Chapter I

Foreword, Introduction and Overview

Contents

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FOREWORD

The European Spallation Source (ESS) Project represents the culmination of a decade of intense research, development and design by a large number of leading scientists and engineers from all over Europe. The single goal is to provide Europe with a neutron facility that meets the scientific requirements well into the 21st century. Some 20 laboratories, universities and research organizations plus a large number of scientists from all over Europe, have joined together to develop the science case and the technical design, and to work on the planning and the realization of the ESS project.

The ESS project proposal [ESS, 2002] was presented to the public, the general neutron user community and European decision makers at a meeting in the former house of parliament in Bonn, 16-17 May 2002. The period from May 2002 until the end of 2003 was intended to advance the proposal into a project baseline report and to initiate the planning, preparation and procedures necessary for the construction of the ESS facility within 8 years after an expected project go-ahead (decision by European governments) early 2004. Following this timescale Europe would be behind the US and Japanese spallation projects by only 4 to 5 years.

In January 2003 it became clear, however, that a decision to build the ESS would not likely be forthcoming by the end of 2003 or early 2004, but rather be delayed by several years - a view that was confirmed in the months to follow. The ESS council therefore decided to wind down all technical and project planning activities and limit the ESS efforts to documenting the current technical and planning status.

The present document is a summary of the substantial amount of work, technical definition and progress achieved during the period from May 2002 to early 2003. It should be read as an update to the May 2002 ESS project Volume III report, and together with all four volumes (The ESS project volumes I to IV) from May 2002 it presents a full description of the ESS project. This report also describes briefly how the decision to stop technical and planning efforts by the beginning of this year will influence the timescale for a re-launch of a MW spallation source project in Europe.

The ESS project acknowledges the advice from our Scientific Advisory Committee (SAC) and Technical Advisory Committee (TAC), the very open and mutually beneficial collaboration with institutions and colleagues working on the US and Japanese spallation source projects, financial support from the European Commission through the neutron round-table and last but not least the massive backing by the users organised in the European Neutron Scattering Association.

On behalf of the ESS project:

The ESS project directorate
Ian S K Gardner, Dieter Richter and Kurt N Clausen

I INTRODUCTION AND OVERVIEW

I.1 DEVELOPMENTS BETWEEN MAY 2002 – JULY 2003

In January 2003 it became clear that the European governments, despite tremendous efforts by the ESS project, the regional 'site consortia', the European neutron users (through ENSA) and the Neutron Round Table, would not decide about a new spallation source by the end of the year. The European governments thus neither live up to their own ambitions, as expressed at the summits in Lisbon and Barcelona, nor follow the OECD recommendations, which they have also endorsed.

In the meantime, the SNS is expected to reach full power (1.4 MW) sometime in 2008/9 with 13 instruments operational in 2010, and to add two new instruments per year. Moreover an upgrade to 2,0 - 2,4 MW and a second target station of 400-600 kW have been identified and positively assessed in the current DoE 20 years Road Map. The SNS power upgrade is likely to start in 2006, which means achieving in excess of 2 MW around 2011. J-PARC will initially operate at a lower power level, but it is also being constructed with an identified upgrade potential.

The American and Japanese initiatives are already draining experts from Europe. Experts, who over the last 40 years have proven their ability to build, utilise and run world leading neutron facilities! It is true that the European Strategy Forum for Research Infrastructure (ESFRI) concluded that Europe needs a major new neutron facility in the long term and hence a decision on such a facility in the medium term. A neutron working group under ESFRI published a report early in 2003 [ESFRI, 2003] pointing out how: a new source optimised for best value and edge vis-à-vis SNS (US) and J-PARC (Japan) could fit into a European 10-20 year strategy for all main neutron facilities. But while the UK government is now engaged in a serious effort to review the UK needs for a next generation neutron source with a view to coming to a formal UK budgetary decision in mid 2006, there is only minimal support among governments to accept even a non-binding tentative common planning horizon, resulting in a decision by the end of 2007.

As a consequence of the early termination of technical activities, the present report cannot be a base-line report, but will present the progress in the different areas after the Bonn presentation in May 2002. It is an update of the Bonn report, Volume III in the form of a supplement, not a replacement of that report. Only where a considerable amount of additional work has been done, and where readability would suffer from presenting only the additional material and occasionally design changes, has it been decided to publish self-contained new chapters which do replace the May 2002 report chapters. The nature of the various chapters will be described in the introduction to each of them.

I.2 THE EUROPEAN SPALLATION SOURCE – MAIN PARAMETERS

The ESS project consists of a 10 MW, H^- accelerator capable of simultaneously delivering 5 MW, 1.4 µs pulses to a short pulse target station (SPTS) operating at 50 Hz and 5 MW, 2 ms long pulses to a long pulse target station (LPTS) operating at 16 $^2/_3$ Hz.

A perspective view of the ESS reference design is shown in figure I.2.1. It consist of a full energy 1.334 GeV linac, a long pulse target station directly following the linac and a double compressor ring compressing the 50 Hz proton pulses by a factor 800 before they are forwarded to the short pulse target station. The required site is 850m x 1150m in extension.

