



**IAEA**

*60 Years*

*Atoms for Peace and Development*

# XRF Related Activities at the IAEA Nuclear Science and Instrumentation Laboratory

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# An autonomous international organization within the United Nations system



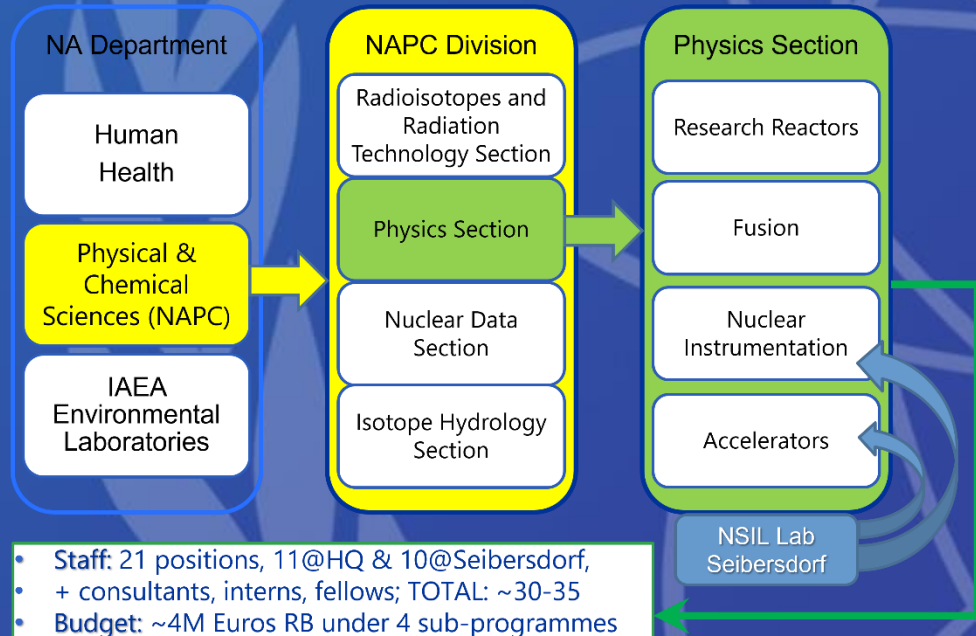
Founded in 1957

178 Member States (as of 19 September 2023); 2500+ staff from over 100 Member States

- HQ in Vienna
- Labs in Seibersdorf, Vienna and Monaco
- Regional offices in Toronto and Tokyo; Liaison offices in New York and Geneva

## The Department of Nuclear Science and Applications (NA)

### Structure



- Staff: 21 positions, 11@HQ & 10@Seibersdorf, + consultants, interns, fellows; TOTAL: ~30-35
- Budget: ~4M Euros RB under 4 sub-programmes



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# IAEA mission - Pillars of the IAEA

*The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose*

- **Nuclear Technology and Applications**

The world's focal point to support peaceful applications of nuclear science and technology in the priority areas of developing MSs

- Energy
- Health
- Addressing environmental issues
- Water
- Food and agriculture
- Industry
- Nuclear Science

- **Safeguards & Verification**

The world's nuclear inspectorate

- **Safety & Security**

Helps countries to establish/upgrade nuclear safety and security infrastructure



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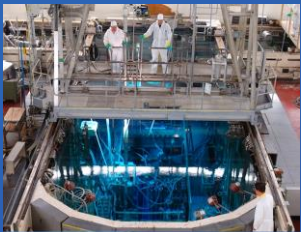
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Science & Technology



Safeguards & Verification



Safety & Security

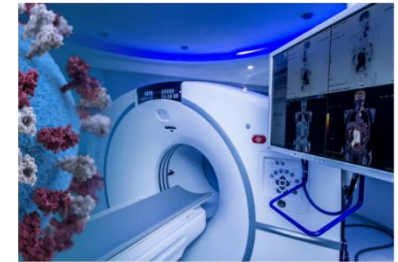
sustainable agricultural development



food security and nutrition



cancer diagnosis and treatment modalities



cleaner water for more people



protecting the environment



Providing expertise for industrial applications



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## The tools

- Consultancy Meetings: 5 to 10 experts are invited to provide specialized advice and recommendations on particular scientific or other aspects of relevance for the IAEA's programmes and activities
- Technical Meetings: Technical events with 30-40 participants, aiming at enhancing interaction among experts, share knowledge and expertise, establish scientific collaborations and create topical networks
- Coordinated Research Projects (CRPs): Networks of 10-15 research institutes from developed and developing countries that work in coordination for 3-5 years to acquire and disseminate new knowledge/technology. Periodic meetings are organized to report progress and plan/coordinate future activities.
- Training Workshops, Courses and dedicated Schools: Events enabling participants to acquire specific knowledge – theoretical or practical or both – on a given subject of interest. Organized at IAEA laboratories, ICTP Trieste, or at labs in member states
- Publications of technical documents and guides: Publications of reported results, shared good practices and lessons learned; produced by CRPs or Technical Meetings.
- National, regional, interregional Technical Coordination (TC) projects: projects to build capacity via Expert Missions, training of personnel, purchase of equipment, assistance in establishing new facilities, ...

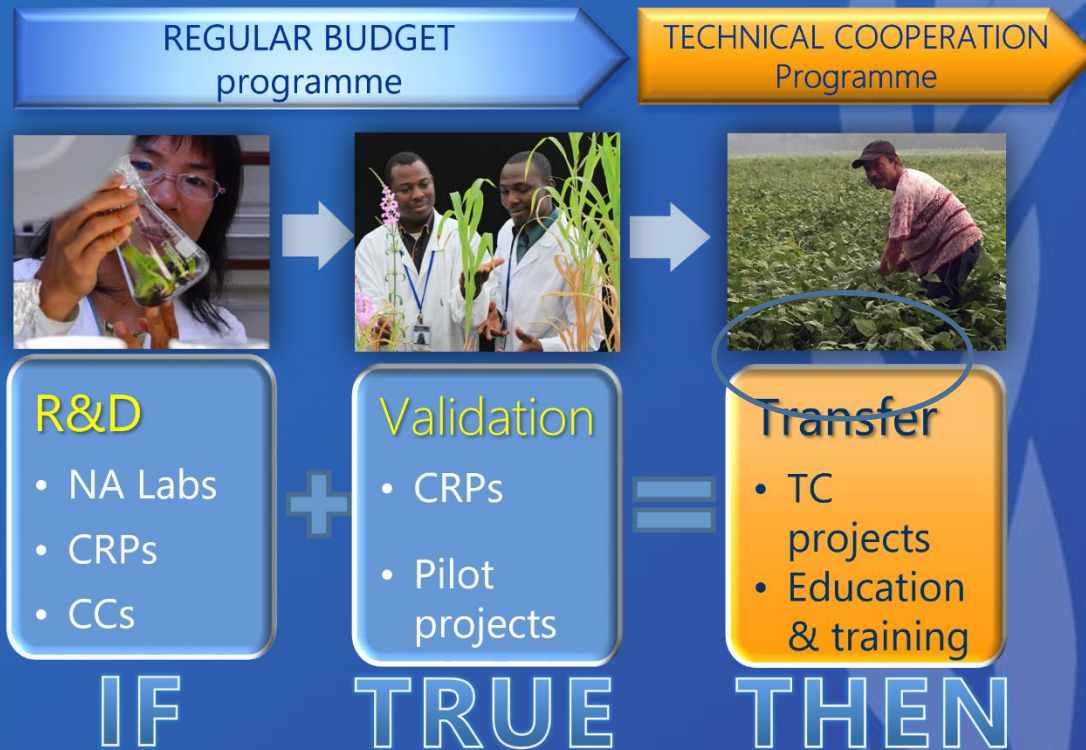


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# The IAEA approach to serve the Member States



## Key Principles for TC Projects

- Contribute to development goals
- Respond to Member States' needs
- Undertake peaceful use of nuclear technology
- Comply to IAEA safety and security rules
- Ensure Member State ownership and shared responsibility
- Ensure non-discrimination of stakeholders
- Ensure cooperation among Member States and with partners
- Transparency



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## The IAEA TC Programme

Primary mechanism for transferring nuclear technology to Member States, implemented through National, Regional or Interregional TC Projects

- Capacity building
- Networking
- Knowledge sharing
- Partnership building



**The SESAME Interregional TC Project  
(2010-2023; ≈2M€)**



(SESAME was inaugurated on May 16, 2017, in Jordan)



Fellowships  
Scientific visits



Equipment &  
materials



Training courses  
& workshops

Expert assistance



Conferences,  
Symposia



Over the last decade IAEA has provided extensive support to train staff at SESAME to commission and run the facility. This has included instruments, the training of 66 technical and scientific fellows in beamline technologies, and over 30 expert missions to SESAME to help build capacity in the installation and testing of equipment.

