Comparison of a new Ge-76 experiment with previous and ongoing experiments

Attempt of an Overview

Stefan Schoenert, MPIK

Meeting about new Ge-76 experiment at LNGS, Feb 26-27, 2004

Experimental situation in the search for 0ν-DBD

Summary of the most sensitive experiments until beginning of 2003

Experiment	Isotope	$\tau_{1/2}^{0\nu}$ (y)	m^*_{ee} (eV)	Range m_{ee}
Heidelberg – Moscow 2001	^{76}Ge	$> 1.9 \times 10^{25}$	< 0.35	< 0.3 – 2.5
IGEX 2002		$> 1.57 \times 10^{25}$	< 0.38	< 0.3 – 2.5
Mi DBD – ν 2002	^{130}Te	$> 2.1 \times 10^{23}$	< 1.5	< 0.9 – 2.1
Bernatowicz et al. 1993 (GEO)	$^{128}Te^{geo}$	$> 7.7 \times 10^{24}$	< 1.0	< 1.0 – 4.4
Belli et al. 2003	^{136}Xe	$> 1.2 \times 10^{24}$	< 1.0	< 0.8 – 2.4
Bizzeti et al. 2003	^{116}Cd	$> 1.7 \times 10^{23}$	< 1.7	< 1.6 – 5.5
Ejiri et al. 2001	^{100}Mo	$> 5.5 \times 10^{22}$	< 4.8	< 1.4 - 256
Osawa I. et al. 2002	^{48}Ca	$> 1.8 \times 10^{22}$	< 6.0	

* Staudt, Muto, Klapdor-Kleingrothaus Europh. Lett 13 (1990) 31

claimed evidence

Joint analysis: → $\tau_{1/2}^{0\nu} > 2.5 \times 10^{25}$ y; $m_{ee} < 0.30$ eV

Yu. Zdezenko et al.

(A. Giuliani, Taup03)

Presently running experiments

CUORICINO (**C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents):
Firenze, Gran Sasso, Insubria, LBNL, Leiden, Milano, Neuchatel, South Carolina, Zaragoza

Location: Gran Sasso Underground Laboratory

Source = detector, TeO_2 (40 kg) $\Rightarrow$ ^{130}Te (13 kg): Q = 2530 keV

NEMO3 (Neutrino Ettore Majorana Observatory): CENBG Bordeaux, Charles Univ. Prague, FNSPE Prague, INEEL, IReS Strasbourg, ITEP Moscow, JINR Dubna, Jyvaskyla Univ., LAL Orsay, LPC Caen, LSCE Gif, Mount Holyoke College, Saga Univ, UCL London

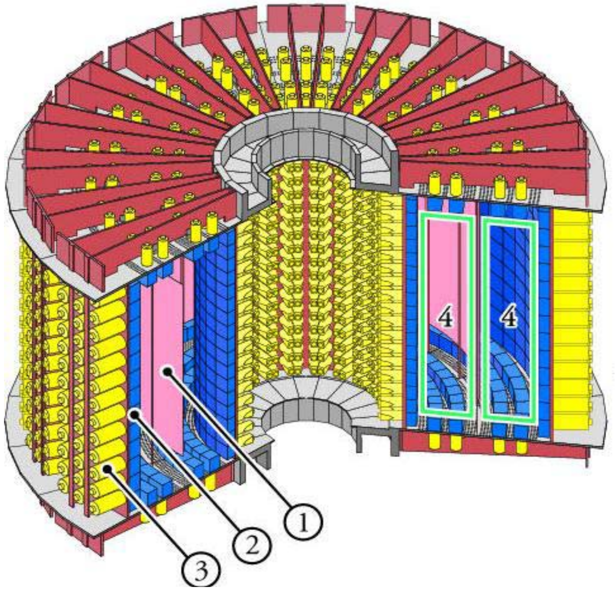
Location: Frejus Underground Laboratory

Source $\neq$ detector $\Rightarrow$ study of different nuclei; main target ^{100}Mo (6.9 kg): Q = 3034 keV

NEMO3

- Source in form of foils:

Isotope	Study	Mass(g)
^{100}Mo	$\beta\beta0\nu,\beta\beta2\nu$	6914
^{82}Se	$\beta\beta0\nu,\beta\beta2\nu$	932
^{116}Cd	$\beta\beta0\nu,\beta\beta2\nu$	405
^{130}Te	$\beta\beta0\nu,\beta\beta2\nu$	454
^{150}Nd	$\beta\beta2\nu$	36.6
^{96}Zr	$\beta\beta2\nu$	9.4
^{48}Ca	$\beta\beta2\nu$	7.0



