Archives

Ref. TH. 886

SPLITTING OF THE CROSS-SECTION INTO NATURAL AND UNNATURAL PARITY EXCHANGE CONTRIBUTIONS FOR QUASI TWO BODY REACTIONS

J.P. Ader and M. Capdeville
Laboratoire de Physique Théorique, Bordeaux

and

G. Cohen-Tannoudji and Ph. Salin
CERN - Geneva

A B S T R A C T

We show that in quasi two-body reactions $1+2 \rightarrow 3+4$ it is possible to split the experimental cross-sections in parts with only natural or unnatural parity exchange, and this for each helicity state of the particles. When one of the initial particle is spinless, the result is readily obtained by looking at very simple linear combinations of the usual measured density matrix elements. When none of the initial particles are spinless one has to perform a single well-defined polarization experiment. We also show that it is experimentally possible to distinguish a Regge pole model with evasive and/or conspiring trajectories, from other possibilities.

68/423/5 - TH. 886
27 March 1968

1. INTRODUCTION

At the present time it seems highly desirable to have some more information about the actual exchange sets of quantum numbers which govern high energy two-body processes. It is clear that important progresses have been performed in the understanding (or in the lack of understanding) of these reactions for which the number of possible exchanged states is limited to one or two. On the other hand, reactions which involve a large number of possible states do not provide a clear cut among various theoretical proposals.

Our purpose is to show that it is possible to extract from the experimental data information about the exact quantum numbers involved in the exchange mechanism. We shall show that it is possible to split the differential cross-sections in a part which contains only natural parity exchange and another one which contains only unnatural parity exchange, and this for each helicity state of emerging particles. Therefore, processes which are complicated because they involve final particles with high spins and/or because several sets of quantum numbers may be exchanged can be reduced to processes as simple as for instance π nucleon charge exchange.

It is already known for a long time that the density matrix elements are good analyzers of the production mechanism, and, for instance that ρ_{oo} in vector meson production measures the unnatural parity contribution [1]. More recently Kaidalov, Ringland and Thews [2] have derived quadratic relations among density matrix elements which have to be satisfied when only one Regge pole can be exchanged. It has also been shown by Contogouris, Lubatti and Tran Thanh Van [3], and by Högaasen and Lubatti [4] that it is possible to isolate the exchange of states with given isospin, G parity and charge conjugation.

In Section 2 we show that very simple linear combinations of density matrix elements allow to extract each parity contributions. The result may be read off from the diagonal and antidiagonal density matrix elements when one of the incident particles is spinless. When both particles in the initial state are not spinless the splitting into each parity involves one single experiment with a polarized incident particle. Further results involving joint density matrix elements are derived in Section 3. In Section 4 we discuss the implications of evasion and conspiracy, and show how to distinguish between a pure Regge pole model and other high energy models. Finally, in Section 5 we analyze a number of experimental results and present some theoretical predictions in the case of photoproduction.

2. CROSS-SECTIONS WITH DOMINANT PARITY

We consider a quasi two-body reaction $1+2 \rightarrow 3+4$, and call λ_1, λ_2, λ_3 and λ_4 the helicities of each particle. We recall that it is possible, both in the t channel and in the s channel, to define helicity amplitudes corresponding to the exchange in the crossed t channel of states with given dominant parity [5] (all through this paper the $+$ index will always refer to natural parity and the $-$ index to unnatural parity);

$$M^{s\pm}_{\lambda_3\lambda_4\lambda_1\lambda_2} = M^{s}_{\lambda_3\lambda_4\lambda_1\lambda_2} \pm \varepsilon\, M^{s}_{-\lambda_3\lambda_4-\lambda_1\lambda_2}$$

$$\varepsilon = \eta_3\eta_1\, (-)^{s_3-s_1}\, (-)^{\lambda_3-\lambda_1}$$

$$M^{t\pm}_{\lambda_3\lambda_1\lambda_4\lambda_2} = M^{t}_{\lambda_3\lambda_1\lambda_4\lambda_2} \pm \varepsilon'\, M^{t}_{-\lambda_3-\lambda_1\lambda_4\lambda_2}$$

$$\varepsilon' = \eta_{\bar{3}}\,\eta_1\, (-)^{s_3-s_1}\, (-)^{\lambda_3-\lambda_1}$$

The density matrix elements of the final states are simply expressed in terms of s channel helicity amplitudes, when helicity is measured in the helicity frame, and in terms of t channel helicity amplitudes when helicity is measured in the Jackson system [1]. In the following we shall express our formulae in terms of s channel helicity amplitudes, but the translation of these formulae in terms of t channel helicity amplitudes and density matrix elements measured in the Jackson system is straightforward. We shall assume everywhere that particles 1 and 3 on the one hand, 2 and 4 on the other, are of the same type (i.e., bosons or fermions), so that we shall be interested in boson exchange processes.

1) Particle 1 has spin zero

In order to illustrate our method we first consider the most interesting case in which particle 1 has spin zero, and we define the following quantities

$$\frac{d\sigma^{\pm}_{\lambda_3}}{dt} = \frac{1}{4}\sum_{2,4}\left|M^{\pm}_{\lambda_3\lambda_4 0\lambda_2}\right|^2$$

$$\sigma^{\pm}_{\lambda_3} = \frac{d\sigma^{\pm}_{\lambda_3}}{dt}\Big/\frac{d\sigma}{dt}$$

$$\sum_{\lambda_3}\left(\sigma^{+}_{\lambda_3} + \sigma^{-}_{\lambda_3}\right) = 1$$

The quantity $^{\pm}{}_{3}$ gives the relative contribution to the differential cross-section of the exchange of states with natural or unnatural parity when particle 3 has the helicity state $_{3}$. It is very easy to express these quantities in terms of the familiar density matrix elements [1] for particle 3

One obtains

$$\boxed{2\sigma_{\lambda_3}^{\pm} = \rho_{\lambda_3\lambda_3} \pm \varepsilon\, \rho_{\lambda_3 -\lambda_3}}\ .$$

If $\lambda_3 = 0$, then

$$\sigma_0^+ = \rho_{00} \qquad \sigma_0^- = 0 \qquad \text{if } \varepsilon = +1$$

$$\sigma_0^+ = 0 \qquad \sigma_0^- = \rho_{00} \qquad \text{if } \varepsilon = -1$$

As a special case we obtain a theorem due to Gottfried and Jackson [1] which states that in reactions $0^- + \frac{1}{2}^+ \rightarrow 1^- + \frac{1}{2}^+ (\varepsilon = -1)$ the density matrix element ρ_{00} gives the contribution of unnatural parity exchange when the vector meson is in helicity state 0. But one sees that it is possible to go further and to isolate also the natural and unnatural parity contributions when the helicity of the vector meson is equal to 1, by looking at the following combinations:

$$2\sigma_1^{\pm} = \rho_{11} \pm \varepsilon\, \rho_{1-1}$$

We shall later on analyze some present experimental results with this formula.

