PROCEEDINGS OF SCIENCE

New Results on Diffractive and Exclusive Production from CDF

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We present results on central exclusive production of $\pi^+\pi^-$ in $\bar{p}p$ collisions at $\sqrt{s} = 900$ and 1960 GeV using events with two charged hadrons in the final state within the pseudorapidity region $|\eta| \leq 1.3$ and no particles in $|\eta| > 1.3$. These results open a new window into hadron spectroscopy, and may be used as benchmarks for testing relevant theoretical models.

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1. Introduction

The CDF Collaboration (CDF) has been studying diffraction in $\bar{p}p$ collisions for the past quarter century, aiming to understand the QCD aspects of the diffractive exchange, a strongly interacting color-singlet quark/gluon combination with vacuum quantum numbers, traditionally referred to as Pomeron ($I\!P$) exchange. Such exchanges lead to large, non-exponentially suppressed pseudorapidity regions devoid of particles, called rapidity[1]gaps. Diffractive processes are classified as single dissociation or single diffraction, SD, characterized by a forward gap adjacent to a surviving $\bar{p}$ or p, double dissociation or double diffraction, DD, characterized by a central gap, and central diffraction or double-Pomeron exchange, CD or DPE, a process with two forward gaps.

A special class of diffraction is central exclusive production, a DPE process in which a specific state is centrally produced [1]. CDF has published results on exclusive *dijet* (2008) [2], $\mu^+\mu^-$: χ_c, J/ψ and $J/\psi(2s)$ (2009) [3], and $\gamma\gamma$ / e^+e^- (2012) [4] production. Here, we report on the observation of exclusive $\pi^+\pi^-$ production [5] and compare the results with theoretical expectations.

2. Central exclusive production of $\pi^+\pi^-$

2.1 Detector, triggers, datasets

Detector. The CDF II detector is shown schematically in Fig 1. It consists of the main detector, labeled CDF-II in this figure, equipped with a tracking system and calorimeters (central: CCAL, plug: PCAL), and the forward components (Cherenkov Luminosity Counters: CLC, MiniPlugs: MP, Roman Pot Spectrometer: RPS). The RPS and MPs were not active in this study, and from the BSCs only those covering the pseudorapidity region of $5.4 < |\eta| < 5.9$ are used.

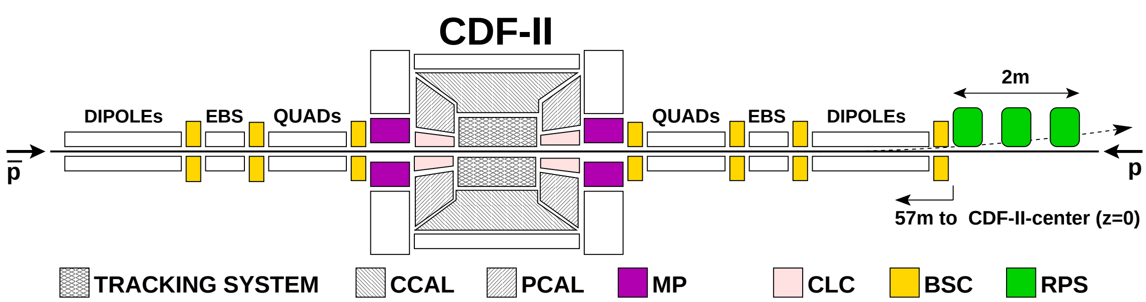

Figure 1: Schematic plan view of the CDF II detector showing the tracking system and calorimeters (CCAL, PCAL), and forward components (MP, CLC, BSC, RPS); EBSs are electrostatic beam separators.

Triggers. The following two triggeres were used for data collection:

- **signal:** two CCAL towers ($|\eta| < 1.3$) with energy E > 0.5 GeV (a very low threshold!) and no energy in BSC ($|\eta| = 5.4-5.9$) and in the Forward Plug Calorimeters ($|\eta| = 2.11-3.64$).
- **zero-bias:** offline selected bunch-crossing events with no tracks for noise/exclusivity studies.

