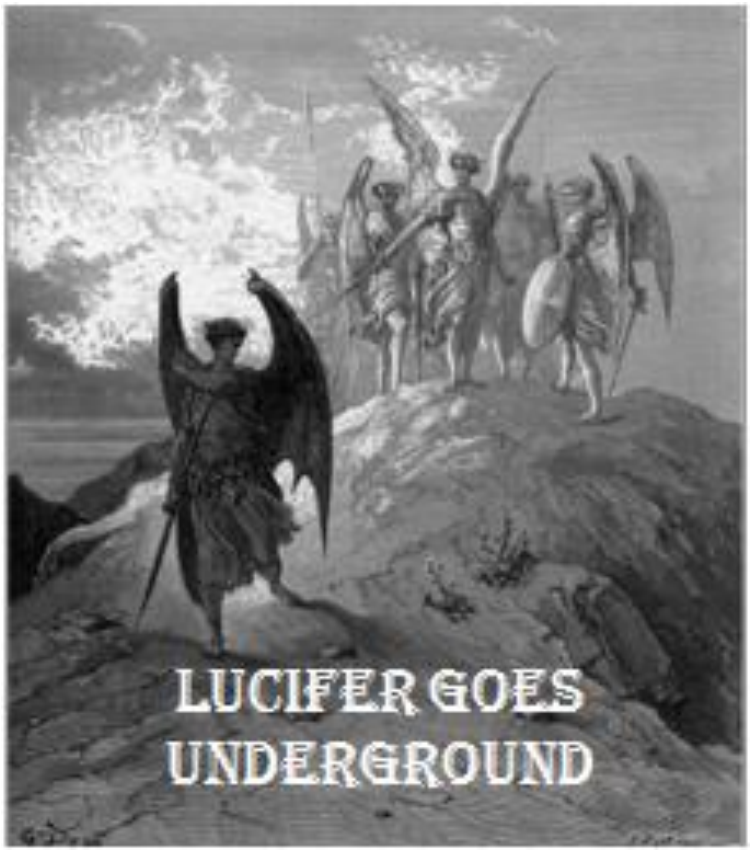
LUCIFER: Neutrinoless Double Beta Decay search with scintillating bolometers



European Research Council

ERC-2009-AdG 247115

Luca Pattavina
INFN – Milano-Bicocca

DISCRETE 2010
Rome 6-11 December 2010

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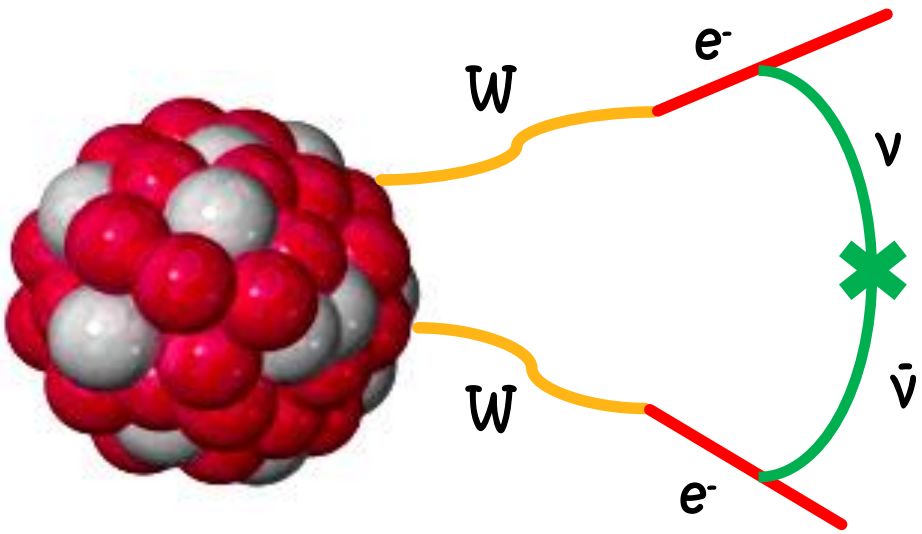
OUTLINE

- DBD0v physics
- Tools for the DBD0v search
- Scintillating Bolometers
- LUCIFER proposal
- LUCIFER R&D
- Conclusions

DBDOν

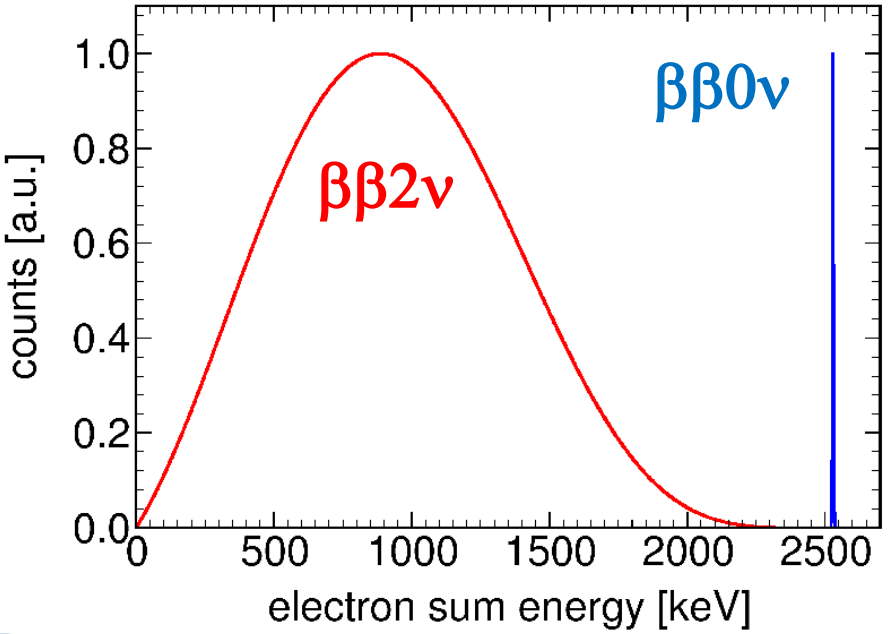


- 2nd order nuclear weak decay
- not allowed in the SM
- $t_{1/2}$ expected > 10^{25} y

