SU(3) THERMODYNAMICS AN THE ONSET OF PERTURBATIVE BEHAVIOUR

SZABOLCS BORSANYI

WUPPERTAL

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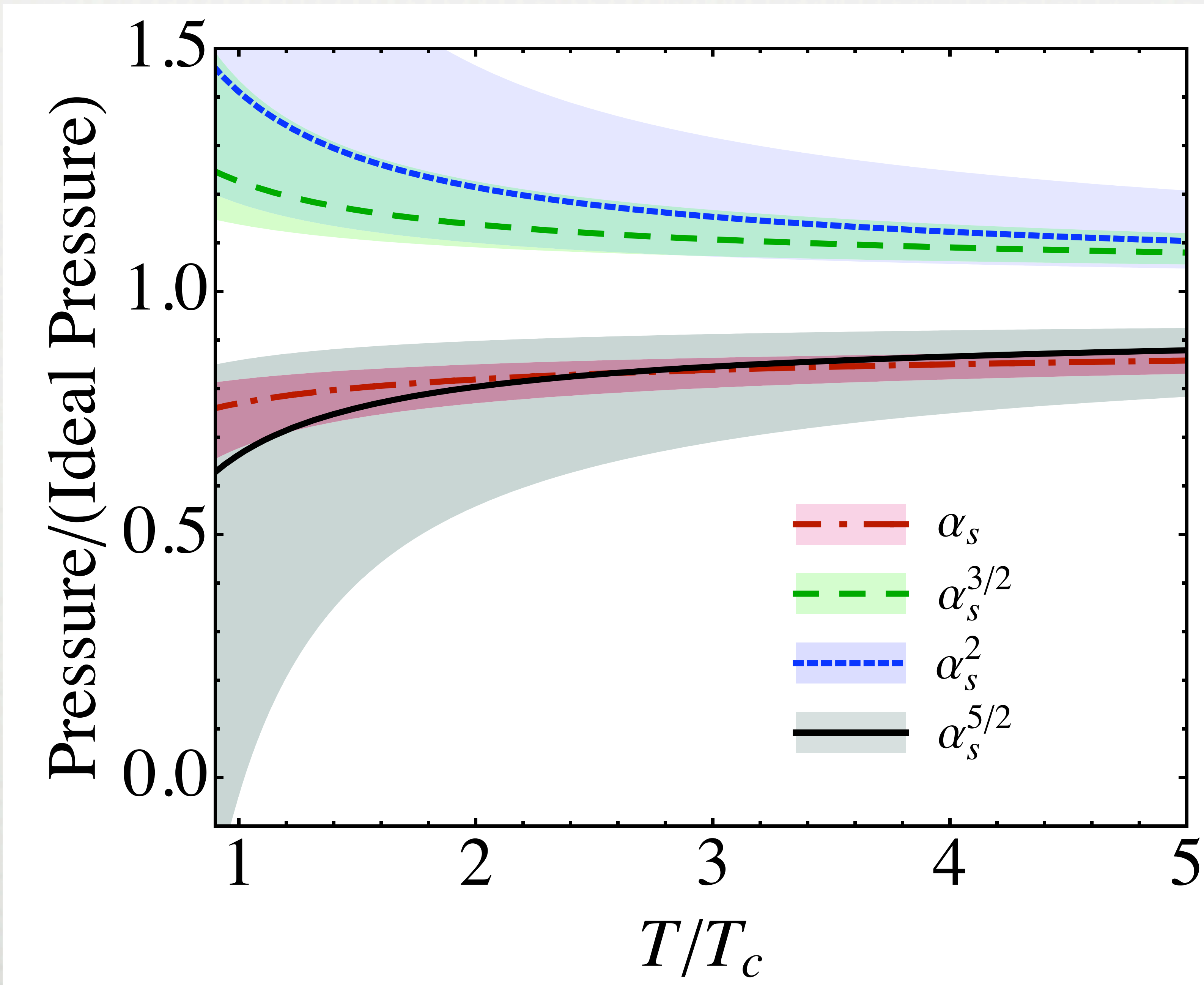
PERTURBATION THEORY

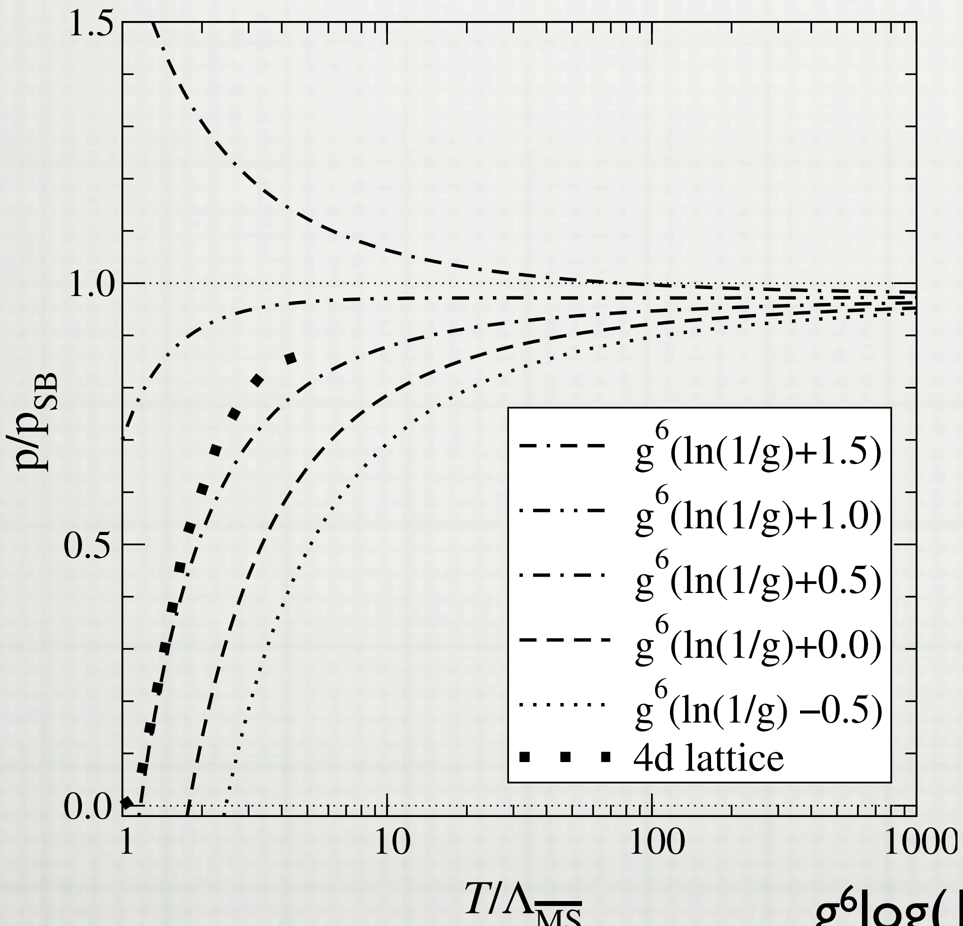


(Plot: Andersen,Strickland, Su: 1005.1603)

