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On the possibility of $\gamma\gamma$ scattering detection at LHC

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The light to light scattering below the new heavy charged particles production threshold could be observable in the collision of virtual photons at proton colliders. At the Large Hadron Collider (LHC) it will be seen as a pair production of photons with energies up to a few TeV and roughly compensated transverse momenta of the same scale.

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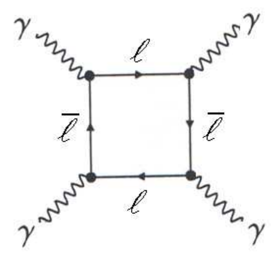
Vacuum polarization in quantum electrodynamics (QED) or Standard Model of elementary particles (SM) is induced by the possibility of transition of photon into particle-antiparticle pair and vice versa. This implies nonlinear interaction between electromagnetic fields even without polarizing media. Such effects were considered for the first time in [1]. The light to light scattering is calculable in fourth order of perturbation theory (see Fig. 1). The main vacuum nonlinear effects here are photon-photon scattering, photon slitting and fusion in the presence of electromagnetic field of the nucleus, photon-nucleus elastic scattering etc. In this paper we are interested in the process of the first type.

Differential and total cross sections of light to light scattering were calculated in low energy limit [2] and high-energy limit [3]. General case was investigated in [4], and its simpler form was obtained in [5] by using the dispersion relations technique. All these calculations were made for electrons and positrons as virtual particles. Analogous cross sections for scalar and vector virtual particles can be found in [6]. As high-energy protons (or nuclea) in colliding beams at Tevatron, RHIC or LHC should rather intensively radiate photons, it seems reasonable to estimate the possibility of detection of two-gamma events corresponding to light to light scattering diagram (see Fig. 1) with the most heavy particles (W-bosons, t-quarks, etc) [7].

Following [6], one can write the differential cross section of photon-photon scattering subprocess for the case of virtual t-quarks as

$$d\sigma(\gamma\gamma \to \gamma\gamma) = \frac{5}{7}\left(\frac{s^2+t^2+u^2}{s^2}\right)^2 \sigma_{tot}\frac{dt}{s},$$



$\ell = q,\ e,\ \mu,\ \tau,\ W$

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where $\sigma_{tot} = R\left(\frac{s}{4}\right)^3$, $R = \frac{28}{405}\frac{1.39}{\pi}\frac{\alpha^4}{m_t^8}$, m_t is the t-quark mass, $\alpha \approx \frac{1}{137}$ - electromagnetic coupling constant and s, t, u - invariant Mandelstam variables.

For the process $pp \to \gamma\gamma X$, where X is a final state ($X = pp$ in elastic case), the cross section is

$$\sigma(pp \to \gamma\gamma X) = \left(\frac{\alpha}{\pi}\right)^2 \int \frac{d\omega_1}{\omega_1}\frac{d\omega_2}{\omega_2}\frac{dQ_1^2}{Q_1^2}\frac{dQ_2^2}{Q_2^2} n_1(\omega_1, Q_1^2) n_2(\omega_2, Q_2^2) d\sigma(\gamma\gamma \to \gamma\gamma),$$

where integration is performed over energies ω_i and momenta Q_i of initial photons. For LHC energy range, direct calculation gives the following estimates:

$$\begin{aligned} \sigma_{tot}(\gamma\gamma \to \gamma\gamma) &= 25\, fbn \\ \sigma(pp \to \boxed{t} \to \gamma\gamma X) &= 10^{-3}\, fbn. \end{aligned} \tag{1}$$

For the case of W-boson as intermediate particle in the box holds:

$$\sigma(pp \to \boxed{W} \to \gamma\gamma X) = 1.2\, fbn. \tag{2}$$

The accuracy of calculation is about 30% due to differences of the extrapolations in various structure function parameterizations and due to higher order corrections. Cross sections (1),(2) are rather low compared with the ones of the QCD-induced background processes, which are of the order 100 *fbn*. Nevertheless, the investigation of two-gamma processes at ATLAS may be useful for the search of the new physics effects, connected with the possible existence of additional W'-bosons or new interactions. If measured cross-sections would be higher than estimates (1),(2), then it could be interpreted as the hint for existence of new heavy particles beyond the Standard Model. The effects of vacuum induced nonlinear photon-photon interaction are in principle noticeable below the new particle production threshold, and deserve more profound analysis.

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