# DIFFRACTIVE PROCESSES IN D0 EXPERIMENT*

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For D0 Experiment

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With the D0 detector, we have investigated events produced in $\bar{p}p$ collisions with large rapidity gaps and with jet production. We present the result of study at two center-of-mass energies, 630 GeV and 1800 GeV. The fractions of forward and central jet events associated with such rapidity gaps are measured and compared to predictions from Monte Carlo models with various structure functions of Pomeron. Hard diffractive events with production of intermediate vector bosons $W, Z$ have been investigated.

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Inelastic diffractive collisions are responsible for 10–15% of the $\overline{p}p$ total cross section. Diffractive events are characterized by the absence of significant hadronic particle activity over a large region of rapidity or pseudorapidity $\eta = -\ln\tan(\frac{\theta}{2})$ where $\theta$ is the angle of particles or jets relative to the beam. Those interactions are described as Pomeron exchange processes, where the Pomeron represents the virtual exchange of a particle with vacuum quantum numbers. Rapidity gaps signify small transverse momenta $t$ between initial and final states of interacting particles [1]. The kinematic variables are summarized in Fig. 1. The fractional momentum loss of the proton $\xi$, is defined as $\xi \approx \frac{1}{\sqrt{s}}\sum_i E_{\mathrm{T}_i} e^{\eta_i}$ where the summation is over all observed particles. The mass of diffractive system $M = \sqrt{\xi s}$ is thus sensitive to the primary energy.

In this report we present measurements of the characteristics of diffractive jet events, and of the fraction of central and forward jet events that contain forward rapidity gaps at center of mass energies $\sqrt{s} = 630$ and 1800 GeV [2–4]. The results are complementary to results obtained in the experiment CDF [5–7]. We also present new result on diffractive production of intermediate bosons $W$ and $Z$. In the D0 detector [8], jets are

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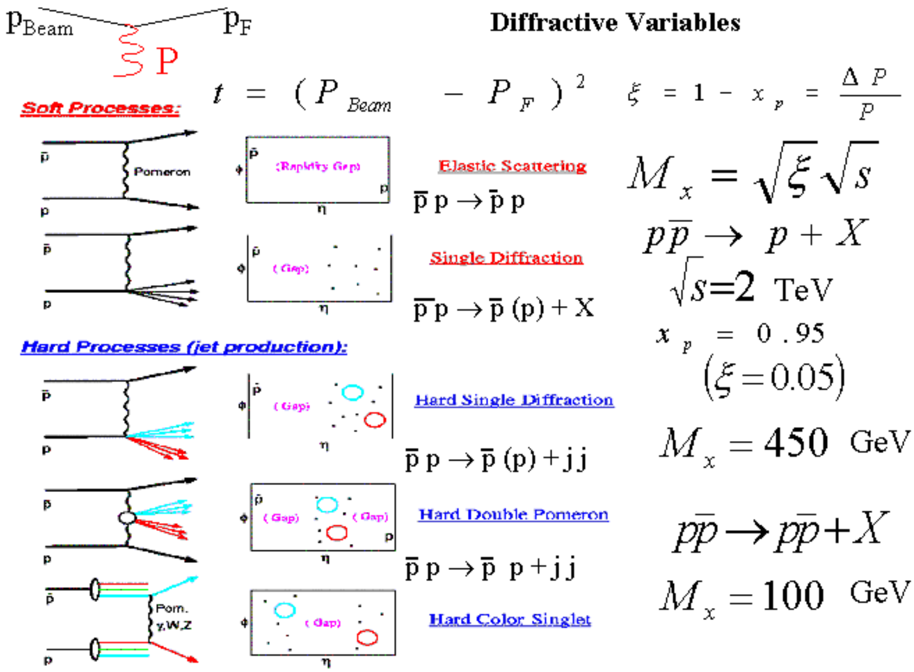


Fig. 1. Kinematics of diffractive processes in $\bar{p}p$ collisions.

measured using the uranium/liquid-argon calorimeters with an electromagnetic section extending to $|\eta| < 4.1$ and coverage for hadrons to $|\eta| < 5.2$ (Fig. 2). Jets are reconstructed using a fixed-cone algorithm with radius $\mathcal{R} = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$ where $\phi$ is the azimuthal angle.

