Opening Remarks

--Clustering as a window on the hierarchical structure of quantum systems

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Clusters & Hierarchies

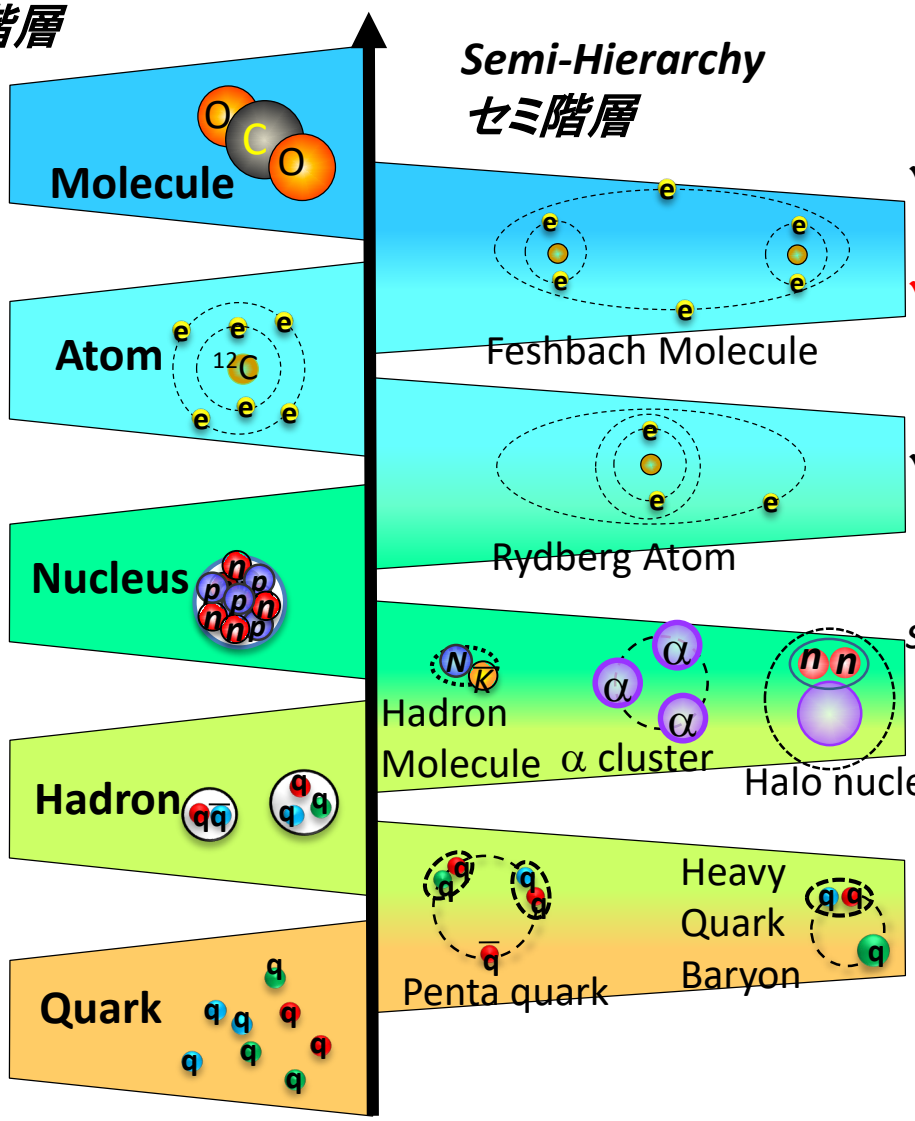
新学術領域「クラスター階層」第４回領域研究会

3rd Symposium on Clustering as as window on the hierarchical structure of quantum systems, 28 May, 2020

Clusters and Semi-Hierarchy

Conventional Hierarchy
従来型階層

- ✓ Big Gap between Hierarchies
- ✓ **Strongly Bound**
  強束縛
- ✓ Simple constituents: Nucleus= "nucleonic" system



