First Measurement of K^+p, K^+d Correlations from pC Collisions at $T_p = 1.2$ and $2.3\,\mathrm{GeV}$

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We present first results of the measurements of K^+p and K^+d correlations from pC collisions. The data were collected in October 2001 during 50 hours at 1200 MeV and during 24 hours at 2300 MeV. The main goal of these test measurements was to demonstrate the feasibility to perform the rather ambitious K^+p, K^+d correlation experiment at ANKE and to estimate the accidental background. The measurements were performed in the standard 1.6 T magnetic field mode of ANKE [1]. Kaons in the momentum range 175–610 MeV/c were detected in the range telescopes using all criteria for kaon identification [2]. Protons or deuterons were selected in the momentum range 400–2500 MeV/c by energy-loss and the TOF difference of kaons and deuterons/protons. The combination of all criteria allows one to separate K^+d correlations, so that at 1.2 GeV the background under the deuteron peak is less than 5% (Fig. 1a). At 2.3 GeV this background is less than 15% and mostly contains protons with momenta higher than 1600 MeV/c (Fig. 1b).

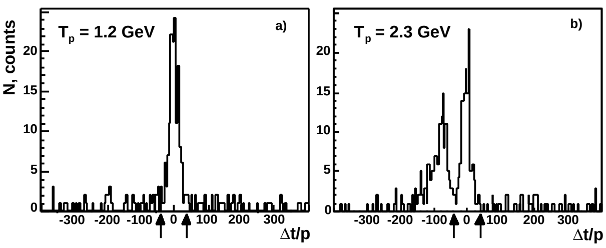

Fig. 1: TOF difference between deuterons and kaons corrected for the deuteron momentum. **a** Proton beam energy $T_p = 1.2\,\mathrm{GeV}$, **b** $T_p = 2.3\,\mathrm{GeV}$.

During the test-run we could not only prove the feasibility to detect K^+p, K^+d correlations with ANKE but could also collect sufficient statistics to draw first conclusions about reaction mechanisms. The final goal of the K^+p, K^+d correlation experiment is to separate direct ($pN \to K^+pY$), cluster (i.e. many-quark correlations) [3, 4] or two-step (via an intermediate pion between two not necessarily neighbouring nucleons) [5] mechanisms and to show to which extent the $pN \to d\pi$ reaction [6] is important as the first stage of the two-step mechanism in subthreshold K^+-production. These questions can be answered from a comparison of K^+p and K^+d correlations as well as from exploiting kinematical features of the different mechanisms. For example, in case of the two-step mechanism via the intermediate $pN \to d\pi$ reaction a 260 MeV/c wide peak at about 960 MeV/c is expected in the deuteron momentum distribution for $T_p = 1200\,\mathrm{MeV}$ [6].

Efficiency and acceptance corrected proton and deuteron momentum distributions measured within a scattering angle of $\vartheta = 8°$ in correlation with kaons are presented in Fig. 2 and Fig. 3.

At 2300 MeV the ratio $(K^+d)/(K^+p) < 3\%$ indicates dominance of the direct mechanism. The momentum spectrum of deuterons at this energy (Fig. 3a) can be described as an exponential distribution $e^{-(p-p_0)/k}$ with $k = 769\,\mathrm{MeV/c}$ (dashed-dotted line in Fig. 3a). Most probably these are coalescent deuterons. A possible enhancement in the region of $p \sim 1000\,\mathrm{MeV/c}$ can be caused by the $pN \to d\pi$ reaction. Its

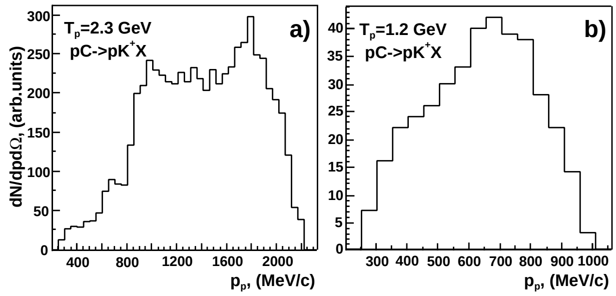

Fig. 2: Proton momentum spectra measured for the reactions indicated in figures with kaons detected in the momentum range 175–610 MeV/c and the full ANKE angular acceptance. Protons are measured within emission angles $\vartheta \leq 8°$. The distributions contain also protons from Λ-decay.

intensity of $(K^+d)/(K^+p) < 0.4\%$ gives an upper limit for the contribution of the two-step process leading to kaon production at 2300 MeV. The enhancement at momenta above $1600\,\mathrm{MeV/c}$ is due to the background protons discussed above. Qualitatively, the results of these measurements are in agreement with the predictions given in Ref. [6].

