Magic number in the super-heavy region

T. Sahoo[1],* S. K. Biswal [2], R. L. Nayak[3], and A. Acharya[4]
[1,3,4] *Veer Surendra Sai University of Technology, Sambalpur, INDIA and*
[2] *Institute of Physics, Bhunaeswar-751005, INDIA*

Introduction

In recent years, the advent of radio ion beam (RIB) facility inspires the nuclear physicists to look into the drip-line and super heavy with more curiosity. Double shell close of proton and neutron number has a special place in the nuclear structure physics. The main objective of searching the magic numbers in the island of the super-heavy element(SHE), which are mostly unstable in nature . Till date, the element with Z=117 has been announced as the heaviest element discovered in the laboratories[1]. The stability of a super-heavy nucleus is determined by the competition between the strong attractive shell correction against the repulsive coulomb term. It is the shell effect that plays a major role for the very existence of nuclei with magic numbers and provides longer lifetime and higher abundance as compared to their neighbors.

The extrapolation of β-stability line towards the super-heavy nuclei challenges the predictive power of a nuclear structure model. In the present manuscript, we have used the density dependent relativistic mean field theory to study various signature of the magic nuclei. The RMF theory has achieved a great success in describing many nuclear phenomena[**?**] compared with the non-relativistic theory. The relativistic Hartee-Bogoliubov(RHB) theory is the extension of RMF and Bogoliubov theory. It has shown a remarkable success in the description of nuclei with unusual N/Z ratio[3]. Here the SHE nuclei are assumed to be spherical, the RHB theory using a co-variant effective interaction with the assumption of spherical shape can be applied to the preliminary scan for magic numbers.

Formalism

In RMF a nucleus is described as a system of Dirac nucleons which interact with each other through exchange various effective meson like, isoscalar-scalar σ meson,the isoscalar-vector ω meson and the isovector-vector ρ meson. The starting point of the RMF theory is the effective Lagrangian which can be written as :

$$\begin{aligned}\text{Ł} =&\bar{\psi}[i\gamma^{\mu}\partial_{\mu} - M - g_{\sigma}\sigma - g_{\omega}\gamma^{\mu}\omega_{\mu} - g_{\rho}\gamma^{\mu}\vec{\tau}\cdot\vec{\rho}_{\mu} \\ &-e\gamma^{\mu}\frac{1-\tau_3}{2}A_{\mu}]\psi + \frac{1}{2}\partial^{\mu}\sigma\partial_{\mu}\sigma - \frac{1}{2}m_{\sigma}^{2}\sigma^{2} \\ &-\frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} + \frac{1}{2}m_{\omega}^{2}\omega^{\mu}\omega_{\mu} \\ &+\frac{1}{4}c_3(\omega^{\mu}\omega_{\mu})^2 - \frac{1}{4}\vec{R}^{\mu\nu}\cdot\vec{R}_{\mu\nu} + \frac{1}{2}m_{\rho}^{2}\vec{\rho}^{\mu}\cdot\vec{\rho}_{\mu} \\ &+\frac{1}{4}d_3(\vec{\rho}^{\mu}\cdot\vec{\rho}_{\mu})^2 - \frac{1}{4}F^{\mu\nu}F_{\mu\nu}\end{aligned} \tag{1}$$

Symbols carry their usual meaning. As the classical meson field are used in the above equation,it do not contain pairing interaction. In order to have the two body interaction one has to quantize the meson fields which lead to a Hamiltonian with two body interaction. Following the standard procedure of Bogoliubov transformation, thr Dirac Hartee-Bogoliubov theory solves the RHB equations.

Result and Discussion

The main objective of this paper is to find the shell closure in the super-heavy valley. There are various signature of the shell closure , out of which we have discussed two-nucleon separation energies S_{2n} and the two-nucleon gaps δ_{2n}. In recent years Z=120 and 126 are consider as the next potential candidate to be magic proton number after Z=82. So we have taken these nuclei and calculated the S_{2n} and Δ_{2n} in the isotopic chain. In this

---

*Electronic address: `trupti9vssut@gmail.com` present work we have used various parameter like DD-ME1,DD-ME2,TW99 and PKDD.

