NEMO3 experiment: results for ^{150}Nd

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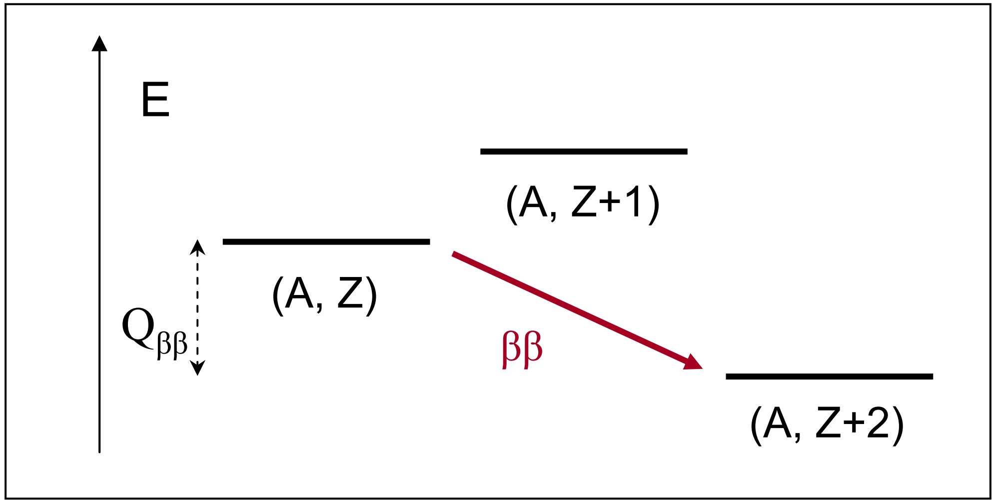
Outline

- Double beta decay physics
- The NEMO3 experiment
- $\beta\beta2\nu$ results for ^{150}Nd
- Background for $\beta\beta0\nu$
- $\beta\beta0\nu$ results for ^{150}Nd
- Conclusions and perspectives

Double beta decay physics



$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}$ ββ2ν decay

ββ2ν decay is allowed by the Standard Model and has been observed for 9 nuclei (7 studied by the NEMO experiments).

$(A,Z) \rightarrow (A,Z+2) + 2e^-$ ββ0ν decay

Beyond Standard Model

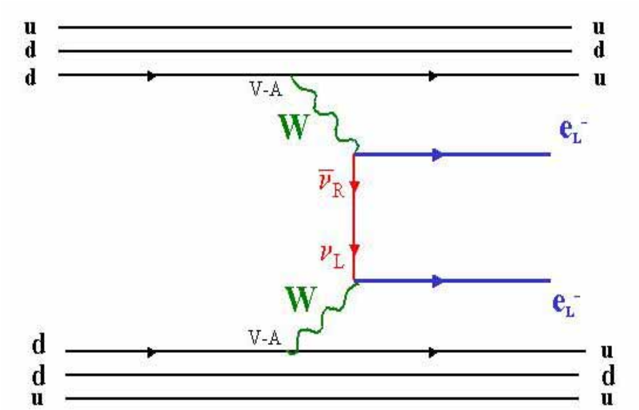
Neutrinoless double beta decay ($\beta\beta0\nu$)

$\beta\beta0\nu$ process: $\Delta L=2$ Violation of the conservation of the lepton number

$\rightarrow$ massive Majorana neutrino

$\rightarrow$ neutrino mass hierarchy

Light neutrino exchange



Phase space factor

Nuclear Matrix Element

$$T^{-1}_{1/2} = F(Q^5_{\beta\beta}, Z)\ |M|^2\ \langle m_\nu \rangle^2$$

Effective mass

$$\langle m_\nu \rangle = m_1|U_{e_1}|^2 + m_2|U_{e_2}|^2.e^{i\alpha_1} + m_3|U_{e_3}|^2.e^{i\alpha_2}$$

