nuclei originating from the reaction d + d → He^3 + n.

The α-particle yield from heavy polyethylene and carbon with an effective momentum 635 Mev/c, corresponding to the α particles of reaction (1), was measured under an angle of 5.6° in the laboratory system, to which an isotropic angle $[\theta = a \times \cos^{-1}(1/\sqrt{3})]$ corresponds approximately in the c.m.s. The absolute cross sections were determined under the same conditions, by recording the deuterons from the reaction $p + p \rightarrow d + \pi^0$, the cross section of which is well known[11] at present. The results of the first measurements have shown that, with a reliability of 90%, the total cross section of reaction (1) is

$$\sigma_t (d + d \rightarrow \pi^0 + He^4) < 1 \cdot 10^{-31} \text{ cm}^2$$

The estimate obtained proves that the cross section of reaction (1) surpasses only a few times the cross section of the electromagnetic process $d + d \rightarrow \gamma + He^4$, which according to the data of the reverse reaction[12] $\gamma + He^4 \rightarrow d + d$ amounts to about 10^{-32}, whereas in the absence of forbiddenness in reaction (1) the cross sections of these two processes may differ by a factor of 10^2.

Since, under the conditions of the given experiments, the α particles resulting from the reaction $d + d \rightarrow \pi_0^0 + He^4$, in which the formation of the isotopically scalar π^0-meson takes place may also be recorded, the estimate of the total cross section received for reaction (1) may be looked upon as an indication that isotopically scalar π^0 mesons are not present in large quantities in the (135^{+15}_{-35}) Mev interval.

We also measured the differential cross section of the reaction $d + d \rightarrow He^3 + n$ for the angle 5.6° in the laboratory system, and found it to be equal, in the center-of-mass system, to

$$\frac{d\sigma}{d\Omega}(15.5^\circ) = (3.8 \pm 0.5) \cdot 10^{-29} \text{ cm}^2/\text{sr}.$$

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ON THE PROBLEM OF PERIPHERAL COLLISIONS OF NUCLEONS WITH HIGH ENERGIES

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TAMM[1] has recently developed a model for the interaction of fast nucleons with large impact parameters, according to which the interaction is due to the exchange of one π meson, whereby one or both nucleons are excited to an isobaric state which subsequently decays.

Together with the excitation of the isobar $(3/2, 3/2)$ (which we shall denote by the symbol X in the following), an interaction with the isotopic spin $1/2$ is also possible. The latter can be interpreted as the excitation of the second isobaric level of the nucleon.[2] This second isobar (which we denote by the symbol Y) can decay according to the following schemes:

$$\begin{array}{ll} 1)\ Y \rightarrow N + \pi, & \omega_1 = 0{,}324; \\ 2)\ Y \rightarrow X + \pi, & \omega_2 = 0{,}418; \\ 3)\ Y \rightarrow N + 2\pi, & \omega_3 = 1 - \omega_1 - \omega_2 = 0{,}258. \end{array}$$

The probabilities, ω, for these decays can be estimated by the statistical weights, assigning to the isobar Y the mass $1.64\, M_{\text{nucl}}$, the isotopic spin $1/2$, and linear dimensions of the order $\hbar/\mu c$. We neglect the possibility of decays leading to the formation of strange particles.

In peripheral interactions of this type the directions of motion of the isobar and of its decay products in the center of mass system do not differ much from the direction of motion of the nucleons before the interaction. According to the criterion chosen in reference 3 for the selection of such peripheral collisions (the presence of a slow proton in the laboratory system), we consider in the following only those "stars" in which there is a proton flying in the backward direction in the center of mass system. Taking this into account and making use of isotopic invariance, we can calculate with the help of the Clebsch-Gordan coefficients the probabilities W_{mn} for the observation of stars in which (in the center of mass system) m charged particles are emitted in the forward direction and n charged particles (including the proton) in the backward direction.

