Status of ETMC simulations with N_f=2+1+1 twisted mass fermions

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ETMC

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Simulations

- 4 flavour twisted mass fermion action: mass degenerate light doublet, mass split heavy doublet: N_f=2+(1+1)
- Iwasaki gauge action
- PHMC algorithm
- Runs without stout, some tests of stout

Fermion action

- N_f=2+1+1 twisted mass Wilson fermions: arXiv:hep-lat/0606011v1 (Chiarappa *et al.*)
- Light doublet as in N_f = 2: $S_l = \bar{\chi}_l Q_l^{(\chi)} \chi_l$
- Twisted basis: $\chi_l = \begin{pmatrix} \chi_u \\ \chi_d \end{pmatrix}$
- $Q_l^{(\chi)} = \tilde{m_{0l}} + i\gamma_5\tau_3 a\mu_l + N + R$
- $\tilde{m_{0l}} = \dfrac{1}{2\kappa_l}$

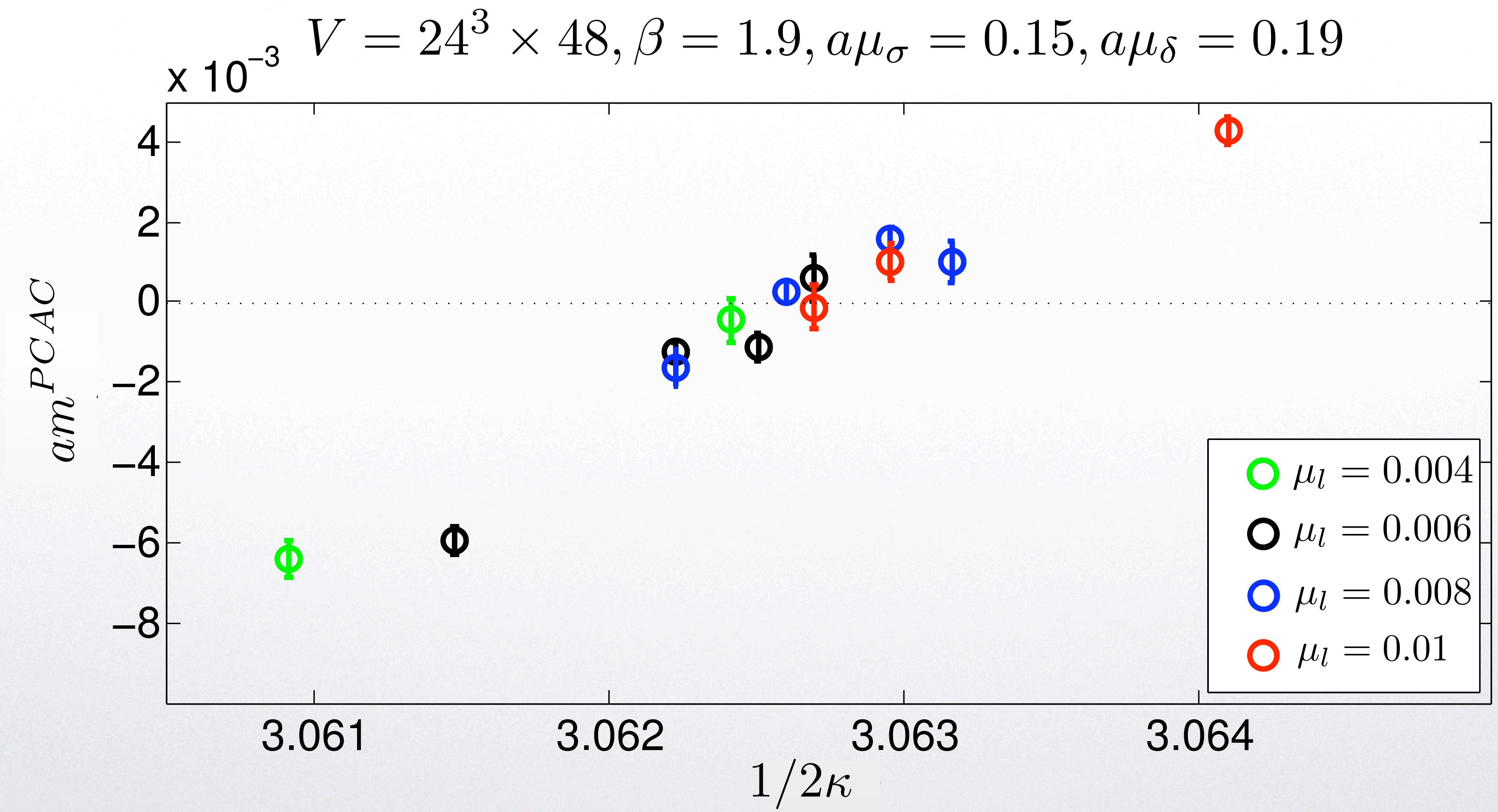
Fermion action II

- Mass-split heavy doublet, details: arXiv:hep-lat/0311008v2 (Frezzotti, Rossi)
- $S_h = \bar{\chi}_h Q_h^{(\chi)} \chi_h \qquad \chi_h = \begin{pmatrix} \chi_c \\ \chi_s \end{pmatrix}$
- $Q_h^{(\chi)} = \tilde{m_{0h}} + i\gamma_5 \tau_1 a\mu_\sigma + \tau_3 a\mu_\delta + N + R$
- $\psi_l^{phys} = e^{\frac{i}{2}\omega_l \gamma_5 \tau_3} \chi_l \quad \omega_l = \frac{\pi}{2}$
- $\psi_h^{phys} = e^{\frac{i}{2}\omega_h \gamma_5 \tau_1} \chi_h \quad \omega_h = \frac{\pi}{2}$

Tuning

- Automatic O(a) improvement at (or near) maximal twist
- $am^{PCAC} = 0 \Leftrightarrow \omega_l = \frac{\pi}{2} \Leftrightarrow \kappa = \kappa_c$
- 4 different values of $a\mu_l$ m_π ~ 315-600 MeV
- Tune heavy doublet: $a\mu_\sigma, a\mu_\delta$ (done)
  m_K ~ 500 MeV, m_c ~ $10m_s$

