Recent results on the Equation of State of QCD

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26.Jun.2014| Stefan Krieg

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Overview

1. N_f=2+1 Equation of State (EoS)
2. Update on the N_f=2+1+1 EoS
   1. LCP
   2. Renormalization
   3. Preliminary results (w/o systematics)
3. Conclusion and outlook

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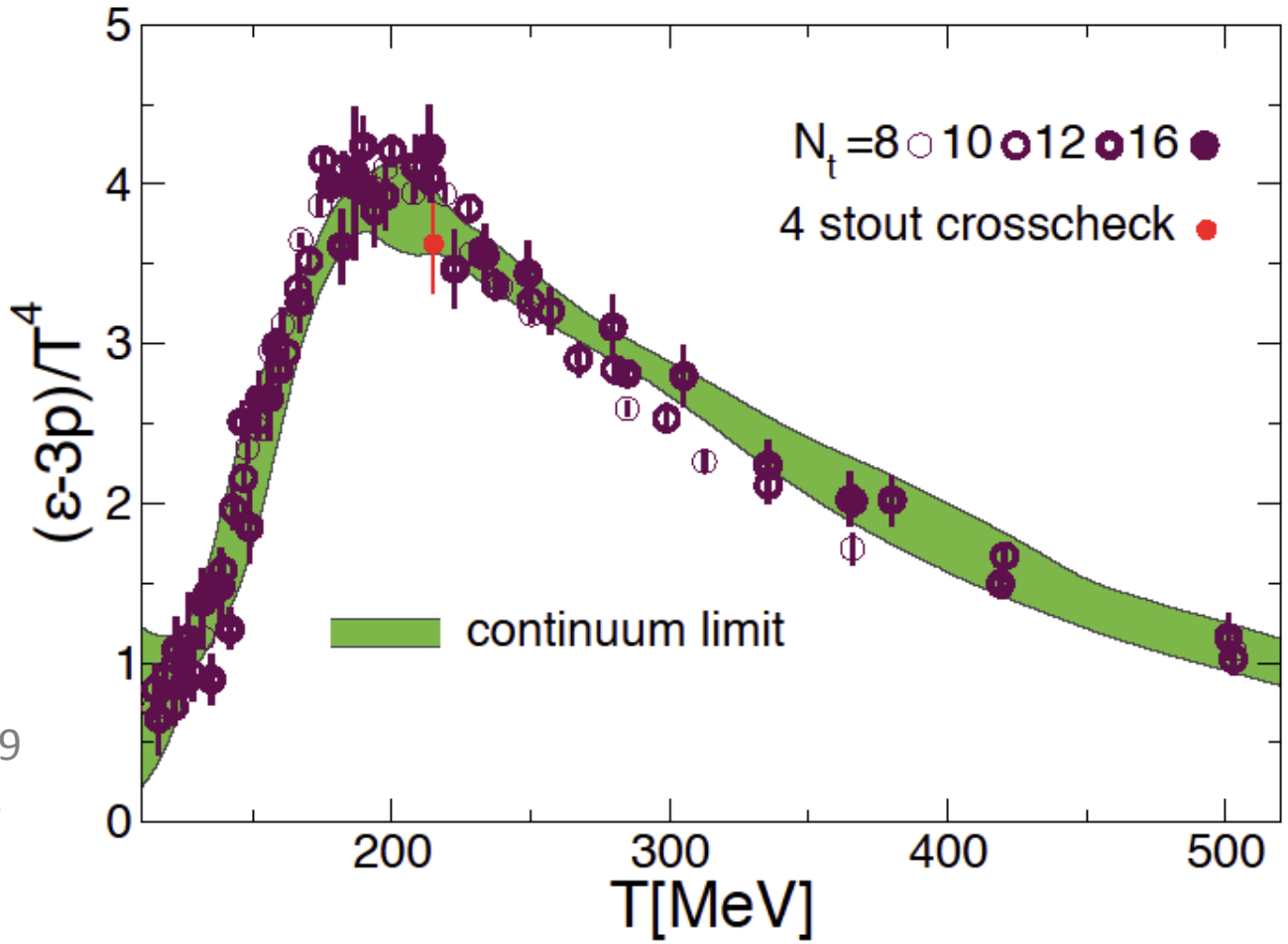
N_f=2+1 EoS



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1309.5258

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N_f=2+1 EoS

M_π = phys, large volumes, pressure scale from mass integration

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 $7\times8\times2\times2\times2\times2$ = 896 different fits

- Histogram method: weighting w/o AICc, checked against Q
- Agreement with HRG at low T

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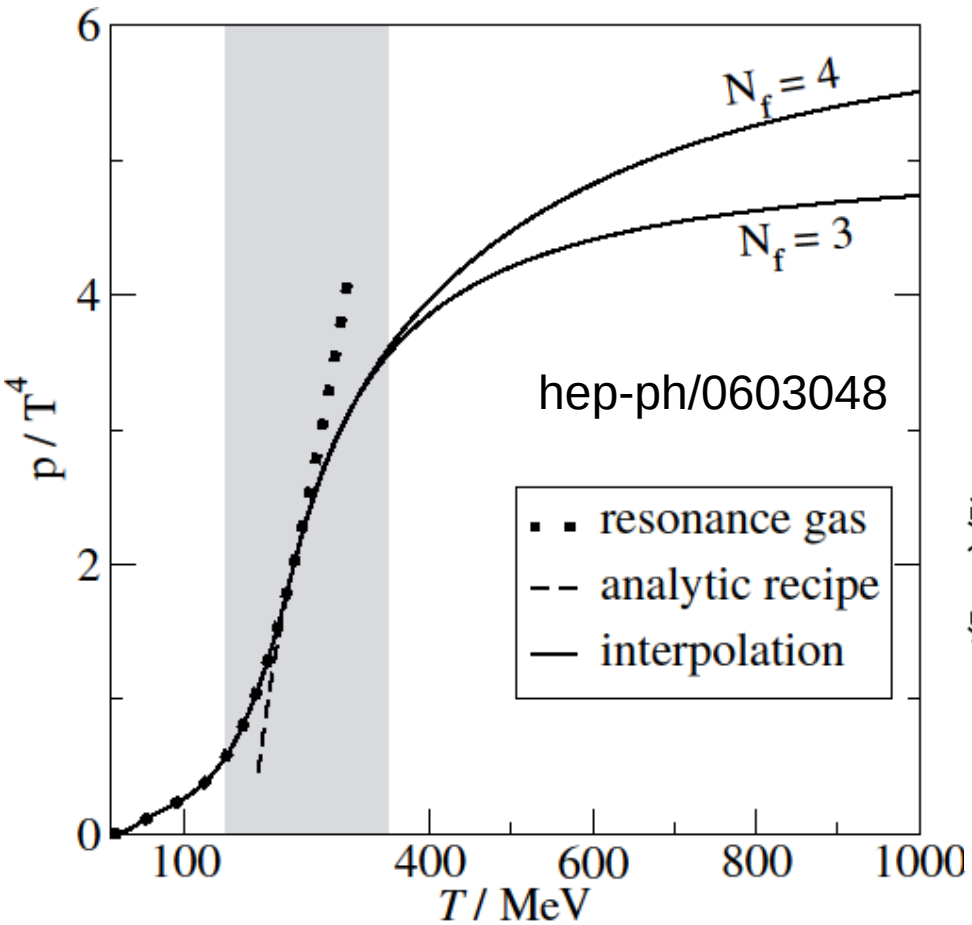
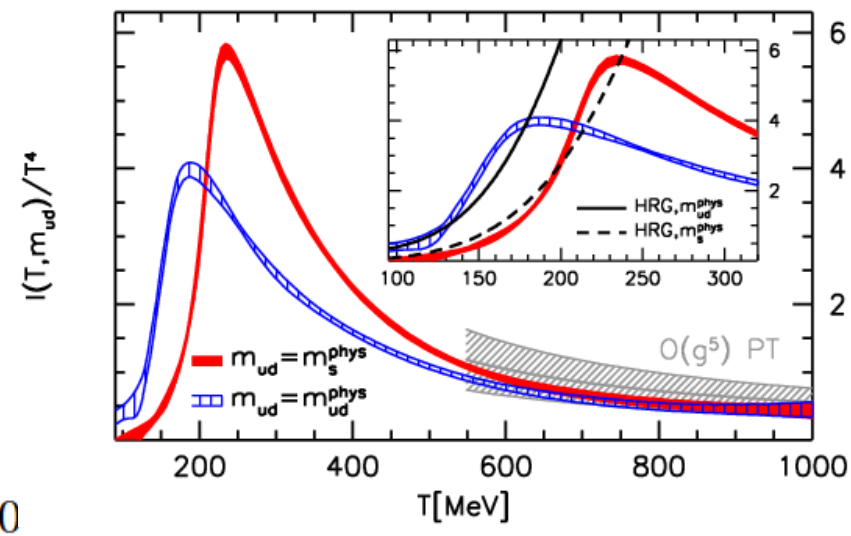
N_f=2+1+1 EoS: perturbation theory