For determination of rapidity gaps, we measure the number of tiles containing a signal in the L0 forward scintillator arrays ($n_{\mathrm{L0}}$), and towers ($\Delta\eta \times \Delta\phi = 0.1 \times 0.1$) above threshold in the calorimeters ($n_{\mathrm{CAL}}$). The L0 arrays provide partial coverage in the region $2.3 < |\eta| < 4.3$. A portion of the two forward calorimeters ($3.0 < |\eta| < 5.2$) is used to measure the calorimeter multiplicity, with a particle tagged by the deposition of more than 150 (500) MeV of energy in an electromagnetic (hadronic) calorimeter tower [9]. The events are selected with the standard criteria of the D0 experiment [10].

To study diffractive two jet production at $\sqrt{s} = 630$ and 1800 GeV, we use two jets with transverse energy $E_{\mathrm{T}} > 12$ or 15 GeV and 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 $|\eta| < 1.0$. At each $\sqrt{s}$, we also implemented the single veto trigger (SV), a dijet trigger that required a rapidity gap on

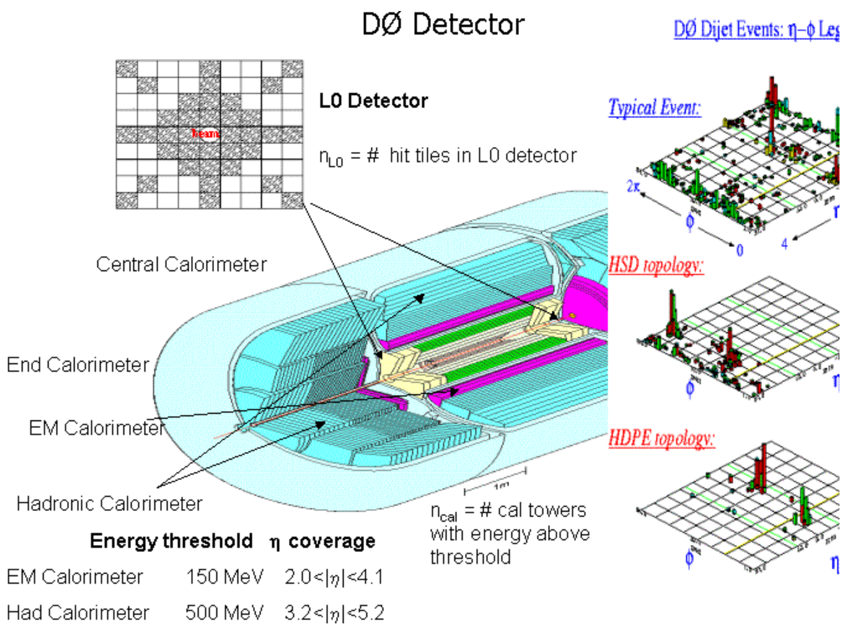


Fig. 2. D0 calorimeter and a scheme of L0 scintillator arrays. Lego plots of examples of diffractive production of jets.

one side (using the L0 detector). The SV trigger was used to obtain large samples of single diffractive candidate events. The number of events in each of the final data samples and the integrated luminosities ($\mathcal{L}$) are given in Table I.

TABLE I

Data samples.

| Data Sample | Jet $\|\eta\|$ | Jet $E_{\rm T}$(GeV) | $\mathcal{L}$ (nb$^{-1}$) | Events |
|---|---|---|---|---|
| 1800 GeV Forward | $> 1.6$ | $> 12$ | 62.9 | 50852 |
| 1800 GeV Central | $< 1.0$ | $> 15$ | 4.55 | 16567 |
| 630 GeV Forward | $> 1.6$ | $> 12$ | 16.9 | 28421 |
| 630 GeV Central | $< 1.0$ | $> 12$ | 8.06 | 48123 |
| 1800 GeV SV | – | $> 15$ | 5700 | 170393 |
| 630 GeV SV | – | $> 12$ | 529 | 64772 |

We compare the data to Monte Carlo (MC) simulations using the hard diffractive event generator POMPYT [11], which is based on the non diffractive PYTHIA program. In POMPYT, a Pomeron is emitted from the proton with a certain probability (flux factor), and has a structure functions $s(x)$, where $x$ is the fractional momentum of the Pomeron carried by the hard parton.

