Present ββ experiments

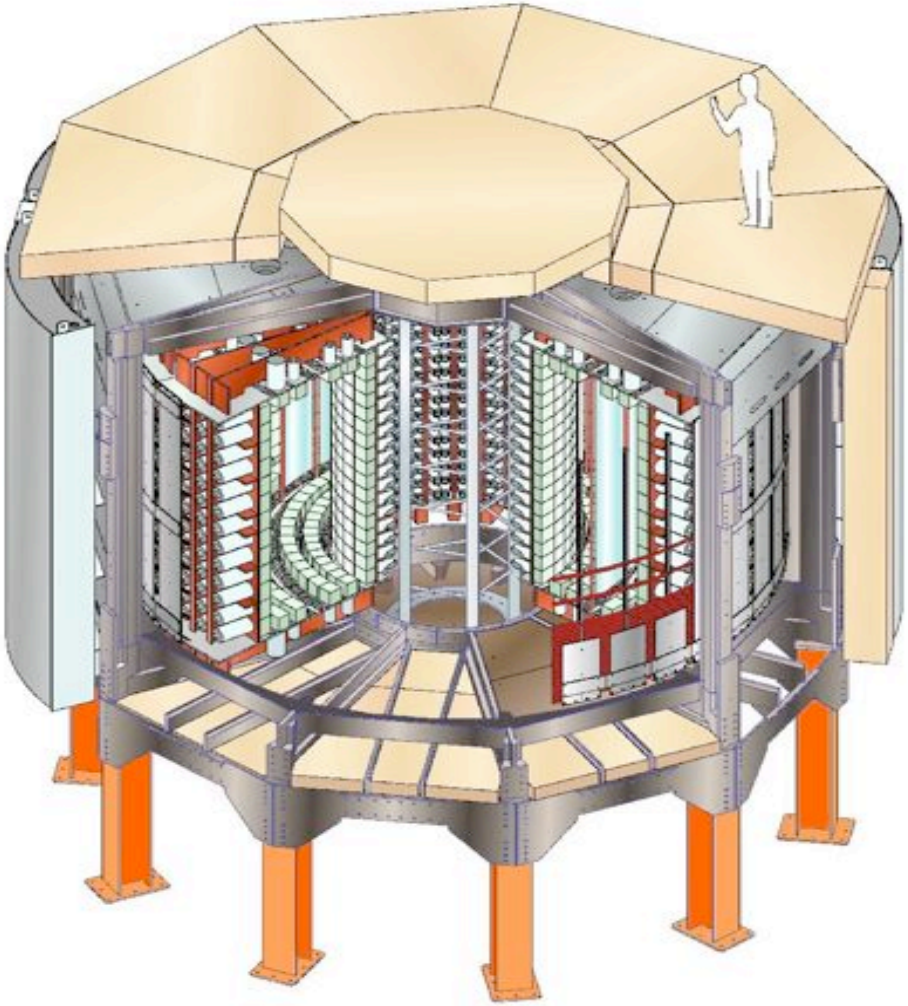
- NEMO-3
- CUORICINO

NEMO3 status

The NEMO3 detector

(France, Finlande, Japon, Maroc, République tchèque, R-U, Russie,Ukraine, USA.)

@ Freius Underground Laboratory : 4800 m.w.e.



Source: 10 kg of ββ isotopes

cylindrical, S = 20 m², 60 mg/cm²

Tracking detector:

99.5 % cells ON

Vertex resolutions :

$\sigma_{\perp}$ **(ΔVertex) = 0.6 cm**

$\sigma_{//}$ **(ΔVertex) = 1.3 cm** (Z=0)

Calorimeter:

97% PM+scintillators ON

TDC resolution : 250 ps @ 1MeV

FWHM (1 MeV) 14% (PM 5") **17%** (PM 3")

Magnetic field: 25 Gauss

Gamma shield: Iron (18 cm)

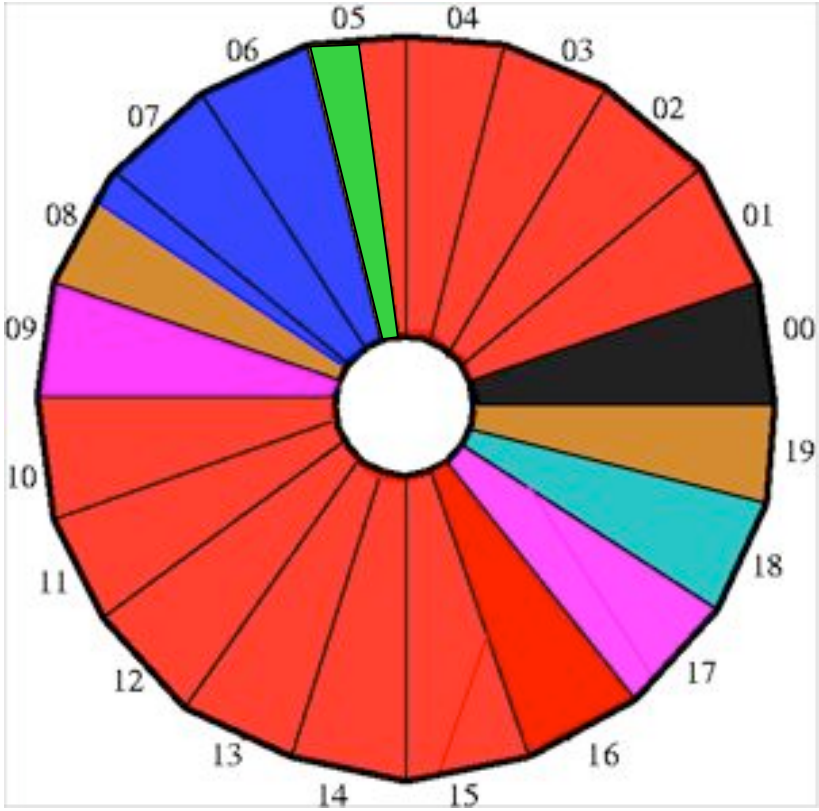
Neutron shield: borated water + wood

⇨ **Identification e^-, e^+, γ and α**

View of one sector during source installation

NEMO3 detector with the radon-free air tent (dec 2004)

ββ decay isotopes in NEMO3 detector



^{100}Mo 6.914 kg
$Q_{\beta\beta}$ = 3034 keV

^{82}Se 0.932 kg
$Q_{\beta\beta}$ = 2995 keV

ββ0ν

^{100}Mo purified at INL (USA) and ITEP (Russia)

