass

$$1/\tau = G(Q,Z)\ |M_{nucl}|^2 \langle m_\nu \rangle^2$$

Experimental approach

Geochemical experiments

^{82}Se = > ^{82}Kr, ^{96}Zr = > ^{96}Mo, ^{128}Te = > ^{128}Xe (non confirmed), ^{130}Te = > ^{130}Te

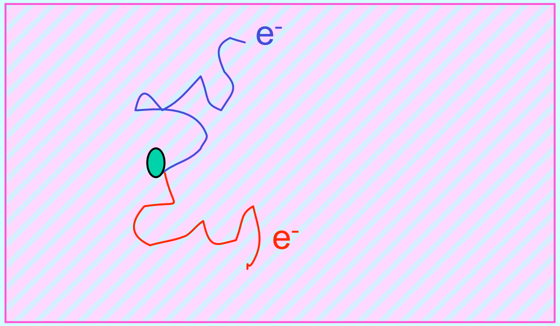
Radiochemical experiments

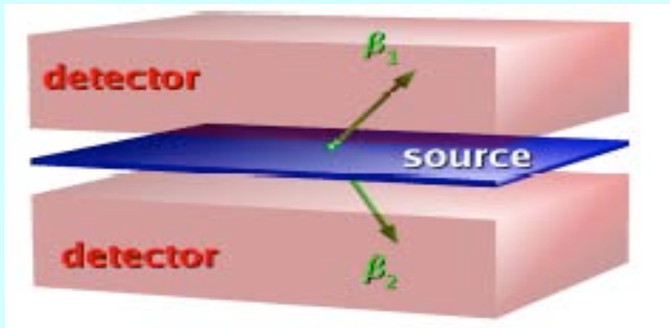
^{238}U = > ^{238}Pu (non confirmed)

Direct ex-periments

Source = detector (calorimetric)

Source ≠ detector





Fiorini - 04

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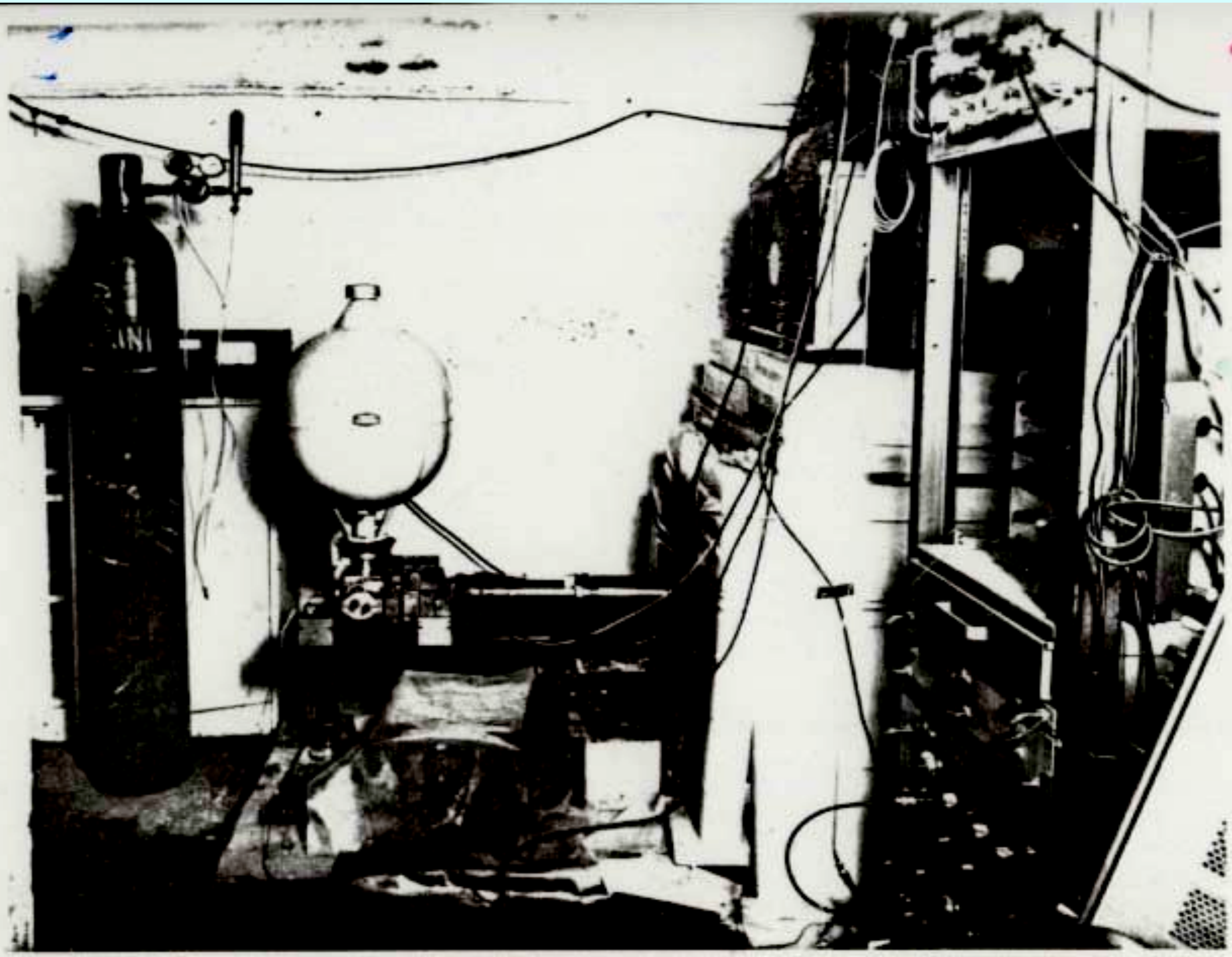


$\tau_{0\nu} > 5\times10^{21}$ $\langle m_\nu \rangle < 30$

i.a. 12

mass $\sqrt{1000}$

t $\sqrt{3}$

ΔE $\sqrt{2}$

Back $\sqrt{15}$

$\downarrow$

3600

$\downarrow$

1.8×10^{25}

$\downarrow$

$\langle m_\nu \rangle < .3$

Recent results on two neutrino bb decay

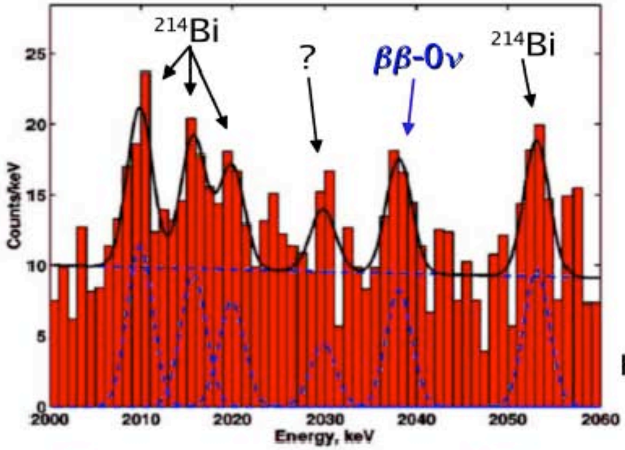
Isotope	$T_{1/2}^{2\nu}$ (y) (measured)	$T_{1/2}^{2\nu}$ (y) (calculated)
^{48}Ca	**(4.2 +2.1-1.0) × 10^{19}**	**6 × 10^{18} - 5 × 10^{20}**
^{76}Ge	**(1.42 +0.09- 0.07) × 10^{21}**	**7 × 10^{19} - 6 × 10^{22}**
^{86}Se	**(0.9 ± 0.1) × 10^{20}**	**3 × 10^{18} - 6 × 10^{21}**
^{96}Zr	**(2.1+0.8-0.4) × 10^{19}**	**3 × 10^{17} - 6 × 10^{20}**
^{100}Mo	**(8.0 ± 0.7) × 10^{18}**	**1 × 10^{17}- 2 × 10^{22}**
^{100}Mo(0^*)	**6.8 ± 1.2) × 10^{20}**	**5 × 10^{19} - 2 × 10^{21}**
^{126}Cd	**(3.3 +0.4-0.3) × 10^{19}**	**3 × 10^{18} - 2 × 10^{21}**
^{128}Te	**(2.5 ± 0.4) × 10^{24}**	**9 × 10^{22} - 3 × 10^{25}**
^{130}Te	**(0.9 ± 0.15) × 10^{21}**	**2 × 10^{19} - 7 × 10^{20}**
^{150}Nd	**(7.0 ± 1.7) × 10^{18}**	**6 × 10^{16}- 4 × 10^{20}**
^{238}U	**(2.0 ± 0.6) × 10^{21}**	**1.2 × 10^{19}**

Present experimental situation

Nucleus	Experiment	%	$Q_{\beta\beta}$	Enr	Technique	$T_{0\nu}$ (y)	$<m_\nu)$
^{48}Ca	Elegant IV	0.2	4271		scintillator	$>1.4x10^{22}$	7-45
^{76}Ge	Heid-Moscow	7.8	2039	87	ionization	$>1.9x10^{25}$	.12 - 1
^{76}Ge	IGEX	7.8	2039	87	ionization	$>1.6x10^{25}$	.14 – 1.2
^{76}Ge	Klapdor et al	7.8	2039	87	ionization	$1.2x10^{25}$	.44
^{82}Se	NEMO 3	9.2	2995	97	tracking	$>1.x10^{23}$	1.8-4.9
^{100}Mo	NEMO 3	9.6	3034	95-99	tracking	$>4.6x10^{23}$	.7-2.8
^{116}Cd	Solotvina	7.5	3034	83	scintillator	$>1.7x10^{23}$	1.7 - ?
^{128}Te	Bernatovitz	34	2529		geochem	$>7.7 \times 10^{24}$	.1-4
^{130}Te	Cuoricino	34	2529		bolometric	$>1.8x10^{24}$	.2-1.1
^{136}Xe	DAMA	8.9	2476	69	scintillator	$>1.2x10^{24}$	1.1 -2.9
^{150}Nd	Irvine	5.6	3367	91	tracking	$>1.2x10^{21}$	3 - ?

Heidelberg-Moscow exp.: evidence for $\beta\beta$-0ν of ^{76}Ge

- best exploitation of the Ge detector technique proposed by E. Fiorini in 1960
  - longest running experiment (13 years) with largest exposure (71.7 kg$\times$y)
  - Status-of-the-art for low background techniques and for enriched Ge detectors
  - reference for all last generation $\beta\beta$-0ν experiments



1990 – 2003 data, all 5 detectors

exposure = 71.7 kg$\times$y

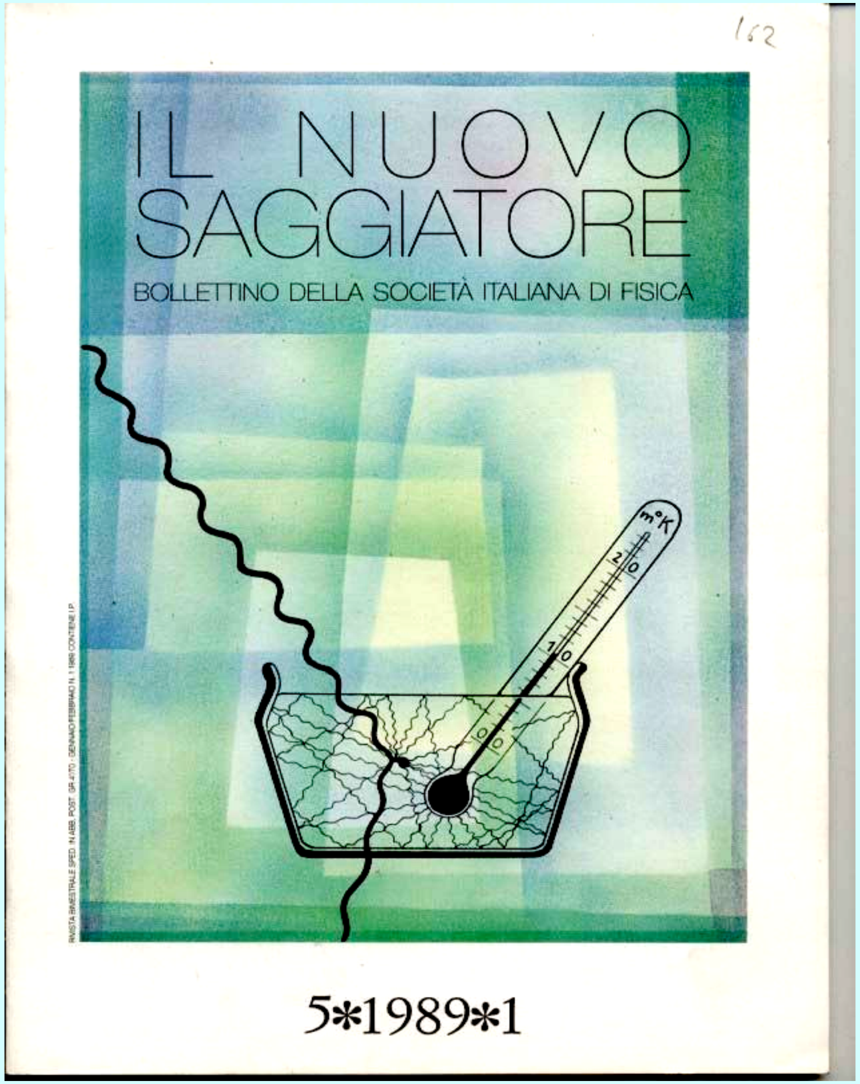
$\tau_{1/2}^{0\nu}$ = 1.2$\times$10^{25} years

$\langle m_\nu \rangle$ = 0.44 eV

H.V.Klapdor-Kleingrothaus *et al.*, Phys. Lett. B 586 (2004) 198

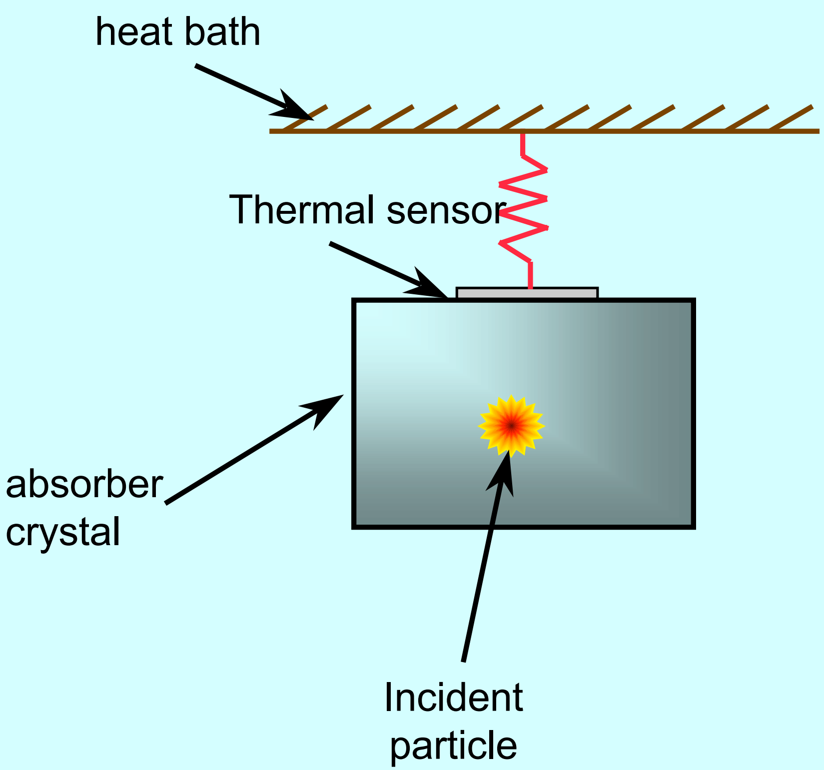
- still, community **does not fully accept the result**, because:
  - signal is indeed **too faint** (4 σ) to be *blindly* accepted: people still find some weak points in the published analysis
  - presence of **not understood peaks** around the signal and with *similar* significance
  - impossibility to check an **energy window larger** than the published one
- nevertheless any future $\beta\beta$-0ν experiment will have to cope with this result

