First results for charm physics with a tmQCD valence action

Javier Ugarrio

Andrea Bussone[1], Gregorio Herdoíza, Carlos Pena, David Preti, José Ángel Romero[2]

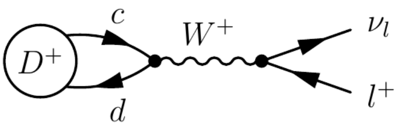
IFT, UAM-CSIC

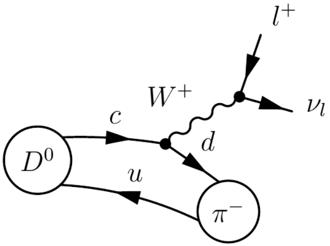
Lattice 2018, East Lansing, MI, USA

[1] Previous talk
[2] Poster

Introduction

- Setup: Mixed action approach
  - $\mapsto$ Wilson CLS $N_f = 2 + 1$ ensembles [1411.3982; 1608.08900]
  - $\mapsto$ Wilson twisted mass $N_f = 2 + 1 + 1$ valence[3] [1711.06017]
- Flavor changing processes in charm sector
- Leptonic and semi-leptonic decays in charm sector





[3] Poster by J. A. Romero

Sea Sector – CLS ensembles

[Bruno et al., 1411.3982; Mohler et al., 1712.04884]

- Lattice action
  - ↦ Tree-level improved Lüscher-Weisz gauge action
  - ↦ Wilson fermions ($N_f = 2 + 1$) with non-perturbative c_{SW}
- Open boundary conditions in time
  - ↦ Topological charge flows through the lattice [Lüscher, 1009.5877; Lüscher and Schaefer, 1105.4749]
  - ↦ Avoid topological freezing
  - ↦ Reaching small lattice spacings crucial for heavy quark physics
- Lattice spacings:

$$a = 0.087,\ 0.077,\ 0.065,\ 0.050,\ 0.039\ \mathrm{fm}$$

Valence Sector – Wilson twisted mass [ALPHA, hep-lat/0101001; Frezzotti and Rossi, hep-lat/0306014; Pena et al., hep-lat/0405028]

- Valence action

$$D_{tm} = \frac{1}{2}\gamma_\mu(\nabla^*_\mu + \nabla_\mu) - \frac{a}{2}\nabla^*_\mu\nabla_\mu + \frac{i}{4}ac_{\rm SW}\sigma_{\mu\nu}F_{\mu\nu} + \mathbf{m^0} + i\boldsymbol{\mu}^{\mathbf{0}}\gamma_5$$

- At maximal twist $(\omega = \pi/2)$

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

$$\boldsymbol{\mu} = {\rm diag}(\mu_l, -\mu_l, \pm\mu_s, \mp\mu_c)$$

- Matching light sector[4] $\quad m_P^2\big|_{\rm v} = m_P^2\big|_{\rm s}, \qquad P = \pi,\, K$
  - $\mapsto \quad \phi_2\big|_{\rm v} = 8t_0\; m_\pi^2\big|_{\rm v} \equiv \phi_2\big|_{\rm s}$
  - $\mapsto \quad \phi_4\big|_{\rm v} = 8t_0\left(\frac{1}{2}\; m_\pi^2\big|_{\rm v} + m_K^2\big|_{\rm v}\right) \equiv \phi_4\big|_{\rm s}$
- Renormalized chiral trajectory [Bruno, Korzec, Schaefer, 1608.08900]
  - $\mapsto \quad {\rm tr}M = {\rm const} \to \phi_4 = {\rm const}$

[4] Poster by J.A. Romero

Technical implementations

- Smearing
  - ↦ heavy-light correlators: signal to noise problem
  - ↦ non-local (in space) interpolating fields
  - ↦ increase plateau length
- Distance Preconditioning[5]
  - ↦ heavy propagators
  - ↦ accurate inversion at large Euclidean time

[5] Talk by A. Bussone

Smearing[6]

Wuppertal + APE

[Alexandrou et al., Phys.Lett. B256 (1991) 60-67; Albanese et al., Phys. Lett. B 192, 163 (1987)]

$$(\Phi\psi)_{\boldsymbol{x}} = \frac{1}{1+2d\varepsilon}\left[\psi_{\boldsymbol{x}} + \varepsilon \sum_{j=\pm 1}^{\pm d} U'_{\boldsymbol{x},j}\psi_{\boldsymbol{x}+\hat{\boldsymbol{j}}}\right]$$

$$U'_j(x) = \mathrm{P}_{SU(3)}\left[(1-\epsilon)U_j(x) + \epsilon \sum_{k\pm 1}^{\pm d} S_{j,k}\right]$$

