COMPARATIVE STUDIES OF THE LOW ENERGY $pp\eta$ AND $pp\eta'$ SYSTEMS WITH THE COSY-11 DETECTOR*

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We present a comparison of the two-body invariant mass distributions for the $pp \to pp\eta$ and $pp \to pp\eta'$ reactions, both measured at a nominal excess energy value of Q = 15.5 MeV. For the $pp \to pp\eta$ reaction, in addition, the differential cross sections were extracted for an excess energy of Q = 10 MeV.
The comparison of the results for the η and η' meson production rather excludes the hypothesis that the enhancement observed in the invariant mass distributions is due to the interaction of the meson and the proton.

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The COSY-11 collaboration carried out experiments aming at the understanding of the near threshold meson production mechanisms, the meson–nucleon interaction and the meson structure. One specific part of the COSY-11 physics program is devoted to the comparative study of the interaction within the $pp\eta$ and $pp\eta'$ systems created near the kinematical threshold.
Near the threshold measurements of nucleon-nucleon collisions allow to study particle production with a dominant contribution from one partial wave only [1]. Also, the interaction between particles in near threshold collisions determines strongly the dependence of the total cross section as a function of the centre-of-mass excess energy. The experimentally determined excitation functions for the $pp \to pp\eta'$ [2, 3] and $pp \to pp\eta$ [3–7] reactions compared to the arbitrarily normalized phase-space integral reveals that proton-proton FSI enhances the total cross section by more than one order of magnitude for low energies. In the case of the η' meson production the data are described well assuming that the on-shell proton-proton amplitude exclusively determines the phase-space population. In the case of the η meson the pp-FSI is not sufficient for the description of the threshold

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enhancement of the excitation function. These observations indicate that the proton-η interaction is larger then the proton-η' interaction and that the latter is too small to manifest itself in the excitation function within the presently achieved statistical uncertainty [8, 9]. The interaction between particles depends on their relative momenta or equivalently on the invariant masses of the two-particles subsystems. It should manifest itself as modification of the phase-space abundance in kinematical regions where particles have small relative velocities. Indeed, a qualitative phenomenological analysis of the determined differential squared invariant proton-proton and proton-η mass distributions for the $pp \to pp\eta$ reaction measured by the COSY-11 collaboration at an excess energy of 15.5 MeV revealed an enhancement of the population density at the kinematical region corresponding to small proton-η momenta [10].
Also for the COSY-11 measurements performed at an excess energy of 4.5 MeV a similar enhancement has been observed [10]. In this contribution we present new results (see figure 1) of the squared invariant proton-proton and proton-η mass distribution determined at Q = 10 MeV. The results are derived from the data analyzed previously in view of the analysing power [11, 12].

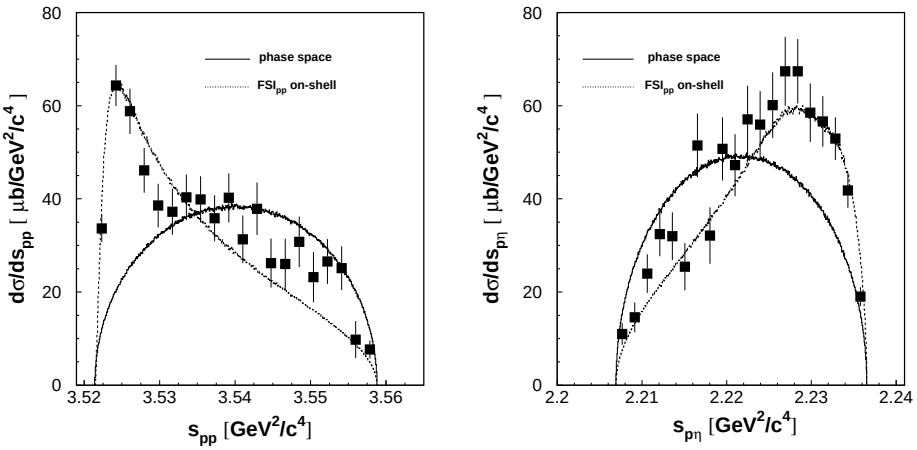

Fig. 1. Distributions of the square of the proton-proton (s_{pp}) (left) and proton-η ($s_{p\eta}$) (right) invariant masses determined experimentally for the $pp \to pp\eta$ reaction at Q = 10 MeV (full squares). The integrals of the phase space weighted by the square of the proton-proton on-shell scattering amplitude (dotted lines), have been normalized arbitrarily at small values of s_{pp}. The expectation under the assumption of a homogeneously populated phase space are shown as thick solid lines.

