Effects of Σ and Ξ isovector potentials to neutron star EOS

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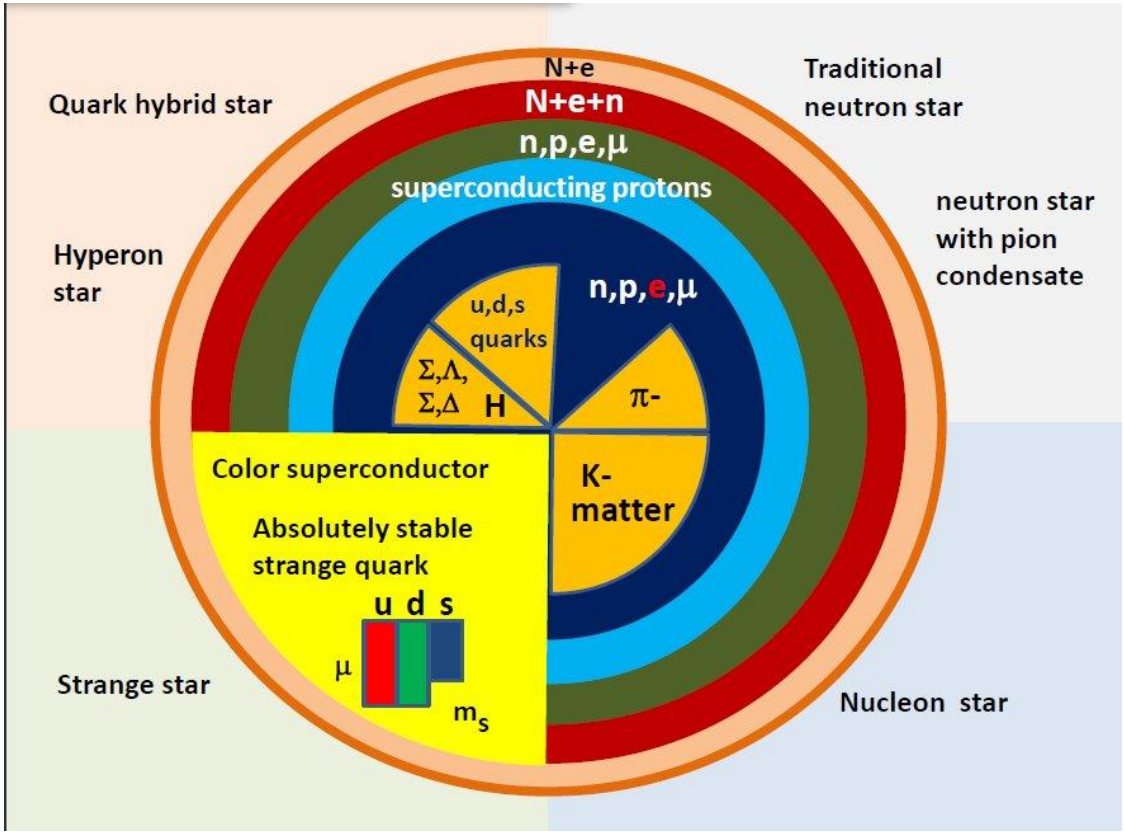
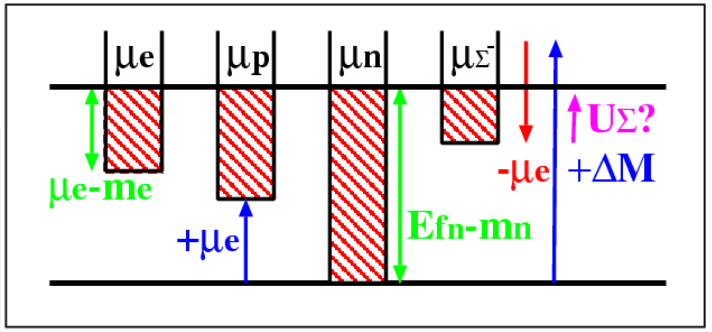
Introduction

