PHYSICAL REVIEW C VOLUME 56, NUMBER 6 DECEMBER 1997

Evidence for a highly deformed oblate 0^+ state in $^{74}_{36}$Kr

C. Chandler,[1] P. H. Regan,[1] C. J. Pearson,[1] B. Blank,[2] A. M. Bruce,[3] W. N. Catford,[1] N. Curtis,[1] S. Czajkowski,[2] W. Gelletly,[1] R. Grzywacz,[4,5] Z. Janas,[2,4] M. Lewitowicz,[5] C. Marchand,[2] N. A. Orr,[6] R. D. Page,[7] A. Petrovici,[8] A. T. Reed,[7] M. G. Saint-Laurent,[5] S. M. Vincent,[1] R. Wadsworth,[9] D. D. Warner,[10] and J. S. Winfield[5]

[1]*Department of Physics, University of Surrey, Guildford, GU2 5XH, United Kingdom*
[2]*CEN Bordeaux-Gradignan, Le Haut-Vigneau, F-33175 Gradignan Cedex, France*
[3]*Cockcroft Building, University of Brighton, Brighton, BN2 4GJ, United Kingdom*
[4]*Institute of Experimental Physics, Warsaw University, Pl-00681, Warsaw, Poland*
[5]*GANIL, BP 5027, F-14000, Caen Cedex, France*
[6]*LPC, IN2P3-CNRS, ISMRA et Université de Caen, Bld. du Marechal Juin, F-14050, Caen Cedex, France*
[7]*Oliver Lodge Laboratory, Department of Physics, University of Liverpool, Liverpool L69 7ZE, United Kingdom*
[8]*Institute for Physics and Nuclear Engineering, PO Box MG-6, R-76900 Bucharest-Magurele, Romania*
[9]*Department of Physics, University of York, Heslington, York Y01 4DD, United Kingdom*
[10]*CCLRC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom*

(Received 28 May 1997)

We present the observation of an isomeric decay in the very neutron deficient nucleus $^{74}_{36}$Kr. The isomer is interpreted as an excited 0^+ state, consistent with the long standing prediction of high deformation prolate/oblate shape coexistence in this nucleus. The magnitude of the $E0$ matrix element deduced for the $0^+_2 \rightarrow 0^+_1$ transition gives strong support to the prediction of a highly deformed oblate rotor. [S0556-2813(97)50712-6]

PACS number(s): 21.10.Tg, 23.20.Lv, 25.70.Mn, 27.50.+e

Spectroscopic studies of neutron deficient nuclei around $A\sim 80$ have produced a wealth of information on the phenomenon of nuclear shape coexistence [1–4]. This effect arises from the competition between nuclear configurations polarized by the presence of regions of low level density, or ''shell gaps'' in the nuclear potential and is well documented in a number of regions of the nuclear chart [5]. In most cases of observed shape coexistence, the competition is between a well-deformed prolate minimum and a spherical or weakly oblate configuration. Indeed, convincing evidence for well-deformed *oblate* nuclear rotors in heavy nuclei is rather sparse, usually coming from either information on the sign of the mixing ratio for $M1/E2$ decays [6] or direct measurement of g-factors [7].

In this Rapid Communication we report the observation of a 0^+ isomeric state in the very neutron deficient nucleus, $^{74}_{36}$Kr with decay properties consistent with a highly deformed oblate shape. It will be demonstrated that the magnitude of the electric monopole transition connecting this isomer with the ground state gives strong support to the deformations of the configurations built on the two 0^+ states being large and of opposite sign.

The neutron deficient nuclei in the $A\sim 70-80$ region have long been proposed as good candidates for well-deformed oblate rotors ($\beta_2 \sim -0.35$) due to the presence of the $N,Z=36$ shell gap in the deformed shell model potential [6]. Indeed, well-deformed oblate shapes have been suggested from lifetime measurements [9] and angular distribution information [7] in the very light selenium nuclei. Competing prolate and spherical structures are also predicted to be favored in this region, due to the presence of competing shell gaps at nucleon numbers 38 and 40, corresponding to well-deformed prolate ($\beta_2 \sim 0.4$) and spherical ($\beta_2 \sim 0$) minima respectively. The effect of these three shell gaps is that the nuclear shape can change dramatically with the addition or subtraction of only a few nucleons.

