Vol. 9 (2016) *Acta Physica Polonica B Proceedings Supplement* No 2

TWO-PARTICLE PROTON CORRELATIONS AT BES ENERGIES*

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(Received June 14, 2016)

Through experiments with heavy-ion collisions at high energies we can study the properties of nuclear matter under extreme conditions. The information on the sizes of the particle-emitting sources can be inferred via the method of femtoscopy. The femtoscopy method uses Quantum Statistics effects and the Final State Interactions to determine the space-time properties of the source. The radii of the sources extracted from two-baryon femtoscopy along with those obtained from two-meson and meson–baryon correlations provide complementary information about the source characteristics. In this report, a status of the STAR analysis of proton and antiproton femtoscopic correlations in Au+Au collisions at $\sqrt{s_{NN}}$ of 7.7 GeV, 11.5 GeV and 39 GeV is presented.

DOI:10.5506/APhysPolBSupp.9.317

1. Introduction

The Beam Energy Scan (BES) program led by the STAR experiment at RHIC focuses on the Quantum Chromodynamics (QCD) phase diagram [1]. As part of the program, STAR has been collecting the data on the Au+Au collisions at $\sqrt{s_{NN}}$ ranging from 7.7 up to 62.4 GeV. The femtoscopy method is employed in order to obtain information about the source sizes.

2. Correlation functions

The femtoscopy relies on information carried by the particles produced in the collision. The sizes of the sources can be obtained from correlation functions (CF). The CF are built using information about the particles

* Presented at WPCF 2015: XI Workshop on Particle Correlations and Femtoscopy, Warszawa, Poland, November 3–7, 2015.

emitted during the collisions. The CF can be described as a ratio between probability of observing two given particles in the same event and the probability of observing those two particles coming from different events, *i.e.* the mixed-event method.

The momentum distributions were measured in the Pair Rest Frame reference system (PRF) as functions of k^* (2.1). The PRF is a system where the pair of particles is looked upon in such a way that their center of mass is at rest. The particle momenta are equal of value and facing opposite to each other

$$k^* = |\vec{p}_1| = |\vec{p}_2| . \tag{2.1}$$

The CF can be divided into two basic groups: identical baryon–baryon (antibaryon–antibaryon) CF and nonidentical baryon–antibaryon CF (Fig. 1) [2].

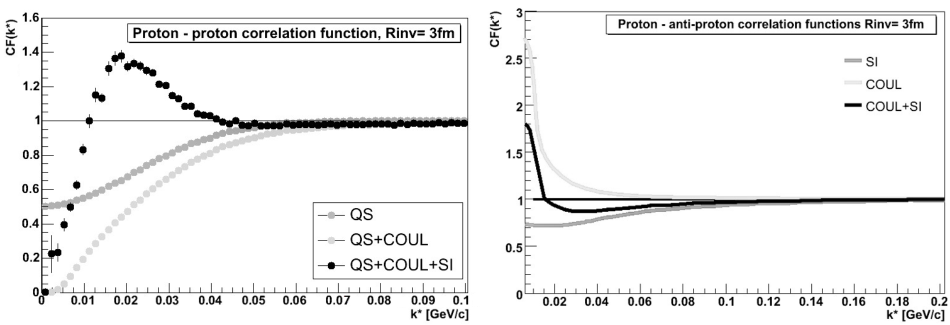

Fig. 1. Theoretical prediction of CF for the source size of 3 fm. Left — identical proton–proton CF. Right — nonidentical proton–antiproton CF [2].

The identical proton–proton CF is sensitive to Quantum Statistics (QS) and Final State Interactions (FSI). The FSI consist of Coulomb and strong interactions.

The nonidentical proton–antiproton CF is sensitive to the FSI only. The effect of the strong interactions is a negative correlation due to the annihilation processes — it is included as the imaginary part of scattering length f_0 in the formalism [2]. It can also be observed that the correlation functions become unity at different points, respectively at ($k^* \approx 50$ MeV/c) for identical and ($k^* \approx 100$ MeV/c) for nonidentical particle combinations.

3. Analysis

The analysis was done for the three BES $\sqrt{s_{NN}}$ energies: 7.7 GeV, 11.5 GeV and 39 GeV. The cuts used in the analysis have been listed in Table I.

TABLE I

List of used cuts.