SOURCE
TRACKING VOLUME
CALORIMETER

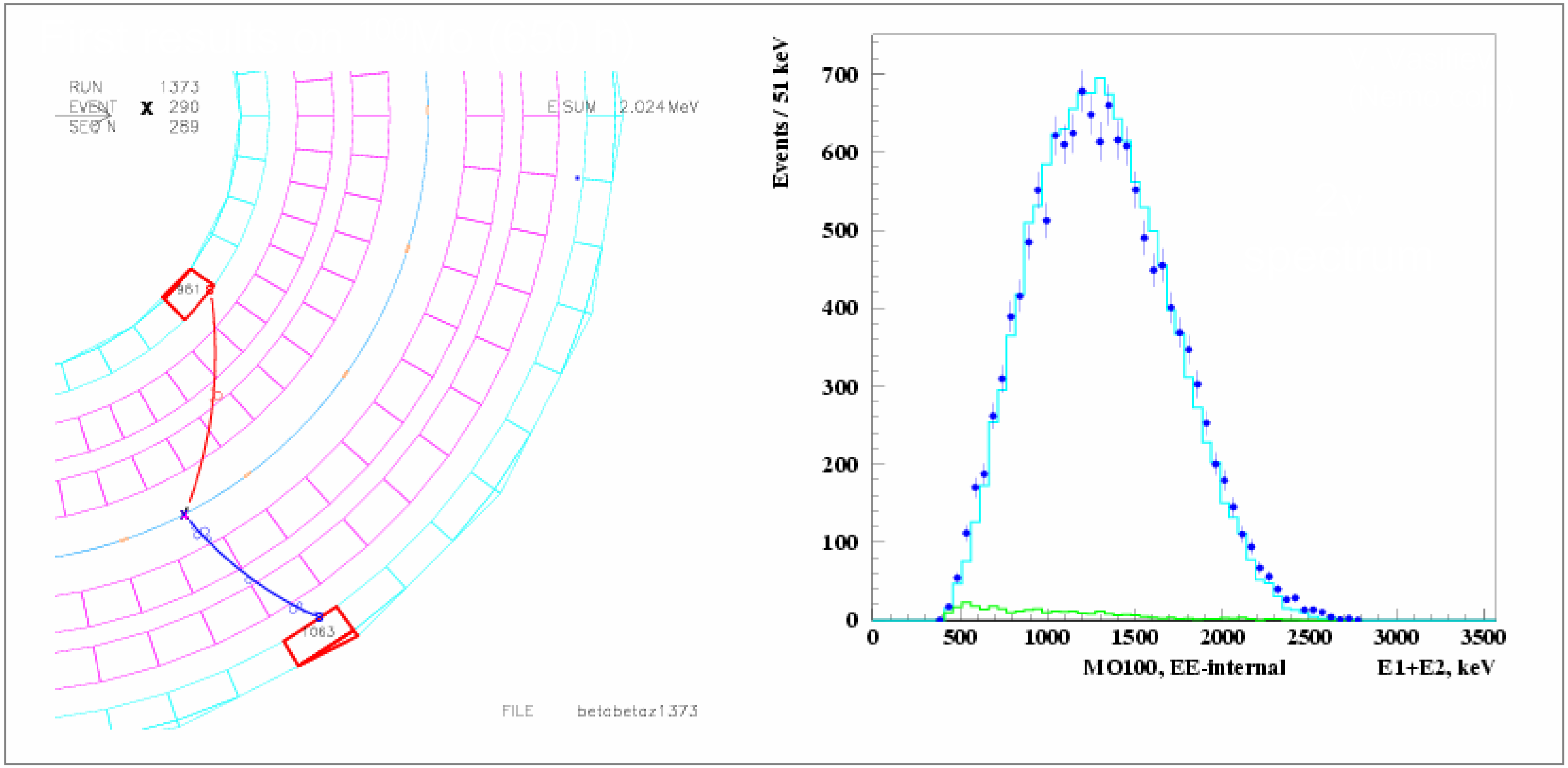
- Tracking volume with Geiger cells

- e^+/e^- separation by magnetic field

- Plastic scintillators for calorimetry and timing

Start data taking February 2003

NEMO3



$t_{1/2}^{2\nu}$ (y) = 7.8 ± 0.09 $_{stat}$ ±0.8 $_{syst}$ $\times 10^{18}$ y

$t_{1/2}^{0\nu}$ (y) > 6 $\times$ 10^{22} y

m_{ee} < 1.8 – 2.9 eV

Expected final sensitivity

$t_{1/2}^{0\nu}$ (y) > 5 $\times$ 10^{24} y

0.2 – 0.4 eV (6.9 kg)

(C. Augier, ECT Trento, 2003)

Future of "à la NEMO"

NEMO3, Phase-2: 10 kg of ^{82}Se or even better: 10 kg of ^{150}Nd

D.O.E. starts purification of Se and Nd (INEEL, Idaho Falls, USA)

10 kg ^{150}Nd, 5 years of data: $\langle m_\nu \rangle < 0.06 - 0.3$ eV

Next step would be 100 kg enriched source: ^{100}Mo (or ^{82}Se or ^{150}Nd)

Background rejection:

NEMO3 after 1 year of data will validate ^{208}Tl and ^{214}Bi purification processes and neutron rejection at the level required for 100 kg of ^{100}Mo

Need to improve Energy Resolution to separate $\beta\beta0\nu$ and $\beta\beta2\nu$

We need FWHM ~ $8\%/\sqrt{E}$ (MeV) (instead of 14% for NEMO-3) in order to have ~ 1 event/year of $\beta\beta2\nu$ in the $\beta\beta0\nu$ energy window (like for NEMO3)

How to improve $\Delta E/E$?

- calorimeter: Silicium (e^-) + small scintillator (γ) ?
- Modular source: bkg rejection + energy loss improvement

