From Cuoricino to CUORE towards the inverted hierarchy region

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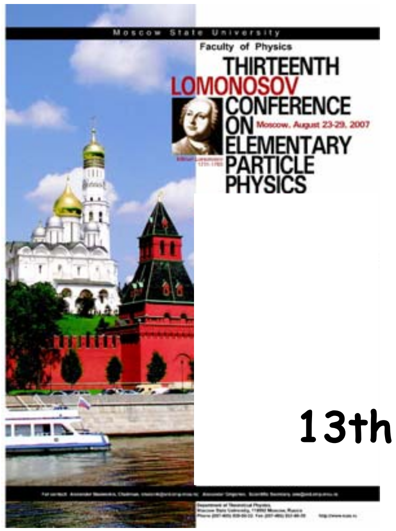
on behalf of the CUORE collaboration



13th Lomonosov Conference on Elementary Particle Physics

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Outline of the talk

- Brief remarks on the bolometric technique and on the choice of ^{130}Te as source of the 0νDBD

- Cuoricino experiment: the detector and the updated results

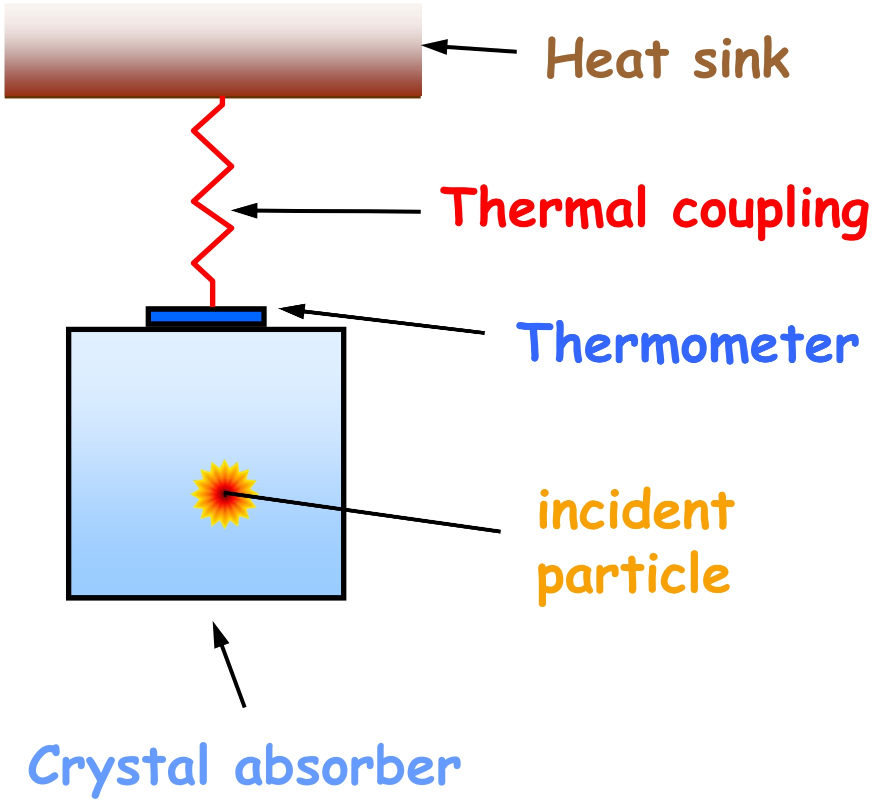
- CUORE project

- Cuoricino vs HEIDELBERG-MOSCOW experiment; ^{130}Te vs other isotopes: comparisons through different N.M.E. calculations

- Conclusions

Brief remarks

The original idea is very simple:



This technique measures **all** the energy deposited by particle in form of increase of temperature in the absorber

↓

Absorber ≡ DBD source

From a very simple thermal model:

