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EUROpean Laboratories for Accelerator Based Science

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DELIVERABLE REPORT

WP3 – REPORT ON THE SERVICE IMPROVEMENTS FOR TECHNOLOGY INFRASTRUCTURES

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Abstract:

The present document reports on the implementation of the planned service improvements at the RI Facilities participating in Task 3.2 of Work Package 3 of EURO-LABS, related to Technology Infrastructures for Accelerator R&D. Service improvements were planned for the FREIA of Univ. Uppsala, LASA and THOR of INFN, MACHAFILM and CRYOMECH of CEA/LRFY-Synergium facilities as outlined in MS19 document. At three facilities, the work is advanced as planned, while for the other two, technical issues have prevented progress.

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TABLE OF CONTENTS

Executive summary

The RI Facilities participating in Task 3.2 of Work Package 3 of EURO-LABS provide Transnational Access (TA) to users, enabling advanced R&D for present and future accelerators, through state-of-the-art technology infrastructure test stands

Service Improvements (SI) were planned for the FREIA, LASA, THOR, MACHAFILM, and CRYOMECH facilities, aimed at enhancing the performance capabilities of the available instrumentation and hardware of the test beds, as detailed in the MS19 document.

At FREIA, the planned SIs were revised to align with the requirements of the TA provided; however, the remaining SIs, which aimed at general enhancements to the facility's instrumentation, were not pursued. At MACHAFLM and CRYOMECH, the SIs were implemented as planned. At LASA and THOR, technical issues have prevented any progress.

In all cases, the unused allocated resources will be redistributed to other facilities within the Task, Works Package, and Project, as outlined in the Grant Agreement.

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.

Within EURO-LABS the Work-Package 3 (WP3) provides Transnational Access (TA) to Research Infrastructures for Accelerator R&D, with the RI Facilities participating in Task 3.1 offering state-of-the-art test beds for accelerator technology R&D on present and future accelerators.

Service Improvements (SI) were planned for the FREIA, LASA, THOR, MACHAFILM and CRYOMECH facilities as outlined in the MS19 document.

The status of implementing these SIs is presented in the following sections for each facility.

2 FREIA – UU

The Facility for Research Instrumentation and Accelerator Development **(FREIA)** laboratory, located at the Department of Physics and Astronomy of Uppsala University, is equipped with advanced RF and cryogenic infrastructure that enables the development and testing of state-of-the-art superconducting accelerator components, magnets, and cavities.

The laboratory hosts two multi-purpose cryostats:

- **GERSEMI**, a vertical cryostat uniquely designed to test magnets and cavities, making it a world-leading facility of its kind.
- **HNOSS**, a horizontal cryostat dedicated to superconducting cavity testing, capable of supporting simultaneous experiments on two cavities equipped with high-power couplers.

2.1 IMPROVEMENTS

Service Improvements were planned in the following areas:

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

Figure 1: Schematic view of the anticryostat. Left: mounted on the cryostat flange, Right: close view of the instrumentation and the rotating coils.

- **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. It can be used in either GERSEMI or HNOSS cryostats – (see **Error! Reference source not found.**).
- **Solid state amplifier for cavity testing**: It can be deployed in either HNOSS or GERSEMI cryostats.

- **Low-level RF (LLRF) improvements for cavity testing**: Enhancements to existing LLRF systems, applicable to either HNOSS or GERSEMI cryostats.

2.2 STATUS

As of today, the magnetic flux sensors have been purchased and are already in use for cavity testing for the TA projects accepted so far – see Figure 2. The anticryostat is in the manufacturing phase, with completion expected by the end of this year.