IAEA also facilitated the networking of SESAME staff with experts from other synchrotron facilities in Europe, the United States and Japan.



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# Physics Section profile

The Physics Section supports the IAEA Member States in the following areas:

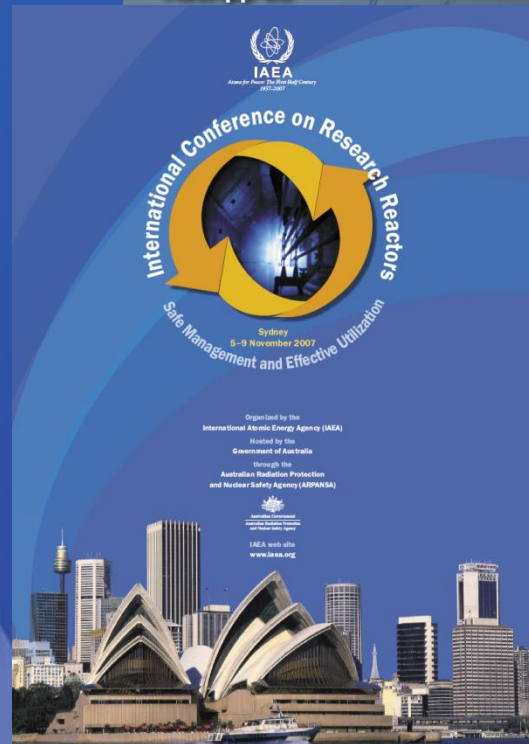
- **Accelerators**
- **Research reactors**
- **Controlled fusion**
- **Nuclear instrumentation and spectrometry**

**Major objective** is to promote nuclear science & technology

22nd IAEA  
Fusion Energy Conference

13–18 October 2008

Ninth International Topical Meeting on  
Nuclear Applications and  
Utilization of Accelerators  
AccApp'09



Self-sustaining plasma  
~ 2030-2050

$10^{22}$   
> (keV)]

org/meetings

lear Society

IAEA.org/meetings  
CN-073





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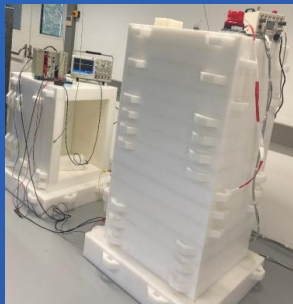
# Physics Section: main technical areas



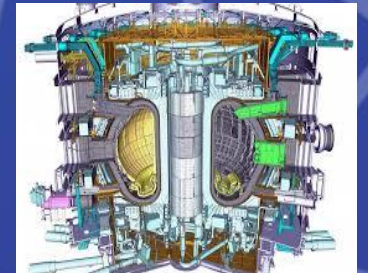
**Research & Applications with Accelerators & Neutron Sources**  
(incl. RR applications)



**Nuclear Instrumentation**  
(incl. laboratory in Seibersdorf)



**Nuclear Fusion**  
**Research & Technology**  
(incl. coop. with ITER)





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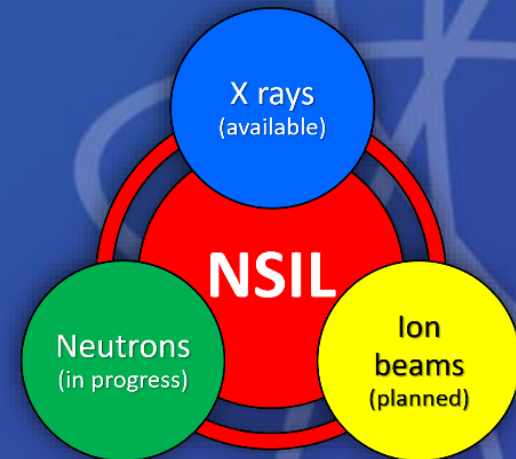
# Nuclear Science & Instrumentation Laboratory

**Mission:** Assisting Member States in introducing and extending the use of nuclear instrumentation and radiation measurement techniques, including related capacity building

**Nuclear Instrumentation:** Enhanced capabilities and applications of nuclear instrumentation for various measurements, monitoring and diagnostic purposes

**Nuclear Spectrometry:** Enhanced usage of versatile, high precision, non-destructive, low-cost analytical techniques for characterization of materials and objects

**Neutron science:** Operation of compact neutron generators for research, demonstration of practical applications and training purposes.



Available/planned facilities



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Where are we?

VIC >

NSIL (current locations)

YAL

GH<sub>s</sub>

FML2

IPCL

MPB

DOL

NSF

The IAEA Laboratories are located about 35 km south of Vienna, Austria



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Where are we?

VIC >

NSIL (future)

NSIL (current locations)





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# NSIL Mission and activities

*Assisting Member States in introducing and extending the use nuclear instrumentation and spectrometry techniques for environmental and other applications*

## Technical Cooperation (TC) Projects (National, Regional or Interregional)

- *Direct support to laboratories in Member States (including technical back-up to TC and analytical services)*
- *Training at Seibersdorf Lab of TC fellows*

## Regular Budget

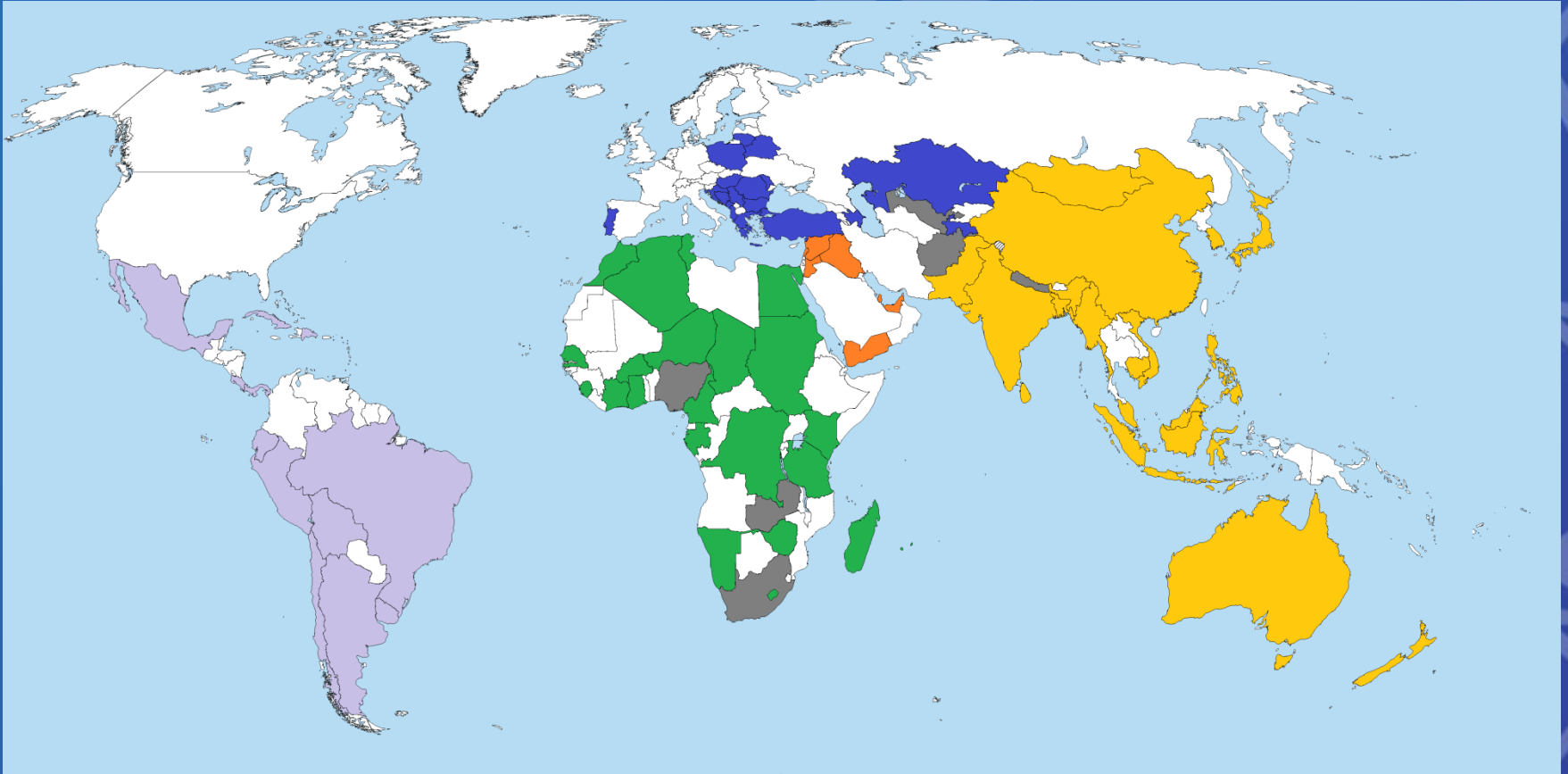
- *Research aimed to improve analytical performance and to extend applicability (Applied/adaptive research and development)*
- *Provide Access to Research Infrastructures (Ruđer Bošković Institute, Croatia and Elettra Sincrotrone Trieste, Italy)*
- *Technical Meetings, Consultancy Meetings, Coordinated Research Projects, ICTP-IAEA events*
- *Dissemination of information (IAEA XRF Newsletter, mailing lists)*
- *Workshops, Schools, Direct support of Int. Conferences, Networks, DBs, Publications etc*
- *Support to regional centres in the field of nuclear instrumentation*
- *Support to other Research Groups/Units at Seibersdorf*
- *Development of QM systems for NI and XRF laboratories*
- *Organization of Proficiency Tests*



