

Hypernuclear Physics (+ α) — Theoretical Aspects —

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1. What We Can Do with 50 GeV PS Machine ?

- ★ 50 GeV proton / 25 A GeV HI / Various Secondary Beams

2. Towards the Highest Density Matter

- ★ Hadronic Matter Phase Diagram
- ★ Towards the Highest Density Matter in Lab.
- ★ Towards the Highest Density Matter in the Universe

3. Desired Strangeness Nuclear Physics Experiments (from a Hadronic Matter Physics View Point)

- ★ Potential Depth of Y , incl. p -dep.
- ★ NY Interaction incl. High Partial Waves
- ★ Low-E. YY and YYY Interaction
- ★ Kaonic Nuclei \leftrightarrow $\Lambda(1405)$ Nuclei
- ★ GMR and GTR of HyperNuclei
- ★ YY Collider (?)

4. Summary

What We Can Do with 50 GeV PS Machine ?

● Primary Beams: 50 GeV proton / 25 A GeV HI

- ★ Proton Beam: 600 MeV \sim 50 GeV (2 orders Energy Range !)
 - ★ Multifragmentation (Banpaku)
 - ★ Production of Various and Multi Particles (Miake)
- ★ HI Beam: 25 A GeV
 - Most Dense Hadronic Matter Formation in Lab.
 - ★ Hydrodynamical Evol., Caloric Curve, EOS, ...
 - ★ Hadrons in Dense and Hot Matter

● Secondary Beams:

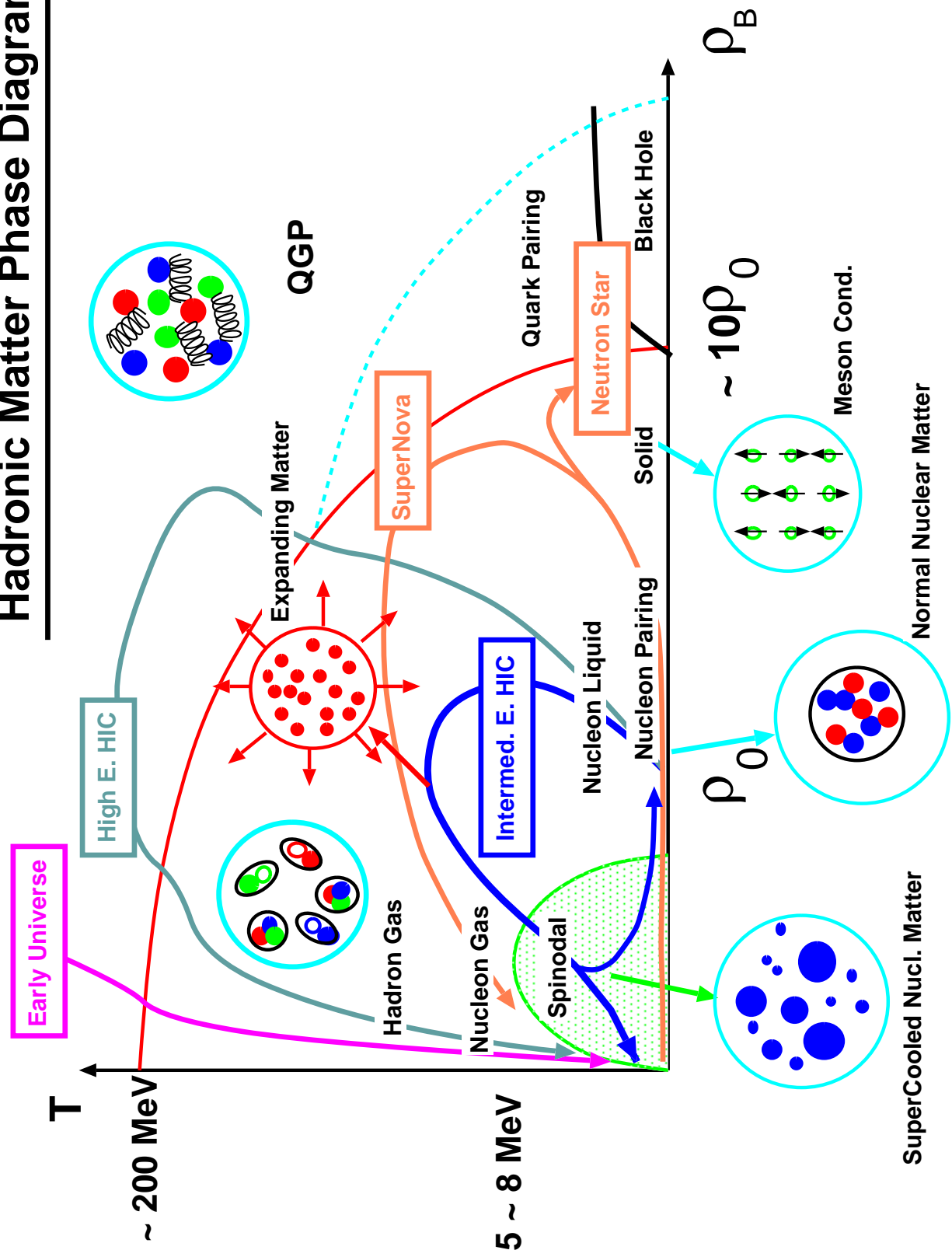
- ★ Exotic Nuclei, Neutron, Muon, Neutrino, Anit-Proton, ...
- ★ Intense Pion/Kaon Beam
- ★ Hyperon Beam (?)



