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

Accurate and reliable nuclear, atomic and molecular data for nuclear technologies are maintained through on-line databases by the Agency for use by its Member States. In 2012, the more than 20 databases received approximately 22 600 hits per month, an increase of about 25% over 2011. In addition, more than 20 000 reports, manuals and technical documents were downloaded during the year.

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The International Networks of the Nuclear Reaction Data Centres (NRDC) and the Nuclear Structure and Decay Data Evaluators (NSDD) continued to play a vital role in coordinating the development and maintenance of the databases for, respectively, the Experimental Nuclear Reaction Data (EXFOR) and the Evaluated Nuclear Structure Data File (ENSDF). One major software improvement to the EXFOR database allows more user-friendly retrieval and display of data by renormalizing old measurements using newly evaluated values. Figure 1 shows both old and updated data for the ^{64}Zn(n, p)^{64}Cu reaction. Such updates can be applied automatically, with an additional option to input user specified changes.

To compile and evaluate existing data on beta-delayed neutron emission, as well as to undertake new measurements and develop models based on theory and systematics, a new CRP was launched in August. In May, a preliminary workshop was conducted at McMaster University, in Canada, in support of the CRP.

The publication *Nuclear Data for the Production of Therapeutic Radionuclides* (Technical Reports Series No. 473) was issued in 2012 following the completion of a CRP on the subject. The report provides standardized data for the production of radionuclides for therapeutic purposes.

A technical meeting on 'Data Evaluation for Atomic, Molecular and Plasma–Material Interaction Processes in Fusion' was organized in September jointly by the Agency and the National Fusion Research Institute in Daejeon, Republic of Korea. The papers from this meeting, which were published

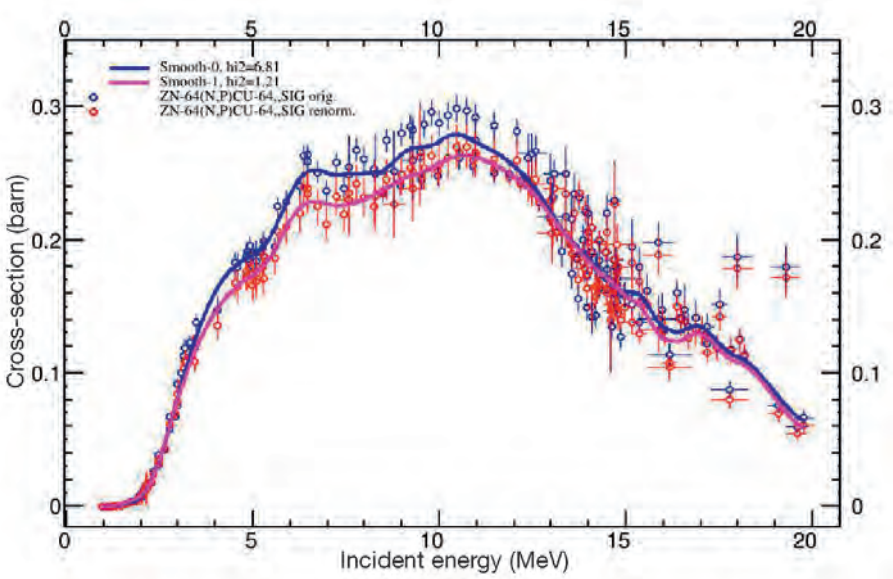

FIG. 1. Original (blue) and renormalized (magenta) experimental data for the ^{64}Zn(n, p)^{64}Cu reaction from EXFOR illustrating improved fitting.

in a special issue of *Fusion Science and Technology*, describe the current status of evaluated databases and improvements to data evaluation methods.

Two key challenges for fusion energy production are wall erosion and tritium retention in wall materials. The Agency is encouraging collaboration on plasma–wall interaction studies for beryllium, tungsten (including irradiated tungsten) and various steels, all of which are regarded as the most important fusion materials. A related CRP on 'Data for Erosion and Tritium Retention in Beryllium Plasma-Facing Materials' was launched in 2012. Owing to the toxicity of beryllium, there has been little experimental work, and materials modelling has an important role to play.

About 45 participants were trained in fusion plasma modelling and nuclear structure and decay data evaluation, at joint Agency–Abdus Salam ICTP workshops in 2012. The workshops covered fusion plasma modelling using atomic and molecular data and nuclear structure and decay data.

Research Reactors

Improving the utilization of research reactors

The Research Reactor Benchmarking Database: Facility Description and Experiments brings together information for carrying out computational code validation exercises across a wide range of research reactor types. It was completed in 2012 through a CRP, which concluded in December.

