３バリオン系における クォーク・パウリ効果

鈴鹿高専　　仲本朝基
新潟大理、理研仁科セ　鈴木宣之

１．Introduction
２．Formulation
３．Results
４．Summary

1. Introduction

3 baryon systemにおける三体力

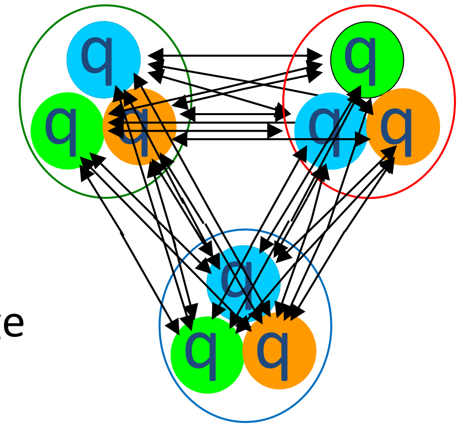
- Few-body system physics
- Nuclear matter physics
- Neutron star physics
- ……

存在するのは確かだが、
その起源は依然として不明確

三体力に対する理論側のアプローチ

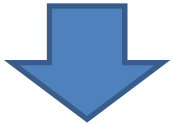
- 2π交換ポテンシャル(藤田・宮沢)
- 現象論的模型
- カイラル摂動理論
- 格子QCD計算(HAL-QCD)
- ……

クォーク模型によるアプローチ



９クォーク3バリオン系（３クラスター９体系）
⇒　複合粒子における構成子効果の発露

- Kinematical：　quark-Pauli effect
- Dynamical：　quark-quark interaction　through quark-exchange



これまでのクォーク模型によるアプローチ

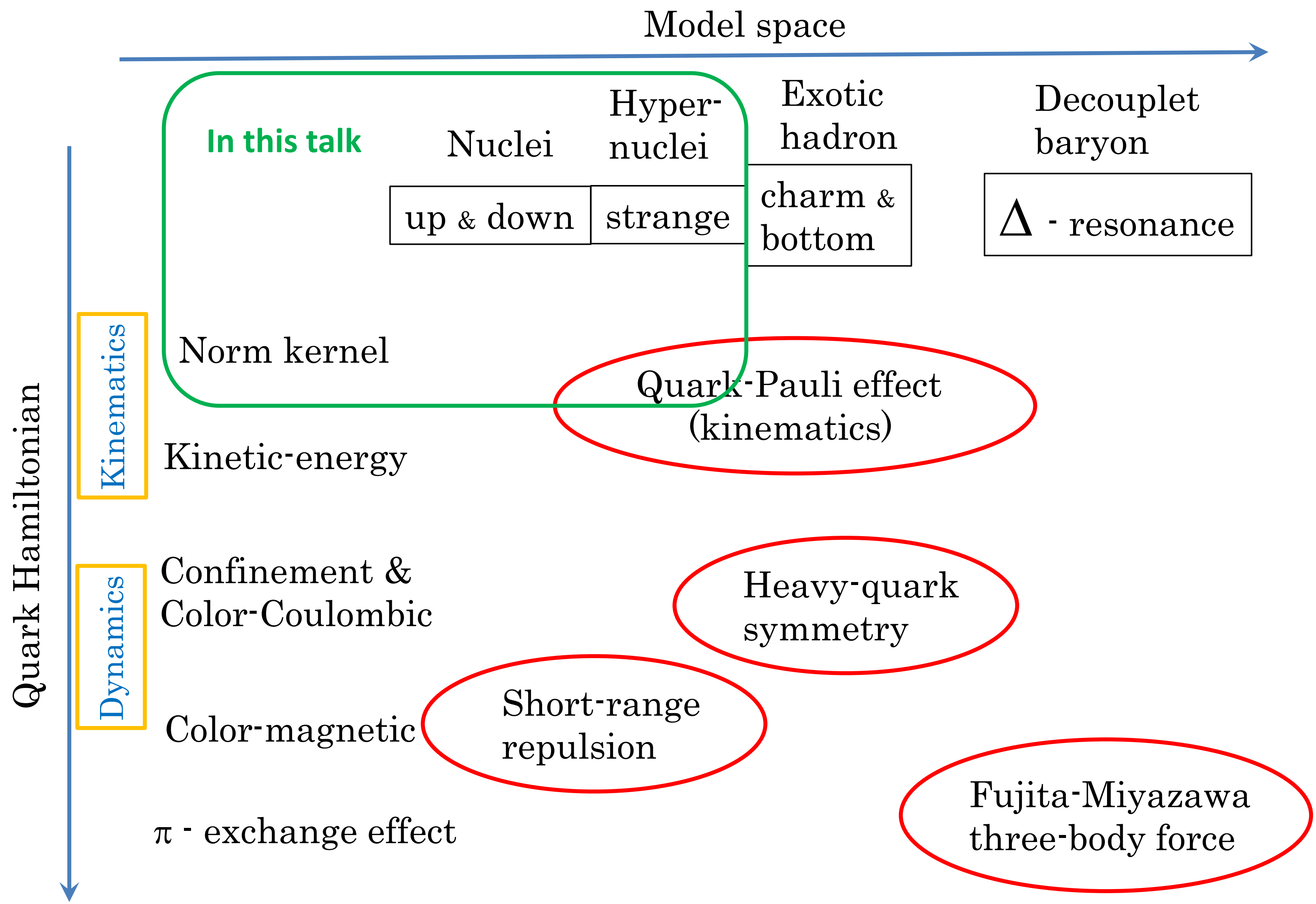
- Toki, Suzuki, Hecht：PRC26 (1982) 736
  NNN系のノルム核を調べて^{3}He densityに対するPauli効果の検証
- Suzuki, Hecht：PRC29 (1984) 1586
  NNN系におけるFermi-Breit interaction(OGEP)核の評価
- Maltman：NPA439 (1985) 648
  NNN及びNNNN系におけるFB int.のcharge form-factorへの寄与
- Takeuchi, Shimizu：PLB179 (1986) 197
  ΛNN及びΛNNN系のノルム核と運動エネルギー項の評価

