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Collective excitations in ^{128}Xe observed following the decay of ^{128}Cs and ^{128}I

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Levels of ^{128}Xe populated by the decays of 1^+ ^{128}Cs and 1^+ ^{128}I were studied by $\gamma\gamma$ angular correlations and Compton-suppressed γ-ray spectroscopy. 0^+ states were established in ^{128}Xe at 1582 and 2598 keV. Experimental branching ratios were compared with those calculated from a fit to the levels of ^{128}Xe and ^{130}Xe by an interacting boson approximation.

[RADIOACTIVITY ^{128}Cs [from ^{133}Cs$(d,7n)^{128}$Ba decay], and ^{128}I [from ^{127}I(n,γ)]; measured E_γ, I_γ, $\gamma\gamma(\theta)$; deduced A_{22}, A_{44}, ^{128}Xe deduced levels, J, π, logft. Ge(Li) detectors, Compton suppression.]

I. INTRODUCTION

The investigation of the level structure of the even-even Xe nuclides can yield important information regarding the collective properties of nuclides which cannot be clearly classified as either rotational or vibrational. Because both Cs and I radioactive precursors may be produced in isotope separators from spallation and fission, respectively, Xe structures are known from ^{116}Xe through ^{140}Xe.[1-8] In beam γ-ray studies[9] utilizing the $(\alpha, xn\gamma)$ reaction on the many stable Te nuclides have complemented the data available from radioactive decay for a number of Xe nuclides. The level properties of Xe nuclei have been described by a number of methods ranging from a simple variable moment of inertia (VMI) approach, in which only the yrast band is considered, to more complex approaches involving collective excitations in which asymmetric states occur at low energies. These triaxial or γ-soft approaches have been particularly useful in understanding the energy of excitation and γ-ray branching of possible low-lying 0^+ states suggested in the nuclides $118 \leq A \leq 130$. However, the certain identification of the low-lying 0^+ states has been made only for ^{120}Xe. With 1^+ Cs parents, a number of states in these nuclides are observed that have no γ-ray transition to the ground state and, hence, are candidates for 0^+ assignments. For instance, evidence has been presented[1] for two states in ^{130}Xe which are strongly fed by 1^+ ^{130}Cs and are not observed in the decay of 2^+ ^{130}I.

Recently, a new theoretical approach, the interacting boson approximation (IBA),[10-13] has been set forth to try to understand the collective structure of even-even nuclides. This approach utilizes group-theoretical methods operating in a boson space to approximate the structure of collective excitations in nuclei. The parameters derived from the best fit to the observed levels should vary smoothly, if at all, and reflect the known shell model properties of nuclei. Although the success or failure of the fit in one particular nuclide is not initially critical, in order for the theory to be ultimately useful it must be refined to reproduce the collective properties of a wide range of nuclides. One unique aspect of the IBA approach is the prediction of low-lying 0^+, 1^+, and 2^+ collective states resulting from antisymmetric motions of the protons and neutrons.

In this paper, we report the results of γ-ray spectroscopic measurements and $\gamma\gamma$ angular-correlation measurements for ^{128}Xe which establish the positions of two 0^+ levels, rule out 0^+ for one level, and suggest 0^+ for a fourth level. We then compare our detailed results with the IBA predictions.

II. EXPERIMENTAL PROCEDURES

Sources of ^{128}Ba were produced at the University of Maryland Cyclotron by the ^{133}Cs$(d, 7n)^{128}$Ba reaction at a beam energy of 80 MeV. The bombardments were for ~400 nA h on a target of 0.3g of CsNO$_3$ powder packaged in Al foil. A chemical separation[14] was performed after 24 h to produce purified samples of ^{128}Ba. All data collected in this study employed samples in which the 3.8 min ^{128}Cs activity was in equilibrium with the 2.4 d

^{128}Ba parent.

The $\gamma\gamma$ angular correlations were measured by a counting system which included four Ge(Li) coaxial detectors with active volumes >55 cm^3 and full width at half maximum values $\leqslant 2.1$ keV for the 1332-keV γ-ray. By placing the detectors at 0°, 90°, 165°, and 300° data were collected simultaneously for the six angles at 15°, 30°, 45°, 60°, 75°, and 90°. An event was recorded whenever at least two detectors collected a γ within a time window of ~100 ns. Over a period of 60 h, approximately 20 million events were recorded onto magnetic tape by a minicomputer system.

The coincidence information was corrected for Compton background events and normalized by the single rates. The data were then fitted by least squares to the function

$$W(\theta) = 1 + A'_{22}P_2(\cos\theta) + A'_{44}P_4(\cos\theta)\,.$$

The experimental coefficients were corrected for the finite solid angles subtended by the detectors[15] in which

$$A_{kk} = A'_{kk}/Q_{kk}\,,$$

where Q_{kk} are the solid angle correction factors. The correlation coefficients A_{kk} were analyzed for spin assignments and γ-ray multipole mixing ratios using the tabulated values and phase convention described by Taylor *et al.*[16]

A similar source was prepared at the University of Maryland Cyclotron and flown to Lawrence Laboratory where the γ-ray singles spectroscopy was performed. Counting was performed with an intrinsic (high-purity) Ge Compton suppression spectrometer. Large volume Ge(Li) spectrometers with up to 1 in. of Pb absorbers were also used to accentuate the low-intensity, high-energy γ rays. Half-lives of the transitions were measured to ensure their association with the decay of ^{128}Ba.

