Study of the relation between confinement and chiral symmetry breaking in a gauge-invariant Dirac-mode expansion method

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Flash talk

Workshop on New-type of Fermions on the Lattice

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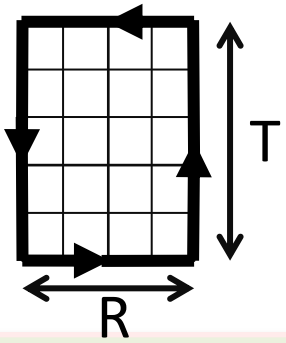
Gauge Invariant Dirac-mode expansion and projection

$\hat{W} = \prod_{k=1}^{L} \hat{U}_{\mu_k}$:Wilson loop operator



insert $\sum_{n_i} |n_i\rangle\langle n_i| = 1$

$$\mathrm{Tr}\hat{W} = \mathrm{tr} \sum_{n_1, n_2, \cdots, n_L} \langle n_1|\hat{U}_{\mu_1}|n_2\rangle\langle n_2|\hat{U}_{\mu_2}|n_3\rangle \cdots \langle n_L|\hat{U}_{\mu_L}|n_1\rangle$$

$$V(R) = -\lim_{T\to\infty} \frac{1}{T} \ln \mathrm{Tr}\hat{W}$$

Projection

$$\sum_{n_i} \to \sum_{n_i \in A} \equiv \sum_{|n_i| > N_{\mathrm{IR}}} \text{ or } \sum_{n_i=-N_{\mathrm{UV}}}^{n_i=N_{\mathrm{UV}}}$$

$$\mathrm{Tr}\hat{W}^P \equiv \mathrm{tr} \sum_{n_1, n_2, \cdots, n_L \in A} \langle n_1|\hat{U}_{\mu_1}|n_2\rangle\langle n_2|\hat{U}_{\mu_2}|n_3\rangle \cdots \langle n_L|\hat{U}_{\mu_L}|n_1\rangle$$

$$V^P(R) = -\lim_{T\to\infty} \frac{1}{T} \ln \mathrm{Tr}\hat{W}^P$$

Gauge Invariant!

Three merits for Gauge-Invariant Dirac-mode expansion and projection

- Gauge-Invariant method
- Investigate the relation between confinement and chiral symmetry breaking via Banks-Casher relation,

$$\langle \bar{q}q \rangle = -\lim_{m\to 0}\lim_{V\to\infty}\frac{\pi}{V}\langle \rho(0)\rangle$$

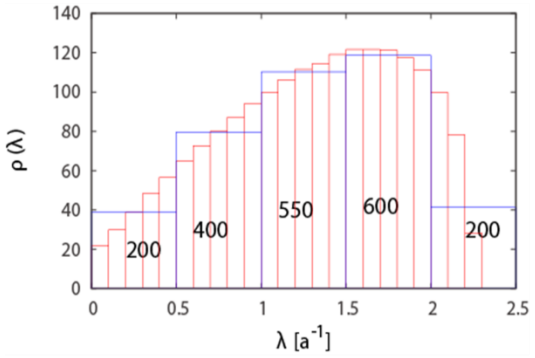
- Investigate the relation between confinement and Topological charge via Atiyah-Singer Index theorem,

$$Q = \frac{g^2}{16\pi^2}\int d^4x \mathrm{Tr} G_{\mu\nu}\tilde{G}^{\mu\nu} = \nu_R - \nu_L$$

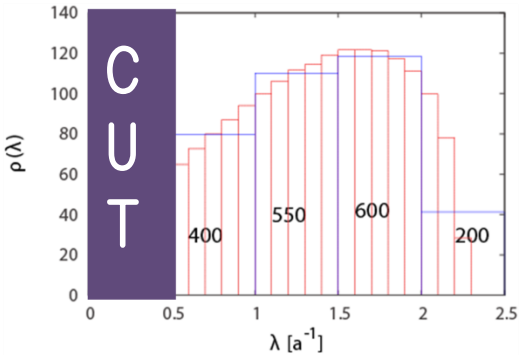
ν_R, ν_L :Right,Left handed zero mode

low-lying mode CUT

$\rho(\lambda)$:Dirac spectral function



Low-lying CUT



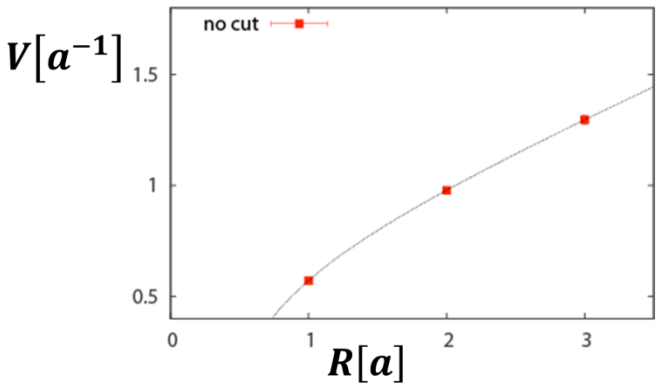
- Chiral Symmetry breaking

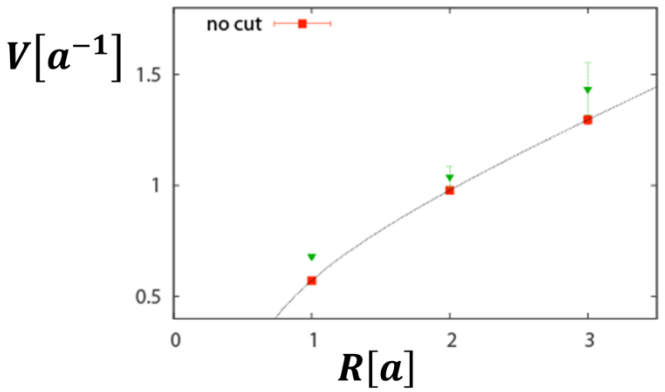
$$\langle \bar{q}q \rangle = -\frac{\pi}{V}\rho(0)$$

$\langle \bar{q}q \rangle$ is Largely Reduced

- Confinement(linear potential)

Almost unchanged





This seems to indicate absence of direct correspondence between Chiral Symmetry breaking and Confinement

Summary and Future work

Summary

- We formulate a **Gauge-Invariant** **Dirac-mode expansion** of the QCD operator.
- **Confinement** is not directly related to **Chiral symmetry breaking** through **the Dirac modes**.
- This suggests that **quark is confined** but **chiral symmetry** **is restored** under some conditions.

Future work

- We investigate the relation between **Topological charge** and **Confinement.**
- We apply this method to **finite temperature**.