orbit, will radiate circularly-polarized gamma quanta. As a consequence of the spin-orbit interaction, which leads to depolarization of the μ^- meson on the orbit, the angular distribution and the angular correlation of these quanta depend on the degree of polarization of the μ^- meson.

Comparison of theory with experiment can yield information on the magnitude of the degree of polarization ($|P|$) and the direction of depolarization (sign of P) of μ^- mesons produced in decay of negative pions.

In the case of lead, according to Wheeler,[1] the energies of the gamma quanta radiated during the cascade transition 2s-2p-1s are respectively equal to 1.33 and 4.42 Mev.*

To obtain the correlation functions it is possible to employ the formula obtained in our preceding work,[3] neglecting the interaction at the first level. It is also necessary to take it into account that for the case of circularly-polarized quanta the formula changes somewhat. A factor† $(-\tau_1)^{\nu_1}(\tau_2)^{\nu_2}$ appears under the summation sign, where ν_1 and ν_2 are the orders of the spherical functions, which (together with the order of the degree of orientation k) can assume also odd values. Inserting the values of the spin of the μ meson ($s = 1/2$) and considering a nucleus of spin $I = 0$, we obtain for the cascade 0(1) 1(1)0

$$W = 1 - \frac{7}{6}\tau_1\tau_2\cos\theta + \frac{4}{9}\tau_2 P\cos\theta_2 + \frac{1}{12}(3\cos^2\theta - 1) \quad (1)$$
$$-\frac{1}{6}\tau_1 P\left[\cos\theta_1(3\cos^2\theta_2 - 1) + 3\cos\theta_2(\cos\theta - \cos\theta_1\cos\theta_2)\right]$$
$$-\frac{1}{18}\tau_2 P\left[\cos\theta_2(3\cos^2\theta_1 - 1) + 3\cos\theta_1(\cos\theta - \cos\theta_1\cos\theta_2)\right].$$

Here θ_i is the angle between the direction of the i-th quantum ($i = 1, 2$) and that of the incident negative muon, and θ is the angle between the two quanta. A value $P > 0$ corresponds to a predominant spin alignment with the direction of the incident negative muon.

If the direction of the first quantum is assumed the same as that of the incident negative muons, then

$$W = 1 + \left(-\frac{7}{6}\tau_1\tau_2 + \frac{1}{3}\tau_2 P\right)\cos\theta$$
$$-\frac{1}{6}\tau_1 P(3\cos^2\theta - 1) + \frac{1}{12}(3\cos^2\theta - 1). \quad (2)$$

When $\theta = 24°39'$ we have $W_{++} = 0.077(1 + 0.9P)$, along with the ratio

$$(W_{++} - W_{--})/(W_{++} + W_{--}) = 0.9P. \quad (3)$$

Here $W_{++}(W_{--})$ denotes the value of W for $\tau_1 = \tau_2 = 1$ ($\tau_1 = \tau_2 = -1$). When $\theta \to 0$ the multiplier of P in Eq. (3) tends to unity, but at the same time $W \to 0$.

Integrating (1) over $d\Omega_1$ we get the angular distribution for the transition $2p \to 1s$

$$W = 1 + {}^4/_9\tau_2 P\cos\theta_2,$$

i.e.,

$$[W(0°) - W(180°)]/W(90°) = {}^8/_9\tau_2 P. \quad (4)$$

We take this opportunity to express our deep gratitude to V. V. Vladimirskii for the interest displayed, and to K. A. Ter-Martirosian for valuable discussions.

*According to data by Fitch and Rainwater,[2] gamma quanta of energy 6.02 Mev are emitted in the transition $2p \to 1s$.

†$\tau = +1$ ($\tau = -1$) for right-hand (left-hand) circularly polarized gamma quantum.

