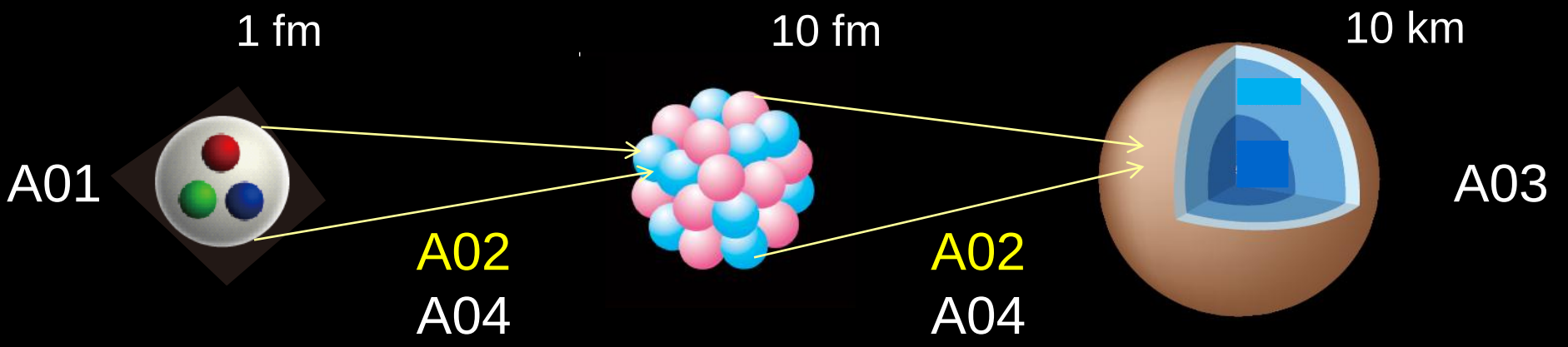
[Group A02] *Nuclear Physics from QCD*



Hadron int. from LQCD
S. Aoki (Tsukuba)
N. Ishii (Tsukuba)
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Ab initio Many-Body Cal.
T. Otsuka (Tokyo)
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Dense Matter
A. Nakamura (Hiroshima)
M. Takano (Waseda)
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S. Ozaki (Tokyo)

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K. Murano (RIKEN)

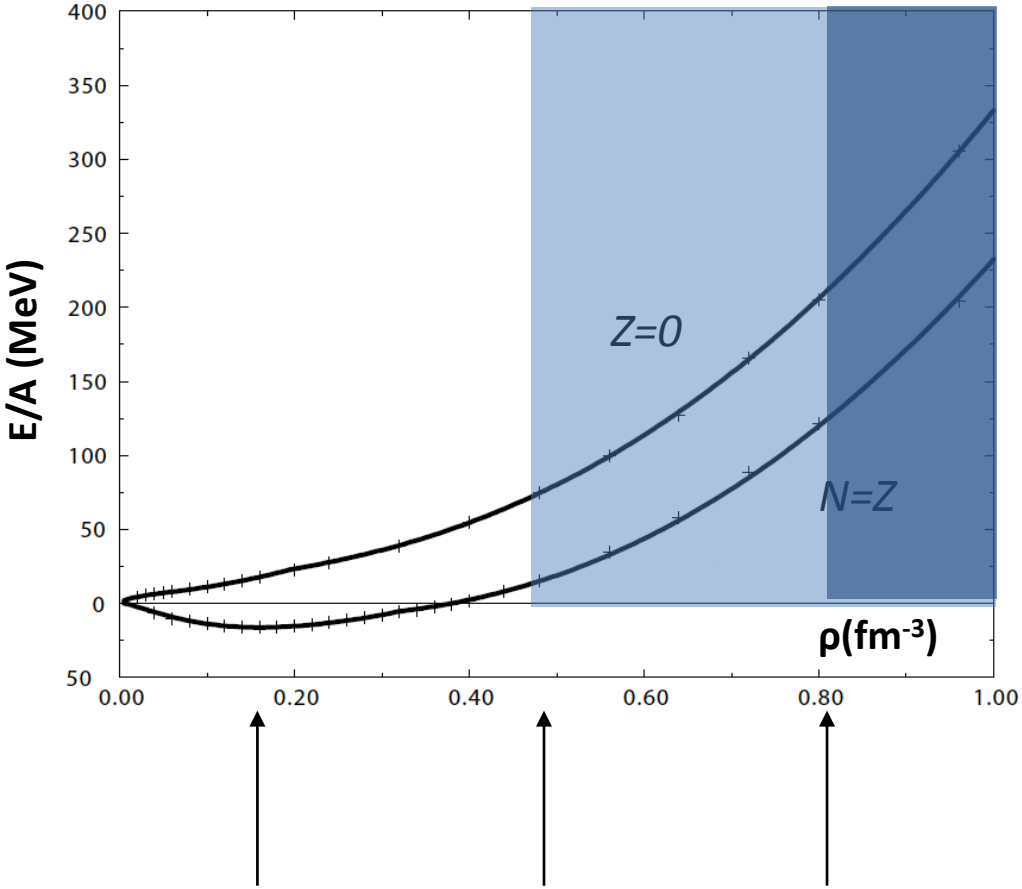
TD-DFT
T. Nakatsukasa (RIKEN)
K. Yabana (Tsukuba)
K. Sato (RIKEN)

T. Hatsuda (Tokyo/RIKEN)

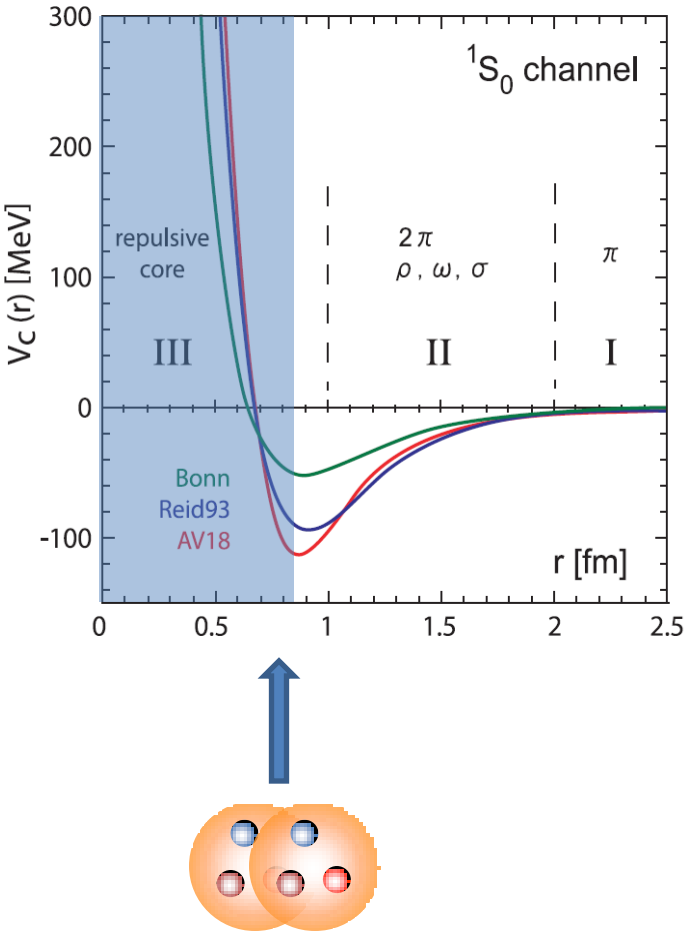
⟷ HPCI Field5 Subject 1

Dense Matter EoS and Nuclear Force

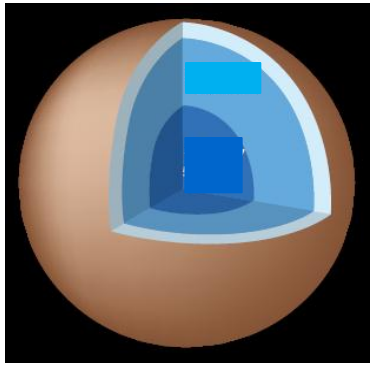
Akmal, Pandharipande & Ravenhall, PRC58 ('98)



