Study on the isospin asymmetric nuclear matter and in-medium pion production

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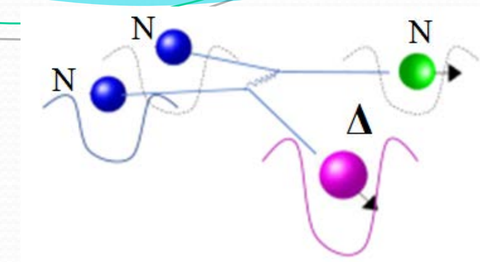
- **To reduce the uncertainties of constraints on symmetry energy, both the constraints on the mean field and medium NN → NΔ cross section are significant.**



The Lagrangian we used is as follows:

$$\mathcal{L} = \mathcal{L}_I + \mathcal{L}_F, \quad (1)$$

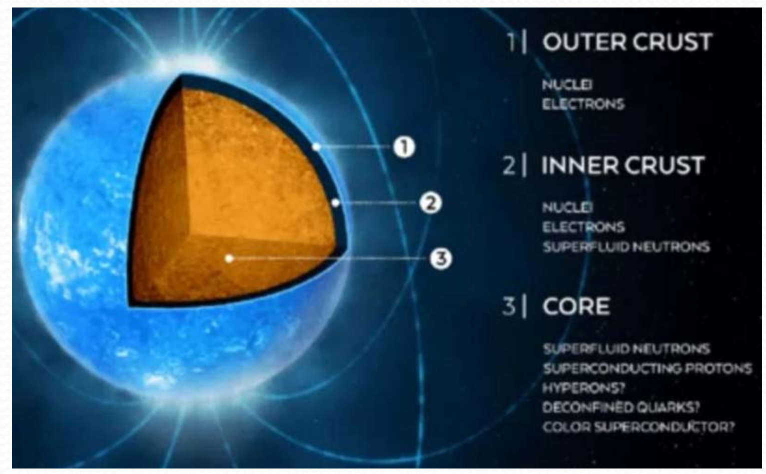
where L_F is

$$\begin{aligned}\mathcal{L}_F = &\bar{\Psi}[i\gamma_\mu\partial^\mu - m_N]\Psi + \bar{\Delta}_\lambda[i\gamma_\mu\partial^\mu - m_\Delta]\Delta^\lambda \\ &+ \frac{1}{2}\partial_\mu\sigma\,\partial^\mu\sigma - \frac{1}{2}m_\sigma^2\sigma^2 - \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 \\ &- \frac{1}{4}\omega_{\mu\nu}\omega^{\mu\nu} + \frac{1}{2}m_\omega^2\omega_\mu\omega^\mu + \frac{1}{2}(\partial_\mu\boldsymbol{\pi}\,\partial^\mu\boldsymbol{\pi} - m_\pi^2\boldsymbol{\pi}^2) \\ &- \frac{1}{4}\boldsymbol{\rho}_{\mu\nu}\boldsymbol{\rho}^{\mu\nu} + \frac{1}{2}m_\rho^2\boldsymbol{\rho}_\mu\boldsymbol{\rho}^\mu + \frac{1}{2}(\partial_\mu\boldsymbol{\delta}\,\partial^\mu\boldsymbol{\delta} - m_\delta^2\boldsymbol{\delta}^2), \quad (2)\end{aligned}$$

