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A VALENCE QUARK MODEL OF MIXED SYMMETRY AND THE s CHANNEL PICTURE OF DEEP INELASTIC SCATTERING

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A B S T R A C T

Within the quark parton model we propose a mixed symmetry scheme for the valence component of the parton distributions. This scheme avoids the difficulty inherent in the symmetric valence quark model when applied to deep inelastic scattering. The s channel pattern of the resonance contributions to the structure functions is found to be ω dependent and in general different from the one observed in hadronic reactions. The polarization asymmetries near threshold are predicted to be $A_{p,n} = 1$.

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1. INTRODUCTION

Deep inelastic lepton-nucleon scattering is most successfully described in terms of two closely related frameworks, the parton model [1),2)] and the light cone approach [3)]. Particularly, interesting results were obtained in the quark parton model and the light cone version of it and the equivalence of both approaches was emphasized [4)]. In the present paper we shall use the term "Quark Parton Model" (QPM) to imply both of these frameworks.

Further specification of the QPM according to the two-component idea of duality was proposed by several authors [5),6)] where the contributions from each quark and antiquark were decomposed into those coming from the valence quarks and those from the SU(3) singlet sea of quark and antiquark pairs.

Here we would like to make the following remark that QPM, when described in terms of valence and sea quarks, does not necessarily predict the minimal value of 2/3 for the ratio F^{en}/F^{ep} of structure function, which is in obvious disagreement with experiment, particularly at $\omega \approx 1$. This minimum value of 2/3 follows only when a common distribution function for all the valence quarks is assumed [2)], which is of course an extra assumption. In order to make our arguments clear, we classify in the Table the various versions of QPM in the order of their generality.

In Ref. 6), where general constraints of duality have been applied to deep inelastic structure functions, it has been shown that if we apply the two-component duality restriction on this process we just recover the second model of the Table, i.e., the valence-sea quark model, where the valence quark component corresponds to the non-exotic contributions and that of the sea to the Pomeron (diffractive) effect. The two independent distribution functions v_p and v_n of the non-exotic part of the structure function are related in this approach to the F and D couplings of the bilocals to the nucleon. Fourier transforms of matrix elements of bilocals are the structure functions of nucleons. There the non-diffractive part of the SU(3) singlet was fixed by requiring the nonet symmetry for the coupling of bilocals to the nucleons [*)].

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*) This assumption is equivalent to the requirement that the currents with the quantum number of φ -f' contribute only to the diffractive part of the structure function, which is a consequence of duality diagram.

In this paper we first modify the symmetric valence quark model [2] along a line suggested by duality. Here we introduce two distribution functions for the non-diffractive part of the structure function: one to describe the two SU(3) antisymmetric valence quarks of the nucleon and the other one describes the third valence quark. It is interesting to note that this model gives the following bound for the ratio F^{en}/F^{ep}

$$\frac{1}{4} \leq \frac{F^{en}}{F^{ep}} \leq 1 \quad ,$$

which is just the experimentally observed one [7].

Next we consider the properties of the s channel resonances in deep inelastic scattering and the polarization asymmetries by examining the behaviour of the effective D/F ratio as a function of ω .

In Section 2, after fixing our notations we introduce a valence quark model of mixed symmetry and extract its consequences. In particular we derive the restrictions on the D/F ratio using this model and the positivity condition of the imaginary part of the forward Compton amplitude. Further we examine various possibilities of how D/F would change as a function of ω , namely whether it would continue to the D/F ratio observed in the Regge limit of the photo-nucleon and meson-nucleon scatterings as $\omega \to \infty$, and also its behaviour as ω approaches unity.

In Section 3, we consider the electroproduction of the s channel resonances in terms of the behaviour of D/F obtained in Section 2. In other words, we want to reproduce the observed structure functions in deep inelastic scattering as a sum of s channel resonances. In particular as ω approaches unity or when the missing mass $W = \sqrt{s}$ is kept fixed and $-q^2$ increases, we expect quite a different pattern of resonances in the s channel compared with that of photo-nucleon or meson-nucleon scatterings. Problems of polarization, especially the behaviour of asymmetry functions are considered in Section 4. A large discrepancy from SU(6) symmetric quark model is expected particularly at $\omega \sim 1$. Section 5 is devoted to discussions and conclusions.

