PROCEEDINGS OF SCIENCE

I=1/2 Scalar and Axial Vector Mesons

Scalar collaboration: Teiji Kunihiro[a], Shin Muroya[b], Atsushi Nakamura[c], Chiho Nonaka[d], Motoo Sekiguchi*[e] and Hiroaki Wada[f]

[a]*YITP, Kyoto University*
Kyoto 606-8502, Japan
[b]*Tokuyama University*
Tokuyama 745-8511, Japan
[c]*RIISE, Hiroshima University*
Higashi-Hiroshima 739-8521, Japan
[d]*School of Physics and Astronomy, University of Minnesota*
Minneapolis, MN 55455, USA
[e]*Faculty of Engineering, Kokushikan University*
Tokyo 154-8515, Japan
E-mail: motoo@kokushikan.ac.jp
[f]*Faculty of Political Science and Economics, Kokushikan University*
Tokyo 154-8515, Japan

We present our recent study of $I = 1/2$ scalar (κ) and axial vector mesons (K_1) in the quenched approximation with the Wilson fermions. Our preliminary results show that these mesons are heavier than K^*.

XXIIIrd International Symposium on Lattice Field Theory
25-30 July 2005
Trinity College, Dublin, Ireland

*Speaker.

PoS(LAT2005)034

1. Introduction

Recently, there has been interest in the structure of the scalar mesons in the hadron physics. In particular the existence of the σ meson (I=0, J^{PC}=0^{++}) was obscure for many years. The confidence level of the σ meson has been increasing. There have been accumulation of experimental evidence of the σ with a low mass 500 $\sim$ 600 MeV [1]. In the non-relativistic constituent quark model, J^{PC}=0^{++} meson is realized as ${}^3P_0$ state, which implies that the mass of the σ should be in 1.2 $\sim$ 1.6GeV region. Therefore some mechanism is needed to down the mass. Many suggestions are discussed in the literature [2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14].

We have presented a lattice calculation of the σ meson, by full lattice QCD simulation on the $8^3 \times 16$ lattice using the plaquette action and Wilson fermions. We have observed that the disconnected diagram makes the σ mass very light [9, 10, 11, 12]. The connected diagram alone gives heavy mass.

If the σ meson exists, it is natural to consider the κ meson as member of the nonet scalar states chiral SU(3)XSU(3) symmetry. Recently, the κ with I=1/2 is reported with mass $m_\kappa \sim 800$ MeV[4, 5]. It is very important to investigate the κ meson by lattice QCD in order to establish the mass spectroscopy of the scalar mesons. Because lattice QCD provides a first principal approach of hadron physics and allows us to study non-perturbative aspects of quark-gluon dynamics. In the previous paper[12, 15], we have treated the s quark as a valence, while u and d quarks dynamical. And Prelosek[16] have presented a rough estimate by extrapolating the mass of κ obtained from the dynamical simulation. They assumed that the u, d and s quarks are degenerate. In our previous simulation, the cutoff was not sufficiently high to accommodate large masses $m_\kappa a > 1$, where a is the lattice spacing. Hence, we present a quench simulation at weaker couplings on a lager lattice. And we shall also mention that our simulation suggests the existence of I=1/2 J^{PC}=1^{++} axial vector (K_1) meson.

2. Propagator

We adopt the following interpolation operator for creating the κ^+ meson with I=1/2 and $J^{PC} = 0^{++}$ as

$$\hat{\kappa}(x) \equiv \sum_{c=1}^{3}\sum_{\alpha=1}^{4} \bar{s}^c_\alpha(x) u^c_\alpha(x), \tag{2.1}$$

where s and u indicate the corresponding quark spinors. Indices c and α stand for color and Dirac spinor indices, respectively. The κ meson propagator is written as

$$\begin{aligned} G(y,x) &= < \mathrm{T}\hat{\kappa}(y)\hat{\kappa}(x)^\dagger > \\ &= \frac{1}{Z}\int DUD\bar{u}DuD\bar{s}Ds \\ & \quad \sum_{a,b=1}^{3}\sum_{\alpha,\beta=1}^{4} \bar{s}^b_\beta(y) u^b_\beta(y) \\ \times & \quad (\bar{s}^a_\alpha(x) u^a_\alpha(x))^\dagger e^{-S_G - \bar{u}W_u u - \bar{s}W_s s}. \end{aligned} \tag{2.2}$$

Table.1 The mass ratios m_π/m_ρ

$h_{u/d}$	0.1583	0.1589	0.1592
Number of Configulations	40	40	30
Our result	0.57(32)	0.45(39)	0.39(67)
CP-PACS	0.593(1)	0.491(2)	0.415(2)

Table.2 The mass ratios m_K/m_{K^*}

	h_s=0.1566	h_s=0.1574
$h_{u/d}$=0.1583	0.63(13)	0.59(16)
$h_{u/d}$=0.1589	0.60(16)	0.55(19)
$h_{u/d}$=0.1592	0.59(19)	0.53(22)

We use 25 configurations for all hopping parameters.

