Report of the ERL Coordination Panel

March 10, 2023

Jorgen D'Hondt (VUB Brussels, Panel Chair), Max Klein (U Liverpool, Deputy, Spokesperson of PERLE), Jens Knobloch (HZB Berlin, Leader of bERLinPro), Achille Stocchi (Director IJCLab Orsay, Leader of PERLE) and Andrew Hutton (Jefferson Lab, R&D oversight).

The present report, for information of CERN Council, summarises recent organisational steps, technical progress, and the future needs for Europe to achieve the ambitious goals on Energy Recovery Linacs (ERL) (Sect.1), which had been endorsed with the Accelerator R&D Roadmap, see arXiv:2201.04236. With the Roadmap), the European ERL efforts have been directed towards the development of novel, sustainable technologies and of two unique, high-power facilities, bERLinPRO at HZB Berlin and PERLE at CNRS Orsay. We herewith report about a very recent, concerted effort of major European laboratories to substantially advance the base technologies, in collaboration with the RF panel, through a programme "Innovate for Sustainable Accelerating Systems" (iSAS, Sect.2) that has been prepared as a Horizon Europe grant request (on March 9, 2023). We also report on the status and progress of bERLinPRO (Sect.3) and PERLE (Sect.4), and their plans. The report is briefly summarised in Sect5.*

1. Energy Recovery Linacs and the Accelerator R&D Roadmap *)

ERLs are a novel, green, potentially revolutionary accelerator technology through recycling the kinetic energy of a used beam for accelerating a newly injected beam, thereby greatly reducing the power consumption, utilising a very high injector brightness and dumping at injection energy which avoids radioactive beam dumps. The potential of this technique, proposed by Tigner in 1965, may be compared with the finest innovations of accelerator technology, such as by Widerøe, Lawrence, Veksler, Kerst, van der Meer and others during the past century. It promises a luminosity increase for physics applications by one or more orders of magnitude at a power consumption comparable to classic lower luminosity solutions. This is a necessary step towards the future of high-energy physics and its sustainability. Conceptual ERL designs for future colliders have recently been made for e^+e^- Higgs facilities and for TeV-energy ep/eA colliders. ERL concepts have also been considered for a future muon collider and for reaching the EIC luminosity targets at BNL. Much enhanced luminosities are similarly crucial for opening new areas of low-energy physics, such as nuclear photonics or the spectroscopy of exotic nuclei. ERLs are close to utilisation in several industrial and scientific applications such as photolithography, free electron lasers, inverse photon scattering and others. Innovations of such depth are very rare, their impact to society and science will be profound, directed to energy economy and sustainability, albeit only approximately predictable.

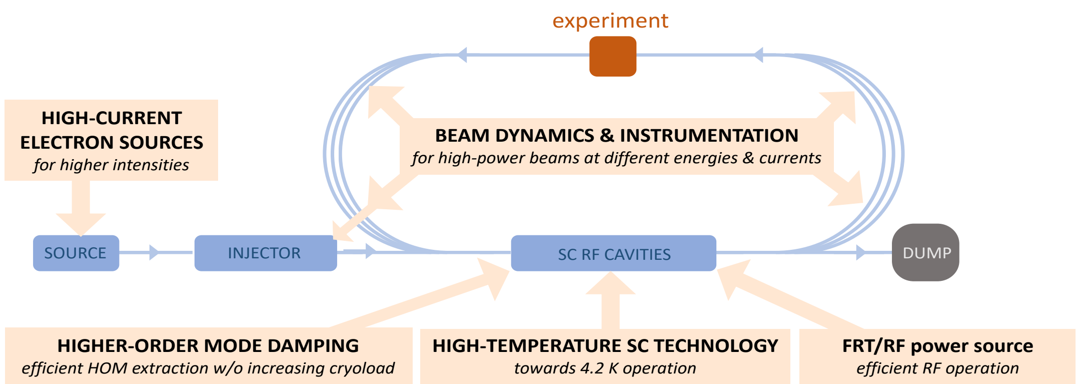

Fig. 1: Key components and technology elements of a recirculating energy recovery linac facility.

