Systematic Experiments for Light Kaonic Nuclei

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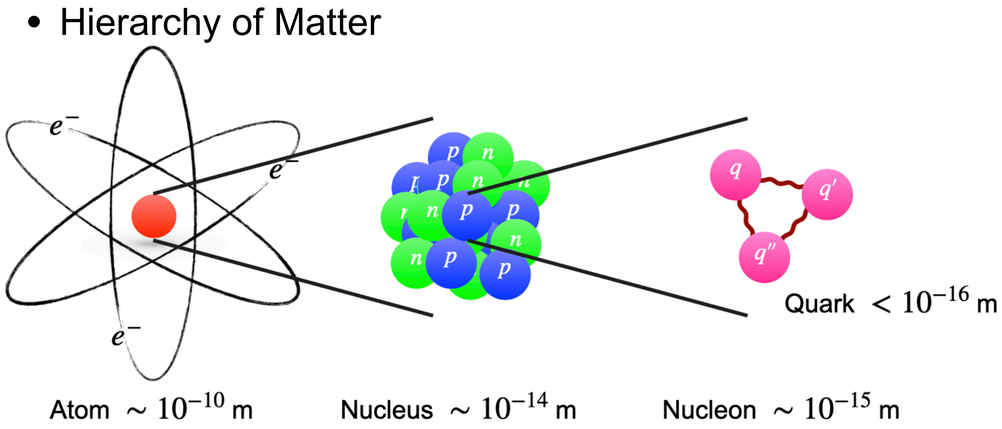
Abstract: We aim to observe "K^-ppn" for the first time in the world. If "K^-ppn" exists, we will investigate how its **binding energy**, **decay width**, and **production cross section** differ from those of "K^-ppn". Furthermore, by analyzing various decay modes — especially **three-body decay channels** — in close collaboration with theoretical studies, we will discuss the **density evolution of kaonic nuclei** and their possible transition to high-density nuclear matter. We are preparing the new detector system for the experiment now.

- Composition of Matter -

- Hierarchy of Matter



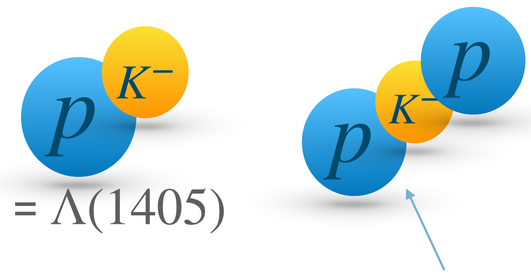
- Quark Flavors

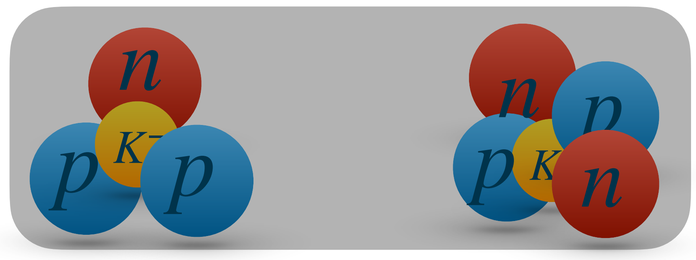
	1st generation	2nd generation	3rd generation
+2/3 e	Mass: ~2.2 MeV/c^2 u "Up"	Mass: ~1.28 GeV/c^2 c "Charm"	Mass: ~173.1 GeV/c^2 t "Top"
-1/3 e	Mass: ~4.7 MeV/c^2 d "Down"	Mass: ~96 MeV/c^2 s "Strange"	Mass: ~4.18 GeV/c^2 b "Bottom"

- Nucleons are a type of particle called "**baryon**", each consisting of **three quarks**.
  - e.g.) proton: **"uud"**, neutron: **"udd"…**
- **In vacuum**, there also exist particles called "**meson**", which consist of **one quark and one anti-quark**.
  - e.g.) π^-: "$\bar{u}d$", K^-: "$\bar{u}s$"…
- Apparently, all matter in the universe is made of **baryons** (and electrons, etc.).
- Can **mesons** also be constituents of matter?
  - If so, what kind of **properties** would such matter have compared with ordinary matter?

- What are "Kaonic Nuclei"? -

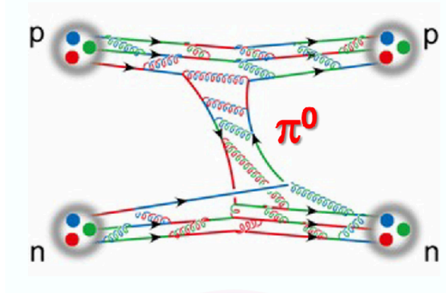
- Kaonic nuclei = anti-kaon($\bar{K}$) — nucleus(N) bound states
  - Predicted from attractive $\bar{K}N$ interaction in $I = 0$ channel and the existence of $\Lambda(1405)$

