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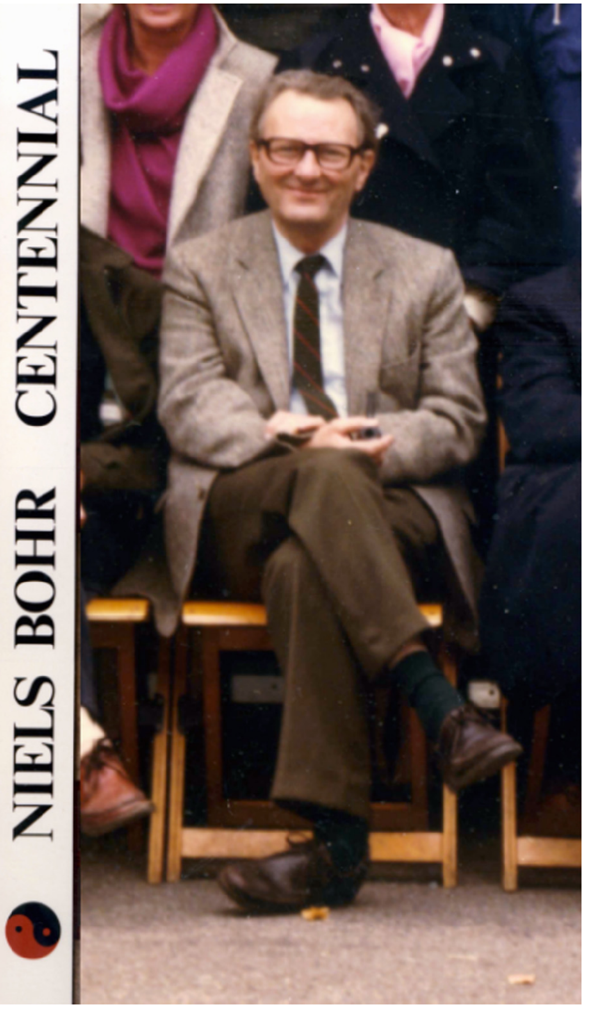
Obituary

Aage Winther (1926–2011)



Aage Winther (with his ever present pipe in his hand): detail of the commemorative group photo of the collaborators, guests and members of The Niels Bohr Institute, of which institution Winther was at that time the Director. The picture was taken on October 7th 1985, in occasion of the 100th anniversary of Niels Bohr's birth.

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On April 2011 Aage Winther, one of the major artificers of the modern theory of nuclear reactions, passed away. Throughout his career he was associated with The Niels Bohr Institute, institution of which he eventually became Director, helping also at establishing its renowned Archive which attracted and continues to attract important figures in the study of the history of science, like the late Abraham Pais.

Aside from his strong commitment with the University of Copenhagen, and in keeping with the truly international atmosphere of his home institution, Aage enjoyed strong connections with research centers around the world, in particular with MIT, Caltech and the University of Basel. He played, together with Renato Ricci, a central role in the creation of NuPECC, the Nuclear Physics European Collaboration Committee of the European Science Foundation, and with Renzo Leonardi in the establishment of the ECT*, the European Centre for Theoretical Studies, becoming its director after Ben Mottelson. While these activities would have been amply sufficient to use up all the attention and energy of lesser characters, this was certainly not the case of Aage, whose main professional passion was research. This allowed him to contribute to nuclear physics, also late in his life, to an extent which few of his contemporaries have been able to do. In fact, a short review of his contributions implies a broad view of the field of nuclear structure and reactions.

A fundamental probe of the structure of atomic nuclei is provided by scattering experiments in which a beam of ions, in particular heavy ions, is aimed at a thin foil made out of a heavy nucleus (target). The properties of the resulting outgoing ions (mass, charge, scattering angle, energy, etc.) are recorded by a detector, or by an array of detectors. The corresponding data contain specific information concerning the microscopic structure of the nuclei involved in the reaction process. The modern theory of low and intermediate energy heavy ion reactions was, to a large extent, developed by Aage Winther, assisted by the group of collaborators who came to work with him at the Niels Bohr Institute. Aage oversaw and coordinated the work, all the time aiming at clarity and consistency.

