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# QCD corrections to $W^+W^-$ production through gluon fusion

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**Abstract**

We compute the next-to-leading order (NLO) QCD corrections to the $gg \to W^+W^- \to l_1^+\nu_1 l_2^- \bar{\nu}_2$ process, mediated by a massless quark loop, at the LHC. This process first contributes to the hadroproduction of $W^+W^-$ at $\mathcal{O}(\alpha_s^2)$, but, nevertheless, has a sizable impact on the total production rate. We find that the NLO QCD corrections to the $gg \to W^+W^-$ process amount to $\mathcal{O}(50)\%$, and increase the NNLO QCD cross sections of $pp \to W^+W^-$ by approximately two percent, at both the 8 TeV and 13 TeV LHC. We also compute the NLO corrections to gluonic $W^+W^-$ production within a fiducial volume used by the ATLAS collaboration in their 8 TeV measurement of the $W^+W^-$ production rate and find that the QCD corrections are significantly smaller than in the inclusive case. While the current experimental uncertainties are still too large to make these differences relevant, the observed strong dependence of perturbative corrections on kinematic cuts underscores that extrapolation from a fiducial measurement to the total cross section is an extremely delicate matter, and calls for the direct comparison of fiducial volume measurements with corresponding theoretical computations.

*Keywords:* QCD, NLO computations, vector bosons, LHC

The production of electroweak di-bosons, $pp \to VV$, is amongst the most important processes studied at the LHC. The Higgs decay mode $H \to VV$ will be central to precision measurements of the Higgs quantum numbers and couplings during Run II [? ? ? ? ? ? ? ? ? ]. This requires extremely good control over the large $pp \to VV$ background, including in the Higgs off-shell region [? ], which can be exploited to constrain $HVV$ couplings [? ] or the Higgs width [? ? ? ]. Additionally, di-boson production probes the nature of the electroweak interactions, allowing New Physics effects to be either discovered or constrained through studies of anomalous gauge couplings. Finally, di-boson production serves as an important testing ground for our understanding of QCD in a collider environment.

At leading order (LO), weak boson pair production $pp \to VV$ occurs only through the $q\bar{q}$ partonic channel. The next-to-leading order (NLO) QCD corrections to this process have been studied extensively in the past [? ? ? ? ? ? ? ? ? ? ]; recently the next-to-next-to-leading order (NNLO) QCD corrections have also been computed [? ? ? ? ? ? ? ]. At this order, the $gg$ partonic channel starts contributing [? ? ? ? ? ? ] and, thanks to a relatively large gluon flux at the LHC, its contribution can be expected to be large. This is exactly what happens: the gluon fusion process contributes 60% of the NNLO QCD corrections in $ZZ$ production, and 35% of the NNLO QCD corrections in $W^+W^-$ production. Radiative corrections to the gluon fusion channel formally contribute at next-to-next-to-next-to-leading order ($\mathrm{N^3LO}$) but are expected to be significant [? ]. Indeed, we showed recently that NLO QCD corrections to $gg \to ZZ$ increase its contribution to $pp \to ZZ$ by almost a factor of two making them important for phenomenology of $ZZ$ production [? ]. Moreover, the magnitude of these corrections exceeds the scale variation uncertainty of the NNLO QCD result which is commonly used to estimate the residual uncertainty of the theory prediction. The aim of this Letter is to report the results of a similar calculation for $gg \to W^+W^-$.

Run I measurements of the $W^+W^-$ cross section undertaken by both ATLAS [? ] and CMS [? ? ] showed a discrepancy at the level of $\mathcal{O}(2-2.5)$ standard deviations compared to the Standard Model (SM) prediction. This deviation has been studied in the context of physics beyond the Standard Model (BSM) [? ? ? ? ? ? ], but there has also been a concerted effort from the theory community to understand the source of this discrepancy in terms of QCD effects. This includes the calculation of the total $W^+W^-$ cross section to NNLO in QCD [? ], as well as the examination of ambiguities caused by an extrapolation from the fiducial region to the total cross section, either in the context of parton showers [? ] or through resummations [? ? ? ]. As a consequence of these efforts, the discrepancy seems to have been resolved without recourse to BSM effects, but these developments underlined the importance of comparing theoretical and experimental results for fiducial volume measurements, avoiding uncertain-