【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Clear measurements of meson mass modifications in nucleus by using high intensity proton beam

OZAWA Kyoichiro
(High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Associate Professor)

Research Project Number: 20H05647 Researcher Number : 20323496
Keyword : Origin of hadron mass, Chiral Symmetry, finite density QCD medium

【Purpose and Background of the Research】

According to a standard quark model, a proton contains three quarks. However, its mass can't be understood as a sum of the quark mass. The proton has the mass of 938MeV/c^2 and the mass of the bare quark is only a few MeV/c^2 generated by a Higgs mechanism. The difference of mass can be understood as a result of a dynamical mass generation caused by a spontaneous breaking of the chiral symmetry.

This understanding is widely accepted and several efforts were performed to measure effects of the symmetry restorations in a medium. However, there is almost no experimental evidence for detections of mass modifications directly. Measured mass is consistent with the mass in a vacuum. Modified mass in a different circumstance is not detected clearly. Thus, the main purpose of this project is a detection of the mass modification in a medium with minimal uncertainties.

In this project, we aim to show a clear mass modification of mesons in a nucleus. Here, we choose the nucleus as a finite density QCD medium and we measure mass spectra of ϕ mesons.

【Research Methods】

We will finish constructions of a beam line and detectors and collect 73000 decays of ϕ mesons. The detectors under construction are shown in Fig. 1.

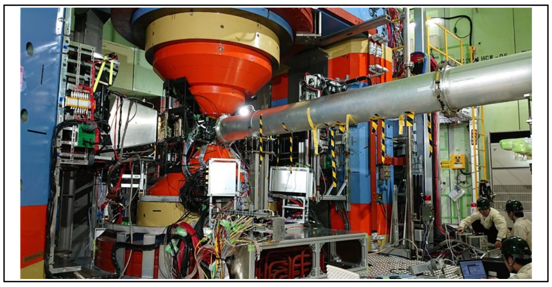

Figure 1 Detectors under construction

In this experiment, a high intensity proton beam (30GeV, 0.5 x 10^{10} protons per second) is delivered from J-PARC Main Ring Accelerator. The beam is injected to thin nuclear targets (Radiation Length 0.5%, Lead 30 μm) and generate ϕ mesons. Decays of ϕ mesons are detected by large acceptance detectors. The interaction rate at the target is very high (1 x 10^7 Hz) and we use Gas Electron Multiplier (GEM) based detectors to cope with such high rate counting. The GEM tracker and a Hadron Blind Detector (HBD), which is a kind of gas Cherenkov counter for electron identifications, were already developed and tested. The performance of the detectors satisfied our requirements.

【Expected Research Achievements and Scientific Significance】

An expected mass spectrum measured by this experiment is shown in Fig. 2. In the spectrum, there are two peaks which are correspond to the mass spectra of ϕ mesons in a free space and in a nucleus. This new peak shows the first observation of a clear evidence for the hadron mass modification in a nucleus.

An amount of the strange quark condensate in the nucleus can be evaluated based on mass spectra of ϕ mesons. The quark condensate is an order parameter of the chiral symmetry. It is a parameter to evaluate a sensitivity of a dark matter search.

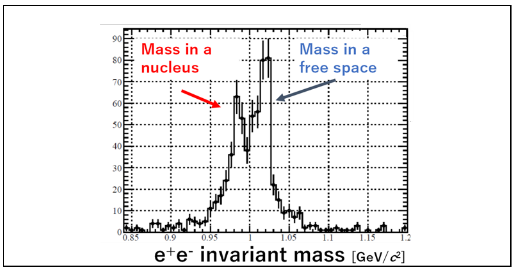

Figure 2 Expected mass spectrum

【Publications Relevant to the Project】

- "Development of a hadron blind detector using a finely segmented pad read-out," K. Kanno et al., Nuclear Instruments and Methods in Physics Research Vol. A819, 20, 24, 2016
- "Observation of ρ/ω meson modification in nuclear matter," K. Ozawa et al., Phys. Rev. Lett. 86, 5019, 5022, 2001

【Term of Project】 FY2020-2024

【Budget Allocation】 149,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://high-p.kek.jp
ozawa@post.kek.jp