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GENERAL APPROACH TO DEEP INELASTIC SCATTERING

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A B S T R A C T

Due to the preliminary indications for a possible scaling violation, it is interesting to clarify which of the parton light cone results are indeed the consequences of a more general scheme. We consider the constraints imposed by the general ideas of duality (absence of exotics in the t channel) applied to deep inelastic single particle distributions. This provides a restrictive scheme, although it allows for a larger set of diagrams than that of the parton model. However, in a particular kinematical region where the diffractive component of total deep inelastic cross-section can be neglected, all the algebraic results of the parton model are recovered by this scheme.

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1. INTRODUCTION

Some years ago, it was pointed out [1] that the principles of hadronic duality give a restrictive scheme for the total deep inelastic processes. Indeed, some of the quark parton model (QPM) results, which are of algebraic nature (e.g., bounds like $1/4 \leq (F_2^{en}/F_2^{ep})$ [2] and local sum rules), follow from the assumption of t channel (current-current channel) non-exoticity combined with the general constraints of duality. In QPM [3], t channel is non-exotic as a consequence of incoherent quark current interaction and in the light cone approach [4] this condition is fulfilled because of the algebra which is assumed on the light cone.

The purpose of this paper is to investigate along similar lines the consequences of hadronic duality for the deep inelastic single particle inclusive processes. Especially now that there exist preliminary indications for a possible scaling violation [5], it is interesting to clarify which of the parton light cone results are the consequences of a more general approach. It turns out that this leads to a more general picture than that of the quark parton model. In particular, the number of diagrams describing the process is larger than the one dictated by the parton model. This was not the case for the total cross-sections, where the general approach came out to be equivalent, in the algebraic sense, to the valence and sea description of the parton model [6].

However, in a specific kinematical range, say $x \gtrsim 0.2$, where the diffractive component of the total cross-section can be neglected, the algebraic results of the present scheme are equivalent to the ones of the parton model.

The duality argument which is extensively utilized in this paper makes it possible to understand the results also from the s channel point of view.

We discuss the similar problem in e^+e^- annihilation into hadrons. Considering the single particle inclusive decay of the virtual photon, we argue again that, e.g., the QPM result for π^0/π^c follows from the assumption of γ-γ channel non-exoticity [7]. Thus any discrepancy for π^0/π^c from the parton result ($\frac{1}{2}$) would suggest that in e^+e^- annihilation t channel non-exoticity is not satisfied and one may have to abandon this assumption.

2. TOTAL CROSS-SECTIONS AND SINGLE PARTICLE INCLUSIVE DISTRIBUTIONS

Let us shortly recapitulate the results of Refs. 1) and 6) for the total deep inelastic structure functions. The t and s channel non-exoticity allows us to express the structure functions considered as imaginary parts of the amplitude for the process

$$b+\beta \longrightarrow a+\alpha$$

as follows :

$$F^{ab}_{\alpha\beta} = (if^{abc}+d^{abc})\left[F(x)\, if_{\alpha c\beta} + D(x)\, d_{\alpha c\beta}\right](1-\delta_{co}) + \left[\tfrac{3}{2}F(x) - \tfrac{1}{2}D(x) + S(x)\right]\delta_{co}\, d_{\alpha o\beta} \,, \tag{1}$$

a and b (α and β) stand for the SU(3) quantum numbers of the currents (hadron targets) and we have separated out the non-diffractive [F(x) and D(x) corresponding to Fig. 1a] and the diffractive [S(x) corresponding to Fig. 1b]. The variable x is defined as $x=-q^2/2p\cdot q$ *). The structure functions of proton and neutron targets can be then written as

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

This expression can easily be understood in terms of the Chan-Paton factor. From Fig. 1a, it is clear that $F^{ab}_{\alpha\beta}$ can be expressed as

$$F^{ab}_{\alpha\beta} \sim \mathrm{tr}\left[\lambda_a \lambda_b \lambda_{\beta\alpha}(F,D)\right] \,,$$

where we have expressed the lower vertex by the 3x3 matrix $\lambda_{\beta\alpha}(F,D)$ defined as

$$\mathrm{tr}\left[\lambda_c \lambda_{\beta\alpha}(F,D)\right] = if_{\alpha c\beta}F + d_{\alpha c\beta}D \,.$$

Remembering that $\frac{1}{2}\mathrm{tr}(\lambda_a\lambda_b\lambda_c) = if_{abc}+d_{abc}$ and adding the contribution from the diffractive component (Fig. 1b), we get Eq. (1). The term $(\frac{3}{2}F(x)-\frac{1}{2}D(x))$ in the singlet component comes from the requirement of decoupling of "φ"-like component from the nucleons [see Ref. 6)].

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*) Although throughout the paper we write down scaling structure functions, all the results are actually independent of the scaling assumption.