Gradient Flow $(d=3)$

[Lüscher,1006.4518; 1302.5246]

$$\chi(t+\varepsilon,x) = (1-2d\varepsilon)\chi(t,x) + \varepsilon \sum_{j=\pm 1}^{\pm d} V_j(t,x)\chi(t,x+\hat{j});\ \chi(0,x) = \psi(x)$$

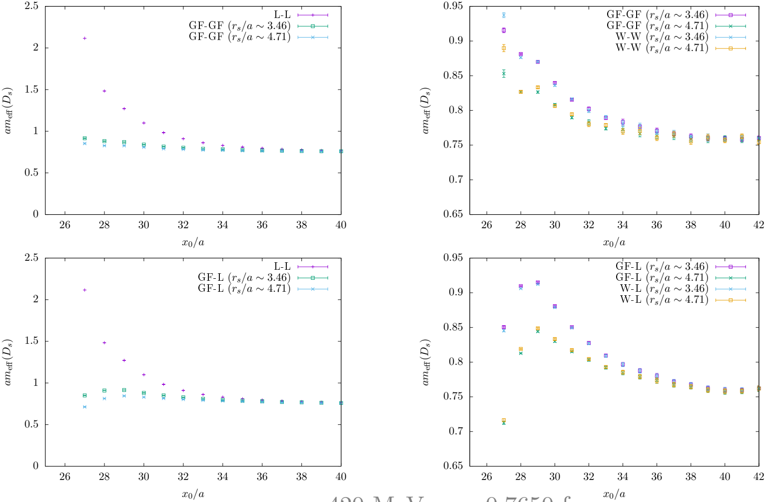
$$V_j(t+\varepsilon,x) = \exp\{-g_0^2\varepsilon\partial_{x,\mu}S_W(V)\}V_j(t,x);\ V_j(0,x) = U_j(x)$$

[6] talk by A. Bussone

Smearing

$$r_s^2 = 2dt = 2dn\varepsilon/(1 + 2d\varepsilon)$$

PRELIMINARY

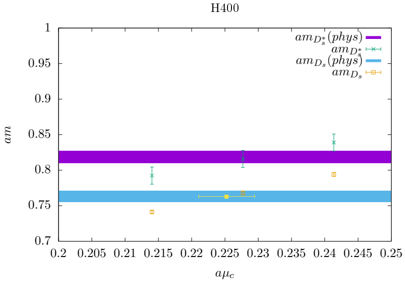


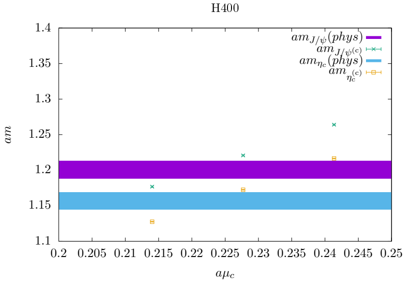
$m_\pi = m_K = 420$ MeV; $a = 0.7650$ fm

Tuning of m_{charm}

- tune $a\mu_c$ such that $\mathcal{O}_c = \mathcal{O}_c^{\text{phys}}$, $\mathcal{O}_c = m_{D_{(s)}}, m_{D^*_{(s)}}, \ldots$
- Tuning $\mu_c \to m_{D_s} \equiv m_{D_s}^{\text{phys}}$
- $m_\pi = m_K = 420$ MeV

PRELIMINARY



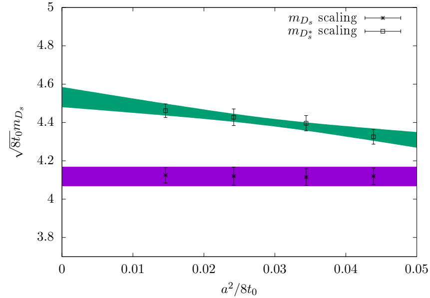


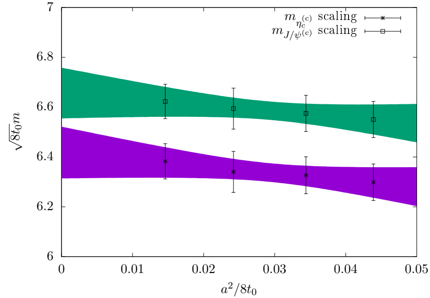
$a\mu_c \simeq 0.215$ – input from FLAG

$a = 0.7650$ fm

Tuning of m_{charm}

PRELIMINARY

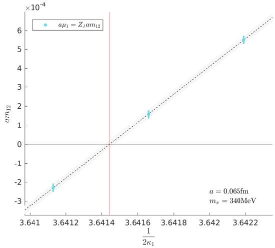




$m_\pi = m_K = 420$ MeV

Tuning of m_{charm}

- Tuning to maximal twist in the light sector[7] $m_{l\,l'} = 0 \leftrightarrow \omega \to \pi/2$



