Medium modification of the nucleon axial form factor

D. H. Lu\textsuperscript{1*}, A. W. Thomas\textsuperscript{2†}, and K. Tsushima\textsuperscript{2,3‡}

\textsuperscript{1}Department of Physics and Zhejiang Institute of Modern Physics, Zhejiang University, Hangzhou 310027, China

\textsuperscript{2}Department of Physics and Mathematical Physics and Special Research Centre for the Subatomic Structure of Matter, University of Adelaide, Australia 5005

\textsuperscript{3}Department of Physics and Astronomy, University of Georgia, Athens, GA 30602, USA

Abstract

We study the modification of the nucleon axial form factor in nuclear matter. The internal quark substructure of the nucleon is self-consistently described by the quark meson coupling model. We find that the axial form factor of the bound nucleon is quenched considerably from that of the free nucleon. The axial vector coupling constant, \( g_A \), is reduced by roughly 10\% at normal nuclear matter density and the axial form factor varies within 8\% for moderate momentum transfer.

PACS numbers: 12.39.Ba, 21.65.+f, 13.40.Gp, 25.70Bc

*dhlu@zimp.zju.edu.cn

†athomas@physics.adelaide.edu.au

‡tsushima@kn3.physast.uga.edu
There is strong evidence that hadron properties must undergo substantial modifications in nuclear medium [1–3]. A number of experiments, such as the variation of nucleon structure functions in lepton deep-inelastic scattering off nuclei (the nuclear EMC effect) [4], the quenching of the axial vector coupling constant, $g_A$, in nuclear $\beta$-decay [5], and the missing strength of the response functions in nuclear quasielastic electron scattering [6], have stimulated investigations of whether or not quark degrees of freedom play any significant role. Though the conventional interpretation arising through polarization effects and other hadronic degrees of freedom ($\Delta$-excitations, meson exchange currents, etc.) undoubtedly play a role [7,8], it is rather interesting to explore, as well, the possible effects of a change in the internal structure of the bound nucleon.

The successes of quantum hadrodynamics (QHD) leave little doubt that relativistic nuclear phenomenology is essential in describing the bulk properties of nuclear matter as well as the properties of finite nuclei [1]. To incorporate the substructure of the nucleon in a relativistic nuclear framework, Guichon proposed a successful hybrid model (the quark-meson coupling (QMC) model) [9], where nuclear matter is described in terms of non-overlapping, MIT bag nucleons [10]. The model was later developed to describe finite nuclei [11] as well as the properties of other hadrons in medium [12]. By analogy with QHD, QMC describes the bulk properties of nuclear systems using scalar ($\sigma$) and vector ($\omega$) meson mean fields. However, the nucleon bound in a nuclear medium here is no longer a point-like particle, it has substructure – quarks confined inside the nucleon bag. It is the quark, rather than the nucleon itself, that is coupled to the $\sigma$ and $\omega$ fields directly. As a result, the internal structure of the bound nucleon is modified by the surrounding medium with respect to that in free space [3,13,14].

Within QMC, the small mass of the quark implies that the lower component of the quark wave function will be enhanced rapidly [1] by the change of its environment (as the

1Considerably more rapidly than that of the nucleon in QHD and for smaller values of the mean-
σ field strength increases), with a consequent decrease in the scalar baryon density. As the scalar baryon density itself is the source of the σ field, this provides a mechanism for the saturation of nuclear matter where the quark substructure plays a vital role. The extra degrees of freedom, corresponding to the internal structure of the nucleon, lead to a reasonable value for the nuclear incompressibilty, once the corresponding quark and meson coupling constants, $g_\sigma^q$ and $g_\omega^q$, are determined to reproduce the empirical values for the saturation density and binding energy of symmetric nuclear matter.

In our previous work, we predicted medium modifications of nucleon electromagnetic form factors [15]. Such a medium effect appears to be supported by a recent experiment at Mainz [16], which measured the polarization transfer in the $^4\text{He}(e',e'p)$ reaction. The polarization transfer double ratio, $(P'_{x}/P'_{z})_{\text{He}}/(P'_{x}/P'_{z})_{\text{free}}$, tends to favor the RDWIA calculations using a medium modified proton form factor. Further study of this reaction has been carried out at Jefferson Lab (E93-049) [17] and other related experiments have been proposed. In this paper, we study the axial form factor of the bound nucleon in symmetric nuclear matter. This is of particular interest in the light of plans to build very high intensity neutrino beams in the near future.

