DØ Rapidity Gap Studies

Andrew Brandt (DØ Collaboration)[a]

[a]University of Texas at Arlington, P.O. Box 19059, Arlington, TX 76019

DØ Run I Rapidity Gap studies are briefly described.

1. Hard Diffraction Introduction

Inelastic diffractive collisions are responsible for 10–15% of the $\overline{p}p$ total cross section and have been described by Regge theory through the exchange of a pomeron. Diffractive events are characterized by the absence of significant hadronic particle activity over a large region of rapidity or pseudorapidity. This empty region is called a rapidity gap and can be used as an experimental signature for diffraction. Recent interest in diffraction has centered on the possible partonic nature of the pomeron in the framework of quantum chromodynamics (QCD), as suggested by Ingelman and Schlein [1]. Hard single diffraction (HSD), which combines diffraction and a hard scatter (such as jet or W-boson production), can be used to study the properties of the pomeron.

The pomeron's partonic nature was first inferred by the UA8 experiment [2]. Recent analyses of diffractive jet production [3–5] and diffractive W-boson production [6] are consistent with a predominantly hard gluonic pomeron, but measured rates at the Fermilab Tevatron are several times lower than predictions based on data from the DESY ep collider HERA [7].

Current analyses in DØ on diffractive W-boson exchange, double pomeron exchange (central jets with a forward and a backward rapidity gap), and diffractive jet production all attempt to provide new insight into the nature of the pomeron and diffractive interactions. Here we present new measurements from the most mature of these analyses, diffractive jet production.

2. Diffractive Jet Production

In the DØ detector [8], jets are measured with the uranium/liquid-argon calorimeters using a fixed-cone algorithm. The jets are corrected using standard DØ routines for jet-energy scale [9], except that there is no subtraction of energy from spectator parton interactions, since these are unlikely for diffractive events. To identify rapidity gaps, we measure the number of tiles containing a signal in the LØ forward scintillator arrays ($n_{\mathrm{L}\emptyset}$), and towers ($\Delta\eta \times \Delta\phi = 0.1 \times 0.1$) above threshold in the calorimeters (n_{CAL}).

For $\sqrt{s} = 630$ and 1800 GeV, we use triggers which required at least two jets with transverse energy $E_T >$ 12 or 15 GeV to study the dependence of the gap fraction on jet location. The forward jet triggers required the two leading jets to both have $\eta > 1.6$ (or $\eta < -1.6$), while the central jet triggers had an offline requirement of $|\eta| < 1.0$. The events in the final data samples all have a single $\overline{p}p$ interaction requirement, a vertex position within 50 cm of the center of the interaction region, and two leading jets that satisfy standard quality criteria [10].

The $n_{\mathrm{L}\emptyset}$ versus n_{CAL} distributions are shown in Fig. 1. For forward jet events, these quantities are defined by the η region on the side opposite the two leading jets, while for central jet events they are defined by the forward η interval that has the lower multiplicity. The distributions display a peak at zero multiplicity ($n_{\mathrm{CAL}} = n_{\mathrm{L}\emptyset} = 0$), in qualitative agreement with expectations for a diffractive component in the data.

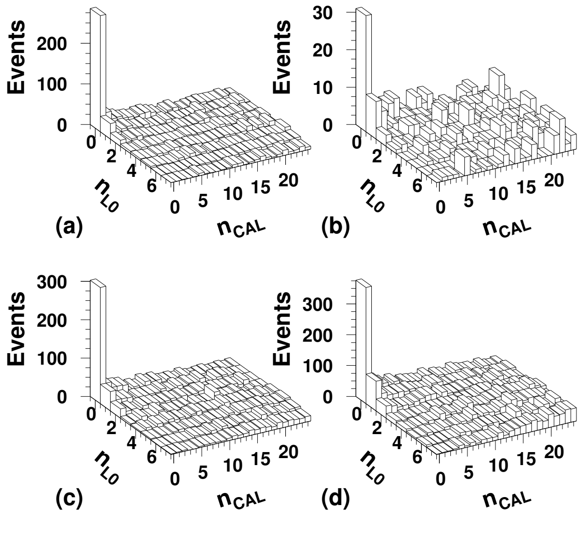

Figure 1. Multiplicity distributions at $\sqrt{s} = 1800\,\mathrm{GeV}$ for (a) forward and (b) central jet events, and at $\sqrt{s} = 630\,\mathrm{GeV}$ for (c) forward and (d) central jet events.

