HORIZON 2020

Research Infrastructures

H2020-INFRAIA-2014-2015

INFRAIA-1-2014-2015 Integrating and opening existing national and regional research infrastructures of European interest

ENSAR2

European Nuclear Science and Application Research 2

Grant Agreement Number: 654002

Deliverable D7.3
Strategy Report "Training Opportunities at European Small-Scale Accelerators"

Version: 1
Author: Sotirios V. Harissopulos
Date: 23 February 2019

PROJECT AND DELIVERABLE INFORMATION SHEET

ENSAR2 Project Ref. №	654002
Project Title	European Nuclear Science and Application Research 2
Project Web Site	http://www.ensarfp7.eu/
Deliverable ID	D7.3
Deliverable Nature	Report
Deliverable Level*	PU
Contractual Date of Delivery	28/2/2019
Actual Date of Delivery	28/2/2019
EC Project Officer	Mina Koleva

* The dissemination level are indicated as follows: PU – Public, PP – Restricted to other participants (including the Commission Services), RE – Restricted to a group specified by the consortium (including the Commission Services). CO – Confidential, only for members of the consortium (including the Commission Services).

DOCUMENT CONTROL SHEET

Document	Title: Strategy Report “Training Opportunities at European Small-Scale Accelerators”	
	ID: D7.3	
	Version: 1	
	Available at: http://www.ensarfp7.eu/	
	Software Tool: Microsoft Office Word 2007	
	File: ENSAR2_Deliverable_D7.3.docx	
Authorship	Written by:	Sotirios V. Harissopulos
	Contributors:	J. Gomez-Camacho
	Reviewed by:	M. N. Harakeh
	Approved by:	K. Turzó

DOCUMENT STATUS SHEET

Version	Date	Status	Comments
0.0	25/2/2019	For internal review	
1.0	28/2/2019	Submitted on EC Participant Portal	
		Final version	

DOCUMENT KEYWORDS

Keywords	

Disclaimer

This deliverable has been prepared by Work Package 7 (ENSAF: European Network of Small-scale Accelerator Facilities) of the Project in accordance with the Consortium Agreement and the Grant Agreement n°654002. It solely reflects the opinion of the parties to such agreements on a collective basis in the context of the Project and to the extent foreseen in such agreements.

Copyright notices

TABLE OF CONTENTS

LIST OF FIGURES

None

REFERENCES AND APPLICABLE DOCUMENTS

[1] ENSAR2 Deliverable D7.1 entitled Strategy Report “Physics Opportunities and Innovation at European Small-Scale Accelerators”

[2] See in https://indico.ific.uv.es/event/2824/

[3] See in http://www.ensarfp7.eu/activities/networking-activities/ensaf/2nd-ensaf-workshop-1

LIST OF ACRONYMS AND ABBREVIATIONS

BGO	Bismuth-Germanate-Oxide
ECR	Electron Cyclotron Resonance
ENSAF	European Network of Small-scale Accelerator Facilities
HPGe	Hyper-Pure Germanium
IBA	Ion-Beam Analysis
NRA	Nuclear Reaction Analysis
PET	Positron-Emission Tomography
RBS	Rutherford BackScattering

Executive Summary

D7.3 reports on Training Opportunities at European Small-Scale Accelerators. These refer to the 15 facilities listed in the deliverable D7.1 [1] of ENSAR2 prepared by ENSAF, the European Network of Small-Scale Accelerator Facilities. During two workshops organised by ENSAF, participants have identified a large number of specific training topics available at small-scale accelerators. These can be grouped in the following eight general training opportunities: a) Energy calibration of accelerators, b) Ion-beam steering and focusing hardware, c) Basic ion-beam sources, d) Vacuum production and control systems, e) Target preparation and analysis, f) Operation and maintenance of HPGe detectors and BGO Anti-Compton shields, g) Operation of scintillation detectors and h) Basic ion-beam analysis techniques.

Introduction

Low-energy stable-beam facilities contribute to our understanding of nuclei through research in nuclear structure, reactions and nuclear astrophysics. In addition, multidisciplinary research, based on well-established nuclear techniques, is additionally conducted in these facilities providing a broad spectrum of basic accelerator techniques for the needs of high-level education of students and training of young researchers. This is the case not only for university-based accelerator laboratories but also for accelerator laboratories operating not as university units. In the following, we provide with two examples, i.e. the Institute for Nuclear Research of the Hungarian Academy of Sciences ATOMKI-HAS in Debrecen, Hungary, and the National Centre of Accelerators, CNA, in Seville, Spain.

