Systematic Exploration of 0^+ States in Deformed Nuclei ◇

D. A. Meyer [a], G. Graw, R. Hertenberger, H.-F. Wirth, R.F. Casten [a], P. von Brentano [b], D. Bucurescu [c], S. Heinze [b], J. L. Jerke [a], J. Jolie [b], R. Krücken, P. Pejovic [b], O. Möller [b], D. Mücher [b], and C. Scholl [b]

[a] Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut 06520-8124, USA
[b] Institut für Kernphysik, Universität zu Köln, D-50937 Köln, Germany
[c] National Institute of Physics and Nuclear Engineering, Bucharest, Romania

The puzzling nature of 0^+ excitations has recently attracted new attention. An experiment [1] measuring 0^+ states in ^{158}Gd by way of the (p,t) transfer reaction unearthed 7 new 0^+ states and confirmed 6 previously known below an excitation energy of ~3.1 MeV. Experiments involving other even-even nuclei, such as those in the actinide [2] and rare earth regions, will show whether such a large number of 0^+ excitations in this energy range is widespread. If indeed it is, we can begin to map out their evolution in energy with N and Z and to interpret their structures. Such an extensive study of collectivity in 0^+ states requires systematic data. As shown in Fig. 1, we examined 16 nuclei spanning the rare earth region: ^{152}Gd, ^{154}Gd, ^{158}Gd (revisited), ^{162}Dy, ^{168}Er, ^{170}Yb, ^{176}Hf, ^{180}W, ^{184}W, ^{190}Os, ^{192}Pt, ^{194}Pt, ^{196}Hg, ^{198}Hg, ^{200}Hg, and ^{202}Hg. These nuclei have very different classifications *i.e.*, transitional, deformed, γ-soft, and spherical. In choosing structurally different nuclei, we hope to gain information about trends and types of possible 0^+ excitations.

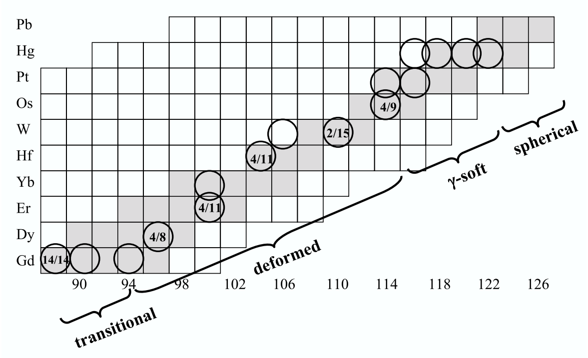

Fig. 1: Portion of the nuclear chart showing the region studied in this work. Shaded boxes are stable nuclei. Final nuclei in the present (p,t) experiments are circled, and pairs of numbers give the previously and presently known numbers of 0^+ states below ~3 MeV. Tentative assignments are not included.

The (p,t) experiments were performed using the Q3D magnetic spectrograph. An unpolarized beam of 25 MeV protons was incident on 16 different isotopically enriched rare earth targets. Outgoing tritons were measured at three different laboratory angles: 5, 17.5, and 30 degrees. The 1 m long focal plane detector [3] identified particles with a resolution of 4–6 keV for tritons of 15–20 MeV. Data for each target were collected up to ~3 MeV excitation energy. To determine the 0^+ states, the relative cross sections were compared to those expected in the distorted wave Born approximation (DWBA). 0^+ states are populated with L = 0 transferred angular momentum which can be identified with the strongly forward-peaking L = 0 angular distribution.

While full analysis remains in progress, preliminary results for six nuclei are compared: ^{158}Gd, ^{162}Dy, ^{168}Er, ^{176}Hf, ^{184}W, and ^{190}Os. The number of 0^+ states in these nuclei (except ^{158}Gd) is much greater than previously recorded in the literature as shown in Fig. 1.

Aside from the number of new states, the energy distributions and relative strengths of the 0^+ states proves interesting as can be seen in Fig. 2. Some nuclei, such as ^{168}Er, have fairly evenly distributed 0+ states. Others, such as ^{162}Dy, show clusters of 0^+ states and fewer in total below ~3 MeV.

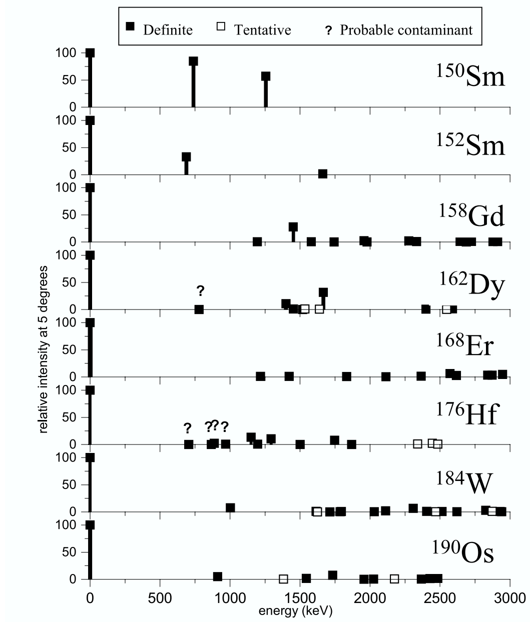

Fig. 2: Energies and cross sections for the 0^+ states in the nuclei studied. The nuclei ^{150,152}Sm are shown for comparison using data from Ref. [4].

Interpretation of 0^+ states in these nuclei is underway. Calculations carried out with the IBA, when compared with the data, show good agreement with yrast level energies. We are investigating whether models with additional degrees of freedom (e.g., multi-quasiparticle excitations or octupole-octupole modes) can account for the present data. Recent calculations [5] suggest that this may be the case, and hopefully such a broad study of the rare earth region will provide a more thorough experimental basis.

References

[1] S. R. Lesher *et al.*, Phys.Rev. **C66** (2002) 051305(R)
[2] H.-F. Wirth *et al.*, Phys.Rev. **C69** (2004) 044310
[3] H.-F. Wirth *et al.*, Annual report 2000, p. 71
[4] P. Debenham and N.M. Hintz, Nucl.Phys. **A195** (1972) 385
[5] N. Lo Iudice *et al.*, Phys.Rev. **C70** (2004) 064316

◇ This work supported by the U. S. DOE under Grant No. DE-FG02-91ER-40609, MLL, and DFG (C4-Gr894/2-3, Jo391/2-1).