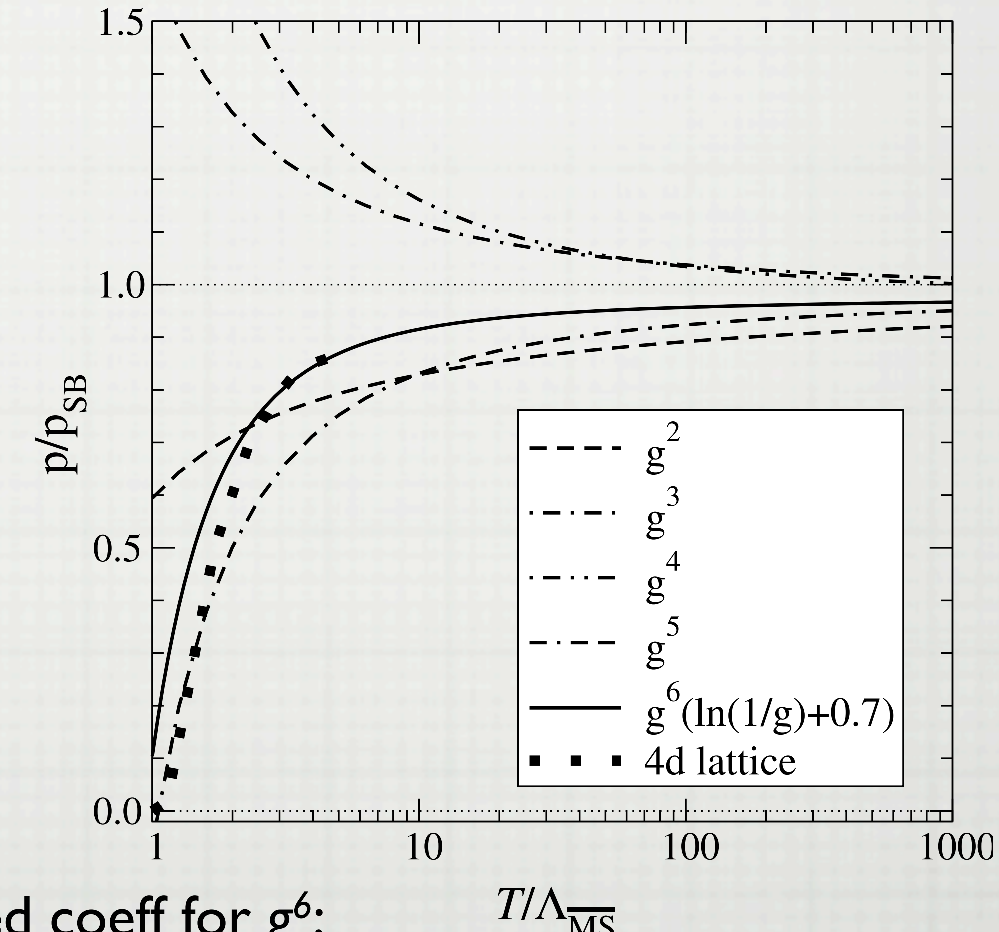
PERTURBATION THEORY

PERTURBATIVE RESULTS ARE KNOWN UP TO $O(g^6 log(1/g))$

THE g^6 COEFFICIENT IS FITTED TO '96 LATTICE DATA

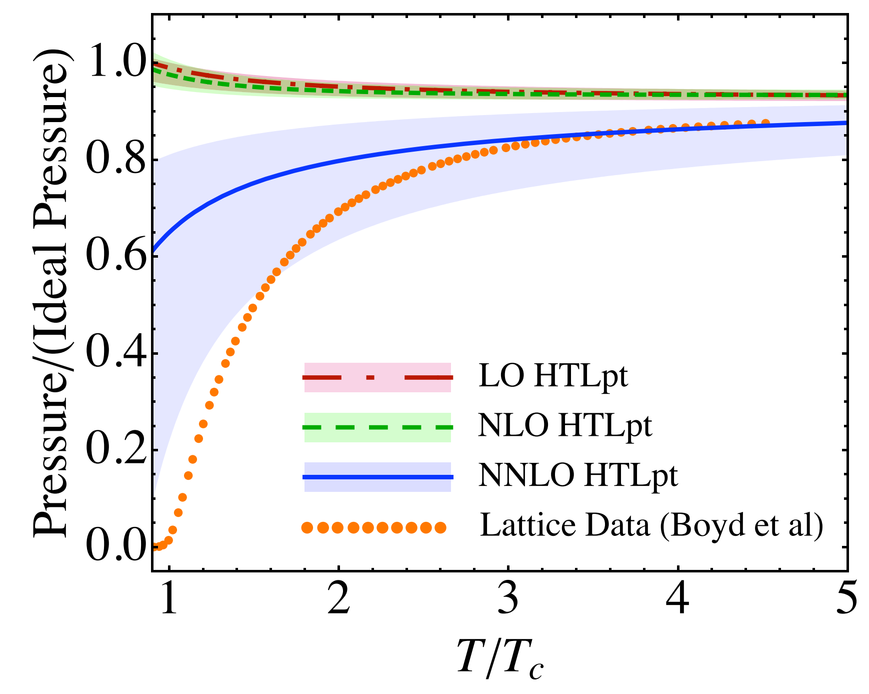


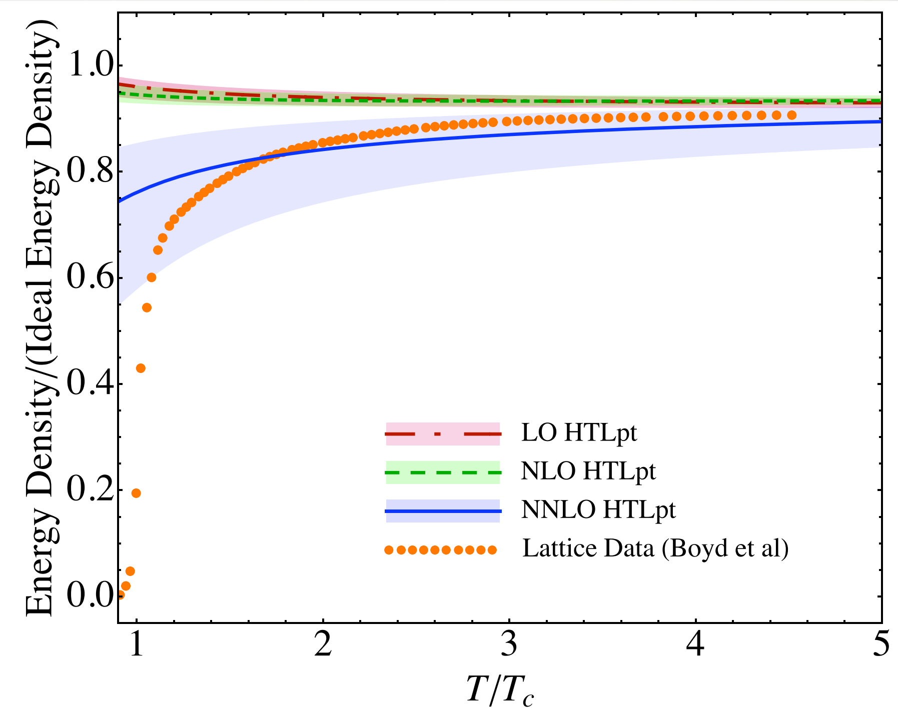
$g^6 \log(1/g)$ + fitted coeff for g^6:

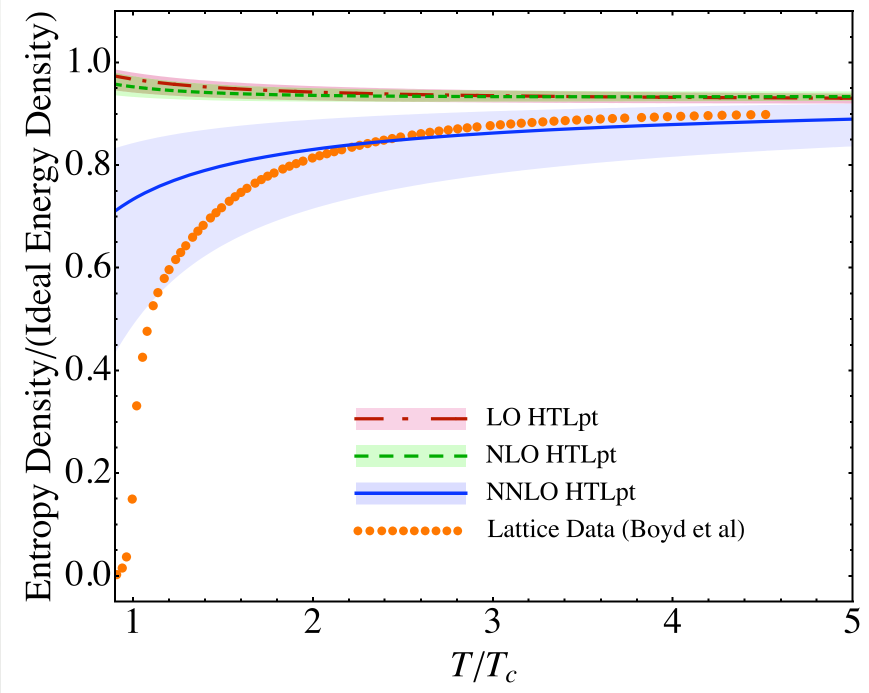


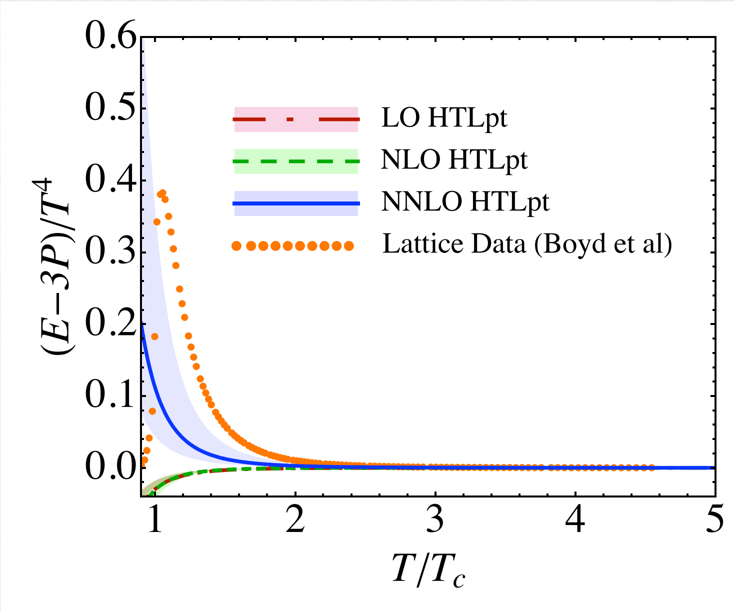
Kajantie, Laine, Rummukainen, Schroder: **Phys.Rev.D67:105008,2003**

