The gluoN_c plasma and its 't Hooft limit $(1, 2, 3, \cdots \infty)$

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RG scaling and 't Hooft scaling

Latent heat

Equation of state

Summary

Limiting procedures

- 't Hooft scaling limit: take $N_c \to \infty$ and $g^2 \to 0$ keeping $\lambda = g^2 N_c$ fixed. Correlation functions can be computed non-perturbatively but diagrammatically by resumming a well-defined class of diagrams. Simple caricature of hadron physics in this limit.

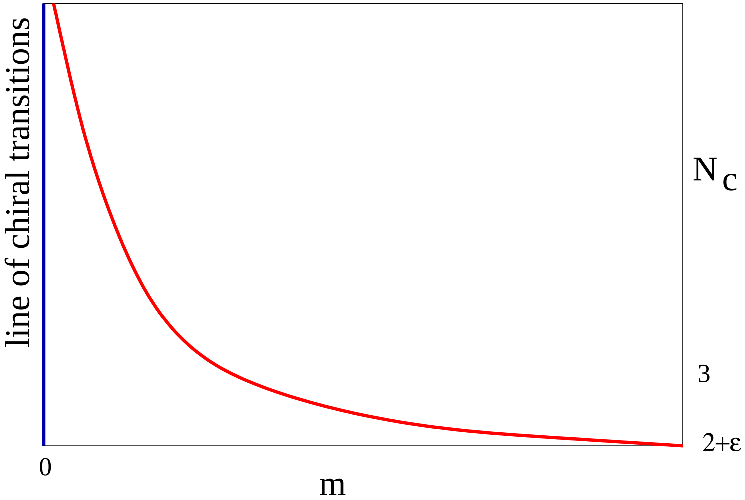
  't Hooft, Coleman; tested by Teper and collaborators

  Extended to many other classes of theories. AdS/CFT correspondence works in the 't Hooft limit of $N_c \to \infty$.
- Strong scaling limit: work at (fixed) long distance scales and take $N_c \to \infty$. Non-perturbative content of the theory may be explored on the lattice and the limit taken.

  Teper, Lucini and collaborators

Corrections organized in power of $1/N_c$

Flag diagram of gluoN_c plasmas



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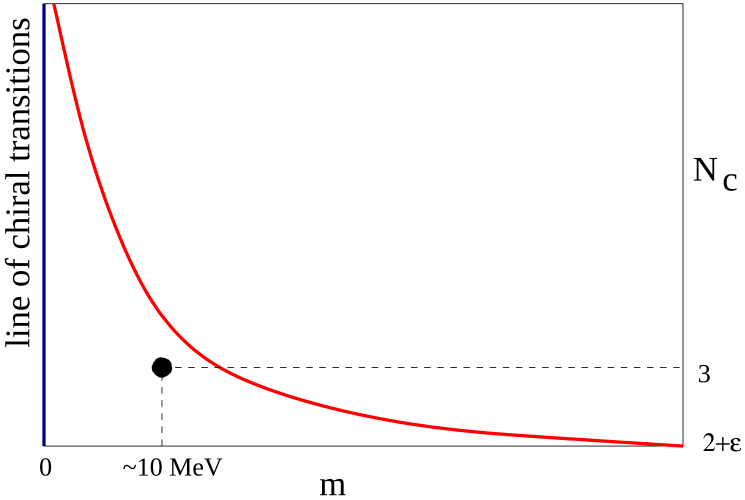

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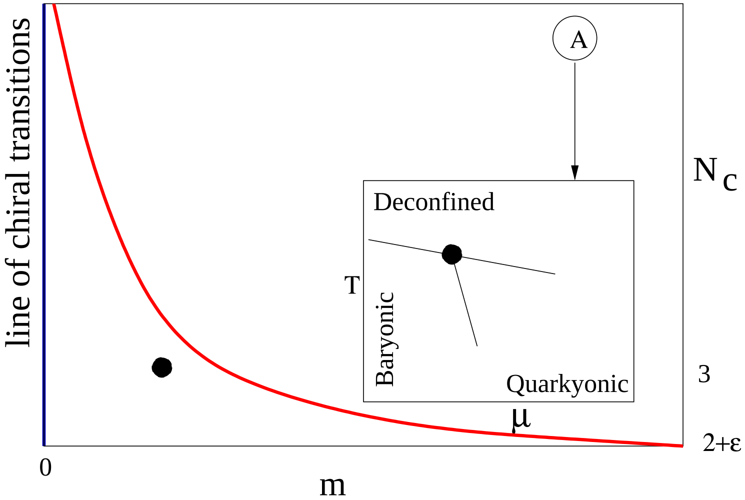

