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Decay of ^{132}Cs and nuclear structure of ^{132}Xe

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Gamma spectroscopy, coincidence, and angular correlation experiments were performed in an extensive study of ^{132}Cs decay. The population intensities of states in ^{132}Xe and ^{132}Ba were measured and some upper limits determined. The $\log ft$ value of the transition to the 4_1^+ state of ^{132}Ba differs significantly from previously published values. A new gamma transition of 688 keV was detected and located in the level scheme of ^{132}Xe. Angular correlation measurements were performed with a Ge(Li)-NaI(Tl) spectrometer. Kumar-Baranger-type calculations were performed for the ^{132}Xe and the results are compared to those of other collective models.

I. INTRODUCTION

The decay modes of ^{132}Cs, leading to states in ^{132}Xe and ^{132}Ba, have been the subject of extensive experimental investigation,[1-4] one of the latest works (especially about ^{132}Xe) being that of de Laat *et al.*[5] Multipole mixing ratios of transitions in ^{132}Xe were also studied by several authors.[5-8]

In this work we present the results of singles, coincidence, and angular correlation measurements to shed light on the following matters.

(i) The resemblance of the level scheme of ^{132}Xe to a quasivibrational nucleus suggests the presence of a possible gamma transition of about 688 keV, between 2_3^+ and 2_2^+ states, and an excited 0^+ state, member of the two-phonon triplet.

(ii) The EC feeding of states 4_1^+ and 4_2^+ is not well established; Ref. 1 shows the value 0.004% for the 1440 keV state, that was calculated from the work of Qaim.[9] With the same data one can evaluate its standard deviation as 0.014. There is no report on EC decay to the 1963 keV state.

(iii) Concerning gamma angular correlation works, examination of the data where authors adopted the spin 3 for the 1803 keV level[4,6-8] indicates the need for a new experimental study. The 1136 keV transition mixing has recent data that are not consistent with the value adopted by the compilation of Lange *et al.*[4] For the 506 keV transition the data presented by Ref. 4 were taken from works of Krane *et al.*,[10,11] who made use of an indirect correlation between the 506 and 668 keV transitions. Their results are not consistent with more recent ones.[6,8]

(iv) The $\log ft$ of the decay to the 4_1^+ state of ^{132}Ba is unusually low, 7.7, for a unique first-forbidden transition with such a low disponible energy, 166 keV.

Collective model calculations were performed for ^{132}Xe, and the results are in disagreement with those of Gneuss and Greiner[18] and dynamic deformation[8] models.

II. EXPERIMENTAL DETAILS

The ^{132}Cs was produced by the reaction $^{133}Cs(\gamma,n)$ with the bremsstrahlung photon beam of the linear accelerator at the Physics Institute of São Paulo University. The source material was $CsNO_3$ with a small presence of Rb.

The bremsstrahlung spectrum was produced by bombarding a 1 mm thick Pb sheet with an electron beam of 1 μA at 35 MeV. Three irradiations of 32 h each produced sources of about 50 μCi that were sealed in cylindrical plastic containers, with 3 mm of internal diameter, 6 mm height, and walls 1 mm thick. The radioactivity of products with half-lives shorter than that of ^{132}Cs was reduced by well suited waiting times.

The angular correlation measurement was performed with an automatic Ge(Li)-NaI(Tl) spectrometer. The Ge(Li) detector was true coaxial with 53 cm^3 of active volume. The other was a 7.6×7.6 cm Harshaw Integral Line NaI(Tl) crystal, coupled to an 8575 RCA photomultiplier tube. The electronics time resolution was 10 ns. Biparametric data in the two energies were accumulated on an array of 4096×256 channels, during 224 h of acquisition. Approximately 3×10^7 events were recorded, totalled over 7 angles.

Measurement of singles and coincidence data was performed with the same Ge(Li) detector above, and a high purity Ge one, with an active volume of 104 cm^3. The time resolution of the coincidence was 13 ns. The detectors were at an angle of 120° and source to detector distances were approximately 5 cm. Pb collimators were used together with 0.16 mm thick Pb absorbers, to stop the very intense Xe *K* x rays, which caused the appearance of sum peaks.

The coincidence acquisition mode was biparametric, on an array of 4096×2048 channels. The total time of measurement was 198 h for coincidences and 140 h for singles. All experiments were controlled by a PDP 11/45 computer, connected to the electronics and electromechanical devices by a CAMAC system. Linear amplifiers ORTEC 572 with pileup rejection circuits were used in the experiments.