Recent results on electron-nucleon and neutrino-nucleon scattering [8] give us an idea about the approximate behaviour of each component. Particularly, the diffractive component $S(x)$ seems to be different from zero in a very restricted region of x, i.e., $0 \leq x \leq 0.2$ and is small compared to the other components. This allows us to extract information about the relative importance of $F(x)$ and $D(x)$ from electron-nucleon data (at least in the region of $0.2 \leq x \leq 1$). The experimental D/F ratio is shown in Fig. 2 [9]. Note that only for $x \cong 1/3$, i.e., an equal momentum distribution among three quarks, the SU(6) value $D/F = 0$ is indicated by the data.

Let us now apply similar duality arguments to the single particle inclusive electron-nucleon scattering. Here, we have to deal with the imaginary part of the forward scattering amplitude $f^{ab}_{\alpha\beta,\sigma\tau}(x,x_F,p_\perp)$ for the process

$$b + \beta + \tau \longrightarrow a + \alpha + \sigma \quad ,$$

in terms of which the invariant cross-section can be expressed as

$$f(a \xrightarrow{\alpha} \sigma) = f^{aa}_{\alpha\alpha,\sigma\sigma}(x, x_F, p_\perp) \quad . \tag{3}$$

Here σ, τ stand for the observed hadron.

Seven dual components shown in Fig. 3, which are expected for hadronic reactions [10], contribute to the single particle inclusive scattering. In Fig. 4, we show also some of the so-called interference terms, which can be neglected in the analysis of inclusive processes based on planar duality [10]. As was mentioned before, we know from the total inclusive results that the diffractive component is very small over almost all the region of x $(x \geq 0.2)$. Therefore, we may neglect for $x \geq 0.2$ the components (5), (6) and (7) of Fig. 3, which are obviously contributing only to S (Fig. 1b). (Note that the contributions from each diagram shown in Fig. 3 are positive definite.) Furthermore, the component (2) in Fig. 3, which looks like a non-diffractive term in the three-body amplitude, contributes - in fact - only to the diffractive component of the total cross-section. To see this, we consider the energy conservation sum rule in the centre-of-mass

$$\sum_{\sigma} \int \frac{d^3p_\sigma}{2E_\sigma} E_\sigma \, f(a \xrightarrow{\alpha} \sigma) = s^{\frac{1}{2}} \sigma^{\alpha\alpha}_{tot} \quad . \tag{4}$$

It is evident from the topology *) of the diagram (2) in Fig. 3, that by summing over σ, one gets the diagram (b) of Fig. 1.

Thus we are left with the components (1), (3) and (4) of Fig. 3. This is, then, the set of graphs which through energy-momentum and charge conservation sum rules are shown to contribute to the non-diffractive component of the total cross-section, i.e., to Fig. 1a. We see, therefore, that for the particular region $x \gtrsim 0.2$, we recover the parton model graphs [11].

The component (3) of Fig. 3 in the Regge phenomenology is considered to contribute only to the target fragmentation. Here, we shall assume this to be the case and shall neglect this diagram in our arguments where we discuss only the current fragmentation region.

Thus, in the current fragmentation region, we are left with the components (1) and (4) of Fig. 3. Their contributions to the amplitude can be expressed as

$$F^{a\ell}_{\alpha\beta,\sigma\tau}(x, x_F, p_\perp) = \mathrm{tr}\left[\lambda_\tau \lambda_\ell \lambda_{\beta\alpha}(\mathcal{F},\mathcal{D}) \lambda_a \lambda_\sigma\right] + \mathrm{tr}\left[\lambda_\tau \lambda_\sigma\right] \mathrm{tr}\left[\lambda_\ell \lambda_{\beta\alpha}(\mathcal{F}',\mathcal{D}') \lambda_a\right] \quad . \tag{5}$$

The first and the second terms in Eq. (5) correspond to the components (1) and (4), respectively; $\lambda_{\beta\alpha}(\mathcal{F},\mathcal{D})$ is defined as :

$$\mathrm{tr}\left[\lambda_c \lambda_{\beta\alpha}(\mathcal{F},\mathcal{D})\right] = i f_{\alpha c\beta}\mathcal{F} + d_{\alpha c\beta}\mathcal{D} \quad , \tag{6}$$

with a similar one for $\lambda_{\beta\alpha}(\mathcal{F}',\mathcal{D}')$ and $\mathcal{F}, \mathcal{D}, \mathcal{F}'$ and $\mathcal{D}'$ are functions of x, x_F and $p_\perp$ (see footnote on p.2).

