

Fluctuations in effective models



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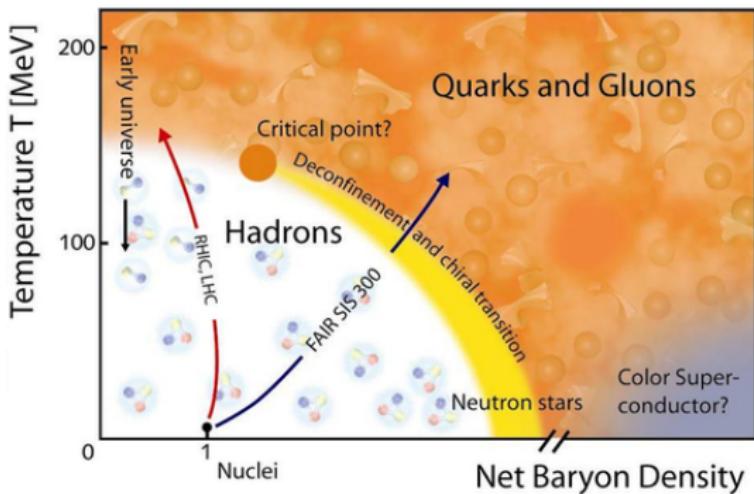
Gábor Almási^a, Bengt Friman^{a,b}, Krzysztof Redlich^{b,c}

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QCD phase diagram



- ▶ Is there a chiral critical end point(CEP)?
- ▶ If yes, where?

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Coming up:

- ▶ Calculation of cumulant ratios (thermal equilibrium)
- ▶ Freeze-out line in effective models
- ▶ Consistency of data with model predictions
- ▶ Effect of the vector interaction

Quark–meson model



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

with the mesonic potential

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

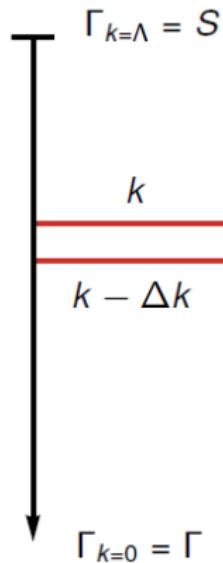
- ▶ Degrees of freedom: light quarks, pions, sigma meson (2 flavors)
- ▶ Low energy effective theory of QCD
- ▶ Describes chiral symmetry breaking
- ▶ Polyakov-loop: suppression of single quark fluctuations at low temperatures
- ▶ Same universality class as QCD

Functional Renormalization Group

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

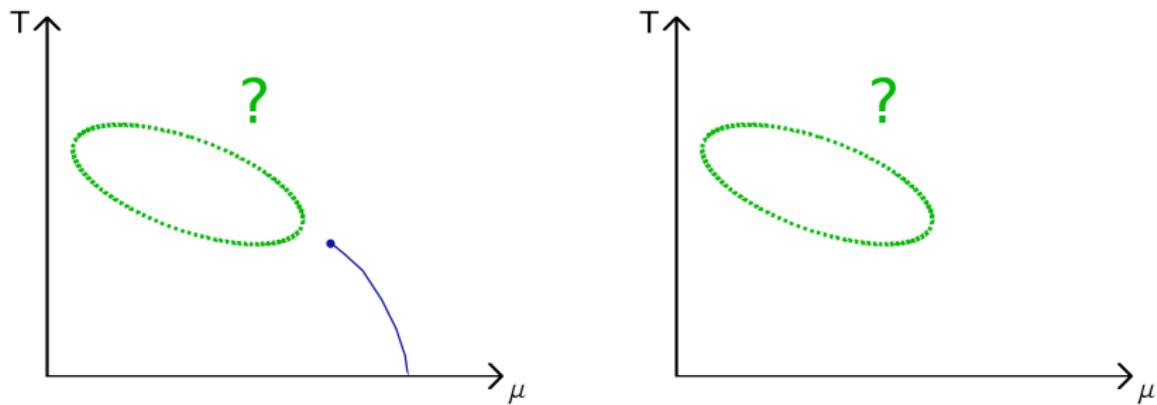
$$\partial_k \Gamma_k[\Phi, \bar{\psi}, \psi] = \frac{1}{2} S \text{Tr} \left[\left(\Gamma^{(2)} + R_k \right)^{-1} \partial_k R_k \right]$$

- ▶ Equation is solved on a grid



Application of the model

- ▶ 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



Freeze-out condition

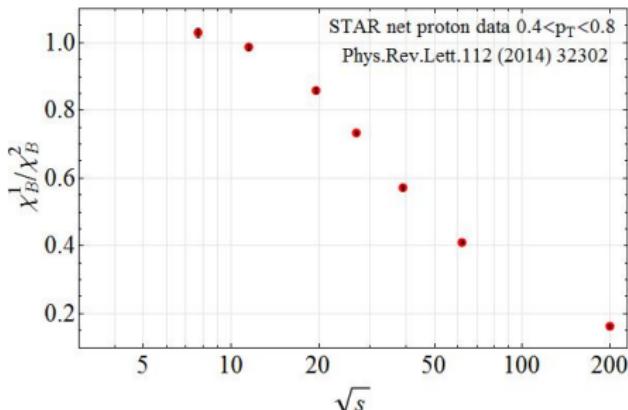
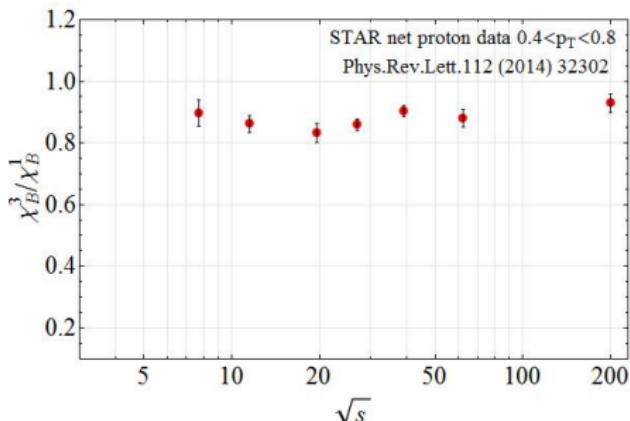


