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Fragmentation differences of quark and gluon jets at Tevatron

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We present the results on fragmentation differences of quark and gluon jets obtained by CDF at $\sqrt{s}$ = 1.8 TeV. We compare the multiplicities and momentum distributions of charged particles in two data samples: dijet data and photon+jet data. These two samples have a different quark/gluon jet content, which allows a measurement of the inclusive properties of gluon and quark jets. The results are compared to the earlier measurements obtained at e+e- collisions and to the re-summed perturbative QCD calculations.

Keywords: Fragmentation; jets; charged particle multiplicity.

1. Introduction

Jet evolution is driven by multi-gluon emission with very small momentum transfers. Studying jet fragmentation allows one to perform detailed experimental tests of perturbative QCD (pQCD). It also helps investigate the borderline between pQCD and non-pQCD domains. In addition, understanding the differences between quark and gluon jets can provide extra tools to suppress multi-jet backgrounds in many high-P_T physics analyses involving b-jets and/or jets from $W^{\pm}\to q`\bar{q}``$ and $Z\to q\bar{q}$ decays (e.g., $t\bar{t}\to b\bar{b}jjjj$ where signal is all quark jets and background is many gluon jets). Finally, jet fragmentation data from Tevatron complement measurements from e^+e^- and ep experiments providing a unique test of universality of jets.

2. Fragmentation of quark and gluon jets

In QCD, quarks and gluons have different coupling strengths for gluon emission expressed by color factors C_F=4/3 and C_A=3, respectively. It is therefore expected that jets produced by quarks and gluons will show differences in their average multiplicity and the shape of momentum spectra of hadrons. Theory views jet fragmentation as a predominantly perturbative QCD process. Analytical predictions are based on the framework of the Next-to-Leading Log Approximation, NLLA[1], and its various extensions[2,3], supplemented with the hypothesis of Local Parton-Hadron Duality, LPHD[4].

3. Measurements and results

The CDF measurement is based on the difference in quark and gluon jet content of dijet events and γ+jet events in $p\bar{p}$ collisions. The analysis is carried out in the dijet or γ+jet center-of-mass frame, where the average jet energies are E_{jet}=41 and 53 GeV. Charged particles are counted in restricted cones with small opening angles θ_c=0.28, 0.36, and 0.47 rad around jet axis. The contribution due to underlying event and multiple interactions is subtracted by using the complementary cone technique[5,6]. Assuming gluon and quark jet properties are the same in dijet and γ+jet samples, the difference in the fraction of gluon jets ($\sim$60% for dijet and $\sim$20% for γ+jet events) in the two samples allows one to algebraically extract the multiplicities and momentum spectra of particles in pure quark and gluon jets.

Fig. 1 shows the evolution of measured charged particle multiplicities in gluon and quark jets with jet hardness scaling variable $Q=2E_{jet}tan(\theta_c/2)$. Also shown on Fig. 1 are the fits to CDF data obtained by using recent 3NLLA expressions[3] with normalization constant as the only free parameter (the other parameter Q_{eff} is set to 230 MeV[6]). The width of bands corresponds to the uncertainty in the overall normalization. One can see that the model-independent e^+e^- results[7,8], except for CLEO data at $Q\sim$5-7 GeV, fall within the fit bands. Fig. 2 shows the comparison of CDF results on multiplicity in gluon jets with recent model-dependent results from OPAL. Data from both experiments is found to be in good agreement. The comparison to Monte Carlo predictions reveals that Herwig 5.6 and Pythia 6.115 reproduce gluon jets fairly well, but they systematically over-estimate the multiplicities in quark jets by $\sim$30%. Fig. 3 shows the results on the ratio of charged particle multiplicities in gluon and quark jets. At Q=19 GeV, we obtain $r=N_g/N_q$=1.64±0.17. The CDF data agrees well with next-to-NLLA calculations[2,3], $1.4\lesssim r\lesssim 1.8$, and it is

