Lattice simulation of N=1 supersymmetric Yang-Mills theory

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N=1 super Yang-Mills on the lattice

- 1 gauge field + 1 adjoint Majorana fermion
- Lattice breaks SUSY, however SUSY restored accidentally in continuum and chiral limits
- Domain wall fermions ideal for N=1 SYM   D. B. Kaplan and M. Schmaltz (1999)
  - good chiral properties, no fine tuning
  - positive definite action

N=1 super Yang-Mills on the lattice

- Test theory predictions about:
  - gluino condensate
  - discrete chiral symmetry breaking, domain walls
  - spectrum
  - sorry, no SUSY breaking in this theory

N=1 super Yang-Mills on the lattice

- Test theory predictions about:
  - gluino condensate — Vranas, Kogut and Fleming (2001)
  - discrete chiral symmetry breaking, domain walls
  - spectrum
  - sorry, no SUSY breaking in this theory

N=1 SYM with DWF

- Since Vranas, et. al.
  - improved algorithms (e.g. RHMC algorithm)
  - faster computers
  - better understanding of DWFs (e.g. L_s dependence of residual mass (m_{res}), etc.)

$$m_{res} \sim \# \frac{e^{-\# L_s}}{L_s} + \# \frac{\rho(0)}{L_s}$$

Numerical simulations

- Wilson gauge action with domain wall fermions
- SU(2) gauge group, adjoint Majorana fermions
- Simulations performed on an appropriately modified version of the Columbia Physics System (CPS)
- 8^3x8xL_s ensembles were generated and measurements made on QCDOC at Columbia University
- 16^3x32xL_s ensembles were generated and measurements made on New York Blue (BlueGene/L)

Code validation

- Reproduce results of Vranas, et. al.
- Ensembles:

vol	β	m_f	$\delta\tau$	N_{step}	N_{traj}	N_{therm}
$8^3 \times 8 \times 12$	2.3	0.02	0.26	5	1000	100
$8^3 \times 8 \times 12$	2.3	0.04	0.2	5	1000	100
$8^3 \times 8 \times 12$	2.3	0.06	0.22	5	1000	100
$8^3 \times 8 \times 12$	2.3	0.08	0.22	5	1000	100
$8^3 \times 8 \times 16$	2.3	0.02	0.22	5	750	100
$8^3 \times 8 \times 16$	2.3	0.04	0.22	5	1166	100
$8^3 \times 8 \times 16$	2.3	0.06	0.22	5	1200	100
$8^3 \times 8 \times 16$	2.3	0.08	0.22	5	1200	100
$8^3 \times 8 \times 20$	2.3	0.02	0.24	5	1000	100
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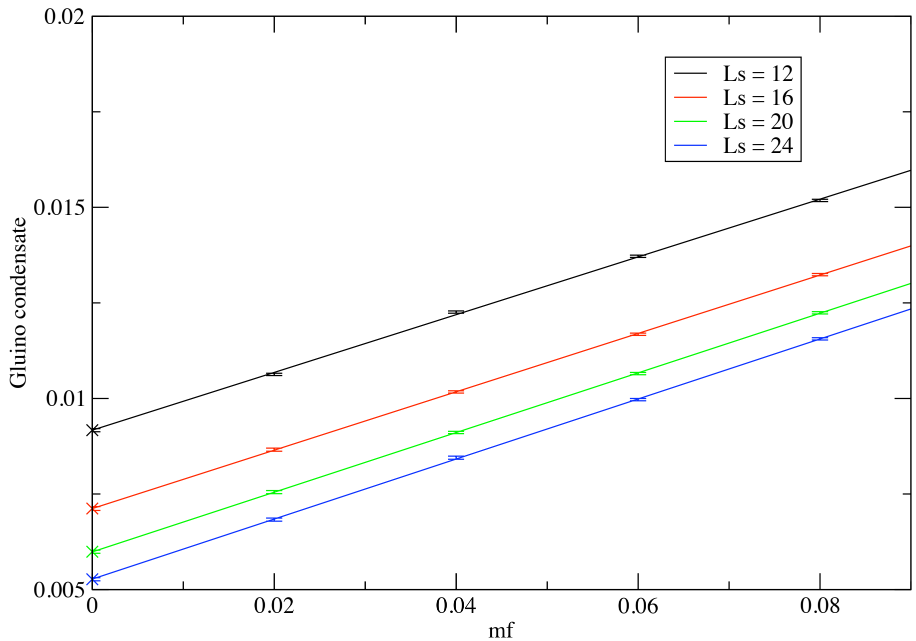
$8^3 \times 8 \times 20$	2.3	0.08	0.23	5	1000	100
$8^3 \times 8 \times 24$	2.3	0.02	0.23	5	1000	100
$8^3 \times 8 \times 24$	2.3	0.04	0.18	5	700	100
$8^3 \times 8 \times 24$	2.3	0.06	0.23	5	1000	100
$8^3 \times 8 \times 24$	2.3	0.08	0.23	5	1000	100