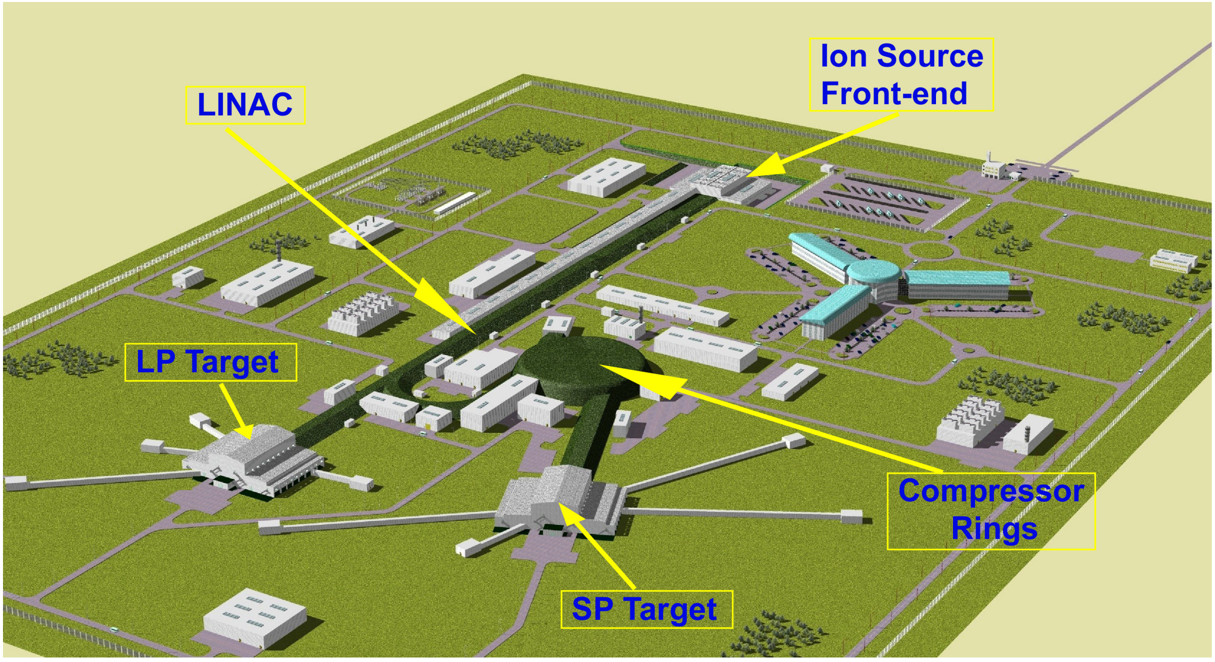

Figure I.2.1: Schematic Layout of the ESS

The final layout for the ESS reference linac has now been established. The high beam power and the complicated pulse structure rules out simple scaling of any of the known accelerator design. The linac is based on a 280 MHz front end with two H^- lines funnelled at 20 MeV. Normal conducting structures at 560 MHz accelerate the beam up to 400 MeV, from where 1120 MHz superconducting structures take over. The layout of the accelerator is shown in figure I.2.2.

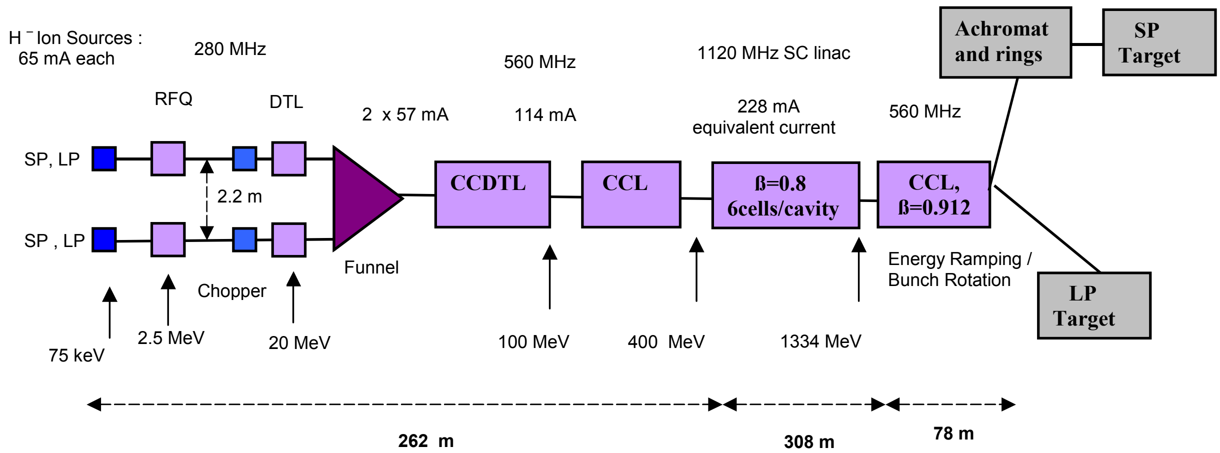

Figure I.2.2: The ESS accelerator layout

The two ESS target stations are basically identical. They are both based on a horizontally extended liquid Hg target. Two moderator assemblies, each with two viewed faces, are inserted horizontally above and below the target respectively. This decouples moderator maintenance from the heavy and difficult to manipulate reflector and allows for future use of advanced cold moderators. Each target station will have 22 beam channels (11 on each side) separated by 11°, and each fitted with a rotating shutter with a replaceable beam channel of outer dimensions 2.8 m long, 23 cm wide and 17 cm high. Guides and other optical elements can be mounted and aligned inside this channel from the top of the target station with the shutter in closed position. The closest distance between moderator and guide entrance is 1.6 m and the first choppers can be mounted 6 m from the moderators. The target station layout is shown in figure I.2.3.

