PERLE Collaboration Agreement

Introduction

The efficient recovery of power to re-excite cavities from the used beam was proposed first for normal conductive facilities accelerating beams at rather low power. The major advances in superconducting RF technology and the consideration of multi-turn recirculation passages have paved the way to the "green" generation of high energy, high brightness, high current beams. Thus, Energy Recovery Linacs (ERL's) are now beginning to assert their potential as game changers in the field of accelerators and their applications. Their unique combination of bright linac-like beam quality, with high average current and extremely flexible time structure, unprecedented operating efficiency and compact footprint opens the door to previously unattainable performance regimes and applications.

PERLE is a compact three-pass ERL project based on SRF technology and targeting the 10 MW beam power range, with about 20 mA electron beam current and 500 MeV electron beam energy. The Conceptual Design Report was published in [1]. The PERLE facility will primarily serve as a hub for the validation and exploration of a broad range of accelerator phenomena in an unexplored operational power regime serving for the development of ERL technology for future energy and intensity frontier machines. It will also host a new generation of nuclear and particle physics experiments. The PERLE facility is intended to be hosted by the CNRS-IN2P3 laboratory IJCLab (Orsay, France).

The present Collaboration Agreement defines the framework and steps of the collaborative effort towards the realization of this project.

1- Parties of the Collaboration Agreement

This Collaboration Agreement (CA) is signed between the member institutes (hereafter called "the Parties"). They form the PERLE collaboration to which this CA applies. The Parties are listed in Annex A.

The entry of new members into the collaboration is conditioned by a unanimous vote of Collaboration Board members (cf. Annex C).

2- Purpose of the CA

[1] PERLE, Powerful Energy Recovery Linac for Experiments, CDR, J.Phys.G 45(2018)6, 065003, arXiv:1705.08783

The purpose of this CA is to specify the intent of the Parties with respect to establishing a collaborative effort for realizing the PERLE Project (hereafter called "the Project"). The CA is also agreed upon to introduce the required level of formality to allow for a coordinated dedication of resources of all the Parties.

None of the Parties will be bound by any legal obligation to the other Parties or incur any associated expense.

3- Scope of the CA

By collaborating on PERLE activities of common interest, as described below, the Parties intend to achieve faster and enduring progress in the Project at lower cost resulting from the sharing of expertise, resources and personnel.

The collaboration between the Parties aims at performing a Technical Detailed Study of the PERLE facility and at preparing the ground for its future construction and operation phase. It will include activities such as:

- design and simulation of the facility and its performance;
- generation and exchange of research results, data, and know-how;
- development, fabrication and exchange of equipment of interest for the Project;
- joint experimental tests;
- development and sharing of software for the analysis and interpretation of data;
- joint publication of results and representation at conferences;
- exchange of personnel, and
- any other form which the Parties might consider appropriate.

As the Project develops and progresses, new areas and needs on collaboration activities between the parties could be agreed and may be described through an amendment or a modification of this CA, as described in Section 7.

4- Contributions and Collaboration Membership

By signing the CA, a Party expresses its readiness to contribute with expert knowledge, studies, equipment, materials, funds and/or other resources.

Except when agreed otherwise, each Party shall bear the cost of its contribution to the Project.

The contribution of a Party to the Project is to be endorsed by the PERLE Collaboration Board and should be detailed as much as possible in Annex D, which shall be subjected to the provisions of this CA. These estimates will be regularly reviewed during PERLE Collaboration Board meetings and the necessary updates, approved by the Board members, will be communicated to the Parties through the PERLE Collaboration Board minutes.

To support the prototyping phase and prepare for construction, major Equipment contributions to the PERLE project will be regulated in dedicated additional Agreements to be signed between a Party and CNRS/IN2P3.

5- Collaboration Board

Each Party shall designate one representative in the PERLE Collaboration Board (CB). The mandate and composition of the CB are detailed in Annex C.

6- Entry into Force and Duration of the CA

This CA is agreed upon for the technical design and the preparatory phase of the Project. It will become effective on the date when at least three Parties have signed it, including CNRS-IN2P3, and shall remain in force for a period of five (5) years or until the start of the Project construction phase. The construction and the operation of the PERLE facility will be the subject of a subsequent dedicated agreement.

Any important modifications to this CA that may arise will be subject to the "Amendments and Modifications of the CA" described in Section 7.

