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Revised B(E3) transition rate and structure of the 3^- level in ^{96}Zr

Ł.W. Iskra [a,*], R. Broda [a], R.V.F. Janssens [b,c,**], M.P. Carpenter [d], B. Fornal [a], T. Lauritsen [d], T. Otsuka [e], T. Togashi [e], Y. Tsunoda [e], W.B. Walters [f], S. Zhu [d]

[a] Institute of Nuclear Physics, PAN, 31-342 Kraków, Poland
[b] Department of Physics and Astronomy, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA
[c] Triangle Universities Nuclear Laboratory, Duke University, Durham, NC 27708, USA
[d] Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA
[e] Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[f] Department of Chemistry and Biochemistry, University of Maryland, College Park, MD 20742, USA

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The $B(E3)$ transition strength from the 1897-keV, 3^- level in ^{96}Zr has been reevaluated from six high-statistics, independent data sets. The measured value of 42(3) W.u. is significantly lower than that adopted in recent compilations. It is, however, in line with the global systematics of collective $B(E3)$ rates found throughout the periodic table. Thus, the "exceptional" character of this transition, that challenged theory, no longer applies. Monte Carlo shell-model calculations indicate that the collectivity of the octupole vibration arises from both proton and neutron excitations involving a large number of orbitals.

The susceptibility of an even–even nucleus to collective octupole correlations is reflected in the energy of its lowest 3^- level and in the enhancement of the rate of the $E3$ transition depopulating it to the 0^+ ground state. Throughout the nuclear chart, a number of nuclei exhibiting strong octupole correlations have been found. Among these, the ^{96}Zr nucleus stands out as it exhibits one of the strongest $E3$ transition rates ever reported [1], an observation for which there is thus far no satisfactory explanation. As discussed below, this unusually large $B(E3)$ rate is the focus of the present work.

Among known nuclei, a 3^- level is the first excited state only in ^{146}Gd and ^{208}Pb [2,3]. Although in both cases the measured $B(E3)$ transition probability displays a large enhancement of the same magnitude (∼35 Weisskopf units (W.u.)), the microscopic structures of these excitations are rather different. In doubly-magic ^{208}Pb, the 3^- level results from a coherent superposition of many particle-hole excitations and none of these contributes to the wave function with an amplitude larger than 10%. In contrast, in the ^{146}Gd nucleus with its closed $N = 82$ neutron shell and $Z = 64$ proton subshell, the collective 3^- state involves, with a large amplitude, the $h_{11/2}d^{-1}_{5/2}$ particle-hole excitation. This accounts for the regular change in the energy of the lowest 3^- level and for the $B(E3)$ values observed in the $N = 82$ isotones. It also explains the lowest 3^- energy and largest $E3$ transition rate occurring in ^{146}Gd with filled $d_{5/2}$ and empty $h_{11/2}$ proton subshells.

The ^{208}Pb and ^{146}Gd regions also exhibit a notable similarity when considering how octupole correlations are affected by the addition of neutrons in heavier isotopes. Neutrons above the $N = 126$ ^{208}Pb core fill the $g_{9/2}$ orbital and this strengthens octupole collectivity through the contribution of an additional amplitude involving the $g_{9/2} \rightarrow j_{15/2}$ excitation. Similarly, the $f_{7/2} \rightarrow i_{13/2}$ excitation enhances octupole correlations in the ^{146}Gd region, when neutrons are added above the $N = 82$ closed shell. The lowering of the 3^- energy by 306 keV in ^{148}Gd when compared to ^{146}Gd, and the increased $B(E3) = 42(5)$ W.u. [4] transition rate confirm the impact of this additional neutron amplitude. Similarly, in the ^{208}Pb region, the significant 745-keV lowering of the 3^- level in

* Corresponding author at: Institute of Nuclear Physics, PAN, 31-342 Kraków, Poland.
** Corresponding author at: Department of Physics and Astronomy, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA.
E-mail addresses: lukasz.iskra@ifj.edu.pl (Ł.W. Iskra), rvfj@email.unc.edu (R.V.F. Janssens).

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^{210}Pb with respect to ^{208}Pb is identified as resulting from access to the newly available $g_{9/2} \rightarrow j_{15/2}$ excitation which builds up the octupole collectivity [5].