Thermal Detectors



$$\Delta T = \frac{Q}{C_V}$$

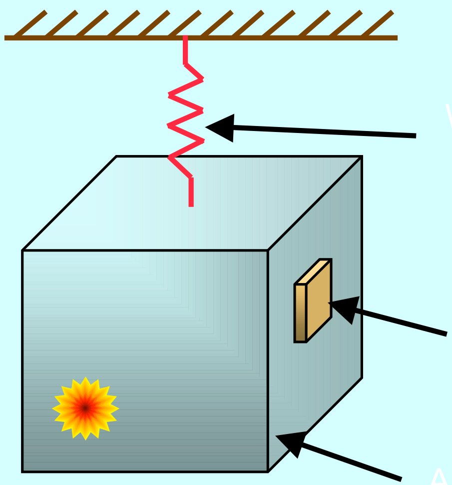
$$C_V = 1944 \frac{V}{V_m} \left(\frac{T}{\Theta}\right)^3 \ \mathrm{J/K}$$

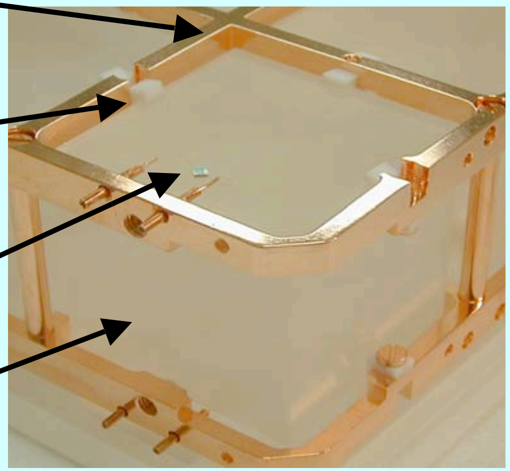


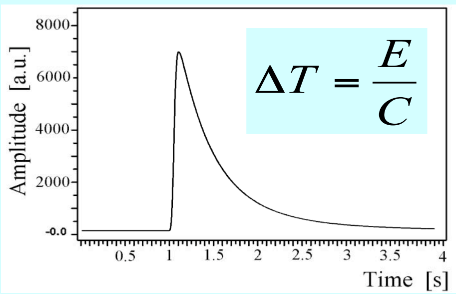
Excellent resolution <1 eV **~ 3 eV** @ 6 keV

~10 eV **~keV** @ 2 MeV

Cryogenic Detectors







Cryodet features

- ▲ wide choice of detector materials
- ▲ good energy resolution
- ▲ true calorimeters
- ▼ velocity

Resolution of the 5x5x5 cm3 (~ 760 g) crystals

:

0.8 keV FWHM @ 46 keV

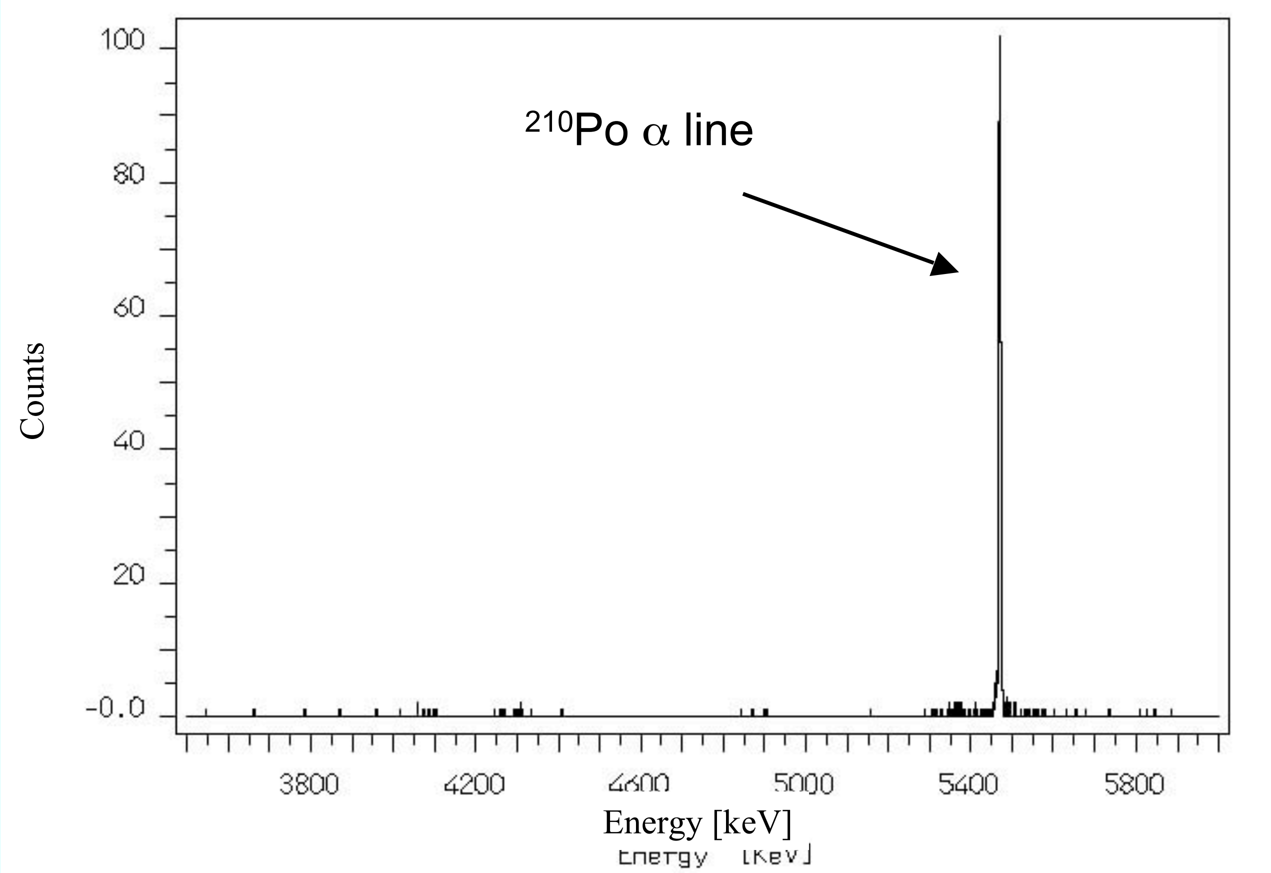
1.4 keV FWHM @ 0.351 MeV

2.1 keV FWHM @ 0.911 MeV

2.6 keV FWHM @ 2.615 MeV

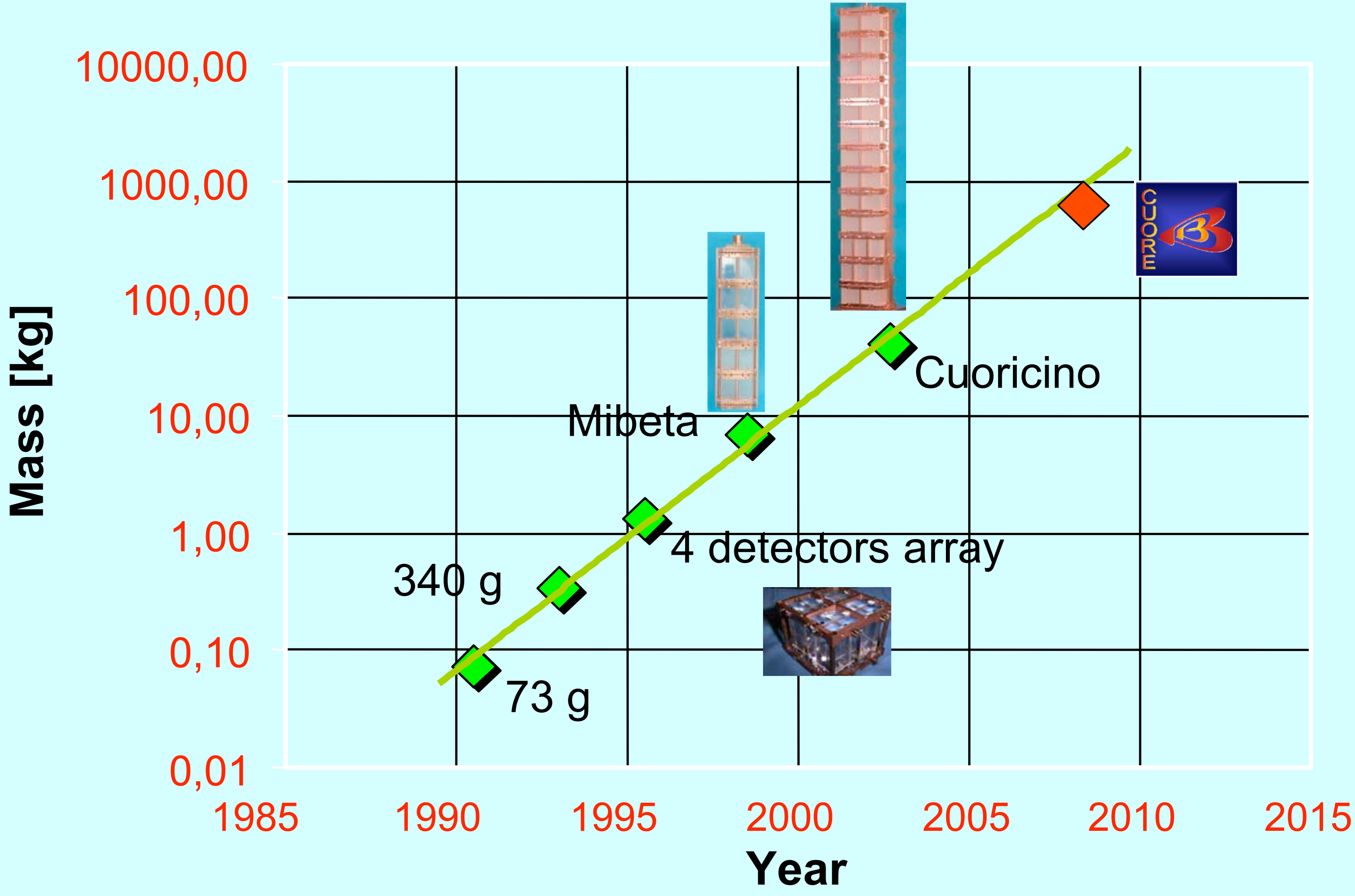
3.2 keV FWHM @ 5.407 MeV

(the best α spectrometer ever realized)



Mass Increase

②



CUORICINO set-up

Total mass
~41 kg

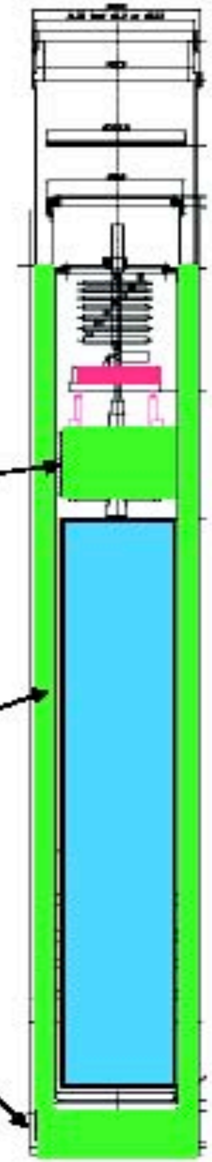
11 modules 4 detector each,
5x5x5 cm³ **790 g** TeO_2 crystals

+

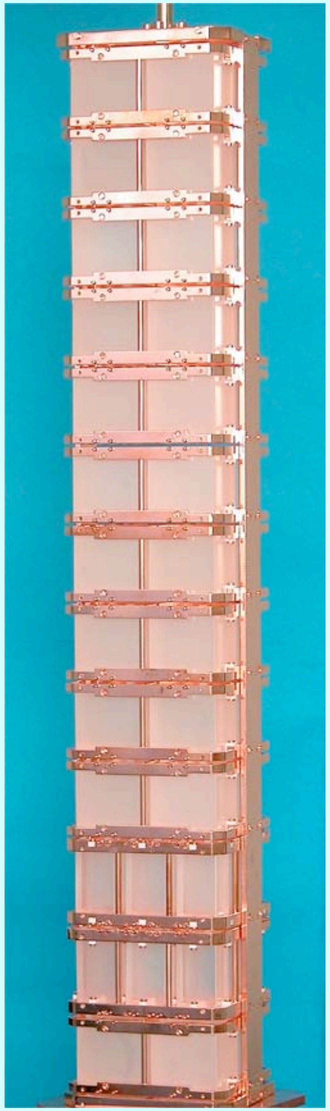
2 modules 9 detector each,
3x3x6 cm³ **330 g** TeO_2 crystals

Particular care devoted to **selection** and **cleaning** of materials:

- -cystals grown from pre-tested low activity powders
- -crystals surface treatment with low activity materials
- -low activity selected copper faced to the detector
- - Copper and PTFE surface cleaning
- - Mounting operations in clean environment



