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Search for phi-nucleus bound states

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In Universe there are many varieties of matter created by the strong interaction, such as hadrons, nuclei and the very high density quark matter which might be formed inside a neutron star. Because those particles and matter are generated by the strong interaction, the theory of strong interaction, i.e. the Quantum Chromo dynamics(QCD), will give answers how those states are forming from elementary particles, i.e. quarks and gluons.

One of the main questions in hadron physics is how the mass of the hadron is generated within QCD. As we know that more than 98% of the hadron mass is generating dynamically via the spontaneous breaking of chiral symmetry(χSB) in the QCD vacuum, therefore the properties of the hadron should strongly be coupled with the order parameter of the χSB, i.e. the value of quark condensati, $< \bar{q}q >$.

One way to study this question is to investigate the properties of mesons inside nuclei, because a partial restoration of the chiral symmetry is expected inside the high density environment, even with normal nuclear matter, where the value of $< \bar{q}q >$ could be decreased compared with the value in vacuum. Thus, if the origin of the hadron mass is indeed the χSB, a reduction of the hadron mass or an attractive interaction between the meson and nuclei will appear. Here we are focusing on the φ meson in nuclei studies.

There are experimental challenges to investigate the property of φ meson in nuclear matter. The NA60 experiment at CERN presented the mass and width of the φ meson in high energy indium-indium collisions as a function of collision centrality, which is equivalent to the energy density of the created high temperature matter. The result shows that no clear modification of the φ meson property inside a high temperature environment. On the other hand, KEK-PS E325 experiment reported about 3.4% mass reduction of the φ meson in medium-heavy nuclei (Cu). This result is possibly an indications of the partial restoration of chiral symmetry in nuclei, however, it is hard to derive strong conclusions from the data.

If the mass of the φ mesons reduced in nuclei, it may indicate an attractive interaction between φ meson and nucleus. If the attraction is strong enough, the formation of a φ meson nucleus bound state is expected. Therefore, we are proposing a new experiment at J-PARC to search for a φ-nucleus bound state and measure its binding energy, using $\bar{p}p \rightarrow \phi\phi$ reaction as an elementary process to produce slowly moving φ mesons. We demonstrate that a completely background-free missing-mass spectrum can be obtained efficiently by spectroscopy together with K+Λ tagging.

This paper gives an overview of the physics motivation and detector concept, explains the direction of the initial research and give the recent status of the detector development.
This presentation is an invited talk to the Session 7 of the conference.

Author: OHNISHI, Hiroaki (Research Center for Electron Photon Science, Tohoku University)

Presenter: OHNISHI, Hiroaki (Research Center for Electron Photon Science, Tohoku University)

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