For the study involving the decay of ^{128}I, samples of PbI$_2$ were exposed to thermal neutron irradiation at the National Bureau of Standards reactor. Counting was performed with large-volume Ge(Li) spectrometers with up to 2 in. of Pb absorbers.

III. EXPERIMENTAL RESULTS

In Fig. 1 we show the decay scheme for ^{128}Cs, and the γ-ray energies and intensities are listed in Table I. Figure 2 presents the decay scheme for ^{128}I. Gamma-ray energies and intensities are tabulated in Table II and upper limits for intensities of unobserved transitions are listed in Table III. A partial level scheme of ^{128}Cs is shown in Fig. 3 which shows states involved in the $\gamma\gamma(\theta)$ study. The experimental A_{22} and A_{44} values for these cascades are listed in Table IV.

Of the levels in ^{128}Xe studied in this study, all

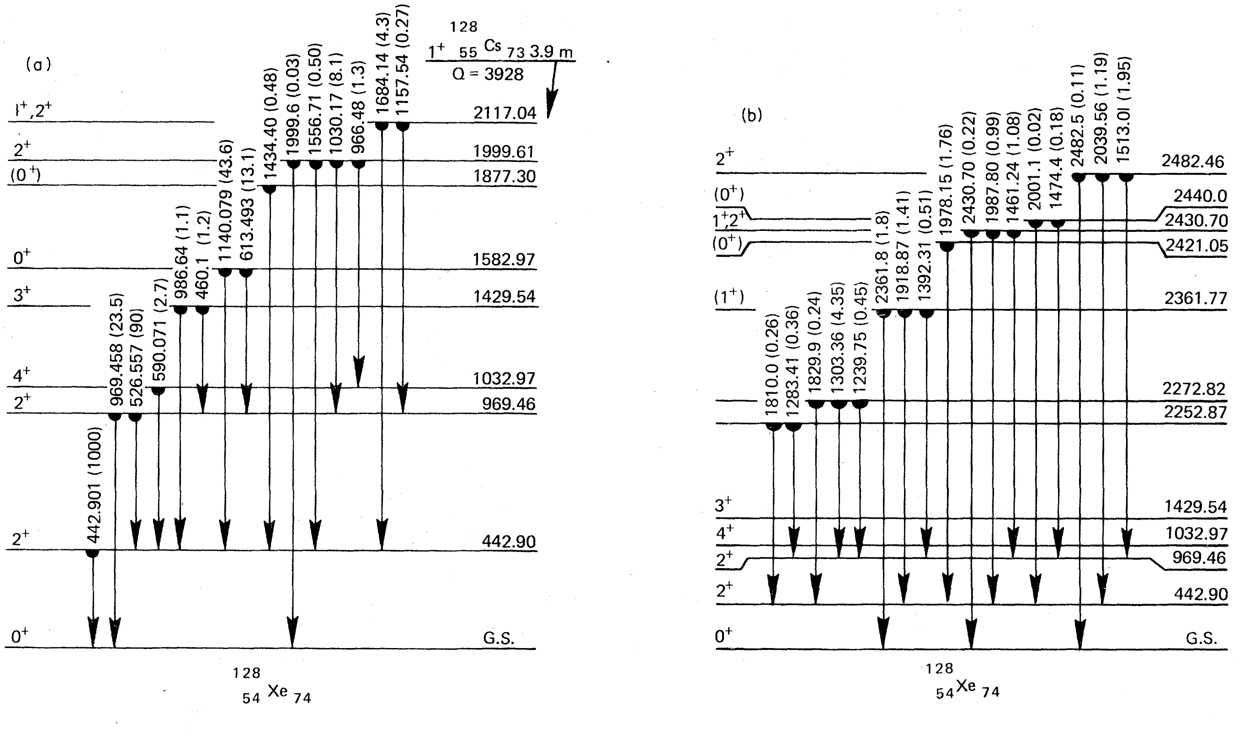

FIG. 1. The level scheme of ^{128}Xe from the β^+ decay of ^{128}Cs: (a) 0–2200 keV; (b) 2220–2500 keV; (c) 2500–2600 keV; (d) 2600–2850 keV; (e) 2850–3500 keV.

