The Search for Neutrinoless Double Beta Decay

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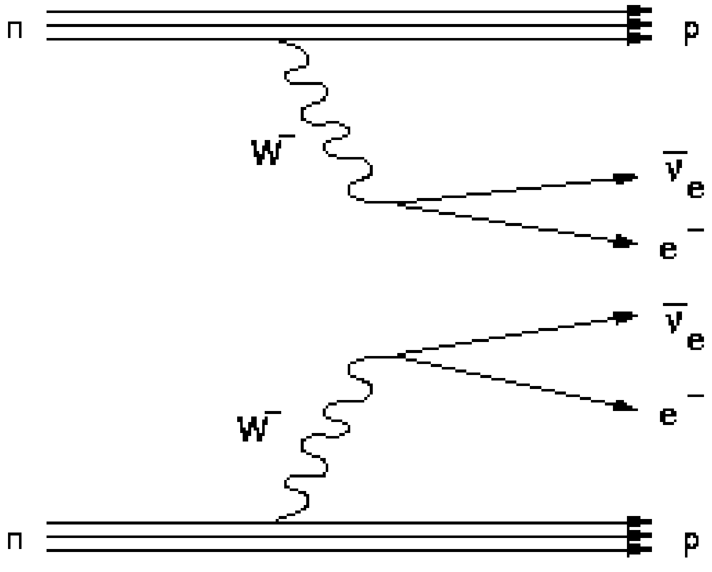
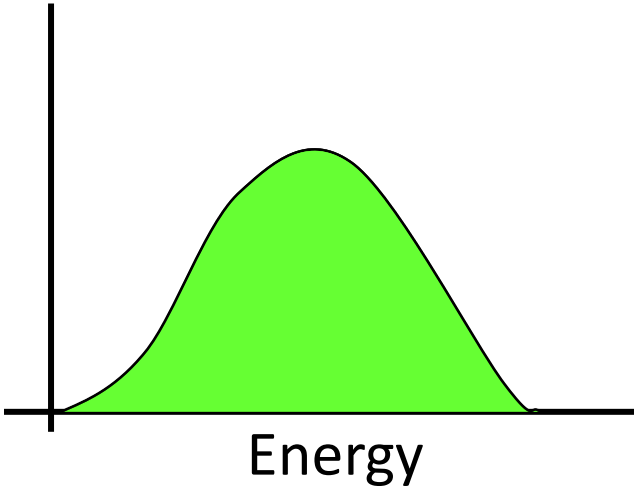
NEMO 3



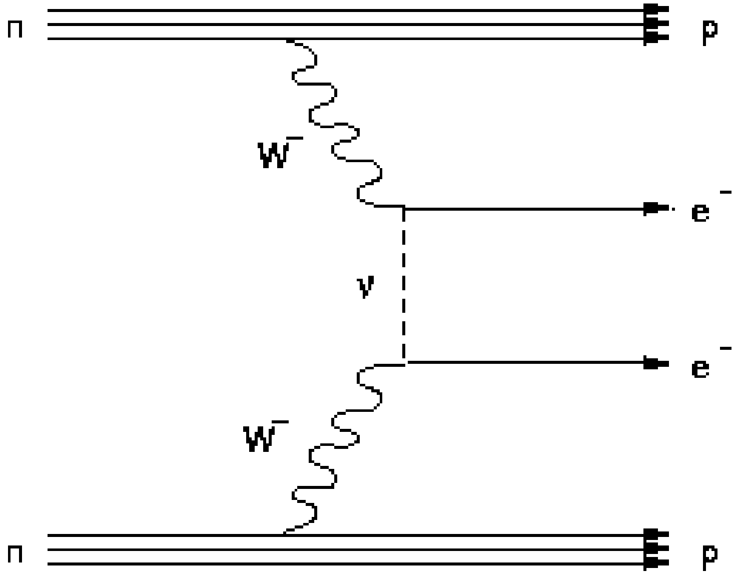
2vββ - Decay

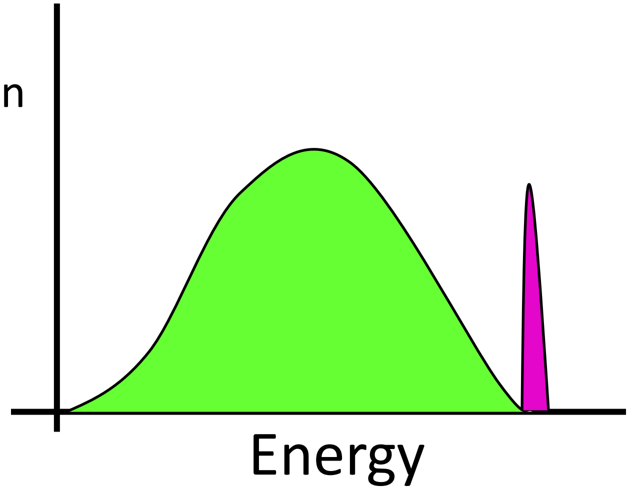
- Some nuclei can decay via the spontaneous emission of 2 electrons and 2 anti-electron neutrinos
- This is a rare process but occurs when it is more energetically favourable to convert 2 neutrons into protons
- Much like single β-decay the electron energies follow a spectrum rather than having fixed values due to the neutrinos



