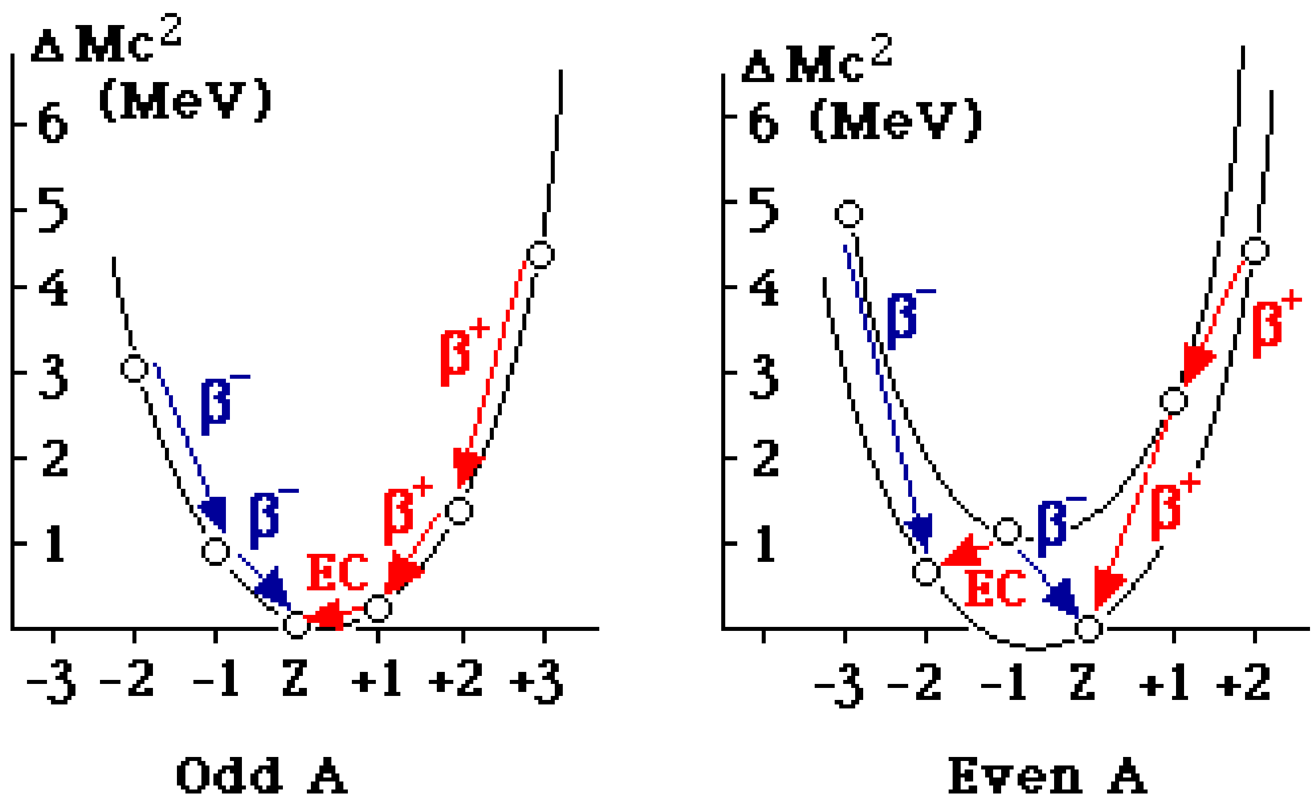
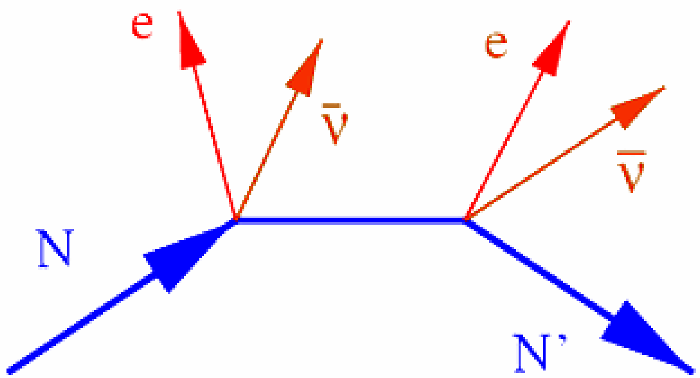
ββ decay and neutrino mass