The Lagrangian density for the QMC model is

$$L_q = \bar{q}(i\gamma^\mu \partial_\mu - m_q)q\theta_V - B_0\theta_V + g_\sigma^q\bar{q}q\sigma - g_\omega^q\bar{q}\gamma_\mu q\gamma^\mu - \frac{1}{2}m_\sigma^2\sigma^2 + \frac{1}{2}m_\omega^2\omega^2,$$  \hspace{1cm} (1)

where $m_q$ is the current quark mass, $B_0$ is the bag constant in vacuum, $g_\sigma^q$ and $g_\omega^q$ are the corresponding quark and meson coupling constants, and $\theta_V$ is a step function which is one inside the bag volume and zero outside.

In mean-field-approximation, the meson fields are treated as classical fields, and the quark field $q(x)$ inside the bag satisfies the equation of motion

$$[i\gamma^\mu \partial_\mu - (m_q - g_\sigma^q\sigma) - g_\omega^q\omega^0]q(x) = 0,$$  \hspace{1cm} (2)
where $\sigma$ and $\omega$ denote the constant mean values of the scalar and the time component of the vector field in symmetric nuclear matter. The normalized solution for the lowest state of the quark is given by \cite{3,10}

$$q(t, \vec{r}) = \frac{N_0}{\sqrt{4\pi}} e^{-i\epsilon_q t/R} \begin{pmatrix} g(r) \\ i\sigma \cdot \hat{r} f(r) \end{pmatrix} \theta(R - r) \chi_q, \tag{3}$$

where

$$g(r) = j_0(xr/R), \quad f(r) = \beta_q j_1(xr/R),$$

$$\epsilon_q = \Omega_q + g^2_\sigma \omega R,$$

$$\beta_q = \sqrt{\frac{\Omega_q - m^*_q R}{\Omega_q + m^*_q R}},$$

$$N_0^{-2} = 2R^3 j_0^2(x)\Omega_q(\Omega_q - 1) + m^*_q R/2]/x^2,$$

with $\Omega_q \equiv \sqrt{x^2 + (m^*_q R)^2}$, $m^*_q \equiv m_q - g^2_\sigma \sigma$, $R (R_0)$ the bag radius (free space), and $\chi_q$ the quark Pauli spinor. The eigen-frequency, $x (x_0)$, of this lowest mode in medium (free space) is determined by the boundary condition at the bag surface,

$$j_0(x) = \beta_q j_1(x). \tag{4}$$

The form of the quark wave function in Eq. (3) is almost identical to that of the solution in free space. However the parameters in the expression have to be substantially modified by the surrounding nuclear medium. Note that as the value of $g^2_\sigma \sigma$ is usually much larger than $m_q$, the quantity, $\beta_q$, becomes larger than unity, which means that the lower component of the Dirac spinor is enhanced. In other words, the quarks in the nucleon embedded in the nuclear medium are more relativistic than those in a free nucleon.

The mean values of the scalar ($\sigma$) and vector ($\omega$) fields in symmetric nuclear matter are self-consistently determined by solving the following set of equations:

$$\omega = \frac{g_\omega \rho}{m^2_\omega}, \tag{5}$$

$$\sigma = \frac{g_\sigma}{m^2_\sigma} C(\sigma) \rho_s = \frac{g_\sigma}{m^2_\sigma} C(\sigma) \frac{4}{(2\pi)^3} \int k_F d^3k \frac{m^*_N(\sigma)}{\sqrt{m^*_N(\sigma) + k^2}}, \tag{6}$$

$$m^*_N(\sigma) = \frac{3\Omega_q(\sigma)}{R} - \frac{z_0}{R} + \frac{4}{3\pi R^3} B_0, \tag{7}$$

$$\frac{\partial m^*_N(\sigma)}{\partial R} = 0, \tag{8}$$
where \( \rho (\rho_s) \) is the baryon (scalar) density and \( k_F \) is the nucleon Fermi momentum, \( g_\sigma = 3g_\sigma^2S(0) \), \( g_\omega = 3g_\omega^2 \), and the quantity, \( C(\sigma) \), is defined by

\[
C(\sigma) \equiv S(\sigma)/S(0) = -\left(\frac{\partial m_N^*(\sigma)}{\partial \sigma}\right)/g_\sigma,
\]

with \( S(\sigma) = f_{bag} d^3r \overline{\mathbf{q}}(\mathbf{r})q(\mathbf{r}) \). Using the quark wave function for the MIT bag, Eq.(3), \( S(\sigma) \) can be explicitly evaluated:

\[
S(\sigma) = \left[\frac{\Omega_q/2 + m_q^* R(\Omega_q - 1)}{[\Omega_q(\Omega_q - 1) + m_q^* R/2]}\right].
\]

The second term in Eq.(6), \( -(z_0/R) \), has multiple roles and it parametrizes the sum of the zero point energy, gluon corrections, and the part of the center-of-mass (c.m.) motion [18].

