THE POSSIBLE CONTRIBUTION OF THE NUCLEAR PHYSICS COMMUNITY TO THE NUCLEAR WASTE PROBLEM

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To day, the nuclear waste problem is at the core of the social acceptability of nuclear energy. Technical options for waste management require an important research and development effort, especially to reduce possible long-term detrimental effects on health and environment due to nuclear waste generation. In France, the Parliament has recently adopted a law, which explicitly stipulates three lines of research concerning:

- the reduction of the long-lived radionuclides inventory, using chemical partitioning and transmutation;
- the reversible or irreversible geological disposal of high level and long-lived nuclear wastes;
- the study of new packaging and of long-term interim storage of nuclear wastes.

One should also consider a fourth line of research, which deals with the reduction, at the production stage, of the long-lived nuclear wastes, and more generally of the radiological and environmental impact.

Although the importance of nuclear waste issues has been recognized from the beginning of the nuclear era, few efforts have been made on the subject. Of course, development of technologies such as PUREX reprocessing and vitrification of high-level liquid wastes started in the 50s, but the main incentive was plutonium extraction from irradiated fuels for energy and military purposes. In those days, top priority was merely given to reactors and fuel cycle development for energy and fissile materials production. However, since the eighties, priorities have started to change. This is due to the halt of nuclear programs worldwide, with the exception of France and Japan, to the need, especially in the United States, for long-term spent fuel management, and more generally to the emergence of environmental concerns within public opinion, suspicious of any kind of nuclear waste disposal site. The fact is that, wherever nuclear energy is at stake, there is now a strong incentive to substantially increase research efforts within national and international nuclear agencies.

A split scientific community

What could be, in this new context, the contribution of the nuclear physics community? Since the 40s, when fission was discovered, this community has largely contribute to set the scientific knowledge without which there could not have been any industrial use of nuclear energy. This scientific community has largely evolved since then, when it was not so highly specialized as now. The three major scientific fields which contribute traditionally to basic research in nuclear energy, namely nuclear physics, reactor physics and nuclear and radiochemistry, were

coexisting in the same community, often in the same laboratories. One could mention the cases of well known physicists, like Weinberg or Wigner, who largely contributed to reactor theories in the 50s. Since that pioneer period, the community has divided into various components, probably more in France for specific reasons than in the Anglo-Saxon world.

In the sixties, the traditional radiochemistry has given birth to new fields of research like nuclear chemistry - which finally used the same methods as nuclear physics -, radiation chemistry and "traditional" radiochemistry. On the other hand, everything related to neutronic and reactor physics became a science of its own, independent from the physics of the nucleus, which on the other hand tended to take up a particle physics approach. Of course this evolution stems from an internal scientific logic as well as from the need to apply scientific results in the nuclear industry. However, in most nuclear states such as United States, UK or France, it leads *to* a strong distinction between university or academic research and finalized research carried on mostly in National Laboratories belonging to Nuclear Agencies, the legitimacy of which lies in the development of nuclear energy applications. In some instances, nuclear physics graduate courses divide into radiochemistry, neutronic physics and nuclear physics. All this of course reinforced the traditional distinction between science for engineers and basic science for scientists. To-day, there exist two fairly distinct communities: the nuclear physics community and the nuclear energy community.

The reasons for an "external" contribution

The recognition, mentioned above, of the need for basic research related to nuclear waste, together with technical developments, could be an opportunity to reassemble in some ways various competencies which potentially exist in the nuclear physics community.

Such contribution is important for various reasons. First, the definition of technically feasible solutions which have to be socially accepted implies the extension of the expertise to a larger scientific community which is not directly or institutionally involved in nuclear energy promotion. This is for example the case of the nuclear physics community represented in Europe through Nupecc, belonging to universities or research agencies such as CNRS in France. Secondly, it should be argued that some of the long-term nuclear waste management schemes, have failed in practice, essentially for socio-political and economic reasons. Fortunately, interim storage of nuclear wastes, which can be extended in time, gives time to explore and evaluate new concepts of nuclear waste management. Because they are new in the field, people belonging to this community may bring a fresh look and make original contributions along new lines. Moreover, as they are not involved in well established nuclear energy programs, nuclear physicists may be in a better position to address new options which could be implemented on a long run, and to look into a large variety of solutions.

