IAEA activities in support of nuclear physics research and applications

D Ridikas on behalf of Physics Section
Division of Physical and Chemical Sciences,
Department of Nuclear Sciences and Applications
International Atomic Energy Agency (IAEA)
Vienna International Centre, PO Box 100, 1400 Vienna, Austria

physics@iaea.org

Abstract. Facilitation of development and promotion of nuclear applications for peaceful purposes and related capacity building are among the IAEA missions where Physics Section contributes most. The relevant activities fall under the IAEA's program ‘nuclear science’ and cover four main thematic areas: applications of particle accelerators, sustainable utilization of research reactors, controlled fusion research and technology, and nuclear instrumentation. The Section also operates the Nuclear Science and Instrumentation Laboratory (NSIL) at Seibersdorf, located approximately 40 km south of Vienna. NSIL's primary mission is to assist IAEA Member States to establish, operate and maintain various nuclear instrumentation and spectrometry-based techniques in support of a wide range of applications such as materials testing. This paper will illustrate through a number of selected examples how the IAEA supports nuclear physics research and diverse applications in order to address key development priorities in many areas of societal importance and economic growth of the developing countries. In addition, some future plans on enhancing capabilities of the Nuclear Science and Instrumentation Laboratory as part of Physics Section will be highlighted, in particular by establishment of the neutron science facility and considerations for a compact ion beam accelerator.

1. Introduction

The Physics Section [1] is one of the four sections of the Division of Physical and Chemical Sciences (NAPC) that is part of the Department of Nuclear Sciences and Applications (NA) of the International Atomic Energy Agency (IAEA). In line with the IAEA’s mission to promote nuclear applications for peaceful purposes and related capacity building, the Physics Section supports IAEA Member States in establishment or strengthening their capabilities in four main thematic areas: applications of particle accelerators, sustainable utilization of research reactors, controlled fusion research and technology, and nuclear instrumentation. The Section’s activities are implemented using various well-established instruments and modalities, just to list some of them:
• Organization of international conferences, technical meetings, training courses and schools; these activities contribute to the knowledge dissemination, networking and capacity building. Some of these events include hands-on-training courses utilizing infrastructure and facilities available at NSIL or offered by the hosting organizations of the IAEA Member States;
• Organization and support of coordinated research projects (CRPs); these are joint international projects bringing together scientists from 10-15 research institutes in both developing and developed countries to collaborate on research and development topics of common interest for 4-5 years;
• Publication of technical documents, guides, proceedings and e-learning tools; these are direct outputs of most of the IAEA technical or consultancy meetings, conferences and coordinated research projects;
• Support to national and regional technical cooperation (TC) projects; these are primary mechanism for transferring nuclear technology and know-how to the IAEA developing Member States;
• Offering specific services; these include organization of periodic proficiency or interlaboratory comparison tests; review, assessment or technical support missions; review of strategic plans, roadmap documents or feasibility studies; offering facilitated access to the state-of-the-art facilities through partnership agreements and practical arrangements, etc.
• Management and updates of various data bases and web portals; these include facilities such as research reactors, particle accelerators, spallation neutron sources, synchrotron light sources and fusion experimental devices.

2. Selected examples of IAEA activities

2.1. Technical Meeting on Advanced Methodologies for the Analysis of Materials in Energy Applications Using Ion Beam Accelerators

Presently, there is a continuously increasing effort worldwide to investigate the physical processes altering the surface and composition of materials to be employed under the extreme physical conditions expected in future fusion energy systems. Ion Beam Analysis (IBA) techniques have been proven as one of the principal methods to investigate these processes due to its unique analytical potential. Among other close to 20 Technical Meetings organized annually, a Technical Meeting on “Advanced Methodologies for the Analysis of Materials in Energy Applications Using Ion Beam Accelerators” was held in October 2018 in Vienna, Austria, attended by 29 scientists from 15 Member States. Its main goal was to review the current state and next steps in the following areas:
• Accelerator laboratories and their IBA potential for materials for fusion applications
• IBA of fusion plasma-facing components and materials, including combinations of different ion beam methods
• Fundamental aspects of employing ion beams to simulate radiation damage in materials for fusion energy production
• Modelling tools and software development for the analysis of materials employed in fusion applications
• Existing and required cross-section databases for IBA in fusion applications
• Setting up a roadmap for future studies of fusion reactor materials using ion beams.
Among other findings and conclusions of the meeting, it was recommended to proceed with a new Coordinated Research Project (CRP) in order to assist the international IBA community to coordinate research efforts in understanding aspects of ion-induced radiation damage in materials relevant to fusion energy as well as their analysis. The new CRP will integrate measurements of new nuclear reaction cross sections with inter-laboratory comparisons that will be implemented by first defining proper international standards and subsequently validating these via a round-robin test exercises among the participating organizations.