If observed:

- the neutrino is a Majorana particle: $\nu_e \equiv \bar{\nu}_e$
- $\Delta L = 2$, lepton number violation
- neutrino mass measurement: $\frac{1}{T_{1/2}^{DBD0\nu}} = G_{0\nu}(Q,Z)|M^{0\nu}|^2 m_{\beta\beta}^2$

What are we looking for ??



Monochromatic signal
@ Q-value

$$S_{0\nu} \propto \varepsilon \frac{i.a.}{A} \sqrt{\frac{M \cdot T}{\Delta E \cdot b}}$$

b ≠ 0

i.a.: isotopic abundance

A: atomic mass number

M: source mass
O(1000 kg)

T: live time O(5 y)

ΔE: FWHM in the ROI
O(~keV)

b: bkg in the ROI
O(0.01 c/keV/kg/y)

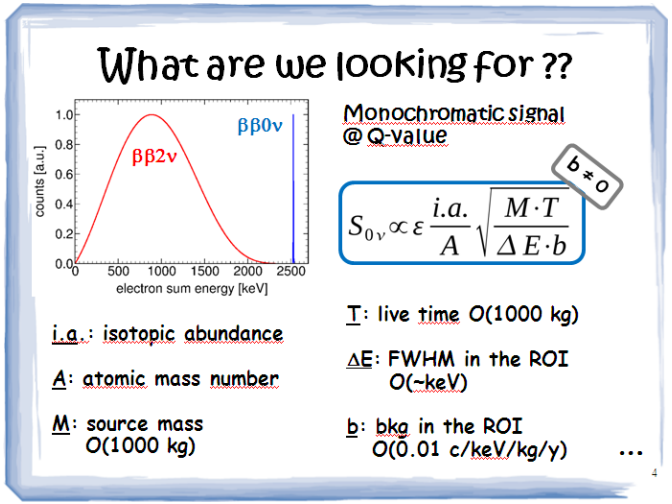
...

The pursuit of DBD0ν

… but if b is very low… "zero background approach"…

$$S_{0\nu} \propto \varepsilon \frac{i.a. \cdot M \cdot T}{A}$$

$$M \cdot T \cdot \Delta E \cdot b << 1$$



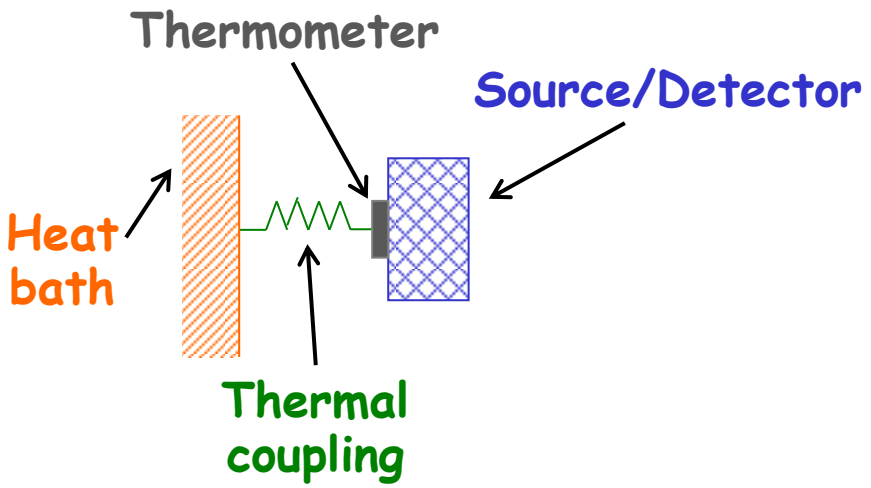
… this background level is achievable:

- high energy resolution => bolometric technique
- removing sources of background => material selection
- background discrimination

