# Exclusive Diffractive Higgs boson production at LHC*

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The analysis of exclusive Higgs boson production at Atlas based on Atlfast simulation is presented in this paper. Significant background processes including pile-up were also simulated. The feasibility of measurement of exclusive diffractive Higgs production is discused at the end.

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## 1. Introduction

For Higgs mass around 120GeV, the Higgs boson decays mostly into $b\bar{b}$ (almost 68%). However the inclusive $H \to b\bar{b}$ can not be observed by Atlas detector because of huge QCD $b\bar{b}$ background [1]. Other channels which are relevant like $\gamma\gamma$ or $\tau^+\tau^-$ are the difficult ones. Promising channel, which has attracted attention in recent time, is $H \to b\bar{b}$ channel in diffractive events, especially in exclusive double pomeron exchange events ([2],[3]).

Double pomeron exchange (DPE) is defined as the process $pp \to p + X + p$, where $X$ is central system produced by pomeron-pomeron fusion, '+' sign denotes rapidity gap and both protons remain intact. DPE can be inclusive or exclusive. In exclusive case, only central certain object is created (e.g. Higgs boson or quark antiquark pair). On the other hand, in the inclusive case, in addition to the central object other particles are also created from the pomeron remnants.

There are two main reasons why the diffraction is interesting for Higgs search. The first one is that the cross section of main contribution to the background, exclusive $b\bar{b}$ production, differs from cross section of the signal only in two orders of magnitude , which is much more better than in case of QCD $b\bar{b}$ production.

The second one is that in the case of exclusive diffractive event we are able to compute mass of produced central object by measuring momentum

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loss of the scattered protons (1). The mass is then computed much more precisely with comparison to the case of computing mass of two calorimeter jets. The expected resolution in mass is of the order of 1 - 2%.

Nevertheless, there are also disadvantages. This channel has quite small cross section and in general diffractive processes are sensitive to pile-up.

Forward proton detectors (FPD) allow to measure fractional momentum loss $\xi$ of the outgoing protons. Then the mass of centrally produced object and also its rapidity can be computed. In the case of exclusive process, the central object is in our case Higgs boson and its mass and rapidity can be expressed as:

$$M_H \approx \sqrt{\xi_1 \xi_2 s} \qquad (1)$$

$$y_H \approx \frac{1}{2} \ln \frac{\xi_1}{\xi_2} \qquad (2)$$

where $\xi = 1 - \frac{p'}{p}$, $p$ being momentum of incoming proton and $p'$ being momentum of scattered proton measured in FPD.

## 2. Applied cuts

Diffractive production was studied using dedicated event generators Dpemc ([7]) and Exhume ([8]). Two models of exclusive diffractive production were considered: Bialas-Landschoff model [4] implemented in Dpemc and Khoze-Marten-Riskin (KMR) model [3] in Exhume. The event selection cuts can be classified in two groups: kinematic cuts (given by detector acceptances and and high $b$-tagging and tracking efficiencies) and cuts based on exclusivity of the event. In the end the $1\sigma$ mass window around Higgs mass was applied.

We require two jets tagged as $b$-jets. One $b$-jet has to have $p_{T1} > 45$ GeV (L1 trigger requires at least one 40GeV jet), the second one $p_{T2} > 30$ GeV. Both jets should be in the central part of calorimeter ($|\eta_{jets}| < 2.5$) to have good effectivity of $b$-tagging and good tracking. Further we require these jets to be back-to-back in azimuthal angle. Both diffractive protons have to be moreover detected by FPD, which means that the $\xi$ of the protons has to be in interval $0.002 < \xi < 0.1$.

As already mentioned, we are able to compute missing mass and rapidity from the detected protons. If the event is exclusive, the missing mass has to be equal to the mass of produced object and the rapidity as well. This means:

$$R_{jj} = \frac{M_{bjet1,bjet2}}{M_X} \approx 1 \qquad (3)$$

$$\Delta\eta = \frac{\eta_{jet1}+\eta_{jet2}}{2} - y_X \approx 0 \qquad (4)$$

In case of $R_{jj}$, the cut $0.8 < R_{jj} < 1.2$ was chosen ($2\sigma$ cut, as the expected di-jet mass resolution is about 10%). The cut rejects the inclusive diffractive background, where $M_{bjet1,bjet2}$ is smaller than $M_X$, and the overlap background, where the di-jet mass is random with respect to the $M_X$. The cut $|\Delta\eta| < 0.1$ was chosen for $\Delta\eta$. This is $1\sigma$ cut which lefts whole signal almost unchanged and pile-up is reduce by factor of more than 20.

