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Hard Diffraction Results Using DØ

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HARD DIFFRACTION RESULTS USING D0

Representing the D0 Collaboration

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ABSTRACT

The preliminary results on the search for hard diffraction in $\overline{p}p$ collisions with the DØ detector at Fermilab are presented. The presence of forward rapidity gaps is observed in events with high transverse momentum jet production at the center of mass energies 1800 and 630 GeV. The fraction of events with rapidity gaps is significantly higher than that expected due to multiplicity fluctuations and is consistent with predictions for hard single diffractive jet production. A class of events containing central dijets and two forward rapidity gaps is observed at $\sqrt{s} = 1800$ GeV consistent with a hard double pomeron exchange event topology.

1. Introduction

The diffractive scattering was first observed and studied in detail for soft processes where its properties are well described by the pomeron exchange with the pomeron being a color singlet with quantum numbers of the vacuum[1,2].

The study of diffractive processes has expanded dramatically in recent years. Results from UA8, HERA, and the Tevatron include studies of diffractive jet production[3-5], rapidity gaps between high transverse energy jets[6-9], and a search for diffractive W-boson production[4]. These results give new insight into the object exchanged in the production of diffractive events.

At the Tevatron we have an opportunity to study the partonic structure of the pomeron using jets produced in hard scattering[10] in the pomeron-(anti)proton vertex. Since the Pomeron is a color singlet, radiation is suppressed in this class of events typically resulting in a large rapidity gap[11] (lack of particle production in a rapidity or pseudorapidity[1] region). Hard single diffraction is a process where the pomeron is emitted by one of the beam particles and then undergoes hard scattering with another one producing high transverse momentum jets in the parent particle direction along with a rapidity gap[12,13] in the opposite one.

If the pomeron is emitted by both beam particles the rapidity gaps are expected in both proton and antiproton directions. Double gap events with centrally produced jets are considered to be an experimental signature of hard double pomeron exchange.

The final state particle multiplicity distribution is a convenient way to distinguish between color exchange and color singlet exchange due to much lower mean multiplicity of color singlet exchange events. Multiplicity of events involving color exchange is well-described by negative binomial (NB) distribution. Both components can be resolved given sufficient detector resolution, sensitivity and statistics. An excess of low multiplicity events with respect to the distribution for color exchange would indicate the presence of a color singlet exchange process.

The DØ detector[14] is suitable for low energy particle detection, since there is no central magnetic field. For the present analysis the most crucial part of the detector is the electromagnetic (EM) section of the calorimeter which is found to be particularly useful for identifying low energy particles due to its low level of noise, ability to detect both charged and neutral pions and wide rapidity coverage $|\eta| < 4.1$. The transverse segmentation of the projective calorimeter towers is typically $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$. A particle is tagged by the deposition of more than 200 MeV of energy in a single EM calorimeter tower.

2. Hard Single Diffraction

To study diffractive jet production the POMPYT 1.0[15] event generator is used. This program is based on PYTHIA but allows for the choice of a pomeron as one of the beam particles. The pseudorapidity jet distribution for events generated using POMPYT with two different choices of pomeron structure (2-gluon or "hard gluon" and "soft gluon") along with jet distribution for nondiffractive events generated with standard PYTHIA 5.7[16] are presented in Fig. 1. The jet system in diffractive events is boosted as expected since the Pomeron carries less than 5% of the incident proton or antiproton momentum. Therefore a forward trigger is expected to provide an enhanced sample of diffractive events.

