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Random Walk through Recent CDF QCD Results

Christina Mesropian

The Rockefeller University

For the CDF Collaboration

Presented at the Xth International Workshop on Deep Inelastic Scattering (DIS2002), Cracow, Poland, 2002.

Random Walk through Recent CDF QCD Results *

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We present recent results on jet fragmentation, jet evolution in jet and minimum bias events, and underlying event studies.

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1. Introduction

The results presented in this talk address significant questions relevant to QCD and, in particular, to jet studies. One topic discussed is jet fragmentation and the possibility of describing it down to very small momentum scales in terms of pQCD. Another topic is the studies of underlying event energy originating from fragmentation of partons not associated with the hard scattering.

2. Jet fragmentation studies

Measurements of inclusive charged particle multiplicities in jets allow testing of Modified Leading Log Approximation (MLLA) calculations [1] complemented by the Local Parton Hadron duality (LPHD) hypothesis [2] which treats jet fragmentation as a predominantly perturbative QCD process. MLLA is the resummed perturbative calculation (cutoff parameter of the model, Q_{eff}, can be as low as Λ_{QCD}) which accounts for terms of order ${\alpha_s}^n \log^{2n} E_{jet}$ and ${\alpha_s}^n \log^{2n-1} E_{jet}$ at all orders n of the perturbative expansion, while taking care of color coherence effects by introducing angular ordering. LPHD is the hypothesis which considers hadronization to be local

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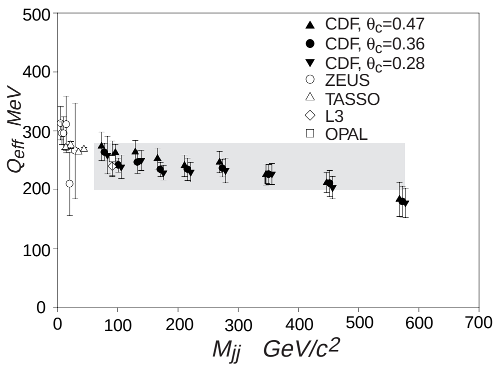

Fig.1.Fitted values of the MLLA parameter Q_{eff} as a function of dijet mass.

and occur at the end of the parton shower development; thus, the hadrons remember the parton distributions, $N_{hadrons} = K_{LPHD} \times N_{partons}$, where K_{LPHD} is an experimentally determined parameter and $N_{partons(hadrons)}$ is the number of partons(hadrons). In the simplest interpretation of LPHD $K_{LPHD} \sim 1$, so that for charged particles $K_{LPHD}^{charged}$ should be between 1/2 to 2/3. The measurements [3] are based on 95 pb^{-1} of data collected during 1993-1995. Clean dijet events with dijet mass in 9 bins from 80 to 590 GeV were selected by requiring two well balanced central jets. The jets in the analysis are reconstructed using the cone algorithm with R =0.7. Charged tracks are counted in restricted cones of sizes 0.28, 0.36, and 0.47 around the jet axis. Corrections were applied to compensate for detector inefficiencies and physics effects. The independent MLLA fits of the inclusive momentum distribution of charged particles in jets for all 9 dijet mass bins for 3 cone sizes allowed us to obtain the Q_{eff} parameter, plotted on Fig.1 as a function of the dijet mass. Q_{eff} tends to become smaller at larger energies. The slight drift in the value of Q_{eff} may be an indication of the presence of higher order contributions and/or non-perturbative effects at the hadronization stage. The final value, calculated as the mean of 27 measurements, is Q_{eff} = 230 ± 40 MeV. This analysis also allowed the simultaneous extraction of $K_{LPHD}^{charged}$ and $r = N_g/N_q$, the ratio of hadron multiplicities in gluon and quark jets. Fig.2 shows the results of

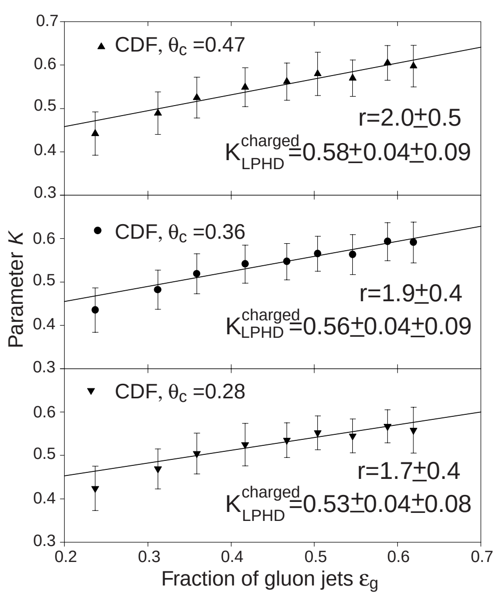

Fig.2.Parameter K as a function of ϵ_g. The first error is the combined statistical and systematic experimental uncertainties; the second error corresponds to a theoretical uncertainty of 0.2 on the nMLLA factor F_{nMLLA}.

