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Editorial

The nuclear many-body problem

Editorial preface to the topical collection

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Abstract This Topical Collection of the European Physics Journal A is devoted to recent progress in the nuclear many-body problem. In particular, it aims at a comprehensive compilation of developments related to the work of a pioneer in that field, Peter Schuck, who passed away in 2022. Together with Peter Ring, he co-authored the book on “The Nuclear Many-Body Problem”. Different concepts presented in this seminal book have been elaborated further within a broad international collaboration. For instance, the quasi-particle approaches in connection with nuclear superfluidity and cluster formation in nuclear systems, in particular alpha-particle condensation and quartetting at subsaturation densities, have been put forward inspired by Peter Schuck. These advances obtained in the nuclear many-body problem can also be applied to other systems, for instance solid state physics. This Topical Collection is considered as addendum and continuation of the textbook of P. Ring and P. Schuck.

The nuclear many-body problem is one of the first many-particle systems where quantum statistics has been applied around a century ago. Degeneracy and strong interaction are challenges, and new concepts such as quasiparticles and bound state formation have been worked out using new methods such as the method of Green functions and the Feynman diagram technique. Other many-body systems, such as solid state physics, strongly coupled Coulomb plasmas and warm dense matter, adapted these methods and developed them.

A pioneer in this field of research is Peter Schuck. Together with Peter Ring, he co-authored the book on “The Nuclear Many-Body Problem” [1] in 1980. This textbook remains until now a standard in the international community and explains various concepts and approximations to treat different effects in many-particle systems. In between, this field has been developed in various directions. First, the theory has been elaborated further, and new concepts and phenomena are described. As example we mention the Interacting Boson Model, the formation of clusters and the occurrence of a Bose condensate of α particles. Second, beyond the analytical approaches which work with various approximations, numerical methods became applicable to strongly interacting systems which allow so-called “ab initio” solutions of the many-body problem. The comparison with analytical approaches is of importance for both approaches. A third direction refers to the fundamentals of our description of the nuclear many-body problem, since the use of interaction potentials is semi-empirical and a QCD background is necessary to describe the interaction processes in nuclear systems. Peter Schuck contributed to the international collaboration in these fields of research. The present Topical Collection is aimed to collect actual research work related to his inspirations and activities. We give a short legacy [2].

Professor Dr. Peter Schuck, one of the leading specialists in many-body physics in Nuclear and other fundamental systems, passed away on the 10th of September, 2022, at the age of 82.

He began his education at the Technical University of Munich in a group headed by Wilhelm Brenig, introducing Green’s function techniques into the description of many-body systems. Following his Ph.D., as a postdoc at MIT in Boston, he worked with Felix Villars on collective vibrations and their coupling to single-particle motion. He went to France, first to the ILL and later to the IPN, in Greno-

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ble. In 1980 he joined the IPN in Orsay, where he became Directeur de Recherche at the CNRS. During his years in Grenoble, he collaborated with Peter Ring on the celebrated book "The Nuclear Many-body Problem" (1980) [1] which is still one of the most important textbooks on nuclear theory, particularly concerning many-body techniques applied to finite self-bound Fermi systems. Generations of young researchers have used this book for their work. Today it is also well known in Physical Chemistry and mesoscopic condensed matter physics.

Peter Schuck also worked on ideas to describe strongly interacting finite Fermi systems as a system of interacting bosons, i.e. on a microscopic interpretation of the phenomenological Interacting Boson Model of Arima and Iachello which was, and is still, used worldwide with great success for the description of nuclear spectra. He also studied collective phenomena as, for example, various forms of scissor mode in deformed proton- and neutron-distributions (isospin-scissors) or spin orientations (spin-scissors) that oscillate against each other.

Together with groups in Barcelona, Catania, and Madrid, he developed a very successful new energy density functional (BCPM) for the universal description of nuclear systems. Peter Schuck also worked on intermediate energy nuclear physics and was the first to predict a strong in-medium dependence of the spectral intensity of the so-called 'sigma' meson. In addition he developed the theory of quantum condensates and pairing. He also made important contributions to the physics of cold atoms and other problems in condensed matter. Over the years, he developed an interest in various extensions of the random phase approximation and the equation-of-motion method.

Since 2000, Peter Schuck became well known in relation to the theory of alpha particle condensation in nuclear systems, e.g., quartetting in the Hoyle state. Since this theory was first proposed in 2001, in a highly cited article in Physical Review Letters [3], it has provoked a strong increase of interest internationally both theoretical and experimental, and initiated a number of conferences and several reviews.

Peter Schuck enjoyed various international collaborations, particularly within Europe and with colleagues from India, Japan, and China. He was Editor of European Physical Journal A and is one of the most respected theoreticians of the EPS. In 2004 he was the recipient of the Gay–Lussac–Humboldt prize and in 2018, together with Peter Ring, the Lise-Meitner prize for Nuclear Science of the EPS.

With the passing of Peter Schuck (Fig. 1) we not only lose a foremost expert in the field of nuclear theory and many-body physics, who inspired many new ideas, initiated discussions and collaborations. Above all, we have lost a friend and congenial colleague who was always helpful and receptive to new problems. We will remember him with great fondness and miss him in future work.

Fig. 1 Peter Schuck (05.05.1940–10.09.2022)

Let give us a citation of one of his last collaborators, Bo Zhou [4], who worked with him until summer 2022 about biexcitons in bilayer systems: "We would like to dedicate this work to the memory of our esteemed colleague and friend, Peter Schuck, with whom we have had the privilege of collaborating for many years. Peter's broad interests and profound insights in nuclear physics have been an inspiration to us all. We are deeply grateful for his companionship and contributions throughout the years. He will be dearly missed. His spirit and dedication to the pursuit of knowledge continue to guide us, and in his memory, we commit to advancing the work he so passionately embraced".

This Topical Collection (TC) aims at a comprehensive compilation of developments that Peter Schuck advanced after the book "The Nuclear Many-Body Problem" [1] was published, so that it could be considered a continuation of this book, devoted to some modern aspects of the nuclear many-body problem. We mention in particular his interest in the formation of α clusters in nuclear systems and the possibility of a Bose condensate. Several times he mentioned that he has the dream to such a condensate in nuclear systems, as a new phase with interesting properties. He was always open for discussions with colleagues working in other fields of research, for example solid state physics, to find new applications of the concepts worked out in the nuclear many-body system.

The TC contains contributions that are related to Peter Schuck and his scientific legacy. They can be grouped according to the following topics:

A. The interacting boson model and collective phenomena in nuclear systems [5–8].
B. Nuclear energy density functionals [9–13].
C. Equation of motion method and extended RPA [14–16].
D. Quantum condensates and pairing [17].
E. Alpha-particle clustering [4,18–22].
F. Pions and related experiments, astrophysics [23–29].
G. Applications in solid state physics, quartetting in semiconductor layers, etc. [30,31].

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