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# EURO-LABS

EUROpean Laboratories for Accelerator Based Sciences  
HORIZON-INFRA-2021-SERV-01-07 Project EURO-LABS

## MILESTONE REPORT

# A) MORE THAN 30% OF AU DELIVERED IN WP4.1: TEST BEAMS

## MILESTONE: MS21

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### Abstract:

Task 4.1 provides Transnational Access to three test beam research infrastructures. (RIs) The beams are used to characterize prototype detectors during their R&D phase. The milestone provides a checkpoint of RIs' delivery of Access Units (AUs) at project midterm. The overall usage is great with the 30% goal exceeded by nearly a factor of three. Detailed analysis by facility reveals substantial differences, none of the facilities, however, are expected to fall behind their pledge at the end of the project.

EURO-LABS Consortium, 2024

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 Horizon Europe programme dedicated to Research Infrastructure (RI) services advancing frontier knowledge under Grant Agreement no. 101057511. EURO-LABS began in September 2022 and will run for 4 years.

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## Executive summary

*Task 4.1 provides Transnational Access to three test beam research infrastructures (RIs) where high-energy particle beams are employed to evaluate prototype detectors during their R&D phase. The M21 milestone provides a checkpoint of RIs' delivery of Access Units (AUs) at project midterm. The overall performance is excellent with the 30% goal exceeded by nearly a factor of three. Detailed analysis by facility reveals substantial differences, yet all the three RIs are expected to fulfil their commitment at the end of the project.*

## 1. INTRODUCTION

WP4 of EURO-LABS is devoted to support detector R&D via Transnational Access (TA) carried out at 11 RIs in Europe. The typical detector R&D cycle consists of constructing a series of prototypes, testing them in high-energy particle beams, irradiating them and possibly evaluating their performance in special characterization facilities. This is followed by the division of WP4 into tasks: WP4.1 supplies the test beams in 3 RIs, WP4.2 offers detector characterization in 2 RIs and WP4.3 irradiation opportunities in 6 RIs.

The three RIs offering test beams in WP4.1 are:

- 4.1.1: CERN PS and SPS test beams
- 4.1.2: DESY-II Test beam Facility
- 4.1.3: PSI PiM1 and UCN test beams

The CERN PS (proton synchrotron) and SPS (super proton synchrotron) test beams provide particle beams in the energy range from  $\sim 1$  GeV to  $\sim 350$  GeV. Upstream of the physicist's test setup sophisticated beam line equipment allows selecting the type, polarity and energy of particles as well as the beam intensity. A total of seven general purpose test beam lines and their large, well-equipped experimental areas are available for detector R&D.

DESY at Hamburg presently operates several particle accelerators of worldwide relevance including PETRA III, FLASH and the European XFEL. The DESY II synchrotron is used as an injector for PETRA III and delivers in parallel electron or positron beams for up to three test beam areas using a fixed secondary target. As the demand on the PETRA III light source is high, DESY II operates with a very high availability of  $>99\%$ . DESY II can provide electron beams with an energy between 1 GeV and 6 GeV, a small energy spread of about 5%, and rates up to several 10 kHz, depending on beam line and the choice of the secondary target.

The Paul Scherrer Institut (PSI) is a multidisciplinary Swiss national research laboratory. Among other accelerators it runs the high intensity proton accelerator (HIPA) complex which delivers protons to the Swiss research infrastructure for particle physics (CHRISP). Both installations of WP4.1.3, PiM1 and UCN, belong to CHRISP and serve both, physics experiments and test beam areas for detector qualification. The secondary beamline PiM1 is designed to provide pions with a very well-defined momentum between 100 and 500 MeV/c. However, also a beam operation mode for electrons and muons exists. The beam profile and particle flux are adjustable by the users. The beam is continuous with a bunch frequency of 50MHz. The ultracold neutron facility (UCN) has 2 beamlines (West-1, West-2). West-1 provides a world-leading UCN intensity and is operated in a pulsed mode with UCN pulses every 300s, or at adjustable longer intervals or lower intensity on user request. West-2 provides about a factor 10 lower intensity.

The report details the AU usage at the test beam facilities in the first two years in the project. The introduction is followed by an overall assessment of the usage, then a short report from the three RIs. An analysis of their performance with an outlook towards the completion of the project concludes the report.

