Roadmap for Construction of Nuclear Physics Research Infrastructures in Europe

In order to provide input to the European Commission and the European funding agencies for developing the roadmap for new research infrastructures in Europe for the next 10 to 20 years, NuPECC briefly presents in the following its Long-Range Plan 2004 (LRP2004). In this LRP2004, "Perspectives for Nuclear Physics Research in Europe in the Coming Decade and Beyond", NuPECC makes recommendations and sets priorities for nuclear physics research in Europe.

The science case for LRP2004 was developed by six expert groups from key subfields of nuclear physics and its applications: 'Quantum Chromodynamics (QCD)', 'Phases of Nuclear Matter', 'Nuclear Structure', 'Nuclei in the Universe', 'Fundamental Interactions' and 'Applications'. In all subfields there is important ongoing research at existing facilities. However, for nuclear physics research in Europe to maintain a leadership position new large infrastructures and novel experimental techniques and equipment have to be developed and realised. This will provide the European nuclear physics community with the opportunity to pursue its future research at the cutting edge.

Recommendations and priorities for the different subfields were arrived at by the expert groups after consultation with the community during specific workshops organised by the groups, and later in a well attended general town meeting at Darmstadt. Based on these, NuPECC formulated a set of general recommendations and a set of specific recommendations connected with the priorities for new construction projects. These recommendations and priorities have received the strong support of the nuclear physics community in Europe.

In the context of this dossier, i.e. providing input to the EC roadmap for European research infrastructures, we first present NuPECC's recommendations for such infrastructures in nuclear science, ordered by priorities, and then report on the set of general recommendations.

NuPECC recommends as the highest priority for a new construction project the building of the international "Facility for Antiproton and Ion Research (FAIR)" at the GSI, Darmstadt. Of all the nuclear physics future projects in Europe, FAIR is the most ambitious scientifically and technically. The total costs (including all effort and inflation) are expected to lie slightly above 950 M€. It has a broad scientific scope allowing forefront research in five different subdisciplines of physics. These scientific pillars of FAIR are i) nuclear structure physics and nuclear astrophysics with radioactive ion beams, ii) hadron physics with antiproton beams, iii) physics of hadronic matter at high density, iv) plasma physics at very high pressure, density and temperature and v) atomic physics and applied sciences. Due to its innovative technical solutions, such as cooled and stored beams and rapidly cycling superconducting magnets, FAIR will allow parallel running of the various research programmes serving simultaneously the different physics communities involved. Because

of these aspects and its great potential for new discoveries the FAIR project has been given highest priority in the NuPECC Long-Range Plan 2004.

After FAIR, NuPECC recommends the highest priority for the construction of EURISOL. EURISOL is a high-power (Megawatt), high-intensity linear accelerator facility for the production of radioactive beams by the ISOL method (isotope separation on-line). The primary research goals are in nuclear structure physics and nuclear astrophysics. Other important programmes involve studies of fundamental symmetries and applications. The preliminary cost estimate for the construction of EURISOL is somewhat above 600 M€.

Following its previous LRP in December 1997, NuPECC had set up a working group to investigate the main options for second-generation radioactive ion beam (RIB) facilities in Europe with the results published in 2000 in a report entitled: "Radioactive Nuclear Beam Facilities". The working group recommended the construction of two new-generation complementary RIB facilities in Europe, one based on the in-flight fragmentation (IFF) or fission method and the other on isotope-separation on-line (ISOL) method.

In the IFF method a high-energy (relativistic) heavy-ion beam (> 1 GeV/u at the GSI facility) bombards a thin target. Fragments of the projectile are then separated in flight and guided to an external target or to a storage cooler ring. In the ISOL method, a thick target is bombarded with a primary, light-ion or heavy-ion beam or with a secondary neutron beam in case of fission targets.. The radioactive nuclei produced are stopped in the target. They are then ionised and post-accelerated to the desired energy, which can easily be manipulated from keV to tens of MeV.

The next-generation IFF facility in Europe will be realised through FAIR, with radioactive beam capabilities expected at the end of 2010. The major next-generation ISOL facility will be realised when the EURISOL facility will be built. Operation of EURISOL is expected around 2015. EURISOL has had a 'Research and Technical Development (RTD)' programme financed in EU FP5. Both, FAIR and EURISOL, have recently been awarded EU 'Design Study' contracts within FP6.

