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CMS Internal Note

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One remark on the $\gamma\gamma$ production in the central exclusive diffraction.

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Abstract

Some important kinematical aspects of the process $pp \to p + \gamma\gamma + p$ are considered.

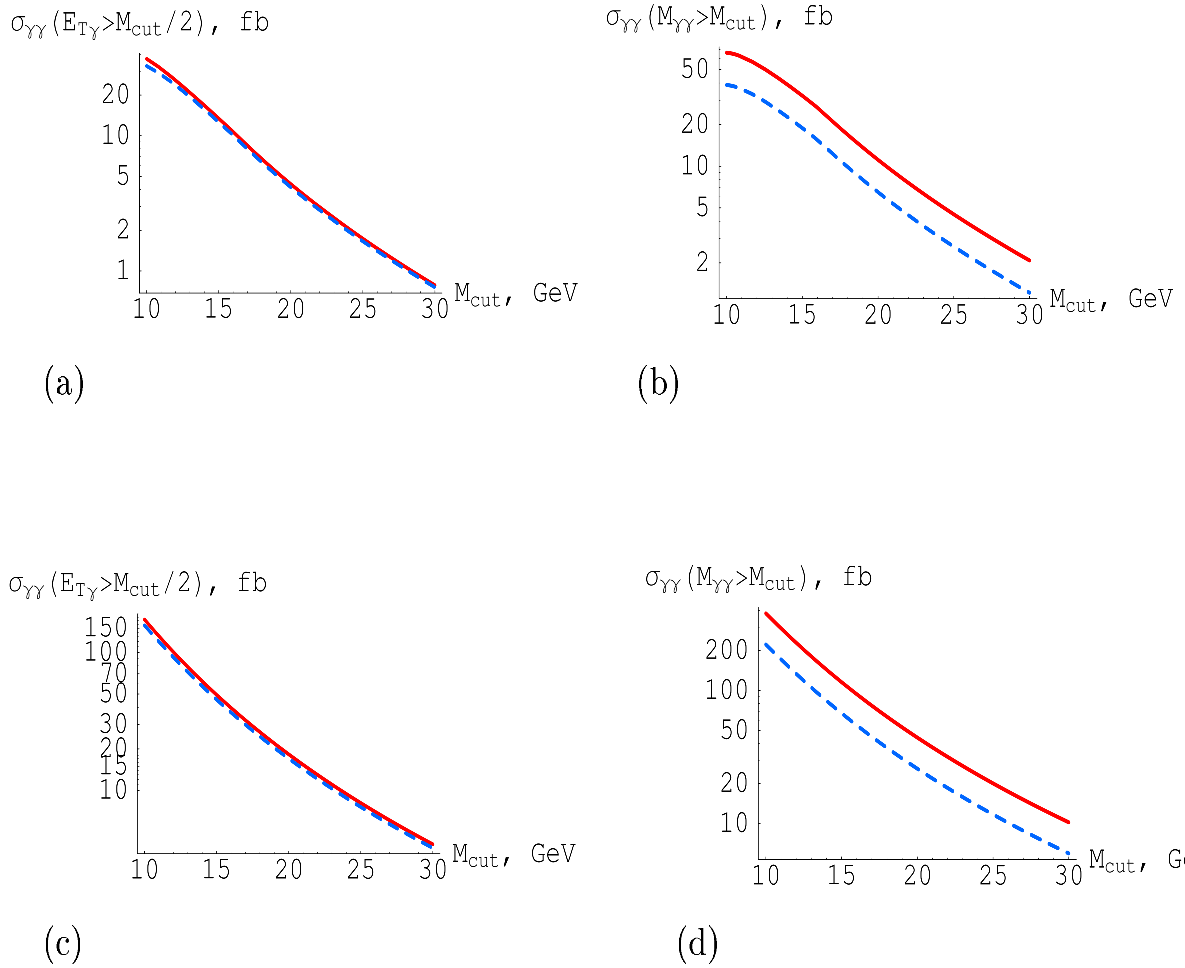

Figure 1: Cross-sections for the process $pp \to p + \gamma\gamma + p$ for different kinematical cuts. Solid and dashed curves correspond to the pseudorapidity cuts $|\eta_\gamma| < 2$ and $|\eta_\gamma| < 1$. a) $\sqrt{s} = 1.8$ TeV, CDF cuts for $\xi_{1,2}$ [9], and cut on the $E_{T\gamma}$; b) $\sqrt{s} = 1.8$ TeV, CDF cuts for $\xi_{1,2}$ [9], and cut on the $M_{\gamma\gamma}$; c) $\sqrt{s} = 14$ TeV, symmetric cuts $0.0003 < \xi_{1,2} < 0.1$, and cut on the $E_{T\gamma}$; d) $\sqrt{s} = 14$ TeV, symmetric cuts $0.0003 < \xi_{1,2} < 0.1$, and cut on the $M_{\gamma\gamma}$.

