PERLE Collaboration Meeting

INTODUCTION

PERLE Timeline for TDR phase and beyond

The current phase of the project:

Technical Design phase (→ 2023)

- Machine design (Injector, 250MeV and 500 MeV configurations)
- Beam dynamics studies
- Main systems design (Buncher, Magnets, HOM couplers, full dressed cavity, power couplers, new CM, IP, dump…)
- In-Kind adaptation and/or upgrade **studies** (DC-Gun, Booster, SPL CM) *
- Definition of the needs (Diags, Cryogenics, CC, LLRF, Shielding, machine interlock system, infrastructure…)
- Experiments with PERLE beam and their specific needs

* Design of some systems could continue after TDR publication

* Prototyping results could be included in the TDR phase if available

Prepare to Build phase (P2B) (→ 2025)

- Prototyping and tests (HOM couplers, Single cell booster cavity, B-COM magnet, 5-cells Nb Cavity) *
- PERLE administrative regime (Dossier ASN)
- Infrastructure (site investigations and work)

And also:

- DC-Gun reinstallation and test
- Equipment specifications and procurement (for DC gun)
- In-Kind adaptation and/or upgrade **work** (DC-Gun, ESS CM)

PERLE Timeline for TDR phase and beyond

Technical Design phase (TDR)

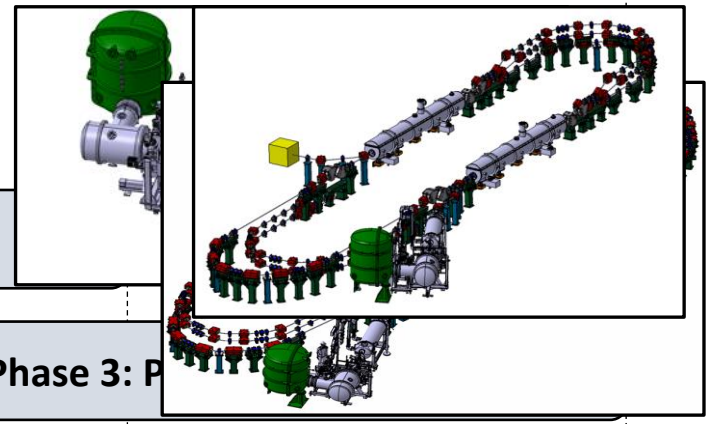
Prepare to Build phase (P2B)

Installation phases

Phase 1: Installation of the injection line

Phase 2: PERLE 250 MeV version

Phase 3: P



2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031

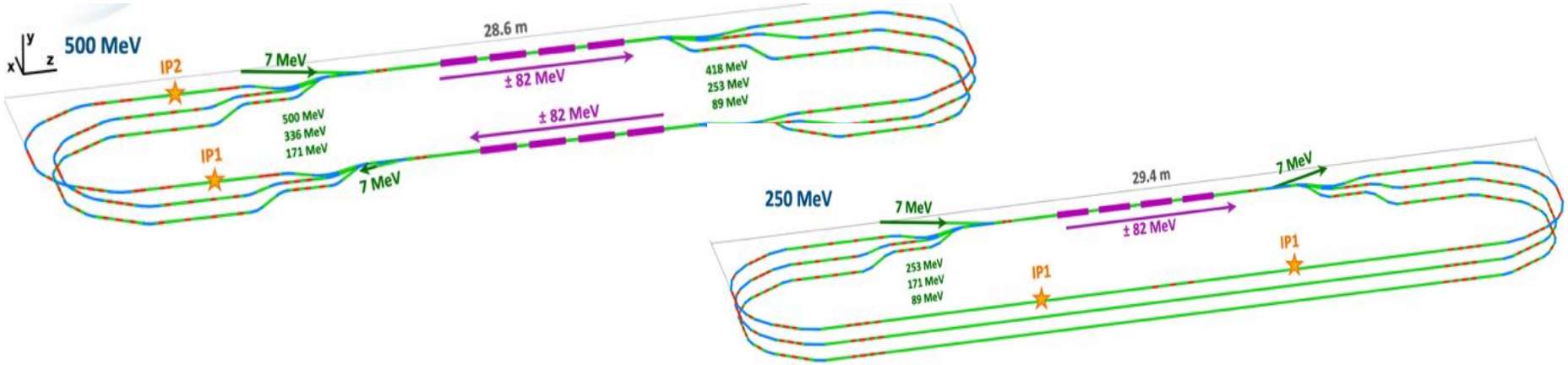
Hightlighst on results of recent months

which will be discussed in details during this collaboration meeting

with some comments on important discussion which could take place.

PERLE Lattice optimization

Lattices and optics for the 500 MeV and 250MeV PERLE versions were studied and optimised:

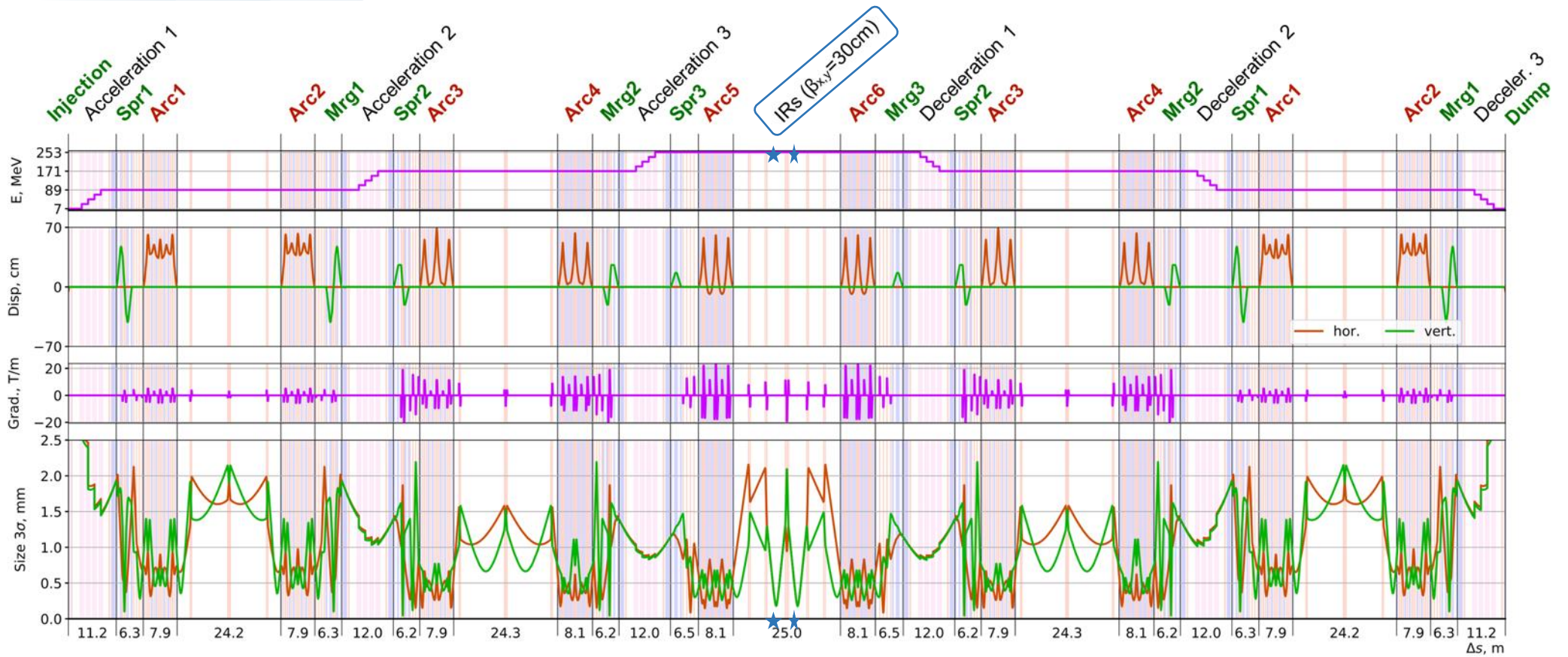


- A full 1st order calculation were finished and a complete 250 and 500 MeV lattice is now available.
- The stability of the lattice was crosscheck with different codes (OPTIM6, MADX & BMAD).
- First specifications of quadrupoles and dipoles in switchyards & arc sections are obtained.

