# THE POLARIZED GAS TARGET FOR THE ANKE SPECTROMETER AT COSY/JÜLICH

M. MIKIRTYTCHIANTS[1,2], R. BRÜGGEMANN[3], R. EMMERICH[3], R. ENGELS[3], H. KLEINES[4], V. KOPTEV[2], P. KRAVTSOV[2], S. LEMAîTRE[3], J. LEY[3], B. LORENTZ[1], S. LORENZ[5], M. NEKIPELOV[1,2], V. NELYUBIN[2], H. PAETZ GEN. SCHIECK[3], F. RATHMANN[1], J. SARKADI[4], H. SEYFARTH[1], E. STEFFENS[5], H. STRÖHER[1], A. VASSILIEV[2], K. ZWOLL[4]

*(1) Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany*
*(2) High Energy Phys. Department, Petersburg Nuclear Physics Institute, 188300 Gatchina, Russia*
*(3) Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany*
*(4) Zentrallabor für Elektronik, Forschungszentrum Jülich, 52425 Jülich, Germany*
*(5) Physikalisches Institut II, Friedrich-Alexander-Universität, 91058 Erlangen, Germany*

The polarized atomic beam source (ABS) will be utilized to feed the storage cell gas target in future experiments at the magnetic spectrometer ANKE. A state-of-the-art system of sextupole magnets has been developed for the source. An intensity of $(6.9 \pm 0.3) \cdot 10^{16}$ atoms/s into a compression tube has been achieved for two hyperfine states of hydrogen. The medium field rf-transition (MFT) unit has been installed. An efficiency of $0.90 \pm 0.05$ has been measured for the 2-3 transition. For future experiments at COSY with polarized internal targets a Lamb-shift polarimeter, built at the University of Cologne, has been installed at the ABS. First measurements of the nuclear polarization of the atomic hydrogen beam, produced by the MFT unit, yield a value of $|P| = 0.889 \pm 0.009$. First studies of the properties of the COSY beam have been carried out with an aperture at the ANKE target position.

A polarized atomic beam source (ABS) will be utilized to feed a gas-storage cell at the magnetic spectrometer ANKE[1] with polarized hydrogen or deuterium atoms. By the use of a storage cell the luminosity will be increased by about two orders of magnitude compared to an atomic gas jet crossing the stored, circulating COSY beam[2]. The ABS has been assembled and tested.

## 1 Layout of the ABS

The layout of the ABS is shown in Fig. 1. A powerful pumping system yields pressures of about $10^{-4}, 10^{-6}, 10^{-7}$, and $5 \cdot 10^{-8}$ mbar in chamber I, II, III, and IV, respectively, at a primary $H_2$ inlet flux of 1.5 mbar·l/s.

In the dissociator (labeled 1 in the figure) a plasma discharge is maintained by coupling of 13.56 MHz. The nozzle at the lower end can be cooled to about 65 K by a cryocooler via a flexible Cu connection and a Cu bridge (label 2). The details at the lower end of the dissociator are shown in Fig. 2. The inner discharge tube (Duran 8330 glass of 14 mm outer diameter and 1.5 mm wall thickness) is cooled by a water flow between coaxial glass tubes. The transition piece from the cold nozzle to the outer dissociator tube avoids forces on the discharge tube. Thermal contact to the lower part of the discharge tube is provided by a modified sliding rf connector. This special construction allows to extract and reinstall the glass tubes and the rf-generating elements without disassembling the heat bridge and nozzle.

The upper baffle, separating the chambers I and II, carries the beam skimmer. The nozzle-to-skimmer distance can be optimized from outside without breaking the vacuum.

Two groups of permanent sextupole magnets (labels 3 and 5), delivered by Vacuumschmelze[a], have been installed. The excellent properties of the magnets are described in ref.[3]. Magnetic field distributions, calculated with the computer code MAFIA, are in perfect agreement with the results of the measurements. Protection of the magnets from hydrogen was done by enclosing them in stainless steel cans with inner tubes of 0.2 mm thickness in order to maximize the free magnet apertures.

