MPI and UE corrections to jet measurements and influence on PDF determination and α_s

Salim Cerci (for the CMS collaboration)[1]

[1]Adiyaman University, Faculty of Arts and Sciences, Department of Physics, 02040 Adiyaman, Turkey.

1 Introduction

Events with jets which are collimated sprays of hadrons and signatures of quarks and gluons in the detector can be described by Quantum Chromodynamics (QCD) in terms of parton-parton scattering. The hard part of QCD considers perturbative QCD (pQCD), parton density functions (PDFs), initial and final state radiation (ISR, FSR) and parton shower (PS) modeling whereas the soft part of QCD deals with fragmentation, multiple parton interactions (MPI) and underlying event (UE). The inclusive jet cross section in pp collision is a fundamental quantity which can be measured and predicted within the framework of pQCD. Because of that, jet measurements can be used to determine the strong coupling constant α_s and to constrain the PDFs. For a comparison of the jet production processes obtained in hadron-hadron collisions with the next-to-leading order (NLO) parton level theory calculations non-perturbative (NP) corrections have to be applied to account for MPI, UE and PS effects [1].

2 Results

NP correction factors are obtained by using Shower Monte Carlo (SMC) event generators. In order to take into account the NP effects coming from MPI and hadronization, the NP corrections factors are applied to next-to-leading order (NLO) theory calculations. A new approach treating NP corrections in the context of NLO-matched PS event generators is also introduced in Ref. [2]. NP correction factors can play important role for quantifying the relation between the perturbative hard processes and the softer interactions of particles involved in hadronization and PS. The leading order correction factors C_{LO}^{NP} are obtained by using leading-order Monte Carlo (LO-MC) generators HERWIG [3,4] and PYTHIA [5]. In this study, C_{LO}^{NP} is calculated as in Refs. [1,6,7]:

$$C_{LO}^{NP} = \frac{d^2\sigma}{dp_T dy}(\mathrm{LO} + \mathrm{PS} + \mathrm{MPI} + \mathrm{HAD}) / \frac{d^2\sigma}{dp_T dy}(\mathrm{LO} + \mathrm{PS}) \tag{1}$$

where in the numerator PS, MPI and hadronization effects and in the denominator only PS effects were included in addition to the LO hard process. The NP correction for LO is evaluated by averaging those provided by PYTHIA 6 (version 4.26), using tune Z2*, and HERWIG++ (version 2.4.2), using tune UE. This is the most obvious way to evaluate NP corrections when only the LO+PS event generators are available. However, once C_{LO}^{NP} corrections are applied on results at NLO parton-level, a potential inconsistency arises because the real correction of the first parton emission is treated differently in the NLO calculation and the PS. To avoid this, an alternative method [2], based on NLO Monte Carlo (NLO-MC) generators, can be used. This method makes possible to study separately correction factors to the fixed-order calculation due to PS effects. The NLO NP corrections are derived using POWHEG [8, 9], interfaced with PYTHIA 6 (version 4.26) for PS, MPI and hadronization. In this case averaging the results for two different tunes of PYTHIA 6, Z2* and P11 are taken. The correction factor between PS and the hadronic final state is defined [2, 10] as

$$C_{NLO}^{NP} = \frac{d^2\sigma}{dp_T dy}(\text{NLO} + \text{PS} + \text{MPI} + \text{HAD}) / \frac{d^2\sigma}{dp_T dy}(\text{NLO} + \text{PS}) \tag{2}$$

$$C_{NLO}^{PS} = \frac{d^2\sigma}{dp_T dy}(\text{NLO} + \text{PS}) / \frac{d^2\sigma}{dp_T dy}(\text{NLO}) \tag{3}$$

where the denominator in Eq. 3 is evaluated by switching off PS+MPI+HAD in the MC simulation. The difference between the correction factors in Eqs. 1 and 2 calculation is due to the matching of multiple parton interactions to the NLO calculation. The transverse momentum p_T scale of MPI is smaller than the p_T scale of the hard process, which is defined by the average p_T of the hard partons in the process. Thus the hard scale in LO and NLO is different, leading to a non-negligible numerical difference in the NP correction factor. In particular, this difference can be seen clearly in the forward rapidity $3.2 < |y| < 4.7$ region and at low p_T as shown in Fig. 1. The correction factor C_{NLO}^{PS} in Eq. 3, is evaluated with the NLO-MC simulation.

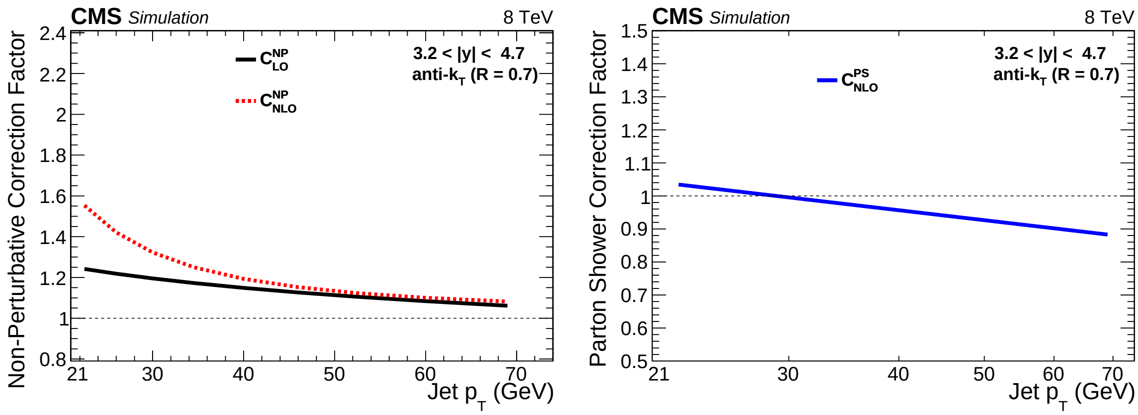

Figure 1: NP correction factor (left) and PS correction factor (right) shown for the forward rapidity $3.2 < |y| < 4.7$ as a function of jet p_T as determined in [1].