→ Further studies are ongoing/to be done: correction of nonlinear aberrations with multipoles, momentum acceptance, longitudinal match…

→ In addition to beam dynamics studies: Start to end simulations with CSR and microbunching, Multiparticle tracking, BBU, Impedance analysis and Wakefield effect mitigation …

Lattice optimization of the 250 MeV version of PERLE

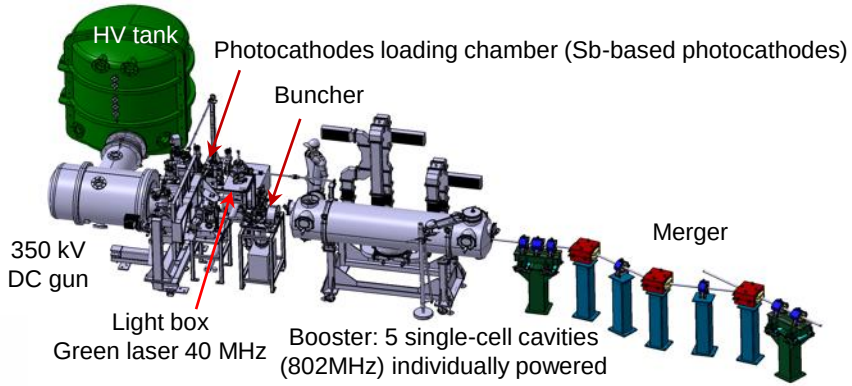


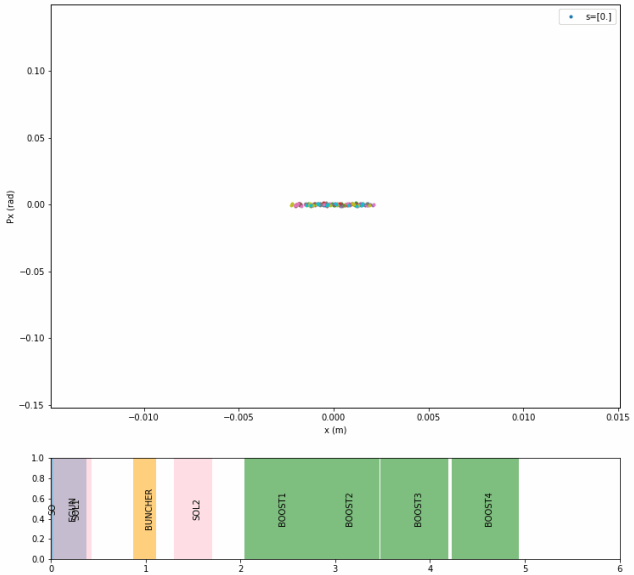
Transverse beam size (3σ radius) $< 2{,}2$ mm (after the 2nd RF cavity), Dispersion < 70 cm and Low beta function @ the 2 IRs

(more details in Alex, Alex, Rasha, Julien, Coline talks)

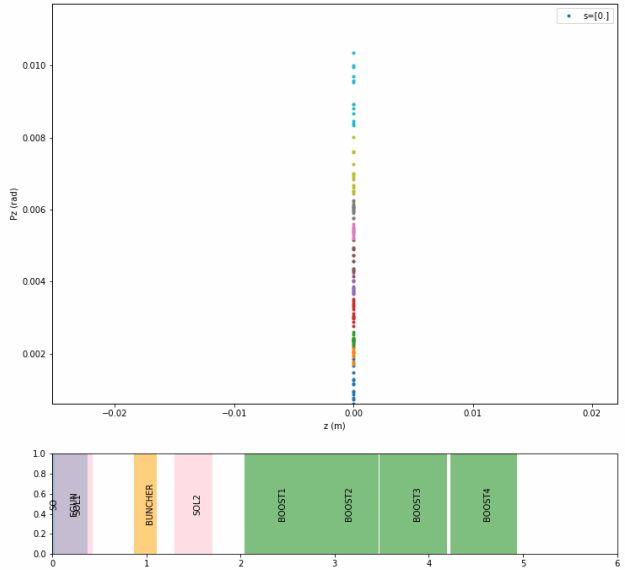
Injection line optimisation

A conceptual design of the PERLE injector was made within a collaboration between AsTeC-Daresbury, UoL and IJCLab. This included the **DC gun cathode shape** optimisation, a **buncher cavity** and the **merger conceptual designs**, besides a complete beam dynamic studies of **space charge effects**, **phase space** and **bunch distributions**, and **emittance**. Further studies and design optimisation of the injector are currently undertaken.





Transverse phase space (x-px)



Longitudinal phase space (z-pz)

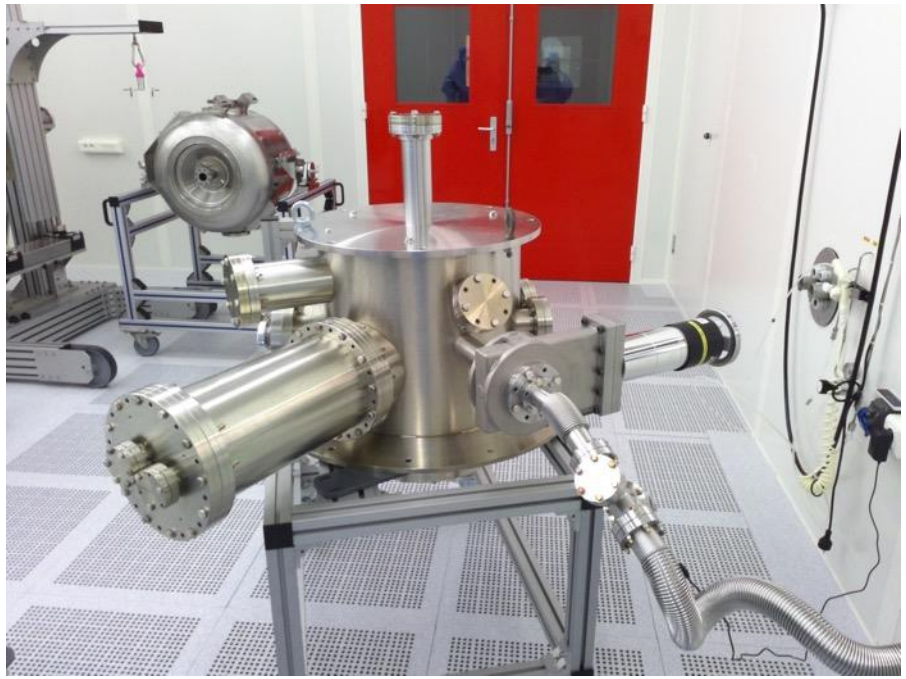
- Solenoids focus beam in transverse plans
- Buncher focus beam in longitudinal
- **M shape in z-pz axis at the end of injector : Might be a problem**

