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

Broad Section B

Title of Project : Origin of hadron mass studied by the systematic measurement of spectral change of mesons in nuclei

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Keyword : Experimental Nuclear Physics, GEM, Electron ID Detector, Tracker, Chiral symmetry

【Purpose and Background of the Research】

We have already published on the signature of the spectral change of vector mesons (ρ, ω, ϕ) in nuclei in 2006-7, as results of the KEK-PS E325 experiment. These are phenomena interpreted as evidence of "the mechanism of hadron mass generation due to the spontaneous broken chiral symmetry", which is proposed by Nambu.

In order to confirm this study, we have proposed J-PARC E16. We will start the commissioning of detectors at the completion of the newly-built high-momentum beamline at J-PARC Hadron experimental facility. We will perform systematic measurements with the 10 times as much statistics as that of E325.

【Research Methods】

We construct the new spectrometer at the high-momentum beamline which is under construction now, and measure the electron-positron pairs from the vector-meson decays. We radiate the primary proton beam (30 GeV, 1 x 10^{10} protons/pulse) from the J-PARC MR to very thin targets (C 400 μm, Cu 80 μm, Pb 30 μm), whose radiation length is up to 0.5% to suppress the electron background from the target material. To cope with the high interaction rate up to 1 x 10^{7} Hz at the target, we use GEM Tracker, which achieves the 100 μm of position resolution in tests, thus the evaluated mass resolution is 6-8 MeV for ϕ mesons. With the combination of two stage of electron identification detectors, Hadron Blind Gas Cherenkov Detector and Lead-glass calorimeter, we can reject background pions down to 0.03%.

【Expected Research Achievements and Scientific Significance】

As a model-independent analysis, we compare the measured invariant mass distribution of mesons with the vacuum-expected shape and difference between the two will be examined systematically. The amount of difference could be depend on the meson velocity and nuclear size, namely, the number of modified meson could be much for more slowly-moving mesons and for larger nuclei, where the probability of inside-nuclear decay is expected higher. Statistically-significant such dependences are the evidence of the spectral change of mesons in nuclei. Such analysis performed for the ϕ meson and ρ/ω mesons.

Also, we compare the data with theoretical calculations of spectral change. Once we reproduce the data shape by fitting with a model calculation, mass change of mesons at the normal nuclear density could be deduced. Particularly, mass change of ϕ meson is interpreted to the strange quark-antiquark pair condensate in nuclear matter, which is an order parameter of the chiral symmetry breaking, using in-medium QCD sum rules. Further, a momentum dependence of such mass is a dispersion relation of mesons in nuclear matter.

Namely, we re-confirm the existence of spectral change of mesons in nuclei and compare the nature of spectral change with the QCD predictions. That is an experimental elucidation of the nature of hadron as the elementary excitation on the QCD vacuum.

【Publications Relevant to the Project】

・"Evidence for In-Medium Modification of the φ meson at Normal Nuclear density", R. Muto et al. Phys. Rev. Lett. 98 (2007) 042501
・ "Experimental signature of the medium modification for rho and omega mesons in 12-GeV p+A reactions", M. Naruki et al. Phys. Rev. Lett. 96 (2006) 092301
・"In-medium mass modification of vector mesons", S. Yokkaichi, Lecture notes in physics 781 (2009) pp161-193, Springer

【Term of Project】 FY2018-2022

【Budget Allocation】 150,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://ribf.riken.jp/~yokkaich/E16/E16-index.html