PROCEEDINGS OF SCIENCE

Exclusive diffractive Higgs and jet production at the LHC

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The implementation of exclusive diffractive production of Higgs boson and dijets in the FPMC (Forward Physics Monte Carlo) framework is presented following the models by Khoze, Martin, Ryskin and Cudell, Dechambre, Hernandez and Ivanov. The predictions of the models are compared to the CDF measurement of exclusive jets and the uncertainties on the Higgs boson and jet production cross sections at the LHC are discussed.

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1. Introduction

The Higgs boson is the last particle of the Standard Model remaining to be discovered. Inclusive searches have been performed at the Tevatron and are being started at the LHC. However the search for the Higgs boson at low mass is complicated – depending on the decay channel – either due to the low branching ratio or due to the huge background coming from QCD jet events. Thus other possibilities have been investigated, in particular using the exclusive diffractive production. In such processes both incoming hadrons, $p\bar{p}$ at the Tevatron and pp at the LHC, remain intact after the interaction and the Higgs decays in the central region. The process involves the exchange of a color singlet, thus large rapidity gaps can remain between the Higgs and the outgoing hadrons. Other particles, or systems of particles, can also be produced, *e.g.* a pair of jets. The great advantage of such production mechanism is the possibility to detect fully exclusive events by tagging both outgoing hadrons. This can lead to good mass resolution and bakground rejection.

2. Theoretical models

The exclusive production can be modeled within QCD. In the simplest case the process can be described as a two-gluon exchange – one gluon involved in the production and the other one screening the color (*e.g* Fig. 1). Such calculation is well understood and under theoretical control, however to make the description realistic following corrections need to be added: impact factor, Sudakov form factor and rapidity gap survival probability.

The impact factor [1] regulates the infra-red divergence and embeds quarks inside the proton. It is modeled phenomenologicaly and includes soft physics. The Sudakov form factor [2] corresponds to virtual vertex corrections and depends on two scales – the hard scale linked to the hard subprocess ($gg \to X$) and the soft scale related to the transverse momentum of the active gluons – the scale from which a virtual parton can be emitted. The Sudakov form factor suppresses the cross section by a factor of the order of 100 to 1000. Finally, additional soft interactions of initial and final state protons can occur [3], which are taken into account by introducing the rapidity gap survival probability.

In this work we study two models of exclusive Higgs and jets production: the Khoze, Martin and Ryskin (KMR) model [2, 4] and the Cudell, Hernández, Ivanov, Dechambre exclusive (CHIDe) model [5]. The models are in fact very similar – both use perturbative calculations and have similar ingredients. However they differ in details, which leads to different predictions.

There are three main differences between the KMR and CHIDe models. The first difference is the collinear approximation used in the KMR model contrary to the exact kinematics used in CHIDe. The second one is the variable used as the upper scale of the Sudakov form factor in the exclusive jet case. It is chosen as the gluon-gluon invariant mass, s_{gg}, in the KMR model, whereas in the CHIDe model the transverse momentum squared of the gluon, k_T, is used (see Fig. 1). The last difference is the impact factor in CHIDe model that suppresses very soft gluon emissions from the proton, which is not present in the KMR model.

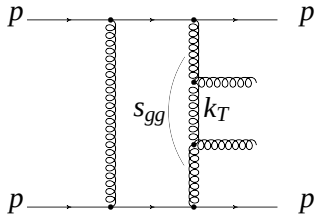

Figure 1: Feynman diagram of exclusive jet production.

3. FPMC – Forward Physics Monte Carlo

The Higgs and jet exclusive production in both KMR and CHIDe models have been implemented in the Forward Proton Monte Carlo (FPMC) [6], a generator that has been designed to study forward physics, especially at the LHC. It aims to provide the user a variety of diffractive processes in one common framework, *e.g.* the following processes have already been implemented: single diffraction, double pomeron exchange, central exclusive production and two-photon exchange.

