Investigation of the ^{3}He η Final State in dp-Reactions at ANKE*

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The existence of η-mesic nuclei is still an open issue of research. To investigate the possibility of the formation of such bound systems, production measurements with one η meson and one light nucleus in the final state are of great interest. By studying the final state interaction at low excess energies, information about the scattering length of the η-nucleus system can be gained. The latter one is closely related to the properties of such a possible bound state and has to be determined with high precision. The available data sets in the close vicinity of the threshold expose discrepancies, which currently forbid the extraction of scattering length information with sufficient precision [1].

Therefore, the reaction d+p$\rightarrow$^{3}He+η has been investigated at the ANKE spectrometer using a continuously ramped accelerator beam at excess energies ranging from below threshold at Q = -5.1 MeV up to Q = +11.3 MeV. Additionally, data at excess energies of Q = 20, 40 and 60 MeV have been recorded in order to determine total cross sections and to investigate contributions from higher partial waves [2]. For the analysis of the continuous ramp all data were sorted by the time information in the ramp. The resulting width of the excess energy interval is 72 keV.

To search for the events of the reaction channel of interest the ^{3}He nuclei are selected using the ANKE forward detector. The production of η-mesons is identified via the missing mass technique. For the reconstruction of the momenta via the magnetic spectrometer the information of the three drift- and multi-wire proportional chambers are used.

The particle identification is achieved by an energy loss versus momentum plot (ΔE/p) for three segmented scintillation walls, two of the forward system and an additional side wall frame of the positive detector placed behind the forward system. A simultaneous cut on the expected region for ^{3}He nuclei in the (ΔE/p) plot in the three scintillation walls allows for a clear identification of the ^{3}He band. The reactions can be identified by plotting the transversal versus the longitudinal reconstructed center of mass (CMS) momenta. For a reaction with two particles in the exit channel one expects a momentum ellipse with a fixed radius.

In the near threshold region the CMS-momenta of the ^{3}He nuclei are small. Due to this fact the scattering angles ϑ^{LS} for the ^{3}He nuclei after the Lorentz transformation into the laboratory system are small and all ^{3}He nuclei of the reaction channel of interest are in the geometrical acceptance of the wire chambers of the forward system. For this reason the dp kinematic was used for the beamtime, leading to a full geometrical acceptance in the wire chambers up to an excess energy of 20 MeV. The result is a characteristic image of the hit position in all chambers.

The identification of the η events is done using the missing mass distribution shown in figure 1b). The challenge of the extraction of the η peak from the background near the kinematical limit can impressively be met by using subthreshold data as it was done in [3]. The background reactions, namely the multi pion production and misidentified protons from breakup reactions, have a high excess energy and vary only slowly with the excess energy for the η-production. Subthreshold data of the continuous ramp analysed with the same kinematical conditions as the analysed data are expected to give a good description of the background behaviour.

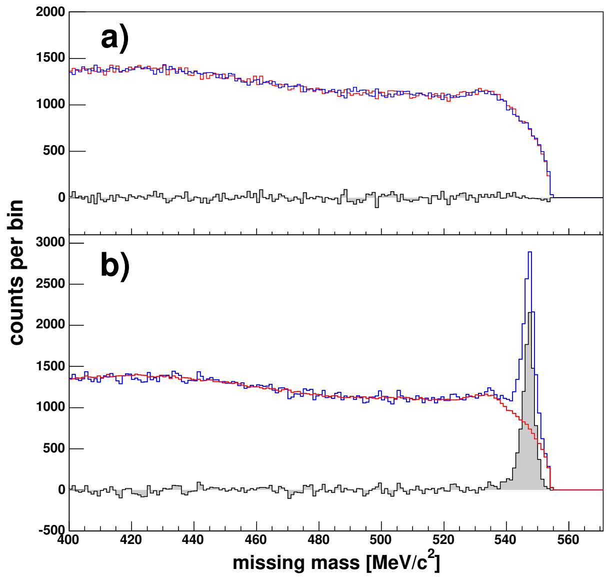

Fig. 1: a) Comparison of the data at Q = -4.75 MeV(blue line) and Q = -0.6 MeV(red line). The difference shown is consistent with zero (blue filled histogram).
b) Missing mass distribution (blue line) at an excess energy of Q = 6.95 MeV. The subtraction of the scaled background description (red line) using all the subthreshold data results in a clean η peak (filled histogram).

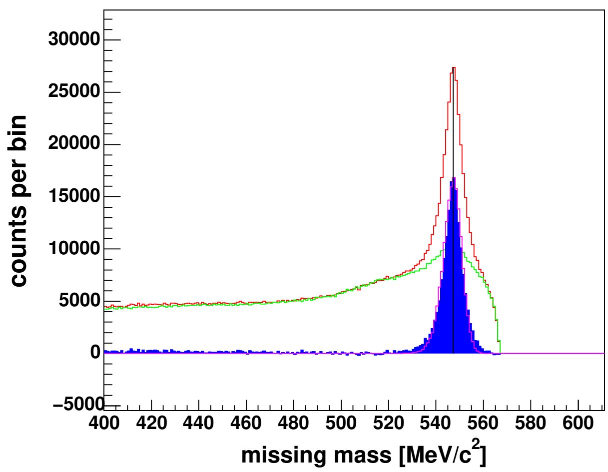

Fig. 2: Preliminary missing mass plot (red line) at an excess energy of Q = 20 MeV. The background description (green line), the subtracted η signal (blue filled histogram) and a Monte-Carlo simulation (pink line) of the η-peak are added.