2. A VALENCE QUARK MODEL WITH MIXED SYMMETRY

In this Section we start with fixing our notations. In the deep inelastic lepton-hadron scattering one measures the structure functions W_1, W_2 and W_3, which are determined by the absorptive part of current-hadron forward scattering amplitude

$$b + \beta \longrightarrow a + \alpha \quad , \tag{1}$$

where a and b (α and β) are the SU(3) quantum numbers of the current (the baryon target). In the Bjorken limit $\nu = p \cdot q$, $-q^2 \to \infty$ with the ratio $\omega = -(2\nu/q^2) = 1/\xi$ fixed, the structure functions become functions of only ω :

$$W_1(\nu, q^2) \longrightarrow F_1(\omega) \;, \; \nu W_2(\nu, q^2)/M^2 \to F_2(\omega) \text{ and } \nu W_3(\nu, q^2)/M^2 \to F_3(\omega). \tag{2}$$

In the QPM we have the relations [4]

$$2F_1(\omega) = \omega F_2(\omega) \,,$$
$$(F_\pm)^{ab}_{\alpha\beta} \equiv F^{ab}_{1,\alpha\beta} \mp \frac{1}{2} F^{ab}_{3,\alpha\beta} = (\pm i f^{abc} + d^{abc}) G^c_{\pm,\alpha\beta} \quad , \tag{3}$$

where we have explicitly displayed the SU(3) dependence for the structure functions. $G^c_{\pm,\alpha\beta}$ can further be expressed as

$$G^c_{\pm,\alpha\beta} = i f_{\alpha c\beta} F_\pm(\omega) + d_{\alpha c\beta}(1-\delta_{c0}) D_\pm(\omega) + d_{\alpha c\beta}\delta_{c0} S_\pm(\omega). \tag{4}$$

By introducing the 3×3 matrix $G_{\pm,\alpha\beta}$ through

$$G_{\pm,\alpha\beta} = \sum_{c=0}^{8} \frac{\lambda^c}{2} G^c_{\pm,\alpha\beta} \quad ,$$

we can relate it to the quark-parton distribution functions:

$$G_+ = \frac{1}{2}\begin{pmatrix} u_p & & 0 \\ & u_n & \\ 0 & & u_\lambda \end{pmatrix} \quad , \qquad G_- = \frac{1}{2}\begin{pmatrix} u_{\bar p} & & 0 \\ & u_{\bar n} & \\ 0 & & u_{\bar\lambda} \end{pmatrix} \quad ,$$

where we have put $\alpha = \beta =$ proton, and the deep inelastic structure function, say, $F_1^{ep}(\xi)$ is expressed in terms of these distribution functions as

$$F_1^{ep}(\xi) = \frac{1}{2}\sum_i Q^2 u_i(\xi) \quad ,$$

where Q_i is the charge of i^{th} quark or antiquark.

In the light cone approach to deep inelastic scattering $F_\pm$, $D_\pm$ and $S_\pm$ introduced in Eq. (4) are related to the matrix elements of bilocals as follows [6]:

$$\begin{aligned} \langle \alpha, p | V_\sigma^c(z,0) | \beta, p \rangle = 2p_\sigma [& i f_{\alpha c\beta}\, g_F(pz) + \\ & d_{\alpha c\beta}(1-\delta_{c0})\, g_D(pz) + d_{\alpha c\beta}\delta_{c0}\, g_S(pz)] \quad , \end{aligned} \tag{5}$$

where

$$V_\sigma^c(x,y) = \bar q(x)\,\gamma_\sigma \frac{\lambda^c}{2}\, q(y) \; .$$

Then

$$\begin{aligned} F_\pm(\xi) &= \pm \frac{1}{4\pi}\int_{-\infty}^{\infty} e^{\pm i\xi pz}\, g_F(pz)\, d(pz) \; , \\ D_\pm(\xi) &= \pm \frac{1}{4\pi}\int_{-\infty}^{\infty} e^{\pm i\xi pz}\, g_D(pz)\, d(pz) \; , \\ S_\pm(\xi) &= \pm \frac{1}{4\pi}\int_{-\infty}^{\infty} e^{\pm i\xi pz}\, g_S(pz)\, d(pz) \; . \end{aligned} \tag{6}$$

