The Role of Baryon Structure in Dense Nuclear Matter

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The Quark-Meson Coupling Model

QMC

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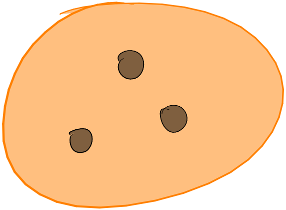

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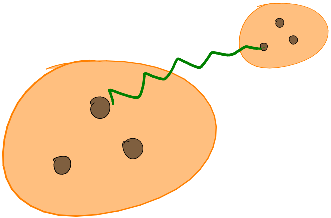
- However, we also want to retain some information on the *baryon structure* – without solving QCD.
- We choose to model baryon-baryon interactions as a quark-meson interaction in the subhadronic level.



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- In MFA we have:

$$(i\partial\!\!\!/ - m^\star)\psi = 0$$

where $m^\star = m - g_\sigma^q \bar{\sigma}$

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Some QMC Highlights

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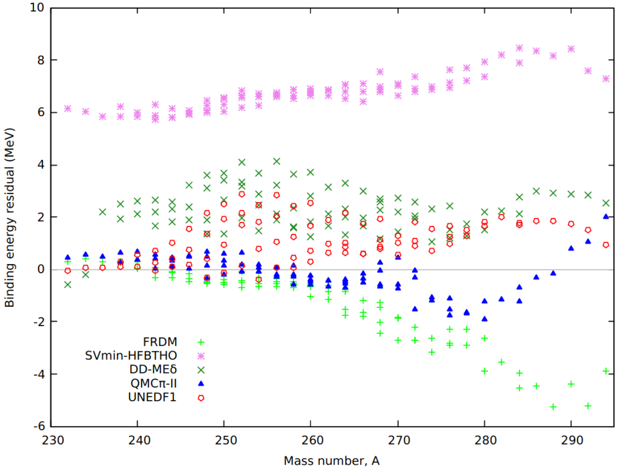

Figure: Nuclei binding energies from (Martinez et al 2019)

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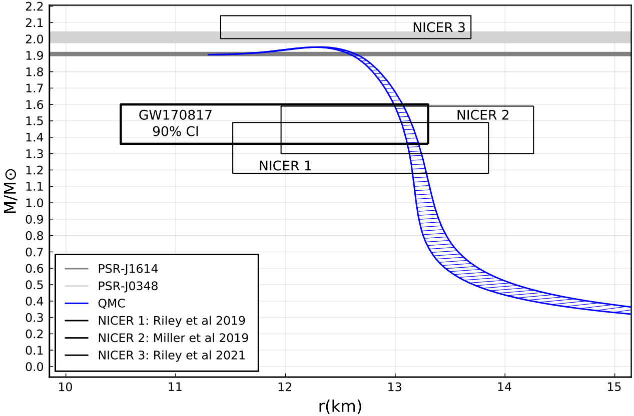
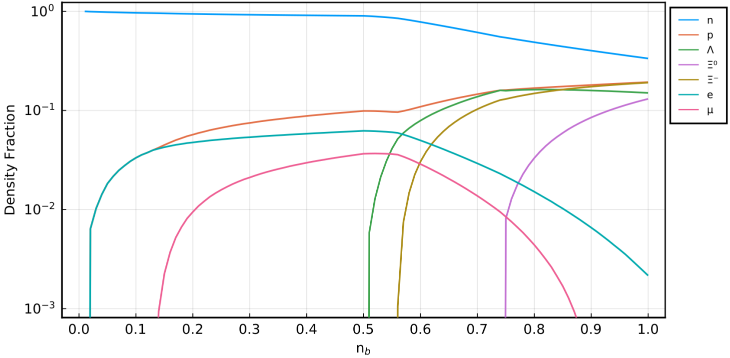


Figure: Stellar structure results from (Motta et al 2019) plus recent NICER results

Content

About the particle content, the QMC model makes a few interesting claims.



