Report from Consultancy Meeting on Trends in Accelerator Instrumentation

IAEA Headquarters,
Vienna, Austria, M 0E68
18 – 20 December 2017

Executive summary

The meeting was organized by the Physics Section personnel from the Nuclear Science and Instrumentation Laboratory (NSIL) at Seibersdorf and the HQ in Vienna. It aimed at:

- exchanging information on the best practices in accelerator analytical techniques, the current status of the instrumentation available at the institutions of the consultants being invited to the meeting and

- discussing possible support from these institutions in facilitating access to their facilities within the framework of the Coordinated Research Project (CRP) to be organized by the IAEA Physics Section with a suggested title "Facilitating experiments with accelerators" that is foreseen within the scope of the IAEA Project 1.4.3.002.

The meeting was attended by IAEA personnel and three consultants from Australia, Greece and Lebanon, who presented their best practices and work relevant to the scope of the Meeting. The list of meeting participants and the meeting agenda are given in Annex 1 and 2, respectively. The presentations resulted in technical discussions on current work conducted at the accelerator facilities introduced by the consultants and their previous experiences in supporting IAEA activities. The participating PS personnel presented recent activities and projects on the utilization of accelerator facilities and nuclear instrumentation running at NSIL and the HQ. The participants discussed in detail the advantages of accelerator analytical techniques and the needs of fostering their use in developing countries, MS of the IAEA, that may lead in an increase of the number of research projects benefiting from the advantages of these techniques. For this purpose it is necessary to broaden the accelerator user communities in developing MS countries and the planned CRP entitled "Facilitating experiments with accelerators" could successfully contribute to achieve this goal. In this context, the meeting participants discussed also the need of IAEA complementary activities of key importance such as Training Workshops with hands-on activities and the publication of supporting material.

The participants concluded that the objectives of the meeting were accomplished by the wealth of information exchanged in presentations and discussions. In summary, the participants came to the following conclusions:

- The state-of-the-art instrumentation available in several accelerator facilities offers many opportunities to implement different accelerator analytical techniques for the needs of users from MS.
- There is an uneven level of user experience across the IAEA developing MS. Training activities could decisively assist existing and potential end-users in formulating sound research projects based on accelerator analytical techniques and to engage in collaborative research projects.
- The organization of Coordinated Research Projects has proven to be an effective mechanism to bridge the gap in accessing advanced facilities in the past. Coordinated Research Projects create substantial linkages between new users, experienced research communities, and state-of-the-art facilities.
- The participants acknowledged the combined efforts of the Nuclear Science and Instrumentation Laboratory (NSIL) and the HQ personnel of Physics Section to facilitate access to accelerator facilities through implementing dedicated projects for this purpose.

- The Accelerator knowledge portal is a very helpful tool for MS while searching for the nearby facilities and available techniques, especially when frequently updated.

As a result of these conclusions, the following recommendations are made to the IAEA:

- To foster the access to accelerator facilities through coordinated research projects. The participation of the existing IAEA Collaborating Centers in these CRPs could be a good starting point to ensure the access to such facilities. The increase of the number of institutions supporting the IAEA in accelerator applications through establishing new Collaborating Centers is also recommended.
- To organize Training Workshops on accelerator analytical techniques complimentary to the organization of CRPs, as a very effective mechanism to: a) raise awareness of researchers from countries not having accelerator facilities, b) transfer specialized knowledge and c) motivate the conception of research projects relying on the use of such techniques and facilities.
- To continue effectively disseminate technical information on accelerator applications through publication of brochures, technical reports, web resources and portals. Access to literature for researchers from some developing countries is very difficult and the IAEA can be facilitator in increasing the access possibilities.
- To continue supporting the modernization of the IAEA Laboratories at Seibersdorf and to consider the possibility of installing an accelerator facility in the near future.
- To organize a follow-up consultancy meeting with the aim to prepare the framework of the planned CRP in the presence of additional accelerator facilities located in different regions, such as Africa, Latin America and Asia.
- To update Accelerator knowledge portal with available analytical nuclear techniques in corresponding facilities

At large, the IAEA is recommended to organize a dedicated CRP on facilitating access to accelerator facilities, continue the training activities on subjects related to the use of accelerator analytical techniques as well as support requests from Member States within relevant TC projects.

