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Nuclear Science and Instrumentation Newsletter

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Contents

Editorial

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

NSIL has commissioned its DD neutron generator as part of the Neutron Science Facility (NSF) in Seibersdorf. This new state-of-the-art infrastructure will offer training and diverse practical applications with neutrons, not available until present. The first tests of the DT neutron generator were also successfully completed, while its commissioning is scheduled for early 2022.

The Worldwide Database of XRF laboratories crossed over 1200 records and the NSIL capabilities for analysis of trace elements by XRF is being enhanced.

The support to accelerator applications included both adaptive research and advisory assessment and infrastructure repair missions to several accelerator facilities.

New developments in UAV based methodologies to detect radioactive sources from outside of the buildings have been successfully tested.

The development of online resources has continued as an alternative to counteract the negative impact that COVID-19 pandemic has imposed into training activities and information exchange. They can be accessed from the Nuclear Science and Instrumentation Portal and from the IAEA Open Learning Management System.

NSIL has enforced the organization of Virtual National, Regional and Interregional Training Courses to support the implementation of Regional Technical Cooperation Projects, as well as several Training Workshops and Technical Meetings using this modality.

Contributions from Cuba, Spain and Sweden are presented in the section of Reports from Member States.

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

Introducing NSIL new Laboratory Head

As part of the rotation policy of the IAEA for staff in the Professional category, Ms Kalliopi Kanaki has been recruited as a new Laboratory Head and will start her appointment in February 2022.

Ms Kanaki studied Physics at the University of Athens, Greece and she got her doctoral degree from the Technical University of Dresden, Germany. Her postdoctoral research continued in Norway as a member of the ALICE High Level Trigger Collaboration (HLT), being responsible for the HLT data quality assessment.

Since 2012 Ms Kanaki has been a member of the European Spallation Source (ESS) Detector Group, and later acted as Detector Systems Design Section Leader. She has been working on detector requirements and qualification studies for various detector technologies.

Her major fields of experience include radiation detection, experimental physics, data analysis and simulations.

1. Laboratory Projects and Activities

1.1 Nuclear Instrumentation

Development of a new board for gamma spectrometry.

In Issue 1 of the Newsletter, NSIL reported about the upgrading of an existing Data Acquisition System (DAS) for Sediment Tracing and Radiotracer Industry applications, which is in use by dozens of countries. The upgrade allowed a signal processing board with spectroscopy capability to be added by end users. However, the upgraded system still relayed on using the original analog front-end electronics (AFE) and high voltage power supply (HVPS) of the employed NaI(Tl) detector, resulting in the following limitations: a) user needs to open the probe to adjust HV, (b) there is no option to adjust transimpedance gain, and (c) the size and type of scintillator cannot be easy changed.
To overcome the above-mentioned limitations, NSIL team commenced to work to expand the DAS upgrade by (1) converting the existing signal processing board, Altaix AFE and HVPS into a compact digital PMT base which can fit a broad range of scintillator-PMT assemblies, and by (2) expanding the software with Resident Time data processing capability. It is planned to finish the development work and perform testing the upgraded DAS during the first quarter of 2022.

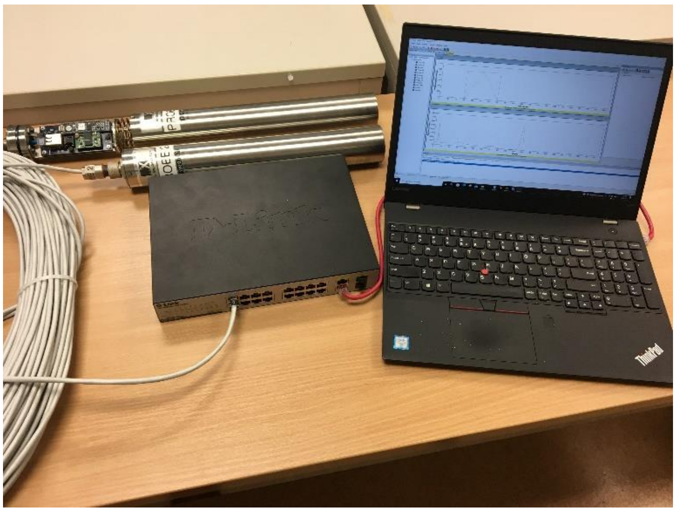


Figure 1: DAS for Sediment Tracing and Radiotracer Industry applications. Detailed view of the PMT base is shown in the upper left corner

1.2 X-ray Fluorescence

Worldwide Database of XRF Laboratories keeps growing.