There has been a significant body of work investigating the competition between these different configurations, notably by the Vanderbuilt/ORNL collaboration [2,3]. This has provided convincing evidence for shape coexistence in ^{76,78}Kr, with 0^+ states observed corresponding to the basis states of both the spherical and prolate deformed minima. The study of ^{78}Kr by Billowes *et al.* [8] suggested an oblate shape for the yrast two-quasi-particle structure above spin $8\hbar$ on the basis of the measured g factors for these states. The presence of the oblate shell gap is proposed to become more influential in the krypton isotopes with decreasing neutron number [6]. The reduction in the excitation energy of the first excited state in going from the $N=Z=36$ system $^{72}_{36}$Kr to the $N=Z=38$ nucleus $^{76}_{38}$Sr has been interpreted [6,10,11] as being due to a sudden alteration in the nuclear shape, from deformed oblate in $^{72}_{36}$Kr to deformed prolate in $^{76}_{38}$Sr. The study by Dejbakhsh *et al.* [4] inferred a well-deformed oblate ground state in the $N=Z=36$ system, ^{72}Kr, which is crossed at spin 2^+ by the highly deformed prolate configuration (although in this case, the decay from the proposed excited 0^+ state was not observed). Notably, the study of the odd-N neighboring nucleus, $^{73}_{36}$Kr did not reveal any evidence for a well deformed oblate structure [12].

The question then arises as to the nature of shape coexistence expected in the $N=38$ isotope, $^{74}_{36}$Kr. The discontinuity in the moment of inertia of the yrast band in this nucleus has been put forwarded by Piercey *et al.* [2] as evidence for a well-deformed, prolate ground state, with a spherical 0^+ state predicted to lie at an excitation energy of approximately 680 keV (assuming a similar mixing matrix element as extracted between the prolate and spherical configurations in ^{76,78}Kr). Theoretically, $^{74}_{36}$Kr$_{38}$ has been put forward [5,6,13]

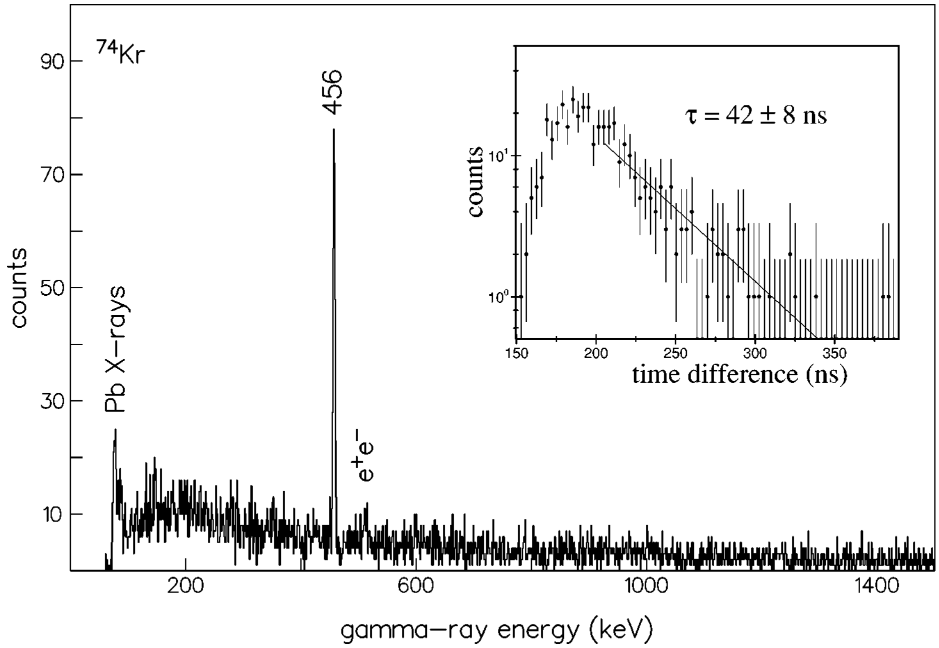

FIG. 1. Gamma-ray and time spectra for ^{74}Kr showing the decay from the proposed 0^+ isomer.

as a prime candidate for prolate/oblate shape coexistence. Nazarewicz *et al.* [6] have suggested that an oblate 0^+ structure lies approximately 600 keV above the prolate ground state configuration in ^{74}Kr. Similar predictions regarding the presence of a low-lying oblate bandhead in this nucleus have been made by Bonche *et al.* [13] and Petrovici *et al.* [14]. Heese *et al.* [15] pointed out that the measured decay lifetimes for the yrast 4^+ and 2^+ states are consistent with an interference effect between coexisting prolate and oblate minima at low spins.

