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Soft QCD at Tevatron

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Experimental studies of soft Quantum Chromodynamics (QCD) at Tevatron are reported in this note. Results on inclusive inelastic interactions, underlying events, double parton interaction and exclusive diffractive production and their implications to the Large Hadron Collider (LHC) physics are discussed.

1 Introduction

In hadron collisions, hard interactions are theoretically defined as collisions of two incoming partons along softer interactions from the remaining partons. The soft effects become especially important in very high luminosity enviromments (such as the Large Hadron Collider) and they need to be accounted for in most of experimental measurements. In a particular case, the incoming hadrons stay intact after the collision producing a clean signature, which can be used to search for new physics.

In this note, we review several experimental results related to soft QCD and their implications to LHC physics: inclusive inelastic interactions (section 2), underlying event (section 3), double parton interactions (section 4) and exclusive diffractive production (section 5).

2 Inclusive inelastic interaction

The so-called "minimum-bias" (MB) interactions are defined as data collected with a trigger set up so as events are selected with uniform acceptance from all possible inelastic interactions. Description of inelastic nondiffractive events can only be accomplished by a nonperturbative phenomenological model such as that made available by the PYTHIA Monte Carlo (MC) generator.

Different observables of the final state of antiproton-proton interactions measured with the CDF detector were compared to PYTHIA Tune A [1]. Both the charged and neutral particle activites were studied. In general, poorly agreement is observed between existing MC and data, and the measurements can be used to improve QCD MC.

Measurements of inclusive invariant p_T differential cross section of centrally produced hyperons ($|\eta| < 1$) were performed in minimum biased events [2]. Cascades (Σ), omegas (Ω) and

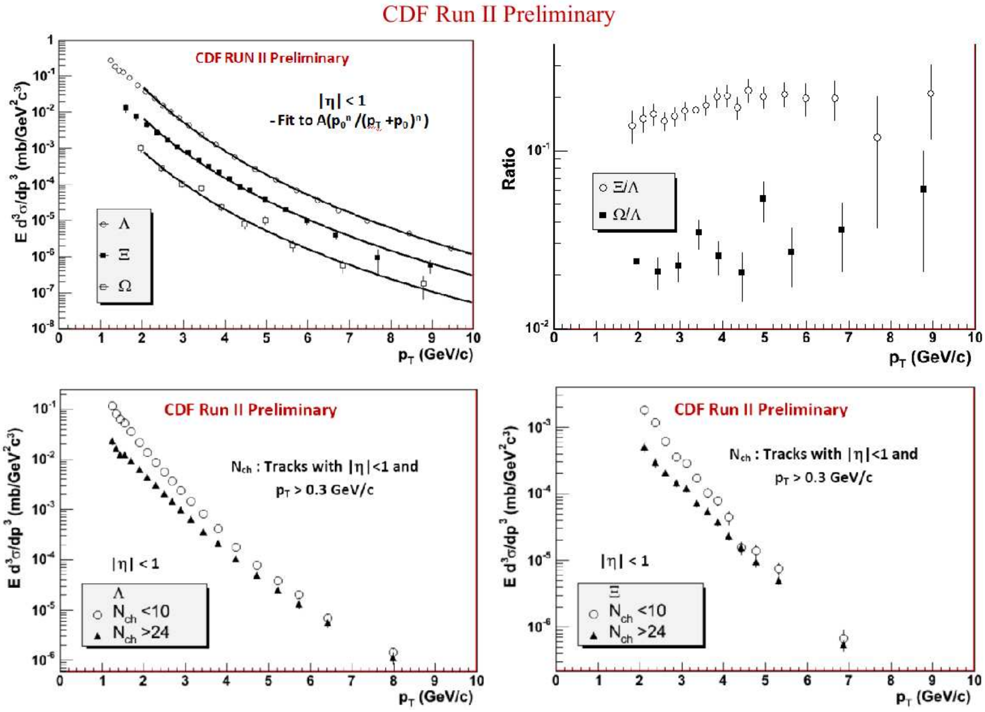

Figure 1: Left upper figure: Inclusive invariant p_T distribution for Λ, Σ and Ω within $|\eta|$ <1. The solid curves are from fit to the functional form $(A)(p0)^n/(pT + p0)^n$ with $p0$ =1.3. Right upper figure: The ratio of Σ/Λ and Ω/Λ as a function of p_T. Two lower figures: The inclusive pT distributions for two different multiplicity regions, number of charged particles $<$ 10 and $>$ 24. Left plot is for lambdas and right plot is for cascades.

lambdas (Λ) particles are selected and their p_T spectrum measured (Fig. 1). It is observed that the production ratio of the three particles is fairly constant as a function of p_T.

3 Underlying Event

The underlying event (UE) consists of the beam-beam remnants minus the hard-scattering products and is becoming increasingly important to the discovery and precision potential at hadron colliders. CDF has conducted UE studies that exploit jet and Drell-Yan event activity topologies to maximize the sensitivity of UE observables [3]. Several distributions of UE-sensitive observables, corrected to the particle level, suggest the UE may be universal (independent of the hard process) and inform MC tuning and development.

A good agreement between data and PYTHIA Tune AW Monte Carlo predictions was observed, except by a slight excess at transverse region compared to toward region, which is caused by transverse regions receiving contributions from away side jet [3].