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Baryon number cumulants:

$$\chi_B^n = \frac{1}{T^4} \frac{\partial^n P(T, \mu)}{\partial(\mu/T)^n}$$

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



Freeze-out condition

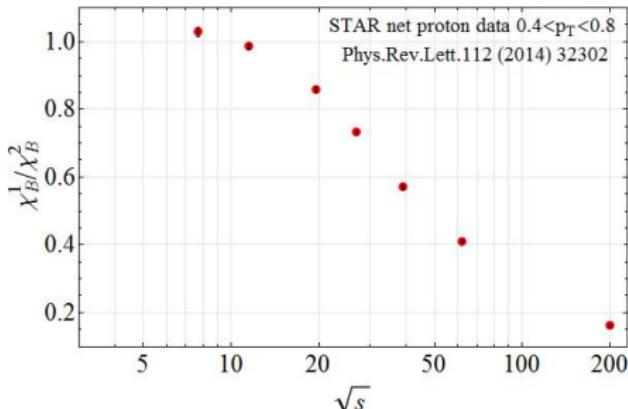
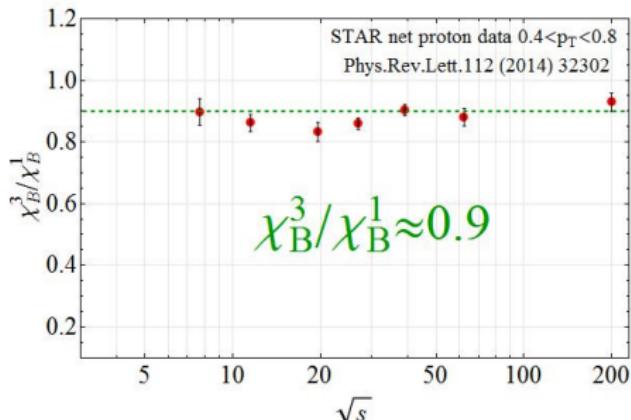


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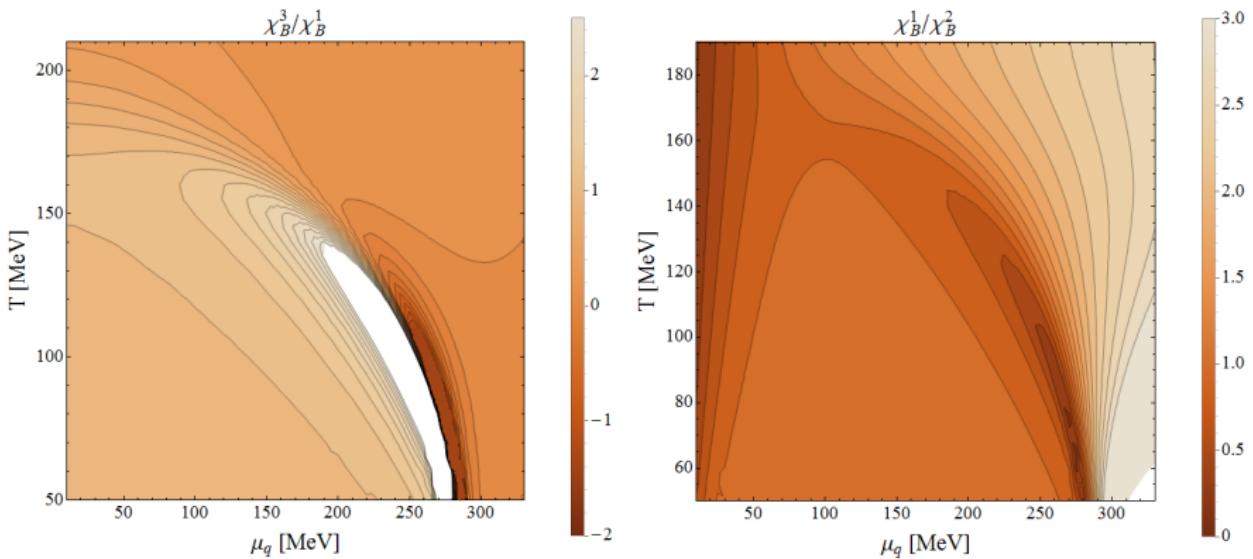
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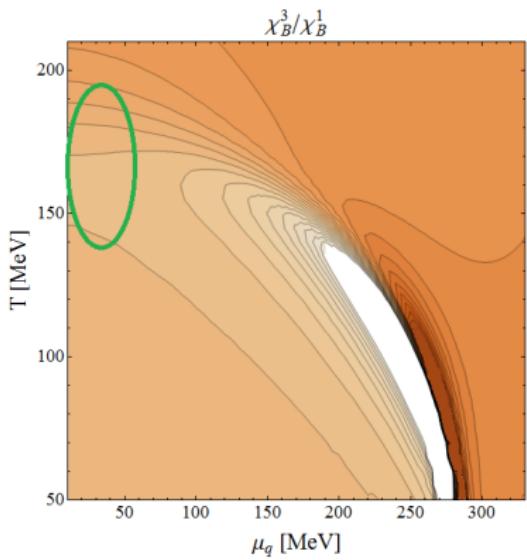
General behavior of the cumulant ratios



