TRANSVERSE MOMENTA OF SHOWER PARTICLES PRODUCED IN HADRON–NUCLEUS INTERACTIONS

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The reason of experimentally observed difference between shower proton and meson transverse momenta in inelastic nucleon–nucleus interactions is discussed. By means of an intranuclear cascade model it is demonstrated that this difference is caused by the Pauli exclusion principle and is in agreement with the theory.

As is known from experiments the transition from inelastic hadron–hadron to inelastic hadron–nucleus interactions is accompanied by an approximately twofold increase of the average shower proton transverse momentum $\langle p_\perp \rangle_p$, while the average value of the shower π-meson transverse momentum $\langle p_\perp \rangle_\pi$ remains practically invariable (see reviews [1, 2]). Presently this fact is often regarded as a convincing evidence of target nucleus transparency towards outgoing mesons and as a principal objection against the intranuclear cascade mechanism (e.g. Ref. [2]).

Our paper is aimed to show that actually there is no contradiction between the observed phenomenon and the cascade model and that the conclusion about the nuclear transparency for π-mesons is groundless.

With this end in view it is necessary to consider the competition between the effects of the influence of the Pauli principle and of the dissipation of shower particle energy in the cascade development process. The summary action of these effects turns out to be different for nucleons and π-mesons.

All intranuclear collisions accompanied by the production of low-energy secondary nucleons are forbidden by the Pauli principle. The transverse momenta of such low-energy nucleons are rather considerable, but altogether they are less than the average value $\langle p_\perp \rangle_N$ in the free π-N and N–N collisions. Therefore the average transverse momenta of particles produced in the interactions permitted by the Pauli principle appear to be

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overestimated.[1] The increase of $\langle p_\perp \rangle_p$ occurs in every intranuclear collision since the shower nucleon takes away a large part of colliding particle energy and its momentum decreases in successive interactions rather slowly. The decrease of total momenta of secondary shower mesons proceeds much faster[2], therefore the value of $\langle p_\perp \rangle_\pi$ having enlarged in the first collision slowly diminishes afterwards and after 2–3 interactions becomes approximately equal to that of π-mesons produced in free-nucleon collisions.

This is perfectly illustrated by the table in which proton–photoemulsion interactions data at the energy about 20 GeV are shown as an example[3].

TABLE

Average transverse momentum (GeV/c) of shower particles outgone from the light (LEm) and heavy (HEm) nuclei of emulsion after n intranuclear interactions initiated by protons at the energy $T = 20$ GeV

	$\langle p_\perp \rangle_p$		$\langle p_\perp \rangle_\pi$	
	LEm	HEm	LEm	HEm
$n = 1$[4]	0.43±0.02	0.45±0.02	0.33±0.01	0.34±0.01
$n = 2$	0.52±0.04	0.52±0.02	0.34±0.01	0.34±0.01
$n = 3$	0.48±0.09	0.55±0.03	0.31±0.02	0.31±0.01
$n = 4$	0.60±0.4	0.56±0.05	0.26±0.04	0.29±0.01
$n = 5$		0.65±0.1		0.29±0.02
after cascade	0.45±0.02	0.51±0.01	0.33±0.01	0.30±0.01
experiment	–	0.64±0.03 [3]	0.284±0.02 [5]	0.32±0.02 [3]
		0.647±0.044 [4]		0.29±0.03 [4]

The calculation has been performed within the framework of a model [6] taking into account the nuclear depletion in the cascade development (the "trailing" effect). To simulate the characteiistics of intranuclear π-N and N–N interactions a method described in Ref. [7] was used. The method approximates well enough angular and momentum distributions of secondaries, and less satisfactorily the transverse momentum distributions, especially for nucleons [1]. This is the reason for some underestimation ($\approx 20\%$) of $\langle p_\perp \rangle_p$ value as compared to the experimental one.

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[1] If $\vec{p}_{\perp N}$ is a recoil nucleon transverse momentum vector, the transverse momentum of the rest secondary particles (in centre mass system) $\vec{p}_\perp = -\vec{p}_{\perp N}$.

[2] In contrast with nucleons the low-energy bound for shower mesons corresponds to the momentum less than $\langle p_\perp \rangle_\pi$. The number of low-energy shower mesons rapidly increases from one generation of cascade particles to another. That circumstance has been emphasized also in the rewiew [2].

[3] Data presented in the table refer to all outgoing shower particles, which at the average undergo less intranuclear collisions than the primary, therefore, the resulting value of $\langle p_\perp \rangle_p$ for the heavy emulsion nucleus is lower than $\langle p_\perp \rangle_p$ for $n = 3,4$ although in this case the primary particle suffers as a rule 3–4 collisions. (In the light emulsion nucleus the average number of intranuclear collisions is $n = 1$–2.)

[4] Transverse momentum for free p–N interactions (average for elastic and inelastic collisions) is 0.40 for protons and 0.30 for mesons.

Within the limits of intranuclear cascade model the average transverse momentum of produced shower pions proves to be close to the experimental value of $\langle p_\perp \rangle_\pi$ without additional assumption of nucleus transparency towards mesons.

The computed ratio $\Delta_{\text{theor}} \equiv \langle p_\perp \rangle_p / \langle p_\perp \rangle_\pi = 1.7 \pm 0.1$ for p+HEm interaction at the energy $T \simeq 20$ GeV is only 15% lower than the measured value $\Delta_{\text{exp}} = 2.0 \pm 0.1$.

It is clear, that the observed effect is explained not only qualitatively but as well quantitatively by the intranuclear cascade model.

REFERENCES

[1] V. S. Barashenkov, V. D. Toneev, *Interactions of High Energy Particles and Atomic Nuclei with Nuclei*, Atomizdat, Moskva 1972 (in Russian).

[2] K. G. Gulamov, U. G. Guliamov, G. M. Chernov, *ECHAYA* **9**, 584 (1978).

[3] S. A. Azimov, L. P. Chernova, G. M. Chernov, *Yad. Fiz.* **7**, 604 (1968).

[4] K. Garbowska et al., *Nucl. Phys.* **60**, 654 (1964).

[5] B. Bhowmik, R. K. Shivpuri, Proc. of 10-th Symposium on Cosmic Rays, Elem. Particle Phys. and Astrophysics, Aligarch 1967, p. 639.

[6] V. S. Barashenkov, A. S. Iljinov, V. D. Toneev, *Yad. Fiz.* **13**, 743 (1971).

[7] V. S. Barashenkov, K. K. Gudima, V. D. Toneev, *Acta Phys. Pol.* **36**, 457 (1969).