

Recent advancements of thermodynamical studies in the framework of three-flavor vector meson extended PQM model

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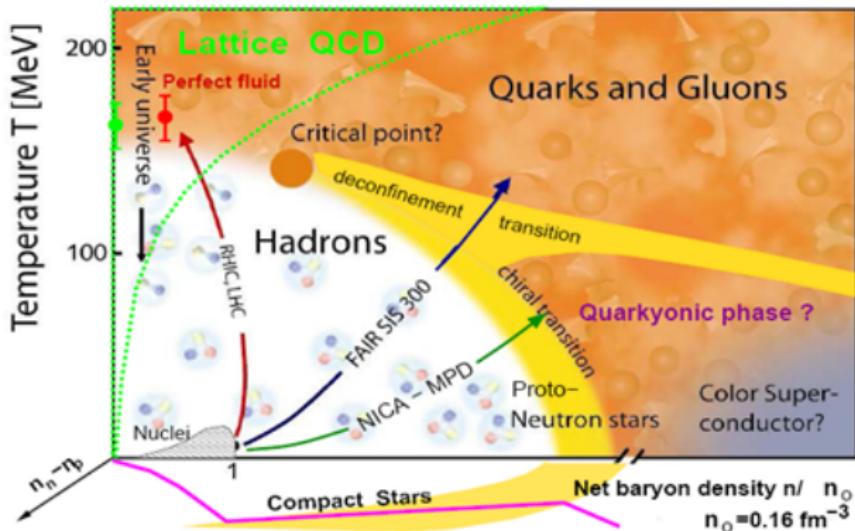
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Overview

1. Introduction/motivation
2. ePQM model
 - Lagrange parameters
 - Some earlier results
3. (Axial)vector curvature masses
 - T-dependence of the masses
4. Hybrid star $M - R$ curves
 - Hadron-quark crossover
5. N_c scaling
 - Phase boundary
6. Conclusion

Envisaged phase diagram of QCD



Important details of the phase diagram is still unknown
(mainly at large baryon density)

Properties of the phase diagram especially at finite baryon densities/baryochemical potential can be well investigated with the help of effective field theories of QCD →
e.g. details of the phase boundary like existence and location of the CEP, in medium dependence of meson masses, or properties of compact stars etc.

The ePQM model

Lagrangian of the ePQM

\mathcal{L} constructed based on linearly realized global $U(3)_L \times U(3)_R$ symmetry and its explicit breaking

$$\begin{aligned} \mathcal{L} = & \text{Tr}[(D_\mu \Phi)^\dagger (D_\mu \Phi)] - m_0^2 \text{Tr}(\Phi^\dagger \Phi) - \lambda_1 [\text{Tr}(\Phi^\dagger \Phi)]^2 - \lambda_2 \text{Tr}(\Phi^\dagger \Phi)^2 \\ & + \textcolor{red}{c_1} (\det \Phi + \det \Phi^\dagger) + \text{Tr}[H(\Phi + \Phi^\dagger)] - \frac{1}{4} \text{Tr}(L_{\mu\nu}^2 + R_{\mu\nu}^2) \\ & + \text{Tr} \left[\left(\frac{m_1^2}{2} \mathbb{1} + \Delta \right) (L_\mu^2 + R_\mu^2) \right] + i \frac{g_2}{2} (\text{Tr}\{L_{\mu\nu}[L^\mu, L^\nu]\} + \text{Tr}\{R_{\mu\nu}[R^\mu, R^\nu]\}) \\ & + \frac{h_1}{2} \text{Tr}(\Phi^\dagger \Phi) \text{Tr}(L_\mu^2 + R_\mu^2) + h_2 \text{Tr}[(L_\mu \Phi)^2 + (\Phi R_\mu)^2] + 2h_3 \text{Tr}(L_\mu \Phi R^\mu \Phi^\dagger) \\ & + \bar{\Psi} (i\gamma^\mu D_\mu - g_F(S - i\gamma_5 P)) \Psi - \textcolor{red}{g_V} \bar{\Psi} (\gamma^\mu (V_\mu + \gamma_5 A_\mu)) \Psi, \end{aligned}$$

$$\begin{aligned} \Phi &= S + iP \equiv \sum_{a=0}^8 (S_a \lambda_a + iP_a \lambda_a) \\ D^\mu \Phi &= \partial^\mu \Phi - ig_1(L^\mu \Phi - \Phi R^\mu) - ieA_e^\mu [T_3, \Phi], \\ L^{\mu\nu} &= \partial^\mu L^\nu - ieA_e^\mu [T_3, L^\nu] - \{\partial^\nu L^\mu - ieA_e^\nu [T_3, L^\mu]\}, \\ R^{\mu\nu} &= \partial^\mu R^\nu - ieA_e^\mu [T_3, R^\nu] - \{\partial^\nu R^\mu - ieA_e^\nu [T_3, R^\mu]\}, \\ D^\mu \Psi &= \partial^\mu \Psi - iG^\mu \Psi, \quad \text{with} \quad G^\mu = g_s G_a^\mu T_a. \end{aligned}$$

+ Polyakov loop potential (for $T > 0$)

Particle content

- Vector and Axial-vector meson nonets

$$V^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\omega_N + \rho^0}{\sqrt{2}} & \rho^+ & K^{*+} \\ \rho^- & \frac{\omega_N - \rho^0}{\sqrt{2}} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & \omega_S \end{pmatrix}^\mu \quad A^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{f_{1N} + a_1^0}{\sqrt{2}} & a_1^+ & K_1^+ \\ a_1^- & \frac{f_{1N} - a_1^0}{\sqrt{2}} & K_1^0 \\ K_1^- & \bar{K}_1^0 & f_{1S} \end{pmatrix}^\mu$$

$\rho \rightarrow \rho(770)$, $K^* \rightarrow K^*(894)$

$\omega_N \rightarrow \omega(782)$, $\omega_S \rightarrow \phi(1020)$

$a_1 \rightarrow a_1(1230)$, $K_1 \rightarrow K_1(1270)$

$f_{1N} \rightarrow f_1(1280)$, $f_{1S} \rightarrow f_1(1426)$

- Scalar ($\sim \bar{q}_i q_j$) and pseudoscalar ($\sim \bar{q}_i \gamma_5 q_j$) meson nonets

$$S = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\sigma_N + a_0^0}{\sqrt{2}} & a_0^+ & K_0^{*+} \\ a_0^- & \frac{\sigma_N - a_0^0}{\sqrt{2}} & K_0^{*0} \\ K_0^{*-} & \bar{K}_0^{*0} & \sigma_S \end{pmatrix} \quad P = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\eta_N + \pi^0}{\sqrt{2}} & \pi^+ & K^+ \\ \pi^- & \frac{\eta_N - \pi^0}{\sqrt{2}} & K^0 \\ K^- & \bar{K}^0 & \eta_S \end{pmatrix}$$

multiple possible assignments
mixing in the $\sigma_N - \sigma_S$ sector

$\pi \rightarrow \pi(138)$, $K \rightarrow K(495)$
mixing: $\eta_N, \eta_S \rightarrow \eta(548), \eta'(958)$