The implementation of the KMR and CHIDe models in FPMC allows their direct comparison using the same framework. In Fig. 2, we present the cross section of exclusive Higgs boson production at the LHC as a function of the Higgs boson mass. In addition, we show the predictions from the KMR original calculation [4] and the results of the implementation of the KMR model in the ExHuME generator [7]. The difference in results between the FPMC and ExHuME implementations of the KMR model is the effect of two factors. First, in ExHuME the value of the gluon distribution is frozen for small Q^2, whereas in FPMC it vanishes to 0. The other reason of the disagreement is a different implementation of the $gg \to H$ vertex – in FPMC the HERWIG implementation is used whereas in ExHuME the vertex is directly implemented.

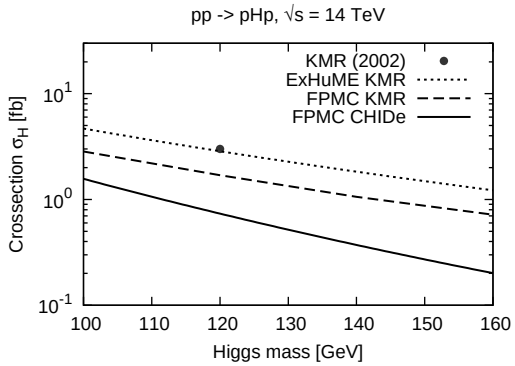

Figure 2: Cross section for exclusive Higgs production at the LHC for various models.

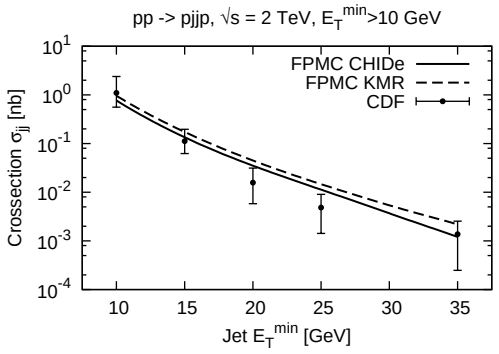

Figure 3: Exclusive jets production cross section at the Tevatron as a function of jets E_T^{min}.

The predictions of the KMR and CHIDe models are compared to the CDF measurement of exclusive jets production at the Tevatron (Fig. 3). A good agreement is found between the CDF measurement and the predictions of both CHIDe and KMR models. The difference between the models is small compared to the data uncertainties.

4. Uncertainties of the models

In this section, we discuss the uncertainties associated with the models of exclusive diffractive processes. For the analysis we use the CHIDe model, expecting the results for the KMR model to be qualitatively similar. There are three main sources of the uncertainties. The first one is the uncertainty on the gap survival probability which will be measured using the first LHC data. In this work we assume a value of 0.1 at the Tevatron and 0.03 at the LHC [8]. An additional source of uncertainty originates from the gluon density, which contains the hard and the soft part. Contrary to the hard part, the soft one is not know precisely and comes from a phenomenological

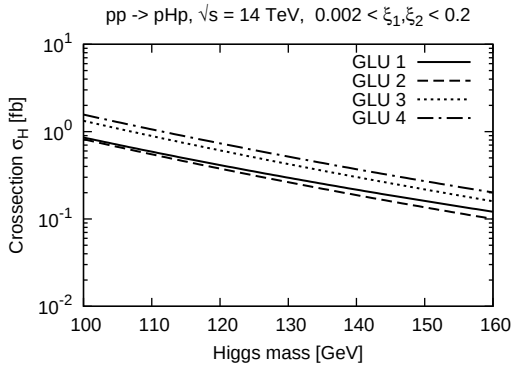

Figure 4: Uncertainty due to the gluon distributions for exclusive Higgs at the LHC.

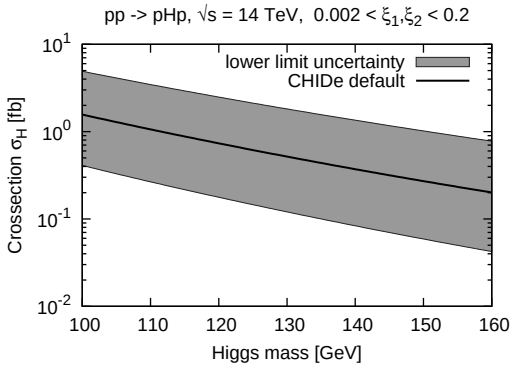

Figure 5: Uncertainty due to the lower Sudakov form factor limit for exclusive Higgs at the LHC.

parametrisation. The last uncertainty comes from the limits of the Sudakov integral, which have not yet been fixed by theoretical calculations (apart from the upper limit for the Higgs case) and thus are not known precisely.