2) General case

We now consider the general case in which particle 1 has spin s_1 and helicity $|\lambda_1|$ and we define the two following states

$$|\alpha\rangle = |\lambda_1\rangle + |-\lambda_1\rangle$$

$$|\beta\rangle = |\lambda_1\rangle - |-\lambda_1\rangle$$

If the spin of particle 1 is $\frac{1}{2}$, then $|\alpha\rangle$ (resp. $|\beta\rangle$) corresponds to a particle with polarization $+\frac{1}{2}$ (resp. $-\frac{1}{2}$) along the x axis (i.e., in the scattering plane). If particle 1 has spin 1 and helicity 1 (for instance a photon) then $|\alpha\rangle$ corresponds to a particle with polarization perpendicular to the scattering plane (along y) and $|\beta\rangle$ to a particle with polarization parallel to the scattering plane (along x).

As in the preceding case, we define now the following cross-sections with defined dominant parity

$$\frac{d\sigma^{\pm}_{\lambda_3\lambda_1}}{dt} = \frac{1}{8}\sum_{2,4}\left\{|M^{\pm}_{\lambda_3\lambda_4\lambda_1\lambda_2}|^2 + |M^{\pm}_{\lambda_3\lambda_4-\lambda_1\lambda_2}|^2\right\}$$

$$\sigma^{\pm}_{\lambda_3\lambda_1} = \frac{d\sigma^{\pm}_{\lambda_3\lambda_1}}{dt} \Big/ \frac{d\sigma}{dt}$$

$$\sum_{\lambda_3}(\sigma^{+}_{\lambda_3 0} + \sigma^{-}_{\lambda_3 0}) + 2\sum_{\lambda_3, |\lambda_1|\neq 0}(\sigma^{+}_{\lambda_3\lambda_1} + \sigma^{-}_{\lambda_3\lambda_1}) = 1$$

We also define density matrix elements $\rho^{\alpha,\beta}_{\lambda_3\lambda_3'}$ related to particle 3 when particle 1 is in the state $|\alpha\rangle$ or $|\beta\rangle$

$$\frac{d\sigma}{dt}\rho^{\alpha_1}_{\lambda_3\lambda'_3} = \frac{1}{4}\sum_{2,4}(M_{\lambda_3\lambda_4\lambda_1\lambda_2} + M_{\lambda_3\lambda_4-\lambda_1\lambda_2})(M_{\lambda'_3\lambda_4\lambda_1\lambda_2} + M_{\lambda'_3\lambda_4-\lambda_1\lambda_2})^*$$

$$\frac{d\sigma}{dt}\rho^{\beta_1}_{\lambda_3\lambda'_3} = \frac{1}{4}\sum_{2,4}(M_{\lambda_3\lambda_4\lambda_1\lambda_2} - M_{\lambda_3\lambda_4-\lambda_1\lambda_2})(M_{\lambda'_3\lambda_4\lambda_1\lambda_2} - M_{\lambda'_3\lambda_4-\lambda_1\lambda_2})^*$$

The $\rho^{\alpha,\beta}$'s are related to the unpolarized density matrix elements by

$$\rho_{\lambda_3\lambda'_3} = \sum_{\lambda_1}(\rho^{\alpha_1}_{\lambda_3\lambda'_3} + \rho^{\beta_1}_{\lambda_3\lambda'_3})$$

If particle 3 is a boson, then all the ρ's are real (for $|\lambda_3| = |\lambda_3'|$), and if particle 3 is a fermion $_{3\ 3}$ is real, $_{3^-\ 3}$ is purely imaginary and

$$\rho^{\alpha\ *}_{\lambda_3-\lambda_3} = -\rho^{\beta}_{\lambda_3-\lambda_3}$$

such that, of course, in any case $\rho^{\alpha}_{\lambda_3-\lambda_3} - \rho^{\beta}_{\lambda_3-\lambda_3}$ is always real.

We then obtain the following relation

$$\boxed{2\,\sigma^{\pm}_{\lambda_3\lambda_1} = \left(\rho^{\alpha_1}_{\lambda_3\lambda_3} \pm \varepsilon\,\rho^{\alpha_1}_{\lambda_3-\lambda_3}\right) + \left(\rho^{\beta_1}_{\lambda_3\lambda_3} \mp \varepsilon\,\rho^{\beta_1}_{\lambda_3-\lambda_3}\right)}$$

a) Photoproduction experiments

For all photoproduction experiments it is possible to split the cross-section into the natural and unnatural parity contributions, with polarized γ rays. In particular, for pion or K meson photoproduction ($\lambda_3 = 0$), one obtains

$$2\,\sigma_1^{\pm} = \left(\rho^{\perp}_{00} \pm \rho^{\perp}_{00}\right) + \left(\rho^{\parallel}_{00} \mp \rho^{\parallel}_{00}\right)$$

or

$$\sigma_1^{+} = \rho^{\perp}_{00}$$

$$\sigma_1^{-} = \rho^{\parallel}_{00}$$

This result is nothing else than a theorem due to Stichel [6] which states that only natural (resp. unnatural) parity exchange contributes to the polarized cross-section, when the photon polarization is perpendicular (resp. parallel) to the scattering plane.

b) Baryon resonance productions

In reactions producing two unstable particles, such as $\pi N \to \rho \Delta$ the splitting of the cross-section into its natural and unnatural parts may be achieved by looking at the ρ density matrix elements. But if one is interested in a splitting of the cross-section for fixed values of the Δ helicity, or in reactions such as $\pi N \to \pi \Delta$, then one has to perform an experiment with a polarized target.

