International Journal of Modern Physics A

ISOSPIN DEPENDENCE OF THE η' MESON PRODUCTION IN NUCLEON-NUCLEON COLLISIONS

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A comparison of the close–to–threshold total cross section for the η' production in $pp \to pp\eta'$ and $pn \to pn\eta'$ reactions constitutes a tool to investigate the η' meson structure and the reaction mechanism in the channels of isospin I = 0 and I = 1 and may provide insight into the flavour-singlet (perhaps also into gluonium) content of the η' meson.

In this contribution we present preliminary results of measurement of the quasi-free production of the η' meson in the proton-neutron collisions conducted using the COSY-11 facility.

Keywords: near threshold meson production; quasi-free reaction

1. Introduction

In the framework of the quark model the η' meson is predominantly a flavour-singlet combination of quark-antiquark pairs, and it is expected to mix with purely gluonic states. Therefore, additionally to the production mechanisms associated with meson exchange[1,2] it is also possible that η' meson is produced from excited glue in the interaction region of the colliding nucleons, which couple to the η' meson directly via its gluonic component or through its SU(3)-flavour-singlet admixture[3]. As suggested in reference[4], the η' meson production via the colour-singlet object does not depend on the total isospin of the colliding nucleons and should lead to the same amplitudes of the production for the $pn \to pn\eta'$ and $pp \to pp\eta'$ reactions. In case of the η meson, the ratio of the total cross sections for the reactions $pn \to pn\eta$ and $pp \to pp\eta$ was determined to be $R_\eta \approx 6.5$[5], and $R_\eta \approx 3$ at threshold[6], what suggest the dominance of isovector meson exchange in the η production in nucleon-

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nucleon collisions. Since the quark structure of η and η' mesons is similar, in case of the dominant isovector meson exchange – by the analogy to the η meson production – we can expect that the ratio $R_{\eta'}$ should be large. 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. The close–to–threshold excitation function for the $pp \to pp\eta'$ reaction has already been established[7] and the determination of the total cross section for the η' meson production in the proton-neutron interaction constitutes the aim of the work reported in this contribution.

2. Experiment

In August 2004 using the COSY–11 facility[8] we have conducted a measurement of the η' meson production in the proton-neutron collision. The experiment has been realized using a proton beam of the cooler synchrotron COSY [9] and a cluster jet deuteron target [10]. Proton and neutron outgoing from the $pn \to pn\eta$ reaction have been registered by means of the COSY-11 facility. For the data analysis the proton from the deuteron is considered as a spectator which does not interact with the bombarding proton, but escapes untouched and hits the detector carrying the Fermi momentum possessed exactly at the time of the reaction. The experiment is based on the registration of all outgoing nucleons from the $pd \to p_{sp}pnX$ reaction [6]. Fast protons are measured in two drift chambers and scintillator detectors [8], neutrons are registered in the neutral particle detector [11], and slow spectator protons moving upwords to the beam are measured by the dedicated silicon-pad detector [12]. Fig. 1(left) shows energy losses in the 1^{st} layer of the spectator detector versus 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 momentum distribution of protons considered as a spectator as determined at COSY-11 with a deuteron target and a proton beam with momentum of 3.35 GeV/c (points) compared with simulations taking into account a Fermi motion of nucleons inside the deuteron (solid line).

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 can be calculated for each event from the vector of the momenta 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 the 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 the 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 the time–of–flight value of 28.5 ns as it is indicated by an arrow in Fig. 2(left). Neutrons having time–of–flight below this value originate from $pn \to pn\ pions$ reactions and are not taken for the further analysis.

