PROCEEDINGS OF SCIENCE

Frozen Spin Target System for High Intensive Gamma-ray Source at DFELL of TUNL

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The UVa group in collaboration with the TUNL group is currently building a frozen spin target system for the high intensity gamma-ray source (HIγS) at the Duke Free Electron Laser Laboratory (HIFROST). The heart of the system is a dilution refrigerator which we rebuilt from the one originally designed by T. Niinikoski and used at CERN and subsequently at GKSS (now HGZ), Germany. The use of a polarized target together with ~100% polarized beams available at HIγS make the HIγS facility ideal for double polarization experiments. The first experiment will utilize a polarized deuteron target with the ~100% circularly polarized gamma-ray beams to measure the Drell-Hearn-Gerasimov sum rule integrand for the deuteron below pion threshold. We report the status of developing this system and describe the first experiment using HIFROST.

XVth International Workshop on Polarized Sources, Targets, and Polarimetry
September 9-13, 2013
Charlottesville, Virginia, USA

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PoS(PSTP 2013)018

1. Introduction

The High Intensity Gamma-ray Source (HIγS) is produced by the Duke Free Electron Laser Laboratory (DFELL) of Triangle Universities Nuclear Laboratory (TUNL). This facility utilizes intra-cavity-back-scattering of the FEL light in order to produce intense gamma-ray beams. Beams are nearly 100% linearly and circularly polarized [1]. This facility is ideal to study a fundamental sum rule in photodisintegration physics known as the Gerasimov-Drell-Hearn (GDH) sum rule using double polarization. The GDH sum rule is a measure of the spin response of any composite system and relates the helicity dependent photoabsorption cross section to the anomalous magnetic moment of a target. We aim to measure the GDH sum rule integrand for the deuteron below pion threshold using double polarization. With this motivation, the UVa group has been developing a frozen spin target system for HIγS in collaboration with the TUNL group. We describe the HIFROST system as well as the status of developing the system.

2. HIFROST

The HIγS Frozen-Spin-Target (HIFROST) system consists of several major subsystems: the dilution refrigerator, pumping, microwave, superconducting magnets, NMR, and polarizable materials. Preparation of HIFROST was initiated at University of Virginia (UVa) and continued at TUNL. While the cryostat/refrigerator has been extensively tested at UVa, the other subsystems and infrastructure of HIFROST were developed at HIγS.

2.1 Dilution refrigerator

The heart of HIFROST is a dilution refrigerator which we rebuilt from the one originally designed by T. Niinikoski [2] and used at CERN and subsequently at GKSS (now HZG) polarized target system, Germany [3]. Main modification was to install a new mixing chamber and new thermal sensors. After extensive tests of the refrigerator at room temperature, the refrigerator was first cooled down with ^{4}He and reached 1K at the target area. After this, a mixture of ^{3}He/^{4}He (ratio around 50/50) was circulated and with about 15% of the volume introduced, temperature in the mixing chamber was 270 mK. At this point the test was stopped because of running out of liquid ^{4}He. The temperature was measured with a calibrated Ge thermal resistor in the target area. After the test, the refrigerator was taken to HIγS.

One of infrastructures for HIFROST is a target stand which supports the dilution refrigerator on the beam line, both vertically for target changes and horizontally for operation as shown in Fig. 1. After mechanical tests of swinging the DR between positions, we pumped the refrigerator together with the pumping system at room temperature for the first time. We tested our LHe transfer line system, and cooled down the dilution refrigerator at HIγS. The initial test was cooling down the ^{4}He parts with newly installed the ^{4}He lines and temperature at evaporator reached of 1K within 2 hours.

Figure 1. A target stand supports the dilution refrigerator on the beam line both (a) vertically for target changes and (b) horizontally for operation.

2.2 Gas/liquid Control System

Some of equipment in our pumping system came from GKSS (HZG) as well. We repaired and modified to make the pumping system for HIFROST. The gas/liquid/vacuum control system consists of the ^{3}He and ^{4}He pumping system, IVC/OVC, filling/flushing gas manifolds, and the LHe transfer line. Since the space to set up experimental equipment at HIγS is limited, part of the HIFROST system is located outside a 2 feet thick wall; ^{3}He and ^{4}He pumping system.

The LHe transfer lines designed by us and fabricated by Cryofab, Inc. were installed and successfully transferred the liquid during our initial cool down. The lines use a combination of flexible parts and rigid lines with vacuum- and super-insulated technology for efficient transfer. In HIFROST, a storage dewar (500L) which is located outside the experimental setup is first filled. Then, we use the transfer line to fill a buffer dewar (100L) which is located close to the refrigerator for continuous feed of LHe to the dilution refrigerator. This line is also used to fill a polarizing superconducting magnet dewar (85L).

HIFROST has three gas storage tanks for ^{3}He, ^{4}He, and a mixture of ^{3}He and ^{4}He for experiments. For cool down to test instruments, two tanks were filled with pure helium-4 (99.97%) gas, while one tank has gas mixture. About10% of ^{3}He is in the mixture.

2.3 Superconducting magnets

HIFROST uses two superconducting magnets; the 2.5T polarizing magnet and a 0.5T holding magnet. Both magnets were tested separately. The uniformity of the polarizing magnet over a 5-cm long target area is 0.01%. The cooled polarizing magnet with LN_2 (60L) was filled with LHe, rolled around the target area, and then aligned with respect to the target as seen in Fig. 2.

