The Polarized Internal Target at ANKE

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In a first stage of the double polarized measurements, to be performed at the magnet spectrometer ANKE, several $\vec{d}\vec{p}$ reactions of actual interest will be investigated with the polarized deuteron beam of COSY and the polarized hydrogen storage-cell target. These include the reactions $\vec{d}\vec{p} \to (2p)n$, $\vec{d}\vec{p} \to (2p)\Delta^0$, $\vec{d}\vec{p} \to dp$, $\vec{d}\vec{p} \to {}^3\mathrm{He}\pi^0$, and $\vec{d}\vec{p} \to {}^3\mathrm{He}\eta$ [1].

In order to maximize the figure of merit for double polarized experiments, two weeks of beam time in February and March 2006 were spent to study the use of stochastic cooling of the unpolarized proton beam circulating through the storage cell and to commission the polarized atomic beam source (ABS) at the ANKE target position near to the spectrometer dipole magnet D2.

Following the test measurements in November 2005 with a storage cell in the ANKE target chamber [2], the support frame with the cell was dismounted and a cryogenic catcher for the ABS beam was installed (Fig. 1). By its use, the

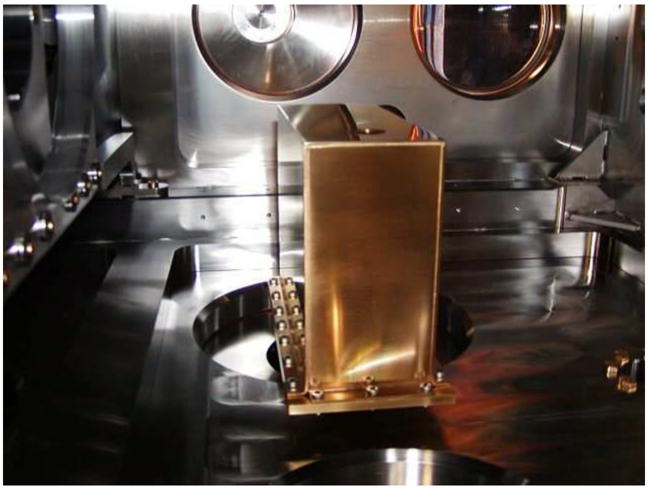

Fig. 1: Side view into the ANKE target chamber with the cryogenic catcher. The outer surface is polished and gold-plated to reduce the radiation-heat load. By a Cu heat bridge the catcher is connected to a cold head, mounted below the target chamber. The vertical beam from the ABS enters the catcher by the hole in the upper surface.

residual gas pressure in the ANKE target chamber could be reduced by one order of magnitude to 3.7×10^{-8} mbar. The measured thickness of the direct ABS jet without storage cell of $(1.5 \pm 0.1) \times 10^{11}$ H atoms/cm^2 (left-hand side of Fig. 2) is in perfect agreement with the calculated value of $(1.6 \pm 0.1) \times 10^{11}$ H atoms/cm^2.

During the measurements with the jet, the medium field transition unit (MFT) of the ABS was working properly. But it was observed that the polarization of the ABS beam could not be switched from the positive value (atoms in hyperfine state 1 / MFT on - WFT off) to the negative value (atoms in hyperfine state 3 / MFT on - WFT on) achieved earlier in the laboratory tests ($Q_z = 0.89$ and $Q_z = -0.90$, respectively). This could be explained by the insufficient shielding of the weak field rf transition unit (WFT) of the ABS, i.e., penetration of the magnetic stray field of the

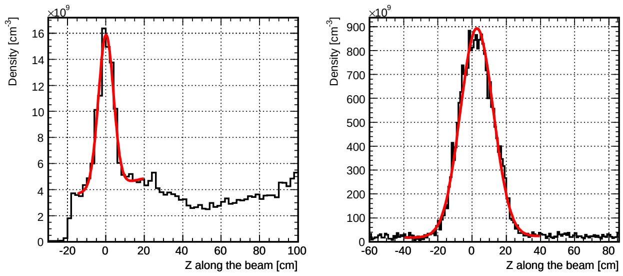

Fig. 2: Density distributions of the target gas along the COSY beam direction measured by use of the $pp \to d\pi^+$ reaction. The target-gas densities, given in the text, result from the summation over the peaks. Left-hand side: Measurement with the jet of H atoms and 600 MeV protons. Right-hand side: Measurement with H_2 gas in the storage cell of 20×20 mm^2 cross section, 380 mm length, and 831 MeV protons. The width of the distribution reflects the length of the storage cell.

magnet D2 into the transition unit [3]. To overcome this problem during the beam time, the direction of the magnetic gradient field in the medium field rf transition unit was reversed to populate the hyperfine state 2 of the H atoms in the ABS beam. According to the magnetic flux density of about 165 G in the interaction region of the COSY beam and the jet, the negative value of the polarization should be about $p_z = -0.31$. In this first measurement, however, only slightly more than 50% of the expected value of the polarization inversion could be achieved.

For the next beam time in March 2006, the ABS and the cryogenic catcher had to be dismounted. Two new storage cells with $20 \times 20 \times 380$ mm^3 and $10 \times 10 \times 380$ mm^3 were implemented. For COSY beam studies these cells were fed with H_2 gas fluxes equivalent to the H beam intensity of the ABS. The unpolarized COSY beam was electron-cooled and stacked during injection. This allowed to accelerate 1.6×10^{10} protons to 831 MeV flat top energy with the larger cell and with the COSY beam in the ANKE setup deflected by $\alpha = 8^\circ$. With the smaller cell only 2.5×10^9 protons could be injected, but they got lost during acceleration. The measured target-density distribution (right-hand side of Fig. 2) shows the triangular shape, expected due to the gas-density distribution in the storage cell along its axis.

