CENTRAL EXCLUSIVE PRODUCTION WITH THE STAR DETECTOR AT RHIC*

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The Central Exclusive Production (CEP) processes with Double Pomeron Exchange (DPE) in proton–proton collisions are particularly intriguing as they can generate the exclusive h^+h^- pair with an even spin and positive parity. This unique characteristic makes them an ideal environment for the exploration and discovery of glueball states. In this work, we will present results on CEP of charged hadron pairs $h^+h^-(h = \pi, K, p)$ measured with the STAR experiment at RHIC in proton–proton collisions at $\sqrt{s} = 200$ GeV and 510 GeV. The differential fiducial cross sections at $\sqrt{s} = 200$ GeV will be presented and compared to the theoretical calculations from DPE models. Structures observed in the mass spectra of $\pi^+\pi^-$ and K^+K^- pairs were found consistent with the DPE model, while angular distributions of pions suggested a dominant spin-0 contribution to $\pi^+\pi^-$ production. We also present preliminary results on the measurement of the same physics process at the higher $\sqrt{s} = 510$ GeV.

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1. Introduction

The Central Exclusive Production (CEP) process in proton–proton collisions, $p + p \to p' + X + p'$, is experimentally recognized when all particles of the centrally-produced neutral state X (here denoting a pair of opposite-charge hadrons, h^+h^-) are well separated in the rapidity space from the intact scattered incoming protons (p'). The CEP process for $X = \pi^+\pi^-$ is shown schematically in Fig. 1 (a). At sufficiently high center-of-mass energies, the process occurs mainly through the Double Pomeron Exchange (DPE) mechanism, which is considered suitable for the production of the gluon bound states (glueballs). In this process, the hadron pair continuum

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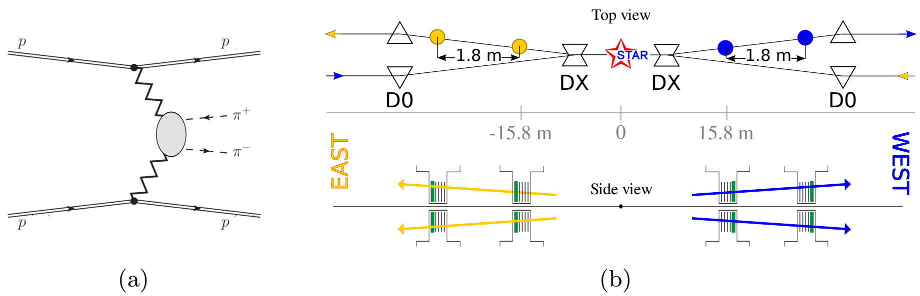


Fig. 1. (a) Diagram of Central Exclusive Production of $\pi^+\pi^-$ pair. (b) Layout of the Roman Pot (RP) system at STAR. Two sets of RPs were installed between the DX and D0 magnets, at 15.8 m and 17.6 m, on either side of the Interaction Point. Arrows at the bottom part of the figure demonstrate combinations of RPs forming four branches, in which proton tracks can be reconstructed.

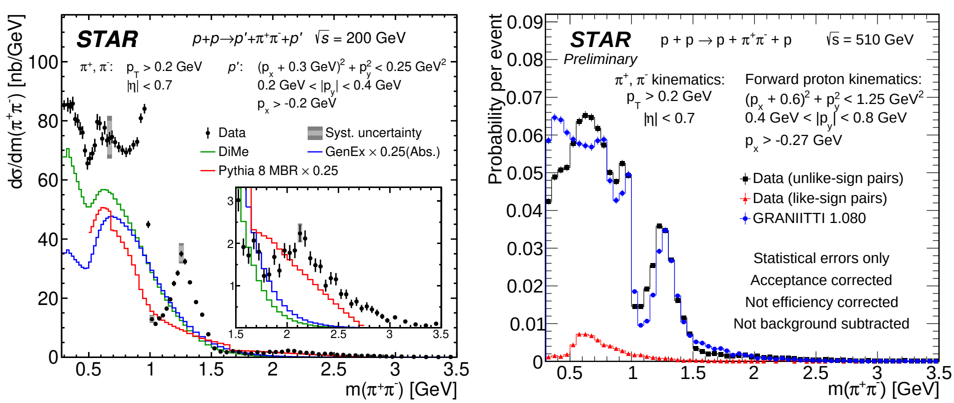
and regular resonances are produced as well, all interfering with each other. Additional soft exchanges are also possible between the particles involved in the process, spoiling the exclusivity of the reaction (so-called absorption and rescattering effects). The theoretical complexity of this topologically-simple process makes it a relevant subject for experimental and theoretical studies [1, 2]. The above models were implemented in Monte Carlo generators. The GenEx [3] and DiMe [2] contain continuum production of $\pi^+\pi^-$ and K^+K^- pairs. In the DiMe event generator, absorption effects are available. In GenEx, the absorption corrections are not taken into account. However, the model developers estimated the suppression factor to be of the order of 2–5 ($\pi^+\pi^-$) and 2 (K^+K^-) [4]. To account for absorption, the $\pi^+\pi^-$ cross sections obtained from GenEx are scaled by 0.25 to fit DiMe predictions for masses above 0.8 GeV, while the K^+K^- cross sections from GenEx are scaled by 0.45 to fit DiMe predictions for masses above 1.2 GeV. The MBR model [5] implemented in PYTHIA 8 [6] was tuned to describe the inclusive cross section for central diffraction (CD), $p + p \to p' + X + p'$, measured by the CDF experiment. In this model, the exclusive h^+h^- final state occurs from the fragmentation and hadronisation of the central state based on the Lund string model.