クォーク模型の利点

- 1-baryonからFew-baryonsまで、統一した枠組みで系統的に調べられる
- Pauli effect, 各種interactionなど、その効果を別々に評価できる

研究目的

- クォーク模型をプローブとして、三核子系のみならず、三体バリオン力の理解を試みる


Model space
In this talk
Nuclei
Hyper-
nuclei
Exotic
hadron
Decouplet
baryon
up & down
strange
charm &
bottom
Δ - resonance
Quark Hamiltonian
Kinematics
Dynamics
Norm kernel
Quark-Pauli effect
(kinematics)
Kinetic-energy
Confinement &
Color-Coulombic
Heavy-quark
symmetry
Color-magnetic
Short-range
repulsion
π - exchange effect
Fujita-Miyazawa
three-body force

今回の発表

RGMノルム核の固有値を求めて、quark-Pauli effectを調べる

中性子星核物質における問題意識との関連

コアにおけるハイペロンやK凝縮の
出現による状態方程式の軟化

⇒ 斥力の不足（２体では記述し得ない？）

⇒ multi-baryon系におけるquark縮退圧効果？

次の２点に注目する

- どの3バリオン系が、全体として強いパウリ斥力を感じるのか
- 3体効果からの寄与

2. Formulation

Resonating-group method (RGM) equation

2-baryon system

$$\int \left[\mathcal{H}(\vec{R'}_{12}, \vec{R}_{12}) - \varepsilon \underline{\mathcal{N}(\vec{R'}_{12}, \vec{R}_{12})}\right] \underline{\chi(\vec{R}_{12})}\, d\vec{R}_{12} = 0$$

RGMノルム核 ← $\mathcal{N}(\vec{R'}_{12}, \vec{R}_{12})$

$\chi(\vec{R}_{12})$ → クラスター間相対波動関数

3-baryon system

$$\int\int \left[\mathcal{H}(\vec{R'}_{12}, \vec{R'}_{12-3}; \vec{R}_{12}, \vec{R}_{12-3}) - \varepsilon \underline{\mathcal{N}(\vec{R'}_{12}, \vec{R'}_{12-3}; \vec{R}_{12}, \vec{R}_{12-3})}\right] \chi(\vec{R}_{12}, \vec{R}_{12-3})\, d\vec{R}_{12} d\vec{R}_{12-3} = 0$$

Eigen-value equation

2-baryon system

$$\int \mathcal{N}(\vec{R'}_{12}\,,\vec{R}_{12})\,\chi_k(\vec{R}_{12})\,d\vec{R}_{12} \;=\; \mu_k\,\chi_k(\vec{R'}_{12})$$

Eigen-value ← μ_k

3-baryon system

$$\int \mathcal{N}(\vec{R'}_{12}\,,\vec{R'}_{12-3}\,;\,\vec{R}_{12}\,,\vec{R}_{12-3})\,\chi_k(\vec{R}_{12}\,,\vec{R}_{12-3})\,d\vec{R}_{12}d\vec{R}_{12-3} \;=\; \mu_k\,\chi_k((\vec{R'}_{12}\,,\vec{R'}_{12-3})$$

$\mu_k = 0$: Pauli forbidden state

$\mu_k \sim 0$: almost Pauli forbidden state

Eigen-value

2-baryon system

$$\mu_{nl} = \int \psi_{nlm}(\vec{R'}_{12})^* \mathcal{N}(\vec{R'}_{12}, \vec{R}_{12}) \underline{\psi_{nlm}(\vec{R}_{12})} \, d\vec{R'}_{12} \, d\vec{R}_{12}$$

→ Harmonic-oscillator function

3-baryon system

$$\mu_{nl} = \int \Psi^{n'l'm'}_{(l'_1 l'_2)}(\vec{R'}_{12}, \vec{R'}_{12-3})^* \underline{\mathcal{N}(\vec{R'}_{12}, \vec{R'}_{12-3}; \vec{R}_{12}, \vec{R}_{12-3})} \Psi^{nlm}_{(l_1 l_2)}(\vec{R}_{12}, \vec{R}_{12-3}) \, d\vec{R'}_{12} \, d\vec{R'}_{12-3} \, d\vec{R}_{12} \, d\vec{R}_{12-3}$$

