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COMPARATIVE STUDY OF THE PROTON-η AND PROTON-η' INTERACTIONS VIA THE PP AND P-MESON INVARIANT MASS DISTRIBUTIONS

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Abstract

The determined pp and $p-meson$ invariant mass distributions for $pp \to pp\eta$ and $pp \to pp\eta'$ reactions are used for comparative study of the interaction within $proton-meson$ system. The elaboration of the measurement of the $pp\eta$ system has been completed and results were published in reference [1]. In this contribution we present preliminary invariant mass distributions determined for the $pp \to pp\eta'$ reaction and compare them to the theoretical predictions.

The COSY-11 collaboration continues the comparative study of interaction of the η and η' mesons with protons. To perform that studies the $pp \to pp\eta$ and $pp \to pp\eta'$ reactions were measured at the same excess energy (Q = 15.5 MeV) corresponding to the beam momentum of 2.0259 GeV/c and 3.257 GeV/c, respectively.
First part of investigations, namely the evaluation of the high-statistics measurement of the $pp \to pp\eta$ reaction is completed and the results are published in reference [1]. The $pp \to pp\eta'$ reaction has also been measured, the data has been analysed and at present the results are being interpreted.
The interaction between particles in close-to-threshold collisions determines strongly the dependence of the total cross section as a function of the centre-of-mass excess energy. The 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 reveal that proton-proton FSI enhances the total cross section by

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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. This indicates that the proton-η' interaction is too small to manifest itself in the excitation function within the presently achieved statistical uncertainty [8].
The interaction between particles depends on their relative momenta or equivalently on the invariant masses of the two-particles subsystems [1]. It should manifest itself as modification of the phase-space abundance in kinematical regions where particles have small relative velocities. Only two invariant masses of three subsystems are independent and therefore the whole accessible information about the final state interaction can be showed in the Dalitz plot. One can also use the projection of the phase-space distribution onto the invariant masses of proton-proton or proton-meson subsystems [1]. Qualitative phenomenological analysis of the determined differential invariant proton-proton and proton-η mass distributions for the $pp \to pp\eta$ reaction revealed an enhancement of the population density at the kinematical region corresponding to the small proton-η momentum [1, 9]. That effect occurs to be unexpectedly large and is not yet understood. The deviations at the small proton-η relative momenta can not be described by the on-shell inclusion of the proton-proton and proton-η FSI. Better discription is achieved when contributions based on calculations under assumption of ${}^3P_0 \to {}^1S_0 s$ as those proposed in references [10,11] and ${}^1S_0 \to {}^3P_0 s$ transition [10], are taken into account. Also three-body calculations presented in references [12,13] describe data well in mentioned proton-η momentum region. In fact, for the simultaneous description of excitation function and invariant mass ditributions a rigorous three-body approach with inclusion of higher partial waves is needed [1].
Using the COSY-11 detection system, utilizing a stochastically cooled proton beam and the hydrogen cluster target, The COSY-11 collaboration performed a high statistics measurement of the $pp \to pp\eta'$ reaction at the beam momentum of 3.257 GeV/c. The experiment was based on registration of the four-momenta of outgoing particles , whereas the η' meson was identified via the missing mass technique. We selected only these events with two reconstructed tracks ($pp \to ppX$). The missing mass resolution depends on the accuracy of the registered protons momentum determination which in case of the reconstruction used by COSY-11 group relies on the knowledge of the position of the center of the interaction region. The possible changes of the position where beam crosses target could have significantly influenced the momentum reconstruction and in consequence could worsen the determination of the mass of undetected particle but shifts of the center of interactions

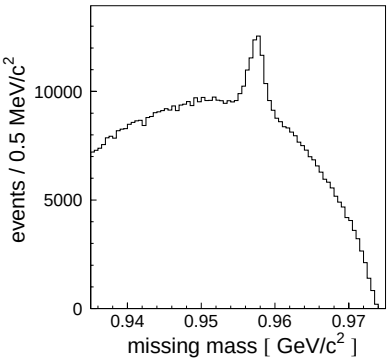

Figure 1: Experimental missing mass spectrum, determined from the whole data set, for the $pp \to ppX$ reaction measured at the beam momentum of 3.257 GeV/c.

were found to be at the negligible level of 0.01 mm [14]. In the figure 1 we present the preliminary missing mass spectrum, determined for the whole data set, for the $pp \to ppX$ reaction measured at the beam momentum of 3.257 GeV/c. In the figure a clear signal corresponding to the $pp \to pp\eta'$ reaction is visible with around 17000 events of the η' meson creation.
Now after introducing the reaction identification, in order to determine the differential cross sections, the luminosity integrated during the measurement time has been established by the comparison of the angular distributions of the elastically scattered protons with the results of the EDDA collaboration [15]. The achieved value of the integrated luminosity amounts to $L = (5.842 \pm 0.072) pb^{-1}$ [14].

The achieved luminosity value allowed for the overall normalization of the derived from data differential cross section as functions of s_{pp} and $s_{p\eta'}$ invariant masses. The preliminary distributions of invariant proton-proton and proton-η' masses are presented in the figure 2. The experimental differential distributions are compared with theoretical calculations. The dotted lines depict calculations where only proton-proton interaction is taken into account and solid lines correspond to homogenous phase-space distribution. The homogenous phase-space distribution deviates strongly from the experimental determined spectra. It is also easily seen that, theoretical calculations including proton-proton on-shell interaction do not fit the experimental data at large values of s_{pp}, similar as it was in case of the $pp \to pp\eta$ reaction. The interpretation of the results is in progress.

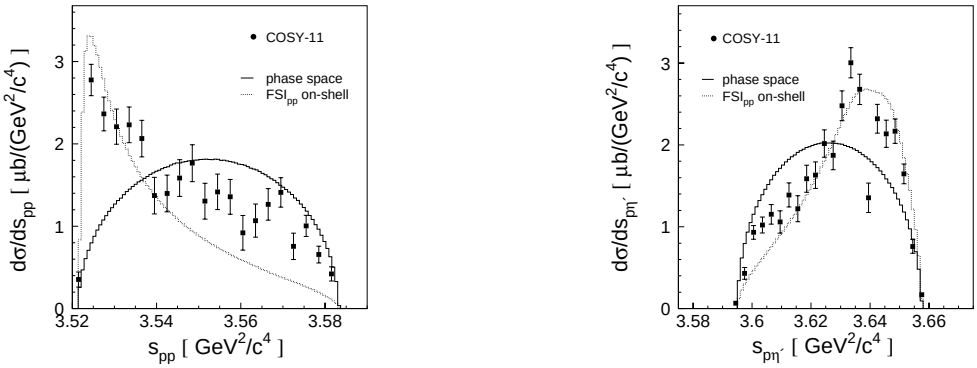

Figure 2: Distributions of the square of the proton-proton (s_{pp}) (left) and proton-η' ($s_{p\eta'}$) (right) invariant masses determined experimentally for the $pp \to pp\eta'$ reaction (full circles). The integrals of the phase space weighted by a square of the proton-proton on-shell scattering amplitude (dotted lines)-FSI_{pp}, have been normalized arbitrarily at small values of s_{pp}. The expectation under the assumption of the homogeneously populated phase space are shown as thick solid lines.

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