QCD results on conserved charge fluctuations and Beam Energy Scan

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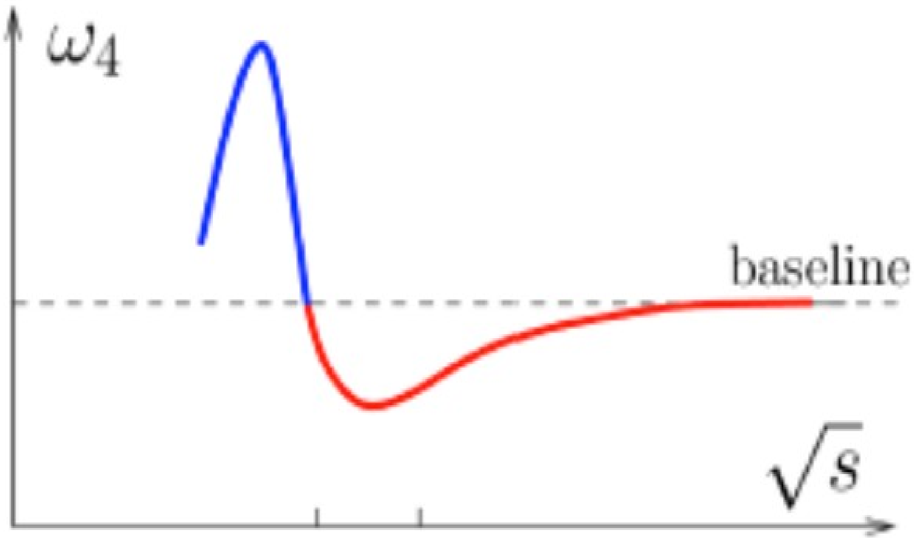
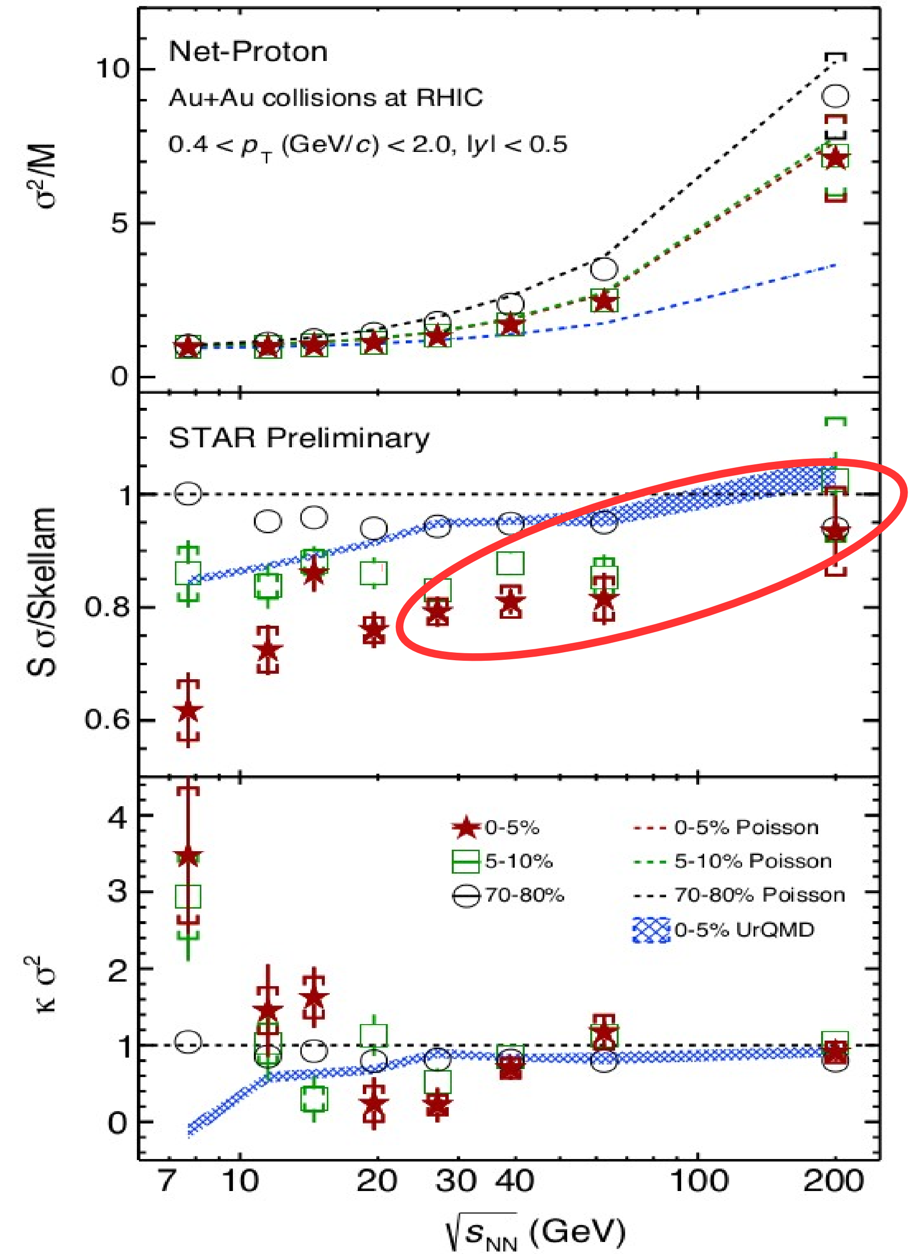
November 2015, GSI, Germany

Baseline ?