⇓

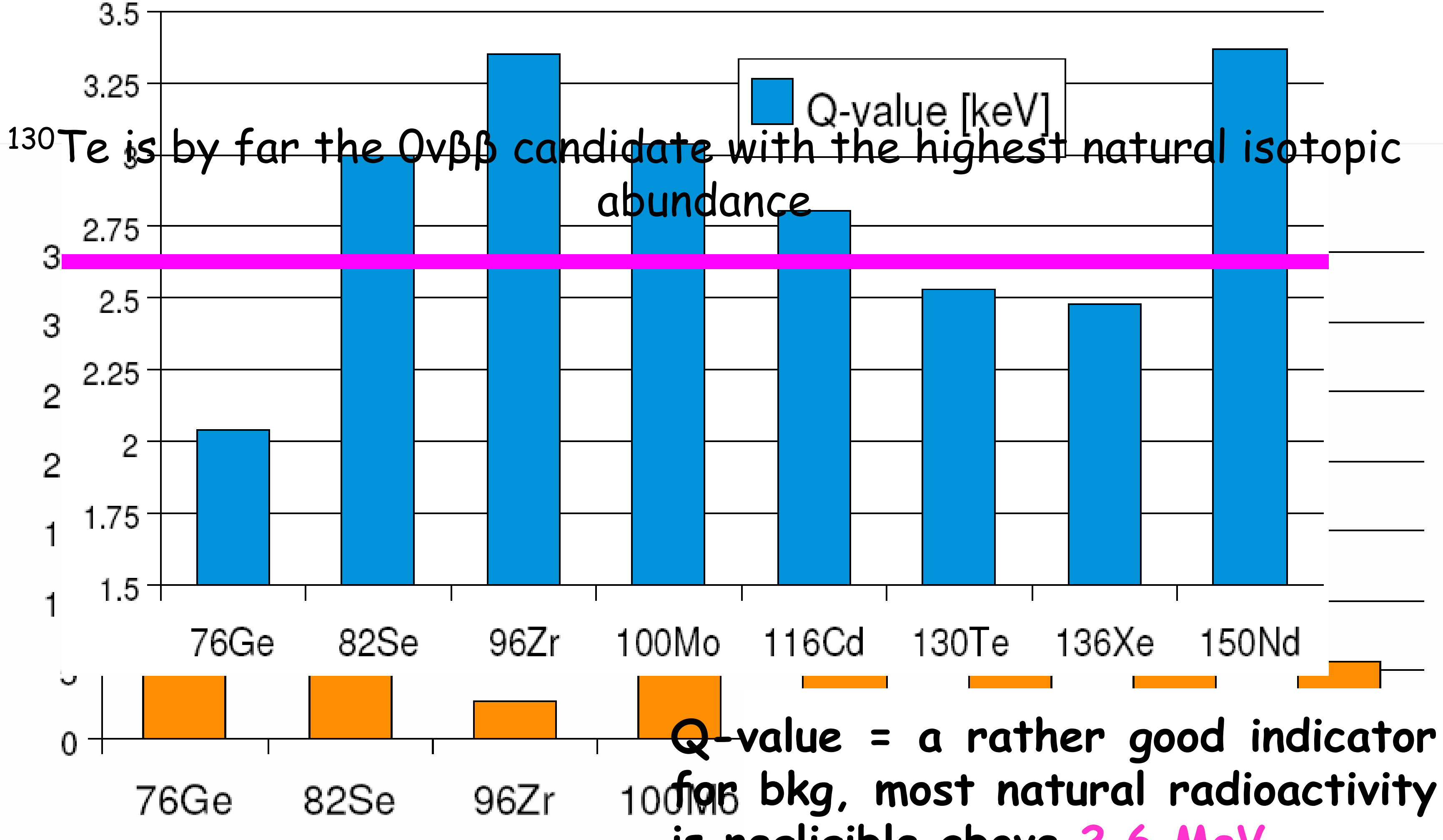
Signal: $\Delta T = E/C$

Time constant $= C/G$

-> to develop high pulses the detector has to work at low temperatures (10mK)

Why ^{130}Te?

^{130}Te is by far the 0νββ candidate with the highest natural isotopic abundance



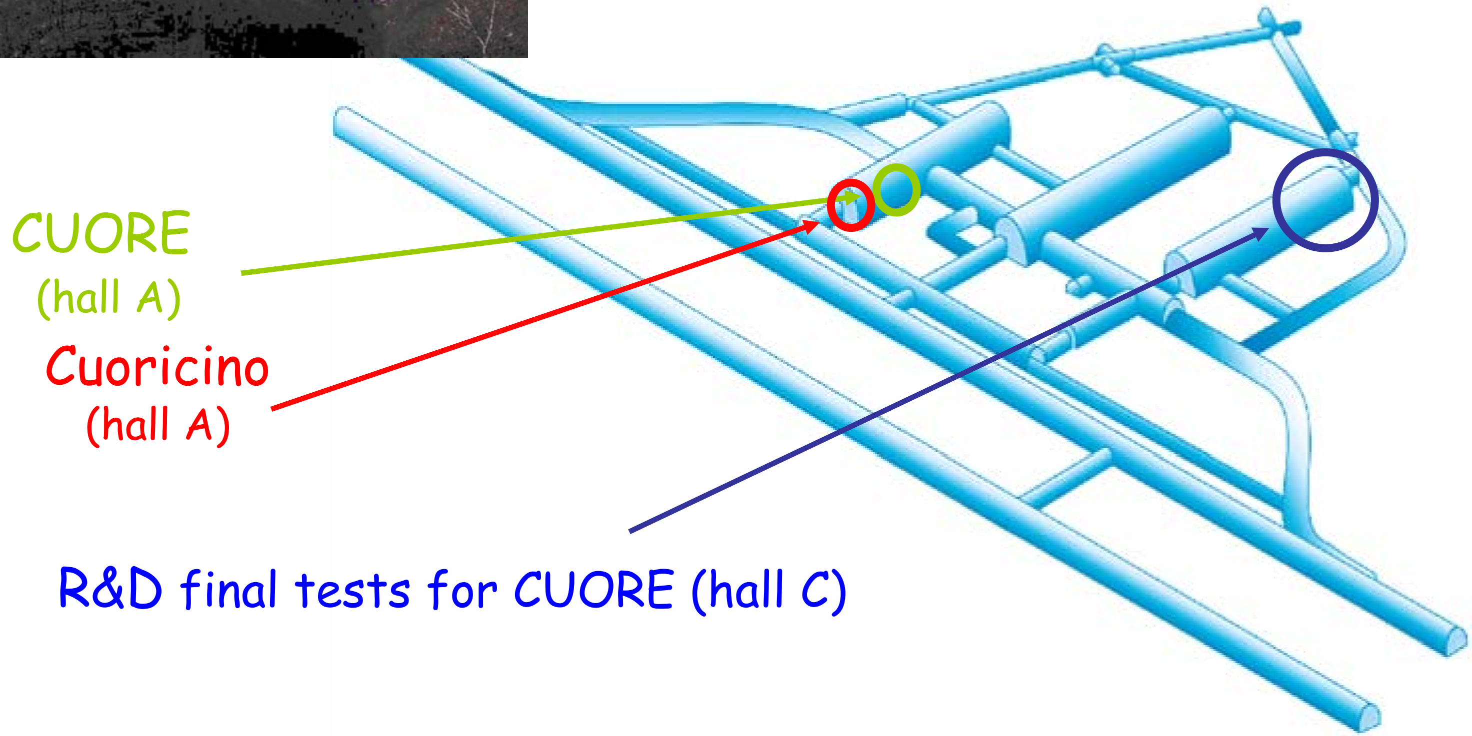
Q-value = a rather good indicator for bkg, most natural radioactivity is negligible above 2.6 MeV

Cuoricino and CUORE Location

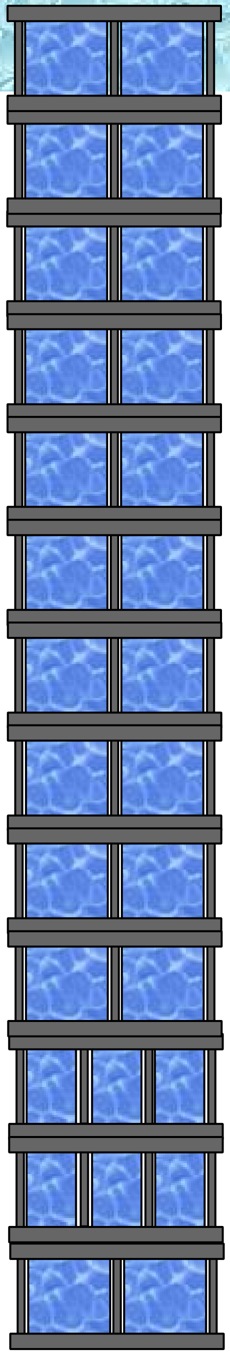
Cuoricino experiment is installed in

Underground National Laboratory
of Gran Sasso
L'Aquila – ITALY

the mountain providing a 3500 m.w.e. shield against cosmic rays



The Cuoricino detector



It is a self-consistent experiment giving significant results on **Double Beta Decay**.

