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Diffraction at CDF

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Abstract: We present results on central exclusive production of $\pi^+\pi^-$ in p̄p 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 (*IP*) exchange[1]. Such exchanges lead to large, non-exponentially suppressed pseudorapidity regions devoid of particles, called rapidity[2] 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 [3]. CDF has published results on exclusive *dijet* (2008) [4], $\mu^+\mu^-$ (χ_c , J/ψ and $J/\psi(2s)$ (2009) [5], and $\gamma\gamma / e^+e^-$ (2012) [6] production. In this paper, we report on the observation of exclusive $\pi^+\pi^-$ production [7] and compare our results with theoretical expectations.

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§On behalf of the CDF Collaboration.

[1]Recent CDF results on diffraction have been presented in *DIFFRACTION 2012* [1]; in the present paper we concentrate on exclusive $\pi^+\pi^-$ production, closely following the CDF presentation in *EDS-2013* [2].

[2]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 approximately equal for particles detected in the calorimeters.

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 MP were not active in this study, and from the BSC only those covering the pseudorapidity region of $5.4 < |\eta| < 5.9$ are used.

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 use in noise/exclusivity studies.

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

2.2. Preliminary Results

We report results for events with exactly two tracks within rapidity $|y_{\pi^+\pi^-}| < 1.0$ and $M_{\pi^+\pi^-} < 0.8$, 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 $1\times10^{30} < L < 2.2\times10^{30}$ cm^{-2} s^{-2} (Fig. **2**-left), and set detector thresholds for optimum signal/noise ratio (Fig. **2**-right).

Fig. (**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.

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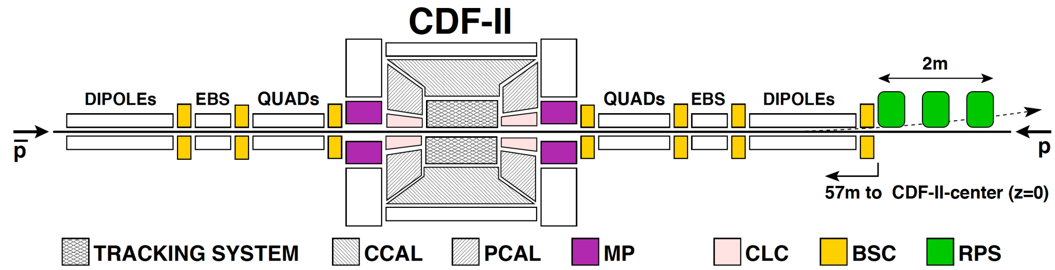

Fig. (1). Schematic plan view of the CDF II detector showing the tracking system and calorimeters (CCAL, PCAL), and forward components (MP, CLC, BSC, RPS); the BSC are electrostatic beam separators.

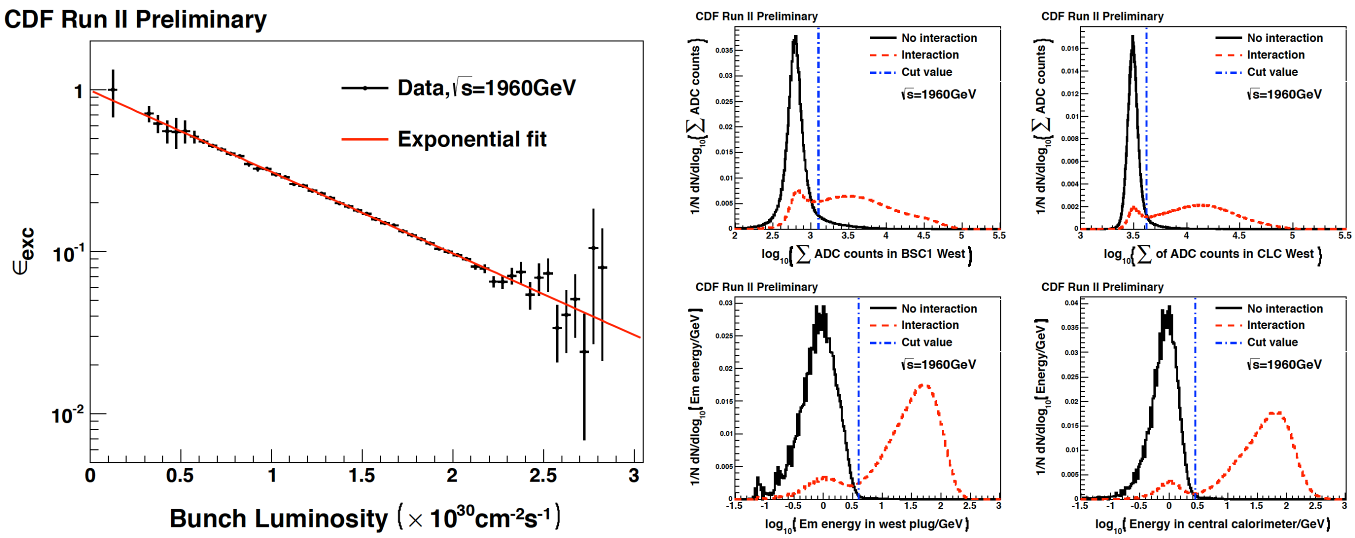

Fig. (2). Zero-bias data sample at $\sqrt{s}=1960$ GeV with an exponential fit: (left) efficiency of event selection (probability that the whole detector is empty) *vs* beam-bunch instantaneous luminosity for a single bunch (the *L* quoted in the text is 36 times larger, as there are 36 colliding bunches); (right) detector-noise levels for "interaction" and "no-intezoomraction" 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 a few %).

