ESS PLANS AND SYNERGY WITH CERN

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Abstract

Summarized are properties of 10 MW ESS H⁻ SC Reference Linac, as described in ESS Update Report 2003. Particles are either injected into 2 accumulator rings, resulting in 1.4 µs pulses sent to a short pulse target station, or 2 ms long pulses directed to a long pulse target station. The 10 MW, 1.334 GeV ESS H⁻linac is 570m in length, modular cryomodules are used above 400 MeV with separated warm quads.

After winding up the ESS Council and the Technical Team by the end of 2003, the neutron scattering community wanted to keep ESS on the political table and demonstrate to young scientist that the struggle for ESS goes on. For this purpose, the ESS-Initiative (ESS-I) was formed to include the European Neutron Scattering Association (ENSA), various consortia for site candidatures and some key European laboratories.

A major highlight was the successful promotion of ESS to be as a high maturity project on the European Road Map of Research Infrastructures, published in October 2006 by the European Strategy Forum on Research Infrastructures (ESFRI). The ESS Preparatory Phase project has been accepted in the meanwhile after a very positive assessment and has been allocated 5 M€ EU support to investigate site independent technical items and answer legal, financial and governance questions, starting January 2008.

ESS 07 will be a 5 MW LP source, the worlds first one to offer the unique capabilities of novel long pulse instruments for almost all of the most interesting areas of science and technology. ESS will be built in such a way that governments can decide later on during its lifetime to increase power and add more target stations, as the future scientific need would arise.

The 5 MW, 1 GeV ESS H⁺ linac is similar to the ESS H⁻ SC Reference Linac, but only 464m in length, as more intense H⁺ sources are available. ESS's world lead would become even more pronounced, even when SNS would upgrade its power to, say, 3 MW, if the ESS beam power would be increased to 7.5 MW. This goal is achievable by enlarging the linac tunnel by 115m, which allows to add later on 16 cyromodules, and increasing the accelerating gradient in all SC cavities by 15 %. The H⁺ linac length of 579 m in this case would still not be larger than the ESS H⁻ SC Reference Linac.

Synergy with the CERN plans would require to avoid the funnel section at 20 MeV, leading to a 5 MW LP power at 2 GeV. Linac length is unchanged by using accelerating high gradient in SC cavities. SPL frequencies can be used, but components will differ, as ESS LP source requires high current and long pulses, whereas SPL linac is designed for high energy and high rep. rate.

ESS UPDATE REPORT, 2003

The European Spallation Source (ESS) project, as defined by the four volumes ESS Report 2002[1], 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, May 2002.

In January 2003 it became clear, that a decision to built ESS would not be likely forthcoming by the end of early 2004. The ESS council therefore decided to wind down all technical & project planning activities and limit the ESS efforts to documenting the technical and planning status.

The ESS Update Report, Dec 2003[2], is a summary of the amount of work, technical definition & progress achieved during the period from May 2002 to early 2003. Main new items are description of SC Reference Linac and improved chapter on Safety and Licensing

Full ESS facility consists of a 10 MW, H⁻ accelerator capable of delivering 5 MW, 1.4 µs pulses to a short pulse (SP) target at 50 Hz & 5 MW, 2 ms pulses to a long pulse (LP) target at 16 2/3 Hz.

In order to deliver 5 MW power in about 1.4 µs to the SP target, the ESS facility needs two accumulator rings with 35 m mean radius in a shared tunnel. Two accumulator rings are necessary to keep temperature rise of H⁻ stripping foils within reasonable limits. Prototype laser striping experiments are performed at SNS, up to now not scalable for MW beam power values[3].

Both targets have 22 beam lines and liquid Hg is chosen as target material. Required area for full ESS facility is 1150 m x 850 m.

SC Reference Linac:114 mA,1.334 GeV, 10 MW

Layout of ESS H⁻ SC Reference Linac is shown in Figure 1. 2 x 65 mA H⁻ beams are combined together at 20 MeV in a funnel section. High frequency Superconducting (SC) cavities accelerate the beam from 400 MeV on. Moderate gradient of 10.2 MV/m in SC linac is used to keep RF power couplers within reasonable limits, 11 % RF duty cycle. After reducing energy spread by bunch rotation (BR) to ±2 MeV, either halo scraping in large 180° achromatic section before injecting into both accumulator rings or 99 m transport to LP target.