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# NSIL support to TC



Legend: ■ National Projects; ■ RAF7016; ■ RAS7029; ■ RER1015; ■ RAS0076; ■ RLA0058

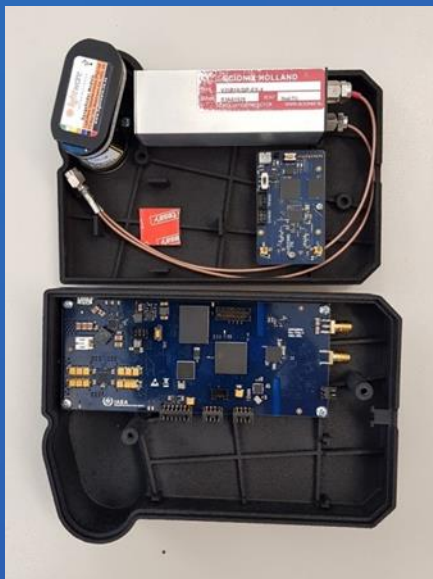


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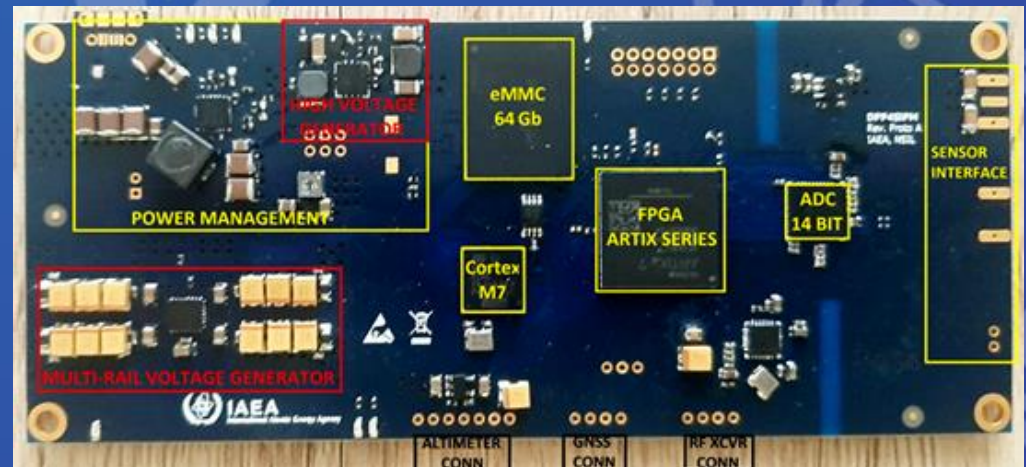
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# Nuclear Instrumentation

NSIL provides support through transfer of expertise, on-site system installations, hands-on training activities on developmental trends in the field of nuclear instrumentation and associated electronics



compact radiation detection module, based on Na & SiPM



Pulse processing board developed by NSIL for the ultralight gamma spectrometry system based on scintillator-SiPM detectors



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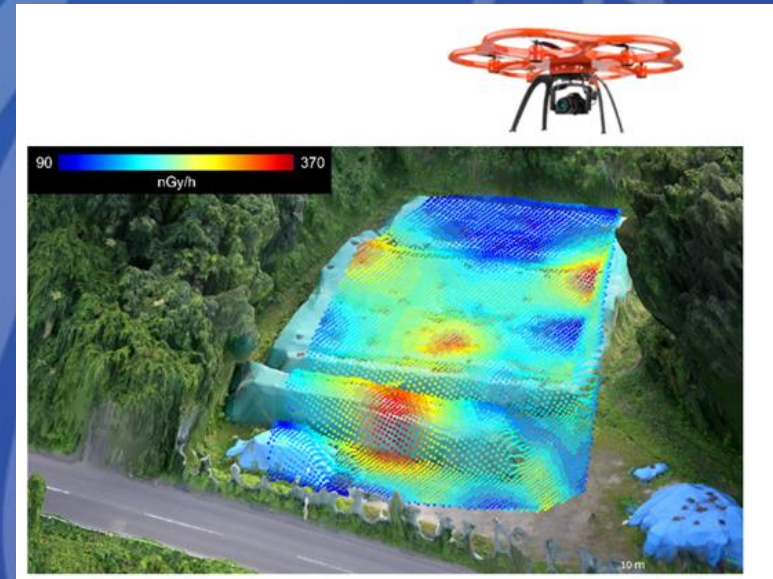
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# Portable detectors and in-situ measurements

NSIL has long-standing experience in development and application of instrumentation techniques for in-situ measurements, especially mobile monitoring such as field portable gamma spectrometers mounted on back-packs or unmanned aerial vehicles (UAVs)



Testing of a backpack gamma spectrometer



Full 3D aerial photogrammetry superimposed with a radiological map was obtained using the same UAV in two consecutive flights





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# Neutron Science Facility at Seibersdorf

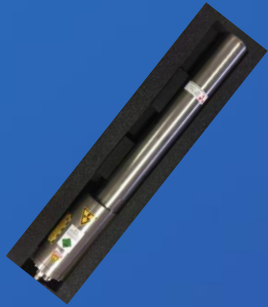
Neutron science facility is based on two neutron generators,

- **D+D reaction** → 2.45 MeV neutron source (fission neutrons) -  $5 \times 10^6$  n/s flux

With US-DOE support: procurement on going

- **D+T reaction** → 14 MeV neutron source (fusion neutrons) -  $2 \times 10^8$  n/s flux

*Donation by Australia: arrived in Seibersdorf*



DT-type generator,  
with massive shielding



DD-type generator,  
with compact shielding





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## NSIL XRF - Applied/adaptive R&D

- *Major focus on extension of the applicability range and on improvements in analytical performance and methodology of XRF and IBA techniques*
- *Emphasis on versatility and cost effectiveness of XRF (important for XRF labs in developing countries)*
- *Emphasis on interdisciplinary applications of XRF/IBA techniques*
- *Integration of R&D with training*



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# NSIL - Facilities and techniques available



- EDXRF spectrometers (commercial/in-house)
- WDXRF spectrometer
- Total reflection XRF spectrometers
- 2D - 3D and transmission micro-XRF spectroscopy
- Portable/Handheld XRF spectrometers
- Multipurpose UHV chamber (mirror of the one at Elettra)
- SEM-EDS
- Sample preparation



- **Access to IBA techniques (PIXE, PIGE, RBS, micro-PIXE) - under an agreement with Ruđer Bošković Institute, Zagreb, Croatia**



- **Access to synchrotron radiation beamline - under an agreement with Elettra Sincrotrone, Trieste, Italy**

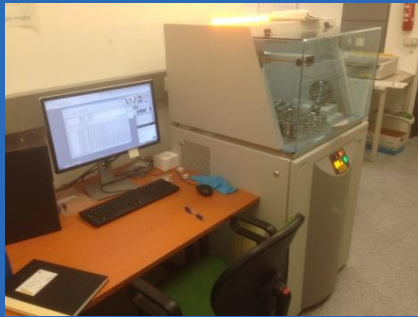


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# XRF spectrometers



Secondary  
Target ED-XRF



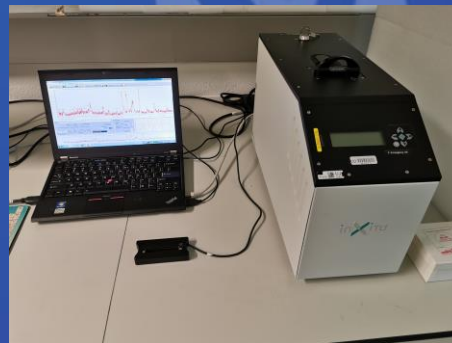
TXRF



Portable/Transportable XRF



WD-XRF



Transportable XRD



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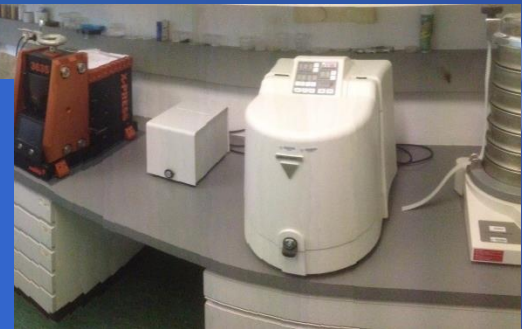
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# Sample preparation



Environmental samples:

- *Geological/sediment/soil*
- *Biological (plants, animals)*
- *Air Particulate Matter*
- *Water, waste liquids*



Cultural Heritage  
Material Science

...