- Ambiguity in dense inner region of NS

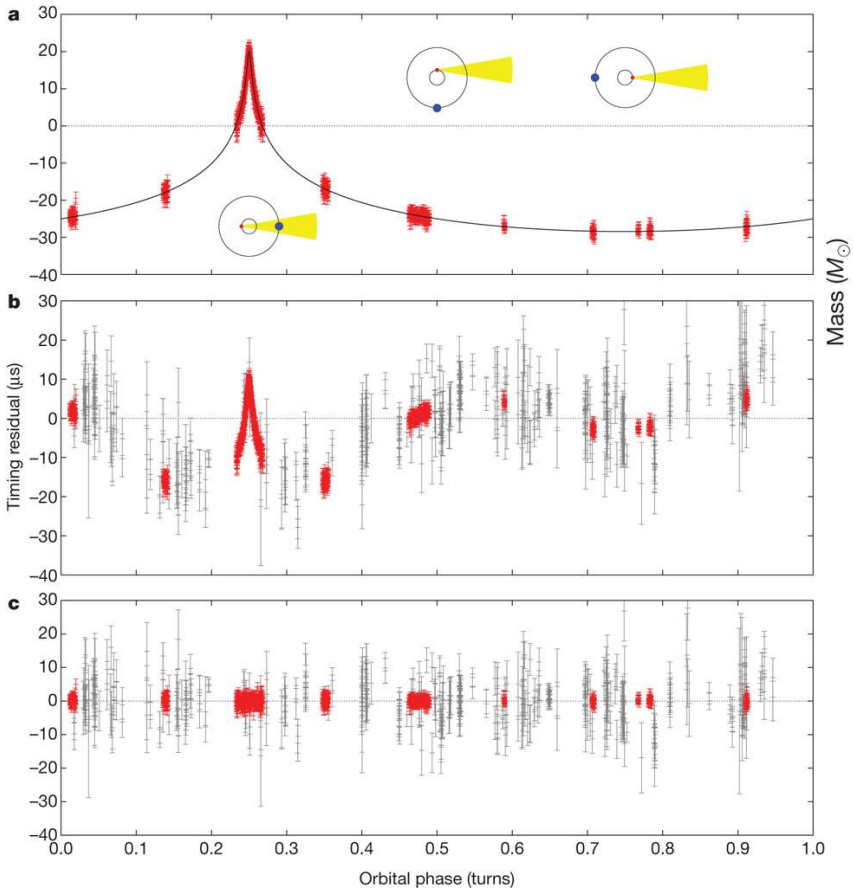


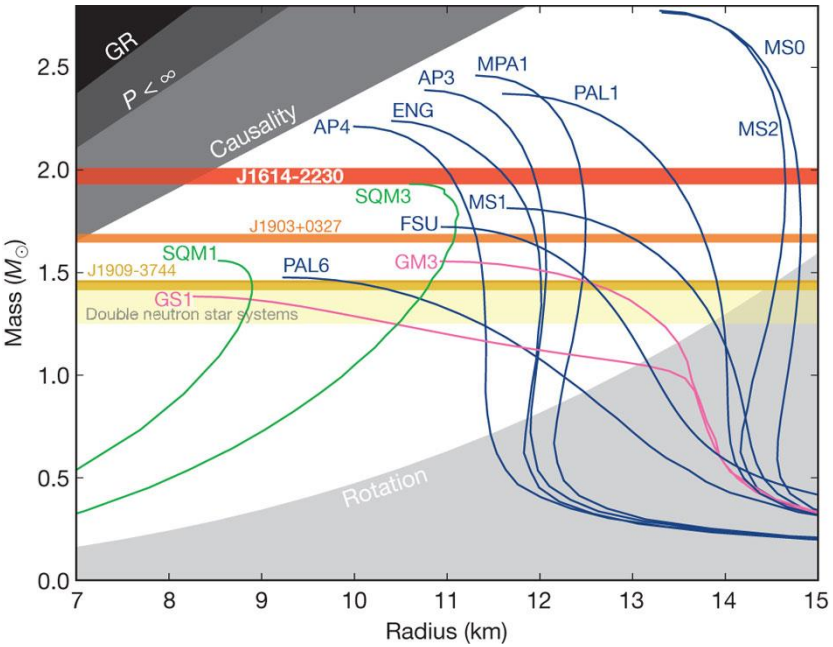


- New DOF such as Exotic particle soften NS EOS
- Emergence of hyperon: needs to treat "finite" hypernuclear systems in order to determine hyperon potential
- Framework which enable to treat finite/infinite system →RMF model

Introduction

- Observation of massive neutron star

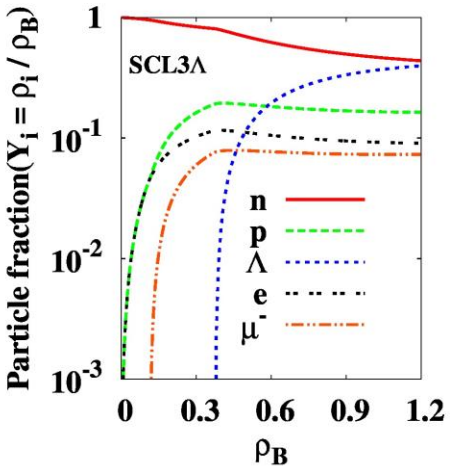


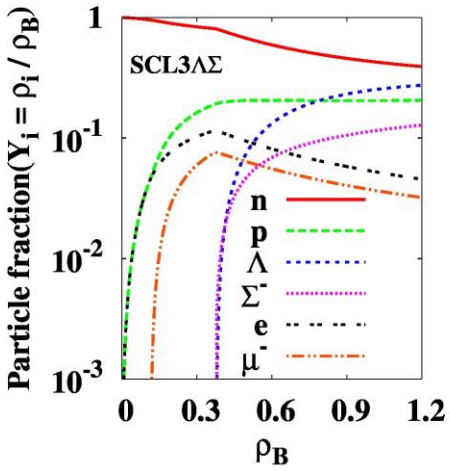


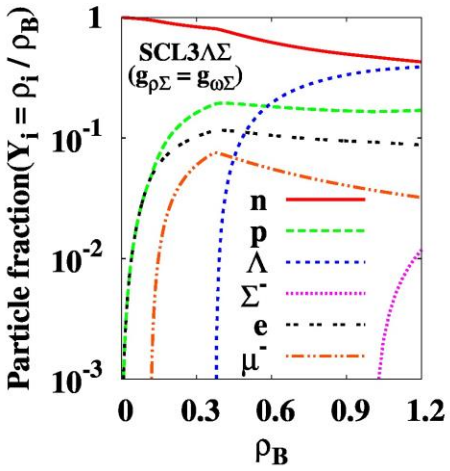
"Most EOS curves involving exotic matter, such as kaon condensates or hyperons tend to predict maximum masses well below 2.0 $M_\odot$ and are therefore ruled out."

