

Status of the search for η -mesic Helium in dd and pd reactions

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In 2010 we performed the measurement dedicated to search for the ${}^4\text{He}-\eta$ bound states in deuteron-deuteron fusion reaction. In 2015 we have completed analysis of the 2010 data sample with 20 times larger statistics with respect to the 2008 data. The η -mesic nuclei were searched via studying of excitation function for the $dd \rightarrow {}^3\text{He}p\pi^-$ [1] and $dd \rightarrow {}^3\text{He}n\pi^0$ [1, 4] reactions in the vicinity of the ${}^4\text{He}\eta$ threshold. During the experiment the beam momentum was changed slowly around the threshold for the $dd \rightarrow {}^4\text{He}\eta$ reaction in each of acceleration cycle. The beam momentum range corresponded to the excess energy region $Q \in (-70, 30)$ MeV.

The obtained excitation functions determined for $dd \rightarrow {}^3\text{He}p\pi^-$ and $dd \rightarrow {}^3\text{He}n\pi^0$ processes, do not show any narrow structure which could be interpreted as a signature of the bound state with width less than 50 MeV. Therefore, the preliminary upper limit of the total cross section for the η -mesic ${}^4\text{He}$ formation and decay was estimated for bound state production and decay in $dd \rightarrow ({}^4\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}N\pi$ processes. The obtained results are presented in Fig. 1.

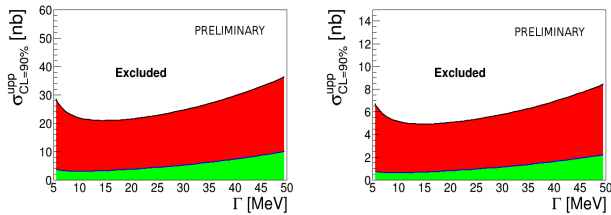


Fig. 1: Preliminary upper limit of the total cross-section for $dd \rightarrow ({}^4\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}n\pi^0$ (left panel) and $dd \rightarrow ({}^4\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}p\pi^-$ (right panel) reaction as a function of the width of the bound state. The binding energy was set to 30 MeV. The green areas denote the systematic uncertainties [4]. The figure is adapted from Ref. [1].

We achieved a sensitivity of the cross section of the order of few nb for the $dd \rightarrow ({}^4\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}p\pi^-$ reaction that is about four times better result in comparison with those obtained from 2008 data [3]. Moreover, the obtained upper limit value does not exclude the cross section $\sigma_{\text{tot}} = 4.5$ nb estimated in Ref. [5]. The excitation function for the $dd \rightarrow ({}^4\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}n\pi^0$ reaction was investigated for the first time. The upper limit obtained in this case is by factor of five larger than predicted value therefore, one can conclude, that the measurement does not exclude the existence of bound state in this process either. The theoretical interpretation with respect to very wide $({}^4\text{He}-\eta)_{\text{bound}}$ or ${}^3\text{He}-N^*$ bound system [6] is in progress.

In May 2014 the measurements for searching η -mesic ${}^3\text{He}$ were also performed [7] in processes corresponding to the three mechanisms: (i) absorption of the η meson by one of the nucleons, which subsequently decays into $N^*-\pi$ pair e.g.: $pd \rightarrow ({}^3\text{He}-\eta)_{\text{bound}} \rightarrow ppp\pi^-$, (ii) decay of the η -meson while it is still "orbiting" around a nucleus e.g.: $pd \rightarrow ({}^3\text{He}-\eta)_{\text{bound}} \rightarrow {}^3\text{He}\gamma$ reactions

and (iii) η meson absorption by few nucleons e.g.: $pd \rightarrow ({}^3\text{He}-\eta)_{\text{bound}} \rightarrow ppn$. The statistics of the data obtained in this experiment is better than it was measured for the same conditions ever before.

Now obtaining luminosity value from $pd \rightarrow {}^3\text{He}\eta$ reaction is in progress. The algorithm of ${}^3\text{He}$ kinetic energy reconstruction has been implemented and conditions for identifying the events corresponding to these reactions have been provided.

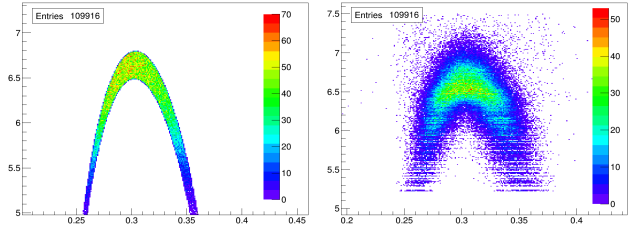


Fig. 2: Kinematic histograms obtained from Monte Carlo simulation for $pd \rightarrow {}^3\text{He}\eta$. Horizontal axes: kinetic energy in GeV. Vertical axes: θ in degrees. Left plot: data obtained from vertices. Right plot: reconstruction of parameters from detector signals.

Even if the analysis does not show the existence of the bound state, the upper limit that would be set for the cross section for its forming will be lower than one obtained in previous measurements for ${}^4\text{He}$. At present the analysis of this data is going on.

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