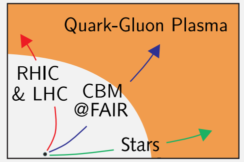

Quarks stars from lattice QCD

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with B. Kämpfer

- QPM with isospin asymmetric chemical potentials
- extrapolation of lattice QCD results to large baryon densities and $T = 0$
- EOS as input for TOV equations

Quarks stars

- static, spherical stellar objects

$$\frac{dp}{dr} = -G\frac{(e+p)(m+4\pi r^3 p)}{r^2(1-\frac{2m}{r}G)}$$
$$\frac{dm}{dr} = 4\pi r^2 e,$$

TOV equations

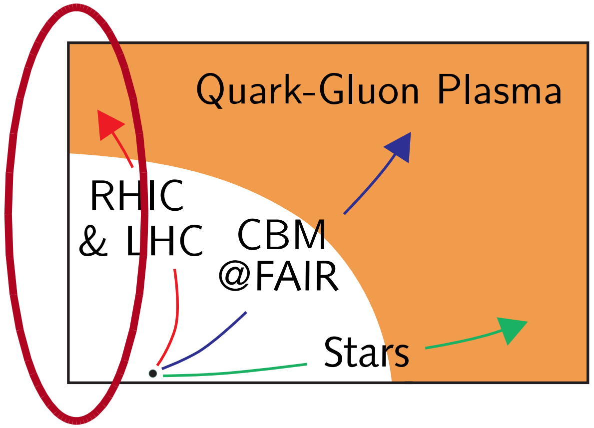
$$e = e(p)$$

- EOS of the quark-gluon plasma

  $\longrightarrow$ from where?

Lattice QCD

- lattice results: availability limited



- one answer: quasiparticle model
  - self-consistency allows mapping to $T = 0$
  - ensure β stability and charge neutrality

Effective QPM

- simplified version of the HTL quasiparticle model: no damping, no coll. modes, asympt. disp. relation

$$s = \sum_i s_i \qquad i = g, u, d, s$$

$$s_i \sim \int_{\mathrm{d}^4k} \frac{\partial\, n_{\mathrm{B/F}}}{\partial T}\, \Theta\left(-\omega^2 + k^2 + m_\infty^2\right)$$

- running/effective coupling

$$g^2(x^2) = \frac{16\pi^2}{\beta_0 \ln(x^2)} \qquad x = \frac{\bar{\mu}}{\Lambda_{\mathrm{QCD}}} \rightarrow \frac{T\text{-}T_s}{\lambda}$$