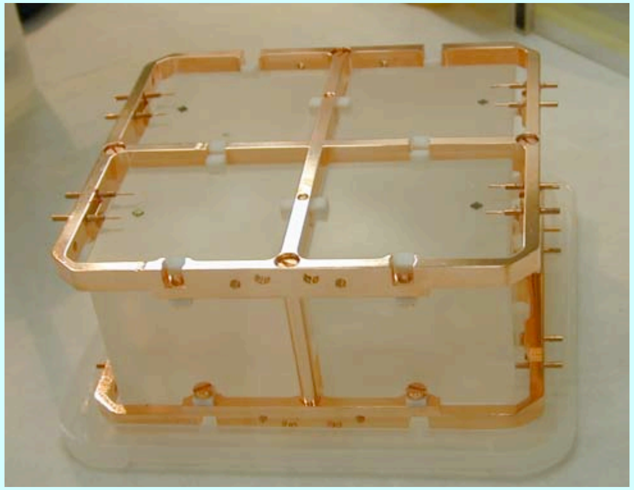
Cuoricino

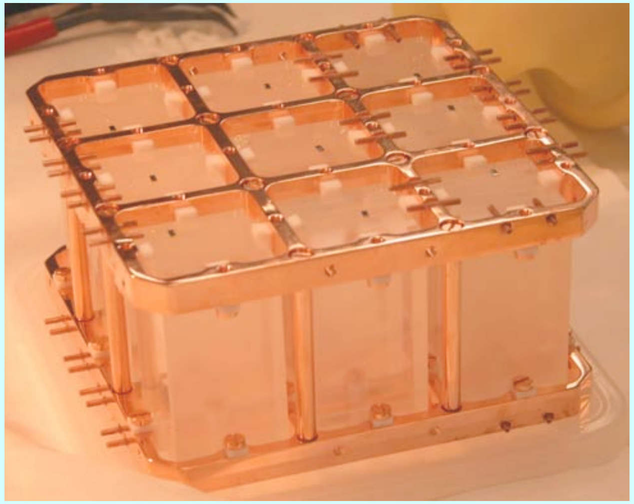


11 modules
4 detectors each
Dimension: 5x5x5 cm^3
Mass: 790 g

Total mass
40.7 kg

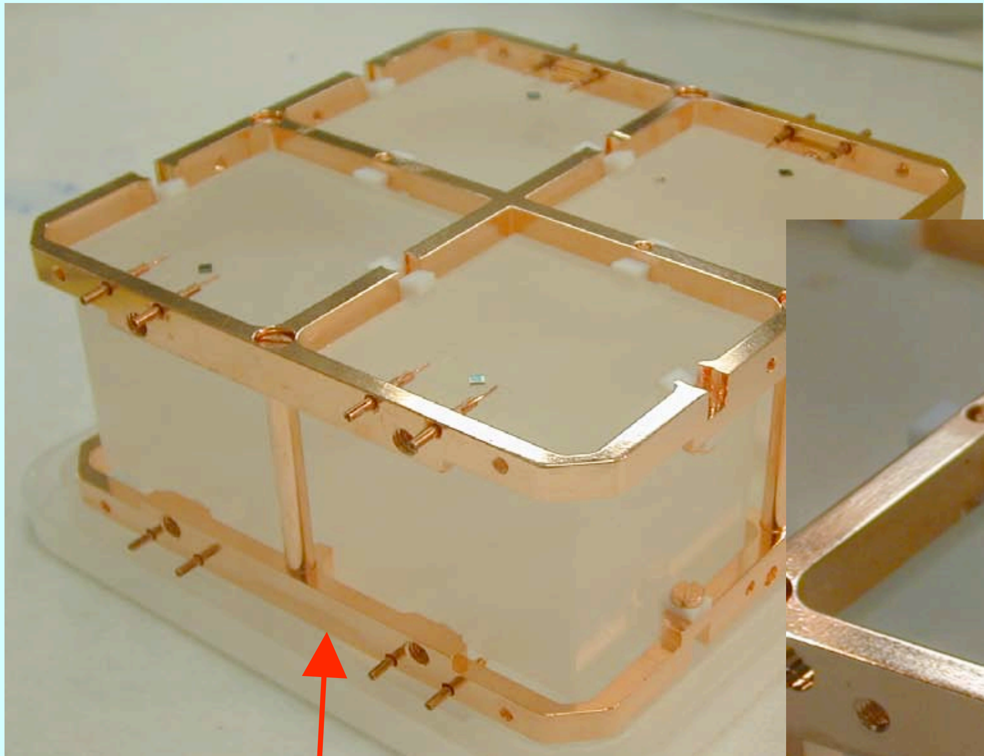
2 modules
9 detectors each,
Dimension: 3x3x6 cm^3
Mass: 330 g

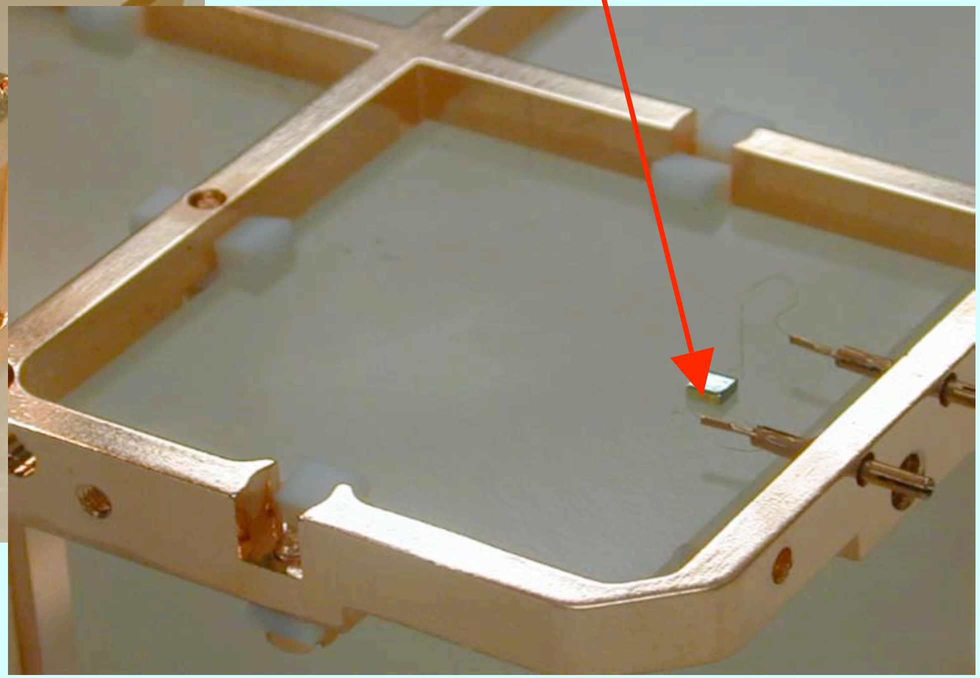




Mass Increase

Ge NTD thermistor





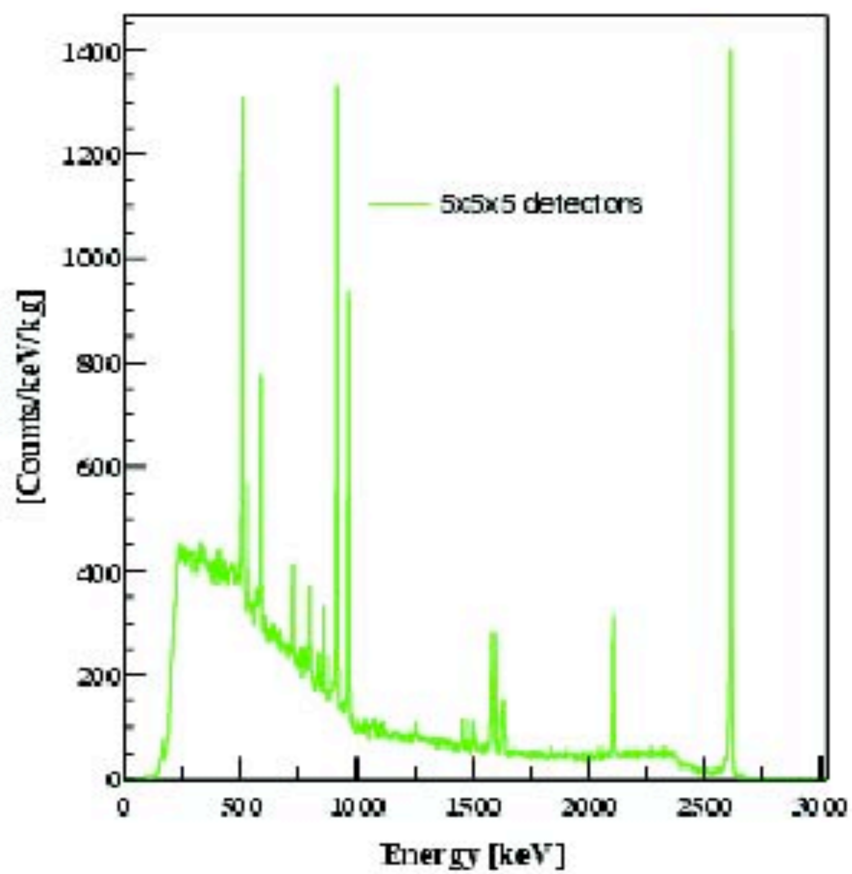
A Cuoricino modulre

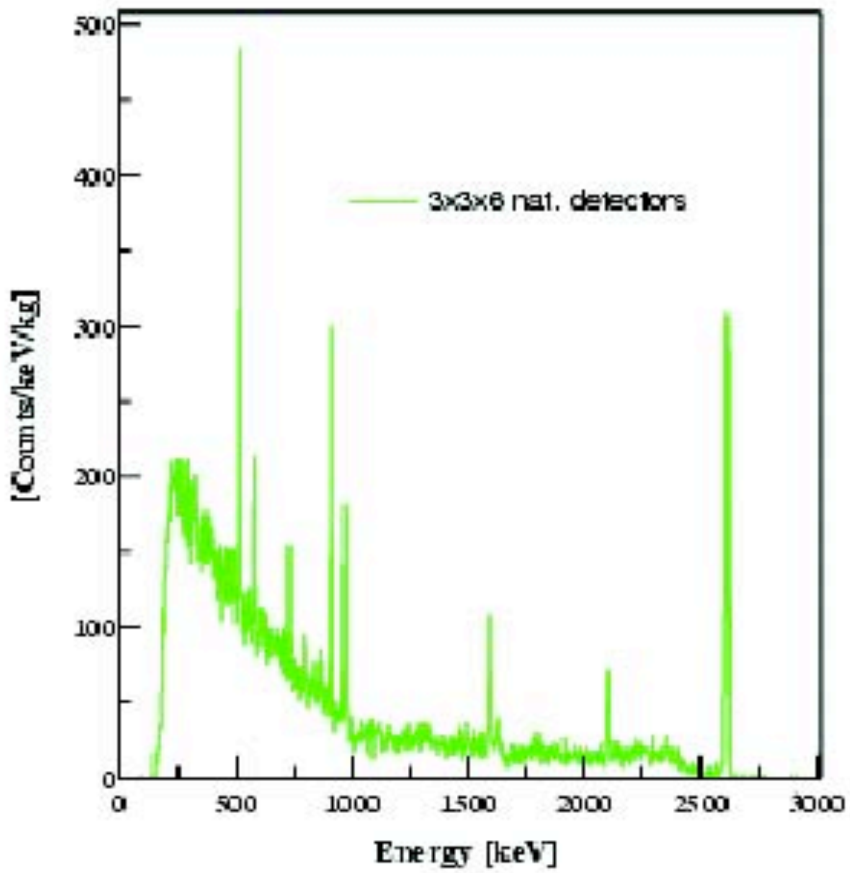
Detectors assembling

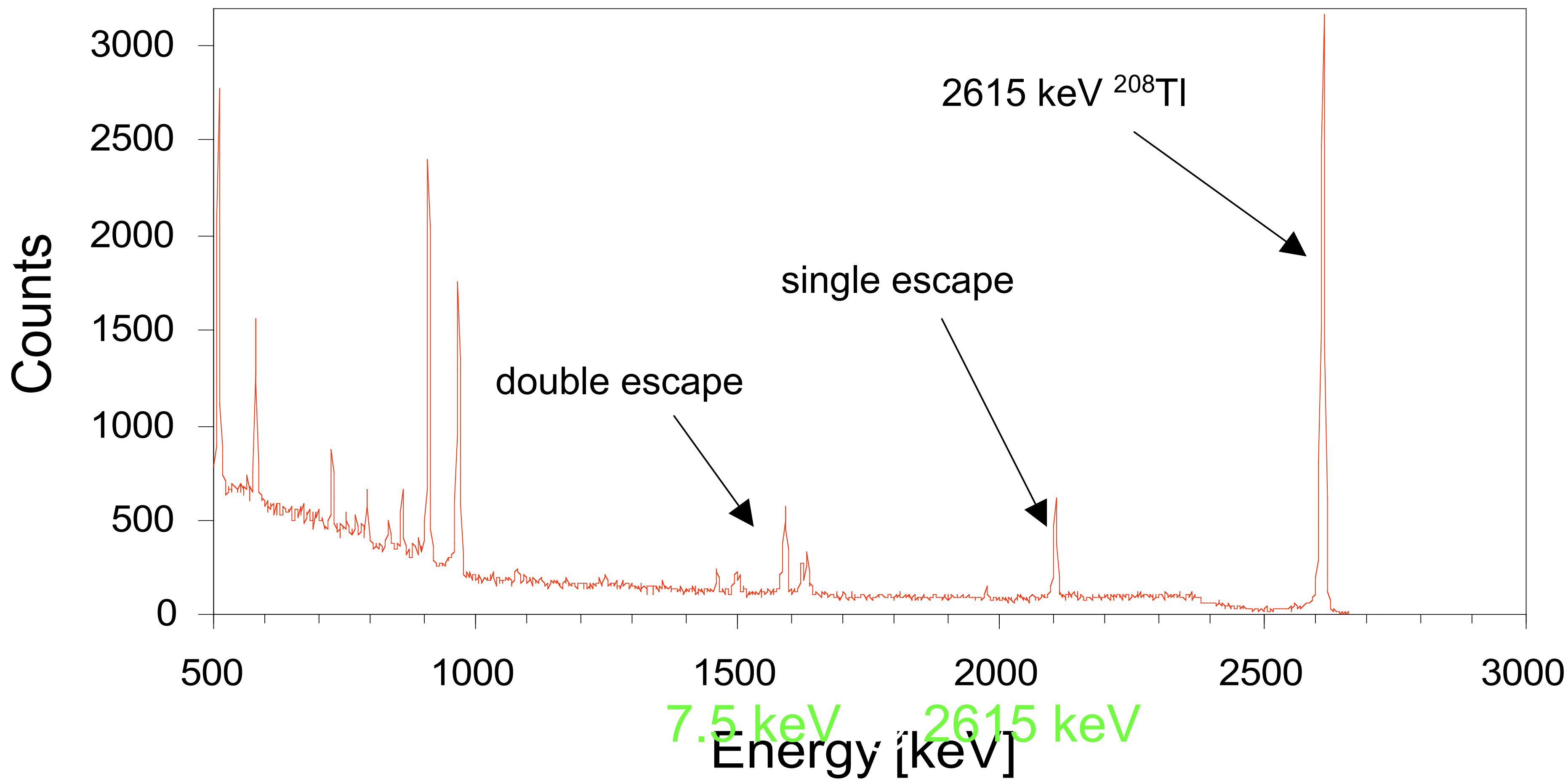
Operations carried out
In a clean room

Tower assembling

^{232}Th wire source







Counts
3000
2500
2000
1500
1000
500
0
2615 keV ^{208}Tl
single escape
double escape
500
1000
1500
2000
2500
3000
Energy [keV]
7.5 keV
2615 keV

Live time

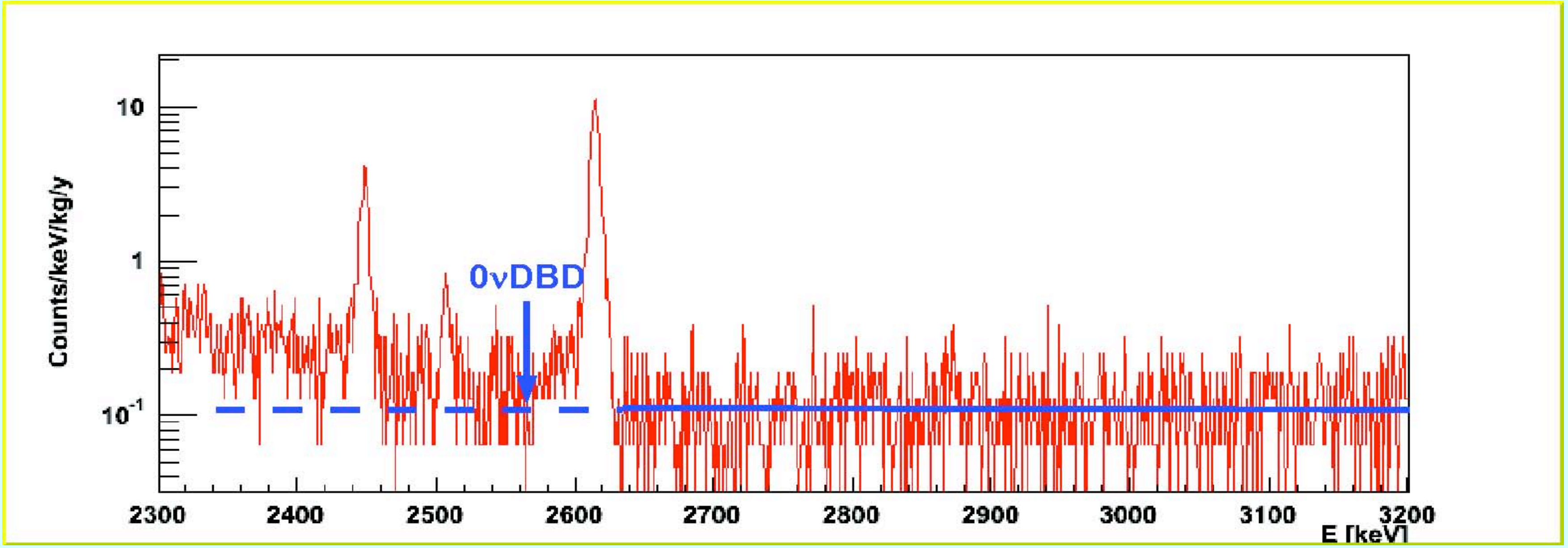
Run I
Cooldown: February 2003
Detectors: 14/62 detectors lost
Working detectors: 73%
Live Time: 23%

