CM-P00060499

Ref.TH.1911-CERN

ON THE ω DEPENDENCE OF EXCLUSIVE HADRONIC FINAL STATES
IN LEPTON - HADRON SCATTERING

J. Cleymans and F.E. Close
CERN -- Geneva

A B S T R A C T

A framework is presented for studying the ω dependence of exclusive hadronic final states in lepton-hadron scattering (ω being Bjorken's scaling variable $2M_N/Q^2$). This is used for the analysis of $K\Sigma$, $K\Lambda$, πN and $\pi\Delta$ final states.

Ref.TH.1911-CERN

22 August 1974

1. - INTRODUCTION

The rapid disappearance of the ratio ¹⁾

$$d\sigma(e^-p \rightarrow e^-K^+\Sigma^0) / d\sigma(e^-p \rightarrow e^-K^+\Lambda^0)$$

with increasing Q^2 has drawn attention again to the idea ²⁾ that in the limit $\omega \rightarrow 1$ mainly p type quarks are being projected out of the proton leaving behind an isospin zero core. When a kaon is then produced in the near forward direction, the production of accompanying $I=1$ baryons is greatly disfavoured compared to the production of $I=0$ baryons (see Fig. 1) ^{3),4)}. The same intuitive picture also predicts that the relative production of $\pi\Delta/\pi N$ final states should become small and that the πN final states should become entirely isospin $\frac{1}{2}$ in the limit $x(\equiv 1/\omega) \rightarrow 1$ implying, e.g., a value 2 for the π^+n/π^0p ratio. These qualitative predictions were first made by one of us ³⁾ and then, in the presence of data ¹⁾, independently by Nachtmann ⁴⁾.

The real surprise about the $K\Sigma/K\Lambda$ ratio is that it tends to zero so rapidly, indeed, at $\omega=4.1$ the ratio is only 0.04 ± 0.05 . This clearly raises several questions which it is the purpose of this paper to investigate.

First, within the framework of the quark-parton model description of $K\Sigma/K\Lambda$, how quickly do the different ratios $K\Sigma/K\Lambda$, $\pi\Delta/\pi N$, π^+n/π^0p , etc., approach their predicted values as Q^2 increases for fixed hadronic mass (i.e., $\omega \rightarrow 1$) ?

Second, just from the empirical behaviour of the total cross-sections what can one say about the final meson-baryon system from $SU(3)$ alone without recourse to the quark-parton model at any stage ?

Finally, what effects do t channel exchanges have on the above conclusions ?

In the quark-parton model framework our conclusions will be that the $K\Sigma/K\Lambda$ ratio is not unique in its rapid approach to zero for increasing Q^2 ; for the $\pi\Delta/\pi N$ ratio we expect a similar rapid decrease to occur. For the π^+n/π^0p ratio, on the other hand, we expect instead a very slow approach to its predicted asymptotic value of two. The main

reason for this is that in the $K\Sigma$ and $\pi\Delta$ decays there is no interference between $I=\frac{1}{2}$ and $I=\frac{3}{2}$ s channel amplitudes because of the quark content of the different states involved. For the πN channel such an interference is always present.

Given the empirical behaviour of $\sqrt{W_2^{\text{en}}(x)}/\sqrt{W_2^{\text{ep}}(x)}$ we find that in the limit $x \rightarrow 1$ the prediction $K\Sigma/KA \rightarrow 0$ is not really dependent upon the quark-parton model per se but follows also from $SU(3)$ considerations and duality arguments. The ratio $\pi\Delta/\pi N$ going to zero does, however, appear to be crucially parton model dependent and so is significant as a further test of these ideas.

We want to emphasize here that we do not expect the exclusive hadronic channels to show scaling in ω but only that they "remember" what the quark structure of the proton is for different values of ω . Implicitly we do assume that the ω and Q^2 dependences factor so that we do expect the relative abundances of various exclusive processes to show scaling in ω .

The plan of the paper is as follows. Section 2 is devoted to the description of the proton and neutron quark wave functions which is a necessary prerequisite to our subsequent analysis. Section 3 discusses quantitatively how the various ratios are expected to approach their asymptotic limits for ω approaching 1, or, for fixed missing mass, for increasing Q^2 . In Section 4, we present $SU(3)$ considerations on the meson-baryon system in the limit $\omega \rightarrow 1$. A discussion of t channel effects is presented in Section 5.

