Storage cell tests and commissioning of the Polarized Internal Gas Target

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In order to study the lateral dimensions of the COSY beam at the ANKE–target position and its intensity with the storage cell at the target position, a setup has been developed which allows one to position diaphragms and storage cells onto the COSY–beam axis, to move them perpendicular to the beam axis in horizontal (ΔX = ±75 mm) and vertical (ΔY = ±12.5 mm) direction, and to tilt the cell–tube axis against the beam axis (Fig. 1). The remote-control system is part of the PIT control and interlock installation [1].

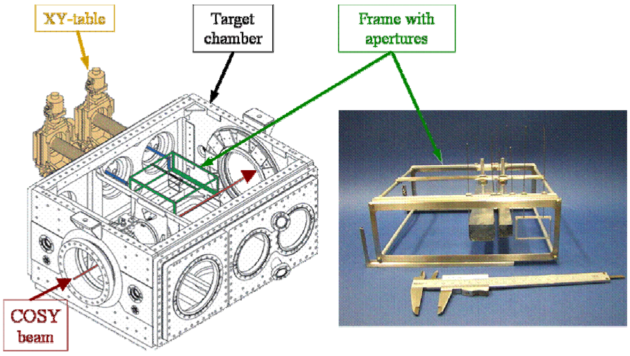

Fig. 1: The new ANKE target chamber (width 60 cm, length 80 cm, and height 40 cm) with the motorized, remote–controlled XY manipulators, used to position the target frame (left–hand part). Various apertures or storage cells can be suspended in the frame (right–hand part).

In February 2005, a second cell test run at ANKE was carried out. Based on the results from previous tests in 2004, new storage cell prototypes were built. Two storage cells made from 25µm thick pure aluminum foil and one aperture with inner size of 40x25 mm^2 were installed in the supporting frame (see right–hand part of Fig. 1) and implemented into the target chamber at ANKE. Both cells had an unpolarized gas feeding tube with a connection to a gas supply to simulate a hydrogen or nitrogen target of a density similar to what is obtained with the Atomic Beam Source (ABS) [2].

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 with a 2.7 GeV proton beam. It was possible to store and accelerate more than 2/3 of the injected deuterons into the ring (~9x10^9 deuterons). By scraping, the dimensions of the stored beam in the cell were decreased to 13x11 mm^2. After that, about 15% of the injected deuterons (1.7x10^9 deuterons) were successfully stored in the COSY ring with the small cell of 15x15 mm^2. The length of both cells was 220 mm and there are no restrictions to use cells up to a length of about 400 mm.

Based on the result of these tests, a new storage cell prototype was built (see Fig. 2.). An aluminum foil, covered with Teflon® PTFE suspension to minimize depolarization on the surface was used. This cell prototype has a feeding tube for the ABS beam and an extraction tube to the Lamb–Shift Polarimeter [3], which is planned to be used for polarization measurements of the target atoms. Since the major tasks for these tests were completed, first measurements with hydrogen gas in the target cell were carried out.

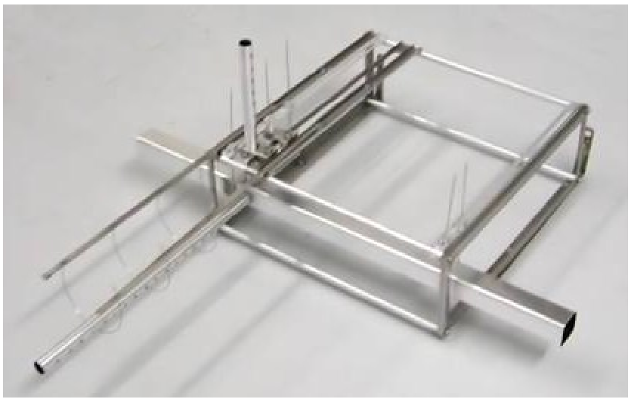

Fig. 2: Storage cell prototype with a feeding and an extraction tubes for tests in November 2005.

In June 2005, the polarized atomic beam source has been installed at the ANKE–target chamber for commissioning and test measurements [4]. Based on earlier studies, using different apertures to determine the lateral COSY–beam dimensions at the ANKE–target position, more extensive measurements were performed with a rectangular 40x25 mm^2 aperture and a storage–cell tube of 20x20 mm^2 cross section and 400 mm length. Cutting the beam by stepwise moving the left, right, upper, and lower edges of the apertures frame towards the beam axis gave lateral and vertical widths of the proton beam at injection energy of 40 MeV of 16 mm horizontal and 15 mm vertical. At its centered position, the aperture reduces the number of stored protons to ~87%. Application of electron cooling [5, 6] results in a reduction of the beam size to ~13 mm horizontal and ~11 mm vertical.