$|U_{e_i}|$: **Mixing matrix element;** α_1 **et** α_2**: Majorana phases**

Other mechanisms: right currents (V+A)

emission of Majoron

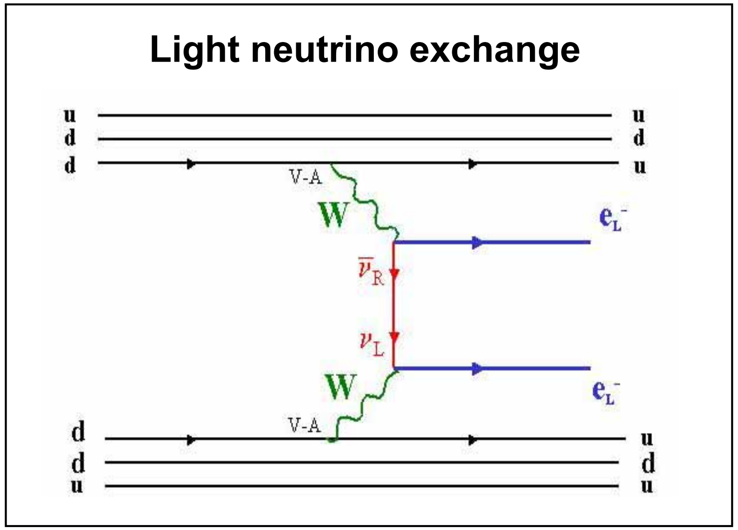
SUSY

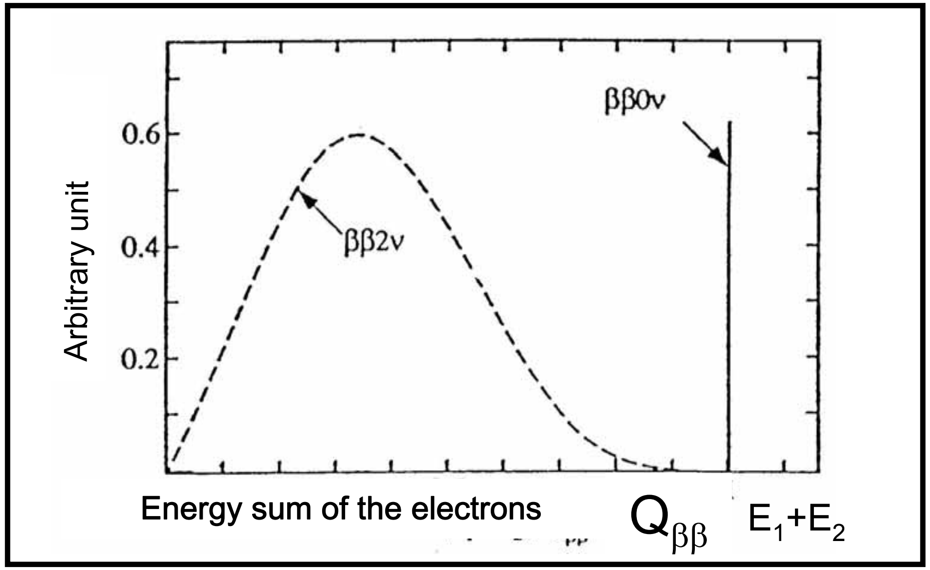
Neutrinoless double beta decay (ββ0ν)

ββ0ν process: ΔL=2 Violation of the conservation of the lepton number

→ massive Majorana neutrino

→ neutrino mass hierarchy





Other mechanisms: right currents (V+A)

