Light meson physics and scale setting from a mixed action with Wilson twisted mass valence quarks

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ALPHA Collaboration

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mixed action

- setup : mixed action with Wilson twisted mass (Wtm) valence quarks
  on CLS $N_f = 2 + 1$ ensembles

motivation :

- alternative/complementary way to control lattice artefacts
  $\rightsquigarrow$ universality
- target : leptonic and semi-leptonic decays in the heavy-quark sector

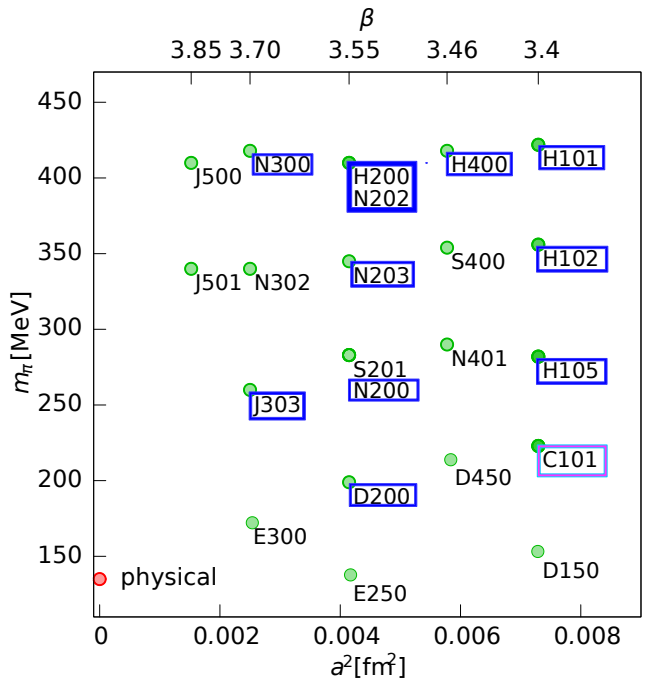
  see talks by Alessandro Conigli [Thu.,5:45] & by Julien Frison [Thu.,14:15]

- this work : light-quark sector
  $\rightsquigarrow$ sea/valence matching, scale setting, quark masses

sea sector: $N_f = 2+1$ CLS [1411.3982, 1608.08900, 1712.04884]

- lattice action:
  - gauge action: Lüscher-Weisz gauge action (tlSym)
  - fermion action: $N_f = 2+1$ Wilson fermions with non-perturbative c_{sw}
- open boundary conditions in time
  - connected topological sectors $\rightsquigarrow$ smooth flow of topological charge
    [Lüscher, 1009.5877; Lüscher & Schaefer, 1105.4749]
  - relevant for heavy-quark physics
- lattice spacings: $a \approx$ 0.087, 0.077, 0.065, 0.050, 0.037 fm

$M_\pi L \geq 3.9$



based on [1712.04884]

see talks by Wolfgang Soeldner [Tue.,13:00] & by Ben Strassberger [Fri.,7:00]

chiral trajectory : $N_f = 2+1$

$$M_q = \mathrm{diag}\,(m_{q\,u}, m_{q\,d}, m_{q\,s})$$

$$\mathrm{tr}\, M_q \;=\; m_{q\,u} + m_{q\,d} + m_{q\,s} \;=\; \text{const.}$$

- constant $O(a\,\mathrm{tr} M_q)$ cutoff effects

renormalised chiral trajectory [Bruno, Korzec, Schaefer, 1608.08900]