HARD THERMAL LOOPS



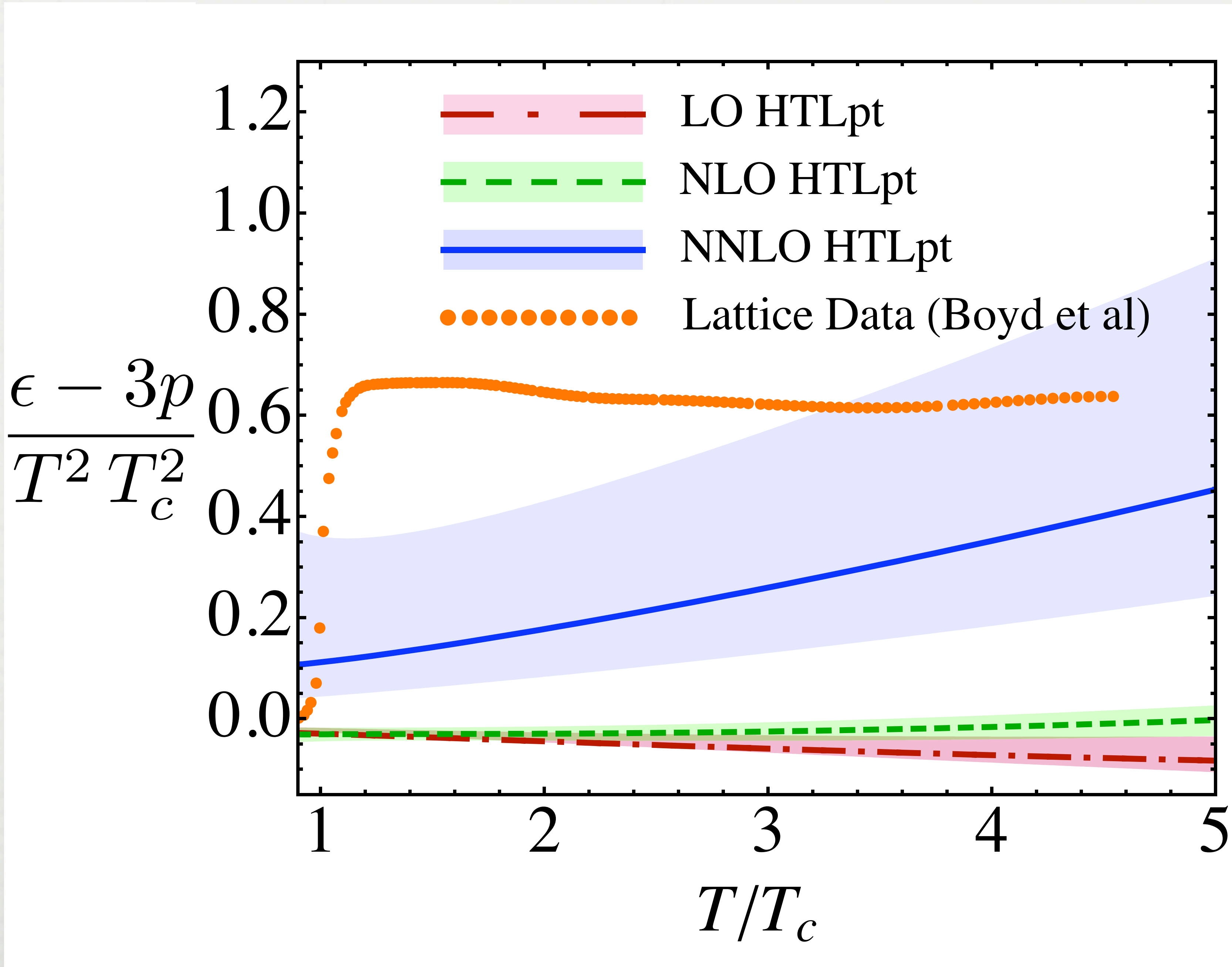






Andersen,Strickland, Su: 1005.1603

RESCALED TRACE ANOMALY



Andersen,Strickland, Su: 1005.1603

GOAL:

LATTICE SU(3)
EQUATION OF STATE
UP TO "PERTURBATIVE"
TEMPERATURES

SU(3) THERMODYNAMICS

- 1996 BOYD ET AL: EQUATION OF STATE
  $T<4.5$ TC (PLAQUETTE ACTION ,NT=8)

- 1998 BEINLICH ET AL: EQUATION OF STATE
  $T<3$ TC(SYMANZIK ACTION, NT=4)

- 2007 GUPTA&KACZMAREK: POLYAKOV LOOP
  $T < 24$ TC (PLAQUETTE ACTION, NT=4)

- 2009 PANERO: EQUATION OF STATE
  $0.8T_c < T < 3.4T_c$ (Nc DEPENDENCE)

- 2010 DATTA&GUPTA: EQUATION OF STATE, LATENT HEAT
  $0.8T_c < T < 4T_c$ (Nc DEPENDENCE,CONT.LIM) [TALK LATER TODAY]

- THIS WORK: EQUATION OF STATE + POLYAKOV LOOP
  0.8 TC $< T < 10000$ TC (TREE LEVEL SYMANZIK ACTION, NT=5,6,8)

CHALLENGES

- SCALE FUNCTION AT HIGH BETA

WHEN DOES THE 2-LOOP RUNNING START?

IMPROVED SCHEMES

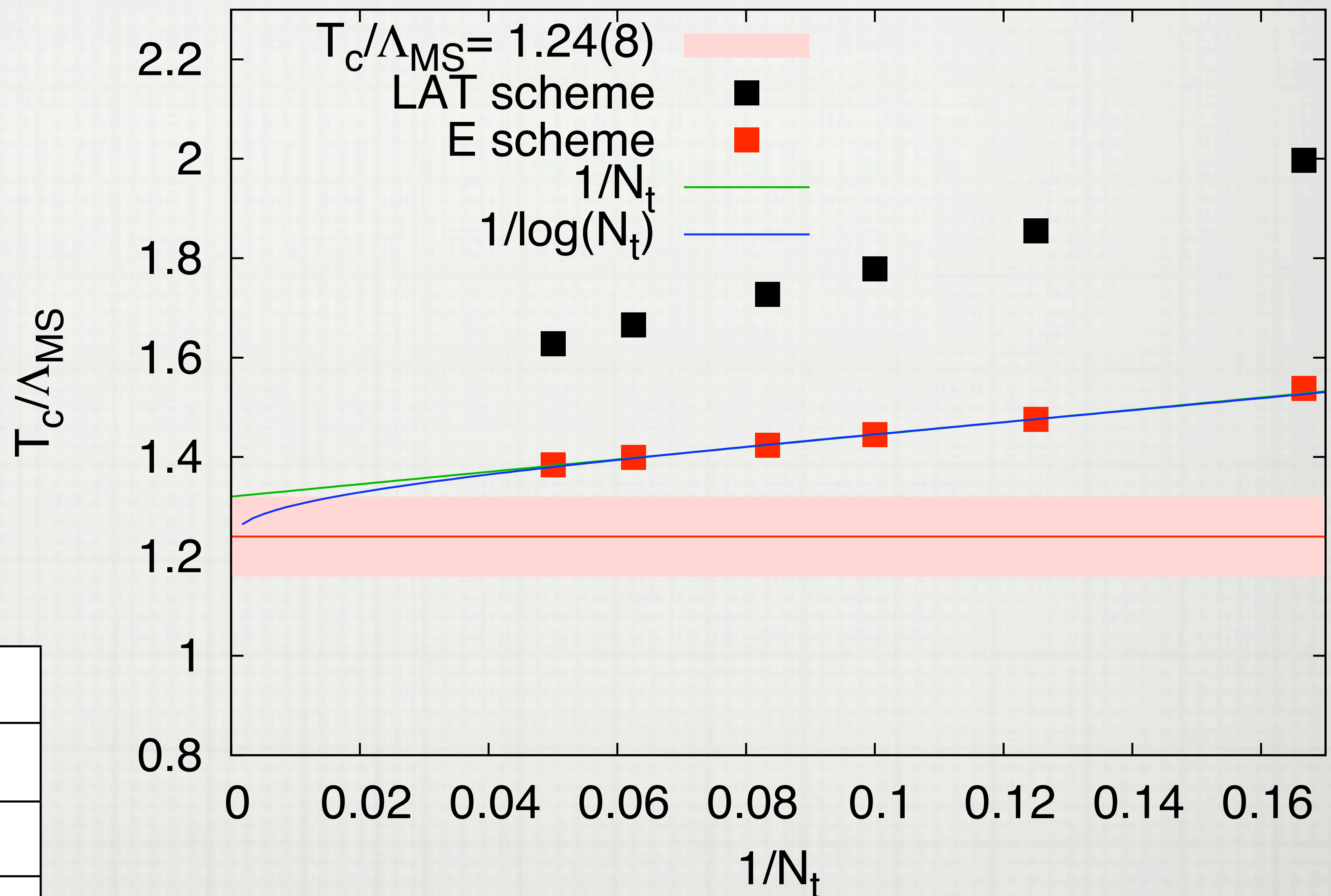
ASYMPTOTIC SCALING

N_τ	β_c (Improved)
3	3.90812(7)
4	4.07252(13)
5	4.19963(14)
6	4.31466(24)

CELLA ET AL 1994

OUR DATA:

Nt	βc
8	4.5092(27)
10	4.6729(75)
12	4.811(10)
16	5.037(16)
20	5.217(30)



E SCHEME A'LA: BALI & SCHILLING 1992

SIMILAR WORK:

PLAQ. ACTION/R0: GÖCKELER ET AL 2005

CHALLENGES

- SCALE FUNCTION AT HIGH BETA

WHEN DOES THE 2-LOOP RUNNING START?

IMPROVED SCHEMES

- AUTOCORRELATION

DOES IT EXPLODE AS BETA GROWS?

FINITE T BOXES, MODERATE VOLUME, 100000 LONG STREAMS

CHALLENGES

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FINITE T BOXES, MODERATE VOLUME, 100000 LONG STREAMS

- LARGE (ENOUGH) VOLUME

SMALL VOLUME MAY KILL NONPERTURBATIVE EFFECTS

VOLUME EFFECTS ARE STRONGLY SUPPRESSED (for EOS only)

