Continuum EoS for QCD with $N_f = 2+1$ flavors

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28.11.2012| Stefan Krieg

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Outline

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- Simulation
  - Ensembles/statistics
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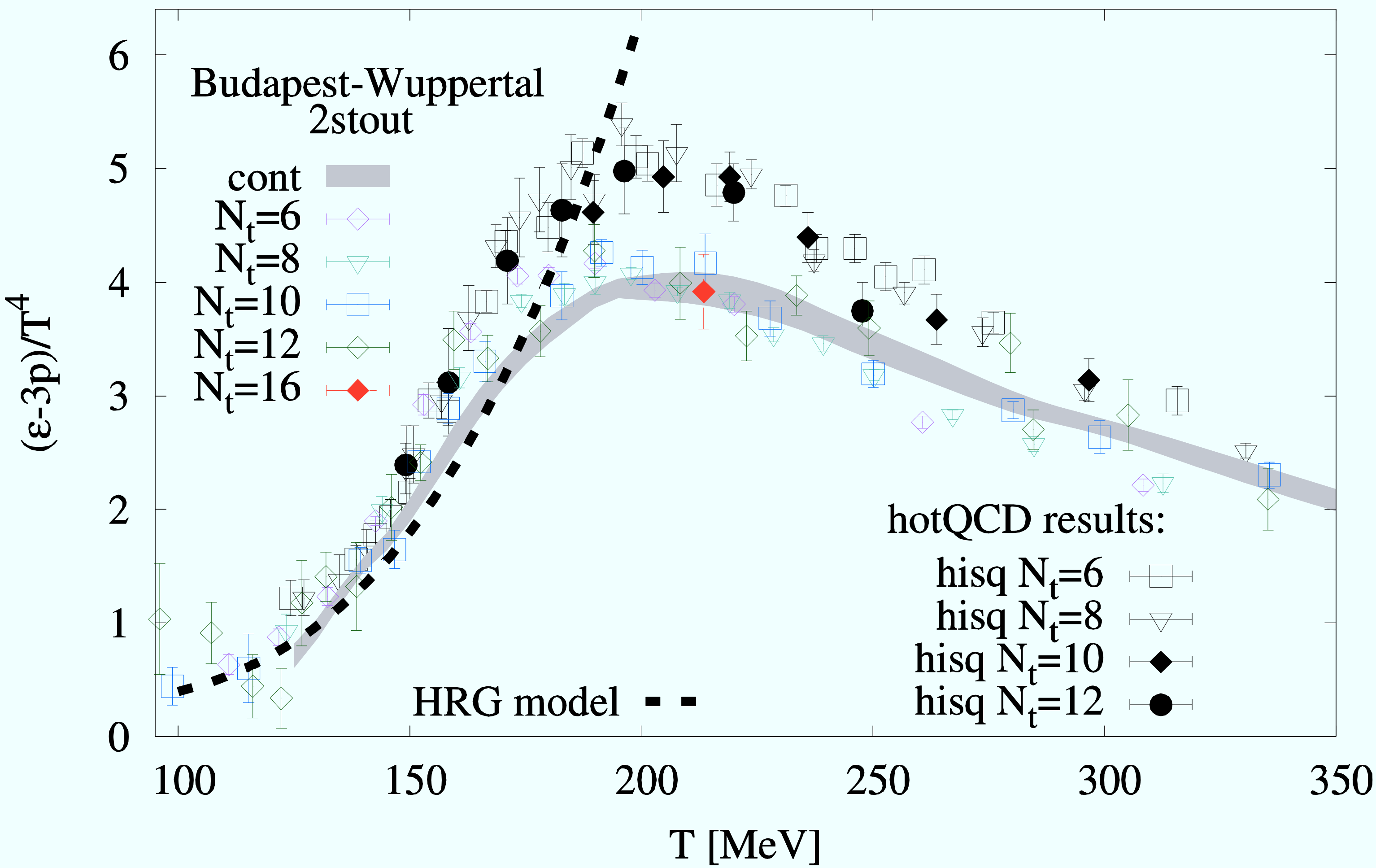
  - T/2 subtraction
  - Systematics: finite vol., lattice spacing, histogram method
- Results
  - Trace Anomaly, comparison with literature
  - Pressure, entropy, energy density, speed of sound
- Conclusions