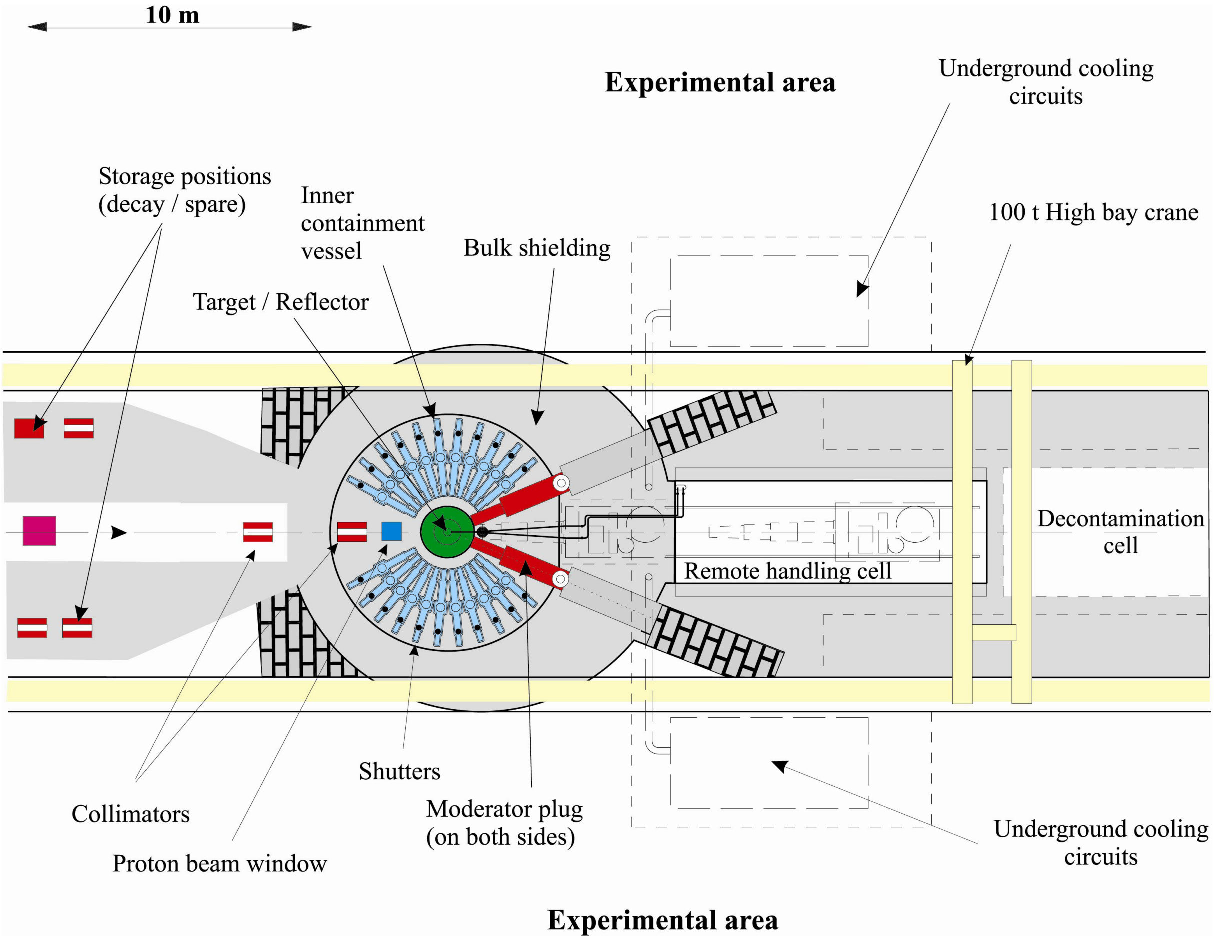

Figure I.2.3: The ESS target station layout

Both target stations are fitted with a D_2O cooled Pb reflector. On the SPTS, the part closest to the moderators may be replaced by Be. The present design is based on the use of a) two extended moderator assemblies in the most brilliant positions above and below the target, b) conventional water and cryogenic hydrogen moderators only, and c) extended water pre-moderators where appropriate.

On the SPTS four different types of beam spectra will be available: Coupled Cold, Decoupled Cold, Decoupled thermal and Bi-spectral (combined cold and thermal). The LPTS will only have Coupled Cold and Bi-spectral beams.

Simulations of these new moderator concepts with engineering details included show that the extended moderators in general have a lower Brilliance but a larger viewable surface i.e. they are only advantageous, when the beam extraction system is designed to view the entire moderator surface and the instrument is designed to utilise the full beam.

The Decoupled cold and thermal beams on the SPTS deliver similar intensities but narrower peaks – better resolution - than the old design. The bi-spectral moderator assembly only provides a gain when it is important to cover on the same instrument a very broad spectrum of both cold and thermal neutrons simultaneously on the same instrument.

The proposed instrument suite is an extrapolation of ISIS instrumentation for the short pulse target station, and for the long pulse target station it relies heavily on the fact that neutrons can be transmitted over large distances with very low loss, that choppers can be used for pulse shaping, repetition rate multiplication and wavelength frame multiplication. The ESS instrumentation groups have based the selection and definition of instruments on science demands from the ESS Science Advisory Committee and detailed performance calculations using Monte Carlo simulation techniques. The detailed moderator reflector design and decision on instrumentation will be a continuous process starting after the decision to build ESS has been taken. The performance of the presented instrument suite has been compared to SNS at 1.4 MW and the best existing neutron facilities, and demonstrated to be world leading across the board (Figure I.2.6).

