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Strangeness form factors of the nucleon and the anomalous magnetic moments of constituent quarks

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The nucleon's strange form factors $G_E^S(Q^2)$ and $G_M^S(Q^2)$, and the neutron's electromagnetic form factors $G_E^n(Q^2)$ and $G_M^n(Q^2)$, are obtained from the light-cone quark model including the quark anomalous moments due to the meson-loop corrections. The anomalous magnetic and strange moments of the constituent quark make significant contributions: Without them, $G_M^S(0)$ vanishes, r_S^2 becomes positive, and the neutron charge radius is too small.

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The strangeness content of the nucleon [1] is a subject of growing interest in various subfields of nuclear and particle physics, such as the strange quark contribution to the proton structure function [2,3], and the weak neutral current process in the lepton or neutrino scattering from nuclear targets [4,5]. Several experiments are planned to measure the strangeness distribution inside the nucleon, the strange electric and magnetic form factors of the nucleon $G_E^S(Q^2)$ [6,7] and $G_M^S(Q^2)$ [8,9] for $0.1 \leq Q^2 < 1$ GeV$^2/c^2$, and the strange axial vector form factor [10]. In contrast, most of the theoretical attempts have focused on the calculation of static observables; for example, the mean square strangeness radius of the nucleon r_S^2 and the strange magnetic moment $\mu_s = G_M^S(0)$ [11–14]. Specifically, they are based on the hadronic degrees of freedom and the intrinsic structure of the nucleon is implicitly taken into account by using effective hadronic form factors.

In this note, we attempt to obtain the nucleon's strange form factors from the quark distribution inside the nucleon, along with the meson cloud corrections to the electroweak properties of the constituent quarks. Within the same framework, we also calculate the neutron's electric and magnetic form factors $G_E^n(Q^2)$ and $G_M^n(Q^2)$. The momentum transfer is larger than the constituent quark mass in the proposed experiments ($Q^2/m^2 \geq 1$), so that a relativistic calculation is necessary in the present approach. Here, we use the light-cone quark model of the nucleon wave function [15].

The net strangeness is zero in the nucleon (similar to the electromagnetic charge of the neutron), therefore, these form factors must be investigated beyond the valence quark degrees of freedom: the $\bar{s}s$ polarization may be associated with the nontrivial vacuum structure of quantum chromodynamics (QCD). However, if the quark and gluon fields are quantized on the surface of the light cone, the vacuum state becomes trivial and completely decouples from the $\bar{q}q$-pairing states, where the broken chiral symmetry phase of QCD still remains and the Goldstone phenomenon takes place [16]. The light-cone quark model (LCQM) [15] is formulated on this simple vacuum and the nature of the chiral symmetry breaking can be handled without the complexity of the conventional nonperturbative vacuum. In the latter model, clouds of the Goldstone boson octet (π, K, η) may induce the electroweak form factors for the constituent quarks (Fig. 1), and in particular, the K meson induces the strangeness mixing [17] for the nonstrange quarks through the $u,d \to s + K \to u,d$ process [18].

To begin with a rather general discussion for the static observables μ_s and r_S^2, we express the matrix elements of the strange-vector and electromagnetic currents carried by the constituent quark in terms of form factors. For the u quark, we have

$$\langle u|\bar{s}\gamma^\mu s|u\rangle = f_1^S(Q^2)\gamma^\mu + \frac{i}{2m} f_2^S(Q^2)\sigma^{\mu\nu}q_\nu, \tag{1a}$$

$$\langle u|\bar{q}e_q\gamma^\mu q|u\rangle = f_{1u}(Q^2)e_u\gamma^\mu + \frac{i}{2m} f_{2u}(Q^2)\sigma^{\mu\nu}q_\nu, \tag{1b}$$

where $e_q = 1/6 + (3/6)\tau_3$ is the quark charge matrix, m is the constituent quark mass, and $Q^2 = \mathbf{q}^2 - q_0^2$. Similar expressions can be given for the d quark, where the strange form factors are the same as the u-quark case. With the electromagnetic current, both the isoscalar and isovector magnetic moments of the nucleon are well reproduced by the SU(6)×O(3) wave function of the nonrelativistic quark model, where the spin magnetization current is $J(\mathbf{r}) = (|e|/2m)\Sigma_{i=1}^3[e_q + \kappa_q]\nabla \times \sigma_{(i)}\delta(\mathbf{r} - \mathbf{x}_i)$. The anomalous magnetic moment $[\kappa_q = f_{2q}(0)]$ is usually neglected since the leading term dominates $[f_{1q}(0) = 1]$. On the other hand, the leading term vanishes in the strangeness current