The process to solve this coupled system is as follows: we first determine \( z_0 \) and \( B_0 \) by requiring the free nucleon mass to be \( m_N(\rho = 0) = 939 \) MeV and by imposing the stability condition, Eq.(8), for a given bag radius, \( R_0 \) (treated as an input parameter). After that, we solve the coupled set of equations at normal nuclear matter density, \( \rho_0 \), and determine the coupling constants, \( g_\sigma^2 \) and \( g_\omega^2 \), required to reproduce nuclear saturation properties. With these parameters, we can solve the whole problem for each finite nuclear matter density, \( \rho \), self-consistently. Typically the quark r.m.s. radius, \( r_q^* \), calculated by the bag wave function is slightly increased, although the bag radius, \( R \), decreases by a few percent at normal nuclear matter density. The properties of these self-consistent solutions as a function of the nuclear matter density, a typical set of parameters and the value of the nuclear incompressibility, \( K \), as well as the possible medium dependence of the bag constant, can be seen in Ref. [15].

It is worthwhile to note that the self-consistency condition in QMC is identical to that in QHD, except that in QHD one has \( C(\sigma) = 1 \) in Eq.(3) [3], which corresponds to a point-like nucleon. Within QMC all information on the internal structure of the nucleon is contained in \( C(\sigma) \).

Once the quark wave function in the bound nucleon is determined, one can proceed to calculate the nucleon axial form factors, which are defined as follows:

\[
\langle p's'|A_\mu^a(0)|ps\rangle = \mathbf{\pi}_{s's}(p') \left[ G_A(Q^2)\gamma^\mu + \frac{G_P(Q^2)}{2m_N} (p' - p)^\mu \right] \gamma^5 \frac{\tau_a}{2} u_s(p),
\]

(11)
where \( Q^2 \equiv -(p' - p)^2 \), \( u_s(p) \) is the nucleon Dirac spinor. Here we shall focus on the axial vector form factor, \( G_A(Q^2) \), since the induced pseudoscalar form factor, \( G_P(Q^2) \), is dominated by the pion pole and thus can be derived using the familiar PCAC relation [19,20].

The relevant axial current operator is then simply

\[
A^\mu_a(x) = \sum_f \bar{q}_f(x) \gamma^\mu \gamma^5 \tau_a q_f(x) \theta(R - r),
\]

where \( q_f(x) \) is the quark field operator for flavor \( f \).

In order to remove the spurious c.m. motion, we construct the momentum eigenstate of a baryon via the Peierls-Thouless (PT) projection method [21,22],

\[
\Psi_{\text{PT}}(\vec{x}_1, \vec{x}_2, \vec{x}_3; \vec{p}) = N_{\text{PT}} e^{i\vec{p} \cdot \vec{x}_{\text{c.m.}}} q(\vec{x}_1 - \vec{x}_{\text{c.m.}}) q(\vec{x}_2 - \vec{x}_{\text{c.m.}}) q(\vec{x}_3 - \vec{x}_{\text{c.m.}}),
\]

where \( N_{\text{PT}} \) is a normalization constant, \( \vec{p} \) the total momentum of the baryon, and \( \vec{x}_{\text{c.m.}} = (\vec{x}_1 + \vec{x}_2 + \vec{x}_3)/3 \) is the center of mass of the baryon (we assume equal mass quarks here). It can be shown that the PT wave function satisfies the condition of translational invariance.

Using Eqs. (12) and (13), the nucleon axial form factors can be expressed as

\[
G_A(Q^2) = \frac{5}{3} \int d^3r \left\{ \left[ g^2(r) - f^2(r) \right] j_0(Qr) + 2 f^2(r) \frac{j_1(Qr)}{Qr} \right\} K(r)/D_{\text{PT}},
\]

\[
D_{\text{PT}} = \int d^3r \rho_q(r) K(r),
\]

where \( D_{\text{PT}} \) is the normalization factor, \( \rho_q(r) \equiv g^2(r) + f^2(r) \), and \( K(r) = \int d^3\tilde{z} \rho_q(\tilde{z}) \rho_q(-\tilde{z} - \vec{r}) \) is the recoil function which accounts for the correlation of the two spectator quarks.

