Measurement of the Reaction $pd \to p_{sp.}d\eta$ at ANKE*

N. Lang[a], A. Khoukaz[a], R. Menke[a], T. Mersmann[a] and R. Santo[a]

In July/August 2002 the near threshold production of η-mesons in proton-neutron collisions was measured at ANKE during a two-weeks beam time. The reaction $pd \to p_{\rm spec}d\eta$ was studied at two beam momenta of $p_{\rm beam1} = 2.055\,{\rm GeV}/c$ and $p_{\rm beam2} = 2.095\,{\rm GeV}/c$. In absence of free neutron targets, the cluster target was operated with deuterium to provide quasifree neutrons, tagged for their Fermi momentum using spectator kinematics.

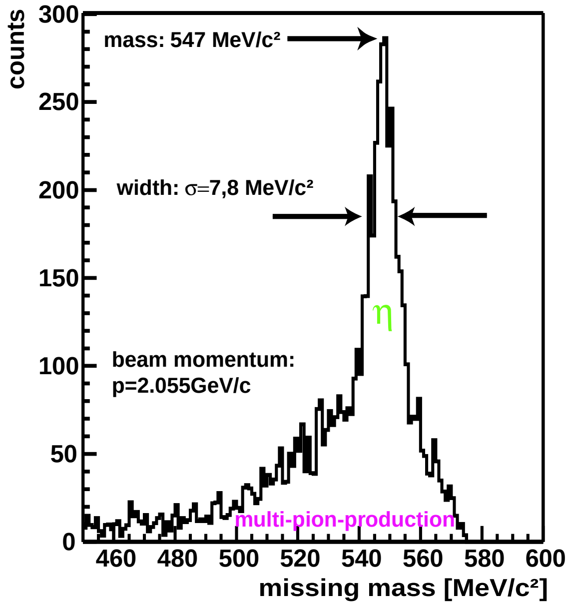

Fig. 1: Missing mass distribution at a beam momentum of $p = 2.055\,{\rm GeV/c}$

The events of the reaction channel of interest were identified by detecting the spectator protons in a dedicated silicon telescope in coincidence with fast forward going deuterons, detected in the ANKE forward detector. The measurement of spectator protons allows for the calculation of the Fermi momentum of the neutron and the Q-value for the reaction for each event [1]. With the chosen beam momenta excess energies of $Q = 0\ldots30$ MeV and $Q = 5\ldots45$ MeV were accessible. The production of η-mesons was identified using the missing mass technique, leading to a clear identification of the η-meson with good resolution on a background from multi pion production, see Fig. 1.

For the reconstruction of the deuteron 4-momenta the information from the two segmented scintillation walls and the two MWPCs of the ANKE forward system are used. Particle identification is achieved by a ΔE-versus-momentum plot. In this plot, due to the Bethe-Bloch energy-loss behaviour, deuterons were separated from the proton background, see Fig. 2. A projection of the ΔE-p plot shown in Fig. 3 gives information about the separation level of protons and deuterons. The data analysis leads to a level of $\approx 11\%$ misidentified deuterons and $\approx 1\%$ lost deuterons. To obtain the excitation function for the reaction $pn \to d\eta$, the missing mass analysis has been performed for different bins of the reconstructed excess energy Q (see Fig. 4).

In the upper spectra of Fig. 4 the missing mass distribution

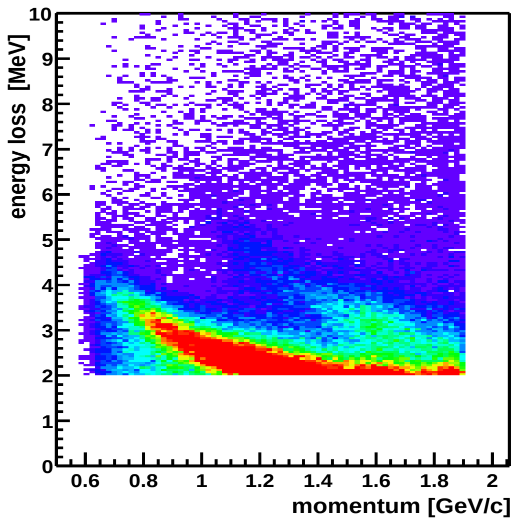

Fig. 2: Energy loss in the first scintillation wall versus the momentum of the incident particle. The larger lower region originates from protons, in the upper smaller band deuterons are visible.

is plotted for two energy intervals without background subtraction. The solid lines indicate the fitted background distributions, which were generated using Monte-Carlo-simulations for multi pion channels. The lower figures show the resulting missing mass distributions after background subtraction. The solid line indicates a gaussian fit to the remaining peak of the η-signal.

The shape of the background distribution induced through multi-pion-production was calculated with Geant4 simulations and was subsequently fitted to the data. The background subtracted spectra show a missing mass peak at the mass of the η-meson with the expected width. The flat distribution in the region of lower masses and the almost perfect argreement of the multipion model with the data at the kinematical limit show that the background description is well suited. The main source of uncertainty to fit the background level to the data is the limited statistics of the measured data. The analysis of the peak area, in combination with acceptance and efficiency calculation, leads to the execss-energy dependence of the η-production cross section. The luminosity determination will be performed using elastically scattered $pd \to pd$ events which were measured simultaneously. A detailed report on the procedure can be found in [2] and in this annual report.