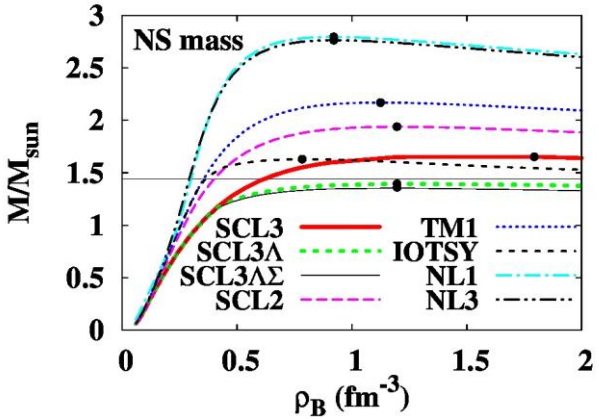
Personal motivation

- Previous works on SCL3 RMF model





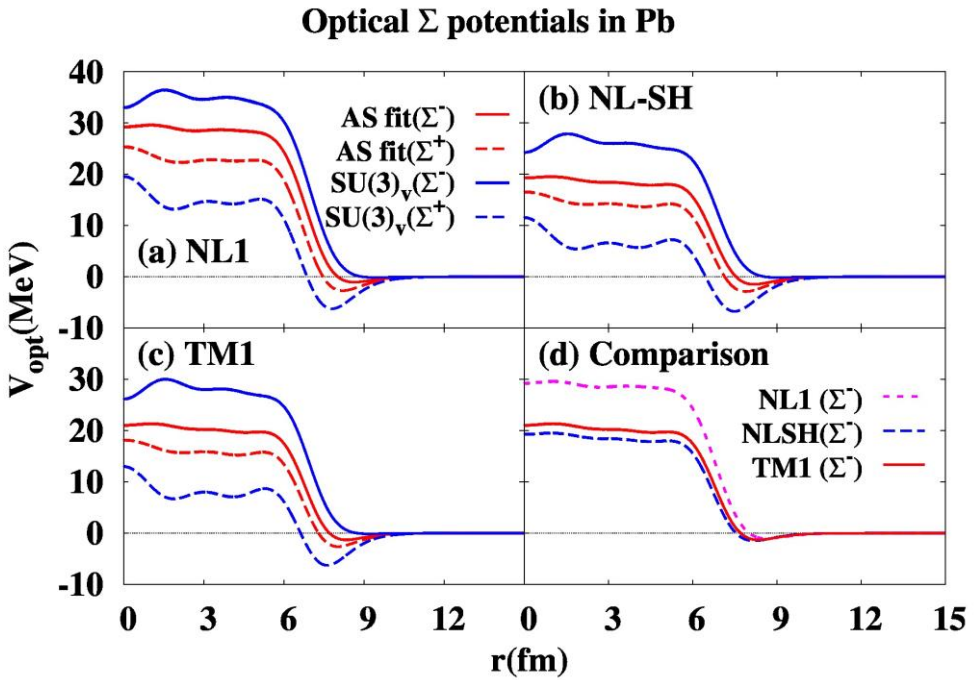


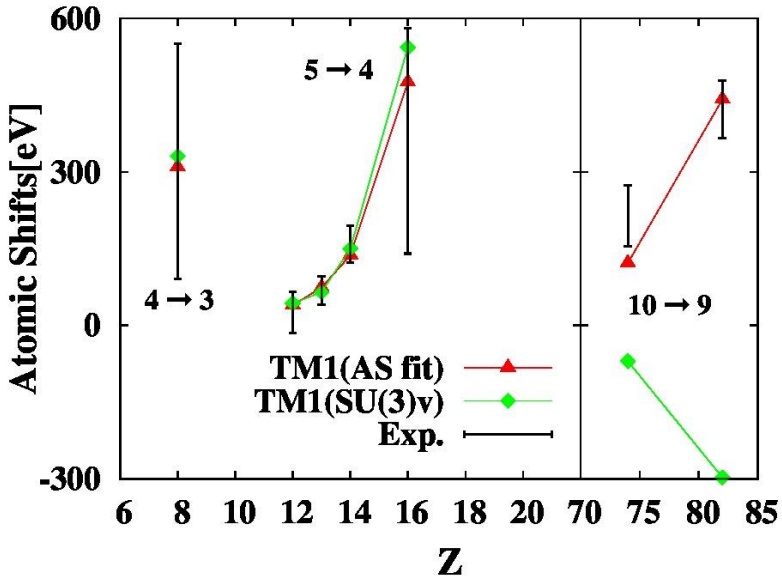


- Logarithmic meson potential derived from Strong Coupling Limit of lattice QCD
- Emergence of Σ^-: suggested from reduced IV potential of Σ
- Smaller NS mass: requirement of many-body interaction in RMF?

Hypernulcer Symmetry Energy

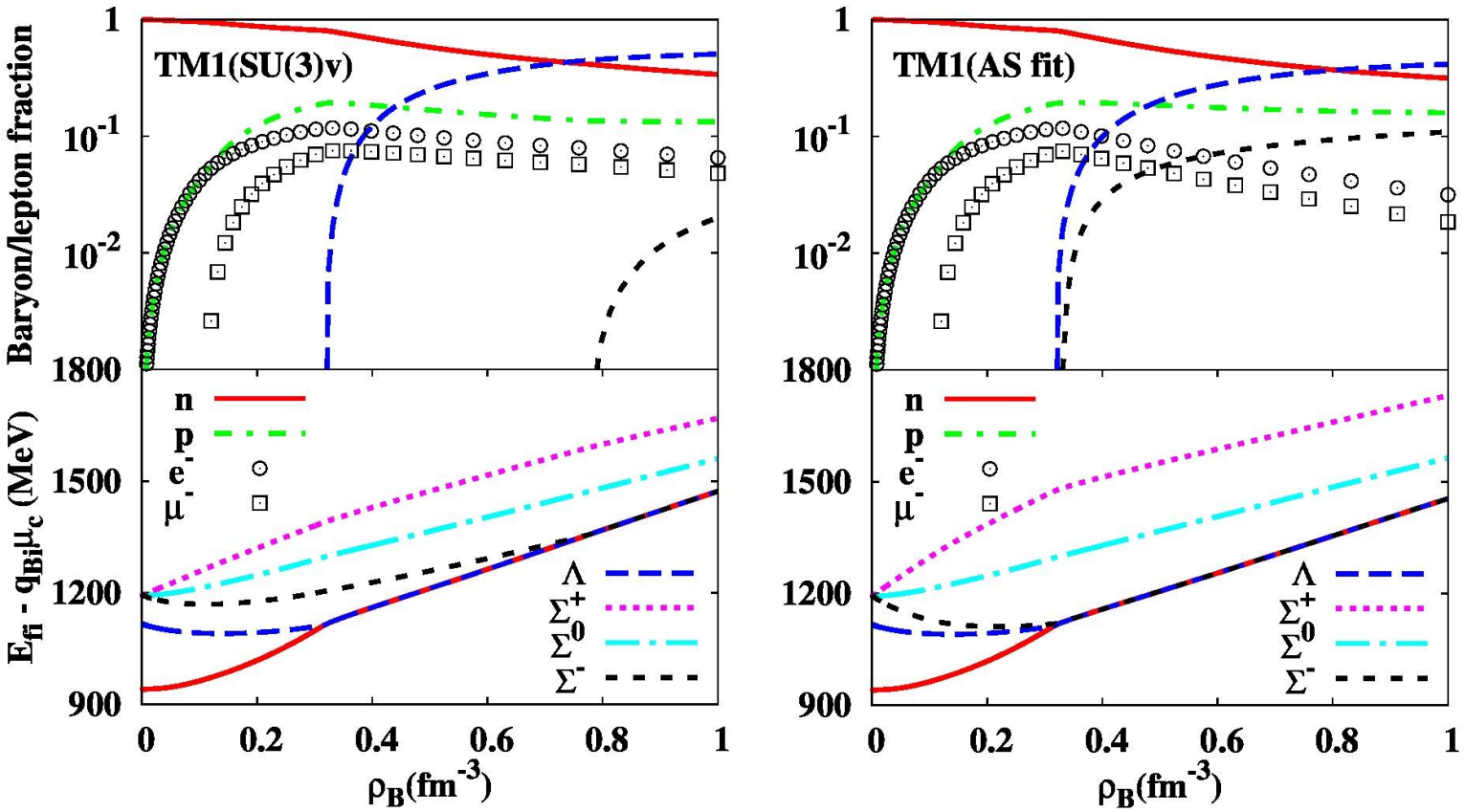
- Atomic shift of Σ^-: Attractive potential around surface
- Difference between Σ^+ and Σ^- potentials→ proportional to "Hypernulcear" symmetry energy: 15MeV(SU(3))→5MeV(fit)





Σ^- fraction in NS EOS

- Baryon fraction and $E_{fi} - q_{Bi}\mu_C$ ($E_{fi} = \sqrt{p_{fi}^2 + M^{*2}} + V_{\mathrm{vec}}$)



Physical motivation

- More massive NS than $2M_{\odot}$:
  How can be explained in RMF model?
  → n=3 meson-baryon couplings

- Can Σ^- survive in NS EOS in case we consider above n= 3 couplings and how large effects does Σ^- take from those couplings
- Heavier negative-charged hyperon Ξ^-:
  Which will appear on NS EOS at high ρ_B, Σ^- or Ξ^-?