Now, if we apply the two-component duality idea to the structure functions we obtain the following relations [6]

$$\hat{S}_+ = \frac{1}{2}(3F_+ - D_+) \ , \quad F_- = D_- = S_- = 0 \ , \tag{7}$$

where $\hat{S}_+$ is the non-Pomeron part in the decomposition

$$S_+ = \hat{S}_+ + S_+^P \ .$$

From now on we drop the suffices + and write simply F, D, etc. Correspondingly we have

$$\hat{q}_S = \frac{1}{2}(3q_F - q_D) \quad \text{and} \quad q_S = \hat{q}_S + q_S^P \tag{8}$$

This amounts to saying that, as far as the non-diffractive part of the structure function is concerned, the octet and singlet components of bi-locals constitute an ideal nonet with canonical mixing angle ($\tan\Theta = 1/\sqrt{2}$) and that this nonet couples to baryons so that the component which behaves like φ or f' decouples from the nucleons.

Thus, we find that the non-Pomeron part of the deep inelastic scattering is described in terms of two independent structure functions which are essentially the F and the D type couplings of bilocals to nucleons. For example, the structure functions for electron-nucleon scattering are expressed as:

$$\begin{aligned} F_1^{ep}(\xi) &= 2F(\xi) - \frac{2}{9}D(\xi) + \frac{8}{9}S^P(\xi) \ , \\ F_1^{en}(\xi) &= \frac{4}{3}F(\xi) - \frac{8}{9}D(\xi) + \frac{8}{9}S^P(\xi) \ . \end{aligned} \tag{9}$$

In the QPM restricted by duality (the second model in the Table) these two structure functions $F(\xi)$ and $D(\xi)$ correspond to the distribution functions of valence quarks $v_p(\xi)$ and $v_n(\xi)$. Here the six distribution functions of quarks and antiquarks are decomposed into those of valence and sea quarks given by the following relations [6]:

$$u_p(\xi) = v_p(\xi) + s(\xi) \quad ,$$
$$u_n(\xi) = v_n(\xi) + s(\xi) \quad ,$$
$$u_{\bar{p}}(\xi) = u_{\bar{n}}(\xi) = s(\xi) \quad , \tag{10}$$
$$u_\lambda(\xi) = u_{\bar{\lambda}}(\xi) = s(\xi) \quad ,$$

and the structure functions of Eq. (9) are expressed now as

$$F_1^{ep} = \frac{4}{9} v_p + \frac{1}{9} v_n + \frac{4}{3} s \quad ,$$
$$F_1^{en} = \frac{4}{9} v_n + \frac{1}{9} v_p + \frac{4}{3} s \quad . \tag{9'}$$

It is interesting to note that the symmetric valence quark-parton model (the fourth model in the Table), in which $v_p(\xi) = 2v_n(\xi)$, corresponds to pure F type coupling of bilocals. In this respect the difficulty which is found there [7], namely that F^{en}/F^{ep} is bounded from below by 2/3, is reminiscent of that connected with "strong" Johnson-Treiman relation [8] for the total meson-baryon scattering which was characteristic to models where three quarks in the baryon were treated symmetrically like in the SU(6) model. This difficulty there was avoided by considering the freedom of the D as well as the F couplings [9].

Here also we are avoiding the difficulty by introducing the two structure functions F and D. However, we have another constraint to be satisfied by these functions. Namely, they should satisfy the positivity conditions for the imaginary part of forward current-hadron scattering amplitude. Then the F and the D are constrained as follows:

$$-3 \leq D/F \leq 1 \tag{11}$$

Note that the lower limit 1/4 of F^{en}/F^{ep} is approached when $F = D$ and in order to have a value below 2/3 for this ratio we should have

$$D/F \geq 0 \quad . \tag{12}$$

On the other hand, we know that for the Regge coupling to baryons a typical value one usually gets is [10]

$$(D/F)_{Regge} \simeq -0.2 \quad . \tag{13}$$

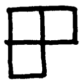
The scaling structure functions of the deep inelastic scattering is sometimes assumed [11] to be described in terms of Regge theory as $\omega \to \infty$. If this is the case the D/F ratio will change from 1 to $(D/F)_{Regge}$ as ω varies from 1 to ∞.

However, it is not clear whether $\omega \to \infty$ region of deep inelastic scattering smoothly connects with the photon-hadron scattering for which Regge description is established. If this is not the case, D/F can change in the region (11) which corresponds to the following inequality for F^{en}/F^{ep}:

$$\frac{1}{4} \leq \frac{F^{en}}{F^{ep}} \leq \frac{3}{2} \tag{14}$$

At this stage we introduce a valence quark model of mixed symmetry. We note first that although the symmetric valence quark model fails to account for the experimental results, especially near the threshold $\omega \simeq 1$ [7], it is not incompatible with experiment over a large region of ω. We ask then whether it is possible to improve the model by a small modification of it.