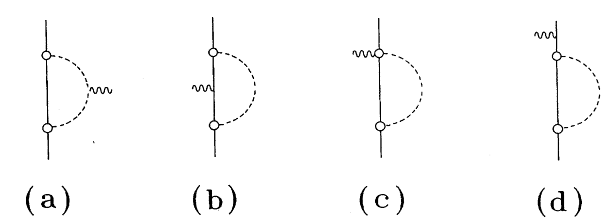

FIG. 1. Meson-loop diagrams for the electroweak coupling of a constituent quark, where the wavy line is the external vector current. The solid line is the quark and the dashed line is a Goldstone boson.

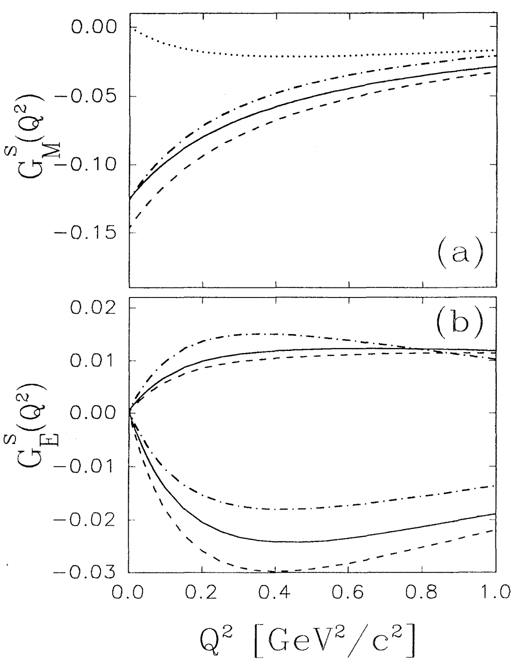

FIG. 2. (a) Strange magnetic form factor of the nucleon, where the solid (dashed) line is the prediction with $\Lambda=1.0$ GeV (0.8 GeV). The dot-dashed line includes the Q^2 dependence of the meson form factor with $\Lambda=1.0$ GeV (see text), and the dotted line is the result without the contribution of $f_2^S(Q^2)$. (b) Strange electric form factor of the nucleon. The lines in the upper (positive) region are the predicted values in the present approach, and the lines in the lower (negative) region do not include the $f_2^S(Q^2)$ term.

$[f_1^S(0)=0]$, so that the nucleon strange magnetic moment is proportional to the strange anomalous moment of the constituent quark [Fig. 2(a)],

$$\mu_s=\alpha f_2^S(0). \tag{2}$$

Here, $\alpha=0.44\times 6$ can be obtained by rescaling the nucleon isoscalar magnetic moment $(\mu_p+\mu_n)/2=0.44$, where we replace the isoscalar quark charge of 1/6 by the unit strangeness. A rough estimate is given for the quark anomalous moment $f_2(0)\sim(m/\Lambda_{\chi S})^2$ by the chiral quark model [19], where $\Lambda_{\chi S}=1$ GeV is the energy scale of the chiral symmetry breaking. This small correction (at the 10% level) is induced by the cloud of Goldstone bosons, and the typical size of the strange magnetic moment will be $|\mu_s|\sim 0.2$ for the nucleon.

