LABORATÓRIO ABERTO

DE FÍSICA NUCLEAR

Proposta de Experimento

Período : 1 ano

Título: Alpha cluster states in light nuclei populated through the (6Li,d) reaction

Responsável: Thereza Borello-Lewin
e-mail: borello@if.usp.br

Participantes: **Márcia Regina Dias Rodrigues, Thereza Borello-Lewin, Lighia Brigitta Horodynski-Matsushigue, José Luciano Miranda Duarte, Gilberto Mitsuo Ukita, Cleber Lima Rodrigues, Marco Antonio Souza,Hideaki Miyake,Angelo Cunsolo,Francesco Cappuzzello, Manuela Cavallaro.**

Porta Voz: Thereza Borello-Lewin
e-mail: borello@if.usp.br

Número de dias solicitados: 5+5 dias
Datas preferidas:
Datas realmente impossíveis:
Canalização: 15° A

Feixe	Est. Carga	$I_{mínima}$ (alvo)	V_{min}	V_{max}	Pulsado?
^{6}Li	3	100 nA	7,5 MV	8,0 MV	não

Alvos: ^{12,13}C, ^{11}B
Pastilhas: fluoreto de Li
Características de Feixe Pulsado:
Continuação da Experiência já Aprovada N°:
Outras informações:

Alpha cluster states in light nuclei populated through the (^{6}Li,d) reaction

T. Borello-Lewin, M. R. Rodrigues, L. B. Horodynski-Matsushigue, J. L. M. Duarte, C. L. Rodrigues, M. A. Souza, H. Miyake
Instituto de Física, Universidade de São Paulo, São Paulo-SP, Brasil

A. Cunsolo, F. Cappuzzello, M. Cavallaro
Universita di Catania and I.N.F.N., Laboratori Nazionali del Sud, Catania, Italy

G. M. Ukita
Faculdade de Psicologia, Universidade de Santo Amaro, São Paulo-SP, Brasil

The alpha cluster correlation is an important concept in the nuclear physics of light nuclei [1]. The main purpose of the research program in progress is the investigation of the alpha clustering phenomenon in (xα) and (xα+n) nuclei through the (^{6}Li,d) alpha transfer reaction. In fact, there is scarce experimental information on the subject, in particular associated with odd-even nuclei and with resonant states predicted near (xα) and (xα+n) breakup thresholds [2].

Focusing on alpha resonant states in the nucleus ^{13}C, measurements of the ^{9}Be(^{6}Li,d) ^{13}C reaction, at an incident energy of 25.5 MeV, have been performed employing the São Paulo Pelletron-Enge Split-Pole facility and the nuclear emulsion detection technique. An excellent energy resolution of 50 keV was achieved, mainly due to the careful determination of the focal plane of the reaction, the use of nuclear emulsion, an uniform target, adequate spectrograph object and the good accelerator characteristics. The data allowed for the separation of the resonant contributions to the known $7/2^{-}$ and $(5/2^{-})$ states near the ^{9}Be+ α threshold, both associated with an L = 4 transfer and reveal, up to 15 MeV of excitation, several narrow alpha resonant states, not previously reported [3]. In particular, the one at the 3α+n threshold, populated by an L=2 transfer at 12.3MeV of excitation, indicates a ^{9}Be+α component for the $½^{-}$ cluster candidate, associated with the ^{12}C Hoyle state. Above approximately 13 MeV of excitation in ^{13}C, due to the joint presence of tracks, in the nuclear plates, of deuterons and elastically and inelastically scattered ions of ^{6}Li (charge state of two), the selective reading methodology was applied, thus removing the undesired background. A large E0 isoscalar transition, the signature of a spatially developed $1/2^{-}$ cluster-state [4], and reported by T. Kawabata [5] was detected near the (3α + n) threshold by alpha inelastic scattering. The L=2 transfer obtained in the excitation of the alpha resonant state at 12.3 MeV in the work under way is in agreement with the $1/2^{-}$ attribution [5] and reveals a ^{9}Be + α component not previously measured, supporting the predictions of the (3α + n) orthogonality condition model (OCM) calculations by Yamada and Funaki [6]. In fact, the OCM results [6] reveal that this state, although presenting a large component of the ^{12}C (Hoyle) + n channel, contains also components of the ^{12}C(2^{+}) + n and ^{9}Be(g.s.) + α channels. On the other hand, the $1/2^{+}$ state near the (3α + n) threshold, with a dilute alpha condensate character [6], was consistently not populated in the present investigation. In fact, the transfer of L = 1 does not reproduce the shape of the experimental angular distribution.