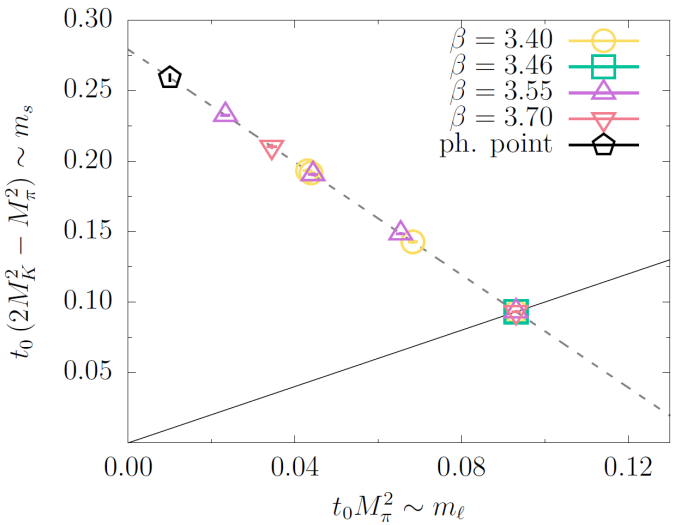
$$\phi_4 \;\equiv\; 8t_0\left(\tfrac{1}{2}M_\pi^2 + M_K^2\right) \;=\; \tfrac{1}{2}\phi_2 + \phi_K \;=\; \text{const} \;=\; \phi_4^{\mathrm{phys}}$$

- ϕ_4^{phys} is not known a priori

- small mass corrections of chiral trajectory through a Taylor expansion
- $O = f(\{A_i\})$ $\qquad \overline{A}_i = \langle A_i \rangle$

$$f(m') = f(m) + (m' - m)\frac{df}{dm}$$

$$\frac{df}{dm} = \sum_i \frac{\partial f}{\partial \overline{A}_i}\left[\left\langle \frac{\partial A_i}{\partial m}\right\rangle - \left\langle \left(A_i - \overline{A}_i\right)\left(\frac{\partial S}{\partial m} - \overline{\frac{\partial S}{\partial m}}\right)\right\rangle\right]$$



valence quarks: Wilson twisted mass

[ALPHA, hep-lat/0101001; Frezzotti and Rossi hep-lat/0306014, Pena et al., hep-lat/0405028]

- valence action

$$D_{\mathrm{Wtm}} \;=\; D_{\mathrm{W}}^{\mathrm{SW}} \;+\; m \;\pm\; i\gamma_5\mu$$

- maximal twist $\omega = \frac{\pi}{2}$:

$$m = m_{cr} \qquad\qquad \rightsquigarrow \quad m_{12}^{\mathrm{val}} = 0$$
$$\mu = \{\mu_{ud}, \mu_s, \mu_c\}$$

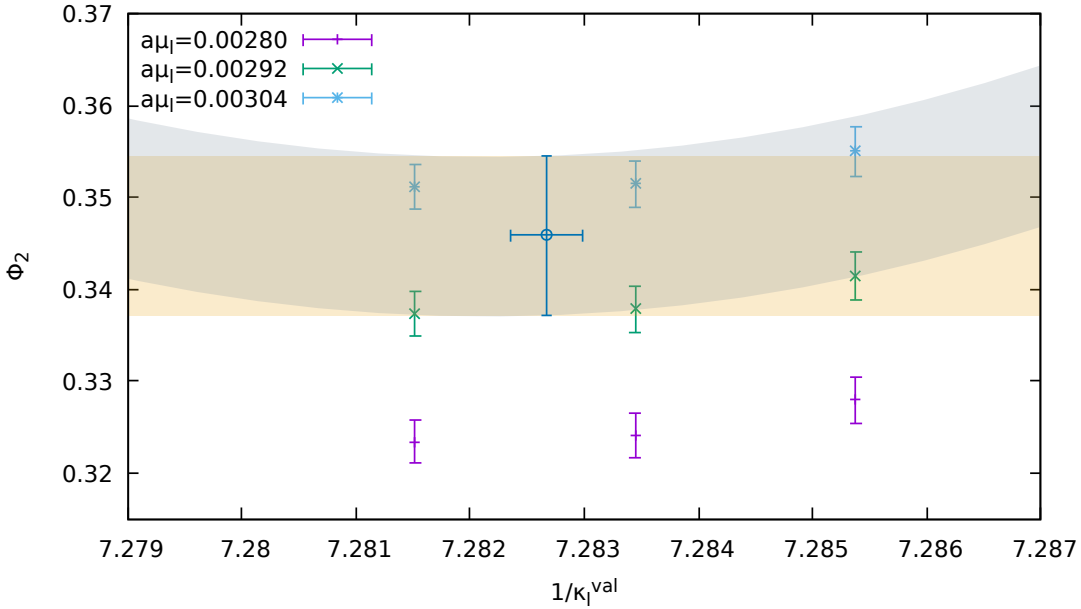
- properties :
  - absence of $\mathcal{O}(a\mu)$ lattice artefacts at maximal twist
  - μ acts as an infrared cutoff
  - valence flavour breaking cutoff effects $\rightsquigarrow$ SW term

