Spectator momentum distribution in $D(x, xp)n$ reactions

V. F. Ksenzov

Institute of Theoretical and Experimental Physics

(Submitted June 21, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 3, 174–177 (August 5, 1975)

The causes of the qualitative differences in the form of the neutron momentum distributions in reactions of the $D(x, xp)n$ type are explained within the framework of the mechanism of quasielastic knock-out followed by np rescattering.

Abundant material has by now been established on proton knock-out from the simplest nuclear target, the deuteron, namely the reactions (e, ep),[1,2] $(p, 2p)$,[3] (K^+, K^0p),[4,5] and (π^-, π^-p).[6] A characteristic feature of the data is the qualitative difference in the form of the distribution with respect to the momentum P_S of the spectator in the different reactions at $P_S > 80$ MeV/c; in some cases [the reactions (e, ep) and $(p, 2p)$] the distribution decreases monotonically and steeply towards the higher values of P_S,[1–3] while in other cases [(K^+, K^0p) and (π^-, π^-p)] the distribution has a minimum near 110 MeV/c, after which it increases slowly.[4–6] It is interesting to note that in the reactions (e, ep) and $\pi^-, \pi^-p)$ the distributions with respect to P_S differ in form at approximately the same momentum q transferred from the initial fast particle to the final one.

An understanding of the causes of this phenomenon is essential, first, as a check on the validity of modern comcepts concerning the nature of direct nuclear reactions.[7,8] Second, this is all the more timely in the case of a deutron, since the deuteron data are the main source of information on the interaction of elementary particles with neutrons, and any doubt on the validity of our understanding of the process casts a shadow on the reliability of the neutron data.

The purpose of the present article is to show that the notion that the process is quasielastic and is followed by np rescattering[9] is sufficient to explain the forms of the distributions with respect to P_S in all cases. The main cause of the differences between the spectra is the difference in the organization of the experiment. In a number of cases the experiment is so performed that the interaction in the final state is kinematically suppressed and the distribution with respect to P_S is determined only by the pole diagram. In other cases there is no such suppression, and at large P_S an important role is assumed by the contribution of the triangular diagram, and this leads to a certain growth of the spectrum.[9] Indeed, since the contribution of the triangular diagram with interaction in the final state, relative to the pole diagram, is given by[9]

$$\frac{f_{NN}(F^*)}{4\pi R\,\xi\,[\phi_d(P_S)/\phi_d(0)]}, \qquad \xi = \begin{cases} 1, & \text{if} \quad qR < 1 \\ qR, & \text{if} \quad qR > 1 \end{cases},$$

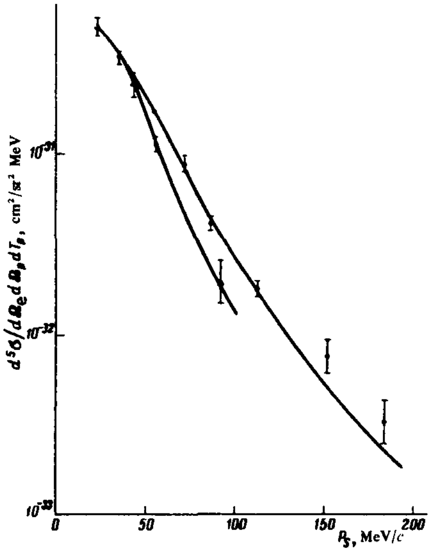

FIG. 1. Spectator-momentum distribution in the reaction $d(e, ep)n$: circles—data of[2], triangles—data of[1], solid lines—results of theoretical calculation.

(R is the radius of the deuteron, $f_{NN}(E^*)$ is the NN amplitude normalized in the usual manner, $d\sigma/d\Omega = |f_{NN}|^2$, E^* is the energy of the nucleons in their c. m. s., $\phi_d(P_S)$ is the deuteron wave function in the momentum representation) it follows that at E^* close to zero and at $P_S > 1/R$ the ratio can even exceed unity (at $P_S < 1/R$ the ratio is never more than of the order of 0.1). And if this is so, then the cross section of the reaction in the kinematic-variable region where $E^* \approx 0$ should increase. It is further clear from an examination of the reactions (e, ep) and $(\pi^-, \pi^- p)$ with close values of q ($\approx$400 MeV/c) that the contributions made to the cross section by the diagram with interaction in the final states are different, since the momentum of the proton was fixed in the reactions (e, ep) at a value close to q, and in this range of variation of P_S, by virtue of the large relative momentum of these two nucleons, their E^* was approximately 50 MeV, whereas in $(\pi^-, \pi^- p)$ the relative momentum of the nucleons can be close to zero in the region $P_S = 100$ to 150 MeV, so that consequently $E^* \approx 0$. It is this difference in E^* which leads to different contributions to the cross section from the diagram with interaction in the final state, since $f_{NN}(50)/f_{NN}(0) = \frac{1}{7}$.

Consequently, the form of the distribution in (e, ep) is determined principally by the pole mechanism, and for a Hulthen wave function the distribution falls off like $1/P_S^4$, while in $(\pi^-\pi^- p)$ at $P_S > 100$ MeV an essential role is assumed by the triangular mechanism, which indeed determines the behavior of the cross section in this region of P_S.

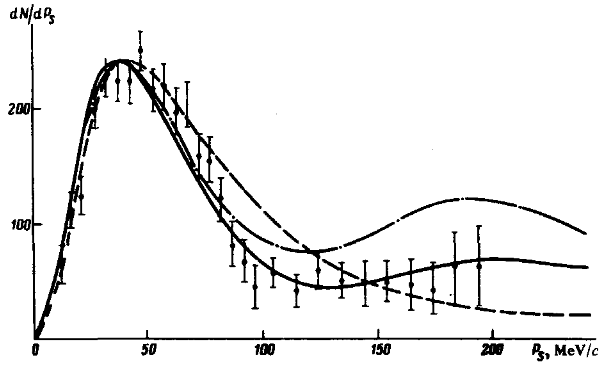

FIG. 2. Spectator-momentum distribution in the reaction $d(\pi^-, \pi^- p)n$; dashed curve—calculation in the pole approximation; dash-dot—pole+triangular mechanism without allowance for the departure of the NN amplitude from the energy shell; solid curve—the same but with allowance for the departure of the NN amplitude from the energy shell. The experimental data are from[6].

The results of numerical calculations for the reactions (e, ep) and $(\pi^-, \pi^- p)$, performed with allowance for the pole diagram with interaction in the final state, are shown in Figs. 1 and 2. They are in good agreement with the experimental data. This shows that the mechanism of the process has been correctly understood.

We note in conclusion that the effect of rescattering in the final state is suppressed by almost a factor of 2 at $E^* \approx 0$, owing to the deviation of the NN amplitude from the energy shell.[9]

The author is grateful to V. M. Kolybasov for suggesting the problem and to I. S. Shapiro for a discussion of the results.

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