Mesonic spectrum of $Sp(4)$ gauge theory with $n_f = 3$ dynamical antisymmetric fermions

Particle physics beyond the Standard Model

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Outline

- Introduction: Sp(4) gauge theory with $n_f = 3$ dynamical **antisymmetric** fermions
- Technique:
  - Smearing (APE & Wuppertal) techniques
  - Extracting excited states: variational method (GEVP)
- Preliminary results: Spectrum and Massless Extrapolation
- Summary and Outlook

Antisymmetric representation

Composite Higgs Model

- Compositeness
  - Two Dirac fermions in fundamental representation
  - Three Dirac fermions in antisymmetric representation

Field	Sp(4) Gauge	SU(4) global	SU(6) global
A_μ	10	1	1
ψ	4	4	1
χ	5	1	6

Antisymmetric representation

Composite Higgs Model

- Breaking pattern:

$$G/H = SU(4)\times SU(6)\ /\ Sp(4)\times SO(6)$$

- SU(3) embedded in antisymmetric representation:

$$SU(6) \to SO(6) \supset SU(3)$$

- Top partner — Chimera baryon

$$\Psi = (\,\chi\psi\psi\,)$$

→ **Important to study $Sp(4)$ gauge theory with $n_f = 3$ dynamical antisymmetric fermions.**

Techniques

- Wuppertal smearing (Gaussian smearing) acts on fermion field increasing the overlap of ground state.

$$q^{(n+1)}(x) = \frac{1}{1+2d\varepsilon}\left[q^{(n)}(x) + \varepsilon \sum_{\mu=\pm 1}^{\pm d} U_\mu(x) q^{(n)}(x+\hat{\mu})\right]$$

- APE smearing averages out UV fluctuations of the gauge fields.

$$U_\mu^{(n+1)}(x) = P\left\{(1-\alpha)U_\mu^{(n)}(x) + \frac{\alpha}{6} S_\mu^{(n)}(x)\right\}, \quad S_\mu(x) = \sum_{\pm\nu\neq\mu} U_\nu(x) U_\mu(x+\hat{\nu}) U_\nu^\dagger(x+\hat{\mu})$$

- Variational method: Generalised Eigenvalue problem

$$C(t_2)v_n(t_2,t_1) = \lambda_n(t_2,t_1)C(t_1)v_n(t_2,t_1) \rightarrow \lambda_n(t_2,\underline{t_1})$$