In the flat top, the COSY beam was stochastically cooled to compensate the beam heating by the target gas. The effect of cooling was studied with the use of the count rate in the Forward-Detector system of ANKE. Without cooling, the beam heating results in a widening of the beam which leads to an increase of the beam interactions with the storage-cell wall (see Fig. 3). As seen in this figure, too, this effect is reduced by the application of stochastic cooling. The trigger rate in the ANKE Forward-Detector system follows the decrease of the COSY beam intensity. As a natural consequence, the life time of the COSY beam is increased by the beam cooling.

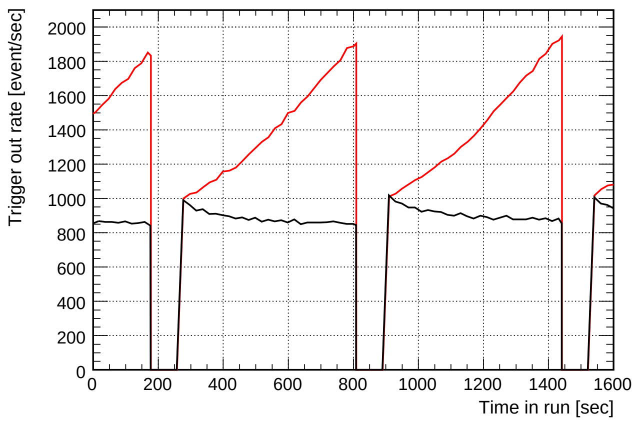

Fig. 3: Time dependence of the trigger rate of the ANKE Forward-Detector system in the 831 MeV flat top without (red) and with stochastic cooling.

For its use in tuning of the ABS, the Lamb-shift polarimeter (LSP) after a number of necessary modifications could be mounted with the ionizer and the 90 ° deflector below the ANKE target chamber. The Fig. 4 shows a part of the LSP components. In the present mode of installation, the LSP is used to measure the jet polarization as in the laboratory before [4].

With the ANKE magnet D2 set to magnetic field strenghts,

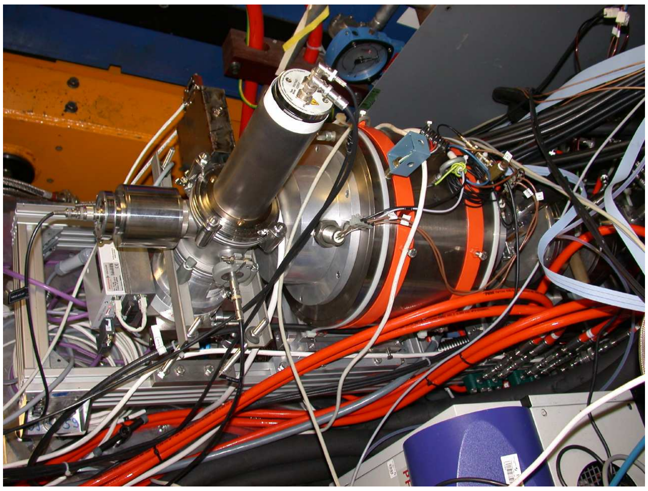

Fig. 4: The Lamb-shift polarimeter at ANKE. From left to right the visible components are the Faraday cup, the quench chamber with the photomultiplier, the spin-filter, and the cesium cell. The Wien filter, the 90° deflector, the ionizer, and the ANKE target chamber follow outside the right-hand edge of the figure.

requested in the beam times in 2007, in December 2006 the LSP could be commissioned. The peak ratios, however, in the Lamb-shift spectra (Fig. 5) were found to be about three times lower than expected. Furthermore, the polarization of the ABS jet resulted with a sign opposite to the expected one. This finding can be explained by the action of the magnetic stray field of the D2 magnet to the ions between the LSP ionizer and cesium cell, leading to changes in the precession of the polarized ions. A special problem was encountered by the variation of strength and probably also

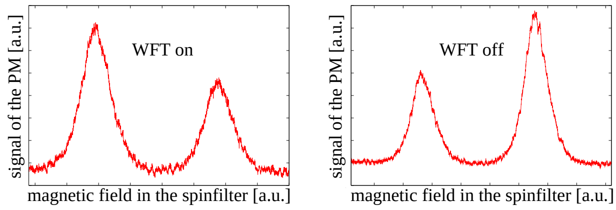

Fig. 5: Lamb-shift spectra measured with the LSP, when the weak field rf transition unit (WFT) was swichted off (left-hand side) and on (right-hand side). The ratio of the two peaks in the spectra yield the polarization of the atomic beam.

the direction of the stray field with the field in the 20 cm gap of the D2 magnet. With additional shielding, the Wien filter, installed between the ionizer and the cesium cell, could be used to partly compensate the induced precession. In spite of the encountered problems, the measured asymmetries were found to be proportional to the polarization of the atomic hydrogen beam from the ABS and they thus could be used to monitor the polarization during the beam-time measurements.

Meanwhile, the insufficient magnetic shielding of the weak field rf transition unit, mentioned above, has been completed. Tests have shown that the operation of the unit now is not affected by the D2 stray field. Tuning of the rf transition units of the ABS is made possible with errors of about 1% in the achieved transition efficiencies. Now the polarization of the $\vec{\mathrm{H}}$ beam from the ABS can be switched between the maximum positive and negative values. The tuning procedures, switching of the polarization and monitoring of the system is done with the use of the slow-control system, developed in collaboration with the Zentralinstitut für Elektronik of FZJ [5].

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