Consultancy Meeting on

Preparation of the Coordinated Research Project on Facilitating Access to Ion Beam Accelerators

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Summary Report

Consultancy Report Prepared By

Mr. Efraín Chávez, UNAM, MEXICO
Mr. Milko Jakšić, LIBI/RBI, CROATIA ***(Chairman)***
Mr. Pawan Kumar Kulriya, IUAC, INDIA (***Rapporteur***)
Mr. Carlos Pineda-Vargas, iThemba LABS, SOUTH AFRICA
Mr. Manfredo Harri Tabacniks, LAMFI/USP, BRAZIL
Mr. Natko Skukan, NSIL, IAEA-NA ***(Convener)***
Mr. Iain Darby, Lab Head, NSIL, IAEA-NA
Mr. Sotirios Charisopoulos, Physics Section, IAEA-NA
Mr. Danas Ridikas, Head Physics Section, IAEA-NA

Executive summary

Objectives

This Consultancy Meeting aimed to discuss:

- The framework and structure as well as the implementation modalities of the new CRP on “Facilitating Access to Ion Beam Accelerators”
- The prerequisites for awarding Technical or Research Contracts or Research Agreements to facilities interested in providing ion-beam access, referred to as the beam providers, as well as the relevant selection process.
- The scientific criteria as well as the timelines for the selection of the researchers from IAEA Member States, referred to as the end-users, interested in performing experiments at the beam-provider facilities or receiving analytical services from the beam providers.
- The worldwide established best practices in providing access to beam-time, the specific procedures applied for the approval of experiments at the facilities represented in the meeting and the timelines between submission of beam-time access requests and the performance of the experiments.

Expected Outputs

The expected outputs of the Consultancy Meeting are:

- Draft structure and implementation modalities of the forthcoming CRP
- Conclusions and recommendations on the other objectives mentioned above

Conclusions

1) The planned Coordinated Research Projects (CRP) is fully in line with the mission of IAEA in strengthening their capacity to adopt and benefit from the usage of accelerators.
2) The CRP will decisively facilitate access to advance ion-beam analytical facilities to Member States without such capabilities. This will create substantial linkages between new users, experienced research communities, and state-of-the-art facilities.
3) Within the course of the proposed CPR, technical contracts (TC) may be awarded to the institutes hosting and operating ion-beam facilities, whereas research contracts (RC) or research agreements (RA) may be awarded to the end-users.
4) The CRP should be open to new researchers from IAEA Member States during its course, so that as many as possible end-users will benefit from the use of accelerators. In this context, the option of granting RC per year should be considered. The award of a RC should be related to an approved and scheduled experiment at an ion-beam provider.
5) There is strong need for hands-on training in addition to theoretical knowledge for the success of the proposed CRP. Therefore, institutes hosting and operating ion-beam facilities participating in the CRP shall be encouraged to plan training activities, such as workshops or schools related to Ion Beam Analysis (IBA) techniques.

6) As per the discussion in both consultancy meetings, eight ion-beam providers are willing to offer their facilities for the needs of the CRP. In addition to these facilities additional ion-beam providers may participate in the CRP. The selection of ion-beam providers should be completed in the CRP's first phase (see in Recommendations below).
7) As per the discussion in both consultancy meetings, the Accelerator Knowledge Portal is a very useful tool for researchers from IAEA Member States. In the case of the planned CRP the Portal is of special importance as it will assist a lot the tentative end-users to search for nearby beam providers and receive detailed information on the available techniques.
8) The Consultants of the meeting should check and update the data relevant to their country that are listed in the Accelerator Knowledge Portal. In addition, the latter should be advertised by inserting a special entry in the websites of their institutions with a proper link.
9) The planned CRP should be advertised in major ion beam conferences to attract the interest of a large number of tentative end-users.
10) The IAEA logo may be displayed at the site of the facilities providing ion-beam access and participating in the CRP.

Recommendations

The following recommendations are made to the IAEA:

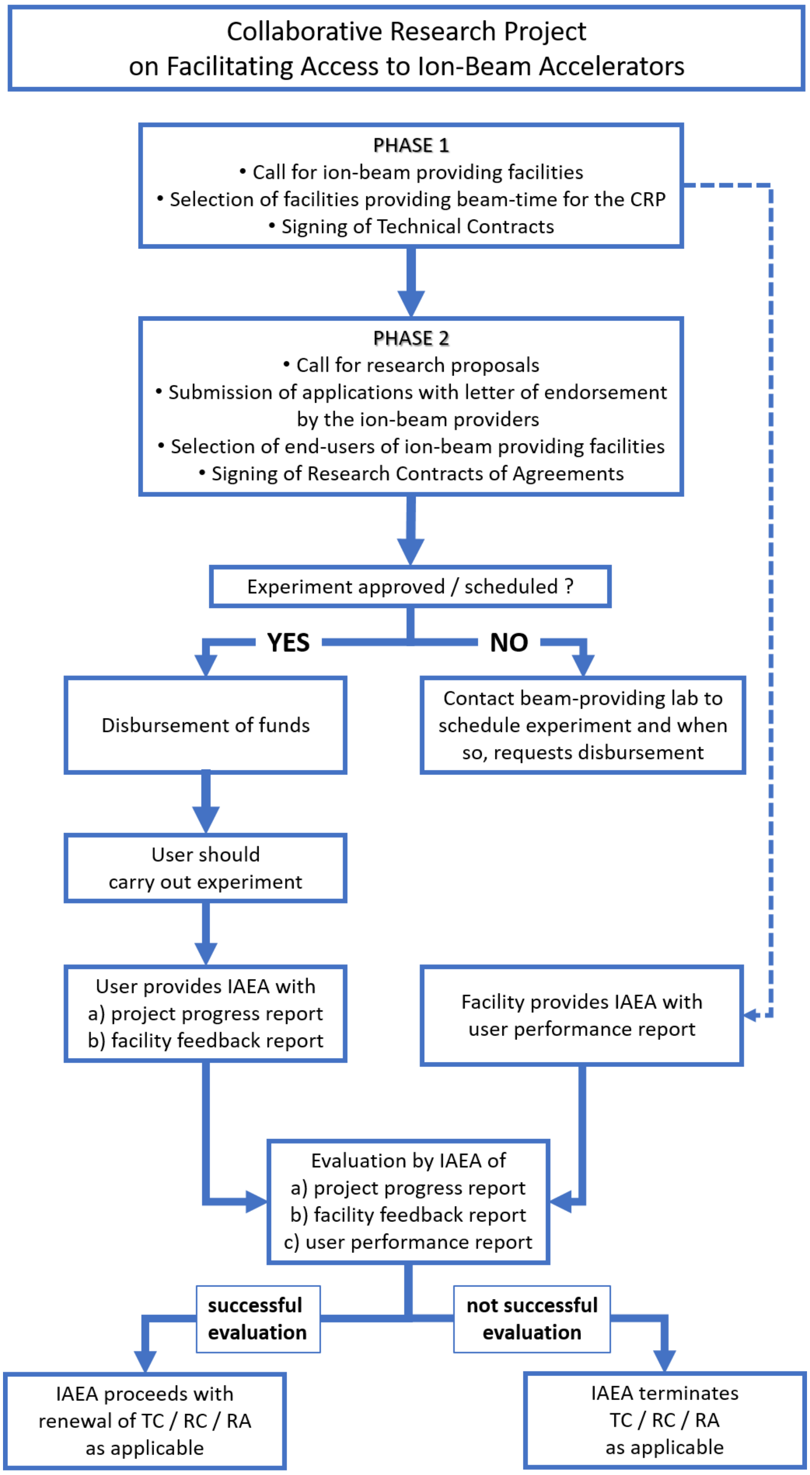
1) To proceed with the organization of the planned CRP as soon as possible.
2) The CRP should be implemented in two phases:
   Phase 1: IAEA should select the facilities that will provide access to users. It is recommended that the selected facilities should be properly distributed geographically to best facilitate access to users from different continents.
   Phase 2: IAEA selects the users, according to CRP rules.
3) The selected facilities should offer beam time and instrumentation for Ion Beam Applications in:
   - Cultural Heritage
   - Environmental monitoring and climate change
   - Earth sciences
   - Biosciences - Human health
   - Materials characterization and modification
   - Material studies for fusion energy
4) The techniques of interest for the CRP should, among others, include:
   - Particle Induced X-ray Emission (PIXE)
   - Particle Induced Gamma-ray Emission (PIGE)
   - Rutherford 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)
- Ion Beam Luminescence (IBIL)
- MeV ion beam modification (implantation and irradiation)

