Implications of Configuration Mixing in The Chiral Quark Model With SU(3) and Axial U(1) Breakings for Nucleon Spin-Flavor Structure.

Harleen Dahiya and Manmohan Gupta
Department of Physics, Panjab University, Chandigarh-160 014, India.

October 27, 2018

Abstract

The implications of Chiral Quark Model with SU(3) and axial U(1) symmetry breakings as well as configuration mixing generated by one gluon exchange forces ($\chi QM_{gcm}$) are discussed in the context of proton flavor and spin structure as well as the hyperon $\beta$-decay data. Apart from reproducing the success of $\chi QM$ with symmetry breaking, it is able to improve upon the agreement with data in several cases such as, $G_A/G_V$, $\Delta_8$, $<A_1^p>$ dependent on spin polarization functions and $(\frac{2s}{u+d})$, $(\frac{2\bar{s}}{u+d})$ and $f_s$ involving the quark distribution functions.

It is well known that the chiral quark model ($\chi QM$) [1, 2, 3] with SU(3) symmetry is not only able to give a fair explanation of “proton spin crisis” [4] but is also able to account for the $\bar{u} - \bar{d}$ asymmetry [5, 6] as well as the existence of significant strange quark content $\bar{s}$ in the nucleon when the asymmetric octet singlet couplings are taken into account [7]. Further, $\chi QM$ with SU(3) symmetry is also able to provide fairly satisfactory explanation for various quark flavor contributions to the proton spin [8], baryon magnetic moments [8, 9] as well as the absence of polarizations of the antiquark sea in the nucleon [8, 10]. However, in the case of hyperon decay parameters the predictions of the $\chi QM$ are not in tune with the data [11], for example, in comparison to the experimental numbers .21 and 2.17 the $\chi QM$ with SU(3) symmetry predicts $f_3/f_8$ and $\Delta_3/\Delta_8$ to be $\frac{2}{3}$ and $\frac{5}{3}$ respectively. It has been shown [3, 4] that when SU(3) breaking effects are taken into consideration within $\chi QM$, the predictions of the $\chi QM$ regarding the above mentioned ratios have much better overlap with the data.
Recently it has been shown [13] that the one gluon mediated configuration mixing, within the premises of constituent quark model, not only explains the neutron charge radius squared ($< r^2_n >$) but is also able to improve $G_A/G_V$ fit in comparison with calculations without configuration mixing. Therefore, it becomes interesting to examine, within the $\chi$QM, the implications of one gluon mediated configuration mixing for flavor and spin structure of nucleon. In particular we would like to examine the nucleon spin polarizations and various hyperon $\beta$-decay constants, violation of Gottfried sum rule, strange quark content in the nucleon, fractions of quark flavor etc. in the $\chi$QM with configuration mixing and with and without symmetry breaking. Further, it would be interesting to examine whether a unified fit could be effected for spin polarization functions as well as quark distribution functions or not.

The details of the $\chi$QM$_{gcm}$ have been discussed in the reference [13], however for the sake of readability of manuscript, we summarize the essential features of $\chi$QM$_{gcm}$. The basic process, in the $\chi$QM, is the emission of a Goldstone Boson (GB) which further splits into $q\bar{q}$ pair, for example,

$$q_{\pm} \rightarrow GB^0 + q'_\pm \rightarrow (q\bar{q}') + q'_\pm.$$  \hfill (1)

The effective Lagrangian describing interaction between quarks and the octet GB and singlet $\eta'$ is

$$L = g_8\bar{q}\phi q,$$  \hfill (2)

where $g_8$ is the coupling constant,

$$q = \begin{pmatrix} u \\ d \\ s \end{pmatrix}$$

and

$$\phi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} + \frac{\eta'}{\sqrt{3}} \\ \pi^- \\ -\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} + \frac{\eta'}{\sqrt{3}} \end{pmatrix} \begin{pmatrix} \pi^+ \\ \alpha K^+ \\ \alpha K^0 \end{pmatrix}.$$  

SU(3) symmetry breaking is introduced by considering different quark masses $m_s > m_{u,d}$ as well as by considering the masses of non-degenerate Goldstone Bosons $M_{K,\eta} > M_\pi$, whereas the axial U(1) breaking is introduced by $M_{\eta'} > M_{K,\eta}$ [3, 4, 5, 6]. The parameter $a(=|g_8|^2)$ denotes the transition probability of chiral fluctuation or the splittings $u(d) \rightarrow d(u) + \pi^{+(0)}$, whereas $\alpha^2 a$ denotes the probability of transition $u(d) \rightarrow s + K^{-0}$. Similarly $\beta^2 a$ and
ζ²a denote the probability of \( u(d, s) \to u(d, s) + \eta \) and \( u(d, s) \to u(d, s) + \eta' \) respectively.