**) The ERL Roadmap has been accompanied by a 200 pages paper on "The Development of Energy Recovery Linacs" (arXiv:2207.02095, to appear in JINST) including a detailed technical assessment of recently proposed concepts for circular and linear ERL Higgs facilities.*

The European ERL Roadmap identified three major interrelated elements for advancing the development of ERLs, which are i) embedded in a global collaborative and competitive effort; needs ii) innovative developments of technology; and requires iii) to reach the 100 mA electron current target in new facilities to be realised. These elements had been presented in its executive summary, see *arXiv:2201.04236*, as follows:

i) Current facilities, including crucial technological developments and operational experience, with S-DALINAC (TU Darmstadt) and MESA (U Mainz) in Germany, cERL (KEK) in Japan and others.
ii) A key technology R&D program, illustrated in figure 1, focused on high-current electron sources and high-power SRF technology development and operation in the years ahead, including the technical target of cavity quality factors, Q_0, approaching 10^{11}. Next-generation ERL requirements have led to the major R&D goals of being able to operate at 4.2 K cryogenic temperature with high Q_0, higher-order mode damping at high temperature, dual-axis cavity developments, and novel high-current ERL diagnostics and beam instrumentation to deal with effects such as beam break-up or RF transients.
iii) New ERL facilities in preparation for reaching higher currents and electron beam energies at minimum power consumption by the mid-twenties. These are, in Europe, bERLinPro (Berlin, Germany) with the goal to operate a 100 mA, 1.3 GHz facility, and PERLE (hosted by IJCLab Orsay, France) as the first multi-turn, high-power, 802 MHz facility with novel physics applications. In the coming years, the US will explore ERL operation near 10 GeV with CEBAF5 (Jefferson Lab, Newport News) and develop a challenging 100mA electron cooler for hadron beams at the EIC (BNL, Brookhaven).

While progress is being made on MESA, S-DALINAC, cERL, at BINP, CEBAF5 and the EIC electron cooler, this report is on realising the ERL Roadmap, i.e., advancing the technology with an extended horizon and a newly developed consortium of laboratories, and it reports on the development of bERLinPRO and PERLE, both offering beam-based tests and applications for the technology programme.

2. Innovate for Sustainable Accelerating Systems (iSAS)

In a society where energy sustainability is critical, keeping energy consumption as low as reasonably possible constitutes an unavoidable challenge for both research infrastructures (RIs) and industry, which collectively operate over 40,000 accelerators. Based on state-of-the-art technology, the portfolio of current and future accelerator-driven RIs in Europe could grow to consume up to 1% of Germany's annual electricity demand. In December 2022, Horizon Europe launched a call to address the energy sustainability of European research infrastructures. With the ambition to maintain the attractiveness and competitiveness of European RIs and to enable Europe's Green Deal, it has been proposed to **Innovate for Sustainable Accelerating Systems (iSAS)** by establishing enhanced collaboration in the field in order to broaden, expedite and amplify the development and impact of novel energy-saving technologies to accelerate particles. For many frontier accelerators, superconducting RF (SRF) systems are the enabling technology. **Exploiting the synergies between the ERL and RF panels, the objective of iSAS is to innovate those technologies that have been identified as being a common core of SRF accelerating systems and that have the largest leverage for energy savings to minimize the intrinsic energy consumption in all phases of operation.** While SRF systems with energy-recovery capability are the enabling technology for high-intensity beams with modern accelerators, the iSAS proposal emerges as the main pathfinder for Europe to deliver the related energy-saving technologies more broadly.

This opportunity was enabled by the extensive developments in preparing the Accelerator R&D Roadmap, and the iSAS application can therefore be considered an initial product of these efforts supported by the CERN Council. Based on the recently established Roadmap, and relying on a collaboration between leading European research institutions and industry, several interconnected technologies will be developed, prototyped, and tested, each enabling significant energy savings on their own in accelerating particles. The collection of energy-saving technologies will be developed at these unique R&D Pathfinder labs with a portfolio of forthcoming applications in mind and to explore energy-saving improvements of existing RIs on the ESFRI Roadmap, for example the ESFRI Landmarks HL-LHC, ESS and EuXFEL. Considering the developments realised, the new technologies will be coherently integrated into the parametric design of a new accelerating system, a LINAC SRF cryomodule, optimised to achieve high beam-power in accelerators with an as low as reasonably possible energy consumption. This new cryomodule design will enable Europe to develop and build future energy-sustainable accelerators.