The dashed lines in both panels of figure 1 depict the result of the

calculations where only the proton-proton interaction has been taken into account. In those calculations the enhancement factor has been calculated as the square of the on-shell proton-proton scattering amplitude, derived using the modified Cini-Fubini-Stanghelini formula including the Wong-Noyes Coulomb corrections [8].
One can see that also at Q = 10 MeV, the discussed enhancement occurs to be too large to be described by the on-shell inclusion of the proton-proton FSI [8].
The observed enhancement could be explained by a significant role of the proton-η interaction [13,14] in the final state, or by an admixture of higher partial waves [15], or by a possible energy dependence of the production amplitude [16]. However, based on the spin-averaged $pp \to pp\eta$ data it is impossible to disentangle between the proposed hypothesis.
This motivated the measurement of the $pp \to pp\eta'$ reaction in order to determine distribution of events over the phase space at an excess energy, equal to 15.5 MeV, the same as for one of the measurements of the $pp \to pp\eta$ reaction [10]. The comparison of differential distributions of proton-proton and proton-meson invariant masses for the η and η' production could help to judge between the postulated explanations of the observed effect and in addition could allow for a quantitative estimation of the interaction between proton-η and proton-η'.

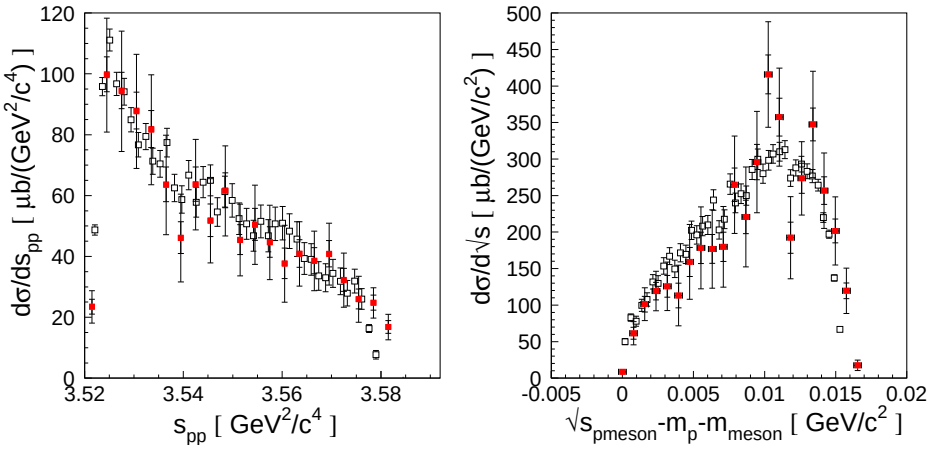

Fig. 2. Comparison of the distributions of the squared proton-proton (s_{pp}) and proton-meson ($\sqrt{s_{pmeson}}$) invariant masses determined experimentally for the $pp \to pp\eta$ (full red squares) and $pp \to pp\eta'$ (open squares) reactions. The distributions for the $pp \to pp\eta'$ reaction were normalized in amplitude to the distributions for the $pp \to pp\eta$ process.

The $pp \to pp\eta'$ reaction has been measured using the COSY-11 detectector setup [17–19]. The experiment was based on the measurement of two protons in the exit channel and the unobserved meson was identified using the missing mass technique. The analysis od the data was described in several references [20–22], and here we would like to present only the final distributions of the square of the proton-proton (s_{pp}) and proton-meson ($s_{p-meson}$) invariant masses.
In figure 2 we compare the distributions of the square of the proton-proton (s_{pp}) and proton-meson ($s_{p-meson}$) invariant masses determined for the $pp \to pp\eta$ and $pp \to pp\eta'$ reactions. In both panels of the figure, it is seen that the experimental points indicating the $pp \to pp\eta$ measurement are in agreement with those from the $pp \to pp\eta'$ reaction within the statistical errors.
Unexpectedly, the shapes do not differ, showing enhancements at the same values of the square of the proton-proton (s_{pp}) invariant mass. If indeed the η'-proton interaction is much smaller than the η-proton as inferred from the excitation function, then the spectra presented in this report rather exclude the hypothesis that the enhancement is due to the interaction of the meson and the proton.

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