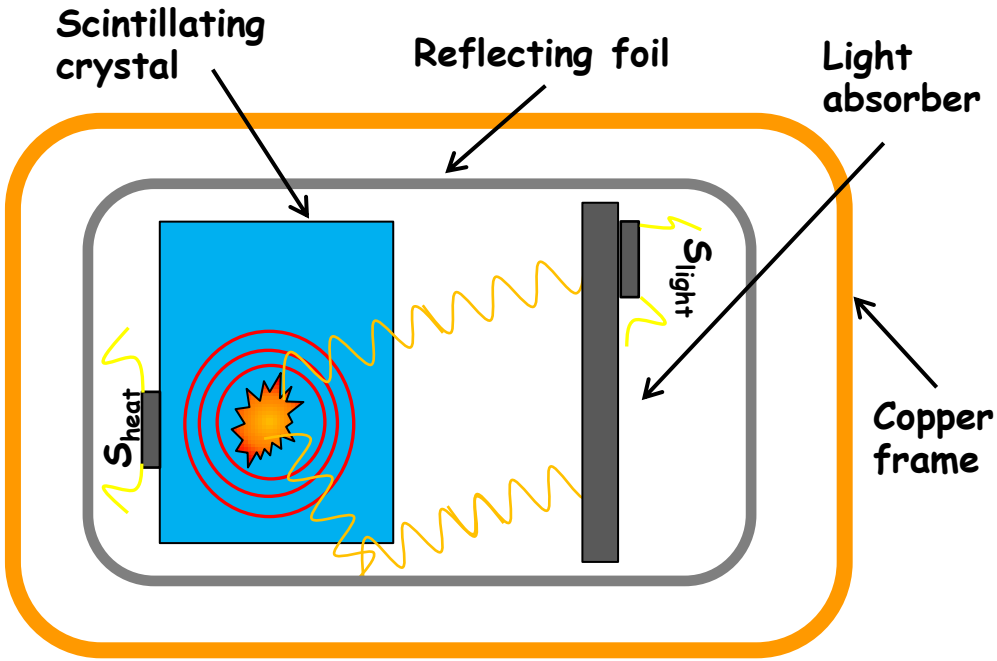
→ SCINTILLATING BOLOMETERS ←

Scintillating Bolometers

A bolometric device able to measure phonon (heat) and photon (light) excitations produced in an absorber by a single radiation interaction



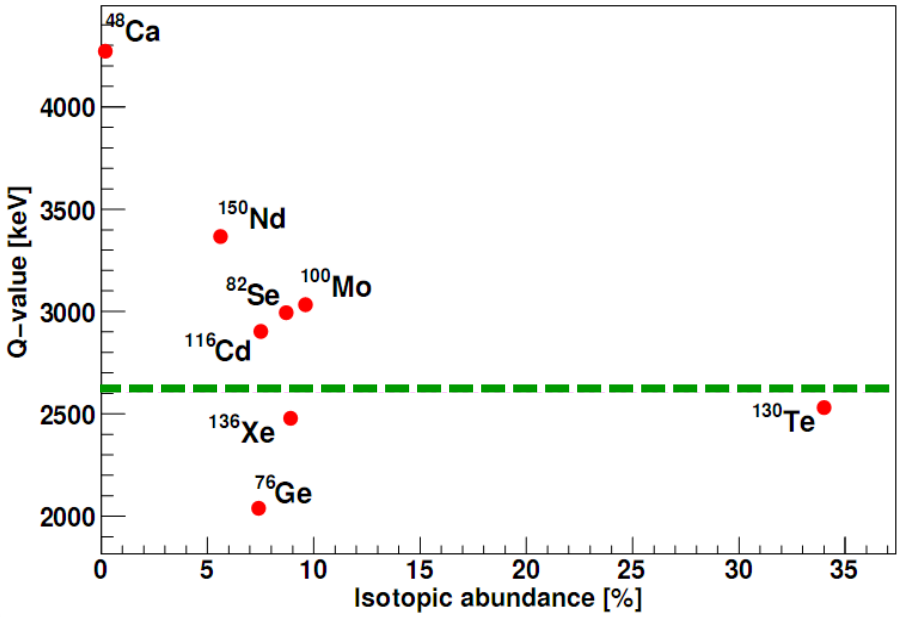
E. Fiorini and T. Niinikoski,
Nucl. Instrum. Methods 83 (1984) 224



