Neutrinoless Double Beta Decay

By

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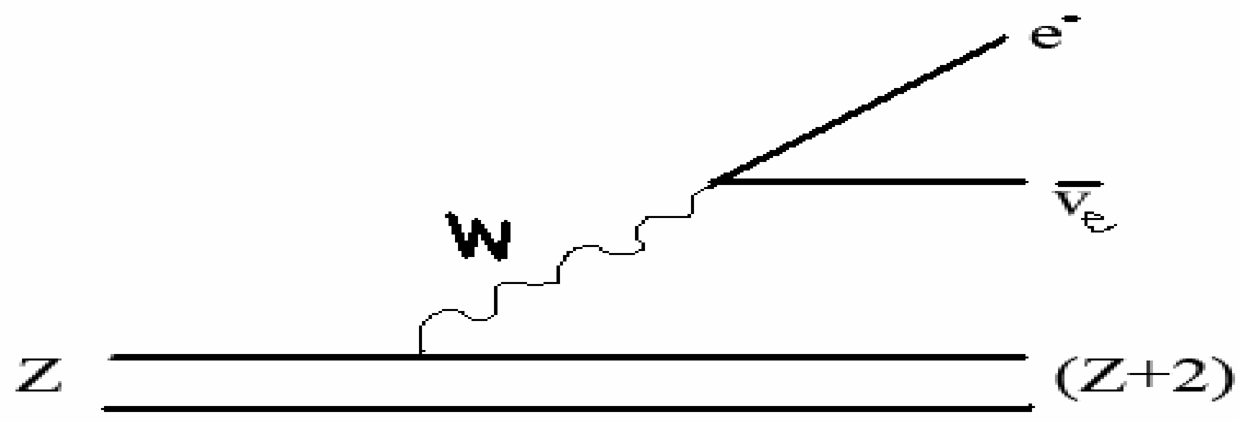
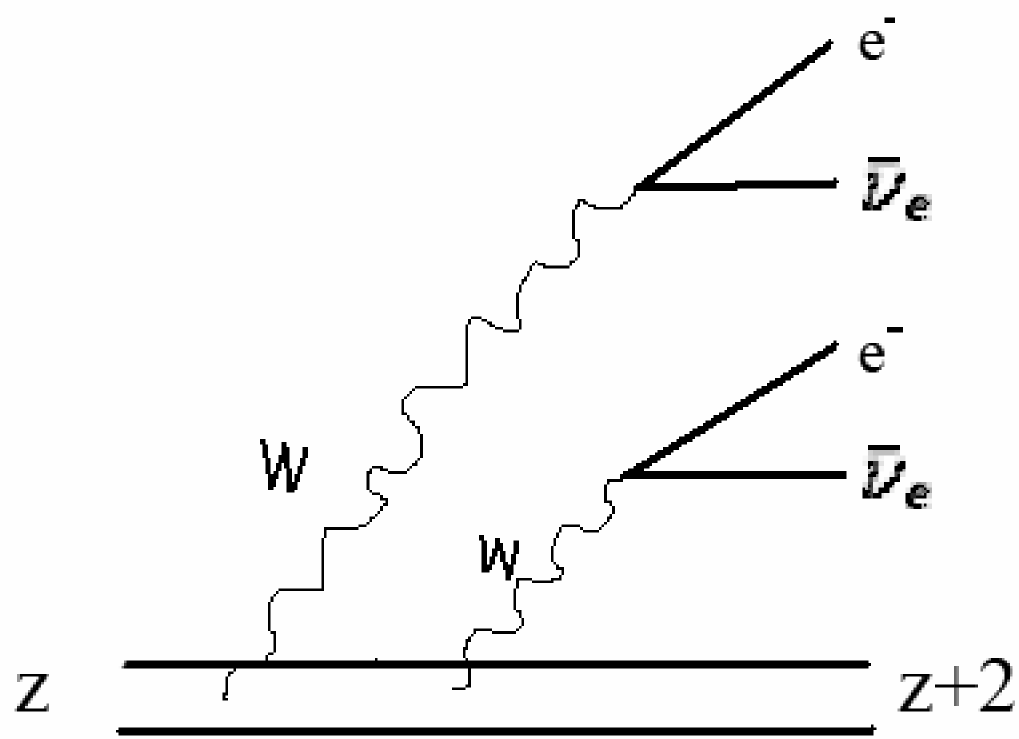
Normal Beta Decay

- $(Z,A) \rightarrow (Z+1,A) + e^- + \bar{\nu}_e$
- Ex. $n \rightarrow p + e^- + \bar{\nu}_e$