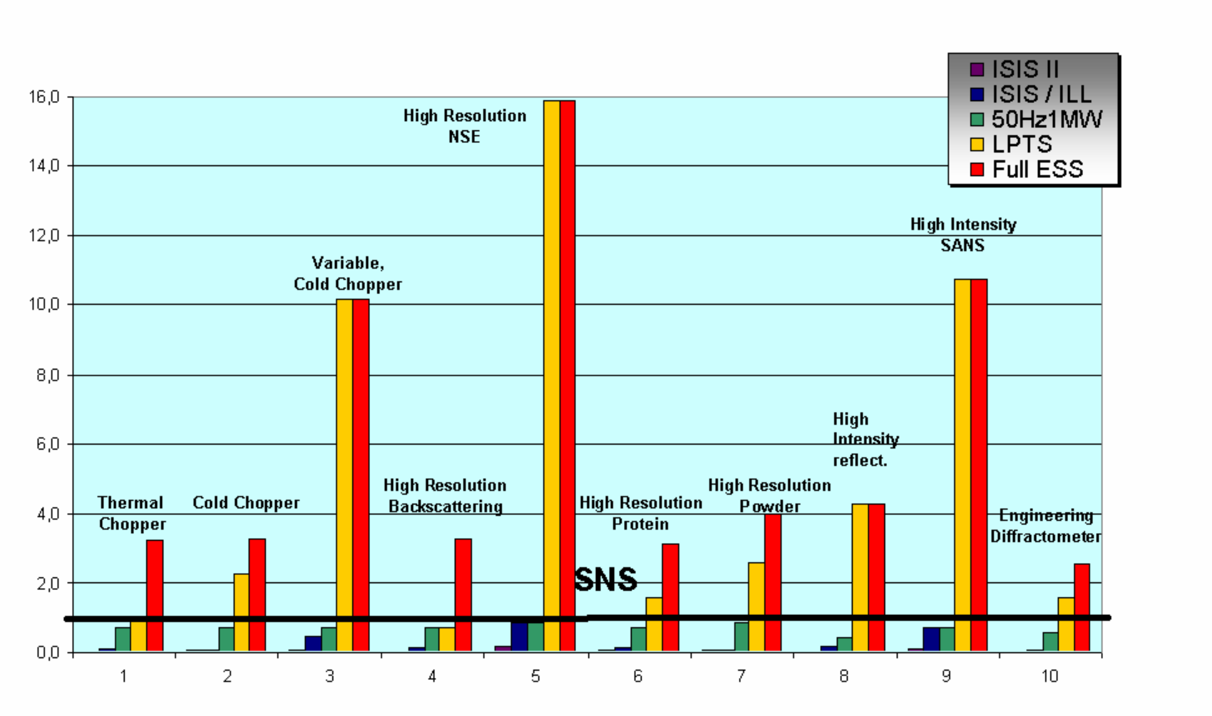

Figure I.2.4: Expected performance of high priority instruments at ESS, scaled to a 1.4 MW SNS facility and compared to the best existing facilities [ESFRI, 2003]

I.3 THE EUROPEAN SPALLATION SOURCE – SAFETY, LICENSING

A key issue for a facility like the ESS is to meet very high safety standards. The ESS is planned to be licensable in an urban area for instance directly adjacent to a university campus. A preliminary safety study for ESS, based on the detailed SNS safety analysis, shows that this is both achievable and affordable. Radiation levels in instrument halls and all other general accessible areas will be below 0.5 µSv/h.

With respect to licensing and authorization of multi MW spallation sources like ESS, it was found that for several EU countries regulations were not yet established: In order to avoid delays during the construction phase, the creation of an adequate basis for ESS licensing and authorization has to be carefully considered by the countries proposing to host ESS.

I.4 THE EUROPEAN SPALLATION SOURCE – COSTS AND SCHEDULE

Due to the premature termination of the technical work on the ESS, several steps of the project preparation phase were not completed. A few technical items need further studies and prototyping, and the project baseline and construction planning are incomplete. To finish these outstanding tasks approximately 40 M€ (man years and equipment) are needed.

In figure I.4.1 a possible scenario for the realisation of an ESS type facility is presented. With the indicated activities in the project approval phase, the construction of the ESS facility could be accomplished in 8 years followed by one year of pre-operations. Prototyping of cost critical items during the base-lining phase would be preferable but could also be delayed in favour of an early start of construction. In the latter case larger uncertainty on costing must be accepted. The advanced technology programme will be important to build technical competence and capability and will enable incorporation of new technologies in the facility, i.e. it is intended to fill the gap until construction is started and to ensure that the proposed facility will remain state of the art.

10 instruments can be ready at the beginning of pre-operation. New instruments will be introduced at a rate of 5 instruments per year during the first years of operation. When all 44 beam-holes are instrumented, refurbishment or replacement will start at a rate of 3 instruments per year.