- fit to e-$3p$ $\rightarrow$ pressure integration constant B_0

Isospin asymmetric QPM

- five chemical potentials

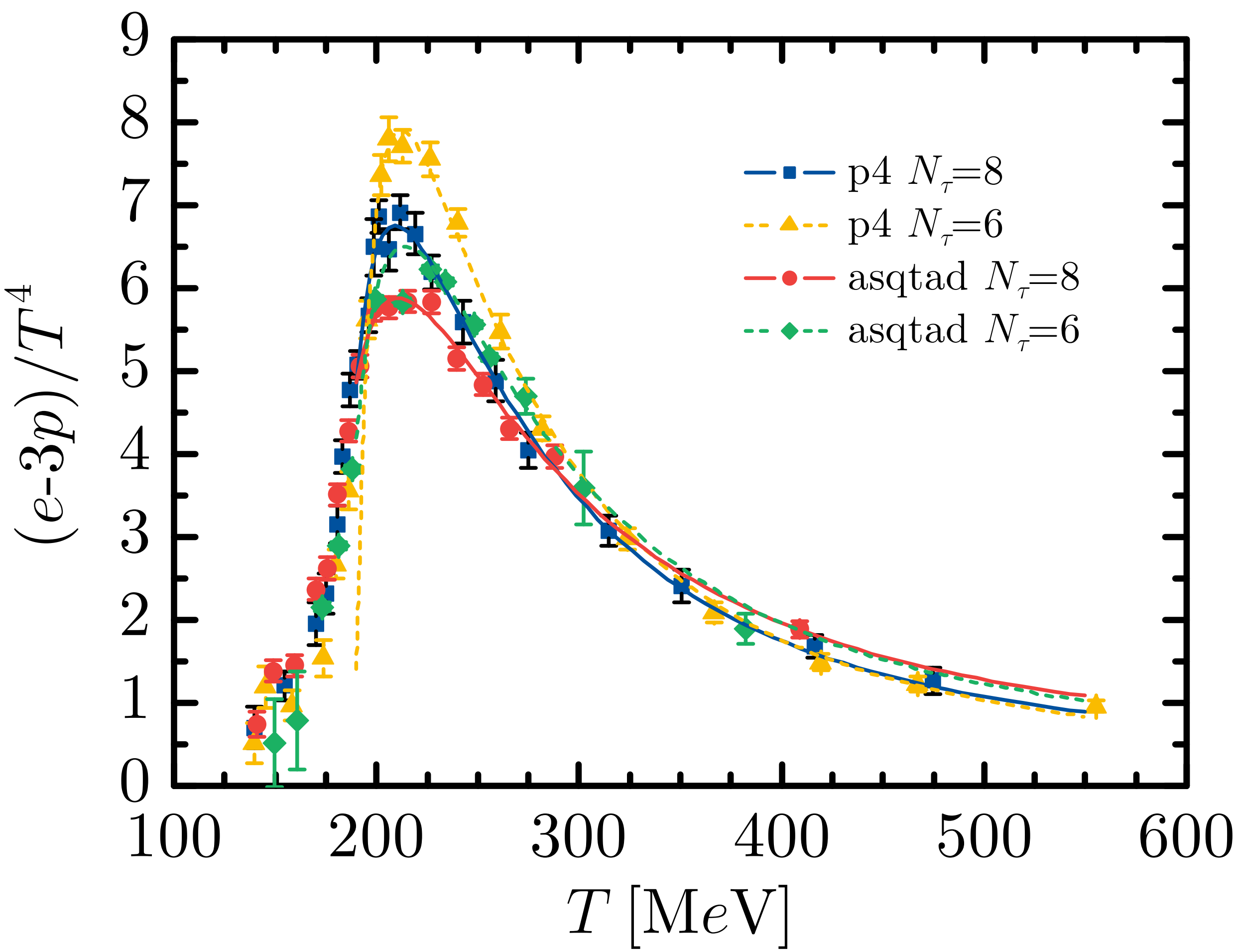
$$\mu_u,\ \mu_d,\ \mu_s \quad + \quad \mu_e,\ \mu_\mu$$

- four side conditions
  - β equilibrium (e.g. $n \leftrightarrow p^+ + e^- + \bar{\nu}_e;\ \mu_d = \mu_u + \mu_e$)
  - equilibrium in strangeness changing decays (e.g. $\Lambda \leftrightarrow p^+ + \pi^-;\ \mu_s = \mu_d$)
  - muon decay (e.g. $\mu^- \leftrightarrow e^- + \bar{\nu}_e + \nu_\mu;\ \mu_\mu = \mu_e$)
  - electric neutrality

$\rightarrow$ only one independent chemical potential $\mu = \mu_u$

At μ=0

- fit to lattice results



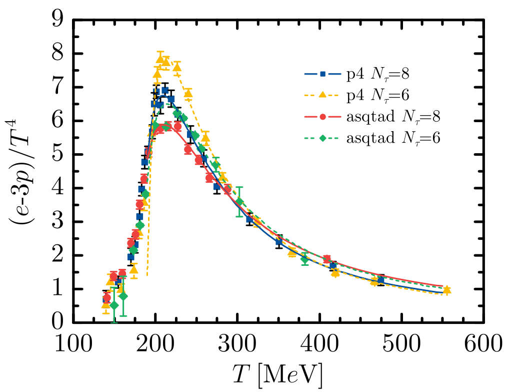
Bazavov et al.: PRD '09

state variables s, n, p, $(e\text{-}3p)$, ...

$\uparrow$

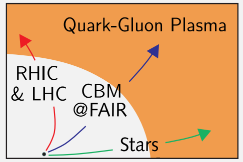
effective coupling G^2, pressure constant B_0

@ $\mu = 0$: @ $\mu \neq 0$:



??

