Study of Medium Modifications with the New Spectrometer ANKE at COSY-Jülich

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The accelerator COSY at the Forschungszentrum Jülich provides proton beams with energies up to 2.6 GeV for medium-energy hadron research. ANKE, an internal target magnetic spectrometer at the internal beam of COSY, is used to investigate medium effects in proton-nucleus reactions. It has been installed in the accelerator ring and commissioned in 1998. As a first experiment, subthreshold K^+-production has been studied in $p^{12}C$ collisions.

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1. The Spectrometer ANKE

In ANKE, the products from proton-induced reactions are separated from the circulating beam of COSY [2] and their emission angles and momenta are determined. Three dipole magnets, see Fig.1 and [3], 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 has a gap of 20 cm height and a large opening in its C-shaped yoke to allow the placement of detectors. The vacuum chamber of this magnet, as well as that of D1, are equipped with 0.5 mm thin Al windows for the exit of the reaction products. Positively charged ejectiles with momenta between about 100 MeV/c and 600 MeV/c, like the kaons in the subthreshold studies, leave the vacuum chamber of D2 through the side window and are identified with a detector system [4, 5] consisting of a time-of-flight setup of 23 start scintillators close to D2 and stop detectors within the 15 telescopes at the focal surface of D2, and energy-loss detectors. Veto counters in these telescopes discriminate against pions and simultaneously allow the identification of K^+-mesons via their delayed decay into muons or pions [5]. Degraders are used for the optimization of the energy losses in the ΔE counters, to stop protons before them and to prevent kaons from reaching the veto detectors. Čerenkov counters support the background suppression. MWPC's allow track reconstruction. Forward detectors consisting of scintillation hodoscopes and MWPC's (# 3–5) have been built for the analysis of positively charged particles with large momentum which leave D2 in forward direction. Scintillators and MWDC's near D1 will be used for the study of backward emitted ejectiles. The detector system for negatively charged particles (Fig.1) is under development.

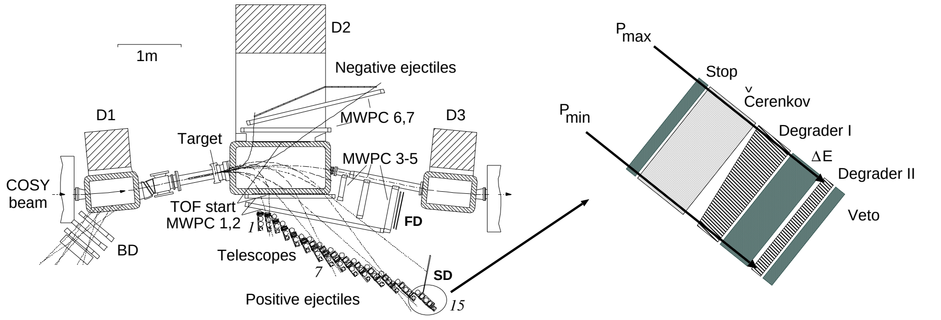

Fig. 1. Floor plan of the ANKE spectrometer.

The momentum calibration of the spectrometer was carried out with forward emitted, almost mono-energetic pions of the reaction $pp \rightarrow \pi^+ d$ in strip targets (2×20 mm^2) of CH_2. The obtained calibration and resolution agree well with the results of simulation calculations using field maps of D2 and with calibration procedures with the floating wire method. The resolution is limited through multiple scattering in the material between target and the wire chambers (vacuum window, start counters and air).

Fig.2a) compares the calculated values for the resolution with the measured ones in the case of a low magnetic field strength B. The good agreement proves the reliability of the calculations which, for higher fields (up to 1.6 T), lead to resolutions around 1%. The resolution of the spectrometer magnet D2 itself (i.e. without multiple scattering) is better than 0.5%.

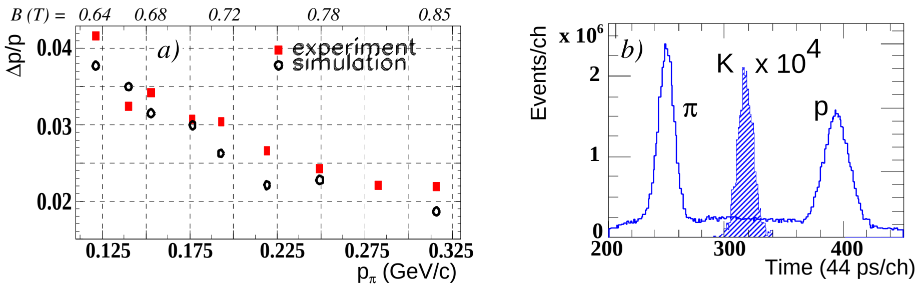

Fig. 2. a)Momentum resolution at ANKE measured with pions. b) Time-of-flight spectrum for kaons (shaded, with off-line cuts) and background particles (raw spectra) detected in telescope 11 at a beam energy of $T = 2.0$ GeV

2. Research on Medium Effects

The investigation of the influence of the nuclear medium on reactions between nucleons is an issue of strong interest. One way to gain information on these effects is the study of particle production in pA interactions at beam energies below the corresponding free nucleon-nucleon threshold. An especially well suited probe is the K^+-meson. It has a large mass so that cooperative effects enabling its production must be strong, and its strangeness content reduces final state interactions. The lower the energy T_p of the projectile proton the stronger must be the cooperative effects. The total cross section for subthreshold production has been measured for several target materials [6] for $0.8 \leq T_\mathrm{p} \leq 1.0$ GeV, hence far below the threshold at 1.58 GeV. The authors have considered different options for the interpretation of their results, e.g. possible contributions of high components of the nuclear wave function or two-step processes (see also [7]) with an intermediate pion.

In order to get more insight into the subthreshold processes, ANKE is used for the measurement of double differential cross sections for the production of forward emitted K^+-mesons, $\mathrm{d}^2\sigma/\mathrm{d}\Omega\,\mathrm{d}p_{\mathrm{K}^+}$. This study is possible [4] for $T_\mathrm{p} \geq 1.0$ GeV in spite of a background of protons and pions with an intensity higher by a factor of up to 10^6. The measurements have already been carried out at $T_\mathrm{p} = 1.0, 1.2, 1.5, 1.8, 2.0$ and 2.3 GeV. The identification of the kaons has been achieved with the use of very efficient hardware triggers based on time-of-flight, energy loss and geometrical criteria, which allow to reduce the integral rate (of mainly background) from about 10^6/s to less than 10^3/s, and with off-line cuts [5]. It should be noted that all particles that hit an individual telescope (and stem from the target) have the same momentum within $\sim 10\%$ due to the positioning in the focal surface. This is basic for the K^+-identification [5]. As an example for the clean information which is achieved in this way, the time-of-flight spectrum of K^+-mesons which has been observed with telescope number 11 is shown in Fig.2b). Such spectra of all telescopes provide the basis for the determination of $\mathrm{d}^2\sigma/\mathrm{d}\Omega\,\mathrm{d}p_{\mathrm{K}^+}$. The results will complement and extend the data from studies at SATURNE [11] and CELSIUS [12], and their comparison with theoretical predictions (see e.g. [7, 13]) is expected to contribute to the understanding of the subthreshold production process.

It is planned to study also correlated K^+-light particle emission which is expected if the K^+-meson production involves nucleon clusters [8]. The observation of K^+ and d coincidences is considered as a fingerprint of the two-step mechanism [6, 9]. Later the subthreshold K^--production will be investigated [10].

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