Transverse Momentum Broadening of High-Energy Partons From 3D Lattice EQCD Simulations

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2018 - 2019

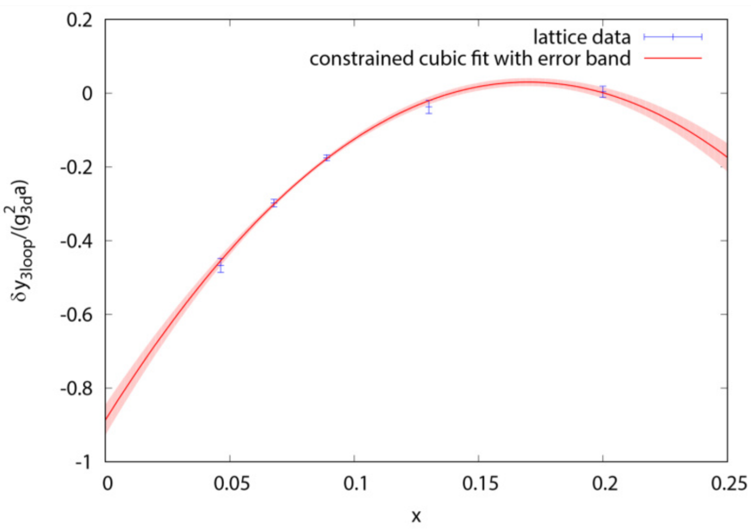
Project Areas
Particles, Nuclei and Fields

Clusters
Lichtenberg Cluster Darmstadt

Additional Software
Own code based on lattice QCD

Institute
Institut für Kernphysik

University
Technische Universität Darmstadt



Introduction

Quantum Chromodynamics (QCD) is the theory of the strong nuclear force. Analogously to the theory of the electromagnetic force, objects can be colour-charged, i.e. they interact via the strong force. In particle collisions, when high-energy strongly-interacting objects are created, they manifest as so-called jets. These jets propagate through the surrounding medium of other products of the collision. While doing so, they scatter in the medium, leading to radiation and changing the structure of the jet. Despite the substantial progress in the field of high-temperature QCD in the last years, the medium modification of jets still remains a puzzle. The dominant contribution to this effect is conjectured to originate from particles in the medium with small momenta. This makes the setup unaccessible for analytical perturbation theory methods. Furthermore, jet broadening is a real-time effect. Consequently, the path integral that describes the system suffers from a severe sign problem. This obstacle can be mostly overcome by the technique of “Euclideanization”, proposed in 2010 by Simon Caron-Huot. Applying Euclideanization, a three dimensional effective theory is left, which can be evaluated on a space-time lattice.

Methods

The resulting effective lattice field theory, lattice EQCD, can be efficiently simulated by Monte Carlo-simulations. This requires for instance advanced methods of pseudo-random number generation and vecorized matrix calculus using “AVX2”. Furthermore, simulations are done at various lattice spacings a and extrapolated to continuum in the end, i.e. the limit $a \to 0$ is taken. This requires generating data at multiple parameter sets and at high precision in order to make a valid statement in the continuum-extrapolated case. The generation of the required data is very involved and exceeds the computational resources at the institute by far.

Results

The authors numerically performed an O(a)-improvement. That is, they determined the linear-in-a behavior of systems known to be at the same physical point. The phase transition of EQCD served as this point of constant physical behavior. Having eliminated the last persisting O(a)-error in the lattice-continuum matching, extrapolations to the continuum do not feature a O(a)-term any more,i.e. the extrapolation tocontinuum has been drastically facilitated. Furthermore, a continuum-extrapolated version of the phase diagram of EQCD was provided, nailing down the conjectured phase structure in [2]. Additional information about the nature of the phase transition has been provided.

Discussion

With the finite lattice spacing introducing a leading quadratic error only, larger lattice spacings already give a close-to-continuum result. Therefore, smaller lattice spacings, which in general feature better statistical errors, are already closer to the continuum. That opens the possibility of extracting high-precission, continuum-extrapolated data for the original objects of interest, the transverse collision kernel $C(b_\perp)$ and the jet-broadening coefficient, via their Wilson loop definition in [3]. A promising first attempt has already been made in [4]. However, this publication did not contain a continuum limit since the improvement program the authors of the present report completed in [1] was not known at that time. For this encounter, we applied for another period of computational resources at the Lichtenberg high-performance computing center of the TU Darmstadt.