A. Two-neutron separation energies

$S_{2n}(N,Z) = E_B(N,Z) - E_B(N-2,Z)$

$E_B(N,Z)$ is the binding energy of a nucleus with N number of neutron and Z number of proton. In Fig. 1 we have shown the S_{2n} energy for the isotopic chain of Z=120 and 126, with four different parameters set. From the figure it is clear that N= 172 and 184 there are a sudden drop in the S_{2n} energy value for both Z=120 and 126. This sudden fall in the S_{2n} is appearing in all parameter set. So it is independent of the nature of the parameter set. The lowering the value of S_{2n} at N=172 and 184 show that more amount of energy required to pull out two neutron from nucleus with N=172 or 184, and Z= 120 or126. This may be due to the occurrence of the shell closer at this particular combination of proton and neutron.

B. Two-nucleon gap

Sometime the magnitude of the S_{2n} in the drip-line and super heavy region are very low, so it can not easily traceable where the sudden fall occurring in the S_{2n} energies. For this reason it is reasonable to calculate the Δ_{2n} energy, which is defined like :

$$\delta_{2n}(N,Z) = S_{2n}(N,Z) - S_{2n}(N+2,Z). \quad (2)$$

In Fig 2. we have given the Δ_{2n} energy in the isotopic chain for Z=120 and 126 with four different parameter set. From the figure it is clear that a prominent peak appearing at the N=172 and 184 for both Z=120 and 126. So it gives a strong support to our earlier prediction of magic number from the S_{2n} energy.

1. conclusion

In summary we have calculated S_{2n} and δ_{2n} gap for isotopic chain for Z=120 and 126. All the calculations are done in the framework spherical code of RHB. with various parameter like DD-ME1,DD-ME2,TW99 and PKDD. From the analysis of S_{2n} energy and Δ_{2n} gap, we concluded that Z=120/126 and N= 172/184 can be considered as magic combination.

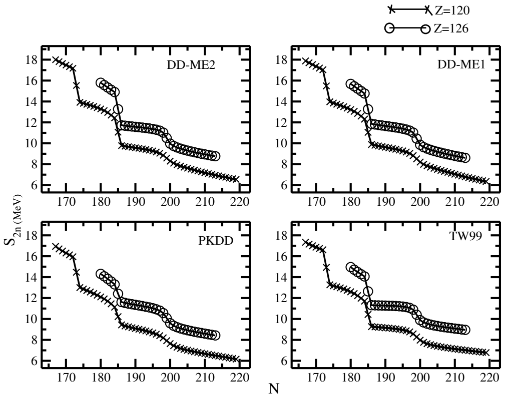

FIG. 1: Two Neutron separation energy for Z=120,126

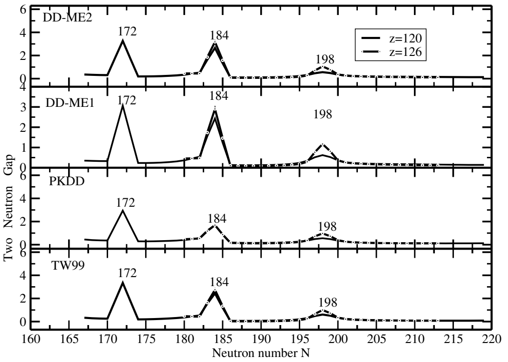

FIG. 2: Two Neutron gap energy for Z=120,126

References

[1] Yu. Ts. Oganessian et al., Phys. Rev. Lett. 109 (2012) 162501.

[2] P. Ring, Prog. Part. Nucl. Phys. 37 (1996) 193.

[3] J. Meng, P. Ring, Phys. Rev. Lett. 77 (1996) 3963.