2004.3.22-24 RCNP研究会「核力と核構造」

AMD triple-Sによる水素とヘリウムアイソトープの分析

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AMD triple-S: AMD Superposition of Selected Snapshot

主な課題

クラスター的取り扱いによるA=20領域までの軽い原子核の系統的分析

A=20領域までにある原子核を全て調べる（つもり）。

クラスター（広義）：α、t、h、d、2n、2p

軽い領域の不安定核において定量性を持った系統的理解（ハロー、共鳴、クラスター構造等）を目指す。

「核力と核構造」の理解

Present Method (AMD triple-S)

In order to treat the spatial extension, we use

AMD+GCM **Enyo *et al.***

N. Itagaki and S. Aoyama, Phys. Rev. C61, 024303 (2000)

In order to treat the large model space, we use

SVM **Kukulin**

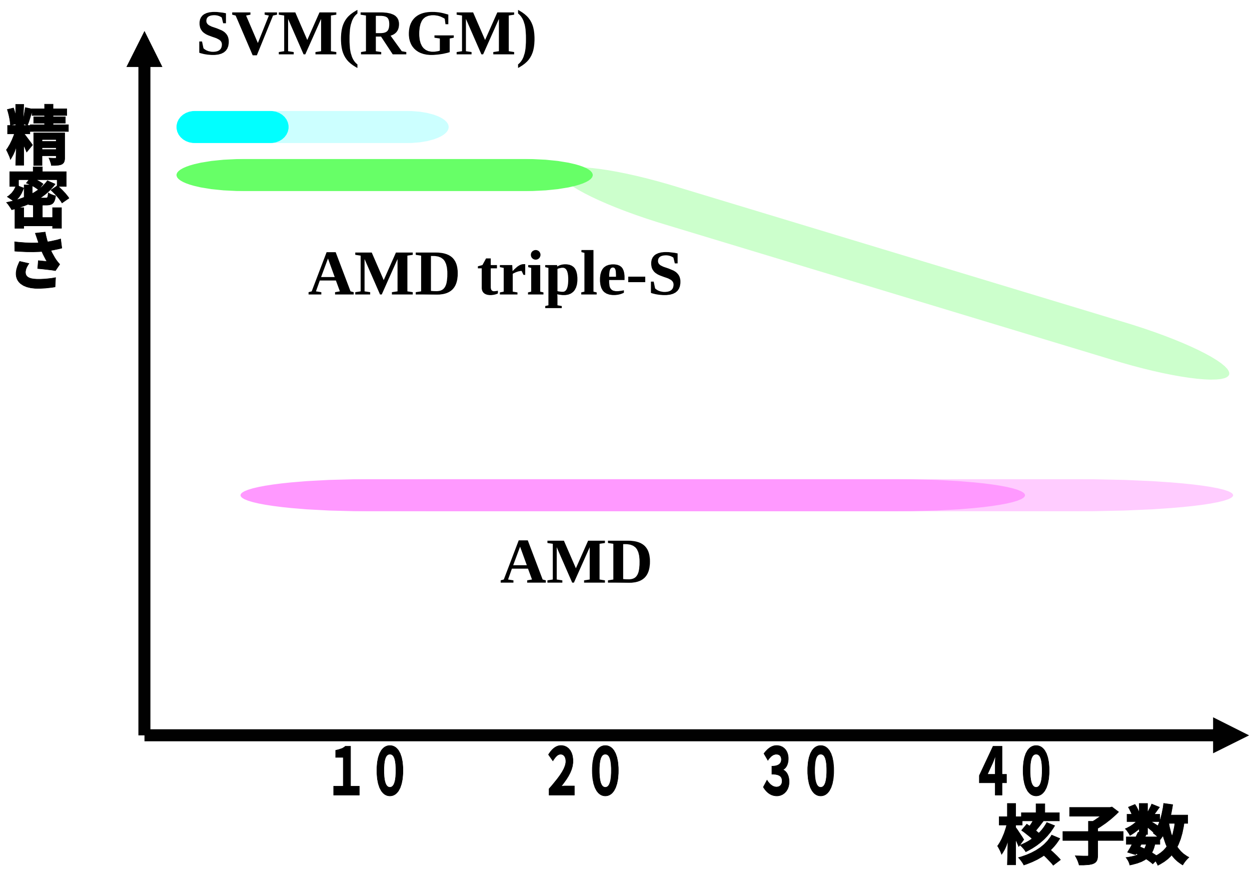
K. Varga, Y. Suzuki, Y. Ohbayashi, Phys. Rev. C50, 189 (1994)

In order to solve the many body resonace, we use

ACCC **Kukulin**

S. Aoyama, Phys. Rev. Lett. 89, 052501 (2002)

AMD+GCM+SVM (+ACCC)


SVM(RGM)
精密さ
AMD triple-S
AMD
10
20
30
40
核子数

1. **The Gaussian center (*z*) of the AMD w.f. is randomly generated.**

AMD w.f.

$$\Psi_k = \mathcal{A}[(\psi_1\chi_1)(\psi_2\chi_2)\cdots\cdot]_k.$$

$$\psi_i = \left(\frac{2\nu}{\pi}\right)^{\frac{3}{4}} \exp[-\nu(\vec{r} - \vec{z}_i/\sqrt{\nu})^2],$$

2. **We solve the frictional cooling equation <u>only for imaginary part</u>.**

$$\frac{dE}{d\tau} = \sum_i^A \frac{\partial E}{\partial \vec{z}_i}\cdot\frac{d\vec{z}_i}{d\tau} + \sum_i^A \frac{\partial E}{\partial \vec{z}_i^*}\cdot\frac{d\vec{z}_i^*}{d\tau},$$

$$\frac{d\vec{z}_i}{d\tau} = -Im[\frac{\partial E}{\partial \vec{z}_i^*}], \quad \frac{d\vec{z}_i^*}{d\tau} = -Im[\frac{\partial E}{\partial \vec{z}_i}].$$