- mixed action : match sea & valence quark masses (at maximal twist)

  performed using M_π and M_K after mass-shifts to renormalized chiral trajectory

  as a check, we use direct quark mass matching

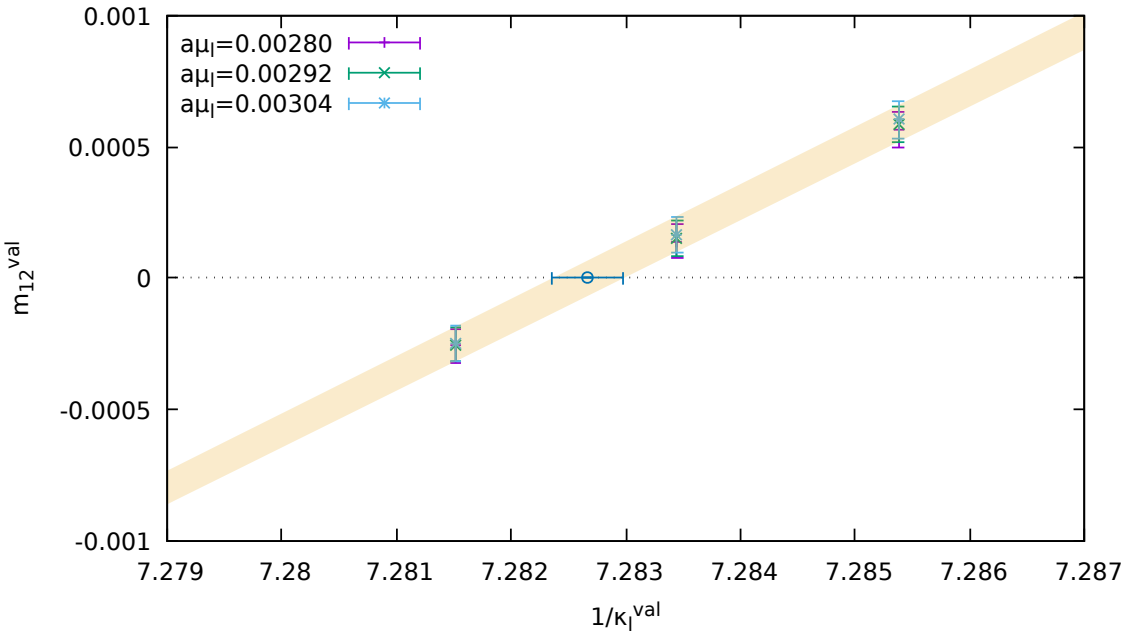
matching of mixed action



$$\phi_4 \equiv 8t_0\left(\frac{1}{2}M_\pi^2 + M_K^2\right) = 1.117(12)\ [1.1\%]$$

$$\phi_2 \equiv 8t_0 M_\pi^2$$

$$M_\pi^2 \propto \sqrt{\left(m_{12}^R\big|_v\right)^2 + \left(\mu_1^R\right)^2}$$



