The Polarized Internal Target at ANKE: First Results

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Abstract. For future few-nucleon interactions studies with polarized beams and targets at COSY-Jülich, a polarized internal storage cell gas target was implemented at the magnetic spectrometer ANKE in summer 2005. First commissioning of the polarized Atomic Beam Source (ABS) at ANKE was carried out and some improvements of the system have been done. At the same time, storage-cell tests to determine the COSY beam dimensions have been performed. In February 2005, a first storage cell prototype was implemented. It was made from an aluminum foil covered by a special PTFE suspension. In November 2005, tests were carried out with a storage cell using a polarized hydrogen beam from the ABS, electron cooling and stacking injection of the COSY beam at different deflection angles of the ANKE spectrometer magnet. An average target polarization of P=0.44±0.03 (November 2005 beamtime) was measured, while we expected about P=0.51-0.55 due to the availability of rf-transition units in the ABS. The jet target thickness was measured as $(1.5\pm0.1)\cdot10^{11}$ atoms/cm^2. In March 2006, measurements with unpolarized protons at T=831 MeV and an unpolarized H_2 beam injected from a gas feeding system into the aluminum storage cell were carried out. The analysis of the $pp \to pp\pi^0$ and $pp \to pn\pi^+$ reactions showed that events from the extended target can be clearly identified in the ANKE forward detector system.

Keywords: Atomic beam source; ANKE; Polarized target; Internal target; Polarimeter; Detection of atomic beams; Spin polarized hydrogen; Deuterium.

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INTRODUCTION

In the end of 2003, the development of the ANKE Atomic Beam Source (ABS) [1] was successfully finished. The source produces polarized hydrogen or deuterium beams, the main parameters like intensity and polarization are shown in Table 1.

TABLE 1. Main parameters of the polarized atomic beam source at ANKE/COSY.

Gas type	Intensity, at/s	Pz	Pzz
Hydrogen	$(7.5\pm0.2)\cdot10^{16}$	+0.89±0.01 –0.96±0.01	-
Deuterium	$(3.9\pm0.1)\cdot10^{16}$	+0.73±0.05 –0.82±0.06	+0.77±0.06 –1.17±0.08

In 2004 the ABS and the Lamb-shift Polarimeter (LSP) [2] were transferred from the laboratory to the COSY building. There it was mounted on a support bridge to be positioned between the first beam-bending and the spectrometer magnet of ANKE (see Fig. 1). The figure also shows the transportation platform for the electronic and power-supply modules. After all necessary tests, in summer 2005 the source was ready for installation at the spectrometer ANKE and further commissioning. Measurements to determine the COSY-beam dimensions at the ANKE target position and first tests with storage-cell prototypes were carried out.

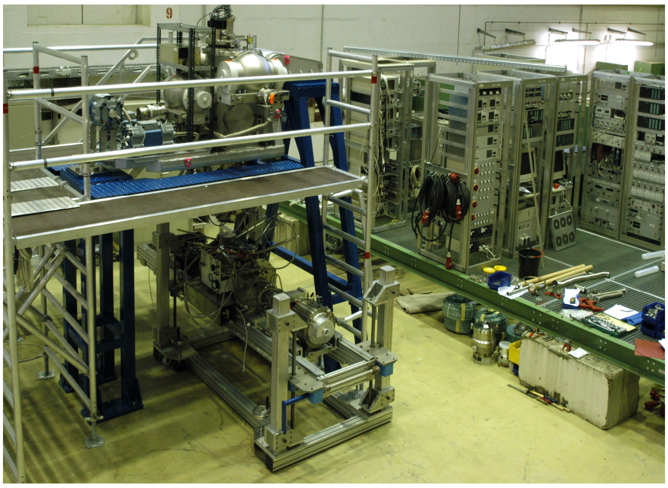

Figure 1. ABS, mounted on the support bridge, with the LSP below and the transportation platform in the COSY hall outside the accelerator tunnel.

