

NUCLEAR PHYSICS IN EUROPE: IMPACT, APPLICATIONS, INTERACTIONS

Preamble

At all times the rich phenomena of nature have fascinated humankind, which has always been driven by inherent curiosity to get a deeper understanding of the underlying laws and mechanisms. This is the basis of science which has become an essential element of culture. At present it satisfies not only our thirst for knowledge but also leads to many benefits in our daily lives. Specifically, this is true for Nuclear Physics aiming at the study of the properties and interactions of the basic building blocks of matter. Despite the fact that most nuclear phenomena are far beyond our daily experience, there is a great variety of related techniques and applications with great impact on society. However, in many cases even scientists are not aware of the benefits associated with the widespread use of nuclear techniques.

A comprehensive survey of the impact of nuclear physics was presented in the report “Impact and Applications of Nuclear Physics in Europe” issued by the Nuclear Physics European Collaboration Committee (NuPECC) in 1994. It showed the wide spectrum of applications of nuclear techniques and the numerous interactions with different fields of science. In the meantime the impact of nuclear science has progressed, new ideas have emerged, leading to significant developments of technological interest. Therefore, it is timely to repeat a similar exercise. Having the survey of 1994 as a comprehensive basis, the present report is focussed on three topics of general interest, which have exhibited a significant dynamical progress in recent years, delineating their developments and achievements.

The first topic deals with nuclear physics contributions to the energy problem, one of the primary problems facing mankind at present. Here, important initiatives have been started which aim at the reduction of nuclear waste, considered a major problem by society, which appears to be manageable by modern nuclear techniques. Significant progress is reported also in inertial-confinement fusion driven by heavy-ion or laser beams. Although these developments are still at a fundamental level, interesting applications may result from this research. Whatever strategy for the solution of the energy problem is chosen by society, research on transmutation and fusion will be of great importance for future developments.

The second topic of the report is focussed on the interfaces between nuclear physics, biology and medicine. Intensified collaborations with biologists and physicians have led to important developments of methods, instruments and facilities which, besides leading to a better understanding of biological processes, have a large impact on our health-care systems. The contribution of nuclear physics is still growing and its great potential is visible in the given review.

The last topic is focussed on the strong interactions with neighbouring fields, namely atomic and condensed-matter physics. It exemplifies the cross-fertilisation of excellent interdisciplinary collaboration and demonstrates the importance of a unified view of science where borders between the fields are only weakly defined.

It is the main task of NuPECC as an expert committee of the European Science Foundation (ESF) to co-ordinate and promote Nuclear Physics in Europe. NuPECC provides updated information, presents highlights and suggests new directions and opportunities. More ambitious is the objective to propose a well-defined strategy for a harmonious and effective

development of nuclear physics research in Europe. Such a process of a broad reflection within the European scientific community has been started in 2002 aiming at the setting-up of a long range plan for Nuclear Physics in Europe .

In this spirit the present report on Impact, Applications and Interactions of Nuclear Physics in Europe is offered to colleagues of the scientific community, science-policy makers and the public. It gives an up-to-date view of the current developments of nuclear techniques with major impact on neighbouring fields and society. It is important to stress that, apart from the three topics extensively treated in the report, important progress has been achieved in numerous applications in other fields. Specifically, the strong interactions with environmental sciences, astrophysics, art and archaeology should be mentioned in this context.

The expertise required for broad surveys, such as the present report, obviously exceeds the expertise of NuPECC. Therefore, three working groups were established with specialists in the fields under review. Their reports were presented and discussed in a workshop, organised with the support of the European Union, at Dourdan (France) in November 22-23, 2001. The present document contains the full contributions of all three groups. NuPECC wishes to express its gratitude to the members of the working groups and is especially grateful to the chairpersons of these groups, C. Cohen, G. Kraft and J.P. Schapira.

The reader who wants to get an overview of the main content of the report may refer to the summaries in front of each chapter. Some "Observations by NuPECC" follow this preamble which suggest a series of specific actions aiming at progress in the most promising nuclear physics techniques and strengthening nuclear science in all its diversity, from fundamental research to the dedicated and most efficient development of applications.