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BREMSSTRAHLUNG AND PAIR PRODUCTION FROM PROTONS WITH ALLOWANCE FOR FORM FACTOR

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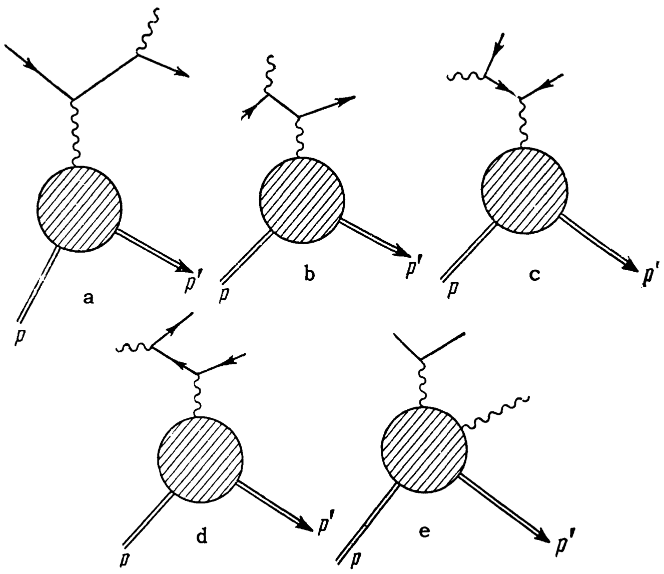
According to the present view, a nucleon consists of a "core" surrounded by a cloud of virtual mesons. The distribution of nucleonic charge and magnetic moment has been studied in detail by Hofstadter in the scattering of high-energy electrons from protons and neutrons. In this connection it is of interest to investigate the influence of the form factor on the related reactions e.g., bremsstrahlung and pair production on nucleons.

We have calculated these processes on protons in the lowest order of perturbation theory (third order in e). Graphs a and b were computed for bremsstrahlung and graphs c and d for pair production. An additional contribution is due to



the meson "jacket" (graph e). However, its evaluation is much more complicated than that of the graphs a, b, c, and d. In this note we shall therefore give only some indications of its contribution. In the graphs a double line denotes a proton, a single line an electron and a wavy line a photon. The proton vertex is described not by $e\gamma_\alpha$, but by the factor[1]

$$e\gamma_\alpha F_1(|p-p'|^2) + (\mu/2M)\, F_2(|p-p'|^2)\,(\sigma_{\alpha\beta}\,(p-p')_\beta),$$

$$\sigma_{\alpha\beta} = {}^1/_2\,(\gamma_\alpha\gamma_\beta - \gamma_\beta\gamma_\alpha),$$

where μ is the anomalous proton magnetic moment, M the proton mass, and F_1 and F_2 form factors that depend on the proton recoil. The computations were performed by the Feynman method.

The formulae obtained are rather lengthy and will not be given here. In the special case where $M \to \infty$ (recoil equals zero; energy conservation is expressed by $\epsilon = k' + \epsilon'$ where ϵ, k' and ϵ' are the energies of the incident electron, the created photon, and the scattered electron respectively) the formulae go over into the Bethe-Heitler expressions[2] for bremsstrahlung and pair production.

In their measurement of bremsstrahlung from 500 and 550 Mev electrons on hydrogen, Bernstein and Panofsky[3] found that the Bethe-Heitler cross sections are true to a high degree of accuracy, at least for small photon emission angles θ_0 (not exceeding 7 to 10°).

One thus can surmise that if deviations from the Bethe-Heitler formulae are observed at all, it will be at large angles θ_0 or at very large electron energies ($\gg 500$ Mev). It therefore follows that if there is a difference between our expressions and the Bethe-Heitler formula, this will indicate not only the influence of the recoil and of the form factor on the cross section of the particular process, but a possible contribution to this cross section from the meson jacket.

We have compared the expressions for the differential cross section for the case where the incoming electron has an energy of 500 Mev. The form factors $F_1(|p-p'|^2)$ and $F_2(|p-p'|^2)$ were taken from Hofstadters experiments[4] on the scattering of electrons of energy ~ 500 Mev on protons (exponential model, $F_1 = F_2$). As an example we list a few members concerning the special case where the momenta of the photon

$\theta_0 = 30°$. Photon energy = 235 Mev

θ	Differential cross section according to the Bethe-Heitler formula ($d\sigma_{B-H}$)	Differential cross section with allowances for recoil and form factor ($d\sigma_{F-F}$)	$\dfrac{d\sigma_{F-F}}{d\sigma_{B-H}}$	Differential cross section without allowance for form factor
30°	31332	27434	0.875	29880
60°	3137	2686	0.855	2780
90°	739	480	0.650	600
120°	127.5	56.4	0.442	92.5
150°	27.85	11.33	0.405	22.3

Note. The differential cross section is given in arbitrary units. θ_0 and θ are the angles between the photon momentum and the momenta of the incident and scattered electron respectively.

and of the electron before and after scattering are complanar.