2. Results

The STAR experiment [7] at RHIC has performed a high-statistics measurement of the CEP process in proton–proton collisions at the center-of-mass energy $\sqrt{s} = 200$ GeV [8]. Recently, preliminary studies at $\sqrt{s} = 510$ GeV were also performed. In both measurements, the Roman Pot (RP) detection system, shown schematically in Fig. 1 (b), allows for the reconstruction of forward-scattered protons at very small angles (typically

2–5 mrad). Larger proton beam energy moves RP geometrical acceptance towards larger proton momenta. Therefore, the $\sqrt{s} = 510$ GeV sample probes larger values of the Mandelstam $-t$ and larger transverse momenta, p_{T}, of the central state X: $0.8 < p_{\mathrm{T}} < 1.6$ GeV compared to $p_{\mathrm{T}} < 0.8$ GeV at $\sqrt{s} = 200$ GeV.

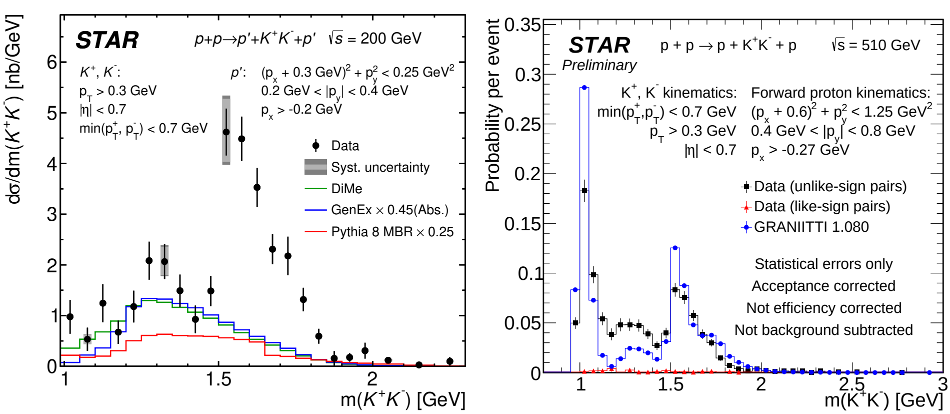
Figure 2 (a) shows the differential cross section for CEP of $\pi^+\pi^-$ pairs as a function of the pair invariant mass at $\sqrt{s} = 200$ GeV. There are several features of the distribution which need to be pointed out. The deep hole observed in the measured differential cross section in the mass region of $m(\pi^+\pi^-) < 0.6$ GeV is mainly due to the fiducial cuts. At larger invariant masses, resonance structures are seen in the data consistent with the $f_0(980)$ and $f_2(1270)$ mesons that are expected to be produced in the Pomeron–Pomeron fusion process. At even higher invariant masses, another resonance is observed around 2.2 GeV. The DiMe prediction describes the continuum best (shape and normalization). Figure 2 (b) shows preliminary results at $\sqrt{s} = 510$ GeV. The ratio $f_2(1270)/f_0(980)$ is significantly higher at $\sqrt{s} = 510$ GeV compared to $\sqrt{s} = 200$ GeV. The Graniitti MC expectation tuned to $\sqrt{s} = 200$ GeV describes shape of $m(\pi^+\pi^-)$ at $\sqrt{s} = 510$ GeV fairly well.



(a) (b)

Fig. 2. Differential cross sections for CEP of $\pi^+\pi^-$ for $\sqrt{s} = 200$ GeV (a) as a function of the invariant mass of the pair, measured in the fiducial region explained in the plots. Data are shown as solid points with error bars representing the statistical uncertainties. Typical systematic uncertainties are shown as grey boxes for only a few data points as they are almost fully correlated between neighbouring bins. Predictions from Monte Carlo models GenEx, DiMe, and MBR are shown as histograms. Efficiency uncorrected, preliminary distribution of the invariant mass of the pair for $\sqrt{s} = 510$ GeV (b) together with distribution for the like-sign pairs. The prediction from the Monte Carlo model Graniitti is shown as a histogram. Both data and MC prediction are normalised to unity.

