

IAEA activities in support of sustainable utilization & applications of research reactors

D. Ridikas, V. Semkova, E. Vargas, M. Romero

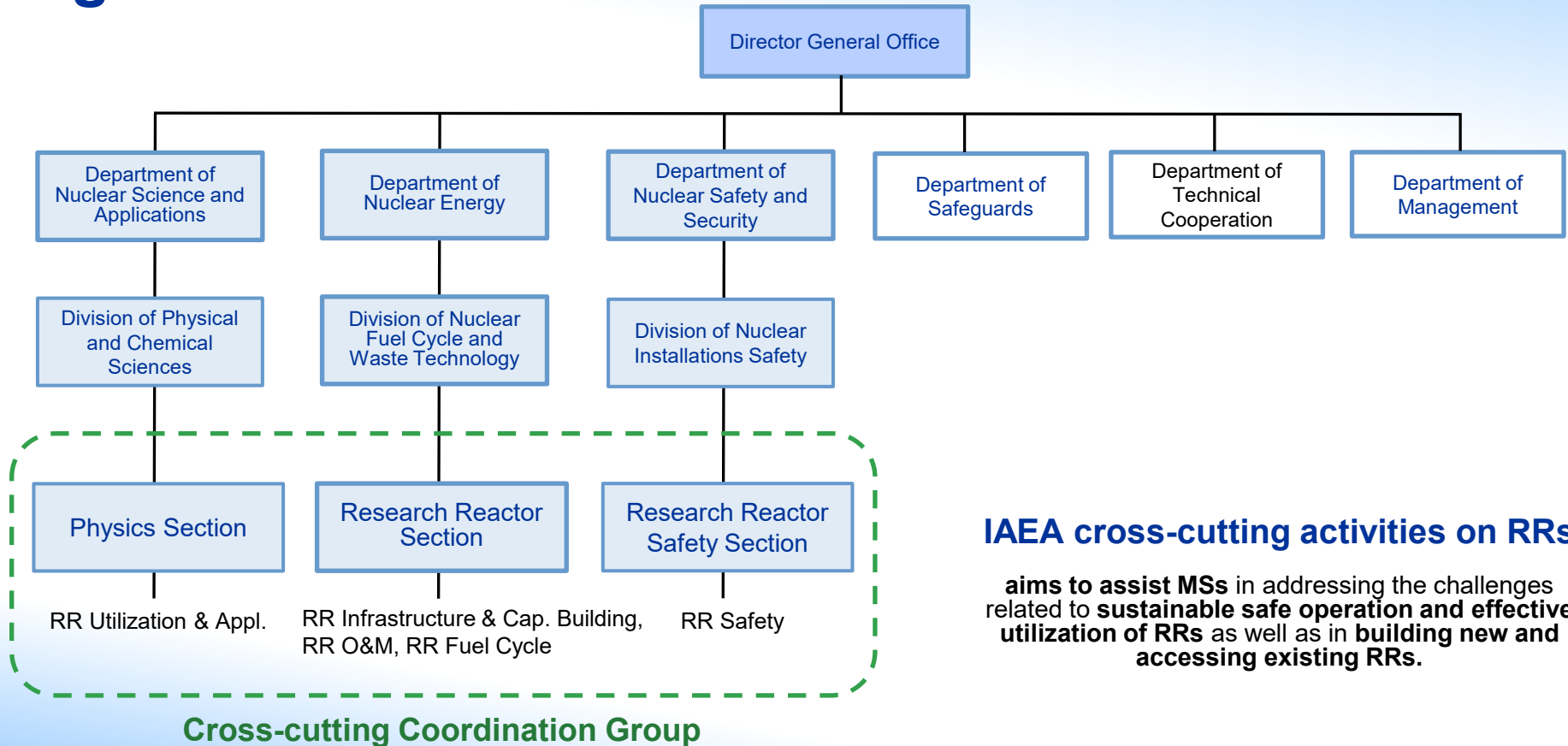
Physics Section
Division of Physical and Chemical Sciences
Department of Nuclear Sciences and Applications

Outline

- **Organization & involved staff**
- **Highlights of recent achievements**
- **Future plans**
- **Neutrons4NA initiative**



IAEA work on research reactors: Organizational structure



IAEA cross-cutting activities on RRs

aims to assist MSs in addressing the challenges related to **sustainable safe operation and effective utilization of RRs** as well as in **building new and accessing existing RRs**.

Physics Section: main technical areas



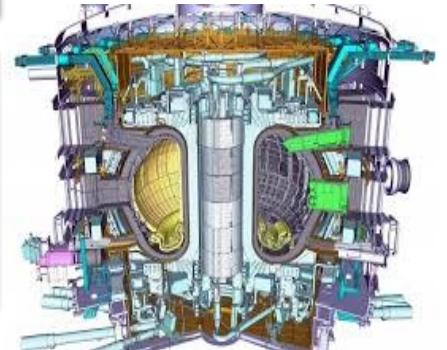
1.4.2 Research & Applications with Accelerators & Neutron Sources (incl. RR applications)



1.4.3 Nuclear Instrumentation (incl. laboratory in Seibersdorf)



1.4.4 Nuclear Fusion Science & Plasma Physics (incl. coop. with ITER)



Subprogramme 1.4.2 Research and Applications with Accelerators and Neutron Sources



Main Objectives:

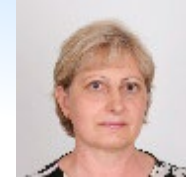
- Support MSs in strengthening their capabilities to conduct research with accelerators and neutron sources (incl. RRs)
- Support MSs in strengthening their capabilities to expand the applications of accelerators and neutron sources (incl. RRs)

