CONCLUDING REMARKS*

F. Azaiez

IPN Orsay, France

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First of all, I would like to thank the organizers of this year's Zakopane symposium for the very interesting program. Most of the recent and hot issues of the study of nuclei under extreme values of temperature, spin and isospin have been covered through the excellent talks we heard these last five days. Enough time was allocated for discussions during the various sessions, which added to the interest of the symposium. I must say that to our great pleasure, in addition to the high quality scientific program, very pleasant social activities have been organized for our afternoons and late nights. For all that, I would like to renew my warmest thanks to Adam Maj and our Polish colleagues for this wonderful symposium. This symposium coincides with the celebration of Rafał Broda's birthday; I would like to present him my personal wishes for a happy and successful continuation.

In the short time left before the closing of the symposium, I would like to make few remarks. All of them are related to the future of our field. First of all, we all could see from the work presented during this symposium that our studies with radioactive beams — although very successful — suffer from their present low intensities. It is obvious that our first priority is to obtain the necessary funding to build the second generation radioactive beam facilities capable of reaching the needed intensities. In Europe the road map for the future radioactive beam facilities has received strong agreement among the community and has been defined to be an 'In Flight' facility at GSI (the FAIR project) and an 'ISOL' facility (EURISOL), both to be built in Europe. The latter will be facilitated by the realization of intermediate-term projects such as SPIRALII at GANIL, SPES at Legnaro and the upgrade of REX-ISOLDE at CERN.

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I would like now to concentrate on the situation of stable beam facilities and their future, which, in my point of view has not been discussed these last years at the level of its importance for our field. In the past a sufficiently large number of facilities have been available to the European Nuclear Physics Community delivering stable heavy ion beams at energies close to the Coulomb barrier with intensities of up to a few 10^{12} particles/sec. Many of these facilities are being recognized as leading European Research Infrastructures. Nevertheless, the last decade has seen the phasing out of several of these facilities in Europe resulting in the consequence that the beam time available to the European Nuclear Physics community has become marginal. As we heard during the symposium, using these conventional "stable beam" facilities radioactive species are produced by nuclear reactions at energies close to the Coulomb barrier, *i.e.* fusion and transfer reactions, as well as deep-inelastic collisions. In this way rare nuclear phenomena have been discovered, among them superdeformation, nuclear superfluidity, first hints for the existence of the "island of stability" for superheavy nuclei and of hyperdeformation at high spin. Further experimental investigations of these rare phenomena require the development of more sensitive instruments as well as facilities capable of higher beam intensities, than those commonly available today. It is highly important to recognize that many fascinating nuclear physics questions can be better addressed — or only addressed — with high intensity stable beams at energies close to the Coulomb barrier. I will use a few examples taken from the talks presented in this symposium:

(i) Heavy element research is an open frontier in nuclear structure and will be the most important part of the science program at the future stable beam facility. A high intensity stable beam facility providing pmA for ions up to $A = 150$ at energies around 7 MeV/A is needed. This program will involve the synthesis of new elements ($Z > 114$), the detailed study of their structure (up to $Z \sim 108$) and the measure of their chemical properties. The focal-plane studies (such as radioactive and isomeric decays) will take advantage of the highest beam intensities. These intensities will be limited primarily by target and recoil separator technologies from few 100 $p\mu$A up to 1 pmA. The part that involves in-beam studies will be limited to lower intensities, due to electronics and data acquisition technologies. Higher detector segmentation, higher performance preamplifiers, digital electronics and time stamping will allow for beams with intensities varying from few 100 pnA to 1 $p\mu$A.

(ii) Identifying and characterizing nuclear states as a function of excitation energy and angular momentum is crucial to understand the underlying single particle and/or collective structure of the nucleus. Questions such as how different nuclear shapes and associated motions develop and disappear, how shell effects and residual interactions survive with spin and temperature and how chaos sets into the nucleus can only be answered by a study of the

nuclear properties in the (E^*, I) plane. Gamma ray emission constitutes a unique probe of nuclear structure. In recent years, large gamma-ray detector arrays have been exploited at several accelerator facilities. Among many other phenomena they have allowed for the discovery of superdeformation and for the first hints of hyperdeformation at the highest angular momentum. The studies that try to answer many of the associated questions will benefit from more intense stable beams than those available today. Further progress can only be made by combining future 4π tracking arrays, such as AGATA and GRETA with more intense stable beams than presently used. Both components are needed if we want to answer the burning questions related to the study of discrete nuclear states at extreme spins. Most of these studies are based on in-beam spectroscopy and will be limited by electronics and data acquisition systems technologies to beam intensities from few 100 pnA to 1 $p\mu$A. I cannot for instance resist raising the question why after the clear indication of hyperdeformation at high spin reported in this symposium through the observation of characteristic ridges, the community does not put back the EUROBALL detectors together with a new digital electronics in order to try to establish its 'discreet picked fence' at some of the stable beam facilities in Europe.

(iii) The study of nuclei along the $N = Z$ line is of special interest due to the particular symmetries between protons and neutrons that can be explored such as proton–neutron pairing correlations, exotic deformations, isospin symmetry in mirror nuclei and isobaric multiplets. These studies are often linked to the use of radioactive ion beams. In contrast with neutron rich isotopes, proton rich nuclei at the $N \sim Z$ line can also be produced in fusion evaporation reactions with stable beams. As long as the intensity of proton-rich radioactive ion beams does not approach the pnA range, the use of very high intensity stable beams can be competitive in a number of well-chosen cases. Of specific interest in this context are cold reactions at even below the Coulomb barrier where only very few particles are evaporated. Under these circumstances evaporation channels involving up to two neutrons can become rather important. Since the total reaction cross section is very small at sub-barrier energies (10 mb or less) a very high primary beam intensity can be used (up to 1 $p\mu$A) leading to a larger production rate of exotic nuclei than is possible with beams from the first generation RIB facilities. For this, it is essential to have access to a stable beam facility which can provide high intensity beams of a large number of different ions with masses up to $A \approx 100$. An advanced detector system is required consisting of a high efficiency Ge array AGATA and light charged particle array. In order to reach the most proton rich nuclei high quality neutron detector system is of utmost importance. As an alternative a very high efficiency recoil spectrometer could be employed. Just like the heavy elements case, focal-

plane studies as well as Coulomb excitation of evaporation residues can be performed using fusion evaporation reactions with very high intensity stable beams from a few 100 $p\mu$A up to 1 pmA.

A high intensity stable beam facility in Europe, capable of accelerating a large variety of ions is vital today for the community. It will enable us to address major physics problems at the frontiers of nuclear structure and reaction studies. This facility will benefit from the tremendous improvement that has been achieved, over the last decade, in accelerator technology making accelerators highly reliable and cost-effective to operate. A super-conducting linear accelerator in conjunction with a high performance ECR source is a good solution that meets all requirements for the needed high intensity stable beam facility. Such a choice will take advantage of the R&D effort for the SPIRAL2 and EURISOL, linear accelerator drivers and the new developments in ion sources, RFQ's and super-conducting cavities. The initiative of starting a discussion on such future project has been launched by a French working group. It has been after that brought to the attention of NuPECC who appointed a European working group with a mission to access the opportunities of up-grading existing facilities or building a new dedicated one in Europe.

I would like to finish these remarks by hoping that by the time of the next Zakopane conference, such a project will receive from the community as much consensus as our future radioactive beam facilities.