ω_4
baseline
$\sqrt{s}$



Net-Proton
Au+Au collisions at RHIC
0.4 < p_T (GeV/c) < 2.0, |y| < 0.5
σ^2/M
STAR Preliminary
S σ/Skellam
κ σ^2
0-5%
5-10%
70-80%
0-5% Poisson
5-10% Poisson
70-80% Poisson
0-5% UrQMD
$\sqrt{s_{NN}}$ (GeV)

Equilibrium QCD baseline ?

(L)QCD cumulants of conserved charge fluctuations along: $T_f(\mu_B^f)$

↑

not a fundamental QCD parameter: expt. input for a given colliding system, phase space cuts, $\sqrt{s}$ …

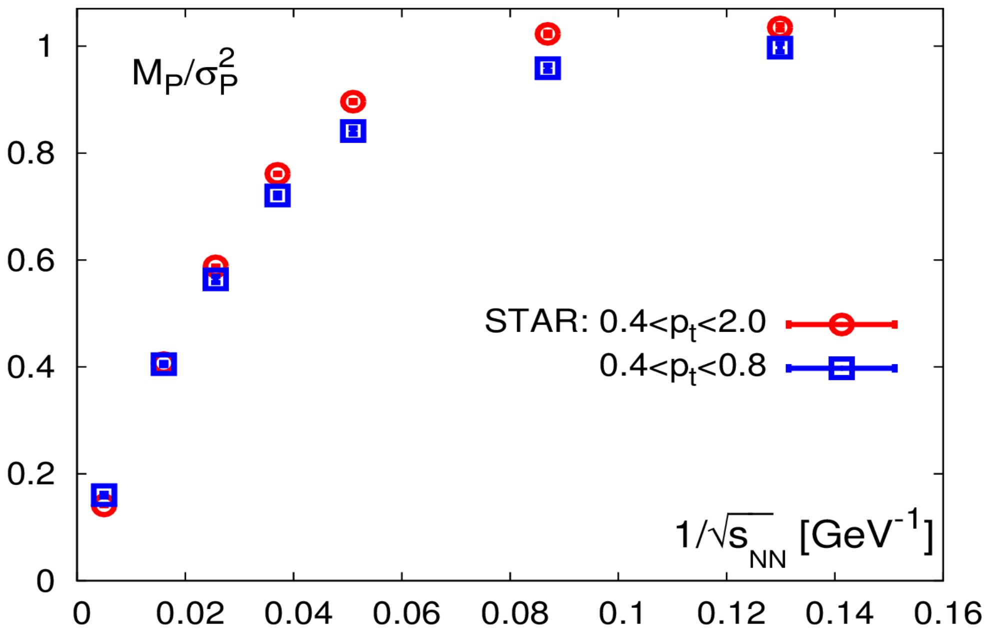
underlying assumption: expt. observables can be mapped into thermodynamic parameters T_f, μ_B^f

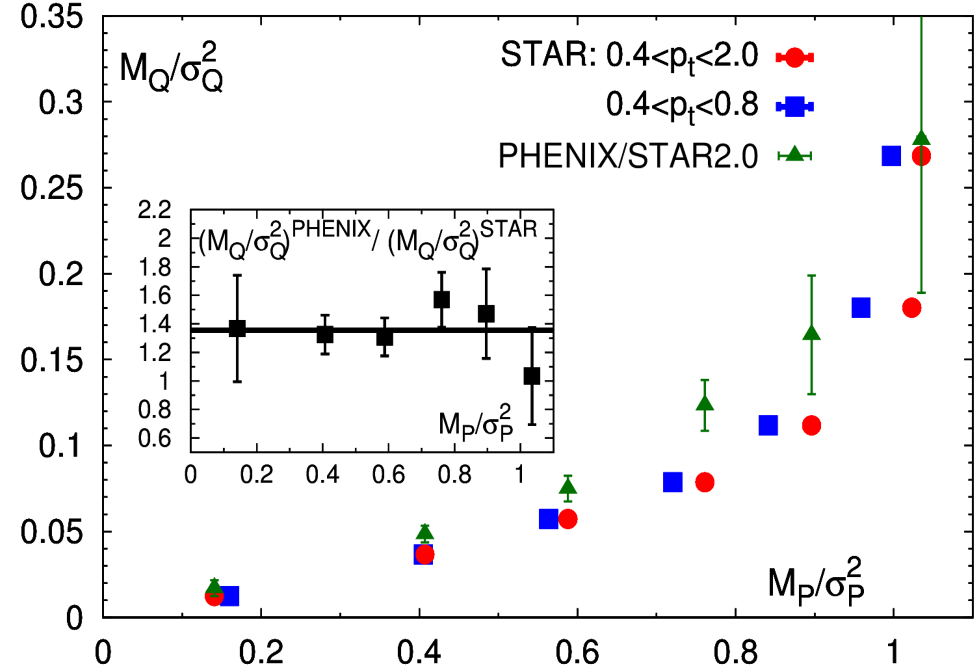
use a 'god-given' $T_f(\mu_B^f)$

OR for consistency:

estimate $T_f(\mu_B^f)$ by matching expt. lower cumulants $M_Q/\sigma_Q^2[M_p/\sigma_p^2]$ with equilibrium QCD $M_Q/\sigma_Q^2[M_B/\sigma_B^2]$ despite all known/unknown caveats

equilibrium QCD baseline for higher cumulants along this $T_f(\mu_B^f)$





$$R^P_{12} \equiv \frac{M_P}{\sigma^2_P}$$

monotonic functions of $\sqrt{s}$

$$R^Q_{12} \equiv \frac{M_Q}{\sigma^2_Q}$$

μ_B/T

$$\frac{\mu_B}{T} = m^B_1 R^B_{12} + m^B_3 \left(R^B_{12}\right)^3 + \mathcal{O}\left(\left(R^B_{12}\right)^5\right)$$

M_X/σ_X along the freeze-out line: $$T_f(\mu_B) = T_{f,0}\left(1 - \kappa_2^f \left(\frac{\mu_B}{T}\right)^2\right)$$

in practice: $M_s=0$, $M_Q/M_B=0.4$ → $\mu_Q(T,\mu_B)$, $\mu_S(T,\mu_B)$

for simplicity of discussion:

$\mu_Q=\mu_S=0$

$$\frac{M_B}{\sigma_B^2} = \frac{\mu_B}{T}\frac{1+\frac{1}{6}\frac{\chi_4^B}{\chi_2^B}\left(\frac{\mu_B}{T}\right)^2}{1+\frac{1}{2}\frac{\chi_4^B}{\chi_2^B}\left(\frac{\mu_B}{T}\right)^2}$$

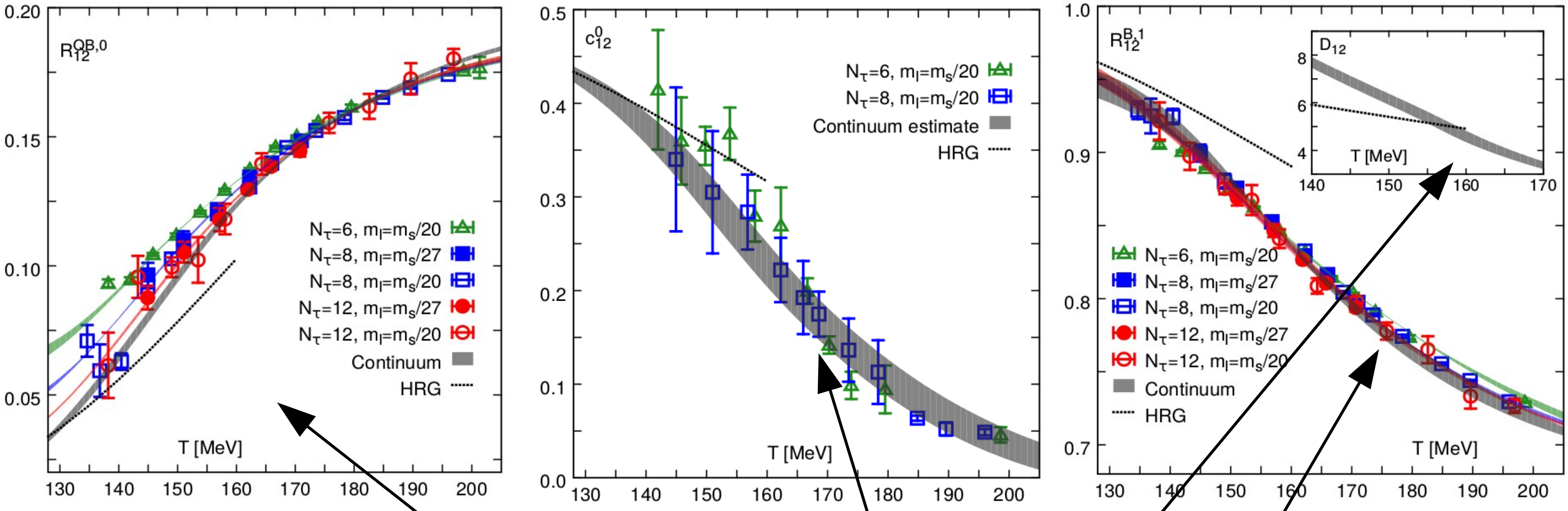
$$\frac{M_Q}{\sigma_Q^2} = \frac{\mu_B}{T}\frac{\chi_{11}^{BQ}}{\chi_2^Q}\frac{1+\frac{1}{6}\frac{\chi_{31}^{BQ}}{\chi_{11}^{BQ}}\left(\frac{\mu_B}{T}\right)^2}{1+\frac{1}{2}\frac{\chi_{22}^{BQ}}{\chi_2^B}\left(\frac{\mu_B}{T}\right)^2}$$

$$\chi(T_f) = \chi(T_{f,0}) - \kappa_2^f\left(\frac{d\chi}{dT}\right)_{T_{f,0}}\left(\frac{\mu_B}{T}\right)^2$$

