CONCLUDING REMARKS*

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Centennial of the discovery of polonium and radium gave a natural pretext to start this conference with the lecture on history. This opening was made in a very eloquent and vivid way by A.K. Wróblewski, who reviewed for us dramatic developments taking place during the first three years of radioactivity studies. Probably all of us followed with deep appreciation the story on ingenuity, imagination and great intuition, as well as stubbornness and hard work of Maria Skłodowska Curie and other pioneers who layed foundation for nuclear physics. After this lecture probably many of us thought that it would be very proper to begin any conference within our field by reminding the related historical background.

Yet, standing here on the fifth and last day of the conference, I have a strong feeling that it is much more difficult to conclude the conference rather than to start it. Certainly I need some sort of warm-up before entering concluding remarks; therefore I shall start atypically by presenting to you one of our recently obtained results. Actually, there are three other reasons why I will do it: Firstly, I declared earlier that I will show this result during the morning panel discussion session. However, this session extended in time and I noticed that I am not the only one who needs a cup of coffee. I made a contact with the chairman asking him to allow my remarks be presented after the coffee break; in all honesty I must admit that this was also my attempt to gain your sympathy. Secondly, I was invited to give a regular talk at this conference and only very late the organizers asked me to take instead the duty to formulate conference concluding remarks. I simply want to give you an example of what you have missed by this risky decision of the conference organizers. Thirdly, I want to demonstrate to you how bad it is when the concluding remarks speaker talks about his own work. Obviously this will be a very brief intrusion.

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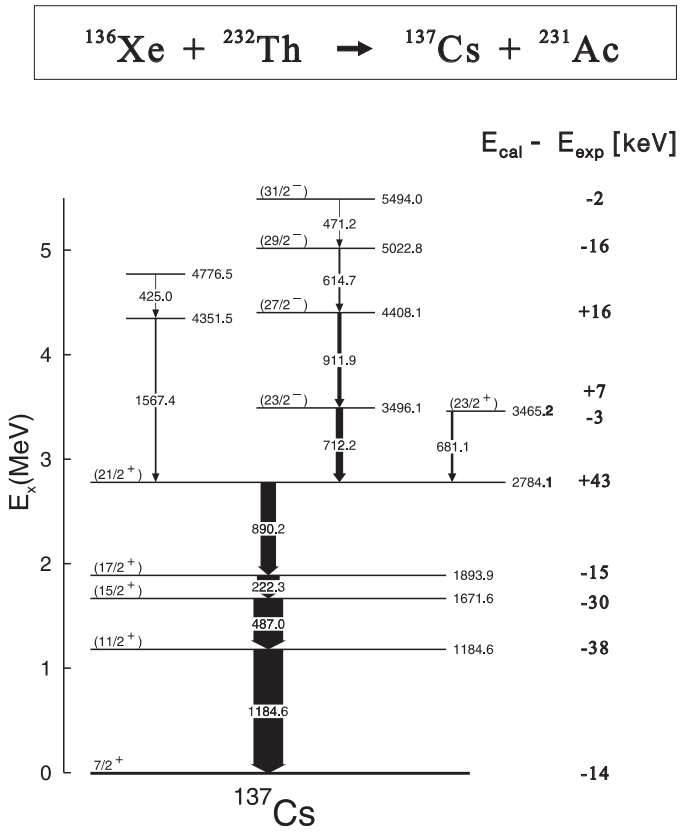

Fig. 1. Yrast levels of ^{137}Cs isotope as recently established in one-proton deep-inelastic transfer reaction indicated above. Spin-parity assignments are based on quantitative level energy predictions from shell model calculations involving semi-empirical interactions; the quality of agreement is marked by column of numbers showing the calculated and experimental level energy differences. Two unassigned states arise from neutron excitation of the ^{132}Sn core.