A manual on *Neutron Transmutation Doping of Silicon at Research Reactors* (IAEA-TECDOC-1681) was published in 2012. The publication also includes a database on experience in Member States and on using neutron irradiation of silicon for the semiconductor industry.

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In October, the Agency cooperated with the Egyptian Atomic Energy Authority in convening the 7th AFRA Conference on Research Reactor Utilization and Safety, held in Cairo, Egypt (Fig. 2). The event provided a forum for managers, operators, users and safety specialists from 17 AFRA Member States to discuss topics related to research reactor utilization, operation and safety. Emphasis was given to the importance of cooperation among States through the sharing of available infrastructure and expertise, enhancing regional networking, promoting national and regional self-reliance, and

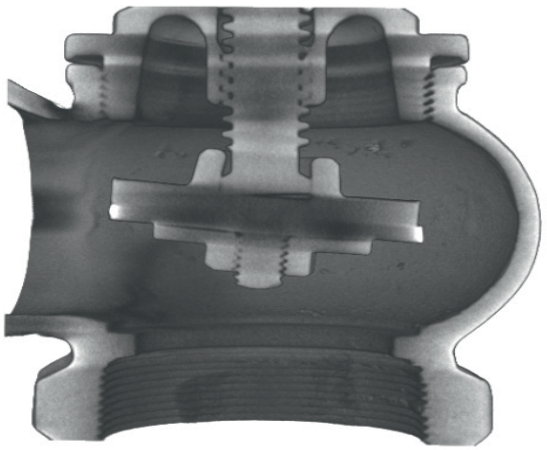

FIG. 2. A digital neutron imaging facility (left) licensed at the ETRR-2 reactor in Egypt. This state of the art installation will provide 2-D and 3-D non-destructive testing capabilities for various applications. On the right is a reconstructed image of a defective valve.

enabling the sustainable utilization and enhanced safety of research reactors.

Research reactors in education and training

A training course to assist Member States interested in initiating new research reactor projects or improving the utilization of existing research reactors was held in 2012. The six week course, organized by the Eastern European Research Reactor Initiative and supported by the Agency, was conducted at research reactors in Austria, the Czech Republic and Slovenia. Since this course was established in 2009, 44 students from Africa, Asia, Europe and Latin America have been trained.

As in previous years, the use and applications of research reactors were addressed in the programme of the School of Nuclear Energy Management. In 2012, two schools were conducted: in January in Abu Dhabi, United Arab Emirates, and in November at the Abdus Salam ICTP, in Trieste, Italy, which also included a technical tour of the TRIGA research reactor in Ljubljana, Slovenia.

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Research reactor infrastructure

A guidance publication stressing the importance of a sound justification for a research reactor based on national or regional needs, *Specific Considerations and Milestones for a Research Reactor Project* (IAEA Nuclear Energy Series No. NP-T-5.1), was issued in 2012.

As part of its activities to assist Member States in the aftermath of the accident at the Fukushima Daiichi nuclear power plant, the Agency developed guidance on performing safety reassessments for research reactors. One of the steps recommended was to carry out a graded approach commensurate with potential hazards.

The Agency's Research Reactor Database (RRDB) continued to be updated during the year. Data for 226 facilities were updated.

Research reactor fuel

The TRIGA MARK III research reactor in Mexico was converted from HEU to LEU fuel, and its final HEU fuel shipped back to the USA in March 2012. In September, conversion of the Maria research reactor in Poland to LEU fuel was also completed using specially designed LEU fuel. In December 2012, the final removal of all HEU from Austria took place following the complete conversion of the Vienna TRIGA reactor to LEU fuel. The safe repatriation of the Austrian fuel marks the removal of all TRIGA HEU fuel from civilian nuclear applications worldwide.

As part of the Russian Research Reactor Fuel Return programme, the Agency assisted in the repatriation to the Russian Federation of fresh HEU fuel and HEU spent fuel from Ukraine. In August and September 2012, HEU spent fuel was shipped from Uzbekistan and Poland. One additional shipment to remove fresh HEU fuel from Poland was also completed.

The Miniature Neutron Source Reactors (MNSRs) Working Group (which coordinates the conversion of MNSRs to LEU and the shipping of HEU spent fuel to China) held a series of meetings to plan the modification of the Skoda VPVR/M spent research reactor fuel casks, purchased in 2006 for the Russian Research Reactor Fuel Return programme, for the project. In China, construction of a test facility to demonstrate LEU fuel design progressed.

