surprisingly similar to structure previously observed in the cross-section excitation function for the $^{27}Al(p,\gamma_0)^{28}Si$ capture reaction.[17] Explanations of the bumps in terms of more general doorway configurations such as particle-vibration coupling[8] may also be possible. In any case, the striking nature of the structure observed here in A_y, compared to the much more gentle average structure observed for so long in cross-section studies, suggests the importance of pursuing this investigation both theoretically and experimentally.

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Magnetic Moment of the 6_1^+ State in ^{42}Ca†

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The g factor of the 6_1^+ state at 3189 keV ($T_{1/2}$ = 5.4 nsec) in ^{42}Ca has been remeasured with a significant improvement in accuracy by a pulsed-beam time-differential method using an in-beam superconducting magnet at 61 kG. The g factor obtained is $g(6_1^+) = -0.415 \pm 0.015$. A $g(\nu f_{7/2}) = -0.53 \pm 0.02$ is extracted from this result by use of the coexistence wave function due to Erikson; this value is in agreement with the single-particle value of -0.547 indicating a negligible orbital anomaly δg_l.

The study of the magnetic moments of nuclear states near doubly closed shells provides a useful probe into the magnetic properties of nucleons inside nuclear matter. Because of the structure of the bare $M1$ operator, there are no first-order core-polarization contributions to the single-particle magnetic moment from a core which is doubly closed in both L-S and j-j coupling, as for the ^{40}Ca nucleus. Recently there have been theoretical efforts[1-4] to understand the magnetic dipole moments of states in the Ca region in terms of effective $f_{7/2}$-nucleon moments and hence to test the additivity of $f_{7/2}$ magnetic moments in this region. The determination of whether there are anomalies in the orbital part of $f_{7/2}$-nucleon g factors, δg_l, due to mesonic effects[5] is of considerable interest. The magnetic moment of the 6_1^+ state in ^{42}Ca plays a pivotal role regarding the deduction of the effective $f_{7/2}$-neutron moment. Unfortunately the existence of two different experimental values[6,7] for the 6_1^+ g factor has rendered the theoretical interpretation somewhat inconclusive.

The important criteria for performing a precision time-differential perturbed-angular-distribution (PAD) measurement of the g factor of a short-lived state are to have a high magnetic field and to observe the spin precession for a long time range, including the region near $t=0$ where the statistical errors are at a minimum. In order to make a significant improvement in precision and reliability over the previous measurements, a superconducting magnet system, which was constructed at the Stony Brook tandem accelerator[8] for this and other in-beam g-factor measurements, was used. The Nb-Ti split solenoid was designed to provide sufficient homogeneity of the applied field for g-factor measurements while maximizing the γ-counter solid angles. The 6_1^+ state in ^{42}Ca at 3189 keV with $T_{1/2} = 5.4$ nsec was populated in this work by two reactions: ^{40}Ca(α, 2p)^{42}Ca with a 23-MeV pulsed α beam on a thick metallic Ca target, and ^{39}K(α, p)^{42}Ca with a 16-MeV pulsed α beam on a thick KI target. Both of the reactions used give similar alignment of the 6_1^+ state in ^{42}Ca, but a 16-MeV α beam incident on a KI target was superior for the g-factor measurement because the γ-ray spectrum was very clean, indicating that the ^{42}Ca(6_1^+) state was selectively populated. For a 23-MeV α beam incident on a ^{40}Ca target, additional neutron background distorted the time spectra near $t=0$, and both the ^{42}Sc(7^+) and ^{43}Sc($\frac{19}{2}^-$) isomers were produced which added to the background at long times. The g factor of ^{42}Ca(6_1^+) was measured by the pulsed-beam–γ time-differential PAD method. The experimental arrangement is shown in Fig. 1. Two large-volume Ge(Li) detectors of two magnetically shielded NaI(Tl) detectors were placed at ± 45° with respect to the effective beam direction. Each NaI(Tl) detector had a 20-cm light pipe to minimize the effect of the fringing field of the superconducting magnet. The overall pulsed-beam–γ time resolution for the 1228 keV ($4^+ \to 2^+$) γ ray was about 6 nsec (full width at half-maximum) with the Ge(Li) detectors and about 3 nsec with the NaI(Tl) detectors.