While the readiness of several energy-saving technologies will be prepared for industrialisation with impact on current RIs, iSAS is also the pathfinder for sustainable future SRF particle accelerators and colliders. Through inter- and multidisciplinary research that delivers and combines various technologies, it is the long-term ambition of iSAS technologies to reduce the energy footprint of SRF accelerators in future RIs by half, and even more when the systems are integrated in Energy-Recovery LINACs. Unlocked by iSAS, Europe's leadership will be maintained for breakthroughs in fundamental sciences and will help enable high-energy collider technology to go beyond the current frontiers of energy and intensity in an energy-sustainable way. In parallel, the new sustainable technologies will empower and stimulate European industry to conceive a portfolio of new applications and to take a leading role in, for example, the semiconductor, particle therapy, security, and environmental sectors.

Modern accelerators largely rely on superconducting cavities, cryogenically cooled to about 2K, that are powered with radio frequency (RF) power generators to provide energy to the particle beams as they traverse a series of cavities. These are energy-intensive devices (Fig.2) that operate at a specific radio frequency and where only a fraction of the power extracted from the grid is effectively transmitted to the accelerated particles. In addition, the beam energy is radiated by recirculating beams and ultimately dumped and lost. Directly connected to the superconducting RF accelerating system itself, three key Technology Areas (TAs) where power is lost have been identified (Figs. 2 and 3). The objective of iSAS is to develop, prototype and validate new impactful energy-saving technologies so that SRF accelerators can operate with the same or improved performance while using significantly less energy.

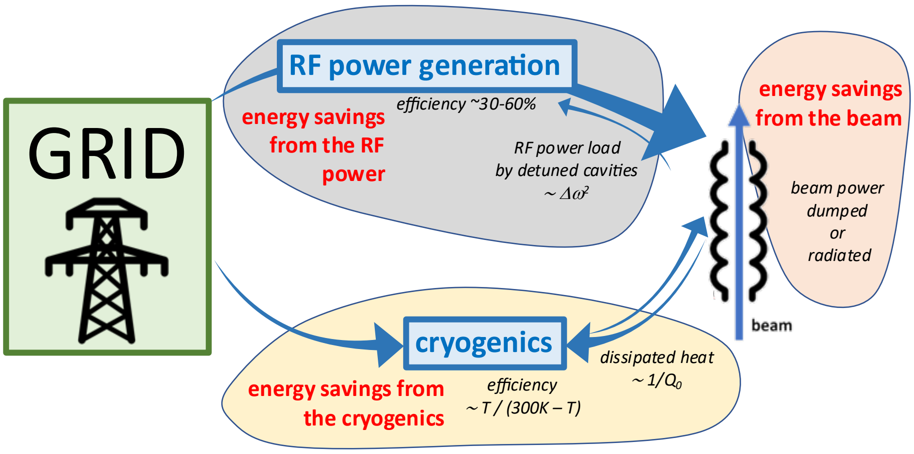

Fig. 2: Power use of SRF accelerating systems - three Technology Areas of interest (see text).

TA#1: energy-savings from RF power – While making great strides in the energy efficiency of various RF power generators, the objective of iSAS is to achieve additional impactful energy savings through coherent integration of the RF power source with smart digital control systems and with novel tuners (FRTs) that compensate rapidly cavity detuning from mechanical vibrations, resulting in a further reduction of power demands by a factor up to 3.

TA#2: energy-savings from cryogenics – While major progress is being made in reusing the heat produced in cryogenics systems, the objective of iSAS is to develop superconducting cavities that operate with high performance at 4.2 K instead of 2 K, reducing the grid-power to operate the cryogenic system by a factor of 3 and requiring less capital investment to build the cryogenic plant.

TA#3: energy-savings from the beam – Significant progress has been achieved in maintaining the brightness of recirculating beams to provide high-intensity collisions to experiments, but most of the particles lose their power through radiation or in the beam dump system. The objective of iSAS is to develop dedicated power couplers for damping the so-called Higher-Order Modes (HOMs) excited by the passage of high-current beams in the super-conducting cavities, enabling efficient recovery of the energy of recirculating beams back into the cavities before it is dumped, resulting in energy reduction for operating, high-energy, high-intensity accelerators by a factor ten.

Through developments at leading European laboratories acting as R&D Pathfinders, significant energy savings are within reach for each of the above technologies when integrated into accelerator facilities and industrial applications. Enabled by the extensive iSAS collaboration and the joint investment between research institutions and industry, iSAS envisages three Integration Activities (INTs) to introduce energy-saving technologies into research facilities.

INT#1: integration into the design of a sustainable LINAC cryomodule – While LINAC cryomodules are designed for specific accelerators, the objective of iSAS is to address the common engineering challenges of integrating iSAS technologies into a parametric design of a new sustainable accelerator system.

