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QCD with jets and photons at ATLAS and CMS

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Abstract

Jets and photons are abundant messengers sensitive to QCD interactions and the structure of hadrons at the LHC. In this note recent results from the ATLAS and CMS Collaborations in proton-proton and proton-lead collisions are summarized. Major progress is being made in the observations and the understanding of those objects. Detailed QCD interpretations are possible today to an accuracy of about 5the close future another step in precision is getting in reach. Further work is also needed in improving the understanding of non-perturbative and soft effects in particular for multi-final states, and to keep up with the significant experimental and theoretical progress.

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QCD with jets and photons at ATLAS and CMS

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Jets and photons are abundant messengers sensitive to QCD interactions and the structure of hadrons at the LHC. In this note recent results from the ATLAS and CMS Collaborations in proton-proton and proton-lead collisions are summarized. Major progress is being made in the observations and the understanding of those objects. Detailed QCD interpretations are possible today to an accuracy of about 5%. With full NNLO prediction becoming available in the close future another step in precision is getting in reach. Further work is also needed in improving the understanding of non-perturbative and soft effects in particular for multi-final states, and to keep up with the significant experimental and theoretical progress.

1 Introduction

The precision of measurements of jets and photons at the CERN LHC makes tremendous progress, and the complexity of observables and final states is more and more increased. The current status of jet and photon measurements by the ATLAS [1] and CMS [2] Collaborations is presented here. The comparison to theory predictions and modelling can in some cases already make statements on the order of 5% accuracy. Further improvements are expected with upcoming full NNLO event generation, combined with simultaneous better understanding of soft and non-perturbative contributions.

2 Review of measurements

In particular for the measurement of inclusive jet and photon production the data can typically be well described by NLO model predictions when they are combined with electroweak and non-perturbative corrections. A powerful demonstration of this are the double-differential inclusive jet cross section measured at 8 TeV [3], see Fig. 1. In the detailed analysis of inclusive jet and di-jet production [4] it is found that NLO predictions describe individual distributions well, with quantitative p-values on the order of $\approx 1\%$, while on a global level there remains tension. For the same data it is found that the NNLO predictions simulated with scale $p_{\mathrm{T}}^{\mathrm{jet}}$ are better compared to the ones simulated with scale $p_{\mathrm{T}}^{\mathrm{max}}$. However, these NNLO modelling uncertainties can not yet be fully determined, making a quantitative analysis not feasible at the moment on this

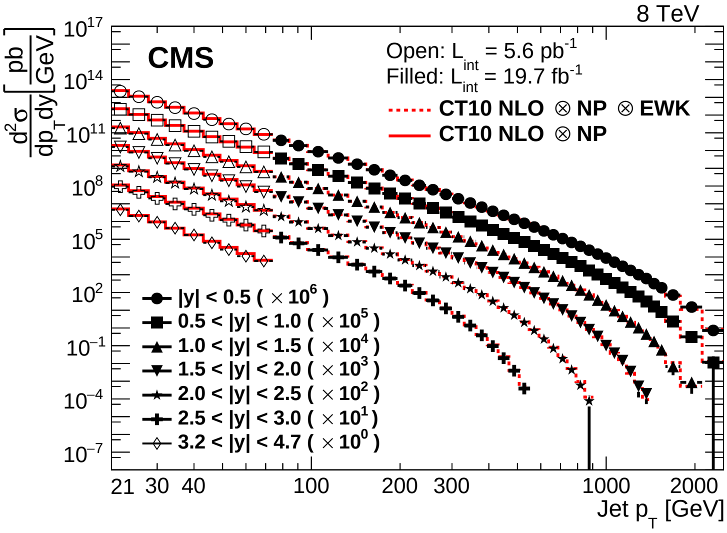

Figure 1 – The double differential jet distributions over a very wide p_{T}−range measured by CMS [3].

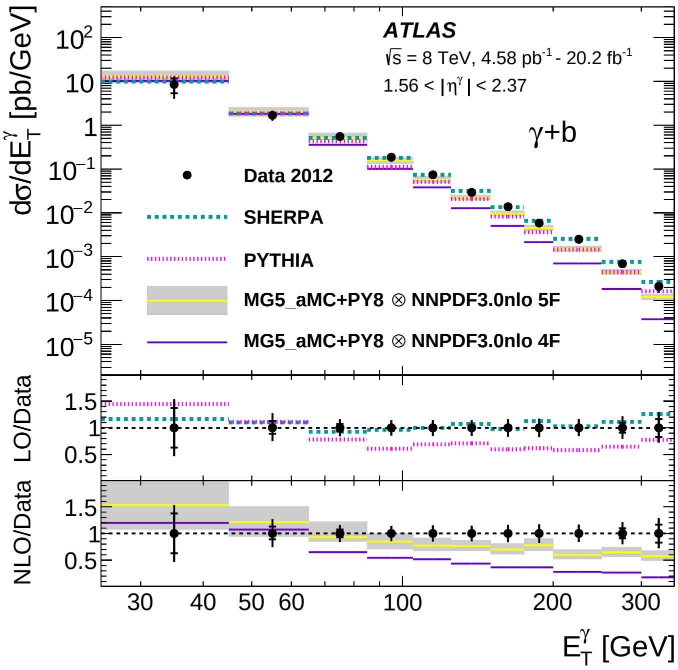

Figure 2 – Photon+heavy flavor jet production with photon in forward direction measured by ATLAS [6].

level. Furthermore, the analysis of photons+jet events illustrates good agreement with NLO predictions [5], whereas already the measurement of a photon plus one heavy-flavor jet illustrates obvious shortcomings of the NLO predictions [6], since the models systematically underestimate the cross sections at higher E_{T}^{γ} values, see Fig. 2. This becomes more obvious in the tri-photon final state, where the NLO predictions consistently remain about a factor of 2 below the measurements [7]. Also the study of correlations in multi-jet final states, with up to four jets, clearly reveals the various shortcomings of existing event generators [8]. Here the HERWIG7 NLO predictions are overall best, but none of the generators describe the data to a reasonable level. It is shown that this result is in particular sensitive to the modeling of parton showers.