4 modules

e = 60 mg/cm^2

Need to increase the $\beta\beta0\nu$ efficiency

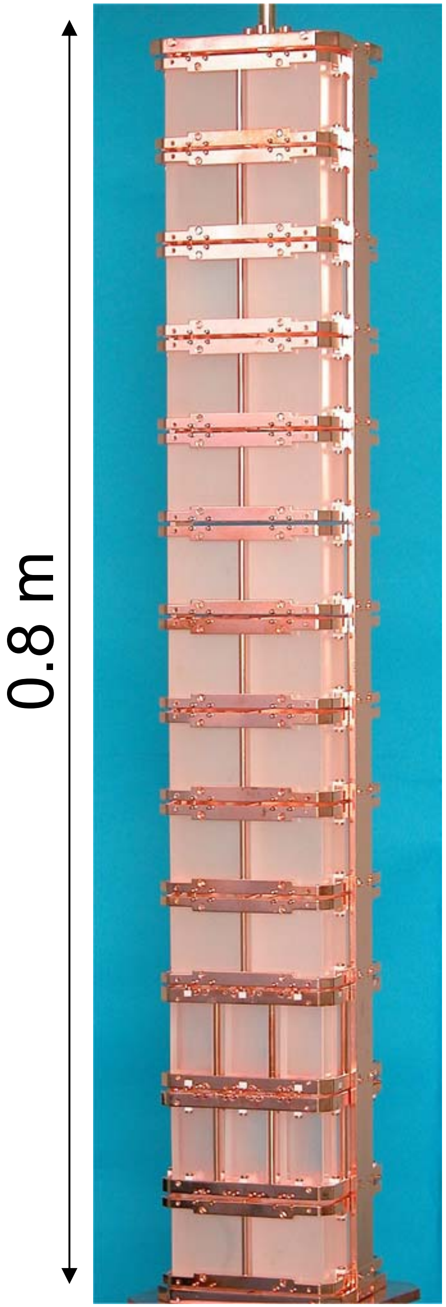
Energy resolution

Geometrical acceptance

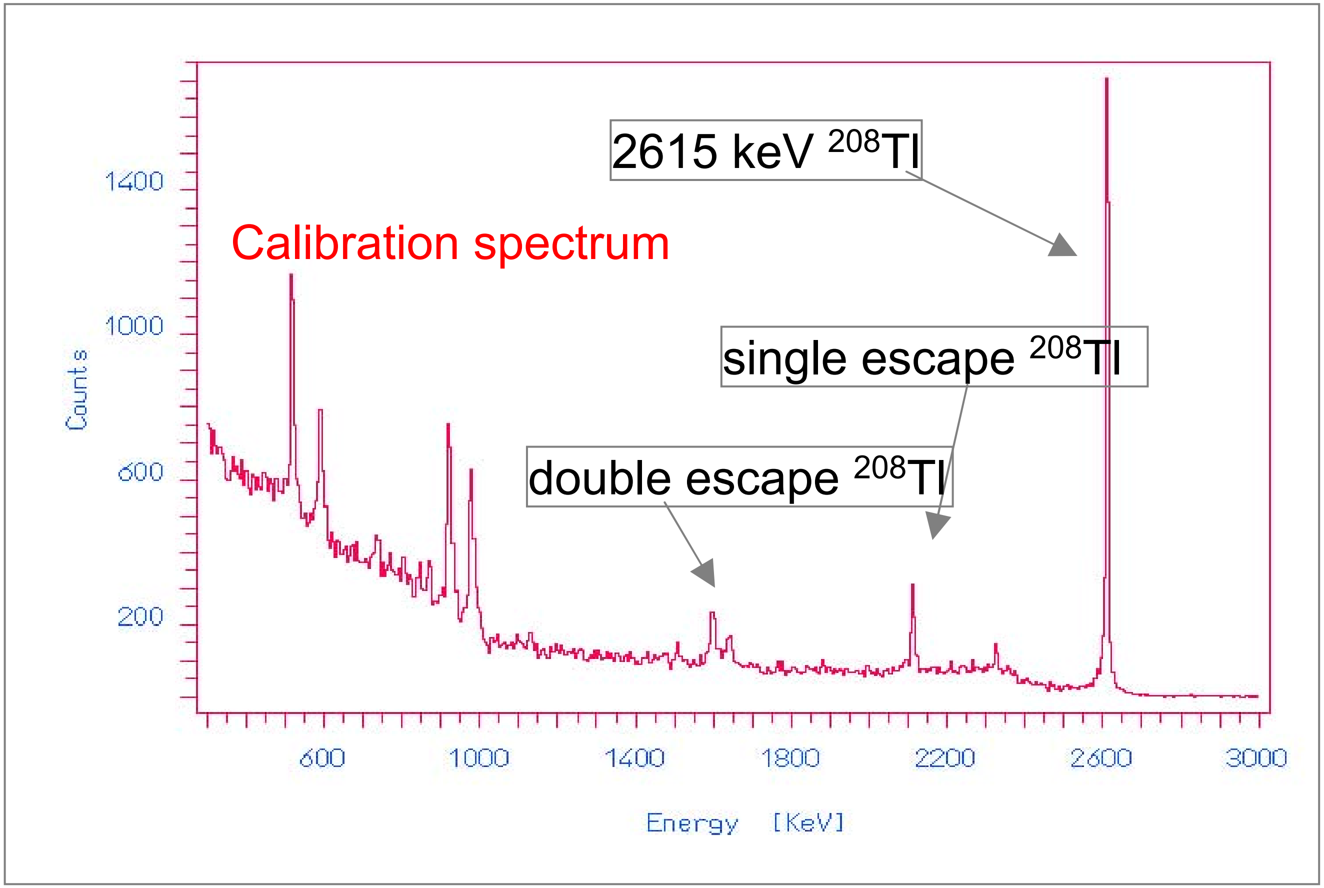
Energy loss of electrons

(C. Augier, ECT 2003)

