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The European Spallation Source (ESS) Project

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Abstract

The European Spallation Source (ESS) is a proposal for a next generation neutron source in Europe. The first phase of the project – establishing the scientific case and the technical feasibility - is now followed by an intensive period of R&D activities. Three target station options: 1) a 5 MW 50 Hz short pulse station, 2) a 1 MW 10 Hz short pulse station and 3) a 4 to 5 MW 16 2/3 Hz 2.5 ms long pulse station, and the use of novel advanced cold moderators will be studied. A superconducting option for the accelerator will be investigated in a Europe-wide feasibility study for a multipurpose facility (CONCERT) with potential applications in areas such as neutron scattering, high power irradiation, R&D on transmutation and radioactive beams. It will explore possible synergies of such a facility compared with a stand-alone solution for the ESS.
The milestones for the next three years are: June 2001 - Decision on neutron parameters and target station options, June 2002 - Conclusion of the Concert multipurpose accelerator study and June 2003 – Proposal ready for submission to funding agencies. The facility could be ready for operation around 2010.

1. Introduction

In the Large Facilities Report to the Commission of the European Community (CEC) in 1990, the Neutron Study Panel underlined the continuing need for neutron scattering and recognised that a major initiative was necessary to secure an effective ongoing neutron science programme in Europe for the year 2000 and beyond. Through a joint initiative of FZ-Jülich and Rutherford Appleton Laboratory, a series of meetings in 1991 and 1992 explored options for such a next generation European Neutron Source. These meetings formed the basis for the specification of the ESS – the European Spallation Source.

The initiative was joined by a number of European laboratories. A Council of representatives from the partner laboratories together with observers from France and Spain was formed to oversee the study, which began in June 1993, and continued from December 1994 with CEC and ESF support. In early 1997, the result of the study was published in 3 volumes :
ESS – A next generation Neutron Source for Europe – Volume 1: The European Spallation Source, volume 2 : The Scientific Case and volume 3: The ESS Technical Study.

2. The ESS Memorandum of Extension

The first phase of the project – establishing the scientific case and the technical feasibility - is now followed by an intensive period of R&D activities to achieve the objective of the new Memorandum adopted in May 2000 by 13 European partners: " to design and construct a European next generation spallation source, that upon completion will be the best neutron source world-wide for all classes of instruments". New technical options such as a superconducting linac and the feasibility of a long pulse target station will be explored to realise this high ambition.

With the appointment of a new Chairman of the ESS Council the ESS project has entered this new phase of concerted activities. A Central Project Team has been set up at the Forschungszentrum Jülich (FZJ), Germany, headed by a new Project Director. The central team will be responsible for the overall progress of the project and will provide the link between the three technical R&D tasks: accelerator, target systems and instrumentation.

These three tasks are managed by lead laboratories: the ISIS Facility, UK and FZJ for the accelerator R&D, the FZJ and the Paul Scherrer Institute, Switzerland, for the target and moderator development, and the Hahn Meitner Institute, Germany and the ISIS Facility for the instrumentation design.

A Science Advisory Committee under the stewardship of the ESS Science Executive is acting as a focus for the users' points of view and will guide the project towards the optimal solution for the next generation Neutron Source in Europe.