In the present context, doubly-magic ^{40}Ca with $Z = N = 20$ is another notable even–even nucleus: its 3^- level is located nearly 400 keV above the lowest 0^+ excited state, but 167 keV below the first 2^+ level. This collective 3^- excitation is depopulated by an enhanced $E3$ transition (31(4) W.u.) [6] to the ground state and, in heavier Ca isotopes, only a small, gradual lowering of the 3^- excitation energy is observed, accompanied by a decrease of the $B(E3)$ values [1].

Considerable experimental and theoretical efforts have also been devoted to the study of the evolution of the 3^- level energies and $E3$ transition rates in the Zr isotopic chain. In ^{90}Zr, with a closed $N = 50$ neutron shell and a $Z = 40$ proton subshell, the 3^- level is located at the relatively high excitation energy of 2748 keV and its $B(E3)$ rate is determined to be 28.9(15) W.u. [1]. Considering all available excitations and the size of the relevant proton and neutron gaps, leads to the conclusion that the collectivity of this octupole state predominantly originates from the amplitudes of proton excitations. However, in Zr isotopes with $N > 50$, the filling of the $d_{5/2}$ neutron orbital gives rise to an increase of the 3^- collectivity, as was the case for protons in the ^{146}Gd region. Indeed, a regular decrease of the 3^- level energy is observed to 2340-, 2058-, and 1897-keV in ^{92}Zr, ^{94}Zr, and ^{96}Zr [1], respectively, and the accompanying rise in octupole collectivity is also reflected in increasing $B(E3)$ rates of 18.1(11) [7], 24(8) [1], and 57(4) W.u. [8]. These $B(E3)$ probabilities have been adopted in the most recent compilations of Refs. [1,7,8] based on thorough reviews of all the available data. Nevertheless, the $B(E3)$ value adopted for ^{90}Zr seems rather puzzling as it is unexpectedly larger than those of ^{92}Zr and ^{94}Zr. Additional experimental verification might be desirable. Furthermore, as already alluded to above, the large $B(E3)$ transition probability in ^{96}Zr stands out: its large 57(4) W.u. value makes it the strongest known $E3$ transition in a spherical nucleus. However, this large enhancement is not understood as it has never been reproduced by theoretical calculations which will be widely discussed below.

In the present work, the $E3/E1$ branching ratio for the transitions depopulating the 3^- level in ^{96}Zr was determined with great accuracy from a number of measurements. The new ratio points to a significantly lower relative intensity for the $E3$ transition than previously reported. This in turn leads to a revision of the corresponding $B(E3)$ strength, and the revised value is more in line with those of the other nuclei exhibiting large octupole correlations discussed above. The reliability of the new result will be discussed. The structure of the 3^- state and the associated $B(E3)$ transition probability will also be compared with the results of calculations carried out within the Monte-Carlo Shell-Model (MCSM) approach of Refs. [10,11]. The calculated wave function indicates that the collectivity of the octupole vibration arises from both proton and neutron excitations and that a number of orbitals is involved, with the main contributions coming from the $p_{3/2} \rightarrow g_{9/2}$ proton and $d_{5/2} \rightarrow h_{11/2}$ neutron excitations.

Since nearly three decades, the half-life of the 3^- level in ^{96}Zr and the relative intensity of the depopulating $E3$ branch have been measured to various degrees of precision and these quantities served to extract the associated $B(E3)$ strength. Although, in general, the half-life values measured by several groups provide consistent results of 88(44) [12], 46(15) [13], and 50(7) ps [14], the recoil-distance-method determination of $T_{1/2} = 67.8(43)$ ps by Horen et al. [15] has to be considered as the most precise and reliable value. It should be noted that the weighted average of all of the results above gives the rather close value of 66.2(40) ps. However, two of the results do not overlap within the claimed uncertainties with the value of Ref. [15] and, therefore, the latter will be used here for the $B(E3)$ determination.