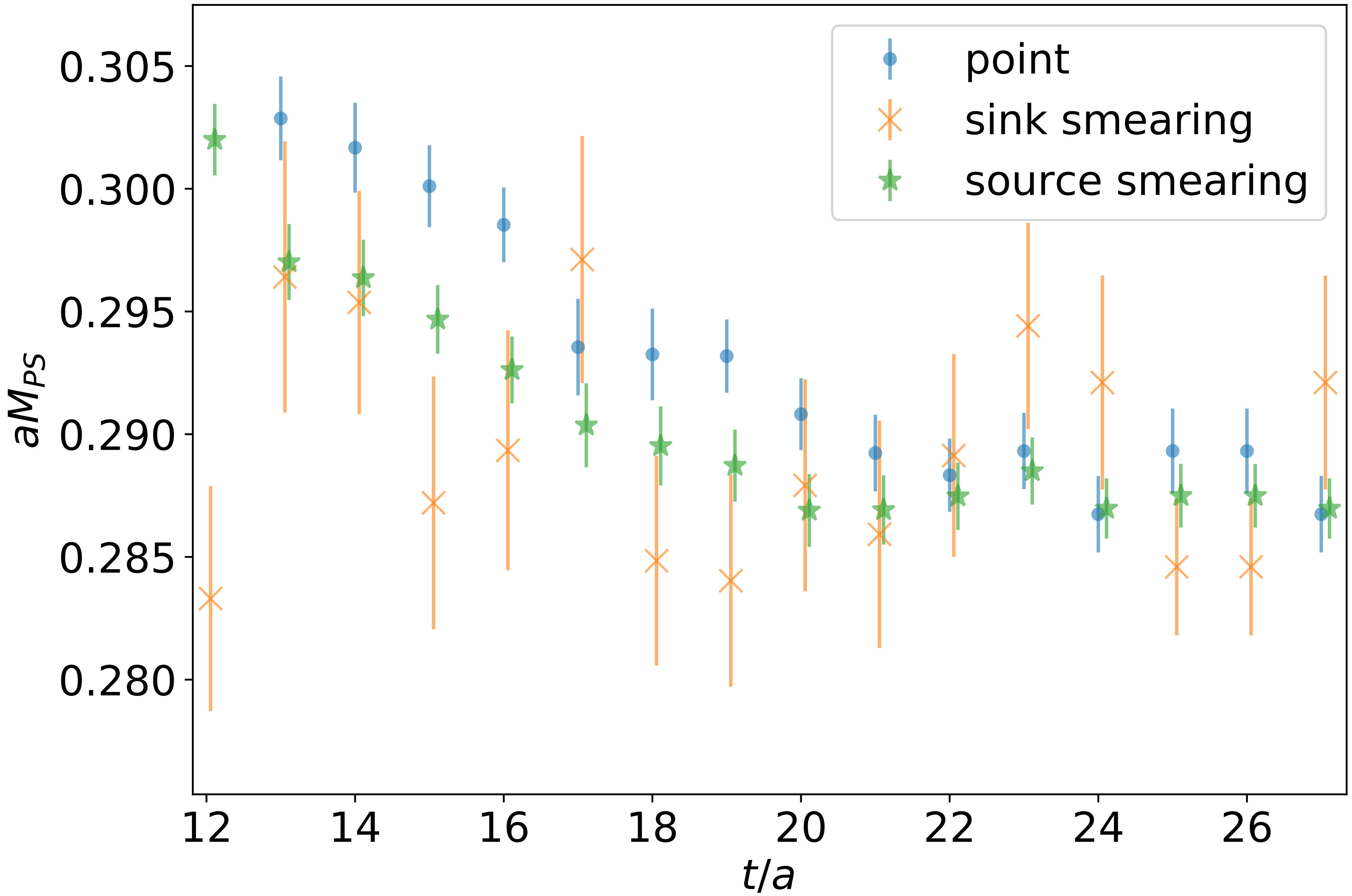
fix $t_1 = 0$

$$C(t) = \begin{pmatrix} c_{VV}(t) & c_{VT}(t) \\ c_{TV}(t) & c_{TT}(t) \end{pmatrix}$$

$$E_n(t) = \cosh^{-1}\left[\frac{\lambda_n(t+1)+\lambda_n(t-1)}{2\lambda_n(t)}\right]$$