The 1.334 GeV H⁻ linac is 570 m in length, 748 m from ion source to LP target, 95 m in length. Linac energy is determined by loss free ring injection. Chopper line needs low frequency to absorb 10 kW power at 4 locations, high frequency SC cavities have large bandwidth and stiffening.
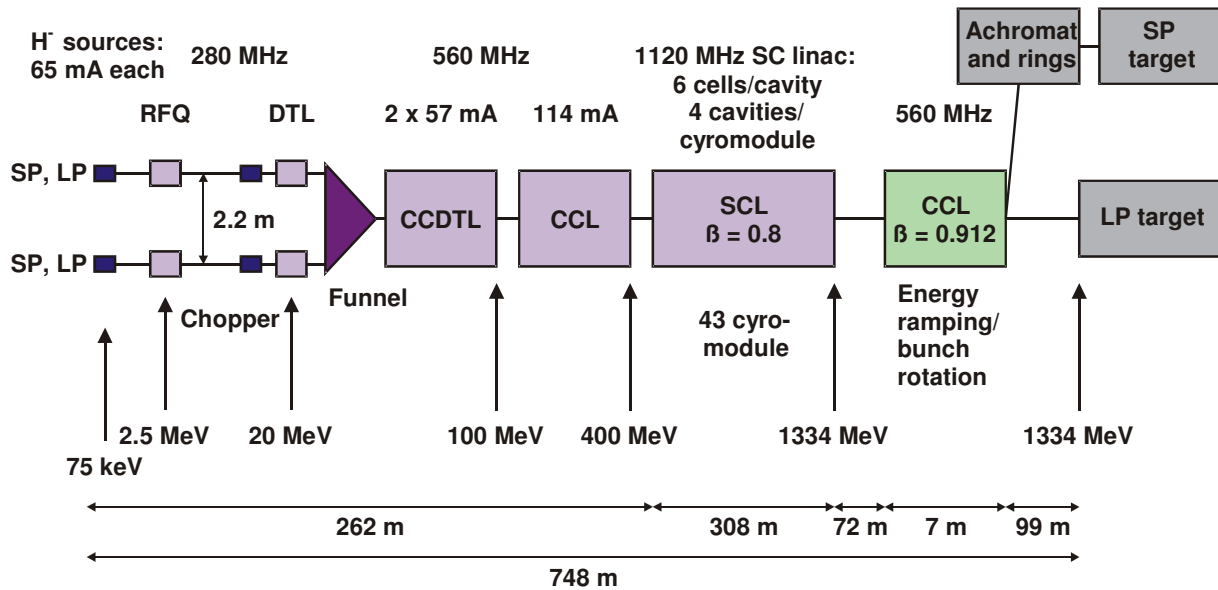
Figure 1 : ESS H⁻ SC Reference Linac, serving SP&LP targets

ESS H⁻ linac: double pulse for SP&LP targets

Two ESS accumulator rings get 2 x 0.48 ms long pulses, 600 turns per ring, with 70% chopping to leave a time gap for the ring extraction kicker magnets. A 100 μs gap is required for vertical deflection of the linac pulse between the rings. LP target get 2 ms pulse, no chopping, which requires 50% more power in SC coupler.

ESS double pulse sequence requires 2 ms unchopped pulse and only 7.7 ms time gap to next 1ms chopped pulse, shown in Figure 2. Not shown is voltage stabilization before beam arrival, done by closing RF loops and reducing RF power, and two other chopped pulse, send to SP target .As consequence, wall deformations are still present at beginning of next chopped pulse[4], requiring sophisticated RF control system, being easy at high frequency, as cavity bandwidth & stiffness are increased.

The ESS facility unique in its neutron scattering performance, but is challenging for same ESS linac components: the front end with its chopper/collector system and layout/RF control of pulsed SC cavities.

The chopping line must be able to switch the beam on and off between RF bunches resulting in elements with a rise time of less than 2 ns to avoid beam loss further down the accelerator. The beam collection system must be able to cope with up to 10 kW power, since both the SP and LP beam will be chopped initially.

The 280 MHz low frequency front end houses the ESS chopper line with its 2 innovative chopper/ collector systems[2,5], collecting up to 10 kW beam power in total 4 different positions. The 57 mA H⁻ bunch is kept focused in all 3 directions by using combined function elements between the deflectors. The complete chopper line from RFQ to DTL entrance is about 3.5 m in length.
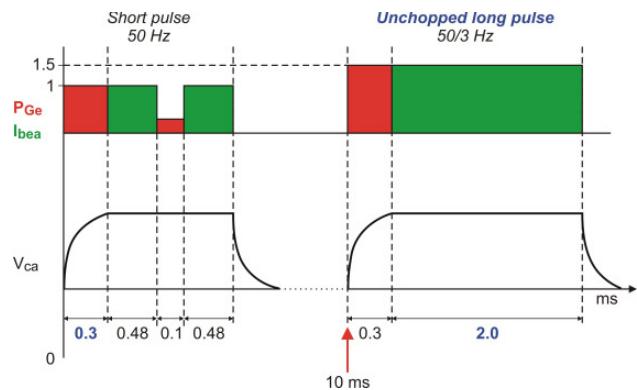

Figure 2: ESS double pulse sequence in SC cavities V_{ca} = cavity voltage, P_{ge} =RF generator power I= beam current, normalized to 70 % chopping .

For Gaussian test bunch at RFQ exit, particle tracking was performed up to 20 MeV DTL end, leading to very small filamentation. [6].