Spontaneous symmetry breaking: $\sigma_{N/S}$ acquire nonzero expectation values $\phi_{N/S}$
fields shifted by their expectation value: $\sigma_{N/S} \rightarrow \sigma_{N/S} + \phi_{N/S}$

In case of compact stars, also vector condensates (see later)

Determination of the parameters

14 unknown parameters ($m_0, \lambda_1, \lambda_2, c_1, m_1, g_1, g_2, h_1, h_2, h_3, \delta_S, \Phi_N, \Phi_S, \text{gf}$) →
determined by the min. of χ^2 :

$$\chi^2(x_1, \dots, x_N) = \sum_{i=1}^M \left[\frac{Q_i(x_1, \dots, x_N) - Q_i^{\exp}}{\delta Q_i} \right]^2,$$

$(x_1, \dots, x_N) = (m_0, \lambda_1, \lambda_2, \dots)$, $Q_i(x_1, \dots, x_N)$ → from the model, Q_i^{\exp} →
PDG value, $\delta Q_i = \max\{5\%, \text{PDG value}\}$
multiparametric minimization → MINUIT

- ▶ PCAC → 2 physical quantities: f_π, f_K
- ▶ Curvature masses → 16 physical quantities:
 $m_u/d, m_s, m_\pi, m_\eta, m_{\eta'}, m_K, m_\rho, m_\Phi, m_{K^*}, m_{a_1}, m_{f_1^H}, m_{K_1}, m_{a_0}, m_{K_s}, m_{f_0^L}, m_{f_0^H}$
- ▶ Decay widths → 12 physical quantities:
 $\Gamma_{\rho \rightarrow \pi\pi}, \Gamma_{\Phi \rightarrow KK}, \Gamma_{K^* \rightarrow K\pi}, \Gamma_{a_1 \rightarrow \pi\gamma}, \Gamma_{a_1 \rightarrow \rho\pi}, \Gamma_{f_1 \rightarrow KK^*}, \Gamma_{a_0}, \Gamma_{K_S \rightarrow K\pi},$
 $\Gamma_{f_0^L \rightarrow \pi\pi}, \Gamma_{f_0^L \rightarrow KK}, \Gamma_{f_0^H \rightarrow \pi\pi}, \Gamma_{f_0^H \rightarrow KK}$
- ▶ Pseudocritical temperature T_c at $\mu_B = 0$

Field equations (FE)

Four coupled field equations are obtained by extremizing the grand potential

$$\Omega(T, \mu_q) = U_{\text{meson}}^{\text{tree}}(\langle M \rangle) + \Omega_{\bar{q}q}^{(0)\text{vac}} + \Omega_{\bar{q}q}^{(0)T}(T, \mu_q) + \mathcal{U}_{\log}(\Phi, \bar{\Phi})$$

using $\frac{\partial \Omega}{\partial \phi_N} = \frac{\partial \Omega}{\partial \phi_S} = \frac{\partial \Omega}{\partial \Phi} = \frac{\partial \Omega}{\partial \bar{\Phi}} = 0$

$$E_f^\pm(p) = E_f(p) \mp \mu_q, \quad E_f^2(p) = p^2 + m_f^2$$

$$1) - \frac{1}{T^4} \frac{dU(\Phi, \bar{\Phi})}{d\Phi} + \frac{6}{T^3} \sum_{f=u,d,s} \int \frac{d^3 p}{(2\pi)^3} \left(\frac{e^{-\beta E_f^-(p)}}{g_f^-(p)} + \frac{e^{-2\beta E_f^+(p)}}{g_f^+(p)} \right) = 0$$

$$2) - \frac{1}{T^4} \frac{dU(\Phi, \bar{\Phi})}{d\bar{\Phi}} + \frac{6}{T^3} \sum_{f=u,d,s} \int \frac{d^3 p}{(2\pi)^3} \left(\frac{e^{-\beta E_f^+(p)}}{g_f^+(p)} + \frac{e^{-2\beta E_f^-(p)}}{g_f^-(p)} \right) = 0$$

$$3) m_0^2 \phi_N + \left(\lambda_1 + \frac{\lambda_2}{2} \right) \phi_N^3 + \lambda_1 \phi_N \phi_S^2 - \frac{c_1}{\sqrt{2}} \phi_N \phi_S - h_{0N} + \frac{3}{2} g_F (\langle \bar{q}_u q_u \rangle_T + \langle \bar{q}_d q_d \rangle_T) = 0$$

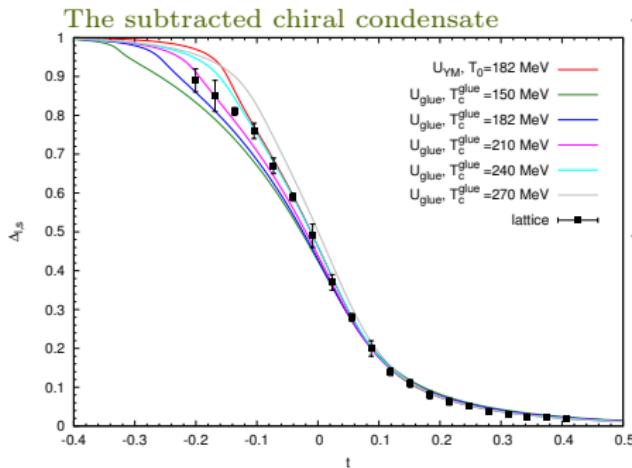
$$4) m_0^2 \phi_S + (\lambda_1 + \lambda_2) \phi_S^3 + \lambda_1 \phi_N^2 \phi_S - \frac{\sqrt{2}}{4} c_1 \phi_N^2 - h_{0S} + \frac{3}{\sqrt{2}} g_F \langle \bar{q}_s q_s \rangle_T = 0$$

renormalized fermion tadpole:

$$m_{u,d} = \frac{g_F}{2} \phi_N \quad \text{and} \quad m_s = \frac{g_F}{\sqrt{2}} \phi_S$$

$$\langle \bar{q}_f q_f \rangle_T = 4m_f \left[-\frac{m_f^2}{16\pi^2} \left(\frac{1}{2} + \ln \frac{m_f^2}{M_0^2} \right) + \int \frac{d^3 p}{(2\pi)^3} \frac{1}{2E_f(p)} (f_f^-(p) + f_f^+(p)) \right]$$

t -dependence of the condensates compared to lattice results



– subtracted chiral condensate:

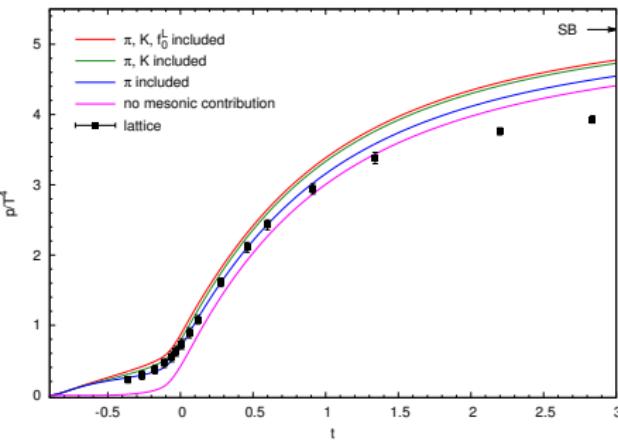
$$\Delta_{l,s} = \frac{\left(\Phi_N - \frac{h_N}{h_S} \cdot \Phi_S \right) \Big|_T}{\left(\Phi_N - \frac{h_N}{h_S} \cdot \Phi_S \right) \Big|_{T=0}}$$