Results

Smearing effects — errors and plateau

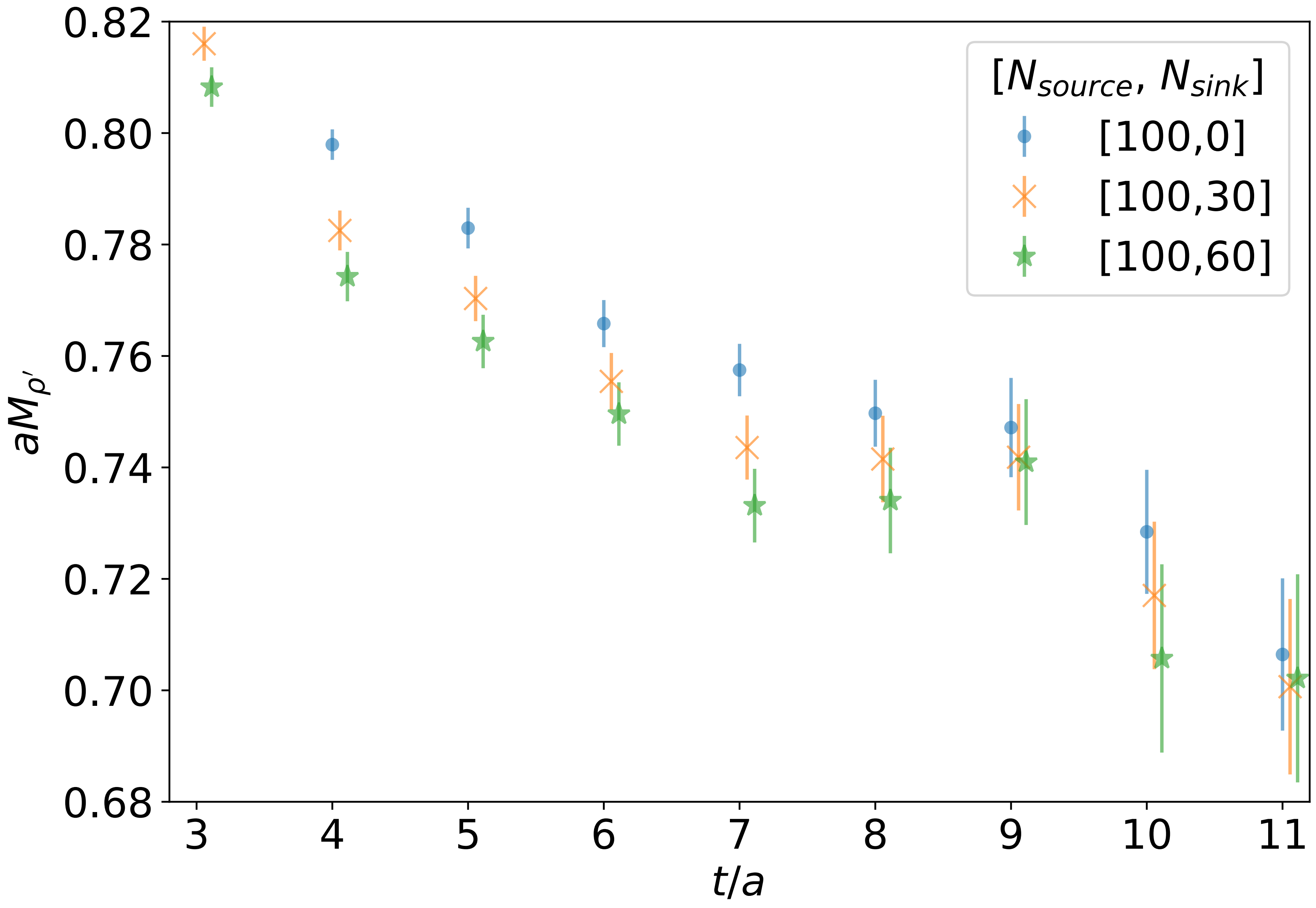


Effective mass plot for pseudoscalar meson with different kind of smearing

- ➡ Error: source smearing < point < sink smearing
- ➡ Earlier and longer plateau with smearing

Techniques

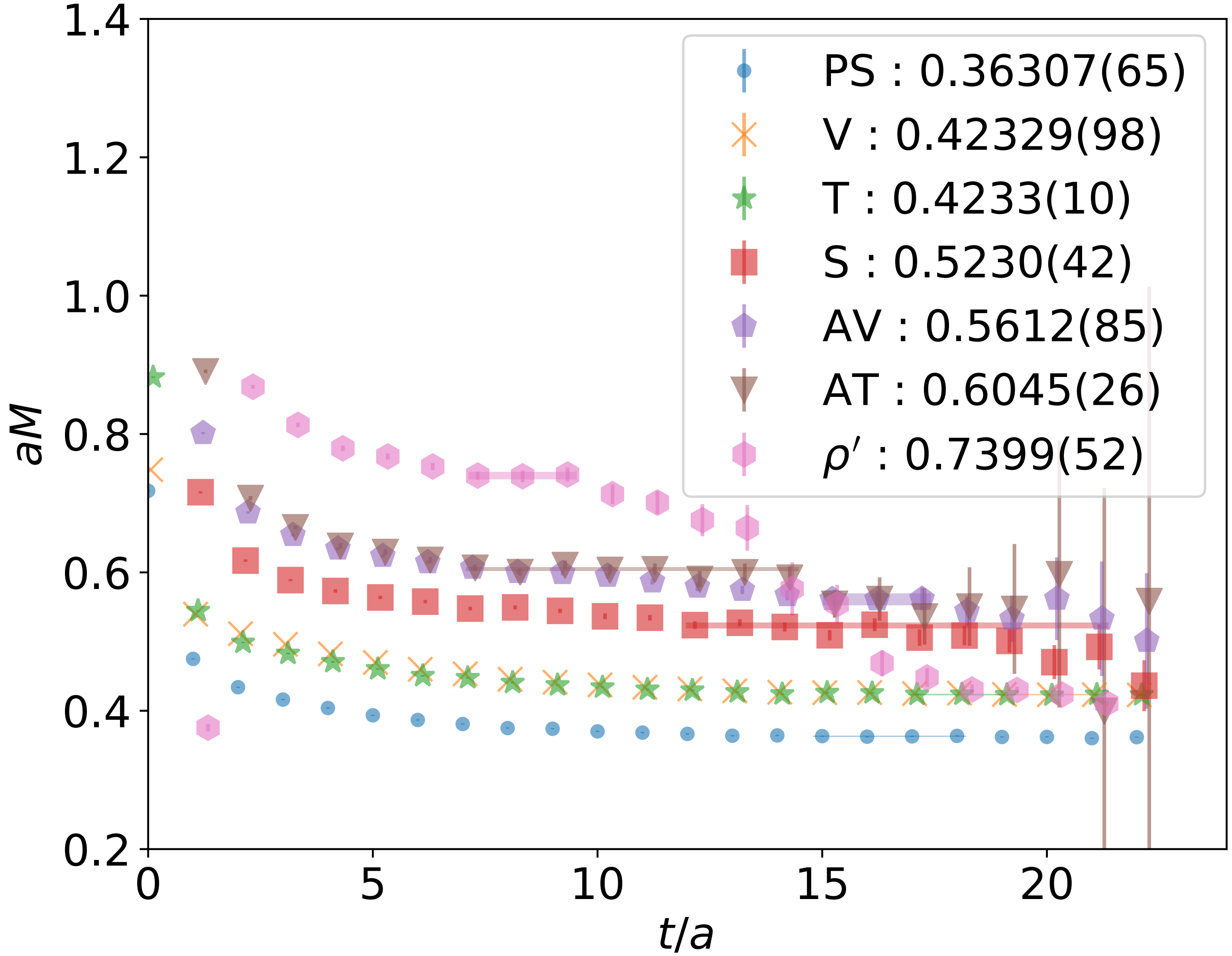
Smearing effects — excited state



Sink smearing effects on excited state.