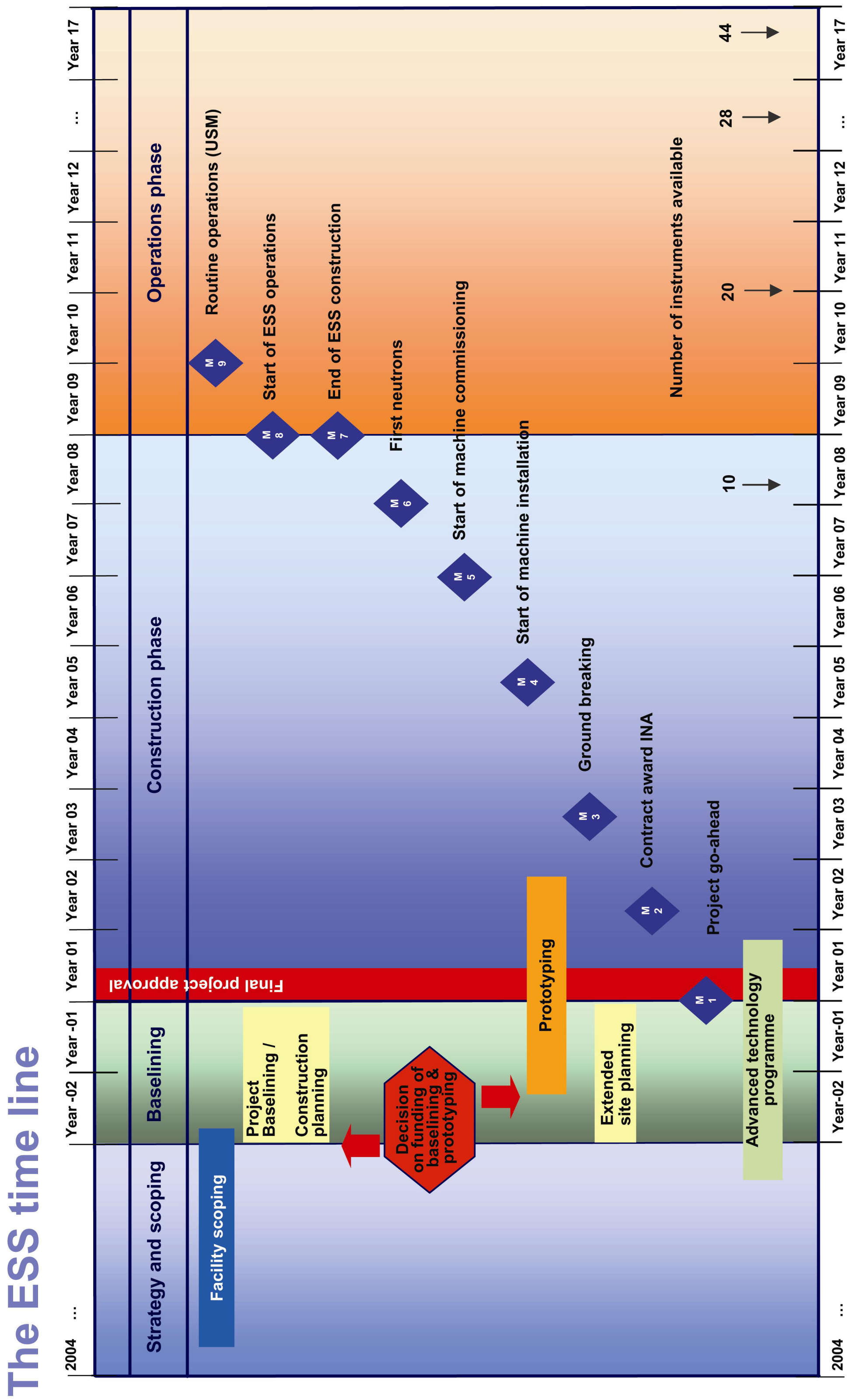

Figure I.4.1: The new ESS time line. Recruiting a new project team and finishing base lining will take approximately 2 years. The 8 year construction period, including assembly and commissioning, has not been changed. The same is true for the operation phase and availability of the 44 instruments.

The construction costs of the ESS facility amount to 1552 Million € at 2000 prices.

This figure includes not only capital investments for all components necessary for the ESS project but also the 3300 years of manpower (in-house plus subcontracted staff) required during construction. A contingency of 15 % is included. Costs for decommissioning and radioactive waste disposal are not included in the capital cost figures.

With regard to the organisation of the facility, the ESRF model will be chosen with a few minor optimisations. The in-house staff will comprise about 650 including 50 PhD students. The ESS will be a highly user oriented facility operating more than 40 instruments in User Service Mode (USM) for 5.500 hours per year.

The annual operating budget amounts to142 Million € at 2000 prices.

This budget includes a recurrent investment for developments, completion of the instrument suite and later the systematic refurbishment/enhancement and replacement of 3 instruments per year.

I.5 NEUTRONS AND MUONS WEB PORTAL

The ESS website has been developed into a common entry point to information. The "*European portal for neutron scattering and muon spectroscopy*" gathers all the European organizations engaged in supporting neutron and muon activities in Europe: ENSA, NMI3, ISMS-E (the International Society for Muon Spectroscopy – Europe) and, of course, the future organization for a Spallation Source for Europe.

The website was launched in the autumn of 2003 and can be accessed at www.neutron-eu.net for the neutron community or www.muon-eu.net for the muon community.