The discussion becomes more involved for the mean-square strangeness radius of the nucleon: $r_S^2=-6[dG_E^S(Q^2)/dQ^2]_{Q^2=0}$. When the momentum transfer is small, $G_E^S(Q^2)$ can be expressed as a product of the quark electric form factor with the quark distribution in the nucleon $\rho(Q^2)$, so we have

$$r_S^2=-6\rho(0)\left[df_1^S(Q^2)/dQ^2-\frac{1}{4m^2}f_2^S(Q^2)\right]_{Q^2=0}. \tag{3}$$

Quarks inside the nucleon carry the comparable size of momentum with the constituent mass, so that relativistic effects become very important for the matrix elements of the currents, especially for the anomalous part $(\sim\sigma^{\mu\nu}q_\nu/m)$. The sign of r_S^2, obviously, is determined by the dominant term in the addition of the terms in Eq. (3).

We calculate the electromagnetic and strangeness form factors of the constituent quarks from the meson-loop model in Fig. 1 [the diagram (d) is absent for the strangeness case, where only the K mesons are included]. The meson cloud corrections to the properties of constituent quarks are largely low-energy phenomena, so that we introduce a momentum-dependent, effective quark-meson vertex $\Gamma^{(i)}(k,p)=\mathcal{N}\gamma^5[1/D(k;p)](\lambda^{(i)}/\sqrt{2N_c})$, where k and p are the relative and total four-momenta of the $q\bar{q}$ pair that couples to the Goldstone boson (i) [18,20]. The flavor dependence is described by the $SU_f(3)$ matrix $\lambda^{(i)}$, and the momentum distribution of the $q\bar{q}$ pair is modeled by a monopole function $D(k;p)=(k^2-\Lambda^2)$, where the cutoff mass is assumed to be the energy scale of the chiral symmetry breaking, $\Lambda\simeq\Lambda_{\chi S}$. The normalization constant $\mathcal{N}$ is obtained from the charge normalization of the charged pion, and the constituent masses are $m=m_u=m_d=0.27$ GeV for the u and d quarks and $m_s=0.43$ GeV for the s quark. This yields the π-*quark* coupling constant $g_{\pi q}=3.1$, and this value corresponds to the πN-coupling constant $g_{\pi N}=\sqrt{2/3}(5/3)(M/m)g_{\pi q}=14.6$ for pseudoscalar-type coupling. The latter value is obtained by equating the spin-isospin matrix element of the nucleon to the one calculated with the wave function of the three-quark system, i.e.,

$$(g_{\pi N}/2M)\langle N|\sigma\tau|N\rangle$$
$$=(g_{\pi q}/2m)\langle N(3q)|\sum_{i=1}^{3}\sigma(i)\tau(i)|N(3q)\rangle,$$

including the correction for center-of-mass motion [21]. The strength of the π-quark coupling is consistent with the Goldberger-Treiman relation at the quark level: $g_{\pi q}=(m/f_\pi)g_A=2.9$, where $f_\pi=93$ MeV is the pion weak decay constant and $g_A=1$ is the quark axial coupling constant.

The electromagnetic form factors of the nucleon have been successfully calculated with the LCQM [15]. This approach is essentially equivalent to the calculation in the infinite momentum frame, where the $J^+(=J^0+J^3)$ component of the vector currents can be expressed in terms of the Pauli matrices. The nucleon strange form factors $F_1^S(Q^2)$ and $F_2^S(Q^2)$ are obtained from

$$\langle N_{s'}|F_1^S(Q_\perp^2)+\frac{i}{2M}F_2^S(Q_\perp^2)[\sigma_N\times\mathbf{Q}_\perp]_z|N_s\rangle$$
$$=\int d\Gamma\langle\Psi_{s'}(3q)|f_1^S(Q_\perp^2)+\frac{i}{2m}f_2^S(Q_\perp^2)$$
$$\times[\sigma_{(3)}\times\mathbf{Q}_\perp]_z|\Psi_s(3q)\rangle, \tag{4}$$

where $d\Gamma$ is the integral measure of the light-cone variables including the spin summation, $d\Gamma=3\Sigma_{s_1s_2}\Sigma_{s_3s_3'}[(2\pi)^6 4x_1x_2x_3x_3']^{-1}d\mathbf{k}_{1\perp}d\mathbf{k}_{2\perp}dx_1dx_2$. The relativistic wave function of the nucleon is obtained by applying the Melosh transformation [15] to the $SU(6)\times O(3)$

