Nuclear Science

Objective

To increase Member State capabilities in the development and application of nuclear science as a tool for their technological and economic development. To assist Member States in the management and effective utilization of research reactors.

Nuclear Data

Physics at entirely different scales of magnitude are currently being bridged by an innovative approach to radiation damage analysis. With the help of current computing power, it is now possible to estimate damage response functions — such as displacements per atom, and kinetic energy released in matter (kerma) and gas production — on a stronger scientific basis, including a quantitative expression of the uncertainties. These developments will shed new light on the shielding of accelerators and of fission and fusion reactors. To support work in this area, the Agency held a Technical Meeting on Nuclear Reaction Data and Uncertainties for Radiation Damage in Vienna in June, with 16 participants from 11 Member States.

The coordinated research project (CRP) entitled 'Nuclear Data for Charged-particle Monitor Reactions and Medical Isotope Production' was concluded at the third Research Coordination Meeting, held in Vienna in June with 14 participants from 13 countries. The project led to improvements in evaluations of decay data and in the charged-particle monitor (standard) reaction database for proton, deuteron, helium-3 and alpha induced reactions relevant for medical isotopes. The related medical radioisotopes production portal on the Agency's web site was updated accordingly.

Research Reactors

Utilization and applications of research reactors

In 2016, the Agency developed a comprehensive set of e-learning tools for neutron activation analysis, including case studies, quizzes and other learning materials. In October, it held a workshop in Vienna attended by 28 participants from 25 Member States, to review and test the new e-learning tools. The participants' comments and other feedback will be used to further improve the quality of the tool before its final release for public use in 2017 (Fig. 1).

In December, the Agency conducted a workshop to assist research reactor managers in reviewing their strategic plans for research reactor utilization. The event, held in Vienna,

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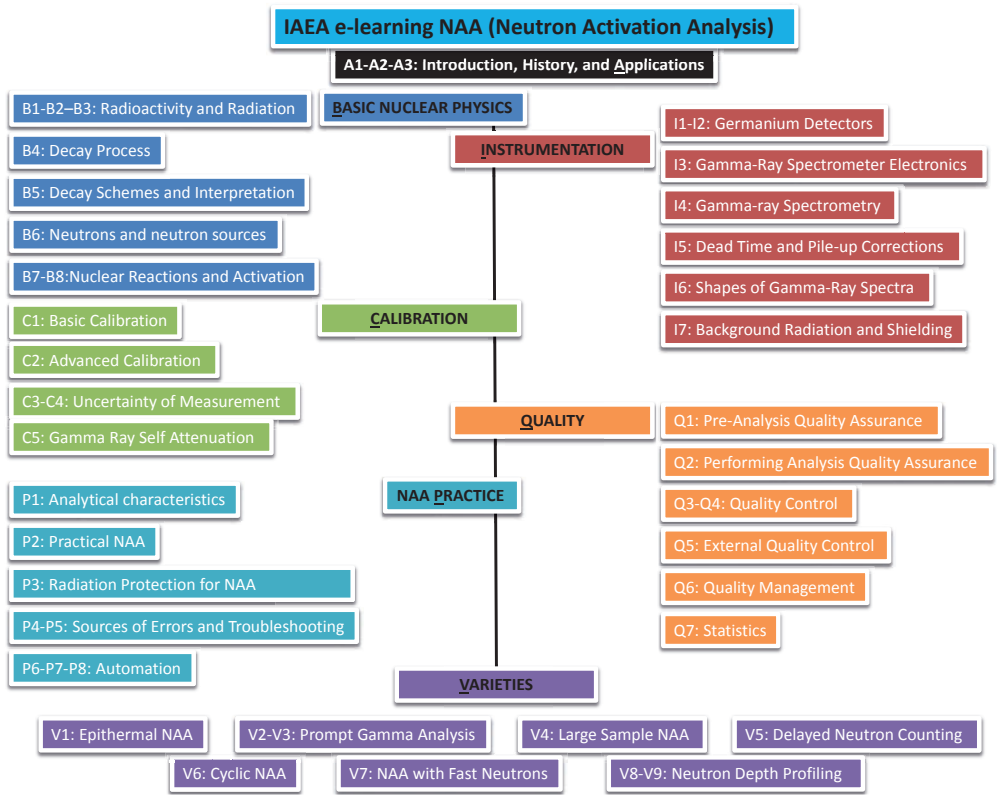

FIG. 1. The Agency's e-learning tools for neutron activation analysis currently comprise 45 modules, including lectures and self-directed learning exercises.

Austria, was attended by 37 participants from 30 Member States and resulted in the review of 26 strategic plans.

Two research reactor organizations were designated as IAEA Collaborating Centres in 2016. The Australian Nuclear Science and Technology Organisation will assist the Agency in implementing selected programmatic activities focused on multi-analytical techniques for materials research, environmental studies and industrial applications. The Reactor Institute Delft, in the Netherlands, will focus on activities related to neutron activation and neutron beam based methodologies of research reactors.