- Sieving
- Surface polishing
- Pulverizing/Pelletizing
- Pulverizing/Fusion
- Freezer/Mill
- LOI
- Acid digestion
- Wet chemistry
- Embedding
- ...

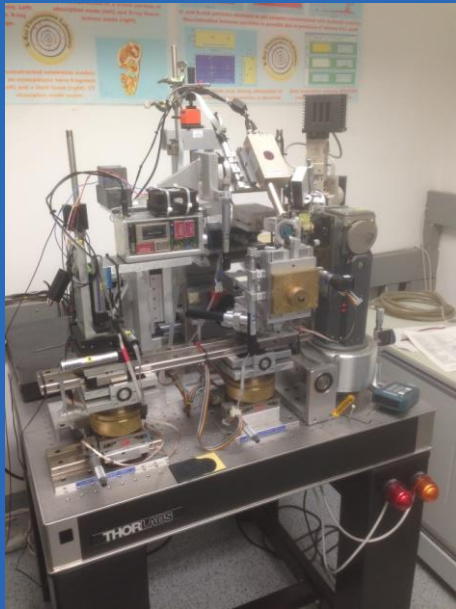


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# Micro-analysis and mapping

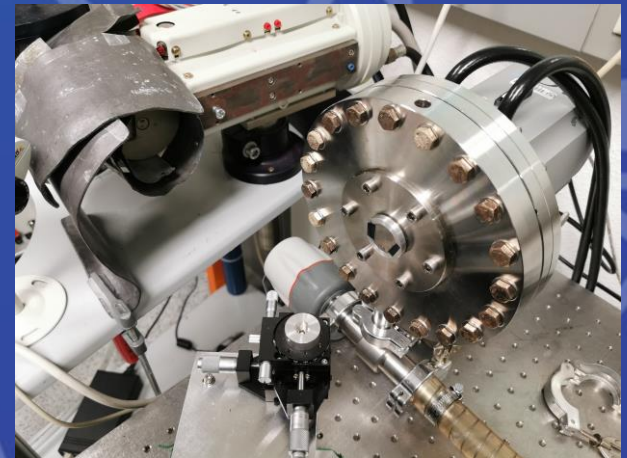


Micro and  
confocal XRF

- *Spatial resolution: 15-40  $\mu$*
- *3 detectors (SDD):  $\mu$ -XRF, confocal and attenuation*
- *3 stages: Alignment-Sample movement*



SEM-EDS



Full-field XRF



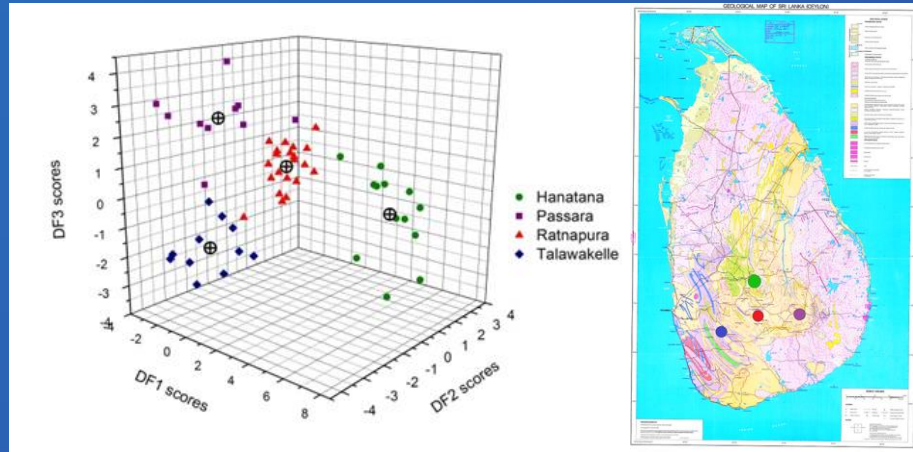
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# Applications

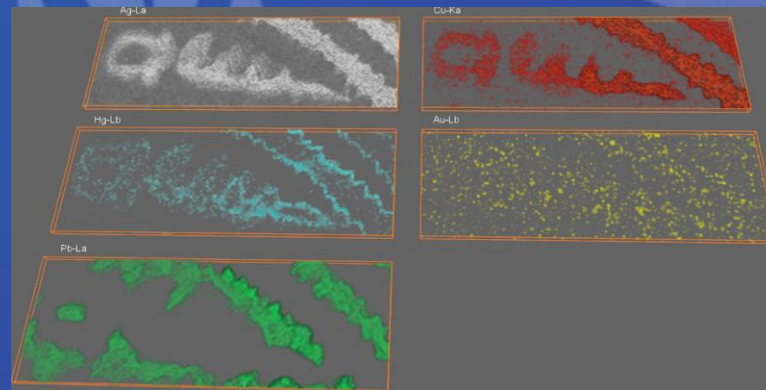


Inspecting a mural painting at the Vienna Institute of Conservation and Restoration



Identification of Sri Lankan tea regional provenance based on their elemental and stable isotope contents

2D and 3D distribution of elements in the altered surface of ancient silver coins



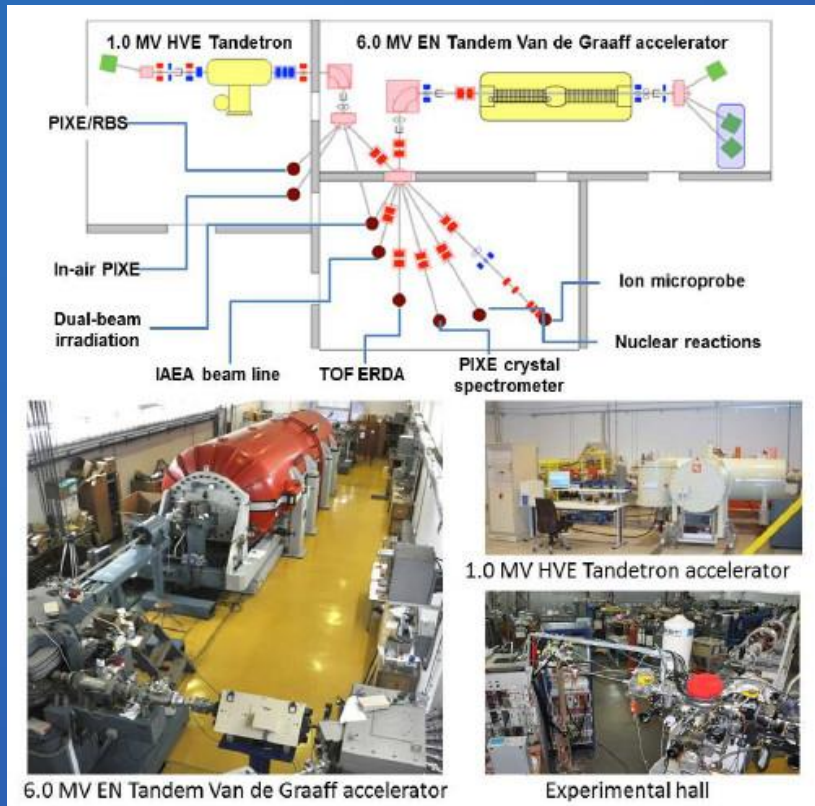


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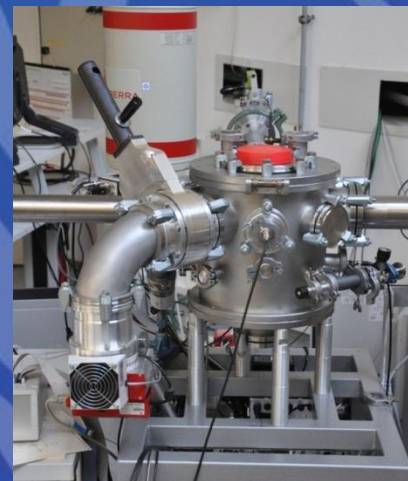
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# IBA at Ruđer Bošković Institute



