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## NEW DIFFRACTION RESULTS FROM CDF

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We report measurements of hard diffractive processes performed by the CDF collaboration in proton-antiproton collisions at the Fermilab Tevatron collider at $\sqrt{s}$=1960 GeV. The characteristics of the diffractive structure function from diffractive dijet production studies are presented. The results of exclusive dijet production in double pomeron exchange are discussed in the context of exclusive Higgs production at the LHC.

## 1  Introduction

A hadronic diffractive process can be defined as a reaction in which no quantum numbers are exchanged between the colliding particles and/or a large, non exponentially suppressed, rapidity gap (region devoid of particles) is present. In the framework of Regge theory diffractive reactions are characterized by the exchange of a *pomeron*, a hypothetical object with vacuum quantum numbers.

Although the term "diffraction" has been used in high-energy physics since the 1950's [1], the era of exciting experimental diffractive measurements, as we know them now, started in the 1980's, when "hard diffraction" was first discussed [2]. Diffractive reactions that incorporate hard processes, such as production of jets in $p\bar{p}$ collisions, allow one to study diffraction in a perturbative QCD framework, thus providing an opportunity to study the nature of the *pomeron*.

The CDF experiment at the Tevatron collider contributed extensively to the field of diffraction during Run I by studying a wide range of physical processes at two different center of mass energies, $\sqrt{s}$=630 and 1800 GeV [a]. Many important observations were made regarding the diffractive structure function of the *pomeron*, the breakdown of QCD factorization in hard diffraction between Tevatron and HERA, and the discovery of large rapidity gaps between two jets [3-5]. In 2001, CDF started a second phase of data-taking (Run II) at $\sqrt{s}$=1960 GeV with new upgraded detectors.

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[a]See K. Goulianos, "Twenty Years of Diffraction at the Tevatron," in these Proceedings.

## 2    CDF Forward Detectors in Run II

Since the identification of diffractive events requires either tagging of the leading particle or observation of a rapidity gap, the forward detectors are very important for the implementation of a diffractive program. The schematic layout of the CDF detectors in Run II is presented in Fig. 1.
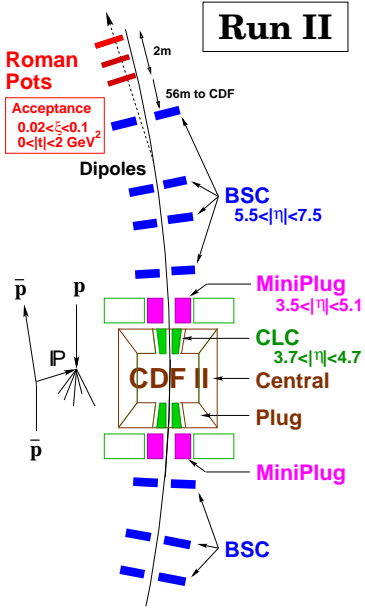


Figure 1: Layout of CDF Run II forward detectors along the beam-pipe (not to scale).

The Forward Detectors include the Roman Pot fiber tracker spectrometer (RPS), the Beam Shower Counters (BSCs), and the Miniplug calorimeters (MP). The RPS was used in Run I and was re-installed for Run II to detect leading anti-protons. It is a fiber detector spectrometer located along the beamline 56 m from the interaction point (IP). It consists of three stations, and a coincidence of three trigger counters, one in each station, selects events with a leading $\bar{p}$. The Beam Shower Counters [6], covering the pseudorapidity range $5.5 < |\eta| < 7.5$, detect particles from the interaction point traveling in either direction along beam-pipe. There are three(four) stations installed at increasing distances in the $p(\bar{p})$ directions. The BSCs are used to select diffractive events by identifying forward rapidity gaps and thus reducing non-diffractive background on the trigger level. Two Miniplug Calorimeters [7] are designed to measure energy and lateral position of both electromagnetic and hadronic showers in the pseudorapidity region of $3.5 < |\eta| < 5.1$. The ability to measure the event energy flow in the very forward rapidity region is extremely valuable for identification of diffractive events in the high luminosity environment of Run II.