Despite this large degree of experimental and theoretical interest, experimental evidence supporting or refuting the existence of a well-deformed oblate minimum in ^{74}Kr has been elusive for two principal reasons. First, the production of $N \sim Z$ nuclei in this region is very difficult and up to now, has been most commonly achieved using fusion evaporation reactions, where the nuclei of interest represent small fractions of the total fusion cross section. Second, finding experimental signatures in even-even nuclei, which can provide a plausible argument for an oblate, rather than prolate, shape is not simple.

In the current work, the ^{74}Kr nuclei were produced via the fragmentation of a ^{92}Mo beam at an energy of 60 MeV/nucleon, on a selection of natural nickel targets with thicknesses between 50 μm and 100 μm. The average primary beam intensity was 1.7×10^{10} particles per second. The LISE3 [16] spectrometer was used with a Be achromatic degrader of thickness 50 μm to separate the beam particles from the fragmentation products. In general, the fragments were fully stripped of their atomic electrons in flight. A four element silicon detector telescope was placed at the final focus of the spectrometer. The first element was 300 μm thick and acted as an energy loss or ΔE detector. The final three silicon detectors each had a thickness of 150 μm and were used to stop the fragments. The secondary fragments were identified unambiguously by their mass to charge state ratio (A/Q) and proton number (Z) from their measured time of flight (TOF) and energy losses, respectively [17]. Gamma rays emitted from isomeric states were measured with an array of seven 70% germanium detectors in close geometry around the silicon stack. The measured absolute photopeak efficiency of this array was approximately 3% for a 1.33 MeV gamma ray.

On detection of an ion passing through the ΔE detector, the data acquisition electronics were enabled, allowing the measurement of delayed gamma rays in each germanium detector during the subsequent 80 μs period. Information on the lifetimes of isomeric states was obtained by recording the time difference between a ΔE timing signal and the detection of a delayed gamma ray. Time spectra over the ranges $0 \rightarrow 600$ ns and $0 \rightarrow 80$ μs were recorded separately, thus allowing good resolution over a wide time range.

In offline analysis, two-dimensional spectra of gamma-ray energy versus delay time were constructed for individual nuclear species. Prompt gamma rays from secondary reactions in the silicon telescope were used to identify and correct for ''time walk'' effects in the germanium counters for low energy gamma rays. Observed decays of previously reported isomers in ^{67}Ge, ^{69}Se, ^{73}Kr, and ^{76}Rb [18] were used to verify the experimental method and to provide internal checks for the energy and time calibrations.

Figure 1 shows the energy spectrum for $^{74}_{36}$Kr$_{38}$ for gamma rays detected after the prompt peak and within 150 ns of the implantation. The yrast 456 keV, $2^+ \rightarrow 0^+$ transition is the only line which is clearly visible. In particular, the yrast $4^+ \rightarrow 2^+$, 558 keV line is *not* present. The time spectrum gated by the 456 keV line (Fig. 1), fitted using the maximum likelihood method [19] yielded a mean lifetime of 42 ± 8 ns. The lifetime of the yrast 2^+ state in ^{74}Kr has previously been measured [20] to be 25 ps. We therefore conclude that the 2^+ level is directly fed by an isomeric state with mean-life 42 ± 8 ns. The non-observation of a transition linking the isomer to the 2^+ state implies a limit of this transition of $\leqslant 85$ keV (set by the energies of the background lead x rays).