1 Introduction

The exclusive double diffraction (Double Pomeron Exchange) is the process of the type $pp \to p + M + p$, where M is the particle or system of particles, and ”+” means Large Rapidity Gap. This process is a unique tool for fundamental investigations (diffractive pattern of the interaction, strong coupling) and discoveries (like Higgs boson and extra dimensions) [1],[2],[3]. DPE cross-sections are going to be measured in the joint CMS/TOTEM experiment at LHC [4].

Since there are a lot of models for the central exclusive diffraction [1],[5],[6],[7], [8], we have to be careful with their normalization on the existing experimental data. It is more convenient to use the same process at lower energies to obtain parameters of the model. Recent experimental data on the so called ”standard candles” $pp \to p + jet\ jet + p$, $pp \to p + \gamma\gamma + p$ and $pp \to p + \chi_{c,b} + p$ from the CDF collaboration [9],[10] is available. In [11] and in the present work we use the normalization on the exclusive di-jet production as more reliable one.

2 Comment on the kinematics of the diphoton exclusive production

First of all I would like to discuss some features of the process $pp \to p + \gamma\gamma + p$, since this process is the ”standard candle”. Cross-sections for this process are presented in the Fig. 1. It is important to note that the cut $E_{T\gamma} > E_{cut} = M_{cut}/2$ is used in the major part of experimental works, that is why we have to use the same one in our calculations. But in some theoretical works [12] $E_T > E_{cut}$ means another cut $M_{\gamma\gamma} > 2E_{cut}$, which leads to the result, similar to the one presented in the Fig. 1b. In this figure cross-section for $|\eta_\gamma| < 2$ is about two times

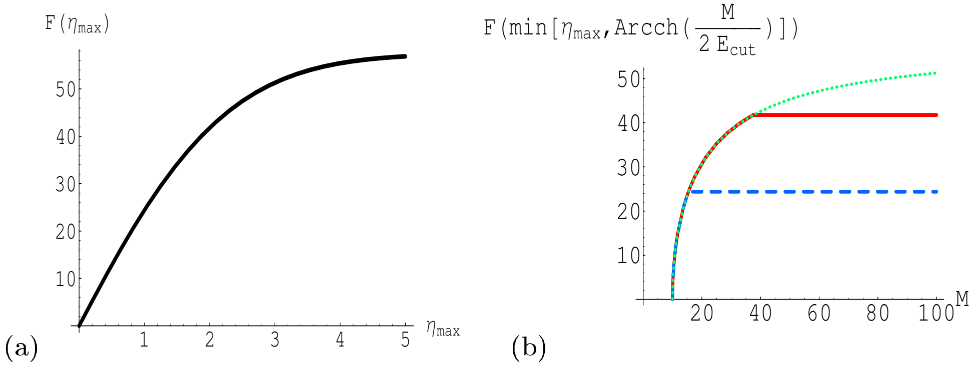

Figure 2: a) Function $F(\eta_{max})$; b) $\eta_{max} = 2$ (solid curve), $\eta_{max} = 1$ (dashed one), $F(\text{Arcch}\frac{M}{2E_{cut}})$ (dotted one), $E_{cut} = 5$ GeV.

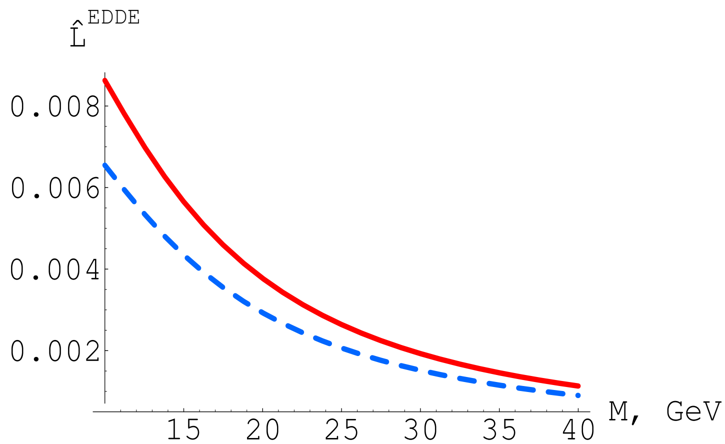

Figure 3: $\hat{L}^{EDDE}$ for LHC (solid curve) and TeVatron (dashed one).