- Charm sector: relative cutoff effects $O(a)$ in the twist angle ω_c

$$m_{c\,c'} = \frac{\partial_0 f_A^{c\,c'} + a c_A \partial_0^2 f_P^{c\,c'}}{2 f_P^{c\,c'}}$$

$$\cot \omega_c = \frac{Z_A m_{c\,c'}}{\mu_c}$$

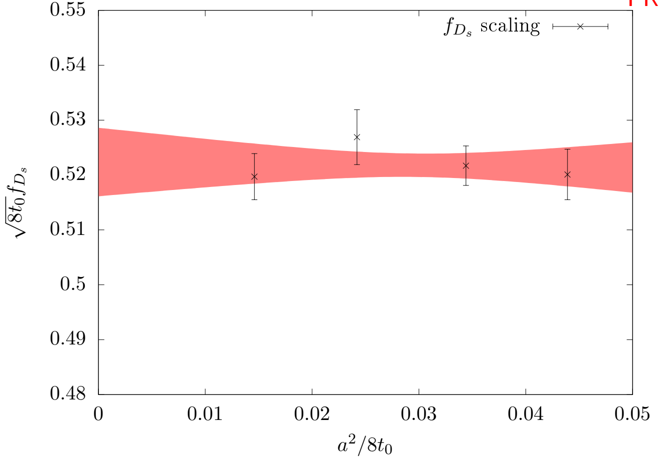
[Bulava et al., 1502.04999; Dalla Brida et al., in preparation]

- $(\omega_c - 90^\circ) \lesssim 8^\circ$

[7] Poster by J. A. Romero

Results: Continuum limit scaling of f_{D_s}

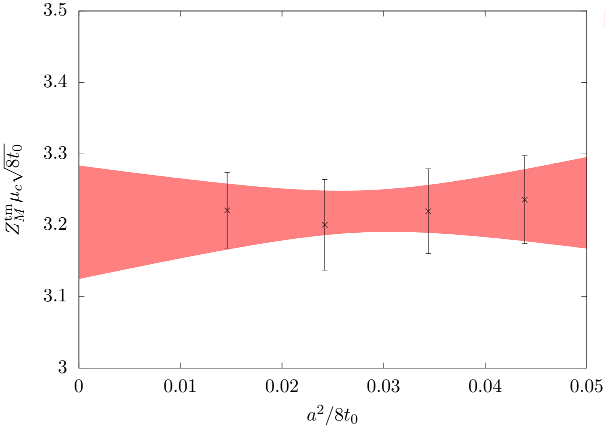
PRELIMINARY



$m_\pi = m_K = 420$ MeV

For a CLS study with Wilson fermions, see [Collins et al., 1711.08657]

Results: Continuum limit scaling of RGI charm quark mass



PRELIMINARY

$m_\pi = m_K = 420$ MeV

Renormalization and running of quark mass [ALPHA, 1802.05243]

Conclusions and Outlook

- Conclusions
  - ↦ Implementations of gradient flow smearing
  - ↦ Tuning of the charm mass quark m_{D_s}
  - ↦ Smooth continuum limit scaling of charm observables m_c, M, f_{D_s}
  - ↦ Promising accuracy of Wtm observables
- Outlook
  - ↦ Tuning of the charm quark mass: Spin-flavor average of meson masses
  - ↦ Ensembles outside the symmetric point (ongoing)
  - ↦ Chiral behaviour
  - ↦ GEVP analysis
  - ↦ Semileptonic observables

First results for charm physics with a tmQCD valence action

Javier Ugarrio

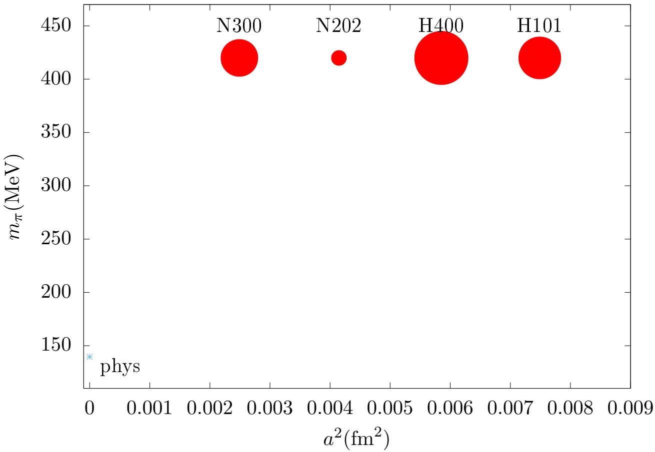
Andrea Bussone[8], Gregorio Herdoíza, Carlos Pena, David Preti, José Ángel Romero[9]

IFT, UAM-CSIC

Lattice 2018, East Lansing, MI, USA

[8] Previous talk
[9] Poster

Ensembles



N300
N202
H400
H101
phys
450
400
350
300
250
200
150
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
m_π(MeV)
a^2(fm^2)