D0 LATEST RUN I QCD RESULTS

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The results of last year publications [1] and [2] ll on RunI D0 inclusive jet production data analysis performed with the use of kt algorithm, are presented. The comparison with the results obtained with the cone algorithm [3] and with the QCD predictions based on different PDF parametrizations are discussed. Also the results of studying the subjet multiplicity of jets reconstructed with the kt algorithm, and of the estimation for the first time for hadron-hadron colliders data of the ratio of mean values of subjet multiplicity in gluon M_g and quark jets M_q are given.

1 Introduction

The kt jet algorithm, proposed in the LEP era in different modifications (see references and discussions in [1] and [2]) has a lot of well known attractive features. So, it was natural to apply this tool to data analysis after the main publication on the study of jet properties using the cone algorithm was issued by the D0 Collaboration in 2001 [3]. The message from this article is that the RunI cone jet data demonstrate high sensitivity to different PDF parametrizations and only few of them are found as leading to a successful data/PQCD agreement. Consideration of kt algorithm may allow to clarify the role of jet finding algorithm in confronting of QCD predictions to hadron colliders data.

2 What new is learned by applying the kt algorithm

The cross section (see Figure 1) of inclusive jet production in the central region of pseudorapidity ($|\eta| < 0.5$) was measured using 87.3 pb^{-1} of data collected with the D0 detector at the Fermilab Tevatron $p\bar{p}$ Collider during RunI and jets offline reconstruction using the kt algorithm, with D = 1.0 (at NLO this value produces a theoretical cross section that is essentially identical to the cone prediction for R = 0.7). The results (see Figure 2) are compared to the pQCD NLO prediction besed on JETRAD program [4] with the renormalization and factorization scales set to $p_t^{max}/2$, where p_t^{max} refers to the P_t of the leading jet in an event. The comparisons are made using parametrizations of the parton distribution functions (PDFs) of the CTEQ [5] and MRST[6] families. Figure 2 shows the ratios of (data-theory)/theory. The predictions lie below the data by about 50% at the lowest pT and by $(10 - 20)\%$ for $pT > 200GeV$.

Though the agreement is reasonable (χ^2/dof ranges from 1.56 to 1.12, the probabilities from 4 to 31%), the differences in normalization and shape, especially at low P_t , are quite large. If the first four data points are not used in the χ^2 comparison, the probability increases from 29% to77% when using the CTEQ4HJ PDF. Also, while the NLO predictions for the inclusive cross section for kt (D = 1.0) and cone jets (R = 0.7, Rsep= 1.3) in the same $|\eta| < 0.5$ interval are within 1% of each other for the pT range of this analysis [7] the measured cross section using kt is 37% (16%) higher than the previously reported cross section using the cone algorithm [3] at 60 (200) GeV.

To understand the origin of this difference a comparison was done of the momenta of jets reconstructed with the DO fixed-cone algorithm to those of kt-jets [2]. It involved about 75% of the events in the 1994 - 1996 data that were used for the analysis of the inclusive cone-jet cross section at s=1800 GeV [3]. The jets reconstructed by each algorithm were compared on an event-by-event basis, associating a cone jet with a kt-jet if they are separated by $\Delta R < 0.5$.

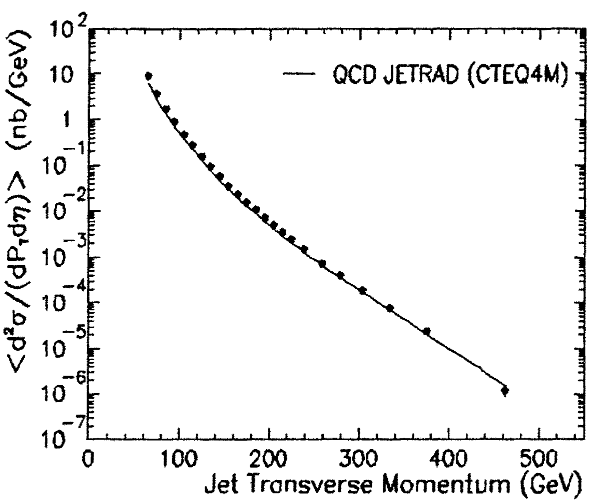

Figure 1. The central ($|\eta| < 0.5$) inclusive jet cross section obtained with kt algorithm at $\sqrt{s} = 1.8$ TeV.

