POLARIZED TARGETS FOR THE CLAS DETECTOR AT JEFFERSON LAB

C. D. KEITH

Thomas Jefferson National Accelerator Facility
Newport News, VA 23606, USA

On behalf of the CLAS Collaboration

The Cebaf Large Acceptance Spectrometer is utilized for a wide ranging physics program at Jefferson Lab, including measurements of polarized structure functions and future tests of the Gerasimov-Drell-Hearn sum rule. To realize the entire extent of the program, polarized targets that can function inside the spectrometer without severely affecting its performance are necessary. In these proceedings I describe a continuously polarized solid target of protons and deuterons that operated inside CLAS for a total of ten months from 1998 to 2001. The conceptual design of a frozen spin target that will more fully exploit the 4π acceptance of CLAS is also introduced.

1. Introduction

Polarized targets are invaluable instruments for investigating the spin structure of nucleons and nuclei, and a number of important measurements, performed with polarized targets, form the basis for our improved understanding of this topic. In these proceedings, I describe a polarized solid target of protons and deuterons that has been used for experiments inside the Cebaf Large Acceptance Spectrometer (CLAS) at Jefferson Lab. The next generation of polarized target for CLAS, namely a frozen-spin target that will provide even greater acceptance for scattered particles is introduced.

2. The EG1 Polarized Target

The EG1 experimental program in Hall B at Jefferson Lab has utilized polarized electron scattering from both polarized protons and polarized deuterons to measure spin observables in the nucleon resonance region. Both inclusive ($\vec{e}\vec{N} \to e'X$) and exclusive ($\vec{e}\vec{N} \to e'N'\pi$) processes were detected [1,2,3,4]. The $^{15}NH_3$ and $^{15}ND_3$ target samples were dynamically polarized by microwave-induced spin flip transitions at 1 K and 5 T.

The broad range of the EG1 program, coupled with the unique features of the CLAS detector system, placed severe demands upon the polarized target and its various subsystems. A partial list of the design requirements for this target is given below:

(1) provide a large angular acceptance for scattered particles;
(2) provide multiple target samples and allow for the rapid exchange of polarized and unpolarized (background) targets;
(3) maintain high polarization of 1-2 gram size samples in a 1-3 nA electron beam current;
(4) operate with little or no user intervention;
(5) have no detrimental effects on the performance of the CLAS detector system, while at the same time, operating inside the system.

The last item in this list was primarily a matter of geometry, and lead to a rather unusual design for the polarized target.

Traditionally, cryogenically (solid) polarized targets have been built with either a vertical or horizontal symmetry axis. The former design, in which the polarizing magnet, refrigerator, and target insert hang from a common vertical axis, allows for easy and rapid selection from more than one target sample. Unfortunately this design could not be made to fit within the horizontal, 1 m diameter bore of CLAS. On the other hand, a horizontal cryostat generally requires that data acquisition be periodically halted while one sample is removed from the cryostat and the next inserted. This process can lead to unacceptably low duty factors and increased systematic uncertainties.

The EG1 target (Fig. 1), which was constructed by a collaboration of Jefferson Lab, the University of Virginia, the INFN-Genova, and Oxford Instruments, has neither a horizontal nor a vertical symmetry axis, but rather a combination of the two. A superconducting Helmholtz magnet is suspended horizontally from the upstream end of the vacuum chamber and produces a 5 T magnetic field parallel to the beam axis. The target stick contains four different samples and is inserted through a flange at the top of the vacuum chamber. The stick can be positioned vertically in the beam path using a remotely controlled stepping motor, thus permitting the user to select between four samples ($^{15}ND_3$, carbon, $^{15}NH_3$, and empty cell). A liquid helium evaporation refrigerator is used to cool the samples. This refrigerator is installed inside the main pumping tube at an angle of 25° from the horizontal. A 3300 m^3/hr pumping system provides a cooling power of 0.8 W at 1.1 K.

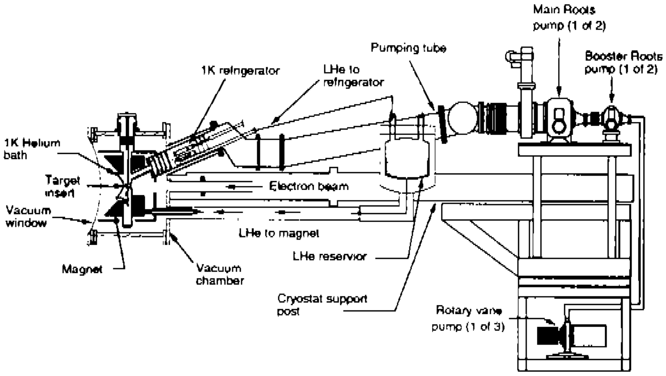

Figure 1. Side view of the EG1 polarized target. The entire apparatus is attached to a rail system and can be moved into and from CLAS in a matter of minutes.

The downstream end of the vacuum chamber is covered by a 70 cm diameter, 0.28 mm thick aluminum window with an opening angle of $\pm 50°$. Six 0.13 mm thick lateral windows on the vacuum chamber also permit the detection of particles scattered at angles $75°$–$105°$ in the azimuthal direction. A more complete description of the EG1 polarized target can be found in Ref. [5].

