Poster presented at Lattice 2015, Jul.14-18, Kobe

S-parameter and vector decay constant in QCD with eight fundamental fermions

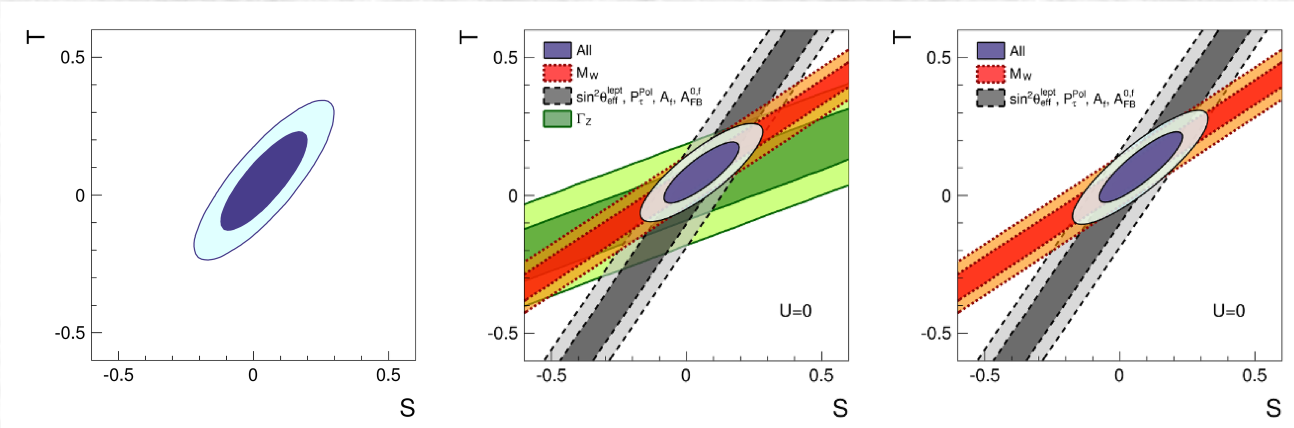
- LatKMI collaboration -

Y. Aoki(1), T. Aoyama(1), E. Bennett(2), M. Kurachi(3), T. Maskawa(1), K. Miura(4), K-i. Nagai(1), H. Ohki(5), E. Rinaldi(6), A. Shibata(3), K. Yamawaki(1), T. Yamazaki(7)

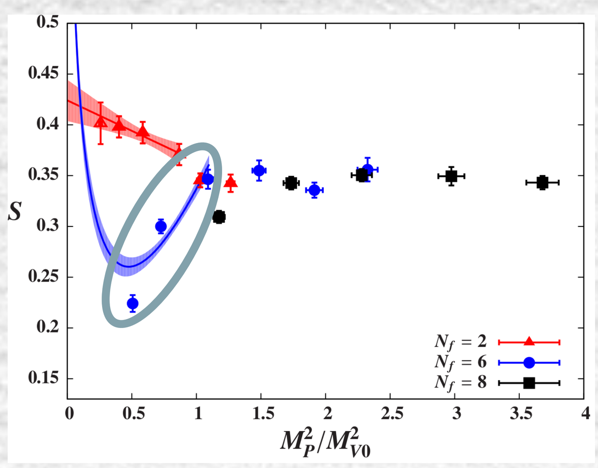
1: KMI/Nagoya, 2: Swansea, 3: KEK, 4: CPT Marseille, 5: RIKEN, 6: LLNL, 7: Tsukuba

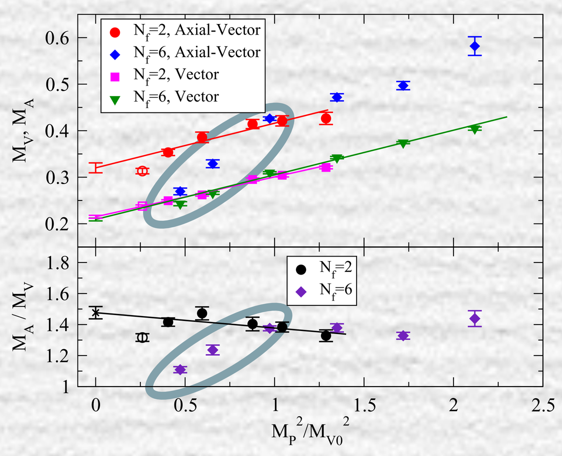
Walking Technicolor Theory (WTC) and S-parameter