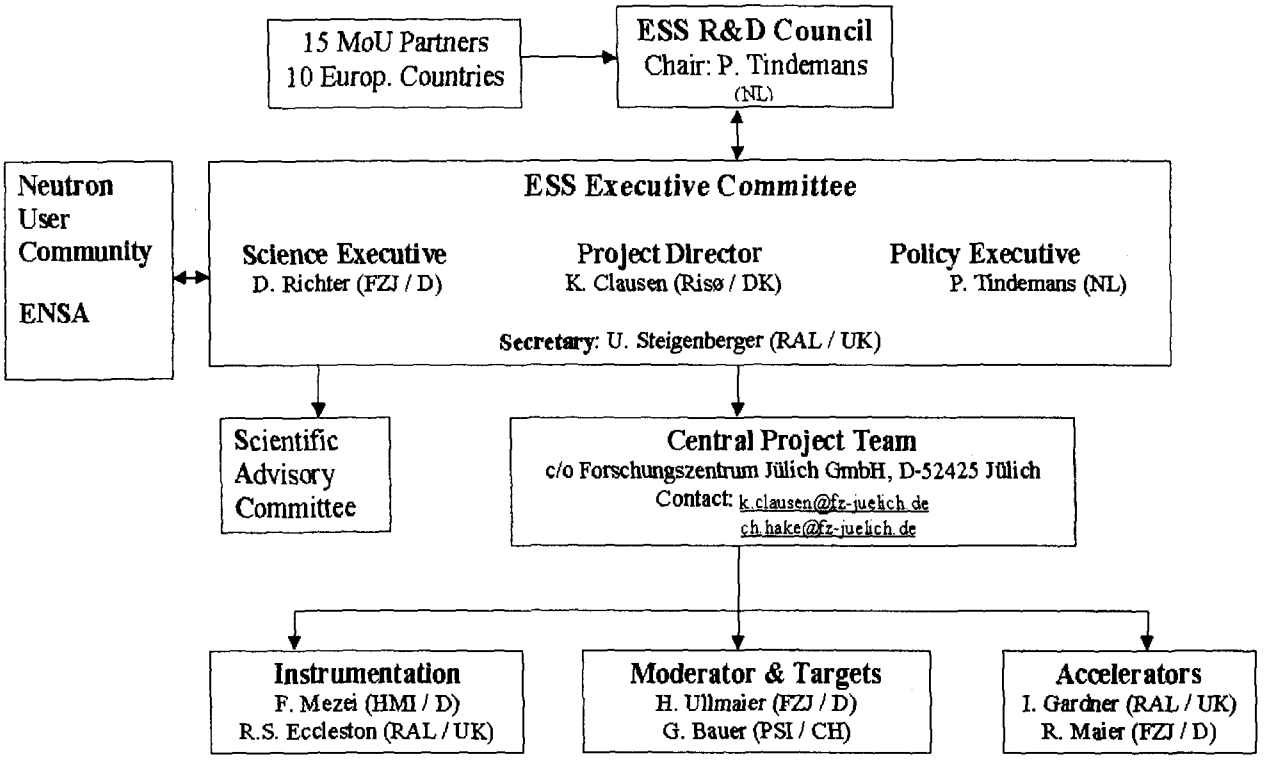

Figure 1: Organisation of the ESS study

3. CONCERT – the feasibility study of a multipurpose accelerator

For the accelerator the superconducting option will be investigated in a Europe-wide 2 year feasibility study for a multipurpose accelerator driven facility (CONCERT). The CEA in France and the ESS have invited the science communities considering the use of high power proton accelerators to participate in a study on the feasibility and cost-effectiveness of an accelerator design that allows the accelerator to be used simultaneously for a number of different purposes such as 1) a neutron spallation target or targets for neutron scattering, 2) a target station or stations for the production of radioactive beams or neutrinos, and 3) a high power irradiation station or stations for materials irradiation, isotope production and R&D required for developing a demonstrator for transmutation of nuclear waste.

The study will be co-ordinated by a team at CEA in Paris under the leadership of Jean-Louis Laclare, and will explore the feasibility and possible synergies of such a facility compared with a stand-alone solution for the ESS and address issues like reliability, R&D needs, construction and operating costs and compatibility both technically and in the mode of operation required by the different user communities. The scope of the study and the number of participants will be finally decided by the end of 2000.

4. The activities of ESS technical teams

In the paragraphs below the status of the work and the planned activities of the technical teams are shortly described

4.1 ESS instrumentation activities

The ultimate goal of the instrument groups is to produce instrument suites for the different target stations. In order to reach the June 2001 milestone – freezing the ESS neutron parameters – the instrument groups together with the SAC science working groups will elaborate on the task to match the identified scientific challenges in different scientific disciplines with instrument and source concepts. This mainly concerns the selection of optimal pulse structures, power distribution and moderator layouts for the different target stations.

At present the main issue concerns the performance of a long pulse target station as compared to the low repetition rate short pulse option. The SAC working groups will propose a series of generic scientific problems from their fields of science to be studied at the ESS. The instrumentation groups will compare the performance of a suite of key instruments at the 3 different target stations in solving these problems. Comparison should also be made with existing instrumentation in order to access new opportunities and scientific impact.

This information will then be used to guide the optimisation of the target stations and select the target station(s) to be included in the proposal. The comparison will be based on scientific capability, expected performance, technical risk plus construction and operation cost. The comparison of instrument performance on the low frequency short and long pulse target stations is a priority.

The instrumentation group will also evaluate the potential of ESS for applications other than neutron scattering: fundamental physics, nuclear physics, muon-resonance, radiography, tomography, irradiation, etc. According to the ESS terms of reference, opportunities for these applications should be maintained, without including this set of applications in the

optimisation criteria of the basic source parameters. An informal working party of expert from the various fields concerned will be convened to evaluate new opportunities of this kind.

4.1 ESS target station activities

Shortly after the completion of the Technical Study by the end of 1996, it was generally recognized that solid methane moderators could offer dramatic gains in cold neutron flux and pulse shape. Development of Advanced Cold Moderators is hence a key goal in the ESS study. The work will encompass a study of the moderator materials methane hydrate and solid methane and look at pellet production, pellet transport systems plus radiation effects, neutronic performance and scattering kernels of these two materials.

