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DOUBLE DIFFRACTION DISSOCIATION IN $\bar{p}p$ COLLISIONS AT THE FERMILAB TEVATRON

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We present results from a study of double diffraction dissociation in $\bar{p}p$ collisions at the Fermilab Tevatron performed by the CDF Collaboration. The production cross section for events with a central pseudorapidity gap (overlapping $\eta = 0$) of width $\Delta\eta^0 > 3$ is found to be $4.57 \pm 0.02(\text{stat})^{+0.99}_{-1.19}(\text{syst})$ mb [$5.45 \pm 0.02(\text{stat})^{+1.10}_{-1.17}(\text{syst})$ mb] at $\sqrt{s} = 630$ [1800] GeV. Our results are compared with previous measurements and with predictions based on Regge theory and factorization.

We report on measurements of the double-diffractive cross section obtained by CDF at the Fermilab Tevatron $\bar{p}p$ collider at $\sqrt{s} = 1800$ and 630 GeV. The CDF detector has calorimeters covering the region $|\eta| < 4.2$. Charged tracks are detected in the region $|\eta| < 1.1$. Beam-beam counters (BBC's) consisting of scintillator cover the region $3.2 < |\eta| < 5.9$ and are used to trigger on beam-beam collisions.

In double-diffractive (DD) events, the exchange of a color singlet with the quantum numbers of the vacuum, the Pomeron ($I\!\!P$), causes both incident hadrons to dissociate (Fig. 1). Since the exchanged object does not radiate, a rapidity gap is formed in the region in between the resulting diffractive mass clusters.

Regge theory gives the total, elastic, and single-diffractive (SD) cross sections in terms of the $I\!\!P$ trajectory $\alpha(t) = 1 + \epsilon + \alpha' t$, the $I\!\!P$-p coupling $\beta(t)$, and the triple-$I\!\!P$ coupling $g(t) \approx g(0) \equiv \kappa\beta(0)$ [1] for momentum transfer t. Factorization yields the DD cross section for diffractive masses M_1 and M_2 from σ_{SD} and σ_{el} as

$$\frac{d^3\sigma_{DD}}{dt\, dM_1^2\, dM_2^2} = \frac{d^2\sigma_{SD}}{dt\, dM_1^2}\, \frac{d^2\sigma_{SD}}{dt\, dM_2^2} \Big/ \frac{d\sigma_{el}}{dt} \tag{1}$$

$$= \frac{\kappa^2 \beta_1^2(0) \beta_2^2(0)}{16\pi}\, \frac{s^{2\epsilon}}{(M_1^2 M_2^2)^{1+\epsilon}}\, e^{b_{DD} t} \tag{2}$$

where the slope parameter is $b_{DD} = 2\alpha' \ln(s s_0 / M_1^2 M_2^2)$. The diffractive masses can be related to the width Δy and center y_0 of the rapidity gap as $\Delta y \approx \ln(s s_0 / M_1^2 M_2^2)$ and $y_0 \approx \ln(M_2/M_1)$. The DD cross section is then

$$\frac{d^3\sigma_{DD}}{dt\, d\Delta y\, dy_0} = \left[\frac{\kappa\beta^2(0)}{16\pi}\, e^{2[\alpha(t)-1]\Delta y}\right] \left[\kappa\beta^2(0) \left(\frac{s'}{s_0}\right)^{\alpha(0)-1}\right]. \tag{3}$$

We take the constant energy scale to be $s_0 = 1$ GeV^2 and use the values obtained from SD measurements of $\kappa\beta^2_{I\!Pp}(0) = 2.82$ mb, $\epsilon = 0.104$, and $\alpha' = 0.25$ GeV^{-2}. [2] The second term in (3), which is a function of the reduced energy squared $s' = se^{-\Delta y}$, we refer to as the reduced-energy cross section, and is also present in the SD differential cross section. The first term depends on Δy, and we think of this as a gap probability. In single diffraction, the measured differential cross section agrees with the Regge theory prediction in shape but not in normalization. [3,2] Agreement in normalization may be obtained by normalizing the SD gap probability to unity. [4,2]

We have studied soft double diffraction by looking for central rapidity gaps in minimum-bias events which have hits in the BBC's. We use gaps which overlap $\eta = 0$ rather than the largest gap anywhere in the detector because the latter method is more likely to be biased by inefficiencies in the calorimeters. The η of the track or calorimeter tower above a given threshold with the smallest $|\eta|$ for $\eta > 0$ ($\eta < 0$) is defined to be $\eta_{max(min)}$, as shown in Fig. 1. Figure 2 compares the data to non-diffractive (ND), SD, and DD Monte Carlo (MC) simulated events as a function of η_{max} and $-\eta_{min}$. Structure due to different thresholds and efficiencies in the calorimeter can be seen, e.g., at the interface between the plug and forward calorimeters at $\eta \sim 2.4$. The bins for $|\eta_{max(min)}| > 3.2$ contain all events with the lowest-$|\eta|$ particle in the BBC, $3.2 < |\eta| < 5.9$.

