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Referee report on Ph.D. thesis entitled:

Studies of Alpha Clustering in Nuclei

The clustering phenomena is one of the most important topic study recently from theoretical and experimental point of view in the nuclear reaction at the varying energy regime. Clustering is natural energy minimization mechanism (from astrophysics: clustering of the Galaxies and Stars, to atomic and subatomic scale: clustering of quarks in nucleons, nucleons in atoms etc.). The concept of the alpha–clustering has found many applications to nuclear reactions and nuclear structure. Calculations of the properties of nuclear matter and experimental measurements indicate that clustering into alpha-particles is occurs in the nuclear matter. MSc **Jinesh Kallunkathariyil** in his thesis present theoretical studies for the possible existence of alpha clustering in nuclei.

The submitted thesis consists of six chapters that are preceded by a short introduction, describing the content of the paper and is finished by an overview that summarizes the results.

The first Chapter (Chapter 2) covers history of studies of the alpha clustering in nuclei. It start from the very early models of atom proposed by Rutherford after that the first alpha particles model proposed by Gamow and its extension is described. Afterwards Author widely has discussed the Bethe–Bacher arguments for the alpha particle like structure of the nuclei and the Hafstad's and Teller's work for the alpha particle model for even and 4n+1 type of nuclei. These descriptions are important from the point of view of one of the next chapters (Chapter 5) where Author disused the dependence of the total binding energy as a function of number of bounds. In some sense the thesis is continuations of the idea given by Bethe-Bacher and Hafstad and Teller. Moreover in the first Chapter one can find the description of the Hoyle state in the nuclei and Ikeada diagram. Finally the recent experimental investigations of the alpha clustering in nuclei are described.

In the Chapter 3 one can find the description of the Microscopic Liquid Drop Model (MLDM) which is the main model development in the thesis. The MLDM is based on the similar assumption as other quantum Molecular Dynamics Models. Author in this chapter has described the idea on the Nuclear Equation of State (EoS), presented Femi gas model of atomic nucleus and what is, in my opinion, the most important from the point of view the dissertation, the author introduce new form (parametrization) of the EoS. Moreover this

chapter consists the calculations of the ground state properties of the nuclei. One can find the short discussion of the energy minimizations produce. Based on this procedure Author claims about the most preferable nucleons configurations. Additionally the determination of the EoS parameters is described in this chapter. The Author determined the parameters based on the ground state properties of the light nuclei such ^{2}H, ^{3}H, ^{3}He and ^{4}He. Finally the chapter ends with the set of parameters of EoS which are used in the future calculations.

The Chapter 4 is, in my opinion, the essence of this dissertations. Here the model calculations and the comparisons with experimental data are performed. The main observables which are disused in this chapter are the binding energy and r.m.s radius of the nuclei. Based on the described model calculations Author introduced additional corrections for the Hamiltion which are responsible for the alpha-alpha interaction itself. When this corrections were applied to the model the better agreement with experimental data was achieved.

Next chapter (Chapter 5) concerns studies of the binding energy curve based on the alpha clustering approach. Following Bethe's predictions of the binding energy depends on number of alpha cluster bounds Author present simple equations. This equations could not explain "kink" in binding energy around ^{56}Ni author has suggested that increase the number of bound by one for the nuclei heavier than ^{60}Zn solved the problem. One can find also simple physics description for this increase.

I have the following comments / questions to the way conducted by PhD student analysis, or interpretation of results:

- In the Chapter 3.6 one can find the description of the calculations produce of the ground state properties of the nuclei. Author has presented the minimization procedure for search of the binding energy and showed configuration of the nucleons for some minimization steps. It is not clear for what kind of nucleus this example is presented. The answer (^{12}C) one can find in the Chapter 5 but in my opinion should appears also in chapter 3.6.
- Based on what assumption the value of $\chi^2=10^{-7}$ was chosen to stopped the minimizations procedure?
- In my opinion the formula 3.67 can't be named as the χ^2. When we check the χ^2 distribution the denominator has no square.
- In the Chapter 4 author claims about the alpha structures of the nuclei. Moreover based on this assumptions divide nuclei in the three different groups. I can't find in the thesis proof how the proposed model supports this configuration.
- In the Chapter 4.1 the descriptions of the binding energy "looks" better when the energy volume parameter is changed. How sensitive is the model for change of the other parameters?
- In the Chapter 4.2 author claims that introduction of the alpha- alpha interactions better describe such observables as binding energy and r.m.s radii of the nuclei, but if one look on this two variables it is difficult to judge that this kind of corrections

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really improves model descriptions. Especially that, so simple, change of the energy volume parameter gives similar answer.

- What kind of condition was used to predicate that one description (Chapter 4.2) better describe experimental data that the second (Chapter 4.1). The comparisons of the model calculations with experimental data were made "by eye" or maybe some kind of statistical test was used?
- In my opinion, again, the prediction that red point in the Figure 4.7 are grouping around 3.5 fm should be prove based on the more quantitatively method.
- In the Chapter 6 the new systematics of the binding energy starting from ^{60}Zn is introduced, in my opinion is interesting to check how the proposed hypothetical description is supported by the model proposed in the thesis. I mean that the calculations on the nuclei with higher Z are very welcome.

The doctoral dissertation MSc Jinesh Kallunkathariyil is written in English, in a simple and understandable, and reading it gave me great pleasure. I have no comments to the language of the thesis, but at the same time I do not feel fully competent to evaluate the thesis in this regard. The following is a list of observed editorial errors:

- The figures 1.1, 2.1, 2.2, 2.4, 2.5 are of poor quality.
- The scales, legends and axis descriptions in my opinion should be bigger, Author should consider that, it happens that, referees haven't sometimes "eagle eye".
- I found that very often Author refers to the work 24 (page 44, 45, 48, 49, 51 and more) but this publication is not available. Moreover the thesis should the main source of information not publication which is (I guess) prepared on the basis of this work.

In summary, I believe that presented thesis makes a fine and valuable contribution to the theoretical understanding of the alpha clustering phenomenon. The proposed model the interaction between nucleons are described by a new form of Equation of State (EOS) of nuclear matter. The comparison of the model with experimental data give satisfactory results and proves's presence of the alpha clustering inside nuclei. The author constantly proves throughout the text his very good knowledge of the theoretical nuclear physics. I little bit missed the discussion of the future possible enhancements of performed studies presented by the Author.

In conclusion, the dissertation presented by Jinesh Kallunkathariyil contains valuable and original results and satisfies all the formal requirements for doctoral thesis and I hereby agree for the public defense.

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