Angular distribution of the relative proton-proton momentum for the $pp \to pp\eta$ reaction at Q = 15.5 MeV

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For excess energies Q < 40 MeV, the energy dependence of the total cross section for the $pp \to pp\eta$ reaction [1] can be well described taking into account that the outgoing particles possess relative angular momenta equal to zero. Contrarily, even at excess energy as small as Q = 15.5 MeV, the experimentally determined distributions of the differential cross sections reveal strong deviations from the calculations accounting for S-wave proton-proton and proton-η interaction only. Figure 1 shows a spectrum of the proton-proton invariant mass at Q = 15.5 MeV as determined using the COSY-11 facility [2]. One clearly recognizes a significant difference between the data and expectation based on the factorization of the transition amplitude into the constant primary production and the on-shell incoherent pairwise interaction among the produced particles (see solid and dashed lines).

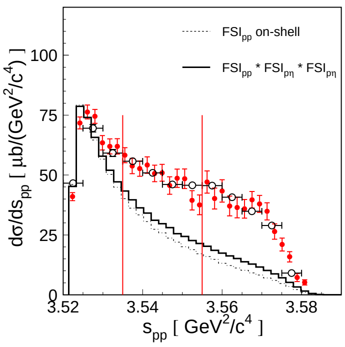

Fig. 1: Distribution of the square of the proton-proton invariant mass (s_{pp}) for the $pp \to pp\eta$ reaction at an excess energy of Q = 15.5 MeV. The data obtained by the TOF collaboration [3](open circles) have been normalized in magnitude to the results of the COSY-11 collaboration [2](filled circles). The integrals of the phase space weighted by the square of the proton-proton on-shell scattering amplitude (dashed line) FSI_{pp}, and by the product of FSI_{pp} and the square of the proton-η scattering amplitude (solid line), have been normalized arbitrarily at small values of s_{pp}. The solid line was obtained assuming a scattering length of $a_{p\eta}$ = 0.7 fm + i 0.4 fm.

The experimental data obtained independently by TOF [3] and COSY-11 [2] using different detection systems agree perfectly with each other and make possible systematical errors rather improbable. The data show also a fully isotropic distribution over the polar emission angle of the η meson in the center-of-mass frame [2, 3], and are consistent with an isotropic angular distribution of the relative momentum of the protons seen in the center-of-mass system [3] (angle θ^* on the left side of figure 2).

According to preliminary investigations based on the meson exchange model [4], the observed distribution of the proton-proton invariant mass cannot be explained assuming that the production of the outgoing particles takes place exclusively with the relative angular momentum equal to zero. The discrepancy between the solid line of figure 2 and the data is also too large to be explained by the underestimation of the s-wave proton-η interaction. Inspired by that difficulty we

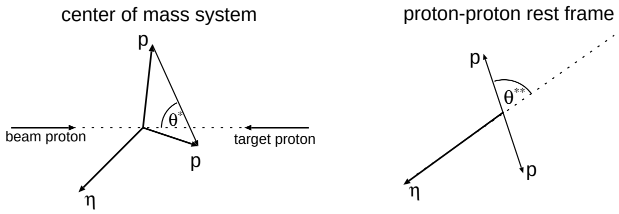

Fig. 2: Definition of the angles used in the text.

checked the partial wave distribution in the proton-proton system deriving – from the data – the angular distribution of the proton momentum in the rest frame of proton-proton system (angle θ^{**} on the right side of figure 2). A possible non-zero angular momentum between the outgoing protons should manifest itself in an unisotropic population of the angle between the relative proton-proton momentum and the recoil particle (η) seen from the di-proton rest system [5]. The distributions determined for three intervals of s_{pp} are shown in figure 3. As a first step we restricted the analysis assuming that only S– and P– waves contribute, and we fit the data by the linear combination of the Legendre polynomials up to the second degree, which in case of two identical particles reads: $\frac{d\sigma}{d\Omega} = a\ (\ 1\ +\ b\, P_2(cos\theta^{**})\ )$. In this representation the parameter b is a measure of the relative amplitude of the P– and S–wave contributions.

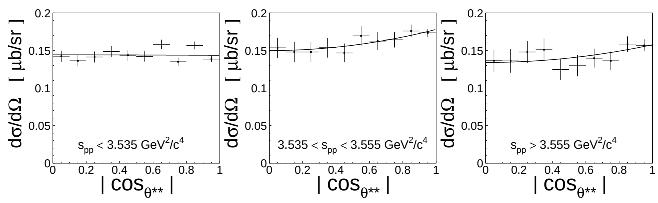

Fig. 3: Distribution of the polar angle of the relative proton-proton momentum with respect to the momentum of the η meson as seen in the di-proton rest frame. The figures correspond to the three different s_{pp} intervals marked by the vertical lines in figure 1.

As a result we obtained that b is consistent with zero for s_{pp} < 3.535 GeV^2/c^4 and amounts to ≈ 0.12 for the middle and upper ranges of s_{pp}. This value supports the hypothesis that an admixture of P-waves in the proton-proton subsystem is not negligible already at an excess energy of Q = 15.5 MeV.

References:

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