A. Alessandrello et al.,
Nuclear Physics B 28 (1992) 233-235

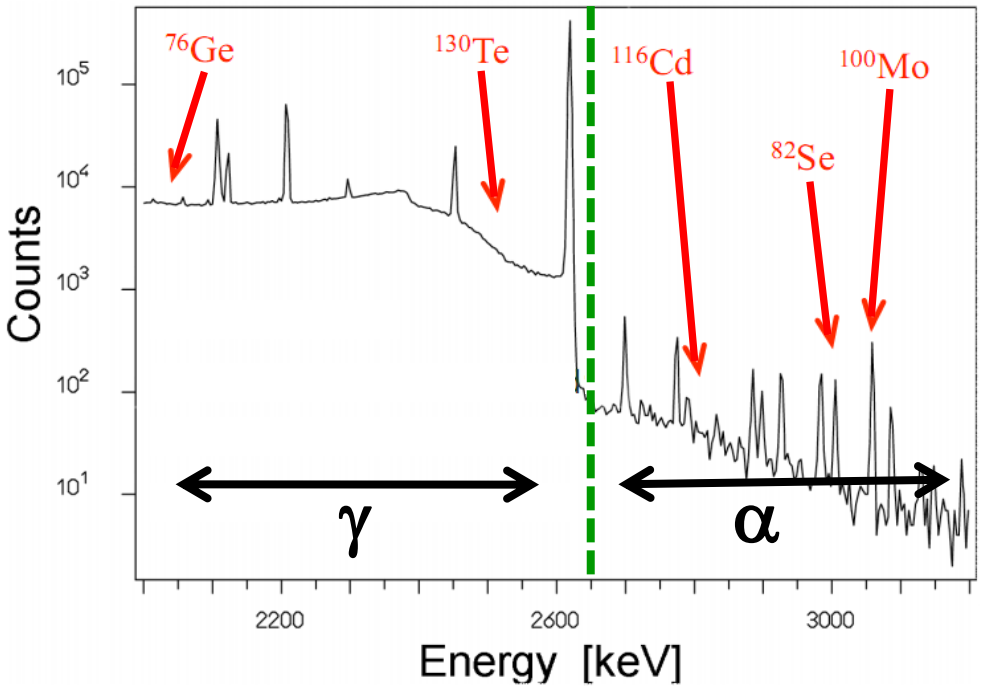
DBD0v candidates

Crucial the DBD0v isotope candidate



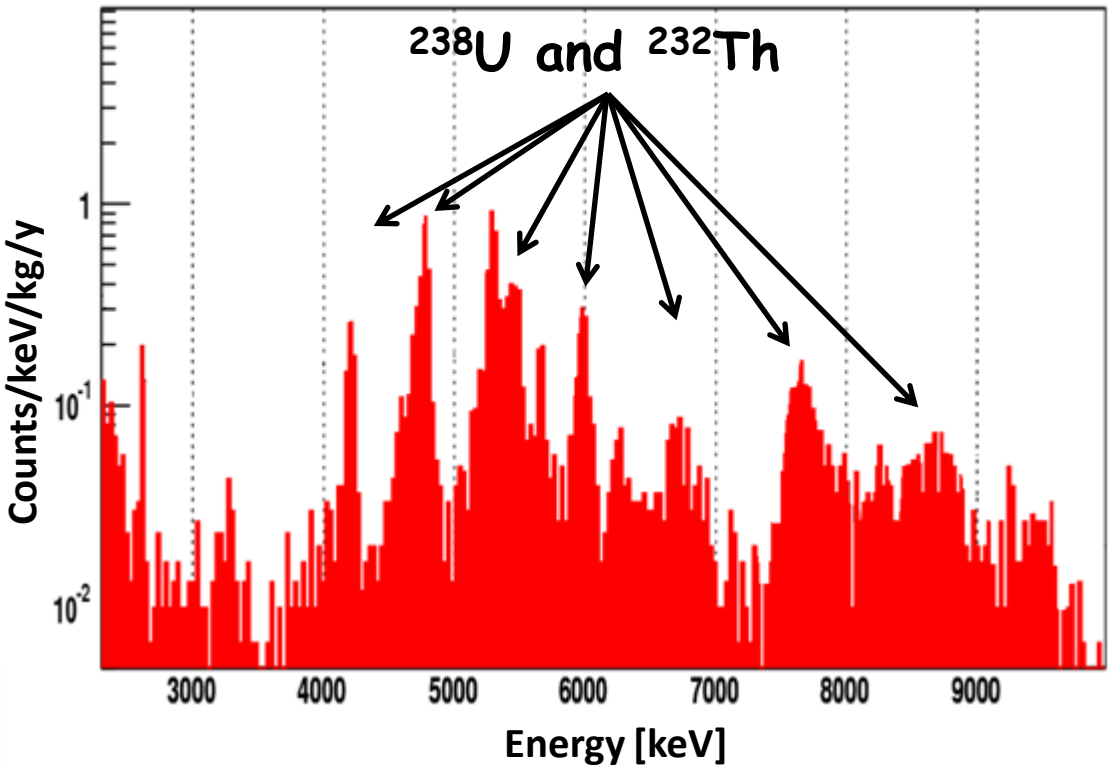
There is no "natural golden isotope"

- high isotopic abundance (or easy enrichment)
- achievable radiopurity
- suitable for the experimental technique



Background issue

Bolometers α-contaminations



Main source of background in the ROI:

↓

Surface contaminations (unknown sources)

↓ ↓ ↓

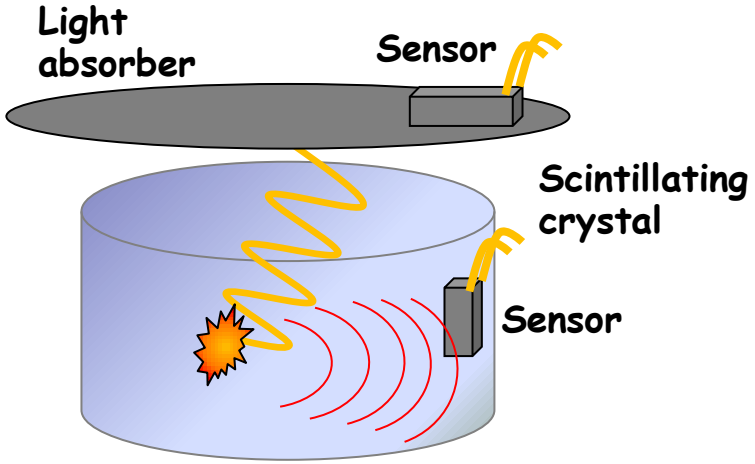
Mainly degraded alphas from surfaces of "passive materials" (e.g. Copper, Teflon, …)