Through many years devoted to study the $N = 82$ isotones, experimental yrast structures were established in a long series of nuclei from ^{132}Sn to ^{154}Hf. These studies demonstrated how the interaction of valence protons, that fill first $g_{7/2}$, $d_{5/2}$ and then $h_{11/2}$ orbitals, can account for the observed pattern of excitations. Quantitative theoretical analysis within the shell model allowed to construct the complete Hamiltonian involving semi-empirical interactions which reproduced very well the observed experimentally level structures and could be subsequently fine tuned using the incoming new experimental facts. Of all $N = 82$ isotones, ranging from the very neutron-rich to very neutron-defficient nuclei, only the five-valence

proton ^{137}Cs yrast structure remained unknown; this isotope could not be accessed in, neither any standard fusion reaction, nor in the fission product spectroscopy. Recently we were able to establish the most important yrast levels of the ^{137}Cs by using the deep-inelastic one-proton transfer reaction taking place in collisions of ^{136}Xe projectiles with ^{232}Th target nuclei. The obtained yrast scheme, displayed in Fig. 1, is very transparent; it reflects one–to–one correspondence with theoretical shell model predictions and, by virtue of excellent quantitative agreement, illustrates the predictive power of shell model calculations based on semi-empirical interactions. With this communication I am ready to enter that part of my talk which is probably more expected by you and especially by the organizers.

When contemplating the conference title: "Nuclear Physics Close to the Barrier", I became almost certain that its double meaning was clearly intended by the conference organizers. First, they wanted to underline that topics to be discussed at the meeting relate to low energy nuclear physics, marked by the energy range not far from the Coulomb barrier. Second aim was to invite our thinking on the present status of nuclear physics — how we are and how we should be viewed today by the scientific community and by more general public.

I shall start with few comments related to such literal understanding of the title "Nuclear Physics Close to the Barrier", which is pictured schematically in Fig. 2. For any branch of science, in order to stay alive and prevent disappearance or decay, it is necessary to preserve safe position within the well of prosperity. The depth of this well is determined by interplay of factors which we ourselves continously affect by our involvment or negligence. We may increase the depth of this well predominantly by our scientific results, some of which occasionaly should induce more general recognition. However, our research activity must necessarily be accompanied by efforts to gain public support, to care for reasonable funding and to ensure uninter-

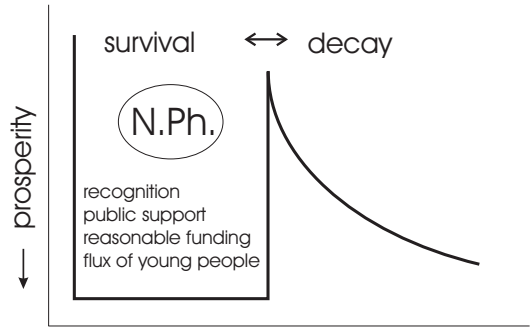

Fig. 2. Nuclear Physics "close to the" barrier

rupted flux of young researchers. I think that in spite of many difficulties, in spite of unavoidable shifts down on the science priority list, the nuclear physics stays today well inside the prosperity well.

In 1975, at one of our Zakopane School conferences, H. Morinaga provoked the audience by loud declaration: "Nuclear physics is dying!". Discomfort shared by many participants induced lengthy discussion which resulted in organization of a special session devoted to clarify this, unusual in those days, statement. I do not remember well how Morinaga connected this topic to Confucius philosophy, but after extended lecture on the basics of this philosophy, he explained convincingly what he meant. Namely, he expressed the opinion that any science which has a clearly attributed name is already on the path of decline. A series of important discoveries result in a birth of new science, which then gets its name and starts to develop detailed knowledge of less fundamental importance. In the process of detailed studies one opens a chance to detect new surprising phenomena which may give a birth of a new branch of science. In nuclear physics most of the fundamental discoveries were indeed made in the first half of this century; naturally our field since long entered the new, probably more difficult phase. Yet, I am very much convinced that it is a very fruitful phase of a mature branch of science, which is far from decline and stays fully alive. H. Morinaga apparently accepted this view, as he stayed very active for the next quarter of century in nuclear physics research and continues until today his close contacts.