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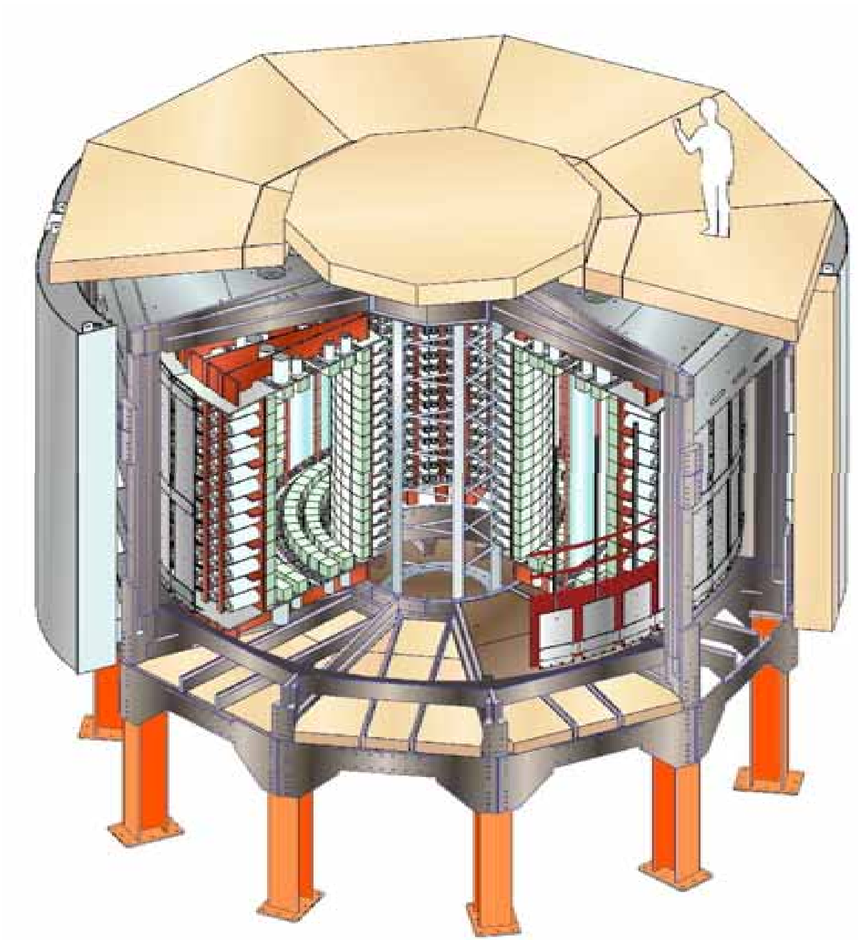
SUSY

The NEMO3 detector



Sources: **10 kg of ββ emitters**
6.914 kg of ^{100}Mo and 0.932 kg of ^{82}Se
$S = 20\ m^2$, $60\ mg/cm^2$

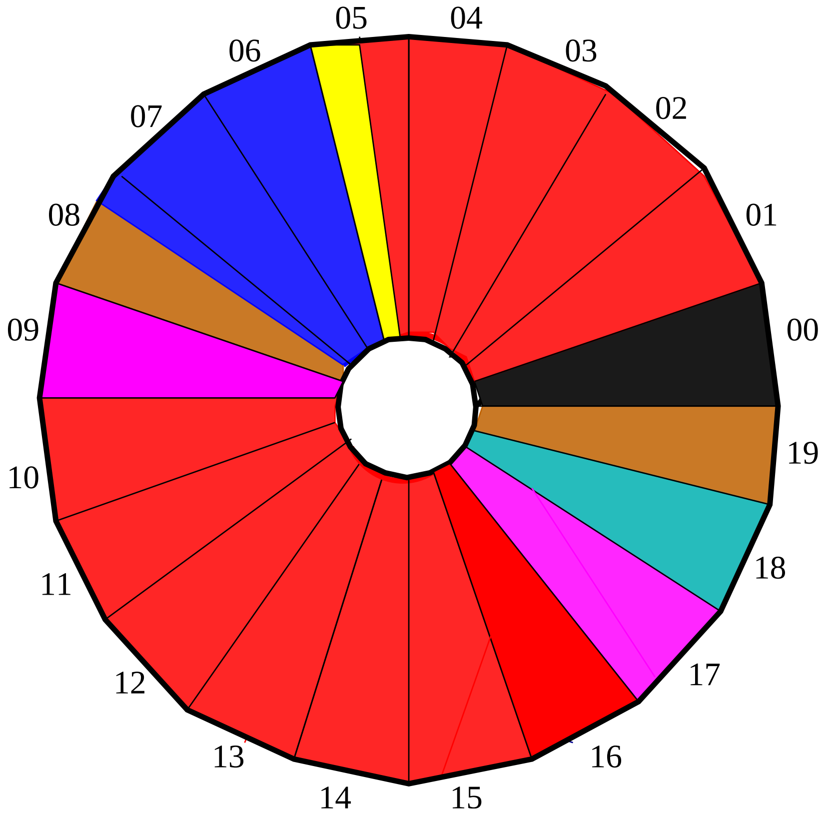
Tracking volume:
Drift chamber (Geiger mode)
6180 cells
Gaz: He + 4% ethanol + 1% Ar + 0.1% H_2O