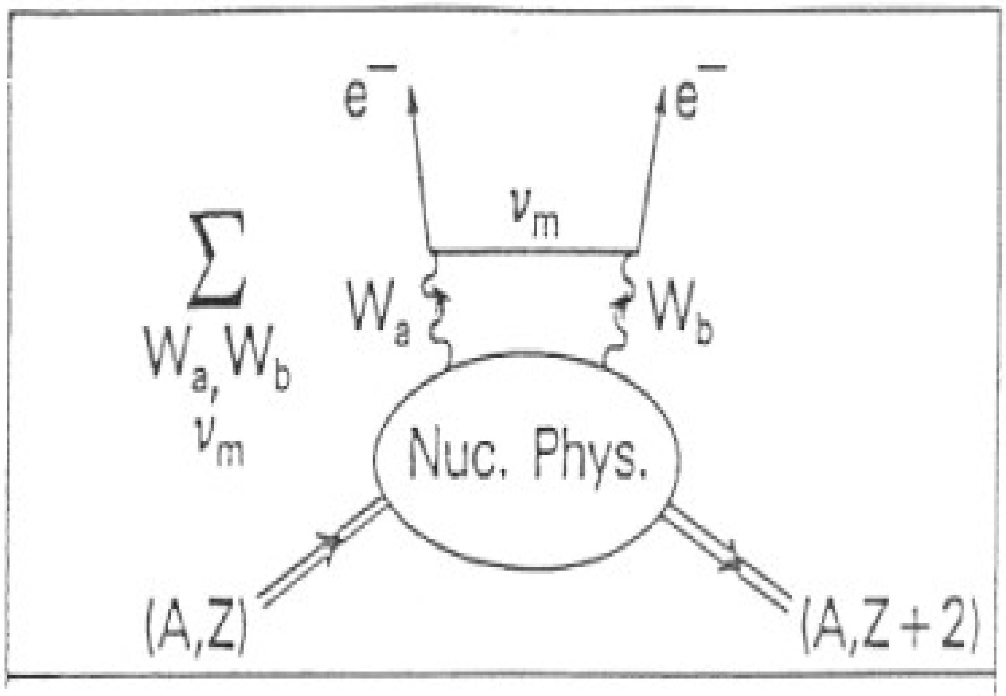
Double Beta Decay ββ(2v)

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



Neutrinoless Double Beta decay
ββ(0v)

(Z,A) →(Z+2, A) + e_1^- + e_2^-



Criteria

1. v=ύ
2. M_v≠0

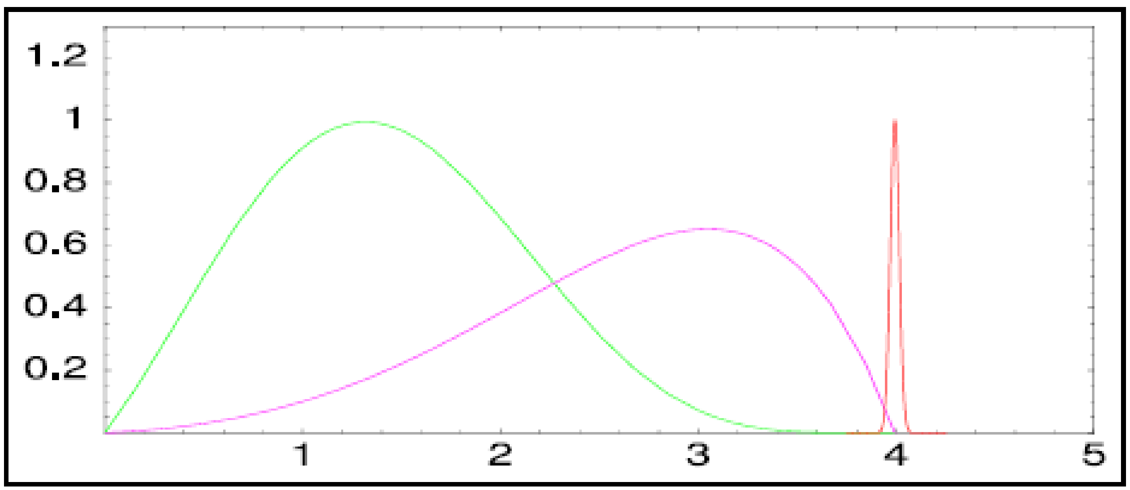
So, if we could observe ββ(0v)…

- Neutrino=antineutrino
- We'll have more to figure out about neutrinos.
- Earlier neutrino oscillation experiments showed that neutrinos have a finite mass.

→ This is encouraging for the search of ββ(0v) decay

How can we observe ββ(0v)

Theoretical Energy spectrum for
0v decay is different from 2v decay



Half-Life of ββ(0ν)

$$[T_{1/2}^{0\nu}]^{-1} = G^{0\nu} \mid M^{0\nu} \mid^2 < m_\nu >^2$$

G0v = two electron phase space integral

M0v=The scattering amplitude

<mv> =effective mass of neutrino

Calculated half-lives corresponding to <mv>=50meV

TABLE 2 $\beta\beta(0\nu)$ half-lives in units of 10^{26} y corresponding to $\langle m_\nu \rangle = 50$ meV for nuclear matrix elements evaluated in the references indicated

	References					
Nucleus	**(20)**	**(80)**	**(81)**	**(82)**	**(24, 83)**	**(84)**
^{48}Ca	12.7	35.3	—	—	—	10.0
^{76}Ge	6.8	70.8	56.0	9.3	12.8	14.4
^{82}Se	2.3	9.6	22.4	2.4	3.2	6.0
^{100}Mo	—	—	4.0	5.1	1.2	15.6
^{116}Cd	—	—	—	1.9	3.1	18.8
^{130}Te	0.6	23.2	2.8	2.0	3.6	3.4
^{136}Xe	—	48.4	13.2	8.8	21.2	7.2
^{150}Nd[a]	—	—	—	0.1	0.2	—
^{160}Gd[a]	—	—	—	3.4	—	—

[a] deformed nucleus; deformation not taken into account.