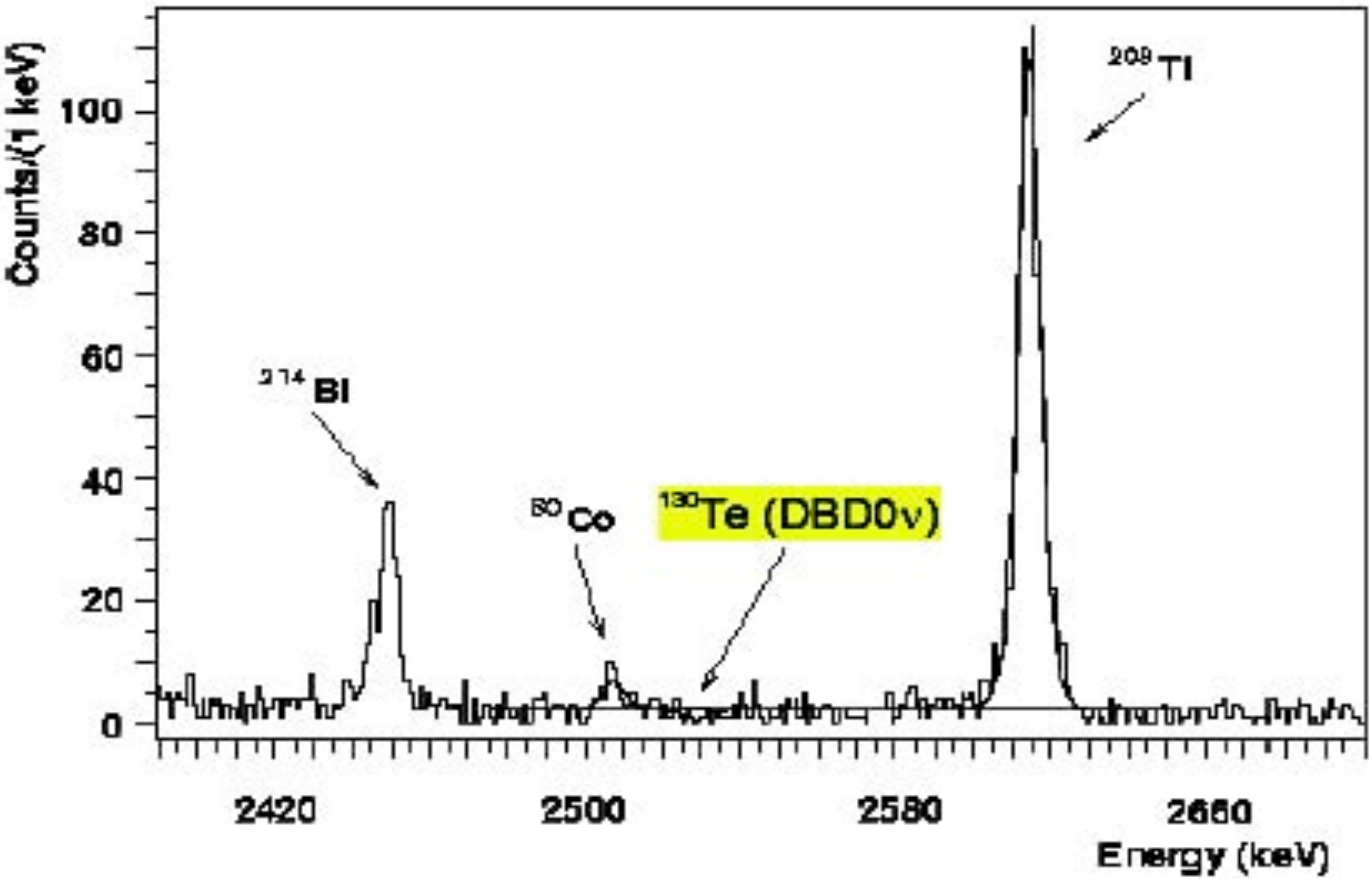
Upgrade: October 2003
- Wiring
- DAQ
- Temperature feedback
- Cryogenics (20 years old cryostat)

Run II
Cooldown: May 2004
Detectors: 2 detectors still dead + 2 with high noise
Working detectors: 94%
Live Time: 64% (+ ~ 10% calibrations time)

Background

- Flat background above 2615 keV
- Natural extrapolation below
- Contribution to the 0ν-DBD region: ~ 60%





Counts/(1 keV)
100
80
60
40
20
0
2420
2500
2580
2660
Energy (keV)
214Bi
60Co
130Te (DBD0ν)
208Tl

Results from data analysis up to May , 2005

~ 5.36 kg xy (^{130}Te)$_{\times\, y}$

Live time ~64% (~74% with calibrations)

- **Background 0.18 ± 0.01 counts keV^{-1} kg-1 y^{-1}**
- **$\tau_{1/2}$ > 1.86 x 10 ^{24} years (90 % c.l.)**
- **<m$_\nu$ > 0.2 - 1 eV**
- **Klaptor et al (0.1-0.9 eV)$^{-1}$**

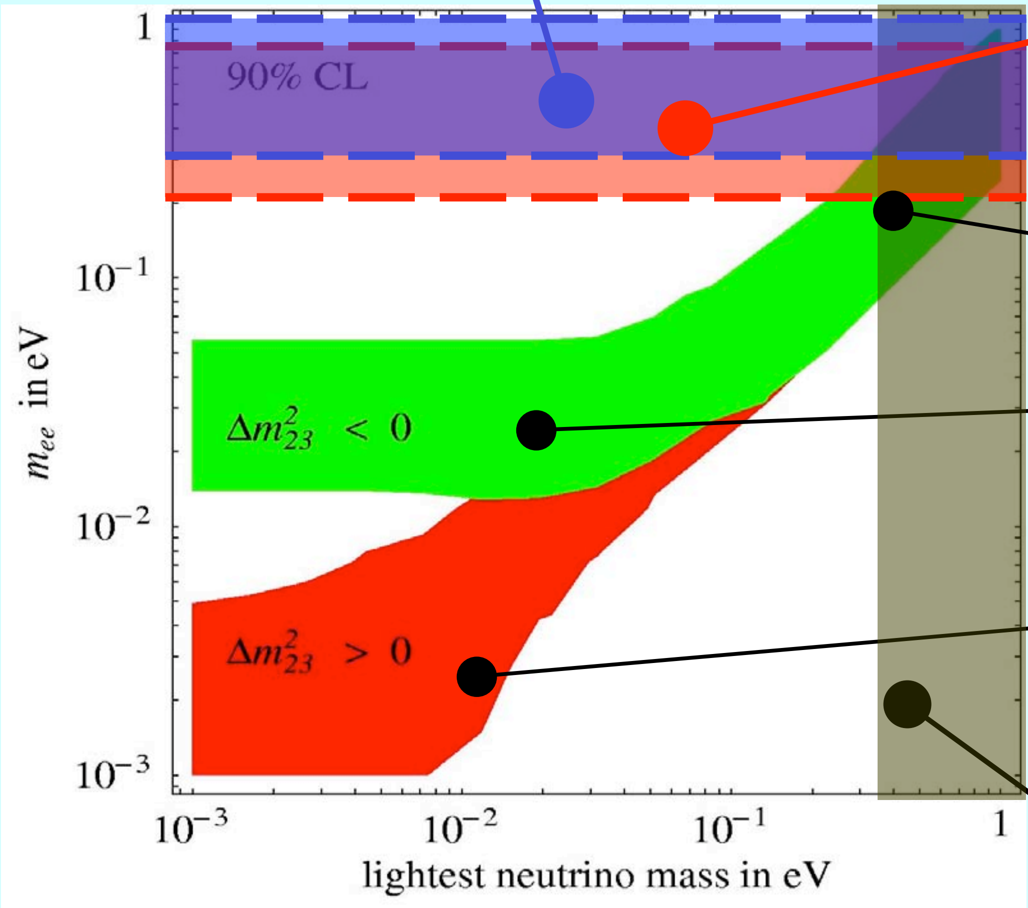
DBD and Neutrino Masses

Present Cuoricino region

Arnaboldi et al., submitted to PRL, hep-ex/0501034 (2005).

Possible evidence (best value 0.39 eV)

H.V. Klapdor-Kleingrothaus et al., Nucl.Instrum.and Meth. ,522, 367 (2004).



Feruglio F. , Strumia A. , Vissani F. hep-ph/0201291

With the same matrix elements the Cuoricino limit is **0.53 eV**

"quasi" degeneracy

$m_1 \approx m_2 \approx m_3$

Inverse hierarchy

$\Delta m^2_{12} = \Delta m^2_{atm}$

Direct hierarchy

$\Delta m^2_{12} = \Delta m^2_{sol}$

Cosmological disfavoured region (WMAP)

Next generation experiments

Name		%	$Q_{\beta\beta}$	% E	B c/y	T (year)	Tech	<m>
CUORE	^{130}Te	34	2533	90	3.5	$1.8x10^{27}$	Bolometric	9-57
GERDA	^{76}Ge	7.8	2039	90	3.85	$2x10^{27}$	Ionization	29-94
Majorana	^{76}Ge	7.8	2039	90	.6	$4x10^{27}$	Ionization	21-67
GENIUS	^{76}Ge	7.8	2039	90	.4	$1x10^{28}$	Ionization	13-42
Supernemo	^{82}Se	8.7	2995	90	1	210^{26}	Tracking	54-167
EXO	^{136}Xe	8.9	2476	65	.55	$1.3x10^{28}$	Tracking	12-31
Moon-3	^{100}Mo	9.6	3034	85	3.8	$1.7x10^{27}$	Tracking	13-48
DCBA-2	^{150}Nd	5.6	3367	80		$1x10^{26}$	Tracking	16-22
Candles	^{48}Ca	.19	4271	-	.35	$3x10^{27}$	Scintillation	29-54
CARVEL	^{48}Ca	.19	4271	-		$3x10^{27}$	Scintillation	50-94
GSO	^{160}Gd	22	1730	-	200	$1x10^{26}$	Scintillation	65-?
COBRA	Te-Cd	7.5	2805				Ionization	
SNOLAB+	^{150}Nd	5.6	3367				Scintillation	

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STUDIORUM UNIVERSITAS FLORENTINA

THE UNIVERSITY OF CALIFORNIA BERKELEY 1868

CUORE

INFN
Istituto Nazionale
di Fisica Nucleare

DIPARTIMENTO DI FISICA UNIVERSITA' DI ROMA LA SAPIENZA

BERKELEY LAB

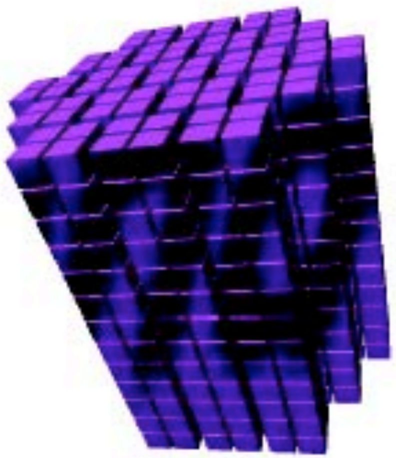
CUORE experimental setup

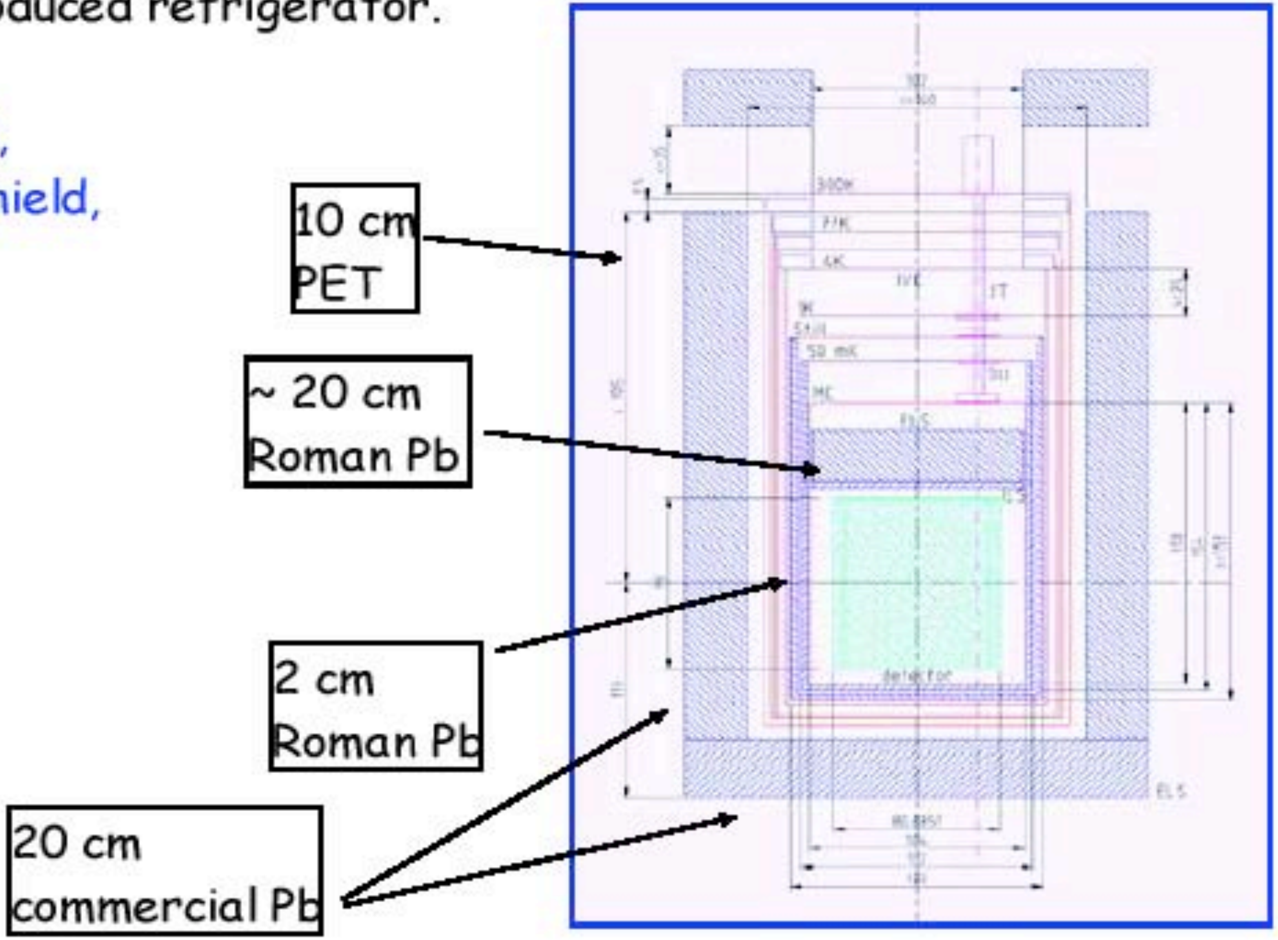
Closely packed array of 988 detectors (750 g each)

M ~ 741 kg

19 towers - 13 modules/tower - 4 detector/module
placed inside a specially produced refrigerator.