Into the T-μ-plane



- $\mu > 0$: stationary potential, self-consistent model
  $\longrightarrow$ impose Maxwell's relation

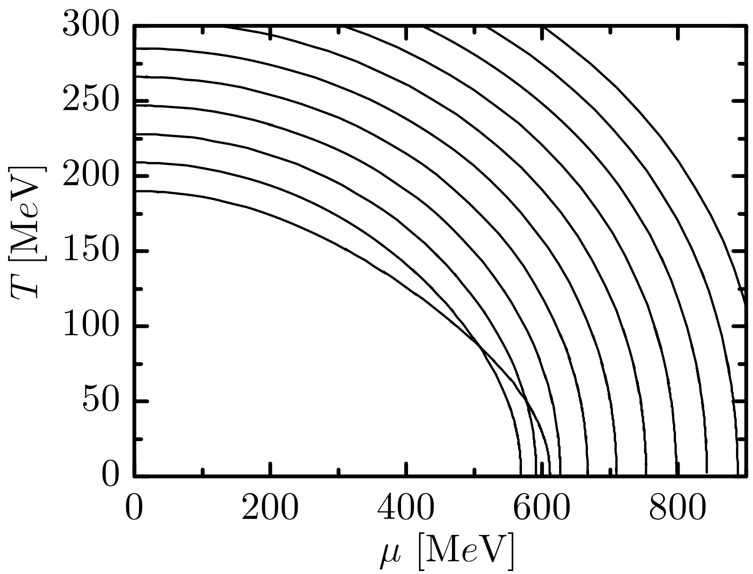
$$\frac{\partial s}{\partial \mu} = \frac{\partial n}{\partial T} \qquad \longrightarrow \qquad a_T \frac{\partial G^2}{\partial T} + a_\mu \frac{\partial G^2}{\partial \mu} = b$$