- WTC is a candidate of BSM model for Higgs sector
- N_f=8 QCD is a candidate of WTC,
  - which could realize 125 GeV Higgs as scalar composite (see talk by Ohki)
- Peskin-Takeuchi S parameter provides important constraint on composite models
  - Ciucini et al JHEP1308 106 (M_H=126GeV)



- One calculation with N_f=8 QCD exists in the literature
  - LSD collaboration using domain-wall fermions: PRD 2014 / PRL 2011





- S decreases towards smaller m_f for N_f=6
- Hint of similar trend for N_f=8

➡ good!

- parity doubling may be responsible

$$S = 4\pi(N_f/2)[\Pi'_{VV}(0) - \Pi'_{AA}(0)] - \Delta S_{SM} = \frac{1}{3\pi}\int_0^\infty \frac{ds}{s}\Big[(N_f/2)[R_V(s) - R_A(s)] - \frac{1}{4}\Big[1 - \Big(1 - \frac{m_H^2}{s}\Big)^3\Big]\theta(s - m_H^2)\Big].$$

S-parameter project by LatKMI

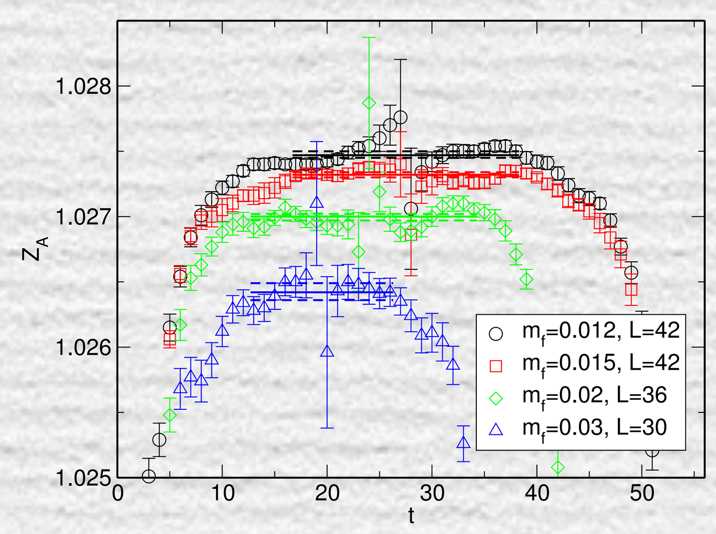
- We want to push further and perform systematic analysis
  - using HISQ
  - especially on finite volume effect
- Method:
  - S is calculated from the slope of $\Pi^{V-A}(q^2)$ at $q^2\to0$
    - $\Pi^{V-A}=\Pi^V-\Pi^A$
    - $\Pi^{A/V}$ is transverse component of vacuum polarization function for (axial) vector
  - Exact chiral symmetry is mandatory, which guarantee no power div. contribution
    - staggered extended chiral symmetry is sufficient: $SU(N_f/4)_V\times SU(N_f/4)_A$
    - HISQ is ideal for N_f=8 → exact $SU(2)_V\times SU(2)_A$ and $SU(8)_V\times SU(8)_A$ is also good
  - practically convenient to take
    - conserved current for sink → Ward-Takahashi identity
    - one-link(non-conserved) current for source → less inversion (numerical effort)

