Grant Agreement No: 101057511

EURO-LABS

EUROpean Laboratories for Accelerator Based Science

HORIZON-INFRA-2021-SERV-01-07 Project EURO-LABS

MILESTONE REPORT

WP3 - WORK ON SERVICE IMPROVEMENTS STARTED

MILESTONE: MS19

Document identifier:	EURO-LABS_Milestone_MS19_v0.2.docx
Due date of deliverable:	End of Month 6 (Febuary 2023)
Justification for delay:	[if delays occurred]
Report release date:	28/02/2023
Work package:	WP 3 : Access to RI for Accelerator R&D
Document status:	Draft

Abstract:

The present document reports on the service improvements planned for the RI Facilities participating to the Work Package 3 of EURO-LABS. Details of the proposed activities, budget and schedule are presented.

For more information on EURO-LABS, its partners and contributors please see https://web.infn.it/EURO-LABS/

The EUROpean Laboratories for Accelerator Based Science (EURO-LABS) project has received funding from the European Union's Horizon 2020 Research Infrastructure (RI) services advancing frontier knowledge under Grant Agreement no. 101057511. EURO-LABS began in September 2022 and will run for 4 years.

Delivery Slip

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Executive summary

The key goal of the EURO-LABS project is to provide Transnational Access (TA) to major Research Infrastructures (RI) in Europe. WP3 groups thirteen facilities focused on High-Energy Accelerator Research.

The document details the proposed work to improve the existing facilities to the profit of the users. The expected budget, resources and schedule for the planned activities is presented.

1. INTRODUCTION

EURO-LABS is a network of 33 research and academic institutions (25 beneficiaries and 8 associated partners) from 18 European and non-EU countries, involving 47 Research Infrastructures within the Nuclear physics, Accelerators and Detectors pillars. In this large network, EURO-LABS will ensure diversity and actively support researchers from different nationalities, gender, age, and variety of professional expertise.

EURO-LABS aims at fostering the sharing of knowledge and technologies across scientific fields to enhance synergies and collaborations between the RIs of the Nuclear and High Energy communities. Within EURO-LABS the Work-Package 3 (WP3) will provide Transnational Access (TA) to Research Infrastructures for Accelerator R&D.

WP3 will provide TA to a broad spectrum of installations, to test concepts for future accelerators, based on improving the present facilities, and for R&D studies for future colliders like CERN/FCC or the Muon Collider. These facilities will provide beam lines for testing advanced accelerator materials, superconducting or normal Radio-Frequency cavities, magnets and acceleration schemes. These tests use different particles and energies (low-energy protons, low-energy electrons, ultra-soft electron bunches and high-intensity high-energy electrons and could also have connections to industrial applications.

Within the EURO-LABS project, a fraction of the available budget is allocated to targeted service improvements in the facilities with the aim of either:

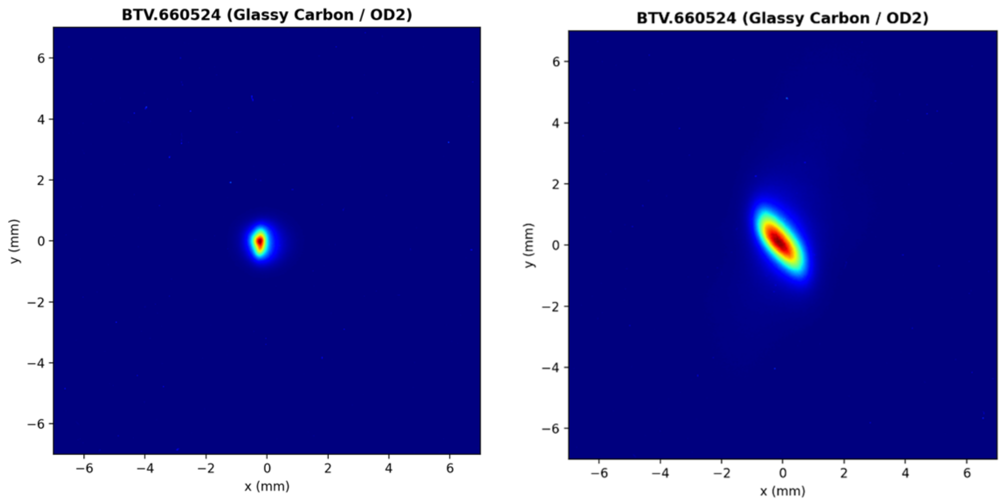
- improving their performance capabilities thus allowing more advanced research, or
- improving operations thus allowing better and more efficient use of the beam time with faster turnover between users, or
- new instrumentation by completing or extending existing equipment or data acquisition systems.