Calculate the EoS from LQCD from 100 to 1000 MeV



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N_f=2+1+1 EoS: LCP

High precision LCP

- 3 regions, depending on applicable algorithms
- Overlap between regions
- We use
  - Spectroscopy (a > 0.08 fm)
  - Flavor symmetric point (0.08 fm > a > 0.05 fm)
  - Step scaling procedure (a < 0.05 fm)
    (e.g. WB, PLB 730, 99)

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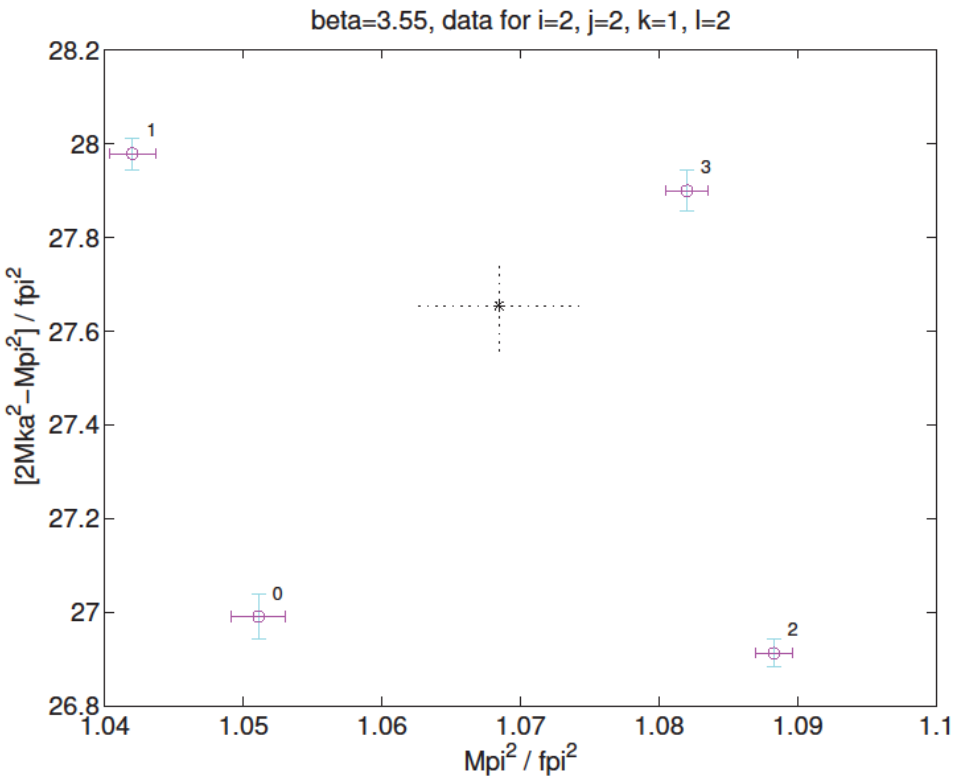
N_f=2+1+1 EoS: LCP, region I

- LCP: tuned by spectral quantities, M_π/f_π, $(2M_K^2-M_\pi^2)/f_\pi^2$ = phys
  - At fixed β, (M_π/f_π, $(2M_K^2-M_\pi^2)/f_\pi^2$) bracket at $\pm$ 2%
  - m_s/m_l not fixed!
  - m_c/m_s at 11.85
- Precise scale setting
  - f_π = 130.41(20) MeV
  - Sub % precision
- 4 levels of stout
  - Improved light meson sector



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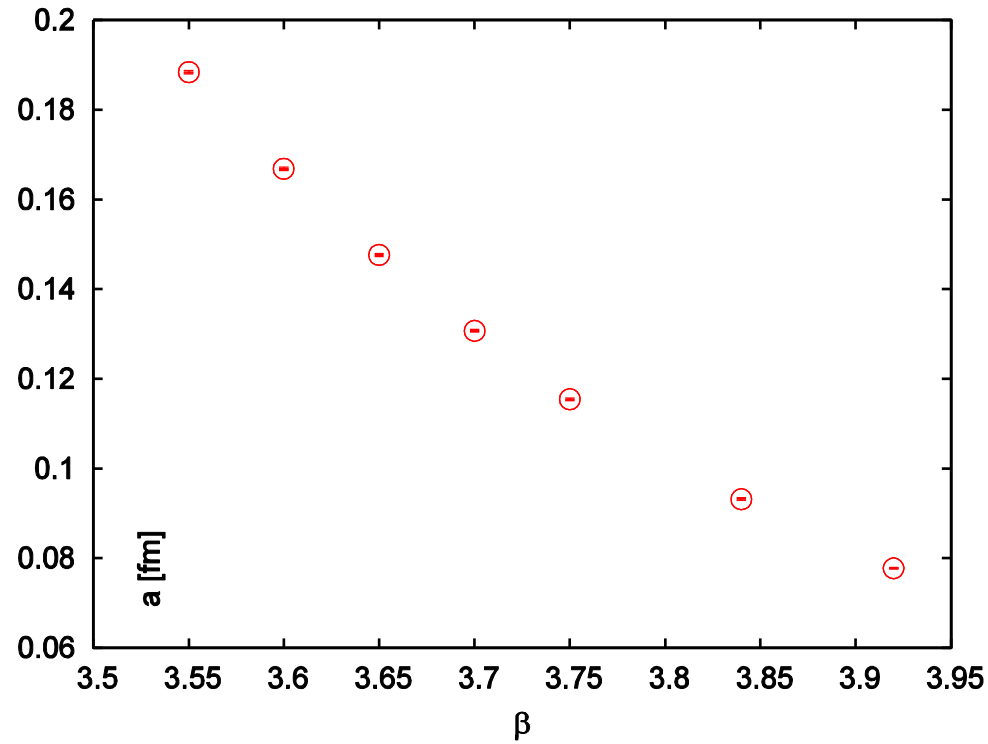

