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ON THE DISTRIBUTION OF SPECTATOR FRAGMENTS IN THE PROCESSES INVOLVING RELATIVISTIC NUCLEI

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ON THE DISTRIBUTION OF SPECTATOR FRAGMENTS IN THE PROCESSES INVOLVING RELATIVISTIC NUCLEI

Гарсеванишвили В.Р. и др. **E2 - 10475**

О распределении фрагментов-спектаторов в процессах с участием релятивистских ядер

Изучено распределение фрагментов-спектаторов в реакциях выбивания нуклонов из релятивистских ядер. Основой рассмотрения служит квазипотенциальный подход в переменных "светового фронта". Распределение спектаторов выражается через интеграл перекрытия волновых функций падающего ядра и ядра-фрагмента. Это распределение позволяет судить о характере "продольного" и поперечного распределений нуклонов в падающем ядре. Полученные результаты можно использовать для анализа данных, полученных в экспериментах с пучками ядер высоких энергий.

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Garsevanishvili V.R. et al. **E2 - 10475**

On the Distribution of Spectator Fragments in the Processes Involving Relativistic Nuclei

Distributions of the spectator fragments are studied in the knock out processes involving relativistic nuclei. Considerations are based on the "light front" form of the quasipotential dynamics. The distribution of spectators is expressed by means of the overlap integral of the relativistic wave functions of the incident nucleus and the fragment one. This distribution allows the picture of the "longitudinal" and transversal motion of nucleons in the incident nucleus to be reproduced. The results obtained can be used for the analysis of data obtained in the experiments with beams of relativistic nuclei.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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The experiments with beams of the relativistic nuclei (see, e.g., review papers [1-4] and references therein) exhibit a number of interesting regularities the theoretical interpretation of which seems to be very actual. In the present paper, the distribution of spectator fragments in the interactions of relativistic nuclei is presented. The consideration is based on the "light-front" form of the many-body quasipotential dynamics [5,6]. A development of the Logunov-Tavkhelidze quasipotential approach [7] in quantum field theory can be traced through review papers [8-13] and references cited therein. Some aspects of the many-body dynamics in the Kadyshevsky approach [14] can be found in ref. [15]. The possibility of constructing the dynamics of quantized fields on the "light front" hyperplane was pointed out by Dirac [16] since 1949. Combinations $(p_0 \pm p_z, \vec{p}_\perp)$ of the 4-momentum components which are characteristic for this approach have appeared in the quasipotential approach in the study of the high energy behaviour of the two-body scattering amplitude [17].

Consider now the process of the knock out of one nucleon from the relativistic nuclei on the hydrogen target in the impulse approximation. In this case one of the N nucleons of an incident nucleus interacts with a target the remaining (N-1) nucleons still existing in the form of the fragment nucleus. The study of the distribution of this fragment (spectator) allows the picture of the internal motion of the incident nucleus to be reproduced.

We will describe the incident nucleus and the spectator one in terms of the quasipotential wave functions $\Phi^{(N)}([x_i^{(N)}, \vec{p}_{i,\perp}])$ with the zero total transverse momentum $\vec{P}_{N,\perp}$. The connection with a $\vec{P}_{N,\perp}$-arbitrary wave function, which is necessary for the calculation, can be found in ref. [6]. Brackets in the arguments of the wave function $\Phi^{(N)}$ denote a set of the corresponding variables $x_i^{(N)}$, $\vec{p}_{i,\perp}$. Scale-invariant variables $x_i^{(N)}$, which describe the "longitudinal motion" of particles, are defined in the following manner:

$$x_i^{(N)} = p_{i,+} / P_{N,+} = (p_{i,0} + p_{i,3}) / (P_{N,0} + P_{N,3}).$$

Here $p_{i,\mu}$ is the individual 4-momentum of an i-th particle in the composite system, $P_{N,\mu}$ is the total 4-momentum of the N particle bound system. In what follows capital letters denote the parameters (momenta, masses, etc.) of the group of particles, whereas small letters denote the individual parameters of nucleons. The superscript of variable $x_i^{(N)}$ means that this variable is defined in the system of particles a number of which is equal to this index. A more detailed information on the methods we exploit here, can be found in refs. [5-10].

The calculation leads to the following distribution of the spectator fragments in the laboratory frame:

$$\frac{d\sigma}{dX^{sp}\, dP_\perp^{sp}} \sim \frac{\lambda^{1/2}(s_{N,N+1}, m_N^2, m_{N+1}^2)}{\lambda^{1/2}(s, M_N^2, m_{N+1}^2)} (P_\perp^{sp}/X^{sp}) \times$$

$$\times \sigma^{el}_{N,N+1}(s_{N,N+1}) \left| \frac{I(X^{sp}, \vec{P}_\perp^{sp})}{1-(1+m_{N+1}/P_{N,+})X^{sp}} \right|^2 ; \qquad (1)$$

$$\lambda(x,y,z) = (x-y-z)^2 - 4yz, \quad P_{N,+} = P_N + E_N,$$

$$X^{sp} = (P^{sp}_{N-1,z} + E^{sp}_{N-1})/(m_{N+1} + P_{N,+}),$$

$$s_{N,N+1} = s(1-X^{sp}) + M^2_{N-1} - (\vec{P}_\perp^{sp\,2} + M^2_{N-1})/X^{sp},$$