More details in Raphael's talk +diagnostics Mohamed

B. Hounsell et al. "Conceptual design of the PERLE injector" LINAC'22- Liverpool, UK- THPOJO26

PERLE e- Source

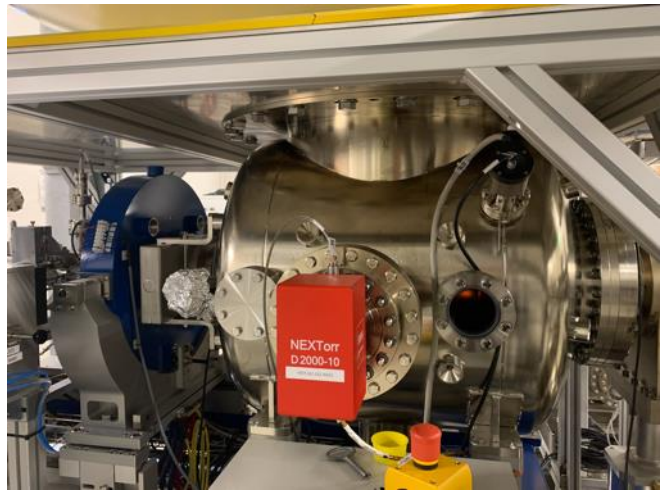
Installation of the gun vessel (November 22)



Vacuum pumping of gun new chamber after ultrasonic cleaning (December 2023)

PERLE e- Source

A new opportunity of a DC gun acquisition raised early in 2023: Ongoing discussions with Research Instruments GmbH (RI)

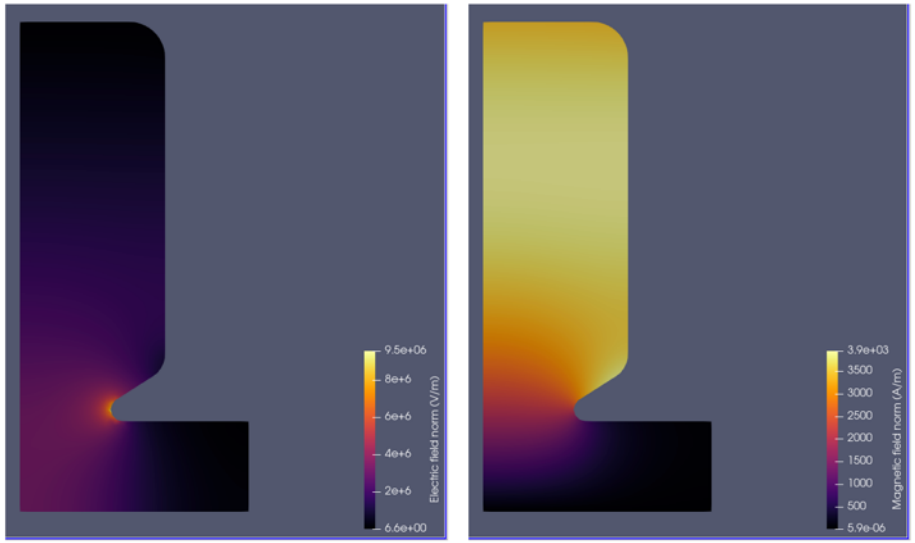


→ A Gun with Cornell design (400 pC, 50 MHz demonstrated), fully equipped (all pumps) in load-lock version
→ Equipped with a Photocathode preparation facility
→ HV power supply suited for high bunch charge (designed for 40 mA, 450 kV)
→ The gun was commissioned and tested at high rep rate, at a limited bunch charge

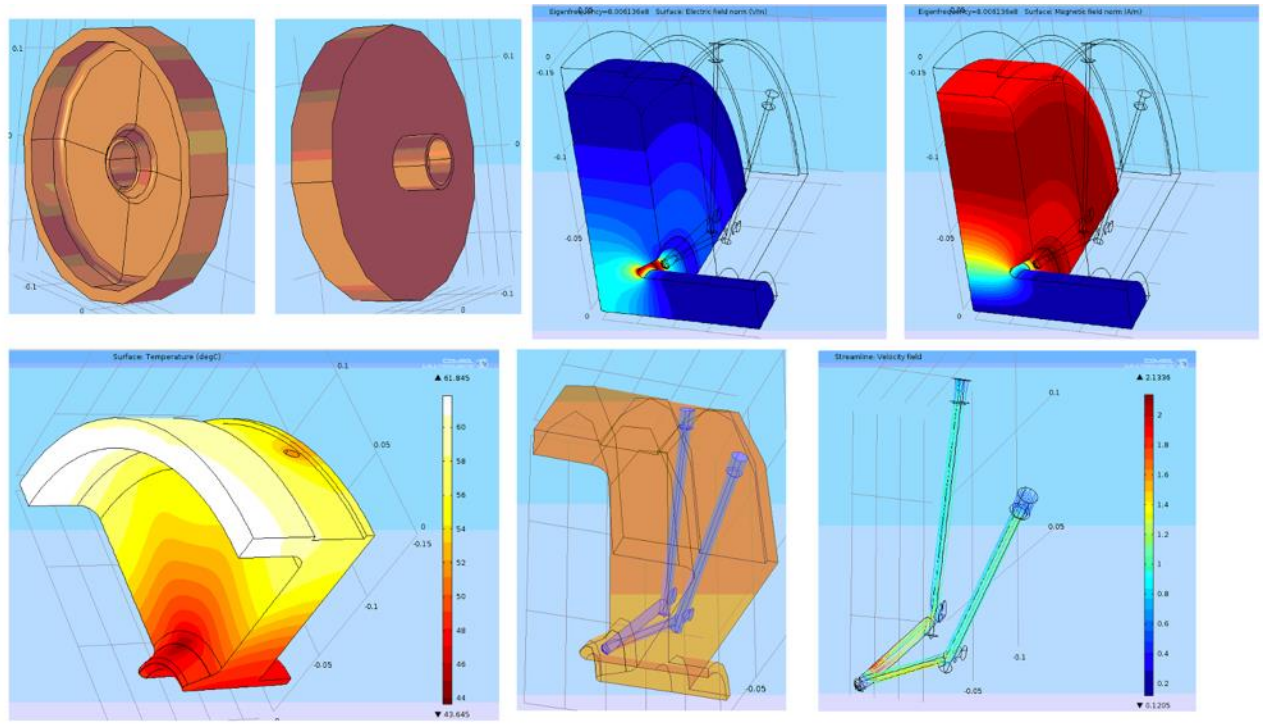
(more details in Maud & Raphael talks)

First simulation of Buncher cavity :

Electric and magnetic field maps



Courtesy to Juan Luis Munoz- ESS- Bilbao

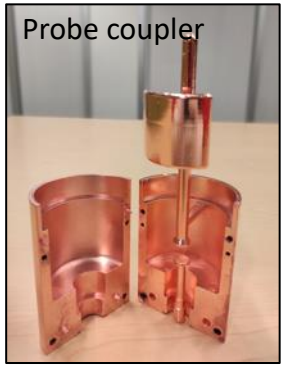


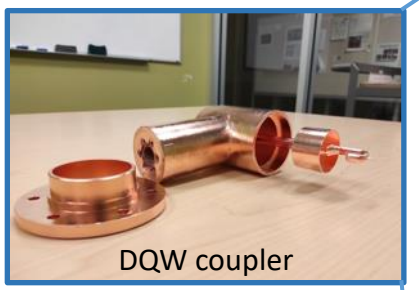
First results of the buncher cavity design (more details in Juan Luis's talk)