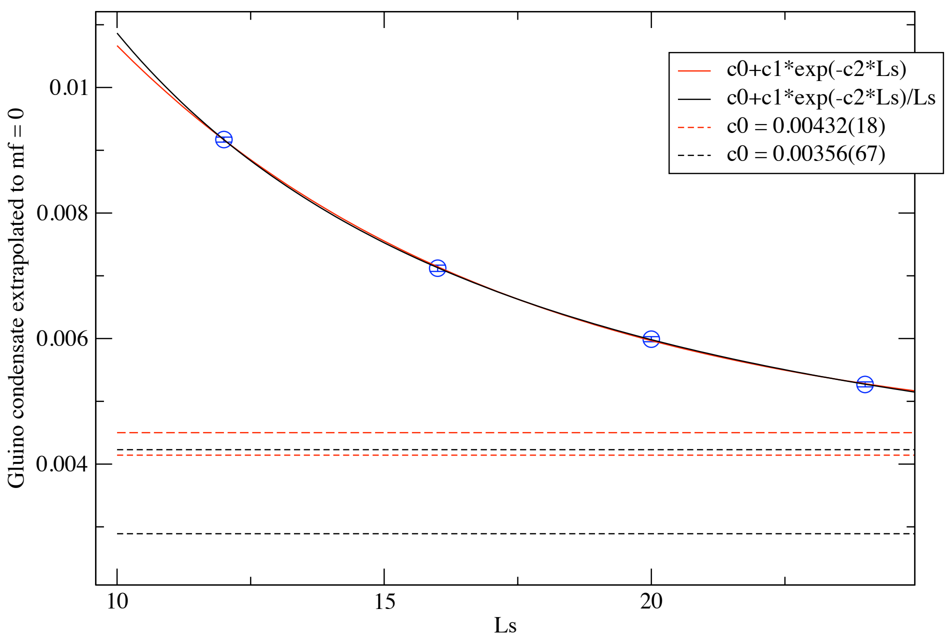
Gluino condensate, chiral limit



L_s	m_f	$\langle\bar{\psi}\psi\rangle(Vranas, et.al.)$	$\langle\bar{\psi}\psi\rangle$
12	0.00^*	0.00904(5)	0.00917(4)
12	0.02	0.01052(4)	0.01063(3)
12	0.04	0.01223(5)	0.01226(3)
12	0.06	0.01370(4)	0.01372(3)
12	0.08	0.01519(3)	0.01518(3)
16	0.00^*	0.00717(6)	0.00712(5)
16	0.02	0.00863(5)	0.00866(4)
16	0.04	0.01026(4)	0.01017(3)
16	0.06	0.01183(4)	0.01168(3)
16	0.08	0.01324(4)	0.01324(3)
20	0.00^*	0.00585(9)	0.00599(4)
20	0.02	0.00735(10)	0.00755(3)
20	0.04	0.00897(7)	0.00911(3)
20	0.06	0.01071(3)	0.01065(3)
20	0.08	0.01221(3)	0.01224(3)
24	0.00^*	0.00538(5)	0.00527(4)
24	0.02	0.00691(4)	0.00683(4)
24	0.04	0.00827(7)	0.00845(4)
24	0.06	0.00992(3)	0.00997(3)
24	0.08	0.01142(3)	0.01156(3)
∞^*	0.02	0.00611(16)	
∞^*	0.04	0.00700(25)	
∞^*	0.06	0.00857(19)	
∞^*	0.08	0.01034(16)	
∞^2	0.00^1	0.00444(21)	0.00432(18)
$\infty^{2'}$	0.00^1	0.00376(57)	0.00356(67)
∞^1	0.00^2	0.00455(21)	