The one gluon exchange forces [15] generate the mixing of the octet in \((56, 0^+)_{N=0}\) with the corresponding octets in \((56, 0^+)_{N=2}\), \((70, 0^+)_{N=2}\) and \((70, 2^+)_{N=2}\) harmonic oscillator bands [16]. The corresponding wave function of the nucleon is given by

\[
|B> = (|56, 0^+ >_{N=0} \cos \theta + |56, 0^+ >_{N=2} \sin \theta) \cos \phi \\
+ (|70, 0^+ >_{N=2} \cos \theta + |70, 2^+ >_{N=2} \sin \theta) \sin \phi. \tag{3}
\]

In the above equation it should be noted that \((56, 0^+)_{N=2}\) does not effect the spin-isospin structure of \((56, 0^+)_{N=0}\), therefore the mixed nucleon wave function can be expressed in terms of \((56, 0^+)_{N=0}\) and \((70, 0^+)_{N=2}\), which we term as non trivial mixing [17] and is given as

\[
|8, \frac{1}{2} > = \cos \phi |56, 0^+ >_{N=0} + \sin \phi |70, 0^+ >_{N=2}. \tag{4}
\]

where

\[
|56, 0^+ >_{N=0,2} = \frac{1}{\sqrt{2}}(\chi' \phi' + \chi'' \phi'') \psi^*, \tag{5}
\]

\[
|70, 0^+ >_{N=2} = \frac{1}{2}[(\psi'' \chi' + \psi' \chi'') \phi' + (\psi' \chi' - \psi'' \chi'') \phi'']. \tag{6}
\]

The spin and isospin wave functions, \(\chi\) and \(\phi\), are given below

\[
\chi' = \frac{1}{\sqrt{2}}(\uparrow \downarrow \uparrow - \downarrow \uparrow \uparrow), \quad \chi'' = \frac{1}{\sqrt{6}}(2 \uparrow \downarrow \downarrow - \uparrow \downarrow \uparrow - \downarrow \uparrow \uparrow),
\]

\[
\phi_p' = \frac{1}{\sqrt{2}}(udu - duu), \quad \phi_p'' = \frac{1}{\sqrt{6}}(2uud - udu - duu),
\]

\[
\phi_n' = \frac{1}{\sqrt{2}}(udd - dud), \quad \phi_n'' = \frac{1}{\sqrt{6}}(udd + dud - 2ddu).
\]

For the definition of the spatial part of the wave function, \((\psi^*, \psi', \psi'')\) as well as the definitions of the spatial overlap integrals we refer the reader to reference [17, 18].

The contribution to the proton spin defined through the equation

\[
\Delta q = q_\uparrow - q_\downarrow + \bar{q}_\uparrow - \bar{q}_\downarrow, \tag{7}
\]

using Equation(4) and following Linde et.at. [14], can be expressed as
\[ \Delta u = \cos^2 \phi \left[ \frac{4}{3} - \frac{a}{3} \left( 7 + 4 \alpha^2 + \frac{4}{3} \beta^2 + \frac{8}{3} \xi^2 \right) \right] + \sin^2 \phi \left[ \frac{2}{3} - \frac{a}{3} \left( 5 + 2 \alpha^2 + \frac{2}{3} \beta^2 + \frac{4}{3} \xi^2 \right) \right], \]  
(8)

\[ \Delta d = \cos^2 \phi \left[ -\frac{1}{3} - \frac{a}{3} (2 - \alpha^2 - \frac{1}{3} \beta^2 - \frac{2}{3} \xi^2) \right] + \sin^2 \phi \left[ \frac{1}{3} - \frac{a}{3} (4 + \alpha^2 + \frac{1}{3} \beta^2 + \frac{2}{3} \xi^2) \right], \]  
(9)

and

\[ \Delta s = \cos^2 \phi \left[ -a \alpha^2 \right] + \sin^2 \phi \left[ -a \alpha^2 \right]. \]  
(10)