3. CORRELATION BETWEEN POLARIZATIONS OF PARTICLE 3 AND 4

In order to extract interesting information from the spin correlations between particle 3 and 4 (we assume in this Section that particle 4 is a fermion and particle 3 a boson), one has to measure density matrix elements which are not accessible in parity conserving decays.

We define the following joint density matrix elements

$$\rho^{\lambda_3 \lambda'_3}_{\lambda_4 \lambda'_4} = \sum_{\lambda_1 \lambda_2} M_{\lambda_3 \lambda_4 \lambda_1 \lambda_2} M^{*}_{\lambda'_3 \lambda'_4 \lambda_1 \lambda_2}$$

If particle 1 is spinless, one can isolate the contribution of natural and unnatural parity exchange by defining the following density matrix for particle 4 when particle 3 is in the helicity state λ_3:

$$\rho^{(\pm)\lambda_3}_{\lambda_4 \lambda'_4} = \rho^{\lambda_3 \lambda_3}_{\lambda_4 \lambda'_4} \pm \varepsilon\, \rho^{\lambda_3 -\lambda_3}_{\lambda_4 \lambda'_4}$$

Now, when only one single state contributes to the natural parity exchange (resp. unnatural exchange), since all amplitudes with this parity have the same phase, then:

$$\rho^{(+)\lambda_3}_{\lambda_4 - \lambda_4} = 0 \qquad (\text{resp. } \rho^{(-)\lambda_3}_{\lambda_4 - \lambda_4} = 0)$$

In particular, if particle 4 is a spin $\frac{1}{2}$ hyperon whose polarizations can be easily measured

$$\rho^{(+)\lambda_3}_{1/2 - 1/2} = 0 \qquad (\text{resp. } \rho^{(-)\lambda_3}_{1/2 - 1/2} = 0)$$

which implies a zero polarization for the hyperon.

Therefore, if the measured polarizations are non-zero, this would imply that at least two states with different phases contribute to each parity.

Let us consider as an example the reaction $\pi N \to K^*Y$. There is only one possible candidate of unnatural parity, the K meson. Then, in a pure exchange model one would expect $\rho^{(-)\lambda_3}_{\frac{1}{2}-\frac{1}{2}} = 0$ for $\lambda_3 = 0, 1$. Other cases of interest would be Y* production with observation of the polarization of its decay product.

4. EVASION AND CONSPIRACY

1) Behaviour near the forward direction

Up to now the implication of an evasive or conspiracy mechanism has been studied only through the observation of peaks or dips in the differential cross-section. The splitting of this cross-section in parts of definite parity for each helicity state of the outgoing particles allows a more accurate investigation of the different dynamical mechanism.

The first observation is that, due to angular momentum conservation, one knows the actual behaviour of each density matrix element near the forward direction, i.e.:

$$\rho_{\lambda_3 \lambda'_3} \sim \sin \frac{\theta_s}{2}^{|\lambda_3 - \lambda'_3|}$$

($\rho_{\lambda_3 \lambda'_3}$ vanishes even more rapidly when $\lambda_3 > s_1+s_2+s_4$).

This implies, when particle 1 is spinless

$$\sigma^{+}_{\lambda_3}(\theta_s = 0) = \sigma^{-}_{\lambda_3}(\theta_s = 0) \qquad (\lambda_3 \neq 0)$$

A priori there is no reason for such an equality between these two cross-sections, and it is clear that in order to satisfy it one is forced either to invoke an evasive mechanism, in which case both cross-sections $\sigma^{\pm}_{\lambda_3}$ vanish near the forward direction like $t^{2\lambda_3}$ 5), or a conspiracy mechanism which precisely relates the two cross-sections.

In the general conspiracy scheme it has been proved 7) that factorization implies that only these amplitudes for which $|\lambda_3 - \lambda_1| = |\lambda_4 - \lambda_2| = M$, where M is the Lorentz pole quantum number introduced by Toller 8), survive near the forward direction. From this we deduce

$$\rho_{\lambda_3 \lambda_3} = 0 \qquad \text{if } \lambda_3 \neq M$$

For instance, a reggeized pion with $M = 1$ would give $\rho_{00} = \rho_{22} = 0$ in f^0 production.

In the case when the spin of particle 1 is not zero, the results are slightly more complicated, since $\rho^{\alpha}_{\lambda_3 \lambda'_3}$ or $\rho^{\beta}_{\lambda_3 \lambda'_3}$ vanish like

$$\sin \frac{\theta_s}{2} \,\big|\, |\lambda'_3 - \lambda_3| - 2|\lambda_1| \,\big|$$

In particular it may happen, even with evasion, that the cross-section with definite parity does not vanish since $|\lambda'_3 - \lambda_3|$ may be equal to $2|\lambda_1|$.

2) Phases of the amplitudes

The observation of forward peaks in differential cross-sections for some processes have been considered as evidence for the conspiratorial mechanism. It is clear that as long as only differential cross-sections are considered, it is always possible to obtain these forward peaks by adding a conspiring pole, say R_2^+, to the previous Regge pole R_1^-. However, the phase of the R_1^- contribution is not changed by this modification. If R_1^- is the only possible pole which can be exchanged with this parity, then, as shown in Section 2

$$\rho^{(-)\lambda_3}_{\lambda_4 -\lambda_4} = 0$$

If one chooses another mechanism (s channel contributions, fixed poles, cuts or absorptive corrections,...), then, one adds to the R_1^- pole another contribution which may have a different phase, and therefore $\rho^{(-)\lambda_3}_{\lambda_4 -\lambda_4}$ is no longer zero.

For instance, in the process $\pi N \to K^* \Lambda$, the K meson trajectory is the only trajectory with unnatural parity which may be exchanged. Even with a conspirator for the K trajectory

$$\rho^{(-)\lambda_3}_{1/2\,-1/2} = 0$$

One has then a way to test different dynamical assumptions, which are difficult to distinguish when only cross-section data are available.

V. ANALYSIS OF SOME EXPERIMENTAL RESULTS

Up to now all density matrix elements have been measured in the Jackson system [1]. We shall therefore use this system of reference in this Section.