- IAEA Vacuum chamber with multiple detectors
- Other beamlines available for NSIL measurements ( $\mu$ -beam, external set-up)
- 6 weeks/year for IAEA use
- Techniques: PIXE, RBS, PIGE
- CRP to be announced



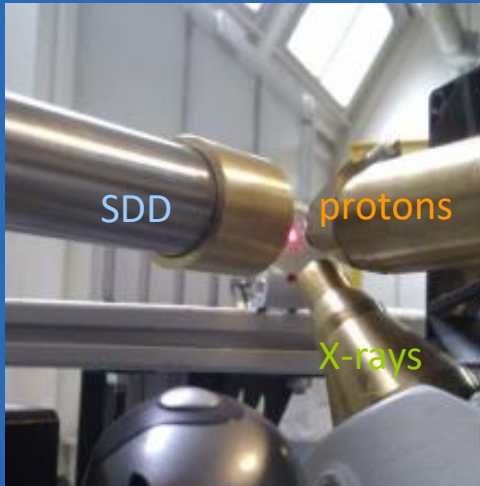




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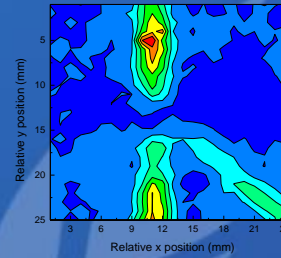
# Combined PIXE-XRF probe



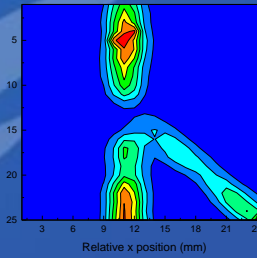
- Proton energy 1580 keV (after exit window and air-path)
- X-ray tube operated at 35-50 kV, 100-200  $\mu$ A
- Beams dimension  $\sim$ 1mm
- SDD and Si(Li) detectors

Ultramarine

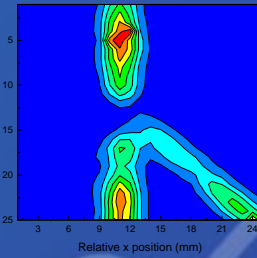
Al K $\alpha$



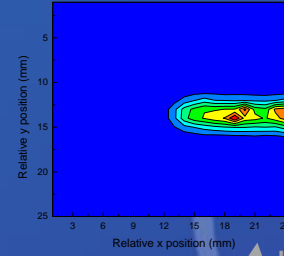
Si K $\alpha$



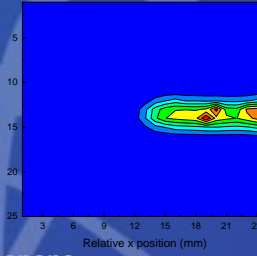
K K $\alpha$



Zn K $\alpha$

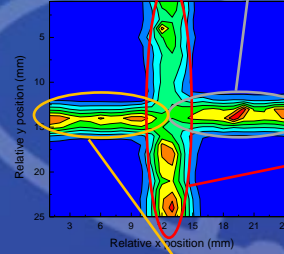


Ba L $\beta$

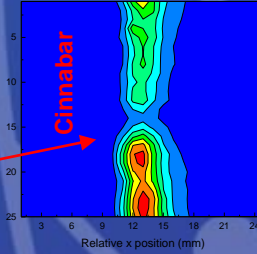


Lithopone

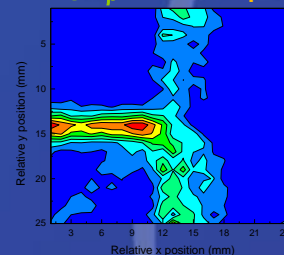
S K $\alpha$



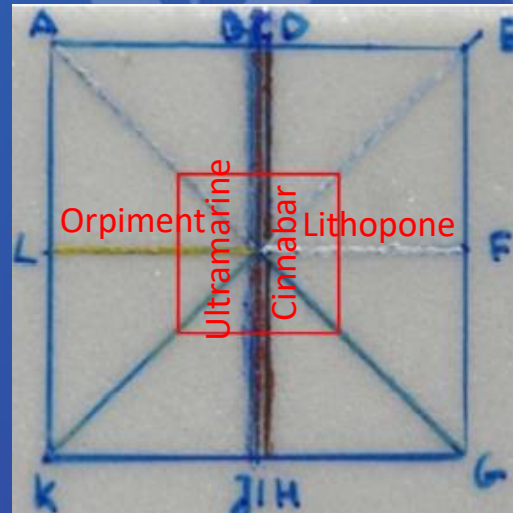
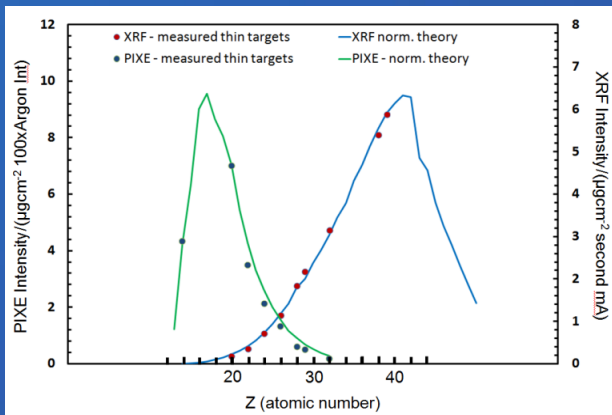
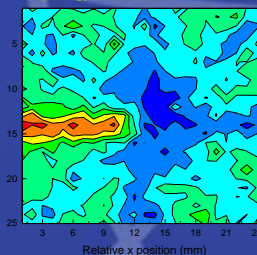
Hg L $\beta$



As K $\beta$



Orpiment As L $\alpha$



Elemental sensitivities



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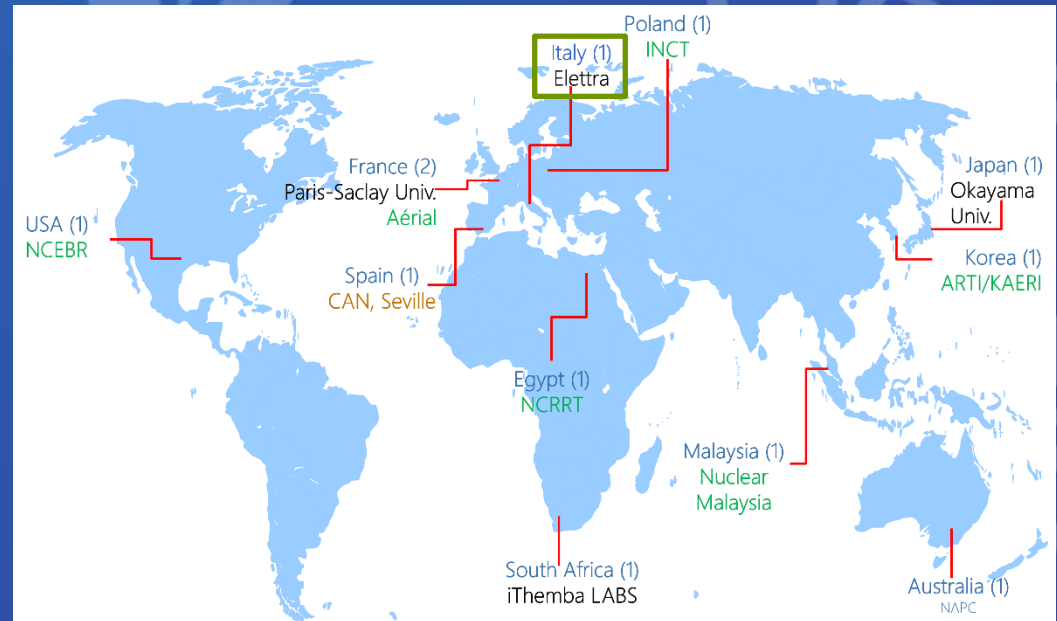
# IAEA Collaborating Centres

## IAEA Member State

institutions/organizations are designated as *IAEA Collaborating Centres (CC)* to cooperate in the implementation of selected programmatic activities of the Agency.

The designation process takes effect with the signing of an Agreement between the IAEA and the CC organization. This is a legally binding document defining the cooperative undertakings, duration of designation, objectives, activities, and expected results and outcomes stated in a jointly agreed Work Plan, which addresses R&D work, educational and training activities and, in many cases, cost-free services to the IAEA and its Member States.

