Nuclear Structure Studies of ^{76}Se and ^{76}Ge from Inelastic Neutron Scattering

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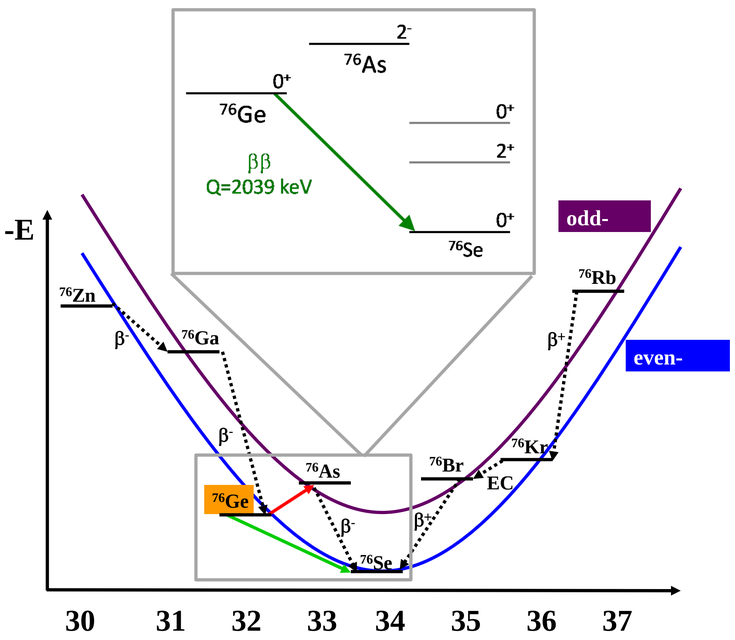
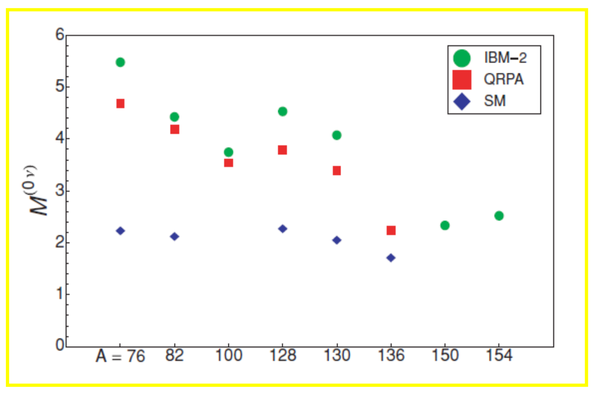
Experimental confirmation of neutrinoless double-beta decay ($0\nu\beta\beta$) would provide evidence of physics beyond the standard model by identifying the neutrino as its own anti-particle, *i.e.*, a Majorana particle. Furthermore, such a confirmation would yield the absolute mass scale of neutrinos, provided that the nuclear matrix elements involved in the calculation are understood to a high degree of accuracy. A favorite candidate for an investigation of the existence of $0\nu\beta\beta$ is the decay of ^{76}Ge to ^{76}Se, since ^{76}Ge can act as a source of the decay as well as a high-resolution detector for the resultant events. In order to increase our knowledge of the structural properties of these nuclei, excitation function and gamma-ray angular distribution measurements utilizing the ^{76}Ge(n,n'γ) and ^{76}Se(n,n'γ) reactions were performed at the University of Kentucky at neutron energies ranging from 2.0 MeV to 4.0 MeV. These measurements yield information on level spins and parities, level lifetimes, transition multipolarities, and transition probabilities.

Motivation for Investigating ^{76}Se and ^{76}Ge

Neutrinoless Double-beta Decay ($0\nu\beta\beta$)



Determination of the nuclear matrix element to some reasonable reliability is crucial to calculating the neutrino mass.



J. Barea and F. Iachello, Phys. Rev. C **79**, 044301 (2009)

$$\left(T_{1/2}^{0\nu}\right)^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)\left|M_{0\nu}\right|^2 \left\langle m_{\beta\beta}\right\rangle^2$$

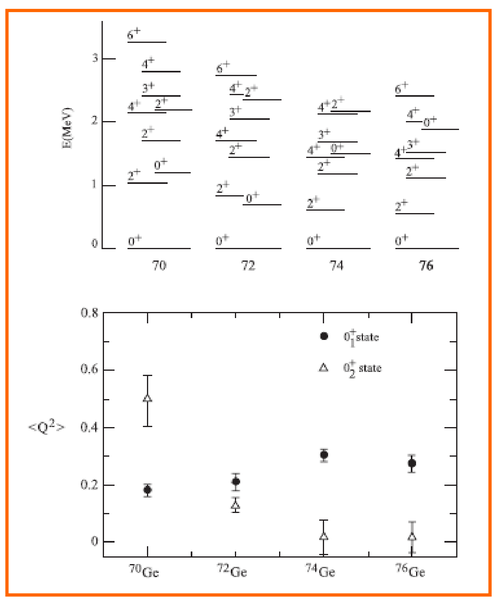
Phase space factor — Nuclear Matrix Element — Effective Majorana neutrino mass

Since $0\nu\beta\beta$ is a lepton-number-violating process, observing it (or not observing it) is a test of one of the fundamental symmetries of nature.

