Hard Diffractive Jet Production at DØ

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Recent results on hard diffraction are discussed for center-of-mass energies of 1800 and 630 GeV, including single diffractive jet production and hard double pomeron exchange. These events have one or two rapidity gaps with concurrent jet production.

1. INTRODUCTION

Diffractive events are characterized by the complete, or nearly complete, absence of hadronic particle activity over a large rapidity or pseudorapidity[1] region. This region is called a 'rapidity gap'. An experimental signature of hard diffractive events is the presence of a rapidity gap [1,2], along with evidence of a hard scattering (jet production, W production, etc.). The existence of one forward rapidity gap in an event with concurrent jet production is a signature for Hard Single Diffraction (HSD). Hard Double Pomeron Exchange (HDPE) is similar, but with two forward rapidity gaps.

Ingelman and Schlein proposed in 1985 [3] that the observation of jets in diffractive scattering would provide information about the structure of the object exchanged. The study of hard diffractive processes has expanded dramatically in recent years with results from UA8 [4], and active analyses at HERA [5], and both CDF [6] and DØ [7] at the TEVATRON. These results are yielding new insight into the object exchanged in the production of diffractive events. In this paper we describe a preliminary measurement of HSD and the observation of HDPE using the DØ detector at Fermilab for center-of-mass energies $\sqrt{s} = 1800$ GeV and 630 GeV.

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

2. HARD SINGLE DIFFRACTION

In the Ingelman-Schlein model, diffractive signatures can be explained in terms of pomeron exchange. Since the pomeron is a color singlet, radiation is suppressed in these events resulting in large rapidity gaps [8]. In hard single diffraction, a pomeron is "emitted" from the incident proton (p) and undergoes a hard scatter with the antiproton ($\overline{p}$), typically leaving a rapidity gap in the direction of the parent proton. We thus examine the process $p + \overline{p} \rightarrow jet + jet + X$ (for both forward and central jet production) and look for the presence of a forward rapidity gap along the direction of one of the initial beam particles.

The DØ detector [9] is used to measure the fraction of forward and central jet events with forward rapidity gaps at $\sqrt{s} = 1800$ and 630 GeV. There are two different low luminosity triggers for each data set to study the dependence of the gap fraction on jet location: a forward jet trigger (two 12 GeV jets with an $|\eta| > 1.6$) and an inclusive jet trigger (two 15 GeV jets at 1800 GeV and two 12 GeV jets at 630 GeV) with an offline η cut ($|\eta| < 1.0$). We tag rapidity gaps using the forward calorimeters with coverage from $3.0 < |\eta| < 5.2$ and the forward scintillator arrays (LevelØ detector) which have partial coverage the region $1.9 < |\eta| < 4.3$. A particle is tagged by the deposition of more than 150 MeV of energy in an electromagnetic calorimeter tower or 500 MeV of energy in a hadronic calorimeter tower, where the thresholds are set just above the noise to maxi-

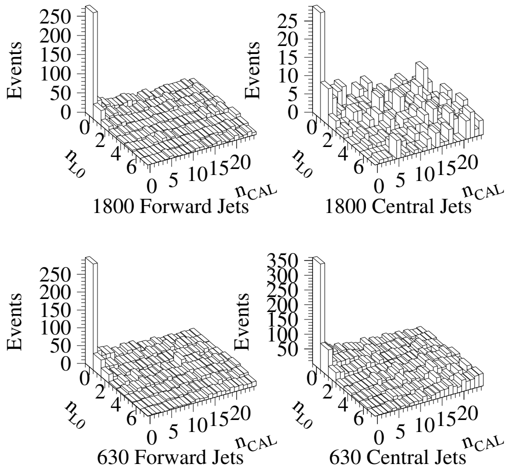

Figure 1. Multiplicity distributions at 1800 GeV (top) and 630 GeV (bottom) for forward jet (left) and central jet (right) events. The clear peak at low multiplicities in all samples is the signature for diffractive events.

mize the sensitivity to particles, or by a hit in the LØ detector.

