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EURO-LABS

EUROpean Laboratories for Accelerator Based Sciences
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MILESTONE REPORT

A) MORE THAN 30% OF AU DELIVERED IN WP4.2: DETECTOR CHARACTERIZATION

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Abstract:

Task 4.2 provides Transnational Access to two detector characterization research infrastructures. (RIs) The infrastructures are used to characterize prototype detectors with micro-beams and detector systems for electromagnetic interference (EMI) during their R&D phase. The milestone provides a checkpoint of RIs' delivery of Access Units (AU) at project midterm. The overall usage is acceptable with the 30% goal accomplished. Detailed analysis by facility is provided. Measures are suggested to ensure the commitment gets fulfilled 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/>

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Executive summary

Task 4.2 provides Transnational Access to two detector characterization research infrastructures (RIs) where micro-beams and electromagnetic interference tests are employed to evaluate prototype detectors during their R&D phase.

The M22 milestone provides a checkpoint of RIs' delivery of Access Units (AUs) at project midterm. The overall performance is acceptable with the 30% goal exceeded. Detailed analysis by facility is provided. Both 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 two RIs offering detector characterization in WP4.2 are:

- 4.2.1: RBI-AF, Croatia
- 4.2.2: ITAINNOVA EMC Lab, Spain

Ruder Boskovic Institute (**RBI**) runs the Tandem accelerator facility (RBI-AF) used for experiments in nuclear physics and applications. RBI-AF is equipped with 1 MV Tandatron and 6 MV EN Tandem accelerators and 9 end-stations, including two ion microbeams, end station for Time-of-Flight Elastic Recoil Detection Analysis (TOF-ERDA), end-station for ion channelling experiments, large vacuum chamber for ion irradiation experiments, etc. Ion microbeam stations have multifunctional capabilities, including ion irradiations at microscopic scale and the use of ion beams as a probe for detector characterization studies using for example Ion Beam Induced Charge technique (IBIC). This facility is a key instrument for detector characterisation at microscopic scales. RBI-AF has been regularly used by many international research groups for various applications, including detector characterisation, mainly by exploiting the IBIC and TRIBIC techniques and irradiation by MeV ions for radiation hardness studies.

The Instituto Tecnológico de Aragón (**ITAINNOVA**) is a non-profit Research and Technology Organisation (RTO). The EMC lab is fully equipped to perform any EMC measurement. Two semi-anechoic chambers and Faraday cage allow to carry out standardized EMC tests as well as EM characterization of mid-scale prototypes. The lab is an accredited laboratory for European Directive and several product standards. The laboratory has several current probes to measure and inject conducted noise from DC up to 400 MHz, antennas to measure noise from few kHz up to 18 GHz and inject noise with generators up to 20 GHz and amplifiers up to 6 GHz.

Since 2008 ITAINNOVA has been working in the domain of physics experiments. It has been involved in several R&D programmes for the new generation of particle accelerators (HL-LHC, Super KEK-B and International Linear Collider) and EU projects (AIDA2020). Over the last years, ITAINNOVA has collaborated with several research centres, such as CERN, KEK, SLAC and FERMILAB. Adapting part of the EMC facility made this facility unique for noise and grounding diagnosis. While there are several EMC facilities focused on aerospace, automobile or household appliances, there is no EMC facility specialised on physics experiments other than ITAINNOVA.

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

ASSESSMENT OF AU USAGE

The usage of AUs at the two RIs of WP4.2 during P1 and P2 (Sep 22 – Aug 24) is summarized in Table 1.

WP4.2	Name	Pledge	Delivered	30% goal	Delivered/goal
WP4.2.1	RBI	504	263	151	174%
WP4.2.2	ITAINNOVA	800	165	240	69%
Total		1304	428	391	109%

Table 1: Usage of AUs in the two RIs of WP4.2. 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 of 30% across task WP4.2 is thus met. Taking the pro-rata mid-term target of 50%, the task is marginal having delivered 33% of the totally pledged AUs. Individually by RIs, RBI with 52% is at its pro-rata goal, while ITTAINNOVA with 20% is underperforming. Given the small number of foreseen projects (12 and 14) the fluctuations are expected to be large, yet at ITTAINNOVA an effort needs to be made to attract more users to the facility. Despite this, at task level but also individually at the two RIs, the pledged amount of AUs could be reached.