Table 1: The number of stored protons N_p at injection energy without cell, with the empty cell tube and with the cell tube fed by gas for the undeflected beam through ANKE (α = 0°) and a chicane angle of α = 9.2° with stacking injection (s) and electron cooling at injection (c).

α	beam	N_p at injection		
		no cell	empty cell	gas–fed cell
0°	c	8.3x10^{10}	6.6x10^9	
9.2°	s+c		8.5x10^9	8.8x10^9

With the storage cell, with stacking injection [5, 6] and with electron cooling, the number of stored protons was measured using the beam–current transformer. These numbers are to be compared with those, achieved without the cell. As an essential step, an appreciable number of protons could be stored with the COSY beam deflected to 9.2° in the ANKE chicane. The data, measured at injection, are collected in Tab. 1, whereas Tab. 2 shows those achieved after acceleration to 600 MeV.

Table 2: The number of stored protons N_p after acceleration to 600 MeV (further explanations see caption of Table 1).

α	beam	N_p at 600 MeV		
		no cell	empty cell	gas–fed cell
0°	c	$1.4x10^{10}$	$3.5x10^9$	
0°	s+c	$2.6x10^{10}$	$2.0x10^9$	
9.2°	s+c		$6.0x10^9$	$6.4x10^9$

The number of $6.4x10^9$ stored and accelerated protons yields an appreciable luminosity up to 10^{30} cm^{-2} s^{-1} for double polarization experiments. Further studies will focus on the additional application of stochastic cooling.

The evaluation of the data from the pp → $d\pi^+$ reaction, measured with injection of hydrogen into the storage cell, is described here.

Prior to the tests with the storage cell filled with hydrogen, a few calibration runs were taken with a polyethylene strip target. The strip target setup was installed at the target chamber at the opposite flange of the cell supporting setup to be able to change the storage cell target with the strip target without breaking the vacuum and to avoid any changes in the cyclotron setup. That exchange can be done within a couple of minutes.

The results of the vertex reconstruction along the X-coordinates (perpendicular to the beam) and Z-coordinates (along the beam), with the origin in the CH_2 target position are shown in Fig. 3. The reconstructed vertex is very close to the real target coordinates. The resolution of the longitudinal coordinate is $\sigma_{\parallel}$~3.5 – 4 cm and transversal $\sigma_{\perp}$~ 0.8 cm.

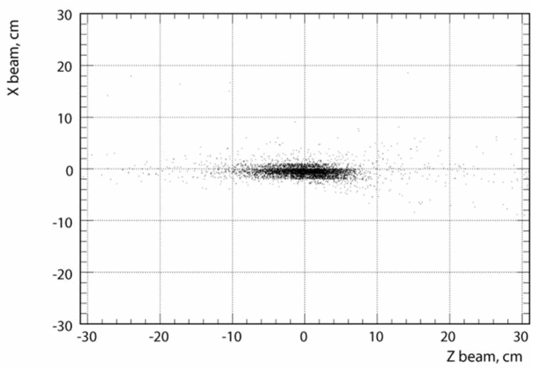

Fig. 3: CH_2 strip target vertex reconstruction.

Events from the storage cell were analyzed to study the vertex distribution. Results of these analyses show the expected ratio when the target consists of atoms of states 1+2 of the hydrogen beam and when into the cell only state 1 is injected (Fig. 4).

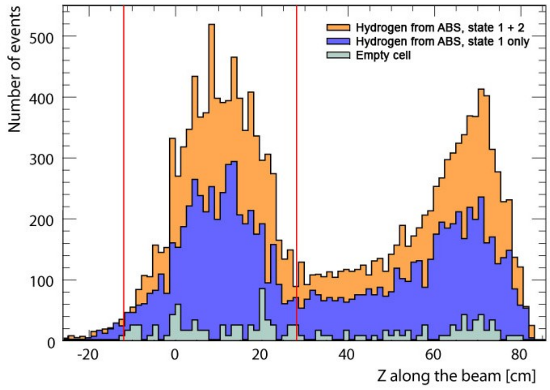

Fig. 4: Number of events from the cell as function of coordinate (along the COSY beam).

The observed event distribution in the cell region (area between two vertical lines in Fig. 4) possesses a triangular shape – well known for the density distribution of a cell target. Its apex is shifted to the right because of the higher acceptance at the cell exit (right vertical line in Fig. 4).

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