

hadronization & lattice QCD

L Del Debbio

Higgs Centre for Theoretical Physics
University of Edinburgh

hadronization

Pythia: "... the fragmentation process has yet to be understood from the QCD lagrangian."

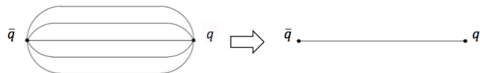
lattice QCD is formulated in Euclidean space: no real time evolution

two complementary approaches

↔ phenomenological models

↔ formulation of the problem in terms of QCD correlators

the QCD string



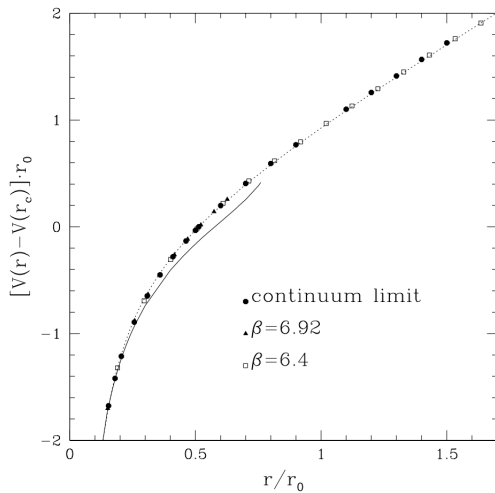
linearly rising potential between $q\bar{q}$ pairs

$$V(r) = \sigma r - \frac{\pi}{12r} + \dots$$

pair production by tunnelling

$$\text{prob} \propto \exp\left(-\frac{\pi m^2}{\sigma}\right) \exp\left(-\frac{\pi p_{\perp}^2}{\sigma}\right)$$

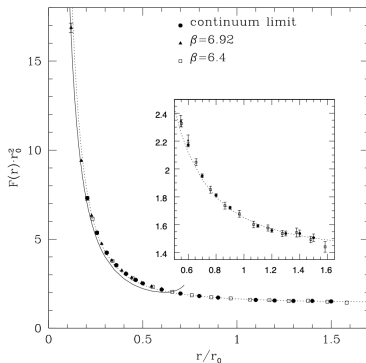
lattice potential - 1



[Necco & Sommer 01]

lattice potential - 2

$$F(r) = \sigma + \frac{\pi}{12r^2}, \quad r_0^2 F(r_0) = 1.65$$

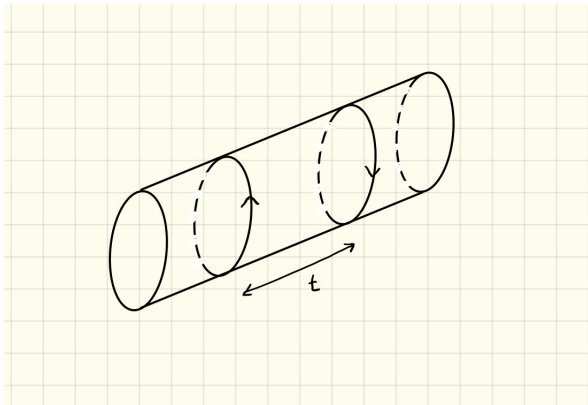


[Necco & Sommer 01]

$$1.65 = r_0^2 \sigma + \frac{\pi}{12}$$

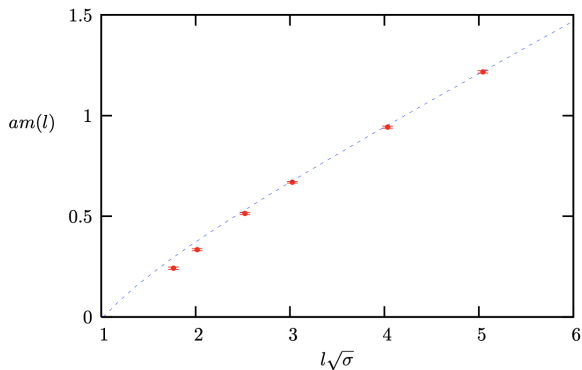
torelon mass

$$\langle \phi_L(t) \phi_L(0)^\dagger \rangle \simeq e^{-m(L)t} + \dots$$



torelon mass

$$m(L) = \sigma L - \frac{\pi}{3L} + \dots$$

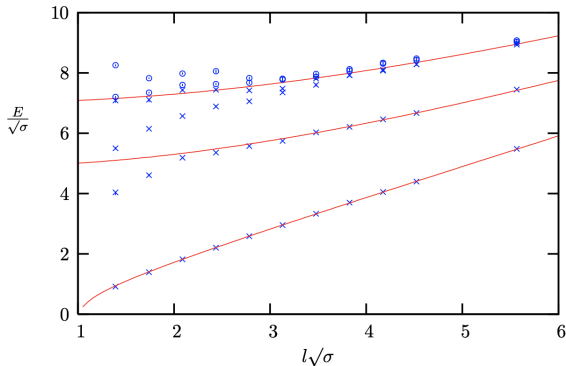


[Teper 09]