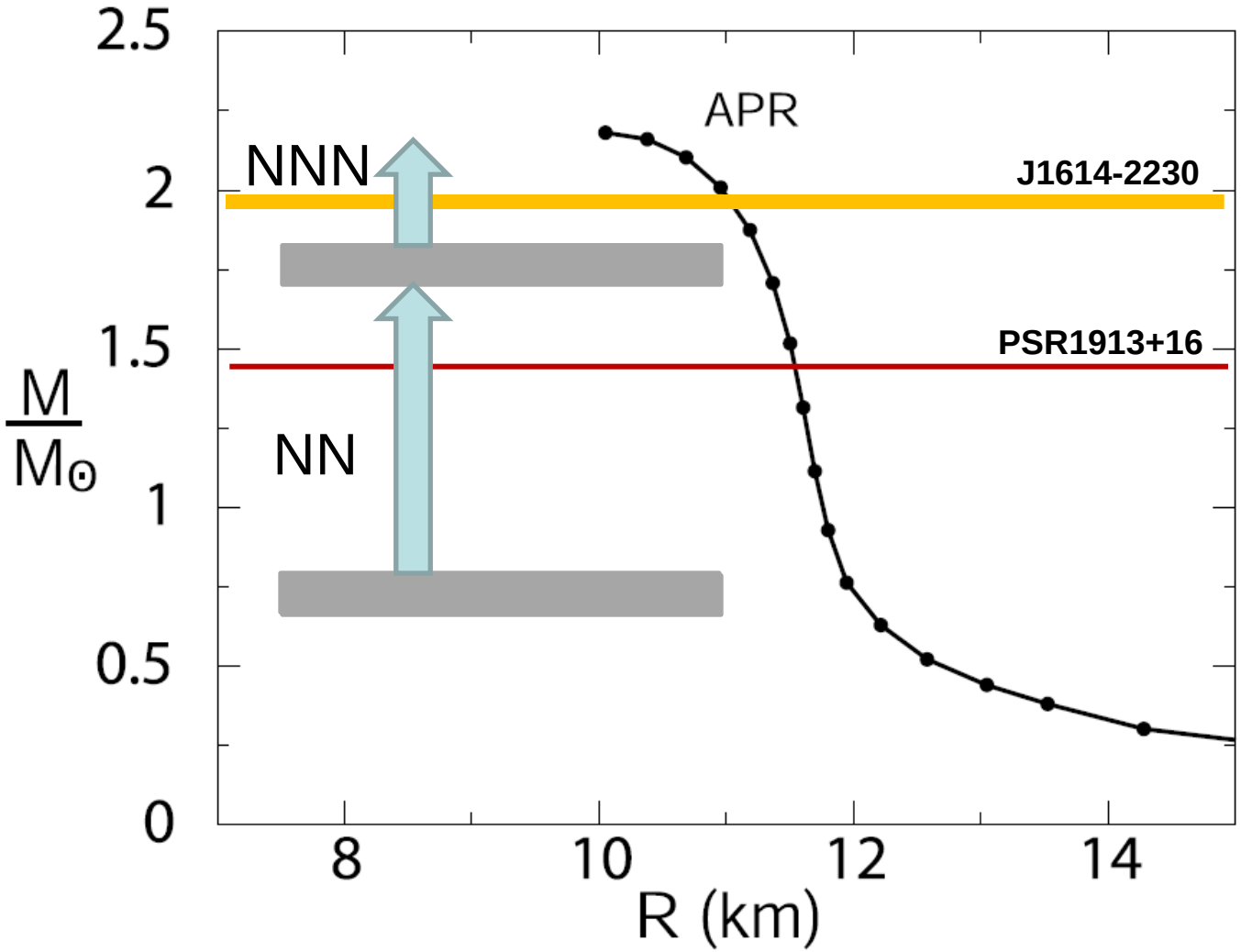
Phenomenological NN forces



Nuclear Force and Neutron Star

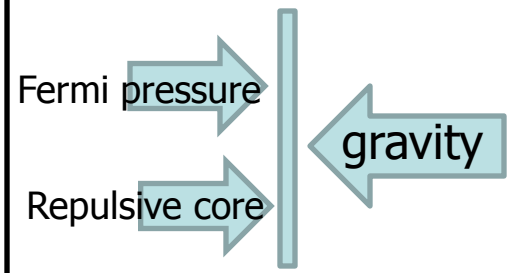


($\rho_{max} \sim 6\rho_0$)