1) Vector meson production

In all reactions with production of a bosonic resonance the cross-sections $\sigma^{\pm}_{\lambda_3}$ are readily obtained from the decay of the resonance. The decay angular distribution of the vector meson is given in terms of $\sigma^{\pm}_{1}$ by

$$W(\cos\theta,\varphi) = \frac{3}{4\pi}\left\{\rho_{00}\cos^2\theta + (\sigma_1^+\sin^2\varphi + \sigma_1^-\cos^2\varphi)\sin^2\theta - \sqrt{2}\,\mathrm{Re}\,\rho_{10}\sin 2\theta\cos\varphi\right\}$$

$$W(\cos\theta) = \frac{3}{4}\left\{2\rho_{00}\cos^2\theta + (\sigma_1^+ + \sigma_1^-)\sin^2\theta\right\}$$

$$W(\varphi) = \frac{1}{2\pi}\left\{\rho_{00} + 2(\sigma_1^+\sin^2\varphi + \sigma_1^-\cos^2\varphi)\right\}$$

In that case one has $\sigma_1^{\pm} = \rho_{11} \pm \rho_{1-1}$; therefore, the sign of ρ_{1-1} gives the relative importance of σ_1^+ with respect to σ_1^-. We have computed $\sigma_1^{\pm}$ from some published values for ρ_{oo} and ρ_{1-1}. We think that the experimental uncertainties on $\sigma_1^{\pm}$ would be less important if they are computed directly from the experimental data, than through the use of ρ_{oo} and ρ_{1-1}.

Before going to some particular cases, we would like to make the following general remark: there is a very strong evidence from all reactions that ρ_{oo} never reaches effectively its upper limit 1 in the forward direction, which means that ρ_{11} is never exactly zero in the forward direction. As shown in the preceding Section this means that either all data have to be corrected for background or that none of high energy scattering processes can be described with only evasive Regge poles.

a) Reaction $\pi^+ p \to \rho^o \Delta^{++}$

This reaction has been of great interest in the past months, because the last results of the Aachen-Berlin-CERN collaboration [9] are considered as the best evidence against conspiracy. But at the same time, the fact that ρ_{oo} is non-zero in the forward direction ($\rho_{oo} = 0.87 \pm 0.05$) may be considered as an indication against pure occurrence of only evasive Regge poles.

The Regge poles which might be exchanged in this reaction are π and A_1 with unnatural parity and A_2 with natural parity. We show on Fig. 1 some values of σ_1^+ and σ_1^-. It is difficult within the present uncertainties to derive definite results, but one could at least remark the tendency for σ_1^+ to dominate over σ_1^-, except in the forward direction, when energy increases. An opposite result would be rather puzzling.

b) Reaction $\pi^+ p \to \omega^0 \Delta^{++}$

This reaction has been already considered by Högaasen and Lubatti [4], and it is known that in order to explain this reaction one is forced to consider at least the contribution of two Regge poles of opposite parity the ρ and the B.

We have plotted on Fig. 2 $\sigma_1^{\pm}$ derived from the experimental data at 5 GeV/c [10]. From this Figure one deduces first that the B contribution, when the helicity is 1, is not negligible, and secondly that σ_1^{+} exhibits a dip around $t = -0.6$, which is compatible with the vanishing of the ρ trajectory. It is worth while to notice that this dip does not appear on the differential cross-section.

c) Reaction $KN \to K^*N$

We present on Table 1 and 2 some different values for $\sigma_1^{\pm}$ computed from experimental data for $K^- p \to K^{*-} p$ and $K^- p \to K^{*0} n$ [11),12]. The corresponding values for $K^+ p \to K^{*+} p$ [13] are essentially the same as for K^{*-} production. It is apparent from the numbers in the Tables that the unnatural parity exchange contributions when the K^* helicity is 1. are always compatible with zero within the experimental errors. Up to our knowledge this result is in fact new, because it has been obtained by Jackson and Pilkuhn [14] within the special model of elementary pion and vector meson exchange only. But we can say even more about the dominant exchanges. P contribution should be small (in fact if the P is a SU_3 singlet then it is not coupled to KK^*), because the cross-sections are rapidly varying functions of the energy, with an effective $\alpha(0)$ dependence of the order of 0.5 (compatible with P', ρ, ω or A_2 dominance). The ρ contribution is presumably small because there is no evidence for a dip near $t = -0,6$ in σ_1^{+} for K^{*0} production [see also Ref. [14]] and therefore K^{*0} production should be dominated by π and A_2 exchange.

These pion and A_2 contributions, due to charge independence, are four times larger in K^{*o} production than in $K^{*\pm}$ production, though the cross-sections for these different processes are roughly of the same order of magnitude. We then conclude that $K^{*\pm}$ production is dominated by P' or ω exchange. The fact that no dip is observed in $\sigma^{+}_{1}(K^{*\pm})$ suggests either a rather flat trajectory for the ω or a P' dominance in charged K* production [15]. The $K^{+}p \rightarrow K^{*o}\Delta^{++}$ reaction at 3.5 and 5 GeV/c [16] is strongly dominated by pion exchange with K* in helicity state zero. When K* in this reaction has helicity state 1, both natural and unnatural parity exchange contributions have about the same order of magnitude (ρ_{1-1} is very small). This suggests that the A_2 coupling to $N\bar{\Delta}$ is much smaller than to $N\bar{N}$.

2) Photoproduction experiments

We have shown in Section 2 that when the initial particle is a photon, the interesting experiments are those with initial polarized photons perpendicular or parallel to the scattering plane. Up to now there are no high energy experiments with polarized photon, but we understand that some experiments of that kind are presently planned [17]. We present therefore some theoretical predictions for these polarized cross-sections, and hope that experiment will be able to distinguish among the various theoretical suggestions proposed in order to explain the same features of the differential cross-section.

We first begin with π^o photoproduction. For this reaction we have proposed [18] a Regge pole fit with only ω and B exchange, which gives a quite good agreement with experimental data. The cross-section with polarized γ rays perpendicular (resp. parallel) to the scattering plane will isolate the ω (resp. the B) contribution.

