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QUANTUM FLUCTUATIONS IN THE BAG AND NUCLEON OBSERVABLES

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The hadronic bag model provides a phenomenological realization of two of the major properties attributed to QCD, asymptotic freedom and confinement, and at the same time is roughly consistent with baryon spectra. Improvements in the original model have been mainly concerned with the incorporation of chiral invariance in the model. Much less attention has been devoted to gluon mediated processes within the bag, which induce quantum fluctuations in the quark fields there.

In the present work, we have developed a time-dependent, perturbative formalism within the static, spherical cavity approximation to describe the effect of such gluon induced quantum fluctuations on static nucleon observables. In contrast to previous work¹, (1) all relevant contributions to second order in the QCD coupling constant are systematically generated from the time-ordered perturbation series and included in the numerical treatment; and (2) the intermediate state sums that occur in normal mode expansions of the fermion and gluon propagators are carried out over a complete set of states consistent with parity and SU(2) coupling rules.

The order g^2 diagrams occurring in the present treatment can be divided into two classes: 2-body diagrams characterized by a gluon exchange between two different valence quarks, which are finite, and 1-body diagrams that involve a single valence quark. Among the full set of 1-body diagrams, only those representing vertex corrections to the external current insertion are actually calculated since 1-body self-energy diagrams are automatically accounted for through mass and wave function renormalization.

In the sum over intermediate states, the 1-body vertex diagrams exhibit the same sort of logarithmic divergences as are associated with loop integrals in the continuum theory. To remove these, we employ a Pauli-Villars regularization in which a finite regularization mass is introduced into the gluon spectrum. The finite part of the renormalization is then fixed by requiring that the renormalized vector and axial vector quark-current couplings be free of gluonic radiative corrections inside the bag where a global SU(2) $\times$ SU(2) chiral

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symmetry is exactly realized in the Wigner-Weyl mode (for zero mass quarks with Goldstone fields excluded from the interior).

Table 1 summarizes the results of this procedure. For the nucleon axial vector coupling constant and the squared EM and axial charge radii, the corrections obtained are non-negligible, but small compared with the zeroth order (MIT) results. Taken by themselves, the results for these observables support the concept of the bag as a bounded, perturbative region within a non-perturbative vacuum. The magnetic moment corrections, on the other hand, are obviously much too large. Through explicit consideration of counter terms in the Lagrangian, one can demonstrate that the magnetic moment results violate the Ward-Takahashi identity, which requires that a single counter term remove the divergences associated with all components of the vector current. Since the vector current renormalization is fixed through the time component (vector coupling constant), and the magnetic moments involve the space components, it is clear that the renormalization prescription employed here is not Lorentz invariant, a deficiency which we believe to be attributable to the static cavity approximation. If this conclusion is correct, it indicates a possible difficulty for static bag models in that meaningful finite results cannot be obtained for all observables beyond zeroth order in perturbation theory on the basis of a single renormalization.

TABLE 1
Calculated and empirical results for several nucleon observables

	Γ_0	$\delta\Gamma$	$\Gamma_0 + \delta\Gamma$	Γ_{exp}
$\langle r_{\text{EM}}^2 \rangle_p$	0.53	-0.082	0.45	0.69
$\langle r_{\text{EM}}^2 \rangle_n$	0	-0.028	-0.028	-0.12
μ_p	1.93	-1.04	0.89	2.79
μ_n	-1.28	0.84	0.44	-1.91
g_A	1.09	0.183	1.27	1.25
$\langle r_A^2 \rangle$	0.50	0.192	0.69	0.7

For each observable, Γ_0 is the zeroth order MIT result, $\delta\Gamma$ the order g^2 correction, and Γ_{exp} the empirical value.

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