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QCD at high Q^2: new Tevatron results and LHC prospects

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A selection of new results on Quantum Chromodynamics (QCD) at high Q^2 obtained at the Tevatron with an integrated luminosity of approximately 1 fb^{-1} is presented and some prospects are given for the LHC.

1. INTRODUCTION

The motivations for high Q^2 QCD measurements at hadron colliders are numerous. The most precise measurements allow stringent tests of perturbative QCD (pQCD) calculations and can be used, in particular, to constrain the Parton Density Functions (PDFs) and the strong coupling constant α_S. Some QCD channels are also directly sensitive to new physics at the highest energy (e.g. quark substructure). More generally, a better understanding of QCD mechanisms is beneficial to most, if not all, physics analyses: for instance, high Q^2 QCD processes are a dominant background in electroweak measurements as well as in searches for new physics beyond the standard model. In this respect, boson+jet(s) events are an important channel to study detailed procedures of parton-jet matching, in view of a better control of this background to, *e.g.* Top measurements or Higgs search. Measurements of photon+jet or diphoton and $b\overline{b}$ processes also allow the validity of detailed calculations to be tested, again with crucial consequences in view of searches at the LHC.

After recalling general experimental features of QCD measurements at the Tevatron in Section 2, Section 3 presents a selection of recent results obtained by the CDF and DØ experiments at Run II, which, in our opinion, are the most significant in terms of impact for LHC physics and precision requirements for theoretical calculations. Section 4 summarizes the results and prospects.

*On behalf of the CDF and DØ collaborations.

2. EXPERIMENTAL FACTS

2.1. Tevatron, CDF and DØ

The Tevatron started its so-called Run II phase in spring 2001. It collides p with $\overline{p}$ beams at $\sqrt{s}$ = 1.96 TeV (1.8 TeV in Run I) with an instantaneous luminosity up to 3 $10^{32}\text{cm}^{-2}\text{s}^{-1}$ (1.5 $10^{31}\text{cm}^{-2}\text{s}^{-1}$ in Run I). The beams comprise 36×36 bunches (6×6 in Run I) with a 396 ns bunch crossing interval (3.5 μs in Run I). The integrated luminosity delivered up to now is close to 3 fb^{-1} (8 fb^{-1} planned at the end of running in 2009) but results shown here only use up to 1.1 fb^{-1}. The CDF [1] and DØ [2] detectors, albeit different in technology choices, are 4π multipurpose detectors with tracking, calorimeter and muon detection capabilities and similar performances. Both experiments presently record Tevatron data with high efficiency (80-90 %) and make full use of these capabilities.

2.2. Jet algorithms

For consistent comparisons between data and theory, jet algorithms have to be used to reconstruct jets in a similar way at the parton, particle and detector levels. Provided jet algorithms are defined as to avoid collinear and infrared singularities [3], partonic pQCD calculations can be regarded as predictions for jets. In addition, at the Tevatron, jet algorithms must be Lorentz-invariant under boosts along the beam axis. Two algorithms, which fulfill the above requirements, are currently used at the Tevatron in Run II.

In the Cone jet algorithm, a jet candidate (protojet) is made of objects inside a “stable” cone

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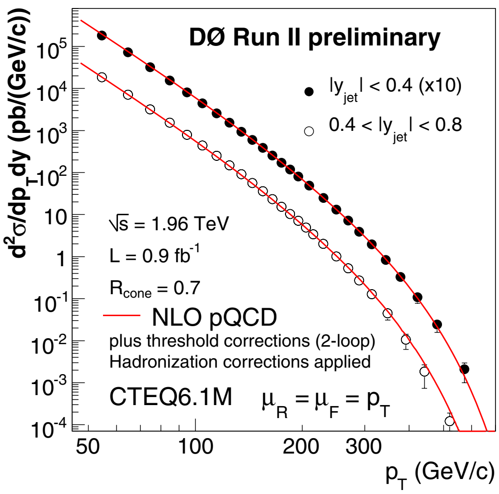

Figure 1. DØ inclusive jet cross section in 2 rapidity ranges for the Cone algorithm.

(*i.e.* whose axis coincides with the sum of the 4 vectors of its objects) of fixed radius R (0.7 by default for QCD analyses) in rapidity and azimuthal angle (Y, φ). Protojets are found iteratively, starting, for computing time reasons, from positions (seeds) corresponding to objects with sufficient transverse momentum p_T. Midpoints between protojets are also used as seeds to ensure infrared and collinear safety [4] and, in the last step, overlapping protojets are merged or splitted to form final jets[2].

The $k_\perp$ algorithm [6] proceeds iteratively, either by clustering pairs of nearby objects, or by considering any isolated object as a jet by itself, until all objects are univocally part of a jet. The representation of $k_\perp$ jets is less intuitive than the cone jets, since their geometrical size is not fixed in advance. However, the $k_\perp$ algorithm has the advantage of being infrared and collinear safe to all orders[3] and free from merging/splitting issues.

2.3. Corrections

In the following, except otherwise noted, comparisons are made at the particle level: measured jet energy and cross sections have been unfolded from detector effects and parton-level pQCD cross sections have been corrected by a p_T-dependent scale factor derived from Monte Carlo simulation to account for parton-showering, fragmentation and underlying event effects.

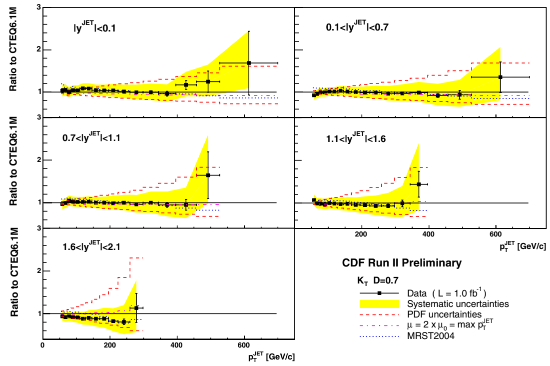

Figure 2. CDF data/theory ratio of the inclusive jet cross section in 5 rapidity ranges for the $k_\perp$ algorithm.

3. RESULTS

3.1. Inclusive jet

Inclusive jet cross sections measurements allow the highest momentum transfers and so the smallest distances for a possible quark substructure to be probed. The running of α_S can also be observed directly, given the very large measured jet p_T range ($\sim$ 600 GeV). At very high p_T, the quark-quark scattering dominates the cross section, but the gluon-quark scattering still contributes a significant part ($\sim$ 30 % at 500 GeV). Inclusive jet cross section measurements thus provide additional information on the poorly constrained gluon PDF at high x.

Results have been obtained by DØ for the Cone algorithm [8] and by CDF for the Cone [9] and $k_\perp$ [10] algorithms. The cross section measured by DØ in 2 rapidity ranges is shown in Fig. 1 in comparison to a Next-to-Leading Order (NLO) pQCD calculation which includes 2-loop NNLL corrections [11]. The cross section measured by CDF using the $k_\perp$ algorithm with $D = 0.7$ divided by NLO prediction is shown in Fig. 2 for 5 rapidity ranges. The data is well described

[2]It can be noted that the cone algorithms actually used in CDF and DØ differ slightly [5], as none follows exactly the recommandations of [4].

[3]The Cone algorithm is only infrared safe up to NNLO [7].

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