5) The laboratories to be selected should provide IAEA in a template form, agreed in advance with:
   - A proper description of their experimental facilities, including at least
     - The available ion beam techniques that can be offered to users of the CRP
     - Information on auxiliary facilities, such as sample preparation, accommodation possibilities, etc.
     - Human resources that will assist users in
       - ✓ Performing experimental work, such as sample preparation, running experiments, data processing, etc.
       - ✓ Organizing their travel, accommodation, visa etc.
       - ✓ Any other resources to be assigned to CRP users
   - Conditions to approve user proposals, such as selection by a Program Advisory Committee, etc.
   - Responsible contact person for the users.
   - An updated website of the facility
   - Capability / experience to host hands-on training courses
6) If selected, the beam proving laboratories should sign a technical contract (TC).
7) For the selection of the users, following aspects should be considered:
   - Users from MSs without accelerator facilities are particularly encouraged to apply.
   - Before submission of any research proposal to IAEA, interested end-users should first contact the laboratory of their interest to discuss the science case and technical feasibility. This requires that the beam providers must already be identified in the CRP call.
   - A RC applicant may be required to justify the selection of the facility based on geographical and technical criteria.
   - In the application for a Research Contract, the applicant should include a letter of endorsement of his research project from the proposed facility signed by the Designated Authority. IAEA will draft the template of the endorsement letter.
   - In case of project approval by IAEA, it is suggested that the transfer of funds to the beneficiary is conditioned to the approval / scheduling of the experiment.
11) The potential for subsequent collaborations, between the end-user(s) and the corresponding beam-providing laboratory should also be considered during the selection of the applications for research contracts.
12) The performance indicators of the CRP shall be:
   a) Number of new users within the CRP
   b) Amount of beam time allocated in experiment to CRP users
   c) Papers submitted for publication

d) Papers presented
e) Data in theses
f) Outreach events
g) User/Facility feedback and satisfaction

13) The beam-providing laboratories will also make a user template form of the facility.
14) Following flow diagram is proposed as guidance for the CRP



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1. Introduction

Ion Beam Analytical (IBA) Techniques have proved to be a very useful tool in different areas of applied science. The availability of these techniques depends on the accessibility of accelerator facilities in Member States (MS) and, especially in developing MS, these are not widespread. To broaden availability of these techniques and consequently increase the number of scientists in developing MS interested in IBA, a new Coordinated Research Project (CRP) is planned to facilitate access to IBA techniques and allocation of beam time for researchers who do not have the possibility of applying and using them in their countries.

The Consultancy Meeting was organized to gather representatives of five accelerator facilities worldwide who previously expressed their willingness to participate in the planned CRP "Facilitating Experiments with Ion Beam Accelerators", some of them having already a Collaboration Agreement with the Agency, e.g. the RBI-Croatia.

Together with three presented facilities from the previous Consultancy Meeting F1-CS-1700003, these new institutions expect to form a core of beam providers for the forthcoming CRP.

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- The scientific criteria as well as the timelines for the selection of the researchers from IAEA Member States, referred to as the end-users, interested in performing experiments at the beam-provider facilities or receiving analytical services from the beam providers.
- The worldwide established best practices in providing access to beam-time, the specific procedures applied for the approval of experiments at the facilities represented in the meeting and the timelines between submission of beam-time access requests and the performance of the experiments.

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2. Accelerators for material analysis: their use and social impact

Accelerator based activities are associated with a broad range of applications having social and technological impact in the development of MSs. The use of accelerators enhances innovation in a variety of fields such as health, material sciences, culture, environment, energy and natural resources. In addition, education and training in advanced technologies are also incorporated and the development of highly specialized technical skills is decisively enhanced through activities based on the use of accelerator instrumentations.

Although IAEA developing MSs recognize accelerator technologies as a key element to promote social and economic development, many of them face difficulties to allocate the funds required for the acquisition, installation and effective operation of accelerator facilities and subsequent operational costs. As a result, researchers from these MSs often have no opportunities to employ accelerator based techniques, or their access to accelerator facilities is limited.

The IAEA has responded to MSs needs by implementing programmatic activities that provide information exchange forums on new trends and applications in accelerator based technology. In this context, IAEA's Physics Section organized several Technical Meetings and successfully implemented CRPs in recent years devoted to the utilization of accelerators for research applications. Moreover, several international conferences, workshops and schools have received financial support from the IAEA within cooperation agreements that allowed participation of researchers from IAEA developing MS. IAEA has also contributed to the development of an experimental end-station at the Ruđer Bošković Institute (RBI) in Zagreb, Croatia. The end-station is available for Ion Beam Analysis (IBA) techniques to scientists from IAEA MSs for four weeks per year.

To disseminate information worldwide on the operation of accelerator research facilities in the IAEA MSs, the Physics Section has established the Accelerator Knowledge Portal in the IAEA website [https://nucleus.iaea.org/sites/accelerators/Pages/default.aspx], providing a database of ion beam accelerators, neutron spallation and synchrotron light sources together with a description of their basic facilities. In parallel, the Nuclear Science and Instrumentation Laboratory (NSIL) of the Physics Section has continuously supported the IAEA MSs in the effective operation and maintenance of instrumentation appropriate for their activities.