The data of the choosen excess energy interval and the subthreshold data were analysed assuming an excess energy of Q = 6.95 MeV. The reconstructed ^{3}He momenta were scaled

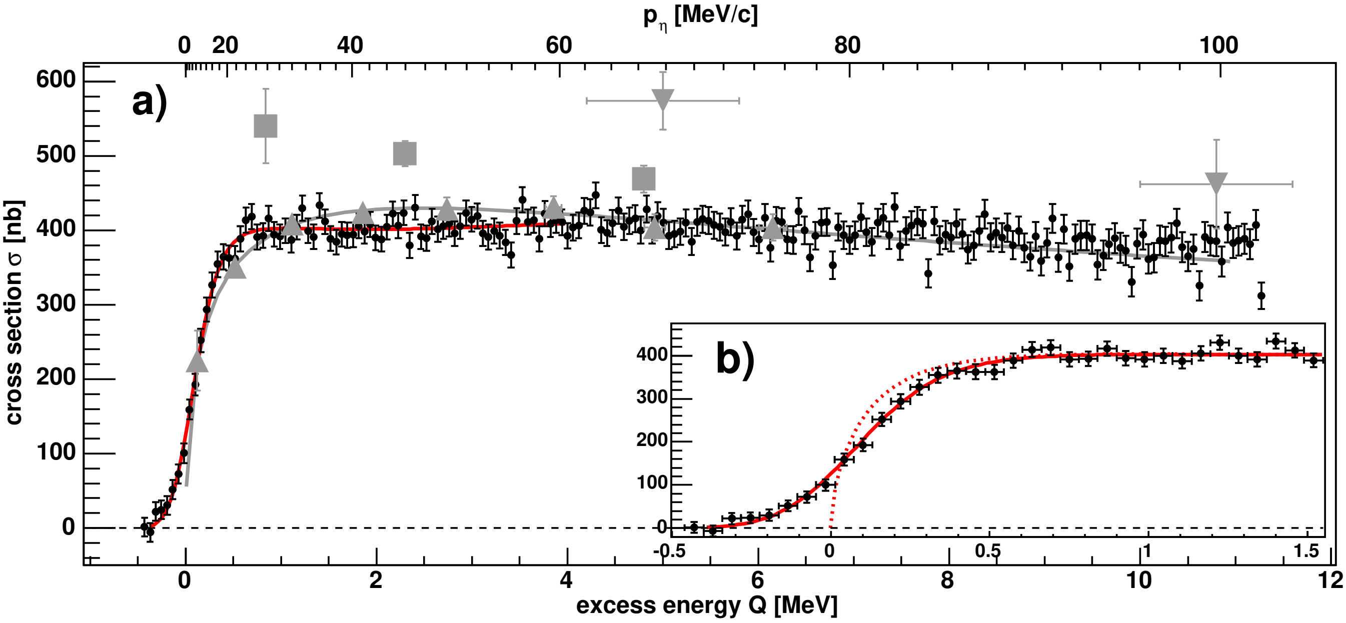

Fig. 3: Comparison of the extracted total cross section data (circles) with data from Ref.[4](squares), Ref.[5](triangles) and Ref.[6](inverted triangles). The red curve is the fit to our data for $Q < 4$ MeV. The grey curve is the SpesII fit to their own data [5]. Not shown are overall uncertainties arising from data normalization.

to the same conditions. In figure 1b) the red line shows the resulting missing mass distribution of the data at Q = 6.95 MeV and the green one of the subthreshold data scaled to the red line. The difference, plotted as the filled histogram, corresponds to pure η production.

A check of the method to describe the background is possible by the comparison of the data obtained at Q = -4.75 MeV (green line) and Q = -0.6 MeV (red line) in figure 1a) where both were analyzed assuming a value of Q = +6.95 MeV. The difference of the scaled curves (blue filled histogram) vanish, therefore the shape of the background does not vary within the first eighty seconds of the ramp. Thus it can be assumed that this behaviour does not change for the following 180 seconds.

The $d+p \to {}^3He+\eta$ total cross sections obtained at 195 bins in excess energy Q are displayed in figure 3. The minimal relative systematic errors resulting from the measurement of the excitation function in a single experiment form a robust data set for any analysis. In 3b) one can see the surprisingly steep rise of the total cross section near treshold that indicates a very strong final state interaction. The shape of the η production below the nominal threshold is well understood and it is a very sensitive measurement of the finite width of the COSY beam. It was also possible to extract the differential cross sections for each excess energy bin and therefore to determine the angular assymmetry parameter α, defined as

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{c.m.}} = \frac{\sigma_{\mathrm{tot}}}{4\pi}\left[1+\alpha\cos\theta_{\mathrm{c.m.}}\right] \qquad (1)$$

The results show a contribution from higher partial waves already above an excess energy of Q = 4 MeV.

The data taken at higher excess energies of Q = 20, 40 and 60 MeV are as well currently analysed. A preliminary missing mass plot is shown in figure 2. Total cross sections as well as differential cross sections will be determined for this energies. Together with the results from the continous ramp data this will form a complete differential and total cross section sample from treshold up to 60 MeV excess energy for the $d+p \to {}^3He+\eta$ reaction.

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* Supported by FZ-Jülich FFE