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Predictions From The Quark-Parton Model And Source Theory For Deep-Inelastic Scattering With Polarized Particles*

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It was reported by Gabathuler/1/that the results of the broken SU(6) version of the quark-parton model/2/ and source theory/3,4/ are nearly the same for the prediction of the asymmetry parameter $A1$ for deep-inelastic scattering of polarized electrons from polarized protons. In fact, both of these approaches are in good agreement with the latest experimental data/5/. It is the purpose of this talk to describe the differences between these two models and to suggest how these two different descriptions of hadronic dynamics may be distintuished experimentally. In this lecture, I will follow the notations that may be found in Ref./6/ where additional details of the scattering process are to be found. For the scattering process considered, an electron(muon) of four-momentum a^μ, energy ω_a and polarization s_a^μ is scattered into a final state of energy ω_c from a proton of four-momentum b^μ, rest mass m, and polarization s_b^μ by way of the exchange of a virtual photon of four-momentum $q^\mu = a^\mu - c^\mu$. From the four-momenta, one can define the Lorentz invariants $4s = (a+b)^2$, $4t = (a-c)^2 = -Q^2$, and $\nu = -b\cdot Q/m$. The asymmetry parameter is defined from the differential cross-sections which represent deep-inelastic scattering with parallel and antiparallel orientations of the spin polarization of the lepton and the hadron as

$$A = \frac{\partial\sigma(\uparrow\uparrow) - \partial\sigma(\uparrow\downarrow)}{\partial\sigma(\uparrow\uparrow) + \partial\sigma(\uparrow\downarrow)}. \tag{1}$$

In the rest system for the nucleon, the differential cross-section can be written as

$$\frac{\partial\sigma(s_a, s_b)}{\partial\Omega_c\partial\omega_c} = \frac{\alpha^2\omega_c}{8\pi m t^2\omega_a} L^{\mu\nu}(s_a) ImH_{\mu\nu}(s_b) \tag{2}$$

where $L^{\mu\nu}(s_a)$ is the lepton polarization tensor and where $ImH^{\mu\nu}(s_b)$ is the hadronic polarization tensor which can be written in terms of the four structure functions $ImH_i(4t,\nu)(i = 1-4)$ and the four gauge invariant tensors $T_i^{\mu\nu}(m)$ as

$$ImH^{\mu\nu}(s_b) = \sum ImH_i(4t,\nu)T_i^{\mu\nu}(s_b). \tag{3}$$

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In terms of these structure functions the asymmetry parameter A becomes

$$A = -\frac{[2m\nu ImH_3 + (\nu^2+Q^2)ImH_4]}{[(\nu^2+Q^2)ImH_2 - Q^2 ImH_1]}. \tag{4}$$

These structure functions are related to the more commonly used functions/7/ as follows:

$$\begin{aligned}
ImH_1(4t,\nu) &= -\frac{\pi}{8mt}[-W_1 + (1-\nu^2/4t)W_2] \\
ImH_2(4t,\nu) &= -\frac{\pi}{8mt}W_2(4t,\nu) \\
ImH_3(4t,\nu) &= -\frac{1}{16m^3}d(4t,\nu) \\
ImH_4(4t,\nu) &= -\frac{1}{8m}g(4t,\nu).
\end{aligned} \tag{5}$$

In the quark-parton model, it is assumed that the lepton is scattered incoherently from a single quark whose four-monentum is a fraction x of the four-momentum of the proton, $q^\mu = xb^\mu$ where $x = Q^2/2m\nu$. This implies that $m_q = xm$ and that

$$\begin{aligned}
T_i^{\mu\nu}(m_q) &= x^2 T_i^{\mu\nu}(m)(i = 1, 2, or 4) \\
T_3^{\mu\nu}(m_q) &= x^3 T_3^{\mu\nu}(m)
\end{aligned} \tag{6}$$

which can be used with (2) and (3) to show that

$$\begin{aligned}
F_1(x) &= mW_1 = (1/2x)F_2(x) \\
F_2(x) &= \nu W_2 = \sum e_i^2 x[f_i(x\uparrow) + f_i(x\downarrow)] \\
(\nu/2\pi)d(4t,\nu) &= \sum e_i^2[f_i(x\uparrow) - f_i(x\downarrow)] \\
g(4t,\nu) &= 0 \\
A/D \approx A1 &= \frac{(\nu/2\pi)d(4t,\nu)}{2F_1}
\end{aligned} \tag{7}$$

where $f_i(x\uparrow)$ is a quark spin distribution function, e_i a quark charge, and D a known kinematical factor. One observes that in the scaling limit the structure function $g(4t,\nu)$ vanishes.

In source theory, the structure functions (5) are obtained from a double spectral integral

$$ImH_i(4t,\nu) = \iint \frac{dM_+^2 dM_-^2 2h_i(M_+,M_-)}{M_+^2 M_-^2[(q+b)^2 - M_+^2][(q-b)^2 - M_-^2]} \tag{8}$$

where $h_i(M_-,M_-)$ is determined from the behaviour of the structure functions near the region for elastic scattering and in the region of absorption of a real photon. Unlike the quark-parton model, source theory predicts a non-zero value for the structure function $g(4t, \nu)$ even in the scaling limit. Using this theory, one can show that

$$4t\nu g(4t, \nu) = \frac{4\pi(1 - 0.3x^{-1/2})x1.8F_2(x)}{(1 + x)}. \tag{9}$$

Numerically the value of (9) approaches zero at $x = 0$ and $x = 1$, and it has a maximun value of 0.78 at $x = 0.39$. Here the values of $F_2(x)$ come from a parameterization of the experimental data similar to that used in Ref./8/.

The results in (5) for the quark-parton model are modified when perturbative QCD corrections are made to the quark distributions and to the structure functions. These may be performed using the evolution equation method/9/. In source theory, scaling violations may be introduced with the aid of a new scaling variable. However, these two approaches produce different Q^2 dependence which results in small corrections to the above results.

Experimentally, one could measure the value of $g(4t, \nu)$ if an helically polarized lepton is scattered from a proton which has its spin parallel or antiparallel to the direction of the virtual photon or if it is polarized in a direction perpenticular to the lepton beam and to the polarization direction of the lepton. The differential cross-sections for these two processes may be found from equations (81) and (82) respectively of Ref./6/. It is anticipated that the soon to be published results of the European Muon Collaboration experiment NA2 performed at CERN in which polarized muons are scattered from polarized nucleons to measure the asymmetry parameter at values of x between 0.04 and 0.2 for values of Q^2 up to $20\,GeV^2$ will aid in the establishment of a realistic description of hadronic matter.

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References

1. E. Gabathuler, Jounral de Physique, Colloque C2 supplément au No 2, 46, C2-141 (1985).
2. R. Carlitz and J. Kaur, Phys. Rev. Lett. 38, 637 (1977).
3. J. Schwinger, Proceedings of the National Academy of Science USA, 72, 1 (1975); 72, 1559 (1975); 73, 3351 (1976); 73, 3861 (1976).
4. J. Schwinger, Nucl. Phys., B123,223 (1977).
5. G. Baum et al., Phys. Rev. Lett., 51, 1135 (1983).
6. T. Garavaglia, Int. J. Theor. Phys., 23, 251 (1984).
7. F. J. Gilman, Physics Reports, 4c-3, 130 (1972).
8. V. Barger and R. J. N. Phillips, Nucl. Phys., B73, 269 (1974)
9. P. Chiappetta and J. Soffer, Phys. Rev., 31, 1019 (1985).