$a = 0.086$ fm

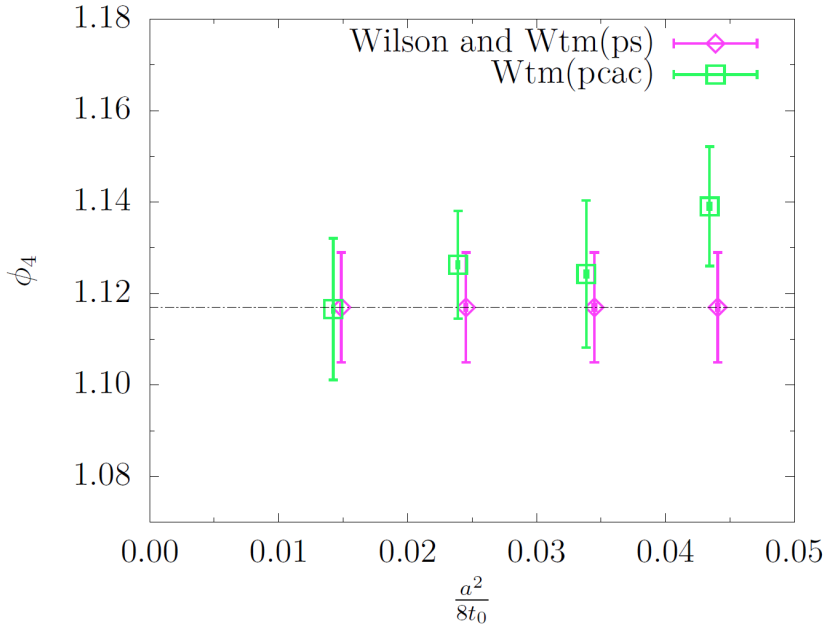
$M_\pi = 280$ MeV

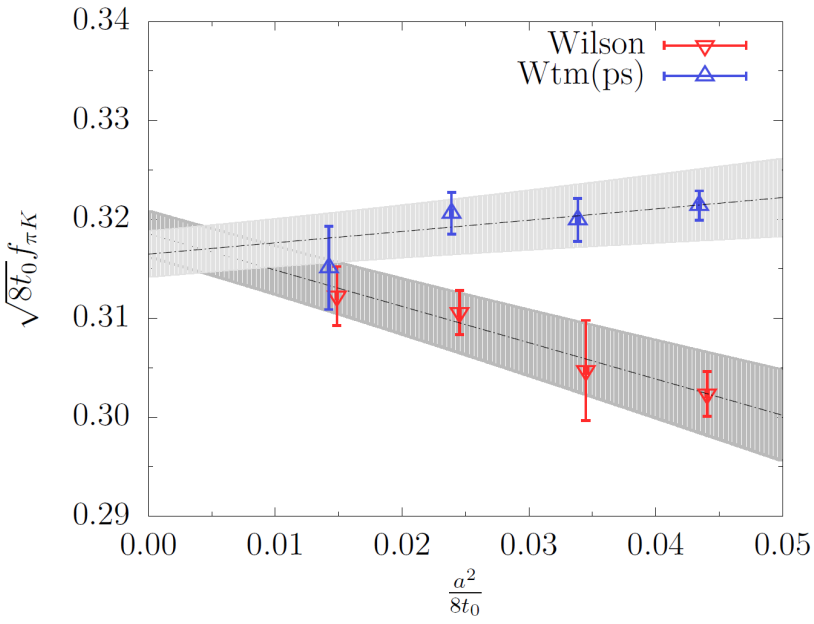
$M_\pi L = 3.9$

continuum-limit scaling

$$\phi_4 \equiv 8t_0\left(\tfrac{1}{2}M_\pi^2 + M_K^2\right)$$

$$f_{\pi K} \equiv \tfrac{2}{3}\left(\tfrac{1}{2}f_\pi + f_K\right)$$



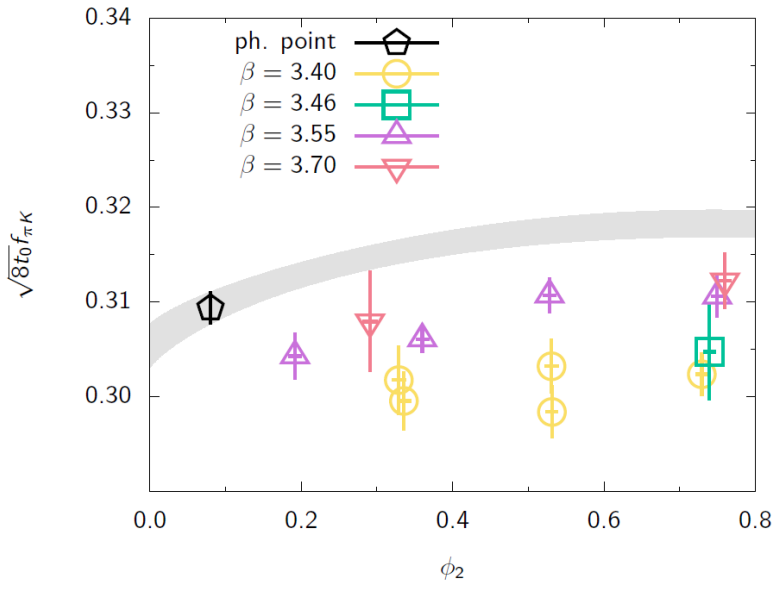