3. We regard it as a basis function for the GCM.

$$\Phi = \sum_k c_k P^J_{MK} \Psi_k$$

4. If the obtained energy decrease, we adopt it.

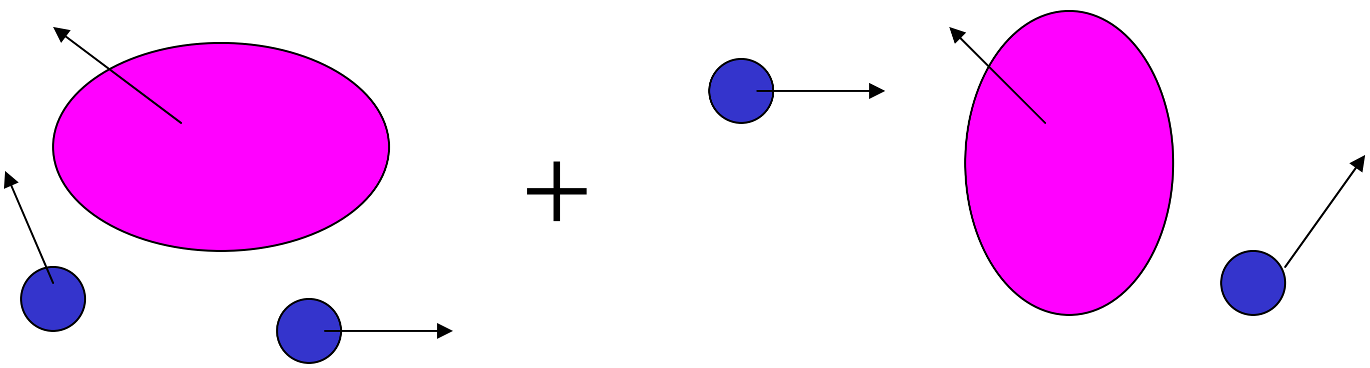
$$\sum_{k=1}^{N} \left| E^k(j) - E^k(j-1) \right| > \epsilon,$$

e.g. N=3, ε =0.05 MeV

5. We return 1, if the energy does not converge.

AMD triple-S基底関数の解釈

核子（クラスター）の運動量期待値＝$\langle p_i \rangle \neq 0$



Snapshot 1　　**Snapshot 2**

AMD triple-S= AMD <u>S</u>uperposition <u>S</u>elected <u>S</u>napshot

Hamiltonian

$$\hat{H} = \sum_{i=1}^{A} \hat{t}_i - \hat{T}_{c.m.} + \sum_{i>j}^{A} \hat{v}_{ij},$$

central Volkov No.2

$$V(r) = (W - MP^\sigma P^\tau + BP^\sigma - HP^\tau) \times (V_1 \exp(-r^2/c_1^2) + V_2 \exp(-r^2/c_2^2)),$$

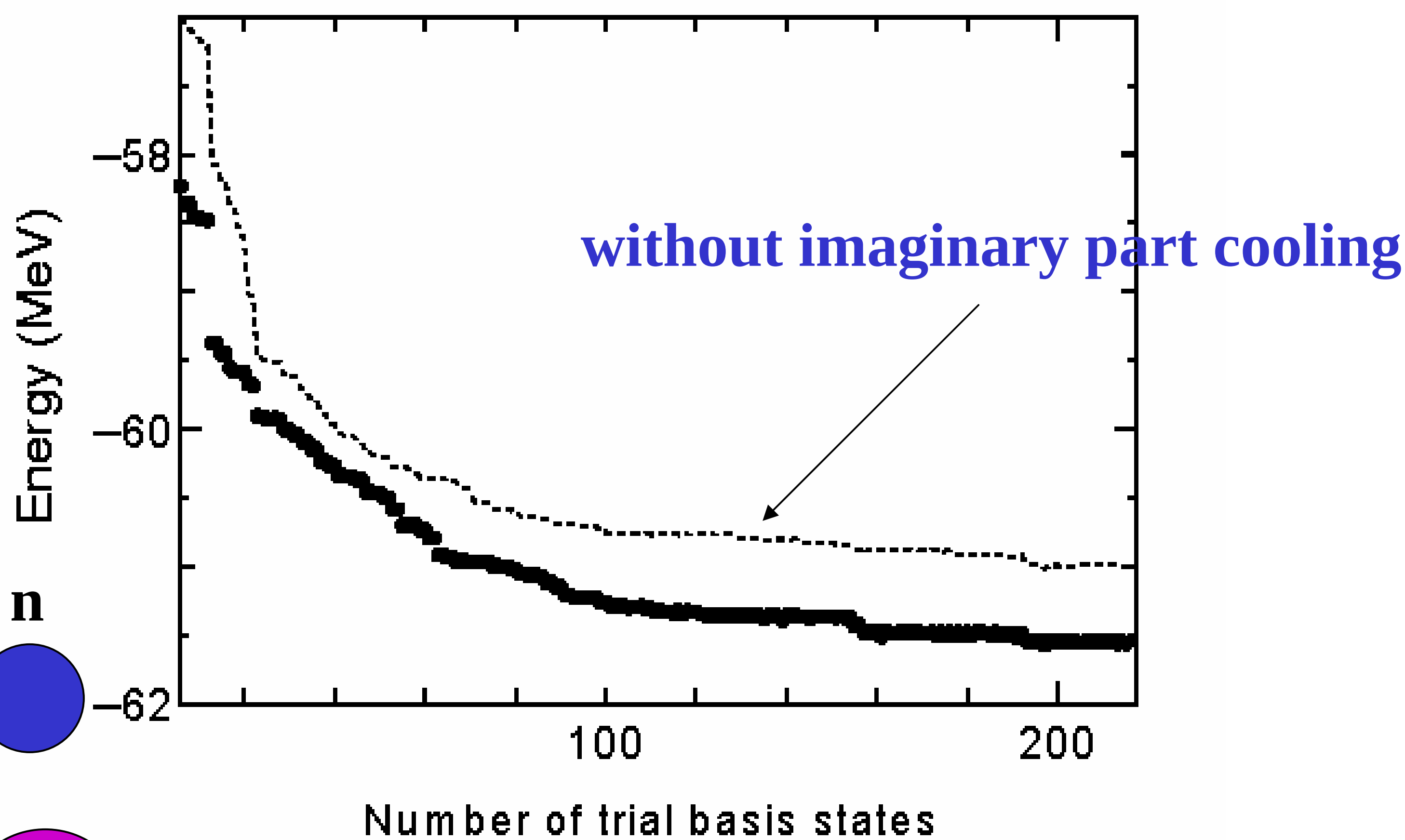
$$W = 1 - M,\ M = 0.60 \text{ and } B = H = 0.125$$