The measured flight time for fully stripped ^{74}Kr ions in the LISE3 spectrometer was 480 ns. For the measured isomeric mean lifetime of 42 ± 8 ns, the fraction of ions which could be created in the isomeric state and reach the end of the LISE3 spectrometer is given by $\exp(-480/42\pm8)$. This puts a three standard deviation limit on the fraction of ions in the isomeric state which one would expect to survive transit through the separator of less than one in 1440. The total number of $^{74}_{36}$Kr ions recorded was 2.32×10^6. Of these, 320 ± 10 yielded counts in the full energy peak for the 456 keV line. From the measured absolute photopeak gamma-ray efficiency of 5% for a 456 keV gamma ray, this corresponds to approximately 6400 ^{74}Kr ions (1 in 360) being in the isomeric state, far more than expected from the measured lifetime of the state. This anomaly can be understood if the decay of the isomer is hindered in flight. One possible explanation for the apparently anomalous lifetime for the isomer in ^{74}Kr arises if the isomer has a spin/parity 0^+.

Assuming a 0^+ assignment for the isomer, the direct decay to the ground state can only proceed through $E0$ internal conversion. However, the ^{74}Kr ions are fully stripped of electrons before their flight through the spectrometer and hence the isomer can only decay via the $E2$ gamma-decay to the yrast 2^+ state, increasing the *effective* lifetime of the isomeric state. (The decay by $E2$ electron conversion to this state is also not possible from the fully stripped ion in flight.) Once the ion is stopped in the silicon stack detector, it regains its atomic electrons and the $E0$ and $E2$ electron conversion partial decay widths take their usual values, allowing the isomer to decay with its (shorter) measured ''atomic'' lifetime.

The Weisskopf single particle estimate for the mean-lifetime of an 85 keV, $0^+\rightarrow2^+$, $E2$ transition in ^{74}Kr is approximately 2 μs, rising to 11 μs for a 60 keV decay. (The electron conversion coefficient for an 85 keV, $E2$ transition in ^{74}Kr is 1.7, increasing to 6.1 for an energy of 60 keV.) Since the flight time through the LISE3 spectrometer is less than 0.5 μs this would explain why the fully stripped isomeric state does not decay in flight. Note that the present experiment was only sensitive to branches of this isomer which gamma-decayed from the yrast 2^+ state. Under normal conditions, the 0^+ isomer will decay principally via $E0$ electron conversion directly to the 0^+ ground state. The measured value of the isomeric ratio for the isomer in ^{74}Kr of approximately 0.3%, although anomalously large compared with the measured isomeric lifetime, is much lower than the isomeric ratios observed for other nuclei in this region using fragmentation reactions where typical values are in the region of 10–30 % [17]. The value for the isomeric ratio in ^{74}Kr is consistent with most of the decay strength decaying by $0^+\rightarrow0^+$ electron emission after implantation.

We propose that the isomeric state is the 0^+ bandhead of the predicted, well-deformed oblate structure in ^{74}Kr. Figure 2 shows the predicted level scheme for this nucleus obtained using a version of the EXCITED VAMPIR approach (for details see [21]). The calculations assumed a closed ^{40}Ca core with valence basis states from the $1p_{1/2}$, $1p_{3/2}$, $0f_{5/2}$, $0f_{7/2}$, $1d_{5/2}$, and $0g_{9/2}$ single particle orbits for both protons and neutrons and effective two-body interactions taken from a renormalized G matrix [21]. The calculations suggest that

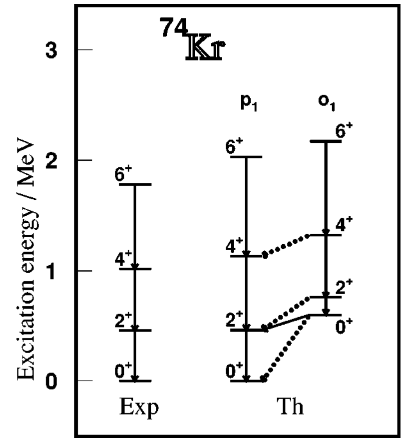

FIG. 2. Results of the EXCITED VAMPIR calculations for ^{74}Kr. The labels o_i and p_i correspond to intrinsically oblate and prolate deformed configurations, respectively.

