QCD STUDIES FOR THE HIGGS PRODUCTION AT A PHOTON LINEAR COLLIDER *

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We present results on the simulation of the processes which are a background for an intermediate mass Standard Model Higgs production in photon collisions.

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1. Introduction

The main backgrounds to an intermediate mass Standard Model Higgs production in photon collisions are the continuum b- and c-quark pair production; the light quarks are very efficiently rejected by the b-tagging. The cross sections of these processes are much higher than the cross sections of the signal, and depend on the polarisation of the colliding photons. Fortunately, when the two photons have the same helicity making the spin of the initial state equal to zero, the cross section in the LO is suppressed by a factor proportional to M_q^2/s. However, this suppression is not maintained when a gluon is radiated and the resulting background $\gamma\gamma \rightarrow q\bar{q}g$ is still very large compared to the signal. Such processes can mimic the 2-jets topology of the signal when two of the three partons are collinear, or when one of the partons is soft or directed down the beam pipe. Therefore, a reliable prediction of the background implies to consider the NLO QCD corrections. These corrections are known. Exact one-loop QCD corrections have been calculated by Jikia and Takbladze [1] for both $J_z = 0$ and $J_z = 2$ states.

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For $J_z = 0$ state it has been found that double logarithmic corrections are also necessary and these were calculated and resumed to all orders in the form of a non-Sudakov form factor in [2]. From the theoretical point of view the situation is clear. The next step now is to use the right generator to simulate this NLO background.

Our choice is the SHERPA [3] generator, a completely new generator which uses the technique to combine the tree level matrix elements for two and three parton states with the parton shower in order to cover the entire phase space. The separation between the two regimes, or in other words the merging process, is controlled by several parameters, among which, an important one is the resolution parameter $y_{\rm cut}$. Since not all matrix elements are considered (the virtual ones are missing) one might expect some dependence of the physical observables on the $y_{\rm cut}$.

2. Dependence of the cross section on the $y_{\rm cut}$

First we investigated the dependence of the cross section for the $\gamma\gamma \to q\bar{q}(g)$ processes on the $y_{\rm cut}$. Figure 1(a) shows this dependence for the total and the 2-jets, respectively 3-jets cross sections, calculated at the NLO and given by SHERPA as a function of the $y_{\rm cut}$ ranging between 0.001 and 0.1 for the $\gamma\gamma \to b\bar{b}(g)$ process and J_z=0. One can see a variation of the total cross section with the $y_{\rm cut}$ of about 20%. In addition a scaling factor between 1.34 to 1.92 has to be applied to the SHERPA total cross section values to match the NLO calculations. Figure 1(b) illustrates the same for the $\gamma\gamma \to c\bar{c}(g)$ process. An even stronger dependence on the $y_{\rm cut}$ is observed and a higher scaling factor needs to be applied on the 2-jets cross section. This happens because the suppression of the $\gamma\gamma \to c\bar{c}$ final state is a factor about 10 higher than for the $\gamma\gamma \to b\bar{b}$ process. The dependence for the J_z=2 state for b- and c-quark pair production is shown in figures 1(c),(d). SHERPA results are very close to the NLO calculations, apart of the very low values of the $y_{\rm cut}$ where the theoretical cross sections for the 2-jets final state approach negative values, therefore they are not reliable for our comparison. This trend towards small values at very low $y_{\rm cut}$ is also visible for the total cross section for the J_z=2 state. In these plots one can see that the 2-jets cross section approaches the theoretical values and the 3-jets cross section needs a factor of about 2.

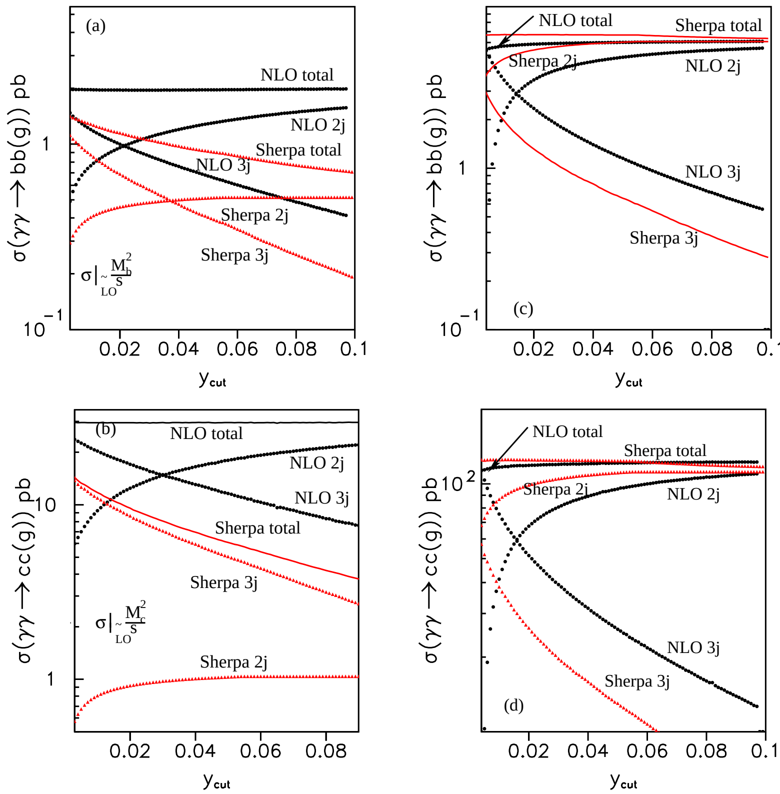

Fig. 1. Comparison between the SHERPA and NLO cross sections.