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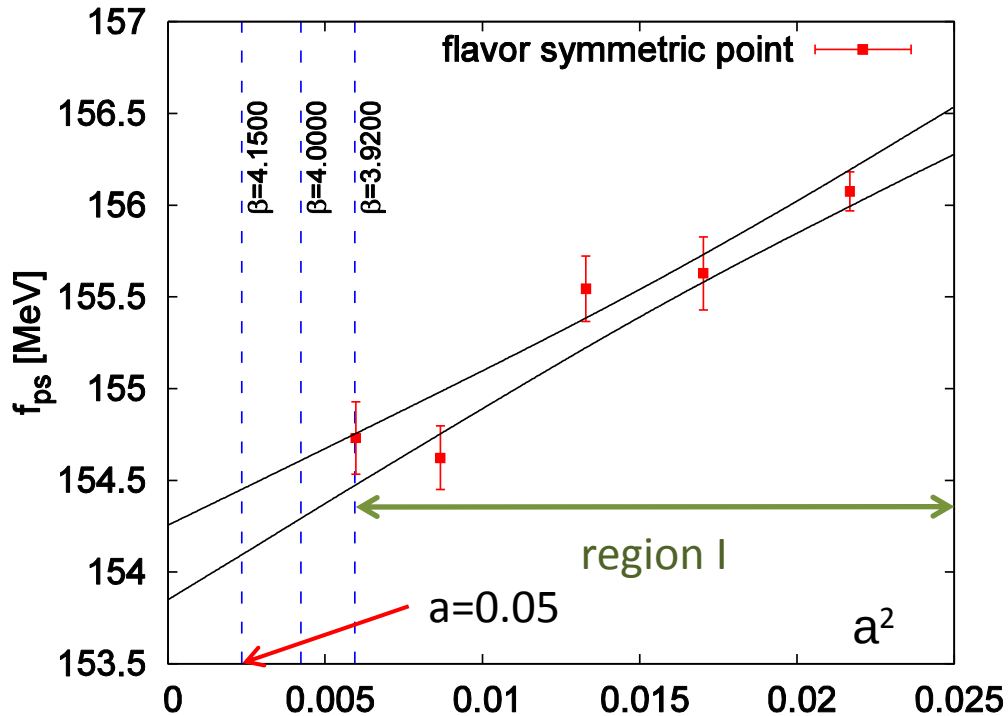
N_f=2+1+1 EoS: LCP, region II

- Procedure based on f_{PS} for 0.08 > a > 0.05 fm
- N_f=3+1 in SU(3) flavor symmetrical point ($\bar{m}$, m_c)
- Use region I param's
- Measure f_{PS} and M_{PS}
- Extrapolate towards continuum
- At target β, simulate several $\bar{m}$
- Interpolate such that M_{PS}/f_{PS} is reproduced



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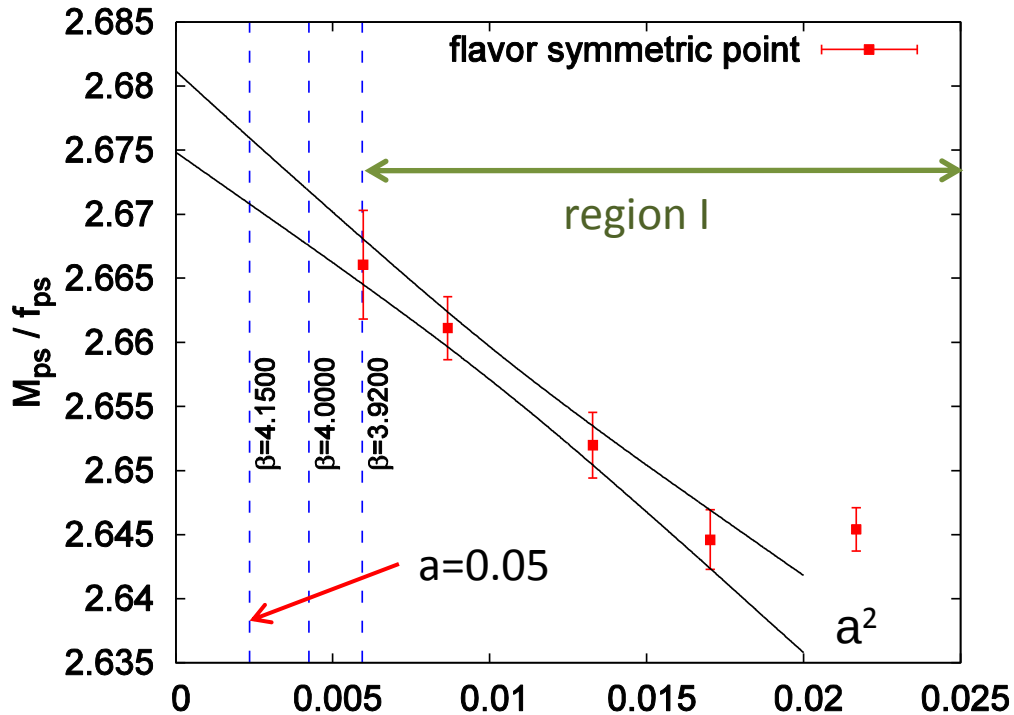

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N_f=2+1+1 EoS: LCP, region III

- Step scaling procedure based on w_0 for small a < 0.05 fm
  - Choose a volume dependent observable

$$\mathcal{O} = t\frac{d}{dt}\left[t^2 E(t)\right]\Big|_{0.01L^2}$$

  - Simulate at fixed V with existing LCP
    - 16^4 (a_0)
    - 20^4 (a_1)
    - 24^4 (a_2)
  - Extrapolate to $a_3 = 24/32 \cdot a_2$
  - Tune β ($L^3T = 32^4$) to match result

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N_f=2+1+1 EoS: renormalization

- Half-temperature subtraction
  (Wuppertal-Budapest, JHEP 1207 056; PoS CPOD07 027)

  $$I_{sub}(T) = (I(T) - I(T/2))_{\beta(a_0)} + (I(T/2) - I(\text{'}T=0\text{'}))_{\beta(2a_0)}$$
- Make use of N_f=2+1 EoS where applicable
- Requires new simulations, however these are still in the high-temperature phase (N_t=8 $\rightarrow$ N_t=16, …)
- More than one intermediate step is possible
  - Require final step being below a threshold temperature T_t<250 MeV
  - Vary threshold temperature for final result