Motivation: status 2012



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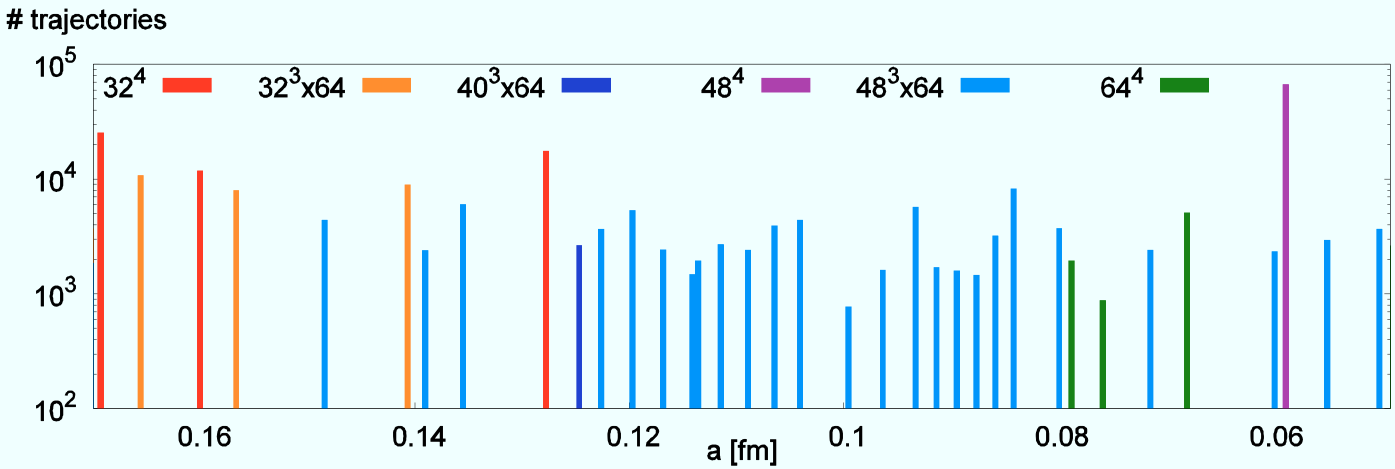
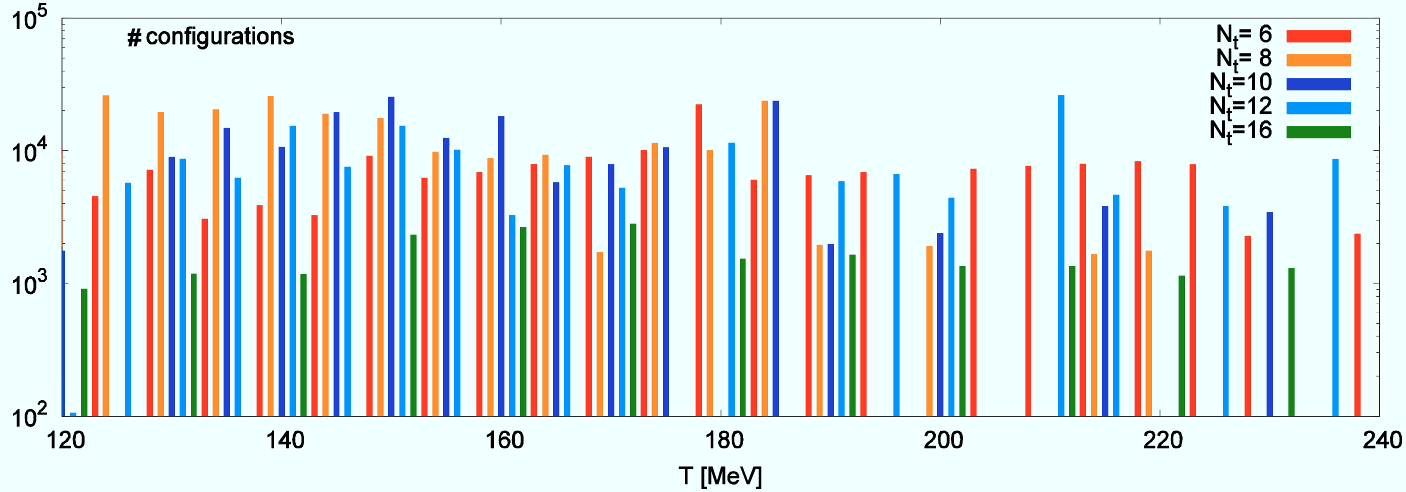
