Proton rms-radii from electron scattering

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The rms-radii (charge and magnetic) of the proton are in general determined by parameterizing the Sachs form factors $G_{e,m}(q)$, with the parameters fitted to the cross sections and polarization transfer data measured in electron-proton (e-p) scattering. The slope of $G(q^2)$ at $q = 0$ yields the radii. The charge rms-radius determined recently from the Lamb shift in muonic Hydrogen [1] disagrees by many standard deviations with the one from both e-p scattering [2] and transition energies in electronic Hydrogen [3]. This has led, among other studies, to a renewed scrutiny concerning the determination of radii from e-p scattering.

The main problem: while the e-p data are sensitive to the proton finite size and radii at momentum transfers $0.6 < q < 1.2\text{fm}^{-1}$ [4], the determination of the rms-radius via the slope of $G(q^2)$ at $q = 0$ involves a substantial extrapolation. This extrapolation is particularly difficult for the proton. The $\pm$ exponential tail of the proton density falls very slowly with increasing radius r; the density at radii outside 3 times the rms-radius, for instance, still contributes $\sim 2\%$ of the rms-radius. This large-r density is poorly determined by the e-p data but affects the shape of $G(q^2)$ below the minimal q_{min} of the data of typically 0.5fm^{-1}.

Starting from several recently published analyses of e-p data [5, 6, 7] we show that the standard approach of parameterizing $G(q)$ can produce unreliable — and occasionally totally unreasonable — results. We identify the main cause: the fact that the parameterizations of $G(q)$ do *not* respect the *physical* condition that the corresponding $\rho(r)$ is =0 outside some radius R_{cut} or that $\rho(r)$ has to fall-off $\pm$ exponentially at large r. The uncontrolled behavior of $G(q > q_{max})$ can cause the corresponding densities to have tails extending to very large radii, which in turn falsifies the extracted rms-radii.

We describe an approach that avoids the above pitfalls and leads to more trustworthy radii. We apply this approach to determine the proton rms-radii from the *world* data on e-p scattering.

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