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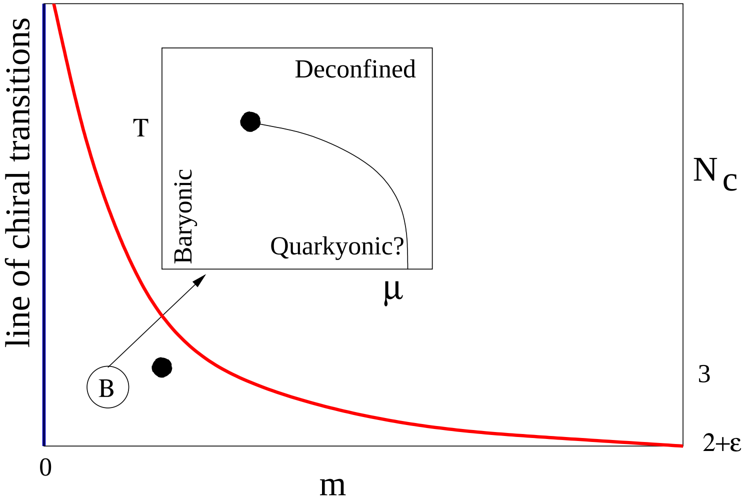

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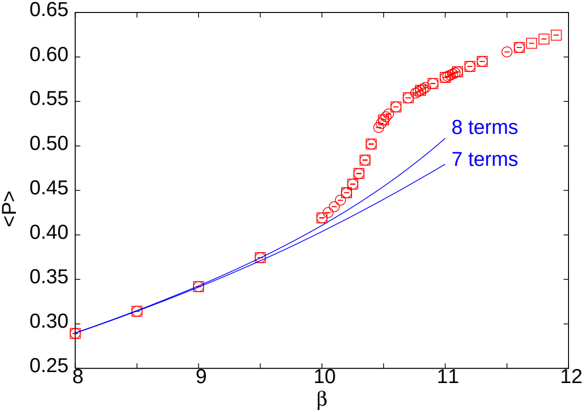
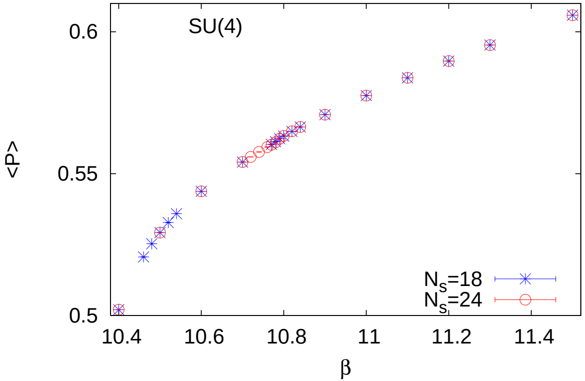
Unphysical strong–weak coupling crossover



Wilson action. Earlier generation of simulations limited by this bulk transition; solution now: move to smaller lattice spacing.

Teper and collaborators, Panero

··· no longer a problem



Clear 1st order transition signal in L but not in plaquette: therefore thermal transition, not bulk. Similarly for $N_c = 6$, 8 and 10. Computations for $N_t = 6, 8, 10$ and (sometimes) 12.

