$N_f = 2 + 1 + 1$ twisted mass + clover towards the physical point?

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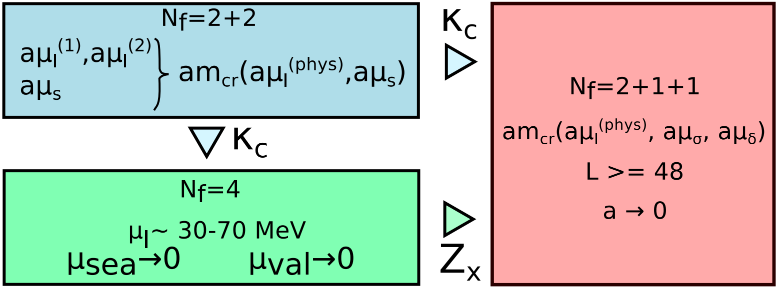
DESY

$N_f = 2+1+1$ simulations

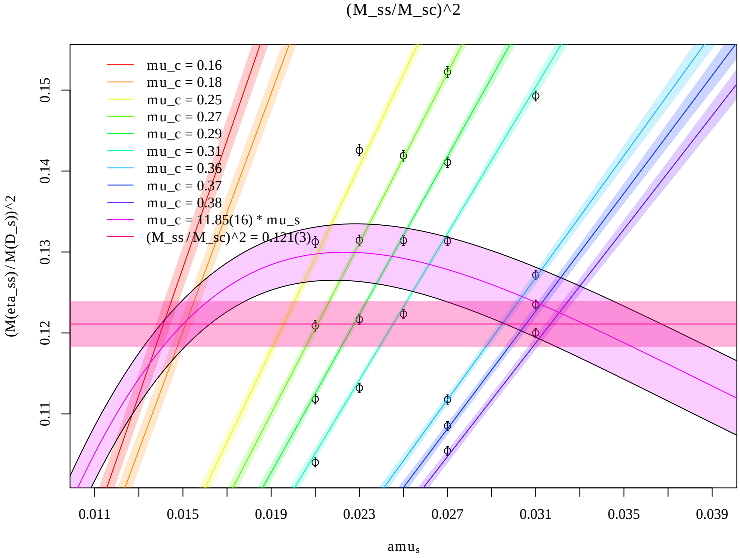
Finding β, κ_c



- Did simulation $N_f = 2+2$, $\mu_l = 0.003, \mu_h = 0.025, L = 24$
- $a \sim 0.095\mathrm{fm}$
- Use η_{ss} and D_s mass ratio to tune heavy sector $\rightarrow$ Osterwalder-Seiler
  - $\mu_s \in [0.015; 0.035]$, $\mu_c \in [0.16; 0.38]$
- Estimate Z_P/Z_S $\rightarrow$ non-degenerate inversions on $N_f = 2+2$ background $\rightarrow$ tune μ_δ to match μ_c

$N_f = 2 + 1 + 1$ simulations

Tuning μ_σ&μ_δ



$N_f = 2 + 1 + 1$ simulations

Tuning $\mu_\sigma \& \mu_\delta$

- Realized: η_{ss}, D_s suffer from cut-off artefacts
  - use $\mu_c/\mu_s \sim 11.8$ and match m_{D_s}/f_{D_s} instead
  - Determined $\mu_s = 0.021, \mu_c = 0.25$