A Party may withdraw from this CA by giving not less than three (3) months' notice, in writing to the PERLE Collaboration Board. The withdrawing party agrees to leave at the disposal of the collaboration the contributions made so far, for the rest of the duration of this CA. On the expiry date of this cooperation agreement, the Equipment provided by the withdrawing party will be returned to it in a similar manner to the provisions of Article 8 of this CA.

7- Amendments and Modifications of the CA

This CA may be amended or modified by the Parties at any time if the modifications are unanimously agreed by the CB.

8- Intellectual Property

Intellectual property such as design drawings, software, or technologies developed within the Project will remain the property of the developing Party or their institution (as applicable).

Items used, built, designed within the Project or any materials that have been or will be purchased for the Project are called Equipment. Unless defined otherwise through a specific dedicated Agreement, Equipment ownership will be shared between the Parties for the duration of this CA and will revert back to the original Parties that had provided them at the completion of the Project.

9- Confidentiality

The Parties shall strive to jointly publish the results of their collaboration in the Project as open Access publications. Publications shall acknowledge the collaboration between the Parties

including, whenever appropriate, the experts having taken part in the development of the results covered by the publication.

For the duration of this CA, all material and results will be openly shared between the Parties unless the developing Party considers the property to be of a confidential nature.

10- Dispute Resolution

Any and all questions that may arise regarding the interpretation of this CA will be resolved consensually between the Parties. Any dispute regarding the collaboration that cannot be unanimously resolved will require a final decision to be taken by a two third majority of the CB members including CNRS-IN2P3.

11- General Provisions

The Parties will conduct the collaboration in terms of this CA in compliance with the applicable laws and regulations. The contributions of each Party are subject to the availability of appropriate funds and human resources.

Nothing in this CA will affect any other agreements concerning the cooperation between the Parties with other Projects.

Each Party shall ensure the selection of experts with the necessary skills and competence to execute its contribution on its behalf, taking into account the nature and the environment of the work.

Contributions to the Project shall be conform to the safety rules, including any specific safety requirements in force at the Parties' site where they will be used.

The following Annexes are an integral part of this CA:

- Annex A: List of Parties and contact persons
- Annex B: PERLE Description, Axes of Collaboration, Stages, Timeline
- Annex C: PERLE Management Structure
- Annex D: Estimates of the Parties' intended contributions

This CA is drawn up and executed in English.

PERLE Collaboration Agreement
Signature Sheet

Centre National de la Recherche Scientifique - Institut National de Physique Nucléaire et de Physique des Particules (CNRS/IN2P3)

Date and place: June 10, 2021 Paris
Signature:

Dr. Reynald Pain
IN2P3 Director

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European Organization for Nuclear Research (CERN)

Nothing in this Collaboration Agreement shall be deemed or interpreted as a waiver, express or implied, of any privileges and immunities accorded to CERN under its constituent documents or under international public law

Date and place: 7th July 2021, Geneva.
Signature:

Dr. Mike LAMONT
Director of Accelerators and Technology

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Science and Technology Facilities Council (STFC) as part of United Kingdom Research and Innovation (UKRI) on behalf and for the account of Daresbury Laboratory

Date and place: 24/6/21 DARESBURY
Signature:

Professor J A Clarke
Director of ASTeC

PERLE Collaboration Agreement
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University of Liverpool

Date and place:
Signature:

Barrie Owens
Research Contracts Officer
Legal and Governance
University of Liverpool
UNIVERSITY OF LIVERPOOL
16/6/21

Position

PERLE Collaboration Agreement

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Cornell University

Date and place: May 25, 2021; Ithaca NY USA
Signature: Sarah Schlagter

Sarah SCHLAGTER
Senior Grant and Contract Officer

PERLE Collaboration Agreement

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Budker Institute of Nuclear Physics (BINP)

Date and place: Novosibirsk, Russia
Signature:

Dr. Pavel V. LOGACHEV
Director

PERLE Collaboration Agreement
Signature Sheet

An-Najah National University, Nablus, Palestine

Date and place: 1st July 2022
Signature:

Dr. Kherieh Rassas
Vice president for international and external affairs

PERLE Collaboration Agreement

Signature Sheet

ESS Bilbao Consortium

Date and place:

Signature:

11832905A
MARIO PEREZ
(R: G95455473)

Firmado digitalmente por 11832905A MARIO PEREZ (R: G95455473)
Fecha: 2022.11.15 14:57:57 +01'00'

Position: Executive Director

Annex A: List of Parties and contact persons

- Centre National de la Recherche Scientifique - Institut National de Physique Nucléaire et de Physique des Particules (CNRS-IN2P3), acting on behalf of the Laboratoire de Physique des Deux Infinis Irène Joliot-Curie (IJCLab, Orsay, France) and of the other IN2P3's laboratories which might be involved in this Collaboration Agreement.