In order to facilitate the transition away from reliance on HEU for global molybdenum-99 (^{99}Mo) supply, the Agency organized a meeting in Vienna in November focused on specific issues confronting major HEU based producers and on opportunities for multilateral cooperation. Support to Member States is to continue until all major producers have converted to LEU by the end of 2015.

Research reactor operation and maintenance

To provide a peer review service on research reactor operational performance complementing Integrated Safety Assessments of Research Reactors (INSARR) missions, the Agency established the Operation and Maintenance Assessment for Research Reactors (OMARR) service in 2012. The first OMARR review mission was concluded in December to the National Institute of Standards and Technology in Maryland, USA. A pre-OMARR review mission to the TRIGA research reactor at

the University of Pavia, Italy, was conducted in October for the OMARR review mission scheduled for March 2013.

Accelerators for Materials Science and Analytical Applications

A CRP on improving the reliability and accuracy of heavy ion beam nuclear analytical techniques, expanding the existing high velocity dataset (Fig. 3), was completed in 2012.

In August, 39 trainees reviewed the status of ion induced radiation effects in semiconductors and insulators in a joint Agency workshop in Trieste, on the physics of radiation effect and its simulation for non-metallic condensed matter.

A technical meeting organized jointly by the Agency, the Support of Public and Industrial Research Using Ion Beam Technology (SPIRIT) and Japan was held in Croatia. The meeting focused on the development and utilization of MeV secondary ion mass spectrometry, and participants examined future R&D needs for molecular surface analysis and imaging.

to accelerator applications to make use of highly specialized applications to monitor, diagnose and remediate environmental and human health related problems (Fig. 4).

The Agency ion beam line at the Ruđer Bošković Institute (RBI) in Zagreb, Croatia, was upgraded to expand the analytical range of its particle induced X ray emission mode and to significantly improve detection limits for trace elements. With Agency support, researchers from Member States conducted a series of joint measurements at RBI in July using the upgraded ion beam line.

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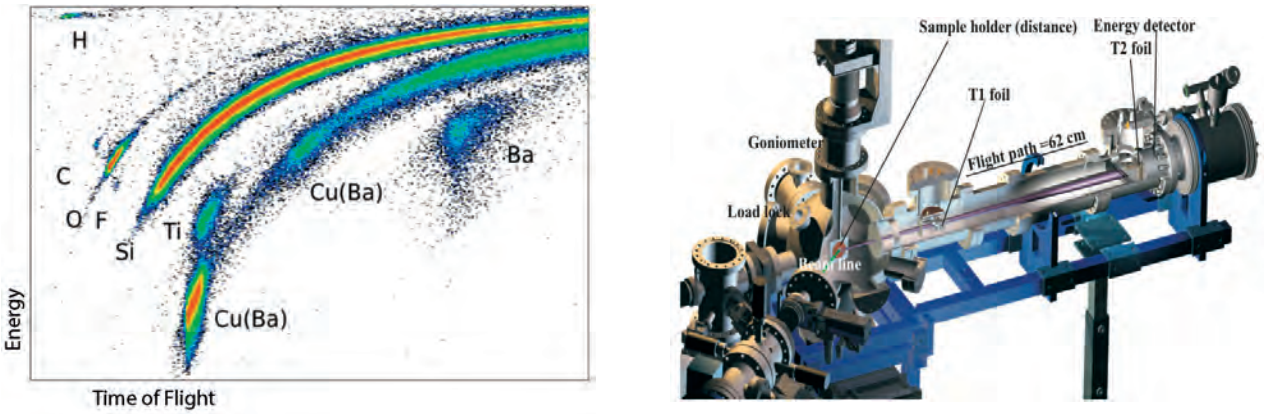

FIG. 3. Time of flight–energy histogram from a thin barium titanate film on silicon measured as part of the CRP on heavy ion beam nuclear analytical techniques (left), and the experimental setup (right).

Nuclear Instrumentation and Spectrometry

The construction of the ultra-high vacuum chamber (UHVC) continued in 2012, with most key phases of the project implementation completed. The UHVC, which is to be installed at the Elettra IAEA Collaborating Centre in Trieste, is being developed in collaboration with the Federal Institute of Physics and Technology, Berlin, and the Technical University of Berlin. The UHVC will enable Member States working on a variety of Agency projects related

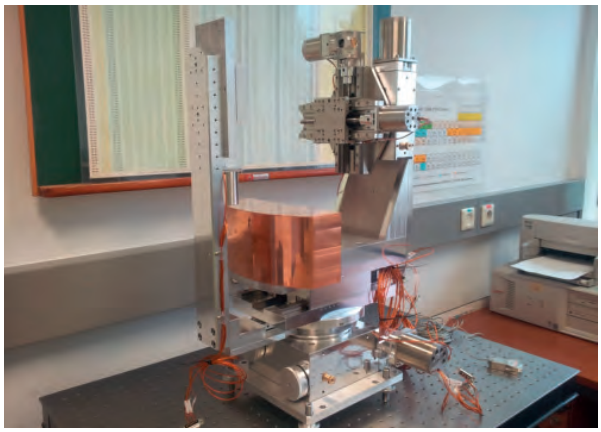

FIG. 4. The seven axis motorized UHVC sample manipulator test setup at the Agency's Nuclear Spectrometry and Applications Laboratory.