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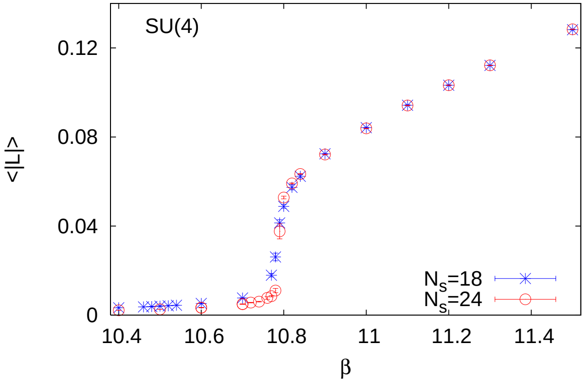

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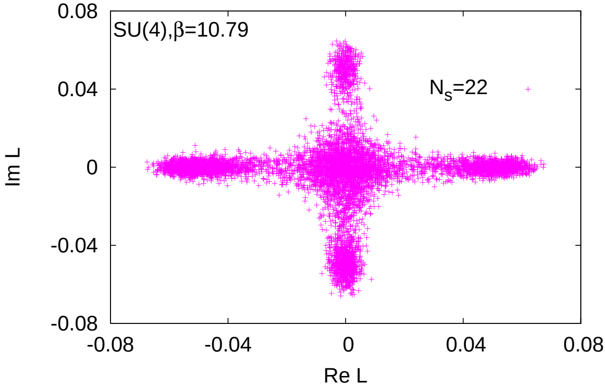

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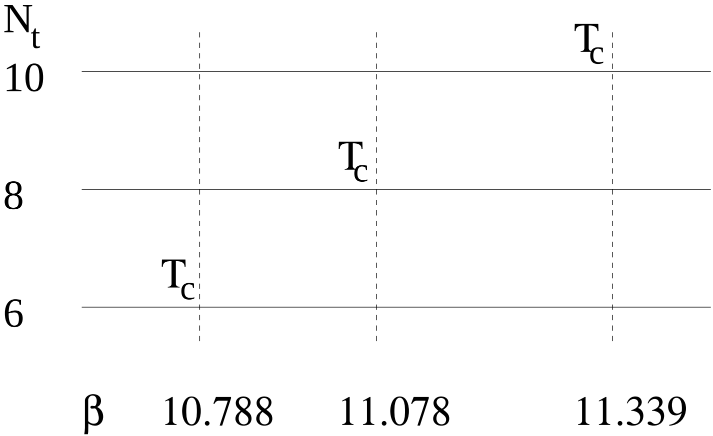
Precision test of RG



β_c determined to one part in 10^4. Strong coupling determined non-perturbatively. 2-loop RG works with precision of two parts in 10^3 for $a \leq 1/(8T_c)$. For larger a: non-perturbative RG.

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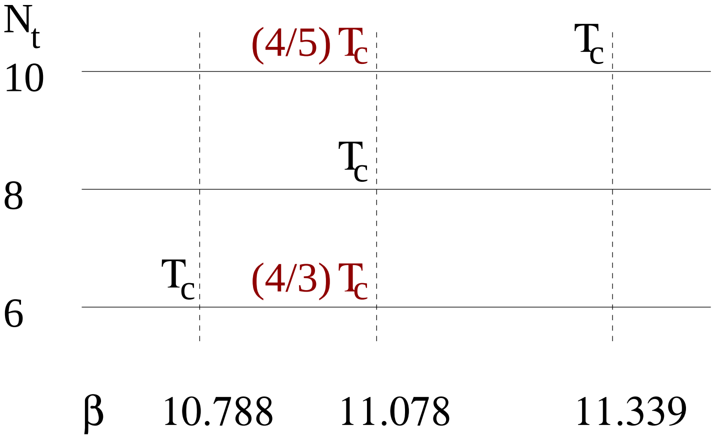

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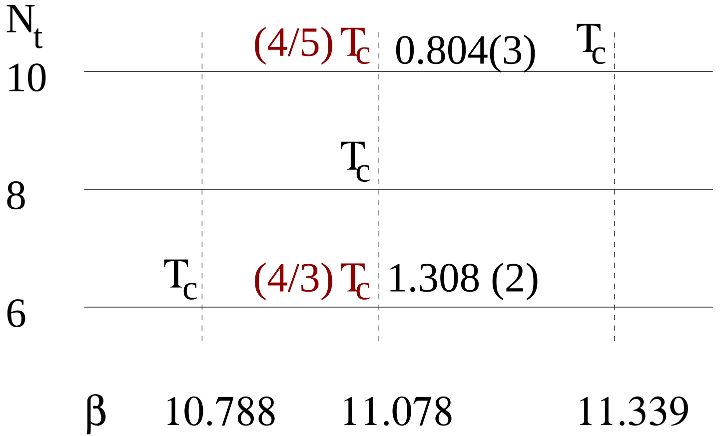