Let me enumerate these features of nuclear physics which, in my opinion, keep her also today as one of the most attractive scientific adventures and bright example for other branches of science. First of all there is an incredible *richness of phenomena* which can be studied in dedicated way. This is accompanied by constant opening of new problems, sometimes exciting puzzles; theory still very much needs support from the experiment. This richness is very much reflected by impressive *variety of methods and techniques* used, as well as constant drive for inventing new tools and building new equipment. Important feature is the exemplary *precision and unambiguity* of conclusions, with constant cross-checking and correction of possible errors or missinterpretations which are unavoidable in the scientific process. Fruitful *contact with other branches of science* is very much cultivated by nuclear physicists and the principle "take and give" can be documented by many examples within our field as well as by numerous *applications* in other sciences and more practical fields of human activity. One of the brightest features of nuclear physics is the *high educational standard* which results in continous output of young, bright and openminded specialists. Significant part of them make their carriers in other fields, outside nuclear physics and usually we may be very proud of them. Finally, looking at many friends gathered in this new conference room of the Heavy Ion Laboratory of the

Warsaw University, I have to emphasize very *special human relations* which are characteristic for our branch of science. The community of nuclear physicists is not very large and this possibly helped to develop very broad and intensive international collaboration which involves people from nearly whole world. Our bonds, friendships and constant mutual communication developed, sometimes in very close, sometimes in more distant cooperation, often in fruitful competition, should remain our enthusiastically continued way; especially that we remember well how our behaviour in this respect preceded in time and possibly even contributed to positive political developments on a much broader scale.

Later, before closing, I plan to come back to this comments by presenting some of my personal suggestions on how we all can contribute to keep nuclear physics alive. Now I want to demonstrate to you that indeed the conference organizers arranged the scientific programme to emphasize features which I underlined in this long introduction and which contribute decisevly to keep safe position of nuclear physics within the prosperity well; in other words, I want to show you that I have read correctly the message involved in the conference title. Let us together make brief excursion back through topics discussed during conference days; this time with more defined title:

"Nuclear Physics Close to the Coulomb Barrier"

I shall certainly neglect chronology and arrange this excursion to show how at this conference the nuclear physics was displayed with her richness of problems and phenomena, variety of methods and techniques, appearance of puzzles, development of new tools, impact on other branches of science and practical applications. Let us then refresh our memory on topics which were discussed:

Borders of nuclear world

Marek Pfützner demonstrated impressive identification of 117 new neutron-rich isotopes, *e.g.* ^{78}Ni produced with cross-section of 0.2 microbarn, as well as identification of exotically proton-rich ^{45}Fe, ^{49}Ni; all of them were produced in fragmentation reactions.

Matti Leino displayed the excellent selectivity of fusion products achieved by the RITU recoil separator and used for identification of $^{202-204}$Ra isotopes.

Robert Smolańczuk gave theoretical guidance in search for super-heavy elements; for experimentalists the usefullnes of this guidance is certainly appreciated by earlier demonstration of predictive power of such calculations.

Properties of weakly-bound nuclei

Jacek Dobaczewski reviewed the present status of mean-field theoretical studies of nuclei at extreme isospin values and pointed at possibility to observe new phenomena, *e.g.* shell quenching.

Experimental results on decay properties and spectroscopy of such nuclei were presented by *Kerttuli Hellariutta* (^{176}Hg), *Ari Jokinen* (^{23}Al, ^{80}Zr, ^{108}Mo, ^{110}Mo), *Andrei Andreyev, Matti Leino, Marek Pfützner* (polonium isotopes) and even unbound nucleus ^{11}N was discussed by *Alinka Lepine-Szily*.

Spectroscopy at the edge of beta stability valley

Bogdan Fornal has shown how the previously inaccessible shell model nuclei ^{135}Te and ^{211}Po, and the neutron-rich nuclei of sdf shells could be studied using fission and deep-inelastic heavy-ion reactions.