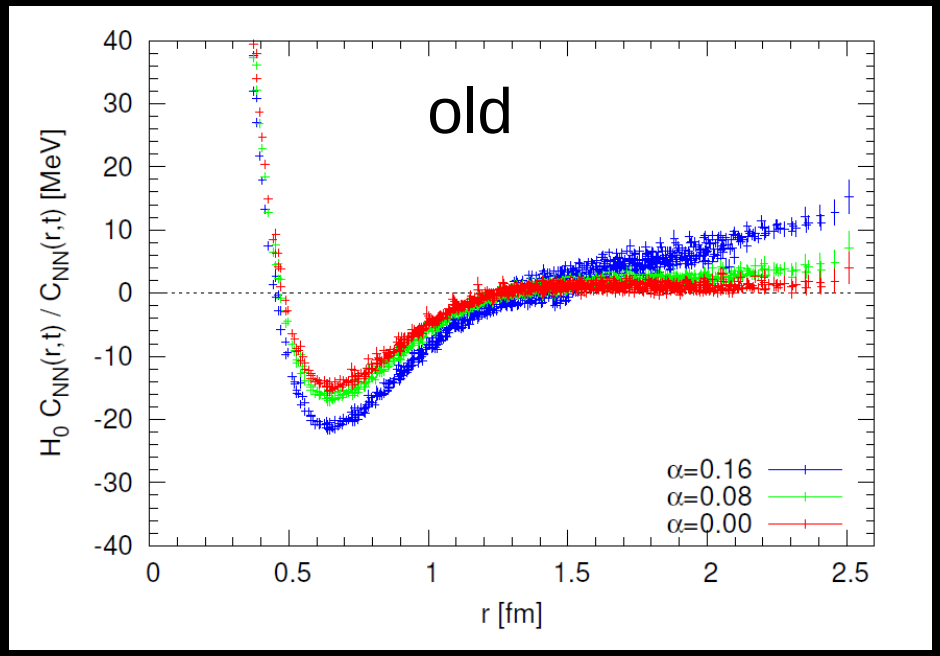
Neutron star binary

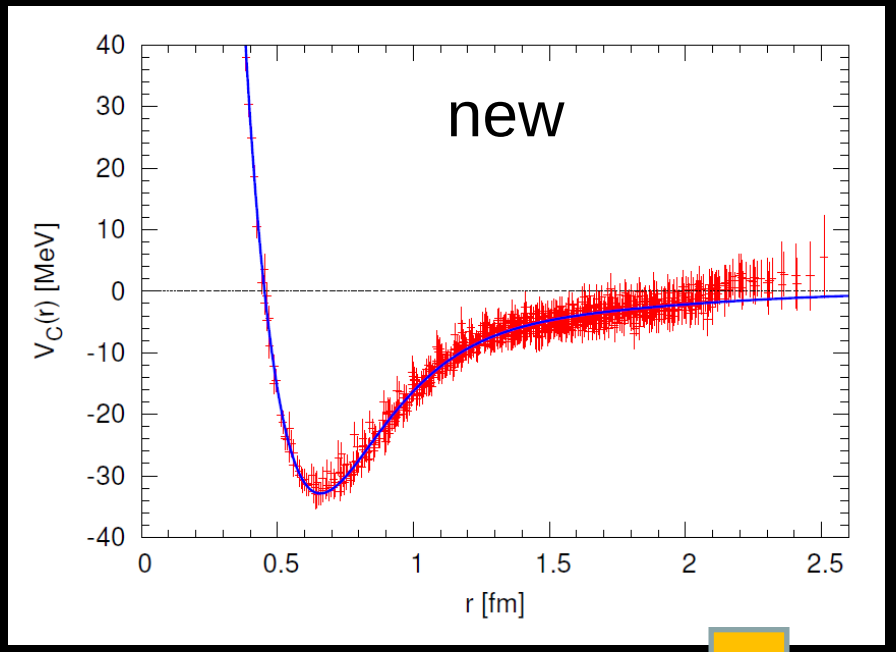
Pressure balance

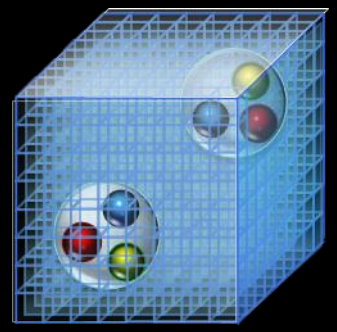


NN & NNN force from lattice QCD

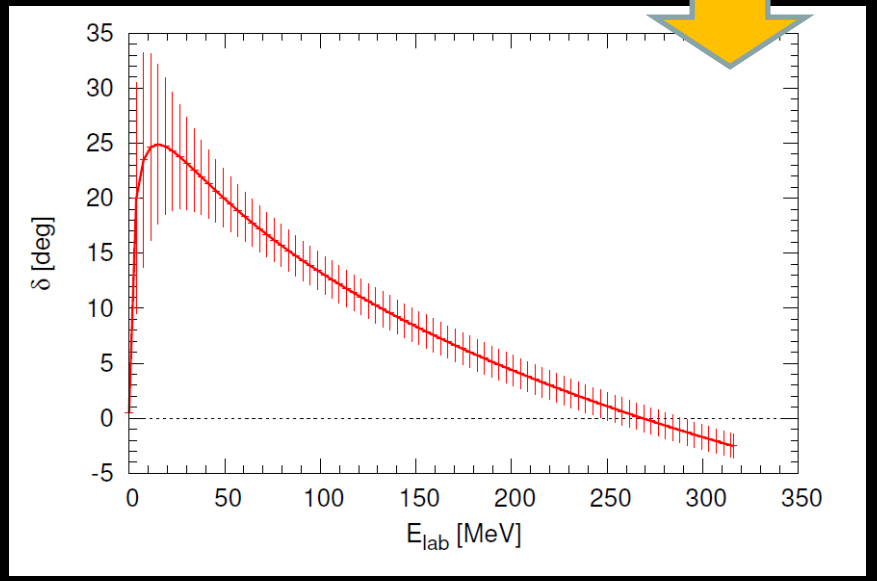
New method (Ishii method) to extract hadron potentials
(stationary Schroedinger eq. → time-dep. Schroedinger eq.)





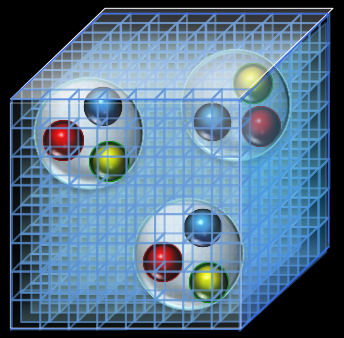


$^1S_0$ channel
(2+1)-flavor
m_π=701 MeV
a=0.091 fm
L=2.90 fm



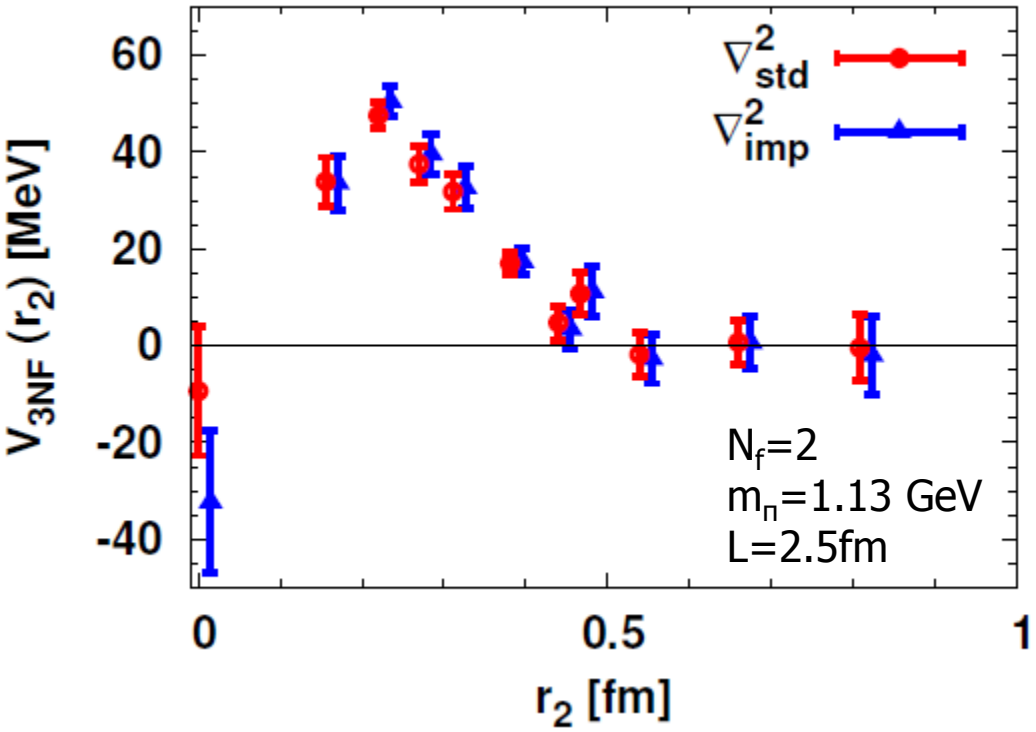
Hadrons to Atomic nuclei
HAL
from Lattice QCD

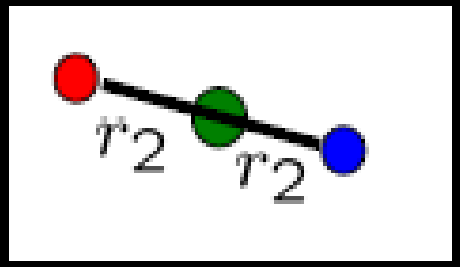
3N force from LQCD

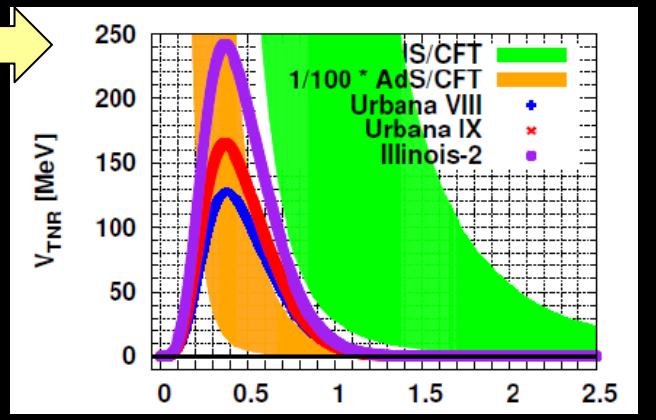


$$\psi_{3N}(\vec{r},\vec{\rho}) \equiv \langle 0|N(\vec{x}_1)N(\vec{x}_2)N(\vec{x}_3)|E_{3N}\rangle,$$

$$\left[-\frac{1}{2\mu_r}\nabla_r^2 - \frac{1}{2\mu_\rho}\nabla_\rho^2 + \sum_{i<j} V_{2N}(\vec{r}_{ij}) + V_{3NF}(\vec{r},\vec{\rho})\right]\psi_{3N}(\vec{r},\vec{\rho}) = E_{3N}\psi_{3N}(\vec{r},\vec{\rho}),$$