These considerations have recently led the Institut National de Physique Nucléaire et de Physique des Particles (IN2P3) of the CNRS IN2P3 to formulate a

program of research called PRACEN (Programme de Recherche sur l'Aval du Cycle ElectroNucléaire) which covers the three topics mentioned above, as well as any research aiming at minimizing waste.

The conditions for such "external" contribution

Some conditions have to be fulfilled for a significant contribution of the nuclear physics community from its own competencies. Because, this research has to be carried out freely and on the basis of personal scientific choice, as it is the way this community works, there must be a general motivation, which can be based on the perception of the social responsibility of scientists. But this not sufficient. It seems quiet likely that, without clear scientific motivation, scientists will not enter the field of nuclear waste. On the other hand, if they do, scientists will have to take into account technical and economical constraints and avoid false solutions. This implies that the nuclear waste issues are well understood. Such an understanding can be achieved through seminars, mutual information sessions organized within laboratories or at the initiative of learning societies (this is recently the case for the French Physical Society).

Nuclear research organisations should consider nuclear waste as part of their environmental program for which they guarantee a minimal funding every year. They should avoid any bureaucratic attitudes, encourage initiatives which could approach a scientific program and give a stronger support to proposals which would have been approved by the usual scientific committees.

TABLE 1: Characteristics of main neutron sources
(Ref: J.M. Carpenter, NIM 145 (1977) 91-1 13)

Process	Examples	Yield	Energetic cost (MeV per neutron)
(d,t) solid target	400 keV on T in titanium	$4*10^{-5}$ n/d	10000
(d,n)	35 MeV on liquid Li	$2.5*10^{-3}$ n/d	10 000
(γ,n)	100 MeV e-on ^{238}U	$5*10^{-2}$ n/e	2000
Spallation	800 MeV p on ^{238}U	30 I'I/p	27 (55 MeV deposit)
Fission at k= 1	$^{235}U(n,f)$	1 n/fission	O (180 MeV deposit)
(d,t) CTR	Inertial fusion with laser	1 n/fusion	? (3 MeV deposit)

The scientific themes

As far transmutation is concerned, neutron induced reactions appear as the practical way of transmuting unwanted nuclei. Moreover, as can be seen from table 1, fission reactors and spallators are presently the best way to produce large number of neutrons at "low" cost. In relation to this, the use of accelerators for nuclear waste transmutation provides an opportunity to bring together the two

scientific communities, nuclear physics and nuclear energy. As it has been pointed out nearly two decades ago by A.A. Harms, P. Grand, W. Haefele and others, synergy between fission and spallation (not to mention fusion) could, in principle, increase energy, fuel and waste sustainabilities compared to what is achieved when each technology is used alone (see fig.1).