Simulation: ensembles/statistics





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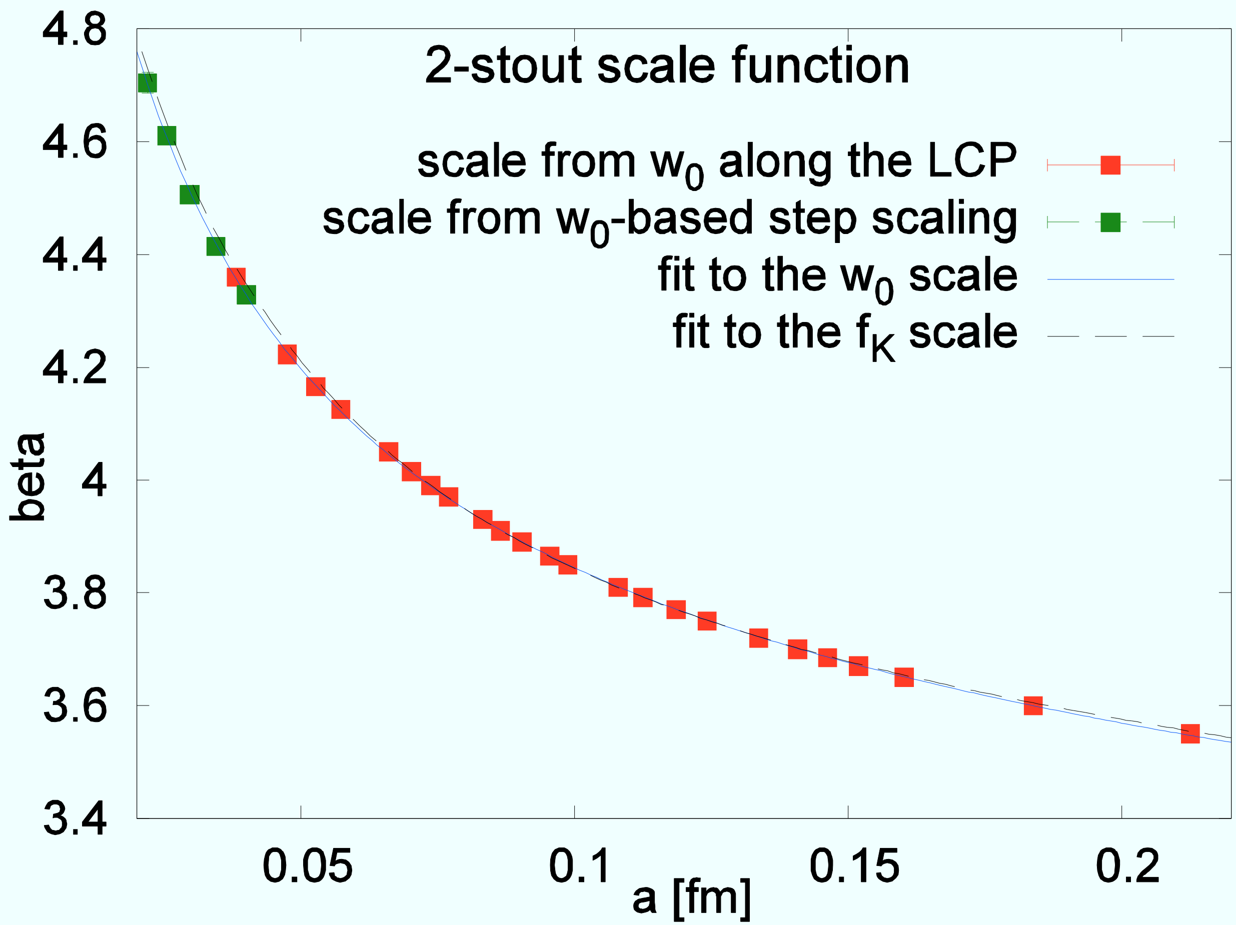
Simulation: scale setting