2.2. The Joint ICTP-IAEA Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science

The Physics Section organizes every year two to three training workshops and schools in cooperation with the Abdus Salam International Centre for Theoretical Physics (ICTP). To help pave the way for their wider use, a joint ICTP-IAEA workshop on enhancing accelerator-based analytical techniques for forensic science [2] was organized in May 2019 in Trieste, Italy. The workshop brought together professionals from diverse fields to help bridge the gap between research and real-world applications; experts presented accelerator-based techniques for forensics and trained scientists, who are looking to branch into or hone their skills in the field, and end-users, such as police forensics investigators, who want to learn about and potentially adopt these powerful methods. Participants also included technology manufacturers that, through further developing and refining instruments, can help advance work in this area. The workshop discussions and presentations provided an in-depth look at accelerator-based techniques, how they can complement various forensics methods as well as challenges and case studies on how to broaden their use. Sessions also covered strategies for effectively implementing these methods into forensics work and for preparing and handling forensic data to ensure results are accurate, credible and can hold up in court.

Fig. 1: Participants at the IAEA/ICTP workshop visit the nearby synchrotron light facility Elettra in Trieste, Italy.

2.3. Facilitating Experiments with Ion Beam Accelerators: a recently launched new CRP

In addition to already active 11 CRPs coordinated by Physics Section [3], a new CRP G42008 entitled “Facilitating Experiments with Ion Beam Accelerators” was recently launched to support scientists without access to accelerator facilities to conduct experiments using accelerator-based ion-beam
analytical techniques. In this context, ten ion-beam accelerator facilities, referred to as the “hosts”, have first been competitively selected from all five continents to provide beam access to external users, referred to as the “guests”, who will be selected in a second stage. The selected hosts are well-established ion beam laboratories with long-term expertise in ion beam analysis IBA and previous experience in assisting guests, including those without any or limited experience in IBA or Accelerator Mass Spectrometry (AMS). Guests can be scientists from any scientific discipline willing to boost their research by benefiting from access to related analytical and irradiation techniques, as well as building the necessary capacity for ion-beam accelerator facilities planned in their countries in the future, where applicable. Depending on the demand for beamtime access, the number of hosts may be increased during the five-year course of the CRP.

It is worth noting that, independent of this CRP, the Physics Section offers already facilitated access to state-of-the-art accelerator facilities through partnership agreements and practical arrangements. For this purpose, the IAEA holds cooperative agreements with the Elettra Synchrotron light source in Trieste [4], Italy and the ion beam accelerator facility at the Ruđer Bošković Institute in Zagreb, Croatia [5].

2.4. Support to Technical Cooperation (TC) projects

In support of the IAEA’s TC Programme [6], Physics Section activities include technical support missions, review of strategic plans, roadmap documents or feasibility studies, and expert assistance in upgrading existing nuclear facilities or the establishment of new facilities, including procurement and installation of equipment. The Section supports typically 50-60 national and regional TC projects, representing almost 50 Member States. The total budget of these TC projects exceeds 2 million Euros. An example is the currently running national TC project entitled “Strengthening Capacity in the Maintenance and Utilization of the Tandem Accelerator Facility”, which aims at strengthening the analytical services of the Tandem Accelerator facility of the Bangladesh Atomic Energy Commission (BAEC) by assisting its scientific and technical personnel in receiving proper training in operating and maintaining the accelerator, as well as by funding accelerator components and their installation under expert supervision.