- Cu shields,
- **Roman Lead** Inner shields,
- 20 cm commercial Lead shield,
- Borated PET,
- nitrogen overpressure,
- a Faraday Cage.





R&D for CUORE

Let us start with CUORICINO

Sources identified as possible responsible for the bkg in the DBD0ν :

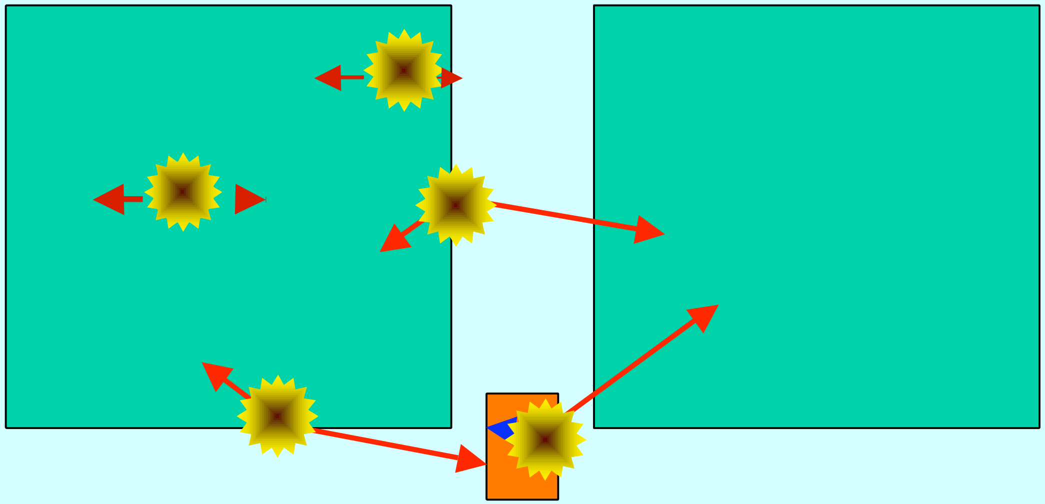
- β and α from TeO_2 surface
- β and α from surface of materials facing the crystals (the bigger surface is Cu)
- ^{208}Tl multi-compton events (^{232}Th contaminations of distant parts)

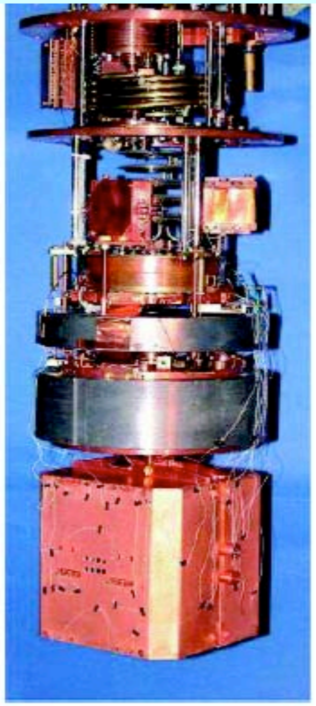
Evaluated surface contamination level:	~ 10^{-9} g/g in U and Th (of both TeO2 and Cu)

Estimated contributions to the DBD0n region:

TeO_2 surface	~ 10 ± 10 %
Cu surface	~ 50 ± 20 %
Th cont. of the set-up	~ 30 ± 10 %

Model of the background in CUORICINO

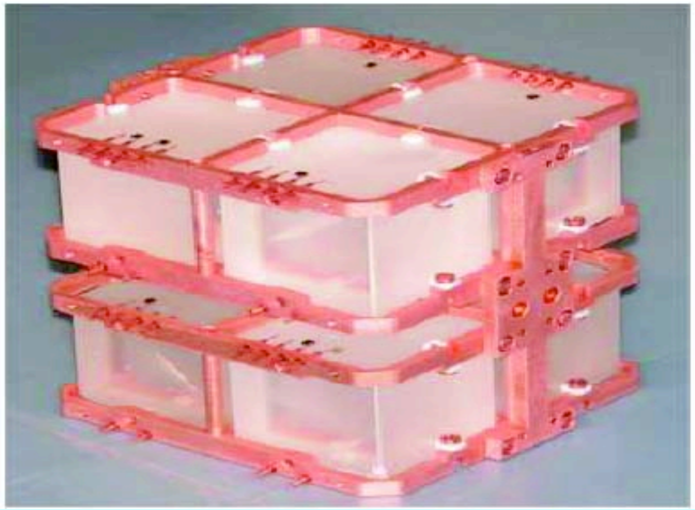


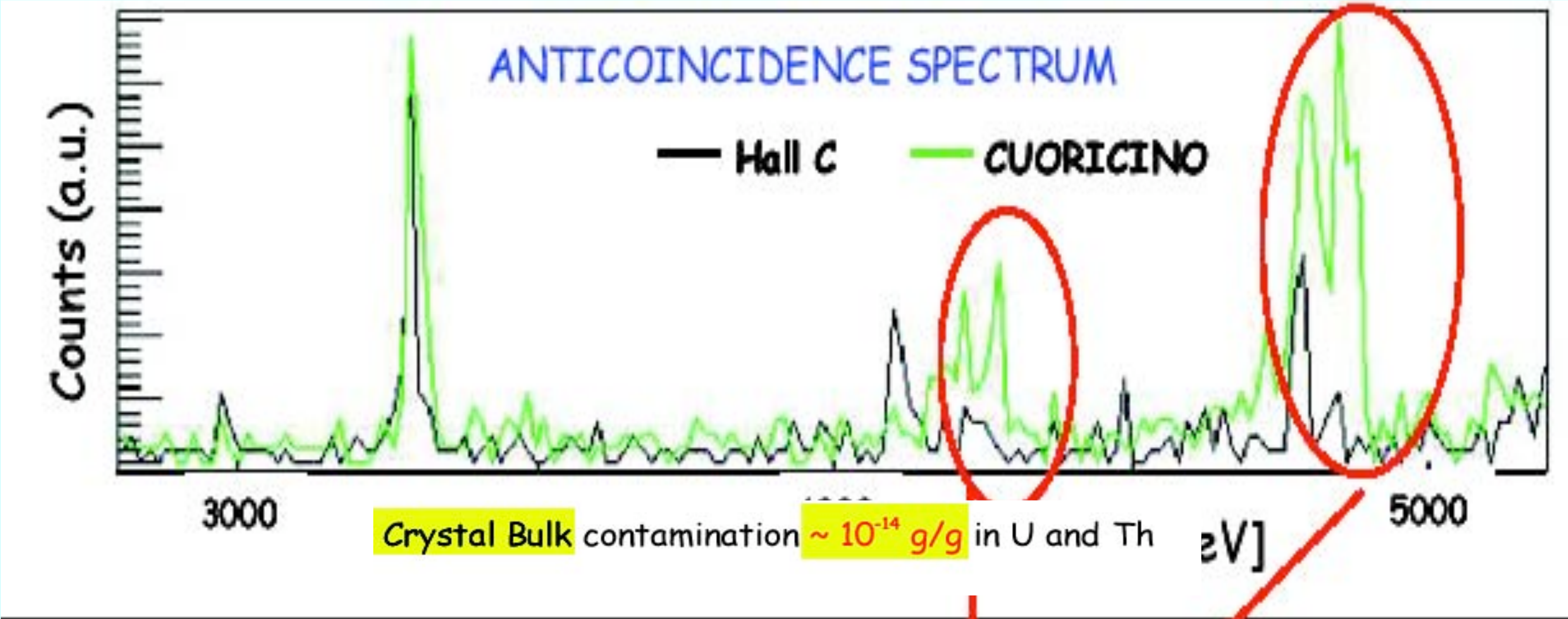


Cu: etching, electropolishing and passivation

TeO2: etching and lapping with clean powders

Assembling with clean materials





Crystal Bulk contamination ~ 10^{-14} g/g in U and Th

Reduction of a factor ~ 4 on crystal surface contaminations:
milestone of CUORE for this task reached.

Reduction of ~ 4 in the crystal surface radioactivity
already achieved

Bulk contamination

Previous analysis by CUORICINO

►Native tellurium → < 10^{-10} g/g

►TeO_2 → ~ 10^{-9} g/g

►Crystals → ~ 10^{-14} g/g

Reduction of Surface Background from Copper only ~ 50%

Could be something different from Copper?

Recent runs

1.Thermistors ► Two Crystals faces ► 5000 mm^2 ► 800 crystals

Wires two crystal faces ► 500 crystals

►Teflon four crystal faces ► 40 crystals

No major contribution

2.New Run Action of surface active detectors :see later

3 Future run Various sources of background

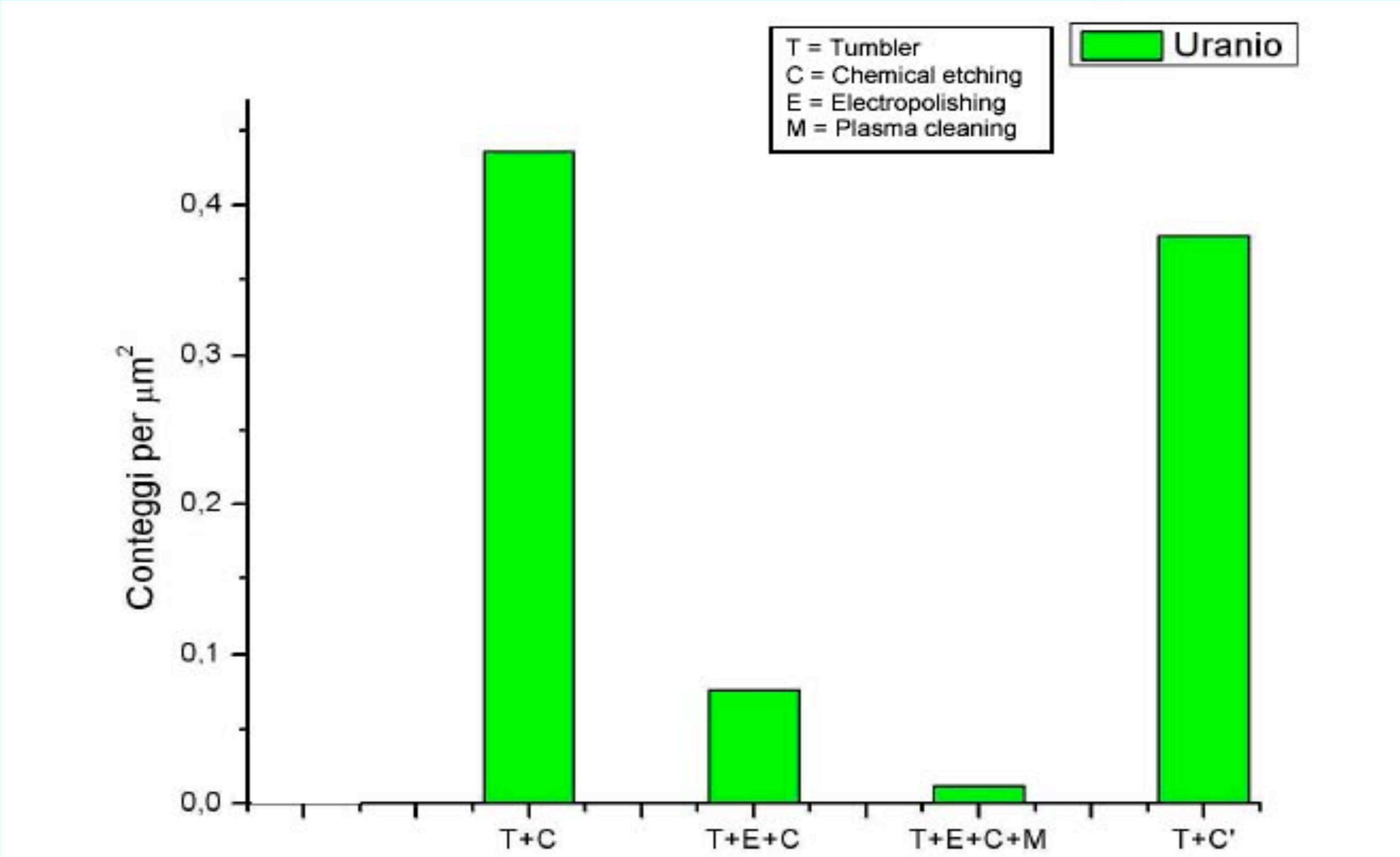
Measurements by ICPMS reported previously surface activity ~ 10^{-9} g/g 10^{-10} - 10^{-11} g/g after a few microns in agreement with Monte Carlo

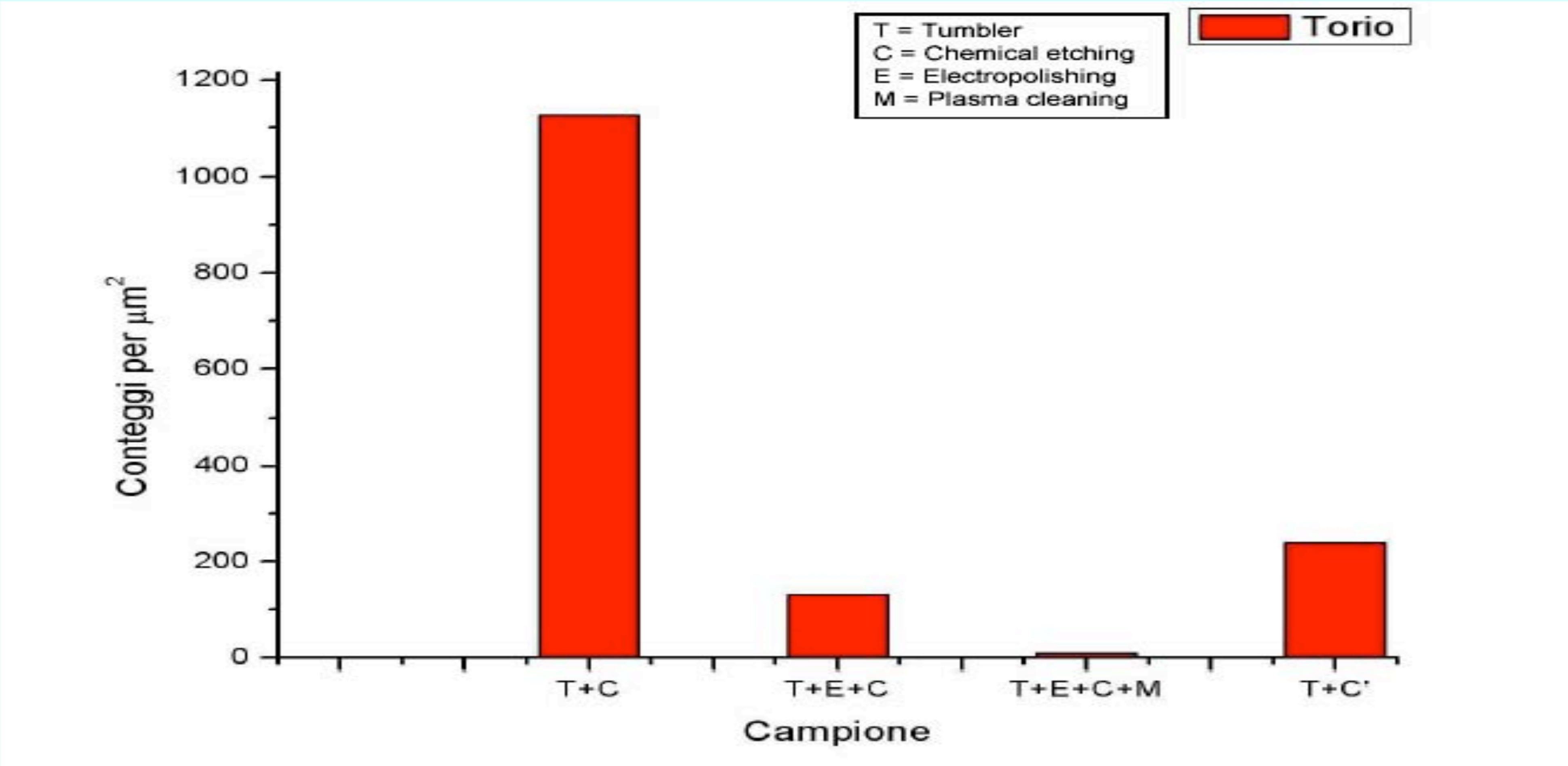
Difficulty Copper pollutes the machine for about three weeks