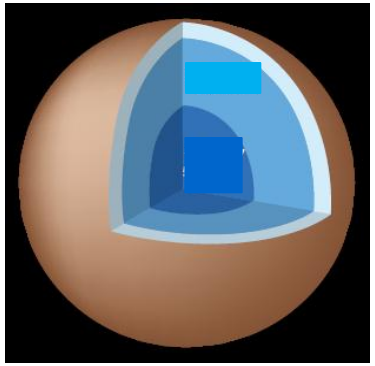


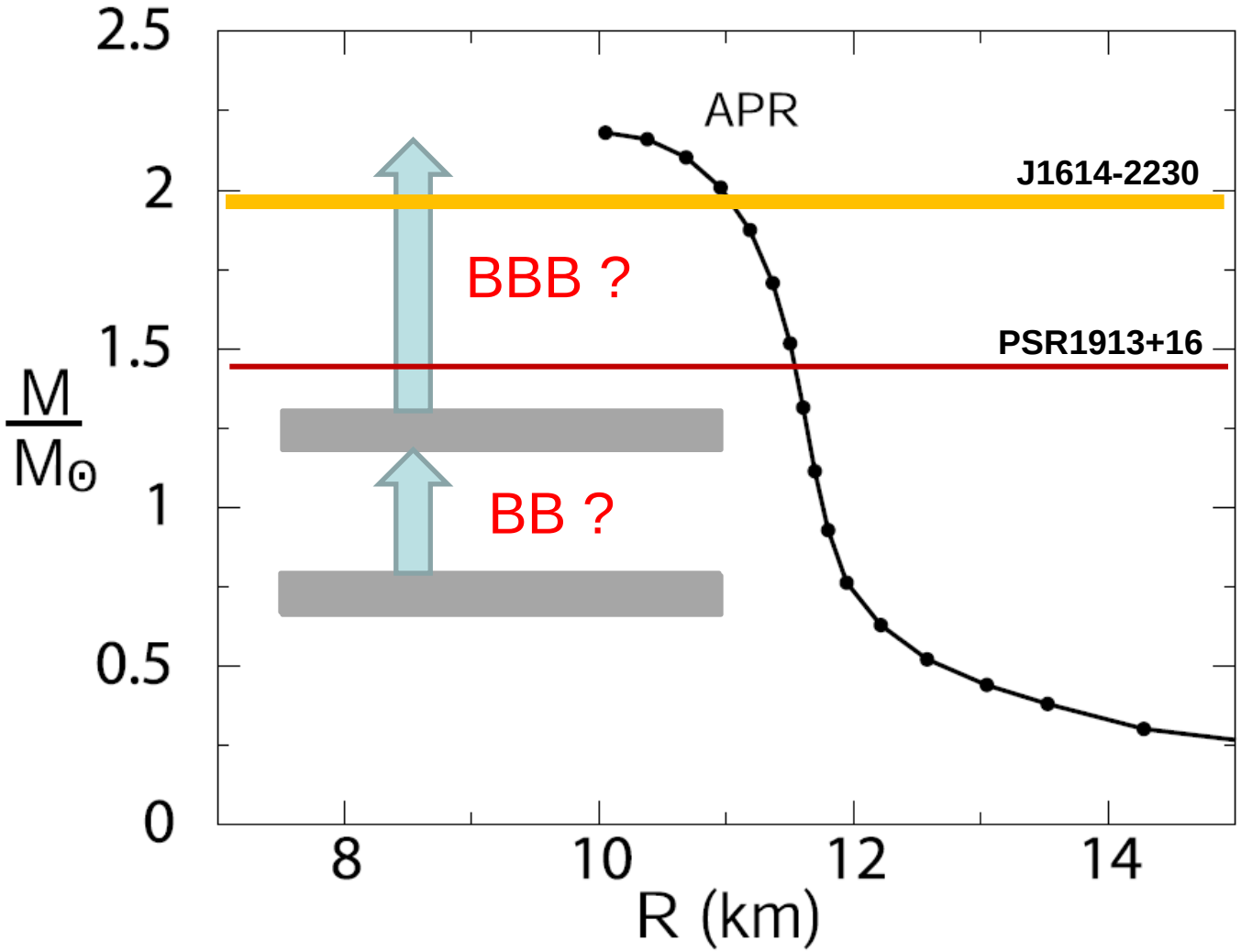




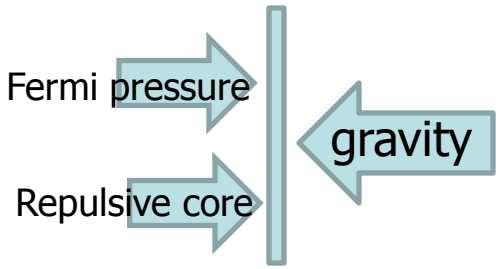
T. Doi et al [HAL QCD Coll.], arXiv:1106.2276[hep-lat]

Baryon Force and Neutron Star



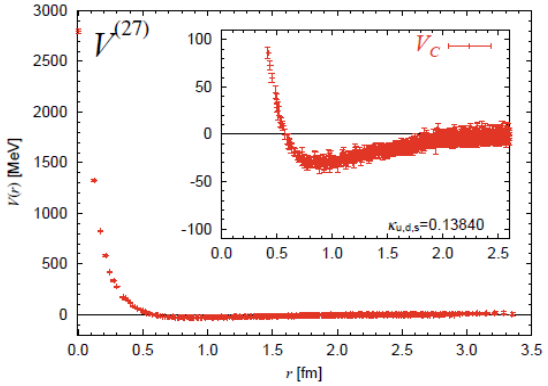


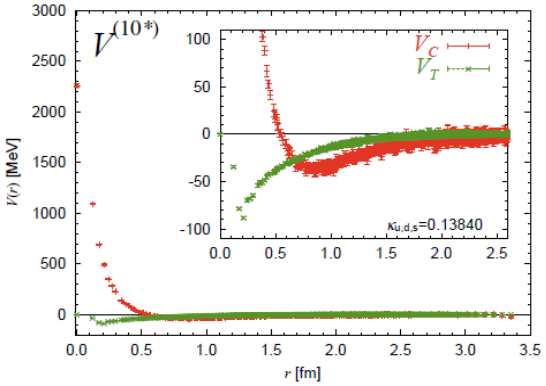
Pressure balance

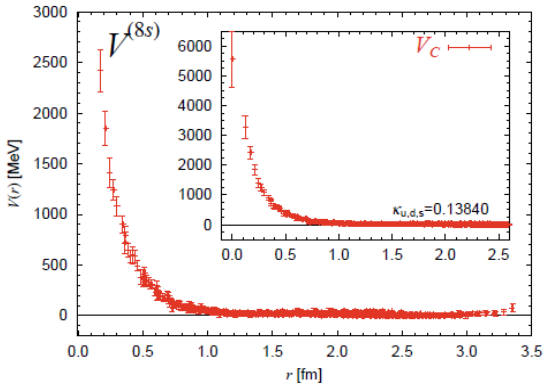


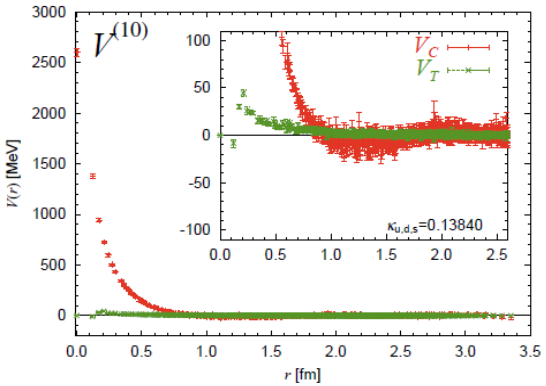
YN, YY force from lattice QCD

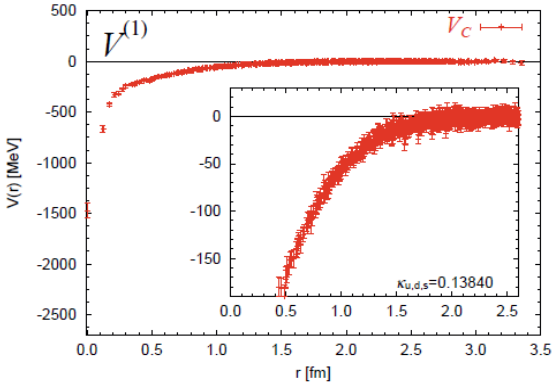
BB forces in the SU(3) limit with new method

