INTERNAL GAS TARGETS IN AmPS

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1 INTRODUCTION

Measurements of spin-dependent electron scattering have the potential to greatly enhance our understanding of nucleon and nuclear structure. For example, spin observables in electron scattering from polarized hydrogen in the Δ-region are sensitive to a possible d-wave admixture in the quark wave functions of the nucleon or Δ-isobar. Measurements of elastic and quasi-elastic scattering from deuterium and ^{3}He are predicted to provide important information on the effects of S′- wave and D-wave components in the ground state of ^{2}H and ^{3}He and the largely unknown charge form factor of the neutron. Furthermore, a combination of measurements on polarized hydrogen, deuterium, and ^{3}He targets in deep-inelastic lepton scattering can be applied to measure the spin structure functions of the nucleon and to verify the Björken sum rule.

The measurement of analyzing powers and spin-correlation parameters in spin-dependent electron scattering from polarized nuclei is optimally performed by scattering electrons from a pure and highly polarized target. Polarized internal gas targets in electron storage rings have the advantage that spin-dependent scattering from chemically and isotopically pure atomic species of high polarization can be realized. They offer rapid polarization reversal and flexible orientation of the nuclear spin direction by using low magnetic holding fields, a low thickness at high luminosity which allows for the detection of low-energy recoiling hadrons, and access to a broad kinematic range by using large acceptance detectors. For polarized deuterium one has the additional ability to reverse the tensor polarization, P_{zz}, at fixed vector polarization, P_z, and vice versa. Subsequently, small systematic errors can be expected.

This technique is currently exploited at the Amsterdam Pulse Stretcher (AmPS) storage ring[1] at NIKHEF, where ultrapure polarized hydrogen, deuterium, and ^{3}He targets are available. In this presentation, we want to discuss the implications of the use of gas targets for the vacuum in the storage ring, and the strategy that was used at NIKHEF to optimize the luminosity by balancing between the conflicting requirements of dense gas targets and high electron beam life time.

In section 2 the polarized internal gas targets are briefly described. In section 3 the implementation of the gas targets in the vacuum system of the ring is discussed.

2 POLARIZED GAS TARGETS

Figure 1 shows a schematic layout of the experimental setup with the hydrogen/deuterium target. An atomic beam source provides the polarized hydrogen or deuterium atoms. The molecules are dissociated into atoms, and an atomic beam is formed at the nozzle, which is cooled to 70 K. The hyperfine states with electron spin down are rejected in the sextupole magnets. With RF-transition units between and after the sextupole magnets, an arbitrary selection of hyperfine states can be made, in such a way that the nuclear polarization can be chosen freely. The atomic beam is injected into a T-shaped, open-ended storage cell, which is cooled to 100 K. The use of such a storage cell gives an increase of target thickness at the place of the electron beam of more than two orders of magnitude for the present configuration. Ions, produced by the electron beam, can be extracted by using a combination of electrostatic lenses, a spherical deflector, a Wien filter, and an ion collector, consisting of a tritiated titanium foil (see Fig. 1). The reaction ^{3}H(d,n)^{4}He was applied to monitor the polarization of the target gas *in situ* [3]. More details on the experimental setup can be found in Refs. [4, 2].

For the experiments on ^{3}He, a metastability-exchange optical pumped target is used. A fraction of the ^{3}He gas in a glass pumping cell is brought into the 2^3S_1 metastable state. These metastables can be polarized by pumping with circularly polarized laser light (1.083 μm) to a 2P state. The atoms in the ground state are polarized by metastability exchange collisions. A fraction of the gas in the pumping cell is injected via a capillary into a cylindrical storage cell, which is cooled to 20 K in order to increase the target thickness at the beam, while keeping the flow limited. For the target currently employed at NIKHEF, we obtained 60 % polarization for a flow of 10^{17} atoms/s. Since the flow for the ^{3}He target is larger than for the deuterium/hydrogen target, and since He is more difficult to pump, we will discuss the vacuum system for the latter target in the next section.