INT#2: integration into existing RIs – While various RIs envisage upgrades, the objective of iSAS is to expedite the technical integration of energy-saving technologies by retrofitting existing accelerating systems. A cryomodule will be adapted, ready to demonstrate energy recovery of high-power recirculating beams in the PERLE research facility, paving the way for high-energy, high-intensity electron beams with minimal energy consumption.

INT#3: integration into industrial solutions – While iSAS technologies are emerging, the objective of iSAS is to plan for concrete co-developments with industry to expedite reaching a TRL sufficiently advanced towards large-scale deployment of the new energy-saving solutions at current and future RIs as well as to prepare the path for industrial applications. For many future RIs and industrial applications SRF is the enabling technology.

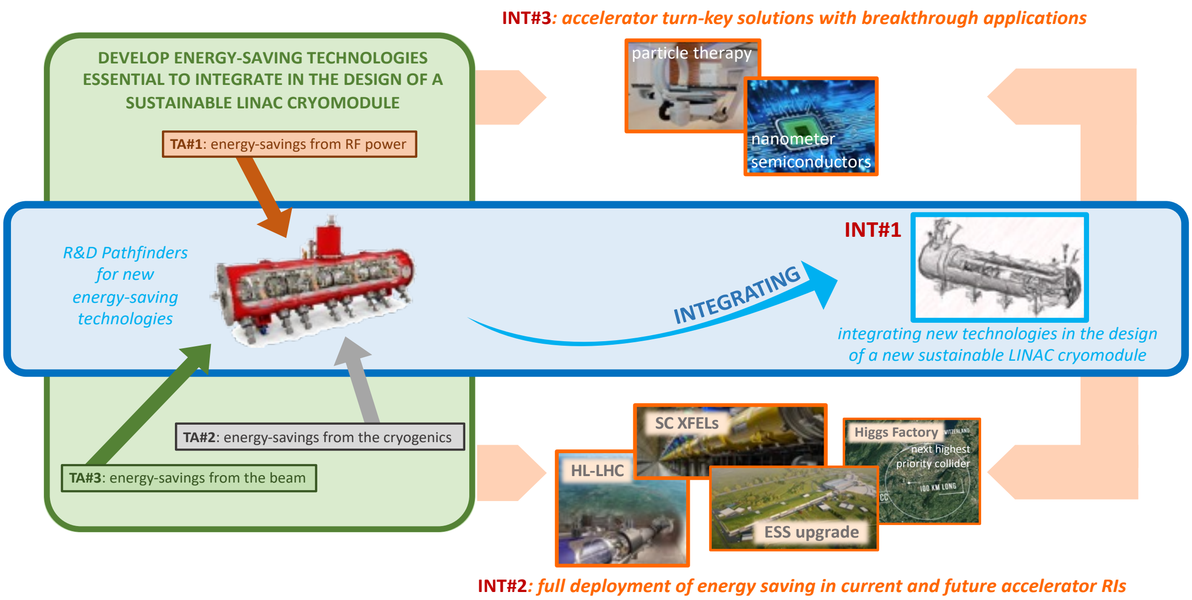

Fig. 3: Power economy of SRF accelerating systems - three Areas of Integration (see text).

The long-term ambition of iSAS is to catalyse the implementation of the European Accelerator R&D Roadmap. Accordingly, the objective of iSAS is not only to prepare the technology readiness to achieve impactful energy savings at RIs, but also to train experts and newcomers in the field. They will be trained to leverage the iSAS project by further developing sustainable accelerating technologies and eventually to operate them when integrated in RIs and in industrial applications. iSAS will contribute to the acceptance of sustainable accelerators in a green Europe. Several key technologies, such as FRTs, HOM damping at higher temperature, cavity operation at 4.2 K in the long term, high quality (Q_0) cavity developments have a direct impact on the performance of future large scale ERL facilities. The complete iSAS report can be obtained on request from the ERL and RF coordinators, Jorgen D'Hondt and Giovanni Bisoffi.

3. Status and Progress on bERLinPRO

Within the scope of the Berlin Energy Recovery Linac Project, a 50MeV ERL facility has been set up at the Helmholtz-Zentrum Berlin. The beam transport system and all necessary technical infrastructure for 100 mA operation are complete, and the single-turn racetrack is closed and under ultra-high vacuum. In a straight continuation of the gun, the 'diagnostics line' offers equipment for extensive gun characterisation. The machine is built in an underground bunker, and able to handle up to 30 kW continuous beam loss at 50 MeV. The Roadmap identified bERLinPRO as a key facility that could prove single turn ERL operation at 100 mA current, serve as a testbed for technology developments and provide crucial operation experience at such large currents. The facility has an important order 10 mA current program, much extended with iSAS, but it will need support to be complemented by a new gun reaching 100 mA and a 1.3 GHz LINAC (new cryomodule) in order to deliver on the Roadmap targets.