ββ(2ν) measurement

^{116}Cd 405 g
$Q_{\beta\beta}$ = 2805 keV

^{96}Zr 9.4 g
$Q_{\beta\beta}$ = 3350 keV

^{150}Nd 37.0 g
$Q_{\beta\beta}$ = 3367 keV

^{48}Ca 7.0 g
$Q_{\beta\beta}$ = 4272 keV

^{130}Te 454 g
$Q_{\beta\beta}$ = 2529 keV

^{nat}Te 491 g

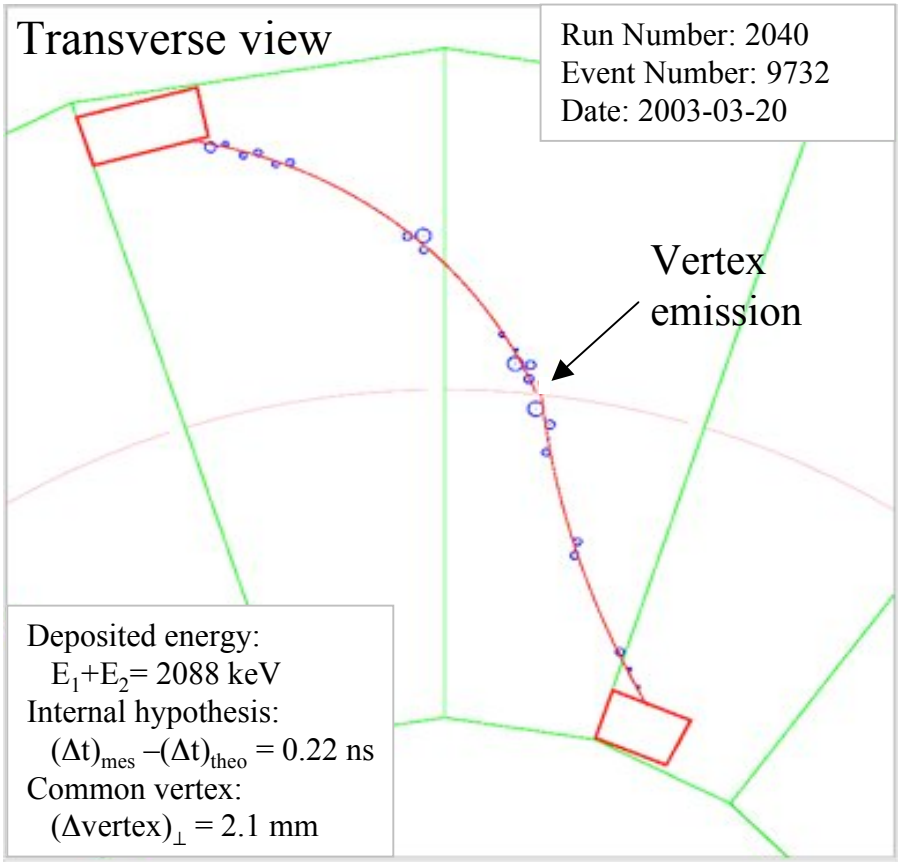
Cu 621 g

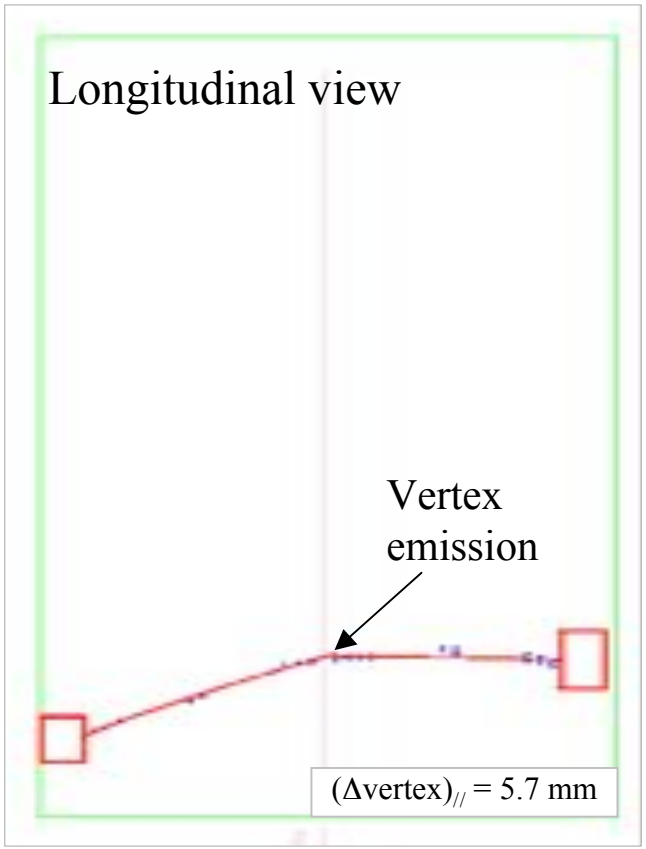
External bkg measurement

(Enriched isotopes produced in Russia)

ββ events selection in NEMO3

Typical ββ2ν event observed from ^{100}Mo





Trigger: 1 PM > 150 keV

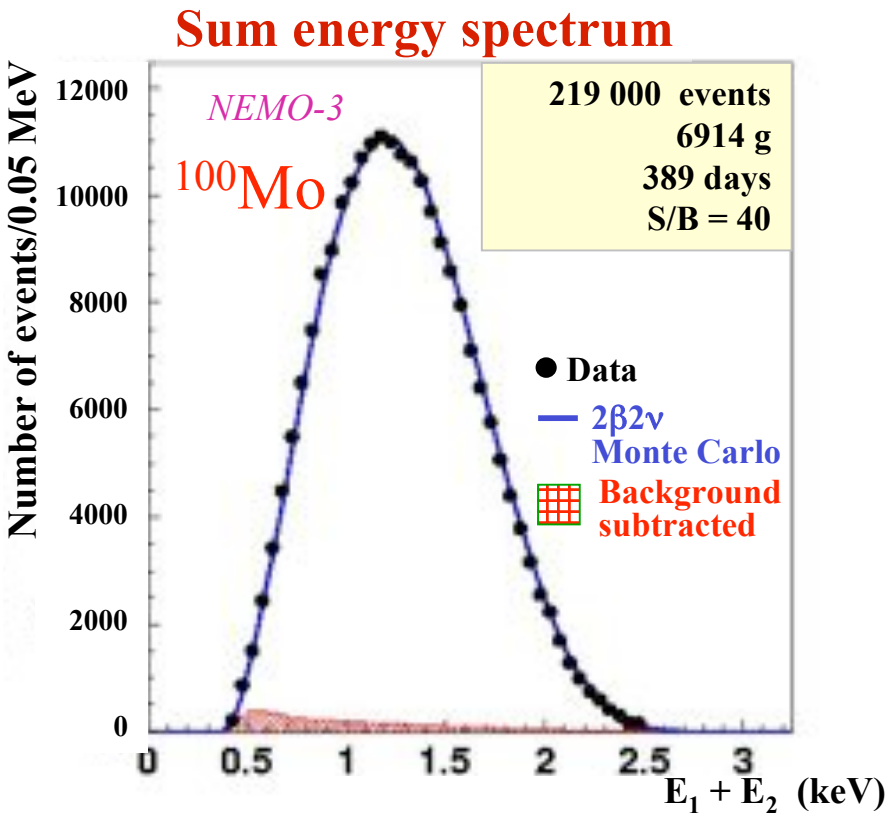
3 Geiger hits (2 neighbour layers + 1)

