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Charge asymmetry in particle production at large transverse momentum

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It is shown that a simple Regge formula explains the recent experimental results on particle asymmetries at large transverse momentum in the forward and backward directions.

Recently charge asymmetries in inelastic $\pi^- p$ interactions at 205 GeV/c ($s = 385$ GeV^2) were reported by a Berkeley-Fermilab collaboration.[1] For $P_T > 1.0$ GeV/c negative particles moving forward in the center-of-mass system outnumber similar positive particles in the ratio of 3.7 to 1, greatly in excess of the corresponding ratio for small transverse momentum. The asymmetry is reversed in the backward direction. In the same paper these results were interpreted as suggestive of hard collisions with structural entities like partons in the pion and proton and of such models as, for example, the quark-fusion model.[2]

It is the purpose to report here that the observed experimental behavior at high P_T can be understood within the framework of the triple-Regge formula. Quantitative predictions for the value of the asymmetry as a function of P_T are presented.

Consider the reactions

$$\pi^- p \rightarrow \pi^\pm + \text{anything} \tag{1}$$

in the fragmentation region of the beam and target. For simplifications we have considered that the produced particles are pions; from the known π/p and π/K ratios, the bulk of the effect is indeed due to π production.

In Fig. 1 we draw the corresponding triple-Regge diagrams. P stands for Pomeron and the $\alpha(t)$ are the exchanged Regge trajectories. In the *backward* direction for π^+ production the dominant exchanged trajectory is the neutron, while for π^- production only the Δ^{++} trajectory is allowed. In the *forward* direction for π^- production the dominant trajectory is the P, and for π^+ production we have an exotic exchange.

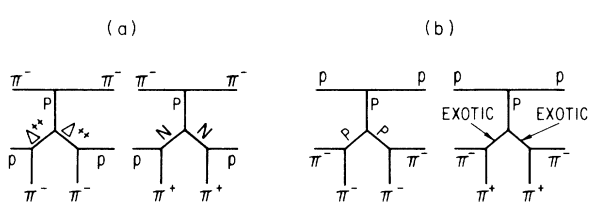

FIG. 1. Triple-Regge diagrams of the reactions $\pi^- p \rightarrow \pi^\pm +$ anything (a) in the fragmentation region of the target, (b) in the fragmentation region of the beam.

We can now write the expressions[3] for the ratio π^+/π^-:

$$R_{\text{Backward}}(\pi^+/\pi^-) = N_B \frac{|\beta_N(t)|^2(1-|x|)^{1-2\alpha_N(t)}}{|\beta_\Delta(t)|^2(1-|x|)^{1-2\alpha_\Delta(t)}}, \tag{2}$$

where $\beta(t)$ are the Regge residues and the other couplings are included in the normalization constant N_B. From kinematics

$$t = m^2(1-|x|) + \mu^2 - (P_T^2 + \mu^2)/|x|, \tag{3}$$

where m is the mass of the proton, μ is the mass of the pion, and P_T is the transverse momentum. We have also used the relation

$$M^2/s \cong 1 - |x|. \tag{4}$$

Similarly, in the forward direction,

$$R_{\text{Forward}}(\pi^+/\pi^-) = N_F \frac{|\beta_{\text{Exotic}}(t)|^2(1-|x|)^{1-2\alpha_{\text{Exotic}}(t)}}{|\beta_P(t)|^2(1-|x|)^{1-2\alpha_P(t)}}. \tag{5}$$

In Table I, we present the values of the different trajectories obtained in inclusive analyses[4,5] and utilized in this calculation. If we integrate relations (2) and (5) with respect to the variable x (with the condition $|x| > 0.8$), we obtain the expressions for the ratio π^+/π^- as a function of P_T.

In Figs. 2 and 3 are shown the values of the ratio π^+/π^- as a function of P_T for the backward and forward directions, respectively. In Fig. 2 the solid curve represents the calculation with the values of $\beta_N(t)$ and $\beta_\Delta(t)$ as obtained in Ref. 4. The dashed curve represents the calculation with $\beta(t)$

TABLE I. Regge trajectories obtained in inclusive analyses. (t in GeV^2.)

$\alpha_N(t) = -1.35 + 0.35t$
$\alpha_\Delta(t) = -1.9 + 0.75t$
$\alpha_P(t) = -0.1 + 0.43t$
$\alpha_{\text{Exotic}}(t)$ [a] $= -0.4 + 0.7t$

[a] We have taken this value as representative of an exotic exchange.