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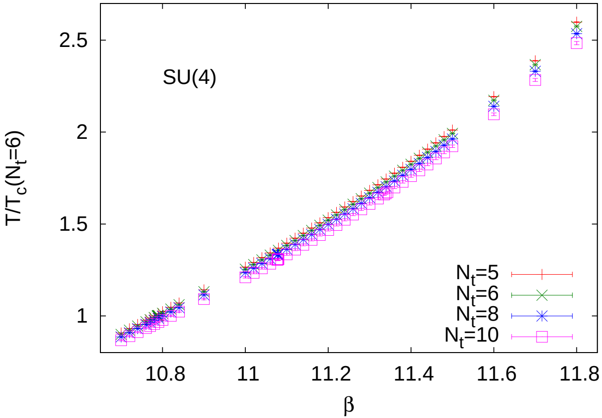

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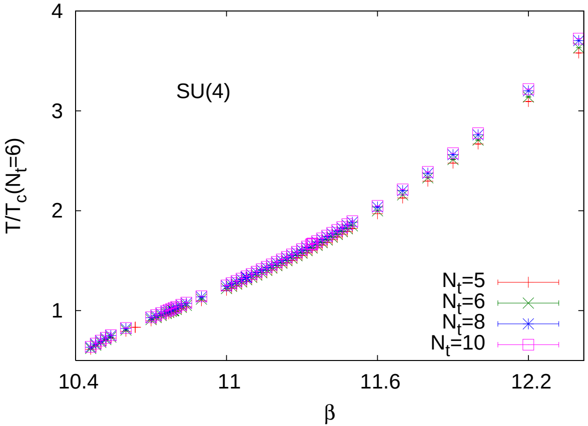

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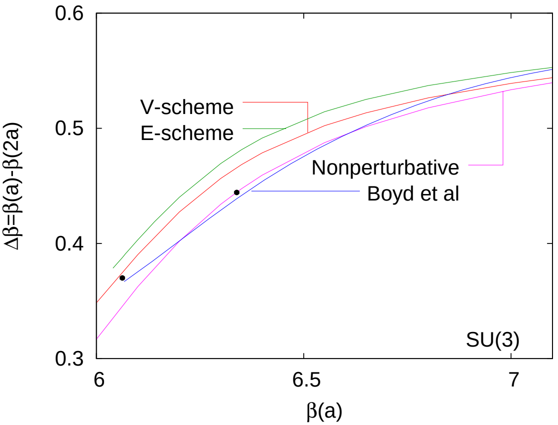

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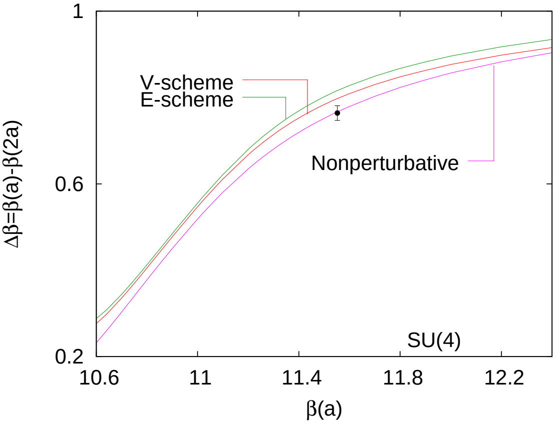
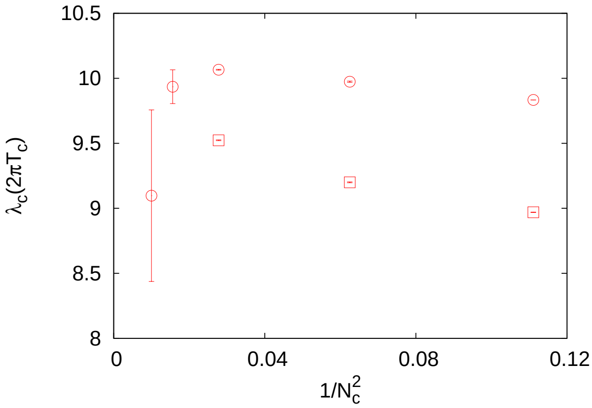