↓

このRGMノルム核がわかればよい

→ orbital part は積分によって消える

→ color, spin, flavor part の factor さえ求めればよい

RGM normalization kernel（RGMノルム核）

2-baryon system

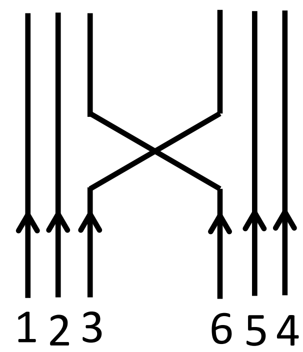
$$\mathcal{N}\left(\vec{R}',\vec{R}\right)=\frac{1}{2!}\left\langle \phi(1,2)_{S\,I}\,\delta(\vec{R}_{12}-\vec{R}')\,\middle|\,\mathcal{A}\,\middle|\,\phi(1,2)_{S\,I}\,\delta(\vec{R}_{12}-\vec{R})\right\rangle$$

$\phi(1,2)_{S\,I}$ → Baryon 1, 2各々の内部波動関数
（spin S, isospin I にcouple）

反対称化演算子 $\mathcal{A}=(1-\mathcal{P})(1-9\,P_{36})$

$\mathcal{P}$ → baryon-exchange operator

P_{36} → quark -exchange operator



20 terms

3-baryon system

$$
\mathcal{N}\left(\vec{R}'_a\,,\vec{R}'_b\,,\vec{R}_a\,,\vec{R}_b\right)
$$

$$
= \frac{1}{3!}\left\langle \phi(1,2,3)_{\frac{1}{2}I}\,\delta(\vec{R}_{12}-\vec{R}'_a)\delta(\vec{R}_{12-3}-\vec{R}'_b)\,\middle|\,\mathcal{A}\,\middle|\,\phi(1,2,3)_{\frac{1}{2}I}\,\delta(\vec{R}_{12}-\vec{R})\delta(\vec{R}_{12-3}-\vec{R}_b)\right\rangle
$$

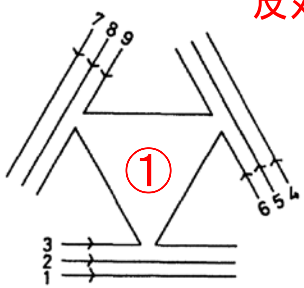
反対称化演算子 $\mathcal{A} = [1$ ← D-term

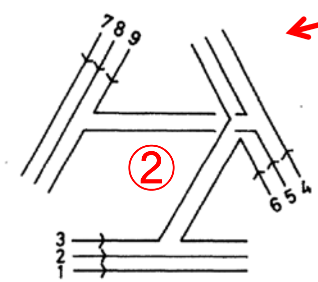
$-9\,(P_{36}+P_{69}+P_{93})$ ← 2B-term

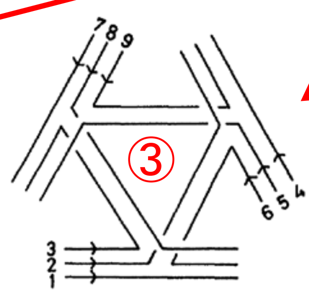
$+27\,(P_{369}+P_{396})$ → ①

$+54\,(P_{36}P_{59}+P_{69}P_{83}+P_{93}P_{26})\,] \times \left[\sum_{\mathcal{P}=1}^{6}(-1)^{\pi(\mathcal{P})}\mathcal{P}\right]$ → ②

$-216\,P_{26}P_{59}P_{83}$ → ③







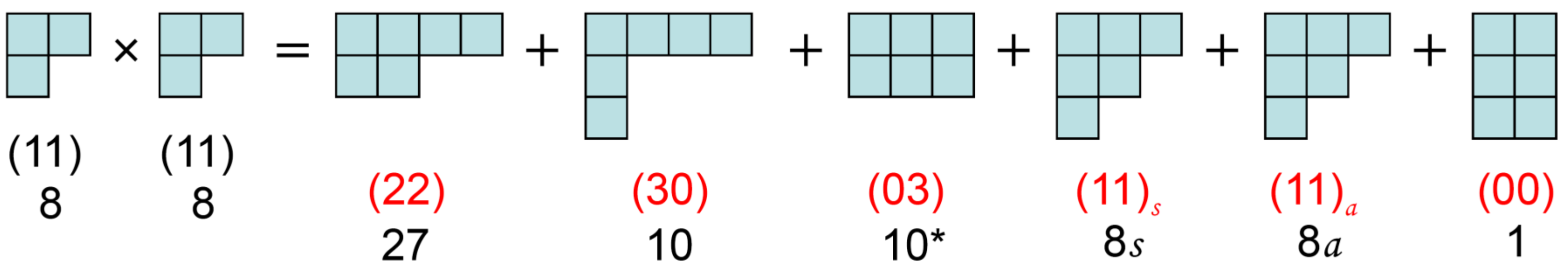
↓ 762 terms

３. Results

2-baryon system

Eigen-value の構成　(color)×(spin-flavor)