$\Rightarrow$ $\mu_\sigma = 0.1355, \mu_\delta = 0.145$

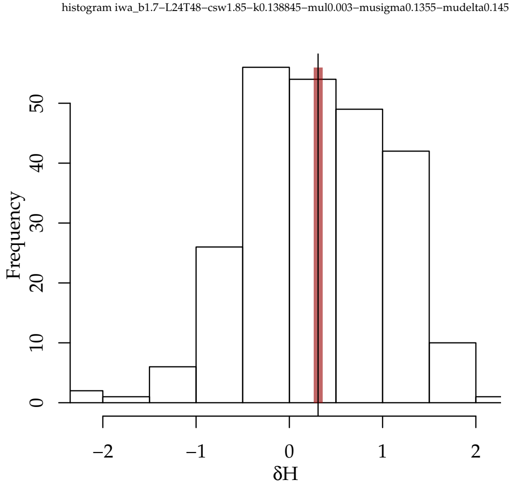
  - So $Z_P/Z_S \sim 0.8$

- Had estimate: $\kappa_c \sim 0.137$ from $N_f = 2 + 2$
  - $\Rightarrow$ $N_f = 2 + 1 + 1$ runs with $\mu_l = 0.003$, $\kappa \sim 0.1388$ to tune kappa

! Simulations suffer from bad acceptance, large δH!

$N_f = 2 + 1 + 1$ simulations

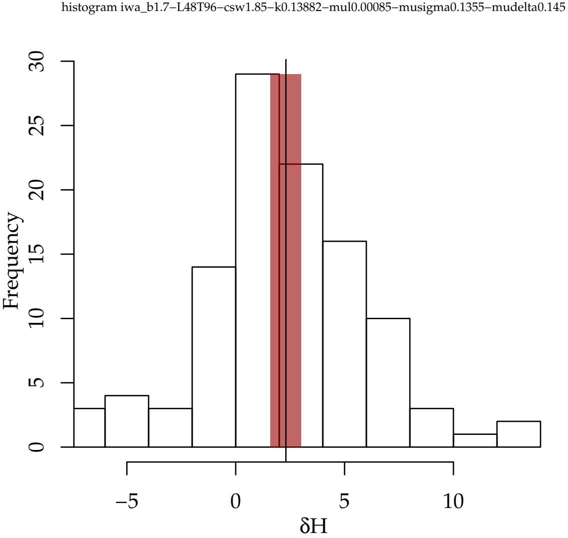
Simulations expensive and unstable!



- very large δH despite many integration steps
- low acceptance, high cost!

$N_f = 2 + 1 + 1$ simulations

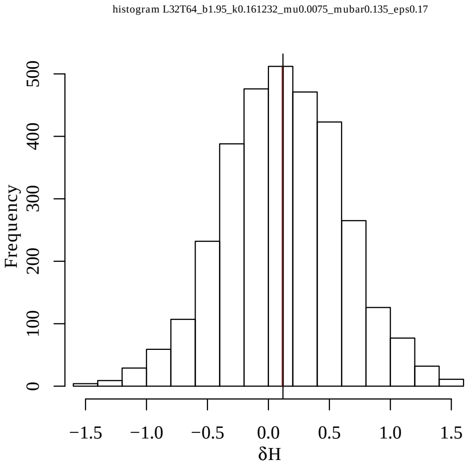
Simulations expensive and unstable!



- Running out of time, attempt physical point run $N_f = 2 + 1 + 1$ with estimated parameters
- Trajectory ~ 4 hours at $\sim 20\%$ acceptance!
- Seemingly impossible!

$N_f = 2 + 1 + 1$ simulations

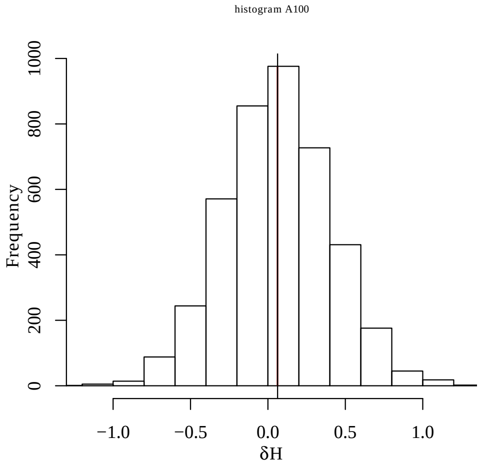
Old $N_f = 2 + 1 + 1$ (B75)



- B75 also had sizeable δH (but still smaller)
- $\sim$ factor 4 lower cost
- more lattice points (although physical volume similar)
- higher acceptance