$$\Lambda_{\overline{\text{MS}}}/\sqrt{\sigma} = 0.511(33)$$

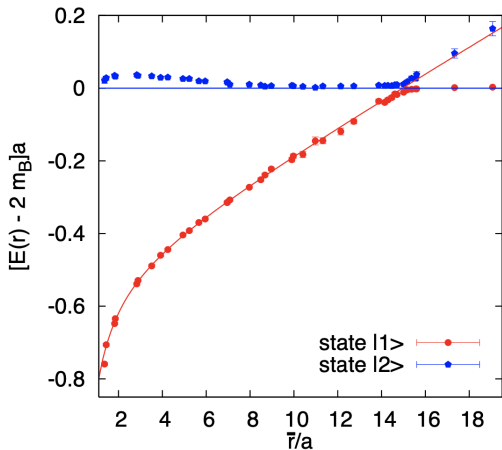
the Nambu-Goto string

- a lot of progress in understanding the QCD string [05-09]
- corrections up to $O(1/L^5)$ computed
- agree with NG prediction



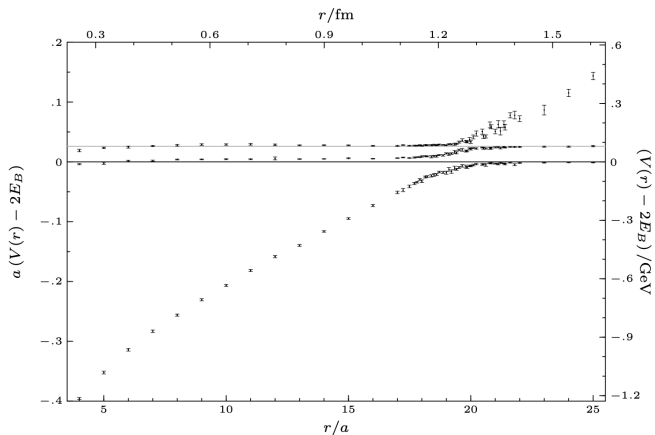
[Teper 09]

string breaking - 1



[Bali 05]

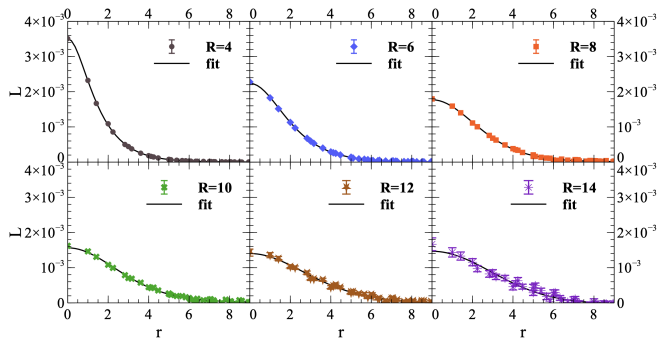
string breaking - 2



[Bulava 19]

is this useful for space-time evolution?

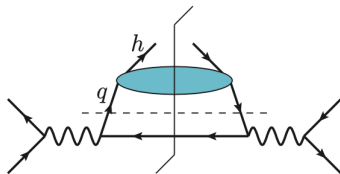
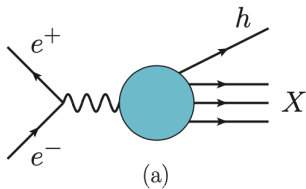
flux tube profile



[Bicudo 13]

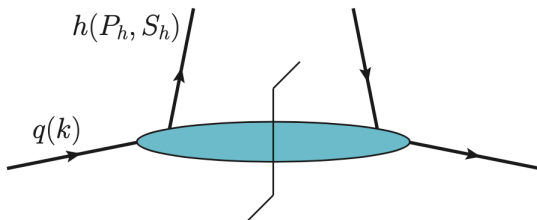
extraction of the penetration length - comparison with superconductor models

fragmentation functions



$$\sigma^{e^+e^- \rightarrow hX} = \hat{\sigma} \otimes \text{FF}$$

QCD correlators



$$\Delta^{h/q}(z; P_h, S_h) = \sum_{\underline{X}} \int \frac{d\xi^+}{2\pi} e^{ik^-\xi^+} \langle 0 | \mathcal{W}(\infty^+, \xi^+) \psi_q(\xi^+, 0^-, \vec{0}_T) | P_h, S_h; X \rangle$$

$$\times \langle P_h, S_h; X | \bar{\psi}_q(0^+, 0^-, \vec{0}_T) \mathcal{W}(0^+, \infty^+) | 0 \rangle,$$

with $\sum_{\underline{X}} \equiv \sum_X \int \frac{d^3 \vec{P}_X}{(2\pi)^3 2P_X^0}.$

[Metz & Vossen 16]

Outlook

- no direct lattice result about hadronization
- is there room to improve the phenomenological models?
 - ◇ detailed structure of the flux tube
 - ◇ space-time evolution, string breaking?
 - ◇ QGP: equation of state
- extracting FF from lattice QCD data?
 - ◇ open issues still to be resolved