$$\times\left\{\beta_0^2+\beta_1^2+4\frac{\beta_0^2\beta_1^2}{(\beta_0^2-\beta_1^2)^2}\left[\frac{\beta_0^2\sin^2\vartheta_0}{(1-\beta_0\cos\vartheta_0)^2}+\frac{2}{3}\beta_1^2\right].\right.$$
$$\left.+\,4\frac{\beta_0^2\beta_1^2}{\beta_0^2-\beta_1^2}\left(\cos^2\vartheta_0-\frac{1}{3}\right)\right\}.$$

The energy distribution of the γ-quanta is obtained after integrating over angles :

$$\frac{dE_\gamma}{\mu c^2}\int\sigma_0 d\Omega_\gamma\, d\Omega_1 \quad (8)$$

$$=4\frac{e^2}{hc}\left(\frac{f^2}{hc}\right)^2\left(\frac{h}{\mu c}\right)^2\frac{k_1}{k_0}\frac{E_\gamma dE_\gamma}{(\mu c^2)^2}$$

$$\times\left\{\beta_0^2+\beta_1^2+\frac{2}{3}\beta_0^2\beta_1^2\frac{1}{E_\gamma^2}\left[(chk_1)^2+(chk_0)^2\right]\right\}.$$

The total cross section for the case $\mu c^2 \ll E_0 \ll mc^2$ takes the form

$$\sigma=\int\sigma_0 d\Omega_\gamma d\Omega_1\frac{dE_\gamma}{\mu c^2} \quad (9)$$

$$=2\frac{e^2}{hc}\left(\frac{f^2}{hc}\right)^2\left(\frac{h}{\mu c}\right)^2\frac{4}{3}\left(\frac{E_0}{\mu c^2}\right)^2\ln\frac{2E_0}{\mu c^2}\ln\frac{E_0}{\delta_E}.$$

Note that the cross section for the process $\pi^+ + p \to \pi^+ + p + \gamma$ differs somewhat from the cross section for the process $\pi^- + p \to \pi^- + p + \gamma$ in the case of pseudovector coupling.

4. The cross section obtained by us, $d\sigma_T$, for bremsstrahlung from a nonrelativistic energy meson and with $E_\gamma \ll E_0$, together with the cross section for elastic scattering of π-mesons by nucleons derived in reference 5, gives the most general relationship

$$d\sigma_T=\frac{2}{3\pi}\frac{e^2}{hc}\frac{(\mathrm{v}_0-\mathrm{v}_1)^2}{c^2}\frac{dE_\gamma}{E_\gamma}d\sigma_{\pi\text{-el.}} \quad (10)$$

An analogous relation has been obtained earlier in references 3-5.

The total cross section for the process of bremsstrahlung from the scattering of π-mesons by nucleons for both types of coupling of the meson to the nucleon has the order of magnitue of 10^{-28} cm^2 for $E_0 \sim 2\mu c^2$, for $\frac{f^2}{hc}=\frac{\mu}{2m}\frac{g^2}{hc}\approx\frac{1}{6}$ and for the energy interval $\delta_E = 1$ mev.

In conclusion, I wish to thank Professors I. I. Pomeranchuk and I. M. Shmushkevich for assistance and guidance in this work.

* This communication is based on work completed in 1952 at the Institute for Nuclear Problems of the Academy of Sciences, USSR.

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The Role of Isobaric States of Nucleons in Meson Creation

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As is known[1], there is experimental evidence that the isobaric states of the nucleons play an important role in the process of meson production in nucleon-nucleon collisions. A series of authors have taken the point of view that the production of pions proceeds entirely through an isobaric state[2-4]. However, it has not been excluded that direct production plays a significant role in such processes.