Calorimeter:
1940 plastic scintillators
associated to low-background PMTs

Gamma shielding: Iron (18 cm)
Neutron shielding: borated water + wood
Magnetic field: 25 Gauss

Identification of e^-, e^+, γ and α

ββ emitters in NEMO3



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

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

ββ0ν

ββ2ν

^{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

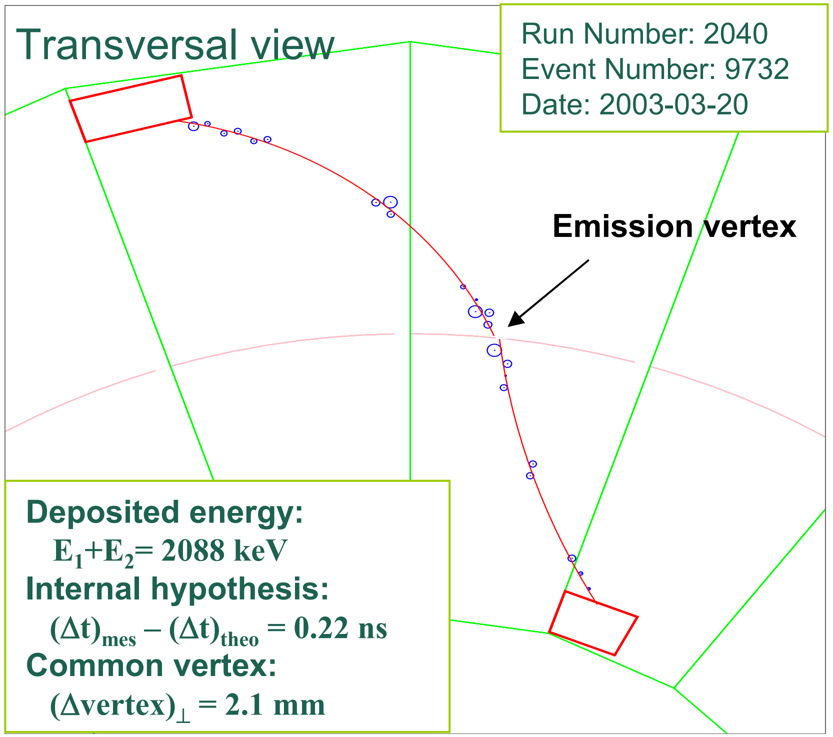
Cu 621 g

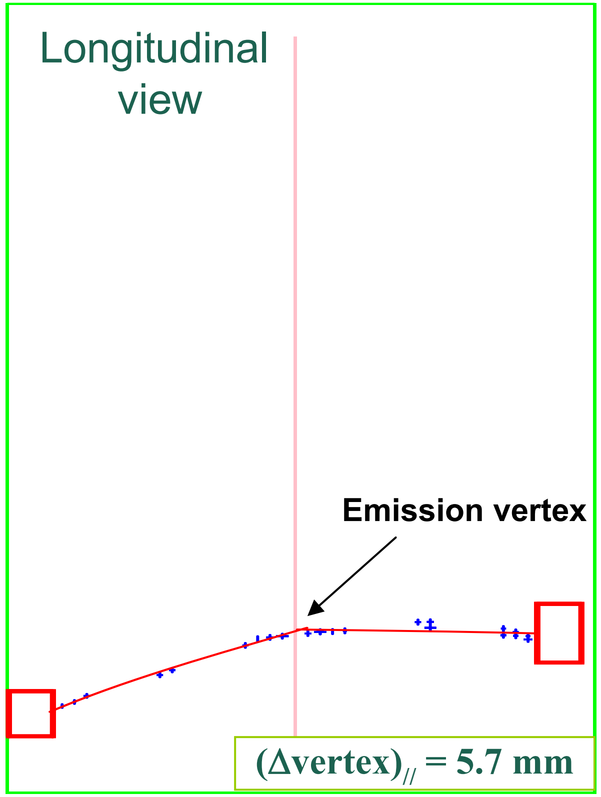
External background measurement

The NEMO3 experiment

The building of NEMO3 detector at the Laboratoire Souterrain de Modane in 2001 and with the anti-radon tent since October 2004