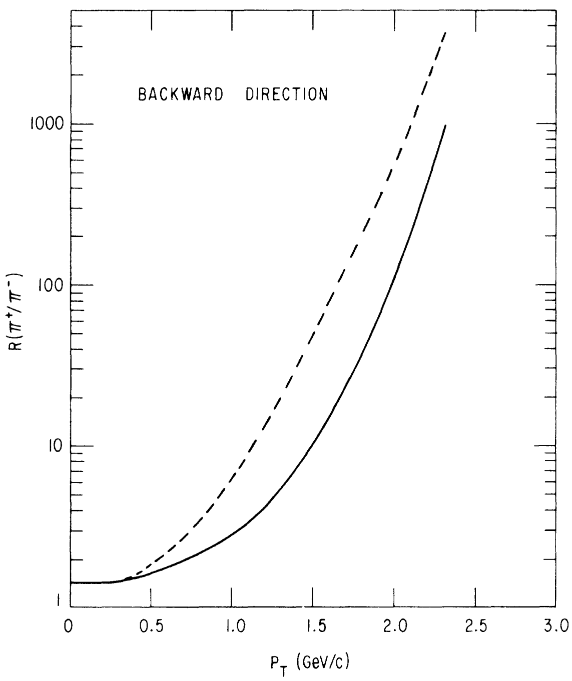

FIG. 2. Predictions for the π^+/π^- asymmetry in the backward direction.

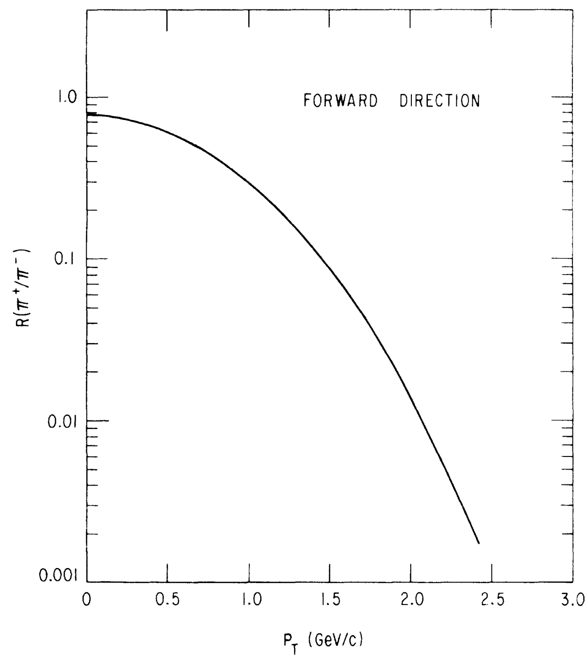

FIG. 3. Predictions for the π^+/π^- asymmetry in the forward direction.

$=1$. In both cases we have normalized to the experimental value obtained in the region $P_T < 0.4$ GeV/c, where the ratio is nearly constant. There is a slow increase (decrease) between 0.5 and 1.0 GeV/c and a drastic change between 1.0 to 2.0 GeV/c attaining a value of 100 (0.01) for P_T greater than 2 GeV/c in the backward (forward) direction.

To be able to compare these predictions with the experimental values of the Berkeley-Fermilab collaboration we have calculated the average values in the corresponding intervals of P_T, weighted by the observed exponential decrease with a slope of ~8.[6] Results are presented in Table II, and they are in very good agreement with the experimental values.

It is important to remark that our results are valid only in the forward and backward directions. Other experimental results have been published on particle production with large P_T in the region of 90° in the center-of-mass system and small charge asymmetries[7] have been reported.

In conclusion, we have shown that a simple Regge expression explains well the recent experimental results on charge asymmetries in particle production at large transverse momentum. For P_T greater than 2 GeV/c we produce mostly particles of one sign, positive in the backward direction and negative in the forward direction. This means that the greater the P_T, the greater is the tendency of the produced particles to be associated as fragments of the beam or of the target.

TABLE II. π^+/π^- asymmetry.

P_T interval (GeV/c)	Backward[a] Experiment	Backward[a] Prediction	Forward Experiment	Forward Prediction
$P_T < 0.5$	1.49 ± 0.07	1.49[b]	0.76 ± 0.04	0.76[b]
$0.5 < P_T < 1.0$	1.85 ± 0.15	1.79	0.53 ± 0.04	0.58
$P_T > 1.0$	3.4 ± 1.1	2.91	0.27 ± 0.06	0.28

[a] Solid-curve predictions.
[b] This region has been used for normalization.

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[7]B. Alper *et al.*, in report to London Conference on High Energy Physics, 1974 (and references therein) (unpublished).