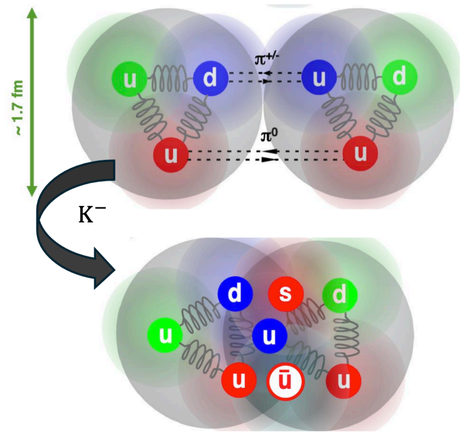




- What is interesting? -

- "Real" meson in nuclei
  - Usualy, meson is "vertial particle" in nuclei (Yukawa theorem). Only in vacuum, real meson exists (cf. meson beam).
- High-density state may emerges
  - Predicted from its bigger binding energy and $\bar{K}N$ attractive force cf. $B.E.(K^-pp) = \sim 50$ MeV, pp -> unbound $B.E.(d = pn) = 2$ MeV
- A hint to understanding the unknown nature of exotic hadrons
  - If these are so dense that their components overlap each other, they could become quark matter, not molecule-like state, I think.

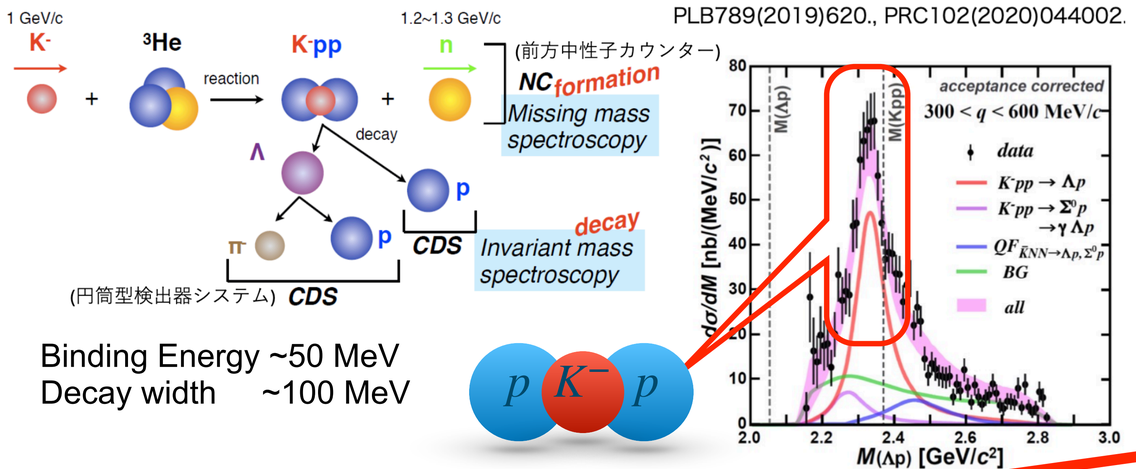




Molucle? Quark matter?

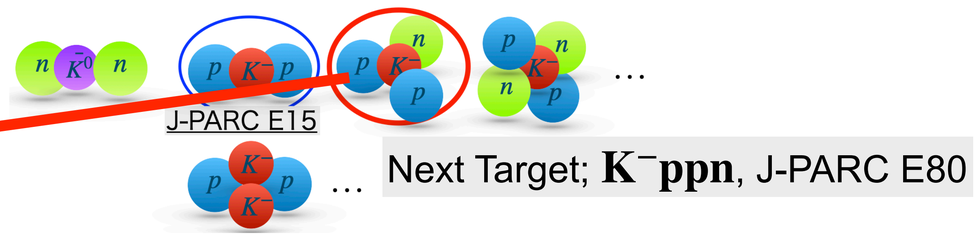
- To J-PAEC E80 From J-PARC E15 and the new Cylindrical Detector System -

J-PARC E15 experiment confirmed the existence of the simplest kaonic nuclei K^-pp.

