

MEASUREMENTS OF PARTICLE SPECTRA IN DIFFRACTIVE PROTON–PROTON COLLISIONS WITH THE STAR DETECTOR AT RHIC*

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We present the inclusive and identified particle (pion, proton and their antiparticle) production in Single Diffraction Dissociation and Central Diffraction processes with the STAR detector at RHIC. The forward-scattered proton(s) are tagged in the STAR Roman Pot system, while the charged particle tracks are reconstructed in the STAR Time Projection Chamber. Ionization energy loss and time of flight of charged particles are used for particle identification. In addition, the proton–antiproton production asymmetry as a function of rapidity is measured and used to study the baryon number transfer over a large rapidity interval in the Single Diffraction Dissociation.

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1. Introduction

Diffraction processes at high energies are characterized by the exchange of a colour singlet object with vacuum quantum numbers, so-called Pomeron, and are well-described by the Regge theory. In $p+p$ collisions, two kinds of processes are of particular interest, Single Diffraction Dissociation (SD: $p + p \rightarrow p + X$) and Central Diffraction (CD: $p + p \rightarrow p + X + p$), where X denotes the diffractively produced system.

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Charged-particle measurements in $p+p$ collisions provide insight into the strong interaction in the low-energy, non-perturbative regime of QCD. Particle interactions at these energy scales are typically described by QCD-inspired models implemented in Monte Carlo (MC) event generators with free parameters that can be constrained by measurements. Charged-particle distributions have been measured previously in minimum bias (MB) inelastic hadron-hadron collisions at various center-of-mass energies [1, 2]. The identified charged particle production in the midrapidity region has been also widely studied starting from the very first experiments performed at ISR at CERN to contemporary measurements with very high center-of-mass energies at RHIC [3] and the LHC [4].

In the Standard Model, the baryon number is a conserved quantity in all interactions. The conserved baryon number associated with the beam particles is called “baryon number transfer” and has been studied both theoretically [5, 6] and experimentally in MB interactions [7] for a long time. The similar effect can be also studied in SD interactions, where the direction of the initial baryon is uniquely defined. The baryon number transfer is quantified by the baryon-to-antibaryon ratios.

In this paper, we report on measurements of inclusive charged-particle distributions and identified particle/antiparticle ratios as a function of transverse momentum p_T and pseudorapidity η in CD and SD $p+p$ collisions at $\sqrt{s} = 200$ GeV using data collected by the STAR experiment in 2015. In addition, we focus on the asymmetry of the production of protons and antiprotons at midrapidity in SD process.

2. Experimental setup

The main components of the STAR detector [8] used in this analysis include the Time Projection Chamber (TPC), which provides information about momentum and ionization energy losses (dE/dx) of charged particles, the Time-Of-Flight (TOF) system which extends the capability of TPC in particle identification, and the Roman Pot detectors (RP) [9], which enable tagging of the forward-scattered protons.

3. Charged-particle distributions

The selection of diffractive events starts with the reconstruction of forward proton tracks. Exactly one track is required on each side of the Interaction Point (IP) for CD and exactly one track on one side only for SD (with fractional momentum loss $0.02 \leq \xi \leq 0.4$). Only one primary vertex with z -component $|V_z| < 80$ cm and at least two charged primary tracks with hits in the TOF system are required. To obtain the charged-particle

multiplicity distributions, the distributions of tracks are unfolded into the distributions of particles using the Bayes theorem. Figure 1 shows the measured distributions of primary charged particles in the kinematic range of $p_T > 200$ MeV/c and $|\eta| < 0.7$ for SD and CD processes together with PYTHIA 8.182 [10] prediction using SaS [11] and MBR [12] Pomeron fluxes, respectively. The analysis is limited to the number of charged particles n_{ch}

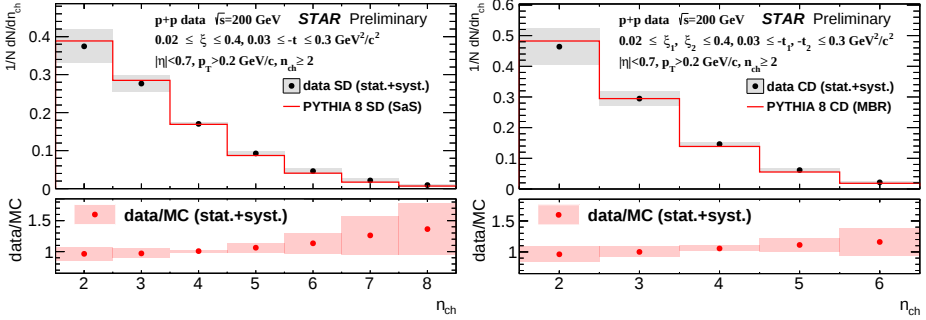


Fig. 1. Multiplicity distributions of primary charged particles for SD (left) and CD (right) processes. Data are compared to PYTHIA 8 Monte Carlo (MC) simulations.