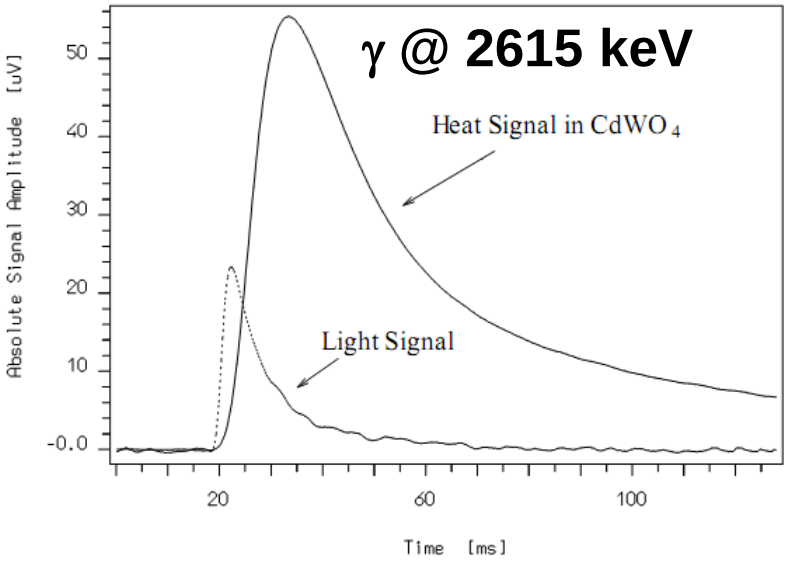
See E.Guardincerri's talk

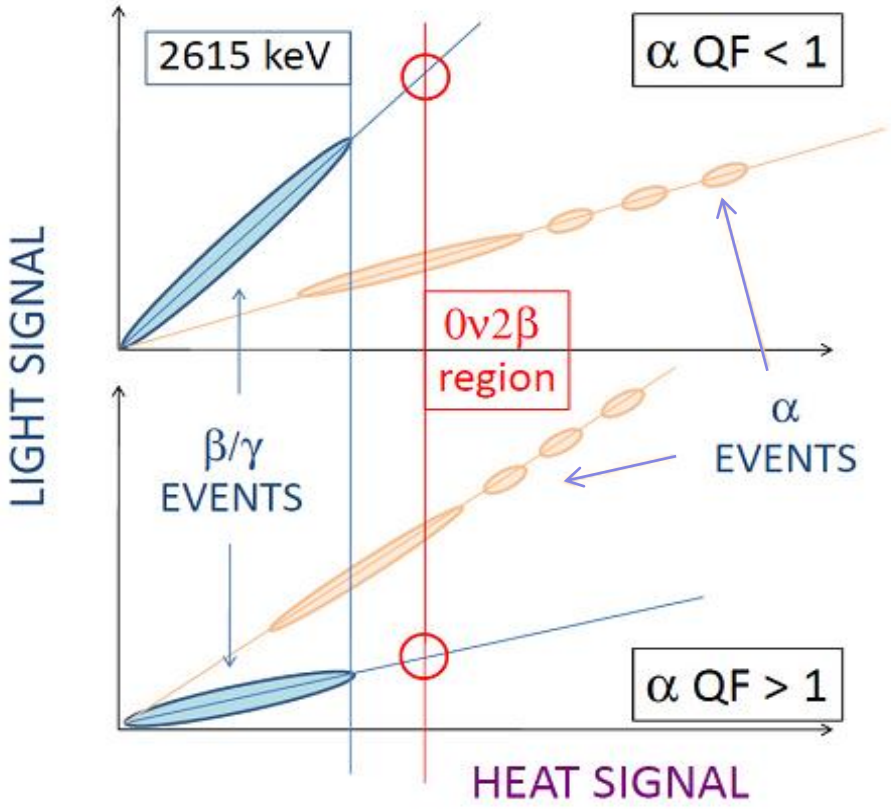
Solution: Particle Discrimination

Discrimination Power

By means of the double (heat-light) read-out
=> particle discrimination α – (γ,β) is possible







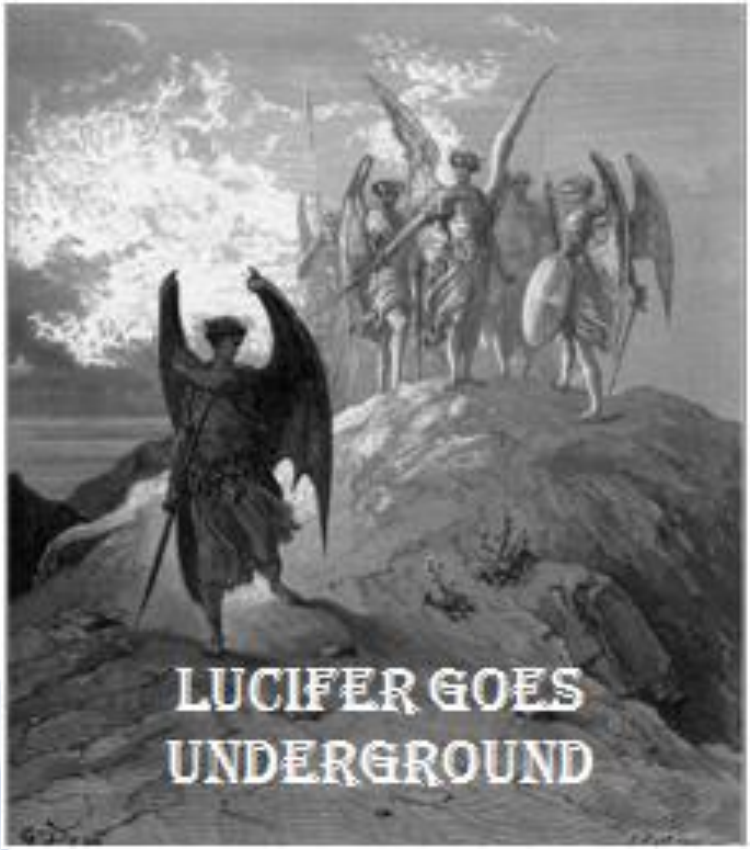
Research Proposal (B1) LUCIFER 2009

L. Gironi et al., Optical Materials, 31 (2009) 1388-1392

LUCIFER

Low-background Underground Cryogenics Installation For Elusive Rates

Principal Investigator: Fernando Ferroni
Co-Investigator : Andrea Giuliani



European Research Council

ERC-2009-AdG 247115

The experimental basis for LUCIFER is the R&D activity performed by S. Pirro at LNGS, in the framework of the programs:

- BOLUX funded by INFN – CSN5
- ILIAS – IDEA funded by the European Commision (WP2 – P2)

Isotope choice

OK
KO
~

	Q-value [keV]	Useful material	LY [keV/MeV]	QF [a.u.]
$^{1}CdWO_4$	^{116}Cd => 2809	32%	17.6	0.19
$^{2}ZnMoO_4$	^{100}Mo => 3034	44%	1.4	0.16
$^{3}ZnSe$	^{82}Se => 2995	56%	7.4	4.2

1 C.Arnaboldi et al., arXiv:1005.1239
2 Research Proposal (B1) LUCIFER 2009
3 Research Proposal (B1) LUCIFER 2009

^{113}Cd : high neutron cross section
natural beta emitter

Lucifer baseline: ZnSe

Active isotope: ^{82}Se
Decay: ^{82}Se -> $^{82}Kr + 2e^-$
Q-Value: 2995 keV
Abundance: 9%

Courtesy of L. Gironi

Various ZnSe

Crystal name	Crystal color	Mass [g]	LY [keV/MeV]	QF_α [a.u.]
Small	Yellow	37.5	1.3	4.4
Large	Red	120	7.5	4.2
Huge	Orange	337	4.6	3

C. Arnaboldi et al, arXiv:1006.2721

Courtesy of L.Gironi

Different Colors => Stoichiometry problems (?)

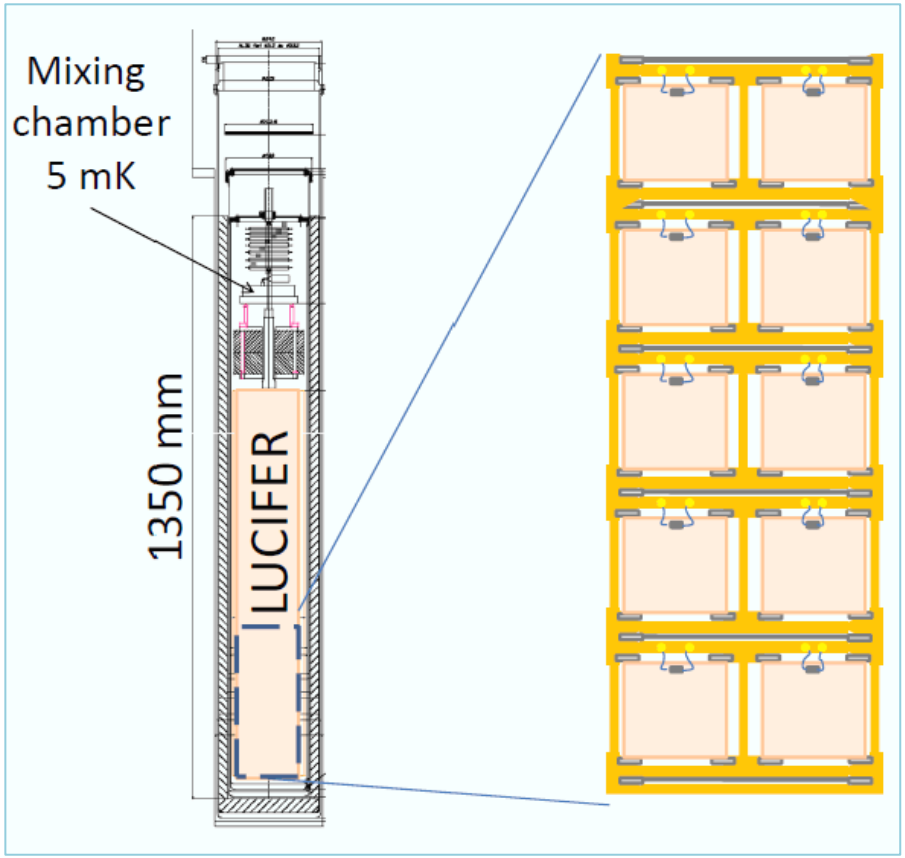
Different LY => Surface treatment (?)

