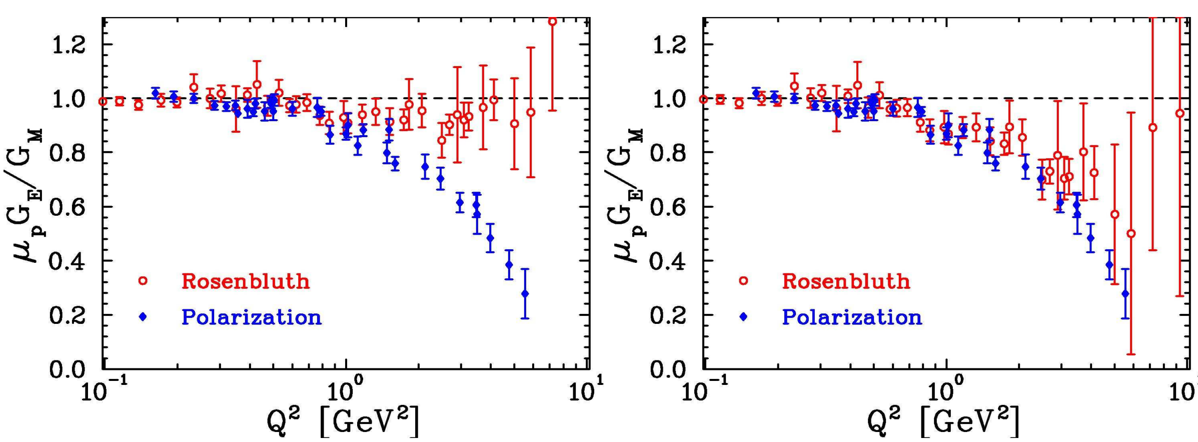
Improved Understanding of the Proton Form Factors: In 1955, elastic electron-proton scattering was used to make the first measurement of the size of the proton. For over forty years, unpolarized e-p scattering was the preferred method used to extract the proton form factors, G_E and G_M, which provide the most direct information on the spatial distribution of electric charge and magnetization in the proton. Low energy (low Q^2) data yield the overall size, and high Q^2 data probe the detailed structure. Recent Jefferson Lab measurements aimed at improving these so-called "Rosenbluth" extractions at high Q^2 used polarization transfer to extract G_E/G_M. They yielded the unexpected result that the electric and magnetic distributions were very different, contradicting the previous results. To examine this discrepancy, we used a new "Super-Rosenbluth" technique to extract G_E/G_M with unprecedented precision. We demonstrated a fundamental difference between the two techniques when interpreted in the standard picture where the scattering is mediated by the exchange of a single photon. This suggested that the exchange of a second photon, two-photon exchange (TPE) contributions, explain the difference. These TPE corrections had been believed to be very small, but if larger than expected, could affect many electron scattering experiments, making a quantitative understanding of TPE crucial.

In 2007, we ran a new Super-Rosenbluth measurement, JLab E05-017, to precisely map out TPE, especially at higher Q^2. In addition, our new analysis of world's data (including positron-proton scattering) demonstrated that recent TPE calculations resolve the discrepancy, fully explaining the data up to Q^2=2-3 GeV^2. Our global reanalysis, corrected for TPE, yields the most precise extraction of the proton form factors. While the TPE corrections decrease G_E/G_M at high Q^2, they increase the ratio at very low Q^2, removing the small deviation between G_E and G_M observed in previous analyses. We used these updated form factors and the TPE calculations to make improved predictions for the parity-violating asymmetry, needed to isolate the contribution of the strange quarks to the form factors. These new results also provide better input for corrections to ultra-precise atomic physics measurements of the hyperfine splitting in the hydrogen ground state (measured to 13 places), and in the comparison of hydrogen and muonium.



Ratio of the electric to magnetic form factors from Rosenbluth and polarization measurements, neglecting TPE (left figure), and including TPE corrections (right figure).

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