III. EXPERIMENTAL RESULTS

A. Singles and gamma-gamma coincidence

The results obtained for gamma ray energies and intensities can be seen in Table I. The method used to deter-

TABLE I. Gamma ray energies and relative intensities.

Other results[a]		This work	
E (keV)	I_{rel}	E (keV)	I_{rel}
363.50(8)	0.76(9)	363.34(41)	0.69(3)
464.59(4)	19.2(10)	464.602(19)	16.7(7)
505.91(9)	8.4(6)	505.757(28)	7.90(33)
Ann. Rad.	7.4(10)	Ann. Rad.	8.05(40)
522.68(7)[b]			<0.011[c]
567.169(20)	2.50(22)	566.820(70)	2.31(8)
630.27(6)	10.2(7)	630.112(28)	9.23(34)
663.106(20)	0.65(19)		<0.033[c]
667.73(5)	1000	667.649(8)	1000
687.72	≈ 0.024	687.71(14)	0.022(5)
772.68(5)	0.76(10)	772.793(40)	0.73(3)
1031.75(3)	1.24(9)	1031.22(17)	1.24(4)
1136.18(8)	5.0(3)	1136.095(63)	4.41(15)
1298.00(8)	0.64(7)	1297.757(44)	0.50(2)
1317.82(18)	6.2(5)	1317.856(35)	5.45(20)
1985.55(18)	0.70(9)	1985.498(36)	0.65(4)

[a]Data taken from Ref. 3, except for the annihilation radiation and the 688 keV transition, taken from Refs. 5 and 1, respectively.
[b]Energy value determined from ^{132}I decay, present in Ref. 3.
[c]The upper limit for the intensity was established within a 95% confidence level, using the method of Ref. 12.

TABLE II. $E2/M1$ multipole mixing data. The convention used for the sign of δ is that of Ref. 13.

Initial state / Transition energy (keV)	δ Ref. 4	δ Ref. 6	δ Ref. 7	δ Ref. 8	This work δ	This work Cascade spins	A_{22}[a] A_{44}
1298/630	$4.8^{+1.2}_{-0.9}$ [b]	$4.50^{+2.00}_{-1.00}$ 4.07(16)	$6.1^{+6.5}_{-2.5}$	4.0(2)	3.70(17)	2_2-2_1-0	−0.241(6) 0.313(13)
1440/772[c]						4_1-2_1-0	0.110(33) −0.005(66)
1803/1136	0.9(3)	$0.22^{+0.15}_{-0.11}$ 0.34(2)	0.45(5)		0.344(26)	3_1-2_1-0	0.156(13) −0.019(26)
1803/506	$-(1.0)^{+2.0}_{-0.9}$ −1.3(4)[d]	7.5(6) or 0.40(2)		$1.7^{+0.6}_{-0.4}$ or $0.35^{+0.32}_{-0.16}$	3.57(47) or 0.09(4)	3_1-2_2-0	0.008(27) −0.071(54)
1803/363		1.10(20)	−0.023(23)		1.59(13)	3_1-4_1-2_1	−0.396(20) −0.182(40)
1986/1318	−0.077(25)	$3.67^{+1.00}_{-0.61}$ or −0.16(6)		−0.16(5)	−0.123(15)	2_3-2_1-0	0.329(10) 0.047(20)
1031/567[e]	$9.6^{+7.6}_{-2.9}$ [b]				19.7(83)	2_2-2_1-0	−0.113(16) 0.325(33)

[a]These coefficients were produced by a Legendre polynomial fit of the data, without the δ constraint between them.
[b]Mixing ratio from combined results.
[c]Transition used as a quality check.
[d]This value was determined by an indirect correlation between the 506 and 668 keV transitions.
[e]Transition in ^{132}Ba.

mine most of the gamma ray energies was of internal-calibration where we performed the measurement of the gamma radiation of the ^{132}Cs together with calibration sources (^{152}Eu in our case). This was inconvenient for a few transitions, due to the superposition of very intense lines from ^{152}Eu. To obtain these energies we first determined the others by the internal-calibration method and then employed these values to perform the calibration of the singles total sum spectrum.

