0νββ
an extreme challenge

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0νββ

does it exist ?

if it does then:

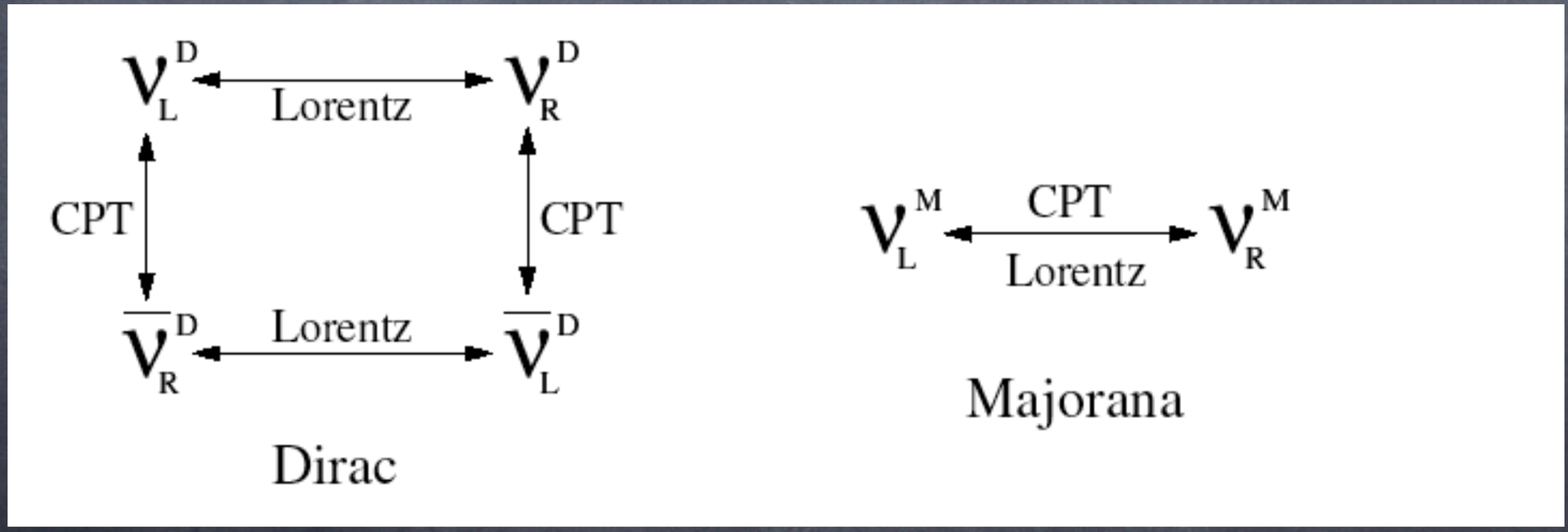
The background, only the background, nothing else than the background

