SU(2) gauge theory with domain-wall fermions in fundamental and adjoint representations

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Introduction

- SU(2) gauge theory
  - Many works on confinement mechanism, finite temperature/density
  - Beyond standard model: technicolor, conformal window, dark matter
    - F. Bursa et al. (2011), H.Ohki et al. (2010), Lewis, Pica, Sannino (2012) T. Karavirta et al. (2012), M. Hayakawa et al. (2013)
- Chiral dynamics depending on gauge group and fermion repr.
  - Different symmetry breaking pattern

Fundamental	Adjoint
SU(2): SU(2Nf) → Sp(2Nf)	SU(N): SU(2Nf) → SO(2Nf)
SU(N) N>2: SU(Nf)xSU(Nf) → SU(Nf)	

  - Dependence on number of flavors
  - Finite temperature/density
  - Eigenvalue distribution – comparison to random matrix theory
- Chiral symmetric fermion is better device
  - Overalp: best symmetry, high numerical cost, involved setup (Aoki phase, etc.) H.M., Kikukawa, Yamada, Nagai, Lattice 2010, 2009
  - Domain-wall: good properties, numerically feasible
    - Approaches to overlap with large Ns
    - Residual mass probes explicit chiral symmetry violation

Domain-wall → Improved domain-wall → Ovelap

- Topology changes
- Large lattice is possible

Mesurement:
- Spectroscopy
- Eigenvalue/vectors, etc.

- Fixed topology
- p-regime/ε-regime

Setup

H.Matsufuru, K-i Nagai, N.Yamada, proceedings of Lattice 2014, 2013

- Lattice actions:
  - Iwasaki gauge action
  - Standard domain-wall fermions: Nf=2, 4, 6, 8
- Survey of Nf-dependence with fixed setup
  - Applicability of domain-wall (and overlap) fermions
  - Confining/conformal feature ?
  - Fundamental setup: making basis for further studies
  - Finite T/μ, adjoint fermions
  - Toward improved domain-wall, dynamicsal overlap, ε-regime
- Lattice size: 16^3x32, Ns=16

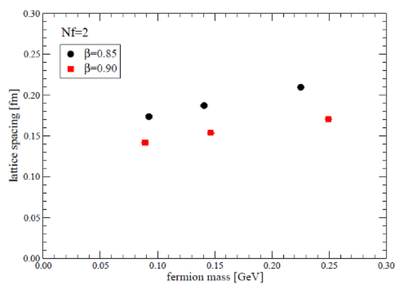
Nf	beta	m
2	0.85	0.20, 0.10, 0.05
	0.90	0.20, 0.10, 0.05
4	0.85	0.20, 0.10, 0.05, 0.03
	0.90	0.20, 0.10, 0.05
6	0.80	0.20, 0.10, 0.05
	0.85	0.20, 0.10, 0.05
	0.90	0.20, 0.10, 0.05
8	0.80	0.20, 0.10, 0.05
	0.85	0.20, 0.10, 0.05

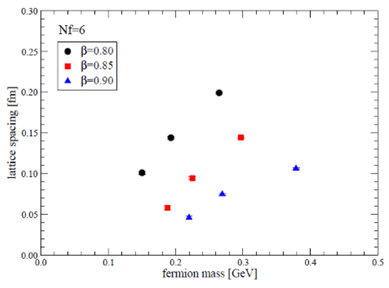
- Machines
  - Hitachi SR16000, IBM Blue Gene/Q at KEK
  - φ at KMI, Nagoya Univ.
- Code:
  - Bridge++ (C++)

- JLDG (Japan Lattice Data Grid)

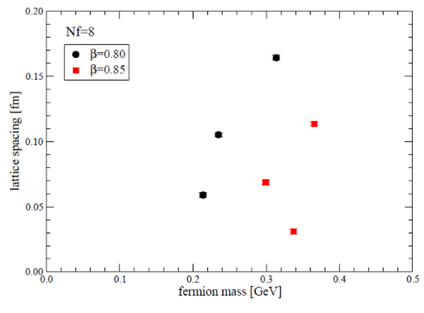
Static potential

- Lattice spacing vs fermion mass (residual + bare)
  - No renormalization for fermion mass
- Extrapolation to massless limit seems successful for Nf=2 while not for Nf=6, and 8 (next page)