To check the uncertainty due to the gluon distributions four different parametrisations of unintegrated skewed gluon densities are used to compute the exclusive jet and Higgs boson cross sections. These four gluon densities represent the uncertainty spread due to the present knowledge of unintegrated parton distribution functions. All of them lead to a fair agreement with the Tevatron exclusive jet measurement and they lead to an uncertainty of about a factor of 3.5 for jets and 2 for Higgs boson exclusive production at the LHC, Here we results for the Higgs case are presented in Fig. 4.

To analyse the uncertainties coming from the Sudakov form factor, both upper and lower limit of integration were varied by a factor 2. The study showed that the effect of changing the upper scale is smaller than for the lower scale. This is especially true at the LHC energies, where the upper scale uncertainty can be usually neglected. In Fig. 5 we show the uncertainty of the lower scale for the Higgs case at the LHC.

5. Predictions at the LHC

To make predictions for exclusive production at the LHC, we need to constrain the model using the Tevatron data. The basic idea is to fit the model parameters to the CDF measurement and use the obtained values at the LHC energy. We take into consideration both the gluon uncertainty and the dominant, lower limit of the Sudakov form factor calculation. The principle is simple: for each gluon density (GLU1 to GLU4), we choose a range of lower limit values which are compatible with the CDF measurement, taking into account the CDF data error. The same limit values are used at LHC energies to predict the jet (Fig. 6) and Higgs (Fig. 7) cross sections. The obtained uncertainty is large, the factor between the lower and upper edges of the uncertainty is greater than 10 for jets and about 25 for Higgs production.

In order to the previously obtained uncertainty on the Higgs boson cross section, we study the possible constraints using early LHC measurement of exclusive jets – we assume a possible measurement for 100 pb^{-1}. In addition to the statistical uncertainties, we consider a conservative

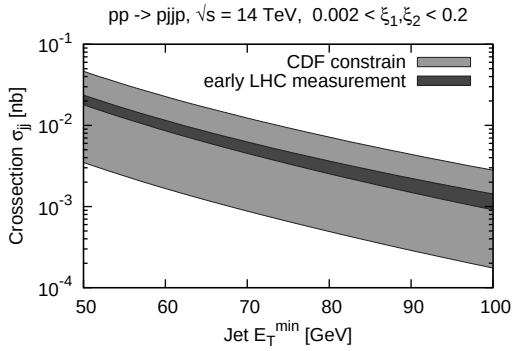

Figure 6: Total uncertainty for exclusive jets at the LHC: constraint from the CDF date and possible LHC data with a low luminosity of 100 pb^{-1}.

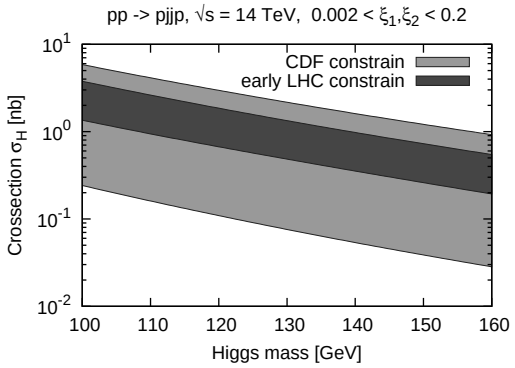

Figure 7: Total uncertainty for exclusive Higgs production at the LHC: constraint from the CDF data and possible LHC data with 100 pb^{-1}.

3% jet energy scale uncertainty as the dominant contribution to the systematic error. A possible result of such measurement is presented in Fig. 6. Using the same prescription as before, we fit the model parameters and obtain the possible constrained prediction for Higgs (Fig. 7).

6. Conclusions

Both KMR and CHIDe models describe fairly the CDF measurement of exclusive jets, but at the LHC energy their predictions differ. This is because there are several sources of uncertainties of such theoretical description and in fact the total uncertainty for exclusive production at the LHC is large (factor 25). It is possible to constrain the Higgs boson cross sections within a factor 2 using early LHC measurement of exclusive jets.

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