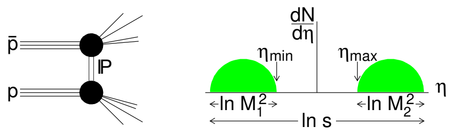

Figure 1: A double-diffractive interaction at center-of-mass energy $\sqrt{s}$, producing diffractive masses M_1 and M_2 separated by a rapidity gap of width $\eta_{max} - \eta_{min}$.

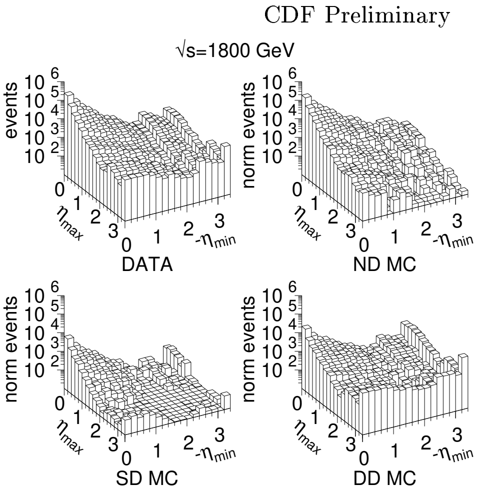

Figure 2: The number of events as a function of η_{max} and $-\eta_{min}$: (a) 1800 GeV data, (b) ND, (c) SD and (d) DD MC-generated events.

The SD contribution is fixed by known cross sections [3] and the fraction of events passing the BBC trigger in the MC. The ND and DD contributions are determined by fitting the MC-generated distributions to the data in Fig. 3, which shows the number of events versus $\Delta\eta^0 = \eta_{max} - \eta_{min}$. The DD MC uses the differential cross section (3), so the agreement between data and MC seen in Fig. 3 shows that the gap-width, or equivalently mass, dependence appears to be consistent with Regge theory, as was also observed by the H1 collaboration for γp double diffraction. [5]

We find cross sections at $\sqrt{s} = 1800$ (630) GeV by measuring $\sigma_{DD}\mathcal{A}$, where $\mathcal{A}$ is the acceptance for DD events triggering the BBC's. From the DD MC, $\mathcal{A} = (56.6 \pm 7.4)\%$ $[(63.2 \pm 6.5)\%]$, which yields $\sigma_{DD}(\Delta\eta^0 > 3) = 5.45 \pm 0.02(\text{stat})^{+1.10}_{-1.17}(\text{syst})$ mb $[\sigma_{DD}(\Delta\eta^0 > 3) = 4.57 \pm 0.02(\text{stat})^{+0.99}_{-1.19}(\text{syst})$ mb$]$.

The extrapolation to all gaps of width $\Delta\eta > 3$ using (3) yields cross sections 1.43 (1.34) times larger. These cross sections are shown in Fig. 4 along with adjusted results from UA5; [6] in extrapolating the UA5 data from the measured region to obtain $\sigma_{DD}(\Delta\eta > 3)$, we use a slope of $b_{DD} = 2\alpha'\Delta\eta$ (2) instead of the slope used by UA5, $b_{DD} = 7$ GeV^{-2}. [7] The measured DD cross sections are much smaller than the Regge theory prediction (solid curve), but are in general agreement with predictions found by normalizing the gap probability in (3) to unity (dashed curve).

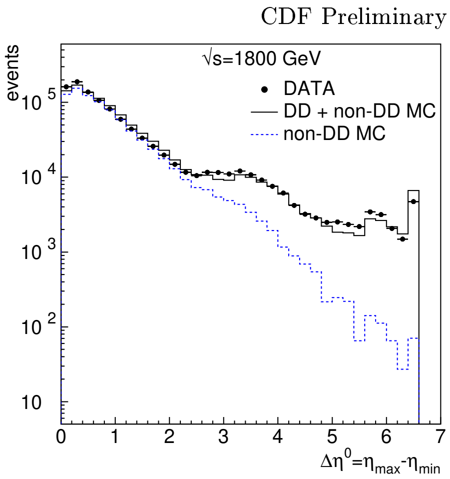

Figure 3: The number of events versus $\Delta\eta^0 = \eta_{max} - \eta_{min}$ for 1800 GeV data, and for DD + non-DD and only non-DD MC-generated events.

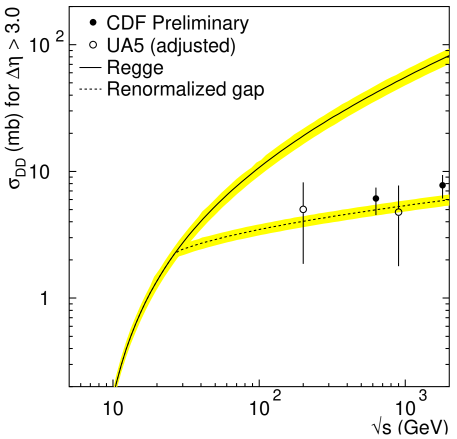

Figure 4: The total DD cross section versus $\sqrt{s}$ compared with predictions from Regge theory and factorization (3) and from normalizing the gap probability to unity in (3).

References

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