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PROBING HARD COLOR SINGLET EXCHANGE AT DØ*

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We present latest preliminary results on hard color-singlet exchange in proton-antiproton collisions. The fraction of dijet events produced via color-singlet exchange is measured as a function of jet transverse energy, dijet pseudorapidity separation, and proton-antiproton center-of-mass energy. The results favour a color-singlet fraction that increases with increasing quark-initiated processes.

I. INTRODUCTION

A signature for dijet production via hard color-singlet exchange is a rapidity gap (no particles in a region of rapidity) between the dijets. Hard color-singlet exchange has been observed at both the Tevatron [1–4] and HERA [5], at a rate of 1% and 10%, respectively. We present new measurements of the fraction of color-singlet exchange in dijet events as a function of dijet transverse energy (E_T), dijet pseudorapidity separation ($\Delta\eta$), and proton-antiproton center-of-mass energy ($\sqrt{s}$), which probe the color-singlet dynamics and its coupling to quarks and gluons. A color singlet that couples more strongly to quarks (gluons) is expected to produce a higher (lower) color-singlet fraction with increasing proportion of initial-state quark processes. The latter is achieved by decreasing $\sqrt{s}$ or increasing the dijet E_T or $\Delta\eta$ (i.e. increasing Bjorken x).

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Models of a color-singlet state that couples more strongly to gluons consist of the exchange of two perturbative gluons [6]. The simple two-gluon picture has been expanded to include certain dynamical effects using a leading-log BFKL approximation [7]. These effects predict a rising color-singlet fraction at large dijet $\Delta\eta$.

Models of a color-singlet state that couples more strongly to quarks include the QCD-based soft color rearrangement model [8] and a model based on the exchange of a hard U(1) gauge boson that couples only to quarks [9].

The color-singlet fraction calculated from models for the exchange of a hard color singlet (i.e. a two-gluon singlet or U(1) boson) includes the probability that the rapidity gap is not contaminated by particles from spectator interactions. This probability ($S \sim 10\%$) [10,11] is expected to be independent of the flavor of the initiating partons in the hard scattering; it depends, however, on the proton-antiproton center-of-mass energy ($S_{630}/S_{1800} = 2.2 \pm 0.2$) [12].

II. MEASUREMENT OF THE COLOR-SINGLET FRACTION

Data from two center-of-mass proton-antiproton energies of $\sqrt{s}$ = 1800 GeV and 630 GeV are used in this analysis. Jets are reconstructed using a cone algorithm with cone radius of 0.7 in $\eta \times \phi$ space. For the comparison between the 630 and 1800 GeV samples, two opposite-side jets with $E_T > 12$ GeV are required. For the measurement of the color-singlet fraction as a function of dijet E_T and $\Delta\eta$, three opposite-side dijet samples at 1800 GeV are used, with jet $E_T >$ 15, 25 and 30 GeV. In all samples, the two jets are required to have $|\eta| > 1.9$ and $\Delta\eta > 4$.

The particle multiplicity in the central rapidity region (within $|\eta| < 1$) is approximated by the multiplicity, n_{cal}, of localized (0.1×0.1 in $\Delta\eta \times \Delta\phi$) transverse energy deposits above 200 MeV in the electromagnetic part of the calorimeter, and by the track multiplicity in the central tracking chamber, n_{trk}.

For the comparison of the 630 and 1800 data, the leading edge of each n_{cal} distribution is fitted using a single negative binomial distribution (NBD). The fraction of rapidity gap events is calculated from the excess of events over the fit in the first two bins ($n_{cal} = 0$ or 1) divided by the total number of entries. It is equal to 1.85 ± 0.09(stat.) $\pm$ 0.37(syst.) at $\sqrt{s} = 630$ GeV and 0.54 ± 0.06(stat.) ± 0.16(syst.) at $\sqrt{s} = 1800$ GeV. The systematic errors are dominated by the fit uncertainties. The ratio R of the rapidity gap fractions at 630 and 1800 GeV is equal to 3.4 ± 1.2.

To avoid large uncertainties in the color-exchange background subtraction when measuring the color-singlet fraction as a function of E_T and $\Delta\eta$, we use the two-dimensional multiplicity distributions (n_{cal} vs. n_{trk}) and define the "2D" color-singlet fraction f_{2D} as the fraction of events with $n_{cal} + n_{trk} < 2$. The results are shown in Fig. 1. The systematic errors include effects from background estimation. The measured color-singlet fraction shows a slight rise as a function of dijet E_T and $\Delta\eta$.

