Scaling properties of fully-twisted quarks on a non-perturbatively $O(a)$ improved Wilson sea

Gregorio Herdoíza, Carlos Pena, David Preti, José Ángel Romero, **Javier Ugarrio***
Departamento de Física Teórica and IFT UAM-CSIC, Universidad Autónoma de Madrid, Madrid (Spain)

Introduction

Motivation: introduce twisted-mass QCD valence sector on non-perturbatively $O(a)$ improved Wilson sea, in order to optimize scaling properties of heavy quark observables from automatic $O(a)$ improvement.

This work:

- Set up valence sector by matching to light physics in the sea.
- Study scaling of simple light-sector observables to quantify relative cutoff effects between sea and valence, and explore scaling potential of mixed-action approach.

Setup

Mixed action with:

- sea: CLS $N_f = 2+1$ non-perturbatively $O(a)$-improved Wilson with open boundary conditions [1].
- valence: tmQCD action given by [2]

$$D_{tm} = \frac{1}{2}\gamma_\mu(\nabla^*_\mu + \nabla_\mu) - \frac{a}{2}\nabla^*_\mu\nabla_\mu + \frac{i}{4}ac_{SW}\sigma_{\mu\nu}F_{\mu\nu} + \mathbf{m} + i\boldsymbol{\mu}\gamma_5$$

$$\mathbf{m} = m_{\rm cr}\mathbf{1}$$

$$\boldsymbol{\mu} = \mathrm{diag}(\mu_u, -\mu_d, -\mu_s, \mu_c)\,,\ \mu_u = \mu_d$$

Main advantage: automatic $O(a)$ improvement up to (small) $O(ag_0^4(m_u+m_d+m_s))$ sea effects.

We follow the chiral trajectory defined in [3] defined by

$$\phi_4 = 8t_0\left(m_K^2 + \frac{1}{2}m_\pi^2\right) = \text{const.}$$

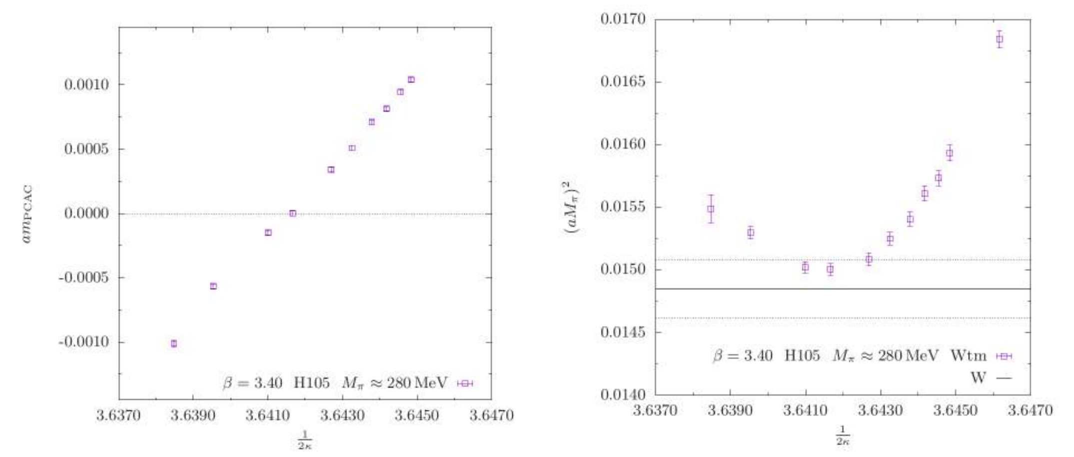
Small mistunings of simulation parameters corrected by shifting observables as proposed in [3].

$$f(m') \to f(m) + (m'-m)\frac{d}{dm}f(m)$$

Matching [talk by JA Romero on Friday]

Sea-valence matching prescription:

1. Tune light sector to maximal twist, $m_{ud}^{\rm val} = 0$.
2. Impose u, d renormalized quark masses equal in sea and valence: $\mu_u = Z_A m_{ud}^{\rm sea}$

