VBS for HE and HL LHC

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Abstract

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Contents

1 Introduction

2 Set-up

The hadronic scattering processes are simulated at the LHC with a centre-of-mass energy $\sqrt{s} = 14\,\text{TeV}$ and $\sqrt{s} = 27\,\text{TeV}$. The NNPDF 3.1 luxQED parton distribution functions (PDFs) [1] with five massless flavours,[1] NLO-QCD evolution, and a strong coupling constant $\alpha_s\,(M_Z) = 0.118$ are employed.[2] Initial-state collinear singularities are factorised according to the $\overline{\text{MS}}$ scheme, consistently with what is done in NNPDF.

For the rest of the input parameters, they have been chosen as in Ref. [3]. For the massive particles, the following masses and decay widths are used:

$$
\begin{aligned}
m_{\text{t}} &= 173.21\,\text{GeV}, & \Gamma_{\text{t}} &= 0\,\text{GeV}, \\
M_{\text{Z}}^{\text{OS}} &= 91.1876\,\text{GeV}, & \Gamma_{\text{Z}}^{\text{OS}} &= 2.4952\,\text{GeV}, \\
M_{\text{W}}^{\text{OS}} &= 80.385\,\text{GeV}, & \Gamma_{\text{W}}^{\text{OS}} &= 2.085\,\text{GeV}, \\
M_{\text{H}} &= 125.0\,\text{GeV}, & \Gamma_{\text{H}} &= 4.07 \times 10^{-3}\,\text{GeV}.
\end{aligned}
\tag{1}
$$

The measured on-shell (OS) values for the masses and widths of the W and Z bosons are converted into pole values for the gauge bosons ($V = \text{W}, \text{Z}$) according to Ref. [4],

$$
\begin{aligned}
M_V &= M_V^{\text{OS}} / \sqrt{1 + (\Gamma_V^{\text{OS}}/M_V^{\text{OS}})^2}, \\
\Gamma_V &= \Gamma_V^{\text{OS}} / \sqrt{1 + (\Gamma_V^{\text{OS}}/M_V^{\text{OS}})^2}.
\end{aligned}
\tag{2}
$$

The EW coupling is renormalised in the G_μ scheme [5] according to

$$
\alpha = \frac{\sqrt{2}}{\pi} G_\mu M_{\text{W}}^2 \left(1 - \frac{M_{\text{W}}^2}{M_{\text{Z}}^2} \right),
\tag{3}
$$

with

$$
G_\mu = 1.16637 \times 10^{-5}\,\text{GeV}^{-2},
\tag{4}
$$

and where M_V^2 corresponds to the real part of the squared pole mass. The numerical value of α, corresponding to the choice of input parameters is

$$
1/\alpha = 132.3572\ldots .
\tag{5}
$$

The Cabibbo–Kobayashi–Maskawa matrix is assumed to be diagonal, meaning that the mixing between different quark generations is neglected. The complex-mass scheme [6–8] is used throughout to treat unstable intermediate particles in a gauge-invariant manner.

The central value of the renormalisation and factorisation scales is set to

$$
\mu_{\text{ren}} = \mu_{\text{fac}} = \sqrt{p_{\text{T,j}_1}\,p_{\text{T,j}_2}},
\tag{6}
$$

defined via the transverse momenta of the two hardest jets (identified with the procedure outlined in the following), event by event. This choice of scale has been shown to provide stable NLO-QCD predictions [9].

Following experimental measurements [10–13] and prospect studies [14], the event selection used in the present study is:

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[1] For the process considered, no bottom (anti-)quarks appear in the initial or final state at LO and NLO, as they would lead to top quarks, and not light jets, in the final state.

[2] The corresponding identifier `lhaid` in the program LHAPDF6 [2] is 324900.

- The two same-sign charged leptons are required to fulfil cuts on transverse momentum, rapidity, and separation in the rapidity–azimuthal-angle separation,

$$p_{\mathrm{T},\ell} > 20\,\mathrm{GeV}, \qquad |y_\ell| < 4.0, \qquad \Delta R_{\ell\ell} > 0.3, \qquad m_{\ell\ell} > 20\,\mathrm{GeV}. \tag{7}$$

- The total missing transverse momentum, computed from the vectorial sum of the transverse momenta of the two neutrinos, is required to be

$$p_{\mathrm{T,miss}} > 40\,\mathrm{GeV}\,. \tag{8}$$

- QCD partons (light quarks and gluons) are clustered together using the anti-k_T algorithm [15], with distance parameter $R = 0.4$. We impose cuts on the jets' transverse momenta and rapidities,

$$p_{\mathrm{T,j}} > 30\,\mathrm{GeV}, \qquad |y_{\mathrm{j}}| < 4.0, \tag{9}$$

VBS cuts are applied on the two jets with largest transverse momentum, unless otherwise stated. In particular, we impose a cut on the invariant mass of the di-jet system, as well as on the rapidity separation of the two jets and their separation from leptons,

$$m_{\mathrm{jj}} > 500\,\mathrm{GeV}, \qquad |\Delta y_{\mathrm{jj}}| > 2.5, \qquad \Delta R_{\mathrm{j}\ell} > 0.3. \tag{10}$$

- Finally, the centrality of the leptons is enforced as defined in Ref. [14]:

$$\zeta = \min\left[\min\left(y_{\ell_1}, y_{\ell_2}\right) - \min\left(y_{\mathrm{j}_1}, y_{\mathrm{j}_2}\right), \max\left(y_{\mathrm{j}_1}, y_{\mathrm{j}_2}\right) - \max\left(y_{\ell_1}, y_{\ell_2}\right)\right] > 0. \tag{11}$$

- When EW corrections are computed, real photons and charged fermions are clustered together using the anti-k_T algorithm with radius parameter $R = 0.1$. In this case, leptons and quarks are understood as *dressed fermions*.

Acknowledgements

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