# *Technology Readiness Level (TRL)*

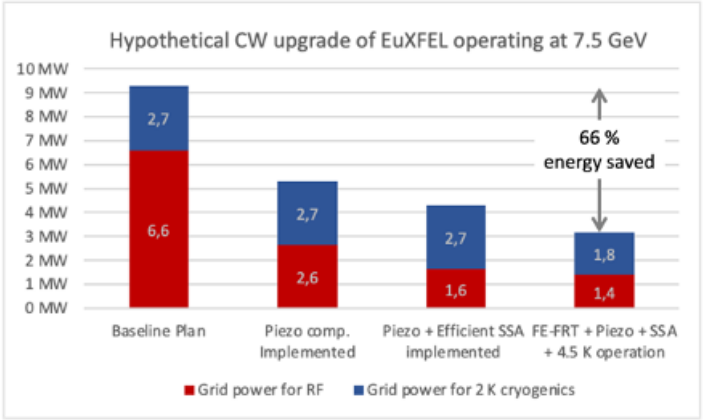
The readiness of the energy-saving iSAS technologies will be improved to prepare them towards industrialisation and cost-effective mass production for current and future RIs.

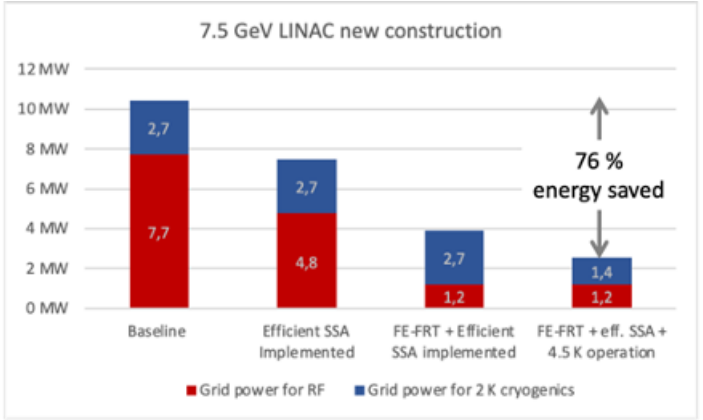
| iSAS Technologies | | initial TRL | target TRL |
|---|---|---|---|
| **TA#1** | FE-FRT for transient detuning @ 400 MHz | 4 | 6 |
| | FE-FRT for transient detuning @ 800 MHz | 1-2 | 4 |
| | FE-FRT for microphonics @ 400 MHz | 3 | 5-6 |
| | FE-FRT for microphonics @ 800-1300 MHz | 1-2 | 5-6 |
| | LLRF controls | 3-4 | 7 |
| | LLRF + FE-FRT controls | 2-3 | 6 |
| **TA#2** | Nb3Sn-on-Cu films for 4.2-K cavity operation | 2-3 | 4-5 |
| **TA#3** | Higher-Order Mode couplers | 2-3 | 5 |
| | Fundamental Power Couplers | 2-3 | 5 |

*The objective of iSAS is for RIs and European industry to co-develop industrial solutions for energy-savings technologies in accelerators, delivering applications that can be implemented across various accelerator-driven research and non-research infrastructures.*