Due to budget limitations the service improvements are limited to some of the facilities participating in WP3. Details of the planned actions, budget and schedule are discussed in the following sections.

2. HIRADMAT - CERN

The beam delivered to HiRadMat is quite challenging to produce, control and monitor, given its very high instantaneous power and the high intensities delivered in HiRadMat. Today there are various operational issues : The exact momentum spread on each bunch is unknown affecting the beam positioning reading at the experimental area ; the Beam TV (BTV) image which is the only available diagnostics for the beam spot-size suffers from noise and screen sensitivity issues ; and more importantly, the beam position seems to be dependent on the momentum spread of the beam at the position of the extraction kicker and this is translated to position fluctuations downstream. All the above issues are hampering the operation and are posing serious problems in the beam quality delivered to the experiments.

Difference in the spot-size in different optics: Not clear what the reason is.



Extraction kicker influence om the horizontal beam position and optics:

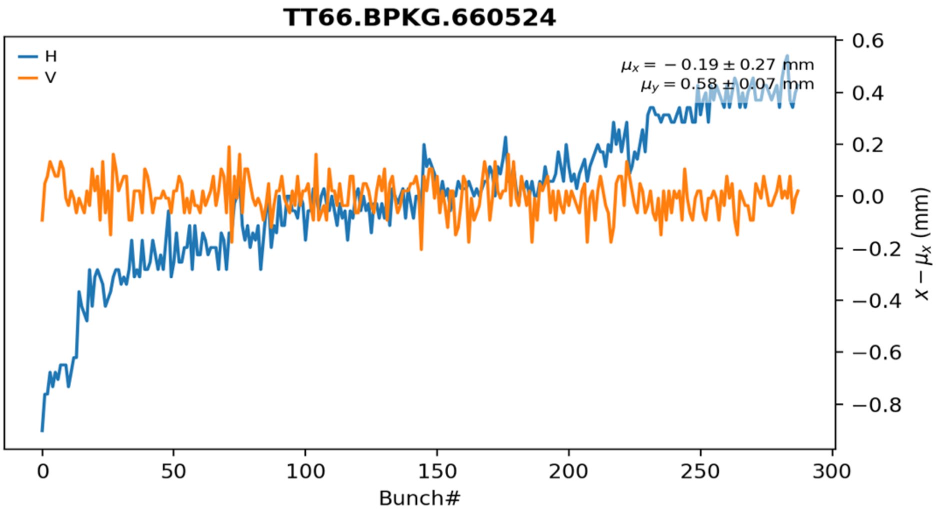


Figure 1- - On the top graph we see possibly a transverse coupling of the beam spot or the effect of noise in the BTV image of the facility, while in the bottom plot we see the bunch-by-bunch drifting in the beam position – currently not understood.

A Doctoral student will be funded for this work in the BE-CSS group at CERN, in collaboration with the university of Oxford. Specifically, the student will work on the implementation of computer vision for the facility's BTV images that will allow an online analysis and subsequent improvement of the quality of the data that are provided to the users concerning the beam shape. The work will focus on a deeper understanding of the effects in conjunction with optics studies and instrumentation studies. Second, given the higher intensities requested by future experiments, the beam position reading at the extraction kicker is today suffering from intensity variations. The development of a ML algorithm via labelling for improving this accuracy will be critical for the future of the facility and the delivered beams to the users.