Total number of detectors: 62

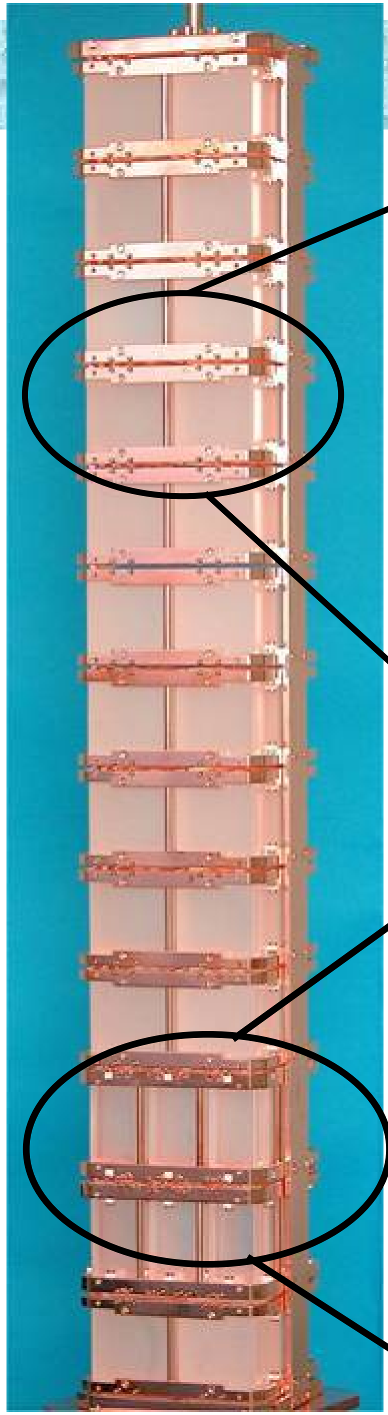
- 11 modules with 4 *big* detectors
  - 44 TeO_2 crystals
  - $5\times5\times5$ cm^3 ⇒ 790 g
  - TeO_2 mass ⇒ 34.76 kg

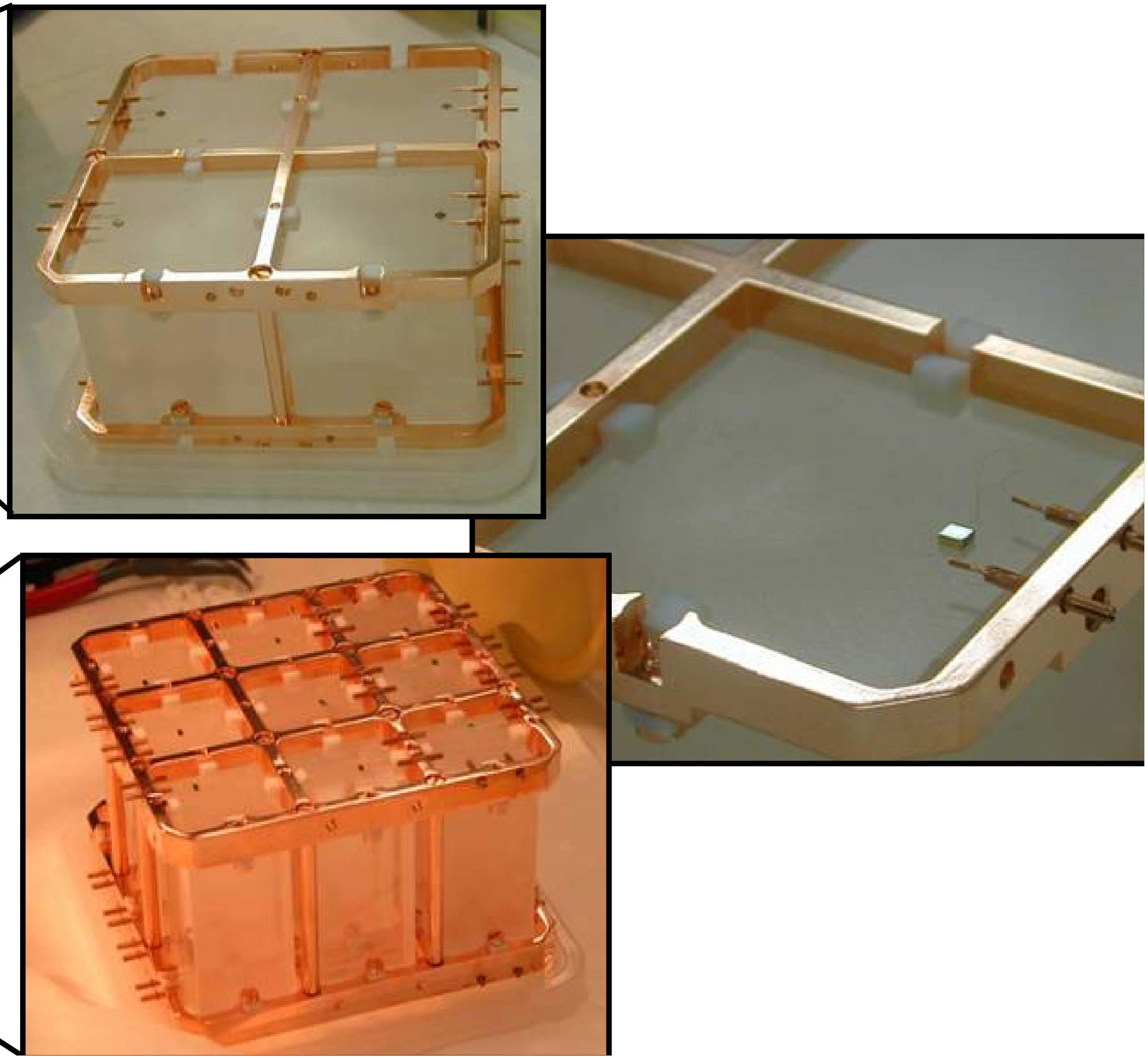
- 2 modules with 9 *small* detectors
  - 18 TeO_2 crystals
  - $3\times3\times6$ cm^3 ⇒ 330 g
  - TeO_2 mass ⇒ 5.94 kg
- 4 crystals are enriched
  - $2\times{}^{130}TeO_2 + 2\times{}^{128}TeO_2$

