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STATUS OF THE ESS ACCELERATOR CONSTRUCTION PROJECT

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Abstract

The European Spallation Source (ESS) is now under construction just outside in Lund in Sweden. The driver is a 5 MW linac operating at a duty factor of 4% and at 2 GeV. The detailed design of the buildings is just being completed, and the casting of the accelerator tunnel has started. The accelerator design is getting mature with the major parts under prototyping. A challenging aspect of the project is the large percentage of in-kind contributions. For the accelerator this is now reaching 50% in pre commitments by institutes and universities in the ESS member states. We will in this paper give an overview of the ESS accelerator design, the status of prototyping and the organization of the in-kind accelerator construction project.

THE ESS PROJECT

The ESS is a multi-disciplinary research centre based on the world's most powerful neutron source. This new facility will be 30–100 times brighter than today's leading facilities, enabling new opportunities for researchers in the fields of life sciences, energy, environmental technology, cultural heritage and fundamental physics. The facility is planned to have 570 MeV protons and first neutrons in 2019 and a user program starting in 2023.

ACCELERATOR BASELINE

The ESS accelerator high-level requirements are to provide a 2.86 ms long proton pulse at 2 GeV and a repetition rate of 14 Hz. This represents 5 MW of average beam power with a 4% duty cycle on target.

The ion source produces a proton beam that is transported through a Low Energy Beam Transport (LEBT) section to the Radio Frequency Quadrupole (RFQ) where it is bunched and accelerated up to 3.6 MeV. In the Medium Energy Beam Transport (MEBT) section the transverse and longitudinal beam characteristics are diagnosed and optimized for further acceleration in the Drift Tube Linac (DTL). The first superconducting section consists of 26 double-spoke cavities (SPK) with an optimum beta value of 0.50. The spoke cavities are followed by 36 Medium Beta Linac (MBL) elliptical cavities with β = 0.67 and 84 High Beta Linac (HBL) elliptical cavities, with β = 0.86. After acceleration the beam is transported to the target through the High Energy Beam Transport (HEBT) section and rastered on the target using an active fast magnet beam delivery system. A block diagram of the ESS accelerator design can be seen in Figure 1.

ACCELERATOR IN-KIND

Introduction

ESS is a new organization at a green field site set up in 2009. The design update of the ESS accelerator, undertaken from 2009 to 2013, was done in a collaboration including INFN in Italy, CEA and CNRS in France, ISA in Denmark, ESS-Bilbao in Spain, Uppsala University and Lund University in Sweden and the emerging ESS accelerator division. The design update resulted in a Technical Design Report [1] for the full facility, which has been the base of further negotiations for the funding of ESS. The funding for the construction is today secured but with a request from the member states for a very high proportion of in-kind financing. The target for the accelerator

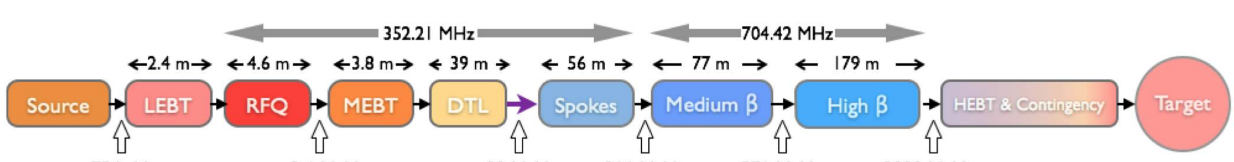

Figure 1: Schematic layout of the ESS linac [2]. Blue colour represents superconducting sections.

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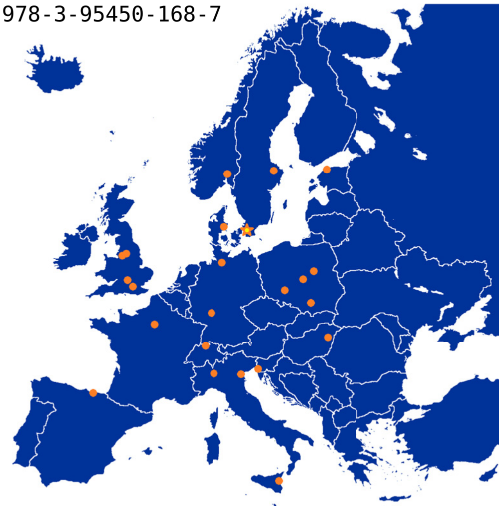

Figure 2: Map of in-kind partners in the ESS accelerator construction.

project was set to 75% of in-kind. It currently has 26 partners in Denmark, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Spain, Sweden, Switzerland and UK covering 50.4% of the project value, see Figure 2.