# Impact of iSAS technologies on FELs

*example EuXFEL*



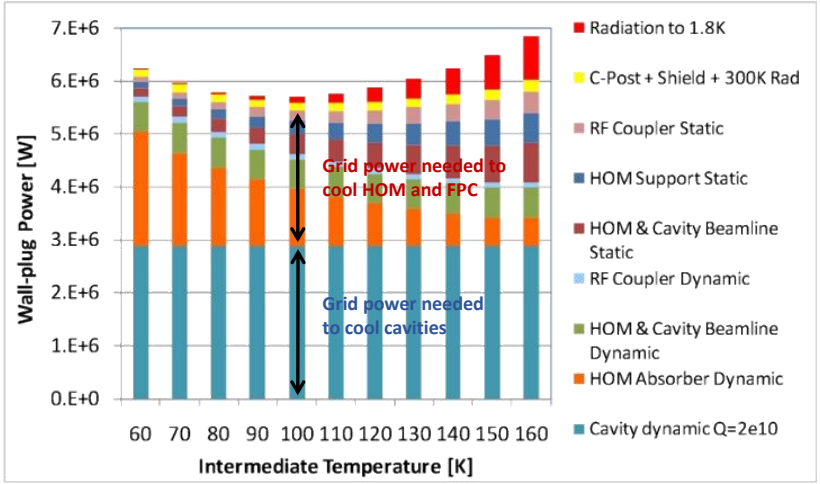

*For an upgrade of EuXFEL to CW, a refurbishment of the injection LINAC cavities is being considered. This could provide the opportunity to retrofit some iSAS technology developments as well. The figure (left) depicts the expected energy savings if various iSAS developed technologies are implemented (assumption: 0.1 mA beam current), the degree of modifications, but also the benefits, are increasing from left to right. The achievable total energy savings amounts to 66%, more than 6 MW, avoiding 2.9 tons $CO_2$ per hour of operation for Germany's electrical energy mix (485 g $CO_2$/kWh). Future LINACs can be optimally designed to take full advantage of the iSAS technologies, as integrated in the cryomodule being designed in iSAS. The right figure shows that the full savings for a 7.5-GeV LINAC is of the order of 76% (RF + cryogenics cavity cooling). Not included here are the additional potential savings by optimizing the heat load from HOM and FPC couplers – for the Cornell system their load accounts for nearly 4 MW – or any scheme to recover the beam power (750 kW in these examples).*

# Impact of iSAS technologies on SRF accelerators

*example Cornell ERL LINAC*

*iSAS develops new designs for both fundamental power couplers and HOM couplers dedicated to beam operation at very high currents while minimizing their static and dynamic heat loads in the cryogenic system. The reduction in the required cryogenic power will depend on the final design but the energy savings potential is expected to be large. As an example, the adjacent figure shows the grid power required to cool various parts of the cryomodules in the 5-GeV Cornell ERL LINAC design for different configurations of the cryogenics. The HOM and fundamental power couplers account for nearly half of the full cryogenic load. Even a moderate improvement can thus save powers in the MW range. The required cooling power scales linearly with the beam energy, so for the most ambitious future SRF accelerators, the savings in wall-plug power can be in the tens of MW and more range.*

*"Cornell Energy Recovery LINAC Project Definition Design Report"*
*G. Hoffstatter, S. Gruner, M. Tigner, eds. (2013)*




*Grid power for cooling the Cornell ERL LINAC.*
*(figure adapted from reference)*