BIG VOLUMES UNTIL $T<20T_c$

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BIG VOLUMES UNTIL $T<20T_c$

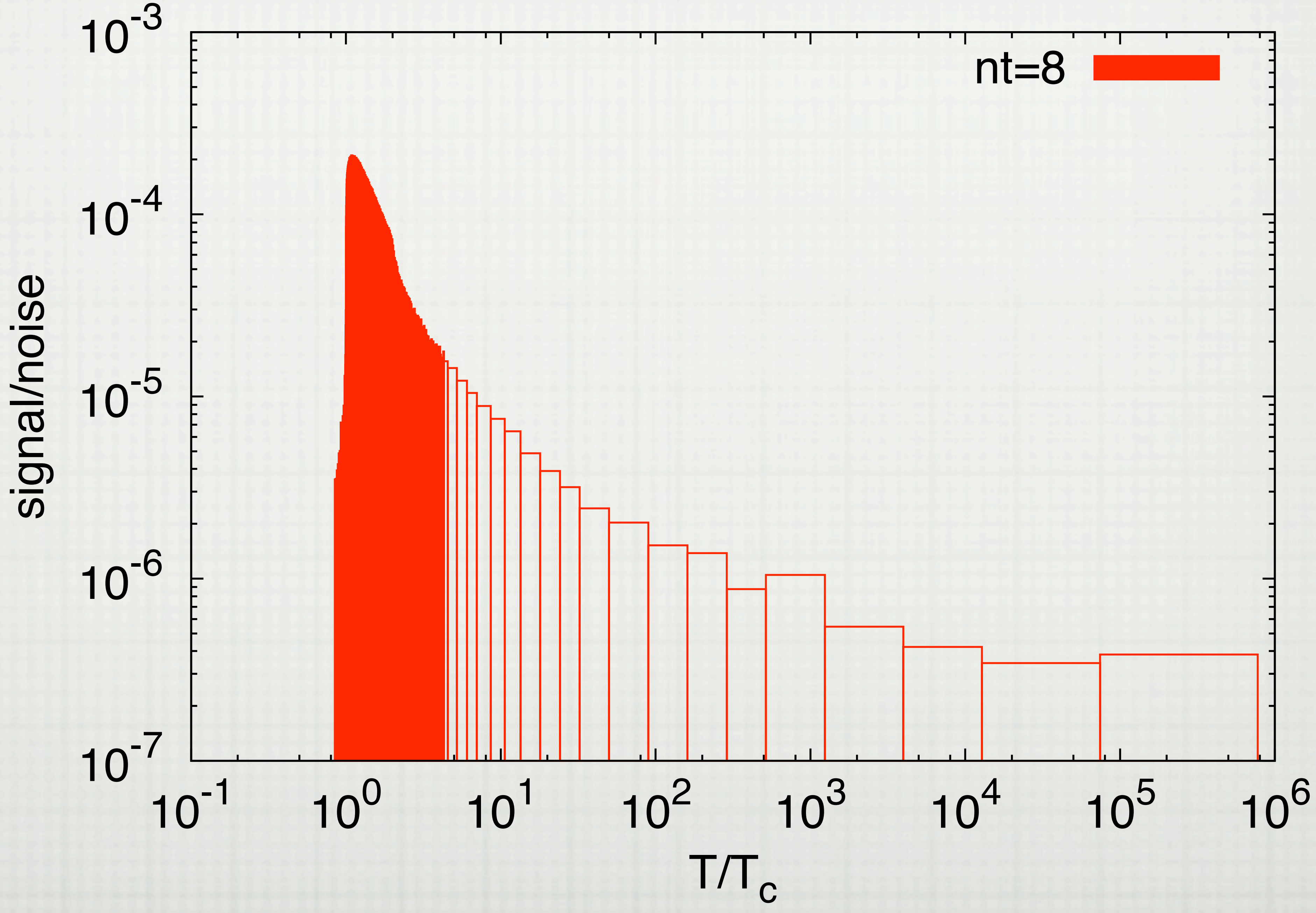
- STATISTICS (NT=5,6,8)

SIGNAL-TO-NOISE RATIO DROPS QUICKLY WITH TEMPERATURE

LARGE SCALE SU(3) PROJECT

QPACE

EVEN SU(3) CAN BE EXPENSIVE



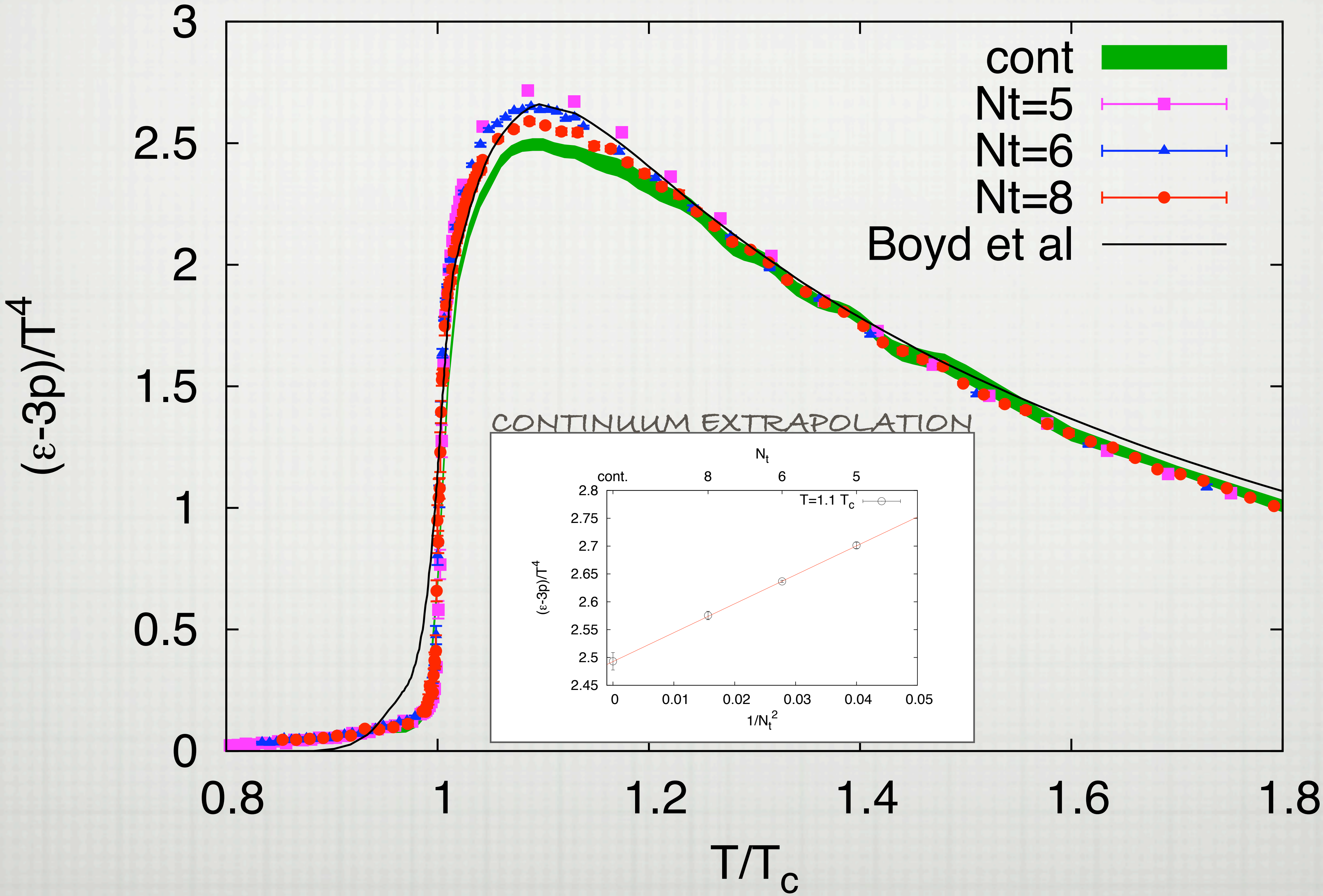
STATISTICS

Lattice	Beta range	Temperature range [Tc]	No. of updates
40^3x5	4.0 - 15.0	0.7 - 400000	182526873
40^3x10			75644407
48^3x6	4.2 - 15.0	0.83 - 330000	136243228
48^3x12			63099000
64^3x8	4.3 - 13.0	0.73 - 23650	89463241
64^3x16			39061437

