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Soft QCD phenomena in events with high-E_T jets at tevatron

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Abstract. Presented are results from the recent jet fragmentation and underlying event structure studies carried out by the CDF Collaboration. Multiplicities of charged particles in quark and gluon jets are measured and their ratio is compared to pQCD predictions. The results are compared to the earlier measurements obtained at e^+e^- colliders. Average charged particle multiplicities and energy flow in the underlying event are compared to Pythia Monte Carlo event generator; the necessary tuning of Pythia parameters needed to make it match the data is discussed.

1 Introduction

Hard scattering of partons in collisions at hadron colliders is accompanied by the following processes all of which are characterized by very small momentum transfers and, therefore, belong to the domain of soft QCD:

- o final state radiation of hard scattered partons, resulting in the phenomenon known as jets,
- o initial state bremsstrahlung radiation,
- o secondary collisions of proton-antiproton partons (multi-parton interactions),
- o proton and antiproton remnants continuing on along the beam direction,
- o hadronization of all partons.

Certainly, there are many presumptions both in breaking up what accompanies a hard scattering event in such a set of distinct soft sub-processes and, also, in treating them as almost independent of each other. The results presented in this report aim at validating/invalidating such views.

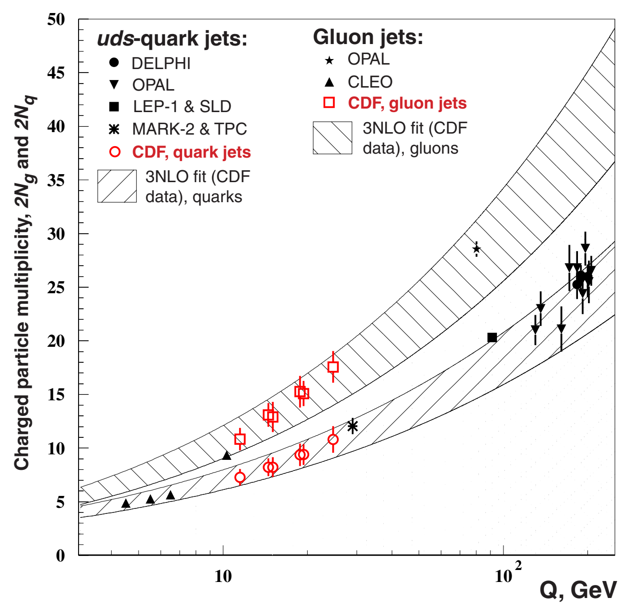

Fig. 1. Multiplicities of charged particles in gluon and quark jets vs jet hardness $Q = E_{jet}\theta$ (see text). The CDF data is fit with 3NLLA (Capella et al. [1])

2 Jet fragmentation

Earlier CDF studies showed that the momentum spectra of charged particles in jets with E_{jet} ∼40-300 GeV could be well described by analytical formulas derived in the context of the Modified Leading Log Approximation. The new result is the analysis comparing differences of quark and gluon jets. The CDF result is based on comparing jets in di-jet and γ-jet events that have very different fractions of quark and gluon jets. This approach minimizes possible experimental biases that might result from attempts to sort out quark/gluon jets on event-by-event basis. Also, we selected only central back-to-back jets and analyzed particle multiplicities in cones with small opening angles θ ($\sim 15 - 30°$) around the jet axis, which allowed for a direct comparison to the theory.

Figure 1 and Fig. 2 show the measured charged particle multiplicities in gluon and quark jets and their ratio vs. jet hardness scaling variable $Q = E_{jet}\theta$. Also, Fig. 1 shows 3NLLA fits, while Fig. 2 shows predictions for the ratio as obtained in various Next-to-Leading-Log calculations. One can see that the data points in Fig. 2 fall right on top of the recent pQCD calculations. Both figures also have some of the recent e^+e^- results, which are believed to be the least biased, both in terms of experimental methods used in sorting out light (u, d, s) quark and gluon jets

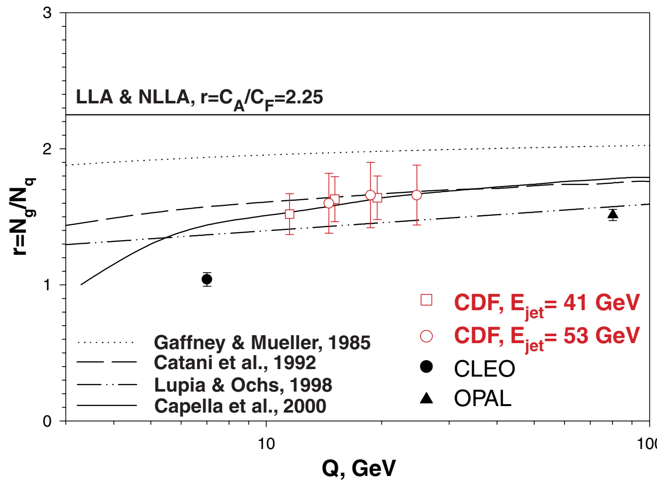

Fig. 2. Ratio of charged particles multiplicities in gluon and quark jets vs jet hardness $Q = E_{jet}\theta$ (see text). The curves correspond to the theoretical calculations by Gaffney and Mueller [2], Catani et al. [3], Lupia and Ochs [4], Capella et al. [1]

and in terms of their reliance on theoretical models in extracting the value of the ratio (there are more than 10 independent LEP results ranging from r=1 to r=1.5).