# Impact of iSAS technologies on HEP $e^+e^-$ colliders

*example future e+e- Higgs Factories*

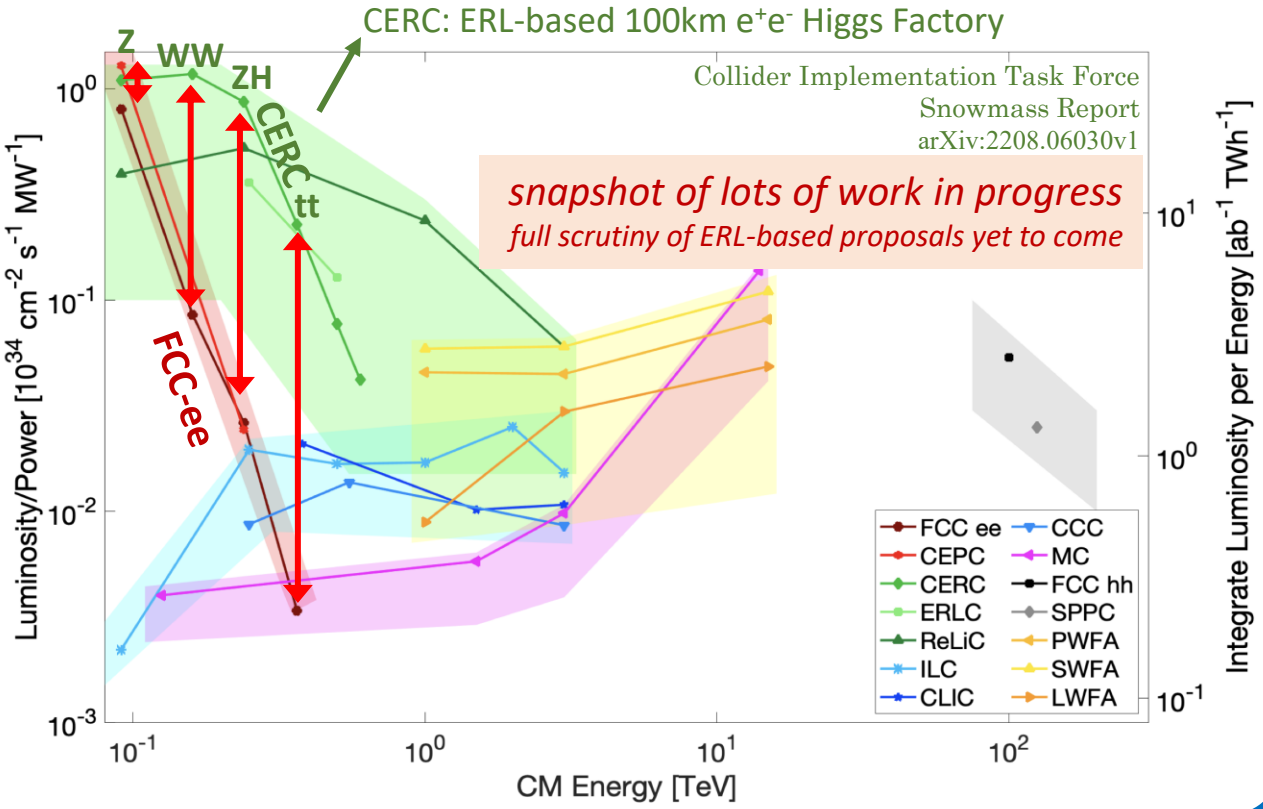
This plot suggests that with an ERL version of a Higgs Factory one might reach

**x10 more Higgs bosons**

or

**x10 less electricity costs**

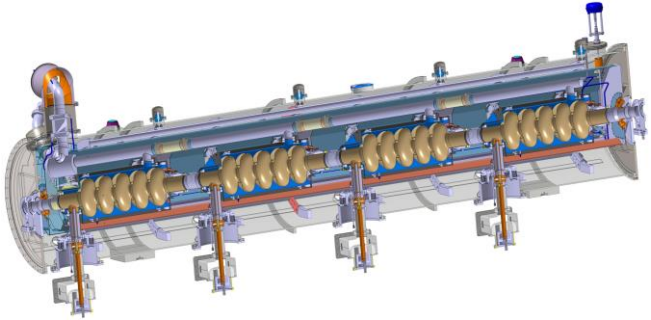
*NOTE: several additional challenges identified to realise these ERL-based Higgs Factories*




*References for CERC: PLB 804 (2020) 135394 and arXiv:2203.07358*

# Innovate for Sustainable Accelerating Systems (iSAS)

- As a leading pathfinder to enable sustainable SRF accelerators, with iSAS the most impactful new energy-saving technologies will be developed, validated, and integrated towards industrial solutions with a direct and verifiable impact on current research infrastructures and their upgrades.



- The outcomes of iSAS are expected to help reshape what is feasible in the future landscape of continuous-wave SRF accelerators.
- As a leading pathfinder to enable sustainable SRF accelerators, In the long term, the impact of iSAS is to reduce the energy footprint of future SRF accelerators in research infrastructures by at least half, and to unlock new facilities that maintain Europe's leading position to enable fundamental science breakthroughs in an energy sustainable manner.
- The new sustainable technologies will stimulate the European industry to take a leading role in building cost- and energy-efficient SRF systems for new accelerators with impact in, for example, the semiconductor and medical sectors.