this extraction for 3 different cone sizes, where one can see that the experimental results agree pretty well with the expected linear dependence of K_{LPHD} on the fraction of gluon jets, ϵ_g. The results support the MLLA+ LPHD description of jet fragmentation as of perturbative nature.

3. Charged jet evolution

In this analysis [4] CDF studied the growth and evolution of charged particle jets produced in $p\bar{p}$ collisions at 1800 GeV. The data are compared with QCD based hard-scattering Monte-Carlo programs HERWIG, PYTHIA, and ISAJET. The jets are reconstructed using a simplified non-standard algorithm with clusters of charged particles in a cone of R =0.7 in $\eta-\phi$ space. Every charged particle in the event is assigned to a jet, with the possibility of having jets that consist of only one particle. This approach is justified since one is dealing with only a few low p_T particles in a jet. First, we studied 'local' jet observables and compare them with QCD Monte-Carlo simulations. Fig.3 shows the average number of charged particles (p_T >0.5 GeV/c and $\mid \eta \mid$<1) within the leading charged jet as a function of P_T. The Min-Bias data (triggered by coincidence in scintillators placed along the beam) smoothly connect to the Jet20 (jet data passing an $E_T \geq$20 GeV trigger). We see evidence of charged particle clusters in the Min-bias data, which become apparent around P_T of 2 GeV/c with about 2 charged particles and growing to 10 charged particles at P_T =50 GeV/c. The jets in Min-bias data look like the extrapolation of jets in Jet20 data down to very small P_T. The QCD hard-scattering Monte-Carlo models agree with the data for 5 GeV/c jets as well as for 50 GeV/c charged particle jets.

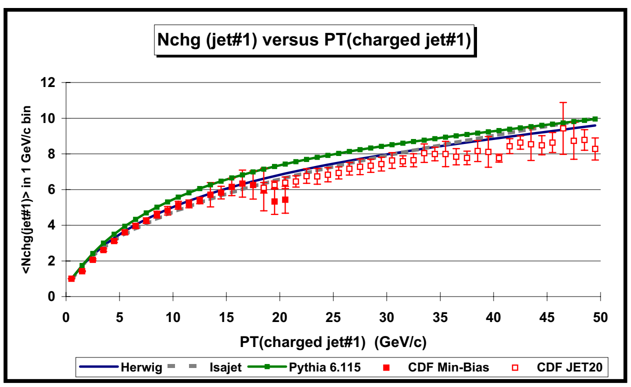

Fig.3.The average number of charged particles within the lading charged jet as a function of p_T.

As a next step we studied 'global' jet observables, where to fit the observable the QCD Monte-Carlo models have to describe correctly the entire event structure. In particular, we examined the 'transverse' region, see Fig.4(right), which is dominated by the underlying event. Fig.4(left) shows that the number of charged particles doubles when moving from P_T =1.5 GeV/c to 2.5 GeV/c and then climbs onto a plateau for P_T >5 GeV/c. In contrast with the 'toward' and 'away' regions, which are fairly well described by the Monte-Carlo programs mentioned above, none of QCD Monte-Carlo

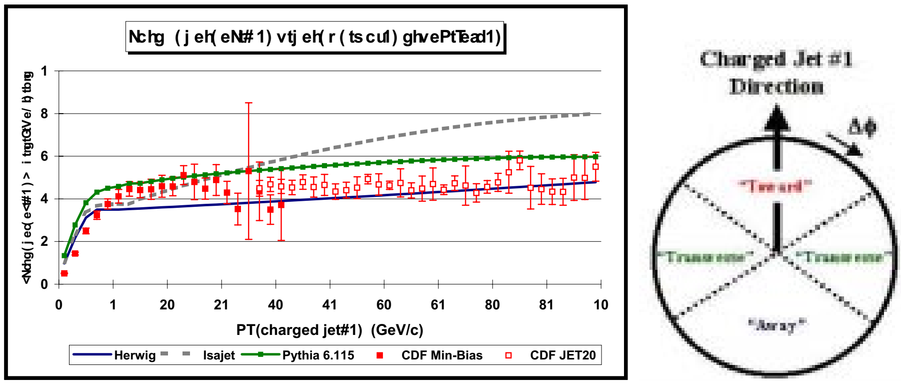

Fig.4.(left) Average number of charged particles as a function of p_T of the leading charged jet for the transverse region; (right)Illustration of correlation in azimuthal angle $\Delta\phi$ relative to the direction of the leading charged jet in the event.

