Comment on "High-Precision Determination of the Electric and Magnetic Form Factors of the Proton"

In a recent Letter, Bernauer *et al.* [1] present fits to the proton electromagnetic form factors $G_E(Q^2)$ and $G_M(Q^2)$, along with extracted proton charge and magnetization radii based on large set of new, high statistical precision ($< 0.2\%$) cross section measurements. The Coulomb corrections (CC) they apply [2] differ dramatically from more modern and complete calculations, implying a significant error in their final results.

It has been shown that two-photon exchange (TPE) corrections are important in the extraction of the form factors [3] and the charge radius [4] of the proton. At low Q^2, the Coulomb correction (representing the soft part of the TPE) yields the dominant contribution and has a significant Q^2 dependence at very low Q^2 [5–7]. In the analysis of Ref. [1], the applied correction [2,8] is the $Q^2 \to 0$ limit of the full calculation:

$$\delta_{CC} = Z\alpha\pi[\sin(\theta/2) - \sin^2(\theta/2)]/\cos^2(\theta/2). \quad (1)$$

Figure 1 shows the CC applied in Ref. [1] along with the full Q^2-dependent result [5]. The full correction is outside of the 50% uncertainty assumed in Ref. [1] for all data above $Q^2 = 0.06\ \mathrm{GeV}^2$. By 0.1 GeV^2, the small-ε correction has changed by 1% which will modify G_M and its Q^2 dependence, altering the extracted magnetic radius. The full δ_{CC} is 2%–3% lower for $Q^2 > 0.3\ \mathrm{GeV}^2$ and low ε: a change several times the total uncertainties on the individual cross sections (which do not include any systematic uncertainties, although all kinematic settings have inflated statistical errors to account for nonstatistical deviations from the global fit [8]). The fits include estimates of systematics and theoretical (TPE) uncertainties which are essentially negligible at small scattering angles and at most ~0.5% at large angles [8], still much smaller than the error in δ_{CC}.

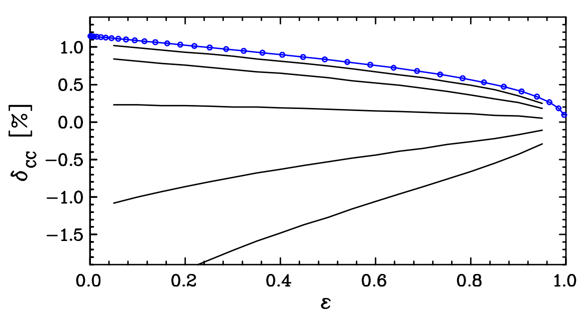

FIG. 1 (color online). The Coulomb correction from Ref. [2] (circles), evaluated at the mean Q^2 of the experiment, and the full CC result [5] for $Q^2 = 0.01$ (top), 0.03, 0.1, 0.3, and 1.0 GeV^2 (bottom). TPE calculations [6,7] yield similar results, with a somewhat weaker Q^2 dependence at low Q^2.

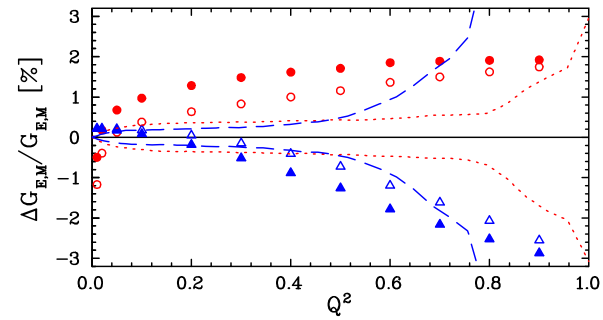

FIG. 2 (color online). Estimated change in G_M (red circles) and G_E (blue triangles). The points show the impact of replacing the CC of Ref. [1] with the full CC [5] (solid symbols) or TPE calculation [7] (hollow symbols), using dipole form factors and assuming that the cross section data cover $0.3 < \varepsilon < 0.9$. The dotted (dashed) lines show the fit uncertainties on G_M (G_E) [1].

Figure 2 shows the estimated impact of the full CC or TPE calculations on a direct Rosenbluth separation of the form factors. This suggests that proper implementation of the corrections will shift the G_M results by more than 2–3 standard deviations, bringing the ratio $\mu_p G_E/G_M$ into better agreement with recent high-precision polarization measurements [9].

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