The nature of fast, "leading," π^+ mesons in π^-N and $\pi^{-}\,{}^{12}$C interactions at 40 GeV/*c*

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It is shown that the sources of the "leading" π^+ mesons in π^-N and π^{-12}C interactions, i.e., those that carry away the largest momentum in an event, are the vector mesons with *G* parity plus one.

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In the study of the interaction of high-energy hadrons with nuclei, we observe the so-called "leading-particle effect." The main point here is that the largest momentum in an interaction is carried away, on the average, by a particle whose quantum number coincides with that of the incident particle. Analysis of the experimental data shows, however, that some events have interactions in which the largest momentum is carried away by a particle with the opposite sign, for example, a π^+ meson when the primary particle is a π^- meson. It is very useful to determine the mechanism for formation of fast, "leading," π^+ mesons.

We have investigated the class of events under consideration, using the example of π^-N and π^{-12}C interactions at 40 GeV/*c*. The experimental data were obtained in a two-meter propane bubble chamber. The method of identifying the π^-p, π^-n, and π^{-12}C interactions was described in detail elsewhere.[1] The results presented below are based on an analysis of $\approx$ 17,000 π^-p events, $\approx$ 6,000 π^-n events, and $\approx$ 17,000 π^{-12}C events. In obtaining the data for π^--nucleon (π^-N) interactions, we averaged the results for π^-p and π^-n collisions over the nucleon target. An analysis shows that in some of the π^-N and π^{-12}C events (28.9 ± 0.6% and 32.7 ± 0.4%, respectively) the largest momentum in the interaction is carried away by a π^+ meson and, as we can see, this fraction is almost independent of the target.

In a study of associative multiplicities of negative, secondary particles $\langle n_{X^-}\rangle$ (more than 95% of them are π^- mesons) in such events, i.e., processes of the type

$$\pi^- + \mathrm{N} \rightarrow \pi^+_{\mathrm{leader}} + X, \tag{1}$$

$$\pi^- + {}^{12}\mathrm{C} \rightarrow \pi^+_{\mathrm{leader}} + X, \tag{2}$$

we found [see Fig. 1(a) and 1(b)] that the dependence of $\langle n_{X^-}\rangle$ on the longitudinal momentum of the leading π^+ meson $P_{\|}(\pi^+_{\mathrm{leader}})$ is not the same in the entire region of investigated $P_{\|}(\pi^+_{\mathrm{leader}})$ values—we can see in Fig. 1(a) and 1(b) that $\langle n_{X^-}\rangle$ decreases almost linearly with $P_{\|}(\pi^+_{\mathrm{leader}})$, but, beginning with $P_{\|}(\pi^+_{\mathrm{leader}}) \gtrsim 18$ GeV/*c* ($X_F^{\mathrm{lab}} = P_{\|}^{\mathrm{lab}}/P_{\mathrm{max}}^{\mathrm{lab}} \gtrsim 0.45$), the dependence is much weaker, i.e., the average multiplicity of negative pions associated with the leading π^+ meson changes slightly with X_F^{lab} when