In this study, the three correction factors evaluated with Eq. 1, 2 and 3, are applied to NLO predictions (CT10 [11]). NP and PS corrections, depend on p_T and y, are obtained for central ($|y| < 3$)

and forward ($3.2 < |y| < 4.7$) regions of CMS [1]. Since the PS effect is largest at large y, only results from the forward region are presented in here. The obtained theoretical results are compared to inclusive jets measurement performed in forward region at $\sqrt{s} = 8$ [1]. Figure 2 (top left) shows the comparison of the experimental data with the theoretical jet distribution obtained by applying only the correction factor C_{LO}^{NP} to NLO prediction. The average of LO and NLO correction factors, $\frac{C_{LO}^{NP}+C_{NLO}^{NP}}{2}$, is applied to NLO prediction and the comparison with the experimental data is shown in Fig. 2 (top right). A further comparison of data to the NLO prediction, in which the correction factor $C_{NLO}^{PS} + (\frac{C_{LO}^{NP}+C_{NLO}^{NP}}{2})$ is applied, is shown in Fig. 2 (bottom). By looking at all the comparisons shown in Fig. 2, the NP corrections change the shape of jet distributions as well as affect significantly the comparison of theory predictions with the experimental data. The PS corrections contribute as well.

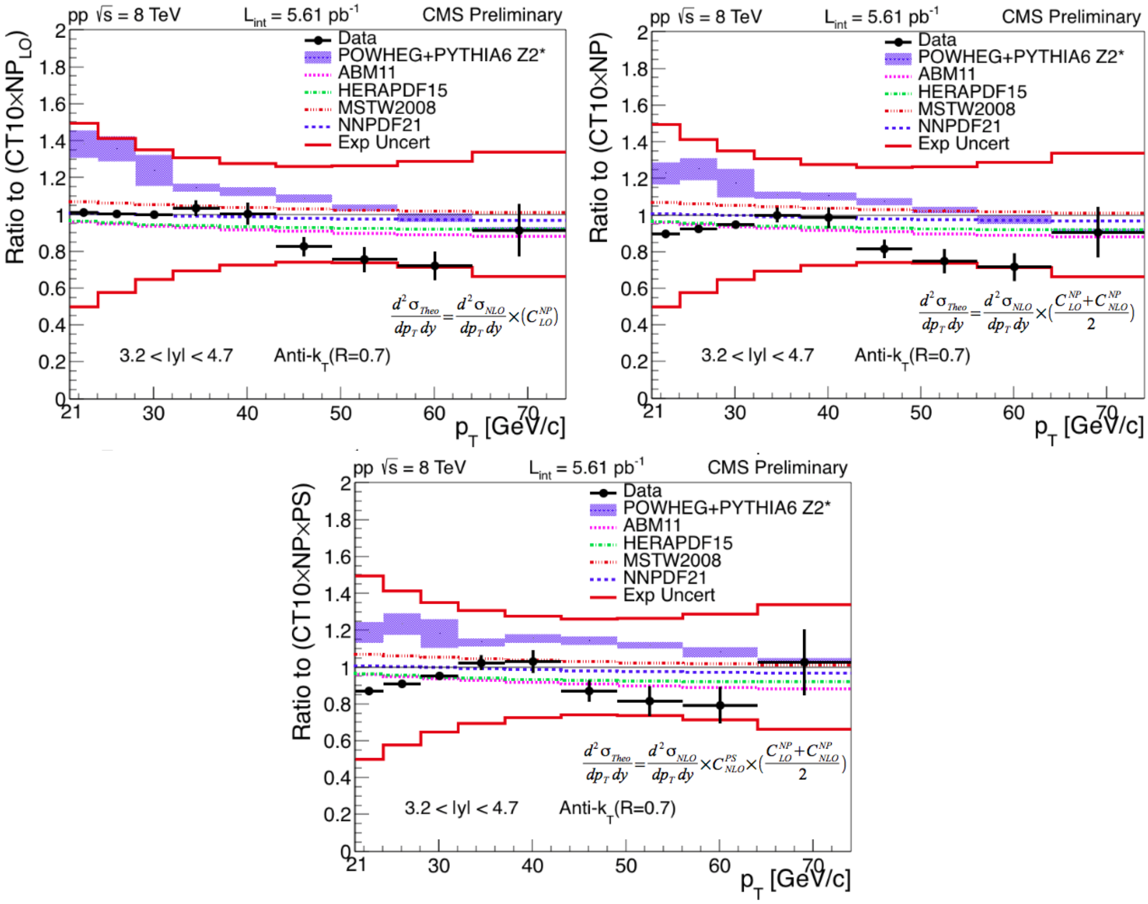

Figure 2: Ratio of inclusive jet cross sections to the theoretical prediction using the central value of the CT10 PDF set which are applied NP and PS correction for forward rapidity ([1])

It can be also concluded that NP corrections have influence on the determinations of parton distributions. Perturbative QCD, supplemented by a small NP correction, is able to describe well the data over a wide range of p_T and y and over many orders of magnitude in cross section. A cross check including PS corrections is performed with CT10 NLO PDF set, and good agreement is observed with each other within the estimated uncertainty limits [1].

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