Acceptance corrections of the two proton correlation fuction determined for the $pp \to pp\eta$ reaction

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

The high statistics data from the $pp \to pp\eta$ reaction measured by the COSY-11 collaboration [1] are now being evaluated using the correlation femtoscopy technique [2]. Our aim is to determine the proton-proton correlation function for the $pp \to pp\eta$ reaction free of the physical multi-pion background and corrected for the limited acceptance of the detection system. We think that the shape of this function will allow us to learn about the size of the interaction region from which protons are emitted. However, it is still a subject of discussions whether this information can be derived from the correlation function in case of the meson productions in the collisions of protons.
The two-proton correlation function $R(q)$ depends on the relative momentum between protons and can be defined [3] as a ratio of the reaction yield $Y_{pp\eta}(q)$ to the uncorrelated yield $Y^*(q)$:

$$R(q) + 1 = C^* \, \frac{Y_{pp\eta}(q)}{Y^*(q)}, \qquad (1)$$

where $Y^*(q)$ can be calculated using the event mixing technique [4], and C^* denotes an appropriate normalization constant.
In the discussed $pp \to pp\eta$ experiment, only four-momenta of two protons were measured and the unobserved meson was identified via the missing mass technique [1]. Therefore, it is impossible to decide whether a given event corresponds to the η meson production or whether it is due to the multi-pion creation. In the reference [5] we have described a method which allows to separate contributions to the correlation function originating from the η meson and multi-pion production. In this report we would like to give an account on a next step of the analysis which was the correction for the acceptance and efficiency of the detector system.
First, 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. The result of the simulations is presented in the figure 1(left). We divided the relative

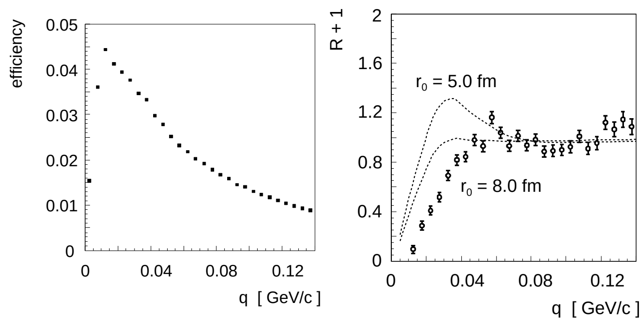

Fig. 1: **Left panel:** Overall detection efficiency (acceptance and efficiency) of the COSY-11 detection setup for the measurement of the $pp \to pp\eta$ reaction at the excess energy of Q = 15.5 MeV.
Right panel: The comparison of the acceptance corrected two-proton experimental correlation function for the $pp \to pp\eta$ reaction, represented by the open circles and theoretical calculations indicated as the two dashed lines for the reaction volume parametrized by the Gaussian distributions with $r_0 = 5.0$ fm and $r_0 = 8.0$ fm, respecively.

momentum range into bins with a width of 5 MeV/c. The width of the bin was chosen to be in the order of the accuracy of the determination of the relative proton momentum ($\sigma(q) \approx 6$ MeV/c). Knowing the acceptance it would be straightforward to correct a nominator of equation 1(left), however the correction of the uncorrelated yield $Y^*(q)$ is not trivial since momenta of protons in the uncorrelated event originates from two idependend real events which in general could correspond to different values of the detection efficiency.
Therefore, in order to derive a correlation function corrected for the acceptance we have created a sample of data as it would be measured with an ideal detector. For this aim we multilplied each reconstructed event so many times as it results from the known acceptance. This means that a given reconstructed $pp \to pp\eta$ event with a proton-proton relative momentum of q was added to the sample 1/A(q) times.
Based on this corrected data sample we calculated the two-proton correlation function according to the formula 1(left). In order to avoid mixing between the same events, a 'mixing step' in calculations was set to a value bigger than the inverse of the lowest acceptance value. The random repetition of the identical combinations was also omitted by increasing correspondingly a 'mixing step'. In particular, a kth real event, from the acceptance corrected data sample, was "mixed" with a (k+n)th event, where $n > max(1/A(q))$. If the (k+1)th event was the same as kth, then this was mixed with a (k+1+2n) event, etc. The two-proton background free correlation function corrected for the acceptance is presented in the figure 1(right).
The results are compared to the calculations, performed assuming a simultaneous emission of two protons and the η meson. The effective spatial shape of the reaction volume is approximated by a Gaussian distribution. A rough comparison between theoretical correlation and the experimental points indicates that the effective size of the emmision source turns out to be large. However, as we stated at the beginning an interpretation of the results still remains a subject of discussions.
From figure 1(right) it is evident, that the calculated and experimental shapes differ at q lower than 0.05 GeV/c. This may be due to the neglect of the experimental resolution in the theoretical calculations or due to the approximations made in the estimation of the interactions of protons in the ppη system. Therefore, as a next step of the analysis we plan to improve the theoretical calculations of the correlation function by taking into account the experimental resolution as well as the experimentally determined interaction between protons in the $pp\eta$ system [1].

References:

[1] P. Moskal et al., Phys. Rev. **C 69**, 025203 (2004)
[2] R. Lednicky, Nukleonika **49 (Sup. 2)**, S3 (2004)
[3] D. H. Boal et al., Rev. Mod. Phys. **62**, 553 (1990)
[4] G. I. Kopylov, M. I. Podgoretsky, Sov. J. Nucl. Phys. **15**, 219 (1972)
[5] P. Klaja et al., Acta Phys. Slovaca **56**, 251 (2006)

[a] Institute of Physics, Jagellonian University, Poland