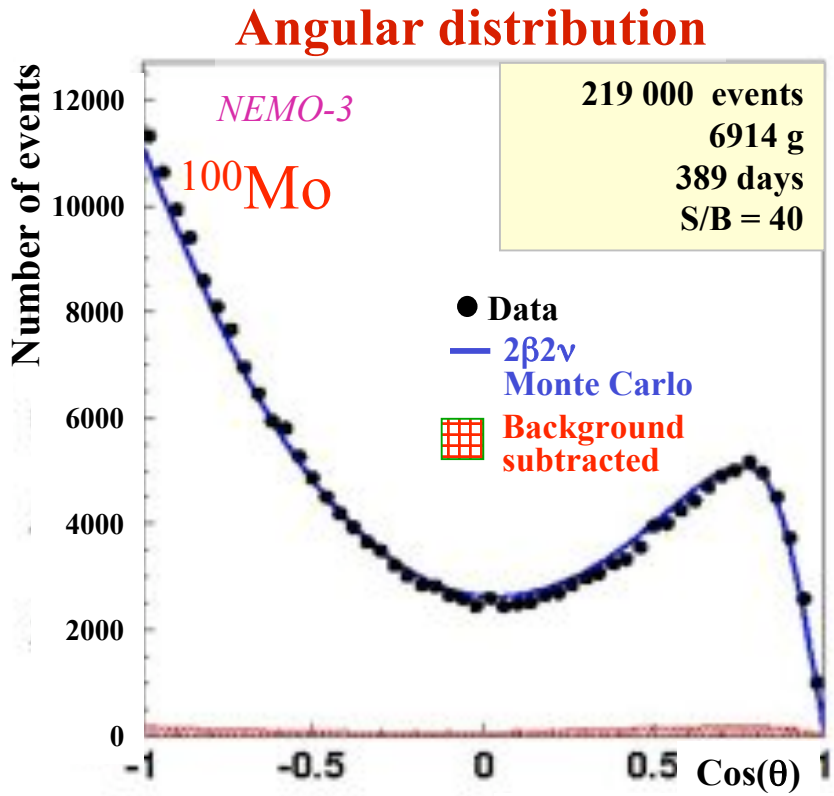
Trigger Rate = 5,8 Hz

ββ evts: 1 event every 2 minutes

^{100}Mo ββ(2ν) Results

Phase 1 Feb. 2003 – Dec. 2004 WITH RADON



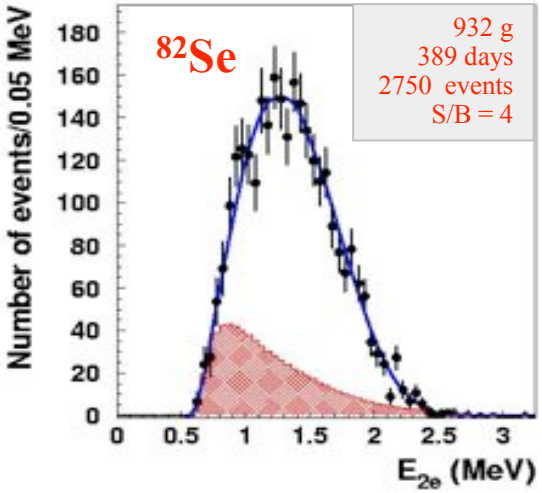


$T_{1/2}(\beta\beta 2\nu) = 7.11 \pm 0.02\ (stat) \pm 0.54\ (syst) \times 10^{18}$ years

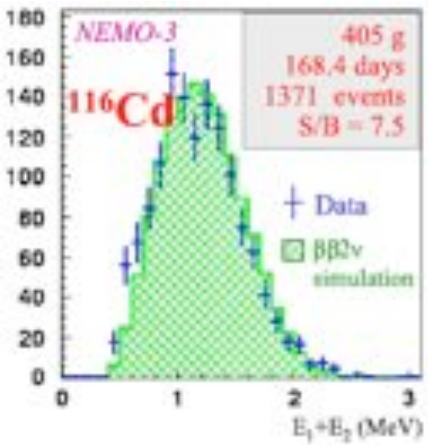
Phys. Rev. Lett. 95 182302 (2005)

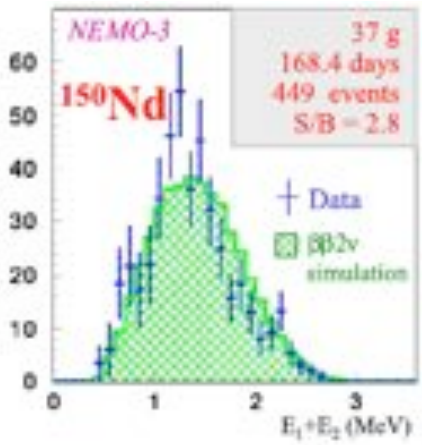
«ββ factory» → tool for precision test

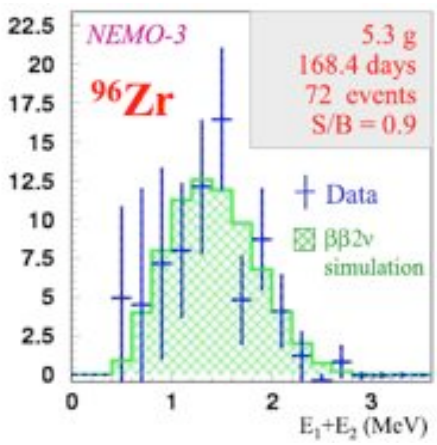
Other Nuclei ββ(2ν) Results

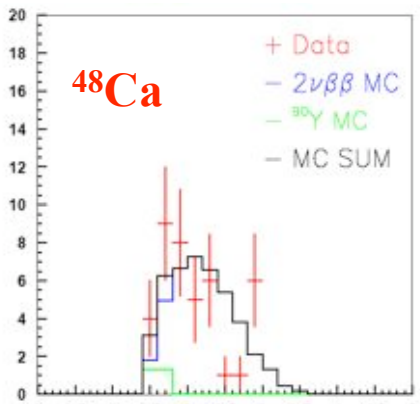


^{82}Se	$T_{1/2} = 10.3 \pm 0.2$ (stat) ± 1.0 (syst) $\times 10^{19}$ y
^{116}Cd	$T_{1/2} = 2.8 \pm 0.1$ (stat) ± 0.3 (syst) $\times 10^{19}$ y
^{150}Nd	$T_{1/2} = 9.7 \pm 0.7$ (stat) ± 1.0 (syst) $\times 10^{18}$ y
^{96}Zr	$T_{1/2} = 2.0 \pm 0.3$ (stat) ± 0.2 (syst) $\times 10^{19}$ y
^{48}Ca	$T_{1/2} = 3.9 \pm 0.7$ (stat) ± 0.6 (syst) $\times 10^{19}$ y