Results

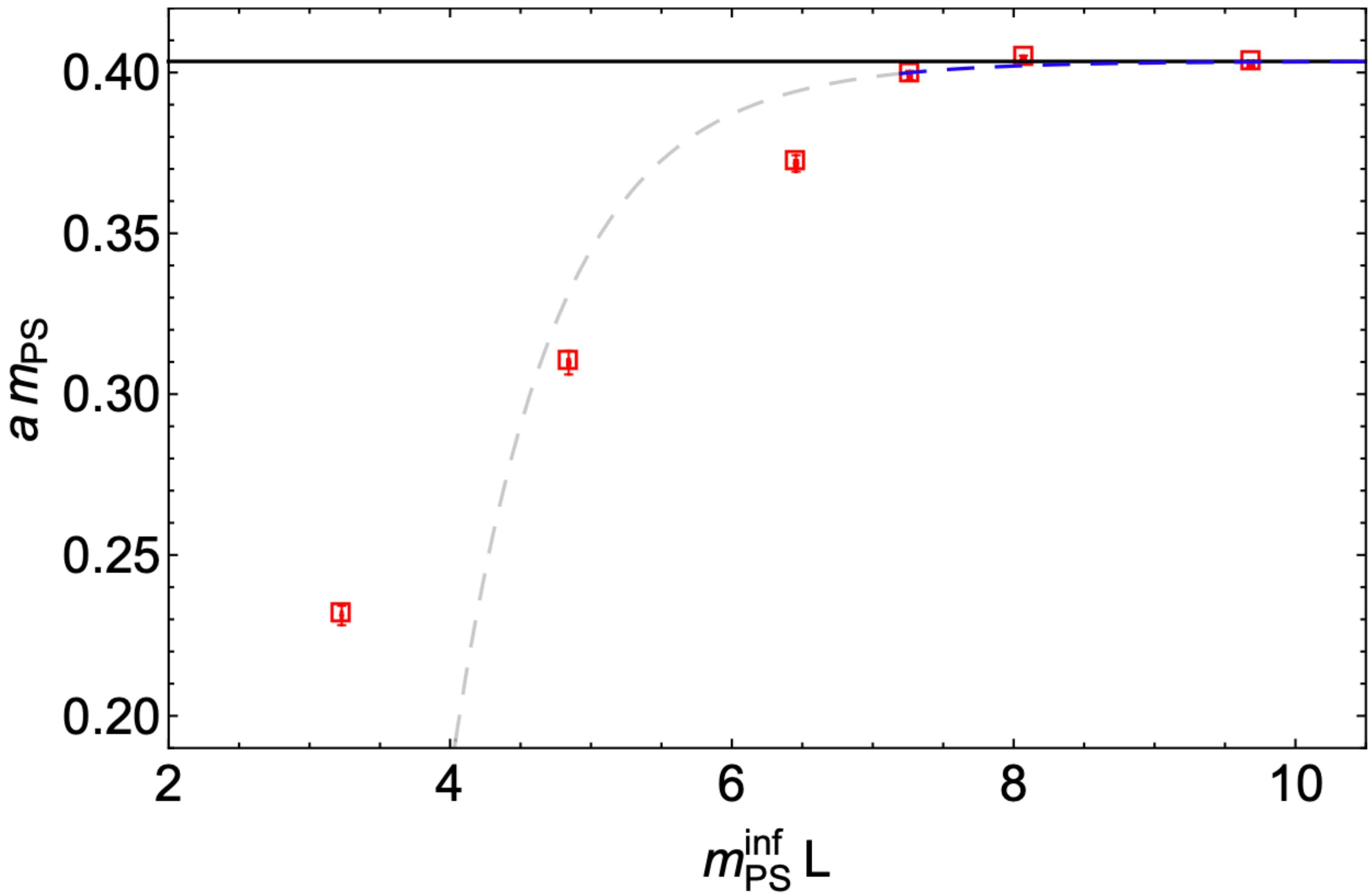
Spectrum



Effective masses plot measured from 48×24^3 lattice. The lattice parameters used for the calculation are $\beta = 6.7$ and $m_0 = -1.06$.