3 Underlying event

CDF continues to pursue rigorous studies of the physics lying behind the underlying event in hard collisions. The underlying event is usually viewed as everything else but jets. The main processes defining its structure are: proton-antiproton remnants, initial states radiation, and secondary parton interactions. Unfortunately, the only tool that we have in our disposal for these studies is a cross-comparison of the data and various Monte Carlo generators. By tuning the knobs made available in generators, we try to match the simulation to the data in the best possible way in order to gain deeper insights into the relative importance of the various contributing sub-processes.

Figure 3 and Fig. 4 show the average charge particle multiplicity flow and the average energy flow at η=0 in the ϕ-direction normal to the leading jet as a function of the leading jet E_T. Both plots reveal a remarkably good agreement of the data and Pythia, which, however, was achieved only after tuning a number of Monte Carlo generator parameters. Differential distributions of energy flow were also monitored in the process of Pythia tuning. This exercise shows that Pythia can be brought into a good agreement with data, but at the price of the following adjustments: the initial state radiation had to be significantly intensified; the dependence of the probability of multi-parton (secondary) interactions on the impact parameter had to be smoothed out; probability of di-gluon production in multi-parton secondary interactions had to be substantially enhanced over di-quark production, and the probability of color connections of products of secondary interactions with $p\bar{p}$-remnants had to be increased. The work on comparing the data and Herwig is underway.

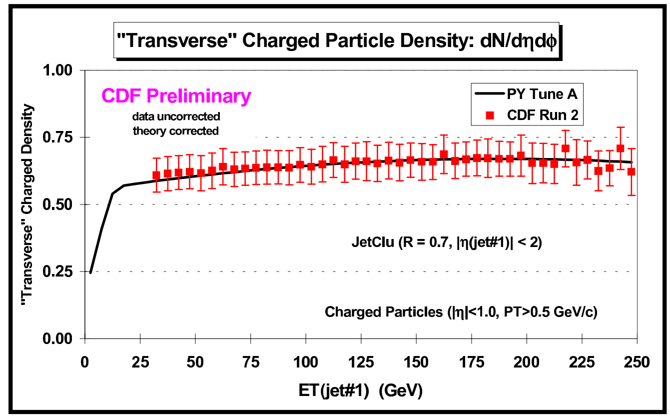

Fig. 3. Average charged particle multiplicity flow density $dN/d\eta d\phi$ at η=0 in the ϕ-direction normal to the leading jet as a function of the leading jet E_T

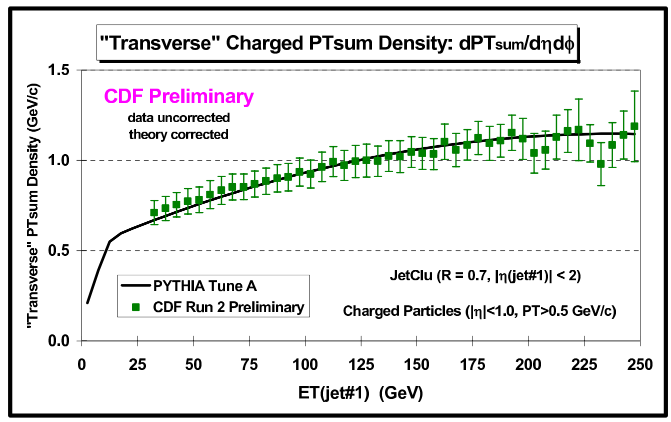

Fig. 4. Average charge particle transverse momentum flow density $d(\Sigma P_T)/d\eta d\phi$ at η=0 in the ϕ-direction normal to the leading jet as a function of the leading jet E_T

4 Conclusions

If the production of high-E_T jets is driven by the hard QCD, the actual structure of such events is largely governed by processes with very small momentum transfers, theoretical treatment of which has been a notoriously challenging task. Presented results show that

- o Analytical resumed pQCD calculations can be successfully used for predicting a broad range of jet properties,
- o Pythia Monte Carlo generator, after proper tuning of its built-in phenomenological parameters, does describe the average properties of the underlying event. Confronting data and alternative Monte Carlo generators (e.g., Herwig) is imperative for gaining deeper insights in physics and significance of such adjustments.

References

1. A. Capella: Phys. Rev. D **61**, 074009 (2000)
2. J.B. Gaffney, A.H. Mueller: Nucl. Phys. B **250**, 109 (1985)
3. S. Catani et al.: Nucl. Phys. B **377**, 445 (1992)
4. S. Lupia and W. Ochs: Phys. Lett. B **418**, 214 (1998)