MAGNETIC MOMENTS AND SHORT-RANGE CORRELATIONS*

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Contrary to previous assertions, Brueckner correlations do affect magnetic moments. The parameterization that emerges seems to work also for lower energy correlations.

The calculation of magnetic moments of nuclei near closed shells was apprently simplified by Amado's observation that the short-range correlations of the Brueckner theory do not influence the moments [1]. We will first show that this assertion is incorrect, and then discuss the effect of intermediate energy correlations, which can be calculated in second-order perturbation theory. These correlations take the theoretical magnetic moment of ^{209}Bi further from experiment.

Amado's proof for the orbital contribution to the magnetic moment rests on the analogy of Brueckner correlations with Jastrow correlations [2,3]. The Jastrow correlation operator $f(r_1 - r_2)$ is a real function which multiplies the two-particle shell model wavefunction. Even after integrating out the second particle the function multiplying the wavefunction of the first particle is real. Since the expectation value of the velocity is not changed by multiplying a wavefunction by a real function, the orbital magnetic moment will not be changed.

The Brueckner theory correlation acts almost exclusively in S-waves. The tensor force is negligible and healing is much faster in other partial waves. This means that for practical purposes the correlation operator is real in the center-of-mass system of the interacting pair. In the lab system we can represent the correlated wavefunction as

$$\psi = \left[1 + f(r_1 - r_2)\ \frac{\exp\{\frac{1}{2}i(k_1 + k_2)(r_1 + r_2)\}}{\exp\{i(k_1 r_1 + k_2 k_2)\}}\right] \times \phi_{k_1}(r_1)\phi_{k_2}(r_2)\ . \qquad (1)$$

We note parenthetically that this form for the correlation operator proved more useful in the problem of 3-body clusters than the Jastrow form [4]. Now the average velocity of a nucleon in the correlation is just the center-of-mass velocity. For a particle on the Fermi surface this would be just half the single-particle velocity. Define the probability of a Brueckner correlation between proton and neutron κ_{pn}. We would then expect that the orbital g-factor for valence protons would be influenced by core neutrons and vice versa according to

$$g_{\text{proton}} = 1 - \tfrac{1}{2}\kappa_{pn}\ , \qquad g_{\text{neutron}} = \tfrac{1}{2}\kappa_{pn}\ . \qquad (3)$$

From nuclear matter calculations, the probability κ_{pn} has been estimated to be of the order 0.15 [5,6].

In a previous paper we calculated the probability of intermediate energy correlations [7]. These are not well treated in the usual Brueckner theory, and so can be regarded as independent correlations. Because of the exclusion principle

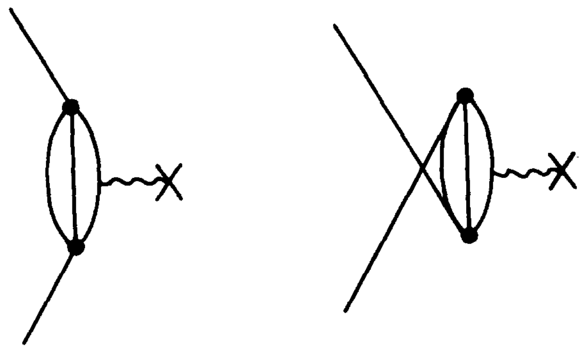

Fig. 1. Perturbation theory diagrams included in the calculation of the magnetic moment of ^{209}Bi.

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Table 1
Effective orbital g-factors of intermediate energy correlations from ref. 8. The effective g-factor is defined.

$$g_{\text{orbital}} \equiv \frac{\mu_{\text{corr}}/\kappa_{\text{corr}} - \mu_{\text{spin}}\,(\text{Schmidt})}{\mu_{\text{orbital}}\,(\text{Schmidt})}$$

Nucleus	^{17}O	^{41}Ca
g_{orbital}	0.59	0.59

and spin-orbit splittings, it is not obvious that the magnetic moment will have the simple behavior of equation (2). Mavromatis et al. [8] have made a complete calculation of intermediate energy second-order effects in ^{17}O and ^{41}Ca, finding a quenching. To see how useful eq. (2) is to describe the quenching, we take their intermediate state magnetic moment, divide by the probability of the correlation, and subtract the spin contribution of the single particle. This gives an effective orbital moment, which we divide by the single-particle orbital moment to get the effective g-factors of table 1. This may be compared with the Brueckner theory value $\frac{1}{2}$, if we assume that all the probability is in pn correlations. Of course, the Brueckner correlations are at high energies, so that the effective g-factors need not be the same.

The second order calculation of the ^{209}Bi magnetic moment by Mavromatis et al. [9] used a very limited configuration space. Because there is a large discrepancy between theory and experiment for this nucleus we repeated the calculation. We used essentially the same parameters, summing all graphs shown in fig. 1 that involve an intermediate energy of 30 MeV or less, as in ref. 7. The resulting second-order magnetic moment is given in table 2, separated into neutron and proton contributions. Dividing by the intermediate state probability and subtracting the $h_{\frac{9}{2}}$ spin contribution, we find the effective g-factors shown. The results for the proton-neutron correlation are in reasonable accord with eq. (2). The g-factor should remain 1 for a proton-proton correlation; the fact that it is higher shows that spin flip is important. This is caused by the single-particle spin-orbit potential.

Table 2
Magnetic moment corrections from correlations in ^{209}Bi.

	proton-proton correlation	proton-neutron correlation
Probability	0.054	0.262
Magnetic moment of correlation	0.238 n.m.	- 0.022 n.m.
effective g_{orbital}	1.36	0.48

The second-order effects give a total contribution to the magnetic moment in ^{209}Bi of - 0.61 nuclear magnetons. This is to be compared with the experimental value of 4.08 n.m. and the best calculated value of ref. 9, 3.21 n.m. Thus disagreement between theory and experiment is much worse than had been suspected. Mesonic effects correct this somewhat, but are far too small to explain the total discrepancy [10,11].

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