The number of calorimeter towers (n_{CAL}) above the energy threshold and the number of L0 scintillator hits (n_{L0}) is measured opposite the leading two jets for the forward jet trigger at both center of mass energies. The same quantities are measured on the minimum calorimeter multiplicity side for the central jets at both center of mass energies. Figure 1 shows the multiplicity distributions, n_{CAL} vs. n_{L0}, for the forward jet and central jet triggers at 1800 and 630 GeV. The distributions all show a peak at zero multiplicity in qualitative agreement with expectations for a diffractive signal component and a large broad mean multiplicity peak associated with non-diffractive events. The diffractive signal component is visible in both distributions, but for the central jets, the signal is a lower percentage of the total sample than for the forward jet sample. The distributions at 630 GeV center of mass energy also show the same qualitative behavior.

These distributions are fit using a simultaneous two-dimensional fit to both the background and signal: the background with a four-parameter polynomial and the signal with a falling expo-

DATA SAMPLE	GAP FRACTION
1800 FWD JET	$0.64\% + 0.05\% - 0.05\%$
1800 CEN JET	$0.20\% + 0.08\% - 0.05\%$
630 FWD JET	$1.23\% + 0.10\% - 0.09\%$
630 CEN JET	$0.91\% + 0.07\% - 0.05\%$

Table 1
The measured gap fractions for each data sample.

nential as suggested from Monte Carlo. The gap fraction is defined as the number of signal events divided by the total number of events in the sample. Table 1 shows the measured gap fractions obtained for the different event samples. The given error on the data is from the fit and is stable with variations of background fit, jet E_T scale, calorimeter energy threshold, luminosity, residual noise contamination, and jet quality cuts. In general, the 630 GeV gap fractions are higher than the 1800 GeV gap fractions, and forward jet gap fractions are higher than central jet gap fractions, as shown in the ratios in Table 2.

The corresponding diffractive Monte Carlo multiplicity distributions with POMPYT 2.6 [10] show the same characteristic peak at low multiplicities as observed in the diffractive data with a tail extending to larger multiplicities that is dependent on the structure function choice. The Monte Carlo gap fraction is the predicted diffractive to non-diffractive rate divided by the fraction of diffractive events that are accepted by the rapidity gap tagging method for that structure. In this way the data is left uncorrected with no pomeron structure dependence and a direct comparison can be made to Monte Carlo. The pomeron structure functions studied are hard gluon (two gluons $x(1-x)$), flat gluon (flat in x), quark (two light quarks $x(1-x)$), and soft gluon (like the average gluon structure of the proton). In general, the Monte Carlo hard and flat gluon gap fractions are higher than that observed in the data. This phenomena has also been observed elsewhere [12], and can be attributed to a non-factorizable contribution. The quark pomeron structure rates are consistent to that observed.

The ratios for the hard gluon and quark structure functions are shown in Table 2. The Monte Carlo 630/1800 ratios for both structures are con-

DATA SAMPLE	RATIO
630/1800 FWD JET	$1.9 + 0.2 - 0.2$
630/1800 CEN JET	$4.6 + 1.2 - 1.8$
1800 FWD/CEN JET	$3.2 + 0.8 - 0.5$
630 FWD/CEN JET	$1.4 + 0.1 - 0.1$
HARD GLUON	MC RATIO
630/1800 FWD JET	2.2 ± 0.5
630/1800 CEN JET	1.8 ± 0.4
1800 FWD/CEN JET	0.8 ± 0.2
630 FWD/CEN JET	0.9 ± 0.2
QUARK	MC RATIO
630/1800 FWD JET	2.4 ± 0.6
630/1800 CEN JET	2.8 ± 1.4
1800 FWD/CEN JET	1.8 ± 0.7
630 FWD/CEN JET	1.6 ± 0.9

Table 2
The measured ratios of the gap fractions for data and the predicted ratios of the Monte Carlo gap fraction for the Hard Gluon and Quark pomeron structure functions.

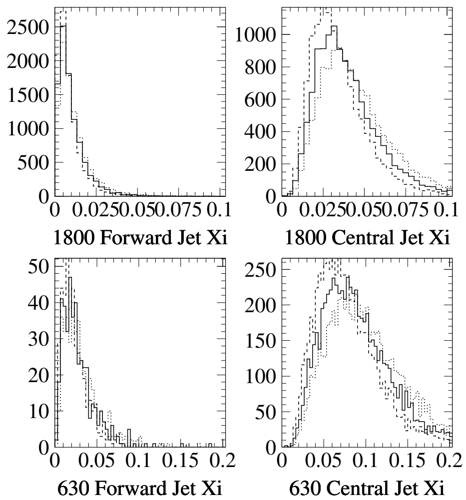

Figure 2. The 1800 GeV and 630 GeV ξ distributions (solid) for forward and central jets. The dotted and dashed curves reflect the high and low error.

sistent with data, where the forward to central jet ratios are inconsistent for the hard gluon structure and consistent for the quark structure. A combination hard and soft gluon structure (not shown) is also consistent with the ratios observed in data, because the soft gluon produces few rapidity gaps for central jet events. The latter choice is consistent with preliminary measurements at CDF [6].