Because of the long time-line for EURISOL, NuPECC recommends the construction of intermediate-generation facilities that will benefit the EURISOL project in terms of R&D and will give the community opportunity to perform research and applications with RIBs of the ISOL scheme. NuPECC recommends to pursue the ongoing French project SPIRAL2 (Système de Production d'Ions Radioactifs Accélérés en Ligne 2) at GANIL, Caen, and the Italian project SPES (Study and Production of Exotic nuclear Species) at Legnaro, as well as the further upgrade of REX-ISOLDE (High Intensity and Energy ISOLDE "HIE-ISOLDE") at CERN and the very specialised project MAFF (München Accelerator for Fission Fragments) at the new research reactor in Garching near München. Of these four intermediate projects, SPIRAL2 and SPES are fully exploring the use of low-energy CW superconducting linacs, which represent the front-end of the EURISOL driver and post-accelerator. SPIRAL2, which is ready for construction, meets in terms of physics potential and size of the investments (total cost estimate around 130 M€) the criteria of European dimension and should provide radioactive beams for users in 2009. Strong common collaborations are foreseen for SPIRAL2 with the SPES project regarding the accelerator structure and with ISOLDE and MAFF for the target ion source systems.

Since EURISOL will use a high-power (several MW) proton/deuteron accelerator which could benefit many other possible projects (e.g. neutrino factory), **NuPECC recommends joining efforts**

with other interested communities to do the R&D and design work necessary to realise the high-power p/d driver in the near future

NuPECC recommends with high priority the installation at the underground laboratory of Gran Sasso of a compact, high-current 5-MV accelerator for light ions equipped with a 4π-array of Ge detectors. Such a facility has the potential to measure astrophysically important reactions down to relevant stellar energies.

NuPECC considers the physics with a high-luminosity multi-GeV lepton scattering facility very interesting and of high physics potential in revealing hadronic structure and testing QCD predictions. **NuPECC encourages the community to pursue this research within an international perspective, incorporating it in existing or planned large-scale facilities worldwide.**

The project AGATA, a 4π array of highly segmented Ge detectors for γ-ray detection and tracking, will benefit research programmes in the various subfields of nuclear science pursued at the various facilities in Europe. **NuPECC gives full support for the construction of AGATA and recommends that the R&D phase be pursued with vigour.**

As indicated above, parallel to the set of specific recommendations made by NuPECC for the future large-scale infrastructures, NuPECC also generated a set of general recommendations with regard to the ongoing research and development activities. These will be briefly discussed in the following.

NuPECC recommends the full exploitation of the existing and competitive lepton, proton, stable-isotope and radioactive-ion beam facilities and instrumentation. Interesting physics results are still emerging from the present facilities that have made large investment in equipment and manpower in the last decade. Furthermore, these facilities will provide detector R&D and training sites for the next decade.

NuPECC strongly recommends the timely completion of the ALICE detector to allow early and full exploitation with the start of LHC. The ALICE detector at CERN is a detector under construction and nearing completion. It has been given highest priority for a new construction project in the last NuPECC LRP (LRP1997). The aim of the ALICE experiment is to investigate the quark-gluon plasma with TeV heavy ions at the Large Hadron Collider (LHC)

NuPECC recommends that efforts should be undertaken to strengthen local theory groups in order to guarantee the theory development needed to address the challenging basic issues that exist or may arise from new experimental observations. This is an obvious recommendation in light of the recent weakening of the theory groups at universities, while – at the same time - the community is embarking on large projects requiring strong theoretical support to address the important scientific issues that will be faced.

NuPECC recommends that efforts to increase literacy in nuclear science among the general public should be intensified. NuPECC together with the Nuclear Physics Board of EPS have been proactive in raising the public awareness of nuclear science (PANS). NuPECC will strive to improve the awareness and understanding of nuclear science – specifically, but also in the context of the overall sciences - at high school and university undergraduate levels, and to have outreach programmes to inform the general public.

To recount briefly: **For the roadmap of new large-scale nuclear physics research infrastructures, it is clear from the above that the nuclear physics community wants to have FAIR as the first priority for new construction project and EURISOL as the second priority. FAIR has a rather broad scope for scientific activities. As far as RIBs are concerned FAIR and EURISOL are complementary. FAIR in its phase one will deliver RIBS by the end of 2010. Because of the time-line of EURISOL NuPECC strongly recommends the building of intermediate-generation RIB facilities of the ISOL type. Of these SPIRAL2 meets the criteria of a European large research infrastructure in terms of scientific potential and size of investment and will deliver RIBs in 2009. Furthermore, timely completion of ALICE for the search for the quark-gluon plasma is mandatory.**