P_N, E_N and P^{sp}_{N-1}, E^{sp}_{N-1} are the momenta and energies of the incident nucleus and the spectator respectively, $\sigma^{el}_{N,N+1}(s_{N,N+1})$ is the total elastic cross section of the interaction of the N-th nucleon with a target ((N+1)-th nucleon), s is the usual Mandelstam variable for the incident nucleus-target system, $s_{N,N+1}$ is the same variable for the subsystem consisting of nucleon having interacted - target, m_i is the mass of the i-th nucleon, M_N is the mass of the incident nucleus, M_{N-1} is the mass of the spectator, $I(X^{sp}, \vec{P}_\perp^{sp})$ is the overlap integral, which is defined by the formula:

$$I(X^{sp}, \vec{P}_\perp^{sp}) = \int_0^1 \prod_{i=1}^{N-1} (dx_i^{(N-1)'}/x_i^{(N-1)'}) \times$$

$$\times \delta(1 - \sum_{i=1}^{N-1} x_i^{(N-1)'}) \times$$

$$\times \int \prod_{i=1}^{N-1} d\vec{p}'_{i,\perp}\ \delta^{(2)}(\vec{P}_{\perp}^{sp} - \sum_{i=1}^{N-1} \vec{p}'_{i,\perp}) \times$$

$$\times \Phi_f^{+(N-1)}([x_i^{(N-1)'}, \vec{p}'_{i,\perp} - x_i^{(N-1)'} \vec{P}_{\perp}^{sp}]) \Phi_i^{(N)}([x_i^{(N)}, \vec{p}_{i,\perp}]).$$

Arguments of the wave function $\Phi_i^{(N)}$ of the incident nucleus are connected with integration variables and observable quantities X^{sp} and $\vec{P}_{\perp}^{sp}$ in the following way

$$x_i^{(N)} = A\, x_i^{(N-1)'} \ ,\ \vec{p}_{i,\perp} = \vec{p}'_{i,\perp}\ ;\ i = 1, 2, \ldots, N-1\ ;$$

$$x_N^{(N)} = 1 - A\ , \qquad \vec{p}_{N,\perp} = -\vec{P}_{\perp}^{sp}\ ;$$

$$A = (1 + m_{N+1} / P_{N,+}) X^{sp}\ .$$

Thus observation of the spectator fragment allows the information on the character of the "longitudinal" and transversal motion of nucleons in the incident nucleus to be obtained. It is interesting to note that in the case $N=2$ formula (1) turns into the distribution of spectator nucleons in the deuteron break up obtained earlier /18/.

Let us choose now the wave functions of the incident nucleus and the fragment one in the form:

$$\Phi_i^{(N)}([x_i^{(N)}, \vec{p}_{i,\perp}]) = N_i \exp[-\alpha_i \sum_{i=1}^{N} (\vec{p}_{i,\perp}^{\,2} + m_i^2)/x_i^{(N)}],$$

$$\Phi_f^{(N-1)}([x_i^{(N-1)}, \vec{p}_{i,\perp}]) = N_f \exp[-\alpha_f \sum_{i=1}^{N-1} (\vec{p}_{i,\perp}^{\,2} + m_i^2)/x_i^{(N-1)}]$$

N_i , N_f are normalization constants. Using the formula

$$\int \prod_{i=1}^{N-1} d\vec{p}_{i,\perp}\, \delta^{(2)}(\vec{P}_\perp - \sum_{i=1}^{N-1} \vec{p}_{i,\perp}) \exp[-\sum_{i=1}^{N-1} A_i \vec{p}_{i,\perp}^{\,2}] =$$

$$= \pi^{N-2} [(\prod_{i=1}^{N-1} A_i)(\sum_{i=1}^{N-1} 1/A_i)]^{-1} \exp[-\vec{P}_\perp^{\,2} / \sum_{i=1}^{N-1} 1/A_i],$$

one obtains the expression for the overlap integral in the form:

$$I(X^{sp}, \vec{P}_\perp^{sp}) = N_f N_i \left(\frac{\pi}{\alpha_f + \alpha_i / A}\right)^{N-2} \times$$

$$\times \exp[-\alpha_i \frac{\vec{P}_\perp^{sp2} + m_N^2}{1-A} - \frac{\alpha_i}{A} \vec{P}_\perp^{sp2}] \times$$

$$\times \int_0^1 \prod_{i=1}^{N-1} dx_i^{(N-1)} \delta(1 - \sum_{i=1}^{N-1} x_i^{(N-1)}) \exp[-(\alpha_f + \frac{\alpha_i}{A}) \sum_{i=1}^{N-1} m_i^2 / x_i^{(N-1)}].$$

Thus the $P_\perp^{sp}$-distribution is obtained in the analytic form. An interesting feature of the X^{sp}-distribution is a prediction of the maximum at $X^{sp} = (N-1)/N(1+m_{N+1}/P_{N,+})$.

The considerations which have been described here can be used also for the analysis of other processes involving relativistic nuclei. The formalism contains also a possibility to go beyond the impulse approximation. The spin and isotopic spin of nucleons can be included in this scheme. (Problems concerning the spins of particles in the equations of the "light front" formalism can be found in refs. [19,20]). We hope to turn back to these and some related problems. A comparison of the results obtained here with experimental data on the break up of the relativistic deuterons and ^{4}He nuclei will be made elsewhere.

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