At different values of the angles θ and θ_0, as well as in the noncomplanar case, we obtain results which differ from the Bethe-Heitler formulae by approximately the same amount as the tabulated values. From the comparison of the cross sections it is clear that even for not too large angles ($\theta_0 \approx 30°$) the difference reaches appreciable values ($\sim 15\%$). This obviously points to a small but perceptible contribution of the meson "jacket" to the bremsstrahlung cross section. At present we are engaged in a calculation of this contribution, upon the completion of which we shall be able to answer this question.

In conclusion the authors express their deep

gratitude to A. A. Logunov and A. N. Tavkhelidze for their valuable discussion of the results obtained.

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DIFFRACTION SCATTERING OF FAST PARTICLES

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THE structure of elementary particles can be determined by studying the elastic scattering of some type of beam by these particles. In the application to nuclei and nucleons, the only example of such a beam up to present is the well known work of the group of Hofstadter with electron scattering, which makes it possible to determine the form factors of the electric charge and of the magnetic moment.[1] However, analysis of the elastic scattering of other types of particles also makes it possible to obtain valuable information about the structure of nucleons and of the nucleus.* By way of example, we consider the scattering of π^- mesons by nucleons.[3,4]

For simplicity, we disregard the spin-dependence of the interaction and neglect the process of charge exchange. We assume also that the real part of the phase shift, $\mathrm{Re}\,\eta_l = 0$, which is in good agreement with experiment for energies $E_\pi \geq 1$ Bev.[2,5] A rigorous solution of the problem will be published later.

In Fig. 1 the solid lines show the quantity

$$\mathrm{Im}\,\eta_l = -\frac{1}{2}\ln\left\{1 - \lambda\!\!\!^{-}{}^{-1}\int_0^\pi \sqrt{(d\sigma_d(\theta)/d\Omega)}\,P_l(\cos\theta)\sin\theta\,d\theta\right\}$$

for the case of scattering of 1.3-Bev π^- mesons.

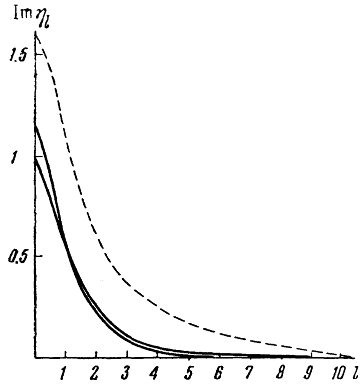

FIG. 1

In order to calculate these functions, curves of least and greatest curvature were constructed between the limits of the experimental values of the differential cross section for elastic scattering ($\sigma_d \approx \sigma_{el}$) from reference 3. The curves in Fig. 1 were drawn through the centers of the rectangles of the corresponding histograms. The dashed line in Fig. 1 gives the values of $\mathrm{Im}\,\eta_l$ calculated from the mean experimental data from reference 4 for the scattering of 5-Bev π^- mesons.

At high energies, where the wavelength $\lambda\!\!\!^{-}$ becomes substantially smaller than the dimensions of the scattering system, and the relative change in the absorption coefficient K over a wavelength $\lambda\!\!\!^{-}$ is small, the quasi-classical approximation can be employed with a high accuracy. Taking $\mathrm{Im}\,\eta_l$ from Fig. 1, we obtain from well-known formulas[6] the values: $\sigma_{in} = (25.5 \pm 1.5)$mb, $\sigma_d = 7.4 \pm 0.1)$mb for E = 1.3 Bev and $\sigma_{in} \approx 23$ mb, $\sigma_d \approx 5$ mb for E = 5 Bev. The good agreement of these quantities, as well as that of the angular distribution we calculated for the elastically scattered particles, with the data of references 3 and 4 is one of the justifications of the following applications of the quasi-classical approximation.

In Fig. 2 we give the values $K = K(r)$ (where r is the distance from the center of the nucleon)

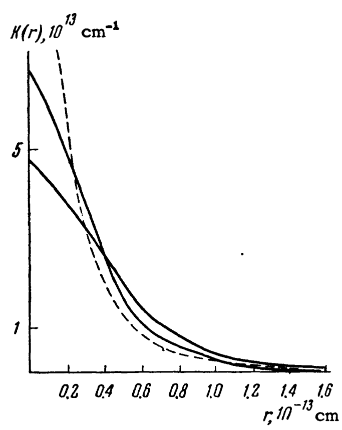

FIG. 2