total active mass

- TeO_2 : 40.7 kg
- ^{130}Te : 11.3 kg
- ^{128}Te : 10.5 kg

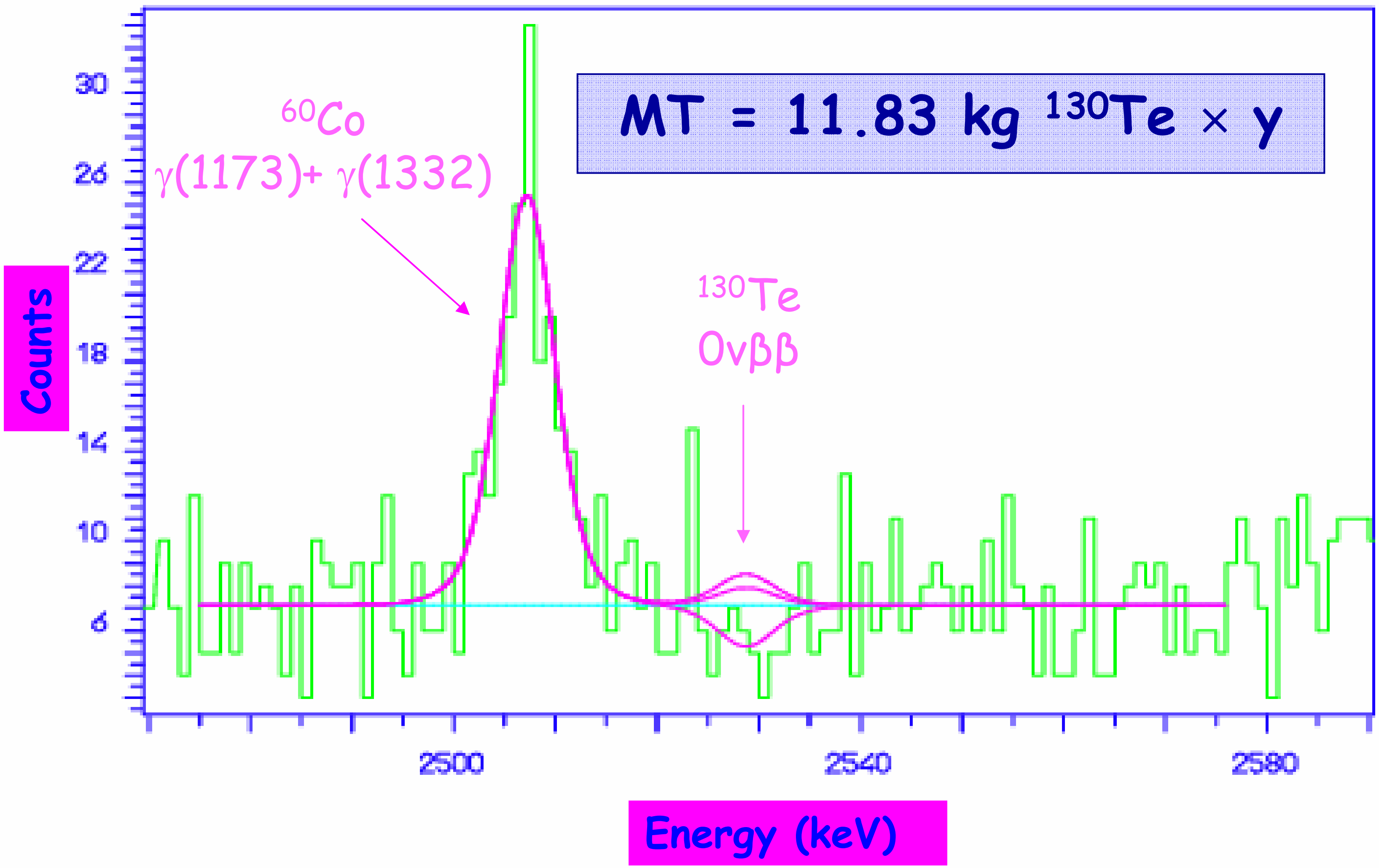
The Cuoricino detector





Neutrinoless DBD results (1)

Background sum spectrum of all the detectors in the DBD region



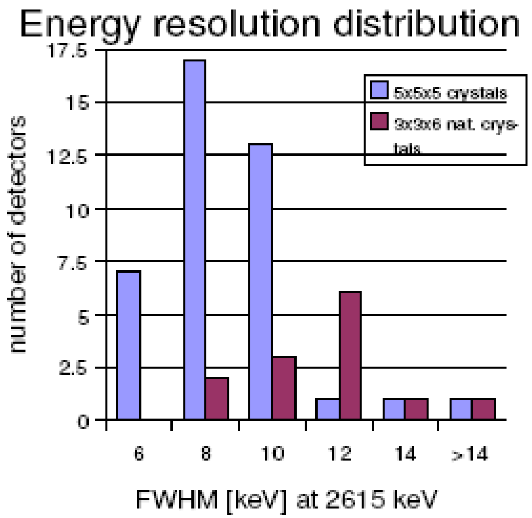
Neutrinoless DBD results (2)

UPDATED RESULTS:

MT = 11.83 kg $^{130}Te \times y$

$T_{1/2}^{0\nu}$ (y) > 3 × 10^{24} y → $m_{\beta\beta} < 0.20 - 0.98$ eV

NME from Rodin et al.
Nucl. Phys. A 2006 Table3



Bkg = 0.18±0.02 c/keV/kg/y

FWHM measured on sum bkg spectrum @ 2.6 MeV ~ **7 keV**

Are we now able to scrutinize the HM claim of evidence?

… we will see in the last part of the talk!!!

