Scaling of velocity distributions in $\pi^- p$ interactions at $P_{\pi^-} = 40$ GeV/c

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The velocity distributions of secondary particles in inelastic $\pi^- p$ interactions in the events with different partial inelastic coefficients behave in a self-similar way. They also have a plateau in the central region.

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It is well known that the velocity distributions of secondary particles produced in inelastic hadron-hadron interactions do not have, at least at the attained energies, a significant plateau in the central region, which is predicted by certain multiperipheral and Regge models at asymptotically high energies (see Ref. 1 and the citations therein). Within the context of such models, this is explained by the fact that there are several mechanisms (processes) of particle generation. Among them there are processes that have asymptotic properties and those responsible for the formation of a plateau, as well as processes whose contributions to the total cross section decline with increasing energy. Since the mechanisms of these processes differ substantially from each other, it has been frequently suggested that they are responsible for the "filling" of different regions of phase space. If this is correct, then the processes in which the velocity distributions of secondary particles have a well-defined plateau can be identified by somehow isolating the different regions of phase space. Such formulation of the problem is not new, since the systematics of associative production of particles have been studied for some time (see, for example, the review article[6]); however, further experimental and theoretical studies of multiple distributions have not been carried out. This is attributable in part to ambiguity in the selection of different regions of phase space and to the difficulty of calculating the phase-volume limitations. From this point of view, it seems to us that the study of semi-inclusive reactions such as

$$\begin{aligned} \pi^- + p &\to n\pi^+ + X \\ \pi^- + p &\to n\pi^- + X \end{aligned} \qquad (1)$$

is very promising. The first result of the analysis of such reactions gave good results.[3] In keeping with the procedure of Ref. 3, below we shall analyze the velocity distributions of positively and negatively charged particles in the reactions (1).

The experimental data used in the analysis are the data for inelastic $\pi^- p$ interactions at $P_{\pi^-} = 40$ GeV/c, which were obtained in a two-meter propane bubble chamber of the High Energy Physics Laboratory of the Joint Institute for Nuclear Research and which were analyzed according to accepted procedures.[4]

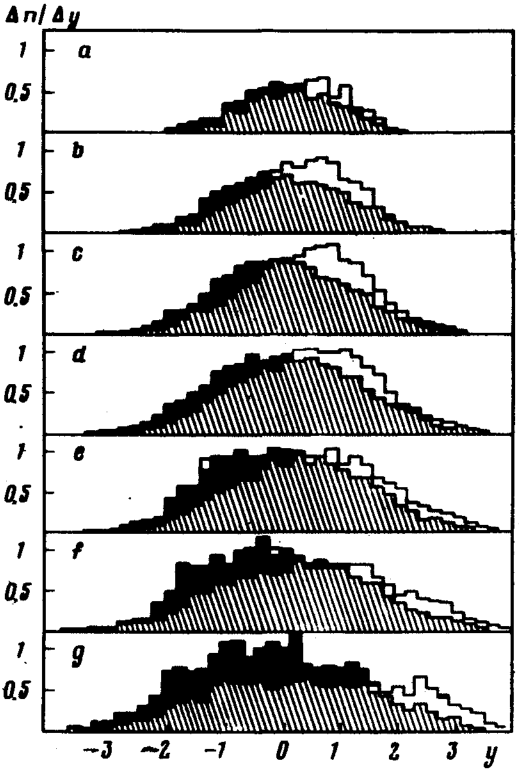

FIG. 1. Velocity distributions of charged particles in $\pi^- p$ interactions in the events corresponding to seven successive intervals of $k^{(\pm)}$: (a) 0–0.07, (b) 0.07–0.14, (c) 0.14–0.21, (d) 0.21–0.28, (e) 0.28–0.35, (f) 0.35–0.42, and (g) 0.42–0.49. The dark histograms represent π^+-meson distributions and the light histograms denote π^--meson distributions. The hatched part of the histograms represents the overlap regions.

We have isolated the phase-space regions by selecting an arbitrary value of the partial inelastic coefficient which was assumed to be the quantity

$$k^{(\pm)} = \Sigma E^*_{\pi^{(\pm)}} / \sqrt{s}, \tag{2}$$

where $\sqrt{s}$ is the total energy in the center-of-mass system of the incident pion and proton of the target (c.m.s.), $E^*_{\pi(\pm)}$ is the energy of positively (negatively) charged π meson in the c.m.s., and the sum in the expression (2) is taken over all the particles of the same sign.[1)] In studying the velocity distributions of positively and negatively charged secondary particles,[1)] we have noticed the following features in the events that differ in the values of $k^{(\pm)}$ (see Fig. 1).

1. The π^+ and π^--meson distributions differ for all partial inelastic coefficients; the π^+-meson distributions are roughly symmetric in the c.m.s. with respect to the point $y = 0$ and the π^--meson distributions are shifted in the forward direction with respect to this point.

2. The π^+-meson distributions for $k^+ > 0.2$ are similar to each other.

3. The velocity distributions of charged particles have a plateau in the events with $k^{(\pm)} > 0.2$, whose width increases with increasing $k^{(\pm)}$.