The intensities were obtained from the total sum spectrum, with the exceptions of the 688 keV and the annihilation radiation: The former was only observed in the

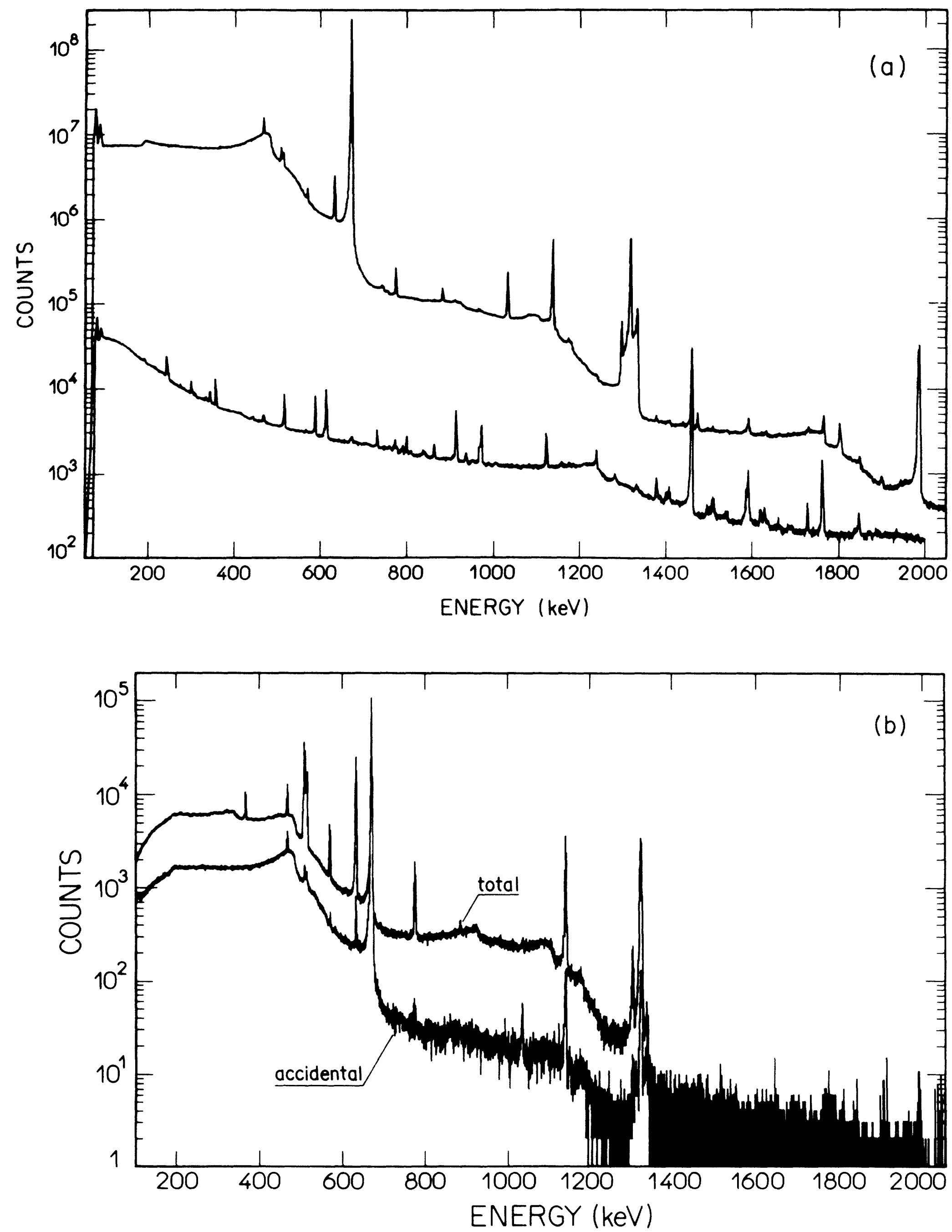

FIG. 1. (a) Singles data (140 h) and background (60 h). (b) Projection of coincidence data on the Ge(Li) energy axis.

coincidence data and the latter was determined from both data, singles and coincidence. Figures 1(a) and 1(b) show typical spectra obtained.

