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Nucleon Unpolarized PDFs at the Physical Point in the Coulomb Gauge

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We present the first Coulomb-gauge calculation of the nucleon unpolarized parton distribution functions (PDFs) at the physical pion mass. Both the isovector and connected isoscalar channels are computed within the large-momentum effective theory (LaMET) framework on a $2 + 1$ flavor ensemble with lattice spacing $a = 0.076$ fm. By employing kinematically enhanced interpolating operators, we successfully reach nucleon boosts up to $P_z = 2.29$ GeV. The light-cone PDFs are extracted by applying next-to-leading-order (NLO) perturbative matching combined with next-to-leading-logarithmic (NLL) renormalization-group resummation (RGR) and exhibit good convergence between $P_z = 1.78$ and 2.29 GeV. The real and imaginary parts of the matrix elements provide access to the valence $q - \bar{q}$ and full $q + \bar{q}$ combinations, respectively, from which we reconstruct the quark and antiquark distributions over the entire kinematic range $x \in [-1, 1]$. The isovector antiquark distribution exhibits a positive $\bar{d} - \bar{u}$ signal consistent with the Gottfried sum rule violation. For the connected isoscalar channel, the RGR substantially mitigates the unphysical excursions of the fixed-order result in the antiquark region, with the residual deviation from NNPDF4.0 expected to arise mainly from the disconnected diagrams not included in this study. Within the reliable moderate window of $0.25 < |x| < 0.65$, our reconstructed NLO+NLL distributions exhibit good agreement with the NNPDF4.0 global analysis.

Primary author: SHI, Qi (Kent State University)

Co-authors: GAO, Xiang (BNL); HANLON, Andrew (Kent State University); HE, Jinchun (University of Maryland); JIANG, Xiangyu (Indiana University); MUKHERJEE, Swagato (Brookhaven National Laboratory); PETREKZKY, Peter (Brookhaven National Laboratory); ZHAO, Yong (Argonne National Laboratory)

Presenter: SHI, Qi (Kent State University)

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