Typical cross-sections at 5 GeV/c are shown on Fig. 3 with its dip structure at nonsense points. As an application of Section 3 the polarization of the recoil neutròn is predicted to be zero. In terms of the s channel helicity amplitudes the polarization is given by

$$P(\theta)\frac{d\sigma}{dt} = -\frac{1}{2}\,\mathrm{Im}\left(f_{1-1}^{+*} f_{11}^{+} + f_{1-1}^{-*} f_{11}^{-}\right)$$

where

$$f_{11}^{\pm} = f_{\frac{1}{2}0-\frac{1}{2}-1} \pm f_{\frac{1}{2}0-\frac{1}{2}-1}$$

$$f_{1-1}^{\pm} = f_{\frac{1}{2}0\frac{1}{2}1} \pm f_{\frac{1}{2}0\frac{1}{2}-1}$$

It is clear that the polarization is zero when only one Regge pole is exchanged in each parity state. (In fact the polarization is not exactly zero because the $f^{\pm}$ amplitudes are only dominant parity amplitudes, but we have checked that at 5 GeV/c the polarization is everywhere less than 5%).

For π^+ photoproduction, experiments with polarized γ rays are not of much help to distinguish among various theoretical predictions. We show on Fig. 4 the cross-sections $d\sigma^{\perp}/dt$ and $d\sigma^{\parallel}/dt$. Up to the energy dependence, which can be checked on the non-polarized differential cross-section, the fixed pole approach [19] and the conspiracy mechanism [20] give essentially the same structure to the polarized cross-sections, with a vanishing of $d\sigma^{\parallel}/dt$ for $\sqrt{-t} \geqslant 0.175$ GeV/c. On the other hand the recoil proton polarization is zero in the conspiratorial case [20], for reasons explained above, though it reaches 20% for $\sqrt{-t} \sim 0.200$ GeV/c in the fixed pole model [19].

6. CONCLUSION

We have thus shown that it is always possible to split the cross-section in parts with only natural (resp. unnatural) parity exchange for each helicity states of the particles occuring in a quasi two-body reaction. When the process is induced by a pion or a K meson, the splitting is completely achieved by measuring the density matrix elements $\rho_{\lambda_3\lambda_3}$ and $\rho_{\lambda_3-\lambda_3}$ of the outgoing bosonic resonance. When none of the initial particle is spinless we have shown which of the possible polarization experiments was of main interest to determine the parity of exchange states. We have also shown that these measurements were able to give information about the detailed dynamical mechanisms (evasive, conspiring Regge poles, absorption, etc.) which cannot be obtained otherwise.

In this paper we have been interested only in the parity of the exchanged states. But it has been shown [3),4)] that information about the G parity or the charge conjugation of these states may be obtained by looking at linear combinations of cross-sections when a resonance with different charge states is produced (such as the ρ for instance). By performing these different combinations on the density matrix elements, one will be able in some cases to determine exactly the whole set of exchanged quantum numbers.

We hope that these considerations will stimulate experiments with polarization measurements, which are at the present time of first interest for the understanding of high energy scattering. It is clear that large improvements, with regard to density matrix elements published up to now, have to be done, and that both their t and energy dependence have to be studied. The problem of the background remains which may alterate all possible conclusions. It is very likely that some theoretical progresses (such as multi-Regge formalism) will allow a better understanding of what is called the background, in order to make sure that one is effectively considering a quasi two-body reaction.

energy \ t		-0.05	-0.15	-0.30	-0.70
4.1 GeV/c 11)	σ_1^+	0.6 ± 0.14	0.7 ± 0.1	0.79 ± 0.08	0.72 ± 0.11
	σ_1^-	0.0 ± 0.14	0.04 ± 0.1	0.07 ± 0.08	0.06 ± 0.11
5.5 GeV/c 11)	σ_1^+	0.61 ± 0.1	0.87 ± 0.08	0.77 ± 0.07	0.82 ± 0.11
	σ_1^-	0.11 ± 0.1	0.11 ± 0.08	0.10 ± 0.07	0.08 ± 0.11
10 GeV/c 12)	σ_1^+	0.70 ± 0.09	0.93 ± 0.1	0.66 ± 0.12	0.80 ± 0.11
	σ_1^-	0.02 ± 0.09	0.01 ± 0.1	0.20 ± 0.12	0.08 ± 0.11

- Table I -

Computation of $\sigma_1^\pm$ for reaction $K^- p \rightarrow pK^{*-}$ (890)

energy \ t		-0.05	-0.15	-0.30	-0.70
4.1 GeV/c 11)	σ_1^+	0.19 ± 0.11	0.21 ± 0.15	0.40 ± 0.16	0.50 ± 0.14
	σ_1^-	0.25 ± 0.11	0.17 ± 0.15	0.21 ± 0.16	0.14 ± 0.14
5.5 GeV/c 11)	σ_1^+	0.17 ± 0.11	0.35 ± 0.14	0.52 ± 0.16	0.58 ± 0.14
	σ_1^-	0.07 ± 0.11	0.15 ± 0.14	0.04 ± 0.16	0.16 ± 0.14
10 GeV/c 12)	σ_1^+	0.35 ± 0.10		0.44 ± 0.18	
	σ_1^-	0.03 ± 0.10		0.08 ± 0.18	

- Table II -

Computation of $\sigma_1^\pm$ for reaction $K^- p \rightarrow K^{*0}$ (890) n

R E F E R E N C E S

1) K. Gottfried and J.D. Jackson, Nuovo Cimento 33, 309 (1964).

2) B. Kaidalov, Phys.Letters 26B, 20 (1967);
G.A. Ringland and R.L. Thews, Berkeley preprint UCRL 18010.

3) A.P. Contogouris, H.J. Lubatti and J. Tran Thanh Van, Orsay preprint TH.220.

4) H. Högaasen and H.J. Lubatti, Phys.Letters 26B, 166 (1968).

5) G. Cohen-Tannoudji, A. Morel and Ph. Salin, CERN preprint TH. 860.

6) P. Stichel, Z.Physik 180, 170 (1964).

7) M. Le Bellac (private communication).

8) G. Cosenza, A. Sciarrino and M. Toller, University of Roma preprint (1967).

9) Aachen-Berlin-CERN collaboration (contribution to the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968).

10) Bonn-Durham-Nijmegen-Paris (E.P.)-Strasbourg and Turin collaboration (Paper presented at the Heidelberg International Conference on Elementary Particles, 1967).