## The 12 NA Collaborating Centres operating accelerators





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# IAEA - Elettra: A Longstanding Collaboration

## IAEA – Elettra Collaborating Centre Agreement

(renewed in May 2020 – terminates 4/2024; can be extended by mutual agreement)

- Synchrotron applications and technologies

*Support the IAEA in the implementation of activities in the IAEA Programme*

*“Nuclear Techniques for Development and Environmental Protection”, and as it may be further developed and agreed ...*



## Work plan

- Assistance to developing MSs who intend to build synchrotron facilities including training their scientists and technologists in light sources design and beamline design - optics, control systems and detectors.
- Assistance to developing MSs in implementation of new methodologies for expanding the application fields of synchrotron and free electron laser techniques.
- Quality control of the performance (machine-beamlines) and utilization (user proposals) of new synchrotron facilities.
- Active participation in IAEA and other National and International Training-Educational Programs
- Joint research activities with scholars and users from developing MSs to boost new knowledge and expertise.
- Promotion and outreach activities in cooperation with the IAEA and other relevant partners on the benefits and state of the art of light sources.



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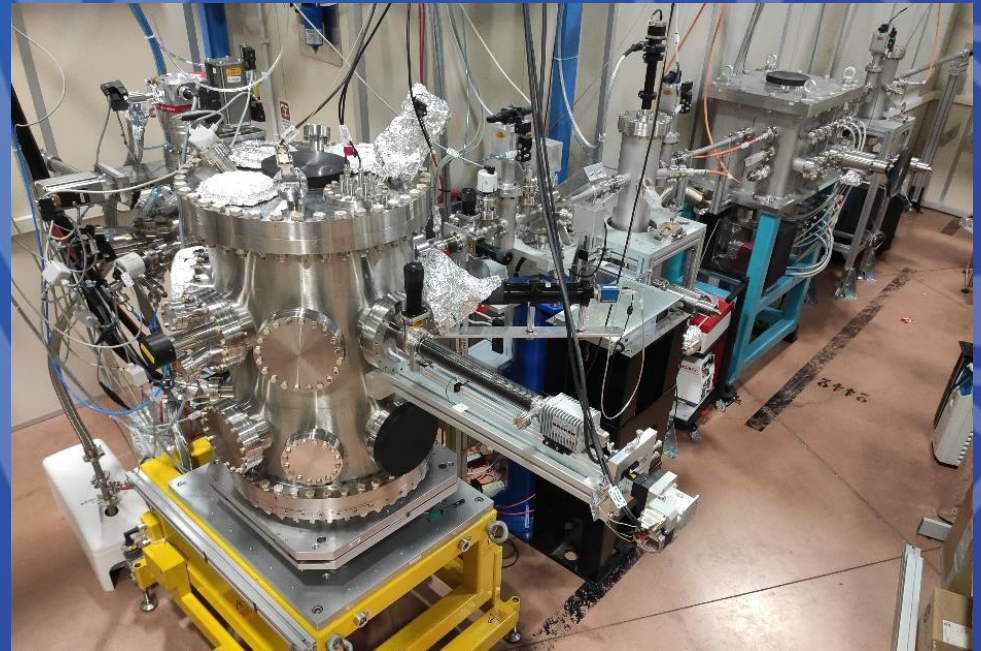
# IAEA - Elettra: A Longstanding Collaboration

## IAEA – Elettra Cooperation Agreement

(since 6/2013 - terminates 12/2024; can be extended by mutual agreement)

*ACCESS TO AND USE OF THE XRF BEAMLINE AND ULTRA HIGH VACUUM CHAMBER FOR ADVANCED X-RAY SPECTROMETRY BASED ANALYTICAL TECHNIQUES AND APPLICATIONS*

- Joint IAEA-Elettra XRF Beamline
- Dedicated beam-time for users
- UHVC ‘Mirror Facility’ commissioned at NSIL, Seibersdorf for pre-experiment training





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# IAEAXspe chamber at Elettra Sincrotrone Trieste

Multipurpose Ultra High Vacuum Chamber facility for applying simultaneously various complementary and advanced variants of X-Ray Spectrometry techniques, including:

- Total Reflection X-ray Fluorescence Analysis (TXRF)
- Grazing Incidence/Exit XRF analysis (GIXRF- GEXRF)
- Near Edge X-ray Absorption Fine Structure (NEXAFS)
- X-ray Reflectometry (XRR)

Overall Objective:

To improve and strengthen the capacity of MSs to effectively utilize SR-XRS based analytical techniques and related nuclear instrumentation in support of their research and sustainable development needs