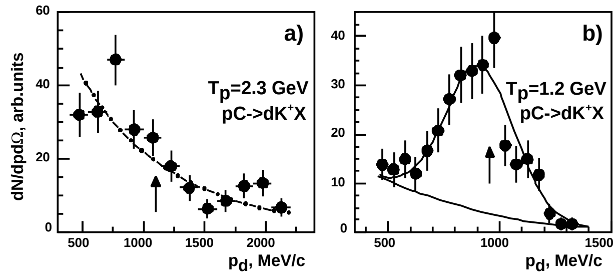

Fig. 3: Deuteron momentum spectra measured for the reactions indicated in figures with kaons detected in the momentum range 175–610 MeV/c and the full ANKE angular acceptance. Deuterons are measured within emission angles $\vartheta \leq 8°$.

It is expected that the two-step and cluster mechanisms dominate below $T_p = 1300\,\mathrm{MeV}$. This is most probably the reason for the drastic change in the deuteron momentum spectrum at 1200 MeV (Fig. 3b) and in the deuteron-proton ratio. In comparison to 2300 MeV the ratio raises by a factor of ≈ 30. About 30% of 321 events in the spectrum of Fig. 3b form an exponential background of coalescent deuterons whereas the other 220–230 deuterons produce a peak structure. The width and position of this peak depend on the best fit approach. If one assumes that it is one slightly distorted peak, then the peak width is $350 \pm 25\,\mathrm{MeV/c}$ with the maximum at $910 \pm 15\,\mathrm{MeV/c}$, which may correspond to the kinematics of the $pN \to d\pi$ reaction. However, the measured peak position is shifted to low momenta with respect to the theoretically predicted position (963 MeV/c) and its width is much larger than predicted (200–250 MeV/c). Moreover, different analyses show that the shape of the peak is rather stable including the shoulder at 1100–1200 MeV/c. The latter may reflect the influence of the cluster mechanism.

About 35–40% of the deuterons in Fig. 3b are correlated with the most energetic kaons with momenta from 400–610 MeV/c and they form a 250 MeV/c wide peak (see Fig. 4a) corresponding to the kinematics of the two-step mechanism via the $pN \to d\pi$ reaction.

The remaining events, located in the momentum region $p_K <$ 400 MeV/c, form a rather flat distribution which needs further exploration. After restricting the deuteron emission angle to $\vartheta < 4°$ we observe a structure consisting of two peaks (see Fig. 4b), which can be understood in the frame of the cluster mechanism. A naive phase-space approach gives a similar structure under the assumption that the incident proton interacts with a 6-quark configuration. Such a configuration (or cluster) in this case has a mass of of $m_d - 16$ MeV.

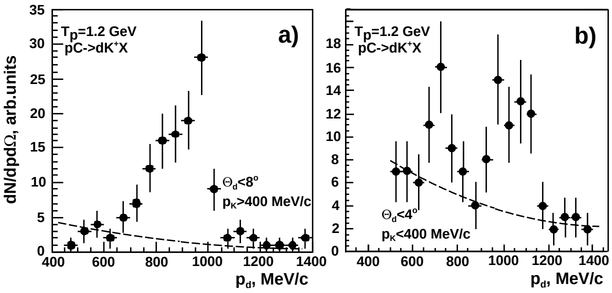

Fig. 4: Deuteron momentum spectra measured within kinematics shown in figures.

Our data provide the first direct experimental evidence for the two-step mechanism in pC reactions at 1200 MeV. The possible contribution of the cluster mechanism can be at a level of 30% compared to $pN \to d\pi$. It is also shown that, exploiting kinematic criteria, it is possible to study these mechanisms individually. However, for more definite conclusions a high-statistics experiment is necessary. Corresponding measurements are scheduled in summer 2003. In addition, we plan to measure 4-fold coincidences $dK^+p\pi^-$, which will permit Λ-identification and will make the experiment more exclusive.

It is very important to also perform this experiment at $T_p =$ 1000 MeV. According to Ref. [6] at this energy the $pN \to d\pi$ channel is three to four times stronger than at 1200 MeV. It is quite probable that at 1000 MeV the role of the two nucleon cluster mechanism will become more important than at 1200 MeV. Moreover, K^+ production on three-nucleon clusters might be significant since the energy of 1000 MeV is close to the threshold of the $p(3N) \to K^+\Lambda(3N)$ reaction. These considerations show the importance of K^+p, K^+d and K^+t correlation experiments in pA collisions at 1000 MeV. Such an experiment is also planned at ANKE.

References:

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