Rapidity Gaps in Jet Events at DØ

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Abstract

Preliminary results from the DØ experiment on jet production with rapidity gaps in $p\overline{p}$ collisions are presented. A class of dijet events with a forward rapidity gap is observed at center-of-mass energies $\sqrt{s} = 1800\,\mathrm{GeV}$ and $630\,\mathrm{GeV}$. The number of events with rapidity gaps at both center-of-mass energies is significantly greater than the expectation from multiplicity fluctuations and is consistent with a hard diffractive process. A class of events with two forward gaps and central dijets is also observed at 1800 GeV. This topology is consistent with hard double pomeron exchange.

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I. INTRODUCTION

The properties of elastic and diffractive scattering are well-described by the phenomenology of pomeron exchange, where the pomeron is a color singlet with quantum numbers of the vacuum [1,2]. It has been proposed that hard diffractive scattering, which refers to the subset of traditional diffractive interactions that has a high transverse momentum (p_T) scattering, would probe the partonic nature of the pomeron [3]. Recent results on hard diffraction [4–7], have provided new insight into the pomeron. In this note we describe a preliminary search for diffraction with high transverse momentum jets with the DØ detector at Fermilab for center-of-mass energies $\sqrt{s} = 1800\,\text{GeV}$ and $630\,\text{GeV}$.

II. ANALYSIS

A. Hard Single Diffraction

An experimental signature of hard diffractive events is the presence of a rapidity gap (lack of particle production in a rapidity or pseudorapidity[1] region), along with a hard scattering (jet production, W production, etc.). Since the pomeron is a color singlet, radiation is suppressed in events with pomeron exchange, typically resulting in a large rapidity gap [8]. In hard single diffraction a pomeron is emitted from one of the incident protons and undergoes a hard scattering with the second proton, often leaving a rapidity gap in the direction of its parent proton. We examine the process $p + \overline{p} \rightarrow j + j + X$ and look for the presence of a forward rapidity gap along the direction of one of the initial beam particles.

The existence of a diffractive signal in the experimental data may be observed as a larger number of rapidity gap events in the forward multiplicity distribution than expected from the non-diffractive background. Given sufficient detector resolution, sensitivity, and statistics, two components in the multiplicity distribution can be resolved and the relative fraction of rapidity gap events in excess of expectations from a smoothly falling multiplicity distribution can be estimated.

The DØ detector [9] is used to provide experimental information on the fraction of jet events with forward rapidity gaps. This analysis primarily utilizes the uranium-liquid argon calorimeters which have full coverage for a pseudorapidity range of $|\eta| < 4.1$. The transverse segmentation of the projective calorimeter towers is typically $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$. The electromagnetic (EM) section of the calorimeters is used to search for rapidity gaps. The EM section is particularly useful for identifying low energy particles due to its low level of noise and ability to detect neutral pions. A particle is tagged by the deposition of more than 200 MeV of energy in a single EM calorimeter tower.

The data used in this study were obtained using a forward trigger requiring at least two jets above 12 GeV in the same hemisphere with both jets having $\eta > 1.6$ or $\eta < -1.6$. Since the pomeron only carries a few per cent of the initial proton momentum, the jet system

[1] Pseudorapidity or $\eta = -ln[tan(\frac{\theta}{2})]$, where θ is the polar angle defined relative to the proton beam direction.

is expected to be boosted in diffractive jet production, thus a forward jet trigger can be utilized to provide an enhanced sample of diffractive events. Offline, two jets above trigger threshold are required and events with multiple $p\overline{p}$ interactions or spurious jets are removed.

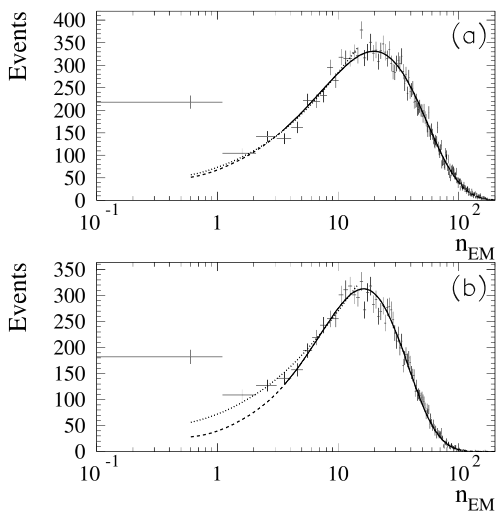

FIG. 1. Number of electromagnetic calorimeter towers (n_{EM}) above a 200 MeV energy threshold for the region $2 < \eta < 4.1$ opposite the forward jets for center-of-mass energies of (a) 1800 GeV and (b) 630 GeV. The curves are negative binomial fits to the data excluding low multiplicity bins.

Jets are reconstructed using a cone algorithm with radius, $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$.