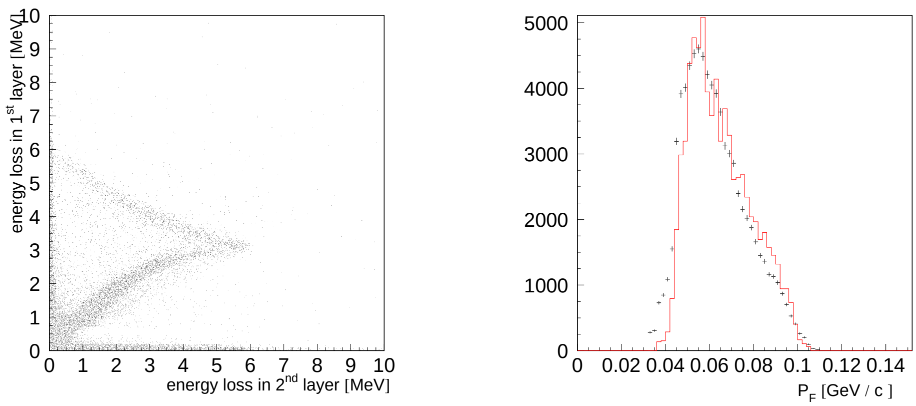

Fig. 1. **Left**: Energy losses in the first layer versus the second layer as measured at COSY–11 with a deuteron target and a proton beam with momentum of 3.35 GeV/c. **Right**: Momentum distribution of the proton spectator as reconstructed in the experiment (points) in comparison with simulation taking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

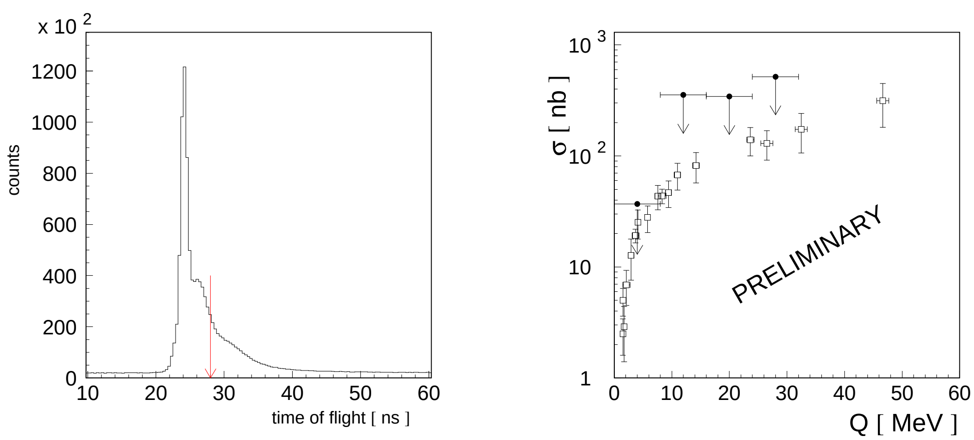

Fig. 2. **Left**: Time–of–flight distribution between the target and the neutron detector as obtained after the time walk correction under condition that in coincidence with neutral particle also two charged particles were identified. **Right**: Total cross sections for the $pp \to pp\eta'$ reaction 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).

Due to the smaller efficiency and lower resolution for the registration of the quasi-free $pn \rightarrow pn$ *meson* reaction in comparison to the measurements of the proton-proton reactions, the elaboration of the data encounters problems of low statistics. Therefore, the excess energy range for $Q \geq 0$ has been divided only into four intervals of 8 MeV width. 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' are expected. Detailed description of the method used for the background subtraction can be found in the dedicated article[13]. After subtracting missing mass distributions for the negative values of Q from spectra for Q values larger than 0 – due to the very high 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 [14] – and the detection efficiency of the COSY-11 system we have estimated the upper limit of the total cross section for the quasi-free $pn \rightarrow pn\eta'$ reaction. The prelimnary result is shown in Fig. 2(right).

3. Acknowledgments

We acknowledge the support by the European Community under the FP6 programme (Hadron Physics, RII3-CT-2004-506078), by the Polish Ministry of Science and Higher Education under grants No. 3240/H03/2006/31, 1202/DFG/2007/03, 0082/B/H03/2008/34, and by the German Research Foundation (DFG).

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