2. - NUCLEON WAVE FUNCTIONS IN THE QUARK-PARTON MODEL

As long as we "look" at a proton with virtual photons (or hypothetical W bosons) having $x(\equiv 1/\omega)$ not too close to zero (e.g., $x \gtrsim 0.2$), neutrino experiments give us some confidence that we can neglect antiquark (and, by comparison with electromagnetic interactions, strange quark) contributions. We therefore consider that only p and n type quarks are responsible for the current proton interaction in the kinematic region of interest ($0.2 \lesssim x \leq 1$). We therefore wish to form a wave function to describe a nucleon as a structure containing a p or n quark (which interacts with the current) and the remaining constituents referred to as a "core". In particular we wish to exhibit the fact that the nucleon has $I = \frac{1}{2}$. Since p and n quarks have $I = \frac{1}{2}$ the core can have $I = 0$ or 1 and so the proton state can be described :

$$|P\rangle = \cos \phi |P_\beta\rangle + \sin \phi |P_\alpha\rangle \quad (1)$$

where $|P_\beta\rangle$ is a state of quark plus $I=0$ core while $|P_\alpha\rangle$ is analogously defined for the $I=1$ core state. The relative importance of these two configurations in the nucleon is a priori arbitrary and expressed in the angle ϕ .

Since $|P_\beta\rangle$ is a proton state containing an $I=0$ core, then the accompanying quark must be p type (u) in order that the total system has proton quantum numbers. Hence we shall write

$$|P_\beta\rangle \equiv |0,0;u\rangle \quad (2)$$

in an obvious notation with $I=I_3=0$ core and u quark. The $I=1$ core can either have $I_3=1$ and be accompanied by an n type quark (d) or have $I_3=0$ implying a p type (u) quark. Combining these two possibilities with Clebsch-Gordan coefficients such that $|P_\alpha\rangle$ has $I = \frac{1}{2}$ yields

$$|P_\alpha\rangle = \sqrt{\frac{2}{3}} |1,1;d\rangle - \frac{1}{\sqrt{3}} |1,0;u\rangle \quad (3)$$

For our subsequent discussion it will be useful to develop the states $|I, I_z(\text{core}); \text{quark} \rangle$ introduced in (2) and (3), into isospin eigenstates :

$$\begin{aligned} |0,0;u\rangle &= |P_\beta\rangle \\ |1,1;d\rangle &= \frac{1}{\sqrt{3}} |\Delta^+\rangle + \sqrt{\frac{2}{3}} |P_\alpha\rangle \\ |1,0;u\rangle &= \sqrt{\frac{2}{3}} |\Delta^+\rangle - \frac{1}{\sqrt{3}} |P_\alpha\rangle \end{aligned} \quad (4)$$

where $|\Delta\rangle$ and $|P_{\beta,\alpha}\rangle$ denote states with isospin $\frac{3}{2}$ and $\frac{1}{2}$, respectively.

To reflect the fact that the current views the nucleon in different ways for different x , we allow the angle ϕ to become dependent on x . In the limit $x \rightarrow 1$ only the $|P_\beta\rangle$ state will be viewed since $5) \nu W_2^{\text{en}}(x)/\nu W_2^{\text{ep}}(x) \rightarrow 1/4$ and so $^{*)} \phi(x=1) = 0$. Taking into account the charges of the different quarks, we obtain the following state after the virtual photon ($x \equiv Q^2/2M\nu$) interacts with the proton :

$$\begin{aligned} |\gamma P\rangle &= \frac{2}{3} \cos \phi(x) |0,0;u\rangle \\ &+ \sin \phi(x) \left\{ -\frac{1}{3} \sqrt{\frac{2}{3}} |1,1;d\rangle - \frac{2}{3\sqrt{3}} |1,0;u\rangle \right\} \end{aligned} \quad (5)$$

The interaction will modify the momentum content of the state $|I, I_z(\text{core}); \text{quark} \rangle$ but not its isospin properties and only these will be relevant for our analysis. Expressed in isospin eigenstates [Eq. (4)] we have :

$$|\gamma P\rangle = \frac{2}{3} \cos \phi(x) |P_\beta\rangle - \frac{\sqrt{2}}{3} \sin \phi(x) |\Delta^+\rangle \quad (6)$$

^{*)} See, e.g., Eq. (10) below or Ref. 6) where the $\phi(x)$ notation was introduced.

