PHOTOPRODUCTION OF NEUTRINO-ANTINEUTRINO PAIRS ON ELECTRONS

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The cross section for the process $\gamma + e^- \to \mu^- + \nu + \bar{\nu}$ is calculated in the extreme relativistic approximation.

TWO years ago, D. I. Blokhintsev[1] pointed out that at sufficiently high energies weak interactions can become comparable with electromagnetic interactions. According to his estimates, the process $\gamma + e^- \to \mu^- + \nu + \bar{\nu}$ has an especially large cross section, which reaches that of the Compton effect at 250 Bev. We have calculated the cross section for this process, and our result confirms this estimate.

The interaction Hamiltonian has the following form:

$$H = ie(\bar{\psi}_e \hat{A} \psi_e) + ie(\hat{\psi}_\mu \hat{A} \psi_\mu) + f(\bar{\psi}_e \gamma_\alpha (1 + \gamma_5) \psi_\mu) \times (\bar{\psi}_\nu \gamma_\alpha (1 + \gamma_5) \psi_\nu) + f(\bar{\psi}_\mu \gamma_\alpha (1 + \gamma_5) \psi_e)(\bar{\psi}_\nu \gamma_\alpha (1 + \gamma_5) \psi_\nu).$$

In the computations, we included the two lowest order diagrams, which are similar to the corresponding diagrams for the Compton effect.

Averaging over initial polarizations and summing over final polarizations, and dropping unimportant terms which contain m_e^2 and m_μ^2, we get the following expression for the total cross section:

$$\sigma_\mu = \frac{1}{v} \frac{e^2 f^2}{(2\pi)^5} \frac{8}{\omega \varepsilon_e} \int \frac{d^3 p_\mu d^3 p_\nu d^3 p_{\bar{\nu}}}{\varepsilon_\mu \varepsilon_\nu \varepsilon_{\bar{\nu}}} \delta^4 (p_e + k - p_\mu - p_\nu - p_{\bar{\nu}})$$
$$\times \Big[- \frac{(kp_e)(p_{\bar{\nu}} k)(p_\nu p_\mu)}{[(p_e + k)^2 + m_e^2]^2} - \frac{(kp_\mu)(p_{\bar{\nu}} p_e)(p_\nu k)}{[(p_\mu - k)^2 + m_\mu^2]^2}$$
$$+ [(p_e + k)^2 + m_e^2]^{-1} [(p_\mu - k)^2 + m_\mu^2]^{-1} \{[2(p_e p_\mu)$$
$$- (p_e k) + (p_\mu k)](p_{\bar{\nu}} p_e)(p_\nu p_\mu) + (p_e p_\mu)(p_{\bar{\nu}} k)(p_\nu p_\mu)$$
$$- (p_e p_\mu)(p_{\bar{\nu}} p_e)(p_\nu k) + (kp_\mu)(p_{\bar{\nu}} p_e)(p_\nu p_e)$$
$$- (kp_e)(p_{\bar{\nu}} p_\mu)(p_\nu p_\mu)\} \Big].$$

We have integrated this expression (in the center-of-mass system) in the following, extreme relativistic, approximation:

$$\varepsilon_e = \omega = E/2, \qquad \varepsilon_\mu = |\mathbf{p}_\mu|, \qquad \varepsilon_\mu^{max} = E/2, \; v = 2,$$

where $E = \omega + \epsilon_e$.

The final expression for the cross section, in this approximation, has the form

$$\sigma_\mu = \frac{e^2 f^2}{4\pi^3} \omega^2 \left(\ln \frac{2\omega}{m_\mu} - 0.798 \right),$$

where ω is the energy of the photon in the c.m. system.

Using the well known expression for the Compton cross section in the c.m. system, we found the following condition for satisfying the inequality $\sigma_\mu \geq \sigma_C$:

$$(e^2 f^2 / 4\pi^3) \omega^2 \geqslant \pi r_0^2 m_e^2 / \omega^2 \equiv \pi (e^2/4\pi)^2 \omega^{-2}.$$

This condition is satisfied for values of ω greater than 242 Bev in the c.m. system.

In conclusion, the authors express their deep gratitude to D. I. Blokhintsev for posing this problem and for valuable discussions.

[1] D. I. Blokhintsev, Nuovo cimento 9, 925 (1958); D. I. Blokhintsev, JETP 35, 254 (1958), Soviet Phys. JETP 8, 174 (1959); M. A. Markow, Hyperonen und K-Mesonen, Verlag der Wissenschaften, Berlin, 1960, p. 292.

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ERRATA

Vol	No	Author	page	col	line	Reads	Should read
13	2	Gofman and Nemets	333	r	Figure	Ordinates of angular distributions for Si, Al, and C should be doubled.	
13	2	Wang et al.	473	r	2nd Eq.	$\sigma_\mu = \frac{e^2 f^2}{4\pi^3}\omega^2 (\ln \frac{2\omega}{m_\mu} - 0.798)$	$\sigma_\mu = \frac{e^2 f^2}{9\pi^3}\omega^2 \left(\ln \frac{2\omega}{m_\mu} - \frac{55}{48}\right)$
			473	r	3rd Eq.	$(e^2f^2/4\pi^3)\,\omega^2 \geqslant \ldots$	$(e^2f^2/9\pi^3)\,\omega^2 \geqslant \ldots$
			473	r	17	242 Bev	292 Bev
14	1	Ivanter	178	r	9	1/73	1.58×10^{-6}
14	1	Laperashvili and Matinyan	196	r	4	statistical	static
14	2	Ustinova	418	r	Eq. (10) 4th line	$[-\frac{1}{4}(3\cos^2\theta - 1)\ldots$	$-[\frac{1}{4}(3\cos^2\theta - 1)\ldots$
14	3	Charakhchyan et al.	533		Table II, col. 6 line 1	1.9	0.9
14	3	Malakhov	550			The statement in the first two phrases following Eq. (5) are in error. Equation (5) is meaningful only when s is not too large compared with the threshold for inelastic processes. The last phrase of the abstract is therefore also in error.	
14	3	Kozhushner and Shabalin	677 ff			The right half of Eq. (7) should be multiplied by 2. Consequently, the expressions for the cross sections of processes (1) and (2) should be doubled.	
14	4	Nezlin	725	r		Fig. 6 is upside down, and the description "upward" in its caption should be "downward."	
14	4	Geĭlikman and Kresin	817	r	Eq. (1.5)	$\ldots\left[b^2 \sum_{s=1}^{\infty} K_2(bs)\right]^2$	$\ldots\left[b^2 \sum_{s=1}^{\infty}(-1)^{s+1} K_2(bs)\right]^2$
			817	r	Eq. (1.6)	$\Phi(T) = \ldots$	$\Phi(T) \approx \ldots$
			818	l	Fig. 6, ordinate axis	$\frac{\varkappa_s(T)}{\varkappa_n(T_c)}$	$\frac{\varkappa_s(T)}{\varkappa_n(T)}$
14	4	Ritus	918	r	4 from bottom	two or three	2.3
14	5	Yurasov and Sirotenko	971	l	Eq. (3)	1 < d/2 < 2	1 < d/r < 2
14	5	Shapiro	1154	l	Table	2306	23.6