11) F. Schweingruber et al., Argonne National Laboratory preprint (to be published in Physical Review).

12) Aachen-Berlin-CERN-London (I.C.)-Vienna collaboration, CERN preprint Physics 68-2.

13) M. Ferro-Luzzi et al., Nuovo Cimento 36, 1101 (1965);
W. De Baere et al., Nuovo Cimento 51A, 401 (1967).

14) J.D. Jackson and H. Pilkuhn, Nuovo Cimento 33, 906 (1964).

15) We recover some qualitative features obtained in a phenomenological fit by M. Markytan, CERN preprint, Physics 67-33.

16) R. George et al., Nuovo Cimento 49, 9 (1967).

17) R.A. Lewis (private communication).

18) J.P. Ader, M. Capdeville and Ph. Salin, Nuclear Phys. B3, 407 (1967).

19) D. Amati, G. Cohen-Tannoudji, R. Jengo and Ph. Salin, CERN preprint TH. 873.

20) J.S. Ball, W.R. Frazer and M. Jacob, UCLA preprint.

21) D. Brown, G. Gidal, R. Birge, R. Bacastow, Sun Yiu Fung, W. Jackson and R. Pu, Phys.Rev.Letters 19, 664 (1967).

22) Aachen-Berlin and CERN collaboration, Phys.Letters 22, 533 (1966).

FIGURE CAPTIONS

FIGURE 1

Experimental plot of $\sigma_1^{\pm}$ for reaction $\pi^+ p \rightarrow \rho^0 \Delta^{++}$ at 4 GeV/c [21], 5 GeV/c [10], and 8 GeV/c [22]. The curves are free hand fits to the data.

FIGURE 2

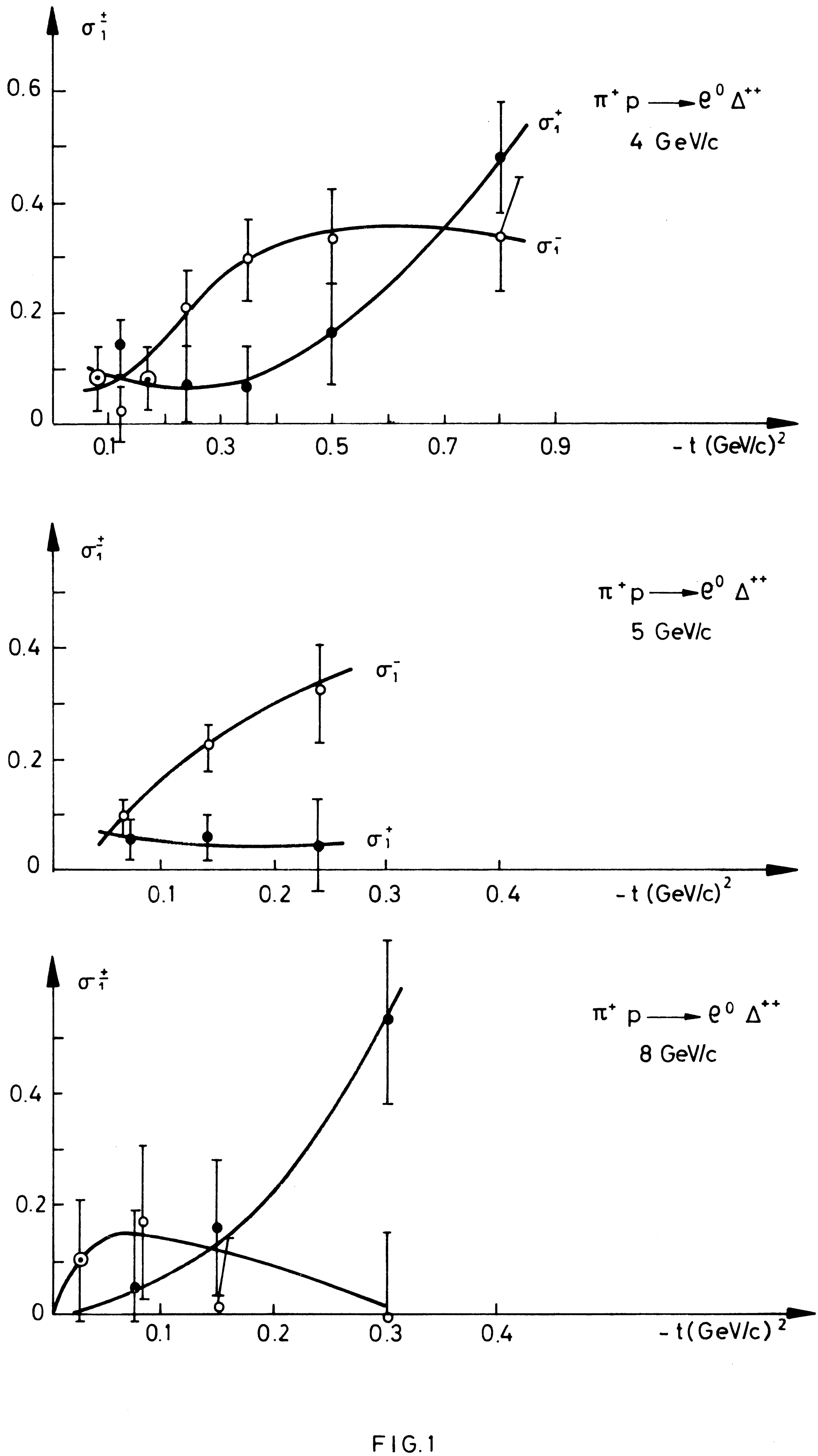
Experimental plot of $\sigma_1^{\pm}$ for reaction $\pi^+ p \rightarrow \omega \Delta^{++}$ at 5 GeV/c [10]. The curves are free hand fit to the data.

FIGURE 3

Polarized differential cross-sections for $\gamma\, p \rightarrow \pi^0 p$ at 5 GeV/c, when the polarization of the photon is parallel or perpendicular to the scattering plane. The curves are theoretical predictions from Ref. [18].