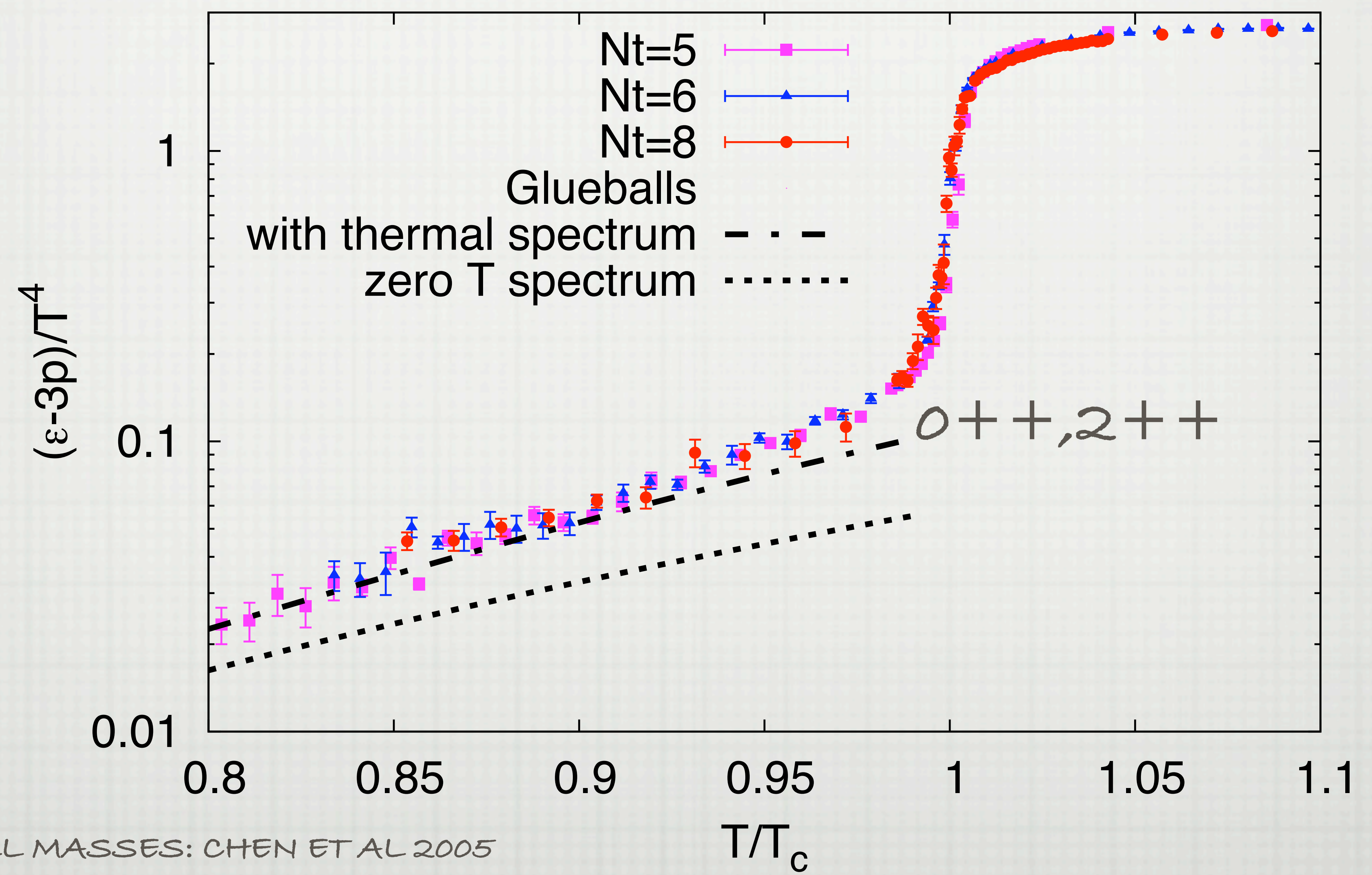
COMPARED TO THE UNQUENCHED (STAGGERED) EOS: 1000X CHEAPER UPDATE

10X MORE SIMULATION POINTS; 10 X SMALLER ERROR BARS

TRANSITION REGION



THERMAL GLUON GAS

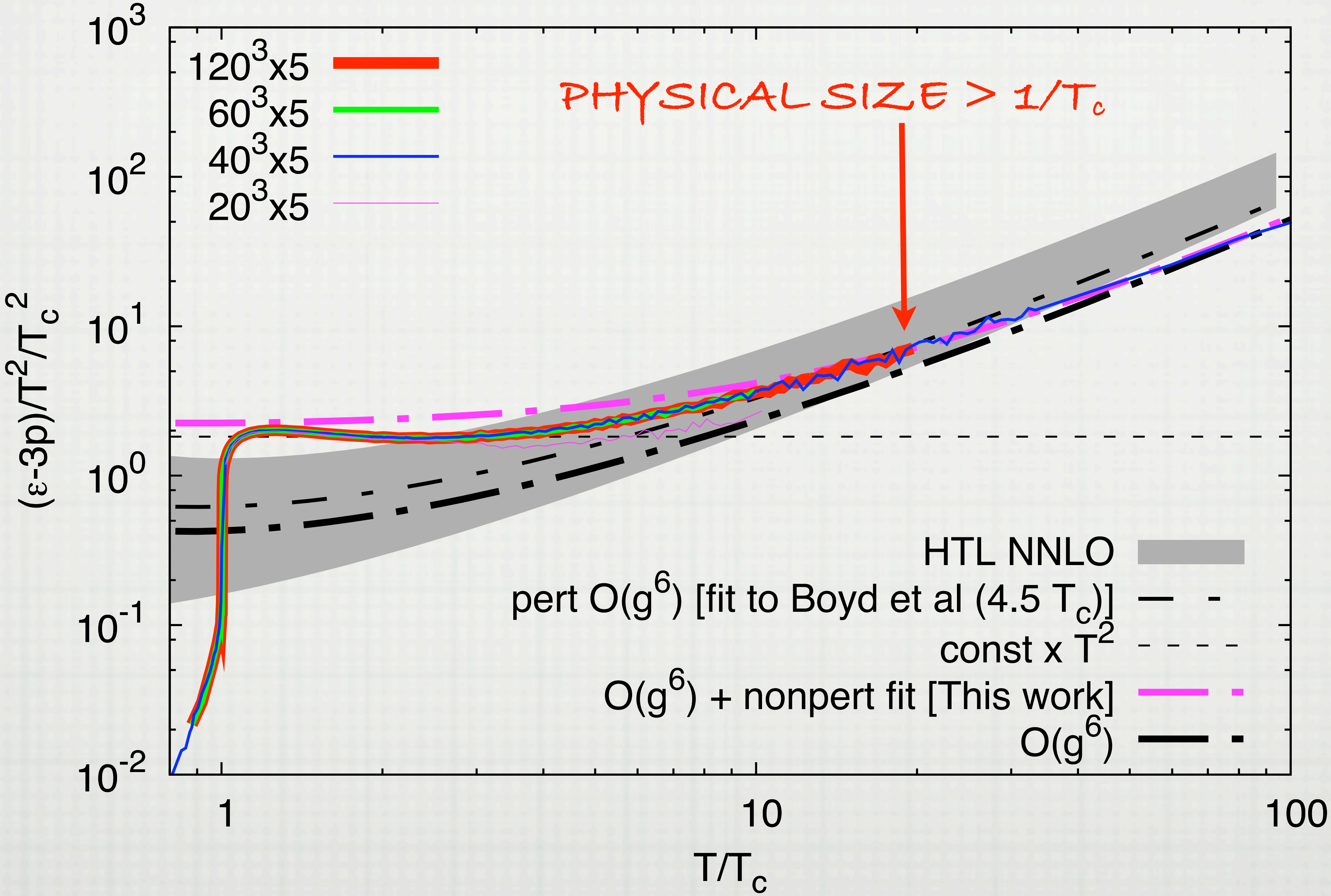


GLUEBALL MASSES: CHEN ET AL 2005

THERMAL GLUEBALL MASSES: ISHII ET AL 2002

SEE ALSO: BUISSERET, 0912.0678

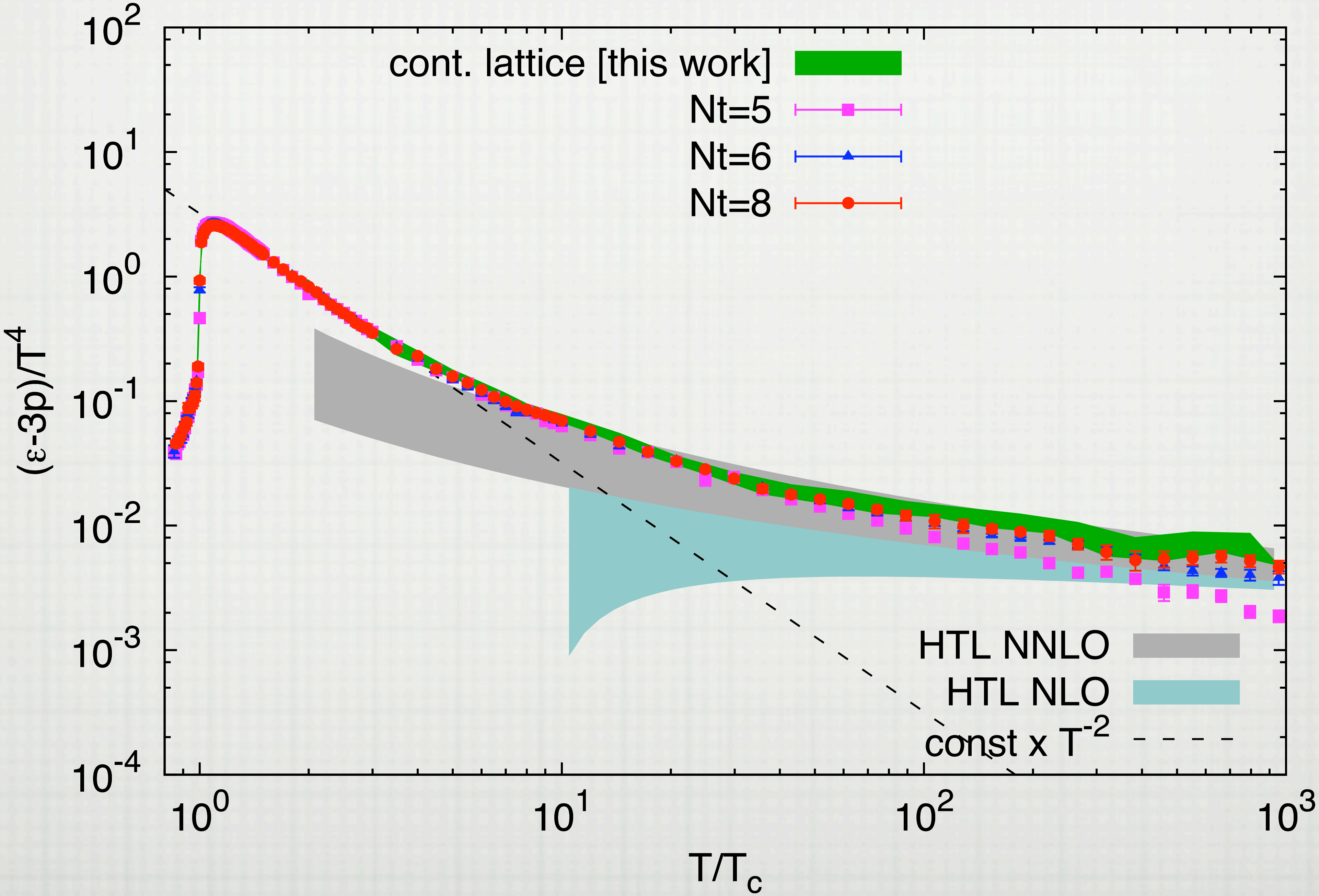
ONSET OF PERTURBATIVE BEHAVIOUR



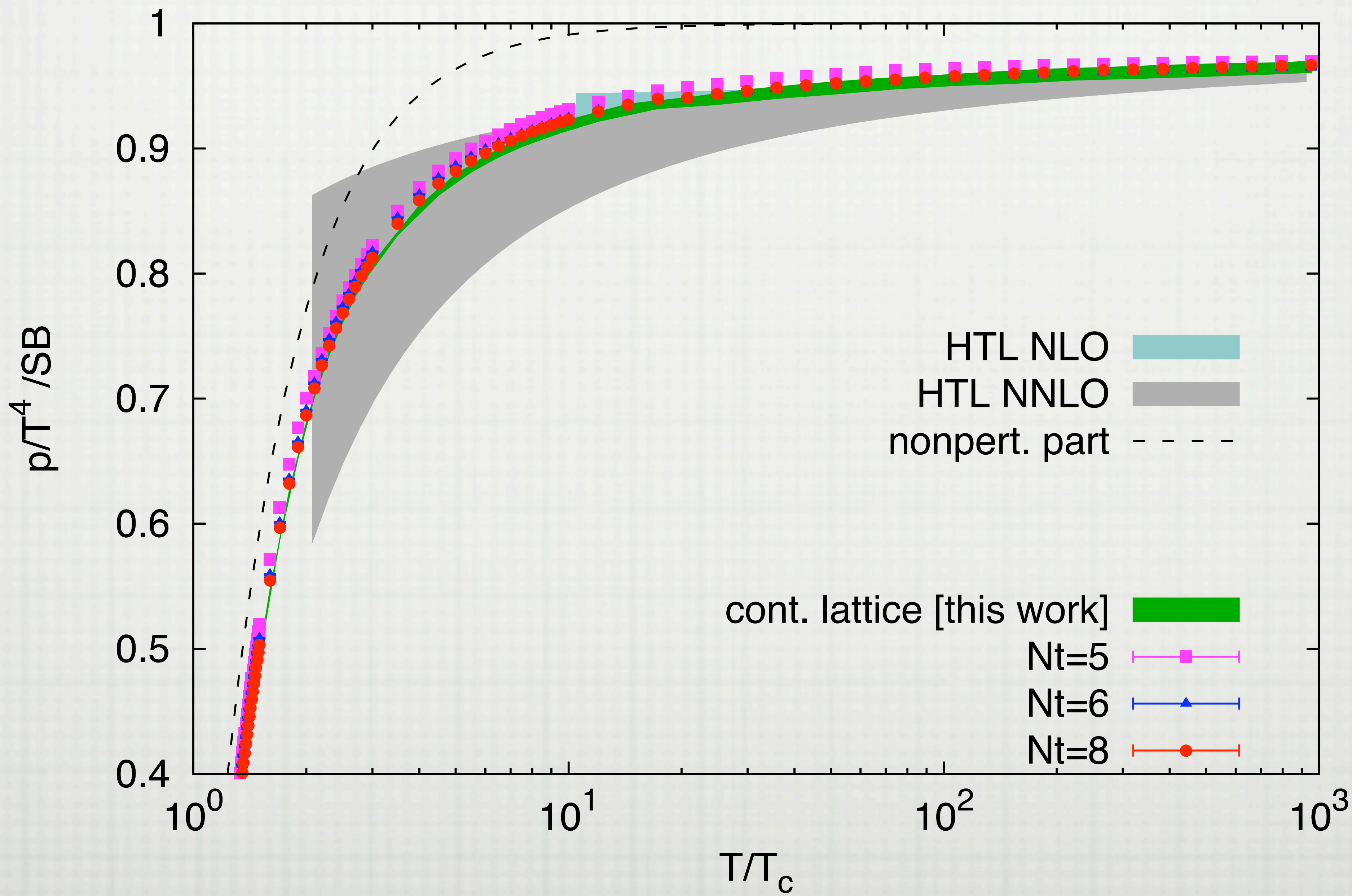
HTL NNLO: Andersen, Strickland, Su **Phys.Rev.Lett.104:122003,2010**