$$R_{12}^{QB,0}(T) = r\,\frac{\chi_2^B(T)}{\chi_2^Q(T)}$$

$$R_{12}^{QB} \equiv \frac{M_Q/\sigma_Q^2}{M_B/\sigma_B^2} = a_{12}\left(1 + c_{12}\left(R_{12}^B\right)^2\right)$$

$$c_{12}(T,\kappa_2^f) \equiv c_{12}^0(T) - \kappa_2^f D_{12}(T)$$



BNL-Bi-CCNU:
arXiv:1509:05786

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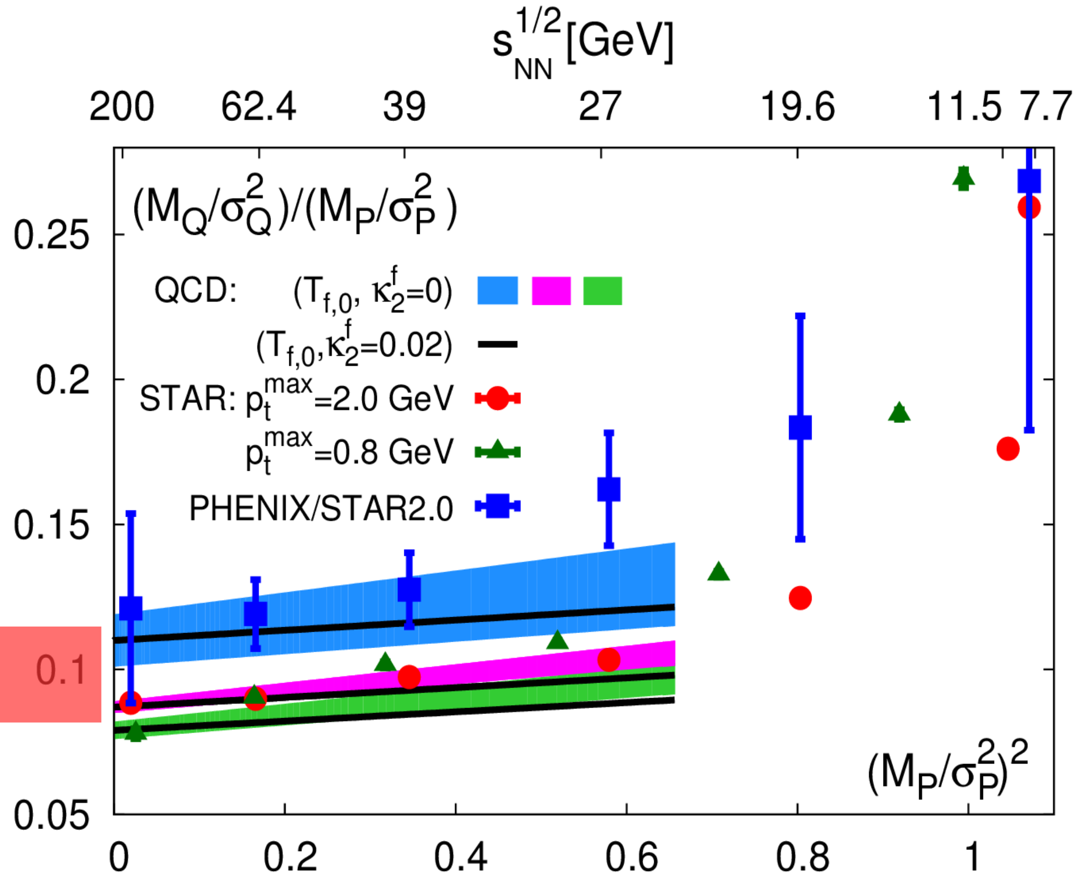
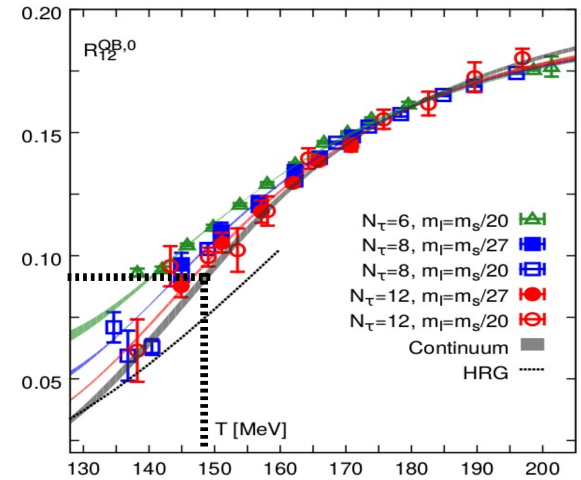