Thomas Haertlein presented detailed study of backbending phenomenon in ^{160,162}Dy isotopes produced by incomplete fusion reactions.

Gilles de France presented the B(E2) mesurements performed with radioactive beams at SPIRAL facility.

Robert Beraud discussed the study of La isotopes with the IGISOL separator.

Nuclear shapes

Peter Butler displayed how pear shapes of Ra isotopes could be studied employing alpha decay, CN reactions, Coulex and multinucleon transfer reactions and discussed the rotation of these octupolly deformed nuclei.

Jocelyne Sauvage presented precise measurements of charge radii of nuclei by high resolution laser spectroscopy and discussed triaxial shapes of Pt isotopes.

Youri Gangrsky demonstrated how this technique works in the case of light nuclei, particularly for Li isotopes.

Coulomb excitation

Douglas Cline gave impressive review of results which could be obtained by combining large Ge detector array with the CHICO — high resolution 4π heavy-ion detector. It involved results of thick target spectroscopy experiments identifying yrast bands up to spin value $I = 34$ in ^{240,242,243,244}Pu and ^{248}Cm isotopes and thin target experiments used for determination of matrix elements in various bands of ^{162}Dy. The double octupole excitation studied in ^{96}Zr and search for such state in ^{208}Pb illustrated further the power of this technique.

Other results obtained with more traditional techniques for CE in ^{142}Nd and ^{128}Xe were presented by *Paweł Napiorkowski* and *Julian Srebrny* correspondingly.

Hans Juergen Wollersheim discussed CE experiments with ^{178}Hf; he pointed at unexpectedly large population of the 8^- K-isomer and demonstrated how a search for states above the 16^+ 30y K-isomer was performed.

Carlos Dasso cautioned the Coulomb excitation experimentalists by considering unsafe Coulex which may contribute even at energies well below the Coulomb barrier.

Giant dipole resonances

Massimo Di Toro reviewed a broad spectrum of theoretical aspects of GDR used as a probe to study nuclei under extreme conditions.

Vladimir Plujko discussed relaxation of fast collective motion in hot nuclei, and on experimental side:

Marta Kicińska-Habior presented inclusive measurements of GDR width and angular distributions used to deduce information on the deformation; she discussed also the contribution from the bremsstrahlung radiation at high energies.

Adam Maj has shown very promising results from exclusive measurements of GDR built on super-deformed states in ^{143}Eu. He posed an unresolved yet question whether the origin of the observed GDR increase comes from the spin or temperature dependence.

Heavy ion reactions

A long series of presented lectures displayed the continued interest in this subfield:

Vadim Volkov emphasized the similarity of deep-inelastic and fusion reactions and came forward with a new concept based on assumption that nuclei preserve their individuality all time until compund nucleus is formed. He claimed that such approach can explain the sub-barrier fusion puzzle.

Ettore Gadioli pointed the importance of preequilibrium emission on the way towards formation of the compund nucleus.

Andrzej Marcinkowski presented the analysis of one-step direct reactions.

Sandrine Courtin discusssed entrance channel effects in the fusion of Ni isotopes.

Albert Lumbroso pointed at serious difficulties and ambiguities involved in extraction of fusion barriers from experiment.

Angela Bonaccorso discussed information on the nuclear periphery which may be obtained from transfer reactions studied at energies near the Coulomb barrier.

Christian Beck presented results of light di-nuclear systems study and argued that fusion–fission may occur in the ^{28}Si + ^{28}Si resonance at $L = 38$.

Dmitry Semkin discussed nuclear reactions taking place in collisions of proton-drip-line nuclei.

Certainly we heard about some unsolved problems,

Puzzles

Hugon Karwowski presented high-precision p–d elaastic scattering data and showed that they cannot be explained utilizing realistic NN potentials — new type long-range $3N$ force might be needed to solve this puzzle.