Tuning status

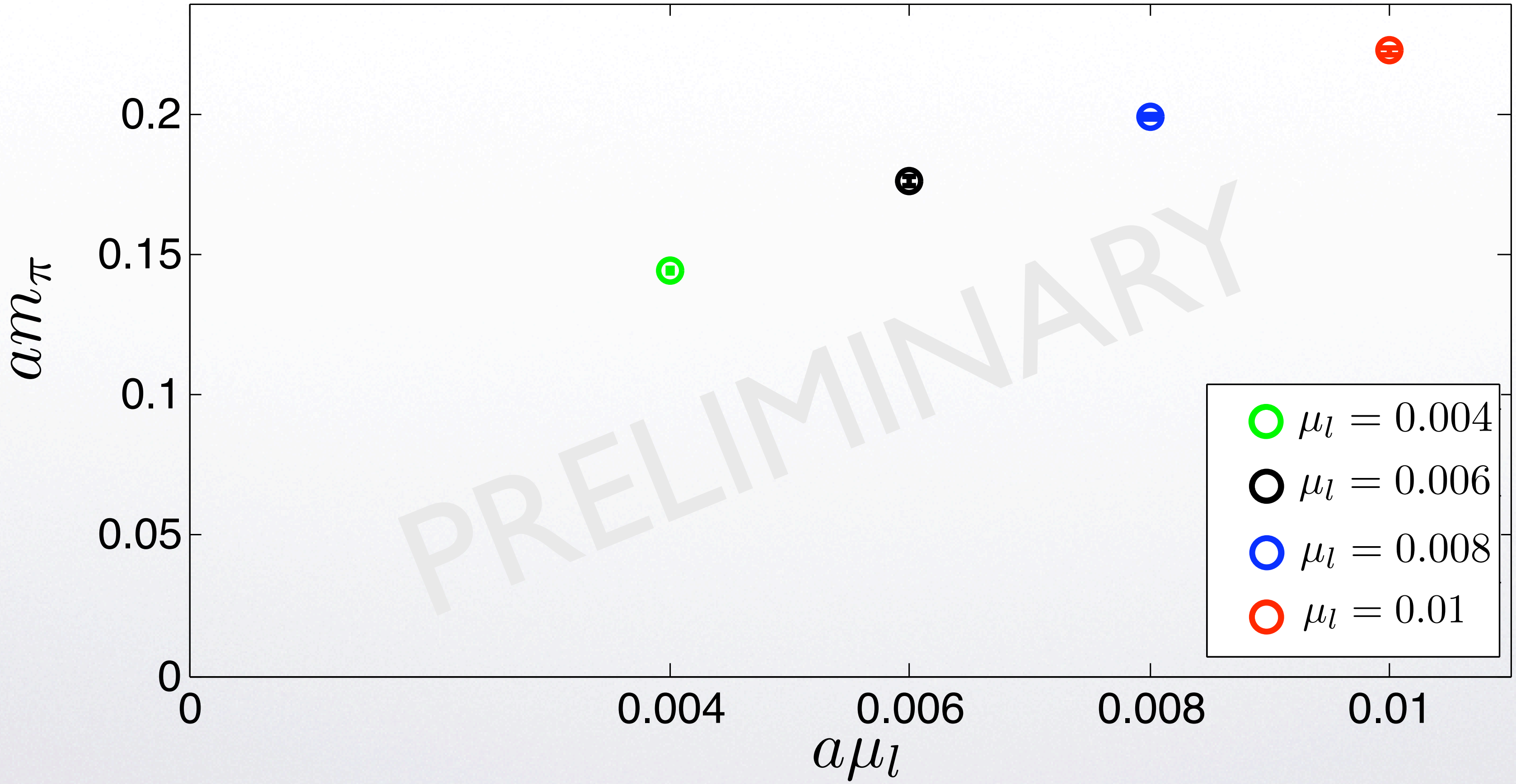


Current runs

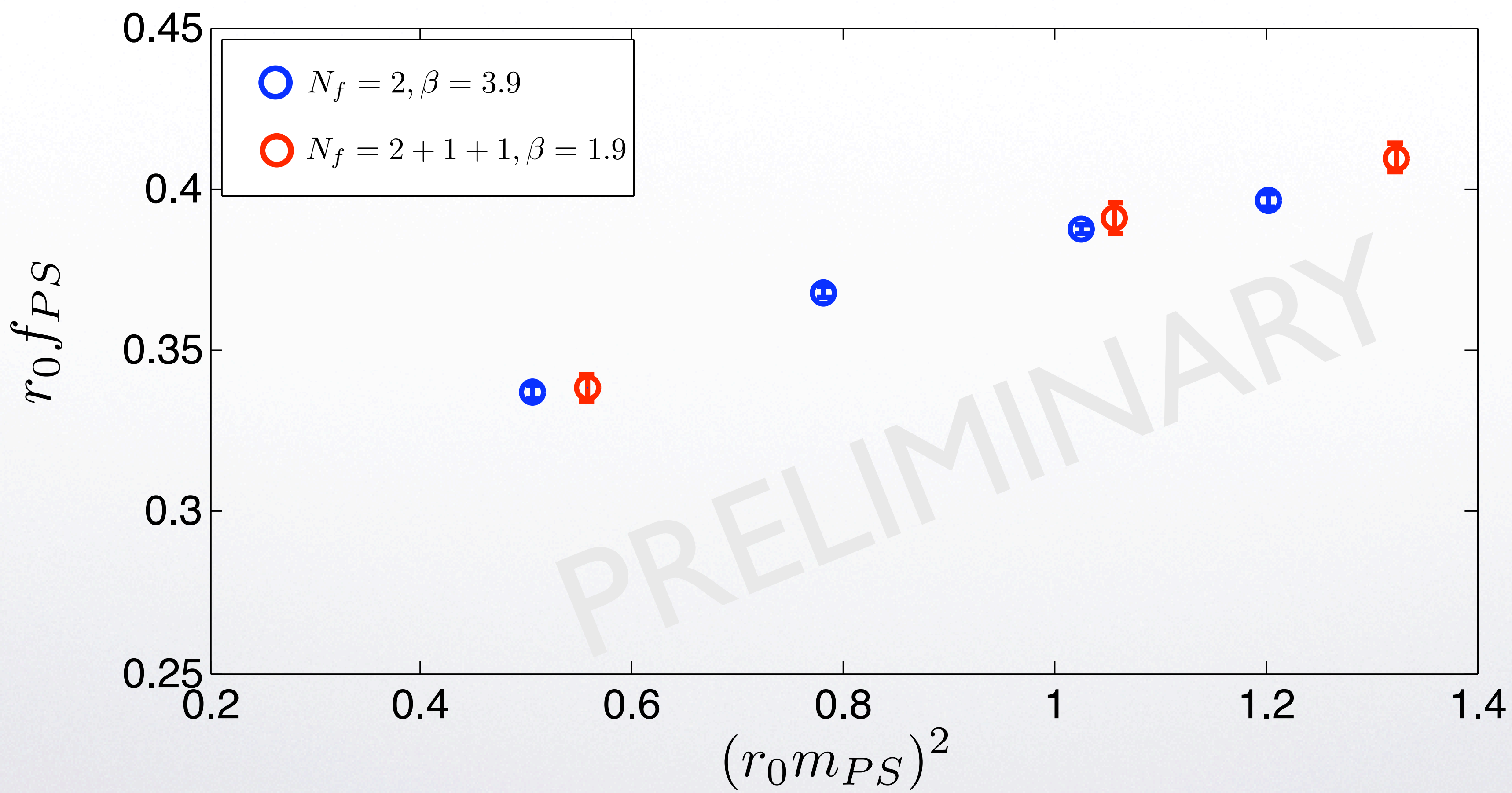
$$V = 24^3 \times 48, \beta = 1.9, a\mu_\sigma = 0.15, a\mu_\delta = 0.19$$

