

G0 Beam Quality and Multiple Linear Regression Corrections

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Abstract. The G0 experiment measures parity-violating elastic e-p scattering asymmetries to probe the strange quark content of the nucleon. The goal is to measure the asymmetries with an overall uncertainty of 5% of the measured asymmetries which will be of order 10^{-5} to 10^{-6} . In order to achieve the above precision, systematic errors which can induce false asymmetries must be controlled. One such systematic error is helicity-correlated changes in beam parameters, which, coupled with the sensitivity of the G0 spectrometer to such beam variations, can induce false asymmetries. Beam parameters monitored for helicity-correlation are beam current, beam position, beam angle, and beam energy. A feedback loop was successfully used to reduce the helicity-correlation in beam current and beam position. The sensitivity of the G0 spectrometer to fluctuations in beam parameters has also been measured, and the false asymmetries have been determined to be of order 10^{-8} . This contribution will address the sensitivity of the G0 spectrometer to changes in beam conditions, the performance of the feedback loops as well as the resulting parity quality of the G0 beam, and the resulting false asymmetry.

PACS. 29.27.Hj Polarized beams – 13.60.-r Photon and charged-lepton interactions with hadrons – 25.30.-c Elastic electron scattering

1 Introduction

The physics process responsible for the asymmetry measured in the G0 experiment is the weak parity-violating amplitude in elastic scattering [1].

$$A = (\sigma_+ - \sigma_-)/(\sigma_+ + \sigma_-) \quad (1)$$

where $\sigma_{+/-}$ are the elastic e-p cross sections in the positive/negative helicity states of the electron beam. Thus, the measured asymmetries are susceptible to helicity-correlated fluctuations in beam conditions. These fluctuations can alter the measured cross section in a manner unrelated to the physics process we wish to probe, and consequently appear as unwanted false asymmetries. As parity-violation experiments strive to achieve greater precision in the measurements of their asymmetries, the tolerance on helicity-correlated fluctuations in beam conditions have become more stringent. However, recent developments in improving beam quality for such experiments have yielded significant results in reducing false asymmetries coming from helicity-correlated beam fluctuations. These developments, together with the standard multiple linear regression analysis techniques, have rendered such false asymmetries to be a well-controllable systematic effect [2] [3]. Although there have been many improvements made both in controlling the helicity-correlation at the

source as well as through improved beam transport, this contribution will detail the methods specifically used by the G0 collaboration to reduce these false asymmetries.

2 Parity Quality Beam

Processes which can induce helicity-correlation in the beam may include effects such as an imperfect circular polarization of the laser, helicity-correlated laser motion at the cathode, and beam loading effects in the accelerating cavities [4]. In the G0 experiment the cumulative effect from all such processes was measured, and an active feedback device was used to null out the resulting helicity-correlated differences. An IA (intensity attenuator) cell and a PZT (piezo-electric transducer) mirror were used to modulate the intensity and position of the laser at the cathode in order to null out any charge asymmetry and position differences that exist within the beam. Existing correlations between charge, position, angle and energy made is possible to reduce all 6 helicity-correlated differences simply by feeding back on the above 3 parameters, although it was not guaranteed that the energy difference would be reduced. The helicity-correlated beam parameters over the entire 700 hours of production run can be seen on Figure 1. All parity quality specifications for the G0 forward angle production run have been met.

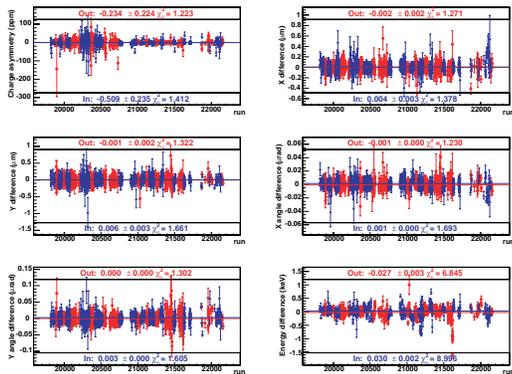


Fig. 1. The 6 helicity-correlated beam parameters (charge, x and y position, x and y angle, and energy) over the course of the entire forward angle production run. A halfwave plate was inserted every couple of days to monitor any additional systematics in the beam parameters. The plot shows the 6 beam parameters for both waveplate states over the entire run.

3 Multiple Linear Regression

In order to determine how much false asymmetry results from the helicity-correlation in the beam, the sensitivity of the G0 spectrometer to changes in beam parameters was measured. The false asymmetry resulting from the helicity-correlated parameter differences is thus, [2]

$$A_{false} = \sum_i (dY/2dP_i) * \delta P_i \quad (2)$$

where δP_i denotes the helicity-correlated differences in the six beam parameters, and dY/dP_i is the slope which characterizes the sensitivity of the spectrometer yield to fluctuations in the beam. The spectrometer is composed of 8 azimuthally symmetric octants, each with an array of 16 detectors which corresponds to different Q^2 , so the false asymmetry contribution due to position and angular motion of the beam tends to cancel out when summed over all octants. In addition to determining the slopes with the natural motion of the beam, a set of steering coils were used upstream of the target to modulate the beam by large amounts in order to gain more dynamic range in determining the sensitivity of the spectrometer to beam position and angle. The two methods have shown consistent results throughout the run. Figure 2 shows the determined sensitivity of the slopes to changes in the 6 beam parameters. As expected, the detector sensitivities show a clear octant dependence to the position and angular motions of the beam. The resulting false asymmetries coming from the 6 beam parameters and the slopes are summarized on Table 1.

4 Conclusions

The parity beam feedback system for the G0 forward angle production was successfully implemented, and all parity quality specifications have been met. The resulting false

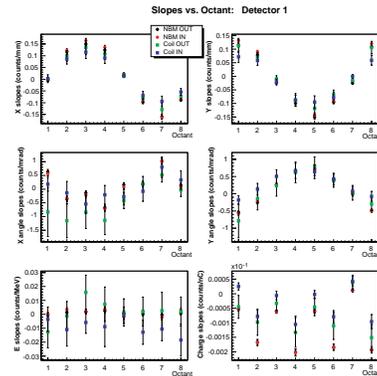


Fig. 2. Linear regression slopes determined from natural beam motion (NBM) and coil modulation show consistent results. The beam current slopes shows a large odd vs even octant dependence due to differing deadtimes from the 2 distinctly separate electronics and detectors that were used in those octants.

Table 1. The false asymmetries from the helicity-correlated differences as well as the sensitivity of the spectrometer.

Beam Parameter	Helicity correlated difference	Slopes (octant dependent)	False asymmetry
x position	6 nm	-1 to 1 %/mm	10^{-9}
y position	8 nm	-1 to 0.8 %/mm	10^{-9}
x angle	2 nrad	-6 to 8 %/mrad	10^{-8}
y angle	3 nrad	-4 to 5 %/mrad	10^{-8}
Energy	58 eV	-0.01 to 0.02 %/MeV	10^{-9}
Beam current	-0.28 ppm	$\sim 10^{-3}$ %/nC	10^{-8}

asymmetry of order 0.01ppm is considered a negligible contribution to the 5% overall uncertainty that the G0 experiment aims for in the determination of its parity-violating asymmetries.

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