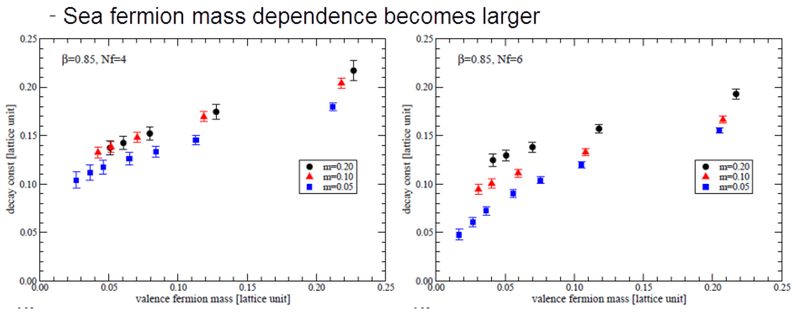


- Nf=8: massless limit is hardly taken
- Confining feature seams to disapper at massless limit
- Caution: at beta=0.85 and m=0.05, volume might be too small

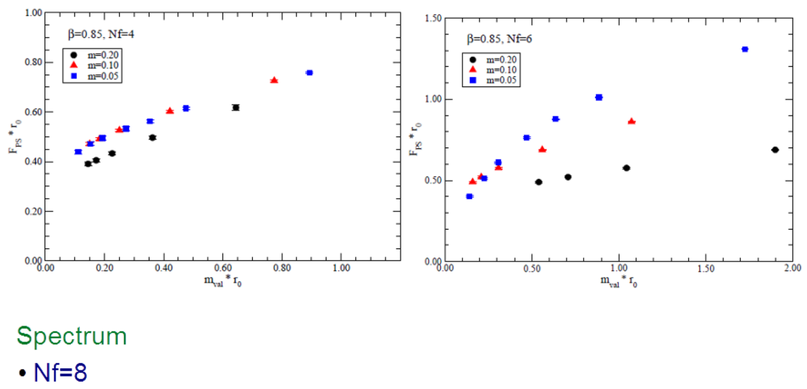


Mass and decay constant

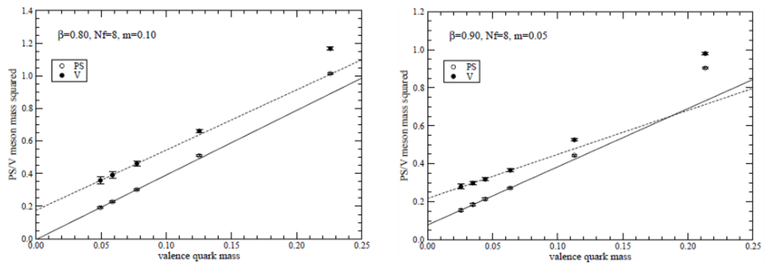
Decay constant
- Nf=4
  - Approaches to finite value as valence mass goes to zero
- Nf=6
  - Sea fermion mass dependence becomes larger



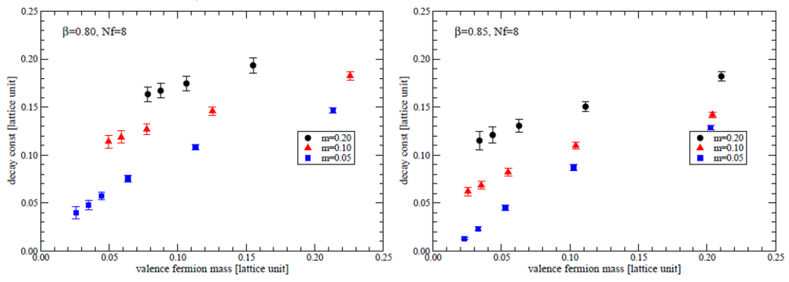
- Scaled by Sommer's scale r_0 form static potential
  - Both F_{PS} and r_0 give lattice scales in QCD
  - Dimensionless combination
  - Nf=4, 6: Similar tendency as results in lattice units