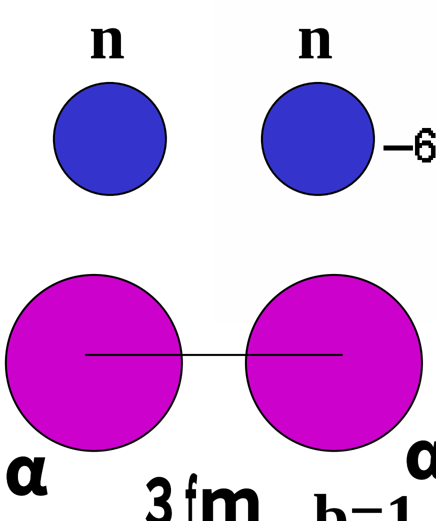
Spin-orbit G3RS

$$V_{ls} = V_0\{e^{-d_1 r^2} - e^{-d_2 r^2}\} P(^3O)\vec{L}\cdot\vec{S},$$

$$d_1 = 5.0 \text{ fm}^{-2},\ d_2 = 2.778 \text{ fm}^{-2},\ V_0 = 2000 \text{ MeV}$$

The energy convergence of the ground state(0+) of ^{10}Be





b=1.46fm Volkov No.2(M=0.6, B=H=0.125) +G3RS

^6He

The energy of single AMD calcualtion is 6.74 MeV higher than present one.

	S_{2n} (MeV)	$E_x(2_1^+)$ (MeV)	r.m.s. radius (fm)
single AMD	-5.75	1.95	2.02
AMD+GCM	-0.73	2.45	2.28
AMD triple-S	$+0.99$	1.89	2.37
Exp.	$+0.98$	1.80[a]	2.33 ± 0.04[b]
			2.48 ± 0.03[c]
			2.57 ± 0.1 [d]

We can not describe the halo structure.

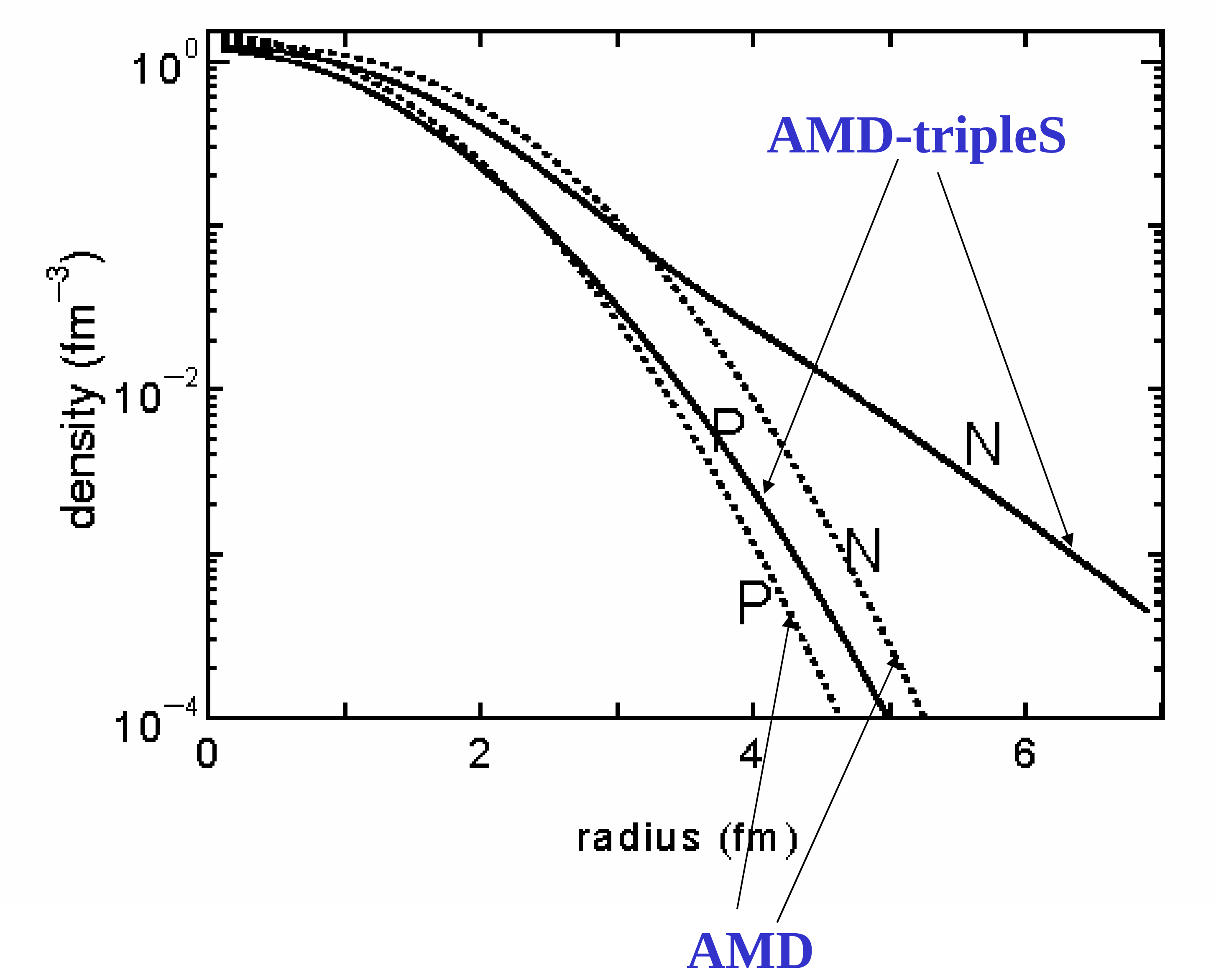
A-body Hamiltonian

$$\hat{H} = \sum_{i=1}^{A} \hat{t}_i - \hat{T}_{c.m.} + \sum_{i>j}^{A} \hat{v}_{ij},$$