– U_{\log}^{glue} with $T_c^{\text{glue}} \in (210, 240) \text{ MeV}$ gives good agreement with the lattice result of

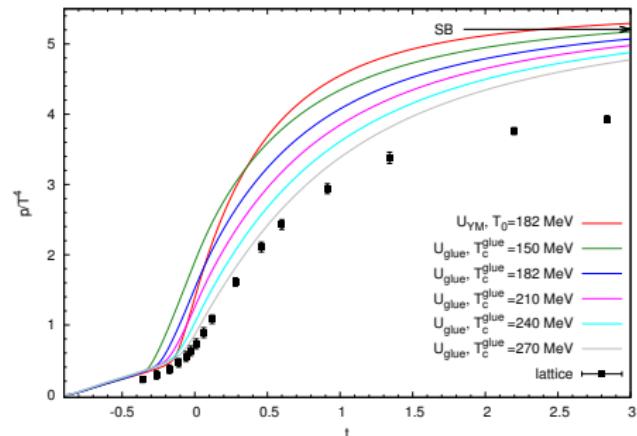
Borsányi et al., JHEP 1009, 073 (2010)

here we use the reduced temperature: $t = (T - T_c)/T_c$

Normalized pressure and the effects of meson contributions



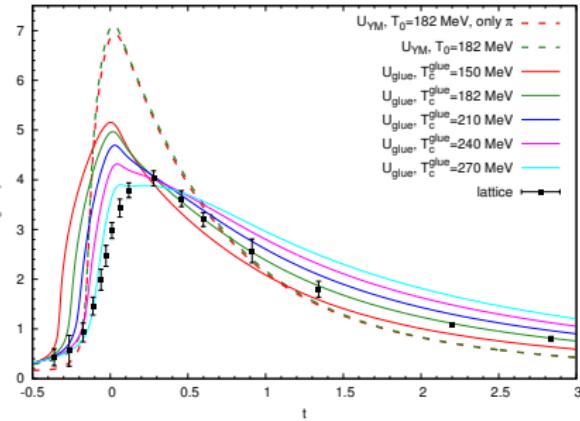
- we used U_{glue} with $T_c^{\text{glue}} = 270$ MeV
- pions dominate the pressure at small T
- contribution of the kaons is important
- at high T the pressure overshoots the lattice data of [Borsányi et al., JHEP 1011, 077 \(2010\)](#)



- overshooting increases with decreasing T_c^{glue}

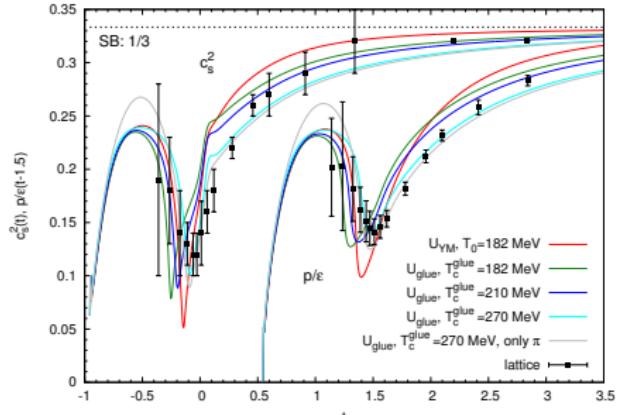
Scaled interaction measure, speed of sound and p/ϵ

Scaled interaction measure



By properly setting the T_c^{glue} parameter \rightarrow good agreement with lattice

Speed of sound and p/ϵ



Axial(vector) curvature masses

Curvature masses

$$\Delta \hat{m}_{ab}^{2,(X)} \equiv \frac{d^2 U_f(\phi, \xi)}{dX_a dX_b} \Big|_{\xi=0}, \quad X \in \{S, P\}$$

$$\Delta \hat{M}_{\mu\nu,ab}^{2,(Y)} \equiv -\frac{d^2 U_f(\phi, \xi)}{dY_a^\mu dY_b^\nu} \Big|_{\xi=0}, \quad Y \in \{V, A\}, \quad \xi \in \{X_a, Y_a\}, \quad \phi \in \{\phi_N, \phi_S, \Phi, \bar{\Phi} \dots\}$$

where U_f is the fermionic contribution to the effective potential,

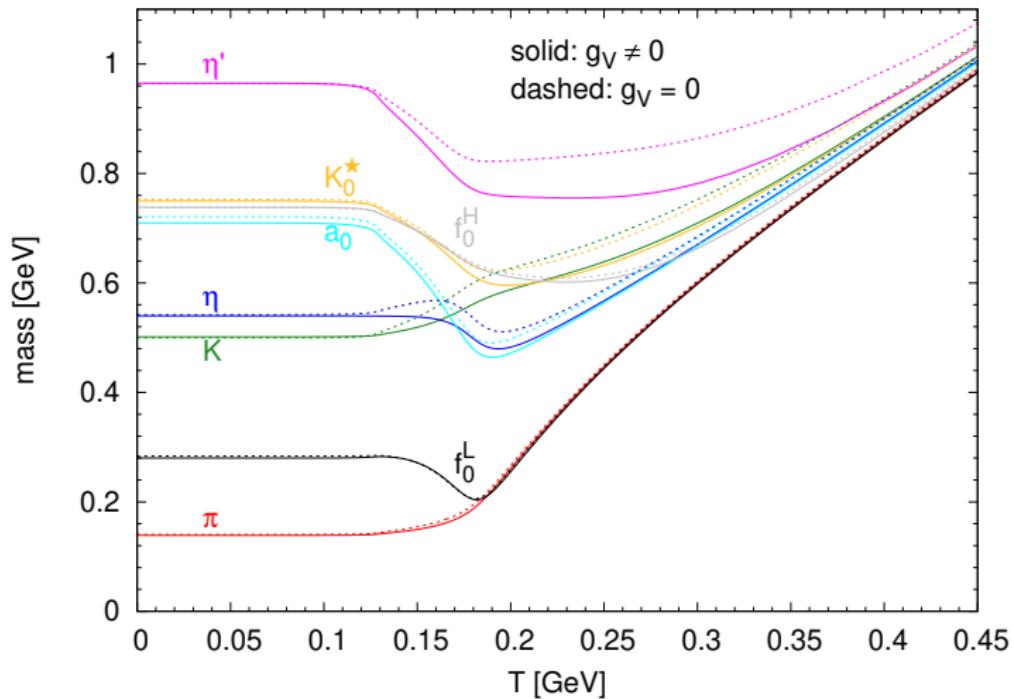
$$U_f(\phi, \xi) = i \text{Tr}_D \int_K \log(i\mathcal{S}^{-1}(K; \xi)) \Big|_{\xi=0} - \frac{i}{2} \text{Tr} \int_K \log \left(i\mathcal{D}_{(\mu\nu),ab}^{-1}(K) - \Pi_{(\mu\nu),ab}(K) \right)$$