O(g^6): Kajantie, Laine, Rummukainen, Schroder: **Phys.Rev.D67:105008,2003**

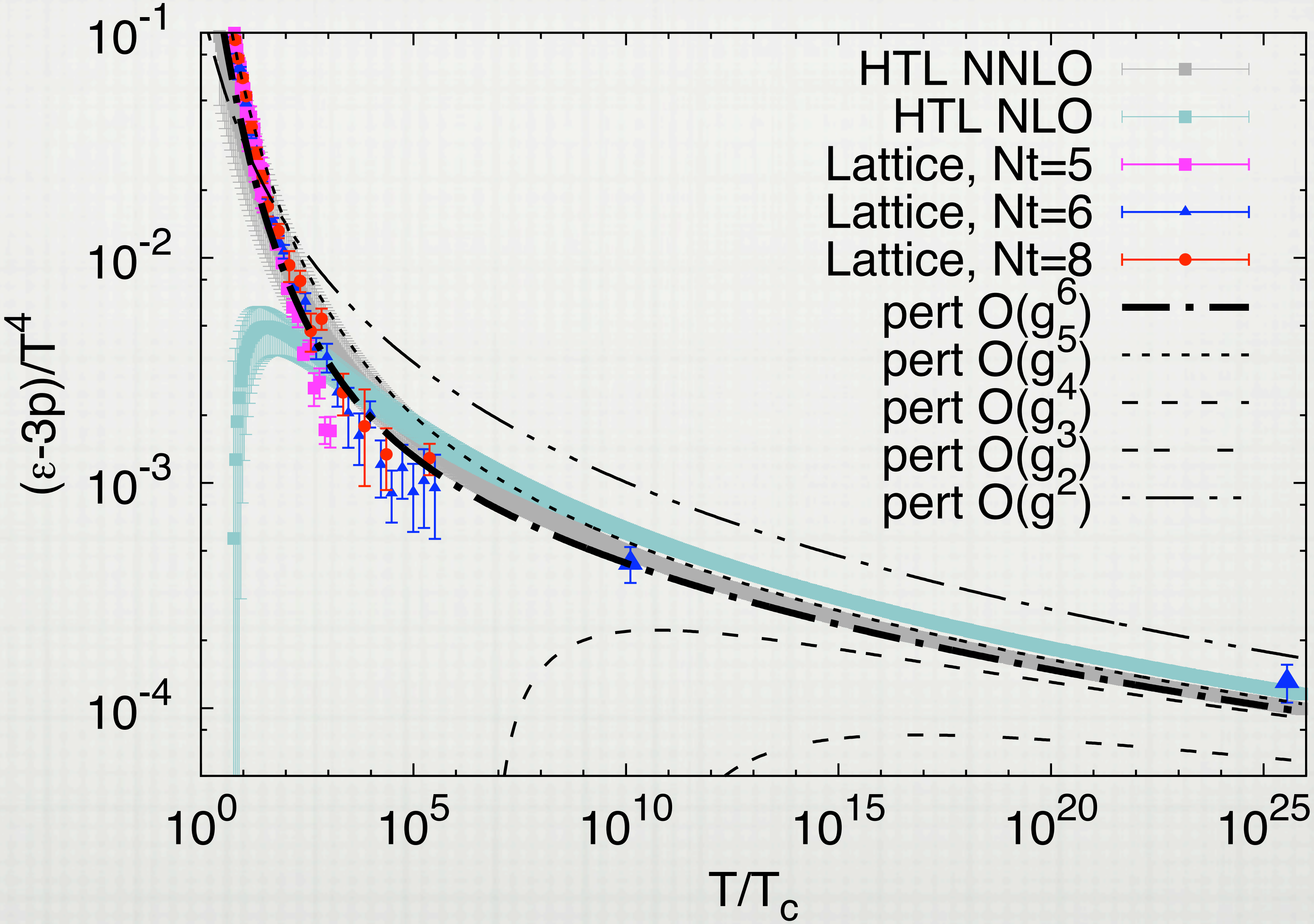
HIGHER TEMPERATURES



LATTICE VS THE PERTURBATIVE EOS



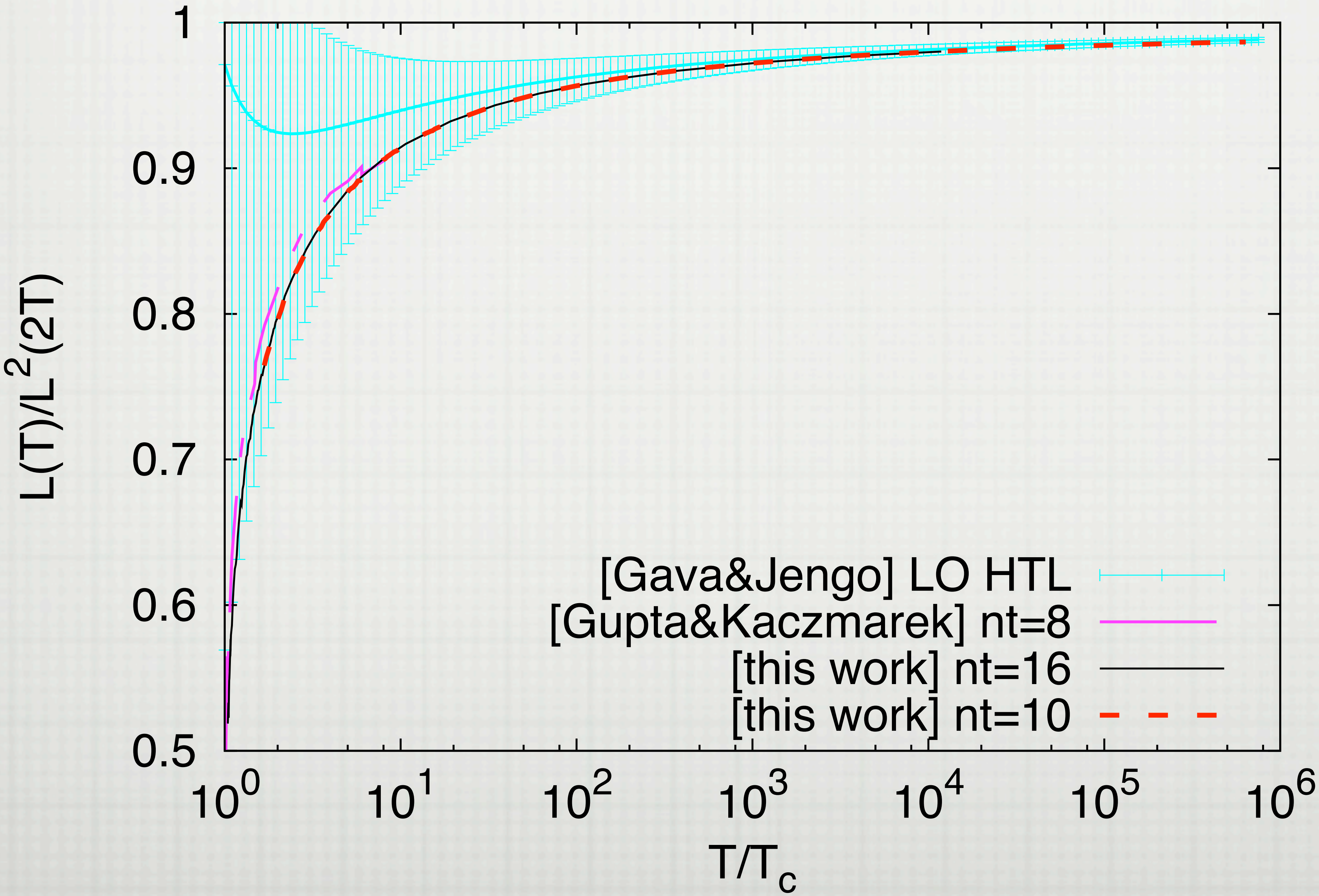
EXTREME HIGH TEMPERATURES



SIMULATED IN "PERTURBATIVELY" SMALL VOLUMES,
BUT THIS OBSERVABLE IS INSENSITIVE TO THAT.

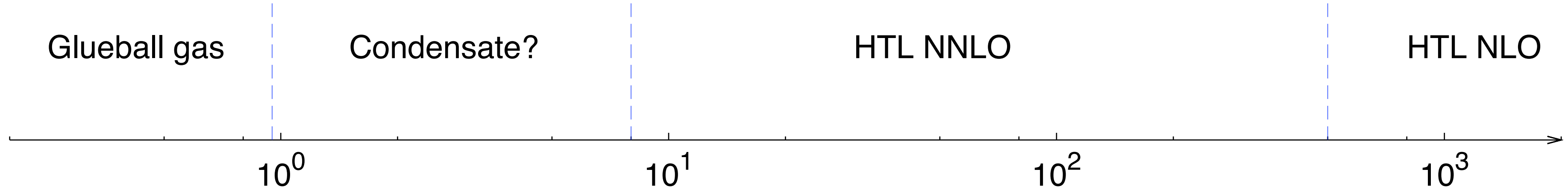
POLYAKOV LOOP

A RENORMALIZATION SCHEME INDEPENDENT COMBINATION:



SUMMARY

- THERMODYNAMICS OF THE SU(3) THEORY HAS BEEN SOLVED UP TO THE TEMPERATURE WHERE ORDERS OF HTL PERTURBATION THEORY START TO AGREE.
- PERTURBATIVE BEHAVIOUR FROM ABOUT 8 T_c



- THE LOW TEMPERATURE REGION IS RESOLVED WITH PRECISION: THERMAL GLUEBALLS DOMINATE
- POLYAKOV LOOP RATIO HAS BEEN DETERMINED FOR ALL TEMPERATURES.
