Report on the work “De semi-magicit´e `a magicit´e dans les isotopes de cuivre riches en neutrons” by Serge Franchoo

This work relates to the nuclear structure of neutron rich nuclei in the neighbourhood of Nickel (Z=28) with special emphasis on Cupper isotopes. The work is timely because of the immense amount of experimental data that has been collected in the last two decades, partially as a consequence of the starting of new or improved radioactive beam facilities and improved detector techniques. This region of nuclei is particularly interesting. The reasons are, on the one hand, the appearance of subshell closure at N=40, and, on the other hand, the fact that at N=50, the doubly magic nucleus 78Ni, lies very close to the drip line. It has been discussed recently if magicity remains far from the line of stability and this is a very interesting case for such a study. In other words, does a doubly magic nucleus retain its properties when the imbalance between protons and neutrons is as extreme as in 78Ni.

A lot of knowledge about nuclear structure existed before the latest developments, but they were of different kinds, for instance nuclear reactions close to stability gave unique information on spectroscopic factors and hence the single particle character of specific levels. This kind of information is scarcely available in nuclei far from the line of stability due to the lack of stable targets. Some attempts have been made far from stability but always with poorer resolution, limited statistics and angular distribution signatures that are not so distinctive. The kind of studies carried out here were previously done in sd shell nuclei and they are described in this text. But these systems are not so complex and shell model calculations can provide an accurate description of nuclear structure effects. In this text a broad description of this previous knowledge is included in the introductory part of the manuscript, slowly moving to the nuclei of interest.

Already in the fpg shell, a very detailed description is provided of the location of the neutron single particle strength above Nickel, focusing in particular on the Cu nuclei.

Perhaps the most ambitious part of the work is the description of the interplay between single particle and collective excitations. Here a variety of experiments are described that were carried out at Isolde, RIKEN, MSU or GANIL. Different techniques are also analysed in detail.

The author places particular emphasis on showing how often experimental observations can lead to contradictory conclusions. Difficulties arise from the fact that single particle as well as collective effects are often masked by other subtle effects and that there are no observables that provide a unique answer. It is very clear, as spelled out in the text, that the energy of the first 2+ state is not enough to determine if a nucleus is spherical or deformed. The other important quantity, namely, the B(E2) cannot be measured directly and different experiments provide different results as explained in this work. This is clearly visible for instance in fig. 2.25 of the text. Another difficulty, also explained here is the fact that even in the same nucleus different shapes may coexist.

Since, in this work, Nickel, Copper and other nuclei from N=40 to N=50 are analysed, all these effects are observed as one transits from "spherical" to deformed and back to "spherical" again. In this work this is looked at in terms of the evolution of the single particle states in the Cu isotopes or the first excited 0+ state in the even-even Nickel nuclei.

Because the region under analysis is relatively new in terms of experimental knowledge, another added difficulty is the incorrect assignment of levels. This is the case of the first 0+ excited state in 68Ni, which was wrongly located for some time and still wrongly quoted in the NNDC data base.

This work also revises the theoretical models and their description of the experimental data. This is based mainly on core-coupling or more complete shell model calculations, but also mean field calculations and symmetric models are mentioned. Special effort is dedicated to describe the different forces developed by different theoretical groups and how they best describe the experimental data.

Finally, the text describes a key experiment approaching the nuclear structure of 78Ni, namely, a proton knock-out reaction on 80Zn, leading to the final nucleus 79Cu. The experiment was carried out at RIKEN with a radioactive beam on the MINUS hydrogen target and using the DALI array to detect the emitted gamma rays. The results, published in Phys. Rev Letters, demonstrate that the Z=28 gap persists at N=50. One of the most relevant results of the whole discussion. This work is led by the author of this manuscript.

In summary, the present text shows a truly up to date knowledge of all the information on the state of the art in this region. It is an important document since the information is otherwise spread over many scientific articles and only brought together here. It is also clear that the author of this manuscript has himself been part of this venture, contributing to experiments carried out at various experimental facilities initially in collaboration with the group in Leuven at LISOL, and later at GANIL, ISOLDE or RIKEN.

Because of the reasons expressed above, I recommend this work for public defense.

Berta Rubio
Profesora de Investigación del
CSIC en el Instituto de Física Corpuscular

Dirección Entrega:
Instituto de Física Corpuscular
Parc Científic Universitat de València
C/ Catedrático Beltrán, 2
E-46980 Paterna (València). España.
Tel.: +34 96 354 34 73

Dirección Postal:
Instituto de Física Corpuscular
Parc Científic Universitat de València
C/ Catedrático Beltrán, 2
E-46980 Paterna (València). España.
Tel.: +34 96 354 34 73