$a\mu_l$	0.004	0.006	0.008	0.01
traj (τ=1)	~5000	~200	~850	~950
am^{pcac} (e-5)	-29(40)	61(56)	28(28)	-12(54)
κ_c	0.16327	0.16323	0.16326	0.163255

m_π


PRELIMINARY
am_π
$a\mu_l$
0
0.05
0.1
0.15
0.2
0
0.004
0.006
0.008
0.01
$\mu_l = 0.004$
$\mu_l = 0.006$
$\mu_l = 0.008$
$\mu_l = 0.01$

N_f=2 vs N_f=2+1+1


0.45
0.4
0.35
0.3
0.25
0.2
0.4
0.6
0.8
1
1.2
1.4
$N_f = 2, \beta = 3.9$
$N_f = 2+1+1, \beta = 1.9$
$r_0 f_{PS}$
$(r_0 m_{PS})^2$
PRELIMINARY

Stout tests

- Caveat: ongoing (statistics, algorithmic)
- $V=24^3 \times 48$, $\beta=1.9$, $a\mu_l=0.004$, one level of stout, $\rho=0.15$
- Retune κ, $a\mu_\sigma$, $a\mu_\delta$

	traj	κ	$a\mu_\sigma$	$a\mu_\delta$	m^{pcac}
no stout	~5000	0.16327	0.15	0.19	-29(40)e-5
stout	~2500	0.14552	0.17	0.185	-16(31)e-5

Stout results

	am_π	af_π	Z_P/Z_S
no stout	0.1447(7)	0.0656(4)	0.6539(16)
stout	0.1237(9)	0.0534(25)	0.752(9)

	am_N	am_Δ^{++}	a_Δ^{+}
no stout	0.552(13)	0.722(21)	0.721(30)
stout	0.519(21)	0.676(35)	0.676(38)

Conclusions

- Tuning is completed for all 4 aμ_l values for the lattices at V=24^3x48 at β=1.9
- Stout smearing looks promising, investigations ongoing
- Next: continue production runs, new lattice spacing, larger volume

Action terms

$$N_{xy} \equiv -\frac{1}{2} \sum_{\mu=\pm 1}^{\pm 4} \partial_{x,y+\hat{\mu}} U_{y\mu} \gamma_\mu$$

$$R_{xy} \equiv -\frac{r}{2} \sum_{\mu=\pm 1}^{\pm 4} \partial_{x,y+\hat{\mu}} U_{y\mu}$$

PCAC mass

$$am_{\chi l}^{PCAC} \equiv \frac{\left\langle \partial_\mu^* A_{l,x\mu}^+ P_{l,y}^- \right\rangle}{2\left\langle P_{l,x}^+ P_{l,y}^- \right\rangle}$$

$$A_{l,x\mu}^a \equiv \bar{\chi}_{l,x} \frac{1}{2} \tau_a \gamma_\mu \gamma_5 \chi_{l,x}$$

$$P_{l,x}^a = \bar{\chi}_{x} \frac{1}{2} \tau_a \gamma_5 \chi_{l,x}$$

$$\tau_\pm = \tau_1 \pm i\tau_2$$

Explicit demixing

$$\begin{pmatrix} \bar{\psi}^{(d)}\gamma_5\psi^{(s)} \\ \bar{\psi}^{(d)}\gamma_5\psi^{(c)} \\ \bar{\psi}^{(d)}\psi^{(s)} \\ \bar{\psi}^{(d)}\psi^{(c)} \end{pmatrix} = \frac{1}{2} \begin{pmatrix} c_l c_h & s_l s_h & -i s_l c_h & +i c_l s_h \\ s_l s_h & c_l c_h & +i c_l s_h & -i s_l c_h \\ -i s_l c_h & +i c_l s_h & c_l c_h & s_l s_h \\ +i c_l s_h & -i s_l c_h & s_l s_h & c_l c_h \end{pmatrix} \begin{pmatrix} Z_P \bar{\chi}^{(d)}\gamma_5\chi^{(s)} \\ Z_P \bar{\chi}^{(d)}\gamma_5\chi^{(c)} \\ Z_S \bar{\chi}^{(d)}\chi^{(s)} \\ Z_S \bar{\chi}^{(d)}\chi^{(c)} \end{pmatrix}$$

$$c_l = \cos(\omega_l/2) \quad s_l = \sin(\omega_l/2) \quad c_h = \cos(\omega_h/2) \quad s_h = \sin(\omega_h/2)$$

For masses: Determine the twist angles and ratio of renormalization factors by requiring that the physical basis correlation matrix is diagonal

Rough estimates

- no stout, mu=0.004, mpi ≈ 315 MeV, mK ≈ 500 MeV, mD ≈ 2000 MeV