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The nucleon's generalized form factors and Mellin moments up to fourth order

The Mellin moments can be used to construct parton distribution functions that are essential for phenomenology. Since they are non-perturbative quantities, they are challenging to compute. Lattice QCD provides the frame to compute generalized form factors (GFFs) providing these moments and unveil the polynomiality structure of generalized parton distributions. In this work, we present the first lattice calculation of the nucleon GFFs up to fourth order using simulations at physical pion mass. While earlier studies were limited to second order for the nucleon or to higher orders for mesons, our calculation extends the landscape of proton structure observables to third- and fourth-order GFFs. The computation is performed using one ensemble at the physical point and employs boosted frames with nonzero sink momentum to access the higher-order contributions. From the resulting GFFs we extract the forward-limit Mellin moments $\langle x^n \rangle$, providing new input for global analyses and phenomenology. These results establish benchmarks for future lattice studies and expand the understanding of the partonic structure of the proton.

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