Peshier, Kämpfer, Soff: PRC'00, PRD'02

- quasilinear PDE for
  $G^2(T, \mu \neq 0)$:
  method of characteristics

  $\longrightarrow$ crossings

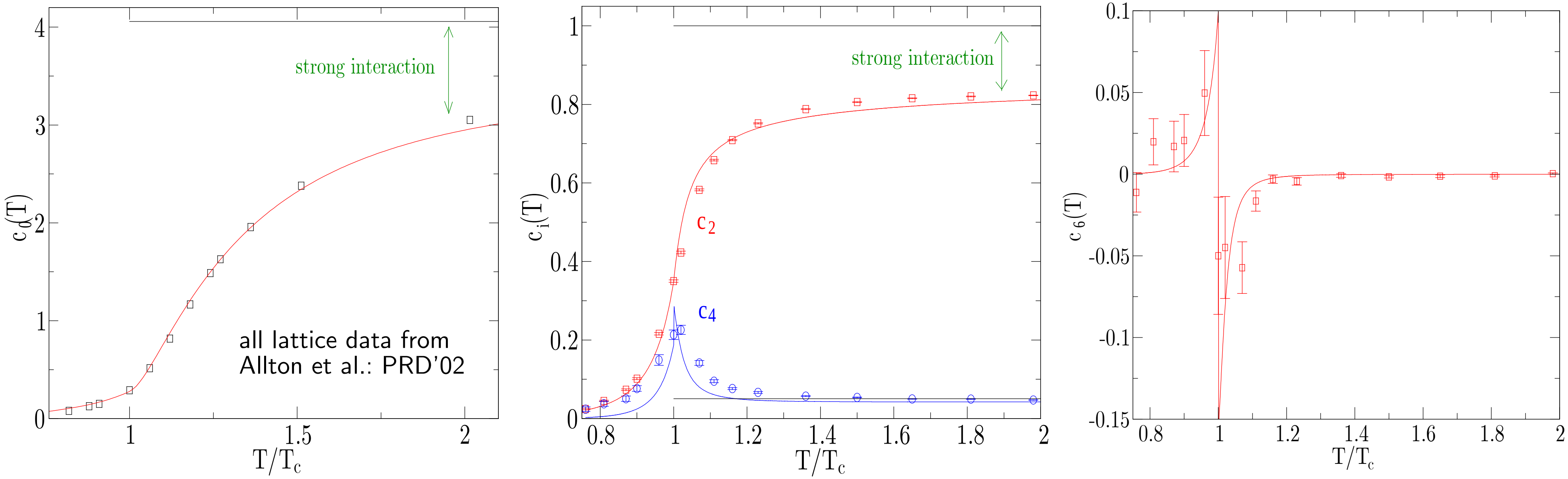
RS, Bluhm, Kämpfer: EPJ ST'08



Small chemical potential

- successful test with $p(T, \mu \gtrsim 0)$ lattice data

$$p = T^4 \sum_n c_n(T) \left(\frac{\mu}{T}\right)^n \qquad c_n(T) = \frac{1}{n!} \frac{\partial^n (p/T^4)}{\partial(\mu/T)^n}$$

