Transverse momenta of particles produced in hadron-nuclear interactions

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A difference in the behavior of the correlation dependences of $\langle P_\perp(P_\parallel^*)\rangle$ in $\pi^- N$ and $r^- C$ collisions at 4 and 40 GeV/c has been observed. The approximate A independence of the average transverse momentum at high energies can be accounted for by the compensation effects that appear in the averaging over the entire phase volume.

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It has been determined experimentally that many common characteristics of multiple production of particles by nuclei depend weakly (or not at all) on the mass

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number A of the target nucleus (see, for example, Ref. 1). Specifically, it appears that the average transverse momentum of produced particles $\langle P_\perp \rangle$ is almost independent of A and of the fast protons knocked out from the nucleus during the interaction. These observations, which contradict the predictions based on the observation of the development of an intranuclear cascade, are often regarded as an indication of the absence of a rescattering in hadron-nuclear (hA) interactions.

On the other hand, the current models of multiple scattering by nuclei typically reveal the presence of various effects, which, individually lead to a strong A dependence of the experimental values, but collectively tend to produce a relative reduction. This results in a rather moderate dependence of the average characteristics of the production process on the target mass. It was shown in terms of those models that these reduction effects are responsible for the nearly total agreement between the CNO functions in hN and hA collisions[2] and for the weak A dependence of the inclusive two- and three-particle correlation functions in the central rapidity region.[3] It is evident that an experimental study of the possible compensation effects for other characteristics of hA interactions is important in order to understand the true mechanism of multiple production of particles by nuclei. In particular, there is evidence[4] that these effects are present in an average transverse momentum of particles.

In this letter we attempt to comparatively analyze the date on the dependence of the average transverse momenta of $\pi^\pm$ mesons on their longitudinal momenta in $\pi^- N$ and $\pi^- C$[1)] collisions at 4 and 40 GeV/c. The experimental data were obtained at the 55-cm and 2-m J.I.N.R. (Joint Institute for Nuclear Research) propane bubble chambers which were irradiated by π^- mesons with momenta $P = 3.97 \pm 0.06$ GeV/c

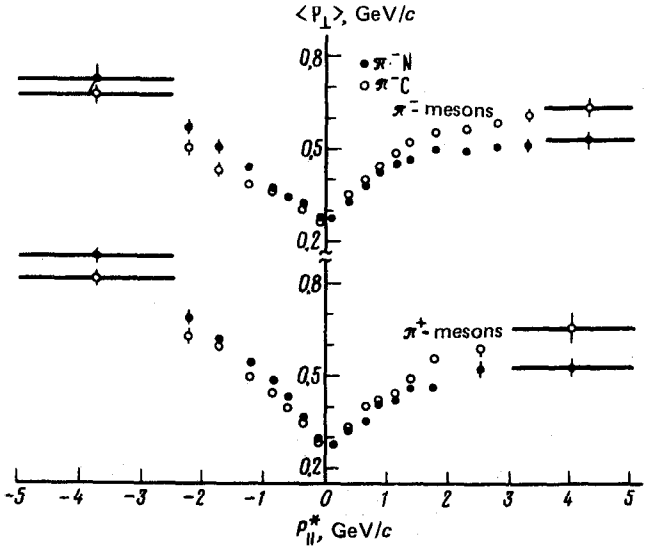

Fig. 1. Dependence of the average transverse momenta of $\pi^\pm$ mesons from $\pi^- N$ and $\pi^- C$ collisions at 40 GeV/c on their longitudinal momenta P^* in the center-of-mass system of the $\pi^- p$ interaction.

TABLE I. Average transverse momenta (GeV/c) of $\pi^{\pm}$ mesons in $\pi^- N$ and $\pi^- C$ interactions at 40 GeV/c.

	$\pi^- N$		$\pi^- C$	
	π^-	π^+	π^-	π^+
$< P_\perp (P_\parallel^* > 0) >$	0,384 ± 0,002	0,352 ± 0,002	0,391 ± 0,003	0,351 ± 0,003
$< P_\perp (P_\parallel^* < 0) >$	0,346 ± 0,002	0,400 ± 0,002	0,329 ± 0,003	0,402 ± 0,003
$< P_\perp >$ all	0,367 ± 0,002	0,378 ± 0,002	0,359 ± 0,003	0,384 ± 0,003

and 40.00 ± 0.24 GeV/c, respectively. The method used to identify and analyze the events was described in detail elsewhere.[5] The total statistics for $\pi^- N$ and $\pi^- C$ collisions at two energies represent ≈34 000 events. The data for π^-nucleon ($\pi^- N$) interactions were obtained by averaging the results for $\pi^- p$ and $\pi^- n$ collisions over the nucleon target.

Figure 1, which illustrates the results of our experiment, is a plot of the average transverse momenta of $\pi^{\pm}$ mesons produced in $\pi^- N$ and $\pi^- C$ collisions at 40 GeV/c as a function of their longitudinal momenta $P_\parallel^*$ in the center-of-mass system of the $\pi^- p$ interaction. Table I gives the transverse momenta of pions, averaged over the entire measurement range of $P_\parallel^*$, as well as over the front hemisphere ($P_\parallel^* > 0$) and over the back hemisphere ($P_\parallel^* < 0$).

The following conclusions can be drawn from the data.

1. Although the $\langle P_\perp (P_\parallel^*) \rangle$ correlation for the $\pi^- N$ collisions is qualitatively similar to that for the $\pi^- C$ collisions, there are significant quantitative differences in the plot of $\langle P_\perp \rangle$ vs the longitudinal particle momenta.

2. If the $P_\parallel^*$ are constant, then the $\langle P_\perp \rangle$ in the front hemisphere are systemically higher for multiple production of particles by nuclei than in the basic event. This difference is more pronounced for π^-mesons, which is presumably attributable to the leading effects. The observed difference, nonetheless, cannot be reduced to the leading effects, because it has also been observed in the case of π^+ mesons. The experimental data can be explained in terms of the multiple-scattering models if we assume the existence of an intermediate leading resonances in the rescattering processes.

3. The opposite picture is observed in the back hemisphere, and the $\langle P_\perp \rangle$ of the secondary particles in $\pi^- C$ collisions, if the $P_\parallel^*$ are constant. This effect is less pronounced for π^+ mesons in the back hemisphere, which can be attributed to the unidentified relativistic protons from the target.

4. Because of the difference in the behavior of $\langle P_\perp \rangle$ mentioned above and because of the difference in the distribution densities in $P_\parallel^*$ (Ref. 6) for the fast and slow particles produced in the $\pi^- C$ and $\pi^- C$ collisions, the A dependence of the transverse momentum averaged over the hemispheres $P_\parallel^* < 0$ and $P_\parallel^* > 0$, as well as over the entire phase volume, is reduced considerably or even vanishes.

The A independence of $\langle P_\perp \rangle$ in hadron-nucleus interactions can therefore be attributed to the compensation effects. To analyze these effects, it is important to determine experimentally the correlation dependences of $\langle P_\perp \rangle$ on the longitudinal characteristics of particles for multiple production of particles by heavier nuclei where their effect is stronger.

The same effects can be observed qualitatively in $\pi^- C$ collisions at 4 GeV/c.

[1)]The quasinucleonic events had to be excluded from the interactions in order to determine the possible A dependence of the correlations between $\langle P_\perp \rangle$ and $P_\parallel^*$.

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