Outline

- The Physics
- The Problem
- The Future

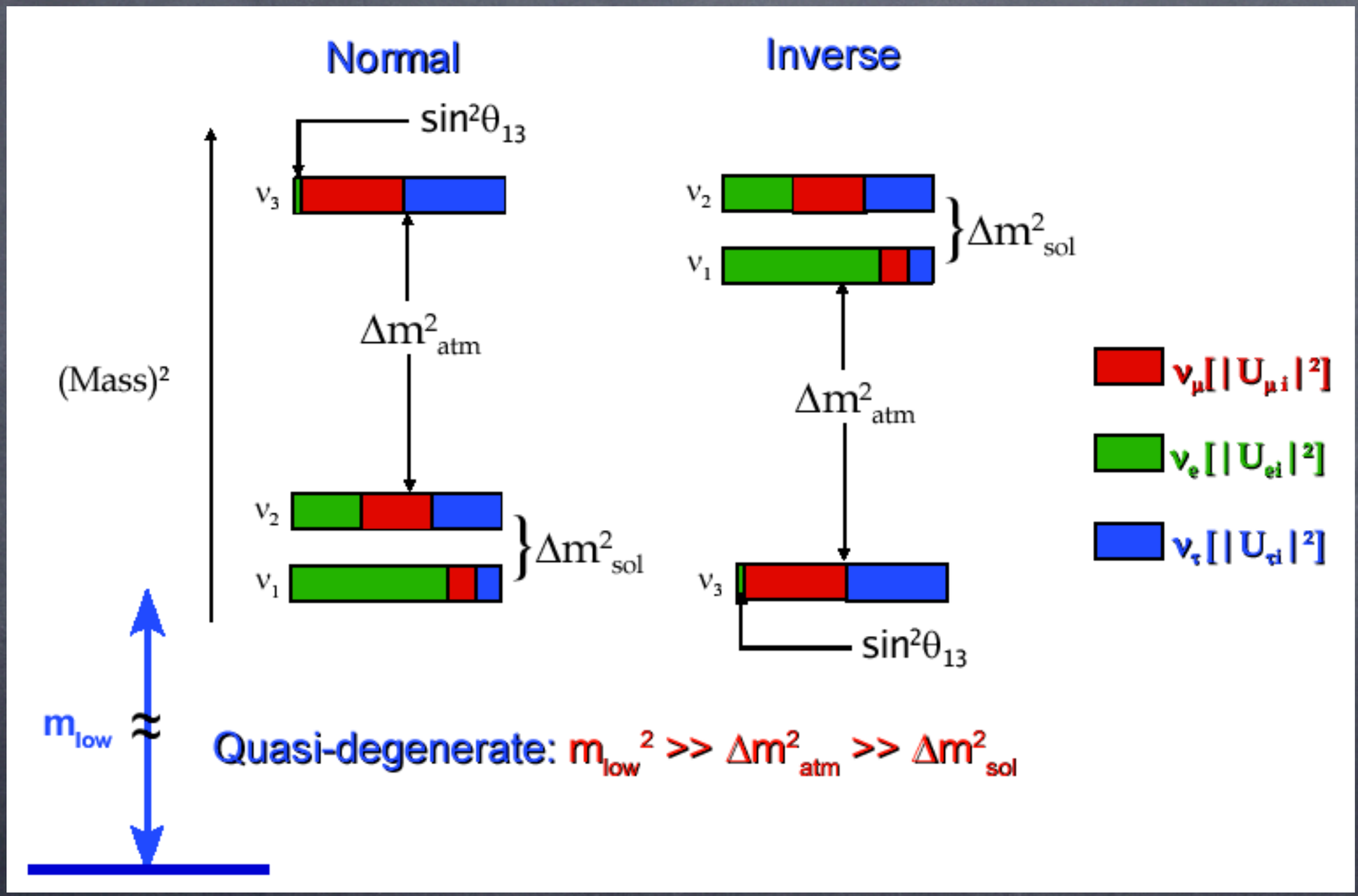
The Physics

Massive neutrinos makes Majorana conjecture very much attractive



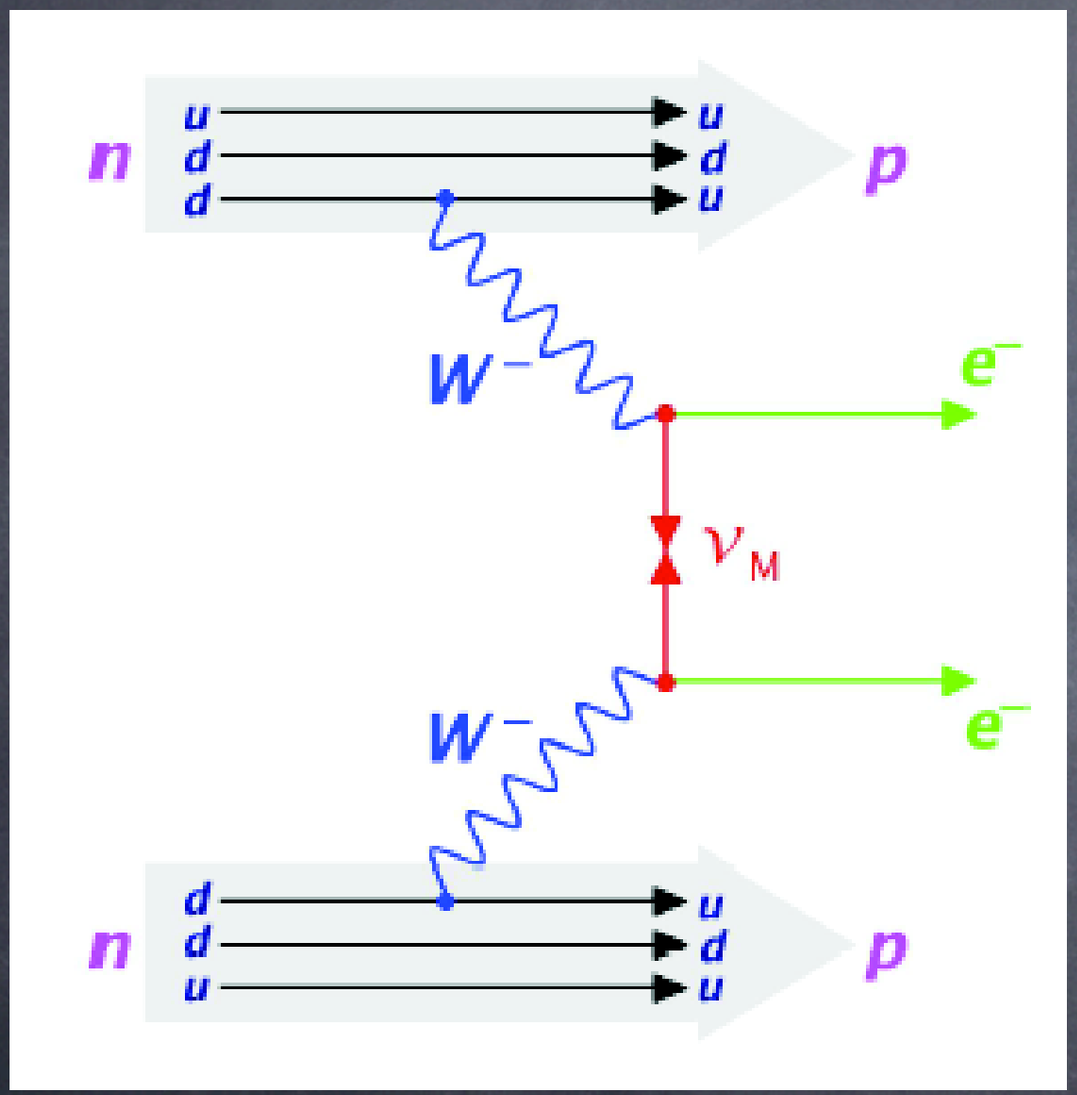
The neutrino mass

Three cases


Normal
Inverse
$\sin^2\theta_{13}$
ν_3
Δm^2_{atm}
ν_2
ν_1
Δm^2_{sol}
(Mass)²
$\nu_\mu[|U_{\mu i}|^2]$
$\nu_e[|U_{ei}|^2]$
$\nu_\tau[|U_{\tau i}|^2]$
$m_{low} \approx$
Quasi-degenerate: $m_{low}^2 >> \Delta m^2_{atm} >> \Delta m^2_{sol}$

Neutrinoless Double Beta Decay

Neutrino-less DBD (0νββ)



The helicity can flip both for a massive Dirac neutrino and for a Majorana one. However in the Dirac case the process is forbidden by lepton number conservation.

If observed the neutrino is a Majorana particle

The neutrino mass connection to DBD

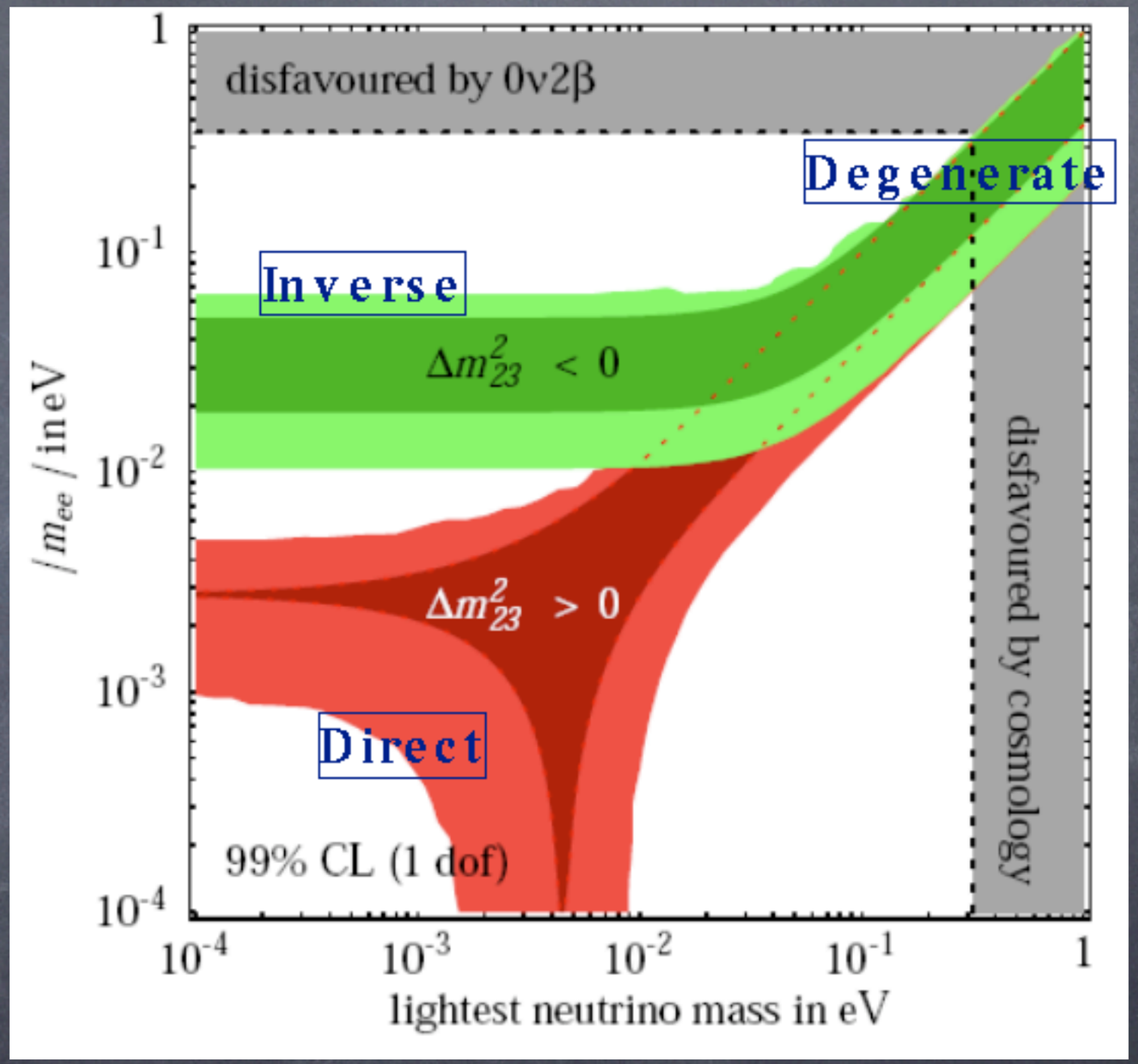
Does DBD measure neutrino mass?

$$m_{\beta\beta} = \sum m_{\nu_k} U_{ek}^2 = \cos^2\theta_{13}\left(m_1 \cos^2\theta_{12} + m_2 e^{2i\alpha} \sin^2\theta_{12}\right) + m_3 e^{2i\beta} \sin^2\theta_{13}$$

not really.... it is a mixture of couplings, mixing angles and masses. Better than nothing though !

$$m_{\beta\beta} = f\left(U_{ek}, m_{lightest}, \delta m_{sol}, \Delta m_{atm}\right)$$

The chances in a slide !



