# Recent results on diffraction from CDF


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We report recent results on diffraction and exclusive production obtained by the CDF collaboration in $p\bar{p}$ collisions at the Fermilab Tevatron collider at $\sqrt{s}$=1.96 TeV. A measurement of the $Q^2$ and $t$ dependence of the diffractive structure function extracted from diffractive dijet production in the range of $10^2 < Q^2 < 10^4$ GeV$^2$ and $|t| < 1$ GeV$^2$ is presented. Results are also presented for exclusive $e^+e^-$, $\gamma\gamma$, and dijet production.


## 1 Introduction

The diffractive process in hadron-hadron colliders can be defined as a reaction in which leading nucleon remains intact, 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 an exchange of the *pomeron*, a hypothetical object with vacuum quantum numbers. Diffractive reactions involving hard processes, such as production of jets, allow to study the nature of the exchanged object, *pomeron*, in the framework of perturbative QCD (pQCD).

CDF collaboration at Fermilab $p\bar{p}$ collider investigated various diffractive reactions at three center of mass energies, $\sqrt{s}$=1800 GeV (Run I), $\sqrt{s}$=630 GeV (Run IC), and $\sqrt{s}$=1960 GeV (Run II). In this proceedings we present the latest results from Run II studies in diffractive dijet production and central exclusive $e^+e^-$, $\gamma\gamma$, and dijet production.

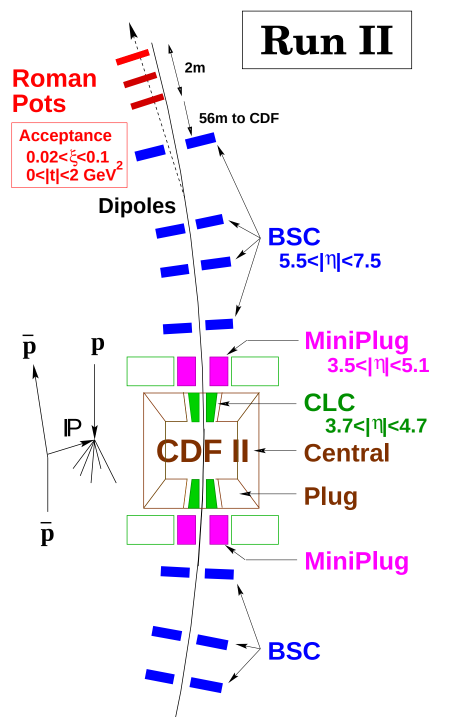


Figure 1: Layout of CDF Run II forward detectors along the beam-pipe (not to scale).

## 2 CDF Forward Detectors

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. The Forward Detectors include the Roman Pot fiber tracker spectrometer (RPS) to detect leading anti-protons; the Beam Shower Counters (BSCs) [1], covering the pseudorapidity range $5.5 < |\eta| < 7.5$, detecting particles from the interaction point traveling in either direction along beam-pipe, used to select diffractive events by identifying forward rapidity gaps, thus reducing non-diffractive background on the trigger level; and the Miniplug calorimeters (MP) [2], 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 Diffractive Dijet Production

The data sample for the study of the single diffractive dijet production is collected by triggering on a leading anti-proton in RPS in combination with at least one jet in the event. By comparing two samples of dijet events, diffractive and non-diffractive, the diffractive structure function is extracted. This study extends our previous results from Run I by studying the $Q^2$ dependence of the diffractive structure function, where $Q^2$ is defined as an average value of the mean dijet $E_T$. In the range of 100< $Q^2$ <10000 GeV$^2$ no significant $Q^2$ dependence is observed, which indicates that QCD evolution of the *pomeron* is similar to that of the proton. CDF also studied $Q^2$ dependence of four-momentum transfer squared, $t$, distributions in soft and hard single diffractive processes. Fig. 2 shows $t$ distributions for different $Q^2$ values. The slope of the distribution at $|\ t\ |$=0 (GeV/c$^2$) does not show any dependence on $Q^2$.