B. Angular correlation

The results for the multipole mixing ratios are given in Table II, compared to other data. The experimental angular correlation function governing the data can be written

$$W_{\exp}(\theta)=\alpha[1+A_{22}(\delta)Q_2P_2(\cos\theta)+A_{44}(\delta)Q_4P_4(\cos\theta)]\ , \qquad (1)$$

where α is the mean coincidence number factor, A_{kk} are the δ-dependent coefficients of the distribution, Q_k are the solid angle and finite source size corrections, $P_k(\cos\theta)$ are the Legendre polynomials of order k, and θ is the angle between the axes of the detectors. Instead of the usual α, A_{22}, and A_{44} fit, the data were submitted to a direct least-squares search for α and δ (Ref. 14), i.e., we took into account the constraint between A_{22} and A_{44}, given by their dependence on the mixing ratio. The standard deviations are evaluated in the usual way and this is why the 1σ intervals around δ are symmetric in Table II. As usual, the fitting of correlation data produces two minima for the χ^2, and the δ associated to the deepest is the one shown in Table II, except for the 506 keV transition, where the difference between the two χ^2 minima is not appreciable.

IV. NUCLEAR STRUCTURE CALCULATIONS FOR ^{132}Xe

We applied Bohr's collective model for ^{132}Xe (Ref. 15) in the form developed by Kumar and Baranger;[16] this model is the precursor of the dynamic deformation model (DDM).[26,27] The Bohr Hamiltonian, describing the collective quadrupole motion of the nucleus, is obtained after quantization of the following classical form:

$$H_{\text{coll}}=V(\beta_0,\beta_{2'})+\tfrac{1}{2}\sum_{\mu\nu}B_{\mu\nu}(\beta_0,\beta_{2'})\dot{\beta}_\mu\dot{\beta}_\nu+\tfrac{1}{2}\sum_{k}\mathcal{J}_k(\beta_0,\beta_{2'})\omega_k^2\ , \qquad (2)$$

with $\mu,\nu=0,2'$, $k=1,2,3$, $\beta_0=\beta\cos\gamma$, and $\beta_{2'}=\beta\sin\gamma$, where β and γ are the usual quadrupole deformation variables, V is the potential energy of deformation, and the remaining terms on its right are the vibrational and rotational kinetic energies, respectively. V, $B_{\mu\nu}$ and $\mathcal{J}_k$ are functions of the deformation variables, determined by a microscopic theory of quadrupole motion, using a many-body Hamiltonian,

$$H_{\text{mic}}=H_{\text{s.p.}}+H_{\text{res}}=\sum_\alpha \epsilon_\alpha c_\alpha^\dagger c_\alpha+\tfrac{1}{2}\sum_{\alpha\beta\gamma\delta}v_{\alpha\beta\gamma\delta}c_\alpha^\dagger c_\beta^\dagger c_\delta c_\gamma\ , \qquad (3)$$

where

$$v_{\alpha\beta\gamma\delta}=-G_\tau s_\alpha s_\gamma \delta_{\beta\bar{\alpha}}\delta_{\delta\bar{\gamma}}-\chi\sum_M(-)^M\langle\alpha|Q_{\overline{M}\tau}|\gamma\rangle\langle\beta|Q_{M\tau'}|\delta\rangle\ , \qquad (4)$$

with $\alpha=nljm\tau$ and $s=(-)^{j-m}$, α are the spherical shell-model single-particle quantum numbers with τ meaning the charge state, ϵ_α includes the kinetic and mean-field energies, $v_{\alpha\beta\gamma\delta}$ is the (nonantisymmetrized) matrix element of the residual interaction, given by the pairing-plus-quadrupole forces, with intensities given by G_τ and χ, respectively, and $Q_{M\tau}$ is the M component of the mass quadrupole tensor for nucleons of charge τ. This Hamiltonian is treated in the adiabatic-time-

TABLE III. Parameters used in the theory applied to ^{132}Xe.

Single-particle levels	Protons N	Protons nlj	Protons Energy[a]	Neutrons N	Neutrons nlj	Neutrons Energy[a]
	3	$1f_{7/2}$	−0.681	4	$1g_{9/2}$	−0.778
		$1f_{5/2}$	−0.298		$1g_{7/2}$	−0.222
		$2p_{3/2}$	−0.315		$2d_{5/2}$	−0.304
		$2p_{1/2}$	−0.142		$2d_{3/2}$	0.021
					$3s_{1/2}$	−0.152
	4	$1g_{9/2}$	0.000	5	$1h_{11/2}$	0.000
		$1g_{7/2}$	0.387		$1h_{9/2}$	0.623
		$2d_{5/2}$	0.390		$2f_{7/2}$	0.652
		$2d_{3/2}$	0.691		$2f_{5/2}$	0.949
		$3s_{1/2}$	0.723		$3p_{3/2}$	0.871
					$3p_{1/2}$	1.021
G (MeV)			$20/A$			
χ (MeV)			0.0847			
F_{in}			1.23			
$e(e_p)$		1.634			0.634	
F_{mag}			2.12			