Within the IAEA's technical cooperation program, many TC projects have been recently implemented to foster the introduction of accelerator techniques. Within these projects, the staff of the Physics Section at HQ and NSIL at Seibersdorf provided training to researchers from IAEA developing MSs in specific accelerator based techniques and associated technologies. Strong interest in creating and strengthening regional networks allowing the access and common use of synchrotron and particle accelerator facilities have also been expressed by MSs (see, e.g., SESAME [http://www.sesame.org.jo/sesame_2018/]).

Throughout these projects, NSIL identified the need to provide access to accelerator facilities to researchers of MSs not having opportunities to benefit from unique research capabilities of certain accelerator based analytical techniques. An ongoing CRP has provided access to the

IAEA Xspe end-station at the Elettra synchrotron facility[1] in Trieste, Italy to 18 research teams since 2014.

Particle accelerator based techniques, such as Particle Induced X-ray and gamma-rays Emission (PIXE/PIGE), Rutherford Backscattering Spectrometry (RBS), Nuclear Reaction Analysis (NRA), Energy Recoil Detection Analysis (ERDA), Accelerator Mass Spectrometry (AMS) and other complementary methods are of great interest to MSs, particularly developing MSs and this is the subject of the present Consultancy Meeting on the establishment of a new Coordinated Research Project on "Facilitating Experiments with Ion Beam Accelerators ".

3. Summary of Presented Accelerator Facilities and Available Analytical Techniques

During the Consultancy Meeting, the consultants presented their facilities, equipment and associated analytical techniques with special accent on IBA techniques and AMS, the fields expected to be included within the planned CRP. Table 3 summarizes the basic technical specifications of the presented facilities and available analytical techniques:

Table 3: Basic technical specifications of the accelerator facilities presented:

S. No.	Name of organization	Technical specifications of operating accelerators	Analytical techniques offered
3.1	Laboratory for Material Analysis using Ion Beams. Institute of Physics, University of Sao Paulo, Brazil	1.7 MV 5SDH Tandem Pelletron	• RBS, NRA, PIGE, PIXE, ERDA, IBIL with high precision charge collection • External Mili-beam- Large area, high precision XYZ computerized table • Provider of Multi-SIMNRA software
3.2	Laboratory for Ion Beam Interactions Department of Experimental Physics, Institute Ruđer Bošković, Zagreb, Croatia	6 MV electrostatic (Tandem) 1 MV Tandetron	• PIXE, PIGE, RBS, NRA, WDX PIXE • RBS channeling • TOF ERDA • IBIC, STIM, IL • Micro beam available • Dual beam irradiation
3.3	Inter-University Accelerator Centre, New Delhi, India	16 MV Pelletron 1.7 MV Pelletron 300 kV Positive Ion implanter 100 kV Negative Ion implanter	• RBS for depth profiling • ERDA for Hydrogen concentration monitoring • Ion Implanters/ irradiation

[1] https://www.elettra.trieste.it/lightsources/elettra/elettra-beamlines/microfluorescence/x-ray-fluorescence.html

3.4	Instituto de Física, Departamento de Física Nuclear Aplicaciones de la Radiación, Universidad Nacional Autónoma de México (UNAM), Mexico	1 MV tandem accelerator 4 MV CN Van de Graaff Accelerator	• PIXE / PIGE • EBS • ERDA • NRA • AMS • RBS
3.5	Materials Research Department & Tandem AMS Department, iThemba LABS, National Research Foundation, Cape Town, South Africa	3 MV Tandetron 6 MV EN Van de Graaff accelerator	• PIXE • RBS/ERDA • *IN-SITU* REAL TIME RBS • MICRO-PIXE • MICRO-RBS • NUCLEAR REACTIONS • HI-ERDA TOF • AMS

3.1 The Laboratory for Material Analysis with Ion Beams Lamfi-USP, Sao Paulo, Brazil

The Laboratory: The LAMFI-USP (Laboratório de Análise de Materiais por Feixe Iônico) of the University of São Paulo in Brazil (www.if.usp.br/lamfi) was created in 1992 aiming the at development and applications of ion beam techniques for the analysis of air pollution samples, environmental samples, semiconductors and thin films in general, and more recently, for the analysis of cultural and archaeological objects. It comprises an 1.7MV 5SDH Pelletron accelerator and three analytical setups: an in vacuum Ion Beam Analysis (RBS, PIXE, ERDA, NRA) eventually under channeling conditions, an in vacuum PIXE analysis optimized for aerosol samples, and an external beam setup for in air PIXE, IBL, NRA and RBS analysis, coupled to a large area, 3 axis (60 cm each), high precision (± 5 μm) computer controlled robotic table. Since 2016, LAMFI provides worldwide access to the Multi-SIMNRA computer software (http://deuterio.if.usp.br /multisimnra/) for accurate elemental depth profiling using Ion Beam methods. Since 1997 LAMFI does an average of 3000 PIXE/RBS analysis a year, mostly for academic use.

The accelerator: The 1.7MV NEC 5SDH tandem Pelletron accelerator uses two ion sources, an RF Alphatross with an Rb charge exchange cell, mostly for He beams, and a SNICS II for H, Li, C, O, Si and heavier beams. Data acquisition is made using standard NIM modules, Maestro© software and Labview© interfaces. All spectra are internet accessible including some accelerator parameters, recorded for each spectrum and used for quality control (http://deuterio.if.usp.br/, user:usuario, psw:iflamfi). Table 3.1.1 summarizes ion beam energies and beam currents available at the LAMFI.
Typical Samples: Typical sample size for the RBS/ERDA setup are 1x1 cm^2 and up to 3mm thick. The PIXE setup uses 1” diameter x 2mm thick disks. The external beam setup accepts samples of any kind and any size.

