Fluctuations in effective models

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QCD phase diagram

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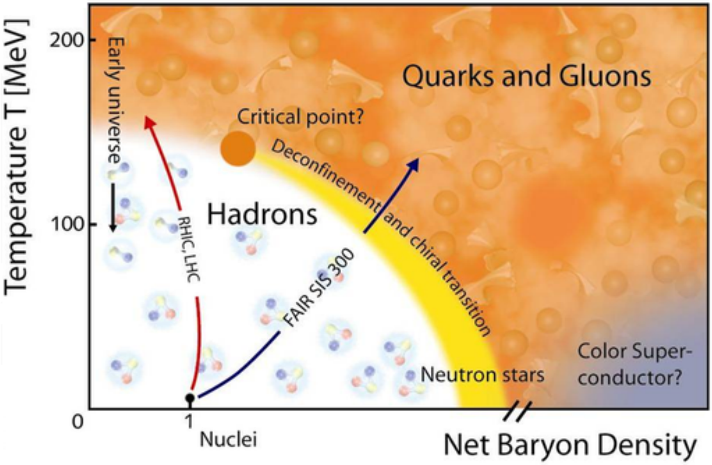

Table of Contents

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Coming up:

- Calculation of baryon number cumulants (thermal equilibrium)
- General structure of cumulants
- Freeze-out line in effective models
- Consistency of data with model predictions
- Effect of the repulsive vector interaction

Polyakov–Quark-Meson model

$$\mathcal{L} = \overline{q}\left[iD_\mu\gamma^\mu - g\left(\sigma + i\gamma_5\vec{\tau}\vec{\pi}\right)\right]q + \frac{1}{2}\left(\partial_\mu\sigma\right)^2 + \frac{1}{2}\left(\partial_\mu\pi\right)^2 - U(\sigma,\vec{\pi}) - U_P(T,\phi,\overline{\phi})$$

with the mesonic potential

$$U(\sigma,\vec{\pi}) = \frac{\lambda}{4}\left(\sigma^2 + \vec{\pi}^2 - v^2\right)^2 - H\sigma$$

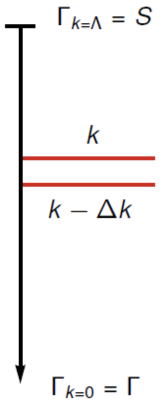
- Degrees of freedom: light quarks, pions, sigma meson (2 flavors)
- Low energy effective theory of QCD
- Describes chiral symmetry breaking
- Polyakov-loop: suppression of single quark fluctuations at low temperatures
- Same universality class as QCD

Functional Renormalization Group

- Nonperturbative method
- Calculates the quantum effective action which translates to the pressure
- Wetterich equation:

$$\partial_k \Gamma_k[\Phi, \overline{\psi}, \psi] = \frac{1}{2} \mathrm{STr} \left[\left(\Gamma^{(2)} + R_k \right)^{-1} \partial_k R_k \right]$$

- Equation is solved on a grid



courtesy A. Tripolt

Application of the model

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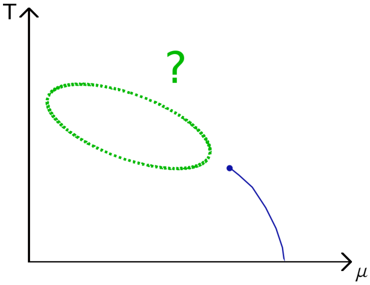
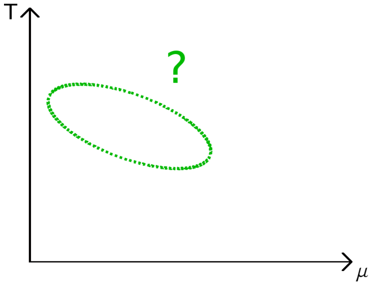
- Qualitative fit to vacuum physics
- Use the remaining freedom to change the CEP location
- Calculate the baryon number cumulants χ_B^n
- Plot cumulant ratios on different lines





Baryon number cumulants - an overview (MF)