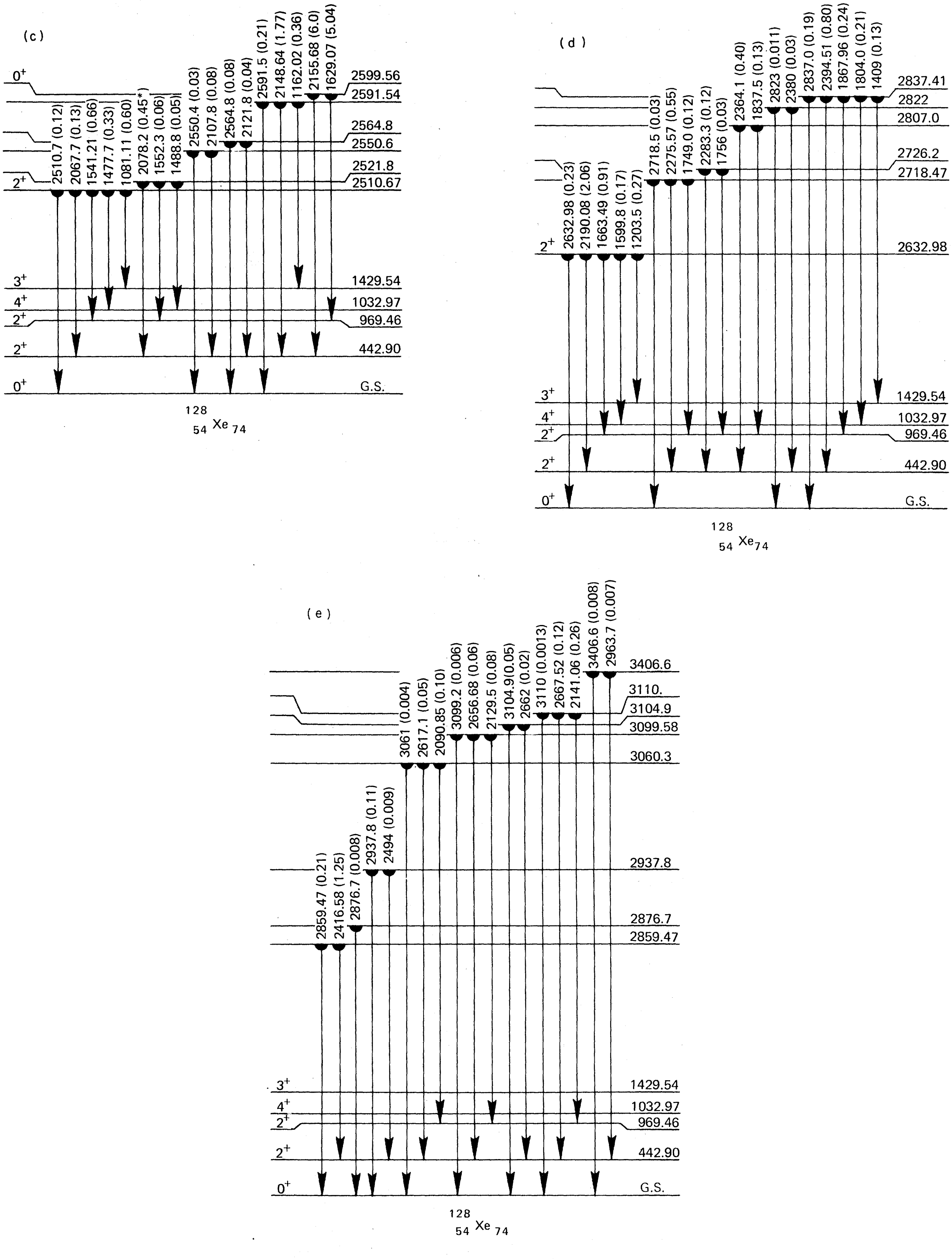

FIG. 1. *(Continued)*

TABLE I. γ rays observed in the decay of 3.9m ^{128}Cs.

Energy[a] (keV)		Relative Intensity[a, b]		Placement (keV)
442.901	(4)	1000[c]	(5)	442–0
460.1	(1)	1.2	(1)	1429–969
526.557	(9)	90	(1)	969–442
590.071	(36)	2.7	(3)	1032–442
613.493	(5)	13.1	(4)	1582–969
(897)[d]	(1)	(0.2)[d]	(1)	
966.483	(35)	1.3	(1)	1999–1032
969.458	(4)	23.5	(7)	969–0
986.640	(27)	1.1	(1)	1429–442
(1001)[d]	(1)	(0.2)[d]	(1)	
1030.170	(6)	8.1	(4)	1999–969
1081.105	(41)	0.60	(4)	2510–1429
(1118)[d]	(1)	(0.12)[d]	(3)	
1140.079	(3)	43.6	(4)	1582–442
1157.544	(62)	0.27	(4)	2127–969
1162.021	(60)	0.36	(5)	2591–1429
1203.5	(1)	0.27	(4)	2632–1429
1239.748	(50)	0.45	(6)	2272–1032, (2823–1582)
1283.406	(53)	0.36	(5)	2252–969
1303.355	(6)	4.35	(15)	2272–969
1376.3	(3)	0.30	(5)	
1392.31	(15)	0.51	(6)	2361–969
1409	(1)	0.13	(3)	2837–1439
1434.398	(73)	0.48	(3)	1877–442
1461.186	(31)	1.08	(7)	2430–969
1474.42	(18)	0.18	(4)	2444–969
1477.0	(2)	0.33	(5)	2510–1032
1488.8	(6)	0.05	(2)	2521–1032
1513.011	(20)	1.95	(7)	2482–969
(1514.5)[d]	(10)	(0.05)[d]	(3)	
1541.209	(49)	0.66	(5)	2510–969
1552.3	(1)	0.06	(2)	2521–969
1556.708	(67)	0.50	(3)	1999–442
1599.8	(2)	0.17	(3)	2632–1032
1629.070	(18)	5.04	(10)	2599–969
1663.490	(35)	0.91	(5)	2632–969
1678.5	(2)	0.16	(4)	
1684.138	(7)	4.3	(1)	2127–442
1749.0	(4)	0.12	(4)	2718–969
1756	(1)	0.03	(2)	2726–969
1795.6	(4)	0.05	(2)	
1804.04	(17)	0.21	(3)	2837–1032
1810.0	(2)	0.26	(2)	2252–442
1829.9	(1)	0.24	(3)	2272–442
1837.5	(2)	0.13	(3)	2807–969
1858.9	(4)	0.08	(3)	
1867.96	(13)	0.24	(3)	2837–969
1918.870	(23)	1.41	(7)	2361–442
1978.151	(17)	1.76	(7)	2421–442
1987.797	(60)	0.99	(5)	2430–442
1999.7	(4)	0.03	(1)	1999–0
2001.1	(4)	0.02	(1)	2444–442
2039.558	(23)	1.19	(9)	2482–442
(2063)[d]	(1)	(0.03)[d]	(2)	
2067.7	(1)	0.13	(2)	2510–442
2078.226	(56)	0.45	(4)	2521–442, (3110–1032)
2090.85	(26)	0.10	(2)	3060–969
2107.8	(2)	0.08	(2)	2550–442
2121.8	(5)	0.04	(2)	2564–442
2129.5	(3)	0.08	(2)	3099–969
2141.06	(9)	0.26	(2)	3110–969
2148.642	(25)	1.77	(12)	2591–442
2155.681	(18)	6.0	(4)	2599–442