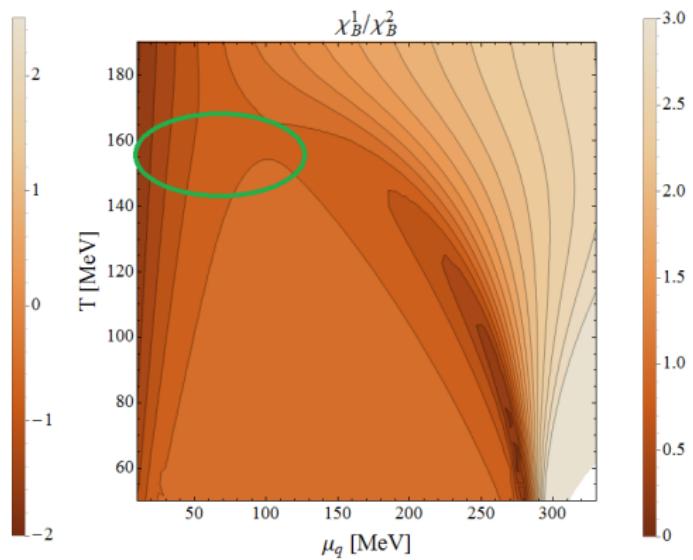
General behavior of the cumulant ratios



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Mainly determined by T

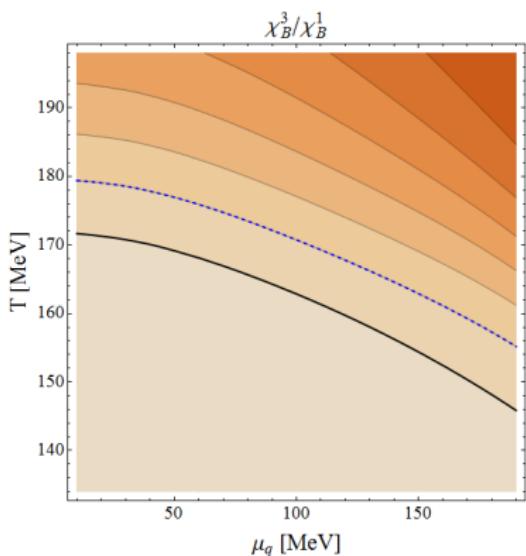


Mainly determined by μ

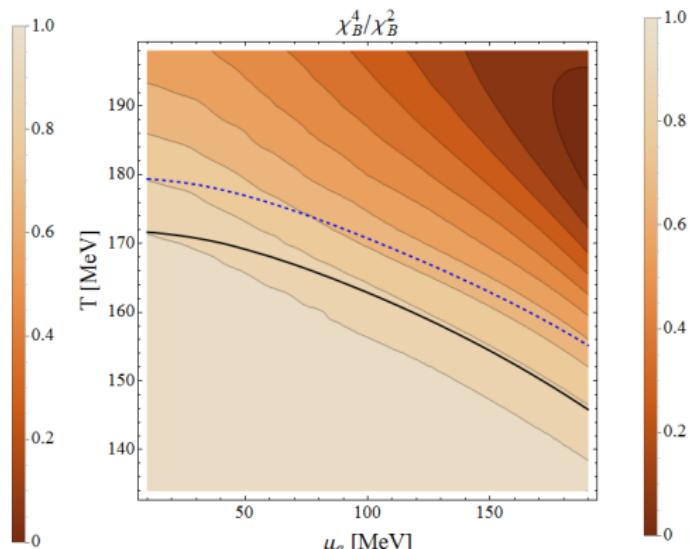
No CEP scenario



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

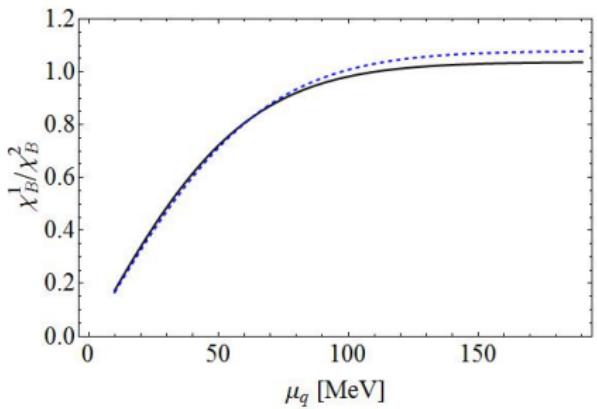


Blue (dashed) line: $\chi_B^4 / \chi_B^2 = 0.8$

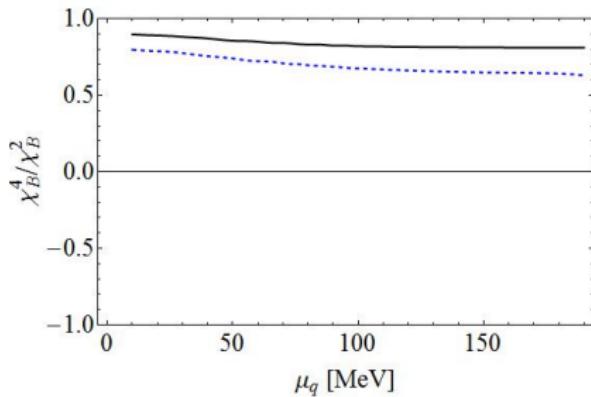
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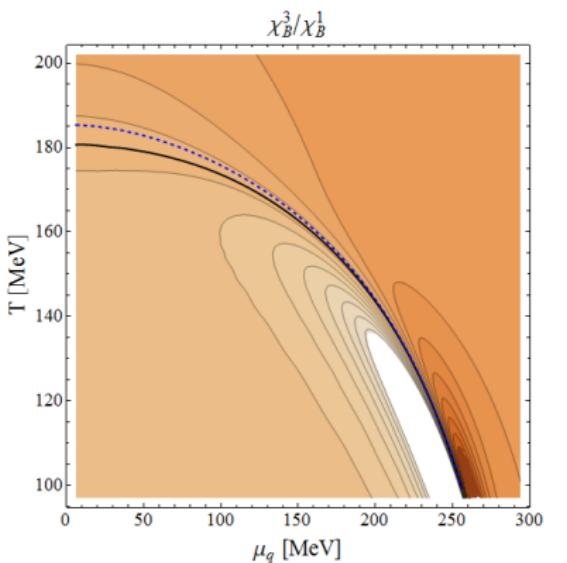


