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Differential Z + multi-jet cross section measurements at CMS

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Abstract

We present a measurement of the cross section of Z/γ^* plus jet events in proton-proton collisions as a function of the vector boson transverse momentum. The data were collected with the CMS detector at $\sqrt{s}$ = 8 TeV, corresponding to an integrated luminosity of 19.7 fb^{-1}. The measurement is performed for vector bosons that have a transverse momentum larger than $p_T > 40$ GeV and for different jet multiplicities. We consider MadGraph[1], Sherpa[2] and BlackHat + Sherpa[3] for Monte Carlo simulation (MC). MadGraph and Sherpa are multi-leg, leading-order matrix elements with parton showering programmes while BlackHat is an NLO parton-level MC. We also study the variables p_{T}^{Z}/H_T and $\log_{10}(p_{\mathrm{T}}^{Z}/p_{\mathrm{T}}^{j1})$ which are suitable to challenge the validity of NLO predictions. In hadronic searches for new physics, p_{T}^{Z}/H_T would correspond to a $\not{E}_T/H_T$ ratio.

Keywords: CMS, Standard Model, QCD, Z physics

1. Introduction

The associated production of a Z/γ^* together with one or more jets in the final state has been extensively studied as these processes are background to many searches for new physics. Precise measurements also provide important tests for the standard model and of parton densities in the proton. They also provide a handle to check and tune models used in the MC simulation. The variables p_{T}^{Z}/H_T and $\log_{10}(p_{\mathrm{T}}^{Z}/p_{\mathrm{T}}^{j1})$ allow us to validate the NLO predictions given by BlackHat as these distributions are quantities in which NLO predictions might reach their calculational limit due to large logarithms or where missing higher-order effects could play a larger role. Here, we use data collected with the CMS detector at $\sqrt{s} = 8TeV$ and an integrated luminosity of 19.7 fb^{-1}[5].

2. p_T^Z Spectrum and cross section ratio

The Z/γ^*+jets p_T^Z spectrum and cross section ratio is briefly presented here [figs 1, 2]. We require that the lepton $p_{\mathrm{T}} > 20$ GeV, $|\eta| < 2.4$ and a Z mass window of $71 < m_{ll} < 111$ GeV for same flavour, opposite sign dileptons.

The uncertainty bands for MadGraph and Sherpa are statistical. The uncertainty bands for BlackHat are from PDF variation (MSTW) and from varying the renormalization and factorization scales up and down by a factor of 2. The systematic uncertainties considered on data are jet energy scale, lepton scale, pileup, background, jet energy resolution, lepton resolution, scale factor and luminosity uncertainties.

MadGraph and Sherpa (scaled to NNLO) overestimate data in the high p_T^Z end. BlackHat underestimates the cross section in the lower end tail. As seen in the good agreement in the 2-jet over 1-jet case, the offset between MadGraph and data is the same in both cases. As seen in the offset between BlackHat and data in the ratio plot, BlackHat agrees with the p_T^Z spectrum in the 2-jet case.

3. $\log_{10}(p_T^Z/p_{\mathrm{T}}^{j1})$ Spectrum

The $\log_{10}(p_T^Z/p_{\mathrm{T}}^{j1})$ cross section ratio is briefly presented here [fig 3]. MadGraph and Sherpa perform