Datasets. The signal datasets consist of 90 (22) $\times\, 10^6$ events at $\sqrt{s} = 1960$ (900) GeV.

[1]Rapidity, $y = \frac{1}{2}\ln\frac{E+p_L}{E-p_L}$, and pseudorapidity, $\eta = -\ln\tan\frac{\theta}{2}$, where θ is the polar angle of a particle w.r.t. the proton beam ($+\hat{z}$), are used interchangeably for particles detected in the calorimeters, as they are approximately equal.

2.2 Preliminary results

We report results for events with exactly two tracks within rapidity $|y_{\pi^+\pi^-}| < 1.0$ and $\mathrm{M}_{\pi^+\pi^-} < 0.8$, where there is useful acceptance at all p_T. No particle ID is (yet) being used, and the observed tracks are assumed to be due to pions.

We select events in regions of instantaneous luminosity $1 \times 10^{30} < L < 2.2\ \times 10^{30}$ cm^{-2} s^{-1} (Fig. 2-left), and set detector thresholds for optimum signal/noise ratio (Fig. 2-right).

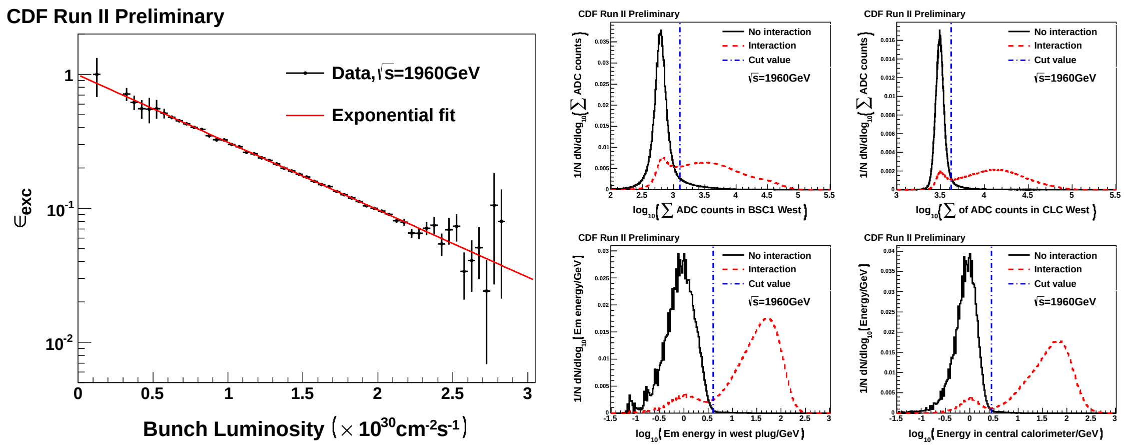

Figure 2: Zero-bias data sample at $\sqrt{s} = 1960$ GeV with an exponential fit: (left) efficiency of event selection (probability that the whole detector is empty) vs beam-bunch instantaneous luminosity for a single bunch (the L quoted in the text is 36 times larger, as there are 36 colliding bunches); (right) detector-noise levels for "interaction" and "no-interaction" events. The vertical dashed lines show the cuts used to define "empty" detectors, or "noise" (the K^+K^- background in this area, measured with K^0K^0 events, amounts to only a few %).

Figure 3 shows mass distributions of $\pi^+\pi^-$ candidate events uncorrected (left) and corrected (right) for acceptance. The f_0 (980), f_2 (1270), and $f_0(1370)$ are clearly visible. The small but significant peak at 3.1 GeV is understood to be from $J/\psi \to e^+e^-$ with $\mathrm{M}_{e^+e^-}$ treated as $\mathrm{M}_{\pi^+\pi^-}$.