0νββ - Decay

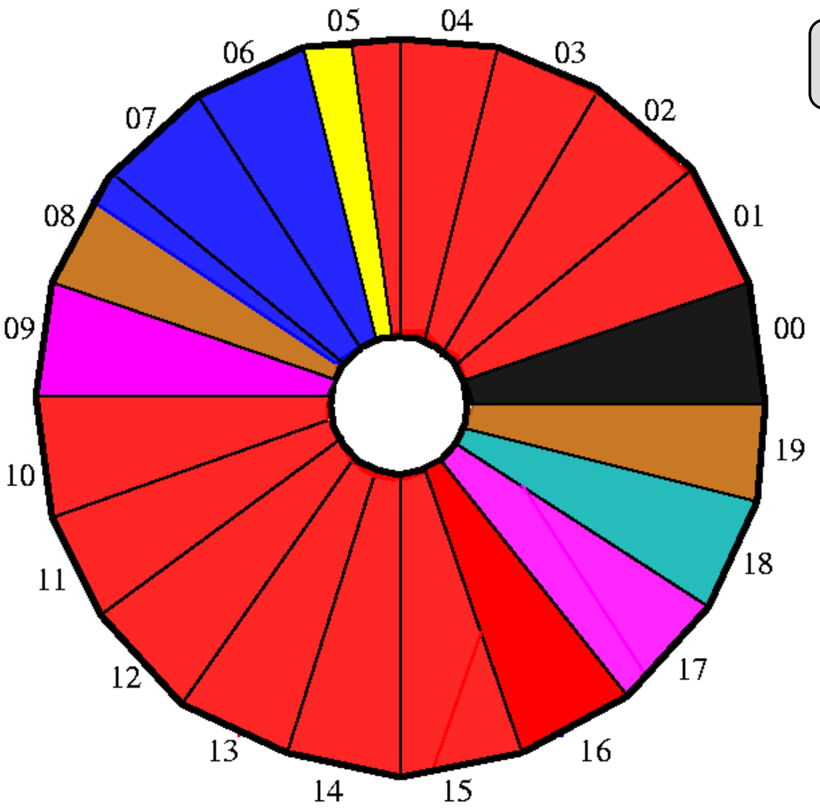
- It may be possible for double beta decay to occur without any neutrinos (predicted in various models)
- Would be a peak in the spectrum at the Q-value of the decay
- For this to happen the neutrino must be its own antiparticle, thus can be emitted in one decay and absorbed in the other
- If this happens then lepton conservation is broken
- This could lead to the answer to why there is more matter than antimatter in the universe
- Also possible to make predictions of the ν_e mass





NEMO 3 SETUP

- View looking from the top of the detector
- Split into segments (shown by different colours)



^{100}Mo 6.914 kg

$Q_{\beta\beta}$ = 3034 keV

^{82}Se 0.932 kg

$Q_{\beta\beta}$ = 2995 keV

ββ0ν search

ββ2ν 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

Detector Components

Cathode rings
Wire chamber

PMTs

Scintillators

ββ isotope foils

Detector Components

Tracking Chambers

On either sides of the thin sources there are gaseous tracking detectors. These consist of 6180 open drift cells operating in the Geiger mode allowing three-dimensional track reconstruction. To minimise the multiple scattering error on these measurements the gas is a mixture of He, 4% Ethyl alcohol, 1% Argon and 0.1% water.

Calorimeter

Outside the tracking regions, the calorimeters are made of 1940 plastic scintillators connected to PMTs. On the inside walls are 3” PMTs and on the outside 5” PMTs with energy resolutions of 17% and 14% at 1 MeV.

