EXCHANGE DEGENERACY AND DIP MECHANISMS IN HIGH ENERGY COLLISIONS

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I. *INTRODUCTION*

This contribution could have been entitled "What can be learnt from differential cross sections in two body reactions ?" My answer to this question is clear : "Because of the lack of any theory of strong interactions, the knowledge of differential cross sections allows one to channel the development of theoretical models about high energy interaction mechanisms".

It is indeed due to the knowledge of differential cross sections in a greater number of reactions that important progress in Regge pole phenomenology have been done. Let us recall the development of Regge pole theory.

In the first applications of Regge poles to high energy phenomenology (1960) the Pomeranchuk trajectory played a central role as it dominated all elastic reactions. At that time, Cocconi's results on elastic proton proton scattering showed a diffraction peak which shrinks as predicted by theory with an universal slope of order of 1 $(\mathrm{GeV})^{-2}$. However, the enthusiasm raised by these results soon vanished when it was found that the diffraction peak of the pion nucleon differential cross sections does not shrink. This fact shows the importance of the contributions due to secondary trajectories as ρ, ω ...It was not before

1965 that an experiment allowing to isolate the contribution of a well defined secondary trajectory was realized. The discovery of the well known dip at $t = - 0.6\ GeV^2$ in $\pi^- p \to \pi^\circ n$ - dip predicted by the presence of a nonsense wrong signature zero of ρ residues at $\alpha_\rho(t) = 0$ - shows the predictive power of Regge pole theory. In 1966, the dip at $u = - 0.2\ GeV^2$ in the backward $\pi^+ p$ scattering also contributed to quick development of Regge poles which then became a working tool for phenomenologists.

About the same time, were found forward peaks in reactions dominated by pion-exchange (pn charge exchange, π^+ photoproduction...) instead of forward dips predicted by evasive Regge poles. These data caused excitement and led, during one year, to the conspiracy phenomena. Fortunately, the results for $\pi^+ p \to \rho\Delta^{++}$ put an end to unphysical complications of conspiracy - i.e. trajectories on which no particle had be seen - and clearly showed the only way to reconcile these different results as well as those for polarization in $\pi^- p \to \pi^\circ n$ was to introduce Regge cuts.

Lastly, due to duality, and consequently to exchange degeneracy, Reggeology has been greatly simplified and it can be said that when Regge cut effects can be neglected, Regge model predictions are clear and unambiguous in a large number of reactions. As we can see later, these predictions agree qualitatively with all experimental data. Before comparing theoretical predictions and experimental data in detail, we will try to answer the following question :

"In which case can a small contribution of Regge cuts be expected ?"

This would allow us to choose the reactions in which we can neglect the Regge cuts, and give a discussion on qualitative aspects of high energy experimental data in relation with the conventional Regge pole theory.

II. *SOME QUALITATIVE FEATURES OF REGGE CUTS*

It is well known that in the angular momentum plane, if there are poles, there are also cuts. Because of the lack of any quantitative theory of cuts, the only reasonable attitude is to try to single out the qualitative features of cuts.

Let us take a simple example : the pion nucleon charge exchange scattering. There are two helicity amplitudes : non helicity flip amplitude f_o and helicity flip amplitude f_1. Now, what could we reasonably say about the relative importance of cuts in these two amplitudes.

When elementary particles are exchanged, the Feynman diagrams are showed in Fig. 1. In Regge pole language, the rescattering diagram is improperly called Regge cuts. As in the Feynman diagrams, it is calculated by taking the convolution of two amplitudes. The first one is the ρ exchange and the second the E exchange. In conventional theory of Regge cuts, the E amplitude is dominated by the elastic amplitude which has a sharp forward peak and which is supposed to be helicity conserving.

a) For the non helicity flip amplitude f_o, with a forward peak the convolution gives a term in $s^{\alpha}/\text{Log } s$

b) For the helicity flip amplitude f_1, which should vanish in the forward direction because of the angular momentum conservation, the convolution gives a smaller result which is easily understood by looking at Fig. 2 and 3. In this case, the f_1 f_E product is always small, since f_1 is small in the forward direction where f_E is important and far of $t = 0$, f_E decreases so rapidly that the f_1 f_E product remains small. Indeed, calculation gives a term in $s^{\alpha}/(\log s)^2$.

This result "The effect of the cut is smaller in the amplitude with helicity flip than in the non helicity flip one" is the only one common to a large number of Regge cut models, the absorption model[(1)] as well as the eikonal[(2)], the SCRAM[(3)] or the Carlitz and Kisslinger[(4)] one.

It is an essential result for the qualitative understanding of high energy experimental data, and we claim that we can give a qualitative interpretation of these data free from any numerical calculation only if the reactions are dominated by flip helicity amplitudes, i.e. where small cut effects are expected. We will see later on that this attitude is justified by experimental data and that

a) in reactions of the type $\pi^+ p \to K^+ \Sigma^+$ and the crossed $s \leftrightarrow u$ reaction $K^- p \to \pi^- \Sigma^+$ where non helicity flip amplitude dominates,

b) in reactions where the cut plays a dominant part, such as polarization in $\pi^- p \to \pi^\circ n$,

we meet with a number of difficulties, and qualitative interpretation without referring to numerical computations proves to be very difficult.

In the following, we concentrate on the 2 points that raised the greatest interest during the last two years, which are :

1. Exchange degeneracy
2. Dip mechanism in differential cross sections in relation with high energy models.

III. *EXCHANGE DEGENERACY*

The notion of exchange degeneracy is due first to Arnold in 1965 but it is only after Veneziano model (1968) and Harari-Rosner (1969) duality diagrams that exchange degeneracy became the leading idea of high energy strong interactions.

1. *Generalities*

a) Freund-Harari Conjoncture [5]

The amplitude of a process may be split as the sum of two contributions :

$$\text{s channel} \; : \; A = A_{\text{Background}} + A_{\text{Resonances}}$$

$$\text{t channel} \; : \; A = A_{\text{Pomeron}} + A_{\text{Regge}}$$

A_{Pomeron} is dual to $A_{\text{Background}}$

A_{Regge} is dual to $A_{\text{Resonances}}$

If we add the hypothesis of the saturation of the imaginary part of the amplitude by resonances, we come to the following consequence : if there is no resonance in the direct channel, then the imaginary part of Regge pole amplitude must be zero. For example, the imaginary part of the amplitude of $K^+n \to K^\circ p$ is zero as there is no K^+ nucleon resonance.

b) Duality diagrams [6]

If we extend the same notions to the quark model we get the duality diagrams. For instance, let us consider the $K^+n \to K^\circ p$ scattering and express their contents in quarks (Fig. 4). We see that we have a quark-quark scattering as an intermediate state in the s-channel, then no resonant state can be formed. The amplitude is therefore real. In this case, the duality diagram is called illegal.

These last results are contained already in the Freund Harari conjecture but duality diagrams also give results for non exotic channel such as $K^-p \to \pi^- \Sigma^+$ (Fig. 5). There is no resonant state with two quarks (λ, n) which leads to a $K^-p \to \pi^- \Sigma^+$ real amplitude although there exist resonances in s-channel. We will see later that the s-u crossed amplitude ($\pi^+p \to K^+ \Sigma^+$) has a rotating phase : $\exp(-i\pi\alpha)$.

Another possible way is to use duality and factorization

. The trajectories and the residues of K^* and K^{**} must be exchanged degenerate

- in $\pi^+ K^+ \to \pi^+ K^+$
- and in $p\, \Sigma^+ \to p\, \Sigma^+$

. By factorization we obtain exchange degeneracy for $\pi^+ p \to K^+ \Sigma^+$ and $K^- p \to \pi^- \Sigma^+$ but the factorization does not give the signs of the residues, i.e. which amplitude must be real and which has a rotating phase. By SU_3 ($\to$ duality diagrams) the sign ambiguity due to factorization is removed.

c) Strong degeneracy and zero mechanism

In the case of $K^+ n \to K^\circ p$, we have exchange degeneracy of ρ and A_2 in the t channel.

$$f\ (K^+ n \to K^\circ p) = \gamma_\rho \frac{(1 - e^{-i\pi\alpha_\rho})}{\sin \pi\alpha_\rho} s^{\alpha_\rho} + \gamma_{A_2} \frac{(1 - e^{-i\pi\alpha_{A_2}})}{\sin \pi\alpha_{A_2}} s^{\alpha_{A_2}}$$

In order that the imaginary part vanishes for any s and t, we must have

$$\alpha_\rho = \alpha_{A_2} = \alpha$$

$$\gamma_\rho = \gamma_{A_2} = \gamma$$

and that is what is called strong exchange degeneracy which is valid for any amplitude. Thus

$$f\ (K^+ n \to K^\circ p) = \frac{2\gamma}{\sin \pi\alpha} s^\alpha$$

In order to kill the ghost at $\alpha = 0, -1, \ldots$ γ must be proportional to α, $\alpha + 1$, ... We then find again the ghost-killing mechanism proposed by Gell Mann several years before. In the following, we call residue the ratio $\gamma/\sin \pi\alpha$ which is assumed to be smooth.

