First Experience with ANKE in COSY

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In May of 1998 first ejectiles from reactions of the circulating proton beam of COSY with an internal target were detected with ANKE.
The experimental program — at first to calibrate the system with monoenergetic pions from the 2 – body reaction $p\,p \rightarrow \pi^+ d$ and then to study the production of K^+ – mesons in pA – reactions below the N – N – threshold — has been started.
The facility is described. Our experience with the commissioning of ANKE in the COSY – ring and with the properties of the spectrometer and its detection system will be presented. First experimental results are shown.

1 Introduction

The production of strangeness in elementary reactions is of fundamental interest in medium energy physics. Both strange and anti – strange quarks are probes to study the influence of the nuclear surroundings on the production process. These effects and questions concerning a (possible) strangeness content of the nucleon and its consequences open a wide field of research.

Many studies, experimental and theoretical, were initiated by the first observation of K^+ – meson production in the reaction $\mathrm{p\,A} \rightarrow \mathrm{K}^+\,\mathrm{X}$ far below the N – N – threshold of 1.58 GeV by Koptev et al. [1].

COSY – Jülich, a cooler synchrotron and storage ring, is designed to accelerate up to about 10^{11} protons, polarized or unpolarized, up to 2.6 GeV. This energy corresponds to a de Broglie wavelength of less than 1 fm and allows studies in the regime of non – pertubative QCD. Three target positions in the long straight sections of the race – track shaped accelerator and one in an arc are well suited to install very thin targets in the circulating beam. One of the internal target facilities is ANKE (Apparatus to study Nucleonic and Kaon Ejectiles), a large acceptance forward angle spectrometer, see figure 1. The side – detector near the dipole D2 of ANKE is optimized for K^+ – meson detection.

Our measurements of double – differential cross sections of the K^+ – meson production in proton – nucleus collisions, performed under forward emission angles, are complementary to others performed at CELSIUS [2] and with SPES3 at SATURNE [3].

2 Layout of the Facility

ANKE with its three C–shaped dipoles (D1, D2 and D3, see figure 1) is installed in the straight section of COSY which also contains the electron cooler.

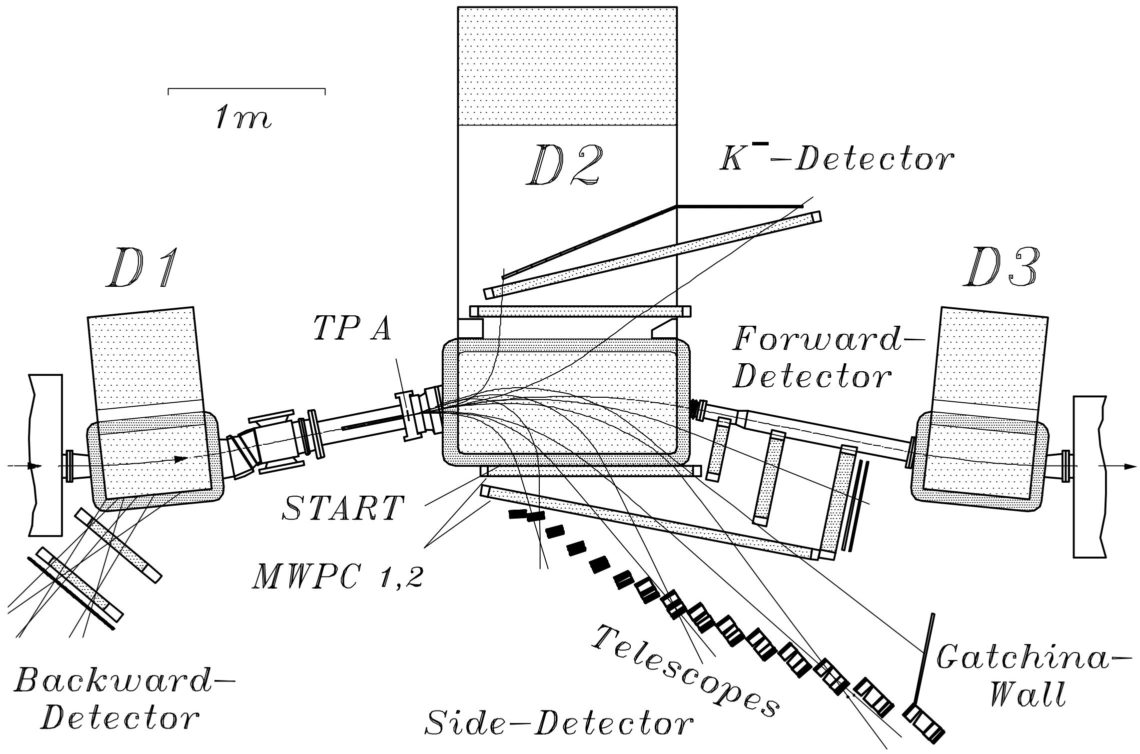

Figure 1: Layout of ANKE.