Projects:

- 1.4.2.1 Accelerator and neutron source applications in multiple disciplines
- 1.4.2.2 Enhancing research with accelerators and neutrons

Involved Staff

- **Mr Danas Ridikas (P5)**, Section Head, 10-15 %
- **Ms Valentina Semkova (P3)**, Nuclear Physicist (Neutrons), 100 %
- **Mr Eugenio Vargas (C1)**, Consultant (Research Reactors), US EB, 100 %
- **Research Reactor Specialist (P4)**, to be advertised



Interns:

- Ms Morgan Romero, 2024-2025, 12 months



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- Neutrons4NA initiative



IAEA International RR Conference, 11-15 Nov. 2024



300+ in person and 200+ virtual participants, over 80 Member States, organized jointly with NE and NS

- **80+ oral presentations**
- **130+ posters**
- **5 side events**
- **Proceedings in progress**



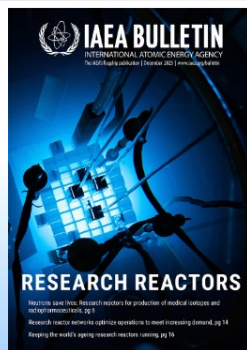
SE1: The role of RRs in advancing SDGs

SE2: Nuclear security enhancement based on emerging technologies and threats

SE3: Capacity building based on RR centres

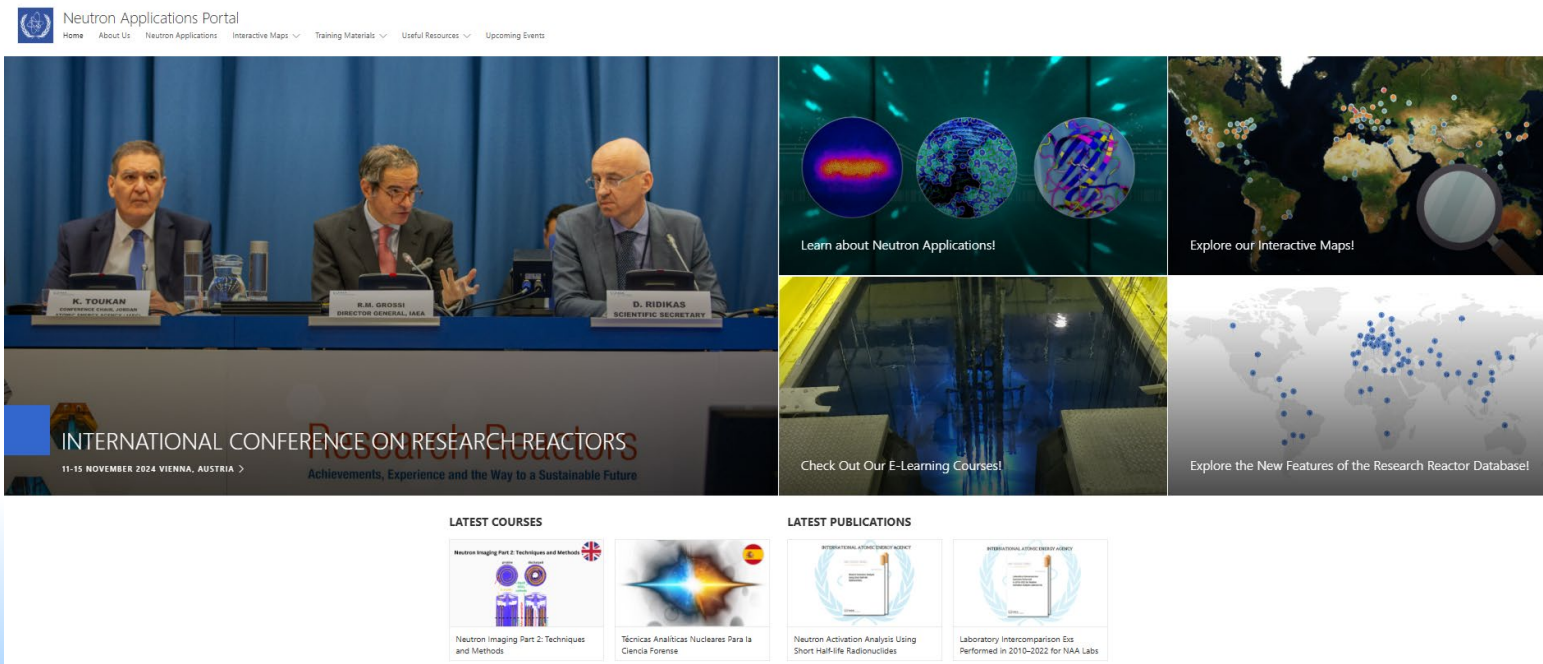
SE4: Safety considerations in use of advanced and innovative technology in RRs

SE5: Women in RRs: challenges and opportunities



Portals and databases (1/2)

- **Neutron Applications Portal fully redesigned and updated**
<https://nucleus.iaea.org/sites/neutrons>
- Number of visitors/users continues to grow



