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Top-pair and tW production at approximate N3LO

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1 Introduction

I present approximate N^{3}LO theoretical results for top-antitop pair production, and for single-top production in association with a W boson. The higher-order corrections are from soft-gluon radiation, which is dominant near partonic threshold. I present results for total cross sections as well as transverse-momentum and rapidity distributions of the top quark, and compare with data at LHC energies.

2 Top-pair production

The top quark is the heaviest elementary particle to have been discovered to date. Because of its large mass, its near-threshold production at current colliders receives large radiative corrections from soft-gluon emission. These corrections have long been known to be significant for $t\bar{t}$ production, and they approximate exact results, when known, very accurately.

Resummation of the double-differential cross section at next-to-next-to-leading logarithm (NNLL) accuracy in moment space was derived in Ref. [1] using the two-loop soft anomalous dimension [1, 2]. Fixed-order expansions of the resummed cross section in momentum space bypass the problem of using a prescription for divergences, and they provide excellent and reliable predictions for the higher-order corrections. General expressions for the expansions have been derived and used for various processes at NNLO [3] and N^{3}LO [4]. Approximate N^{3}LO (aN^{3}LO) predictions for double-differential cross sections in $t\bar{t}$ production have appeared in Ref. [5]. These aN^{3}LO corrections are needed for precision physics as they considerably enhance the total cross section and differential distributions.

An interesting question in the study of $t\bar{t}$ production is the effect of scale choice on the top-quark p_T distributions. Traditionally, two central choices have been made

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for the factorization and renormalization scales: $\mu = m$, the top quark mass; and $\mu = m_T = (p_T^2 + m^2)^{1/2}$, the transverse mass. The difference in the p_T distributions using the two scales thus grows with p_T.

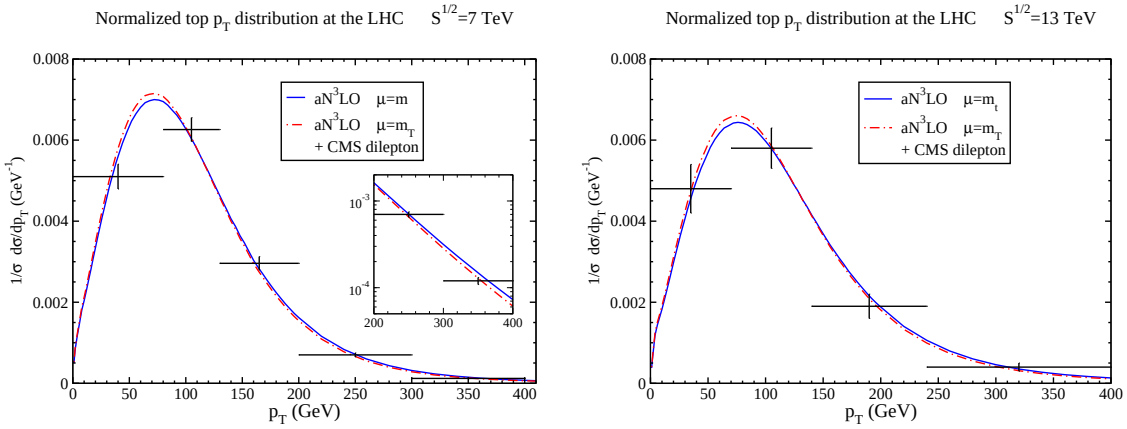

Figure 1: Top quark aN^{3}LO normalized p_T distributions compared with CMS dilepton data at (left) 7 TeV [6] and (right) 13 TeV [7] LHC energies.

In Fig. 1 we display the top quark normalized p_T distributions at 7 TeV (left plot) and 13 TeV (right plot) LHC energies. We compare with data from CMS in the dilepton channel at 7 TeV [6] and 13 TeV [7]. We find excellent agreement in both cases, especially with the choice $\mu = m_T$, which better describes the data at high p_T. We have used MMHT2014 pdf [8]; the results with CT14 pdf [9] are similar.

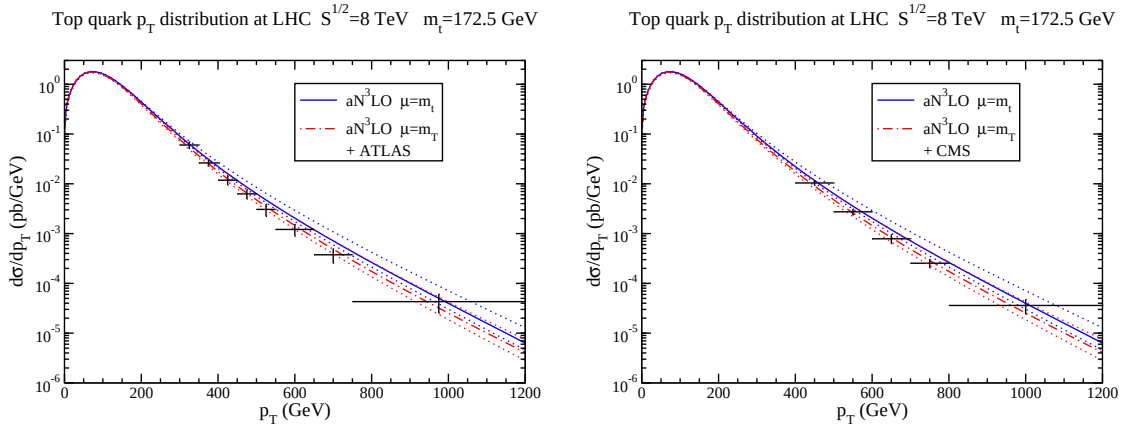

Figure 2: Top quark aN^{3}LO p_T distributions compared with (left) ATLAS [10] and (right) CMS [11] lepton+jets data at 8 TeV LHC energy.