More confusing is the situation regarding the relative intensities of the $E1$ and $E3$ transitions depopulating this 3^- state in ^{96}Zr. First information about the branching ratio between the two γ rays can be found in publications by Klein et al. [16] and Sadler et al. [17], where the intensity of the 1897-keV $E3$ transition has been measured as 16.8(18)% and 15.1(20)%, respectively, relative to the 147-keV $E1$ transition, adopted as 100%, including the total electron conversion branch. A similar value of 14.2% was reported in Ref. [18] for the 1897-keV line, but with unspecified precision. A significantly larger intensity of 18.0(8)% has been measured by Molnar et al., [19] in studies following both (n,n'γ) and (p,p'γ) reactions. Finally, Mach et al. [20] determined a 1897-keV branch of 19(6)% from ^{96}Y ground-state β decay. Whereas the most precise value measured by Molnar et al. [19] was understandably used to deduce a large $B(E3)$ value in the main compilations of Refs. [1,8], a preliminary inspection of data available for the present work appeared to indicate a significantly smaller intensity for this 1897-keV $E3$ transition. This preliminary observation provided the motivation to resolve this inconsistency between reported branching ratios by taking advantage of extensive coincidence data from six independent experiments performed earlier to study nuclei produced in so-called deep-inelastic heavy-ion collisions carried out at energies 10 to 20% above the Coulomb barrier.

The experiments were all conducted at Argonne National Laboratory using the ATLAS superconducting linear accelerator and the Gammasphere detector array consisting of 101 Compton-suppressed germanium spectrometers [21]. The detailed description of these measurements can be found in a number of publications devoted to high-spin state investigations of neutron-rich nuclei produced in deep-inelastic reactions focusing mostly on the Ni [22] and Pb [23] regions, although the same data were also used to study neutron-rich Sn isotopes [24,25] produced in fusion–fission and/or induced-fission reactions with the same projectile-target combinations. Similarly, fission processes were also found to produce ^{96}Zr with high yields in six experiments selected for the present analysis. In four of these, a thick ($\sim$50 mg/cm^2)^{238}U target was bombarded by the ^{76}Ge, ^{64}Ni, ^{48}Ca, and ^{208}Pb beams and, in the other two, a ^{76}Ge beam was directed onto ^{208}Pb and ^{198}Pt targets of comparable thickness. In all cases, the reaction products were stopped in the target.

The partial ^{96}Zr level scheme of Fig. 1(c) indicates that the depopulation of the 3^- level to the ground state proceeds via the 1897.2-keV $E3$ transition and the much stronger 146.6-keV $E1$ branch, where the latter γ ray is followed by the 1750.4-keV $2^+ \rightarrow 0^+$ ground-state transition. The scheme of Fig. 1(c) also includes a cascade, established in previous studies [8], of three additional transitions feeding the 3^- level. This sequence was observed in all six data sets as it constitutes the main yrast path. It turned out that coincidence spectra gated on these three higher-lying transitions provided, with high statistics, the information required to determine precisely the intensity ratio between the 1897.2- and 1750.4-keV transitions. This quantity is a direct measure of the sought-after 3^- branching as the coincidence requirement on transitions located above the 3^- state of interest prevents unwanted contributions from any other feeding. Apart from the clean selection of ^{96}Zr events, this approach has the important additional advantage of comparing intensities of two close-lying, high-energy lines in a spectral region where the background is well defined and the detector efficiencies well established. In all previous measurements, the 1897.2-keV transition intensity had to be compared directly with that of the 146.6-keV low-energy transition for which an accurate efficiency determination is potentially more challenging due, mostly, to the potential for unwanted electronic effects