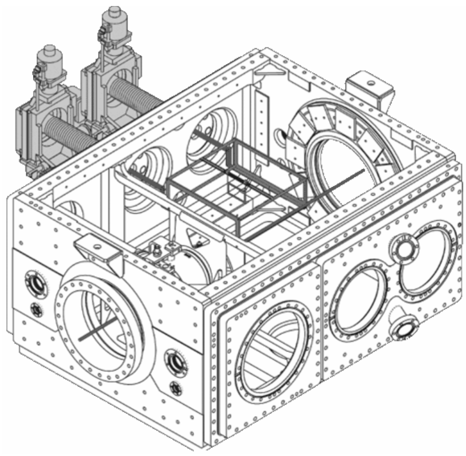

Figure 2. ANKE target chamber with XY-coordinate manipulator and the frame supporting the diaphragms.

COSY BEAM STUDIES

To achieve the maximum thickness of the internal gas target one has to determine the minimal size of the beam-tube of the storage cell. This was done during the first test in February 2004. Prior to these tests, it was not known which size at ANKE the COSY beam has at injection and after acceleration. For these tests, a frame carrying various diaphragms was constructed. The diaphragm, which was mainly used, had inner dimensions of $50_{hor}x25_{vert}$ mm^2, i.e. larger than the expected beam size. In order to move it, a XY-manipulator was mounted at the target chamber (as is shown in Fig. 2). During the tests, the supporting frame was moved by using stepper motors[1]. The center of the diaphragm was placed at the expected center of the COSY beam. By moving the diaphragm edges, the COSY beam is gradually destroyed and its full size can be measured[2]. At injection, the beam has elliptical shape and its full size was 38x17 mm^2. The accelerated beam without target has a size of 9x14 mm^2. With the cluster target beam[3] it increased to 17x17 mm^2 due to beam heating by the target.

[1] Each motor has a step size of about 50 μm and is equipped with a position sensor, which counts the steps.
[2] All size measurements were done with 2.1 GeV proton beam without using any cooling procedures (electron cooling at injection, stochastic cooling at energies higher then 800 MeV) and stacking procedure at injection.
[3] During this measurements cluster target density was about 10^{12} cm^{-2} that is 10 times higher then unpolarized jet-target density.

STORAGE CELL PREPARATION AND TESTS

Based on the measured results, two storage cell prototypes were built from a 25 μm aluminum foil (99.95 Al) for the February 2005 beamtime. After acceleration of an unpolarized deuteron beam through the large cell (30x20 mm^2) at an energy of about 2.1 GeV, the size of the beam did not change much compared to earlier tests. It was possible to store and accelerate more than 2/3 of the injected deuterons in the COSY ring (~$9\cdot10^9$ deuterons[4]). Using beam scrapers in the opposite section of the accelerator ring, the dimensions of the stored beam in the cell were decreased to 13x11 mm^2 and with $1.7\cdot10^9$ deuterons about 15% of the injected deuterons were successfully stored in the COSY ring with the small cell of 15x15 mm^2 positioned in the ANKE target chamber around the circulating beam. The length of both cells was 220 mm and there are no restrictions to use storage cells up to a length of about 400 mm.

POLARIZED INTERNAL GAS TARGET COMMISSIONING

When the first cell test at ANKE was finished, preparation for the beamtime in autumn 2005 started. An aluminum foil, covered with PTFE[5] to minimize depolarization on the surface, was used for the new prototype of the storage cell. During the run, stacking injection [3] and electron cooling was used to increase the number of stored or accelerated protons with the storage cell. Finally, when the ANKE spectrometer magnet was moved to a beam bending angle of 9.2° and the H_2 flow fed the cell, $6.4\cdot10^9$ protons were stored and accelerated in the ring. This was about 50% of the number of particles which can be accelerated without cell and stacking at injection. This number yields an appreciable luminosity up to 10^{30} $cm^{-2}s^{-1}$ for double polarization experiments.

Prior to these tests with the storage cell, calibration runs were made with a polyethylene strip target of ~2mm width. The strip target was installed in the target chamber to allow exchange of the storage cell target and the strip target without breaking the vacuum. A position of the strip target along the COSY beam was very close to the location of the maximum intensity of the storage cell target. The reconstructed vertex distribution for the strip target (longitudinal and transversal resolutions are $\sigma_{\parallel}$ ~35–40 mm and $\sigma_{\perp}$ ~8 mm, respectively) then allows the appropriate cut in the distributions measured with the storage cell.

