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SEARCH FOR η-NUCLEUS BOUND STATES

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Abstract

We have performed an experiment to search for the formation of η-mesic nuclear states using recoil-free $(p, {}^3He)$ transfer reactions on ^{27}Al nuclei. The decay of such states is expected to proceed through $N^*(1535)$ resonance which would lead to the proton-π^- pair emitted in opposite direction. A coincidence measurement of ^3He particles with the η-mesic decay particles shows a low statistics enhancement in the excitation energy spectra of the residual system below the free η production threshold.

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1 Introduction

The possible existence of a bound state of η-meson and a nucleus, the so-called η-mesic nuclei, was first proposed by Haider and Liu two decades ago [1]. This came out as a result of their theoretical findings that the low energy η-nucleon interaction is attractive and it can bind η in nuclei. This attraction arises because the η-nucleon (ηN) interaction at low energies is strongly influenced by the presence of the S-wave nucleon resonance $N^*(1535)$ which lies close to the η-nucleon production threshold. Since then a large number of theoretical calculations have been performed and almost all of them predict the possibility of η-nucleus bound state formation. However, depending on the value of η-nucleon scattering length $a_{\eta N}$ that is used in the calculations, different limits for mass numbers A are predicted for which a η-bound state can exist. The detailed calculations of C. Garcia-Recio et al however, suggest that it is only in the region of mass region $A = 24$ that the bound state peaks with widths comparable to binding energy can be experimentally observed [2].

Initial experimental measurements for search of bound η -meson states with the (π^+, p) reaction at Brookhaven AGS [3] couldn't confirm their existence. Recent data on photoproduction of η meson on ^{3}He and ^{12}C [4] nuclei have been interpreted to provide signatures of η-mesic nucleus formation. More direct measurements with better statistics are required however for any conclusive evidence. In this contribution, we describe an experiment to search for the η- nucleus bound state formation that has been performed at COSY using the (p,^{3}He) reaction on ^{27}Al target at recoilless kinematic conditions.

2 Experiment

The experimental search employs the reaction $p + {}^{27}Al \rightarrow {}^{3}He + {}^{25}Mg \otimes \eta$ at the recoil-free conditions (p_beam =1745 MeV/c) in which the bound state formation and decay takes place via η + N $\rightarrow$N* $\rightarrow \pi^-$ + p. The outgoing ^{3}He particles have been measured under zero degree by the 3D2Q magnetic spectrometer BigKarl(BK) along with its focal plane detectors. Tracks of ^{3}He particles were measured in the focal plane of the spectrometer with two stacks of multi-wire drift chambers (MWDC) followed by two layers of scintillator hodoscopes to measure energy loss and time of flight of particles. Two momenta settings of spectrometer at 859 MeV/c and 897 MeV/c were used to measure ^{3}He particles, which cover $\sim$ 80 MeV range each in the missing mass spectrum. To enhance the sensitivity of measurement the decay products of

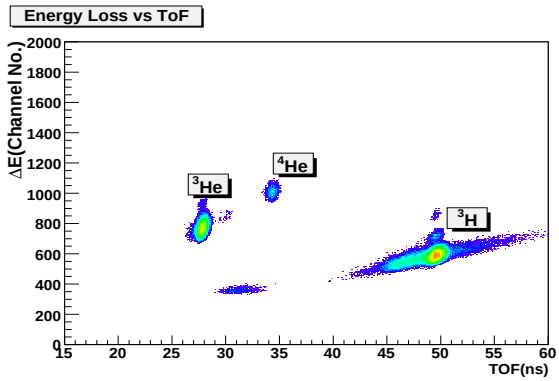

Figure 1: **Left**: Energy loss versus the Time of Flight spectra from the focal plane hodoscopes. ^{3}He particles can be clearly identified.

the η mesic nuclei are measured in a large acceptance plastic scintillator detector ENSTAR [5] in coincidence with ^{3}He particles. The signature for the η-bound formation in this experiment is a peak in the missing mass spectrum of residual nuclear system at the excitation energies corresponding to the production of negative energy η's in two-body kinematics.

3 Data Analysis and Results

The energy loss in the first hodoscope layer is shown in Fig. 1 as a function of time of flight of the different particle groups. Clearly the ^{3}He ions can be identified by from the spectra. The inclusive missing mass spectra of the residual reaction products in $p^{27}Al \rightarrow^3 HeX$ reaction is a uniform distribution which show mainly the acceptance of the spectrograph. To suppress the background and select signal corresponding to η bound state formation coincidence conditions from ENSTAR detector were used. Events corresponding to the coincidence peak in the time spectrum of the ENSTAR detectors have been selected and background has been estimated. Missing mass spectra for selected events corresponding to two decay particles emitted back-to-back measured in ENSTAR shows a low statistics enhancement at almost similar range of values in both momentum setting of spectrograph as shown in Fig. 2. Based on the estimates of detection efficiency due to detector geometry and analysis cuts of 0.7 we obtain $\frac{d\sigma}{d\Omega_{^3He}}(\theta_{^3He} = 0^\circ, (p\pi^-)) = 0.2 \pm 0.08$ nb/sr. If this structure corresponds to the decay of a bound η decaying via $N^* \rightarrow \pi^- + p$ an upper limit of ~ 0.5 nb/sr on the formation cross section

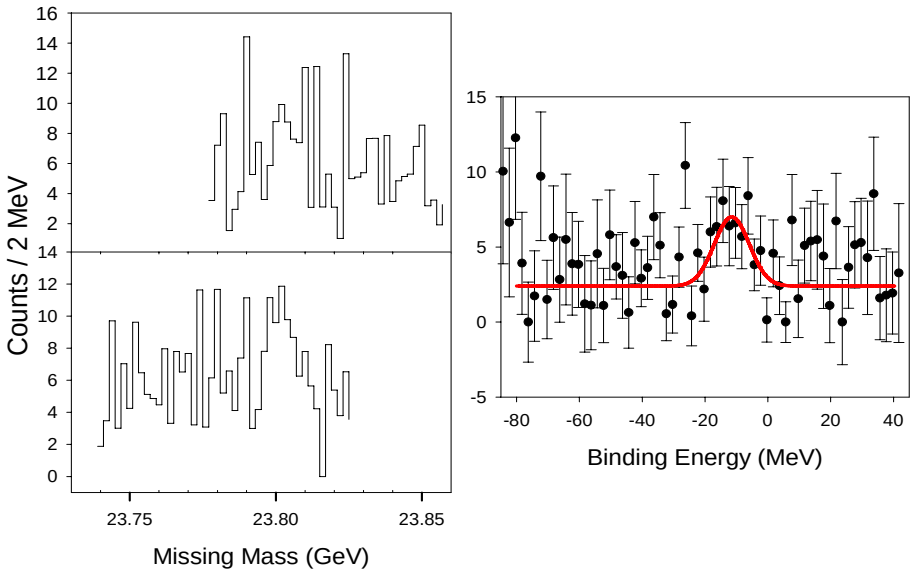

Figure 2: **a**: Missing mass spectra of residual nuclear products in coincidence with ENSTAR cuts at two Big Karl settings. **b**: Summed binding energy spectra at two settings fitted with the background plus a gaussian.

of η-bound state can be estimated.

4 Summary

In summary, we have performed a dedicated experiment to search for the signals of formation of eta-,mesic nuclei using the reaction $p^{27}Al \rightarrow^{3} He + \pi^{-} + p + X$. In two missing mass spectra taken at independent spectrograph settings, we observe an enhancement for negative binding energies. An upper bound of $\sim$0.5 nb for the formation cross section of η-nucleus bound state has been estimated.

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