An interesting feature about this state is that no $|P_\alpha\rangle$ appears. A similar procedure can be followed for the neutron wave function with the result :

$$|\pi N\rangle = -\frac{1}{3} \cos\phi(x) |N_\beta\rangle + \frac{1}{3} \sin\phi(x) \{ |N_\alpha\rangle - \sqrt{2} |\Delta^+\rangle \} \quad (7)$$

In the case of charge-changing weak currents we analogously obtain

$$|\nu P\rangle = \sqrt{\frac{2}{3}} \sin\phi(x) |\Delta^{++}\rangle \quad (8)$$

$$|\nu N\rangle = \cos\phi(x) |P_\beta\rangle + \frac{1}{3} \sin\phi(x) \{ -|P_\alpha\rangle + \sqrt{2} |\Delta^+\rangle \} \quad (9)$$

Equations (6), (7), (8) and (9) form the basis for all our subsequent discussions. We now proceed to estimate $\cos^2\phi(x)$ and $\sin^2\phi(x)$ from the behaviour of the ratio of inelastic electron-neutron to electron-proton structure functions. From Eqs. (6) and (7) we deduce ⁶⁾ :

$$\frac{F_2^{en}(x)}{F_2^{ep}(x)} = \frac{\cos^2\phi(x) + 3 \sin^2\phi(x)}{4 \cos^2\phi(x) + 2 \sin^2\phi(x)} \quad (10)$$

valid for $0.2 \lesssim x \lesssim 1.0$. From (10) we can readily extract $\cos^2\phi(x)$ and $\sin^2\phi(x)$. These are shown in Fig. 2. Notice that only the squares are determined this way. In terms of the familiar $u(x)$ and $d(x)$ we have :

$$\cos^2\phi(x) = \frac{u(x) - \frac{1}{2} d(x)}{u(x) + d(x)} \quad (11a)$$

$$\sin^2\phi(x) = \frac{\frac{3}{2} d(x)}{u(x) + d(x)} \quad (11b)$$

valid as long as we can neglect antiquark and strange quark contributions.

Having thus parametrized the x dependence of the current-proton state we can now discuss the dependence of exclusive final states on x , or, equivalently, for a fixed missing hadron mass, on Q^2 . This will be done in the next section.

3. - EXCLUSIVE HADRONIC FINAL STATES

From Eqs. (6), (7), (8) and (9), we can deduce several interesting consequences for final exclusive hadronic channels. We will discuss these at increasingly specific levels.

At the first level we use only the isospin content of the final state. This allows us to treat, e.g., the π^+n/π^0p ratio in electroproduction or the π^+/π^0 ratio in neutrino interactions at low W^2 . At a second level we make use of the $SU(3)$ content of the final state. From the specific quark structure of the P_F state one deduces ⁷⁾ that it has $F=D$ when coupled to pseudoscalar mesons while the P_α state has $F=-\frac{1}{3}D$. This is independent of the spin content of the core. This allows us to treat the $K\Sigma/K\Lambda$ ratio. Finally, for the $\pi\Delta/\pi n$ ratio we need information at the $SU(6)$ level or make specific assumptions about the decay mechanism.

3.1. - Isospin content of the final state

As a specific example of direct experimental interest we will discuss the π^+n/π^0p ratio in electroproduction. Equation (6) gives us here :

$$\langle n\pi^+ | \gamma p \rangle = -\frac{2}{3} \sqrt{\frac{2}{3}} \cos\phi(x) N_\beta - \frac{\sqrt{2}}{3\sqrt{3}} \sin\phi(x) \Delta \quad (12a)$$

$$\langle p\pi^0 | \gamma p \rangle = +\frac{2}{3} \frac{1}{\sqrt{3}} \cos\phi(x) N_\beta - \frac{2}{3\sqrt{3}} \sin\phi(x) \Delta \quad (12b)$$

N_β and Δ are now reduced matrix elements independent of x . Equations (12a) and (12b) will be most reliable when the pion is projected forward in the direction of the momentum of the current ($m_\pi^2 < |t| \lesssim 1 \text{ GeV}^2$). The x dependence of the π^+n and π^0p is thus determined completely by $\cos\phi(x)$ and $\sin\phi(x)$. As we have seen in the previous section, the squares of these functions can be extracted from deep inelastic electron-proton and electron-neutron scattering. The sign between $\cos\phi(x)$ and $\sin\phi(x)$ is thus left undetermined.