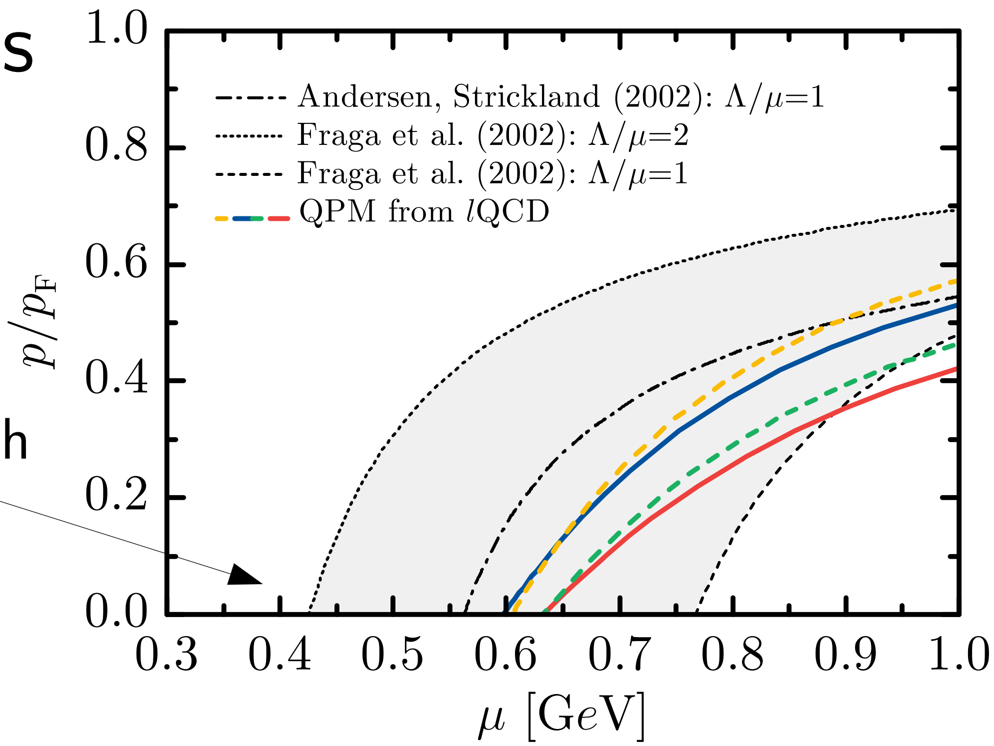


Bluhm, Kämpfer, Soff: PLB'05
Bluhm, Kämpfer, RS, Seipt: EPJC'07

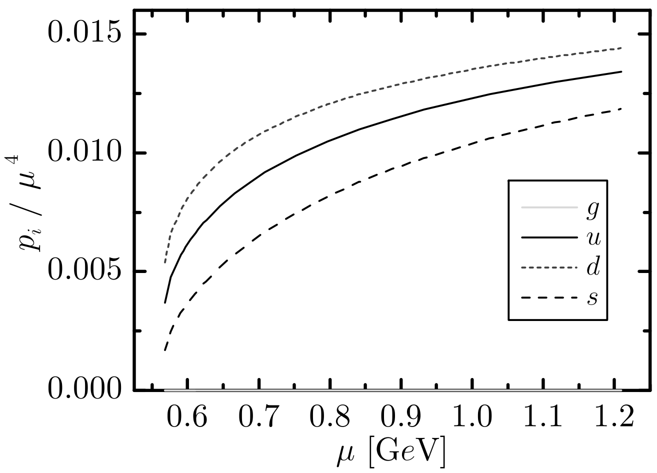
At $T=0$

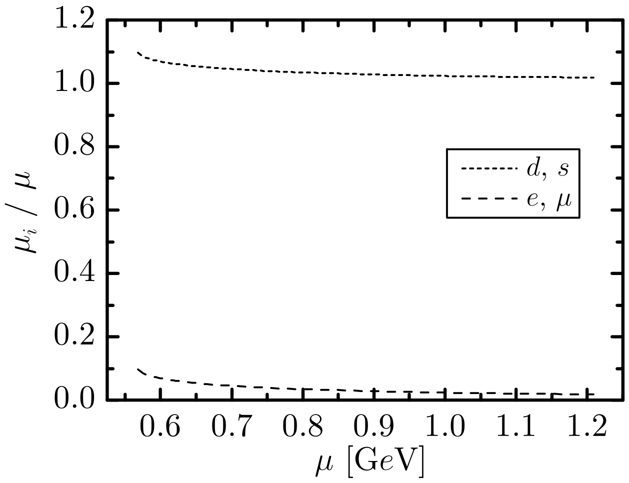
- thermodynamic quantities well within perturbative predictions