$N_f = 2 + 1 + 1$ simulations

Old $N_f = 2 + 1 + 1$ (A100)



- A100

$N_f = 2 + 1 + 1$ simulations

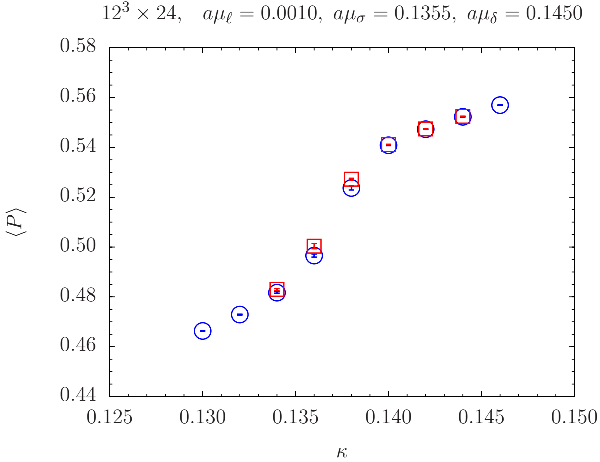
So where is the δH coming from?

Possible sources of large δH

- Bug in ND doublet + clover?
  - PHMC and RHMC without clover well-tested
  - PHMC/RHMC + clover tested to give same results
  - stability regained for $\mu_\delta << 1$
  - $\Rightarrow$ can exclude bugs
- "Phase transitions"?
  - No hysteresis in κ thermal cycle
- Mistuning of heavy sector?
  - Once we have pinned down κ_c, do ND inversions for Kaon and D_s meson masses
  - in any case, certainly less than 10% effect
- Lattice artefacts from heavy sector?
  - reducing μ_c while keeping μ_s constant seems to really help
- Eigenvalue fluctuations in heavy sector?

$N_f = 2 + 1 + 1$ simulations

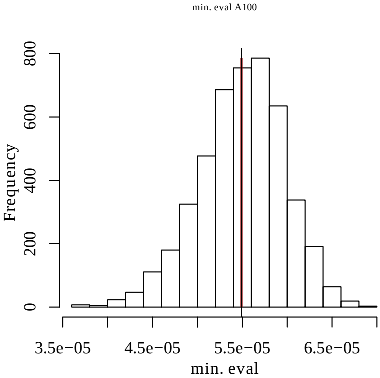
$N_f = 2 + 1 + 1$ + clover thermal cycle

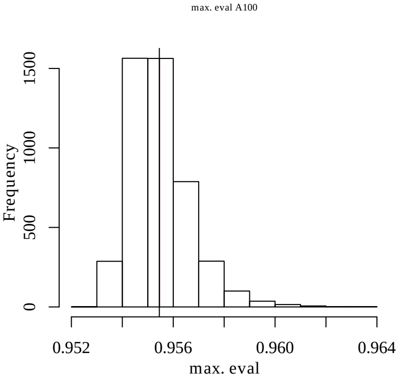


$\Rightarrow$ no sign of "phase transition"

$N_f = 2 + 1 + 1$ simulations
Eigenvalue fluctuations?

This is what eigenvalue fluctuations looked like for old A100 ensemble:

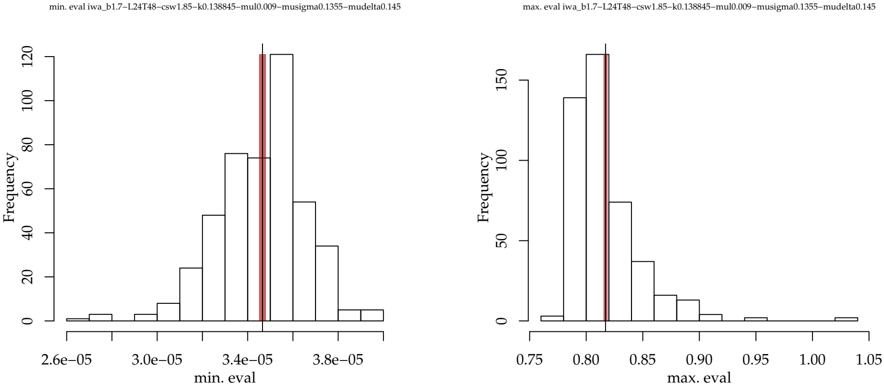




$N_f = 2+1+1$ simulations

Eigenvalue fluctuations?

