Erratum: NNLO QCD corrections for Drell-Yan p_T^Z and ϕ_η^* observables at the LHC

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ABSTRACT: We correct an error in the implementation of the NNLO corrections, which modifies the numerical predictions. In the light of these modifications, we re-assess the kinematical range of applicability of the fixed-order NNLO predictions.

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1 Introduction

We computed the NNLO QCD corrections to the Drell–Yan p_T^Z and ϕ_η^* observables in [1]. In the region of low p_T^Z or low ϕ_η^* , these distributions receive large logarithmic corrections at all orders in perturbation theory. The resummation of these corrections has been accomplished recently [2] to third logarithmic order (N³LL). By expanding the N³LL resummation in the strong coupling α_s , all large logarithmic terms up to NNLO can be predicted.

In comparing our predictions from [1] with the predicted logarithmic behaviour at low p_T^Z or low ϕ_η^* , we uncovered an error in the numerical implementation of the NNLO corrections. This error is now corrected, and we have recomputed all numerical results reported in [1], which are documented in the following.

Numbering of Sections and Figures is as in [1].

3 Numerical results

3.1 Calculational setup

The setup of the calculation is described in detail in [1]. Its kinematical selection criteria follow the ATLAS 8 TeV measurement [3] of the p_T^Z and ϕ_η^* distributions.

3.2 The transverse momentum distribution at low p_T^Z

Figures 2 and 3 compare the measured p_T^Z distribution to the NLO and NNLO predictions. While the NLO calculation does not describe the shape of the data below $p_T^Z \approx 40$ GeV, the NNLO calculation agrees with the data down to lower values of $p_T^Z \approx 15$ GeV.

By comparing with our NNLO results initially presented in [1], we observe that the implementation error resulted in visible deviations on the NNLO predictions only for values of $p_T^Z < 20$ GeV. The NNLO results for larger values of the Z-boson transverse momentum [4] as well as for Z+jet production [5] are unaffected by this error and remain unchanged.

We note that the description of the low- p_T^Z tail of the data at NNLO now deviates at larger values of the transverse momentum ($p_T^Z \sim 15$ GeV) than initially observed in [1] ($p_T^Z \sim 4$ GeV), indicating the onset of large logarithmic corrections that require resummation.

Figure 2. Normalized transverse momentum distribution differential in $m_{\ell\ell}$ at NLO and NNLO compared to ATLAS data [3]. The distribution is normalised to the NLO prediction. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

3.3 The large ϕ_η^* region

Figures 4 and 5 display the ϕ_η^* distribution for $\phi_\eta^* > 0.051$, for the on-shell invariant mass range as well as for the two off-shell mass ranges. These figures span the range from large values of ϕ_η^* , where we observe that the NNLO prediction provides an excellent description of the data, towards the onset of deviations from the fixed order predictions, which is seen at different values of ϕ_η^* in the three invariant mass bins. Similarly to the p_T^Z distribution in the previous section, we observe that the corrected distributions deviate from the data at somewhat larger values of ϕ_η^* than initially seen in [1]. The breakdown of the fixed-order description in the lower tail of the ϕ_η^* -distribution is investigated in more detail in the next subsection.

3.4 The small ϕ_η^* region

At smaller values of ϕ_η^* , we enter the domain of the large logarithms where the fixed-order perturbative prediction breaks down. In [1], we investigated the relation between p_T^Z and ϕ_η^* both from the purely kinematical point of view (Section 2) as well as by inspecting the leading logarithmic terms in this limit (Section 3.4). From kinematical considerations, an

Figure 3. Normalized transverse momentum distribution differential in y^Z for the on-resonance bin at NLO and NNLO compared to ATLAS data [3]. The distribution is normalised to the NLO prediction. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

Figure 4. The ϕ_η^* distribution for $\phi_\eta^* > 0.051$ for the on-resonance region $66 \text{ GeV} < m_{\ell\ell} < 116 \text{ GeV}$ in 6 different rapidity slices. The distribution is normalised to the NLO prediction. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

Figure 5. The ϕ_η^* distribution for $\phi_\eta^* > 0.051$ for the two off-resonance $m_{\ell\ell}$ bins, $46 \text{ GeV} < m_{\ell\ell} < 66 \text{ GeV}$ (top) and $116 \text{ GeV} < m_{\ell\ell} < 150 \text{ GeV}$ (bottom) in 3 different rapidity slices. The distribution is normalised to the NLO prediction. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

Figure 6. The ϕ_η^* distribution for $\phi_\eta^* > \phi_{\eta,\text{cut}}^*$ for the on-resonance mass bin $66 \text{ GeV} < m_{\ell\ell} < 116 \text{ GeV}$. The distribution is normalised to the experimental data. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

approximate relation between ϕ_η^* and p_T^Z can be established:

$$\phi_\eta^* \approx p_T^Z / m_{\ell\ell}, \quad (3.6)$$

which can be used as guidance in the comparison of these distributions in the region of low- p_T^Z and low- ϕ_η^* . We notice that the inspection of the leading logarithmic structure suggested a factor of 2 on the left hand side of the above equation [1], which is however broken by subleading logarithmic terms. We therefore use the purely kinematical relation (3.6) for our comparisons.