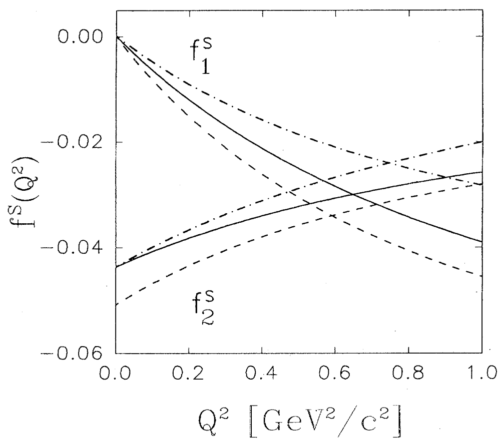

FIG. 3. Form factors of the constituent quark, $f_1^S(Q^2)$ and $f_2^S(Q^2)$. The dashed line is the result with $\Lambda=0.8$ GeV. The solid line is the result with $\Lambda=1.0$ GeV, and the dot-dashed line includes the Q^2 dependence of the meson form factor.

wave function of the nonrelativistic quark model. We then have, for example, the proton wave function

$$|\Psi_s(3q)\rangle=\Phi(M_0^2)\{[U_{S_3}^{\dagger u}\chi_S]([U_{S_2}^{\dagger d}\sigma_y U_{S_1}^u]-[U_{S_2}^{\dagger u}\sigma_y U_{S_1}^d]) + \text{transposition}\}, \tag{5}$$

where U_S is the Melosh transformation matrix

$$U_{Si}=\sum_{S'}|\chi_{S'}\rangle\langle\chi_{S'}|\frac{1}{E(i)}[m_i+M_0x_i+i(\sigma_i\times\mathbf{k}_{i\perp})]|\chi_{S_i}\rangle \tag{6}$$

with $E(i)=\sqrt{k_{i\perp}^2+(m_i+M_0x_i)^2}$. The quark momentum is given by $\mathbf{p}_i=x_i\mathbf{P}_z+\mathbf{k}_{i\perp}$, where $\mathbf{P}_z$ is the total momentum of the nucleon moving towards the z direction, x_i is the momentum fraction of the ith quark, and $\Sigma_{i=1}^3 x_i=1$. The total momentum perpendicular to $\mathbf{P}_z$ vanishes; $\Sigma_{i=1}^3\mathbf{k}_{i\perp}=0$. The momentum distribution function $\Phi(M_0^2)$ depends on the invariant mass of the three quarks $M_0^2=\Sigma_i(\mathbf{k}_{i\perp}^2+m_i^2)/x_i$, and we use the Gaussian function $\Phi(M_0^2)=NM_0^{-2}\exp(-M_0^2/6\gamma^2)$ with $\gamma=0.38$ GeV. With this model, the electromagnetic form factors of the proton are well reproduced for $Q^2\leqslant 3$ GeV$^2/c^2$.

The numerical results are given in Fig. 3 for the strangeness form factors of the constituent quarks. The Dirac form factor $f_1^S(Q^2)$ vanishes at $Q^2=0$ and monotonically decreases from zero, while $f_2^S(Q^2)$ has a weak Q^2 dependence. In Fig. 2(a), the prediction is given for the strange magnetic form factor of the nucleon $G_M^S(Q^2)=F_1^S(Q^2)+F_2^S(Q^2)$. The same form factor without the contribution of the anomalous current is also shown for comparison, where we omit the $f_2^S(Q^2)$ term in Eq. (4). Without this contribution, $G_M^S(Q^2)$ vanishes at $Q^2=0$ and the momentum dependence is quite different from that of the full calculation.

Figure 2(b) shows the strange electric form factor of the nucleon $G_E^S(Q^2)=F_1^S(Q^2)-(Q^2/4M^2)F_2^S(Q^2)$, where M is the nucleon mass. If we omit the contribution of $f_2^S(Q^2)$, then $G_E^S(Q^2)$ is predicted to be significantly different from the full calculation. The numerical results of the static observables are given in Table I, where the sign of r_S^2 is negative, the same sign as obtained in the meson-loop calculations with hadronic degrees of freedom [12–14], but opposite to the pole model approach [11]. In the present approach, $df_1^S(Q^2)/dQ^2$ and $f_2^S(0)$ are both negative, and the overall sign of r_S^2 is determined from the dominant of the two terms in Eq. (3). (The sign becomes positive if we omit the $f_2^S(0)$ term, e.g., $r_S^2=4.87\times10^{-2}$ fm^2 for $\Lambda=1.0$ GeV.)

