$N_f = 2 + 1 + 1$ runs with stout smearing

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Stout smearing

Colin Morningstar, Mike J. Peardon, Phys.Rev. D69:054501,2004; hep-lat/0311018.
Analytic smearing of SU(3) link variables in lattice QCD.

Gauge link variables: $U_{x,\mu} \in \mathrm{SU}(N_c)$
Sum of staples:

$$C_{x,\mu} \equiv \sum_{\nu\neq\mu} \rho_{\mu\nu} \left(U^\dagger_{x+\hat{\mu},\nu} U_{x+\hat{\nu},\mu} U_{x,\nu} + U_{x-\hat{\nu}+\hat{\mu},\nu} U_{x-\hat{\nu},\mu} U^\dagger_{x-\hat{\nu},\nu} \right) ,$$

$$\Omega_{x,\mu} \equiv U^\dagger_{x,\mu} C_{x,\mu}$$

Analytic smeared links:

$$U^{(1)}_{x,\mu} \equiv U_{x,\mu} \exp\left\{ \frac{1}{2}\left(\Omega_{x,\mu} - \Omega^\dagger_{x,\mu}\right) - \frac{1}{2N_c} \mathrm{Tr}\left(\Omega_{x,\mu} - \Omega^\dagger_{x,\mu}\right) \right\}$$

This can be iterated: $U_{x,\mu} \to U^{(1)}_{x,\mu} \to U^{(2)}_{x,\mu} \to \ldots$

The main effect of gauge field smearing is to reduce the number of small eigenvalues of the fermion matrix. Renormalisations become weaker.

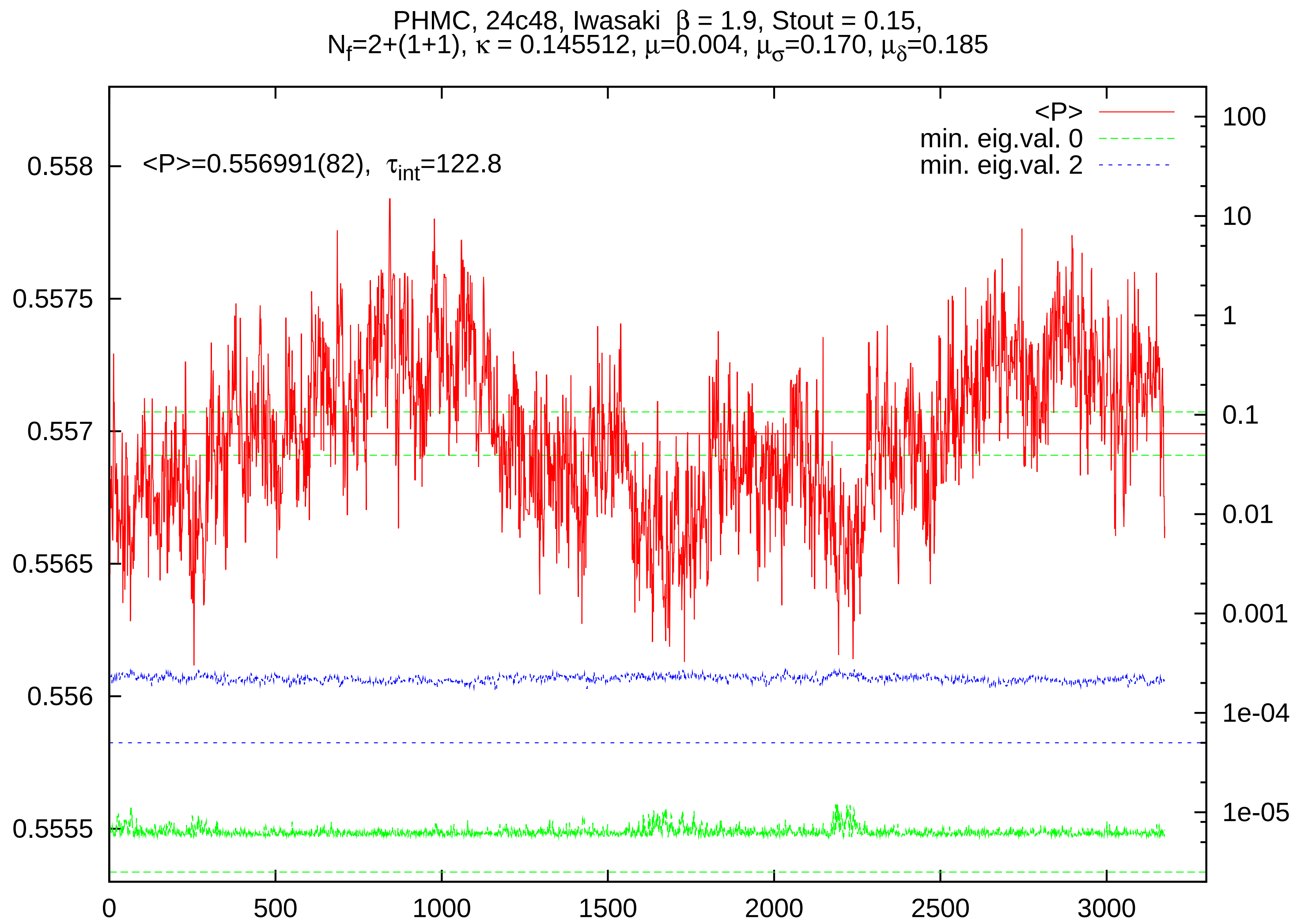
Table 1: *Run parameters on $24^3 \cdot 48$ lattice at $\beta = 1.9$.*