2. *A Simple case : ρ and A_2 exchange degeneracy*

Let us consider the meson baryon charge exchange reactions. According to exchange degeneracy we have :

$$f\,(\pi^- p \to \pi^\circ n) = a_1\, G\,(1 - e^{-i\pi\alpha})\, s^\alpha$$

$$f\,(\pi^- p \to \eta n) = a_2\, G\,(1 + e^{-i\pi\alpha})\, s^\alpha$$

$$f\,(K^+ n \to K^\circ p) = 2\, a_3\, G\, s^\alpha$$

$$f\,(K^- p \to \overline{K}^\circ n) = 2\, a_3\, G\, e^{-i\pi\alpha}\, s^\alpha$$

Since differential cross sections of $\pi^- p \to \pi^\circ n$ show a pronounced forward dip, helicity flip amplitude must dominate - It is precisely what vector dominance tells us. Indeed, if we use the $\gamma \leftrightarrow \rho$ analogy, the ratio of ρNN couplings is equal to that of charge and anomalous magnetic moment of the nucleon in the isovector state.

$$\frac{g^\rho_{+-}}{g^\rho_{++}} = \chi_\rho - \chi_N = 3.7$$

Through exchange degeneracy, the A_2NN coupling is also essentially helicity flip and the dominating amplitude in these four reactions is the helicity flip amplitude. Cut effects are thus expected to be small in this set of reactions and the qualitative predictions of Regge poles and exchange degeneracy verified by experiment.

What are the predictions that can be obtained from these formulas ? :

a) The differential cross sections of K nucleon charge exchange must be equal. Above 5 GeV (in fact at 5.5 and 12 GeV)[7] experimental results confirm this prediction (Figs. 6 and 7). Let us notice that this equality can be obtained from weak exchange degeneracy only i.e. equality of trajectories $\alpha_\rho = \alpha_{A_2}$.

b) Since by exchange degeneracy, helicity flip amplitude dominates in these four reactions, a forward dip is expected in $\pi^- p \to \eta n$ as well as in K nucleon charge exchange reactions. Experimental results, though rather scarce in the forward direction, show nevertheless a qualitative dip (Fig. 8).

c) Dip structure in differential cross section is clearly displayed. No dip is expected for K nucleon charge exchange, a dip at $\alpha = 0$ (i.e. $t \simeq -0.6\ \mathrm{GeV}^2$) for $\pi^- p \to \pi^\circ n$ and a dip at $\alpha = -1$ (i.e. $t \simeq -1.6\ \mathrm{GeV}^2$) for $\pi^- p \to \eta n$. If SU_3 is now assumed, the coefficients a_1, a_2, a_3 are respectively equal to $\sqrt{2}$, $\sqrt{\frac{2}{3}}$, 1. In Fig. 9 we show Sonderegger's compilation at 5.9 GeV. The curves are from Regge pole model with strong exchange degeneracy and SU_3. The agreement seems to be striking for a prediction almost without parameters.[8]

d) The same arguments may be used for Δ production and same results obtained. Moreover, we can give some more predictions :

<u>d.1</u> : The ratio of differential cross sections with or without Δ production is the same in these reaction

$$R = \frac{\sigma\ (\pi\Delta)}{\sigma\ (\pi N)} = \frac{\sigma\ (\eta\Delta)}{\sigma\ (\eta N)} = \frac{\sigma\ (K\Delta)}{\sigma\ (KN)}$$

In this ratio, the coupling constants at the bosonic vertex, the squares of the signature factors disappeared, only the sum of the squares of the residues, which is the same by exchange degeneracy in these four reactions, remains. Using the experimental data at 4-5 GeV[9] we obtain the results showed in Fig. 10. The agreement is quite good.

d.2 : The Δ density matrix elements are the same in these four reactions. Fig. 11, 12, 13 show the transfer momentum dependence of density matrix elements in 3 reactions. Fig. 14 shows their energy dependence. The curves $\rho_{3,3} = \frac{3}{8}$, Re $\rho_{3,-1} = \frac{\sqrt{3}}{8}$, Re $\rho_{3,1} = 0$, come from the magnetic dipole coupling hypothesis for ρNN coupling. As is verified, experimental results agree very well with these predictions.[10]

3. *K^* and K^{**} exchange degeneracy*

3.a Meson baryon scattering

We have seen that duality diagrams show that the amplitudes $K^- p \to \pi^- \Sigma^+$ and $K^- n \to \pi^- \Lambda$ are real.

$$f\ (K^- p \to \pi^- \Sigma^+) = g\ s^{\alpha}$$

$$f\ (\pi^+ p \to K^+ \Sigma^+) = g\ e^{-i\pi\alpha}\ s^{\alpha}$$

The first prediction is equality of differential cross sections for s $\to$ u crossed reactions. Comparison with experiments shows that it is not verified. More precisely, induced K cross sections have a clear propensity to be more important than the π ones.[11]

The second prediction is differential cross section without structure. But very clear dip structure at $t = -0.4$ GeV^2 exists in $\pi^+ p \to K^+ \Sigma^+$ at least to 5-7 GeV (Fig. 15).[12]

Why thus does exchange degeneracy which works so well with $\rho - A_2$ exchange seem to be questioned in $K^* K^{**}$ exchange ?

We can find the answer in examinating forward differential cross sections. They all present a forward peak which implies a dominance of non flip helicity amplitude. According to what was said in Section II the cut contribution may be important and thus change the qualitative features of Regge pole exchange degeneracy.

3.b K^* photoproduction

A. CAPELLA and myself (13) have proposed the use of duality diagrams in K^+ meson photoproduction. Indeed, by vector meson dominance model, the photon is connected with the vector mesons ρ, ω, ϕ.

If we consider the duality diagrams, we find for ρ, ω and for ϕ opposite results. The duality diagrams corresponding to $\phi p \to K^+ \Sigma^\circ$ and $K^- p \to (\rho,\omega) \Sigma^\circ$ are illegal diagrams and the corresponding amplitudes are real (Fig. 16).

Thus if the $\lambda\bar{\lambda}$ component of the photon (i.e. ϕ) dominates, the K^+ photoproduction amplitude is real whereas it has a rotating phase if the non strange (ρ,ω) components dominate. In what follows, we will find it is the γ-ρ component which is dominating K^+ photoproduction.

We can write the photoproduction amplitude as :

$$A\ (\gamma p \to K^+ \Sigma^\circ) = \sum_{V=\rho,\omega,\phi} g_{\gamma V}\ A\ (Vp \to K^+ \Sigma^\circ)$$

$g^2_{\gamma\rho} : g^2_{\gamma\omega} : g^2_{\gamma\phi}$ are proportional to $9 : 1 : 2$ from SU(6) and approximately verified by the results from Orsay storage rings

On the other hand, we have at 3 GeV[14]

$$\sigma\,(K^- p \to \rho\,\Sigma) \;\simeq\; \sigma\,(K^- p \to \omega\,\Sigma) \;>\; 2\sigma\,(K^- p \to \phi\,\Sigma)$$

thus we see that the contribution to the photoproduction cross sections of the ρ component is approximately 9 times that of the ϕ component It is then justified to neglect the photon-ϕ component and we have then a rotating phase for the photoproduction amplitude.

If we neglect the contribution of K trajectory the amplitude is proportional to $\exp\,(-\,i\pi\alpha_{K^*-K^{**}})$ and the cross section has no structure at $\alpha_{K^*} = 0$. We see from Fig. 17 and 18 that essentially the experimental cross-sections do not show any structure and that a fit with weak cuts agrees well with the experimental data.[13]

The following question immediately arises :

Why does the exchange degeneracy $K^* - K^{**}$ which is disastrous in $\pi^+ p \to K^+\,\Sigma^+$ (and $K^- p \to \pi^-\,\Sigma^+$) works well here ?

The answer comes from the factorization of the residues of $K^* - K^{**}$. We have seen that the non helicity flip amplitude dominates in $\pi^+ p \to K^+\,\Sigma^+$ i.e. the coupling K^* NΣ is non helicity flip. As the helicity change is necessarily equal to 1 at the $\gamma\,K^*K$ vertex ($\lambda_\gamma = \pm 1$), the photoproduction of K is dominated by single helicity flip amplitude. Thus factorization predicts a kinematical forward dip which is effectively observed experimentally. As a consequence of the dominance of the helicity flip amplitude, the cuts are small and we expect from this, that the exchange degeneracy will be approximately verified.

Is this exchange degeneracy verified if we consider low energy data and finite energy sum rules ? In a communication to this Rencontre,

F. RENARD[15] has shown that it is so and that the dominant amplitude has a large imaginary part contrary to what is observed in a $K^-p \to K^o n$ at 180°
In this last reaction, F.E.S.R. gives an almost real amplitude.[16]

4. *Polarization*

So far we have not discussed the polarization data because it involves the interference term between the flip and non flip helicity amplitudes. In the case of meson baryon scattering with charge or hypercharge exchange, due to exchange degeneracy, the Regge pole contributions have the same phase in the two amplitudes and thus give zero polarization. The only way to get a polarization is then by a pole-cut interference and this depends strongly on the detailed structure of the cut model.