Agreeing on Contributions

The contribution from each country was agreed at highest political level with a target set for the percentage for in-kind from each country (generally set at 70%). The in-kind agreements have a legal part, dealing with issues such as taxation and IP, which has also been agreed at high level. For the accelerator and the other projects it remains to agree on technical details and write specifications. The description of work in each project has been made available to possible partners through a cost book with a work breakdown structure down to work-unit level, and partners have been encouraged to submit expressions of interest for work they wish to do for the given cost book value. The process has been managed through an In-Kind Coordination Team at ESS, which assures that the contributions from the different countries are allocated to the projects in appropriate ways.

Partners in the accelerator construction are both those that have contributed in the design phase and new ones joining based on expressions of interest submitted to ESS.

Setting Requirements for IK Contributions

A particular challenge at ESS is that the work of writing the requirements is, to a large extent, taking place with the in-kind partners. In some cases the requirements were already written during the design phase, and for some others this is still in progress. Requirements have been managed centrally at ESS by an integration team using web based requirement gathering tools, thus allowing ease of access to them, including for the in-kind contributors.

In terms of process, agreed requirements are then reviewed in so called vertical sub-system reviews, which are conducted by the Project Chief Engineer. The vertical reviews take as starting point the accelerator Product Breakdown Structure (PBS) and cover all requirements linked to each sub-system element. Although interface requirements are proposed by the sub-system responsible, vertical reviews also cover these as a supplementary means of verification. The project Chief Engineer then supplies a full review report to the Project Leader. Finally, the Project Leader is responsible for the approval of the agreed requirements.

TECHNICAL DEVELOPMENTS

The ESS accelerator project will have a higher average beam power on the target than any previous spallation facility. This requires new developments to assure safe and efficient operation of the facility. Here are a few examples of developments undertaken within the project:

Elliptical Cavities

The elliptical cavities have been developed by CEA-Saclay. So far two prototypes for the high beta five-cell cavities have been built and tested in a vertical test stand [3]. The cavities performed above the ESS specification of 19.9 MV/m at a Q_0 of 5×10^9. There is still some development to do for the heat treatment of the cavities after processing. The five additional high beta cavities and five medium cavities which now are being ordered will permit further development to assure that the requirements can be met. The prototype for the elliptical cavities cryomodule is developed by CEA-Saclay in collaboration with IPN-Orsay, and it is now being assembled in Saclay.

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Spoke Cavities

The spoke cavities and cryomodules have been developed by IPN-Orsay [4], which is part of CNRS in France. Two different manufacturers have produced three prototype cavities and all cavities have tested well above the specification of 9 MV/m at a Q_0 of 1×10^9. IPN has also designed and is now building a prototype cryomodule for the spoke cavities.

RF Sources

The RF sources [5] for the RFQ and DTL will be 352 MHz, 2.8 MW high-power klystrons, which can be bought “off the shelf” today. The spoke section will use classical tetrode technology, and the medium beta elliptical section will use 704 MHz, 1.5 MW klystrons. Three industrial prototypes for these klystrons have been ordered. The baseline for the high beta section is to use high power multi-beam IOTs, for which two industrial R&D contracts have been placed. A decision on whether to use klystrons or IOTs for the high beta section will be taken early in 2018 when test results from the IOT R&D will be available.

Modulators

ESS and its partner labs have placed several contracts in industry for 330 kVA modulators that can power two 704 MHz klystrons. These modulators will be used at different ESS related test stands, assuring that there is a modulator design available and tested for ESS. However, the wish for an energy efficient and more compact design which can power up to four 704 MHz ESS klystrons has led ESS to launch its own development of a new modulator topology, a so called stacked multi-level design [6]. The construction and validation of a reduced scale prototype rated for 120 kVA (115 kV/20 A, 3.5 ms/14 Hz) in collaboration with Lund University was launched in 2013. An upgrade to the full scale system of 660 kVA (115 kV/100 A, 3.5 ms/14 Hz) is a matter of thermal re-design and selection of components rated for higher currents.

Beam Delivery System

The beam delivery system at ESS is a raster magnet system sweeping the beam in a crosshatch pattern on the target within the 2.86 ms ESS pulse [7]. It consists of eight collinear magnets that are individually powered. The system has been developed at ISA, Aarhus University and is based on a previous design from Los Alamos National Laboratory [8]. A prototype magnet and power supply will be ordered in late summer 2015.

SUMMARY

We have in this paper given an overview of the status of the ESS accelerator project with its particular challenge due to the large proportion of in-kind contributions. The methodology is meant to be suitable for a collaborative project where partners participate also in the development phase. Many of the technical developments are state-of-the-art and will undoubtedly benefit the accelerator community. Civil Engineering as well as equipment construction have now started in view of accelerating the first beam in 2019.

ACKNOWLEDGMENT

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