FORMATION OF η-MESIC NUCLEI USING THE RECOILLESS (d,^{3}He) REACTIONS

Ryugo S. Hayano and Satoru Hirenzaki[a]

Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113, Japan
[a]Department of Physics, Nara Women's University, Nara 630-8506, Japan

In our recent experiment at GSI, we discovered deeply-bound pionic states in the ^{208}Pb(d,^{3}He) reaction [1]. From the observed strong-interaction shift of the $2p$ state of the pionic atom, the π^- mass was found to become heavier by about 14% at the center of Pb nucleus [2].

We propose here to extend the study of meson mass shift in nuclei by using the (d,^{3}He) reaction to produce η meson near the recoilless condition. Such experiment is indeed possible at GSI, using the same setup used to discover the deeply-bound pionic states [3]. This is a novel approach to study meson mass shift in nuclei, alternative to experiments using heavy-ion collisions, as summarized in the Table 1.

The mass shift of η meson is expected to be negative, and hence forms meson-nucleus bound states. In order to study the structure of η-mesic nuclei, we used the first-order η-nucleus optical potential with the η-nucleon scattering length determined in ref. [4]. With this potential, we calculated the η-nucleus binding energies and widths for various nuclei in a conventional way of solving the Klein-Gordon equation. The results are shown in Table 2. We find that the half widths are comparable or smaller than the binding energies and/or level spacing for lighter nuclei, so that it is justified to call these as quasi-stable η-mesic nuclei.

In the proposed experiment, the meson-nucleus binding energy can be determined unambiguously from the location of the bound-state peak in the (d,^{3}He) Q-value spectra. The meson mass shift can be inferred from the measured binding energies reliably since the the η-nucleus interaction is dominated by the S-wave term due to strong coupling to N*(1535) resonance. The bound state of η in light nuclei like ^{11}B is expected to be observed by the ^{12}C(d,^{3}He) reaction according to our theoretical calculation [3, 5].

In conclusion, the proposed recoilless (d,^{3}He) reaction should be a promising tool to study the η-nucleus system, and we should be able to determine the η-nucleus potential (and the possible η mass shift in nuclei) from the Q-value spectra. This method is alternative to the lepton pair invariant-mass reconstruction method (such as $\omega \to e^+e^-$). An experiment based on this principle has recently been approved at GSI(S214) [3]. In principle, this method can be extended to study the behavior of other mesons such as ω in nuclei, but in practice, there is at present no facility in the world where we can produce ω near the recoilless condition ($T_d \sim 10$GeV is required).

Table 1 The features of the (d,^{3}He) reaction are compared with those of heavy-ion experiments.

Production	(d,^{3}He) recoilless	High-energy nuclear collisions
Nuclear medium	Normal nuclear density	Hot/Dense, transient
State of the meson	$\sim$ stationary	moving
Mass measurement	Peak in Q-value spectra	l^+l^- invariant-mass spectra
Applicable to	π, η, ω, ...	vector mesons (ρ, ω, ϕ, ...)

Table 2 A-dependence of the η-nucleus binding energies and widths. We use $a_\eta = 0.717 + 0.263i$ $[fm]$ as η-N scattering length.

A	$\ell = 0$		$\ell = 1$		$\ell = 2$		$\ell = 3$	
	B.E.(MeV)	Γ (MeV)	B.E.(MeV)	Γ (MeV)	B.E.(MeV)	Γ (MeV)	B.E.(MeV)	Γ (MeV)
6	17.4	33.5						
11	35.3	48.8						
15	44.4	55.5	9.61	35.9				
19	50.8	59.9	17.7	43.0				
31	62.0	66.3	34.1	55.2	5.87	40.2		
	4.36	34.4						
39	66.4	68.2	40.8	59.1	15.0	48.0		
	11.8	44.5						
64	74.3	71.8	53.3	63.4	31.4	58.8	10.6	52.0
	25.8	58.2						
88	77.6	73.2	61.0	66.8	40.1	59.4	21.4	60.1
	33.3	56.7						
132	80.5	73.2	67.9	70.4	52.6	64.2	32.5	56.9
	47.4	61.4	20.9	53.1				
207	83.0	73.5	72.4	70.1	62.1	69.8	49.5	64.8
	58.5	70.6	43.4	62.1	15.7	39.6		
	11.4	30.4						

References

[1] T. Yamazaki *et al.*, Z. Phys. A355 (1996) 219

[2] T. Waas, R. Brockmann, W. Weise, Phys. Lett. B405 (1997) 215; T. Yamazaki *et al.*, Phys. Lett. in press.

[3] R. S. Hayano *et al.*, GSI proposal S214 (1997), approved.

[4] M. Batinić *et al.*, nucl-th/9703023

[5] R. S. Hayano, S. Hirenzaki, in preparation