The main concern, however, are RF phase & amplitude jitter due to ringing of the power supplies. First simulations are indicating much smaller energy, phase deviation of the beam at 20 MeV [6], than used for the particle tracking along the SC linac, see beam dynamics section afterwards.

1120 MHz ESS SC high β linac

Above 400 MeV, 1120 MHz SC cavities accelerate the ESS beam up to its full 1334 MeV final energy. SC structures offer a reduction in operating costs compared to warm NC ones, but it requires a careful look at the pulsed RF control system especially fore the double pulse to SP&LP targets.. Higher frequency SC structures are beneficial for the demanding ESS requirements and offer headroom for capital cost saving. As the ESS front end prefers low frequencies, a change in frequency from 560 MHz to 1120 MHz at 400 MeV is foreseen for the ESS SC Reference Linac.

Schematic drawing of a lattice period of the ESS SC linac is shown in Figure 3, adapted from SNS high ß SC linac. SNS high ß cryomodule can be quickly disconnected from the beam line , energy upgrade is planned by adding cryomodules afterwards[7].

The SC part of the ESS linac uses 43 cryomodules, each housing 4 elliptical bulk Nb SC cavities, 4cm iris aperture, 0.7 m cavity to cavity spacing. Large aperture minimize the risk of inadequate damping of higher order dipole modes which could be excited by the beam. Each cavity consists of 6 cells of ß=0.8 equipped with one SC main coupler. Doublets in the warm intersections provide the transverse focusing, see Figure 3. Each quadrupole is 30 cm in length, has 14 T/m focusing strength and 4 cm aperture radius.
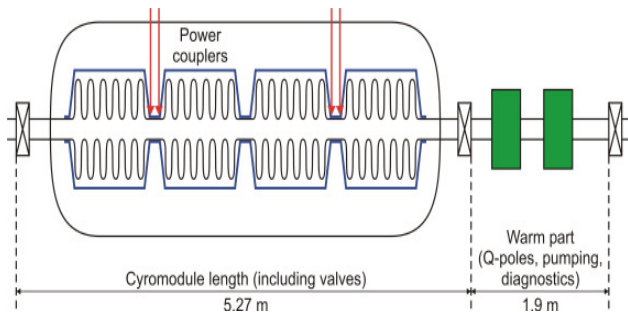

Figure 3:Schematic drawing of a lattice period of ESS SC linac

As the overall RF duty cycle is about 11%, we limited ourselves to only 0.85 MW peak power for the 114 mA LP beam, included are 30% surplus for RF control, leading to 80 kW SP&LP averaged power. Not planned was use of two couplers / cavity, as major concern about voltage stabilisation by RF vector-sum , lack of individual knobs for both couplers.

Only 10.2 MV/m accelerating gradient at $Q_0 = 10^{10}$ (2K) is required, keeping peak surface peak magnetic / electric field well below 50 mT / 25 MV/m. Matched 3 db cavity bandwidth is ±2 kHz for the 114 mA LP beam and R/Q=440Ω/m, linac definition. For the 1 ms, 70% chopped pulse to SP target, Figure 2, voltage fluctuation due to mismatch can be compensated by the foreseen 40% RF control power. Cavity stiffening methods for reducing the Lorentz-force frequency detuning are under investigation, absolutely necessary even for the envisaged 10.2 MV/m accelerating gradient due to the ESS double pulse,Figure 2. Sufficient cell-to-cell coupling is required.

Symmetric arrangement of power couplers leads to only 2 feed through per cryomodule. No power spitting between cavities, but combined High Voltage Power Supplies (HVPS) with central energy storage. Klystron peak power varies only by 25% along the SC linac.

Beam Dynamics in 1120 MHz SC high ß linac

Detailed Monte Carlo simulations with complete 3d space charge have been performed to demonstrate the

capability of the 1120 MHz ESS SC linac to handle the 228 mA bunch current (114 mA pulse current) from 400 MeV onwards by using ß=0.8, 6 cell cavities only. Figure 4 shows the phase slip of the bunch centre for each cell of the total 172 cavities. The phase is always between ±90°, which means energy gain in each cell and therefore stable synchrotron oscillations. Figure 5 show quite small longitudinal filamentation at ring injection.
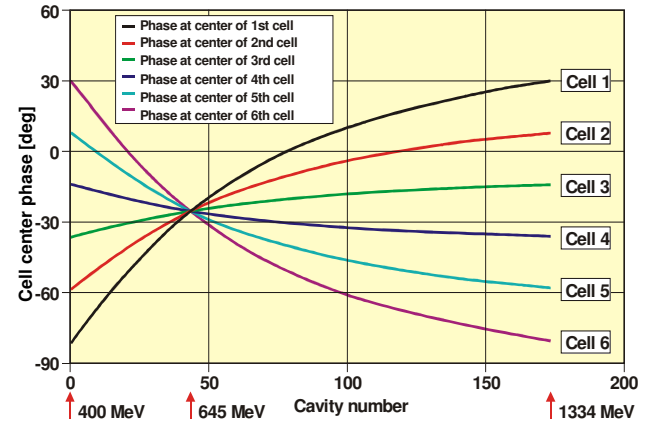

Figure 4 :Phase slip of the bunch centre in each of the six cells for all 172 SC cavities.