The SU(3) symmetric calculations can easily be obtained from Equations (8), (9), (10) by considering \( \alpha, \beta = 1 \). The corresponding equations can be expressed as

\[ \Delta u = \cos^2 \phi \left[ \frac{4}{3} - \frac{a}{9} (37 + 8 \xi^2) \right] + \sin^2 \phi \left[ \frac{2}{3} - \frac{a}{9} (23 + 4 \xi^2) \right], \]  
(11)

\[ \Delta d = \cos^2 \phi \left[ -\frac{1}{3} - \frac{2a}{9} (\xi^2 - 1) \right] + \sin^2 \phi \left[ \frac{1}{3} - \frac{a}{9} (16 + 2 \xi^2) \right], \]  
(12)

and

\[ \Delta s = -a. \]  
(13)

After having examined the effect of one gluon exchange inspired configuration mixing on the spin polarizations of various quarks \( \Delta u, \Delta d \) and \( \Delta s \), we can calculate the following quantities

\[ G_A / G_V = \Delta_3 = \Delta u - \Delta d, \]  
(14)

\[ \Delta_8 = \Delta u + \Delta d - 2 \Delta s, \]  
(15)

The asymmetry \( \langle A_1^p \rangle \) measured in deep inelastic scattering

\[ \langle A_1^p \rangle = 2 < x > \frac{\sum e_q^2 \Delta q}{\sum e_q^2 q}, \]  
(16)

can also be calculated in terms of the spin polarization functions.

Similarly the hyperon \( \beta \) decay data \([19, 20, 21, 22]\) can also be expressed in terms of the spin polarization functions, for example,

\[ \Delta_3 = \Delta u - \Delta d = F + D, \]  
(17)
\[ \Delta_8 = \Delta u + \Delta d - 2\Delta s = 3F - D. \]  

Before we present our results it is perhaps desirable to discuss certain aspects of the symmetry breaking parameters employed here. As has been considered by Cheng and Li [3], the singlet octet symmetry breaking parameter \( \zeta \) is related to \( \bar{u} - \bar{d} \) asymmetry [5, 6], we have also taken \( \zeta \) to be responsible for the \( \bar{u} - \bar{d} \) asymmetry in the \( \chi \)QM with SU(3) symmetry breaking and configuration mixing. Further, we have used the relation \( \zeta = -0.7 - \frac{\beta}{2} \) in order to keep \( a=0.1 \) as has been used by various authors [3, 8, 9, 12, 14]. With these restrictions on parameters, we have carried out a \( \chi^2 \) minimization for spin as well as quark distribution functions.

In Table 1 we have presented the results of our calculations pertaining to spin polarization functions \( \Delta u, \Delta d, \Delta s \) whereas in Table 2 the corresponding hyperon \( \beta \)-decay parameters dependent on the spin distribution functions have been presented. Since one of the purpose of the present calculation is to compare the present results with those of the results corresponding to only SU(3) breaking, therefore we have included in Table 1 and 2 the results of Song et al. [9]. The corresponding results of Cheng and Li [12] have not been included because they have not fitted \( \bar{u}/\bar{d} \) through the singlet octet SU(3) breaking parameter \( \zeta \). In Table 1 and 2 we have also included the results of NRQM and \( \chi \)QM with SU(3) symmetry and the corresponding results after including configuration mixing. This has been carried out to understand the implications of configuration mixing in effecting the fit.

A general look at Table 1 makes it clear that we have been able to get an excellent fit to the spin polarization data for the values of symmetry breaking parameters \( \alpha = .4, \beta = .7 \) obtained by \( \chi^2 \) minimization. It is perhaps desirable to mention that the spin distribution functions \( \Delta u, \Delta d, \Delta s \) show much better agreement with data when the contribution of anomaly [23] is included. Similarly in Table 2 we find that the success of the fit obtained with \( \alpha = .4, \beta = .7 \) hardly leaves anything to desire. The agreement is striking in the case of parameters \( F+D/3 \) and \( F \). We therefore conclude that the \( \chi \)QM with SU(3) and axial U(1) symmetry breakings along with configuration mixing generated by one gluon exchange forces provides a satisfactory description of the spin polarization functions and the hyperon decay data.