- Fit form: $b_0 + b_1 m_f$

Gluino condensate, chiral limit



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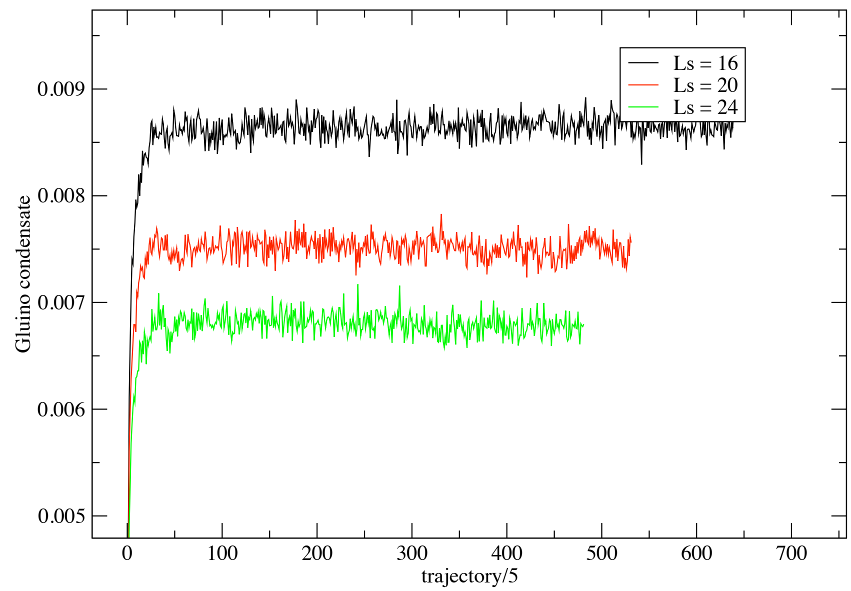
- Fit form:

$$c_0 + c_1 e^{-c_2 L_s}$$

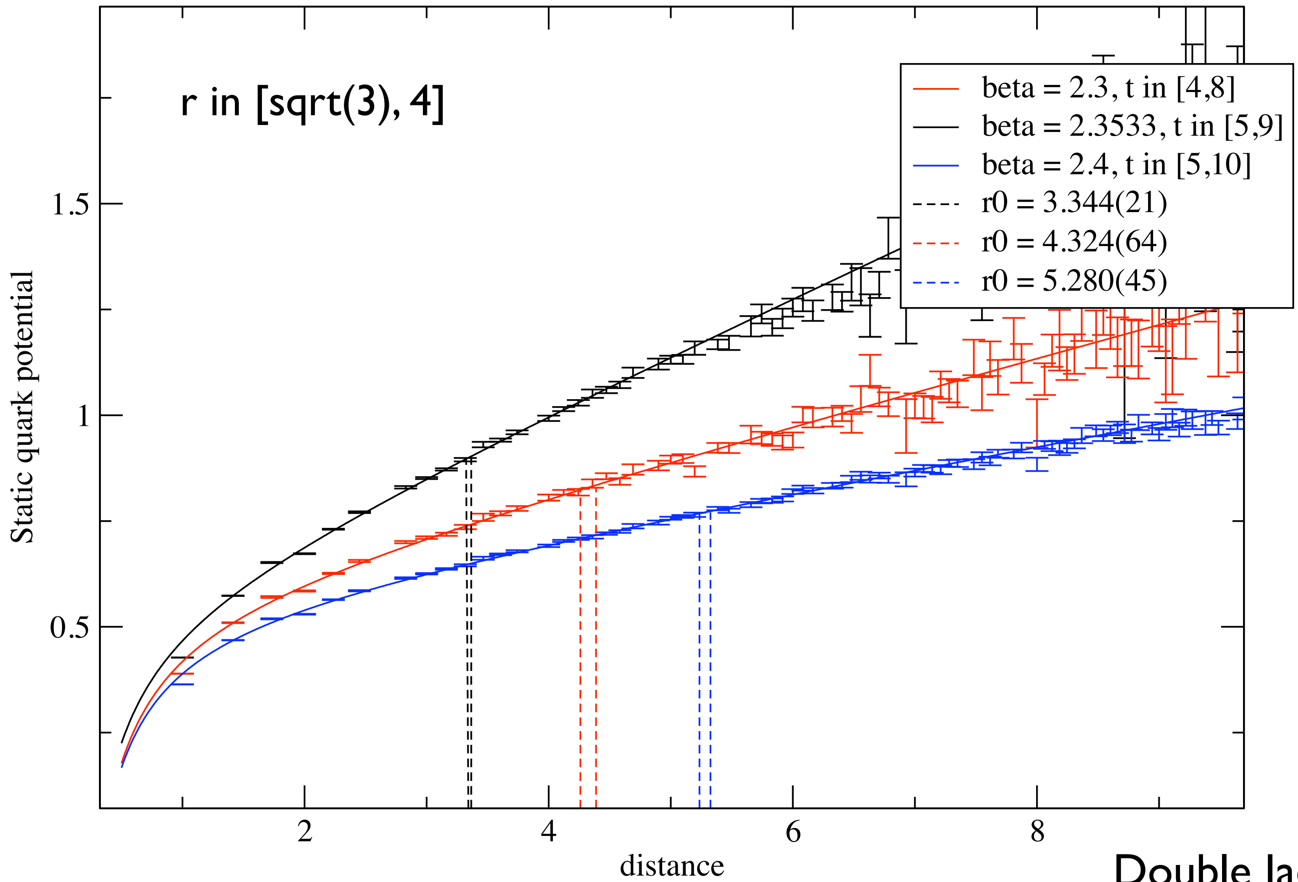
$$c_0 + c_1 e^{-c_2 L_s} / L_s$$

Simulation parameters

vol	β	m_f	$\delta\tau$	N_{step}	acceptance	N_{traj}	N_{therm}
$16^3 \times 32 \times 16$	2.3	0.02	0.16	5	0.76	3200	500
$16^3 \times 32 \times 16$	2.3533	0.02	0.163	5	0.82	1950	500
$16^3 \times 32 \times 16$	2.4	0.02	0.16	5	0.82	2710	500
$16^3 \times 32 \times 16$	2.3	0.04	0.16	5	0.77	2795	500
$16^3 \times 32 \times 20$	2.3	0.02	0.155	5	0.72	2660	500
$16^3 \times 32 \times 20$	2.3	0.04	0.16	5	0.75	2765	500
$16^3 \times 32 \times 24$	2.3	0.02	0.145	5	0.78	2405	500
$16^3 \times 32 \times 24$	2.3	0.04	0.155	5	0.76	2615	500



Static quark potential, coupling dependence



Double Jackknife fits by I. Mihailescu

- Assuming r_0 = 0.5 fm, lattice scale is $a^{-1} \approx$ 1.3 GeV, 1.7 GeV and 2.1GeV for beta = 2.3, 2.3533 and 2.4, respectively

Spectrum

N=1 SYM	QCD
$Tr\,\bar{\psi}\psi$	f_0
$Tr\,\bar{\psi}\gamma_5\psi$	η'
$Tr\,F_{\mu\nu}\sigma_{\mu\nu}\psi$	no analogue
glueballs	glueballs