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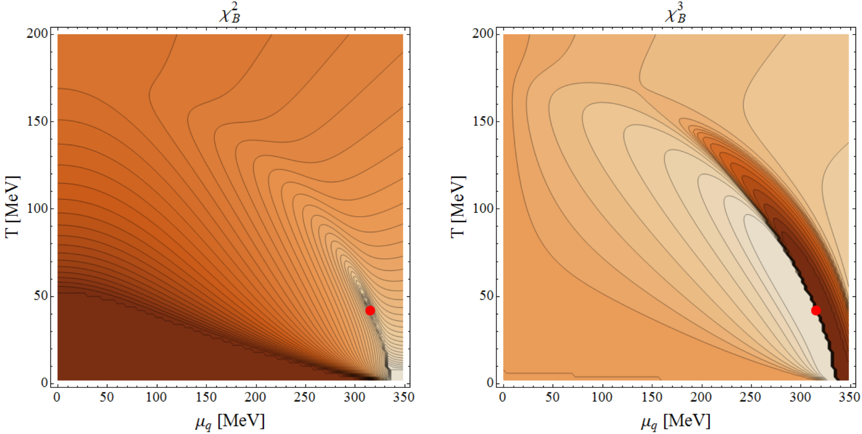
$$\chi_B^n = \frac{1}{T^4} \frac{\partial^n P(T,\mu_B)}{\partial(\mu_B/T)^n}, \qquad \mu_B = 3\mu_q$$



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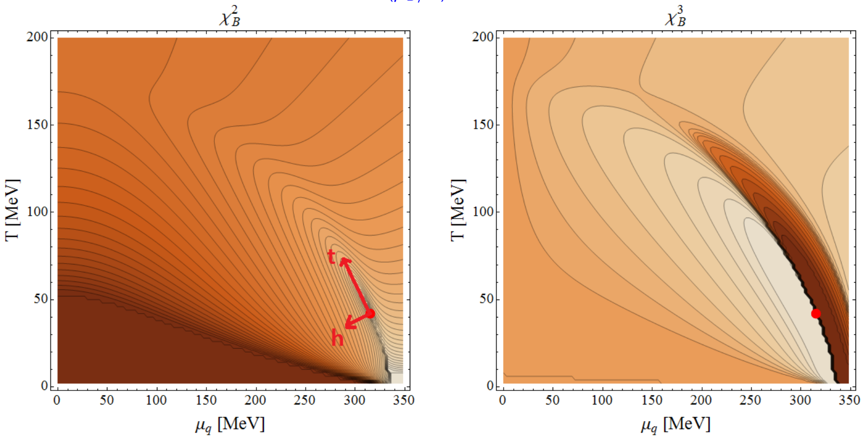

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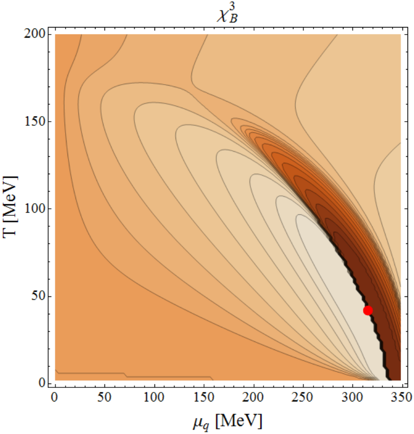
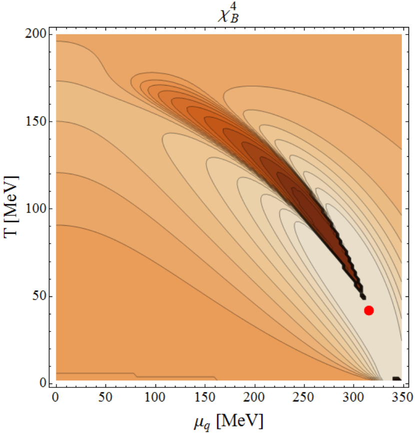
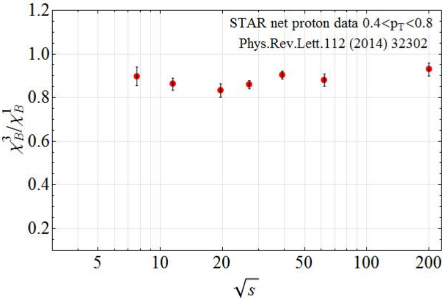