Observations by NuPECC

The three topics, which are presented in this report, illustrate the continuously increasing contribution of nuclear physics to demands of society as well as to technological developments. Furthermore, nuclear physics has interfaces with numerous fields. Maintaining a high level of involvement in basic sciences is a necessary condition for an efficient development of multidisciplinary activities. The impact of basic research, both directly and indirectly, is very often underestimated by scientists as well as by the public. This is particularly true for nuclear physics which makes an essential contribution to the welfare of our society. The energy involved in any nuclear phenomenon exceeds our everyday experience and has generated – triggered by military use and accidents – strong negative emotions against this field. Therefore, much effort must be put in to an increased understanding of nuclear science and public awareness of its benefits for society.

The report clearly indicates the potential of nuclear physics for interdisciplinary research. This requires that open-minded scientists pay attention to the demands of society and communicate beyond the borders of their traditional fields. Support not only from its own community but also from the scientific community at large and from the outside world is an important prerequisite for the healthy development of any field of science. As an outcome of this report the following observations have been made by NuPECC.

- There are many problems of modern society where nuclear science can contribute to their solution. The nuclear physics community should address the challenges of the demands of society related to the field and should take its responsibility in the search for solutions. At present the provision of energy and the management of high-level nuclear waste is of major concern for mankind. Whatever the future of nuclear energy will be, nuclear physicists must play a role in finding innovative solutions, help decision makers to identify valid options and contribute to rational discussions of this issue in public. From the present viewpoint, strong support for applied research associated with the development of new concepts such as hybrid reactors for the transmutation of nuclear wastes (e.g. accelerator-driven systems (ADS)) appears necessary. A preliminary design study for such an ADS is an important step and should be considered in the forthcoming European framework programmes.
- The contribution of nuclear physics to medical sciences, biology and radiobiology is now well recognised and is an excellent example of a specific know-how applied to another field. Indeed nuclear techniques applied to life sciences play a major role. They have contributed essentially to recent progress via use of radioactive tracers, accelerator mass spectroscopy (AMS), employment of nuclear imaging techniques of various types (SPECT, PET, NMR, MicroPET), study of radiation effects on biological material, and development of dedicated accelerators and high-quality beams for proton and hadron therapy. In this context, increased formation of interdisciplinary collaborations is strongly needed and the activities of combined teams must be encouraged. Specifically, nuclear physicists should help, jointly with the medical doctors, in the promotion and the development of techniques associated with proton and ion-beam therapy.

- Even when dealing with basic problems, the interaction with other communities could be of mutual benefit as different fields very often share concepts, models and techniques. This report presents a very nice illustration of the cross-fertilisation that may exist between nuclear science and atomic and condensed-matter physics. Good examples are the use and development of ion sources and atomic traps. These communities are, next to nuclear physicists, important users of the large infrastructures oriented towards nuclear physics. Collaborations must be encouraged and further developed.
- Spin-offs of nuclear technology, namely accelerators and detectors are of major importance and are quite often the link with other fields for basic research. These technological developments should be strongly supported and the discussion on future tools for nuclear science should systematically include the multidisciplinary aspects of the projects. The importance of technological developments has been recognised through many RTD contracts financed within the 5th European framework programme. However, a general assessment and better planning should be envisaged at the European level for an improved co-ordination of such developments.
- The widespread applications of nuclear techniques and their strong impact on society require an education of the general public in the concept of elementary nuclear phenomena. This is needed to promote effective and balanced discussions of nuclear science issues that are of importance for society at large. Enhancing nuclear physics knowledge will help the understanding of science in general. Therefore, the basics of nuclear physics have to be taught in all secondary schools and the curricula at all universities should include nuclear physics courses. This, together with training of graduate students in nuclear science fields, will ensure that future facilities can be provided with experienced staff, and that expertise will be available to tackle problems and provide innovative solutions may the need arise in the future. At present these conditions are far from being realised everywhere in all NuPECC countries. A stronger visibility of applied nuclear science at universities could significantly help. In this context, the formation of small nuclear science research teams in many more universities is of prime importance. NuPECC alone has no direct influence to improve the present situation but, together with other institutions, it is ready to initiate discussions with the appropriate authorities.