Since late 2022, progress was made in preparing the SRF photo-injector module for beam operation. The first assembly of the cold string had activated a field emitter, necessitating re-assembly with a second cavity and new couplers. The injector is equipped with XFEL/TTF-III couplers, with improved cooling to accommodate higher CW power operation. They have been tested to 8 kW CW, limited by thermal effects. As two couplers are used to operate the injector cavity, a total of 16 kW allows an average current of 7.5 mA at 1.4 MeV, a lower bound for reasonable injector operation. 5 mA can be accelerated to 3.5 MeV. Assembly has been completed and the cryomodule is now installed at the injector location of bERLinPro. Cryogenic tests of the module will start in April 2022. In the meantime, administrative procedures to obtain a radiation permit for operations continue—it is expected that RF testing can start in summer this year. In parallel, the cathode transfer system was assembled in the cleanroom and will be moved to bERLinPro in the next weeks. First, an in-vacuum particle counter will be used to ensure that the exchange mechanism will not contaminate the cavity. Once RF tests are completed, the transfer system will be installed to commence beam operation in Q4 2023. The cathode-laser system is already installed and ready for operation. The beam will be characterized by diagnostics in the injector straight. In Q2 2024 CW beam operation up to 6 mA CW is foreseen. However, even higher currents may be possible as coupler conditioning showed very long thermal time constants, of order 1 hour, permitting (pulsed) high current operation, provided the average power remains within the coupler limits. The feasibility of long-pulse / high-current operation will be explored in Q3 2024. If successful, valuable information can be obtained on high-current operation, without the immediate need to replace the cavity-coupler system.

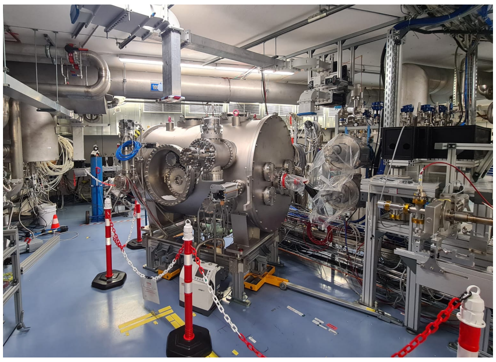

Figure 4: The SRF photo-injector during its installation in bERLinPro.

In 2024 a total time of nine weeks is foreseen for beam operation, limited primarily by budgetary constraints. This run will include a proof-of-principle ultra-fast electron diffraction (UED) experiment at low bunch charge to explore the suitability of SRF injectors for this application. The assembly of the Booster module will commence in mid-2023. All components for the module are in house, and the critical 120-kW high-power couplers have been conditioned to 60 kW CW / 120 kW pulsed. Completion of the booster module and its installation in bERLinPro is planned for Q4 2024. RF and cryogenic commissioning is planned for Q1 2025, with beam operation in Q3 2025. bERLinPro was designed to operate at 100 mA at 50 MeV in its nominal configuration. However, funds for a full 100-mA CW photoinjector and a LINAC module are presently not available. Given the current budget, the work will focus on commissioning of the injector with about 6mA in CW mode and higher currents to be studied in a macro-pulse mode with the existing SRF photoinjector.

In the framework of the recently submitted EU HORIZON iSAS program, the SRF photo-injector will already serve as a testbed for the newly developed LLRF detuning control and AI/ML assisted methods to improve the beam stability and therefore the beam quality. A key element of the iSAS developments will be the design of ferro-electric fast reactive tuners (FE-FRT) to compensate the negative impact of microphonic detuning on cavity operation and RF power consumption. Tests of such systems will take place in SupraLab with TESLA cavities in 2025. If successful, they can be transferred to the bERLinPro LINAC-type cavities and incorporated in a LINAC module. The design for this module is well advanced and plans call for a study to incorporate FE-FRTs.

A second important iSAS research area is the development of 1.3-GHz cavities operating at 4.5K based on Nb_3Sn coated on copper that would save a factor of 3 in cryogenic power which will be crucial for very large accelerator systems, such as a 500 GeV ERL Higgs facility. It is envisaged that the LINAC module cryogenics will be adapted to accommodate at least one such cavity in the future, although the initial installation will likely consist of bulk Niobium cavities operated at 2 K.