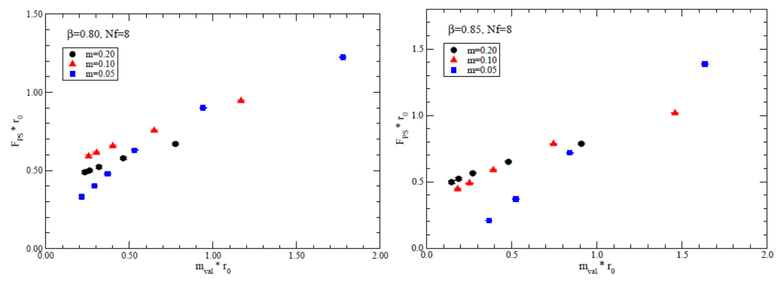
Spectrum
- Nf=8
  - As sea fermion mass decreases, deviation from GMOR relation
  - Finite size effect ?
- Caution:
  - Ground state plateau behavior is transient
    → to be comapred with smeared correlation functions



Decay constant
- Nf=8
  - Sea fermion mass dependence is amplified
  - At beta=0.85, no finite massless limit



- Nf=8 (scaled)
  - Consistent with no finite massless limit



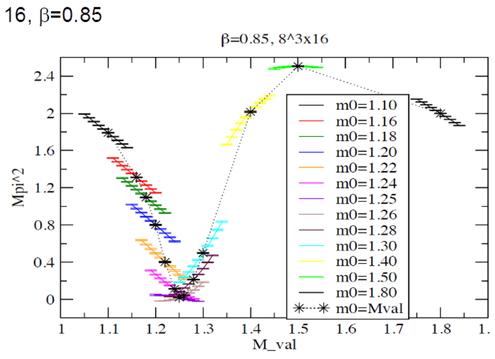
- Summary
  - SU(2) gauge theory with domainwall fermions of Nf=2,4,6,8
  - Nf=8: confining feature tends to disappear at small m
  - Nf=6 is similar, but no unusual behavior in PS and V meson spectra
  - More detailed analyses are underway
- To do
  - So far analysis based on confining/chral symmetry broken phase were applied
  - Analysis to test conformality such as hyperscaling is planned
  - Locality of domainwall/overlap fermion to be confirmed
  - Method to improve signals needed for other channels
  - Eigenmodes of domainwall/overlap fermion operators

Adjoint fermion

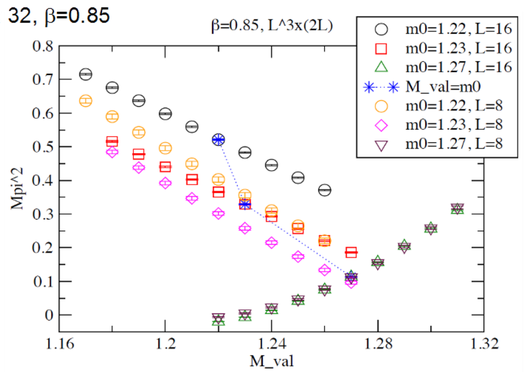
- Aoki phase
  - For locality of Domain-wall/overlap fermion, Wilson kernel should be well outside the Aoki phase

H.Matsufuru, Y.Kikukawa, K. Nagai and N.Yamada, Lattice 2010, 2009

  - Dynamical simulation with Wilson fermion (Nf=2)
  - β = 0.85, 0.90, 1.0
    - 8^3 x 16, β=0.85



    - 16^3 x 32, β=0.85



  - Finite size effect is being quantified
  - Phase transition around M_0~1.25 at β = 0.85
- Simulation with adjoint domain-wall fermions is in progress