w_0: JHEP **1209** 010

Aim: estimate error of scale setting procedure

- original LCP
- step-scaling procedure like in 2010, w_0 based observable
- deviations on the 2% level
- Included in analysis

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Simulation: T/2 subtraction

- Reaching large temperatures requires small lattice spacings
- Algorithmically T=0 runs have difficulties to reach a<0.05 fm (frozen topology, diverging autocorrelation times).
- Solution: T/2 subtraction:

$$I_{sub}(T) = (\ I(T) - I(T/2)\ )_{-(a_0)} + (\ I(T/2) - I(\text{'}T=0\text{'})\ )_{-(2a_0)}$$

- Requires new simulations, however these are still in the high-temperature phase ($N_t=8 \rightarrow N_t=16$, …)

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Systematics

- Finite volume effects
  - Studied explicitly in 2010 (see also Lattice 2011):
    - no effects (larger that statistical errors) seen.
  - This study includes larger volumes

  → Finite volume effects will be negligible compared to other systematic uncertainties
- Scale setting and lattice spacing artifacts
  - We vary the range of lattice spacings in our fits:
    - N_t=6 is included or left out
  - We use different scale settings
  - We include $O(a^4)$ in our fit procedure

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Simulation: systematics, histogram method

- vacuum fits
  - 7 different fit models (incl. direct subtr. w. interp.)
- continuum extrapolation
  - Vary node points (8 different sets)
  - Include or leave out leave N_t=6
  - With or without improvement factors
  - We use two different scale settings (f_k vs. w_0)
  - Fit includes a^2 or a^2 and a^4 terms

→ This results in 7£ 8£ 2£ 2£ 2£ 2 = 896 different fits

- Weighting: we consider AICc, Q, or unweighted histograms

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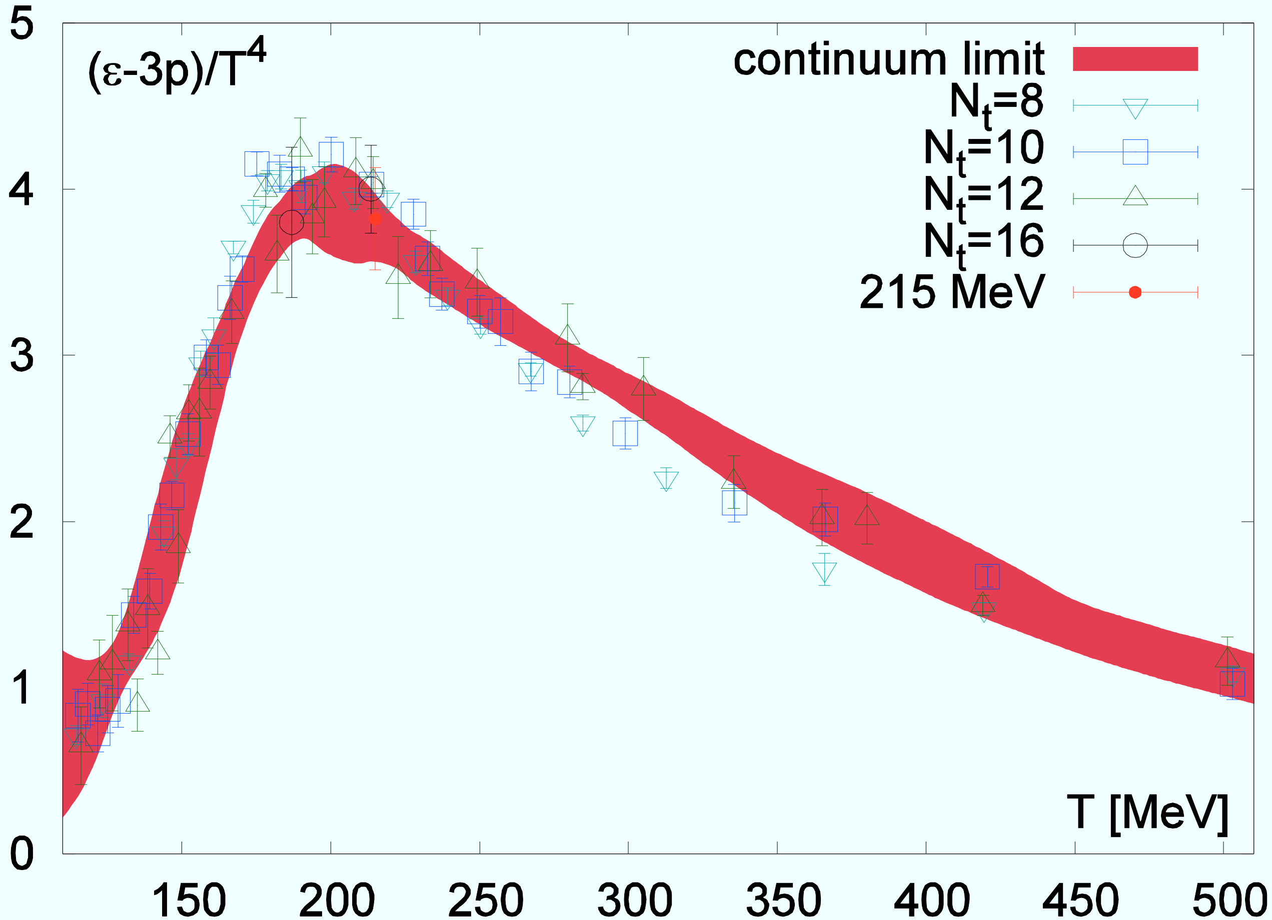
Results: trace anomaly