Status of HOM studies :

From RF design to performance measurements: collaborative effort between IJCLab, Jefferson Lab & CERN

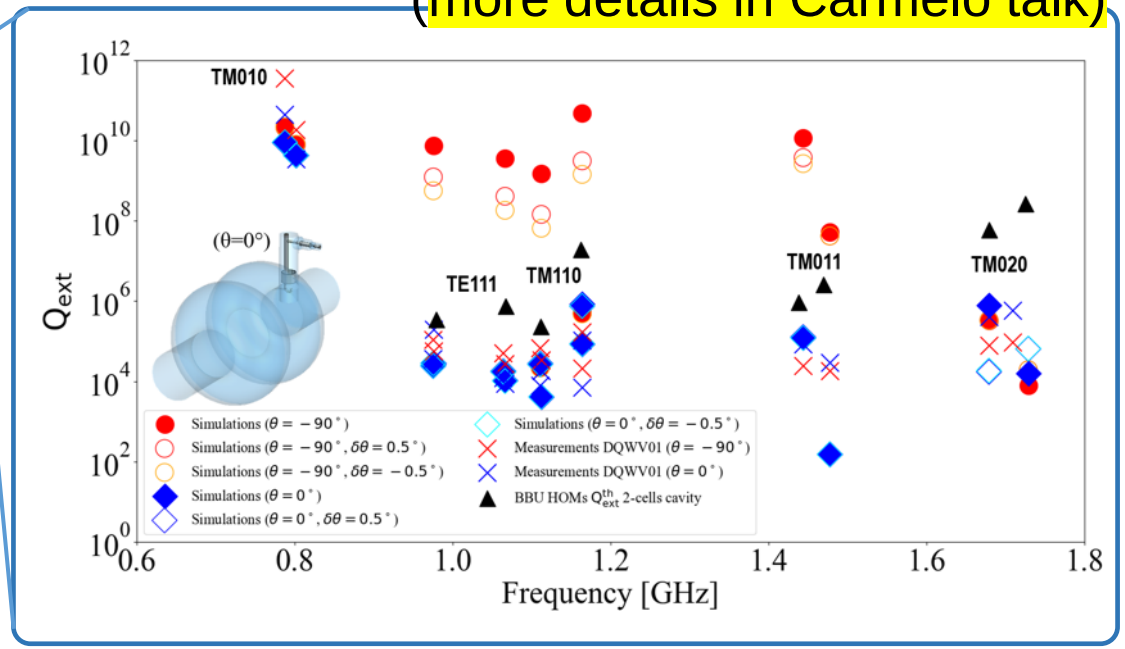
(more details in Carmelo talk)





3D-printed prototype (Epoxy Accura 48) copper-coated @CERN

Installation in a double-cell Cu cavity and test of performances (S12, β_1, β_2, Q_L and Q_{ext}) @JLab



- Measurements are made as a function of rotation angle of HOM coupler hook.
- Good rejection of Fundamental Mode, Q_{ext} > 1E+09.
- Measured Q_{ext} for HOMs are below BBU limit thresholds.
- Good agreement between measured and simulated Q_{ext} → could be improved with more appropriate boundary conditions at beam pipe apertures.

C. Barbagallo et al. "First RF measurements of coaxial HOM coupler prototypes in a copper cavity for the PERLE project"- IPAC'23- MOPA025

Plans on HOMs and cavity activities :

(more details in Bob & Haipeng talks)

IJCLab- JLab- CERN Collaboration

- A 5-Cell copper cavity under fabrication @Jlab (same design as the 1st Nb 5-cell cavity fabricated in 2017) to allow end group design optimisation and to test several HOM couplers combinations to assess the best HOM damping scheme.

Copper half-Cells production at Jlab for the 5-Cell "clamped" cavity

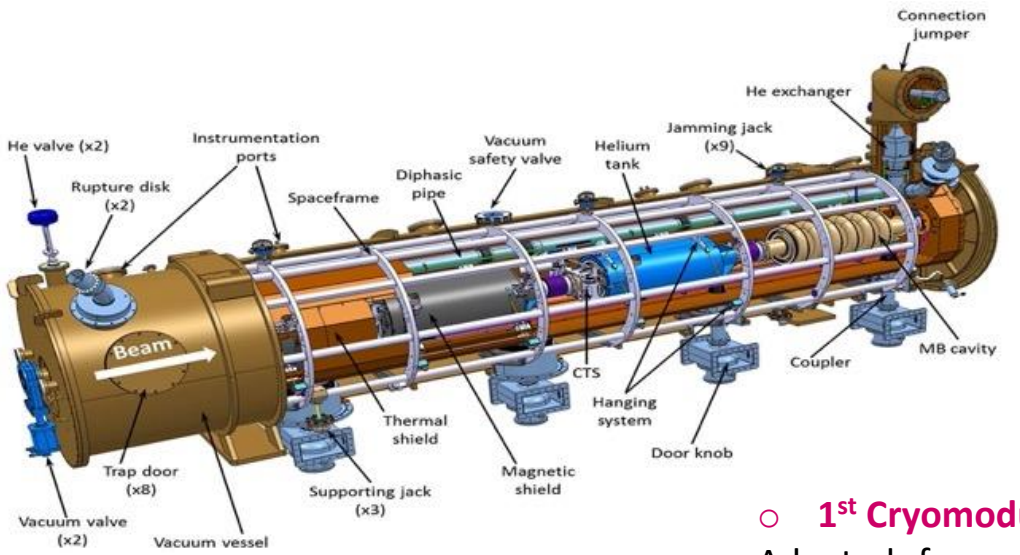
3D-printed HOM port to beam transition- France

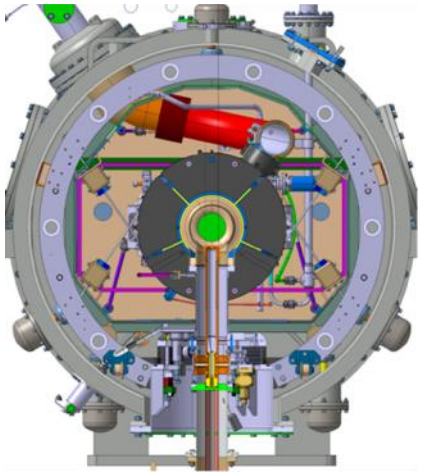
- Ultimately, we aim to produce Nb HOM couplers with optimised design and and install them on a new Nb 5-cell PERLE cavity with optimised end groups. **The Production of 4 cavity scheduled within the ISAS program (Starting from 2024).**

→ A global technical review (HOM dumping scheme + cavity end cell design) to be settled before moving to fabrication

Cryomodule design:

(more details in Gilles talk)





ESS Cryomodule design was selected:

- Intermediate supporting structure (spaceframe)
- Cavity string hung by rods
- Insertion of the cavity string by the extremity (rollers)
- Trap doors for tuner access
- Connexion to the valve box on the top of the vacuum vessel
- Important space available inside
- Design validated: series fab. & tests ongoing (Qty 30)

- **1st Cryomodule: Foreseen for 2027**

Adapted from ESS design, it will be optimised for efficient high current ERL operation within the ***European Infra-Tech program iSAS**. It will host cavities equipped with HOM couplers and FPC optimised and developed within the same program.