Suitable for studying "Hadronic Phase Diagram"
esp., "Highly Dense Matter incl. Strangeness"

- Proton Beam: Elem. Proc., incl. Res.
- HI Beam: EOS of Dense Matter
- Pion/Kaon Beam: Strangeness Production, Υ Potentials

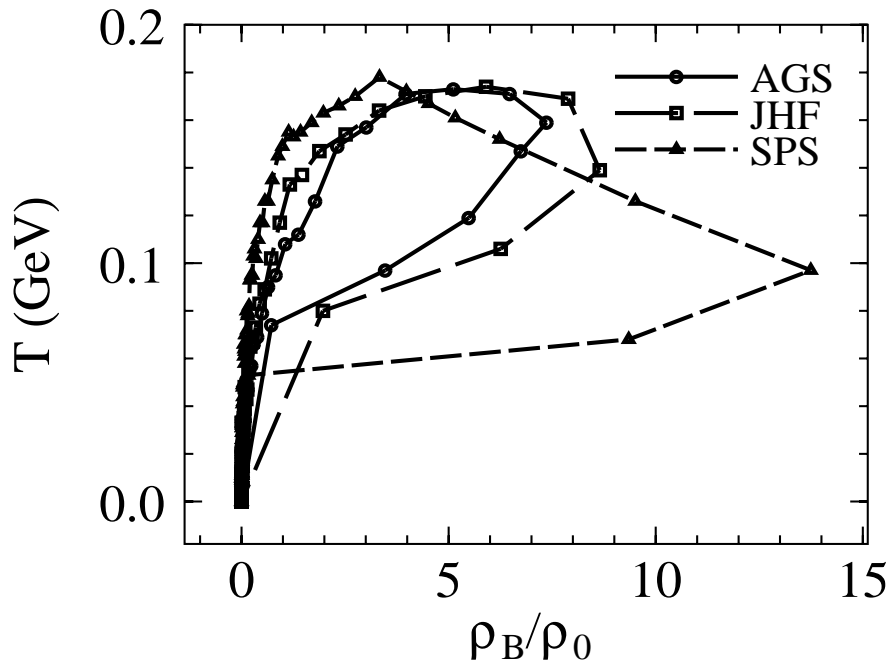
Hadronic Matter Phase Diagram



Toward the Highest Density Matter in Lab.

• HI Collision at 25 A GeV

- ... can (may) make the Highest Density Hadronic Matter at Approximate Equilibrium



(JAM Calc., Y. Nara, FRONP99, 8/2-4, 1999 at JAERI)

• Three Major Topics in HEHI

1. Collective Flow: EOS at **High Density**
2. Low-Mass Lepton Pair: Hadron Masses at **High Density**
3. High-Mass Lepton Pair: J/ψ Suppression at **High Temperature**