Background subtracted

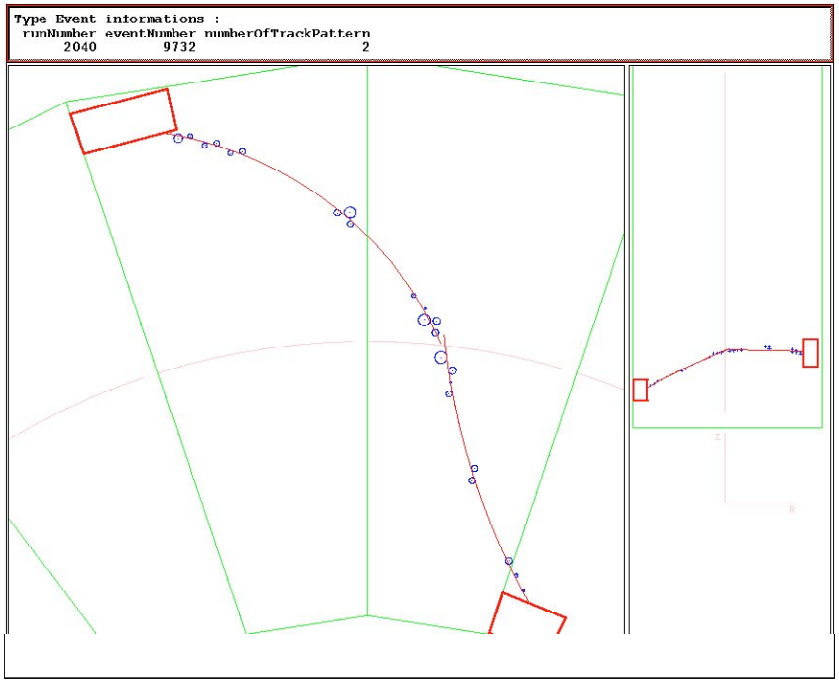
ββ(0ν) research: measurement of backgrounds

NEMO3 is able to measure each componant of its background by different analysis channels

External BKG: ^{208}Tl (PMTs)
channel external (e^-, γ)
~ 10^{-3} evts y^{-1} kg^{-1} $2.8<E_1+E_2<3.2$ MeV

External BKG: neutrons and γ > 3MeV
channel crossing e^- or $(e^-,e^+)_{int}$ with $E_1+E_2 > 4$ MeV
~ 3. 10^{-3} evts y^{-1} kg^{-1} $2.8<E_1+E_2<3.2$ MeV

^{208}Tl in the ββ foils : 80 ± 20 μBq/kg
Channels (e^-,2γ), (e^-,3γ) coming from the foil
~ 0.1 evts y^{-1} kg^{-1} $2.8<E_1+E_2<3.2$ MeV



^{214}Bi in NEMO3
~ 0.1 evts y^{-1} kg^{-1} $2.8<E_1+E_2<3.2$ MeV

Background radon level suppressed
by a factor 10 in Dec. 2004
with the radon-free air purification system

^{100}Mo ββ2ν $T_{1/2} = 7.11\ 10^{18}$ y
~ 0.3 evts y^{-1} kg^{-1} $2.8<E_1+E_2<3.2$ MeV

Two phases of runs in NEMO-3

Phase I: Radon contamination

February 2003 - September 2004

394 days of data taking

$\beta\beta0\nu$ publication: Phys. Rev. Lett. 95, 182302 (2005)