The hiring process will be concluded in September 2023 and the student should not start later than April 2024. In detail:

- Student enrols in Oxford University: Q4-2023
- Student applies in the DOCT program of CERN: Q4-2023
- Student starts at CERN: Q2-2024
- First studies and results: Q4-2024
- Completion of the beam studies data taking: Q4-2025
- Q1-2026 to Q2-2026: Offline data analysis
- Thesis writing and relevant publications: Q3-Q4-2026

The budget profiling will be approximately 32kCHF per year for the three years 2024 – 2025 – 2026, with the first results already available by the end of 2024. The full cost of this studentship will be complemented by internal CERN funding.

3. FREIA – UU

Figure 2- Graphs or of the anticryostat

- ***Anticryostat***: Is a magnetic-measurement test bench inserted into the Gersemi cryostat at the bore of the superconducting magnet during their qualification tests. It will allow locating devices to measure the magnetic flux density field and field quality of the superconducting magnets with a minimum of 50 mm diameter bore operated at cryogenic temperatures. It uses a rotating coil scanner working at room temperature and pressure. This is custom-made equipment realised through a running projects project in collaboration with CERN.

- ***A magnetic flux sensor for cavity testing***. This equipment would be used to measure the presence of low magnetic fields on the cavity during and after cooldown, if any. Could be placed at Gersemi or HNOSS.
- ***Solid state amplifier*** for cavity testing, for either HNOSS or Gersemi.
- ***LLRF*** for cavity testing, for either HNOSS or Gersemi.

Budget planning:

Equipment	Specific Item	Price/Unit	# Units	Price Total
Anticryostat		123 k€	1	123 k€
Magnetic Flux sensor	3-axis sensor head	2 850 GBP	3	8 550 GBP
	Cryogenic cable (5m)	255 GBP		765 GBP
	Power supply and display unit	2 555 GBP		7 665 GBP
RF Amplifier	0.7-2.7 GHz, 126-158 W	15 813 €	1	15 813 €
Digital FPGA[1]*	Up to 6 GHz	718 000 SEK	1	718 000 SEK

Schedule

Equipment	Schedule
Anticryostat	Q4 2025
Magnetic Flux sensor	Q3 2023
RF Amplifier	Q3 2023
Digital FPGA*	Q1 2024

[1] This equipment will not be part of the improvement services if the anticryostat is approved as being a service.

4. INFN-LASA – IT

LASA is characterized by the presence of four test facilities devoted to:

- Superconducting (SC) Magnets
- Superconducting (SC) RF Cavities
- High Brightness Photocathodes for Electron Sources
- Laser Applications to High Power Fabry Perot Cavities and Advanced Timing Systems.

The four facilities have been conceived at the beginning as research facilities for the activities undergoing at LASA. The more relevant part of efforts has been dedicated equipping them with advanced instrumentation.

The service improvements foreseen in this program are devoted to revamp the control and data acquisition infrastructures in order to facilitate their usage from external users. Moreover, we have to consider that the usage of the 2 SC based facilities require very expensive consumables (a RF cavity test may require 200-300 LHe and the cost of it is of the order of 25 Euro/l).

The possibility to expand the number and the panorama of users will request few improvement activities on the following subsystems:

- control system performances
- automatized data acquisition procedures
- new data storage and analysis networks
- more comfortable HMI facilities

Budget Planning and Schedule

We are going to give priority to improvements in automatic control and data acquisition procedures to allow an easier access to the facilities. EURO-LABS will cover the costs of these improvements up to the ceiling of 100kEuros, while the laboratory will cover the remaining costs.

This will involve an unbalanced expenditure commitment towards the first two years (2023-2024) of EURO-LABS.

5. INFN-THOR – IT

Figure 3- View of the THOR Lab at University of Salerno – Italy.