symmetric point: $m_\ell = m_s$, $M_\pi = M_K = 420\,\mathrm{MeV}$

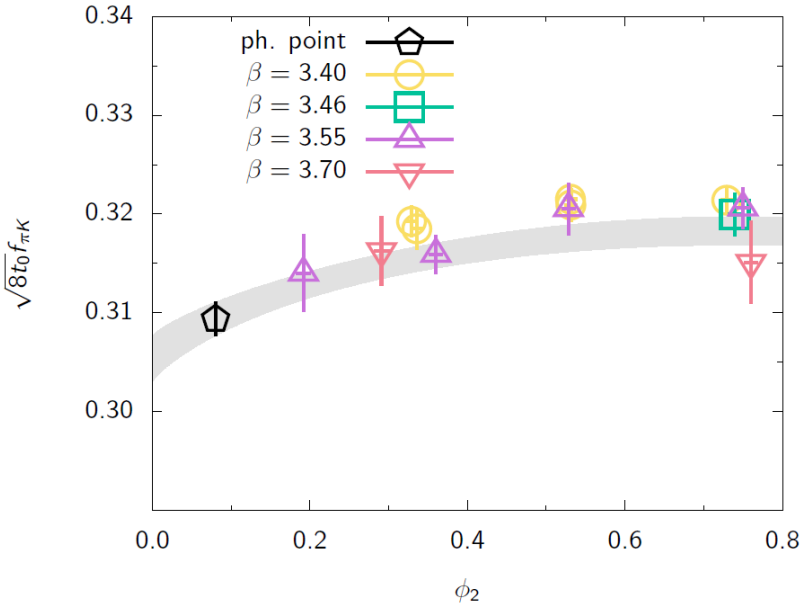
continuum-chiral extrapolation of $f_{\pi K}$

$$f_{\pi K} \equiv \frac{2}{3}\left(\frac{1}{2} f_\pi + f_K\right)$$

Wilson



Wilson twisted mass

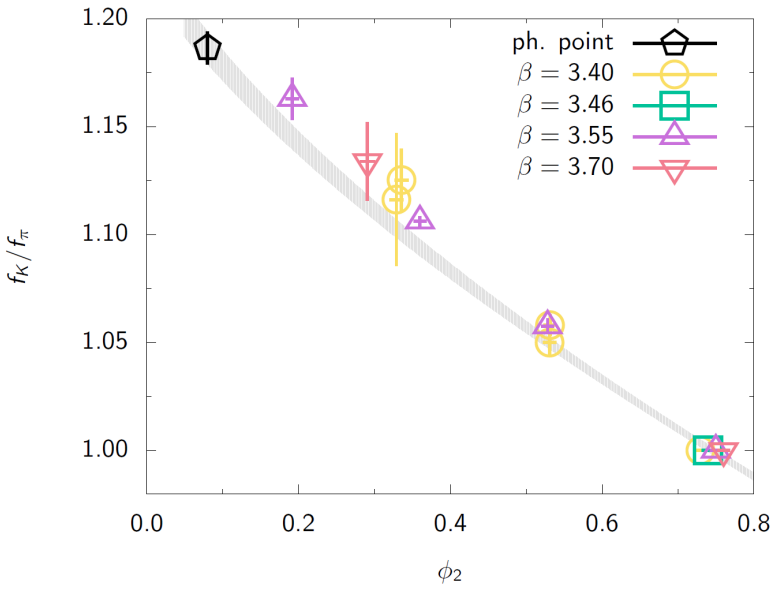


Systematic effects [ongoing] :