TABLE I. *(Continued)*

Energy[a] (keV)		Relative Intensity[a,b]		Placement (keV)
2190.081	(14)	2.06	(14)	2632–442
2232.40	(17)	0.10	(2)	
2255.2	(2)	0.05	(2)	
2275.570	(34)	0.55	(4)	2718–442
2283.30	(14)	0.12	(2)	2726–442
2314.9	(4)	0.03	(1)	
2326.8	(4)	0.02	(1)	
2348.4	(3)	0.04	(1)	(2876–442)
2361.8	(1)	1.76	(15)	2361–0
2364.1	(3)	0.40	(10)	2806–442
2380.8	(5)	0.03	(1)	2823–442
2394.506	(23)	0.80	(4)	2837–442
2416.583	(21)	1.25	(8)	2859–442
2430.698	(69)	0.22	(2)	2430–0
2467.0	(3)	0.04	(1)	
2482.7	(1)	0.11	(1)	2482–0
2494	(1)	0.009	(3)	2937–442
2510.78	(8)	0.12	(1)	2510–0
2550.4	(4)	0.03	(1)	2550–0
2564.76	(15)	0.08	(1)	2564–0
2591.54	(6)	0.21	(2)	2591–0
2617.1	(2)	0.05	(1)	3060–0
2633.9	(2)	0.23	(2)	2633–0
2656.68	(2)	0.06	(1)	3099–442
2662	(1)	0.02	(1)	3104–442
2667.52	(8)	0.12	(1)	3110–442
2683.5	(4)	0.007	(4)	
2718.5	(2)	0.03	(1)	2718–0
2723.9	(3)	0.03	(1)	
(2747.0)[d]	(1)	(0.08)[d]	(1)	
2796.8	(4)	0.016	(4)	
2814.8	(4)	0.013	(5)	
2823.0	(4)	0.011	(4)	2823–0
2838.07	(6)	0.194	(15)	2837–0
2859.47	(5)	0.208	(15)	2859–0
2876.7	(5)	0.008	(3)	2876–0
(2893)[d]	(1)	0.003	(2)	
2937.79	(9)	0.11	(1)	2937–0
2963.7	(5)	0.007	(3)	3406–442
3061.9	(5)	0.004	(2)	3060–0
3099.2	(6)	0.006	(2)	3099–0
3104.9	(3)	0.050	(4)	3104–0
3110	(1)	0.0013	(7)	3110–0
(3125)[d]	(1)	(0.0008)[d]	(6)	
3167.2	(1)	0.009	(1)	
(3204)[d]	(1)	(0.0007)[d]	(7)	
3406.6	(2)	0.008	(2)	3406–0
(3493)[d]	(1)	(0.003)[d]	(1)	

[a] Values shown as 442.901 (4), for example, mean 442.901 ± 0.004.

[b] The intensity values are relative to a value of 1000 for the 442-keV transition.

[c] Fiducial γ ray. Error represents peakfitting error only.

[d] Tentatively assigned to ^{128}Cs decay.

have log*ft* values $\leqslant 6.5$ and are assumed to be allowed transitions, limiting the J^π values to be 0^+, 1^+, or 2^+ in each case.

A. Multipolarity of the 526-keV γ ray

Figure 4 plots the experimental results for cascade involving a 2^+ to 0^+ transition. The value of δ for the 526-keV $M1+E2$ transition is deduced from the location of the experimental A_{22} and A_{44} values for the 442–526 keV cascade on the 2(1,2)2(2)0 theoretical curve. A value of $\delta(526) = +6^{+4}_{-2}$ has been obtained.

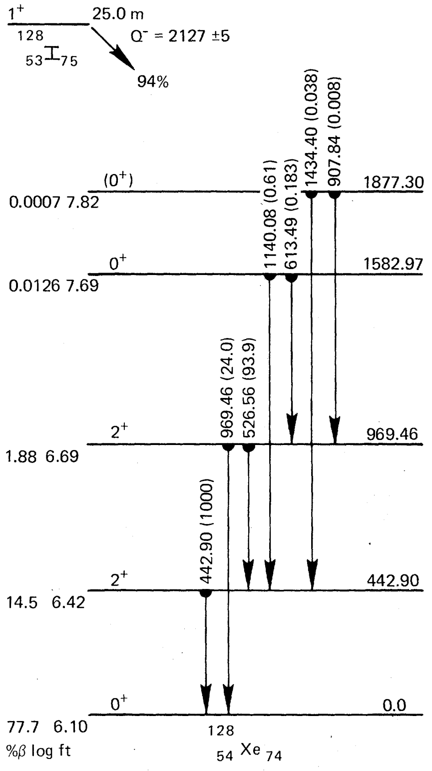

FIG. 2. The level scheme of ^{128}Xe populated in the β^- decay of ^{128}I.

