η and η' meson production in free and quasi–free nucleon–nucleon collisions at COSY-11

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Introduction

The most remarkable feature – in the frame of the quark model – distinguishing the η' meson from all other pseudoscalar and vector ground state mesons, is the fact, that the η' is predominantly a flavour - singlet combination of quark-antiquark pairs and therefore can mix with purely gluonic states.
A comparison of the close–to–threshold total cross section for the η' production in both the $pp \to pp\eta'$ and $pn \to pn\eta'$ reaction constitutes a tool to investigate the η' meson structure and the reaction mechanism and may provide – as suggested in reference [1, 2, 3] – insight into the flavour-singlet (perhaps also into gluonium) content of the η' meson and the relevance of quark-gluon or hadronic degrees of freedom in the creation process.
By the analogy to the η meson production – in case of the dominant isovector meson exchange we can expect that the ratio $R_\eta = \frac{\sigma(pn\to pn\eta)}{\sigma(pp\to pp\eta)}$ should be about 6.5 [4]. If however η' meson is produced via its flavour-blind gluonium component from the colour-singlet glue excited in the interaction region the ratio should approach unity after corrections for the initial and final state interactions [1].

η and η' meson production in quasi-free reactions

The close–to–threshold excitation function for the $pp \to pp\eta'$ reaction has already been determined [5, 6, 7, 8], whereas the total cross section for η' meson production in the proton-neutron interaction - a second part of our studies - is still unknown.
In August 2004, for the first time we have conducted the measurement of the quasi-free $pn \to pn\eta'$ reaction at the COSY-11 facility. In order to measure quasi-free $pn \to pnX$ reaction by means of the proton beam, deuterons are used as a source of

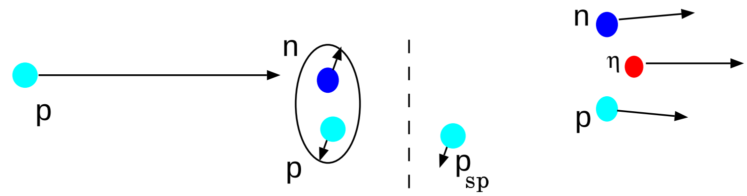

Figure 1: Schematic picture of the quasi-free η meson production.

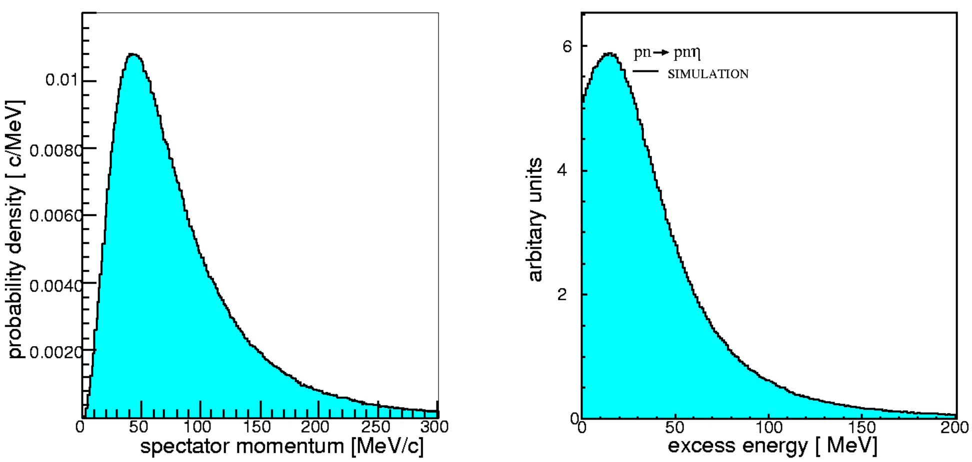

Figure 2: **(left)** Momentum distribution of nucleons inside a deuteron calculated from Paris potential [9] **(right)** Distribution of the excess energy for the quasi-free $pn \to pn\eta$ reaction

neutrons since a pure neutron target does not exist. The reaction is schematically shown in figure 1.

