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The Unpolarized Proton PDF at NNLO from Lattice QCD with Physical Quark Masses

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We present a lattice QCD calculation of the unpolarized isovector quark parton distribution function (PDF) of the proton utilizing a perturbative matching at next-to-next-leading-order (NNLO). The calculations are carried out using a single ensemble of gauge configurations generated with N_f = 2+1 highly improved staggered quarks with physical masses and a lattice spacing of a =0.076 fm. We use one iteration of hypercubic smearing on these gauge configurations, and the resulting smeared configurations are then used for all aspects of the subsequent calculation. For the valence quarks, we use the Wilson-clover action with physical quark masses. We consider several methods for extracting information on the PDF. We first extract the lowest four Mellin moments using the leading-twist operator product expansion approximation. Then, we determine the x dependence of the PDF through a deep neural network within the pseudo-PDF approach and additionally through the framework of large-momentum effective theory utilizing a hybrid renormalization scheme. This is the first application of the NNLO matching coefficients for the nucleon directly at the physical point.

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Primary author: Dr HOLLIGAN, Jack (University of Maryland)

Presenter: Dr HOLLIGAN, Jack (University of Maryland)

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