The $^{44,46}Ar(n,\gamma)^{45,47}Ar$ reaction rates studied by (d,p) transfer reactions

L. Gaudefroy[1], O. Sorlin[2], Y. Blumenfeld[1], K.-L. Kratz[3], A.N.Ostrowski[4] and the MuST-Collaboration

[1] Institut de Physique Nucléaire, F-91406 Orsay Cedex, France; [2]GANIL, F-14076 Caen Cedex 5, France; [3] Institut für Kernchemie, Universität Mainz, D-55099 Mainz, Germany; [4]Fakultät für Physik & Astronomie, Universität Heidelberg, D-69120 Heidelberg, Germany;

The aim of our experiment is to determine the $^{44}Ar(n,\gamma)^{45}Ar_{27}$ and $^{46}Ar(n,\gamma)^{47}Ar_{29}$ reaction rates by measuring the $^{44}Ar(d,p)^{45}Ar$ and $^{46}Ar(d,p)^{47}Ar$ transfer reactions in order to evaluate the role of the N=28 closed shell on astrophysical relevant neutron-capture rates and determine the size of the N=28 gap.

The motivation of this study is therefore twofold, one is of astrophysical, the other of nuclear physics interest. In astrophysics, this experiment will help to understand the large $^{48}Ca/^{46}Ca$ abundance ratio (60 - 250) in certain refractory meteoritic inclusions, e.g. the EK 1-4-1 sample from the Allende meteorite. The ^{46}Ar is thought to be the main progenitor of ^{46}Ca and the determination of its neutron capture cross section provides a constraint for astro-physicists on the neutron densities which should be present in explosive stellar environments to account for the large isotopic ratio found.

In nuclear physics, neither the size of the N=28 shell gap (between $f_{7/2}$ and $p_{3/2}$), nor the occupation of these orbitals have been determined in any of these nuclei yet. The study of ^{44}Ar and ^{46}Ar transfer reaction experiments will determine the size of the N=28 gap, and the occupation probabilities of the two orbitals $f_{7/2}$ and $p_{3/2}$. These results will firmly establish an erosion or persistence of the N=28 closed-shell below ^{48}Ca.

The transfer $^{44,46}Ar(d,p)$ reactions have been performed at 10 MeV per nucleon incident energy at the GANIL/SPIRAL1 facility in reverse kinematics A deuterated polythene target of 0.3 mg/cm^2 area density was used. Beam intensities of $2x10^5$ and $2x10^4$ incident ions per second have beeri obtained for the radioactive ^{44}Ar and ^{46}Ar beams, respectively. The target was surrounded by 8 modules of the MuST silicon strip detector array located between 110 and 170 degrees in the laboratory frame. The beam profile was monitored by a gas filled tracking detector in order to reconstruct the reactions´ locations in the target.

The transfer-like products were detected in the focal plane of the magnetic spectrometer SPEG using a combination of drift chambers and a plastic scintillator. Energy-loss and time of flight information were recorded. The use of the high segmentation of the MuST detector as well as the high position resolution of the beam tracking detector was found to be essential for the reconstruction of the kinematics of the reaction. This was necessary in order to infer the levels which were involved in the transfer leading to the A+1 nuclei.

The $^{41}Ar(d,p)$ reaction was utilized in order to calibrate our set up, and we were able to measure the population of the known levels of ^{41}Ar and determine the corresponding spectroscopic factors. Analysis in the case of the ^{44}Ar induced transfer is in progress and already at least 7 excited states are clearly identifiable - among them half exhibit an l=1 angular pattern (cf. Figs.1 and 2). The other half have rather an l=3 behaviour. Spectroscopic factors for these levels will enable us to determine the size of the N=28 gaps and henceforth the strength of the $f_{7/2}$-$f_{5/2}$ spin orbit splitting south of the doubly magic ^{48}Ca nucleus. The analysis of ^{46}Ar transfer has just been started.

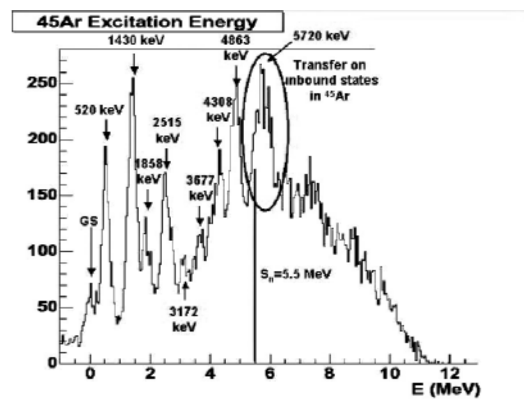

Figure 1: Preliminary proton spectrum of the $^{44}Ar(d,p)^{45}Ar$ reaction at 10 A.MeV. The energy scale is calibrated on ^{45}Ar revealing known states in this nucleus.

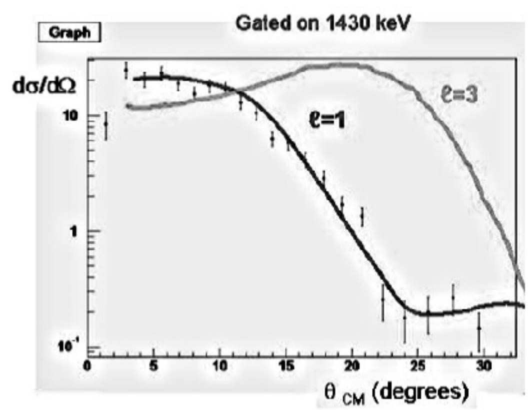

Figure 2:Preliminary angular distribution of the $^{44}Ar(d,p)^{45}Ar(E_x$=1430keV) transfer reaction.