For the ratio of these cross-sections we have :

$$\begin{aligned} & \frac{d\sigma(e^-p \rightarrow e^- \pi^+ n)}{d\sigma(e^-p \rightarrow e^- \pi^0 p)} \\ &= \frac{4\cos^2\phi(x) N_\beta^2 + \sin^2\phi(x) \Delta^2 + 4\cos\phi(x) \sin\phi(x) N_\beta \Delta}{2\cos^2\phi(x) N_\beta^2 + 2\sin^2\phi(x) \Delta^2 - 4\cos\phi(x) \sin\phi(x) N_\beta \Delta} \end{aligned} \quad (13)$$

This ratio is plotted in Fig. 3 for different values of the parameter Δ/N_β and for one specific choice in the relative sign of $\cos\phi(x)$ and $\sin\phi(x)$. We see that the ratio (13) is very sensitive to Δ/N_β and, in the kinematical region of interest, the approach to the asymptotic value of 2 is extremely slow. We emphasize here that Eq. (13) will be most reliable for near forward moving pions (small t or current fragmentation region), but away from the pion pole ($m_\pi^2 < |t| \lesssim 1 \text{ GeV}^2$).

3.2. - SU(3) content of final state

From Eq. (6), we obtain for the $K\Sigma$ and $K\Lambda$ final states :

$$\begin{aligned} \langle \Sigma^0 K^+ | \gamma p \rangle &= -\frac{2}{3\sqrt{3}} \sin\phi(x) \Delta \\ &\quad - \frac{2}{3} \sqrt{\frac{1}{3}} (F-D) \cos\phi(x) N_\beta \end{aligned} \quad (14)$$

$$\langle \Lambda^0 K^+ | \gamma p \rangle = \frac{2}{3} \left(-F - \frac{1}{3} D \right) \cos \phi(x) N_\beta \quad (15)$$

Because of the explicit quark content of the $|P_\beta\rangle$ state one can deduce that it couples to pseudoscalar mesons with an F/D ratio equal to one. Equations (14) and (15) then become :

$$\langle \Sigma^0 K^+ | \gamma p \rangle = -\frac{2}{3\sqrt{3}} \sin \phi(x) \Delta \quad (16)$$

$$\langle \Lambda^0 K^+ | \gamma p \rangle = -\frac{4}{9} F_\beta N_\beta \cos \phi(x) \quad (17)$$

where $F_\beta \equiv 2F$.

This time the cross-section ratio is directly proportional to a steeply falling function of x :

$$\frac{d\sigma(\bar{e}p \rightarrow \bar{e} \Sigma^0 K^+)}{d\sigma(\bar{e}p \rightarrow \bar{e} \Lambda^0 K^+)} = \frac{3\Delta^2}{4N_\beta^2 F_\beta^2} \frac{\sin^2 \phi(x)}{\cos^2 \phi(x)} \quad (18)$$

This ratio is shown in Fig. 4 for different values of $\Delta/N_\beta F_\beta$. Because the function $\tan^2 \phi(x)$ is so rapidly falling with x , the ratio (18) will also approach rapidly its asymptotic value zero. If we express $\cos^2 \phi(x)$ and $\sin^2 \phi(x)$ in terms of the electron-proton and electron-neutron structure functions through Eq. (11) we find that (18) is precisely the x dependence given by Nachtmann⁴⁾. The freedom in Δ/N_β corresponds to the freedom in $\alpha_\Sigma/\alpha_\Lambda$ of Nachtmann.

A very interesting relation is obtained when one considers the $\Sigma^0 K^+$ and $\Sigma^+ K^0$ final states. Since these differ only by a Clebsch-Gordan coefficient and since there is no N_β coupling because of the quark content of the different states we have :

$$\frac{d\sigma(e^-p \rightarrow e^- \Sigma^0 K^+)}{d\sigma(e^-p \rightarrow e^- \Sigma^+ K^0)} = 2 \quad (19)$$

independently of any parameter and of x (as long as $0.2 \lesssim x \leq 1$). In other words, the ΣK channel should proceed entirely through $I = \frac{3}{2}$ ^{*)}. This is a very striking result of our approach and should be valid whenever our approximations are, i.e., whenever the value of x exceeds 0.2 and the K 's are going near forward.