## 2. ASSESSMENT OF AU USAGE

The usage of AUs at the three RIs of WP4.1 during P1 and P2 (Sep 22 – Aug 24) is summarized in Table 1.

WP4.1	Name	Pledge	Delivered	30% goal	Delivered/goal
WP4.1.1	CERN	8736	13508	2621	515%
WP4.1.2	DESY	8640	4207	2592	162%
WP4.1.3	PSI	5376	1296	1613	80%
<b>Total</b>		<b>22752</b>	<b>19011</b>	<b>6826</b>	<b>279%</b>

Table 1: Usage of AUs in the three RIs of WP4.1. The AUs pledged for the duration of the project, the AUs delivered by mid-term, the MS goal of 30% and the accomplished percentage of the goal are given by RI and for the whole task.

The overall milestone goal across task WP4.1 is thus exceeded by nearly a factor of three. Even taking the pro-rata mid-term target of 50%, the task is still extremely successful having already delivered 84% of the totally pledged AUs.

Individually by RIs, CERN has already surpassed their full pledge of AUs. On the other hand, it can be expected that the test-beams at CERN will not be available in 2026, so this advancement of AU usage is appreciated.

DESY is delivering almost exactly at the pro-rata rate with 49% of the total AUs delivered.

PSI is on the low side with 80% of the goal reached. They, however, experienced a late start due to finalization of their specific funding arrangements with the Swiss State Secretariat for Education, Research and Innovation (SERI). Given the foreseen unavailability of CERN in 2026, they can be expected to catch up to their full pledge in the second half of the project.

## 3. REPORTS FROM RI'S

### 3.1. CERN

The CERN Proton Synchrotron (PS) and Super Proton Synchrotron (SPS) accelerator facilities are key components of CERN's infrastructure, providing essential beamlines for various experimental research activities. Being the main test beam provider of CERN, the PS/SPS beamlines hosts around 100 different experiments per beam year, often with multiple beam times spread throughout the year. The PS east hall provides a 25 GeV proton beam to the IRRAD (CERN proton IRRADIation) and CHARM (Cern High energy Accelerator Mixed field) facility and secondary particle beams to three general use beam lines. The SPS can provide a wide range of high energy beams to four multiple purpose beamlines hosted in the North Hall (EHN1) as well as to two dedicated beam lines to ECN3 and EHN2. The EHN1 beamlines have multiple user accessible zones along the beam line to enable an optimal usage of the available beam time per year by hosting parallel user in addition to the main user. An example of a typical experimental area on one of the EHN1 beam lines can be seen in Fig. 1.



*Figure 1: Installation of a user experiment in one of the experimental zones on the H8 beamline in the EHNI building.*

In the context of the EURO-LABS project, the PS and SPS test beam facilities have facilitated multiple transnational access (TA) visits for research purposes in both 2023 and 2024.

The beam period for the PS & SPS test beam facility in 2023 ran from April 2023 and will continue till October 2024, covering both reporting periods (P1 and P2) of the EURO-LABS project. During this time, we received 42 applications for a total of 12,260 access units.