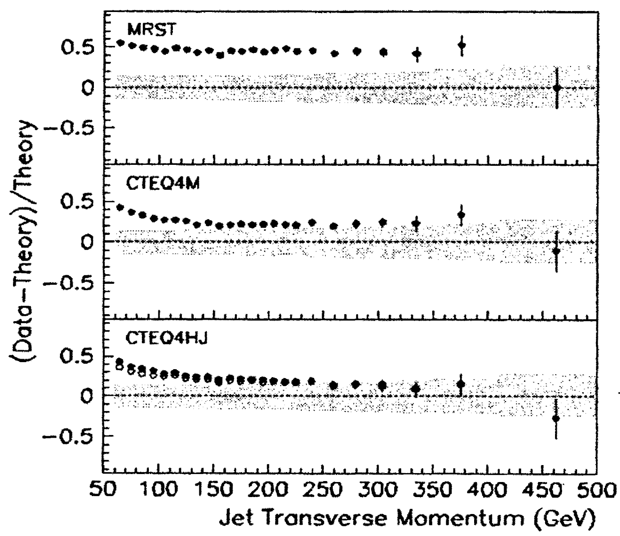

Figure 2. Difference between data and JETRAD. The shaded bands represent the total systematic uncertainty.

Figure 3 shows the difference $pT(ktjet) - ET(conejet)$ as a function of P_t(kt jet). Generally, the P_t of kt jets ($D = 1.0$) is higher than the $ET(= P_t)$ of associated cone jets ($R = 0.7$). The difference increases approximately linearly with P_t jet, from about 5 GeV (or 6%) at $P_t = 90$ GeV to about 8 GeV (or 3%) at $P_t = 240$ GeV. This difference in the cross sections is consistent with the measured difference in pT for cone jets matched in $\eta - \phi$ space to kt jets.

In addition the study was done to estimate the effect of final-state hadronization on reconstructed energy (using HERWIG, version 5.9, [7] simulations), which might account for the difference between the observed cross section using kt and the NLO predictions at low P_t. Figure 4 shows the ratio of P_t spectra for particle-level to parton-level jets, for both the kt and cone algorithms. Particle cone jets, reconstructed after hadronization from final state particles (after hadronization), have less P_t than the parton jets (before hadronization), because of the energy loss outside the cone. In contrast, kt particle jets are more energetic than their progenitors at the parton level, due to the merging of nearby partons into a single particle jet.

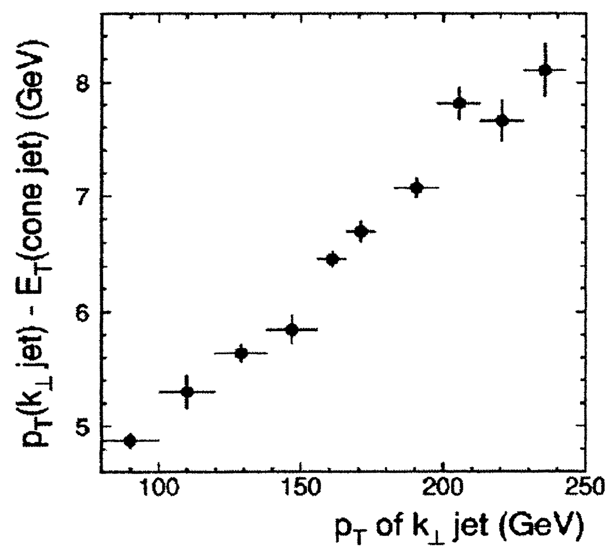

Figure 3. The difference $pT(ktjet) - ET(conejet)$ as a function of the kt jet p_t.

