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New insights into the nucleon form factor and proton radius from dispersive analysis

We present a combined analysis of the electromagnetic form factors of the nucleon in the space- and timelike regions using dispersion theory. Our framework provides a consistent description of the experimental data over the full range of momentum transfer, in line with the strictures from analyticity and unitarity. The statistical uncertainties of the extracted form factors are estimated using the bootstrap method, while systematic errors are determined from variations of the spectral functions. We also perform a high-precision extraction of the nucleon radii and find good agreement with previous analyses of spacelike data alone. For the proton charge radius, we find

$r_E^p = 0.840^{+0.003\,+0.002}_{-0.002\,-0.002}$ fm,

where the first error is statistical and the second one is systematic. The Zemach radius and third moment are in agreement with Lamb shift measurements and hyperfine splittings. The combined data set of space- and timelike data disfavors a zero crossing of $\mu_p G_E^p/G_M^p$ in the spacelike region. Finally, we discuss the status and perspectives of modulus and phase of the form factors in the timelike region in the context of future experiments as well as the onset of perturbative QCD.

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