In this analysis we compare our data with four structure functions:

*(i)* 'hard gluon', a Pomeron consisting of two gluons, $s(x) \propto x(1-x)$;

*(ii)* 'flat gluon', $s(x) \propto$ constant;

*(iii)* 'soft gluon', $s(x) \propto (1-x)^5$; and

*(iv)* 'quark', the two-quark analog of *(i)*.

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.

Monte Carlo fits of gap fractions and ratios of gap fractions for the two studied energies are shown in Fig. 3. The hard gluons and flat gluon rates are higher than experimental data. The energy rates of forward jets is lower then for central jets. This seems to be more compatible with combination of soft and hard gluon structure functions.

**Gap Fraction Results**

| Data Sample | Measured Gap Fraction (#Diffractive Dijet / #All Dijets) | Data Sample | Gap Fraction Ratios |
|---|---|---|---|
| 1800 Forward Jets | 0.65% + 0.04% - 0.04% | 630/1800 Forward Jets | 1.8 + 0.2 - 0.2 |
| 1800 Central Jets | 0.22% + 0.05% - 0.04% | 630/1800 Central Jets | 4.1 + 0.8 - 1.0 |
| 630 Forward Jets | 1.19% + 0.08% - 0.08% | 1800 Fwd/Cent Jets | 3.0 + 0.7 - 0.7 |
| 630 Central Jets | 0.90% + 0.06% - 0.06% | 630 Fwd/Cent Jets | 1.3 + 0.1 - 0.1 |

-Forward Jets Gap Fraction > Central Jets Gap Fraction-630GeV -Gap Fraction > 1800GeV Gap Fraction

| Event Sample | Hard Glu | Flat Glu | Quark |
|---|---|---|---|
| 630/1800 FWD | 1.7 ± 0.4 | 1.4 ± 0.3 | 2.7 ± 0.6 |
| 630/1800 CEN | 2.1 ± 0.4 | 1.8 ± 0.3 | 3.2 ± 0.5 |
| 1800 FWD/CEN | 0.9 ± 0.2 | 0.6 ± 0.1 | 1.6 ± 0.3 |
| 630 FWD/CEN | 0.8 ± 0.2 | 0.5 ± 0.1 | 1.4 ± 0.3 |

| Event Sample | Soft Glu | DATA |
|---|---|---|
| 630/1800 FWD | 1.4 ± 0.3 | **1.8 ± 0.2** |
| 630/1800 CEN | 3.1 ± 1.1 | **4.1 ± 0.9** |
| 1800 FWD/CEN | 30. ± 8. | **3.0 ± 0.7** |
| 630 FWD/CEN | 13. ± 4. | **1.3 ± 0.1** |

•Hard Gluon & Flat Gluon forward jet rate is lower than central jet rate -- and lower than observed in data

*Quark rates and ratios are similar to observed

*Combination of Soft Gluon and harder gluon structure is also possible for pomeron structure

Fig. 3. Results of jet productions in $\bar{p}p$ diffractive processes.

A hard gluonic Pomeron is capable of describing previous measurements in experiments Zeus,H1,CDF [12–14], which require a significant amount of soft gluon as well. A comparison of jet properties for diffractive and non-diffractive cases is presented in Fig. 4. The diffractive jets have less radiation, smaller width and are more balanced in azimuthal angle.