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1. Introduction

Accelerator based analytical techniques, including Particle Induced X-ray and gamma Emission (PIXE/PIGE), the Rutherford Back Scattering Spectrometry (RBS), the Nuclear Reaction Analysis (NRA), the Elastic Recoil Detection Analysis (ERDA), the Accelerator Mass Spectrometry and other complementary methods provide with unique research capabilities.

The Nuclear Science and Instrumentation Laboratory (NSIL) of the Physics Section of IAEA/NAPC supports the IAEA Member States in the effective operation and maintenance of instrumentation appropriate for their activities, including the application of nuclear analytical techniques in different fields of research. In this context, the Physics Section leads a number CRPs and TC projects, listed in Annex 3, that are closely connected to nuclear analytical techniques.
Additionally, Accelerator knowledge portal (https://nucleus.iaea.org/sites/accelerators/Pages/default.aspx) was set up to simplify the search and browsing through different accelerator facilities across the world

NSIL identified the need to provide access to accelerator facilities by researchers of MS not having opportunities to benefit from unique research capabilities of accelerator based analytical techniques. In this context, the Consultancy Meeting was organized with the aim to discuss the current status of aforementioned techniques and developments of related instrumentation used at accelerator facilities represented at the meeting in view of the planned CRP.

Moreover, the consultants discussed ways of providing access to accelerator facilities for researchers from developing Member States as part of the planned CRP. These facilities could participate in the CRP through Research Agreements and Technical Contracts. In parallel, the planned CRP may provide the means to researchers, academic personnel and PhD students from Member States to access accelerator facilities, receive hands-on training and implement their research projects.

2. Description of presented accelerator facilities and available analytical techniques

The consultants gave an overview on their facilities, equipment and associated analytical techniques as well as the research activities implemented in their laboratories during the meeting. According to the presentations, following scientific fields are covered by research activities performed at the presented facilities:

1. Cultural heritage
2. Environmental monitoring and Climate change
3. Materials characterization and modification
4. Material studies for fusion energy
5. Earth sciences
6. Biosciences-Human health

The techniques available in the represented facilities are:

Particle induced a-ray emission (PIXE)
Particle induced gamma emission (PIGE)
Rutheford backscattering/ Backscattering/ Elastic backscattering (RBS/BS/EBS)
Proton elastic spectroscopy analysis (PESA)

Nuclear reaction analysis (NRA)
Scanning transmission ion spectroscopy (STIM)
Accelerator mass spectroscopy (AMS)
MeV Secondary ion mass spectrometry (MeV SIMS)

Table 1. lists the techniques available at the facilities presented by the consultants during the Meeting. Details are given in Annexes 4, 5, and 6.

Table 1.

Short description of the presented facilities and available techniques.

Name	Technical specifications	Analytical techniques
ANSTO	2 and 6 MV Tandem electrostatic accelerators (Microbeam available at the 6 MV Tandem)	PIXE, PIGE BS PESA STIM/Off-AXIS AMS
NCSR "Demokritos"	5.5 MV Tandem electrostatic accelerator with microbeam	PIXE off-axis STIM RBS, NRA, PIGE Resonant PIGE for Hydrogen profiling
LAEC-CNRS	1.7 MV Tandem electrostatic accelerator with external microbeam	PIXE, PIGE RBS-EBS μ-PIXE (available by end of 2018)

3. Discussions

In view of the increasing demand of MS for accelerator based analytical services, following topics were discussed during the meeting:

1 The scientific background and the specific needs for analytical techniques of researchers from MS. Potential users without access to facilities providing accelerator analytical techniques can be classified in the following three groups:

- Not aware of the capabilities of these techniques
- Strong interest but no on hands experience
- Experienced users

2. Potential collaborating facilities providing access were discussed with regards to access procedures by external users. There are two types of general procedures through which an external user can access these facilities:

- Project proposals by external users submitted in order to perform experiments at these facilities are evaluated by Program Advisory Committee (PAC) based on Research Merit Criteria.
- Project proposals by external users submitted in order to perform experiments at these facilities are internally evaluated.