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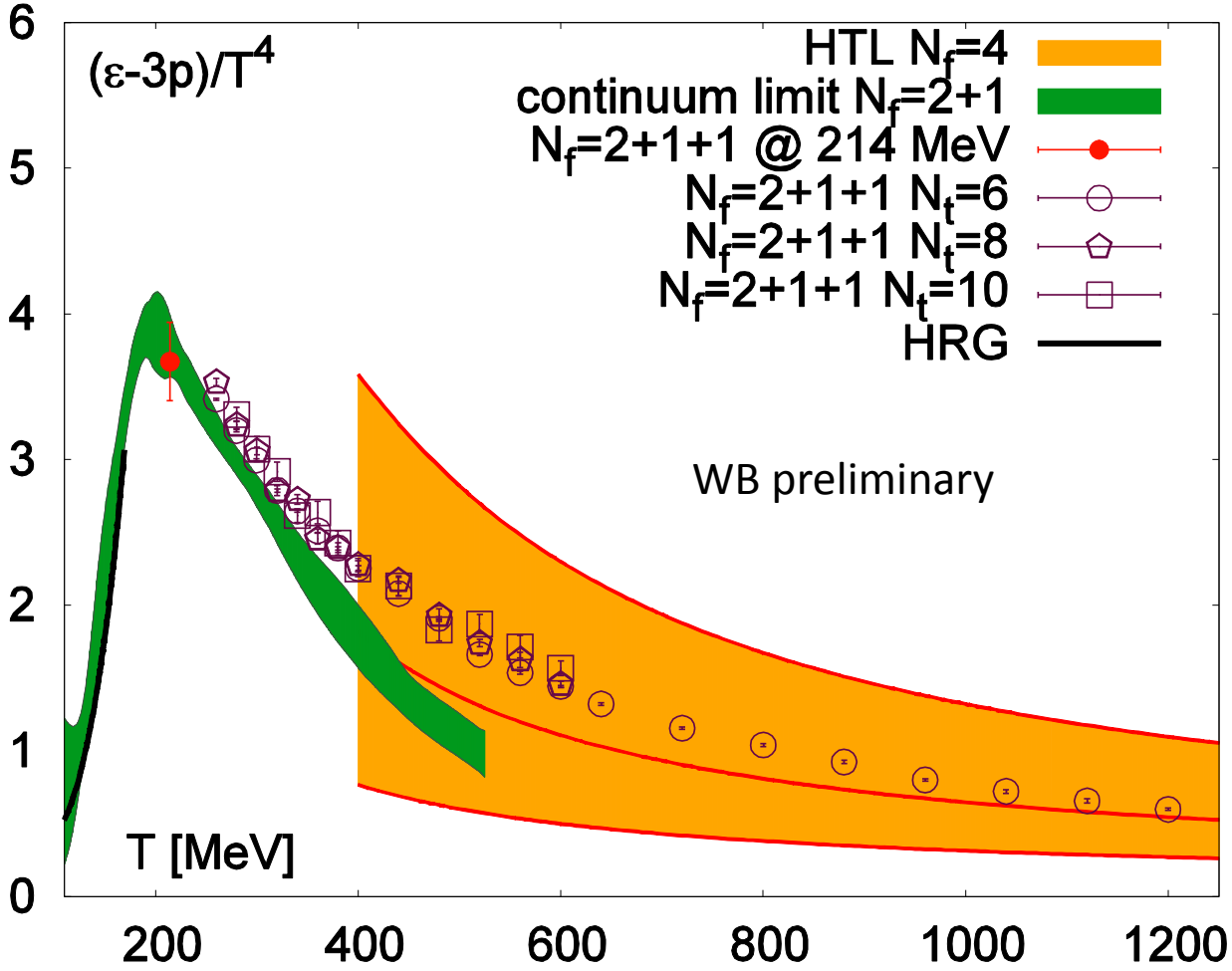
Update: N_f=2+1+1 EoS



HTL:
JHEP 1108 053

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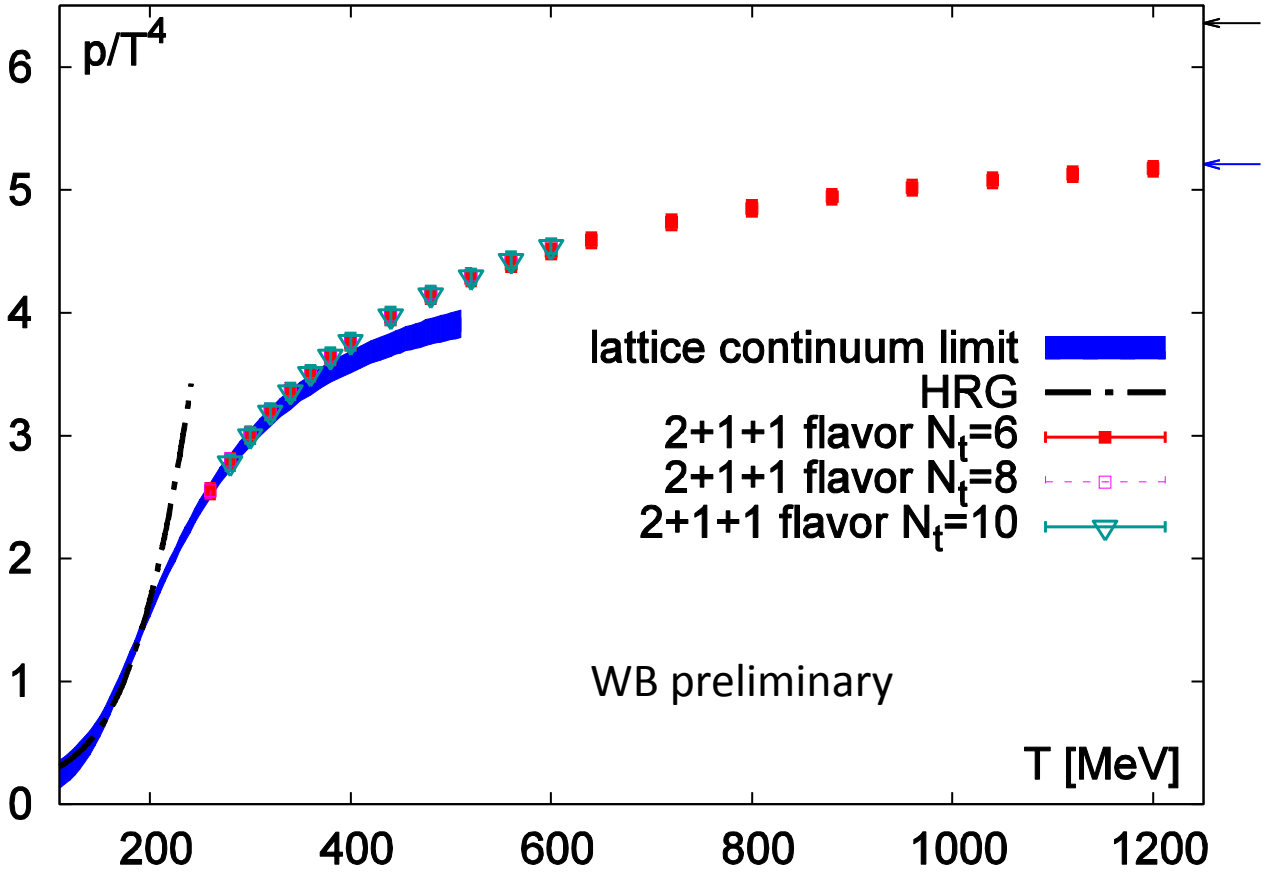

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Conclusion & outlook

- N_f=2+1 EoS
- Charmed LCP
  - 3 regions optimizing precision
  - Spectroscopy (a > 0.08 fm)
  - Flavor symmetric point (0.08 fm > a > 0.05 fm)
  - Step scaling procedure (a < 0.05 fm)
- Renormalization
  - “half-subtraction” until T_t < 250 MeV (to be tuned)
  - At T_t < 250 MeV use full 2+1 result (PLB 730, 99)
- Preliminary data looks promising
- In the future: go to N_t=12

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Thank You.