TABLE I. Strange anomalous moment of the constituent quark $f_2^S(0)$, and the static observables of the nucleon.

Λ [GeV]	$f_2^S(0)$	μ_S [nm]	r_S^2 [fm^2]	r_n^2 [fm^2]
0.8	−0.051	−0.146	-1.89×10^{-2}	−0.133
1.0	−0.043	−0.125	-2.16×10^{-2}	−0.110
Ref. [12]		$-(0.31\sim0.40)$	$-(2.71\sim3.23)\times10^{-2}$	

In the present approach, the Goldstone bosons are assumed to be composite. Therefore, the extended nature of the mesons should be taken into account, for example, by introducing the strangeness form factor of the virtual K meson in the diagram of Fig. 1(a). We calculate the meson form factor by using the vertex function $\Gamma^{(i)}(k,p)$. If we add this correction, the magnitude of $f_1^S(Q^2)$ is then significantly reduced, while $f_2^S(Q^2)$ is relatively insensitive to this effect. Consequently, the strange electric form factor of the nucleon, $G_E^S(Q^2)$, receives a notable correction [dot-dashed line in Fig. 2(b)]. The mean square strangeness radius is increased by about 50% in magnitude; from the value $r_S^2=-2.16\times10^{-2}(-1.89\times10^{-2})$ [fm^2] to $r_S^2=-3.12\times10^{-2}(-2.94\times10^{-2})$ [fm^2] for $\Lambda=1$ GeV (0.8 GeV).

The form factor $G_E^S(Q^2)$ is expected to be measured in the asymmetry of the parity violating electron scattering from ^{4}He. The predicted form factor (including the effect of the K-meson form factor) reaches a size of $G_E^S(Q^2)=0.014$ at the kinematics of the approved CEBAF experiment E-91-004 ($Q^2=0.6$ GeV$^2/c^2$) [6], where the experimental accuracy is expected to be $\Delta G_E^S\sim0.06$. The relative size $R\equiv G_E^S(Q^2)/G_E^{T=0}(Q^2)$, in the formula for the asymmetry [4], to the isoscalar nucleon form factor becomes appreciable ($R=0.11$) compared to the nonstrange asymmetry given by the Weinberg angle: $4\sin^2\theta_W\simeq0.92$. However, it should be noted that an explicit nuclear structure calculation, with the one-body current operator, indicates the presence of a diffraction minimum at this kinematics. Therefore, the contribution of the two-body strange vector current [22] is dominant at this momentum transfer: a 15% correction to the nonstrange asymmetry, while the contribution of the nucleonic strange vector current (impulse amplitude) is negligible. The impulse amplitude becomes dominant at the lower values of momentum transfer. For the kinematics of the other CEBAF experiment E-91-010 ($Q^2=0.13$ GeV$^2/c^2$) [7], the present calculation predicts $G_E^S(Q^2)=0.012$ and $R=0.04$.

The electromagnetic form factors of the nucleon are calculated in the same way. The quark form factors in Eq. (1b) are obtained from the diagrams in Fig. 1 including π, K, and η mesons, and the quark anomalous magnetic moments are found to be $f_{2u}(0)=0.11(0.15)$ and $f_{2d}(0)=-0.09(-0.14)$ for $\Lambda=1.0$ GeV (0.8 GeV) [18]. The re-