ββ event selection





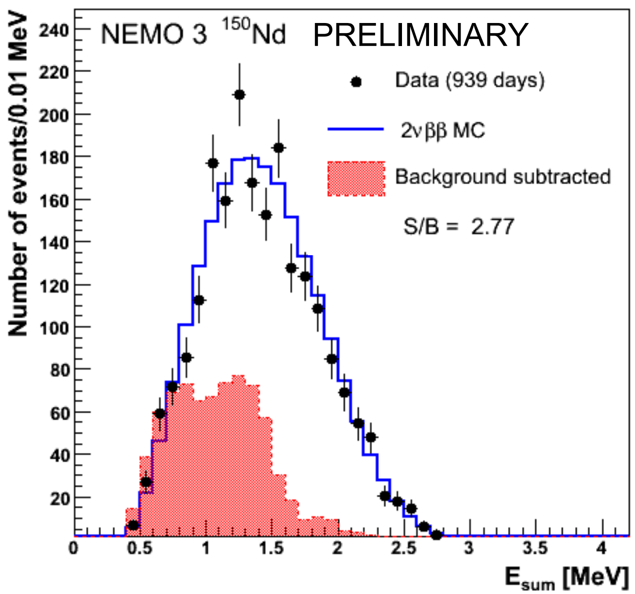
Selection criteria

- 2 tracks associated with negatively charged particles
- 2 PMTs, energy deposit greater than 200 keV
- PMT-Track association
- Common vertex
- Internal hypothesis (external event rejection)
- No other isolated PMT (γ rejection)
- No delayed track (^{214}Bi rejection)

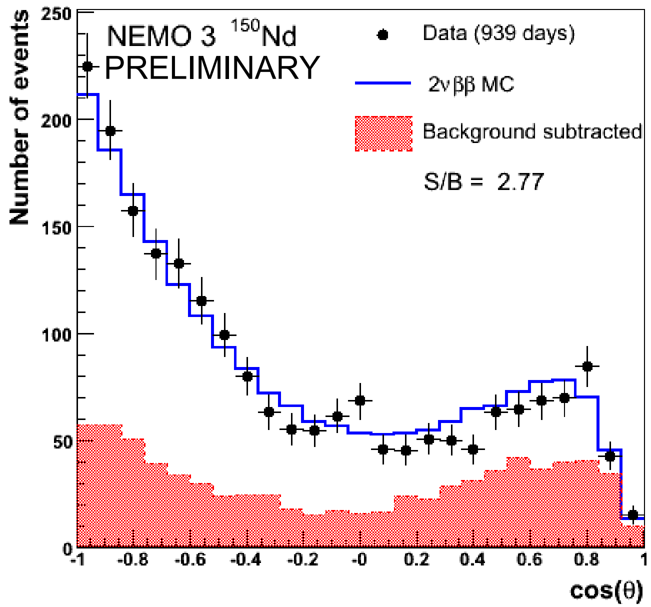
ββ2ν results for ^{150}Nd

$Q_{\beta\beta}$ = 3.367 MeV 46.6 g of Nd_2O_3 enriched to 91%, equivalent to 37 g of ^{150}Nd
Feb 2003 – Dec 2006 : 939 days of data collection
2828 events observed