Let us consider the invariant amplitudes for π^+ and π^- production on proton and neutron targets. Their amplitudes can now be expressed as

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*) This can be shown as follows. The SU(3) structure of the component (2) of Fig. 3 can be expressed as

$$f^{a\ell}_{\alpha\beta,\sigma\tau}(2) \sim \mathrm{tr}\left[\lambda_a \lambda_\ell \lambda_\tau \lambda_{\beta\alpha}(F,D) \lambda_\sigma\right] \quad .$$

Therefore, if we sum over σ in Eq. (4), we obtain

$$\sum_\sigma \mathrm{tr}\left[\lambda_a \lambda_{\bar a} \lambda_{\bar\sigma} \lambda_{\bar\alpha\alpha}(F,D) \lambda_\sigma\right] \to \mathrm{tr}(\lambda_a \lambda_{\bar a})\,\mathrm{tr}\left[\lambda_{\bar\alpha\alpha}(F,D)\right] \quad .$$

$$
\begin{aligned}
f(\gamma \xrightarrow{p} \pi^+) &= 4(2\mathcal{F}) + 9\mathcal{F}' - \mathcal{D}' \quad ,\\
f(\gamma \xrightarrow{p} \pi^-) &= \mathcal{F} - \mathcal{D} + 9\mathcal{F}' - \mathcal{D}' \quad ,\\
f(\gamma \xrightarrow{n} \pi^+) &= 4(\mathcal{F} - \mathcal{D}) + 6\mathcal{F}' - 4\mathcal{D}' \quad ,\\
f(\gamma \xrightarrow{n} \pi^-) &= 2\mathcal{F} + 6\mathcal{F}' - 4\mathcal{D}' \quad .
\end{aligned} \tag{7}
$$

Analogous expressions can be written down for the neutrino reactions in terms of the same functions $\mathcal{F}, \mathcal{D}, \mathcal{F}'$ and $\mathcal{D}'$. This implies that all the neutrino reactions can be expressed in terms of the four processes of Eq. (7). The corresponding sum rules are exactly the ones previously derived in the parton model [11].

The positivity of imaginary parts of the amplitudes for each SU(3) decomposition in the missing mass channel (current nucleon hadron channel) implies the following inequalities for the $\mathcal{F}$, $\mathcal{D}$ and $\mathcal{F}'$, $\mathcal{D}'$:

$$
\begin{aligned}
3\mathcal{F} + \mathcal{D} &\geq 0 \quad ,\\
\mathcal{F} - \mathcal{D} &\geq 0
\end{aligned} \tag{8}
$$

and

$$
\begin{aligned}
3\mathcal{F}' + \mathcal{D}' &\geq 0 \quad ,\\
\mathcal{F}' - \mathcal{D}' &\geq 0 \quad .
\end{aligned} \tag{9}
$$

The positivity relations (8) and (9) now can give all the standard bounds of the dual (valence + sea) quark parton model [11], as for instance

$$
0 \leq \frac{f(\gamma \xrightarrow{p} \pi^-)}{f(\gamma \xrightarrow{p} \pi^+)} \leq 1
$$

and

$$
\frac{1}{4} \leq \frac{f(\gamma \xrightarrow{n} \pi^-)}{f(\gamma \xrightarrow{p} \pi^+)} \leq \frac{3}{2} \quad . \tag{10}
$$

For a more complete list of such bounds, see Ref. 11).

We know from the arguments on the total inclusive cross-sections that duality correlates the D/F ratio in the t channel to the relative importance of different resonances in the s channel [12]. Namely, we can write

$$\frac{\underset{\sim}{8} - \underset{\sim\sim}{10}}{\underset{\sim}{1} - \underset{\sim}{8}} = \frac{3(F-D)}{3F+D} \qquad (11)$$

where $\underset{\sim}{8}-\underset{\sim\sim}{10}$ $(\underset{\sim}{1}-\underset{\sim}{8})$ implies the contribution from the exchange degenerate baryon trajectories, consisting of octets and decuplets (singlets and octets) which are identified actually with $\frac{3}{2}^+, \frac{5}{2}^-, \frac{7}{2}^+, \ldots$ $(\frac{1}{2}^+, \frac{3}{2}^-, \frac{5}{2}^+, \ldots)$, i.e., β–δ $(\alpha$–$\gamma)$ sequence of resonances [13]. Particularly, as $x \to 1$ we have $D/F \to 1$ and thus the contributions from the $\underset{\sim}{8}-\underset{\sim\sim}{10}$ series should die out in this limit.

As $x \to 1$ in the total cross-section, the series of $\underset{\sim}{8}-\underset{\sim\sim}{10}$ resonances in γ–N channel vanish. Through inclusive sum rule, then, one can conclude that each cross-section with $\underset{\sim}{8}-\underset{\sim\sim}{10}$ resonances in the γ–N channel vanishes for any produced hadron h, i.e., one has

$$\sigma^{h}_{\gamma N\{8-10\}} \xrightarrow[\text{as } x \to 1]{} 0 \qquad . \qquad (12)$$

Let us emphasize that the conclusion (12) is model independent and, in particular, it is valid for any kinematical region of the observed hadron *).