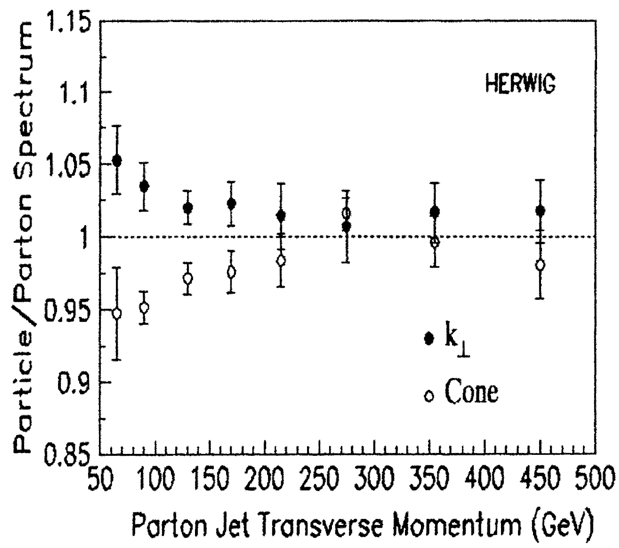

Figure 4. The ratio of paricle-level over parton-level HERWIG p_t spectra for jets as a function of parton jet p_t .

3 Subjet multiplicity of gluon and quark jets reconstructed with kt algorithm in $p\bar{p}$ collisions

The kt algorithm already was applied to study the subjet multiplicities of jets produced at LEP by OPAL [8] ALEPH [9] and DELPHI [10] Collaborations (see more references on this subject in [2]).

The idea is based on the form of QCD Lagrangian which predicts that the probability for a gluon to radiate a gluon is proportional to the color factor $CA = 3$, while gluon radiation from a quark is proportional to the color factor $CF = 4/3$. To this reason the average number of objects radiated by a gluon is expected to be a factor $CA/CF = 9/4$ higher than the number of objects radiated by a quark.

To pass from the parton to jet level the QCD estimation of the relative admixture of gluon and quark jets (passed a set of kinematic criteria) in $p\bar{p}$ collision events at different values of center-of-mass energy $\sqrt{s}$ was done using HERWIG v5.9 event generator. This simalation allowed to track the correspondence of the final state jet to be of gluon(quark) origin. and to elaborate the distance criteria (in $\eta - \phi$ space) to establish the correlation between jets in the calorimeter and partons from the hard scatter. The gluon-jet fraction f was defined as the number of $2 \to 2$ final state gluons that passed the selections (kinematic, geometrical and e.t.c.) divided by the total number of the final state partons that pass the selections. The P_t and $\sqrt{s}$ dependence of gluon-jet fraction was also estimated from the Monte Carlo simulation.

Finally the following nominal gluon-jet fractions $f_{1800} = 0.59$ and $f_{630} = 0.33$, obtained from Monte Carlo events at the calorimeter level for $55 < P_t < 100$ GeV, were used to determine the subjet multiplicity in gluon M_g and quark jets M_q. The subjet multiplicity in a mixed sample of gluon and quark jets can be written as the following linear combination of subjet multiplicity in gluon M_g and quark jets M_q:

$$M = fM_g + (1-f)M_q \ . \qquad (1)$$

The coefficients are the fractions of gluon and quark jets in the mixed sample, f and $(1-f)$, respectively. Considering Eq. (1) for two samples of jets at $\sqrt{s} = 1800$ GeV and 630GeV, and assuming that the multiplicities M_g and M_q are independent of s one gets from (1):

$$M_g = ((1-f_{630})M_{1800} - (1-f_{1800})M_{630}) \ / \ (f_{1800} - f_{630}), \qquad (2)$$

$$M_q = (f_{1800}M_{630} - f_{630}M_{1800}) \ / \ (f_{1800} - f_{630}), \qquad (3)$$

where M_{1800} and M_{630} are the measured multiplicities in the mixed-jet samples at $\sqrt{s} = 1800$ GeV and 630 GeV, and f_{1800} and f_{630} are the gluon-jet fractions defined as before in the two samples of Monte Carlo events.

Using the expected fractions of gluon and quark jets at each s, the measurement of multiplicity of subjets in gluon and in quark jets was done on a statistical basis following [8]. The results are presented as a ratio of average multiplicities of subjets in gluon jets to quark jets:

$$r = (< M_g > -1)/(< M_q > -1) \tag{4}$$

because the statistical uncertainty on $< M_g^{meas} >$ is correlated with that on $< M_q^{meas} >$. A deviation of the value of r from 1 would mean that the substructure of gluon jets differs from that of quark jets.