The superconducting magnet which was operated in its persistent mode produced a magnetic field of 60.9± 0.4 kG. The magnetic field was calibrated[8] by time-differential PAD measurements of the 8^+ state in ^{210}Po and the $\frac{5}{2}^+$ state in ^{19}F. The usual ratio $R(t) = [N(-45°) - N(45°)]/[N(-45°) + N(45°)]$ data for the reaction ^{39}K(α, p)^{42}Ca are shown in Fig. 2 along with least-squares fits; the Larmor frequencies ω_L deduced from these

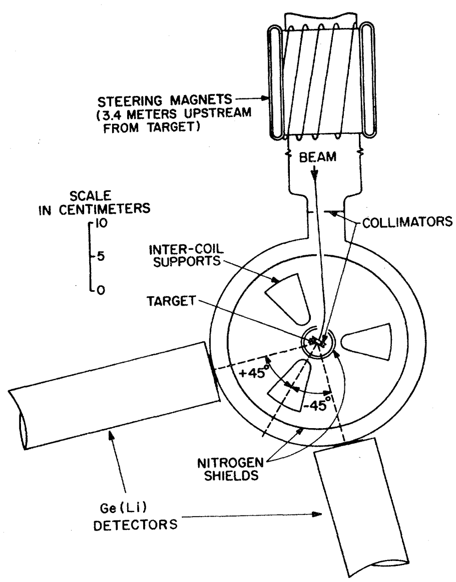

FIG. 1. Top view of the experimental arrangement in the mid-plane of the superconducting magnet. For some of the measurements, the Ge(Li) detectors were replaced with NaI(Tl) detectors.

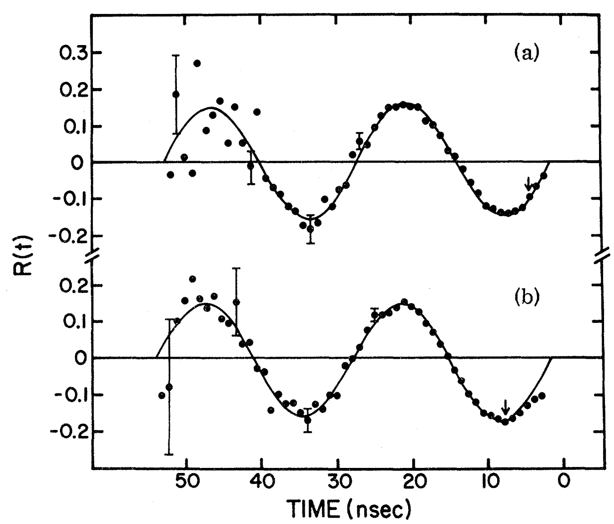

FIG. 2. The ratio $R(t)$ (see text) as a function of time after the beam pulse for two separate experiments with the reaction ^{39}K(α, p)^{42}Ca and a magnetic field of 60.9 kG. (a) Data were taken with NaI(Tl) detectors, and the least-squares fit shown gave $\omega_L = 0.119(6)$ nsec^{-1}. (b) Data were taken with Ge(Li) detectors and gave $\omega_L = 0.1224(25)$ nsec^{-1}. The small arrow near $t=0$ in each curve indicates the starting point of the fit.

fits are given in the figure caption. The results for the reaction $^{40}Ca(\alpha, 2p)^{42}Ca$ yielded Larmor frequencies in agreement with the $^{39}K(\alpha, p)^{42}Ca$ results, although the uncertainties are larger because of the increased background. Diamagnetic and Knight-shift corrections to the magnetic field are less than 0.2%. The value of the g factor obtained from a weighted sum of all of the data is $g(6_1^+) = -0.415 \pm 0.015$. This result agrees with the previous integral measurement of Marmor, Cochavi, and Fossan[6] ($g = -0.42 \pm 0.03$) but is in disagreement with the time-differential measurement of Nomura *et al.*[7] ($g = -0.50^{+0.02}_{-0.03}$). The new result for ^{42}Ca is shown in Table I along with known g factors and related β-decay matrix elements for nuclei near ^{40}Ca.

The analysis of the $^{42}Ca(6_1^+)$ g factor is complicated by the existence of particle-hole (p-h) deformed states in this region. Two approaches to understand this g factor have been developed. In the phenomenological approach of Arima,[1] the wave function of the $^{42}Ca(6_1^+)$ state is written as

$$|^{42}\mathrm{Ca}(6_1^+)\rangle = (f_{7/2})^2(6^+) + \alpha(f_{7/2}, f_{5/2})(6^+).$$

The admixture of the configuration $(f_{7/2}, f_{5/2})$ in $^{42}Ca(6_1^+)$ is determined to be $\alpha = -0.096$ from a comparison of the β-decay matrix elements of $^{41}Sc \to {}^{41}Ca$ and $^{42}Sc \to {}^{42}Ca$ whose wave functions were assumed to have an $f_{7/2}$ structure. A calculation using the bare Kuo-Brown interaction and the $f_{7/2}$-$f_{5/2}$ energy spacing as 5.5 MeV gives $\alpha = -0.092$ in agreement with the value obtained from the β decay. To evaluate the $^{42}Ca(6_1^+)$ g factor, Arima used the g factor of the $^{41}Ca(\frac{7}{2}^-)$ ground state as an effective $f_{7/2}$ g factor. The cross term $\langle f_{7/2}{}^2 | M1 | f_{7/2}, f_{5/2}\rangle$ was obtained with the single-particle $M1$ operator. Using the value of α from the most recent β-decay measurements[9,10] one then obtains $g(^{42}Ca(6_1^+)) = -0.413$ in excellent agreement with the experimental value. This agreement suggests that the corrections to the moment from the deformed states can be renormalized into the ^{41}Ca effective moment. However, in order to examine the $f_{7/2}$ magnetic moment operator itself, an explicit calculation of the effect of these core-excited deformed states must be included.

