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.

Atomic and Nuclear Data

The Agency maintains a wide range of databases of nuclear, atomic and molecular data which underpin modern technology applications in fission and fusion energy production as well as medical and analytical applications. The databases are available primarily through on-line services to Member States and, in 2011, received approximately 175 000 hits, an increase of about 16% over the previous year. In addition, more than 11 000 reports, manuals and technical documents were downloaded.

An important activity is the development of software tools that enable data to be retrieved and displayed in ways that make the data more understandable and useful. The Evaluated Nuclear Data File (ENDF) and the Experimental Nuclear Reaction Data (EXFOR) links at *http://www-nds.iaea.org/* have recently acquired new features, including the ability to upload a user's data and to apply a wide range of 'corrections' to the experimental data to allow for changing standards.

Figure 1 shows an example of a cross-section curve used in ion beam analysis and stored in the Ion Beam Analysis Nuclear Data Library (IBANDL). Such data can also be displayed via EXFOR. Another major class of data deals with the static properties of nuclides, such as half-lives, decay modes and energy levels of excited states, as featured in the *Live Chart of Nuclides*, which was significantly extended during 2011 to show a wider range of nuclear properties *(http://www-nds.iaea.org/livechart/)*.

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The XML Schema for Atoms, Molecules and Solids, developed with the Agency's support and guidance, is being widely implemented through the (European) Virtual Atomic and Molecular Data Centre.

The Agency supports relevant code comparison efforts to test the predictive powers of various model codes. A workshop on computation of collisional

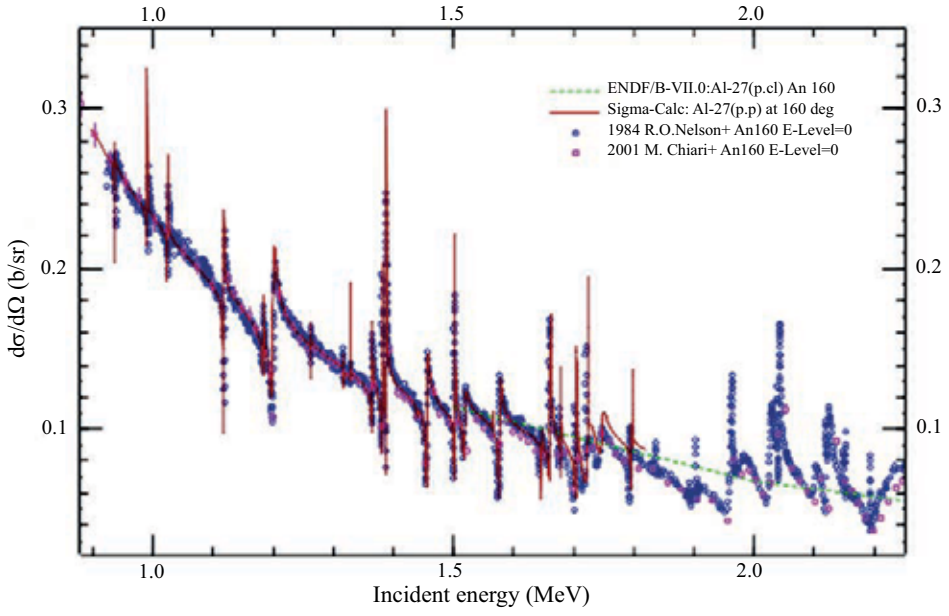

FIG.1. Experimental data on the elastic scattering of protons on aluminium (shown by the symbols) compared with a theoretical calculation carried out using the tools in IBANDL. Such data are important in ion beam analysis.

and radiative properties of atoms and ions away from local thermodynamic equilibrium was held in December 2011 in Vienna with Agency support, which provided valuable benchmarking of about twenty calculational codes.

Three training workshops were organized by the Agency in 2011, one in Trieste in cooperation with the Abdus Salam ICTP entitled 'Monte Carlo Radiation Transport and Associated Data Needs for Medical Applications', and the other two in Vienna to train new compilers of EXFOR and to teach the basics of covariances and the use of Global Assessment of Nuclear Data Requirements (GANDR). Approximately 75 participants received training during these events.

