Magicity of N=50 persists at neutron drip line in ground and excited states of ^{78}Ni

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Introduction

The recent experimental observation [1, 2] of magicity in the extremely neutron rich exotic nucleus ^{78}Ni has invoked tremendous interest to examine the persistence of the magicity across the N=50 shell gap in ^{78}Ni which has extreme neutron to proton ratio with the proximity to the neutron drip-line and continuum. The advent of technology has enabled the study of exotic nuclei near the drip line where the emergence of new magic numbers and the disappearance of old magic numbers point towards the importance of a systematic analysis of the magicity in these exotic nuclei. However, the shell structure of the nucleus gets altered due to the rearrangement of particles near the fermi level with the excitations [3] due to temperature or rotation or both. Hence the temperature and rotation induced effects on the magicity or rather persistence of magicity at certain critical temperature is an interesting subject of research [4]. With the increasing excitation energy, the density of the quantum mechanical states increases rapidly and the statistical concepts like level density (LD) [5, 6] play an important role in exploring the perturbation in the shell structure due to excitations. Since the level density parameter 'a' and entropy of the system is expected to be minimum at the shell closures, we study level density parameter 'a' (=$S^2/4E_x$) and entropy (S) of Ni isotopes at different temperatures (T).

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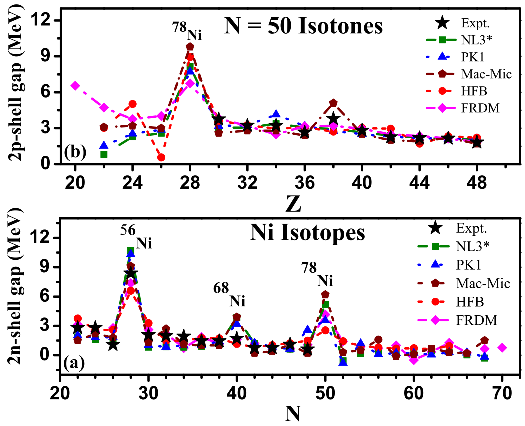

FIG. 1: Two neutron shell gap [$S_{2n}(N, Z)-S_{2n}(N+2, Z)$] and two proton shell gap [$S_{2p}(N, Z)-S_{2p}(N, Z+2)$] for (a) Ni isotopes and (b) N=50 isotones using RMF and NSM compared with HFB, FRDM and Expt.

Brief description of work

We use relativistic mean-field (RMF) [7, 8] and the triaxially deformed Nilson Strutinsky model (NSM) [9] for ground state. Excited states are treated using the Statistical theory of [3] hot rotating nuclei. We compute entropy and minimize the free energy F = E $-TS$ for Nilsson deformation parameters β and γ which give deformation and shape of the excited nuclei. We evaluate LD parameter and entropy as a function of temperature (T) = 0.8 to 3 MeV.

Results and Discussion

In Fig. 1(a) and (b), we compare two neutron shell gap and two proton shell gap for Ni isotopes and N=50 isotones respectively calculated using RMF (with NL3* and PK1 parameters), and Nilson Strutinsky Model

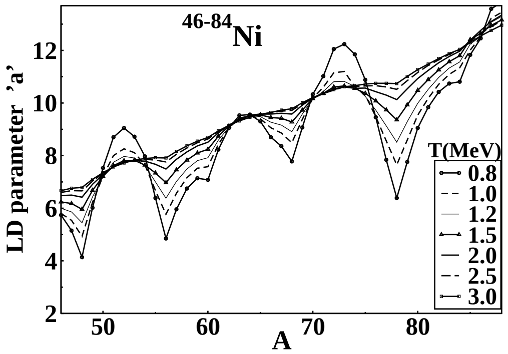

FIG. 2: Level density parameter vs. A for various
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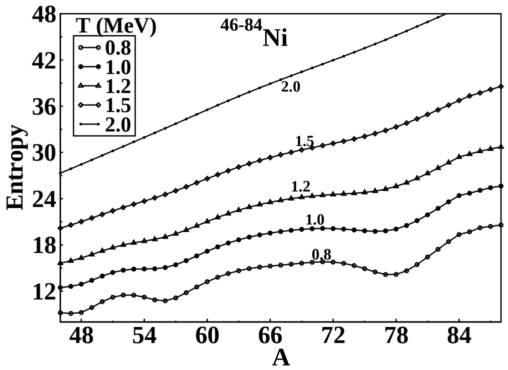

FIG. 3: Entropy vs. A for Ni isotopes at different T

(NSM) [9]. The comparison with HFB-24 [10], FRDM [11] and available experimental data [12] shows good match. The large peak shows strong magicity evident in ^{78}Ni.

Figs. 2 and 3 show LD parameter and entropy vs. N respectively for Ni isotopes for T = 0.8 − 3 MeV, where the minima in N = 50 (^{78}Ni) appears to be the most predominant though it lies near the drip line. The magicity in (^{78}Ni persists upto the temperatures T = 1.5 − 2 MeV. With further increasing T, shell effects appear to diminish and a variation becomes more and more smooth with N and the kink in the curve disappears completely at T = 3 MeV. The sharpest peaks at ^{78}Ni in ground as well as excited state shows strong evidence of magicity in extremely neutron rich region in most exotic magic nucleus ^{78}Ni known so far.

Conclusion

Experimentally identified doubly magic ^{78}Ni shows strong doubly magic character with a sharp peak at N = 50 (Z=28) within the theoretical framework of RMF and NSM, showing that the magicity persists in extremely neutron rich region. In excited state, variation of level density parameter and entropy with temperature shows strong magicity in ^{78}Ni,with a deep minima at N=50, which, persists up to the temperatures 1.5 − 2 MeV and then slowly disappear with increasing temperature.

Acknowledgments

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