The background

… the crucial problem…

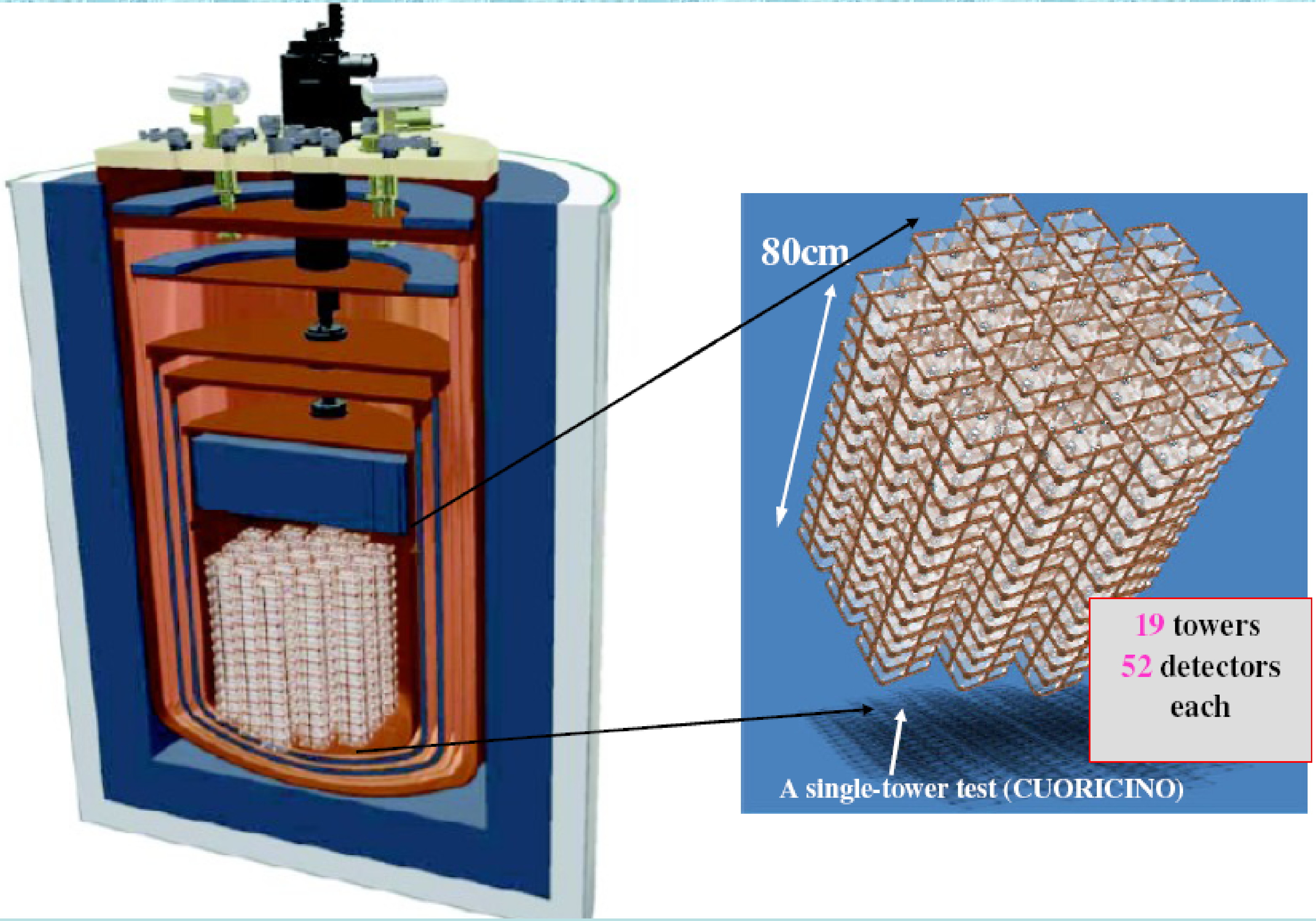
Cuoricino bkg: ~ 0.18 c/keV/y/kg at Q-value

Background model: 30% ± 10% ^{208}Tl (cryostat contamination)
20% ± 10% TeO_2 surfaces (α contaminations)
50% ± 10% Cu surfaces (α contaminations)

~ 0 from $2\nu\beta\beta$ < 0.01 from cosmic rays (n and μ)

In view of CUORE, a big effort is in progress to reduce the bkg and to improve the sensitivity!

From Cuoricino to CUORE
(Cryogenic Underground Observatory for Rare Events)



Closed packed array of 988 TeO_2 5x5x5 cm^3 crystals → 741 kg TeO_2 → 204 kg ^{130}Te

CUORE status

CUORE is an ... n and the 3
main fund... and NSF

CUORE is on ... master plan

CUO... NGS

Data taking foreseen in 2011

From the experiment towards the neutrino mass…

$$\frac{1}{T^{0\nu}_{1/2}} = G^{0\nu} * \left| M^{0\nu} \right|^2 * \left\langle m_{\beta\beta} \right\rangle^2$$

What we measure

The real uncertainty

What we are looking for

QRPA

1) J. Suhonen – O. Civitarese and the Jyväskylä group

2) A. Faessler, the Tuebingen group et al.

Shell Model

E. Caurier, F. Nowacki, A. Poves, et al.

… but so what can we do with our value of $T^{0\nu}_{1/2}$?

- to evaluate m_ν
- to scrutinize the HM result
- to compare next generation experiments

Cuoricino prospects

Are we able now to scrutinize the HM claim of evidence?