ATOMKI in collaboration with the University of Debrecen offers laboratory exercises for physics students at the Master's level, which include among others topics related to accelerator-based research of accelerator operation. These topics are a) accelerator energy calibration, b) efficiency determination of a gamma detector, c) basic target preparation techniques and d) measurement of the Tandetron accelerator operation parameters (voltage ripple, long-term stability etc.). In addition to these laboratory exercises, a Master degree on "Ion beams for Material Science" has been established offering courses related to accelerators, vacuum systems, detectors and electronics, Ion-Beam Analysis (IBA) methods and Proton-Beam Writing.

Similarly, CNA provides access to undergraduates in Physics Engineering and Archaeology degrees of the University of Seville to its accelerators. Within Master's level, CNA provides courses on nuclear physics applications, with extensive use of the accelerators, for the Spanish Inter-University course in nuclear physics (with participation of 10 Spanish institutions) and the Erasmus Mundus Master programme in nuclear physics (with participation of 9 institutions from Italy, France and Spain). At the level of PhD students, CNA provides training to experimental nuclear physics students, related to: vacuum in a scattering chamber, target positioning, detector and geometry of the detector arrays, data acquisition, and data processing. These aspects are crucial as a preparation for the participation in larger-scale facilities, where these aspects are beyond the user control.

During the two workshops organised by ENSAF on October 19-21, 2016, in Seville, Spain [2] and on October 3-4, 2018, in Athens, Greece [3], a round-table discussion served to identify training opportunities at European small-scale accelerator facilities. A high-number of training topics were proposed. During the discussion, it was often mentioned that small-scale facilities should provide training not only for young researchers working almost entirely at these facilities but also for those students who pursue parts of their thesis research at large-scale facilities, where the much higher demand for beam-time by numerous external users does not allow for extensive training prior to the experiments. In this context, young researchers should have the opportunity to get acquainted with basic principles of techniques employed at large-scale facilities as well as get on hands-on training in certain equipment, which are not always accessible for training needs at large-scale facilities because of continuous operation. Under these conditions, eight general training opportunities have been selected as first priorities. These are given below.

SECTION 1: Training topics at European Small-Scale Accelerators

- Energy Calibration of accelerators

The accurate knowledge of the energy of the accelerated ion beams is a basic parameter in many nuclear physics investigations, such as cross-section measurements in nuclear astrophysics, and excitation function and resonance-strength measurements in nuclear structure studies. The energy calibration of an accelerator is, furthermore, of key information in many Ion-Beam Analysis (IBA) techniques. Small-scale tandem accelerators are ideal to provide training on the relevant procedure by means of yield measurements of well-known resonances of nuclear reactions on light elements, such as ^{27}Al(p,γ)^{28}Si or ^{7}Li(p,n)^{7}Be at proton beam energies of 991.2 and 1880.4 keV, respectively.

- Ion-Beam steering and focusing hardware

Steering of an ion beam from its initial production location to the target is a basic operation in all accelerators. The shape and area of the beam spot on the target together with the beam intensity can play a decisive role in the experiment’s success, especially in applications based on micro-beams, i.e. ion beams with cross-sections around or even smaller than one micro-meter. Micro-beam systems are installed in many small-scale accelerator facilities, thus providing opportunities for a hands-on training on beam-steering and focusing elements.

- Basic ion-beam sources

The production of ion beams requires operating sources based on a variety of physics phenomena coming into play in surface science, physical chemistry and basic laws of electromagnetism. A “good” ion-beam should have specific properties such as purity, brilliance and intensity. The interaction between operators and experimentalists is often necessary to prepare a beam meeting the needs of an experiment. Small-scale accelerator facilities can provide a training in the operation of basic ion-beam sources for young researchers. The vast majority of tandem accelerators use standard ion-beam sources, i.e. duoplasmatrons and sputter sources. Standalone ECR-type sources can also be used for this purpose.

