Precision Theory for Precision Measurements: Tests of Standard Model via Parity-Violating Electron-Proton and Møller Scattering

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ABSTRACT

As the experimental techniques continue to be developed and improved, they will require more precise contributions from theory. The indirect tests of the Standard Model via high-precision measurements like Q_{Weak} and 11 GeV^2 Møller scattering planned at JLab will demand a complete theoretical evaluation of the Next-to-Leading-Order and higher-order effects in electroweak interactions done at unprecedented precision. We show what kind of theoretical support our group can provide to above and other experiments with the new computational packages we have developed. Some of the key features of our approach, including our method for dealing with many-body effects in *e-p* scattering, a rigorous treatment of the Hard Photon Bremsstrahlung and asymptotic results, which provide both good code rate and accuracy, will be discussed in the paper to follow.

IMPORTANCE OF ELECTROWEAK CORRECTIONS

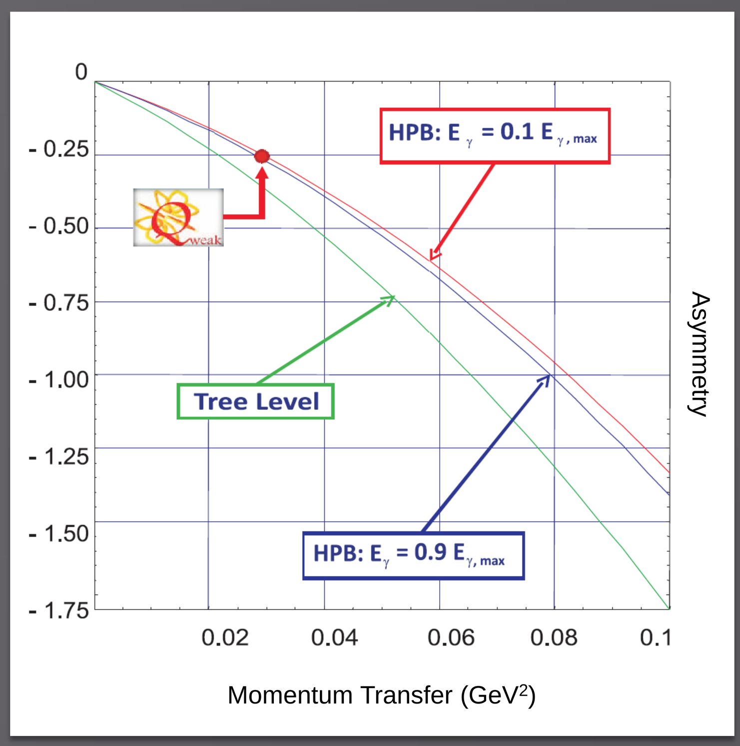
The Standard Model introduces an asymmetry between left and right-handed particles and predicts parity violating interference between the weak and electromagnetic forces. These interference effects are very small but have been clearly detected and can give us access to parameters like the weak charges of electron and nucleon. Although the evidence for new physics through the indirect tests of the Standard Model via high-precision measurements can be model-dependent, low-energy electroweak measurements are an essential compliment to the LHC program. The inclusion of radiative corrections is an indispensable part of any modern experiment, but experiments like Q_{Weak} and 11GeV^2 Møller will require the NLO electroweak radiative effects calculated with unprecedented completeness and accuracy. At certain conditions, these corrections can be very large. For example, the asymmetry measured in the E-158 kinematical region is approximately 40% less than its theoretical value calculated at the tree level. For 11GeV^2 Møller scattering, the corrections can reach up to 60%.

KEY FEATURES OF OUR APPROACH

Computer packages such as FeynArts, FormCalc, LoopTools and Form created a possibility to both handle the huge volume of work reasonably quickly and to avoid rapid error accumulation often unavoidable with purely numerical methods. One of the key features of our approach is the considerable improvement of the precision for the *e-p* radiative corrections by addressing hadronic effects. For the lepton-hadron scattering, we can do the exact calculation of the model-independent corrections to the lepton current, and do model-dependent evaluation of hadronic current corrections, box graphs, self energies contribution and electromagnetic radiation of the charged particles (soft and hard photon bremsstrahlung). For the model-independent lepton current corrections, we can potentially consider RC up to the second, Next-to-Next-to-Leading-Order (NNLO).