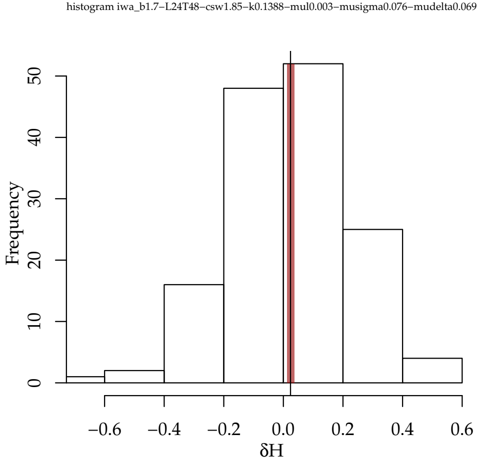
This is what they look like now:



Large fluctuations in maximum eigenvalue, need to have very large interval!

$N_f = 2 + 1 + 1$ simulations

$N_f = 2 + 1 + 1 +$ clover, $\mu_l = 0.003, \mu_c \to 0.13, \mu_\sigma \to 0.076, \mu_\delta \to 0.069$

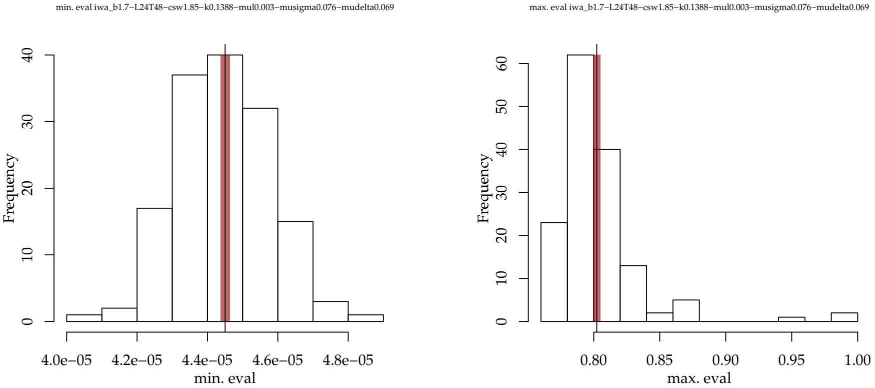


- δH much smaller
- acceptance $> 90\%$
- could reduce cost significantly now

$N_f = 2 + 1 + 1$ simulations

Eigenvalue fluctuations?

For reduced μ_c, eigenvalues look similar:



Fluctuations are comparable to problematic run... so where are the problems coming from?!

$N_f = 2 + 1 + 1$ simulations

Where to go from here?

It is known that simulations can become difficult if forces /eigenvalues fluctuate strongly.

Sources for eigenvalue / force fluctuations

- Problems in light quark mass regime excluded
  - indications for small pion mass splitting, no hysteresis despite coarse lattice spacing
- Does RHMC/PHMC have problems with μ_c + clover?
  - Check with $N_f = 2 + 2$ simulation, 2 light, 2 charm
- If no problem, perhaps action has a problem with μ_c + clover?
  - in $\langle Q^2 - \langle Q \rangle^2 \rangle$ spectral decomposition, maybe terms of the form $\sim c_{\mathrm{SW}}^2 \mu_c^2$ problematic? This is potentially large! [certainly of $\mathcal{O}(1)$]
  - Would explain improvement for $c_{\mathrm{SW}} \to 0, \mu_c \to 0$