On the other hand: The curvature masses are the one-loop self-energies at vanishing momentum:

$$\Pi_{ab}^{(V/A)\mu\nu}(Q) = i2N_c g_V^2 \int_K \frac{g^{\mu\nu}(\pm m_a m_b - K^2 + K \cdot Q) + 2K^\mu K^\nu - K^\mu Q^\nu - Q^\mu K^\nu}{(K^2 - m_a^2)((K - Q)^2 - m_b^2)} \quad (1)$$

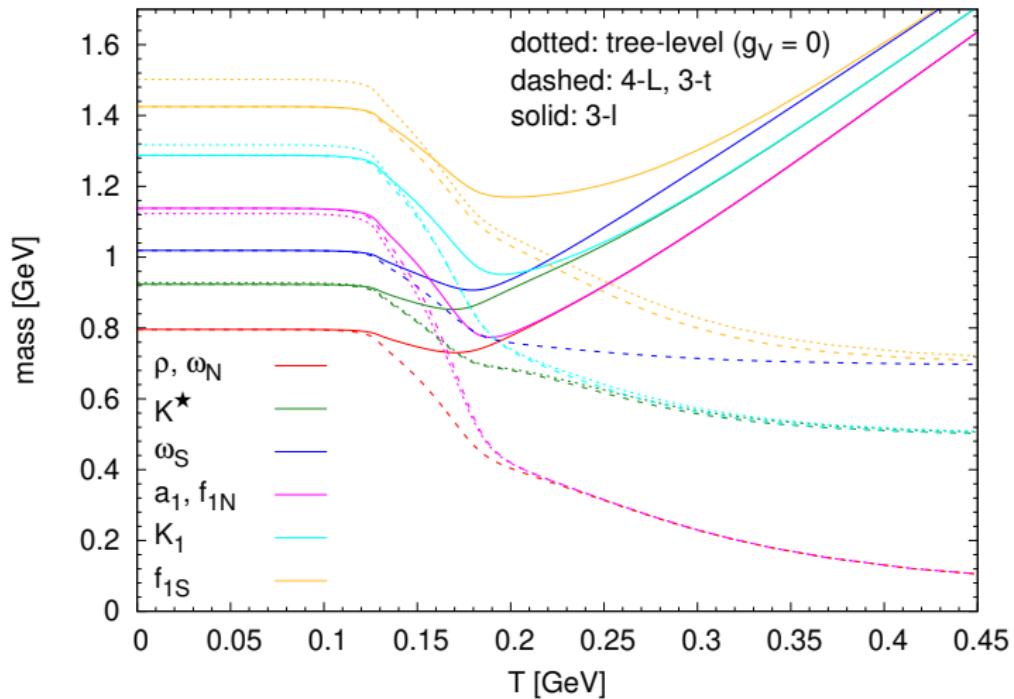
- At $T = 0 \rightarrow$ vacuum self-energy \rightarrow renormalization \rightarrow dimensional regularization
- At $T \neq 0 \longrightarrow$ matter part (with statistical function)
 \rightarrow Wick rotation, Matsubara sum, $\int_K \rightarrow iT \sum_n \int \frac{d^3 k}{(2\pi)^3}$

T dependence of (pseudo)scalar masses



From the χ^2 fit the vector coupling: $g_V \approx 5$

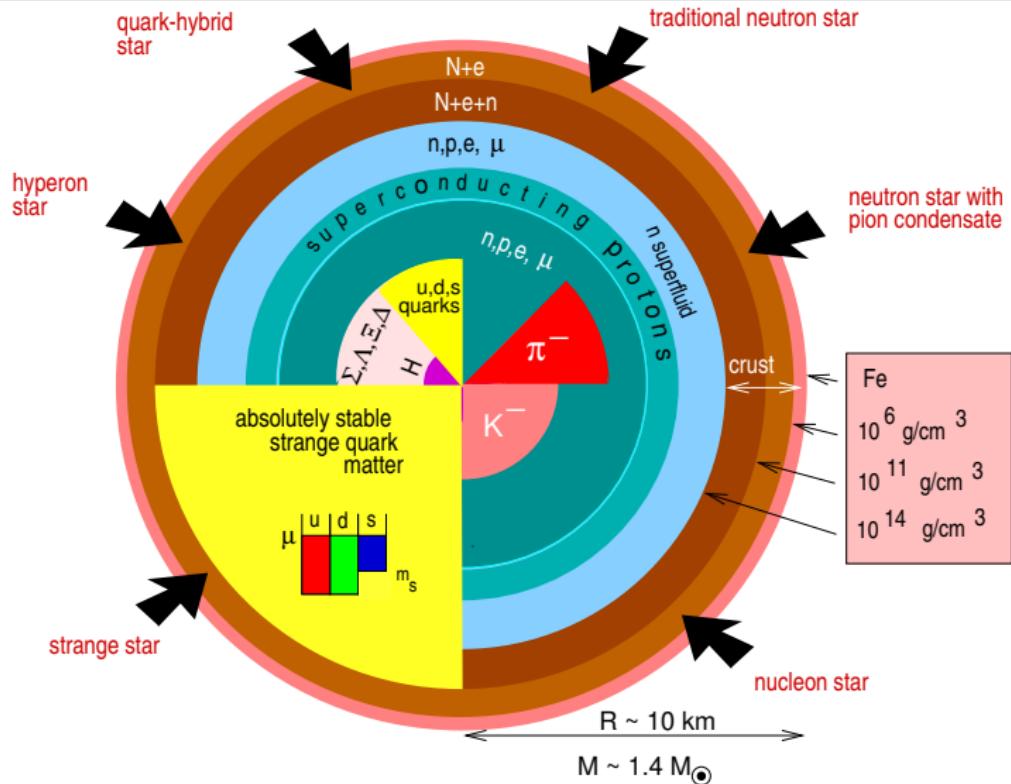
T dependence of (axial)vector masses



From the χ^2 fit the vector coupling: $g_V \approx 5$

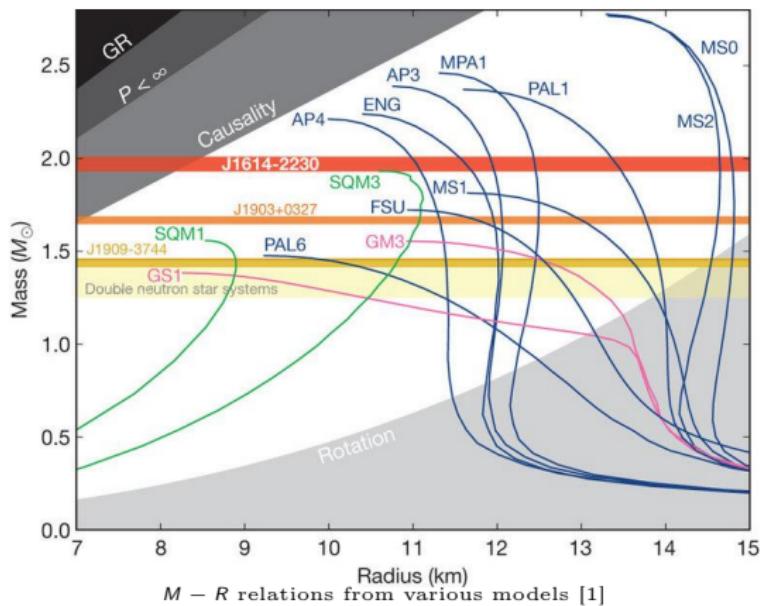
$M - R$ curves of hybrid stars

Structure of compact stars



Various $M - R$ curves for different compact star EoS's

- ▶ QCD directly unsolvable at finite density
- ▶ One can use effective models in the zero temperature finite density region
- ▶ Neutron star observations restrict such models [1,2]