①n=3 RMF model

FOR UNDERSTANDING
MAXIMUM MASS OF NS

RMF model

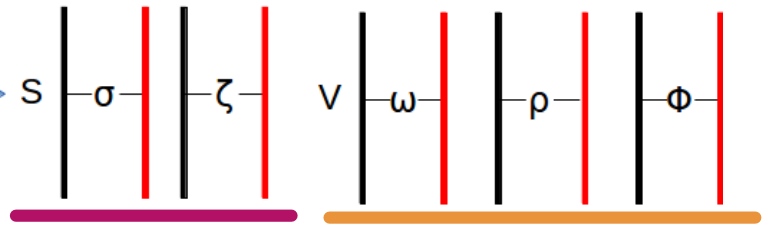
- n=B/2+M+D=2 RMF Lagrangian + meson potentials

$$\mathcal{L} = \sum_i \bar{\psi}\left[i\partial - M_i^* - \gamma_\mu V^\mu\right]\psi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}$$

$$+\frac{1}{2}\partial_\mu\varphi_\sigma\partial^\mu\varphi_\sigma - \frac{m_\sigma^2}{2}\varphi_\sigma^2 + \frac{1}{2}\partial_\mu\varphi_\zeta\partial^\mu\varphi_\zeta - \frac{m_\sigma^2}{2}\varphi_\zeta^2 - V_{\sigma\zeta}$$

$$-\frac{1}{4}W_{\mu\nu}W^{\mu\nu} + \frac{m_\omega^2}{2}\omega_\mu\omega^\nu - \frac{1}{4}R_{\mu\nu}R^{\mu\nu} + \frac{m_\rho^2}{2}\rho_\mu\rho^\nu - \frac{1}{4}\phi_{\mu\nu}\phi^{\mu\nu} + \frac{m_\phi^2}{2}\phi_\mu\phi^\nu + \frac{C_{\omega 4}}{4}\left(\omega_\nu\omega^\nu\right)^2$$

$\overline{\Psi}_B g_{mB} m \Psi_B$ 

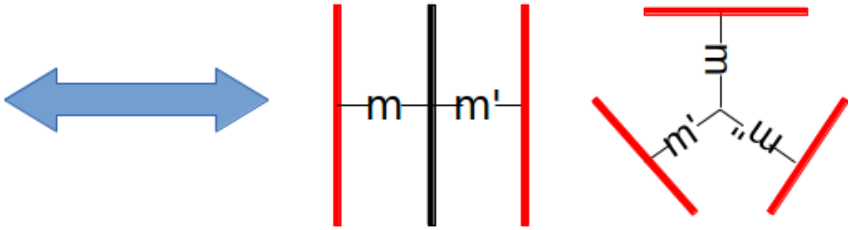


- Non-linear meson potentials
  - Interactions among mesons in finite/infinite system
  - Higher order terms than n=3 meson-baryon couplings

n=3 coupling in RMF

- n=B/2+m+D=3 couplings

$$\bar{\Psi}_B m m' \Psi_B, \; m m' m''$$



  - Number n corresponds to the number of baryons participating in each interaction

- Isoscalar type couplings

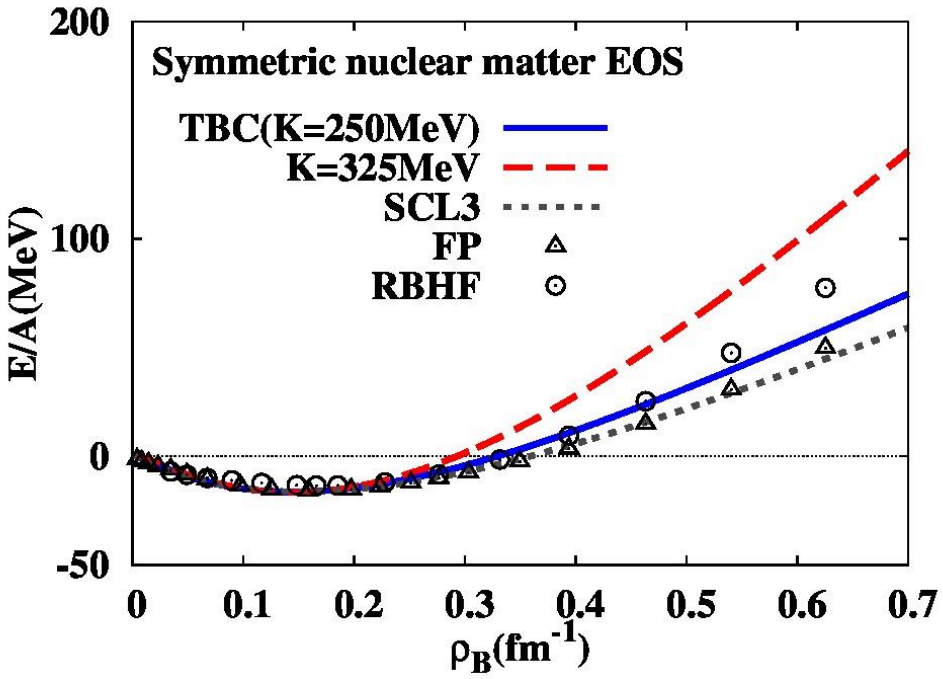
$$\bar{\Psi}_B \left(g_{\sigma\sigma B}\varphi_\sigma^2/f_\pi\right)\Psi_B, \; \bar{\Psi}_B \left(g_{\sigma\omega B}\varphi_\sigma\omega/f_\pi\right)\Psi_B, \; \bar{\Psi}_B \left(g_{\omega\omega B}\omega^2/f_\pi\right)\Psi_B, \; \frac{C_{\sigma\omega 2}}{2} f_\pi \varphi_\sigma \omega^2$$