Another topic to be studied is the impact on the target station design and cost of new cold moderator systems, advanced shutter design with in shield neutron optical components, and an optimised reflector design. The long pulse target station albeit very similar to the short pulse target station will however require substantial phase space tailoring of the neutron beams by neutron optical methods and choppers and another reflector design.

The target pressure wave issue will be subject to a theoretical and experimental assessment of the magnitude of the stress problem including an investigation of the onset and possible effect of cavitation in the mercury, the effect of impact on the wall surface and mitigation studies.

All 4 types of candidate structural materials (austenitic and martensitic steels, Ni- based high strength alloy and pure Ta) will be investigated using high energy particle transport (HET) codes and structural mechanics codes, and extensive post-irradiation testing of samples irradiated for doses up to 10 dpa (corresponding to 2 months of full power ESS operation.

The mercury loop design and manufacturing studies will include both computational (thermohydraulics and fluid dynamics), experimental and conceptual work, such as the evaluation of newly developed components, safety considerations (e.g. recovery from spills), manufacturing techniques, remote handling concepts, etc.

4.3 ESS accelerator activities

Phase 1 of the ESS design study was completed with publication of a report in November 1996 [2]. Since then the R&D phase has started to tackle the problems identified in the study, to rectify weak links in the original design and to consider alternative ideas. The current status of the design and the progress are outlined in a short ESS report [3] and in Figure (2).

The linac design [4] has evolved to a normal conducting coupled cavity linac (NCCCL) operating at 560 MHz. Studies of the beam funnel showed that the beam energy had to be increased to 20 MeV to obtain short enough bunch lengths for effective funnelling. The reduction in operating frequencies from 175, 350, 700 to 280, 560 MHz is a good compromise for various linac stages. The peak bunch current in the main part of the accelerator is reduced by a factor of two compared with the original reference design as each rf cycle now contains beam. Complete beam tracking with space charge effects has now been carried out from the RFQ to the exit of the CCL. The final beam emittances are a factor of two lower in the transverse planes and a factor three lower in the longitudinal plane in comparison with the earlier design [5].

The Compressor Ring design has also evolved to reduce the very high temperature predicted for the H^- to proton beam stripping foil. In the current reference design the chopping duty factor has been increased from 60% to 70% and the circumference has been increased by 34.6% compared with the original reference design.

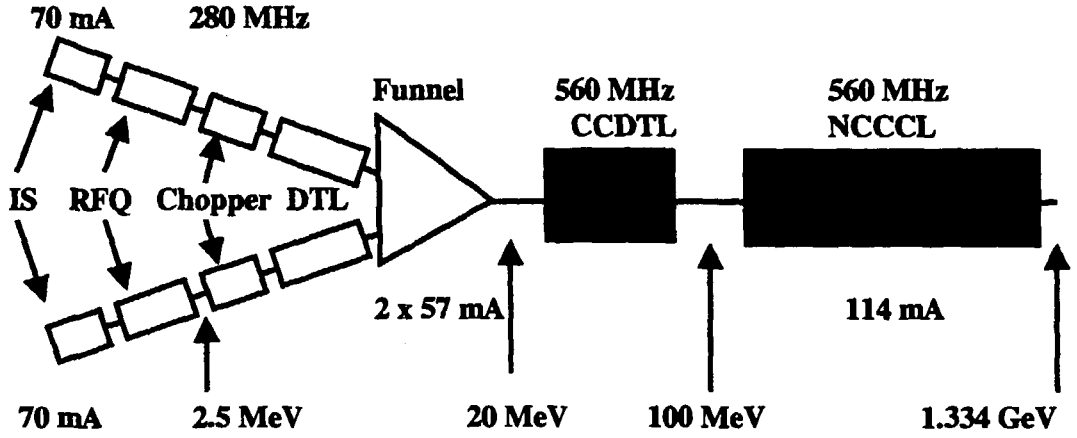

Figure 2: The current Linac reference design.

In the coming month the above reference design will be fully documented and two new options will be studied: 1) a superconducting version of the high energy Linac and 2) the changes to the present design required to deliver additionally a 2.5 msec long pulse interleaved on the accelerator after every 3rd pulse (16.67 Hz) directly to a long pulse target station. The accelerator work will be done in close collaboration with the CONCERT team – it will be an essential part of the ESS contribution as partner in this study.

5. Milestones

The main aim of the ESS study is to examine and compare the relevant options for the realisation of ESS and have a proposal for funding ready in 2003. In June 2001 we will start to select options i.e. make a decision on the neutron parameters and target station options, by June 2002 a conclusion of the Concert multipurpose accelerator study will be made and a proposal for submission to European governments and other funding agencies will be prepared for June 2003. The facility could be ready for operation around 2010.

References

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