Shape Coexistence

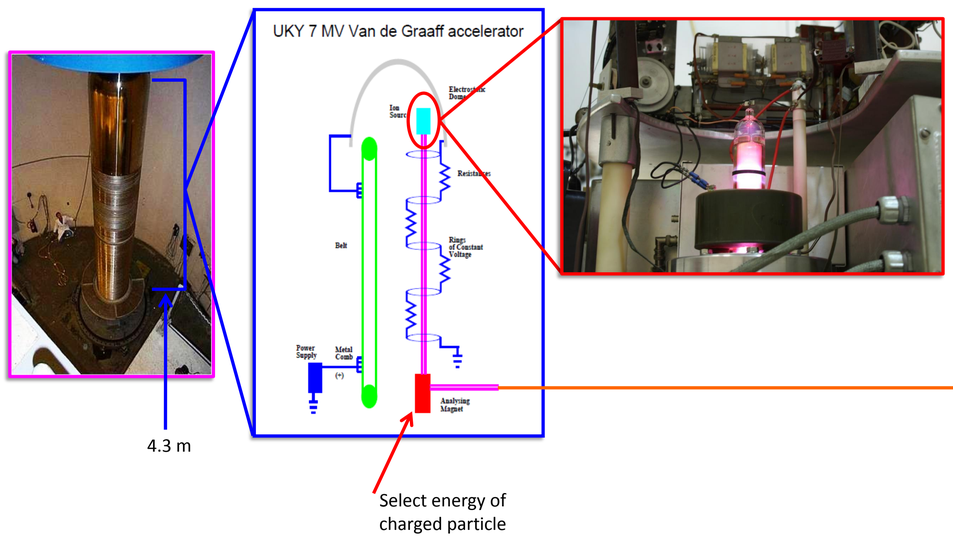
Shape coexistence has been identified in this mass region.

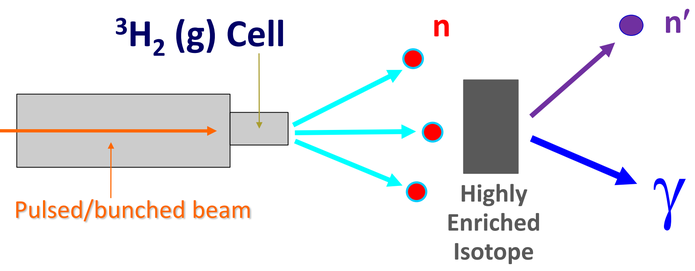
Further investigation into excited 0^+ states and possible rotational bands in this region may shed light on the role that subshells play in coexistence and collectivity.