[a]In units of $41.2A^{-1/3}$ MeV.

dependent-Hartree-Bogolyubov approximation becoming a Nilsson triaxial problem with pairing, applied to the upmost filled major oscillator shell and the next (to take into account the spread of the Fermi surface due to pairing), for protons and neutrons. The parameters entering here are the single-particle level spacings, taken from Uher and Sorensen,[17] the pairing and quadrupole intensities, given in Table III. All parameters were kept fixed, except for the quadrupole intensity and F_{in}, the inertial effect of the remaining nucleons, used as a renormalization of the inertial functions entering the Bohr Hamiltonian. χ and F_{in} were used to adjust the 4-2-0 spacings. Kinetic and potential energies are found by calculating the expectation value of the many-body Hamiltonian on the BCS ground state, and the macroscopic function V results as the BCS ground-state energy for each deformation plus a quadratic function of β, due to the quadrupole force. $B_{\mu\nu}$ and $\mathcal{J}_k$ are found by writing the kinetic part in the intrinsic reference frame and identifying the corresponding terms. The electromagnetic properties use two more parameters, the effective neutron charge, adjusted by the experimental $B(E2;2_2^+\rightarrow 2_1^+)$ and the magnetic renormalization factor, usually determined by the experimental $\mu(2_1^+)$ (we used the $\delta(E2/M1)$ of the transition $2_2^+\rightarrow 2_1^+$). These parameters are also given in Table III.

We calculated the collective wave functions of ^{132}Xe positive parity states, with spins ranging from 0 up to 6, below 2.5 MeV. Their electric quadrupole and magnetic dipole moments were obtained and some $E2$ and $M1$ reduced transition probabilities calculated (Tables V and VI).

V. DISCUSSION AND CONCLUSIONS

A. Energies and intensities

The energies deduced in this experiment are consistent with earlier data but, in general, more precise. The work of Hamada *et al.*,[8] on the isotopes 130 and 132 of xenon, pointed out the presence of a 686.35 keV transition, attributed, however, to the isotope 130 of xenon. Our coincidence data revealed the presence of a 687.69 keV transition, clearly linked to the 2_2^+ to 2_1^+ and 2_1^+ to 0_1^+ transitions. Its energy value and coincidence relations were enough to identify it as the 2_3^+ to 2_2^+ transition.

There was no evidence for the presence of the 0^+ excited state, member of the two-phonon triplet. If there exists such a state, the gamma intensities related to it are beyond the lowest intensity limit of this work.

The study of singles and coincidence data at the region of the 523 keV transition permitted the stipulation of an upper limit for its intensity and consequently for the EC feeding of the 4_2^+ state of ^{132}Xe.

The intensity balance concerning transitions to and from the 4_1^+ state of ^{132}Xe produced a better value for its EC feeding, with a 1σ interval less than 100% and its $\log ft$ was deduced.

The coincidence data with the 464 keV transition in ^{132}Ba produced the spectrum shown in Fig. 2, corrected for chance coincidences. If the intensity of β^- feeding of the 1128 keV state given by Qaim were correct, this spectrum should contain a photopeak of approximately 2000 counts at the position of the 664 keV energy. We thus set