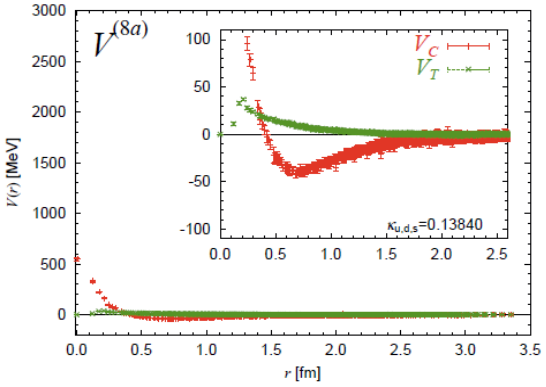


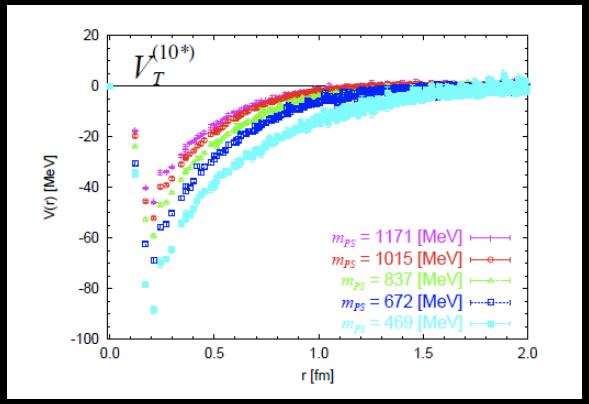


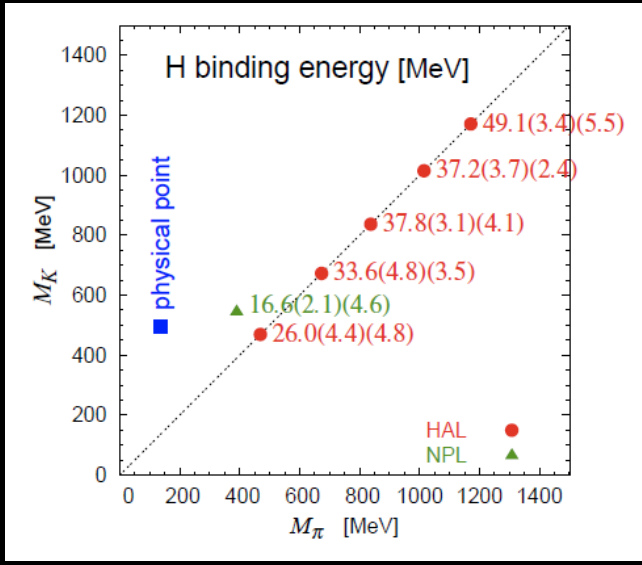








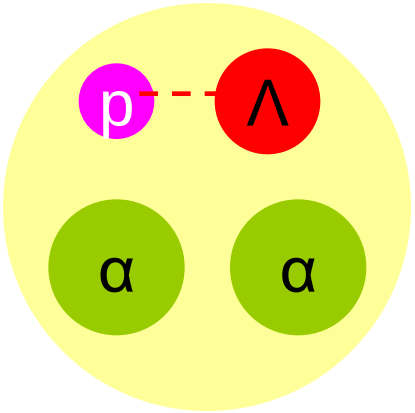




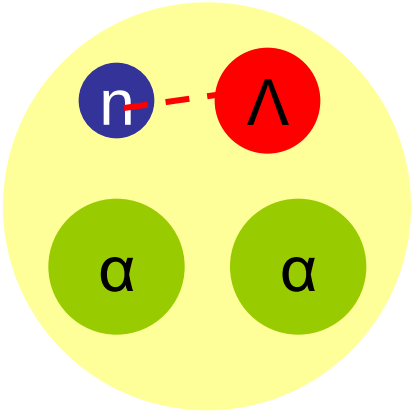
T. Inoue et al [HAL QCD],
PRL 106 (2011) 16202
NPA in preparation.

Ab initio nuclear few-body calculations

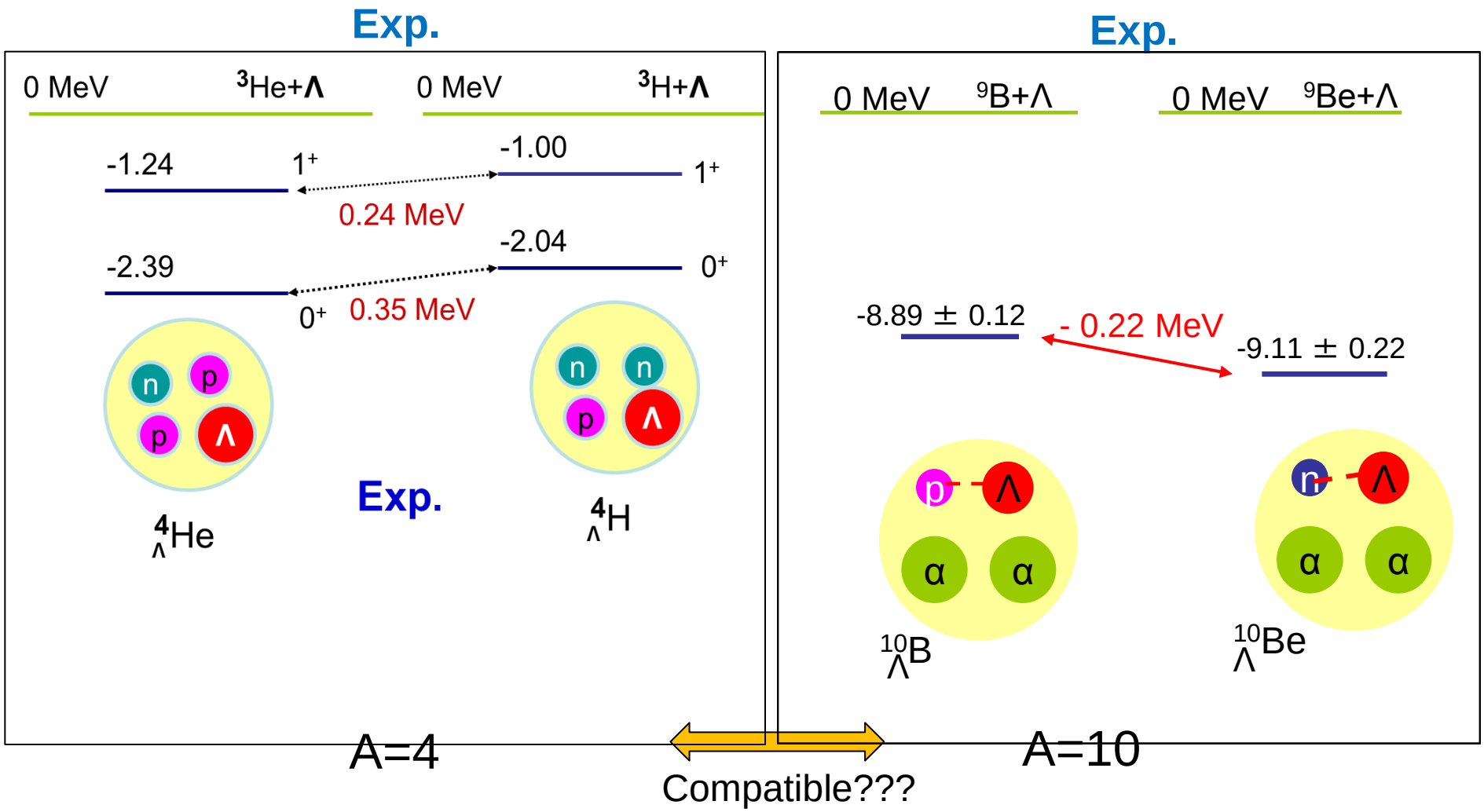
The study of four-body structure of these hypernuclei is important for the study of ΛN spin-dependent force and charge symmetry breaking interaction.



