The ANKE Spectrometer at COSY-Jülich and Studies of the Subthreshold K^+-Production

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The new spectrometer ANKE has been put into operation at the accelerator COSY of the Forschungszentrum Jülich. It enables the study of forward going ejectiles from proton-induced reactions at internal targets in COSY. First measurements of the double differential cross sections for the subthreshold K^+-production in pA collisions have been performed at projectile energies as low as 1.0 GeV, i.e. 0.58 GeV below the free nucleon-nucleon threshold.

*For a complete collaboration list see [1]

1. THE SPECTROMETER ANKE

In 1998 the ANKE spectrometer has been installed in the cooler section of the race-track shaped COSY accelerator. It has been designed for the investigation of meson production in elementary pp and pn processes as well as of medium modifications in pA reactions, with luminosities of up to 10^{33} cm^{-2}s^{-1}. It uses thin internal targets through which the COSY beam passes many times, separates forward going ejectiles from the beam, and allows the analysis of their momenta and emission angles.

The spectrometer (Fig.1) consists of three dipoles (D1, D2, D3) with an UHV system and a target station and is equipped with detectors for positively charged particles with momenta from 0.1 to 0.6 GeV/c (23 start counters at the side of D2, 15 telescopes in its focal surface and 2 MWPC's with 3 planes (x,u,v) each). For the first measurements of K^+-production in pC interactions at projectile energies below the nucleon-nucleon threshold energy at 1.58 GeV ("subthreshold K^+- production"), these detectors have been used. Side (SD) and forward (FD) detector systems (scintillation counters and MWPC's) analyze p's and d's in the momentum range from 0.6 to 3 GeV/c. The backward-detector (BD) system (drift chambers and scintillation counters) analyzes backward π^+'s and p's with momenta up to 0.5 GeV/c. Each plastic scintillator is read out by two photomultipliers. To achieve good time resolution ($\sim$ 0.6 ns FWHM), specially designed mean-timers and discriminators are used. The readout of the the MWPC's is performed with a highly integrated chamber-mounted system [2]. The data acquisition is based on a system of PC's and can write on DLT tapes up to 10^4 events/s.

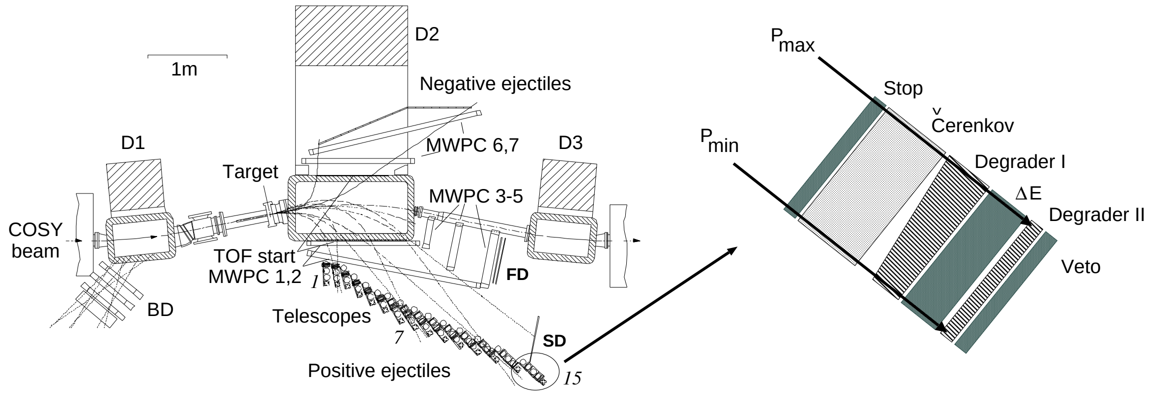

Figure 1. Sketch of the ANKE spectrometer. The insert shows the composition of one of the focal-surface telescopes.

The central dipole magnet, D2, has pole shoes of 461 $\times$ 1214 mm^2 and a gap of 200 mm height as well as a large opening in its C-shaped yoke (1144 $\times$ 1400 $\times$ 1400 mm^3) to place detectors for negatively charged ejectiles. The maximum field strength is 1.6 T. The vacuum chambers of D1 and D2 have 0.5 mm thin Al-windows. Magnetic field maps of D1 and D2 were measured by Hall-probes using a device from GSI (Darmstadt). The position of the D2 focal surface was checked with the floating-wire method. By pions from the reaction pp $\rightarrow \pi^+$d the spectrometer characteristics of D2, predicted from simulation calculations, were confirmed with an accuracy better than 1%.

2. THE K^+-MESON STUDIES

The study of subthreshold K^+-production is an especially useful means to investigate the influence of the nuclear medium on elementary processes, since the interaction of the produced kaons with nucleons is small. Once produced, the kaon leaves the target basically undisturbed. The production of K^+-mesons in pA interactions with different target nuclei has been investigated [3] for 0.8 to 1.0 GeV protons. The authors have published total cross sections as function of A and the projectile energy $T_{\rm p}$. They as well as the authors of subsequent theoretical publications (see, e.g., [4,5]) have discussed different options for the subthreshold production mechanisms, e.g. the first collision process in which the projectile interacts with a nucleon of large Fermi momentum, or two-step events in which an intermediate pion is formed. In order to extract scientific information on medium effects from a comparison with results of theoretical studies, more detailed experimental data such as double differential cross sections $d^2\sigma/d\Omega\,dp_{K^+}$ are needed. The lowest energy at which inclusive double differential cross sections were measured is $T_{\rm p} = 1.2$ GeV: experiments at SATURNE [6] and CELSIUS [7] have been performed at emission angles 40° (kaon momenta > 0.5 GeV/c) and 90° (kaon momenta $0.15 - 0.25$ GeV/c), respectively.