3. Simulation of the background processes

In general, it is known that the rates given by SHERPA need to be scaled according to the NLO calculations. Given the dependence on the y_{cut} value, what should be the right production value to correctly generate the data sample?

Figure 2(a) shows the differential $2 \to 3$ jet rate distributions as a function of the $\log(y_{23})$. The sample shown in figure 2(a) was produced with a y_{cut}=0.01. Shown are the total sample, the events produced only by the three parton matrix elements, as well as the events produced by the two parton matrix elements and the parton shower. A good matching of the matrix elements and the parton shower would produce a smooth distribution without any visible holes around the resolution cut value. Figure 2(a) shows a pronounced hole reflecting the failure of the parton shower to fill appropriately the phase space for the hard p_{T} emission. This problem arises due to missing $b\bar{b}g$-events where one b-quark has very low energy or the two quarks are very collinear so that y_{23} falls below $y_{\rm cut}$. Such events are quite abundant for $J_z = 0$ since the α_s/π factor in the cross section is compensated by the missing helicity suppression, but as genuine 3-jet events they are not simulated in a Born-level generator like SHERPA. The same distributions for lower $y_{\rm cut}$ values, namely $y_{\rm cut}$=0.001 and $y_{\rm cut}$=0.0001 are shown in figures 2(b), (c). Going to lower values the situation improves considerably and for $y_{\rm cut}$=0.0001 the entire phase space is covered. We think that $y_{\rm cut}$=0.0001 is a good value for our simulation. At too low $y_{\rm cut}$ values the gluon emission becomes singular due to the missing of the virtual diagrams. We check the validity of the $y_{\rm cut}$=0.0001 cut in the following way: we produce the data sample and reconstruct the jets using the DURHAM algorithm with a jet resolution cut variated between 0.01 and 0.09. The 2-jets and 3-jets fractions given by the SHERPA generator were compared to the theoretical NLO calculations. This resulted in a good agreement within 10%. Figures 3(a), (b) show a comparison between the scaled SHERPA cross sections and the NLO calculations for the $\gamma\gamma \to b\bar{b}(g)$ and $\gamma\gamma \to c\bar{c}(g)$ processes.

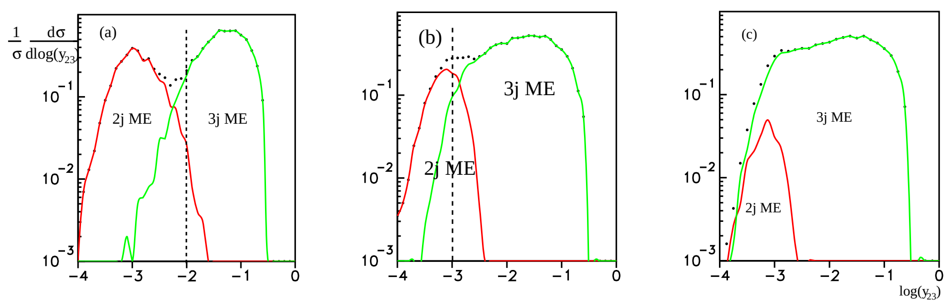

Fig. 2. Differential $3 \to 2$ jet rate for different $y_{\rm cut}$ values of 0.01, 0.001 and 0.0001.

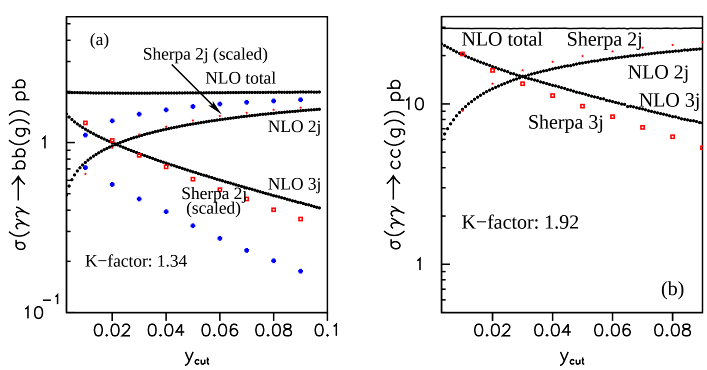

Fig. 3. Scaled SHERPA cross sections compared to the NLO calculations.

4. Conclusions

We presented results on Sherpa simulation of the $\gamma\gamma \to q\bar{q}(g)$ processes and compared them to the NLO calculations. Good agreement within 10% has been achieved choosing a production $y_{\rm cut}$ value of 0.0001 and scaling the total cross section by a factor between 1.34 and 1.92.

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