Analytical setups

Fig. 1. In-vacuum RBS setup with two detectors and charge shields

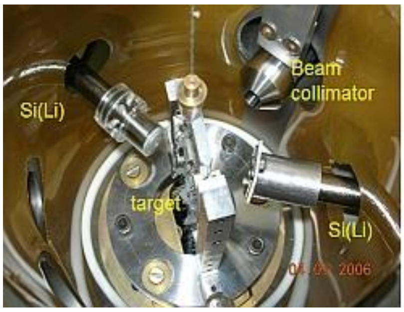


Fig. 2 PIXE setup at LAMFI

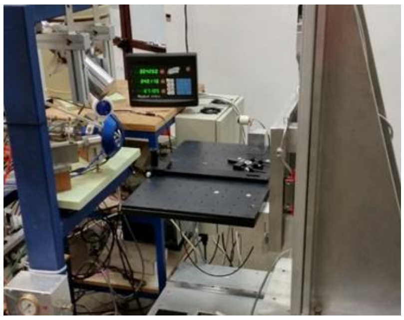


Fig. 3. External beam setup and the robotic table

Figures 1-3 show the three analytical setups of LAMFI. The RBS-FRS station is a standard NEC high vacuum chamber (43cm ID and 15cm high) with a 5 DF computer controlled goniometer. Beam charge integration is better than 0.8%. The PIXE station in Fig. 2, is a homemade chamber (15cm ID, 25cm high), in use since 1976, for the analysis of air pollution on nuclepore filters. The PIXE setup uses two Si(Li) detectors and a computer controlled linear target holder for 18 samples. Charge integration is better than 1%. The sub-millimeter external beam setup can collimate the beam to 0.1 – 1 mm diameter through a thin Al exit window. The robotic table can position large samples up to 60 cm in any direction with a precision of 5 µm. An automated computer vision controls the focal point to ±50 µm for accurate PIXE analysis. Quantitative calibration is performed using standard samples verified by Robin-Round experiments. A comprehensive uncertainty budget of the accelerator parameters and the RBS setup has been done recently (Phys. Rev. A 93, 022704, 2016). Details of the basic setups and analytical techniques available at the LAMFI are provided in Table 3.1.2.

Table 3.1.1 Ion Beam energies and beam currents available at the LAMFI

	Beams	**Energies (MeV)**	**Intensity**
LAMFI	H^+, He^+	0.7 – 3.4	typical up to 30 nA
LAMFI	He^{++}	1– 5.4	typical up to 20 nA
LAMFI	Heavy ion	case by case.	
Ext Beam	H^+	1 – 3	typical up to 10 nA.

Table 3.1.2 Basic Setups, Analytical Techniques available at the LAMFI

Setups	**Techniques**
External Mili-beam	Large area, high precision XYZ computerized table (60cm ± 5µm for each axis). Beam diameter can be set between 0.1 – 1mm. Automatic focus control to ±50 µm. PIXE, RBS (with limited resolution), NRA, IBIL, micro-height optical scan.

IBA	RBS, NRA, PIGE, PIXE, ERDA. High precision charge collection ± 0.8% Beam collimation from 0.1 to 3mm
PIXE	PIXE (two detectors) optimized for the analysis of thin nuclepore/mylar filters.
Multi-SIMNRA	Worldwide provider and support of Multi-SIMNRA, especially for precise ion beam depth profiling.

3.2 Laboratory for Ion Beam Interactions, Department of Experimental Physics, Institute Ruđer Bošković (RBI), Zagreb, Croatia

The RBI accelerator facility consists of two accelerators, 1.0 and 6.0 MV tandem accelerators (HVEC EN Tandem Van de Graaff and 1.0 MV HVE Tandetron) and 8 beam lines. Small (Tandetron) accelerator is equipped with direct extraction duoplasmatron source (typically H, D and O negative ions) and sputtering ion source used for other ions (typically Li, C, and Si, but also almost all other from the periodic table). Large accelerator (EN) has three ion sources, namely RF source with charge exchange for He^- ions, multi-cathode sputtering ion source for large variety of ion species (H, Li, B, C, O, Si, Cl, Cu, Br, Au, etc.) and finally home built sputtering source for rare beams including short lived radioactive beams. The machines are fully operated through in house built digital control system, which allows us easy implementation of changes.

The main advantage of the RBI accelerator facility over similar facilities can be identified only by its unique features at the following beam lines:

- Heavy ion microprobe – with a possibility to focus ion beams up to 15 MeV ME/q^2 minimum spot size of only 250 nm, and numerous available techniques (PIXE, ERDA, RBS, IL, SEI, STIM and STIM tomography, MeV SIMS, IBIC, etc.) is one of the most utilized microprobe facilities in Europe. Significant part of time is being used for IBIC and TCT tests of novel detector structures (e.g. 3D diamond detectors for future high energy physics experiments). In addition to team members, 11 foreign groups have used microprobe beam line in 2012.
- ToF ERDA – beam line has been constructed in house and is one of only few such facilities worldwide. It is workhorse for materials science applications (near surface depth profiling and elemental composition) used in 2012 by 9 foreign groups. Increased usage of the TOF ERDA line is expected in the field of fusion related materials' research.
- Dual beam irradiation chamber for fusion materials (DiFu): It is a new development at the RBI, which uses the fact that two accelerators can deliver ion beam to the same sample simultaneously. Irradiation by two beams simulates conditions found of fusion reactors.
- Joint IAEA-RBI investment into the dual micro-beam chamber: Presently this beam line is equipped with a homemade triplet quadrupole micro-beam (with ion beams

delivered by the Tandetron accelerator and collimated beam from Tandem Van de Graaff accelerator. It is also equipped with a goniometer for channeling experiments using RBS and PIXE. The development of this beam line is supported through a IAEA-RBI beam line agreement

Other routine scattering chambers include:

- Nuclear reactions chamber capable for use with solid and gas targets and use of many position sensitive silicon detectors, as well as neutron and gamma triggering capability. Nuclear physics group owns state of the art position sensitive silicon detector array built from strip detectors of different geometry and thickness and capable for particle identification in wide mass and energy range, as well as associated electronics and DAQ system.
- Two HR-PIXE crystal spectrometers are dedicated to studies of chemical effects in X-ray spectra. The broad ion beam system uses proportional counter. The ion micro-beam system with CCD x-ray sensor in unique compact (downsized) layout of the WDX spectrometer has capability to analyze samples as small as 10 micrometers.
- PIXE/RBS/PIGE chamber for routine applications
- External beam (in air) PIXE coupled with XRF system has enhanced sensitivity for detection of heavy elements in particular importance for cultural heritage samples. XYZ stage has capability to image elemental distributions in several cm scan sizes.

Details information about the technical capabilities of the accelerators and ion beam analysis techniques are given in the tables 3.2.1, 3.2.1, and 3.2.1.

Table 3.2.1 Beam lines of the RBI accelerator laboratory that could accept ion beams from both 1.0 and 2.0 MV tandem accelerators and that can be used for ion beam analysis and/or materials modification:

BEAM LINE	Technique
μ-beam	PIXE, RBS, NRA, IBIC, STIM, IL
HR PIXE chamber	PIXE with WDX spectrometer
TOF ERDA	TOF ERDA
Dual beam line	Irradiation with beams from both tandem accelerators
Dual microbeam	PIXE and RBS channeling, μ-PIXE imaging

Table 3.2.2 Beam lines of the RBI accelerator laboratory that could accept ion beams from 1.0 tandem accelerator

BEAM LINE	Technique
In air beamline	PIXE analysis with 1 mm collimated beam
Routine IBA	PIXE (low and high energy region), RBS, PESA with 3 to 8 mm collimated beam

Table 3.2.3 Typical ion beams that can be delivered by 1.0 and 6.0 MV tandem accelerators