In the Issue 2 of the Newsletter, NSIL announced the development of a Worldwide Database of XRF laboratories. By the end of 2021, the number of records of analytical laboratories employing XRF techniques for applied & fundamental research, analytical services, and education & training has increased to more than 1200 laboratories.

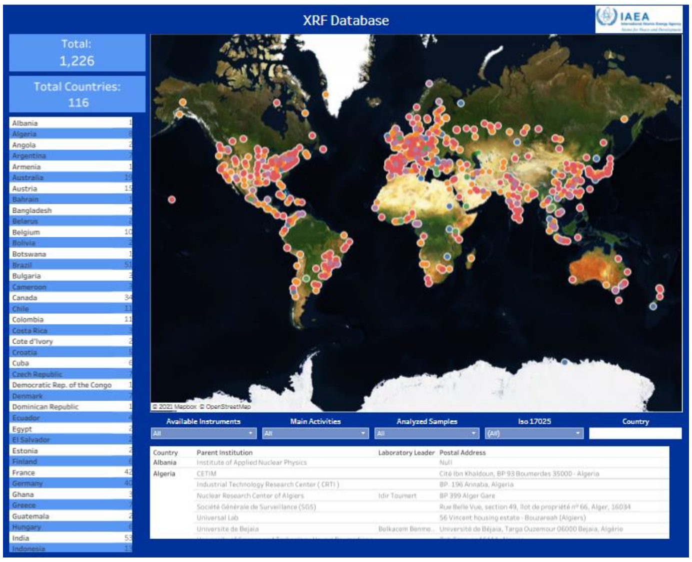


Figure 2: Interactive Map of XRF Laboratories as of January 2022.

Most of the information used to develop the database is collected from different publicly accessible sources, including scientific articles and institutional websites. The remainder is directly recorded from the responses received from the organizations operating these facilities through the online form. It undergoes a process of light review by our NSIL team and is updated on a weekly basis. NSIL wish to extend thanks to all those who returned their responses in the online form and helped us further expand the database.

Although it has grown significantly in the past months, it is likely that many institutions that may benefit from further exposure to the scientific community, whose information is not publicly available, are still missing from the database. If your institution employs XRF techniques and is not registered, we kindly invite you to input your XRF laboratory’s information directly, including name of parent institution, address, GPS coordinates and types of samples analysed.

Results from validation of trace element analysis in samples of marine biota.

A new method for the analysis of trace elements in marine biota samples was successfully validated at NSIL. Samples of marine biota have high contents of chlorine (Cl) and sodium (Na), thus making difficult the correction of attenuation effects by using fundamental parameter-based algorithms, especially for low characteristic emission energies.

This dedicated method was developed based on linear calibrations of characteristic emission counts, normalized to that of the excitation radiation scatter and ensuring that no significant jumps in the sample effective mass attenuation coefficient are present between these two energies. Samples are grinded and pellets (weighting 2 g and with a size of 2.5 cm diameter) were prepared for the measurements. with EDXRF spectrometers using secondary targets for excitation. Calibration lines were prepared measuring 23 certified reference materials (CRMs) of biological origin. The method accuracy was evaluated by analysing the IAEA 452 CRM (trace elements in scallop tissue) to assess the trueness and precision of the results. An external quality control of the measurement results was conducted by participating in the Interlaboratory Comparison IAEA-MEL-2021-01-ILC-TE-BIOTA, organized by the IAEA Marine Environmental Laboratory, located in Monaco. In both cases, ***z*** and ***zeta*** scores were used as indicator of quality of results [1]. The results of this assessment are summarized in Table 1.

The method can be applied to the analysis of any type of biological samples, providing that no significant jumps in the sample effective mass attenuation coefficient are present between the characteristic emission energy and the energy of scattered radiation selected for normalization.