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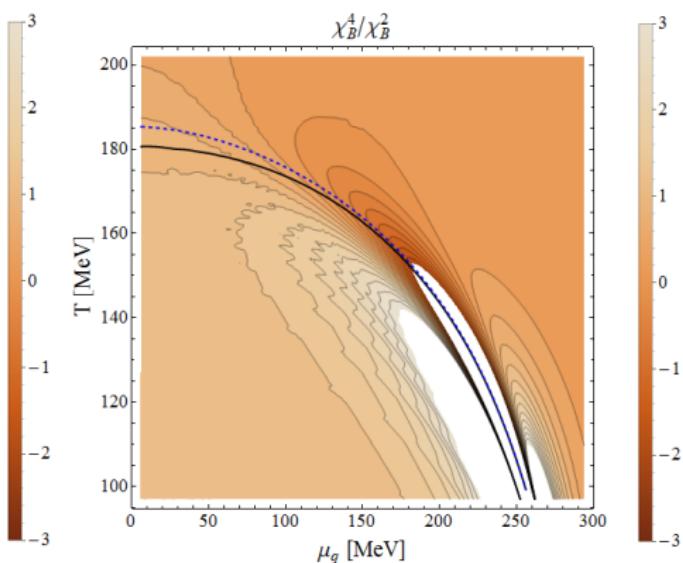
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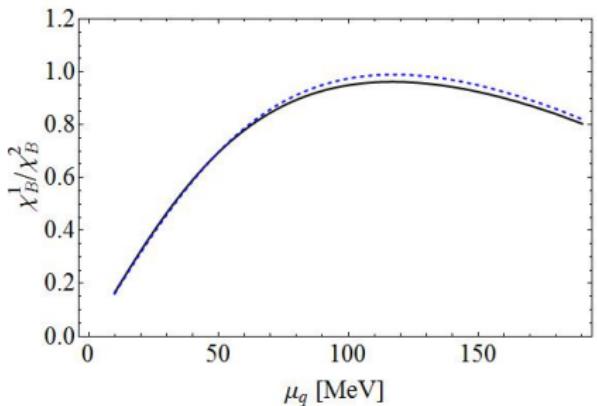


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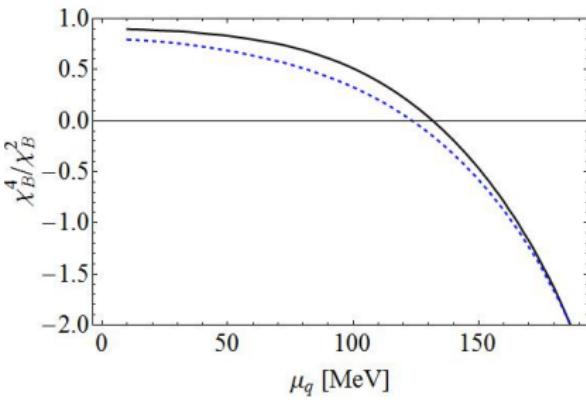
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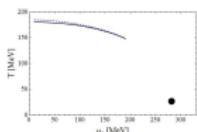


Black line: $\chi_B^3/\chi_B^1 = 0.9$
 χ_B^1/χ_B^2 has a maximum

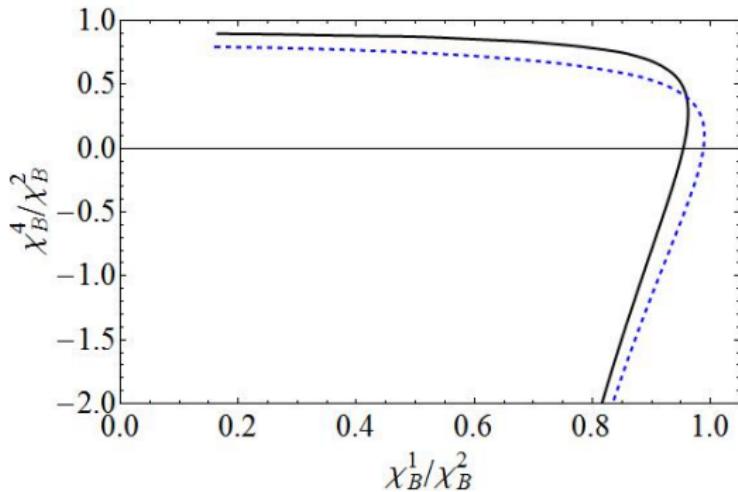
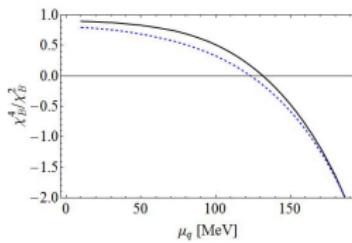
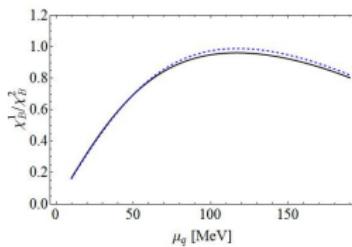


Blue (dashed) line: $\chi_B^3/\chi_B^1 = 0.8$
 χ_B^4/χ_B^2 decreases monotonously