At this stage, there is no satisfactory covariant treatment for the MIT bag model. On the other hand, relativistic effects are important for most dynamic variables, especially for form factors at large momentum transfer. They lead to a sizable correction for the r.m.s. radius of the nucleon. In this paper, we use a semi-phenomenological method to account for the relativistic corrections which is consistent with a mean field treatment of the QMC model. Since a static MIT bag is an extended spherical object, it would be deformed if it were viewed in a moving frame of reference. It is crucial to include this Lorentz contraction of the bag for calculating form factors at moderate momentum transfer [21,23]. In the preferred Breit frame, the resulting form factors can be expressed through a simple rescaling, i.e.,
$G_A(Q^2) = \left( \frac{m_N^*}{E^*} \right)^2 G_{A}^{\text{sph}}(Q^2, m_N^*/E^*)$, \( \text{(16)} \)

where $E^* = \sqrt{m_N^* + Q^2/4}$ and $G_{A}^{\text{sph}}(Q^2)$ are the form factors calculated with the spherical bag wave function. The scaling factor in the argument arises from the coordinate transformation of the struck quark whereas the prefactor, $(m_N^*/E^*)^2$, comes from the reduction of the integral measure of two spectator quarks in the Breit frame \[23]. \ The axial radius squared is given by,

$$r_A^2 = -\frac{6}{g_A} \frac{dG_A(Q^2)}{dQ^2} \bigg|_{Q^2 \to 0},$$

which results in $12/m_A^2$ for a dipole form: $G_A(Q^2) = 1/(1 + Q^2/m_A^2)^2$.

Note that the pion cloud of the nucleon only plays an indirect role in calculating the axial vector form factor, in contrast to the electromagnetic properties of the nucleon. In fact, the matrix element of the pionic axial current, $f_\pi \partial^\mu \pi$, vanishes in any chiral bag model if the pion cloud exists in all space \[19,27\].

The nucleon axial form factor in free space is illustrated in Fig. 1. The experimental data from neutrino scattering is not shown directly, rather we show a dipole form with the mass parameter in the range found by Kitagachi et al. \[24\]. \( \text{(We note that the pion electroproduction data \[25\] is consistent with this after the small correction from chiral perturbation theory is applied \[26\].)} \) The corrections for the center-of-mass motion and Lorentz contraction lead to a significant improvement over static bag model calculations, in particular, at moderate momentum transfers \[27\]. \( \text{The results are not sensitive to the current quark mass, so we use } m_q = 0 \text{ in this paper.} \) The axial radii are 0.587, 0.614 and 0.640 fm, corresponding to the bag radii of 0.90, 0.95 and 1.00 fm, respectively. These r.m.s. radii are in good agreement with the experimental value $(0.635 \pm 0.023)$ fm \[28\]. \( \text{The axial coupling constant, } g_A \equiv G_A(Q^2 = 0), \text{ is about 1.14 after the c.m. correction, which is about 5% increase from the static MIT bag value, 1.09. Finite quark mass and pion renormalization may be expected to lead to further corrections at the level of 10%.} \)

Fig. 2 shows the medium dependence of the axial form factors at several momentum transfers (with $R_0 = 0.95$ fm). For $Q^2 < 2$ GeV$^2$, the axial form factor decreases as the
density $\rho$ increases. The axial vector coupling constant (the solid line in this figure), $g_A$, would be reduced by 12% at normal nuclear matter density, $\rho_0$, and 9% at the average density of finite nuclei, $0.7\rho_0$, where the latter is to be compared with the experimental 20% reduction seen in Gamow-Teller transitions [5].

The momentum dependence of the axial form factors ($R_0 = 0.95$ fm again) is shown in Fig. 3. The nuclear medium does indeed modify the shape of the momentum dependence. The medium effect increases as the density increases and tends to be larger for smaller momentum transfers. However the overall effect is less than roughly 8%, depending on the bag radius.