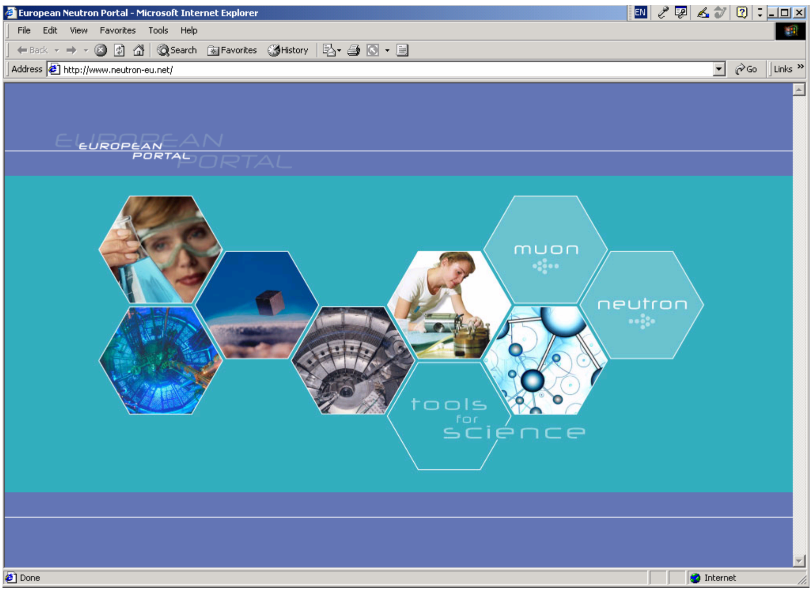

Figure I.5.1: The web portal http://www.neutron-eu.net or http://www.muon-eu.net

I.6 OTHER POTENTIAL USAGES

Provision for uses other than neutron scattering is not included in the project proposal or the ESS design and costs. However, the ESS design is rather flexible. It allows consideration of the facility for other uses. The CONCERT study carried out by the CEA and ESS has shown that a pulsed accelerator of the type designed for ESS can accommodate all these other usages. In contrast, other concepts (e.g. under consideration by CERN – the SPL design – or the ADS community) do not seem to offer the versatility and performance required for a world leading neutron scattering source. Most of these other usages would require major new facilities but can be added later if the site layout allows for the physical space. For some applications major resources are necessary and the relevant communities would need to secure these.

The other usages being considered by the respective communities are:

- An irradiation facility in one of the LP or SP target station
- A radioactive beam facility
- Production of radioisotopes
- An Ultra Cold Neutron source
- A muon facility in the transfer line between rings and SP target
- A neutrino facility in a cave below the SP target

If such additional uses are desired in a future European spallation facility, it would be beneficial, to include them in the concept from the very beginning.

I.7 CONCLUSION AND NEXT STEPS

The ESS project is backed by a strong science case. It is unanimously supported by the European neutron user community. The timescales are supported by EC and OECD studies, and the design presents a step beyond similar projects underway in the US and Japan.

A Technical Advisory Committee consisting of world leading experts in all relevant areas – accelerators, rings, targets, instrumentation and infrastructure – have previously reviewed the project. This committee deemed the ESS project "*a worthwhile project of the greatest importance for European science and technology, whose design and construction is within the competence and capabilities of the collaborating European laboratories*".

To realise a next generation multi MW spallation neutron source in Europe the project must be carried forward scientifically, technically and politically. This calls for a new organisation to be formed and to establish close collaboration with funding agencies. A staged approach, starting with a 5 MW LP target station, later upgradeable to a higher power and a second target station, would be possible within a construction budget around 1 G€ and with the full potential to build a truly world leading facility with unprecedented performance.

II LIST OF PARAMETERS, TIME SCALE &ORGANISATION

II.1 LIST OF MAIN PARAMETERS

The site layout is shown in Figure II.1; the main parameters are summarized in table II.1.

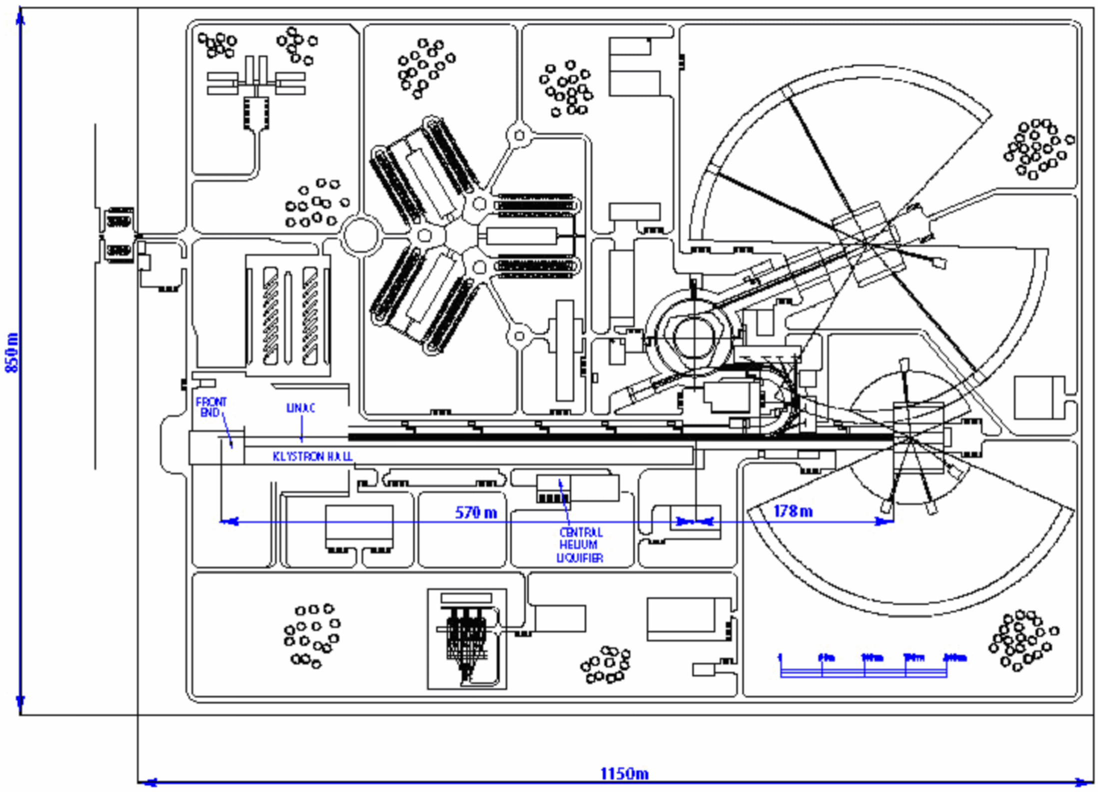

Figure II.1: ESS site with SC linac, achromat and compressor rings, LP and SP targets

The ESS facility has a site footprint of 1150m x 850 m to house the accelerator part, the SP and LP target stations and up to 200 m long instruments. A 180° achromatic bend allows longitudinal & transverse halo scraping of the H^- beam before ring injection. In the LP beam line a H^- stripping foil is placed near the achromat in order to separate the H^+ beam for the LP target station. Beam development dumps are placed under both targets.