THOR is a test facility for superconducting magnets in their horizontal cryostats. The maximum size for the cryostat is approx. 5 m long and weight up to 20 t. The facility is equipped with a cryogenic refrigerator supplying 15 g/s of supercritical He at 4.5 K and 10 bar or 120 l/h of liquid He. The refrigerator is connected to the test feed boxes (a second feed box is foreseen and under procurement) through to a cryogenic transfer line. The Feed Box hosts a set of cryogenic valves for regulating the flow of the cryogenic liquid inside the cooling lines of the magnets. It is also provided with a set of vacuum gauges and a pumping system for the insulation vacuum as well as two cryogenic flow meters for mass flow measurements of the coolant. Accelerator magnets with cryogenic beam pipe integrated can be also installed, as the line is integrated with an End Box where secondary UHV pumping system, vacuum gauges and a residual gas analyser are present for vacuum level and RGA measurements.

The foreseen activities of THOR will include a dedicated cryostat and equipment to carry out tests and development on devices for cryogenic application. Among these activities, large interest is both in the cryogenic flow meter measuring techniques, and in the development of optimized HTS current leads for superconducting devices. Part of the activities can include this field of research and development as the test facility is equipped with 20 kA power converter and electrical insulation testing equipment.

Budget planning

A dedicated stand for cryogenic tests can be created starting from an additional cryostat already present in our laboratory.

€ 12.000 for cryogenic fluids
€ 8.000 other consumable and services

Schedule
We will start procurements in 2024

6. CEA/LRFU-SYNERGIUM – FR

1.1. MACHAFILM

Figure 4- View of the MACHAFILM test stand

The atomic layer deposition laboratory is composed of two Atomic Layer Deposition (ALD) systems; a first research scale reactor is used to develop and test new compounds and structures on test samples. The second reactor have been developed to scale up optimized processes on large objects. The research scale reactor is mostly used for oxides and nitrides growth whereas the development scale reactor is mostly used for nitrides synthesis for a foreseeable future. In addition to these 2 ALD reactors, other lab capabilities include a Glove box under N_2, Sorbonne, Room temperature 4 points measurement, optical microscope, 3 zones tubular oven under gas (Ar, N2, O2, N2-H2) up to 1100°C (6 cm x 50 cm).

The cryostat setup allows measurement of the residual resistivity ratio (RRR) to extract sample purity as well as low temperature effects like Kondo effect or superconductivity. The cryostat can run from 4,2 K to 293 K.

The proposed improvements include:

- a more robust pump for long halides deposition for the ALD facility, and
- installation of new low-noise electronic for the RRR set up to enable high RRR (>150) samples to be measured.

For the ALD set up, the planned activities include depositions on coupons (up to 6x20cm) and 1.3 GHz SRF cavities of nitrides and oxides layers. Up to 5 depositions can be envision per year. The maximum film thicknesses are 100 nm for oxides and nitrides.

Concerning the RRR set up, up to 5 measurements from room temperature down to 4.2K can be carried out per year.

Budget planning and schedule

Item	Cost	schedule
Two stage rotary pump	4 k€	Q3 2023
Keithley 2182A	6 k€	Q3 2023
Total	**10k€**	

1.2. CRYOMECHA

With the aim of upgrade the measurement capabilities, the mechanical Lab wishes to update the present software, the mechanical sensors as well as to extend its range of load cells.