In order to appreciate the role of configuration mixing in effecting the fit, we first compare the results of NRQM with those of NRQM_{gcm} [13]. One observes that configuration mixing corrects the result of the quantities in the right direction but this is not to the desirable level. Further, in order to understand the role of configuration mixing and SU(3) symmetry with and without breaking in \( \chi \)QM, we can compare the results of \( \chi \)QM with SU(3) symmetry to those of \( \chi \)QM_{gcm} with SU(3) symmetry. Curiously \( \chi \)QM_{gcm} compares
| Parameter | Expt value | NRQM results | NRQM\textsubscript{gcm} | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry breaking | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry breaking |
|-----------|------------|--------------|----------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
|           |            |              | \(\alpha = 1\) | \(\beta = 1\) | \(\alpha = 0.5\) | \(\beta = 1\) | \(\alpha = 0.4\) | \(\beta = 0.7\) |
| \(\Delta u\) | 0.85 \pm 0.05 | 1.33 | 1.25 | 0.79 | 0.86 | 0.77 | 0.90, 0.86\* |
| \(\Delta d\) | -.41 \pm 0.05 | -0.33 | -0.26 | -0.32 | -0.34 | -0.27 | -0.32, -0.36\* |
| \(\Delta s\) | -0.07 \pm 0.05 | 0 | 0 | -0.10 | -0.05 | -0.10 | -0.02, -0.06\* |
| \(G_A/G_V\) | 1.26 \pm .0028 | 1.66 | 1.51 | 1.11 | 1.20 | 1.04 | 1.22, 1.22\* |
| \(\Delta_8\) | .58 \pm 0.025 | 1 | .99 | .67 | .62 | .70 | .61, .62\* |
| \(\langle A_1^P \rangle\) | 0.40 \pm 0.10 | - | - | .28 | .35 | .31 | .38, .36\* |

* Values after inclusion of the contribution from anomaly [2 3].

Table 1: The calculated values of spin polarization functions \(\Delta u\), \(\Delta d\), \(\Delta s\), and quantities dependent on these: \(G_A/G_V\), \(\Delta_8\) and \(\langle A_1^P \rangle\). The last two columns respectively list the values in the \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry and with SU(3) \(\times\) U(1) symmetry breakings for the values of \(\alpha\) and \(\beta\) obtained by \(\chi^2\) minimization.

| Parameter | Expt value | NRQM results | NRQM\textsubscript{gcm} | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry breaking | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry | \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry breaking |
|-----------|------------|--------------|----------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
|           |            |              | \(\alpha = 1\) | \(\beta = 1\) | \(\alpha = 0.5\) | \(\beta = 1\) | \(\alpha = 0.4\) | \(\beta = 0.7\) |
| \(F+D\)  | 1.26 \pm .0028 | 1.66 | 1.51 | 1.11 | 1.20 | 1.04 | 1.22 |
| \(F+D/3\) | .718 \pm .015 | 1 | .92 | .67 | .70 | .64 | .71 |
| \(F-D\)  | -.34 \pm .017 | -.33 | -.26 | -.22 | -.29 | -.17 | -.30 |
| \(F-D/3\) | .25 \pm .05 | .33 | .33 | .22 | .21 | .23 | .21 |
| \(F/D\)  | .575 \pm .016 | .67 | .71 | .67 | .61 | .72 | .60 |
| \(F\)    | .462 | .665 | .625 | .445 | .455 | .435 | .46 |
| \(D\)    | .794 | 1 | .885 | .665 | .745 | .605 | .76 |

Table 2: The last two columns respectively list the calculated values the hyperon \(\beta\) decay data in the \(\chi\text{QM}_{\text{gcm}}\) with SU(3) symmetry and with SU(3) \(\times\) U(1) symmetry breakings for the values of \(\alpha\) and \(\beta\) obtained by \(\chi^2\) minimization.
unfavourably with $\chi$QM in case of most of the calculated quantities. This indicates that configuration mixing alone is not enough to generate an appropriate fit in $\chi$QM. However when $\chi$QM$_{gcm}$ is used with SU(3) and axial U(1) symmetry breakings then the results show uniform improvement over the corresponding results of $\chi$QM with SU(3) and axial U(1) symmetry breakings [9]. In particular there is discernible improvement in the case of $G_A/G_V$, $\Delta_8$ and $<A_1^p>$. To summarize the discussion of these results, one finds that both configuration mixing and symmetry breaking are very much needed to fit the data within $\chi$QM. It should also be borne in mind that the improvement in the above mentioned case is while maintaining the success of $\chi$QM with SU(3) symmetry breaking.

