Evidence for Sigma Meson in Lattice QCD

Scalar Collaboration

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Motivation

- I=0, J=0 meson called "f_0(600) or σ" appeared in the 2004 edition of PDG.
  m_σ=400−1200MeV, Full width Γ=300−500MeV

- The contributions of the sigma pole were significantly identified in the decay processes of
  D → πππ[E791:PRL86,770(2001)].
  It should be noted that a recent analysis clearly shows phase motion consistent with resonance behavior[E791:hep-ex/030907(2003)].
- The role of the sigma was recently examined in
  B → ρπ decay.
  A. Deandrea and A. D. Plosa, Phys. Rev. Lett. 86 (2001) 216.
  S. Gardner and U-G. Meißner, Phys. Rev. D65 (2002) 094004.
- This decay process has relevance to the measurement of the CP violations. The contribution of Sigma is expected to be measured in LHC-B at CERN.

Objective

- It is an important task to confirm the properties of the sigma meson based on a first principle calculation of QCD.

- We present a lattice calculation of the sigma meson using full QCD .

  (Our simulation includes the dynamical quark effects.)

Operator of Sigma Meson

- I=0, Scalar

$$\sigma(x) \equiv \sum_{c=1}^{3} \overline{\psi}_c(x)\psi^c(x)$$

$$= \sum_{c=1}^{3}\sum_{\alpha=1}^{4} \frac{\overline{u}_\alpha^c(x)u_\alpha^c(x) + \overline{d}_\alpha^c(x)d_\alpha^c(x)}{\sqrt{2}}$$

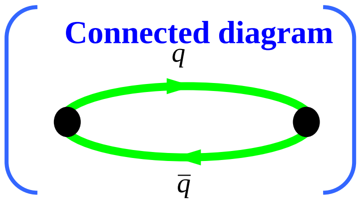
c＝1,2,3 ･･･color

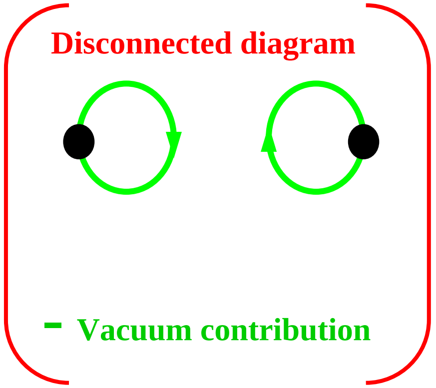
α =1,2,3,4･･･Dirac spin

$$\psi \equiv \begin{pmatrix} u \\ d \end{pmatrix}$$

Sigma propagator

$$G(x,y) = -< TrW^{-1}(x,y)W^{-1}(y,x) >$$
$$+2 < (\sigma(x) - <\sigma>)(\sigma(y) - <\sigma>) >$$





where

$$\sigma(x) \equiv TrW^{-1}(x,x) = \bar{\psi}(x)\psi(x)$$

$W^{-1}(x,y)$:quark propagator

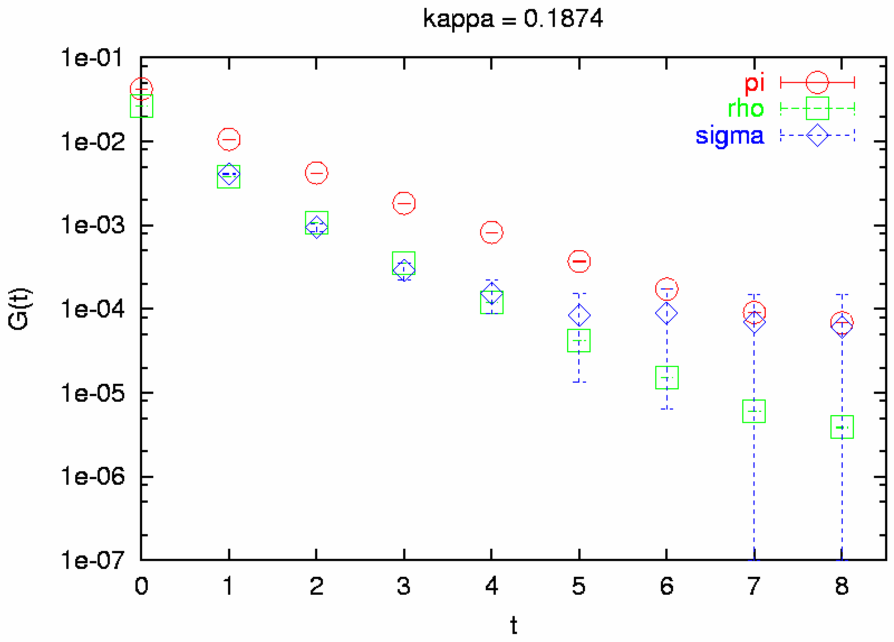
$$G(t) = \sum_{\vec{x}} G(\vec{x},t;0,0)$$

