Modeling nonperturbative structure of the pion

Research project objectives/Research hypothesis

Our main goals are to explore and understand recent lattice QCD data concerning two-current correlations and double parton distributions of the pion in terms of simple theoretical models.

1. Analysis of current correlators in the pion within chiral quark models and in the meson dominance approach. Recently, new and very interesting lattice QCD results for the properties of the pion were released by the Regensburg collaboration. They open a new scope of investigations, providing for first time an *ab initio* view on a class of hadronic four-point functions. We plan to evaluate two-current correlations in the pion, using two basic and complementary approaches: i) chiral quark models, and ii) the meson dominance/Regge models. The results will be compared to the lattice simulations in a detailed manner, including all possible channels and varying pion mass.

2. Evaluation of double parton distributions of the pion in chiral quark models. The issue of dPDFs (of the nucleon) has recently received a lot of attention due to potential relevance for the double parton scattering at the LHC. We plan to carry out a model evaluation of the pion dPDFs and their Mellin moments, and compare the results to the present and future lattice data, as well as test the factorization approximation into the product of single parton distributions.

3. Evaluation of the partonic Wigner distribution of the pion in chiral quark models. The Wigner distributions of the pion have recently acquired a lot of theoretical attention, as other theoretical quantities, such as the generalized parton distribution, the transverse-momentum distributions, the angular momentum decomposition, etc., may all be derived from them. We plan to evaluate the Wigner and the related Husimi distributions, applying our models and methods. The model results will be analytic, which will shed light on the involved theoretical issues, underlying their physical features.

Parton-hadron duality in large-N_c Regge models. Finally, we wish to explore the parton-hadron duality realized within the Regge approach. These models invoke infinitely many hadronic intermediate states (resonances) in the evaluation of matrix elements of correlators. We wish to determine whether in the high-energy limit the partonic substructure could actually be described solely in terms of infinitely many colorless resonances.

Research project methodology

The calculation in chiral quark models in the large-N_c limit amounts to evaluating one-loop diagrams, where due to the spontaneous chiral symmetry breaking, the quarks are massive. A suitable regularization, introducing the high-energy cut-off, will be used. In our study we will use the Nambu–Jona-Lasinio model with Pauli-Villars or the proper-time regularization, and the Spectral Quark Model, as these schemes preserve the necessary Lorentz and gauge invariance. Another key element is the QCD evolution, which is necessary to elevate the model results from the low-energy quark-model energy scale to experimental or lattice.

The complementary meson-dominance approach to the soft-matrix elements follows from the concepts, where the currents of given quantum numbers are saturated with a few lowest meson states, and intermediate states are modeled with the Regge approach.

Expected impact of the research project on the development of science

Since the lattice simulations incorporate *all* aspects of QCD in a numerical fashion, they cannot give us any clear hint what leading physical mechanisms are responsible for specific properties of the observables in question. In contrast, effective models, which incorporate only certain but crucial aspects of QCD, provide us with an intuitive insight of the underlying physics.

By carrying out the proposed tasks, which have not been carried out nor even considered previously, we are hoping to get more valuable and simple understanding of these difficult nonperturbative aspects of the dynamics of strong interactions, and to provide explanations and further outreach to the lattice-QCD community.