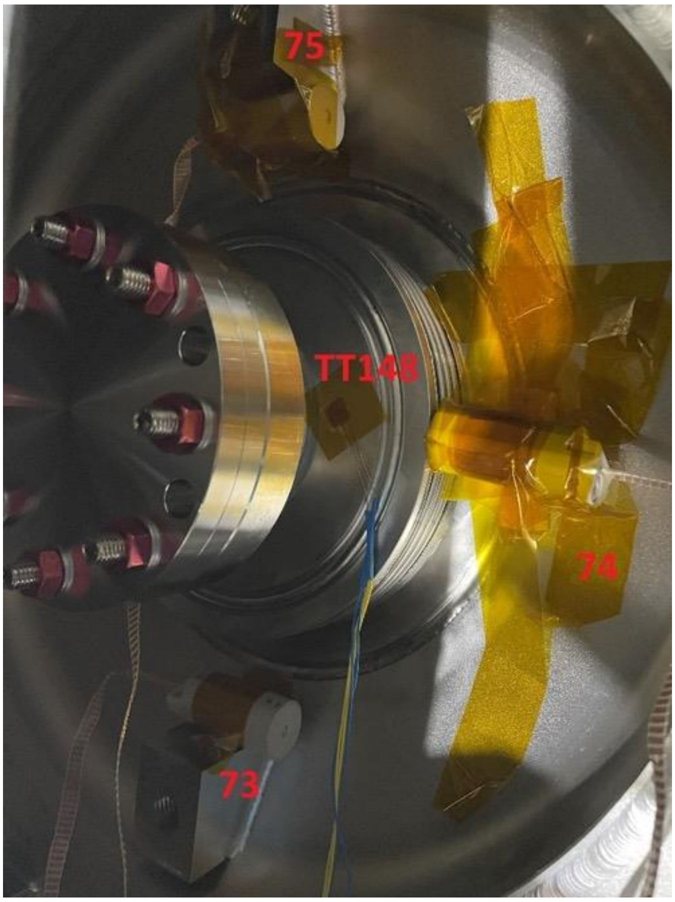

Figure 2: The three magnetic flux sensors positioned close to a cavity for testing.

The RF amplifier and the digital FPGA-based LLRF system have not yet been procured, as the TA requests received so far did not require such equipment. Currently, no further TA requests are being accepted, as the facility's available time is fully dedicated to fulfilling a contract for series production testing of modules for a future accelerator; therefore, no further activities are planned.

2.3 USE OF RESOURCES

The planned expenses are summarized in the table below.

Item	Equipment	Specific Item	Price/Unit	Units	Price Total
1	Anticryostat		123 k€	1	123 k€

2	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
3	RF Amplifier	0.7-2.7 GHz, 126-158 W	15,813 €	1	15,813 €
4	Digital FPGA	Up to 6 GHz	718,000 SEK	1	718,000 SEK

The budget for item 2 has been fully used. The remaining resources will be reallocated to other facilities within the Task, the Work Package, and Project, as outlined in the Grant Agreement.

2.4 FEEDBACK FROM OPERATIONS

The magnetic flux sensors have already been used at FREIA several times for the testing of cavities equipped with a magnetic shield in HNOSS. Thanks to these sensors, the measurement of the magnetic field close to one of the cavities was made from room temperature to 2 K. The results of these tests will be reported in a future conference proceedings.

3 INFN-LASA – IT

LASA (Laboratory for Accelerators and Applied Superconductivity) at INFN Milano, hosts four test facilities dedicated to: superconducting (SC) magnets, superconducting (SC) RF cavities, high-brightness photocathodes for electron sources, and laser applications to high-power Fabry–Perot cavities and advanced timing systems. These facilities were initially conceived to support LASA's internal research activities.

3.1 IMPROVEMENTS

The planned service improvements were primarily aimed at revamping the control and data acquisition infrastructures, as well as the user interface, in order to facilitate their use by external users.

3.2 STATUS

So far, due to technical issues related to ongoing upgrade and relocation works at the Laboratory, decided after the start of EURO-LABS, LASA has not been able to accept any transnational access (TA) projects, and as a consequence no progress has been made on the planned Service Improvements.

As a result, the allocated resources of 100k Euros will be reallocated to other facilities within the Task, Work Package, and Project, as outlined in the Grant Agreement.

4 INFN-THOR – IT

The THOR (Test in Horizontal) facility in Salerno is focused on superconducting magnet systems testing. Equipped with advanced cryogenic, vacuum, and electrical testing setups, the facility ensures high-quality assessments of critical technologies in the field of superconductivity.

4.1 IMPROVEMENTS

The planned Service Improvement activities of THOR included adapting an existing cryostat, equipping it with flow meter instruments, and modifying HTS (High-Temperature Superconductor) current leads to enable general-purpose tests by users.

4.2 STATUS

So far, due to the facility being fully occupied with high-priority activities by signed agreements of the laboratory, THOR has not been able to accept any TAs, nor has progress been made on the planned Service Improvements.

As a result, the allocated resources of 20k Euros will be reallocated to other facilities within the Task, Work Package, and Project, as outlined in the Grant Agreement.

5 CEA/IRFU-SYNERGIUM – MACHAFILM & CRYOMECH

The CEA-IRFU Synergium hosts two platforms: MACHAFILM and CRYOMECH, which specialize in materials science at cryogenic temperatures.

