ELECTROMAGNETIC SCATTERING OF PARTICLES OF SPIN ½

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A general formula has been obtained for the electromagnetic scattering of two different longitudinally polarized particles of spin ½.

ONE of the consequences of parity nonconservation in weak interactions is the longitudinal polarization of the fermions produced in the process, in particular of μ mesons formed in the decay of π mesons. Therefore, it is useful to generalize Nikishov's formula[1] for the cross section for the scattering of a μ meson by a nucleon to the case of longitudinally polarized particles.

The calculation has been carried out on the basis of the scattering matrix including the Pauli interaction,[2] taking the internal structure of the particles into account by means of the form-factors $F_\mu(k^2)$, $l_\mu(k^2)$ and $F_N(k^2)$, $l_N(k^2)$, for the meson and the nucleon respectively (k is the transferred momentum). The square of the matrix element containing the initial spin states of definite polarization and summed over the final states was found by means of the method of projection operators.[2,3] The calculations were carried out in the laboratory system, and because of this the spin projection operator of the incident meson was taken for the spin projection operator of the nucleon at rest.

As a result of this calculation the following expression was obtained for the differential scattering cross section

$$\frac{d\sigma}{d\Omega} = \frac{e^4 \rho}{(2\pi)^2 v_{\mathrm{rel}}} \{|\mathfrak{M}|^2 \pm |R|^2\}.$$

In this expression

$$e^2/4\pi = 1/137, \quad v_{\mathrm{rel}} = |\mathbf{p}_0|/E_0,$$

$$\rho = \mathbf{p}_\mu^2 WE/[|\mathbf{p}_\mu|(M+E_0) - E|\mathbf{p}_0|\cos\vartheta],$$

the + and − signs refer to the case of parallel and antiparallel spins respectively; $|\mathfrak{M}|^2$ is the square of the matrix element for the scattering of unpolarized particles which coincides with the expression obtained by Nikishov[1] if we take it in the laboratory system and assume that $\Phi = l/2$, while $|R|^2$ has the following form

$$\begin{aligned} |R|^2 = \frac{1}{MWE_0Ek^4} \Big\{ & F_\mu^2 \left[\tfrac{1}{4} F_N^2 \left(\tfrac{1}{2} k^4 + 2ME_0 \mathbf{p}_\mu^2 \sin^2\vartheta\right) \right. \\ & \left. + l_N F_N M \left(\tfrac{1}{2} k^4 + ME_0 \mathbf{p}_\mu^2 \sin^2\vartheta\right) + \tfrac{1}{2} l_N^2 M^2 k^4 \right] \\ & + \mu l_\mu F_\mu \left[F_N^2 \left(\tfrac{1}{2} k^4 + ME_0 \mathbf{p}_\mu^2 \sin^2\vartheta\right) \right. \\ & + l_N F_N M \left(4k^4 - k^2 \mathbf{p}_\mu^2 \sin^2\vartheta + 2ME_0 \mathbf{p}_\mu^2 \sin^2\vartheta\right) \\ & \left. + l_N^2 M^2 k^2 \left(2k^2 - \mathbf{p}_\mu^2 \sin^2\vartheta\right) \right] + \tfrac{1}{2} \mu^2 l_\mu^2 k^4 (F_N + 2l_N M)^2 \Big\}, \end{aligned}$$

where the notation of reference 1 has been used, i.e., M and μ are the nucleon and meson masses; E_0, $\mathbf{p}_0$ and E, $\mathbf{p}_\mu$ are the initial and final energy and momentum of the meson; W is the final nucleon energy.

In the case when the particles are point particles and the incident particle has no anomalous magnetic moment, i.e., for $F_\mu = F_N = 1$, $l_\mu = 0$ the expression for the differential cross section becomes simplified:

$$\begin{aligned} \frac{d\sigma}{d\Omega} = \frac{e^4}{(2\pi)^2} \frac{\rho}{v_{\mathrm{rel}} MWE_0Ek^4} \{ & M\left(ME_0^2 - \tfrac{1}{2} E_0 k^2 - \tfrac{1}{4} Mk^2\right) \\ & \times (1 + l_N^2 k^2) + \tfrac{1}{4} k^2 \left(\tfrac{1}{2} k^2 - \mu^2\right)(1 + 2l_N M^2) \pm \\ & \pm \tfrac{1}{2} \left[\tfrac{1}{4} k^2 (1 + 2l_N M) + ME_0 \mathbf{p}_\mu^2 \sin^2\vartheta\right](1 + 2l_N M)\}. \end{aligned}$$

After transition to the laboratory system the formula for the scattering of an electron by a proton given in Bincer's paper[4] assumes the same form.

In conclusion I express my gratitude to F. I. Fedorov for the method of calculation suggested by him.

[1] A. I. Nikishov, JETP **36**, 1604 (1959), Soviet Phys. JETP **9**, 1140 (1959).

[2] L. G. Moroz and F. I. Fedorov, JETP **39**, 293 (1960), Soviet Phys. JETP **12**, 209 (1961).

[4] A. Bincer, Phys. Rev. **107**, 1467 (1957).

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