High precision study on the η-meson production channel $d + p \to {}^3\mathrm{He} + \eta$*

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The ANKE collaboration has performed a beam time to determine the η meson mass with high precision using the $d + p \to {}^3\mathrm{He} + \eta$ reaction [1] and to study the two pion production using $d + p \to {}^3\mathrm{He} + \pi^+ + \pi^-$ [2]. In order to determine the η mass, data has been studied at 18 deuteron beam momenta in a range between $3120.17\ \mathrm{MeV}/c \leq p_d \leq 3204.16\ \mathrm{MeV}/c$ which could be extracted very accurately via the resonant depolarization technique with a precision of $\Delta p_d/p_d < 6 \times 10^{-5}$ [1, 3].

Moreover, due to the high statistics of more than 1×10^5 ${}^3\mathrm{He}\eta$ events per energy in combination with full angular coverage these high precision ANKE data allow to investigate the total and differential cross sections of the reaction $d + p \to {}^3\mathrm{He} + \eta$. Such data are of special interest since they differ strongly from a pure phase space behaviour near threshold. Furthermore, analysis of the asymmetry factor

$$\alpha = \frac{d}{d\cos\vartheta_\eta^{\mathrm{CMS}}} \ln\left(\frac{d\sigma}{d\Omega}\right)_{\cos\vartheta_\eta^{\mathrm{CMS}}=0} \qquad (1)$$

of the differential cross sections show a distinct effect of s- and p-wave interference with the η momentum, which can be explained by a rapid variation of the relative phase. These effects are an indication for an unexpected strong final state interaction (FSI) between η mesons and ${}^3\mathrm{He}$ nuclei which could lead to the formation of a quasi-bound state of the $\eta{}^3\mathrm{He}$-system [4, 5].

To extract total and differential cross sections of the η production channel $d + p \to {}^3\mathrm{He} + \eta$ with high precision, a careful luminosity determination was performed for each of the 18 beam momenta of the beam time via dp-elastic scattering [6]. Thereby it was possible to achieve statistical uncertainties of $\Delta_{\mathrm{stat}} = 1\%$ and systematic uncertainties of $\Delta_{\mathrm{sys}} = 6\%$ which leads to an improvement by at least a factor of two compared to previous measurements.

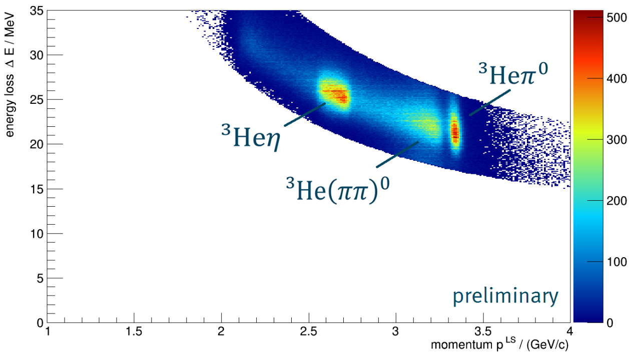

Fig. 1: The two-dimensional distribution of the energy loss information in the forward scintillator hodoscopes of the first layer versus the particles laboratory momentum for a beam momentum of $3158.71\ \mathrm{MeV}/c$. A clear ${}^3\mathrm{He}$ band becomes visible consisting of the single-, multi-pion, and η production.

Identification of the η production channel is achieved by detecting the ${}^3\mathrm{He}$-nuclei in the ANKE Forward Detection system ("FD system") with the calibrated energy loss information [7] in the scintillator hodoscopes. After cutting on the characteristical $\Delta E/p$ band of ${}^3\mathrm{He}$-nuclei (cf. Figure 1), missing mass analyses show a distinct η signal for each beam momentum with more than 10^5 ${}^3\mathrm{He}\eta$ events per energy. The background description is done with data taken below the η production threshold at a beam momentum of $3120.17\ \mathrm{MeV}/c$, therefore allowing a model independent approach. In order to do this, the subthreshold data will be analyzed with the desired laboratory momentum which leads to a shift of the kinematical limit in the missing mass spectra, using

$$\vec{p}_{\mathrm{LS}}^{\,\mathrm{desired}} = \frac{p_{\mathrm{beam}}^{\mathrm{desired}}}{p_{\mathrm{beam}}^{\mathrm{subth.}}} \cdot \vec{p}_{\mathrm{beam}}^{\,\mathrm{subth.}} \quad , \qquad (2)$$

and is then scaled to fit the data. After background subtraction a clear η peak is left (cf. Figure 2).

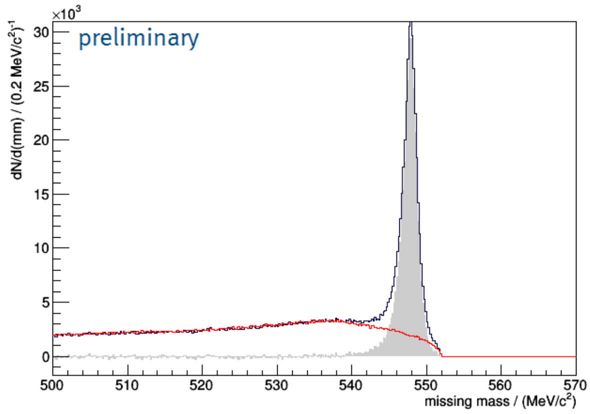

Fig. 2: Missing mass distribution of the events passing the energy loss selection cut for a beam momentum of $3158.71\ \mathrm{MeV}/c$ (blue) and for data taken below the η production threshold (red) as a model independent background description (see text for more detailed information). After background subtraction a clear η peak is left (shaded grey).

Due to the high statistics and the full geometric acceptance of ANKE, this analysis can be performed bin-wise over the entire angular range. An acceptance correction via Monte Carlo simulations is in progress, so that first results will be available soon.

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* Supported by the COSY-FFE program of the Forschungszentrum Jülich
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