Spectrum

N=1 SYM

$Tr\,\bar{\psi}\psi$

$Tr\,\bar{\psi}\gamma_5\psi$

$Tr\,F_{\mu\nu}\sigma_{\mu\nu}\psi$

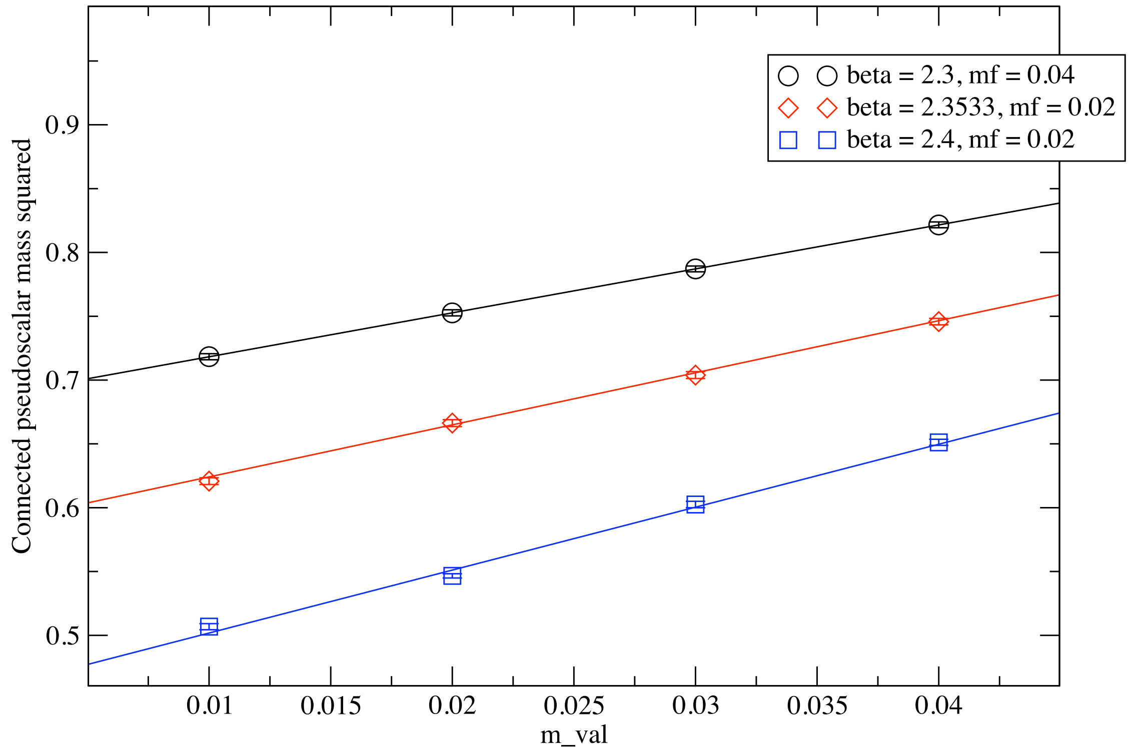
glueballs

⇒ Supermultiplets

Veneziano and Yankilowicz (1982)