κ	$a\mu_l$	$a\mu_h$	N_{conf}	plaquette	$\tau_{plaq}^{traject}$	r_0/a
0.145512	0.004	0.170 ± 0.185	100-3185	0.556991(82)	122.8	5.313(25)
0.145511	0.006	0.170 ± 0.185	100-3241	0.557000(60)	85.8	5.300(37)
0.145510	0.008	0.170 ± 0.185	100-2101	0.557019(42)	33.9	5.353(43)

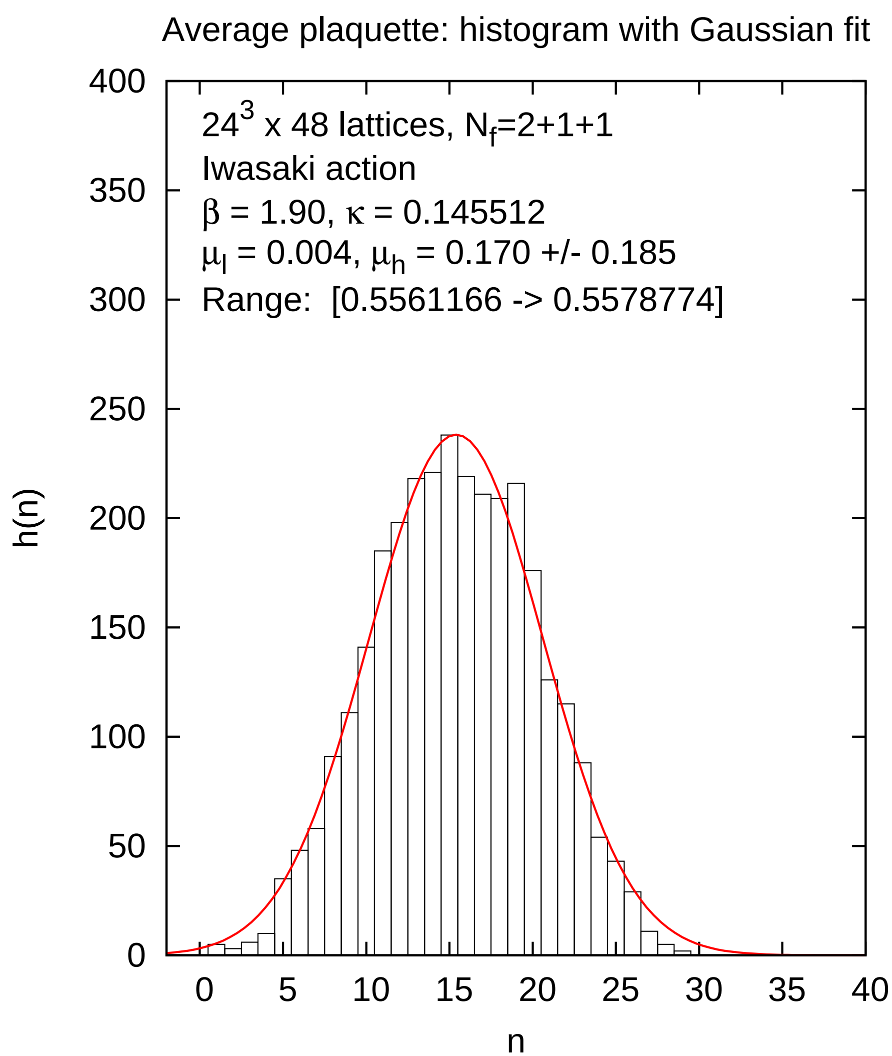
Table 2: *Results with stout smearing at $\beta = 1.9$.*