- REFINED ESTIMATE: $T_c/\Lambda(\overline{MS}) = 1.24(8)$

SPARE SLIDES

POLYAKOV LOOP

A RENORMALIZATION SCHEME INDEPENDENT COMBINATION:

$$L_r(T) = L_0(\beta) * Z(\beta)^{N_t}$$

$$L_r(2*T) = L_0(\beta) * Z(\beta)^{N_t/2}$$

$$\frac{L_r(T)}{[L_r(2*T)]^2} = \frac{L_0(\beta;N_t)}{[L_0(\beta;N_t/2)]^2}$$

THE RENORMALIZED POLYAKOV LOOP IS KNOWN TO LEADING ORDER IN HTL PERTURBAITON THEORY. THIS COMBINATION, TOO, IS ACCESSIBLE.

SEE ALSO: GUPTA&KACZMAREK 2007

LATTICE VOLUMES

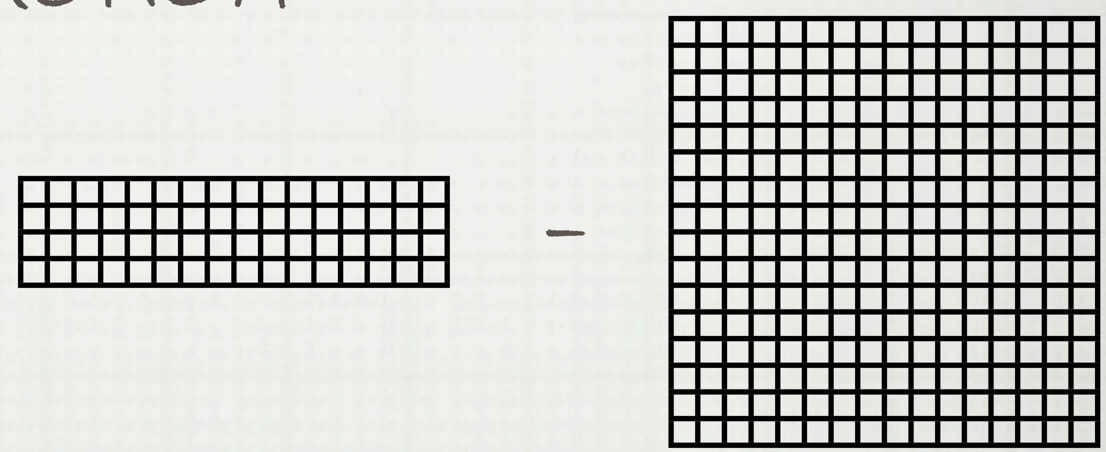
STANDARD RUNS: $40^3 \times 5$, $48^3 \times 6$, $64^3 \times 8$

BIG VOLUMES: $60^3 \times 5$, $120^3 \times 5$

TREE LEVEL SYMANZIK ACTION

(DOES NOT FIT)

RENORAMALIZATION:



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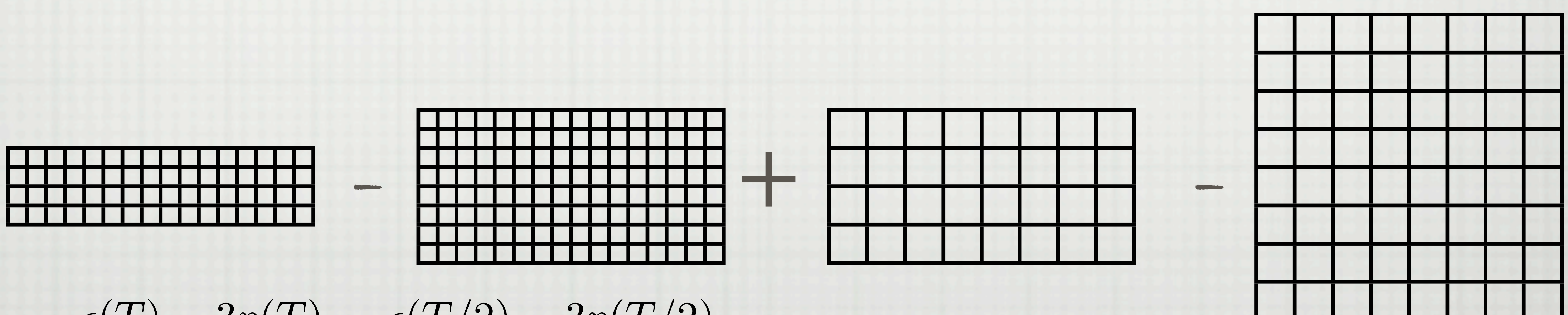
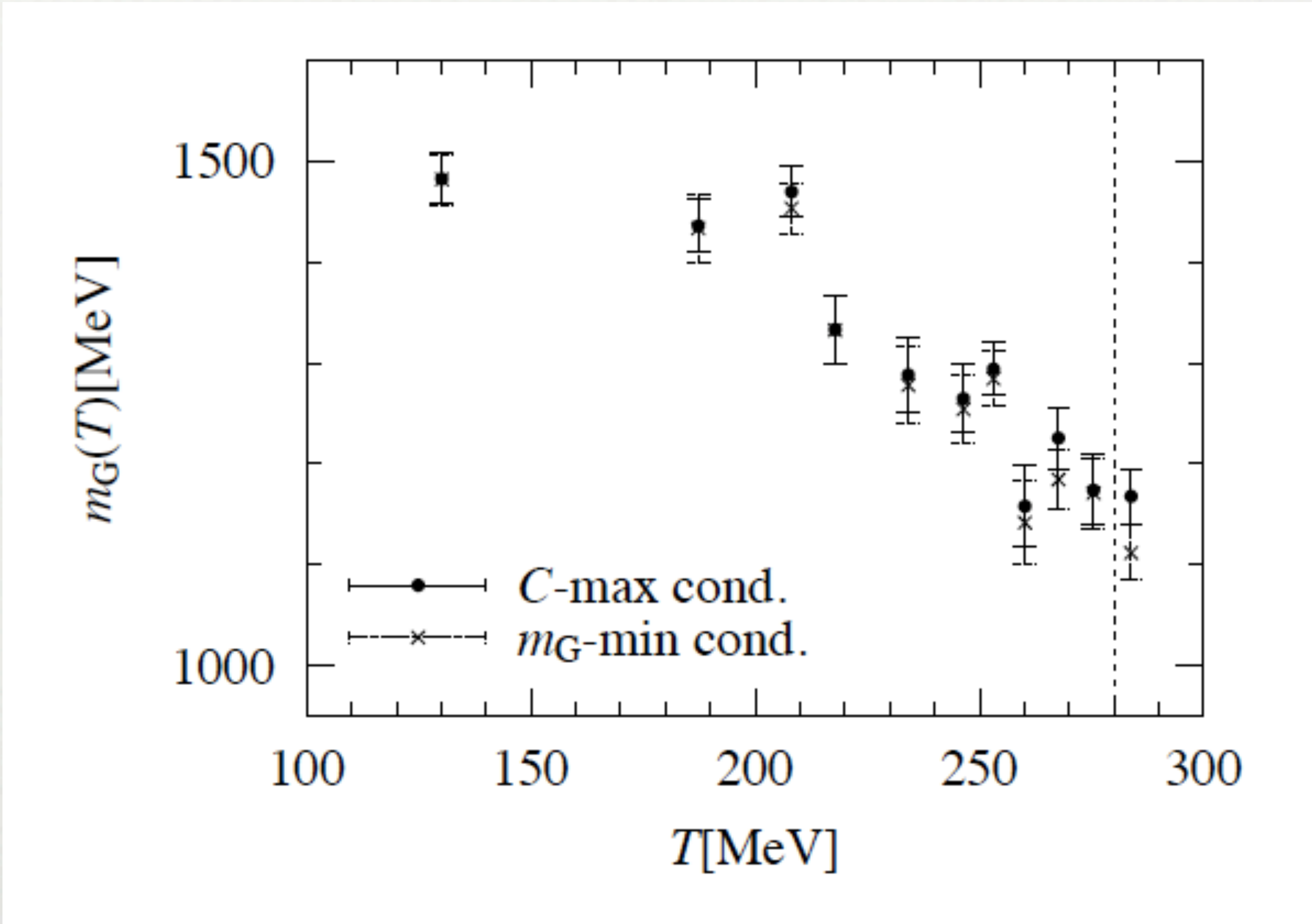