Petr Alexa discussed the, yet unsolved, ^{180}Ta puzzle — why does it not decay? how was it produced?

New facilities

Takahisa Itahashi presented the compact low-energy, high-current accelerator to study the fusion reaction ^{3}He(^{3}He,2p)^{4}He at Osaka.

Gilles de France described new tools for research with radioactive beams from SPIRAL at GANIL — the EXOGAM and VAMOS spectrometers.

Dieter Habs displayed the new project of the MAFF — radioactive beam faciliy which should be able to produce high intensity beams.

The contribution of nucler physics to other branches of science and applications was illustrated by many speakers throughout all conference days:

Astrophysics

Paweł Haensel described interesting features of the neutron star crust which in the bottom layer, where the proton fraction is 4%, should contain extremely neutron-rich nuclei. He underlined the importance of this feature for dynamics and evolution of NS and stressed that nuclear structure should disappear at star densities larger than 0.5 of the nuclear density.

Solid state physics

Doris Forkel-Wirth reviewed nuclear methods used in condensed matter studies (Moessbauer effect, perturbed angular correlation, beta-nuclear magnetic resonance, channeling *etc.*) and pointed that more than 100 radioisotopes are employed in this field of science.

Walter Assman presented the ERDA (elastic recoil detection analysis) technique and showed how thin film analysis is able to analyse light and heavy element components.

Andrzej Turos discussed polygonisation of single crystals by ion bombardments.

Atomic physics

Ziemowid Sujkowski reviewed the study of multiple ionization in heavy ion–atom collisions.

Environmental studies

Jorge Fernandez-Niello presented results of atomic mass spectrometry used for determination of the ^{36}Cl/Cl ratio in rainfall.

Informatics, electronics

Dezso Novak gave us warning by presenting the results of upset tests which show how radiation may affect events stored in computers.

Finally, it is probably most proper to close this list by reminding to you one of the most attractive presentations on

Medical research

in which *Anne M.J. Paans* displayed the power of Positron Emission Tomography in studying functions of human brain.

I think it was worthwhile to review this broad programme to appreciate fully the idea of the conference organizers who wanted to show the beauty and richness of nuclear physics 100 years after the fundamental discoveries of polonium and radium. I guess we all feel much better now, realising how priviledged we are being able to participate directly in this great endeavor of humanity. Let us express our thanks to Jurek Jastrzębski and Tomek Czosnyka, as well as to all friends involved in the Organizing Committee, for their thoughtful and fruitful effort. However, before inviting you to express this thanks with applause, I would like to close in a more active way. Namely, I would like to invite you to consider few inside factors, which possibly may help nuclear physics to stay alive — factors which depend primarily on our own behaviour. The selection is based on on my very personal experience and judgment. I shall list these suggestions related to various aspects of our scientific activity without much explanation. I hope that each of us critically considers the validity and usefullness of the following advices:

> *information* — sometimes, forced by well known circumstances, we publish too fast and the quality of publications suffers — we should all care for reducing the information noise.

fashion — some topics become artificially fashionable; we should avoid following uncritically the fashion — the variety is one of the strong features of nuclear physics giving the guarantee that in general we stay on a right track.

beaurocracy — keep as limited as reasonably achievable.

crowding — whereas in natural and obvious development our research group sizes increase, we all know that efficiency, personal involvment and shared responsibility is optimal in small teams. We should reduce the crowding as much as possible — often the competition produces better fruits than expanded collaboration.

room for discoveries — it is unavoidable that we mostly perform very selective, dedicated experiments. However the gate for discoveries should be kept open as broadly as possible. In particular members of various PAC's should occasionally accept projects which are not completely rounded and involve arguments based on intuition.

theory — should more often demonstrate the predictive power.

popularization — anyone who can, should contribute.

With these very personal remarks I invite you to applaude the Organizing Committee of this conference, in particular Jurek Jastrzębski, Tomek Czosnyka and all charming ladies who's great effort contributed to the success of this meeting.