RESULTS OF THE COMMISSIONING

For the beamtime in March 2006 the storage-cell prototype made from uncoated pure aluminum foil was used and unpolarized H_2 was injected from a gas feeding system into the storage cell. The analysis of the $pp \to pp\pi^0$ and $pp \to pn\pi^+$ reactions shows (Fig. 3) that events from the extended target can be clearly identified in the ANKE forward detector system. Using unpolarized N_2 in the cell, the background

[4] We quote here the number of particles in the COSY ring measured by the beam–current transformer.
[5] A kind of a **p**oly**t**etra**f**luoro**e**thylene suspension

from the Al cell-wall material could be determined as well, due to the similar nuclear masses [4]. To determine the asymmetry of the $p\vec{p} \to d\pi^+$ reaction (Fig. 4) with the direct ABS hydrogen jet, measurements with the beam atoms in hyperfine state 1 or 2 were necessary. This was caused by problems in operating the weak field transition unit (WFT) because of insufficient shielding against the stray field from the spectrometer magnet. An average target polarization of P=0.44±0.03 was measured, while we expected it to be about P=0.51–0.55. The jet target thickness was $(1.5\pm0.1)\cdot10^{11}$ at/cm^2. The target thickness with a hydrogen beam injected into the cell in hyperfine state 1 amounts to about $2\cdot10^{13}$ at/cm^2.

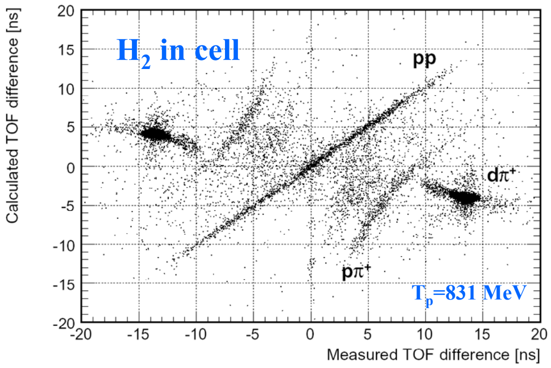

Figure 3. Time difference of the two detected charged particles, calculated under the assumption that both of them are protons.

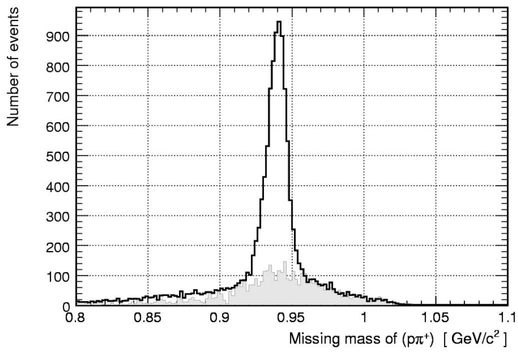

Figure 4. Missing mass distribution from the $pp \to pn\pi^+$ **reaction. Shaded area – background distribution, measured with** N_2**.**

For future beamtimes, the Lamb-shift polarimeter will be mounted below the target chamber to allow for tuning of the transition units and monitoring of the ABS beam polarization during the run. The configuration of the target cell and its support mechanism will be upgraded to allow for the installation of the Silicon Tracking Telescopes (STT) near the target cell. The new setup will be installed at ANKE in December 2006 for final commissioning. A first double polarized experiment is planned for January 2007.

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REFERENCES

1. F. Rathmann *et al.*, Proc. 15th Int. Spin Physics Symposium, Upton, NY, USA, 2002. AIP Conf. Proc. **675** (2003) 553.
2. R. Engels *et al.*, Rev. Sci. Instrum. **74** (2003) 4607.
3. H.J. Stein *et al.*, Proc. 18th Conf. on Charged Particle Accelerators,(RUPAC 2002), Obninsk, Russia, 2002. I.N. Meshkov (Ed. in chief), NRCRF Obninsk (2004) 220.
4. F. Rathmann *et al.*, Phys. Rev. C **58**, 658 (1998)