[1] P. Demorest et al. (2010), *Nature* **467**, 1081

[2] J. Antoniadis et al. (2013), *Science* **340**, 6131

Elements of the quark EOS

For large density e(P)QM model is used, but with additional vector condensates

- ▶ non-zero vector condensates: $\langle(\rho^0)^0\rangle = \phi_\rho$, $\langle(\omega^0)\rangle = \phi_\omega$, $\langle(\Phi^0)\rangle = \phi_\Phi$
- ▶ free electron gas + β -equilibrium
- ▶ modified chemical potentials:

$$\mu_u = \mu_q - \frac{2}{3}\mu_e - \frac{1}{2}g_V(\phi_\omega + \phi_\rho)$$

$$\mu_d = \mu_q + \frac{1}{3}\mu_e - \frac{1}{2}g_V(\phi_\omega - \phi_\rho)$$

$$\mu_s = \mu_q + \frac{1}{3}\mu_e - \frac{1}{\sqrt{2}}g_V\phi_\Phi$$

- ▶ charge neutrality: $\frac{2}{3}n_u - \frac{1}{3}n_d - \frac{1}{3}n_s - n_e = 0$
- ▶ field equations:

$$\frac{\partial \Omega_{tot}}{\partial \phi_N} = \frac{\partial \Omega_{tot}}{\partial \phi_S} = \frac{\partial \Omega_{tot}}{\partial \phi_\rho} = \frac{\partial \Omega_{tot}}{\partial \phi_\omega} = \frac{\partial \Omega_{tot}}{\partial \phi_\Phi} = 0 \quad \rightarrow p(\varepsilon) \text{curve}$$

Tolman-Oppenheimer-Volkoff (TOV) equation

Solving the Einstein's equation for spherically symmetric case and homogeneous matter \rightarrow TOV eqs.:

$$\frac{dp}{dr} = -\frac{[p(r) + \varepsilon(r)][M(r) + 4\pi r^3 p(r)]}{r[r - 2M(r)]} \quad (2)$$

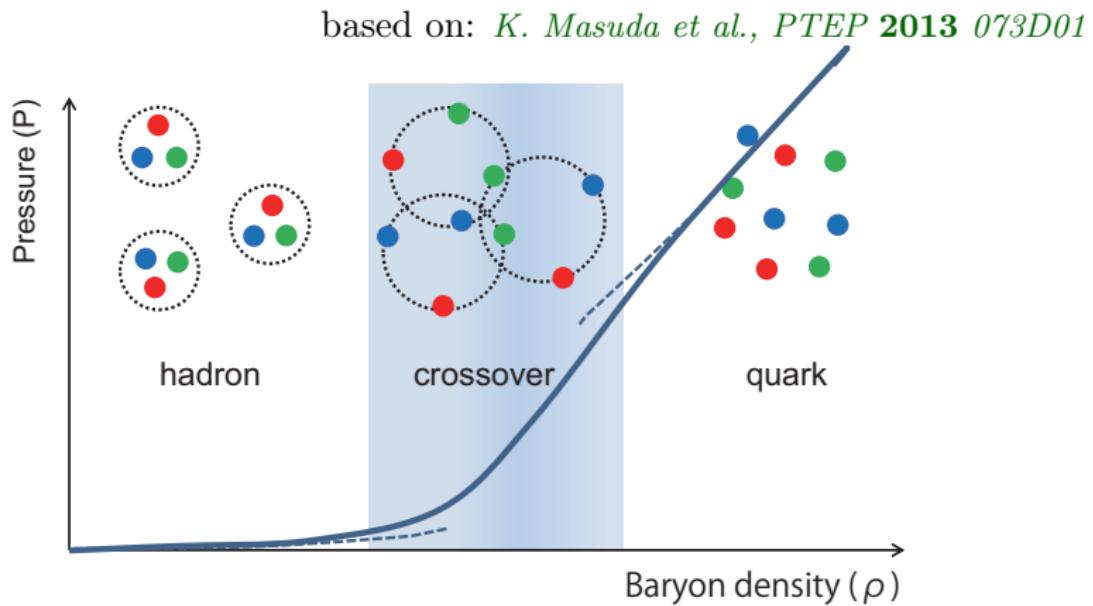
with

$$\frac{dM}{dr} = 4\pi r^2 \varepsilon(r)$$

These are integrated numerically for a specific $p(\varepsilon)$

- ▶ For a fixed ε_c central energy density Eq. (2) is integrated until $p = 0$
- ▶ Varying ε_c a series of compact stars is obtained (with given M and R)
- ▶ Once the maximal mass is reached, the stable series of compact stars ends

Schematic picture of pressure (H-Q crossover)



In the crossover region hadrons starts to overlap
 → both low and high ρ_B models loose their validity.
 Gibbs condition (extrapolation from the dashed lines) can be misleading.

Hadron-quark crossover with P -interpolation

Features of the model:

- ▶ H-EOS: Relativistic Mean Field (RMF) models: Steiner-Fischer-Hempel (SFHo) [1], density-dependent RMF model (DD2) [2]
- ▶ Q-EOS: e(P)QM model with u, d, s quarks and vector interaction
- ▶ mean-field approximation

P -interpolation ($\rho = \rho_B$):

$$P(\rho) = P_H(\rho)f_-(\rho) + P_Q(\rho)f_+(\rho), \quad (3)$$

$$f_{\pm}(\rho) = \frac{1}{2} \left(1 \pm \tanh \left(\frac{\rho - \bar{\rho}}{\Gamma} \right) \right) \quad (4)$$