Table 1: Main properties of the spectrometer dipole D2.

Gap height	20 cm
Max. field strength	1.6 T
Max. deflection angle	21.2°
Horizontal angular acceptance	± 10°
Vertical angular acceptance	up to ± 5°
Total acceptance	≥ 50 msr
Momentum acceptance of the side – detector	150 – 600 MeV/c

D1 guides the beam to the target which in the studies described here is a solid strip target made of carbon or polyethylene. D2 serves as the spectrometer magnet for the positively or negatively charged ejectiles which are emitted forward whereas D3 (identical to D1) inflects the beam back into its original orbit. These magnets are ramped synchronously with the COSY magnets during the acceleration phase. By the use of independent power supplies particles with a fixed momentum are focused to the same position in the image surface of D2 for any projectile energy, if the magnetic field in the flat top after acceleration is kept fixed. The main properties of D2 are given in table 1.

The side – detector of ANKE allows the identification of the positively charged ejectiles based on time – of – flight and energy – loss measurements together with additional information from Cherenkov – detectors obtained from the telescopes, see figure 2.

These telescopes are positioned along the curved focal surface of D2. Due to the focusing properties of D2 each telescope can be optimized for a narrow momentum bite of typically $\pm 5\,\%$. This precise fine adjustment is necessary, because the K^+ – mesons are produced together with an immense background of protons and pions which has to be suppressed by up to seven orders of magnitude in order to allow the study of the subthreshold K^+ – meson production in carbon nuclei at proton energies as low as 1.0 GeV.

Each telescope consists of a STOP – counter, a Cherenkov – counter (in telescopes 7 – 15 only), a ΔE – counter and a VETO – counter.

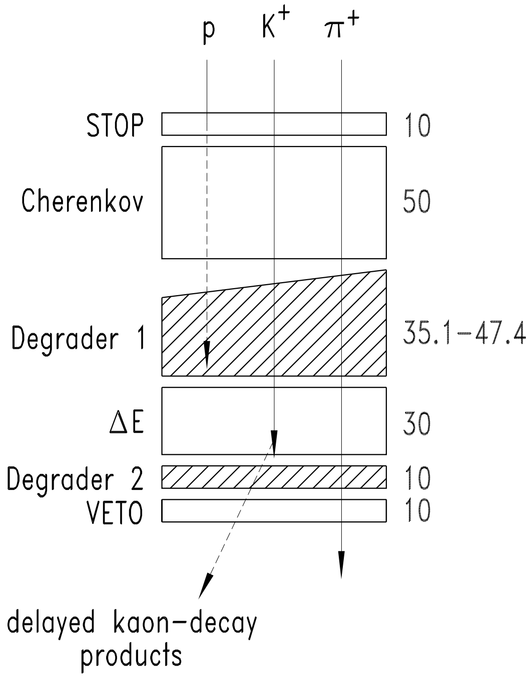

Figure 2: Sketch of telescope no. 11 (top view) optimized for an ejectile momentum of approximately 450 MeV / c. The thicknesses are given in mm, the width of all components is 100 mm, the length 1000 mm.

The time – of – flight is measured between the STOP – counter and the thin START – detectors vertically placed very close to the lateral exit window of D2. The thickness of the 28 cm long START – counters amounts to only 0.5 – 2 mm; it has been minimized in order to reduce small – angle scattering.

The measurement of the energy loss in the ΔE – counter is based on the fact that at a given momentum the range of a particle in matter decreases with increasing particle mass. Pions punch through the whole telescope and are mainly identified by the VETO – counter. Protons are stopped in front of the ΔE – counter. Thus, no signal is provided by that counter and the rejection of them is easy.

A degrader in front of the ΔE – counter slows down kaons in such a way that they are almost stopped in that counter. In this situation $\Delta E(K^+)$ is maximized. Since pions are basically unaffected by the degrader the ratio $\Delta E(K^+) / \Delta E(\pi^+)$ is maximized, too. A second degrader placed behind the ΔE – counter avoids kaons to reach the VETO – counter and fake pions.

Cherenkov – counters are installed to suppress pions and leptonic background. They are used as threshold counters in the telescopes for higher momenta where the pions produce Cherenkov – light while the kaons do not or only very little.