In view of the fact that flavor structure of nucleon is not affected by configuration mixing, therefore it would seem that the results of $\chi$QM with SU(3) breaking will be exactly similar to those of $\chi$QM$_{gcm}$ with SU(3) breaking. However, as mentioned earlier, one of the purpose of the present communication is to have a unified fit to spin polarization functions as well as quark distribution functions, therefore it is interesting to compare our results with those obtained in $\chi$QM with and without symmetry breaking. To that end, we first mention the quantities which we have calculated. The basic quantities of interest in this case are the unpolarized quark distribution functions, particularly the antiquark contents given as under [14]

$$\bar{u} = \frac{1}{12}[(2\zeta + \beta + 1)^2 + 20]a, \quad (19)$$

$$\bar{d} = \frac{1}{12}[(2\zeta + \beta - 1)^2 + 32]a, \quad (20)$$

$$\bar{s} = \frac{1}{3}[(\zeta - \beta)^2 + 9\alpha^2]a, \quad (21)$$

For the quark number in the proton, we have

$$u = 2 + \bar{u}, \quad d = 1 + \bar{d}, \quad s = \bar{s}. \quad (22)$$

There are important experimentally measurable quantities dependent on the above distributions. The deviation from the Gottfried sum rule [3] is one such quantity which measures the asymmetry between the $\bar{u}$ and $\bar{d}$ quarks in the nucleon sea. In the $\chi$QM the deviation of Gottfried sum rule from 1/3rd is expressed as

$$\left[ \int_0^1 dx \frac{F_p^p(x) - F_p^n(x)}{x} - \frac{1}{3} \right] = \frac{2}{3}(\bar{u} - \bar{d}). \quad (23)$$
Similarly the $\bar{u}/\bar{d}$ which can be measured through the ratio of muon pair production cross sections $\sigma_{pp}$ and $\sigma_{pn}$ is also an important parameter which gives an insight into the $\bar{u}, \bar{d}$ content [27]. The other quantities of interest is the quark flavor fraction in a proton, $f_q$, defined as

$$f_q = \frac{q + \bar{q}}{[\sum_q (q + \bar{q})]}$$  \hspace{1cm} (24)$$

where $q$’s stand for the quark numbers in the proton. Also we have calculated the ratio of the total strange sea to the light antiquark contents given by

$$\frac{2\bar{s}}{\bar{u} + \bar{d}}$$  \hspace{1cm} (25)$$

and the ratio of the total strange sea to the light quark contents given by

$$\frac{2s}{u + d}.$$  \hspace{1cm} (26)$$

The above mentioned quantities based on quark distribution functions have been calculated using the set of parameters, $\alpha = .4$ and $\beta = .7$, which minimizes the $\chi^2$ fit for the spin distribution functions and quark distribution functions. The results of our calculations are presented in Table 3. The general survey of Table 3 immediately makes it clear that the success achieved in the case of spin polarization functions is very well maintained in this case also. Apparently it would seem that $\chiQM_{gcm}$ with SU(3) symmetry breaking would not add anything to the success in $\chiQM$ with SU(3) symmetry breaking. However, a closer look at the table indicates that we have been able to improve upon the results of reference [9] without any further input. We would again like to mention here that we have not included the results of Cheng et.al. [12] for comparison because they have not fitted the value of $\bar{u}/\bar{d}$ for the value of the singlet octet breaking parameter $\zeta$. In almost all the quantities, which have been measured experimentally, our fit leaves hardly anything to be desired, in contrast to the results of [9]. In comparison with the results of [9] our results show considerable improvement in the case of ratio of the total strange sea to the light antiquark contents ($\frac{2s}{u+d}$) whereas there is a big improvement in the case of ratio of the total strange sea to the light quark contents ($\frac{2s}{u+d}$) and the strange flavor fraction ($f_s$).

In conclusion we would like to mention that the $\chiQM$ with configuration mixing generated by one gluon mediated forces ($\chiQM_{gcm}$) [13] with SU(3) and axial U(1) symmetry breakings, is not only able to fit the data regarding spin polarization functions and the quark distribution functions but is also able to improve upon the results of $\chiQM$ with SU(3) symmetry breaking. In particular it is able to give an improved fit in the case of $G_A/G_V$, $\Delta_8$ and $<A_V^p>$ as well
Table 3: The last column lists the quark distribution functions and other dependent quantities as calculated in the \( \chi_{QM_{gcm}} \) with SU(3) symmetry breaking.
as for \( \frac{2s}{u+d}, \frac{2s}{u+d} \) and \( f_s \), in contrast to the \( \chi \)QM with SU(3) symmetry breaking \[9\].