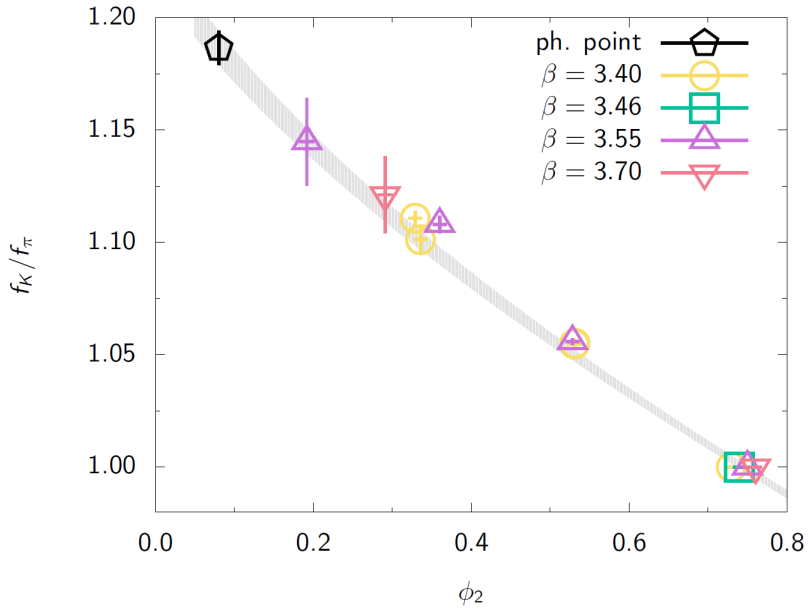
- SU(3) NLO χPT + Taylor series of f_π, f_K, f_K/f_π, $f_{\pi K}$
- cuts in M_π
- discretization effets: $O(a^2)$, $O(\phi_2 a^2)$
- excited states contamination

continuum-chiral extrapolation of f_K/f_π

Wilson



Wilson twisted mass



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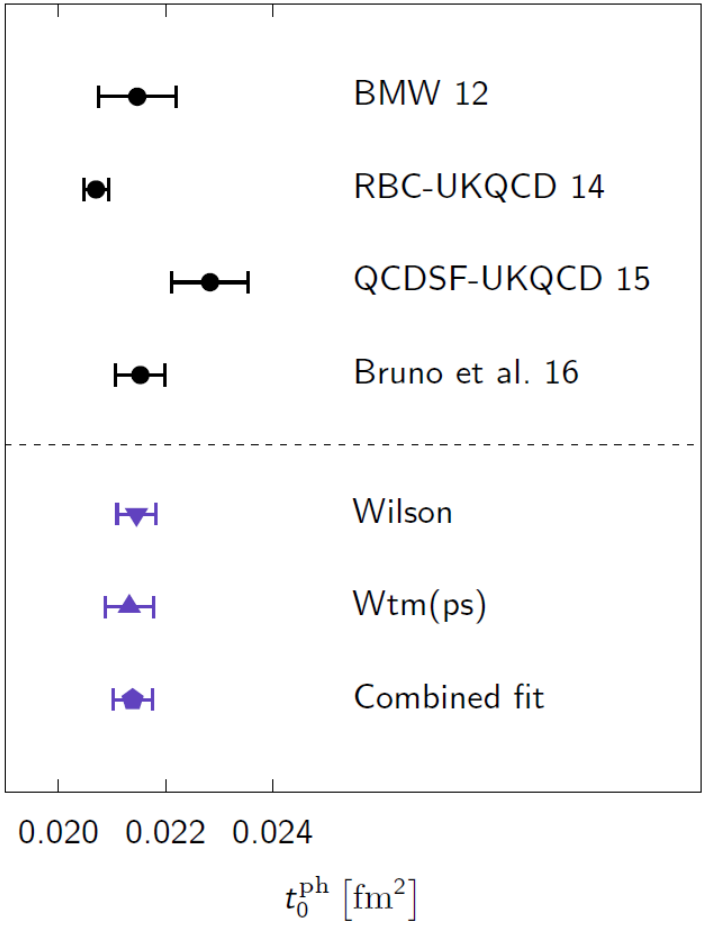
scale setting : t_0 $N_f = 2 + 1$ preliminary