The Agency's Research Reactor Database (RRDB) provides comprehensive technical information on some 770 research reactors in 67 Member States, including their utilization. Based on inputs from Member States, information on some 95 facilities was updated in the RRDB in 2016.

In July, the Agency published *History, Development and Future of TRIGA Research Reactors* (Technical Report Series No. 482), summarizing the information available on TRIGA reactors and providing an overview of the potential challenges to be addressed by TRIGA operating organizations in the near future. It also issued a revision of its brochure *Research Reactors: Purpose and Future*.

New research reactor projects, infrastructure development and capacity building

At a Technical Meeting on the Role of Research Reactors in Providing Support for Nuclear Power Programmes, held in Vienna in June, 32 meeting participants from 24 Member States concluded that research reactors can play an important role in supporting new and ongoing nuclear power programmes, and identified areas where these reactors can make important contributions. At a workshop on the Agency's 'Milestones' approach for research reactors, held in Vienna in October, the Agency provided practical information and related

knowledge to 20 participants from 17 Member States. A preparatory Integrated Research Reactor Infrastructure Assessment (IRRIA) mission was undertaken to Mongolia in April, to provide guidance on planning for a new research reactor.

The Agency's Internet Reactor Laboratory project was fully implemented in Latin America, Europe and Africa in 2016. Live transmissions were carried out from two host facilities: Argentina's RA-6 reactor and the French Alternative Energies and Atomic Energy Commission (CEA) ISIS reactor.

During the 60th regular session of the Agency's General Conference, the Research Institute of Atomic Reactors in the Russian Federation was designated as an IAEA-designated International Centre based on Research Reactor.

Research reactor fuel cycle

The Agency supported Ghana's efforts to convert its miniature neutron source reactor from high enriched uranium (HEU) fuel to low enriched uranium (LEU) fuel. In July, it held an international meeting in China, in cooperation with the China Institute of Atomic Energy (CIAE), for high level delegates from all Member States operating a miniature neutron source reactor to witness the first criticality test of the LEU core for the Ghana Research Reactor.

In September, the last 61 kilograms of HEU remaining in Poland was repatriated to the Russian Federation.

Research reactor operation and maintenance

In 2016, the Agency initiated several activities to help Member States address challenges related to ageing management and lifetime extension of research reactors and the optimization of their operational performance. In January, it held the first Research Coordination Meeting of the CRP entitled 'Condition Monitoring and Incipient Failure Detection of Rotating Equipment at Research Reactors' at its Headquarters in Vienna. Project participants are investigating the latest advances in rotating equipment monitoring and diagnostic techniques, including the use of state of the art rotational monitoring sensors and data transmission techniques such as wireless technologies. In April, the Agency undertook two expert missions: the first, to Indonesia, provided advice on the design of an instrumentation and control system for a research reactor; the second, to Pakistan, provided advice concerning an ageing management programme for the country's PARR-1 research reactor.

The Agency conducted a Workshop on Safety Reassessment of Research Reactors following the Feedback from the Accident at the Fukushima Daiichi Nuclear Power Plant, in Vienna in September, with 40 participants from 34 Member States. In November, it organized a training workshop on integrated management systems for research reactors in Vienna, attended by 31 participants from 29 Member States. Workshop participants exchanged knowledge and experience on developing, implementing and continuously improving management systems, which are essential for ensuring safe and effective operation of research reactors.

During the year, the Agency's Research Reactor Ageing Database (RRADB) was migrated to a new platform offering more advanced features such as extended criteria for filtering to generate more detailed reports for selected combinations of ageing mechanisms and affected structures, systems and components. The RRADB now includes both the legacy database and new information provided by Member States during the year.

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Accelerator Applications

The Agency's Accelerator Knowledge Portal, launched in 2014, offers a database of particle accelerators in the world and includes several networking features. In 2016, the Agency introduced several upgrades to the Portal: the platform now has geographic capabilities, and support was augmented for environmental applications such as pollution monitoring and provenance studies using synchrotrons and ion beam accelerators.

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During the year, researchers from Member States participating in the CRP entitled 'Experiments with Synchrotron Radiation for Modern Environmental and Industrial Applications' made use of the Agency's X ray fluorescence beamline at the Elettra synchrotron in Trieste to carry out 12 experiments focused on environmental science and industrial applications.

In its work on materials modification and analysis using accelerator based techniques, the Agency focused predominantly on three areas in 2016. The first area of focus was development of ion beam analytical methods and high precision fingerprinting of trace elements using accelerators. In September, the Agency held a Technical Meeting on Enhancing Nuclear Technologies to Meet the Needs of Forensic Science at the University of Surrey, Guildford, United Kingdom, that resulted in the proposal, and subsequent approval, of a new CRP on this subject. The second area of focus was radiation damage, including studies to determine the effects of analytical ion beams on materials of cultural heritage. In 2016, research by members of the 'Utilization of Ion Accelerators for Studying and Modelling of Radiation Induced Defects in Semiconductors and Insulators' CRP was published in a special section of *Nuclear Instruments and Methods in Physics Research*. The third area of focus was the use of accelerators to emulate damage and gas build-up in structural materials such as fuel cladding for fast reactors, and long term damage processes in nuclear waste forms. A new CRP entitled 'Accelerator Simulation and Theoretical Modelling of Radiation Effects — SMoRE-II' was approved in support of research in this area.