The current schedule of bERLinPRO is summarised in Table 1. The production strategy of a 100-mA photoinjector depends on results from the long-pulse / high-current investigation with the existing injector and is thus currently open.

Time	**Goal**	**bERLiPro funded**	**iSAS funded**	**Not funded**
Q4 2023 – Q3 2024	Injector beam exp. including UED pilot experiment	X		
Q4 2024	Beam operation with Booster	X		
Q4 2024	Explore pulsed high-current mode			
2024	FE-FRT proof-of-principle test w/ single cell	X	X	
2025	FE-FRT tests with a full TESLA cavity		X	
2025 – 2026	ML/AI LLRF tests with SRF injector		X	
2025	Start: Adapt LINAC module for FE-FRT		X	
2026 – 2028	Procure LINAC module and cavities			X

Table 1: Schedule of bERLinPRO developments

4. Status and Progress on PERLE

PERLE, a **P**owerful **E**nergy **R**ecovery **L**inac for **E**xperiments, emerged from the design of the Large Hadron Electron Collider and the FCC-eh, as a three-turn racetrack configuration with a linac in each straight. The Roadmap identified PERLE as the ideal next-generation ERL facility with which a new generation of HEP colliders, beyond ep, can be prepared. PERLE has three turns (a cost-efficient way to reach high energies), a high, 20 mA current (leading to 120 mA cavity load), an 802 MHz frequency (adapted to the FCC), and 500 MeV energy. PERLE will study the 10 MW power regime and novel low-energy high-intensity experiments will be pursued, with opportunities for electron-radioactive ion scattering, photo-nuclear science and possibly electroweak interactions. The novel experiments it can host are due to its unique beam characteristics, with an intensity, for example exceeding that of ELI by 2-3 orders of magnitude. But PERLE will also serve as a hub for the validation and exploration of a broad range of accelerator phenomena in an unexplored operational power regime. PERLE will support the development of sustainable technology for efficient ERL operation at future energy and intensity frontier machines as foreseen in the iSAS proposal,.

The main beam parameters of PERLE facility are summarised in the following table:

Target parameter	Unit	Value
Injection energy	MeV	7
Electron beam energy	MeV	500
Norm. Emittance $\gamma\varepsilon_{x,y}$	mm·mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	Mm	3
Bunch spacing	Ns	25
RF frequency	MHz	801.6
Duty factor		CW

Table 2: PERLE Beam Parameters

Following the publication of the Accelerator R&D Roadmap, significant progress has been made by the PERLE Collaboration, which is continuing to grow as shown in the Appendix on the ERL project organization. Notably the following milestones and developments can be mentioned here:

- In a successful collaboration between IJCLab, Jefferson Lab and CERN, a 5-cell 802 MHz Niobium cavity was built and tested as a joint PERLE, LHeC and FCC-ee project, with the striking result of stability up to almost 30 MV/m (exceeding the operational goal of 18 MV/m) with a Q_0 of 2-3 x 10^{10}.

- A collaboration of AsTEC Daresbury, University of Liverpool, IJCLab and Jlab led to a tentative design of the PERLE injector, confirming the design goals as listed in Table 2. This included the DC gun cathode shape, a buncher cavity and the merger designs, besides thorough beam dynamic studies of space charge effects, phase space and bunch distribution, and emittance.

- An optimised ERL lattice design, worked out by a collaboration of JLab, IJClab and CERN, is now ready for both versions of PERLE: the initial 250 MeV machine and for the fully equipped 500 MeV, with beam dynamics studies that are quite advanced.

- As reported at the ERL workshop (Cornell, October 2022), significant progress has been made with the installation of the 5 mA DC gun (see Fig. 5), obtained from Daresbury and augmented with several hardware elements. It should be completed by the end of 2023.

Fig. 5: Installation of the PERLE electron gun at IJCLab (Orsay, January 23).

Since the publication of the Roadmap, the effort and FTE investments have been largely strengthened, mainly by CNRS but also including the partners. This is leading to important and rapid progress in several areas, notably:

- Work is continuing at IJCLab, CERN and JLab on dressing the bare 801.6 MHz five-cell ERL linac cavity produced at JLab. A particular effort concerns HOM damping, an important issue for high current, multi-turn ERL, that strongly impacts beam stability and machine functioning. The aim is to obtain a first full dressed cavity for PERLE, equipped with HOM coupler(s), towards the end of 2023.