The investigation of resonant states which are predicted above the 4α and 4α+n breakup thresholds, through the ^{12,13}C(^{6}Li,d)^{16,17}O alpha transfer reactions not previously measured, is proposed as the next step of the present research program. Above the 4α threshold in ^{16}O at 14.4

MeV, preliminary data taken at a bombarding energy of 25.5 MeV reveal, up to approximately 20 MeV of excitation, several narrow alpha resonances previously unreported, some of them appearing in the spectra as doublets. Important $\alpha + {}^{12}C$ (g.s.) components are present in these detected states with a quasi-bound behaviour, embedded in the continuum. One of these corresponds to the known 0^+ state at 15.1 MeV of excitation that has probably the gas-like configuration of the 4α condensate state, with a very dilute density and a large component of $\alpha + {}^{12}C$(Hoyle) configuration [7,8]. On the other hand, the existence of a rotational band with the $\alpha+{}^{12}C$ (Hoyle) cluster state structure was recently demonstrated by Ohkubo and Hirabayashi [9].

The data will be taken using the Pelletron-Enge-Split-Pole facility, which is extremely adequate for this kind of experiment, as was already pointed out. The Pelletron accelerator provides a beam with an excellent profile and energy resolution, characteristics which are essential for the good quality of the data. The reaction products will be momentum analyzed by the Enge Spectrograph, which due to its focusing properties allows, for the same charge, the discrimination of different linear momenta of the particles, with an intrinsic resolution of $\Delta E/E \sim 3.6\ 10^{-4}$ .The detection with nuclear emulsion plates, which cover 50 cm along the focal plane, is especially relevant. This detector does not respond to the abundant background, mostly γ and X rays from (n,γ) reactions in the spectrograph iron core. Furthermore, the intrinsic resolution of this detector is negligible, maintaining the high resolution of the facility, an essential point in addition to its much reduced sensibility to the background, if low cross section results are to be detected in the presence of contaminant peaks. On the other hand, only three spectra can be measured with the same emulsion plate, i. e. without breaking the vacuum in the spectrograph.

Considering the ${}^{12,13}C({}^{6}Li,d){}^{16,17}O$ reactions and the respective positive Q values of 5.69 MeV and 4.88 MeV, at a terminal tension of 8.0MV, the maximum deuteron energies at 4α and 4α +n thresholds (14.4MeV and 18.3MeV excitation energies) are 23.3 MeV and 18.6 MeV, respectively. Cross sections between 2 and 15 μb/sr are expected. The exposition time for ~100 counts in one peak corresponds to runs of ~2.5 h per angle, considering a target thickness of 100 $\mu g/cm^2$ and an ion beam of 200 nA on the target, with a solid angle of the spectrograph of 2.68 msr. For measurements of angular distributions, meant to allow L discrimination, 5+5 days of data acquisition will be necessary in the first year. For the analysis of the experimental angular distributions associated with the quasi-bound resonances, DWBA predictions using, as form factors, wave functions to be calculated in the frame of the phenomenological alpha cluster model [10] will be employed, allowing the extraction of the experimental reduced alpha widths.

Within the international collaboration between the Nuclear Spectroscopy with Light Ions Group and the MAGNEX-Large-Acceptance Spectrometer Group - South Laboratory, INFN, Catania, Italy, further measurements will also be taken in that laboratory. The MAGNEX is a Large-Acceptance Spectrometer with a solid angle of 50 msr (20 times bigger than the São Paulo Spectrograph) and a momentum resolution of ~1/2000, favored by the ion optics and the trajectory reconstruction programs.

The pursuing of the study by measuring preliminary data for the ${}^{11}B({}^{6}Li,d){}^{15}N$ reaction is included in this proposal.

References:

[1] K. Ikeda, N. Takigawa and H. Horiuchi, Prog. Theor. Phys. Suppl. 464-475 (1968).
[2] M. R. D. Rodrigues et al., 12th International Conference on Nuclear Reaction Mechanism, Varenna, Italy 2009, edited by F. Cerutti and A. Ferrari, CERN Proc. 01, 331-335 (2010).
[3] T. Borello-Lewin et al., Proceedings of SOTANCP2, Brussels, Belgium 2010, edited by P. Descouvemont et al., to be published in Int. J. Mod. Phys E.
[4]Y. Sassamoto et al., Mod. Phys. Lett. A21, 2393 (2006).
[5]T. Kawabata, "Alpha inelastic scattering and cluster structures in light nuclei" in 12th International Conference on Nuclear Reaction Mechanism, Varenna, Italy, edited by F. Cerutti and A. Ferrari , CERN Proceedings, 01, 95-98 (2010)
[6]T. Yamada and Y. Funaki, Int. J. Mod. Phys. E 17, 2101 (2008).
[7] Y. Funaki, T. Yamada, H. Horiuchi, G. Ropke, P. Schuck,A. Tohsaki Phys. Rev. Lett. 101, 082502 (2008)
[8] Y. Funaki, T. Yamada, A. Tohsaki, H. Horiuchi, G Ropke, and P. Schuck Phys. Rev. C 82, 024312 (2010).
[9] S. Okubo and Y. Hirabayashi Phys.Lett. B 681 ,127-131 (2010)
[10] B. Buck, C. B. Dover and J. P. Vary, Phys. Rev. C **11** , 1803 (1975)