This explains why, at present, one does not understand the main features of the polarization in these reactions (or rather one does not understand at all : see Guisan's lecture at this meeting). Of course, a number of people have obtained a "good" description of the polarization in $\pi^-p \to \pi^o n$ and in hypercharge exchange reactions Krzywicki and myself[17] have got a good prediction of the polarization in one reaction when we use as input the experimental data for the polarization of the $s \leftrightarrow u$ crossed reaction. In spite of this, I believe that these results are strongly model dependent.

Where then, should we search for reactions in which the polarization can be reasonably predicted by exchange degeneracy ?

The answer is : among the elastic reactions.

In fact, in the elastic reactions, the helicity non flip amplitude is dominated by vacuum or Pomeron exchange. The Regge pole contributions can, in the first approximation, be neglected in this amplitude.

The usual hypothesis (verified by experiments, for instance, measurements of A and R in pion nucleon scattering), is that the Pomeron does not couple to helicity flip amplitude which then has contributions from Regge pole only. As the cut is small in the latter amplitude and as the structure of Pomeron contribution is smooth (see the high energy elastic differential cross sections at small t), we would expect to be able to predict the qualitative behaviour of the polarizations.

a) Polarization in K^+p and K^-p elastic scattering

Exchange degeneracy of ω, ρ, f_o and A_2 gives :

		K^+p	K^-p
f_{++}	$\approx$	$i\,P\,s$	$i\,P\,s$
f_{+-}	$\approx$	$\sqrt{-t}\,G\,s^{\alpha}$	$\sqrt{-t}\,G\,e^{-i\pi\alpha}$
Polarization	$\approx$	$\sqrt{-t}\,P\,G$	$\sqrt{-t}\,P\,G\,\cos\pi\alpha$

We see that the polarization in K^+p has a constant sign whereas for K^-p the polarization is oscillating. In Fig. 19 we show the data obtained by Anderson et al[18] at 2.74 GeV/c. The agreement is perfect :

$$\text{at} \quad t = -0.5\ \text{GeV}^2 \quad P(K^+p) = P(K^-p)$$
$$t = -1.5\ \text{GeV}^2 \quad P(K^+p) = -P(K^-p)$$

b) Polarization of pp and $\bar{p}p$

The contribution of π being excepted, by the same arguments as before we obtain the same predictions for the behaviour of the polarization. For $\bar{p}p$ there are few experimental data, but for pp there is no structure, at least for t not too large, in accordance with the exchange degeneracy predictions.

c) Polarization of π^+p and π^-p

Here the exchange degeneracy does not enter but for completness, I would remark that the mirror symmetric picture[18] of the polarizations with a double zero at $t \simeq -0.5$ GeV^2 (Fig. 20) confirms our conjecture that the cuts have little influence on the helicity flip amplitude.

Thus concluding our study on exchange degeneracy, we can say that experimental data seems to support the hypothesis of Regge pole exchange degeneracy and that Regge cuts can violate this exchange degeneracy in the helicity non flip amplitude. Then, if there is a duality, it is a duality of Resonances $\rightarrow$ Regge poles and not one of Resonances $\rightarrow$ (Regge poles + Regge cuts).

We will examine now, in this search of reactions in which the cuts are expected to be small, the dip structure of differential cross sections.

IV. *STRUCTURE MINIMA IN THE DIFFERENTIAL CROSS SECTIONS AND THE TWO CLASSES OF HIGH ENERGY MODELS*

Some years after the spectacular success of Regge pole theory as dips in $\pi^-p \rightarrow \pi^\circ n$ and in $\pi^+p \rightarrow p\pi^+$ backward scattering, people started to be excited by the erratic behaviour of some differential cross sections. Indeed, if $\pi^-p \rightarrow \pi^\circ n$ and $\pi^+p \rightarrow \pi^\circ\Delta^{++}$ show a dip at $t = -0.5$ GeV^2 owing to the exchange of ρ, why does observe a dip at $t = -0.5$ GeV^2 in $\pi^+n \rightarrow \omega p$ and $\pi^+p \rightarrow \omega\Delta^{++}$. And yet we expect that ρ is also exchanged here. The same remark also applies to the difference.

$$\sigma\ (\gamma_\perp\ p \rightarrow \pi^+ n) - \sigma\ (\gamma_\perp n \rightarrow \pi p)$$

which is proportional to the interference $\rho . A_2$. This interference should, in principle, be zero at $t = -0.5$ GeV^2, due to $\alpha_\rho = 0$, but no change of sign of experimental data is observed.

In what concerns ω-exchange, Contogouris, Lubatti and myself[19] have isolated its contribution in $\pi N \to \rho N$. This contribution has a minimum at $t = - 0.5$ GeV^2 as is expected in the good old Regge pole theory. This minimum is also observed in the photoproduction of π° where, in principle ω and ρ are exchanged but contrary to this, there is no minimum in η photoproduction where the same trajectories are expected to be exchanged.

How can we solve this puzzle ?

Two global explanations have been proposed the two last years :

The first one, as reported by Harari[20] at the Liverpool Conference, is based on a geometrical description of the amplitude, and emerges from the works of Dar[21] and the Michigan[22] models. (SCRAM). Essentially, if the single flip helicity (difference of the helicity changes at the two vertices $\Delta h = 1$) dominates, a dip is expected and if $\Delta h = 0$ and $\Delta h = 2$ amplitudes dominate, there is no dip. One of the weak points of SCRAM is the lack of exchange degeneracy and the loss of informations coming from duality. Consequently, many more parameters are needed in this last model.

The second one[23], as I have proposed at the Vth Moriond meeting, used the conventional Regge pole theory and is motived by the two following observations :

a) Experimentally, both the energy dependence of the differential cross sections as well as the large value of the density matrix elements ρ^s_{oo} in the s channel helicity system for the reaction $\pi^+ n \to \omega p$[24] and $\pi^+ p \to \omega\Delta^{++}$[25], show that an important unatural parity contribution is needed. This latter contribution is expected to be due to B exchange mainly because it is the only unatural parity meson which couples strongly to $\pi\omega$. Let us note that B decay rate to $\omega\pi$ is almost 100 %, then it is natural to expect a large contribution of B exchange in ω production. The large value of ρ^s_{oo} show clearly that, in any model, (for example, in the geometrical models), one must introduce a B contribution.

b) Theoretically, for evasive trajectories, all the Regge pole contributions to these reactions vanish at $t = 0$. As showed in Section II the cut contributions are expected to be small and the main qualitative features must be those of the conventional Regge pole theory.

In Ref.[23] we show that ρ, ω and B exchanges plus small cuts can explain the dip structure of the reactions of the Harari's list. We refer the reader to the original papers[20, 21, 22, 23] on these two classes of models for more details. Let us now make some remarks before discussing the tests of these two classes of models :

a) These two classes of models are usually differenciated in strong cut or weak cut models. However, for some time, phenomenologists have enhanced cut contribution by a factor λ varying between 1 and 1.5 or even 2. Thus the adequate distinction is that in the Regge pole model we have the nonsense wrong signature zeros (N.W.S.Z.) in the amplitudes whereas in the geometrical model, pole terms do not have them.

One example would enlighten this distinction. In $\pi^- p \to \pi^\circ n$ scattering where helicity flip amplitude dominates, even if the cut contribution is multiplied by 2, the dip position due to N.W.S.Z. is very slightly modified.

What is important is the presence or absence of N.W.S.Z. and not the strenght of the cut because a variation of λ between 1 to 2 does not change the qualitative features of the helicity flip amplitude in conventional Regge pole theory with N.W.S.Z.

b) The Dar model as well as SCRAM one are until now applied only to inelastic reactions. Recently, Harari[26] added a phase to the non Pomeron contributions in the helicity flip amplitude (which is equivalent to add the signature factor) in order to obtain the mirror symmetry for π^+p and π^-p polarizations. It seems to me quite unatural to make this assumption only for the helicity flip amplitude and if we extended this assumption to the helicity non flip amplitude, the polarization in $\pi^-p \to \pi^\circ n$ would be zero. On the other hand, it is not clear why $\alpha(t) = 0$ and $J_1(R\sqrt{-t}) = 0$ must occur exactly at the same value of t. A little difference for the t values for which $\alpha(t)$ and $J_1(R\sqrt{-t})$ vanish would give large oscillations in the corresponding amplitudes.

V. *SOME DECISIVE TESTS OF THE TWO CLASSES OF MODELS*

Berger and Fox[27] have proposed some tests to decide among these two high energy classes of models. In particular, they proposed to measure :

a) A and R parameters in meson-nucleon scattering

$$A = \left[|f_{++}|^2 - |f_{+-}|^2\right] \Big/ \left[|f_{++}|^2 + |f_{+-}|^2\right]$$

and

$$R = 2\,\mathrm{Re}\,(f_{++}\,f^*_{+-}) \Big/ \left[|f_{++}|^2 + |f_{+-}|^2\right]$$

b) Polarization effects in photoproduction experiments

Let us note first that, in order to give a clear and unambiguous prediction, we must choose a reaction in which either one Regge pole or two exchange degenerate Regge pole contributions dominate. We can see that both polarization and R values are proportional to the interference term between non flip and flip helicity amplitudes and depend critically on the large Regge cut contribution in the non flip amplitude. On the other hand, A measures the difference between two squares of amplitudes, and a little variation in each amplitude (when they are of the same order of magnitude) can change appreciably the difference and then the predictions. The following example will show clearly how sensible is A with the details of the models.