References

[1] ISO 13528 (2015) (Cor. 2016-10): Statistical methods for use in proficiency testing by interlaboratory comparison

Table 1 Assessment of method's performance (values in italic characters correspond to measurement results close to the detection limits.

		IAEA-452 (Trace elements in Scallop Tissue)				IAEA-MEL-2021-01-ILC-TE-BIOTA (Fish Tissue)			
El	**DL**	**Cert ± unc**	**Exp ± unc**	***z***	***Zeta***	**Cert ± unc**	**Exp ± unc**	***z***	***Zeta***
As	0.5	17.9 ± 1.1	16.9 ± 0.3	-0.91	-0.88	4.5 ± 0.3	4.1 ± 0.4	-0.71	-1.6
Cr	3.5	5.2 ± 1.7	*< DL*	-	-	0.6 ± 0.2	< DL	-	-
Cu	1.5	11.0 ± 0.8	12.5 ± 0.3	1.88	1.76	3.9 ± 0.2	4.9 ± 0.4	2.19	4.79
Fe	3	1070 ± 470	970 ± 9	-0.21	-0.21	140 ± 15	159 ± 12	1.11	2.03
Mn	2	279 ± 14	222 ± 4	-4.07	-3.91	6.1 ± 0.4	*3.7 ± 0.4*	*-3.14*	*-8.46*
Ni	1.5	3.7 ± 0.4	4.3 ± 0.1	1.56	1.52	0.62 ± 0.10	< DL	-	-
Pb	1.5	2.4 ± 0.3	*4.2 ± 0.3*	*6.00*	*4.24*	0.054± 0.008	< DL	-	-
Se	0.5	6.41 ± 0.25	6.8 ± 0.1	1.40	1.30	3 ± 0.3	2.9 ± 0.4	-0.05	-.0.08
Sr	1	83.5 ± 3.4	71.1 ± 0.6	-3.65	-3.59	-	-	-	-
Zn	1	167 ± 10	162 ± 1.3	-0.50	-0.50	102 ± 8	95 ± 3	-0.57	-1.70

Enhancing NSIL capabilities for TXRF Analysis

Total Reflection X-ray Fluorescence (TXRF) spectrometry has been part of the analytical infrastructure of NSIL since the early 1990's. The laboratory has developed several analytical procedures and contributed to training on this technique through years at both laboratory scale and at the joint IAEA-Elettra XRF beamline in Elettra Sincrotrone Trieste.

Due to the ageing of the instrument currently available at NSIL, it has been decided to enhance the analytical capabilities of the laboratory by acquiring a more advanced spectrometer.

The new spectrometer will feature three different excitation conditions based on the use of two X-ray tubes (Mo and W anode, respectively) in combination with multilayers tuned at the energies of 8.54 (W-La), 17.44 (Mo-Ka) and 35 kV (Bremsstrahlung).

The use of these conditions will allow to improve the instrumental detection limits (to the levels of 1 pg for Ni, 200 pg for Cd and 3 pg for Cr) by increasing the X-ray production for three groups of elements, correspondingly. The instrument also uses a large area SDD (60 mm^2) and includes an automatic sample changer accommodating different types of sample holders.

The installation and commissioning of the new spectrometer is expected to take place in March 2022.

1.3 In-situ Radiation Monitoring

NSIL has continued developing and testing field portable gamma spectrometers mounted on backpacks or drones. Modern in-situ techniques can offer tailored solutions for all those situations.

UAS - based measurements to detect radioactive sources in buildings

Recent progress in the Unmanned Aircraft Systems (UAS) technology enabled their incorporation into various fields, including environmental monitoring, radiation protection, remediation, and nuclear security, among others. Increasing performance of aerial vehicles allows deploying higher payload such as gamma spectroscopy detectors. Not only large areas but also detailed objects can be subject to monitoring. Utilization of UAS in radiation mapping of various buildings and industrial facilities can assist in search for uncontrolled radiation sources, monitoring of illegal transportation of nuclear materials or supervision of using/storing radioactive substances. Benefits of such approach include fast acquisition of primary information, no necessity to enter potentially dangerous objects or the possibility to build a 3D model of the studied area using the aerial photogrammetry.