Figs. 6–8 use the above relation to compare these distributions for the on-resonance invariant mass range and for the two invariant mass ranges below and above resonance. For better visibility over the kinematical range, we show

$$\langle \mathcal{O} \rangle_{\text{bin}} \times \frac{\frac{1}{\sigma} \frac{d\sigma}{d\mathcal{O}}|_{\text{Theory}}}{\frac{1}{\sigma} \frac{d\sigma}{d\mathcal{O}}|_{\text{Data}}} \quad \text{with} \quad \mathcal{O} = \phi_\eta^*, p_T^Z,$$

i.e. the ratio of normalised distributions weighted by the central bin values. The p_T^Z range is fixed to $[0, 20] \text{ GeV}$, while the ϕ_η^* range is chosen according to the above equation for each mass bin, using the central value of $m_{\ell\ell}$. The first bins contain the zero value and are not accessible by a fixed-order calculation of the p_T^Z or ϕ_η^* distributions, which diverges there.

Figure 7. The ϕ_η^* distribution for $\phi_\eta^* > \phi_{\eta,\text{cut}}^*$ for the below resonance mass bin $46 \text{ GeV} < m_{\ell\ell} < 66 \text{ GeV}$. The distribution is normalised to the experimental data. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

In these figures, we observe that the NNLO predictions deviate from the data at larger values of p_T^Z or ϕ_η^* than at NLO, which is mainly due to the considerable reduction in the scale uncertainty: the larger NLO uncertainty band allows to remain compatible with the data. In terms of describing the shape of the data, the NNLO predictions better reproduce the general tendency of the data in this region, however without providing a detailed quantitative agreement. For both distributions, we also recall that the NNLO corrections improve the description of the shape of the distribution at larger values of p_T^Z or ϕ_η^* (outside the plotting range here). By comparing the departure points between theory and data for both observables, we are able to test the approximate kinematic relation $p_T^Z \sim m_{\ell\ell} \phi_\eta^*$. The results are summarised in Table 1 and show that the relation is indeed fulfilled to a reasonable level.

4 Summary and conclusions

In this erratum, we have corrected an implementation error in the calculation of the NNLO QCD corrections to the p_T^Z and ϕ_η^* distributions computed in [1]. We have performed in-depth studies on the numerical impact resulting from this error, which is found to be negligible for $p_T^Z > 20 \text{ GeV}$, but induces sizeable modifications in the region of low- p_T^Z or low- ϕ_η^* .

Figure 8. The ϕ_η^* distribution for $\phi_\eta^* > \phi_{\eta,\text{cut}}^*$ for the above resonance mass bin $116 \text{ GeV} < m_{\ell\ell} < 150 \text{ GeV}$. The distribution is normalised to the experimental data. The green bands denote the NLO prediction with scale uncertainty and the blue bands show the NNLO prediction with scale uncertainty.

	$m_{\ell\ell}\text{-bin [GeV]}$	$\phi_{\eta,\text{depart}}^*$	$p_{T,\text{depart}}^Z$	$\langle m_{\ell\ell} \rangle \phi_{\eta,\text{depart}}^*$
NLO	46–66	~ 0.14	$\sim 9 \text{ GeV}$	8 GeV
	66–116	~ 0.11	$\sim 11 \text{ GeV}$	10 GeV
	116–150	~ 0.08	$\sim 12 \text{ GeV}$	11 GeV
NNLO	46–66	~ 0.17	$\sim 10 \text{ GeV}$	10 GeV
	66–116	~ 0.14	$\sim 15 \text{ GeV}$	13 GeV
	116–150	~ 0.13	$\sim 20 \text{ GeV}$	17 GeV

Table 1. Values of $\phi_{\eta,\text{depart}}^*$ and $p_{T,\text{depart}}^Z$ for the three mass windows corresponding to the values of ϕ_η^* and p_T^Z where the fixed order predictions of the distributions start to deviate from the experimental data.

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