  Contact person: Walid Kaabi (kaabi@lal.in2p3.fr)

- Conseil Européen pour la Recherche Nucléaire (CERN), Switzerland

  Contact person: Julia Double (julia.double@cern.ch)

- Thomas Jefferson National Accelerator Facility (JLAB), USA

  Contact person: Andrew Hutton (andrew@jlab.org)

- Science and Technology Facilities Council (STFC) as part of United Kingdom Research and Innovation (UKRI) for and on behalf of Daresbury Laboratory, Sci-Tech Daresbury Keckwick Lane, Daresbury, Warrington, WA4 4AD, UK

  Contact person: Deepa Angal-Kalinin (deepa.angal-kalinin@stfc.ac.uk)

- University of Liverpool, Physics Department, Liverpool, UK

  Contact person: Carsten Welsch (C.P.Welsch@liverpool.ac.uk)

- Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia

  Contact person: Eugène Levichev (E.B.Levichev@inp.nsk.su)

- Cornell University, Ithaca, New York State, USA

  Contact person: Georg Hoffstaetter (georg.hoffstaetter@cornell.edu)

- An-Najah National University, Nablus, Palestine

  Contact person: Hadil Abualrob (hadil.abualrob@najah.edu)

- Commissariat à l'Énergie Atomique et aux Énergies Alternatives, acting on behalf of Institut de Recherche sur les lois Fondamentales de l'Univers (IRFU, CEA/DRF), Saclay, France

  Contact person: Pierre Vedrine (pierre.vedrine@cea.fr)

- …

Annex B: PERLE Description, Axes of Collaboration, Stages, Timeline

1. PERLE design and Main Parameters

The PERLE accelerator complex, cf. Fig.1, is arranged in a racetrack configuration hosting two cryomodules, each located in one of two parallel straights completed with a vertical stack of likely three, 180° recirculating arcs on each side. Additional space between the straights and the arcs is taken by long spreaders/recombiners, including matching sections. The spreaders are placed directly after each linac to separate beams of different energies and to route them to the corresponding arcs. The recombiners facilitate just the opposite: merging the beams of different energies into the same trajectory before entering the next linac. The path-length of each arc is chosen to be an integer number of RF wavelengths except for the highest energy pass, arc 6, whose length is longer by half of the RF wavelength to shift the RF phase from accelerating to decelerating, switching to the energy recovery mode. All six, 180° horizontal arcs are configured with Flexible Momentum Compaction (FMC) optics to ease individual adjustment of M56 in each arc (needed for the longitudinal phase-space reshaping, essential for operation with energy recovery).

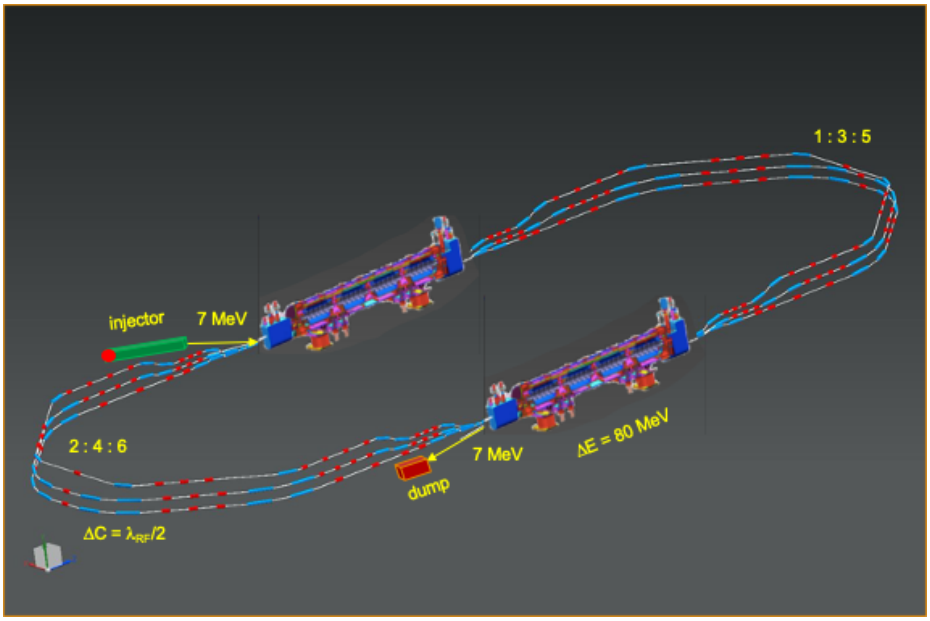

Figure 1: PERLE layout featuring two parallel linacs each hosting a cryomodule housing four 5-cell SC cavities, achieving 500 MeV in three passes.