PREDICTIONS FOR QWEAK EXPERIMENT

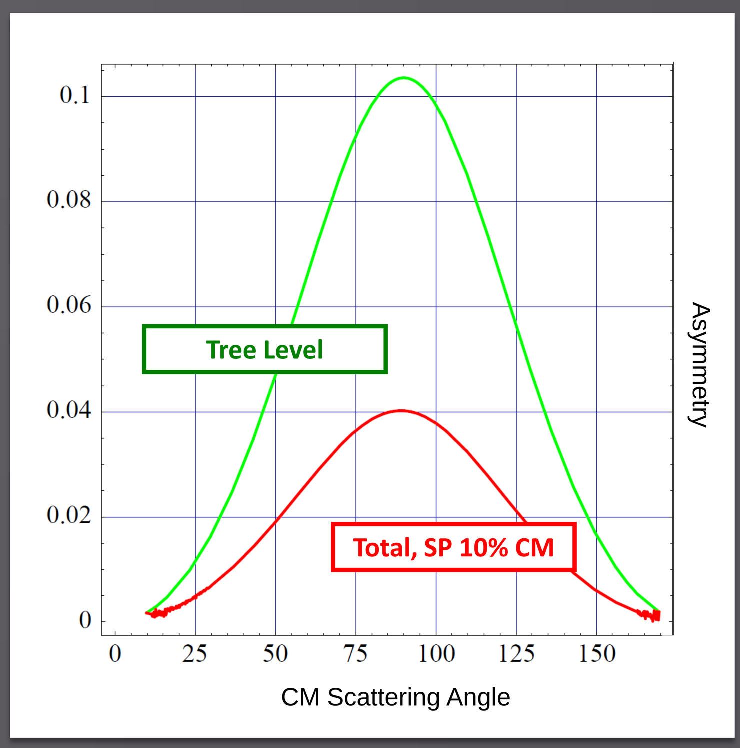
For the Q_{Weak} experiment, our calculations are done in the on-shell renormalization scheme using Feynman gauge. Here, we include the Dirac and Pauli form factor type of coupling in the boson-nucleon interaction using the multipole expansion up to the second order (dipole).



For more details, please see "Computational Model for Electron-Nucleon Scattering and Weak Charge of the Nucleon", Aleksejevs, Barkanova, Blunden, 2009.

PREDICTIONS FOR 11GEV MØLLER EXPERIMENT

The complexity of the problem and the current demand for precision requires the tuned comparison between theory groups using different schemes. We compare the results by Aleksejevs + Barkanova (on-shell renormalisation scheme by Denner) with the results by Ilyichev + Zykunov (on-shell renormalisation scheme by Hollik) and find them almost identical.



(The maximum energy for the soft-photon bremsstrahlung is taken as 10% of the CM energy.)

For more details, please see "Electroweak Corrections for Polarized 11GeV^2 Møller Scattering", Aleksejevs, Barkanova, Ilyichev, Zykunov, 2010.

PUBLIC RELEASE OF THE SOFTWARE

There are many packages developed for high-energy physics, but the low-energy sector is not served nearly as well. The partially computerized procedure developed by our group allows calculating large number of Feynman diagrams at different momentum transfers as well as performing an extensive analysis of the dependence on poorly constrained parameters to evaluate realistic uncertainties. Not only have we included all the possible contributions arising from the Standard Model degrees of freedom, but made much progress towards accounting for the hadronic degrees of freedom. Our computational models can be used for a wide range of applications and serve a much larger community. At the moment, our software is not very "user-friendly", but we are working towards making it ready for a public release.