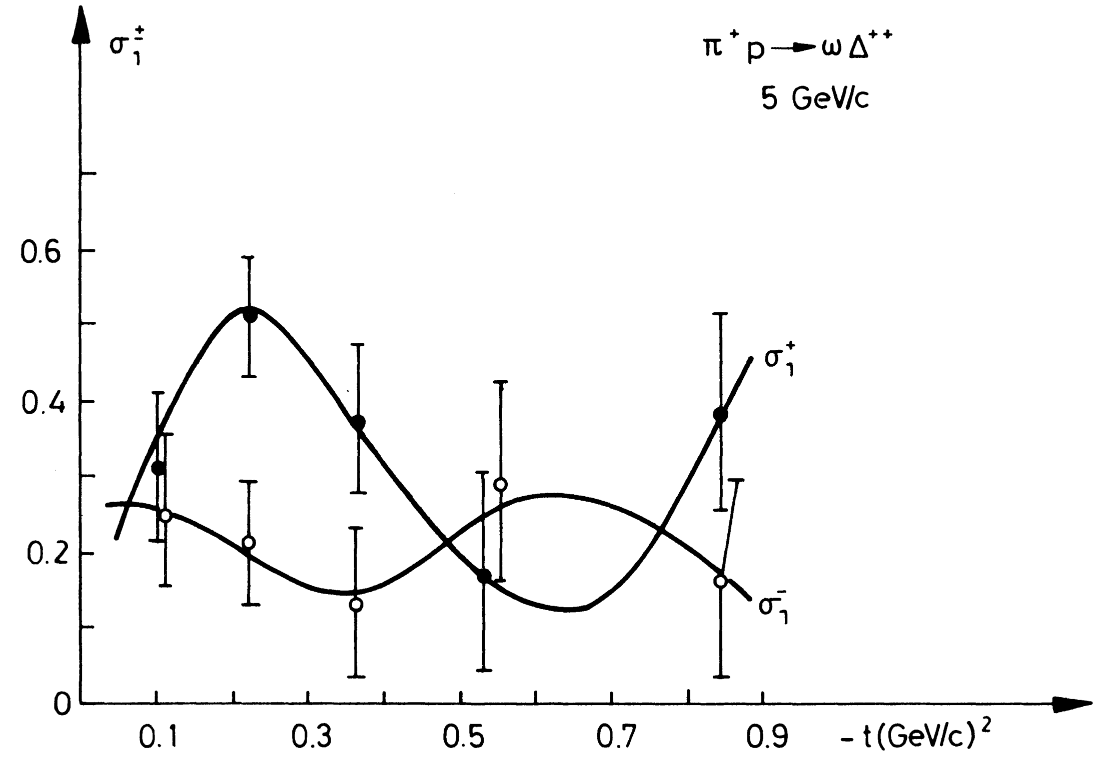
FIGURE 4

Polarized differential cross-sections for $\gamma\, p \rightarrow \pi^+ n$ at 5 GeV/c. Curves 1 and 2 are respectively predictions from the theoretical calculations of Refs. [19] and [20].



$\sigma_1^\pm$
0.6
0.4
0.2
0
$\pi^+ p \longrightarrow \rho^0 \Delta^{++}$
4 GeV/c
σ_1^+
σ_1^-
0.1
0.3
0.5
0.7
0.9
$-t\ (GeV/c)^2$
$\sigma_1^\pm$
0.4
0.2
0
$\pi^+ p \longrightarrow \rho^0 \Delta^{++}$
5 GeV/c
σ_1^-
σ_1^+
0.1
0.2
0.3
0.4
$-t\ (GeV/c)^2$
$\sigma_1^\pm$
0.4
0.2
0
$\pi^+ p \longrightarrow \rho^0 \Delta^{++}$
8 GeV/c
0.1
0.2
0.3
0.4
$-t\ (GeV/c)^2$

FIG.1



$\sigma_1^{\pm}$
$\pi^+ p \rightarrow \omega \Delta^{++}$
5 GeV/c
0.6
0.4
0.2
0
σ_1^{+}
σ_1^{-}
0.1
0.3
0.5
0.7
0.9
$-t\,(\mathrm{GeV}/c)^2$