Maximal energy gain of 5.65 MeV/cavity occurs at 645 MeV, ß=0.8, 5% higher than average gain of 5.43 MeV/cavity. Minimal energy gain of 4.24 MeV occurs at 1.334 GeV final energy [8].

The transverse full current tune is set to be 45° all along the ESS linac. Tune depressions are above 0.55 and the transverse / longitudinal temperature ratio varies between 0.3 and 1.3 [9],avoiding emittance exchange during acceleration, see Figure 5. Less than 10 % rms emittance increase.

For high current linacs, onset of envelope instabilities must be avoided, limiting longitudinal zero current tune below 90° [10], being in conflict with high accelerating fields and long SC lattice periods. For the 7.17 m long ESS SC lattice and at 400 MeV, accelerating gradient has to smaller than 16 MV/m.

For a matched 6d Gaussian "control" beam as input to the SC linac and in the absence of RF field errors, very little filamentation is seen at 1334 MeV and the energy spread at the ring injection point, 71 m behind the BR cavity, is limited to ±0.5 MeV, only a quarter of the ±2 MeV constraint for loss free ring injection, red lines are ±0.5 MeV boundaries .Transverse & longitudinal rms emittances at 400 MeV are assumed to be 20% larger than those at 20 MeV. Beam radii are smaller than 1 cm all along the SC linac, maximal phase extend is about ±30° (1120 MHz), position of BR cavity.
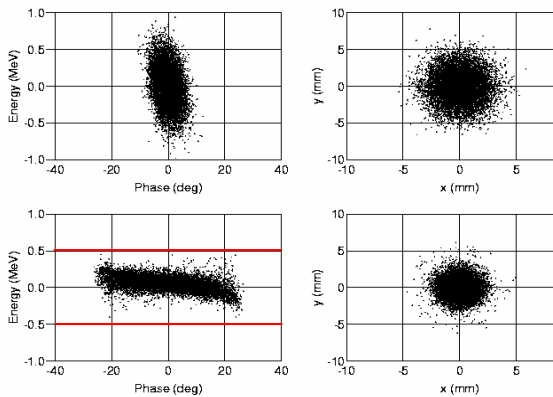
Figure 5 Longitudinal phase space & beam radii along the ESS SC linac for a matched 6d Gaussian "control "beam and without RF errors. 1.row is at 400 MeV injection, 2.row at 1334 MeV ring injection.

Energy spread reduction is obtained by placing warm ß=0.912 CCL structures 78 m downstream the SC linac, delivering a 13 MV rotation voltage to the beam, see Figure1. Due to 228 mA bunch current, rms energy spread increases by more than a factor 2 between linac end and position of BR cavity.

As accumulated errors in the NC part of the ESS linac leads to mismatch and phase space filamentation at injection into the SC part, we carefully checked the design of the 228 mA SC linac to be insensitive against strong initial mismatch and different input distributions. As an example we excited a pure "low" mode (radial by +15%, axial by –30% change in initial radii) at 400 MeV for a 6d Gaussian "control" beam in an error free SC linac. Both radii are oscillating out of phase with the bunch length (rms phase width), as expected [11]. In phase oscillations of the transverse beam radii are visible all along the linac and up to ring injection. The beam is kept transversely focused.

Resulting phase space and radii plots show much larger axial than radial filamentation compared to the matched case of Figure 5. This is as predicted for the "low" mode excitation, as at input only longitudinal halo particles can be in resonance with the oscillating beam core [11].The energy spread at the ring injection point is limited to ±1 MeV, still only half of the ±2 MeV constraint for loss free ring injection. About 10^{-3} particles are outside ±0.5 MeV.

Exciting the "low" mode or another bunched beam eigenmode [11] for a 6d Waterbag instead of a Gaussian beam at 400 MeV leads to almost the same phase space plots at ring injection, indicating the insensitive of the 228 mA ESS design against details of the input distribution.

RF field errors along the ESS linac will lead to a shift of the beam centre in energy and phase/time, possibly leading to unacceptable large energy shifts after final bunch rotation. The input values at 400 MeV of ±4.5° (1120 MHz) phase resp. ±1.3 MeV energy deviation of the beam centre, accumulated from RF errors in the

preceding warm structures, are about 10 times larger than obtained after the DTL at 20 MeV [6].