The number of EM towers (n_{EM}) above a 200 MeV energy threshold is measured in the hemisphere opposite the leading two jets in the region $2 < |\eta| < 4.1$. The (n_{EM}) distribution for the forward trigger is shown in Fig. 1 for $\sqrt{s}$ of (a) 1800 GeV and (b) 630 GeV. The distributions at both center-of-mass energies show a peak at zero multiplicity in qualitative agreement with expectations for a diffractive signal component. Negative binomial fits to the leading edge and the whole distribution (excluding $n_{EM} = 0$) have been used to estimate the non-diffractive background. A fractional excess of rapidity gap events is defined to be the number of zero multiplicity events in excess of those predicted by the fit divided by the total number of events in the sample. The fractional excess observed in the forward region for the $\sqrt{s} = 1800$ GeV sample is $0.67 \pm 0.05\%$, where the error includes only statistical uncertainties and a systematic uncertainty based on the choice of range for the fit. An excess of rapidity gap events is also clearly observed at 630 GeV with a magnitude of $1 - 2\%$. Systematic studies have not been completed, but effects such as gap detection efficiency are expected to reduce the number of observed rapidity gaps, and correcting for these effects is expected to give a modest increase in the magnitude of the signal measurement. The observed fractional excess is relatively insensitive to the calorimeter energy threshold, and rapidity gap events ($n_{EM} = 0$) typically have zero multiplicity in other available detectors, such as hadronic calorimeters, forward tracking, beam hodoscopes, and forward muon chambers.

The forward gap fraction measurement for the $\sqrt{s} = 1800$ GeV sample has been extended to unrestricted jet topologies using an inclusive jet trigger and we observe that the gap fraction increases with the boost of the jets, consistent with the expected behavior of diffractive events discussed earlier.

B. Hard Double Pomeron Exchange

The same experimental methods may be applied to a search for hard double pomeron exchange. In this process both incoming protons emit a pomeron and the two pomerons interact to produce a jet system. Rapidity gaps are expected to be produced along each forward beam direction, since there is no color connection between the jet system and the beam particles. In this analysis we have selected an enhanced sample of forward rapidity gap events with a dedicated single gap trigger, which, in addition to the jet requirements, vetoes on forward particles in either beam direction using the scintillator beam hodoscopes which bracket the DØ collision region. Events were selected to have a rapidity gap ($n_{EM} = 0$) in the direction of the online veto. These data consist of about 40,000 single gap events at $\sqrt{s} = 1800\,\text{GeV}$, compared to the approximately 200 events observed in the forward trigger sample after background subtraction. This enhanced diffractive sample is used to search for double forward gap events, in which we require no towers above threshold in both forward calorimeter regions along with two jets with $E_T > 15\,\text{GeV}$ and $|\eta| < 1.0$. This is an expected topology for events produced in hard double pomeron exchange. The n_{EM} distribution for the veto-trigger is plotted in Fig. 2 for the forward region ($2 < |\eta| < 4.1$) opposite the tagged rapidity gap. We clearly observe a sample of double gap events, although an interpretation of them in terms of hard double pomeron exchange requires further study.

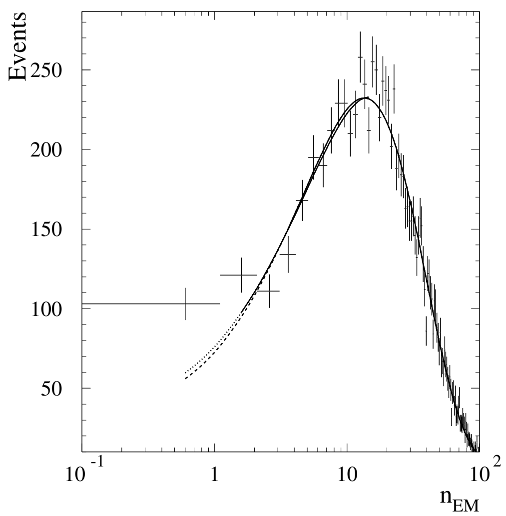

FIG. 2. The n_{EM} distribution opposite the tagged gap for single gap trigger data. The zero multiplicity events are double gap events in this sample. The curves are negative binomial fits to the data excluding low multiplicity bins as described in the previous section.

III. CONCLUSION

We have observed the presence of forward rapidity gaps in events with high E_T jet production with the DØ detector at Fermilab. The fraction of forward rapidity gap events observed is in excess of those expected to be produced via multiplicity fluctuations at center-of-mass energies of 1800 GeV and 630 GeV. This is consistent with expectations from hard single diffractive jet production and provides the first experimental evidence for this process at $\sqrt{s} = 1800$ GeV. We also observe a class of events containing high E_T central jets and two forward rapidity gaps, consistent with a hard double pomeron exchange event topology.

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