Furthermore, one has

$$\frac{\mathcal{D}}{\mathcal{F}} \, , \, \frac{\mathcal{D}'}{\mathcal{F}'} \xrightarrow[\text{as } x \to 1]{} 1 \qquad (13)$$

which imply, for instance, that

$$\frac{f(\gamma \xrightarrow{n} \pi^-)}{f(\gamma \xrightarrow{p} \pi^+)} = \frac{f(\gamma \xrightarrow{n} \pi^+)}{f(\gamma \xrightarrow{p} \pi^-)} = \frac{1}{4} \qquad . \qquad (14)$$

$$\text{as } x \to 1 \text{ independent of } x_F$$

In the deep fragmentation region $x_F \approx 1$, where one expects that the diagram (4) of Fig. 3 is negligible $(\mathcal{F}' = \mathcal{D}' = 0)$, and at $x \approx 1$ one has $f(\gamma \xrightarrow{p} \pi^-)$ or $f(\gamma \xrightarrow{n} \pi^+)$ suppressed in comparison with $f(\gamma \xrightarrow{p} \pi^+)$ or $f(\gamma \xrightarrow{n} \pi^-)$, respectively. In this case, the contributions of exchange degenerate

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*) This general argument is sufficient to derive part of the conclusions of Ref. 14), where the parton picture was used.

8–10 resonances in the missing mass (γ–N hadron) channel are suppressed. More physically, this can be understood as follows : if the missing mass channel is built of only resonances and the contribution of Δ resonances (and therefore 8–10 series) in this channel dies out, this implies that the production of π^- (π^+) is suppressed compared with π^+ (π^-) for the proton (neutron) target. When this suppression happens, the production of π^+ (π^-) off proton (neutron) target should be due to the s channel resonances belonging to the 1–8 exchange degenerate trajectory in the γ nucleon channel. This is, in fact, what has been observed by Meyer [15),*)] that the excess of π^+ over π^- is due to contributions from the region of the second and the third resonances $D_{13}(N(1520), J^P=\frac{3}{2}^-)$ and $F_{15}(N(1688), J^P=\frac{5}{2}^+)$.

Thus we can conclude that a bigger asymmetry of π^+/π^- in electroproduction compared with photoproduction off protons can be attributed first to the suppression of the Pomeron effect and second to the change of $\mathcal{D}/\mathcal{F}$ coupling to nucleon of the exchanged objects in the t channel.

So far, for the region $x \gtrsim 0.2$, we have been left with just two graphs (1) and (4) of Fig. 3, which reproduce the sum rules and inequalities of parton model for non-integrated quantities.

The difference between the present approach and the parton model is that in the latter, in addition to scaling, the extra factorization property (after integration over $p_\perp$) :

$$\begin{aligned}
\mathcal{F}(x, x_F) &= G(x_F)\, F(x) \\
\mathcal{D}(x, x_F) &= G(x_F)\, D(x) \\
\mathcal{F}'(x, x_F) &= G'(x_F)\, F(x) \\
\mathcal{D}'(x, x_F) &= G'(x_F)\, D(x)
\end{aligned} \qquad (15)$$

is suggested.

For the kinematical region $x \lesssim 0.2$ (i.e., $\omega = 1/x \gtrsim 5$), in general we have the seven graphs of Fig. 3. In the parton model, however, the graph (2) of Fig. 3 is absent due to dynamical features of parton models. Graph (2) has the opposite effect for the π^+/π^- ratio, as compared with graph (1).

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*) Our reasoning is, however, different from that of Ref. 15), where the phenomenon is considered to be an effect of π exchange in t channel.

This fact could destroy the inequalities of the parton model in the region $x \lesssim 0.2$ in the current fragmentation region. The present experimental data do not violate the quark parton model bounds. However, this does not imply the absence of a graph like (2), especially for the small q^2 region and photoproduction. While in the hadronic reactions graph (2) in the projectile fragmentation region has a considerable contribution, its effect in the deep inelastic scattering seems to be small when one compares, for instance, the π^+/π^- ratios off nucleons [16].

The contribution of graph (2) (non-parton component) of Fig. 3 for the electroproduction of π^+ and π^- off nucleons can be calculated as follows :

$$\begin{aligned}
\tilde{f}(\gamma \xrightarrow{p} \pi^+) &= 2\tilde{\mathcal{F}} ,\\
\tilde{f}(\gamma \xrightarrow{p} \pi^-) &= 4(\tilde{\mathcal{F}} - \tilde{\mathcal{D}}) ,\\
\tilde{f}(\gamma \xrightarrow{n} \pi^+) &= \tilde{\mathcal{F}} - \tilde{\mathcal{D}} ,\\
\tilde{f}(\gamma \xrightarrow{n} \pi^-) &= 4\tilde{\mathcal{F}} ,
\end{aligned} \tag{16}$$