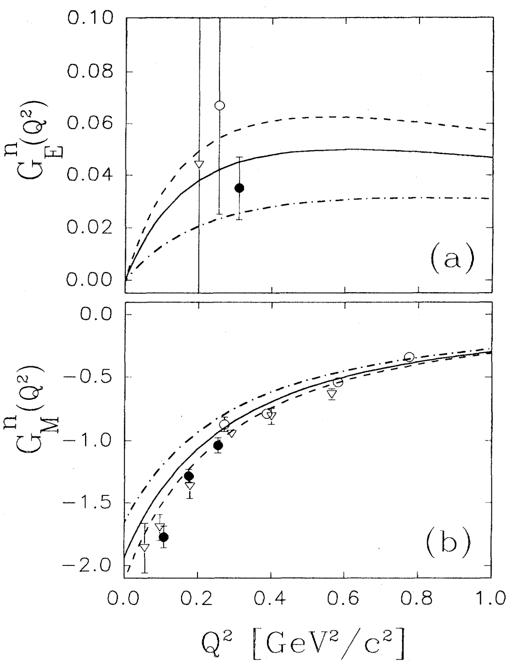

FIG. 4. (a) Electric and (b) magnetic form factors of the neutron. The solid (dashed) line is the prediction of the present approach with $\Lambda = 1.0$ GeV (0.8 GeV), and the $f_2(Q^2)$ term is omitted in the dot-dashed line. The experimental data are [24] (triangle) [25], (open circle), and [26] (solid circle) in (a), and [27] (open circle) [28], (triangle), and [29] (solid circle) in (b).

sults for the mean square charge radius of the neutron are given in Table I, where the experimental data is $r_n^2 = -0.117 \pm 0.002$ fm^2 [23]. In this case, the contribution of the quark anomalous moment has the same sign as the normal current contribution, and we find $r_n^2 = -0.39 \times 10^{-1}$ fm^2 by omitting $f_{2u}(0)$ and $f_{2d}(0)$. (r_n^2 vanishes if calculated with the nonrelativistic SU(6)$\times$O(3) wave function without any other corrections.) The anomalous current is also important for the neutron electric form factor $G_E^n(Q^2)$ shown Fig. 4(a), while the other electromagnetic form factors are insensitive to it. Figure 4(b) shows the results of $G_M^n(Q^2)$.

It is instructive to discuss the meson cloud corrections in the limit of the exact flavor SU(3) symmetry, i.e., $m_u = m_d = m_s$ and $m_\pi = m_K$. If it were the case in QCD, we would have simple relations between the π- and K-meson contributions in the electromagnetic and strange vector currents: In the amplitude of Fig. 1(a), which is a dominant process in the quark anomalous magnetic moment, we have several different combinations of flavor-mixing states; $d \to u + \pi^- \to d$ and $d \to s + K^0 \to d$ for the d quark, for example. Here, the contribution of the π meson in the electromagnetic current would be the same as that of the K meson in the strange vector current because of the flavor symmetry [18]. Similar relations can be found in the other amplitudes in Fig. 1, apart from the different multiplicative factors associated with the electromagnetic charge and strangeness. The present calculation ($m_u = m_d < m_s$ and $m_\pi < m_K$) yields the different sizes of $f_{2d}(0)$ and $f_2^S(0)$, but the same order of magnitudes. This is due to the weak dependence of the meson loop amplitudes on the different kinematical conditions ($m_\pi / m_u \sim 0.5$ and $m_K / m_s \sim 1.1$).

In summary, we have calculated the strangeness and electromagnetic form factors of the nucleon within the relativistic quark model of hadrons. The clouds of the pseudoscalar Goldstone bosons are assumed to generate the electroweak form factors of constituent quarks. Therefore, the present approach is limited to the processes involving the momentum transfer less than the scale of the chiral symmetry breaking in QCD ($\Lambda_{\chi S} \sim 1$ GeV). We have found that the anomalous strange vector current carried by the constituent quarks makes important contributions in the strangeness form factors of the nucleon: Without the strange anomalous moment $f_2^S(0)$, $G_M^S(Q^2)$ would vanish at the photon point and r_S^2 would be positive. We also point out the importance of the quark magnetic moment in the neutron electric form factor.