Results

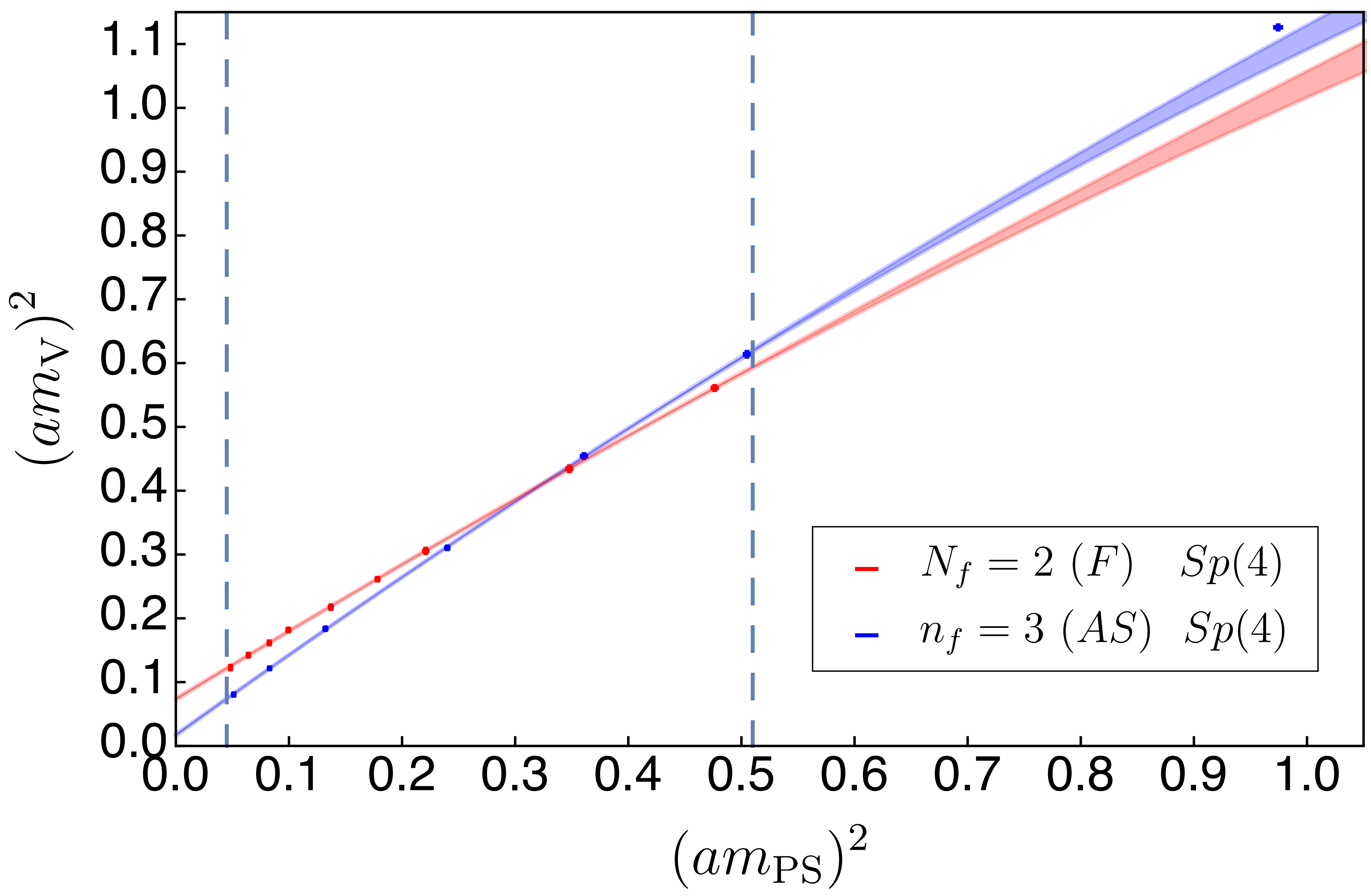
Finite volume correlation



The lattice parameters used for the calculation are $\beta = 6.8$ and $m_0 = -1.03$. The pseudoscalar mass at the infinite volume is estimated by taking the one measured at the largest volume of 54×24^3.