- **2nd Cryomodule: Foreseen for 2030**

May include some/all the technologies studied within ***iSAS program*** to improve the efficiency of Cryomodules: Fast Reactive Tuner (FRT) for microphonics mitigation, LLRF managed by AI and 4.2 K Cavities operating.

(more details in Nick talk)

****More information on iSAS program: https://indico.ijclab.in2p3.fr/event/9521/***

Administrative Classification of PERLE

(more details in Walid talk)

A study was ordered to IRSD in 2018 and released in 2019.

- Code de l'environnement L593-2
- Décret n°2007-830 du 11 mai 2007
  - Accélérateur d'électrons :
    - Énergie du faisceau supérieure à 50 MeV
    - Puissance du faisceau supérieure à 1 kW
- C
  a

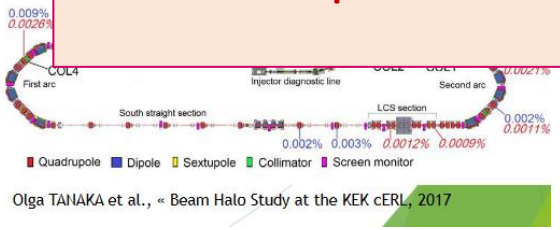
iRSD ingénierie Radioprotection Sûreté et Démantèlement	DE/LAL/RP/18/01
	Date : 24/05/2018
	Indice : 0
	Page : 1/104

~100 pages document

Définition du régime administratif d'autorisation et

JM. HORODYNSKI *PCR LAL*	F. CHAPELLE *PCR LAL*	P. ROBERT *Directeur de l'iRSD*
Rédacteur	**Vérificateur**	**Approbateur**

NOMS (unité et fonction) & VISAS



Olga TANAKA et al., « Beam Halo Study at the KEK cERL, 2017

Some benchmarking with cERL and JLab former ERLs.

Preliminary conclusions.

Types de pertes	Puissance perdue	Durée du phénomène	Phénomènes physiques limitant le phénomène
Pertes d'exploitation			
Perte continue sur le piège à faisceau d'exploitation	75 kW	Continue	Énergie des électrons de 7 MeV
Perte continue en exploitation normale le long de l'accélérateur	Inférieure à 1 kW	Continue si pas de systèmes de protection machine (MPS) Avec MPS, durée inférieure à la seconde	Échauffement des éléments par interaction avec le faisceau primaire d'électrons
Perte instantanée sur un piège à faisceau d'urgence	Puissance crête : 16 MW - 30 MW Puissance moyenne : 5 W	175 ns	
Pertes accidentelles			
Pertes de faisceau sur les cavités supraconductrices	Inférieure à 1kW	0,4 µs	Quench dû à l'échauffement local des parois des cavités supraconductrices
Pertes de faisceau sur les arcs de recirculation ou un collimateur	Inférieure à 1 kW	Chambre à vide : 2,4 ms - 17 ms	Fusion locale du matériau entraînant la dégradation de la qualité du vide
	Inférieure à 1 kW		
Perte sur cible épaisse - Arc de recirculation 1-5	Inférieure à 1 kW	10 ms	Fusion locale de la cible entraînant la dégradation de la qualité du vide
Perte sur cible mince au niveau d'une cavité supraconductrice ou une chambre à vide amont/aval	Inférieure à 1 kW	Variable suivant le matériau : 2 ms -7 ms	Fusion locale de la cible entraînant la dégradation de la qualité du vide
Perte sur cible mince au niveau d'un arc de recirculation 1 - 5	SI perte d'énergie inférieure à 25 keV : Inférieure à 1 kW Inférieure à 1 kW	Continue Inférieure à 1 seconde	Fusion locale de la cible entraînant la dégradation de la qualité du vide
Perte sur cible mince au niveau d'un arc de recirculation 6	SI perte d'énergie inférieure à 50 keV : Inférieure à 1 kW Inférieure à 1 kW	Continue Inférieure à 1 seconde	Fusion locale de la cible entraînant la dégradation de la qualité du vide

Synthèse des résultats

Des limites physiques au maintien d'une perte de faisceau dont la puissance crête est supérieure à 1 kW existent.

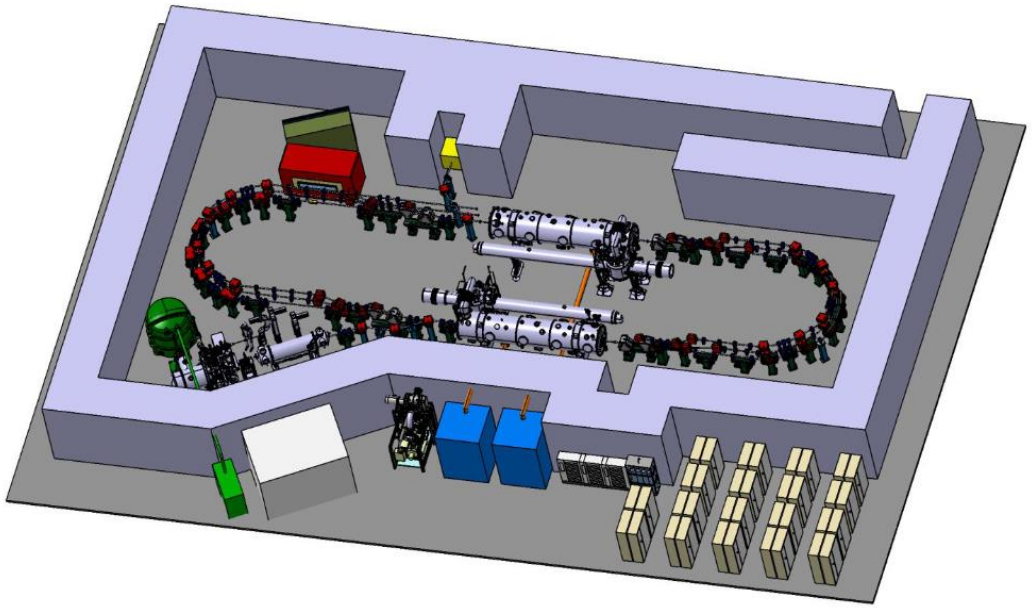
La durée du phénomène serait inférieure à la seconde.

Par conséquent, l'installation PERLE@Orsay pourrait être soumis à une « simple » demande d'autorisation auprès de l'ASN

Today, a task-force is formed to:

