Exclusive diffraction using the rapidity gap method in CDF

Christina Mesropian

on behalf of the CDF collaboration
The Rockefeller University
1230 York Avenue, New York, NY, USA

We report results on exclusive diffraction obtained by the CDF collaboration in $p\bar{p}$ collisions at the Fermilab Tevatron collider at $\sqrt{s}$ =1.96 TeV. The first experimental observation of exclusive dijets, exclusive χ_{c0} mesons, and search for exclusive diphotons are discussed.

1 Introduction

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 nucleons, 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, allowing the leading hadrons to stay intact. This is also a special case of dijet/diphoton production in double pomeron Exchange (DPE), $p + \bar{p} \rightarrow p + X + \bar{p}$. Several different heavy systems X can be considered, but the main motivation for these studies is to use the process $p + \bar{p} \rightarrow p + H + \bar{p}$, see Fig. 1(a), to discover Higgs boson at the LHC. 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. Fig. 1(b-d) shows processes corresponding to studies in exclusive physics at the Tevatron: exclusive dijet, χ_c meson, and diphoton productions.

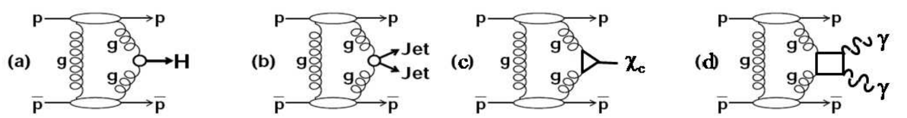

Figure 1: diagrams of exclusive production of (a) Higgs boson, (b) dijet, (c) χ_c, and (d) a photon-photon pair.

2 CDF II Detector

The schematic layout of CDF II detector is presented in Fig. 2. The detector components most relevant for this analysis are the charged particle tracking system, the central and plug calorimeters, and a set of detectors instrumented in the forward pseudorapidity region. The CDF tracking system consists of a silicon vertex detector (SVX II) and an open-cell drift chamber. Surrounding the tracking detectors is a superconducting solenoid, which provides a magnetic field of 1.4 T. The forward detectors are very important for the identification of a large rapidity gap in forward region, that central exclusive processes. The Forward Detectors, which extend the coverage into the η region beyond 3.6, consist of the MiniPlug calorimeters, the beam shower counters (BSCs), a Roman pot spectrometer (RPS), and a system of Cherenkov luminosity counters (CLC). The MiniPlug calorimeters designed to measure the energy and lateral position of electromagnetic and hadronic showers in the pseudorapidity region of 3.5<| η |<5.1. The Beam Shower Counters (BSCs) surrounding the beam pipe at three (four) different locations on the outgoing proton (antiproton) side of the CDF II detector. covering the range 5.4<| η |<5.9 is the BSC1 system, which is closest to the interaction point and is used for triggering on events with forward rapidity gaps. The RPS, located at ~57 m downstream in the antiproton directions, consists of three Roman pot stations, each containing a scintillation counter used for triggering on the $\bar{p}$, and a scintillation fiber tracking detector for measuring position and angle of the detected $\bar{p}$.

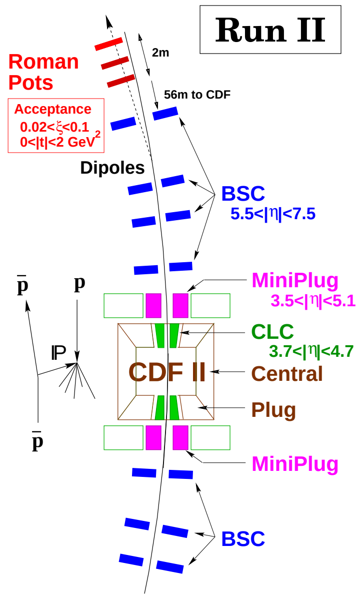

Figure 2: Schematic drawing of the CDF II detector.