$\sqrt{t_0}$ uncertainty : $\sim$ 1%

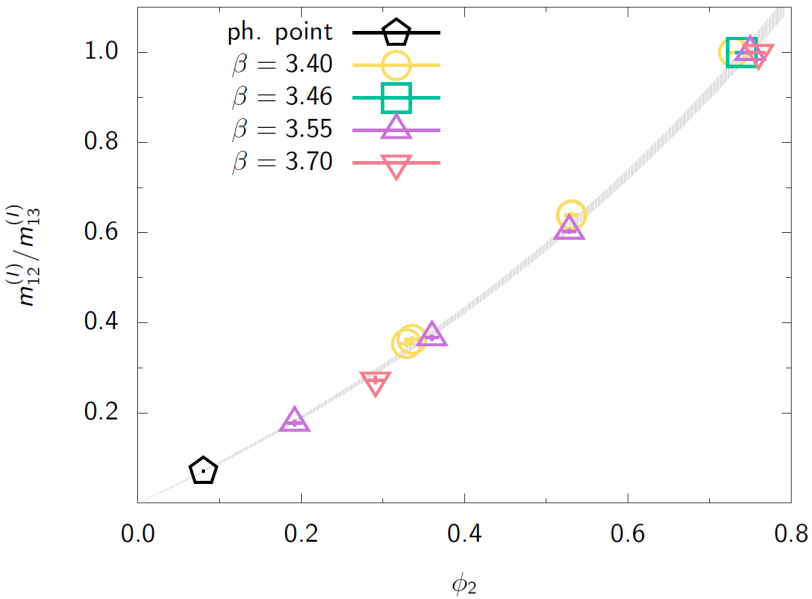
physical input : M_π, M_K, f_π, f_K [FLAG & PDG]

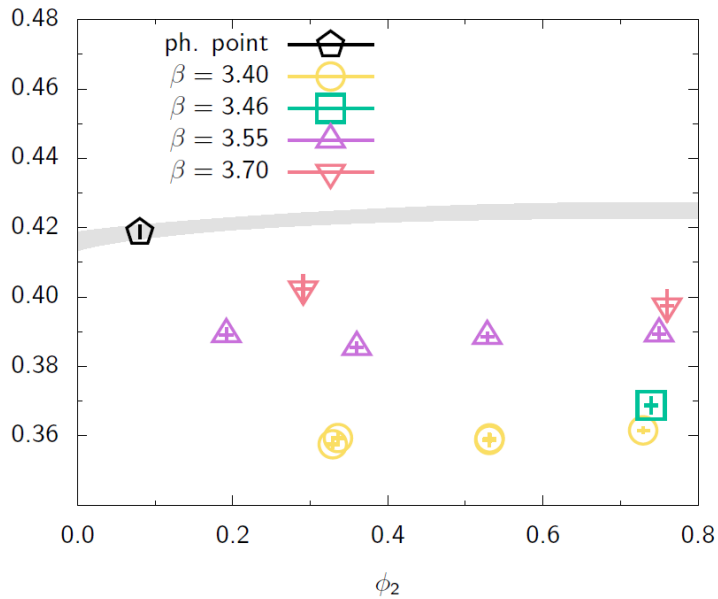
light-quark masses

non-perturbative renormalization and running [Schrödinger Functional] [ALPHA, 1802.05243]

$$\frac{m_{12}}{m_{13}} \propto \frac{2m_{ud}}{m_{ud}+m_s}$$

$$\frac{1}{\sqrt{8t_0}}\left(\frac{m_{12}^R}{M_\pi^2}+2\frac{m_{13}^R}{M_K^2}\right)$$



