Searching for the pentaquark Θ^+ at COSY-11

J. Przerwa[1], R. Czyżykiewicz, P. Moskal and C. Piskor-Ignatowicz[1] for the COSY-11 collaboration

Several recent experiments have reported evidence for a narrow resonance Θ^+, with strangeness S = +1 [1, 2]. It was seen as a peak in the nK^+ invariant mass distribution at 1.54 GeV/c^2 with a width smaller than 25 MeV/c^2. The extracted mass and width are consistent with those of the pentaquark baryon Θ^+ consisting of $uudd\bar{s}$ quarks predicted in the chiral soliton model [3]. In the hitherto performed experiments the hypothetical Θ^+ resonance was produced either in the electroweak interactions [1] or in the strong interaction between positively charged kaons and the nuclei [2]. Production of the Θ^+ in the elementary proton-proton interaction, might be investigated at COSY and in particular also at the COSY-11 facility. A signature of the Θ^+ production may be the presence of a 1.54 GeV peak in the K$^+$n invariant-mass distribution for the $pp \to nK^+\Sigma^+$ reaction.

In order to study the Θ^+ production an additional trigger enabling a simultaneous registration of kaons and neutrons had been arrangedduring the experiment performed in September 2003. Therefore, additionally to the planned studies of the $pp \to pp\eta'$ we registered on tapes also events corresponding to the $pp \to nK^+\Sigma^+$ reaction. Kaons were detected by means of the drift chambers and scintillator hodoscopes: Start and S1 [1]. Neutrons were registered in a special detector built out of slices of scintillator– and lead sheets [2]. The identificaton of the short living Σ^+ hyperons is done via the missing mass technique, where the momenta of the kaons are reconstructed by tracking back their trajectories to the target point and the neutron's momentum is calculated from the time-of-flight measurement between target and neutron detector.

The data analysis aiming for the determination of the nK$^+$ invariant mass distribution has just started. Therefore in this report only the performed Monte Carlo simulations are presented.

In order to determine the acceptance of the COSY-11 detection system for the $pp \to nK^+\Sigma^+$ reaction we have simulated the response of the detectors for $6 \cdot 10^7$ events generated in the target. The solid line in figure 1a shows the distribution of the K$^+$n invariant mass for the generated events, whereas the dashed histograms represents the spectrum which was reconstructed from the signals simulated in the detectors. The ratio of the obtained missing mass distributions results in the differential acceptance of COSY-11 for detecting the $pp \to nK^+\Sigma^+$ reaction as shown in figure 1b. Thus the overall integrated acceptance of our detection setup for the reaction $pp \to nK^+\Sigma^+$ at the beam momentum of 3.257 GeV/c, at which the measurement was performed, is equal to 10^{-4}.

Further the simulation of the invariant mass distribution of the process $pp \to \Sigma^+\Theta^+ \to \Sigma^+nK^+$ has been performed, taking into account the width of Θ^+ equal to 5 MeV [5]. The result of this simulations is presented

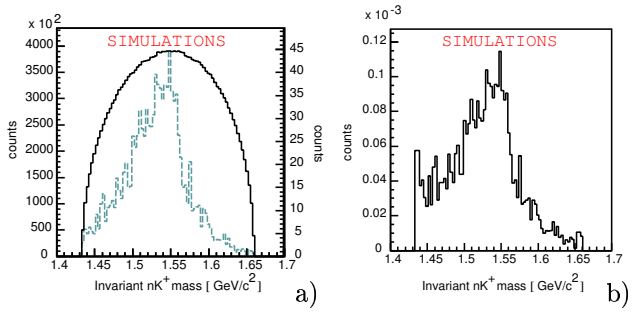

Fig. 1: (a) Phase space distribution of the invariant mass of nK$^+$ system of the $pp \to nK^+\Sigma^+$ reaction (solid line) and its convolution with the COSY-11 acceptance (dashed line). Note that the scale for the dashed histogram is on the right side of the figure. (b) The acceptance of COSY-11 detection setup for the $pp \to nK^+\Sigma^+$ reaction.

in fig. 2a, and the expectations for the full invariant mass distribution of the nK^+ system are shown in figure 2b. Here we assume arbitrarily that the total cross section for the $pp \to \Sigma^+\ \Theta^+$ reaction is ten times smaller than the one for the $pp \to \Sigma^+nK^+$ reaction. If the performed assumptions are realistic, we should observe a clear signal in the experiment originating in the Θ^+ production as it is visible in figure 2b.

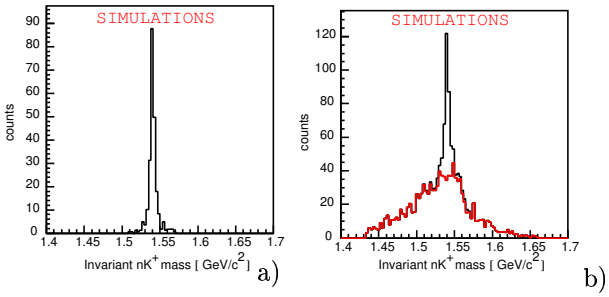

Fig. 2: (a) Invariant mass distribution of the nK^+ system as obtained in Monte-Carlo calculations for the $pp \to \Sigma^+\Theta^+ \to \Sigma^+nK^+$ reaction. (b) The expected signal from the $pp \to \Sigma^+\Theta^+$ together with the background from the direct $pp \to \Sigma^+nK^+$ reaction.

The analysis of the data from the September's run is proceeding and the preliminary results are expected during the next year.

References:

[1] T.Nakano et al, Phys.Rev.Lett **91** (2003) 012002; S.Stepanyan et al, arXiv: hep-ex/0303018; J.Barth et al, arXiv: hep-ex/0307083.

[2] V.V.Barmin et al, arXiv: hep-ex/0304040.

[3] D.Diakonov, V.Petrov, and M.Poliakov, Z.Phys. A**359** (1997) 305.

[4] P. Moskal et al., Ann. Rep. 1996, IKP FZ-Jülich, **Jül - 3365**, 35; R.Czyżykiewicz, Diploma Thesis, Jagellonian University (2002).

[5] M.Poliakov, talk presented at CANU meeting, Bad Honnef (2003).

[1] Institute of Physics, Jagellonian University, Cracow, PL-30-059 Poland

[1]For the arrangement of the individual detectors in COSY-11 facility see for example the contribution of T. Rozek and D. Grzonka to this report.

[2]COSY-11 neutron detector structure is presented in [4]