NEUTRINOLESS DOUBLE β DECAY:
THE NUCLEAR STRUCTURE INGREDIENT

Benjamin P. Kay[1], John P. Schiffer[1], Sean Freeman[2], Tatsuya Adachi[6], Jason A. Clark[3], Catherine M. Deibel[3], H. Fujita[6], Yoshitaka Fujita[6], Peter Grabmayr[5], Kichiji Hatanaka[6], D. Ishikawa[6], Yoshikazu Meada[6], H. Matsubara[6], Hiroyuki Okamura[6], Karl E. Rehm[1], Y. Sakemi[6], Y. Shimizu[6], H. Shimoda[6], K. Suda[6], Y. Tameshige[6], Atsushi Tamii[6], Antonio C. C. Villari[4], Christopher Wrede[3]
[1]Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439; [2]Schuster Laboratory, University of Manchester, M13 9PL, UK; [3]Wright Nuclear Structure Laboratory, Yale University, CT 06520; [4]GANIL (IN2P3/CNRS – DSM/CEA) B.P. 55027 14076 Caen Cedex 5, France; [5]Physikalisches Institut, Universitat Tubingen, D-72076 Tubingen, Germany; [6]Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan

INTRODUCTION

The observation of neutrinoless double β decay would offer an opportunity to determine the mass of the neutrino, if the nuclear matrix element was known. As it stands, there is a lack of clarity in the approaches to calculating the nuclear matrix elements; variations at the 'order-of-magnitude' level are seen in the results. This would be reflected in the uncertainty of any calculated mass following a positive observation of the process and constitutes a concern in the community (1).

In order to constrain the calculations, we set out to provide nuclear-structure information relevant to the decay process. There is no reaction that directly mimics neutrinoless double β decay. However, the ground-state wave functions of the parent and daughter nuclei, and the differences between them, must be important ingredients—these can be probed using single-nucleon transfer reactions. In this work we study neutrinoless double β decay candidate nuclei ^{76}Ge (parent) and ^{76}Se (daughter) aiming to map out the proton and neutron occupancies of their ground states.

EXPERIMENTAL

This program of research was performed as several experiments, each in a similar manner, best exploiting two facilities: the Wright Nuclear Structure Laboratory (WNSL—Yale) and the Research Center for Nuclear Physics (RCNP—Osaka). At WNSL, the neutron-adding and removing reactions, (p,d), (^{3}He,α), (d,p) and (α,^{3}He), were performed (2). The respective beams bombarding isotopically enriched targets of ^{76}Ge and ^{76}Se (^{74}Ge and ^{78}Se were also used for consistency checks) at energies favorable for single-nucleon transfer. The outgoing ions were momentum analyzed by an Enge split-pole spectrograph at various angles. A gas-filled focal-plane detector backed by a plastic scintillator provided particle identification. The angular distribution of the outgoing ions provides information on angular-momentum transfer. To deduce absolute cross sections, the elastic scattering cross section was measured at angles corresponding to Rutherford scattering.

The proton adding and removing reactions, (^{3}He,d) and (d,^{3}He) were measured at RCNP using the Grand Raiden spectrometer (3). In order to deduce the spins of the states populated in the (d,^{3}He) reaction a polarized deuteron beam was used. The focal-plane detector consisted of vertical drift chambers backed by a plastic scinitllator.

RESULTS

Cross sections extracted from the data were used to extract spectroscopic factors and hence determine the occupations using the Macfarlane and French sum rules. The results for both neutrons and protons are shown in Figure 1 (3), and compared to recent theoretical results. It is seen that the Fermi surface is much more diffuse than result (A) suggests. Both results (B) and (C) are tuned to spectroscopic data, hence the apparent improvement.

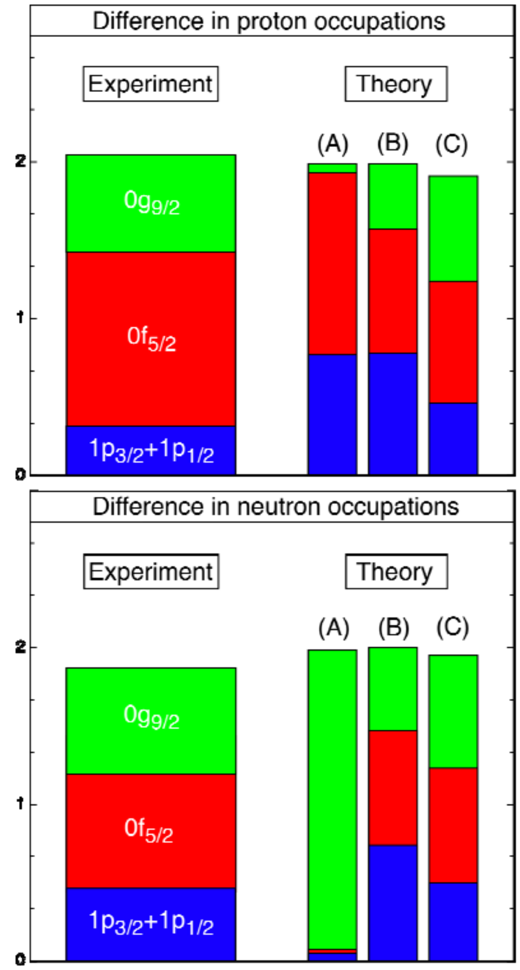

Figure 1. Experimental results compared with theoretical results from References (4), (5) and (6).

ACKNOWLEDGMENTS

This work is supported by the UK Science and Technology Facilities Council, the US Department of Energy, Office of Nuclear Physics, under Contract Nos. DE-FG02-91ER-40609 and DE-AC02-06CH11357, the IN2P3 / CNRS-France and the German BMBF.

REFERENCES

1. J.N. Bahcall, H. Murayama, and C. Pena-Garay, Phys. Rev. D 70, 033012 (2004).
2. J.P. Schiffer *et al.*, Phys.Rev.Lett. 100, 112501 (2008).
3. J.P. Schiffer *et al.*, in preparation (2008).
4. V.A. Rodin and A. Faessler, private communication, see Phys. Rev. C 68, 044302 (2003) and Nucl. Phys. A766, 107 (2006) for method.
5. E. Caurier et al., private communication, see Phys. Rev. Lett. 100, 052503 (2008) for method.
6. J. Suhonen and O. Civitarese, arXiv:0803.1375v2 [nucl-th].