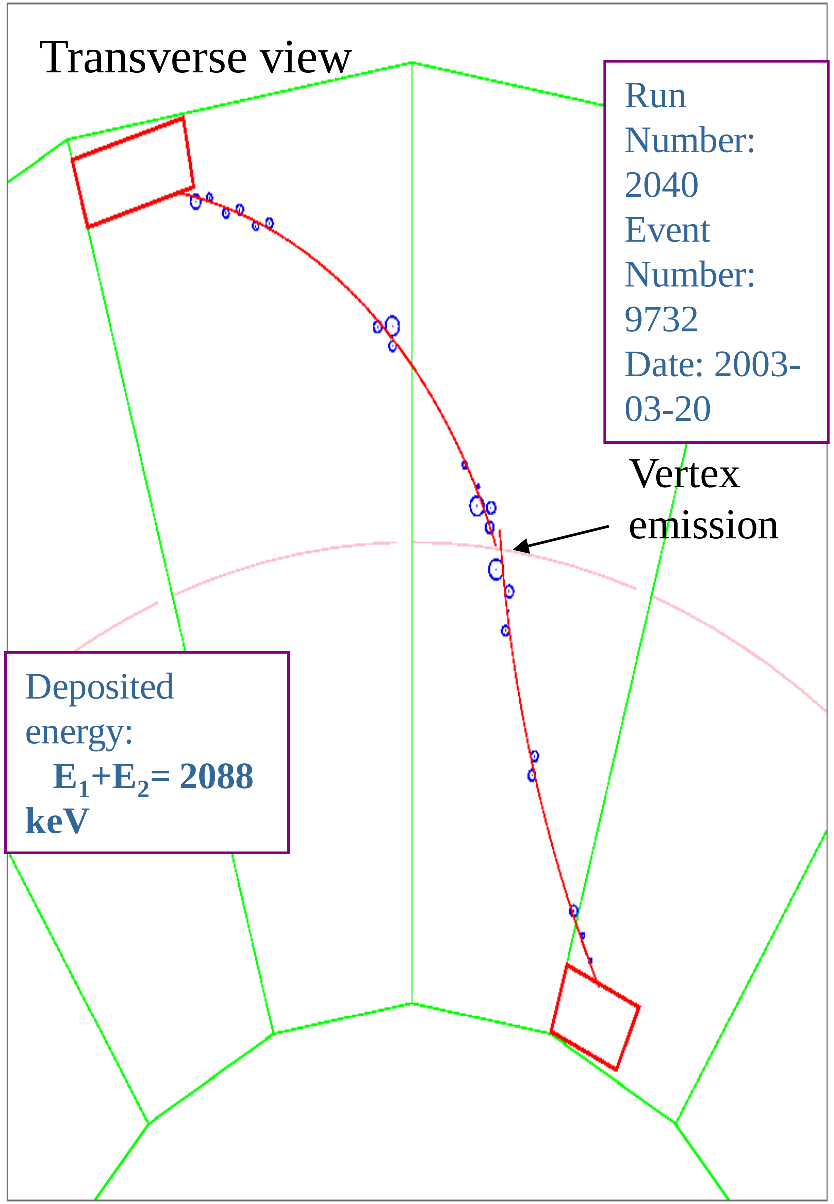
Solenoid Magnet

A surrounding field of 25 gauss allows electrons to be distinguished from positrons in the trackers.

2νββ – Decay Results

A 2νββ event is identified by the following

- 2 tracks come from the same vertex on the source foil
- Each track must fire a scintillator
- Curvature must correspond to a negative particle
- Energy thresholds of
  - 200 KeV fo ^{100}Mo
  - 300 KeV fo ^{82}Se