In conventional nuclear physics, the nucleon is immutable and the electroweak properties of a nucleus are often described by a combination of individual nucleon contributions and various meson exchange current corrections. This is particularly important for the axial charge of finite nuclei [29]. For the quenching of $g_A$, conventional mechanisms (medium polarization) also exist, however it is fundamentally interesting to explore this new mechanism arising from possible changes of the internal structure of the nucleon. Clearly it would be very valuable to study the effect of the medium modified axial form factor in the context of neutrino-nucleus scattering [30] and the solar neutrino problem [31].

In summary, the nucleon axial form factor is significantly modified in nuclear matter through a new mechanism, namely the change of the internal substructure of the bound nucleon. We have calculated the density dependence of the axial form factor of the bound nucleon in the QMC model and found that it is quenched considerably compared with that of the free nucleon. The axial vector coupling constant, $g_A$, is reduced by roughly 10% at $\rho_0$ and the axial form factor would vary within 8% for moderate momentum transfers.

D.H.Lu is grateful to the Y.C.Tang Disciplinary Development Fund in Zhejiang University and would like to acknowledge the warm hospitality of the CSSM in Adelaide University. This work was supported in part by the National Natural Science Fund of China and by the Australian Research Council.
REFERENCES

[1] B. D. Serot and J. D. Walecka, Adv. Nucl. Phys. 16, 1 (1986); B. D. Serot and J. D. Walecka, Int. J. Mod. Phys. E 6, 515 (1997).

[2] R. Brockmann and R. Machleidt, in “Open Problems in Nuclear Matter”, ed. M. Baldo et al. (World Scientific, Singapore, 1997); G. E. Brown and M. Rho, Phys. Rev. Lett. 66, 2720 (1991).

[3] K. Saito and A. W. Thomas, Phys. Lett. B 327, 9 (1994); Phys. Rev. C 51, 2757 (1995); ibid. 52, 2789 (1995); K. Saito, K. Tsushima, and A. W. Thomas, Phys. Rev. C 55, 2637 (1997); K. Tsushima, A. Sibirtsev, K. Saito, A. W. Thomas, D. H. Lu, Nucl. Phys. A680, 279 (2001).

[4] J. J. Aubert et al., Phys. Lett. B123, 275 (1983); D. F. Geesaman, K. Saito, A. W. Thomas, Annu. Rev. Nucl. Part. Sci. 45, 337 (1995), and references therein.

[5] B. Buck and S.M. Perez, Phys. Rev. Lett. 50 (1983) 1975; C. D. Goodman et. al., Phy. Rev. Lett. 54, 877 (1985).

[6] R. Artemus et al., Phys. Rev. Lett. 44 (1980) 965; R. Barreau et al., Nucl. Phys. A402 (1983) 515; J. Jourdan, Phys. Lett. B353, 189 (1995).

[7] P. J. Mulders, Phys. Rep. 185 (1990) 83; H. Kurasawa and T. Suzuki, Phys. Lett. B 208 (1988) 160.

[8] W. M. Alberico, T. W. Donnelly and A. Molinari, Nucl. Phys. A512 (1990) 541; J. W. Van Orden and T. W. Donnelly, Ann. Phys. 131 (1981) 451; W. M. Alberico, M. Ericson and A. Molinari, Ann. Phys. 154 (1984) 356.

[9] P. A. M. Guichon, Phys. Lett. B 200, 235 (1988); S. Fleck, W. Bentz, K. Shimizu, and K. Yazaki, Nucl. Phys. A 510, 731 (1990).

[10] A. Chodos, R. L. Jaffe, K. Johnson, C. B. Thorn and V. F. Weisskopf, Phys. Rev. D9,
3471 (1974); A. Chodos, R. L. Jaffe, K. Johnson and C. B. Thorn, Phys. Rev. D10, 2599 (1974); T. A. DeGrand, R. L. Jaffe, K. Johnson and J. Kiskis, Phys. Rev. D12, 2060 (1975).

[11] K. Saito, K. Tsushima, A. W. Thomas, Nucl. Phys. A609, 339 (1996).

[12] K. Tsushima, K. Saito, A. W. Thomas, Phys. Lett. B 411, 9 (1997); K. Tsushima, K. Saito, J. Haidenbauer, A. W. Thomas, Nucl. Phys. A630, 691 (1998); K. Tsushima, D. H. Lu, A. W. Thomas, K. Saito, Phys. Lett. B 443, 26 (1998); K. Tsushima, D. H. Lu, A. W. Thomas, K. Saito, R.H. Landau, Phys. Rev. C 59, 2824 (1999).