where $\tilde{\mathcal{F}}$ and $\tilde{\mathcal{D}}$ are defined similarly to Eq. (6) as

$$\mathrm{tr}\left[\lambda_c \lambda_{\beta\alpha}(\tilde{\mathcal{F}}, \tilde{\mathcal{D}})\right] = i f_{\alpha c \beta}\tilde{\mathcal{F}} + d_{\alpha c \beta}\tilde{\mathcal{D}} \tag{17}$$

and the contribution to the amplitude being expressed as

$$\tilde{F}^{ab}_{\alpha\beta,\sigma\tau} = \mathrm{tr}\left[\lambda_b \lambda_\tau \lambda_{\beta\alpha}(\tilde{\mathcal{F}}, \tilde{\mathcal{D}}) \lambda_\sigma \lambda_a\right] . \tag{18}$$

The $\tilde{\mathcal{F}}$ and $\tilde{\mathcal{D}}$ couplings of the t channel object coupled to the baryon in graph (2) of Fig. 3 satisfy the same positivity conditions, as in Eqs. (8) and (9)

$$\begin{aligned}
3\tilde{\mathcal{F}} + \tilde{\mathcal{D}} &\geq 0 ,\\
\tilde{\mathcal{F}} - \tilde{\mathcal{D}} &\geq 0 .
\end{aligned} \tag{19}$$

3. π^o/π^c IN e^+e^- ANNIHILATION

Recent experiments on e^+e^- annihilation into hadrons may indicate a possible difficulty for the QPM. The one which we are going to discuss here is the π^o/π^c ratio. Experiment shows that a certain fraction of energy goes into neutrals and if one assumes that the average energy per particle, most of which can be considered to be pions *), is the same for charged and for neutrals, one has to conclude that

$$\frac{n_{\pi^o}}{n_{\pi^c}} > \frac{1}{2} \tag{20}$$

As is well known, QPM predicts

$$\frac{n_{\pi^o}}{n_{\pi^c}} = \frac{1}{2} \tag{21}$$

It can be easily shown that the QPM result of Eq. (21) is more generally a consequence of the t channel ($\gamma\gamma$ channel) non-exoticity, if we think of the process as a single particle inclusive annihilation. Thus, if (20) is actually the case, we are led to the conclusion that the assumption of t channel non-exoticity seems to be violated here.

From duality point of view, this implies that we have to consider not only the (st) term, which is non-exotic in both s and t channels, but also the (su) term, which is exotic in the t channel. It was, in fact, pointed out in Ref. 7) that if the (su) term is present, Eq. (21) is not valid any more and the ratio can take any value.

Let us consider the invariant cross-section for the single particle decay of the virtual photon with $I = 1$. We can decompose it according to the isospin of the missing mass channel

$$\begin{aligned} \frac{d\sigma^{\pi^\pm}}{dp^3/2E} &= \frac{1}{2} A_1 + \frac{3}{10} A_2 \quad , \\ \frac{d\sigma^{\pi^o}}{dp^3/2E} &= A_0 + \frac{2}{5} A_2 \quad . \end{aligned} \tag{22}$$

Each isospin component can in turn be expressed in terms of the contributions from (st), (su) and the sea components :

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*) Due to newly discovered ψ particles and their non-negligible radiative decay rates, the situation may be completely different than what was assumed.

$$\begin{aligned} A_0 &= (A_{st} + A_{su}) + \tfrac{1}{3} A_{Sea} \quad , \\ A_1 &= 2(A_{st} - A_{su}) + A_{Sea} \quad , \\ A_2 &= \tfrac{5}{3} A_{Sea} \end{aligned} \tag{23}$$

and π^0/π^c can be expressed as

$$\frac{\pi^0}{\pi^c} = \frac{A_{st} + A_{su} + A_{Sea}}{2(A_{st} - A_{su}) + 2 A_{Sea}} \quad . \tag{24}$$

We examine the implications of Eq. (24) by considering several extreme cases.

a) $A_{su} = 0$: this case corresponds to the QPM where the (su) term is absent because of the assumption of complete incoherence of the photon-parton interaction, and we get the well-known result of Eq. (21).

b) $A_{su} = A_{st}$: this case may be considered as another extreme of complete coherence where (st) and (su) terms cancel each other in $I = 1$ missing mass channel [Eq. (23)]. The result one gets is the lower bound :

$$\frac{\pi^0}{\pi^c} \geq \frac{1}{2}$$

If it is at all meaningful, one may try to estimate, quite roughly, the relative magnitudes of A_{st} and A_{su}. By connecting, as a first apporximation, the functions A_{st} and A_{su} to the fragmentation functions D_i^h of QPM which describes the production of hadron h from the quark i, one has

$$\begin{aligned} A_{st} + A_{Sea} &\sim D_u^{\pi^+} + D_{\bar{d}}^{\pi^+} \quad , \\ A_{Sea} &\sim D_u^{\pi^-} + D_{\bar{d}}^{\pi^-} \quad . \end{aligned} \tag{25}$$