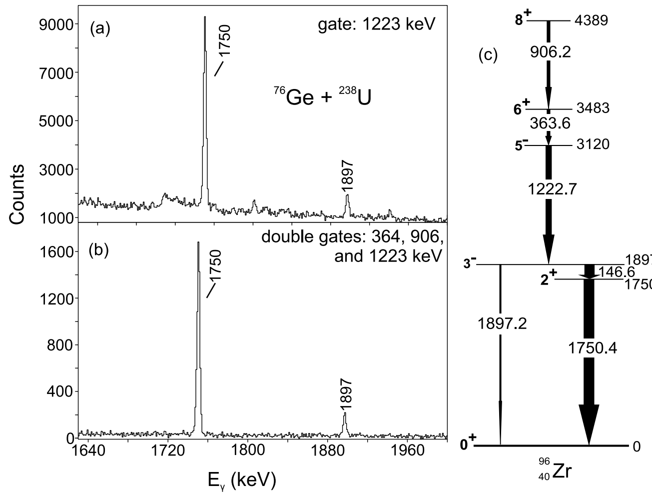

Fig. 1. Representative coincidence spectra, (a and b), used to determine the branching ratio in the decay of the 3^- level together with the partial level scheme of ^{96}Zr crucial for this determination (c). Both spectra were obtained from the ^{76}Ge + ^{238}U data, using either (a) the γ–γ coincidence matrix with a single gate placed on the 1223-keV transition or (b) the γ–γ–γ cube with double gates placed on all combinations of the 364-, 906-, and 1223-keV transitions from the yrast sequence populating the 3^- level.

(time walk in discriminators). In addition, it should be noted that the intensity determination for the 1750.4-keV line in coincidence spectra gated by upper transitions automatically includes the 3.7% internal electron conversion branch of the 146.6-keV $E1$ transition, which had to be accounted for separately in earlier branching determinations.

Data from each of the six experiments were unfolded into double- and triple-γ coincidence events. A "prompt" coincidence condition was applied requiring that all detected γ rays were measured within a 30-ns window, herewith practically excluding contributions from random events. Both γ–γ matrices and γ–γ–γ cubes were used in the analysis, as illustrated by the sample coincidence spectra from the ^{76}Ge + ^{238}U experiment of Figs. 1(a) and (b). The upper spectrum was obtained from the γ–γ matrix with a single gate placed on the 1222.7-keV transition. It demonstrates the absence of any strong contaminating line in the energy range of interest. Hence, the intensity ratio between the 1897.2- and 1750.4-keV transitions can be determined with high statistical significance. The lower spectrum was obtained from the γ–γ–γ cube with double gates on all three combinations of transitions in the cascade feeding the 3^- level. Although the number of counts is smaller by a factor 5 than in Fig. 1(a), this spectrum is devoid of any contaminant transition and the background is well defined. In fact, the required intensity ratio can be determined with a precision comparable to that obtained from spectrum (a). These two approaches were systematically used in analyses performed for all six data sets. They resulted in consistent values of the intensity ratio between the 1897.2- and 1750.4-keV transitions in all cases. The data confirmed the smaller intensity of the $E3$ branch when compared to the adopted value of Refs. [1,8]. The results are summarized in Table 1: for each reaction, the relative intensity of the 1897.2-keV $E3$ γ ray, with respect to the 100 intensity units adopted for the 1750.4-keV transition, is given separately from double- and triple-coincidence spectra. The intensities show small dispersions and the weighted average of 13.0(3) overlaps within errors with all partial results. The precision achieved in this approach justifies consideration of a small correction accounting for the summing of 146.6- and 1750.4-keV photons in a single detector. This effect has been investigated for the Gammasphere array [9] and was determined from the present data to be 0.16

Table 1
Relative intensity of the 1897-keV transition determined from the data obtained in six experiments using different collision systems. The final value of the 1897-keV $E3$ branch intensity is determined as 12.8(3) after a small correction accounting for the summing effect (see text).

Reaction type	Intensity of the 1897-keV line$^{(a)}$		
	3 gates$^{(b)}$	gate: 1223 keV	gate: 364 keV
^{76}Ge + ^{238}U	13.3(13)	13.5(6)	12.5(5)
^{64}Ni + ^{238}U	12.7(13)	13.2(6)	12.8(6)
^{48}Ca + ^{238}U	13.5(13)	12.8(6)	13.2(6)
^{208}Pb + ^{238}U	13.4(27)	13.0(13)	13.6(11)
^{76}Ge + ^{208}Pb	12.4(33)	12.3(11)	12.8(11)
^{76}Ge + ^{198}Pt	12.9(30)	12.4(12)	13.7(12)
	13.1(7)$^{(c)}$	13.0(3)$^{(c)}$	12.9(3)$^{(c)}$

$^{(a)}$ – normalized to the 1750-keV transition intensity defined as 100 units.
$^{(b)}$ – combined double coincidence gates on 364-, 906-, and 1223-keV transitions.
$^{(c)}$ – weighted average values, 13.0(3) final result was adopted with uncertainty taking into account that the data used are partly correlated.

in intensity units of Table 1. Hence, the corrected final value of 12.8(3) for the 1897.2-keV $E3$ relative transition intensity is used below for the $B(E3)$ determination.