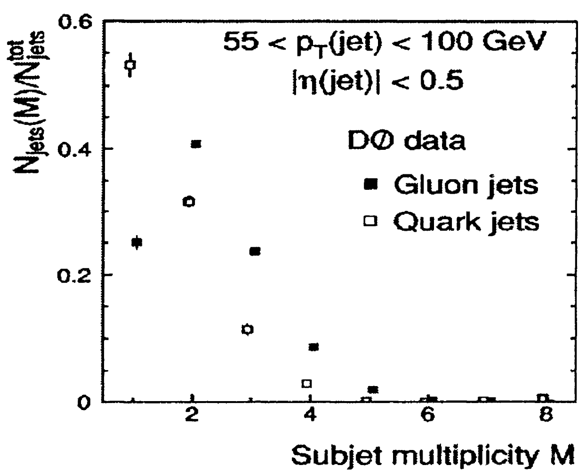

Figure 5. Corrected subjet multiplicity for gluon M_g and quark M_q jets, extracted from D0 data.

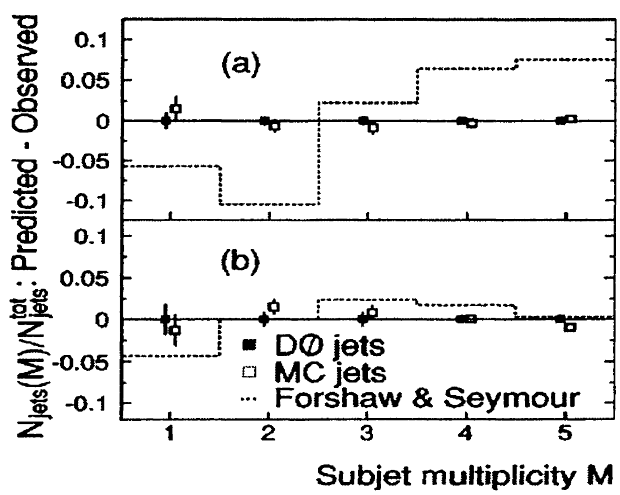

Figure 6. The difference between D0 data on M_g and M_q with theory [11] and HERWIG/JETRAD predictions.

Two data samples of 11 007 jets at $\sqrt{s}$ = 1800 GeV, and 1194 jets at $\sqrt{s}$=630 GeV with P_t between 55 and 100 GeV were selected . These jets were reconstructed with the kt algorithm for $D = 0.5$. This choice tends to select events with fewer subjets from initial-state radiation, which can vary with $\sqrt{s}$. This is the first measurement of its kind at a hadron collider. The values of subjet multiplicities extracted from this measurement are shown on Figure 5 while Figure 6 show the difference of D0 data (and Monte Carlo) with the predictions of [11]. The average number of subjets in jets at $\sqrt{s} = 1800$ GeV is $< M_{1800} >= 2.74 \pm 0.01$, where the error is statistical. This is higher than the value of $< M_{630} >= 2.54 \pm 0.03$ at $\sqrt{s} = 630GeV$. With these results the ratio has a value of

$$r = 1.84 \pm 0.15(stat) \pm 0.22(syst). \tag{5}$$

The ratio measured by D0 agrees with the result of $r = 1.7 \pm 0.1$ from ALEPH, measured in e^+e^- annihilations at $\sqrt{s} = M_Z$ [9], and with the associated Monte Carlo and re-summation prediction [12], but is higher than the ratio measured at DELPHI [10].

4 Conclusion

The DO Collaboration has studied for the first time the properties of hadron-collider jets reconstructed with successive-combination algorithm based on relative transverse momenta (kt) of energy clusters. The results obtained with the kt algorithm in the central region of pseudorapidity, exhibits reasonable agreement of the inclusive jet cross section with next-to-leading order QCD predictions, except at low P_t^{Jet} where the agreement is marginal.

The kt algorithm was used to study the substructure of jets. The subjet multiplicities in quark and gluon jets are measured and their ratio is found to be in a good agreement with QCD prediction. The DO result demonstrates that gluon and quark jets are significantly different in hadron collisions, and that it may be possible to discriminate between them on an individual basis. The identification of gluon and quark jets may provide a powerful tool in the study of hadron-collider physics, for example, in case of "boson + jet" events.

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