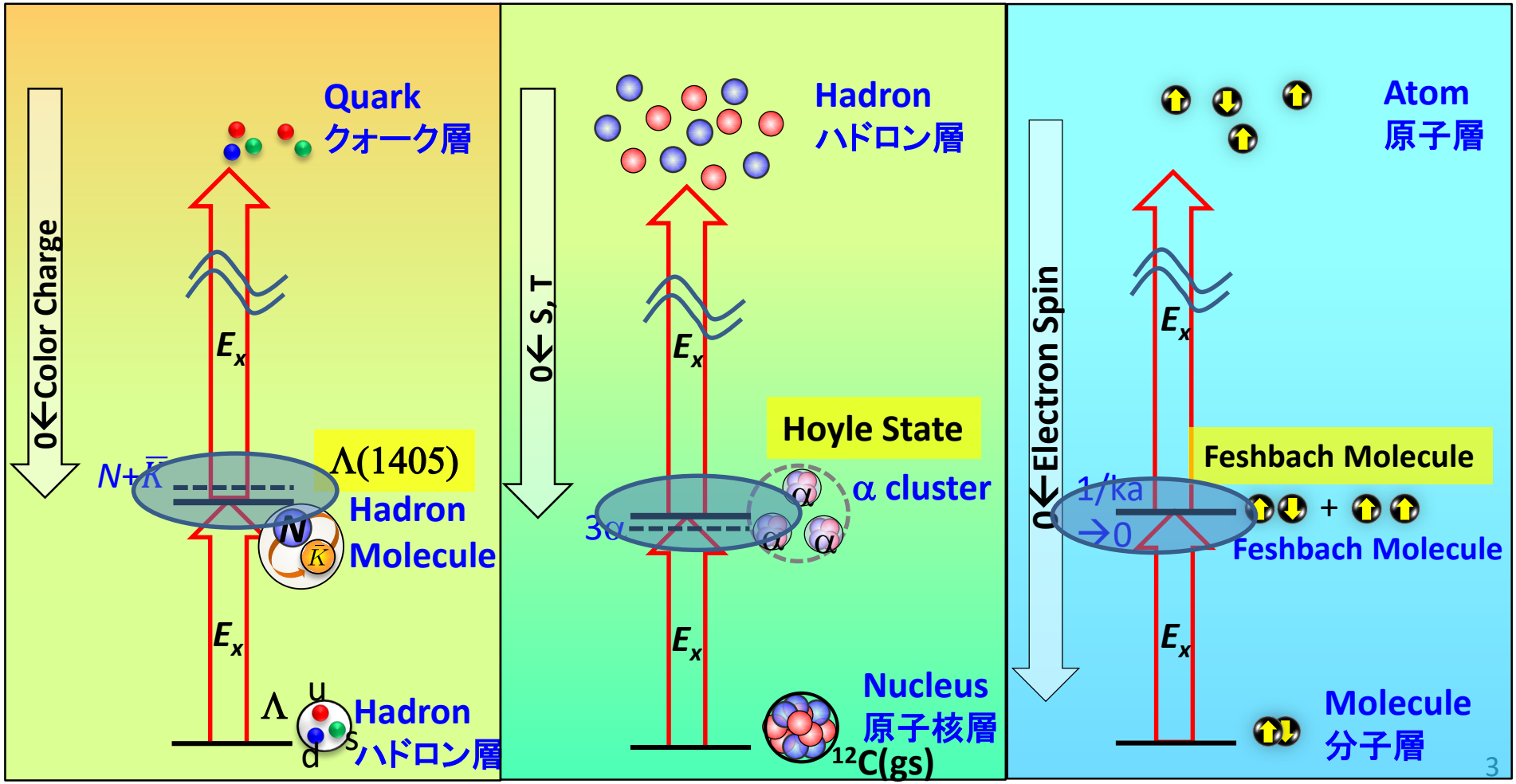
- ✓ Smaller Gap between Hierarchies
- ✓ **Weakly Bound (Unbound)**
  弱束縛(弱非束縛)
- ✓ Mixed constituents: Halo Nucleus
  ="nucleonic"+"dineutron" system

Semi-Hierarchy: Key Aspects to understand the hierarchical structure of matter

This Research Area → "Three Key Indexes to Connect Hierarchies"

本領域研究→「階層間をつなぐ3つの指標」を確立

- ✓ Degree of Freedom自由度 : Charge, Spin Isospin → Neutralization→ Hierarchy
- ✓ Threshold Rule 閾値則 : Near Threshold →Cluster (Hierarchy)
- ✓ Degree of Separatin 分離度 : Quantify Separation by Purity of "Cluster state"



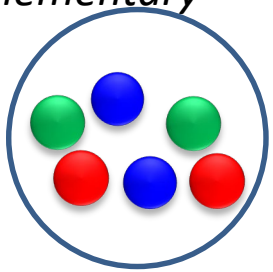
Question:

Why deuteron is pn, not 6q?

D.o. Separation: "Compositeness : Z"
(Field renormalization constant)

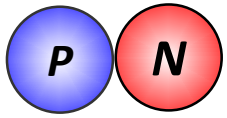
S. Weinberg, PR 137, 672 (1965)
T. Hyodo, IJMPA 28, 1330045 (2013)

Hadron-like deuteron
: *elementary*



Z~1

Nuclear-like deuteron
: *composite (cluster)*



Z~0

$$|many\ body\ state\rangle = \sqrt{Z}|elementary\rangle + \sqrt{1-Z}|composite\rangle$$

$$a = \frac{2(1-Z)}{2-Z}R + o(m_\pi^{-1})$$

$$r_e = -\frac{Z}{1-Z}R + o(m_\pi^{-1})$$

$$R = \frac{1}{\sqrt{2\mu B}} = 4.31\ fm$$

Deuteron: Weakly bound limit (B=2.23 MeV, $a = 5.42$fm, $r_e = 1.74$fm)

⇒ Z~0

One explanation how "the threshold" makes "Cluster state"

How "Neutralization of Color Charge (d.o.f)" is included in this picture?
How "interaction" between pn is included in this picture?

Question:

How "partial neutralization" affects the clustering picture?

Partial Neutralization

- Diquark Spin-singlet (S=0), But Colorful
- Dineutron Spin-singlet (S=0), But T=1
- Deuteron(Pn) T=0, but Spin-triplet (S=1)

…

Summary of the 3rd Meeting (5/18/2020)

敬称略

- Shirotori: Detectors/Electronics
- Ishikawa: Scattering length
- Dozono: pairing vibration
- Kawabata: Alpha condensate
- Nakazawa: Hypernuclei
- Kobayashi: 3body system: Efimov
- Horiuchi: Triple-alpha: Medium effect
- Oka: diquark
- Shikano: Quantum computing→Many-body problem
- Otsuka: Binding Limit vs. Shape
- Hyodo : Compositeness (relevant to Halo)
- Ejiri: QCD phase diagram
- Nakatsukasa: Nuclear reaction/Shape/alpha-cluster
- Tachikawa: Ab-initio calc. Multi-component system
- A. Ohnishi: Scattering length and correlation function/threshold
- Miyabayashi: hadron molecule/tetra quark

- Threshold (weakly bound/unbound)
- Detectors
- Scattering Length
- 3-body problem
- Diquark/dineutron/pairing
- Macro (Shape) vs Micro
- Ab-initio Calc/ Lattice QCD