Fast Modulation Test for Hall A Proton Parity Experiment

Richard S. Holmes

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1 Introduction

This document presents a description of plans for testing the fast beam modulation system required for a measurement of parity violation in the elastic scattering of polarized electrons from hydrogen (E91-010). Such a test is one of several planned in preparation for this experiment as described briefly in [1]. Herein we provide more details of the beam modulation system and its impact on accelerator operation.

Understanding and control of the systematic errors associated with helicity-correlated changes in beam position, angle, energy, and intensity requires that we measure changes in the measured cross section as a function of these parameters. Such measurements are best done concurrently with experimental data taking. In order to minimize sensitivity to 60 Hz noise and slow drifts, we need to modulate these beam parameters on time scales of several tens of milliseconds; the amplitude of the modulation needs to be large enough to permit accurate measurements when averaged over periods of minutes but small enough not to significantly impact the error in the cross section measurement.

Operation at such rates precludes the use of EPICS for this purpose. The beam modulation system will be implemented directly in VxWorks.

Beam position and angle will be modulated using corrector coils in the A line. In order to allow us to disentangle measurements of these parameters and energy, the coils have been positioned between the switchyard and the arc. To permit sufficient accuracy in measurement, the size of the deflection imparted by the coils should give rise to position changes on the order of 1 mm in the BPMs near the Hall A target. We note that the coils at present are powered by standard trim cards which may not offer fast enough response time for our purposes. We would like to replace these with modified trim cards, of the kind used in the accelerator feedback studies, having a voltage input to drive an offset from the set point directly, and DACs to drive them.

Modulation of the beam energy will be accomplished by varying cavities at the end of the north linac. A modulation amplitude on the order of 10^{-4} of the beam energy is appropriate.

Modulation of the beam intensity at a level of a few parts in 10^{-3} will be the subject of future tests, not described here.

Obviously, the energy modulation will affect beam to all three halls. However, the size of the modulation is comparable to or smaller than the noise in the unmodulated beam. It therefore will be visible only when integrating over millisecond time scales at subharmonics of 30 Hz, as we will do, and will have negligible effect on other experiments.

The frequency and duration of the beam modulation measurements will depend on the size of the effects we observe. For the ^{12}C parity experiment at Bates, a 15-second beam modulation sequence took place about every 45 seconds throughout data taking.

2 Control of beam modulation

The elements involved in beam modulation are under direct control of accelerator system IOCs. Close cooperation between these IOCs and the parity experiment's data acquisition system (DAQ) will be a necessary feature of the beam modulation system. At minimum, the accelerator IOCs will need to supply information on the state of the modulation elements to the DAQ, and the DAQ will need to be able to request starting and stopping of beam modulation as appropriate.

The most straightforward way to accomplish this communication is via client-server software on the accelerator IOCs and the DAQ, communicating over the network on TCP sockets. Similar methods are used in the accelerator fast feedback software, and one of the fast feedback authors, Mahesh Chowdhary, has participated in the early implementation of the modulation system.

We propose a protocol in which the modulation pattern, frequency, and amplitude originates at the DAQ system, with the accelerator IOCs being responsible for enforcing limits on the modulation to ensure safety. In this model, the DAQ would periodically transmit requests for new settings for coil and cavity values to the respective accelerator IOCs. On receipt of such a request, the IOC would inspect the requested value to verify that it falls within safety limits. If so, it would set the coil or cavity to the requested new value and send an acknowledgement back to the DAQ; otherwise it would simply respond with an error code. Such a system would allow flexibility in adapting beam modulation patterns to reflect current conditions while leaving final control of accelerator elements to the accelerator IOCs. We believe that such a system can be demonstrated not to compromise accelerator safety.

For example, the DAC used to modulate the beam energy has a range of 0 to 65,535 corresponding to ± 0.4 MeV for each cavity per pass. Thus the maximum modulation attainable for 4.45 GeV beam using a single cavity is ± 1.6 MeV, or 3.6 parts in 10^4. If required, a simple `if` statement in the IOC code before the write to the DAC can tighten this constraint, say to 1–2 parts in 10^4. This is on the order of the energy spread in the beam, but large enough for our purposes.

We note that a separate but similar system will be necessary to cancel systematic effects originating in the polarized source via a feedback loop in which the DAQ will modulate the high voltage on the helicity-flipping Pockels cell.

3 Tests to date

There have been three significant tests of beam modulation so far. The first, between August and October 1996, was a "slow modulation test" in which an EPICS script (written by Mike Tiefenback) performed modulation of energy, intensity, and position and angle. Rates were slow (time scale on the order of 1 s) and there was no communication with the DAQ, but stable operation and satisfactory beam monitor response were demonstrated.

At the end of December a similar test was done at the VxWorks level. A program written by Mahesh Chowdhary running on IOCSE7 modulated the beam energy by 1–2 parts in 10^4 at rates of 0.5–1 Hz. Chowdhary's code did not communicate with the DAQ but otherwise was similar to what we plan to use. Again, the test went smoothly and satisfactory monitor response was recorded.

Finally, a prototype client-server pair of processes communicating via TCP sockets was tested by Richard Holmes in November. This software implements a proposed beam modulation protocol of the type discussed above, in which one process requests beam element settings and the other accepts or rejects these requests based on predefined safety criteria. Both processes ran in the same VxWorks system (the DAQ crate) and of course there was no actual communication with the DACs controlling the beam elements. These processes ran overnight without incurring any observed errors.

4 Next steps

The next steps in the implementation of the beam modulation system are as follows:

- Installation of modified trim cards and DACs for at least one of the air core correctors. If tests with such a system are successful, we would want to put modified trim cards and DACs on all eight coils.

- Cabling and installation of SEE sample and hold card for one BPM in the arc (probably IPM1C12) and two BPMs upstream of the arc (e.g. IPM1C07 and IPM1C08). The new sample and hold cards designed by Tom Powers are now or will soon be available. Cables need to be run to bring the analog signals (4 per BPM) to the Hall A counting house. A bundle of 16 cables would give us 4 spares. We need to investigate whether standard BNC cables are adequeate or if shielded twisted pair cables are needed.

- Improvements to client-server software. At present the software will control only a single set of DACs from a single IOC. It needs to be modified to handle the full set of coils and energy.
- Offline tests of client-server software. Before any tests with the accelerator running, the software should be tested on the actual IOCs that will be used along with the DAQ system.
- Review of safety constraints. The procedures and limits implemented in the software need to be checked for correctness and approved.

References

[1] P. A. Souder, "Proposed Tests and Plans for Hall A Proton Parity Experiment in the Elastic Scattering of Polarized Electrons from Hydrogen (E91-010)," memo to the TJNAF PAC dated Sept. 18, 1996.