HM experimental results:

$T_{1/2}^{0\nu}$ (y) = (0.69-4.18) × 10^{25} (3σ range)

Best value: 1.19×10^{25} y

REF. Klapdor et al., Physics Letters B 586 (2004) 198-212

$m_{\beta\beta}$ = 0.24 – 0.58 eV (3σ range)

Nuclear matrix element of Muto-Bender-Klapdor

What I have done…

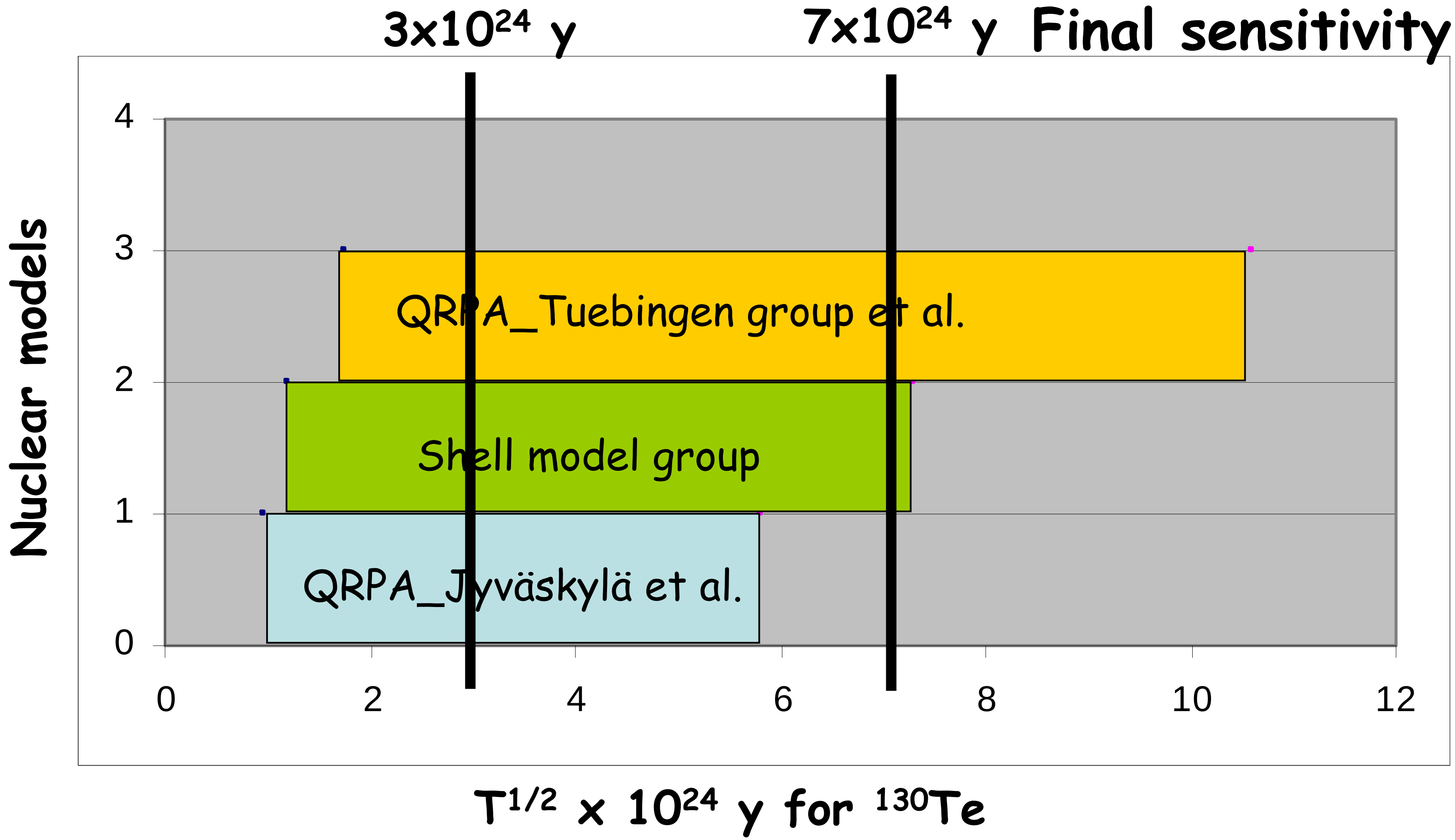
$T_{1/2}^{0\nu}$ (Klapdor) → Choose a nuclear model → $T_{1/2}^{0\nu}$ (^{130}Te)

$$T_{1/2}^{0\nu}(^{130}Te) = \frac{T_{1/2}^{0\nu}(Klapdor)}{\frac{G^{0\nu}_{^{130}Te}}{G^{0\nu}_{^{76}Ge}} \cdot \left| \frac{M^{0\nu}_{refA(^{130}Te)}}{M^{0\nu}_{refA(^{76}Ge)}} \right|^2}$$

References

- ❖Tuebingen's group: erratum of nucl-th/0503063
- ❖ Suhonen's group: nucl-th/0208005
- ❖ Shell Model: Poves' talk @ 4th ILIAS Annual Meeting - Chambery

Cuoricino limit vs Klapdor's claim of evidence



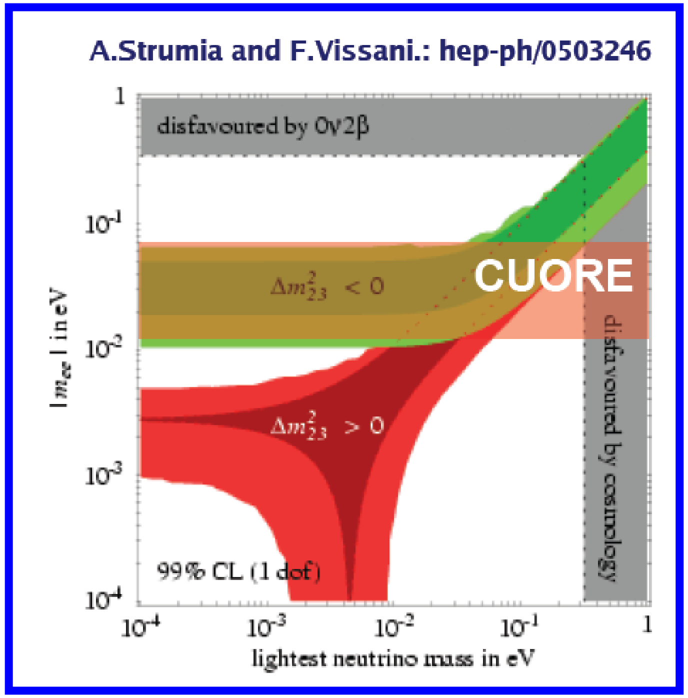
N.B.: No univoque definition of $G^{0\nu}$ and $M^{0\nu}$!!!

And what about CUORE?