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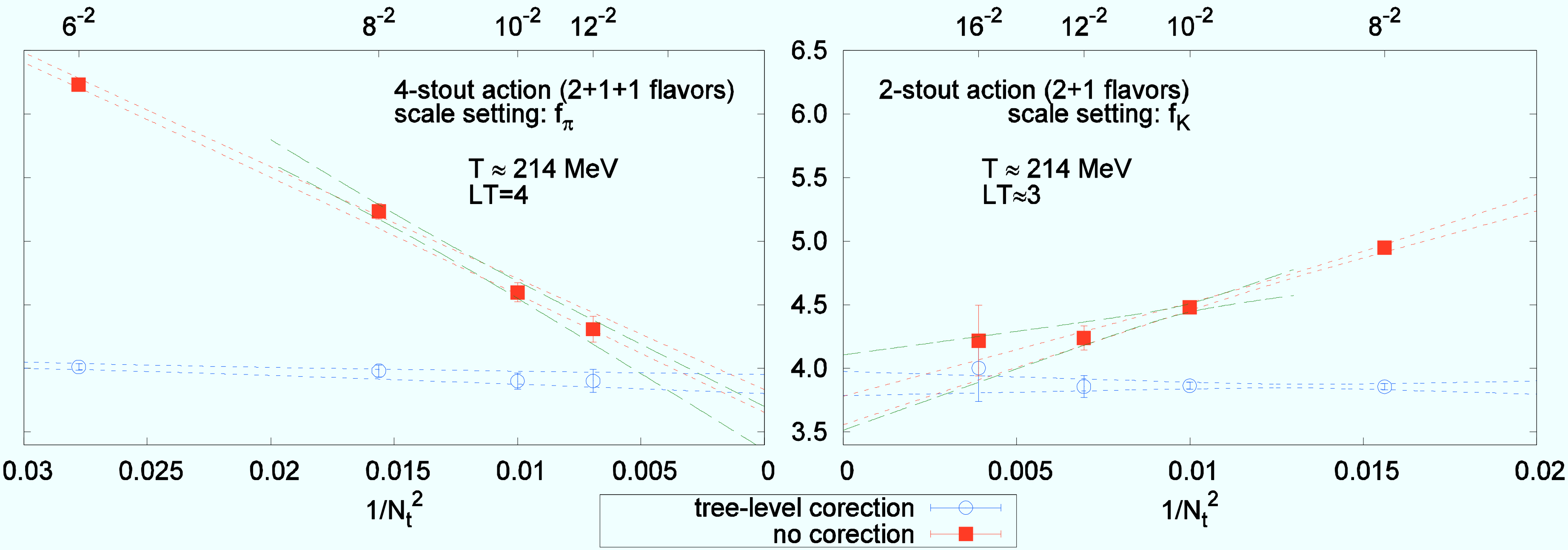
Results: trace anomaly @ 215 MeV



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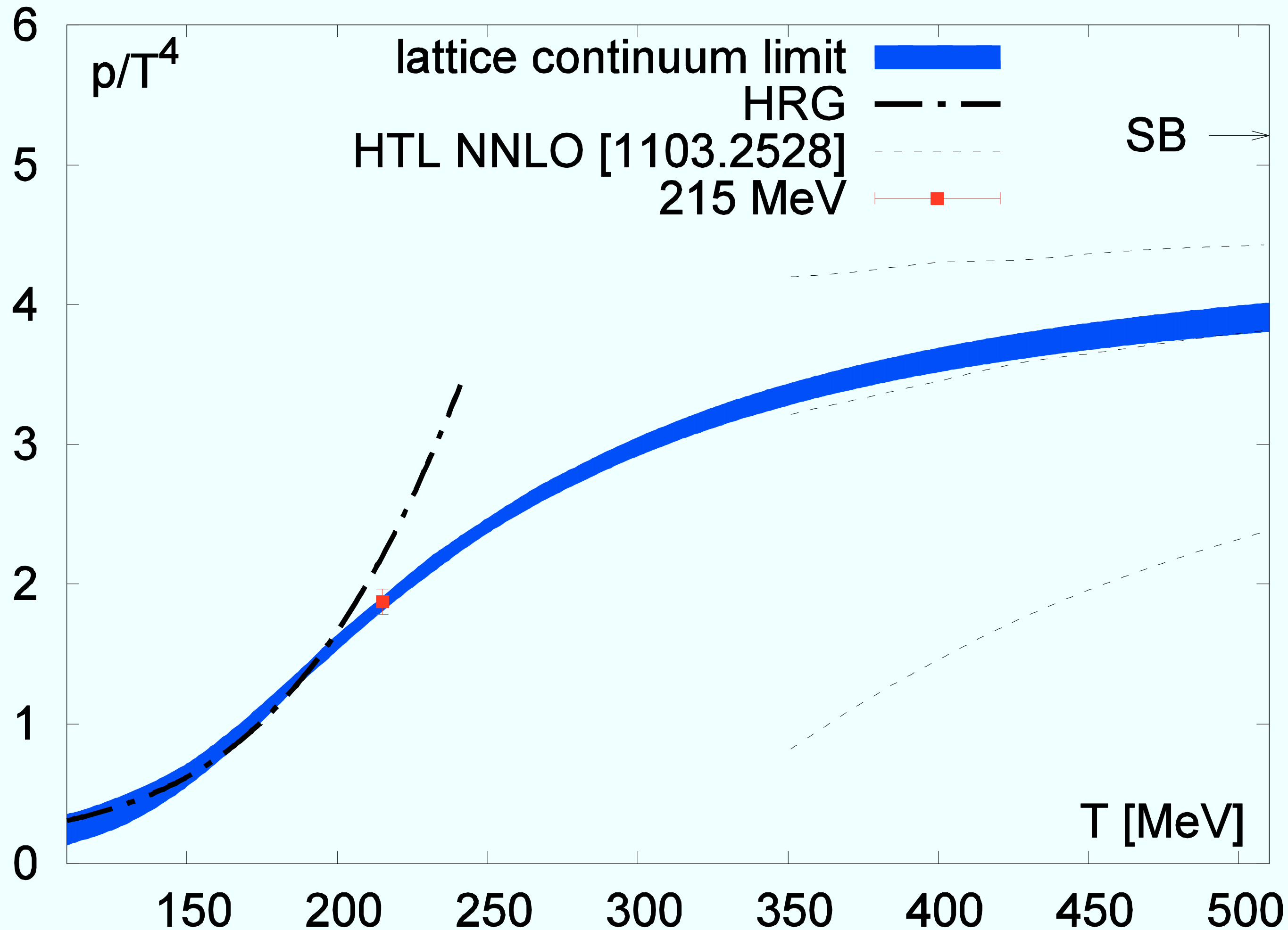
Results: pressure