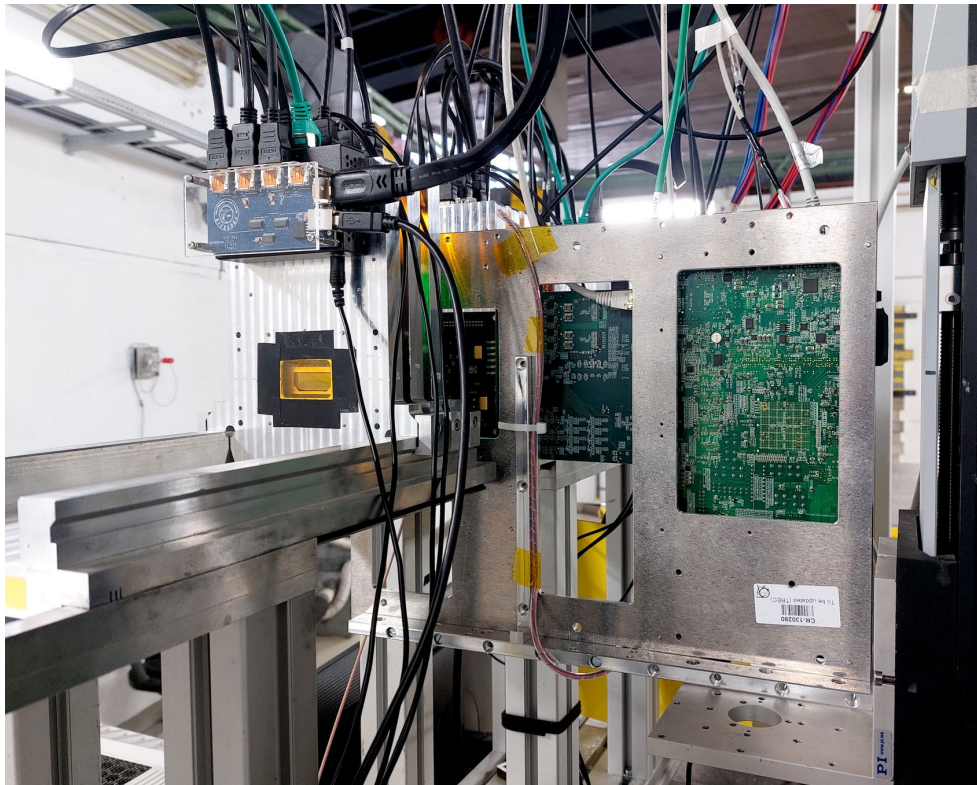
Similarly, in 2024, beam operations began in March and are expected to continue through the end of November. A call for transnational access applications has been issued, and we are currently collecting submissions. We anticipate at least five additional visits, accounting for 1,248 access units by the end of the current reporting period. These numbers may increase, depending on the approval of additional applications.

Given our current position within the LHC Run 3 schedule and WP4's focus on detector R&D, the number of activities eligible for TA this year is expected to decrease compared to 2023. Many R&D efforts are nearing their readiness reviews or similar milestones. However, we still anticipate several activities applying for TA in 2024 and 2025. The number of access units provided has already surpassed the pledged amount for the entire runtime.

### 3.2. DESY

The DESY test beam facility operates at the DESY-II accelerator and is equipped with three test beam lines, providing up to 1,000 particles per cm<sup>2</sup> with energies from 1 to 6 GeV, an energy spread of ~5% and a divergence of ~1mrad. Access to these beam lines coupled with extensive technical and

administrative user sort is the main objective in the EURO-LABS Transnational Access programme at DESY (WP4.1.2).



*Figure 2: Set-up with RD50-MPW4 D-MAPS CMOS sensor in the DESY II test beam facility. Performance of detectors before and after irradiation was evaluated and compared with results from the previous submission.*

During the first two years of the project, 20 user groups with a total of 95 users from 14 different countries have applied for TA. Of those, 63 users requested funding from EURO-LABS. To expedite and simplify all needed administrative processing required at the DESY II Test beam facility a new Registration Control System (RCS) had been designed and implemented. It includes scheduling, safety control and user's general management tools and provides with it a comprehensive service for all user groups planning their measurements campaigns at the DESY II Test Beam. In the first two years of the project, international teams that requested TA support have been granted 4207 beam-hours (AUs) of transnational access in total.

### 3.3. PSI

The EURO-LABS project in Switzerland could only be started in 2023 as the funds for TA support needed to be confirmed by SERI. The first 4.5 month of the beam period in 2023 were dedicated to a physics experiment, MUSE. Test beams were scheduled for the time after October. Only 2 teams doing test beams applied for TA support: COMET and a group from Mainz and Heidelberg.

