Contribution ID: **46** Type: **Parallel Sessions**

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

Tuesday, 11 September 2018 15:45 (25 minutes)

Quark orbital angular momentum (OAM) in the proton can be calculated directly if a Wigner function encoding the simultaneous distribution of quark transverse positions and momenta is given. 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). Consequently, to generate the weighting by quark transverse position needed to calculate OAM, a derivative with respect to momentum transfer is required. A Lattice QCD calculation is presented in which 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 317 MeV pion mass 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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Session Classification: 3D Structure of the Nucleon: TMDs

Track Classification: 3D Structure of the Nucleon: TMDs