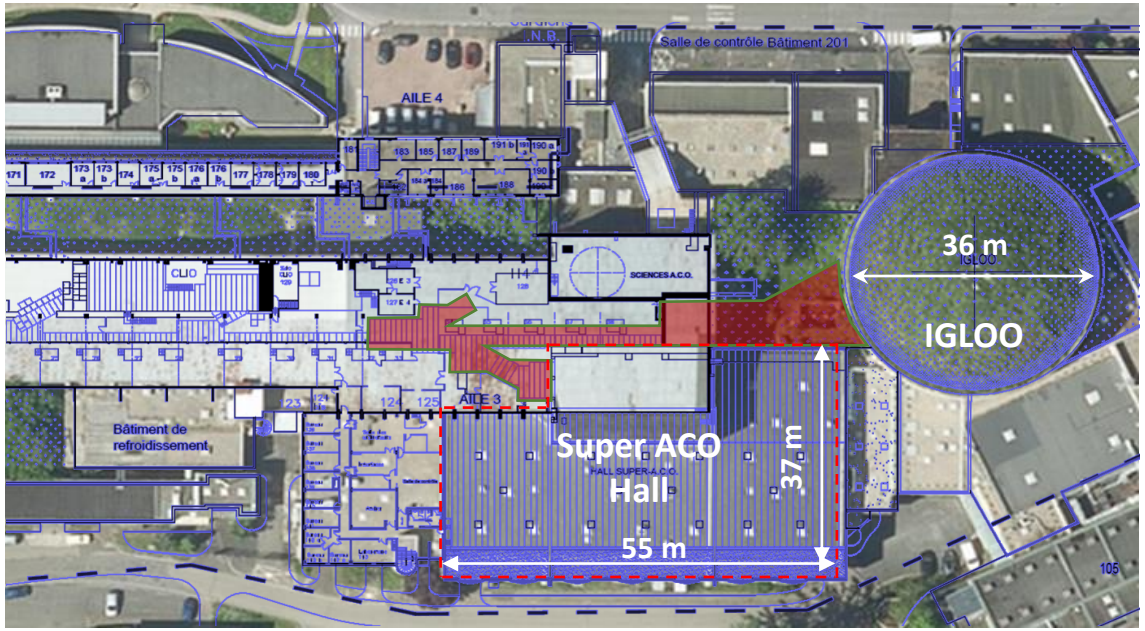
- **Continue and complement these studies to have a preliminary discussion with ASN by Summer 2023.**
- **Start the required studies and the draft of the ASN document for PERLE in the upcoming years**

PERLE Footprint and site studies

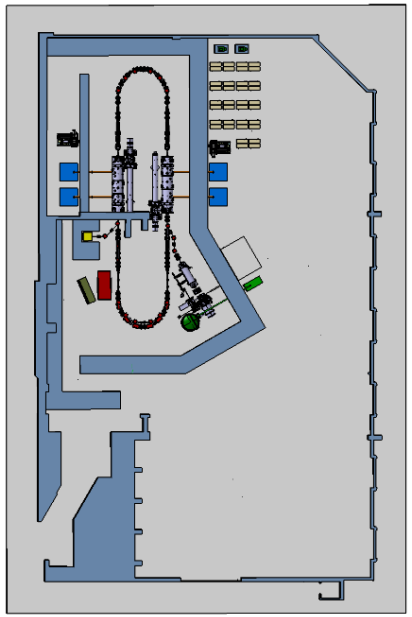


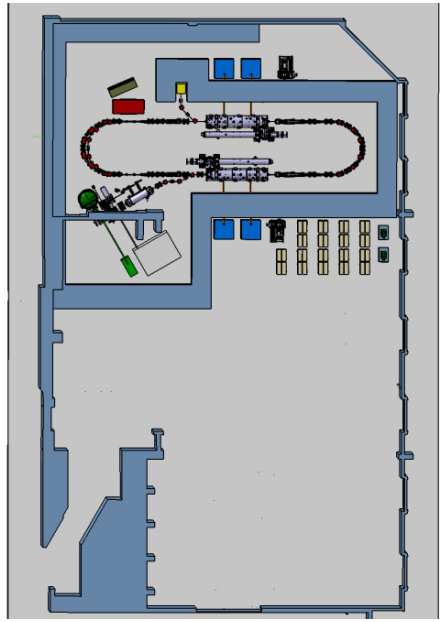
PERLE feature a total footprint of:
30 meters long, 15 meters wide and 3.4 meters high.

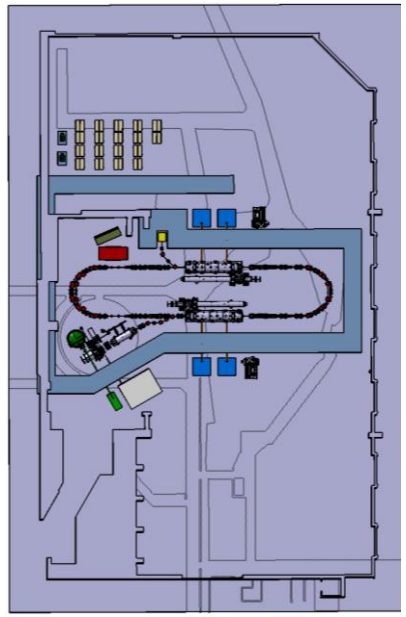
Two sites are currently considered and will be studied in details within the CPER program for possibly host PERLE: The Super ACO hall and the IGLOO.

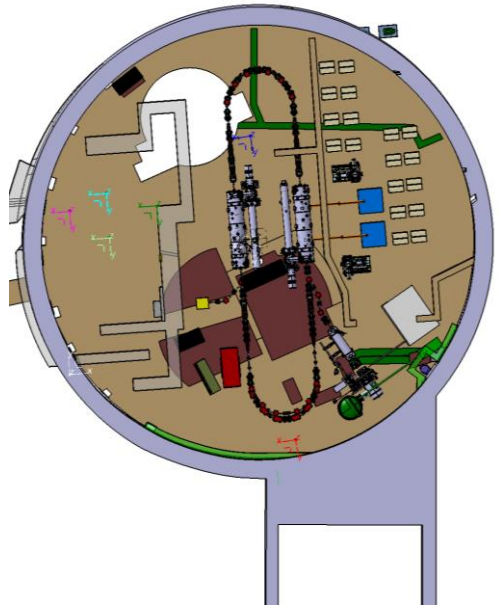


PERLE Footprint and site studies





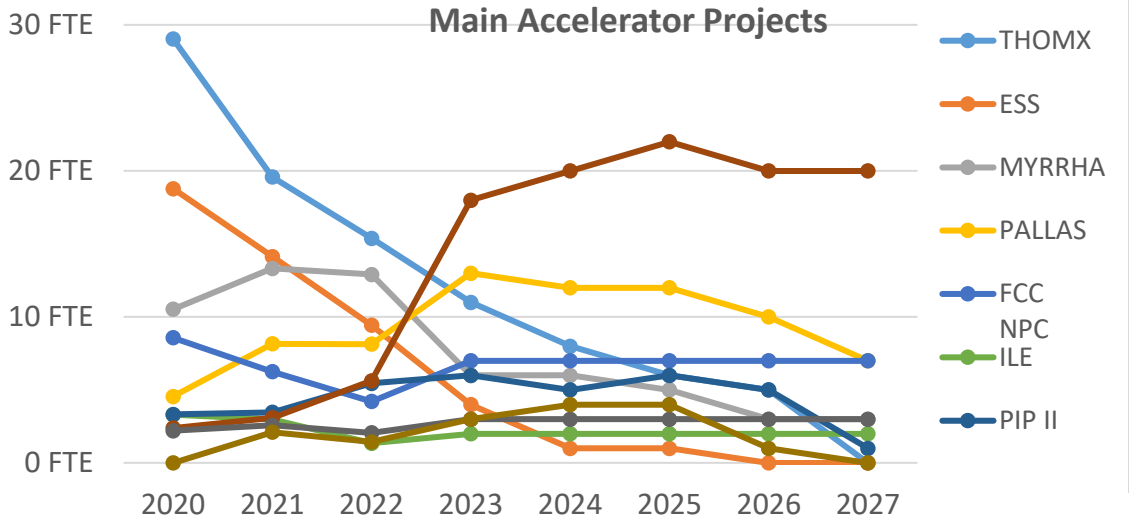




(more details in Walid talk)

HR involvement and projection - French level mostly

Significant increase in 2022 of the forces contributing to PERLE that will continue in the coming years according to the phasing strategy.



Up to 20 FTE secured.
IJCLab/ France has to increase that.
BUT
We need similar exercise from the other partners.