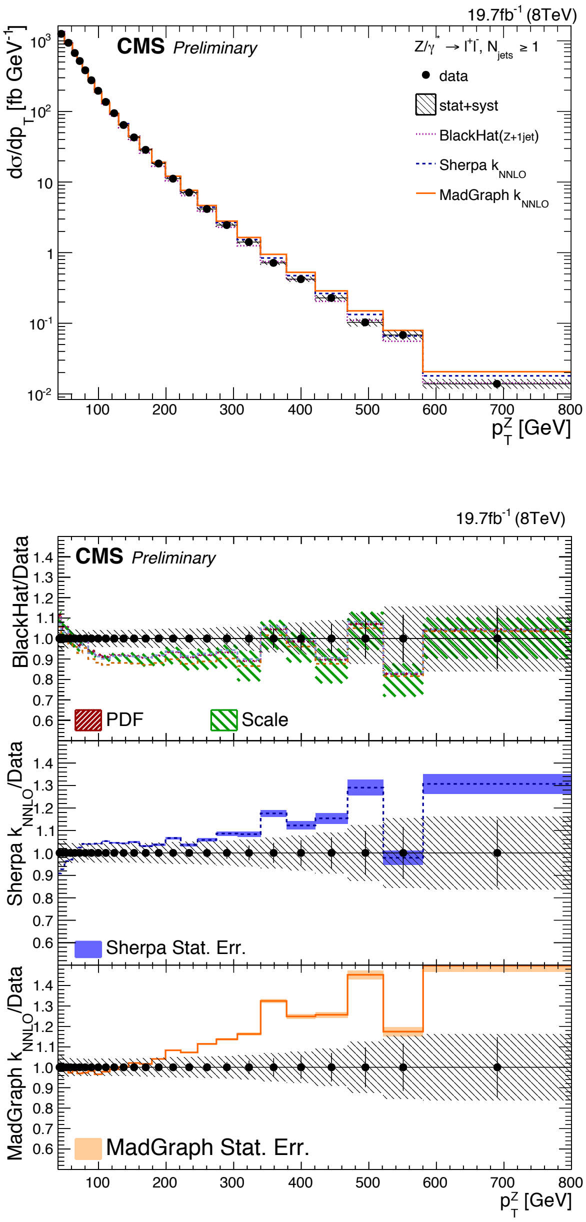

Figure 1: The p_T^Z spectrum in the $n_{\text{jets}} \geq 1$ selection.

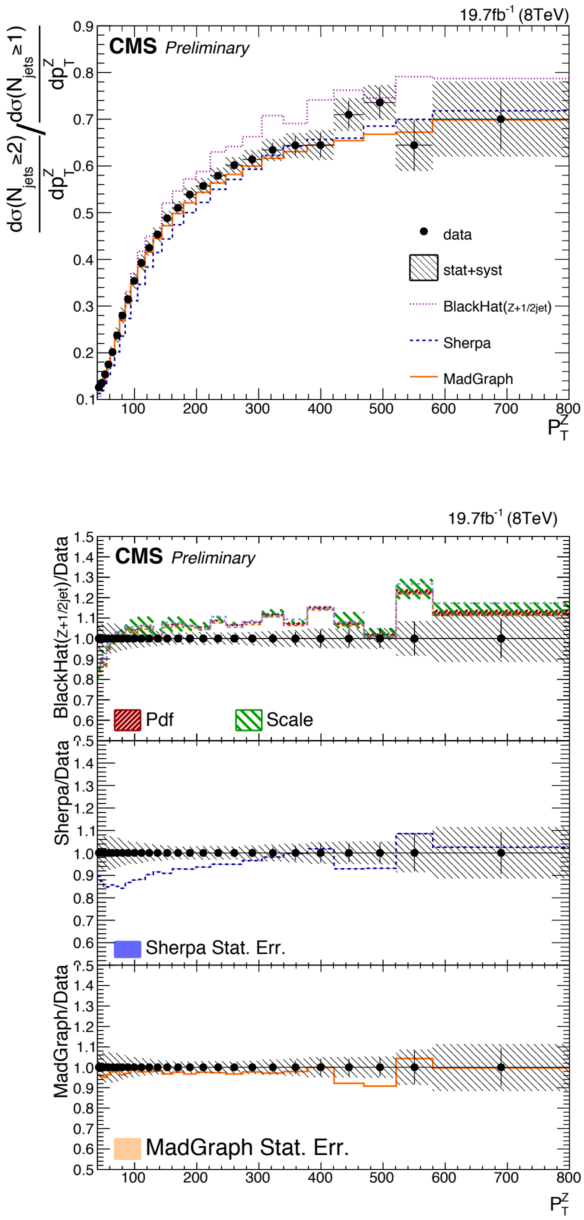

Figure 2: Cross section ratio of $n_{\text{jets}} \geq 2$ to $n_{\text{jets}} \geq 1$.

well. BlackHat performs well in the central region, but disagrees below at the low and high ends. The disagreement occurs in regions where BlackHat's NLO n-jet calculation produces an extra jet with only LO accuracy, i.e. where non-leading order terms dominate in the BlackHat prediction which leads to larger uncertainties.

