PROCEEDINGS OF SCIENCE

Study of the central exclusive production of $\pi^+\pi^-$, K^+K^- and $p\bar{p}$ pairs in proton-proton collisions at $\sqrt{s}$ = 510 GeV with the STAR detector at RHIC

Tomáš Truhlář[1,*]

Czech Technical University in Prague,
Faculty of Nuclear Sciences and Physical Engineering,
Brehova 78/7, Prague 115 19, Czech Republic

E-mail: Tomas.Truhlar@fjfi.cvut.cz

We report on the measurement of the central exclusive production process $pp \rightarrow pXp$ in proton-proton collisions at RHIC with the STAR detector at $\sqrt{s}$ = 510 GeV. At this energy, this process is dominated by a double Pomeron exchange mechanism. The tracks of the centrally produced system X were reconstructed in the central detector of STAR, the Time Projection Chamber and the Time of Flight systems, and the particles were identified using the ionization energy loss and the time of flight method. The diffractively scattered protons, moving intact inside the RHIC beam pipe after the collision, were measured in the Roman Pots system allowing full control of the interaction's kinematics and verification of its exclusivity. The preliminary results on the invariant mass distributions of centrally produced $\pi^+\pi^-$, K^+K^- and $p\bar{p}$ pairs measured within the STAR acceptance are presented.

**** The European Physical Society Conference on High Energy Physics (EPS-HEP2021), ****
**** 26-30 July 2021 ****
**** Online conference, jointly organized by Universität Hamburg and the research center DESY ****

[1]For the STAR Collaboration.
[*]Speaker

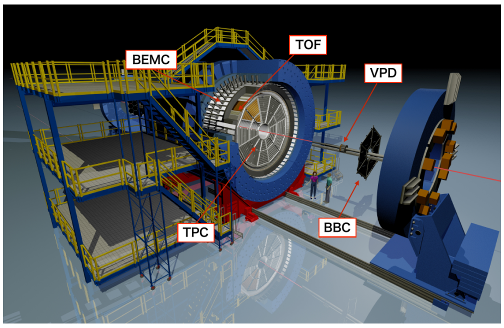
PoS(EPS-HEP2021)339

1. Introduction

The central exclusive production (CEP) [1] is a process when colliding protons stay intact after the collision and the produced central system is separated by rapidity gaps from outgoing protons. At RHIC [2] energies, the CEP through double Pomeron exchange (DIPE) is expected to be dominant. The DIPE is a mechanism when each protons "emits" a Pomeron. The Pomerons fuse and produce neutral central system.

2. Experimental setup

The STAR detector has unique capabilities for CEP studies due to the high-resolution tracking of charged particles in the Time Projection Chamber (TPC) covering full azimuthal angle and pseudorapidity $|\eta| \leq 1$. The precise particle identification is performed through the measurement of the ionization energy loss in the TPC and the time of flight (TOF) information. The Beam-Beam Counters at forward (backward) rapidity are used to ensure rapidity gaps between the produced central system and forward protons. In addition, Silicon Strip Detectors installed in Roman Pots [3] are used to measure forward protons, thus allowing full control of the interaction's kinematics and verification of exclusivity in the process. The schematic view of the STAR experiment with main sub-detectors and with current layout of Roman Pots detectors can be seen in Fig. 1.



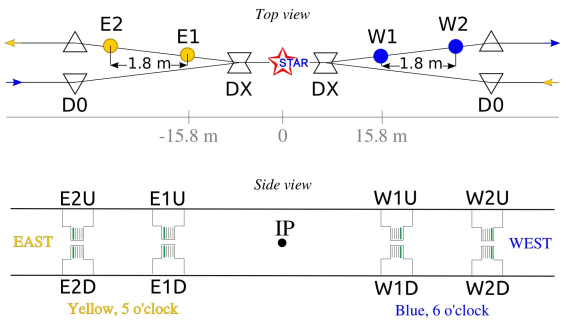


Figure 1: Left: The schematic view of the STAR experiment with highlighted main sub-detectors. Right: The Roman Pot Phase II* layout. Top view with highlighted Roman Pot stations E1, E2, W1, W2 and dipole magnets DX, D0. Side view with depicted Roman Pots installed on both sides of the central detector.