## 3    Run II Diffraction Measurements

### 3.1   Diffractive Structure Function

The data sample for single diffractive (SD) dijet studies is collected by triggering on a leading anti-proton in combination with at least one calorimeter tower with $E_T > 5$ GeV. The control non-diffractive (ND) dijet sample is triggered on the same calorimeter tower requirement. The ratio of SD to ND dijet production rates in leading order QCD is equal to the ratio of the corresponding structure functions at a given $x_{Bj}$, where $x_{Bj}$ is evaluated for each event from the $E_T$ and $\eta$ of the jets according to the formula: $x_{Bj} = \frac{1}{\sqrt{s}} \sum_{i=1}^{n} E_T^i e^{-\eta^i}$. The results are in good agreement with the Run I measurement. Preliminary results also show that there is no significant dependence of the ratio on $Q^2 \equiv \langle E_T^2 \rangle$ in the $Q^2$ range from 100 GeV$^2$ to 1600 GeV$^2$(see Fig. 2(left)), which indicates that the *pomeron* $Q^2$ evolution is similar to that of the proton.

### 3.2   Exclusive Dijet Production

The possibility of observing the Higgs boson in central exclusive production at the Large Hadron Collider (LHC) has received considerable attention in the last few years (see [9]). The process $pp \rightarrow p + H + p$, where the $+$ sign denotes presence of a rapidity gap, has many appealing properties, such as possible determination of the Higgs mass with good accuracy and clean environment due to the presence of rapidity gaps. Although the cross section for exclusive Higgs

production is too small to be observed at the Tevatron, there are several processes which could be studied to calibrate theoretical predictions. The two cleanest signatures are exclusive $\chi_c^0$ production and central exclusive $\gamma\gamma$ production. These processes are under study and an upper limit of $49\pm18(stat)\pm39(syst)$pb for exclusive $\chi_c^0$ production from a search for $J/\psi + \gamma$ events has been obtained by CDF. However, the process with the highest rate is predicted to be central exclusive dijet production.

Exclusive dijet production by double pomeron exchange (DPE) was studied by the CDF collaboration in Run I[8]. In Run II our sample is collected with a dedicated trigger requiring a BSC gap on the proton side, a leading anti-proton in the RPS, and a single calorimeter tower with $E_T > 5$ GeV. An additional offline requirement of a gap in the MP on the proton side enhances the signal in the initial sample. For the resulting DPE candidate events, the "dijet mass fraction", $R_{jj}$, is defined as the ratio of the invariant mass of the two leading jets, $M_{jj}$, to the mass of the entire system, excluding leading $p$ and $\bar{p}$, $M_X$. The dijet mass $M_{jj}$ is measured from the energies of the calorimeter towers inside the jet cones, and the mass of the system is calculated according to $M_X = \sqrt{\xi_p \cdot \xi_{\bar{p}} \cdot s}$, where the values of $\xi$ are calculated from all calorimeter towers. If the dijets were produced exclusively, $R_{jj}$ would be, by definition, equal to unity. However, taking into account resolution effects, the exclusive region is experimentally defined as $R_{jj} > 0.8$. Fig. 2 (right) shows the $R_{jj}$ distributions for DPE dijets, compared with those from the single diffractive sample. No significant excess is observed for $R_{jj} > 0.8$ over a smooth distribution. The upper limit for exclusive dijet production, taken as cross section for DPE events with $R_{jj} > 0.8$, is $1.14 \pm 0.06(stat)^{+0.47}_{-0.45}(syst)$ nb and $25 \pm 3(stat)^{+15}_{-10}(syst)$ pb for leading jet $E_T > 10$ and 25 GeV, respectively (see Fig. 3(left)). These experimental numbers are consistent with recent theoretical predictions[10].
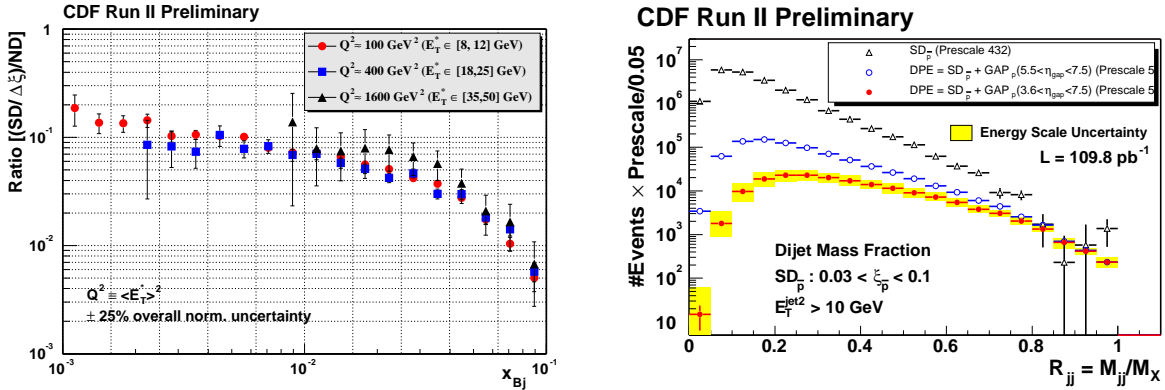


Figure 2: (left) Ratio of SD to ND dijet event rates per unit $\xi$ as a function of $x$-Bjorken at various $Q^2$ ranges; (right) Dijet mass fraction distributions for DPE events with $5.5 < \eta_{gap} < 7.5$ (open circles) and $3.6 < \eta_{gap} < 7.5$ (filled circles), and for SD events (triangles).