The half-life of 67.8(43) ps of Ref. [15] and the γ-ray relative intensities established in the present work result in a partial half-life of 0.60(4) ns for the 1897.2-keV $E3$ transition to the 0^+ ground state. The determined reduced transition probability of $B(E3) = 23(2) \times 10^3$ e^2 fm^6 then corresponds to a strength of 42(3) W.u., still defining the 1897.2-keV transition as strongly collective, but not as enhanced as previously thought. In fact, this new $B(E3)$ value is nearly 30% lower than that accepted in the NNDC data base [8]. Consequently, in this same data base, the rate for the 146.6-keV $E1$ transition has to be modified slightly as well, yielding a value $B(E1) = 18(1) \times 10^{-4}$ e^2 fm or $133(8) \times 10^{-5}$ W.u.

The enhancement of octupole collectivity in ^{96}Zr has also been studied using a number of theoretical approaches. The first attempt to describe the observed strength was proposed by Kusnezov et al. [26] who calculated a $B(E3)$ value of 36.4 W.u. However, the energy of the 3^- state was computed about 400 keV lower than the experimental excitation. Later, a calculation by Ohm et al. based on the Interaction Boson Model (IBM) [13], which included s, p, d, and f bosons, resulted in a significantly lower transition probability than the experimental strength. Therefore, these authors explored the potential of the Random Phase Approximation (RPA) methodology to account for the large $B(E3)$ value. From their work, the authors concluded that the observed enhancement could be reproduced only when $3\hbar\omega$ excitations were included, although the main contribution to the $B(E3)$ probability comes from both $g_{9/2} \to p_{3/2}$ proton and $h_{11/2} \to d_{5/2}$ neutron transitions. Rosso et al. [27] extended these RPA calculations significantly while restricting their configuration space to $2\hbar\omega$ excitations, and obtained a 28.2 W.u. value. However, better agreement (37.9 W.u.) was achieved when applying a Quasiparticle RPA (QRPA) approach including both particle-hole and particle–particle excitations. Moreover, these authors pointed out that the inclusion of both the particle-particle channel and pairing correlations enhanced the collectivity up to 42.8 W.u. In all the calculations of Ref. [27], the coherent superposition of neutron and proton excitations where shown to contribute with similar magnitude to the excitation. Another attempt to describe the data within the QRPA framework can be found in Ref. [28], where the inclusion of two-phonon excitations resulted in a 39.2 W.u. calculated strength, with only a minor contribution attributed to pairing. In yet another theoretical effort within the RPA approach, Mach et al. [14] discussed a significantly lower $B(E3)$ value of 19 W.u. and proposed a different origin for the octupole enhancement. Their calculations, based on the deformed shell model, suggested that the octupole instability around ^{96}Zr involves a rather complex anharmonic motion and points to the special role of the $h_{11/2}$ orbital in the enhancement of 3^- collectivity. On the other hand, the experimental g-factor study of Refs. [29,30] supported by shell-model calculations (carried out with the OXBASH code [31]) suggests a single-proton configuration for the 3^- state.

Generally speaking, these theoretical efforts resulted in scattered values of the computed $B(E3)$ rate, most often lower than the experimental strength adopted prior to the present work. It can be noted that, in fact, some of the calculated values now come rather close to this revised experimental one. Nevertheless, while most of the theoretical attempts have been carried out within the RPA and QRPA frameworks, each of the calculations, through its own limitations, is such that theoretical results are inconsistent with one another and no firm conclusion can be drawn about the relative contributions of proton and neutron excitations to the octupole collectivity.