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

The tough life of an experimentalist

The name of the game

expected number of ββ0ν events

$$S = \frac{M \cdot N_A \cdot a}{W} \cdot \ln(2) \cdot \frac{t}{T^{0\nu}_{1/2}} \cdot \varepsilon$$

detector mass; isotopic abundance; molecular mass; live time; efficiency; ββ0ν half-life

mean number of background counts around the Q-value

$$B = b \cdot M \cdot \Delta E \cdot t$$

background rate in counts/keV/kg/y; energy resolution (detector FWHM); detector mass; live time

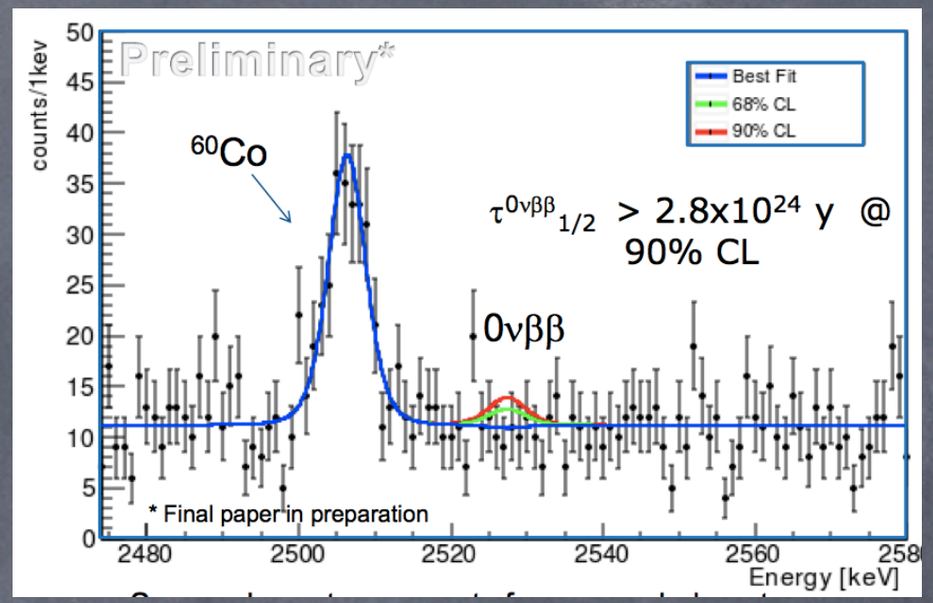
Sensitivity

Sensitivity $\propto K\sqrt{\dfrac{M \cdot t}{B \cdot \Delta E}}$ (i.a. • ε)

$m_{\beta\beta} \propto \sqrt{(1/\tau)}$

To be crystal clear:
a factor 10 better on the mass = a factor 100 in sensitivity

just to impress you



- Cuoricino limit: 2.8 x 10^24 y says roughly m < 400mev
- The center of 'inverted hierarchy band' is at 50 meV
- to get at it you shall climb up to > 10^26

$$t_{1/2} > 10^{26}$$

Cuoricino starting point

- livetime 2 years
- energy resolution 5 keV
- mass 50 kg
- background 0.2 counts/keV/Kg/year

not much to work with !

A new experiment aiming to improve a factor 10 on $m_{\beta\beta}$, has to increase by 100 the sensitivity

here is the menu:

M	5 Ton	instead of 50 Kg
t	500 y	instead of 5 y
ΔE	50 eV	instead of 5 keV

None of these !!!!!!

B 0.001 instead of 0.2

Attention please

- what counts is the product $\Delta E \times b$
- I am using the example of the best detector you can todate employ: bolometers, Ge calorimeters pointing to 5 keV energy resolution (FWHM) at the Q-value

On the market

- GERDA (Ge-calo) : b=0.01 ΔE=5
- EXO (Xe liquid) : b=0.0015 ΔE=100
- CUORE (TeO2 xtal): b=0.01 ΔE=5

after this humanly controlled parameters Nature comes in with Matrix Elements (not discussed further)

The background

A\Z	81	82	83	84	85	86	87	88	89	90
232										^{232}Th 14.05 Gy
228								^{228}Ra 5.75 y	^{228}Ac 6.15 h	^{228}Th 1.913 y
224							(^{224}Fr) 3.3 m	^{224}Ra 3.66 d		
220						^{220}Rn 55.6 s				
216				^{216}Po 0.145 s						
212		^{212}Pb 10.64 h	^{212}Bi 60.6 m	^{212}Po 0.299 ms						
208	^{208}Tl 3.05 m	^{208}Pb stable								

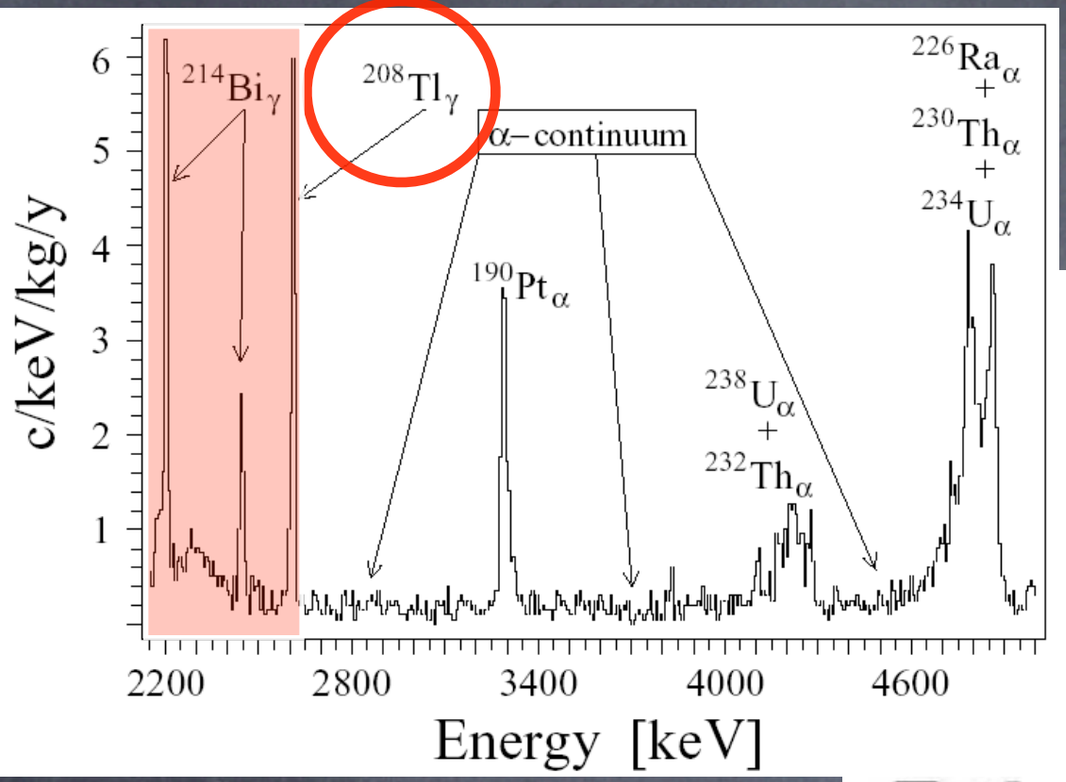
A\Z	80	81	82	83	84	85	86	87	88	89	90	91	92
238													^{238}U 4.468 Gy
234											^{234}Th 24.10 d	^{234m}Pa 70.2 s / ^{234}Pa 6.70 h	^{234}U 245 ky
230											^{230}Th 75.4 ky		
226										^{226}Ra 1600 y			
222									^{222}Rn 3.8235 d				
218								^{218}Po 186 s	^{218}At 1.6 s	^{218}Rn 35 ms			
214							^{214}Pb 27 m	^{214}Bi 19.9 m	^{214}Po 164 μs				
210					^{210}Tl 1.30 m		^{210}Pb 22.3 y	^{210}Bi 5.013 d	^{210}Po 138.376 d				
206	^{206}Hg 8.2 m		^{206}Tl 4.20 m		^{206}Pb stable								