Let us start with the following observation. Owing to the octet nature of the nucleon, in order to construct, say a proton, out of three valence quarks, p, p and n two of them, namely p and n must be in an SU(3) anti-symmetric state. In other words, the proton as a member of octet is described by the following Young tableau:



Consequently, we assume a common distribution function $v(\xi)$ for the two quarks in the anti-symmetric state, while the last quark p is described by another function $w(\xi)$ *). This amounts to assuming

$$
\begin{aligned}
v_p(\xi) &= v(\xi) + w(\xi) \quad , \\
v_n(\xi) &= v(\xi) \quad .
\end{aligned}
\tag{15}
$$

for the distribution functions of valence quarks in Eq. (10). The symmetric quark-parton model demands $v = w$.

According to our approach the decuplet of baryons would have a single distribution function associated with all three valence quarks, since in this case all the quarks are on the same footing (the Young tableau for the decuplet is

Now it is straightforward to express the observable quantities in terms of v, w and s. By requiring separate positivity for all three distribution functions $v(\xi)$, $w(\xi)$ and $s(\xi)$, we have now **)

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*) The other possibility of writing the wave function of a proton in terms of three quarks is the one in which two of the quarks are in a symmetric state, namely: $P = \{p,p\}\, n - \{p,n\}\, p$. By attributing a common distribution function now to the quarks in the symmetric state and another function to the third quark, one obtains $7/13 \leq F_1^{en}/F_1^{ep} \leq 1$ which is experimentally ruled out.

**) The present model described by Eq. (15) gives a more stringent bound: $0 \leq F_1(\nu p)/F_1(ep) \leq 18/5$. In the second model of the Table described by Eq. (10) the upper limit for this ratio was 6.

$$\frac{1}{4} \leq \frac{F^{en}}{F^{ep}} \leq 1 \quad , \tag{16}$$

where the lower limit, which seems to be realized experimentally [7] near the threshold $\xi \approx 1$, is reached when $v = s = 0$ and $w \neq 0$. It is interesting to note that as ξ approaches 1 this picture, where only one quark with the distribution function $w(\xi)$ survives is just the picture suggested by Feynman [12], where he demands that all the quarks but one must be pushed to the low ξ in this kinematical region. In our scheme the total magnetic form factors G_M^p and G_M^n at $q^2 \to -\infty$ are controlled only by w and we also expect this ratio

$$G_M^n / G_M^p \longrightarrow -\frac{1}{2} \qquad \text{as} \quad q^2 \longrightarrow -\infty$$

(The charge ratio of the w quark in neutron and proton is equal to $-\frac{1}{3}/\frac{2}{3} = -\frac{1}{2}$.) The upper limit of (16) is approached in the following two cases 1) $w = 0$ and $s \neq 0$ or 2) $w = 0$ and $v \neq 0$.

If the lower limit of Eq. (16) is actually approached near $\omega \simeq 1$, all the structure functions can be described in terms of one independent function and we have the relations like

$$F_1(en) \simeq \frac{1}{4} F_1(ep) \quad ,$$

$$F_1(\nu p) \simeq 0 \quad , \qquad F_1(\bar{\nu} p) \simeq \frac{9}{2} F_1(ep) \, ,$$

$$F_3(\nu p) \simeq 0 \quad , \qquad F_3(\bar{\nu} p) \simeq -9 F_1(ep) \, .$$

The functions $v(\xi)$ and $w(\xi)$ can be expressed in terms of the F and the D type structure functions as

$$\begin{aligned} v(\xi) &= 2\,(F(\xi) - D(\xi)) \quad , \\ w(\xi) &= 2\,(F(\xi) + D(\xi)) \quad . \end{aligned} \tag{17}$$

Separate positivity of $v(\xi)$ and $w(\xi)$, which leads to Eq. (16) implies

$$-1 \leq D/F \leq 1 \quad , \tag{18}$$

which is stronger than the Ineq. (11), which was a consequence of the separate positivity of the imaginary part of the diffractive and the non-diffractive forward current-hadron scattering amplitude (the second model in the Table).