3 Exclusive Dijet Production

The exclusive dijet production was first studied by CDF in Run I data and the limit of σ_{excl} <3.7 nb (95% CL) was placed [1]. The data sample of 313 pb^{-1} for the exclu-

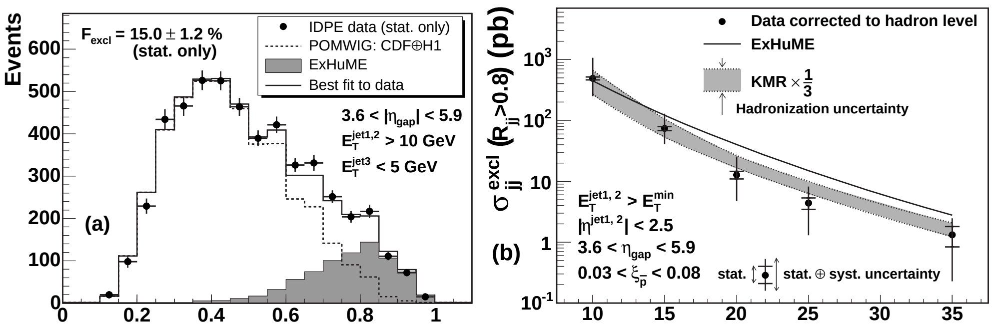

Figure 3: Schematic drawing of the CDF II detector.

sive dijet production was collected in Run II with the 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 exclusive signal is extracted using the dijet mass fraction method: from the energies and momenta of the jets in an event, the ratio $R_{jj} \equiv M_{jj}/M_X$ of the dijet mass M_{jj} to the total mass M_X of the final state (excluding the p and $\bar{p}$) is formed and used to discriminate between the signal of exclusive dijets, expected to appear at R_{jj} =1, and the background of inclusive DPE dijets, expected to have a continuous distribution concentrated at lower R_{jj} values. Because of smearing effects in the measurement of ${E_T}^{jet}$ and jet and gluon radiation from the jets, the exclusive dijet peak is broadened and shifts to lower R_{jj} values. The exclusive signal is obtained by a fit of the R_{jj} distribution to expected signal and background shapes generated by Monte Carlo (MC) simulations. The data clearly show an excess at high R_{jj}, see Fig. 3 (left) over the non-DPE background events and inclusive DPE predictions obtained from POMWIG MC. The shape of excess is well described by exclusive dijet MC based on two models (ExHuME [2], DPEMC [3]); however, the measured cross section [4], see Fig. 3 (right) disfavors DPEMC. Predictions by Khoze et al. [5] are found to be consistent with data within its factor of 3 uncertainty.

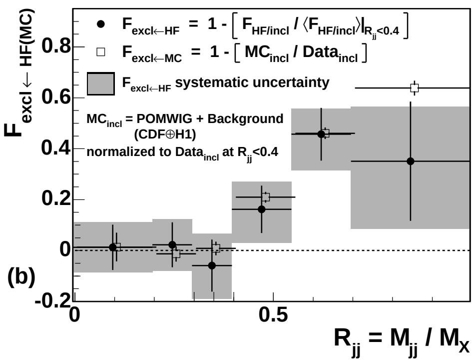

Figure 4: Measured ration F_{HF} (filled circles) of heavy flavor jets to all inclusive jets and the exclusive dijet ratio F_{excl} (open squares) obtained by comparison between inclusive dijet events and POMWIG MC.

The results could also be checked with an event sample of heavy quark flavor dijets, for which exclusive production is expected to be suppressed in LO QCD by the J_z =0 selection rule of the hard scattered digluon system, where J_z is the projection of the total angular momentum of the system along the beam direction. Fig. 4 shows comparison between exclusive dijet results obtained with MC-based method and the data based suppression of the exclusive heavy flavor to inclusive dijet production rates. The results are consistent with each other.

4 Exclusive Diphoton Production

Another process which is closely related to exclusive Higgs production is exclusive diphoton production $p\bar{p} \rightarrow p\gamma\gamma\bar{p}$. CDF has performed search for exclusive $\gamma\gamma$ using 0.5 fb^{-1} data sample 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 $p\bar{p} \rightarrow p + e^+e^- + \bar{p}$ through two photon exchange. This was the first observation of exclusive e^+e^- production in hadron colliders [6]. In the same dataset 3 candidate events were found, by requiring all calorimeters to be empty, and no tracks to be associated with two EM trigger

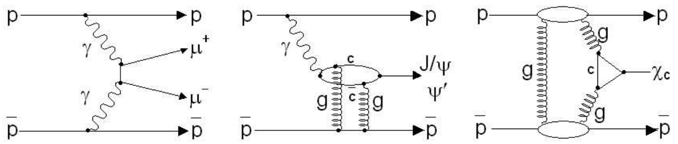

Figure 5: Diagrams for (a) $\gamma\gamma \to \mu^+\mu^-$, (b) photoproduced J/ψ or $\psi(2S)$, and (c) $\chi_{c0} \to J/\psi + \gamma \to \mu^+\mu^- + \gamma$.

towers. Two of these events are likely to be $\gamma\gamma$, and the third is more likely to be of $\pi^0\pi^0$ origin. The probability of observing at least three such events is found to be $1.7{\times}10^{-4}$, which allows us to place a limit on exclusive diphoton production of 410 fb at 95% CL [7]. The prediction [8] is compatible with this limit. CDF plans to update this measurement with additional available data.