U

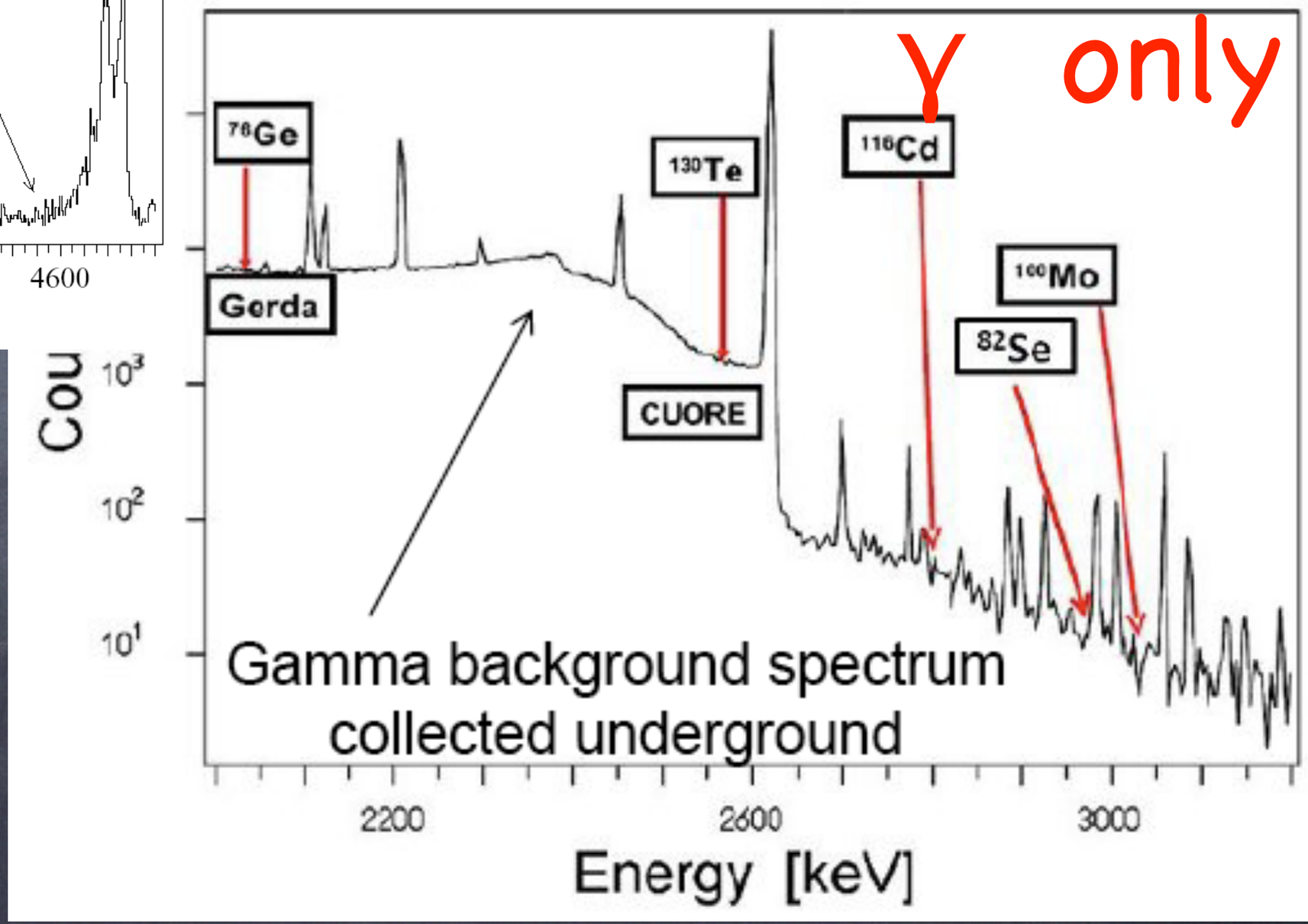
e

Th

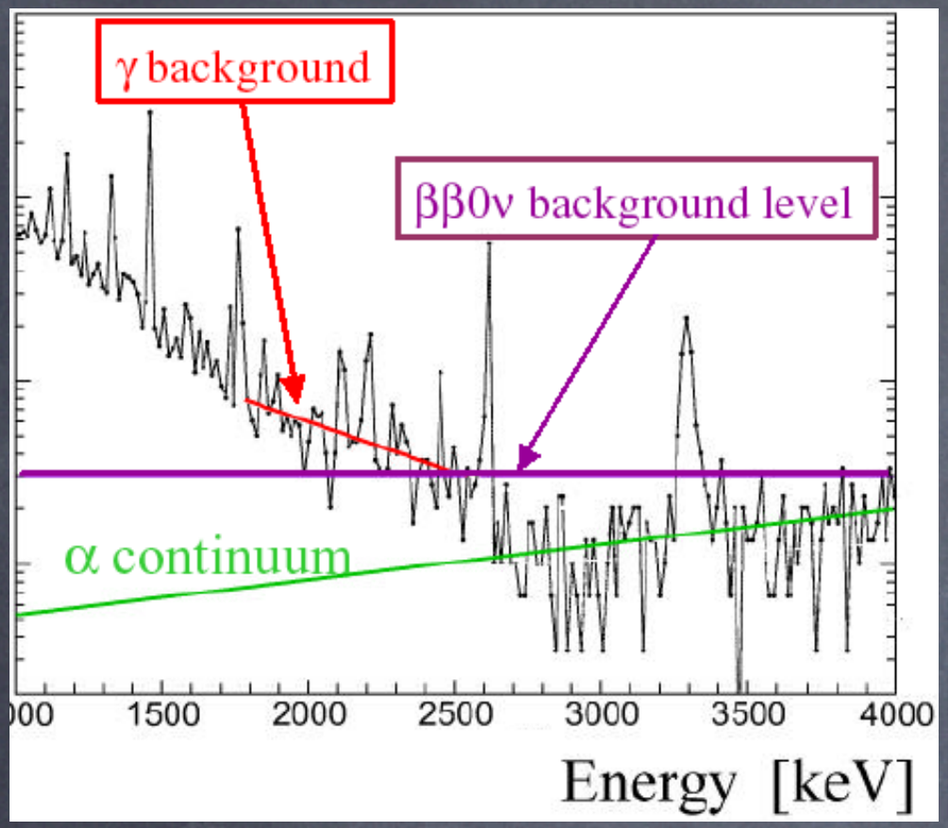
Natural radioactivity



above ^{208}Tl there is the α land

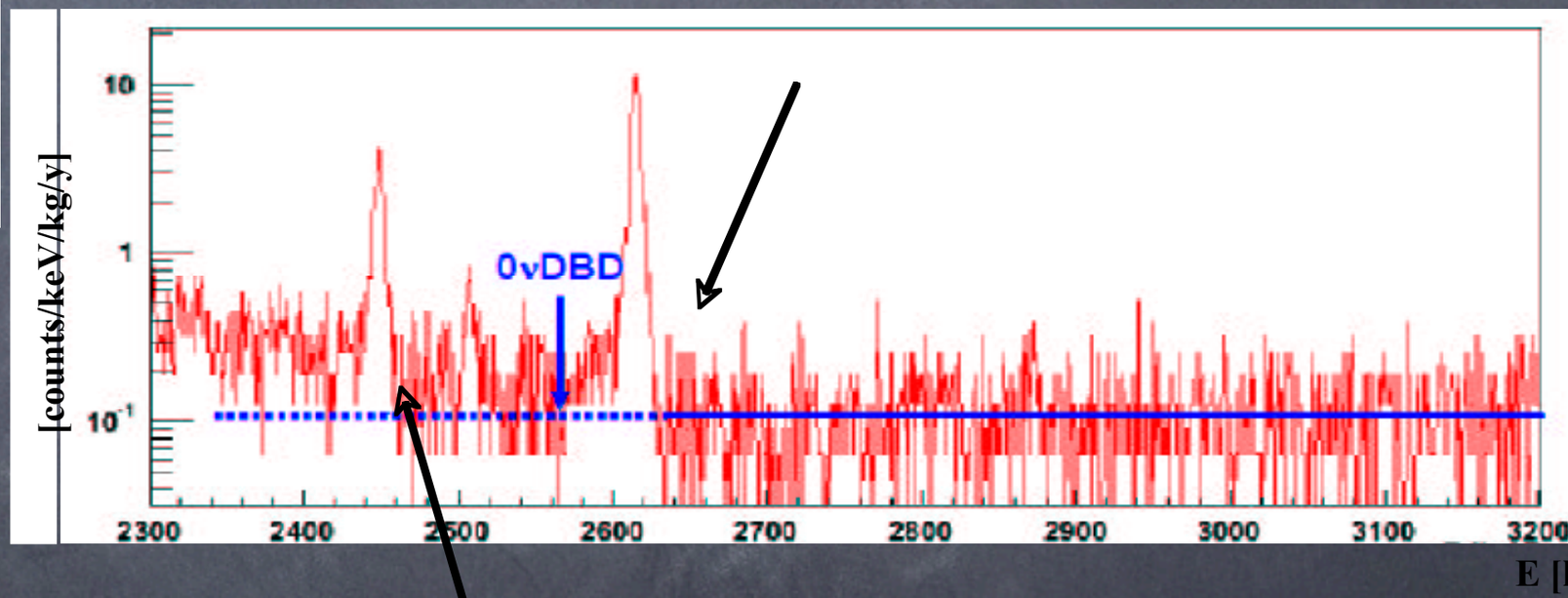


Cuoricino: Background



2615 keV Tl line: contribution to the DBD bkg due to a Th contamination (multicompton). .

Th (Tl) contribution to DBD background: **~ 40%**