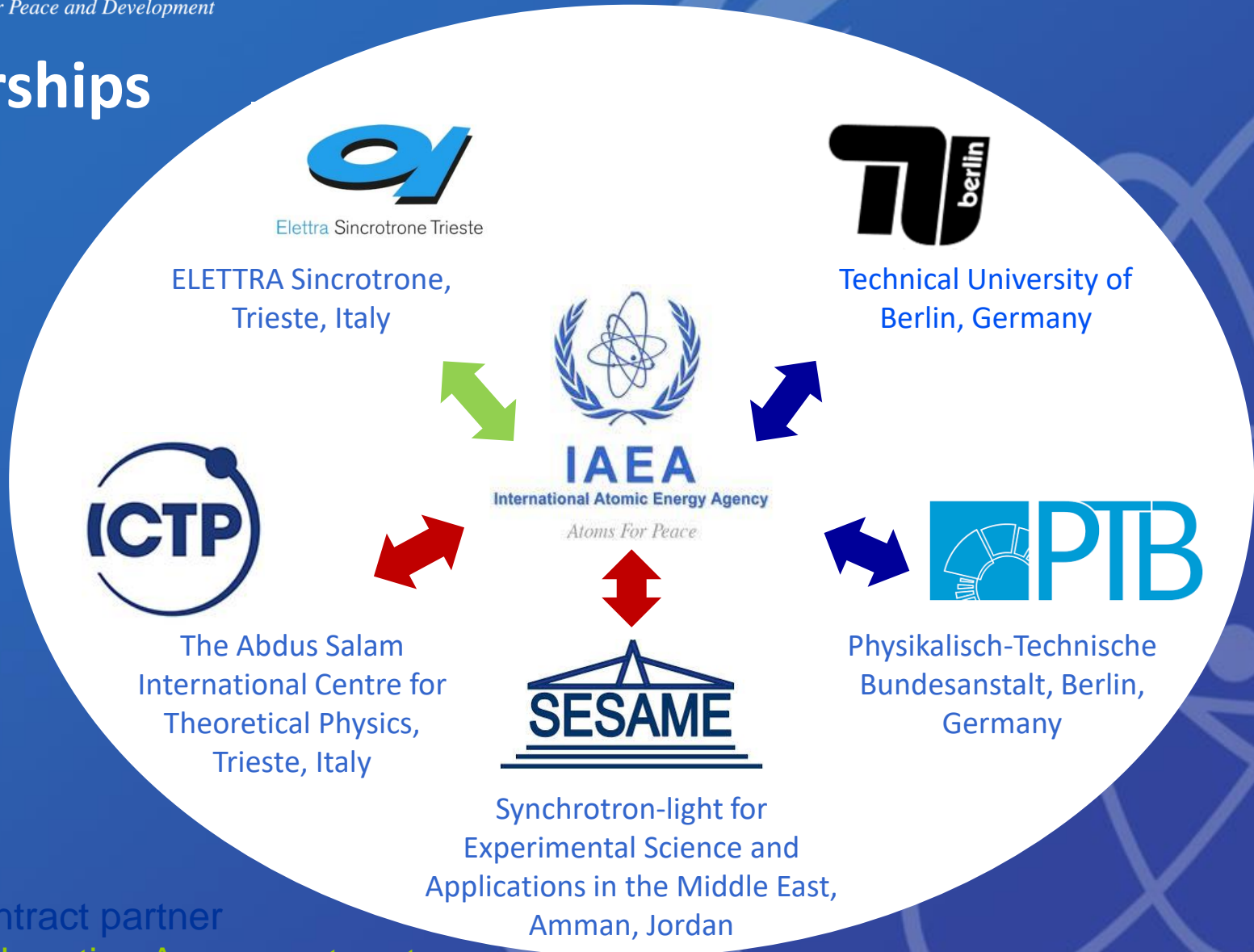


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# Partnerships



Stakeholders

Research Contract partner

Specific Collaboration Agreement partner



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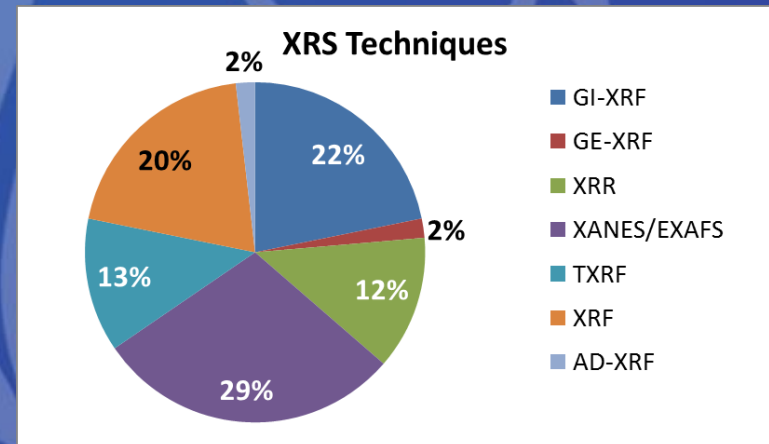
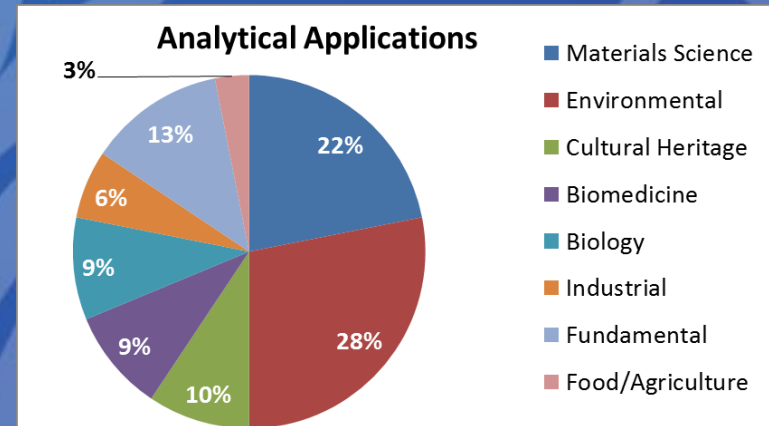
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# IAEA Coordinated Research Project G42005

*Experiments with Synchrotron Radiation for Modern Environmental and Industrial Applications*

**18 Countries involved**

- **Materials Science:** Structured materials for energy storage and conversion technologies
- **Nanomedicine - Biosensing technologies**
- **Environmental monitoring:** air particulate matter, water
- **Biological:** Elemental distribution/speciation on plant organ (leaves, roots, shoots, seeds, etc.)
- **Cultural Heritage -preventive conservation**
- **Food products security – Authenticity**
- **Determination of X-Ray Fundamental Parameters**





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# The IAEAXspe mirror at Seibersdorf

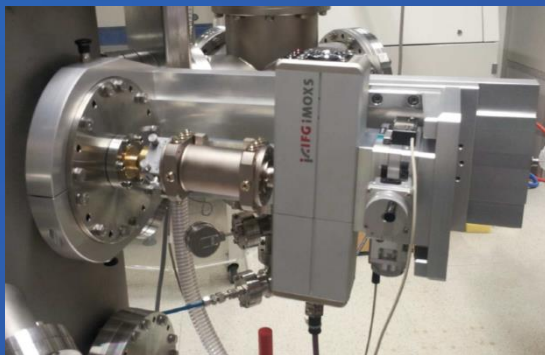


Same design as the one at Elettra  
Used for training and test of new devices

**Low-power air-cooled Mo anode X-ray tube,  
max 30 W, 50 kV**

**X-ray optics that would deliver:**

- *A monochromatic Mo Ka radiation*
- *A parallel exciting beam with a squared beam profile of about 0.3mm x 0.3mm*
- *Energy resolution about of 1% bandwidth*
- *Divergence of the parallel beam equal or less than 0.02° in both directions*
- *Integral photon intensity after the optics more than  $2 \cdot 10^6$  photons/s*



**X-ray source + ASTIX-c 2 optics attached through a CF-160  
flange and Be window to the UHV chamber**

**ASTIX-c 2-dimensional  
Parallel X-ray Optics  
(AXO Dresden GmbH)**





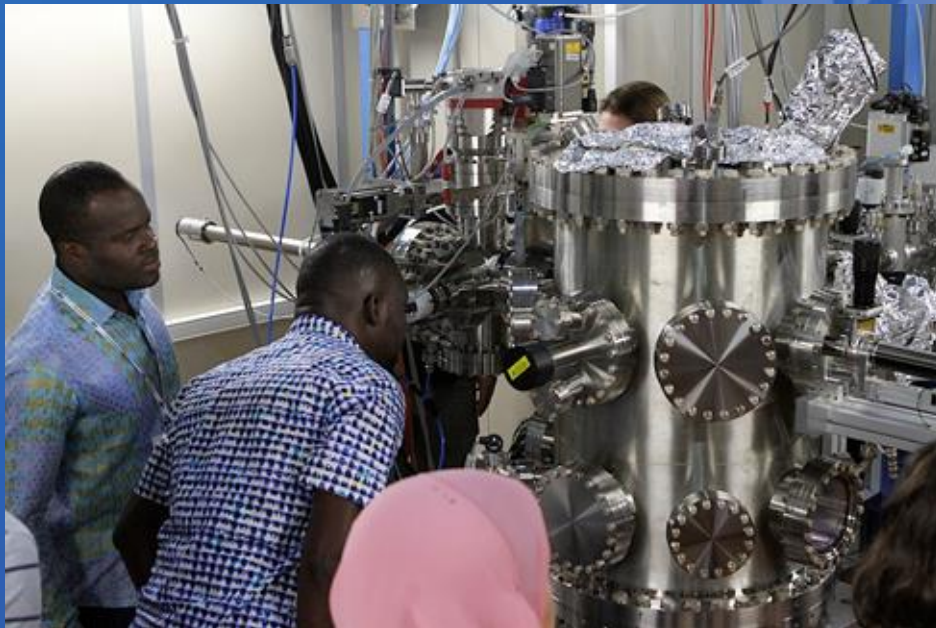
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# Hands-on-training at accelerator facilities

NSIL provides practical and experimental tools to foster the effective use of nuclear instrumentation and related capacity building in support of a wide range of applications, from environmental monitoring to material science



Researchers attending hands-on-training at the IAEA X-ray spectrometry end-station at the X-ray Fluorescence beamline in Elettra Sincrotrone

Similar training organized at RBI



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# Emphasis on Capacity building

## 2018-19

Activity	Number of events	Number of trainees
Training events, including hands-on training (1-2 weeks courses)	11	183
Fellowship training (2 months or longer)	6	23
Scientific Visitors	6	12

## 2020-21: The challenges of the COVID-19 pandemic

Activity	Events / trainees
Training events, including hands-on training - Implemented with virtual events	2 /
Fellowship training - Fostered via e-learning and on-line materials	8 modules 4 (8) videos 3 (15) lectures
Scientific Visitors	2

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In situ measurements and mapping to support radiological characterization of sites

