Study of the N=28 shell closure through (d,p) reaction at SPIRAL/GANIL

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The study of the N=28 shell closure far from the valley of stability has been investigated through various complementary techniques which point out to a progressive reduction of the shell gap south to ^{48}Ca (e.g. [1,2]). The present experiment focuses on the neutron-rich $^{45,47}Ar_{27,29}$ nuclei, located at each side of the N=28 shell closure, in order to determine how magicity is preserved in the Ar isotopic chain. The Ar isotopic chain should exhibit clues for understanding the emergence of collectivity form the doubly magic nucleus $^{48}_{20}Ca_{28}$ to $^{44}_{16}S_{28}$. Neutron pick-up reactions constitute an ideal probe to study shell closures as it provides the energy, angular momenta and occupation probabilities of valence orbitals.

The transfer reaction study (d,p) has been performed at GANIL using the radioactive beams of ^{44,46}Ar at 10A·MeV produced by the SPIRAL facility at GANIL. Neutron pick-up reactions (d,p) were induced by a 380 μgcm^{-2} thick CD_2 target. The tracking of the secondary beams was achieved by a position sensitive gas filled detector CATS [3] located downstream the target. Protons were detected at backward angles (between 110 and 170 degrees) using the 8 highly segmented MUST telescopes [4], whose first stages consist in a 300 μm thick, 60 × 60 mm^2 double sided Si-strip detectors with 60 horizontal and 60 vertical strips. The energy spectra of ^{45,47}Ar were obtained by using the measured proton energy and angle in MUST in the relativistic kinematics formula. The angular distributions in the center of mass have been obtained for both nuclei in order to determine the spin and spectroscopic factors of the levels. Clear signatures of ℓ=1,3 angular distributions have been found, as expected for valence neutrons in the fp shell. Good agreement between experiment and shell model calculations is found. The small reduction of the N=28 shell gap is not enough in the Ar chain to induce collectivity through intruder state excitations as in the S chain. These present results have been subsequently used to infer (n,γ) cross sections in the Ar isotopic chain for astrophysical purposes. The presence of low-lying bound states $3/2^-$ in ^{45,47}Ar with sizeable spectroscopic factors favors direct capture cross section, as for ^{48}Ca. This leads to a drastic increase of the (n,γ) cross-section, speeding up the neutron-capture rate as at$N \simeq 28$ as compared to what normally occurs at shell closures. In particular, the enhanced neutron-capture rate at A=46 quickly shift the matter flow to A=48 in the Ar chain. In astrophysical environments where a neutron-capture and β-decay process (weak r process) occur, it reduces drastically the amount ^{46}Ca which is synthesized by theβ-decay of its progenitor isobar ^{46}Ar. Consequently the ^{48}Ca would be more abundant, which would nicely explain the large abundance ratio of ^{48}Ca/^{46}Ca=250 in certain refractory inclusions of meteorites.

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