B/F/421–13 IPPP/13/62 SLAC–PUB–15709
UCLA–13–TEP–105 IPhT–T13/205

PROCEEDINGS OF SCIENCE

High multiplicity W+jets predictions at NLO

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In these proceedings we present results from a recent calculation for the production of a W boson in conjunction with five jets at next-to-leading order in perturbative QCD. We also use results at lower multiplicities to extrapolate the cross section to the same process with six jets.

XXI International Workshop on Deep-Inelastic Scattering and Related Subject -DIS2013,
22-26 April 2013
Marseilles,France

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Published in arXiv:1308.3986.

Work supported by US Department of Energy under contract DE-AC02-76SF00515 and HEP.

1. Introduction

The production of a vector boson in conjunction with jets is an important benchmark process for experiments at hadron colliders. Reliable predictions for these processes are needed both as a test of our understanding of Standard-Model measurements and because they represent important backgrounds to many searches for physics beyond the Standard Model (BSM). The study of the newly discovered Higgs-like boson [1, 2] and searches for BSM signals requires good modeling of high-multiplicity final states. The same holds true for Standard-Model processes such as top-pair and di-boson production, for which W+multijet processes represent an important background. Because the neutrino from the leptonic decay of the W boson escapes the dectector, W+jets processes represent an irreducible background for many searches involving missing transverse energy.

Next-to-leading order (NLO) in the strong coupling constant is the lowest order at which reliable quantitative predictions for cross sections are possible. Theoretical predictions for the production of a W boson in assoctiation with up to two jets at NLO have been available for a long time [3, 4, 5]. At higher multiplicities, predictions have become available only in recent years: the so-called unitarity method (for a review, see Refs. [6, 7]) has been used successfully for W-boson production in association with three [8], four [9] and most recently five jets [10].

Vector boson production has been measured in association with up to four jets at the LHC with a center of mass energy of 7 TeV [11, 12] and good agreement was found with NLO predictions.

2. W+jets at NLO

We use SHERPA [13] in association with the virtual matrix elements from BLACKHAT [14] to obtain our NLO predictions. We apply the jet and lepton cuts given in Ref. [10]. The results for the total cross sections for $W+$ 1-jet through $W+$ 5-jet production are given in table 1 of [10]. In Figure 1 we present the transverse momentum distribution of the leading five jets. The striking feature is the reduction of the scale variation obtained by going from LO to NLO. One can also see that the radiative corrections affect not only the overall normalization but also the shape of distributions.

Given that cross sections σ_n are now available for a large number of jet multiplicities n, one can investigate several ratios involving these processes, which are interesting because some sources of uncertainties largely cancel, both on the experimental and theoretical side. The jet production and charge asymmetry ratios are defined as

$$R^{W^\pm}_{n/(n-1)} = \frac{\sigma(W^\pm + n\,\text{jets})}{\sigma(W^\pm + (n-1)\,\text{jets})}\,, \qquad R_{W^+/W^-} = \frac{\sigma(W^+ + n\,\text{jets})}{\sigma(W^- + n\,\text{jets})}\,,$$

repectively. Excluding the case $n = 2$ where new partonic channels open in the denominator, both ratios can be consistently described using a linear interpolation, both at LO and NLO.

We collect the coefficients of the interpolation $R = an + b$ for both ratios in the following table.

	a_{LO}	b_{LO}	a_{NLO}	b_{NLO}
$R^{W^+}_{n/(n-1)}$	-0.0177 ± 0.0004	0.320 ± 0.002	-0.009 ± 0.003	0.263 ± 0.009
$R^{W^-}_{n/(n-1)}$	-0.0165 ± 0.0005	0.301 ± 0.002	0.009 ± 0.002	0.248 ± 0.008
R_{W^+/W^-}	0.102 ± 0.002	1.347 ± 0.006	0.11 ± 0.01	1.27 ± 0.03