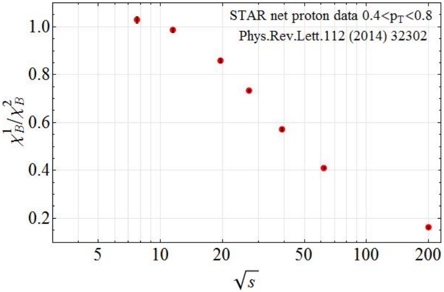


Freeze-out condition

Baryon number cumulants: $\chi_B^n = \frac{1}{T^4}\frac{\partial^n P(T,\mu_B)}{\partial(\mu_B/T)^n}$

$\chi_B^1/\chi_B^2 \leftrightarrow M/\sigma^2 \qquad \chi_B^3/\chi_B^1 \leftrightarrow S\sigma^3/M \qquad \chi_B^4/\chi_B^2 \leftrightarrow \kappa\sigma^2$





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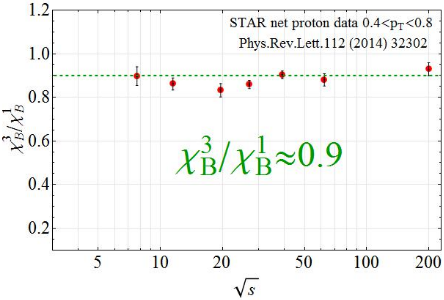

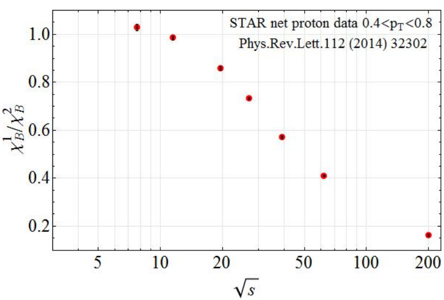

General behavior of the cumulant ratios

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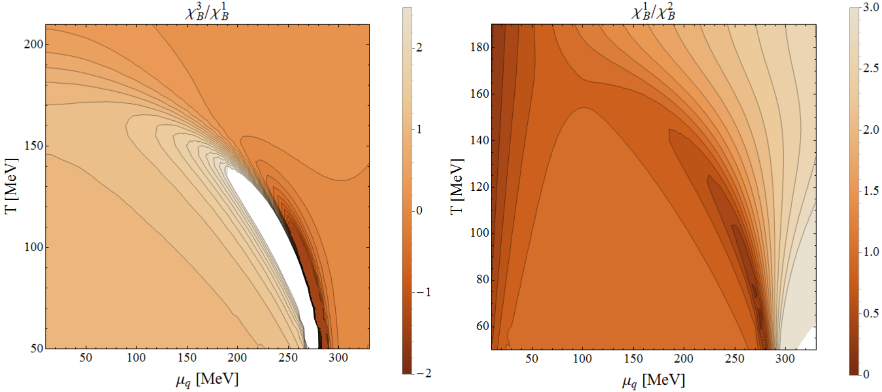

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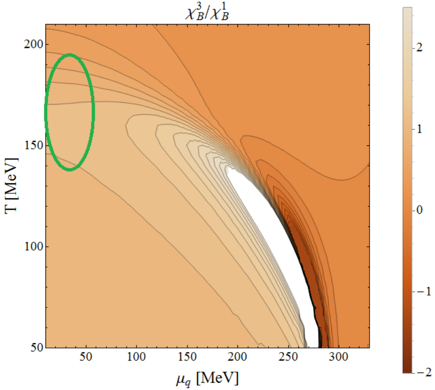