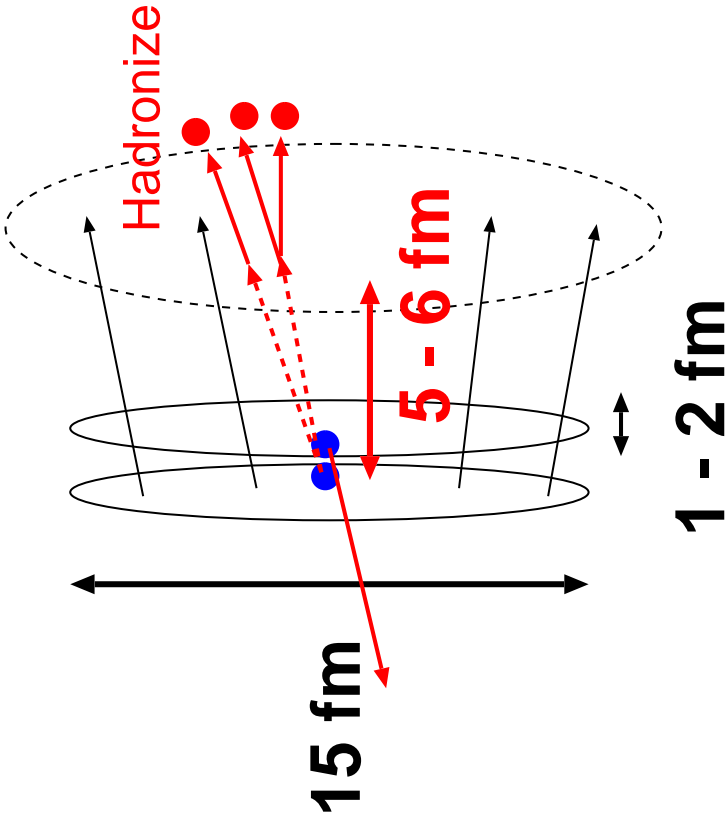
Study of Highly Dense Hadronic Matter

is **NECESSARY**

and it's difficult to make at SPS and RHIC Energies
(e.g.: 40 A GeV @ SPS)

SPS Energies

$\gamma_{\text{cm}} \simeq 10$, $\tau \simeq 0.5 - 1 \text{ fm}/c$

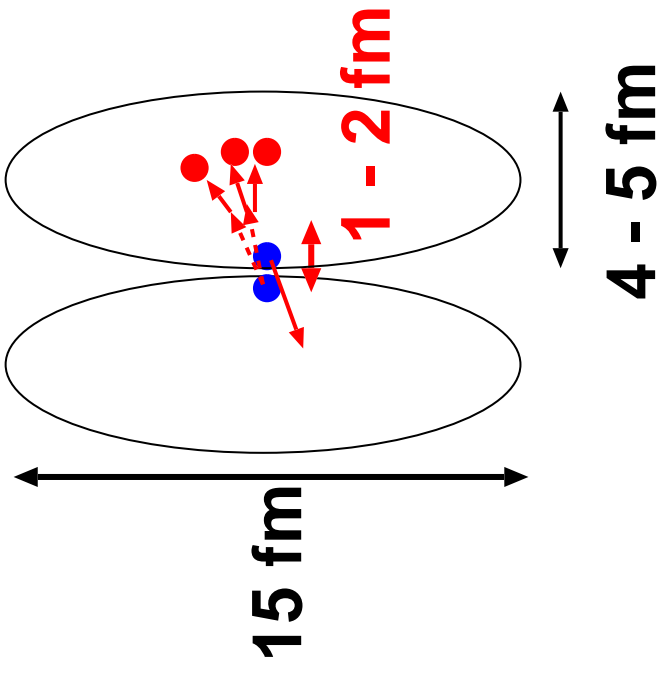


String-String, String-Hadron Int.

+ Int. within Co-Movers

JHF Energies

$\gamma_{\text{cm}} \simeq 3.5$, $\tau \simeq 0.5 - 1 \text{ fm}/c$



Multiple Hadron-Hadron Collisions

☞ (Approx.) Thermalized Hadron Gas

Toward the Highest Density Matter in the Universe

• What Happens in the Neutron Star Core ?

★ Neutron Superfluid (1S_0 , 3P_2)

★ Pion Condensation

★ Hyperon Matter ← Strangeness

··· Tsuruta-Cameron (66), Langer-Rosen (70), Pandharipande (71), Itoh(75), Glendenning, Weber-Weigel, Sugahara-Toki, Schaffner-Mishustin, Balberg-Gal, Baldo et al., Vidana et al., Nishizaki-Yamamoto-Takatsuka...