Two octet-baryon(B_8B_8) state



対応する次元表現: $\dim(\lambda\mu) = \frac{1}{2}(\lambda+1)(\mu+1)(\lambda+\mu+2)$

各種２バリオン系

$$\begin{array}{cccccccc} 8 & 8 & 27 & 10 & 10^* & 8s & 8a & 1 \end{array}$$

B_8B_8 states : $(11) \times (11) = (22) + (30) + (03) + (11)_s + (11)_a + (00)$

S	B_8B_8(isospin)	$\mathcal{P}=+1$(symmetric)	$\mathcal{P}=-1$(antisymmetric)	norm eigenvalue	
		^1E or ^3O	^3E or ^1O	^1S	^3S
0	$NN(0)$	$-$	(03)	$-$	$\frac{10}{9}$
	$NN(1)$	(22)	$-$	$\frac{10}{9}$	$-$
-1	ΛN	$\frac{1}{\sqrt{10}}[(11)_s + 3(22)]$	$\frac{1}{\sqrt{2}}[-(11)_a + (03)]$	1	1
	$\Sigma N(\frac{1}{2})$	$\frac{1}{\sqrt{10}}[3(11)_s - (22)]$	$\frac{1}{\sqrt{2}}[(11)_a + (03)]$	$\frac{1}{9}$	1
	$\Sigma N(\frac{3}{2})$	(22)	(30)	$\frac{10}{9}$	$\frac{2}{9}$
-2	$\Lambda\Lambda$	$\frac{1}{\sqrt{5}}(11)_s + \frac{9}{2\sqrt{30}}(22) + \frac{1}{2\sqrt{2}}(00)$	$-$	1	$-$
	$\Xi N(0)$	$\frac{1}{\sqrt{5}}(11)_s - \sqrt{\frac{3}{10}}(22) + \frac{1}{\sqrt{2}}(00)$	$(11)_a$	$\frac{4}{3}$	$\frac{8}{9}$
	$\Xi N(1)$	$\sqrt{\frac{3}{5}}(11)_s + \sqrt{\frac{2}{5}}(22)$	$\frac{1}{\sqrt{3}}[-(11)_a + (30) + (03)]$	$\frac{4}{9}$	$\frac{20}{27}$
	$\Sigma\Lambda$	$-\sqrt{\frac{2}{5}}(11)_s + \sqrt{\frac{3}{5}}(22)$	$\frac{1}{\sqrt{2}}[(30) - (03)]$	$\frac{2}{3}$	$\frac{2}{3}$
	$\Sigma\Sigma(0)$	$\sqrt{\frac{3}{5}}(11)_s - \frac{1}{2\sqrt{10}}(22) - \sqrt{\frac{3}{8}}(00)$	$-$	$\frac{7}{9}$	$-$
	$\Sigma\Sigma(1)$	$-$	$\frac{1}{\sqrt{6}}[2(11)_a + (30) + (03)]$	$-$	$\frac{22}{27}$
	$\Sigma\Sigma(2)$	(22)	$-$	$\frac{10}{9}$	$-$
-3	$\Xi\Lambda$	$\frac{1}{\sqrt{10}}[(11)_s + 3(22)]$	$\frac{1}{\sqrt{2}}[-(11)_a + (30)]$	1	$\frac{5}{9}$
	$\Xi\Sigma(\frac{1}{2})$	$\frac{1}{\sqrt{10}}[3(11)_s - (22)]$	$\frac{1}{\sqrt{2}}[(11)_a + (30)]$	$\frac{1}{9}$	$\frac{5}{9}$
	$\Xi\Sigma(\frac{3}{2})$	(22)	(03)	$\frac{10}{9}$	$\frac{10}{9}$
-4	$\Xi\Xi(0)$	$-$	(30)	$-$	$\frac{2}{9}$
	$\Xi\Xi(1)$	(22)	$-$	$\frac{10}{9}$	$-$

２バリオン系の結果

B_8B_8 states : $\overset{8}{(11)} \times \overset{8}{(11)} = \overset{27}{(22)} + \overset{10}{(30)} + \overset{10^*}{(03)} + \overset{8s}{(11)_s} + \overset{8a}{(11)_a} + \overset{1}{(00)}$