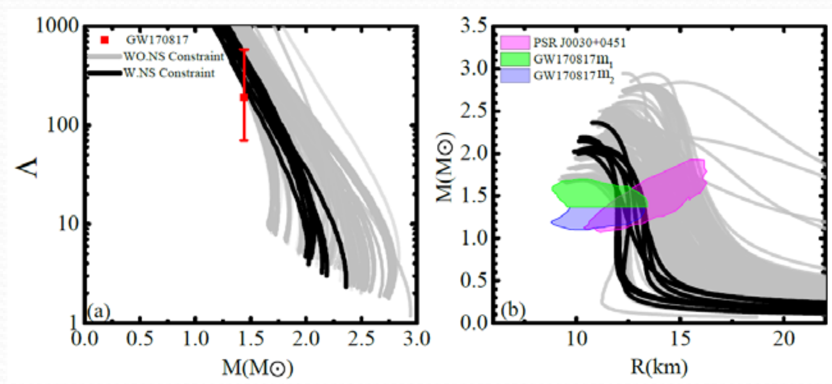
and L_I is

$$\begin{aligned}\mathcal{L}_I = &\mathcal{L}_{NN} + \mathcal{L}_{\Delta\Delta} + \mathcal{L}_{N\Delta} \\ = &g_{\sigma NN}\bar{\Psi}\Psi\sigma - g_{\omega NN}\bar{\Psi}\gamma_\mu\Psi\omega^\mu - g_{\rho NN}\bar{\Psi}\gamma_\mu\boldsymbol{\tau}\cdot\Psi\boldsymbol{\rho}^\mu \\ &+ \frac{g_{\pi NN}}{m_\pi}\bar{\Psi}\gamma_\mu\gamma_5\boldsymbol{\tau}\cdot\Psi\,\partial^\mu\boldsymbol{\pi} + g_{\delta NN}\bar{\Psi}\boldsymbol{\tau}\cdot\Psi\boldsymbol{\delta} \\ &+ g_{\sigma\Delta\Delta}\bar{\Delta}_\mu\Delta^\mu\sigma - g_{\omega\Delta\Delta}\bar{\Delta}_\mu\gamma_\nu\Delta^\mu\omega^\nu \\ &- g_{\rho\Delta\Delta}\bar{\Delta}_\mu\gamma_\nu\mathbf{T}\cdot\Delta^\mu\boldsymbol{\rho}^\nu + \frac{g_{\pi\Delta\Delta}}{m_\pi}\bar{\Delta}_\mu\gamma_\nu\gamma_5\mathbf{T}\cdot\Delta^\mu\partial^\nu\boldsymbol{\pi} \\ &+ g_{\delta\Delta\Delta}\bar{\Delta}_\mu\mathbf{T}\cdot\Delta^\mu\boldsymbol{\delta} + \frac{g_{\pi N\Delta}}{m_\pi}\bar{\Delta}_\mu\boldsymbol{\mathcal{T}}\cdot\Psi\,\partial^\mu\boldsymbol{\pi} \\ &+ \frac{ig_{\rho N\Delta}}{m_\rho}\bar{\Delta}_\mu\gamma_\nu\gamma_5\boldsymbol{\mathcal{T}}\cdot\Psi(\partial^\nu\boldsymbol{\rho}^\mu - \partial^\mu\boldsymbol{\rho}^\nu) + \text{h.c.} \quad (3)\end{aligned}$$

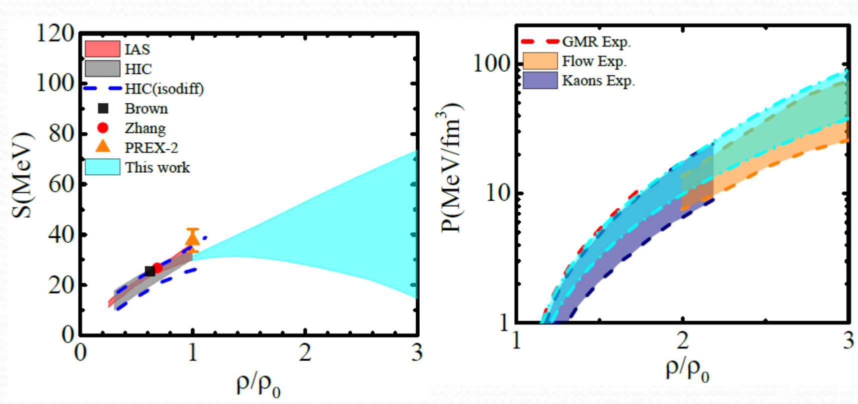
1. The possible relativistic mean field is constrained from the tidal deformability and the mass-radius relationship of neutron star .



The parameter sets in Lagrangian are determined by the NS constraints.



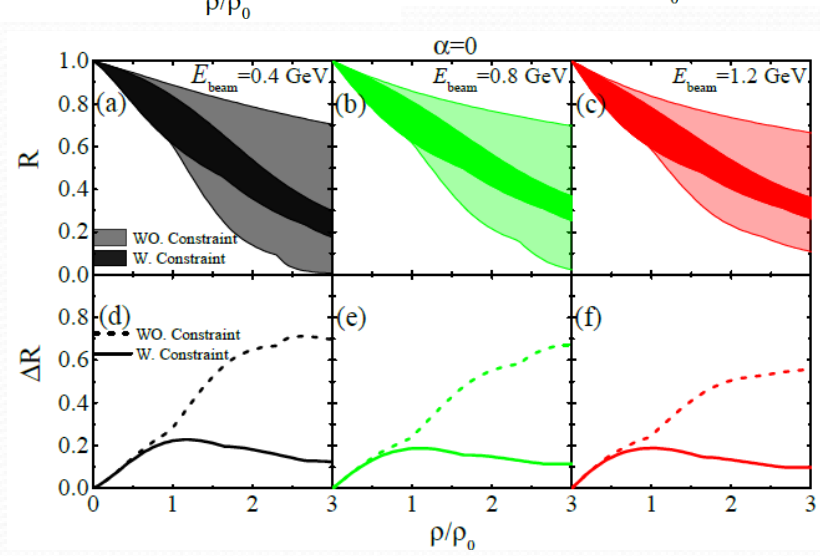
The symmetry energy constrained by NS at high density, $S(2\rho_0)$ =40.54+/-12.47 MeV and $S(3\rho_0)$ = 44.12+/-29.38 MeV from NS observables.



2. The medium correction factor $\mathbf{R=\sigma^*_{NN\to N\Delta}/\,\sigma^{free}_{NN\to N\Delta}}$ with the theoretical uncertainty are obtained.

With the neutron star constraints, the range of R is Δ R = 0.182+/- (with constraint), while Δ R = 0.648 (without constraint) at $2\rho_0$; Δ R = 0.125 (with constraint) from Δ R = 0.696 (without constraint) at $3\rho_0$ for E_{beam} = 0.4 GeV,

At Ebeam=0.4 GeV, the uncertainties, i.e., $\Delta R = \mathbf{R_{max}} - \mathbf{R_{min}}$ decrease by 72% and 82% at $2\rho_0$ and $3\rho_0$ respectivel.



1.Ying Cui, Yingxun Zhang, and Zhuxia Li, **to be submitted.**
2.Ying Cui, Yingxun Zhang, and Zhuxia Li, **in preparation.**