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COMPTON TERMS IN INELASTIC PHOTOPRODUCTION OF MU-PAIRS*

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ABSTRACT

Given the parton model of the nucleon, the cross section for photoproduction of high-energy mu-pairs of small invariant mass and high transverse momentum is estimated.

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In a recent paper[1] we proposed an experimental check of the parton model[2] by comparing inelastic electron-proton scattering to inelastic Compton scattering. It was found that the ratio of the two processes is independent of the parton spin and distribution of longitudinal momentum, but depends sensitively on the parton charge. A related experiment with perhaps better signature is to consider the "Compton" terms in inelastic photoproduction of μ-pairs. The contributing diagrams in this case are shown in Fig. 1. In this case, one would look for μ-pairs produced with small invariant mass and at large angles to the incident γ-rays. Hopefully the angular correlation of the two muons provides a signature sufficiently unique to distinguish this "Compton" process from the two major sources of background: muons from $\pi^{\pm}$ or $K^{\pm}$ decay and mu-pairs from Bethe-Heitler process. We have not calculated these backgrounds in detail; they depend upon the specific experimental configuration to be used. However, as the energy and transverse momentum of the Compton μ-pairs increase, the relative importance of both backgrounds will decrease.

We have calculated this Compton process in the parton model. To this end, we calculated first the point cross section for the diagrams in Fig. 1. All variables are in the laboratory frame and are defined as follows:

$k' = k_+ + k_-$ = energy of virtual photon

$\nu = k - k'$

$\Delta^\mu = k_+^\mu - k_-^\mu$: 4-momentum difference between final muons

M, m_μ, σ : masses of proton, muon and virtual photon

θ : angle of virtual photon relative to incident photon

$q^2 = (k-k')^2 = \sigma^2 - 2k(k' - \sqrt{k'^2 - \sigma^2})$

ϵ_μ : polarization of the initial photon

The point cross section from a spin 1/2 particle of unit charge is given by:

$$\frac{d\sigma}{d\Omega_+ d\Omega_- dE_+ dE_-} = \frac{\alpha^3}{\pi^2} \frac{1}{\sigma^4} \frac{E_+E_-}{Mk} \left\{ (m_\mu^2 + p_+ \cdot p_-) \left[\frac{k'}{k} \left(1 - \frac{\sigma^2}{2Mk'}\right) + \frac{k}{k'} \frac{1}{\left(1 - \frac{\sigma^2}{2Mk'}\right)} - 2\left(\frac{\epsilon \cdot k'}{k'}\right)^2 \frac{1 + \frac{\sigma^2}{2M^2}}{\left(1 - \frac{\sigma^2}{2Mk'}\right)} \right] \right.$$

$$+ \frac{1}{4} (\Delta \cdot \Delta) \frac{k'}{k} \left(1 - \frac{\sigma^2}{2Mk'}\right) \left(1 - \frac{k}{k'} \frac{1}{1 - \frac{\sigma^2}{2Mk'}}\right)^2 + \frac{1}{4} \frac{(k \cdot \Delta)^2}{M^2 kk'} \frac{\sigma^2}{\left(1 - \frac{\sigma^2}{2Mk'}\right)} - \left((\epsilon \cdot \Delta) - \frac{\Delta_0}{k'} \frac{\epsilon \cdot k'}{1 - \frac{\sigma^2}{2Mk'}}\right)^2$$

$$\left. - \frac{\sigma^2 \Delta \cdot \Delta}{4M^2 k'^2} \frac{(\epsilon \cdot k')^2}{\left(1 - \frac{\sigma^2}{2Mk'}\right)} \right\} \delta\, (2M\nu + q^2) \qquad (1)$$

The final result for the scattering of unpolarized photons is obtained by averaging over the initial photon polarizations.

In checking the trace calculation of the hadronic part of the diagrams, we explicitly verified that $T^{\mu\nu}$ satisfies

(i) Gauge invariance $T^{\mu\nu} k'_\mu k'_\nu = 0$.

(ii) Gives the ordinary Compton cross section when we interpret $\Delta\mu$ as a polarization vector ϵ'_μ and take the limit of $\sigma^2 \to 0$.

To obtain the cross section from a proton in the parton model we replace M by Mx, then multiply by the distribution function $f_N(x)$ and by P(N), and then integrate over x as has been discussed in Ref. 1. The final result is given below for the case of spin-1/2 integer-charge partons. With

$$x = \frac{-q^2}{2M\nu} \qquad \text{and} \qquad \xi = 1 - \frac{\sigma^2}{2Mxk'}$$

$$\frac{d\sigma}{d\Omega_+ d\Omega_- dE_+ dE_-} = \frac{\alpha^3}{2\pi^2} \frac{E_+E_-}{M^2x^2k\nu\sigma^4} \Bigg\{ (m_\mu^2 + p_+ \cdot p_-) \left[\frac{k'}{k}\xi + \frac{k}{k'}\frac{1}{\xi} - 2\left(\frac{\epsilon \cdot k'}{k'}\right)^2 \frac{1+\frac{\sigma^2}{2M^2x^2}}{\xi} \right]$$