Results

Massless extrapolation



m_{PS}/m_V

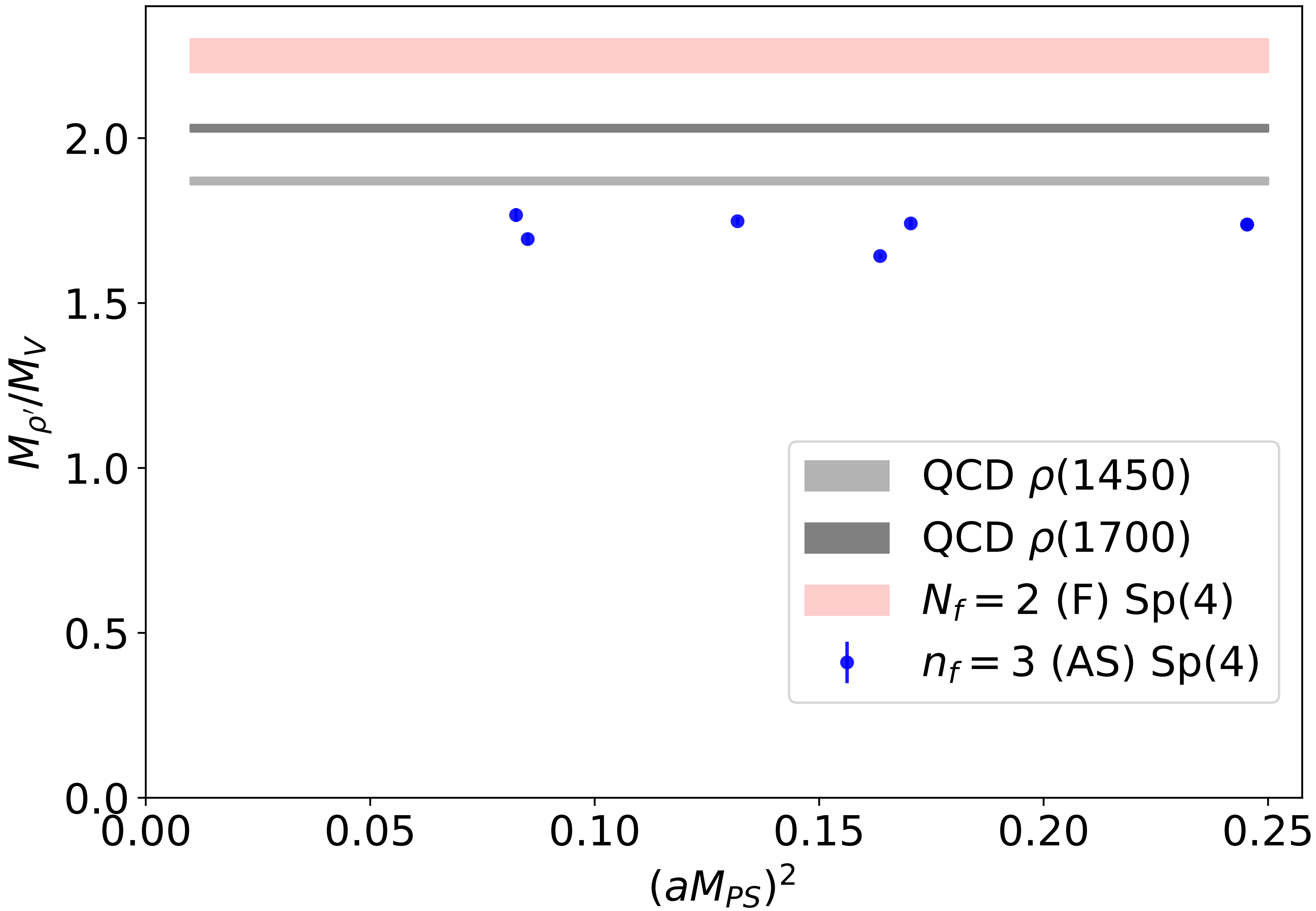
0.63 ~ 0.92

0.8 ~ 0.93

The massless extrapolations obtained with fixed beta values, which are 7.2 and 6.7 for fundamental and antisymmetric representation respectively. The dash lines refer to the fit range.