't Hooft scaling: fixed λ, fixed physics



$\lambda_c = g^2(T_c)N_c$. Clearly non-linear (even ignoring $N_t = 8$ and 10).

Very large corrections

Best-fit function:

$$\lambda_c = \begin{cases} 9.8771(4) - \frac{14.2562(2)}{N_c^2} + \frac{54.7830(2)}{N_c^4} & \text{(non-perturbative)}, \\ 9.9904(6) + \frac{1.2081(3)}{N_c^2} - \frac{23.5709(3)}{N_c^4} & \text{(2-loop)}. \end{cases}$$

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For $N_c = 3$

$$\lambda_c = \begin{cases} 9.8771(4) - 1.584 + 0.676 & \text{(non-perturbative)}, \\ 9.9904(6) + 0.134 - 0.291 & \text{(2-loop)}. \end{cases}$$

$1/N_c^2$ and $1/N_c^4$ corrections nearly equal to each other.

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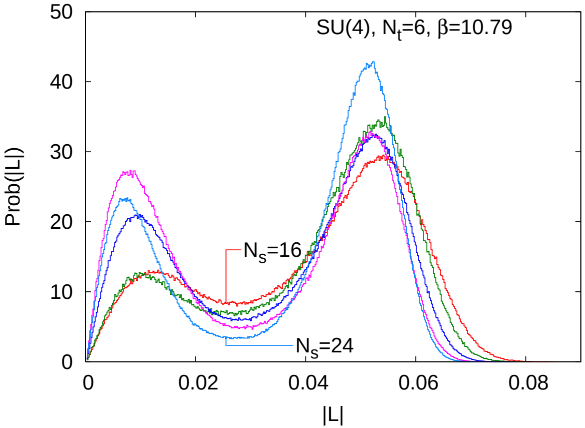
Multiple peaks?



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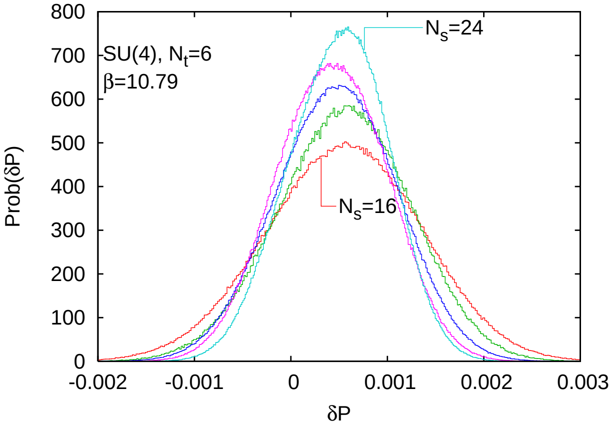

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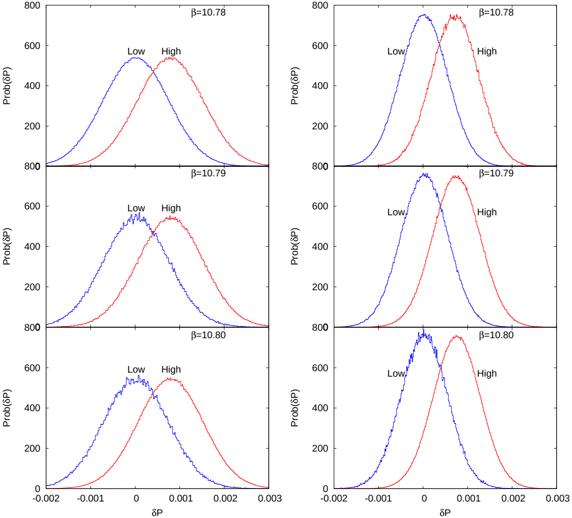
Isolate phases using order parameter



Stable against change in V and a

Is $N_c = 3$ special?