35 isotopes in nature

Most sensitive neutrino mass measurements can be obtained from double-beta decay

$2\nu\ \beta\beta$ decay: a standard process in nuclear physics

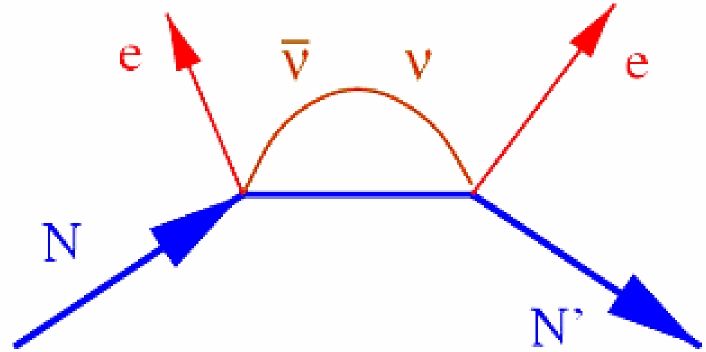


$0\nu\ \beta\beta$ decay: a hypothetical process

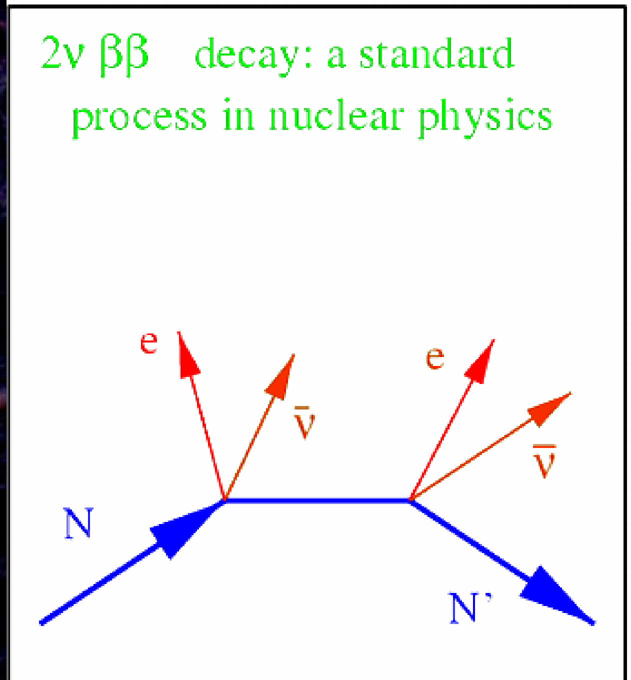
→ $m_\nu \neq 0$

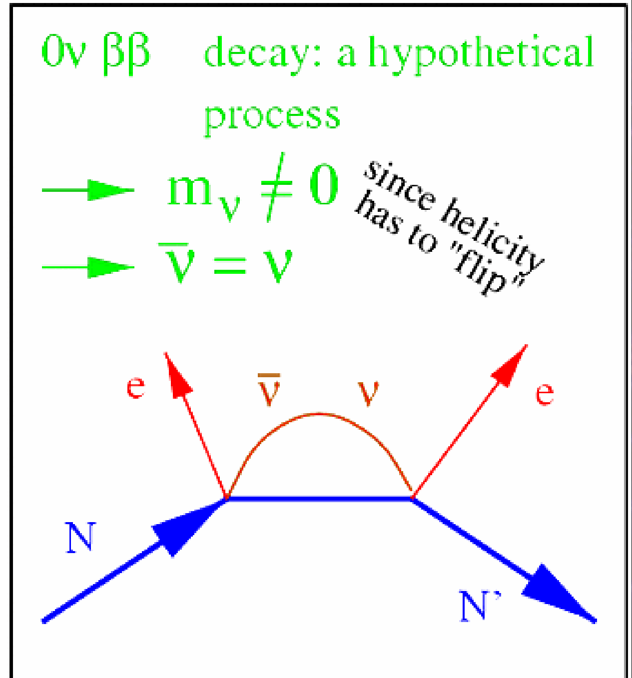
→ $\bar{\nu} = \nu$

since helicity has to "flip"



Most sensitive neutrino mass measurements can be obtained from double-beta decay



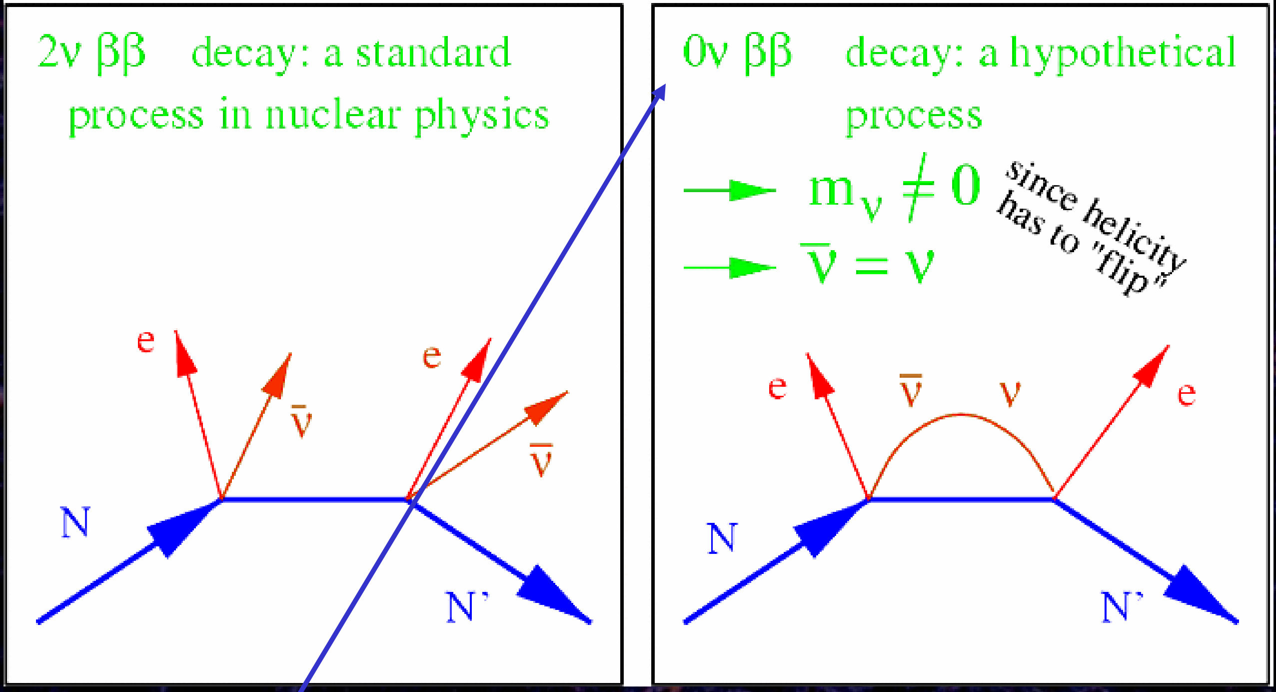


$$\langle m_\nu \rangle = m_{ee} = \left| \sum_k U_{ek}^2 m_k \right| = \left| \sum_k |U_{ek}|^2 e^{i\alpha_{ek}} m_k \right|$$