CEP scenario



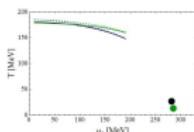
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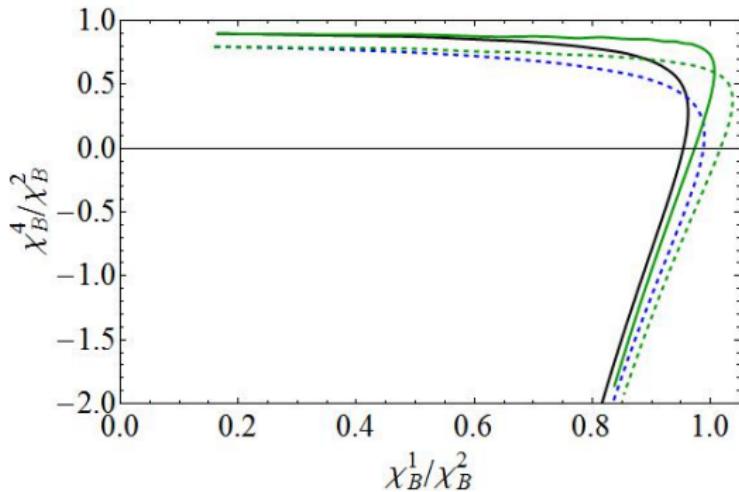
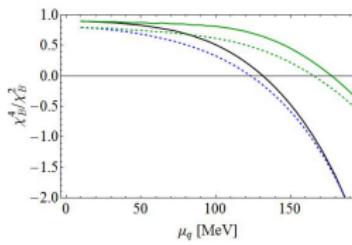
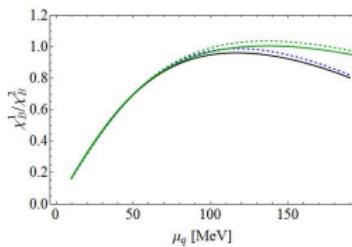
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CEP scenario



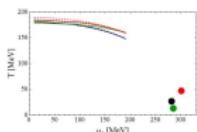
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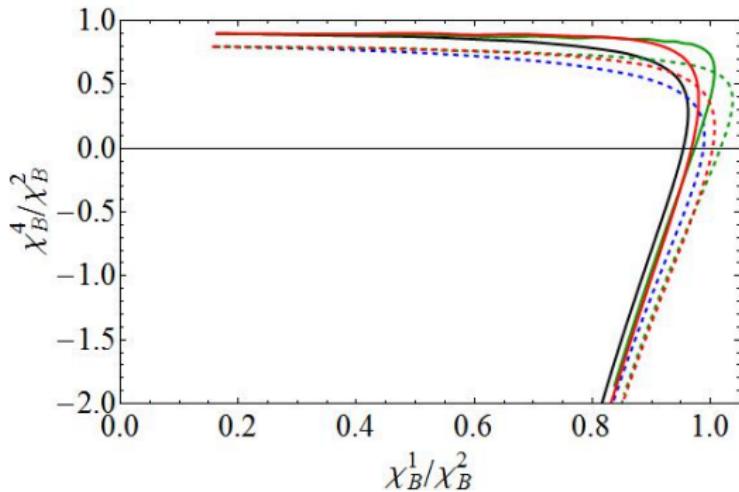
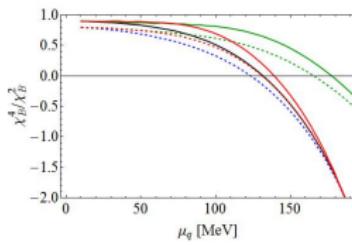
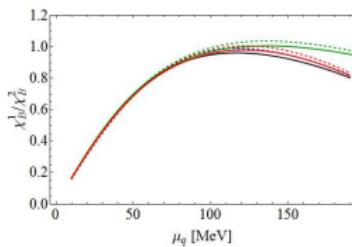
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CEP scenario



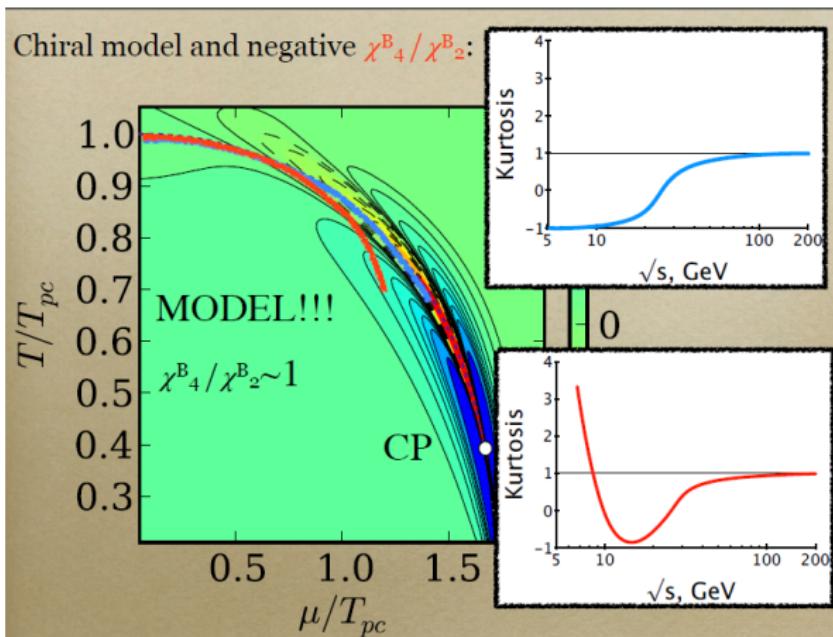
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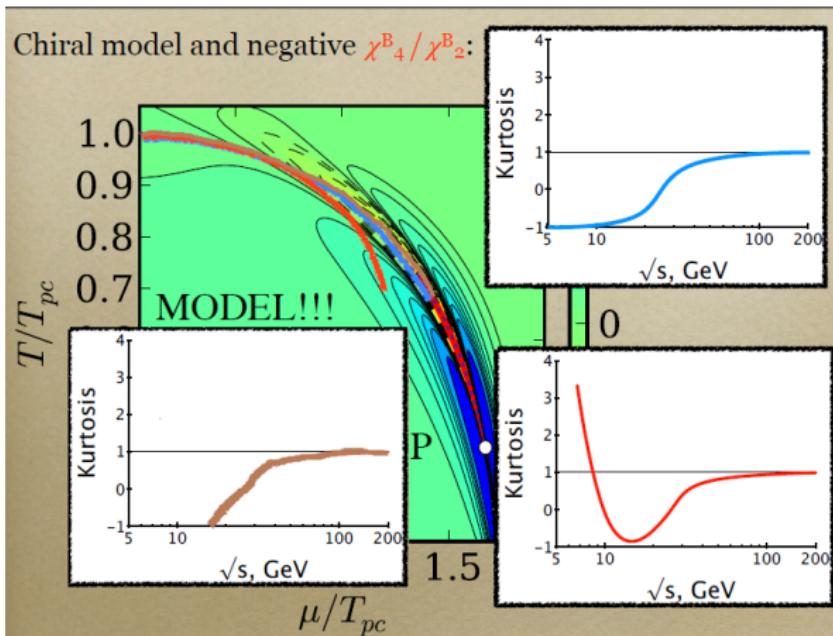
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Importance of self-consistency