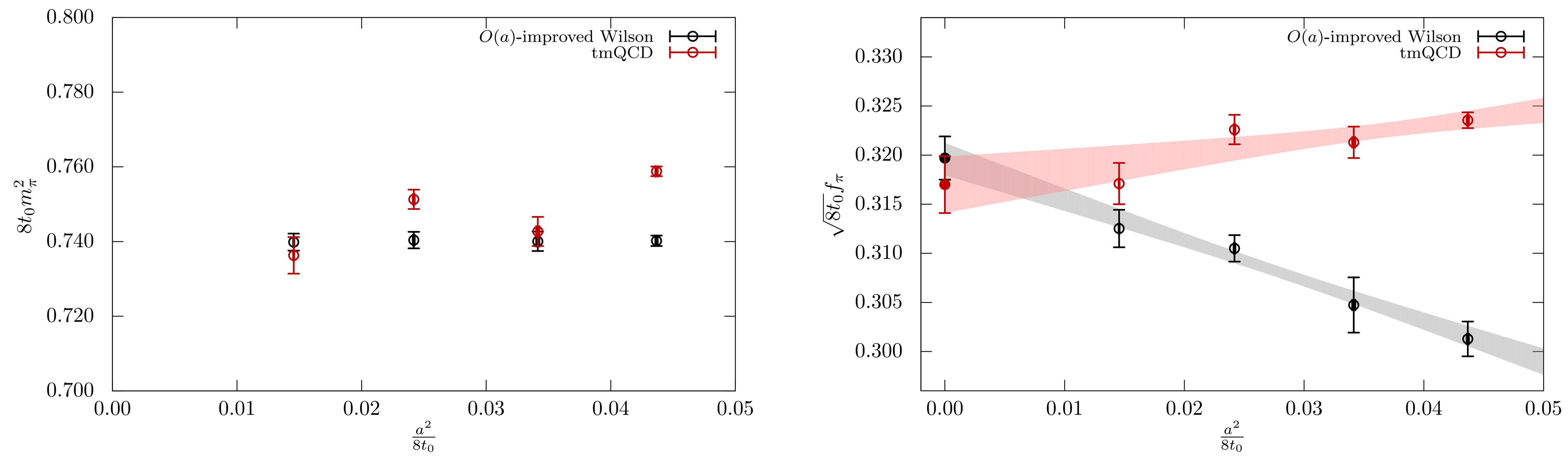


Results

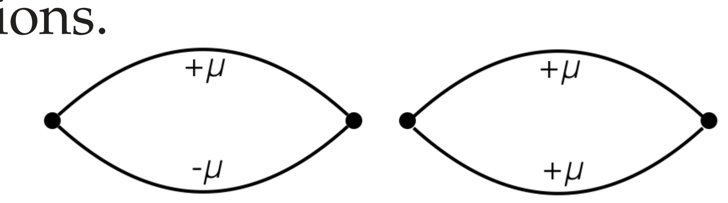
Pion masses and decay constants computed from pseudoscalar density two-point function and PCVC:

$$f_\pi = \frac{2\mu_u}{m_\pi}|\langle 0|P|\pi\rangle|\,, \quad \sqrt{\frac{f_P(x_0,y_0)f_P(x_0,T-y_0)}{f_P(T-y_0,y_0)}} \approx |\langle 0|P|\pi\rangle| + \text{excited states}$$

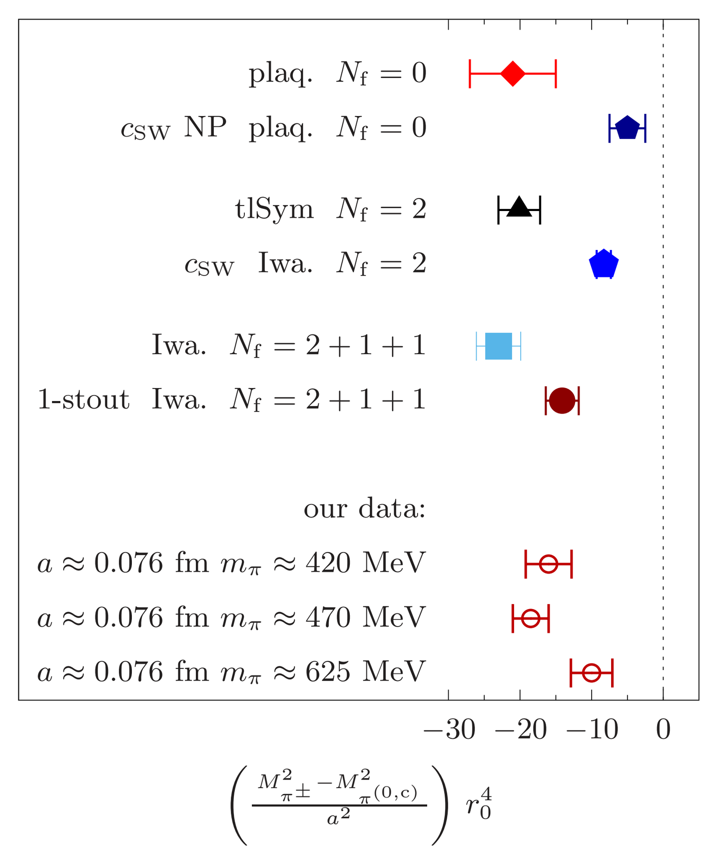
Results for $\phi_4 \simeq 1.11$, $m_\pi = m_K$ compared to results in [3]:



tmQCD-induced isospin breaking can be quantified through the mass difference between charged and neutral pions, keeping only the contribution to the latter from connected Wick contractions.



Comparison with summary from [4]:



Conclusions and outlook

Conclusions:

- m_π shows small valence-sea deviations, reflecting small $O(a^2)$ residual effects from matching.
- f_π shows $\lesssim 10\%$ relative valence-sea difference very good $O(a^2)$ scaling to continuum limit.
- f_π scaling better in valence sector (CL extrapolation has slope $\sim 70\%$ smaller.
- Isospin breaking effects in similar ballpark as other tmQCD studies.

Next steps:

1. Study $O(a^2)$ effects in twist angle for strange and charm + relative valence-sea effects for $m_K \neq m_\pi$.
2. Study charm sector.

References

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[2] C. Pena, S. Sint, and A. Vladikas *JHEP*, vol. 09, p. 069, 2004.

[3] M. Bruno, T. Korzec, and S. Schaefer *Phys. Rev.*, vol. D95, no. 7, p. 074504, 2017.

[4] G. Herdoiza, K. Jansen, C. Michael, K. Ottnad, and C. Urbach *JHEP*, vol. 05, p. 038, 2013.

Acknowledgments

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