New CDF Results on Diffraction.

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We report new diffraction results obtained by the CDF collaboration in proton-antiproton collisions at the Fermilab Tevatron collider at $\sqrt{s}$ =1.96 TeV. The first experimental evidence of exclusive dijet and diphoton production is presented. The exclusive results are discussed in context of the exclusive Higgs production at LHC. We also present the measurement of the Q^2 and t dependence of the diffractive structure function.

Keywords: QCD, diffraction, exclusive production

I. INTRODUCTION

Diffractive reactions, which constitute a substantial fraction of the total cross section in hadron-hadron scattering, can be described in terms of the *pomeron* exchange, hypothetical object with the quantum numbers of the vacuum. The experimental signatures of the diffraction consist in particular kinematic configurations of the final states: presence of non-exponentially suppressed large rapidity gaps and/or presence of the intact leading particles. The diffractive processes became an important tool in understanding many interesting aspects of QCD such as low-x structure of the proton, behavior of QCD in the high density regime. Recently, a lot of attention was drawn to the possibility of discovering the diffractively produced Higgs boson at the Large Hadron Collider (LHC).

Significant progress in understanding diffraction has been made at the Tevatron $p\bar{p}$ collider. CDF collaboration contributed extensively by studying a wide variety of diffractive processes at three different center-of-mass energies: $\sqrt{s}$ =630 GeV, 1800 GeV - Run I, and 1960 GeV - Run II. 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 [1]-[3].

II. DIFFRACTIVE DIJET PRODUCTION

One of the diffractive processes studied during Run I and Run II is the hard single diffraction, which from the phenomenological point of view is described by assuming that a *pomeron* emitted by the incident antiproton undergoes a hard scattering with the proton. Comparing two samples of dijet events, diffractive (SD), triggered by the presence of intact antiproton, detected in the Roman Pot Spectrometer (RPS), and non-diffractive (ND), the diffractive structure function can be extracted. We extended our results from Run I by examining the Q^2 dependence of the structure function, where Q^2 is defined as an average value of the mean dijet E_T. Fig. 1 shows the ratio of single diffractive dijet event rate to those of non-diffractive, R^{SD}_{ND}, as a function of x_{Bj}. In the range of 100< Q^2 <10000 GeV^2 no significant Q^2 dependence is observed.

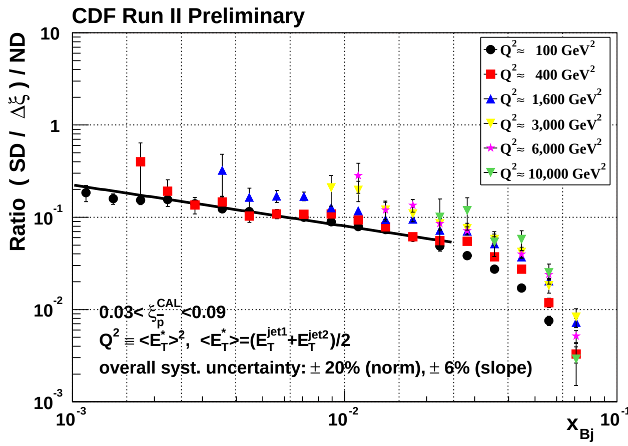

FIG. 1: Ratio of SD to ND event rates as a function of x_{Bj} for different Q^2 ranges

CDF also studied the Q^2 dependence of t, four-momentum transfer squared, distributions in both soft and hard single diffractive processes. Fig. 2 shows t distributions for different Q^2 values in the range 0<$|t|$<1 (GeV/c)^2. The slope of the distributions at $|t|$=0 (GeV/c)^2 does not show any dependence on Q^2.

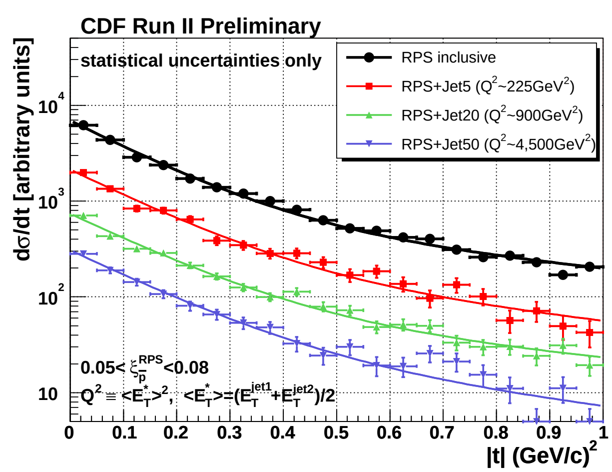

FIG. 2: t distributions in soft and hard SD events for different Q^2 ranges.