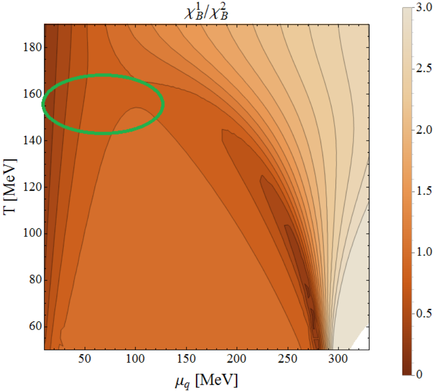

Mainly determined by T

Mainly determined by μ

No CEP scenario

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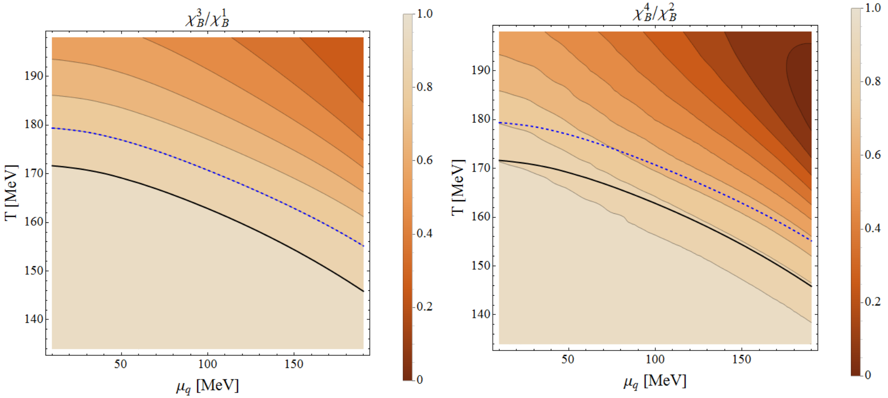
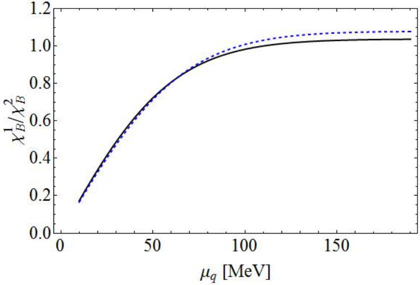
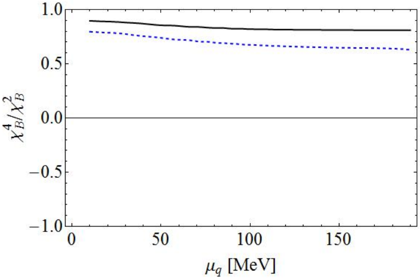


Black line: $\chi_B^3/\chi_B^1 = 0.9$

Blue (dashed) line: $\chi_B^3/\chi_B^1 = 0.8$

No CEP scenario





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CEP scenario

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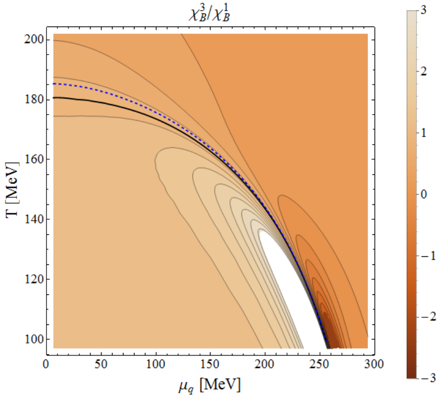

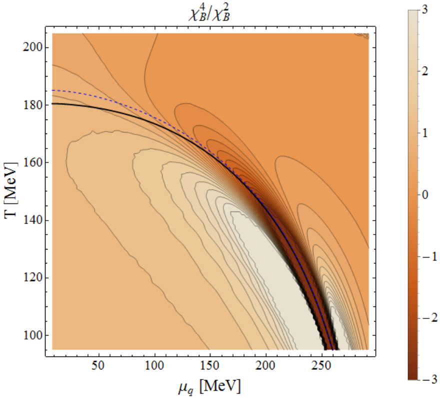

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CEP scenario

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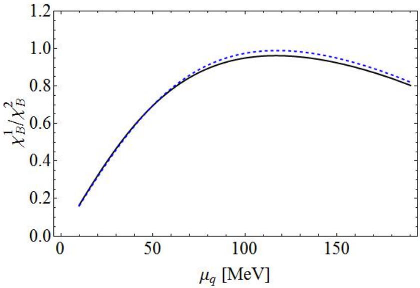
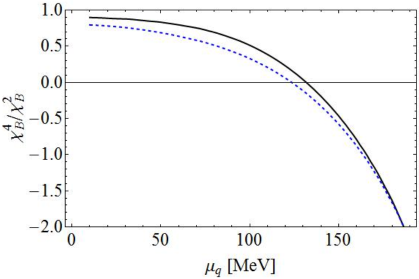