New approach ►Laser Ablation ICPMS (LNL and CNR Padua)

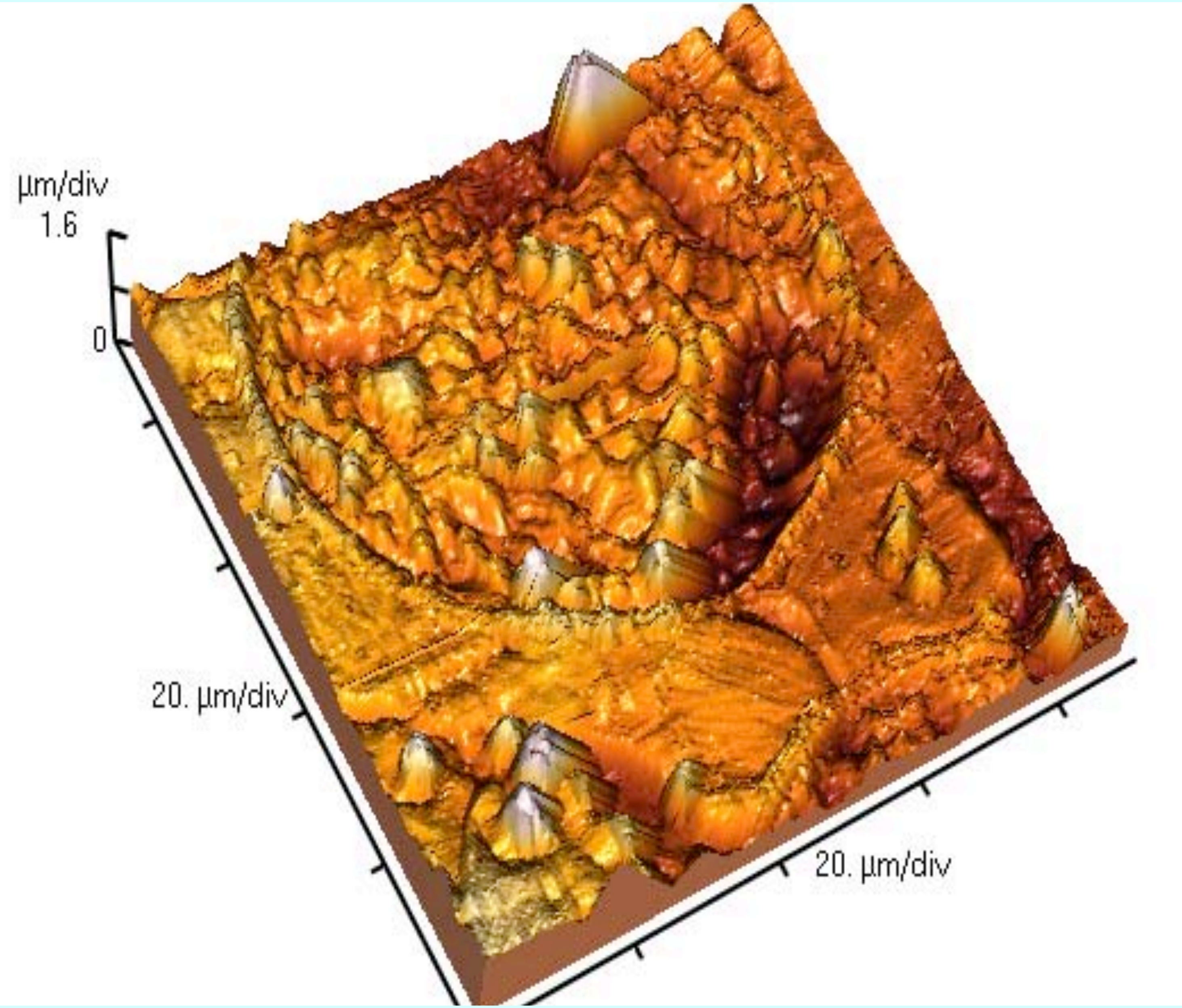
Preliminary results

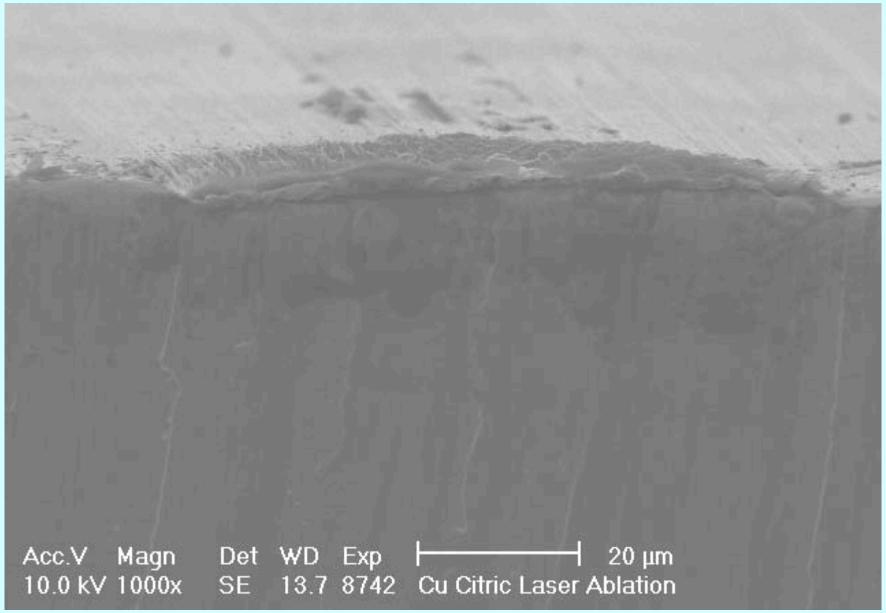
- Copper samples with different cleaning procedure
- Tumbling ► electropolishing ►chemical etching►plasma cleaning
- With plasma cleaning an apparent reduction of U and Th contamination by an order of magnitude
- Problem difficulty to extract the mass of the ablated Copper due to the surface property
- New approach ►Measurement of the extracted volume by cutting each copper sample in two
- Counts of ^{65}Cu ► ablated volume
- Ablated volume ►Number of spots

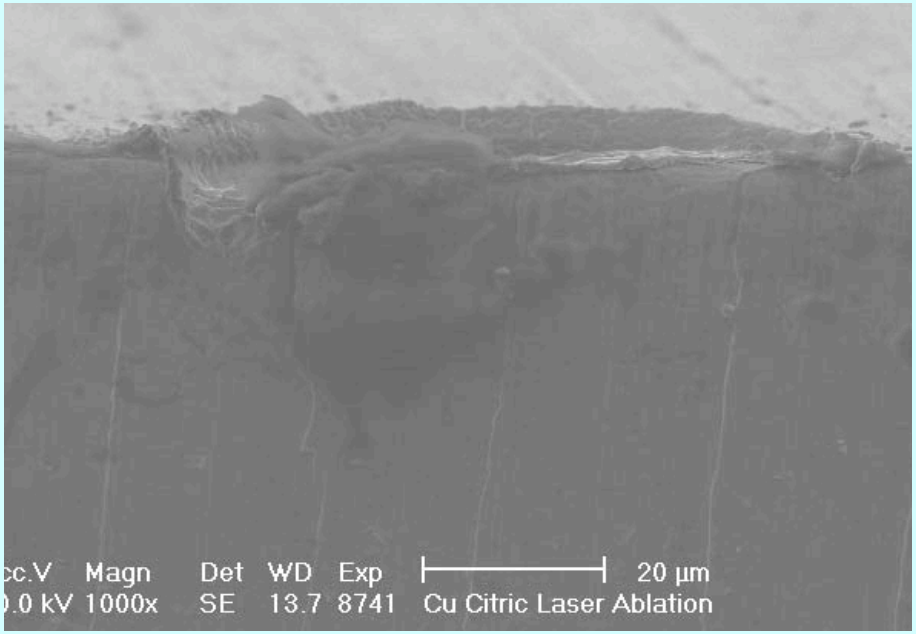

T = Tumbler
C = Chemical etching
E = Electropolishing
M = Plasma cleaning
Uranio
Conteggi per μm^2
0,0
0,1
0,2
0,3
0,4
T+C
T+E+C
T+E+C+M
T+C'

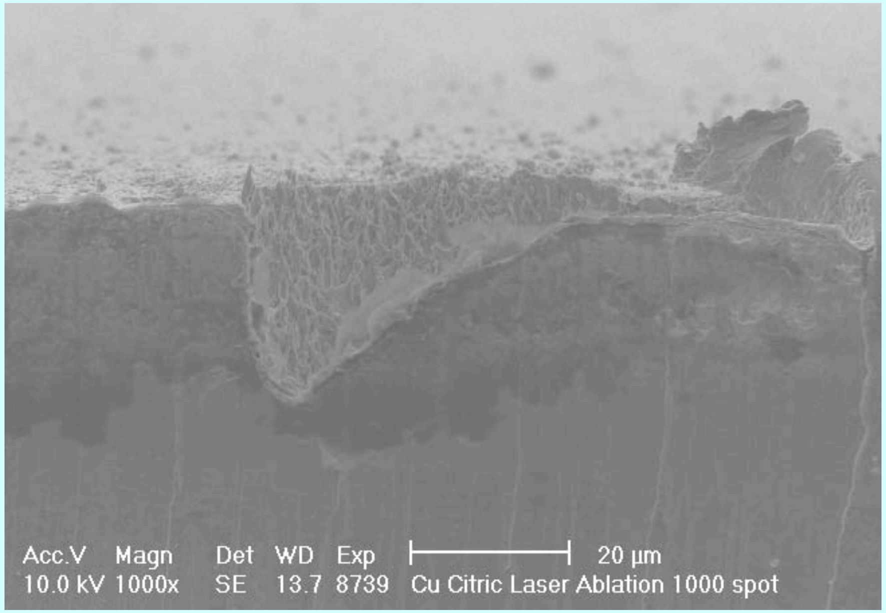


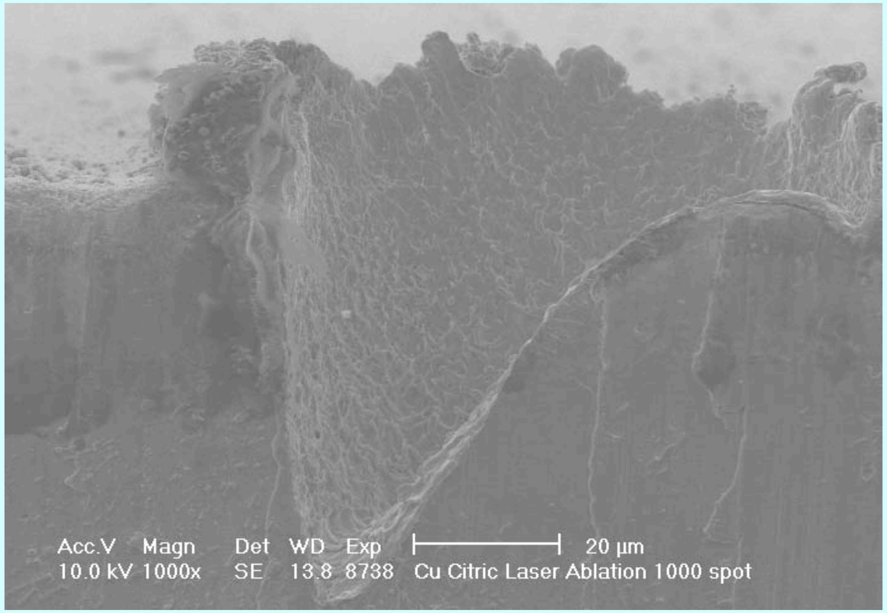
T = Tumbler
C = Chemical etching
E = Electropolishing
M = Plasma cleaning
Torio
Conteggi per μm²
1200
1000
800
600
400
200
0
T+C
T+E+C
T+E+C+M
T+C'
Campione