$T_{f,0}$

155 MeV

147 MeV

145 MeV



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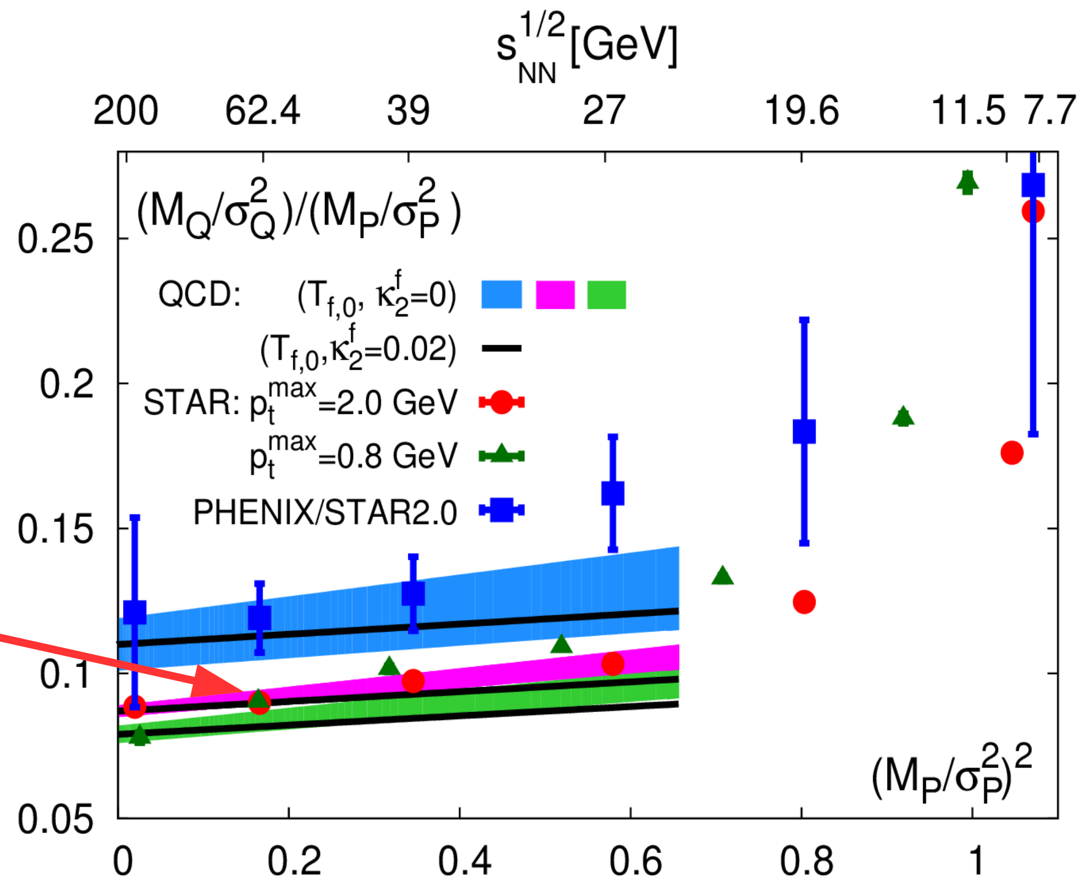
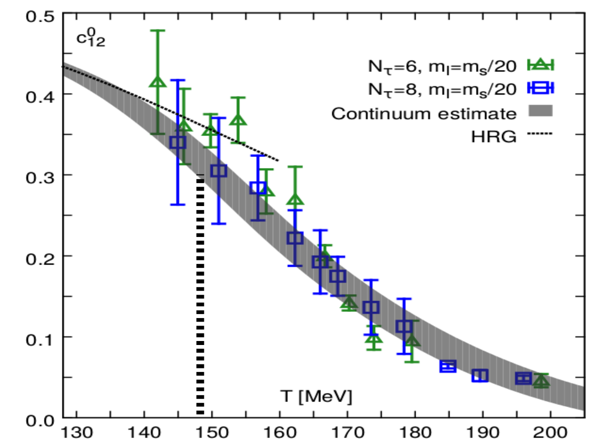
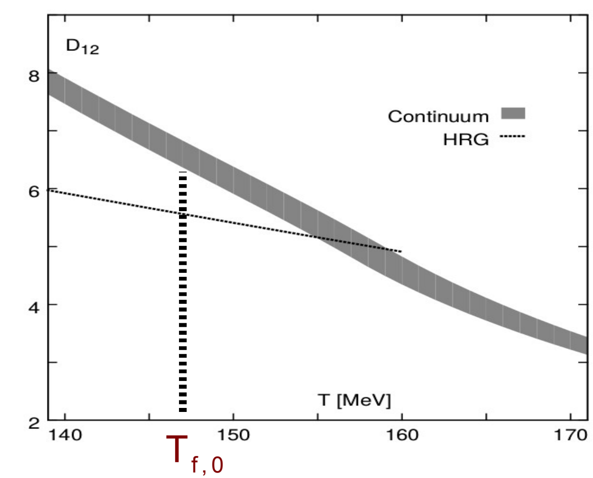
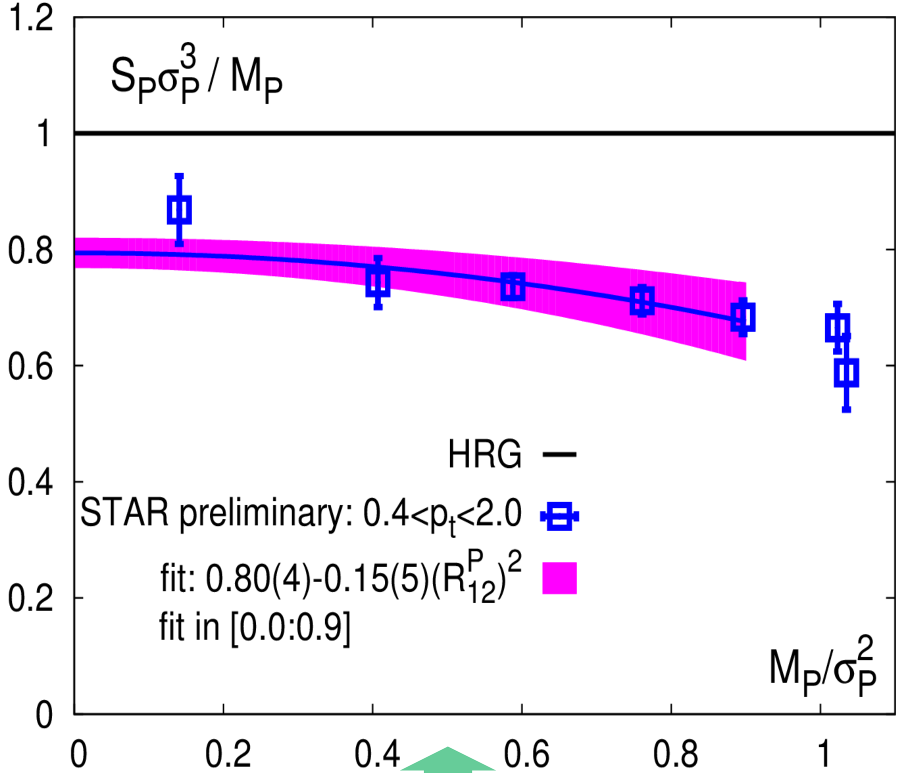