Phase II: Low level of radon

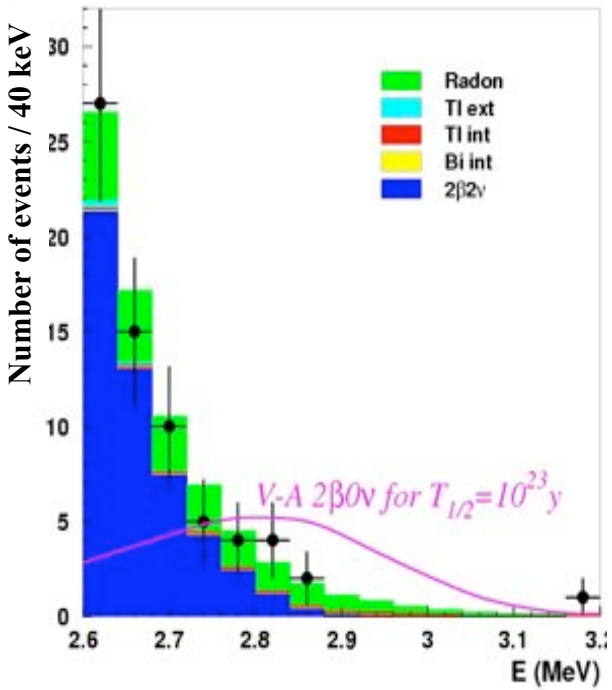
December 2004 - today

290 days of data taking have been preliminary analysed

ββ0ν results with ^{100}Mo

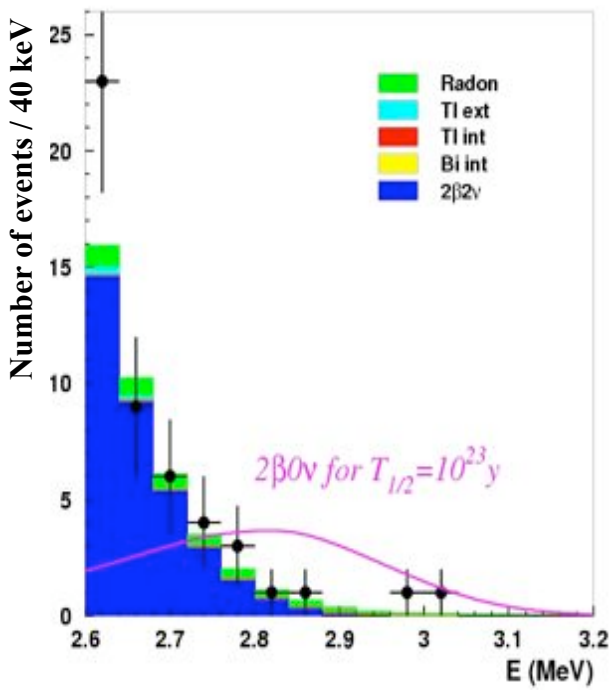
^{100}Mo, 7 kg

Phase I, High radon
394 days



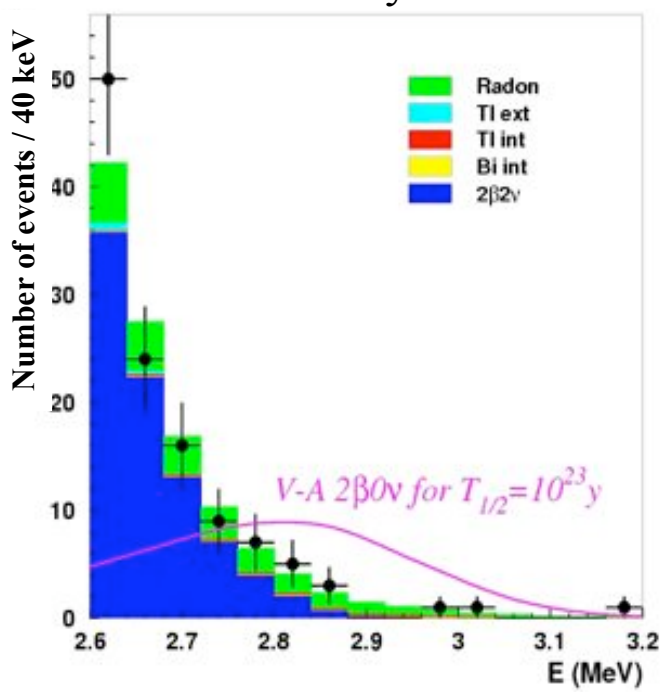
[2.8-3.2] MeV: ε(ββ0ν) = 8 %
Expected bkg = 8.1 events
$N_{observed}$ = 7 events

Phase II, Low radon
299 days



[2.8-3.2] MeV: ε(ββ0ν) = 8 %
Expected bkg = 3.0 events
$N_{observed}$ = 4 events

Phase I + II
693 days



Phases I + II **$T_{1/2}(ββ0ν) > 5.8\ 10^{23}$ (90 % C.L.)**

Expected in 2009 **$T_{1/2}(ββ0ν) > 2\ 10^{24}$ (90 % C.L.)**

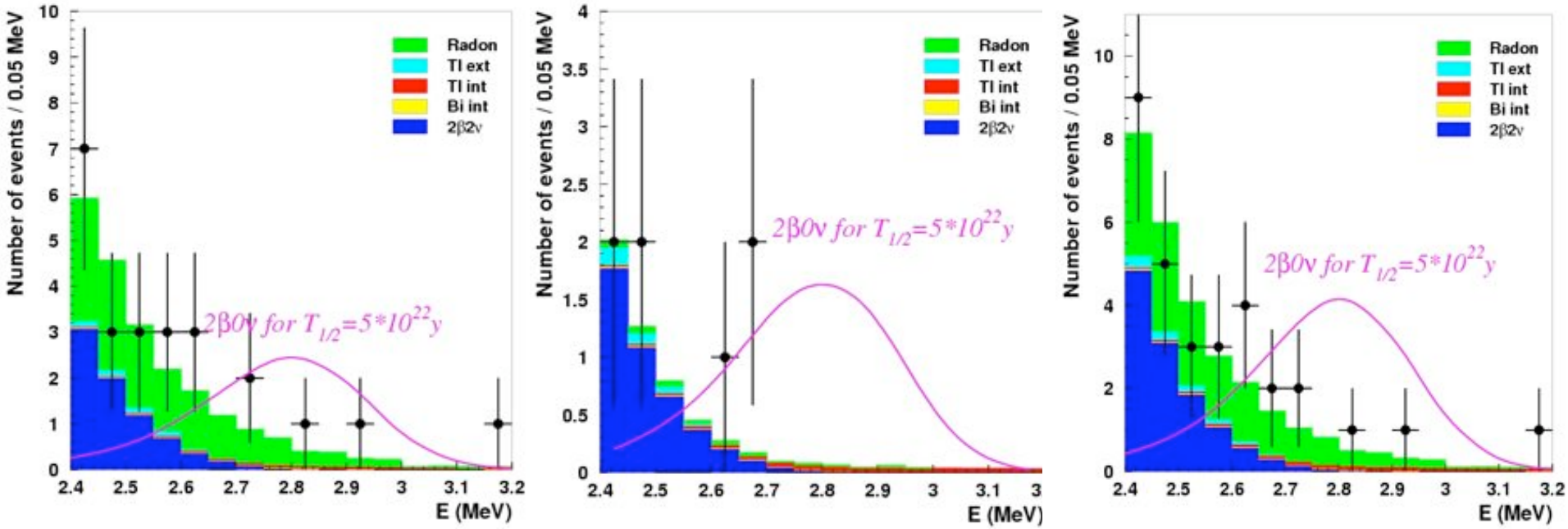
ββ0ν results with ^{82}Se

^{82}Se, 1 kg

Phase I, High radon
394 days

Phase II, Low radon
299 days

Phase I + II
693 days



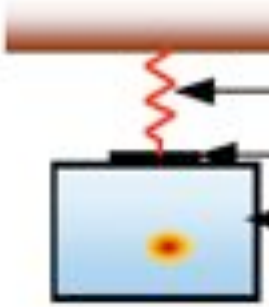
Phases I + II **$T_{1/2}(\beta\beta0\nu) > 1.2\ 10^{23}$ (90 % C.L.)**

Expected in 2009 **$T_{1/2}(\beta\beta0\nu) > 8\ 10^{23}$ (90 % C.L.)**

CUORICINO STATUS

CUORICINO Bolometer

TeO_2 Bolometer: Source = Detector



Heat sink: Cu structure (8 mK)
Thermal coupling: Teflon (G = 4 pW/mK)
Thermometer: NTD Ge-thermistor (dR/dT ≅ 100 kΩ/μK)
Absorber: TeO_2 crystal (C ≅ 2 nJ/K ≅ 1 MeV / 0.1 mK)

For E = 1 MeV:

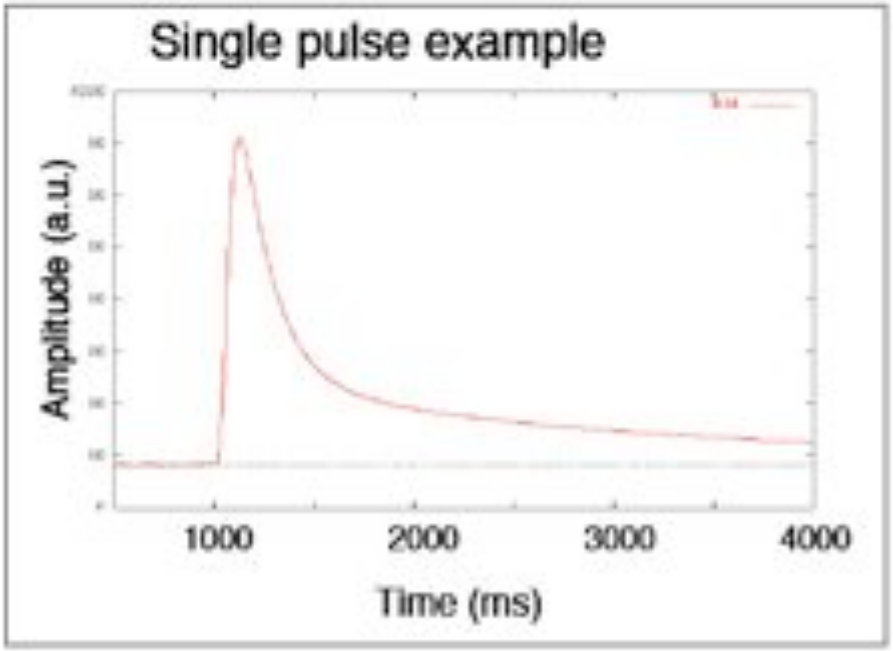
$\Delta T = E/C \cong 0.1$ mK

Signal size: 1 mV

Time constant:

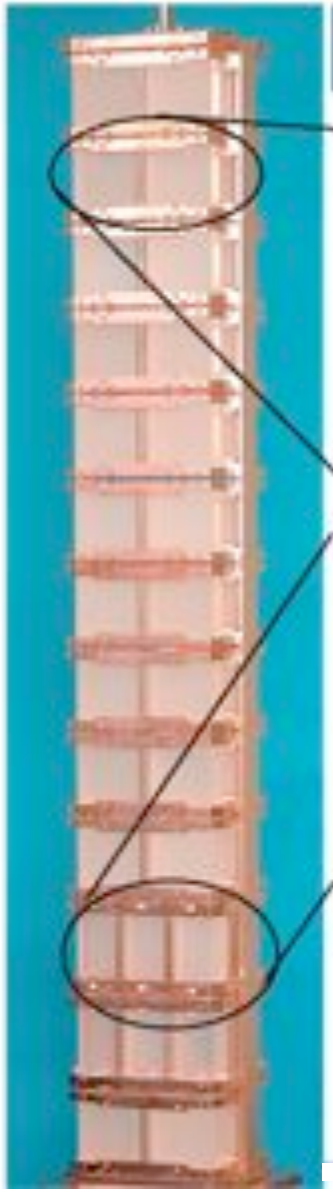
$\tau = C/G = 0.5$ s

Energy resolution (FWHM):
~ 5-10 keV at 2.5 MeV

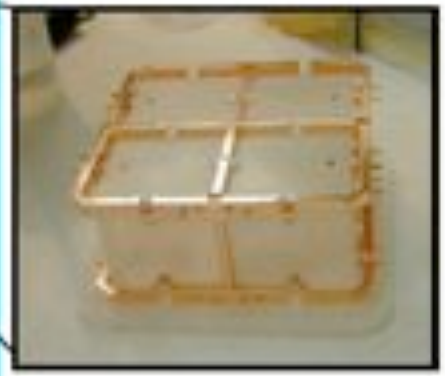


CUORICINO DETECTOR

Gran Sasso Underground Laboratory (Italy), 3500 m.w.e.



Total detector mass: 40.7 kg ⇒ 11.64 kg ^{130}Te



11 modules, 4 detector each,
crystal dimension: 5x5x5 cm^3
crystal mass: 790 g
44 x 0.79 = **34.76 kg of TeO_2**

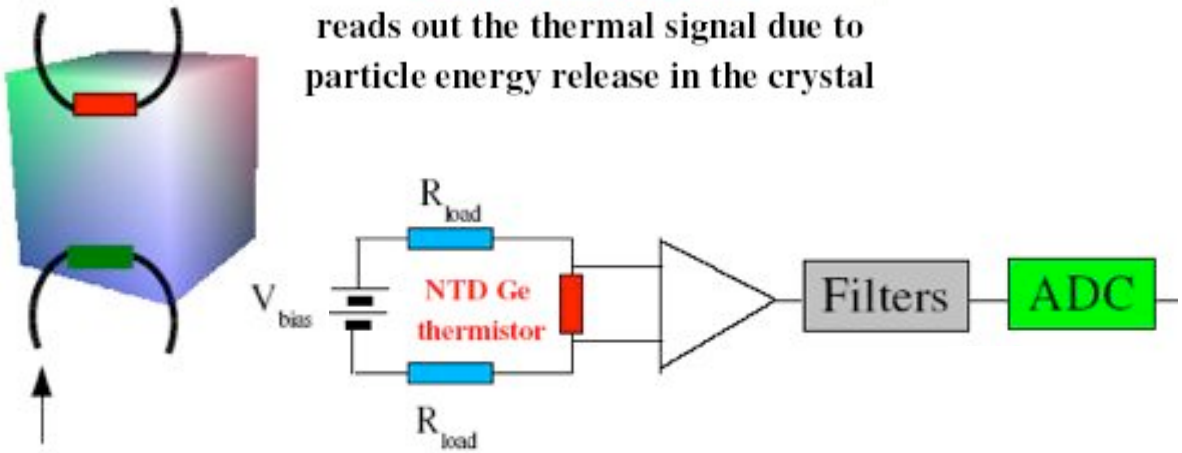
2 modules x 9 crystals each
crystal dimension: 3x3x6 cm^3
crystal mass: 330 g
9 x 2 x 0.33 = **5.94 kg of TeO_2**
(2 enriched in ^{128}Te @82.3%)
(2 enriched in ^{130}Te @75%)

Shielding:

- Cu box + Roman Pb inside cryostat
- 20 cm Pb & 10 cm borated polyethylene outside

Survey of the gain stability

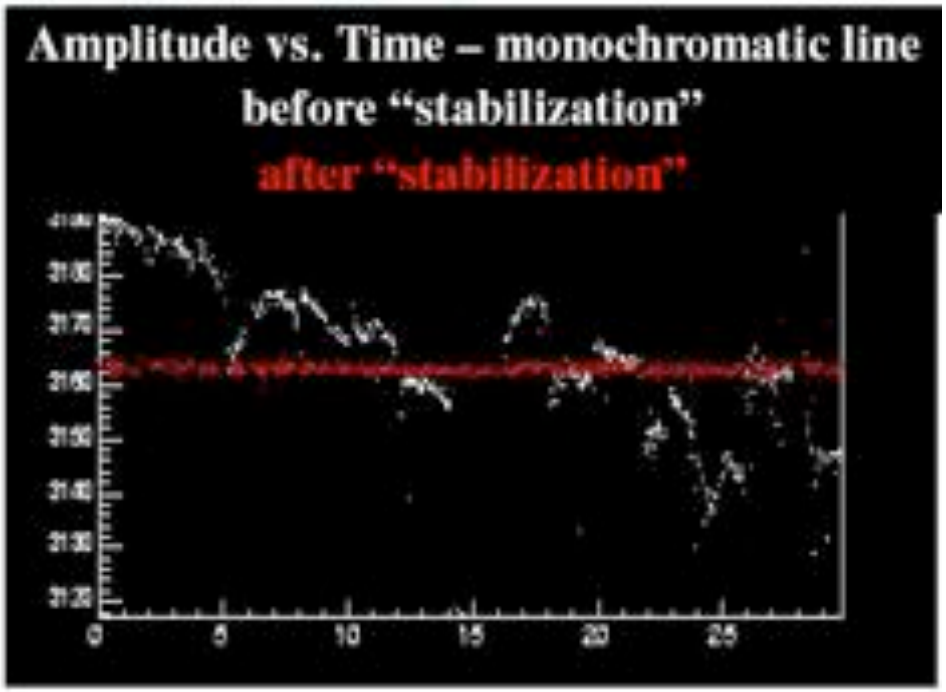
NTD Ge – thermistor:
reads out the thermal signal due to particle energy release in the crystal