3. Data sample and event selection

Presented results are based on 622 million events collected by the STAR experiment using a special CEP trigger in proton-proton collision at $\sqrt{s}$ = 510 GeV. The following selection criteria were used to select a sample of CEP events. First, only events with one proton on each side of the interaction point were selected. In addition, all eight silicon planes were required to be used in the proton reconstruction to ensure good quality of the proton track. Furthermore, the reconstructed proton has to be inside a fiducial region listed in the legend of Figs. 2 and 3 to ensure high geometrical acceptance. Second, only events with exactly two opposite-sign TPC tracks matched with two TOF hits and originating from the same vertex were selected. Cuts on the $z-$position of the vertex

(|z-position of vertex| < 80 cm) and on pseudorapidity of central tracks ($|\eta| < 0.7$) was applied to ensure high geometrical acceptance in the entire fiducial phase space. Next, the TPC tracks must have enough number of hits used in track reconstruction (> 25) and enough number of hits used for determining the ionization energy loss (> 15). Third, the cut on missing transverse momentum (p_{T}^{miss} < 100 MeV) was applied to ensure exclusivity of the event. Finally, particle identification cuts was applied and 62077 $\pi^+\pi^-$, 1697 K^+K^- and 125 $p\bar{p}$ CEP event candidates were obtained.

4. Results

Figures 2 and 3 show invariant mass distributions of centrally produced $\pi^+\pi^-$, K^+K^- and $p\bar{p}$ pairs measured within the STAR acceptance in proton-proton collisions at $\sqrt{s}$ = 510 GeV. All invariant mass distributions are corrected using acceptance corrections obtained from pure single particle STARsim simulation and are normalized to one. Shown error bars represent the statistical uncertainties. The results are compared with a new tune of GRANIITTI, a Monte Carlo event generator for high energy diffraction [4]. GRANIITTI calculates invariant mass spectra assuming continuum and resonance contributions. Hence, it takes into account significant interference effects between resonance and continuum production. The following resonances were included in GRANIITTI calculation: $f_0(500)$, $\rho(770)$, $f_0(980)$, $\phi(1020)$, $f_2(1270)$, $f_0(1500)$, $f_2(1525)$, and $f_0(1710)$. Significant rescattering effects via additional interaction between the protons and/or hadron-proton are also embedded. The new tune GRANIITTI v. 1.080 includes CEP resonance couplings tuned to the STAR CEP results at $\sqrt{s}$ = 200 GeV [5], the highest center-of-mass energy at which the DIPE has been measured with the detection of the forward-scattered protons.

The invariant mass distribution of selected $\pi^+\pi^-$ pairs is differentiated in two regions of $\Delta\varphi$, where $\Delta\varphi$ is the difference of azimuthal angles between the forward protons, and can be seen in Fig. 2. Invariant mass of $\pi^+\pi^-$ shows the expected features, a drop at about 1 GeV and a peak consistent with the $f_2(1270)$. A suppression of $f_2(1270)$ and an enhancement at low invariant mass in $\Delta\varphi < 90°$ are seen. Figure 3 illustrates invariant mass distributions of selected K^+K^- and $p\bar{p}$ pairs measured within the STAR acceptance. The invariant mass of K^+K^- shows a peak at about 1.5 GeV, possible $f_2(1525)$, and a strong enhancement at low invariant mass, possible $f_0(980)$ or $\phi(1020)$. The invariant mass distribution of $p\overline{p}$ pairs does not show any resonances.

5. Summary

The preliminary STAR results on CEP of charged particle pairs produced in proton-proton collisions at $\sqrt{s}$ = 510 GeV with measured forward scattered protons have been presented. In general, the presented results confirm features seen in previous experiments. The new Monte Carlo event generator, GRANIITTI, is able to describe the shape of the data suggesting significant role of resonance production.

Acknowledgments

This work was supported from the project LTT18002 of the Ministry of Education, Youth, and Sport of the Czech Republic and from European Regional Development Fund-Project "Center of Advanced Applied Science" No. CZ.02.1.01/0.0/0.0/16-019/0000778.