S	B_8B_8(isospin)	$\mathcal{P}=+1$(symmetric)	$\mathcal{P}=-1$(antisymmetric)	norm eigenvalue	
		^1E or ^3O	^3E or ^1O	^1S	^3S
0	$NN(0)$	–	(03)	–	$\frac{10}{9}$
	$NN(1)$	(22)	–	$\frac{10}{9}$	–
	ΛN	$\frac{1}{\sqrt{10}}[(11)_s + 3(22)]$	$\frac{1}{\sqrt{2}}[-(11)_a + (03)]$	1	1
−1	$\Sigma N(\frac{1}{2})$	$\frac{1}{\sqrt{10}}[3(11)_s - (22)]$	$\frac{1}{\sqrt{2}}[(11)_a + (03)]$	$\frac{1}{9}$	1
	$\Sigma N(\frac{3}{2})$	(22)	(30)	$\frac{10}{9}$	$\frac{2}{9}$
	$\Lambda\Lambda$	$\frac{1}{\sqrt{5}}(11)_s + \frac{9}{2\sqrt{30}}(22) + \frac{1}{2\sqrt{2}}(00)$	–	1	–
	$\Xi N(0)$	$\frac{1}{\sqrt{5}}(11)_s - \sqrt{\frac{3}{10}}(22) + \frac{1}{\sqrt{2}}(00)$	$(11)_a$	$\frac{4}{3}$	$\frac{8}{9}$
	$\Xi N(1)$	$\sqrt{\frac{3}{5}}(11)_s + \sqrt{\frac{2}{5}}(22)$	$\frac{1}{\sqrt{3}}[-(11)_a + (30) + (03)]$	$\frac{4}{9}$	$\frac{20}{27}$
−2	$\Sigma\Lambda$	$-\sqrt{\frac{2}{5}}(11)_s + \sqrt{\frac{3}{5}}(22)$	$\frac{1}{\sqrt{2}}[(30) - (03)]$	$\frac{2}{3}$	$\frac{2}{3}$
	$\Sigma\Sigma(0)$	$\sqrt{\frac{3}{5}}(11)_s - \frac{1}{2\sqrt{10}}(22) - \sqrt{\frac{3}{8}}(00)$	–	$\frac{7}{9}$	–
	$\Sigma\Sigma(1)$	–	$\frac{1}{\sqrt{6}}[2(11)_a + (30) + (03)]$	–	$\frac{22}{27}$
	$\Sigma\Sigma(2)$	(22)	–	$\frac{10}{9}$	–
	$\Xi\Lambda$	$\frac{1}{\sqrt{10}}[(11)_s + 3(22)]$	$\frac{1}{\sqrt{2}}[-(11)_a + (30)]$	1	$\frac{5}{9}$
−3	$\Xi\Sigma(\frac{1}{2})$	$\frac{1}{\sqrt{10}}[3(11)_s - (22)]$	$\frac{1}{\sqrt{2}}[(11)_a + (30)]$	$\frac{1}{9}$	$\frac{5}{9}$
	$\Xi\Sigma(\frac{3}{2})$	(22)	(03)	$\frac{10}{9}$	$\frac{10}{9}$
−4	$\Xi\Xi(0)$	–	(30)	–	$\frac{2}{9}$
	$\Xi\Xi(1)$	(22)	–	$\frac{10}{9}$	–

Origin of repulsive Σ nuclear potential

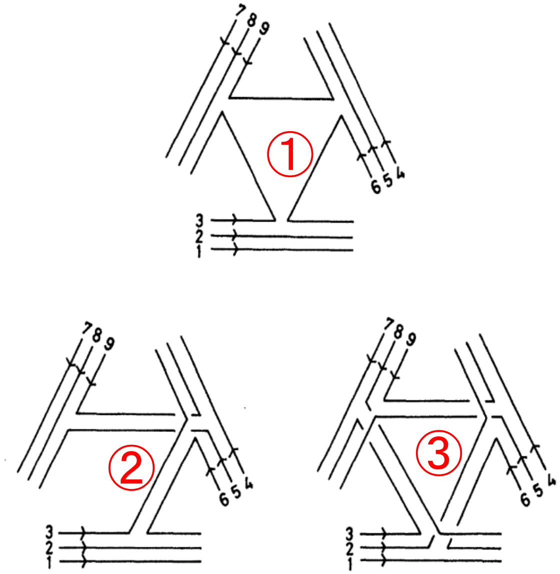
3-baryon system

Eigen-value の構成　(color)×(spin-flavor)

各バリオンのcolor-singlet condition

D−term	2B−term	①	②	③
1	$\frac{1}{3}$	$\frac{1}{9}$	$\frac{1}{9}$	0

Type-③を考える必要なし



3-baryon system

Eigen-value の構成　(color) × (spin-flavor)

$B_8 B_8 B_8$ system

$$
\begin{aligned}
(22) \otimes (11) &= (41) \oplus (33) \oplus (30) \oplus (22)_s \oplus (22)_a \oplus (14) \oplus (11) \oplus (03) \\
(30) \otimes (11) &= (41) \oplus (30) \oplus (22) \oplus (11) \\
(03) \otimes (11) &= (22) \oplus (14) \oplus (11) \oplus (03) \\
(11) \otimes (11) &= (22) \oplus (30) \oplus (03) \oplus (11)_s \oplus (11)_a \oplus (00) \\
(00) \otimes (11) &= (11)
\end{aligned}
$$

対応する次元表現: $\dim(\lambda\mu) = \frac{1}{2}(\lambda + 1)(\mu + 1)(\lambda + \mu + 2)$