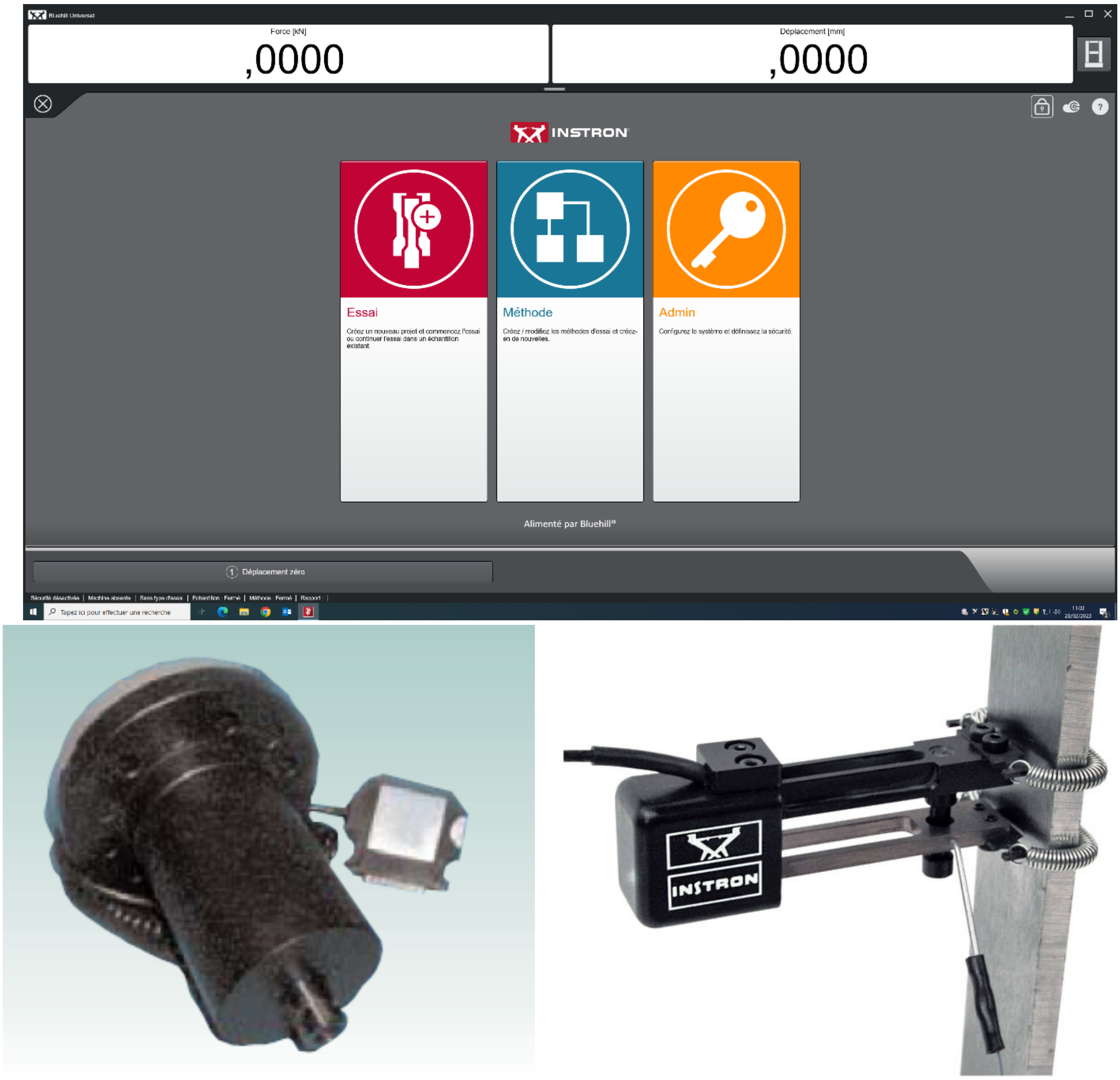


Figure 5 - Graphs or photos to show or justify the proposed improvements.

During mechanical tests at cold temperature, the sensors must be connected to dedicated racks to take into account the temperature effect; the present software driving the tensile machine cannot be easily interfaced with these racks, and that influences the measurement quality. The tensile machine manufacturer - **Instron** – proposes an **update of our present software.**

1. Instron offers a wide measurement range of load cell with high accuracy, high stiffness, resistance to offset loads, accurate alignment and excellent zero stability. All Instron load cells are individually temperature-compensated and tested for accuracy and repeatability on a calibration apparatus that is traceable to international standards, with a measurement of uncertainty that does not exceed one-third of the permissible error of the load cell. The lab is equipped with the load cells from 300 kN to 2 kN. The measurements at lower force levels will allow increasing the accuracy for the less stiff samples, as insulation materials for which the lab is regularly solicited with the increase of the hydrogen program.