5.1 IMPROVEMENTS

MACHAFILM

The atomic layer deposition laboratory comprises two Atomic Layer Deposition (ALD) systems. A first research-scale deposition system is used to develop and test new compounds and structures on test samples. The second deposition apparatus has been designed to scale up optimized processes on large objects such as SRF cavities. The research scale ALD chamber is primarily used for the growth of oxides and nitrides, whereas the development scale setup is mainly used for nitride synthesis in the foreseeable future. In addition to these two ALD apparatus, other lab capabilities include a Glove box under N_2, a chemical fume hood, a room temperature four-point measurement, an optical microscope, and a three zones tubular ovens under gas (Ar, N_2, O_2, N_2-H2) up to 1100°C (6 cm x 50 cm).

A 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 tunneling spectroscopy apparatus enables measurements and mapping of the surface superconducting density of states and critical temperature on lateral scales of hundreds of microns, spanning the temperature range from 1.3 to 293 K.

Figure 3 View of the MACHAFILM test stand

The CEA synergium facilities includes also a class 4 clean room, an electropolishing chemical etching set up and a high vacuum oven to conduct various bulk Nb surface treatments.

The proposed improvements include:

- Purchase of X-ray and TEM fitting program CrystalMaker@ to extract thin film material properties. (2,1k€)
- Purchase of Cernox temperature and Helium level sensors for the low temperature material characterization platform (Tunneling spectroscopy and magnetometry – 8 k€)

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 five depositions can be envisioned per year. The maximum film thicknesses are 100 nm for oxides and nitrides. Concerning the RRR set up, up to five measurements from room temperature down to 4.2K can be carried out per year. For the tunneling spectroscopy experiment, up to three measurements can be carried out per years. The Synergium facility can be used for bulk Nb cavities and Quadrupole resonators (QPR) surface treatments.

CRYOMECH

CRYOMECH includes: a test station dedicated to the measurement of thermal conductivity of insulators and conductors at low temperature, and a mechanical test laboratory for traction, compression, bending and slippage tests equipped with a hydraulic press with a compression capacity of 1600kN, an Instron electromechanical machine with a traction and compression force of 300 kN, an Instron electromechanical machine with a traction and compression force of 150 kN. This machine can be fitted with two cryostats for tests at cryogenic temperatures: one with a traction and flexion capacity of 45 kN, and the other with a traction capacity of 80 kN and a compression capacity of 150 kN.

The planned Service Improvements aim to upgrade the measurement capabilities of the facility, the existing software, and the mechanical sensors, as well as to extend the range of load cells.

5.2 STATUS

Progress on all SI works is done as planned for both facilities.

MACHAFILM

Progress on all SI works was done as planned. The ALD apparatus and tunneling spectroscopy setup have been operational and used regularly for over four years already. Within the EURO-LABS project, we have conducted over ten measurements for users from INFN, JLAB, STFC, and CERN with the tunneling spectroscopy apparatus. We have measured by XRD and analysed with the CrystalMaker@ program over ten (Nb3Sn, NbTiN, Nb) films on various substrates for the same users. One niobium cavity from STFC has been HPR (High Pressure Rinsing), leak tested, and sent back to STFC; two more are expected to be treated by early 2026. We have electropolished and thermally annealed four QPR for HZB, DESY and Hamburg University, and two more are expected to be shipped by HZB before the end of 2025.

By early 2026, we will have fully utilized the allocated Access Units for CEA/IRFU, leveraging all implemented service improvements. A request for an additional 115 Access Units has been made to fulfill users' requests.

CRYOMECH

The purchase of the dedicated software to model the behaviour of liquid Helium and mechanical properties at cryogenic temperature on the CRYOMECH Platform is completed as well as the purchase of the upgraded load cells and sensors.

5.3 USE OF RESOURCES

MACHAFILM

The CrystalMaker@ program is used regularly to extract crystal structure information of films deposited by users and by CEA. Two Cernox sensors are in use on the tunneling spectroscopy experiment and the remaining six are spares.

The full allocated budget of 10k Euros has been committed, with a large fraction already spent.

CRYOMECH

The full allocated budget of 40k Euros has been committed, with a large fraction already spent.

5.4 FEEDBACK FROM OPERATIONS

MACHAFILM

The new Cernox sensors enabled successful tunneling spectroscopy measurements of five films from users, and the CrystalMaker@ software is used to extract crystalline information (lattice parameters, strain, and grain size, phase ratios) of Nb3Sn films deposited by STFC, INFN, CERN, and FNAL, and NbTiN and Nb films deposited by JLAB and CERN.