Let us take π° photoproduction. In the ω + B exchange model[28] we have for the asymmetry between π° photoproduction with perpendicular or parallel (to the production plane)polarized photons

$$A = \frac{\sigma(\gamma_\perp) - \sigma(\gamma_\perp)}{\sigma(\gamma_\perp) + \sigma(\gamma_{/\!/})} = \frac{|\omega|^2 - |B|^2}{|\omega|^2 + |B|^2}$$

In the Regge pole model, the ω contribution dominates over the B contribution except at $t = - 0.5\ \text{GeV}^2$ where it vanishes. The value for A is here - 1 and the corresponding prediction is shown on Fig. (21). However with the same model, adding small absorption type corrections, the prediction can be changed completely. See Fig. (21)

Hence, no test of high energy models can be decisive if it does not satisfy simultaneously the three following conditions :

1) *The measured quantity depends only on one exchanged trajectory*

2) *The experimental observable depends only on - or dominated by - one single amplitude*

3) *This amplitude depends little on cut effects i.e. it must be a helicity flip amplitude*

These three conditions are fulfilled if one measures in the s channel helicity system the ρ_{oo} density matrix element of the ω meson in the following reactions :

$$\pi^+ n \to \omega p$$

or $$\pi^- p \to \omega n$$

We have $$\rho^s_{oo} \frac{d\sigma}{dt} = \left| f_{0,\frac{1}{2},0,\frac{1}{2}} \right|^2 + \left| f_{0,\frac{1}{2},0,-\frac{1}{2}} \right|^2$$

It is well know that ρ exchange does not couple to ω helicity equal to zero, $\lambda_\omega = 0$[29]. Only unatural parity exchange in the t channel can contribute to such an amplitude (with $\lambda_\omega = 0$) and in this case it is the B meson[30]. Let us now introduce B meson contribution in these two classes of models and deduce consequences on ρ^s_{oo}.

Fortunately, because of its charge conjugation, B meson couples only to non helicity flip nucleon-antinucleon vertex in the t channel. As a consequence, in the s channel, B meson contributes at high energy only to nucleon-nucleon helicity flip amplitude. *Then, only one amplitude contributes to* ρ^s_{oo} *and this amplitude* $f^s_{0,1/2,\lambda=0,-1/2}$ *is a helicity flip amplitude with a total change of helicities* $\Delta h = 1$.

$$\rho^s_{oo} \frac{d\sigma}{dt} = \left| f^s_{0,\frac{1}{2},0,-\frac{1}{2}} \right|^2$$

The following predictions are then obtained :

1) Prediction common to the two classes of models

$\rho^s_{oo} \frac{d\sigma}{dt}$ has a forward dip which is seen in experimental data[24].

2) Prediction different for these two classes

. In geometrical models (Dar, SCRAM, Harari) a minimum at $t = -0.5\ \mathrm{GeV}^2$ is expected due to the zero in the single helicity flip amplitude.

. In models with nonsense wrong signature zero, dip is expected at $\alpha_B(t) = 0$. As we observed a dip at $t = -0.2\ \mathrm{GeV}^2$ in $\sigma_1^- = \rho_{1,1} - \rho_{1,-1}$ (only B contribution) we are tempted to associate this minimum to the point $\alpha_B = 0$. Then ρ^s_{oo} must have a dip at $t = -0.2\ \mathrm{GeV}^2$.

This dip structure at the same momentum transfer values for ρ_{00} and σ_1^-, which have different geometrical structure, is a typical prediction of models with nonsense wrong signature zeros. It seems that experimental results tend to confirm this picture.

Another test is the forward behaviour of differential cross section of $\pi^- p \to \eta n$. Here only two amplitudes contribute. If there is a clear forward dip, it means that helicity flip dominates strongly and the three preceeding conditions are almost fulfilled. The predictions are now :

If there is a forward dip in $\pi^- p \to \eta n$

. Dar and SCRAM predict a dip in differential cross section at $t = - 0.5$ GeV^2

. whereas models with nonsense wrong signature zeros do not predict a dip at $t = - 0.5$ GeV^2 but at $t = - 1.5$ GeV^2 ($\alpha_{A_2}(t) = - 1$).

Experimentally, no dip is observed at $t = - 0.5$ GeV^2 for $\pi^- p \to \eta n$[31], but a dip seems to be present at $t = - 1.5$ GeV^2[32].

A precise $\pi^- p \to \eta n$ experiment in the forward direction is a crucial experiment because

- *if it gives a clear forward dip, Dar and SCRAM models cannot survive*
- *and if it gives a forward peak, it excludes definitely exchange degeneracy.*

VI. CONCLUSIONS

In this contribution, we have asked the following question : Is exchange degeneracy verified by experiments ? It is clear that in reactions in which Regge cuts are small, exchange degeneracy for ρ-A_2

as well as K^{*} - K^{**} seems to be well verified. We have also discussed the two classes of high energy models which are characterized mainly by the presence or the absence of nonsense wrong signature zeros. Two tests are crucial to distinguish their predictions :

- measurement of ρ^{s}_{oo} in $\pi^{+}n \rightarrow \omega p$ or $\pi^{-}p \rightarrow \omega n$
- precise measurement of the differential cross section of $\pi^{-}p \rightarrow \eta n$ at very small t as well as at large t.

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(29) This statement is true when the t channel exchange object has a definite spin parity. In Dar's model where an elementary particle is exchanged, far from the pole (for example in the $t < 0$ region), the particle exchanged contribution does not have a well definite parity. Then $f_{\lambda\omega=0}$ can have a non leading contribution from elementary ρ exchange. I thank Arnon Dar for a discussion concerning this point.

(30) This unnatural parity contribution could be either B meson exchange and its corresponding cuts or double Regge exchange cuts. Let us now invoke some reasons to prefer the first alternative.

a) it is well known that even in the case where the individual Regge pole amplitudes show some structure, for example zero at $t \simeq -0.6\ (\text{GeV})^2$, the double Regge exchange cuts which involve a convolution over all t values are in general smooth functions of t. Then one expects a ρ^s_{oo} without structure. As the experimental behaviour of ρ^s_{oo} shows clearly a dip structure at $t \simeq -0.20\ (\text{GeV})^2$, it is unlikely that the effect comes only from double Regge exchange cuts.

b) if the effect comes from B exchange, we will see later that only the amplitude which has $|\Delta h| = 1$, contributes to ρ^s_{oo}. As this amplitude vanishes, by angular momentum conservation, at $t = 0$, $\rho^s_{oo} \frac{d\sigma}{dt}$, as well as $\rho^t_{oo} \frac{d\sigma}{dt}$ by using crossing relations, must have a forward dip. On the contrary, in the case of double Regge exchange cuts, for example $\rho \otimes \rho$ cuts, one can expect an appreciable contribution to non flip amplitudes and consequently no forward dip in $\rho^s_{oo} \frac{d\sigma}{dt}$. The experimental results are not precise, but a forward dip in $\rho^t_{oo} \frac{d\sigma}{dt}$ is suggested by the data at 5.08 GeV[7,11]. However, more precise data at smaller t are needed.

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FIGURE CAPTIONS

Fig. 1 Feynmann diagrams for particule exchange and rescattering.

Fig. 2 Regge cut convolution for helicity non flip amplitude.

Fig. 3 Regge cut convolution for helicity flip amplitude.

Fig. 4 Illegal duality diagrams for $K^+n \to K^\circ p$.

Fig. 5 Illegal duality diagrams for $K^-p \to \pi^- \Sigma^+$.

Fig. 6 Comparison of $K^+n \to K^\circ p$ and $K^-p \to \bar{K}^\circ n$ differential cross sections at 5.5 GeV/c .[7]

Fig. 7 Comparison of $K^+n \to K^\circ p$ and $K^-p \to \bar{K}^\circ n$ differential cross section at 12 GeV/c.[7]

Fig. 8 Differential cross section for charge exchange reactions.
(a) $\pi^+p \to \pi^\circ\Delta^{++}$ at 3-4 GeV/c and $\pi^-p \to \pi^\circ n$ at 3.67 GeV/c
(b) $\pi^+p \to \eta^\circ\Delta^{++}$ at 3-4 GeV/c and $\pi^-p \to \eta^\circ n$ at 3.72 GeV/c
(c) $K^+p \to K^\circ\Delta^{++}$ and $K^-p \to \bar{K}^\circ n$ both at 5.0 GeV/c.