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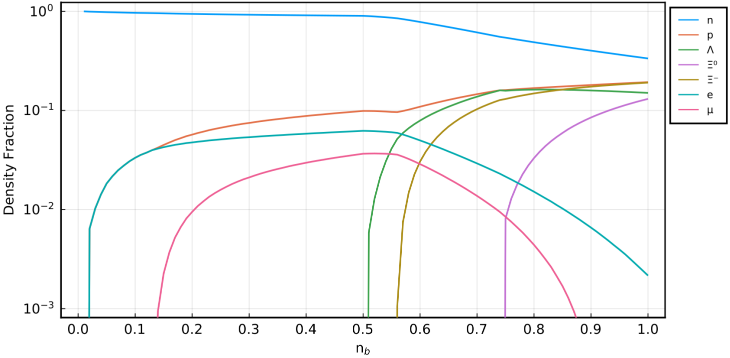

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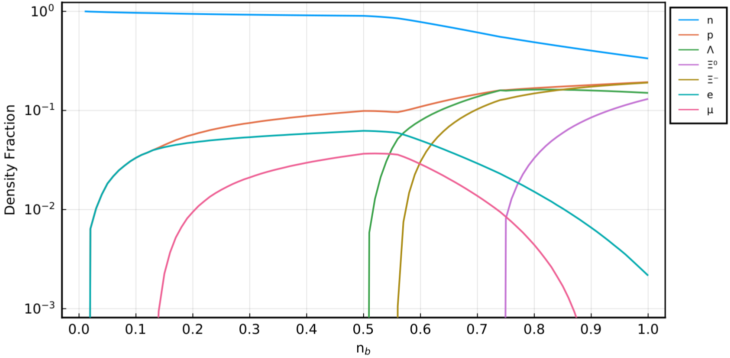

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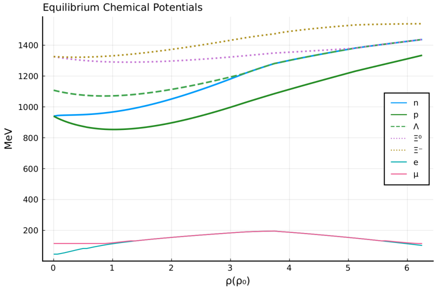
Delta Isobars



Chemical potentials in equilibrium. Say, after $\mu_n = \mu_\Lambda$ they merge and the Λs start to populate the system.

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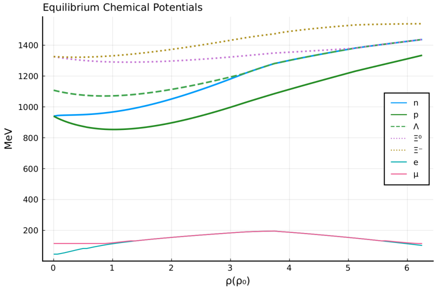
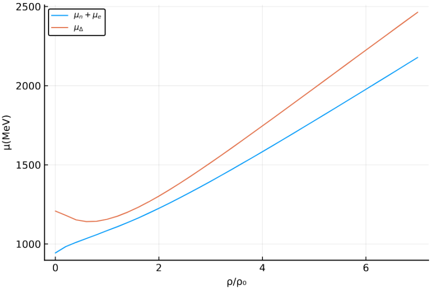


It so happens that, due to the natural repulsion that arises from the QMC model, the $\mu_n + \mu_e$ combination never reaches μ_Δ.



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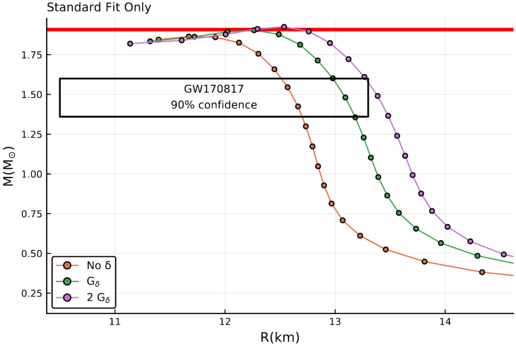
Detla Meson

$$M_B^{\star}(\bar{\sigma},\bar{\delta}) = M_B - g_\sigma\bar{\sigma} + \frac{d}{2}\left(g_\sigma\bar{\sigma}\right)^2 - t_B^\delta g_\delta I_B\bar{\delta} + \tilde{t}_B^\delta\left(g_\delta\bar{\delta}\right)^2 + \tilde{d} g_\sigma g_\delta \bar{\sigma} I_B \bar{\delta}$$

Detla Meson

$$\begin{aligned} M_B^\star(\bar\sigma,\bar\delta) =& M_B - g_\sigma\bar\sigma + \frac{d}{2}\left(g_\sigma\bar\sigma\right)^2 \\ & - t_B^\delta g_\delta I_B\bar\delta + \tilde t_B^\delta\left(g_\delta\bar\delta\right)^2 + \tilde d g_\sigma g_\delta\bar\sigma I_B\bar\delta \\ =& M_B - g_\sigma^B(\bar\sigma,\bar\delta)\sigma - g_\delta^B(\bar\sigma,\bar\delta) I_B\bar\delta. \end{aligned}$$



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- The N-DM form factor is usually taken to be a constant; calculated at zero momentum transfer.
- However, given the density of a NS, the neutrons have very high momenta. A constant form factor is a poor approximation.
- Furthermore, the in-structure of the nucleon is not only relevant at high momentum transfer, but it's also *modified by the medium*.

