PROCEEDINGS OF SCIENCE

Higgs production within k_t-factorization with unintegrated gluon distribution functions

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We present results for Higgs boson production in the k_t-factorization approach. Both leading-order and next-to-leading-order results are presented. In contrast to a recent calculation the leading-order $gg \to H$ contribution is rather small compared to the ATLAS experimental data ($\gamma\gamma$ transverse momentum and rapidity distributions) for all unintegrated gluon distributions from the literature. We include also higher-order contribution $gg \to H(\to \gamma\gamma)g$ and find it to be rather large. We argue that there is almost no double counting when adding $gg \to H$ and $gg \to Hg$ contributions due to different topology of correponding Feynman diagrams.

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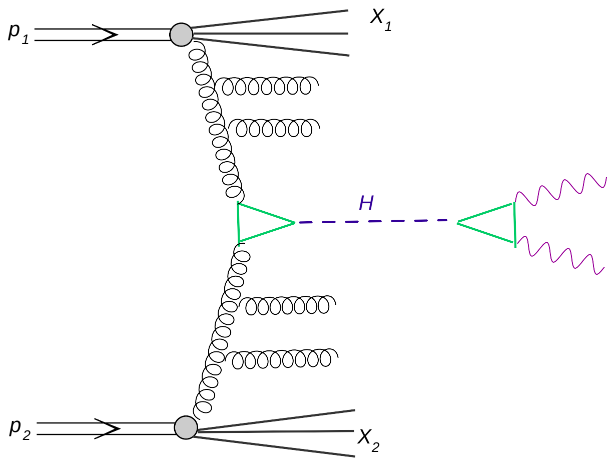

Figure 1: Dominant leading-order diagram for inclusive Higgs production in the two-photon channel.

1. Introduction

Both ATLAS and CMS collaborations at the LHC have discovered recently the Higgs boson [1]. We slowly enter era of more detailed studies.

It was advocated recently that precise differential data for the Higgs boson in the two-photon final channel could be very useful to test and explore unintegrated gluon distribution functions (UGDFs) [2]. It was shown very recently [3] that the k_t-factorization formalism with commonly used UGDFs gives a reasonable description of recent ATLAS data obtained at $\sqrt{s} = 8$ TeV [4]. We perform similar calculation but draw somewhat different conclusions.

This presentation is based on our recent paper [5].

2. Sketch of formalism

In the k_t-factorization approach the cross section for the Higgs boson production can be written somewhat formally as:

$$\sigma_{pp\to H} = \int \frac{dx_1}{x_1}\frac{dx_2}{x_2}\frac{d^2q_{1t}}{\pi}\frac{d^2q_{2t}}{\pi} \quad \delta\left((q_1+q_2)^2 - M_H^2\right)\sigma_{gg\to H}(x_1,x_2,q_1,q_2) \\ \times \mathscr{F}_g(x_1,q_{1t}^2,\mu_F^2)\mathscr{F}_g(x_2,q_{2t}^2,\mu_F^2)\,, \tag{2.1}$$

where $\mathscr{F}_g$ are so-called unintegrated (or transverse-momentum-dependent) gluon distributions and $\sigma_{gg\to H}$ is $gg \to H$ (off-shell) cross section. The situation is illustrated diagramatically in Fig. 1.

In the following we shall calculate also the higher-order $gg \to Hg$ contribution also, taking into account transverse momenta of initial gluons. In the k_t-factorization the NLO differential cross section can be written as:

$$\frac{d\sigma(pp\to HgX)}{dy_H dy_g d^2p_{H,t} d^2p_{g,t}} = \frac{1}{16\pi^2\hat{s}^2}\int\frac{d^2q_{1t}}{\pi}\frac{d^2q_{2t}}{\pi}\overline{|\mathscr{M}^{off-shell}_{g^*g^*\to Hg}|^2} \\ \times\ \delta^2\left(\vec{q}_{1t}+\vec{q}_{2t}-\vec{p}_{H,t}-\vec{p}_{g,t}\right)\mathscr{F}(x_1,q_{1t}^2,\mu^2)\mathscr{F}(x_2,q_{2t}^2,\mu^2)\,. \tag{2.2}$$

This can be further simplified as discussed e.g. in Ref. [6].

