Single-particle states in neutron-rich ^{69,71}Cu by means of the (d,^{3}He) transfer reaction

In two (d,^{3}He) transfer reactions with MUST2 at GANIL and the split-pole at Orsay, we have determined the position of the proton-hole states in the neutron-rich ^{71}Cu ($N = 42$) and ^{69}Cu ($N = 40$) isotopes. We have found that in ^{71}Cu the hole strength of the $\pi f_{7/2}$ orbital lies at higher excitation energies than expected.

From β-decay and laser spectroscopy, the $\pi f_{5/2}$ first excited particle state in these isotopes was known to come down rapidly in energy when passing $N = 40$ and even become the ground state in ^{75}Cu. This sudden energy shift has been explained in a number of theoretical works. The prediction for the $f_{7/2}$ spin-orbit partner was that it would change in energy too through a related effect. Experimentally, the $\pi f_{7/2}^{-1}$ proton-hole state is not known for $N > 40$. In ^{71}Cu two $7/2^-$ states around 1 MeV are candidates to be a proton-hole.

The experiment at GANIL took place in March 2011. A secondary beam of ^{72}Zn at 38 AMeV was produced by fragmentation and purified through the LISE spectrometer. The transfer reaction in inverse kinematics was studied with the MUST2 detectors plus four 20 μm silicon detector to identified the ^{3}He of low kinetic energy. The excitation spectrum of ^{71}Cu was reconstruct thanks to the missing mass method and the angular distributions were extracted and compared with a reaction model using the DWUCK4 and DWUCK5 code. From this work no states have been populated around 1 MeV concluding that the centroid of the $\pi f_{7/2}$ lies at higher excitation energy.

We then remeasured the single-particle strength in ^{69}Cu in the corresponding (d,^{3}He) reaction at Orsay in March 2013 in order to extend the existing data where 60% of the $\pi f_{7/2}$ strength is missing and make sure that there is a consistent analysis of spectroscopic factors between both isotopes in order to well understood and well quantify the evolution of the $f_{7/2}$ orbital when we start filling the $\nu g_{9/2}$ orbital. In this second experiment we have performed the reaction in direct kinematics using a deuteron beam at 27 MeV provided by the tandem and a target of ^{70}Zn of 18.7 μg/cm^2. In this work we were able to extract three new angular distributions and we have measured a new part of the $\pi f_{7/2}$ strength.

Finally in order to interpret the results we have obtained from those two experiments, state-of-the-art shell-model calculations have been carried out in collaboration with the Strasbourg group using the Antoine code. The valence space consists in a core of ^{48}Ca with the valence orbitals for protons $f_{7/2}$, $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and the orbitals $p_{3/2}$, $f_{5/2}$, $p_{1/2}$, $g_{9/2}$, $d_{5/2}$ for neutrons. The calculations have been done allowing 8p-8h and show that the strength is indeed at high energy and no $f_{7/2}$ proton-hole state lies around 1 MeV in ^{71}Cu.