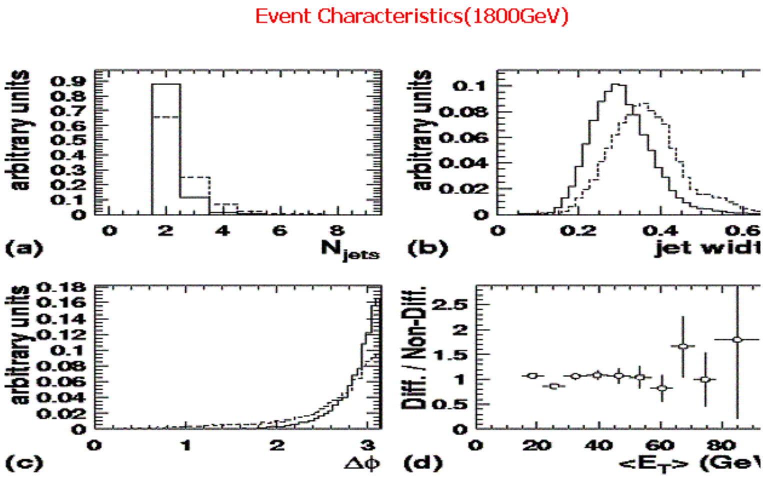


Fig. 4. Properties of diffractively produced jets (full lines) compared with inclusive jets dashed lines).

The multiplicity distributions of events with hard double Pomeron exchange (with two rapidity gaps and central jet productions) at 1800 GeV are presented in Fig. 5. The distributions are compared with the central jet production with one rapidity gap and with inclusive jets. The distributions at both energies $\sqrt{s} = 630$ and 1800 GeVare similar. A clear peak at the low multiplicities is observed, as expected from Hard Double Pomeron exchange.

Diffractively produced $W$ and $Z$ bosons are important for understanding the structure of the Pomeron. The production of intermediate bosons is due to annihilation of quark–antiquark pairs and therefore a good probe of the quark content of the Pomeron. In Fig. 6. the $\xi$ distribution and typical lego-plots for $W$-boson sample are also shown. The distributions of decay variables of diffrative $W$-boson sample are similar to the inclusive $W$-boson distributions (Fig. 7).

We have selected 12622 event of $W$ sample with electrons/positrons and with $E_{\mathrm{T}} > 25$ GeV. There are 8724 events in the central region $|\eta| < 1.1$ and 3898 in the forward regions $|\eta| < 1.1$. The total number of Z bosons decaying into electrons and positrons $E_{\mathrm{T}} > 25$ GeV is 811. From those samples the diffractively produced intermediate bosons have been selected [16]. The results are summarized in Fig. 8.

The percentage of diffractively produced $W$ and $Z$ bosons are compared with Monte Carlo calculation for different structure function. Jets with associated $W$ are also investigated. The ratio of the diffractive $W$ and $Z$ bosons production is not significantly different from 10, which is the ratio for the inclusive sample.

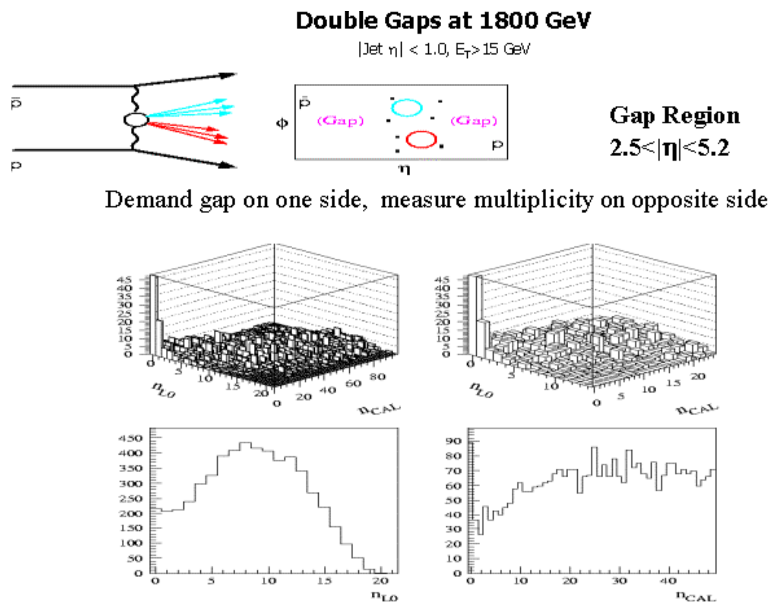


Fig. 5. Double Pomeron exchange and multiplicities distributions in calorimeter.