Jan-20 Feb-20

Neutron In-situ Neutron Electro

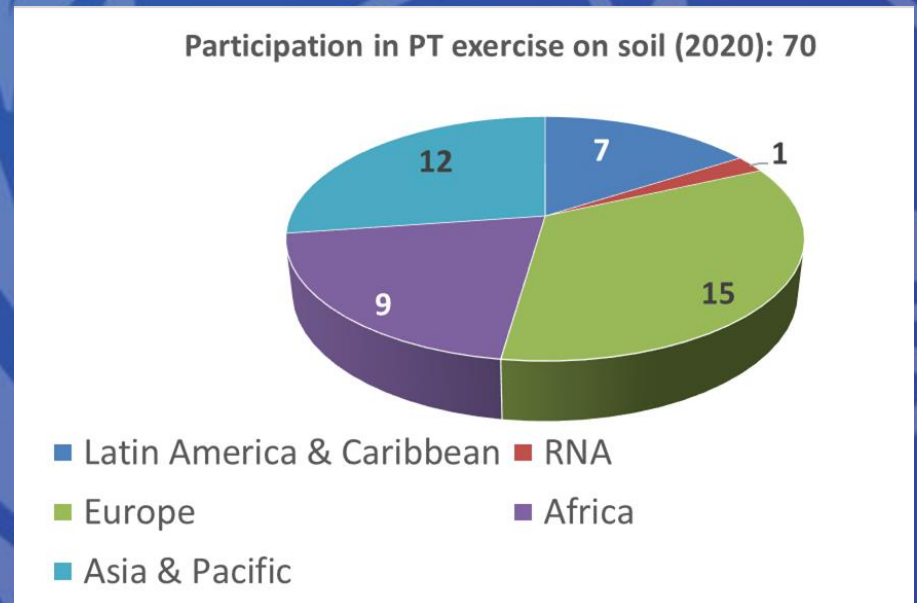
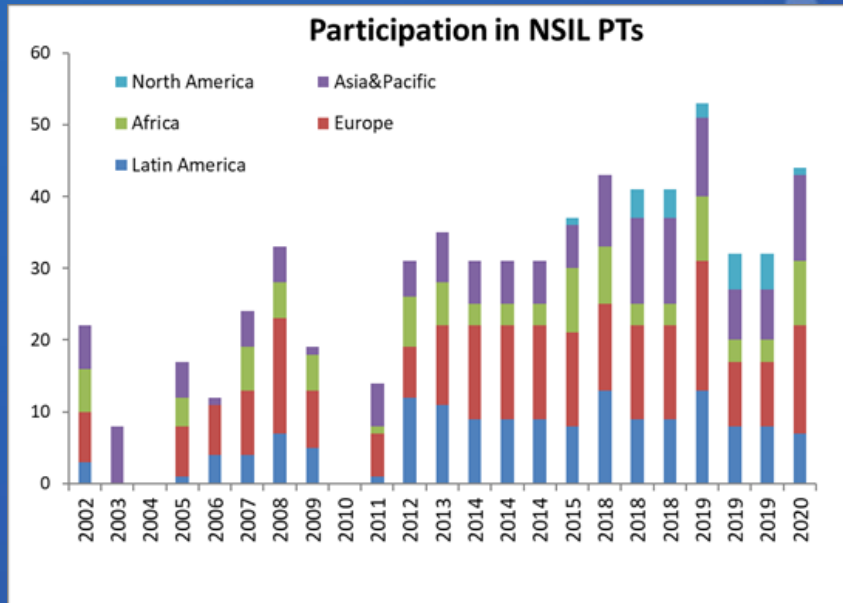


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# QA/QC services

Coordination of Proficiency  
(compliant with ISO17045)





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# Scheme of the PT

## **Full anonymity of laboratories is granted:**

*Laboratory code is only known too each laboratory and to the PT coordinator*

## **Quantitative:**

*The results of a quantitative measurement are numerical and are reported on an interval or a ratio scale*

## **Simultaneous:**

*Randomly selected sub-samples from a source of material being distributed simultaneously to participants for concurrent testing*

## **Continuous:**

*Organized once per year*

## **No criteria for quality management to be met for participation:**

*Different levels of maturity/performance must however be declared*

## **Laboratories are asked to use their established and proven analytical procedures for the determination of concentrations of chemical elements:**

*Provisions taken to assess if the participants' results obtained by different test or measurement methods are technically equivalent*

- Evaluation of Trueness ( $z/z'$  values)
- Evaluation of Precision ( $zeta$  values)
- Determination of consensus values



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# Online resources for Information exchange

## NSI Portal

## NSI Newsletter

IAEA.org NUCLEUS

IAEA Nuclear Instrumentation

Home Interactive maps Training X-rays Ion Beams Neutrons Portable Detectors Proficiency Tests Nuclear Electronics Downloads & Databases

### Welcome to the Nuclear Science and Instrumentation Portal!

This portal aims at providing the community of users of nuclear instrumentation for different applications with a variety of tools and documents useful for their work.

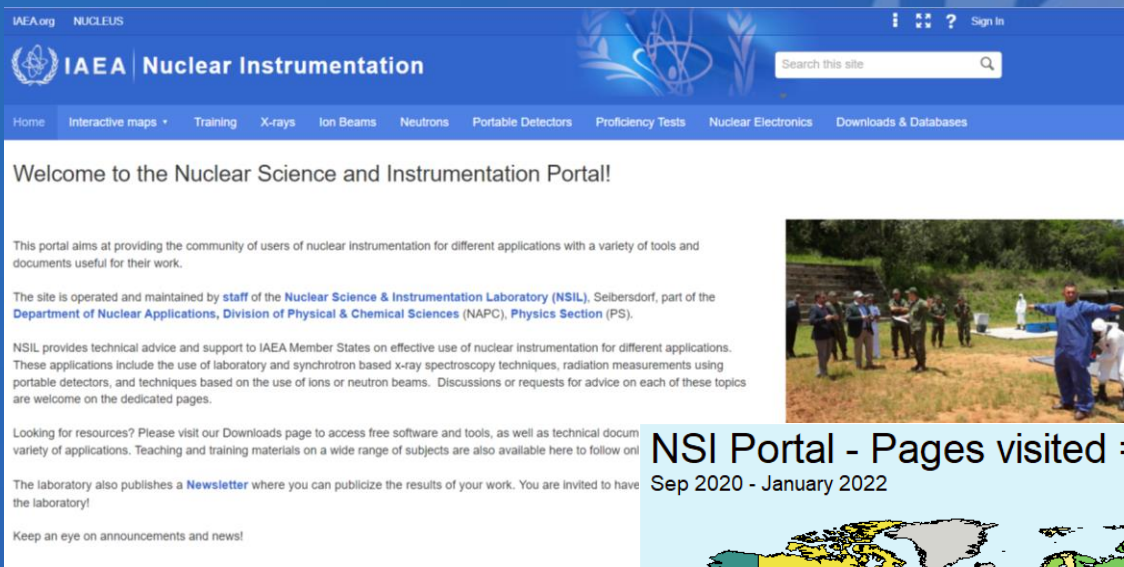
The site is operated and maintained by staff of the Nuclear Science & Instrumentation Laboratory (NSIL), Selbersdorf, part of the Department of Nuclear Applications, Division of Physical & Chemical Sciences (NAPC), Physics Section (PS).

NSIL provides technical advice and support to IAEA Member States on effective use of nuclear instrumentation for different applications. These applications include the use of laboratory and synchrotron based x-ray spectroscopy techniques, radiation measurements using portable detectors, and techniques based on the use of ions or neutron beams. Discussions or requests for advice on each of these topics are welcome on the dedicated pages.

Looking for resources? Please visit our Downloads page to access free software and tools, as well as technical document variety of applications. Teaching and training materials on a wide range of subjects are also available here to follow on!

The laboratory also publishes a Newsletter where you can publicize the results of your work. You are invited to have the laboratory!

Keep an eye on announcements and news!



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### Editorial

The Nuclear Science and Instrumentation Laboratory (NSIL) is pleased to bring to your attention the second issue of its Newsletter!

Since the release of Issue No. 1, a significant progress has been made in the development of online resources to strengthen the information exchange with laboratories of IAEA Member States, including the creation of online databases of different types of nuclear instrumentation facilities, the increase of training materials (introductory courses, video demonstrations and lectures), all available from the Nuclear Science and Instrumentation Portal (<http://www.nsi-iaea.org>).



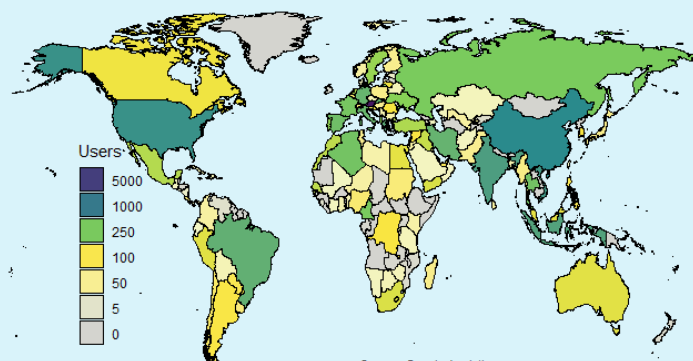
NSIL staff (from left to right): Mr. Daniel Buhara (Section Head), Mr. Raphael Atia (Team Assistant), Mr. Jacopo Orsini (Consultant), Mr. Marco Magno Dieneri, Mr. Nabea Shaban (Associate NS Specialist), Mr. Miriam Bepko (Senior Laboratory Technician), Mr. Pragnan Gan Dieneri, Mr. Paw Sladok and Mr. Ralf Ben Abdoumalik (NS Specialists), Mr. Farhad Memariani (Electronics Technician), Mr. Alessandro Migliori (Senior Laboratory Technician), Mr. Saman Khalifa (NS Physicist), Mr. Saverio Melloni (Asst. Project Officer), and Mr. Milan Manic (Senior Laboratory Technician, Nuclear Science).

NSIL looks forward to receiving both contributions and feedback from different Member State counterparts and stakeholders to this Newsletter, to help the laboratory to best continue supporting projects, fellowships, scientific and technical visits, and addressing research & development needs by national facilities worldwide.

of the views and policies of the IAEA, except where explicitly identified.

### NSI Portal - Pages visited = 23133

Sep 2020 - January 2022





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*Thank you  
for your  
attention!*

