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PROTON-PROTON CORRELATIONSFOR THE $pp \to pp\eta$ REACTION MEASURED WITH COSY-11

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Abstract

Based on the high statistics data for the $pp \to ppX$ reaction measured by the COSY-11 collaboration [1] we have derived a two-proton correlation function for the production of the $pp\eta$ and $pp + pions$ systems. The measured correlation function normalized to the value simulated for a point-like source was compared with a theoretical prediction in order to estimate the size of the reaction volume. The presented poster comprises summary of results recently reported in the proceedings of the Symposium on Meson Physics of the COSY-11 and WASA-at-COSY [2].

The momentum correlations of particles at small relative velocities are widely used to study the spatio-temporal characteristics of the production processes in the relativistic heavy ion collisions [3]. This technique, called after Lednicky *a correlation femtoscopy* [4], was initiated in intensity interferometry by Hanbury-Brown and Twiss [5]. Implemented into nuclear physics [4, 6, 7] it permits to determine the duration of the emission process and the sizes of the source from which the particles are emitted [4]. It is based on the correlation function [4]. The importance of the correlation femtoscopy has been well established in heavy ion collisions with high multiplicity. However, as pointed out by Chajecki [8], in the case of low-multiplicity collisions the interpretation of the correlation function measurements is still not fully satisfactory, especially in view of the surprising STAR collaboration observation indicating universality of the resulting femtoscopic radii for both, the hadronic (proton-proton), and heavy ion collisions [9]. The understanding

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of the contributions from the non-femtoscopic correlations which may be induced by the decays of resonances, global conservations laws [8], or by other unaccounted for interactions, is one of major goals. In particle physics the best place to study two-proton correlations are exclusive measurements of meson production in the collisions of hadrons conducted close to the kinematical threshold where the fraction of the available phase-space associated with low relative momenta between ejectiles is large [10]. Here, we report on measurements of the two-proton correlation function for the η meson and multi-pion production, in which the mesons were generated in the collisions of protons at the beam momentum close to the kinematical threshold for the $pp \to pp\eta$ reaction. The experiment was conducted using the proton beam of the cooler synchrotron COSY [11] and the internal hydrogen cluster target [12]. Momentum vectors of outgoing protons from the $pp \to ppX$ reaction were measured by means of the COSY-11 facility [13]. The two-proton correlation function $R(q)$ [3] was determined for the $pp\eta$ and $pp(m\pi)$ systems, respectively. It was calculated as a ratio of the reaction yield $Y(q)$ to the uncorrelated yield $Y^*(q)$ according to the formula (c.f. [15])

$$R(q) + 1 = C^* \frac{Y(q)}{Y^*(q)}, \tag{1}$$

where C^* denotes an appropriate normalization constant. $Y^*(q)$ was derived from the uncorrelated reference sample obtained by using the event mixing technique [7]. In the discussed experiment, only four-momenta of two protons were measured and the unobserved meson was identified via the missing mass technique [1, 16]. It is impossible to know whether in a given event the η meson or a few pions have been created. However, statistically, one can separate these groups of events on the basis of the missing mass spectra, for each chosen region of the phase-space. As a next step, we calculated the acceptances and efficiencies of the COSY-11 system for the registration and reconstruction of the $pp \to pp\eta$ and $pp \to pp(m\pi)$ reactions as functions of the relative momentum of the outgoing protons. For details of analysis the interested reader is referred to [17] and [2]. In order to estimate the influence of the shape induced by the kinematical bounds we have reconstructed the correlation functions from the data for both, the $pp \to pp\eta$ and $pp \to pp + pions$ reaction assuming a point-like source and using a Monte-Carlo simulation. The shape of the correlation function free from the influence of the energy

[3] Here, $R(q)$ denotes a projection of the correlation function onto the relative momentum of emitted particles $q = |\mathbf{p_1} - \mathbf{p_2}|$. Note, that some authors instead of q take as the independent variable the proton-proton center-of-mass momentum $k = q/2$ (c.f. reference [14]).

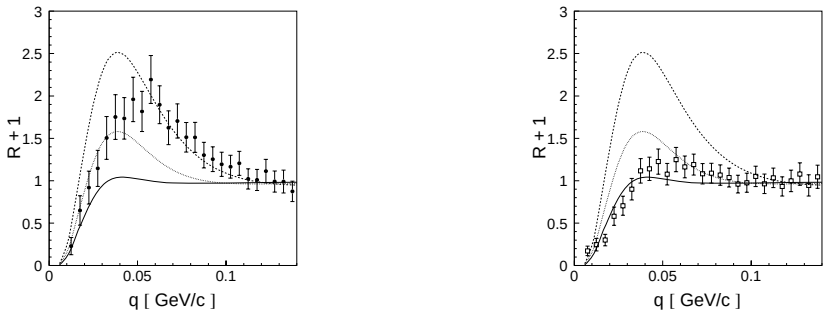

Figure 1: The two-proton correlation functions corrected for acceptance and normalized to the corresponding correlation function simulated for the point-like source. Full dots and open squares represent experimental points for the $pp \to pp\eta$ and $pp \to pp + pions$ reaction, respectively. The superimposed lines show the result of calculations [14] for the reaction volume parametrized by a Gaussian with radius $r_0 = 2.0$ fm (dashed line), $r_0 = 3.0$ fm (dotted line) and $r_0 = 5.0$ fm (solid line), respectively.

and momentum conservation was extracted from the experimental data by constructing a double ratio:

$$R(q) + 1 = C_{exp/MC} \left(\frac{Y_{exp}(q)}{Y^*_{exp}(q)} / \frac{Y_{MC}(q)}{Y^*_{MC}(q)} \right), \tag{2}$$

where $C_{exp/MC}$ denotes the normalization constant, the indices 'exp' and 'MC' refer to the experimental and simulated samples, respectively. The determined double ratios are presented in figure 1. Such procedure is used e.g. by the ALEPH collaboration for the studies of correlations in the Z decays [18] or W-pairs decays [19]. In order to estimate the size of the emission source the results are compared with theoretical predictions, obtained by assuming a simultaneous emission of the two protons and derived under the assumption that the final-state interaction between the two detected particles dominates, while other interactions are negligible. The source density was taken to be a Gaussian specified by a radius parameter r_0 and further particulars of the calculations are presented in reference [14]. A rough comparison between the theoretical correlation function and the experimental points indicates that the effective size of the emission source amounts to about 2.4 fm for the $pp\eta$ system and about 4 fm for the $pp + pions$ system. Extended calculations including the production of the η meson [20] and a detailed comparison and interpretation of results is in progress.

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