FIG. 2

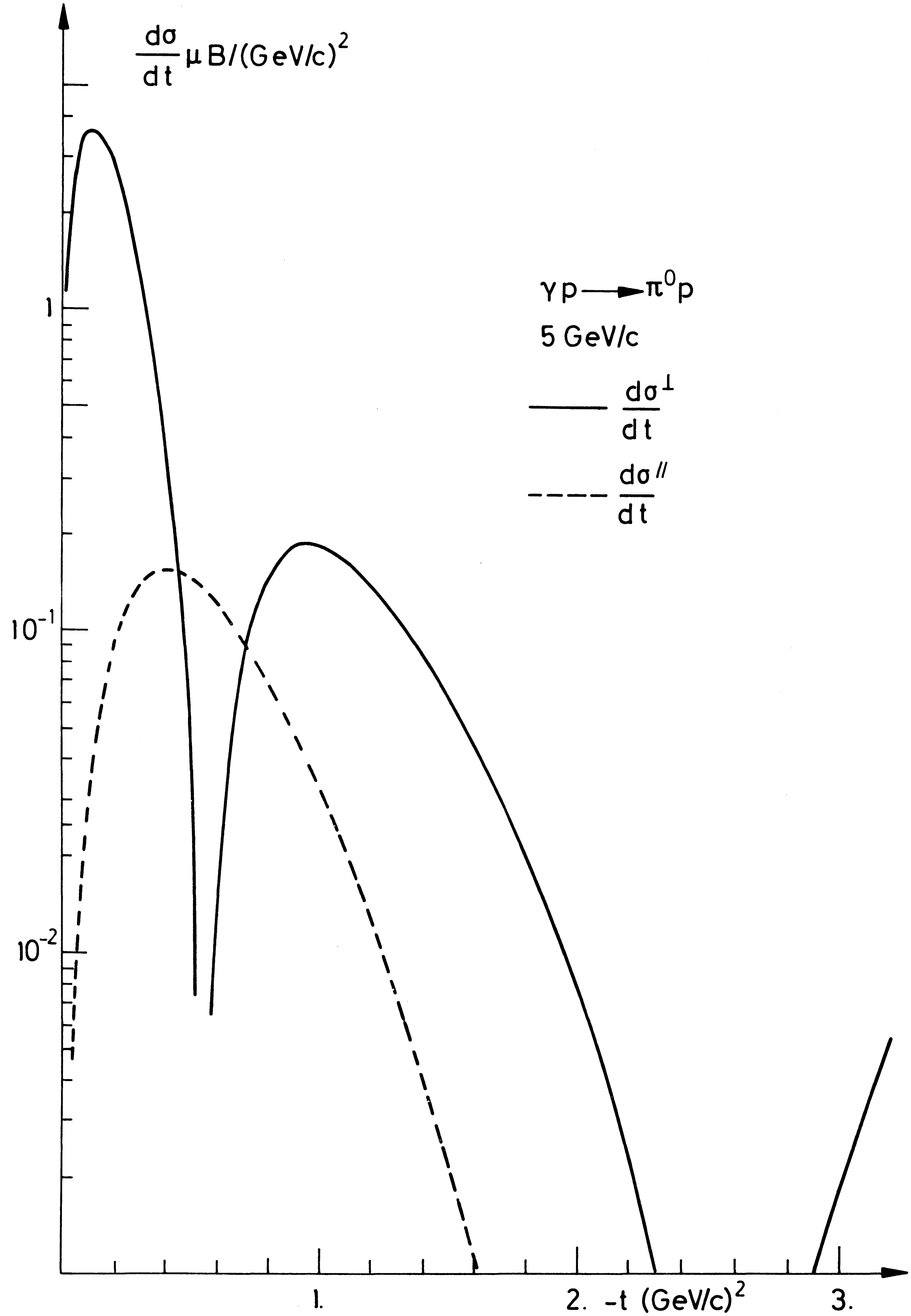
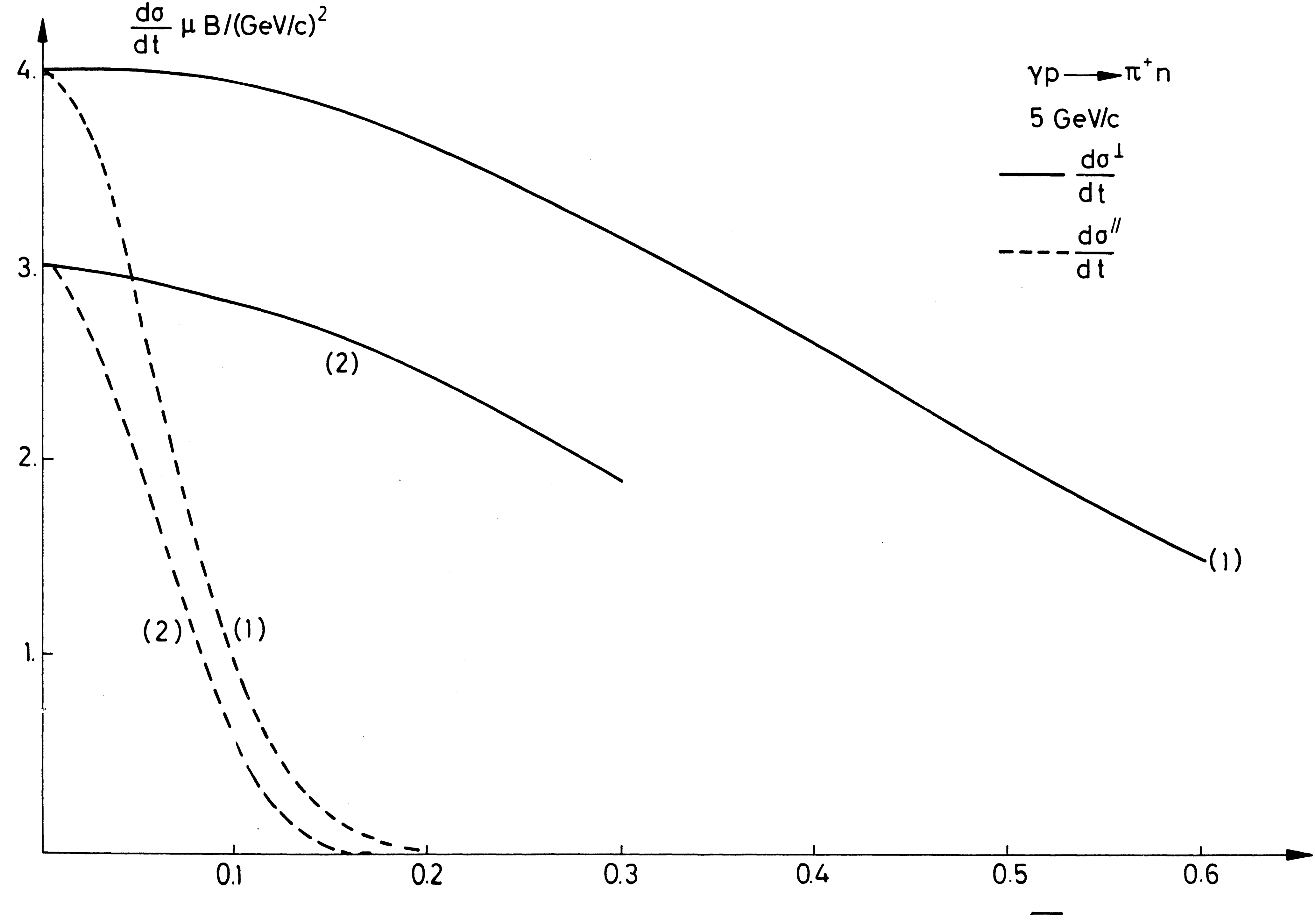

$\frac{d\sigma}{dt}$ μB/(GeV/c)^2
1
10^{-1}
10^{-2}
$\gamma p \rightarrow \pi^0 p$
5 GeV/c
$\frac{d\sigma^{\perp}}{dt}$
$\frac{d\sigma^{//}}{dt}$
1.
2.
3.
$-t$ (GeV/c)^2

FIG.3



dσ/dt μB/(GeV/c)^2
4.
3.
2.
1.
γp ⟶ π⁺n
5 GeV/c
dσ⊥/dt
dσ∥/dt
(1)
(2)
(2)
(1)
0.1
0.2
0.3
0.4
0.5
0.6
√-t GeV/c

FIG 4