[13] X. M. Jin and B. K. Jennings, Phys. Lett B 374, 13 (1996); P. G. Blunden and G. A. Miller, Phys. Rev. C 54, 359 (1996); R. Aguirre and M. Schvellinger, Phys. Lett. B 400, 245 (1997); E. Naar and M. C. Birse, Phys. Lett. B 305, 190 (1993); M. K. Banerjee, Phys. Rev. C 45, 1359 (1992).

[14] H. Q. Song and R. K. Su, Phys. Lett. B 358, 179 (1995); H. Shen and H. Toki, Phys. Rev. C 61, 045205 (2000); Guo Hua, Y. X. Liu, and S. Yang, Phys. Rev. C 63, 044320 (2001).

[15] D. H. Lu, A. W. Thomas, K. Tsushima, A. G. Williams, and K. Saito, Phys. Rev. C 60 068201 (1999); *ibid.*, Nucl. Phys. A634, 443 (1998); *ibid.*, Phys. Lett. B 417, 217 (1998).

[16] S. Dieterich *et al.*, Phys. Lett. B 500, 47 (2001).

[17] S. Dieterich *et al.*, Nucl. Phys. A690, 231 (2001); P. E. Ulmer *et al.*, Nucl. Phys. A689, 94 (2001).

[18] P. A. M. Guichon, K. Saito, E. Rodionov and A. W. Thomas, Nucl. Phys. A 601, 349 (1996); K. Saito, K. Tsushima, and A. W. Thomas, *ibid*. A 609, 339 (1996).

[19] R. Tegen, M Schedl, and W. Weise, Phys. Lett. B 125, 9 (1983); R. Tegen and W.
Weise, Z. Phy. A 314, 357 (1983).

[20] A. W. Thomas, Adv. in Nucl. Phys., 13, 1 (1984); G. A. Miller, Int. Rev. Nucl. Phys. 1, 190 (1984); A. W. Thomas, S. Théberge, and G. A. Miller, Phys. Rev. D 24, 216 (1981); S. Théberge, G. A. Miller, and A. W. Thomas, Can. J. Phys. 60, 59 (1982).

[21] D. H. Lu, A. W. Thomas, and A. G. Williams, Phys. Rev. C 57, 2628(1998); D. H. Lu, A. W. Thomas, and A. G. Williams, Phys. Rev. C 55, 3108 (1997).

[22] R. E. Peierls and D. J. Thouless, Nucl. Phys. 38, 154 (1962).

[23] A. L. Licht and A. Pagnamenta, Phys. Rev. D2, 1156 (1970); X. Ji, Phys. Lett. B254 (1991).

[24] T. Kitagaki et al., Phys. Rev. D. 28, 436 (1983).

[25] A. Liesenfeld et al., Phys. Lett. B 468 (1990) 20.

[26] V. Bernard, L. Elouadrhiri, U. G. Meissner, hep-ph/0107088; V. Bernard, U. G. Meissner, N. Kaiser, Phys. Rev. Lett. 72, 2810 (1994).

[27] D. H. Lu and A. W. Thomas, in preparation.

[28] A. W. Thomas and W. Weise, The Structure of the Nucleon (Berlin, Wiley-VCH, 2001).

[29] K. Kubodera, J. Delorme and M. Rho, Phys. Rev. Lett. 40, 755 (1978).

[30] K. Kubodera and S. Nozawa, Int. J. Mod. Phys. E 3, 101 (1994).

[31] W. C. Haxton, Ann. Rev. Astron. Astro. Phys. 33, 459 (1995).
FIG. 1. The nucleon axial form factor in free space for three different bag radii. Experimental data are summarised by a dipole form: $G_A(Q^2) = g_A/(1 + Q^2/m_A^2)^2$, with $m_A = (1.03 \pm 0.04)$ GeV. The value of $g_A$ in our calculation is 1.14, compared with the experimental value of 1.26.
FIG. 2. The density dependence of the nucleon axial form factor with $R_0 = 0.95$ fm. The value of $g_A$ is quenched in nuclear matter, resulting in a reduction of roughly 12% and 9% at $\rho_0$ and $0.7\rho_0$, respectively.
FIG. 3. The momentum dependence of the nucleon axial form factor at different densities with $R_0 = 0.95$ fm. The effect of medium modification, which is more important in small momentum transfer region, glows as the baryon density increases.