Abstract

We propose a new precision measurement of parity violating electron scattering on the proton at very low Q^2 and forward angles to challenge predictions of the Standard Model and search for new physics. A unique opportunity exists to carry out the first precision measurement of the proton's weak charge, $Q_W^p = 1 - 4\sin^2\theta_W$, at JLab, building on technical advances that have been made in the laboratory's world-leading parity violation program and using the results of earlier experiments to constrain hadronic corrections. A 2200 hour measurement of the parity violating asymmetry in elastic ep scattering at $Q^2 = 0.03\ (GeV/c)^2$ employing 180 μA of 80% polarized beam on a 35 cm liquid Hydrogen target will determine the proton's weak charge with $\simeq 4\%$ combined statistical and systematic errors. The Standard Model makes a firm prediction of Q_W^p, based on the running of the weak mixing angle $\sin^2\theta_W$ from the Z^0 pole down to low energies, corresponding to a 10σ effect in our experiment. Any significant deviation of $\sin^2\theta_W$ from the Standard Model prediction at low Q^2 would be a signal of new physics, whereas agreement would place new and significant constraints on possible Standard Model extensions. In the absence of physics beyond the Standard Model, our experiment will provide a $\simeq 0.3\%$ measurement of $\sin^2\theta_W$, making this a very competitive standalone measurement of the weak mixing angle.

1 Introduction

Precision tests have traditionally played a crucial role in elucidating the structure of the electroweak interaction. Measurements to date have provided an impressive array of constraints both on the Standard Model as well as on proposed scenarios for extending it. Measurements at the Z^0 pole have constrained the weak mixing angle $\sin^2\theta_W$ to impressive precision at that energy scale. However, a precision experimental study of the evolution of the weak mixing angle to lower energies has not yet successfully been carried out. The Standard Model evolution predicts a shift of $\Delta\sin^2\theta_W = +0.007$ at low Q^2 with respect to the Z^0 pole best fit value of 0.23113 $\pm$ 0.00015 (Figure 1). This shift corresponds to a 10 standard deviation effect in our proposed measurement, including both experimental and theoretical systematic errors. Any significant deviation of $\sin^2\theta_W$ from the Standard Model prediction at low Q^2 would be a signal of new physics, whereas agreement would place new and significant constraints on possible Standard Model extensions.

It must be stressed that there is an essential complementary between high energy studies at the Z^0 pole in e^+e^- collisions and precision low energy tests, of which the proposed experiment is one. Small but perceptible deviations of a handful of low energy observables from their Standard Model predicted values are already beginning to provide new clues about the nature of physics that lies beyond. Hints of a deviation from the Standard Model evolution of $\sin^2\theta_W$ may have been seen in atomic parity violation experiments which determine the weak charges of heavy nuclei, but a significant uncertainty in the theoretical interpretation severely limits the impact of the atomic physics results. In contrast, a precision measurement of the weak charge of the proton, $Q_W^p = 1 - 4\sin^2\theta_W$, proposed here at Jefferson Laboratory, addresses the same physics issues but is free of many-body theoretical uncertainties. The dominant hadronic effects that must be accounted for in extracting Q_W^p from the data are contained in form factor