5 Exclusive χ_c Production

CDF II also studied dimuon production, when the event signature requires two oppositely charged central muons, and either no other particles (large forward rapidity gaps), or one additional photon detected. There are many physics processes in these data: exclusive dimuon production directly as in QED, from photoproduced $J/\psi(3097)$ or $\psi(2S)(3986)$ decay, and $\chi_{c0} \to J/\psi + \gamma \to \mu^+\mu^-\gamma$, see Fig. 5. Within a kinematic region $\mid \eta(\mu) \mid <0.6$ and $M_{\mu\mu} \in [3.0, 4.0]$ GeV/c^2, there are 402 events with no EM shower, see the $M_{\mu\mu}$ spectrum in Fig. 6.

The J/ψ and $\psi(2S)$ are prominent, together with a continuum. By requiring one EM shower with E_T^{EM} >80 MeV in addition to the requirement mentioned above, we are able to measure χ_{c0} production. Allowing EM tower causes large increase (+ 66 events) in the $J\psi$ peak and minor change (+1 event) in the $\psi(2S)$ peak. We interpret resulting 65 events as $\chi_{c0} \to J/\psi + \gamma$ decay. After correcting for background, efficiencies and applying the branching fraction, we obtain following cross section for exclusive χ_{c0} production 75±10(stat)±10(syst) nb [9], which is compatible with the theoretical predictions [10]-[12].

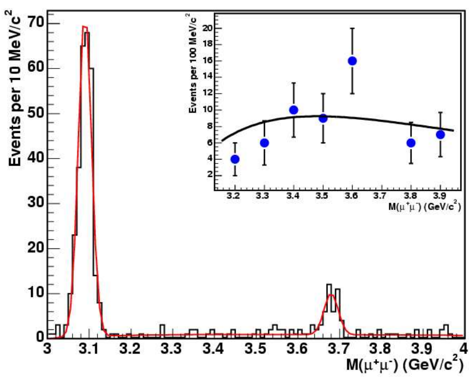

Figure 6: Mass $M_{\mu\mu}$ distribution of 402 exclusive events, with no EM shower, (histogram) together with a fit to two Gaussians for the J/ψ and $\psi(2S)$, and a QED continuum. All three shapes are predetermined, with only the normalizations floating. Inset: Data above the J/ψ and excluding $3.65 < M_{\mu\mu} < 3.75$ GeV/c^2 ($\psi(2S)$) with the fit to the QED spectrum times acceptance (statistical uncertainties only).

6 Conclusions

CDF reported a first observation of exclusive dijet production, exclusive DPE production of χ_{c0}. We also set an upper limit on diphoton production. These results in addition to their intrinsic interest also provide a valuable calibration for the predictions on exclusive Higgs production at the LHC.

7 Acknowledgments

I would like to thank the organizers of XVII International Workshop on Deep-Inelastic Scattering, DIS2009 for warm hospitality and for an exciting conference.

References

[1] T. Affolder *et al.,* Phys.Rev.Lett. **85**, 4215 (2000).

[2] J. Monk and A. Pilkington, Comput.Phys.Commun. **175**, 232 (2006).

[3] M. Boonekamp and T. Kuss, Comput.Phys. Commun. **167**, 217 (2005).

[4] T. Aaltonen *et al.,* Phys.Rev. D **77** 052004 (2008).

[5] V.A. Khoze *et al.,* Eur. Phys.J. C **14**, 525 (2000); V.A. Khoze *et al.,* arXiv:0705.2314.

[6] A. Abulencia *et al.,* Phys. Rev. Lett. **98** 112001 (2007).

[7] T. Aaltonen *et al.,* Phys. Rev. Lett. **99** 242002 (2007).

[8] V.A. Khoze *et al.,* Eur. Phys. J. C **38**, 475 (2005).

[9] T. Aaltonen *et al.,* Phys.Rev.Lett. **102** 242001 (2009).

[10] V.A. Khoze *et al.,* Eur.Phys.J. C **35** 211 (2004); V.A. Khoze *et al.,* Eur.Phys.J. C **19** 599(E) (2001).

[11] F. Yuan, Phys.Lett. B **510**, 155 (2001).

[12] A. Bzdak, Phys.Lett. B **619**, 288 (2005).