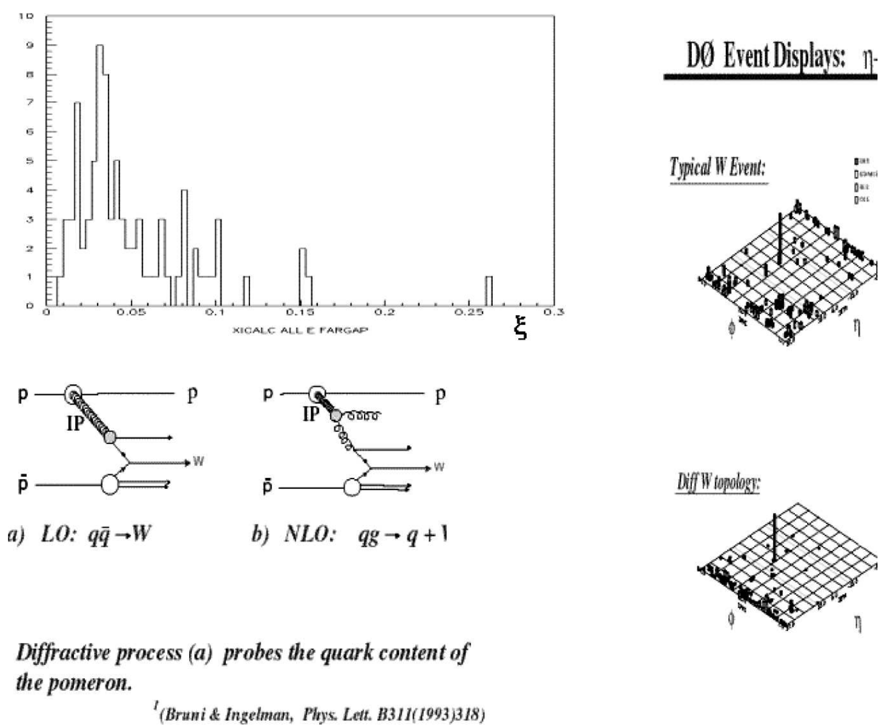


Fig. 6. Mechanisms and examples of $W$-boson production via pomeron exchange.

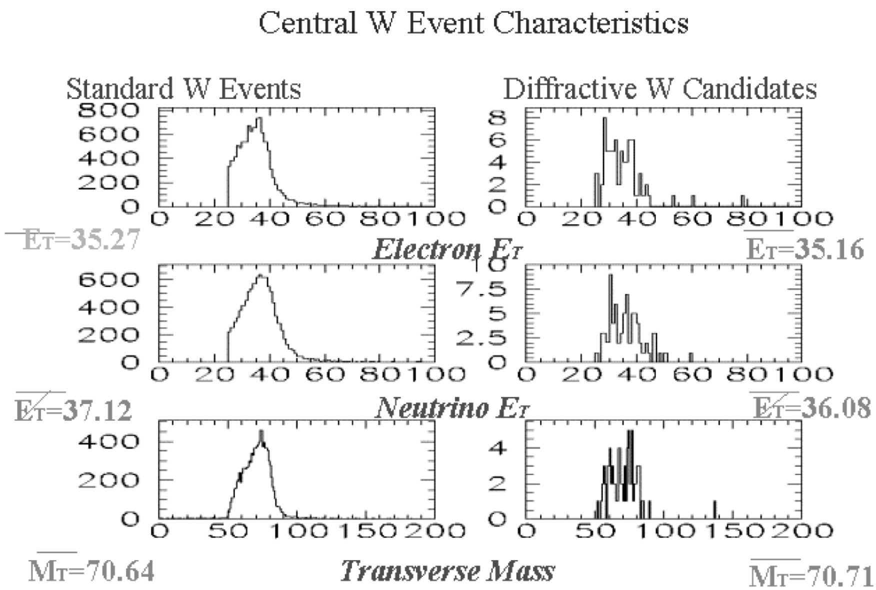


Fig. 7. Comparison of kinematic quantities distributions for normal and diffractively produced $W$.

