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Towards low-dimensionalization of four dimensional QCD

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In four-dimensional (4D) QCD, quark confinement is characterized by one-dimensional color-electric flux-tube formation, which leads to a linear interquark potential. The flux-tube formation implies a possibility of low-dimensionalization of 4D QCD. We propose a new gauge fixing of "dimensional reduction (DR) gauge" defined so as to minimize
$R_{\rm DR} \equiv \int d^4s \, {\rm Tr} \left[A_x^2(s) + A_y^2(s)\right]$.

In the DR gauge, there remains a residual gauge symmetry for the gauge function $\Omega(t,z)$ like 2D QCD on the tz-plane. We define the "tz-projection" as removal of $A_{x,y}(s) \to 0$. After the tz-projection in the DR gauge, 4D QCD is regarded as an ensemble of 2D QCD-like systems on the tz-plane, which are piled in the x and y directions and interact with neighboring planes.

We also formulate the DR gauge and the tz-projection on lattice, and investigate low-dimensionalization in SU(3) lattice QCD at $\beta = 6.0$. We find that the amplitude of two components $A_x(s)$ and $A_y(s)$ are strongly suppressed in the DR gauge. In the DR gauge, the interquark potential is not changed by the tz-projection, and the two components $A_t(s)$ and $A_z(s)$ play a dominant role in quark confinement.

We calculate a spatial correlation $\langle {\rm Tr} A_\perp(s) A_\perp(s + r a_\perp) \rangle$ ($\perp = x, y$) and estimate the spatial mass of $A_\perp(s)$ ($\perp = x, y$) as $M \simeq 1.7$ GeV in the DR gauge. It is conjectured that this large mass makes $A_\perp(s)$ inactive in the infrared region, which realizes the dominance of $A_t(s)$ and $A_z(s)$ in the DR gauge.

We also calculate spatial correlation of two temporal link-variables, and find that the correlation decreases as $\exp(-mr)$ with $m \simeq 0.6$ GeV, which corresponds to the correlation length $\xi \equiv 1/m \simeq 0.3$ fm. Using a rough approximation, 4D QCD is found to be regarded as an ensemble of 2D QCD systems with the coupling of $g_{\rm 2D} = gm$.

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