$a\mu_l$	am_χ^{PCAC}	am_π	am_K	am_D	f_π	am_N
0.004	0.0003(12)	0.1252(11)	0.2514(14)	0.96(6)		
	-0.00006(84)	0.12608(99)	0.2526(7)	0.8320(38)	0.05760(70)	0.504(9)
0.006	0.00004(93)	0.14818(70)	0.25670(76)	0.86(2)		
	-0.00017(54)	0.14834(72)	0.2571(5)	0.8232(29)	0.06481(44)	0.526(5)
0.008	-0.0004(18)	0.17041(73)	0.26320(96)	0.89(5)		
	-0.00067(49)	0.17084(68)	0.2656(8)	0.851(17)	0.06855(29)	0.552(4)

Run histories show long autocorrelations:

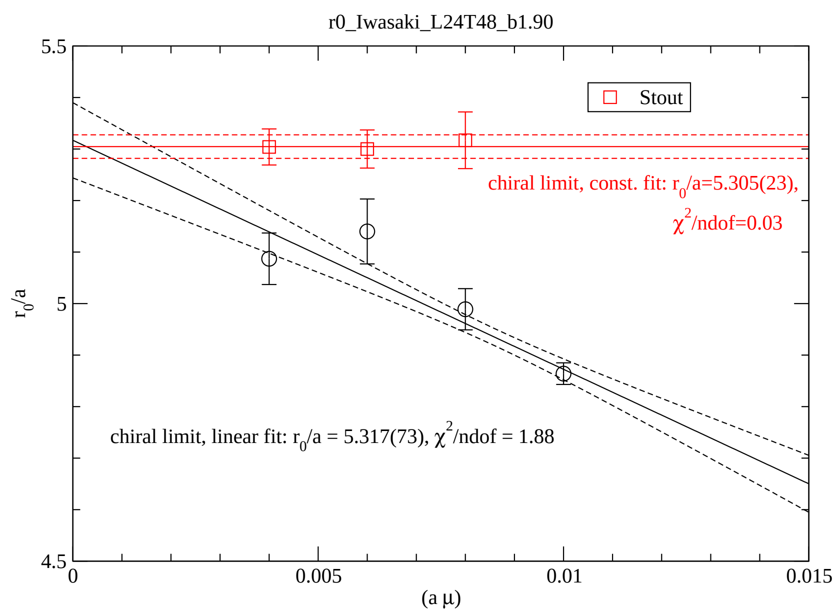


The average plaquette distribution can be well fitted by a Gaussian:



Comparing with non-stout:

- The Z-factors come closer to 1: at $\beta = 1.9$
  $Z_P/Z_S: \quad 0.59 \rightarrow 0.74$.
- As a consequence, smaller pion masses: e.g. at $a\mu = 0.004$
  $am_\pi: \quad 0.1464 \rightarrow 0.1255 \qquad (r_0 m_\pi: \quad 0.75 \rightarrow 0.67)$.
- r_0/a does not depend on $a\mu$ (Urs Wenger):



But:

- The π^0 mass-splitting is practically unchanged!

For instance, at $a\mu = 0.006$ (Carsten Urbach):

$$m_{\pi 0}/m_{\pi +} = 0.51(5).$$

It does not seem to be an ultraviolet effect!?

$$\Downarrow$$

D-meson state and mass

See the wiki-page: Rémi Baron, Siebren Reker, Marc Wagner (based on GEP).