3 VACUUM SYSTEM AT THE TARGET AREA

The use of gas targets may compromise the vacuum in the storage ring. This will deteriorate the beam life time and may introduce unwanted background from interactions with the rest gas. In the case of the NIKHEF storage ring, the vacuum has to be of high quality (better than 10^{-8} mbar) especially downstream from the target area, since there a Laser-Compton Backscattering polarimeter is used to measure the polarization of the electron beam. The main background for this polarimeter is due to interactions of the beam with rest gas. Furthermore, the pumps in the ring outside the target region are titanium getter pumps, which cannot handle excessive loads of helium gas. The capacity for helium for the pumps in the AmPS ring (Varian Starcell

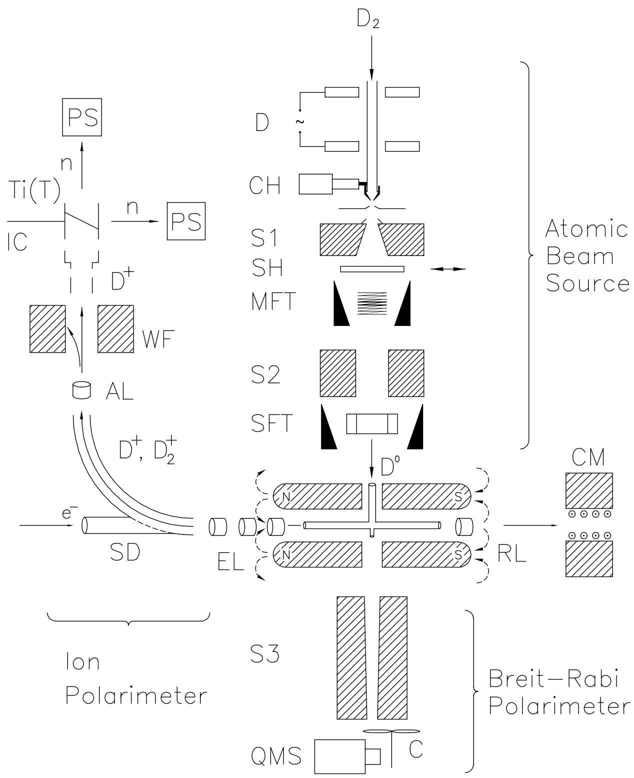

Figure 1: Schematic outline of the atomic beam source, Breit-Rabi polarimeter, internal target, and ion-extraction system. All components, except the target holding field, the neutron detectors (PS), and the correction magnets (CM), are inside the vacuum system. D: RF dissociator; CH: cold head; S1, S2, S3: sextupole magnets; MFT, SFT: medium- and strong-field transition units; SH: shutter; C: chopper; QMS: quadrupole mass spectrometer; RL: repeller lens; EL: triplet of ion-extraction lenses; SD: spherical deflector; AL: electrostatic lens; WF: Wien filter; IC: ion collector.

919-0103) is limited to about 1 mbar*l per pump. It is clear, that one wants to minimize the gas load of the target to the ring vacuum. Therefore a differential pumping system has been developed. The sections are separated by (movable) conductance limiters, which have a circular aperture through which the electron beam can pass. The positions and diameters of the conductance limiters are optimized for the boundary conditions set by the β functions of the electron beam and the ratio between ballistic and molecular flow (where the ballistic flow consists of atoms leaving the storage cell at such small angles with respect to the electron beam that they can pass the conductance limiters without a single wall collision).

Figure 2 shows the setup in the target area. Monte-Carlo studies were performed to choose the optimal solution in terms of costs and pumping speed for the target area section [5]. The target chamber is pumped by two pumping stations containing 3200 l/s turbo pumps (2200 l/s for N_2, 3200 l/s for He). The ring is separated by the target chamber by three sets of conductance limiters. The first and second differential pumping stage contain 1450 l/s and 300 l/s turbo molecular pumps, respectively. All turbo molecular pumps are backed up by a turbo drag pump to obtain a high enough compression ratio. In order to assure an oil-free vacuum, membrane roughing pumps are used. Figure 3 shows the helium pressure profile for an experiment with a flow of 4.2×10^{16} ^{3}He atoms/s. In a region of 1.5 meter the gas pressure drops by 5 orders of magnitude. Note, that the base pressure of the AmPS storage ring (without the presence of a gas target) is about 10^{-9} mbar.

Studies of the gas pressure in the ring and in the target region for different gas flows demonstrated, that the Monte Carlo code predicts the local pressure correctly within better than a factor of two.

In summary, the requirements of dense gas targets and high vacuum in the storage ring have been met by designing a three-stage differential pumping system. The system is capable to reduce the gas load of the target to the storage ring sufficiently, obtaining a decrease in pressure of five orders of magnitude in only 1.5 meter. The system has been tested in the ring and performs in accordance with the specifications.

