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BREMSSTRAHLUNG FROM A DISTRIBUTED PROTON

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An expression is obtained for the form factor of a proton emitting bremsstrahlung radiation as a result of diffraction scattering in a nuclear field.

DIFFRACTION radiation of photons by fast particles of spin $1/2$ has been considered in the work of Akhiezer.[1] Sitenko, who calculated the effective cross section for radiation during the scattering of protons, took into account the Coulomb interaction.[2] As shown in these papers, however, a consistent discussion requires that the anomalous magnetic moment and "diffuseness" of the proton should be taken into account.

This is all the more important in light of experimental investigations of the scattering of fast electrons on protons conducted by Hofstadter's group.[3] As a result of this work, it was explained, in particular, that for large momenta of the recoil proton it is necessary to take into account the interaction of the proton with the mesic vacuum. It was shown that, for the calculation of this interaction, the operator γ_μ in the expression for the proton current density $u_2\gamma_\mu u_1$ should be replaced by the vertex operator[4]

$$\Gamma_\mu = a(q^2)\gamma_\mu + \frac{ib(q^2)}{2M}\gamma_\mu\hat{q}, \tag{1}$$

where q is the difference of the 4-momenta of the proton in the initial and final states; $a(q^2)$ and $b(q^2)$ are real invariant functions, the first of which describes the charge distribution and the Dirac magnetic moment of the proton, and the second the distribution of its anomalous moment.

Using the same method, we have calculated in the present work the influence of the proton structure and anomalous magnetic moment on the bremsstrahlung from the proton for diffraction scattering in the field of a nucleus. It is assumed that the form of "diffuseness" of the proton does not depend on the character of the electromagnetic process and is completely determined by the value of the proton recoil.

The matrix element of the bremsstrahlung of ultrarelativistic protons in a central field has the form

$$S_{i\to f} = -\frac{2\pi ie}{\sqrt{2\omega}}\int \bar{\psi}_{p'}^{(-)}(\mathbf{r})\,\gamma_\mu\psi_p^{(+)}(\mathbf{r})\,e_\mu \exp(-i\mathbf{kr})\,d\mathbf{r}. \tag{2}$$

In accordance with (1), we replace γ_μ in (2) by

$$A\gamma_\mu - (iB/2M)\,\gamma_\mu\hat{k}. \tag{3}$$

The minus sign in front of the second term corresponds to the radiation of a photon by the proton. In the general case, A and B are functions of the invariants

$$E\omega - \mathbf{pk}, \qquad E'\omega - \mathbf{p'k}, \qquad EE' - \mathbf{pp'} - M^2.$$

If in the radiation process the proton acceleration is not too great and, consequently, the energies of the radiated photons are not large, one may neglect the quantities $(E\omega - \mathbf{p}\cdot\mathbf{k}) - (E'\omega - \mathbf{p}\cdot\mathbf{k})$ and $EE' - \mathbf{p}\cdot\mathbf{p}' - M^2$ in comparison with M^2. Then A and B will depend only on $E\omega - \mathbf{p}\cdot\mathbf{k}$ and will coincide with the functions a and b describing the structure of the protons in elastic scattering of electrons on protons.* Carrying out the calculation of the effective bremsstrahlung cross section, we obtain

$$d\sigma = \frac{e^2}{4\pi^3}\frac{E'}{E}\left|\frac{RJ_1(MR\,|\mathbf{x}+\mathbf{y}|)}{|\mathbf{x}+\mathbf{y}|} + \frac{2in}{|\mathbf{x}+\mathbf{y}|}\int_R^\infty \exp\{2i[\eta(\rho) - \eta(R)]\}\,J_1(MR\,|\mathbf{x}+\mathbf{y}|\,\rho)\,d\rho\right|^2 \left\{\left(\frac{\mathbf{x}}{1+x^2}+\frac{\mathbf{y}}{1+y^2}\right)^2 + \frac{\omega}{2EE'}\frac{(\mathbf{x}+\mathbf{y})^2}{(1+x^2)(1+y^2)}\right\} F^2\frac{d\omega}{\omega}\,d\mathbf{x}d\mathbf{y},$$

$$F^2 = A^2\left[1 + \mu\frac{\omega}{2E}(1+x^2) - \frac{\mu^2\omega^2}{8E^2}\left(1+x^2\right)^2\right], \tag{4}$$

where $\mu = B/A$, the remaining notation being the same as in reference 2. Expression (4) differs from Sitenko's formula by a factor F^2. The form of the factor F^2 corresponds to the conclusions of Landau and Pomeranchuk, who base themselves on general considerations.[5] It should be noted that formula (4) ceases to be valid for $E\omega - \mathbf{p}\cdot\mathbf{k} \sim M^2$.

*They will differ only in their arguments: q^2 in the case of elastic scattering and $2pk$ in the case of bremsstrahlung.

The same factor F^2, of course, enters into the formula relating the bremsstrahlung cross section and the elastic cross section obtained by Sitenko.[2]

In a similar way, the influence of the proton "structure" on the process of diffraction production of electron — positron pairs in the scattering of the proton in a central field may be taken into account.

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[2] A. G. Sitenko, JETP **32**, 1505 (1957), Soviet Phys. JETP **5**, 1223 (1957).

[3] Hofstadter, Bumiller, and Yearian, Revs. Modern Phys. **30**, 482 (1958).

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[5] L. D. Landau and I. Ya. Pomeranchuk, JETP **24**, 505 (1953).

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