[Vladimir Skokov, QM 2012]

Importance of self-consistency

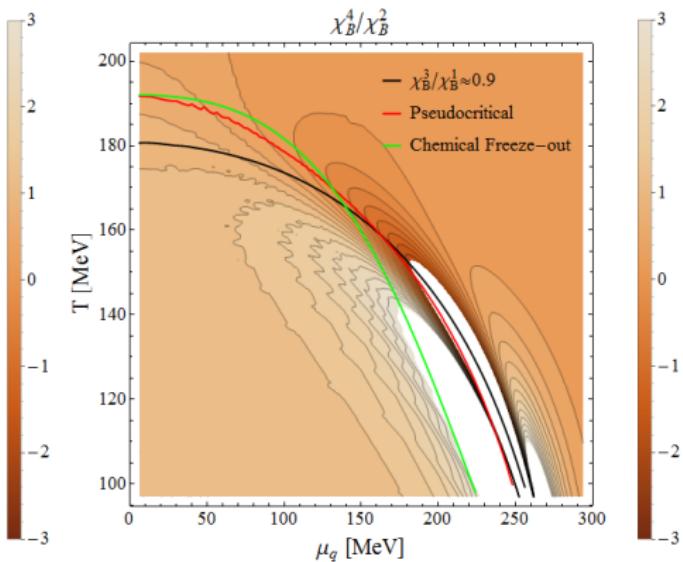
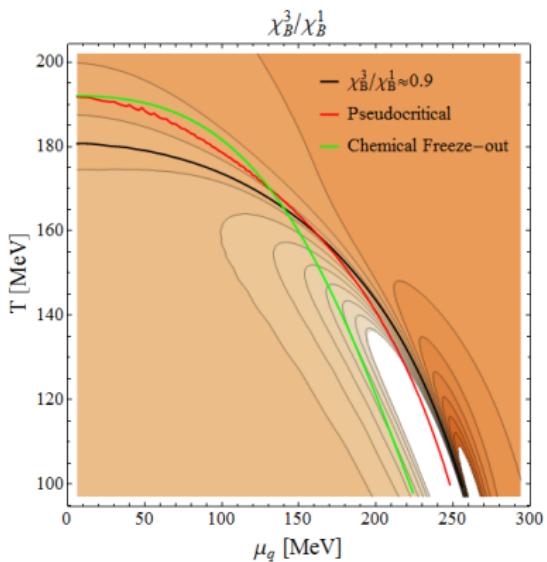


[Vladimir Skokov, QM 2012]

Comparision of different "freeze-out" lines



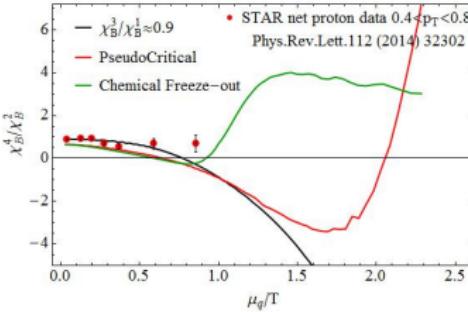
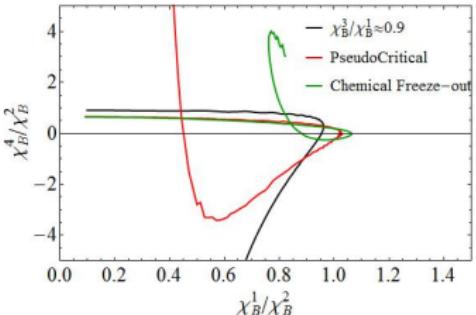
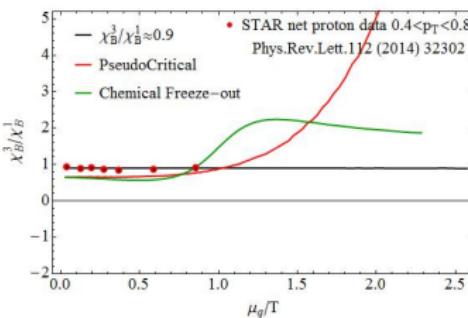
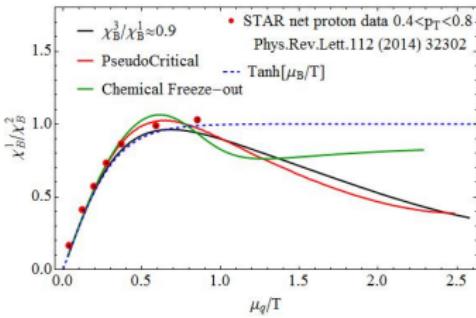
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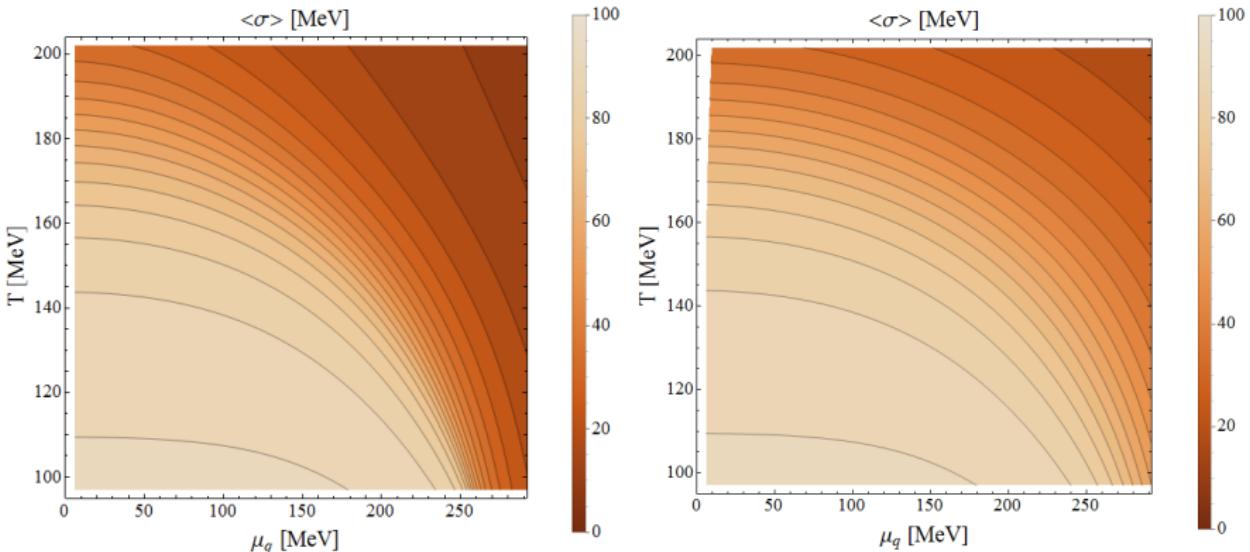
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Effect of vector interaction – condensate