Assuming ±1%, ±1° RF amplitude and phase errors in each SC cavity, randomly distributed along the 172 SC cavities, and applying the same bunch rotation voltage as used for the Gaussian "control" beam, energy deviation of the bunch centre is reduced by a factor 2, ±1 0 MeV after bunch rotation in about 1 in 10^3 cases, see Figure 6.The red curves represent 10^{-3} error boundary, increased by more than factor 2 due to RF random distributed RF errors in the SC cavities. Red lines are ±1 MeV boundaries.
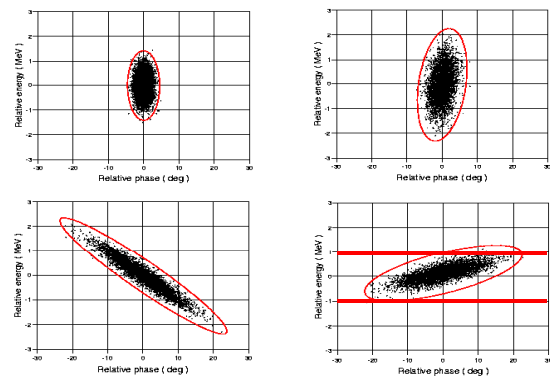

Figure 6 :Scatter plot along the ESS SC linac

Phase displacement of bunch centre is increased to ±25° (1120 MHz), result of accumulated RF amplitude and phase errors. As consequence, single particles can be ±50° (1120 MHz) away from design phase , excluding use of a SC ß=0.8, 6 cell cavity for energy spread reduction. There is no phase slip by using 560 MHz CCL, ß=0.912, and maximal single particle phase deviation is only ±25° (560 MHz).

ESS INITIATIVE (ESS-I) AND ESFRI REPORT 2006

After winding up the ESS Council and the Technical Team by the end of 2003, the neutron scattering community wanted to keep ESS on the political table and demonstrate to young scientist that the struggle for ESS goes on.

For this purpose, the ESS-Initiative (ESS-I) was formed [12] to include the European Neutron Scattering Association (ENSA) [13], various consortia for site candidatures and some key European laboratories.

ILL Grenoble is hosting ESS-I, and it is lead by an independent chair. The overview given here borrows from what Peter Tindemans, chair of ESS-I, presented at ICANS XVIII, Dongguan, April 2007[14].

A major highlight was the successful promotion of ESS to be as a high maturity project on the European Road Map of Research Infrastructures, published in October 2006 by the European Strategy Forum on Research Infrastructures (ESFRI) [15]. In doing so, ESFRI has both honoured and vindicated the effort of all major neutron

labs and more than 100 leading scientists all over Europe who for the past 13 years have developed the ESS project.

ESS will be a 5 MW LP source, the worlds first one to offer the unique capabilities of novel long pulse instruments for almost all of the most interesting areas of science and technology. The intention is that ESS will be built in such a way that governments can decide later on during its lifetime to increase power and add more target stations, as the future scientific need would arise.

ESS's world lead would become even more pronounced, even when SNS would upgrade its power to, say, 3 MW, if the ESS beam power would be increased to 7.5 MW.

ESS PREPARATORY PHASE PROJECT & 3 SERIOUS SITE CANDIDATES

A special call was issued by the EU for projects on the ESFRI Road Map to submit ESS EU FP 7 Preparatory Phase projects. ESS has done so and asked for financial support to site independent technical items and answer legal, financial and governance questions concerning ESS. The ESS Preparatory Phase project has been accepted in the meanwhile after a very positive assessment and has been allocated 5 M€ EU support to investigate all the issues mentioned above, starting January 2008.

A coordination team involving members of all 3 site candidates leads the ESS Preparatory Phase project.

Sweden: Lund

Sweden proposes to locate ESS in Lund[16], and offers to pay about 30% of construction costs. A new organization has been set up temporarily at Lund University, to be transformed later as a national structure. 10 M€ is available till the end of 2008. ESS will have a carbon-neutral, energy-efficient concept. In March 2007, ESS-S organized a well attended target workshop at Lund. Negotiations have now started with various countries and a series of Round Tables is being organised.

Spain / Basque Country: Bilbao

Spain has put forward a bid to host ESS near Bilbao[17]. It too offers around 30% of construction costs, and has made available funds for the current phase. It has recently joined forces with Hungary by concluding an MoU to coordinate the search for international partners. Spain and Hungary will appoint a joint Project Director and a joint International Advisory Board. The Spanish, as well as the joint Spanish/Hungarian financial bid are based on the idea that shares will be issued which provide use rights. Two sites are being discussed, both close to Bilbao.

Hungary: Debrecen or Székesfehérvár

Hungary too offers to host ESS[18], and is willing to pay a substantial share of the construction costs. Spain and Hungary have agreed on a procedure to select the site, if ESS goes their way. For Hungary, the first phase of the site selection has reduced 6 candidates to 2, one site in Debrecen, the other in Székesfehérvár, some 50 km from Budapest. Hungary has a financial scheme quite similar to the Spanish one.