Form Factors

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- Including the effective mass dependence we already have

$$
\begin{aligned}
c_n^S\left(m_n^{\text{eff}}\right) &= \frac{2\left(m_n^{\text{eff}}\right)^2}{\Lambda^4 v^2}\left[\sum_{q=u,d,s} f_{T_q}^{(n)} + \frac{2}{9} f_{T_G}^{(n)}\right]^2 \\
c_n^P\left(m_n^{\text{eff}}\right) &= \frac{2\left(m_n^{\text{eff}}\right)^2}{\Lambda^4 v^2}\left[\sum_{q=u,d,s}\left(1 - 3\frac{\bar{m}}{m_q}\right)\Delta_q^{(n)}\right]^2 \\
c_n^V = \frac{9}{\Lambda^4}, &\quad c_n^A = \frac{1}{\Lambda^4}\left[\sum_{q=u,d,s}\Delta_q^{(n)}\right]^2
\end{aligned} \tag{1}
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- On top of that, considering the energy scale of the interaction, we introduce the t momentum dependence in the standard way

$$c_n^I(t) = \frac{c_n^I}{\left(1 - t/Q_0^2\right)^2}, \quad I \in \{S, P, V, A, T\} \tag{2}$$

Interaction rate

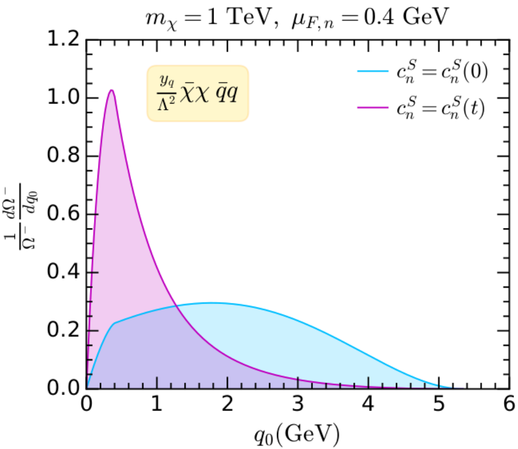
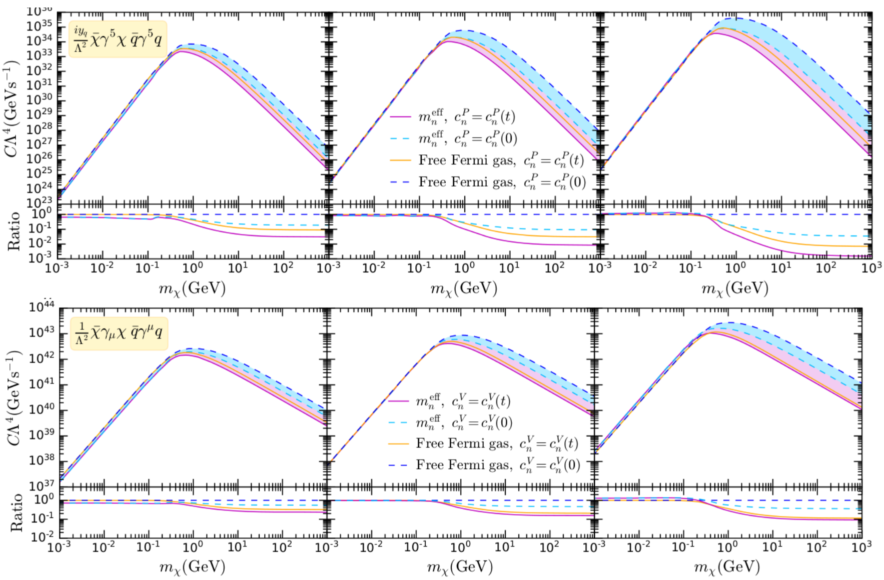


Figure: Normalised differential DM-neutron interaction rate per DM energy loss. Constant neutron coupling $c_n^S(0)$ (light blue line) and w/ transferred momentum form factor dependence (magenta line), $m_\chi = 1$TeV, $B = 0.5$, $\mu_{F,n} = 0.4$GeV and $Q_0 = 1$GeV.

Capture rate



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