Recently, NSIL has made use of aerial photogrammetry to acquire a 3D model of building under inspection. It was discovered that the structure and construction materials of the studied building have a significant influence on the results. The ability to estimate the location of radiation was also tested in previous studies.

For the real measurement, a DJI Mavic 2 Zoom drone was used for the photogrammetry measurement and DJI Matrice 210 V2 drone was used for the radiation measurements. DJI Matrice allows the payload capacity of 1.3 kg. As a radiation detector, a 2x2 inch NaI(Tl) scintillation detector was deployed, connected to a multichannel analyser with datalogger to store the measured data. The system also included a GNSS antenna and GNSS receiver to measure the position at the measured datapoints. As a receiver, a Geodetic RTK GNSS receiver provided a precise accurate position of ground control points for the photogrammetry and take-off/landing points for radiation measurements.

The study site was in Tisnov (Czech Republic) and it is a Training Centre of the local Fire Rescue Service. The building has 3 floors, and its dimensions are approximately 37×19×11 m. The three radioactive sources were placed inside the building. The first source (Cs-137, 10 GBq) was kept in a container on the ground floor. The second one (Cs-137, 3 GBq) was placed on the 2nd floor, whereas the third source (Co-60, 1 GBq) was placed on the 3rd floor. The positions of the sources are shown in Figure 3.

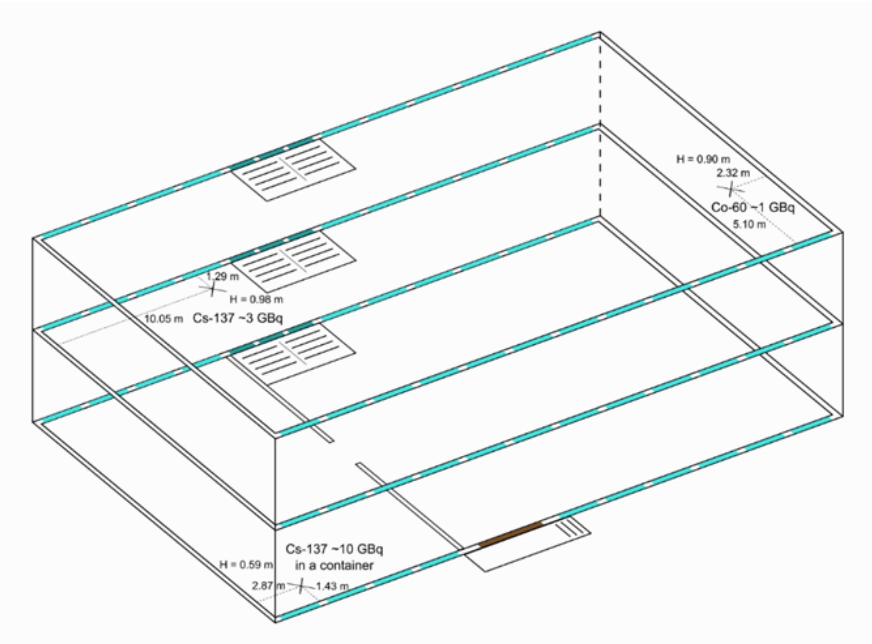


Figure 3 The position of the radiation sources in the building

At first, a photogrammetry measurement flight was performed. The data collection was fully automatic waypoint based, and 12 ground locations were targeted around the studied building. Six of them were used as a target for the georeferencing and the other six were used as a target for the accuracy assessment. During the measurement, 186 aerial images were acquired. The 3D model was processed using the software Agisoft Metashape Professional. It has 12million points in the dense point cloud model and the error of the georeferencing is about 5.1 cm horizontally and 5.7 cm vertically. After the photogrammetry measurement was finished, the flight plan of radiation mapping was prepared. The flight was manual with 6 horizontal lines along each wall with 2 m spacing separation and 9 lines over the roof with 2 m spacing, resulting in 33 lines in total as illustrated in Figure 4.

