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TRIPLE REGGE BEHAVIOUR IN INCLUSIVE REACTIONS

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A B S T R A C T

Prominent features associated with a triple Reggeon formula are found to meet the low momentum transfer domain of the $K^+p(K^0)$ inclusive reaction.

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Results on the inclusive reaction $K^+p \rightarrow K^0 + \text{anything}$ have recently become available at 5 and 8.2 GeV/c¹⁾. In this note, we present an analysis of these data together with some preliminary data at 16 GeV/c²⁾ on the same reaction. This analysis gives support for a description of the small momentum transfer region in terms of a triple Reggeon picture. The $\rho - A_2$ trajectory, as determined in this way, is in reasonable agreement with expectations drawn from the analysis of two-body processes. The missing mass spectra, as predicted by this leading trajectory for different values of the momentum transfer, agree with observation. A simplified asymptotic picture is thus found to work reasonably well at relatively low energies.

Several features of the $K^+p(K^0)$ and $K^-p(\bar{K}^0)$ inclusive reactions have been already reported in detail¹⁾. Among the prominent facts we notice that

- i) a very large fraction of the observed events correspond to low momentum transfer $|t|$ between the initial and final kaons;
- ii) for each value of $|t|$ the missing mass spectra show an increase which is the fastest the higher t is in absolute value. At the same time the mass spectra suggest an overall scaling when one goes from the 5 GeV/c to the 8.2 GeV/c results. In particular, the conspicuous resonance bumps and the smother "background" appear to drop down at the same pace, a feature the reliable check of which obviously calls for more accurate results at higher energies;
- iii) as previously remarked¹⁾, the combined 5 and 8.2 GeV/c results may look to an "optimistic eye" as evidence for Feynman's scaling property³⁾.

The first feature calls for a simple Regge exchange model which, for each narrow missing mass range, thought of as an effective one-particle state, leads to our considering of the reaction amplitude depicted by Fig. 1a, and to our writing of the inclusive cross-section (at low $|t|$ values) as

$$\omega \frac{d\sigma}{dq_L dq_\perp^2} = \frac{1}{pm} (\beta(t))^2 M^2 \sigma_{\text{tot}}(M^2, t) \left(\frac{s}{M^2}\right)^{2\alpha(t)} \quad (1)$$

q_L , $q_\perp$ and ω respectively stand for the longitudinal momentum, transverse momentum and energy of the secondary (K^0). p is the laboratory momentum of the incident particle (K^+) and m the target (proton) mass. s is the centre-of-mass energy squared and M stands for the missing mass to the selected secondary (K^0). $\sigma_{\text{tot}}(M^2, t)$ is the total Reggeon proton cross-section for a centre-of-mass energy M and a Reggeon mass squared t . $\alpha(t)$ stands for the leading exchanged trajectory (ρ - A_2).

This expression is expected to be reliable when s/M^2 is large. As an alternative to this description, one may associate the inclusive cross-section to the term obtained from the inelastic contribution to the imaginary part of the K^+p amplitude when one does not perform the phase-space integration over the intermediate K^0 , assumed to proceed from the incident K^+ through simple Regge exchange. This is justified for low transfers. This is illustrated by Fig. 1b and warrants our writing of (1) for an arbitrary M^2 range provided that s/M^2 is large ⁴⁾. At large values of M^2 we would now expect the total Reggeon proton cross-section to be given by Pomeron exchange and one is thus led to approximate the term associated with Fig. 1b by the one given by Fig. 1c, whereby a triple Reggeon vertex, involving the Pomeron P once, has been introduced. At intermediate values of M^2 we expect low trajectories R to be also of some importance. Through duality this picture can furthermore be extended to still lower M^2 values, the P and R contributions interpolating respectively the background and the resonances ⁵⁾. Since we consider a charge exchange reaction, we do not have to introduce multi-Pomeron couplings which, if large as to be relevant, would lead to theoretical

troubles ⁶⁾. Furthermore, since the incoming and outgoing Reggeons are not Pomeranchons but ordinary trajectories, it is reliable to assume that the energy dependence of the Reggeon proton total cross-section is similar to that of a standard two-body cross-section.

This reasoning then leads to the following formula

$$\omega \frac{d\sigma}{dq_L dq_\perp^2} = \frac{1}{p_m} (\gamma(t))^2 \left(\frac{s}{M^2}\right)^{2\alpha(t)} (M^2)^{\bar{\alpha}(0)} \quad (2)$$

where $\bar{\alpha}(0)$ stands for an effective intercept for the trajectories (P and R) which describe the energy behaviour of the Reggeon proton total cross-section. At large M^2 , $\bar{\alpha}(0)$ should be 1 but it is expected to drift somewhat closer to $\frac{1}{2}$ as M^2 decreases. We rewrite (2) as

$$\frac{d\sigma}{dt dM} = \frac{1}{p^2} B(t) \left(\frac{s}{M^2}\right)^{2\alpha(t)} M^{2\bar{\alpha}(0)+1} \quad (3)$$

The comparison with experiment proceeds as follows: the leading trajectory $\alpha(t)$ can be determined for several t intervals using the accurate 5 and 8.2 GeV/c data and a help from the preliminary results at 16 GeV/c. This can be done for different M ranges, (3) being expected to be the more accurate the higher s/M^2 is. Not to be affected by the kinematic boundaries, we made a separate determination of $\alpha(t)$ for two missing mass intervals $1 < M < 1.7$ GeV and $1.7 < M < 2.2$ GeV using four $|t|$ ranges $[0.05-0.2; 0.2-0.4; 0.4-0.6$ and $0.6-1$ (GeV/c)²]. The results obtained are shown on Fig. 2. For the large mass values the points fall somewhat below the value of $\alpha(t)$ which one

expects from the analysis of two-body reactions. Nevertheless, they well reproduce the general trend which is predicted and, in particular, shows shrinkage. Discrepancies between the two determinations can be attributed to the decreasing reliability of (3) as M increases for fixed s . In (3) we have used the correct kinematical factor p^{-2} but kept the asymptotic term s/M^2 . Indeed, in the framework of an analysis in terms of leading Regge poles, it is irrelevant to try to improve on it.