$^{10}_{\Lambda}$B



$^{10}_{\Lambda}$Be



Future exp.
A=4 at JLAB (^{4}He (e, e'K^{+}) $^{4}_{\Lambda}$H)
A=10 at J-PARC (to be proposed)

Exp: - 0.22 ±0.25 MeV
Cal: - 0.17 MeV (without CSB)
Cal: + 0.01 MeV (with CSB)

Hiyama, Zhang, Yamamoto (2011)

Ab initio nuclear many-body calculations

Nuclear Forces, Exotic nuclei and Stellar Evolution

T. Otsuka @ OMEG11

1. Novelties in nuclear forces and in their effects on the structure of exotic nuclei (e.g. shell evolution)

2. Tensor force : in-medium ~ bare (*no empirical tuning*)
   under the concept Renormalization Persistency
   -> shell evolution, resultant deformation (e.g., ^{42}Si), *etc.*

3. Fujita-Miyazawa 3-body force produces
   repulsive effective interaction
   between valence neutrons robustly.
   -> location of dripline (particularly, oxygen and calcium isotopes),
   shell evolution *contrary to shell quenching scenario (RIA white paper)*
   same force as the one relevant to neutron matter (star)

4. Visible effects on astrophysical phenomena
   electron capture by Ni isotopes
   3rd peak of the abundance
   R process, e.g., around ^{78}Ni
   More will come with K computer … suggestions welcome

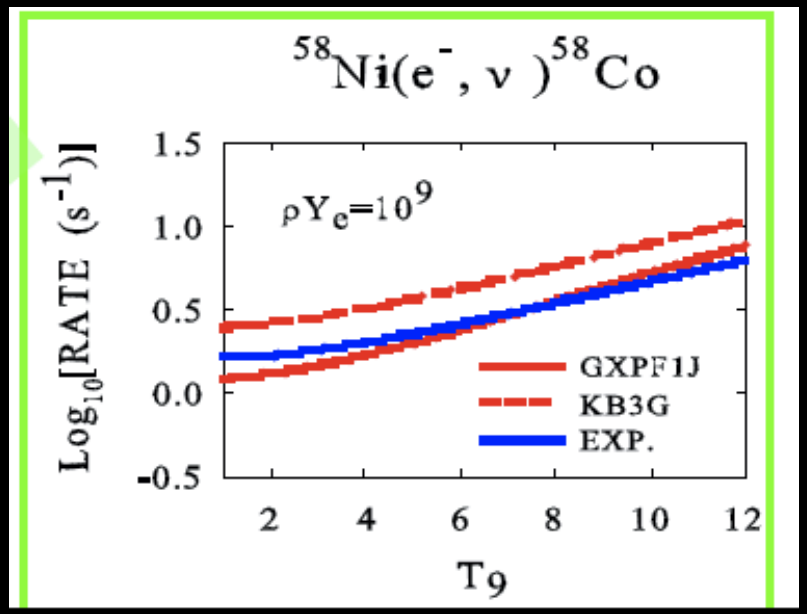
- GT strengths in Ni isotopes by new shell model Hamiltonians, GXPF1

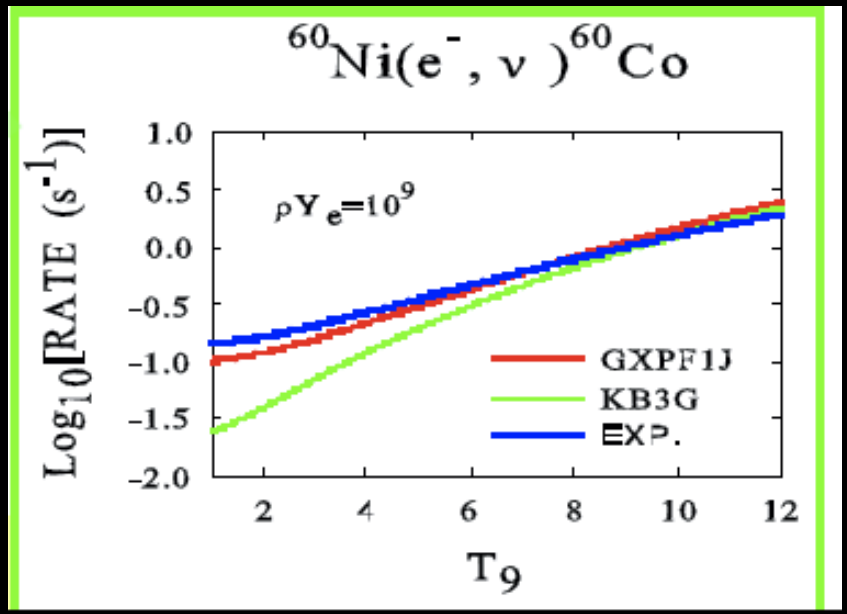
GXPF1 = microscopic G-matrix <-> tensor force
+ phenomenological corrections
<-> 3-body force

- Electron capture reactions in Ni isotopes in stellar environments

Suzuki, Honma, Mao, Otsuka, Kajino, PR C83, 044619 (2011).

$^{58}Ni(e^-,\nu)^{58}Co$ $^{60}Ni(e^-,\nu)^{60}Co$

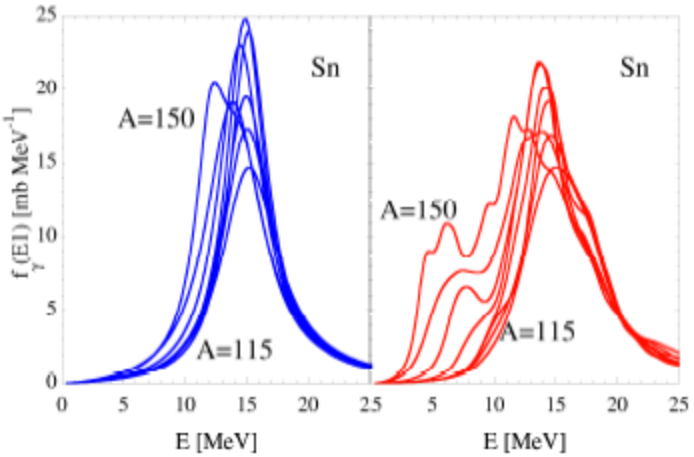




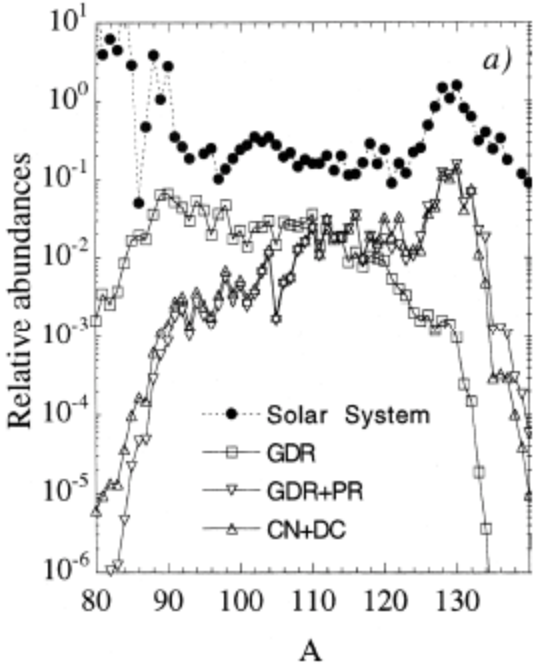
Time Dependent Density Functional Theory