The small but significant peak at 3.1 GeV is understood to be from $J/\psi \to e^+e^-$ with $M_{e^+e^-}$ treated as $M_{\pi^+\pi^-}$. The integrated cross section over the region $0 < M_{\pi^+\pi^-} < 5$ GeV and $|y_{\pi^+\pi^-}| < 1.0$ at $\sqrt{s}=1960$ GeV [900 GeV] is $1910 \pm 4\,(stat.) \pm 380\,(syst.)$ [825 ± 11 (stat) ± 160 (syst)] nb. The higher cross section at $\sqrt{s}=1960$ GeV may be due to the same $\eta_{max}=5.9$ cut at both energies, while the proton beam rapidity is $y_{beam}=\ln(\sqrt{s}/m_p)=7.64$ [y_{beam} = 6.87], allowing higher $M_{\pi^+\pi^-}$ values at 1960 GeV.

Fig. (**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*

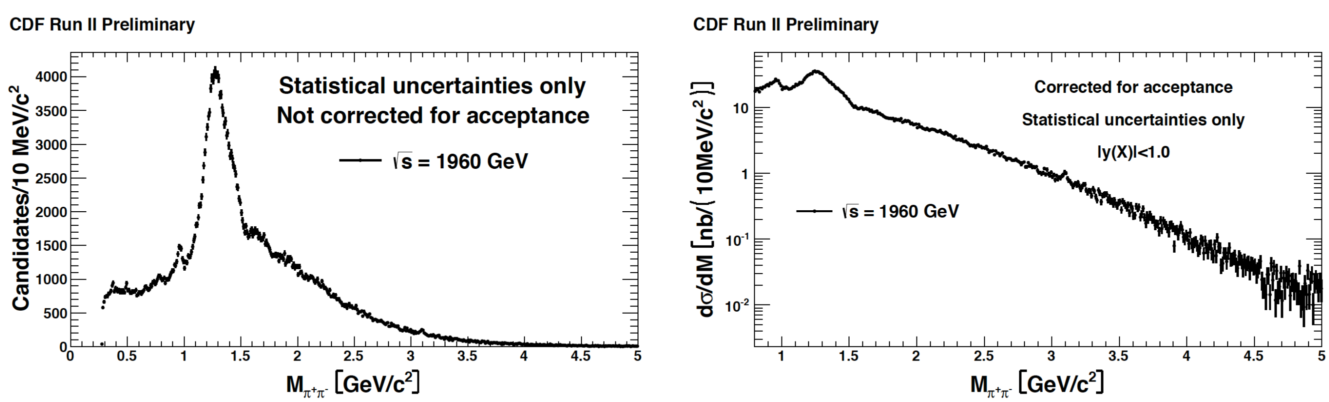

Fig. (3). $M_{\pi^+\pi^-}$ distributions at $\sqrt{s}=1960$ GeV not corrected (left) and corrected (right) for acceptance.