Taken from Ref. 9

Fig. 9 Compilation of 5.9 GeV charge exchange data. The curves are from Regge pole model with strong exchange degeneracy and SU_3. Ref. 8

Fig. 10 Ratio of charge exchange cross sections with/without Δ production. Data taken from Ref. 9

Fig. 11 Δ density matrix elements for $\pi^+p \to \pi^\circ\Delta$

Fig. 12 Δ density matrix elements for $\pi^+ p \to \eta\Delta$ [10]

Fig. 13 Δ density matrix elements for $K^+ p \to K^\circ \Delta$ [10]

Fig. 14 Energy dependence of Δ density matrix elements [9]

Fig. 15 Differential cross sections for $\pi^+ p \to K^+ \Sigma^+$ [12]

Fig. 16 Duality diagrams for $\phi p \to K^+ \Sigma^\circ$ and $K^- p \to \rho \Sigma^\circ$

Fig. 17 Differential cross sections for $\gamma p \to K^+ \Lambda$ [13]

Fig. 18 Differential cross sections for $\gamma p \to K^+ \Sigma^\circ$ [13]

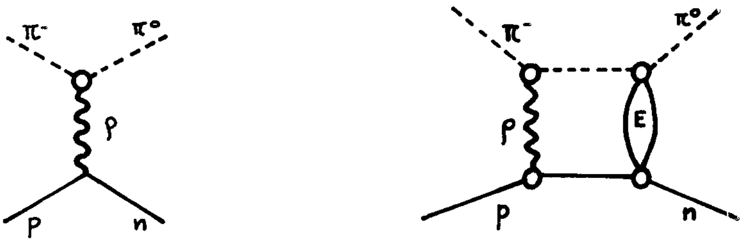
Fig. 19 $K^+ p$ and $K^- p$ elastic polarizations [18]

Fig. 20 $\pi^+ p$ and $\pi^- p$ elastic polarizations [18]

Fig. 21 Asymmetry in π° photoproduction

——— Asymmetry ω + B exchanged Regge Poles

- - - - - - Asymmetry ω + B exchanged Regge Poles + absorption



Particle Pole exchange   Rescattering

Fig. 1

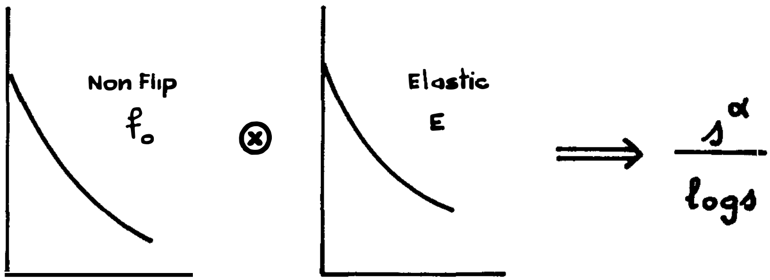


Fig. 2

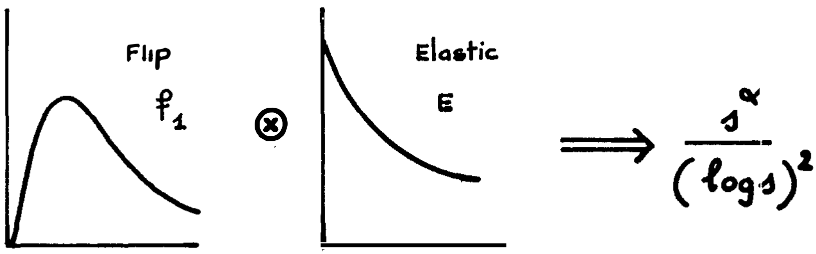
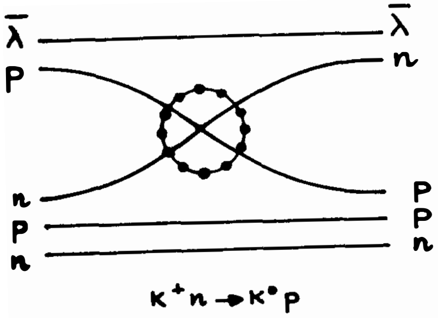
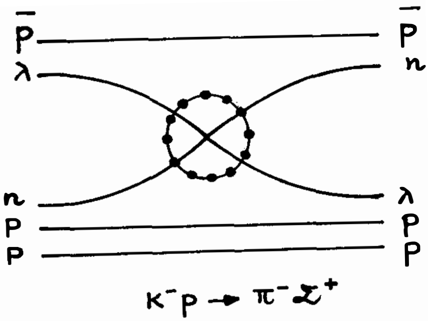


Fig. 3



Ilegal duality diagrams for $K^+n \to K^\circ p$.

Fig. 4



Illegal duality diagrams for $K^-p \to \pi^- \Sigma^+$.

Fig. 5

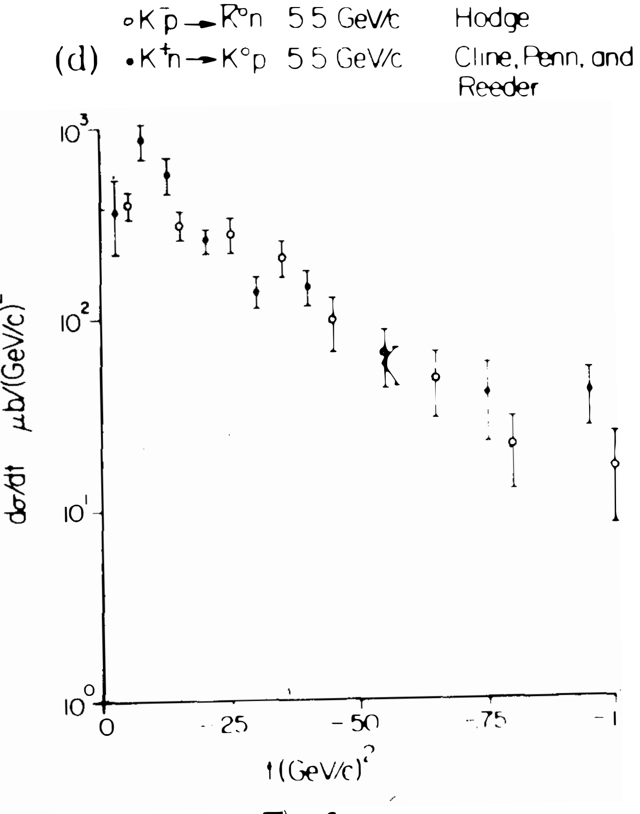
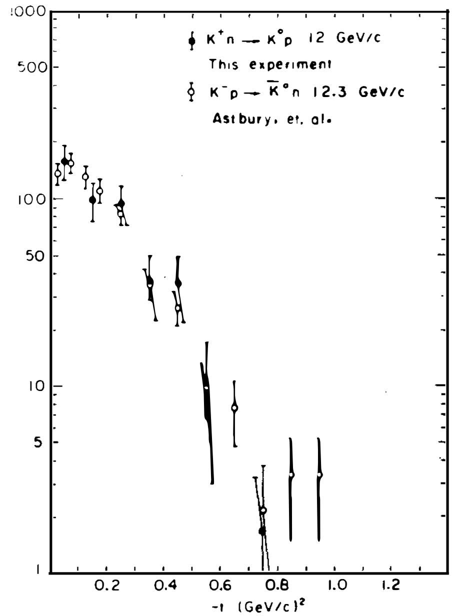
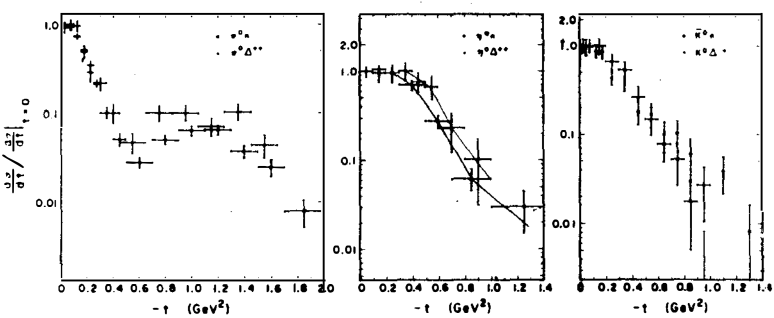


Fig 6



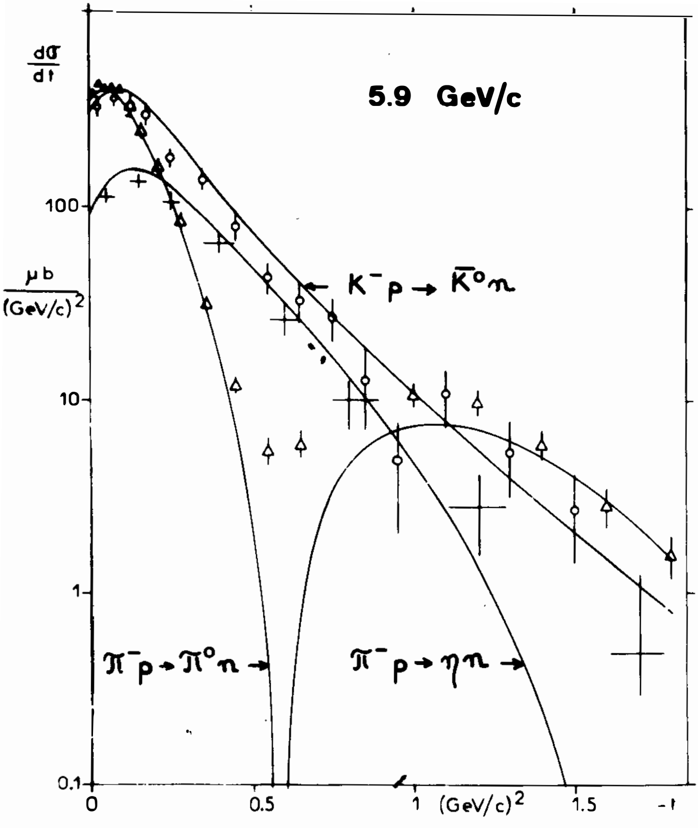
K⁺n → K°p 12 GeV/c
This experiment
K⁻p → K̄°n 12.3 GeV/c
Astbury, et. al.
-t (GeV/c)²