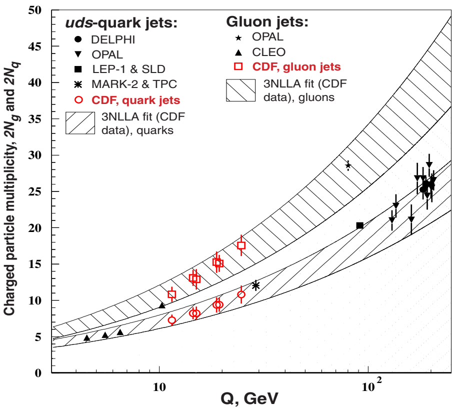

Fig. 1. Average charged particle multiplicities in gluon and quark jets as a function of jet hardness Q, which is $Q\simeq E_{jet}\theta_c$ for CDF data and $Q=E_{c.m.}=2E_{jet}$ for e^+e^- data.

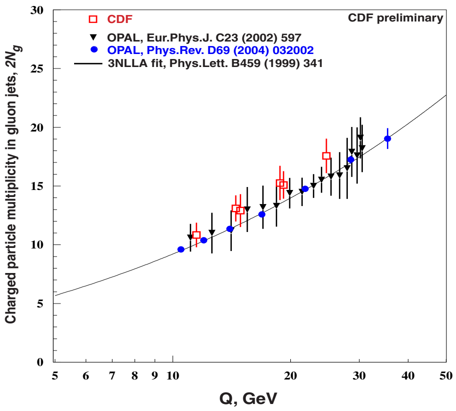

Fig. 2. Comparison of CDF results on charged particle multiplicity in gluon jets with recent model-dependent results from OPAL.

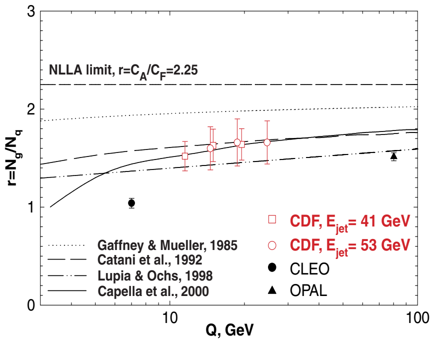

Fig. 3. The ratio of charged particle multiplicities in gluon and quark jets as a function of jet hardness Q.

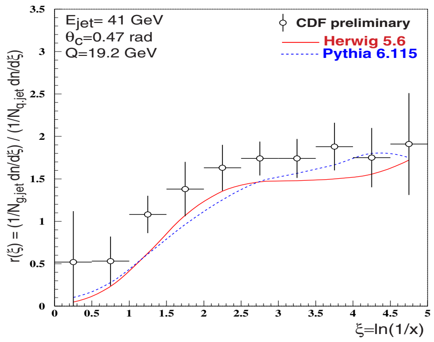

Fig. 4. The ratio of momentum distributions, $r(\xi)$ (where ξ=log (E_{jet}/p)), of charged particles in gluon and quark jets.

consistent with recent OPAL result[8], $r \simeq 1.5$, and previous CDF model-dependent measurement[5], r=1.7±0.3. Fig. 4 demonstrates the measured ratio of momentum distributions, $r(\xi)$, of charged particles from gluon and quark jets. The ratio $r(\xi)$ is significantly below unity for energetic particles, and it is monotonicly growing as particle momentum gets softer. The ratio appears to saturate at $r_{soft} \simeq 1.8$. The same trend in $r(\xi)$ is also observed by OPAL[8]. Fig. 4 shows that Monte Carlo qualitatively describe the data, but predict lower ratio in all range of particle momenta.

4. Conclusion

CDF has studied the fragmentation differences of gluon and quark jets. The results are found to agree with re-summed NLLA calculations. Consistency of the CDF data with recent e^+e^- measurements demonstrates universality of jets.

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