Energy sum of the electrons



Angular distribution



$T_{1/2}$ (ββ2ν) = (9.20 $^{+0.25}_{-0.22}$ (*stat*) ± 0.73 (*syst*)). 10^{18} y

Results of previous experiments

ITEP TPC experiment

9 events observed, 38 days, natural Nd_2O_3 (2.5g of ^{150}Nd)

36 events observed, 53 days, 51.5 g of enriched Nd_2O_3 (*V. Artemiev et al.,Phys. Let. B., 345, (1995) 564*)

$$T_{\frac{1}{2}}(\beta\beta 2\nu) = (1.88^{+0.66}_{-0.39}(\text{stat}) \pm 0.19(\text{syst})).10^{19}\ \text{y}$$

University of California (Irvine) group TPC experiment

476 events observed, 262 days, 15.5 g of Nd_2O_3 enriched to 91 % in ^{150}Nd (*A. De Silva et al., Phys. Rev. C 56 (1997) 2451*)

$$T_{\frac{1}{2}}(\beta\beta 2\nu) = (6.75^{+0.37}_{-0.42}(\text{stat}) \pm 0.68(\text{syst})).10^{18}\ \text{y}$$

Background measurement for ββ0ν

^{208}Tl, ^{214}Bi in calorimeter, neutrons
One-crossing-electron channel
Δt = 3 ns

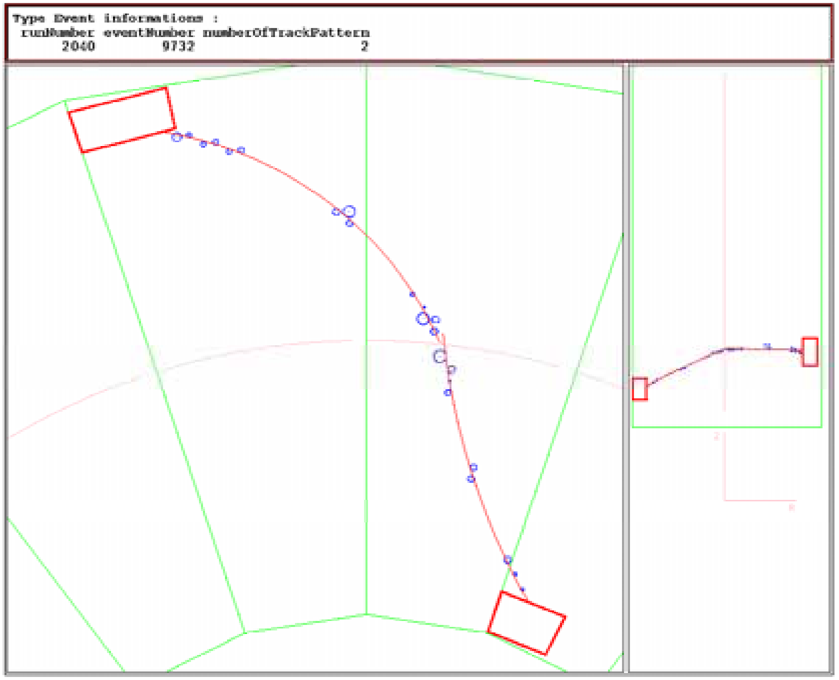
External (e^-, γ) channel
Δt = 3 ns

γ from radiative capture of neutrons,
γ > 3 MeV
Pair creation $(e^-,e^+)_{int}$
Δt = 0 ns

^{208}Tl inside the sources
(e^-,2 γ), (e^-,3 γ) from foil
Δt = 0 ns

Radon/^{214}Bi in the foils or gas
(e^-, γ, α) from foil or gas
Δt = 0 ns

ββ2ν from foil
2 e^- channel from foil
Δt = 0 ns



ββ0ν results for ^{150}Nd

Light Neutrino exchange
Collie statistical method above 2.5 MeV
Detection efficiency: 19%