Backup

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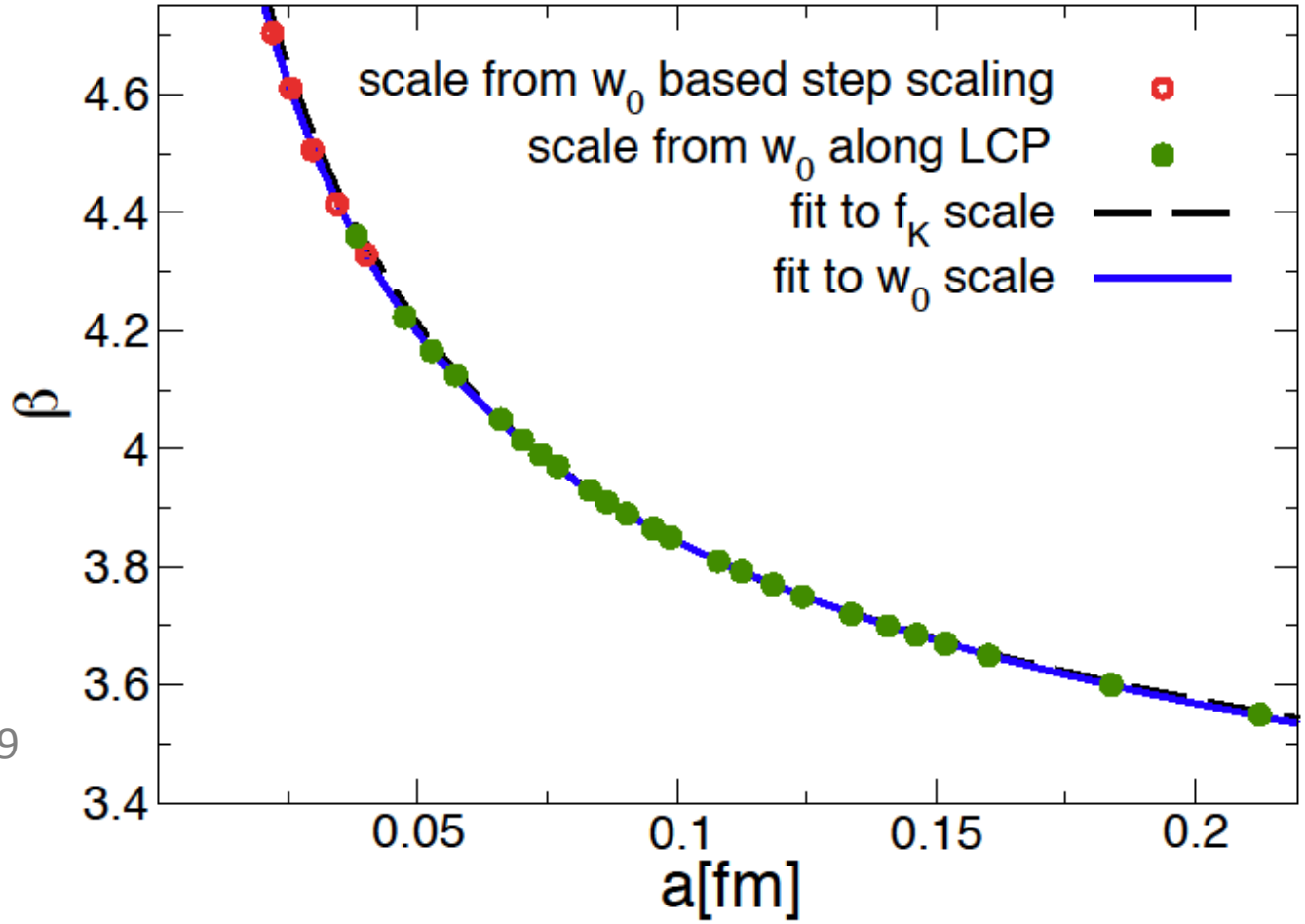
EoS: Scale setting



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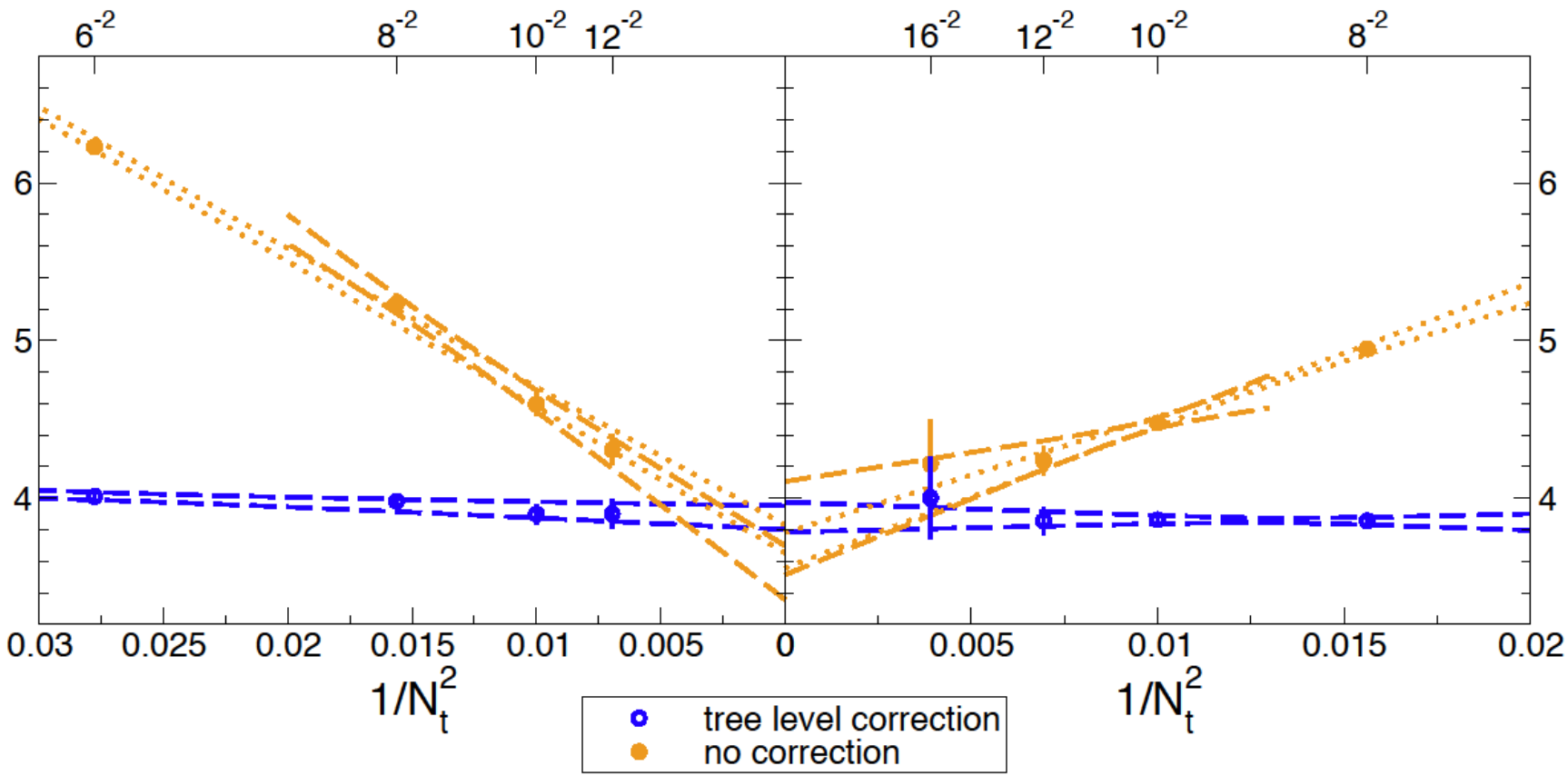
N_f=2+1 EoS: 214 MeV crosscheck