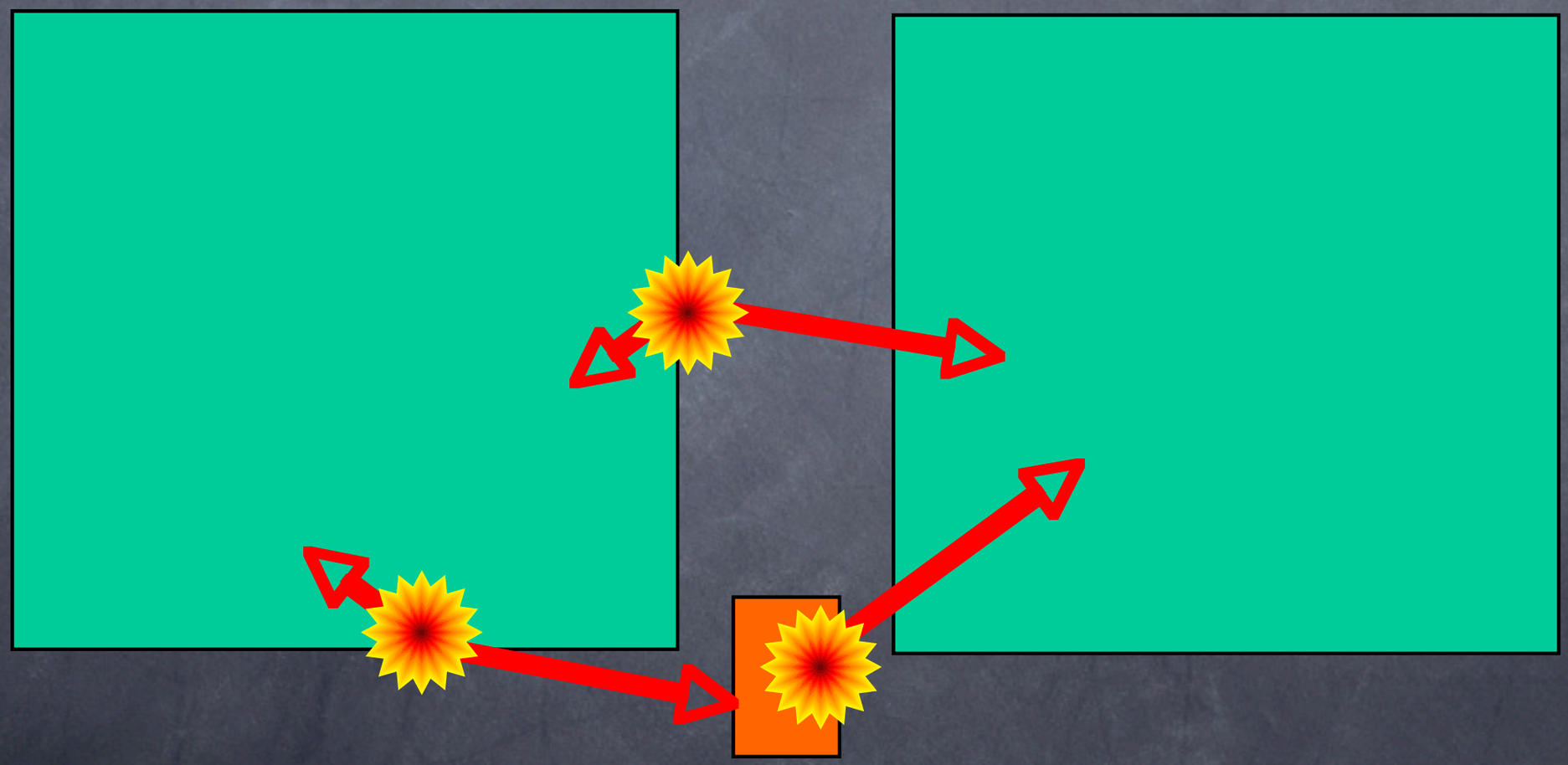


Cuoricino
b=0.18 ± 0.02
c/keV/kg/y

2505 keV line: sum of the 2 ^{60}Co gammas (1173 and 1332 keV)
Most probable source: neutron activation of the Copper
Contribution to DBD background: negligible

Flat background in the energy region above the ^{208}Tl 2615 line
Contribution to the counting rate in the 0νDBD region: ~ 60%
Degraded alpha particles