If the Regge limit of the deep inelastic scattering can be smoothly connected with the photon-hadron scattering we would have

$$-0.2 \simeq (D/F)_{Regge} \leq D/F \leq 1 \tag{19}$$

It would be interesting to distinguish experimentally between two possibilities (18) and (19). We shall discuss this point in the next Section.

3. DUALITY AND s CHANNEL RESONANCE PATTERN IN DEEP INELASTIC SCATTERING

In the previous sections we were concerned with the algebraic structure of the non-diffractive part of deep inelastic structure functions, which results from duality combined with the requirement of non-existence of exotics in the relevant channels.

Now we turn to a more direct argument of duality in deep inelastic region, which was first pointed out by Bloom and Gilman [13] who have shown how the behaviour of deep inelastic electron-nucleon scattering is related to electroproduction of the nucleon resonances.

In this section we want to examine the behaviour of baryon resonances produced in the direct channel by utilizing the behaviour of F and D type structure functions for the non-diffractive part of lepton-nucleon scattering as a function of ω. We predict this pattern of baryon resonances to be quite different from that of resonances produced in photon-nucleon and meson-nucleon scattering in a certain region of ω.

In purely hadronic process the problem of what pattern of s channel resonances would reproduce the t channel (Regge) description of the same process, has been exploited some time ago [14] by using SU(3) crossing matrices. Two simple solutions were found for pseudo-scalar meson-baryon scattering, where the pattern of the low energy resonances dominating in the s channel was given by the following two exchange degenerate sets

$$\underset{\sim}{8}_\alpha \left(J^P = 1/2^+, 5/2^+ \cdots\right) — \left(\underset{\sim}{8} + \underset{\sim}{1}\right)_\gamma \left(J^P = 3/2^-, 7/2^- \cdots\right)$$

and

$$\left(\underset{\sim}{10} + \underset{\sim}{8}\right)_\delta \left(J^P = 3/2^+, 7/2^+ \cdots\right) — \underset{\sim}{8}_\beta \left(J^P = 5/2^-, 9/2^- \cdots\right)$$

with definite relations among the couplings of resonances of each set to M-B system. Surprisingly, the well established baryon resonances were classified according to these two solutions as is given in brackets. An interesting property of the solutions is that these two sets satisfy the constraints of duality separately and that the relative amount of contribution from each group is not fixed by duality. It was shown, however, that the F/D ratio of couplings to baryons of the nonet of Reggeons exchanged in the t channel controls the relative importance of these two solutions [15].

In the deep inelastic case this can also be seen using the valence quark model of mixed symmetry described in the previous section. Namely we find that the 10-8-8 states contribute proportionally to v, because if the valence quark described by w is knocked out off the target baryon, we shall be left with two valence quarks which are in SU(3) antisymmetric state and consequently no 10 state is allowed in the s channel. Similarly, we can show that the contribution from 8-8-1 states is proportional to $\frac{1}{2}v + w$. Alternatively, using Eq. (17) we can say that 10-8-8 (8-8-1) states contribute in the s channel proportional to F-D ($\frac{1}{3}(3F+D)$), where D and F are now baryon matrix elements of the bilocals as introduced in Section 2, instead of couplings of the Regge trajectories.

We have learned in the previous section that the D/F ratio varies as a function of ω within a definite region given by Eq. (11), determined from positivity.

As we have seen in the previous section, experiment shows that D/F approaches its upper limit as we approach the threshold $\omega \to 1$. Consequently in this kinematical region we can expect that only 8-8-1 pattern of resonances in the s channel will survive and all the resonances belonging to 10-8-8, i.e., abnormal parity resonances with $J^P = (\frac{3}{2}^+, \frac{5}{2}^- \ldots)$ will become less prominant in this limit. This means that the transition form factors of the abnormal parity resonances, e.g., $\Delta(1236)$ $(J^P = \frac{3}{2}^+)$, $N^*(1670)$ $(J^P = \frac{5}{2}^-)$ etc., should fall faster than the form factors of the normal parity resonances, i.e., elastic form factor, $N^*(1520)$ $(J^P = \frac{3}{2}^-)$ transition form factor, etc. Vanishing of the s channel decuplet contributions when $\sigma_n/\sigma_p = \frac{1}{4}$ was first pointed out in Ref. 16).