Both ESS target stations are basically identical, using liquid Hg as target material. The proton beam windows consist of an array of thin walled aluminum pipes connected to each other. The window has to withstand about 9 N/mm² stress from cooling water and about 37 N/mm² of bending stress. Stress pulse mitigation in the liquid Hg target material is provided by injection of He bubbles. Each ESS target station is equipped with 2 moderators and designed to have up to 22 instruments.

Radioactive inventories in used cores from neutron beam research reactors and in ESS mercury targets are of comparable size. But it must be noted that the mercury is never changed, whereas research reactor use many fuel cores in their lifetime. Safety problems associated with the radioactive inventory of the ESS mercury targets can be solved.

Table II.1: Main Parameters of the 10 MW ESS Facility

General Parameters	
Final beam energy	1.334 GeV
Average beam power on SP/LP targets	5 MW/5 MW
Pulse frequency SP/LP targets	50 Hz / 16 $^2/_3$ Hz
Pulse width on SP/LP targets	1.4 µs / 2 ms
Number of shutters & beam lines / target	22
Angular separation between beam lines	11°
Number of instruments / target	22+
Average /peak thermal neutron flux (n/cm^{2}s)	3.1*10^{14} / 1.3*10^{17} (SP), 1.0*10^{16} (LP)
ESS SC reference linac	
H$^-$ion sources for SP&LP beams	2* 65 mA (SP/ LP beams are separated by 10 ms)
Peak current	114 mA
Chopping factor.	70 % for SP, 100 % for LP (70 % during start-up)
NC 280/ 560 MHz structure up to 400 MeV	262 m
SC 1120 MHz section above 400 MeV	308 m
Total length from ion source to LP target	748 m
RF wall plug power in NC/SC part	20 MW /26 MW
AC Cryo power in SC part	4 MW
Accumulator rings	
Double-ring design in a shared tunnel	35 m mean radius, 1.242 MHz rev. Frequency
800 turn injection scheme	only 560 ns pulses for each 800 ns long turn
Peak current in accumulator ring	62.5 A
Pulse width on SP target	1.4 µs(2*0.6 µs with 0.2 µs gap)
H$^+$ beam transfer to LP/SP targets	
Length of transport lines	100 m to LP, 135 m to SP target
Target injection & accelerator dumps	Beams are lifted, dumps below SP/LP targets
Pair of collimators in front of LP/SP targets	2*200 kW in front of each target window
SP/LP liquid Hg targets	
Mass / target, input / output temperature	15 *10^3 kg , 100 °C / <280 °C
Energy content / pulse for SP/LP target	100 kJ in 1.4 µs / 300 kJ in 2 ms
Stress pulse mitigation	injection of He bubbles
H$^+$ Window **:** array of thin walled pipes	0.3 mm wall thickness, 3 mm outer radius
H$^+$ Window**:** size/current density/temperature	60mm*200mm / < 100µA/cm^2 / < 400°C
Target building	< 0.5 µSv/h radiation level in instrument hall, up to 80t/m^2 floor load
Total activity for each target (30 years operation)	8.6*10^{7}GBq at shutdown / 5.5*10^{6}G Bq after 1 year
After heat for each target (30 years operation)	26 kW at shutdown / 0.42 kW after 1 year
Reflector & 2 moderator assemblies in SP target	* Pb (D_2 O cooled) reflector * decoupled cold /thermal moderator * coupled bi-spectral /cold moderator
Reflector & 2 moderator assemblies in LP target	* Pb (D_2 O cooled) reflector * coupled cold moderator * coupled bi-spectral side-by-side moderator
Beam stops	
9 actively cooled dumps & collimators (4 collimators before LP/SP target are included)	2*500 kW linac & ring development dumps, 3*100 kW collimators: 2* ring injection , LP line
14 passively cooled beam catchers, few kW	scraping in achromat & neutron catchers, halo scraping in both rings

II.2 TIME SCALE & ORGANISATION

Time Scale

The overall ESS time-line is shown in figure I.3.1. A more detailed project schedule is shown in figure II.2

First neutrons (commissioning)	7 years after decision
End of construction, start of pre-operation	8 years after decision
Full user mode	9 years after decision

Without the two initial stages – advanced technology programme plus construction planning, project base lining and prototyping, (full cost ca 40 M€) the project will be extended in time.

Construction costs

All costs are given at 2000 prices.

