First results from subthreshold K^+-production measurements with ANKE

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The new spectrometer ANKE has been put into operation at the accelerator COSY of the Forschungszentrum Jülich. An initial scientific goal is to study K^+-production in pA collisions at subthreshold energies below the free NN-threshold of $T = 1.58$ GeV. First measurements of double differential cross sections in $p^{12}C$ collisions at emission angles around 0° have been performed at $T = 1.0, 1.2$ and 2.0 GeV. The challenge is to identify the kaons in a huge background of pions and protons, since the signal to background ratio decreases to about 10^{-6} at $T = 1.0$ GeV. For background suppression detectors and a trigger system based on energy-loss and time-of-flight measurements have been developed. In the analysis the decay of kaons ($\tau = 12.4$ ns) stopped in the detection system into μ^+ and π^+ is exploited as well as the track information from the wire chambers.

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1. DESCRIPTION OF THE SPECTROMETER

In ANKE [2] the products from proton-induced reactions are separated from the circulating beam of COSY and their emission angles and momenta are determined. Three dipole magnets guide the beam out of its nominal path in a straight section of the race-track shaped accelerator ring towards the target and back into the standard orbit. The central magnet D2, see Fig.1, has a gap of 20 cm height thus providing a large solid angle for measurements at low cross sections. For the measurements described here, the detection system positioned at the side of D2 was optimized for K^+-detection.

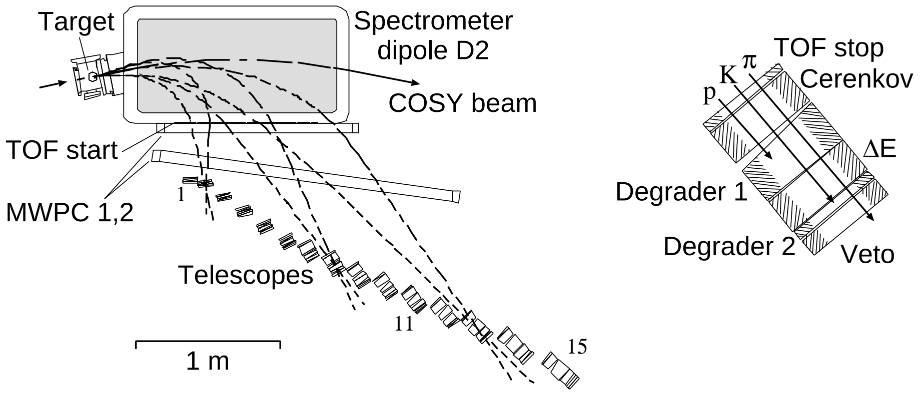

Figure 1. Top view of the ANKE spectrometer and telescope #14 in the K^+-detection system.

The K^+-detectors consist of: i) 23 start counters close to the vacuum window made of Al at the side of D2. Each of them has a horizontal angular acceptance of $6° - 2°$ depending on the ejectile momenta. ii) 15 telescopes [2,3] which are placed at the D2 focal surface to detect positively charged ejectiles in the momentum range from 0.15 GeV/c to 0.5 GeV/c (at $B = 1.3$ T in D2). The horizontal acceptance of each telescope can vary from $\pm 1°$ to $\pm 15°$ depending on the on- or off-line coincidences with the corresponding start counters. Every telescope (see Fig. 1) is composed of Stop, ΔE, Veto scintillation counters and two degraders made of Copper. Telescopes 7–15 contain also lucite Cherenkov counters. iii) 2 multi-wire proportional chambers (MWPC1 and MWPC2) which are used to reconstruct ejectile trajectories. Each of them has three anode planes with vertical and $\pm 30°$ inclined tungsten wires.

2. RESULT OF FIRST MEASUREMENTS

The measurements of K^+-spectra were performed with a carbon-strip target (polycrystalline diamond, $d \approx 1-2$ μm) at luminosities of $(1-2) \cdot 10^{32}$ cm$^{-2} \cdot$ s^{-1}. The coincidence rate of all Stop with the proper Start counters was $\sim 10^5$ s^{-1}, which is more than 10^6 times higher than the K^+-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 protons scattered in the vacuum chamber and on D2. To identify kaons and to suppress background (to less than 1000 counts/s) a fast hardware trigger based on the following criteria was used: i) The ejectile momenta are defined within $\approx 10\%$ by the 10 cm wide telescopes at the focal surface of D2. They were kept constant for all beam energies by fixing the D2-field strength and the relative target-D2-detector geometry. ii) For a given momentum pions, kaons and protons have different ranges. The thicknesses of the scintillators and of the degraders 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 and scattered protons with the same velocity as kaons traverse all counters of the telescopes if they do not undergo a nuclear reaction. The degraders installed in front of the ΔE counters are tapered to compensate for the momentum spread across each telescope. iii) Fast hardware coincidences between the Start and Stop counters allow to select particles with the same momentum but different emission angles and to set narrow gates on the TOF spectra for kaons. iv) As in previous studies [4] the decay of kaons with a lifetime of 12.4 ns has been used as a strong criterion for the selection of K^+ candidates. In the analysis performed so far, only events have been accepted with signals in the Veto counters delayed by more than 1.3 ns with respect to prompt particles detected in the same telescope. A combination of these criteria with an off-line analysis of the MWPC information and of energy losses in all scintillation counters permits to identify kaons. The effect of the different cuts is shown in Figs. 2 and 3.