CUORICINO

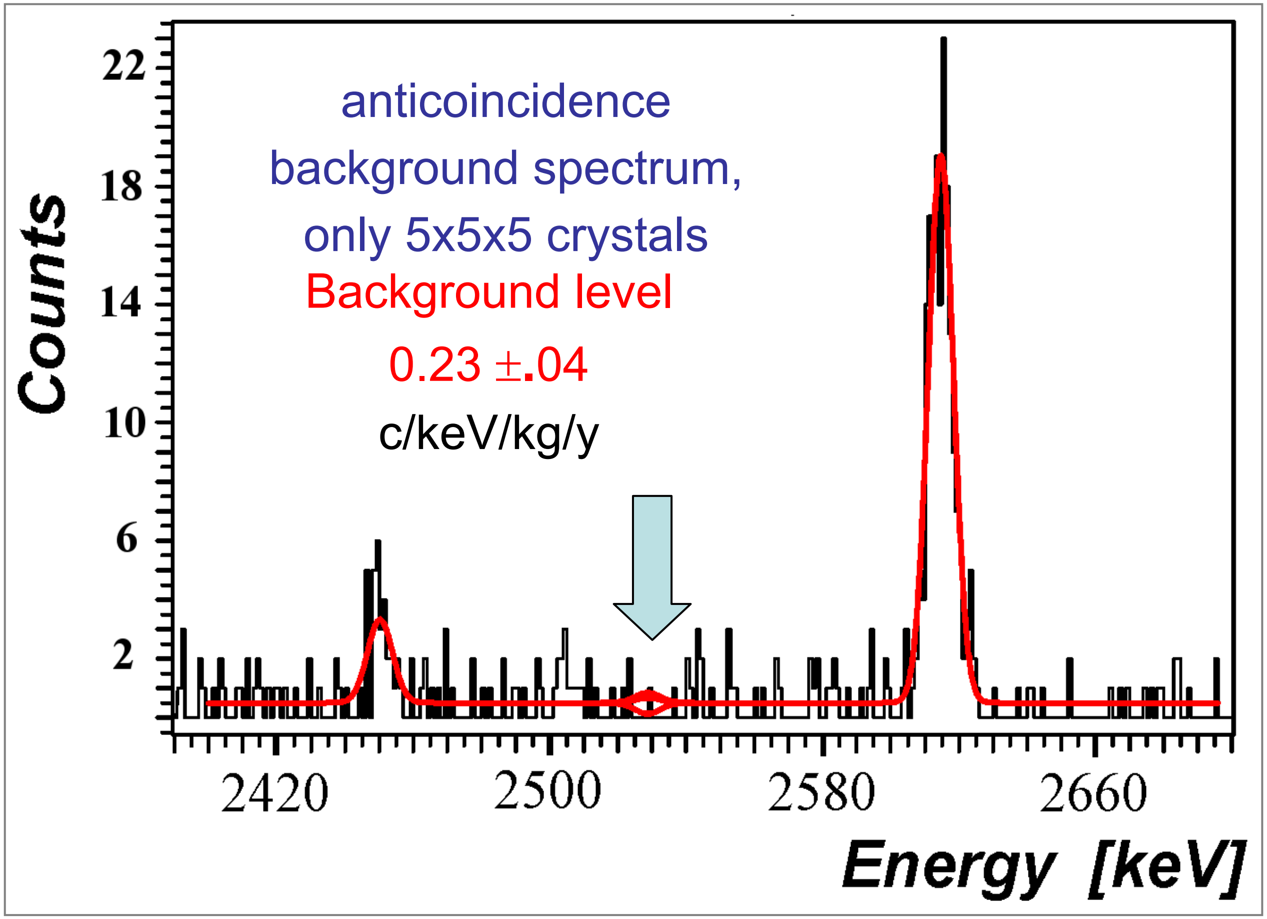


Start data taking february 2003
Energy resolution: 7 keV FWHM
TeO2 (40 kg) ⇒ 130Te (13 kg): Q = 2530 keV



(A. Giuliani, Taup03)

CUORICINO: first results



$\tau_{1/2}^{0\nu} > 5 \times 10^{23}$ y
$m_{ee} < 0.58 - 1.4$ eV
(90% c.l.)

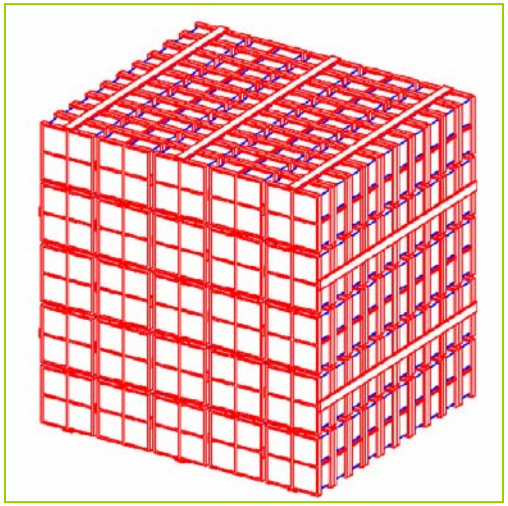
3 y sensitivity (with present performance):
1×10^{25} y $\Rightarrow m_{ee} < 0.13 - 0.31$ eV

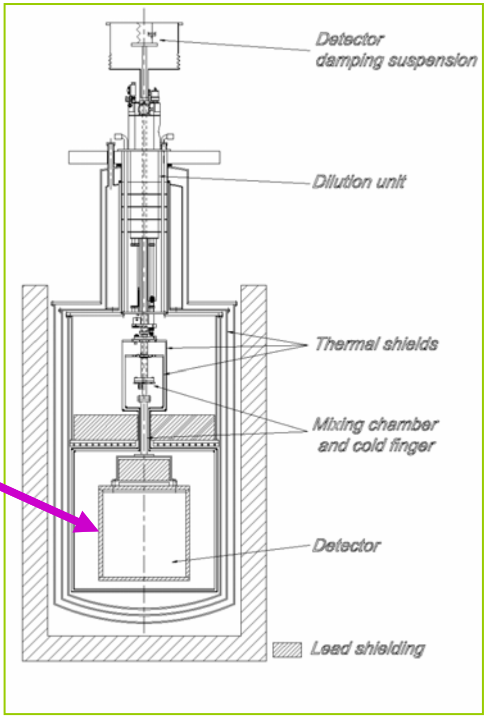
(A. Giuliani, Taup03)

Cuoricino ⇒ Cuore

CUORE = closely packed array of 1000 detectors
25 towers - 10 modules/tower - 4 detector/module
M = 790 kg

Each tower is a CUORICINO-like detector





Expected final sensitivity:

If b = 0.01 counts/(keV kg y) $m_{ee} < 28 – 68$ meV

If b = 0.001 counts/(keV kg y) $m_{ee} < 16 – 38$ meV

(A. Giuliani, Taup03)

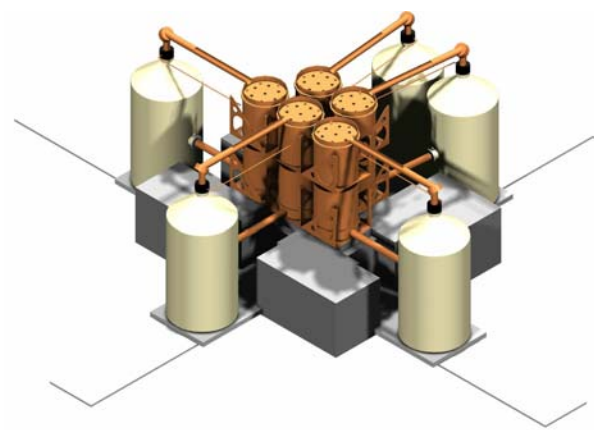
MAJORANA PROJECT

hep-ex/0201021 – 11 jan 2002

Dubna, ITEP, JINR, New Mexico State, Pacific Northwest Natl Lab, South Carolina, TUNL, University of Washington