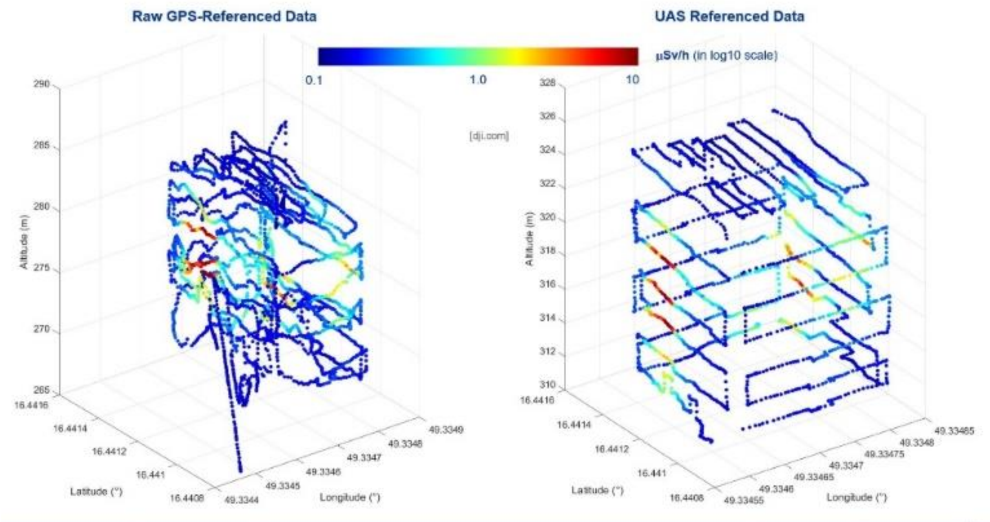


Figure 4: Comparison of the georeferenced radiation measurement results: left - raw GPS coordinates; right - UAS-referenced data

The distance of the drone to the surface of the wall/roof was kept at 2 m, which was feasible only in conditions of light breeze. Otherwise, an obstacle avoidance system allowing to fly at 3.5 m from the floor or wall was possible. The average speed of the drone was approximately 0.6 m/s. The UAS position data were used for georeferencing the measurements. These data are filtered and of more precise position than those acquired with raw GPS coordinates. The data from the UAS have time stamp as well as the data from the radiation system which have time stamp provided by the GNSS receiver. Therefore, it was possible to synchronize the position data from the UAS with the radiation data to acquire quite well georeferenced radiation data points.

The final photogrammetry model of the building from both the sides with the radiation data points measured represent the data points in the 2-meter distance from the walls and the floor. These data points were later projected to the surface of the building and interpolated to the radiation map onto the building surface as shown in the Figure 5.

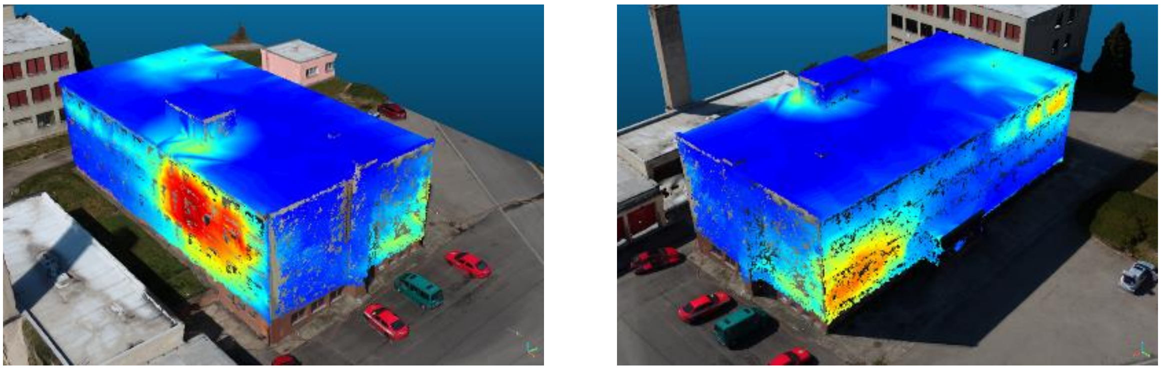


Figure 5 The radiation data measured and interpolated to the surface of the building

As can be seen from the picture, the position of all the sources is well revealed. It is also possible to see the influence of different building structures such as windows and walls.