4 REFERENCES

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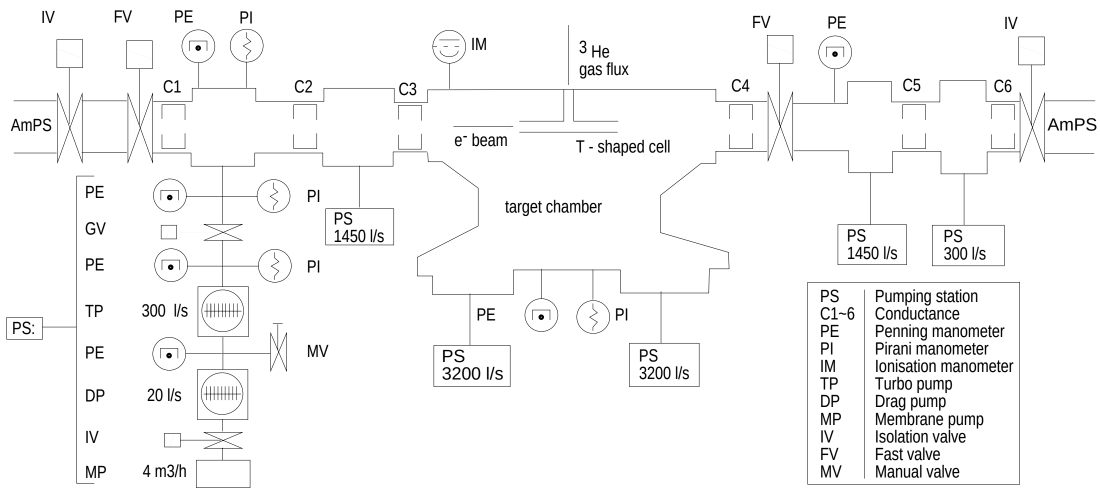

Figure 2: The differential pump system in the target area

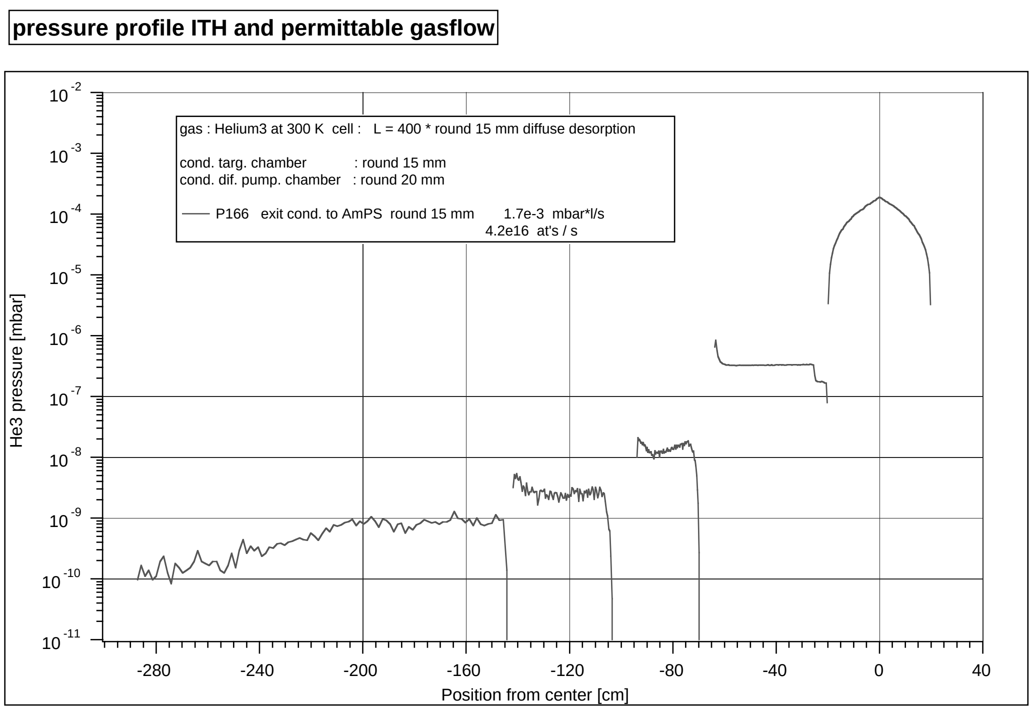

Figure 3: The pressure profile for an experiment, flowing 4.2×10^{16} atoms/s of helium gas