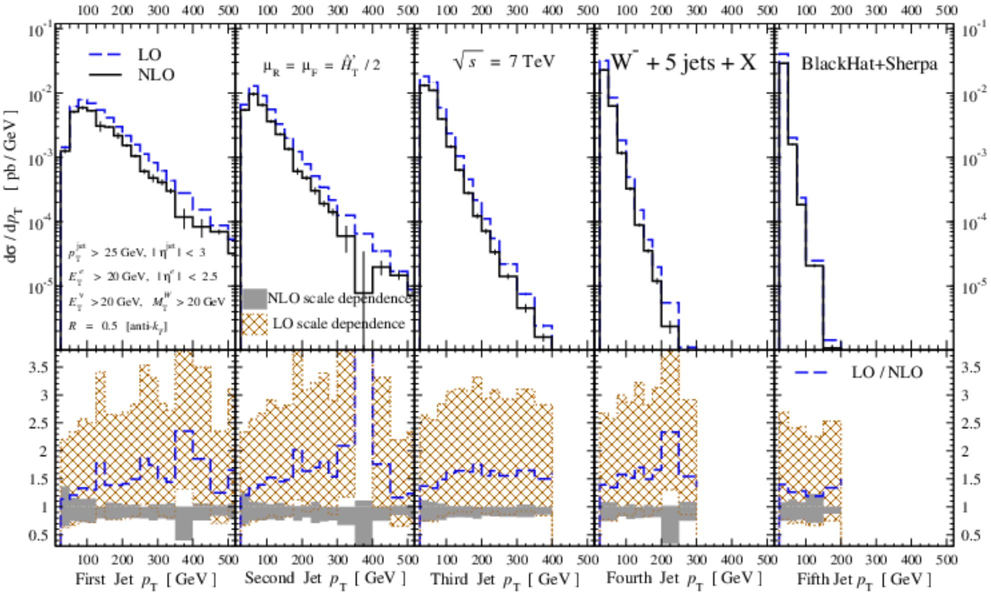

Figure 1: The p_T distributions of the leading five jets in $W^- + 5$-jet production at the LHC at $\sqrt{s} = 7$ TeV. In the upper panels, the NLO predictions are shown as solid (black) lines, while the LO predictions are shown as dashed (blue) lines. The lower panels show the predictions for the LO distribution and scale-dependence bands normalized to the NLO prediction (at the scale $\mu = \hat{H}'_\mathrm{T}/2$). The LO distribution is the dashed (blue) line, and the scale-dependence bands are shaded (gray) for NLO and cross-hatched (brown) for LO.

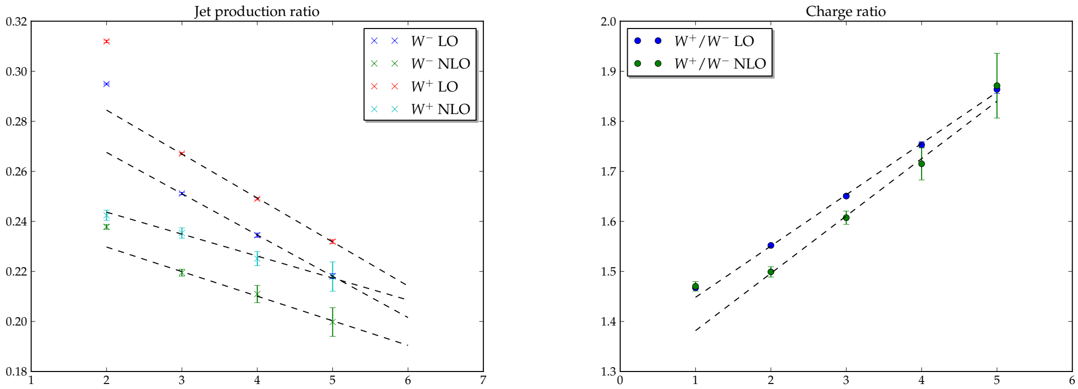

Figure 2: Linear fits for the jet production and charge asymmetry ratios.

Using this linear regression one can extrapolate to obtain a prediction for the $W + 6$-jet cross section:

$$\sigma^{\mathrm{extr}}(W^+ + 6\,\mathrm{jets}) = 0.30 \pm 0.03\ \mathrm{pb}\,,$$
$$\sigma^{\mathrm{extr}}(W^- + 6\,\mathrm{jets}) = 0.15 \pm 0.01\ \mathrm{pb}\,.$$

Englert *et al.* recently investigated [15] such an extrapolation using jet calculus methods, and found it to be a good approximation when the jets are required to have the same minimum transverse momenta. In our extrapolation, the errors are computed from the variance of a large set of synthetic data distributed in Gaussians around the central values of the cross sections, with widths set to the corresponding Monte-Carlo statistical errors. The procedure is illustrated in Fig 3.

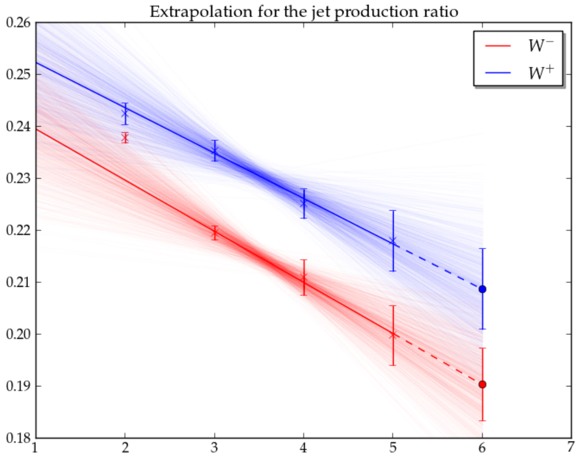

Figure 3: Extrapolation of the jet production ratio. The error of the extrapolation is estimated from the variance of a synthetic set of linear extrapolations based on synthetic input data distributed in a gaussian around the central values with the width given by the statistical error. Each line represents one of these fits.

3. Conclusions

We have presented results from a NLO calculation for the production of a W boson in association with up to five jets. We used these results to provide an extrapolation for the cross section of the corresponding process with six jets.

Acknowledgments

This research was supported by the US Department of Energy under contracts DE–FG03–91ER40662 and DE–AC02–76SF00515. DAK's research is supported by the European Research Council under Advanced Investigator Grant ERC–AdG–228301. DM's work was supported by the Research Executive Agency (REA) of the European Union under the Grant Agreement number PITN–GA–2010–264564 (LHCPhenoNet). The work of KJO and SH was partly supported by a grant from the US LHC Theory Initiative through NSF contract PHY–0705682. This research used resources of Academic Technology Services at UCLA, and of the National Energy Research Scientific Computing Center, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE–AC02–05CH11231.

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