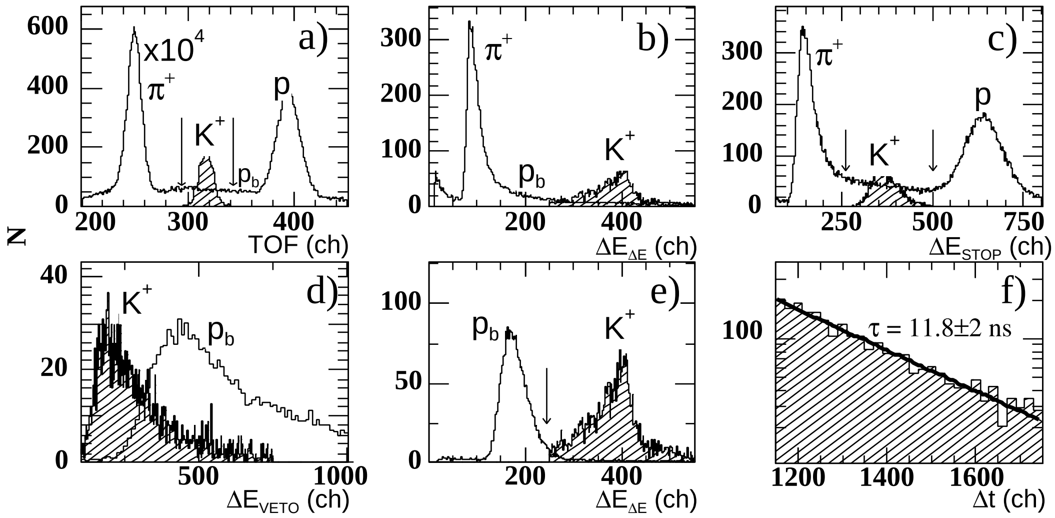

Figure 2. **a)** TOF and energy-loss distribution of kaons and background particles in the **b)** ΔE and **c)** Stop counters for telescope 11 (π^+, p: pions and protons from the target, p_b: background protons scattered from D2 and the vacuum chamber). Energy loss of delayed pions and muons in **d)** the Veto counter and **e)** kaons in the ΔE counter after TOF and energy-loss cuts (as indicated in spectra **a)** and **c)**). For comparison, background protons after cuts on TOF and energy loss in Start and Stop counters are shown. **f)** Time difference between Stop and Veto counter of telescope 11.

Target pions and protons are strongly suppressed by the hardware criteria. After fine tuning of the Start and Stop energy-loss cuts mostly the p_b remain as background (Fig. 2 d, e). These protons have the same velocity as kaons (due to equal TOF cuts) but about twice the momentum. Their energy losses in ΔE or Veto counters are different from those of kaons or delayed muons and pions and can be suppressed in the off-line analysis. The strongest criterion to reject these protons is a vertical angle cut obtained from the

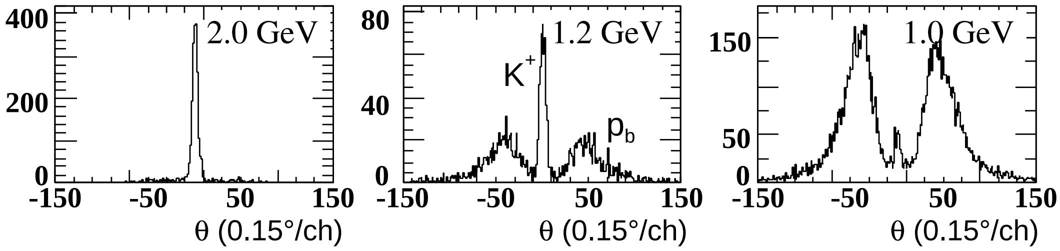

Figure 3. Vertical angle θ distributions, obtained from MWPCs information for 1.0, 1.2 and 2.0 GeV after energy loss and TOF criteria (c.f. Fig. 2) are applied.

MWPC information. Ejectiles from the target have a characteristic dependence between the vertical coordinate and the vertical angle so that they are grouped into a narrow peak around this angle (shifted to zero in Fig. 3). The p_b-protons have no such characteristic dependence and therefore they are either nearly homogeneously spread around zero or form broad distributions at larger angles (left and right wings in Fig. 3 are the p_b-protons scattered from the D2 pole shoes).

After applying all criteria, K^+-mesons have been clearly identified at all projectile energies. The K^+-momentum spectra for different energies are shown in Fig. 4. The presented numbers of identified kaons in each telescope are not yet corrected for the K^+-detection efficiency in each telescope. Corresponding calibration measurements have already been carried out and are under analysis.

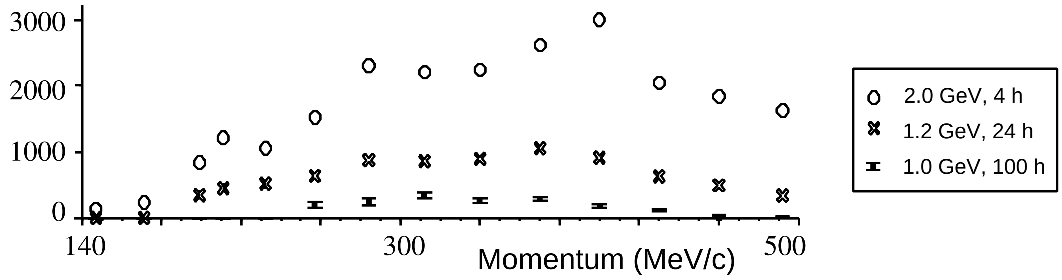

Figure 4. K^+-momentum spectra at 1.0, 1.2 and 2.0 GeV. The numbers of kaons in each telescope are not yet corrected for the different kaon-detection efficiencies. For 1.2 and 2.0 GeV the statistical errors are within the symbol size.

As a next step it is planned to continue the K^+-measurements for different target nuclei (e.g. Al, Cu, Au) at various beam energies as well as K^+-p and K^+-d coincidence measurements. These data, together with the ones presented here, should provide much more detailed insight into the reaction mechanisms in subthreshold K^+-production.

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