Results

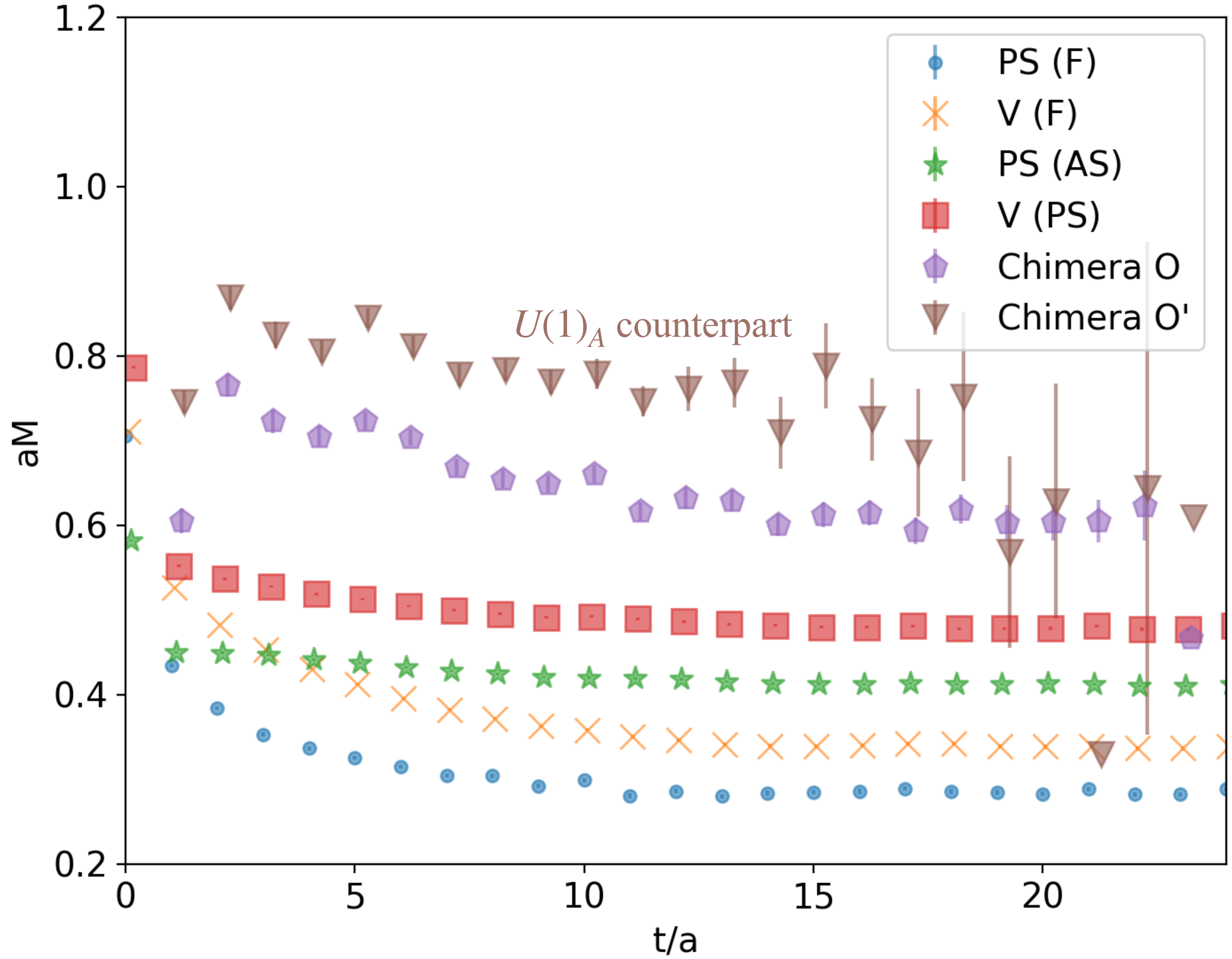
The ratio $R_{\rho'/\rho}$



The plot of ratio $R_{\rho'/\rho}$ against $(aM_{ps})^2$. The blue dots are in antisymmetric representation. The red band represents our ongoing results of the ratio in fundamental representation.