The future work will be focused on the comparison of the data acquired by using a smaller system carrying a more compact detector pack, based on a 1.5×1.5 NaI(Tl) scintillator connected to a SiPM photomultiplier. Another step will be implementing a dose-rate calibration to convert the measured data to dose rate, to estimate the position and activities of the sources and to employ different projection algorithms, which allows more precise assignment of dose rate or CPS value to the building surface.

Some additional simulation study is envisaged, and the results will be compared with those of the real experimental measurements. Ideally, one would like to make the data collection phase fully autonomous. However, this would require a good GNSS reception, and since near the walls the GNSS reception is quite poor, the autonomous measurement procedure remains quite challenging.

In conclusion, the aim of this study was to proof the concept of UAS to be used for radiation mapping of buildings and other objects. The proposed methodology and acquired data seem to be suitable for estimating the radioactive source parameters.

1.4 Accelerator Technology and Applications

Elettra Sincrotrone

For the current year 21 proposals for access to the XRF beamline were approved, including 4 that were postponed from 2020 due to the COVID-19 pandemic. By the end of November there were 5 studies completed, two of which were implemented via remote access and supported by XRFbeamline scientists.

Maintenance works at XRF beamline end station

Since August 2021 two missions were implemented to perform urgent maintenance works at the manipulator of the joint end station of the XRF beamline at Elettra Sincrotrone Trieste. One of the two main goniometers (the theta axis) showed malfunctions while moving.

During the first visit (August 22-24) the lubrication of the theta axis of the manipulator, as suggested by the manufacturer, was performed. It included opening of the feedthrough flange and the one close to this, to facilitate the inspection of the manipulator. Lubrication in different points of the gear of the theta axis and inspection with optical fibre of the distribution of the lubricant was carried out. After these actions, the fangles were reinstalled, and the vacuum restored. The movement of the stage was verified.

After short time, the problems with the theta axis persisted, making it necessary to send the manipulator for maintenance. Taking the opportunity of the shutdown of Elettra in October and the availability of a second manipulator at NSIL in Seibersdorf, the defective manipulator was replaced with the one from the NSIL mirror chamber.

The work involved at the beginning the venting of the chamber and disassembling of all devices and parts connected to the main chamber. The main body of the chamber was then removed, and the defective manipulator was uninstalled and packed for shipping.

The second part of the work focused on the installation, testing and alignment of the other manipulator. The chamber and all devices were then reinstalled, and the vacuum started. All the work was performed with the support of the XRF beamline staff. The whole procedure took about 10 days; the end station was again operative for the first day after shutdown, on the 29th of October 2021. These prompt actions allowed to continue the provision of beamtime to users without any delay.

Ruđer Bošković Institute (1)

NSIL coordinated in August 2021 the design, production, installation and test of the external dual beam (protons and X-rays) set-up at the 1MV accelerator of Ruđer Bošković Institute (RBIZagreb, Croatia). The goal of using a double beam set-up was to combine the high X-ray production cross sections in different regions of the X-ray spectrum, from the ion beam for low energies X-rays and from the X-ray beam for the medium-high energies. The set-up (ion beam plus X-ray beam) was tested some years ago but was then disassembled. Some of the results obtained with the previous set-up can be found in a previous publication [2]. Figure 6 shows K alpha X-ray yields obtained from thin mono-elemental samples using either a proton beam or the X-ray tube excitation obtained using the first set-up.

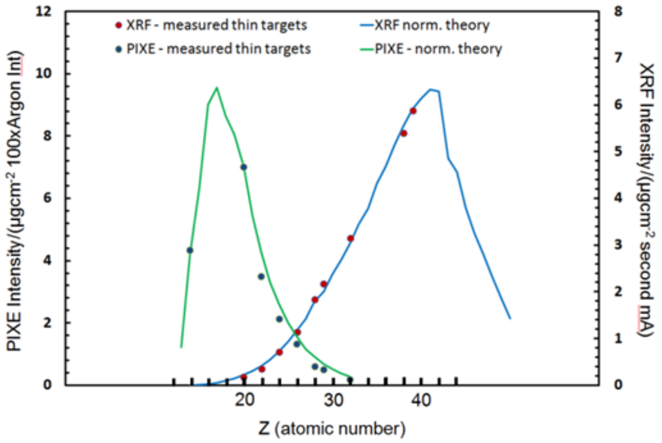


Figure 6. Thin target X-ray production yields for PIXE and XRF excitation modes.