while the yrast states up to spin 10^+ are prolate deformed, the first excited 0^+ bandhead at approximately 600 keV is predominantly oblate deformed. The oblate-prolate mixing in the structure of the wave functions for the first two 0^+ states is predicted to be approximately 30% and reduces with increasing spin, essentially disappearing above spin 8^+. The calculated $B(E2;2^+\rightarrow0^+)$ strengths are 1419 e^2 fm^4 and 1385 e^2 fm^4 for the yrast (prolate) and yrare (oblate) band, respectively, suggesting approximately equal magnitudes for the deformation but opposite signs. The predicted strength of the $0_2^+\rightarrow2_1^+$ partial decay is $B(E2;0_2^+\rightarrow2_1^+)=123e^2$ fm^4. The calculations give a value for the $E0$ matrix element for the $0_2^+\rightarrow0_1^+$ decay of $\rho(E0)=0.17$ ($\rho^2=0.029$).

The ρ^2 value can be directly related to the partial lifetime for the $E0$ decay, τ, using the expression [22],

$$\frac{1}{\tau}=\rho^2(E0)\sum_j \Omega_j(Z,K), \tag{1}$$

where $\Omega_j(Z,K)$ is the electronic factor for the jth atomic shell [23]. For a 510 ± 50 keV transition in ^{74}Kr, the Ω_K/Ω_L ratio is greater than 90% and thus we can assume $\Sigma_j\Omega_j(Z,K)\approx\Omega_K$ (i.e., K-shell electron emission dominates) and from Ref. [23], $\Omega_K=2.64\pm0.30\times10^8$ s^{-1}. Assuming that the partial lifetime for the $E0$ decay branch is considerably shorter than the $0_2^+\rightarrow2_1^+$ branch (which seems reasonable in light of the anomalously large isomeric ratio deduced from the observed lifetime), for $\tau=42\pm8$ ns, we obtain an experimental value of $\rho^2=0.090\pm0.020$ (3.23 ± 0.71 single particle units [22]).

Heyde and Meyer [24] have pointed out that the size of the $E0$ matrix element can be used as a measure of the mixing between nuclear states with largely different radii, and hence differing deformations. The monopole operator can be expanded in terms of the deformation variables β and γ as [25]

$$m(E0)=\left(\frac{3Z}{4\pi}\right)\left[\frac{4\pi}{5}+\beta^2+\left(\frac{5\sqrt{5}}{21\sqrt{\pi}}\right)\beta^3\cos\gamma\right]. \tag{2}$$

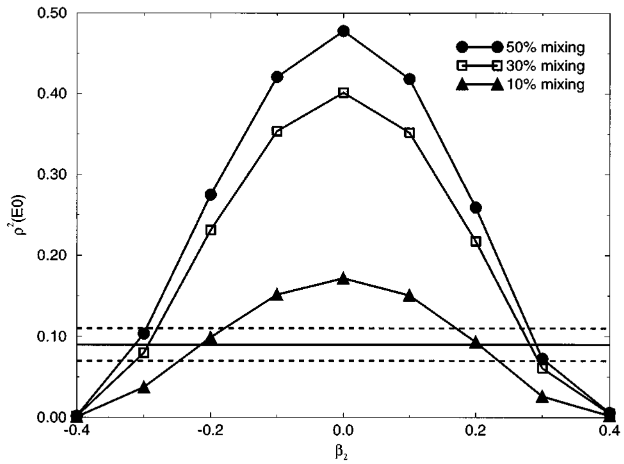

FIG. 3. Variation of $\rho^2(E0)$ value with β_2 for ^{74}Kr assuming a β_1 value of +0.38. The dotted lines represent the limits of the experimentally deduced value.

In the limit of simple two-state mixing between configurations with deformations γ_1, β_1 and γ_2, β_2, if a is the mixing amplitude between the configurations, the resulting monopole strength is given by

$$\rho^2(E0)=\left(\frac{3Z}{4\pi}\right)^2 a^2(1-a^2)\left[(\beta_1^2-\beta_2^2)+\left(\frac{5\sqrt{5}}{21\sqrt{\pi}}\right)\times(\beta_1^3\cos\gamma_1-\beta_2^3\cos\gamma_2)\right]^2. \quad (3)$$

Most observed $0^+\rightarrow 0^+$ $E0$ decays are between states where at least one of the states is predominantly spherical in nature [22,24] and it is usual to keep terms only up to order β^2 in Eqs. (2) and (3). However, it has been suggested [26] that in the case of prolate/oblate mixing, the second term may become important since the first vanishes for equal deformations of opposite sign.