Each of the two cryomodules contains four, 5-cell cavities operating at 801.6 MHz. For a CW gradient of about 20 MV/m , each cryomodule provides 82 MeV energy boost. Adding the initial injection energy of 7 MeV this yields a total energy of approximately 500 MeV. A first phase is considered with one cryomodule only delivering half the final energy. The main beam parameters of PERLE facility are summarised in the following table:

Table 1: PERLE Beam Parameters

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

Initial technical choices, the full configuration and challenges of a realisation have been described in the PERLE CDR [1] and updated in Ref. [2].

[2] The Large Hadron-Electron Collider at the HL-LHC, CERN ACC-Note-2020-0002, to be published

2. Axes of Collaboration

The Table below shows a breakdown structure of the main collaboration axes initially directed to the Technical Design Report of PERLE, divided into tasks and sub-tasks.

Axes of Collaboration
TASK 1: Lattice and optics
▪ T 1-1: Linear lattice optimization Initial magnet specs
▪ T 1-2: Momentum acceptance and longitudinal match
▪ T 1-3: Correction of nonlinear aberrations with multipole magnets
▪ T 1-4: Final magnet specs
▪ T 1-5: Repository and data base with version control
TASK 2: Beam Dynamics
▪ T 2-1: Start-to-End simulation with CSR & micro-bunching
▪ T 2-2: BBU studies
▪ T 2-3: Space-charge studies at injection
▪ T 2-4: Multi-particle tracking studies, error effects and halo formation
▪ T2-5: Impedance analysis and wakefield effect mitigation
TASK 3: Electron source and injection
▪ T 3-1: DC Gun upgrade
▪ T 3-2: Photocathode fabrication and load lock system design
▪ T 3-3: Buncher design
▪ T 3-4: Booster studies and design
▪ T 3-5: Laser system
▪ T 3-6: Merger design
TASK 4: SRF Cavity and cryomodule
▪ T 4-1: RF cavity design
▪ T 4-2: Fabrication & tests
▪ T 4-3: HOM study
▪ T 4-4: Power coupler design and study
▪ T 4-5: Cryomodule design
TASK 5: Magnets & power supplies
▪ T 5-1: Arc magnets design
▪ T 5-2: Spreaders & combiners magnets design
▪ T 5-3: Injection and extraction magnets design
▪ T 5-4: Multipole magnets design
TASK 6: Beam instrumentations
▪ T 6-1: Charge measurements
▪ T 6-2: Beam position measurements
▪ T 6-3: Transverse profile measurements including halo
▪ T 6-4: Longitudinal measurements including profile and sub-structures (CSR, CTR…)
▪ T 6-5: Losses
▪ T 6-6: Polarisation measurements

TASK 7: Beam dumps
▪ T 7-1: Setup dump
▪ T 7-2: Transfer line
TASK 8: LLRF
▪ T 8-1: Synchronisation
▪ T 8-2: Feedbacks
TASK 9: Safety and radioprotection
▪ T 9-1: Site Shielding
▪ T 9-2: Personal Protection System
▪ T 9-3: Machine Protection System
TASK 10: RF Power sources
TASK 11: Cryogenic equipment
TASK 12: Physics Experiments - selections and preparations
▪ T 12-1: Photo-nuclear physics
▪ T 12-2: e- probe on Self-Confining Radioactive Ion Target
▪ T 12-3: ep scattering, dark photon detection, proton radius, weak interaction

3. Stages and Timeline

The PERLE Project starts with a design and prototyping phase as detailed in the table above. This preparatory phase will in particular produce a PERLE Technical Design Report (TDR).

There follow three phases of construction, commissioning and exploitation which are summarized here below and will be subject to changes as the Project develops. These phases will be the subject of a subsequent dedicated agreement.

- **Phase 0:** Installation of the injection line with a beam dump at its end.