III. EXCLUSIVE DIJET PRODUCTION

Observation of the Higgs boson is one of the main goals of the LHC at CERN. Recently, considerable interest has been drawn to the subject of "exclusive" Higgs boson production $pp \to p + H + p$ in double *pomeron* exchange (DPE), where central heavy object is produced alone, separated from outgoing hadrons by rapidity gaps. The exclusive double diffractive Higgs production has unique experimental advantages such as clean final state which contains only the Higgs boson and very forward leading nucleons, improved mass resolution, and small background from the direct $b\bar{b}$ production, due to the several suppression mechanisms. 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 higher production rates can be studied to calibrate theoretical predictions. In this proceedings we present results of exclusive dijet production in hadron colliders.

The characteristic signature of this process is the presence of intact leading nucleons with exclusive dijet final state. At CDF the leading antiproton is detected by the RPS, and the presence of the leading proton is inferred from the large forward rapidity gap with $\Delta\eta < 3$. The observable, sensitive to the amount of event energy concentrated in dijet, is R_{jj}, the dijet mass fraction, defined as the invariant mass of the two highest E_T jets, M_{jj}, divided by the mass M_X of the whole system with the exception of the leading particles. R_{jj} of exclusive dijet is expected to be peaked around $R_{jj} \sim 0.8$ and have a long tail towards low value due to the hadronization of partons causing energy spills from the jet cones and gluon radiation in initial and final states.

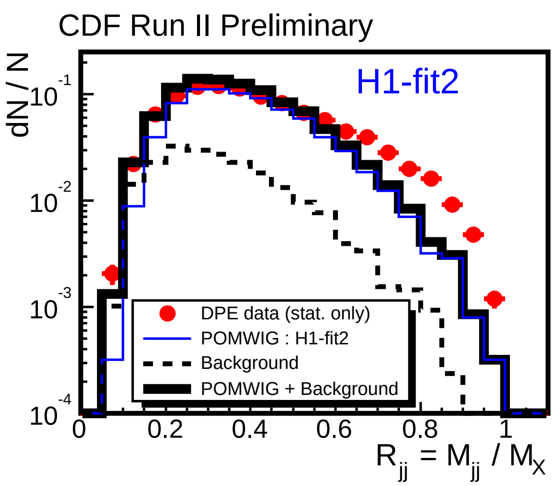

FIG. 3: R_{jj} distribution for data (dark points) and MC predictions (thick solid line) composed of DPE dijet events (thin line) and non-DPE background (dashed line).The data and MC results are normalized to the same area.

The search for the exclusive dijets is performed by comparing data with Monte Carlo, MC, expectations. We use POMWIG [4] MC event generator with detector simulation to obtain DPE dijets, see Fig. 3 which shows a comparison of the shape of R_{jj} for data and MC results, composed of DPE dijet events and non-DPE background. The evaluation of different Pomeron PDFs and underlying events (Pomeron remnants) in MC showed that these variations cannot account for the excess observed in data at high R_{jj} . Two different exclusive dijet production models [5]-[6] implemented in ExHuME [7] and DPEMC [8] MC simulations have been also studied. Fig. 4 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 in events with dijet E_T >10 GeV and a veto on third jet. As can be seen from this plot, the data excess at high R_{jj} can be well described by the exclusive dijet production. The exclusive MC DPEMC, not shown here, also provides a good agreement with data.

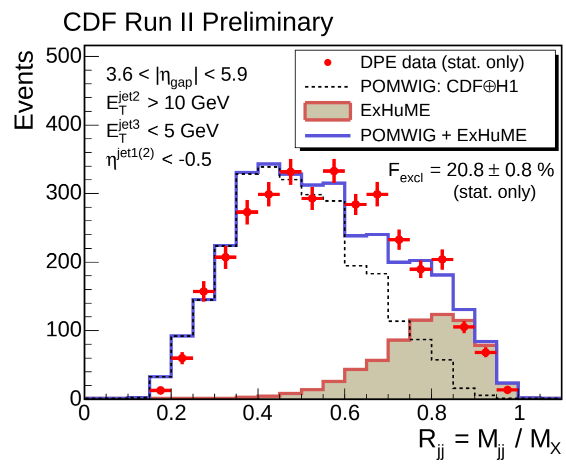

FIG. 4: Dijet mass fraction R_{jj} in DPE data (dark points) and best fit (solid line) obtained using inclusive (dashed line) and exclusive ExHuME (shaded line) MC predictions.