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Research Reactors

Addressing the shortage of molybdenum-99 supplies

As part of ongoing efforts to prevent future shortages of molybdenum-99 (^{99}Mo) supplies and to move away from the use of high enriched uranium (HEU), the Agency organized an international meeting to further international collaboration on conversion to low enriched uranium (LEU) based ^{99}Mo production. The December meeting focused on the specific technical and policy challenges confronting major HEU based producers and on advancing opportunities for potential multilateral cooperation that commenced in 2010. The meeting defined the scope of cooperation possible in a commercial ^{99}Mo production environment and the Agency's role in supporting that conversion. It started a discussion on optimization of a high density LEU target for ^{99}Mo production. This work — especially on a high density target — is envisaged to continue until all the major producers are converted to LEU in 2015.

The Agency completed its comparative assessment of non-HEU technologies for the production of ^{99}Mo. The assessment, which will be published in 2012, will supplement reports published by the OECD/NEA High-level Group on the Security of Supply of Medical Radioisotopes, of which the Agency is a member. The report of the CRP related to the production of ^{99}Mo using LEU targets, which held its final Research Coordination Meeting in December, will also be published in 2012.

Improving the utilization of research reactors

Collaborative efforts between Member States (both with and without research reactors) to improve utilization were further enhanced in 2011 with the creation in July of the Central African Research Reactor Network, a technical meeting in October on access to research reactors by Member States that do not host such facilities, and the December 2011

FIG. 2. The new very-high-flux PIK research reactor in the Russian Federation attained its first physical criticality on 28 February 2011 (left: reactor hall; right: reactor control room). (Photographs courtesy of PNPI 2011.)

final coordination meeting of a technical cooperation project on 'Enhancing the Sustainability of Research Reactors and Their Safe Operation through Regional Cooperation, Networking and Coalitions', which proposed the creation of a new coalition covering the Commonwealth of Independent States (CIS).

A further initiative to encourage the development of very-high-flux research reactors (such as CARR in China, JHR in France and PIK in the Russian Federation) as international facilities with potentially shared ownership was launched in 2011 (Fig. 2).

An international conference on 'Research Reactors: Safe Management and Effective Utilization', organized every four years by the Agency, was hosted in Rabat in November 2011 by the Government of Morocco. The more than 200 participants from 42 Member States discussed key issues facing the research reactor community, including safe utilization. These included possible implications of the accident at TEPCO's Fukushima Daiichi nuclear power plant (hereinafter the Fukushima Daiichi accident) for some research reactors, utilization and maintenance issues, and preparations for new research reactors. A number of participants stressed the need for a 'milestones approach' for new research reactors comparable to the Agency's approach for new nuclear power plants.

The development of an integrated approach to routine automation of neutron activation analysis is the aim of a new CRP initiated in 2011. The CRP is expected to result in an increased neutron activation analysis (NAA) service capacity, and thus enhanced research reactor utilization.

Two Agency publications on research reactors were issued in 2011, *Research Reactor Application for Materials under High Neutron Fluence* (IAEA-TECDOC-1659) and a booklet entitled *Research Reactors in Africa.* The first publication focused on research reactor utilization for materials development and testing for both fission and fusion based nuclear power plants. The second highlighted the services available from African reactors to stakeholders in health, research, agriculture and other areas.

Research reactors in education and training

Three Research Reactor Group Fellowship Training Courses, organized by the Eastern European Research Reactor Initiative and supported by the Agency, were held in 2011 to assist Member States interested in either initiating new research reactor projects or improving the utilization of existing research reactors. The six week courses were conducted at research reactors in Austria, the Czech Republic, Hungary and Slovenia. They included theory and practical work and technical visits.

For the past two years, the Abdus Salam ICTP–IAEA School of Nuclear Energy Management has included in its programme a session on the 'Fundamentals of Nuclear Applications', which presents the diverse applications of research reactors for both nuclear power related research and non-power applications. The session also highlighted the role of research reactors in developing the national nuclear infrastructure necessary for introducing nuclear power.

Research reactor infrastructure

The contents and format of the Agency's Research Reactor Database (RRDB), available through the Nucleus web portal (*http://nucleus.iaea.org/RRDB/*), were reviewed in June by a group of external experts. Based on their comments, an updated version of the RRDB was released with advanced capabilities, including a guide to assist experts as they update the database, integrated map displays and a significantly improved revision management system.

