Search for ^{4}He-η bound states with the WASA-at-COSY facility*

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Introduction

The new kind of exotic nuclear matter consisting of nucleus bound with η meson via strong interaction was postulated by Haider and Liu in 1986 [1]. The existence of η-mesic bound states would allow to investigate interaction of the η meson and nucleons inside a nuclear matter. Moreover it would provide information about the N*(1535) resonance [2] and about the η meson properties in a nuclear matter [3], as well as about contribution of the flavour singlet component of the quark-gluon wave function of the η meson [4]. According to the theoretical considerations, the formation of the η-mesic nucleus can only take place if the real part of the η-nucleus scattering length is negative (attractive nature of the interaction), and the magnitude of the real part is greater than the magnitude of the imaginary part:

$$|Re(a_{\eta-nucleus})| > |Im(a_{\eta-nucleus})|. \quad (1)$$

A wide range of possible values of the s-wave ηN scattering lenght, from $a_{\eta N}$=(0.27 + 0.22i) fm up to $a_{\eta N}$=(1.05 + 0.27i) fm, calculated for hadronic- and photoproduction of the η meson has not exluded the formation of η-nucleus bound states for a light nuclei as ^{3,4}He, T [5] and even for deuteron [6]. Those bound states have been searched in many experiments, however none of them gave empirical confirmation of their existence. There are only a promising experimental observations which might be interpreted as indications of the η-mesic nuclei.For example, experimental observations which might suggest the possibility of the existence of the ^{3}He-η bound system were found by SPES-4 [7], SPES-2 [8], ANKE [9], COSY-11 [10] and TAPS [11] collaborations.

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Experiment at WASA-at-COSY

The new high-statictics measurement of the ^{4}He-η bound states is performed with unique precision at the COSY accelerator by means of the WASA detection system. Signals of the η-mesic nuclei are searched for via studying the excitation function of specific decay channels of the ^{4}He-η system, formed in deuteron-deuteron collision [12, 13]. The measurement is performed for the beam momenta varying continously around the η meson production threshold. The beam ramping technique allows to reduce the systematic uncertainities. The existence of the bound system should manifest itself as a resonance-like structure in the excitation curve of eg. $dd \rightarrow (^4\text{He-}\eta)_{bs} \rightarrow$ $^3\text{He}p\pi^-$ reaction below the $dd \rightarrow {}^4$He-η reaction threshold. The kinematics of the reaction is schematically presented in Fig. 1.

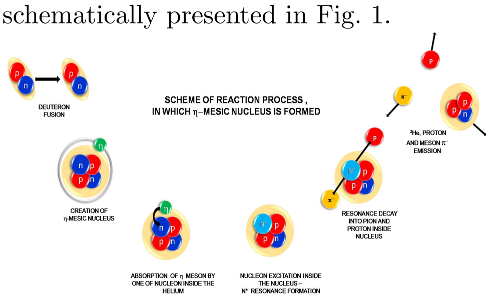

FIG. 1: Reaction process of the (^{4}He-η)$_{bs}$ production and decay.

The deuteron beam - deuteron target collision leads to the creation of the ^{4}He nucleus bound with the η meson via strong interaction. The η meson can be absorbed by one of the nucleons inside helium and may propagate in the nucleus via consecutive excitation of nucleons to the N*(1525) state until the resonance decays into the pion-proton pair outgoing from the nucleus [14]. The relative angle between p and π^- is equal to 180° in the N* reference frame and it is smeared by about 30° in the center-of-mass frame due to the Fermi motion of the nucleons inside the helium nucleus.

In June 2008 a search for the ^{4}He-η bound state was performed by measuring the excitation function of the $dd \to {}^3\mathrm{He}p\pi^-$ reaction near the η production threshold. During the experimental run the momentum of the deuteron b/eam was varied continuously within each acceleration cycle from 2.185 GeV/c to 2.400 GeV/c, crossing the kinematic threshold for the η production in the $dd \to {}^4\mathrm{He}\eta$ reaction at 2.336 GeV/c. This range of beam momenta corresponds to the variation of ^{4}He-η excess energy from -51.4 MeV to 22 MeV.

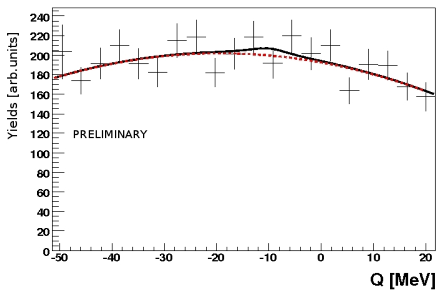

FIG. 2: Excitation function for the $dd \to {}^3\mathrm{He}p\pi^-$ reaction obtained by normalizing events selected in individual excess energy intervals by corresponding integrated luminosities. The solid line represents a fit with second order polynomialcombined with Breit-Wigner function with fixed binding energy and width equal to -10 and 10 MeV, respectively. The dotted line corresponds to the contribution from the second order polynomial in the performed fit. The σ values are not corrected for the acceptance end efficiency of cuts.

Excitation function was determined after applying cuts on the p and π^- kinetic energy distribution and the $p - \pi^-$ opening angle in the CM system [15]. The result is shown in Fig. 2. The relative normalization of points of the $dd \to {}^3\mathrm{He}p\pi^-$ excitation function was based on the quasi-elastic proton-proton scattering. In the excitation function there is no structure which could be interpreted as a resonance originating from decay of the η-mesic ^{4}He. During the experiment, in November 2010, two channels of the eta-mesic helium decay were measured: $dd \to ({}^4\mathrm{He}\text{-}\eta)_{bs} \to {}^3\mathrm{He}p\pi^-$ and $dd \to ({}^4\mathrm{He}\text{-}\eta)_{bs} \to {}^3\mathrm{He}n\pi^0 \to {}^3\mathrm{He}n\gamma\gamma$. The measurement was performed with the beam momentum ramping from 2.127GeV/c to 2.422GeV/c, corresponding to the range of the excess energy Q∈(-70,30) MeV. The poster/talk will include description of the experimental method and status of the analysis.

Acknowledgements

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