In Eq.(2.2), W_u^{-1} (W_s^{-1})'s is u (s) quark propagator, U's are link variables of gluon, and S_G is the gauge action. By integrating over u, $\bar{u}$, s and $\bar{s}$ fields, the κ meson propagator is given by

$$G(y,x) \;=\; -<\mathrm{Tr}W_s^{-1}(x,y)W_u^{-1}(y,x)> \qquad (2.3)$$

where "Tr" represents summation over color and Dirac spinor indices. From Eq.(2.3), we can see that κ propagator is composed of a connected diagram and contains no disconnected part, the latter of which was the origin of the light mass of the σ meson. For K_1, the operator is $K_1^+=\bar{s}\gamma^\mu\gamma_5 u$ and also the K_1 meson propagator is composed of a connected diagram. We employ Wilson fermions and the plaquette gauge action.

3. Numerical Simulations

As for the simulation parameters, we first note that CP-PACS performed the quenched approximation calculation of the light meson spectroscopy with great success[17]. Therefore, we use the same values of the simulation parameters as those used by CP-PACS, i.e., β=5.9, and the following three values for the u and d quark hopping parameter $h_{u/d}$=0.1583, 0.1589 and 0.1592, and the two values for the s quark hopping parameter h_s=0.1566 and 0.1574, except for the lattice size; our lattice size is $20^3\times 24$. The meson propagators are calculated on a configuration in every 2000 trajectories generated by the heat bath method. We shall use the point source and sink, which together with the smaller lattice size , leads to large masses due to mixture of higher mass states. In other words, the masses to be obtained in our simulation should be considered as upper limits. The mass ratios of m_π/m_ρ are summarized in Table 1. Our results have large error bars. The propagators of the K, K^*, κ andK_1 are shown Fig. 1, 2. The mass rations of m_K/m_{K^*}, m_κ/m_{K^*} and m_{K_1}/m_{K^*} are summarized in Table 2 $\sim$ 4.

PoS(LAT2005)034

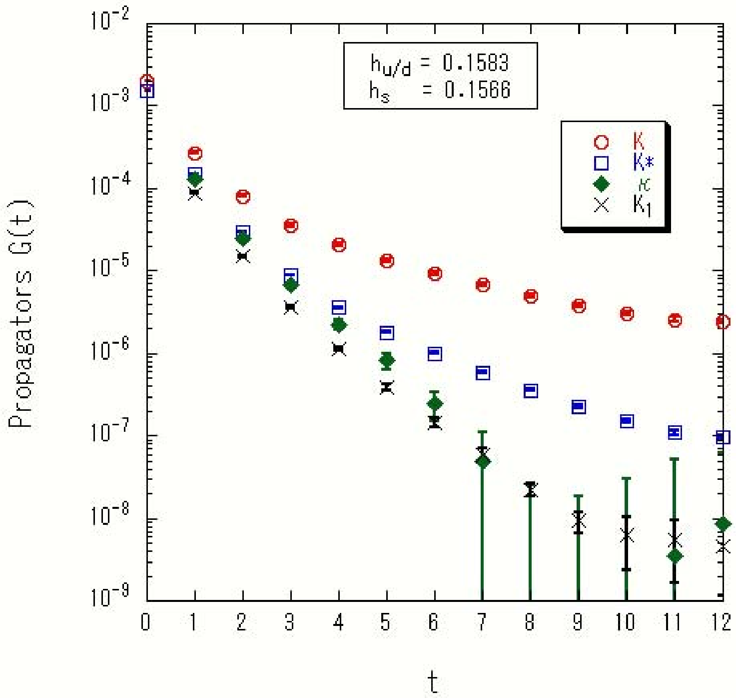

Figure 1: Propagators of K, K^*, κ and K_1 for $h_{u/d} = 0.1583$ and $h_s = 0.1566$.

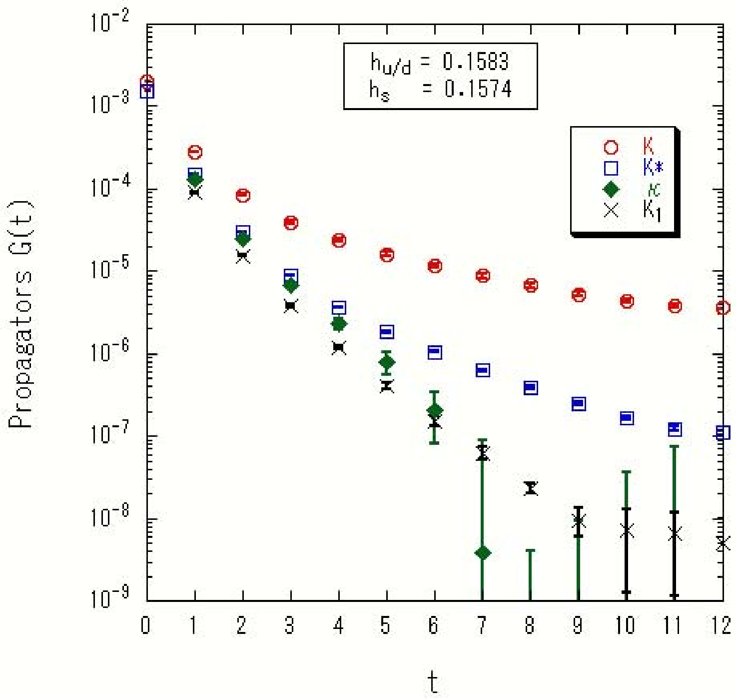

Figure 2: Propagators of K, K^*, κ and K_1 for $h_{u/d} = 0.1583$ and $h_s = 0.1574$.