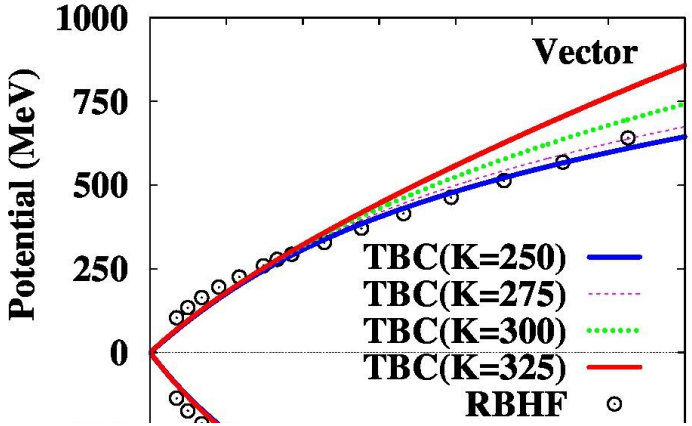
- Isovector type couplings

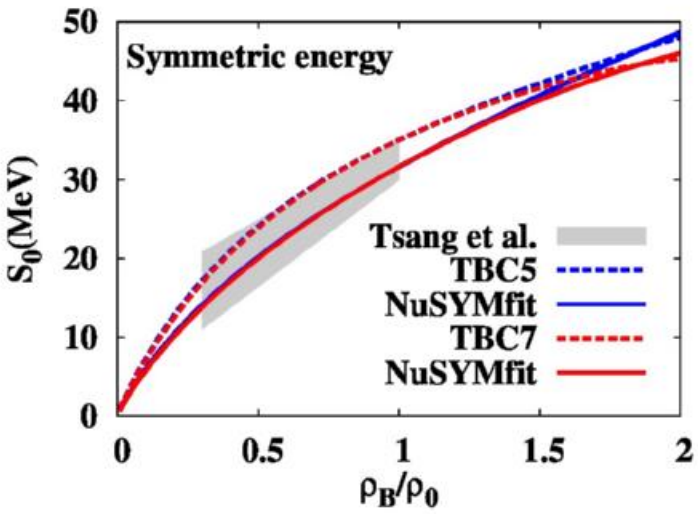
$$\bar{\Psi}_B \left(g_{\rho\sigma B}\rho\varphi_\sigma/f_\pi\right)\Psi_B, \; \bar{\Psi}_B \left(g_{\omega\rho B}\omega\rho/f_\pi\right)\Psi_B, \; \bar{\Psi}_B \left(g_{\rho\rho B}\rho^2/f_\pi\right)\Psi_B, \; \frac{C_{\sigma\rho 2}}{2} f_\pi \varphi_\sigma \rho^2$$