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Research reactor fuel

The Agency published *Good Practices for Water Quality Management in Research Reactors and Spent Fuel Storage Facilities* (IAEA Nuclear Energy Series No. NP-T-5.2) to assist research reactor managers and operators in implementing water quality programmes. In addition, two meetings relating to the management of spent research reactor fuel were organized. The first covered good practices in management and storage of spent research reactor fuel and guidelines for interim wet and dry storage. The second was a kick-off meeting to elaborate an Agency report on commercial options for the back end management of spent research reactor fuel.

Research reactor operation and maintenance

In parallel with a meeting on research reactor ageing management held in October, the Agency carried out a project to revise and update a database on operating experience related to ageing. This extensive effort yielded over 200 responses from research reactor operators around the world; the information represents a unique collection of operating experience.

Accelerators for Materials Science and Analytical Applications

The Tenth International Topical Meeting on 'Nuclear Applications of Accelerators', held in April 2011 in Knoxville, USA, brought together 130 experts from 20 countries in a conference co-chaired by representatives of the American Nuclear Society and the Agency. A significant outcome of the meeting was its demonstration of increased international interest in accelerator driven systems (ADSs) (Fig. 3).

Ion beam analysis, in particular applications in material science, cultural heritage and studies of nuclear technology materials, was a key area of work in 2011. Two new CRPs were initiated, one on 'Benchmarking of Structural Materials Pre-selected for Advanced Nuclear Reactors' and the other on the 'Utilization of Ion Accelerators for Studying and Modelling of Radiation Induced Defects in Semiconductors and Insulators'.

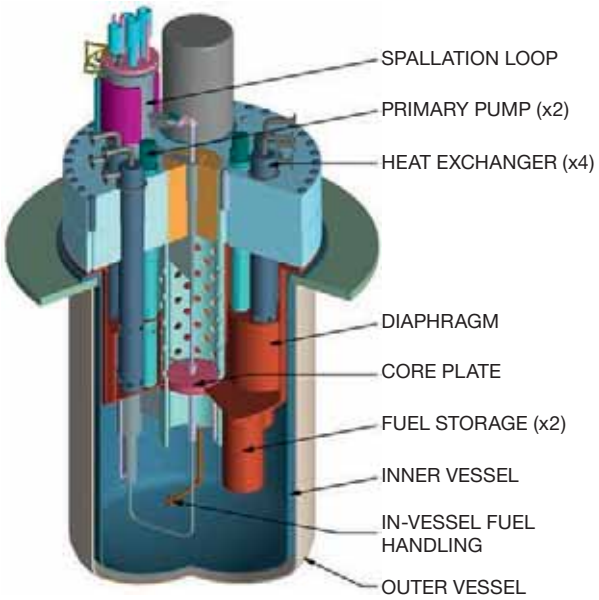

FIG. 3. Schematic drawing of the MYRRHA ADS.

Nuclear Instrumentation and Spectrometry

Following a meeting on 'Future Perspectives for the Nuclear Spectrometry and Applications Laboratory (NSAL)' held in March 2011, two activities proposed at the meeting were initiated: construction of an ultra-high vacuum chamber (UHVC) and mobile gamma spectrometry and environmental mapping activities. Both of these projects are especially significant within the context of the Fukushima Daiichi accident and site remediation.