Volkov No.2 (M=0.6, B=H=0.125)
+G3RS (*ls* potental)

b=1.46fm

Neutron Tail of 6He



Check for absolute values of the binding energy

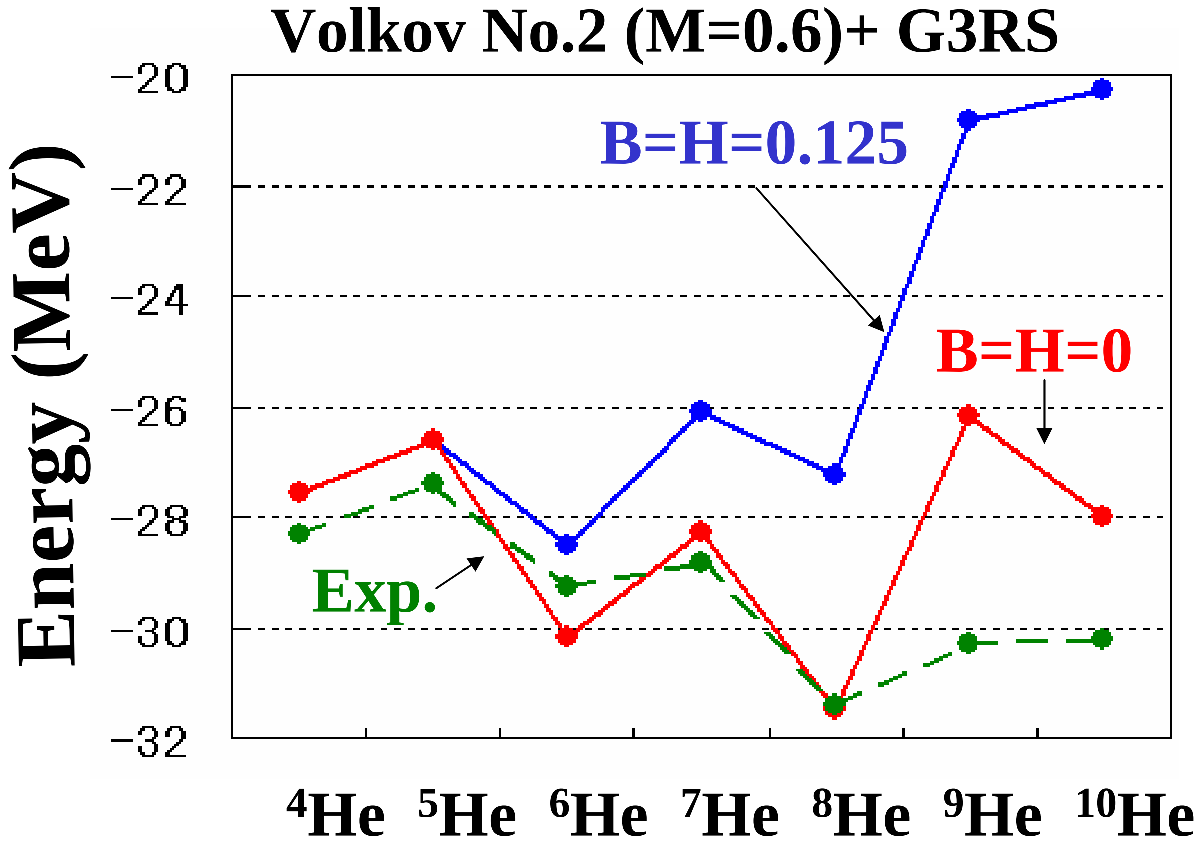
	AMD triple-S	RGM
^{6}He	E= -28.56MeV	E= -28.34MeV
		K. Arai

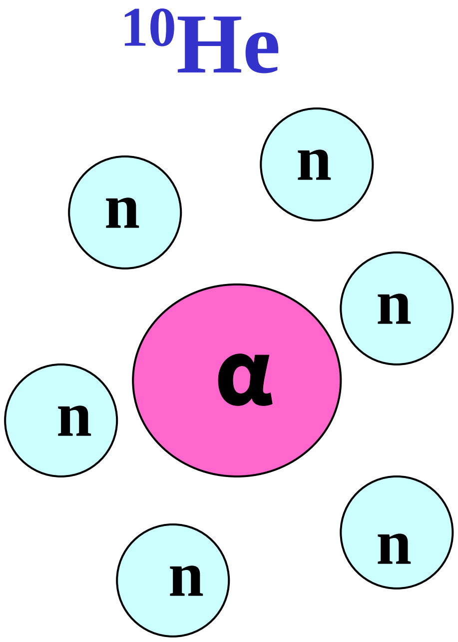
6.26 MeV

AMD: E= <u>-21.82</u> MeV

(Single Slater, VBP)