The results of applying Eq. (3) to ^{74}Kr are shown in Fig. 3 for three values of the mixing amplitude a, using the deduced ground state deformation of $\beta_1=0.38$ [20]. We have also assumed triaxiality parameters of $\gamma_1=0°$ and $\gamma_2=60°$ for the nominally prolate and oblate configuations respectively. A number of important points emerge. First, the cubic term is small and, for *exactly* equal deformations of opposite sign, is not sufficient to account for the observed value of $\rho^2(E0)$. The experimental value can be explained either by strong prolate-oblate mixing between two configurations of large and similar (but not identical) magnitudes of β_1 and β_2 ($|\beta_2|\simeq 0.3$) or by a much weaker degree of mixing between two prolate configurations with a much larger difference in deformation. The third solution, which appears in Fig. 3 involving two configurations that both have large and similar *prolate* deformations, can be discounted on the grounds that potential energy surface calculations do not predict minima separated by such a small difference in β and also because the simple formalism of Eqs. (2) and (3) would not be applicable, given the probable overlap of the collective wave functions in such a case [27].

This analysis shows the dependence of the monopole strength on the mixing amplitude and deformation of the excited configuration and an unambiguous empirical determination of one would require an equivalent knowledge of the other. Nevertheless, the treatment shows that the observed $E0$ strength is fully consistent with the *predicted* [8] deformation of $\beta_2=-0.32$ of the oblate state.

In summary, we have used fragmentation reactions to populate a 0^+ isomeric state in the $N=Z+2$ system, $^{74}_{36}$Kr which supports the predictions of prolate/oblate shape coexistence in this nucleus. A simple treatment based on two-state mixing between configurations of differing quadrupole deformation suggests that an oblate deformation in the region of $\beta_2=-0.3$ is required to produce the observed result. The identification of isomeric states can be useful as an experimental ''tag'' for future in-beam experiments, where the delayed gamma rays from decays via an isomer can be correlated with prompt, in-beam decays. Using a high-granularity, high-efficiency gamma-ray array, further detailed spectroscopy in ^{74}Kr should be possible and may reveal the structure of the band built on the excited 0^+ state identified here, thus shedding further light on the extent of the configuration mixing.

The authors are grateful to Prof. R. Julin and Dr. T. Kibédi, for discussions on E0 decays. This work was supported by EPSRC (UK), IN2P3 and CEA (France), the Polish Committee of Scientific Research (Grant No. 2PO3BO3913) and The European Community under Contract No. CHGE-CT94-0056 (Human Capital and Mobility, Access to the GANIL large scale facility).

[1] R. M. Ronningen, A. V. Ramayya, J. H. Hamilton, W. Lourens, J. Lange, H. K. Carter, and R. O. Sayer, Nucl. Phys. **A261**, 439 (1976); J. H. Hamilton *et al.*, Phys. Rev. Lett. **36**, 340 (1976); J. H. Hamilton, A. V. Ramayya, W. T. Pinkston, R. M. Ronningen, G. Garcia-Bermudez, H. K. Carter, R. L. Robinson, H. J. Kim, and R. O. Sayer, *ibid.* **32**, 239 (1974); R. B. Piercey, A. V. Ramayya, R. M. Ronningen, J. H. Hamilton, V. Maruhn-Rezwani, R. L. Robinson, and H. J. Kim, Phys. Rev. C **19**, 1344 (1979); L. Chaturverdi *et al.*, *ibid.* **43**, 2541 (1991).

[2] R. B. Piercey *et al.*, Phys. Rev. Lett. **47**, 1514 (1981); R. B. Piercey, A. V. Ramayya, J. H. Hamilton, X. J. Sun, Z. Z. Zhao, R. L. Robinson, H. J. Kim, and John C. Wells, Phys. Rev. C **25**, 1941 (1982).

[3] R. L. Robinson, H. J. Kim, R. O. Sayer, W. T. Milner, R. B. Piercey, J. H. Hamilton, A. V. Ramayya, J. C. Wells, Jr. and A. J. Caffrey, Phys. Rev. C **21**, 603 (1990).