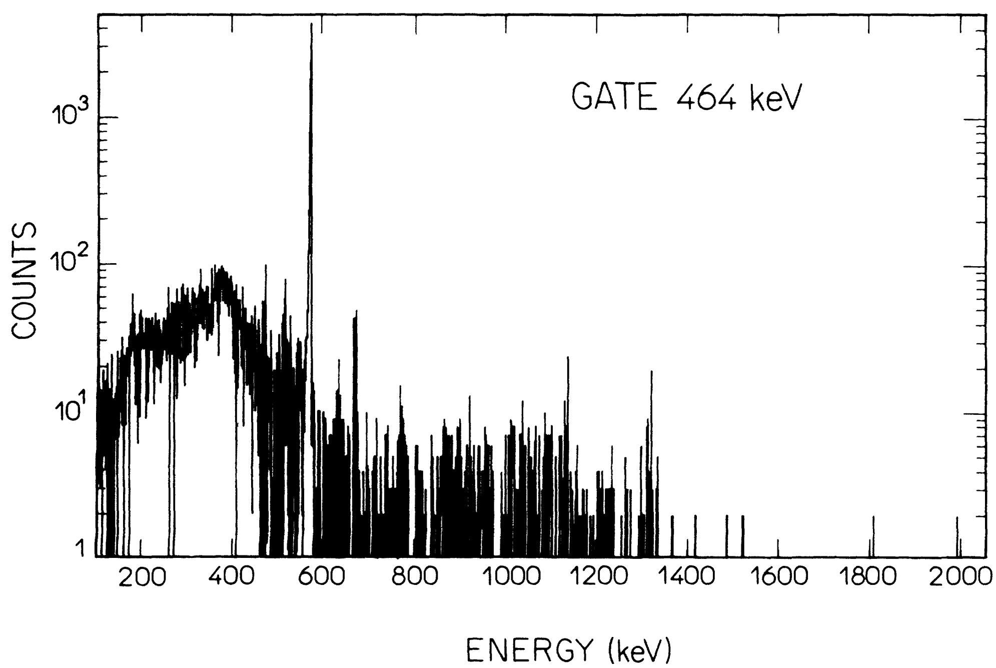

FIG. 2. Coincidence data gated by the 464 keV transition, true events only.

TABLE IV. $\beta^{\pm}$ and EC decay intensities deduced in this work.

State energy[a] (keV)	Feeding intensity (%)	logft	Gamma[a] transition (keV)	Branching ratio (%)
668	96(3) EC+0.39(2) β^+		668	
1298	0.20(4) EC		630	94.7
			1298	5.3
1440	0.010(4) EC	10.2	772	
1803	1.27(3) EC		363	5.0
			506	59.7
			1136	35.3
1963	<0.0012 EC	>8.3	b	
1986	0.63(2) EC		688	0.3
			1318	88.9
			1986	10.8
464	1.34(7) β^-		464	
1031	0.35(1) β^-		567	64.1
			1031	35.9
1128	<0.0032 β^-	>8.4	b	

[a]Energy values rounded off to keV.
[b]Gamma transitions following the decay of these states were not observed.

an upper limit for the β^- feeding intensity to that state and its new logft is consistent with a unique first-forbidden transition.

We deduced the positron decay intensity of ^{132}Cs from the annihilation radiation, with the singles and coincidence data. Our value is consistent with that of de Laat *et al.* Information on $\beta^{\pm}$ and EC decays is given in Table IV.

B. Multipole mixing ratios

The levels of ^{132}Xe are considered in order of increasing energy. The 1031 keV level of ^{132}Ba is treated at the end.

1298 keV level: Recent data and the compilation of Lange *et al.*[4] show several experimental values for the 630 keV, 2_2^+ to 2_1^+, transition mixing and the results contain no serious discrepancies.

1440 keV level: The 772–668 keV cascade was used as a quality check of the experiment (see Table II for the anisotropy coefficients).

1803 keV level: The 363 keV, 3_1^+ to 4_1^+, transition mixing had only one previous experimental value determined by the angular correlation method (Sooch *et al.*[7]), with a 1σ interval of 100%. It does not agree with the value presented by Girit *et al.*, which was obtained by measuring the gamma angular distribution from oriented nuclei. Our experimental value is consistent with that of Girit *et al.* Older data concerning transitions of 1136 and 506 keV, 3_1^+ to 2_1^+ and 3_1^+ to 2_2^+, respectively, show severe discrepancies. Our result for the 1136 keV transition agrees with that of Girit *et al.*; the 506 keV transition was studied by Krane and Steffen,[9] using the 506–668 keV indirect cascade. We studied the direct 506–1298 keV 3-2-0 cascade, producing two values quoted in Table II, which are in clear disagreement with earlier data. One of the recent results of Hamada *et al.*[8] is in agreement with one of the two values quoted by Girit *et al.*,[6] but the latter authors discarded this result, preferring the value 7.5(6) for the mixing ratio of the 506 keV transition. Our more probable result agrees with one of the pair given by Ref. 8. We believe that this low intensity cascade (506–1298 keV) needs even higher counting statistics to clearly define which chi-squared minimum is the physical one.

