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Can we improve sustainability of large scale SRF accelerator driven science?

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To start with a prominent example, the LHC at CERN transforms yearly electric energy, which is comparable to a twohundred thousand citizen town in a developed country or the whole Kanton of Geneva with half a milion inhabitants.
The European XFEL's RF system alone requires 5 MW of power input. In the view of these numbers and regarding how fast
human driven climate change is accelerating, especially actually in Europe, any large scale future scientific installation
needs to tackle the problem to significantly reduce the required power for accelerator driven experiments and also to maximize
the figure of merit, which could be for example luminosity or brilliance per kW.
Energy recovery linacs (ERL) form a class of SRF driven accelerators, which are inherently efficient, as there is close to zero net power transfer
between the accelerated beam and the RF driving the cavities. However, even here is still room for improvement. SRF cavities at low
beam-loading are driven overcoupled for stability reasons to counter cavity detuning. For Niobium cavities, the optimum operation
temperature is in the range of 1.8-2K, thus that the real cryogenics efficency is on the order of per mille. Can we reduce this required RF power and improve on cryogenic efficency?
As a recent example to work on these problems, the EU Horizon funded iSAS [1] program has targeted these main "energy hungry" technologies by studying
ERL technology within the PERLE project as a demonstrator for the LHeC electron-hadron collider, the tuning of SRF cavities by
means of ferroelectric fact reactive tuner to reduce RF power and to study coating of Nb3Sn on Copper host cavities for higher temperature SRF operation.
In this contribution, the energy efficency of ERLs will be discussed and the means to further improve it in the framework
of the iSAS program.

[1] https://isas.ijclab.in2p3.fr/

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