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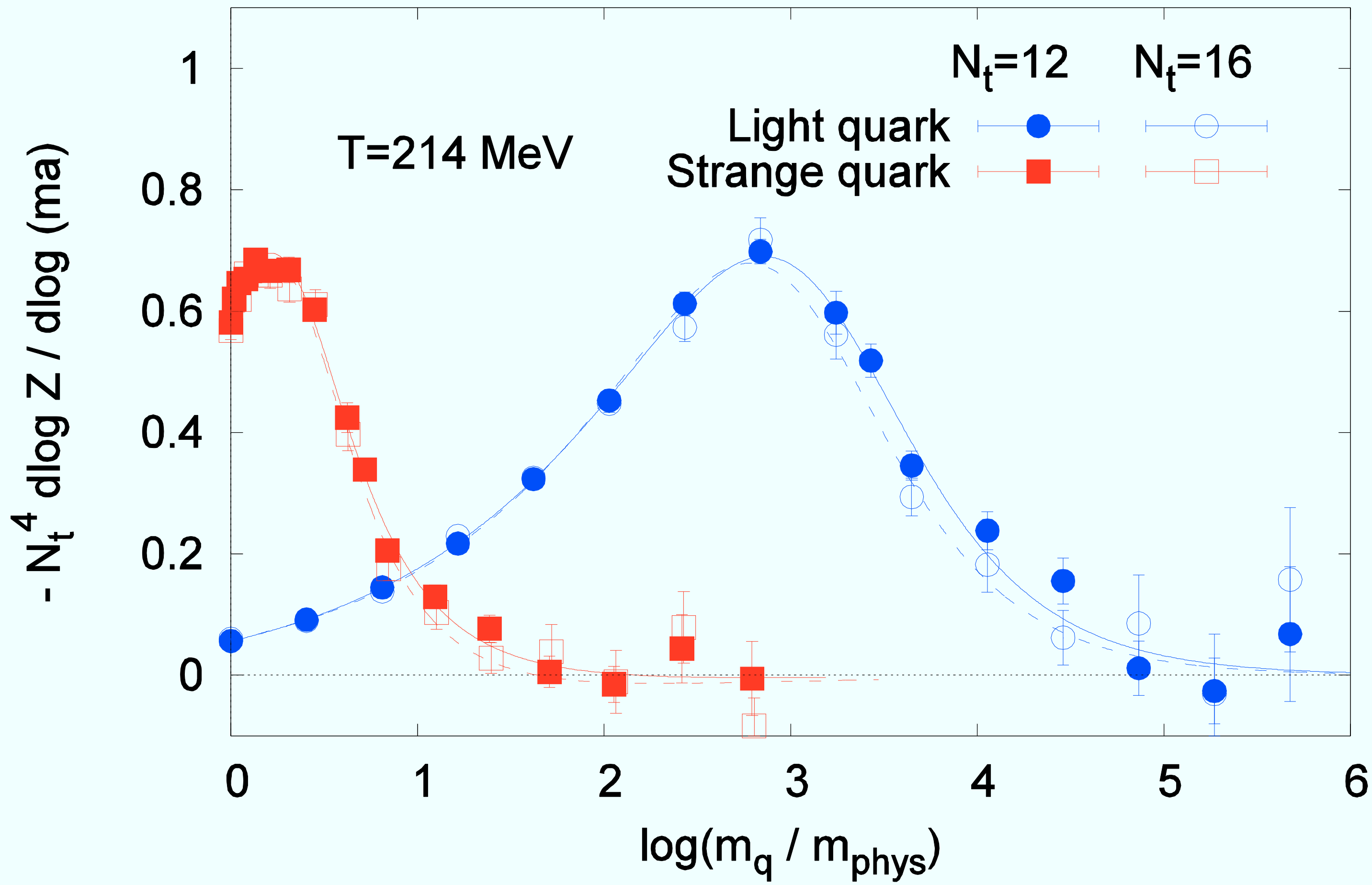
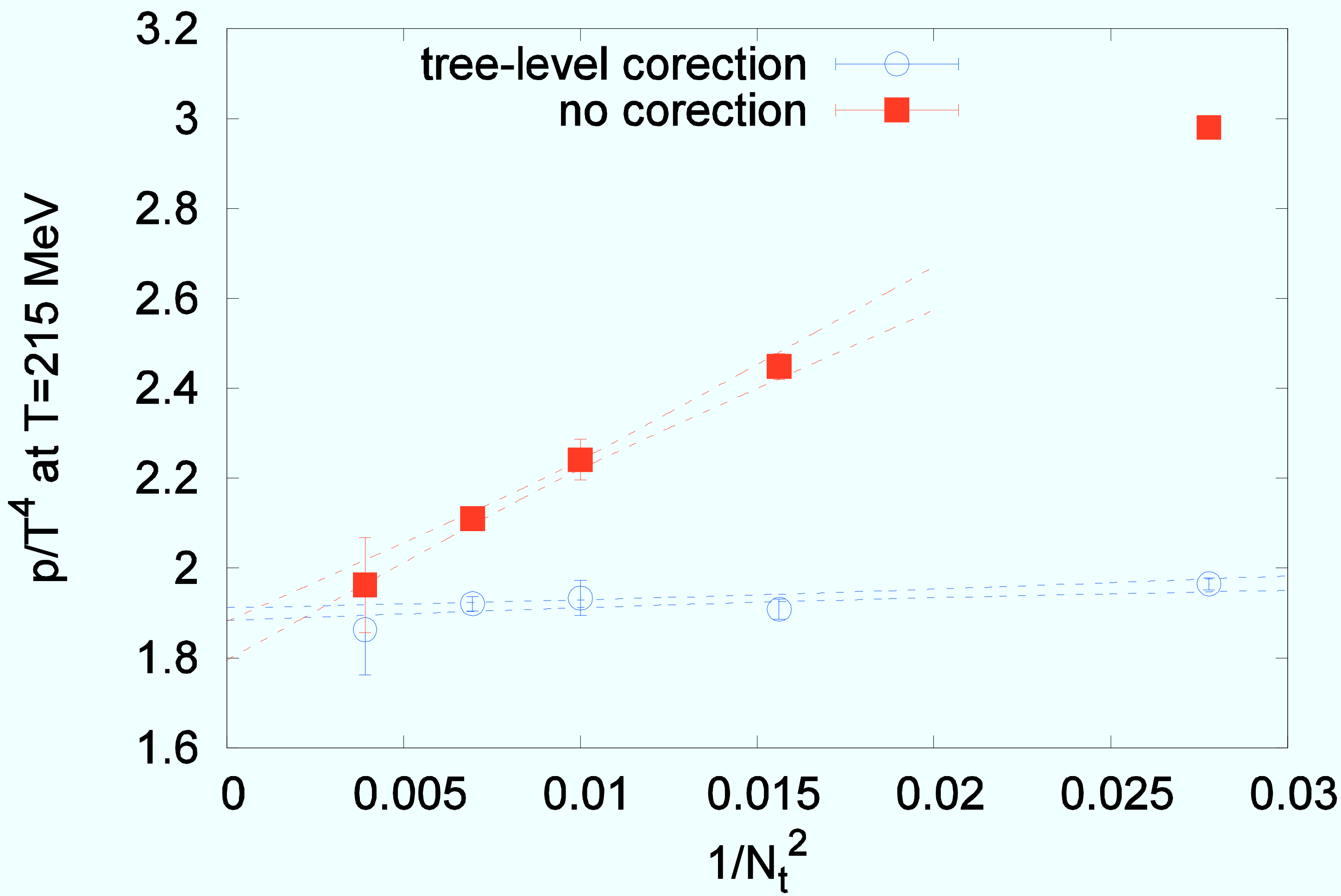
Results: pressure @ 215 MeV