2. REPORTS FROM RI'S

2.1. RBI

The Tandem Accelerator Facility at the Rudjer Bošković Institute (RBI-AF) is one of the two facilities within the task 4.2 Detector Characterization of WP4. At RBI-AF users can perform:

- (i) in vacuum and in-air IBIC (Ion Beam Induced Charge) imaging of charge collection properties using protons of up to 10 MeV with 1 μm resolution and heavy ions on demand and/or time resolved IBIC (TRIBIC),
- (ii) radiation hardness studies with real-time controlled radiation damage of small detector area using protons or heavier ions, including ion beam analysis.

For such studies users can use two ion microprobe end-stations and other end stations, depending on the actual objectives of the proposed work.

In one of the performed TA user projects charge transport response of SiC sensors to harsh environments and to single ion implantation has been studied. The experiment was mostly focused on characterization of world's first in-line sensor for single ion implantation applications. In the experiment unique capabilities for deterministic heavy ion counting of the novel ultra-thin SiC radiation detectors realized by STLab srl were investigated by users from Switzerland and Italy.

Detailed 3D charge collection efficiency (CCE) characterization of large area single pad SiC detectors dedicated to the use for the particle identification by the MAGNEX focal plane detector within the NUMEN project at LNS Catania were investigated by users from Italy.

CCE characterization of position sensing photodiodes as detectors to determine the impact position of monoenergetic MeV ions was the next subject studied. The spatial resolution and radiation hardness of this position sensitive detector has been characterized by the analysis of experimental data supported by a suitable theoretical model.

The behaviour and resulting concentration in depth profiles of MeV ⁷Li ions implanted in novel commercial detector crystalline materials, such as artificial diamond and SiC polytypes was studied. The implantation has been carried out in the axial channelling mode.

High temperature implantation of Group IV elements into diamond was investigated. Group IV defects in diamond offer a promising platform for applications in quantum technology, quantum sensing and device fabrication, including magnetic field sensors and quantum thermometry.

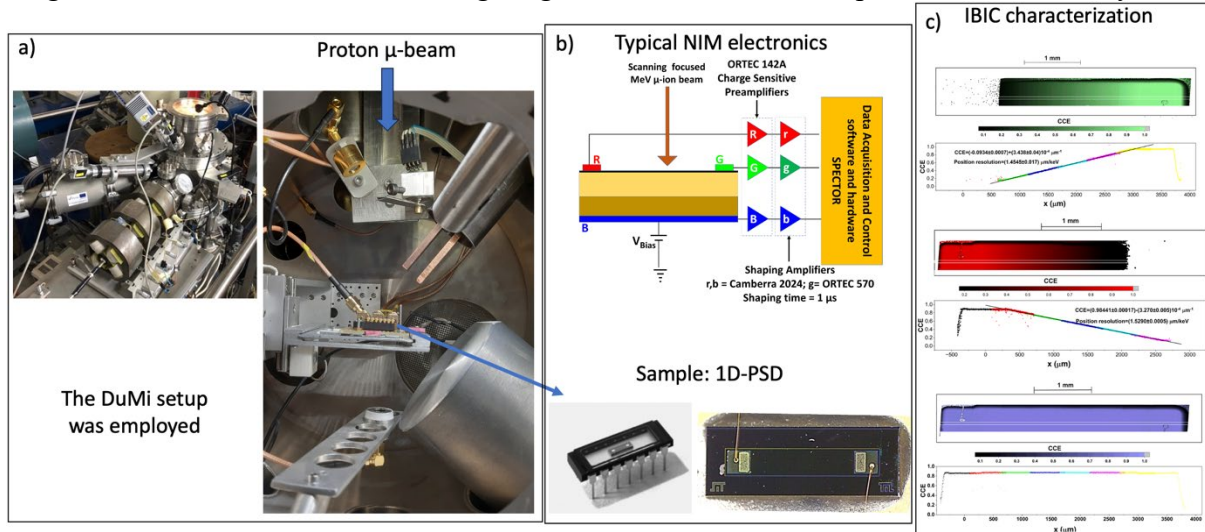


Figure 1: EURO-LABS experiment for the characterization and modification of a 1D-PSD. a) The experiment was carried out at the Dual Microprobe (DuMi) end-station, b) the detectors were read out with NIM-based electronic units, c) IBIC microscopy was carried out. After characterization, the detector was modified by means of controlled irradiations aiming to obtain a 2D-PSD response.