3. Accelerator facilities willing to participate in the CRP and provide access might apply for research agreements or technical contracts. The latter would offer a partial compensation to cover costs associated to performing experiments by external users.

4. The IAEA has contributed to development and operates an Ion Beam Analysis experimental station at the Ruder Boskovic Institute (RBI) in Zagreb, Croatia.

5. The IAEA and the MS would be able to access facilities under (3. and 4.) without passing the conventional competitive proposal reviewing process associated to requests for beam time use.

6. Need to involve several facilities from different regions, preferably having a status of IAEA Collaborating Centres, in order to facilitate access to end users which gravitate to these centres.

7. Pathways to maximize the number of end-users, i.e. experimental output, within allocated funds by providing research contracts of different time duration. Beneficiaries of research contracts might be entitled for one to three year duration of the contract to perform requested experiments. In this way the IAEA can increase the number of end users with the same allocated funds. It is suggested to the CRP organizers to keep reasonable time frame both for individual research proposals and total beam time to be provided by facilities.

8. Sample preparation required for performing a required analysis should be discussed between end users and providers case by case.

9. The primary criteria for evaluation of end user proposals for a research contract or research agreement should be the technical feasibility and the quality of the proposed research.

A factor limiting a wider use of accelerator analytical techniques is the uneven level of knowledge and experience on such techniques across the IAEA Members States. Therefore,

there is a need to disseminate technical information on these fields through publication of brochures, technical report series, web resources and other media. Additionally, training activities could be offered by NSIL, and the organization of Training Workshops is a modality that could serve to present the option to groups of specialists working in many fields of research.

4. Conclusions and recommendations

The participants concluded that the objectives of the meeting were accomplished by the wealth of information exchanged in presentations and discussions. Summarizing, the participants came to the following conclusions:

- The state-of-the-art instrumentation available in several accelerator facilities offers many opportunities to implement different accelerator analytical techniques in support of a wide variety of investigations for the needs of users from MS.
- There is an uneven level of user experience in using accelerator techniques across the IAEA developing Members States. Training activities could decisively assist existing and potential end-users in formulating sound research projects based on accelerator analytical techniques and to engage in collaborative research projects.
- The organization of Coordinated Research Projects has proven to be an effective mechanism to bridge the gap in accessing advanced facilities in the past. Coordinated Research Projects serves to create substantial linkages between new users and, experienced research communities, and as well as to the state-of-the-art facilities.
- The participants acknowledged the combined efforts of the Nuclear Science and Instrumentation Laboratory (IAEA-NSIL) and the HQ personnel of Physics Section to facilitate the access to accelerator facilities by implementing dedicated projects.
- The Accelerator knowledge portal is a very helpful tool for MS while searching for the nearby facilities and available techniques. It would be more useful if updated with associated nuclear techniques in each facility and data kept up to date

As a result of these conclusions, the following recommendations are made to the IAEA:

- To foster the access to accelerator facilities through coordinated research projects. The participation of the existing IAEA Collaborating Centers in these CRPs could be a good starting point to ensure the access to such facilities. The increase of the number of institutions supporting the IAEA in accelerator applications through establishing new Collaborating Centers is also recommended.
- To organize Training Workshops on accelerator analytical techniques complimentary to the organization of CRPs, as a very effective mechanism to: a) raise awareness of researchers from countries not having accelerator facilities, b) transfer specialized knowledge and c) motivate the conception of research projects relying on the use of such techniques and facilities.
- To continue effectively disseminate technical information on accelerator applications through publication of brochures, technical reports, web resources and portals. Access to literature for researchers from some developing countries is very difficult and the IAEA can be facilitator in increasing the access possibilities.