Nucleons bound inside the deuteron are not in the rest, but they are moving with a Fermi momentum as shown in the fig.2 (left). For the data analysis the proton from the deuteron is considered as a spectator which does not interact with the bombarding proton but rather escapes untouched and hits the detectors carrying the Fermi momentum possessed at the time of the reaction. Since the neutron momentum varies from event to event, the excess energy will also change from event to event. Fermi motion of neutron inside the deuteron enables to scan a large range of excess energies with one constant beam momentum (see fig.2 right), however this requires the determination of the excess energy for each event.

The experiment at the COSY-11 facility is based on the measurement of the four-momenta of the outgoing nucleons, whereas events corresponding to the creation of η' meson are identified off-line via the missing mass technique. Protons are registered in two drift chambers and in the scintillator hadoscopes [10, 11]. Neutrons are measured in the neutral particle detector. The spectator protons are measured by the dedicated silicon-pad detector [12, 13]. From the measurement of the momentum vector of the spectator proton one can infer the momentum vector of the neutron at the moment of the collisions, and hence calculate the excess energy [14, 15]

The experiments and the evaluation of the data from the proton-neutron interaction is much more difficult in comparison to the measurements of the proton-

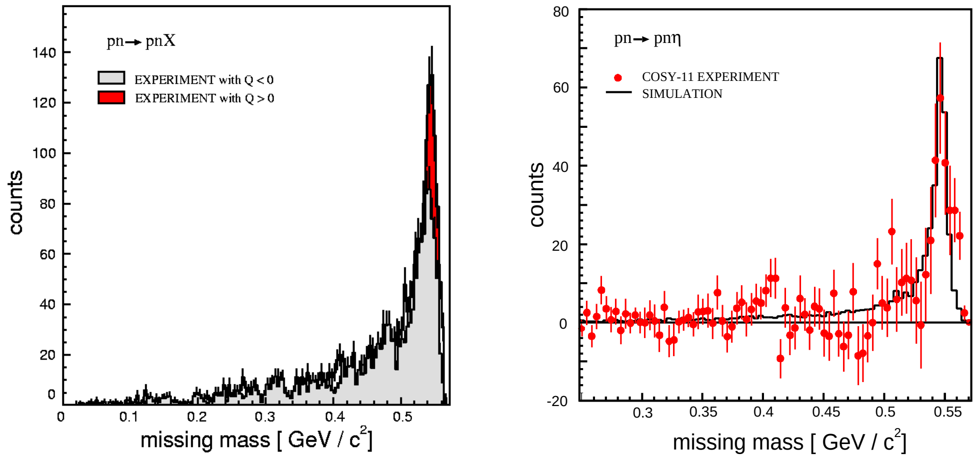

Figure 3: **(left)** Missing mass spectra of the $pn \to pn\eta$ process determined for the excess energies larger and smaller than zero. **(right)** Missing mass spectrum for Q larger than 0 after the subtraction of the multi-pion background. The solid line, normalized in amplitude to the data points, corresponds to the Monte-Carlo simulation

proton reactions. To define the full kinematics of the $pn \to pnX$ events one needs to measure at least one more particle comparing to the analog meson production in proton-proton interaction. Moreover the efficiency for the registration of the quasi-free $pn \to pn\ meson$ process decreases by a large factor in comparison to the $pp \to pp\ meson$ reaction. The elaboration of the data encounters problems of low statistic, however one can extract the number of registered $pn \to pn\ meson$ events from the missing mass distribution provided that the contribution of the continuous spectrum originting from the multi-pion production can be disentangled from the signal resulting from the production of the investigated meson. This can be done by comparison of the missing mass distribution for the negative values of Q, when only pions may be created and the missing mass distribution for Q larger than zero [16]. In case of the positive values of Q a signal from the $\eta(\eta')$ meson is expected on the top of the multi-pion mass distribution. Example of application of this method (depicted in details in ref. [16]) in the analysis of the quasi-free $pn \to pn\eta$ reaction is shown in the fig.3. Figure 3 (left) presents the missing mass spectra for Q larger then zero (solid line) and the corresponding background histograms (shaded area). Figure 3 (right) shows the spectrum of the missing mass for Q larger than zero after the subtraction of the background. One can see a good agreement between the experimental distribution and the simulation.
This method will be also used for the extraction of the signal of the η' meson production via $pn \to pn\eta'$ reaction from the data.

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