2.2. ITAINNOVA

During this phase of the project, CERN requested access for an initial test aimed to measure the noise susceptibility of a complete serial chain of modules for the CMS Phase-2 pixel upgrade. To achieve this, a serial chain of two prototype tracker barrel pixel modules, each with 2 RD53A readout chips (2x2 TBPX RD53A modules) with planar sensors, as illustrated in Fig. 2, was utilized. The test showed valuable insights for the CMS inner tracker FEE designers regarding critical aspects of FEE design, including noise transfer function (TF) variations between chips (Fig. 2) and the noise TF identification of high voltage lines.

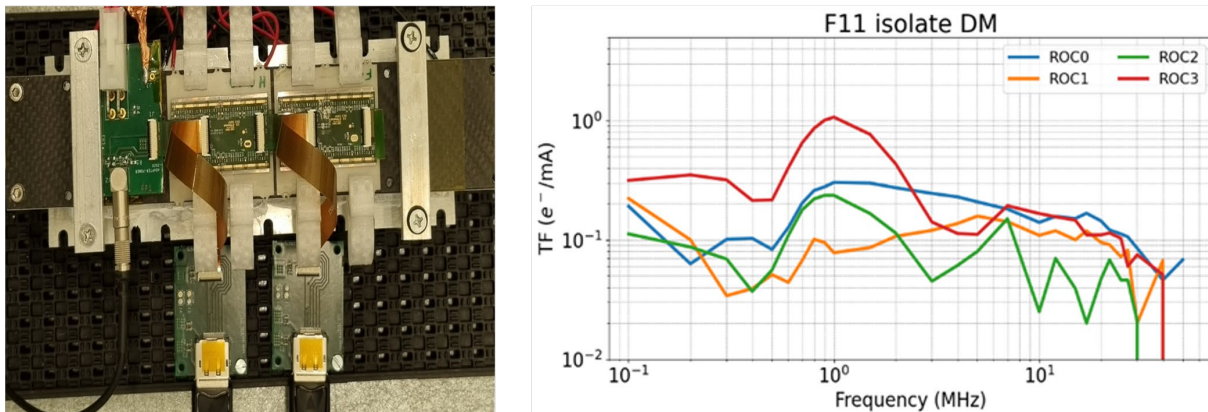


Figure 2: Inner Tracker Phase-2 prototype module (left) and the measured noise transfer function of 4 readout chips of one 2x2 TBPX prototype module (right).

Only 20% of the planned AU have been covered in two projects. Access to the facility started with some delay due to the completion of the planned improvements at the EMCLab. These upgrades included a Graphical User Interface (GUI) and a new cooling system. A comprehensive view of the new TF measurement system with both upgrades included is shown in Fig. 3.



Figure 3: New TF measurement system for physics detectors (including GUI and cooling system)

The newly developed GUI simplifies electromagnetic noise characterization tests. It enables users to set up and conduct tests without needing extensive knowledge of Data Acquisition (DAQ) systems and detector hardware, thereby enhancing detector performance and the reliability of noise tests. The cooling system, which comprises a chiller, an isothermal enclosure, and a cooling plate, was also developed in the initial part of the project. This system can achieve temperatures as low as -30°C , which is essential for the typical operating conditions of detector chips and sensors in LHC trackers. Both upgrades are now complete and available for use by project participants throughout the remainder of the project.

3. ANALYSIS AND OUTLOOK

An analysis of projects during the first two years of EURO-LABS in detector characterization RIs of WP4.2 showed the diversity of the users involved in experiments carried out within the TA framework. Based on the location of their institute, the 15 users come from 7 European countries, four of them EU member states. The gender balance with 40% of female participation is very good. The proportion of Early Career Researchers (ECRs), especially for the financially supported users, is very high due to intentional preference of funding students and post-docs.

