Nuclear structure study around $Z = 28$ in $f_{5/2}pg_{9/2}$ space

P.C. Srivastava[1,2,3*] and I. Mehrotra[3]

[1] *Instituto de Ciencias Nucleares, UNAM, 04510 México, D.F., México,*

[2] *GANIL, CEA/DSM–CNRS/IN2P3, BP 55027, F-14076 Caen Cedex 5, France and*

[3] *Department of Physics, University of Allahabad, Allahabad-211002, India.*

Introduction

The neutron-rich nuclei near nickel region is one of the fascinating subject because many intensive experimental investigations have been done in the last few years. The reason for this interest is due to the evolution of the single-particle structure towards ^{78}Ni which is a testing ground for the nuclear shell model and importance of astrophysical r process, which is the mechanism of rapid neutron capture by seed nuclei in explosive stellar environments. A hitherto question in this region related to rapid reduction in the energy of $5/2^-$ state as the filling of neutrons started in the $\nu g_{9/2}$ orbital in the Cu isotopes. The importance of monopole term from the tensor force is pointed out by Otsuka *et al.*, to understand the evolution of nuclear structure in this region. Collectivity, and $B(E2)$ enhancement around $N = 40$ for Cr, Fe and Ni isotopes recently studied by including $\pi f_{7/2}$ and $\nu d_{5/2}$ orbitals in the model space. It is found that for neutron rich fp shell nuclei the deformation is appears in these nuclei due to coupling of unfilled $f_{7/2}$ proton shell to neutron in sdg shell.

The experimental $E(2_1^+)$ for $Z = 28$ to $Z = 36$ are shown in Fig. 1. In this figure $E(2_1^+)$ states in Zn are overall lower compared to Ni and an additional decrease of the $E(2_1^+)$ energy in Zn isotopes is obtained between N=40-50 compared to N=28-40. This figure also reveal the enhancement of collectivity beyond $Z = 30$, because of rapid decrease of $E(2^+)$. Below the Ni chain, the spectroscopy of Cr, Fe isotopes shown an increased collectivity toward $N = 40$, revealing the collapse of this shell closure.

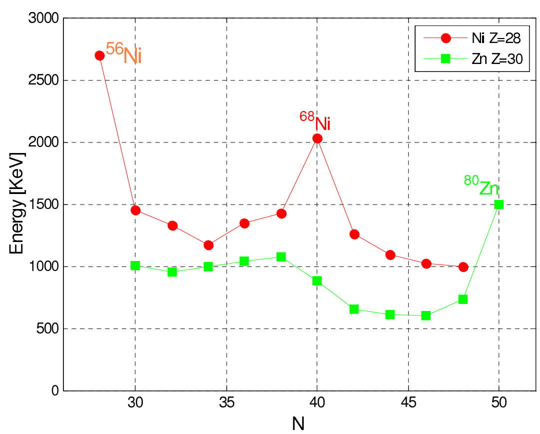

FIG. 1: Systematic of the experimentally observed $E(2_1^+)$ in the stable and neutron-rich Ni and Zn isotopes near the $N = 40$ and 50 shell closure.

Shell Model Results

The calculations have been performed using $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ valence space taking ^{56}Ni as a core [1]. In the present calculation we use three different sets of interactions. The first set of large scale shell model calculations (labeled LSSMI) utilizes the realistic effective nucleon-nucleon interaction based on G-matrix theory by Hjorth-Jensen [2] with the monopole modification by Nowacki [3, 4]. The second set of calculations (labeled LSSMII) are obtained with the JJ44B effective interaction [5]. The third set of calculations (labeled LSSMIII) is performed with JUN45 interaction due to Honma *et al.* [6]. The results with LSSMIII (JUN45) interaction for Ni, Cu and Zn isotopes are shown in Fig. 2.

*praveen.srivastava@nucleares.unam.mx

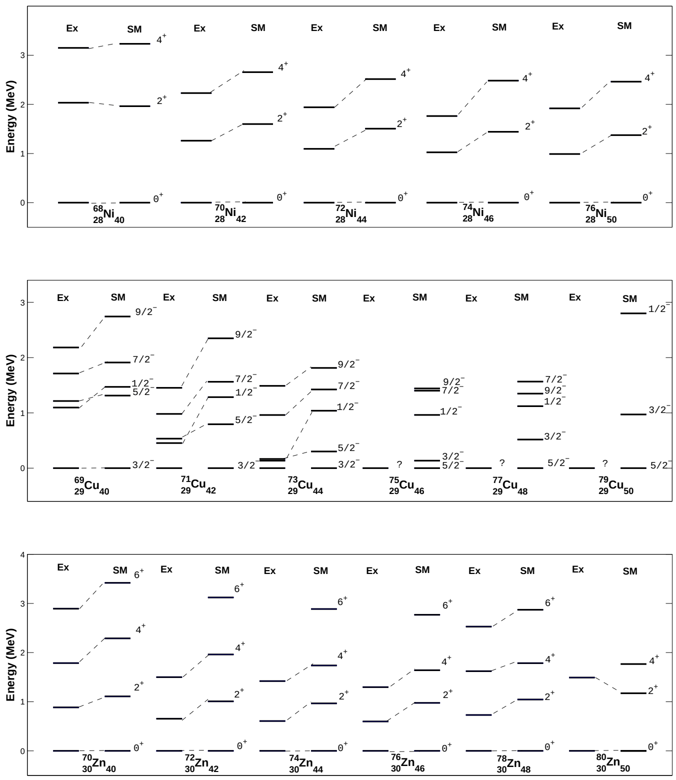

FIG. 2: Yrast levels of Ni, Cu and Zn isotopes using LSSMIII (JUN45) interaction.

These results indicate an importance of inclusion of $\pi f_{7/2}$ and $\nu d_{5/2}$ orbitals in the model space to reproduce collectivity in this region.

Summary

The large $E(2_1^+)$ values for Ni and Zn isotopes and corresponding low $B(E2)$ values indicate that the inclusion of $\pi f_{7/2}$ and $\nu d_{5/2}$ orbitals in the model space is important. The increase of the $B(E2)$ values beyond $N = 40$ suggests an increase of the collectivity induced by the interaction of protons in the pf shell and neutron in the sdg shell. Recently LNPS interaction for $fpgd$ space due to Lenzi *et al.* [7] have been reported in the literature. This interaction account collectivity toward $N = 40$ for Cr, Fe and Ni isotopes.

References

[1] P.C. Srivastava and I. Mehrotra, Int. J. Mod. Phys. E **21**, 1250007 (2012).

[2] M.H. Jensen *et al.*, Phys. Rep. **261**, 125 (1995).

[3] F. Nowacki, Ph.D. thesis (IRes, Strasbourg, 1996).

[4] N. A. Smirnova *et al.*, Phys. Rev. C **69**, 044306 (2004).

[5] B.A. Brown and A.F. Lisetskiy (unpublished).

[6] M. Honma, T. Otsuka, T. Mizusaki and M. Hjorth-Jensen, Phys. Rev. C **80**, 064323 (2009).

[7] S.M. Lenzi, F. Nowacki, A.Poves and K. Sieja, Phys. Rev. C **82**, 054301 (2010).