Long-range behavior of QCD color-dependent forces

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Nonperturbative study of color QCD forces between static quarks is important for understanding quark confinement and hadron phenomenology. The behavior of a heavy-quark potential that is defined by the closed gauge-invariant Wilson loop, has been studied extensively in lattice simulations; the heavy-quark potential is a linearly rising potential, which can be explained with the Coulomb term and the linear term with the string tension. In most previous studies of heavy-quark potentials, a color singlet channel, which yields a physical potential, has been investigated. There are, however, several other color channels between two quarks. According to the $SU(3)$ color decomposition for a quark-antiquark sector $q\bar{q}$, $3 \otimes \bar{3} = 1 \oplus 8$. The octet channel is significant for the extensive analysis of J/ψ photoproduction. Furthermore, we have $3 \otimes 3 = \bar{3} \oplus 6$ for a quark-quark sector qq, and in particular, the antisymmetric qq channel plays an essential role in the phenomenology of penta-quark hadrons [1, 2], in which the existence of a highly correlated diquark is assumed [2]. Since the usual Wilson loop cannot give the color-decomposed potentials separately, the lattice study along this line was considered as very difficult.

Numerical results of the color decomposed potentials are displayed in Fig. 1. It is shown that the antisymmetric qq channel behaves as a linearly rising potential for large quark separations. We further find that the $q\bar{q}$ octet and qq symmetric channels have the complex dependence on the distance; at short distances they are repulsive forces, while at large distances, they show linearly rising feature. Ratio of string tensions between $q\bar{q}$ singlet and qq antisymmetric potentials for large quark separations is described in terms of the Casimir factor.

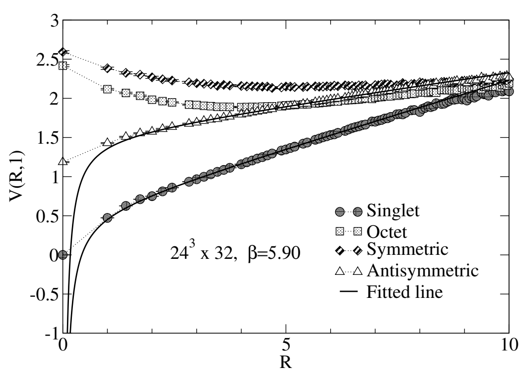

Figure 1: Singlet and octet potentials for $q\bar{q}$ and symmetric and antisymmetric potentials for qq.

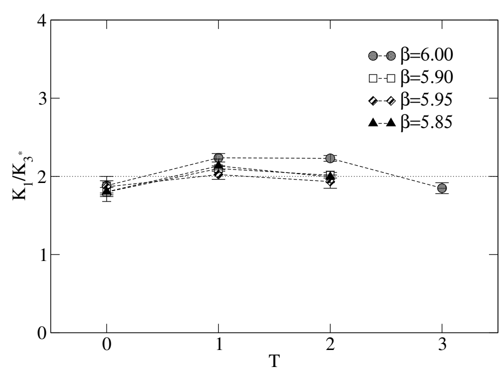

Figure 2: Ratios of string tensions in the singlet and antisymmetric channels.

The simulations were performed on SX-5(NEC) vector-parallel computer at the RCNP of Osaka University.

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