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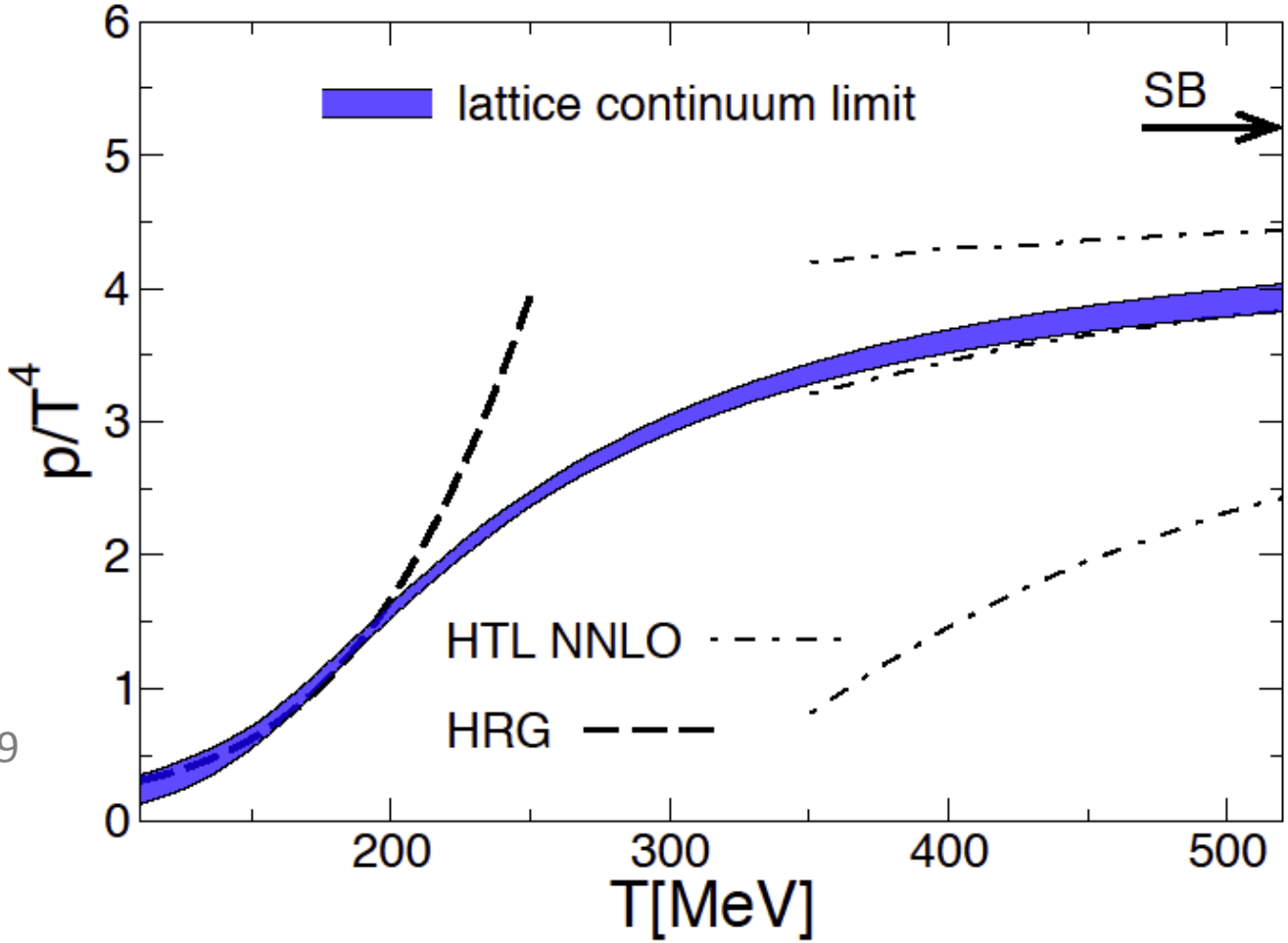
N_f=2+1 EoS: pressure et al.



