Comment on "Anomalously Hindered $E2$ Strength $B(E2;2_1^+\to 0^+)$ in ^{16}C"

In a recent Letter [1], Imai *et al.* have measured an anomalously hindered $E2$ transition in ^{16}C between the first 2^+ state and the ground state with a value of $B(E2;2_1^+\to 0_1^+) = 0.63e^2$ fm^4, or 0.26 Weisskopf units (WU). Comparing this value with other $B(E2)$ values in light and medium-heavy nuclei, typical values of 10–30 WU result in open-shell nuclei whereas for single-closed-shell nuclei smaller values result.

The authors start from a simple two-level model treating the 2_1^+ state in ^{16}C as the result of coupling the two-proton hole $2_1^+(\pi)$ times neutron closed-shell $0_1^+(\nu)$ configuration in ^{14}C with the complementary proton closed-shell $0_1^+(\pi)$ times two-neutron particle $2_1^+(\nu)$ configuration in ^{18}O. Moreover, by using as input the experimental energies for the 2_1^+ energies in these semiclosed shell nuclei, i.e., 7.01 MeV (^{14}C) and 1.98 MeV (^{18}O), as well as the experimental energy of 1.77 MeV for the measured 2_1^+ level in ^{16}C, a coupling matrix element between the two "unperturbed" configurations has been derived as well as the wave function corresponding to this 2_1^+ state. This latter wave function then reads

$$|2_1^+;{}^{16}\mathrm{C}\rangle = 0.20|2_1^+(\pi)\otimes 0_1^+(\nu)\rangle - 0.98|0_1^+(\pi)\otimes 2_1^+(\nu)\rangle. \quad (1)$$

The subsequent conclusion that the two $E2$ components will lead to a destructive interference, with the resulting $B(E2)$ of $7.0e^2$ fm^4, however, is generally incorrect.

As discussed in [2], it has been shown that, irrespective of the precise nature of the proton and neutron building blocks that make up the final state (2p-2p, 2h-2h or 2p-2h and 2h-2p), the lowest $2_1^+\to 0_1^+$ $E2$ transition in the coupled system is always a coherent combination of the separate $E2$ matrix elements starting from an attractive particle-particle interaction. The expression in [2] reads as follows:

$$\langle 0_1^+\|T(E2)\|2_i^+\rangle = \frac{1}{\sqrt{2}}[\langle 0_1^+(1)\|T(E2)\|2_1^+(1)\rangle - (-1)^i\langle 0_1^+(2)\|T(E2)\|2_1^+(2)\rangle], \quad (2)$$

where the indices (1) and (2) indicate the matrix elements in the subsystems (in the present case for ^{14}C and ^{18}O, respectively) and the index i labels the first and second ($i = 1, 2$) 2^+ state in the coupled system (here ^{16}C). This expression holds if one considers the subsystems to be of 2p-2p or 2h-2h character with a constructive interference for the $E2$ transition from the first excited 2_1^+ state, and with degenerate 2^+ energies in the two subsystems. One might have the impression that for 2p-2h (or 2h-2p) systems the sign of the wave function will modify this rule, but this is not the case since the $E2$ matrix elements in the two subsystems also give rise to a relative change of sign compared to the 2p-2p (or 2h-2h) systems [2]. Thus, coherence is restored for the lowest 2^+ state irrespective of the character of the separate building blocks giving rise to an isoscalar $E2$ transition.

Using the values given in [1] and using the correct method, we obtain as the new result the value of $12.4e^2$ fm^4. Thereby, the difference between the calculated value [1] and the measured value even increases. Thus, as a conclusion, it seems impossible to obtain a quenching of the valence-shell $E2$ strength anywhere near the experimentally observed value.

Considering, moreover, the high excitation energy of the 2_1^+ state in ^{14}C at 7.01 MeV, it is clear that a simple two-level model as used by the authors of [1] is too simplistic, and the next excited 2^+ states have to be incorporated, too (the next state appears at 8.32 MeV). Since we cannot find a mechanism acting within the proton and neutron valence space that would explain the very small $B(E2)$ value, we propose the possibility that the observed 2_1^+ state in ^{16}C is built on an excited 0^+ intruder state [3] and that the main $E2$ strength proceeds into this proposed 0^+ state. To obtain a reasonable $B(E2)$ value, this 0^+ state would have to occur at about 800 keV below the 1766 keV 2^+ state. Experiments by Balamuth *et al.* [4] using the ^{14}C$(t,p)^{16}$C reaction gave rise to spectra showing some irregularities below the 1.77 MeV level in the final nucleus; however, the use of NaI(Tl) detectors is not conclusive in pointing out the existence of a lower-lying 0^+ level in ^{16}C.

To conclude, the analysis as carried out in Ref. [1], leading to a desctructive interference between the separate $E2$ components, is generally incorrect, and the use of a simple two-level model is too crude to analyze the present $E2$ decay. It would be very interesting to perform measurements of the γ-ray spectrum with a highly increased resolution in the energy region below 1.5 MeV to search for excited states in ^{16}C below the 1.77 MeV 2^+ state.

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