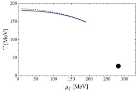
Black line: $\chi_B^3/\chi_B^1 = 0.9$

χ_B^1/χ_B^2 has a maximum

Blue (dashed) line: $\chi_B^3/\chi_B^1 = 0.8$

χ_B^4/χ_B^2 decreases monotonously

CEP scenario



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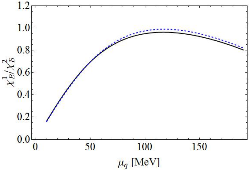

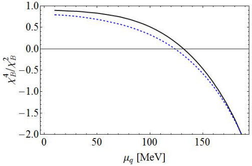

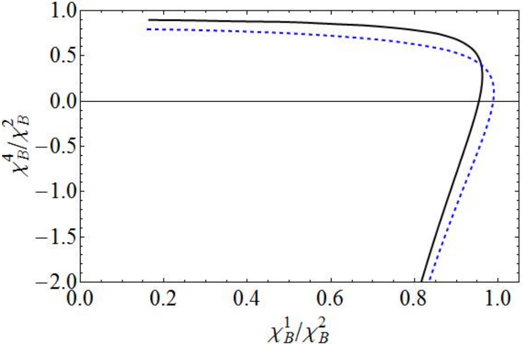

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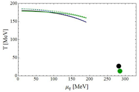

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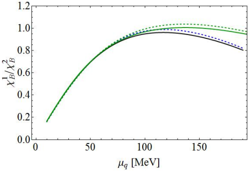

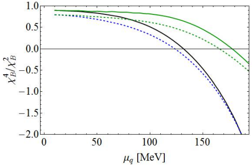

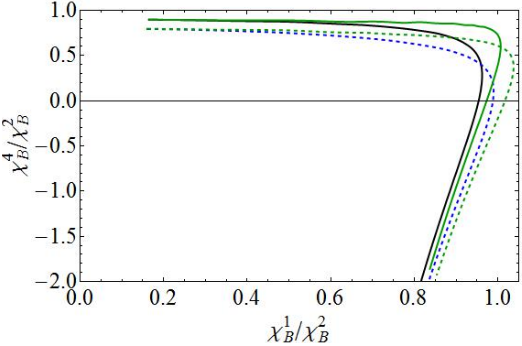

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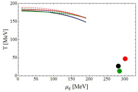

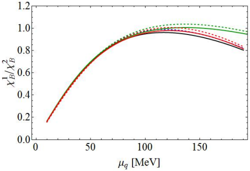

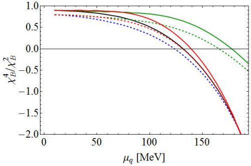

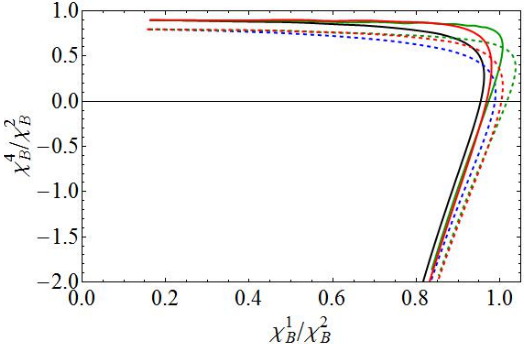

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Comparision of different "freeze-out" lines

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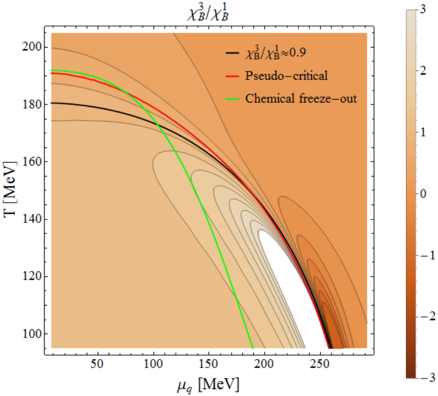