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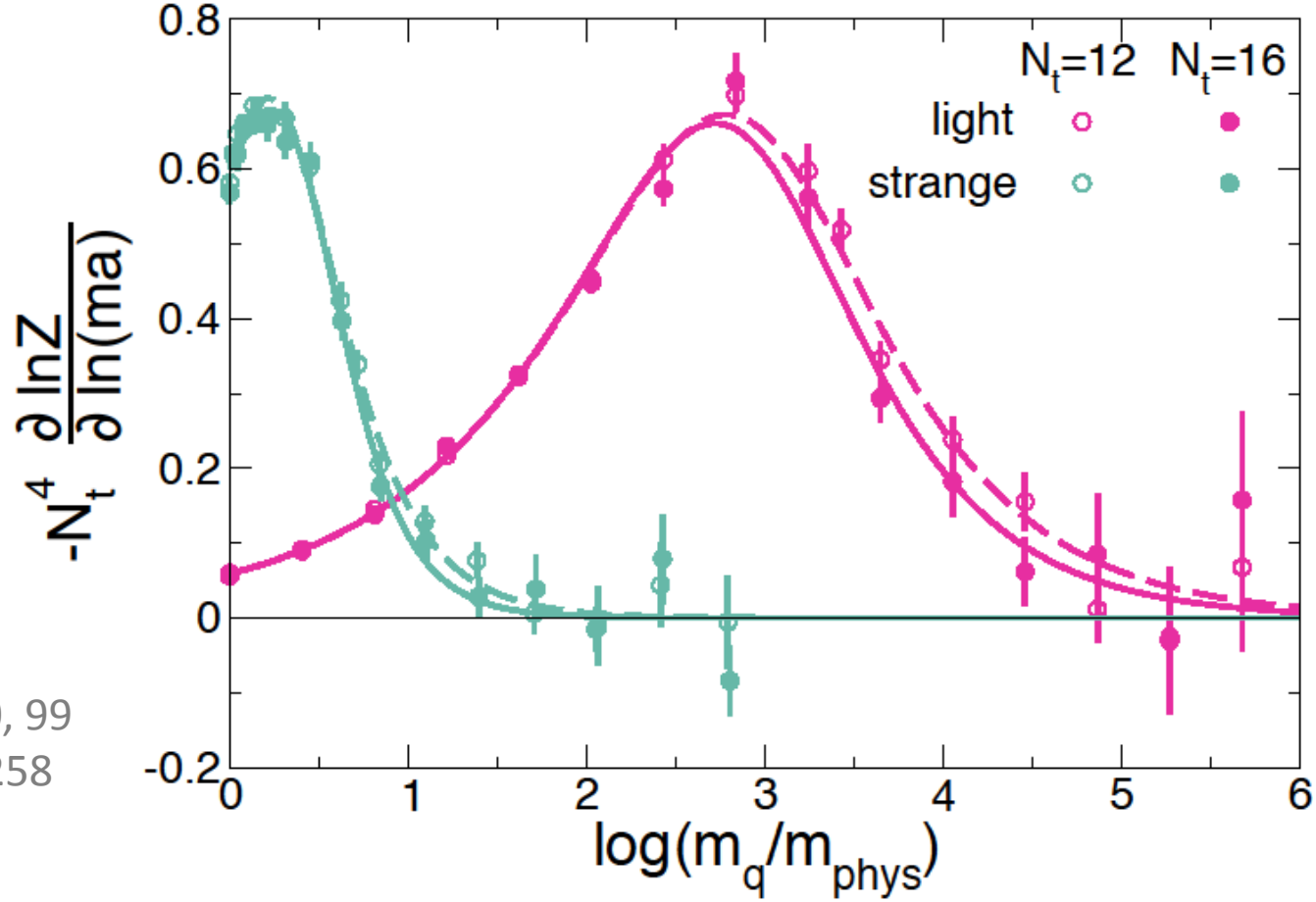
N_f=2+1 EoS: Normalization



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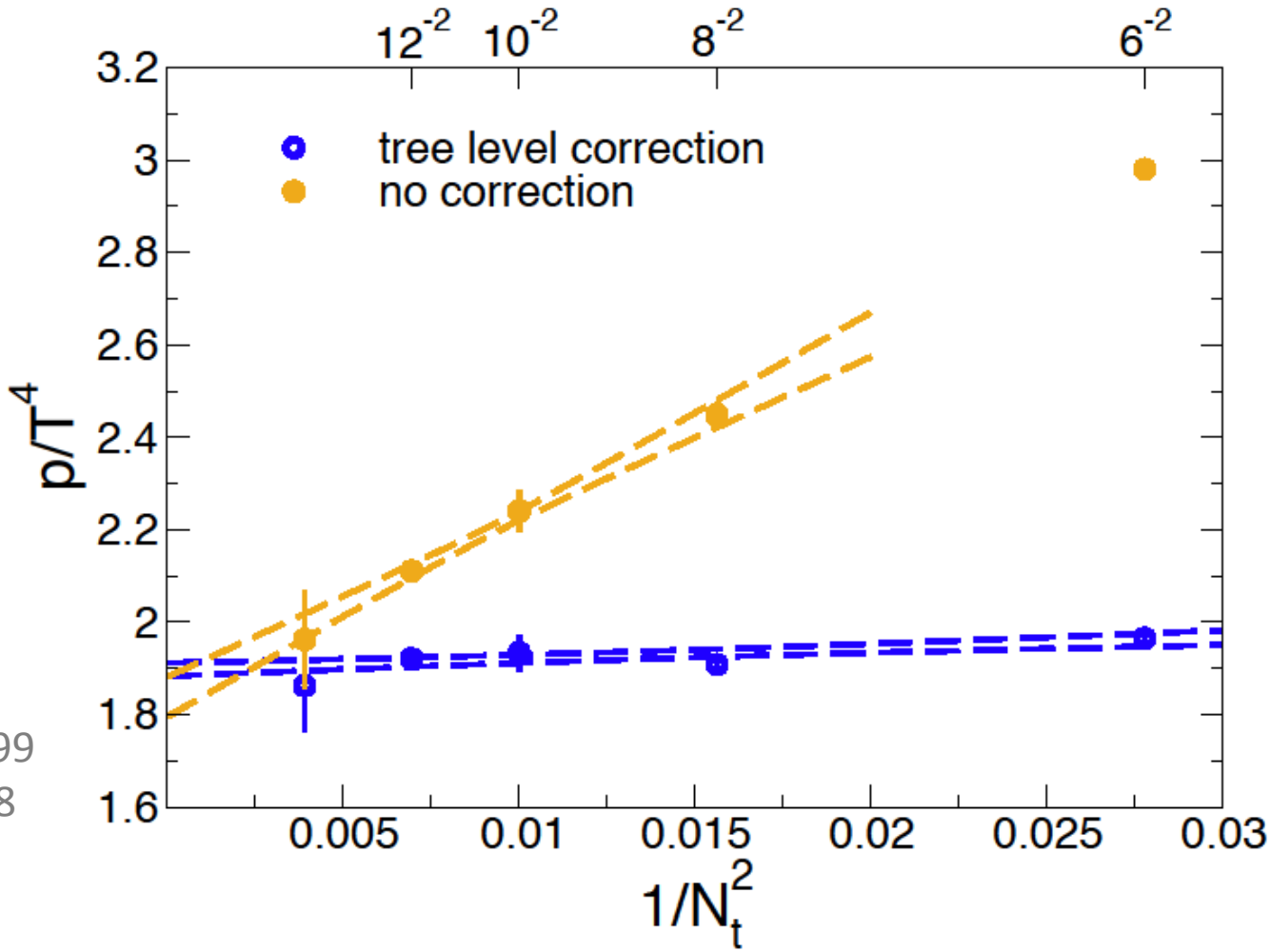