The screenshot displays the Neutron Applications Portal website. At the top, the IAEA logo is on the left, and the text "Neutron Applications Portal" is followed by a navigation menu: Home, About Us, Neutron Applications, Interactive Maps, Training Materials, Useful Resources, and Upcoming Events. The main content area is divided into several sections. On the left, a large banner features a photograph of three men at a conference table with the text "INTERNATIONAL CONFERENCE ON RESEARCH REACTORS" and "11-15 NOVEMBER 2024 VIENNA, AUSTRIA". To the right of this banner are four smaller promotional tiles: "Learn about Neutron Applications!" with three circular icons, "Explore our Interactive Maps!" with a world map and a magnifying glass, "Check Out Our E-Learning Courses!" with a reactor core image, and "Explore the New Features of the Research Reactor Database!" with a world map and blue dots. Below these tiles are two columns of "LATEST COURSES" and "LATEST PUBLICATIONS". The "LATEST COURSES" section includes "Neutron Imaging Part 2: Techniques and Methods" (with a UK flag) and "Técnicas Analíticas Nucleares Para la Ciencia Forense" (with a Spain flag). The "LATEST PUBLICATIONS" section includes "Neutron Activation Analysis Using Short Half-Life Radionuclides" and "Laboratory Intercomparison EIS Performed in 2010-2022 for NAA Labs".

Neutron Applications Portal

Home About Us Neutron Applications Interactive Maps Training Materials Useful Resources Upcoming Events

INTERNATIONAL CONFERENCE ON RESEARCH REACTORS

11-15 NOVEMBER 2024 VIENNA, AUSTRIA >

Achievements, Experience and the Way to a Sustainable Future

Learn about Neutron Applications!

Explore our Interactive Maps!

Check Out Our E-Learning Courses!

Explore the New Features of the Research Reactor Database!

LATEST COURSES

Neutron Imaging Part 2: Techniques and Methods

Neutron Imaging Part 2: Techniques and Methods

Técnicas Analíticas Nucleares Para la Ciencia Forense

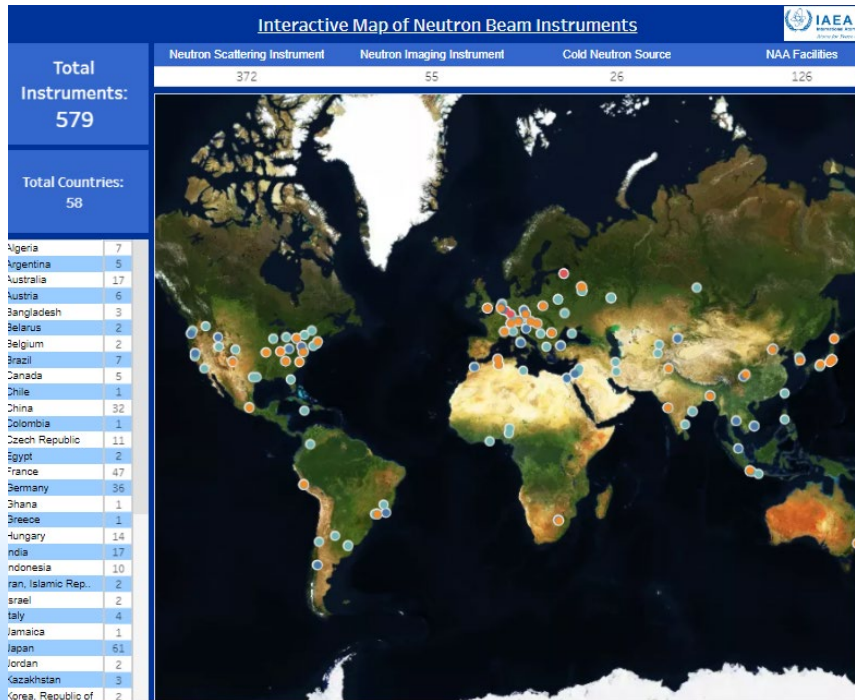
LATEST PUBLICATIONS

Neutron Activation Analysis Using Short Half-Life Radionuclides

Laboratory Intercomparison EIS Performed in 2010-2022 for NAA Labs

Portals and databases (2/2)

- Updated online databases
- Neutron applications explained
- Linkage to IAEA RRDB clearly established
- More improvements ongoing





IAEA

Neutron Applications

Neutron Applications: Unlocking Innovation Across Disciplines

Neutrons play a vital role in advancing science, technology, and medicine. Their unique characteristics—such as deep penetration, non-destructive interaction with matter, and sensitivity to light elements—make them ideal for a broad range of applications.

From enhancing materials and supporting clean energy solutions to enabling precise medical diagnostics and treatments, neutron-based techniques are used by researchers, industry professionals, and educators around the world. This section provides an overview of these diverse applications and their impact across disciplines.

Use the navigation menu to explore specific application areas in more detail.



- Doping of Silicon (Si)
- Education and Training
- Gemstone Colouration
- Geochronology
- Isotope Production
- Material and Fuel Irradiation
- Neutron Activation Analysis (NAA)
- Neutron Imaging
- Neutron Scattering
- Neutron Therapy
- Nuclear Data Provision
- Other Applications

Doping of Silicon (Si)

Doping of Silicon (Si)

Neutron Transmutation Doping (NTD) is a method used to introduce phosphorus atoms into high-purity silicon crystals by exposing them to thermal neutrons. The process transforms silicon atoms into phosphorus atoms through nuclear reactions, creating uniformly doped silicon with precise electrical properties for high-performance semiconductor applications.

Scientific process:

- Silicon-30 captures a neutron to form radioactive silicon-31
- Silicon-31 undergoes beta decay to become phosphorus-31
- Phosphorus atoms act as uniform n-type dopants in the silicon lattice
- No physical diffusion is required, ensuring high doping homogeneity

Why it matters:

- Enables production of high-power, high-voltage semiconductors
- Offers better uniformity than conventional chemical doping methods
- Supports electronics in electric vehicles, rail systems, and aerospace
- Reduces production defects and improves energy efficiency in devices

Where it's used:

- Research reactors with precise thermal neutron flux capabilities
- Semiconductor manufacturing industries
- Power electronics suppliers for energy, automotive, and aviation sectors



Click here to see which research reactors use this technique.