Nuclear Fusion

The 24th IAEA Fusion Energy Conference, held in October in San Diego, USA, attracted nearly 850 participants from 37 Member States and 5 international organizations. Approximately 700 papers were presented, including results of the ITER like wall experiment (Fig. 5) on the Joint European Torus (JET) fusion device in the United Kingdom. The conference provided encouraging news of advances in fusion research, including the steady progress in the construction of ITER, and numerous advances at different laboratories in the physics basis for runaway electron control and the mitigation of disruptive instabilities in ITER.

With ITER under construction and many countries initiating R&D activities as part of the Demonstration Power Plant (DEMO), which envisions the use of fusion energy on an industrial, power plant scale, the Agency established an annual series of DEMO Programme Workshops to facilitate international cooperation and define and coordinate DEMO activities. Approximately 70 participants attended the first of such workshops, held in October at the University of California, Los Angeles, USA. Discussions highlighted the importance of ITER as a critical element of the DEMO programme. Although countries are developing their own strategies independently, given the breadth of expertise and the scale of facilities and activities required to develop fusion, international collaboration will remain an essential component for advancing in this area.

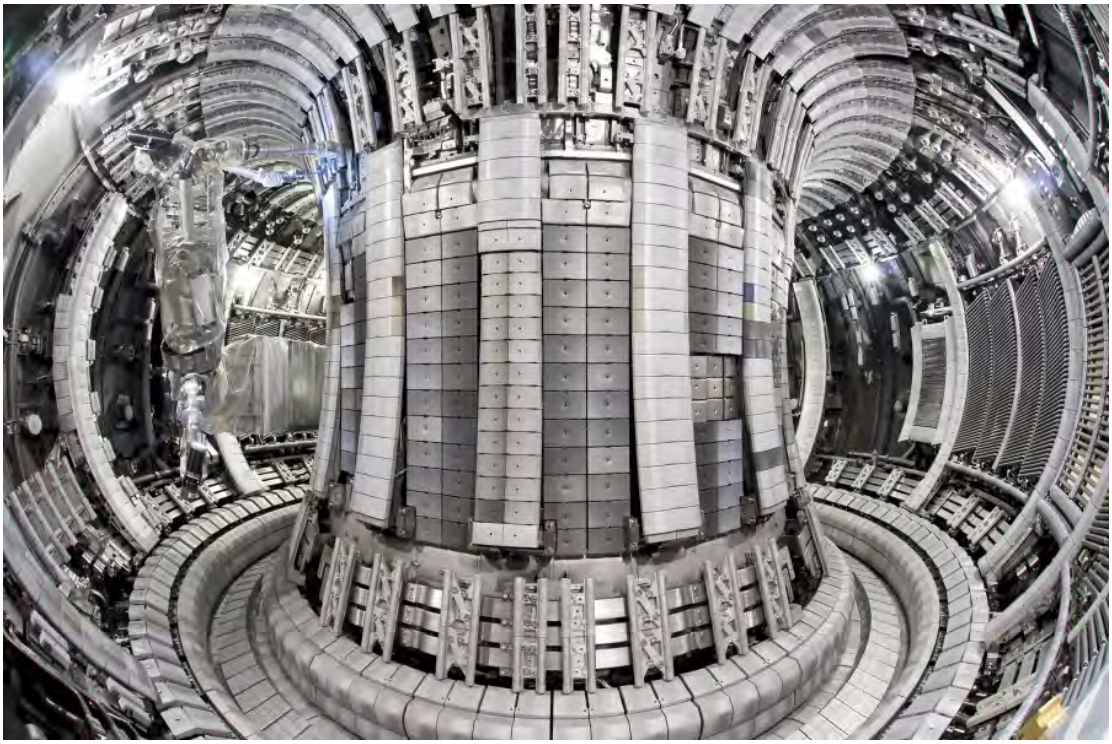

FIG. 5. The inside of the JET vacuum vessel with the installation of the ITER-like wall completed.