# $a_0(980)$ production in the reaction $dd \to {}^4\text{He}\ a_0^0$ and $a_0(980)$-$f_0(980)$ mixing*

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It is known (see e.g. Ref. [1]) that the coupling of the $a_0(980)$- and $f_0(980)$-resonances to the $K\bar{K}$ continuum may lead to $a_0(980)$-$f_0(980)$ mixing. As it was noted by Close and Kirk [2] the data from the WA102 collaboration at CERN [3] on central $f_0$ and $a_0$ production in the reaction $pp \to p_s X p_f$ provide evidence for a significant $f_0$-$a_0$ mixing intensity as large as $|\xi|^2 = 8 \pm 3\%$. In Ref. [4] we have discussed the effects of isospin violation in the reactions $pN \to da_0$, $pn \to df_0$, $pd \to {}^3\text{He}/{}^3\text{H}\, a_0$ and $dd \to {}^4\text{He}\, a_0^0$ which can be induced by $f_0$-$a_0$ mixing. It has been demonstrated that for a mixing intensity of about $(8 \pm 3)\%$, the effect of isospin violation in the ratio of the differential cross sections of the reactions $pp \to da_0^+ \to d\pi^+\eta$ and $pn \to da_0^0 \to d\pi^0\eta$ as well as in the forward-backward asymmetry in the reaction $pn \to da_0^0 \to d\pi^0\eta$ not far from threshold may be about 50–100%. A similar isospin violation is expected in the ratio of the differential cross sections of the reactions $pd \to {}^3\text{H}\, a_0^+(\pi^+\eta)$ and $pd \to {}^3\text{He}\, a_0^0(\pi^0\eta)$.

Direct production of the $a_0$ resonance in the reaction $dd \to {}^4\text{He}\, a_0^0$ is forbidden if isospin is conserved. It can, however, be observed due to $f_0$-$a_0$ mixing:

$$\sigma(dd \to {}^4\text{He}\, a_0^0) = |\xi|^2 \cdot \sigma(dd \to {}^4\text{He}\, f_0). \tag{1}$$

Therefore it is very interesting to study the reaction

$$dd \to {}^4\text{He}\,(\pi^0\ \eta) \tag{2}$$

at $m^2_{\pi\eta} \sim (980\text{MeV})^2$. Any signal of reaction (2) can be related to isospin breaking, which is expected to be more pronounced near the $f_0$ threshold as compared to the region below (or above).

An important point for the feasibility of such measurements is the magnitude of the cross sections $\sigma(dd \to {}^4\text{He}\, a_0^0)$ and $\sigma(dd \to {}^4\text{He}\, f_0)$. Experimental data are not available yet and we try to give a qualitative estimate of these cross sections.

According to Refs. [5, 6, 7], the cross-section ratio $\sigma(dd \to {}^4\text{He}\,\eta)/\sigma(dd \to {}^3\text{He}\,\eta)$ is about 0.04 at $Q \simeq 10$ MeV. We assume an approximately equal ratio for the case of $K^+K^-$ production near the threshold:

$$\sigma(dd \to {}^4\text{He}\, K^+K^-) = 0.04 \cdot \sigma(pd \to {}^3\text{He}\, K^+K^-)\ . \tag{3}$$

Using the MOMO data [8] on the reaction $pd \to {}^3\text{He}\, K^+K^-$ we find:

$$\sigma(dd \to {}^4\text{He}\, K^+K^-) \simeq 0.4\ \text{ nb} \tag{4}$$

at $Q = 40$ MeV. The MOMO collaboration notes that their invariant $K^+K^-$ mass distributions contain a broad peak which follows phase space. However, as it was shown for the case of the $a_0$ resonance in Ref. [9], the shape of the invariant mass spectrum following phase space cannot be distinguished from resonance production at $Q \leq \Gamma \leq 70$ MeV.

Therefore the broad mass distribution of the MOMO data may also be related to the $f_0$. This statement is supported by the two-step model where the amplitude of the reaction $pd \to {}^3\text{He}\ f_0$ can be constructed from the subprocesses $pp \to d\pi^+$ and $\pi^+n \to p\ f_0$ (cf. Refs. [10, 11]). As it is known from the available experimental data [12] the cross section of the reaction $\pi N \to NK\bar{K}$ near threshold has an essential contribution from the $f_0$ resonance in the case of isoscalar $K\bar{K}$ production. Thus the cross section of the reaction $pd \to {}^3\text{He}\ f_0 \to {}^3\text{He}\ K^+K^-$ near threshold is expected to be not essentially smaller than its upper limit from MOMO of about $10 \div 20$ nb at $Q = 40 \div 60$ MeV.

For an estimate of $\sigma(dd \to {}^4\text{He}\ \pi^+\pi^-)$ at $m_{\pi\pi} \sim m_{f_0}$ we assume that the cross section $\sigma(dd \to {}^4\text{He}\ K^+K^-)$ is also dominated by the resonant $f_0$ contribution at $m_{K\bar{K}} \sim m_{f_0}$, and that $\Gamma_{f_0 \to K\bar{K}} = (0.1 \div 0.4) \cdot \Gamma_{f_0 \to \pi\pi}$ [13]. This yields:

$$\sigma(dd \to {}^4\text{He}\ f_0 \to {}^4\text{He}\,\pi^+\pi^-) = 1 \div 4\ \text{nb}\ . \tag{5}$$

Finally, using Eq.(1), we get for $|\xi|^2$=0.05:

$$\sigma(dd \to {}^4\text{He}\, a_0^0) \simeq 0.05 \div 0.2\ \text{nb}. \tag{6}$$

The measurement of reactions (4) and (5) with cross sections in the sub-nb range are possible at the ANKE spectrometer (see Ref. [14]).

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