Role of effective interaction in study of neutron rich nuclei in Shell Model

A. Shukla
Rajiv Gandhi Institute of Petroleum Technology, Ratapur Chowk, Raebareli-229316, U. P. INDIA
** email: ashukla@lngs.infn.it, amritanshu.shukla@gmail.com*

Introduction

The nuclear structure of nuclei far from the beta stability line in general and towards neutron rich side in particular has gained considerable interest, theoretically as well as experimentally in recent past. The exotic phenomenon are expected to appear at the extremes of isospin, especially between the valley of stability and the neutron-rich extreme of nuclear existence which may change the conventional concept of Shell quenching and magic numbers. Apart from strong interest in nuclear structure aspects of neutron rich nuclei, study of these exotic nuclei has also far reaching astrophysical implications, especially in the context of r-process mechanism.

Among all nuclear models employed to study the nuclear structure for variety of nuclei, the nuclear shell model has been very successful in our understanding of nuclear structure: once a suitable effective interaction is found, the shell model can be used to predict various observables accurately and systematically. However, the predictive power of Shell model as well as other nuclear structure models becomes quite limited for exotic nuclei due to variety of effective interactions available for a given basis. Shell-model interactions are adjusted by exploiting new experimental data as and when these become available.

The spectroscopy of nuclei, in the fp-shell region, has been well described within the shell model framework. Extensive shell model calculations have been performed in this mass region, using several model spaces and two-body interactions, the most remarkable work of Brown and co-workers [1]. As the mass region A~50, lying in fp-shell is quite important for variety of problems in nuclear structure, we present the shell model calculations for energy levels and beta decay for the neutron rich nuclei namely Ca and Sc isotopes to test the ability of the different effective interactions in reproducing the available experimental data and predictability for ongoing experimental work.

Result and Calculations

The systematic spectroscopic study and beta decay half-life calculations for the neutron-rich nuclei near A~50 has been done and results are compared with the experimental data, if available. These calculations have been carried out using the code Nushell@MSU [2] in the *fp* model space which comprised of the $1p_{3/2}$, $1p_{1/2}$, $0f_{7/2}$ and $0f_{5/2}$ valence orbits outside the ^{40}Ca. Five different effective interactions (gx1pn, gx1apn, kb3gpn, fpd6pn, fpd6npn) were employed for the calculations of level spectra and beta decay half-lives.

Fig. 1, Fig. 2 and Fig. 3 presents the comparison of the experimental excitation energies (if available) of neutron rich ^{52}Ca, ^{53}Ca and ^{54}Ca isotopes respectively with calculated values using gx1pn, gx1apn, kb3gpn, fpd6pn, fpd6npn effective interactions. Experimental values are taken from NNDC [3].

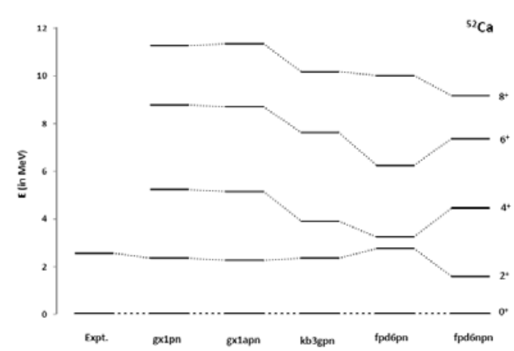

Fig.1. Comparison of the yrast experimental and calculated excitation energies for ^{52}Ca.

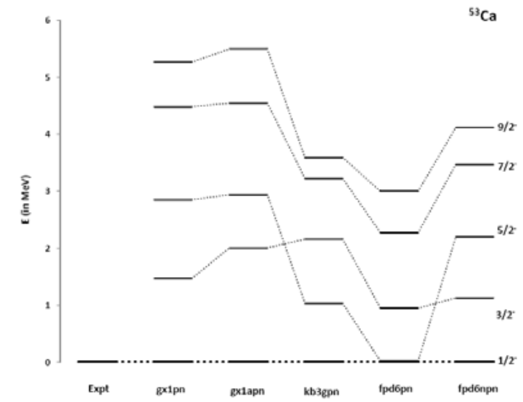

Fig.2. Same as Fig.1 but for ^{53}Ca

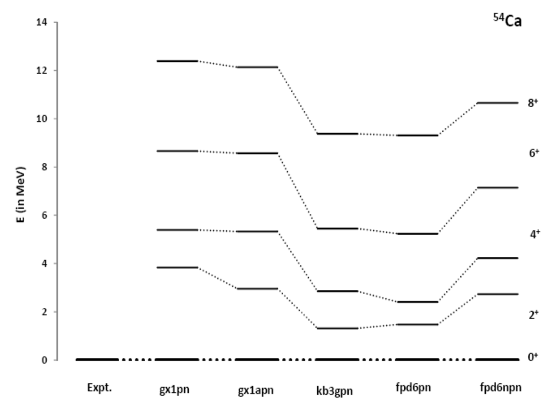

Fig. 3 Same as Fig.1 but for ^{54}Ca

From Fig. 1, we can notice that gx1pn, gx1apn and kb3gpn are in excellent agreement for observed 2^+ state of ^{52}Ca, with considerable difference from the values obtained from fpd6pn and fpd6npn effective interactions. Moreover, for ^{52}Ca itself, the values calculated for 4^+, 6^+ and 8^+ states are different (obtained by using gx1pn and gx1apn interaction) than those obtained using kb3gpn interaction. Although, it is difficult to comment regarding the spectra of ^{53}Ca and ^{54}Ca due to lack of experimental data yet it is evident from Fig.2 and Fig.3 that the yrast spectra calculated using gx1pn, gx1apn, kb3gpn, fpd6pn, fpd6npn effective interactions for ^{53}Ca and ^{54}Ca differs significantly.

Using the same set of wave-functions, employed to calculate yrast spectra, we have also calculated beta decay half-lives of neutron rich Ca and Sc isotopes. These calculated half-lives are compared with experimentally observed values from very recent experiments [4, 5], and will be presented in symposia.

Conclusion & Summary

Study of neutron rich nuclei reveal much about the microscopy of structural evolution and undoubtedly disclose new types of correlations and collectivity with different effective *pn* interaction as new shell gaps appear and ”traditional” magic numbers vanish in the regime of pronounced asymmetry between proton and neutron numbers. These changes could be attributed to the proton-neutron monopole interaction strength as one move from beta stability line to neutron rich side. It is seen explicitly that the energy levels as well as beta decay half-lives are quite sensitive to the choice of effective *pn* interaction.

Acknowledgement

I would like to acknowledge Physical Research Laboratory, Ahmadabad for providing me the financial support and warm hospitality through PRL associateship scheme for carrying out present research work.

References

[1] B. A. Brown, Progress in Particle and Nuclear Physics 47, 517 (2001).

[2] Nushell@MSU, B. A. Brown and W. D. M. Rae, MSU-NSCL report (2007).

[3] http://www.nndc.bnl.gov/nudat2/

[4] H.L. Crawford, R.V.F. Janssens, P.F. Mantica *et al.*, Acta Phys. Polon. B40:481(2009); arXiv:0901.3490

[5] P.F. Mantica, R. Broda, H.L. Crawford *et al.*, Phys.Rev.C77, 014313 (2008); arXiv:0801.0994