The last exclusivity cut is based on multiplicity of charged particles and particles transverse to the jet axis. Let us introduce variable $N_C$, which is number of charged particles outside di-jet coming from primary vertex. By multiplicity of transverse particles to di-jet ($N_C^{\perp}$) we mean number of charged particles outside of di-jet but transverse to the leading jet [5]. By transverse is meant that $\frac{\pi}{3} < |\phi_{track} - \phi_{jet}| < \frac{2\pi}{3}$ or $\frac{4\pi}{3} < |\phi_{track} - \phi_{jet}| < \frac{5\pi}{3}$. We also require that $p_T$ of track must be over 0.5 GeV. The final cut was chosen as follows: $N_C < 4$ and $N_C^{\perp} < 3$. The suppression factor for this cut is however strongly dependent on used soft underlying event model. It's very important to tune the MC to describe this events properly, however for this the first data from LHC are needed.

## 3. Types of background

**Exclusive DPE $b\bar{b}$ production:** This type of background is very hard to separate because exclusive $b\bar{b}$ events behave almost in the same way as exclusive $H \to b\bar{b}$ and pass all cuts almost unchanged. This background is suppressed mainly by the mass window. At low luminosities the $b\bar{b}$ background is the dominant background (at high luminosities main background is pile-up).

**Exclusive DPE $gg$ production:** This type of background occurs due to mis-tagging gluon jets as $b$-jets. Expected mis-tag of gluon jet as $b$-jet is (at Atlas) of 1.3% for a 60% $b$-jet efficiency. As this process is also exclusive (therefore passes cuts on exclusivity) and its cross section is quite big ($\sigma = 1.22 \cdot 10^6$fb), this process is also non-negligible contribution to the background.

**Pile-up:** Pile-up events are several independent interaction in single bunch crossing. It's expected more than 30 interaction in bunch crossing at highest luminosity. This means that there can be several protons coming from e.g. single diffraction in one bunch crossing, which can be misidentified as protons from exclusive diffractive Higgs production. Combining with the additional non-diffractive hard event, this gives to rise to so called pile-up (or more precisely overlap) background. Pile-up background grows quadrat-

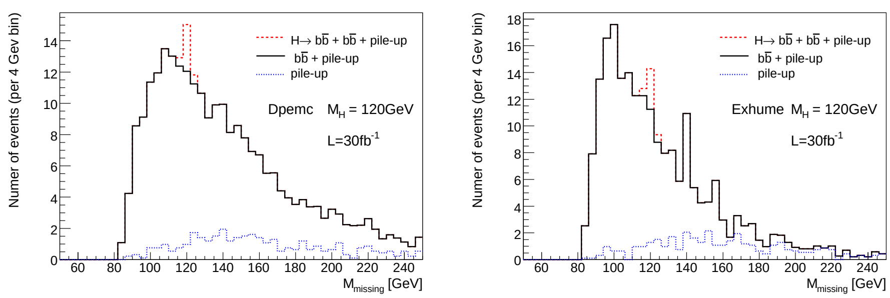


Fig. 1. Signal and background after all cuts above, for integrated luminosity of $30\text{fb}^{-1}$ and instatenous luminosity $1 \cdot 10^{33}\text{cm}^{-2}\text{s}^{-1}$

ically with increasing interactions in bunch crossing. One possibility [1] how to obtain statistical significant results is to work at low luminosities. At low luminosities almost all pile-up can be suppressed by cuts on exclusivity.

## 4. Results

The final results for exclusive $H \rightarrow b\bar{b}$ as signal and exclusive $b\bar{b}$ and pile-up as background processes are on Fig. 4 (for Bialas-Landschoff model in Dpemc on the left and for KMR model in Exhume on the right). The results are for 3.5 interactions in bunch crossing (which corresponds to luminosity $1 \cdot 10^{33}\text{cm}^{-2}\text{s}^{-1}$) and integrated luminosity $30\text{fb}^{-1}$. At this instatenous luminosity, the integrated luminosity of $30\text{fb}^{-1}$ will be taken up in 3 years and it is expected to observe in mass window about 2-3 events of signal and 10-15 events of background.

From the results above, we can conclude, that the main problem in diffractive Higgs measurement is very small statistics. There are however still some opened questions. The most important ones are cross section of diffractive Higgs production, the proper simulation of pile-up and tuning of soft underlying models in MC event generators.

## REFERENCES

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