In the p_T^Z/H_T case, MadGraph and Sherpa again perform well. BlackHat performs well in the low region, but analogous behavior to $\log_{10}(p_T^Z/p_{\mathrm{T}}^{j1})$ was observed in the high end tail of the distribution, in the region where $p_T^Z/H_T > 1$. The disagreements occur in regions where the fixed-order calculation reaches its limit.

4. Conclusion

We find that the ratio of MC to data for Z/γ^* + jets is not well reproduced by MadGraph and Sherpa at high vector boson p_{T}. Furthermore, this discrepancy increases as function of Z p_{T}. However, using NLO calculations, we find a reduction in the discrepancy between data and MC, indicating that this might be related to missing higher orders.

Disagreements between between BlackHat and data occur exactly in those kinematic regions where NLO QCD is well understood to be unreliable and can be seen in the large scale errors. In these regions the LO + parton shower descriptions (MadGraph and Sherpa) are superior.

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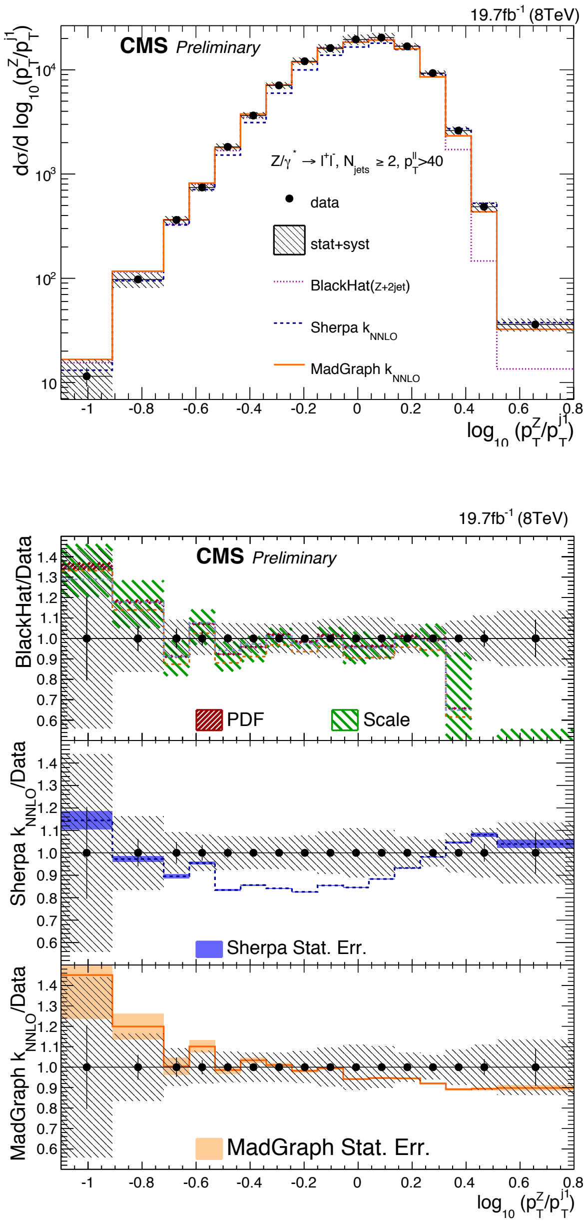

Figure 3: The $\log_{10}(p_T^Z/p_{\mathrm{T}}^{j1})$ ratio in the $n_{\mathrm{jets}} \geq 2$ selection.