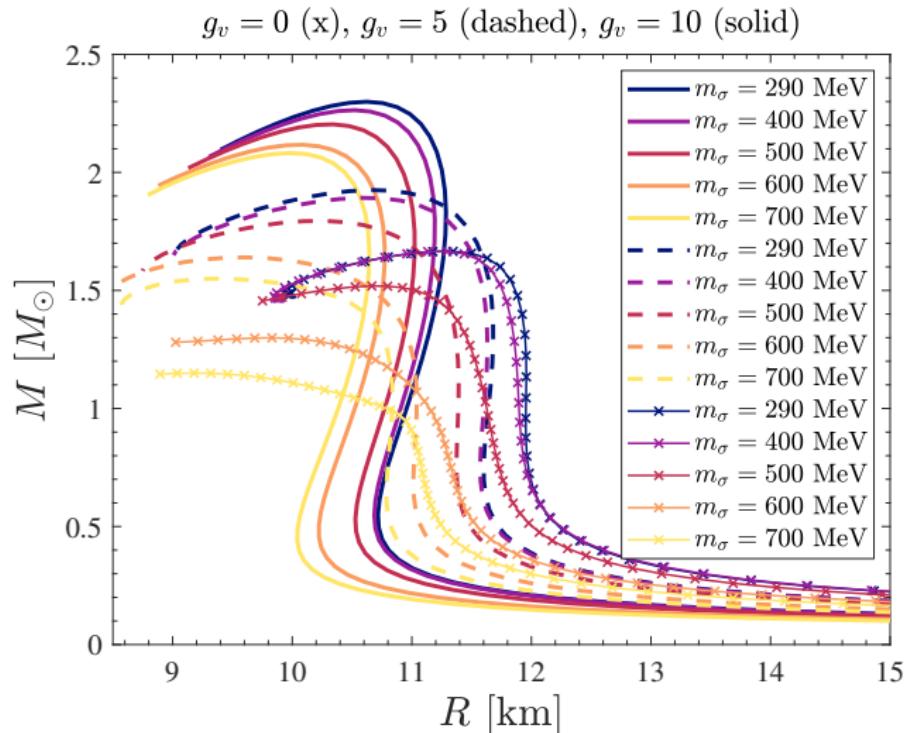
$$\varepsilon(\rho) = \varepsilon_H(\rho)f_-(\rho) + \varepsilon_Q(\rho)f_+(\rho) + \Delta\varepsilon \quad (5)$$

$$\Delta\varepsilon = \rho \int_{\bar{\rho}}^{\rho} (\varepsilon_H(\rho') - \varepsilon_Q(\rho')) \frac{g(\rho')}{\rho'} d\rho' \quad (6)$$

[1] A. W. Steiner *et al.*, *Astrophys.J.* **774**, 17 (2013)

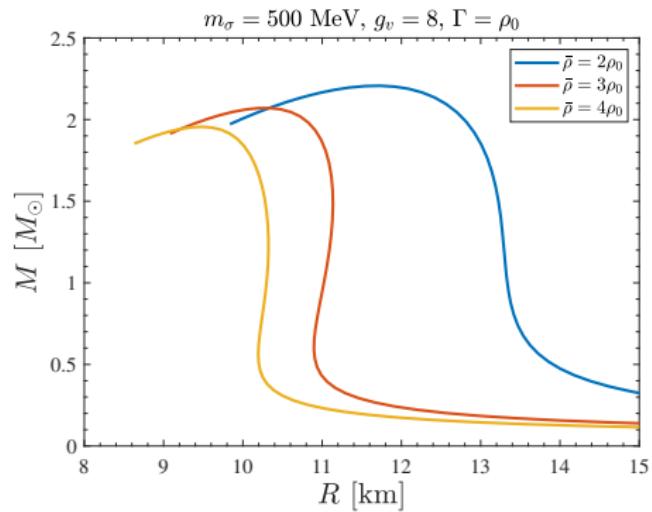
[2] S. Typel *et al.*, *Phys. Rev.* **C81**, 015803 (2010)

$M - R$ relations of BPS+SFHo+e(P)QM

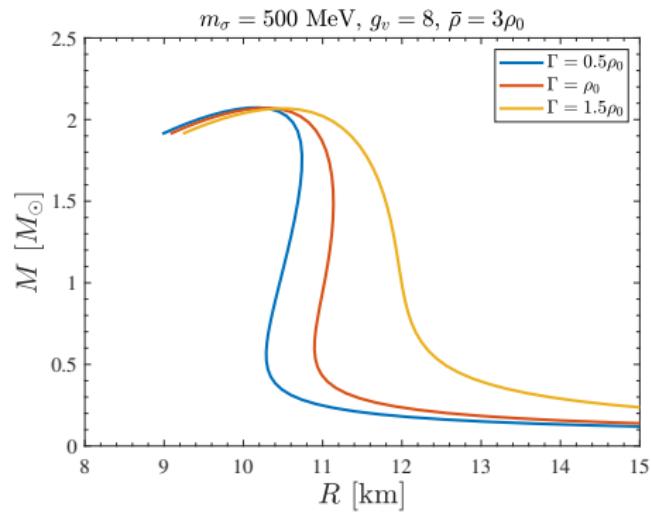


$\bar{\rho} = 3\rho_0, \Gamma = \rho_0$, From (axial)vector curvature masses: $g_V \approx 5$

Dependence of $M - R$ curves on crossover params



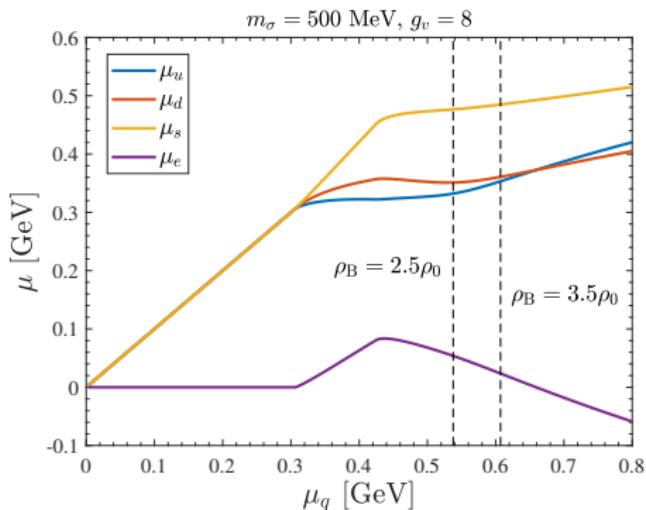
dep. on position of concatenation



dep. on width of concatenation

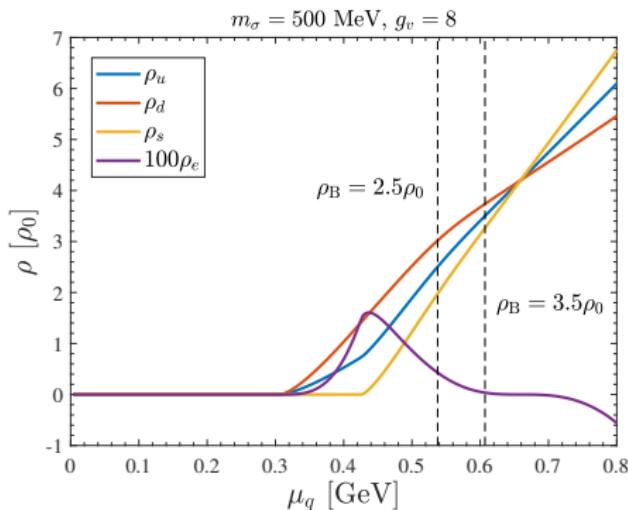
More accurate radius measurements can restrict model parameters/scenarios

Chemical potentials and densities



chemical potentials of the quarks and the electron

Vertical lines shows typical crossover region



number densities of quarks and the electron (enlarged by 100×)

Large N_c thermodynamics

Some properties of mesons and baryons for Large N_c

- ▶ $g_{QCD} \sim \frac{1}{\sqrt{N_c}}$
- ▶ quark loops are $1/N_c$ suppressed
- ▶ leading diagrams are planar diagrams with minimum number of quark loops
- ▶ mesons are free, stable, and non-interacting
- ▶ mesons are pure $q\bar{q}$ for Large N_c
- ▶ meson masses $\sim N_c^0$
- ▶ meson decay amplitudes $\sim 1/\sqrt{N_c}$
- ▶ for one meson creation: $\langle 0|J|m \rangle \sim \sqrt{N_c}$
- ▶ k meson vertex $\sim N_c^{1-k/2}$. Specifically, the three- and four-meson vertices are $\sim 1/\sqrt{N_c}$ and $\sim 1/N_c$, respectively
- ▶ baryon masses $\sim N_c$. Consequently constituent quark masses $\sim N_c^0$

