Update on the g2p/gep Polarized Target

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1 Target Description

The g2p and gep experiments in Hall A will utilize a dynamically polarized ammonia (NH_3) target that has been used on three previous occasions in Hall C and likewise on three occasions at SLAC. Its last use was for the SANE experiment in Hall C in 2008 and 2009. The main components of this apparatus are:

- a 5 T superconducting, split-coil magnet. This is designed to provide a $\pm 50^\circ$ open angle for scattered particles when the field direction is parallel to the incident electron beam, and approximately $\pm 16^\circ$ when the field is perpendicular to the beam.
- a 1 K helium evaporation refrigerator with an associated pumping system of 12000 m^3 h^{-1}.
- a target "insert" which locates the target samples in the middle of the 5 T field. The insert has multiple sample cells, including two for NH_3 samples. A motorized system is used to remotely move from one cell to the next.
- a 140 GHz microwave system for dynamically polarizing the NH_3 samples.
- a continuous-wave NMR system for measuring the target polarization.
- a large, vacuum-insulated scattering chamber surrounding both the superconducting magnet and 1 K refrigerator. The scattering chamber has multiple thin windows so that experiments can be performed at a wide variety of field angles with respect to the electron beam.

A more complete description of the system is provided by Averett et al.[1]

2 Target Use during SANE

The SANE experiment was severely compromised by the poor performance of two primary subsystems of the polarized target.

The 5 T magnet quenched and suffered damage during 2008. Subsequent inspection revealed that multiple coil leads were broken near the magnet's quench protection circuits. These were hastily repaired by JLab personnel, working with an engineer from Oxford Scientific Instruments, the magnet's manufacturer. While the magnet was operated successfully after these repairs, it continued to sporadically quench throughout the remainder of the experiment, albeit

[1] T.D. Averett, et al., Nucl. Instr. Methods A **427** (1999) 440–454

without any apparent damage. While the reason for these quenches was never fully understood, they were believed to result from non-uniform stresses induced by a large, iron shielding wall located approximately 2 m away.

The 1 K refrigerator suffered a severe vacuum leak in the 4 K pot, or "separator". This leak was the result of corrosion caused by ammonia samples that were allowed to sublimate during the target's previous use. Attempts to repair the leak in a timely manner failed, and the refrigerator was replaced by a similar one used for testing purposes by the UVa target group.

3 Modifications for g2p/gep

The superconducting magnet was returned to Oxford Instruments for refurbishment. The cost for this work was paid for by the UVa Target Group, and consisted of:

- Four out of approximately 16 diodes in the magnet's quench protection circuit were replaced.
- The bolts that are used to clamp the magnet's superconducting coils in place were re-tightened. It was Oxford's opinion that the bolts had loosened over the years, resulting in the numerous quenches that took place during SANE.
- New conically-shaped endcaps for the magnet's LHe dewar were fabricated and welded in place.
- The magnet was energized to 5 T and maintained at that field for approximately 4 hours, with no quenches.

The magnet was returned to JLab on April 25, 2011. Unfortunately, the new quench protection diodes had been installed in an orientation that prevented the top of the magnet's LHe dewar from being welded back in place. The JLab Target Group re-oriented the diodes and welded the cover plate in place, with assistance from the JLab Alignment Group. (The cover plate determines the orientation of the magnet inside the target cryostat.)

A number of vacuum leaks at the top of the target cryostat were repaired. Rubber o-ring seals that were prone to freezing were replaced with all-metal, conflat flanges.

A new scheme for rotating the target on the beam line was designed and implemented. This was necessary because there was insufficient space above the target to accommodate the existing rotation scheme in Hall A. In the past, the entire cryostat (consisting of the scattering chamber, magnet, refrigerator, and insert) rotated in order to change the magnetic field orientation. The new scheme utilizes a rotatable vacuum seal between the cryostat and refrigerator, allowing both the 'fridge and insert to remain fixed on the beam line, while only the magnet and scattering chamber rotate.

A new 1 K refrigerator was constructed by the JLab Target Group. Likewise, new target inserts were fabricated.

New rotary-vane vacuum pumps were purchased to replace three pumps damaged during SANE. The control system for the pumps was overhauled by the JLab Target Group. A complete, back-up pumping set (6000 m^3 h^{-1}) has been loaned to us from ORNL/UNH.

4 Test Results prior to g2p/gep

The magnet was successfully energized in the the EEL on at least three separate occasions. During the final tests of the polarized target in August of 2011, the magnet quenched at approximately 3.7 T and was again severely damaged. The cause of this quench is unknown. Further investigations by the Target Group revealed three broken wires near or inside the superconducting coils themselves. After consultation with Oxford engineers, and based on the magnet's recent history, we decided to abandon the magnet. Instead a similar magnet, built for the Hall B polarized target, would be used in its place. This magnet, while somewhat smaller in volume, has a much better track record at JLab. It has been used on six separate occasions in Hall B and has never experienced any difficulties. The magnet has been removed from the Hall B cryostat and all modifications necessary to incorporate it into the Hall A cryostat have been completed. Minor changes have been made to the g2p/gep run plan to accommodate slight differences between the upstream geometry of the Hall B magnet and the one it replaces.

The new 1 K refrigerator was successfully tested in August. The new target inserts, as well as the pumping system were also tested. It was not possible to dynamically polarize any material due to the failure of the superconducting magnet.

5 Target Status and Installation Plans

The Hall B magnet has been installed inside the g2p/gep cryostat. It has been helium-leak tested at room temperature, and the wiring to its temperature sensors has been accomplished. Alignment between the magnet, the target insert, and the scattering chamber has been checked and deemed sufficient. Some last minute items, delayed by the magnet failure, are being fabricated now. These include new mounting brackets for the stepper motors that drive valves on the 1 K refrigerator, and carbon and CH_2 samples for the target inserts. Installation in Hall A is anticipated to begin on January 17, 2012 and is expected to last four weeks. The pumping system for the target, and most of the electronics are already in place. The 500 liter LHe buffer dewar for operating the system is installed and connected to the End Station Refrigerator.

Initial tests in Hall A obviously include energization of the magnet to 5.0 T and dynamic polarization of NH_3 material provided by our UVa collaborators.

The g2p/gep collaborations have also requested an accurate determination of the magnetic field direction. This has been performed previously for the Hall C magnet using a Hall probe inserted into the bore of the magnet using the same feed-thru as the target samples. The Hall probe is still in hand but requires minor modification for use in the new system. It will also require calibration in order to accurately determine the axis of the probe itself, and we are consulting with the JLab magnet mapping group with this in mind. This measurement could be made prior to taking beam, or at some later, convenient time.