On the other hand, the ratio of π^+/π^- (π^-/π^+) production in the neutrino-(antineutrino)-proton reactions is expressed in the parton model as

$$\left(\frac{\pi^+}{\pi^-}\right)_{\nu p} = \left(\frac{\pi^-}{\pi^+}\right)_{\bar{\nu} p} = \frac{D_u^{\pi^+} + D_{\bar{d}}^{\pi^+}}{D_u^{\pi^-} + D_{\bar{d}}^{\pi^-}} \tag{26}$$

Experimentally, $(\pi^+/\pi^-)_{\nu p} \sim 2$ to 3 which, through (25) and (26), implies $(A_{sea}/A_{st}) \sim \frac{1}{2}$ to 1. If $(A_{su}/A_{st}) = \epsilon$, a value of - say - 2/3 for π^0/π^c would give $\epsilon = 2/7$ to $3/7$.

Anyhow, the possible excess of neutral pions over charged ones implies a kind of suppression of $I = 1$ contributions in the missing mass channel, while non-exoticity of t channel requires equal contributions from $I = 1$ and $I = 0$ states in the s (missing mass) channel.

We wish to thank F. Ravndal, J. Weyers and Y. Zarmi for useful discussions.

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FIGURE CAPTIONS

Figure 1 : The two duality components for the forward Compton scattering.

Figure 2 : The behaviour of the D/F coupling of the t channel object to nucleon as a function of scaling variable x extracted from the data on F^{en}/F^{ep} [9]. When S(x) is negligible, from Eq. (2) :

$$D/F = 9\left(\frac{2}{3} - \frac{F^{en}}{F^{ep}}\right) \Big/ \left(4 - \frac{F^{en}}{F^{ep}}\right) .$$

Figure 3 : Seven topologically different (diagonal) duality components contributing to the single particle inclusive electron-nucleon scattering.

Figure 4 : Some interference components.

Figure 5 : Among the interference components of Fig. 4, the first two graphs, when summed over the observed hadron σ according to the sum rule Eq. (4), give the diagrams shown in Fig. 5 which are absent in the total cross-section. The first diagram of Fig. 5 is not a duality diagram of Harari-Freund type; it is proportional to δ_{ao}. In the second diagram the $N\bar{N}$ channel is exotic and should be absent due to the assumption of t channel non-exoticity.