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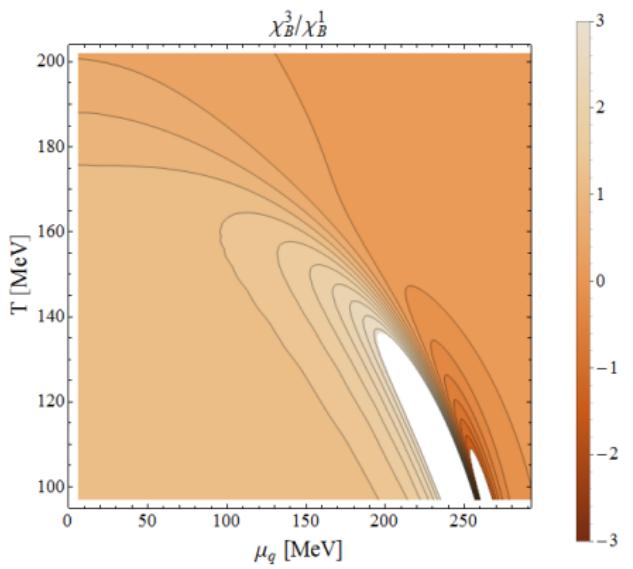


Rescaling of the μ axis: $\mu = \mu_{\text{eff}} + G_V \langle n \rangle_{\mu_{\text{eff}}}$

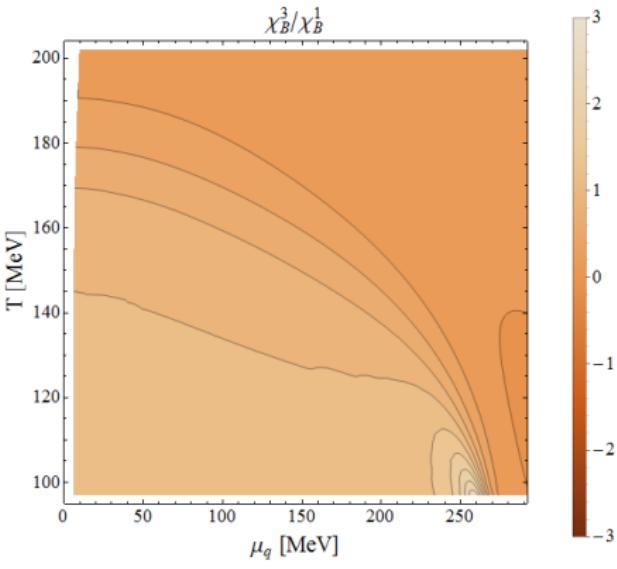
Effect of vector interaction – χ_B^3/χ_B^1