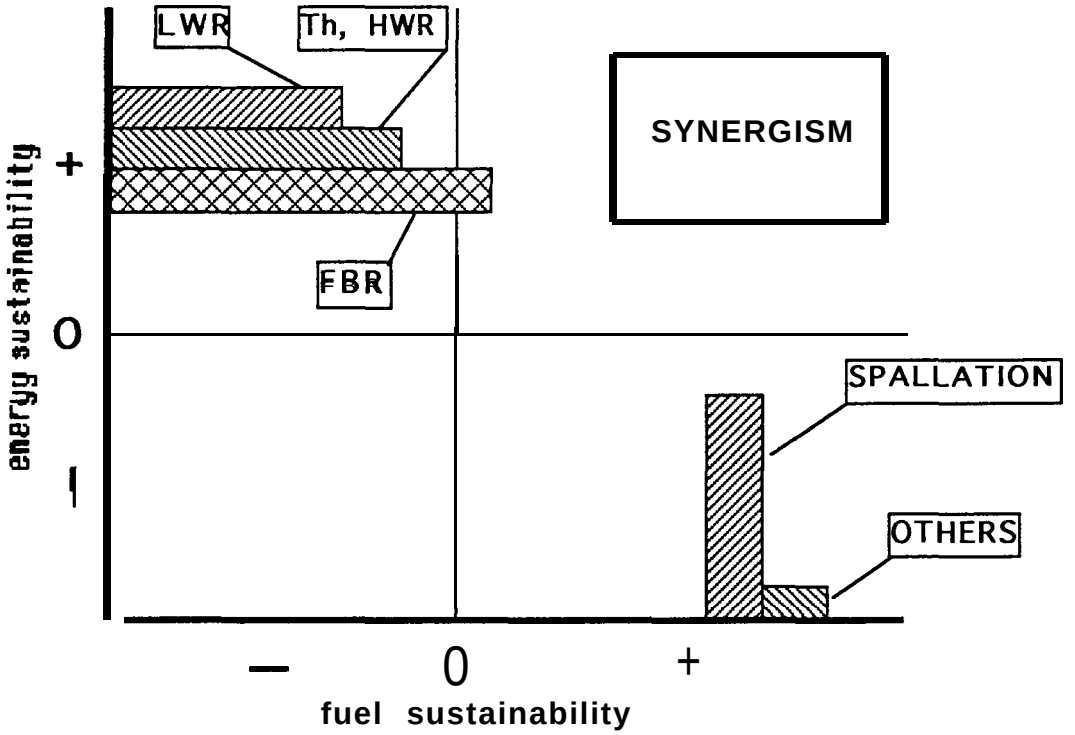

Fig 1: Synergy between fission and spallation
(from A.A. Harms and W. Haefele, American Scientist, & 3, (May-June 1981)

In that respect, nuclear physicists can contribute to:

1 *Neutron cross section measurements,* for some long-lived fission products, such as ^{99}Tc, in the neutron energy range found in reactors or hybrid systems.

2. *Hybrid system related studies.* The nuclear physics community, in a broad sense, can contribute to the development of such systems coupling a high intensity accelerator to a sub-critical blanket.

From the NEA evaluation study, it appears that there is a need for more

reliable simulation tools to describe the complete nuclear processes from the interaction of an high energy light particle with a nucleus (intra-nuclear cascade, evaporation, high energy fission) down to neutron thermalization. On the other hand, it is proposed to extend the present evaluated data file beyond 20 MeV.

There are actually two approaches. The first one aims at simulating an hybrid system in the most reliable way. Some thin and thick targets experiments are undertaken, especially at Saturne, in order to assess the actual validity of codes and improve them. On the other hand, more systematic measurements are needed if one wants to extend actual nuclear data files.

An other approach is to directly undertake integral measurements, possibly in relation with a definite set-up, like the one proposed by C. Bowman or C. Rubbia. In this approach, one aims at measuring basic parameters, such as neutron multiplicity, with thick target (the use of sophisticated neutron detectors such as ORION could be very useful in this respect), energy deposition either by usual activity measurements or by fission products detection (such as proposed at CERN).

Accelerator physics is the other field, normally developed within the nuclear physics community. High intensity technology is mainly developed at PSI for cyclotron and Los Alamos for linac. There is obviously a need to evaluate the various problems (beam dynamic, ion source, beam loading and RF yield...) arising with accelerators able to deliver beam intensities from 10 to 100-200 mA.

If such needs are well documented, it remains that a national and international (specially at the european level) consensus to go in this direction would represent a strong incentive for nuclear physicists to carry out the corresponding research efforts. This means at least two things: that one preserves the possibility to use actual high energy accelerators (such as Saturne) for experimental work on accelerator based transmutation systems, and that one goes beyond paper work by undertaking some related technological studies.