N_c scaling of the Lagrange parameters

The parameters are: $m_0, \lambda_1, \lambda_2, c_1, m_1, g_1, g_2, h_1, h_2, h_3, \delta_s, \Phi_N, \Phi_S, g_F, h_N, h_S$

- $m_0^2, m_1^2, \delta_s \sim N_c^0$, because terms of tree level meson masses
- $g_1, g_2 \sim \frac{1}{\sqrt{N_c}}$, three couplings
- $\lambda_2, h_2, h_3 \sim \frac{1}{N_c}$, four couplings
- $\lambda_1, h_1 \sim \frac{1}{N_c^{3/2}}$, four couplings with different trace structure
- $c_1 \sim \frac{1}{N_c^{3/2}}$ $U_A(1)$ anomaly term has extra $1/N_c$ suppression
- $\Phi_{N/S} \sim \sqrt{N_c}$, $\Phi_N = Z_\pi f_\pi$, $f_\pi \sim \sqrt{N_c}$
- $h_{N/S} \sim \sqrt{N_c}$, Goldstone-theorem: $m_\pi^2 \Phi_N = Z_\pi^2 h_N$
- $g_F \sim \frac{1}{\sqrt{N_c}}$, $m_{u/d} = g_F \Phi_N$

practically: $g_1 \longrightarrow g_1 \sqrt{\frac{3}{N_c}}$, $\Phi_{N/S} \longrightarrow \Phi_{N/S} \sqrt{\frac{N_c}{3}} \dots$ etc.

Field equations, masses in Large N_c

Field equations:

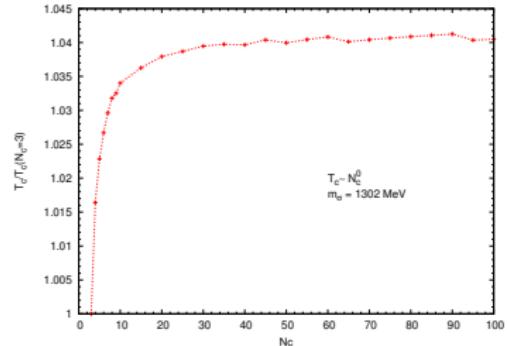
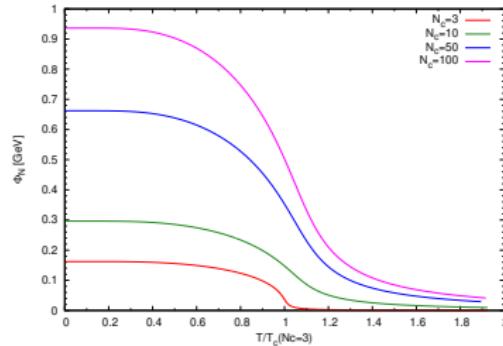
$$m_0^2 \Phi_N \sqrt{\frac{N_c}{3}} + \left(\lambda_1 \frac{3}{N_c} + \frac{\lambda_2}{2} \right) \Phi_N^3 \sqrt{\frac{N_c}{3}} + \lambda_1 \Phi_N \Phi_S^2 \sqrt{\frac{3}{N_c}} - \frac{1}{\sqrt{2}} c_1 \sqrt{\frac{3}{N_c}} \Phi_N \Phi_S \\ - h_N \sqrt{\frac{N_c}{3}} + \frac{3}{2} g_F (\text{Tad}_u + \text{Tad}_d) = 0$$

$$m_0^2 \Phi_S \sqrt{\frac{N_c}{3}} + \left(\lambda_1 \frac{3}{N_c} + \lambda_2 \right) \Phi_S^3 \sqrt{\frac{N_c}{3}} + \lambda_1 \Phi_N^2 \Phi_S \sqrt{\frac{3}{N_c}} - \frac{1}{2\sqrt{2}} c_1 \sqrt{\frac{3}{N_c}} \Phi_N^2 \\ - h_S \sqrt{\frac{N_c}{3}} + \frac{3}{\sqrt{2}} g_F \text{Tad}_s = 0$$

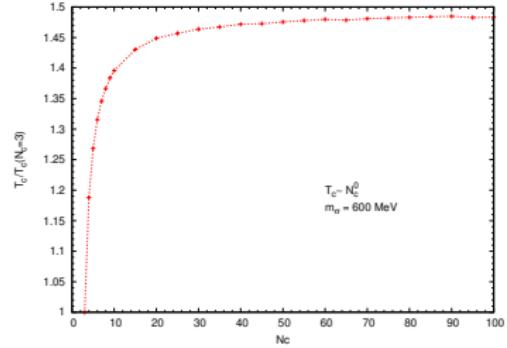
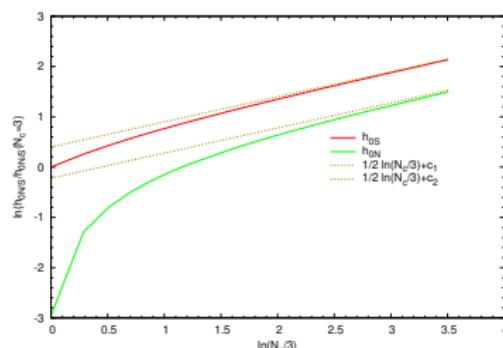
Pion three-level mass:

$$m_\pi^2 = Z_\pi^2 \left(m_0^2 + \left(\lambda_1 \frac{3}{N_c} + \frac{\lambda_2}{2} \right) \Phi_N^2 + \lambda_1 \frac{3}{N_c} \Phi_S^2 - c_1 \frac{3}{N_c} \frac{\Phi_S}{\sqrt{2}} \right)$$

$\phi_N(T)$ and N_c scaling of $T_c, h_{N/S}$



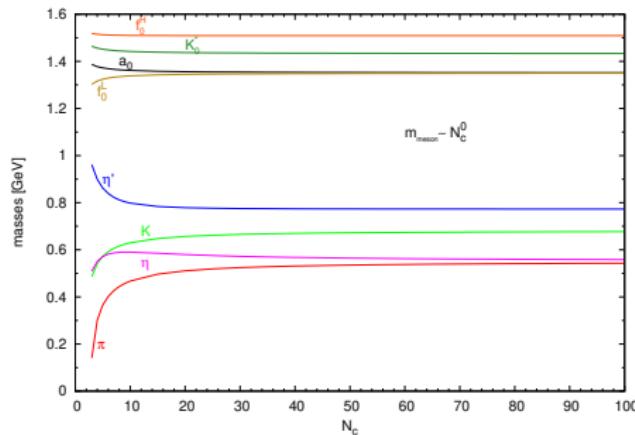
From $N_c = 3$ to $N_c = 100$: T_c changes $\approx 4\%$