- An important design change has been decided by the Collaboration Board; replacing the originally anticipated SPL cryomodule (CM) by the better suited ESS module. Within the iSAS agreements, it is foreseen that an ESS cryostat will be provided in kind to PERLE such that it is realistic to achieve 250 MeV operation in the not-too-distant future. The engineering adaption of that CM for PERLE is ongoing, regarding internal available space, cavity string insertion, mechanical support and access to other components such as the tuners and the cryogenic distribution. 30 cryomodules have already been assembled at ESS and are presently being validated successfully for installation into the ESS tunnel, so the ESS cryomodule is a solid basis for the PERLE retrofitted cryomodule, which will be adapted for high-current ERL operation.

It is important to mention that the work on the site and the footprint (Fig. 6) is progressing well. The lattice design of PERLE occupies a rectangle of 28 x 6 m^2. Two zones have now been identified and are both available and civil engineering studies are ongoing. Work has also been launched on infrastructure and on the administrative classification of PERLE (ASN authorisation request).

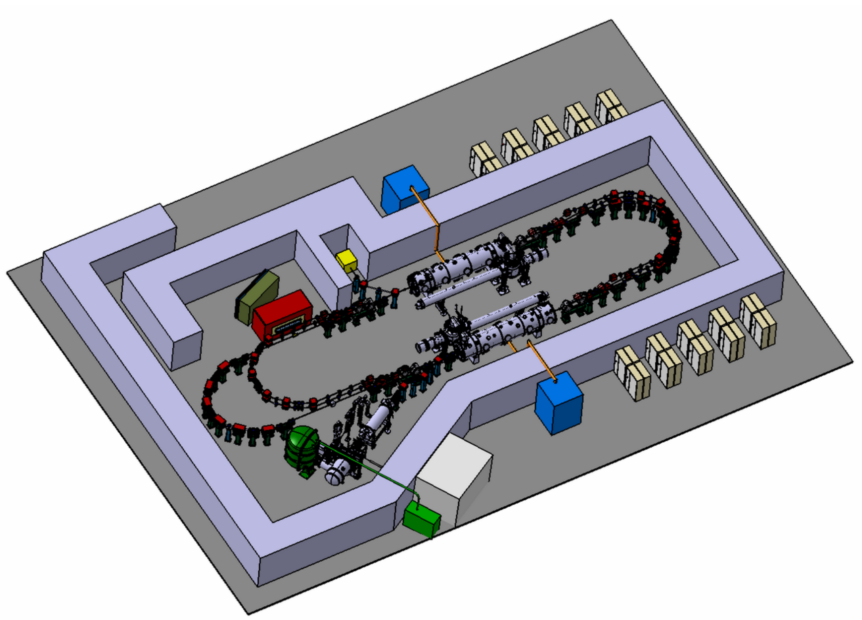

Fig. 6: Footprint of the 500 MeV PERLE recirculating energy recovery linac facility at IJCLab Orsay.

Three PERLE construction phases have tentatively been defined. Phase 1: Installation of the injection line (2022- 2027); Phase 2: 250 MeV version of PERLE (2024-2028) and Phase 3: 500 MeV version of PERLE (2028-2031). PERLE has been recognized as a novel facility of fundamental interest for high energy, nuclear and applied physics, and a hub for accelerator technology and method developments. It has therefore been recognized as a key project for CNRS and exemplifies the finest traditions that LAL Orsay and the newly associated labs represent for our field.

5. Outlook

A key ambition expressed in the European Strategy for Particle Physics has been that "*the energy efficiency of present and future accelerators [...] is and should remain an area requiring constant attention*". Accordingly, "*a detailed plan for the [...] saving and re-use of energy should be part of the approval process for any major project*". The ERL developments are an original and very far-reaching answer to this request. The Roadmap has shown the path forward for European efforts towards high-power ERLs and sustainable technologies towards applications in future particle physics colliders. With the iSAS programme and request to Horizon Europe, uniformly supported by the leading labs and coordinating bodies, such as TIARA and many others, a path is being created for the development of energy-efficient new technologies for SRF and energy recovery linacs. This collaboration of the ERL and the RF panels links well to sustainable technology development efforts forthcoming at CERN. The iSAS project responds optimally to the technology programme laid out in the ERL and RF Roadmaps. In addition, ways have to be found to access the funds detailed in the Roadmap for realising a competitive, far reaching, high-power ERL programme, i.e. for equipping bERLinPRO as a 100 mA, 50 mA LINAC ERL and for building a 10 MW power PERLE as planned. The funding has been detailed in the Roadmap, see *arXiv:2201.04236,* and amount to a total of about 25 MCHF for the next 5 years. This will require attention and support by the Funding Agencies, beyond Germany for bERLinPRO and France for PERLE. Given the outstanding perspectives and benefits, for high energy physics and beyond, the panel is convinced that the success of the ERL programme is possible with the attention and continued support by the CERN Council and the integration of ERLs into CERN's R&D priorities at an appropriate level.