Preliminary

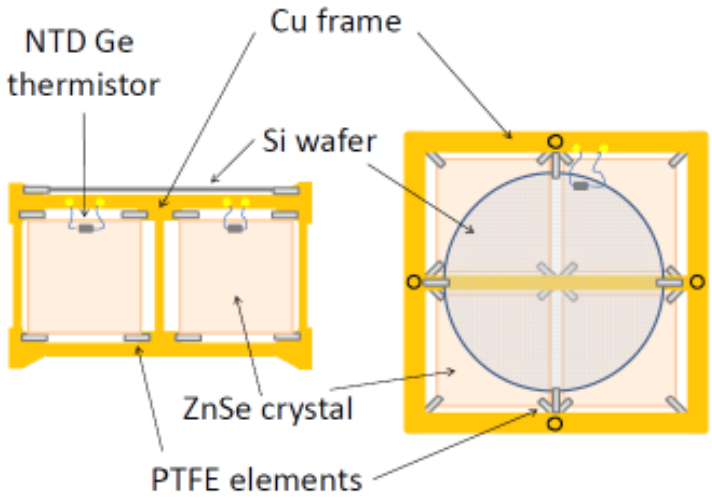
STRUCTURE

Cryostat possible location: ex-Cuoricino cryostat @ LNGS

Tower:
12 single modules



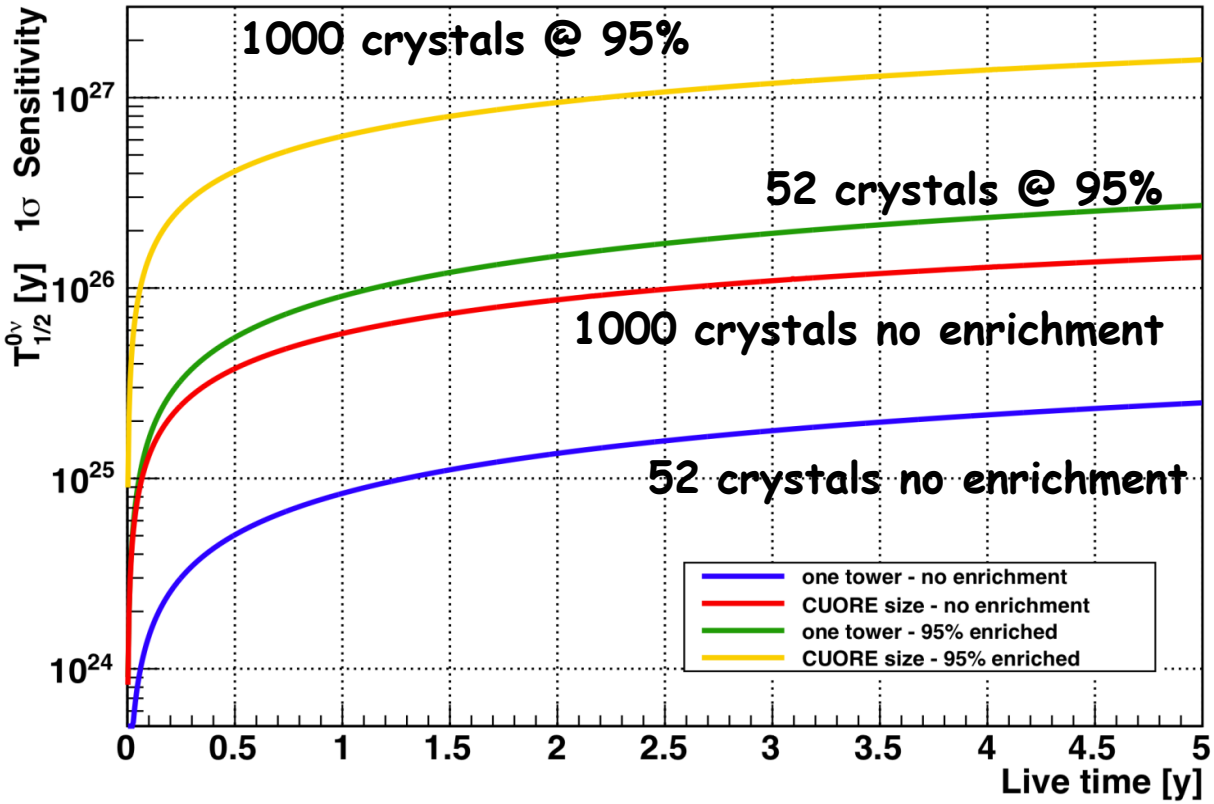
Single module:
4 ZnSe crystals
and 1 light detector



Research Proposal (B1) LUCIFER 2009

SENSITIVITY

Sensitivity of ZnSe scintillating bolometer experiments (background ~ 10^{-3} counts/keV/kg/y)



S. Sangiorgio presentation @ NuMass Seattle 2010

LUCIFER

$\langle m_{ee} \rangle$ ~ 52-65 meV

T = 5 y
b = 10^{-3} counts/keV/kg/y
ΔE = 5 keV
a.i. = 95%
M = 31.7 kg (17.6 kg ^{82}Se)