	Beams	Energies (MeV)	Intensity (nA)
1.0 Tandetron	Protons	0.2 – 2	1 – 1000
	Li	0.5 – 4	1 – 100
	C	0.5 – 5	1 – 500
	Si	0.5 – 6	1 – 100
6.0 MV Tandem	Protons	1-10	1 – 500
	He, Li	0.5 – 6	1 – 100
	C, Si	1 – 20	1 – 500
	Cl, I	1 – 30	1 – 100
Microbeams	Ions as above	Max. rigidity - 10 MeV (ME/q^2)	0.1 fA – 1 nA

3.3 Inter-University Accelerator Centre (IUAC) New Delhi, India

The basic objective of the Inter-University Accelerator Centre (IUAC) New Delhi is to provide front ranking accelerator based research facilities to Indian researchers from universities, institutes, and national laboratories as well as international users from academia and government funded research laboratories. IUAC has been playing a very special role of a research institute within the university system where the scientific and technical staff has dual responsibilities of facilitating research for a large user community as well as conducting their own research. The centre is equipped with sophisticated accelerator systems and experimental facilities for carrying out research in the areas of Nuclear Physics, Materials Science, Atomic Physics, Radiation Physics and Accelerator Mass Spectrometry.

The accelerator facilities at IUAC includes a Pelletron (16 MV NEC Pelletron) with seven beamlines and a SNICS ion source; A Superconducting LINAC accelerator (2005, designed initially in collaboration with ANL, USA) with four beamlines, positive and negative ion implanters, as well as Rutherford backscattering spectrometer (2013, 1.7 MV NEC Pelletron)

The Pelletron accelerator system provides high-energy (a few hundred of MeV)/current (few particle nanoampere) positive ions beams of stable elements by stripping electrons from negative ions of most elements in the periodic table (from H to Pb) using the multi cathode source of negative ion using Cesium sputtering (SNICS) source. In the materials science beamline, accelerated beams of positive ions can be utilized for surface modification of materials, depth profiling of lighter element using elastic recoil detection for mass spectrometric analysis (ERDA), analysis of residual gases using an online residual gas analysis-quadruple mass analysis (RGA-QMA), and online electrical transport measurement of the semiconductor devices. The majority of the beamline systems including end-stations and associated equipment were designed in-house and assembled from commercial or in-house produced components using local expertise.

The Pelletron beam is further boosted using a niobium quarter wave resonator based superconducting LINAC accelerator. The materials science beamline in the LINAC accelerator is equipped with state of art in-situ facilities namely in-situ Micro-Raman spectroscopy, in-situ X-ray diffractometer (XRD), and in-situ high temperature irradiation facility. These facilities can be used to investigate the short range as well as long range ordering of the materials on exposure to swift heavy ion irradiation. Technical capabilities of the ion beam facilities at IUAC is given in Table 3.3.1.

The low energy 1.7 MV Pelletron ion accelerator is used for ion implantation from tens to hundreds of keV/amu. The accelerator can be used for the RBS, channeling and ERDA analysis.

Table 3.3.1: IUAC capabilities on offer for proposed CRP project

Capabilities of IUAC	Ion Beam	In-situ/online Facilities
16 MV Pelletron	50 MeV Li^+, 80-100 MeV O^+ & Si^+, 100-200 Ag^+ & Au^+	ERDA, RGA-QMA
Positive Ion implanter	500 keV He^+, ~ 1 MeV Ar^+, 1-3 MeV Kr^+ & Xe^+	
Negative Ion implanter	Metal Ions (Pd, Ag, Au) of ~100 keV	
1.7 MV Pelletron	1.7 MeV He^+	RBS, ERDA

3.4 Instituto de Física, Departamento de Física Nuclear Aplicaciones de la Radiación, Universidad Nacional Autónoma de México (UNAM), Mexico

The Institute of Physics, which is part of the National Autonomous University of Mexico (IFUNAM), owns the only AMS facility in the country with a 1 MV tandem accelerator (LEMA). It has the responsibility of providing AMS services to fulfill the national needs in radioisotope concentration characterization. Its main activity deals with $^{14}C/^{12}C$ measurements, but $^{10}Be/^{9}Be$, $^{26}Al/^{27}Al$ and actinides are also measured. A new beam line extension has been installed (2017) that makes LEMA a hybrid facility, since now besides the routine AMS activities, time is available for some IBA work.
IBA work is mainly carried out on a 5.5 CN-Van de Graaff accelerator which provides light ion beams at energies below 4 MeV. Elastic-Back Scattering (EBS), Particle Induced X-ray Emission (PIXE), Nuclear Reaction Analysis (NRA), Energy Recoil Detection Analysis (ERDA) are the analytical techniques normally used (see table 3.4.1).

Table 3.4.1: IFUNAM capabilities on offer for proposed CRP project

Technique	LEMA	CN Van de Graaff
PIXE	Protons (2 MeV)	Protons, deuterons, alphas
EBS	Protons and $^{12,13}C$ (2-5 MeV)	Protons, deuterons, alphas
ERDA	$^{12,13}C$ (2-5 MeV)	Alphas
NRA	Protons (2 MeV)	Protons, deuterons, alphas
AMS	$^{14}C/^{12}C$, $^{10}Be/^{9}Be$, $^{26}Al/^{27}Al$, actinides.	

More information can be found in the web-pages of these laboratories:
For LEMA: http://laboratorios.fisica.unam.mx/home?id=11
The Van de Graaff: http://laboratorios.fisica.unam.mx/home?id=13

3.5 The Materials Research Department (MRD) at iThemba LABS, Faure, Cape Town

The Materials Research Department (MRD) at iThemba LABS, Faure, Cape Town provides Ion Beam Analysis (IBA) capabilities for South African researchers including an extensive array of national and international users from academia, publicly-funded research institutions, industry and government. Also provides key infrastructure for supporting activities of different groups working in wide fields of research by research scientists and Post-graduates from African countries and international groups form developed MS countries. It also provides training across a broad range of disciplines and technologies related to materials research, including the use of ion beams for surface characterization. This infrastructure may be suitable to create collaboration agreements with international institutions including the IAEA.

At the end of 2015 the MRD decommissioned the 50-years CN 5.5 MV Van de Graaff accelerator and purchased a new state-of-the-art 3MV Tandetron that was commissioned recently. The new accelerator will provide high stability, low ripple frequencies to continue with our successful Nuclear Microprobe work that has facilitated research of high impact micro-PIXE, micro-RBS for a wide community of South African, African and international researches.

