Two proton correlation function determined for the $pp \to pp\eta'$ reaction

P. Klaja and P. Moskal[a] for the COSY-11 collaboration

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 [1]. This technique, called *correlation femtoscopy* [2], originated from intensity interferometry [3]. It is based on the correlation function [2]. The importance of correlation femtoscopy has been well established in heavy ion collisions with high multiplicity of produced particles. However, as pointed out by Chajecki [4], in the case of low-multiplicity collisions the interpretation of the correlation function measurements is still not fully satisfactory [5]. The understanding of contributions from the non-femtoscopic correlations which may be induced by the decays of resonances, global conservations laws [4], or by other unaccounted for interactions, is a major goal of present investigations. In particle physics the best place to study two-proton correlations is exclusive measurements of meson production in the collisions of hadrons conducted close to the kinematical threshold [6]. Here, we report on measurement of the two-proton correlation function for the η meson production in the collisions of protons at the beam momentum close to the kinematical threshold for the $pp \to pp\eta$ reaction [7]. The two-proton correlation function $R(q)$ [1] was calculated as the ratio of the reaction yield $Y(q)$ to the uncorrelated yield $Y^*(q)$ according to the formula (c.f. [9])

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

where C^* denotes an appropriate normalization constant. $Y^*(q)$ was derived from the uncorrelated reference sample obtained by using the event mixing technique [10]. In this experiment, only the four-momenta of two protons were measured and the unobserved meson was identified via the missing mass technique [7, 11]. Therefore, it is impossible to establish whether in a given event the η meson or several pions have been created. However, one can statistically 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 acceptance and efficiency of the COSY-11 system for the registration and reconstruction of the $pp \to pp\eta$ reaction as a function of the relative momentum of the outgoing protons. For details of the analysis the interested reader is referred to articles [12] and [13]. In order to estimate the influence of the shape induced by the kinematical bounds we have reconstructed the correlation functions for the simulated sample of $pp \to pp\eta'$ events assuming a point-like source. Next, the shape of the correlation function free from the influence of the energy and momentum conservation was extracted from the experimental data by constructing a double ratio:

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

where $C_{exp/MC}$ denotes the normalization constant, and 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

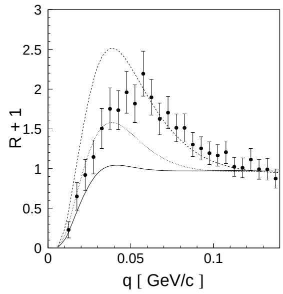

Fig. 1: The two-proton correlation function corrected for acceptance and normalized to the corresponding correlation function simulated for a point-like source. Full dots represent experimental points for the $pp \to pp\eta$ reaction. The superimposed lines show the result of calculations [8] for the 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.

ALEPH collaboration [14, 15]. 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 [8]. 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. Extended calculations including the production of the η meson [16] and a detailed comparison and interpretation of results are in progress.

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[a] Institute of Physics, Jagellonian University, Cracow, Poland

[1] Here, $R(q)$ denotes a projection of the correlation function onto the relative momentum of the emitted particles $q = |\vec{p}_1 - \vec{p}_2|$. 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 [8]).