Examples of Main Technical Meetings



- TM on **Advances in Neutron Scattering and Imaging at Low and Medium Flux Accelerator and RR-based Neutron Sources**, April 2024, Vienna; 16 participants from 12 MSs
- TM on **Products and Services of RRs**, July 2024, Vienna; 14 participants from 14 MSs
- Joint IAEA–French CEA TM on **Neutrons for Nuclear Sciences and Applications (Neutrons4NA)**, France, October 2024, 35 participants from 23 MSs
- TM on **Role of Neutron Analytical Techniques in Socioeconomic Development**, Vienna, Austria, 22-25 April 2025 with 15 participants from 15 MSs.
- IGORR Conference and IAEA TM on **Integrated Management Systems for the Sustainable Safe Operation and Effective Utilization of Research Reactors**, Mito, Japan, 16-19 June 2025; cross-cutting

Examples of Main Training Events



- TR Workshop on **Practical Approaches for NAA**, Ljubljana, Slovenia, 30 September 2024; 10 participants from 8 MSs
- TR Workshop on **Strategic Planning for RRs**, Vienna, Austria, October 2024; 12 participants from 10 MSs.
- The 13th annual **AONSA Neutron School**, organized in cooperation with the IAEA Mumbai, India, 24-28 November 2024 with 110 Indian participants, and 20 overseas participants from 7 MSs
- TR Workshop on **Application of k₀-method for NAA**, was held at IAEA Headquarters, Vienna, Austria, 5-9 May 2025 with 9 participants from 7 MSs.
- TR Workshop on **Strategic Planning for RRs**, Vienna, Austria, 9–23 May 2025 with 13 participants from 8 MSs.

Examples of webinars

- **Webinar on Importance of Strategic Planning to Increase the Sustainable Value Creation in Nuclear Science and Technology**, 11 September 2024. Experts from Argentina, Japan and South Africa shared their experience on different neutron facilities and highlighted the importance of strategic planning to create value. ~50 participants.
- **Webinar on the Advancements in Cancer Care Through BNCT**, 25 September 2024. Experts from: UK, USA, Japan, China and Germany shared their experience, latest developments and future prospects of BNCT. ~150 participants.
- **Webinar on “Neutrons4NA: Empowering Progress in Nuclear Sciences and Applications With Neutrons”**, 31 January 2025. Experts from Japan, USA, UK, Czech Republic, France and IAEA contributed and facilitated panel discussions on projects to establish and operate neutron sources globally, highlighting their positive outcomes on society and opportunities for the future. ~130 participants.
- **Webinar on Harnessing Neutron Transmutation Doping of Silicon for Clean Energy and Innovation**, 26 March 2025. Experts from Germany, Japan, South Africa, and the IAEA provided an update on the latest advances, current challenges, and future plans related to NTD-Si. ~120 participants

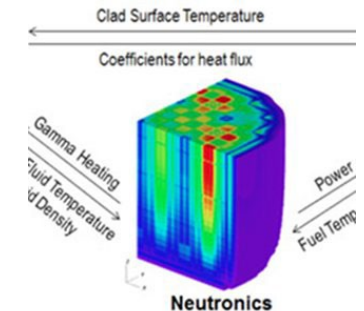
Coordinated Research Projects

Cross-cutting CRP on **Development of Coupled Neutronic and Thermal-Hydraulic Calculational Methodologies for Research Reactors including Analysis and Treatment of Uncertainties** (2022-2026), **NA/NE/NS** with EB support from France and USA

→ Will result in **more accurate, higher fidelity, multi-physics approaches** in performing research reactor analysis. It also aims to develop both computational benchmarks (for code verification) and benchmarks based on experimental data (for code validation).

→ **Partners (14):** Argentina, Australia, Canada, China, Czech Republic, France, Korea, Algeria, Bangladesh, Egypt, Ghana, Indonesia, Morocco, South Africa

- 1st RCM, Vienna, Austria; in 2022; 43 participants from 16 MSs
- **TR Workshop, ANL, USA, in 2023; 68 participants from 17 MSs**
- 2nd RCM, Bariloche, Argentina, in 2024, 32 participants from 22 MSs
- 3rd RCM, Venna, Austria in 2025



Integrated RR Utilization Review missions

Objectives

- **Assess current utilization profile**
- **Identify opportunities to expand utilization**
- **Strengthen user community and enlarge the utilization base**

IAEA Missions Highlight Potential of Research Reactors for Innovative Nuclear Energy Solutions

Emma Midgley, IAEA Office of Public Information and Communication

JUL
31
2023



Related stories

-  [IAEA Conducts First Integrated Research Reactor Utilization Review](#)
-  [Integrated Research Reactor Utilization Review Mission Concludes in Italy](#)
-  [Supporting the Operation and Safety of Research Reactors: Exploring the IAEA's Peer Review Missions](#)
-  [Strategically Harnessing the Full Potential of Research Reactors](#)



IRRUR

Integrated Research Reactor
Utilization Review

Assess current utilization
profile of a research reactor

Identify opportunities
to expand utilization in
education and training, R&D
and provision of products
and services

Strengthen the
research reactor
user community and
enlarge the utilization
base

IRRUR missions (8) implemented so far



2022:

1. **Chile (RECH-1):** 5 MW RECH-1 located at La Reina Nuclear Centre, Chile, and operated by the CChEN.
2. **Peru (RP-10 and RP-0):** 10 MW RP-10 located at Nuclear Centre Oscar Miroquesada de la Guerra (RACSO), Peru, and operated by the IPEN.
3. **South Africa (SAFARI-1):** 20 MW SAFARI-1, operated by NECSA.