  The injection line includes the DC gun, the load lock photocathode system, solenoids, buncher, booster, merger and required beam instrumentations to qualify the generated beam.

  The commissioning of the injection line will require the installation of cryogenics, RF power source, power supplies for the optics, photocathode laser, beam dump, control-command, vacuum systems, site shielding, safety control system, fluids, etc. Many of these installations must be already sized according to the final configuration of PERLE.

- **Phase 1:** 250 MeV Version of PERLE

  Installation of a single linac in the first straight and installation of beam pipe and complete return arcs. The switchyards have to be chosen according to the beam energy at each end (energy acceptance ratio: 1:2:3 for the spreader and combiner). This version of the race track is connected to the injection line built in phase 0, via the merger.

This particular staging is determined by the existence of the SPL cryomodule which will permit a rather rapid realisation of a 250 MeV machine possibly still using the ALICE gun.

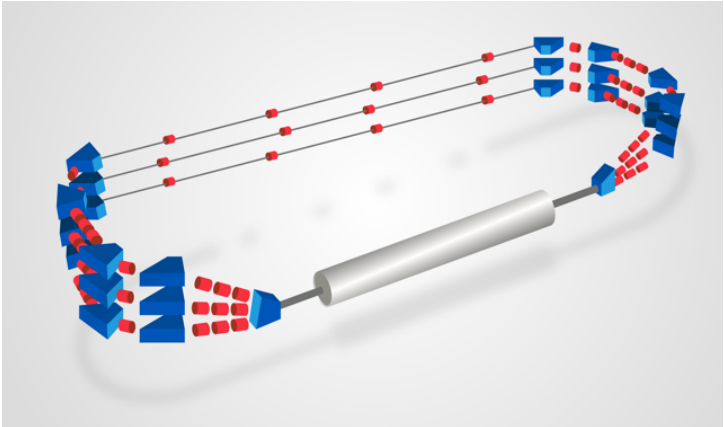

Figure 2: PERLE-Phase 1 layout featuring a single Linac in the first straight and solely beam lines in the second straight, achieving 250 MeV electron energy in three passes.

- **Phase 2:** 500 MeV version of PERLE

The second phase is for the realisation of PERLE at its design parameters, as a 10 MW machine which requires the nominal electron current, i.e. the upgraded e^- gun and the completion of the production of a dedicated further cryomodule. Also, a second spreader and recombiner at the required acceptance ratio need to be installed on both sides of the second cryomodule.

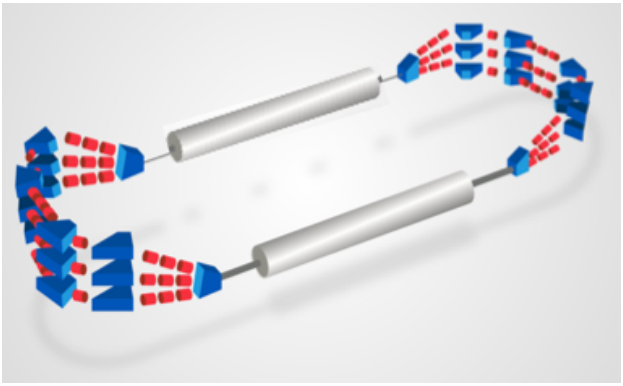

Figure 3: PERLE-Phase 2 layout featuring two Linacs, achieving 500 MeV in three passes.

During the design and preparatory phase, the Collaboration will develop a detailed **time schedule**. Currently it is expected to complete the TDR by end 2022, Phase 0 by 2025, Phase 1 by 2028 and Phase 2 by 2030. A scheme of milestones will be worked out and agreed upon with emphasis on the accelerator but including a timeline for future experiments.

Annex C: PERLE Management Structure

The organization of the PERLE Project comprises the following bodies and responsibilities.

- The PERLE Collaboration Board (CB), acting on behalf of the Parties, is responsible for the science policy of the Collaboration. It approves at the unanimity of his members, the entry of the new memberships into the Collaboration, it takes notice of the withdrawal of collaborating institutes, nominates the Spokesperson of the Collaboration and endorses the Project Leader. It oversees the progress made by the Project, reviews Parties' contributions estimates and ensures an efficient communication between the collaborators, providing a coherent communication channel and advice to the Project management.

- The PERLE Project Leader (PL) is appointed by the direction of CNRS-IN2P3. Assisted by the Spokesperson (SP) and the PERLE Management Board (MB), he is responsible for the execution of the Project.

The terms of reference of each of these bodies are given in more detail below.

