Study of the ^{45}Sc($\vec{p},\alpha$)^{42}Ca Reaction ◇

P. Guazzoni [a], M. Jaskola [a], L. Zetta [a], Gh. Cata-Danil [b], A. Vitturi [c], J. Gu [c], G. Staudt [d], A. Gollwitzer, R. Hertenberger, B. D. Valnion, and G. Graw

[b] Institute of Atomic Physics, Bucarest, Romania
[a] Dipartimento di Fisica dell'Università and I.N.F.N., Milano, Italy
[c] Dipartimento di Fisica dell'Università and I.N.F.N., Padova, Italy
[d] Physikalisches Institut, Universität Tübingen

The concept of homology as spectroscopic tool in mass regions with A$\sim$ 90 and A$\sim$ 210 (1) has been already validated both from an experimental point of view and with shell model calculations. However some unsolved problems still exist, like fragmentation of parent states in a number of corresponding homologous states (CHMS) greater than that foreseen by the (2J+1) rule, as in ^{91}Zr($\vec{p},\alpha$)^{88}Y. In this case the incomplete knowledge of the residual nucleus ^{88}Y, does not allow to give an answer to the question regarding the possible rules followed in the fragmentation and to attribute also the spin and not only the parity to the fragmentated members of the multiplets. For this reason it is very important, in order to increase the knowledge about the homology and the validity of the weak coupling model in (p,α) reactions, to study the ^{44}Ca($\vec{p},\alpha$)^{41}K and ^{45}Sc($\vec{p},\alpha$)^{42}Ca reactions, never measured before. In this case the residual nuclei being in the $f_{7/2}$ shell, excitation energies, spins and parities are very well known for all the states both of ^{41}K and ^{42}Ca.

In fig.1 the spin up spectrum is reported for ^{45}Sc($\vec{p},\alpha$)^{42}Ca, measured at 22 MeV, with the Q3D spectrometer at $\theta = 25°$. While the first 0^+, 2^+, 4^+, 6^+ state starting from the ^{42}Ca ground state represents the lowest respective neutron (f7/2)^2 excitation, the 1.387 MeV 0^+ and 2.424 MeV 2^+ levels correspond to four-particles-two-holes excitation. The levels that we expect to be excited as homologous, in the hypothesis of weak coupling of the 21st extrashell 1f7/2 proton of ^{45}Sc with the parent states in ^{41}K, are proton-core excitation states. These states of negative parity start from an excitation energy of 3.4 MeV, just equal to the Q-value difference between ^{45}Sc($\vec{p},\alpha$)^{42}Ca and ^{44}Ca($\vec{p},\alpha$)^{41}K, as foreseen by the homology concept and clearly shown in fig.1.

It has also to be noted the high selectivity of this reaction. Only 47 states of the over 81 levels adopted up to 6.145 MeV of excitation energy are excited in (p,α).

From a theoretical point of view, the study of the ^{44}Ca($\vec{p},\alpha$)^{41}K reaction is interesting by itself (and not only as a tool for studying CHMS of ^{42}Ca) as compared with the analysis of single proton transfer reactions as ^{42}Ca(d,^{3}He)^{41}K or ^{42}Ca(t,α)^{41}K. It allows to extract informations about the reaction mechanism, because of the larger number of states that may be reached in a direct one-step process with three nucleon transfer, assuming for a ν(f7/2)$^4{}_{L=0}$ and ν(f7/2)$^2{}_{L=0}$ initial configuration for ^{44}Ca and ^{42}Ca, respectively. The (d,^{3}He) reaction is only expected to populate strongly the single proton-hole states (a hole in $d_{3/2}$ or in $s_{1/2}$, always with ν(f7/2)$^2{}_{L=0}$) or weakly, via two-step process, a state in the ^{41}K with a $d_{3/2}$ proton-hole and with ν(f7/2)$^2{}_{L=2}$. The (p,α) reaction, instead, should strongly populate in a direct one-step process not only the previous states, but also states as π(d3/2)$^{-1}\nu$(d3/2)$^{-2}\nu$(f7/2)^4.

With regards to the homology, in the hypothesis of weak coupling of the 21st extrashell 1f$_{7/2}$ proton of ^{45}Sc, assumed as a simple $[\pi(\mathrm{f7/2})\otimes\nu(\mathrm{f7/2})^4{}_{L=0}]_{7/2^-}$, with the parent state in ^{41}K, one should populate in the ^{45}Sc($\vec{p},\alpha$)^{42}Ca reaction, in addition to the simple low-lying states, both ν(f7/2)^2 and ν(f7/2)$^4\nu$(d3/2)$^{-2}$, multiplets of states of ^{42}Ca homologous to those excited in the ^{44}Ca($\vec{p},\alpha$)^{41}K, as π(d3/2)$^{-1}\pi$(f7/2)ν(f7/2)^2 or (d3/2)$^{-1}\pi$(f7/2)ν(d3/2)$^{-2}\nu$(f7/2)^4.

Due to the richness offered by the three-nucleon transfer, it is expected that in ^{45}Sc($\vec{p},\alpha$)^{42}Ca states as 2^- and 4^- should be excited that cannot be populated in other direct reactions, as inelastic excitation or single proton transfer.

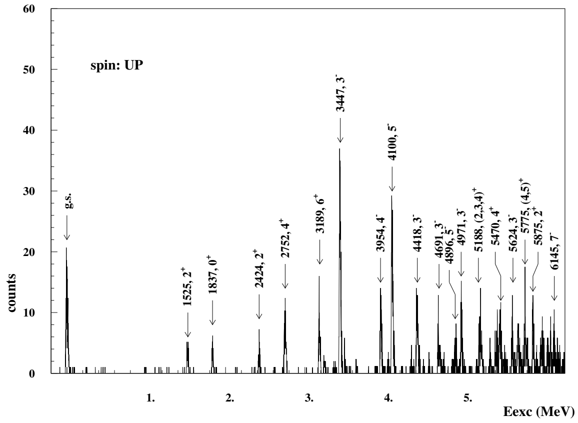

Fig. 1: Spin-up spectrum for emitted α-particles

◇Work supported in part by the DFG under IIC4-Gr 894/2