Thickness optimization of the telescope components, specially of the first degraders, was done using GEANT.

A set of two wire chambers [4] (three planes each, one vertical, two inclined by ± 30 degrees, wire spacing 2.54 mm, totally $\approx$ 4000 wires) allows the reconstruction of the absolute momentum and the emission angles at the target.

A more detailed description of the detector system is given in [5].

3 Commissioning of ANKE

In May of 1998 ANKE was installed in the ring. The three additional magnets influence the acceleration behaviour, namely:

- The vacuum system, in particular the large vacuum chamber of the spectrometer dipole D2, causes eddy currents due to ramping (up to 1 T / s).
- The length of the closed orbit is enlarged.

To minimize eddy currents the vacuum chambers of the magnets have been built with as little material as possible. The top and bottom plates are made of stainless steel with a thickness of 2 mm only. The plates are fixed to the yoke of the magnets to stand the atmospheric pressure. Nevertheless, difficulties were encountered for the acceleration of intense proton beams, in particular for the maximum deflection angle of D2. By the use of backleg windings this loss can be avoided.

The length of the closed orbit increases by not more than 7 cm. This is comparable to the changes for different tunes of COSY which are easy to handle.

During commissioning it was finally possible to accelerate up to $4 \cdot 10^{10}$ protons for various experimental conditions (T = 1.2 – 2.3 GeV, all deflection angles up to 21.2 degrees).

The first measurements have been carried out with 2 mm wide solid – state strip targets made of carbon ($\approx 40\,\mu g / cm^2$) or polyethylene ($\approx 200\,\mu g / cm^2$). The accelerated beam was moved onto the target by two vertical steerers. This movement was chosen in such a way that the reaction rate was nearly constant and a peak rate at the beginning of a cycle was avoided.

The data acquisition system for about 4000 wires of the chambers and about 300 amplitude and timing signals is based on parallel working PCs reading out CAMAC, FASTBUS and VME modules [6]. The scalable system can easily be modified if new modules are used or further detectors are installed. A high data rate of approximately 5000 events per second can be processed. For the chamber on – board electronics with implemented data reduction is used (RAL 118 and RAL 111 [7]).

The goal of our first studies was to check whether the data acquisition system and all detectors work properly according to expectations and to check whether K^+ – meson identification for projectile energies down to 1.0 GeV is feasible.

4 First Results

First measurements were done with monoenergetic pions from the 2 – body reaction $p\,p \rightarrow d\,\pi^+$. By varying the energy of the proton beam between 312 and 534 MeV and the magnetic field strength of the ANKE magnets most of the telescopes can be tested by these pions. Using all information from both wire chambers with a preliminary software the momentum of the emitted pions can be calculated. A momentum resolution of typically 2.5 % (FWHM) was found. Improvements are expected by using a more elaborate cluster analysis for the wire chambers and a new algorithm for the momentum reconstruction and by interchanging the window of the vacuum chamber of D2 (0.5 mm aluminium now to 0.3 mm carbon – fibre – supported epoxy window with an aluminium layer inside).

Next, measurements were done using the ejectiles from proton – carbon interactions at T = 2.2 GeV. At first, degraders were not installed to allow the protons to reach the ΔE – counter. Figure 3 shows the time – of – flight spectrum between START – counter no. 13 and the STOP – counter of telescope no. 11. Two peaks with resolutions (FWHM) of 690 ps (pions) and 820 ps (protons) are clearly visible. The gap is filled by K^+ – mesons and background protons, mainly scattered in D2.

An analysis of of all time – of – flight spectra between one fixed STOP – counter and all the possible START – counters is a well – suited tool to study the horizontal angular acceptance of ANKE. Only ejectiles stemming from the target which are deflected by D2 onto the telescopes have a definite momentum in the image surface and thus form narrow peaks in the time – of – flight distributions.

