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Extremely large oblate deformation of the first excitation in ^{12}C: a new challenge to modern nuclear theory

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A high-statistics Coulomb-excitation (CE) study of ^{12}C onto an enriched ^{208}Pb target has been carried out at safe energies using the high-resolution {\sc Q3D} magnetic spectrometer at the Maier-Leibnitz Laboratory (MLL) in Munich (Germany). Measurements at different scattering angles and beam currents of approximately 10^{11} pps allowed the determination of the spectroscopic quadrupole moment for the first excitation at 4.439 MeV in ^{12}C, $\mathrm{Q}_S(2_1^+)$, with unprecedented accuracy. The effect of the nuclear electric dipole (E1) polarizability on the $\mathrm{Q}_S(2_1^+)$ measurement has been investigated using the no-core shell model (NCSM) with the N^{4}LO500-srg2.4 chiral effective-field-theory (χEFT) interaction, where the Lanczos continued fraction algorithm was applied for the first time to sum up contributions of all excited states and allow the calculation of hundreds of E1 transitions up to 70 MeV; a huge improvement compared to previous NCSM calculations [1,2]. The NCSM calculation predicts $\kappa(2_1^+) = 1.40(5)$. Using this result and the weighted average $B(E2; 0_1^+ \to 2_1^+) = 39.1(8)$ e^{2}fm^4 from all previous measurements (excluding CE measurements) we get a large $\mathrm{Q}_S(2_1^+) = 10.5(10)$ efm^2, confirming the oblate but enhanced deformation for the 2_1^+ state, in agreement with a recent Coulomb-excitation measurement using particle-γ coincidences with a double-sided silicon detector at backward angles [3]. Such a large $\mathrm{Q}_S(2_1^+)$ value challenges modern theoretical calculations which generally predict $\mathrm{Q}_S(2_1^+) \approx 6$ efm^2; independent of the interaction in the case of NCSM calculations. The most likely explanation for the larger oblate deformation found in this work concerns α-cluster effects that are not properly included in the NCSM [4,5,6]. Finally, this work emphasizes the need of dedicated measurements of the E1 polarizability using stable and radioactive-ion beams, which will also be briefly discussed.

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