Table.3 The mass ratios m_κ/m_{K^*}

	h_s=0.1566	h_s=0.1574
$h_{u/d}$=0.1583	2.36(47)	2.28(42)
$h_{u/d}$=0.1589	2.150(89)	2.26(1.20)
$h_{u/d}$=0.1592	2.41(1.60)	2.66(2.41)

We use 25 configurations for all hopping parameters.

Table.4 The mass ratios m_{K_1}/m_{K^*}

	h_s=0.1566	h_s=0.1574
$h_{u/d}$=0.1583	1.71(50)	1.77(54)
$h_{u/d}$=0.1589	1.77(63)	1.86(18)
$h_{u/d}$=0.1592	2.10(1.88)	2.07(1.22)

We use 25 configurations for all hopping parameters.

4. Concluding remarks

We have reported our preliminary results on the κ and K_1 meson propagtor based on the quenched QCD. We see that the κ and K_1mass are almost twice as havey as the K^* meson for all values of the hopping parameter. Our preliminary result of κ meson does not agree with recent experimental values. It is necessary to generate much more gauge configurations and improve the statistical precision of the estimation of κ and K_1 propagators.

Acknowledgment

Simulations were performed on SX5 at RCNP, Osaka Univ., SR8000 at KEK.

References

[1] **Particle Data Group**, S. Eidlman *et al.*, *Review of Particle Physics*, Phys. Lett. **B592** (2004) 1.

[2] For example, see *Possible existence of the sigma-meson and its implications to hadron physics*, KEK Proceedings 2000-4, Soryushiron Kenkyu (kyoto) **102** (2001)E1.

[3] F.E. Close and N. A. Törnqvist, *Scalar mesons above and below 1 GeV*, J. Phys. G: Nucl. Part. Phys. **28**(2002) R249 [hep-ph/0204205].

[4] **E791** Collaboration, M. Aitala *et al*, Phys. Rev. Lett. **89** (2002) 121801, [hep-ex/0204018].

[5] **BES** Collaboration, *Evidence for κ meson production in $J/\psi \to \bar{K^*}$ (892) K^+ π process*, [hep-ex/0506055]

[6] M. Alfold and R. L. Jaffe, *Insight into the scalar mesons from lattice calculation*, Nucl. Phys. **B578** (2000) 367, [hep-lat/0001023].

[7] W. Lee and D. Weingarten, *Scalar quarkonium masses and mixing with the lightest scalar glueball*, Phys. Rev. **D61** (1999) 014015, [hep-lat/9910008].

[8] C. McNeile and C. Michael, *Mixing of scalar glueballs and flavor singlet scalar mesons*, Phys. Rev. **D63** (2001) 114503, [hep-lat/0010019].

PoS(LAT2005)034

[9] **SCALAR** Collaboration, *I=0 scalar channel*, Nucl. Phys. Proc. Suppl. **106** (2002) 272, [hep-lat/0112012].

[10] **SCALAR** Collaboration, *Lattice study of "$f_0(600)$ or σ"*, Nucl. Phys. Proc. Suppl. **119** (2003) 275, [hep-lat/0210012].

[11] **SCALAR** Collaboration, H. Wada, *Study of the 0^+ scalar mesons in lattice QCD*, Nucl. Phys. Proc. Suppl. **129** (2004) 432.

[12] **SCALAR** Collaboration, *Scalar mesons in lattice QCD*, Phys. Rev. **D70** (2004) 034504, [hep-ph/0310312].

[13] S. Prelovsek and K. Orginos, *Quenched scalar meson correlator with Domain Wall Fermions*, Nucl. Phys. Proc. Suppl. **119** (2003) 822, [hep-lat/0209132].

[14] χ**QCD Collaboration**, N. Mathur, et al., *A study of tetraquark mesonium on the lattice with overlap fermion*, these proceedings.

[15] **SCALAR** Collaboration, *Lattice Study of the κ Scalar Meson*, Nucl. Phys. Proc. Suppl. **129** (2004) 242.

[16] S. Prelovsek, C. Dawson, T. Izubuchi K. Orginos and A. Soni, *Scalar meson in dynamical and partially quenched two-flavor QCD: Lattice results and chiral loops*, Phys. Rev. **D70** (2004) 094503, [hep-lat/0407037].

[17] **CP-PACS** Collaboration, S. Aoki, et al., *Light hadron spectrum and quark masses from quenched lattice QCD*, Phys. Rev. **D67** (2003) 034503, [hep-lat/0206009].