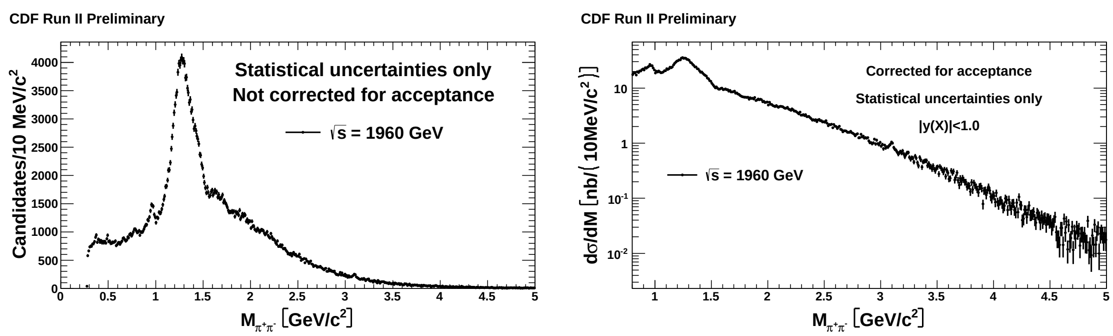

Figure 3: $\mathrm{M}_{\pi^+\pi^-}$ distributions at $\sqrt{s} = 1960$ GeV not corrected (left) and corrected (right) for acceptance.

Figure 4 shows the ratio of $\pi^+\pi^-$ candidates at $\sqrt{s} = 1960/900$ GeV (top), and the mean p_t for $\sqrt{s} = 1960$ GeV (bottom-left) and $\sqrt{s} = 900$ GeV (bottom-right) vs $\mathrm{M}_{\pi^+\pi^-}$.The statistically more significant data at $\sqrt{s} = 1960$ GeV show structures at 1.5 GeV, 2.25 GeV, and between 3 GeV and 4 GeV. Work is in progress to understand these structures, including a phase-shift analysis.