Collaboration Board

The Collaboration Board shall consist of one representative of each Party of the CA. The CB has a Chairman which is elected by the CB, for a period of two (2) years, renewable.

The Project Leader and the Spokesperson are ex-officio members of the CB. The CB can invite others to attend as may be needed for consultation.

The CB addresses the following matters:

- Definition and approval of the scientific policy of the PERLE Collaboration.
- Advise to the Project Leader and members of the PERLE Management Board.
- Supervision of scientific and technical choices,
- Monitoring the progress and completion of the tasks.
- Evolution of collaborating members and associated contributions.
- Proposals for changes to this CA.
- and similar tasks

The CB shall meet at least once per year, and more often upon request as, e.g. for important decisions or modifications of the Project.

Decisions in the CB shall be taken by consensus or, in exceptional cases, by a two-third majority of its members including CNRS-IN2P3.

Minutes of each meeting shall be drafted and communicated to the other members.

The minutes of each meeting shall be considered as accepted by the other members if, within thirty (30) calendar days from receipt, the other members have not objected to the chairperson and they will take into account their possible comments.

The CB chair signs on behalf of the CB all written agreements as appropriate.

Project Leader

The PERLE Project Leader is appointed by the direction of CNRS-IN2P3 and is endorsed by the CB. Assisted by the Spokesperson and the Project Management Board, he/she is responsible for coordinating the different tasks of the Project described under this CA and for defining the Project annual activity plan, in accordance with the resources allocated by each Party. He/she is also responsible for reporting the progress made by the Project to the CB and to the direction of CNRS-IN2P3.

Spokesperson

The Collaboration has a Spokesperson to assist the Project Leader. His/her task is to care for the formation, representation and operation of the Collaboration so that the PERLE Project can be executed in an optimum way. The Spokesperson is elected by the CB and endorsed by the direction of CNRS-IN2P3.

Management Board

The Management Board consists of the Project Leader, the Spokesperson and expert members which are nominated by the PL and endorsed by the CB and by the Party they belong to. The MB meets regularly, at least once per month. The MB has a primarily technical role. It assists the PL to define the various project tasks, at IJCLab Orsay and/or other collaboration sites, and to ensure the execution and monitoring of the Project.

Annex D: Estimates of the Parties' intended contributions

This annex provides an estimation of each Party's intended contribution to the PERLE project under the scope of this Collaboration Agreement:

- Centre National de la Recherche Scientifique - Institut National de Physique Nucléaire et de Physique des Particules (CNRS-IN2P3)
    - Axes of collaboration addressed: besides its roles of collaboration coordination and project management, CNRS-IN2P3 will be involved in several collaboration axes, such as the beam dynamic studies and simulations, design and prototyping of the main components (Injection line, SRF systems, magnets, instrumentation) and studies related to safety and integration of the facility.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): CNRS-IN2P3 will involve the required manpower in the different addressed axes and will apply for fund opportunities to finance the project in its different phases.

- Conseil Européen pour la Recherche Nucléaire (CERN)
    - Axes of collaboration addressed: power coupler design and study, Cryomodule design. Collaboration envisaged on already existing items: cryomodule design, cryomodule hardware, assembly procedures, existing FPC design and hardware; envisaged contribution to fast reactive tuner design, HOM mechanical design and FPC modification.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): to be defined later on; potential use of CERN infrastructure for assemblies and tests.

- Science and Technology Facilities Council (STFC)
    - Axes of collaboration addressed: generic ERL expertise; electron source and injector.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): to be defined later on.

- University of Liverpool, Physics Department
    - Axes of collaboration addressed: Physics program, accelerator design and optimization, instrumentation and sensor development.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): PhD students, academic staff and, subject to funding, postdocs, technical and admin staff.

- Budker Institute of Nuclear Physics (BINP)
    - Axes of collaboration addressed: Magnet design and prototype fabrication; vacuum chambers design and fabrication; Magnets power supplies design.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): to be defined later.

- Cornell University
    - Axes of collaboration addressed: expertise on ERL technologies.
    - Associated resources envisaged (staff, equipment/material when applicable, etc.): to be defined later on.

- An-Najah National University, Nablus, Palestine
    - Axes of collaboration addressed: Lattice design and optimization, beam dynamics study, magnets design and prototyping, measurement of the accelerator magnets.

    - Associated resources envisaged (staff, equipment/material when applicable, etc.): PhD students and master students, academic staff, engineers, technicians.