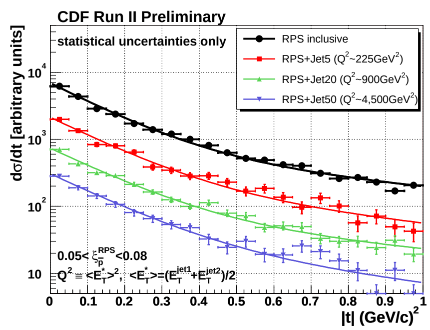


Figure 2: $t$ distributions in soft and hard SD events for different $Q^2$ ranges. Data sample of 128 pb$^{-1}$.

## 4 Exclusive Dijet Production

Central exclusive production became a very interesting topic of study at CDF. In leading order QCD such exclusive processes can occur through exchange of a color-singlet two gluon system between nucleon, leaving large rapidity gaps in forward regions. One of the gluons participates in a hard interaction and additional screening gluon is exchanged to cancel the color of the interacting gluons, and allowing the leading hadrons to stay intact. This is also a special case of dijet/diphoton production in double *pomeron* Exchange (DPE), $p + \bar{p} \to p + X + \bar{p}$. Central exclusive production is generally suppressed by the Sudakov form factor, however it is potentially useful channel to search for the light Standard Model Higgs boson, predominantly decaying to $b\bar{b}$, at the LHC, since exclusive $b\bar{b}$ production is expected to be significantly suppressed by a helicity selection ($J_Z = 0$) rule. Although the cross section for the exclusive Higgs production is too small to be observed at the Tevatron, several processes mediated by the same mechanism but with the higher production rates can be studied to check theoretical predictions.

The data sample of 313 pb$^{-1}$ for the exclusive dijet production was collected with the

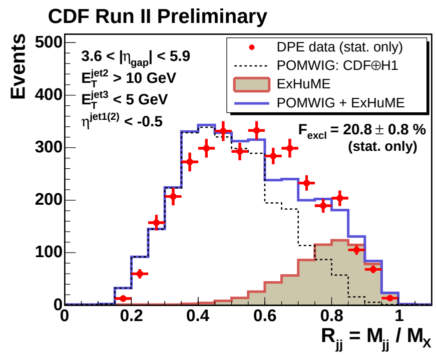


Figure 3: Dijet mass fraction $R_{jj}$ in data (dark points) and best fit (solid line) obtained using inclusive (dashed line) and exclusive ExHuME (shaded area) MC predictions.

dedicated trigger requiring a BSC gap on the proton side in the addition to the requirement for the leading anti-proton in the RPS and at least one calorimeter tower with $E_T$ >5 GeV. The events in data sample also passed the offline requirement of additional gap in MP on the proton-side. The observable sensitive to the amount of energy concentrated in dijet, is the dijet mass fraction $R_{jj} = M_{jj}/M_X$, where $M_{jj}$ is the invariant mass of the two highest $E_T$ jets, and $M_X$ is the mass of the whole system with the exception of the leading particles. $R_{jj}$ of exclusive dijet is expected to peak around $R_{jj} \sim 0.8$ and have a long tail toward low values due to hadronization of partons causing energy spills from the jet cones and gluon radiation in initial and final states. The exclusive signal is extracted by comparing the dijet data with inclusive DPE Monte Carlo predictions, POMWIG [3] event generator with the detector simulation, and by looking for the excess at high $R_{jj}$ values. The $R_{jj}$ distributions comparison shows clear excess of data at high $R_{jj}$. The excess at high $R_{jj}$ values is compared with different exclusive dijet production models [4]-[5] implemented in ExHuME [6] and DPEMC [7] MC simulations. Fig. 3 shows the $R_{jj}$ distribution for the data and the best fit to the data shape obtained from the inclusive POMWIG and exclusive ExHuME predictions. As can be seen from this plot, the data excess at high $R_{jj}$ can be well described by the exclusive dijet production. From the MC fits to the data, we measure the cross section of exclusive dijet production as a function of minimum second jet $E_T$, see Fig. 4(left). The data prefer ExHuME MC and pQCD calculations at LO parton level (KMR) [4] calculations.

