Monte Carlo comparisons
VBSCAN Cost Action

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May 23, 2017

Abstract

Part I

Introduction

Part II

$\mathbf{pp} \to \mu^+\nu_\mu\mathbf{e}^+\nu_\mathbf{e}\mathbf{jj}$

0.1 Input parameters

- Centre-of-mass energy of 13 TeV at the LHC.
- Parton distribution function (PDF): NNPDF-3.0 at NLO with $\alpha_s(M_Z) = 0.118$ (we use it at both LO and NLO). The LHAPDF ID for this set is 260000.
- Flavour scheme: fixed $N_F = 5$ flavour scheme (no bottom quark appear in the final or initial state). This means that the bottom quark is considered massless.
- Renormalisation scheme: complex-mass scheme if possible. If other schemes are used, we have to estimate the possible differences. - Factorisation scheme: $\overline{\text{MS}}$ as for NNPDF.
- Scales: factorisation and renormalisation scale, $\mu_R = \mu_F = M_W$.
- α: G_μ scheme with:

$$\alpha = \frac{\sqrt{2}}{\pi} G_\mu M_W^2 \left(1 - \frac{M_W^2}{M_Z^2}\right) \qquad \text{with} \qquad G_\mu = 1.16637 \times 10^{-5}\,\text{GeV}. \tag{1}$$

The numerical value is: $\alpha = 7.555310522369 \times 10^{-3}$.
- Mass and width of the massive particles:

$$\begin{aligned} m_t &= 173.21\,\text{GeV}, & \Gamma_t &= 0\,\text{GeV}, \\ M_Z^{\text{OS}} &= 91.1876\,\text{GeV}, & \Gamma_Z^{\text{OS}} &= 2.4952\,\text{GeV}, \\ M_W^{\text{OS}} &= 80.385\,\text{GeV}, & \Gamma_W^{\text{OS}} &= 2.085\,\text{GeV}, \\ M_H &= 125.0\,\text{GeV}, & \Gamma_H &= 4.07 \times 10^{-3}\,\text{GeV}. \end{aligned} \tag{2}$$

The pole masses and widths entering the calculation are expressed in terms of the measured on-shell (OS) values for the W and Z bosons according to

$$M_V = M_V^{\text{OS}} / \sqrt{1 + (\Gamma_V^{\text{OS}}/M_V^{\text{OS}})^2}\,, \qquad \Gamma_V = \Gamma_V^{\text{OS}} / \sqrt{1 + (\Gamma_V^{\text{OS}}/M_V^{\text{OS}})^2}. \tag{3}$$

Hence the numerical values are

$$\begin{aligned} M_Z &= 91.1534806191827\,\text{GeV}, & \Gamma_Z &= 2.494266378772824\,\text{GeV}, \\ M_W &= 80.3579736098775\,\text{GeV}, & \Gamma_W &= 2.084298998278219\,\text{GeV}. \end{aligned} \tag{4}$$

- Experimental signature: two equally charged leptons, missing transverse energy and at least two jets.
- Clustering: QCD partons are clustered into jets using the anti-k_T algorithm with jet-resolution parameter $R = 0.4$. Photons from real radiation are recombined with the final-state quarks into jets or with the charged leptons into dressed leptons, in both cases via the anti-k_T algorithm and a resolution parameter $R = 0.1$ (this applies only when computing the EW corrections).
- Rapidity definition: $y = \frac{1}{2} \ln \frac{E+p_z}{E-p_z}$ where E is the energy of the parton and p_z the component of its momentum along the beam axis.
- Distance definition:

$$\Delta R_{ij} = \sqrt{(\Delta\phi_{ij})^2 + (\Delta y_{ij})^2}, \tag{5}$$

with $\Delta\phi_{ij} = \phi_i - \phi_j$ being the azimuthal-angle difference and $\Delta y_{ij} = y_i - y_j$ being the rapidity difference.
- Definition of the missing transverse energy: transverse momentum of the sum

of the two neutrinos momenta.
- Cuts on the leptons:

$$p_{\mathrm{T},\ell} > 20\,\mathrm{GeV}, \qquad |y_\ell| < 2.5, \qquad \Delta R_{\ell\ell} > 0.3. \tag{6}$$

- Missing energy cut:

$$E_{\mathrm{T,miss}} = p_{\mathrm{T,miss}} > 40\,\mathrm{GeV} \tag{7}$$

- Jet definition:

$$p_{\mathrm{T,j}} > 30\,\mathrm{GeV}, \qquad |y_{\mathrm{j}}| < 4.5, \qquad \Delta R_{\mathrm{j}\ell} > 0.3. \tag{8}$$

- Out of these 2/3 jets, the two hardest in pT (tagged jets)are required to have:

$$m_{\mathrm{jj}} > 500\,\mathrm{GeV}, \qquad |\Delta y_{\mathrm{jj}}| > 2.5. \tag{9}$$

0.2 Codes

0.2.1 POWHEG: Alexander Karlberg

VBF approximation?

0.2.2 VBFNLO: Michael Rauch

VBF approximation

0.2.3 WHIZARD: Jürgen Reuter

Full matrix element

0.2.4 Recola: Mathieu Pellen

Full matrix element

0.2.5 MadGraph5_aMC@NLO: Marco Zaro

To be checked what is possible

0.3 Observables

- Cross section within cuts.
- Distribution in the number of jets.
- Invariant mass of the two hardest jets (two tagged jets).
[0; 4 TeV] with bins of size 100 GeV (40 bins).
- $p_{\mathrm{T,j_1,j_2}}$ and $y_{\mathrm{j_1,j_2}}$ of the two tagged jets (not their sum)

$p_{\mathrm{T,j_1,j_2}}$: $[0; 1\,\mathrm{TeV}]$ with bins of size $25\,\mathrm{GeV}$ (40 bins).
$y_{\mathrm{j_1,j_2}}$: $[-5; 5]$ with bins of size 0.5 (20 bins).
- Invariant mass of the two charged leptons.
$[0; 4\,\mathrm{TeV}]$ with bins of size $100\,\mathrm{GeV}$ (40 bins).
- Zeppenfeld variable for μ^+ and e^+:
$z^*_\ell = |y_\ell - \left(y_{\mathrm{j_1}} + y_{\mathrm{j_2}}\right)/2|/|\Delta y_{\mathrm{jj}}|$
$[0; 1.5]$ with bins of size 0.05 (30 bins).

0.4 Numerical results

0.4.1 LO $\mathcal{O}\left(\alpha^6\right)$

0.4.2 NLO $\mathcal{O}\left(\alpha^6\alpha_{\mathrm{s}}\right)$

Part III

Conclusion

Part IV

Acknowledgments

Karlsruhe for hosting the documents used for the comparison.