- Vacuum production and control systems

Almost all nuclear structure and nuclear astrophysics measurements are based on bombarding, in vacuum, target-nuclei (sample) with ion-beams. There are some exceptions where irradiations in-air are necessary. In all cases, however, the beam is guided to the target position in tubes under vacuum. It is therefore mandatory for an experimentalist to understand the operation of all systems related to vacuum production and control, i.e. pumps, gauges etc. Small-scale accelerators are equipped with all basic vacuum-producing hardware and a relevant training can be offered.

- Target preparation and analysis

Independently of the method and the setup used in nuclear physics experiments, their success depends strongly not only on the efficiency of the detectors used and their overall response but also on the quality and stability of the targets employed. In their vast majority, targets for nuclear physics experiments are produced via evaporation and sputtering techniques using special instruments. These techniques require knowledge of specific physical properties of the target material, such as melting or evaporation temperatures, surface cohesion grade, etc.. Given the drastically decreased number of experts in target preparation worldwide, there is an urgent need for training young nuclear physicists in these techniques and a few small-scale facilities equipped with the necessary instruments can play a role by contributing decisively to this goal.

The analysis of the target properties, such as thickness, homogeneity etc., is a further topic where small-scale accelerator facilities can offer training since most of them are equipped with the necessary setups. These include setups for Rutherford Backscattering (RBS) analysis and Nuclear Reaction Analysis (NRA). Training in applying these methods can also be of importance for young nuclear scientists.

- <u>Operation and maintenance of HPGe detectors and BGO Anti-Compton shields</u>

In gamma-ray spectrometry, Compton suppression is a technique that reduces the background by preventing registration of signals from gamma-rays, scattered from the main detector. All modern γ-ray detection arrays employed in large-scale accelerator facilities implement the Compton-suppression technique by combining hyper-pure Germanium (HPGe) detectors with Bismuth-Germanate-Oxide (BGO) scintillation detectors. When Compton-scattered gamma rays escape from the HPGe detector and are absorbed and detected in the BGO, a veto signal can be set to block the registration of the Compton interaction event by the HPGe detector. As almost all γ-ray detection arrays are equipped with HPGe detectors with BGO shields, it is very useful for young researchers to be trained in operating and maintaining these types of detectors as well as in setting up an electronic circuit to create a veto signal. Many small-scale accelerator facilities are nowadays equipped with the basic instruments (HPGe and BGO detectors and necessary electronic units) required for such a training.

- <u>Operation of scintillation detectors</u>

Scintillation detectors are extensively used not only in nuclear physics research but also in medical applications (imaging techniques in Positron-Emission Tomography - PET), security (cargo and luggage scanning), mineral assays and many others. Traditional scintillators, like Sodium Iodide (NaI) detectors, exist in almost every small-scale accelerator laboratory. As these facilities are becoming gradually more equipped with “last generation” scintillators like Lanthanum Bromide ($LaBr_3$) or Cerium Bromide ($CeBr_3$) detectors they can offer excellent training opportunities in operating a wide category of scintillation detectors and testing them under real experimental conditions.

- <u>Basic Ion-Beam Analysis Techniques</u>

Ion-beam Analysis (IBA) is a group of analytical techniques based on the use of ion beams from low-energy accelerators. They are implemented in order to probe the composition and obtain elemental depth profiles in the near-surface layer of solids. All IBA methods are highly sensitive and allow the detection of elements in the sub-monolayer range. As such, they are extensively used in materials science and nanotechnology. Almost all small-scale accelerator laboratories are equipped with IBA setups. As such they can offer training possibilities to young scientists from the graduate to post-doctoral level.

Conclusion

Small-scale accelerator facilities can provide a large number of training topics to young researchers from the graduate up to post-doctoral level. University-based accelerator laboratories as well as accelerator facilities not hosted by universities have long-term expertise in providing courses within Master and PhD degree programmes. All small-scale accelerator facilities listed in deliverable D7.1 [1] are very well-equipped to meet the demands of highly-specialised training in nuclear physics. In addition, the beam-time load in these facilities is less than that of the large-scale facilities and, therefore, beam time could be provided also for training purposes. Based on the discussions held during the two ENSAF Workshops [2,3], the training topics at small-scale accelerators can be grouped in eight categories that are described in Section 1.