Figures

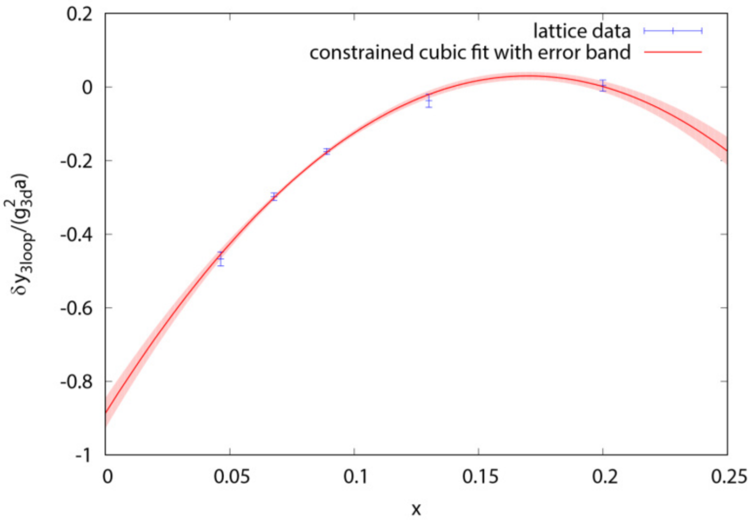


Figure 1:Grand fit of O(a)-correction at different scalar self-couplings x.

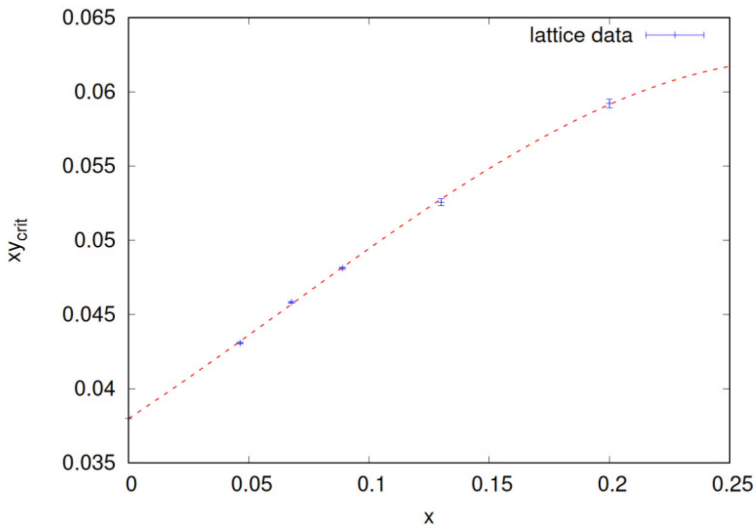


Figure 2: Continuum-extrapolated phase diagram of electrostatic QCD.

Publications

Moore, G.D.; Schlusser, N.: Full O(a) improvement in electrostatic EQCD, Technical University of Darmstadt, 2019.
https://arxiv.org/abs/1905.09708

Moore, G.D.; Schlusser, N.: FullO(a)-improvement of EQCD, Poster presented at the 37th International Symposium on Lattice Field Theory, China, July 16-22 2019.
https://indico.cern.ch/event/764552/contributions/3420435/attachments/1863176/3062780/Schlusser_lattice_2019.pdf

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[2] Kajantie, K.; Laine M.; Rajantie, A.; Rummukainen, K.; Tsypin, M.: The Phase diagram of three-dimensional SU(3) + adjoint Higgs theory, JHEP, 11:011, 1998. https://doi.org/10.1088/1126-6708/1998/11/011

[3] Caron-Huot, S.: O(g) plasma effects in jet quenching, Phys. Rev., D79:065039, 2009. https://doi.org/10.1103/PhysRevD.79.065039

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[5] Simulation program for lattice QCD
http://luscher.web.cern.ch/luscher/openQCD/index.html

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