Transverse view

Run Number: 2040
Event Number: 9732
Date: 2003-03-20

Vertex emission

Deposited energy:
E_1+E_2= 2088 keV

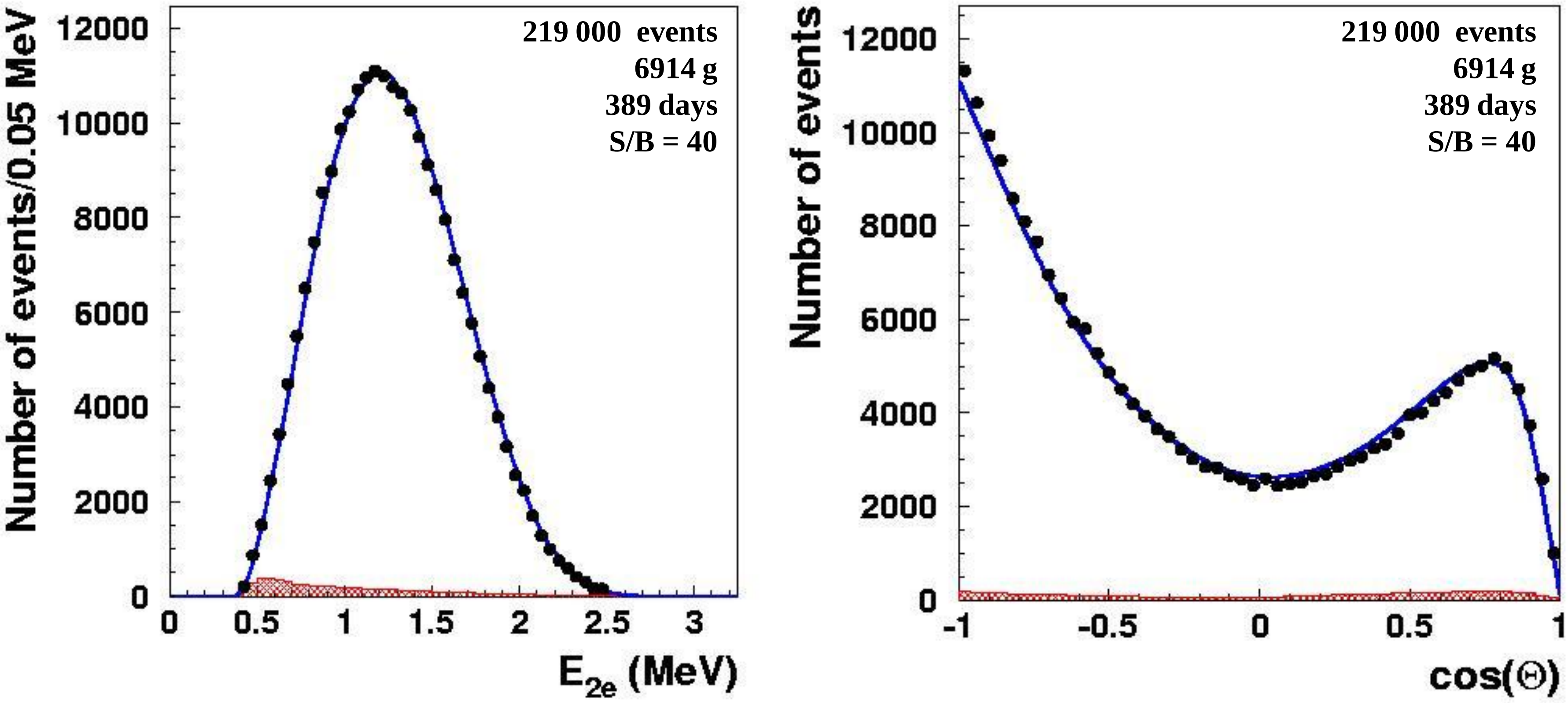
2νββ – Decay Results

^{100}Mo Results

Blue line = model

Red region = background

Dots = results



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

0νββ – Decay

Expect peaks in the 0νββ between combined electron energies of 2.8-3.2 MeV. Needed a detailed measurement of all the backgrounds to be taken at this energy in order to understand results.

	^{100}Mo	^{82}Se
External Sources		
^{214}Bi and ^{208}Tl in PMT	$\leq 10^{-3}$	$\leq 10^{-3}$
n and high-Energy γ (>4 Mev)	$\approx 3x10^{-3}$	$\approx 3x10^{-3}$
Internal Sources		
^{208}Tl impurities in source	0.1	0.3
Tail of 2νββ	0.3	0.2
Radon Gas in the trackers	1	1

All values are in units of count.kg^{-1}.yr^{-1}

$0\nu\beta\beta$ – Decay

Over the time of the experiment (389 days) these background rates correspond to values of

- 8.1 ± 1.3 events in the energy window 2.8-3.2 MeV for ^{100}Mo
    - 7 Events Observed!!
- 3.1 10 ± 0.6 events in the energy window 2.7-3.2 MeV for ^{82}Se
    - 5 Events Observed!!

Thus cannot say that $0\nu\beta\beta$ – Decay has been observed at NEMO 3

Maximum likelihood Analysis

To maximise the data from the experiment a likelihood fit was done using the electron pairs with energy > 2 MeV using the variables of E_{tot}, E_{min}, cosθ.

A 3D probability is given by

$$P^{3D} = P(E_{tot})P(\frac{E_{\min}}{E_{tot}})P(\frac{\cos\vartheta}{E_{\min}})$$

And the likelihood is given by

$$L = \prod_{i=1}^{N_{tot}}(\sum_{k=1}^{8} x_k P_k^{3D})$$

Maximum likelihood Analysis

Leads to values for the half life with a 90% C.L. To be,

$$T_{\frac{1}{2}}(0\upsilon\beta\beta) > 4.6\times10^{23}yr$$ For ^{100}Mo

$$T_{\frac{1}{2}}(0\upsilon\beta\beta) > 1\times10^{23}yr$$ For ^{82}Se

Mass estimates can be given using the half life by,

$$\frac{1}{T^{0\nu}_{1/2}} = G^{0\nu}(Q,Z)|M^{0\nu}|^2\langle m_\nu\rangle^2$$

Where G^{0v} and M^{0v} are matrix elements and $<m_v>$ is the expectation value of the neutrino mass

Maximum likelihood Analysis

$$\frac{1}{T_{1/2}^{0\nu}} = G^{0\nu}(Q,Z)|M^{0\nu}|^2\langle m_\nu\rangle^2$$

The mass depends on the matrix elements used but the mass ranges from

0.7-2.8 eV for 100Mo

1.7-4.9 eV for 82 Se

Any Questions?