The aim is now to arrive at a site decision early 2008, and a full financial governmental agreement by the end of 2008. In that case the ESS facility can deliver its first neutrons by the end of 2017 with full operational mode in 2019/2020. For all the three sites, the ESS facility will not be regarded as a nuclear facility.

ESS 07: 5 MW LP SOURCE, POSSIBLE FOR UPGRADE

improved neutron performance

Stimulated by the ESFRI 2003 findings [19], beginning 2003 discussions started about the scientific relevance of pure LP facility, compared to full ESS facility, SP&LP target stations.

In response to these discussions, layout of 15 MW, 3 GeV H^+ linac was included in ESS Update Report 2003.
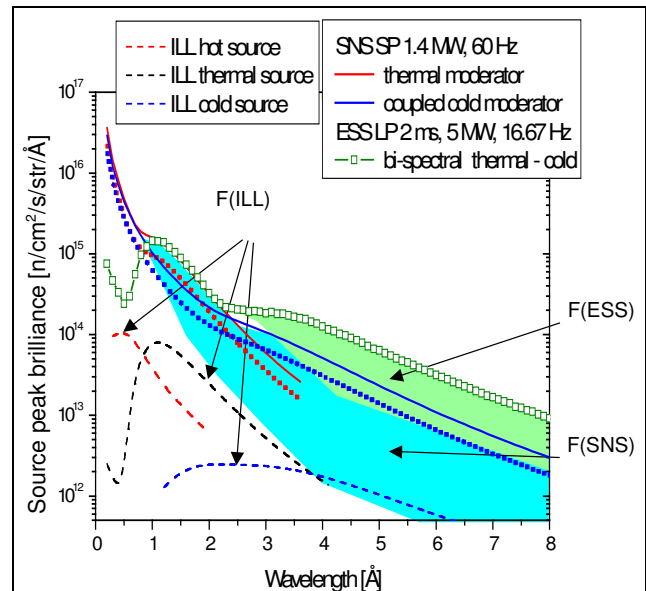

Figure 7 : neutron flux, figure of merit (F) for proposed ESS 5MW LP source compared to most powerful reactor & SP facility

Since than, neutron instrument experts and instrument modellers discussed and assessed potential gains expected from the ESS LP target station with bi-spectral thermal-cold moderators. Results were accepted at the ESS-I Rencurel workshop, Sep2006 [20]. Confirmed was multi-spectral beam extraction scheme, mentioned in ESS Update Report, meanwhile successfully implemented and tested at BENSC EXED beamline [21]. Improved neutron fluxes for 5MW ESS LP source are shown in Figure 7 [22].

Compared to fully upgraded ILL reactor at Grenoble or to 1.4 MW SNS SP facility, most powerful existing ones, proposed 5 MW ESS LP source will leap in neutron performance, as for thermal neutrons: 20x ILL & (1-5)x
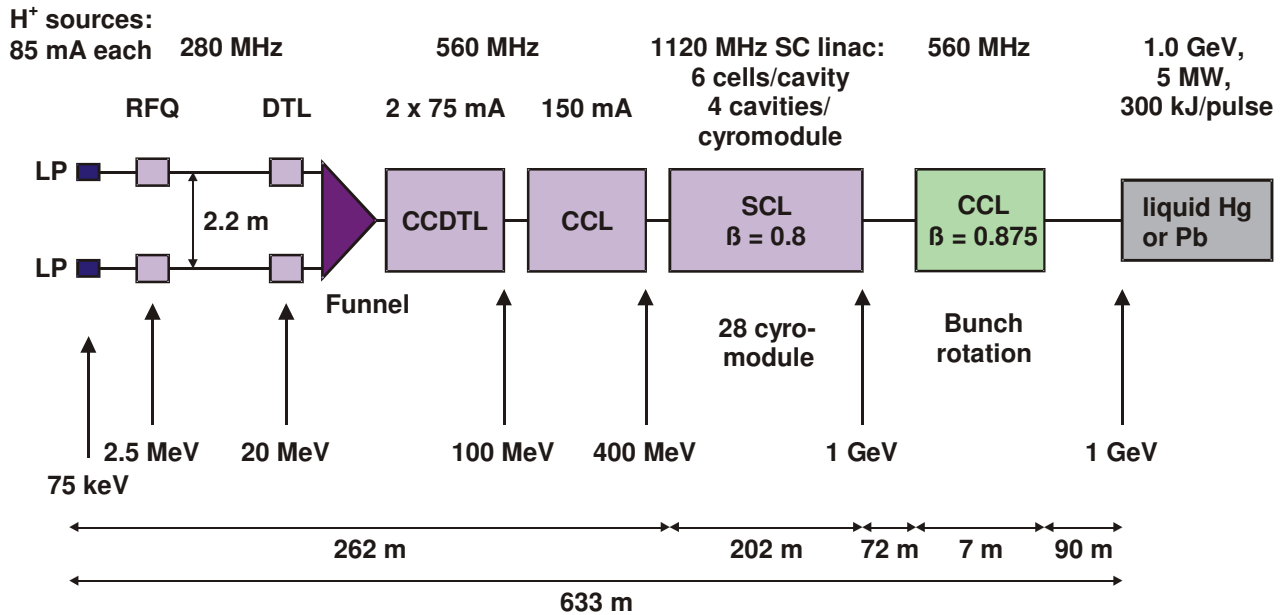
Figure 8: ESS H+ SC linac, serving only LP target

SNS, whereas for cold neutrons: (10-40)x ILL & (3-15)x SNS. Hot neutrons (wavelength <0.7 Å, 100 meV to beyond 1eV) are relatively small chapter of neutron research, well served by existing reactors with hot source and SP sources.