The above mentioned results imply that we shall have quite a different resonance pattern in the missing mass of the deep inelastic scattering as ω approaches unity or if the missing mass $W = \sqrt{s}$ is kept fixed and $-q^2$ increases, compared to that of hadronic process and the photo-absorption case.

As we go away from the threshold the s channel resonance pattern changes gradually and the contribution from 10-8-8 exchange degenerate set starts to appear and finally in the region of $\omega \to \infty$ we have the following two possibilities corresponding to two different possibilities of the lower limit in Eqs. (18) and (19).

If D/F smoothly approaches $(D/F)_{Regge}$ as in Eq. (19), the s channel pattern will also approach the pattern of hadronic meson-baryon or photo-baryon scattering, where the relative importance of 10-8-8 series and that of 8-8-1 is

$$\left(\frac{3(F-D)}{3F+D}\right)_{Regge} \simeq 1.3 \quad .$$

If, on the other hand, D/F approaches -1 in this limit, the above-mentioned ratio will be equal to 3. Namely, contribution from 10-8-8 series will be dominating in this region.

4. POLARIZATION ASYMMETRY

Since the measurements for the scattering of polarized electrons on polarized target will soon be carried out in SLAC [17], it is of interest to examine the behaviour of the polarization asymmetry in the deep inelastic scattering. This quantity is particularly useful in analyzing the properties of the non-diffractive component of the scattering. Polarization asymmetry A is defined as

$$A(\nu, q^2) = \frac{d\sigma(\uparrow\downarrow) - d\sigma(\uparrow\uparrow)}{d\sigma(\uparrow\downarrow) + d\sigma(\uparrow\uparrow)} , \tag{20}$$

where $d\sigma(\uparrow\downarrow)$ and $d\sigma(\uparrow\uparrow)$ denote the differential cross-sections for scattering in the anti-parallel and parallel spin configurations respectively. A in general can vary in the region

$$-1 \leq A \leq 1 \tag{21}$$

The symmetric quark parton model or SU(6), when the diffractive part (the sea contribution) is neglected *) (ω near 1), predicts for the asymmetry of proton and neutron the following values [2]:

$$A_p = 5/9 \quad \text{and} \quad A_n = 0 . \tag{22}$$

However, it is obvious that this estimation cannot be true especially as $\omega \to 1$, because of the apparent experimental violation [7] of the lower bound 2/3 for F^{en}/F^{ep}, which is predicted in this model [2] near $\omega = 1$.

In the QPM the polarization asymmetry can be expressed as

$$A = \frac{\sum_i u_{i\sigma}(\xi)\, \sigma\, Q_i^2}{\sum_i u_i(\xi)\, Q_i^2} \tag{23}$$

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*) When the sea contribution is included, with the assumption that the diffractive component is spin independent [2], the symmetric quark model predicts

$$0 \leq A_p \leq 5/9 \quad \text{and} \quad A_n = 0 \tag{22'}$$

where $u_{i\sigma}(\xi)$ is the distribution function of quark i with spin direction σ relative to the nucleon spin. In the symmetric QPM from the SU(6) spin-unitary-spin wave function of the proton one has the following expressions for the distribution functions of the valence quarks:

$$
\begin{aligned}
v_p\uparrow &= \frac{5}{3}v \,, \\
v_p\downarrow &= \frac{1}{3}v \,, \\
v_n\uparrow &= \frac{1}{3}v \,, \\
v_n\downarrow &= \frac{2}{3}v \,,
\end{aligned}
\tag{24}
$$

which gives the Eq. (22). Addition of a spinless sea of quark and antiquark pairs gives Eq. (22').

In order to give predictive power to our model of valence quarks with mixed symmetry we should specify the spin state of quarks with the distribution functions $v(\xi)$ and $w(\xi)$. Following Feynman [12] we can assume that the total angular momentum of the antisymmetric pair of valence quarks with the distribution function $v(\xi)$ to be zero near the threshold $\omega \simeq 1$. Then the spin-unitary-spin wave function of proton is given by

$$
1/\sqrt{2}\; p\uparrow\,(p\uparrow n\downarrow - n\uparrow p\downarrow)
$$

which implies the following expressions for the spin dependent distribution functions of the valence quarks of proton

$$
\begin{aligned}
v_p\uparrow &= w + v/2 \,, \\
v_p\downarrow &= \frac{v}{2} \,, \\
v_n\uparrow &= \frac{v}{2} \,, \\
v_n\downarrow &= \frac{v}{2} \,.
\end{aligned}
\tag{25}
$$