- To continue supporting the modernization of the IAEA Laboratories at Seibersdorf and to consider the possibility of installing an accelerator facility in the near future.
- To organize a follow-up consultancy meeting with the aim to prepare the framework of the planned CRP in the presence of additional accelerator facilities located in different regions, such as Africa, Latin America and Asia.
- To update Accelerator knowledge portal with available analytical nuclear techniques in corresponding facilities

Annex 1

Participants of Consultancy Meeting on

Trends in Accelerator Instrumentation

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Annex 2

Agenda of Consultancy Meeting on Trends in Accelerator Instrumentation

IAEA Headquarters,

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Monday 18		
08:30 – 09:30	Registration	
09:30 – 09:45	Official Opening:	*Mr Danas Ridikas, Head Physics Section, IAEA-NA*
09:45 – 10:00	Brief self-introduction of the participants	
10:00 – 10:30	Organizational arrangements	*Mr Natko Skukan NSIL, IAEA-NA*
10:30 – 10:45	***Coffee Break***	
10:45 – 11:15	The contribution of NSIL to facilitating MSs access to accelerators	*Mr Natko Skukan NSIL, IAEA-NA*
11:15 – 11:45	IAEA activities in accelerator applications	*Mr Sotirios Charisopoulos Physics Section, IAEA-NA*
11:45 – 13:45	***Lunch Break***	
	Session one: Description of accelerator facilities	
14:00 – 14:45	Description of the facility	*Mr* Anastasios Lagogiannis *NCSR Demokritos, GREECE*
14:45 – 15:30	Description of the facility	*Mr Mohamad Roumie CNRS, LEBANON*
15:30 – 15:45	***Coffee Break***	
15:45 – 16:15	Description of the facility	*Mr Zeljko Pastuovic ANSTO, AUSTRALIA*
16:15 – 17:00	Introduction to new CRP: 2123 Facilitating Experiments with Ion Beam Accelerators	*Mr Natko Skukan NSIL, IAEA-NA*

Tuesday 19	Session 2: Discussion on training needs for IAEA Member States (*Mr Skukan*)
09:00 – 09:45	Discussion
09:45 – 10:30	Discussion
10:30 – 10:45	***Coffee Break***
	Session 3: Discussion on feasibility of providing access to accelerator facilities (*Mr Skukan*)
10:45 – 12:15	Working groups
12:15 – 13:45	***Lunch Break***
13:45 – 17:00	Working in groups

Wednesday 20	Session 4: Drafting meeting report	
10:45 – 12:15	Working groups	
12:15 – 13:45	***Lunch Break***	
13:45 – 15:00	Working in groups	
15:00 – 15:30	*Coffee Break*	
15:30 – 16:30	Final remarks and closing of the meeting	

Annex 3

CRPs and TC projects relevant to nuclear analytical techniques led by the Physics Section

Collaborative Research Projects (CRPs)			
Project Number	**Project Title**		**Status**
	Experiments with Synchrotron Radiation for Modern Environmental and Industrial Applications		
	In Situ Measurements for Rapid Environmental Mapping of Contaminated Sites		
	Nuclear Techniques and Novel Instrumentation for Low-Z isotope analysis in Food Products		

Technical Cooperation (TC) Projects			
Project Number	**Project Title**	**1st year of approval**	**Status**
AFG0004	Development of Nuclear Physics Laboratory for Bachelor and Master Students	2014	Closure In Progress
ALG0018	Supporting the Establishment of a National Network of Particle Accelerators and for Analyses Using Nuclear Techniques	2014	Closure In Progress
ALG1018	Supporting the Creation of a National Network of Particle Accelerators and for Analyses Using Nuclear Techniques, Phase II	2016	Active
ARG0015	Improving and Strengthening Human Resources in the Areas of Environment, Mining, Nuclear Reactors, Nuclear Fuel, Human Health and Agriculture	2016	Active
EGY0019	Supporting Design and Implementation of High Sensitivity Radiation Monitoring Equipment	2014	Active
EGY1026	Strengthening the Applications Associated with the Second Research Reactor	2016	Active
GAB0004	Establishing Preventive Maintenance and Sustainable Management of Medical and Scientific Equipment at the Oncology Institute in Libreville	2012	Closure In Progress
GHA0016	Utilizing the Pelletron Accelerator	2016	Active