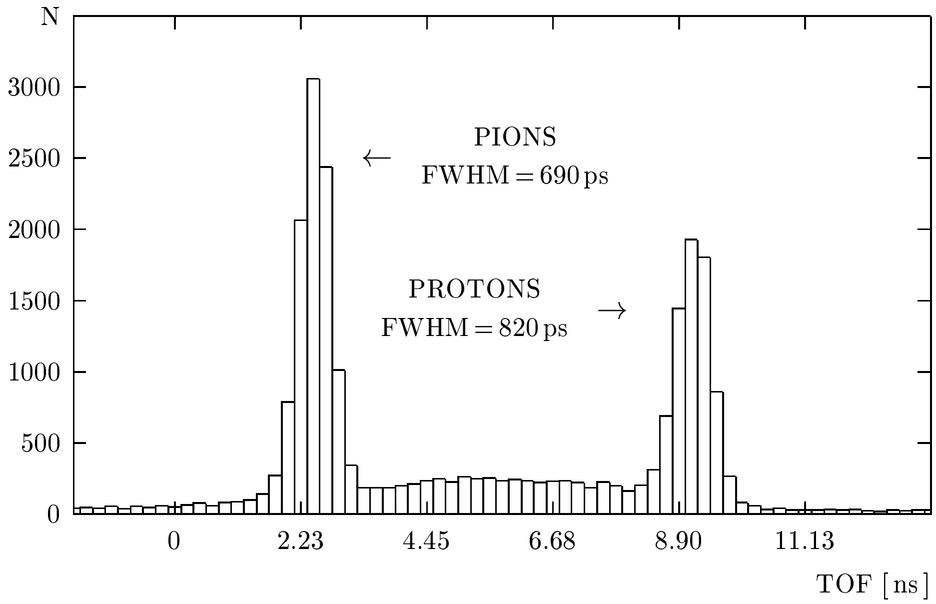

Figure 3: Time – of – flight spectrum between START – counter no. 13 and STOP – counter of telescope no. 11. The broadening for protons compared to the pions is mainly caused by the momentum spread due to the width of the telescope.

Studying all START – STOP – combinations it was found out that the horizontal angular acceptance was even larger than the expected $\pm$ 10 degrees.

To investigate the K^+ – meson production the same beam energy of 2.2 GeV was chosen. At that energy a background – to – kaon ratio of approximately 100 is expected. Degraders were installed to improve on the particle identification as described in section 2.

The analysis has been done up to now without using the information from the two wire chambers where the analysis software is still being developed, and Cherenkov – detectors. Pions were suppressed by applying high thresholds to the measured amplitudes of all the STOP – and ΔE – detectors. Nevertheless, kaons did not show up above background in the time – of – flight spectra. They become visible by studying the time – of – flight between the STOP – counter and the VETO – counter in each single telescope. For telescope no. 11 this spectrum is shown in figure 4. The shape of the distribution can be explained with help of figure 2: pions created in the target lead to a prompt signal since the distance between the two counters is small whereas decay products from kaons, which are stopped in the energy – loss counter or in the second degrader reach the VETO – counter with the delay caused by the kaon lifetime of 12.4 ns.

Such a delayed time spectrum can be extracted for all 15 telescopes. After applying a software cut as indicated in figure 4 and adding all distributions the spectrum shown in figure 5 is generated. One can see that the remaining events show an exponential

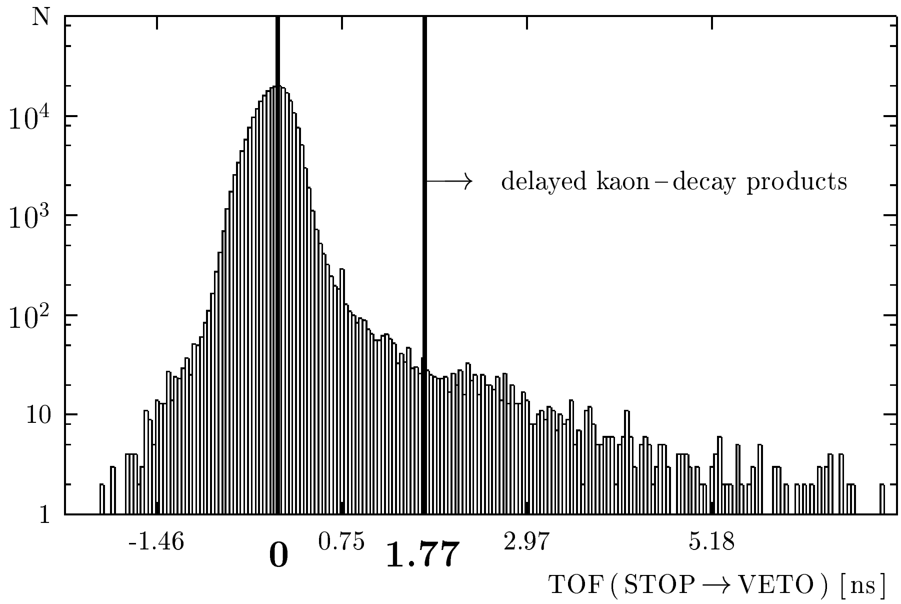

Figure 4: Time – of – flight between STOP – and VETO – counter in telescope no. 11 using a proton beam of 2.2 GeV interacting with a carbon target. (TOF = 0 is, as indicated, defined by the maximum of this distribution)

slope which is equal to 11.8 ns [1]. This result is very close to the expected decay time of 12.4 ns for kaons so that it is concluded that most of these events are, in fact, kaons. It should be noted that the analysis described here is fast but only makes use of about a quarter of all good events because of the isotropic emission of the kaon – decay products at rest. The final analysis will make use of all the data.