3.3. - SU(6) content of final state

As a last example, we examine the $\pi\Delta/\pi n$ ratio. For the $\pi\Delta$ final state, Eq. (6) gives :

$$\begin{aligned} \langle \Delta^0 \pi^+ | \gamma p \rangle &= \frac{\sqrt{2}}{3\sqrt{3}} \cos \phi(x) N'_\beta \\ &+ \frac{4}{3\sqrt{15}} \sin \phi(x) \Delta' \end{aligned} \quad (20)$$

where N'_β and Δ' are reduced matrix elements at the SU(2) level. In our case, N'_β is identically zero. This is due to the fact that the $|P_\beta\rangle$ state has a quark-core with isospin zero while the Δ^0 necessarily has a quark-core with isospin one. These two states are therefore orthogonal to each other. This means that only the term proportional to $\sin \phi(x)$ is present on the right-hand side of Eq. (20) :

$$\langle \Delta^0 \pi^+ | \gamma p \rangle = \frac{4}{3\sqrt{15}} \sin \phi(x) \Delta' \quad (21)$$

The $\pi^+ n$ final state has been considered already in Eq. (11). For the cross-section ratio we now have :

^{*)} I.e., $I = \frac{1}{2}$ channels are out of phase and mutually cancel.

$$\frac{d\sigma(e^-p \rightarrow e^- \pi^+ \Delta^0)}{d\sigma(e^-p \rightarrow e^- \pi^+ n)} = \frac{\frac{8}{15} \sin^2 \phi(x) \Delta'^2}{\frac{4}{3} \cos^2 \phi(x) N_\beta^2 + \frac{1}{3} \sin^2 \phi(x) \Delta^2 + \frac{4}{3} \cos \phi(x) \sin \phi(x) N_\beta \Delta} \quad (22)$$

Because there is no interference term between $I=\frac{1}{2}$ and $I=\frac{3}{2}$ amplitudes in the numerator, this ratio will approach rapidly its asymptotic value of zero.

4. - CONSTRAINTS FROM SU(3) ALONE

We now examine the constraints placed on the content of the final hadronic state given the empirical behaviour of the structure function ratio $\nu W_2^{\text{en}}(x)/\nu W_2^{\text{ep}}(x)$. Our approach here is a natural outgrowth of the work of Pallua and Renner⁸⁾ and does not involve any reference to quarks.

In the normalizations of the present paper, the F and D couplings of photon-nucleon to a baryon octet are :

$$\langle \gamma p | p^* \rangle \sim F + \frac{1}{3} D \quad (23a)$$

$$\langle \gamma n | n^* \rangle \sim -\frac{2}{3} D \quad (23b)$$

while for decuplet states one has :

$$\langle \gamma p | \Delta^+ \rangle = \langle \gamma n | \Delta^0 \rangle \equiv \Delta \quad (24)$$

For purposes of simplification we restrict our attention to the non-diffractive part of $\sqrt{W_2}$ as this seems to be dominant in the region of interest. The contributions from octet and decuplet baryonic states to the structure function ratio is then given by ^{*}) :

$$\frac{\sqrt{W_2}^{\text{en}}}{\sqrt{W_2}^{\text{ep}}} = \frac{\left(-\frac{2}{3}D\right)^2 + \Delta^2}{\left(F + \frac{1}{3}D\right)^2 + \Delta^2} \quad (25)$$

The behaviour of $\sqrt{W_2}^{\text{en}}(x)/\sqrt{W_2}^{\text{ep}}(x)$ is thus related to $\Delta(x)/D(x)$ and to $F(x)/D(x)$. In the limit $x \rightarrow 1$, if we believe that $\sqrt{W_2}^{\text{en}}(x)/\sqrt{W_2}^{\text{ep}}(x) \rightarrow \frac{1}{4}$, Δ/D and Δ/F go to zero and so :

$$\frac{\left(-\frac{2}{3}D\right)^2}{\left(F + \frac{1}{3}D\right)^2} = \frac{1}{4} \quad \text{for } x \rightarrow 1 \quad (26)$$

This has two solutions : $F=D$ and $F=-\frac{5}{3}$, corresponding respectively to $\sqrt{W_2}^{\text{en}}/\sqrt{W_2}^{\text{ep}} = (-\frac{1}{2})^2$ and $(+\frac{1}{2})^2$. If one makes the demand that no exotic exchanges occur in the t channel of the forward Compton amplitude then only the solution $F=D$ is allowed ^{**}). With our choice of normalization the $SU(3)$ isoscalar factors for meson-baryon final states in octets are : $N\pi : \Lambda K : N\eta : \Sigma K = F+D : -(F+\frac{1}{3}D) : F-\frac{1}{3}D : F-D$ and so as $x \rightarrow 1$ and $F \rightarrow D$ we obtain for the rates $N\pi : \Lambda K : N\eta : \Sigma K = 9 : 4 : 1 : 0$.