At bombarding energies below the Coulomb barrier, one observes typical Rutherford scattering, that is the elastic deflection of the bombarding nucleus by the Coulomb field of the target, as well as Coulomb excitation. The latter is a process in which part of the relative motion energy and angular momentum is transferred, through the electromagnetic field, to the internal degrees of freedom of the colliding nuclei. Coulomb excitation probes surface and density nuclear degrees of freedom (vibrations and rotations). Also one- and two-particle transfer processes occur at such low energies, specifically probing independent particle nuclear motion, and pairing correlations (nuclear superfluidity and superconductivity). Increasing the bombarding energy one can observe multiple particle transfer and inelastic processes leading eventually to deep inelastic collisions, where the contact between target and projectile, although involving essentially only the nuclear surfaces, strongly increases as compared to grazing collisions, leading to large energy losses. In this regime, large amplitude collective motion in both normal space (surface-deformation) and gauge space (number of nucleons) can be studied. It is the strength of the couplings of relative motion to the nuclear surface and the nucleon transfer degrees of freedom, which eventually decides whether projectile and target fuse together, leading to a single, highly excited, heated nucleus. This is why the description of fusion processes constitutes a natural subject of the general theory of direct heavy ion reactions.

Typical of Aage's attitude concerning research, was that he started his studies of heavy ion reactions from the beginning and finished them at the end, providing in the process basic and definitive answers to Coulomb excitation, to one- and two-nucleon transfer reactions, to deep inelastic processes, as well as to sub-barrier fusion reactions. The monograph he wrote with

Kurt Alder on Coulomb excitation remains to date the reference book in the subject, while the Review of Modern Physics paper "Study of Nuclear Structure by Electromagnetic Excitation with Accelerated Ions", of which the first and last authors are Alder and Winther respectively, is one of the most cited RMP papers ever. Although these achievements, together with the software "COULEX", containing also many contributions from Jorrit de Boer, constitute milestones in the study of nuclear structure with heavy ion collisions, it is likely that Aage's contribution to (one-, two- and multiple-) particle transfer processes will stand out as a more important piece of research which only few scientists could have made. He brought to such rather difficult, highly technical subject a level of clarity which allowed for direct insight into the multitude of effects, like coherence, non-locality, recoil, etc., resulting from the coupling between the relative motion of the interacting ions and the variety of transfer processes.

Aage was able to achieve such a result by applying to the subject his mastery in what it is known as the semiclassical approximation. Quantal particles, similar to light (photons), give rise to interference phenomena. This is also true for atomic nuclei at large, and for heavy ions in particular. One can capture the essence of heavy ion reactions by adding the quantal transition amplitudes multiplied by the corresponding (action) phases, calculated along the few classical trajectories of relative motion contributing to the same scattering angle. Students working with Aage got somewhat restless at the amount of time and effort needed to keep track of amplitudes, phases and the like as a function of time along the classical trajectories to obtain results which could readily be obtained with the help of softwares which solved the Schrödinger equation for the corresponding bombarding and outgoing conditions. Such an attitude changed into deep appreciation, as soon as the newcomer understood that, in Aage's approach to reaction theory, the semiclassical approximation was not, or at least not only a computational tool, but a powerful way to provide insight in the quantal physics which eventually gives rise to the distribution of clicks of the detectors and the traces on the photographic plates.

Aage's use of the semiclassical approximation of heavy ion reactions bears much of the insight provided by Feynman's path integral version of quantum mechanics. Within this context, while one refers to the Born approximation the substitution, in a scattering process, of the total field by the incident field, it will only be fair to call the Winther (Winther–Brink) approximation, the semiclassical description of heavy ion collisions.

For Aage, nuclear structure and nuclear reactions were, to a large extent, the bound and the continuum aspects of the same physics. This view was instrumental in the quest of elucidating a central issue connected with Cooper pair tunneling between superfluid nuclei. Namely, that the only possible way to explain the observed experimental cross sections was to accept the fact that the (fermionic) partners of a Cooper pair of nucleons were essentially transferred one at a time (successive transfer), involving also situations in which the two nucleons were so far away from each other, that they had to traverse regions where the pairing gap vanished. He could demonstrate this by making use of his mastery in reaction theory in particular, and in quantum mechanics at large, playing in this case with a mixed representation of the transfer process (post–prior representation).

Such a question had already emerged in relation with what is now known as the Josephson effect, in connection with the rejection of Josephson's paper to PRL by Bardeen. The issue was eventually cleared up in favor of Josephson by, among others, Phil Anderson and Leo Falicov. At the time of the studies of Cooper pair transfer between nuclei, Leo was a distinguished visitor at the HCØ Institute in Copenhagen. From him, Aage received full support for the post–prior interpretation of two-nucleon transfer process.

Once one- and two-nucleon transfer reactions, let alone elastic, Coulomb excitation and inelastic processes, were under control, the quest of developing the theory of heavy ion reactions into a self-consistent tool, to probe nuclear structure, had reached its goal. This is in keeping with the fact that multiparticle transfer beyond Cooper pair tunneling can be described in terms of one- and two-particle transfer, determined by the same matrix elements (spectroscopic amplitudes) used in nuclear structure calculations. Within this context, the imaginary part of the optical potential, and thus elastic, inelastic and direct transfer reactions, can be microscopically calculated with the above-mentioned elements. The same is true concerning the absolute cross sections associated with deep inelastic processes and with sub-barrier fusion reactions.