In order to compare the data with the existing data set from CELSIUS [3], in particular in the very-close-to-threshold region below $Q < 10\,{\rm MeV}$, the achieved resolution in Q is not sufficient. The shown width of the Q-bin intervals results mainly from the limited spatial resolution of the spectator detector and the target size. Simulations on the resolution in Q (see Fig. 5) have resulted in a full width of $\Delta Q \approx 10\,{\rm MeV}$. The calculated width motivates the binning of the data points shown in Fig. 6.

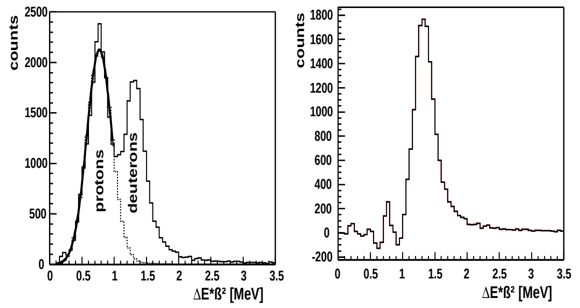

Fig. 3: Number of detected events in the forward detector as function of $\Delta E \cdot \beta^2$. The left peak is fitted with a convolution of a gaussian and a landau function (solid line). The extrapolated shape of this distribution is subtracted from the peak on the right hand side. The remaining part in the right hand side picture represents the identified deuterons which show up as a Landau distribution.

Due to the ongoing normalisation of the data the numbers for the cross section in Fig. 6 are still arbitrary. A first cautious interpretation of the shape of the excitation function reveals that it is compatible with phase-space behaviour for higher Q-values. At low Q-values the data seems also to be compatible with an enhancement as compared to phase-space exspectations.
Concluding, the presented results show the feasibility to scan a broad range of the excitation function with one fixed beam momentum and the ability for a precise identification of the $pn \to d\eta$ channel at ANKE.

References:

[1] I. Lehmann, *Studies on a Detection System for Spectator Protons at ANKE*, Diploma thesis, Institut für Kernphysik Forschungszentrum Jülich (2000)

[2] T. Mersmann, *Untersuchungen zur Proton-Deuteron-Streuung an einem Deuterium Clusterstrahl am Magnetspektrometer ANKE*, Diploma thesis, Institut für Kernphysik, Westfälische Wilhelms-Universität Münster (2003)

[3] H. Calén et al. Phys.Rev.Lett **80**, 2069 (1998)

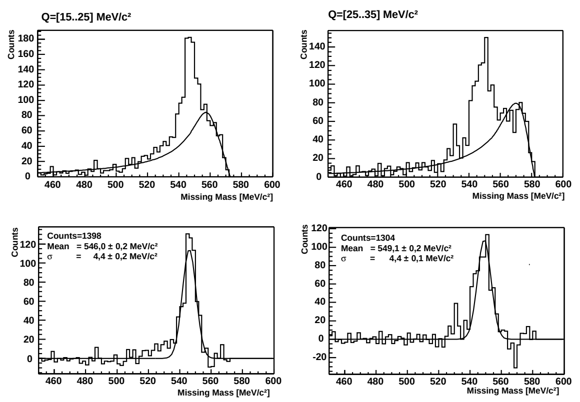

Fig. 4: Q-binned missing mass analysis of the data at $p = 2.095\,\mathrm{GeV/c}$.

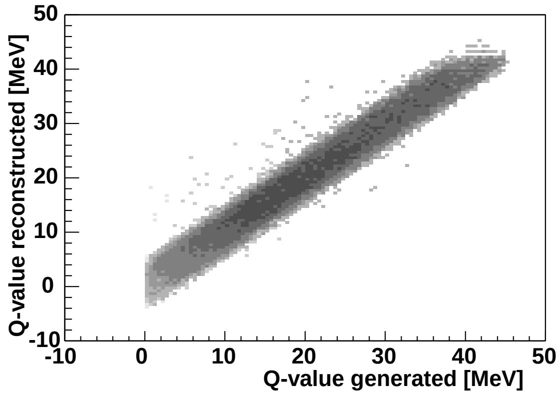

Fig. 5: Simulated distribution of reconstructed Q-values versus original Q-Values with the current geometry. The broad band leads to a binning of Q-intervals of 10MeV full width.

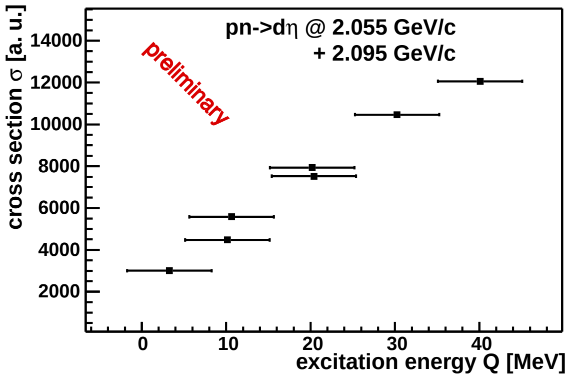

Fig. 6: Extracted excitation function with data from both beam momenta. The data still is preliminary.

[a] Institut für Kernphysik, Westfälische Wilhelms-Universität, 45159 Münster, Germany

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