2. In order to increase our measurement capacity, some specific sensors for mechanical measurement in cryogenic environment are requested. Instron or HBM propose sensors answering to the different types of mechanical solicitations.

Budget planning

The request for quotation is in progress. The Lab has planned the following budget. Discussions are underway to determine the most appropriate options.

Equipment	Specific Item	Price/Unit	# Units	Price Total
The new software driving the tensile machine		18 k€	1	18 k€
Load cell		10 k€	1	10 k€
Sensors		3 k€	4	12 k€

Schedule

The target dates for the upgrade are listed in the table below. The goal is to have the works completed and put in operation during 2023.

Equipment	Schedule
Instron Software	Q2 2023
Load cell	Q4 2023
Sensors	Q4 2023

7. KIT-ALFA(KARA – FLUTE) – GE

ALFA (**AcceLerator Facilities)** is the name of the accelerator facilities as part of KIT's cross-institutional ATP (Accelerator Technology Platform). The main ALFA accelerator facilities are the linear accelerator-based FLUTE (compact Far-infrared Linear accelerator and Test Experiment) and the electron storage ring KARA (KArlsruhe Research Accelerator). ALFA provide a multitude of operation modes as well as diagnostic devices with high data throughput. These diagnostic sensor networks are capable of taking synchronized data from different detector system which enables new beam diagnostic methods and detailed beam dynamic analysis. For the analysis, the knowledge of all machine settings at the same time of the data is essential.

Due to the flexibility of KARA and FLUTE the parameter space is too large for a parameter scan for each measurement. Hence, it is essential to implement a meta database, e.g., based on B2SHARE (EUDAT) to collect all parameter settings and link them to the data set. This would make it possible to combine data from different measurements in the data analysis. With this tool, users could make use of other measurements carried out in the past. The careful preparation and planning of experiments is essential to make use of the expensive beam time at accelerator test facilities. An integrated simulation and measurement framework will help to prepare experiments much more in detail and will allow for more automated measurements and data analysis. With the availability of a meta data base measurement could be simulated and tested in advance to identify the optimum setting for the planned experiment at the accelerator test facilities KARA and FLUTE.

As part of the EURO-LABS funded service improvements, KIT will develop an integrated simulation and measurement framework for facilities with large amounts of data and complex dependencies, such as accelerator facilities, so that users and operators can prepare, plan, perform and evaluate experiments more efficiently. The aim is to implement an integrated simulation and measurement framework within two years at ALFA, based on B2SHARE - EUDAT services, to be able to test it at the KIT facilities KARA and FLUTE. If successful, other research institutions or even companies, including those outside of accelerator research, could take over the development of this integrated simulation and measurement framework and adapt it for their applications.

Details on the planned activities

1. Identify relevant meta-data:
   Collection of meta-data for each measurement type possibilities to add custom meta-data individually were identified.
2. Implement data structure:
   Implementation of the data structure for meta-data, simulation- and measurement data is implemented in (e.g. in eudat/b2share)
3. Data-flow documentation:
   Documentation of the desired data flow for automated transfer from measurement to permanent storage including meta-data.
4. Evaluation of existing tools:
   Evaluation of existing simulation and measurement tools as well as existing frameworks for integrations
5. Simulation framework:
   Implementation of a framework that allows the integration of simulation codes into the control system including an example integration.

6. Measurement Framework:
   Implementation of a framework that allows the integration of measurement devices into the control system including an example integration.
7. Simulation and Measurement Framework Documentation:
   Documentation of the frameworks for simulation and measurements
8. Unified Access Framework:
   Implementation and documentation of a framework for unified access across measurement files and simulation results including an example integration.
9. Documentation of Access Framework:
   Documentation of the framework for unified access to measurement and simulation data

Budget planning

The EC contribution amounts to 150,000 €, the additional budget for development and testing will be borne by the Institute.

In contrast to the EURO-LABS proposal, the task is not to be awarded externally via the materials budget approved by the EC, but is to be carried out by a KIT scientist who already has some experience on data management at ALFA.