それぞれscalar、vector型結合

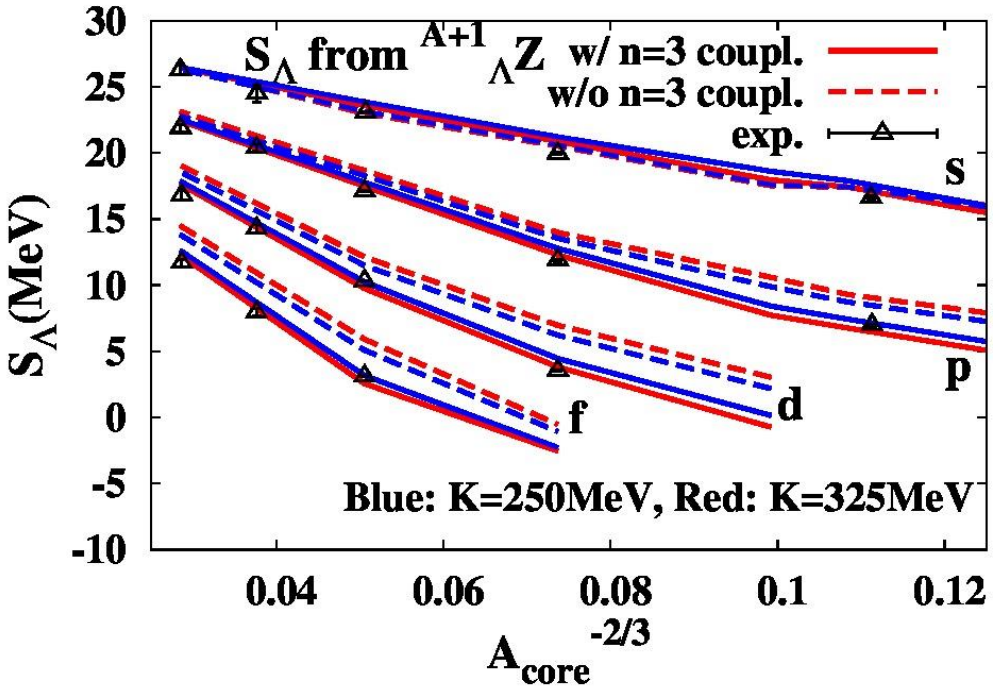
Parameter setting





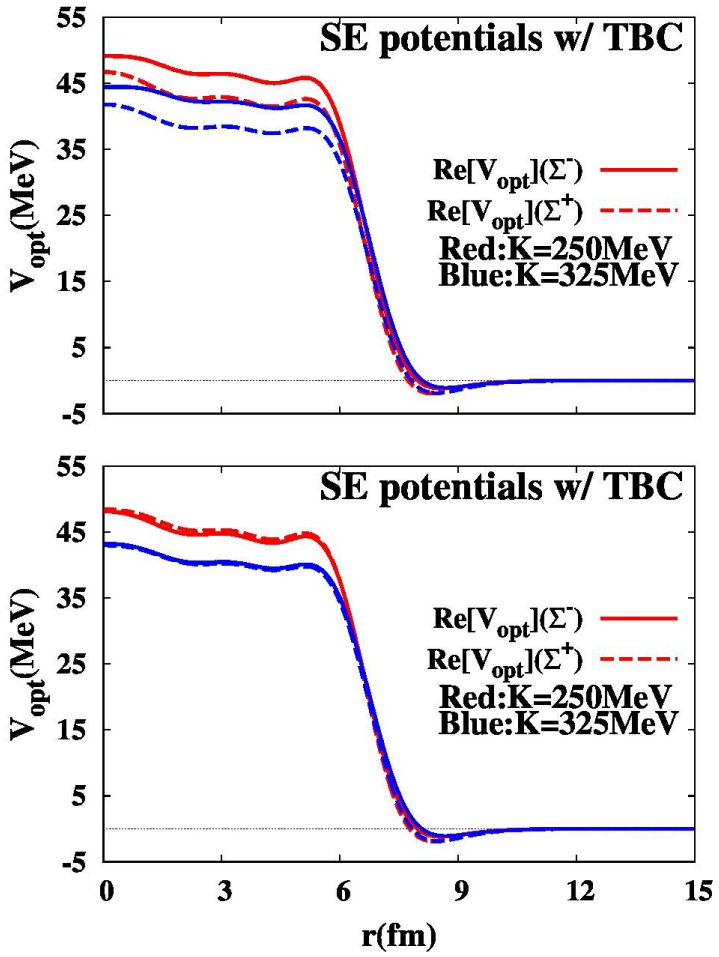


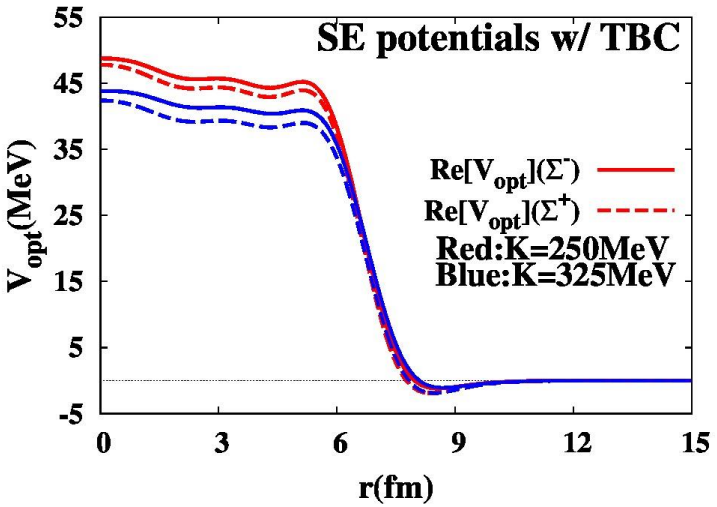
Results: S_Λ from single Λ hypernuclei



- Role of incompressibility to S_Λ ⇒ Almost free if we decide n=3 couplings where Λ participate
  ⇔ We can determine the strengths of n=3 couplings of Λ enough to each parameter set characterized by the incompressibility.

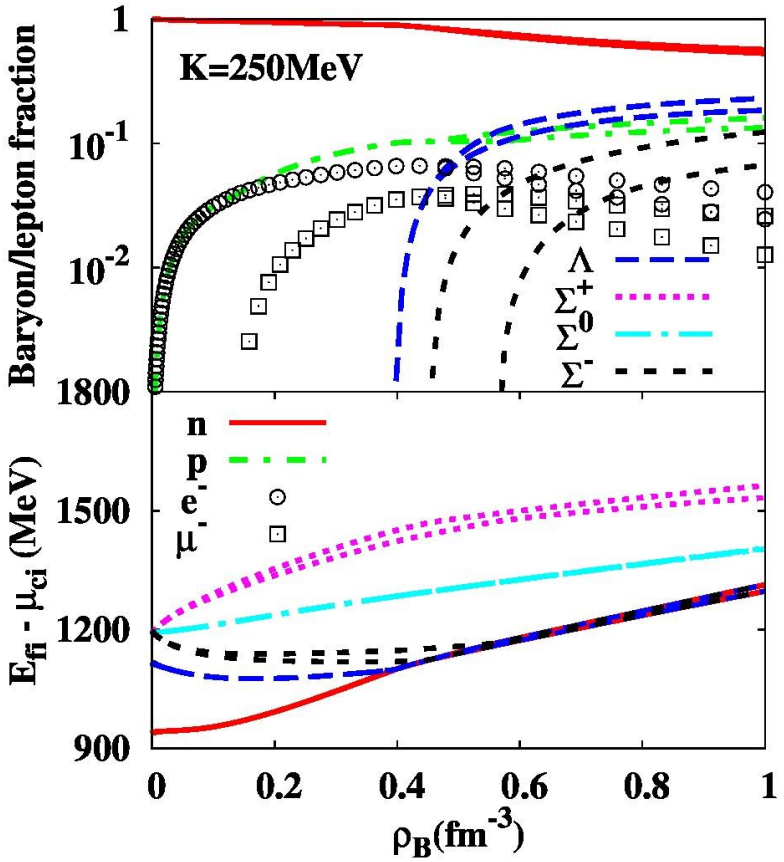
Results: Σ^- optical potential

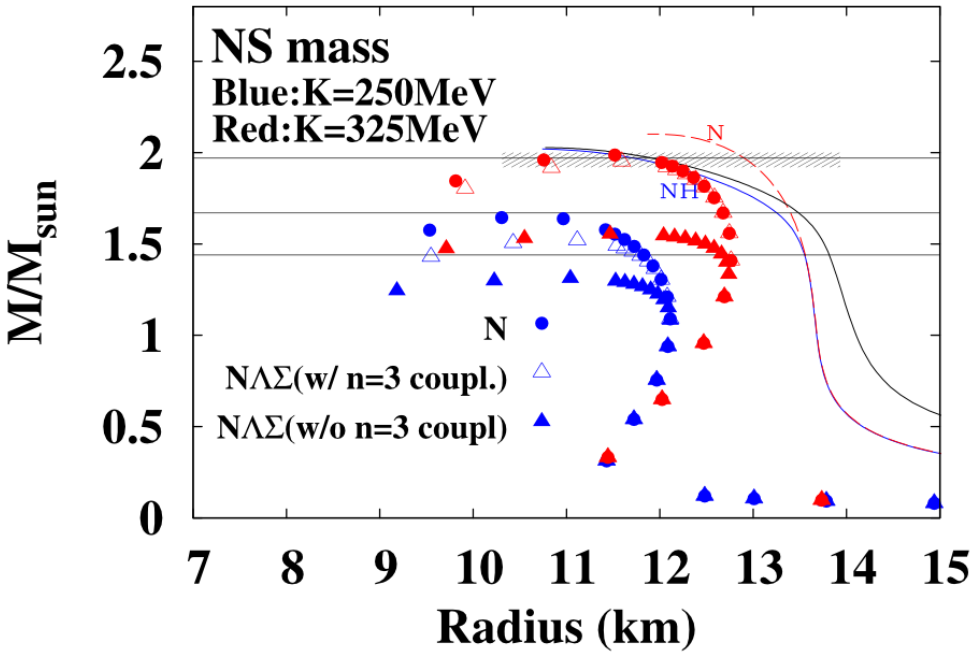




Smaller hypernuclear symmetry energy: 5∼0MeV suggested from factorized n=3 coupling of Σ^-