In an attempt to remedy this situation, the present work considers a new theoretical approach based on the Monte Carlo shell model (MCSM) [10,11]. In the MCSM calculations, a large configuration space was used consisting of the full sdg shell for all nucleons. Moreover, the proton $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$ and neutron $1h_{11/2}$, $3p_{3/2}$, $2f_{7/2}$ orbitals have been included as well. Effective $E3$ charges of $e_p = 1.24e$ and $e_n = 0.82e$ were adopted as explained in Ref. [33]. The description of the various inputs to the calculations and of their detailed application to the Zr isotopic chain can be found in the recent work of Togashi et al. [32]. In Ref. [33], the results of these calculations were found to satisfactorily reproduce the measured transition strengths to the ^{96}Zr 2_1^+ and 2_2^+ states, herewith validating an interpretation in terms of coexisting spherical and deformed shapes (so-called Type-II shell evolution [34]).

Further information on the results of these MCSM calculations are provided in the present work with the purpose of exploring the exact nature of the 3_1^- level, and of informing on the role of octupole correlations. Results of these calculations are summarized in Fig. 2 and Table 2, where all the contributions to the $B(E3)$ transition probability are listed in terms of the specific proton and neutron excitations involved.

Fig. 2 indicates that the calculated 3^- is located somewhat too high in comparison with the data, but the general low-spin level structure accounts for the shape coexistence picture described above. The first observation to be made from Table 2 is that both proton and neutron excitations are strongly involved in building octupole collectivity. The second striking feature, however, concerns the anticipated role of the $p_{3/2} \rightarrow g_{9/2}$ proton and $d_{5/2} \rightarrow h_{11/2}$ neutron excitations with the calculations indicating only 13% and 30% contributions, respectively.

Furthermore, the results of Table 2 also point to a sizable role for excitations involving orbitals located above the shell gaps and occupied as the Fermi surface is diffused by the pairing interaction. For instance, the $g_{9/2} \rightarrow p_{3/2}$ proton transition has a contribution exceeding 5% while the $h_{11/2} \rightarrow d_{5/2}$ neutron one is of the order of 9.8%. Considering that these excitations have to be summed

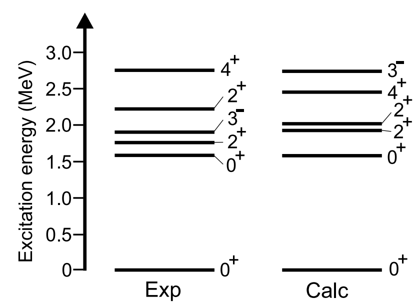

Fig. 2. Comparison of the low-spin ^{96}Zr levels with the results of MCSM calculations described in the text.

Table 2
Contributions of the various proton and neutron excitations to the B(E3; $3^- \rightarrow 0^+$) transition probability in ^{96}Zr calculated using the MCSM approach described in the text.

Proton				Neutron			
Initial orbit	Final orbit	Contribution [%]		Initial orbit	Final orbit	Contribution [%]	
$0f_{5/2}$	$0g_{9/2}$	1.3	6.0	$0g_{9/2}$	$0h_{11/2}$	6.3	8.2
	$1d_{5/2}$	0.7			$1f_{7/2}$	1.5	
	$2s_{1/2}$	0.7			$2p_{3/2}$	0.4	
	$1d_{3/2}$	1.0		$1d_{5/2}$	$0h_{11/2}$	29.8	33.5
	$0g_{7/2}$	2.3			$1f_{7/2}$	3.2	
$1p_{3/2}$	$0g_{9/2}$	13.1	17.2		$2p_{3/2}$	0.5	
	$1d_{5/2}$	1.3		$2s_{1/2}$	$1f_{7/2}$	0.2	0.2
	$1d_{3/2}$	1.9		$1d_{3/2}$	$2p_{3/2}$	0.1	0.1
	$0g_{7/2}$	0.9		$0g_{7/2}$	$0h_{11/2}$	0.1	0.1
$1p_{1/2}$	$1d_{5/2}$	1.9	4.9				
	$0g_{7/2}$	3.0					
$0g_{9/2}$	$0f_{5/2}$	0.7	5.8	$0h_{11/2}$	$0g_{9/2}$	3.1	13.0
	$1p_{3/2}$	5.1			$1d_{5/2}$	9.8	
$1d_{5/2}$	$0f_{5/2}$	0.4	2.2		$0g_{7/2}$	0.1	
	$1p_{3/2}$	0.7		$1f_{7/2}$	$0g_{9/2}$	1.0	3.0
	$1p_{1/2}$	1.1			$1d_{5/2}$	1.7	
$2s_{1/2}$	$0f_{5/2}$	0.5	0.5		$2s_{1/2}$	0.2	
$1d_{3/2}$	$0f_{5/2}$	0.6	1.7		$1d_{3/2}$	0.1	
	$1p_{3/2}$	1.1		$2p_{3/2}$	$0g_{9/2}$	0.3	0.6
$0g_{7/2}$	$0f_{5/2}$	1.3	3.3		$1d_{5/2}$	0.2	
	$1p_{3/2}$	0.5			$1d_{3/2}$	0.1	
	$1p_{1/2}$	1.5					
Sum			41.6				58.7

