Contribution ID: **130** Type: **Oral**

Nucleon Structure from Basis Light-Front Quantization : Status and Prospects

We report recent advancements in understanding nucleon structure within the Basis Light-Front Quantization (BLFQ) framework—a fully relativistic, nonperturbative approach to solving quantum field theories. Starting with the leading Fock sector $|qqq\rangle$ and an effective light-front Hamiltonian incorporating confinement and one-gluon exchange, BLFQ has successfully described key nucleon observables. The framework has since been extended to include the next-to-leading Fock sector $|qqqg\rangle$, enabling studies of gluonic contributions to the nucleon's internal structure, including gluon helicity, orbital angular momentum, and three-dimensional imaging through GPDs and TMDs. Most recently, BLFQ has achieved a significant milestone by computing nucleon light-front wavefunctions as eigenstates of the QCD Hamiltonian without an explicit confining potential. These calculations, including Fock sectors up to $|qqqq\bar{q}\rangle$, allow towards first-principles predictions of quark and gluon matter densities, helicity and transversity distributions, and spin observables, showing qualitative agreement with experimental and phenomenological results. Together, these developments highlight BLFQ ' s growing capacity to provide an increasingly complete and realistic picture of nucleon structure grounded in QCD.

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Session Classification: Parallel

Track Classification: Three-dimensional structure of the nucleon: generalized parton distributions and form factors