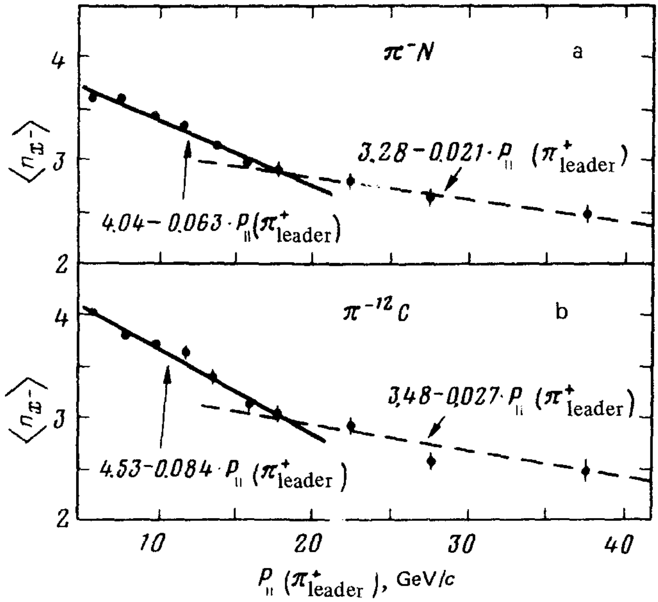

FIG. 1. Dependence of $\langle n_{X^-}\rangle$ on $P_{\parallel}(\pi^+_{\text{leader}})$ in π^-N (a) and π^{-12} c (b) interactions. The solid and dashed lines are the results of an approximation by the function $\langle n_{X^-}\rangle = a + b\,P_{\parallel}(\pi^+_{\text{leader}})$.

$X_F^{\text{lab}}(\pi^+_{\text{leader}})\gtrsim 0.45$. This suggests that the sources of the leading π^+ mesons could be the fast resonances ($\rho^\circ, f^\circ, g^\circ$, and ω°) that are produced in the π^-N and $\pi^{-12}C$ collisions.

To verify this assumption in the reactions (1) and (2), we investigated the spectra of the effective masses $M(\pi^+_{\text{leader}}\pi^-)$ of the leading π^+ meson and of any secondary π^- meson, which were produced in the interaction. The $M(\pi^+_{\text{leader}}\pi^-)$ distributions for the reactions (1) and (2) are shown in Figs. 2(a) and 2(b). The curves represent the result of an approximation obtained by using the function[2]:

$$F[M(\pi^+_{\text{leader}}\pi^-)] = (1 - a_\rho - a_f - a_g - a_\omega)\,\Phi(M) + a_\rho BW_\rho(M)$$

$$+ a_f BW_f(M) + a_g BW_g(M) + a_\omega \Phi(M_\omega), \tag{3}$$

where $M \equiv M(\pi^+_{\text{leader}}\pi^-)$; $a_{\rho,f,g,\omega}$ are the relative contributions of the resonances: $\rho^\circ, f^\circ, g^\circ \to \pi^+\pi^-$, and $\omega^\circ \to \pi^+\pi^-\pi^\circ$; $\Phi(M_\omega)$ is the distribution function of the effective mass of $(\pi^+\pi^-)$ mesons from the decay of a π° meson, taking into account the matrix element of the decay[2]; $\Phi(M)$ is the background distribution obtained from the $(\pi^-_{\text{leader}}\pi^-)$ combinations that were weighted in order to differentiate between the leading π^+ and π^- mesons in the spectra; and $BW_{\rho,f,g}(M)$ are the relativistic Breit-Wigner functions.[3] In the approximation of the experimental data the resonance masses and widths given in the table were specified for the functions