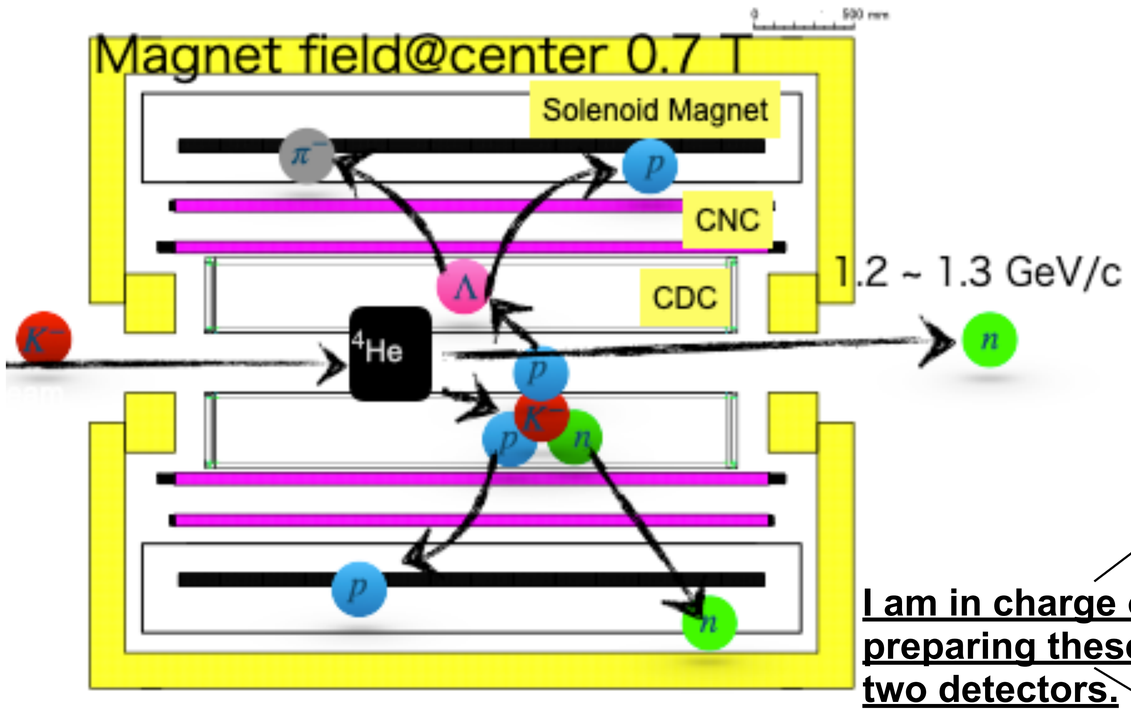


Binding Energy ~50 MeV
Decay width ~100 MeV

- Kaonic nuclei are formed by the strongly attractive $\bar{K}N$ interaction
  —> The best probe to understand $\bar{K}N$ interaction in the subthreshold region.
- Deeper binding energy than normal nuclei
  —> Could this suggest high dense matter?
- The system includes a real boson.
  —> Potential to gain new insight into the composition of matter



J-PARC E80 We aim to obtain the **binding energy, decay width and branching ratio of the** K^-ppn.



- The neutrons to be detected are produced.
- The number of final-state particles increases compared to E15

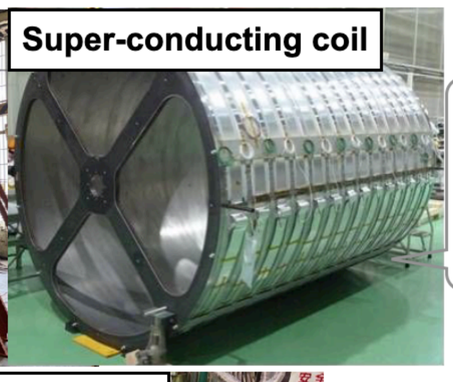
Large solid angle and high neutron detection efficiency of the detector system is neccesary.

A new detector system is under construction.

I am in charge of preparing these two detectors.

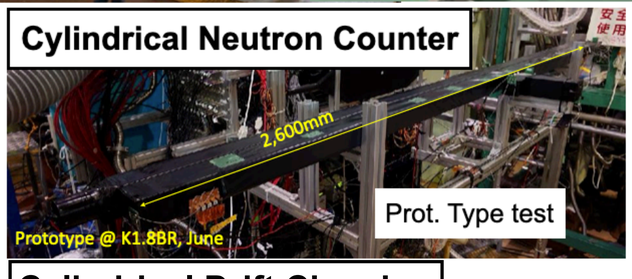
Solenoid York

Super-conducting coil



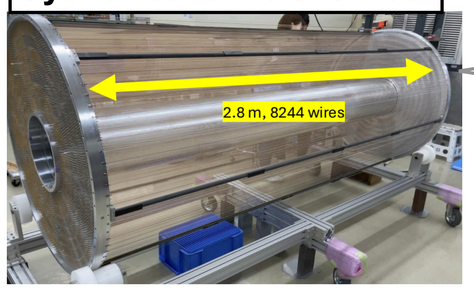
- 3.3m x 3.3m x 3.9m, ~108t in total
- Max. Field of 1.0T @ center
  - 189A - 10V
- NbTi/Cu SC wire, 98km in total
- Have been built in Feb. 2025
- Magnet field measurement -> no probrem

Cylindrical Neutron Counter



- Scintillator array: 2 layers, 12 cm thickness
- MPPC array
- Neutron detection efficiency of 12~36%
- Intrinsic time resolution of ~80ps

Cylindrical Drift Chamber



- The CDC consists of two aluminum end plates and a CFRP cylinder as the inner wall.
- 8,244 wires(The wire tension was applied so that the wire sag was less than 200 um.)
- 15 layers of hexagonal cells with a typical drift length of 9 mm
- Preamplifiers with ASAGI (developped by SPADI-A)

- Prospect -

Installation of the new CDS to K1.8BR beamline in J-PARC is scheduled for 2026, and we plan to start the physics run (J-PARC E80) in 2027.