NME =
J.Mendez et al. arXiv:0801.3760;
F.Simkovic et al. Phys.Rev. C77 (2008);
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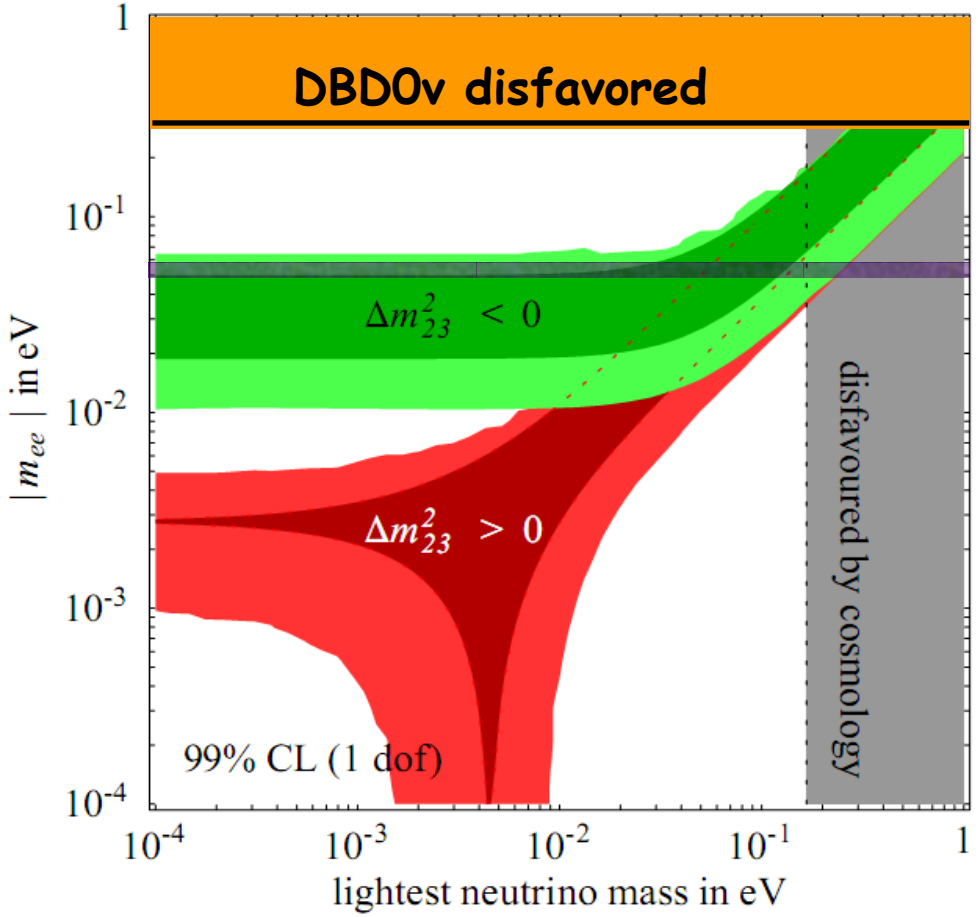

Strumia, Vissani arXiv:hep-ph/0606054v2

LUCIFER
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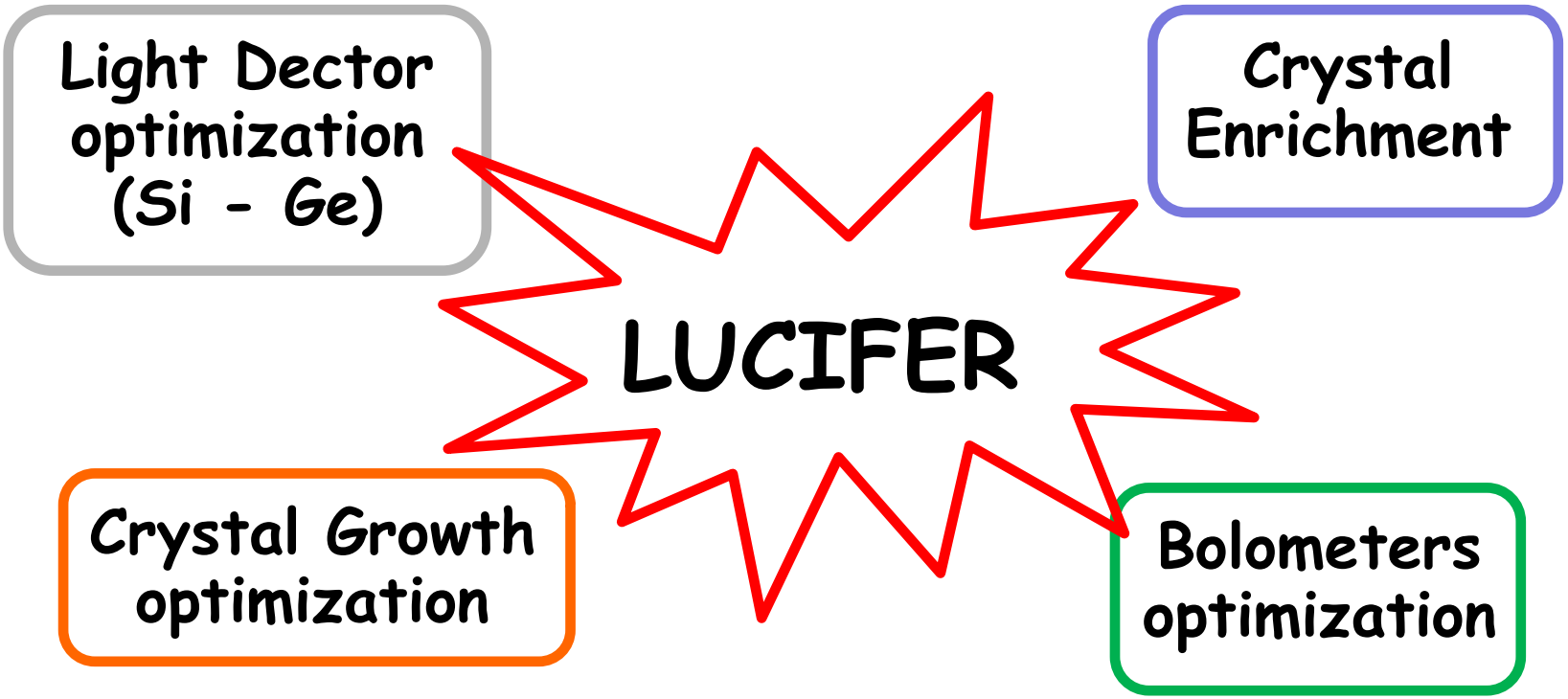
LUCIFER R&D



Data taking: 2014

CONCLUSIONS

- In DBD0v is mandatory the bkg reduction
- Zero background approach can be achieved with double read-out
- Scintillating bolometers are a perfect tool
- ..still some work to do for LUCIFER
- Data taking foreseen in 2014

… stay tuned