Results: pressure @ 215 MeV



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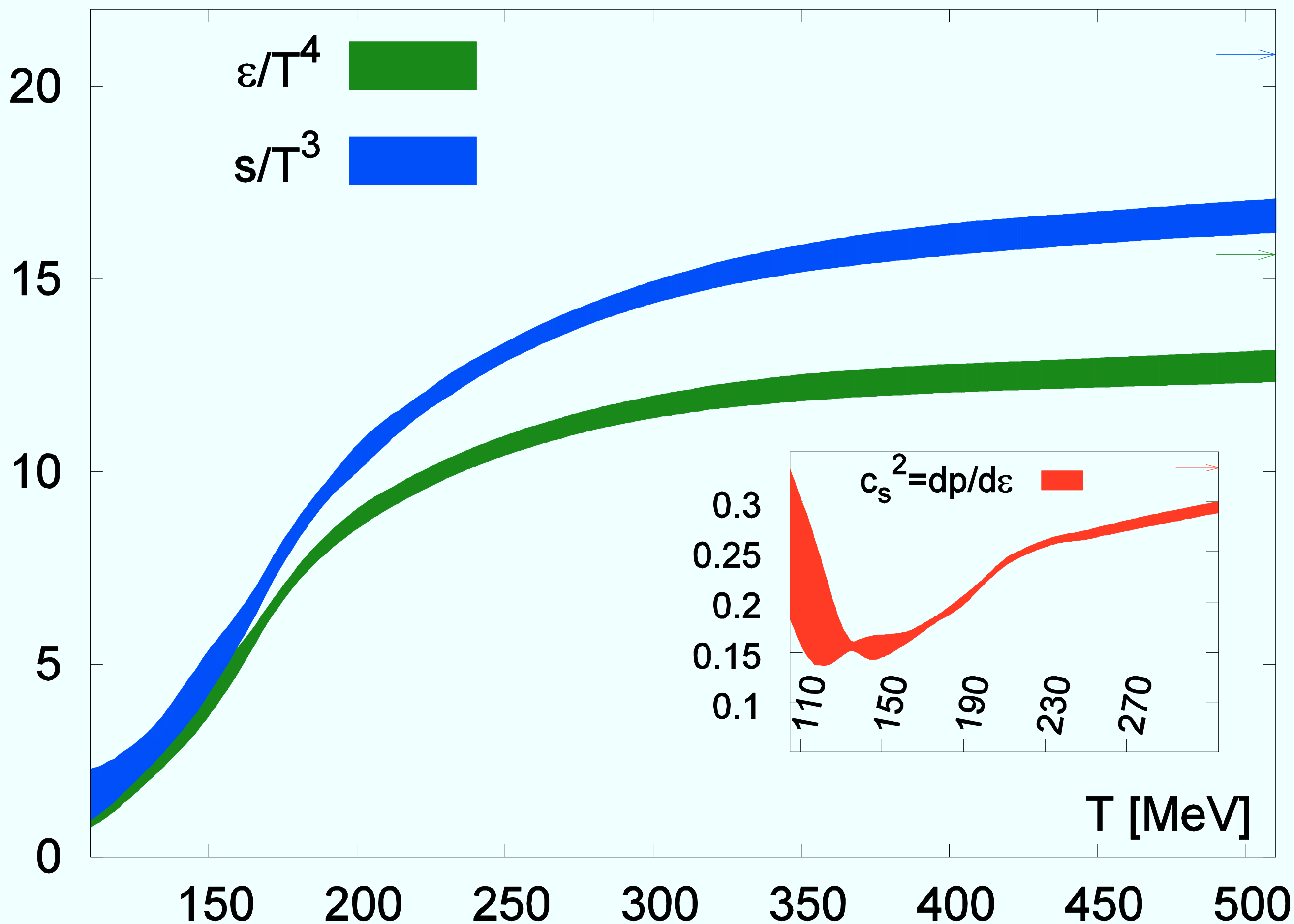
Results: entropy et al.



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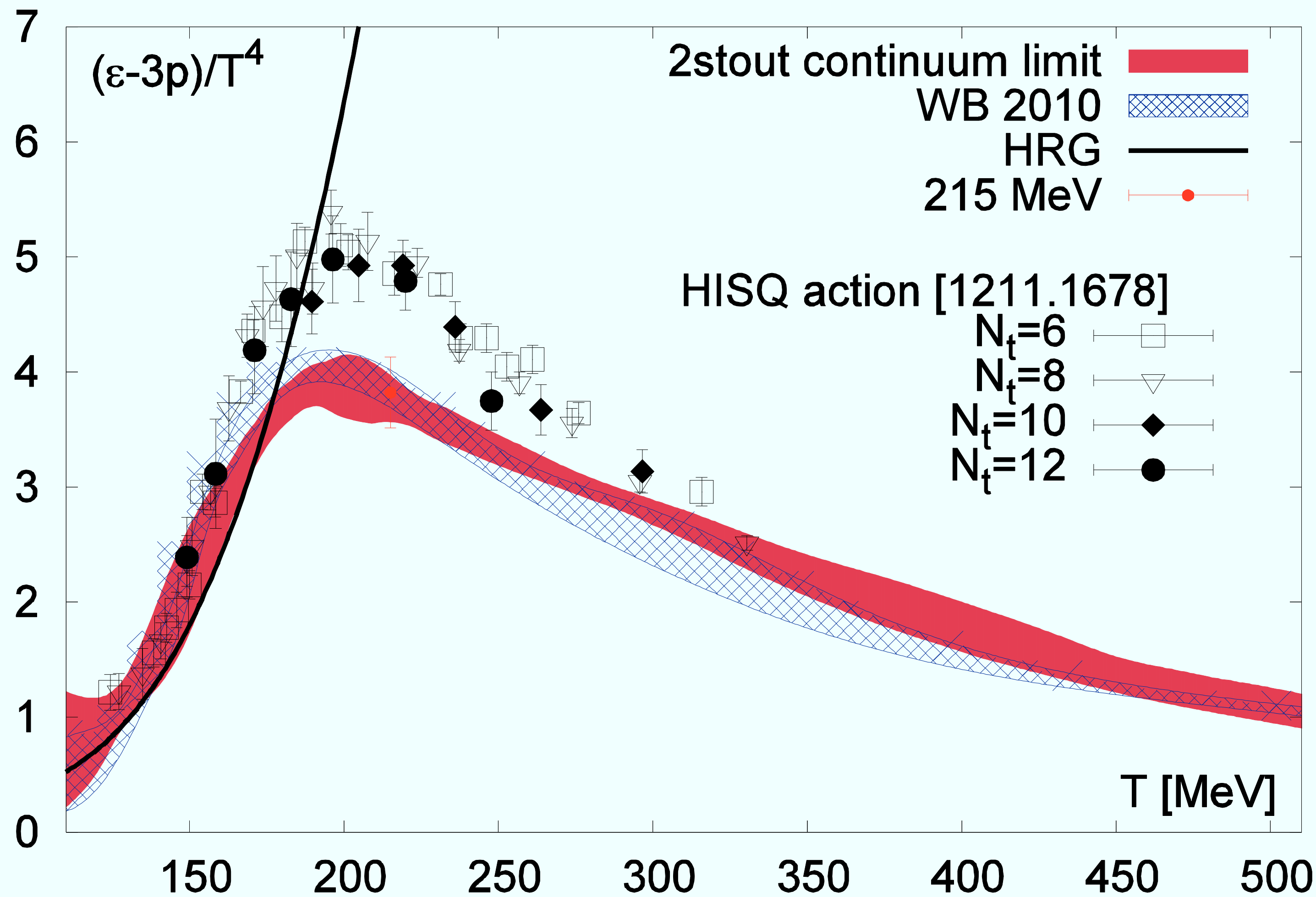
Results: trace anomaly



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Conclusions

- We have performed a continuum extrapolation of the EoS for $N_f=2+1$ QCD
- We carefully studied and included systematic uncertainties
- Within our error the discrepancy to the hotQCD/HISQ results remains
- Final conclusion requires continuum extrapolation of HISQ data combined with a study of systematic uncertainties.
- In any case above T¼300 MeV charm effects become important.