FIG. 2. As part of the Agency's unmanned aerial vehicle system for rapid environmental monitoring, drones mounted with sensors and cameras are used to remotely collect data in preparation for environmental remediation.

Nuclear Instrumentation

The Agency's unmanned aerial vehicle system for rapid environmental mapping — developed for monitoring hard to reach areas where the level of contamination is unknown — was handed over to Fukushima Prefecture in July (Fig. 2). During the year, the system, which can help Member States to monitor radiation after mining or remediation activities, was successfully deployed for training and modelling assessment in Japan and at a uranium mine in Argentina; and mobile gamma spectrometry with backpack detectors was used for site assessments related to copper mining activities in Zambia, and for radiation mapping in Nepal.

Installation of the ultra-high vacuum chamber (UHVC) at the Nuclear Science and Instrumentation Laboratory in Seibersdorf was

completed in April (Fig. 3). The installation provides a much needed complementary 'mirror' endstation for training users on the experimental apparatus prior to experimentation at the IAEA XRF beamline at the Elettra synchrotron facility in Trieste, Italy. The new training facility will be used to expand the pool of trained experimenters in Member States and to support the use of this important technology.

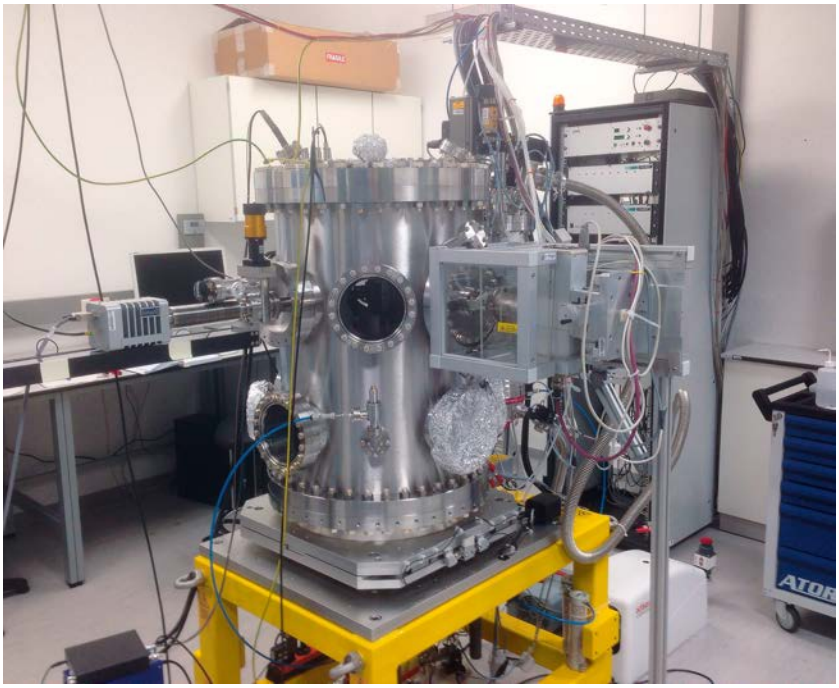

FIG. 3. The ultra-high vacuum chamber at the Agency's Seibersdorf laboratory will be used to train scientists to carry out experiments at the IAEA XRF beamline at the Elettra synchrotron in Trieste, Italy.

Nuclear Fusion

The Agency hosted numerous workshops and meetings of the world's fusion community in 2016. Among them was the 26th IAEA Fusion Energy Conference, held in October in Kyoto, Japan. The FEC is the world's leading event on fusion science and technology; this year's FEC attracted almost 1000 participants and had a record number of conference contributions. Updates on all major projects were presented in about 90 plenary talks and over 600 posters. The fourth DEMO (Demonstration Fusion Power Plant) Programme Workshop, held in November in Karlsruhe, Germany, was attended by 78 participants from 11 Member States and representatives of ITER. The workshop provided an opportunity to review the status of different DEMO related projects and to present results on aspects such as materials science and power extraction. During the year, construction of ITER continued and the Wendelstein 7-X stellarator in Germany was commissioned.

Joint Activities with the ICTP

In 2016, the Agency and International Centre for Theoretical Physics (ICTP) conducted 11 joint activities for 578 participants from 100 Member States, 352 of whom were from developing Member States. The Agency supported ten PhD students from developing countries through the STEP (Sandwich Training Educational Programme) fellowship, enabling them to carry out research at institutes having state of the art equipment. Over the past 13 years, STEP fellowships have been awarded to 180 students from all over the world. Throughout this time, the fellowship has promoted gender balance, and of the current 35 STEP students, 18 are women.

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