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No vector interaction

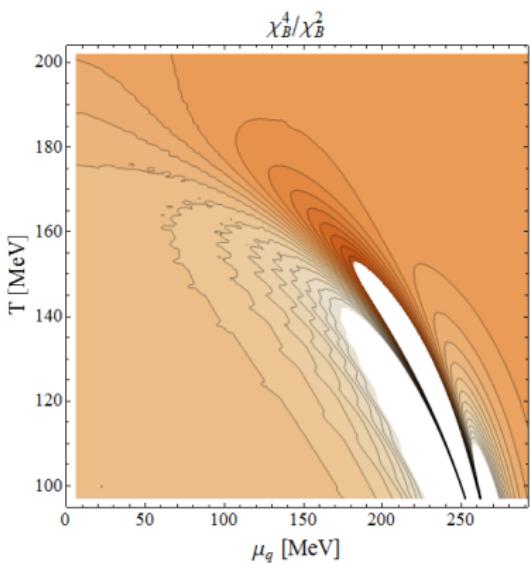


Significant vector interaction

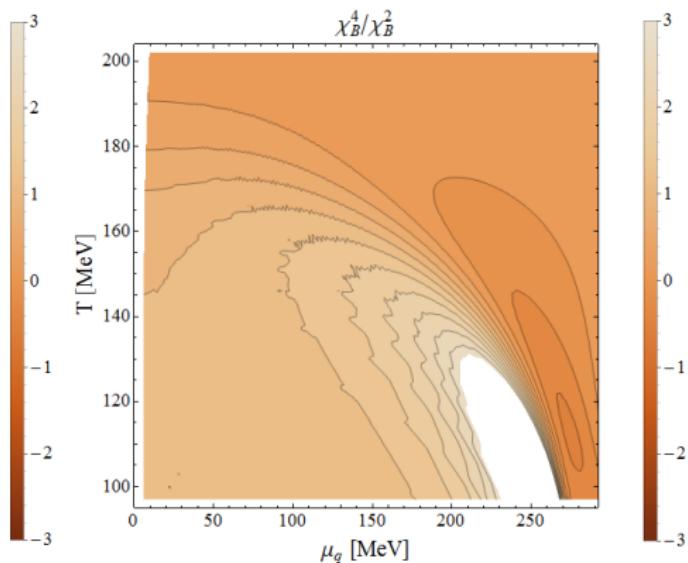
Effect of vector interaction – χ_B^4/χ_B^2



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No vector interaction

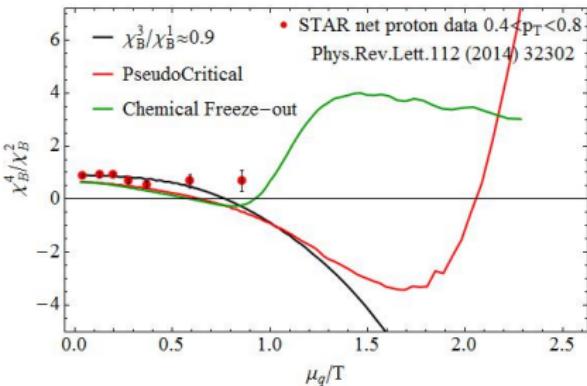
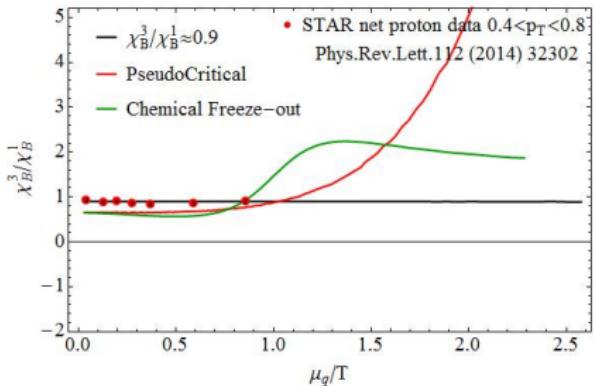


Significant vector interaction

Effect of vector interaction – Curves



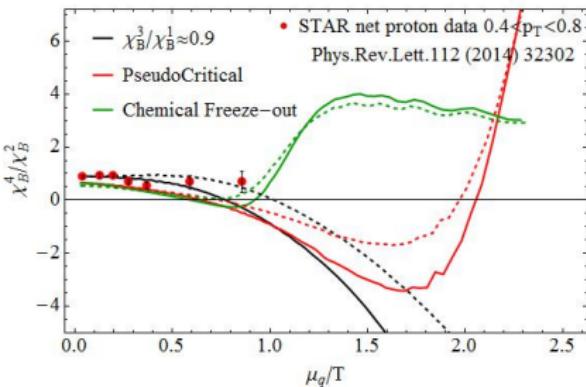
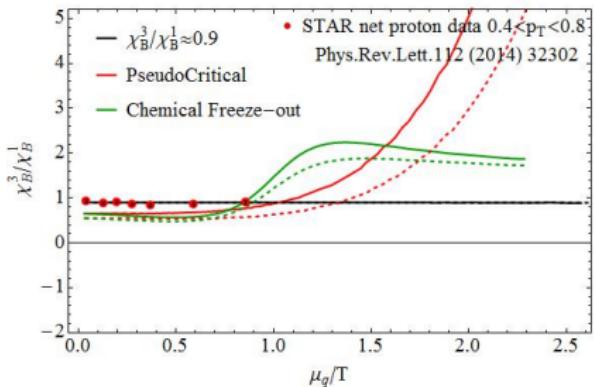
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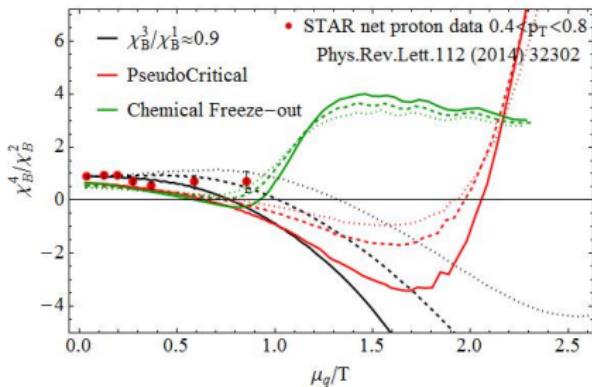
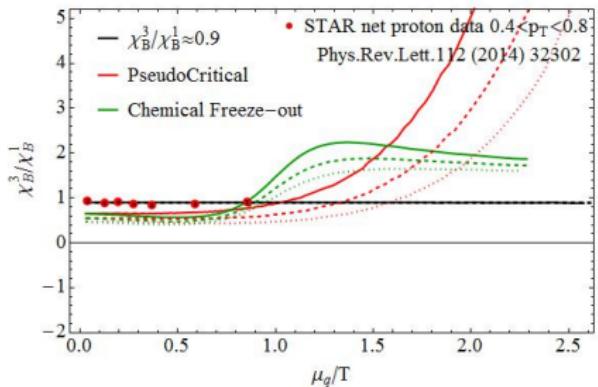
Effect of vector interaction – Curves



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Effect of vector interaction – Curves



Vector interaction suppresses χ^3/χ^1 and removes the minimum in χ^4/χ^2

Backup

Density



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