210 enriched (84%) Ge detectors, 2.4 kg each: total mass = 500 kg (420 kg ^{76}Ge)

Long project: ~ 10 years of R&D and construction + 10 years of data tacking



Cosmogenic activity (^{68}Ge and ^{60}Co) was the limiting bkg for IGEX

➔ IGEX without Pulse Shape Discri.: 0.2 counts/keV/kg/y

- **Fabrication of detectors at an underground facility**

  ^{68}Ge decay ($T_{1/2}$=271 days) : Reduction Factor = 10

  ^{60}Co decay ($T_{1/2}$=5.7 years) : Reduction Factor = 2

- **New Pulse Shape Discrimination (PNNL/USC)**

  Demonstrated Reduction Factor = 3.8

- **Detectors Segmentation 6-axial + 2-azimuthal**

  Monte-Carlo Reduction Factor = 7.2

Total expected background at 2039 keV

in the energy window 3.57 keV (2.8 σ) = 6.5 events

➔ 1.1 10^{-3} counts/FWHM/kg/y

Expected sensitivity:
efficiency = 73%
FWHM = 3 keV
$T^{0\nu}$ = 4.0 10^{27} y
$\langle m_\nu \rangle$ = 0.02 – 0.07 eV

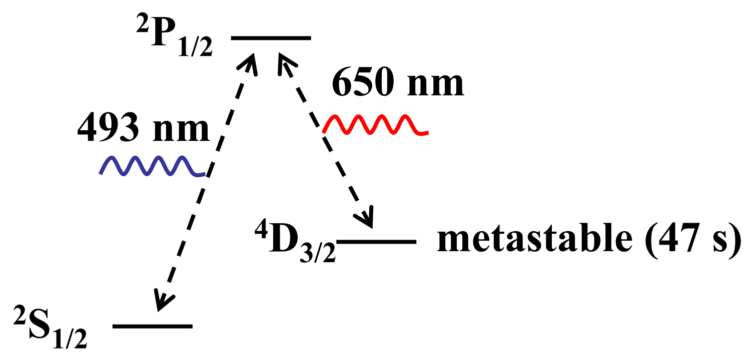
(C. Augier, ECT Trento 2003)

EXO (^{136}Xe) : Enriched Xenon Observatory

Phys. Lett., B480, 12 (2000)

Univ. of Alabama, Caltech, IBM Almaden, UC Irvine, ITEP Moscow, Neuchatel, Stanford, Torino, Trieste

Up to 10 tons of 80% enriched ^{136}Xe
Detect the $^{136}Ba^{+}$ daughter ion correlated with the ββ decay ($^{136}Xe \rightarrow ^{136}Ba^{++}\, e^{-}\, e^{-}$) using optical spectroscopy (Moe, Phys. Rev. C44, 931, 1991)



Expected sensitivity:

Mass (ton)	Enrich. (%)	Eff. (%)	Measur. Time (yr)	Background	$T_{1/2}(0\nu)$	$\langle m_\nu \rangle$ (eV)
1	80	70	5	0 + 1.8 events	$8.3\ 10^{26}$	0.05 – 0.13
10	80	70	10	0 + 5.5 events	$1.3\ 10^{28}$	0.012 – 0.032

Latest publication from H.V. Klapdor-Kleingrothaus' group

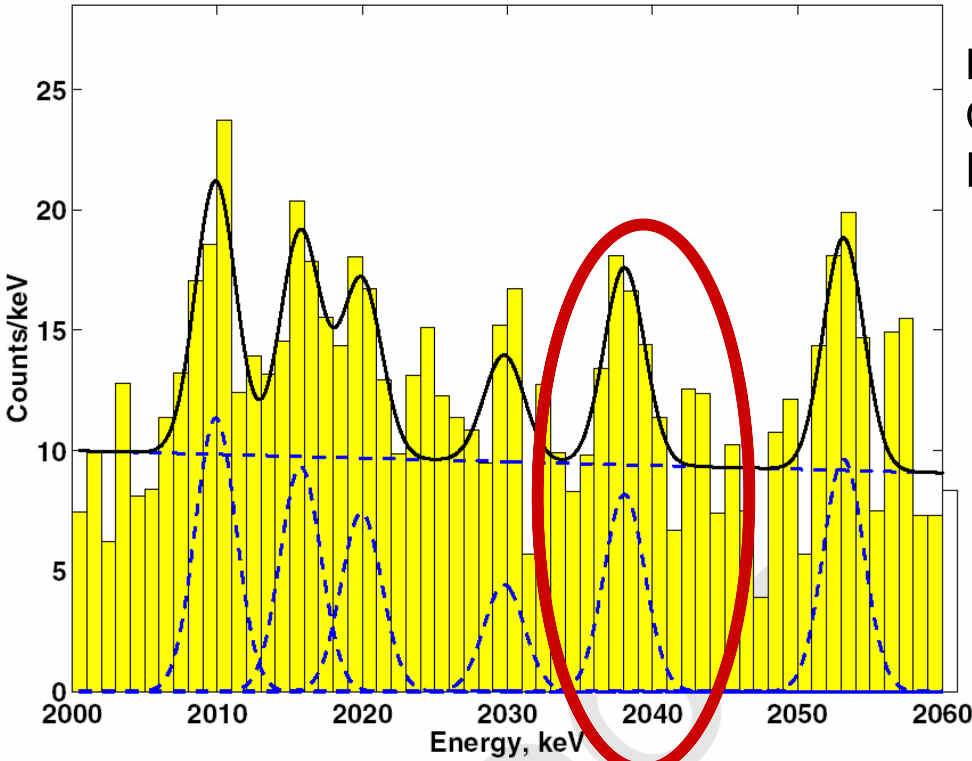


Fig. 17. The total sum spectrum of all five detectors (in total 10.96 kg enriched in ^{76}Ge), for the period November 1990–May 2003 (71.7 kg year) in the range 2000–2060 keV and its fit (see Section 3.2).