Fig. 7



-t (GeV²)
-t (GeV²)
-t (GeV²)

Fig. 8



$\frac{d\sigma}{dt}$
5.9 GeV/c
100
$\frac{\mu b}{(GeV/c)^2}$
10
1
0.1
$K^- p \rightarrow \bar{K}^o n$
$\pi^- p \rightarrow \pi^o n$
$\pi^- p \rightarrow \eta n$
0
0.5
1
$(GeV/c)^2$
1.5
-t

Fig. 9

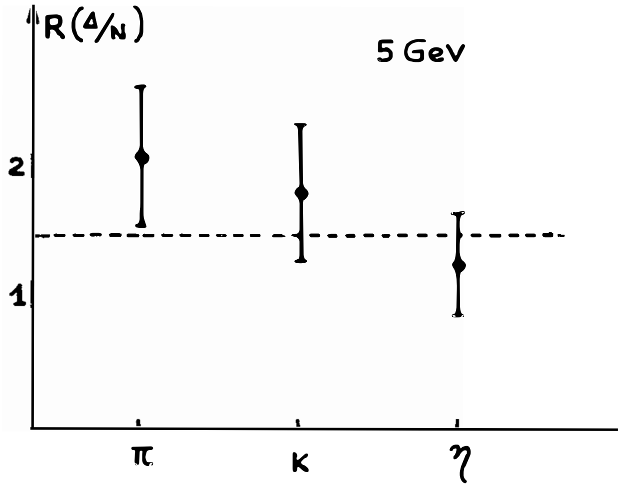


Fig. 10

Ratio of charge exchange cross sections with/without Δ production. Data taken from Ref. 9

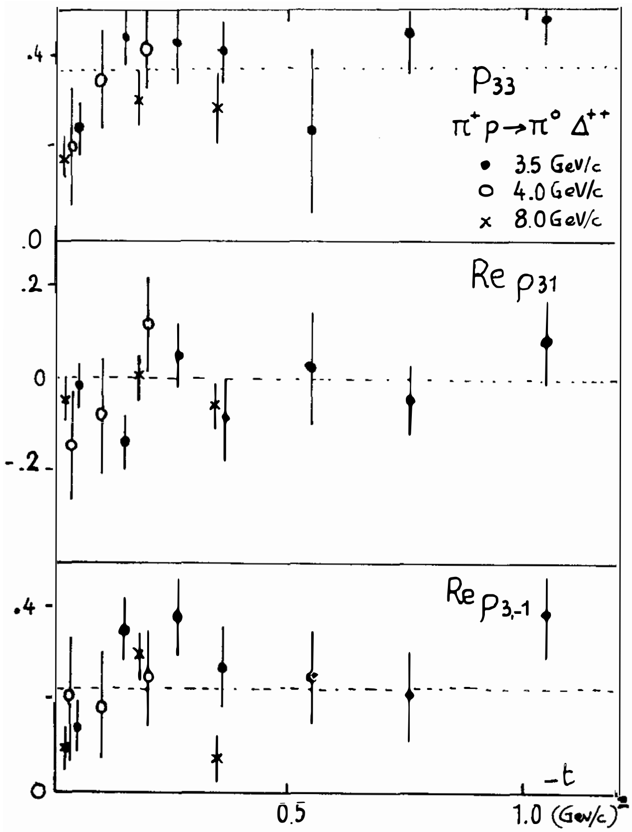


Fig. 11

Δ density matrix elements for $\pi^+ p \to \pi^\circ \Delta$ (10)

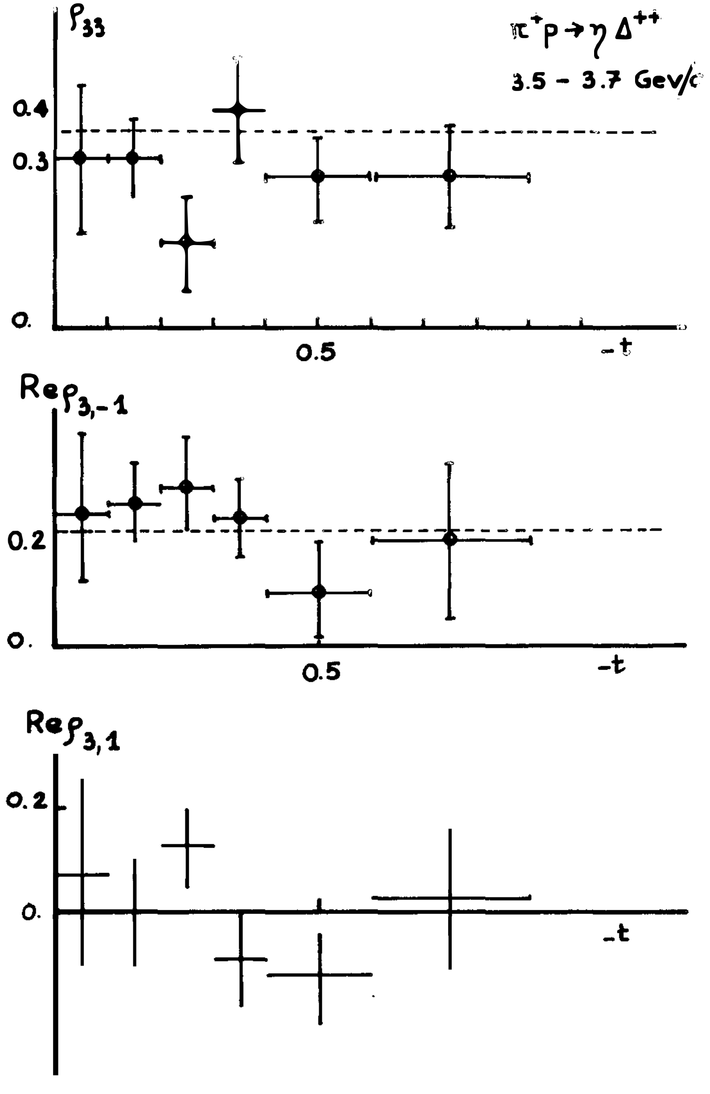
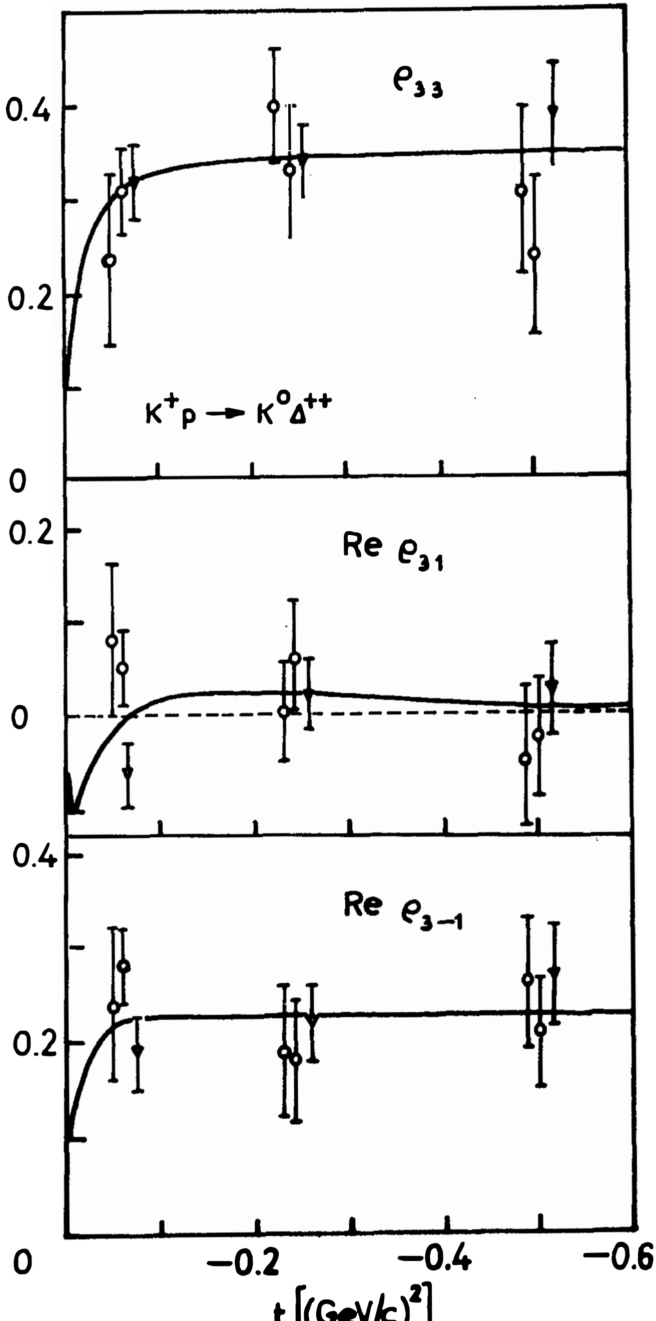