The correlator matrix, in general: a $D \times D$ (real symmetric) matrix.
For instance, for $D = 2$ and considering only two energy eigenstates

$$C(t,0) = \begin{pmatrix} (a|1)_t \cdot (a|1)_0 + (a|2)_t \cdot (a|2)_0 & (a|1)_t \cdot (b|1)_0 + (a|2)_t \cdot (b|2)_0 \\ (a|1)_t \cdot (b|1)_0 + (a|2)_t \cdot (b|2)_0 & (b|1)_t \cdot (b|1)_0 + (b|2)_t \cdot (b|2)_0 \end{pmatrix}$$

with the notation

$$\langle 0|\mathcal{O}_a(t)|1\rangle = \langle 1|\mathcal{O}_a(t)|0\rangle \equiv (a|1)_t \qquad (a, b, \ldots;\ 1, 2, \ldots)$$

For bosonic variables we have periodicity:

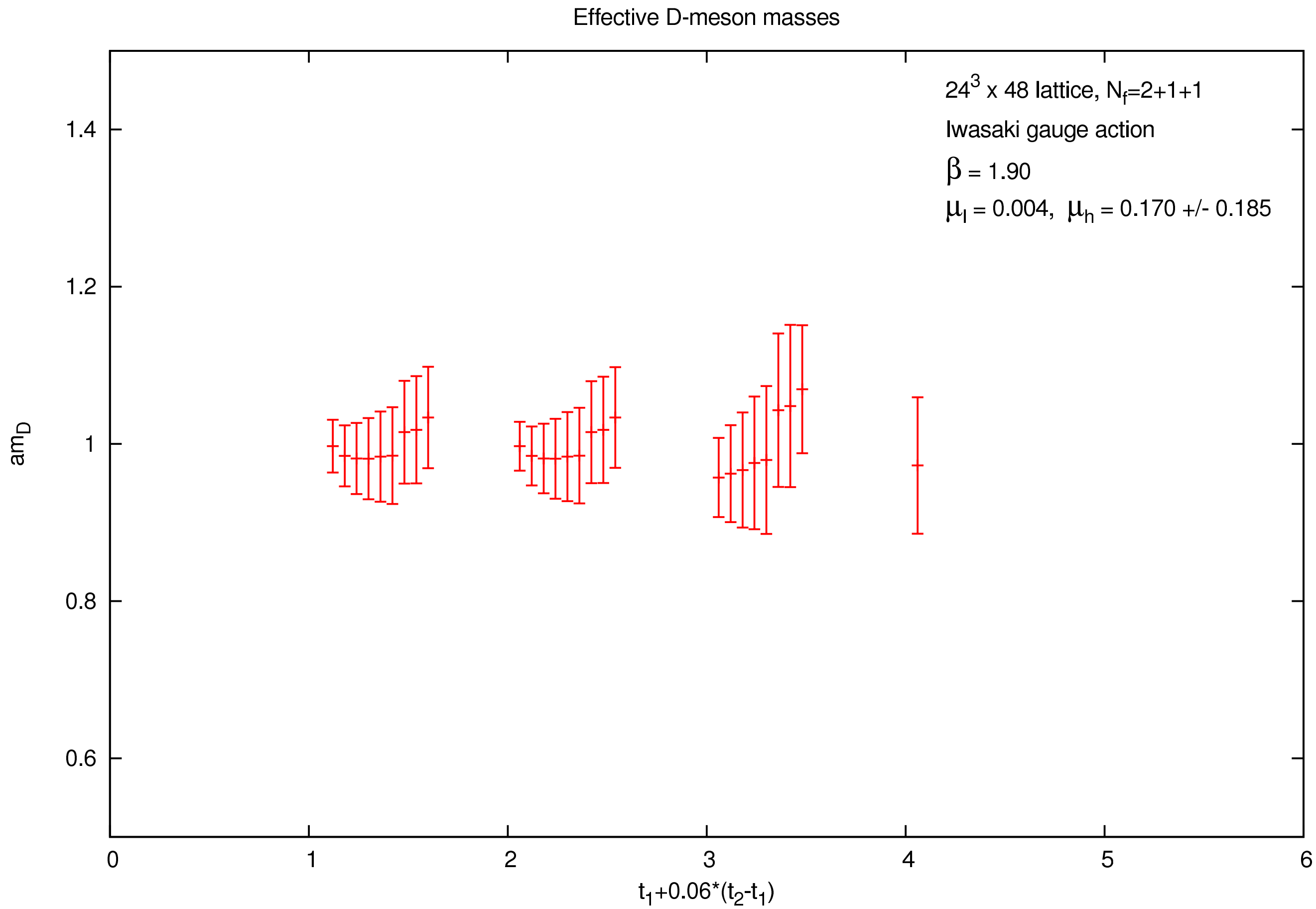
$$(a|n)_t = (a|n)\{\exp[-tE_n] + \exp[-(T-t)E_n]\}$$