1963 keV level: The ^{132}Cs EC feeding of this state was not sufficiently intense to perform any angular correlation measurement.

1986 keV level: The 1318 keV, 2_3^+ to 2_1^+, transition has mixing values obtained by the angular correlation

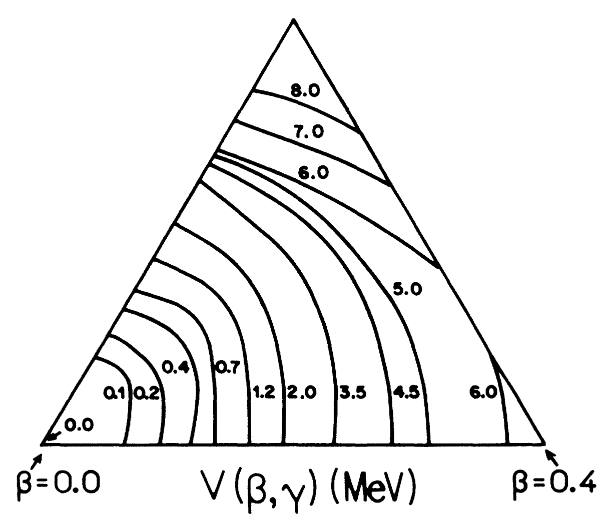

FIG. 3. Potential energy surface on the (β,γ) plane, for ^{132}Xe.

method with two NaI(Tl) detectors,[4] information from oriented nuclei[6] and from on-line correlations;[8] the value shown by de Laat *et al.* was calculated using other results and its sign disagrees with that of other data. Girit *et al.* show two values for this multipole mixing and the result of Hamada *et al.* agrees with one of them. Our result is also consistent with these two.

1031 keV *level*: The multipole mixing of the 567 keV, 2_2^+ to 2_1^+ transition in ^{132}Ba, was also determined in this work, showing a strong $E2$ composition as already evidenced in other experiments.

C. Theoretical results

The calculations of Habs *et al.*[18] with the Gneuss and Greiner model[19] produced a potential energy surface (PES) which shows a minimum in the form of a narrow (β,γ) valley, going from the spherical to the triaxial region, with $\gamma=31^0$. This PES characterizes a relatively β-soft and γ-rigid nucleus, where the β band is lowered and the γ band is moved towards higher excitation energies. The presence of a relatively low 0^+ excited state, at 1.63 MeV, is indeed expected by the Gneuss and Greiner model, and it is not true that this model accounts for the absence of a β-like band, as pointed out by Girit *et al.* The energy level scheme produced by this model is shown in Fig. 3. The $\gamma\approx 30^0$ triaxiality is also reinforced by the experimental level scheme, when we perform calculations with the triaxial rigid rotor.[20]

It would be of great interest to have an experimental value for the electric quadrupole moment of the 2_1^+ state of ^{132}Xe, since the model of Gneuss and Greiner gives a value of -0.01 e b, which is in severe disagreement with our calculated result, $+0.14$ e b. Half-life data for the excited states other than the 2_1^+ are important for a complete comparison.

Recent calculations of Hamada *et al.* using IBM-1,

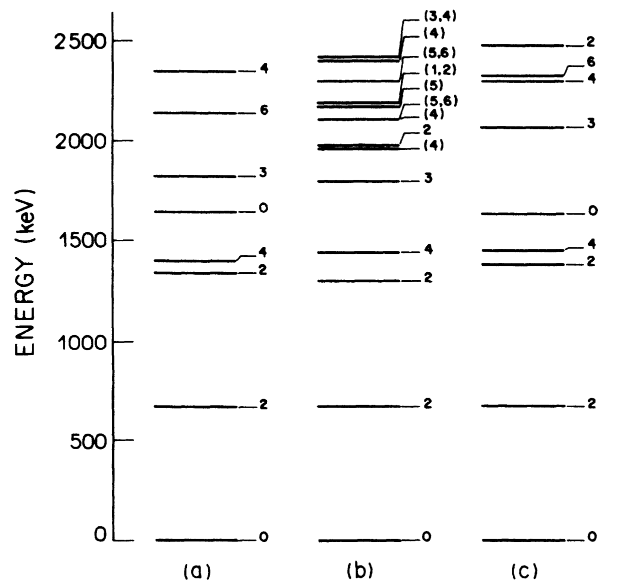

FIG. 4. Level schemes for ^{132}Xe: (a) from Habs *et al.* (Ref. 18) with the Gneuss-Greiner model; (b) experimental; (c) theoretical level scheme obtained in this work.