higher than for $|\eta_\gamma| < 1$. Such difference is only possible in the kinematics, when $M_{\gamma\gamma} > 2E_{cut}$. It follows from rather simple calculations. Total cross-section for the process $gg \to \gamma\gamma$ can be represented as [13]

$$\hat{\sigma}^{J_z=0}_{gg\to\gamma\gamma}(M_{\gamma\gamma}, \eta_{max}) = C_{\gamma\gamma} F(\eta_{max}) \frac{\alpha_s(M_{\gamma\gamma}/2)^2}{M^2_{\gamma\gamma}} \ , \tag{1}$$

where η_{max} is the pseudorapidity cut in the central mass frame of the diphoton system, $C_{\gamma\gamma}$ is the constant,

$$F(\eta_{max}) = \int_{-\eta_{max}}^{\eta_{max}} \frac{d\eta}{\text{ch}^2\eta} \left[1 + \left(1 - 2\eta\ \text{th}\ \eta + \frac{1}{4}\left(\pi^2 + 4\eta^2\right)\left(1 + \text{th}^2\eta\right) \right)^2 \right] \tag{2}$$

is depicted in the Fig. 2a.

And for the process $pp \to p + \gamma\gamma + p$ we have

$$\sigma_{pp\to p+\gamma\gamma+p}(E_{cut}, \eta_{max}) \simeq \int_{2E_{cut}}^{\sqrt{\xi_{1max}\xi_{2max}s}} \frac{dM^2}{M^2} \hat{L}^{EDDE}(M) \hat{\sigma}^{J_z=0}_{gg\to\gamma\gamma}(M, \eta_{max}) \Delta y \ , \tag{3}$$

where $\hat{L}^{EDDE}$ is the $g^{IP}g^{IP}$ luminocity (see formula (15) of [11]) and it is depicted in the Fig. 3.

We are interested in the ratio of total cross-sections for different η_{max}. Let us consider first the kinematics with cuts

$$M_{\gamma\gamma} > 2E_{cut} \ , \ |\eta_\gamma| < \eta_{max} \ . \tag{4}$$

In this case

$$\frac{\sigma_{pp\to p+\gamma\gamma+p}(M > 2E_{cut}, |\eta| < 2)}{\sigma_{pp\to p+\gamma\gamma+p}(M > 2E_{cut}, |\eta| < 1)} \simeq \frac{F(2)}{F(1)} \simeq 1.7 \ . \tag{5}$$

Since in the central mass frame of the diphoton system we have $M_{\gamma\gamma} = 2E_{T\gamma}\mathrm{ch}\,\eta_\gamma$, in the kinematics with

$$E_{T\gamma} = \frac{M_{\gamma\gamma}}{2\ \mathrm{ch}\ \eta_\gamma} > E_{cut}\ ,\ |\eta_\gamma| < \eta_{max} \tag{6}$$

we have additional cut

$$|\eta_\gamma| < \mathrm{Arcch}\ \frac{M_{\gamma\gamma}}{2E_{cut}}\ , \tag{7}$$

and we should use $F\left(\min\left[\eta_{max}, \mathrm{Arcch}\ \frac{M_{\gamma\gamma}}{2E_{cut}}\right]\right)$ instead of $F(\eta_{max})$ in (1). This new function is shown in the Fig. 2b. The main contribution to the integral comes from small masses due to fast decrease in M, but in this region we have the same cut $|\eta| < \mathrm{Arcch}\frac{M}{2E_{cut}}$ for different η_{max}. And it is easy to get the following result

$$\frac{\sigma_{pp\to p+\gamma\gamma+p}(E_T > E_{cut}, |\eta| < 2)}{\sigma_{pp\to p+\gamma\gamma+p}(E_T > E_{cut}, |\eta| < 1)} \simeq 1.1 \text{ for } E_{cut} = 5 \text{ GeV}\ . \tag{8}$$

Even if we take $\alpha_s = const$ and $\hat{L}^{EDDE} = const$, we will get the ratio 1.3, and not ~ 2 as in [12]. This simple example shows that we should be carefull with the kinematics during our calculations, since this could lead to different predictions. Now we can compare our result with the latest preliminary data on the exclusive $\gamma\gamma$ production from CDF [10]

$$\sigma_{pp\to p+\gamma\gamma+p}(E_{T\gamma} > 5 \text{ GeV}, |\eta_\gamma| < 2) = 0.14\begin{matrix}+0.14\\-0.04\end{matrix} \text{ (stat.) } \pm 0.03 \text{ (syst.) pb}\ . \tag{9}$$

This prediction is at least $1.2 \div 2$ times higher than our calculations based on the di-jet production [9]. The possible reason is that in $\gamma\gamma$ production we use the region of small masses for the normalization of our parameters (and higher masses for the di-jet production), but the uncertainty in the scale dependence of the cross-section is rather large (factor ~ 2). This result from CDF may serve a good signal for the future exclusive Higgs boson production, since it makes the cross-section higher by about two times.

Aknowledgements

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