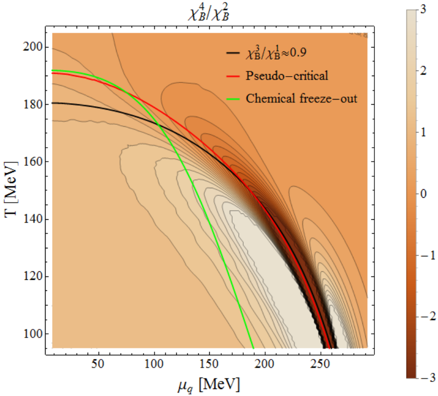

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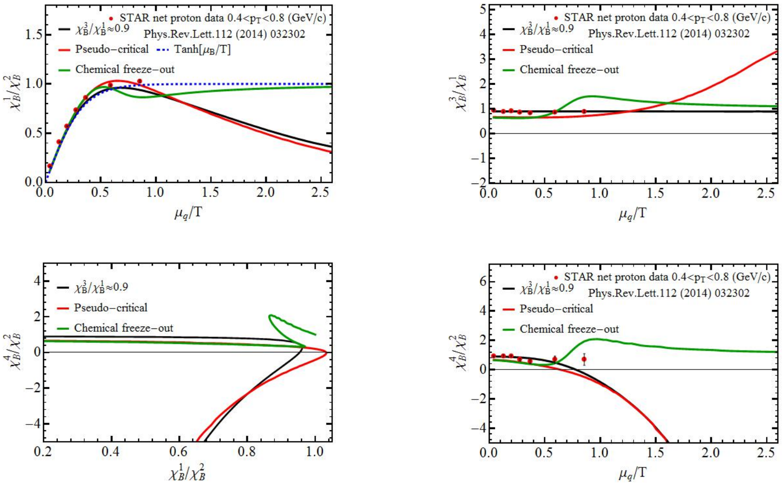
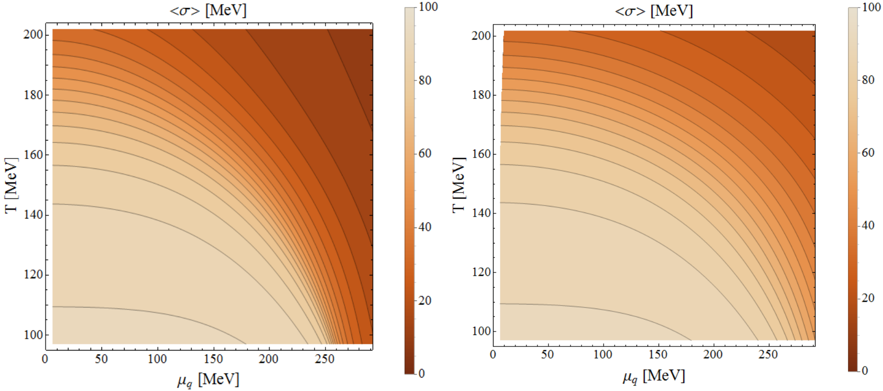


Effect of vector interaction – condensate



Rescaling of the μ axis: $\mu = \mu_{eff} + G_v \langle n \rangle_{\mu_{eff}}$

Effect of vector interaction – χ_B^3/χ_B^1

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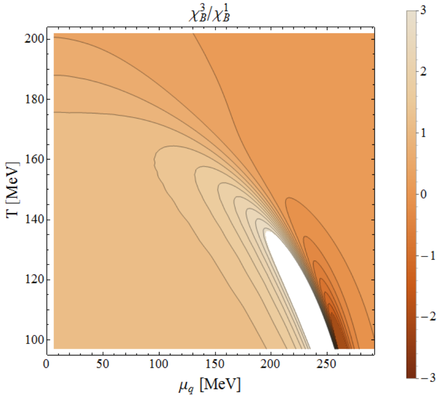
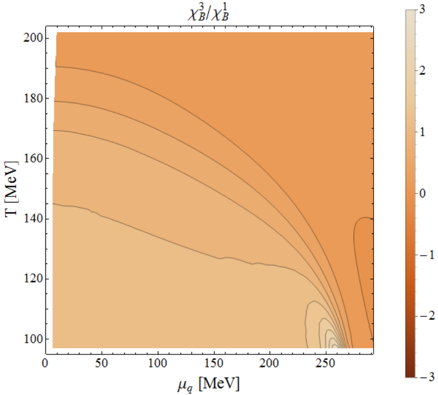