2023:

4. **IRAN (Isfahan):** 3 Isfahan Research Reactors: 30 kW MNSR type, the HWZPR critical assembly, and the LWSCR subcritical assembly, operated by the Isfahan Nuclear Technology Centre.
5. **USA (NRAD):** 250kW NRAD operated by the INL.
6. **USA (MITR):** 6MW MIT Research Reactor operated by the MIT Nuclear Reactor Laboratory.

2024:

7. **Canada (McMaster):** 3MW McMaster University Nuclear Reactor.

2025:

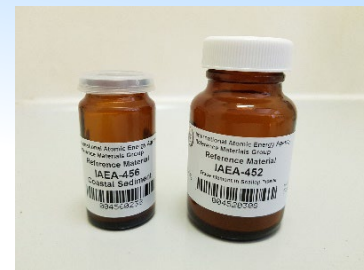
8. **Ghana (GHARR-1):** Pre-IRRUR mission to Ghana Research Reactor, operated by GAEC.

Proficiency Tests for NAA & other Analytical Techniques



Organized twice a year in support IAEA Member States laboratories to:

- identify analytical problems
- improve the quality of their analytical results
- acquire / maintain their accreditation
- provide a regular forum for discussion and technology transfer in this area
- **In 2025: +100 analytical laboratories participate, representing +50 countries**



Scheme of the proficiency test:

- Provision of various samples at no cost
- Full anonymity of laboratories is granted
- Issue of final reports



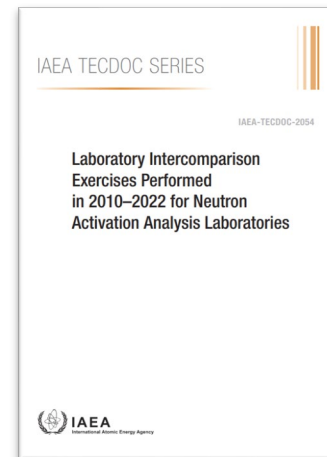
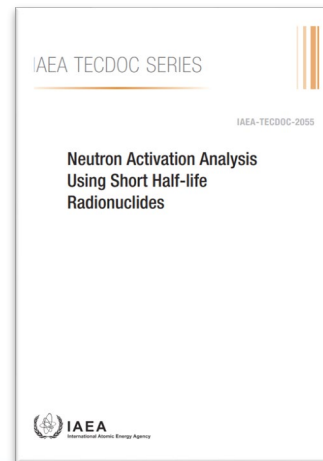
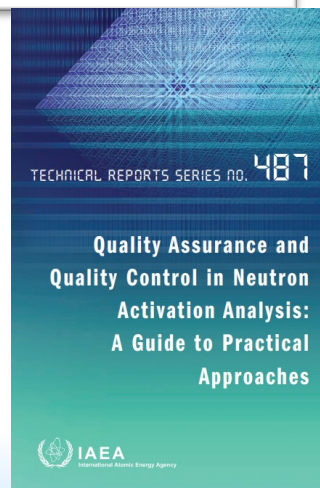
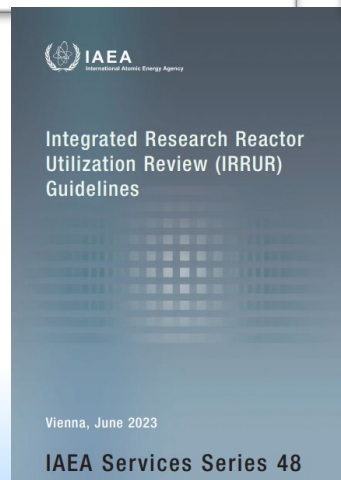
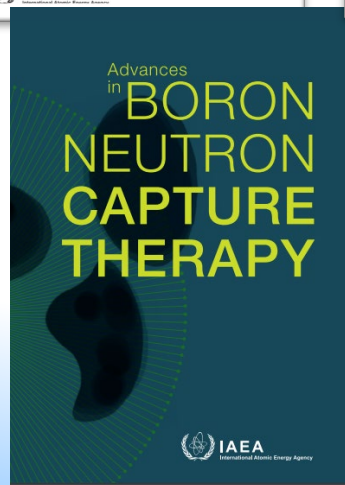
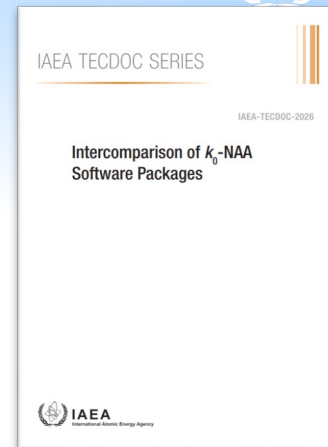
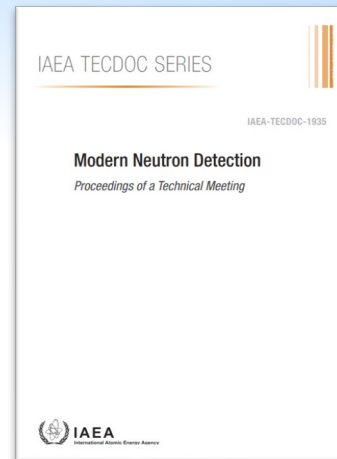
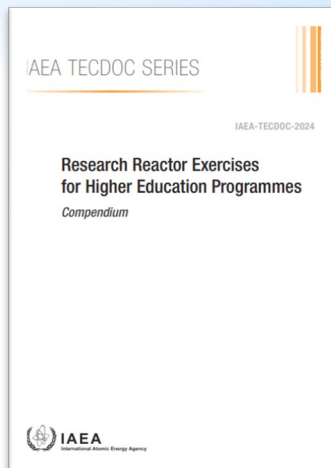
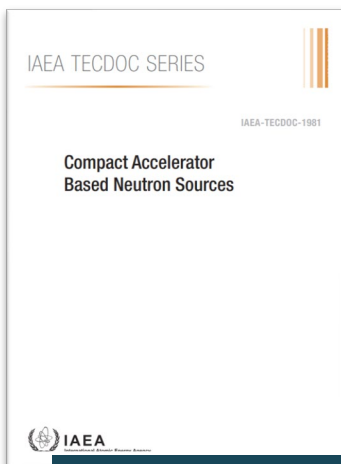
Previous Proficiency Tests

