Single Neutron Pick-up on ^{104}Pd

M. R. D. Rodrigues[1],J. P. A. M. de André[1], T. Borello-Lewin[1], L. B. Horodynski-Matsushigue[1], J. L. M. Duarte[1], C. L. Rodrigues[1], and G. M. Ukita[1,2]
[1]*Instituto de Física, Universidade de São Paulo - Caixa Postal 66318, CEP 05389-970, São Paulo, SP, Brazil and*
[2]*Faculdade de Psicologia, Universidade de Santo Amaro,*
Rua Professor Enéas da Siqueira Neto, 340, CEP 04829-300, São Paulo, SP, Brazil

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Low-lying levels of ^{103}Pd have been investigated through the (d,t) reaction on ^{104}Pd, at an incident deuteron energy of 15.0 MeV. Outgoing particles were momentum analyzed by an Enge magnetic spectrograph and detected in nuclear emulsion plates, with an energy resolution of 8 keV. Previous (d,t) work suffered from a much worse resolution than that here achieved. A partial analysis of the data obtained is reported, referring to six out of the fourteen scattering angles for which data were obtained. Angular distributions associated with eight of the thirteen levels seen up to 1.1 MeV of excitation have been compared to DWBA one-neutron pick-up predictions. Both, the attributed excitation energy values and the transferred angular momenta are in excellent agreement with the results of other kind of experiments, as tabulated by the Nuclear Data Sheets. Some peculiar structure characteristics, associated with the yrast $5/2^+$, $3/2^+$ and $7/2^+$ states found in the Ru chain could be recognized also in ^{103}Pd, pointing to the possibility of a more global understanding of this transitional mass region.

Keywords: Low-lying levels of ^{103}Pd; (d,t) reaction

I. INTRODUCTION

The transitional $A \sim 100$ mass region presents several intriguing aspects, which so far have defied a complete understanding. Among those, several have been put forward by investigations performed by the S. Paulo Nuclear Spectroscopy with Light Ions Group [1–6].

The nuclear emulsion technique, employed in association with the good characteristics of the Pelletron-Enge-Spectrograph system in São Paulo, puts the Group in a very competitive position with respect to one-neutron transfer studies, as are (d,t) [2, 6] and (d,p) [3, 4] reactions, where high energy resolution and low background are mandatory for best experimental results. One-neutron transfer is very conclusive for disclosing similarities between low-lying states in neighbouring nuclei, being thus ideal for comparative structure studies along nuclear chains. An exhaustive study has been performed by the Group on the Ru isotopic chain [2–6],which demonstrated that some low-lying, in particular the yrast levels, contain structure information which may be tracked along the whole $A \sim 100$ region [5]. This bibliographic research showed, however, that the quality of the data available throughout the region is well bellow what has been achieved for Ru.

The present investigation aims at filling the gap for the Pd isotopic chain. This paper concerns partial results on the ^{104}Pd$(d,t)^{103}$Pd reaction which were presented at the XXVIII Workshop on Nuclear Physics in Guarujá, S. Paulo, Brazil. The previous ^{104}Pd$(d,t)^{103}$Pd data of Scholten et al. [7], had a typical resolution of 65 keV, much worse than what can be achieved by the techniques in use by the S. Paulo Group. There is, in addition, an older (d,t) study on ^{104}Pd [8], which has not been published, but was taken by the Nuclear Data Sheets compilation [9] as reference for excitation energy values, with an estimated uncertainty of 2 keV, instead of the 15 keV typical for the results of Scholten et al. [7]

II. EXPERIMENTAL PROCEDURE

Spectra associated with a total of fourteen scattering angles, judiciously chosen, were measured for the ^{104}Pd$(d,t)^{103}$Pd reaction at an incident energy of 15.0 MeV, with the S. Paulo Pelletron-Enge-Spectrograph system. The target of ^{104}Pd, isotopically enriched to 98.98%, with a thickness of 20 μg/cm^2, was produced in São Paulo by the electron bombardment method. Only rather small amounts of the usual contaminations by C, N, O, Si, S, K e W were diagnosed.

The emerging tritons were momentum analyzed by the Enge Magnetic Spectrograph and detected in nuclear emulsion plates (Fuji 7D, 50 μm thick), which covered 50 cm along the focal plane. After processing, the exposed plates were scanned in strips of 200 μm across the plates. An energy resolution of 8 keV was achieved.

One great advantage of the nuclear emulsion detector is its insensibility to the abundant background, mostly X and γ rays from (n,γ) reactions in the spectrograph iron core after deuteron break-up. FIG.1 displays the triton spectra obtained at 20^0 and at 46^0 laboratory scattering angles.

III. SOME RESULTS AND DISCUSSION

Inspection of FIG.1, where the position, L, along the focal plane is proportional to the momentum of the emerging triton, demonstrates the very low background attained in this energy region and the excellent resolution. Some of the small peaks indicated in FIG.1 could be identified with the help of the other spectra already processed.