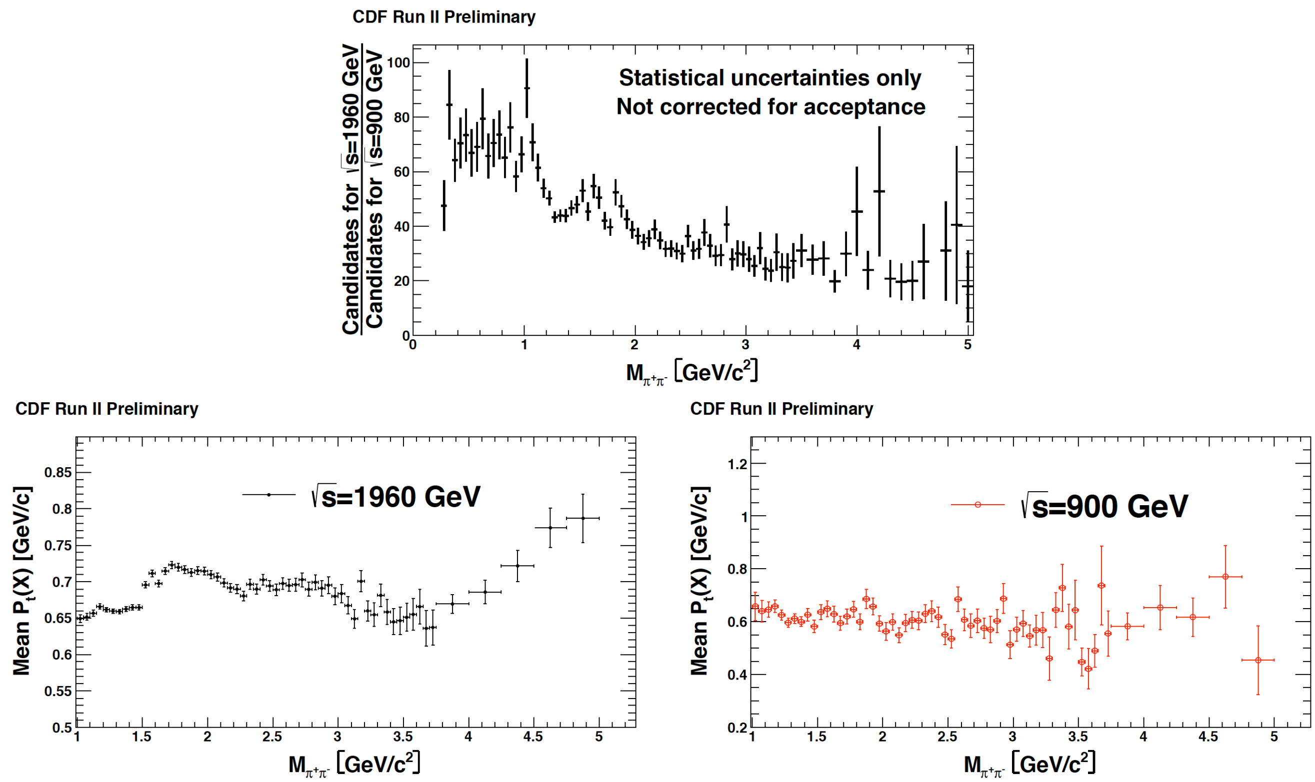

Fig. (4). Ratio of events at $\sqrt{s} = 1960/900$ GeV (top), and mean p$_t$ of π^+/π^- (left/right) *vs* $M_{\pi^+\pi^-}$.

$M_{\pi^+\pi^-}$. 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.

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 ongoing studies.

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 $M_{\pi^+\pi^-} < 5$ GeV. We observe the well known resonances f_0

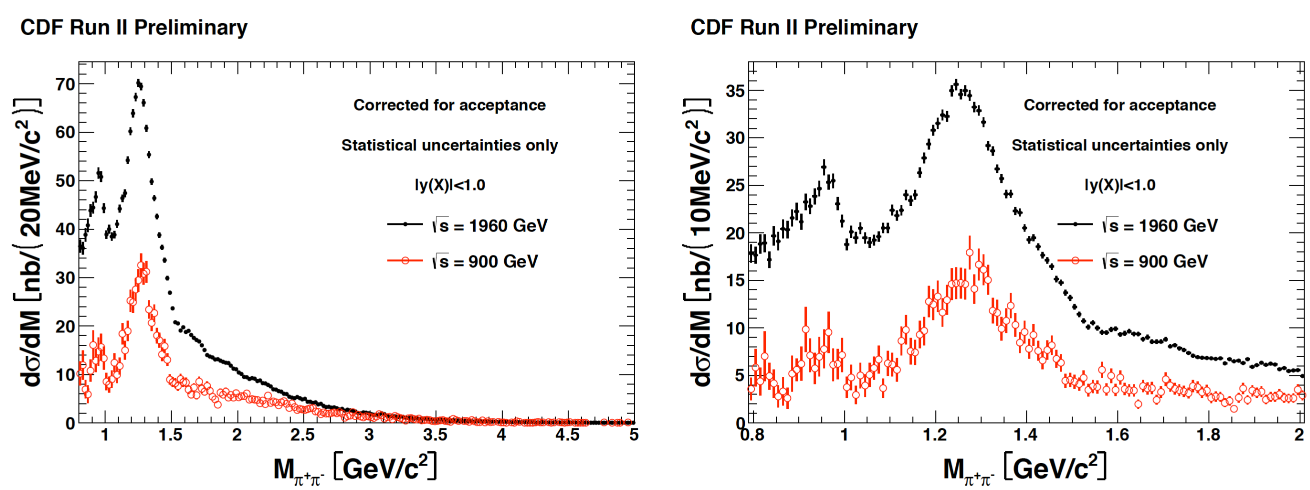

Fig. (5). Differential cross sections $d\sigma / dM_{\pi^+\pi^-}$ *vs* $M_{\pi^+\pi^-}$ at $\sqrt{s} = 1960$ and 900 GeV for $M_{\pi^+\pi^-} < 5$ GeV (left) and $M_{\pi^+\pi^-} < 2$ GeV (right).

(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 $M_{e^+e^-}$ assumed as $M_{\pi^+\pi^-}$. We also observe features at $M_{\pi^+\pi^-} > 1.5$ GeV, which are not yet understood. Further investigations of these features, including a partial wave analysis, are currently underway.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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