Each is ±1 if CP conserved, but there can still be cancellations

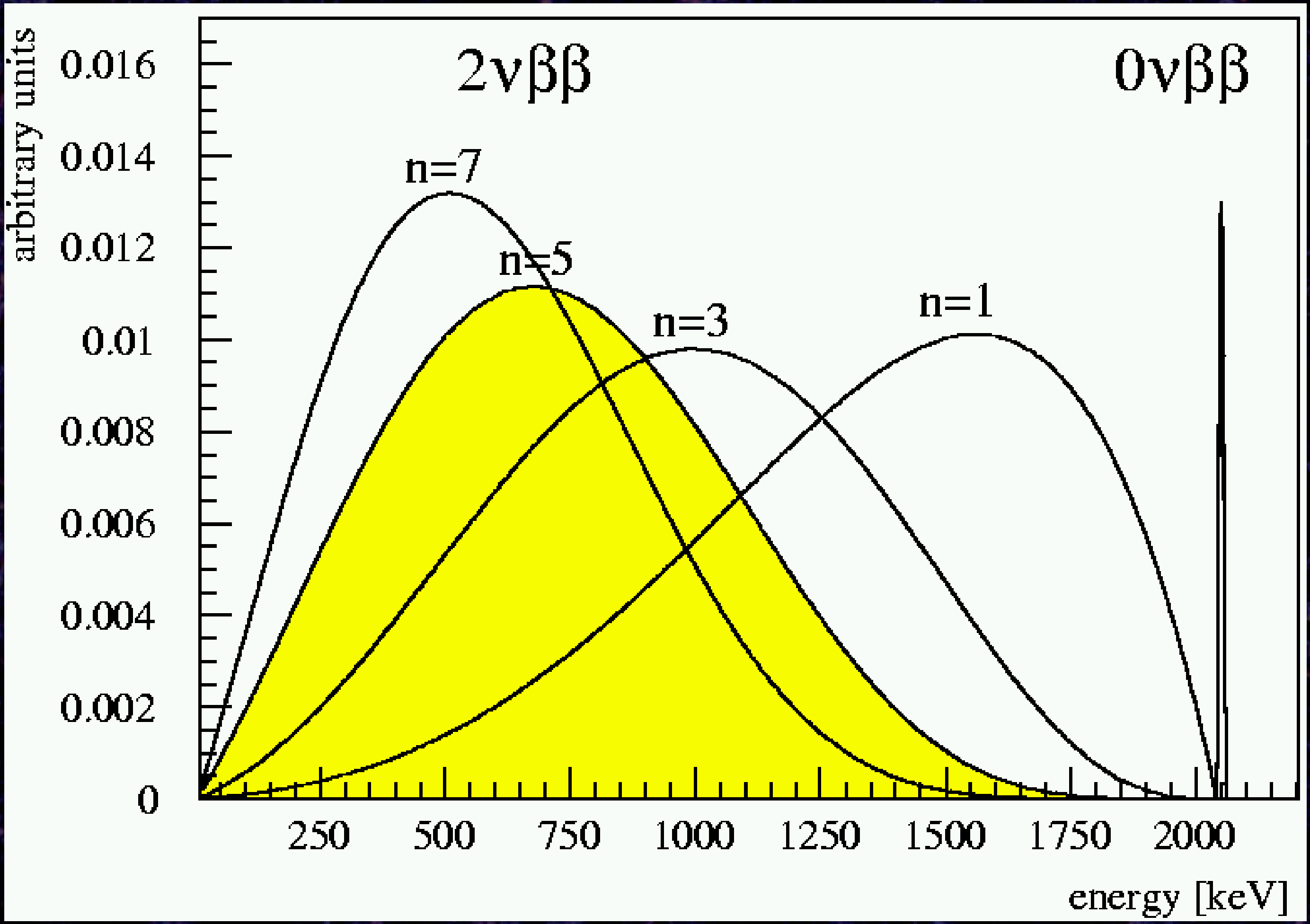
Dave Wark
Imperial College/RAL

Most sensitive neutrino mass measurements can be obtained from double-beta decay



$$1/t_{1/2} = (\text{phase space}) \cdot \left(\frac{\langle m_\nu \rangle}{m_e} \right)^2 \cdot \left| \sum M_{if} \right|^2$$

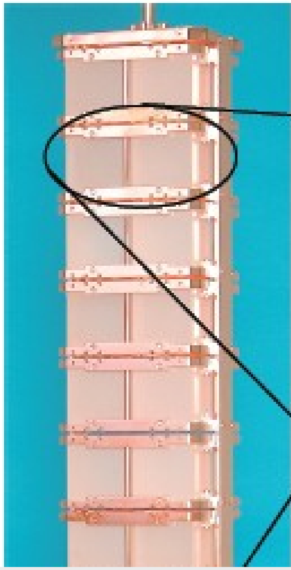
$0\nu\beta\beta$: Peak at Q-value of nuclear transition