Exclusive dijet production at LO is dominated by $gg \to gg$, while contributions from $gg \to q\bar{q}$ are strongly suppressed [4] by the helicity selections. Confirming this suppression will provide additional evidence to support the results obtained from MC based extraction of the exclusive dijet signal. We measure the ratio $F_1$ of heavy flavor quark jets to all jets as a function of $R_{jj}$ using data sample of 200 pb$^{-1}$ triggered by the presence of anti-proton in RPS, forward gap on proton side, dijets in central region and at least one displaced vertex track with $p_T$ >2 GeV/c. The last requirement enhances the heavy flavor content of the sample. The results, see Fig. 4(right), show the normalized ratio of heavy flavor jets to all jets as a function of $R_{jj}$. The decreasing trend of the $F_1$ ratio toward high $R_{jj}$ values is compared with MC based results presented as $F_2$, where $F_2$ is the ratio of the inclusive MC predicted events, which are normalized to the data at $R_{jj}$ >0.4. The two results are consistent with each other.

## 5 Exclusive $e^+e^-$ and $\gamma\gamma$ Production

In these proceedings we report the observation of exclusive $e^+e^-$ production at hadron colliders. The data sample used for this study, corresponds to an integrated luminosity of 532 pb$^{-1}$, and was collected with the dedicated trigger requiring absence of any particle

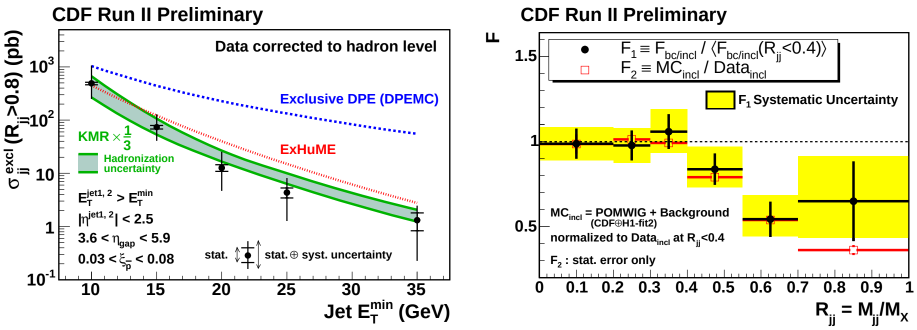


Figure 4: (left) Measured exclusive dijet cross section for $R_{jj}$ >0.8 as a function of minimum second jet $E_T$. The dashed (dotted) lines show the ExHuME (DPEMC) Monte Carlo predictions, shaded band is the KMR calculations at LO parton level, scaled down by a factor 3; (right) Values of $F_1$ (black points) and $F_2$ (white squares) as function of $R_{jj}$, where $F_1$ is the ratio of heavy flavor jets to all inclusive jets, normalized to the weighted average value in the region of $R_{jj}$ >0.4, $F_2$ is the ratio of POMWIG MC to inclusive DPE dijet data, systematic error is the shaded band.

signatures in the detector, except for $e^+$ or $e^-$ candidates, each with the transverse energy $E_T$ >5 GeV and pseudorapidity $|\eta|$ <2. With these criteria 16 events were observed compared to a background expectation of 1.9± 0.3 events. These events are consistent in cross section and properties with the Quantum Electro-Dynamics process $p\bar{p} \rightarrow p + e^+e^- + \bar{p}$ through two photon exchange. The measured cross section is $1.6^{+0.5}_{-0.3}(stat) \pm 0.3(syst)$ pb, which agrees well with the theoretical prediction of 1.71±0.001 pb. This agreement is the evidence that the cuts we make to define the central exclusive processes are correct.

Search for exclusive diphoton events, $p\bar{p} \rightarrow p + \gamma\gamma + \bar{p}$ follows the same events criteria as the exclusive $e^+e^-$ search, and is using the same date sample, except that the photon candidates, defined as an electromagnetic clusters with $E_T$ >5 GeV and $|\eta|$ <1, have no tracks pointing to the clusters. The three events pass these criteria. Backgrounds to $\gamma\gamma$ production can arise from exclusive pair production of neutral mesons, ($\pi^0\pi^0$ and $\eta\eta$). These processes cannot be unambiguously distinguished from $\gamma\gamma$ production on an event by event basis. Therefore a 95% C.L. upper limit on the exclusive $\gamma\gamma$ production cross section of 410 fb is reported, approximately a factor of 10 higher than the theoretical prediction [8].

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