B. 1582-keV level and the 2598-keV level

As seen in Fig. 3, three cascades involve the 1582-keV level. The results of the angular correlations from the 613–969 keV cascade and the 442–1140 keV cascade, plotted in Fig. 4, are consistent only with a J^π assignment of 0^+. If the mixing ratio of the 526-keV $M1+E2$ transition is extracted from the 442–526 keV cascade, the 526–613 angular correlation also provides an additional confirmation for the assignment of 0^+ to the 1582-keV level. Figure 5 presents this information. Although the uncertainty in $\delta(526)$ causes some uncertainty in the placement of the theoretical A_{22} and A_{44} values, the experimental coefficients for the 613–526 keV cascade agree within one standard deviation of the 0(2)2(1,2)2 point.

The spin and parity of the level at 2598 keV is determined to be 0^+ from the experimental results of the 442–2155 keV cascade, shown in Fig. 4. The large positive value of A_{44} eliminates both 1^+ and 2^+ assignments for this state. As in the case of the 1582-keV level, a cascade involving the 526-keV transition also depopulated the 2598-keV

TABLE II. γ rays observed in the decay of 25.0–min ^{128}I.

Energy[a,b] (keV)	Relative intensity[a,c]	Placement (keV)
442.901 (4)	1000[d] (31)	442–0
526.557 (9)	93.9 (35)	969–442
613.493 (5)	0.183 (13)	1582–969
743.5[e] (1)	9.2 (4)	
907.84 (5)	0.008 (4)	1877–969
969.458 (4)	24.0 (8)	969–0
1140.079 (3)	0.61 (3)	1582–442
1434.40 (7)	0.038 (3)	1877–442

[a] Values shown as 442.901 (4), for example, mean 442.901 ± 0.004.

[b] Energy and associated uncertainty values have been taken from ^{128}Cs decay.

[c] The intensity values are relative to a value of 1000 for the 442–keV transition.

[d] Fiducial γ ray. The error represents peakfitting error only.

[e] β^+ decay to the 743.5–keV state in ^{128}Te.

TABLE III. Intensity upper limits for unobserved transactions in the decay of ^{128}I.

Energy (keV)	Relative intensity upper limit[a]	Placement
460.1	0.0060	1429–969
986.6	0.0019	1429–442
1030.2	0.0016	1999–969
1283.4	0.0010	2252–969
1877.3	0.00036	1877–0

[a] Relative to a value of 1000 for the 442–keV transition.

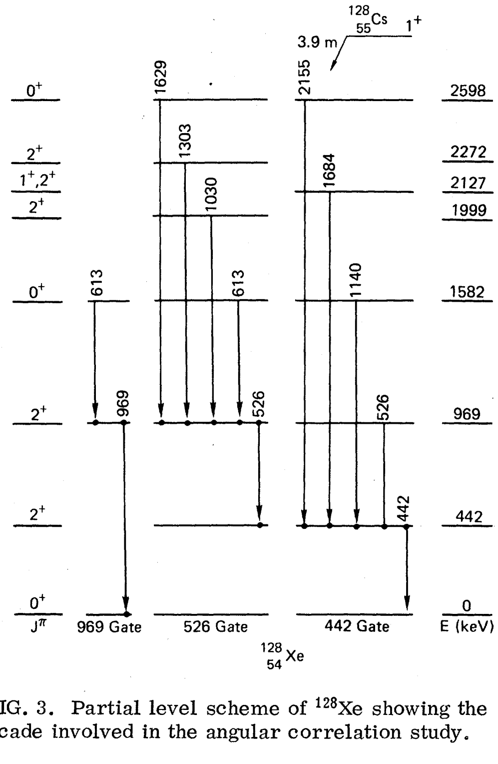

FIG. 3. Partial level scheme of ^{128}Xe showing the cascade involved in the angular correlation study.

TABLE IV. Angular correlation coefficients in the decay of ^{128}Xe. Uncertainties in the last digit(s) are indicated in parentheses.

Cascade E_γ (keV)	A_{22}	A_{44}
442–526	−0.20 (4)	0.38 (6)
442–1140	0.37 (11)	1.21 (14)
442–1684	0.29 (17)	−0.05 (22)
442–2155	0.13 (19)	1.01 (27)
526–613	0.06 (6)	0.25 (8)
526–1030	−0.09 (12)	−0.09 (17)
526–1303	0.06 (17)	−0.04 (23)
526–1629	−0.02 (19)	0.36 (27)
969–613	0.39 (22)	0.76 (29)

level. The results of the 526–1629 cascade are plotted in Fig. 5. Although the uncertainties are large, the assignment of 0^+ is most consistent with the experimental data.

C. 1999-keV level and the 2272-keV level

The levels at 1999 and 2272 keV were studied by the 526–1030 keV and 526–1303 cascade, respectively. The results, shown in Fig. 5, suggest 1^+ or 2^+ assignments. Because both levels have decay branches to the 4^+ state at 1033 keV, these states must have $J^\pi = 2^+$.