Calculation of the off-shell matrix element for the process under consideration is rather complicated in general case as it involves loops (triangles and boxes). Since the box diagrams with very heavy top quarks/antiquarks dominate at high energies we expect that the off-shell effects should be relatively small. In the present approach we make the following replacement to simplify the calculation:

$$\overline{|\mathcal{M}^{off-shell}_{g^*g^*\to Hg}|^2} \to \overline{|\mathcal{M}^{on-shell}_{gg\to Hg}(s,t,u)|^2}\,, \tag{2.3}$$

where the latter is analytical continuation of the on-shell matrix element off mass shell.

3. Results

In order to cmpare results of our calculations with the preliminary ATLAS data [4] extra cuts on photon rapidities and transverse momenta must be imposed in addition. We require:

$$-2.37 < \eta_{\gamma,1}, \eta_{\gamma,2} < 2.37, \tag{3.1}$$

$$\max(p_{1t}, p_{2t}) > 0.35 \times M_{\gamma\gamma}, \quad \min(p_{1t}, p_{2t}) > 0.25 \times M_{\gamma\gamma}, \tag{3.2}$$

$$105 \text{ GeV} < M_{\gamma\gamma} < 160 \text{ GeV}\,. \tag{3.3}$$

The distribution in transverse momentum of the photon pairs from the Higgs boson decay produced in the $gg \to H$ process is shown in Fig. 2 for different UGDFs from the literature together with the ATLAS data [4]. The calculated distributions lay much below the ATLAS data in contrast to the recent calculation in Ref. [3].

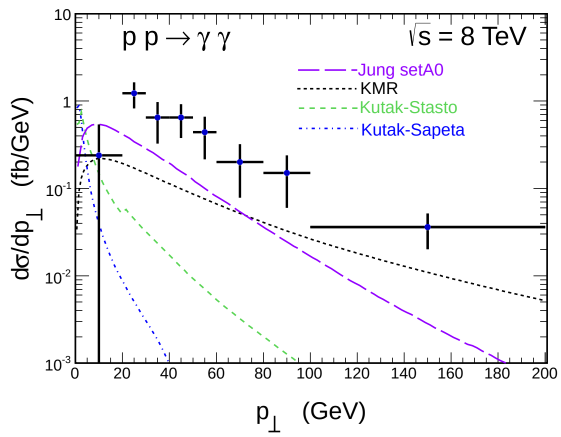

Figure 2: Transverse momentum distribution of the Higgs boson produced in the $gg \to H$ subprocess in the $\gamma\gamma$ channels for different UGDFs from the literature. The ATLAS experimental cuts have been imposed.

In Fig. 3 we show similar distributions for the NLO process $gg \to Hg$ again for the four UGDFs used in the present study. It is worth to notice that the inclusion of gluon transverse momenta automatically removes singular behaviour of the cross section at $p_t \to 0$. We observe that the cross section for the $gg \to Hg$ mechanism is of the same order of magnitude as that shown before for the

$gg \to H$ one. We wish to notice here (a discussion will be given elsewhwere [5]) that in contrast to other gluon initiated processes the dominant piece of the $gg \to Hg$ is not included in the calculation of $gg \to H$. .

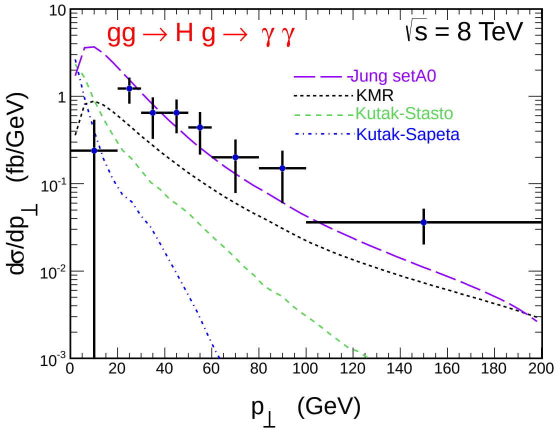

Figure 3: Transverse momentum distribution of the Higgs boson in the $\gamma\gamma$-channel produced in the $gg \to Hg$ subprocess for different UGDFs from the literature. The ATLAS experimental cuts have been imposed.