**ACKNOWLEDGMENTS**

H.D. would like to thank CSIR, Govt. of India, for financial support and the chairman, Department of Physics, for providing facilities to work in the department.

**References**

[1] A. Manohar and H. Georgi, Nucl. Phys. **B 234**, 189(1984).

[2] S. Weinberg, Physica **A 96**, 327(1979).

[3] T.P. Cheng and Ling Fong Li, Phys. Rev. Lett. **74**, 2872(1995).

[4] J. Ashman et. al., Phys. Lett. **B 206**, 364(1998), Nucl. Phys. **B 328**, 1(1990).

[5] New Muon Collaboration, P. Amaudruz et.al., Phys. Rev. Lett. **66**, 2712(1991); M. Arneodo et.al., Phys. Rev. **D 50**, R1(1994).

[6] K. Gottfried, Phys. Rev. Lett. **18**, 1174(1967).

[7] T.P. Cheng, Phys. Rev. **D 13**, 2161(1976); NA51 Collaboration, A. Baldit *et.al.*, Phys. Lett. **B 332**, 244(1994).

[8] E.J. Eichten, I. Hinchliffe and C. Quigg, Phys. Rev. **D 45**, 2269(1992).

[9] X. Song, J.S. McCarthy and H.J. Weber, Phys. Rev. **D 55**, 2624(1997).

[10] S.J. Brodsky and B.Q. Ma, Phys. Lett. **B 381**, 317(1996); SMC Collaboration, B. Adeva, *et.al.*, Phys. Lett. **B 369**, 93(1996).

[11] J. Ellis and R.L. Jaffe, Phys. Rev. **D 9**, 1444(1974); R.L. Jaffe, Phys. Today. **48**(9), 24(1995).

[12] T.P. Cheng and Ling Fong Li, Phys. Rev. **D 57**, 344(1998).

[13] H. Dahiya and M.M. Gupta, [hep-ph/0003217](https://arxiv.org/abs/hep-ph/0003217).

[14] J. Linde, T. Ohlsson and Hakan Snellman, Phys. Rev. **D 57**, 452(1998).

[15] A. De Rujula, H. Georgi and S.L. Glashow, Phys. Rev. **D 12**, 147(1975).
[16] N. Isgur and G. Karl, Phys. Lett. 72B, 109(1977); 74B, 353(1978); Phys. Rev. D 18, 4187(1978); D 19, 2653(1979); D 21, 3175(1980); K.T. Chao, N. Isgur and G. Karl, Phys. Rev. D 23, 155(1981).

[17] M. Gupta and N. Kaur, Phys. Rev. D 28, 534(1983); M. Gupta, J. Phys. G: Nucl. Phys. 16, L213(1990).

[18] A. Le Yaouanc, L. Oliver, O. Pene and J.C. Raynal, Phys. Rev. D 12, 2137(1975); D 15, 844(1977).

[19] Particle Data Group, R.M. Barnett et.al., Phys. Rev. D 50, 1173(1994).

[20] F.E. Close and R.G. Roberts, Phys. Lett. B 316, 165(1993).

[21] P.G. Ratcliffe, Phys. Lett. B 365, 383(1996).

[22] X. Song, P.K. Kabir and J.S. McCarthy, Phys. Rev. D 54, 2108(1996).

[23] A.V. Efremov and O.V. Teryaev, Dubna Report No. JIN-E2-88-287, 1988 (unpublished); G. Altarelli and G. Roos, Phys. Lett. B 212, 391(1988); R.D. Carlitz, J.D. Collins and A.H. Mueller, ibid. 214, 229(1988).

[24] P.Adams et.al., Phys. Rev. D 56, 5330(1997).

[25] Particle Data Group, R.M. Barnett et.al., Phys. Rev. D 54, 1(1996).

[26] The E143 Collaboration, K. Abe et.al., Phys. Rev. Lett. 74, 346(1995); 75, 25(1995).

[27] A. Baldit et.al., NA51 Collaboration, Phys. Lett. B 253, 252(1994).

[28] A.O. Bazarko, et.al., Z. Phys C 65, 189(1995).

[29] J. Grasser, H. Leutwyler and M.E. Saino, Phys. Lett. B 253, 252(1991).