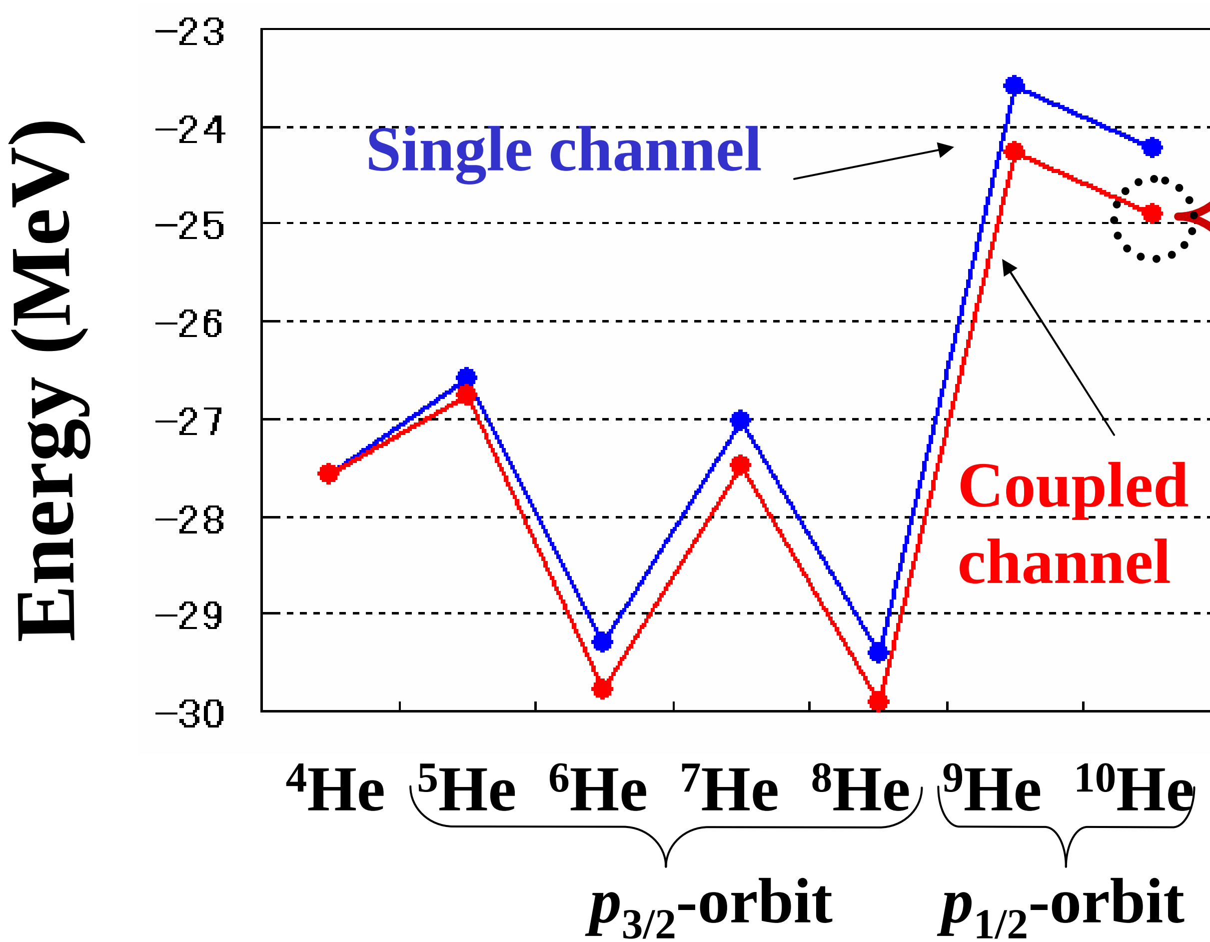
Calculated Energies for He-isotopes

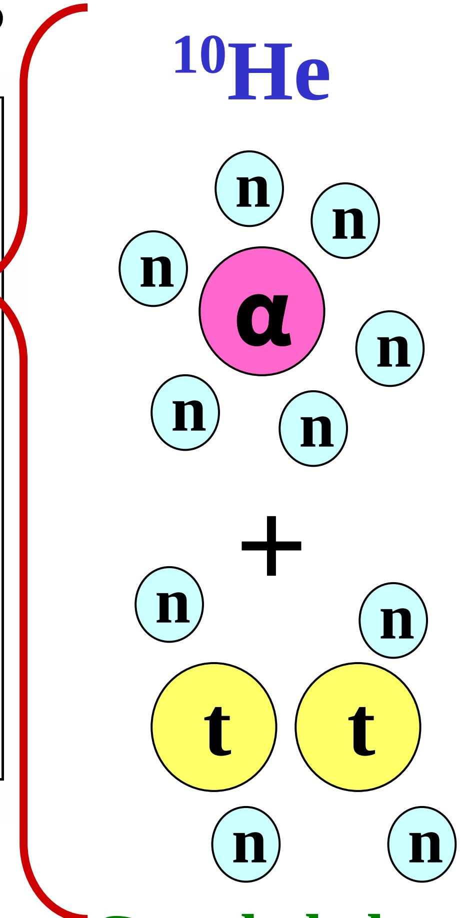




t-t conribution in He-isotopes

Volkov No.2 (M=0.6, B=H=0.06)+ G3RS





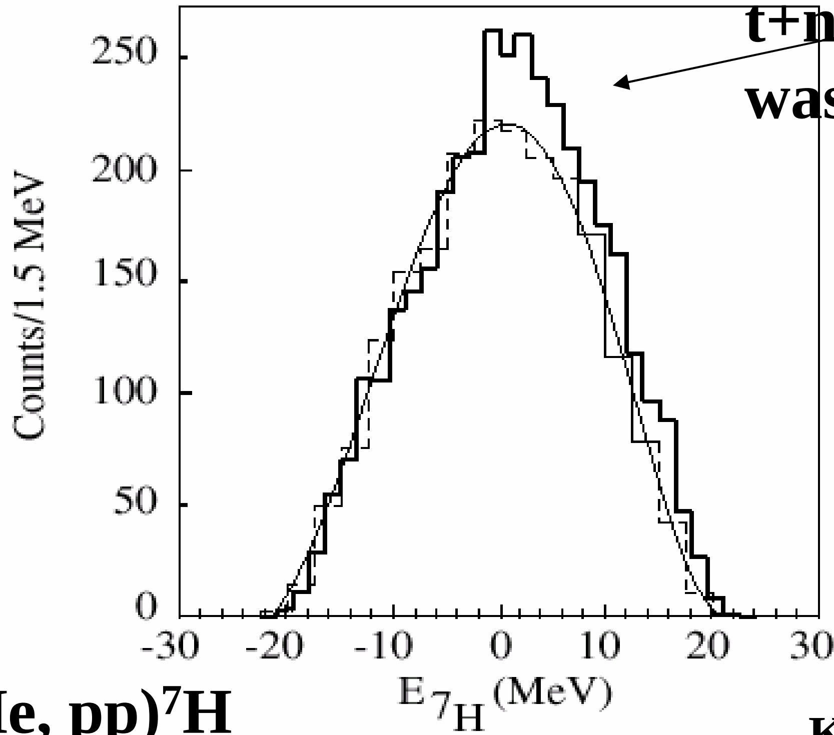
Coupled channel problem for 7-body system

Single channel: α-core model

Coupled channel: α-core + (t+t)-core model

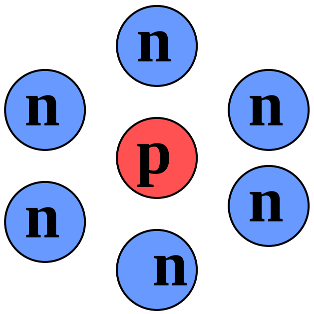
Very recently, ^{7}H is observed in RIKEN!