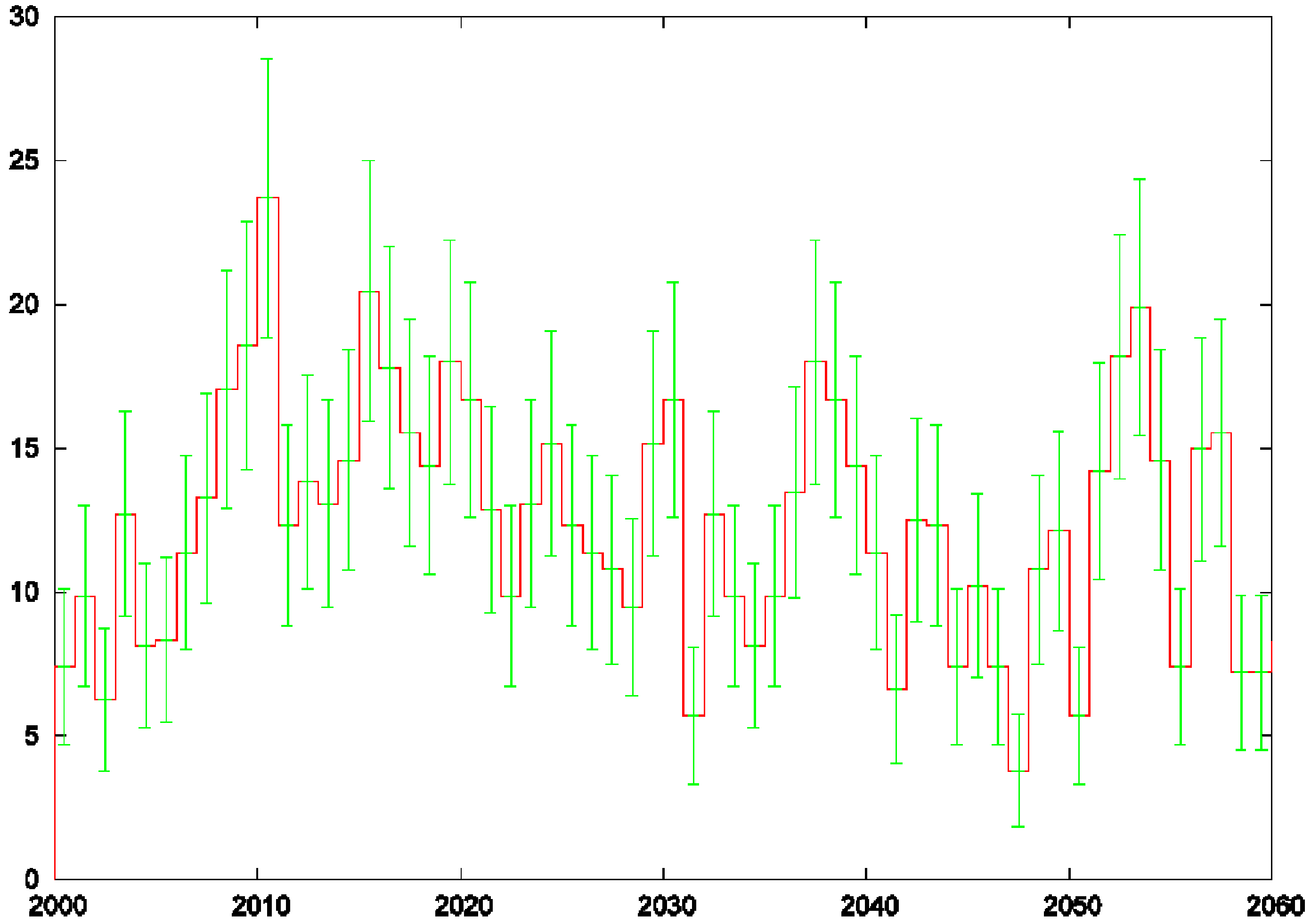
H.V. Klapdor-Kleingrothaus, A. Dietz, O. Chkvorets, I.V. Krivosheina
NIMA : 42464 (uncorrected proof)

- Nov 1990- May 2003
- 71.7 kg year
- Bgd 0.11 / kg y keV
- 28.75 ± 6.87 events
- 4.2 sigma evidence for $0\nu\beta\beta$