Maximum proton and deuteron polarizations of 96% and 46%, respectively, were achieved during a total of 10 months of data acquisition. These polarizations were measured using NMR with the standard Liverpool Q-meter arrangement [6]. In addition, proton and deuteron polarizations we extracted from known elastic scattering asymmetries. The two techniques are compared in Fig.2.

From the figure it is apparent that while the two methods initially agree, the polarization determined by the elastic scattering asymmetries decreases more rapidly than the NMR measurements as electron charge is accumulated on the target. The reason for this is clear. To eliminate scattering from the BeCu NMR coils, the coils were wrapped around the outside of the NH_3 and ND_3 samples. Thus located, the NMR measurements were most sensitive to the polarization of material nearest the sample perimeter. (The NH_3 and ND_3 samples were both 1.5 cm in diameter and 1.0 cm long.) However, the electron beam was only rastered over a 1.2 cm diameter at the center of the target, and so the NMR coils were relatively insensitive to beam-induced radiation damage which progressively lowered the target polarization. At the point indicated in the figure, this damage to the NH_3 target was repaired by annealing the sample at 80 K for 15 minutes. After this procedure, the two polarimetry methods return to temporary agree-

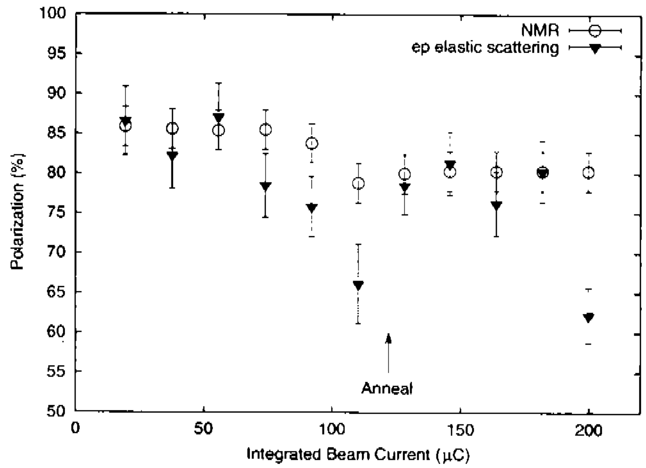

Figure 2. Comparison of the proton polarization in a NH_3 target determined using NMR and electron elastic scattering asymmetries. At the point indicated by the arrow, data acquisition was halted and the beam-induced radiation damage in the target material was repaired by annealing the material at 80 K for about 15 minutes.

ment.

During the latter half of the EG1 experiments, a second target insert was used for studies of the $^{15}NH_3$ and $^{15}ND_3$ dilution factors. This insert contained a a 1.6 cm diameter, 1.3 cm long kapton cell that was filled with solid ^{15}N. A duplicate of the carbon disk in the polarized target insert was located beneath the ^{15}N sample and was used to cross calibrate the ^{15}N and carbon backgrounds. This insert proved quite valuable. It permitted, for the first time, unambiguous extraction of ammonia's dilution factor without any need for nuclear structure corrections.

3. Frozen Spin Target

In order to fully utilize the large acceptance of the CLAS detector system, we are constructing a frozen-spin polarized target to be used in experiments with tagged photon beams [7]. The proposed target material will be 1 mm beads of frozen butanol and deuterated butanol doped with porphyrexide. The material will be dynamically polarized at 0.3 K by 70 GHz microwave irradiation inside the warm bore of a 2.5 T superconducting magnet. At the end of the polarization process, the material will be further cooled to about 0.05 K in order to increase the nuclear spin relaxation time and the polarization axis preserved by a 0.3 T holding field. This field will be generated by a thin, superconducting coil wound around a 1 K heat shield inside the target cryostat. The use of such "internal" holding coils has already been demonstrated by the Bonn Polarized Target Group [8].

The frozen spin target will be constructed as a collaborative effort between the Jefferson Lab Target Group, the University of Virginia, and the University of South Carolina. Design of the target cryostat, dilution refrigerator, and internal holding coil are currently underway.

4. Summary

The design and performance of a solid polarized target used in electron scattering experiments within the Cebaf Large Acceptance Spectrometer (CLAS) has been described. The target operated successfully inside CLAS for a total of ten months and provided proton (deuteron) polarizations in excess of 90% (40%). Discrepancies between target polarizations obtained by the traditional method of NMR and by elastic scattering asymmetries were observed and can be traced to an undersized beam spot on the target samples.

The construction of a frozen spin target that will more fully exploit the nearly 4π acceptance of CLAS is underway.

Acknowledgments

This work was supported in part by grants from the United States Department of Energy and the National Science Foundation, and by an Academic Enhancement Program grant from the University of Virginia.

References

1. JLab E91-023, Spokespersons V. D. Burkert, D. G. Crabb and R. Minehart.
2. JLab E93-009, Spokespersons S. E. Kuhn, G. E. Dodge and M. Taiuti.
3. JLab E93-036, Spokespersons M. Anghinolfi, R. Minehart and H. Weller.
4. JLab E94-003, Spokespersons P. Stoler, R. Minehart and M. Taiuti.
5. C. D. Keith *et al.* submitted to Nucl. Inst. and Meth. A.
6. G. R. Court, *et al.* Nucl. Instr. and Meth. A, **324**, 433 (1993).
7. JLab E02112 Spokespersons P. Eugenio, F. Klein and L. Todor.
8. Ch. Bradtke *et. al.* Nucl. Instr. and Meth. A, **436** (1999) 430-442.