Il modello standard del fondo



Degraded α's

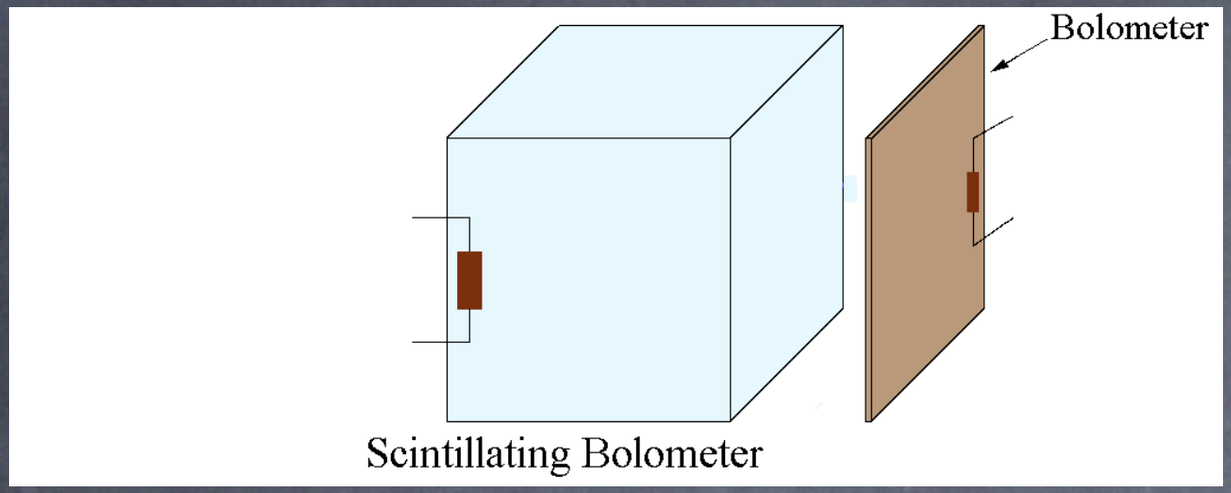
Quindi c'e' spazio per pensare

LUCIFER

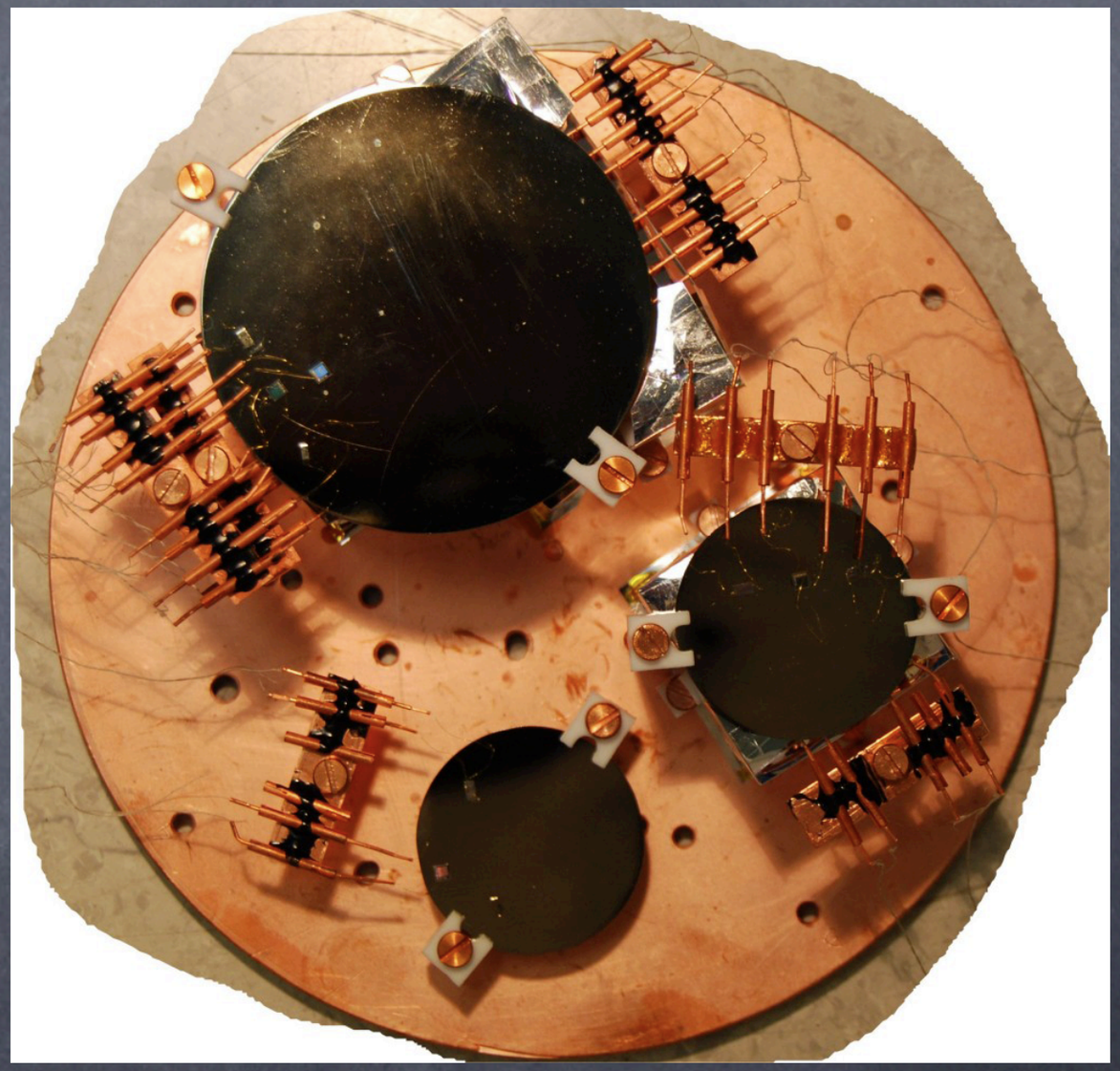
concept

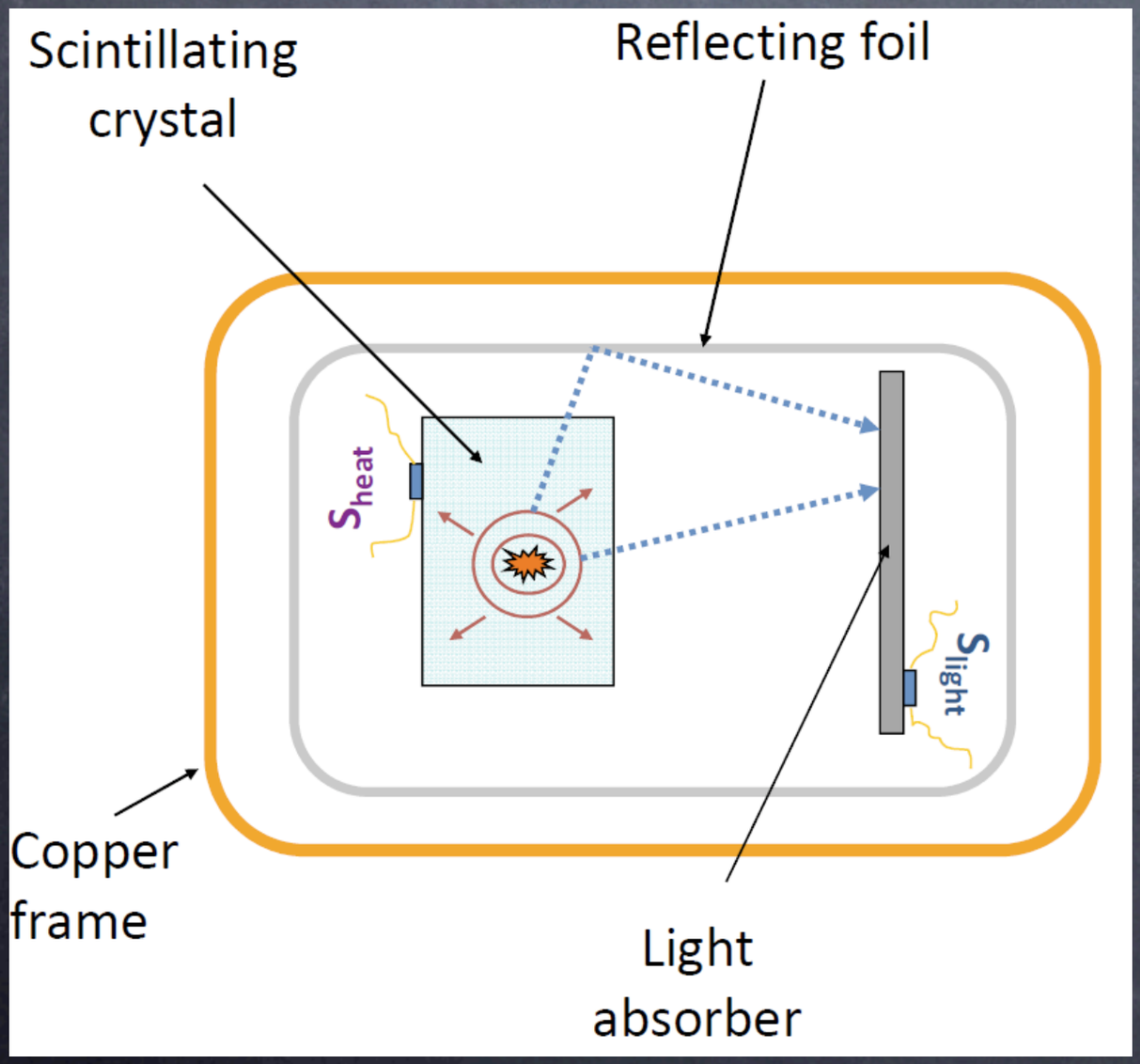
Bringing
light
underground

Double read-out



BOLUX@CSN5