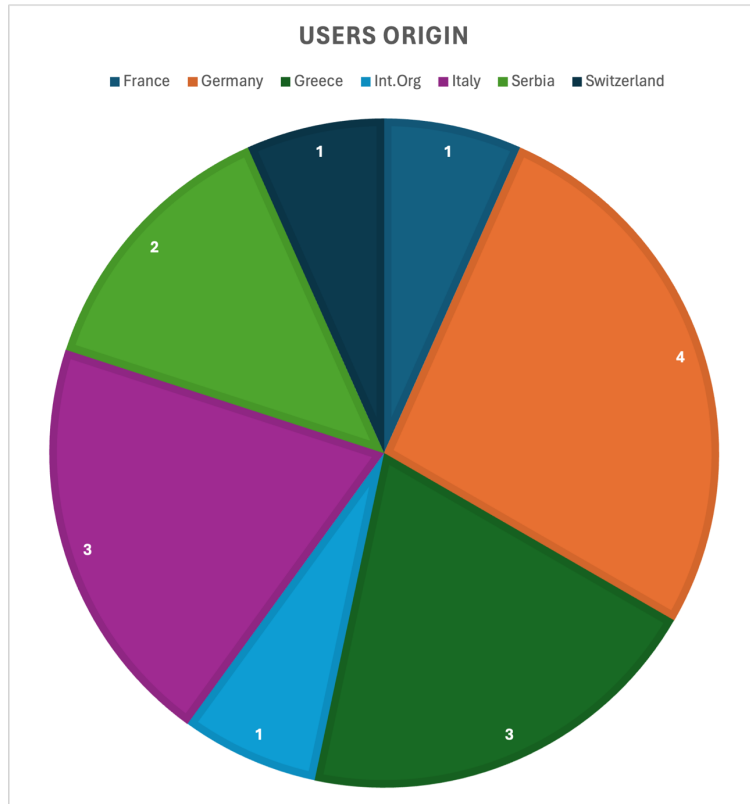


Figure 4: Distribution of TA users in WP4.2 by country in the first two years

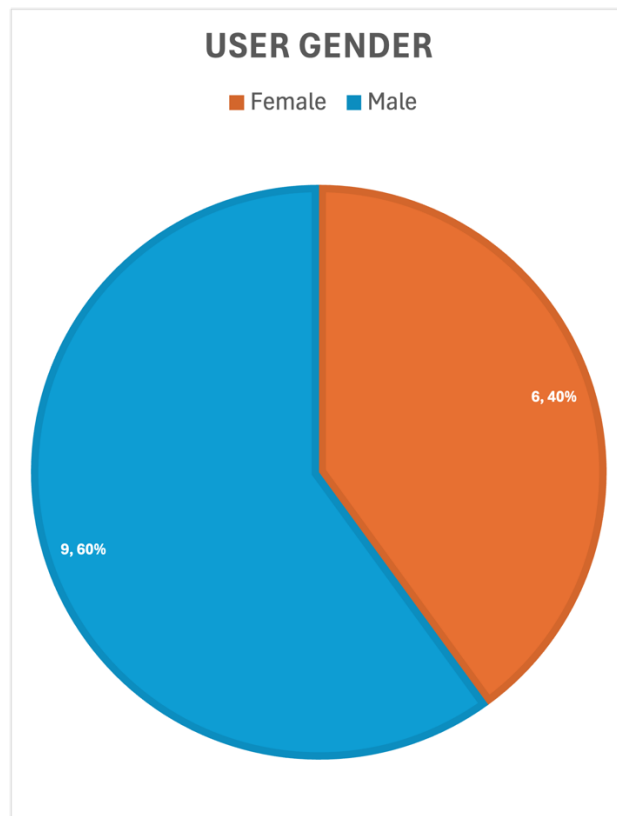


Figure 5: Distribution of TA users in WP4.2 by gender in the first two years

In the remaining two years both RIs of WP4.2 can be expected to fulfil their pledge of AU in TA of EURO-LABS. For RBI that involves keeping their pace; based on the flow of executed projects their user pool looks relatively stable. At ITTAINNOVA a larger effort is needed to persuade the builders of detector systems to conduct the tests of their detector assemblies at this unique facility. An investment needs to be made to educate the users of the advantages of those tests, best by presenting successful usage cases at internal meetings of the potential user communities.

ANNEX: GLOSSARY

Acronym	Definition
RI	Research Infrastructure
TA	Transnational Access
AU	Access Unit, usually equal to a beam hour
ECR	Early Career Researcher