Low-x physics results from CMS

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Abstract

The internal structure of hadrons at low momentum fractions is known only poorly. However, it is important, for example, to understand background processes at hadron colliders. The parton density rises fast with decreasing values of x. This growth is dominated by gluons and at some critical scale the gluon density will enter a state of saturation. The production of jets is sensitive to the partonic structure of hadrons. We report on recent results on forward and multiple hard jet production in pp collisions at CMS. Correlations between central and forward jet production are studied as well as additional jet radiation in events with dijets at large rapidity separation. Also the forward and very forward directed energy flow in pp and PbPb collisions are presented.

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1 Introduction

The microscopic partonic structure of hadrons imposes some severe theoretical and experimental challenges nowadays. The fast growth of gluons towards very small longitudinal momenta fractions $x = p_{\text{parton}}/p_{\text{hadron}}$ was first discovered at HERA [1]. It is obvious that this growth of the gluon density cannot be indefinite. At the scale $Q_s$ gluons will recombine and enter a phase of saturation. Saturation in hadronic collisions will start to originate from the phase space regions with the highest gluon densities, which is at low-$x$. At the same time, the complex structure of hadrons has various consequences on hadronic final states at hadron colliders. The related hadronic multiparton production cannot be calculated from first principles in the framework of QCD. The underlying event is an inherent background to almost all studies at hadron colliders, in particular also to the search for high-$p_T$ phenomena.

The study of the low-$x$ structure of protons at LHC is very important in this context. Events with forward jets are a signature of very asymmetric parton momenta from the two colliding hadrons, and thus are useful to probe the low-$x$ regime. Different parton evolution models, such as e.g. DGLAP [2–5] or BFKL [6–8], make different predictions in particular for soft processes.

2 The CMS experiment

The main feature of the CMS experiment [9] is the central superconducting solenoid magnet. The silicon trackers but also the electromagnetic and hadronic calorimeters are built within the central field of this magnet. The muon detectors are within the return yoke on the outside of the magnet coil. This central part of CMS is complemented by detectors in the forward region. There is the hadronic forward calorimeter at pseudorapidity $3 < |\eta| < 5.2$, CASTOR at $-6.6 < \eta < -5.2$ and also the zero degree calorimeters for neutral particles.
Multiple analyses making use of forward jets are performed within the CMS Collaboration. Here the simultaneous observation of central ($|\eta| < 2.8$) and forward jets ($3.2 < |\eta| < 4.7$) is discussed [10]. These results are based on 3.14 pb$^{-1}$ of data at $\sqrt{s} = 7$ TeV and a lower $p_T$ threshold of $35$ GeV/c$^2$. In Fig. 1 the residual of the measured cross sections is plotted over the $p_T$ of the forward and central jets. The main discrepancy between data and MC originates from the low-$p_T$ forward jets. All models, regardless of BFKL or DGLAP motivated, overpredict this part of the cross section. The result is a normalization problem when looking at the central jets. Here only CASCADE [11] also exhibits a different shape with respect to all other models. However, currently there are no overall consistent indications to prefer either BFKL nor DGLAP motivated models.

The measurement of the very forward energy flow in PbPb minimum bias data are shown in Fig. 3 [16]. This analysis extends the pseudorapidity coverage of CMS by 1.5 units of pseudorapidity towards the beam rapidity, which is a unique feature at LHC. This wide acceptance allows to explore phase-space regions not accessible to other experiments. While the centrality-dependence of the very forward energy flow relative to the most central events is almost independent of pseudorapidity up to $|\eta| < 5$, in the very forward direction it is distinctively different. This result indicates significantly less dependence on the impact parameter of the collision at low-$x$.

Also here, when these data are confronted to existing models it is found that no model can describe all aspects of the observed phase-space. The Gribov-Regge type models EPOS [15] and QGSJetII [14] perform better in the forward region, while HYDJET [17] and AMPT [18] are
Figure 3: Left panel: Measurements of the average energy deposit per unit of pseudorapidity in PbPb events over the full CMS acceptance range. Right panel: Energy flow relative to most central PbPb collisions as a function of centrality for different pseudorapidities.

5 Conclusion

In particular the forward detectors of CMS are very relevant in studying the low-x structure of hadrons. We demonstrated how data from the HF and CASTOR calorimeters are used to explore this phase-space region. The difficulties in these analyses are very large, in particular lowering the $p_T$ threshold of such analyses would yield a much better sensitivity. Given the present status of the analyses we conclude that re-tuned versions of interaction models describe the data reasonably well, however, there is right now not a single model that can conclusively explain all observations.

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References


