Detection possibilities of the quasi–free $p\,n \to p\,n\,\eta'$ reaction at the WASA detector

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In August 2004, for the first time the η' meson production in the proton–neutron collision [1] has been studied close to the kinematical threshold at the COSY–11 facility, an internal magnetic spectrometer installed at the cooler synchrotron COSY. The measurement of the quasi–free $p\,n \to p\,n\,\eta'$ reaction was conducted with a proton beam ($p_{beam} = 3.35 GeV/c$) and with a deuteron cluster target. The expriment was based on the measurement of the four-momenta of the outgoing nucleons. Events corresponding to the creation of the η' meson will be identified off-line via the missing mass technique, and the total energy available for the quasi-free proton-neutron reaction can be calculated for each event from the vector of the momentum of the spectator proton. The spectator protons are measured by the dedicated silicon-pad detector [2]. At present the analysis aiming for establishing the excitation function for the $p\,n \to p\,n\,\eta'$ reaction is in progress and will deliver values for the total cross section in the excess energy range between 0 and 20 MeV. A tentative elaboration of the quasi-free elastic proton-proton scattering showed that the luminosity averaged over the three weeks of measurement amounted to about $4 \cdot 10^{30}$ cm^{-2} s^{-1}. With such luminosity – depending on the anticipated reaction mechanism – we expect between 40 and 260 measured and reconstructed events per day [1].

Such investigation could be extended to excess energies (up to $\approx$ 150 MeV) using the WASA facility at COSY [5, 6]. In this case the method of the measurement will be different from the one used at COSY-11, since with the present WASA set-up one cannot detect spectator protons. Yet, as it is shown for the studies of the $pd \to pn\eta p_{sp}$ reaction at CELSIUS [4], the measurement of the gamma quanta originating from the decays of the η' and the registration of the fast outgoing proton suffice to distinguish the quasi-free $pn \to pn\eta'$ process from other recations and to reconstruct the excess energy for each event [3]. If the spectator proton and outgoing neutron are not measured than one can calculate the excess energy only approximately since in this case we deal with six unknown variables (two unknown momentum vectors) and only four equations for energy and momentum conservation. Assuming that the transverse component of the momentum of the target nucleon is equal to zero one can calculate the approximate value of the excess energy [4, 3]. Figure 1 demonstrates the excess energy distribution simulated for the $pd \to pn\eta' p_{sp}$ reaction (dashed line) and the result obtained when applying the above approximation (solid line). On the average the reconstructed values of Q are a few MeV larger then generated (see also Figure 2). Such a shift, however, is much smaller than the smearing caused by the experimental resolution of the measurement of the four-momentum vectors of the gamma quanta and the proton. For example, the experimental smearing in the case of the $pn \to pn\eta$ reaction is about 8 MeV [4]. In order to estimate this for the $pn \to pn\eta'$ reaction we have performed simulation studies of the response of the WASA detector assuming the detection arrangement as it is used at present at CELSIUS [7]. As a first step we have chosen only one decay channel of the η' meson with a branching ratio 0.02, viz $p\,n \to p\,n\,\eta' \to p\,n\,\gamma\gamma$ process. Figure 3 depicts result obtained for the distribution of the difference between the generated and reconstructed excess energies. The resolution is unacceptable to perform the study of the $pn \to pn\eta'$ reaction using the present WASA detection system and the temporary reconstruction algorithm, which was optimized for the less energetic protons. For the discussed investigations the present configuration of the forward detector must be improved in order to allow a better determination of the energy of the forward scattered protons. This resolution could be improved also when taking into account signals from neutrons which may react in the forward detector with 36% probability [5]. A quantitative answer requires further investgations.

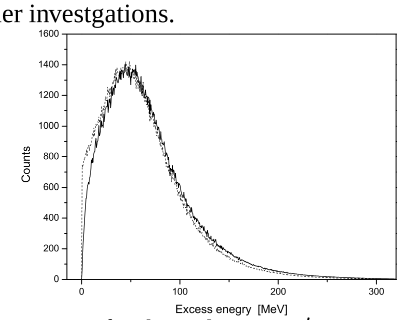

Fig. 1: Excess energy for the $p\,d \to p\,n\,\eta' p_{sp}$ reaction simulated at a proton beam momentum of 3.35 GeV/c. For details see text.

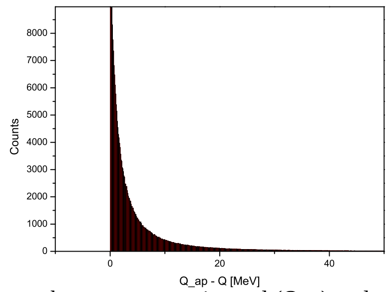

Fig. 2: Difference between approximated (Q_{ap}) and real (Q) excess energy for the $p\,n \to p\,n\,\eta'$ reaction.

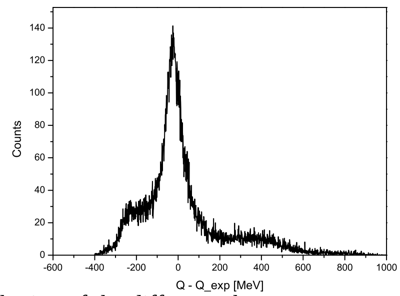

Fig. 3: Distribution of the difference between generated and reconstructed excess energy.

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