models examined describes correctly all the properties of the underlying event in the data, with HERWIG and PYTHIA 6.125 not having enough activity in the underlying event, and ISAJET having a lot of activity and with the wrong P_T dependence. The information obtained from these studies can be used to better tune beam-beam scattering components of QCD hard scattering Monte-Carlo models.

4. The underlying event

The underlying event energy is essential for a description of non-perturbative processes and improvement in jet energy measurements. Since the jet reconstruction in recent CDF measurements was based on the fixed cone algorithm, the underlying event energy should be extracted from the jet energy before comparison with theoretical predictions. To study the contribution of the underlying event in jet events, two cones with R =0.7 at the same pseudorapidity but $\pm 90°$ in azimuth from the leading (central) jet were considered [5]. For each event, the cone which has the largest $\sum p_T$ - sum of transverse momentum of tracks inside the cone is called *max* cone and the other *min* cone. NLO perturbative corrections to the 2→2 hard scattering process could contribute only to one of these two cones; thus difference between *max* and *min* cones represents this contribution while *min* cone corresponds to the contribution from the underlying event. Fig.5 shows $\sum p_T$ inside the *max* and *min* cones for the 1800 GeV jet data (left) and 630 GeV jet data (right) and for the Monte-Carlo samples with the same experimental cuts. The HERWIG+QFL and PYTHIA6.115+QFL show similar behavior for *max* and *min* cones as the data: the *min* cone $\sum p_T$ stays flat, while the *max* cone increases with leading jet energy, E_T, due to the contribution of the third jet in the event. Despite the fact that PYTHIA was tuned to the data, it is still considerably higher than the *max* cone data for both the 1800 and 630 GeV data samples. The same studies were repeated for minimum bias data with the conclusion that the underlying event in a hard scattering is more active than in a soft collision, with the p_T inside a random cone varying up to 20% from the *min* cone in jet events, depending on the vertex selection criteria.

These measurements will help to tune Monte-Carlo programs in order to better reproduce the data.

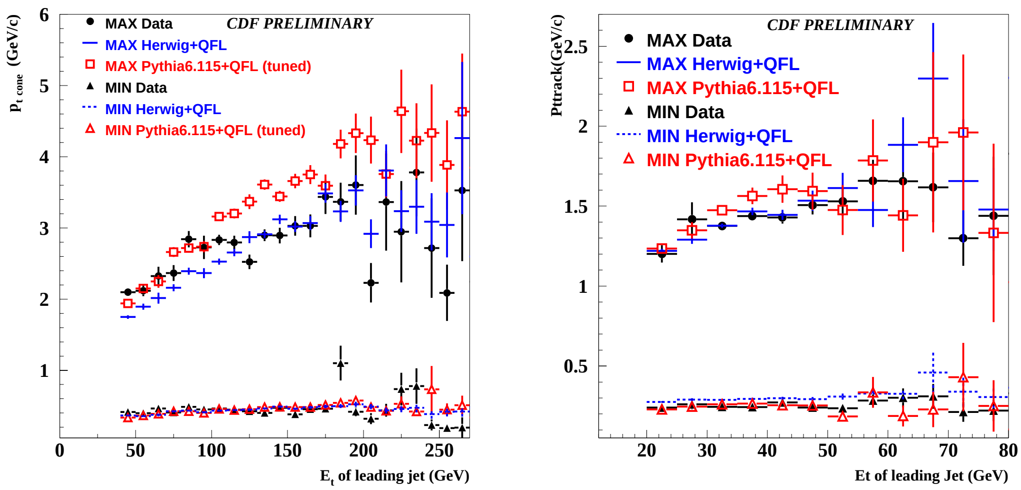

Fig.5.(left)$\sum p_T$ inside the *max* and *min* cone in jet events as a function of E_T of the leading jet for 1800 GeV(left) and 630 GeV(right).

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