To emphasize the second point more clearly, we shall use the hypothesis of velocity-distribution scaling,[5] which essentially states that

$$\frac{dn}{dy} = \Phi(Y)\,\phi(y/Y), \tag{3}$$

where Y is a scale factor. It follows directly from the relation (3) that

$$\begin{cases} \left.\dfrac{dn}{dy}\right|_{y=0} = \Phi(Y)\,c_1 & c_1 = \phi(0) \\ \bar{n} = \int \dfrac{dn}{dy}\,dy = Y\Phi(Y)\,c_2 & c_2 = \int \phi(z)\,dz \end{cases} \tag{4}$$

Solving Eqs. (4) for the unknown Y and $\Phi(Y)$ and using them in the relation (3), we

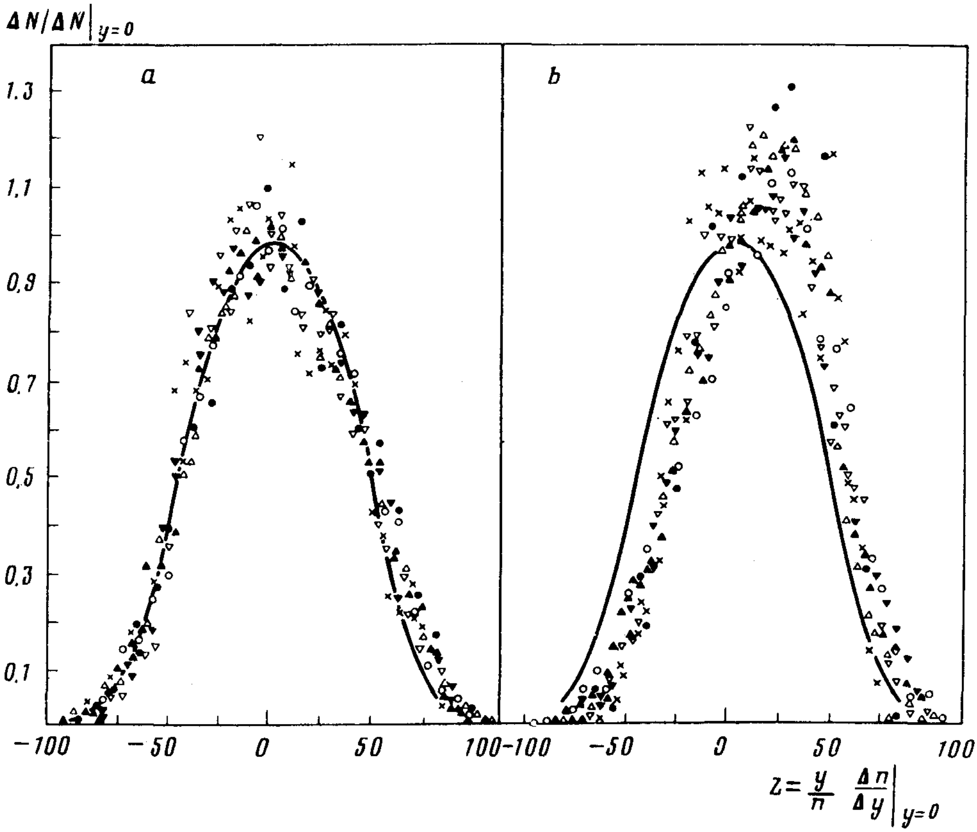

FIG. 2. The distributions in Fig. 1 are shown in scaled form (a) for π^+ mesons and (b) for π^- mesons. The points •, ○, ▲, △, ▼, ▽, and × correspond to the seven intervals of $k^{(\pm)}$ indicated in Fig. 1.

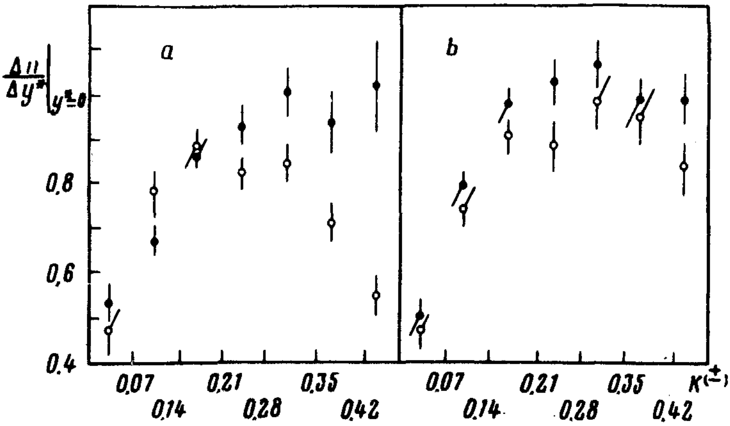

FIG. 3. The quantity $dn/dy|_{y=0}$ for π^+ mesons (dark circles) and for π^- mesons (light circles) is plotted as a function of $k^{(\pm)}$ (a) for all the events and (b) for the nondiffraction events.

find that

$$\frac{dn}{dy} \bigg/ \frac{dn}{dy}\bigg|_{y=0} = \frac{1}{c_1}\,\phi\left(y c_2 \frac{dn}{dy}\bigg|_{y=0} \bigg/ c_1 \bar{n}\right) = \psi\left(\frac{y}{\bar{n}}\,\frac{dn}{dy}\bigg|_{y=0}\right) \quad (5)$$

if the velocity-distribution scaling is realized. The distributions in Fig. 1, which are represented in appropriate form (see Fig. 2), show that there is a velocity-distribution scaling in the investigated interactions. It is clear that the theoretical models mentioned above presuppose its existence if the generation mechanism can be identified in some way. Thus the velocity-distribution scaling and the existence of a plateau show that the particles apparently are generated in the events with a fixed value of $k^{(\pm)}$ according to a single production mechanism. If a subsequent theoretical analysis will confirm this assumption, then a direct experimental verification of the different predictions of the multiperipheral models will be possible. The existence of distributions, which have a plateau, is important in itself, irrespective of this possibility.

In conclusion, we note that the height of the plateau of the π^--meson distributions is determined to a large extent by the diffraction processes. We can see that the characteristics of π^+ mesons are similar to those of π^- mesons after the elimination of diffraction events (Fig. 3).

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[1)] In addition to the identified protons, all the positively and negatively charged particles are assumed to be π mesons.

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