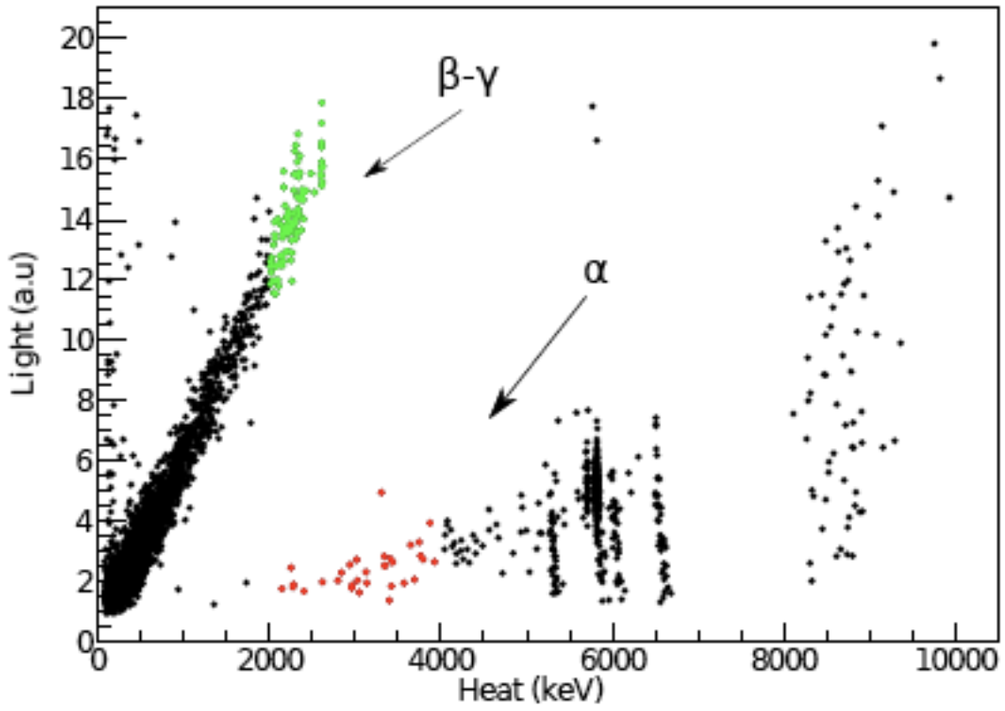


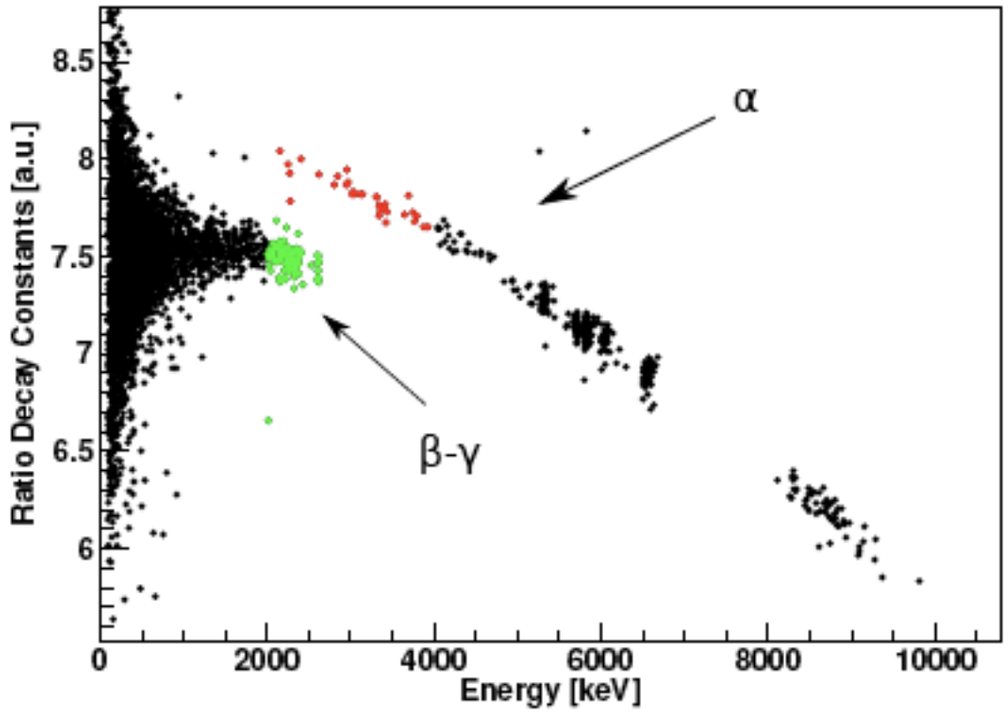
S. Pirro@LNGS

The total war

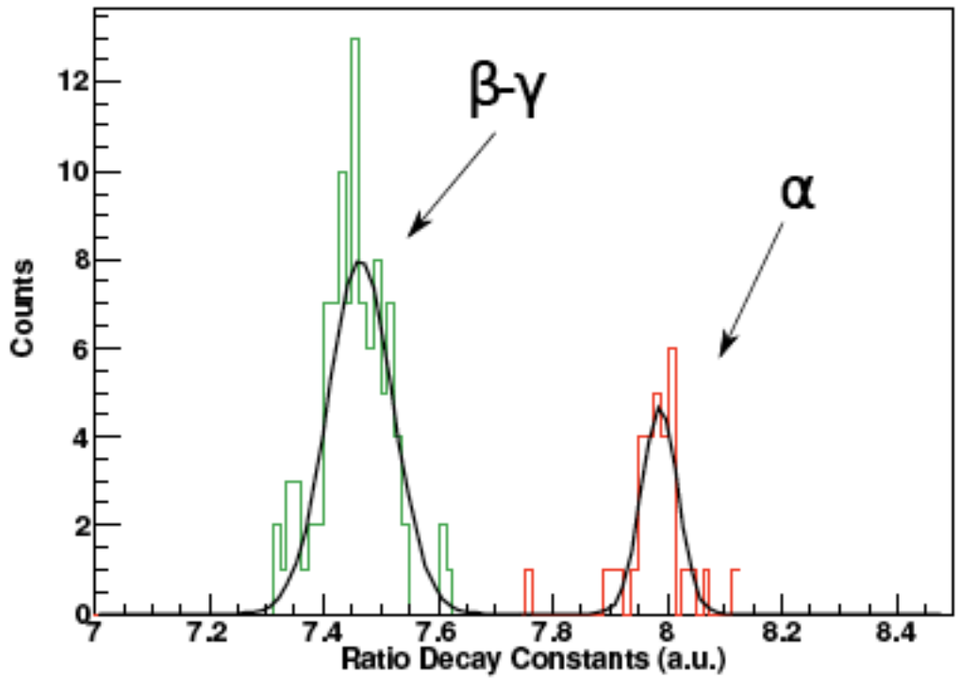
- Go above Thallium peak at 2610 KeV
- Kill all the alfas by energy release and shape

$ZnMoO_4$





Large crystals have not (yet) been produced.