Action on going.

→ Here the evolution of IJCLab manpower implication on the project in the past three years and an estimation for the 3 upcoming ones:

Year	2020	2021	2022	2023	2024	2025
FTEs	1,9	3	7	16	18	20

* For the past years, the table do not include other French lab involvements (LPSC + GANIL) + a split site PhD with Liverpool University.

Financial resources- Budget Estimation and spending profile

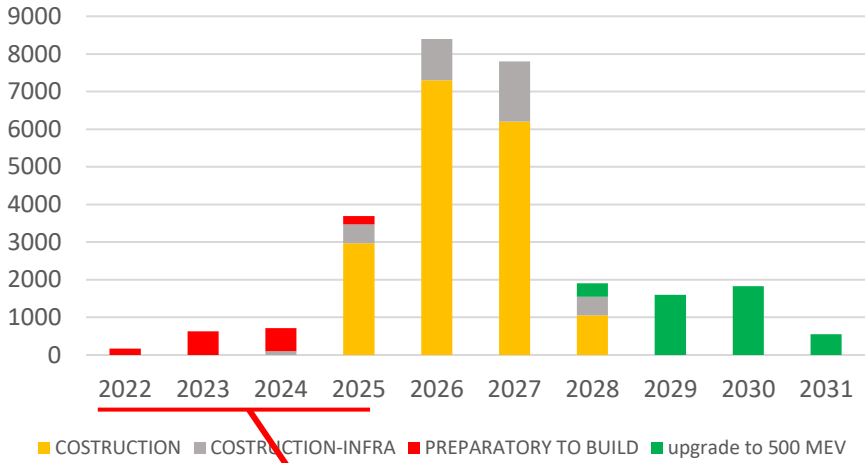
The global cost of the full machine ~27 MEuros.
(This estimation did not include manpower cost)

The following table presents an Ideal Spending Profile splitted in P2B phase, Construction, Construction-Infra (infrastructure equipment installation) and Upgrade to 500 MeV.

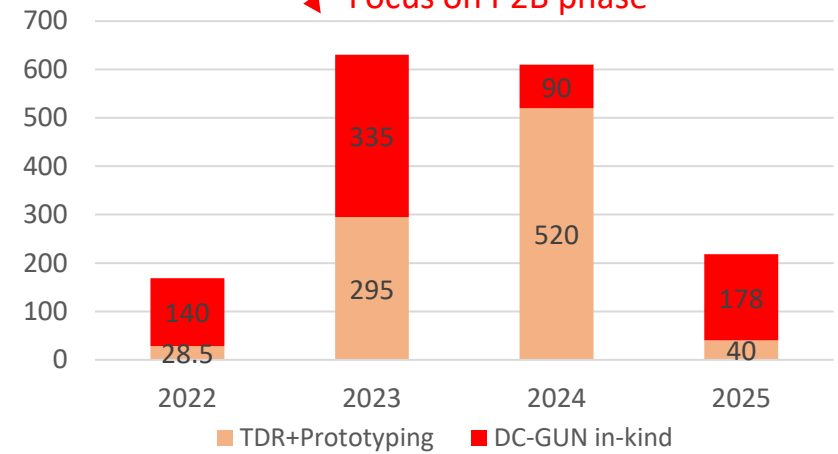
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	**Total (k€)**
P2B (k€)	168,5	630	610	218	0	0	0	0	0	0	1626,5
Construction (k€)	0	0	0	2970	7300	6200	1050	0	0	0	17520
Constr.-Infra (k€)	0		100	500	1100	1600	500	0	0	0	3800
Upgrade 500 MeV (k€)	0	0	0	0	0	0	350	1600	1830	550	4330

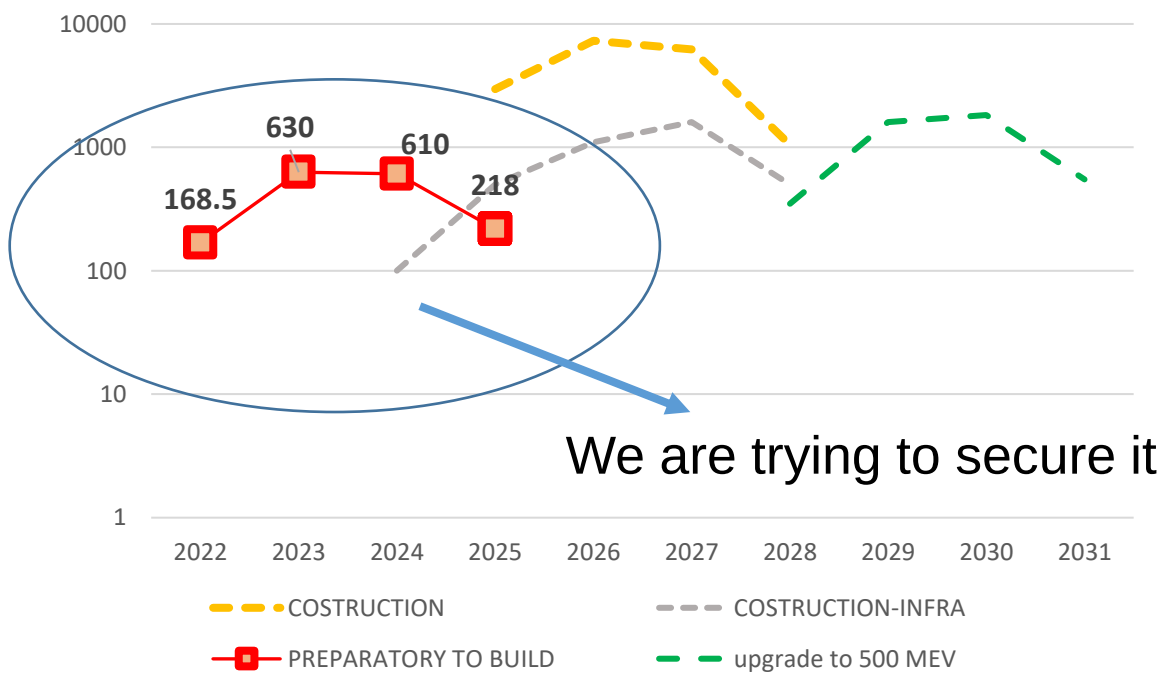
Budget – Spending profile in graphs

Ideal Spending Profile in k€ splitted in P2B phase, CONSTRUCTION, CONSTRUCION-INFRA and UPGRADE to 500 MeV.



Focus on P2B phase





We are trying to secure it

Spending Profile in k€ for P2B phase detailing the cost for TDR + Prototyping and the installation of the DC-Gun.

Search for financial support

We are actively looking at different possibilities to get extra funds for the P2B phase and beyond.

- Beyond PERLE, but really PERLE and bERLinPro oriented, we are about signing an MoU CNRS/HZB

- **iSAS:** European INFRA-TECH project 11 research partners (CNRS, CERN, ESS, DESY, VUB, CEA, HZB, INFN, UKRI, UL, EPFL) Asked 5M€. Financial support for the construction of the full cryomodule of a cost of about 3M€. The IN2P3 has guarantee the matching funds at the level of 1.0M€ complemented by the lab.

→ Possibility of having ESS and INFN-LASA-Milano in PERLE Coll.

→ Contribution ESS vessel cryomodule

- France 2030 will propose new project oriented calls (current 2023) ~5M€. Call in fall.