![Fig. 2: Trouble shooting with the help of international experts at the ion beam facility in Bangladesh, constructed and maintained with the support by the IAEA.](image)
2.5. Accelerator Knowledge Portal (AKP)

The Physics Section, among other data bases and web-based tools relevant to fusion research and research reactor applications, operates and maintains the Accelerator Knowledge Portal (AKP) [7] - a website providing information about many accelerators operating worldwide, such as type, country of location, maximum beam energy or power capacity. Up to date, AKP offers a comprehensive list and an interactive map of 350 electrostatic accelerator facilities including AMS systems, more than 1000 medical cyclotrons, 64 synchrotron light sources and 10 spallation neutron sources. The portal has several networking and communication features aiming at providing not only technical information but also links to conferences, workshops and schools, technical reports, journal articles and books as well as links to software packages and databases. “Case studies”, where applications of ions and neutrons, spanning from atomic dimensions to the interstellar space, are also displayed in a dedicated page. The AKP is being continuously expanded with additional types of accelerators, like free electron laser sources (FELs) and hadron therapy facilities.

2.6. Support to QA/QC and capacity building of analytical laboratories

In 2018 the Physics Section, through its Nuclear Science and Instrumentation Laboratory, coordinated two proficiency test campaigns [8] for the interested analytical laboratories helping Member States to improve the quality of analytical results: (a) Urban Dust Loaded on Air Filters (with participation of 43 laboratories) and (b) Marine Sediment & Animal Tissue (with participation of 41 laboratory). During the same period, the Physics Section also supported 41 Neutron Activation Analysis (NAA) laboratories from 29 Member States to give evidence of the validity of their measurement results by participation in proficiency testing by inter-laboratory comparison. This was followed by Training Workshop on ‘IAEA Neutron Activation Analysis E-learning Course’ with 28 participants from 22 Member States in September 2018.

![Fig. 3. Topical distribution of E-learning NAA activities completed on line by registered users.](image)

As a related activity, the Physics Section has recently implemented a detailed E-Learning on-line course in NAA, with the overall objective to realize a ‘living book’, summarizing the basic concepts of NAA and providing practical information on the implementation of the methodologies which can be much easier updated than a common book, allowing also for visualization using contemporary media. The IAEA E-learning tool will have teachers as points of contact with learners at different experiences going online to follow the course. The E-learning tool comprises over 2,500 power point slides in 60
modules, grouped in 7 main themes, viz. (1) Introduction, History and Applications, (2) Basic Nuclear Physics, (3) Instrumentation, (4) Calibration, (5) Quality, (6) NAA Practice and (7) Varieties. By the midst 2019, there were 216 registered users on-line from over 50 Member States, 150 CD ROMs distributed, and the off-line version was downloaded 98 times. There were a total 2840 activities completed on-line, where an activity is going through a lecture of successfully completing the associated quizzes.

2.7. IAEA’s support to fusion research and technology

2018 was very busy and productive year for fusion related activities at the IAEA [10], including cooperative arrangements for joint activities with ITER Organization [11]. Below section summarises just a few selected key activities led and implemented by Physics Section.

The 27th IAEA Fusion Energy Conference (FEC 2018), which is the reference conference in the field and the largest organised by the Agency, took place in Ahmedabad, Gujarat, India, from 22nd to 27th October 2018. The Department of Atomic Energy and the Institute for Plasma Research successfully hosted this important event, for the first time in India. The conference was attended by 718 experts from 39 Members States and 4 International Organisations. In conjunction with this conference the annual meeting of the International Fusion Research Council (IFRC) that provides advice to the IAEA Director General about Fusion took place also in Ahmedabad, counting with the present of ITER IO DG Mr B. Bigot among other relevant party representatives.

The DEMO Programme Workshop took place in this occasion in Daejeon (Republic of Korea) organized by the IAEA and hosted by the National Fusion Research Institute in May. This edition was devoted to the assessment of the present status and prospect for the progress in the use of magnet technology for magnetic confinement fusion, control of DEMO Plasmas and remote maintenance and plant logistics. Besides that, three special topics were included in the programme: integrated assessment of liquid metals as Plasma Facing Components on the First Wall and Divertor; K-DEMO status and progress and JT60 – SA, status and scientific objectives. The workshop was attended by 64 experts from 12 Members States and one International Organisation.