Table 1
The measured and predicted gap fractions and their ratios.

Sample	Data	Hard Gluon	Flat Gluon	Soft Gluon	Quark
			Gap Fractions		
1800 GeV $\|\eta\| > 1.6$	$(0.65 \pm 0.04)\%$	$(2.2 \pm 0.3)\%$	$(2.2 \pm 0.3)\%$	$(1.4 \pm 0.2)\%$	$(0.79 \pm 0.12)\%$
1800 GeV $\|\eta\| < 1.0$	$(0.22 \pm 0.05\%$	$(2.5 \pm 0.4)\%$	$(3.5 \pm 0.5)\%$	$(0.05 \pm 0.01)\%$	$(0.49 \pm 0.06)\%$
630 GeV $\|\eta\| > 1.6$	$(1.19 \pm 0.08)\%$	$(3.9 \pm 0.9)\%$	$(3.1 \pm 0.8)\%$	$(1.9 \pm 0.4)\%$	$(2.2 \pm 0.5)\%$
630 GeV $\|\eta\| < 1.0$	$(0.90 \pm 0.06)\%$	$(5.2 \pm 0.7)\%$	$(6.3 \pm 0.9)\%$	$(0.14 \pm 0.04)\%$	$(1.6 \pm 0.2)\%$
			Ratios of Gap Fractions		
630/1800 $\|\eta\| > 1.6$	1.8 ± 0.2	1.7 ± 0.4	1.4 ± 0.3	1.4 ± 0.3	2.7 ± 0.6
630/1800 $\|\eta\| < 1.0$	4.1 ± 0.9	2.1 ± 0.4	1.8 ± 0.3	3.1 ± 1.1	3.2 ± 0.5
1800 $\|\eta\| > 1.6/\|\eta\| < 1.0$	3.0 ± 0.7	0.88 ± 0.18	0.64 ± 0.12	$30. \pm 8.$	1.6 ± 0.3
630 $\|\eta\| > 1.6/\|\eta\| < 1.0$	1.3 ± 0.1	0.75 ± 0.16	0.48 ± 0.12	$13. \pm 4.$	1.4 ± 0.3

The gap fraction is extracted from a two-dimensional fit to the lego plot of $n_{\mathrm{L}Ø}$ versus n_{CAL}. Table 1 shows the gap fractions obtained for the four event samples. Uncertainties are dominated by those on the fit parameters. Table 1 shows that the gap fractions at $\sqrt{s} = 630$ GeV are larger than gap fractions at $\sqrt{s} = 1800$ GeV and that gap fractions for forward jets are larger than for central jets. Table 1 also lists predicted gap fractions for several possible pomeron structure functions.

We compare the data to Monte Carlo (MC) simulations using the hard diffractive event generator POMPYT [11]. In POMPYT, a pomeron is emitted from the proton with a certain probability (called the flux factor [1]), and has a structure functions $s(\beta)$, where β is the fractional momentum of the pomeron carried by the hard parton. We used the standard Donnachie-Lanshoff flux factor [12] in this analysis and compare our data to several typical structure function choices. In each case, the gap fraction is defined as the cross section for jet events with a rapidity gap based on POMPYT divided by the jet cross section from PYTHIA [13]. Many uncertainties, such as the choice of proton parton densities, cancel in the ratio. The MC values are corrected for diffractive events that fail the gap selection criteria.

Monte Carlo gap fractions are shown in Table 1. The systematic uncertainties are dominated by the difference in energy scale between data and MC. We observe that rates for harder gluon structures are far higher than supported by data, while the quark structure is in reasonable agreement with the data. The quark structure, however, has previously been shown to predict an excessive rate of diffractive W-Bosons [6].

A hard gluonic pomeron is capable of describing previous measurements [3–6], if combined with a flux factor that decreases with increasing $\sqrt{s}$ [14]. The ratios of gap fractions shown in the lower half of Table 1 provide new information, since the flux factor cancels for the same $\sqrt{s}$, and dependence on the flux factor is reduced for different $\sqrt{s}$. The ratios for jets with $|\eta| > 1.6$ to jets with $|\eta| < 1.0$ show clear disagreement between the data and predictions for a hard-gluon pomeron structure, despite this cancellation. A gluon-dominated pomeron containing both soft and hard components, combined with a reduced flux factor, could describe all the data samples.

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