Measurements of the g Factor and Lifetime of the $^{46}Ca(2_1^+)$ State ◇

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The surprising g factor results from recent measurements on ^{42,44}Ca isotopes [1,2] have motivated us to determine also the g factor of ^{46}Ca. In this specific case large scale shell model calculations (LSSM) predicted an even larger positive value compared to the lighter isotopes which should be measurable in the same efficient way with our technique of projectile Coulomb excitation in inverse kinematics using an isotopically pure calcium beam and a carbon target. However, the natural abundance of ^{46}Ca is with 0.004 % so low that only with a commercial enrichment of 7.5 % this experiment was feasible; altogether becoming a costly and difficult measurement.
A pure ^{46}Ca beam of 95 MeV was provided with an intensity of $\sim$ 0.5 enA on the target by the Cologne tandem accelerator whereby the first-stage acceleration required a negatively charged $^{46}\mathrm{Ca}H_2^-$ beam. The multilayered target consisted of thin layers of $^{nat}C - Gd - Ta - Cu$ where the Coulomb excited ^{46}Ca projectiles experienced the transient field of the Gd layer and were stopped in the Cu backing. Deexcitation γ rays were measured with NaI(Tl) scintillators in coincidence with forward scattered carbon ions and were registered in a Si detector. In addition, a Ge detector at 0° was used to determine the lifetime of the nuclear state via the Doppler-Shift-Attenuation method by analyzing the Doppler-broadened lineshape.

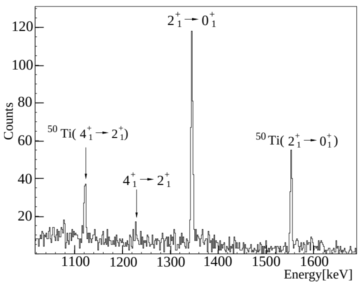

Fig. 1: The γ coincidence spectrum of ^{46}Ca and ^{50}Ti.

Fig. 1 shows a Ge coincidence spectrum with the lines of interest. There are also γ lines from ^{50}Ti which was formed in an α-transfer reaction from carbon to ^{46}Ca; the lines were well resolved from the $^{46}\mathrm{Ca}(2_1^+ \to 0_1^+)$ line, even in the scintillators' spectra.
The results are shown in Fig. 2 together with our former data for ^{42,44}Ca in comparison with the LSSM predictions [3]. The $B(E2)$ was deduced from the measured lifetime of $\tau(2_1^+) = 6.6(15)$ ps which very well agrees with the literature value confirming the significant difference to the ^{42}Ca data. Evidently, the g factor is in striking disagreement with the calculations: its sign is definitely negative contrary to the prediction. It is noted that the LSSM calculations included sd shell core excitations into the fp shell which accounted very well for both the ^{42}Ca and ^{44}Ca results. Only in this extended model space the large experimental $B(E2)$'s as well as the positive g factor values could be explained.
For understanding the ^{46}Ca results full fp shell calculations have been performed using KB3 and FPD6 as effective interactions. The best agreement with the experimental g factor and $B(E2)$ was obtained with FPD6. The calculated values are $g = -0.271$ and $B(E2; 0_1^+ \to 2_1^+) = 0.0108\ e^2b^2$ which very well agree with experimental data of $g = -0.19(12)$ and $B(E2) = 0.014(3)\ e^2b^2$. Evidently, the collectivity of the $^{46}\mathrm{Ca}(2_1^+)$ state in terms of particle-hole excitations of the ^{40}Ca core is substantially overestimated by the LSSM calculations. As seen in Fig. 2 the calculated $B(E2)$ is similar to that of ^{42}Ca whereas the experimental values differ by almost a factor 3. This difference in the $B(E2)$'s has been confirmed by the present remeasurement of the lifetime. The fact that the ^{46}Ca has a much smaller core excitation component in its wave function compared to the two lighter isotopes is not yet fully understood.

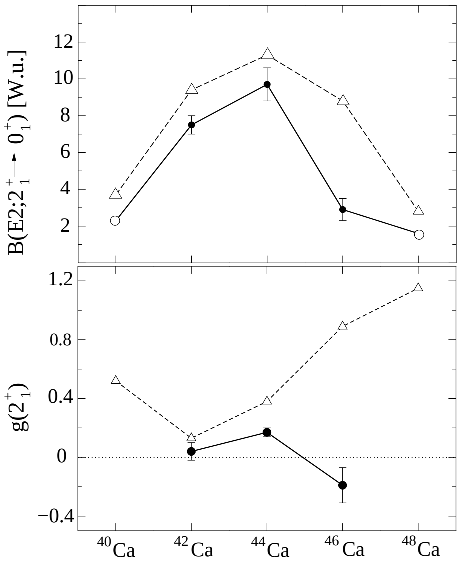

Fig. 2: $B(E2)$'s (in Weisskopf units) and $g(2_1^+)$ factors for all stable even-A Ca isotopes. Closed circles refer to present and former data [2]. The g factors are compared to results of LSSM calculations (triangles, see text).

References

[1] M.J. Taylor *et al.*, Phys. Lett. **B559** (2003) 187
[2] S. Schielke *et al.*, Phys. Lett. **B571** (2003) 29
[3] K.-H. Speidel *et al.*, Phys. Rev. **C68** (2003) 061302(R)

◇ work supported by DFG