IV Concluding remarks and recommendations

Stable beam facilities in Europe, capable of accelerating a large variety of ions at high intensity are vital for the community. They will continue to address major physics problems at the frontiers of nuclear structure and reaction studies. For the range of the physics cases outlined one can identify two categories:

1. Prompt in-beam studies at the target position: In these experiments the beam intensity is limited by the capabilities of the detectors around the target, the associated electronics and data acquisition system to distinguish and resolve correlated radiations (originating from the same event) and uncorrelated radiations (coming from two different reactions). Taking into account the ongoing and future development of highly segmented detectors, digital electronics and triggerless data acquisition systems, beam intensities in this type of experiments are unlikely to exceed few 100 *p*nA. We refer to them as 'medium intensity' case.

2. Studies away from the primary target: In these experiments the maximum beam intensity is dictated by the target's capability to sustain a large power deposition and by the resolving and rejection power of separators. The most advanced cooling technologies in conjunction with novel approaches to target composition as well as advances in recoil spectrometer design mean that the highest beam intensities usable in this type of experiment are of the order of 100 *p*μA which we refer to as 'high intensity' case.

We envisaged to take advantage of the existing stable beam facilities mainly JYFL-Jyväskylä, KVI-Groningen and LNL-Legnaro. **JYFL** is currently capable of providing up to 100 *p*nA of several of the stable beam species and is actively pushing the necessary ion source R&D to extend the list of available beams. **KVI** is planning an upgrade that will allow a considerable increase of the available beam intensities. **LNL** is soon expected to reach this level of beam intensities also for very heavy elements, once PIAVE will routinely replace the tandem as the injector for the ALPI linear accelerator.

Several low energy nuclear physics and nuclear astrophysics studies, complementary to those performed at Large Scale Facilities, will be carried out also at existing Small Scale Nuclear Facilities with unique experimental capabilities. Among those will be facilities in the Central and South-east EC (new) countries, ie. in Athens (Democritos), Bucharest (IFIN-HH), Debrecen (Atomki), Prague(Rez), Warsaw (SLCJ) and Zagreb (Ruder Boskovic).

The recommendation of the committee is to ensure a strong support from both the nuclear physics community and the funding agencies for existing stable ion beam facilities not only for their accelerator system development but also for the

instrumentation and experimental infrastructure that are needed to host dedicated research programmes.

Stable ion beams with the medium intensities can also be provided by the UNILAC at GSI and by either the CSS1 or the CIME cyclotron at GANIL (both separately or simultaneously). However, the committee feels that in-beam studies at medium beam intensity are but one aspect of the wide and varied research programmes at these two facilities.

It is beyond the remit of this report to make detailed recommendations for the next generation of instrumentation, indeed, specifications have to follow the physics goals of the user community. However, we recommend that the necessary advances in instrumentation must be developed in parallel to the design of the accelerator and be an integral part of a comprehensive design study.

An important challenge is the development of appropriate instrumentation that needs to keep step with the increasing beam currents. While the highest beam currents naturally are envisioned for experiments using in-flight separation techniques, the prompt spectroscopy at the target position presents its own set of challenges at currents more than one order of magnitude higher than currently used and must be considered at the same time as the upgrade of beam current.

Concerning the second category that needs the highest intensity beams, it appears clear that none of the existing, upgraded or future facilities in Europe fits the required specification.

The UNILAC upgrade will provide one order-of-magnitude greater beam intensities than available today reaching the level of tens of pμA. This is a major improvement, which will greatly enhance the programme to search for and study SHEs. The big advantage of the UNILAC will be its dedication for the SHE research field. **The realisation of this upgrade is considered highly important and the committee lends it its full support.**

LINAG, the SPIRAL2 driver is another attractive possibility as it fully matches the specification of the needed high intensity stable ion beam facility, except that it will be limited to light and medium-mass ions. The upgrade with a new RFQ suitable for heavier ions is possible but is envisaged only as a longer-term perspective. **Nevertheless, the LINAG project is recommended as a first technological step to the desired facility.** It is an important proof of feasibility and bench test for all technical issues related to very high intensity heavy ion beams. Moreover, despite its primary dedication as a deuteron accelerator driver for the production of neutron rich radioactive beams at SPIRAL2, a significant amount of beam time is foreseen to be used for the production of high intensity light and medium mass stable ion beams. This makes it ideal for typical dedicated experiments and also provides important tests with the highest intensity heavy ion beams in several physics areas such as the production and study of nuclei at and beyond the proton drip line through fusion evaporation reactions.

The use of the upgraded UNILAC and the very intense light and medium-mass beams from LINAG is an attractive medium range perspective for the community from the point of view of the physics opportunities and also from the point of view of the possibilities of testing and improving instruments and methods. **The long-term goal for a new dedicated high intensity stable ion beam facility in Europe, with energies at and above the Coulomb barrier, is**

considered to be one of the important issues to be discussed in the next Long Range Plan of the nuclear physics community.

In order to be ready for this new project it is also highly important that research and development on the various related keys issues such as target, spectrometers and ion sources, electronics and data acquisition systems are initiated and organised at the European level in synergy with future RNB projects.

A low-energy (well below the Coulomb Barrier) and high-intensity stable-ion beam facility dedicated to nuclear astrophysics is seen as vitally important to improvement of our current understanding of stellar evolution and nucleosynthesis. Such a facility will complement the considerable efforts currently devoted in Europe to radioactive ion beam facilities relevant to nuclear astrophysics studies. Such a facility, built on the earth's surface, will have to meet demanding specifications if it is to resolve outstanding open questions in nuclear astrophysics. It will, also, help reveal those challenging issues that can only be met by studies in existing or future underground laboratories. In this direction, the opportunities for the development of a high-intensity accelerator at LUNA as well as in a salt mine should be thoroughly explored.