Color Evaporation Induced Rapidity Gaps

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We show that soft color rearrangement of final states can account for the appearance of rapidity gaps between jets. In the color evaporation model the probability to form a gap is simply determined by the color multiplicity of the final state. This model has no free parameters and reproduces all data obtained by the ZEUS, H1, DØ, and CDF collaborations.

1. Introduction

The inclusion of soft color interactions between the dynamical partons leads to a parameter–free calculation of the formation rate of rapidity gaps. The idea is extremely simple. A rapidity gap occurs whenever final state partons form color singlet clusters separated in rapidity. As the partons propagate within the hadronic medium, they exchange soft gluons which modify the string configuration. The probability to form a rapidity gap is then determined by the color multiplicity of the final states formed by the dynamical partons, and nothing else. All data obtained by ZEUS, H1, DØ, and CDF collaborations are reproduced when this color structure of the interactions is superimposed on the usual perturbative QCD calculation for the production of the hard jets. We pointed out [1] that this soft color mechanism is identical to the color evaporation mechanism [2] for computing the production rates of heavy quark pairs produced in color singlet onium states, like J/ψ. Moreover, we also suggested that the soft color model could provide a description for the production of rapidity gaps in hadronic collisions [1].

The success of the color evaporation model to explain the data on quarkonium production is unquestionable [3]. We showed [5] that the straightforward application of the color evaporation approach to the string picture of QCD readily explains the formation of rapidity gaps between jets at the Tevatron and HERA colliders.

2. Color Counting Rules

In the color evaporation scheme for calculating quarkonium production, it is assumed that all color configurations of the quark pair occur with equal probability. We propose that the same color counting applies to the final state partons in high E_T jet production. In complete analogy with quarkonium, the production of high energy jets is a two–step process where a pair of high E_T partons is perturbatively produced at a scale E_T, and hadronize into jets at a scale of order Λ_{QCD} by stretching color strings between the partons and spectators. The strings subsequently hadronize. Rapidity gaps appear when a cluster of dynamical partons, *i.e.* interacting partons or spectators, form a color singlet. As before, the probability for forming a color singlet cluster is inversely proportional to its color multiplicity.

The soft color procedure is obvious in a specific example: let us calculate the gap formation probability for the subprocesses $p\bar{p} \to Q^V \bar{Q}^V \to Q\bar{Q}XY$, where Q^V stands for u or d valence quark, and X (Y) is the diquark remnant of the proton (antiproton). The final state is composed of the X ($\mathbf{3} \otimes \mathbf{3}$) color spectator system with rapidity $\eta_X = +\infty$, the Y ($\bar{\mathbf{3}} \otimes \bar{\mathbf{3}}$) color spectator system with $\eta_Y = -\infty$, one $\mathbf{3}$ parton j_1, and one $\bar{\mathbf{3}}$ parton j_2. It is the basic assumption of the soft color scheme that by the time these systems hadronize, any color state is equally likely. One can form a color singlet final state between X and j_1 since $\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = \mathbf{10} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{1}$, with probability 1/27. Because of overall color conservation, once the system $X \otimes j_1$ is in a color singlet, so is the system $Y \otimes j_2$. Moreover, to form a rapidity gap these systems ($j_1 \otimes X$ and $j_2 \otimes Y$) must not overlap in rapidity space. In this configuration, the color strings linking the remnant and the parton will not hadronize in the region between the two jets. We have thus produced two jets separated by a rapidity gap using the color counting rules which form the basis of the color evaporation scheme for calculating quarkonium production.