If the measurements are analysed on inclusive level, fundamental conclusions can be derived from this on the level 5% accuracy. This has been exploited by various determinations of the strong coupling constant α_{S} using different methods [11,3]. But also impressive constraints on the

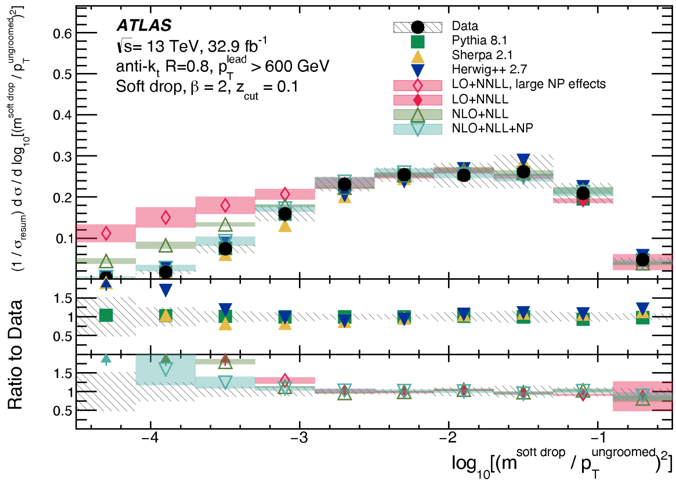

Figure 3 – The groomed jet structure measured by ATLAS [9] showing a mismatch of NLO predictions in the soft region.

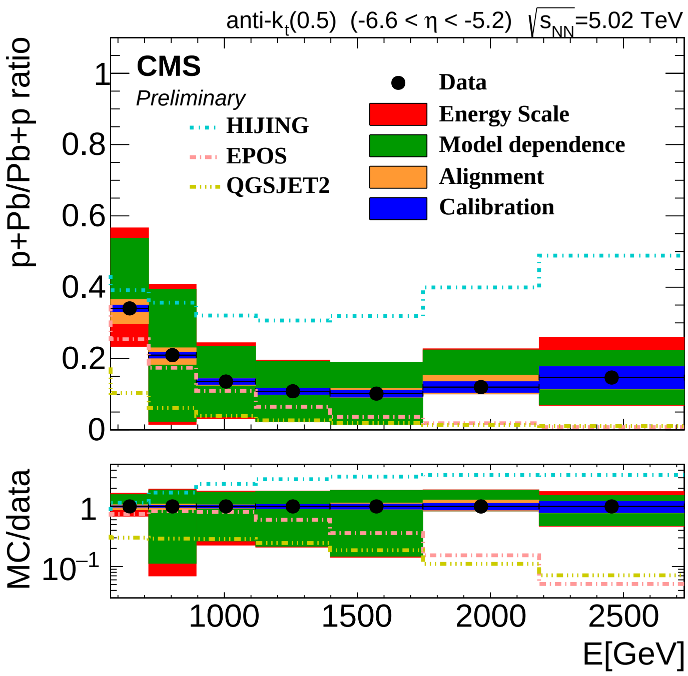

Figure 4 – Inclusive very-forward jet production in proton-lead collisions. Shown is the ratio between jet production in proton-lead relative to lead-proton in CMS/CASTOR [13].

parton density functions in the proton have been obtained [12]. The parton density of gluons at high values of x can be considerably better understood when LHC jet data is included in the analysis together with HERA data.

Dedicated measurements with increased sensitivity to non-pQCD effects indicate the need to also better understand non-perturbative and soft effects. The analysis of jet sub structure reveals the need for non-perturbative contributions in the domain more sensitive to soft physics [9]. However, otherwise these data are well described by NNLL predictions, c.f. Fig. 3. Also the measurement of the jet charge is an interesting probe [10]. Finally, also the measurement of very-forward directed jets is in particular sensitive to soft QCD and low-x effects. A measurement of the inclusive jet cross section in $-6.6 < \eta < -5.2$ in proton-lead collisions (see Fig. 4) illustrates a major opportunity to significantly improve model predictions[13] and learn about the very low-x QCD dynamics as well as soft contributions in this phase-space.

3 Conclusion

NLO predictions with non-perturbative and EW corrections are able to well describe data in huge phase-space regions. Detailed QCD interpretations are possible to an accuracy of about 5%. NNLO predictions with full uncertainties are needed to make the next step, and this will have a huge potential to enter true precision QCD interpretation at LHC.

Soft and non-perturbative effects are typically described better by event generators compared to NLO model predictions. Some work is needed in non-perturbative physics to keep up with the increased level of precision in particular for multi-final states, and other more complex observables.

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