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Parity Violation in Elastic Scattering from the Proton and ^{4}He

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The strangeness content of the nucleon is known to be 0.06 based on measurements of incoherent charm production by neutrinos. An important question is do these moderate number of quarks play a significant role in the properties of the nucleon, such as the electric and magnetic form factors, G_E and G_M. These quantities depend on the matrix elements $\bar{s}\gamma_\mu s$ and $\bar{s}\sigma_{\mu\upsilon}q^\upsilon$ respectively, where s is the wavefunction of the strange quarks, rather than simply momentum distributions of the quarks. Based on violations of the Ellis-Jaffe sum rule in polarized deep inelastic lepton scattering, it is known that the axial matrix element $\bar{s}\gamma_\mu\gamma_5 s$ is important for the nucleon.

Separating the roles of up, down, and strange quarks requires three independent measurements. Elastic scattering from the proton and neutron provide two. The third may be provided by exchanging the Z boson instead of a photon, either by neutrino or electron scattering. It turns out that the best way to isolate the vector form factors is to use electron scattering by measuring the parity-violating asymmetry

$$A^{pv} = (\sigma_R - \sigma_L)/(\sigma_R + \sigma_L)$$

where $\sigma_R(\sigma_L)$ is the differential cross section for the scattering of electrons with right (left) helicity. Although the projected asymmetries are small, $\sim 10^{-5}$, they are tractable. By varying the kinematics and the nucleus, one may obtain sensitivity to different form factors. Elastic scattering from hydrogen in the forward direction determines a combination of G_E^8 and G_M^8, whereas elastic scattering from hydrogen in the forward direction determines a combination of G_E^8. Here the superscript s refers to the strange quark contribution to the form factor.

The experiment will be comprised of a polarized electron source, a well-instrumented beam transport line, and the pair of Hall A spectrometers. Electrons elastically scattered from a cryogenic hydrogen or helium target will be spatially focused by the spectrometers and detected by lead-glass Čerenkov counters designed especially for this experiment. Backgrounds will be small enough so that the signals may be integrated instead of counted, simplifying data acquisition at the high rates required. Typical statistical errors will be less than 5% of the asymmetry assuming the Standard Model and negligible effects of strange quarks. Running times per kinematic point will be ~ 300 hours with 100 μA of 80% polarized beam. Systematic errors, including the measurement of the beam polarization, will be of comparable size. The effects of the strange quarks on the asymmetry could be as large as 50% or so, based on the optimistic published speculations.