Momentum (p)	$0.4 < p < 3.0$ [GeV/c]
Transverse momentum (p_{T})	$0.4 < p_{\mathrm{T}} < 2.5$ [GeV/c]
Pseudorapidity (η)	$-0.5 < \eta < 0.5$
Distance of closest approach (DCA)	DCA < 1 [cm]
Mass window	$0.76 < m^2 < 1.03$ [GeV$^2/c^4$]
$N\sigma$	$-3.0 < N < 3.0$
z vertex:	[cm]
• 7.7 GeV	$-70 < z < 70$
• 11.5 GeV	$-50 < z < 50$
• 39 GeV	$-30 < z < 30$

The data have been divided into 3 centrality groups: the central collisions group made of 10% most central of all the collisions, medium group made of 20% of all the collisions and peripheral group made of 50% of all the collisions.

In order to illustrate centrality dependence, the correlation functions for different centrality groups at given energy will be compared.

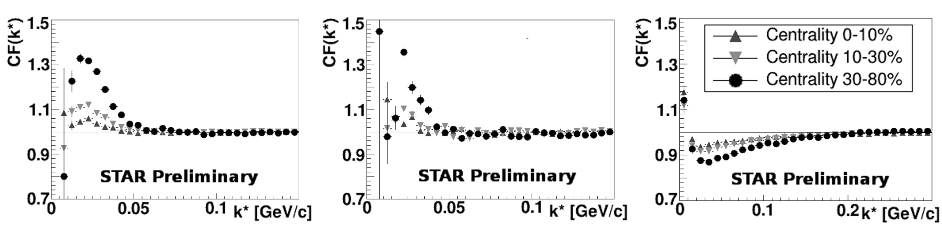

Fig. 2. CF of different centrality classes at the $\sqrt{s_{NN}} = 39$ GeV. Proton–proton (left), antiproton–antiproton (central) and proton–antiproton (right).

The plots show that there is a clear centrality dependence of source size. The radii increase with centrality at fixed $\sqrt{s_{NN}}$ (3.1)

$$R_{p-p}(0\text{–}10\%) > R_{p-p}(10\text{–}30\%) > R_{p-p}(30\text{–}80\%)\,. \qquad (3.1)$$

To better understand the energy dependence, the centrality groups are merged into a group of 0–80% most central collisions. The proton–proton and antiproton–antiproton pairs were added together into the group of the Identical Baryons (Fig. 3).

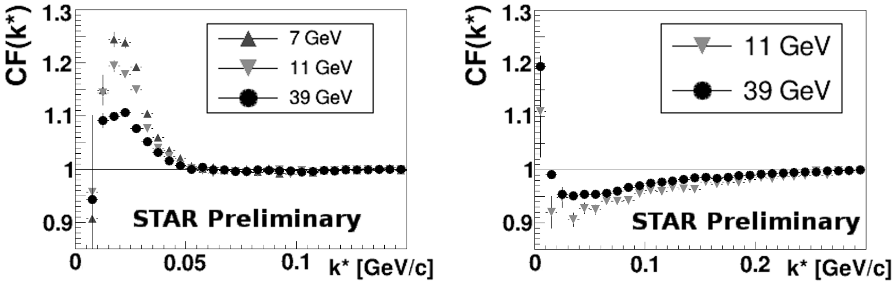

Fig. 3. CF for 0–80% most central collisions at different $\sqrt{s_{NN}}$ of identical baryons (left) and nonidentical baryons (right).

The plots indicate that there is a clear energy dependence of source size as well. The radii increase with $\sqrt{s_{NN}}$ (3.2)

$$R_{p-p}(39\ \text{GeV}) > R_{p-p}(11.5\ \text{GeV}) > R_{p-p}(7.7\ \text{GeV})\,. \tag{3.2}$$

The observed CF for identical baryons becomes unity at $k^* \approx 50$ MeV$/c$, while the CF for nonidentical baryons becomes unity at $k^* \approx 250$ MeV$/c$.

4. Summary

The (anti)proton femtoscopy is sensitive to the Quantum Statistics Effects and the Final State Interactions. The strong interactions give different effect for identical and nonidentical baryon systems due to the annihilation processes included as the imaginary part of scattering length f_0.

The analysis has been done for 3 of the BES energies. Three systems have been checked: proton–proton, proton–antiproton and antiproton–antiproton. It has been observed that the CF for identical and nonidentical particle combinations become unity at different points. The results allowed for qualitative source-size observations. The radii increase with collision energy at fixed centralities (3.1) and increase with centrality at fixed collision energy (3.2).

This work was supported by the grants: UMO-2012/07/D/ST2/02123 and UMO-2014/13/B/ST2/04054 supported by the National Science Centre, Poland.

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