PTNATIAEA/20	April 2022 - December 2022	clay sample plant sample	Download PDF final report
PTNATIAEA/19	May 2021 - March 2022	clay sample plant sample	Download PDF final report
PTNATIAEA/18	February 2020 - May 2021	Soil	Download PDF final report

More info: <http://www.pt-nsil.com/>

Selected Publications

<https://www.iaea.org/publications>



Outline

- Organization & involved staff
- Highlights of recent achievements
- **Future plans**
- Neutrons4NA initiative



Future plans



- **IRRUR missions**

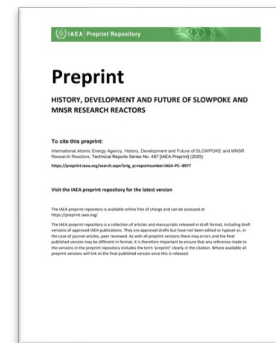
- GAEC, Ghana; planned in Dec. 2025
- Requests expected from Asia-Pacific region in 2025-2026

- **New CRPs**

- Neutron beam instrumentation at low and medium intensity neutron sources; RB budget secured; expected to start in 2025
- Boron Neutron Capture Therapy; EB funding secured; expected to start in 2026

- **Publications in progress**

- History, Development and Future of the SLOWPOKE and MNSR RRs; preprint issued
- Research Reactor Produced Radioisotopes, update of TECDOC 1340; in draft
- Applications of Research Reactors (Rev.1), Nuclear Energy Series; in draft
- ...



Future plans



- **Events in 2025**

- **Joint IAEA–Consultative Committee** for Ionizing Radiation Workshop on Neutron Beams at High Energy: Applications and Metrology, Vienna, Austria, 7-8 July 2025, jointly with NDS/NAPC
- **Regional Training Workshop** on Strategic Planning for Research Reactors, Bangkok, Thailand, 4 – 8 August 2025
- Participation/contribution to **International HANARO Symposium**, Daejeon, South Korea, 10-12 September 2025
- **Training Workshop** on Advanced Use of Neutron Imaging for Research and Applications, Prague, Czech Republic, 6-10 October 2025
- **Annual Training Workshop** on the Safe Operation and Applications of Neutron Generators, Seibersdorf, Austria, 13-24 October 2025
- **Training Workshop** on Advances in BNCT, Okayama, Japan, 18-21 November 2025
- **The 14th annual AONSA Neutron School, organized in cooperation with the IAEA**, Tokai Ibaraki, Japan, 18-21 November 2025

Outline

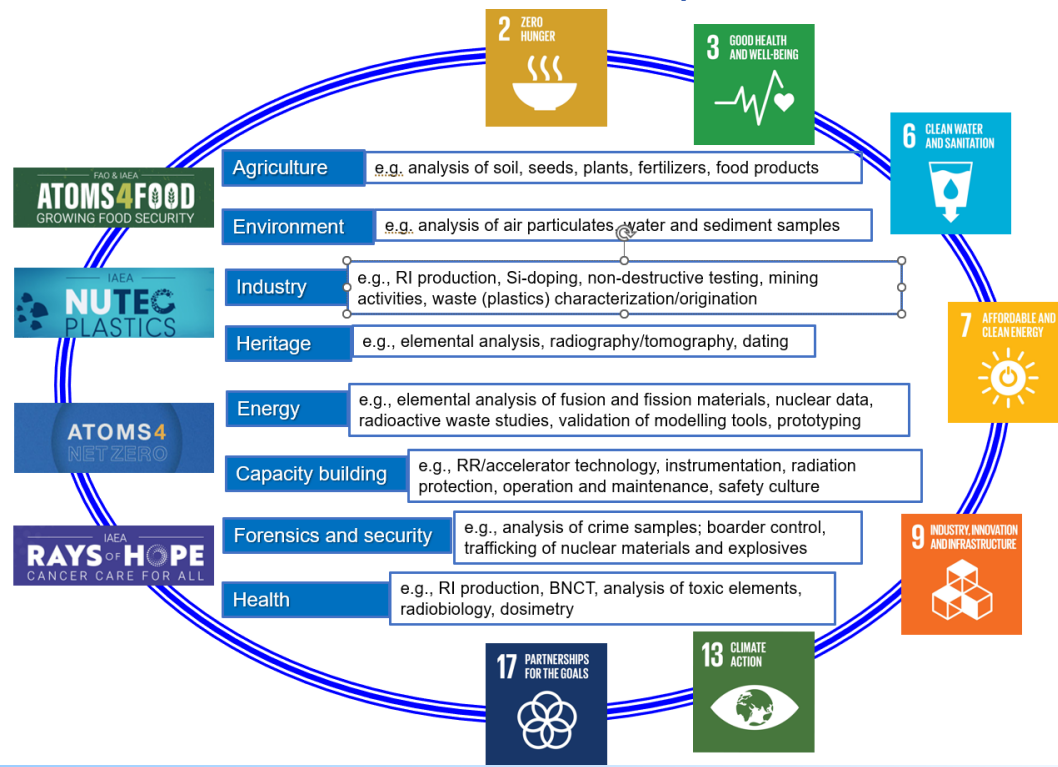
- Organization & involved staff
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- **Neutrons4NA initiative**