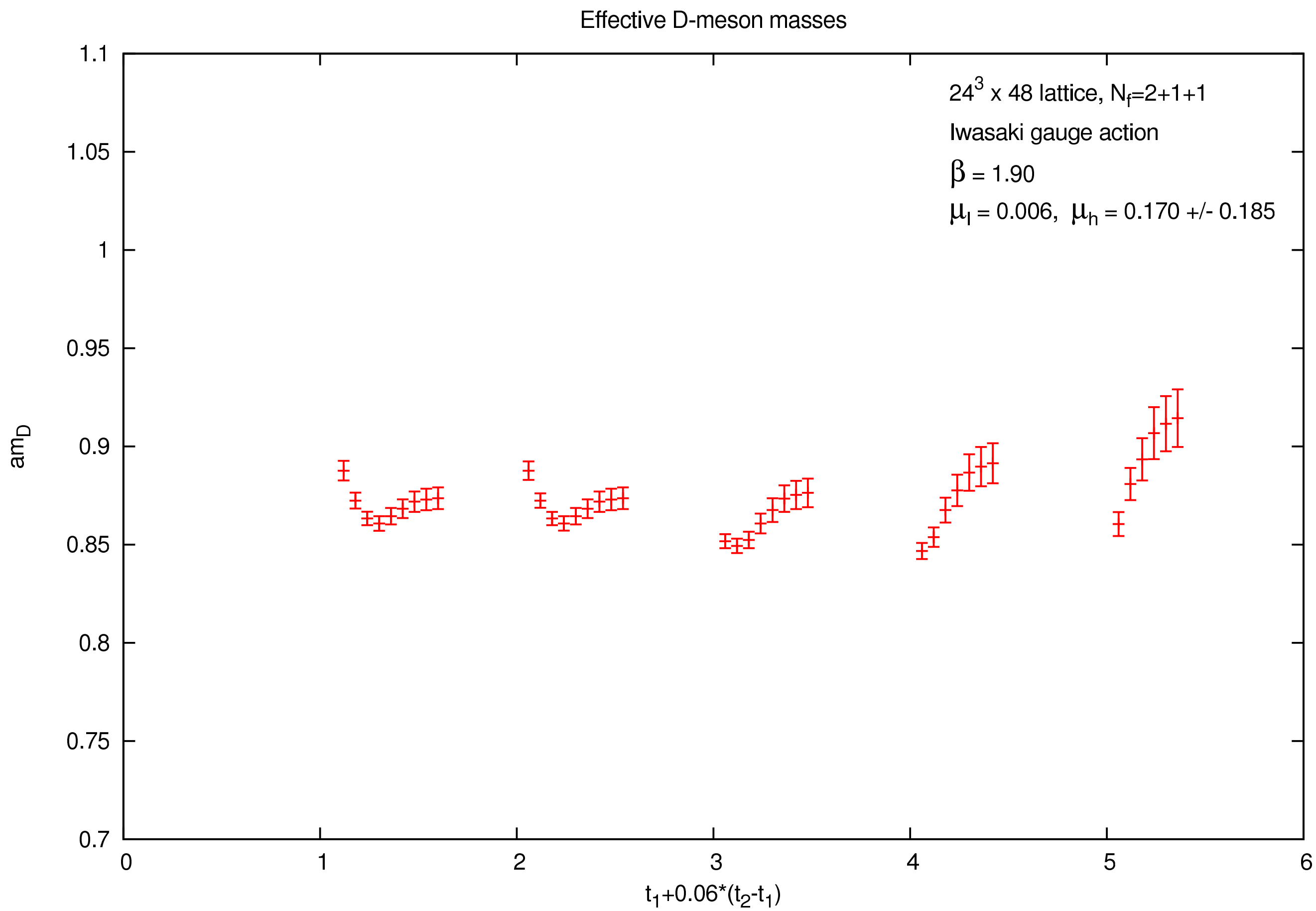
- One can solve $C(t_1, 0)$ and $C(t_2, 0)$ for $(a|1), (a|2), (b|1), (b|2), E_1, E_2$.
  In case of a $D \times D$ matrix there are
  $D(D+1)$ variables and $D(D+1)$ equations.