Appendix on Organisation

An ERL coordination panel has been formed with the composition: Jorgen D'Hondt (VUB Brussels, Panel Chair), Max Klein (U Liverpool, Deputy, Spokesperson of PERLE), Jens Knobloch (HZB Berlin, Leader of bERLinPro) Achille Stocchi (Director IJCLab Orsay, Leader of PERLE) and Andrew Hutton (Jefferson Lab, R&D oversight). The panel reports to the LDG. It is advised by an International Advisory Board, Chaired by Frederick Bordry, the other members are still being finalised.

iSAS is a consortium of 10 Beneficiary (CNRS, CERN, ESS, DESY, Vrije Universiteit Brussel, CEA, HZB, INFN, UKRI, University of Lancaster) and 7 Associated Partners (incl. EPFL) from 7 countries in Europe, spanning from Sweden in the north to Italy in the south. The earmarked EU budget is €5M, and the consortium brings over €7M additional matching funds. The strength of iSAS lies in bringing together the major European laboratories with a high-level of expertise in accelerator physics and a successful experience of producing key accelerator components. This consortium is built around a leading core of world-class research infrastructures: HL-LHC at CERN, EuXFEL at DESY, and ESS. The iSAS organisation is shown in Fig.6

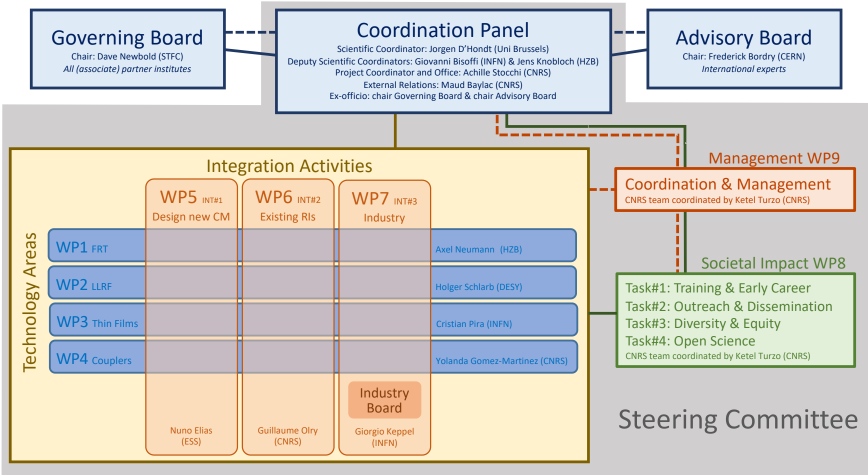

Fig.6 iSAS organisation for the development of sustainable SRF and ERL technology

Two research facilities in Europe are the main pathfinders for high-current ERL technologies: **bERLinPro at HZB and PERLE at IJCLab**. In February 2023, both institutions signed a Memorandum of Understanding to profoundly collaborate in realising the ambitions expressed in the European Accelerator R&D Roadmap. bERLinPRO has been a project of the Berlin Helmholtz Center. PERLE has been set up as an International Collaboration with decisions taken by a Collaboration Board chaired by Oliver Bruening (CERN). The facility is being established as a key future project for CNRS, hosted and coordinated by IJCLab at Orsay. As of today, the Collaboration includes CERN, Jefferson Lab, STFC-Daresbury, University of Liverpool, Cornell University, An-Najah University, ESS-Bilbao and CNRS (IJCLab + LPSC). Discussions are taking place with ESS Lund, INFN Milano and TU Darmstadt about becoming members of PERLE, while the membership of BINP Novosibirsk had been suspended. Collaborative efforts are being investigated between PERLE and the EIC electron cooler project.

Acknowledgement: The panel wishes to acknowledge the continued support by Council and the LDG group, the excellent cooperation with the RF panel, the strong efforts of a growing community and for this report the important input obtained from Axel Neumann and Walid Kaabi.