Neutrons4NA initiative: rationale



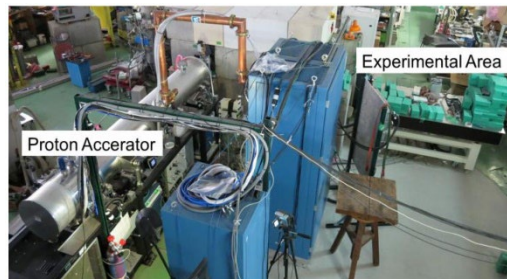
Tailored and stepwise approach through promotion, capacity building, technology transfer and facilitated access to **Neutrons4NA** and resulting socioeconomic development in the Member States



Neutrons4NA: objective



**Bridging the gap between neutron generators, CANS and RRs:
tailored and stepwise approach**



	Neutron generator	Compact accelerator-based neutron source	Research reactor / spallation source
Neutron source, n/s	$<10^{10}$	$<10^{14}$	$>10^{15}$
Capital cost, €M	0.1-0.2	3-10	60-700
O&M costs, €M	0.02	0.2-1.0	3-100
Staff, number	1	2-3	10-100

Neutrons4NA: scope of support

- Well established facilities offering expertise and advice services to perform justification statement and feasibility study for decision making-process on investment:
 - Quantification of needs,
 - Choice of tailored and cost-effective technology,
 - Infrastructure assessment,
 - Cost-benefit and risk analysis.
- Long term facilitated support of the project at different stages of implementation, e.g.
 - Capacity building (hands on training...),
 - Share of experience from well-established and relevant facilities,
 - Share of experience regarding tailored and cost-effective technology selection.



E.g. IAEA Neutron Science Facility (NSF) at SEIB

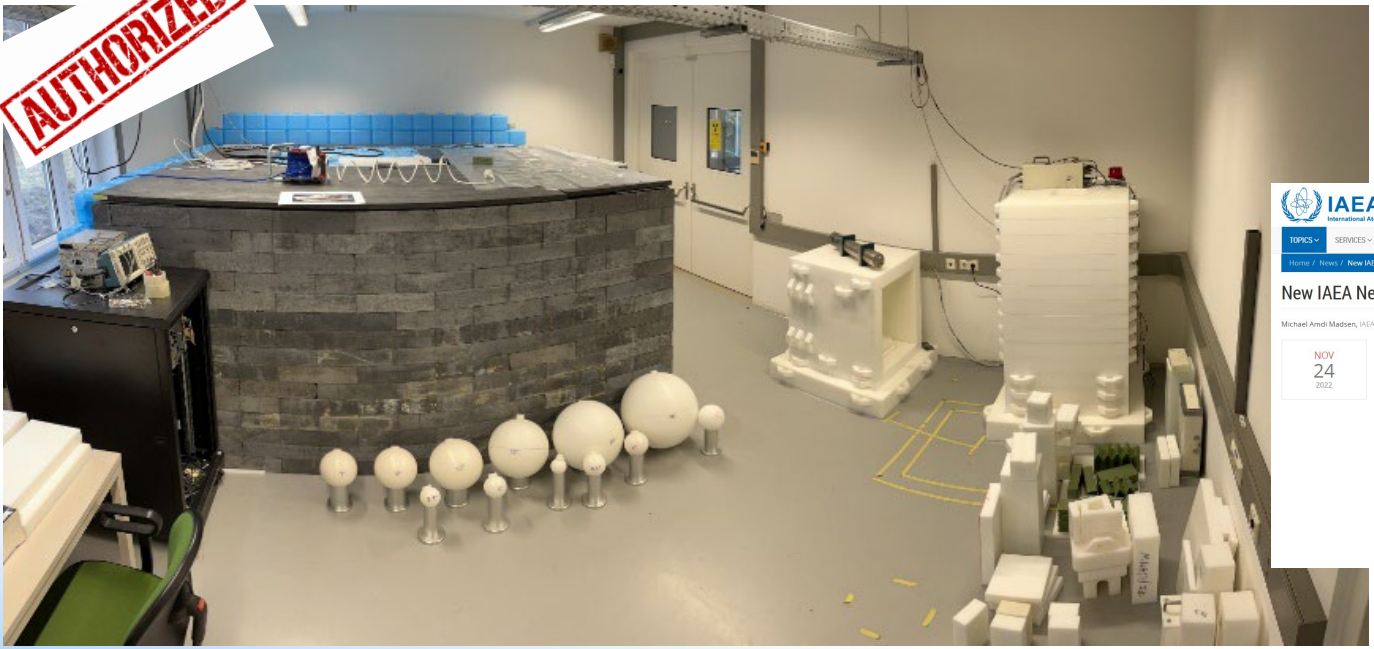



NSF is based on two neutron generators, **operational since 2022**

- **D+D reaction → 2.45 MeV neutron source** (fission neutrons, 5e6 n/s); US EB funded
- **D+T reaction → 14.1 MeV neutron source** (fusion neutrons, 5e8 n/s); Australia donation