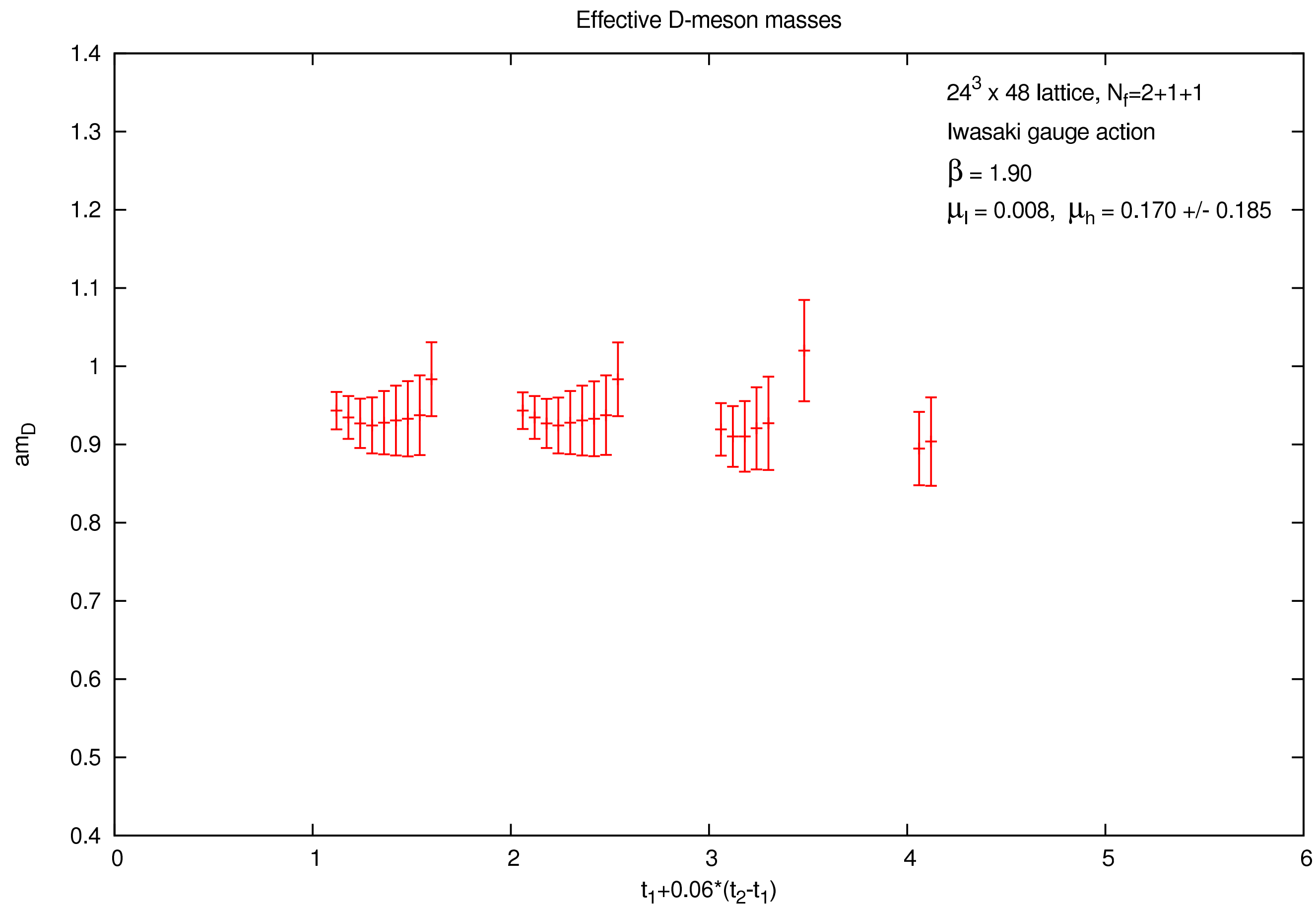
- One can, instead, fit for $t_1 \leq t \leq t_2$.

- In case of the KD-system:
  in twisted mass simulations one can determine the two lowest states for large (t_1, t_2) and substract their contributions at small distances.
  The D-meson can be extracted from the left over part.

Preliminary results for m_D: using the Gauss-smeared correlators by Rémi Baron




Effective D-meson masses
24^3 x 48 lattice, N_f=2+1+1
Iwasaki gauge action
β = 1.90
μ_l = 0.006, μ_h = 0.170 +/- 0.185
am_D
t_1+0.06*(t_2-t_1)
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
1
2
3
4
5
6



Effective D-meson masses
24^3 x 48 lattice, N_f=2+1+1
Iwasaki gauge action
β = 1.90
μ_l = 0.008, μ_h = 0.170 +/- 0.185
am_D
t_1+0.06*(t_2-t_1)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
1
2
3
4
5
6