Schedule

The estimated time for the planned KIT activities.

1.	Identify relevant meta-data	(50d)
2.	Implement data structure	(40d)
3.	Data-flow documentation	(35d)
4.	Evaluation of existing tools	(45d)
5.	Simulation framework	(85d)
6.	Measurement Framework	(85d)
7.	Simulation and Measurement Framework Documentation	(30d)
8.	Unified Access Framework	(75d)
9.	Documentation of Access Framework	(15d)

Some of the activities can be carried out in parallel or in a flexible sequence. The proposed service improvements are expected to be developed in the first two years of the project EURO-LABS so that they will be operational from M30 as planned.

8. CEA/LIDYL-LPA-UHI100 – FR

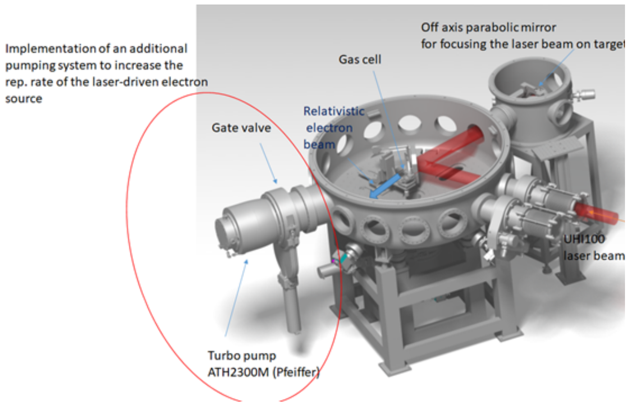


Figure 6- left: view of the radioprotected experimental room for electron source acceleration- © L. Godart/CEA , right: sketch of a part of the service improvements (increase of the pumping speed to increase the repetition rate)

The LPA-UHI100 facility delivers electron source in the 100MeV range, issued from laser-plasma acceleration mechanism. The maximum repetition rate of the source is directly linked to the repetition rate of the laser itself. Most of the laser-driven electron source are generated from Ti:Sapphire laser system, delivering from few to 100's of TW power. The maximum repetition rate of such system is generally around 10 Hz, but the electron source doesn't often exploit this property as it requires a specifically designed target coupled to very demanding pumping system.

Increasing the frequency of the electron source is a big issue, in particular for medical applications or even for material testing. **We propose to boost the pumping system of the interaction chamber hosting the acceleration process to work at 1Hz** (instead of 0,03Hz which is our actual rep. rate). This will offer new possibilities for data accumulation and then could attract more users on the facility. And in addition, this is the less costly solution before changing the driving laser for higher frequency system, keeping the same level of power. If the addition of one new turbo pump to the existing system is not enough to reach the 1 Hz repetition rate, we plan to design and **implement a differential pumping system**. The last point to take care to is the loss of reflectivity of the last compressor grating (meaning degradation of the electron acceleration process) due to a potential carbon burns that can be due to pollution of the vacuum chambers combined to the high repetition rate.
To overcome this problem, we investigate a new solution consisting of to implement a system that deliver **oxygen leakage in the compressor chamber to avoid the carbon deposition on gratings**.

Budget and work-plan

Planning	Budget	Tasks
April 2023	5k€	Overall maintenance, and cleaning of a turbo pump ATH2300M Pfeiffer that has been given to our team (reorganization and retirement…)
May 2023	7k€	Design and implementation of the turbo pump (gate valve, connectors, pump) on the experimental chamber dedicated to laser-driven electron source

Sept 2023	5k€	Differential pumping system design and implementation if 1Hz is not yet accessible after the addition of the turbo pump ATH2300M
Dec. 2023	5k€	Implementation of a cleaning system on the compressor to preserve the reflectivity of the overall ensemble and guarantee the efficiency of laser-driven particle source generation.

ANNEX: GLOSSARY

Acronym	Definition
TA	Transnational Access
VA	Virtual Access
RI	Research Infrastructure