The results of this research, formulated into a workable theoretical scheme, amenable to an eventual translation into a software, with the help of which one could calculate absolute two-particle transfer cross sections among superfluid nuclei (nuclear version of Josephson's calculation of the associated super current), was eventually published in a book of the title "Heavy Ion Reactions" in collaboration with Ricardo Broglia. Of it, Dirk Schwalm, director of the Max Planck Institute of Nuclear Physics of Heidelberg, himself a central figure in the experimental development of heavy ion reactions, commented: "This is a nice book. It contains all what you need to analyze an experiment. Also to plan a new one".

Within this context, 2012 has marked the year of the last publication of a twelve year long experimental research project which provides state of the art information concerning Cooper pair transfer between members of the best well developed pairing rotational band known in nuclei, namely the stable isotopes of Sn (superfluid tunneling to nuclear condensates). The numerical applications of the theory of Cooper pair transfer, as outlined in the monograph "Heavy Ion Reactions", extended to light ion processes is able to account for the observed absolute cross sections, within experimental errors. Furthermore, the variation from isotope to isotope of Sn of the differential pair transfer absolute cross sections, is quantitatively explained by the theory. Within this context, the actuality of Aage's contribution to the field of heavy ion reactions is underscored by the announcement, arrived at the time of the writing of this obituary, of the second GOSIA Workshop (Warsaw, Poland, 9–11 April 2013). In it one reads: "The Coulomb Excitation method is presently used by many scientific collaborations all over the world. Interest in COULEX has increased after successful experimental campaigns at radioactive beam facilities as well as new results on the structure of stable nuclei".

After the publication of the first volume (elastic, inelastic and one- and two-particle transfer) of the book on heavy ion reactions, Aage went on, this time in collaboration with Giovanni Pollarolo, to the fulfillment of his quest for a unified description of the full variety of aspects of heavy ion reactions. Thus, he concentrated his research on multi-nucleon transfer. He, rightly considered these processes to be at the basis of the large enhancements observed, with respect to the expectations of standard static barrier tunneling models, in fusion reaction cross sections at energies below the Coulomb barrier, as well as in deep inelastic reactions. These subjects were planned to be the content of the last two chapters of the second volume of the theory of heavy ion reaction monograph.

Besides being a first class theorist, Aage constantly interacted with the experimental community, providing predictions and suggesting new experiments to try them out, as well as getting intellectual nourishment from the hard facts. To further strengthen the connection to experiment, Aage had the ambition to develop a software (GRAZING) to be used by theorists and experimentalists alike, based on all what he, together with his collaborators, in particular also Carlos Dasso, had learned and developed within the field of heavy ion reactions. It took short of ten years for him and his collaborator (GP) to reach that goal. This software made it possible to foresee, among other things, the production of very neutron rich nuclei with neutron number around $N = 126$, which are astrophysical r-process waiting point nuclei, thus opening up one of the most promising lines of research to be taken up with forthcoming radioactive beams.

What Aage Winther accomplished within the field of heavy ion reactions, and its natural extension to light ion physics, is there to remain. It also reflects Aage's personality, not only as an eminent scientist, but as a remarkable human being at large. A block of pure Carrara's marble. You either took it all or none. In spite of his concerns for others, his compassionate attitude in general, and his joy of living, he was not able to come to compromises. Regarding his scientific activity, he had a Kant-like attitude. The central issue was not so much, or at least not only, how much could one learn about a phenomenon, but rather not to err.

Sometimes, such an attitude led to borderline actions, as when he threw away, as soon as the galley proofs of the book arrived and to the dismay of his younger collaborator, all the supporting notes worked out during the nearly fifteen years which the writing of "Heavy Ion Reactions" had taken. In this way, the checking of the manuscript and of the hundreds of equations had to be taken seriously.

It is fair to say that he enjoyed equally well hard work as joyful get together. It was a tradition for him to treat his collaborators to cosy "frokosts" and to delightful dinners, making them feel as a part of the family. So was him, deeply committed, responsible, and at the same time ironic, cheerful, compassionate. This is the reason why he left, unarguably, a permanent contribution to physics, and to all of those who had the privilege of being close to him.

Ricardo A. Broglia
University of Milan, Italy

Thomas Døssing
Niels Bohr Institute, University of Copenhagen, Denmark

Giovanni Pollarolo
University of Torino, Italy

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