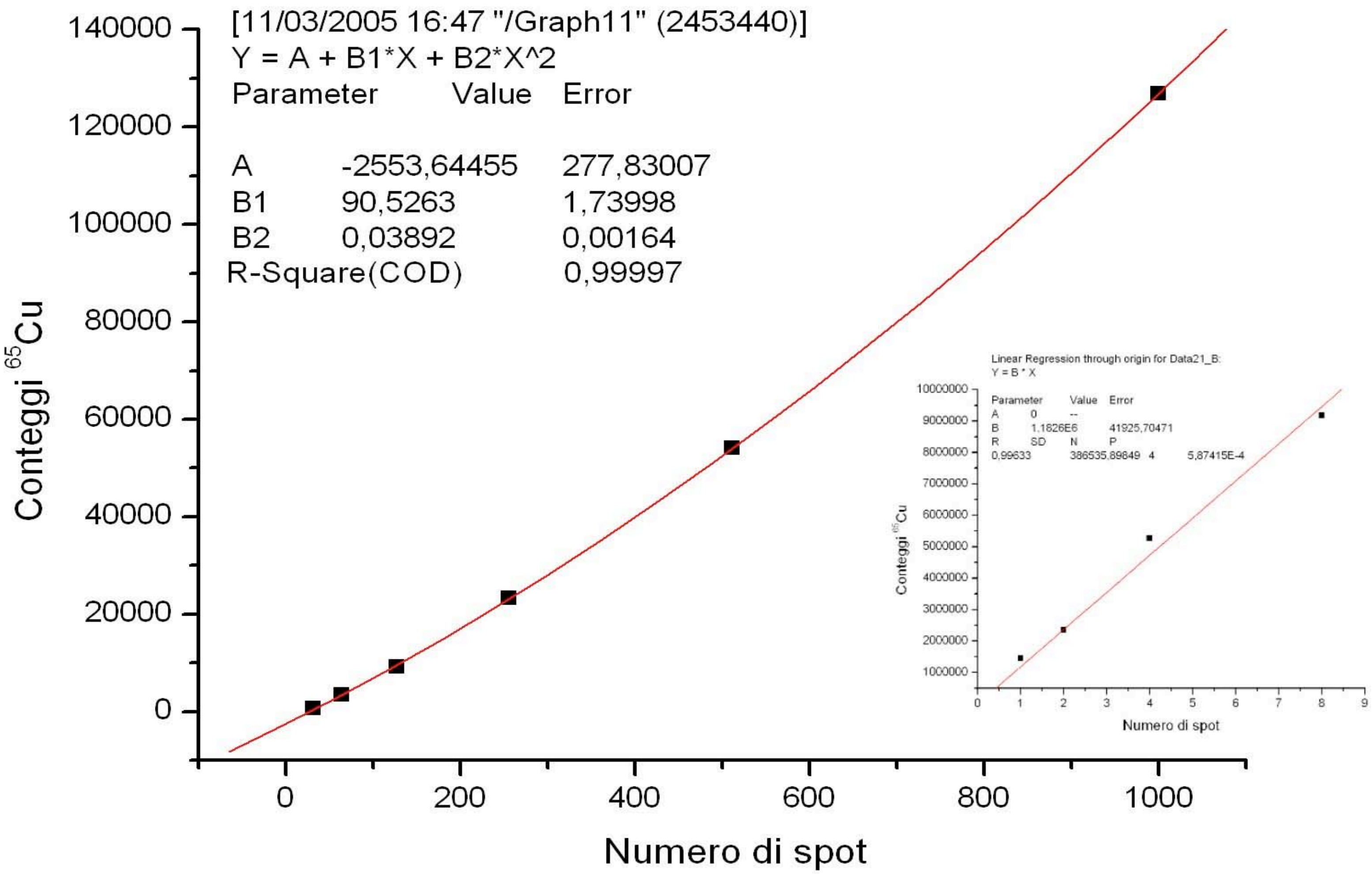

µm/div
1.6
0
20. µm/div
20. µm/div


Acc.V Magn Det WD Exp 20 µm
10.0 kV 1000x SE 13.7 8742 Cu Citric Laser Ablation

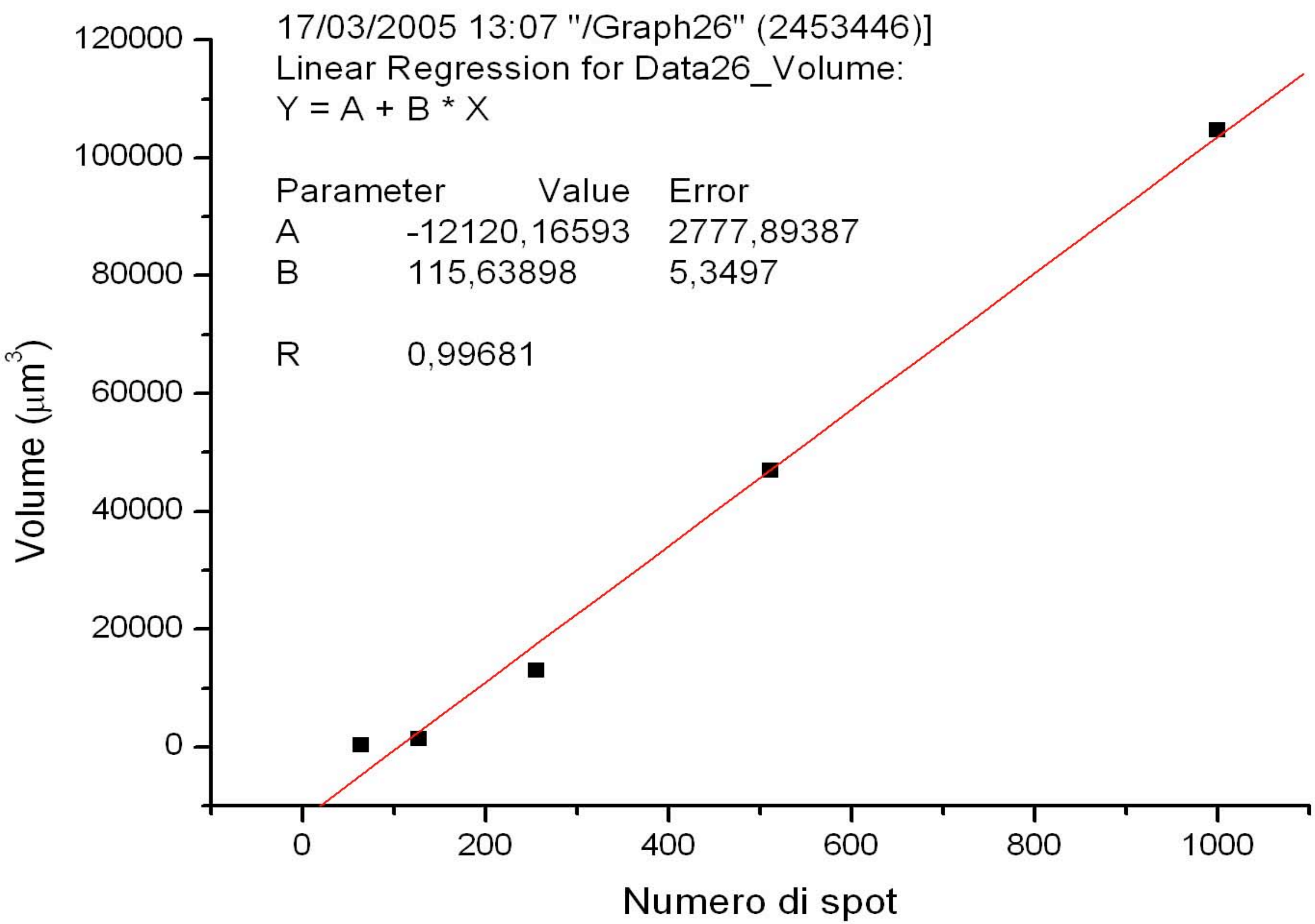

cc.V Magn Det WD Exp 20 µm
.0 kV 1000x SE 13.7 8741 Cu Citric Laser Ablation


Acc.V Magn Det WD Exp 20 µm
10.0 kV 1000x SE 13.7 8739 Cu Citric Laser Ablation 1000 spot


Acc.V Magn Det WD Exp 20 µm
10.0 kV 1000x SE 13.8 8738 Cu Citric Laser Ablation 1000 spot

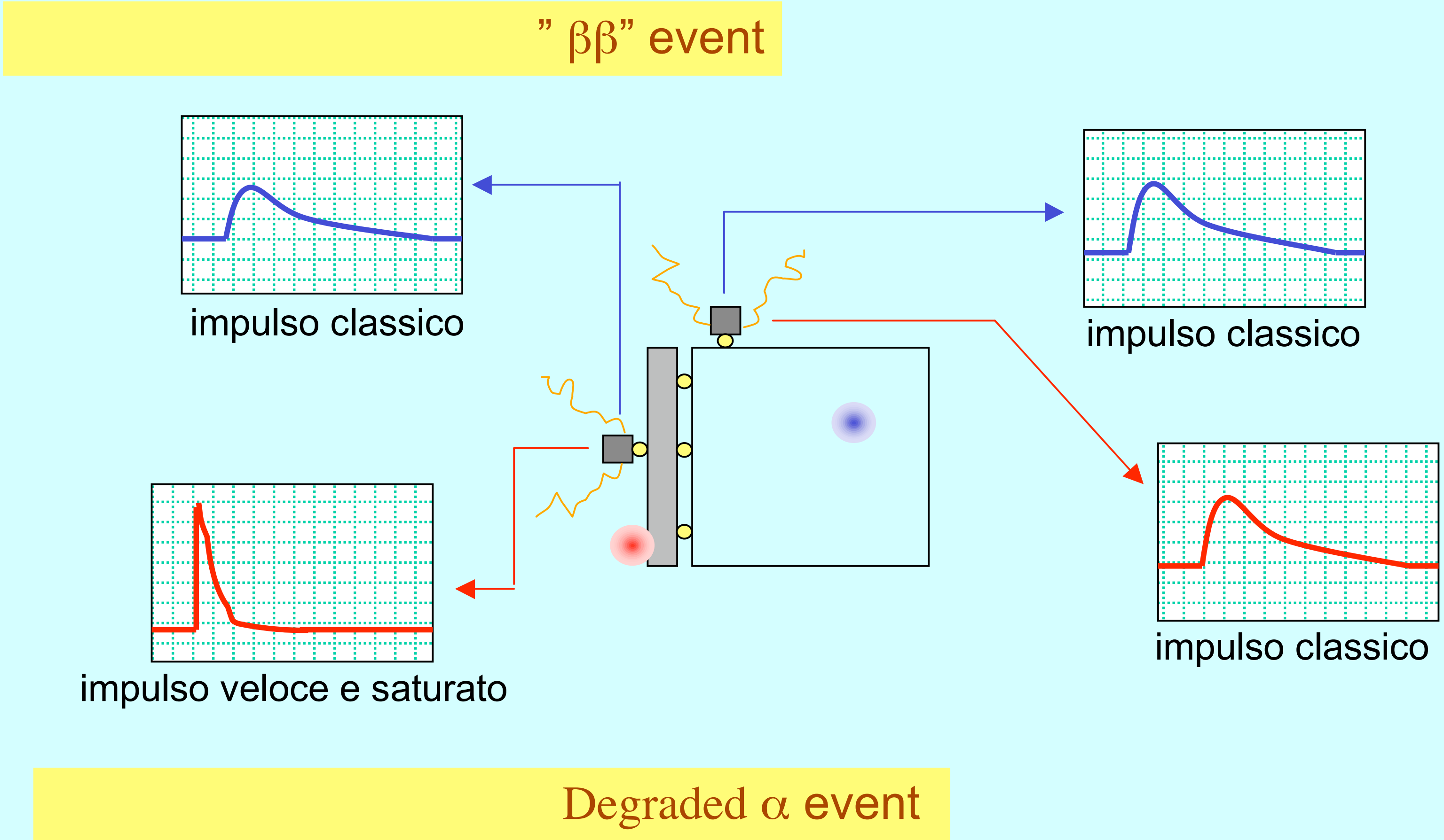


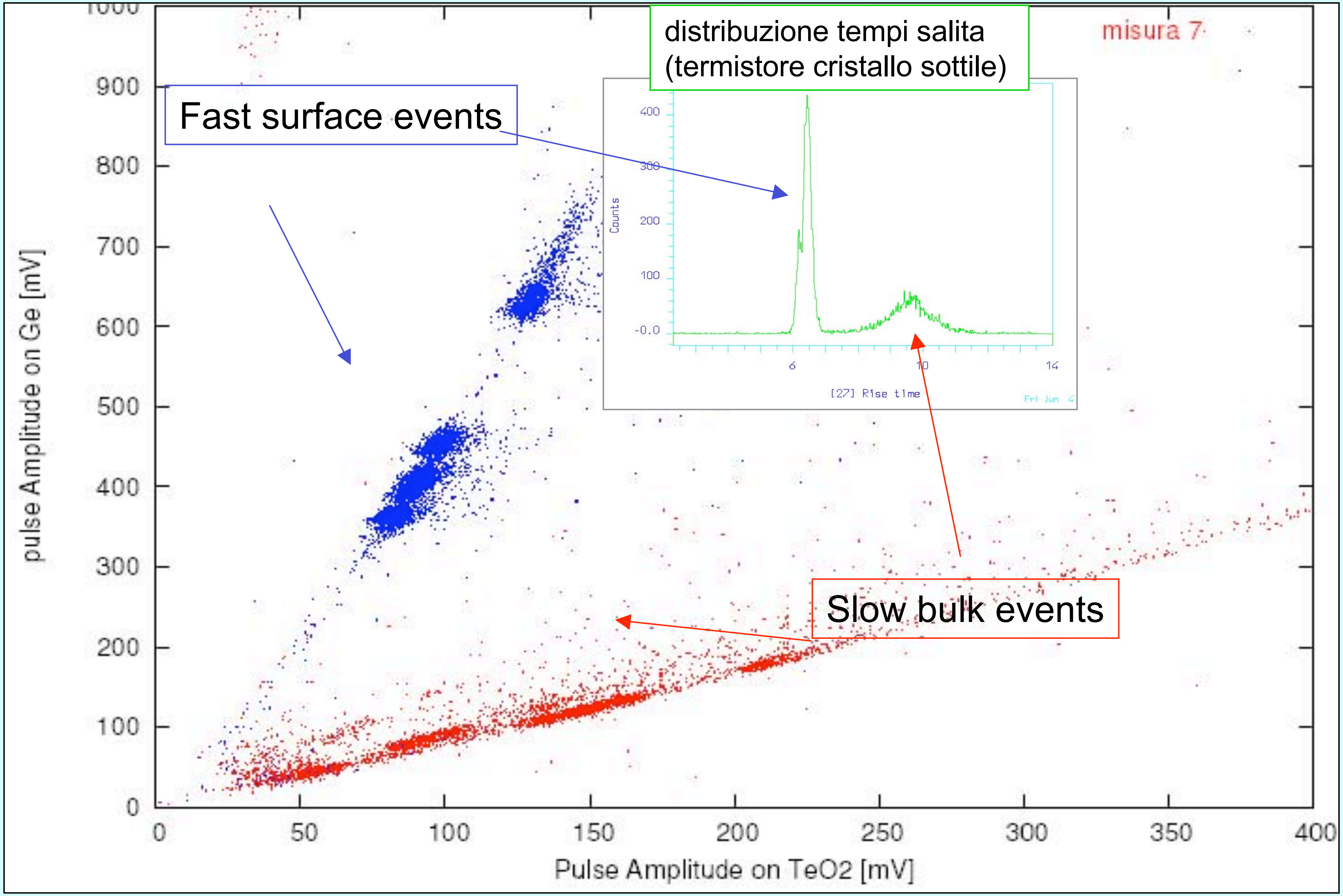
[11/03/2005 16:47 "/Graph11" (2453440)]
Y = A + B1*X + B2*X^2
Parameter Value Error
A -2553,64455 277,83007
B1 90,5263 1,73998
B2 0,03892 0,00164
R-Square(COD) 0,99997
Conteggi 65Cu
Numero di spot
140000
120000
100000
80000
60000
40000
20000
0
200
400
600
800
1000
Linear Regression through origin for Data21_B:
Y = B * X
Parameter Value Error
A 0 --
B 1,1826E6 41925,70471
R SD N P
0,99633 386535,89849 4 5,87415E-4
10000000
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
1
2
3
4
5
6
7
8
9


17/03/2005 13:07 "/Graph26" (2453446)]
Linear Regression for Data26_Volume:
Y = A + B * X
Parameter Value Error
A -12120,16593 2777,89387
B 115,63898 5,3497
R 0,99681
Volume (μm3)
Numero di spot
120000
100000
80000
60000
40000
20000
0
0
200
400
600
800
1000