$$+ \frac{1}{4}(\Delta\cdot\Delta)\frac{k'}{k}\left(1 - \frac{k}{k'}\frac{1}{\xi}\right)^2 \xi + \frac{1}{4}\frac{(k\cdot\Delta)^2}{M^2x^2}\frac{\sigma^2}{kk'}\frac{1}{\xi} - \left(\epsilon\cdot\Delta - \frac{\Delta_0}{k'}\frac{\epsilon\cdot k'}{\xi}\right)^2$$

$$- \frac{\Delta\cdot\Delta}{4M^2x^2}\frac{\sigma^2}{k'^2}\frac{(\epsilon\cdot k')^2}{\xi} \Bigg\} F(x) \qquad (2)$$

where F(x) is the structure function $\nu W_2(q^2, \nu)$ measured in inelastic electron proton scattering.[3] We can also integrate over the relative phase-space between the muons to obtain a triple differential cross section with respect to the solid angle, energy and mass-square of the outgoing virtual photon.

$$\frac{d\bar{\sigma}}{d\Omega dk' d\sigma^2} = \frac{\alpha^3}{6\pi} \frac{1}{M^2x^2k\nu\sigma^2} \sqrt{1 - \frac{4m_\mu^2}{\sigma^2}} \left(1 + \frac{2m_\mu^2}{\sigma^2}\right) \sqrt{k'^2 - \sigma^2}$$

$$\cdot \left\{ \frac{k'}{k}\xi + \frac{k}{k'}\frac{1}{\xi} - 2\left(1 + \frac{\sigma^2}{2M^2x^2}\right)\left(\frac{\epsilon\cdot k'}{k'}\right)^2 \frac{1}{\xi} \right\} F(x) \qquad (3)$$

We have calculated the counting rates at large momentum transfers using a bremsstrahlung spectrum and (3) for several experimental situations at SLAC and Cornell and we found that they are small but measurable. A more formidable problem perhaps is the elimination of the backgrounds. The accidental muons from $\pi^\pm$ and $K^\pm$ depends critically on the experimental apparatus and the duty cycle of the accelerator. On the other hand, the mu-pairs from Bethe-Heitler process are completely predictable[4] once the inelastic form factors $W_1(q^2, \nu)$ and $W_2(q^2, \nu)$ become available.

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FIGURE CAPTION

1. Feynman diagrams for the Compton terms in the photoproduction of muon pairs.

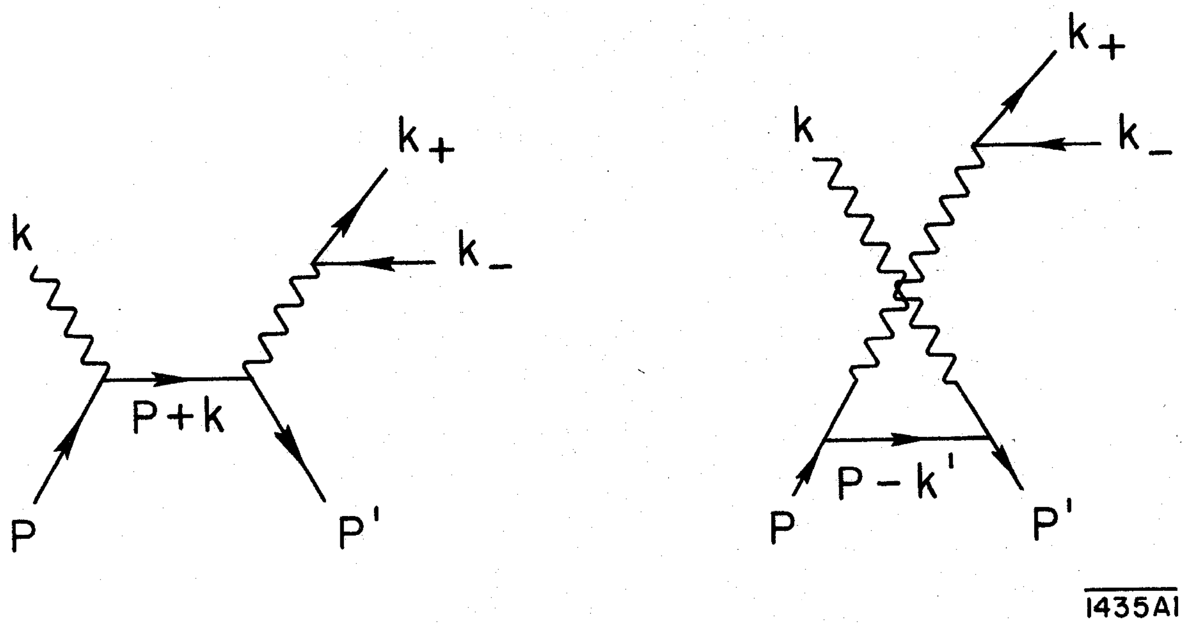

Fig. 1