ρ_{33}
$\pi^+ p \to \eta \Delta^{++}$
3.5 - 3.7 Gev/c
0.4
0.3
0.
0.5
-t
$Re\rho_{3,-1}$
0.2
0.
0.5
-t
$Re\rho_{3,1}$
0.2
0.
-t

Fig. 12



ρ_{33}
$K^+p \to K^0\Delta^{++}$
Re ρ_{31}
Re ρ_{3-1}
0.4
0.2
0
0.2
0
0.4
0.2
0
−0.2
−0.4
−0.6
t [(GeV/c)^2]

Fig. 13

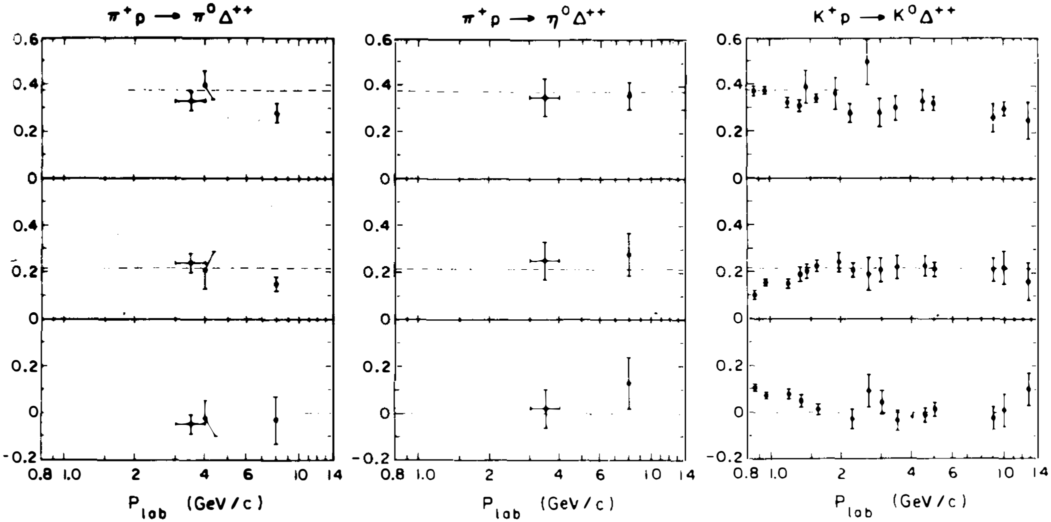
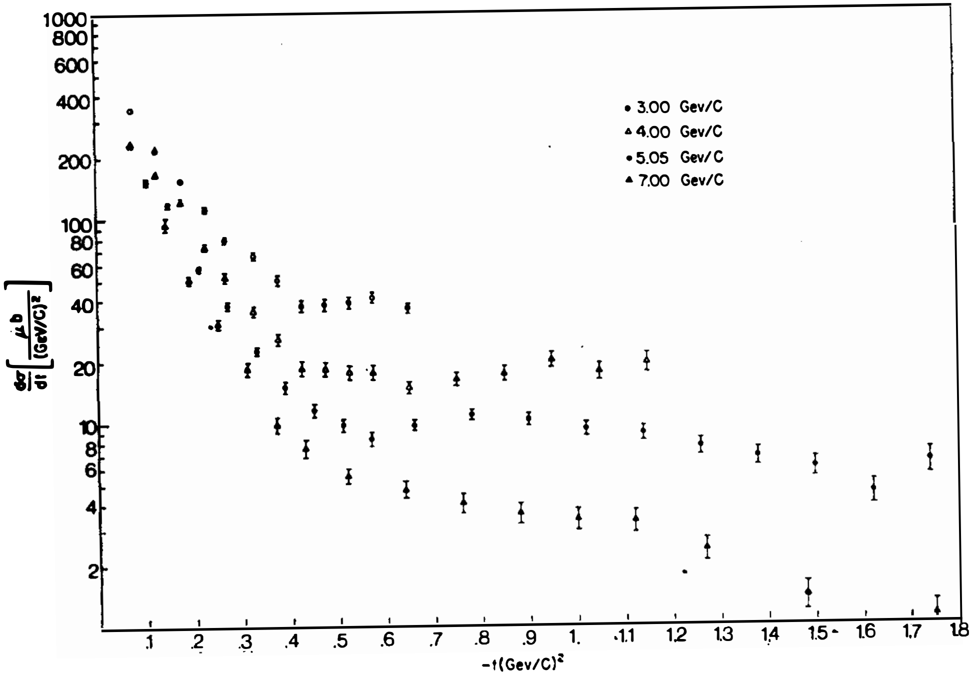


Fig. 14



1000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
dσ/dt [μb/(GeV/C)²]
3.00 Gev/C
4.00 Gev/C
5.05 Gev/C
7.00 Gev/C
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
-t(Gev/C)²

Fig. 15

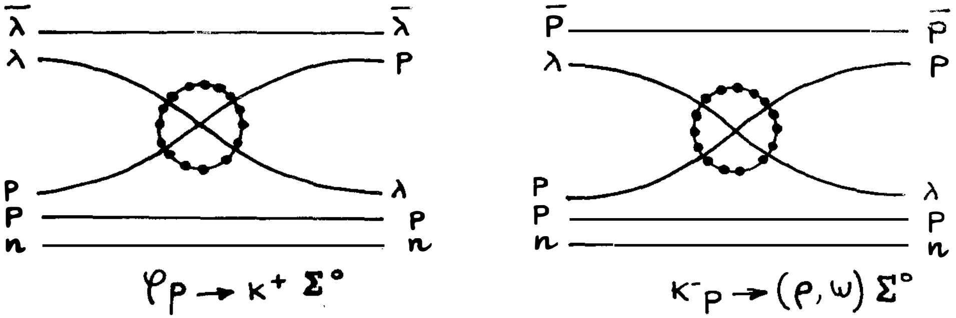


Fig.16

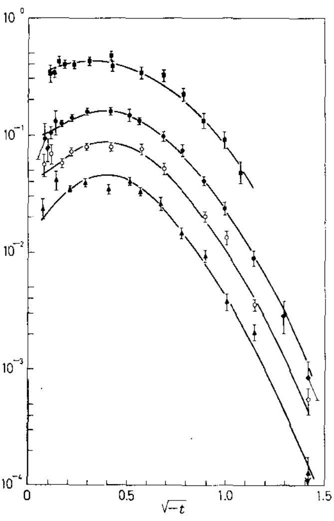


Fig.17 – $K^+\Lambda$, ■ 5 GeV, ● 8 GeV, ○ 11 GeV, ▲ 16 GeV.

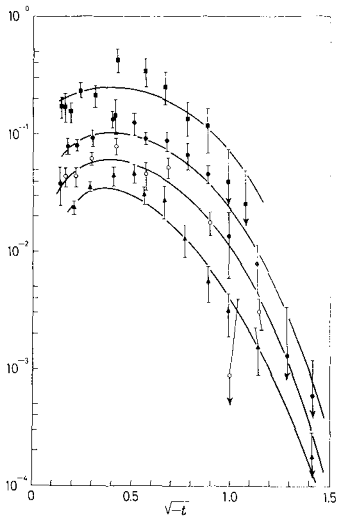


Fig.18 – $K^+\Sigma^0$, ■ 5 GeV, ● 8 GeV, ○ 11 GeV, ▲ 16 GeV.