D. 2127-keV level

The level at 2127-keV was studied via the 442–1684 keV cascade. In Fig. 4 the experimental result is shown to be consistent with an assignment of 1^+ or 2^+, but not 0^+.

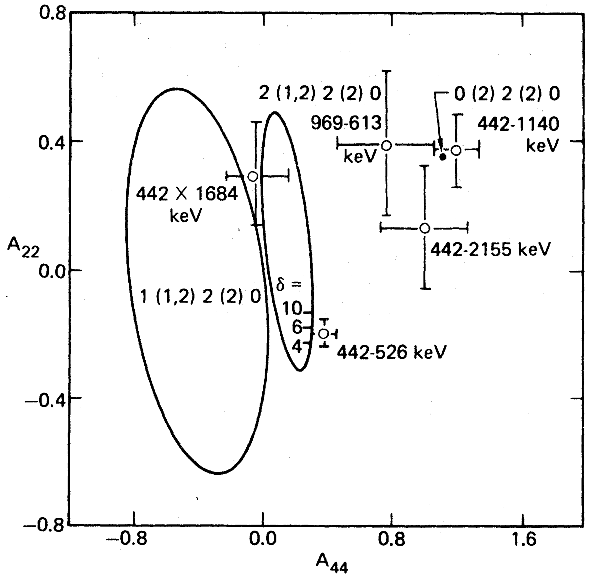

FIG. 4. Angular correlation results for cascades in ^{128}Xe involving a $2^+ \rightarrow 0^+$ transition.

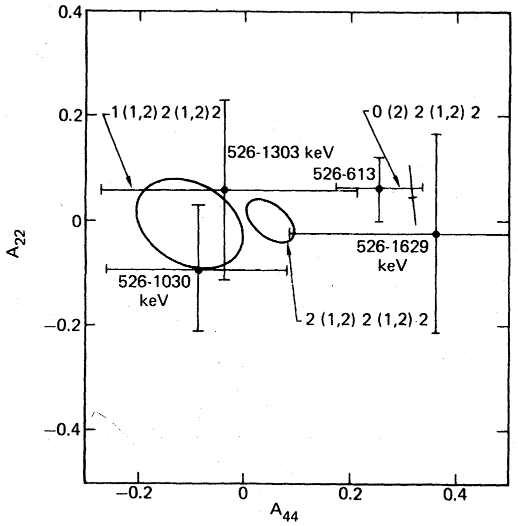

FIG. 5. Angular correlation results in ^{128}Xe for cascades involving the 526–keV $M1 + E2$ transition.

IV. DISCUSSION

The interacting boson approximation (IBA) has been developed at three different levels of sophistication. The most elementary level gives equations that can be solved algebraically for properties of nuclei that can be described near the three analytical limits: SU(5), appropriate for anharmonic vibrational nuclei[11] near the beginning of major shells; SU(3), useful for axial rotators near the middle of major shells[17]; and O(6), appropriate near the end of major shells.[13] There are many examples of nuclei with properties close to those given by the SU(5) and SU(3) limiting cases. Moreover, recent studies[18] of ^{196}Pt with six bosons, identical to ^{128}Xe, have shown close fits to the O(6) calculations. A more sophisticated approach recognizes that many nuclides do not fall near the simple limits and uses computational procedure[19] which treat neutron and proton bosons identically exists in which neutron and proton bosons are treated separately. Such a procedure is particularly appropriate for Ba and Xe nuclides where the protons are near the beginning of the 50–82 shell and the neutrons vary over the whole shell from 50 to 82. Arima *et al.*[20] have shown that structures varying from SU(5) to SU(3) to O(6) can be calculated for the Ba nuclei as N goes from 50–82 with good fits to much of the limited experimental data for $64 \leq N \leq 82$.

In Fig. 6, we show the low-lying levels of ^{128}Xe and ^{130}Xe along with the best fit to the ^{128}Xe and ^{130}Xe levels obtained by varying χ_{nn}, ϵ_d, and κ, the neutron-neutron coupling constant, the phonon energy, and the quadrupole coupling constant, respectively. The computation procedure[21] treated