In Fig. 2 we display the boosted top quark p_T distributions, with theoretical uncertainty, at 8 TeV LHC energy, and compare with lepton+jets data from ATLAS [10] (left plot) and CMS [11] (right plot). Again, the calculations with the choice $\mu = m_T$ better describe the data at high p_T.

3 tW production

The associated production of a top quark and a W boson, via the partonic process $bg \to tW^-$, was studied at NNLL accuracy in Ref. [12] using results for the two-loop soft anomalous dimension. Approximate NNLO (aNNLO) predictions for the total tW^- production cross section were given in [12]. The cross section for $\bar{t}W^+$ production is the same.

Top-quark p_T distributions at aNNLO for this process were given in Ref. [13]. More recently, aN^{3}LO results for the total cross section and the top p_T and rapidity distributions in tW production were presented in Ref. [14].

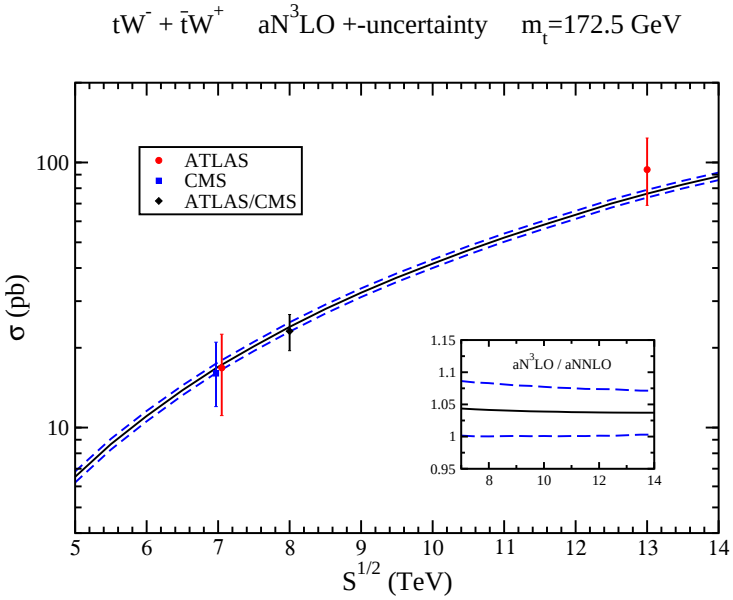

Figure 3: Total aN^{3}LO cross section for tW production at LHC energies compared with data [15, 16, 17, 18] from ATLAS and CMS.

In Fig. 3 we show the total aN^{3}LO cross section, together with theoretical uncertainty, for tW production and compare with LHC data. The theoretical predictions are in very good agreement with the data from ATLAS [15] and CMS [16] at 7 TeV, an ATLAS/CMS combination at 8 TeV [17], and ATLAS at 13 TeV [18].

The inset plot in Fig. 3 shows the aN^{3}LO/aNNLO ratio. It is clear that the third-order soft-gluon corrections are non-negligible.

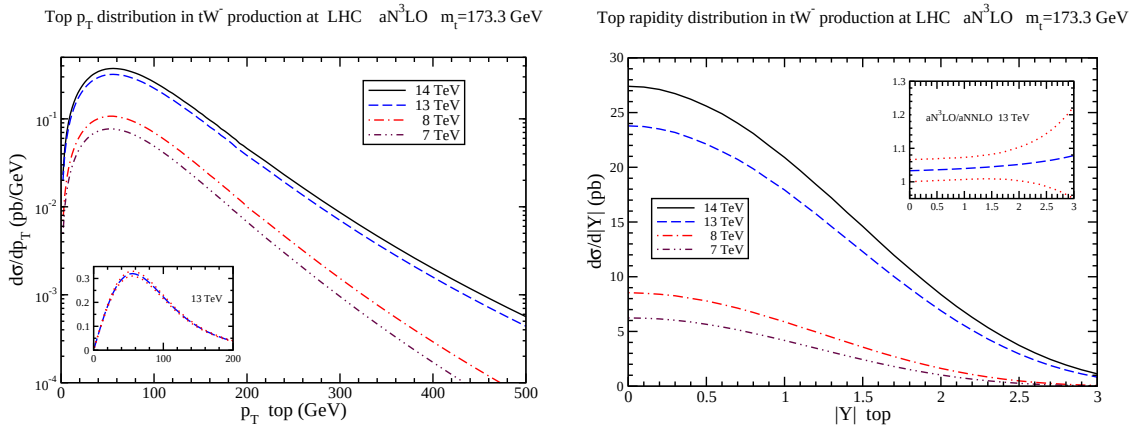

Figure 4: Top quark aN^{3}LO p_T and rapidity distributions in tW production.

In the left plot of Fig. 4 we display the aN^{3}LO top quark p_T distributions in tW production at LHC energies. The inset plot shows the distribution at 13 TeV energy together with the theoretical uncertainty.

In the right plot of Fig. 4 we display the aN^{3}LO top quark rapidity distributions in tW production at LHC energies. The inset plot shows the aN^{3}LO/aNNLO ratio, with theoretical uncertainty, at 13 TeV. We observe that the soft-gluon corrections are substantial, particularly at large values of rapidity.

Acknowledgements

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