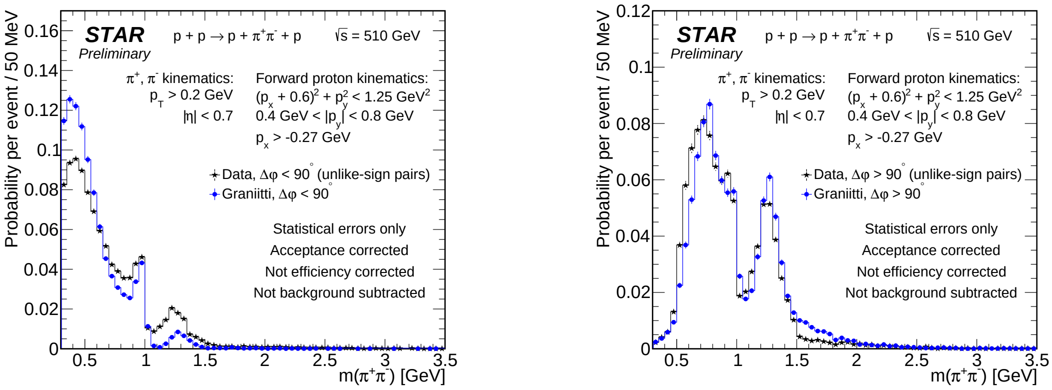


Figure 2: The acceptance corrected invariant mass spectrum of exclusively produced $\pi^+\pi^-$ pairs differentiated in two regions of the difference of azimuthal angles of the forward protons: $\Delta\varphi < 90°$ (left) and $\Delta\varphi > 90°$ (right). Results are compared with a new tune of GRANIITTI [4]. Error bars represent the statistical uncertainties.

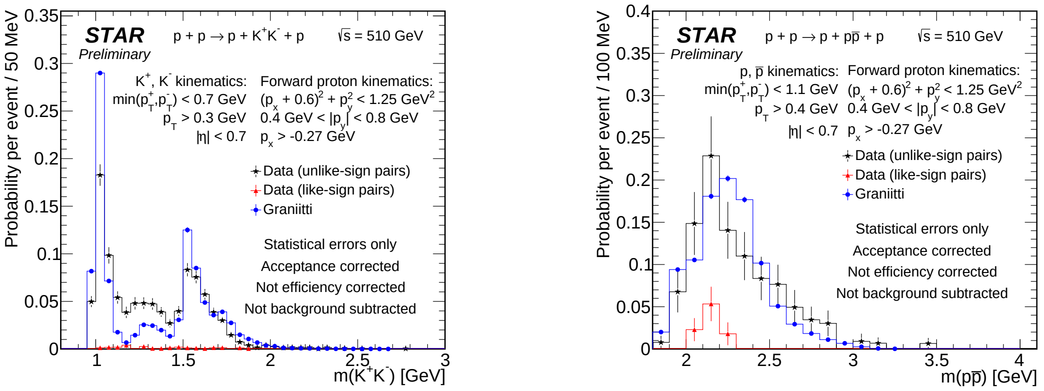


Figure 3: The acceptance corrected invariant mass spectrum of exclusively produced K^+K^- pairs (left) and $p\bar{p}$ pairs (right). Results are compared with a new tune of GRANIITTI [4]. Error bars represent the statistical uncertainties.

References

[1] M. G. Albrow, T.D. Coughlin and J.R. Forshaw, *Central Exclusive Particle Production at High Energy Hadron Colliders*, Prog. Part. Nucl. Phys. 65 (2010) 149.

[2] H. Hahn, *et al.*, *The RHIC design overview*, Nucl. Instrum. Meth. A 499 (2003) 245.

[3] S. Bultmann, *et al.*, *The PP2PP experiment at RHIC: silicon detectors installed in Roman Pots for forward proton detection close to the beam*, Nucl. Instrum. Meth. A **535** (2004), 415-420

[4] M. Mieskolainen, *GRANIITTI: A Monte Carlo Event Generator for High Energy Diffraction*, *arXiv*:1910.06300

[5] STAR Collaboration, J. Adam, *et al.*, *Measurement of the central exclusive production of charged particle pairs in proton-proton collisions at $\sqrt{s}$ = 200 GeV with the STAR detector at RHIC*, *JHEP* **07** (2020) 178.