N_t	N_s	$\Delta E/T_c^4$	$\Delta E/\Delta_{\max}$
4	16	2.06(1)(3)	
	24	1.93(1)(3)	
	32	1.90(2)(2)	
6	16	1.79(2)(4)	0.65(2)
	32	1.54(2)(5)	
	48	1.44(4)(3)	

$N_c \geq 4$ results stable for $N_s/N_t \simeq 3$. But large finite size effect for $N_c = 3$.

Scaling with N_c

Latent heat depends on N_c even after scaling by number of gluons: $T_A = N_c^2 - 1$. Best fit result—

$$\frac{\Delta\epsilon}{T_A T_c^4} = 0.388(3) - \frac{1.61(4)}{N_c^2}.$$

$N_c = 3$ may have larger finite volume effects than larger N_c.

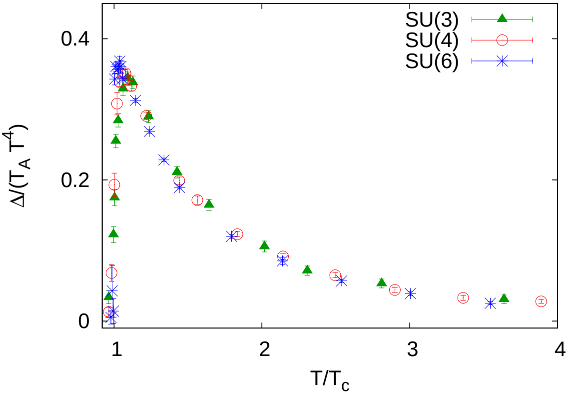
For $N_c = 2$

$$\frac{\Delta\epsilon}{T_A T_c^4} = 0.388(3) - 0.40(1) = 0!$$

Good news? Bad news?

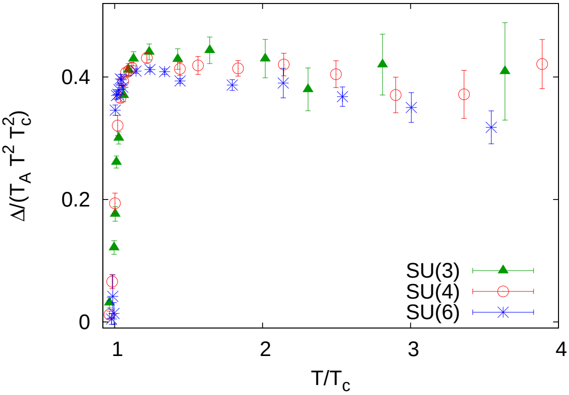
Outline

Conformal symmetry breaking



Good scaling of $\Delta/T^4 = (E - 3P)/T^4$ with N_c at fixed T/T_c (strong N_c scaling).
$\Delta^{1/4} \simeq T$ even at $T \simeq 2T_c$ for $N_c = 3$: conformal symmetry

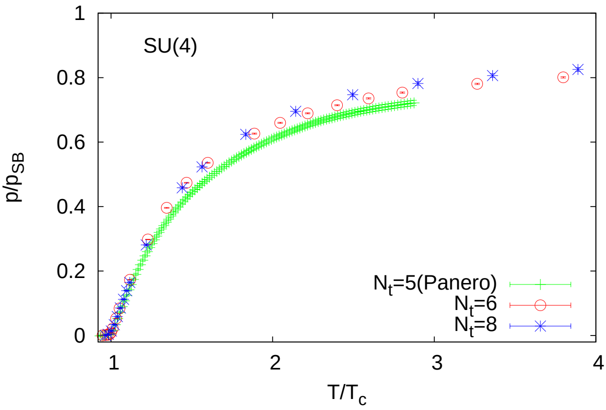
Evidence for mass?