between 2 and 8 for SD and $2 \leq n_{ch} \leq 6$ for CD, to avoid large background. The measurements could be described by the PYTHIA 8 simulation very well. Figure 2 shows the charged-particle transverse momentum distributions in SD and CD $p + p$ collisions. Generally, data are underestimated by PYTHIA 8 especially for relatively high- p_T ($p_T > 0.8$ GeV/c). Analysing the η distribution requires to define a new variable $\bar{\eta} = \frac{p_z^{\text{proton}}}{|p_z^{\text{proton}}|} \times \eta$ for SD, where p_z^{proton} is the longitudinal momentum of the forward proton: positive

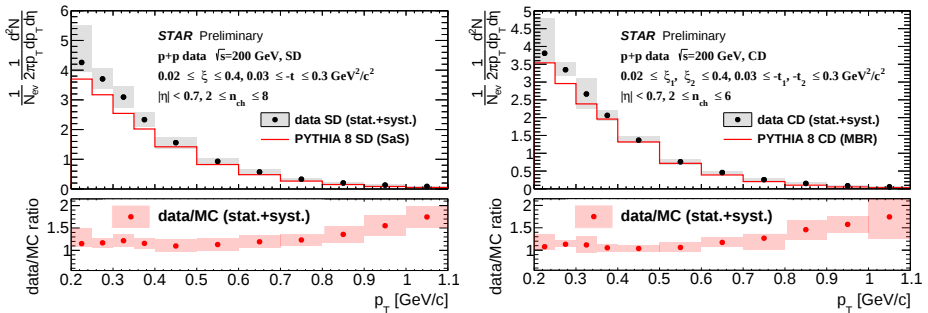


Fig. 2. The rate of charged particles as a function of transverse momentum for SD (left) and CD (right) processes. Data are compared to PYTHIA 8 MC simulations.

$\bar{\eta}$ for particles produced on the outgoing proton direction and negative on the opposite side of the IP. Figure 3 shows the density of charged particles as a function of pseudorapidity. PYTHIA 8 simulations describe the data within 5% accuracy.

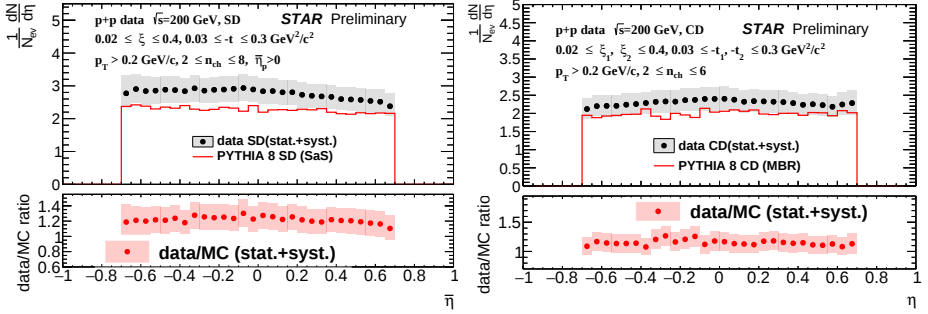


Fig. 3. Pseudorapidity ($\bar{\eta}$ for SD, η for CD) dependence of the charged particles for SD (left) and CD (right). Data are compared to PYTHIA 8 MC simulations.

4. Identified particle spectra

In the case of the identified particle spectra measurements, we require $|V_z| < 100$ cm and $\xi < 0.6$. The charged tracks are measured in the kinematic range of $p_T > 200$ MeV/c and $|\eta| < 1$. The combined information from TPC and TOF is used to identify charged pions ($\pi^\pm$), protons and antiprotons.

The particle-to-antiparticle ratios for pions and protons are shown in Fig. 4 for CD process and in Fig. 5 for SD process. The comparison of particle-antiparticle ratios between SD and CD in most central pseudora-

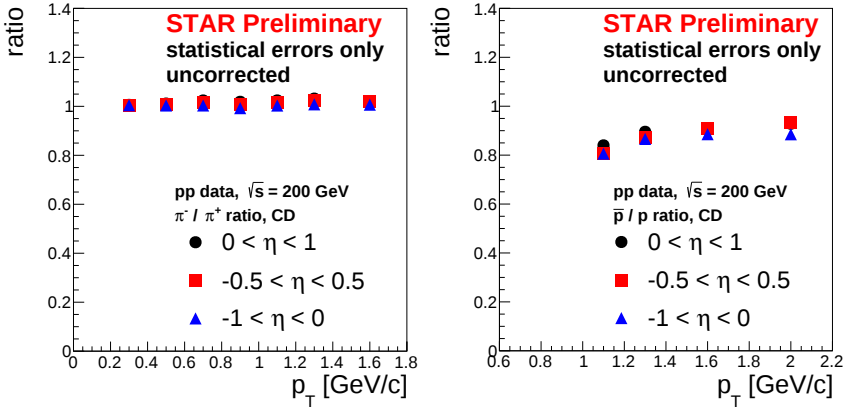


Fig. 4. The π^-/π^+ (left) and $\bar{p}/p$ (right) ratios measured at three pseudorapidity ranges in CD process.