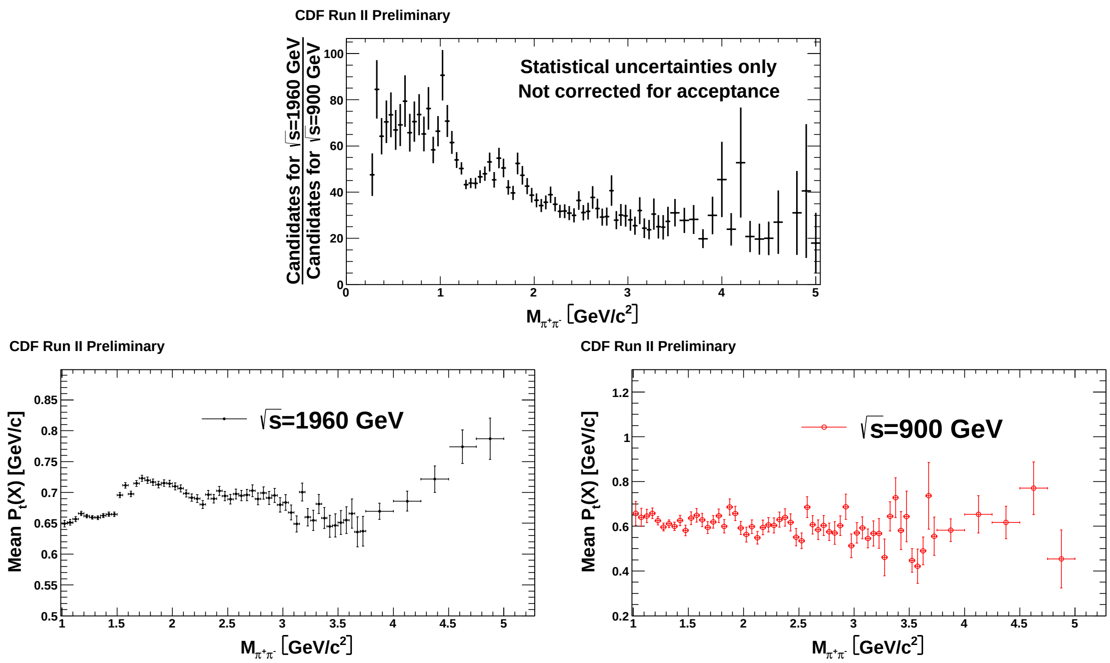

Figure 4: Ratio of events at $\sqrt{s} = 1960/900$ GeV (top), and mean p_t of π^+/π^- (left/right) vs $M_{\pi^+\pi^-}$.

In Fig. 5, we compare the distributions of $d\sigma/dM_{\pi^+\pi^-}$ of events at $\sqrt{s} = 1960$ and 900 GeV for $M_{\pi^+\pi^-} < 5$ GeV (left), and zoom into the region of $M_{\pi^+\pi^-} < 2$ GeV (right) for an expanded view. At $M_{\pi^+\pi^-} > 1.5$ GeV, we observe features in the mass spectrum which are not yet understood and are the subject of further studies currently underway, including a partial wave analysis.

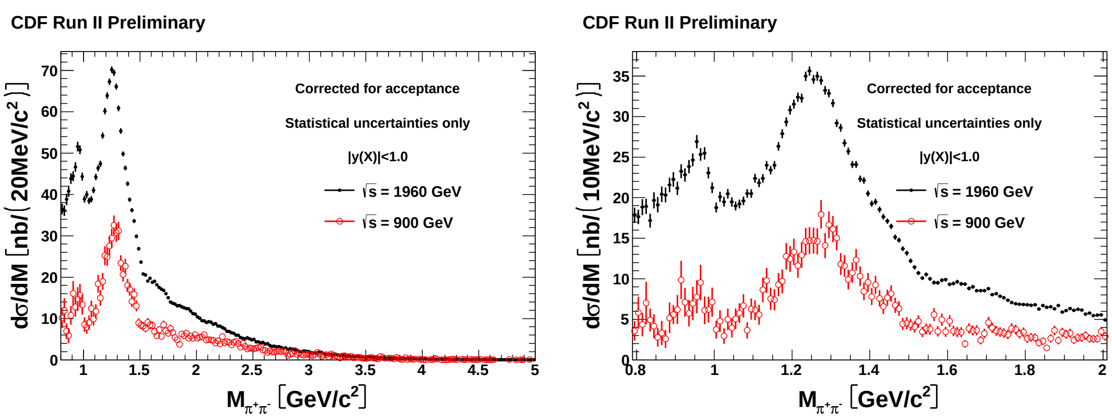

Figure 5: Differential cross sections $d\sigma/dM_{\pi^+\pi^-}$ vs $M_{\pi^+\pi^-}$ at $\sqrt{s} = 1960$ and 900 GeV for the mass regions $M_{\pi^+\pi^-} < 5$ GeV (left) and $M_{\pi^+\pi^-} < 2$ GeV (right).

3. Summary

We have measured exclusive $\pi^+\pi^-$ production in $\bar{p}p$ collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 1960$ GeV with the CDF II detector at the Fermilab Tevatron Collider. Using tracks, assumed to be from pions which are the dominant charged-pair component, we explored the low mass region of $\mathrm{M}_{\pi^+\pi^-} < 5$ GeV. We observe the well known resonances f_0 (980) and f_2 (1270), and see a small but significant peak at 3.1 GeV understood to be from $J/\psi \rightarrow e^+e^-$ with $\mathrm{M}_{e^+e^-}$ assumed as $\mathrm{M}_{\pi^+\pi^-}$. We also observe features at $\mathrm{M}_{\pi^+\pi^-} > 1.5$ GeV which are not yet understood. Further investigations of these features and a partial wave analysis are currently underway.

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