Baryon Fraction plot with μ





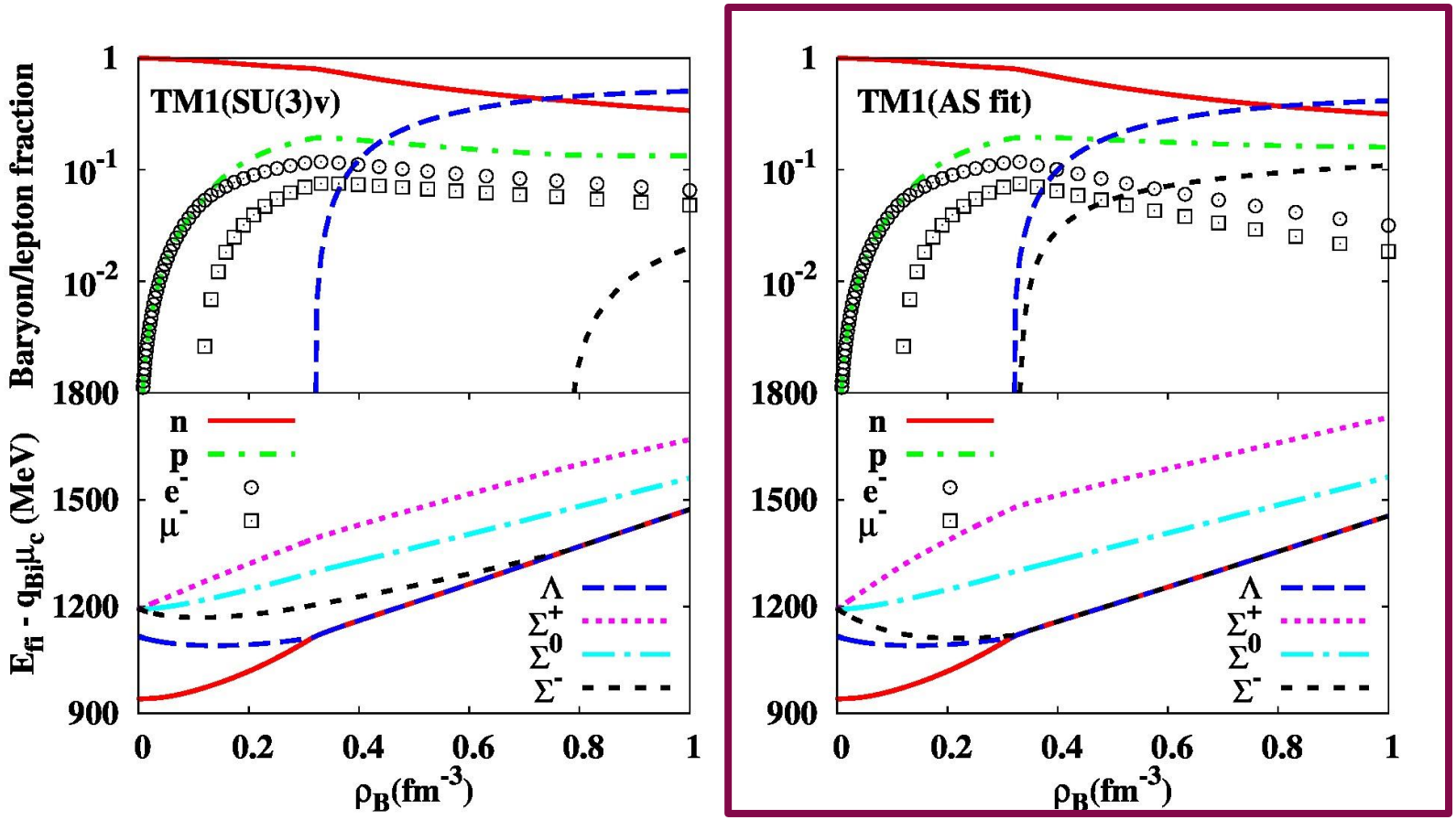
- Emergence of hyperons is pushed to higher ρ_B region.
- Calculated NS mass can excess $2M_\odot$ although hyperons are taken into account.(K=325MeV)

②Isovector pot. of hyperons

FOR UNDERSTANDING COMPOSITION OF NS

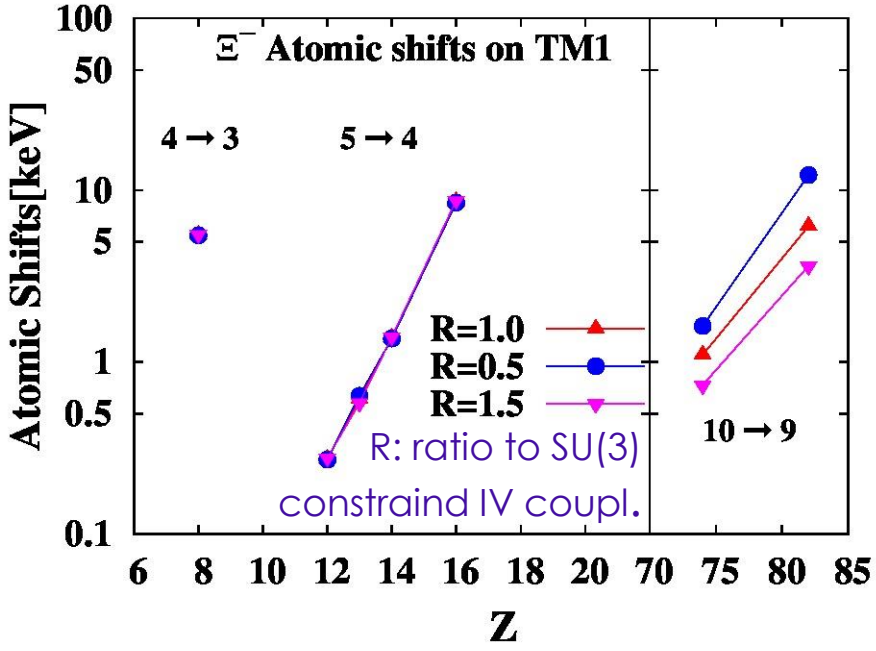
Σ^- fraction in NS EOS

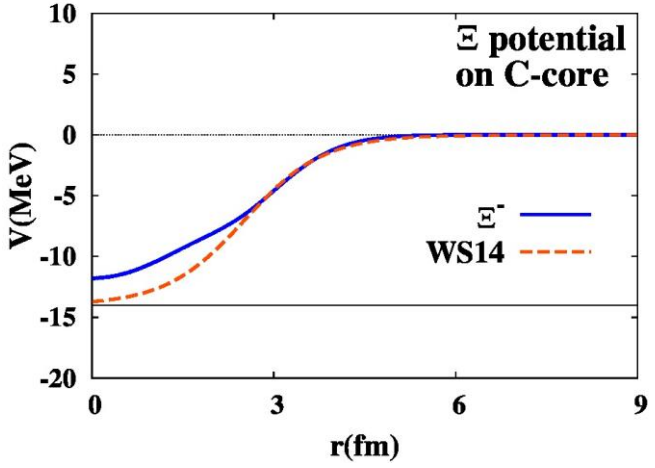
- For simplicity, we start from TM1 RMF model (n=2 coupl. and U_{eff})