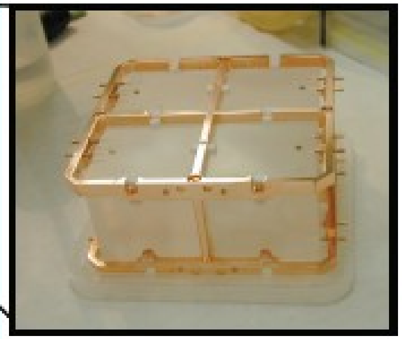
Sum energy spectrum of both electrons

Dave Wark
Imperial College/RAL

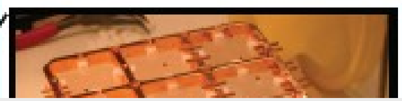
Cuoricino



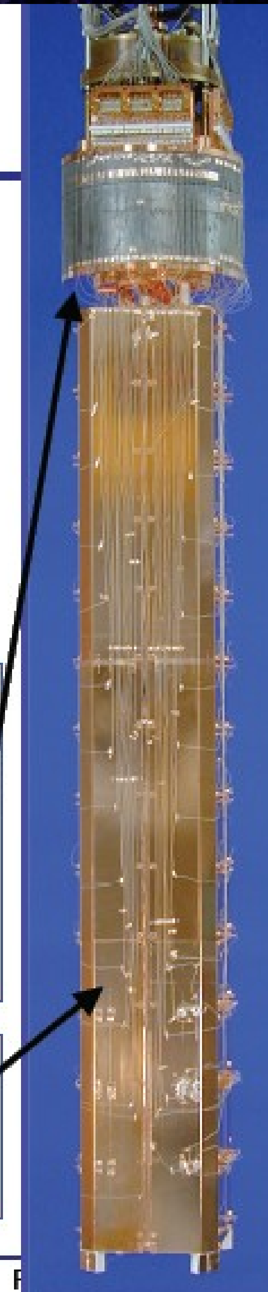
Total detector mass: 40.7 kg ⇒ 11.64 kg ^{130}Te



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



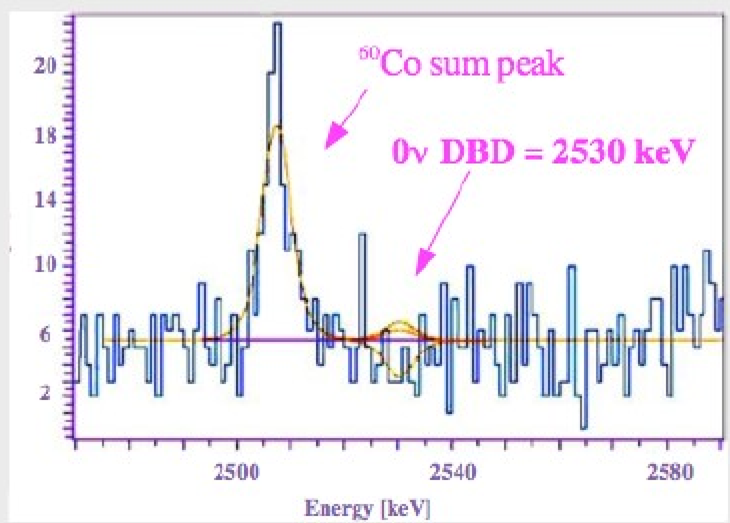
2 modules x 9 crystals each
crystal dimension: 3x3x6 cm^3