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Thank You for Your attention!

Simulation: ensembles/statistics

- Vacuum (T=0) runs:
  - Renormalization (& w_0 scale setting):
    - Volumes: 32^4, 48^4, 64^4
    - #traj.: O(10^4) for 32^4
      O(10^5) for 48^4
      O(10^3) for 64^4
  - Scale setting (f_k):
    - Volumes: 32^3£ 64, 40^3£ 64, 48^3£ 64
    - #traj.: O(10^4) for 32^3£ 64,
      O(10^3) for 40^3£ 64 and 48^3£ 64

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Simulation: ensembles/statistics

- Used available ensembles (see *e.g.* 1305.5161)
- Added ensembles:
  - 32^3£ 6, 32^3£ 8, with 13-50£ 10^3 trajectories
- Use sufficently large volumes only
  - L>2 fm for all T
  - L>5.3 (12); 4.2 (10); 5.2 (8) @ 150 MeV
    - 48^3£ 8
    - 64^3£ 10
    - 64^3£ 12

    @ O(10^4) trajectories each
- Additional 48^3£ 16, 64^3£ 20, 64^3£ 24 ensembles (T/2 subtraction, 215 MeV point)

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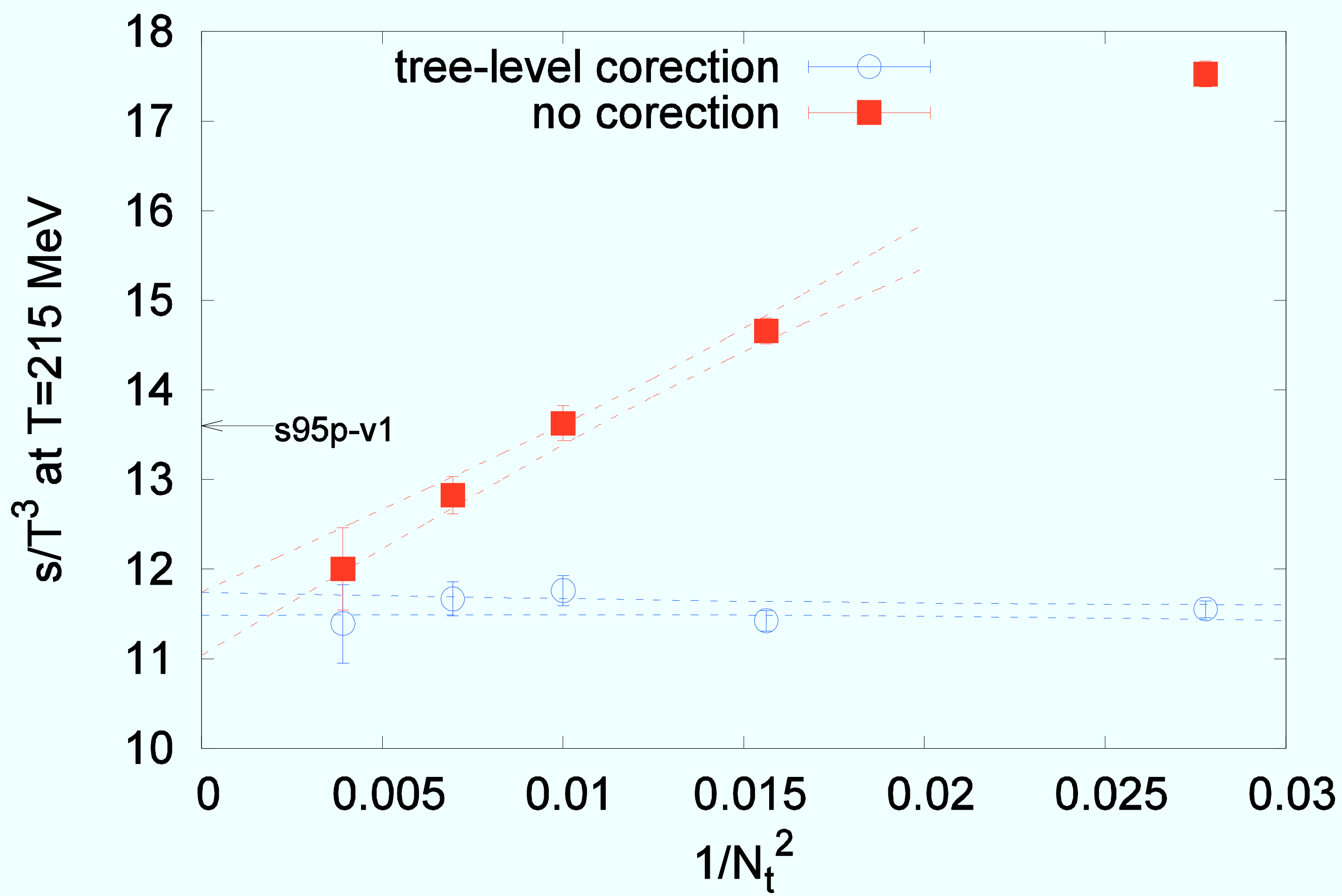
Results: entropy @ 215 MeV



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