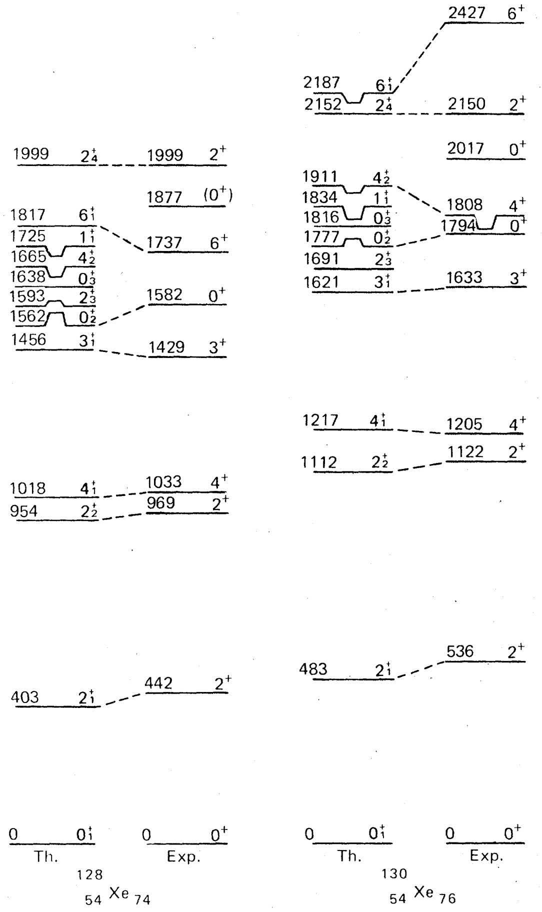

FIG. 6. Comparison of the calculated levels in ^{128}Xe and ^{130}Xe (Ref. 21) with the corresponding experimental states. The lowest observed 6^+ state in ^{130}Xe at 1944 keV is not included because of its strong two-particle character. Although 2^+ states lie at nearly the exact energies of the 2_4^+ levels for both nuclides, two-particle mixing may have altered their character from that predicted by any collective approach.

proton bosons separately and held χ_{pp} constant at -0.7 for both nuclides.

The 0_3^+, 1_1^+, and 2_3^+ states arise in the calculation from the antisymmetric motions of the neutron and proton bosons. Their positions depend strongly on the neutron-proton coupling constant χ_{np}, for which there is little experimental data on which to base an estimate. The estimate used in this calculation places these states below the pairing energy. In ^{130}Xe, there are no levels that can be identified with these three states as the 0^+ level at 2017 keV and the 2^+ level at 2150 keV identify more closely with the 0_4^+ and 2_4^+ states, respectively. In ^{128}Xe, only the 1877-keV level is a possible candidate for such a state.

We tabulate in Table V the experimental and calculated branching ratios for the states in ^{128}Xe and ^{130}Xe shown in Fig. 6. We note the close agreement for the branching from the 2_2^+ in both nuclides and for the 3_1^+ in ^{130}Xe. Agreement for the major branches from the 2_4^+ state in ^{128}Xe and 4_2^+ state in ^{130}Xe is also found. As the latter levels lie near the pairing energy, admixtures of two-particle structures can readily enhance transitions where the collective strength is small.

Among the known and possible 0^+ levels in ^{128}Xe, agreement with the calculations is found only for the 0_2^+ state. The observed branchings for two other 0^+ levels (the possible 0^+ level at 1877 keV and the 0^+ level at 2599 keV) have been tabulated as the 0_3^+ and 0_4^+ levels, respectively. Both of these levels show much larger branches to the 2_1^+ level than is calculated for either 0^+ collective level. In ^{130}Xe, the particular choice of parameters used in this computation results in the above noted good agreements for the branching from the 2_1^+, 3_1^+, and 4_2^+ states but unrealistic branching for the 0_2^+ and 0_3^+ states. It may bee seen, however, that the branching for the possible 0^+ level at 2017 keV,

TABLE V. Summary of branching ratio comparisons between experimental data and theoretical predictions for the excited states of ^{128}Xe and ^{130}Xe.

Transition ratio $\frac{J_i^\pi \to J_f^\pi}{J^\pi \to J_{f'}^\pi}$	^{128}Xe Experimental^{a,b}	Theory^{b,c}	^{130}Xe Experimental^{a,b}	Theory^{b,c}
$\frac{2_2^+ \to 0_1^+}{2_2^+ \to 2_1^+}$	12	8.5	6.1	6.0
$\frac{3_1^+ \to 2_1^+}{3_1^+ \to 2_2^+}$	23	6.9	14	5.8
$\frac{3_1^+ \to 4_1^+}{3_1^+ \to 2_2^+}$		320	240	250
$\frac{0_2^+ \to 2_1^+}{0_2^+ \to 2_2^+}$	150	150	270	41 000
$\frac{0_3^+ \to 2_1^+}{0_3^+ \to 2_2^+}$	(483)^d	97		0.056

TABLE V. *(Continued)*

Transition ratio	^{128}Xe		^{130}Xe	
$\frac{J_i^\pi \to J_f^\pi}{J^\pi \to J_{fl}^\pi}$	Experimental[a,b]	Theory[b,c]	Experimental[a,b]	Theory[b,c]
$\frac{0_4^+ \to 2_1^+}{0_4^+ \to 2_2^+}$	(280)[e]	8.8	(4.8)[f]	1.5
$\frac{4_2^+ \to 2_1^+}{4_2^+ \to 2_2^+}$		2.3	31	1.7
$\frac{4_2^+ \to 4_1^+}{4_2^+ \to 2_2^+}$		840	1080	770
$\frac{2_4^+ \to 0_1^+}{2_4^+ \to 2_2^+}$	0.13	12	13.3	3.3
$\frac{2_4^+ \to 2_1^+}{2_4^+ \to 2_2^+}$	7.8	68	1190	12
$\frac{2_4^+ \to 4_1^+}{2_4^+ \to 2_2^+}$	220	480	30	150

[a] Experimental ratios were computed assuming $E2$ multipolarity only and experimental relative intensities were taken from this work for ^{128}Xe and Refs. 1–3 for ^{130}Xe.
[b] Ratios have been multiplied by 10^3.
[c] From Ref. 21.
[d] 1877 keV level.
[e] 2599 keV level.
[f] 2017 keV level.

tabulated as 0_4^+, is in reasonable agreement with the calculated branching for the 0_4^+ state.

