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

Broad Section B

Title of Project : Study of the origin of hadron mass via eta-prime photoproduction inside a nucleus

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Keyword : Origin of hadron mass, η′ meson, Photoproduction in nuclei, Chiral symmetry, $U_A(1)$ quantum anomaly

【Purpose and Background of the Research】

The origin of hadron mass is thought to come from a change of the vacuum or the spontaneous breaking of a chiral symmetry. In order to experimentally confirm the mass generation mechanism, it is important to observe the phenomenon that the hadron mass decreases in the nucleus where the chiral symmetry is partially restored. We focus on the γγ decay of the η′ meson, which have a large mass due to the $U_A(1)$ anomaly, and measure a distribution of their invariant mass by using the high-resolution and large-acceptance electromagnetic calorimeter "BGOegg". We aim to quantitatively measure the mass reduction in a nucleus by this next-generation experiment with high statistics and low background.

【Research Methods】

In this study, the existing BGOegg experimental setup will be upgraded at the SPring-8 LEPS2 beamline. Firstly, a high-power ultraviolet pulsed laser with an externally synchronized output will be prepared for efficient laser Compton scattering via laser injection at the timing of an electron beam bunch of SPring-8. Simultaneous operation of two pulsed lasers enables to increase the photon beam intensity and the data statistics. Then, we will introduce a copper target, whose nuclear radius is 1.8 times larger than that of the carbon used in the previous BGOegg experiment. The target thickness can be reduced with the increased weight per unit area, so that both the invariant mass resolution and the data statistics will be largely improved.

A large-acceptance electromagnetic calorimeter system will be set up as shown in Fig.1. The polar angle range of 24–144 degrees around the copper target is covered by the existing calorimeter BGOegg, which is an egg-shaped assembly of 1320 BGO crystals and achieves the world's highest energy resolution of 1.3% for 1-GeV γ-rays. We plan to add a few layers of BGO crystals in the forward acceptance hole of the BGOegg. Another calorimeter composed of 252 PWO crystals will be also installed in the extremely forward region. The coverage of mostly 4π solid angles makes it possible to discriminate the multi-π^0 photoproduction that contributes as a main background in the γγ invariant mass distribution. In the data analysis, a low-momentum sample where the ratio of in-medium decays increases will be selected to compare its spectral shape with that of a high-momentum sample. As reference, data will be collected also using a liquid hydrogen target.

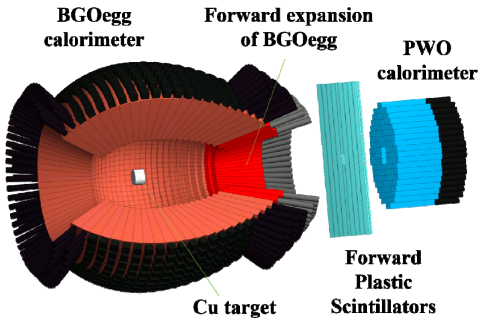

Figure 1 Experimental setup of this research.

【Expected Research Achievements and Scientific Significance】

The previous BGOegg experiment using a carbon target showed a sign of η′ mass reduction in the nucleus while its statistical significance was insufficient. In this study, the photon beam intensity will be increased to around 5 MHz, which is nearly double the previous one, and the nuclear target thickness will also be increased about twice in the total number of nucleons. By covering most of the solid angles with the electromagnetic calorimeter system, the background is reduced to about 1/40. If the in-medium mass reduction actually occurs, it can be confirmed by collecting data for a few months to two years depending on the signal amount. Three effective hadron models have been proposed to calculate the mass reduction of η′ mesons at the nuclear density, but there is wide variation in the theoretical predictions. Our research contributes to the understanding of hadron natures through the measurement of in-medium mass and decay width.

【Publications Relevant to the Project】

- N. Muramatsu, et al. (LEPS2/BGOegg Collaboration), "Differential cross sections, photon beam asymmetries, and spin density matrix elements of ω photoproduction off the proton at E_γ = 1.3−2.4 GeV", Phys. Rev. C 102 (2020) 025201.
- N. Tomida, N. Muramatsu, M. Niiyama, et al. (LEPS2/BGOegg Collaboration), "Search for η′ Bound Nuclei in the $^{12}C(\gamma, p)$ Reaction with Simultaneous Detection of Decay Products", Phys. Rev. Lett. 124 (2020) 202501.
- N. Muramatsu, et al. (LEPS2/BGOegg Collaboration), "Measurement of neutral pion photoproduction off the proton with the large acceptance electromagnetic calorimeter BGOegg", Phys. Rev. C 100 (2019) 055202.

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