Equation (1) [and a fortiori Eq. (3)] predicts a similar shape for the M spectra at fixed t obtained for different values of s . As shown on Fig. 3, it is well satisfied by the data. Alternatively, this can be seen from the general agreement between values of $\chi(t)$ obtained for different values of M , as shown by Fig. 2. As clear from relation (2), the s dependence is disconnected from the M behaviour. The resonances and the "background" should therefore behave the same way as s varies. Rephrased according to (3) this means that the triple Reggeon couplings without Pomeron (dual to the resonances) and with one single Pomeron (dual to the background) are both present. Furthermore, once $\chi(t)$ has been determined, (3) fixes the M distribution. The linear behaviour of $\log(d\sigma/dM)$ is well reproduced if one keeps in mind that a fixed value for $\bar{\alpha}(0)$ is but an approximation with the data we are considering. The actual value of the slope which varies much from one t interval to the other is also reasonably well predicted. Indeed, $\bar{\alpha}(0)$, as defined in Eq. (3), can be fitted to the data and Fig. 4 gives, for instance, the values obtained for the different t intervals considered using the 8.2 GeV/c data. This is compatible with a value of $\bar{\alpha}(0)$ close to 1, when we expect an effective intercept somewhere between $\frac{1}{2}$ and 1. Equation (3) exhibits an obvious scaling property in the high s , high M^2 and fixed s/M^2 limit. This requires $\bar{\alpha}(0) = 1$, as expected and found compatible with the present data.

We, therefore, come to the conclusion that a simple Regge model reproduces the most significant features of the low momentum transfer data. Our using of a charge exchange reaction with data at different energies should be a more reliable procedure than the missing mass analysis with leading Pomeron and baryon exchange recently attempted for pp inclusive reactions at $19.2 \text{ GeV}/c$ ⁷⁾. The success which we meet in contradistinction to the pessimistic conclusions of Ref. 7), speaks in favour of Regge models as a guide to charge exchange inclusive reactions at present machine energies.

We close with a few general remarks. The same type of analysis should obviously also apply to the $K^-p(\bar{K}^0)$ inclusive reaction and a similar analysis of the 4 and 10 GeV/c data soon to be available ⁸⁾ should be made. According to the Regge model, differences between the $K^+p(K^0)$ and $K^-p(\bar{K}^0)$ inclusive reactions are to be attributed to mixed ρA_2 exchange. Such terms should, however, vanish if the ρ and A_2 trajectories are exchange degenerate, an approximation which should be quite reliable for the present purposes. We should, however, stress that such an equality between the K^+ and K^- data should hold only in the Regge limit here considered and not for $K^0(\bar{K}^0)$ which would be slow in the centre-of-mass. The $K^+p(K^*)$ inclusive reactions should obviously also follow the same pattern (again for low transfer K^*s) since vector and tensor exchange are known to play a leading role in K^* production. This is, furthermore, the case if one considers $(\rho_{11} + \rho_{1-1}) \sigma$ rather than the total K^* inclusive cross-section σ . Were one to consider instead $\rho_{00} \sigma$, pion exchange would be isolated and, according to (3), one would expect a quite different behaviour in M and in s . We predict that the $\rho_{00} \sigma$ inclusive cross-section should show a sharper increase in M than the $(\rho_{11} + \rho_{1-1}) \sigma$ one. This is most interesting to test and will be the object of a forthcoming analysis. Another reaction in which pion exchange could also enter the same way is the $pp \rightarrow (n)$ inclusive reaction which could be studied at the ISR.

The analysis can obviously be extended to hypercharge exchange reactions and the K^- data show slow Λ 's (small momentum transfer between the target proton and the produced Λ) for which a relation such as (3) with K^*-K^{*0} exchange should be tried.

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FIGURE CAPTIONS

Figure 1a : Regge exchange in production process.

Figure 1b : Regge exchange contribution to an inclusive reaction cross-section.

Figure 1c : Triple Reggeon coupling term summarizing the inclusive cross-section for large missing mass.

Figure 2 : Leading Regge trajectory as determined from the data using the $1 < M < 1.7$ GeV and $1.7 < M < 2.2$ GeV mass intervals.

Figure 3 : $\log (d\sigma/dM)$ as a function of $\log M$ for four-momentum transfer intervals $0.05 < |t| < 0.2$, $0.2 < |t| < 0.4$, $0.4 < |t| < 0.6$ and $0.6 < |t| < 1$.

a - 5 GeV/c data

b - 8.2 GeV/c data.

Figure 4 : Effective intercept as determined from the mass distribution for the different t intervals at 8.2 GeV/c.

FIG. 1

Fig.2

Fig. 3

Fig. 4