The 3 MV Tandetron accelerator was acquired with two multicusp ion sources: one for protons and a second one for He-ion beams. These two ion sources produced negative ions of high charge (700 eμA for protons and 30 eμA for He). Another cesium sputter source for heavy ions was purchased that will provide high-energy (MeV)/current (μA) beams of negative ions of stable elements (from H to Pb). After tandem acceleration beams of positive ions with different Mass/Energy configuration can be utilized for Heavy Ion ERDA ToF spectrometry, X-ray production cross section in transition metals with Heavy Ions as well as materials implantation and modifications. Initially the two most used beam lines: NMP and RBS/ERDA will be re-implemented for nuclear microscopy and broad beam material analysis and modification

A second 6 MV EN Tandem accelerator located at the Tandem Accelerator Mass Spectrometry (TAMS) Department in Johannesburg has beam refurbished and digitalized. This accelerator commissioned in 1965 is being used for low energy nuclear physics and ion beam analysis. Typicaly is fitted with three beam lines: one used for low energy nuclear reaction for nuclear physics research, a second one dedicated to the Nuclear Microprobe for materials characterization and a third beam line that has been used since 2011 for Heavy Ion ERDA ToF spectrometry. The accelerator was further developed recently to house an AMS facility for radiocarbon age determination in paleontology, archaeology and geology including environmental studies. The ion source for AMS was funded by IAEA, mass spectrometer and detectors were also implemented. The AMS facility is operational for the determination of traces of C-14 for radiocarbon characterization. A laboratory for preparation of samples for AMS C-14 analysis was also commissioned and is available for users to prepared highly precise required sample-targets for studies by AMS. A summary of the techniques available in each accelerator is presented in Table 3.5.1

Table 3.5.1: iThemba LABS capabilities on offer for proposed CRP project

Acc. Anal.	**Tandetron (3MV)**	**EN Tandem (6MV)**
PIXE	Protons, Heavy Ions	Protons
BS	Protons & helium	Protons & helium
PIGE	Protons	
RBS/ERDA	Helium	Helium
In situ RT RBS	Helium	
Micro-PIXE	Protons	Protons, helium
Micro-RBS	Protons, helium	Protons, helium
Nuclear		Different light ions
HI-ERDA ToF		Heavy Ions up to Cu^{+7}
AMS		C-14

4. Proposed procedures for the selection of ion-beam facilities and users

For the subsequent discussion following definitions are used:

Beam Provider: A laboratory with accelerator based techniques willing to allocate for the needs of the CRP, resources and beam time to external users, possibly dependent on PAC's approval. The beam provider shall be selected by IAEA based on certain criteria.

End-User: A person or principal investigator from a MS, willing to use the facilities of the beam-provider for his/her research defined in a scientific project. The end-user submits a research proposal to IAEA, within the call of the CRP and is selected by IAEA based on certain criteria

4.1. Selection of Beam Providers

Providers are expected to be well established ion beam laboratories with long term experience on accelerator based analytical techniques such as ion beam analysis (IBA) and/or Accelerator Mass Spectrometry (AMS) and associated techniques. Beam Providers need to have experience in assisting external or unskilled users willing to use accelerator techniques for the analysis of their samples. Unskilled user can be a scientist or a researcher from any scientific discipline, not necessarily familiar with accelerator techniques, but willing to boost his/her research by producing and benefiting of data resulting from ion beam analysis.

A Beam Provider will have to provide with at least:

a) A comprehensive web-based homepage in English language describing its facilities, localization, addresses, contact media (e-mails, telephones, etc.), scientific and technical staff, scientific committee, user's committee (if existing), available accelerator techniques and their specifications, facilities for sample preparation, application forms for beam (or laboratory) time, PAC rules (if necessary), application examples, links to tutorials and explanations, list of published papers, practical examples, etc.
b) A contact person able to discuss technical details on a new user's experiment and able to help the user in preparing a PAC application or submitting a beam time request.
c) Available beam time for each technique and a calendar of its availability together with a yearly plan for beam time allocated to the CRP.
d) Advise and practical assistance, if possible with proper links, for housing and/or accommodation, local transportation and assistance with MS immigration regulations.

Beam Providers will be selected and identified by IAEA after applying to a call of the CRP on *Facilitating Experiments with Ion Beam Accelerators to all MSs,* considering:

a) The location pertaining to the regional accessibility to Accelerator-based analytical techniques to researchers from Member States not having easy access to such capabilities
b) Available techniques
c) Experience in assisting external users in the use of Accelerator Techniques for Material Analysis
d) The beam time as well as allocated to the CRP. The use of supporting facilities, such as target fabrication or preparation labs, should also be considered.
e) Willingness or experience in providing training courses or workshops on accelerator-based analytical techniques with emphasis on Material Analysis

4.2. Selection of End-Users

End-Users will be selected in a second phase following the selection of beam providers. End-Users from Member States without accelerator facilities are particularly encouraged to apply for a Research Contract or a Research Agreement. Depending on their research interests and affiliation they may be required to justify the selection of the beam provider's facility based on geographical and technical criteria. In this context, the applicant should justify the selected accelerator-based technique to solve the scientific problem addressed in his/her research proposal. Alternative techniques should also be mentioned and commented.

Applications for an IAEA Research Contracts within the CRP in consideration should be accompanied by a letter of endorsement signed by the Designated Authority of the beam provider. In this letter, the interest of the beam provider to host the applicant's project should be expressed and the technical feasibility of the proposed experiments should be acknowledged.

IAEA will contract only one Research Proposal per Member State. It is acknowledged that IAEA may realize the transfer of funds to the End-User once the experiment is officially scheduled.

6. Conclusions and Recommendations

6.1 Conclusions

1) The planned Coordinated Research Projects (CRP) is fully in line with the mission of IAEA in strengthening their capacity to adopt and benefit from the usage of accelerators.
2) The CRP will decisively facilitate access to advance ion-beam analytical facilities to Member States without such capabilities. This will create substantial linkages between new users, experienced research communities, and state-of-the-art facilities.
3) Within the course of the proposed CPR, technical contracts (TC) may be awarded to the institutes hosting and operating ion-beam facilities, whereas research contracts (RC) or research agreements (RA) may be awarded to the end-users.
4) The CRP should be open to new researchers from IAEA Member States during its course, so that as many as possible end-users will benefit from the use of accelerators. In this context, the option of granting RC per year should be considered. The award of a RC should be related to an approved and scheduled experiment at an ion-beam provider.
5) There is strong need for hands-on training in addition to theoretical knowledge for the success of the proposed CRP. Therefore, institutes hosting and operating ion-beam facilities participating in the CRP shall be encouraged to plan training activities, such as workshops or schools related to Ion Beam Analysis (IBA) techniques.
6) As per the discussion in both consultancy meetings, eight ion-beam providers are willing to offer their facilities for the needs of the CRP. In addition to these facilities additional ion-beam providers may participate in the CRP. The selection of ion-beam providers should be completed in the CRP's first phase (see in Recommendations below).
7) As per the discussion in both consultancy meetings, the Accelerator Knowledge Portal is a very useful tool for researchers from IAEA Member States. In the case of the planned CRP the Portal is of special importance as it will assist a lot the tentative end-users to search for nearby beam providers and receive detailed information on the available techniques.