2.4 Microwave system

HIFROST has two sets of microwave generating systems to produce 70 GHz in a 2.5T magnetic field for polarizing via dynamic-nuclear-polarization (DNP) technique. One option is an extended- interaction oscillator (EIO) driven by a Cober power supply, which was

Figure 2. The 2.5T polarizing magnet was filled with LHe (left), rolled the magnet assembly near to the target area (middle), and then aligned the magnet with respect to the target (right).

refurbished. The other is a Carcinotron driven by a Siemel power supply. Both generators are deionized-water-cooled. Results of testing each microwave system agreed with the test data. The EIO and Cober power supply are our main microwave system, and the other system will be used as backup.

2.5 NMR

The continuous wave NMR system is based on the Liverpool Q-meter[4]. Two coils for a small target (5cm long) are formed with 0.5mm-diameter cupro-nickle wire; one for proton polarization and the other for deuteron polarization. The coils are connected to the Q-meters by cables of length $\lambda/2$ at their resonant frequencies. The Q-meters were tested with Labview-operating DAQ. The system is planned to test with the 2.5-T polarizing magnet at 1K in near future.

2.6 Target material

Various polarizable materials (e.g., butanol) and their deuterated versions are available for HIFROST. For the initial test of the HIFROST system, we used non-irradiated CD_2. The 15g of the target beads are held in 1-mm perforated FEP housing in the quartz mixing chamber for tests. In the actual experiment, we plan to use irradiated D-butanol.

3. GDH Sum rule on deuteron

The first experiment using HIFROST will measure the GDH sum rule on the deuteron and test theoretical GDH prediction [5]. The experiment requires a circularly polarized photon beam, a polarized deuteron target, and the neutron detector array to detect neutrons from photodisintegration of deuteron. In September 2013, while the detector system was tested, we were able to study background that the target/cryostat may create. Non-irradiated CD_2 beads were placed in the target holder. We also used this opportunity to check alignment of the target with a photon beam. The target aligned with respect to the neutron detector array was imaged with a CCD camera. Alignment and the image taken are shown in Fig. 3.

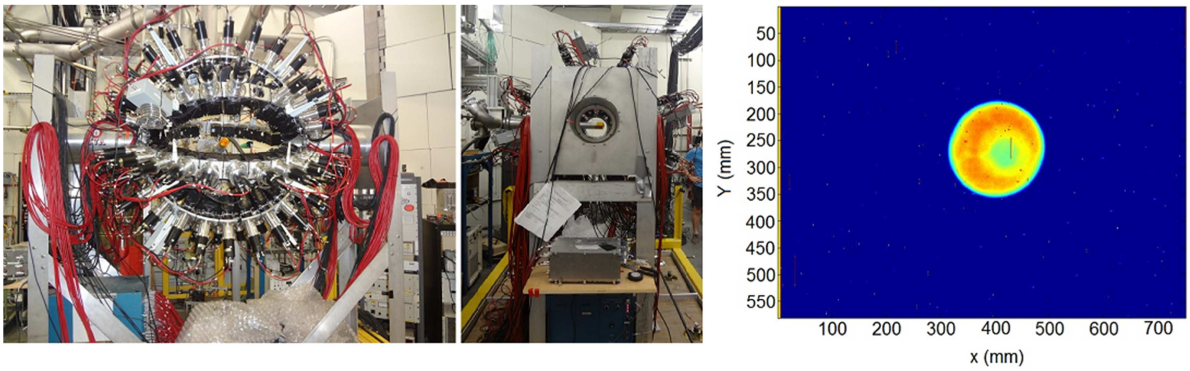

Figure 3. The dilution refrigerator was aligned with the neutron detector array. It was seen from the front (left) and from the side (middle). The target image with a photon beam is in right.

4. Summary

A new frozen polarized target system is under way at Triangle Universities Nuclear Laboratory (TUNL) at Duke University for high intensity gamma-ray beams. The status of constructing HIFROST is close to commissioning the system for the beam. In September 2013, we have tested HIFROST cryostat with a dummy target (CD_2) to study the background and beam alignment. In October 2013, we cooled down the ^{4}He line of the dilution refrigerator for the first time and temperature was reached to 1K at evaporator pot. We plan to test the system soon before commissioning it.

Acknowledgement

This work was supported by U.S. Department of Energy under grant numbers, DE-FG02-97ER41025 at UVa and DE-FG02-97ER41033 at TUNL.

References

[1] H.R. Weller et al, *Research opportunities at the upgraded HIγS facility*, Prog. Part. and Nucl. Phys. **62** (2009) 257

[2] T.O. Niinikoski, *"Frozen Spin" Polarized Target*, Nucl. Inst. And Meth. **134** (1976) 219

[3] J. Zhao et al., *The polarized target station at GKSS*, Nucl. Inst. And Meth. **356** (1995) 133

[4] G. Court et al., "Polarization measurement with Q-meter" Proc. 2nd Workshop on Polarized Target Materials (1980), 76

[5] H. Arenhövel, A. Fix, and M. Schwamb, "*Spin Asymmery and Gerasimov-Drell-Hearn Sum Rule for the deuteron*", PRL **93** (2004) 202301