III. COMPARISON TO THE COLOR-SINGLET MODELS

We compare our results to color-singlet models using HERWIG 5.9 which includes parton showering and hadronization of the final states and allows detector simulation. Monte Carlo samples were generated using CTEQ-2M parton distribution functions. Jets were reconstructed at the particle level using a cone algorithm with cone radius of 0.7. Detector effects were simulated by smearing the jet E_T and η according to DØ jet resolutions. The two leading jets were required to have $|\eta| > 1.9$ and $\Delta\eta > 4$ just as in the data samples.

HERWIG 5.9 includes a BFKL two-gluon exchange process (based on the calculations of Ref. 7) and a t-channel photon exchange process.

We also construct a set of naïve "color factor" models in which the color singlet dynamics is assumed to be described by single gluon exchange but may have different color factors depending on the parton types undergoing the hard interaction. We denote by C_{qg} and C_{gg} the effective color factors for quark-gluon and gluon-gluon processes compared to quark-quark processes ($C_{qq} \equiv 1$). For a single-gluon exchange $C_{gg} = C_{qg} = 1$. In the soft-color rearrangement model, initial quarks have fewer color combinations and thus, a higher probability of being rearranged into a colorless state than gluons, i.e. $C_{gg} < C_{qg} < C_{qq}$.

We fit the Monte Carlo models to the E_T and $\Delta\eta$ dependence of the color-singlet fraction in the data. The results of the fits, plotted as a function of the mean dijet E_T, are shown in Fig. 2. Assuming a survival probability independent of E_T and $\Delta\eta$, the data favour quark-initiated color-singlet models. A single-gluon model can not be excluded.

IV. CONCLUSIONS

We have presented new information on the fraction of dijet events produced via color-singlet exchange in $p\bar{p}$ collisions. The measured fraction decreases with proton-antiproton center-of-mass energy, consistent with a recent prediction for the energy dependence of the survival probability [12]. The fraction increases slightly as a function of dijet transverse energy and dijet pseudorapidity separation. Assuming that the survival probability does not depend on the above variables, the data are qualitatively consistent with a color-singlet fraction that increases with increasing quark content.

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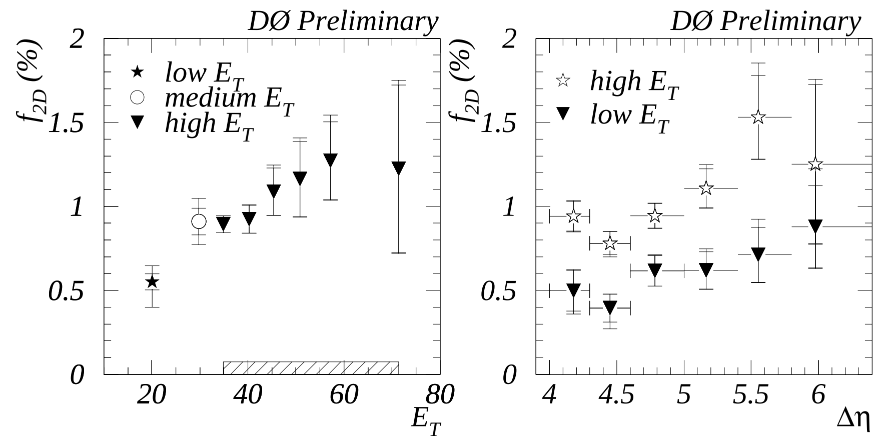

FIG. 1. The color-singlet fraction: (a) as a function of the second leading jet E_T plotted at the average dijet E_T for that bin; (b) as a function of $\Delta\eta$ between the leading dijets. Statistical (inner error bars) and statistical plus systematic errors (outer error bars) are shown. The error band at the bottom shows the normalization uncertainty (not included in the plotted systematic error).

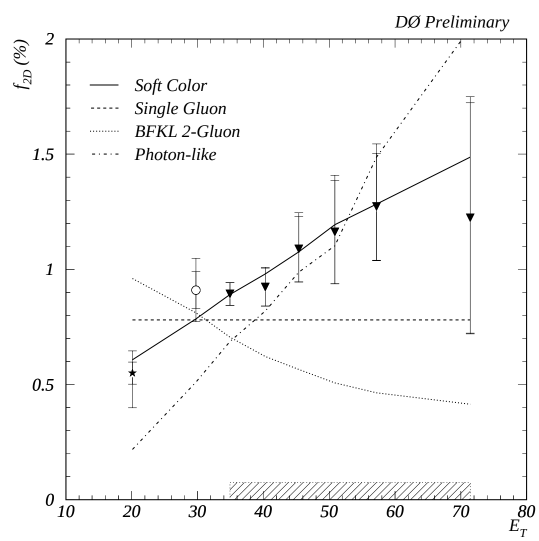

FIG. 2. Monte Carlo fits to the measured color-singlet fraction f_{2D}. The normalization is allowed to float.