Erikson[11] determined the composition of the lowest 6^+ state of ^{42}Ca by combining the ideas of Kuo and Brown,[12] who included the configurations $(f_{7/2})^2$, $(f_{7/2}, f_{5/2})$ and $(g_{9/2})^2$, and those of Gerace and Green[13] who introduced deformed 4p-2h core-excited components. He gave the following expression for the 6_1^+-state magnetic moment,

$$\mu(6_1^+) = 6a^2 g(\nu f_{7/2}) + (\tfrac{2}{7}b^2 + \tfrac{4}{3}c^2 + \tfrac{2}{7}\sqrt{6}\,2ab) \times (-1.913) + 3.52d^2,$$

in terms of the $^{42}Ca(6_1^+)$ wave function

$$|^{42}\mathrm{Ca}(6_1^+)\rangle = a(f_{7/2})^2 + b(f_{7/2}, f_{5/2}) + c(g_{9/2})^2 + d(\text{4p-2h}),$$

where $g(\nu f_{7/2})$ denotes the g factor of the $f_{7/2}$ neutron, and $a = 0.968$, $b = -0.136$, $c = -0.066$, and $d = 0.199$. The g factor of the 4p-2h deformed state was calculated to be $+0.587$ by using a projection technique, whereas single-particle operators were used to evaluate the other contributions. The $f_{7/2}$-neutron g factor extracted from a comparison of this theoretical expression and the present experimental value is $g(\nu f_{7/2}) = -0.53 \pm 0.02$, which is very close to the single-particle value of -0.547. If Erikson's wave function adequately describes the ^{42}Ca state, this agreement

TABLE I. g factors and β-decay matrix elements for nuclei near ^{40}Ca.

Nucleus	J^π	Main configuration	g_{exp}[a]	$\langle\sigma\rangle / \langle\sigma\rangle_{s.p.}$
^{41}Sc	$(7/2)^-$	$\pi f_{7/2}$	1.551(6)	0.761(6)[b]
^{41}Ca	$(7/2)^-$	$\nu f_{7/2}$	−0.45561	
^{42}Sc	7^+	$\pi f_{7/2}\nu f_{7/2}$		0.995(3)[c]
^{42}Ca	6^+	$(\nu f_{7/2})^2$	−0.415(15)	
^{43}Sc	$(19/2)^-$	$(\pi f_{7/2})(\nu f_{7/2})^2$	0.331(2)	

[a]Except for ^{42}Ca, all values are from the collection of $f_{7/2}$ magnetic moments by T. Nomura, J. Phys. Soc. Jpn., Suppl. 34, 619 (1973).

[b]Ref. 9.

[c]Ref. 10.

indicates that the $f_{7/2}$ moment as observed in this region can be understood without invoking an anomalous orbital g factor. Quantitatively, this comparison yields $\delta g_l(\nu) = 0.02 \pm 0.02$ for the $f_{7/2}$ neutron.

Recent studies[14] of one- and two-nucleon-transfer reactions have indicated that the 3p-2h components may be present to the extent of 10% to 20% in the ground state in ^{41}Ca. Gerace and Green[13] predicted a 15% admixture of the deformed 3p-2h component into the ground state of ^{41}Ca. A calculation of the ^{41}Ca g factor, using this admixture and the $g(\nu f_{7/2})$ obtained from the present ^{42}Ca result, does not agree with the experimental g factor. However, since the ^{41}Ca g factor is quite sensitive to this deformed admixture, a slightly smaller admixture of 10% produces consistency between the ^{41}Ca and ^{42}Ca moments. Similarly the admixtures of the components in the ^{42}Ca(6_1^+) state might also be subject to small changes. Any future improvements in the accuracy of the ^{42}Ca wave function should be used together with the present experimental result to gain a better understanding of the $\nu f_{7/2}$ magnetic moment operator.

The interpretation of the g factor of the ^{42}Ca(6_1^+) state is closely related to other measured quantities in the ^{40}Ca region, namely the β-decay matrix elements in ^{41}Sc and ^{42}Sc in addition to other g factors. These measurements are summarized in Table I. A comprehensive interpretation of all of these precisely measured quantities in terms of one consistent theoretical framework is needed to obtain a better understanding of the nuclear structure and effective operators for the ^{40}Ca region.

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