$$\frac{\epsilon(T) - 3p(T)}{T^4} - \frac{\epsilon(T/2) - 3p(T/2)}{T^4}$$

COARSE LATTICE'S CONTRIBUTION IS SUPPRESSED BY 1/16

THERMAL GLUEBALLS

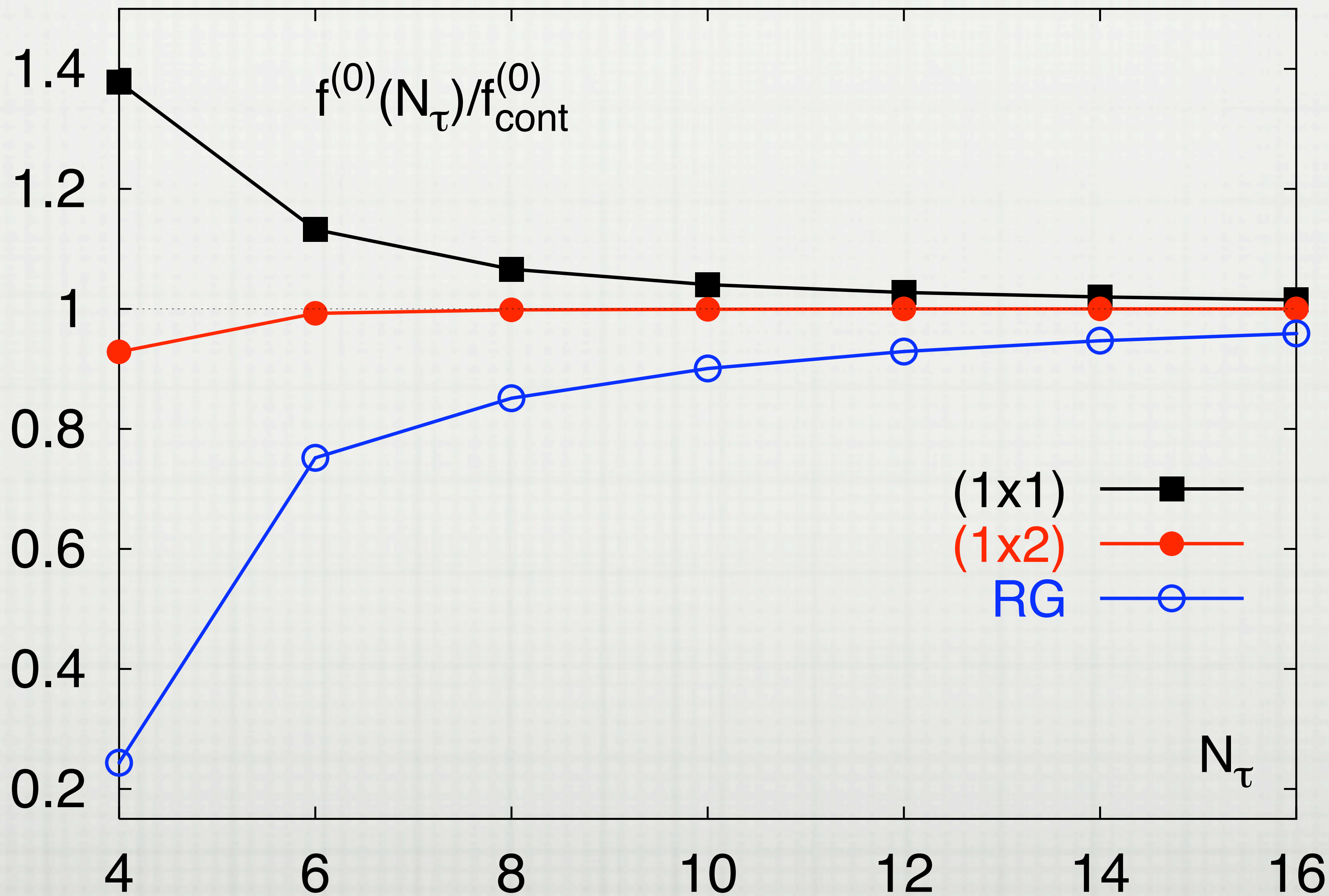
0++ GLUON MASS VS TEMPERATURE:



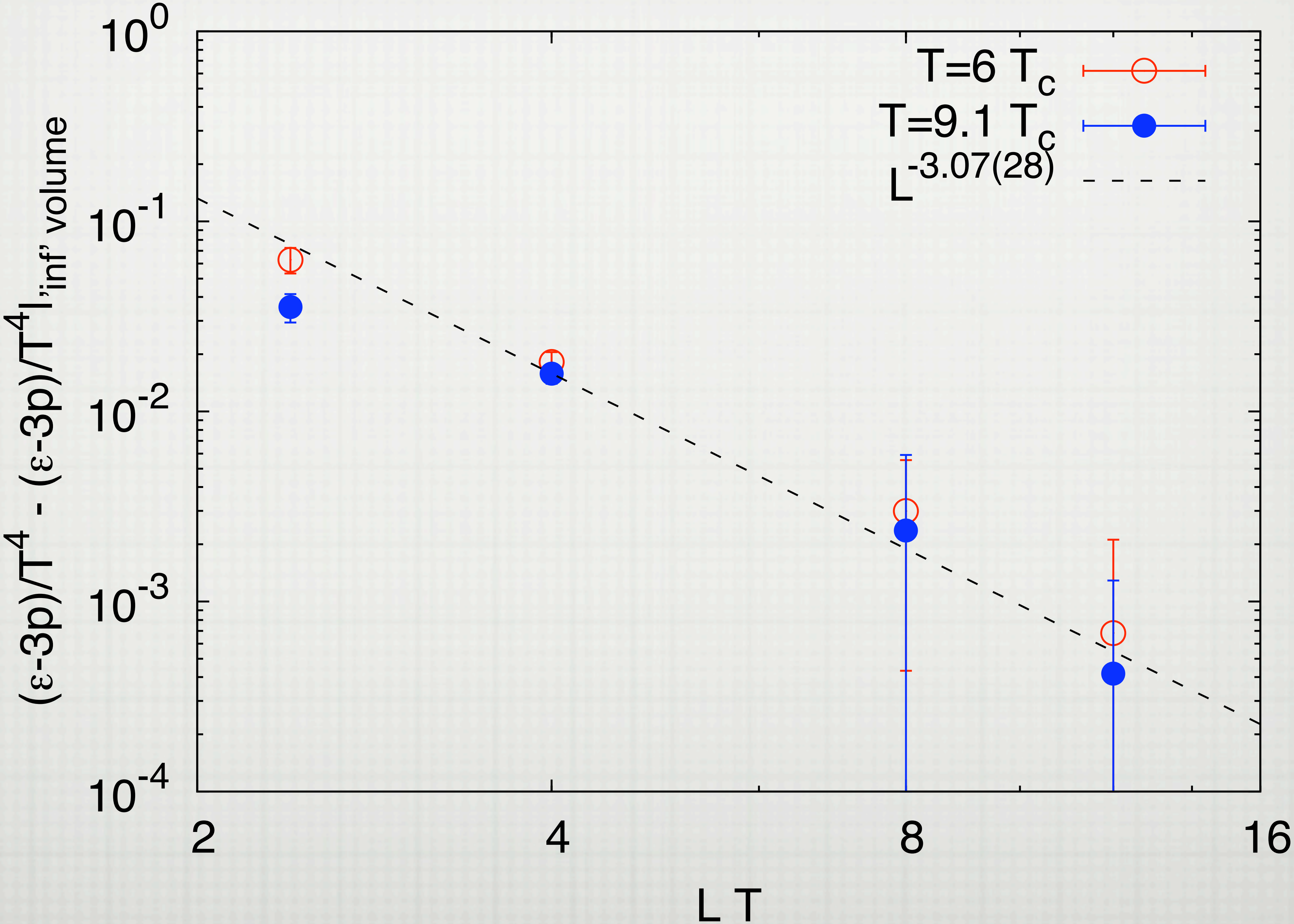
THERMAL GLUEBALL MASSES: ISHII ET AL 2002

IMPROVED ACTIONS

FREE ENERGY AT INFINITE TEMPERATURE



SCALING WITH VOLUME



UNQUENCHED ENTROPY