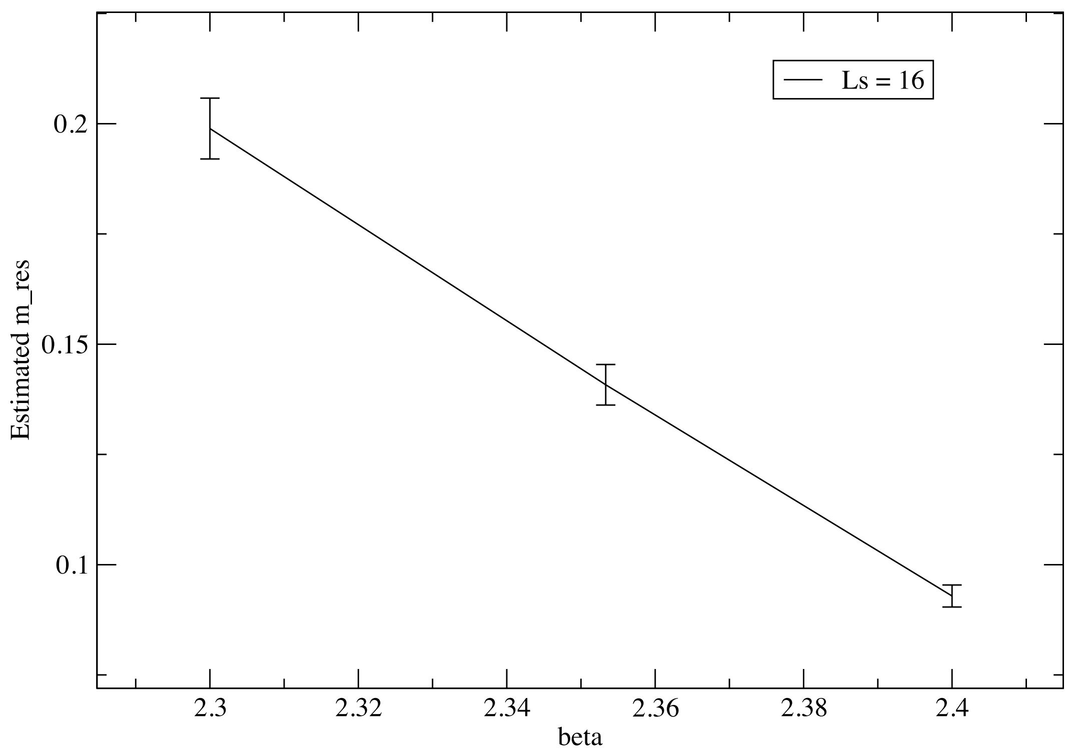
(NO SUSY BREAKING)

m_{val} extrapolation of connected pseudo-scalar



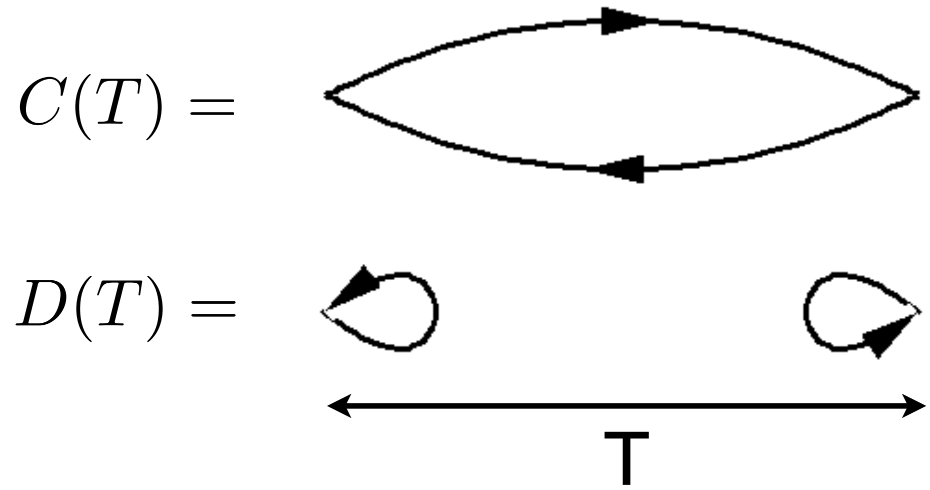
- Estimated m_{res} using extrapolated value of the valence mass (m_{val}) to m_{val}=0 in the partially quenched theory

Beta dependence of residual mass



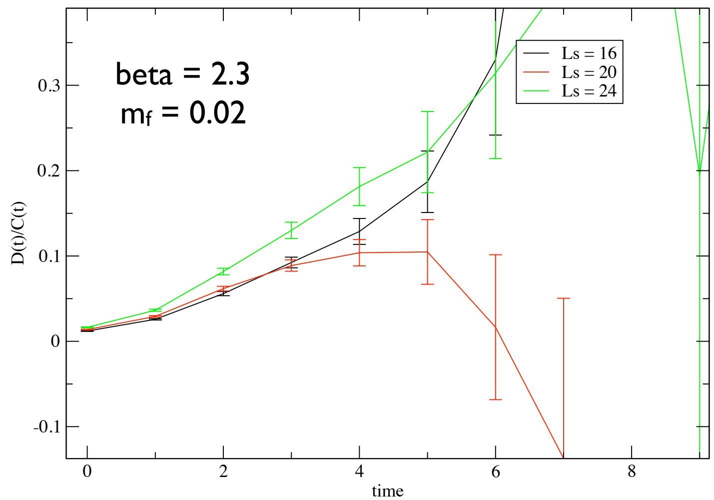
- Strong beta dependence suggests dislocation term dominates residual mass