4 Double parton interaction

D0 has studied γ+3-jet events to measure double parton scattering (DPS), whereby two pairs of partons undergo hard interactions in a single $p\bar{p}$ collision. DPS is not only a background to many rare processes, especially at higher luminosities, but also provides insight into the spatial distribution of partons in the colliding hadrons. The DPS cross section is expressed as $\sigma_{DPS^{\gamma+3jet}} = \sigma_{jj}\sigma_{\gamma j}/\sigma_{eff}$, where σ_{eff} is the effective interaction region that decreases for less uniform spatial parton distributions. D0 measures a mean of $\sigma_{eff} = 16.4 \pm 2.3$ mb [4], which is consistent with an earlier CDF result [5], and finds σ_{eff} to be independent of jet p_T in the second

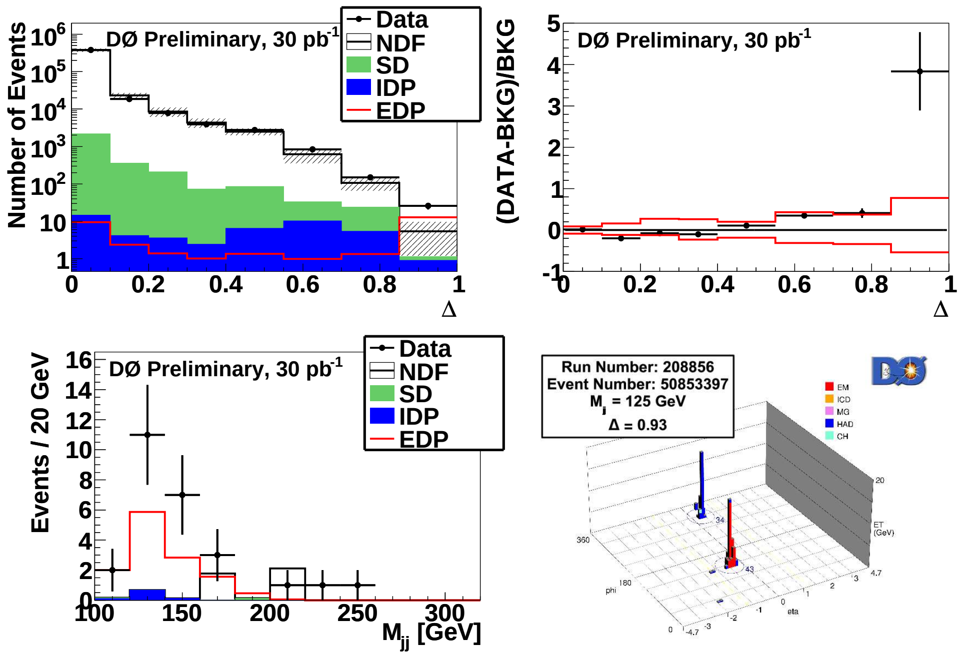

Figure 2: Top Left Figure: Δ distribution for data and background (nondiffractive (NDF), single-diffractive (SD) and inclusive double pomeron (IDP)). A good agreement is observed between data and background except at high values of Δ where exclusive diffracitve production (EDP) dominates. The hatched band indicates the total uncertainty on the background. Top Right Figure: MC background (BKG) subtracted data divided by background. The solid lines are ± 1 standard deviation systematic uncertainty on the background. Bottom Left Figure: Dijet invariant mass distribution for MC and data after applying the cut on $\Delta \geq 0.85$. The total background prediction is of $5.4\ ^{+4.2}_{-2.9}$ events and 26 signal candidate events are observed in data. Bottom Right Figure: Exclusive diffractive candidate event. No energy deposition is present in the forward regions, only two central jets are observed in the detector

interaction. More precise studies can reveal a σ_{eff} sensitivity to jet p_T, this could indicate a dynamical departure from the naïve assumption that DPS depends on an uncorrelated product of σ_{jj} and $\sigma_{\gamma j}$.

5 Exclusive Diffractive Production

Exclusive diffrative processes are those where the colliding hadrons emerge intact, but part of their momentum is lost producing central objetcs, with surrounding rapidity regions devoid of particles. CDF recently reported observations of $p\bar{p} \rightarrow p$+dijet+$\bar{p}$, with $p_T^{jet} > 10$ GeV; and $p\bar{p} \rightarrow p+[\mu^-\mu^+, J/\Psi, \Psi(2S), \chi_C^0]+\bar{p}$ with two oppositely charged central muons and either no other particles or one additional photon detected [6].

D0 recently reported an evidence for diffractive exclusive dijet production with an invariant mass greater than 100 GeV. A discriminant variable (Δ based on calorimeter information was used to demonstrate a significant excess of events with very little energy outside the dijet system (Fig. 2). The probability for the observed excess to be explained by other dijet production processes is 2×10^5 , corresponding to a 4.1 standard deviation significance [7].

Tevatron results support the viability of exclusive Standard Model Higgs production through p+H+p processes at the LHC, which are expected to play an important role in future studies of new physics [8].

6 Conclusion

The Tevatron experiments provide soft QCD physics studies at $\sqrt{s} = 1.96$ TeV. These results are based on less than one third of the anticipated complete Run II sample, therefore more measurements are expected in the coming years to illuminate the Large Hadron Collider physics results.

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