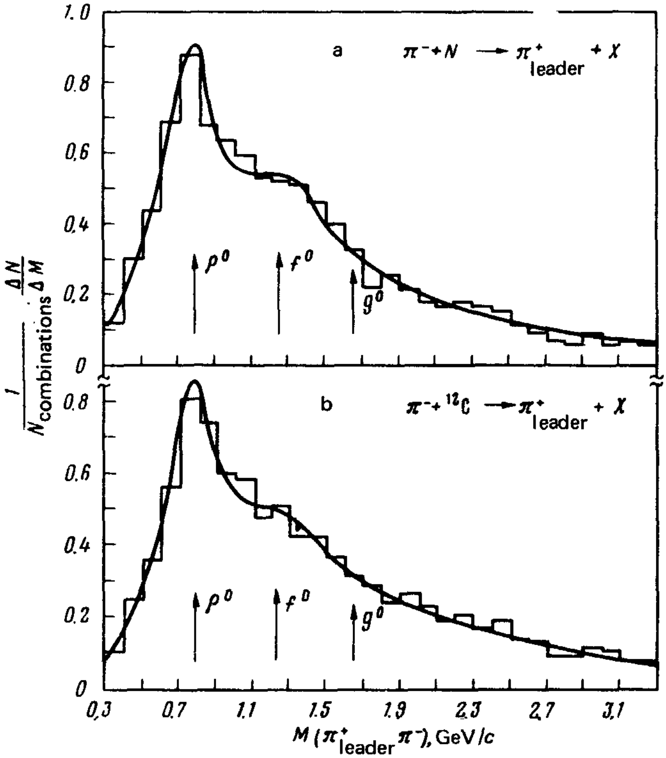

FIG. 2. Distributions of the effective mass $M(\pi^+_{\text{leader}}\pi^-)$ in the reactions (1) and (2). The curves are the results of an approximation using Eq. (3).

$BW_{\rho, f, g}(M)$ and the distortion of these functions because of the experimental errors in measuring $M(\pi^+_{\text{leader}}\pi^-)$ was taken into account.[2]

As a result of the approximation (χ^2, the number of degrees of freedom, is equal to 1.75 for the π^-N interaction and 0.71 for the π^{-12}C interaction), we determined the average multiplicities of the resonances given in Table I with allowance for the corrections of the decay modes. Table I also gives the fraction of the π^-N and π^{-12}C interactions in which $X_F^{\text{lab}}(\pi^+_{\text{leader}}) \geqslant 0.45$.

As seen in Table I, the average multiplicities of the $\rho°$ and $f°$ mesons, respective-

TABLE I.

	$\langle n_{\rho^0} \rangle$	$\langle n_{f^0} \rangle$	$\langle n_{\omega^0} \rangle$	$\langle n_{g^0} \rangle$	$\sigma(\pi^+_{\text{leader}}, X_{\text{lab}} \geqslant 0{,}45) / \sigma_{tot}$
π^-N	0.52 ±0.05	0.34 ±0.06	0.03 ±0.02	– 0.02 ±0.04	0.051 ± 0.003
π^{-12}C	0.57 ±0.10	0.27 ±0.07	0.05 ±0.06	– 0.01 ± 0.05	0.047 ± 0.002

ly, are identical, within the error limits, in the π^-N and π^{-12}C interactions, i.e., the yields of fast ρ° and f° mesons do not depend on the target type. On the other hand, the experimental data indicate that approximately 90% of all the leading π^+ mesons are produced in the $\rho^\circ \to \pi^+\pi^-$ and $f^\circ \to \pi^+\pi^-$ decays. Finally, the fact that the average multiplicities of the ω° mesons are equal to zero within the error limits indicates that the processes (1) and (2) for $X_F(\pi^+_{\text{leader}}) \gtrsim 0.45$ apparently occur as a result of a one-pion exchange–in terms of this approach, the production of an ω° meson is forbidden by G-parity conservation, which is observed in the experiment. It must be noted that the resonance yield does not change within a 10% limit when the coherent and diffraction events are disregarded in the reactions (1) and (2).

In conclusion, we note that the slight absorption of fast particles produced in hadron-nuclear interactions in some parton and multiperipheral models of hadron-nuclear interactions (see, for example, Ref. 4) is explained by an increase of the formation lengths l_f of secondary particles with an increase of their momentum P: $l_f \approx P/m^2$, where $m^2 \approx (1\text{-}2)\,\text{GeV}^2/c^2$. This means that the nuclear matter is transparent to secondary particles with $l_f > R_A \approx r_0 A^{1/3}$ (A is the mass number and R_A is the radius of the nucleus). The ρ° and f° mesons in our case are "newly produced" particles with momenta $P > 28$ GeV/c. We can assume from the approximate equality of their average multiplicities in the nucleon and nucleus that they are absorbed very weakly in the nucleus (see Table I). The formation length of these mesons is equal to more than 2.7 F, which exceeds the radius of a carbon nucleus ($R_C = 2.24$ F)–this is consistent with the model assumptions.[4]

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