voltage pulse injection

Si – resistor:
produce a particle like signal through Joule power dissipation

- Calibrated voltage pulse injected every 300 sec. on Si-resistor to correct gain instabilities of the detector
- Joule dissipation on the resistor produces an energy pulse in the crystal read like a signal



CUORICINO RUNNING

Run I: 22 Apr. 2003 → 27 Oct. 2003

29 crystals 5x5x5
11 crystal 3x3x6
2 crystals ^{130}Te 3x3x6

Total ^{130}Te MASS = 59 moles
$\Delta E/E$ @ 2.6 MeV FWHM = 9.2 keV (bkg spect.)

Run II: 7 May 2004 → Today

40 crystals 5x5x5
13 crystal 3x3x6
2 crystals ^{130}Te 3x3x6

Total ^{130}Te MASS = 83 moles
$\Delta E/E$ @ 2.6 MeV FWHM = 6.3 keV (bkg spect.)

Total exposure (10 may 2006):
8.38 kg.year of ^{130}Te

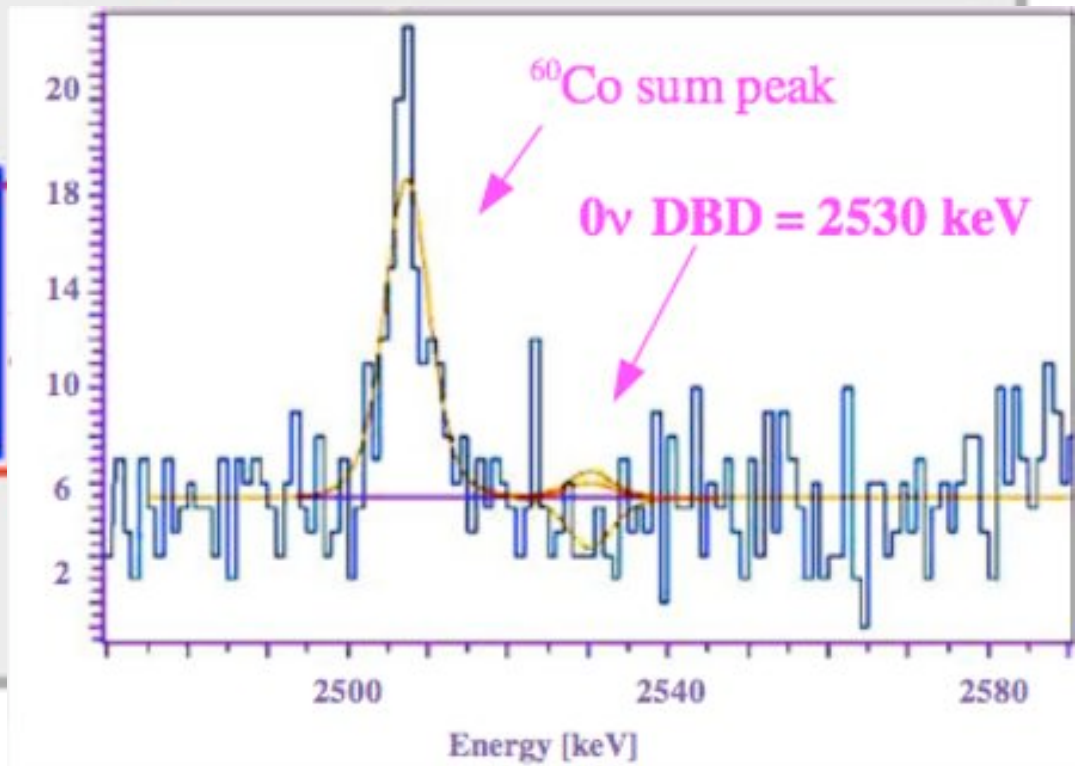
CURICINO RESULTS

Total Exposure: **8.38 kg-y of ^{130}Te**
BKG: **0.18 ± 0.01 cnts/(keV-kg-y)**
FWHM at 2615 keV: **~ 8 keV**

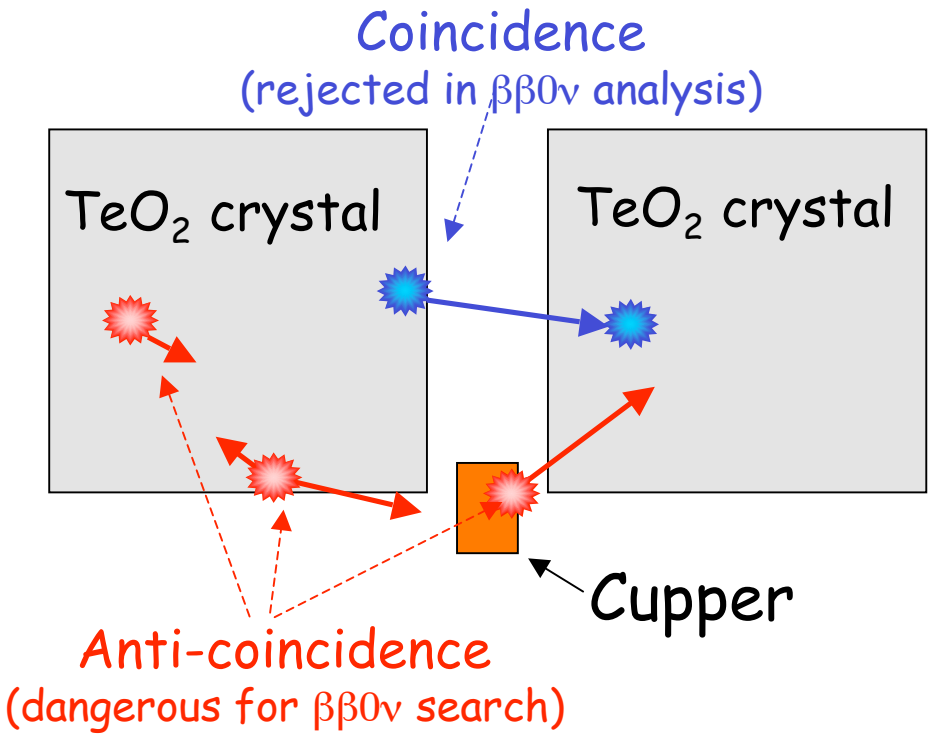
April 2003 - May 2006

0ν –DBD result

$\tau_{1/2} > 2.4\ 10^{24}$ [y]
@ 90% C.L.