Let us examine the experiments on production of charged pions in the reaction $Be^9 + p$ [2]. In these experiments the ratio $\rho = \pi^+/\pi^-$ (π^+ and π^- indicating the number of π^+ and π^- mesons formed) is equal to 6 at an energy of 1 bev, and to 1.8 at 2.3 bev. In the paper of Peaslee[2] there is a discussion of the possibility of explaining such a dependence of ρ on energy by assuming that the production of pions proceeds only through an isobaric state. At an energy of 2.3 bev, in order to calculate ρ, one must evaluate matrix elements or else make definite assumptions about them[2]. At 1 bev, however, there is not enough energy to produce real excitation of two isobaric states and one must therefore assume that the production of pions goes only by the excitation of one isobaric state. Then, assuming only the hypothesis of charge independence, it is easy to calculate ρ. The result obtained by Peaslee[2] for ρ is equal to 6, agreeing well with experiment. However, in this work an error was made, as pointed out by the author himself in a following paper[3]. The corrected value of ρ at 1 bev is equal to 9, no longer agreeing with the experiment.

We have carried out a calculation of ρ on a statistical theory [4]. In the calculation we have included both the production of pions via the isobaric state and direct production. The relative importance of the two processes is determined only by statistical weights. It is assumed that at these energies in the reaction $Be^9 + p$, the incoming proton interacts with each of the nucleons of the nucleus as if it were free.

Let us examine first the situation when the energy of the incoming protons is equal to 1 bev. Then only the following processes are important: NN, NN', $NN\pi$(N – nucleon, N' – isobaric state). These correspond to elastic scattering, excitation of one isobar and direct production of one meson . These processes are easily calculated by the formulas given by Belinfante[4]. Simple calculations yield 5 for the value of ρ. At a proton energy of 2.3 bev, besides processes producing 1 or 2 mesons, 3 meson production has some importance. This corresponds to the processes $N'N'\pi$, $NN'\pi\pi$ and $NN\pi\pi\pi$. Evaluation indicates, however, that these reactions occur in only 4 to 5% of all collisions. The calculation of ρ at 2.3 bev yields 1.8, agreeing exactly with the experimental result.

We have calculated, likewise, values of ρ for intermediate energies. These are as follows:

E	ρ
1	5
1.46	2.7
1.75	2
2.3	1.8

Thus, both the value of ρ and its dependence on energy agree with the calculation according to the statistical theory, in which is included both direct production of π mesons and their creation via isobaric states. Inclusion in the statistical theory only of direct production of mesons given at 1 bev, $\rho = 3.5$ and at 2.3 bev, $\rho = 2.7$.

In conclusion, I am grateful to Professor C. E. Belen'kii for cricticism of this work and for valuable suggestions.

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Numerical Values of the Constant of the Triplet Beta-Interaction

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THE ratio of the constants of the two elementary interactions leading to allowed beta-transitions can be estimated from experimental data[1,2] which have appeared in recent times. We shall employ nonrelativistic terminology and call these interactions singlet (Fermi selection rules) and triplet (Gamow-Teller rules).

In the general case of a mixed transition the ft value found from experimental data is connected with the interaction constants by the equation

$$ft\left[\frac{M_0^2}{A_0} + \frac{M_1^2}{A_1}\right] = 1, \qquad (1)$$

where M_0 and M_1 are the nuclear matrix elements for the singlet and triplet interactions; the universal times A_0 and A_1 are inversely proportional to the squares of the interaction constants G:

$$A = \frac{2\pi^3 \ln 2\, \hbar^7}{m_0^5 c^4 G^2} = \frac{1.2 \cdot 10^{-94}}{G^2}. \qquad (2)$$

For a pure process $A = ftM^2$.

The nuclear matrix elements M_0 for the singlet interaction are found theoretically. For this, no other assumptions are required besides that of charge invariance. The latter is violated only at the expense of a distortion of the nucleon wave functions by the Coulomb field. For the triplet interaction the nuclear matrix elements M_1 can be found theoretically only for pure states.

Because of the indicated reasons only the singlet constant can be found directly from the ft value for a pure process. For the singlet interaction it was found directly from the decay of O^{14} that $A_0 = ftM_0^2 = 6550 \pm 150$ sec.

For processes going by a pure triplet interaction the matrix elements are unknown. Therefore, one has to turn to mixed transitions for an estimate of the triplet constant. An exact value of the matrix element M_1 is known only for the free neutron, whose lifetime has been measured with very low accuracy. But we can give an accurate upper limit of the quantity A_1 in those transitions for which an upper limit of M_1^2 is known. The beta decay of triton yields the extreme of such