TABLE V. Theoretical $B(E2)$, $B(M1)$, δ, branching ratios and half-lives. Experimental δ and branching ratios are also shown.

States i	States f	$B(E2)$ (e^2b^2)	$B(M1)$ ($10^{-3}\mu_N^2$)	δ Theo.	δ Expt.	Branching ratios Theo.	Branching ratios Expt.	$t_{1/2}(i)$ Theo. (ps)
2_1	0_1	0.087[a]						4.7
2_2	2_1	0.147	3.88	3.66[b]		87	94.7	1.7
	0_1	0.001				13	5.3	
4_1	2_1	0.153				100	100	1.3
3_1	4_1	0.067	1.94	3.03	1.49	15	5.0	1.2
	2_2	0.162	3.71	−3.77	3.57	56	59.7	
	2_1	0.001	1.65	1.03	0.344	29	35.3	
4_2	3_1	0.003	3.20	−0.18		0.05		0.51
	4_1	0.084	8.76	2.20		41	89	
	2_2	0.100				58		
	2_1	0.0001				1	11	
2_3	4_2	0.006						1.0
	3_1	0.022	0.46	2.44		0.3		
	4_1	0.035				34.0		
	2_2	0.019	0.99	4.08		27.0	0.3	
	2_1	8×10^{-7}	0.72	−0.05	−0.125	4.9	88.9	
	0_2	0.089				33.6		
	0_1	2×10^{-6}				0.1	10.8	

[a]This value was fitted to the experimental one by choosing e_n, the effective neutron charge.

[b]This value was fitted to the experimental one by choosing F_{mag}, the magnetic renormalization factor.

TABLE VI. Theoretical Q and μ.

State	$Q(e\,\text{b})$	$\mu(\mu_N)$
2_1	0.141	2.61
2_2	−0.117	2.45
2_3	0.006	2.62
4_1	0.160	5.28
4_2	−0.011	5.13
3_1	0.000	3.77
6_1	0.142	7.97

IBM-2, and the DDM, show interesting features. IBM calculations seem to describe well the energy level density increase around 2 MeV, and the parameter-free DDM does not. Diversely from its early version,[15,16] the DDM shows an important displacement of the two-phonon triplet members with respect to the experimental values.

Our results with the Kumar-Baranger model showed the character of an anharmonic quadrupole vibrator, this owing to the regular experimental spacings between the states 4_1^+, 2_1^+, and 0_1^+, parameters of this calculation. The resulting PES is shown in Fig. 3. The theoretical results for energy levels and several electromagnetic properties are given in Fig. 4 and Tables V and VI.

Other theoretical calculations for the even-mass Xe isotopes, although not ranging to ^{132}Xe, are found in the literature. Other IBM approaches[21–23] classify the Xe isotopes under the O(6) limit, or γ-unstable nuclei, and the main disagreements with the experiment are the spacings between levels of the γ band and the relative position of 0_2^+ and 3_1^+ states. Casten *et al.*[21] achieve better results by introducing triaxial degrees of freedom in the Hamiltonian, thus breaking the γ instability. This means that the staggering of the γ-band states may well be the fingerprint of nuclear triaxiality.

Realistic interaction calculations around mass 130 performed by Hammarén *et al.*[24] show good agreement with experiment for $B(E2)$ values, but the best results concern energies of yrast states.

We concluded that the earlier Kumar-Baranger-type calculations are also able to produce approximately γ-unstable nuclei, if we relax the use of the 4_1^+-2_1^+-0_1^+ spacings as parameters. A shortcoming is that this model either does not produce stable triaxial nuclear shapes, or only very slight ones. Hayashi *et al.*[25] suggested that this behavior is characteristic of all variation-after-projection (VAP) calculations.

Still concerning the calculations done in this work, we believe that the introduction of the two quasiparticle component in the microscopic part of the Kumar-Baranger model may produce better results. This improvement is under way, on the lines of the work of Trefz *et al.*,[28] but extending the calculations to several single-particle levels.

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