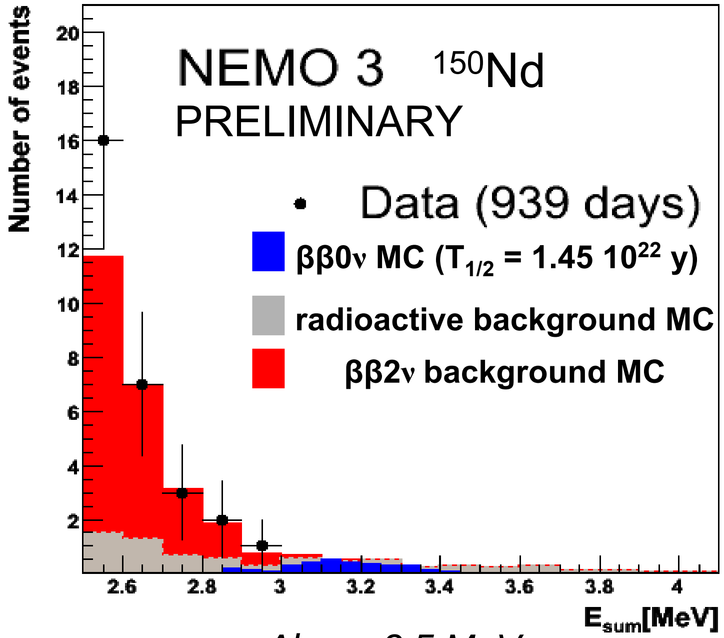
$T_{1/2}$ (ββ0ν) > 1.45 10^{22} y   90 % CL

$<m_\nu>$ < 3.7 – 5.1 eV

V.A. Rodin et al., Nucl. Phys. A 766 (2006) 107

Previous result: $T_{1/2}$ > 1.7 10^{21} y   90 % CL

A.A. Klimenko et al., Nucl. Instr. Meth. B 17 (1986) 445



Above 2.5 MeV
28.6 ± 2.7 events expected from background
29 events observed

Right currents:
$T_{1/2}$ (ββ0ν) > 1.27 10^{22} y   90 % CL

Emission of Majoron (M1) :
$T_{1/2}$ (ββ0ν) > 1.55 10^{21} y   90 % CL

Summary of NEMO3 results

Isotope	Data	$T_{1/2}$ ($\beta\beta2\nu$) - years
^{100}Mo *	389 days - Phase 1	**7.11 ± 0.02 (stat) ± 0.54 (syst) $\times 10^{18}$**
^{82}Se *	389 days - Phase 1	**9.6 ± 0.3 (stat) ± 1.0 (syst) $\times 10^{19}$**
^{116}Cd	365 days - Phase 1	**2.8 ± 0.1 (stat) ± 0.3 (syst) $\times 10^{19}$**
^{96}Zr	365 days - Phase 1	**2.0 ± 0.3 (stat) ± 0.2 (syst) $\times 10^{19}$**
^{48}Ca	365 days - Phase 1	**3.9 ± 0.7 (stat) ± 0.6 (syst) $\times 10^{19}$**
^{130}Te	534 days - Phases 1 + 2	**7.6 ± 1.5 (stat) ± 0.8 (syst) $\times 10^{20}$**

* *R. Arnold et al., Phys. Rev. Lett. 95 182302 (2005)*

Isotope	Data	$T_{1/2}$ ($\beta\beta0\nu$) - years	$\langle m_\nu \rangle$
^{100}Mo	693 days - Phases 1 + 2	**> 5.8 x 10^{23}**	**< 0.8 – 1.3 eV**
^{82}Se	693 days - Phases 1 + 2	**> 2.1 x 10^{23}**	**< 1.4 – 2.2 eV**

Conclusion and perspectives

- The NEMO3 detector is still collecting data.

- The following value of the half-life for the $\beta\beta2\nu$ decay of ^{150}Nd was obtained:

  $T_{1/2}$ ($\beta\beta2\nu$) = (9.20 $^{+0.25}_{-0.22}$ (*stat*) ± 0.73 (*syst*)). 10^{18} y

- The limit on the half-life value for the $\beta\beta0\nu$ process has been improved.

