【Grant-in-Aid for Specially Promoted Research】

Toward revolutionary Nuclear Study via revealing Internal Structure of Kaonic Nuclei

Principal Investigator	RIKEN, Cluster for Pioneering Research, Chief Scientist IWASAKI Masahiko	Researcher Number:60183745
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Purpose and Background of the Research

●Outline of the Research

Mesons have been generally considered to be a virtual state repeating creation and annihilation in nuclei. On the other hand, Λ(1405) resonance has been theoretically suggested that the it may have a molecule-like hadronic internal structure consisting of two particles, i.e., kaon and proton. If this is correct, there should be a nuclear state in which a K meson and nucleons are bound together as shown in Figure 1. As a result of an experimental search, we found a "K-pp" molecule-like state consisting of a K meson and two protons. Starting from this state, we will conduct a systematic study to unravel the fundamental properties of "K mesonic nucleus".

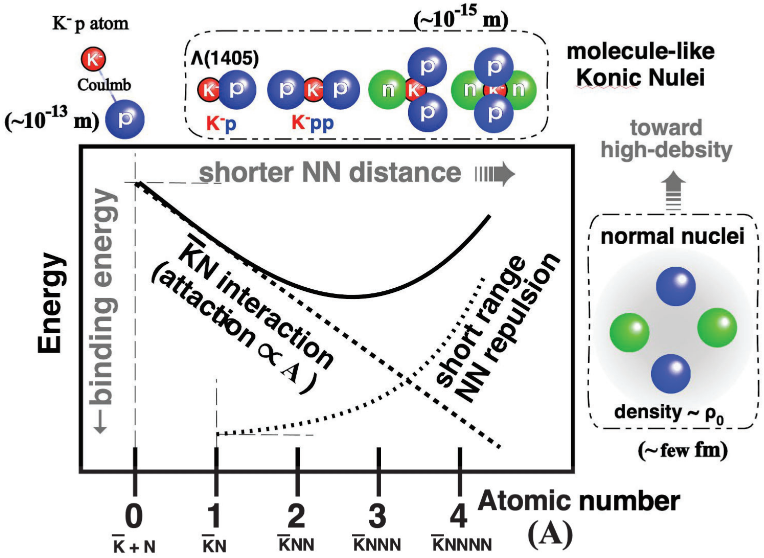

Figure 1. K mesons and nucleons (protons or neutrons) in the nucleus have a very strong attraction. Thus, the more nucleons there are, the more strongly bound nuclei are formed with K mesons. This state overcomes the short-range inter-nucleon repulsion and forms a peculiar "ultra-dense nucleus with molecule-like spatial configuration".

●Toward understanding of the fundamental properties of Kaonic nuclei

Nucleons such as protons and neutrons are composite particles consisting of three quarks, but each nucleon behaves as an individual particle in the nucleus. Mesons are virtual particles in the nucleus and were thought to be insubstantial. Thus, the "K-pp" state is an extremely unique state in which the K mesons are bound as individual particles keeping their intrinsic masses as particles. By investigating the internal state of this novel state, we will study how molecule-like nuclei are formed and what kind of fundamental properties they possess.

●Internal structure and symmetry of Kaonic nucleus

The nucleons, the proton and neutron, are particles composed of three light quarks (u, d), having spin 1/2 (intrinsic angular momentum) and almost identical mass. On the other hand, the K meson is composed of s-quark and anti-u or d quark and has two charge states: negative K^- and uncharged $\bar{K}^0$, respectively. Both are spin 0 particles and the masses are almost equal.

The "K^-pp" is a system in which two nucleons are bound by a Kaon by the strong interaction with good internal symmetry, having molecule-like spatial configuration as shown in Figure 2.

To verify whether this understanding is correct, we shall determine the internal charge and spin symmetry, experimentally. This internal structural is determined by the quantum number the state, *i.e.*, $I(J^P)$ that defines the structure shown in Figure 2. By utilizing the study as a stepping stone for the further study on multi-nucleon systems shown in the upper part of Fig. 1.

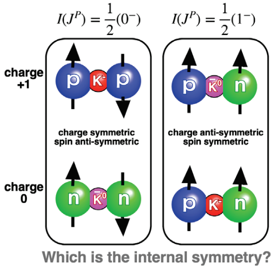

Figure 2. Two possible internal structures of the simp-lest kaonic nucleus "K^-pp", which must be examined experimentally.

Expected Research Achievements

●The kaonic nuclear bound state as a new research field

By experimentally clarifying the internal symmetry of the Kaonic nuclear bound state using the spin-spin angular correlation as shown in Fig. 3, with the experimental apparatus shown in Fig. 4, we will clarify the fundamental properties of the Kaonic nuclear bound state. We also develop lattice QCD to understand the state, by bridging from ab-initio calculation to effective field theory based on chiral symmetry, etc., and apply that to the reaction and structure calculations based on ab-initio calculation. We will challenge to form a new academic field of the "Kaonic nuclear bound state" through fundamental cooperation between experiment and theory.

We will shed light on the following issues in the physical realm that connects two heterogeneous matter-hierarchies of the "QCD phase" in which gluons dominate the exchange "colors", and the "hadronic phase" which consists of colorless quark composite particles, by means of anti-K meson as a probe locates in between the two. ◎**Hadronization of quarks**: (colorless-particle formation at the phase boundary): How are colorless-hadrons produced as independent particles from the QCD phase? ◎**Origin of Hadron Mas**s: Why is the hadron mass much larger than the sum of quark masses? ◎**High Density Physics** (Equation of State of Matter): Why a neutron star does not crush by its own weight?

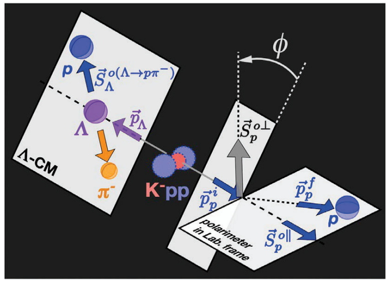

Figure 3 Schematic of experimental principle, how to determine the internal structure of "K^-pp". It can be determined by the relative angles of spins in between Λ and proton in the Λp decaying mode. The Λ spin is measured by the direction of the $p\pi^-$ decay (left panel) and the proton scattering direction (right panel) by the polarimeter shown in red in Figure 4.

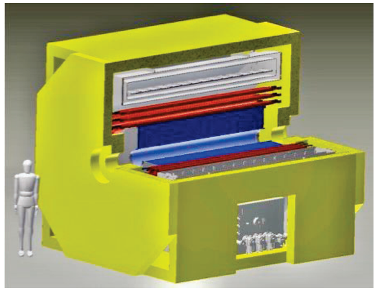

Figure 4. Conceptual drawing of the spectrometer to be created in this research project, composed of a cylindrical drift chamber (shown in blue) placed inside a large superconducting solenoid (white) and neutron detector array (red), which also utilized as a spin polarimeter to efficiently elucidate the properties of Kaonic nuclear bound state in nuclei.

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