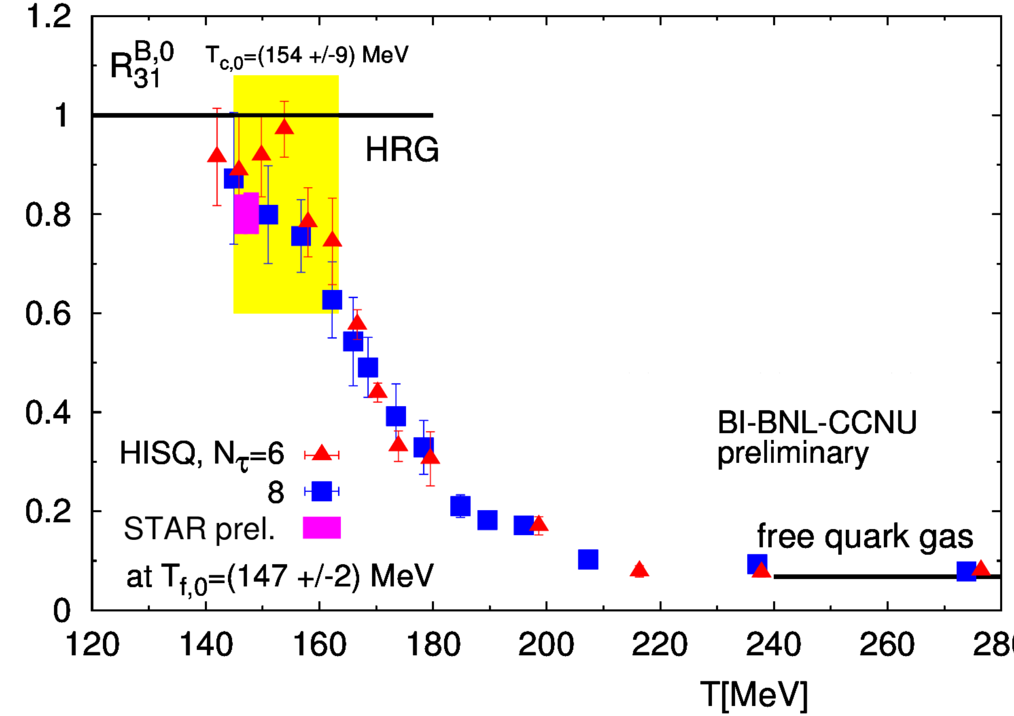
slope:

$\kappa_2^f < 0.011$







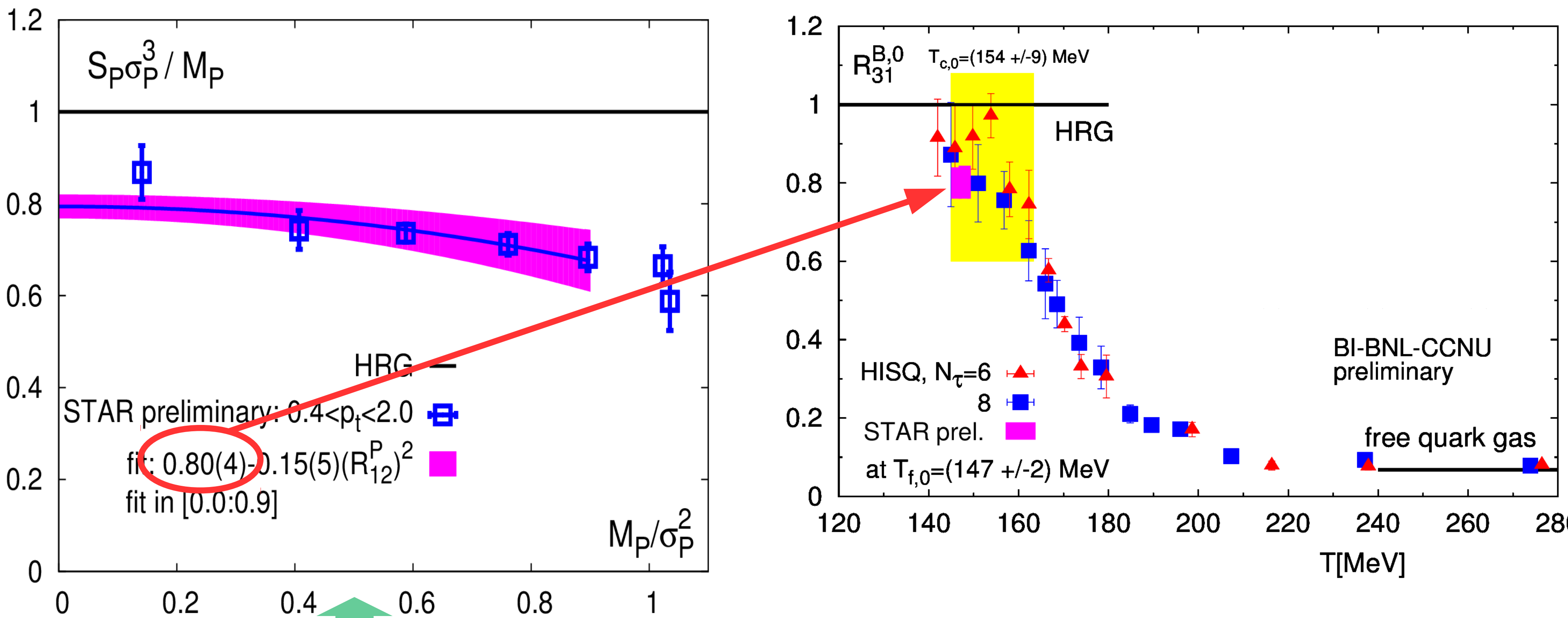


$$\frac{S_B\sigma_B^3}{M_B} = R_{31}^{B,0} + R_{31}^{B,2}\left(R_{12}^B\right)^2$$

choosing for simplicity:

$\mu_Q = \mu_S = \kappa_2^f = 0$

$$S_B\sigma_B = \frac{\chi_4^B}{\chi_2^B}\frac{M_B}{\sigma_B^2} + \frac{1}{6}\left(\frac{\chi_6^B}{\chi_2^B} - \left(\frac{\chi_4^B}{\chi_2^B}\right)^2\right)\left(\frac{M_B}{\sigma_B^2}\right)^3 + \ldots$$



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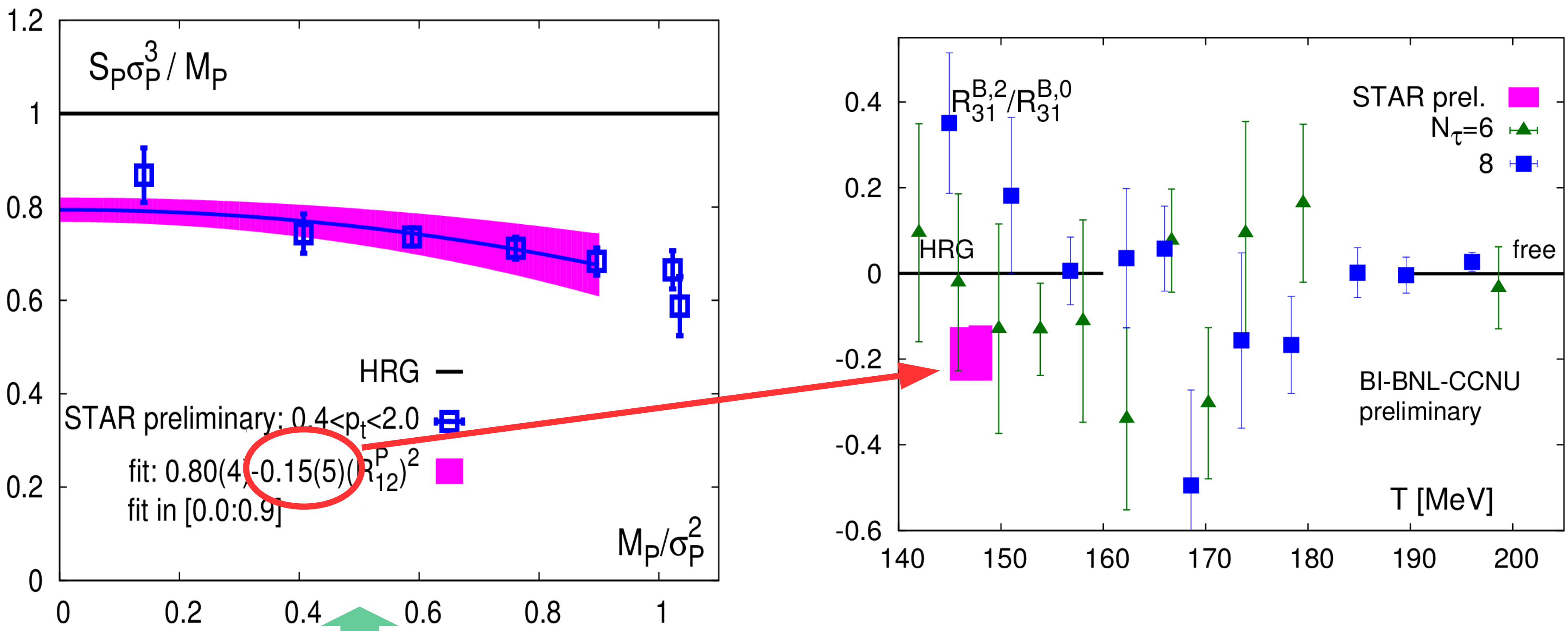