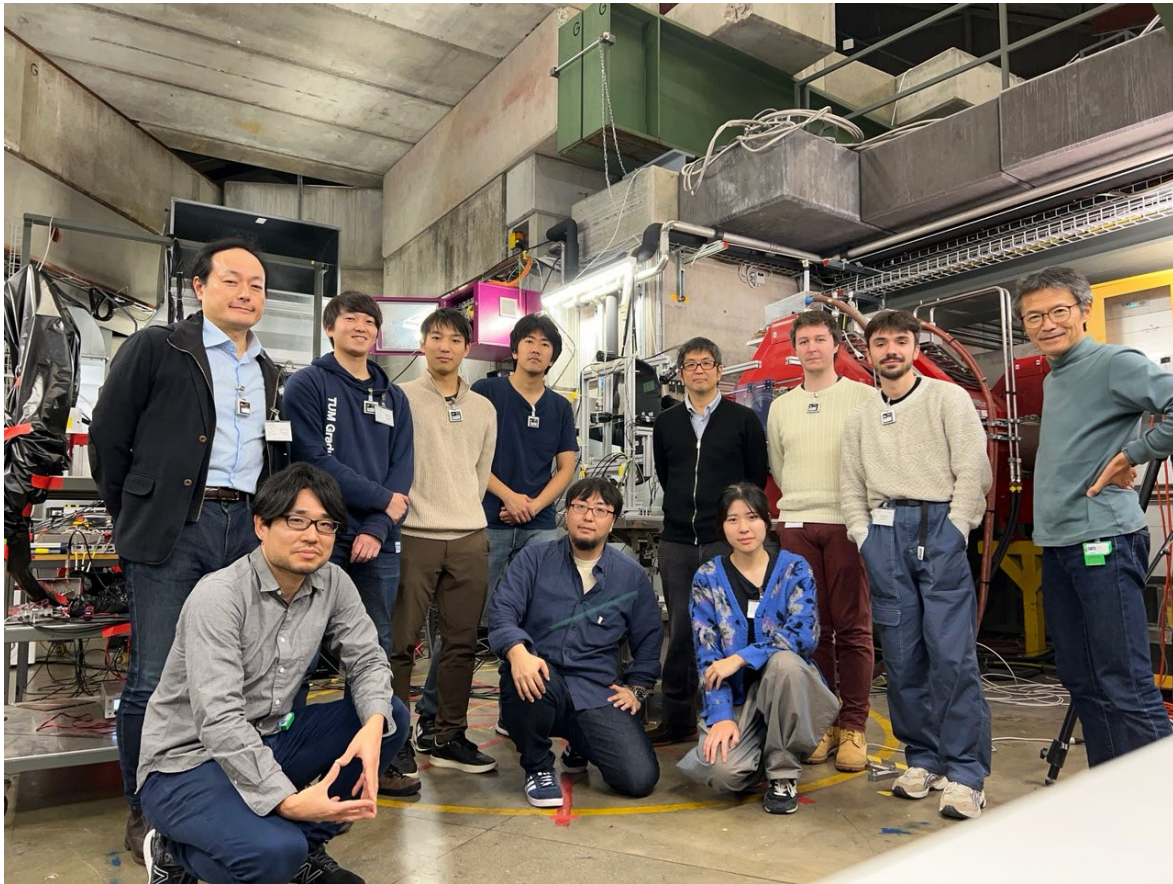


Figure 3: Members of the COMET test beam team at the PiM1 line in PSI, their set-up in the background.

The COMET experiment will search for the muon-to-electron conversion process at J-PARC, Japan. This project will primarily involve negative pions, muons, and electrons with a momentum of  $<200$  MeV/c. The primary objective of the test beam was to scrutinise the secondary particles emanating from tungsten blocks, subjected to pions and muons. This analysis was facilitated by a set of plastic scintillating counters. Both tested detectors will contribute to the particle-type identification of these secondary particles. In addition, two COMET detectors, the Range Counter and a prototype of the Cylindrical Trigger Hodoscope were also tested with muon beams in parallel. Those results have also independently contributed to the development of the COMET experiment. The group consisted of 12 scientists from Japan, France, and the UK. Five of them - all PhD students - were supported in the framework of the EURO-LABS project.

The second group supported tested a very compact spectrometer consisting of a four-layer pixel detector and a strong permanent neodymium dipole magnet. This setup serves as a demonstrator for a "photon tracker", where the conversion electron positron pair is tracked in double layers of pixel detectors. The pixel tracker is based on MuPix sensors developed for the Mu3e experiment. The project was granted two weeks of beam time. Four undergrad-students from the Universities of Heidelberg and Mainz obtained TA support.

In 2024 the schedule is similar to 2023. The PiM1 beam line is dedicated to the MUSE experiment up to mid-August and from the second half of October. Test beams are only scheduled for the time in-between. Several groups have applied for TA funding.