ANALYSIS OF BACKGROUND in ββ0ν region



In the COINCIDENCE spectrum ONLY CRYSTAL SURFACE contam. contribute

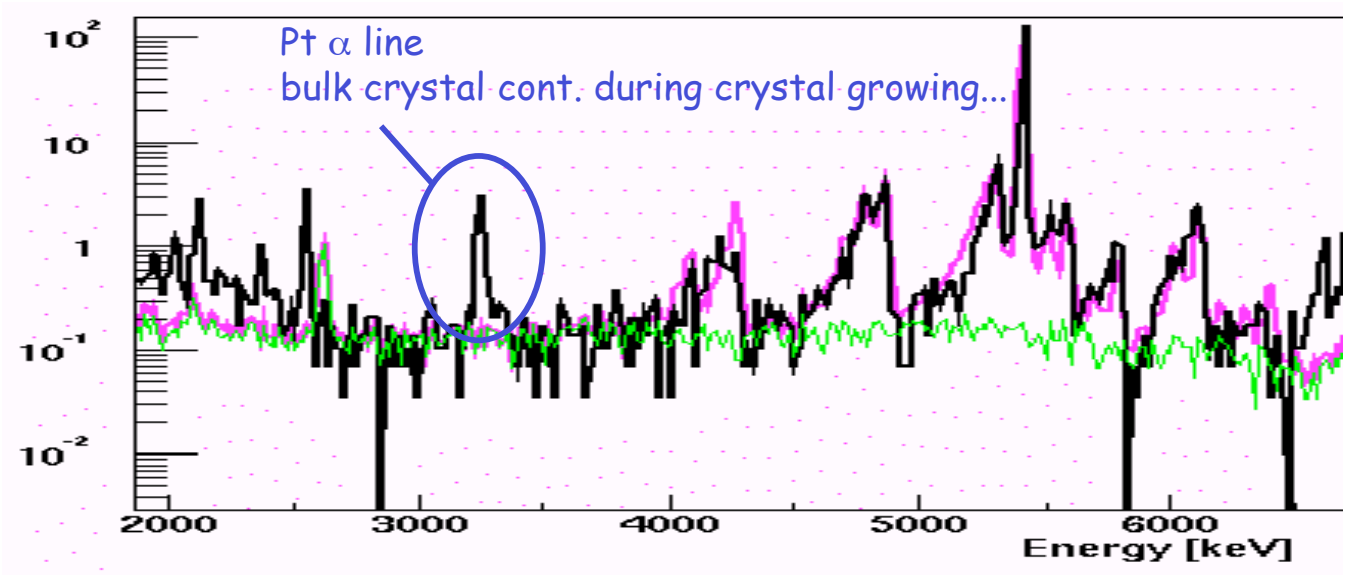
In the ANTI-COINCIDENCE bkg spectrum

- Crystal bulk contaminations determine gaussian peaks at the Q-value of the decay
- Surface contaminations determine peaks at the α energy, with tails (shape depending on contamination depth)

ANALYSIS OF BACKGROUND in ββ0ν region

Model of background

Source	^{208}Tl	$\beta\beta(0\nu)$ region	3-4 MeV region
TeO_2 ^{238}U and ^{232}Th surface contamination	-	20± 15%	20± 10%
Cu ^{238}U and ^{232}Th surface contamination	~15%	50± 20%	80± 10%
^{232}Th contamination of cryostat Cu shields	~85%	30± 10%	-



Important part of background due to ^{238}U or ^{232}Th contamination on the surface of crystal and Cu structure facing the detectors

surface contamination level: ~ 1 ng/g vs bulk c.l. : < 1 (0.1) pg/g for Cu (TeO_2)
contamination depth: ~ 5 μm in agreement with direct measurement on Cu

Experiment	nuclei	Mass (kg)	$T_{1/2}(\beta\beta0\nu)$	$\langle m_\nu \rangle$ (eV)		
				QRPA [1-3]	QRPA [4]	Shell Model (Caurier)
HM-IGEX	^{76}Ge	6-10	$> 1.9\ 10^{25}$	0.3 – 0.9	0.5 – 0.6	1.0
CUORICINO	^{130}Te	11.6	$> 2.4\ 10^{24}$	0.4 – 0.8	0.9 – 1.1	0.6
end 2009 (*)			***$> 6\ 10^{24}$***	***0.25 – 0.5***	***0.6 – 0.7***	***0.4***
NEMO-3	^{100}Mo	6.91	$> 5.8\ 10^{23}$	0.6 – 0.9	2.1 – 2.7	
end 2009 (**)			***$> 2\ 10^{24}$***	***0.3 – 0.45***	***1.1 – 1.4***	
NEMO-3	^{82}Se	0.93	$> 2.\ 10^{23}$	1.2 – 2.5	2.6 – 3.2	3.5
end 2009 (**)			***$> 8\ 10^{23}$***	***0.6 – 1.2***	***1.3 – 1.6***	***1.7***
NEMO-3	^{150}Nd	0.037	$> 1.7\ 10^{22}$		3.7 – 4.2	
end 2009 (**)			***$> 5\ 10^{22}$***		***2.1 – 2.4***	

(*) CUORICINO: with 60% live time
(**) NEMO-3: with 80% live time

[1] Simkovic et al, Phys. Rev. 60 (1999) 055502
[2] Stoica et al, Nucl. Phys. A 694 (2001) 269
[3] Suhonen et al., Nucl. Phys. A 729 (2003) 867
[4] Rodin et al., Nucl. Phys. A 766 (2006) 107

CONCLUSIONS

Two $\beta\beta0\nu$ experiments are running today: NEMO-3 and CUORICINO
With large mass ~10 kg of $\beta\beta$ isotopes and low background

Two complementary techniques:

CUORICINO: largest Cryogenic bolometer in the world
real technical performance in the last 20 years
compact detector
Bkg ~1.5 counts/kg/y/FWHM

NEMO-3: tracko-calo detector allows a direct 2 e^- detection
reject any unknown gamma line
Bk > 2.8 MeV ~0.5 counts/kg/y with ^{100}Mo ($T_{1/2}$=7 10^{18} y)
~0.1 counts/kg/y with ^{82}Se ($T_{1/2}$=10^{20} y)

Both techniques NEMO-3 and CUORICINO are as mature as HPGe detectors
$\Rightarrow$ can be extrapolated to larger mass