Experimental Criteria

$$< m_\nu > = (2.67 * 10^{-8} eV)[\frac{W}{fx\varepsilon G^{0\nu} | M^{0\nu} |^2}]^{1/2}[\frac{b\Delta E}{MT}]^{1/4}$$

To reach <mv>~ 50meV, approximately a ton of isotope will be required.

Best reported limits on $T_{1/2}^{0\nu}$

TABLE 3 Best reported limits[a] on $T_{1/2}^{0\nu}$

Isotope	$T_{1/2}^{0\nu}$ (y)	$\langle m_\nu \rangle$ (eV)	Reference
^{48}Ca	$>9.5 \times 10^{21}$ (76%)	<8.3	(98)
^{76}Ge	$>1.9 \times 10^{25}$	<0.35	(57)
	$>1.6 \times 10^{25}$	<0.33–1.35	(99)
^{82}Se	$>2.7 \times 10^{22}$ (68%)	<5	(60)
^{100}Mo	$>5.5 \times 10^{22}$	<2.1	(100)
^{116}Cd	$>7 \times 10^{22}$	<2.6	(73)
^{128,130}Te	$\frac{T_{1/2}(130)}{T_{1/2}(128)} = (3.52 \pm 0.11) \times 10^{-4}$ (geochemical)	<1.1–1.5	(75)
^{128}Te	$>7.7 \times 10^{24}$	<1.1–1.5	(75)
^{130}Te	$>1.4 \times 10^{23}$	<1.1–2.6	(101)
^{136}Xe	$>4.4 \times 10^{23}$	<1.8–5.2	(102)
^{150}Nd	$>1.2 \times 10^{21}$	<3	(68)

[a] The $\langle m_\nu \rangle$ limits and ranges are those deduced by the authors using their choices of matrix elements in the experimental papers cited. All are quoted at the 90% confidence level except as noted. The range of matrix elements that relate $T_{1/2}^{0\nu}$ to $\langle m_\nu \rangle$ can be found in Table 2.

Gotthard Tunnel Experiment

- 62.5%enriched^{136}Xe was used
- Detector tracked two-electrons, indicating of double beta decay.
- The energy resolution at the ββ(0v) endpoint(2.481Mev) was ~165keV (6.6%).
- The dominant background was Compton-scattered electrons from natural gamma activities.

Future experiments

TABLE 5 Proposed or suggested future $\beta\beta(0\nu)$ experiments, grouped by the magnitude of the proposed isotope mass[a]

Experiment	Source	Detector description	Sensitivity to $T_{1/2}^{0\nu}$ (y)
COBRA (111)	^{130}Te	10 kg CdTe semiconductors	1×10^{24}
DCBA (112)	^{150}Nd	20 kg ^{enr}Nd layers between tracking chambers	2×10^{25}
NEMO-3 (113)	^{100}Mo	10 kg of $\beta\beta(0\nu)$ isotopes (7 kg Mo) with tracking	4×10^{24}
CAMEO (114)	^{116}Cd	1 t $CdWO_4$ crystals in liquid scintillator	$>10^{26}$
CANDLES (115)	^{48}Ca	several tons of CaF_2 crystals in liquid scintillator	1×10^{26}
CUORE (116)	^{130}Te	750 kg TeO_2 bolometers	2×10^{26}
EXO (73)	^{136}Xe	1 t ^{enr}Xe TPC (gas or liquid)	8×10^{26}
GEM (117)	^{76}Ge	1 t ^{enr}Ge diodes in liquid N	7×10^{27}
GENIUS (118)	^{76}Ge	1 t 86% ^{enr}Ge diodes in liquid N	1×10^{28}
GSO (119, 120)	^{160}Gd	2 t Gd_2SiO_5:Ce crystal scintillator in liquid scintillator	2×10^{26}
Majorana (121)	^{76}Ge	0.5 t 86% segmented ^{enr}Ge diodes	3×10^{27}
MOON (122)	^{100}Mo	34 t ^{nat}Mo sheets between plastic scintillator	1×10^{27}
Xe (123)	^{136}Xe	1.56 t of ^{enr}Xe in liquid scintillator	5×10^{26}
XMASS (124)	^{136}Xe	10 t of liquid Xe	3×10^{26}