★ Kaon Condensation ← Strangeness

··· Kaplan-Nelson(88), Forkel-Rho et al.(SUNY), Davidson-Miller, Claymans et al., Politzer-Wise, Miller et al., Muto-Tatsumi, Brown-Thorsson-Lee-Rho-Min, Fujii et al., Yabu et al, Maruyama et al., Ellis-Knorren-Prakashi (with Y), Li-Ning, Li-Brown, Tiwari-Prasad-Singh, Glendenning-Schaffner,

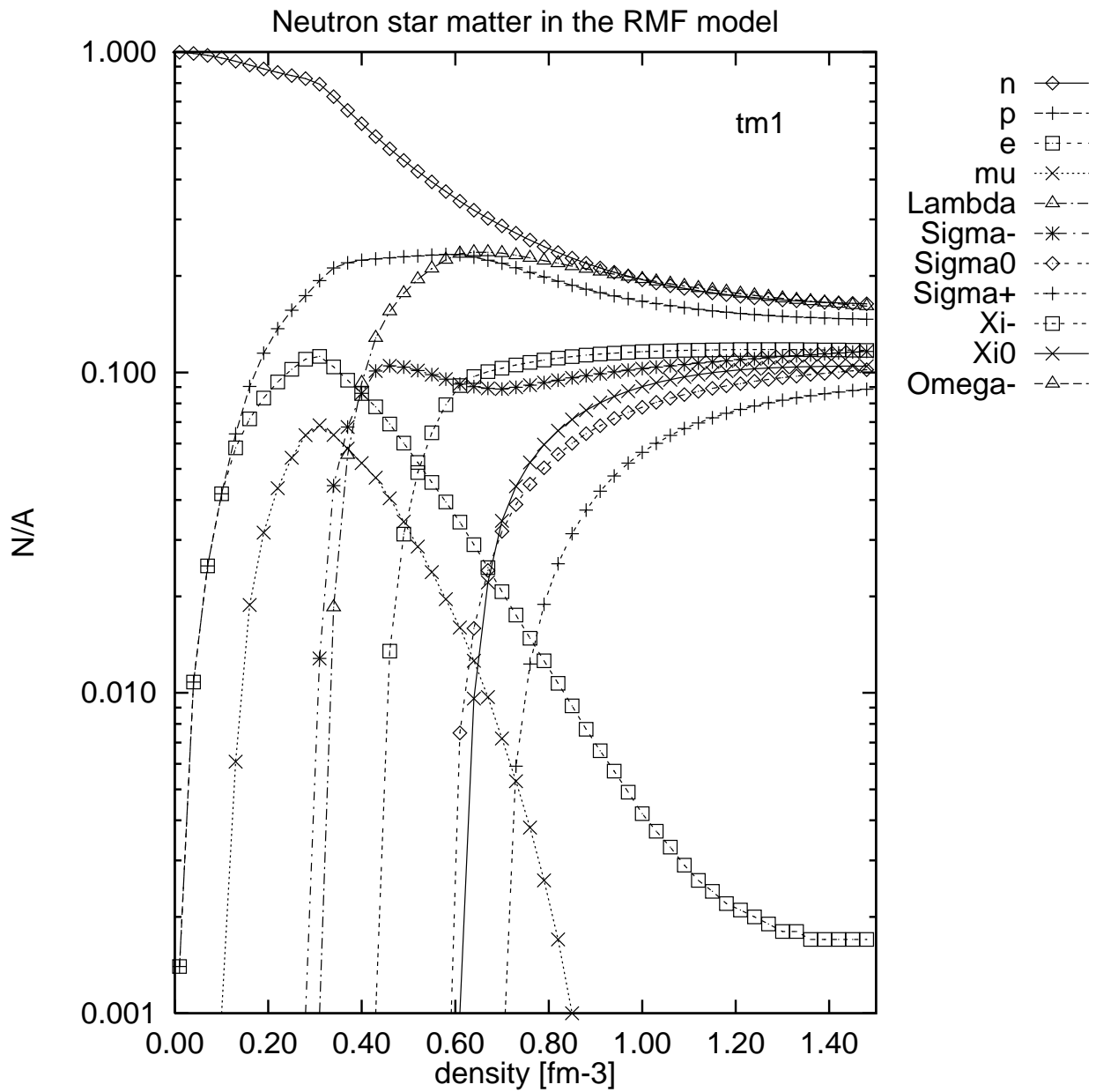
★ Quark-Gluon Plasma



We cannot understand
Highly Dense Hadronic Matter
without the Knowledge of
Strangeness Nuclear Physics

Hyperon Composition in Dense Matter

Schaffner-Mishustin, PRC53(96)1416 (TM1+SU3)