In order to achieve vector and tensor nuclear polarization of hydrogen and deuterium, medium- and weak-field rf transition units have been designed and built at Universität Erlangen[4]. The latter unit and the strong-field units for H and D, man-

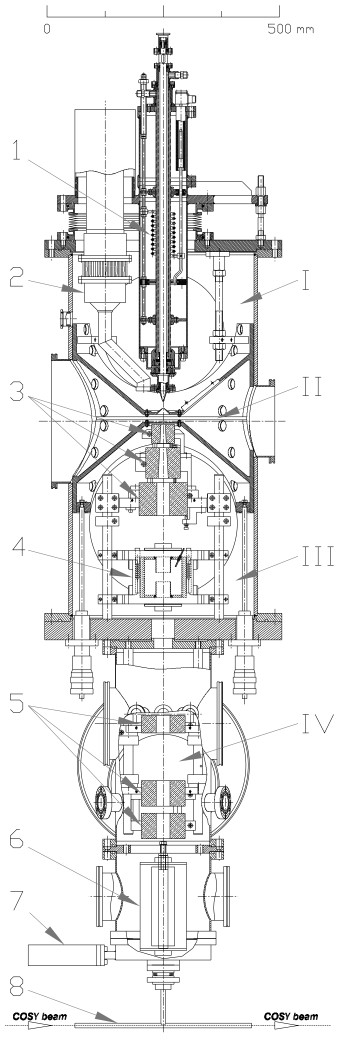


Figure 1. Layout of the ANKE polarized atomic beam source (for details see text).

[a] Vacuumschmelze GmbH, D-63450 Hanau, Germany.

ufactured following an earlier design[5], are combined into one unit (label 6).

A special vacuum gate valve[b] (label 7) allows one to disconnect the ABS chamber from the target chamber with the storage cell (label 8), i.e. from the COSY beam line system.

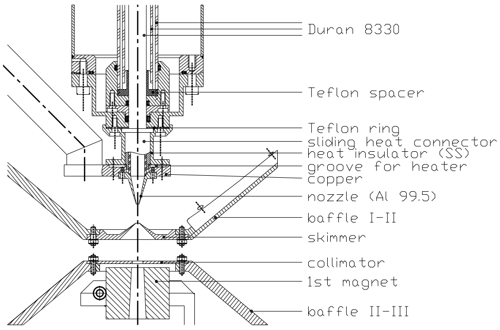


Figure 2. The region between the lower end of the dissociator and the first sextupole magnet.

## 2 Results of the beam studies

The intensity of the polarized beam, as it will feed the storage cell, has been measured with a compression tube, having the dimensions of the feeding tube of the storage cell (10 mm diameter, 100 mm length) and installed at its position (entrance 300 mm behind the exit of the last magnet).

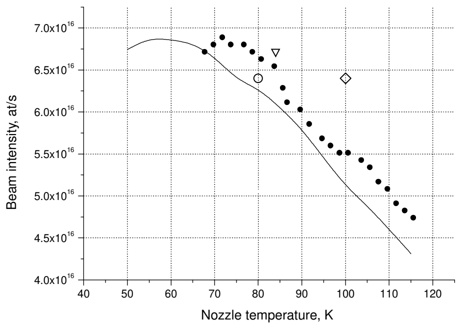


Figure 3. Absolute beam intensity as a function of the nozzle temperature. For the comparison, data from the HERMES ABS(◇) and PINTEX (▽) ABS and Munich ion source (○) are shown on the figure. The solid line represents results of simulations.[6]

The obtained absolute beam intensity as a function of the nozzle temperature is shown in Fig. 3. The maximum of $(6.9 \pm 0.3) \cdot 10^{16}$ H atoms per second is achieved around 72 K at primary $H_2$ flow of 1 mbar·l/s, $O_2$ admixture of 0.1% and dissociator power 300 W. The measured slope is reproduced well by the result of a trajectory calculations, which assumed a constant degree of dissociation, verified through earlier measurements[7]. The discrepancy at lower temperatures may be explained by increasing intra-beam and rest-gas scattering, which is not taken into account in the simulations. The present results are compared with the maximum intensities given for the sources operated at HERMES (DESY)[8], PINTEX (IUCF)[9], and the polarized ion source at tandem accelerator in Munich, Germany[10].

[b]VAT Deutschland GmbH, D-85630, Grasbrunn, Germany.

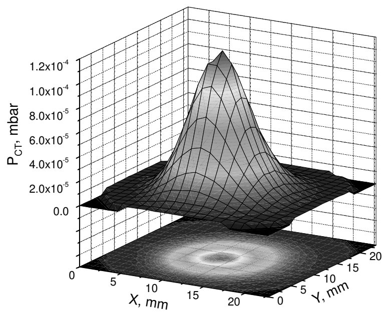


Figure 4. $xy$-distribution of the pressure in the compression volume measured with narrow (5 mm diameter) compression tube 300 mm behind the last magnet.