Enhancement above t+n+n+n+n threshold was observed



$p(^{8}He, pp)^{7}H$

FIG. 3. Spectrum of ^{7}H from the reaction $p(^{8}He, pp)^{7}H$. The solid histogram was obtained with the proton target. The dashed histogram shows the empty-target background.



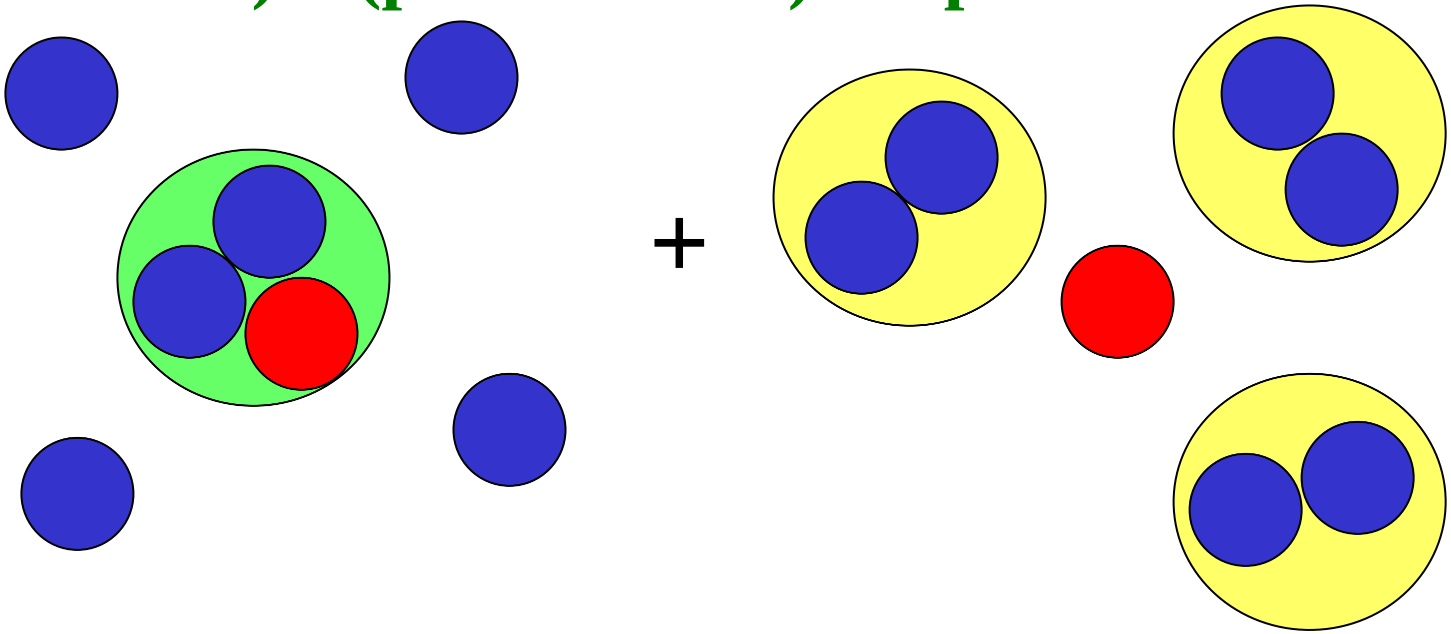
N/Z=6 very large value
～neutron star

Korsheninnnikov et al., PRL90(2003)

One proton in the six-neutron system

Ikeda and Horiuchi's advise

(t+n+n+n+n) + (p+2n+2n+2n) coupled channel model



In this study, we investigate H-isotopes by using AMD triple-S.

(Antisymmetrized Molecular Dynamics Superposition Selected Snapshot)

⇨ **AMD+GCM is combined with SVM.**

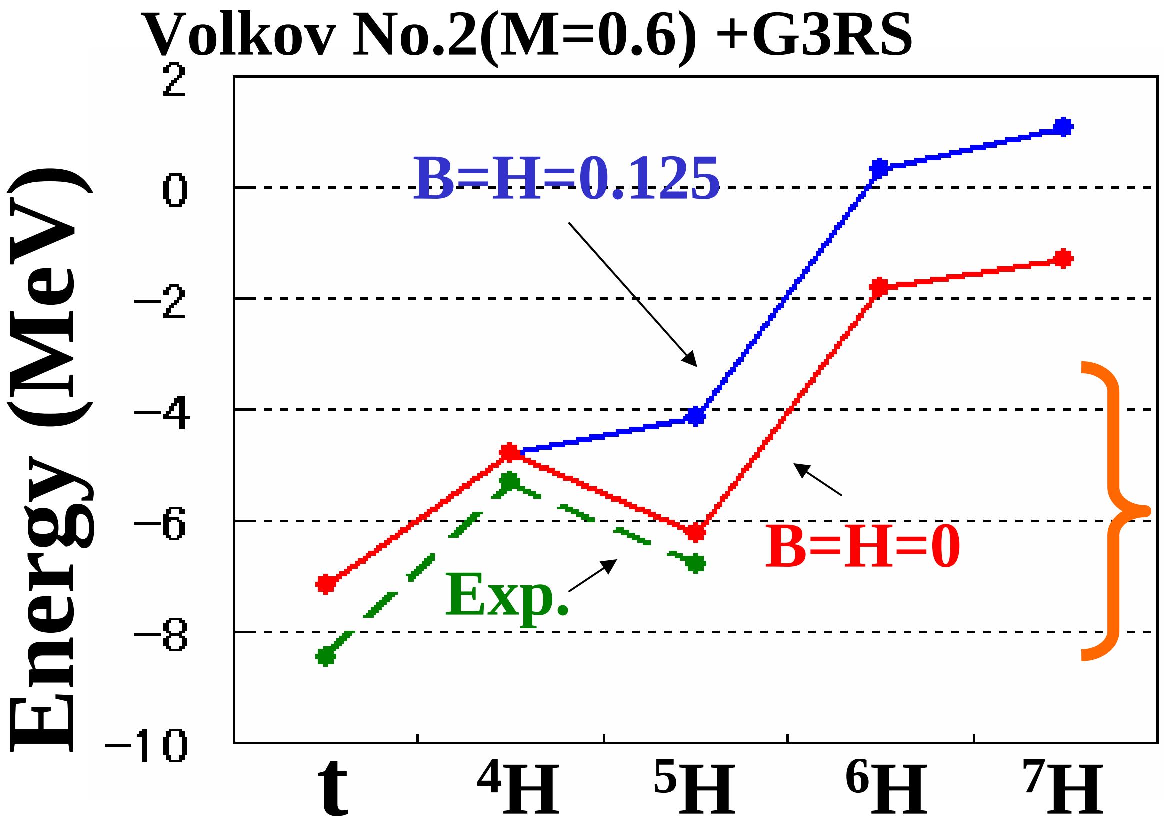
(Stochastic Variational Method)

In order to solve the many body resonance, we will use ACCC.

