IL NUOVO CIMENTO Vol. 36 C, N. 1 Gennaio-Febbraio 2013
DOI 10.1393/ncc/i2013-11454-1

Colloquia: IFAE 2012

Theoretical aspects of the H → WW → $l\nu l\nu$ analysis at the LHC

S. Diglio
The University of Melbourne - Melbourne, Australia

ricevuto il 31 Agosto 2012

Summary. — Associated uncertainties on the Higgs boson production cross section and decays rates in two W's with dilepton final state and their effects on the discovery potential of the Higgs boson will be discussed.

PACS 14.80.Bn – Standard-model Higgs bosons.

The search for the Higgs boson in the decay chain H → WW → $l\nu l\nu$ is affected by relatively large uncertainties both in the signal yield and in the background contamination. The uncertainties on the signal yield impact mainly on the exclusion power and the compatibility of an observed excess with the signal plus background hypothesis, while the background uncertainty mainly affects the significance of an observed excess.

In order to maximise the sensitivity, the analysis is performed dividing the data sample in three jet categories: exclusive H + 0 jets, exclusive H + 1 jet and inclusive H+ ≥ 2 jets. The scale uncertainties on the exclusive jet cross sections are bin by bin correlated: this means that the increase in one jet bin can produce a decrease in the following bin. This pointed to several studies [1] that have shown the conventional scale uncertainty variation underestimate the exclusive jet bin uncertainty. In order to compute more realistic uncertainties a procedure has been set up: it consists in evaluating the scale uncertainty on the inclusive multi-jet cross sections (that are not correlated), $\sigma_{\geq 0}$, $\sigma_{\geq 1}$, and $\sigma_{\geq 2}$, and in propagating them uncorrelated to the exclusive jet bins [2].

The inclusive multi-jet uncertainties on $\sigma_{\geq 0}$ and $\sigma_{\geq 1}$ have been computed using HNNLO. The results show an uncertaintiy of 10% on $\Delta\sigma_{\geq 0}$ and of 20% on $\Delta\sigma_{\geq 1}$. Those numbers are used to calculate the exclusive jet bin uncertainties in 0 and 1 jet channel.

A recent NLO calculation [3] implemented in MCFM has been used to evaluate the uncertainty on the inclusive pp → H + 2 jets cross section [4]. It reduces the scale uncertainty on the cross section from 70% at LO to 25% at NLO [1]. In order to use the smaller error from MCFM a comparison between the cross section computed with

TABLE I. – *Scale and PDF uncertainties on WW extrapolation parameters α.*

qq/qg → WW	scale	PDFs	gg → WW	scale	PDFs
α^{0j}_{WW}	2.5%	3.7%	α^{0j}_{WW}	6%	4.4%
α^{1j}_{WW}	4%	2.9%	α^{1j}_{WW}	9%	4.6%

MCFM v6.0 and the respective ones computed with POWHEG [5] is needed. The ratio between of the two results to be compatible with unity inside the 10% uncertainty over a wide mass range $130\,\text{GeV} < M_H < 300\,\text{GeV}$.

The scale uncertainty in the 2 jet bin have been evaluated as the maximum spread in the cross section obtained spanning the renormalization and factorization values $\frac{M_H}{2} < \mu_R, \mu_F < 2M_H$ but keeping $\frac{1}{2} < \frac{\mu_R}{\mu_F} < 2$. This uncertainty is less than 25% over the full explored mass range ($130\,\text{GeV} < M_H < 220\,\text{GeV}$). These results allow to quote an uncertainty on the inclusive 2 jet bin cross section of 25%.

The main backgrounds to the H → WW channel are due to top pair production, Drell-Yan, pp → W + jets, with W → lν, when a fake lepton is reconstructed from the jets, and irreducible pp → WW background. The reducible backgrounds are estimated with data-driven techniques. The treatment of the irreducible WW background is mainly affected by theoretical uncertainties.

In order to estrapolate the background contribution in the signal region (SR), it is necessary to define control regions (CR) by inverting and modifying some selection cuts with respect to the signal region [6]. The event yield of the WW background is computed in the control region and extrapolated to the signal region. The WW yield in the signal region is computed using

$$N^{\text{WW0j}}_{\text{SR}} = \alpha_{0\text{j}} N^{\text{WW0j}}_{\text{CR}}, \qquad N^{\text{WW1j}}_{\text{SR}} = \alpha_{1\text{j}} N^{\text{WW1j}}_{\text{CR}}.$$

The value of α is affected both by theoretical and experimental errors. Since α is defined using only leptonic quantities, the experimental uncertainty is negligible and only the theoretical one needs to be carefully evaluated. The theoretical uncertainty can be separated in three main contributions due to modelling, PDF and scale uncertainties. The modelling uncertainty on the α parameter has been evaluated to be 3.5%. The effect of PDF and scale uncertainties on the α parameter is summarized in table I for the two channels: qq/qg → WW and gg → WW.

For $M_H > 200\,\text{GeV}$ the WW statistic in the control region decreases and the control region gets contaminated by a significant signal fraction, therefore the WW yield needs to be determined directly from the theoretical expectation.

MC@NLO [7] has been used in order to evaluate the scale uncertainties per jet bin. The uncertainties on the inclusive n-jet cross sections are summarised in table II.

TABLE II. – *Uncertainties on the inclusive jet cross sections due to scale and modelling.*

$\Delta\sigma_{\geq 0}$ (%)	$\Delta\sigma_{\geq 1}$ (%)	$\Delta\sigma_{\geq 2}$ (%)	$\Delta\sigma_{\geq 3}$ (%)
3	6	42	100

REFERENCES

[1] Dittmaier D. *et al.*, *Handbook of LHC Higgs cross sections*, arXiv:1201.3084v1.
[2] Stewart I. W. and Tackmann F. J., *Theory uncertainties for Higgs and other searches using jet bins*, arXiv:1107.2117.
[3] Campbell J. M. *et al.*, *Hadronic production of a Higgs boson and two jets at next-to-leading order*, *Phys. Rev. D*, **81** (2010) 074023, arXiv:1001.4495.
[4] Campbell J. M. and Ellis R. K., *MCFM for the Tevatron and the LHC*, arXiv: 1007.3492v1.
[5] Frixione S. *et al.*, *Matching NLO QCD computations with Parton Shower simulations: the POWHEG method*, *JHEP*, **11** (2007) 070 [arXiv:0709.2092].
[6] ATLAS Collaboration, *Search for the Higgs Boson in the $H \to WW^{(*)} \to l^+\nu l^-\overline{\nu}$ Decay Channel in pp Collisions at $\sqrt{s} = 7\,\text{TeV}$ with the ATLAS Detector*, 10.1103/PhysRevLett. 108.111802.
[7] Frixione S. *et al.*, *The MC@NLO 4.0 Event Generator* arXiv:1010.0819v1.