Further data was taken at beam energies T = 1.2, 1.5, 1.8 and 2.3 GeV. Data analysis is in progress. The preliminary results show a strong evidence of subthreshold kaon production at 1.5 GeV.

Finally it can be noted that ANKE has been successfully installed and that all detectors are working with the expected performace.

5 Outlook

The analysis of existing data has shown that some degrader thicknesses still have to be optimized. Thus, in April 99 (one week of beamtime), measurements of the reaction $p + C \rightarrow K^+ X$ will be redone for T = 1.2 and 1.5 GeV with an improved set of degraders. An even more important goal of this week is to use the fast time – of – flight trigger which has been developed at FZ Jülich and tested successfully. This system strongly suppresses background by the selection of geo-

[1] In the meantime the analysis has been done for TOF (STOP → VETO) at T = 2.3 GeV and for TOF (ΔE → VETO) at T = 2.2 and 2.3 GeV. The average slope is 12.4 ± ($\sigma = 0.4$) (stat.) ns.

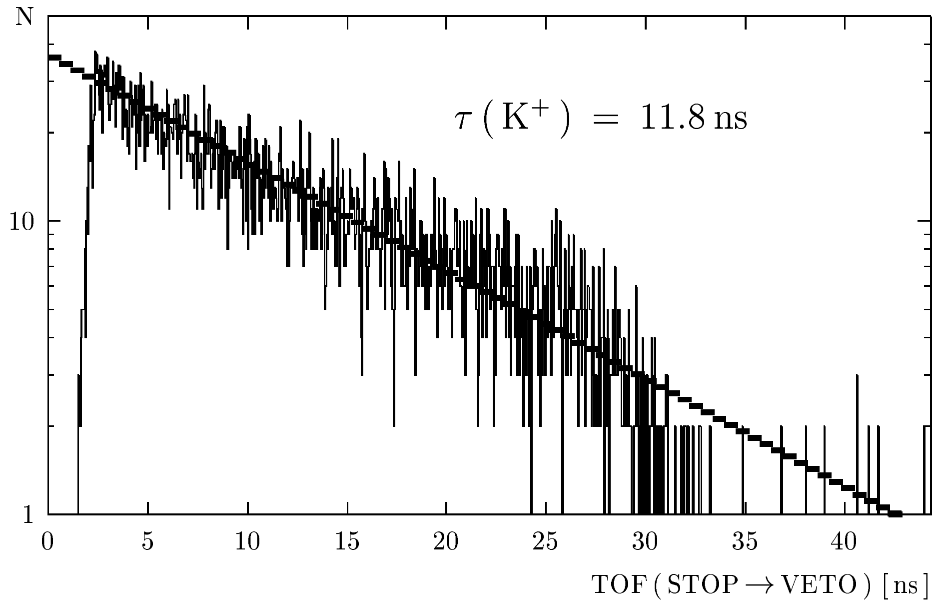

Figure 5: Time difference between detection of particles in the STOP – and VETO – counter for T = 2.2 GeV. Prompt signals caused by pions which are not suppressed by the amplitude thresholds are rejected (see text for details).

metrically allowed START – STOP – combinations and by setting the corresponding time – of – flight gates for kaons.

This trigger is necessary in order to be able to use as high luminosity as only possible for the production run at a projectile energy of 1.0 GeV, which is scheduled for June of 1999.

Afterwards (in week 31 / 99) a cluster target [8] for H_2 and D_2 will be installed to allow studies of proton – proton and proton – neutron reactions. The cluster target is now undergoing a test outside the accelerator.

Further in the future a pellet target as well as a storage cell target with an ABS for polarized protons and deuterons will be available.

In parallel to the development of new targets, the detection system of ANKE will be extended, e.g. to allow the detection of negatively charged particles at the left – hand side of D2 in figure 1.

6 Acknowledgement

The extremely efficient way in which members of the accelerator division have implemented ANKE into COSY and commissioned the spectrometer is gratefully acknowledged. They have provided proton beams of high quality for the first experiments at the facility.

The author would like to thank those colleagues from the ANKE – collaboration who contributed most strongly to the production of the data presented here.

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