Hence the ΣK final state is predicted to vanish relative to ΛK even in this approach and so is not a crucial test for the quark-parton model. Note also that if the bound of $\frac{1}{4}$ is empirically attained then in this limit t channel pion exchange cannot be important since this contributes equally to $\gamma n \rightarrow \pi^- p$ and to $\gamma p \rightarrow \pi^+ n$. The $\frac{1}{4}$ ratio says that the γn and γp are "as different as they can be" and some mechanism in the s channel seems essential.

^{*}) The arguments can be straightforwardly extended to include $\overline{10}$, 27.
See Ref. 8).

^{**}) Only singlet and octet in the t channel. There is clearly a very close parallelism with the quark model here and the $-\frac{1}{2}$ is "allowed" since the d to u quark charges are in ratio $-\frac{1}{2}$ and not $+\frac{1}{2}$.

5. - DISCUSSION

Throughout this paper we have examined the processes $\gamma_N \rightarrow MB$ from an s channel point of view where the current-nucleon interaction forms some intermediate state. The x dependence of this state was determined by the empirical behaviour of the total cross-section ratio $\nu W_2^{\text{en}}(x)/\nu W_2^{\text{ep}}(x)$.

If this were the only mechanism in nature for the process $\gamma_N \rightarrow MB$ then our conclusions could be immediately confronted with data. However, things are not so simple because t and u channel exchanges will also contribute to the cross-sections and so our results will only be relevant in a region where the s channel mechanism dominates over these competitors. The kinematic region in which the model should work best is for small t ($\lesssim 1(\text{GeV}/c)^2$) so that u channel mechanisms can be ignored. However, for $|t| \lesssim m_\pi^2$ the model predictions are presumably swamped by π exchange effects (or similarly K exchange where relevant). There is some indication that this is so when $Q^2 = 0$ where the model of Ref. 9^{*}) (which is a forerunner of the present model) gave a good description of $\gamma_N \rightarrow \pi \Delta$ data for $m_\pi^2 \lesssim |t| < 1(\text{GeV}/c)^2$. This indicates that a first test of our ideas should be for $(d\sigma/dt)(\gamma_N \rightarrow MB)$ in a similar kinematic region, i.e., $m_\pi^2 \leq |t| < 1(\text{GeV}/c)^2$. As one increases Q^2 for fixed W^2 the pion pole moves away from the physical region because of the increase in the value of $|t|_{\text{min}}$ ^{**)}. Therefore, our model will become better for large Q^2 and fixed missing mass W ^{***)}. Our predictions should then become increasingly good approximations to the integrated cross-sections unless σ_L is very large in which case the elementary meson exchange could still be significant.

^{}) Our results are strictly true only for the imaginary parts of the amplitudes. For the justification for claiming that these results obtain to a good approximation for the observed cross-sections and for the neglect of diagrams where the meson is emitted before the photon is absorbed, see Ref. 9).

**^{*}) A similar argument favouring the importance of s channel processes at small values of w has been made by Bjorken and Kogut¹⁰⁾.

***^{*}) In this connection, see, e.g., the remarks of Clegg¹¹⁾ concerning the model of Ref. 9).

To recapitulate, our approach is most reliable for large Q^2 and for t in the range $m_\pi^2 \lesssim |t| < 1(\text{GeV}/c)^2$. When precise angular distributions become available it will be possible to separate σ_T from σ_L , remove the meson exchange contribution and perform more quantitative comparisons. At present it does not seem possible to go beyond these first semi-quantitative considerations.

6. - CONCLUSIONS

We have highlighted the constraints that the observed behaviour of $\sqrt{W_2^{\text{en}}(x)}/\sqrt{W_2^{\text{ep}}(x)}$ places upon various exclusive channels. In the quark-parton framework we have shown that the $K\Sigma/K\Lambda$ ratio is not unique in its rapid approach to zero for increasing Q^2 , for the $\pi\Delta/\pi N$ ratio a similar rapid decrease is expected to occur. For the π^+n/π^0p ratio, on the other hand, we expect a very slow approach to its predicted asymptotic value of two. The reason for this is that in the πN channel an interference is always present between $I=\frac{1}{2}$ and $I=\frac{3}{2}$ channels contrary to the case for the $\pi\Delta$ and $K\Sigma$ reactions.