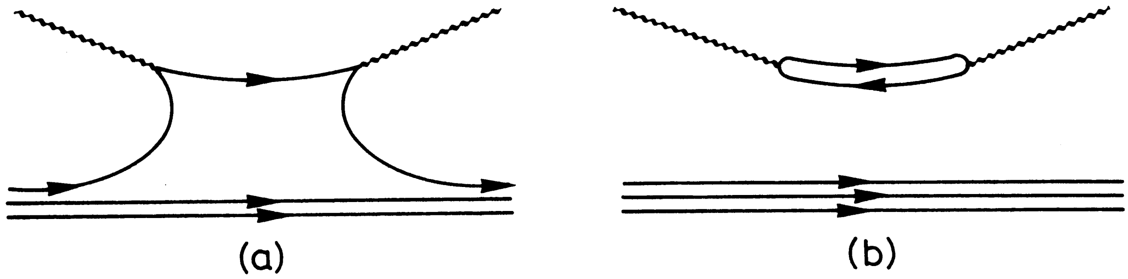

Fig. 1

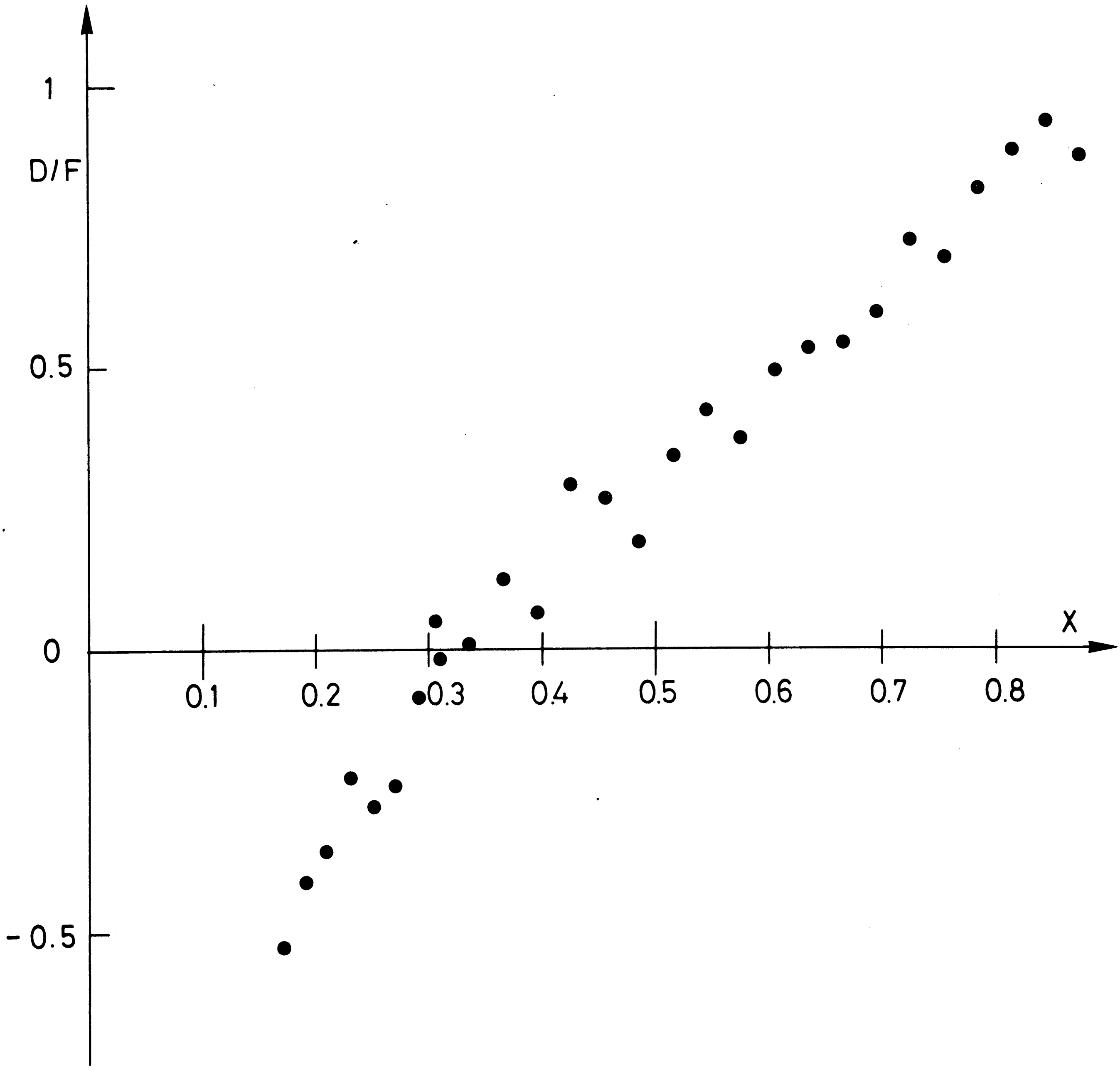

Fig. 2

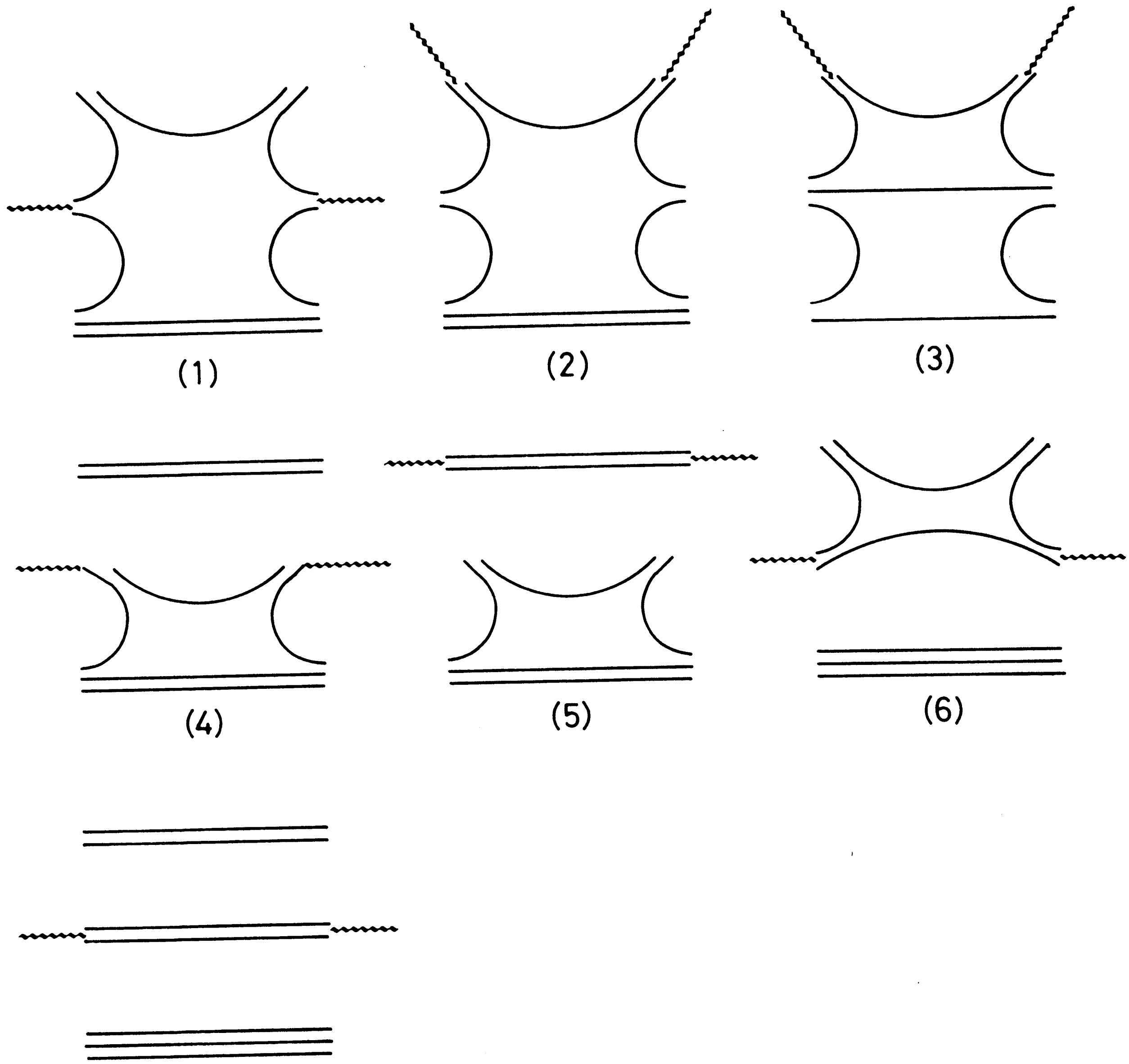