The main goal of CUORE is to test the inverted hierarchy

$$m_3 << m_1 \approx m_2$$

$$|m_{ee}| = (19 - 50)\ meV$$



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

CUORE_conservative	CUORE_aggressive
b=0.01 – Γ=5 – T=5y	b=0.001 – Γ=5 – T=5y
$F^{0\nu}$ = 2.1 x 10^{26} y (1σ)	$F^{0\nu}$ = 6.6 x 10^{26} y (1σ)

The CUORE background model

The sources of the background

1. Radioactive contamination in the detector materials (bulk and surface)
2. Radioactive contamination in the set-up, shielding included
3. Neutrons from rock radioactivity
4. Muon-induced neutrons

Monte Carlo simulation of the CUORE background based on:

1. CUORE baseline structure and geometry
2. Gamma and alpha counting with HPGe and Si-barrier detectors
3. Cuoricino experience ⇒ Cuoricino background model
4. Specific measurements with dedicated detectors in test refrigerator in LNGS

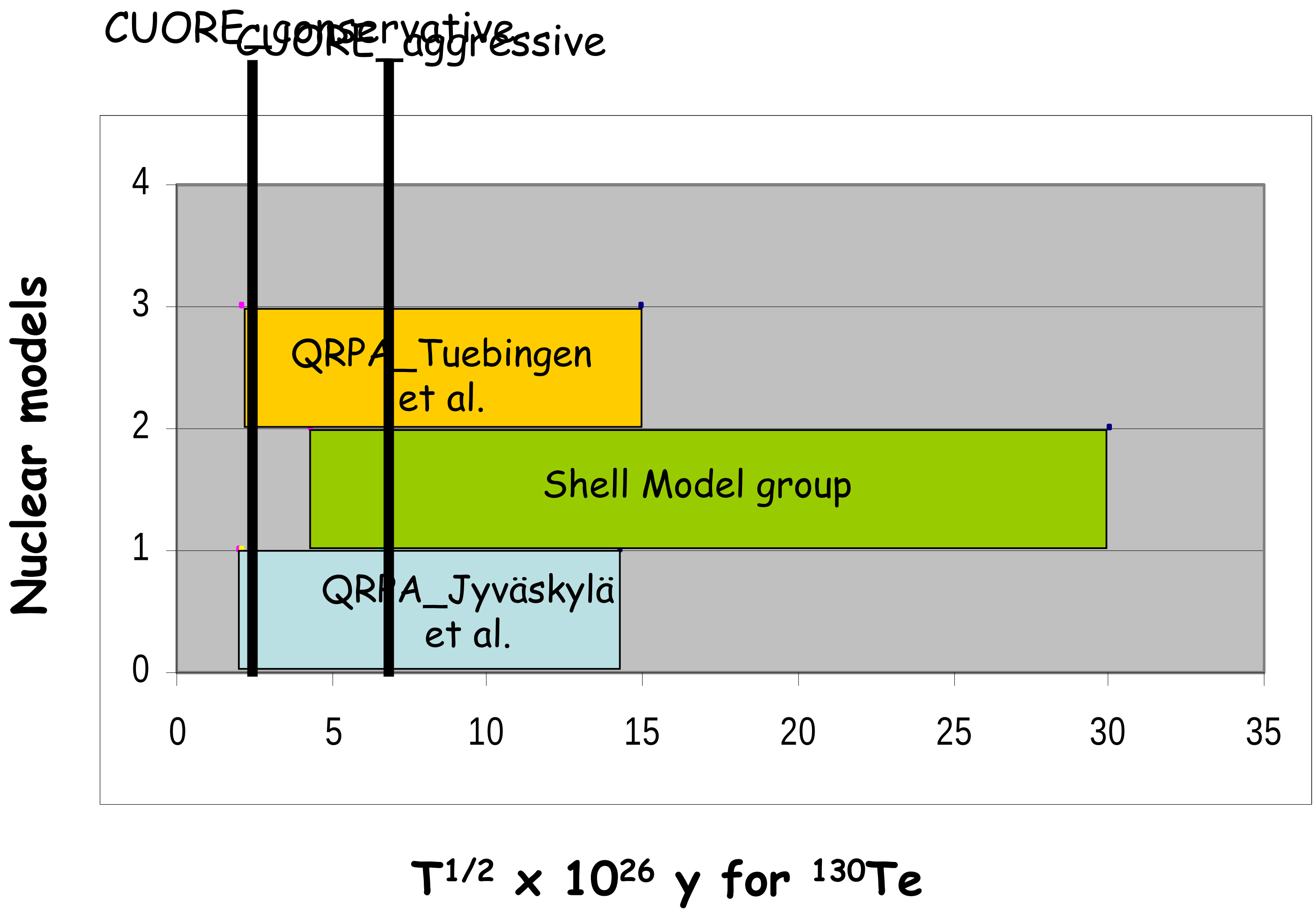
Results.....

The CUORE background components

Component	Background in DBD region (10^{-3} counts/keV kg y)
Environmental gamma	< 1
Apparatus gamma	< 1
Crystal bulk	~ 0.1
Crystal surfaces	[illegible]
Inert det. material bulk	[illegible]
Inert det. material surface	~ 20 - 40
Neutrons	~ 0.01
Muons	~ 0.01

The only limiting factor

CUORE and the inverted hierarchy



What about ^{130}Te compared with other isotopes?

Isotope	Q_value (keV)	Isotopic abundance (%)
^{48}Ca	4271	0.0035
^{76}Ge	2039	9.2
^{82}Se	2995	9.2
^{100}Mo	3034	9.6
^{116}Cd	2802	7.5
^{130}Te	2530	33.8
^{136}Xe	2479	8.9

a) I fix the range of the mass -> inverted hierarchy (19-50 meV)

b) I use the 3 main "schools of thoughts" in terms of N.M.E.