At ANKE the K^+-spectra from pC interactions have been measured at $T_{\rm p} = 2.3$, 2.0, 1.8, 1.5, 1.2 and 1.0 GeV in the kaon-momentum range $0.1 - 0.6$ GeV/c. Measurements were done with a carbon-strip target (polycrystalline diamond, $d \approx 2\ \mu$m) at luminosities of $(1-2)\cdot 10^{32}$ cm^{-2}s^{-1}. The count rate of all start counters together amounted to about $6\cdot 10^5$ s^{-1}. The coincidence rate of all telescopes with the start counters was about 10^5 s^{-1}, which is more than 10^6 times higher than the kaon count rate at $T_{\rm p} = 1.0$ GeV. About 80% of the observed particles are pions and protons from the target. The remaining particles are mostly scattered protons ($p_{\rm b}$ in Fig.2) from the vacuum chamber and D2.

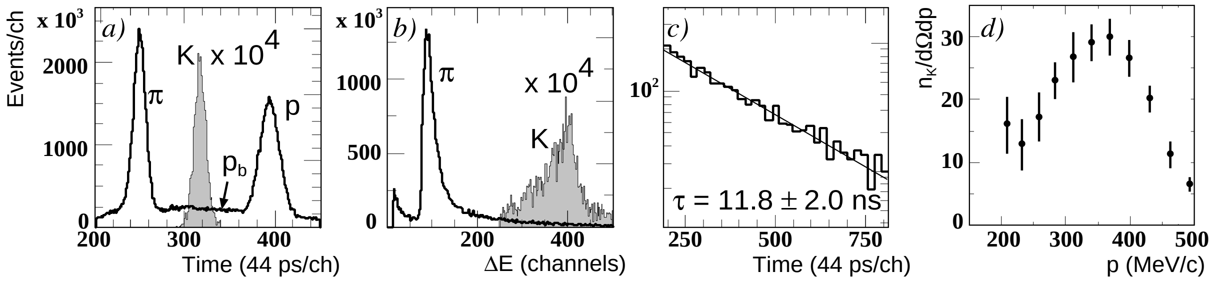

Figure 2. a) Time-of-flight spectrum for ejectiles which hit telescope 11 (unshaded = without cuts, shaded = with cuts). b) Energy-loss in the ΔE counter. c) Events with delayed signals in the veto counter. Spectra a)–c) were obtained at $T_{\rm p} = 2.0$ GeV. d) Preliminary K^+-momentum spectrum at 1.2 GeV.

To identify kaons and to suppress background (to less than 1000 counts/s) a fast hardware trigger based on the following criteria was used: (1) the ejectile momenta are defined within $\sim 10\%$ by the 10 cm wide telescopes at the focal surface of D2. (2) For the given momenta pions, kaons and protons have different ranges. The thicknesses of the scintillation counters and of the Cu-degraders in the telescopes were chosen such that protons from the target are stopped before they reach the ΔE counters. Kaons are stopped in the second degraders or in the far end of the ΔE counters whereas pions traverse all counters of the telescopes. This maximizes the energy-loss differences between kaons and pions in the ΔE counters. (3) Fast coincidences between the start counters at D2 and the stop counters in the telescopes allow to select particles with the same momentum but different emission angles and to set narrow gates on the TOF regions for kaons. (4) As in previous studies [3,9] the decay of kaons with a mean life time of 12.4 ns has been used as a strong criterion for the selection of K^+-candidates. In the analyses performed so far, only events have been accepted with signals in the veto counters delayed by more than 1.3 ns with respect to the ones in the stop and ΔE counters of the same telescope. A combination of these criteria with the off-line analysis of the information obtained from the MWPC's (particles stemming from the target have characteristic vertical emission angles) and of energy losses in all scintillation counters permitted to identify kaons.

The effect of the different cuts is shown in Fig.2 a)–c). K^+-mesons have been clearly identified at all projectile energies. The information which can be expected for the K^+-momentum spectra is indicated in Fig.2 d). These are the numbers of the identified kaons in the individual telescopes corrected for the momentum and angular acceptances and differences in the kaon decay-in-flight but not yet for the K^+-detection efficiency in each telescope.

3. CONCLUSIONS

The ANKE spectrometer fulfills the predicted specifications, and the envisaged studies of the double differential cross sections for the subthreshold K^+-production have started successfully. The experiments will be continued for different targets. Afterwards, studies of correlated K^+-light particle events [3–5,10] will be carried out. Predictions are that the observation of K^+-d coincidences [3,5] will provide clear fingerprints for the two-step reaction mechanism.

The authors acknowledge the many contributions to the construction of ANKE and the detection devices by the infrastructure divisions of their home laboratories as well as financial support by the national funding agencies, a special grant by the state of North-Rhine Westphalia and INTAS grants.

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