(Analytical Continuation in the Coupling Constant)

V.I.Kukulin et al., JPA10 (1977)

Calculated Energies for H-isotopes



^{4}H
Tilley et al.
NPA541(1992)
^{5}H
Korsheninnikov et al.
PRL87(2001)

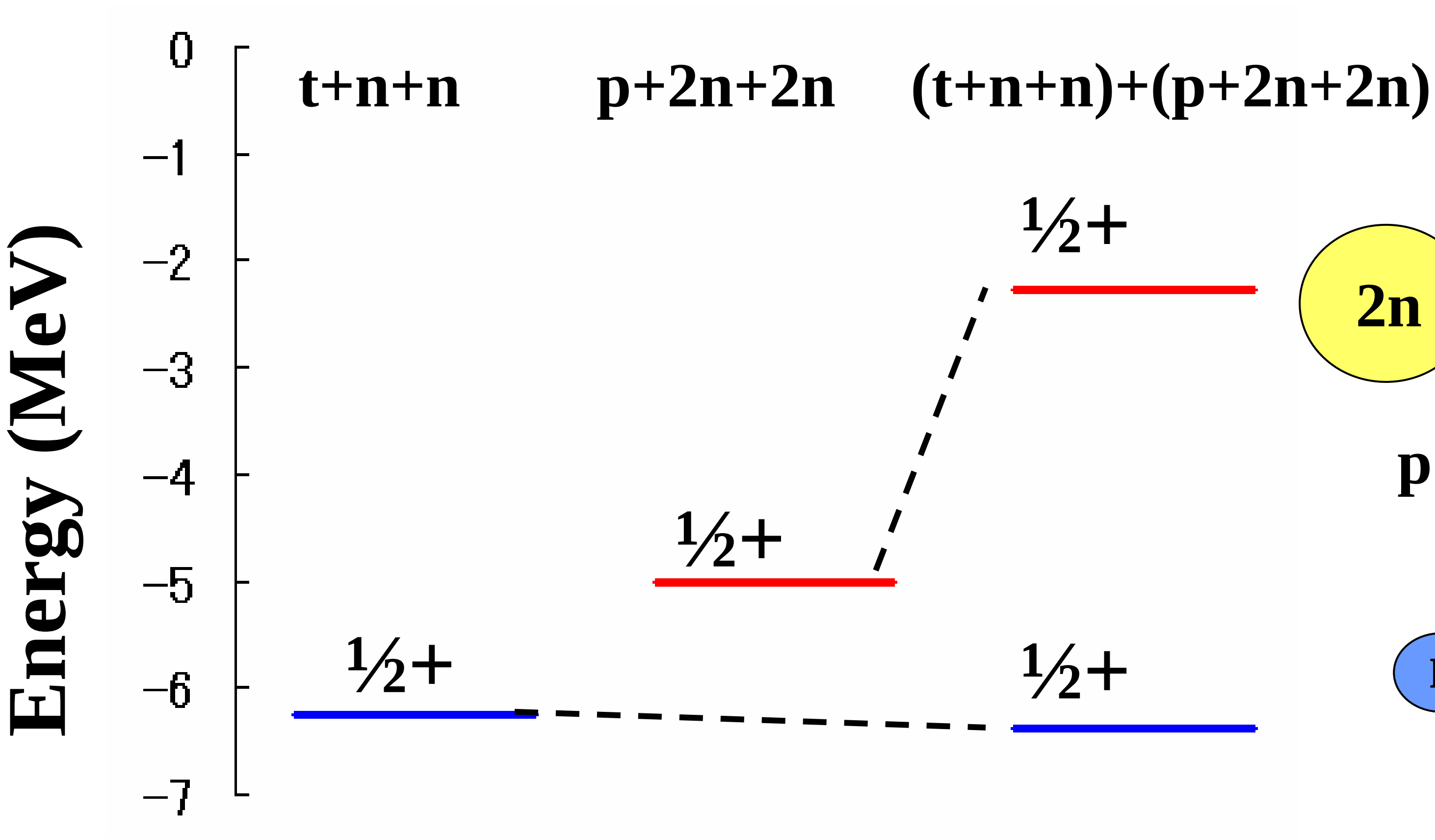
Experimental energy for ^{7}H by Korsheninnikov ?

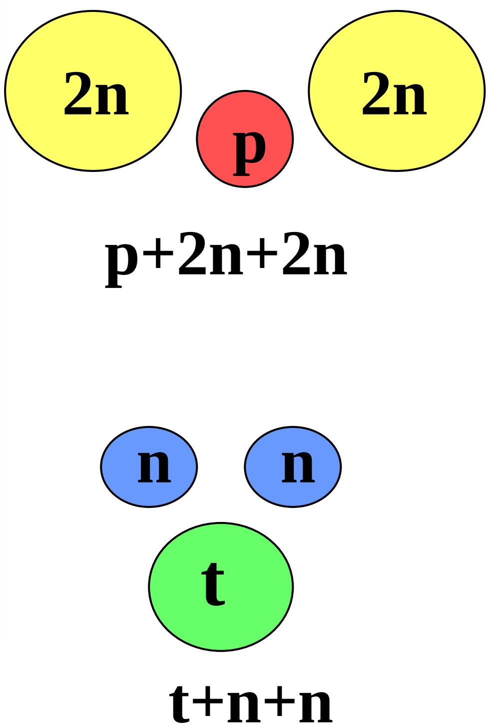
The present effective interaction does not reproduce tendency of the experimental binding energy for ^{7}H.