The first international reference document on Safety guidelines for Fusion applications was published as IAEA-TECDOC-1851: Integrated Approach to Safety Classification of Mechanical Components for Fusion Applications [12]. This publication highlights the existing differences between fission and fusion reactors in identification and classification of structures, systems and components that are important to safety and offers guidance for fusion applications. This publication also provides guidance on inclusion of the new design extension conditions, which have been added after the review of IAEA Safety Guides following the Fukushima Daiichi NPP accident.
3. Enhancing Infrastructure and Capabilities of NSIL/Physics

As part of the IAEA Physics Section [13], the Nuclear Science and Instrumentation Laboratory (NSIL) [14] helps Member States (MSs) develop, operate and maintain various nuclear instrumentation and spectrometry equipment in support of a wide range of applications. Presently, in-house NSIL facilities are limited to X-ray-based analytical techniques and gamma spectrometry. Limited space and outdated infrastructure currently constrain the capacity of NSIL to meet surging MS demand for services. These constraints will partially be addressed in the next phase of an ongoing project to renovate the NA laboratories at Seibersdorf (ReNuAL+).

Fig. 4. Structure of IAEA-TECDOC-1851 based on an integrated approach. Reproduced from [12].

Fig. 5. Schematic representation of existing and planned capabilities available at NSIL/Physics.
Related to the ReNuAL+ initiative, the NSIL plans to establish a Neutron Science Facility (NSF) in order to expand NSIL capabilities to assist MSs utilizing and developing the peaceful use of nuclear techniques and related applications based on neutrons. In addition, the establishment of an Ion Beam Facility (IBF) is envisioned, which will allow the NSIL to offer scientists and engineers from developing MSs access to three complementary probes for applied research, irradiation and analytical services [15].

Due to their unique analytical capabilities, neutron and ion beam-based techniques play a major role in solving problems of modern society related to environmental pollution and monitoring, water and air quality, agriculture and food safety, forensics, cultural heritage, development of advanced materials, and many other fields. The establishment of NSF and IBF in Seibersdorf will expand IAEA’s capabilities to assist its MSs with emerging nuclear techniques, related applications and capacity building based on neutrons and ion beams. It will also provide other internal IAEA organizational units access to and use of state-of-the-art facilities through joint projects.

Relevant feasibility studies have been completed in consultation with close to 40 MSs and numerous internal IAEA stakeholders to assess their needs. The studies showed high demand for training in accelerator technologies as well as for analytical services in almost all areas of neutron and ion beam applications. Appropriate facility designs, matching the IAEA’s programme for capacity building and provision to MSs of products and services across many fields of interest were identified and finalized. The NSF and IBF will be implemented with currently available human resources. However, further extrabudgetary and in-kind support will be needed to realize the full vision of a fit-for-purpose NSIL that includes these additional capabilities.

References
[1] International Atomic Energy Agency, Physics Section, 2019; [web link].
[2] International Atomic Energy Agency, News release on forensics, 2019; [web link].
[3] International Atomic Energy Agency, Coordinated Research Activities, 2019; [web link].
[4] Elettra-Sincrotrone Trieste S.C.p.A, News release on bilateral agreement, 2019; [web link].
[5] International Atomic Energy Agency, News release on dual beam, 2019; [web link].
[6] International Atomic Energy Agency, Technical Cooperation Programme, 2019; [web link].
[7] International Atomic Energy Agency, Accelerator Knowledge Portal (AKP), 2019; [web link].
[8] International Atomic Energy Agency, Proficiency Testing Exercises, 2019; [web link].
[9] International Atomic Energy Agency, E-learning NAA tool, 2019; [web link].
[10] International Atomic Energy Agency, Fusion Portal, 2019; [web link].
[11] International Atomic Energy Agency, News release on practical arrangements, 2019; [web link].
[12] International Atomic Energy Agency, Integrated Approach to Safety Classification of Mechanical Components for Fusion Applications. IAEA-TECDOC-1851, 2019; [web link].
[13] International Atomic Energy Agency, Physics Section Factsheet, 2018; [web link].
[14] International Atomic Energy Agency, Nuclear Science and Instrumentation Laboratory Fact Sheet, 2018; [web link].
[15] International Atomic Energy Agency, Ion Beam Accelerator Project, 2018; [web link].