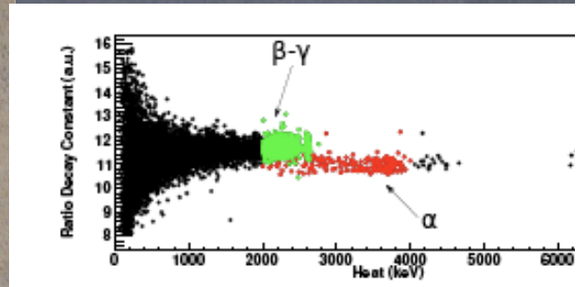
1011.5415

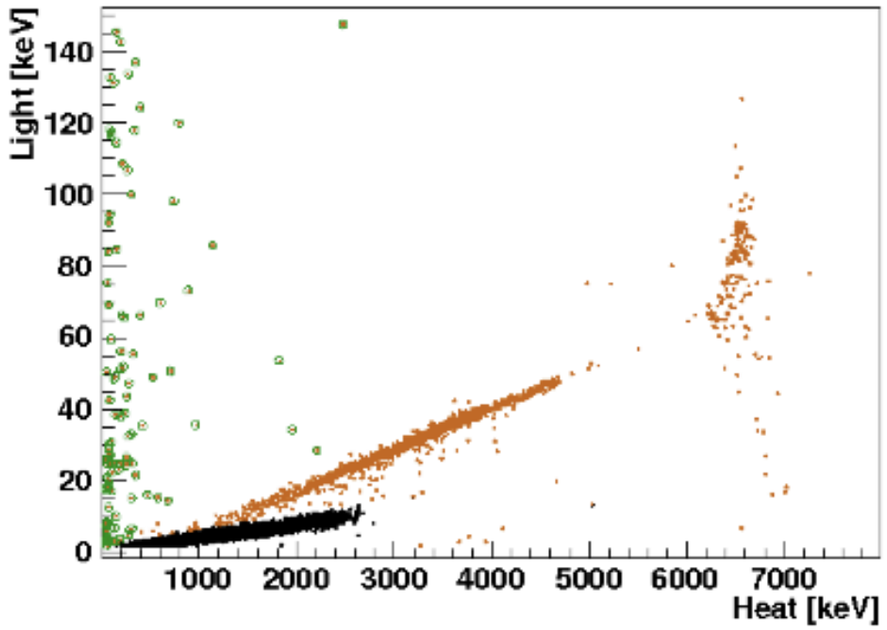
A novel class of bolometric detectors

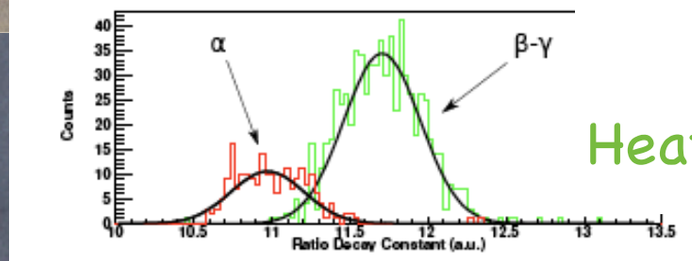
C.Arnaboldi[a], C.Brofferio[a,b], O.Cremonesi[a], L.Gironi[*,a,b], M.Pavan[a,b], G.Pessina[a], S.Pirro[a], E.Previtali[a]

The most intriguing crystal

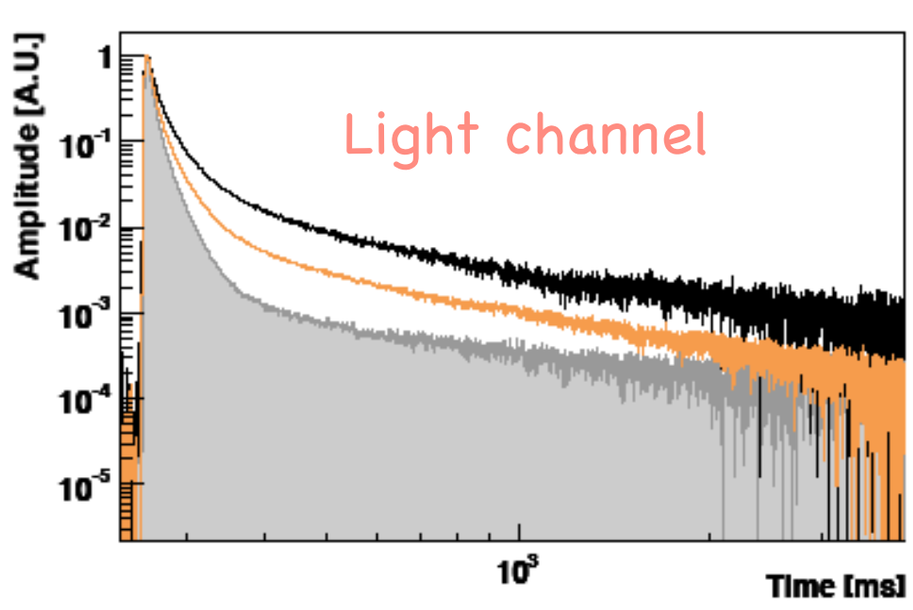
ZnSe

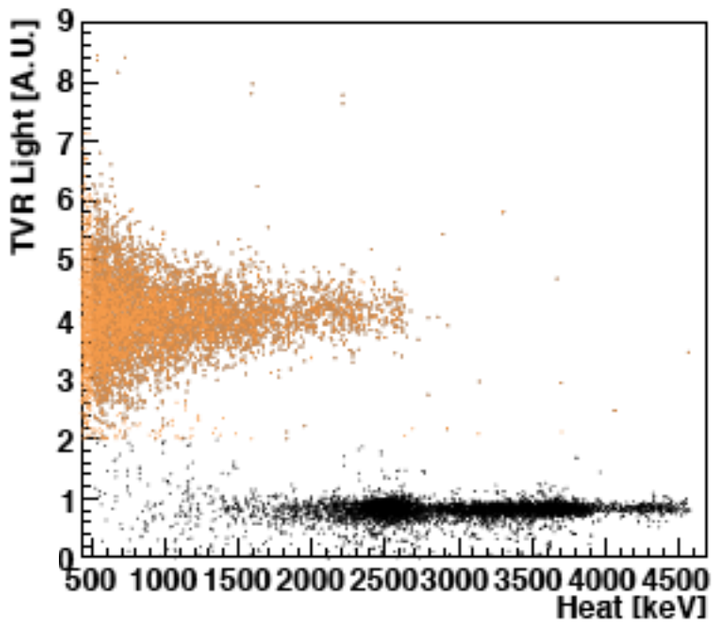


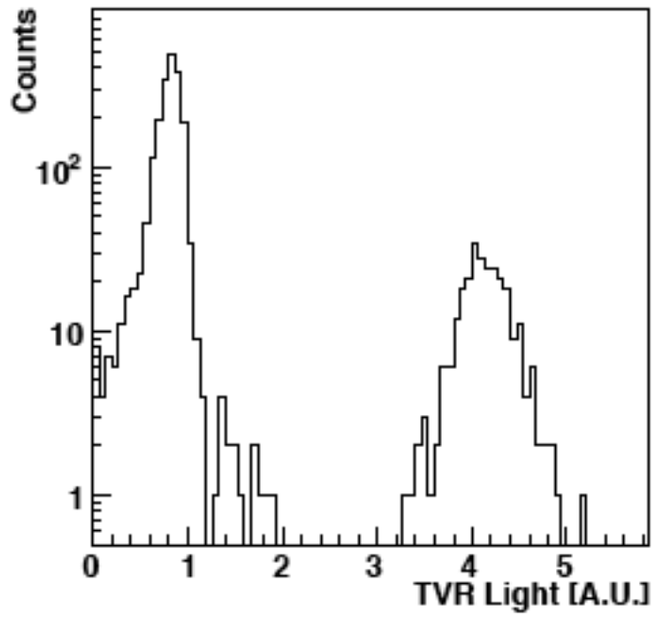




Heat channel







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ZnSe scintillating bolometers for Double Beta Decay

C. Arnaboldi[a], S. Capelli[b,a], O. Cremonesi[a], L. Gironi[b,a], M. Pavan[b,a], G. Pessina[a], S. Pirro[a]

Why not ?

- need to proof the concept in a pretty solid way

- ^{100}Mo or ^{82}Se are rather expensive. 75 Euro/gram not counting crystal production and efficiency

- 1 Ton, say 100 MEuro to invest to get at 10^26

Quality parameter

Exp	ΔE (keV)	b (c kev kg y)	ΔE x b (c Ton y)
Gerda	4.5	0.02	90
EXO	80	0.0015	120
CUORE	5	0.02	100
'Lucifer'	10	0.001	10

this is again too simple, no NME , no fidvol, no cost

Conclusions

(requests to the Nature)

- makes the neutrinos to be Majorana particles
- command the hierarchy to be inverted
- find a way to make the process of enrichment cheap (or in alternative switch off most of the radioactive decays !
  [remember R. Giskard Reventlov in Asimov multi-logy ?]