For p-p collisions we find

$$W_{11} = \tfrac{4}{15}\sigma_{pp}(X, X) + \tfrac{1}{16}(1 + \omega_1 + \tfrac{1}{27}\omega_2)\sigma_{pp}(X, Y)$$
$$+ \tfrac{1}{12}(1 - \omega_1 - \tfrac{1}{9}\omega_2)(1 + \omega_1 - \tfrac{1}{3}\omega_2)\sigma_{pp}(Y, Y),$$
$$W_{02} = \tfrac{1}{5}\sigma_{pp}(X, X) + \tfrac{1}{16}(1 + \omega_1 + \tfrac{1}{3}\omega_2)\sigma_{pp}(X, Y),$$
$$W_{22} = \tfrac{1}{5}\sigma_{pp}(X, X) + \tfrac{1}{16}(7 + \omega_1 - \omega_2)\sigma_{pp}(X, Y)$$

(we do not give the expressions for W_{13}, W_{31}, and W_{33}, since these cases were neglected in the analysis of the experiment[3]). For p-n collisions we find

$$W_{01} = \tfrac{2}{63}\sigma_{pn}(X, X) + \tfrac{1}{18}(1 + \omega_1 + \tfrac{1}{3}\omega_2)\sigma_{pn}(X, Y)$$
$$+ \tfrac{2}{15}(1 + \omega_1 + \tfrac{1}{3}\omega_2)^2\sigma_{pn}(Y, Y),$$
$$W_{21} = \tfrac{1}{63}\sigma_{pn}(X, X) + \tfrac{1}{72}(11 - \omega_1 - \tfrac{1}{3}\omega_2)\sigma_{pn}(X, Y)$$
$$+ \tfrac{1}{45}(5 - \omega_1 - \tfrac{1}{3}\omega_2)(1 + \omega_1 + \tfrac{1}{3}\omega_2)\sigma_{pn}(Y, Y),$$
$$W_{12} = \tfrac{2}{21}\sigma_{pn}(X, X) + \tfrac{1}{8}(1 + \omega_1 - \tfrac{7}{27}\omega_2)\sigma_{pn}(X, Y)$$
$$+ \tfrac{1}{30}(1 + \omega_1 - \tfrac{1}{3}\omega_2)^2\sigma_{pn}(Y, Y),$$

where $\sigma_{pp}(X, X)$ is the cross section for formation of two isobars in p-p collisions, etc.

For a more rigorous choice of cases of peripheral collisions of this type, those cases in reference 3 were selected in which there is a fast proton in addition to the slow one. We denote the corresponding probabilities by $W_{mn}^{(p)}$:

$$W_{11}^{(p)} = \tfrac{8}{45}\sigma_{pp}(X, X) + \tfrac{1}{36}(1 + \omega_1 + \tfrac{1}{3}\omega_2)\sigma_{pp}(X, Y)$$
$$+ \tfrac{1}{36}(1 + \omega_1 + \tfrac{1}{3}\omega_2)^2\sigma_{pp}(Y, Y),$$
$$W_{22}^{(p)} = \tfrac{1}{5}\sigma_{pp}(X, X) + \tfrac{1}{4}(1 + \omega_1 - \tfrac{1}{3}\omega_2)\sigma_{pp}(X, Y).$$

Dremin and Chernavskiĭ[4] recently made a quantitative estimate of the cross sections for these processes. Using their data and substituting the values of ω_i quoted above, we obtain characteristic numbers (see column a in the table) which can be compared with the results of the experiment.[3] In column b of the table we list for comparison the results of the calculation under the assumption that always only 2X are formed.

	Experiment	Calculation	
		a	b
$W_{22}/(W_{11} + W_{02})$	0.47	0.73	0.43
$-2W_{02}/(W_{11} + W_{02})$	—0.56	—0.88	—0.86
W_{02}/W_{11}	0.39±0.13	0.79	0.75
$W_{11}^{(p)}/W_{22}^{(p)}$	14/8=1.75±0.77	0.60	0.89
$(W_{21} - W_{12})/(W_{21} + W_{12})$	0.33	—0.46	—0.71
W_{12}/W_{21}	1.3	2.6	6

In conclusion I express my deep gratitude to I. E. Tamm and I. L. Rozental' for discussing this paper and also to D. S. Chernavskiĭ, I. M. Dremin, and the authors of reference 3 for providing me with the results of their work before publication.

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ON GAUGE TRANSFORMATIONS IN QUANTUM ELECTRODYNAMICS

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INVARIANCE of a quantum-mechanical theory with respect to a particular group of transformations is ordinarily associated with the existence