8) The Consultants of the meeting should check and update the data relevant to their country that are listed in the Accelerator Knowledge Portal. In addition, the latter should be advertised by inserting a special entry in the websites of their institutions with a proper link.
9) The planned CRP should be advertised in major ion beam conferences to attract the interest of many tentative end-users.
10) The IAEA logo may be displayed at the site of the facilities providing ion-beam access and participating in the CRP.

6.2 Recommendations

Following recommendations are made to the IAEA:

1) To proceed with the organization of the planned CRP as soon as possible.
2) The CRP should be implemented in two phases:
   Phase 1: IAEA should select the facilities that will provide access to users. It is recommended that the selected facilities should be properly distributed geographically to best facilitate access to users from different continents.
   Phase 2: IAEA selects the users, according to CRP rules.
   The selected facilities should offer beam time and instrumentation for Ion Beam Applications in:
   - Cultural Heritage
   - Environmental monitoring and climate change
   - Earth sciences
   - Biosciences - Human health
   - Materials characterization and modification
   - Material studies for fusion energy
3) The techniques of interest for the CRP should, among others, include:
   - Particle Induced X-ray Emission (PIXE)
   - Particle Induced Gamma-ray Emission (PIGE)
   - Rutherford 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)
   - Ion Beam Luminescence (IBIL)
   - MeV ion beam modification (implantation and irradiation)
4) The laboratories to be selected should provide IAEA in a template form, agreed in advance with:
   - A proper description of their experimental facilities, including at least

- o The available ion beam techniques that can be offered to users of the CRP
    - o Information on auxiliary facilities, such as sample preparation, accommodation possibilities, etc.
    - o Human resources that will assist users in
        - ✓ Performing experimental work, such as sample preparation, running experiments, data processing, etc.
        - ✓ Organizing their travel, accommodation, visa etc.
        - ✓ Any other resources to be assigned to CRP users
- Conditions to approve user proposals, such as selection by a Program Advisory Committee, etc.
- Responsible contact person for the users.
- An updated website of the facility
- Capability / experience to host hands-on training courses

5) If selected, the beam proving laboratories should sign a technical contract (TC).

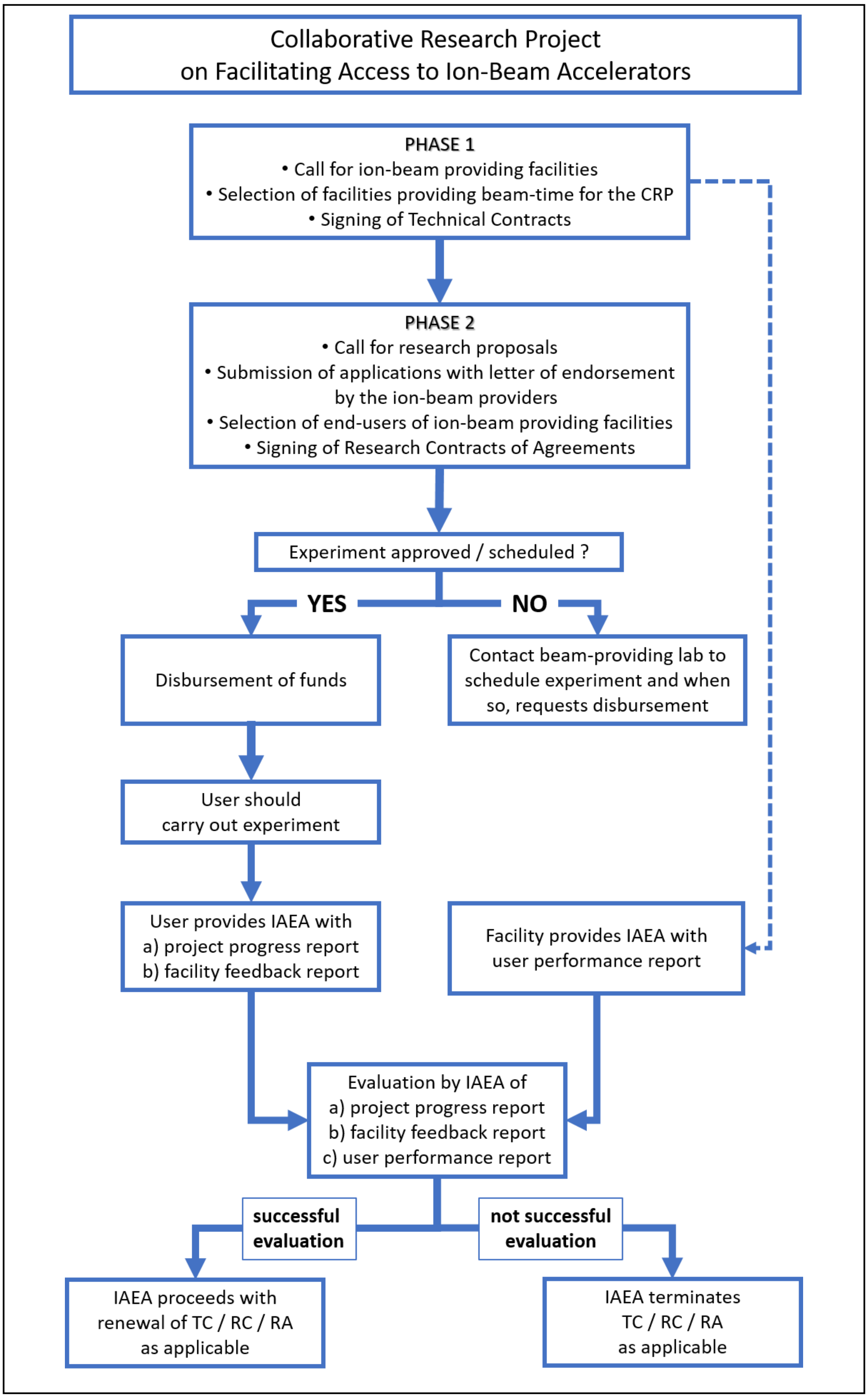
6) For the selection of the users, following aspects should be considered:
    - Users from MSs without accelerator facilities are particularly encouraged to apply.
    - Before submission of any research proposal to IAEA, interested end-users should first contact the laboratory of their interest to discuss the science case and technical feasibility. This requires that the beam providers must already be identified in the CRP call.
    - A RC applicant may be required to justify the selection of the facility based on geographical and technical criteria.
    - In the application for a Research Contract, the applicant should include a letter of endorsement of his research project from the proposed facility signed by the Designated Authority. IAEA will draft the template of the endorsement letter.
    - In case of project approval by IAEA, it is suggested that the transfer of funds to the beneficiary is conditioned to the approval / scheduling of the experiment.

11) The potential for subsequent collaborations, between the end-user(s) and the corresponding beam-providing laboratory should also be considered during the selection of the applications for research contracts.

