Two-proton correlation function for the $pp \to pp\eta$ reaction.

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A large enhancement in the excitation function of the $pp \to pp\eta$ reaction observed close to the kinematical threshold indicates a strong attractive interaction within the $pp\eta$ system [1]. The effect can be described assuming, that the proton-proton pair is produced from a large object of a 4 fm radius [2]. A study of the $pp\eta$ system is particularly interesting in the context of the search for the Borromean states. As Borromean we call a bound three-body system in which none of the two-body subsystems is bound. In nuclear physics the ^{11}Li and ^{6}He nuclei have been found to have such a property [3]. At present it is still not established whether the low energy $pp\eta$ system can form a Borromean or resonant state. Recently the COSY-11 collaboration published high statistics data for the $pp \to pp\eta$ reaction which will be used to elucidate this question [1]. These data are presently evaluated using the well known intensity interferometry method, commonly referred to as the HBT effect [4]. This technique permits to determine the size of the source from which the protons are emitted. It is based on the correlation function of the relative momenta between the two protons, which relates the space-time separation of the particles at the emission time to their momenta p_1 and p_2. This function can be expressed in terms of pair- and single-particle cross section [4]:

$$R(p_1, p_2) = C \cdot \frac{d^6\sigma/d^3p_1 d^3p_2}{(d^3\sigma/d^3p_1)(d^3\sigma/d^3p_2)} - 1, \qquad (1)$$

where C denotes the overall normalization constant. The shape of two-proton correlation function calculated including Coulomb interaction and Pauli exclusion principle depends on the spatial size of the source. In a present analysis we consider only the projection of the R function onto one dimension corresponding to the relative momentum of emitted protons $q = |\vec{p}_1 - \vec{p}_2|$. In the calculations we tentatively assumed a simultaneous emission of the two protons and approximated the effective spatial shape of the emission zone by the Gaussian distribution. In such case the standard deviation of this distribution - hereafter referred to as r_0 - constitutes the measure of the dimension of the source. For the simulations we adapted a computing procedure written by R. Lednicky [5]. Figure 1 displays proton-proton correlation functions calculated for the, $pp \to pp\eta$ reaction, assuming four different sizes of the emission source.

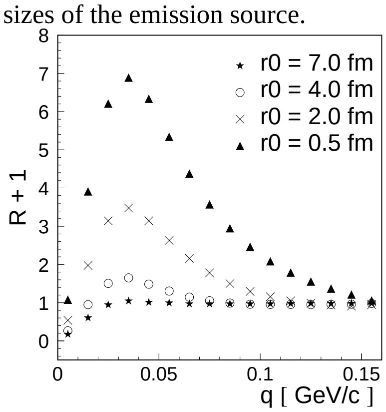

Fig. 1: Theoretical correlation functions of two protons for $r_0 = 0.5, 2.0, 4.0$ and $7.0 fm$.

One can see that the height of the peak at q ≈ 40 MeV/c depends significantly on the value of r_0 and therefore the magnitude of this maximum may serve as a measure of the volume of the reaction zone. Of course, generally the size of the reaction zone can be extracted by the comparison of the experimental and simulated correlation functions treating r_0 as a fitting parameter.

Since in the experiment the single particle yield has not been measured it is not possible to determine directly the denominator of equation 1. Therefore, in order to facilitate an extraction of the considered correlation function from the data, an alternative function $R(q)$ can be defined [4] as a ratio of the reaction yield $Y_{pp\eta}(q)$ to the uncorrelated yield $Y^*(q)$:

$$R(q) + 1 = C^* \frac{Y_{pp\eta}(q)}{Y^*(q)}, \qquad (2)$$

where C^* denotes an appropriate normalization constant. In practice, $Y^*(q)$ can be obtained via event mixing techniques, taking momentum of one proton from event m, and the momentum of the second proton from event m+k, where k is arbitrarily chosen. The correlation function derived from the data according to the formula 2 is presented in figure 2.

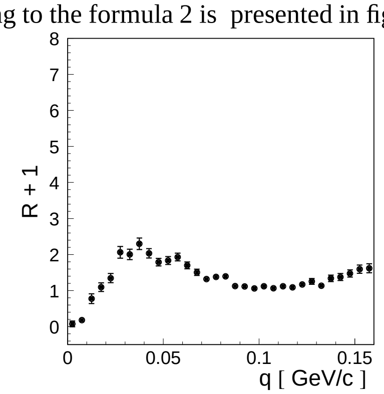

Fig. 2: The experimental two protons correlation function calculated from data [1] for the $pp \to ppX$ reaction.

A determined experimental spectrum shows a maximum at a value of q as predicted by simulations. A rough comparison between theoretical correlation functions shown in figure 1 and the experimental one indicates that the size of the reaction volume can be approximated by the Gaussian distribution with $r_0 \approx 3$ fm. However, in order to draw final conclusions we need to take into account an experimental spread in the theoretical calculations, and to distinguish between the multi-pion and η meson creation when evaluating the experimental data. At present, in order to calculate the coincidence ($Y_{pp\eta}(q)$) and uncorrelated ($Y^*(q)$) yields we took into account all events corresponding to the $pp \to ppX$ reaction for which the mass of the unobserved system X differs by no more than 1 MeV/c^2 from the mass of the η meson. In the near future, as a next step of the analysis, we will extract the correlation function for the $pp \to pp\eta$ reaction free of the multi-pion production background, and compare it to the calculations performed taking into account experimental resolution of the determination of q.

References:

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