0ν –DBD result

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

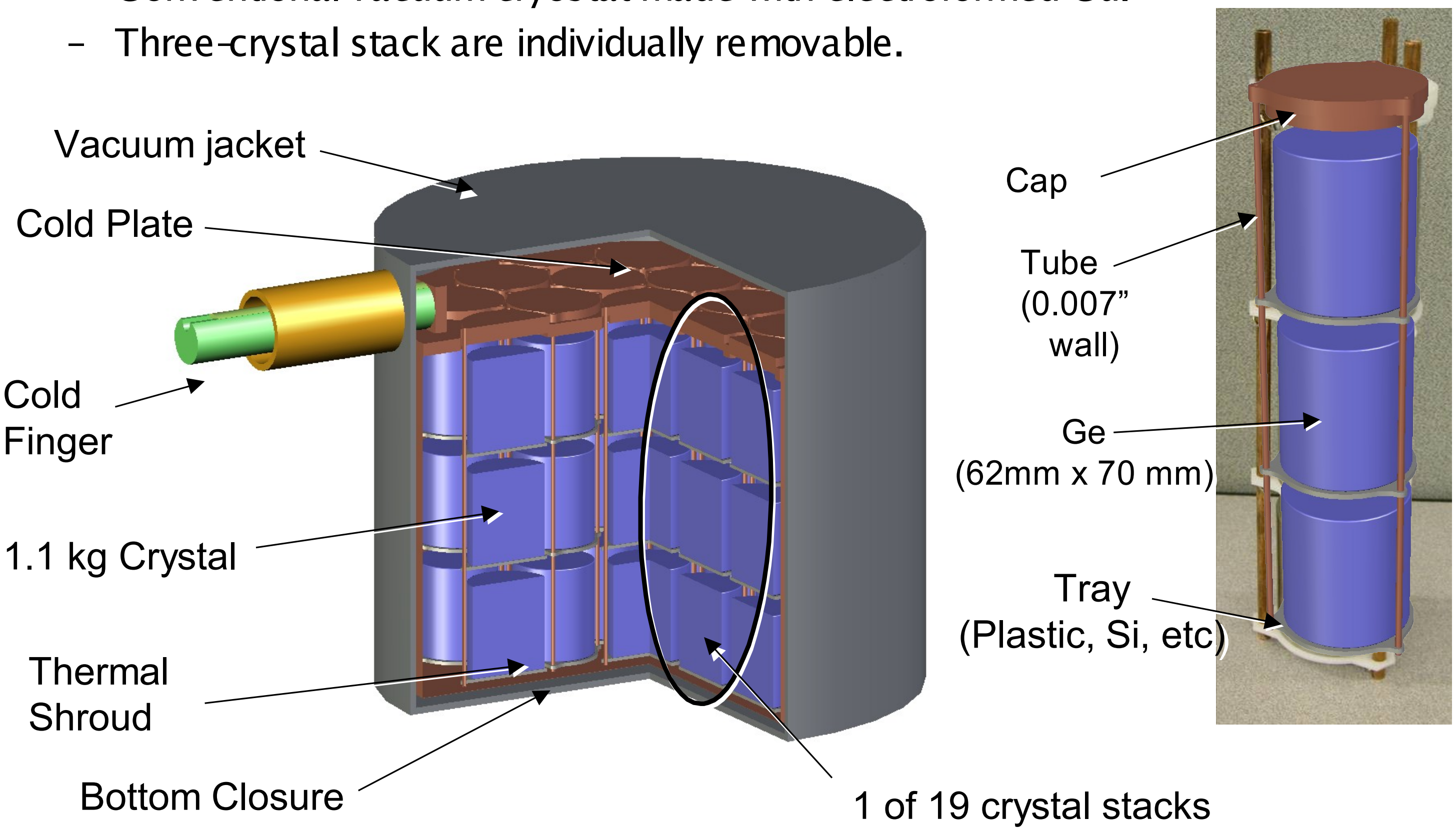
April 2003 - May 2006



Large-scale ^{76}Ge experiments also proceeding.

The Majorana Modular Approach

- 57 crystal module
  - Conventional vacuum cryostat made with electroformed Cu.
  - Three-crystal stack are individually removable.



Dave Wark
Imperial College/RAL

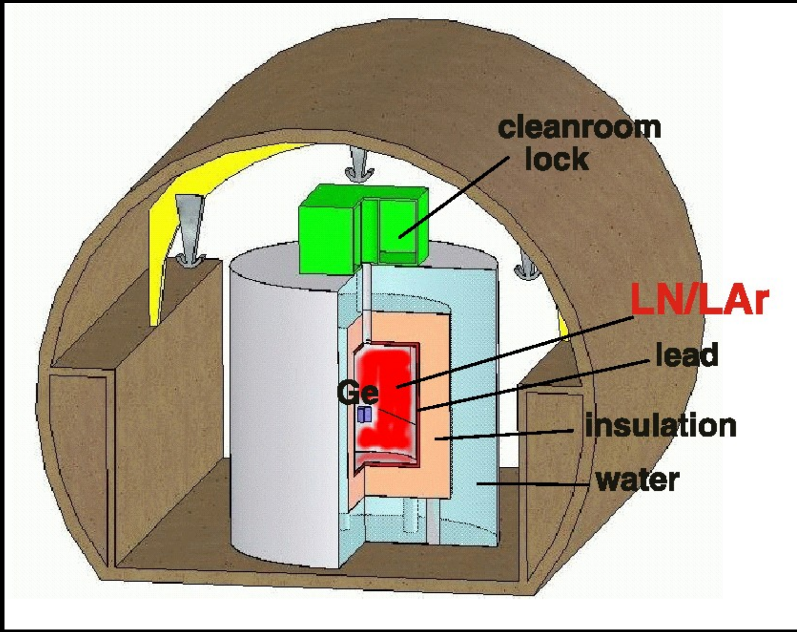
^{76}Ge effort also underway at LNGS.

GERDA's Experimental Concept

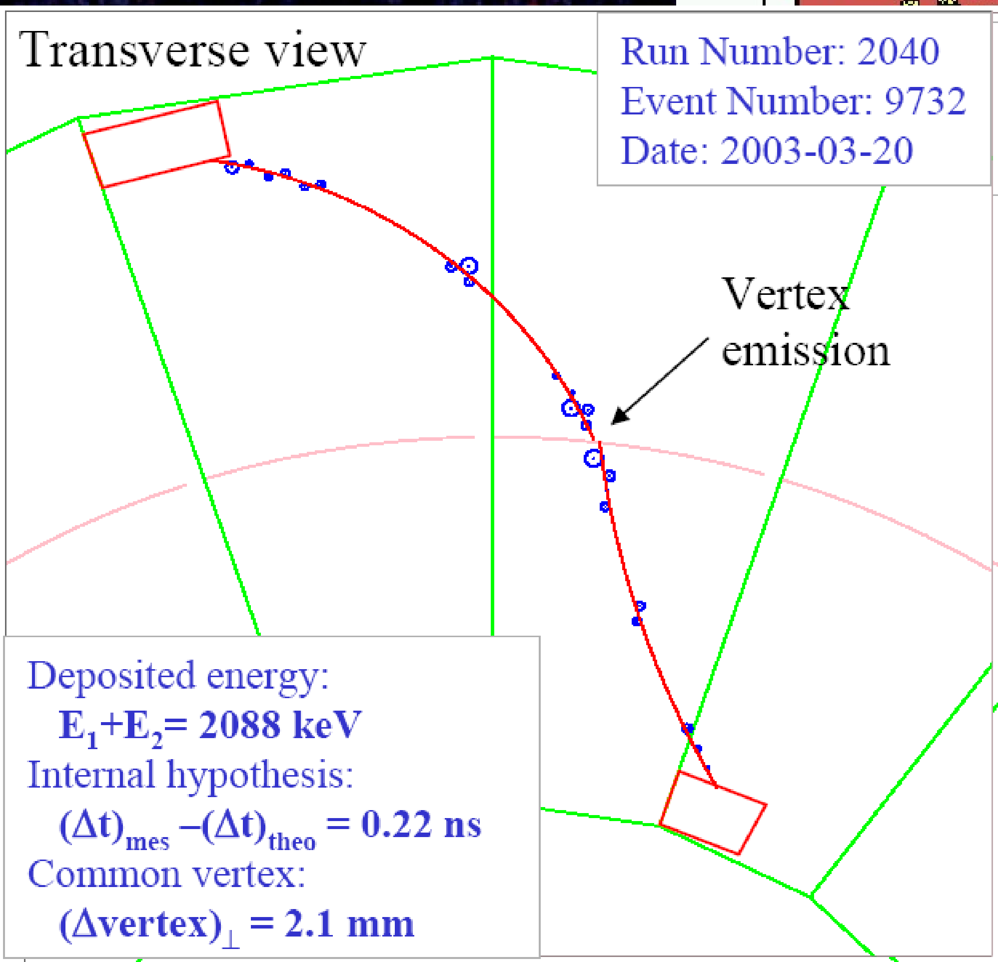
Assumption: External background is dominant