Construction = 8 year period between the decision and the start of pre-operation phase.
Integrated costs (capital + personnel + running costs for the project):
1.55 G€ at 2000 prices including 15% contingency

Organization

ESRF model (shift organization, no guards, no firemen)
Personnel 600 + 50 students (excl CRG)
3 operational divisions (experiments, target systems, accelerator)
3 support divisions (administration, computing services, technical services)
1 directorate

Distribution of personnel:

Directorate	28
Administration	37
Technical services	70
Computing services	49
Accelerators	91 + 4 students
Targets	54 + 2 students
Instruments	271 (including 40 post docs) + 44 students

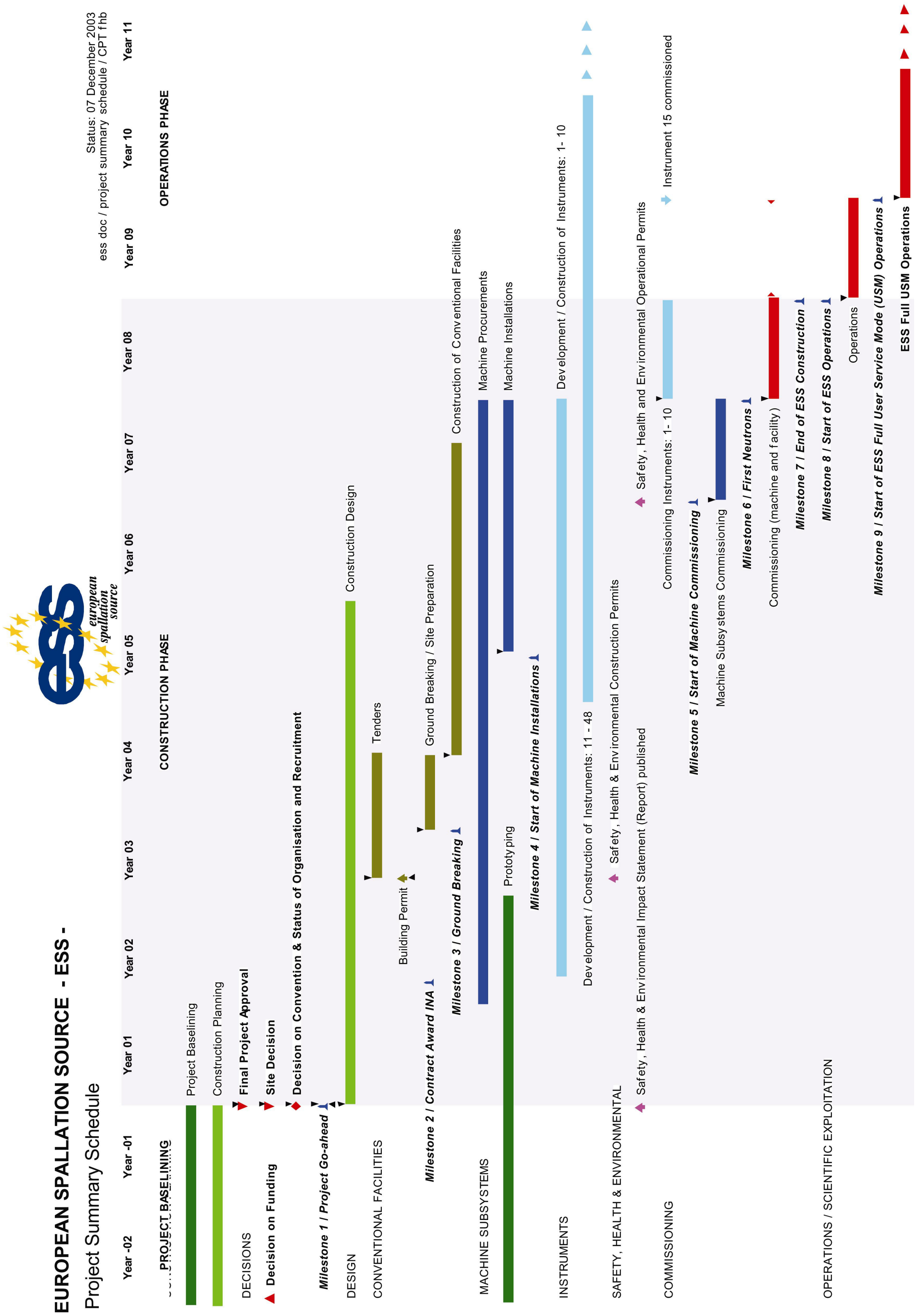

Figure II.2: Detailed project schedule

Operation cycles and budget

142 M€ per year at 2000 prices
Includes budget to refurbish/replace 3 instruments per year on the long term

Beam delivery 5 500 h/year
Light maintenance and accelerator development 1344 h
Shut downs 2016 h

Operating schedule:
- 5 cycles each 45 days of beam delivery interleaved with 14 days of shut down for light maintenance between the cycles.
- 1 long annual shut down of 12 weeks for major maintenance tasks, upgrades to the facility and installation of new instruments

Beam reliability 95% of the scheduled time at full power (5 years after start of full user mode)

- Break down of User Service Mode
- 75 % attribution by evaluation committees including 5 % thesis related works (long term scheduled user work)
- 5 % rapid access and laboratory priorities
- 20 % maintenance and development with neutron beams and in-house research (incl rescheduling)

Scientific staff can dedicate up to 30 % of their working time to personal research

Instruments

Number of instruments at start of commissioning: SPTS/LPTS:	5/5
Number of instruments at start of user mode: SPTS/LPTS:	10/10
Number of new instruments per year SPTS/LPTS	1.5 / 1.5
Number of CRG's per SPTS/LPTS:	4/4
Average cost of instrument (incl. manpower)	8.5 M€

Users

Potential number of users per year: 4-5000 when fully instrumented

Other potential usages

- Irradiation of materials in existing target station
- Radioactive beam facility
- Production of radioisotopes
- Ultra Cold Neutron (UCN) source (in dedicated target station).
- Muon facility in the transfer to the SP target
- Neutrino facility in a cave below the SP target

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