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New IAEA Neutron Facility Delivers First Hands-on Training

Michael Ansh Madsen, IAEA Office of Public Information and Communication

NOV 24 2022



Francisco Idigoras handles a neutron generator at the new IAEA facility in Seibersdorf, Austria. (Photo: D. Calma/IAEA)

Related stories

- Fingerprinting Materials: IAEA Updates Neutron Activation Analysis E-learning Course
- What Are Particle Accelerators?
- Neutronic Blast Fusion Materials in New IAEA Project
- IAEA Breaks Ground to Expand and Modernize its Seibersdorf Laboratories
- IAEA Nuclear Security Training and Demonstration Centre Nears Completion

E.g. IAEA Ion Beam Facility (IBF) project at SEIB

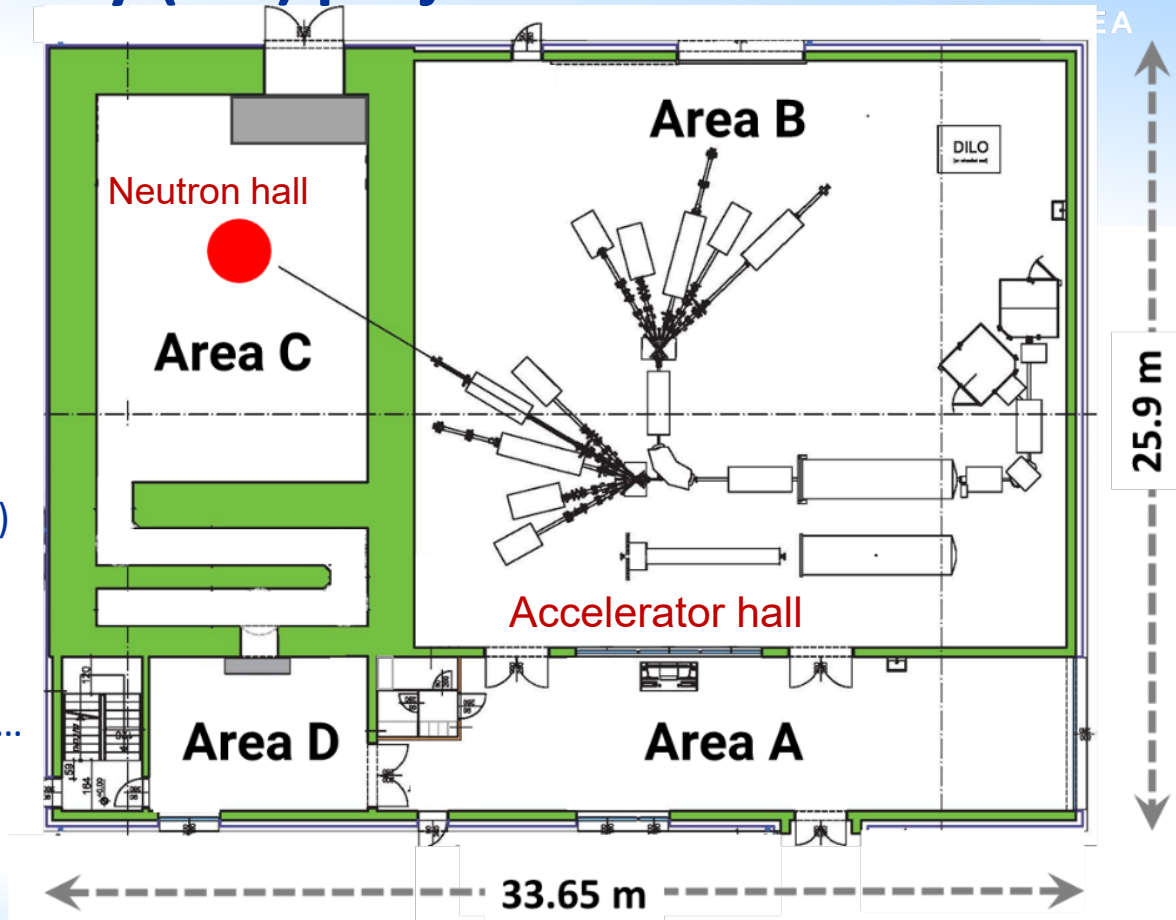


→ 6MeV protons (up to 50μA current)
+ heavier ions

→ Multiple beam lines/end-stations
(PIXE, PIGE, RBS, Microbeam, implanter...)

→ **Neutron production capability**

- **Max. source intensity:** 5×10^{11} n/s
- **Max. thermal flux:** 10^6 n s⁻¹cm⁻²





IAEA

International Atomic Energy Agency

Thanks for your attention!



IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY
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RESEARCH REACTORS

Neutrons save lives: Research reactors for production of medical isotopes and radiopharmaceuticals, pg 6
Research reactor networks optimize operations to meet increasing demand, pg 14
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Establishing ionizing radiation facilities in the Philippines and beyond, pg 22



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Fusion Energy

What is fusion, and why is it so difficult to achieve? page 4
ITER: The world's largest fusion experiment, page 10
Uniting countries through fusion research and cooperation, page 22