One of the crucial advantages of exclusive central production is the suppression at the leading order of the background sub-process $gg \to q\bar{q}$, as $m^2/M \to 0$ ($J_z=0$ selection rule). This condition is satisfied when the quarks are light or when the dijet mass is much larger than the quark mass. The $q\bar{q}$ suppression mechanism can be used to extract exclusive dijets by identifying jets originating from quarks and looking for the suppression of quark jets relative to all jets at high $R_{jj}$. CDF has performed this study by using jets from heavy flavor (HF) quarks. The advantage of the method is the relatively good efficiency of HF jet identification, while a disadvantage is the necessity of separating flavor creation HF jets from those coming from gluon splitting. CDF studied the production of bottom quark jets in a 110 pb$^{-1}$ data sample of DPE jet events and found the fractions of b-tagged jets in the inclusive DPE dijet events, $R_{btag}$, as a function of $R_{jj}$ presented in Fig. 3(right). A decreasing trend is observed in

the $R_{jj} > 0.7$ region, although no definite conclusion can be made due to the still large statistical and systematic uncertainties. To quantify the magnitude of the difference at the last bin, the ratio of the weighted averages of $R_{btag}$ for $R_{jj} > 0.7$ and $R_{btag}$ for $R_{jj} > 0.4$ is measured to be $0.59 \pm 0.33(stat) \pm 0.23(syst)$.
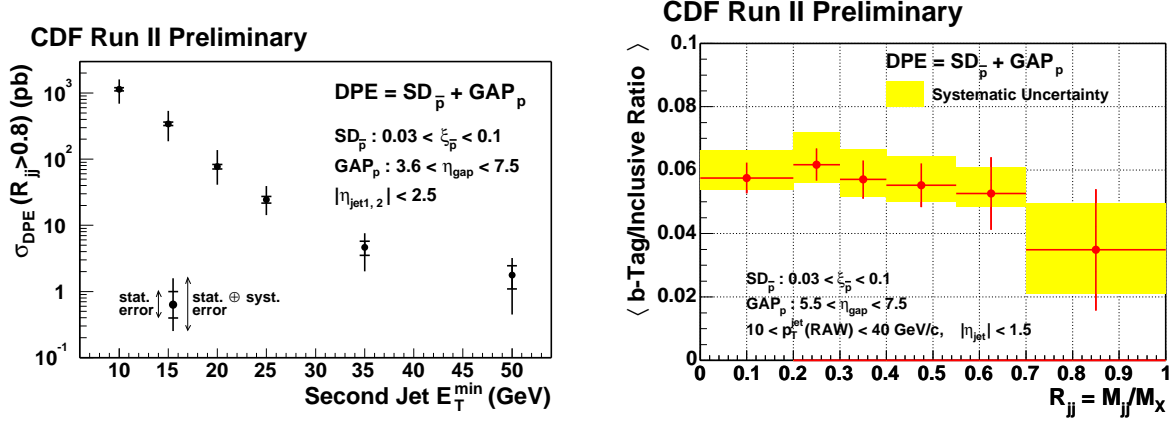


Figure 3: (left) DPE dijet cross section for $R_{jj} > 0.8$ as a function of $E_T^{min}$, the $E_T$ of the next to the highest $E_T$ jet; (right) Ratio of b-tagged jets to all inclusive jets as function of a dijet mass fraction, $R_{jj}$.

## 4   Conclusion

The CDF collaboration continues an extensive program of diffractive studies. The data obtained with dedicated triggers are being used to further our knowledge of the diffractive structure function, in particular, its $\xi$ and $Q^2$ dependence. Understanding the exclusive production in DPE processes is another goal for Run II. Upper limits on exclusive dijet production cross sections are comparable with theoretical calculations. The results from the Tevatron data and from interpretations of these measurements can be applied to calibrate predictions for central exclusive production cross sections at the LHC.

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