Interesting $B_8B_8B_8$-systems

Triton $\left|NNN(I=\frac{1}{2})\right\rangle$

Hyper-triton $|NN\Lambda(I=0)\rangle$, $|NN\Lambda(I=1)\rangle$

$nn\Lambda$

nnn $\left|NNN(I=\frac{3}{2})\right\rangle$

$nn\Sigma^-$ $|NN\Sigma(I=2)\rangle$

$nn\Xi^-$ $\left|NN\Xi(I=\frac{3}{2})\right\rangle$

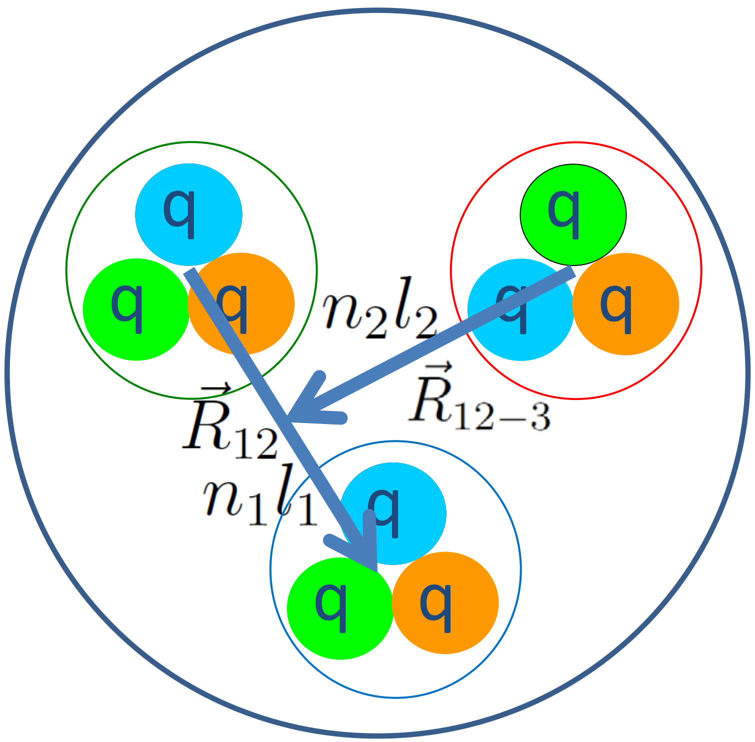
$\Lambda\Lambda\Lambda$ $|\Lambda\Lambda\Lambda\rangle$

$\Sigma^-\Sigma^-\Sigma^-$ $|\Sigma\Sigma\Sigma(I=3)\rangle$

$\Xi^-\Xi^-\Xi^-$ $\left|\Xi\Xi\Xi(I=\frac{3}{2})\right\rangle$

$\left|\Xi\Xi\Xi(I=\frac{1}{2})\right\rangle$

Eigenvalue for $B_8B_8B_8$



Total spin : S = ½

$(n\,l) = (00)$

Eigenvalue $\mu^{B_1 B_2 B_3}_{[SI(l_1 l_2)l]}$

$= (\text{D-term}) + (\text{2B-term}) + (\ ①\ ) + (\ ②\ )$

$(n_1 l_1) = (n_2 l_2) = \underline{(00)}$

内部相対軌道角運動量はS波のみ

Interesting $B_8B_8B_8$-systems

Triton $\left|NNN(I=\frac{1}{2})\right\rangle$ =(14)

$\Lambda\Lambda\Lambda$ $|\Lambda\Lambda\Lambda\rangle$

$\Sigma^-\Sigma^-\Sigma^-$ $|\Sigma\Sigma\Sigma(I=3)\rangle$

Hyper-triton
- $|NN\Lambda(I=0)\rangle$
- $|NN\Lambda(I=1)\rangle$

$\Xi^-\Xi^-\Xi^-$ $\left|\Xi\Xi\Xi(I=\frac{3}{2})\right\rangle$

$nn\Lambda$

nnn $\left|NNN(I=\frac{3}{2})\right\rangle$

$\left|\Xi\Xi\Xi(I=\frac{1}{2})\right\rangle$ =(41)

$nn\Sigma^-$ $|NN\Sigma(I=2)\rangle$

$nn\Xi^-$ $\left|NN\Xi(I=\frac{3}{2})\right\rangle$

$$\left|NNN(I=\tfrac{1}{2})\right\rangle \quad \& \quad \left|\Xi\Xi\Xi(I=\tfrac{1}{2})\right\rangle$$

RGMノルム核の構成

(color) × (spin-flavor) × (orbital)

NNN system

$$[[NN]_{I=1}N]_{I=\frac{3}{2}} = (33)$$

$$[[NN]_{I=1}N]_{I=\frac{1}{2}} = (14)$$

$$[[NN]_{I=0}N]_{I=\frac{1}{2}} = (14)$$

$$\left[[NN]_{(22)}N\right]_{I=\frac{3}{2}} = (33)$$

$$\left[[NN]_{(22)}N\right]_{I=\frac{1}{2}} = (14)$$

$$\left[[NN]_{(03)}N\right]_{I=\frac{1}{2}} = (14)$$

$$\left| NNN(I=\tfrac{1}{2}) \right\rangle \quad \& \quad \left| \Xi\Xi\Xi(I=\tfrac{1}{2}) \right\rangle$$

RGMノルム核の構成

(color) × (spin-flavor) × (orbital)

↓ ΞΞΞ system

$$[[\Xi\Xi]_{I=1}\,\Xi]_{I=\frac{3}{2}} = (33) \quad \Rightarrow \quad \left[[\Xi\Xi]_{(22)}\,\Xi\right]_{I=\frac{3}{2}} = (33)$$

$$[[\Xi\Xi]_{I=1}\,\Xi]_{I=\frac{1}{2}} = (41) \quad \Rightarrow \quad \left[[\Xi\Xi]_{(22)}\,\Xi\right]_{I=\frac{1}{2}} = (41)$$

$$[[\Xi\Xi]_{I=0}\,\Xi]_{I=\frac{1}{2}} = (41) \quad \Rightarrow \quad \left[[\Xi\Xi]_{(30)}\,\Xi\right]_{I=\frac{1}{2}} = (41)$$

$$\left|NNN(I=\tfrac{1}{2})\right\rangle \quad \& \quad \left|\Xi\Xi\Xi(I=\tfrac{1}{2})\right\rangle$$

