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Spectra of Produced Pions in Meson-Nucleon Collisions in the Diffractive Model *

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The longitudinal-momentum distributions of produced pions in Kp and πp inclusive reactions are calculated in the framework of the diffractive model. Not only is the backward-forward asymmetry predicted, but the absolute slopes are also determined without any parameters in good agreement with experiment.

This note is an addendum to Ref. 1 in which the proton and pion spectra in pp collisions have been studied in the diffractive model. The extension of that work to Kp and πp inclusive reactions is considered here.

Let us first summarize briefly the basis of the model. A multiparticle production process at high energy is viewed in this model as a collision in which the two incident hadrons are diffractively scattered (via the exchange of the Pomeranchukon) into two excited states. The latter subsequently decay isotropically in their respective rest frames with an average energy for each pion that is independent of the incident energy and the number of particles produced. The production cross section depends on the masses of the excited states in a way that is in accordance with the vanishing of the triple-Pomeranchukon coupling. In fact, we found

$$d\sigma/dM_1 \propto M_1^{-2}, \tag{1}$$

where M_1 is the mass of one of the excited states. Because the Pomeranchukon has been assumed factorizable, the same can be written for M_2, the mass of the other excited state; moreover, this dependence on M_1 and M_2 is independent of the nature of the incident particles. Consequently, the analysis in Ref. 1 can be straightforwardly applied to the meson-nucleon collisions.

The pion spectra on the proton side of these collisions are identical to those in the pp collisions. The pion spectra on the meson side differ only slightly. For a Kp collision, the "nucleus" of the decay cluster of the excited-K state is the kaon just as it is for the proton in the case of the excited-proton state. Thus, all we need is to replace M (mass of proton) in Ref. 1 by M_K, the mass of the K meson. The invariant cross section for the pion spectrum at infinite energy has the same form as before [Eq. (15) of Ref. 1].

$$F(x) = x\frac{d\sigma}{dx} = \xi A\left(\frac{\alpha}{\pi}\right)^{1/2}(G_1 - \xi x G_2), \tag{2}$$

where

$$G_1 = \tfrac{1}{2}(\pi/\alpha)^{1/2}(1 - \mathrm{erf}\{\sqrt{\alpha}[(\xi+n_0)x - 1]\}), \tag{3}$$

$$G_2 = \int_{(\xi+n_0)x}^{\infty}(dz/z)e^{-\alpha(z-1)^2}, \tag{4}$$

$$\alpha \equiv E^2/\langle k_\perp^2\rangle = \langle k^0\rangle^2/\langle k_\perp^2\rangle = 1.516. \tag{5}$$

The only difference is that the parameter ξ should now be M_K/E rather than M/E. The multiplicity n_0 of the produced pions in a minimal cluster should be 1 if the pion detected from the kaon side has the same charge as the kaon; otherwise it should be 2.

For πp collisions, all the decay products of the excited-π cluster are pions. Thus, they should all be treated on equal footing. Since n_1 is the number of produced pions in the (first) cluster, the mass of the cluster should, therefore, be $M_1 = (n_1+1)E$. Hence, $\xi = 1$. This is the only modification we need in the above equations to determine $F(x)$ for πp collisions. It is, however, important to note in the present case that the spectrum so determined should correspond only to the produced pions, since the "through-going" pions have not been properly taken into account. That means that the results are valid only for $\pi^\pm p \to \pi^\mp +$ anything. The value of n_0 is 2 in either case because the pion cluster is always odd for diffractive excitation.

We have computed $F(x)/x$ at infinite energy with $n_0 = 2$ for both Kp and πp collisions; they are shown as heavy solid lines on the right side of Fig. 1. The left side is the pion spectrum from the proton also for $n_0 = 2$, as calculated in Ref. 1. Note that we have plotted $d\sigma/dx$ instead of the invariant cross

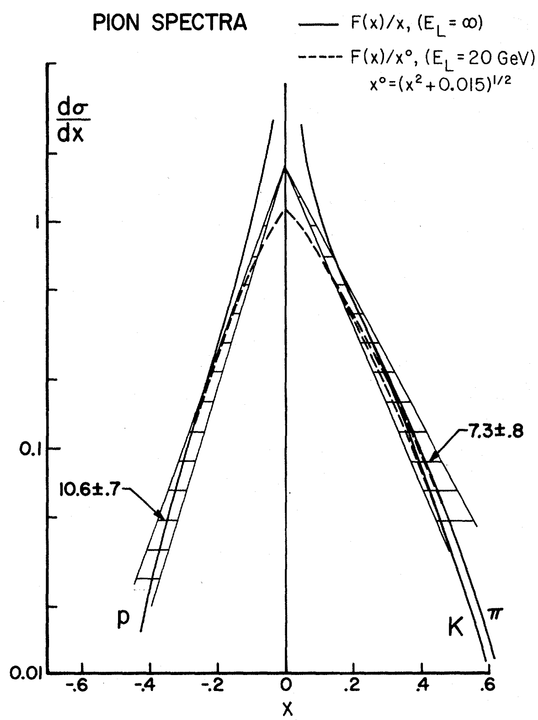

FIG. 1. Pion spectra in Kp and πp collisions. Solid curves are for infinite energy; broken curves are for $E_L = 20$ GeV. The experimental points (Refs. 2–6) all fall within the shaded regions.

section $F(x)$ because the experimental data at laboratory energies appear simplest in that plot. Our results show divergence at $x = 0$ because the incident energy has been taken to be infinity. To correct for this unreality, we have also plotted $F(x)/x^0$, where $x^0 = 2k^{*0}/\sqrt{s}$, k^{*0} being the c.m. pion energy and s corresponding to 20 GeV. The supposition here is that $F(x)$ is limiting at 20 GeV already. The results are shown in broken lines. There is no significant variation in the shapes of these curves if the incident energy is varied from 10 to 25 GeV.

Data are available for $K^+p \to \pi^- X$ (11.8 GeV),[2] $\pi^- p \to \pi^\pm X$ (25 GeV),[3] $\pi^+ p \to \pi^- X$ (18.5 GeV),[4] $K^+p \to \pi^- X$ (12.7 GeV),[5] and $K^- p \to \pi^+ X$ (9 GeV).[6] Though taken at various energies, they are all remarkably straight in the log plot and are all confined to the shaded regions in Fig. 1. The agreement between theory and experiment is evidently good.

We remark that we have used no free parameters except in the normalizations which are adjusted separately on the two sides. We have no reliable way to obtain the constant A which may be different for the two clusters. Thus, our claim here is in the prediction of the shapes of the pion spectra. The slope on the proton side is steeper because for the same number of pions emitted, the proton cluster moves slower in the c.m. system than the meson cluster; consequently, the pions emitted on that side have smaller longitudinal momenta. There is no need to invoke the quark picture to explain the asymmetry.[3,7]

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[7]See also W. Ko and R. L. Lander, Phys. Rev. Letters 26, 1284 (1971); Stone *et al.*, Ref. 5.