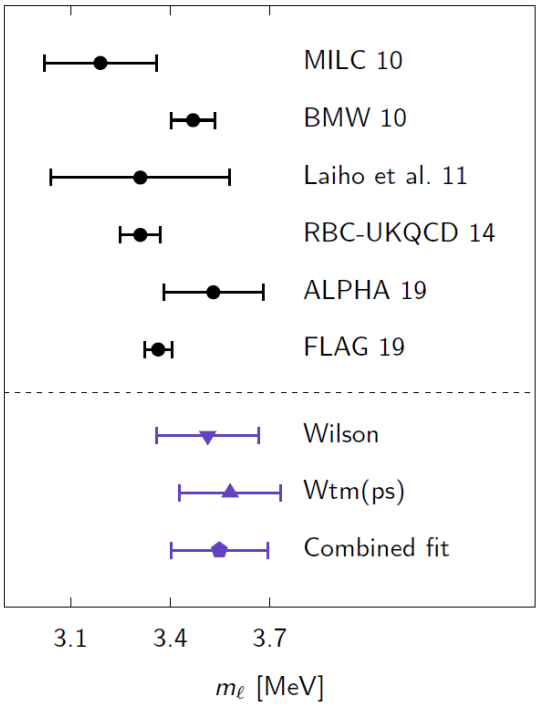


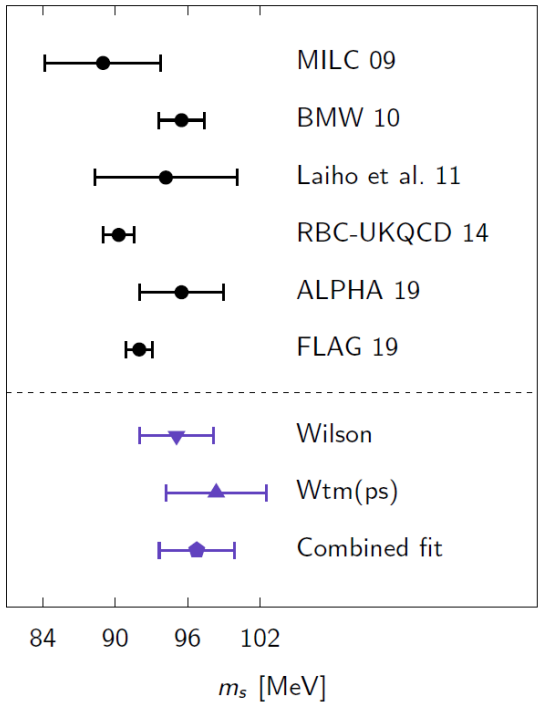
Wilson twisted mass [similar behaviour for Wilson]

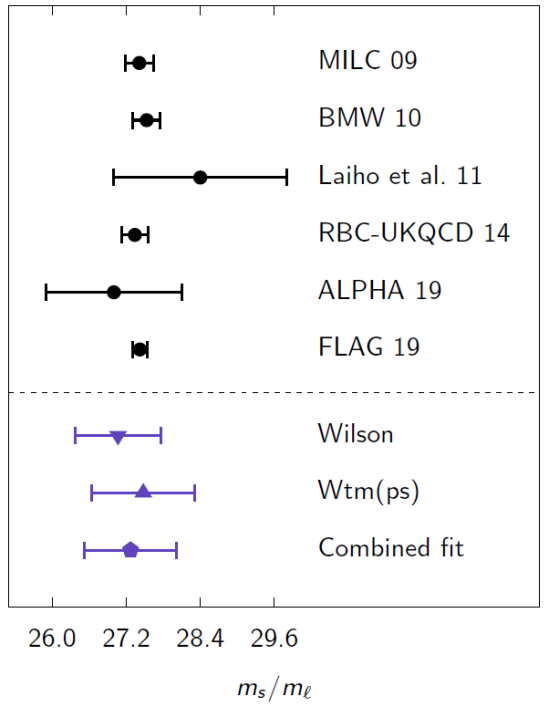
Systematic effects [ongoing] :

- SU(3) NLO χPT + Taylor series of m_{12}, m_{13}, m_{12}/m_{13}, $m_{12}/M_\pi^2 + 2m_{13}/M_K^2$
- cuts in M_π
- discretization effets: $O(a^2)$, $O(\phi_2 a^2)$
- excited states contamination

light-quark masses $N_f = 2 + 1$ preliminary







m_ℓ & m_s in $\overline{\text{MS}}$ at 2 GeV

conclusions

- mixed action : Wilson twisted mass on Wilson fermions
- scale setting : t_0 combining Wilson & Wtm
- determination of quark masses : m_{ud}, m_s
- ongoing analysis of systematic effects
- extend analysis to lighter ensembles and finer lattice spacing
- heavy-quark physics

see talks by Alessandro Conigli [Thu.,5:45] & by Julien Frison [Thu.,14:15]