12) The performance indicators of the CRP shall be:
    a) Number of new users within the CRP
    b) Amount of beam time allocated in experiment to CRP users
    c) Papers submitted for publication
    d) Papers presented
    e) Data in theses
    f) Outreach events
    g) User/Facility feedback and satisfaction

13) The beam-providing laboratories will also make a user template form of the facility.

14) Following flow diagram is proposed as guidance for the CRP


Collaborative Research Project
on Facilitating Access to Ion-Beam Accelerators
PHASE 1
• Call for ion-beam providing facilities
• Selection of facilities providing beam-time for the CRP
• Signing of Technical Contracts
PHASE 2
• Call for research proposals
• Submission of applications with letter of endorsement by the ion-beam providers
• Selection of end-users of ion-beam providing facilities
• Signing of Research Contracts of Agreements
Experiment approved / scheduled ?
YES
NO
Disbursement of funds
Contact beam-providing lab to schedule experiment and when so, requests disbursement
User should carry out experiment
User provides IAEA with
a) project progress report
b) facility feedback report
Facility provides IAEA with user performance report
Evaluation by IAEA of
a) project progress report
b) facility feedback report
c) user performance report
successful evaluation
not successful evaluation
IAEA proceeds with renewal of TC / RC / RA as applicable
IAEA terminates TC / RC / RA as applicable

Annex I

Participants of the Consultancy Meeting on
Preparation of the Coordinated Research Project on Facilitating Access to Ion-Beam Accelerators

1	Mr. Efraín CHÁVEZ	Nuclear Physics and Radiation Applications Universidad Nacional Autónoma de México (UNAM) University City MEXICO CITY MEXICO chavez@fisica.unam.mx
2	Mr. Milko JAKŠIĆ	Laboratory for Ion Beam Interactions Department of Experimental Physics Institute Ruđer Bošković Bijenicka cesta 54, P.O. Box 180 HR-10002 ZAGREB CROATIA jaksic@irb.hr
3	Mr. Pawan KUMAR KULRIYA	Inter-University Accelerator Centre (IUAC) Ministry of HRD, Government of India Aruna Asaf Ali Road NEW DELHI INDIA pawan@iuac.res.in
4	Mr. Carlos PINEDA-VARGAS	Materials Research Department iThemba LABS National Research Foundation (NRF) P.O. Box 722 Sommerset West, 7129 WESTERN CAPE PROVINCE SOUTH AFRICA pineda@tlabs.ac.za
5	Mr. Manfredo Harri TABACNIKS	Laboratório de Materiais e Feixes Iônicos LAMFI Instituto de Física da Universidade de São Paulo (USP) Rua do Matão, Travessa R, 187 05508-090 SÃO PAULO BRAZIL tabacniks@if.usp.br
6	Mr. Natko SKUKAN	International Atomic Energy Agency Department of Nuclear Sciences and Applications Division of Physical and Chemical Sciences Physics Section, Nuclear Science and Instrumentation Laboratory IAEA Laboratories Seibersdorf Friendesstrasse 1 2444 SEIBERSDORF, Austria N.Skukan@iaea.org

7	Mr. Iain DARBY	International Atomic Energy Agency Department of Nuclear Sciences and Applications Division of Physical and Chemical Sciences Physics Section, Nuclear Science and Instrumentation Laboratory IAEA Laboratories Seibersdorf Friendesstrasse 1 2444 SEIBERSDORF, Austria I.Darby@iaea.org
8	Mr. Sotirios CHARISOPOULOS	International Atomic Energy Agency Department of Nuclear Sciences and Applications Division of Physical and Chemical Sciences Physics Section P.O. Box 100, Vienna International Centre Wagramer Straße 5 1400 VIENNA, Austria S.Charisopoulos@iaea.org
9	Mr. Danas RIDIKAS	International Atomic Energy Agency Department of Nuclear Sciences and Applications Division of Physical and Chemical Sciences Physics Section P.O. Box 100, Vienna International Centre Wagramer Straße 5 1400 VIENNA, Austria D.Ridikas@iaea.org

Annex II:
Agenda of the Consultancy Meeting on Preparation of the Coordinated Research Project on Facilitating Access to Ion-Beam Accelerators

IAEA Headquarters,

Vienna, Austria, C0731 (C Building, 7th floor),

12 – 14 March 2018

Monday, March 12, 2018		
08:30 – 09:15	Registration	
09:15 – 09:30	Official Opening:	*Mr Danas Ridikas, Head Physics Section, IAEA-NA*
09:30 – 09:45	Brief self-introduction of the participants	
09:45 – 10:00	Organizational arrangements	*Mr Natko Skukan NSIL, IAEA-NA*
10:00 – 10:30	The contribution of NSIL to facilitating MSs access to accelerators	*Mr Iain Darby LH-NSIL, IAEA-NA*
10:30 – 10:45	***Coffee Break***	
10:45 – 11:00	IAEA activities in accelerator applications	*Mr Sotirios Charisopoulos Physics Section, IAEA-NA*
	Session one: Description of accelerator facilities I	
11:00 – 11:30	Description of the LAMFI/USP facility	*Mr Manfredo Harri Tabacniks LAMFI/USP BRAZIL*
11:30 – 12:00	Description of the LIBI/RBI facility	*Mr Milko Jakšić LIBI/RBI CROATIA*
12:00 – 14:00	***Lunch Break***	
	Session one: Description of accelerator facilities I	
14:00 – 14:30	Description of the IUAC facility	*Mr Pawan Kumar Kulriya IUAC INDIA*
14:30 – 15:00	Description of the UNAM facility	*Mr Efraín Chávez UNAM MEXICO*
15:00 – 15:30	Description of the iThemba Labs	*Mr Carlos Pineda-Vargas Ithemba Labs SOUTH AFRICA*
15:30 – 16:00	***Coffee Break***	
16:00 – 17:00	Introduction to new CRP: 2123 *Facilitating Experiments with Ion Beam Accelerators*	
16:00 – 17:00	Introduction to new CRP: 2123 *Facilitating Experiments with Ion Beam Accelerators*	*Mr Natko Skukan NSIL, IAEA-NA*

Tuesday, March 13, 2018		
09:30 – 10:30	Session 2: Discussion on modalities of providing access to accelerator facilities within the CRP	*Mr Sotirios Charisopoulos / Mr Natko Skukan*
10:30 – 11:00	***Coffee Break***	
11:00 – 12:00	Working in groups	
12:00 – 14:00	***Lunch Break***	
14:00 – 16:30	Working in groups	

Wednesday, March 14, 2018		
09:30 – 10:30	Session 3: Drafting meeting report	Working in groups
10:30 – 10:45	***Coffee Break***	
10:45 – 11:45	Drafting meeting report (cont'd)	Working in groups
11:45 – 13:30	***Lunch Break***	
13:30 – 15:00	Session 4: Finalizing meeting report	Working in groups
15:00 – 15:30	***Coffee Break***	
15:30 – 16:30	Final remarks and closing of the meeting	