In Fig. 4 we show sum of the leading ($gg \to H$) and the next-to-leading ($gg \to Hg$) contributions again for different UGDFs used so far. The results for the KMR and Jung CCFM set $A0$ UGDFs are already almost consistent with the new ATLAS data.

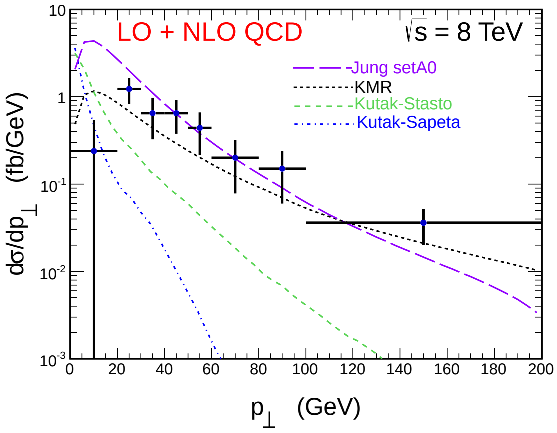

Figure 4: Transverse momentum distribution of the Higgs boson in the $\gamma\gamma$-channel produced in the $gg \to H$ and in the $gg \to Hg$ subprocesses for different UGDFs from the literature. The ATLAS experimental cuts have been imposed.

In Fig. 5 we present some contributions discussed here together with the ATLAS experimental data. The NLO $gg \to Hg$ contribution (dashed line) is bigger, especially at intermediate Higgs boson transverse momenta, than the LO $gg \to H$ contribution (solid line). The WW fusion gives sizeable contribution at larger Higgs boson transverse momenta. If we add all the contributions together we almost describe the ATLAS data.

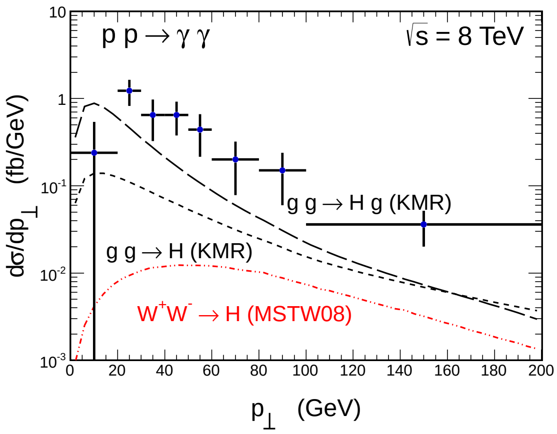

Figure 5: Transverse momentum distribution of the Higgs boson in the $\gamma\gamma$ channels for different mechanisms: $gg \to H$ (solid line), $gg \to Hg$ (dashed line) and $WW \to H$ (dash-dotted line). The ATLAS experimental cuts have been imposed.

4. Conclusions

We have carefully analysed Higgs boson production in the $\gamma\gamma$ channel. This is important in the light of new ATLAS data.

Here we have concentrated rather on QCD contributions. The $gg \to H$ mechanism has been considered within k_t-factorization approach. Different unintegrated gluon distributions from the literature have been used. In contrast to recent claims in the literature, the leading-order $gg \to H$ calculation does not describe the preliminary ATLAS data.

Higher-order corrections within k_t-factorization approach such as $gg \to Hg$ have been discussed in addition. Their contribution turned out to be of similar order as that for $gg \to H$. We have argued that there is almost no double counting when adding the leading-order $gg \to H$ and next-to-leading order $gg \to Hg$ contributions in the k_t-factorization approach.

The sum of all (QCD and electroweak) contributions gives a result which is almost consistent with the ATLAS preliminary data. The production of the Higgs boson in the $\gamma\gamma$ channel can be used to test unintegrated gluon distributions provided all contributions to the cross section are carefully taken into account.

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