NNN system

$$\left[[NN]_{(22)}\,N\right]_{I=\frac{1}{2}} = (14)$$

$$\left[[NN]_{(03)}\,N\right]_{I=\frac{1}{2}} = (14)$$

(03): 10*, (14): 35*

ΞΞΞ system

$$\left[[\Xi\Xi]_{(22)}\,\Xi\right]_{I=\frac{1}{2}} = (41)$$

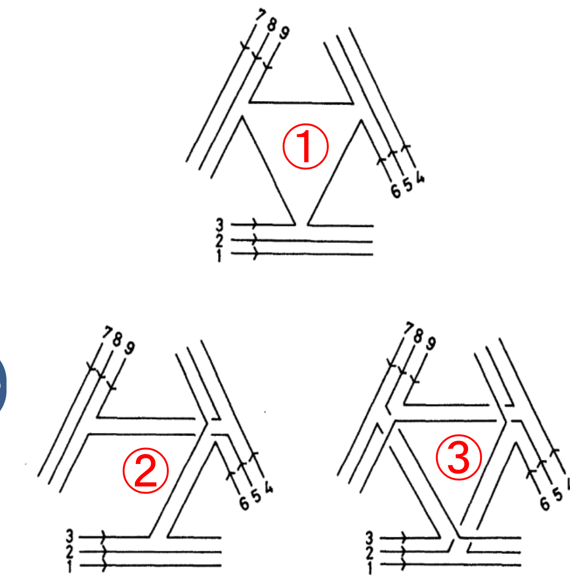
$$\left[[\Xi\Xi]_{(30)}\,\Xi\right]_{I=\frac{1}{2}} = (41)$$

(30): 10, (41): 35

対応する次元表現: $\dim(\lambda\mu) = \frac{1}{2}(\lambda+1)(\mu+1)(\lambda+\mu+2)$

$$\left|NNN(I=\tfrac{1}{2})\right\rangle \quad \& \quad \left|\Xi\Xi\Xi(I=\tfrac{1}{2})\right\rangle$$

$\mu^{B_1B_2B_3}_{[SI(l_1l_2)l]}$		D-term	2B-term	①	②	Total
$\mu^{NNN}_{[\frac{1}{2}\frac{1}{2}(00)0]}$	NNN	1	$\frac{1}{3}$	$\frac{22}{81}$	$-\frac{30}{81}$	$\frac{100}{81}$
$\mu^{\Xi\Xi\Xi}_{[\frac{1}{2}\frac{1}{2}(00)0]}$	ΞΞΞ	1	-1	$-\frac{14}{81}$	$\frac{18}{81}$	$\frac{4}{81}$



- ΞΞΞ(SI=½½) state ⇒ 強いパウリ斥力
- NNN系とΞΞΞ系では quark-exchange contribution が逆
- 3-baryon 間の quark-exchange contribution は、2-baryon 間のそれに対して逆符号で1/3~1/20(今回は)

Interesting $B_8B_8B_8$-systems

Triton $\left|NNN(I=\frac{1}{2})\right\rangle$

Hyper-triton
$|NN\Lambda(I=0)\rangle$
$|NN\Lambda(I=1)\rangle$

$nn\Lambda$

nnn $\left|NNN(I=\frac{3}{2})\right\rangle$ ＝(33)

$nn\Sigma^-$ $|NN\Sigma(I=2)\rangle$

$nn\Xi^-$ $\left|NN\Xi(I=\frac{3}{2})\right\rangle$

$\Lambda\Lambda\Lambda$ $|\Lambda\Lambda\Lambda\rangle$

$\Sigma^-\Sigma^-\Sigma^-$ $|\Sigma\Sigma\Sigma(I=3)\rangle$ ＝(33)

$\Xi^-\Xi^-\Xi^-$ $\left|\Xi\Xi\Xi(I=\frac{3}{2})\right\rangle$ ＝(33)

$\left|\Xi\Xi\Xi(I=\frac{1}{2})\right\rangle$

Complete Pauli-forbidden states

nnn $\left|NNN(I=\frac{3}{2})\right\rangle$

$\Sigma^-\Sigma^-\Sigma^-$ $|\Sigma\Sigma\Sigma(I=3)\rangle$

$\Xi^-\Xi^-\Xi^-$ $\left|\Xi\Xi\Xi(I=\frac{3}{2})\right\rangle$

$= (33)$ 64

$$|\Lambda\Lambda\Lambda\rangle = \sqrt{\frac{540}{1400}}(33) + \sqrt{\frac{216}{1400}}(22)_s + \sqrt{\frac{189}{1400}}(22)$$

64 27s 27

$$+\sqrt{\frac{56}{1400}}(11)_s+\sqrt{\frac{189}{1400}}(11)_{(22)}+\sqrt{\frac{175}{1400}}(11)_{(00)}+\sqrt{\frac{35}{1400}}(00)$$

8s 8 derived from 27 $\otimes$ 8 8 derived from 1 $\otimes$ 8 1

All eigen-value in (0s)-state are 0

$\langle\Lambda\Lambda\Lambda\,|\mathcal{A}|\,\Lambda\Lambda\Lambda\rangle = 0$ ⇒ Check of calculation : OK!

