Preface

This is the third volume in the series of *Lecture Notes in Physics* entitled "Clusters in Nuclei" based on the well known Cluster Conferences that have been running since decades, on two recent "State Of The Art in Nuclear Cluster Physics" Workshops, as well as on successfull Theoretical Winter Schools, tradionnally held on the Campus of the Université de Strasbourg, Strasbourg, France.

A great deal of research work has been accomplished in the field of alpha clustering and in cluster studies of light neutron-rich nuclei. The scope of this Series of lecture notes is to deepen our knowledge of the field of nuclear cluster physics which is one of the domains of heavy-ion nuclear physics facing the greatest challenges and opportunities.

The purpose of this third and last volume of *Lecture Notes in Physics* "Clusters in Nuclei", is to promote the exchange of ideas and discuss new developments in "Clustering Phenomena in Nuclear Physics and Nuclear Astrophysics" from both the theoretical and experimental points of views. It is aimed to retain the pedagogical nature of our earlier Theoretical Winter Schools and should provide a helpful reference for young researchers entering the field and wishing to get a feel of contemporary research in a number of areas.

The various aspects of the main topics in this last volume of "Clusters in Nuclei" are divided into six chapters, each highlighting new ideas that have emerged in recent years:

- Faddeev Equation Approach for Three-Cluster Nuclear Reactions
- Electromagnetic Transitions as a Probe of Nuclear Clustering
- "Tomography" of the Cluster Structure of Light Nuclei via Relativistic Dissociation
- From Light to Hyper-heavy Molecules and Neutron-Star Crusts in a Dynamical Mean-Field Approach
- Covalent Binding on the Femtometer Scale: Nuclear Molecules
- Clusterization in Ternary Fission

The first chapter entitled *Faddeev Equation Approach for Three-Cluster Nuclear Reactions* by Deltuva, Fonseca and Lazauskas shows how well the formalism based

on Faddeev-like equations is capable to describe nuclear three-cluster reactions, which include elastic, break-up and transfer channels. For the sake of pedagogy, the formalism is presented in two different techniques based on momentum space and configuration space represention explained in detail. Comparison with previous calculations based on approximate methods used in nuclear reaction theory is discussed.

The second chapter of Jenkins on *Electromagnetic Transitions as a Probe of Nuclear Clustering* investigates a number of cases where electromagnetic transitions can be used to further our understanding of clustering, from heavy-ion radiative capture to superdeformation in alpha-conjugate nuclei.

"*Tomography*" *of the Cluster Structure of Light Nuclei via Relativistic Dissociation* is deeply discussed in Chap. 3 by Zarubin to demonstrate the capabilities of relativistic nuclear physics for the development of the physics of nuclear clusters. Nuclear track emulsion is an effective technique for pilot studies to study the cluster dissociation of a wide variety of light relativistic nuclei within a common approach. Analysis of the peripheral interactions of relativistic isotopes of beryllium, boron, carbon and nitrogen, including radioactive ones, with nuclei of the emulsion composition, allows the clustering pattern to be presented for a whole family of light nuclei.

The Chap. 4 entitled *From Light to Hyper-Heavy Molecules in Dynamical Mean-Field Approach* by Simenel describes a microscopic approach for low-energy collisions between atomic nuclei is the time-dependent Hartree-Fock theory, providing a mean-field dynamics of the system. This approach and some of its extensions are used to predict the evolution of out-of-equilibrium nuclear systems. The formation of light molecules and the dynamics of α-clustering are discussed. Di-nuclear systems formed in transfer, deep-inelastic, and quasi-fission reactions, as well as hyper-heavy molecules produced in reactions between actinides are also investigated. The formation and stability of structures in neutron star crusts are finally discussed.

von Oertzen and Milin are trying in Chap. 5 (*Covalent Binding on the Femtometer Scale: Nuclear Molecules*) to definitively demontrate that Nuclear molecules are objects having two or more individual clusters as centres with extra nucleons (usually neutrons) binding them. The clusters have to be strongly bound themselves, while they get bound into molecules due to the specific properties of the nucleus-nucleus potentials and exchange of nucleons. A large number of strongly deformed nuclear states in light nuclei with neutron excess have been experimentally identified in the last decades, and some of them have been associated with covalent structures, mainly via their grouping into rotational bands.

Finally, the last chapter *Clusterization in Ternary Fission* proposed by Kamanin and Pyatkov treats most of experimental findings of the new kind of ternary decay of low excited heavy nuclei called "collinear cluster tri-partition" due to the features of the effect observed namely decay partners fly away almost collinearly and at least one of them has magic nucleon composition. At the early stage of our work the process of "true ternary fission" (fission of the nucleus into three fragments of comparable masses) was considered to be undiscovered for low excited heavy nuclei.

Manifestations of new decay channel observed in the frame of different experimental approaches are discussed. Special attention is paid to the connection between conventional binary fission and ternary fission processes.

Each of the three volumes contains lectures covering a wide range of topics from nuclear cluster theory to experimental applications that have gained a renewed interest with available Radioactive Ion Beams facilities and modern detection techniques. We stress that the contributions in these volumes are not review articles and so are not meant to contain all the latest results or to provide an exhaustive coverage of the field but are written instead in the pedagogical style of graduate lectures and thus have a reasonable long 'shelf life'.

The edition of this book could not have been possible without stimulous discussions with Profs. Greiner, Horiuchi, Schuck and Zagrebaev. Our appreciation goes to all our co-lectures for their valuable contributions. We acknowledge also all the referees for their comments on the Chapters that are included in this volume. I would like here to thank, more particularly, Prof. Poenaru for his constant helpful suggestions from the beginning to the end. Special thanks go Dr. Christian Caron and all the members of his Springer-Verlag team (in particular, Mrs Angela Schulze-Thomin, Gabriele Hakuba, and Donatas Akmanavičius) for their help, fruitful collaboration and continued support for this ongoing project.

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