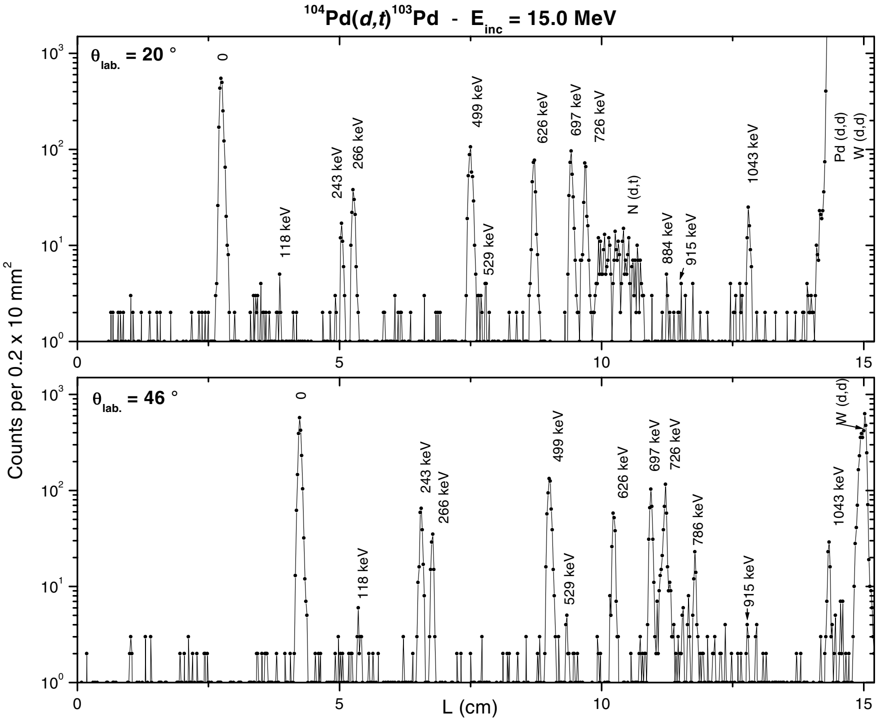

FIG. 1: Triton spectra obtained at 20^0 and at 46^0 laboratory scattering angles.The excitation energies attributed to the levels populated in the reaction are indicated above each of the corresponding triton peaks.

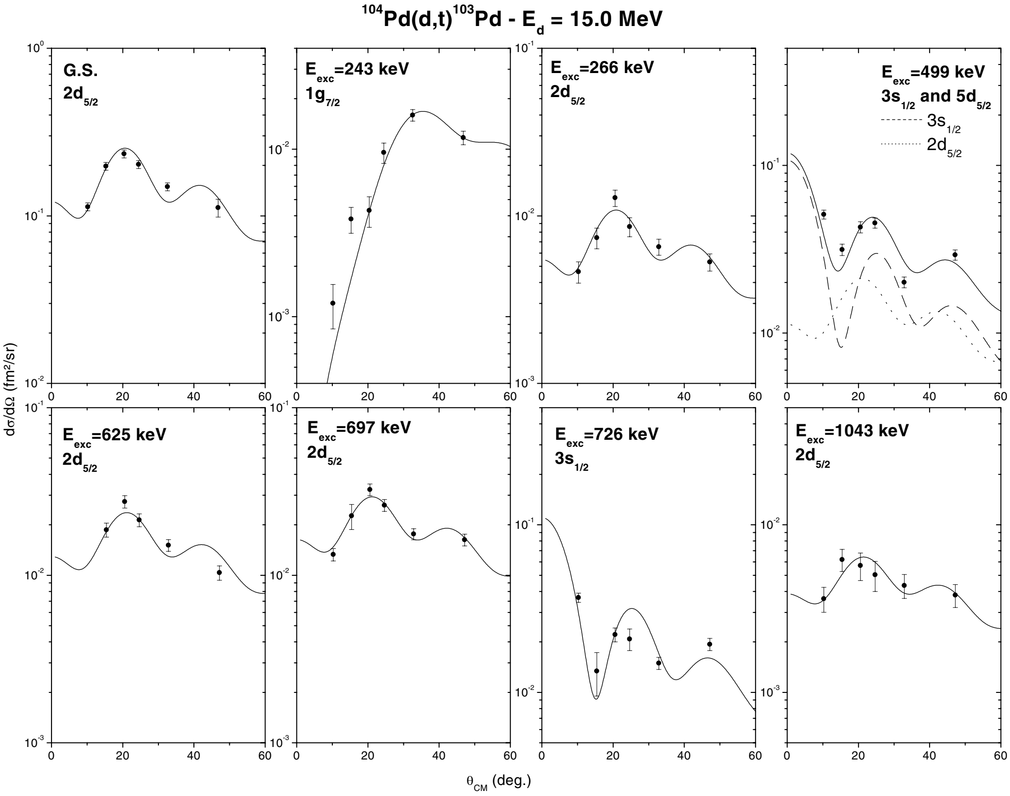

FIG. 2: Experimental angular distributions of ^{104}Pd(d,t)^{103}Pd in comparison with DWBA one-neutron pick-up predictions.