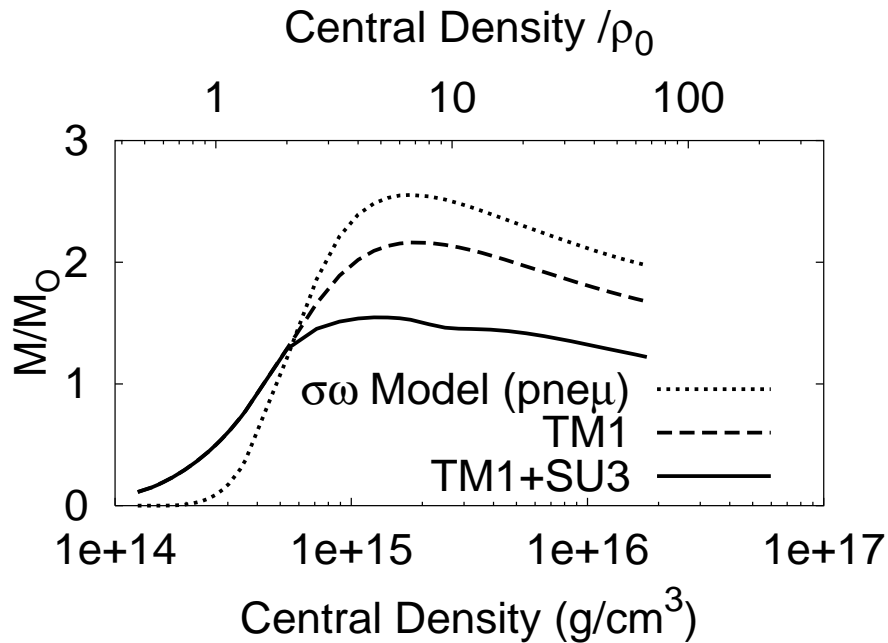


→ SU(3) Symmetric Matter

Hyperon Effect on Neutron Star

- Neutron Star Max. Mass $\dots M_{max}$ Reduction $\simeq 0.5-1.0 M_{\odot}$

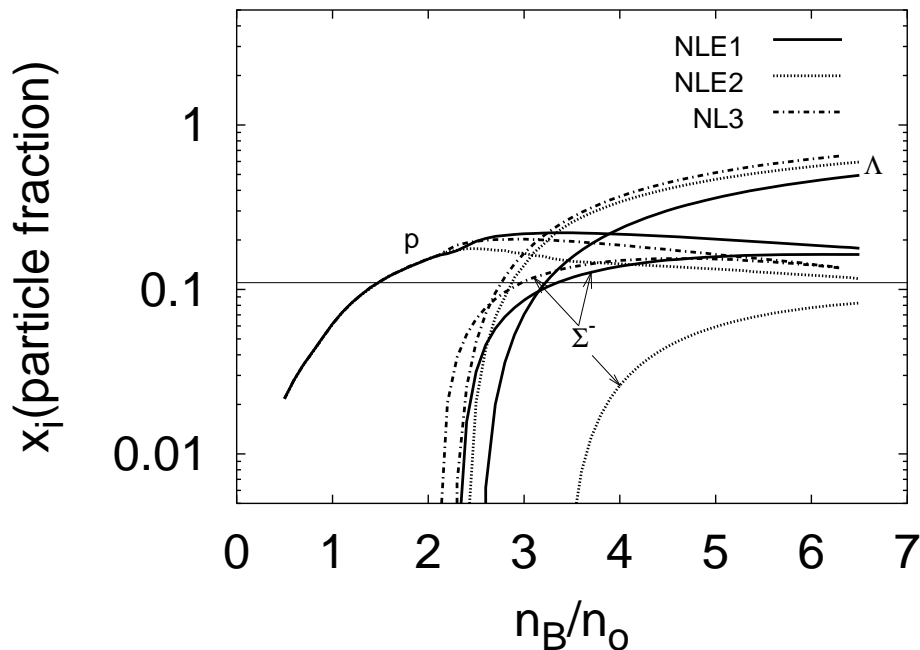
A. Isshiki-A.O., JPS@Akita; Selot-Walecka ($\sigma\omega$);
Sugahara-Toki (TM1); Schaffner-Mishustin (TM1+SU3); Glendenning