with the "reverse" ones; e.g., $p_{3/2} \to g_{9/2}$ (13%) and $d_{5/2} \to h_{11/2}$ (30%) (which, for simplicity, can be written as $g_{9/2} \leftrightarrow p_{3/2}$ and $h_{11/2} \leftrightarrow d_{5/2}$), these main proton and neutron contributions account for 18% and 40% of the total, respectively. In a similar way, the summing of dual contributions in Table 2 from other excitations provides additional, but significantly lower contributions; e.g., from the $f_{5/2} \leftrightarrow g_{7/2}$ (2.3%), $p_{1/2} \leftrightarrow g_{7/2}$ (3.0%) proton and $g_{9/2} \leftrightarrow h_{11/2}$ (6.3%), $d_{5/2} \leftrightarrow f_{7/2}$ (3.2%) neutron excitations. A number of other excitations contributing to the structure of the 3^- level are listed in Table 2 as well, reflecting the complexity of this state. Interestingly, it should be noted that the calculated $E3$ matrix elements for the individual combinations of the initial and final orbitals were found to be all in phase. The largest ones involve correspondingly the main neutron and proton components of the 3^- level and contributions are more fragmented for protons.

The calculated transition strength of $B(E3; 3^- \to 0^+) = 46.6$ W.u. obtained from the present MCSM calculations agrees well with both the previous (53(6) W.u.) [1] and the new (42(3) W.u) values. Hence, the calculation indicates that the 3^- state in ^{96}Zr gets its octupole collectivity from both neutron and proton excitations with the total contribution from neutrons being larger and reaching nearly 59%. It remains, however, unclear whether the proton and neutron modes are correlated with one another. If present, this effect should be reflected in the evolution of the $B(E3)$ values across the Zr isotopic chain. Experimentally, this strength of the $B(E3)$ probability evolves from 18.1(11) in ^{92}Zr to 24(8) in ^{94}Zr, and to 42(3) W.u in ^{96}Zr, presumably reflecting the growing contributions from neutron excitations. In this context, the experimental strength of 28.9(15) W.u for ^{90}Zr, where proton excitations may be expected to dominate, seems rather puzzling, but can be viewed as uncertain. Although the relevant $E3/E1$ branching in the depopulation of the 3^- state is known [8], the half-life was not measured and the $B(E3)$ value adopted in the compilations [1,8] is based on (^{17}O,^{17}O') [35] and (e,e') [36] inelastic scattering cross sections with conflicting results. Hence, a new determination of the $B(E3)$ strength in ^{90}Zr appears warranted as, based on the considerations above, a smaller value than that in ^{92}Zr would be anticipated.

In summary, in the present work the $E3$ branch in the decay of the 3^- state in ^{96}Zr was determined to be of significantly lower intensity than previously reported. This in turn required a revision of the value of the B(E3; $3^- \to 0^+$) transition probability and the new value of 42(3) W.u. is nearly 30% lower than the one adopted previously. As a result, this $3^- \to 0^+$ transition no longer stands out as being associated with a notably large strength. The new value reported here is based on consistent results from six independent measurements with Gammasphere that benefited from the power of selective gamma coincidences techniques. The new value also compares well with state-of-the-art Monte Carlo shell-model calculations which indicate that the collectivity of the octupole vibration arises from both proton and neutron excitations and that a large number of orbitals is involved, in contradiction with some of the interpretations proposed previously.

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