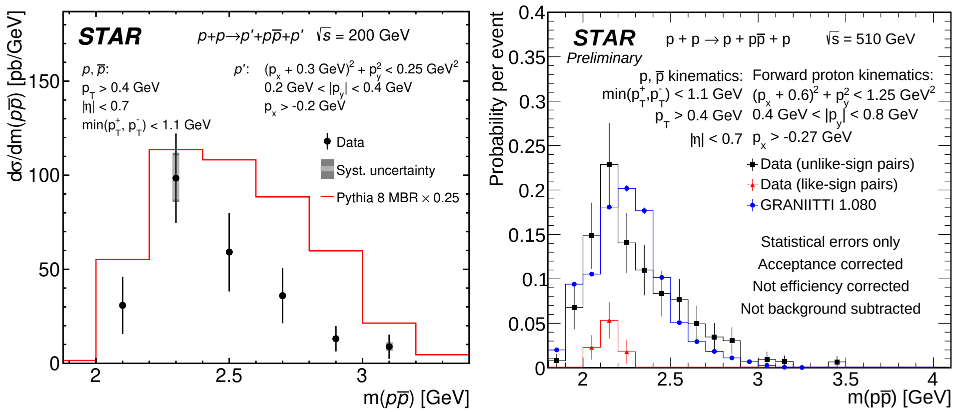
Figure 3 (a) shows the differential cross section for CEP of K^+K^- pairs as a function of the pair invariant mass at $\sqrt{s} = 200$ GeV. The measured differential cross section shows significant enhancement in the $f_2(1525)$ mass region and a possible smaller resonant signal in the mass region of $f_2(1270)$. Both structures are expected to be produced in the Pomeron–Pomeron fusion process. The ratio of the cross sections for $\pi^+\pi^-$ to K^+K^- production in the $f_2(1270)$ mass region is roughly 18, consistent with the PDG ratio of the $f_2(1270)$ branching fractions for its decays into $\pi^+\pi^-$ and K^+K^-. The DiMe and GenEx predictions roughly describe the non-resonant contribution to the data in the resonance region. Figure 3 (b) shows preliminary results at $\sqrt{s} = 510$ GeV. Data show the significant peak above the K^+K^- mass threshold not visible at $\sqrt{s} = 200$ GeV. The experimental setup at $\sqrt{s} = 510$ GeV opened up acceptance for relatively high transverse momenta, $0.8 < p_{\mathrm{T}} < 1.6$ GeV, of the central states and therefore observation of states close to the K^+K^- mass threshold. According to the Graniitti expectations, the peak near the K^+K^- mass threshold is predominantly due to interference of the $f_0(980)$ with continuum.



(a) (b)

Fig. 3. Differential cross sections for CEP of K^+K^- for $\sqrt{s} = 200$ GeV (a) as a function of the invariant mass of the pair, measured in the fiducial region explained in the plots. Data are shown as solid points with error bars representing the statistical uncertainties. Typical systematic uncertainties are shown as grey boxes for only a few data points as they are almost fully correlated between neighbouring bins. Predictions from Monte Carlo models GenEx, DiMe, and MBR are shown as histograms. Efficiency uncorrected, preliminary distribution of the invariant mass of the pair for $\sqrt{s} = 510$ GeV (b) together with distribution for the like-sign pairs. The prediction from the Monte Carlo model Graniitti is shown as a histogram. Both data and MC prediction are normalised to unity.

Figure 4 (a) shows the differential cross section for CEP of K^+K^- pairs as a function of the pair invariant mass at $\sqrt{s} = 200$ GeV. The invariant mass spectrum of $p\bar{p}$ pairs does not show any obvious resonance peaks. The MBR model overestimates the data by a factor of eight. Figure 4 (b) shows preliminary results at $\sqrt{s} = 510$ GeV. The Graniitti model describes the shape of the distribution fairly well.



(a) (b)

Fig. 4. Differential cross sections for CEP of $p\bar{p}$ for $\sqrt{s} = 200$ GeV (a) as a function of the invariant mass of the pair, measured in the fiducial region explained in the plots. Data are shown as solid points with error bars representing the statistical uncertainties. Typical systematic uncertainties are shown as grey boxes for only a few data points as they are almost fully correlated between neighbouring bins. The prediction from the Monte Carlo model MBR is shown as a histogram. Efficiency uncorrected, preliminary distribution of the invariant mass of the pair for $\sqrt{s} =$ 510 GeV (b) together with distribution for the like-sign pairs. The prediction from Monte Carlo model Graniitti is shown as a histogram. Both data and MC prediction are normalised to unity.

3. Summary

Results on CEP of charged hadron pairs: $\pi^+\pi^-$, K^+K^-, and $p\bar{p}$ in proton–proton collisions at $\sqrt{s} = 200$ GeV (published results) and $\sqrt{s} =$ 510 GeV (preliminary results) obtained by the STAR experiment have been presented. These are currently the highest center-of-mass energies at which this process is measured with the detection of the forward-scattered protons. The obtained results are expected to help in understanding the Pomeron structure and developing phenomenological models of the DPE process.

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