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Costs to Shorten the Pulse and Increase the Peak Power

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The ESS linac will be design to produce a peak proton current of 50 mA at 2.5 GeV in 2 ms long pulses with a repetition rate of 20 Hz. There is however a desire to shorten the pulses to 1.3 ms and increase the peak current to 75 mA, as to keep the average beam power of 5 MW the same. The task of this note is to estimate the increased capital costs and power consumption in terms of scaling laws.

Assume that the maximum power to the beam per high beta ellitical cavity is 1 MW, then for each mA increase in peak current, an additional

$$N = \frac{2.5 \text{ GV}}{1 \text{ MW}} = 2.5 \text{ cavities/mA}$$

number of high beta elliptical cavities is needed. Thus, to increase the peak power from 50 mA to 75 mA, 63 extra cavities are needed.

To do a better estimate we need a reference layout for the ESS accelerator that does not take into account future upgrades. The latest baseline, which was presented at IPAC'10 [1] is however optimized for a peak current of 75 mA, but operated at 50 mA. The superconducting part of this accelerator is made up of 42 triple spoke resonators, 40 low beta elliptical cavities and 152 high beta elliptical cavities, i.e., a total of 234 superconducting cavities. An upgrade to 75 mA is done by adding 16 high beta elliptical cavities.

If we compare this configuration with the baseline presented at PAC'09 [2], which includes 24 single spoke resonators, 32 triple spoke resonators, 40 high beta elliptical cavities and 96 high beta elliptical cavities, we can conclude that the superconducting part of the accelerator has increased by 42 cavities, only in order to prepare the accelerator for a future upgrade.

The baseline of PAC'09 is based on single and triple spoke cavities. Since then the design has shifted towards a layout with only one type of spoke resonators. Therefore, the reference Linac in this work will be an accelerator

Table 1: Block layout of RF super conducting structures based on data from Mohammad Eshraqi

Structure	**Energy** [MeV]	**Freq.** [MHz]	**Cavities**	**Length** [m]
Reference baseline				
Spokes	260	352.21	$16 \cdot 3 = 48$	64
Elliptical 1	570	704.42	$9 \cdot 4 = 36$	53
Elliptical 2	2500	704.42	$14 \cdot 8 = 112$	169
In total			**196**	**286+30**
Upgradable baseline				
Spokes	200	352.21	$14 \cdot 3 = 42$	51
Elliptical 1	500	704.42	$10 \cdot 4 = 40$	57
Elliptical 2	2500	704.42	$19 \cdot 8 = 152$	215
In total			**234**	**324+30**
Upgraded baseline				
Spokes	200	352.21	$14 \cdot 3 = 42$	51
Elliptical 1	500	704.42	$10 \cdot 4 = 40$	57
Elliptical 2	2500	704.42	$21 \cdot 8 = 168$	238
In total			**250**	**347+30**

using one type of spoke resonators, as in the IPAC10 paper, but which is optimized and operated at 50 mA. The block of rf structures for this linac is shown in table 1 together with parameters for the upgradable baseline (optimized for 75 mA and operated 50 mA) and the upgraded baseline (optimized and operated at 75 mA). The power to the beam for these three examples are shown in fig 1

From table 1 it can be concluded that an increase in peak power from 50 mA to 75 mA leads to an increase of the total Linac length from 316 m to 377 m, i.e. by 61 m. The number of cavities increases from 196 to 250, or by 28 %. Assuming that the capital cost for the warm part of the accelerator is negligible, then it follows that a 50% increase in peak power increases the total cost of the accelerator and rf power source by approximately 30%.

Another interesting detail is the power consumption. By lowering the pulse with from 2 ms to 1.3 ms, the average beam power is still 5 MW. Howerver, the rf power consumption will increase due to the fact that the