INS1026	Utilising Neutron Beam Techniques to Support Research on Industrial Applications	2016	Active
INT0089	Developing Human Resources and Supporting Nuclear Technology	2014	Active
INT0092	Building Human Capacity for the Construction, Operation and Use of Synchrotron-Light for Experimental Science and Applications for the Middle East	2016	Active
JAM1001	Upgrading the Research Reactor Infrastructure at the University of West Indies, Slowpoke, Facility JM-1	2016	Active
LEB0006	Improving Analytical Capabilities and Technical Performance of the Pelletron Accelerator	2014	Active
LEB0007	Strengthening Nuclear and Related Analytical Technique Capabilities in the Field of Forensic Sciences	2014	Active
LEB0008	Enhancing the Performance and Capacity of the New External Microbeam for the Analysis of Biomedical and Atmospheric Aerosol Samples	2016	Active
LEB0009	Strengthening Capabilities for Sample Analysis of Inorganic Specimens	2016	Active
MOR1010	Developing Utilization of the Triga Mark II Reactor for Applications in Socioeconomic Sectors	2016	Active
NEP0002	Developing Capacity for Nuclear Physics and Nuclear Chemistry Teaching Programmes at Tribhuvan University	2014	Active
NIR7004	Designing and Developing a National Ambient Air Quality Monitoring Network for Potential Mega Cities	2016	Active
PAL0007	Establishing Alquds National Nuclear Physics Laboratory for Training and Research	2014	Active
PAL0008	Building Capacity and Enhancing the Alquds National Nuclear Physics Laboratory for Training and Research	2016	Active
RAF0041	Sharing Best Practices in Preventive Maintenance of Nuclear Equipment (AFRA)	2012	Active
RAF1005	Strengthening the Capacity for Research Reactor Safety and Applications in Africa (AFRA)	2014	Active
RAF7016	Establishing and Improving Air Pollution Monitoring	2016	Active
RAS0076	Investigating Atmospheric Particulate Matter and Pollution Source Contributions in Urban Environments	2016	Active

	Using Nuclear Analytical Techniques (ARASIA)		
RAS7029	Assessing the Impact of Urban Air Particulate Matter on Air Quality (RCA)	2016	Active
RER1015	Apportioning Air Pollution Sources on a Regional Scale	2016	Active
RER1016	Enhancing Utilization and Safety of Research Reactors	2016	Active
RLA0058	Using Nuclear Techniques to Support Conservation and Preservation of Cultural Heritage Objects	2016	Active
RLA1012	Developing a Capacity Building Programme to Ensure Sustainable Operation of Nuclear Research Reactors through Personnel Training (ARCAL CLI)	2016	Active
SIL0007	Re-Establishing a Nuclear Science Laboratory at Fourah Bay College for the Training of All Personnel	2012	Closure In Progress
SUD1007	Sustaining Nuclear Instrumentation Maintenance Capabilities (Medical and Scientific Equipment)	2016	Active
SYR0022	Upgrading the Instrumental and Analytical Capabilities in the Tandem Accelerator	2016	Active
THA0015	Establishing an Accelerator Center for Research and Education	2016	Active
UZB0005	Improving Training Capacity in Nuclear Science at the National University of Uzbekistan (NUU) and the Samarkand State University (SSU)	2016	Active
YEM0004	Improving Nuclear Instrumentation Capability - Phase II	2016	Active
ZAM0007	Establishing Teaching Programmes in Nuclear Science and Technology	2016	Active

Annex 4

Summary of available facilities and techniques at ANSTO

Techique	**Accelerator Facility**	**Accelerator Facility**	**Accelerator Facility**
	Broad beam–STAR (2MV)	**Broad beam–SIRIUS (6MV)**	**Microbeam-SIRIUS (6 MV)**
PIXE	Protons	Protons	Proton & carbon beam
BS	Protons & helium	Protons & helium	Proton & helium beam
PIGE	Protons		
PESA	Protons		
STIM/Off-AXIS			Proton & helium beam
AMS	C-14	Be-10, Cl-36	