In addition to the absolute beam intensity the atomic beam profile has been measured. These studies were carried out with a compression tube of 5 mm diameter and 50 mm length at two positions: 300 mm (1) and 337 mm (2) behind the last magnet. Figure 4 shows the $xy$-distribution of the pressure in the compression volume measured 300 mm behind the last magnet. Both measured distributions (1) and (2) can be reproduced by calculations performed under the assumption of the gaussian beam profile with $\sigma_1 = 2.85 \pm 0.42$ mm and $\sigma_2 = 2.95 \pm 0.43$ mm, respectively.

At present only the medium-field rf transition unit has been installed. Its efficiency has been measured with the compression-tube set-up. Preliminary results show that the efficiency of the medium-field rf transition unit is $0.90 \pm 0.05$, which corresponds to a polarization larger than 85%.

This result is confirmed by measurements with the recently installed Lamb-shift polarimeter (LSP), which yields the polarization of the H beam behind the second group of magnets to be $|P| = 0.889 \pm 0.009$. The polarimeter has been designed and built at University of Cologne[11]. At present its commissioning is completed and it is used for further studies of the ABS beam properties and for fine-tuning of the transition units. Later it will serve for investigations of the polarization of the gas in the storage cell.

The construction of the LSP necessitates its horizontal position. Thus a 90° electrostatic spherical deflector[c] was installed between the vertical ABS and the ionizer and the subsequent components of the LSP: Wien filter, Cs cell for charge exchange and excitation of atoms into the metastable 2S state, spin filter as the heart of the set-up to select the atoms in the different nuclear spin states (magnetic quantum numbers $m = \pm 1/2$ for H and $m = +1, 0, -1$ for D) for D), and finally the quenching chamber with the photomultiplier to measure the light from the Lyman-$\alpha$ transitions into the ground state.

[c]on loan from University of Wisconsin, Madison (W. Heberli)

## 3 Future developments

Since the future experiments (e.g. pd breakup[12]) at ANKE will require the use of a storage cell it is very important to study the properties of the COSY beam and to define the dimensions of the storage cell. These studies have been started with simple rectangular and elliptical diaphragms, 10 mm high and 30 mm wide, placed at the ANKE-target position. With the available vertical steerers and the rectangular diaphragm $9.6 \cdot 10^9$ protons could be accelerated and stored, whereas in the same steering mode but without the diaphragm this value is about $\sim 1.2 \cdot 10^{10}$. Without this additional steering a higher number of $\sim 1 \cdot 10^{11}$ protons could be stored which indicates beam losses elsewhere in the COSY ring. Thus additional vertical steerers are needed and will be installed for the next beam studies. In parallel to these activities the design work on a new large target chamber (length 800 mm, width 600 mm and height 400 mm) is in progress. The chamber will allow us to carry out beam studies with storage cell prototypes next year. It will also house new beam-position monitors and the set-up of silicon vertex detectors.

## References


1. S. Barsov *et al*, *Nucl. Instrum. Methods* A **462**, 364 (2001).
2. W. Haeberli, Proc. $2^{nd}$ Int. Symp. On Polarization Phenomena, eds. P. Huber and H. Schopper, Experientia Suppl. **12** (Birkhauser, Basel, 1966), p. 64.
3. A. Vassiliev *et al*, *Rev. Sci. Instrum.* **71** (2000) 3331.
4. S. Lorenz, Diploma thesis, Universität Erlangen-Nürnberg (1999).
5. F.Stock, PhD thesis, MPI Heidelberg (1994).
6. Based on a code obtained from D. Toporkov, BINP Novosibirsk.
7. M. Mikirtytchiants, Diploma thesis, St. Petersburg State Technical University (1999).
8. J. Stewart *et al*, AIP Conf. Proc. **421**, 69 (1998).
9. F. Rathmann *et al*, AIP Conf. Proc. **421**, 89 (1998).
10. R. Hertenberger *et al*, Proc. $8^{th}$ Int. Workshop on Polarized Sources and Targets (PST99), Erlangen, 1999. Edt. A. Gute, S. Lorenz, E. Steffens (Universität Erlangen-Nürnberg, 1999) , p. 52.
11. R. Engels, contribution to these proceedings.
12. S.V. Dshemuchadze *et al*, COSY Exp. Proposal No. 20 (1991); update V. Abazov *et al* (1999), spokesperson V. Komarov. available via `http://www.fz-juelich.de/ikp/anke`