→ **Search for other effective interactions and correlations**

Gas-like State in ^{5}H

Volkov No.2(M=0.6, B=H=0) +G3RS



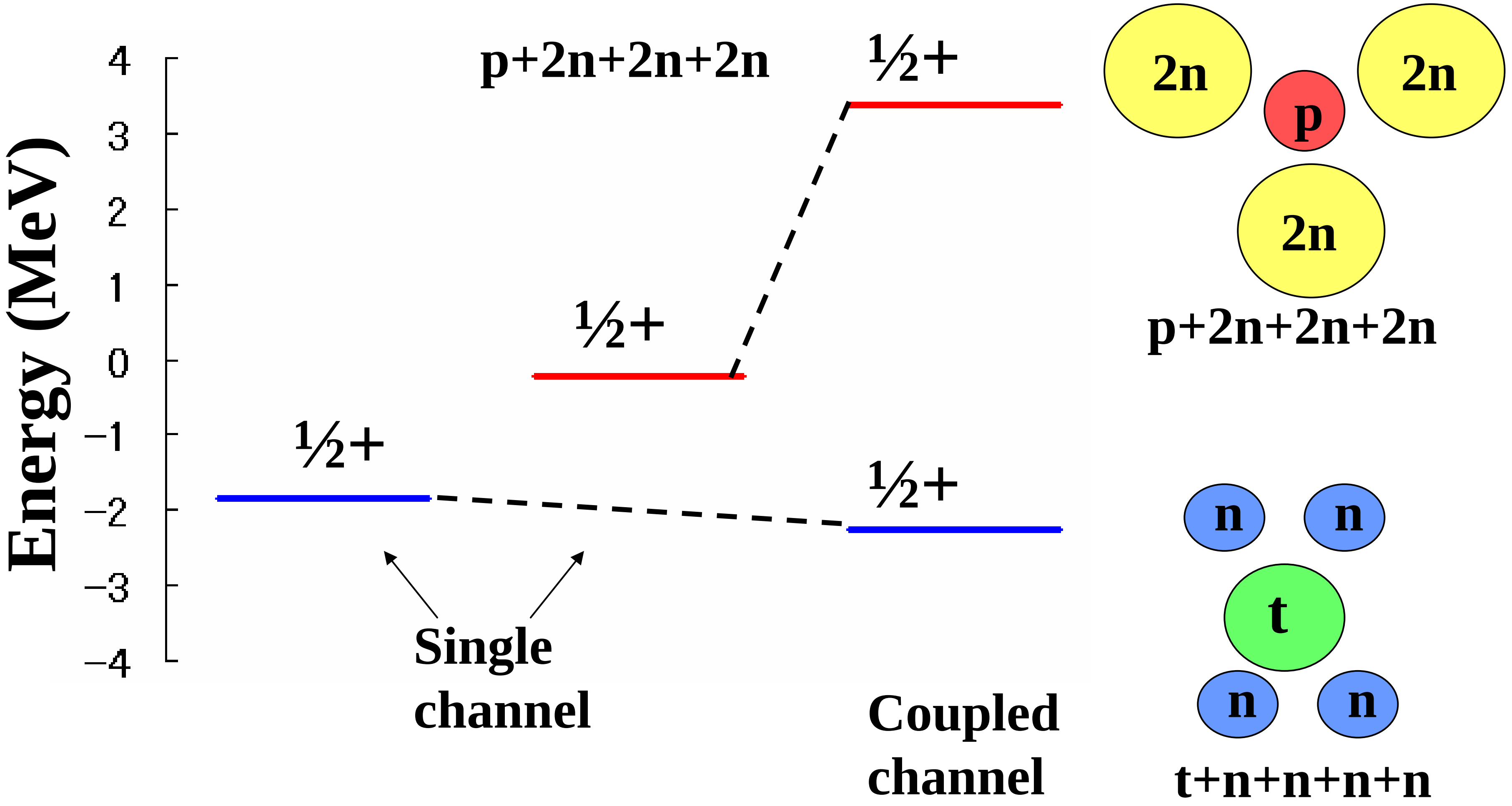


Di-neutron gas-like state may exists, although we should solve it as a resonance.

Gas-like State in ^{7}H

Volkov No.2(M=0.6, B=H=0) +G3RS

t+n+n+n+n **(t+n+n+n+n)+(p+2n+2n+2n)**



ACCC (Analytical Continuation in the Coupling Constant)

V.I.Kukulin et al., J. Phys. A10 (1977)

Application of ^{9}Be (α + α +n)

N.Tanaka, Y.Suzuki, K.Varga, G.Lovas, Phys. Rev. C59 (1999)

$$H=H_0+\delta V \qquad H=T+V+\delta V=T+\lambda V$$

coupling constant (δ) potential (V)

Pade approximation

$$k_l^{MN}(\delta) = i\,\frac{c_0+c_1x+c_2x^2+\cdots+c^M x^M}{d_0+d_1x+d_2x^2+\cdots+c^N x^N}$$

$$x=(\delta-\delta_0)^{1/2}$$

coupling constant (δ)

coupling constant at threshold (δ_0) (except for s- wave)

Energy Levels of ^{6}He

We can solve the resonance by using ACCC !

	Exp.	Cal.	
2+	Er=0.825 Γ =0.113	Er=0.875 Γ =0.115	Bound state approximation Er=0.90 MeV
0+	E= -0.98	E= -0.99	in MeV

N. Itagaki, A. Kobayakawa, S. Aoyama, PRC68, 055302(2003)

$$H=H_0+\delta V$$

Pade approximation

$$k_l^{MN}(\delta) = i\,\frac{c_0+c_1x+c_2x^2+\cdots+c^Mx^M}{d_0+d_1x+d_2x^2+\cdots+c^Nx^N}$$

$$x=(\delta-\delta_0)^{1/2}$$

Summary

We develop a new method: AMD triple-S.

- **We understand that the AMD triple-S is useful for the analyses of extremely neutron-rich nuclei .**
- **t-t component is also important for extremely neutron-rich He-isotopes.**
- **Gas-like configurations may exist in H-isotopes.**
- **The present effective interaction does not reproduce tendency of the experimental binding energy of H- and He-isotopes.**
- **We can solve three-body resonance: As a first step, 2+ state of ^{6}He is solved by using AMD triple-S combined with ACCC.**

Next

1. We are going to investigate other effective interactions and correlations.

2.We solve it as a resonance with ACCC.