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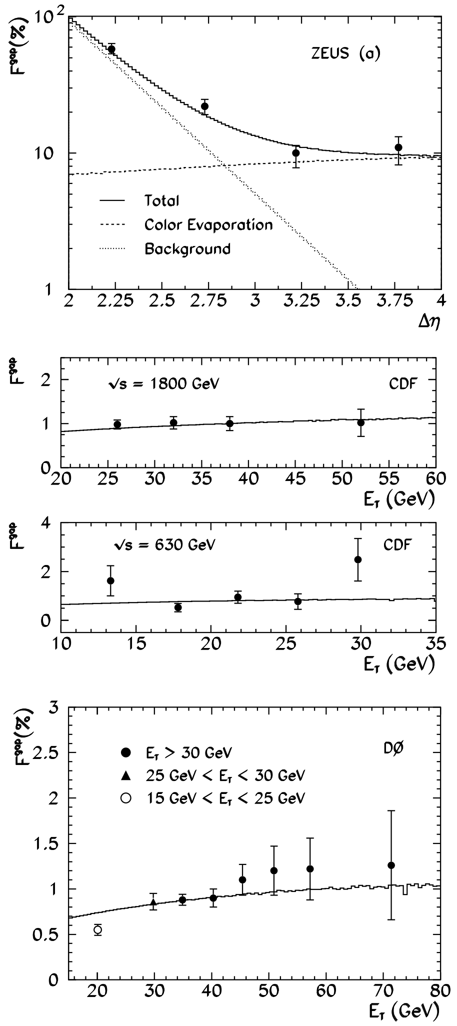

Figure 1. Frequency of events with rapidity gap between jets as a function of the gap size $\Delta\eta$ in γp collisions, and as function of the jets transverse energy in $p\bar{p}$ collisions.

3. Rapidity Gaps at HERA

The differential cross section has two sources of gap events: color evaporation gaps ($d\sigma^{gap}_{cem}$) and background gaps ($d\sigma^{gap}_{bg}$). In our model, the gap cross section is the weighted sum over resolved events, $d\sigma^{gap}_{cem} = \sum_N F_N \; d\sigma^N_{res}$, with gap probability F_N for the different processes. Background gaps are formed when the region of rapidity between the jets is devoid of hadrons because of statistical fluctuation of ordinary soft particle production. Their rate should fall exponentially as the rapidity separation $\Delta\eta$ between the jets increases. We parametrize the background gap probability as $F_{bg}(\Delta\eta) = e^{b(2-\Delta\eta)}$, where b is a constant. The background gap cross section is then written as $d\sigma^{gap}_{bg} = F_{bg}(\Delta\eta) d\sigma^{jets} - d\sigma^{gap}_{cem})$.

The gap frequency $F^{gap}(\Delta\eta) = d\sigma^{gap}/d\sigma^{jets}$ is shown in the figure, where we depict the contributions of the color evaporation mechanism and the background.

4. Rapidity Gaps at Tevatron

The color evaporation model prediction for the gap production rates in $p\bar{p}$ collisions is analogous to the one in $p\gamma$ interactions, with the obvious replacement of the photon by the antiproton, represented as a $\bar{\mathbf{3}} \otimes \bar{\mathbf{3}} \otimes \bar{\mathbf{3}}$ system.

The distributions presented by CDF are normalized to unity on average. Therefore our predictions do not exhibit any free parameter to be adjusted. In the figure we compare our predictions with CDF results of the gap fraction as a function of the jets transverse energy. To compare with DØ results we assumed an *ad-hoc* survival probability of 30%.

We can also compare the ratio $R = F^{gap}_{630}/F^{gap}_{1800}$ with the experimental result. DØ has measured this fraction for jets with $E_T > 12$ GeV for both energies, and they found $R = 3.4 \pm 1.2$; we predict $R = 2.5 \pm 0.5$. On the other hand, CDF measured this ratio using different values for E^{min}_T at 630 GeV and 1800 GeV; they obtained $R = 2.0 \pm 0.9$ while we obtained $R = 2.0 \pm 0.4$ for the same kinematical arrangement.

5. Conclusion

In summary, the occurrence of rapidity gaps between hard jets can be understood by simply applying the color evaporation scheme for calculating quarkonium production to the conventional perturbative QCD calculation of the production of hard jets. The agreement between data and this model is impressive.

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