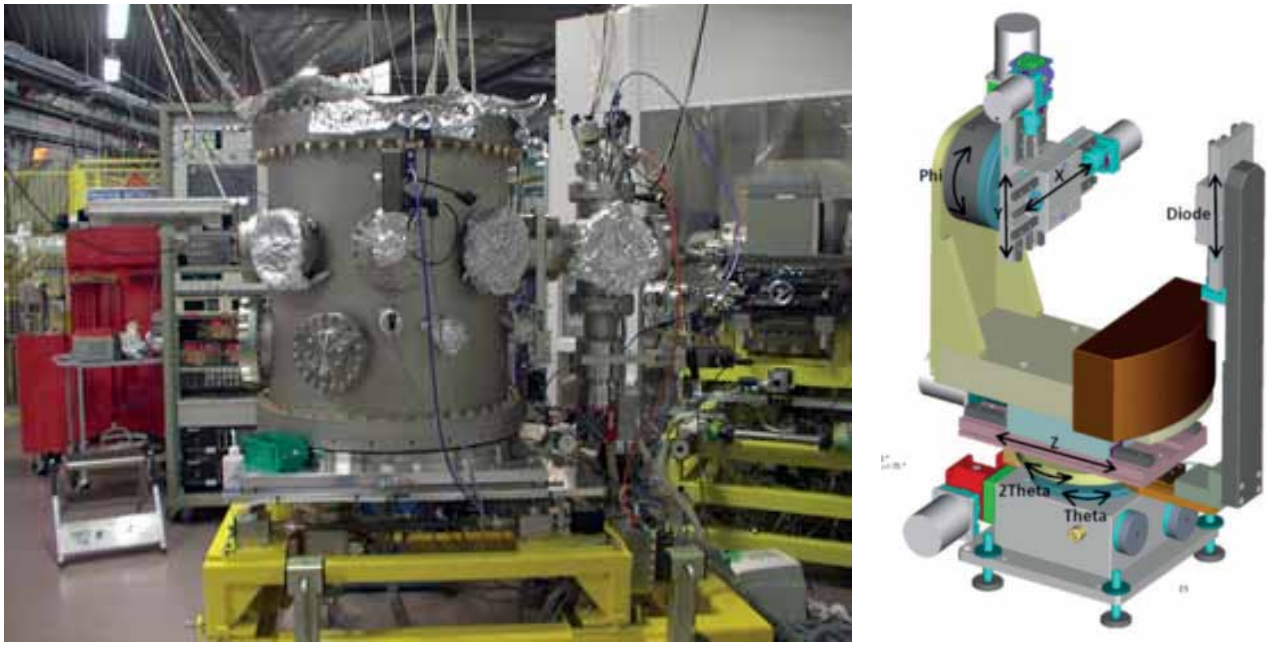

FIG. 4. The UHVC at the Federal Institute of Physics and Technology, Berlin (left), and the seven axis motorized sample manipulator under construction for the Agency's UHVC (right).

FIG. 5. A 16th century Mexican headdress (left) being examined with a hand-held X ray fluorescence spectrometer (right).

The new UHVC is being designed and constructed in collaboration with the Federal Institute of Physics and Technology, Berlin, and the Technical University of Berlin, and is expected to be installed in 2013 at Elettra, the IAEA Collaborating Centre in Trieste, Italy. The UHVC will significantly expand the capacity of the NSAL for advanced elemental analysis of materials and will allow advanced hands-on training to fellows from Member States (Fig. 4).

In 2011, NSAL conducted a non-invasive analysis of two valuable exhibits from a collection of Mexican artefacts at the Art History Museum in Vienna. The analysis was designed to establish the presence of toxic elements which would suggest the use of pesticides in past treatments of objects for conservation and to establish the authenticity of gold decorations and elements (Fig. 5).

Nuclear Fusion

Agency cooperation with ITER in Cadarache, France, continued. The past year saw the completion of the first large building on the ITER site, the 257 m long by 49 m wide poloidal field coil hall (Fig. 6), which will house the assembly of part of ITER's magnetic confinement system. With diameters of up to 24 m, the poloidal field coils are too large to be

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FIG. 6. The first completed ITER building, the poloidal field coil hall.

transported in their finished state and will therefore be wound on-site.

In support of fusion energy technology, the Agency focuses on the development and evaluation of data for processes that involve plasma particles interacting with the wall of the fusion confinement device. In 2011, a CRP began on molecular processes in the near-wall plasma, and work continued on tungsten and beryllium as fusion related materials. These are foreseen as the main wall materials for the ITER experimental reactor and a future fusion power plant.

Reflecting the growth of the field of plasma physics and nuclear fusion worldwide in the context of ITER and other research activities for future fusion power stations, two new CRPs were initiated in 2011 on 'Small Magnetic Fusion Devices for Mainstream Fusion Research' and 'Materials under High Repetition and Intense Fusion Pulses'.