c) I compare the capability to explore the inverted hierarchy region

References

- Tuebingen's group: erratum of nucl-th/0503063
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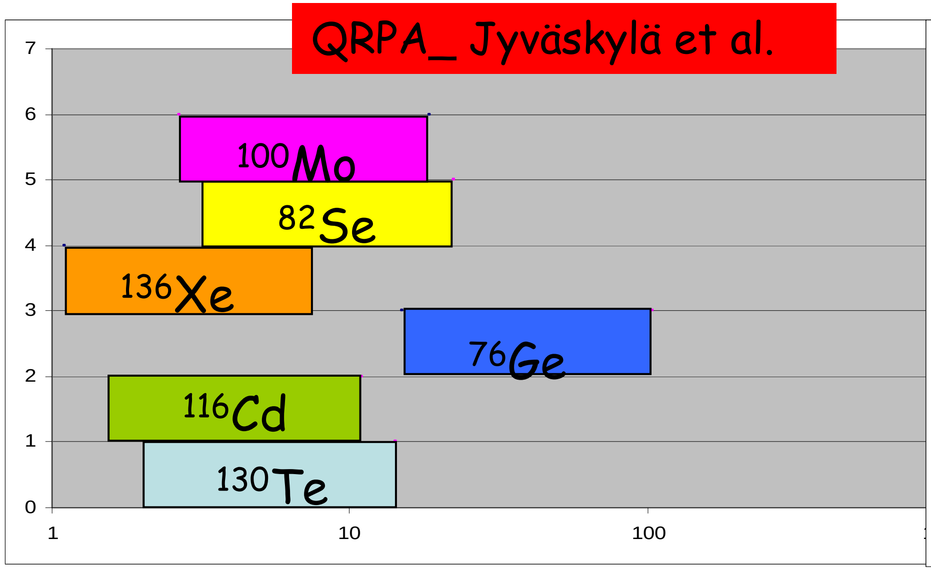
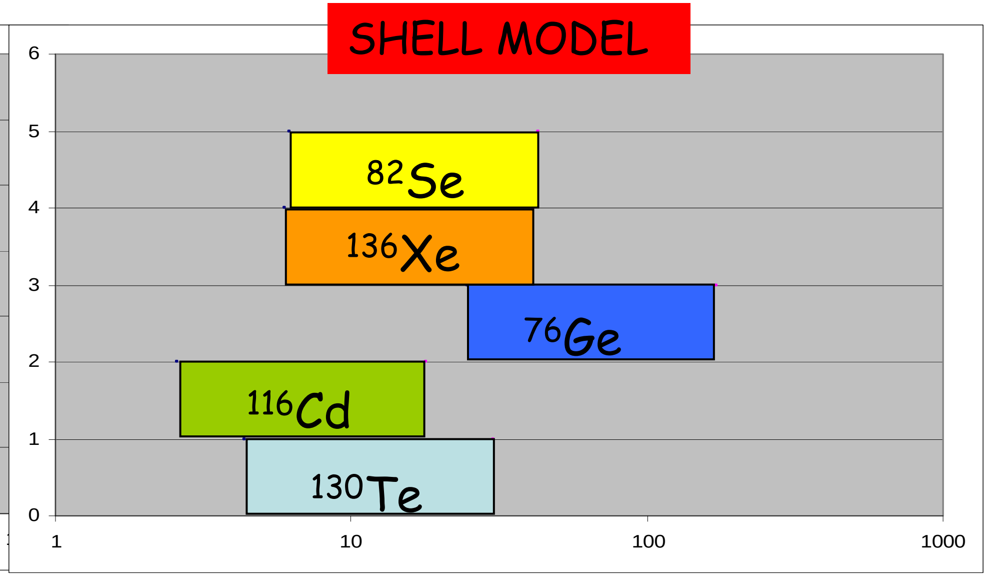
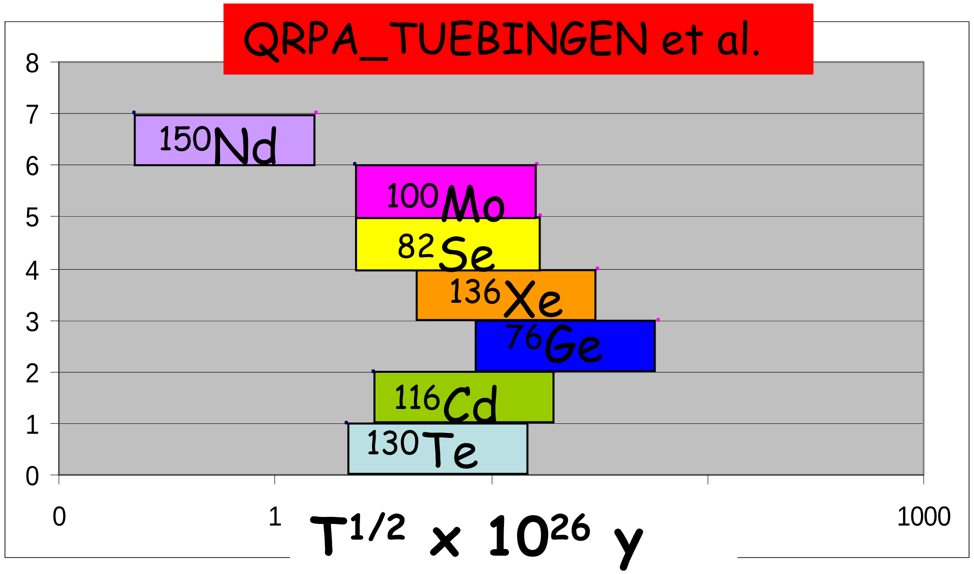


$T^{1/2} \times 10^{26}$ y



$T^{1/2} \times 10^{26}$ y



Conclusions

✓ Cuoricino is presently the most sensitive 0vDBD running experiment, capable to confirm the KK-HM evidence.

✓ Cuoricino demonstrates the feasibility of a large scale bolometric detector (CUORE) with good energy resolution and bkg on many detectors.

✓ CUORE, a second generation detector, will be built and start up in the next 4 years.

✓ Recent results on background suppression confirm the capability to start to explore the inverted hierarchy mass region.

Unit:y

	Suhonen + SM	Rodin
Isotope	$G^{0\nu}$ (g_A=1.25 r_0=1.2fm)	$G^{0\nu}$ (g_A=1.25 r_0=1.1fm)
^{76}Ge	6.31×10^{-15}	7.92×10^{-15}
^{82}Se	2.73×10^{-14}	3.52×10^{-14}
^{100}Mo	4.42×10^{-14}	5.73×10^{-14}
^{116}Cd	4.68×10^{-14}	6.22×10^{-14}
^{130}Te	4.14×10^{-14}	5.54×10^{-14}
^{136}Xe	4.37×10^{-14}	5.91×10^{-14}
^{150}Nd	1.94×10^{-13}	2.70×10^{-13}

There is a difference of about 25%