The forward trigger used in the study[17] requires at least two jets above 12 GeV both located in the region $\eta > 1.6$ or $\eta < -1.6$ and offline, two "good" jets are required and events

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

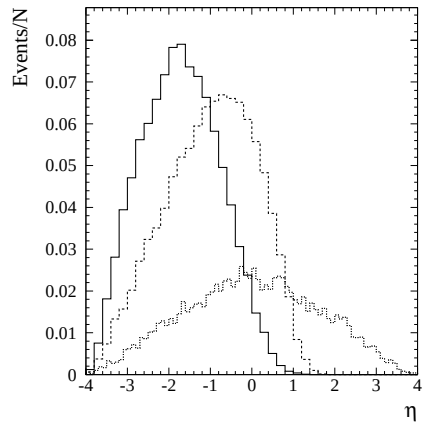

Figure 1: Pseudorapidity distribution of the two leading jets in the events having at least two jets with $E_T >$ 15 GeV generated using PYTHIA (dotted histogram) and POMPYT (solid histogram is for the "soft gluon" and dashed histogram is for the "hard gluon" pomeron structure function).

with multiple $p\overline{p}$ interactions or spurious jets are removed. Jets are reconstructed using a cone algorithm with radius, $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$.

To search for hard single diffraction the forward calorimeter EM tower multiplicity above the 200 MeV threshold on the side opposite dijets in the forward detector pseudorapidity region $2 < |\eta| < 4.1$ is measured. Fig. 2(a) shows the distribution of the number of EM towers (n_{EM}) for $\sqrt{s} = 1800$ GeV along with the NB fits to the data. The dotted line is a fit to the rising edge of the distribution (from $n_{EM} = 1$ to $n_{EM} = 14$), the dashed line is a fit from $n_{EM} = 3$ to $n_{EM} = 100$. Both fits are extrapolated to $n_{EM} = 0$ to estimate the background from the zero multiplicity events coming from multiplicity fluctuations in color exchange background. The fractional excess of rapidity gap events defined as the number of

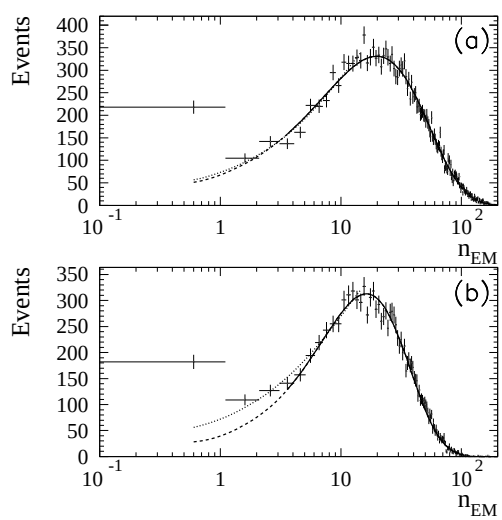

Figure 2: Number of electromagnetic calorimeter towers (n_{EM}) above a 200 MeV energy threshold for the region $2 < |\eta| < 4.1$ opposite the forward jets for center-of-mass energies of (a) 1800 GeV and (b) 630 GeV. The curves are NB fits to the data excluding low multiplicity bins as described in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

zero multiplicity events in excess of those predicted by the fit divided by the total number of events in the sample, is measured to be $(0.67 \pm 0.05)\%$ in the forward region. The error includes statistical uncertainty and a systematical one due to the choice of the fit range.

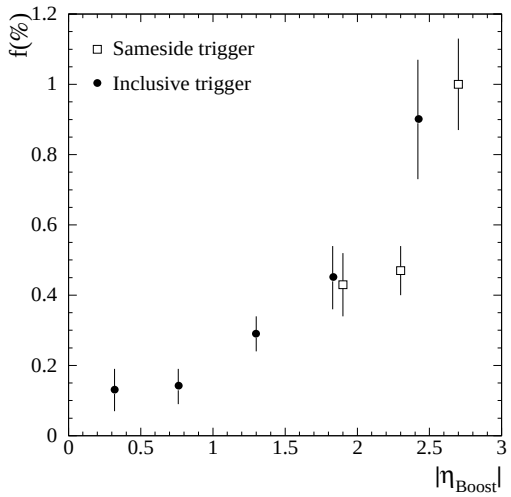

Figure 3: Forward gap fraction as a function of $|\eta_{\mathrm{Boost}}|$ for the 1800 GeV data. Data from the inclusive trigger are shown as circles, the forward (same-side) trigger data are shown as squares.