Interesting $B_8B_8B_8$-systems

Triton $\left|NNN(I=\frac{1}{2})\right\rangle$

Hyper-triton
- $|NN\Lambda(I=0)\rangle$
- $|NN\Lambda(I=1)\rangle$

$nn\Lambda$

nnn $\left|NNN(I=\frac{3}{2})\right\rangle$

$nn\Sigma^-$ $|NN\Sigma(I=2)\rangle$

$nn\Xi^-$ $\left|NN\Xi(I=\frac{3}{2})\right\rangle$

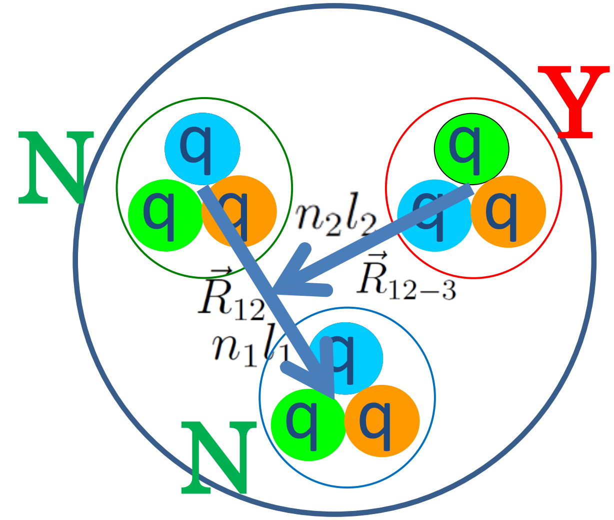
$\Lambda\Lambda\Lambda$ $|\Lambda\Lambda\Lambda\rangle$

$\Sigma^-\Sigma^-\Sigma^-$ $|\Sigma\Sigma\Sigma(I=3)\rangle$

$\Xi^-\Xi^-\Xi^-$ $\left|\Xi\Xi\Xi(I=\frac{3}{2})\right\rangle$

$\left|\Xi\Xi\Xi(I=\frac{1}{2})\right\rangle$

NNY systems



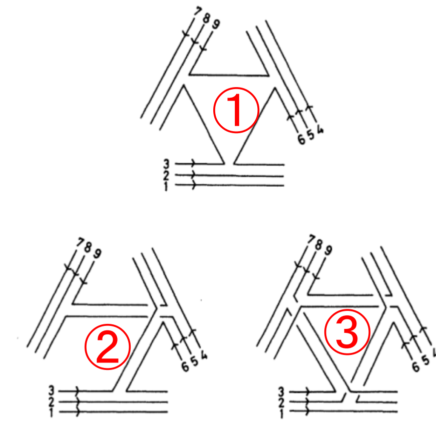
$$|NN\Lambda(I=0)\rangle = \sqrt{\tfrac{1}{2}}\,[(14)+(03)]$$

$$|NN\Lambda(I=1)\rangle = \sqrt{\tfrac{16}{56}}(33) + \sqrt{\tfrac{5}{56}}(22)_s + \sqrt{\tfrac{21}{56}}(22)_a - \sqrt{\tfrac{14}{56}}(14)$$

$$|NN\Sigma(I=2)\rangle = -\sqrt{\tfrac{2}{3}}(41) + \sqrt{\tfrac{1}{3}}(33)$$

$$\left|NN\Xi(I=\tfrac{3}{2})\right\rangle = -\sqrt{\tfrac{70}{504}}(41) + \sqrt{\tfrac{40}{504}}(33) - \sqrt{\tfrac{140}{504}}(30) + \sqrt{\tfrac{135}{504}}(22)_s + \sqrt{\tfrac{63}{504}}(22)_a - \sqrt{\tfrac{56}{504}}(14)$$

NNY systems



	D-term	2B-term	①	②	①+②	Total
NNN (I=1/2)	1	$\frac{1}{3}$	$\frac{22}{81}$	$-\frac{30}{81}$	$-\frac{8}{81}$	$\frac{100}{81}$
ΞΞΞ (I=1/2)	1	−1	$-\frac{14}{81}$	$\frac{18}{81}$	$\frac{4}{81}$	$\frac{4}{81}$
NNΛ (I=1)	1	$\frac{1}{9}$	$\frac{8}{27}$	$-\frac{13}{27}$	$-\frac{5}{27}$	$\frac{25}{27}$
NNΣ (I=2)	1	−1	$-\frac{14}{81}$	$\frac{18}{81}$	$\frac{4}{81}$	$\frac{4}{81}$
NNΞ (I=3/2)	1	$-\frac{5}{9}$	$-\frac{2}{27}$	0	$-\frac{2}{27}$	$\frac{10}{27}$

NNN: 3体効果：斥力

パウリ斥力は
NNNと比べて

NNΛ: パウリ斥力：弱い
3体効果：斥力

NNΣ: パウリ斥力：強い
3体効果：no斥力

NNΞ: パウリ斥力：強い
3体効果：斥力

4. Summary

- RGMノルム核の評価を通して、$B_8B_8B_8$系におけるクォーク･パウリ効果について調べた。
- クォーク･パウリ斥力効果の強い3バリオン系の順番：

$$nn\Sigma^- > nn\Xi^- > nn\Lambda$$

- パウリ斥力に対する3体効果からの寄与は、系依存性があるように見える

Future

・S = 3/2 state ⇐ 今回の研究の追加課題

・kinetic 及び interaction項の評価

・decouplet baryonを含んだ評価

⇐ 今後の目標