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Quark orbital angular momentum in the proton evaluated using a direct derivative method

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Quark orbital angular momentum (OAM) in the proton can be calculated directly given a Wigner function encoding the simultaneous distribution of quark transverse positions and momenta. This distribution can be accessed via proton matrix elements of a quark bilocal operator (the separation in which is Fourier conjugate to the quark momentum) featuring a momentum transfer (which is Fourier conjugate to the quark position). To generate the weighting by quark transverse position needed to calculate OAM, a derivative with respect to momentum transfer is consequently required. This derivative is evaluated using a direct derivative method, i.e., a method in which the momentum derivative of a correlator is directly sampled in the lattice calculation, as opposed to extracting it a posteriori from the numerical correlator data. The method removes the bias stemming from estimating the derivative a posteriori that was seen to afflict a previous exploratory calculation. Data for Ji OAM generated on a clover ensemble at pion mass $m_\pi = 317\,\mathrm{MeV}$ are seen to agree with the result obtained via the traditional Ji sum rule method. By varying the gauge connection in the quark bilocal operator, also Jaffe-Manohar OAM is extracted, and seen to be enhanced significantly compared to Ji OAM.

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