2.1. Event characteristics

We trigger on a rapidity gap in the L0 detector with concurrent jet production to obtain a large number of high-purity single diffractive candidate events with which to study the momentum lost by the diffracted proton, ξ. After reinforcing the rapidity gap in the calorimeter, we measure the ξ distribution using [11]

$$\xi \approx \Sigma \frac{E_{T_i} e^{y_i}}{\sqrt{s}}, \qquad (1)$$

summing over the particles with the highest rapidity, y, and largest E_T. The outgoing diffracted proton (or the rapidity gap) is defined to be at positive η. This formula measures ξ using only the calorimeter, emphasizing the well-measured central region close the gap. It has no model-dependence, and it can be defined even for non-diffractive events. After correcting for energy scale differences between Monte Carlo and data, the ξ distribution (solid) for 1800 GeV and 630 GeV forward and central jets are shown in Figure 2. The dotted and dashed curves reflect the high and low error.

The forward jet ξ distribution at both 1800 and 630 GeV is peaked toward lower values of ξ, although separated from zero because a certain amount of momentum is required to create two 12 GeV jets. The central jet ξ distribution is spread over higher values, consistent with the pomeron requiring more momentum to balance the parton in the non-diffracted (anti)proton. The ξ distribution at 630 GeV is higher overall than at 1800 GeV. With the same jet requirements, more momentum is needed from the pomeron. Although the trends of the ξ distribution are consistent with expectations, pomeron exchange is typically thought to dominate for very low values of $\xi < 0.05$. The large values of ξ observed can be reproduced well in POMPYT.

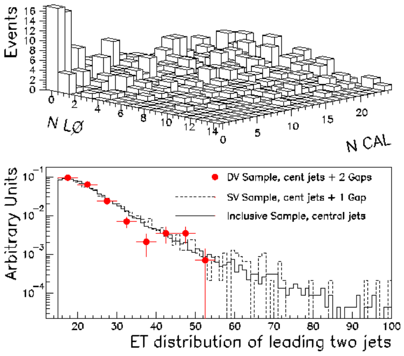

Figure 3. The multiplicity at 1800 GeV after requiring a rapidity gap on the opposite side. The peak in the low multiplicity bins shows a clear double gap signal. The bottom figure is the corresponding jet E_T distribution for the double gap (circles), one gap (dotted), and an inclusive jet (solid) samples.

3. HARD DOUBLE POMERON EXCHANGE

Hard double pomeron exchange, with two forward rapidity gaps and central jet production, is another process to enable better understanding of diffraction. In the Ingelman-Schlein model, both the incoming proton and anti-proton can be said to emit a pomeron and the two pomerons interact to produce a massive system.

The data analysis for HDPE is analagous to hard single diffraction, except that we require a rapidity gap on one side from $2.5 < |\eta| < 5.2$ and plot the multiplicity on the opposite side in the same region. We trigger at 1800 GeV (630 GeV) on two 15 (12) GeV jets and a rapidity gap in the L0 detector. Figure 3 shows the multiplicity distributions at 1800. The distributions at 630 GeV are similar. A clear peak at low multiplicity is observed in both distributions above a flat background in qualitative agreement with expectations for an HDPE signal. Figure 3 also shows the jet E_T distribution for events with two gaps, one gap, and an inclusive distribution. The jet E_T spectra for jets in both kinds of gap events are observed to be similar to the inclusive $p\overline{p}$ scattering.

4. CONCLUSION

We have presented a preliminary measurement of HSD with the DØ detector at Fermilab at 1800 and 630 GeV for forward and central jet events. We find for the Ingelman-Schlein model to describe the data, the data requires either a quark structure or a combination hard or flat gluon structure with a soft gluon component, although the rates are high for the latter. We have also measured the momentum lost by the diffracted proton and found it greater than expected in the standard picture of diffractive physics. In addition, we have also observed a class of events with two rapidity gaps and high E_T jet production consistent with expectations for HDPE.

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