$\approx \exp(-m\,t)$ at large t

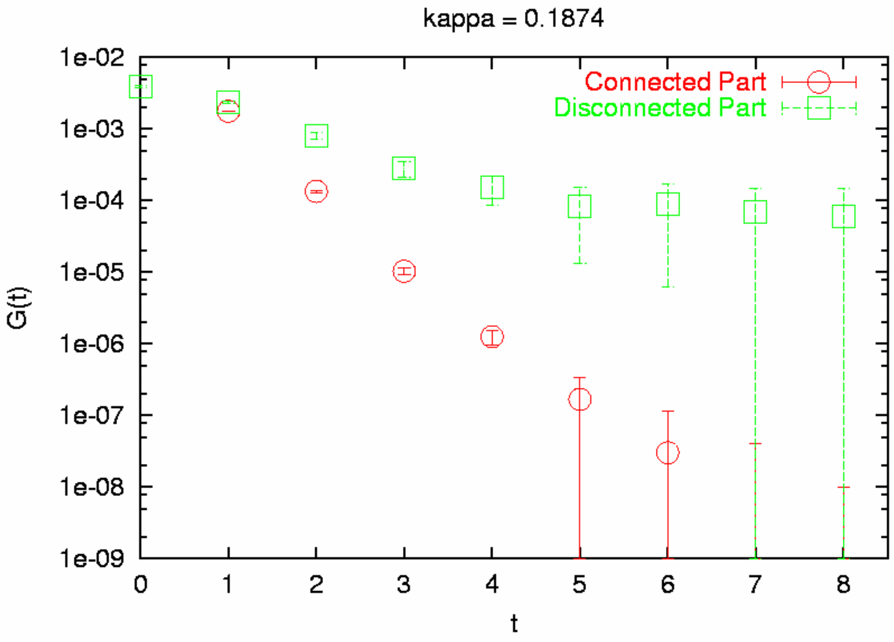
The mass of Sigma meson

Simulation

Propagators for π, ρ, σ mesons (κ =0.1874)



Sigma meson propagator Connected Part & Disconnected Part (κ = 0.1874)



Results

- Simulation parameters

  Lattice size: 8x8x8x16

  $\beta = 6/g^2 = 4.8$

  hopping parameters

  $\kappa = 0.1846, 0.1874, 0.1891$

  (well established by CP-PACS, a=0.197(2) fm, κ_c=0.19286(14), CP-PACS, Phys.Rev.D60(1999)114508)

  Wilson Fermions + Plaquette gauge action

  We use Z_2 noise method to the disconnected diagram.

  (Number of the Z_2 noise = 1000)

  Gauge configurations are created by Hybrid Monte Carlo.

κ	0.1846	0.1874	0.1891
Statistic (Number of configurations)	1110	860	730
CP-PACS m_π/m_σ	0.8291(12)	0.7715(17)	0.7026(32)
Our result m_π/m_σ	0.825(2)	0.757(2)	0.693(3)
Our result m_σ/m_ρ	1.6(1)	1.34(8)	1.11(6)
Our result $m_{connect}/m_\rho$	2.40(2)	2.44(3)	2.48(4)

Summary

- We indicate the existence of a light sigma meson in the region

$$m_\pi < m_\sigma \le m_\rho .$$

- The disconnected diagram makes the sigma meson light.
- Clearly more works are needed to elucidate the physical contents (e.g. glueball, multi-quark states) of the sigma meson.
- More detail see, hep-ph/0310312 .

(submitted to Phys. Rev. D)