#### 4. ANALYSIS AND OUTLOOK

An analysis of the more than 60 projects with 344 users executed during the first two years of EURO-LABS in test beam RIs of WP4.1 reveals a great diversity of the users involved in experiments carried out within the TA framework. Based on the location of their institute, the 344 users come from 22 countries on three continents including an almost perfect coverage of EU member states. The gender balance with one quarter of female participation is not ideal, but typical for the field. The proportion of ECRs, especially for the financially supported users, is very high due to intentional preference of funding students and post-docs.

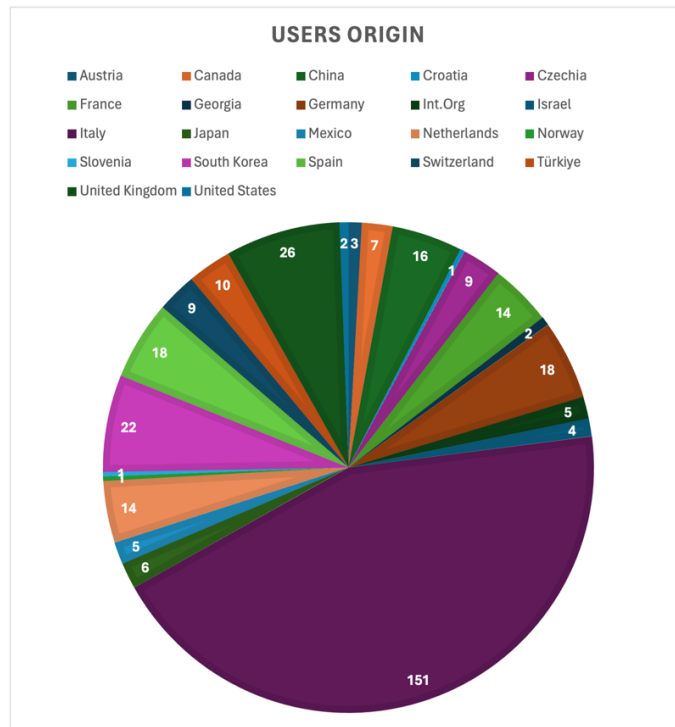


Figure 4: Distribution of TA users in WP4.1 by country in the first two years

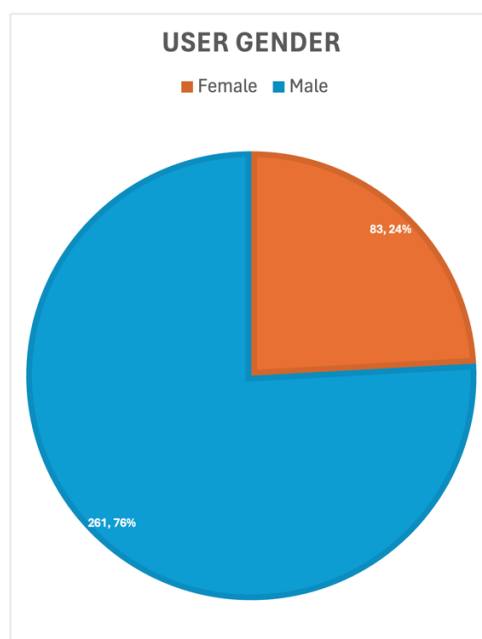


Figure 5: Distribution of TA users in WP4.1 by gender in the first two years

In the remaining two years all the three RIs of WP4.1 can be reasonably expected to fulfil their pledge of AU in TA of EURO-LABS. While CERN has already done so, they will continue to deliver AUs to users interested in detector R&D as long as the overall accelerator schedule allows them to continue. DESY is keeping a steady pace towards their target and, barring unforeseen events, can be expected to continue this way. PSI, although experiencing a somewhat slower start, is catching up rapidly and, based on the substantial number of recently submitted applications, is also heading towards timely completion of its contribution.

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## ANNEX: GLOSSARY

<b>Acronym</b>	<b>Definition</b>
RI	Research Infrastructure
TA	Transnational Access
AU	Access Unit, usually equal to a beam hour
SERI	Swiss State Secretariat for Education, Research and Innovation
IRRAD	CERN Proton Irradiation
CHRISP	Swiss Research Infrastructure for Particle Physics
PSI	Paul Scherer Institut
DESY	Deutsches Elektronen Synchrotron