Low-energy *E1* strength (Pygmy dipole resonance [PDR])

- Astrophysical interests
  - Strong impact on the r-process abundances
  - Constraint on neutron matter EOS

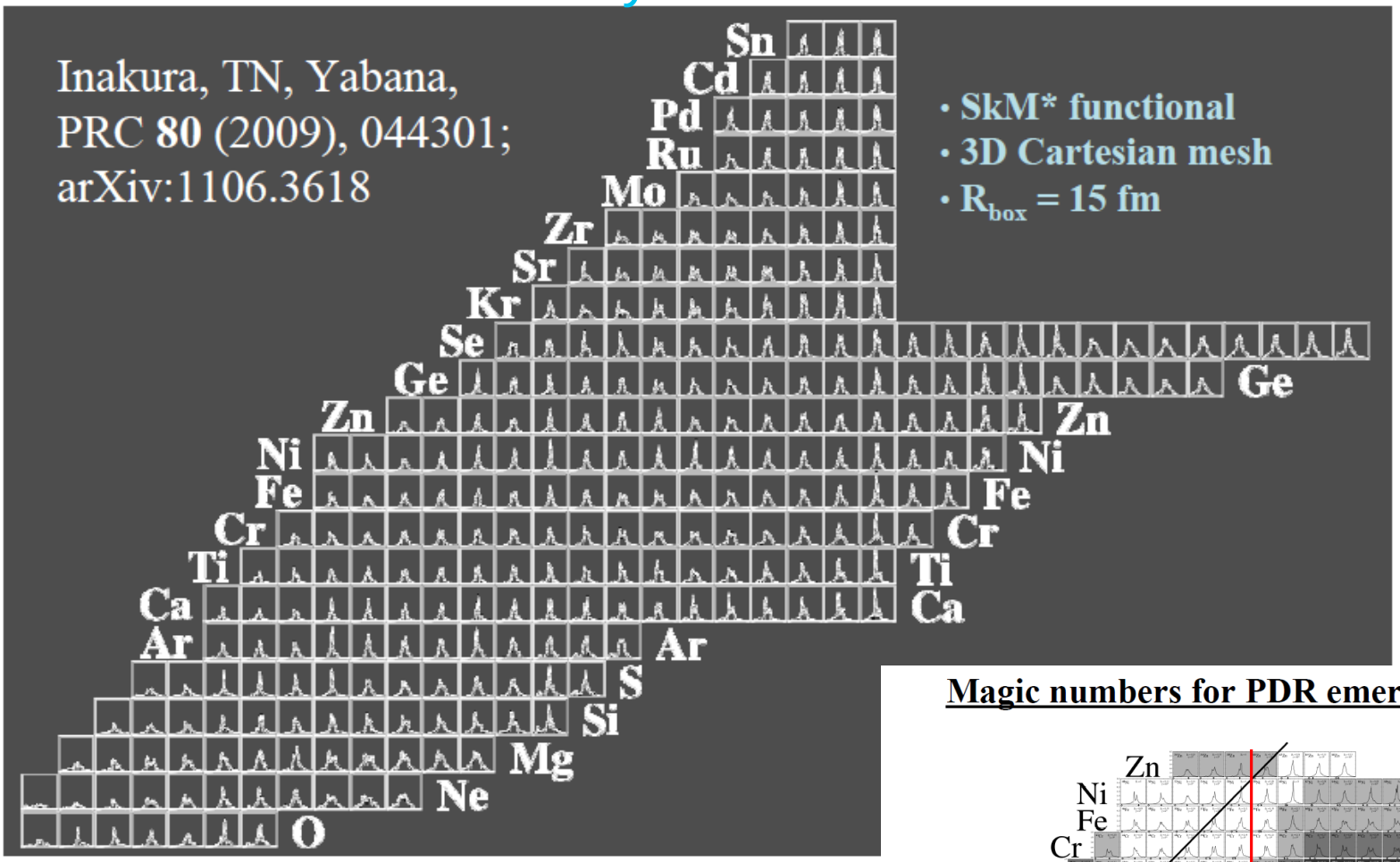


S. Goriely, Phys. Lett. **B436**, 10 (1998)

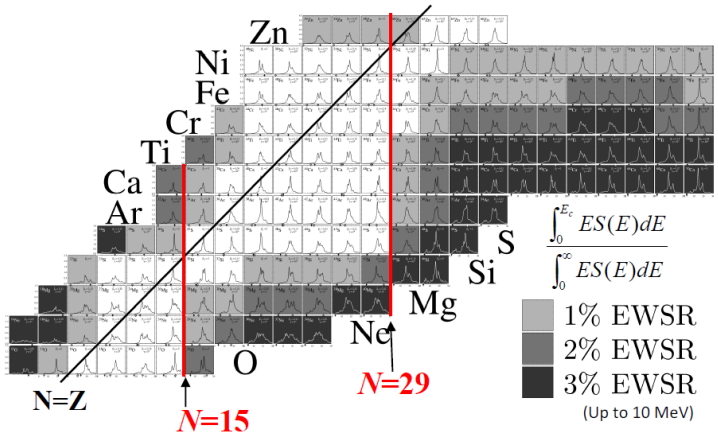


Computational nuclear data tables

by TDDFT

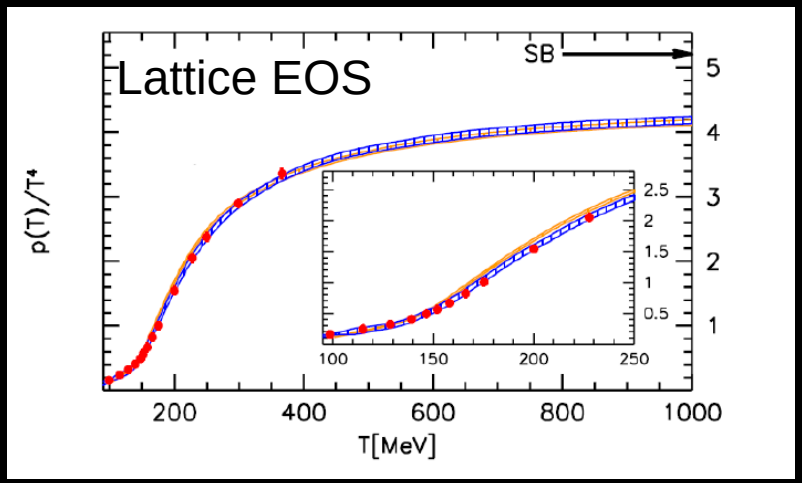


Magic numbers for PDR emergence



Nakatsukasa@OMEG11

EOS for Neutron Star Matter

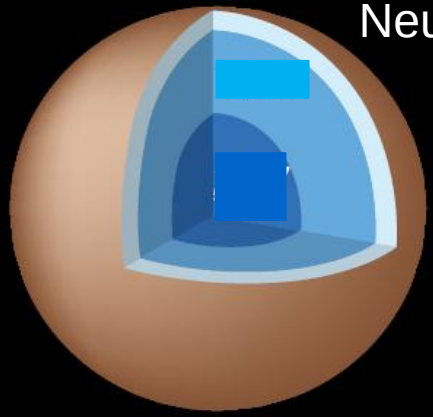


3D hydro.