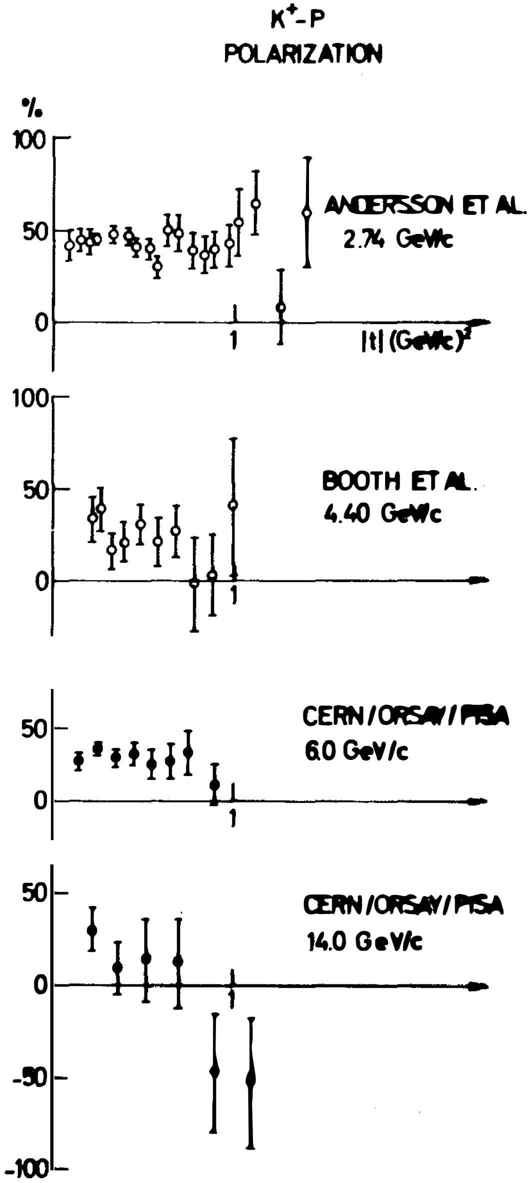

K+-P
POLARIZATION
%
100
50
0
1
|t| (GeV/c)²
ANDERSSON ET AL.
2.74 GeV/c
100
50
0
1
BOOTH ET AL.
4.40 GeV/c
50
0
1
CERN/ORSAY/PISA
6.0 GeV/c
50
0
1
-50
-100
CERN/ORSAY/PISA
14.0 GeV/c

FIG.19 a

K⁻P POLARIZATION

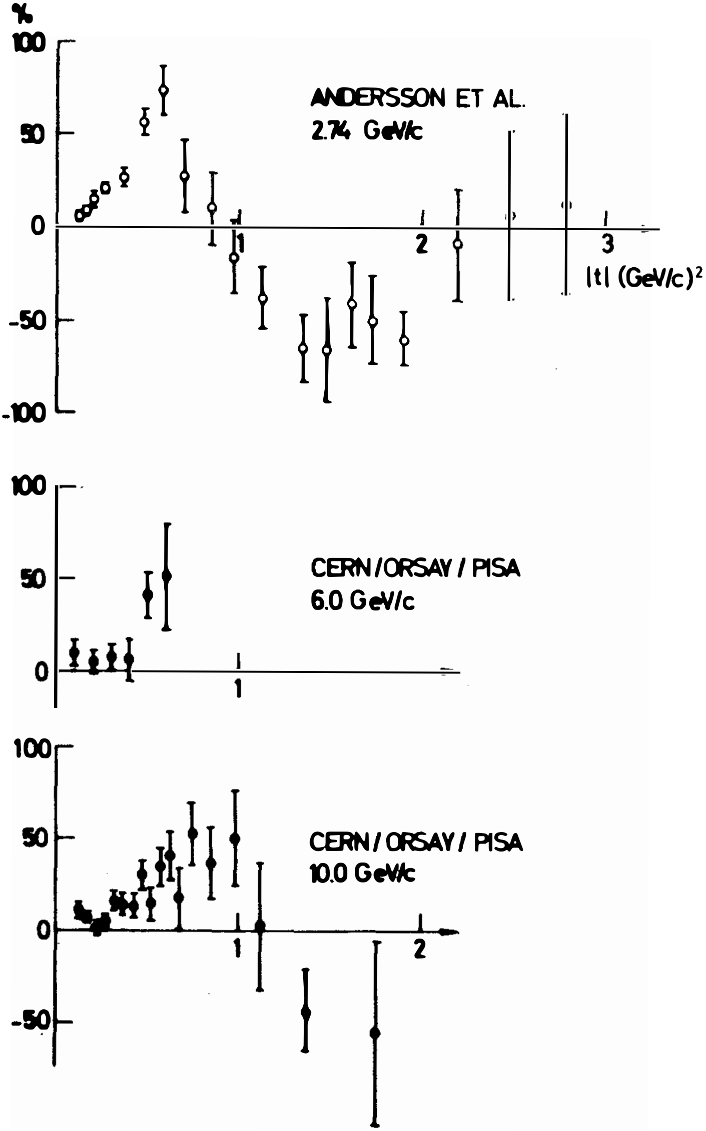
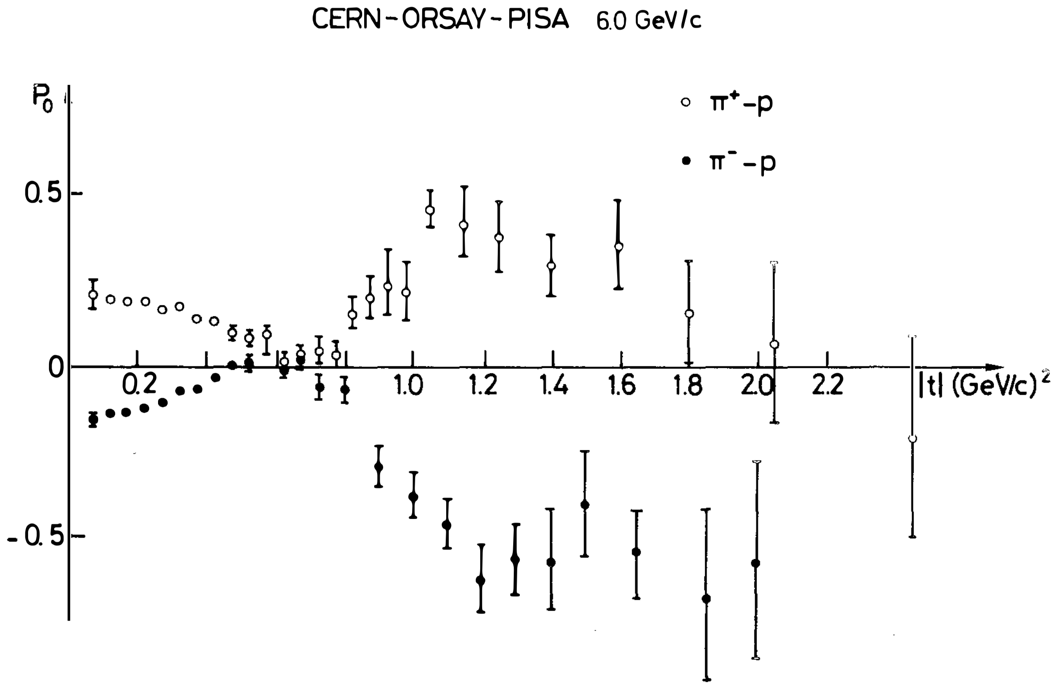
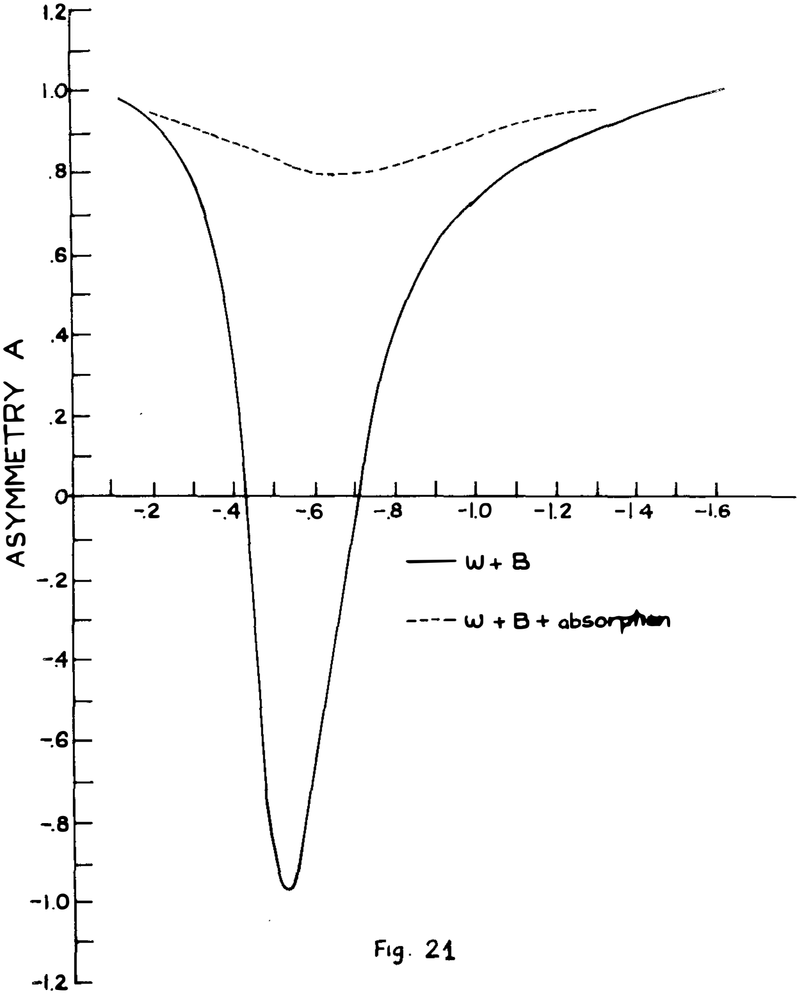


FIG. 10 b



CERN-ORSAY-PISA 6.0 GeV/c
P0
0.5
0
-0.5
π+-p
π−-p
0.2
1.0
1.2
1.4
1.6
1.8
2.0
2.2
|t| (GeV/c)2

FIG. 20



ASYMMETRY A
1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4
-1.6
ω + B
ω + B + absorption

Fig. 21