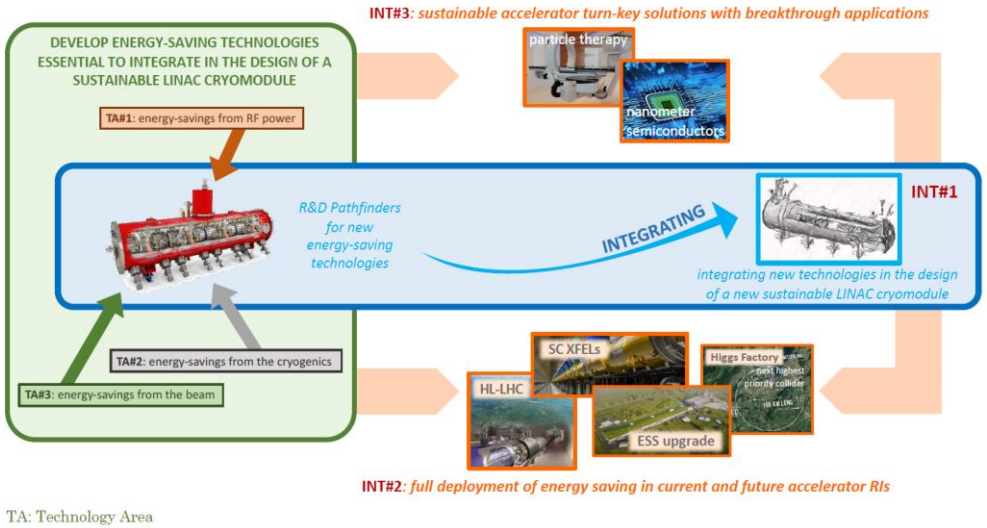
- Important role played by ERL panel with a mandate by the CERN Council in the ESPP Roadmap has as a main task to guarantee that the ERL RoadMap and so PERLE could get the sufficient financial support to success the ESPP strategy.

- In-Kind contributions:
  - Approved: DC gun from Daresbury, CM vessel ESS (around 700k€).
  - Potential in-Kind Contributions under discussions: CBETA equipment, Booster (Jlab ?), Buncher (ESS-Bilbao?)

ISAS: Innovate for Sustainable Accelerating Systems

- EU call HORIZON-INFRA-2023-TECH-01-01: **New technologies and solutions for reducing the environmental and climate footprint of RIs.** Project submitted to EU on March 9, 2023
- **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 with a view to minimizing the intrinsic energy consumption in all phases of operation
- **Project lead by CNRS**
  - Scientific coordinator : J. D'Hondt (VUB)
  - Project coordinator : A. Stocchi
- **International consortium :**
  - 11 research partners (CNRS, CERN, ESS, DESY, VUB, CEA, HZB, INFN, UKRI, UL, EPFL)
  - 6 industrial partners

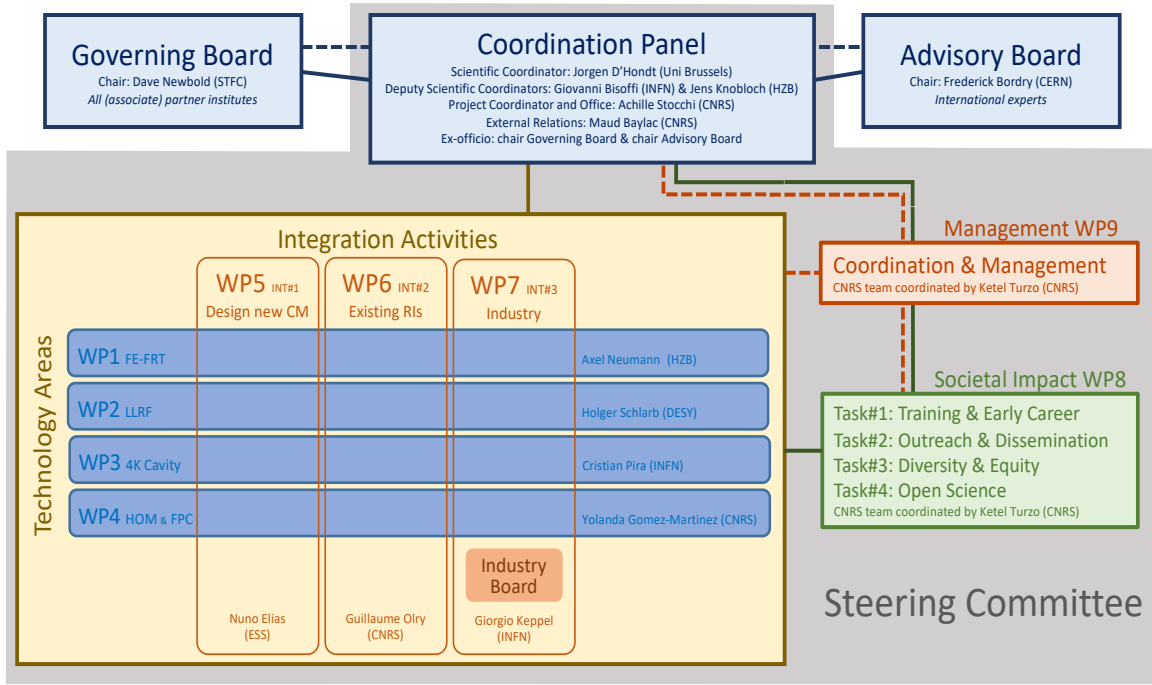
ISAS: Innovate for Sustainable Accelerating Systems



TA: Technology Area

"Innovate for Sustainable Accelerating Systems" (iSAS) – *concrete Work Packages*

- **R&D Pathfinders for three Technology Areas (TA) for energy-saving**
  - **TA#1: energy savings from the RF power** *(short-term and very wide applications)*
    - *WP.1: optimal integration of Fast Reactive Tuners to deal with microphonics (400, 800 and 1300 MHz)*
    - *WP.2: LLRF controls (incl. AI)*
  - **TA#2: energy savings from the cryogenics** *(medium-term and wide applications)*
    - *WP.3: high-temperature SRF cavities (thin films (e.g., Nb_3Sn) on Cu)*
  - **TA#3: energy savings from the beam** *(long-term and specific applications)*
    - *WP.4: Higher-Order Mode damping and fundamental couplers*
- **INT#1: integrate these technologies into the design of a sustainable LINAC cryomodule**
  - *WP.5: based on the ESS cryomodules, develop a parametric design for an optimally sustainable LINAC cryomodule, ready to be adapted and built for various applications in industry and in accelerator RIs*
- **INT#2: integrate these technologies into existing LINAC cryomodules at RIs**
  - *WP.6: engineering aspects to integrate and test energy-saving FRT, HOM and fundamental couplers technologies in existing structures at RIs, with a focus on ESS, HL-LHC, EU XFEL (i.e., addressing directly the scope of this Horizon Europe call)*
- **INT#3: integrate into turn-key solutions and revolutionising applications in industry**
  - *WP.7: prepare the co-developments with industrial partners such that when the new technologies and the new designed LINAC cryomodule are developed and validated their Technology Readiness Level is sufficient such that industry can consider building them*



- Very nice progress on the project in the last few months (DC-gun, injection, cryomodules, HOM, beam dynamics..)

- The success of some very promising initiative could be a game changer for PERLE (iSAS, Recovery plan projects..). Still not enough for the full PERLE construction

- Manpower largely not sufficient as soon as we enter in the next phase. Action on going at IJCLab and more clear discussions to be made with partners

I wish us a fruitfull meeting !