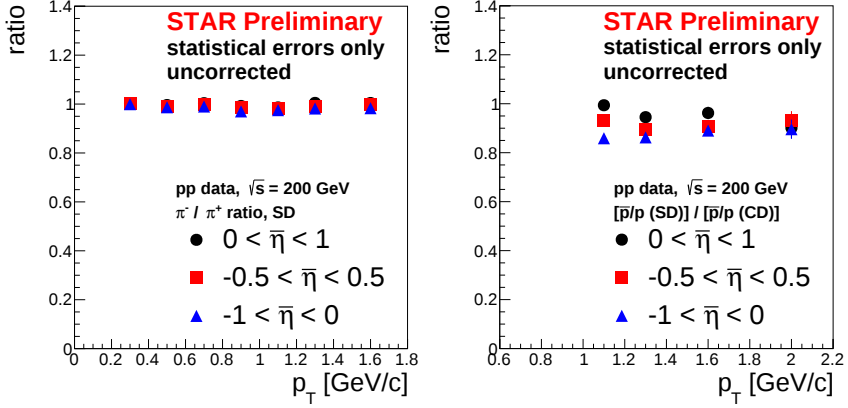


Fig. 5. The particles ratio measured in SD events for three $\bar{\eta}$ bins. The $\bar{p}/p$ ratio in SD is corrected for the $\bar{p}$ absorption (right) using CD.

pidity interval $-0.5 < \eta < 0.5$ is presented in Fig. 6. Charged pions are identified with transverse momentum $0.2 \leq p_T \leq 1.8$ GeV/c. In both processes, the π^-/π^+ ratio is equal to 1 in almost all p_T bins and all $\eta(\bar{\eta})$ ranges. This result is also consistent with the STAR minimum bias inelastic measurements [3]. The $\bar{p}/p$ ratio is analysed for particles with $1 < p_T < 2.2$ GeV/c because in that p_T range the background from secondary interactions is expected to be small.

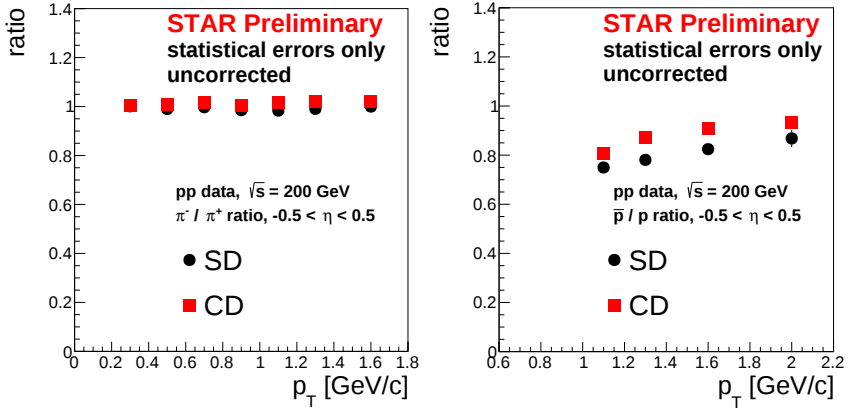


Fig. 6. Comparison of the π^-/π^+ (left) and $\bar{p}/p$ (right) ratios in $|\eta| < 0.5$ interval between CD and SD processes.

Due to the antiproton absorption, the TPC track reconstruction efficiency is smaller for antiprotons than that for protons. Hence, the $\bar{p}/p$ ratio is below 1 in CD, but the same in all three η ranges. Nevertheless, it is noticed that this ratio is smaller in SD than that in CD. The $\bar{p}/p$ ratio in SD divided by the $\bar{p}/p$ ratio in CD, $[\bar{p}/p(\text{SD})]/[\bar{p}/p(\text{CD})]$, gives the ratio in SD corrected for p , $\bar{p}$ efficiencies (Fig. 5). As a result, the $\bar{p}/p$ ratio in the SD for particles within $-0.5 < \bar{\eta} < 0.5$ varies between 0.9 and 0.95. The ratio is greater than that in STAR minimum bias inelastic measurements, where it is between 0.75 and 0.85. Moreover, the comparison of the $\bar{p}/p$ ratio in different $\bar{\eta}$ ranges indicates that baryon number transfer is smaller in the outgoing proton direction.

5. Summary

The distributions of charged-particle multiplicity, p_T and η measured in SD and CD processes are not well-reproduced by PYTHIA 8 simulations in full accessible ranges. The preliminary results on π^-/π^+ ratios are in agreement with the STAR MB inelastic measurements, while the $\bar{p}/p$ ratio in SD is measured to be greater than that in MB inelastic $p+p$ collisions.

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