Probing The Short Range Effect of n-Core Interaction in ^{20}C halo Nucleus

V.S. Bhasin[1] and I. Mazumdar[2*]

[1]Department of Physics & Astrophysics, University of Delhi, Delhi-110007, INDIA and
[2]Deptartment of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA

It has now been well accepted that the 2-neutron halo nucleus ^{20}C is arguably the most promising candidate to support the elusive Efimov states in an atomic nucleus [1,2,3]. Working within the framework of a three-body model (^{18}C core − n −n) with non-local, separable potentials the authors [1-3] have shown the emergence of Efimov states in c and their subsequent evolution into Fano resonances as the two-body (n-core) interaction is increased beyond a certain limit. The only free parameters involved in the theoretical analysis are the range and strength parameters of the n-core interaction. The n-n interaction parameters for the two valence, halo neutrons are fixed from known values from experiments. For a given value of the range parameter (β), the strength parameter (λ) is varied to get the solutions for the three body equations to yield the bound energy states. It is this kind of analysis that shows the emergence of the bound Efimov states below the two-body breakup threshold. However, beyond a certain value of the strength parameter λ the bound Efimov states move over to the two-body continuum and appear as asymmetric resonances. This region demands the analysis to be in the scattering sector for a neutron (n) and ^{19}C system.

Before we move over to the scattering sector, it would be relevant to probe and compare the sensitivity of different sets of the two body potential parameters on the three body ground and excited states. Since the experimentally known parameter for the ^{19}C state is only the two body binding energy, we have to find those sets which can reproduce the same binding energy of the n-^{18}C system. This study may also be quite important to find out how far we can improve upon the Efimov criterion, viz., a $>> r_{eff}$ by increasing the value of the range parameter β, hereby going to the short range region and yet predict the reasonable values of the three body energies. Thus, choosing a realistic value of n-^{18}C binding energy to be 180 keV, we increased the values of β from 5.2α to 7.5α and 10 α and obtained the corresponding values of strength parameter λ to be 47.31 α^3 and 109.4 α^3 respectively. α being the energy parameter given in terms of the deuteron binding energy. By feeding these values and the corresponding values of the parameter β in the expressions for the scattering length (a_s) and effective range (r_{eff}), we found a_s= 12.04fm and r_{eff}=1.615fm for β=7.5 α and a_s= 11.67fm and r_{eff}=1.33fm for β=10 α. These values are to be compared with a_s= 12.34fm and r_{eff}=2.273fm for the set of values, β=5.2α and λ=16.49α^3, which we used in the calculations to predict the ground and excited state energies for the three body ^{20}C system. The first point to note from the two body parameters is that while the values of range parameter do decrease by increasing the value of β, as expected, but so do the values of the scattering length parameter. With the result that the ratio, $\frac{a_s}{r_{eff}}$ only marginally increases. The table given below presents a comparative study of the three body ground and excited state energies as predicted by the two body parameters.

It is clear from the table that the three body ground state energy drastically changes from its realistic value; the corresponding excited state energies also depict a substantial change. The sharp increase in the ground state energy, as we move over the short range, demonstrates that we are probably approaching more towards the region of Thomas collapse rather than to the Efimov region. The calculations were repeated for the case of n-^{18}C BE, ϵ_2 = 80 keV. The values of the strength parameter λ as calculated for different values of range parameter β. The values of β varied from 5.2α 10α correspond to effective range reducing from 2.3fm to 1.2fm. It was found that as far as the solutions for the three-body bound state energies are concerned, the overal trend is same as was seen for ϵ_2= 180keV. β= 5.2α is a realistic value for generating the Efimov states whereas at higher values (smaller ranges) tending towards the zero range limit we are in the Thomas Collapse region where the binding energies tend to infinity. This study is rather important in scanning the entire parameter space for the realistic determination of the range and strength parameters responsible for the generation of the Efimov states.

References

[1] I. Mazumdar *et al.*, Phys. Lett B. 704 (2011).
[2] I. Mazumdar *et al.*, Phys. Rev. Lett. 97, 062503 (2006).
[3] V. Arora*et al.*, Phys. Rev. C 69, 061301 (2004).

*Electronic address: indra@tifr.res.in

ε_2, B.E of $n-{}^{18}C$	β_1 in units of α	λ_1 in units of α^3	a_s in fm	r_{eff} in fm	$\varepsilon_3(G\,S)$	ε_{31}	ε_{32}
180 keV	5.2	16.46	12.34	2.273	3.29 MeV	188 keV	
180 keV	7.5	47.31	12.04	1.615	41.5 MeV	410 keV	
180 keV	10.0	109.4	11.67	1.330	156.4 MeV	5.78 eV	399keV

Table: Comparison of 3 - body energies (ground, 1st and 2nd excited states) predicted by different sets of parameters