[4] H. Dejbakhsh *et al.*, Phys. Lett. B **249**, 195 (1990).

[5] J. L. Wood, K. Heyde, W. Nazarewicz, M. Huyse, and P. van Duppen, Phys. Rep. **215**, 101 (1992).

[6] M. Wiosna, J. Busch, J. Eberth, M. Liebchen, T. Mylaeus, N. Schmal, R. Sefzig, S. Skoda, and W. Teichert, Phys. Lett. B **200**, 255 (1988); J. W. Arrison, D. P. Balamuth, T. Chapuran, D. G. Popescu, J. Görres, and U. J. Hüttmeier, Phys. Rev. C **40**, 2010 (1989).

[7] J. Billowes, F. Chriostancho, H. Grawe, C. J. Gross, J. Heese, A. W. Mountford, and M. Weiszflog, Phys. Rev. C **47**, R917 (1993).
[8] W. Nazarewicz, J. Dudek, R. Bengtsson, and I. Ragnarsson, Nucl. Phys. **A435**, 397 (1985).
[9] J. Heese, K. P. Lieb, L. Lühmann, F. Raether, B. Wörman, D. Alber, H. Grawe, J. Eberth, and T. Mylaeus, Z. Phys. A **325**, 45 (1986).
[10] W. Gelletly, M. A. Bentley, H. G. Price, J. Simpson, C. J. Gross, J. L. Durell, B. J. Varley, O. Skeppstedt, and S. Rastikerdar, Phys. Lett. B **253**, 287 (1991).
[11] C. J. Lister, P. J. Ennis, A. A. Chishti, B. J. Varley, W. Gelletly, H. G. Price, and A. N. James, Phys. Rev. C **42**, R1191 (1990).
[12] S. Freund *et al.*, Phys. Lett. B **302**, 167 (1993).
[13] P. Bonche, H. Flocard, P. H. Heenen, S. J. Kreiger, and M. S. Weiss, Nucl. Phys. **A443**, 39 (1985).
[14] A. Petrovici, A. Faessler, and Th. Koppel, Z. Phys. A **314**, 227 (1983).
[15] J. Heese, D. J. Blumenthal, A. A. Chishti, P. Chowdhury, B. Crowell, P. J. Ennis, C. J. Lister, and Ch. Winter, Phys. Rev. C **43**, R921 (1991).
[16] A. C. Mueller and R. Anne, Nucl. Phys. **B56/57**, 559 (1991).
[17] R. Grzywacz *et al.*, Phys. Lett. B **355**, 439 (1995).
[18] M. R. Bhat, Nucl. Data Sheets **64**, 875 (1991); **58**, 1 (1989); **69**, 857 (1993); S. Hofmann, I. Zychor, F. P. Wessberger, and G. Munzenberg, Z. Phys. A **325**, 37 (1986).
[19] S. L. Mayer, *Data Analysis for Scientists and Engineers* (Wiley, New York, 1975), p. 326.
[20] S. L. Tabor, P. D. Cottle, J. W. Holcomb, T. D. Johnson, P. C. Womble, S. G. Buccino, and F. E. Durham, Phys. Rev. C **41**, 2658 (1990).
[21] A. Petrovici, K. W. Schmidt, and A. Faessler, Nucl. Phys. **A605**, 290 (1996).
[22] J. Kantele, in *Heavy Ions and Nuclear Structure, Vol. 5 of Nuclear Science Research Conference Series*, edited by B. Sikora and Z. Wilhemi (Harwood, Chur, 1984), p. 397.
[23] D. A. Bell, C. A. Aveledo, M. G. Davidson, and J. P. Davidson, Can. J. Phys. **44**, 2542 (1970); A. Passoja and T. Salonen, (unpublished).
[24] K. Heyde and R. A. Meyer, Phys. Rev. C **37**, 2170 (1988).
[25] J. P. Davidson, Rev. Mod. Phys. **37**, 105 (1965).
[26] H. Mach, M. Moszynski, R. L. Gill, G. Molnar, F. K. Wohn, J. A. Winger, and J. C. Hill, Phys. Rev. C **42**, 793 (1990).
[27] K. Heyde and R. A. Meyer, Phys. Rev. C **42**, 790 (1990).