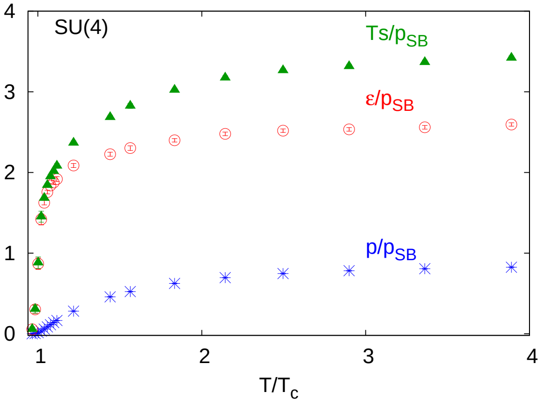
$\Delta/T^2 \simeq$ constant is generic evidence for mass scales persisting in the high temperature phase.

Meisinger, Miller, Ogilvie, 2002; Pisarski, 2007

Cutoff dependence of pressure



Main results



Far from ideal gas.
Good scaling of EOS with N_c at fixed T/T_c (strong N_c scaling).

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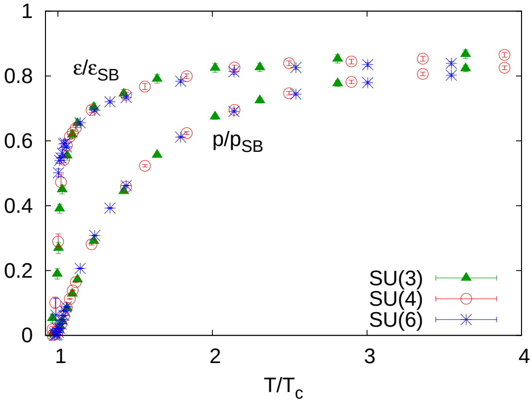

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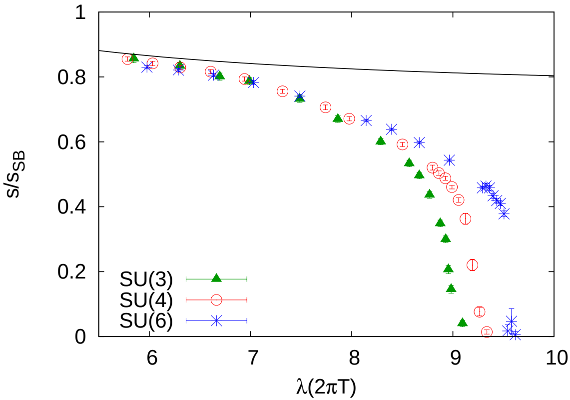
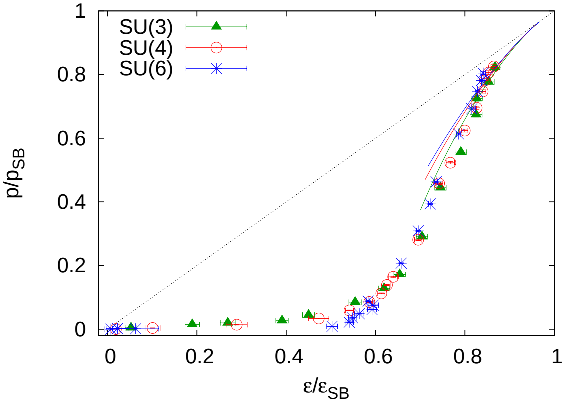


't Hooft scaling fails for $T \leq 2T_c$.

$\mathcal{N} = 4$ SYM does not describe pure gauge theory.

Conformal theory?



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Main results

- Location of deconfining first order transition measured with high accuracy. Yields high precision test of RG scaling and 't Hooft scaling. 't Hooft coupling at T_c has large $1/N_c$ corrections near $N_c = 3$. Signs of breakdown of the 't Hooft procedure.
- New method developed for determination of latent heat in gluoN_c plasmas. Find

$$\frac{\Delta\epsilon}{T_A T_c^4} = 0.388(3) - \frac{1.61(4)}{N_c^2}.$$

- Strong N_c scaling works very well for EOS. Conformal symmetry strongly broken up to $T \simeq 3T_c$. Resummed weak coupling theory works much better in description of lattice data.