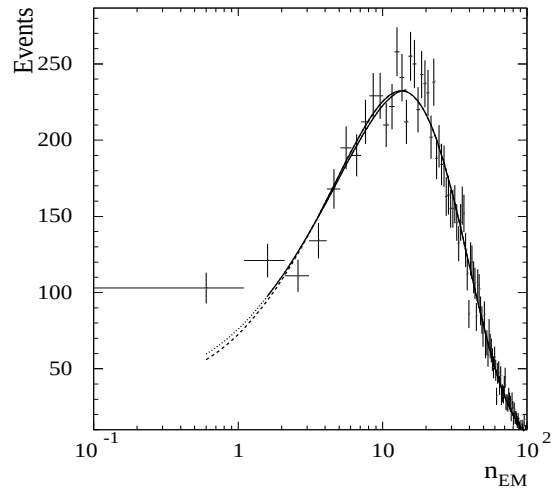

Figure 4: The n_{EM} distribution opposite the tagged gap for single gap trigger data. The zero multiplicity events are double gap events in this sample. The curves are NB fits to the data excluding low multiplicity bins as described in the previous section.

The same analysis was performed using the event sample collected at $\sqrt{s} = 630$ GeV. An excess of rapidity gap events over expectations from smoothly falling multiplicity distribution is clearly seen in Fig. 2(b) at this energy with a magnitude of 1-2%. To compare directly the results from two samples at different energies a complete analysis of the systematic effects such as noise, multiple $p\overline{p}$ collisions in a single event, particle showering outside of jet cones, and particle production from spectator interactions, should be performed.

The inclusive jet sample provides a method to look at hard single diffraction as a function of the boost of leading dijet system. An inclusive single jet trigger used for this analysis requires at least one jet above 15 GeV E_T.

The inclusive jet sample was divided into several subsamples according to the measured boost of the two leading jets defined as $\eta_{\mathrm{Boost}} = (\eta_1 + \eta_2)/2$. Fig. 3 shows the fraction of events in the zero multiplicity bin after background subtraction as a function of the η_{Boost}. A clear increase in single diffractive candidate events is observed with increasing η_{Boost}. This effect continues with higher values of η_{Boost} where the forward jet trigger mentioned above is used to extend the range of η_{Boost}. This is consistent with expectations from hard diffraction.

3. Hard Double Pomeron Exchange

Hard double pomeron exchange implies that both the proton and antiproton emit a color-singlet 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. The same jet requirements were implemented as in the inclusive trigger, but we additionally required a veto 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 ($n_{\mathrm{EM}} = 0$) in the direction of the online veto. These data consist of about 40,000 single gap events at $\sqrt{s} = 1800$ 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 $E_T > 15\,\mathrm{GeV}$ 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. 4 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. The relative rate of these events is estimated to be $O(10^{-6})$ of the inclusive sample with two jets with $E_T >$ 15 GeV produced within $|\eta| < 1$.

4. Conclusions

The presence of forward rapidity gaps is observed in events with high E_T jet production with the DØ detector at Fermilab. The fraction of forward rapidity gap events observed is significantly higher than that expected to be produced via multiplicity fluctuations at center-of-mass energies of 1800 GeV and 630 GeV. This is consistent with predictions for hard single diffractive jet production and provides the first experimental evidence for this process at $\sqrt{s} = 1800\,\mathrm{GeV}$. The forward gap fraction is observed to increase with the boost of the leading dijet system in the 1800 GeV data. A class of events containing high E_T central jets and two forward rapidity gaps is observed, consistent with a hard double pomeron exchange event topology at the rate of $O(10^{-6})$ of inclusive jet events.

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