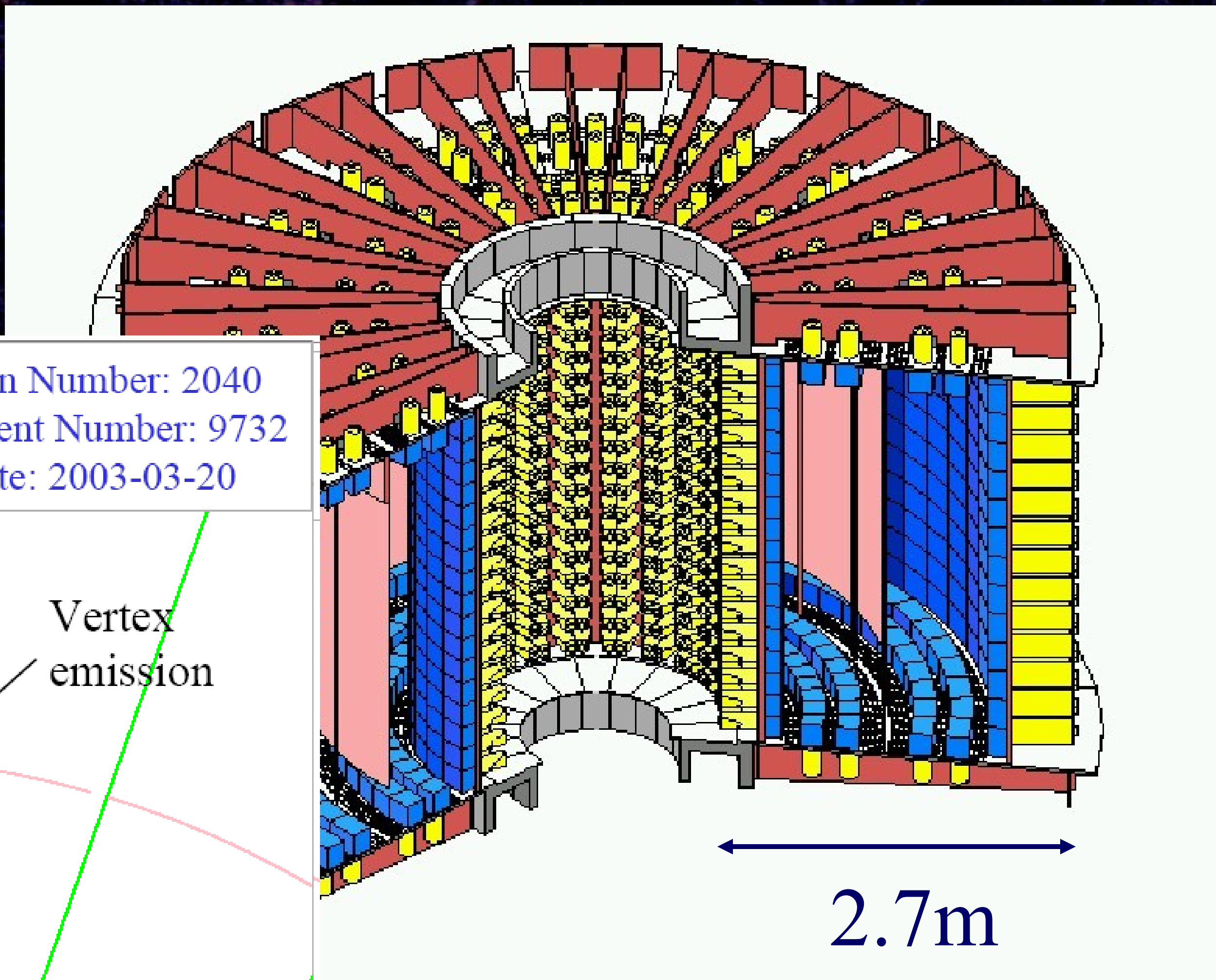
- Minimize all impure materials close to Ge diodes
- Operate Ge diodes in ultraclean environment
  → cryogenic liquid shield (LN or LAr); graded shielding
- Reject remaining background (internal and external) by exploiting different interaction topology
  (single-site ↔ multi-site; PSA)