| Sample | Diffractive /All |
|---|---|
| Central W | (1.08 + 0.21 - 0.19)% |
| Forward W | (0.64 + 0.19 - 0.16)% |
| All W | (0.89 + 0.20 – 0.19)% |
| Z | (1.44 + 0.62 - 0.54)% |

R = (all W/all Z) = 10.34 ± 0.15 ± 0.20 ± 0.10

(Diffractive W/All W) = (0.89 +0.20-0.19)%

(Diffractive Z/All Z) = (1.44 +0.62-0.54)%

$$\frac{\text{Diffractive W}}{\text{Diffractive Z}} = \frac{0.89}{1.44} \times 10.43 = 6.45 \pm {}^{3.14}_{2.79}$$

FINAL GAP FRACTION and STRUCTURE FUNCTIONS

| Sample | Data | Quark | Hard Gluon |
|---|---|---|---|
| Cen W | (1.08 + 0.21 - 0.19)% | (4.1 ± 0.8)% | (0.15 ± 0.02)% |
| For W | (0.64 + 0.19 - 0.16)% | (7.2 ± 1.3)% | (0.25 ± 0.04)% |
| Z | (1.44 + 0.62 - 0.54)% | (3.8 ± 0.7)% | (0.16 ± 0.02)% |

| | Jet $E_T$ | Data | Quark | Hard Gluon |
|---|---|---|---|---|
| W+Jet Rates | >8GeV | (10 ± 3)% | 14-20% | 89 % |
| | >15GeV | (9 ± 3)% | 4-9 % | 53 % |
| | >25GeV | (8 ± 3)% | 1-3 % | 25 % |

Fig. 8. Result of $W$ and $Z$ boson production in diffractive events and comparison with structure functions of Pomeron.

For Run II of the D0 experiment we have installed Roman pots to detect outgoing protons and anti-antiprotons after the interaction, which will enable us to trigger more effectively on diffreactive processes (Fig. 9). Also shown is a projected number of diffractive events, and couple of representative plots of results from 1 $fm^{-1}$ of data.

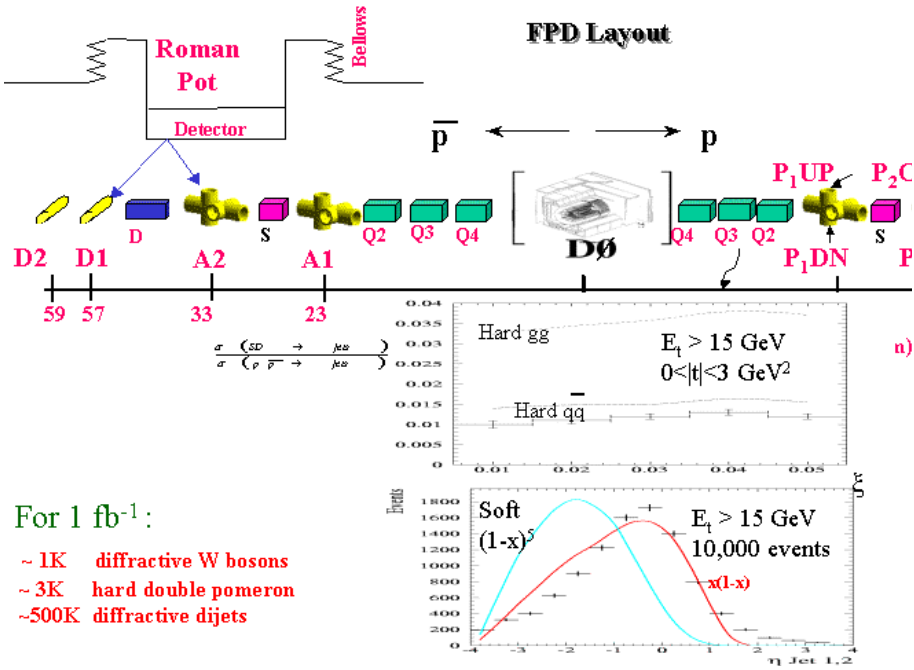


Fig. 9. Layout of the D0 experiment for Run II, and a projection of observed events and tests of Pomeron structure.

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