  $T_{1/2} > 1.45\ 10^{22}$ y 90% CL $\langle m_\nu \rangle < 3.7 – 5.1$ eV

- ^{150}Nd is a good candidate for the SuperNEMO and SNO+ projects:
  - high $Q_{\beta\beta}$ value
  - large phase space factor

  Enrichment by laser isotope separation of large masses of ^{150}Nd currently under consideration.

Back up slides

Search for double beta decay experimentally

Calorimeter

HPGe – bolometer Te – scintillator

HM, IGEX, CUORICINO

Very good efficiency and energy resolution

TPC

Irvine, Gotthard, EXO

Large mass (^{136}Xe) and efficiency

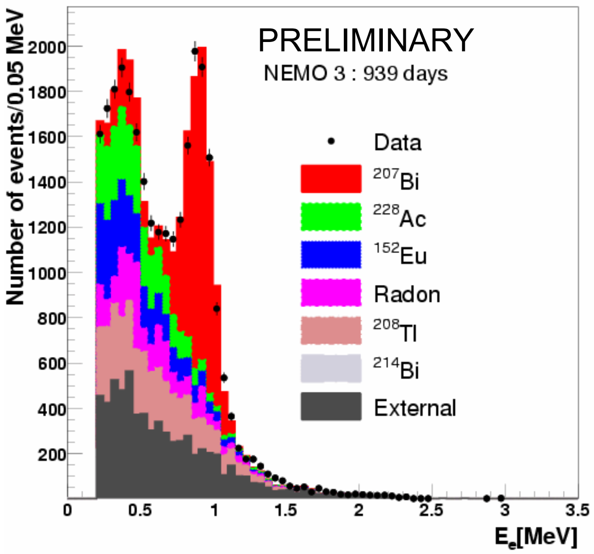
Tracking + calorimeter

NEMO

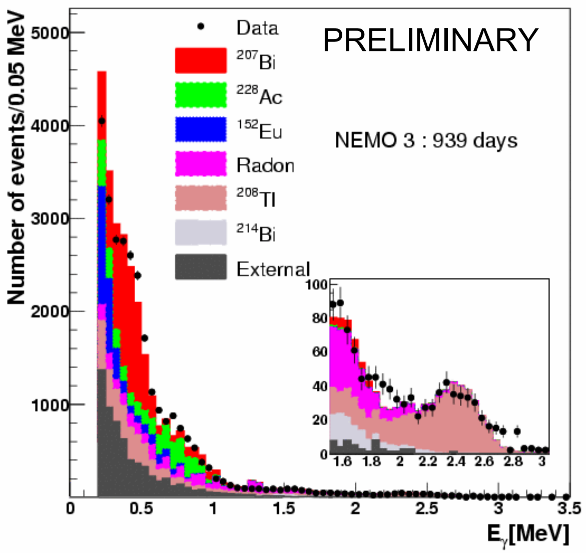
Direct identification of the electrons, identification of the background, angular measurement, several isotopes studied at once.

Background measurement

Internal e$^-$ - γ analysis channel

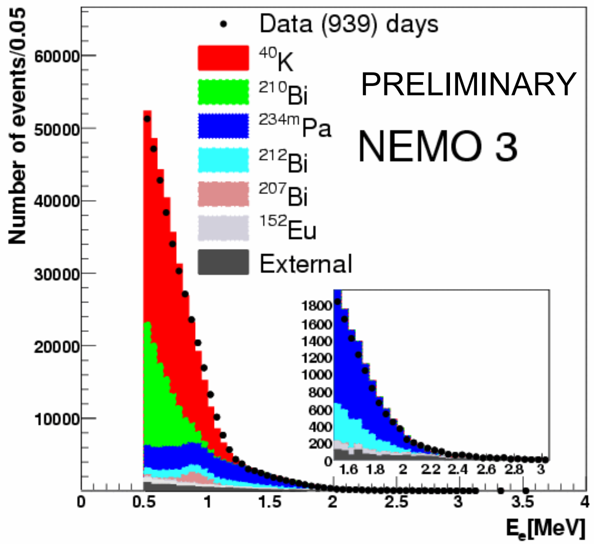


Energy of the electron



Energy of the γ

Single e$^-$ analysis channel



Energy of the electron