Annex 5

Summary of available facilities and techniques at the Tandem Accelerator Laboratory of NCSR "Demokritos"

A short presentation was given about the Institute of Nuclear and Particle Physics, NCSR "Demokritos" emphasizing on the analytical capabilities of the 5.5 MV Tandem van de Graaff accelerator installed there. After the presentation of the accelerator along with its future upgrades, each experimental setup presently installed, was discussed focusing on the experiments that can performed with it. In short, the experimental setups for performing IBA techniques (RBS, NRA, PIXE and PIGE) with a milli-beam, as well as, the micro-beam setup. For each of the aforementioned techniques examples of previous experiments were presented. Regarding the basic research program of the laboratory, the working principle of the existing 4pi – summing crystal and the BGO ball was demonstrated, as well as, their use in measuring capture reaction cross sections relevant to Nuclear Astrophysics. In the same scope, the setup for measuring gamma-ray angular distributions and the one for particle induced differential cross sections were discussed. Finally, the capability of producing quasi monoenergetic neutron beams through various proton and deuteron induced reactions was presented. The presentation closed with the presentation of the newly installed 250kV electrostatic accelerator – PAPAP.

The 5.5 MV Tandem laboratory can provide the following analytical techniques:

SETUP	Technique
μ-beam	PIXE, off-axis STIM, RBS, NRA
IBA chamber	RBS, NRA, PIGE
PIXE chamber	PIXE
4π γ – summing crystal (14inch x 14inch NaI(Tl)	Resonant PIGE for Hydrogen profiling
γ – angular distribution array	PIGE

Techique	Beams	Energies (MeV)	Intensity
RBS	p, d, ^{12}C, ^{16}O	1 – 6	3 – 30 nA
NRA	p. d	1 – 6	3 – 30 nA
PIXE	p	1 – 3	3 – 30 nA
PIGE	P, ^{19}F	1 – 3	10 – 50 nA
μ - PIXE	p	1 – 3	10 – 100 pA
Off – axis STIM	p	1 – 3	10 pA

Annex 6
Summary of available facilities and techniques at LAEC-CNRS

The Lebanese ion beam analysis facility consists of a 5 SDH Tandem Pelletron from NEC of 1.7 MV. It was installed in 1999 through a national IAEA-TC project and was upgrading within the TC program over the years. The actual status contains a working alphatross ion source capable to deliver mainly protons and alpha-particles beam that are accelerated to energies as high as 3.4 MeV for protons and up to 5.1 MeV for alpha. Several ion beam analysis techniques are developed and performed such as PIXE, PIGE and RBS for different applications in cultural heritage, environment and materials science. For now, the measurements are done under vacuum in a scattering chamber containing 3 detectors (SDD for X-rays, HPGe for gamma rays and a PIPS detector for elastic backscattering spectroscopy). The novelty is the installation of a new external microbeam having the possibility of imaging too. This new setup is still under preparation that can be ended by the installation of a dual ion source comprising a duoplasmatron beside the actual one, the Alphatross (IAEA-TC LEB0008). An overview of the latest technical progress and the different applications that are developed till now in the accelerator lab are shown. The collaboration aspect is also shown either locally with researchers from Lebanese universities or at the regional level such as the collaborative IAEA RAS0076 project on the analysis of atmospheric particulate matter, knowing that, since ten years, we are leading all the regional activities pertinent to the applications of accelerators in ARASIA region.

IBA Technique	Ion type	Energy	Current Intensity	Spectra treatment
PIXE	proton	300-3400 keV	0.5-200 nA	GUPIXWIN
PIGE	proton	Up to 3.4 MeV	Up to 200 nA	Spectr
RBS-EBS	Alphas and protons	Up to 5.1 MeV (α) Up to 3.4 MeV (p)	Up to 30 nA (α)	SIMNRA
μ-PIXE (available by the end of 2018)				