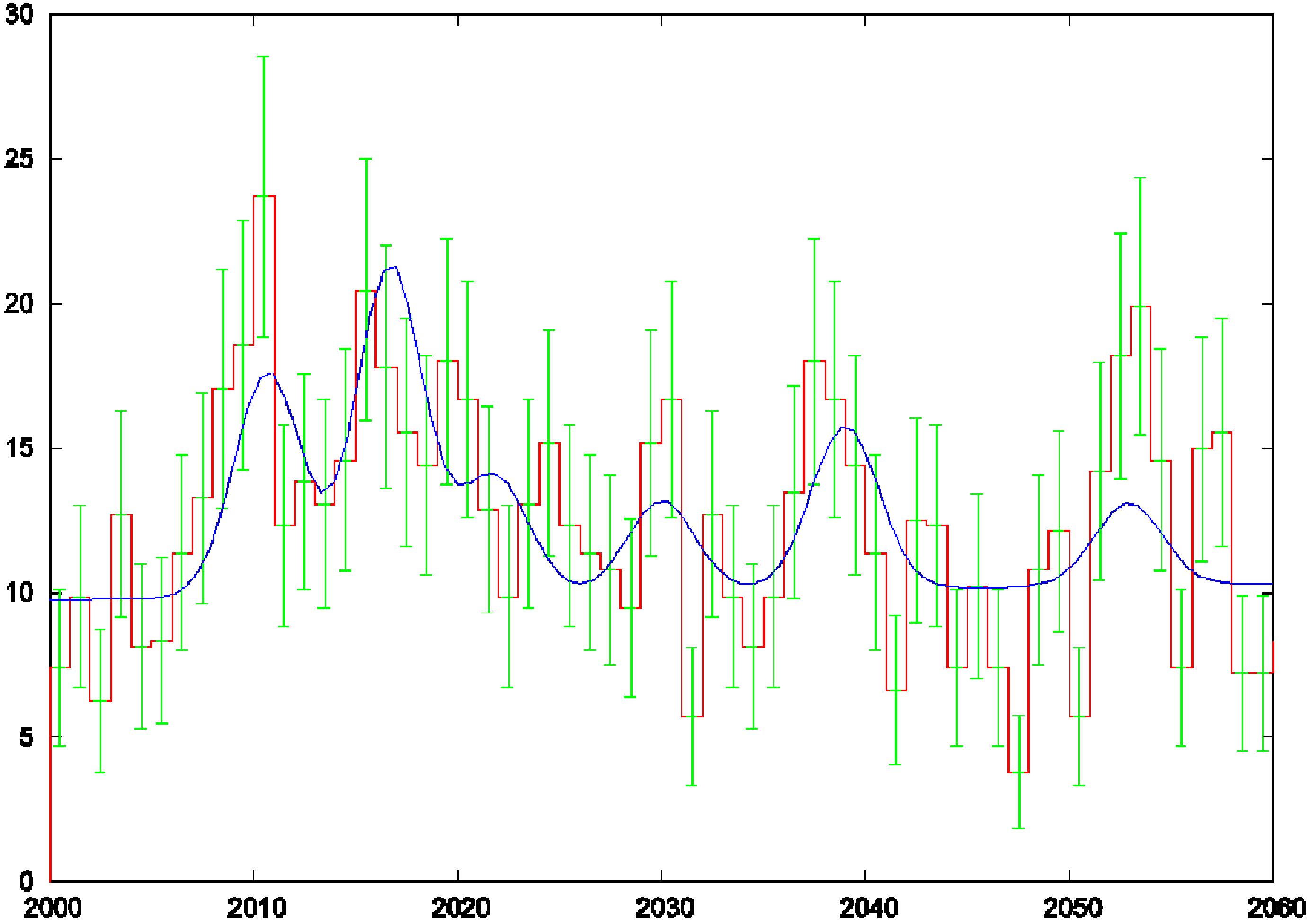
- 0.34-2.03 $\times 10^{25}$ y (3 sigma)
- Best fit 1.19 $\times 10^{25}$ y

- m_{ee} = 0.1-0.9 eV
- best fit 0.44 eV

Spectrum without fit as published



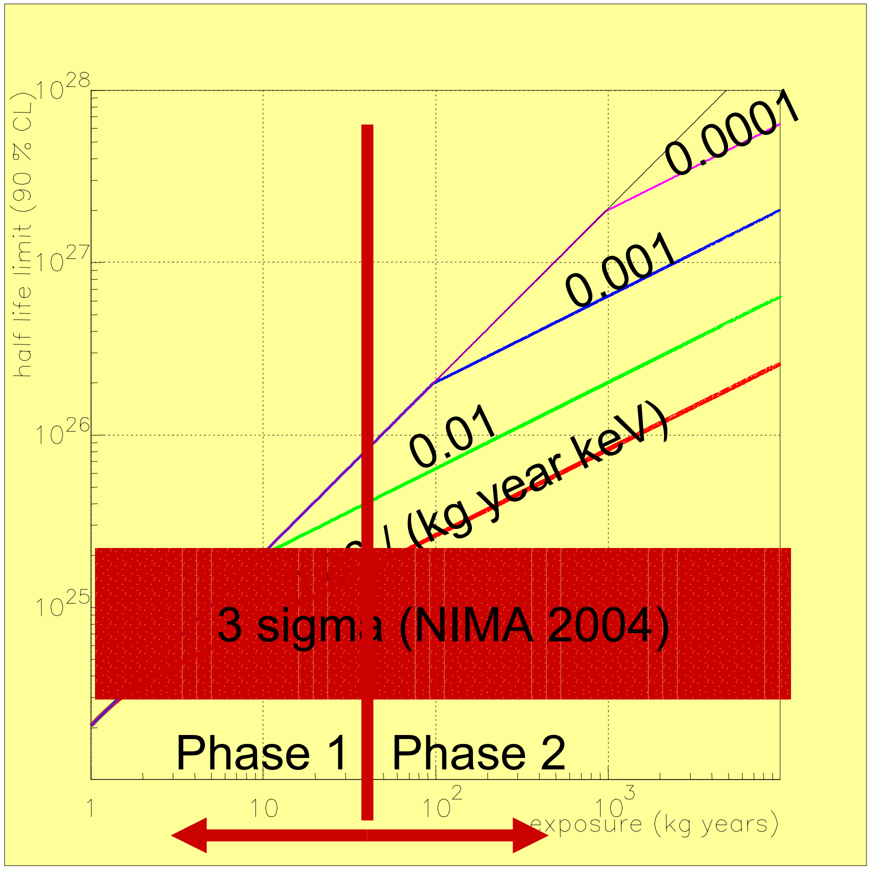
Not an analysis – just for illustration!