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 200 pb^{-1} of data triggered by the presence of anti-proton in RPS, forward gap on proton side, dijets in the central region and at least one displaced vertex track with $p_T > 2$ GeV/c.The last requirement effectively enhances the heavy flavor content of the sample. Fig. 5 shows the normalized ratio of heavy flavor jets to all jets as a function of R_{jj} of DPE b-jet events. The decreasing trend of the normalized ratio towards high R_{jj} could indicate the suppression of heavy flavor jets in the exclusive signal region. The observed behavior of heavy flavor jet production relative to the inclusive jets is consistent with the results of exclusive dijet signal search in inclusive DPE data sample.

The cross section of exclusive dijet production can be measured by multiplying the cross section of the DPE sample by the fraction of exclusive events and by accounting for acceptances. Fig. 6 shows the exclusive cross section obtained from the data sample compared with predictions from two Monte

Carlo simulations, ExHuME and DPEMC. The data clearly favors the ExHuME.

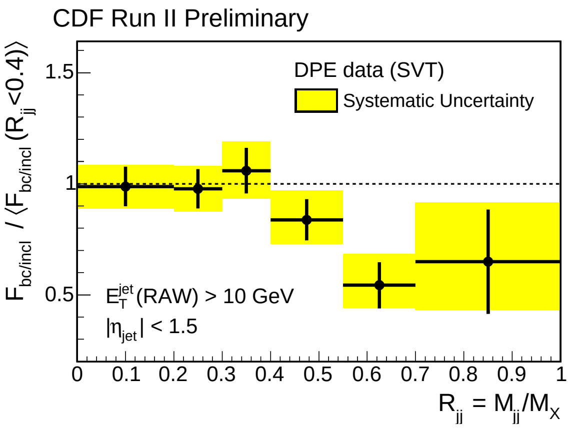

FIG. 5: Ratio of heavy flavor jets to inclusive jets with $E_T > 10$ GeV and $|\eta| < 1.5$ as a function of R_{jj}. The ratio is divided by the weighted average of the ratio in the range $R_{jj} < 0.4$. The shaded band shows systematic uncertainty on the ratio.

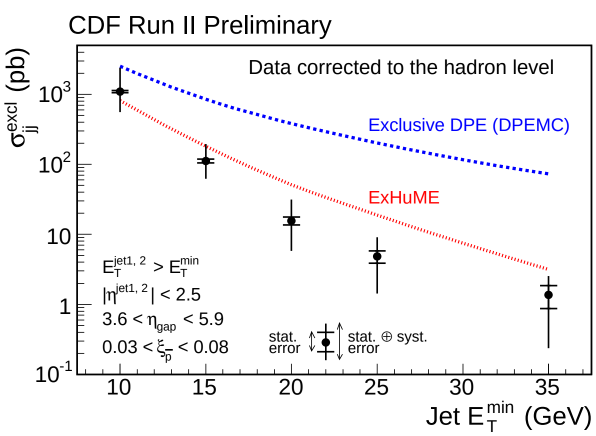

FIG. 6: Exclusive dijet cross section measured from the data as a function of minimum second jet E_T. The dashed (dotted) lines shows the ExHuME (DPEMC) Monte Carlo predictions.

IV. EXCLUSIVE DIPHOTON PRODUCTION

Another process which is closely related to exclusive Higgs production is exclusive diphoton production $p\bar{p} \to p\gamma\gamma\bar{p}$. CDF has performed search for exclusive $\gamma\gamma$ using data obtained with the trigger requiring presence of two electromagnetic (EM) towers and forward gaps in both forward directions. 16 events containing two electron candidates are found after requiring all calorimeters to be empty, except for two trigger EM towers with $E_T > 5$ GeV.The observed events are consistent with QED-mediated dielectron production $p\bar{p} \to p + e^+e^- + \bar{p}$ through two photon exchange. In the same dataset 3 candidate events are found, by requiring all calorimeters to be empty, and no tracks to be associated with two EM trigger towers. The exclusive production estimates [5], implemented in ExHuME Monte Carlo generator predict 1^{+3}_{-1} exclusive $\gamma\gamma$ events. The background estimates are still in process.

V. CONCLUSIONS

The CDF experiment continues to carry a strong program on diffractive physics during Run II. The studies of diffractive structure functions were extended by measuring Q^2 dependence in the wide range of the values from 100 to 10000 GeV^2. The t distribution dependence on Q^2 was also presented. New results on exclusive dijet production demonstrate an excess of data events over backgrounds obtained from Monte Carlo predictions and are consistent with predictions from exclusive dijet production Monte Carlo simulations. The results from the exclusive dijet and diphoton production are an important calibration tools for theoretical models describing diffractive Higgs production at LHC.

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