hybrid approach possible



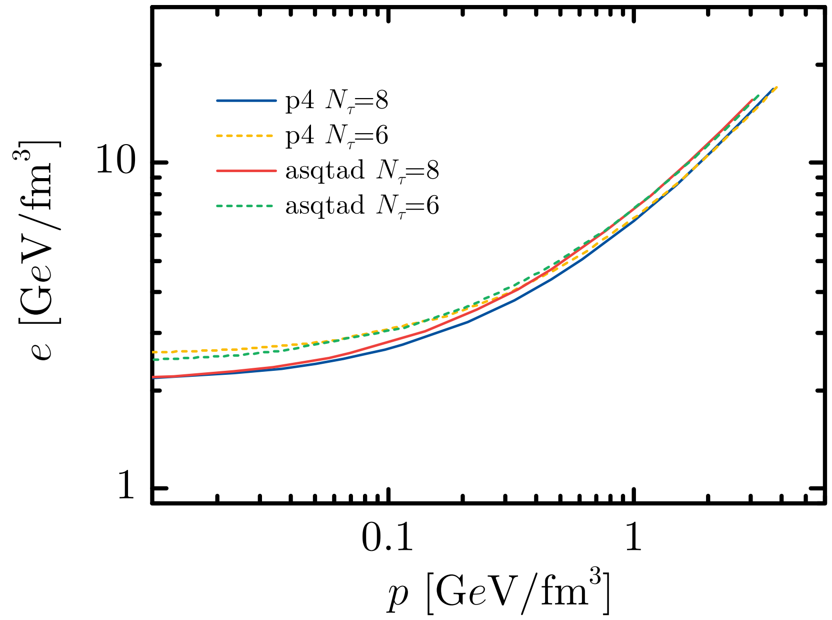
- single contributions





At T=0

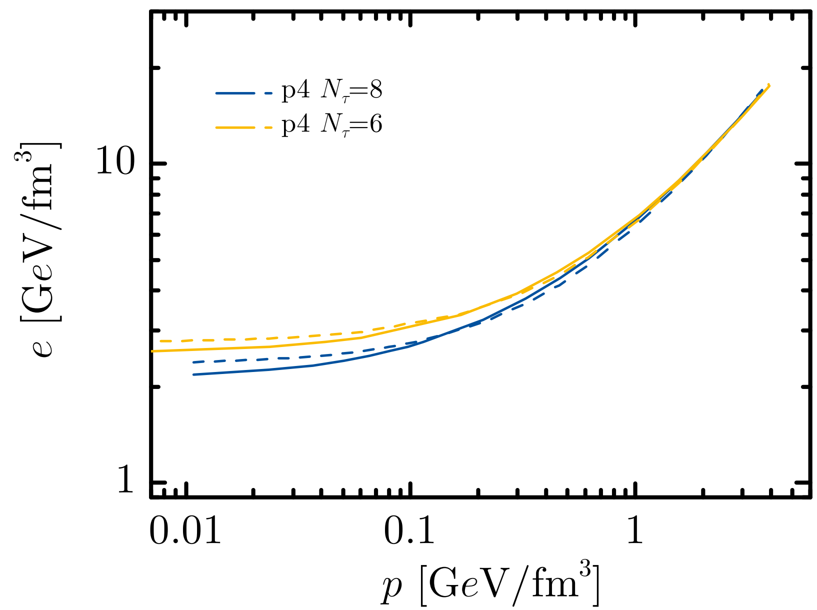
- EOS: narrow range for all actions
  - vacuum energy depends on lattice spacing
  - asymptotics governed by lattice action



- linear approximation for num. comparison

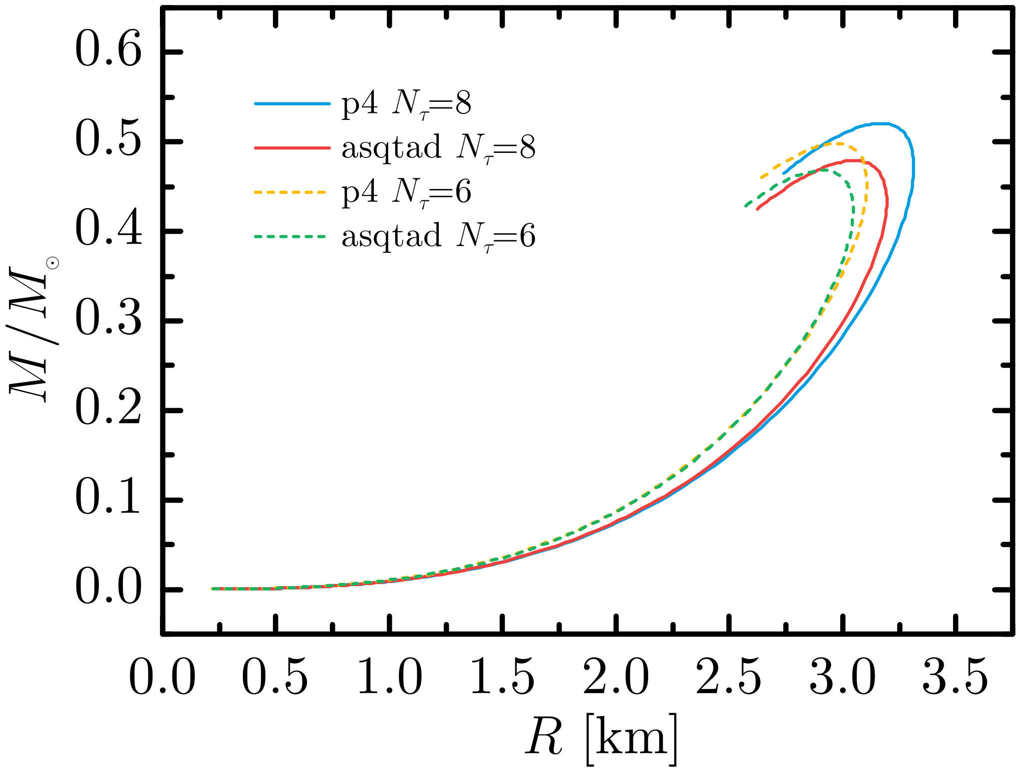
$$e = v_s^{-2} p + e_0$$

$3.8 - 4.5$ $\quad$ $(365 - 380\text{MeV})^4$



Quark stars

- solutions of TOV equations



$\longrightarrow$ rather small and light

$\longrightarrow$ no twin candidates

Summary & Outlook

- ℓQCD results mapped to large μ, even $T{=}0$
- EOS for quark stars similar for all actions
- quark stars with rather smaller radii

- outlook: hybrid stars
  full HTL quasiparticle model with
  Landau damping and collective modes
  rotating quark stars
  EOS for FAIR/CBM