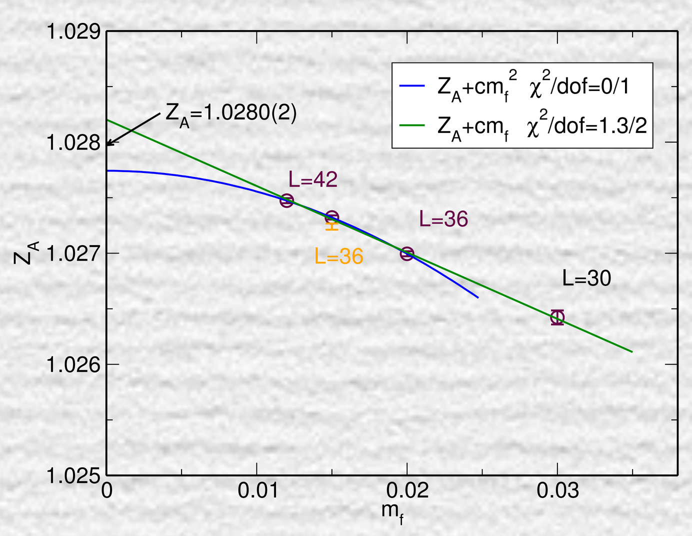
$$\langle \mathcal{A}_\mu^{(1,2)}(x)\ A_\nu^{(2,1)}(0)\rangle$$

  - renormalization needed for one-link operator

$$\mathcal{A}_\mu = Z_A A_\mu$$

$$Z_A = \frac{\langle \mathcal{A}_4(t)P(0)\rangle}{\langle A_4(t)P(0)\rangle}$$



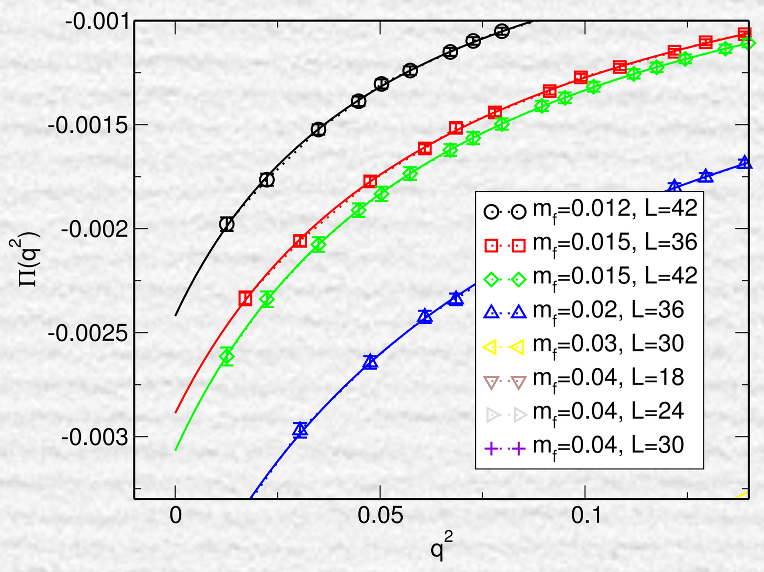


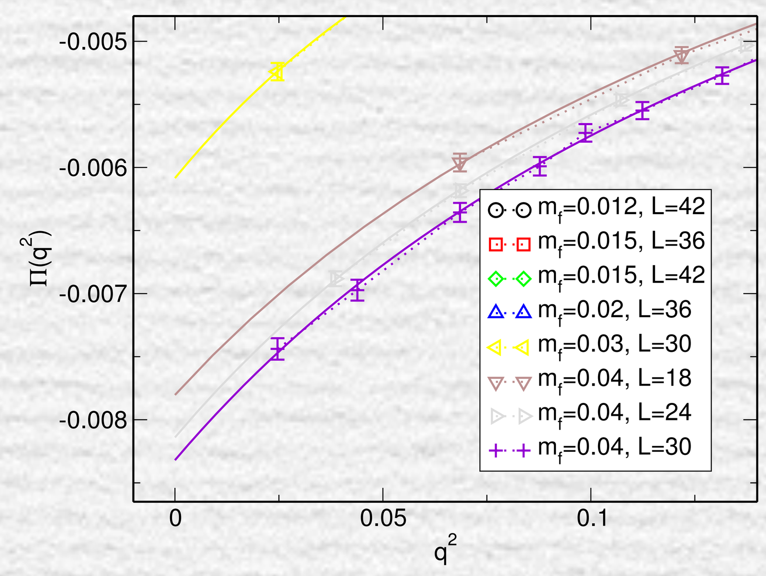
- $\mathcal{V}_\mu = Z_V V_\mu \qquad Z_V = Z_A$ (chiral symmetry)