We have shown that in the limit $\omega=1$ the vanishing of the $K\Sigma/K\Lambda$ ratio follows from considerations more general than the parton model. In the limit $\omega=1$ the quantum numbers governing the final meson-baryon state will be $I=\frac{1}{2}$ and the decay products will be from octets with $F=D$ coupling. Hence the vanishing of the $\Sigma K/\Lambda K$ ratio in the limit $\omega=1$ need not depend upon the particular features of the quark model.

A second phenomenon which could cause the vanishing of the $\Sigma K/\Lambda K$ ratio is K exchange. If σ_L gets relatively more important at large Q^2 then this would cause the $\Sigma K/\Lambda K$ ratio to die because of the smallness of the coupling constant ratio $g_{K\Sigma N}/g_{K\Lambda N}$. To remove this effect from the data requires separation of σ_L and σ_T . At present this has not been done and so one cannot yet conclude that the parton mechanism is responsible for the observed suppression.

The place where the quark-parton model does seem to have a clear prediction is the suppression of $\pi\Delta/\pi N$. We would therefore urge that measurements of $d\sigma/dt$ in the range $m_\pi^2 \lesssim |t| < 1(\text{GeV}/c)^2$ be made as a function of ω . The one unknown parameter [see Eq. (22)] can be determined at some value of ω and then a unique prediction for the ω dependence in the range $1 \leq \omega \lesssim 5$ follows.

The present work can be straightforwardly extended to neutrino-initiated processes starting from Eqs. (8) and (9) and similar remarks can be made there.

ACKNOWLEDGEMENTS

Conversations with M. Chaichian, C. Michael, O. Nachtmann and H. Rubinstein are gratefully acknowledged. One of us (F.E.C.) thanks Dr. E. Obryk for his hospitality at the Cracow Summer School where useful discussions were held with K. Berkelman, J.D. Bjorken, F. Gutbrod and R. Worden.

REFERENCES

- 1) C.J. Bebek et al. - Phys.Rev.Letters 32, 21 (1974).
- 2) R.P. Feynman - "Photon-Hadron Interactions", Benjamin, New York (1972).
- 3) F.E. Close - Nuclear Phys. B73, 410 (1974).
- 4) O. Nachtmann - Nuclear Phys. B74, 422 (1974).
- 5) A. Bodek et al. - SLAC Preprint, SLAC-PUB-1399 (1974).
- 6) F.E. Close - CERN Preprint TH. 1975 (1974) (Nuclear Phys., in press).
- 7) M. Chaichian and S. Kitakado - Nuclear Phys. B59, 285 (1973) ;
R.P. Feynman, M. Kislinger and F. Ravndal - Phys.Rev.D3, 2706 (1971).
- 8) S. Pallua and B. Renner - Phys.Letters 38B, 105 (1972).
- 9) I. Barbour and R.G. Moorhouse - Nuclear Phys. B20, 629 (1970) ;
I. Barbour, W. Malone and R.G. Moorhouse - Phys.Rev. D4, 1521 (1971).
- 10) J.D. Bjorken and J. Kogut - Phys.Rev. D8, 1341 (1973).
- 11) A.B. Clegg - Proceedings of Bonn Conference on Electron and Photon
Interactions at High Energies, North Holland Publishing
Company, Amsterdam (1974).

FIGURE CAPTIONS

- Figure 1 Current proton scattering in the Breit frame in the limit $x \rightarrow 1$
with production of a K^+ in the forward direction.
- Figure 2 Plot of the functions $\cos^2\phi(x)$ and $\sin^2\phi(x)$.
- Figure 3 Plot of Eq. (13) for different values of the parameter Δ/N_β .
Higher values of W^2 can be obtained by scaling, correspondingly,
the Q^2 axis to Q^2/W^2 .
- Figure 4 Plot of $\tan^2\phi(x)$ and of Eq. (18) with $N \equiv N_\beta F_\beta$. The experi-
mental data points are from Ref. 1).

(a) Before

(b) After

Fig 1

FIG.2

Fig 3

FIG. 4