- Σ Potential Effect in Hyperon Composition

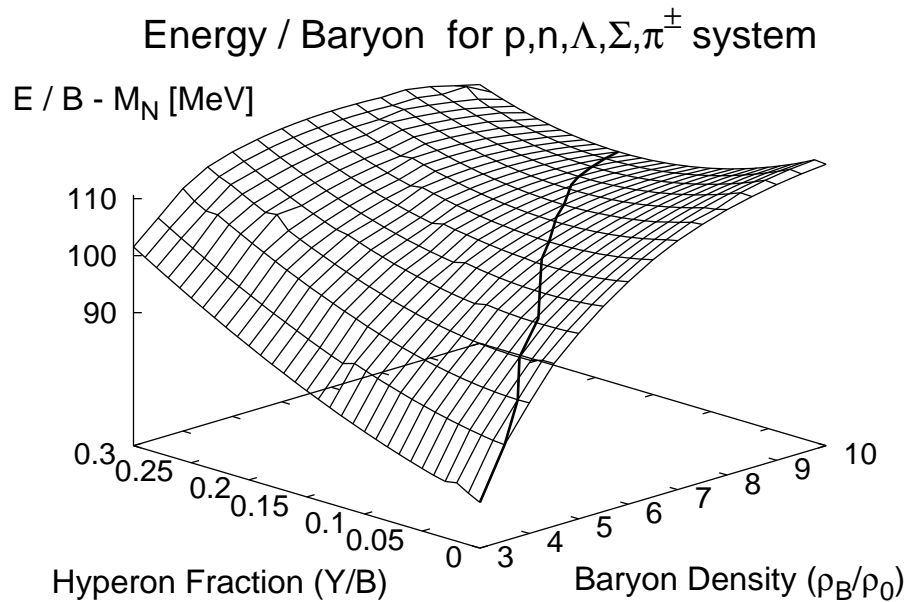
\dots Large Dep. on $U(\Sigma^-)$ ($-30 \text{ MeV} \sim +10 \text{ MeV}$)

P.K.Sahu, submitted



• Coexistence of Hyperons and π Condensation

A. Isshiki-A.O., to be submitted.



... $\rho \geq 3.5\rho_0$, without Isoscalar Mean Field (cf. $\rho_c \simeq 7\rho_0$ for F.G.)



Too much THEORETICAL conjectures

NEED Experimental Data

... What is Necessary ?

What is Necessary to understand

High Density Hyperon Rich Matter (HRM) ?

• Equation of State and (Weak) Transition Rate

at Various Strangeness Fraction and Z/A Ratio

$$\text{EOS: } P = \varepsilon(\rho_B, T, Y_l/Y_B, -S/B)$$

★ Can you Determine **EOS of Dense (and Cold) HRM**

under Various Condition ? ($T, -S/B, Z/A, \dots$)

★ Can you Measure **Weak Transition Rate** at Various Density ?

• Baryon Effective Int. and Weak Decay of HyperNuclei

” Effective Int. \rightarrow EOS”

+ ” Verification of Constructed EOS”

★ Can you Measure the **InCompressibility (K)** of HRM ? (\rightarrow GMR)

★ Can you Measure **Landau-Migdal Parameters for Hyperons**

($g'_{\Lambda\Sigma}, g'_{\Lambda\Sigma^*}, g'_{\Sigma\Sigma^*}$) ? (\rightarrow G.-T. Trans. of Hyp.Nucl.)

★ Can you Measure the **Potential Depth** of Hyperons at Various ρ_B ?

(\rightarrow QF Hyperon Prod., YA Scatt., Hyperon Flow)

★ Can you Solve **Γ_n/Γ_p Puzzle** Experimentally ?

★ Can you Measure **P-wave (or more) YN Int., YY Int. and YYY**

(**Hyperon 3-body**) Int. in Medium ? (\rightarrow Spectroscopy of $S = -1, -2, -3$ Hyp. Nucl.)

★ Can you Measure **Anti-Kaon Interaction in Medium** ?

(\rightarrow Kaonic Nuclei, K^- Prod., ...)



Is Your Eff. Int. Consistent with Bare Int. ?

• Baryon Bare Int., T -Matrix incl. Weak Vertex

"Bare Int. \rightarrow Eff. Int."
 + "Verification of Constructed Eff. Int."

- ★ Is HyperNuclear Weak Dec. Consistent with **Weak Prod.** ?
- ★ Can you Measure **Bare YN and YY Int.** ? ($\rightarrow YN$ Scattering, YY Corr.,...)
- ★ Do We Understand **Elem. Strangeness Exch./Prod. Processes** Correctly ? (\rightarrow Particle Prod.)