J. L. Wood and K. Heyde, Rev. Mod. Phys. **83** 1467 (2011)

Studies at the University of Kentucky using Inelastic Neutron Scattering



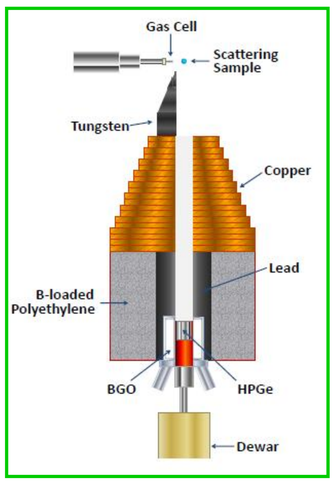


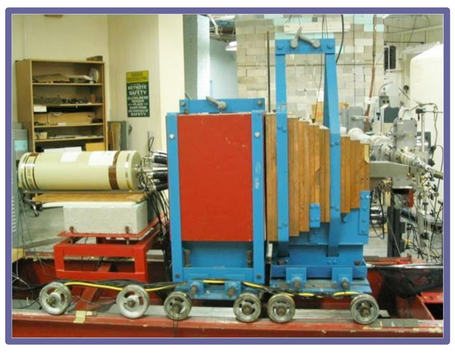
Monoenergetic Neutron Production

^{3}H (p,n)^{3}He Q = -1 MeV

γ-ray Detection

Compton-Suppressed HPGe Detector





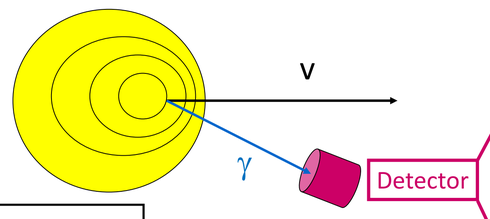
^{76}Ge, ^{76}Se

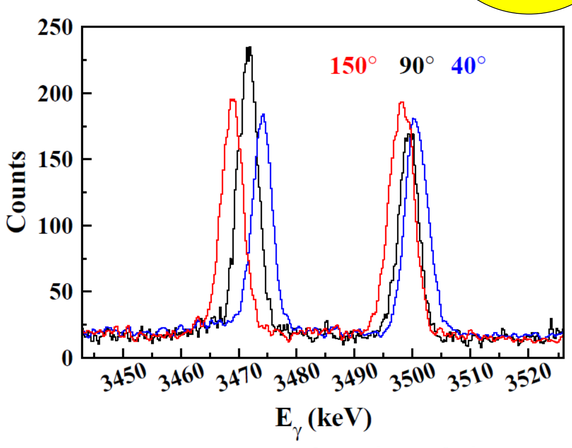
Excitation Function: 2.0 – 4.0 MeV

Angular Distribution: 3.0 and 3.7 MeV at 11 angles

Doppler-shift Attenuation Method (DSAM)

Determine lifetimes in the range of 10^{-15} to 10^{-12} s



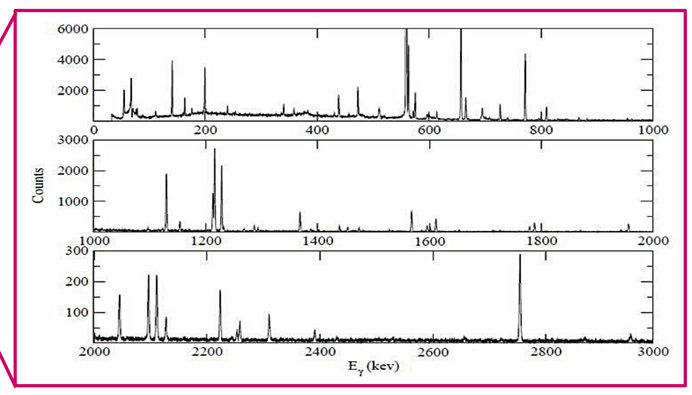


Singles (n,n'γ)

Excitation Functions: Energy Thresholds, Spins

Angular Distributions: Spins, Lifetimes, Branching Ratios, Multipole Mixing Ratios (δ), Transition Strengths

^{76}Se(n,n'γ), E_n = 3.0 MeV



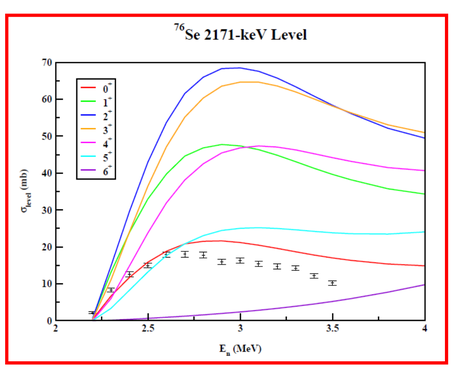
Doppler-shifted energy of gamma ray

$$E_\gamma(\theta) = E_0[1 + F_{\exp}(\tau)\beta\cos\theta]$$

$$\beta = \frac{v_{cm}}{c} = 0.04635\left(\frac{A_n}{A_n + A_A}\right)\sqrt{\frac{E_n}{A_n}}$$

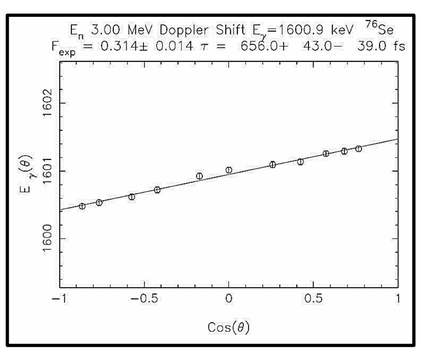
T. Belgya, G. Molnár, and S.W. Yates, Nucl. Phys. **A607**, 43 (1996).

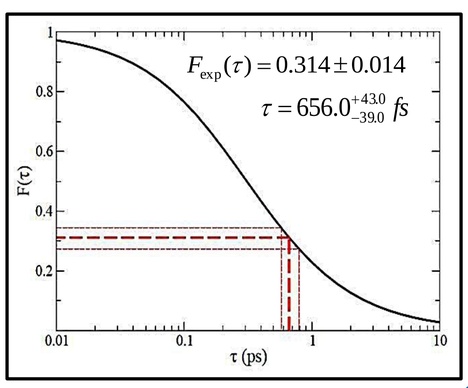
Excitation Functions



Comparison of experimental cross sections with statistical model (CINDY) calculations supports the tentative 0^+ spin assignment of the 2171-keV level in ^{76}Se.

Angular Distributions (DSAM)





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