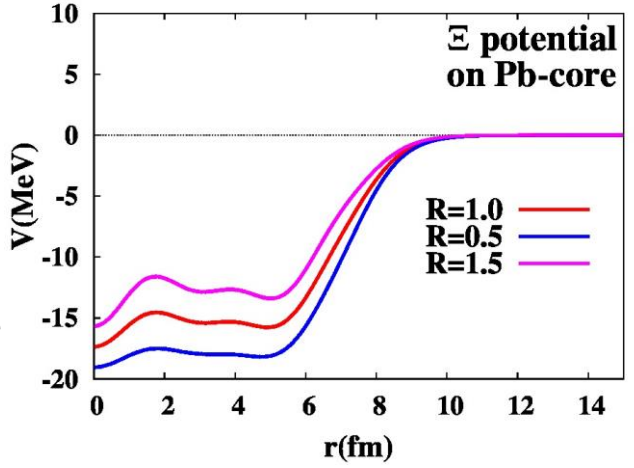


Ξ^- Atomic Shifts (Preliminary results)

- Difference from isovector(IV) pot.

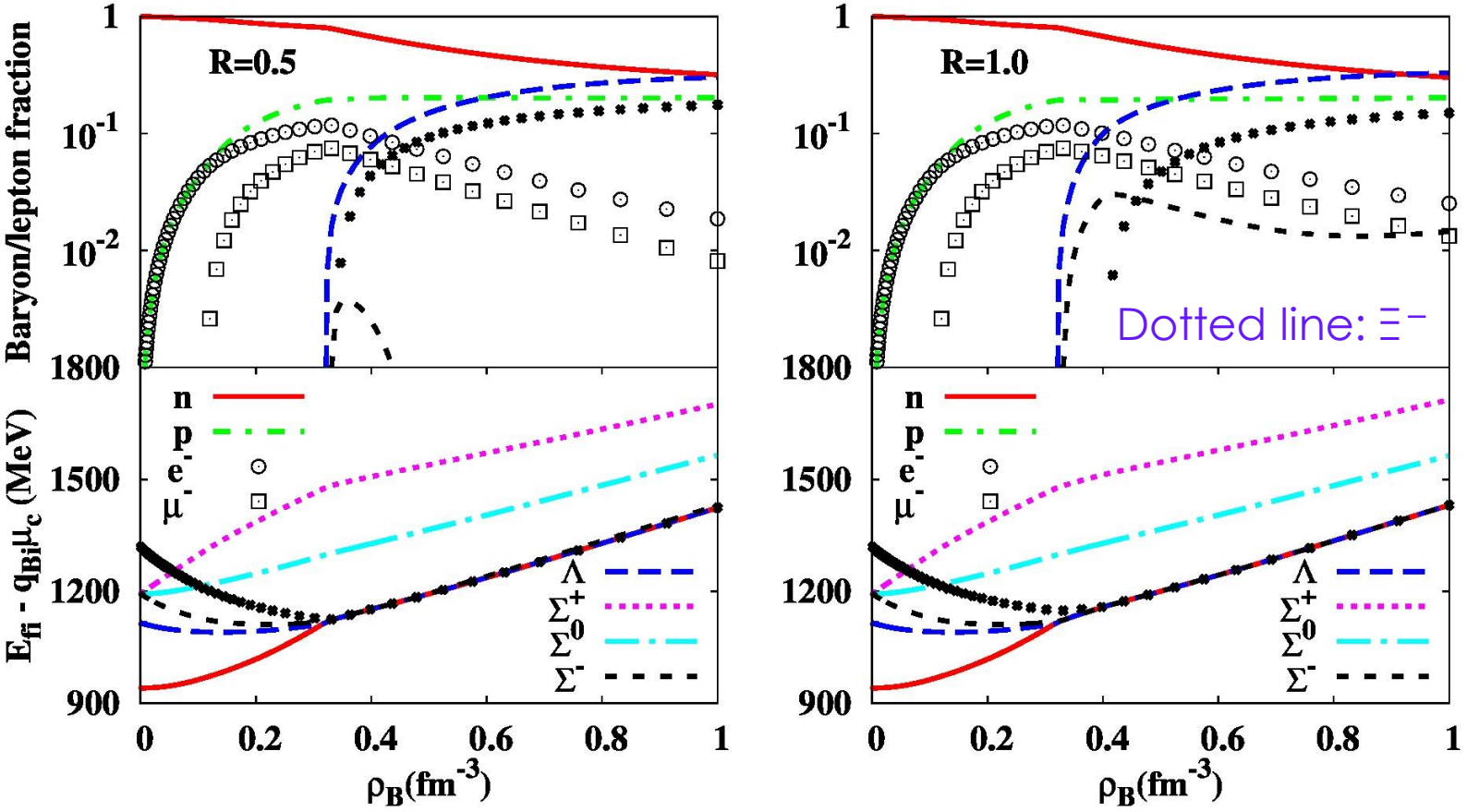






- Difference on Ξ^- AS: seen in heavier core
- Almost free from hyperon-hyperon int.
  ⇒constrained by SU(6)/SU(3) symmetry

Baryon Fraction of Σ and Ξ (Preliminary results)



Σ^- may survive in NS matter even if Ξ^- is taken into account (U_Ξ(12C-Ξ^-)=-14MeV).

Summary

- Σ^- may allow to emerge in NS matter EOS if we respect the experimental results of Σ^- atomic shifts.
- Ξ^- may be dominant negative-charged hyperon but $\Sigma-$ may also survive and that depends on Ξ^- IV interaction which may be examined by Ξ^- atomic shifts.
- n=3 couplings in RMF model:
  well characterized by incompressibility and constrained by reproducing experimental/empirical values of nuclear/hypernuclear systems.
- Calculated NS mass excess $2M_{\odot}$(K=325MeV).
- Even if we introduced n=3 coupling to Σ^-, Σ^- may appear in NS EOS as substitute of negative particles.

Thank you for your listening.

THAT'S ALL.