Some preliminary results

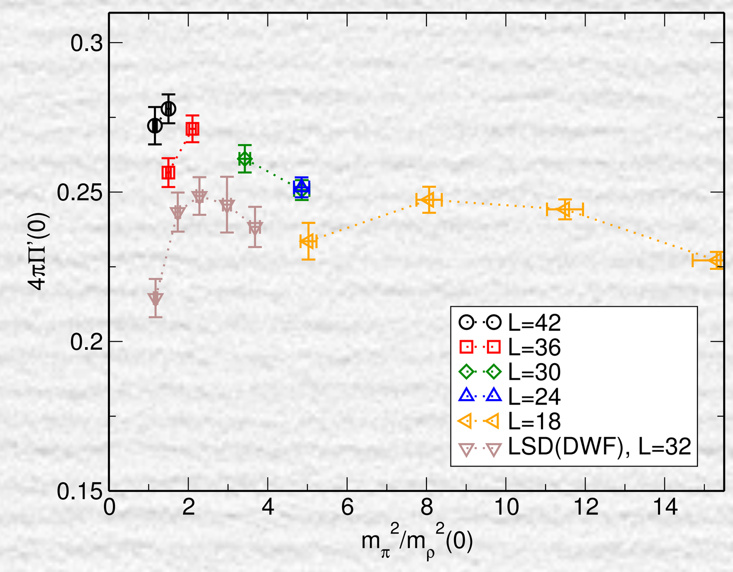
- V-A vacuum polarization function (transverse component)

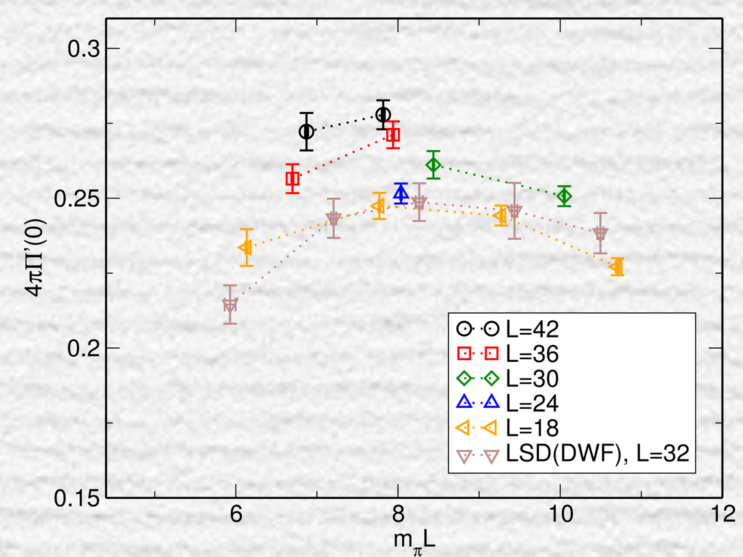
2 volumes for m_f=0.015 — 3 volumes for m_f=0.04