Goal: Background index of 0.001 cts / (keV kg y) at $Q_{\beta\beta}$=2039 keV



NEMO-3



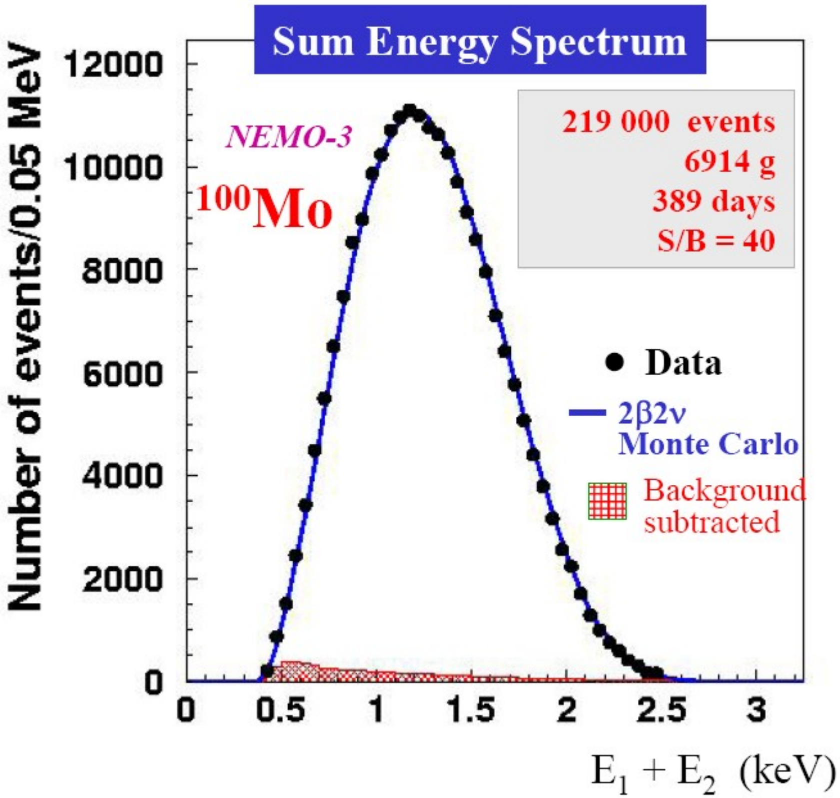


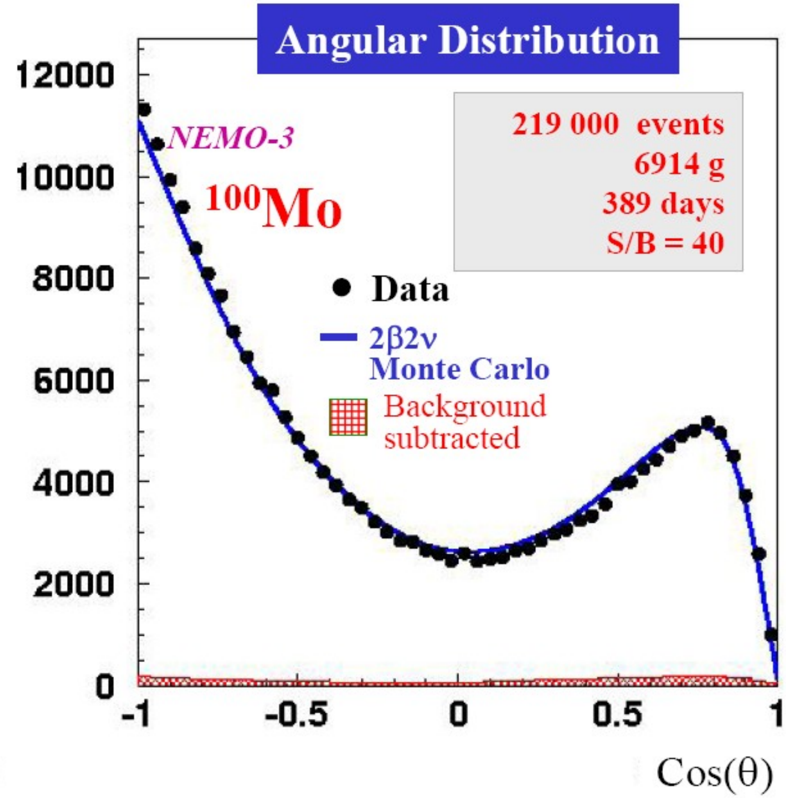
1. Layout of the NEMO-3 detector.

NEMO-3

^{100}Mo 2β2ν preliminary results

(Data Feb. 2003 – Dec. 2004)