ESS H+ linac layout & target options

Layout of 5MW ESS H+ LP facility is shown in Figure 8, based on the ESS H- SC Reference Linac, using more powerful H- beam instead, but without 2.5 MeV chopper line and achromatic bending section. Serving only LP target station, 2 ms pulse every 60 ms, 16 2/3 Hz, allows to have 150 mA current after 20 MeV funnel section. Reduced linac energy of 1 GeV requires only 28 cryomodules from 400 MeV on, 202 m in length,for unchanged moderate accelerating gradient of 10.2 MV/m.

Peak power in SC main coupler is less than 1.15 MW, including 30% surplus for RF control, whereas average power is reduced to less than 45 kW, as only 4% RF duty cycle, 2.3 ms every 60 ms. 262 m NC 400 MeV linac is unchanged in length, but with reduced structure cooling. Two more 5 MW peak power klystrons are needed for CCL section, as increased linac current. Linac length is 464 m, whereas 633 m is total length from H+ source to LP target, about 95 m in length.

Similar to layout of ESS H- SC Reference Linac, energy spread is reduced by 560 MHz BR cavity, 20 MV rotation voltage & 3.5 MW peak RF power, needed to install dipol magnet before LP target in order to reduce backstreaming neutrons in 90 m long transport line. BR cavity is placed 72 m behind linac end, same distance as for ESS H- SC Reference Linac. Larger increase in energy spread for 150 mA, 1 GeV H+ beam, compared to more than factor 2 for 114 mA, 1.334 GeV H- beam, is tolerable, as less restrictions for H+ beam, but has to be studied.

Liquid metal target are preferred choice for ESS LP target station, either with Hg or Pb eutectics. Pb/Bi Megapie target at PSI Zürich was successful operated with 1600 MWh accumulated power during 4 month period, August to December 2006 [23].After stop of the beam, Pb/Bi eutectic in the target has been solidified. After extraction from SIN-Q facility, the target will be stored for about one and a half years. It will than be opened and the status of the internal components and structural materials will be analysed.

Thermal-hydraulic studies are required for both target materials. ESS LP target station has 22 beam holes, but multi-spectral beam extraction scheme allow to install up to 44 instruments afterwards. In terms of capacity, ESS plant will than provide twice as many beamlines for experimental work as SNS and J-PARC.

Performance & power upgrade

The 1 GeV, 5 MW ESS H+ linac is a cost effective and power efficient accelerator for a LP neutron facility, therefore decided to be the basis of the ESS EU FP 7 Preparatory Phase project. Scientific capability is doubled by installing additional instruments afterwards.

In order to pronounce ESS facility as the world leading neutron source, even when 3 MW SNS, Japanese MW J-PARC facility [24]and fully upgraded ILL are ready, ESS beam power should be 7.5 MW, 50% increase. As 2 ms pulse length and 60 ms rep. time are fixed parameters for LP target, either current or energy must be increased. Increase of H+ source current is not considered, as two almost identical high current H+ sources are required.

As accelerating gradient in NC structures is also fixed, only enlarged can either linac tunnel and / or accelerating gradient in SC cavities. High ß bulk Nb SC cavities are tested for much higher gradients than assumed10.2 MV/m, but not for 2 ms pulse length. In addition, shortening rep. time limits accelerating gradient in high ß

SNS SC cryomodules, as cross-talk of the 4 cavities inside one cryomodule [25]. But as ESS LP source has 60 ms rep. time, almost factor 4 longer than SNS value, latterly 15% increase of accelerating gradient leads to 700 MeV energy gain instead of 600 MeV. Klystrons and SC couplers are designed for 30% surplus in peak power, reducing RF control power from 30% to 15% is possible after extended learning period.

Enlarging linac tunnel by 115m allows to add latterly 16 cryomodules, leading to additional 400 MeV energy gain, also operating at 15% higher gradients. Total length from H^+ source to 7.5 MW LP target is 748 m, almost the same as for 5 MW ESS H^- SC Reference Linac. Without 15% larger gradients in SC cavities, 6.7 MW beam power is reached at 1.35 GeV. BR cavity can still be placed 72 m behind linac end, maybe improved adjustment of linac bunch is necessary by phase shifting of same previous SC cavities. 90 m long transfer to LP target is adequate even for a 1.5 GeV beam.