- S parameter contribution per EW doublet

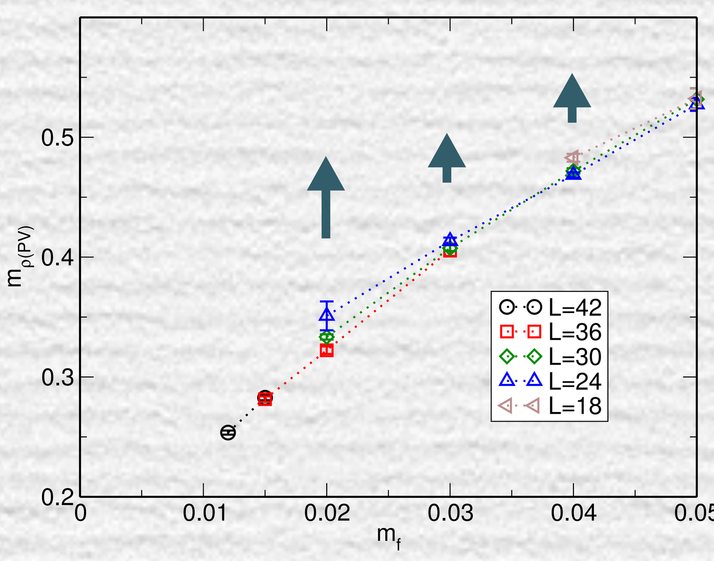


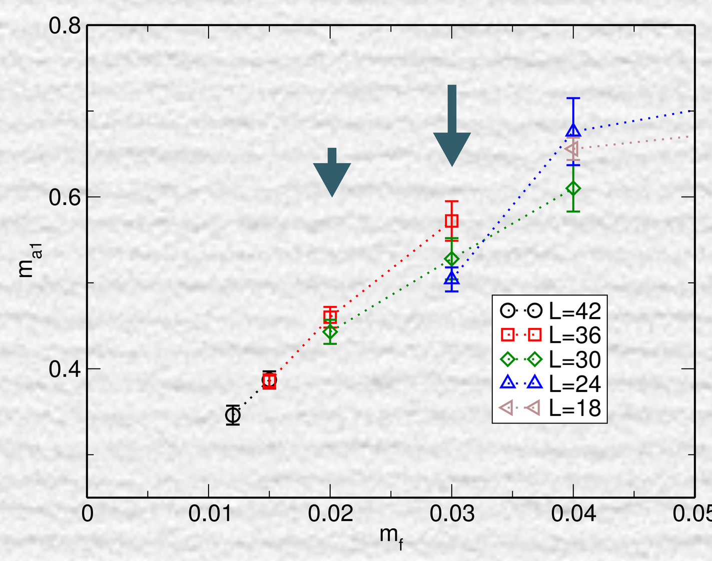


- x axes: normalized with ρ mass in $m_f\to0$ (linearly extrapolated)
- Fixed L & m_f↓ tends to reduce S
- **Large finite volume effect observed**
- LSD results are superimposed
- x axes: $m_\pi L$
- $m_\pi L \lesssim 7$ likely affected by finite volume effect

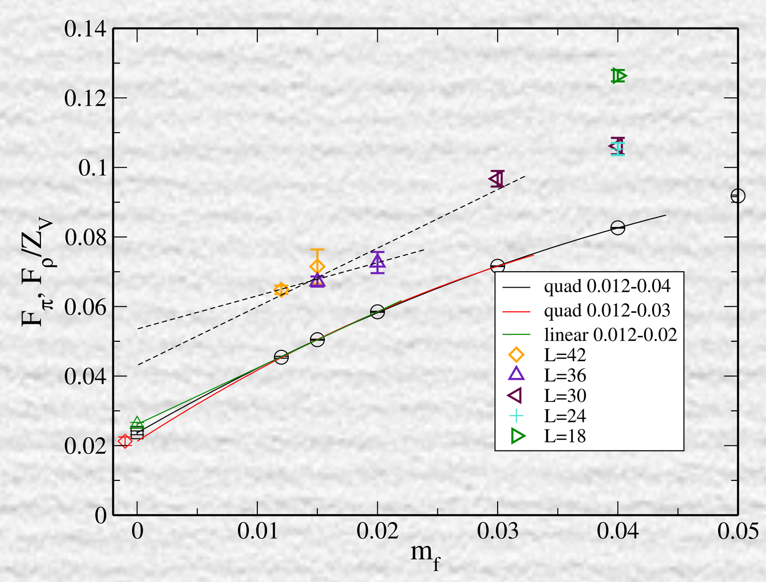
➡8%↓ @ mf=0.015; L=42→36
c.f. pion mass: 0.04%↓
(zero consistent)

- spectrum of vector / axial vector mesons





- **finite volume effect** tends to drive the spectrum to parity doubling



- $F_\rho \approx 2 F_\pi$ at chiral limit
  - consistent with LSD 2014
- axial vector channel too noisy
  - due to mixing with vector channel
  - axial is an excited state
  - weak point of staggered fermions

- Summary and Outlook
  - S parameter is investigated for N_f=8 QCD
  - staggered SU(Nf/4) vector & axial exact symmetry yields a clean calculation
  - large “finite volume effect” on S, to drive it reduced, is observed
  - axial vector meson mass has interesting volume effect
  - further checks required for establish the observation
  - for sure, one needs careful volume analysis for the S parameter
  - more mass, volumes will be analyzed for a consistent picture of volume dep.
  - idea of less noisy axial vector amplitude needed
    - using non-conserved taste (local) with proper matching might help