No vector interaction



Significant vector interaction

Effect of vector interaction – χ_B^4/χ_B^2

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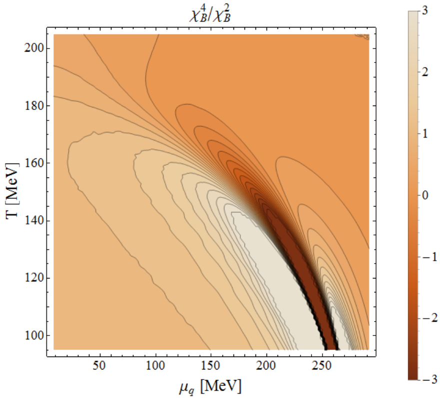

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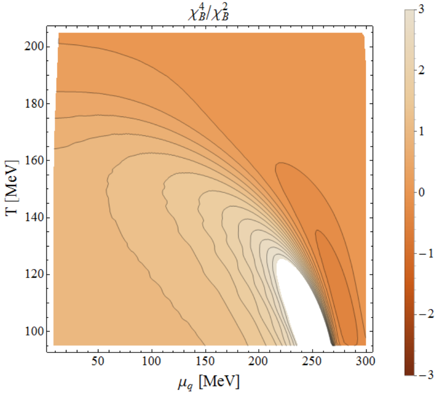
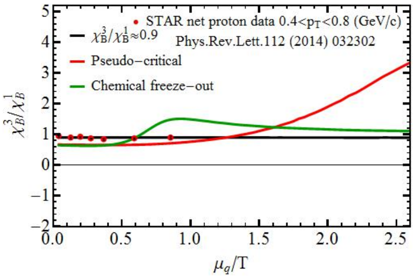
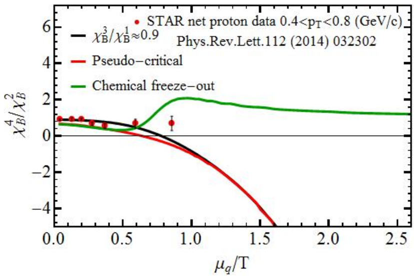


Significant vector interaction

Effect of vector interaction – Curves





Effect of vector interaction – Curves

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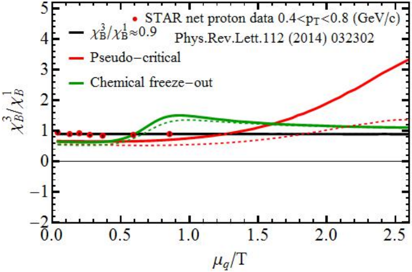

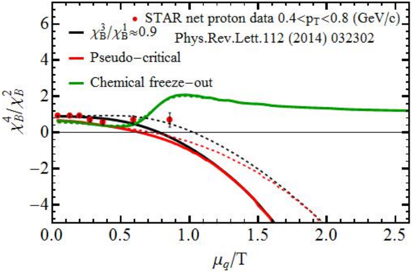

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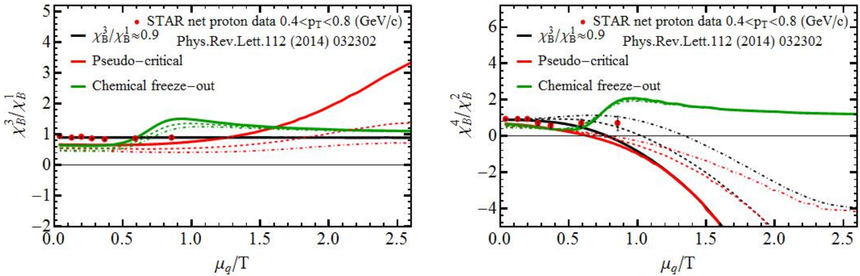

Vector interaction decreases the signal of the CEP at fixed small chemical potentials

Summary

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- Baryon number cumulants up to χ_B^4 obtained in the FRG framework
- Consistent freeze-out line determination is important
- The CEP does influence the behavior of the cumulants
- Correlation between χ_B^4/χ_B^2 and χ_B^3/χ_B^1
- Vector interaction decreases the effect of the CEP

Backup

Ising model in Landau-theory

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gap equation: $M^3 + a(T - T_c)M - H = 0$

susceptibility: $\chi = \frac{\chi_0}{a(T-T_c)+3M^2}$

$T = Tc$ limit:

$M \sim H^{1/3}$

$\chi \sim H^{-2/3}$

$H = 0$ limit:

$M \sim (T - T_c)^{1/2}$

$\chi \sim (T - T_c)^{-1}$