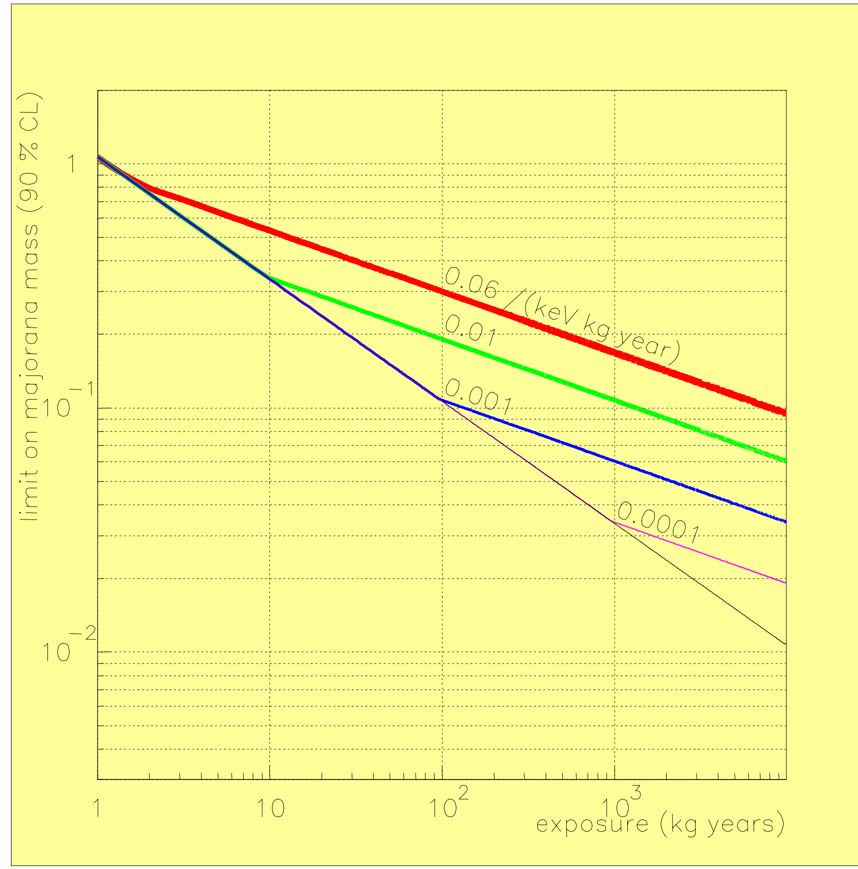


- Fit with
- Fixed energy scale
- Fixed Bi-214 ratios from measurement (summing included)
- 2030 keV inserted ad hoc

⇒ Peak at $Q_{\beta\beta}$
⇒Problems with Bi-214 spectrum as explanation of residual spectrum

^{76}Ge: sensitivity, exposure and background





HEIDELBERG-MOSCOW Collaboration,
Eur. Phys. J. A 12 (2001) 147:

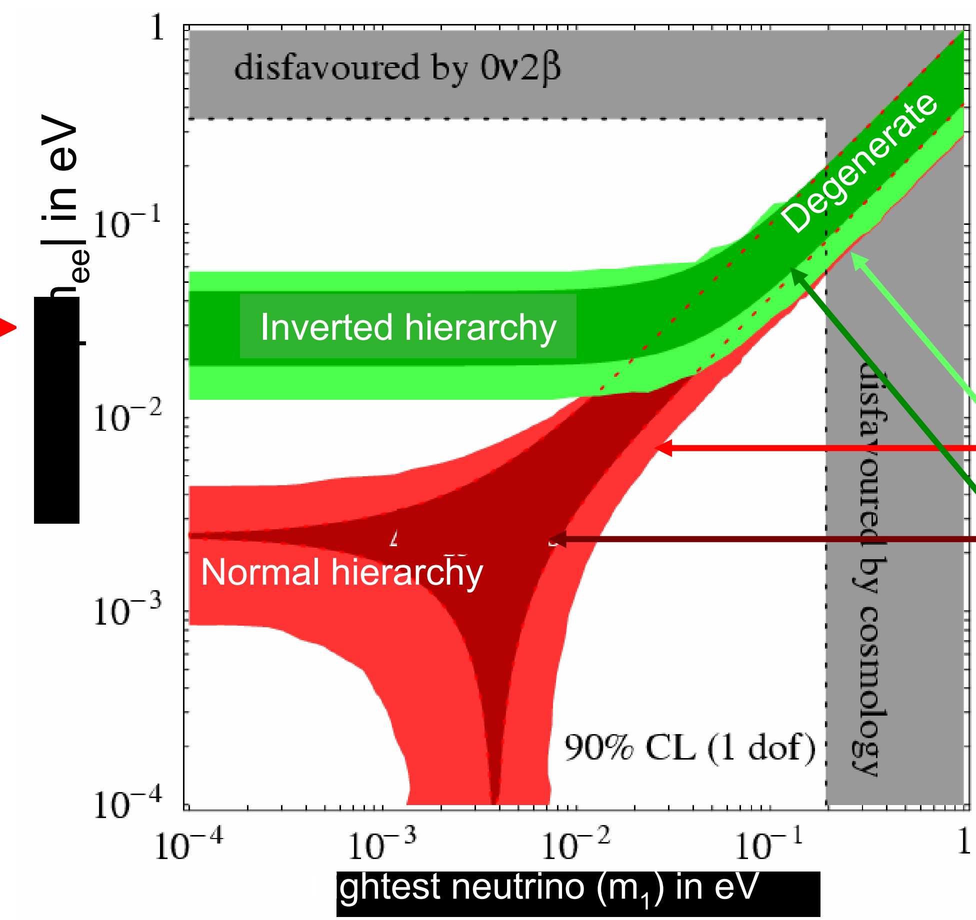
$M \cdot T$ = 35.5 kg y, b = 6 $\cdot 10^{-2}$ (kg y keV),
$\Delta E \sim 4.2$ keV

Sensitivity (with bgd):
$m_{ee} \propto (b\ \Delta E / M\ T)^{1/4}$

Range of m_{ee} derived from oscillation experiments

Goal of next generation experiments: ~few 10 meV

NH:	1-4 meV
IV:	14-57 meV
DG:	<1 eV
	(90% CL)



F.Feruglio,
A. Strumia,
F. Vissani,
NPB 637

90% CL

Negligible errors from oscillations; width due to CP phases

⇒ hierarchy, absolute mass scale, Majorana CP phases α,β

Let's assume it's $0\nu\beta\beta$

- What would Couricino observe:
  - Couricino: 6-30 /year; bgd ~ 60 per year

- NEMO3:
  - 10 – 50 / year; bgd ?

Some remarks for discussion

If analysis of new Klapdor-Kleingrothaus et al. paper holds (careful check needed):

1. clear goal for new Ge-76 initiative (phase 1): falsify claim or confirm with improved significance
2. CUORICINO and/or NEMO3 will not be able to falsify claim because of matrix element uncertainties
3. However, conceivable that CUORICINO or NEMO observes signal prior to start-up of new Ge-76 experiment