The expected N_c scaling ($h_{N/S} \sim \sqrt{N_c}$) are calc. from the FE at $T = \mu_B = 0$)

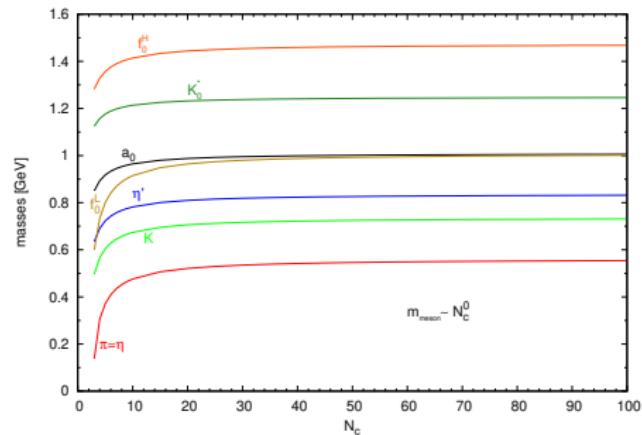
From $N_c = 3$ to $N_c = 100$: T_c changes $\approx 50\%$. In both cases $T_c \sim N_c^0$ as expected

N_c scaling of meson masses

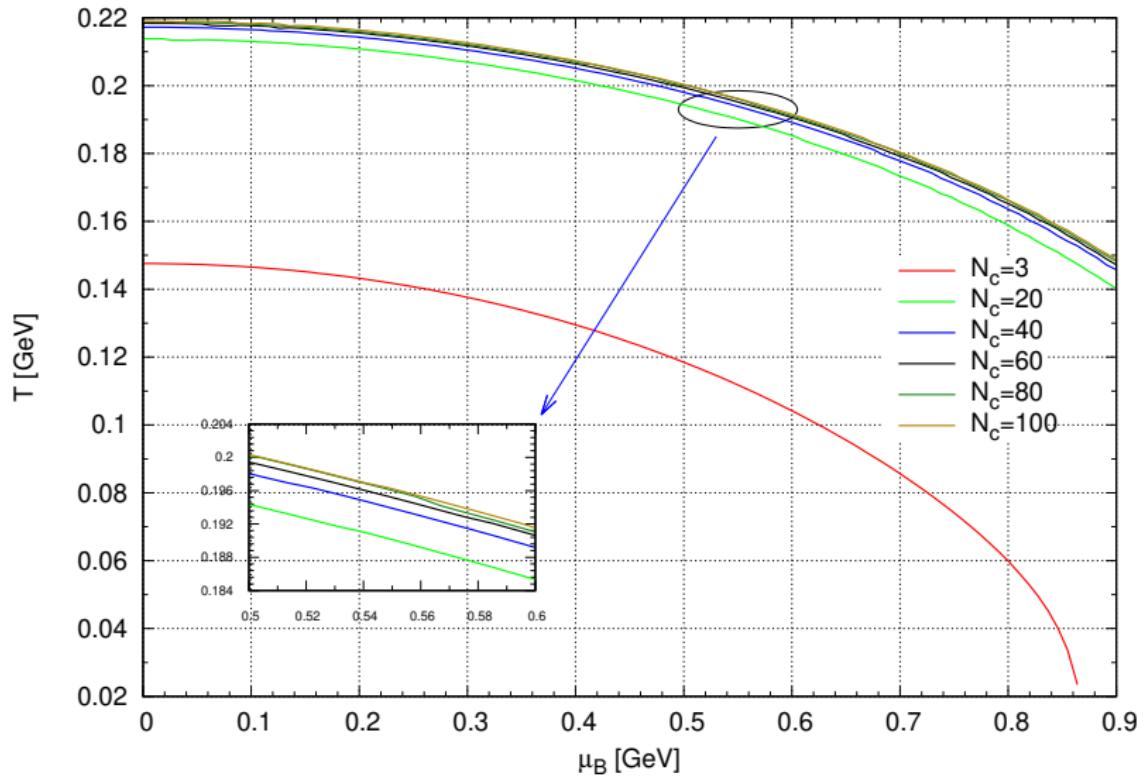


parameterization with $m_\sigma = 1300$ MeV

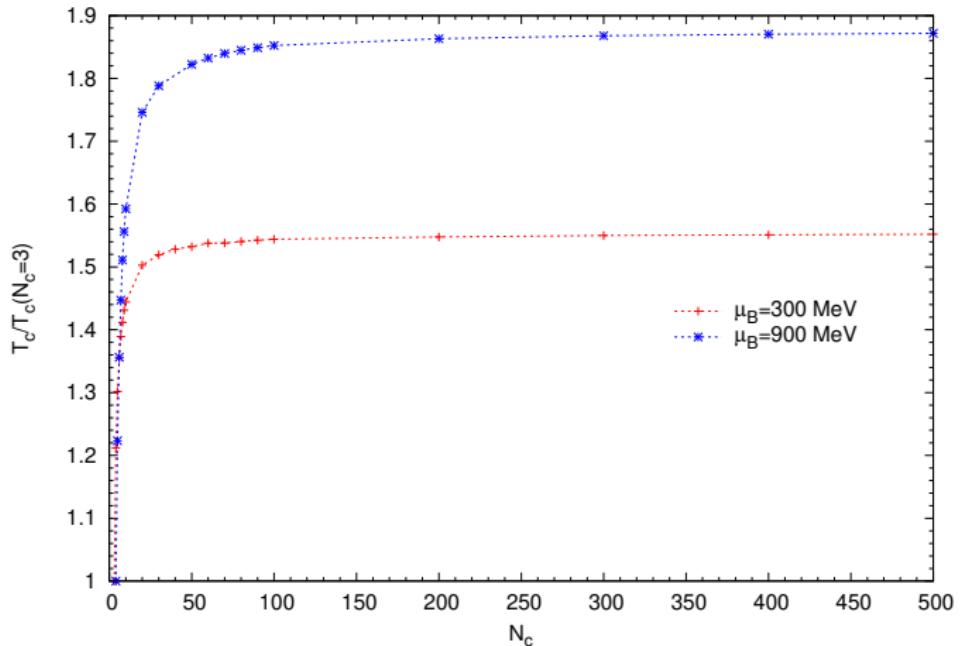
At larger N_c the masses scale as expected that is independent of N_c



parameterization with $m_\sigma = 600$ MeV

Phase boundary at diff. N_c 's ($m_\sigma = 600$ MeV)

T_c scaling at different μ_B 's



For both low and high μ_B : T_c scales as $\sim N_c^0$. What happens if there is a CEP at large N_c ?

Conclusion

Conclusion

- ▶ ePQM model can be used for various in medium investigations
- ▶ (Axial)vector meson curvature masses were calculated at one-loop level
- ▶ Parameterization determines gv
- ▶ Large N_c scaling was also investigated
- ▶ Hybrid star $M - R$ curves were calculated and curves compatible with current observations

Plans

- ▶ Solve the model in the Gaussian approximation
- ▶ Determine the phase boundary and the CEP
- ▶ Investigate the Large N_c scaling of the CEP if it exists
- ▶ Beside the $M - R$ curves also calculate tidal deformabilities
- ▶ Consequences of the gv determination on the compact star properties

Thank you for your attention!