Equations (25) together with Eq. (23) gives

$$
\begin{aligned}
A_p &= \frac{4w}{5v+4w} \,, \\
A_n &= \frac{w}{5v+w} \,.
\end{aligned}
\tag{26}
$$

At the threshold we have $v/w \to 0$ and therefore we obtain unity [18] for both proton and neutron asymmetry functions:

$$A_p \to 1 \quad , \quad A_n \to 1 \qquad \text{as} \quad \omega \to 1 \tag{27}$$

As $\omega \to \infty$ the dominance of the diffractive part together with its spin independence assumption gives *)

$$A_p \to 0 \quad , \quad A_n \to 0 \qquad \text{as} \quad \omega \to \infty \tag{28}$$

5. CONCLUSIONS AND DISCUSSIONS

We have seen how the prediction of the symmetric valence quark model, for which $2/3 \leq F^{en}/F^{ep} \leq 1$, can be avoided by taking into account the octet property of nucleons. In our model the non-diffractive part of the structure function is described in terms of two independent functions instead of one, as was the case in the symmetric quark model. This amounts to allowing for the D coupling of bilocals to nucleons as well as F coupling. Our valence quark model of mixed symmetry predicts $1/4 \leq F^{en}/F^{ep} \leq 1$, when we demand separate positivity of distribution functions.

Next we have found the pattern of s channel resonance contributions, which would reproduce the behaviour of the structure functions observed in deep inelastic scattering. This pattern is found to be different from the one occurring in the hadronic or photo-absorption case.

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*) If one assumes that the total angular momentum of the two v quarks is zero for all the values of ω, one obtains the following allowed regions

$$0 \leq A_{p,n} \leq 1 \quad ,$$

where the diffraction component has been taken into account as well. When we allow for a possible total angular momentum 1 for the antisymmetric pair of valence quarks we would get:

$$-\frac{1}{3} \leq A_{p,n} \leq 1 \quad .$$

Finally we have considered the polarization asymmetry in deep inelastic scattering. We have found the predictions which are quite different from that of the symmetric quark model. For example, we predict $A_{p,n} \rightarrow 1$ as $\omega \rightarrow 1$.

We would like to conclude with a few remarks.

1) As we have seen, although the behaviour of the structure functions near the threshold $\omega \simeq 1$ is comparatively clear, there is an ambiguity concerning their behaviour as $\omega \rightarrow \infty$. If there is a smooth transition from deep inelastic region to photo-nucleon scattering, the structure functions will be described by Regge theory as $\omega \rightarrow \infty$. However, it is not yet clear whether this is the case.

2) The fact that we were able to describe the non-diffractive part of deep inelastic scattering by two independent structure functions, depends on the assumption that currents with $(\varphi\,,\ f')$ quantum numbers do not couple to nucleons, which has experimental support from low energy hadron processes and also from Reggeon couplings. However, it might happen that $q^2 \rightarrow -\infty$ this would not be the case anymore.

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Models	Independent structure Functions	Bounds for $F^{en}/F^{ep}(\equiv r)$	Effective D/F ratio for coupling of bi-locals to nucleons (non-diffractive component)	References
1. General quark parton model	u_p $u_{\bar{p}}$ u_n $u_{\bar{n}}$ u_λ $u_{\bar{\lambda}}$	$\frac{1}{4} \leq r \leq 4$		Ref. 19)
2. Valence quark parton model with sea	$u_p = v_p + s$ $u_n = v_n + s$ $u_\lambda = u_{\bar{\lambda}} = u_{\bar{p}} = u_{\bar{n}} = s$	$\frac{1}{4} \leq r < \frac{3}{2}$	$-3 \leq D/F \leq 1$	Ref. 6)
3. Valence quark parton model of mixed symmetry	$u_p = v + w + s$ $u_n = v + s$ $u_\lambda = u_{\bar{\lambda}} = u_{\bar{p}} = u_{\bar{n}} = s$	$\frac{1}{4} \leq r \leq 1$	$-1 \leq D/F \leq 1$	Present paper
4. Symmetric valence quark parton model with sea	$u_p = 2v + s$ $u_n = v + s$ $u_\lambda = u_{\bar{\lambda}} = u_{\bar{p}} = u_{\bar{n}} = s$	$\frac{2}{3} \leq r \leq 1$	$D/F = 0$	Ref. 2)

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