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[1] T. P. Chen and R. Dashen, Phys. Rev. Lett. **26**, 594 (1971); J. F. Donoghue and C. R. Nappi, Phys. Lett. **168B**, 105 (1986); J. Gasser, H. Leutwyler, and M. E. Sainio, Phys. Lett. B **253**, 252 (1991).
[2] J. Ashman *et al.*, Phys. Lett. B **206**, 364 (1988); Nucl. Phys. **B328**, 1 (1989).
[3] R. L. Jaffe and A. Manohar, Nucl. Phys. **B337**, 509 (1990).
[4] M. J. Musolf, T. W. Donnelly, J. Dubach, S. J. Pollock, S. Kowalski, and E. J. Beise, Phys. Rep. **239**, 1 (1994).
[5] G. Garvey, E. Kolbe, K. Langanke, and S. Krewald, Phys. Rev. C **48**, 1919 (1993).
[6] CEBAF experiment E-91-004, E. J. Beise, spokesperson.
[7] CEBAF experiment E-91-010, J. M. Finn and P. A. Souder, spokesperson.
[8] MIT/Bates experiment 89-06, R. McKeown and D. H. Beck, contact people.
[9] CEBAF experiment E-91-017, D. H. Beck, spokesperson.
[10] G. T. Garvey, W. C. Louis, and D. H. White, Phys. Rev. C **48**, 761 (1993).
[11] R. L. Jaffe, Phys. Lett. B **229**, 275 (1989).
[12] M. J. Musolf and M. Burkardt, Z. Phys. C **61**, 433 (1994).
[13] T. D. Cohen, H. Forkel, and M. Nielsen, Phys. Lett. B **316**, 1 (1993); Phys. Rev. C **50**, 3108 (1994).
[14] W. Koepf, E. M. Henley, and S. J. Pollock, Phys. Lett. B **288**, 11 (1992).
[15] P. L. Chung and F. Coester, Phys. Rev. D **44**, 229 (1991); S. J. Brodsky and F. Schlumpf, Phys. Lett. B **329**, 111 (1994); I. G. Aznauryan, A. S. Bagdasaryan, and N. L. Ter-Isaakyan, Yad. Fiz. **36**, 1278 (1982).

[16] R. J. Perry, A. Harindranath, and K. G. Wilson, Phys. Rev. Lett. **65**, 2959 (1990); Y. Kim, S. Tsujimaru, and K. Yamawaki, *ibid.* **74**, 4771 (1995).

[17] D. B. Kaplan and A. Manohar, Nucl. Phys. **B310**, 527 (1988); V. Bernard, R. L. Jaffe, and U.-G. Meissner, *ibid.* **B308**, 753 (1988).

[18] H. Ito, Phys. Lett. B **353**, 13 (1995); in *Proceedings of the 14th International Conference of Few-Body Problems in Physics*, Williamsburg, 1994 (AIP, New York, 1995).

[19] A. Manohar and H. Georgi, Nucl. Phys. **B234**, 189 (1984).

[20] H. Ito and F. Gross, Phys. Rev. Lett. **71**, 2555 (1993); H. Ito, W. W. Buck, and F. Gross, Phys. Lett. B **287**, 23 (1992).

[21] Z-J. Cao and L. S. Kisslinger, Phys. Rev. Lett. **64**, 1007 (1990); J-L. Dethier, R. Goldflam, E. M. Henley, and L. Wilets, Phys. Rev. D **27**, 2191 (1983); J. F. Donoghue and K. Johnson, Phys. Rev. D **21**, 1975 (1980).

[22] M. J. Musolf, R. Schiavilla, and T. W. Donnelly, Phys. Rev. C **50**, 2173 (1994).

[23] L. Koester, W. Nistler, and W. Waschkowski, Phys. Rev. Lett. **36**, 1021 (1976).

[24] A. K. Thompson *et al.*, Phys. Rev. Lett. **68**, 2901 (1992).

[25] T. Eden *et al.*, Phys. Rev. C **50**, R1749 (1994).

[26] M. Meyerhoff *et al.*, Phys. Lett. B **327**, 201 (1994).

[27] K. M. Hanson *et al.*, Phys. Rev. D **8**, 753 (1973).

[28] E. B. Hughes *et al.*, Phys. Rev. **146**, 973 (1966).

[29] P. Markowitz *et al.*, Phys. Rev. C **48**, R5 (1993).