Results

Partially quenched Chimera Baryon

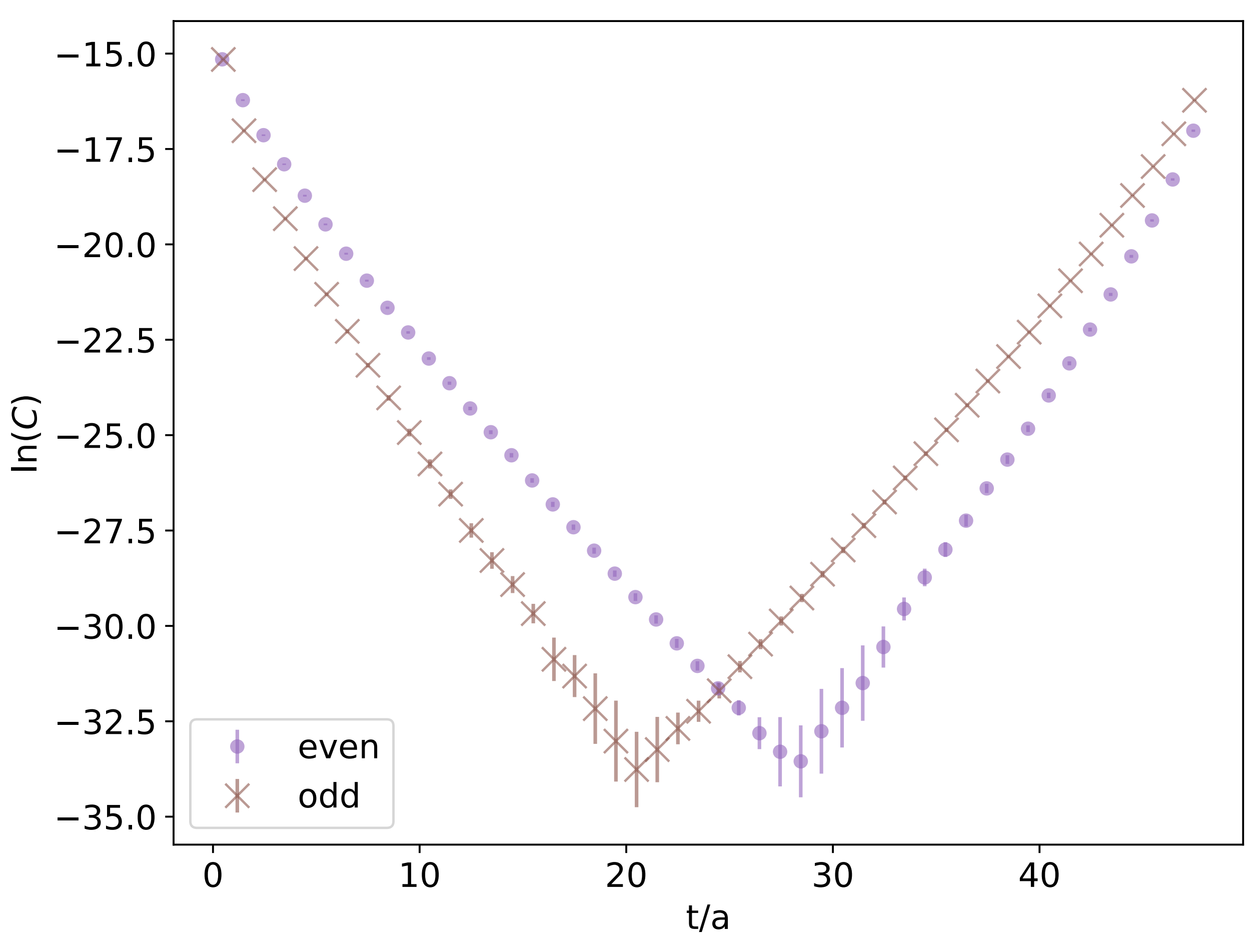


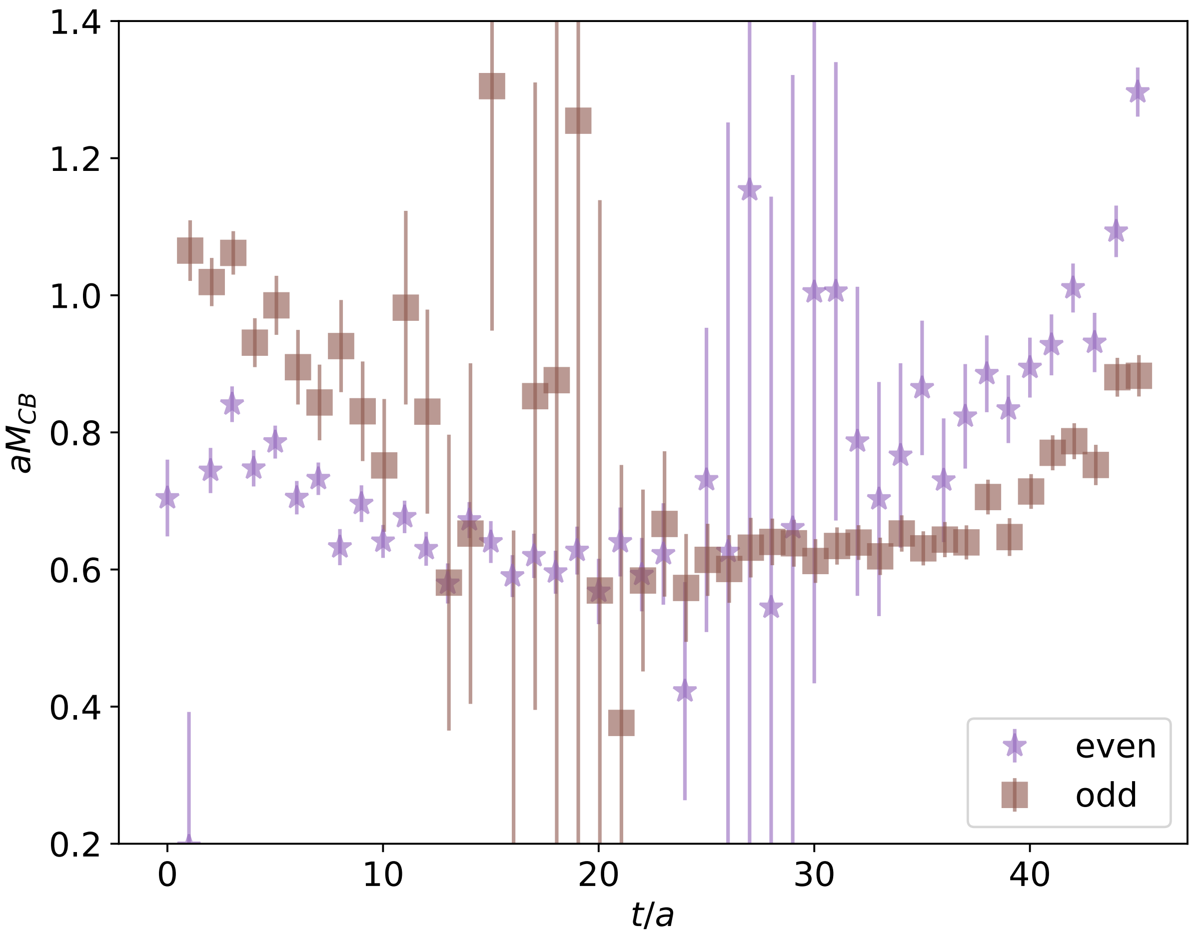
Effective masses plot measured from 48×24^3 lattice with dynamical antisymmetric fermion. The parameters used for the calculation are $\beta = 6.65$ and $m_0 = -1.07$. We control the ratio of M_{PS}/M_V having close value in two representations, where the quenched fundamental bare mass is $m_F = -0.734$.

Results

Partially quenched Chimera Baryon

- Parity projection $P = \frac{1}{2}(1 \pm \gamma_0)$





The log plot of the chimera baryon correlators (left) and their effective mass plot (right) with the parity projection.

Summary and Outlook

- We examine the finite volume corrections by computing $M_{PS}L$. In our study, we control the value being larger than 8.
- Discrepancy in the massless extrapolation of $(aM_V)^2$ against $(aM_{PS})^2$. The continuum extrapolations will be our future work.
- The ratio of M_ρ and $M_{\rho'}$ is about 1.7 in antisymmetric representation. In fundamental representation, it is around 2.2. Compare to QCD resonances, the former is slightly below, and the later is above it.
- We present our exploratory results of the chimera baryon spectrum with partially quenched setup. In the future, we plan to measure the chimera baryon in fully dynamical mix representation ensembles.

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