7.37 kg.y

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

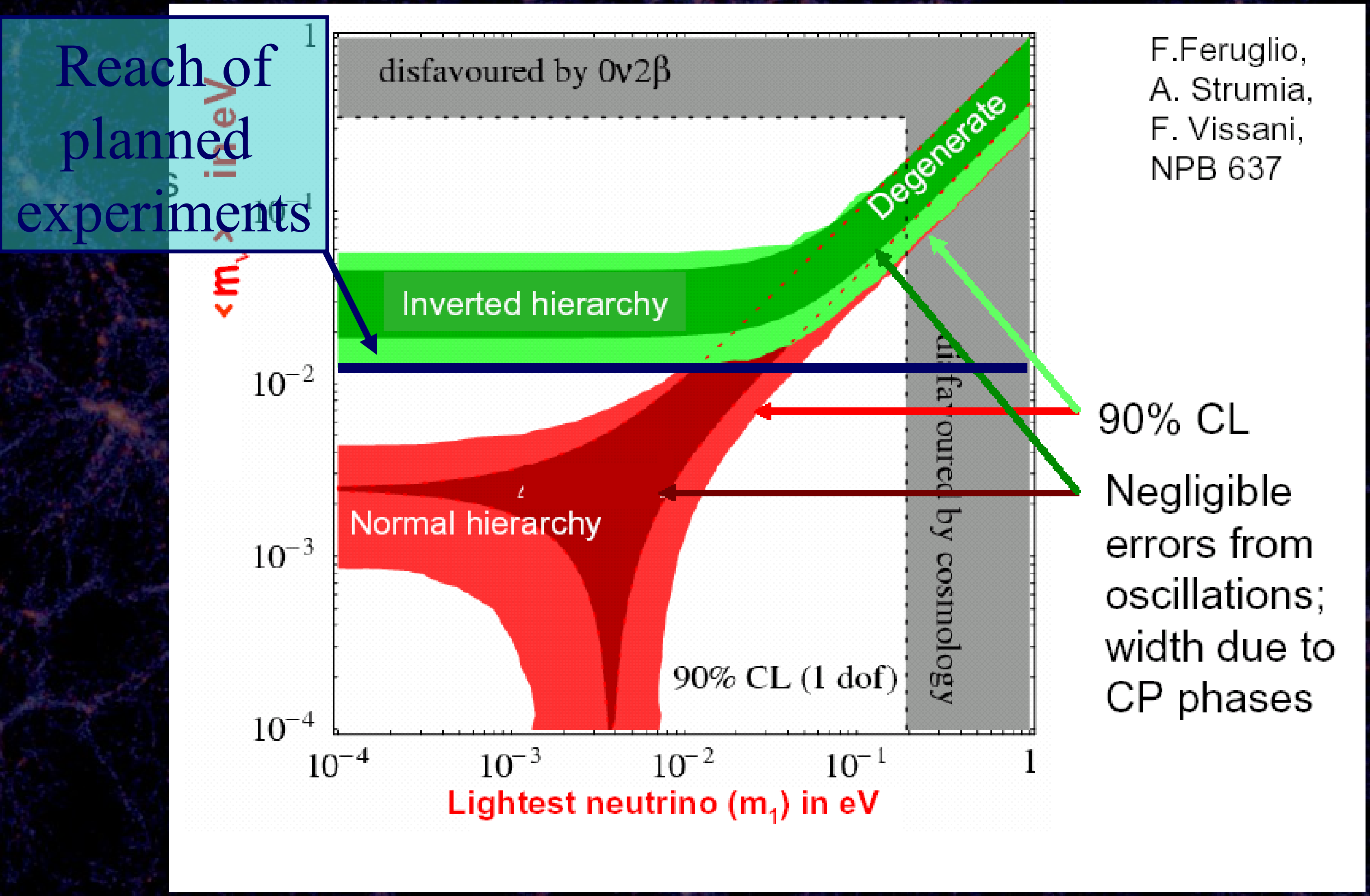
Neutrinoless ββ-decay limits

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

From Elliot and Vogel, hep-ph/0202264

Neutrinoless ββ-decay Future Projects

Experiment	Author	Isotope	Detector description	$T^{5y}_{1/2}$(y)	$\langle m_\nu \rangle$*
COBRA	Zuber 2001	^{130}Te	10 kg CdTe semiconductors	1×10^{24}	0.71
CUORICINO	Arnaboldi et al 2001	^{130}Te	40 kg of TeO_2 bolometers	1.5×10^{25}	0.19
NEMO3	Sarazin et al 2000	^{100}Mo	10 kg of bb(0n) isotopes (7 kg Mo) with tracking	4×10^{24}	0.56
CUORE	Arnaboldi et al. 2001	^{130}Te	760 kg of TeO_2 bolometers	7×10^{26}	0.027
EXO	Danevich et al 2000	^{136}Xe	1 t enriched Xe TPC	8×10^{26}	0.052
GEM	Zdesenko et al 2001	^{76}Ge	1 t enriched Ge diodes in liquid nitrogen + water shield	7×10^{27}	0.018
GENIUS	Klapdor-Kleingrothaus et al 2001	^{76}Ge	1 t enriched Ge diodes in liquid nitrogen	1×10^{28}	0.015
MAJORANA	Aalseth et al 2002	^{76}Ge	0.5 t enriched Ge segmented diodes	4×10^{27}	0.025
DCBA	Ishihara et al 2000	^{150}Nd	20 kg enriched Nd layers with tracking	2×10^{25}	0.035
CAMEO	Bellini et al 2001	^{116}Cd	1 t $CdWO_4$ crystals in liquid scintillator	$> 10^{26}$	0.069
CANDLES	Kishimoto et al	^{48}Ca	several tons of CaF_2 crystal in liquid scintillator	1×10^{26}	
GSO	Danevich 2001	^{160}Gd	2 t Gd_2SiO_5:Ce cristal scintillator in liquid scintillator	2×10^{26}	0.065
MOON	Ejiri et al 2000	^{100}Mo	34 t natural Mo sheets between plastic scintillator	1×10^{27}	0.036
Xe	Caccianiga et al 2001	^{136}Xe	1.56 t of enriched Xe in liquid scintillator	5×10^{26}	0.066
XMASS	Moriyama et al 2001	^{136}Xe	10 t of liquid Xe	3×10^{26}	0.086



Need new ideas to reach < 10 meV