Only six of the fourteen spectra measured at different scattering angles have been analyzed up to now. Further work is in progress. Even so, experimental angular distributions have been obtained for eight of the thirteen levels identified up to 1.1 MeV. The respective excitation energies are presented in FIG.1, also for those peaks confirmed only by the whole set of analyzed spectra. Previously published (d,t) work on ^{104}Pd had identified, in this same energy region, only eight states [7]. That study, by Scholten et al. [7], was clearly unable to distinguish the 243 keV + 266 keV doublet, presenting only a level populated by ℓ = 4 at 0.24 MeV. Furthermore, it did not see the 726 keV (ℓ = 0) state and the three weakly excited levels. There is the unpublished study by Rickey et al. [8], which also reported a total of thirteen levels. However, their tentative state [8] at 905 keV is, up to now, not confirmed by the present data. There is no hint in those previous studies for the weakly excited 118 keV level. The excitation energies presented by this unpublished work are in rather good accord with those of the present research, for which an uncertainty of 1 keV is estimated.

The excitation energies attributed in the present study are moreover in excellent agreement with the precise gamma ray results tabulated in the Nuclear Data Sheet (NDS) compilation [9]. Of the levels there reported, only three have not been identified in the present nor in any of the former (d,t) studies [7, 8]. These are levels of spins $9/2^+$ and $11/2^+$, two of which have been associated, respectively, with the second members of bands built on the ground state and on the $7/2^+$ level. As for the 815(2) keV level, reported in NDS as corresponding to a ℓ = 2 transfer in (d,t) [9], it was seen neither by Scholten et al. [7], nor in the present experiment.

The experimental angular distributions are shown in FIG.2, in comparison with DWBA predictions, calculated in the usual manner [6]. The orbitals attributed to the transferred neutron are indicated in the figure.

The transferred angular momentum (ℓ) values are very well discriminated by the angular distribution shapes and also in perfect agreement with informations gathered by previous experiments [9]. The nature of the ℓ = 0+2 doublet detected at 499 keV, which corresponds to the 498.948 keV ($1/2^+$) and 504.24 keV ($3/2^+$) levels reported by NDS, could be more clearly assessed than in the former (d,t) work [7], due to the much improved resolution.

Also for ^{103}Pd, as had been stressed for the isotone ^{101}Ru in a previous publication by the S. Paulo Group [6], the yrast ℓ = 2 (J^π=$5/2^+$), and ℓ = 4 (J^π=$7/2^+$) levels carry most of the respective spectroscopic strengths. In particular, the $7/2_1^+$ state, which in ^{103}Pd is located at 243 keV, is part of an intriguing systematics of low-lying levels of similar characteristics found between 0.2 and 0.4 MeV throughout the region [5]. In ^{103}Pd this state has been identified as bandhead of a rotational structure which was seen up to $19/2^+$, at 2764.38 keV, in a gamma ray study [9].

Another aspect which is worth mentioning is that the peculiar low-lying $3/2_1^+$ level, which becomes ground-state in ^{103}Ru, maintains in this (d,t) study the characteristic of being very weakly excited, corresponding in ^{103}Pd to an excitation energy at 118 keV. In fact, the $3/2_1^+$ level is barely seen in the spectra shown in FIG.1, taken at two rather distinct scattering angles. This particular $3/2^+$ level may be followed throughout most part of the $A \sim 100$ region, having been interpreted by the S. Paulo Group as indicative of a coexisting configuration [5].

Acknowledgments

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[1] M. R. D. Rodrigues, C. L. Rodrigues, T. Borello-Lewin, L. B. Horodynski-Matsushigue, J. L. M. Duarte, and G. M. Ukita, Braz. J. Phys. **34**, 777 (2004).
[2] M. R. D. Rodrigues, T. Borello-Lewin, L.B. Horodynski-Matsushigue, J. L. M. Duarte, C. L. Rodrigues, M. D. L. Barbosa, G. M. Ukita, and G. B. da Silva, Phys. Rev. C **66**, 034314 (2002).
[3] L.B. Horodynski-Matsushigue,; C.L. Rodrigues, F.C. Sampaio, and T. Borello-Lewin, Nucl. Phys. A **709**, 73 (2002).
[4] M. D. L. Barbosa, T. Borello-Lewin, L. B. Horodynski-Matsushigue, J. L. M. Duarte, G. M. Ukita, and L. C. Gomes, Phys. Rev. C **59**, 2689 (1998).
[5] T. Borello-Lewin, J. L. M. Duarte, L. B. Horodynski-Matsushigue, and M. D. L. Barbosa, Phys. Rev. C **57**, 967 (1998).
[6] J. L. M. Duarte, L. B. Horodynski-Matsushigue, and T. Borello-Lewin, Phys. Rev. C **50**, 666 (1994).
[7] O. Scholten et al., Nucl.Phys. A**348**, 301 (1980).
[8] F. A. Rickey, R. E. Anderson, and J. R. Tesmer, Priv. Comm. (1973).
[9] D. de Frenne and E. Jacobs, Nucl. Data Sheets, **93**, 447 (2001).