Status of the analysis of the $pn \to pn\eta'$ reaction

J. Klaja and P. Moskal for the COSY-11 collaboration

In August 2004 –for the first time– using the COSY–11 [1] facility we have conducted a measurement of the η' meson production in proton-neutron collisions [2]. The aim of the experiment is a determination of the total cross section of the $pn \to pn\eta'$ reaction near the kinematical threshold. The comparison of the $pp \to pp\eta'$ and $pn \to pn\eta'$ total cross sections will help to understand production of the η' meson in different isospin channels and to investigate aspects of the gluonium component of this meson.
The experiment has been realized using a proton beam and a deuteron cluster target, since pure neutron targets do not exist. For the data analysis the proton from the deuteron is considered as a spectator which does not interact with the bombarding proton, but escapes undisturbed and hits the detector carrying the Fermi momentum possessed exactly at the time of the reaction. The Fermi motion of the target nucleons affects the centre-of-mass energy of the system, resulting from the 4-momentum of the beam proton and target neutron, on an event-by-event basis. Thus, the centre-of-mass energy of the final state can be reconstructed for each event provided that enough information is available. Therefore, the experiment is based on the registration of all outgoing nucleons from the $pd \to p_{sp}pnX$ reaction. Fast protons are measured in two drift chambers and scintillator detectors, neutrons are registered in the neutral particle detector, and slow spectator protons moving upstream compared to the beam are measured by a dedicated two-layer silicon-pad detector.

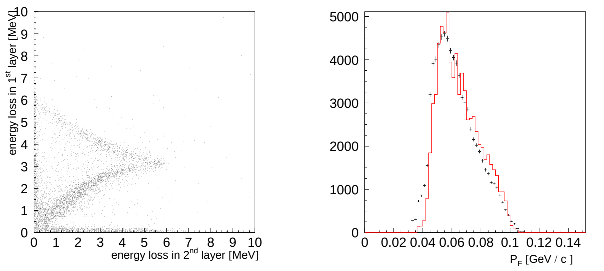

Fig. 1: **Left**: Energy losses in the first layer versus the second layer of the spectator detector as measured at COSY–11 with a deuteron target and a proton beam with momentu of 3.35 GeV/c. **Right**: Momentum distribution of the proton spectator as reconstructed in the experiment (points) in comparison with simulation taking into account Fermi momentum distribution of nucleons inside the deuteron (solid histogram).

Fig. 1 (left) shows energy losses in the 1^{st} layer of the spectator detector versus the 2^{nd} layer. Slow spectator protons are stopped in the first or second layer of the detector whereas fast particles cross both detection layers. Having the deposited energy and the emission angle we calculate the kinetic energy of the spectator proton and its momentum. Fig. 1 (right) shows the momentum distribution of protons considered as a spectator, as determined at COSY–11 with a deuteron target and a proton beam with a momentum of 3.35 GeV/c (points) compared to simulations taking into account a Fermi motion of nucleons inside the deuteron (solid line). The application of the missing mass technique allows to identify events with the creation of the meson under investigation. The total energy available for the quasi-free proton-neutron reaction is calculated for each event from the momentum vector of the spectator and beam protons. The absolute momentum of neutrons is determined from the time-of-flight between the target and the neutron detector. Fig. 2 (left) presents the time-of-flight distribution – for neutral particles – measured between the target and the neutral particle detector. A clear signal originating from gamma rays is seen over a broad enhancement from neutrons. This histogram shows that discrimination between signals originating from neutrons and gamma quanta can be done by a cut on the time of flight. From Monte Carlo simulations of the $pn \to pn\eta'$ reaction the largest expected momentum value of the neutron is eqaul to 1.4 GeV/c which corresponds to a time-of-flight value of 28.5 ns as it is indicated by the arrow in fig. 2 (left). Due to the smaller efficiency and lower resolution for the registration of the quasi-free $pn \to pn$ *meson* reaction in comparison to the measurements of the proton-proton reactions, the data collected have low statistics. Therefore, the excess energy range for $Q \geq 0$ has been divided only into four intervals of 8 MeV width each. For each interval we have calculated the missing mass. Next, from events with negative Q value the corresponding background missing mass spectrum was constructed, shifted to the kinematical limit and normalized to the experimental distribution at the very low mass values where no events from the η' production are expected.

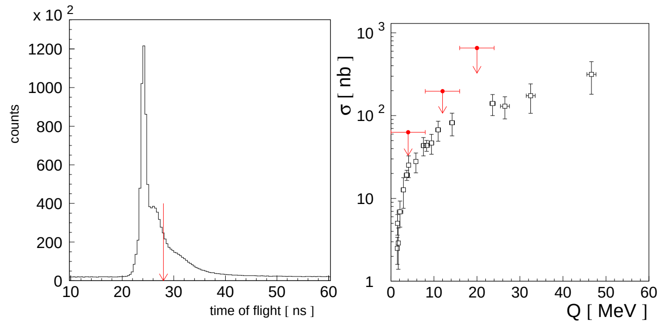

Fig. 2: **Left**: Distribution of the time–of–flight between the target and the neutron detector. **Right**: Total cross sections for the $pp \to pp\eta'$ reaction as a function of the excess energy (open symbols). Upper limit for the total cross section for the $pn \to pn\eta'$ reaction as a function of the excess energy (closed symbols).

After subtracting missing mass distributions for negative values of Q from spectra for Q values larger than 0 – due to the very low signal–to–background ratio – at the present stage of the data analysis, the signal from the η' meson was found to be statistically insignificant. Nevertheless, having the luminosity – established from the number of the quasi-free proton-proton elastic scattering events [3] – and the detection efficiency of the COSY-11 system we have estimated the upper limit of the total cross section for the quasi-free $pn \to pn\eta'$ reaction. The prelimnary results are shown in Fig. 2(right).

References:

[1] S. Brauksiepe et al., NIM **A 376** 396 (1996).
[2] P. Moskal et al., COSY Proposal **No. 133** (2003).
[3] P. Moskal, R. Czyżykiewicz, *AIP Conf. Proc.* **950**, 118 (2007).