For optimal neutron production rate, maybe moderators in LP target must be changed for going from a 1 GeV, 5 MW beam to a 1.5 GeV, 7.5 MW beam. Enlarged pulse content of 450 kJ must be considered.

Adding latterly dedicated low power target station, like proposed long wavelength one for SNS[26], is possible by adding pulsed dipol after BR cavity. Innovative chopper collector systems can be easily added into 2.5 MeV transfer line from RFQ to DTL.

As higher accelerating gradients are possible for the ESS H^+ linac, changing from 6 cells, ß=0.8 SC cavity to 5 cells, ß=0.85 SC cavity gives less phase slip at 400 MeV and improved energy gain up to 1.5 GeV, as maximal efficiency is shifted towards 850 MeV, see Fig4. Symmetric 5 cell cavity maintain field flatness over a wide tuning range by providing an identical deformation of both end-cells. Cryomodule and SC linac length are unchanged in length, if accelerating gradient is increased by less than 12%.

SYNERGY WITH CERN

The 1 GeV, 5 MW ESS H^+ linac is a cost effective and power efficient accelerator for a LP neutron facility, but needs 3 different frequencies due to 20 MeV funnel. Low energy, but high beam current requires moderate accelerating gradient in SC cavities to limit peak values in SC power couplers.

Layout of 1 GeV, 5 MW ESS H^+ linac is unique, as most other pulsed high power linacs need high energy, less current. But ESS H^+ linac can also operate at slightly modified frequencies, 325/650/1300 MHz, to more overlap with CERN & DESY, leading labs for NC&SC parts.

Planned CERN Linac4 operates at 350 MHz, the 1st NC H^+ linac to be built in Europe after 30 years[27].Construction of Linac4 (160MeV,H^-) is approved as a high priority project intended to start in January 2008 and last 4 years(2008-2011).The 2012 PS Booster start-up is foreseen with the new Linac4 beam.

Tesla Test Facility at DESY has produced more than 100 ß=1 multi-cell 1.3 GHz SC cavities, reaching gradients well above 20 MV/m, .installed in long cryomodules[28]. Multi-beam klystrons with more than 10 MW peak power are driving string of cavities, 1 ms pulse and 5 Hz rep. rate.

Using 5 cells, ß=0.85 1.3 GHz SC cavity above 400 MeV for the ESS H^+ linac require accelerating gradient below 15.3 MV/m to preserve 748 m length of ESS 7.5 MW H^+ facility.. Matched 3db cavity bandwidth is ±1.5 kHz for the 114 mA LP beam and R/Q=440 Ω/m, linac definition. Investigated must 1.3 GHz SC main couplers, 1.15 MW peak power for 2.3 ms and average power of 45 kW.

Avoiding 20 MeV funnel section will give 5MW LP power at 2 GeV. For the ESS SC lattice period, shown in Figure 3,linac length is unchanged by using about 25MV/m accelerating gradient in SC cavities. In Table 1, main linac parameters are shown for 2 GeV, 5 MW ESS H^+ linac, compared to 5 GeV, 4 MW CERN SPL one [29].

Table 1: 5 MW ESS compared CERN-SPL

	ESS: 5 MW LP	CERN-SPL: 4 MW
Energy, length	2 GeV, 464 m	5 GeV, 534 m
Pulse current	75 mA	40 mA
Pulse length, rep. rate	2 ms, 16.67 Hz	0.4 ms, 50 Hz
Klystrons, cavities in high ß SC part	112, 112: no power splitting	32, 136: up to 8 fold power splitting

Synergy with the CERN plans would require to avoid the funnel section at 20 MeV, leading to a 5 MW LP power at 2 GeV.Linac length is unchanged by using high gradient in SC cavities. SPL frequencies can be used, but components will differ, as ESS LP source requires high current and long pulses, whereas SPL linac is designed for high energy and high rep. rate. SPL design report, including costs, will be available in 2011 / 2012.

SUMMARY

After completing ESS Update Report by end of 2003. aiming for 10 MW H^- facility with SP and LP targets, neutron scientist have gained improved understanding for unique capabilities of novel long pulse instruments.. ESS 07 will be a 5 MW H^+ facility serving only LP target, built in such a way that governments can decide later on its lifetime to increase power and add more target stations, as the future scientific need would arise.

Later on, goal of 7.5 MW beam power is achievable by enlarging linac tunnel by 115m, allows to add latterly 16 cyromodules, and increasing accelerating gradient in all SC cavities by 15%.

Avoiding 20 MeV funnel section will give 5 MW LP power at 2 GeV. Linac length is unchanged by using high accelerating gradient in SC cavities. SPL frequencies can be used, but components will differ,as ESS LP source

requires high current and long pulses, whereas SPL linac is designed for high energy and high rep. rate.

ACKNOWLEDMENT

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