ALICE@LHC

P=P(μ) from QCD ?

TOV eq.



Neutron stars

Variational Method with the Energy Functional

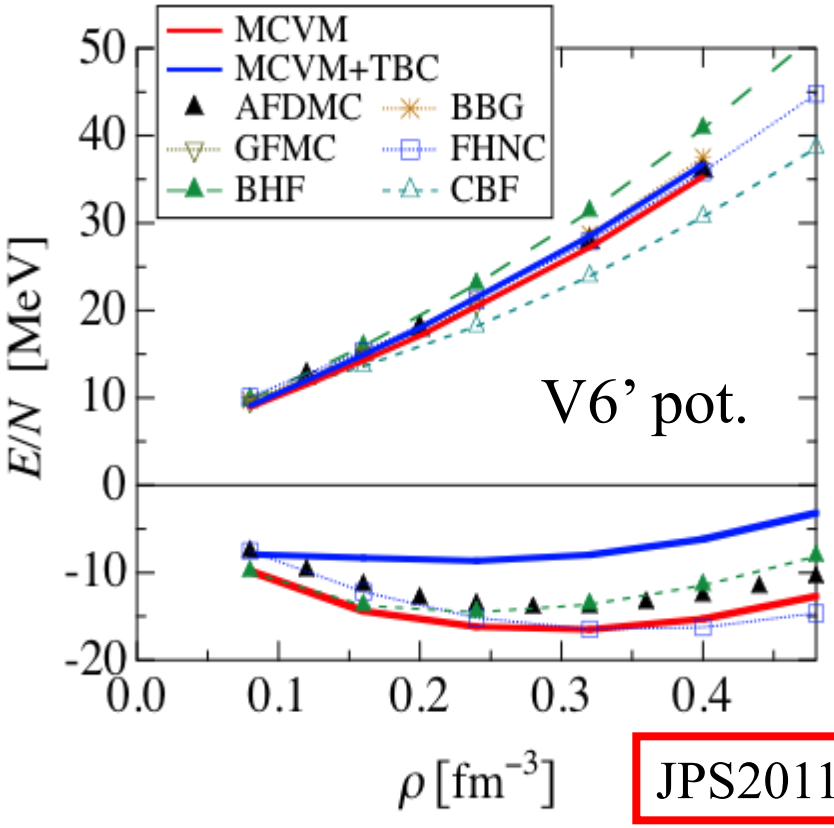
Uniform nuclear matter at zero temperature (M. Takano)

The central + tensor forces

Moderately constrained VM

+

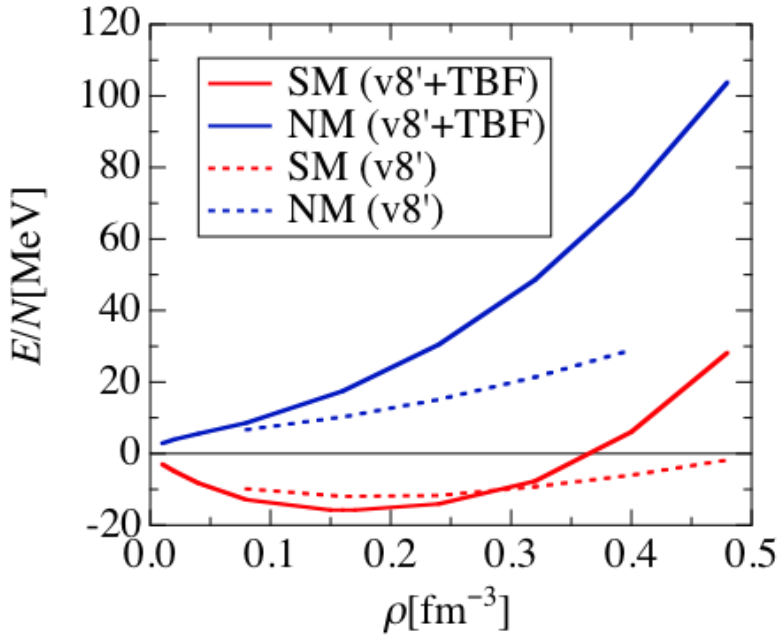
All the three-body cluster terms



JPS2011

Extension to the spin-orbit force

v8' pot. + phenomenological TBF



Two-body part: the tensor and spin-orbit correlations are constrained.

Three-body part: tuned so as to reproduce the saturation point

NUFRA2011

Further refinement is in progress

Reduction Formula

For Fermion Determinant $\det \Delta(\mu)$
find a smaller matrix A such that

$$\det \Delta = \det A$$

Keitaro Nagata and Atsushi Nakamura
Phys. Rev. D82,094027 (2010).
See also, A.Alexandru and U. Wenger,
Phys. Rev. D 83, 034502 (2011)

$$\frac{\det \Delta(\mu)}{\det \Delta(0)} = \frac{\det(\xi + Q)}{\det(1+Q)} \qquad \xi \equiv e^{-\mu/T} \text{ (fugacity)}$$

Q is $(4N_cN_xN_yN_z) \times (4N_cN_xN_yN_z)$ matrix. No N_t !

In case of KS matrix, the corresponding matrix is $(2N_cN_xN_yN_z) \times (2N_cN_xN_yN_z)$

Diagonalize Q,

$$Q \to \begin{pmatrix} \lambda_1 & & & \\ & \lambda_2 & & \\ & & \cdots & \\ & & & \lambda_{N_{red}} \end{pmatrix}$$

$$\det(\xi + Q) = \prod(\xi + \lambda_n)$$

λ_n does not depend on μ.

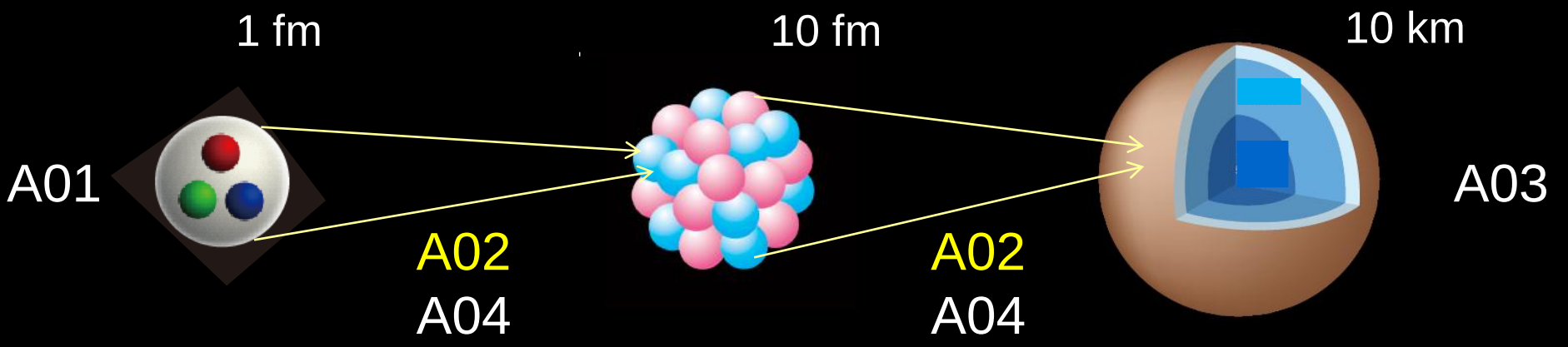
Once we calculate λ_n,
we can evaluate $\det \Delta(\mu)$ for any μ.

$$\det(\xi + Q) = \Pi(\xi + \lambda_k) = \sum C_n \xi^n$$

Fugacity dependence is explicit.

We can calculate $\det \Delta(\mu)$at any values of fugacity, $\xi = e^{\mu/T}$

[Group A02] *Nuclear Physics from QCD*



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⟷ HPCI Field5 Subject 1