Spectrum



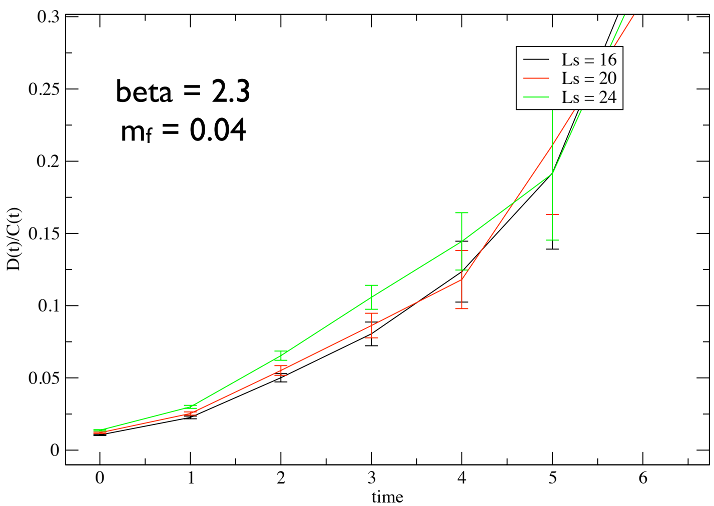
- Connected and disconnected diagrams evaluated using random wall and volume sources respectively
  - 1 hit for connected
  - 5 hits for disconnected

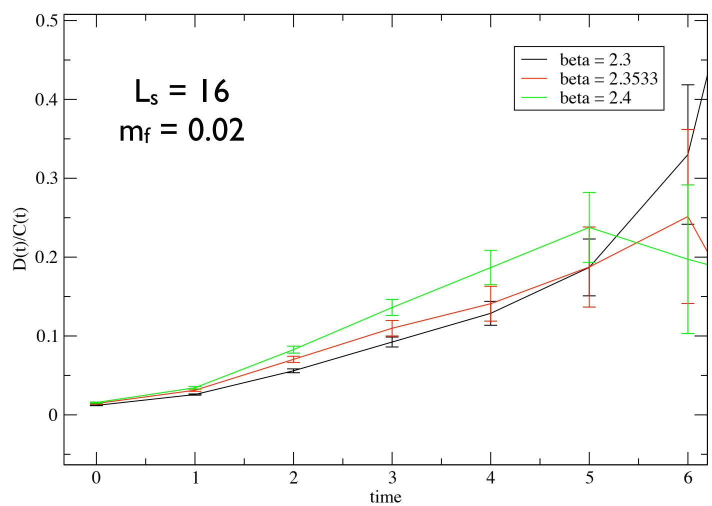
Ratio D(t)/C(t) for pseudo-scalar



$$D(T)/C(t) \approx a + be^{-\Delta m t}$$

$$\Delta m = m_{pscalar} - m_{connected}$$





Future tasks and directions

- m_{res} appears to be large
  - larger L_s
  - alternative gauge actions
- Obtain a better determination of residual mass
- Continue spectrum measurements
  - increased statistics
  - write code for fermion super-partner
- Continuum extrapolation of gluino condensate
  - needs more beta values

Acknowledgements

- I would like to thank N. Christ, C. Kim and R. Mawhinney for numerous helpful discussions, I. Mihailescu for fitting the static quark potential data and C. Jung for technical assistance with compiling and running CPS on QCDOC and New York Blue.
- Simulations performed using a modified version of the Columbia Physics System (CPS v4.9.16).
- Numerical simulations were performed on QCDOC at Columbia University and New York Blue (BlueGene/L) at Brookhaven National Laboratory.