Scintillation vs.heat or surface sensitive bolometers

A composite bolometer with a thin crystal of Ge, Si o TeO2



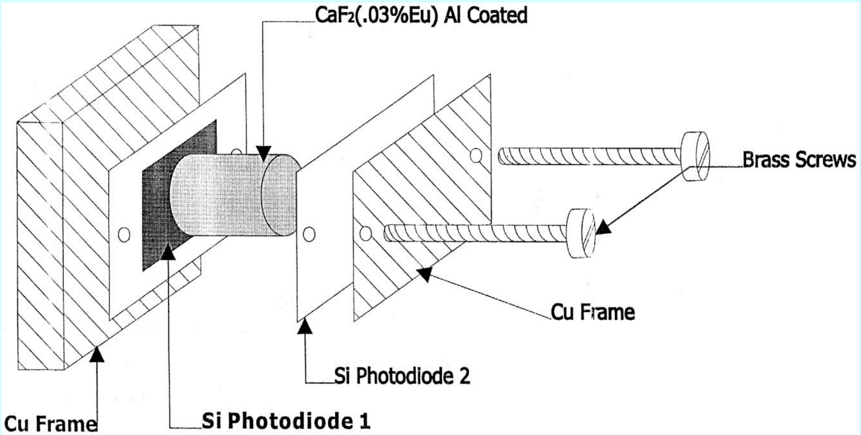


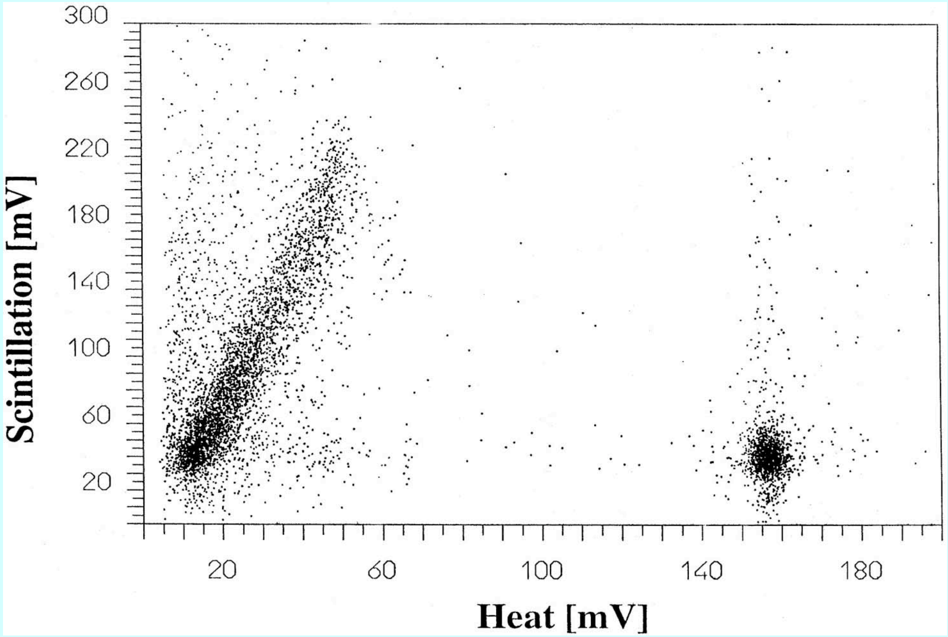
distribuzione tempi salita
(termistore cristallo sottile)
misura 7
Fast surface events
Slow bulk events
pulse Amplitude on Ge [mV]
Pulse Amplitude on TeO2 [mV]
Counts
[27] Rise time

Scintillation vs heat

The scintillating bolometer

Proved for CaF_2 being studied for TeO_2





CUORE SENSITIVITY

$F^{0\nu} = 9.4 \times 10^{25} \times (T[y])^{1/2}$ | < m > | (0.024- 0.13 eV in 5 y)

$F^{0\nu} = 3 \times 10^{26} \times (T[y])^{1/2}$ | < m > | (0.016- 0.09 eV in 5 y)

CUORE Background in the neutrinoless ββ region

Monte Carlo results , supported by CUORICINO

Bulk crystal (<.1 pg/g) and external activity negligible

a. **γ cryostat activity** (thermal shield larger in in CUORICINO then MIDBD)
Increased Roman lead and no thermal shields < .0038 counts/keV/kg/year

b. **α & β surface activity from Copper structure**

(Monte Carlo => ~ 1 ng/g v.s. < 1 pg/g internal) proved!

c. **α & β surface activity of crystals** (Monte Carlo ~ 1 ng/g v.s. < .1 pg/g internal)
however =>

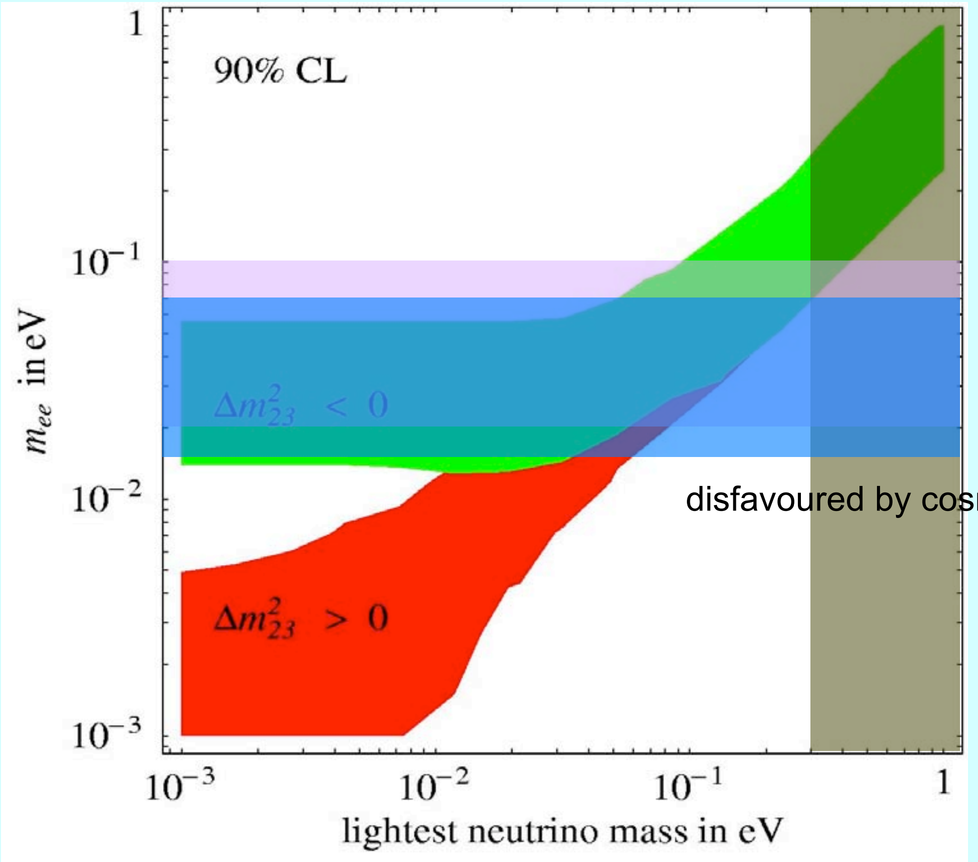
New results of a dedicated run in Hall C

Surface activity of the crystals reduced by a factor of 4

Possible to detect bulk activity of TeO_2 crystals

$< 9 \times 10^{-15}$ U and $< 2.5 \times 10^{14}$ Th

CUORE expected sensitivity



Strumia A. and Vissani F. hep-ph/0503246

In 5 years:

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

CUORE time schedule

Letter of Intent

1. Crystals (Material selection,procedure settling,growth and preparation ,possible enrichment)	USA
2. Thermistors (R&D and Ge irradiation.Production	USA
3. Detector structure (design,material selection,production	INFN
4. Cryostat & cryogenics (design and material selection, construction,installation and test)	**INFN**
5. Passive shielding (design and material selection,construction)	INFN
6. Underground laboratory (design, installation)	**INFN**
7. Electronics, design and test, production, installation)	USA
8. Data acquisition, R&D and prototyping,final design, DAQ SW development, production,installation	INFN
9. CUORE assembly	INFN & USA

Frank Avignone and Ettore Fiorini

TOTAL COST 14 M euro INFN 6.5 USA 7.5

Present status of CUORE

- - April 2 , 2004 Approval of CUORE by the S.C. of LNGS
- - June 7 Scientific approval by the Commissione.2 of INFN
- - July American proposal (Frank Avignone) => Production iin USA the "hearth " of CUORE (4 colums with 144 cristals) enriched and growin in the States , all other 844 cristals (natural) produced in China => conditional approval (see later)
- - September Final localization decided in Gran Sasso
- - September 28 Final approval by the Commissione 2 and .5 M$ for R&D with the following recommendations:
- final decisions on surface treatment improvements within 2005
- - tests and final decision on enrichment with two natural and two enriched crystals within the same year
- September 30 Final approval 1.06 M Euro for the dilution refrigerator
- December 17 => tender started
- May 2005 APS report : neutrinoless double beta decay as first priority

December 17 => tender started

- May 2005 APS report : neutrinoless double beta decay as first priority
- May 31 First meeting of NuSAG
- August 22 Recommendationsto DOE and NSF : first priority to CUORE, EXO and Majorana
- The CUORE experiment has potential for good energy resolution and low background…The schedule of CUORE is timely

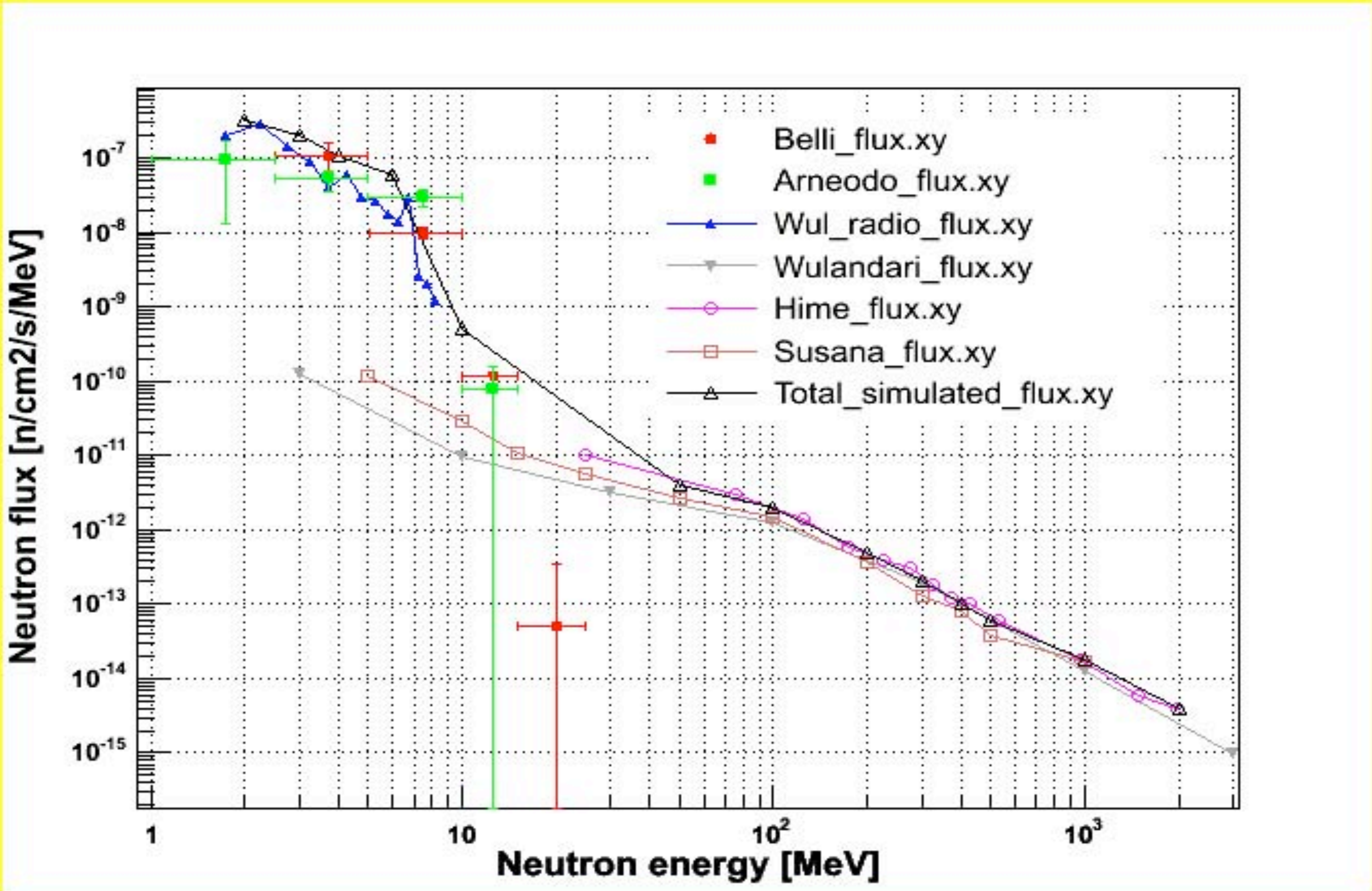
- Thermal detectors are very flexible, and allow to study different nuclei

Compound	Isotopic abundance	Transition energy
^{48}**Ca**F_2	.0187 %	4272 keV
^{76}**Ge**	7.44 "	2038.7 "
^{100}**Mo**PbO_4	9.63 "	3034 "
^{116}**Cd**WO_4	7.49 "	2804 "
^{130}**Te**O_2	34 "	2528 "
^{150}**Nd**F_3 ^{150}**Nd**GaO_3	5.64 "	3368 "

- ^{130}Te has high transition energy and 34% isotopic abundance => enrichment non needed and/or very cheap. Any future extensions are possible
- Performance of CUORE, amply tested with CUORICINO
- - CUORE has been approved and has already an underground location
  Dilution refrigerator already funded

DEPTH AND NEUTRON BACKGROUND PROBLEM

- Next generation experiments in search of dark matter and neutrinoless double beta decay require depths in excess of 5000 m.w.e. to reach desired sensitivity … Otherwise heroic efforts are required to tag/veto such background. Andrew Hime
  - Answer for CUORE (the gang of four Maura,Oliviero,Susana,Silvia)



CUORE background

Expected from surface contamination, and bulk crystal activity

Conservative 0.01 c/kev/y/kg **Realistic 0.001 c/kev/y/kg**

Neutron background in CUORE:

- neutrons produced in **the rock by radioactivity**
  - total $8\ 10^{-3}$ c/keV/kg/y
  - anticoincidence **$2\ 10^{-4}$ c/keV/kg/y**

  Can be reduced by neutron shield
- neutrons produced in **the rock by muon**
  - total $6\ 10^{-5}$ c/keV/kg/y
  - anticoincidence **$1\ 10^{-6}$ c/keV/kg/y**

  Negligible
- neutrons produced in **the lead shield by muon**
  - total $2\ 10^{-3}$ c/keV/kg/y
  - anticoincidence **$1\ 10^{-4}$ c/keV/kg/y**

  Can be reduced by muon veto

No limit to CUORE sensitivitydue to *neutron flux* @ LNGS

No heroism is needed!

Conclusions

- Evidence for a peak in the region of neutrinoless double beta decay could not be sufficient (it could be mimiked by radioactivity)
- Need to explore at least two different nuclei
- Advantage of thermal detectors => flexibility
- CUORE has been approved and funded by INFN, has a definite location, cryostat designed and tender almost concluded
- American funds likely and hopefully consistent
- CUORICINO is working very well and it is substantially a tower of CUORE
- Background from crystal reduced by a factor of four and from crystals hopefully by an order of magnitude at least (3-4 aready) with respect to CUORICINO
- R&D activity in time
- Multisciplinarity particularly for this type of experiment