



**The FP420 R&D Project**

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# A study of central exclusive production of $H \rightarrow WW$ at CMS

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## **Abstract**

We show the expected yields for the Central Exclusive Production (CEP) of a Higgs boson, in the  $WW$  decay channel, after  $60 \text{ fb}^{-1}$  with the CMS detector. The background coming from  $W + 2\text{jet}$  events overlaid with protons from pile-up is considered, together with possible cuts to suppress it.

# 1 Introduction

This note presents a study of the Central Exclusive Production (CEP) of a Higgs boson at CMS,  $pp \rightarrow pHp$ . The Higgs boson was considered to decay in two W bosons, one of which decays in a lepton ( $e$  or  $\mu$ ) and the other to jets. The ExHuME Monte Carlo was used, version 1.3.1 [1]. The Higgs boson was assumed to have a mass of 165 GeV. For simulating the detector response, the Fast Simulation software of CMS FAMOS was used, version 1.4.0 [4].

The only source of background studied was  $W + 2$ jets, generated with AlpGen [2], in which the W boson is only allowed to decay leptonically. The background sample passed the same CMS detector simulation as the signal.

The simulation chain included the mixing of 7 minimum bias (MB) pile-up events on average (according to a Poisson distribution) per bunch crossing, generated with PHOJET [3], which includes the elastic and diffractive components, that is, single diffraction, double diffraction and double pomeron exchange. This is the expected number of pile-up events for instantaneous luminosities of  $\mathcal{L} = 2 \times 10^{33} \text{ s}^{-1} \text{ cm}^{-2}$ .

The proton taggers information (FP420 and TOTEM 220m Roman Pots) was obtained through acceptance tables in the FAMOS package. This way each proton carries an acceptance “weight” (smearing of the proton kinematics is also included). The proton is accepted or not according to this weight.

## 2 Summary of signal selection

Given the high multiplicity of pile-up events, several protons may be detected in the forward proton taggers in a single bunch crossing. To resolve the ambiguity, the combination in which the proton pair has the missing mass closest to the nominal Higgs mass is chosen.

The following selection cuts were applied:

- The events were required to pass the HLT criteria (single muon or the single electron bits).
- In the final state at least 1 isolated muon (electron) with  $p_T > 20$  GeV (25 GeV) was required, along with 2 jets (reconstructed with an Iterative Cone algorithm of size of 0.5) with  $E_T > 25$  GeV and  $\cancel{E}_T > 25$  GeV.
- To exploit the exclusivity of the signal events, the number of tracks ( $p_T > 0.9$  GeV) outside the jets’ cones and not associated with the candidate lepton was required to be  $N_{trk} < 4$ . These tracks were also required to be associated to the primary vertex.
- A pair of accepted protons was required on opposite sides of the interaction point.
- The following variables were considered in order to take advantage of the central vs. forward correlations in the signal events:
  1.  $R_{CM}$ : This variable was defined as the ratio of the “cluster mass” to the missing mass,  $R_{CM} = M_{CM}/\Delta M$ , where the  $M_{CM}$  is defined as  $M_{CM} = \sqrt{p_T^2(jj\bar{l}) + m^2(jj\bar{l})} + \cancel{E}_T$ . The events were required to satisfy  $0.6 < R_{CM} < 1.3$ .
  2.  $\Delta y_{jj}$ : This variable was defined as the difference between the average rapidity of the jets and the rapidity of the central system as obtained from the protons:  $\Delta y_{jj} = |0.5(\eta_{j1} + \eta_{j2}) - 0.5 \ln(\frac{\xi_1}{\xi_2})|$ , where  $\xi_1$  and  $\xi_2$  are the momentum fractions lost by the protons in the z-plus and z-minus sides, respectively. The cut  $\Delta y_{jj} < 0.4$  was imposed.
  3. Finally the reconstructed missing mass from the protons was required to be in a mass window around the generated Higgs mass:  $159.5 < \Delta M < 170.5$  GeV when considering the scenario in which both FP420 and TOTEM 220m RP’s are present and  $161.5 < \Delta M < 168.5$  GeV when considering the scenario in which only FP420 is present.

## 3 Results

Table 1 shows the cumulative selection efficiencies for both the signal and background, after the cuts described above, for the scenario in which only FP420 is present. Also shown are the expected yields after  $60 \text{ fb}^{-1}$ . The error shown for the  $W + 2$ jets is statistical and reflects the limited sample size available. Table 2 shows the analogous

efficiencies and event yields for  $60 \text{ fb}^{-1}$  when both FP420 and the TOTEM 220m RP's are combined. Here one obtains an increase in the signal yield, however at the cost of a worse S/B ratio.

For the calculation of the event yields, the inclusive CEP  $H \rightarrow WW$  cross section assumed was  $\sigma_{WW} = 1 \text{ fb}$ , with a branching ratio of 29.6% for the considered decay channels. For the  $W + 2\text{jets}$  background the cross section used was 2.5 nb, considering already only the leptonic decay channels. A reduction factor of 40 was also assumed to simulate the effect of the timing cuts that will allow for the reduction of the pile-up background, but which are not included in the simulation.

Table 1: Selection efficiencies and event yields for an integrated luminosity of  $60 \text{ fb}^{-1}$ , assuming that only FP420 is present.

	$H \rightarrow WW$	W+2jets
HLT $1\mu$ or $1e$	0.60	0.40
$1\mu(e) p_T > 20 \text{ GeV}$ (25 GeV)	0.55	0.36
2 jets $E_T > 25 \text{ GeV}$	0.21	0.20
$\cancel{E}_T > 25 \text{ GeV}$	0.18	0.16
$N_{\text{chg}} < 4$	0.15	0.009
RP's Accep.	0.04	0.00007
$0.6 < R_{\text{CM}} < 1.3$	0.03	0.000003
$\Delta y_{(\text{jj})} < 0.4$	0.03	0.0000005
$161.5 < \Delta M < 168.5 \text{ (GeV)}$	0.03	0.00000004
N events ( $60\text{fb}^{-1}$ )	0.47	$0.14 \pm 0.08$

Table 2: Selection efficiencies and event yields for an integrated luminosity of  $60 \text{ fb}^{-1}$ , assuming both FP420 and TOTEM 220m RP's present.

	$H \rightarrow WW$	W+2jets
HLT $1\mu$ or $1e$	0.60	0.40
$1\mu(e) p_T > 20 \text{ GeV}$ (25 GeV)	0.55	0.36
2 jets $E_T > 25 \text{ GeV}$	0.21	0.20
$\cancel{E}_T > 25 \text{ GeV}$	0.18	0.16
$N_{\text{chg}} < 4$	0.15	0.009
RP's Accep.	0.12	0.0002
$0.6 < R_{\text{CM}} < 1.3$	0.11	0.00009
$\Delta y_{(\text{jj})} < 0.4$	0.11	0.000014
$159.5 < \Delta M < 170.5 \text{ (GeV)}$	0.08	0.0000004
N events ( $60\text{fb}^{-1}$ )	1.40	$1.46 \pm 0.49$

## 4 Conclusion

A procedure has been discussed to select central exclusive  $H \rightarrow WW$  events at CMS, with the use of the proton taggers of FP420 and TOTEM. The main background coming from  $W + \text{jets}$  events overlaid with protons from the pile-up has been shown to be largely suppressed by applying cuts that correlate the central system with the information from the proton taggers.

The final signal yields may become larger after optimization, for instance, of the jet reconstruction and identification at low  $E_T$ . Improvements in the background rejection are also expected by optimizing the track multiplicity cut, by reconstructing tracks at lower  $p_T$ .

## References

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