Jets in Hadron Colliders at Order α_s^3 [†]

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Abstract

Recent results from the study of hadronic jets in hadron-hadron collisions at order α_s^3 in perturbation theory are presented. The numerical results are in good agreement with data and this agreement is illustrated where possible.

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ABSTRACT

Recent results from the study of hadronic jets in hadron-hadron collisions at order α_s^3 in perturbation theory are presented. The numerical results are in good agreement with data and this agreement is illustrated where possible.

In the following short discussion, we present a brief summary of recent results[1, 2] in the field of jet studies. Due to the brevity of this report, it can function only as a menu of results with references to more lengthy discussions[3, 4, 5].

Like the experimental data, the theoretical inclusive jet cross section is a function of the physical variables s , the total energy, E_T , the transverse energy of the jet ($E_T = E \sin \theta$), and η , the rapidity of the jet ($= \ln \cot(\theta/2)$) and the definition of the jet. It also depends on the *unphysical* renormalization/factorization scale μ and on the specific choice of parton distribution functions. The situation at order α_s^3 is a major improvement over the order α_s^2 Born result both because the μ dependence is reduced and because the cross section exhibits a reasonable dependence on the jet definition. While the Born cross section exhibits monotonic dependence on μ , the higher order result is relatively insensitive to the value of μ in a broad region near $\mu \simeq E_T/2$. We estimate[3] that the uncertainty associated with the truncation of the perturbation series, as indicated by the residual μ dependence, is $\sim 10\%$. (We also estimate that the uncalculated power suppressed fragmentation effects are of order $\sim 6 \text{ GeV}/E_T$.) The quality of the agreement with data is indicated in Fig. 1 where the inclusive single jet cross section is plotted versus E_T at $\sqrt{s} = 1800 \text{ GeV}$ and compared to recent data from CDF[1]. The cross section is averaged over the CDF range, $0.1 < |\eta| < 0.7$, and the theory curve corresponds to $\mu = E_T/2$ calculated with the HMRSB[6] structure functions (we estimate that there is a residual theoretical uncertainty of

Figure 1: Inclusive jet cross section versus E_T .

order 20% associated with the current uncertainties in the parton distributions). This agreement strongly suggests that there is no deviation from the Standard Model (e.g., due to quark compositeness) even at parton-parton scattering energies of order $\sim 1 \text{ TeV}$.

At hadron colliders jets are defined[7] in terms of the transverse energy inside a cone of radius $R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$. While the Born cross section with only a single parton per jet is R independent, the order α_s^3 cross section can have 2 partons inside a jet and is R dependent. The results plotted in Fig. 1 correspond to $R = 0.7$. The theoretical R dependence is shown in Fig. 2 where the inclusive single jet cross section at $E_T = 100 \text{ GeV}$ is plotted versus R along with preliminary results from CDF[1]. Since dependence on R is not present in the Born cross section, this dependence is in some sense a lowest order result at order α_s^3 . Thus, while the cross section itself is relatively μ independent, the R dependence of the cross section is μ dependent as indicated by the 3 curves in Fig. 2 for different μ values. The general behavior is easily understood

*Talk presented by S.D. Ellis

Figure 2: Inclusive jet cross section versus R .

Figure 3: $F(r, R, E_T)$ versus r .

by noting that the slope with R is proportional to α_s^3 , which decreases with increasing μ . A more complete discussion of this behavior will appear elsewhere[4]. The agreement between theory and experiment is quite good given the current uncertainties.

Another way to study the internal structure of jets that arises at order α_s^3 is to consider the average fraction of the jet energy, E_T , found inside a second smaller radius $r < R$, for fixed R . This quantity, $F(r, R, E_T)$, is plotted in Fig. 3 versus the inner radius r with $R = 1.0$ and compared to preliminary CDF data[1]. Again curves for three choices of μ are exhibited. The agreement between theory and experiment is once more quite reassuring.

Finally we have calculated[4] the 2-jet inclusive cross section at order α_s^3 . With 3 partons in the final state one of the two jets can contain 2 partons and exhibit real R dependence. For example Fig. 4 shows the angular distribution of the 2 jets in the variable $\lambda = 0.5 \sinh(\eta_1 - \eta_2)$ for jet pair masses ≥ 200 GeV. Preliminary data from CDF[1] are also shown. The normalization is to unit integral. For comparison the dashed curve exhibits the cross section for s -wave scat-

Figure 4: $(1/\sigma_{JJ})d\sigma_{JJ}/d\lambda$ versus λ .

tering rather than vector exchange as in QCD. The data obviously favor the shape of vector exchange.

Clearly jets studies at order α_s^3 are rich in detail that can be confronted with data. We look forward to considerable clarification of our understanding of jets from this work. Useful extensions would be to study jets in e^+e^- collisions, where the background events are very different, using similar jet definitions and to proceed to order α_s^4 .

References

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