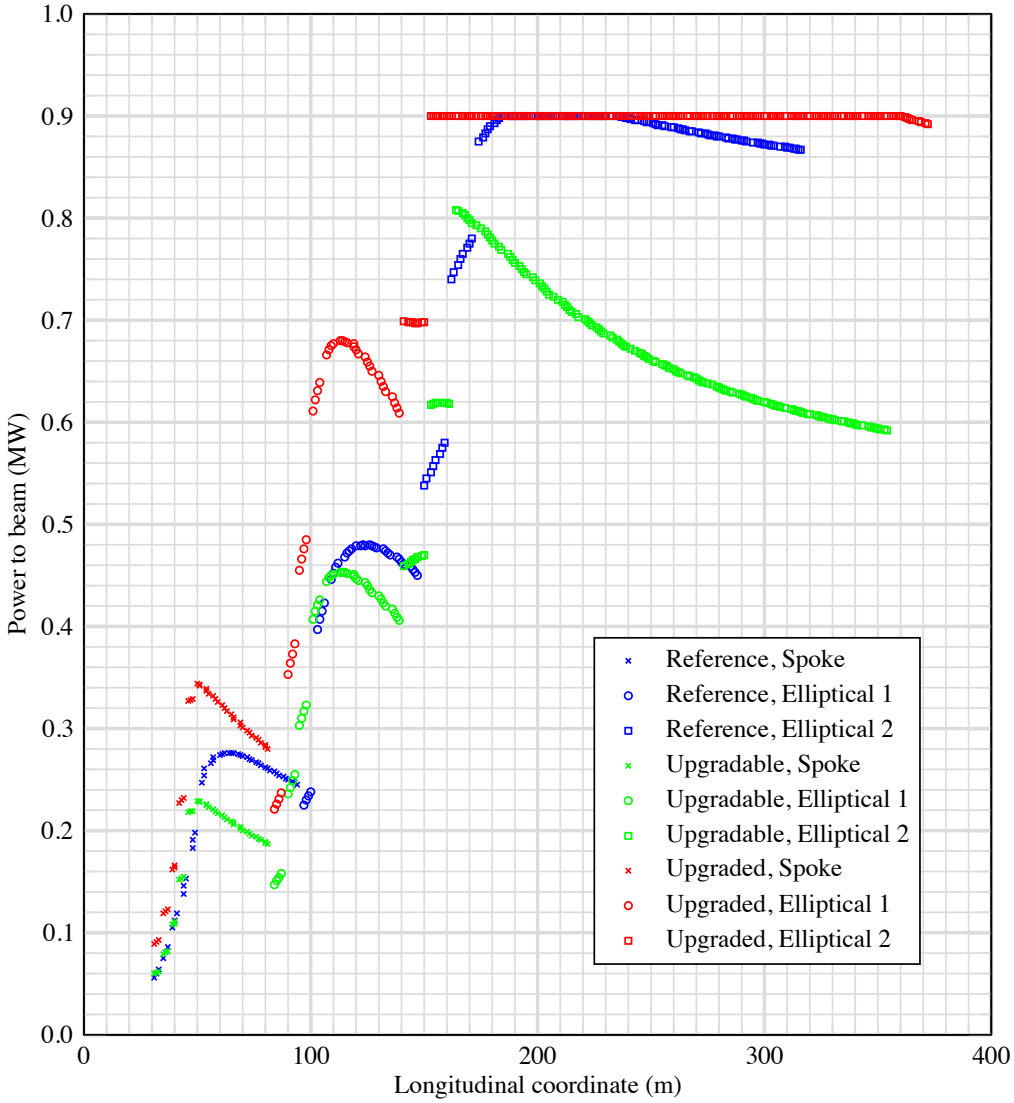

Figure 1: The power to beam for the three accelerator configurations given in table 1. Calculations by Mohamad Eshraqi.

filling time is still 0.5 ms. [1] Therefore, the efficiency in the klystron gallery is reduced from 30% to approximately 25%, which increases the power consumption from 17 MW to 20 MW. Assuming 5 280 h annual operation of the facility (including start up and and r&d) the annual power consumption increases from 92 GWh to 106 GWh. This corresponds to an increase in power usage for ESS as a whole, which is roughly 300 GWh, by 5%.

References

[1] M. Eshraqi et al. Conceptual Design of the ESS Linac. In *Proceedings of IPAC'10, Kyoto, Japan*, 2010.

[2] S. Peggs et al. Conceptual Design of the ESS-Scandinavia. In *Proceedings of PAC09, Vancouver, BC, Canada*, 2009.

[1] If the accelerator is upgraded from 50 mA to 75 mA then the power coupler will not be matched for both peak currents, which is not taken to account in this calculation.