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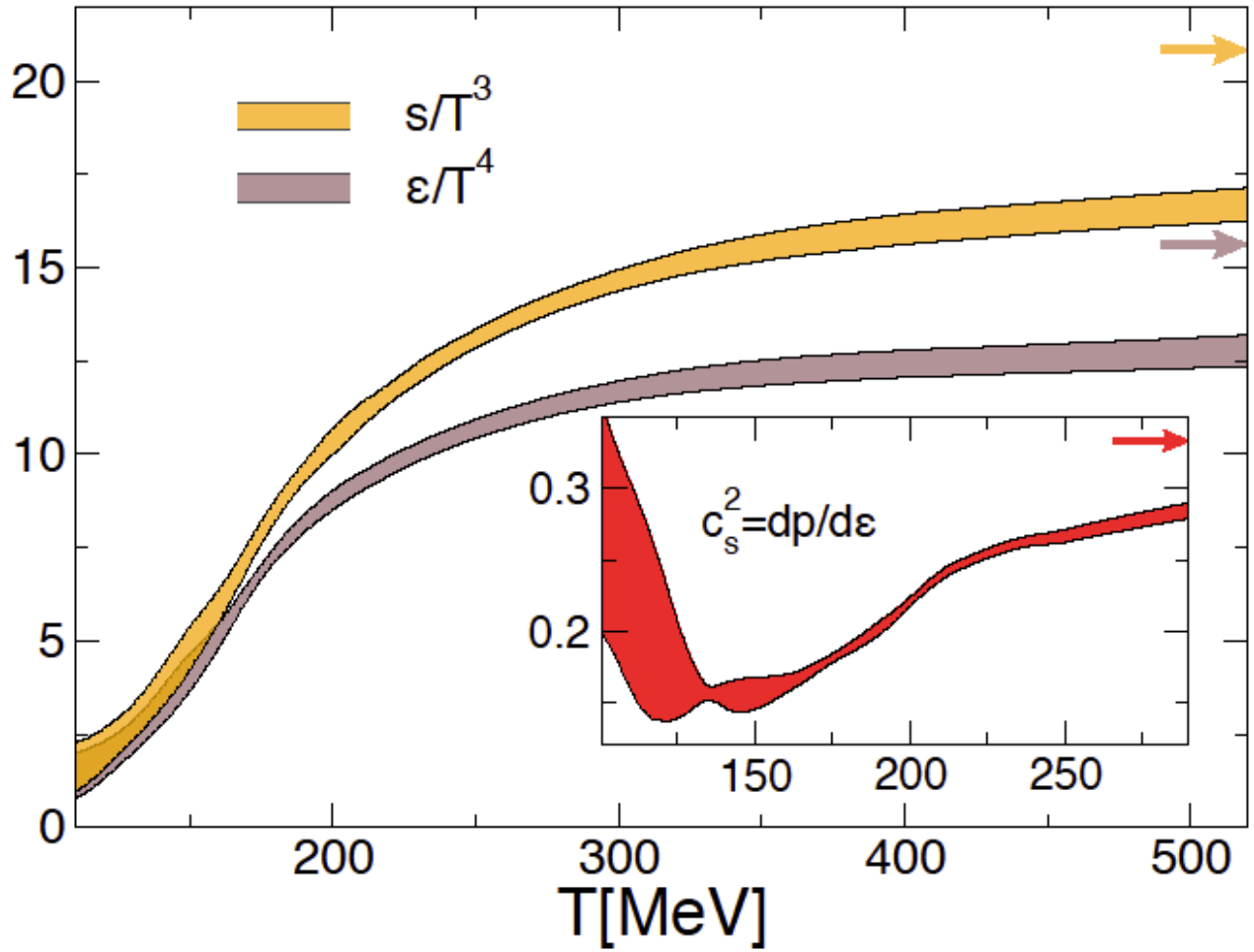
N_f=2+1 EoS: pressure et al.



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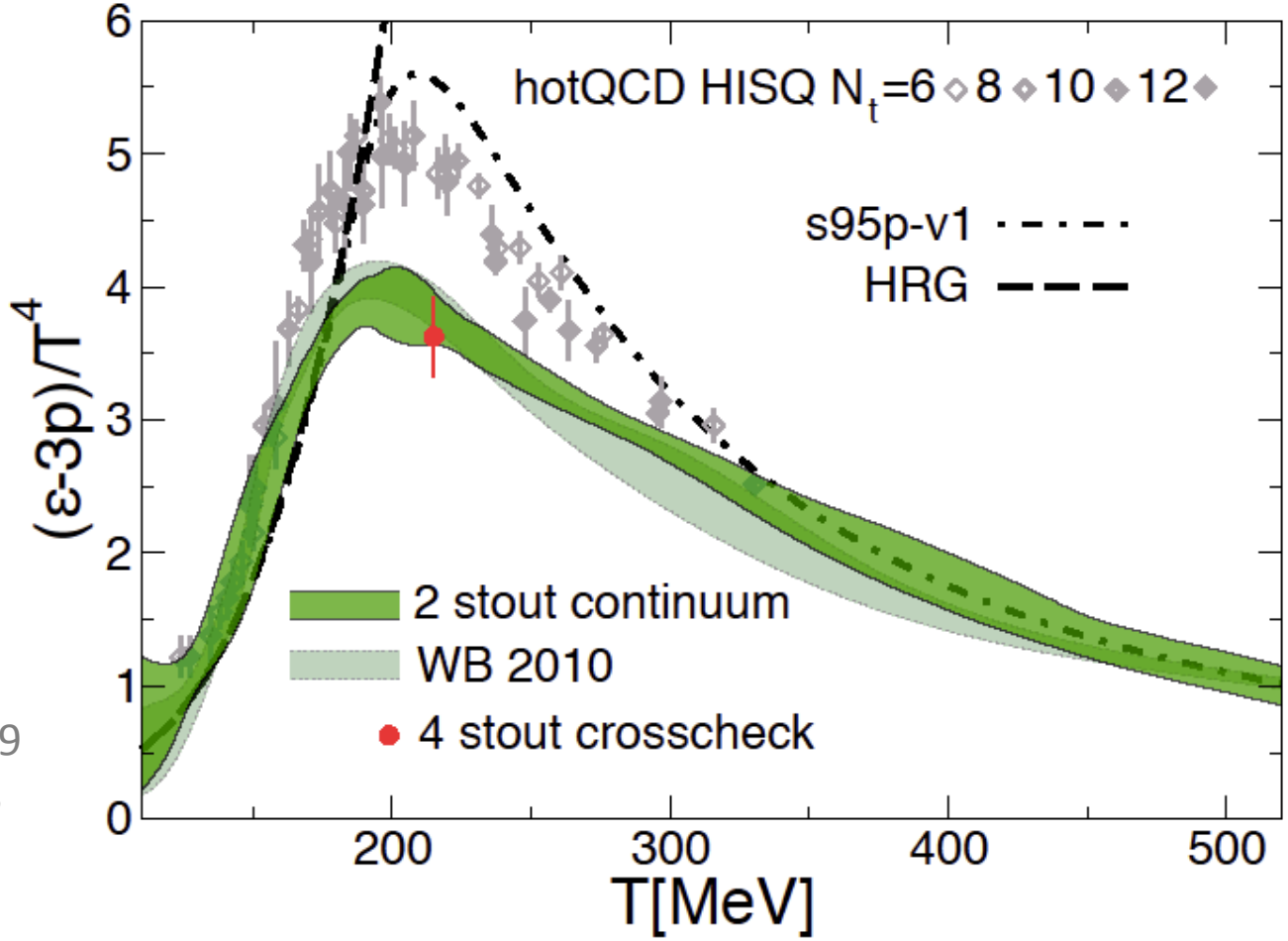
N_f=2+1 EoS: Comparison



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