Fig. 3

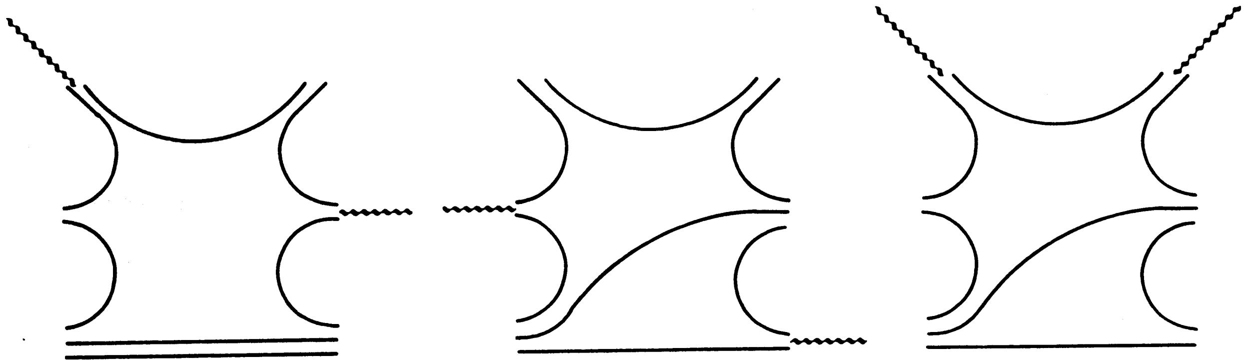

Fig. 4

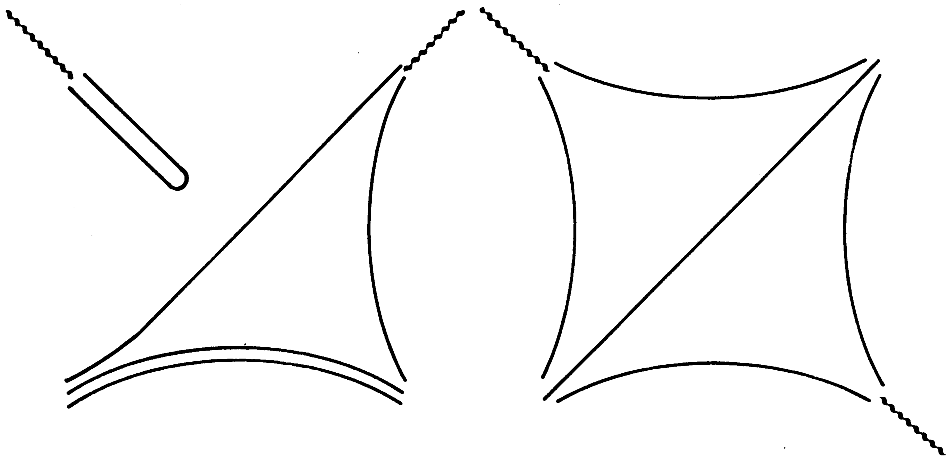

Fig. 5