$$\frac{S_B\sigma_B^3}{M_B} = R_{31}^{B,0} + R_{31}^{B,2}\left(R_{12}^B\right)^2$$

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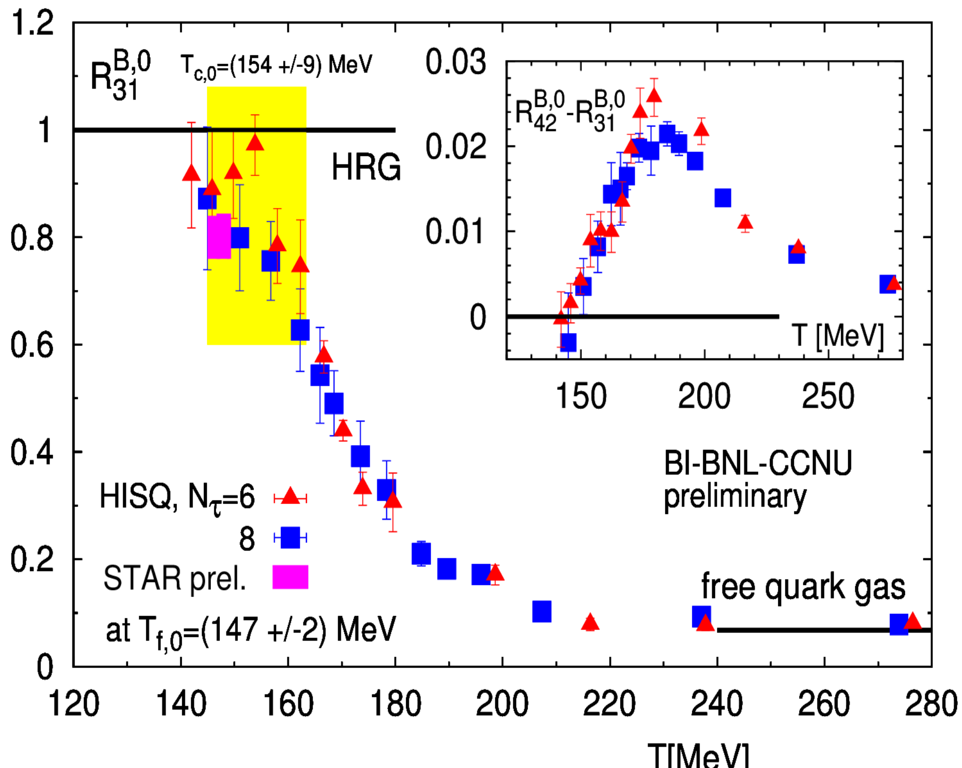
$$R_{31}^{B} \equiv S_B \sigma_B^3 / M_B$$

$$R_{31}^{B} = R_{31}^{B,0} + R_{31}^{B,2} \left(R_{12}^{B}\right)^2$$

$$R_{42}^{B} \equiv \kappa_B \sigma_B^2$$

$$R_{42}^{B} = R_{42}^{B,0} + R_{42}^{B,2} \left(R_{12}^{B}\right)^2$$

$$R_{42}^{B,0} \simeq R_{31}^{B,0}$$



$$R_{42}^{B,2} = 3R_{31}^{B,2} = \frac{1}{2}\left(\frac{\chi_6^B}{\chi_2^B} - \left(\frac{\chi_4^B}{\chi_2^B}\right)^2\right)$$

choosing for simplicity:

$\mu_Q = \mu_S = \kappa_2^f = 0$

$$R_{31}^B \equiv S_B\sigma_B^3/M_B$$

$$R_{31}^B = R_{31}^{B,0} + R_{31}^{B,2}\left(R_{12}^B\right)^2$$

$$R_{42}^B \equiv \kappa_B\sigma_B^2$$

$$R_{42}^B = R_{42}^{B,0} + R_{42}^{B,2}\left(R_{12}^B\right)^2$$

$$R_{42}^{B,0} \simeq R_{31}^{B,0}$$

$$R_{42}^{B,2} = 3R_{31}^{B,2} = \frac{1}{2}\left(\frac{\chi_6^B}{\chi_2^B} - \left(\frac{\chi_4^B}{\chi_2^B}\right)^2\right)$$