Difficulties in fitting the branching and positions for the 0^+ levels are not confined to ^{128}Xe and ^{130}Xe. Extension of these calculations[22] to the lighter Xe nuclides results in a sharp change in χ_{nn} and κ at $N = 68$. This change is a consequence of the sharp drop in the positions of the observed[7,8] 0_2^+ and 2_4^+ states. It is possible that noncollective character is present in all of these 0^+ states and that a model for collective structure should not fit such states well. The 0_2^+ state in Te nuclides is also known[23] to drop sharply as N drops to 68. Recent studies[24] of the even-even Sn nuclides have revealed the presence of collective bands built on 0^+ states which have been identified[25] as having sizeable two-proton character. Particle-hole excitations are well known[26-29] in Ag, In, Sb, I, and Cs nuclides and it is possible that the excited 0^+ states in Te and Xe are strongly influenced by proton-particle-hole excitations to such an extent that models for collective properties will necessary give a poor fit.

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[1] P. K. Hopke, A. G. Jones, W. B. Walters, A. Prindle, and R. A. Meyer, Phys. Rev. C 8, 745 (1973).
[2] W. Gelletly, W. R. Kane, and D. R. MacKenzie, Phys. Rev. C 9, 2363 (1974).
[3] R. A. Meyer and W. B. Walters, Phys. Rev. C 9, 2379 (1974).
[4] Ch. Droste, K. H. Blinowska, L. Goettig, T. Morek, J. Srebrny, A. Turowiecki, and T. Czosnyka, Z. Phys. A277, 167 (1976).
[5] Ch. Droste, L. Goettig, T. Morek, J. Srebrny, J. Bucka, J. Dobaczewski, and S. G. Rohozinski, Z. Phys. A284, 297 (1978).
[6] R. G. Helmer, C. W. Reich, R. J. Gehrke, R. C. Greenwood, and R. A. Anderl, Phys. Rev. C 15, 1453 (1977).

[7] A. Charvet, J. Genevey-Rivier, L. C. Carraz, C. Richard-Serre, A. Knipper, and G. Walter, J. Phys. Lett. 38, L-241 (1977).

[8] J. Genevey-Rivier, A. Charvet, G. Marguier, C. Richard-Serre, A. Knipper, and G. Walter, J. Phys. Lett. 38, L-241 (1977).

[8] J. Genevey-Rivier, A. Charvet, G. Marguier, C. Richard-Serre, J. D'Auria, A. Huck, G. Klatz, A. Knipper, and G. Walter, Nucl. Phys. A283, 45 (1977).

[9] I. Bergstrom, C. J. Herrlander, A. Kerek, and A. Luukko, Nucl. Phys. A123, 99 (1969).

[10] F. Iachello and A. Arima, Phys. Lett. 53B, 309 (1974).

[11] A. Arima and F. Iachello, Ann. Phys. (N.Y.) 99, 253 (1976).

[12] A. Arima, T. Otsuka, F. Iachello, and I. Talmi, Phys. Lett. 66B, 205 (1977).

[13] A. Arima and F. Iachello, Phys. Rev. Lett. 40, 385 (1978).

[14] W. G. Warren, Los Alamos Scientific Laboratory Report No. LA-1721, 15, 1967 (unpublished).

[15] D. C. Camp and A. L. Van Lehn, Nucl. Instrum. Methods 76, 192 (1969).

[16] H. W. Taylor, B. Singh, F. S. Prato, and R. McPherson, Nucl. Data A9, 1 (1971).

[17] A. Arima and F. Iachello, Ann. Phys. (N.Y.) 111, 201 (1978).

[18] J. A. Cizewski, R. F. Casten, G. J. Smith, M. L. Stelts, W. R. Kane, H. G. Borner, and W. F. Davidson, Phys. Rev. Lett. 40, 167 (1978).

[19] The program was written by T. Otsuka and O. Scholten, KVI, Groningen, 1977 (unpublished).

[20] T. Otsuka, A. Arima, F. Iachello, and I. Talmi, Phys. Lett. 76B, 139 (1978).

[21] The computation was done by G. Puddu, KVI, Groningen, 1978 (unpublished).

[22] G Puddu and O. Schalten, private communication (1978).

[23] S. V. Jackson and R. A. Meyer, Phys. Rev. C 15, 1806 (1977).

[24] J. Bron, W. H. A. Hesseling, L. K. Peker, A. Van Poelgeest, J. Vitzenger, H. Verheul, and J. Zalmstra, J. Phys. Soc. Jpn. 44, 513 suppl (1978).

[25] H. W. Fielding, R. E. Anderson, C. D. Zafiratos, D. A. Lind, F. E. Cecil, H. M. Wiemand, and W. P. Alford, Nucl. Phys. A281, 389 (1977).

[26] M. D. Glascock, E. W. Schneider, W. B. Walters, and R. A. Meyer, Z. Phys. A283, 415 (1977).

[27] K. Heyde, M. Waroquier, and R. A. Meyer, Phys. Rev. C 17, 1219 (1978).

[28] P. vanIsacker, M. Waroquier, H. Vincx, and K. Heyde, Nucl. Phys. A292, 125 (1977).

[29] V. Garg, T. P. Sjoreen, and D. B. Fossan, in *Proceedings of the International Conference on Nuclear Structure, Tokyo, 1977*, edited by T. Marumori (Physical Society of Japan, Tokyo, 1978), p. 360.