The set-up (see Figure 7) was re-designed and installed at the beamline for "external" measurements connected, as in the previous arrangement, to the 1MV accelerator of RBI. The work was performed following these steps:

1. Design of a new support for the X-ray tube
2. Production of the support in the mechanical workshop
3. Installation of the X-ray tube
4. Alignment of the system using a fluorescent screen
5. Test of the set-up with sample containing different pigments (characterized by different elements)

The 2 MeV proton beam was extracted to the air through 8 μm thin Al foil and it was directed to the sample positioned at about 8.5 mm from the exit foil. Due to the traveling through the exit window and the air-path, the resulting energy of the proton beam on target was about 1580 keV.

A portable light weight (500 g) Moxtek Magnum transmission anode X-ray was used for primary X-ray production. The tube is equipped with a grounded Rh anode and 0.25 mm thick Be exit window. Maximum high voltage and beam current are -50 kV and 200 μA respectively, with a maximum power of 10W.

The size of the proton beam was defined by collimators and was of about 1mm at the sample position. The X-ray beam was collimated to have the same dimension on the sample as the proton beam. The X-ray tube was tested using different absorbers to "clean" from background the region of interest in the spectrum. A final combination of 50 µm Cu foil and 50 µm Ti foil was used.

At the end of this mission, the very first tests on a sample containing different pigments were successfully performed.

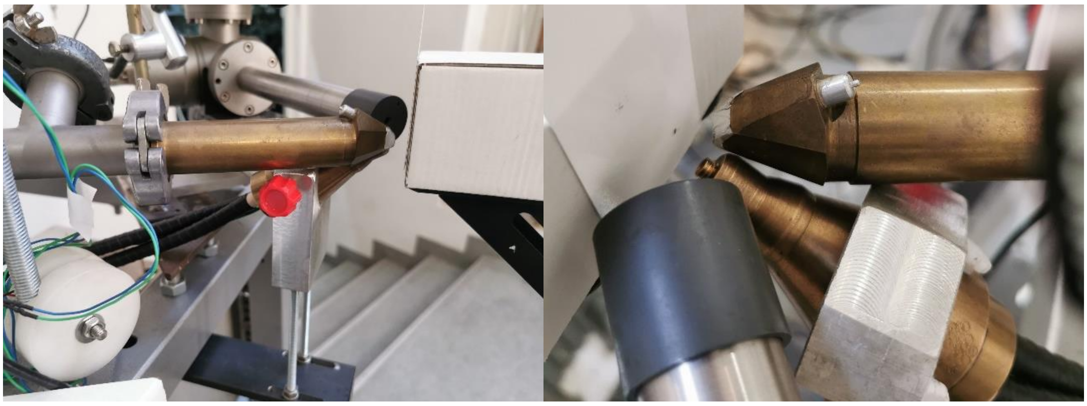


Figure 7. The dual beam (protons and X-rays) external set-up at the 1 MeV accelerator of RBI

Ruđer Bošković Institute (2)

A fault-finding mission was field in to RBI during the week of July 5-9 with the aim to assist local staff in tracing of the cause of the decrease of negative He output from the new duo-plasmatron source. After three days of tests the cause was identified, and corrective actions were taken. The last two days of the mission were used to test the transmission of the ion beam to the new microbeam line and some minor adjustments were made to the sputtering negative ion source.

Tandem Accelerator Laboratory, NCSR Demokritos

The Laboratory belongs to the Institute of Nuclear Physics (INP), one of the eight Institutes of the National Centre for Scientific Research "Demokritos" (NCSRD). It hosts a 5MV Tandem accelerator which is the only one operating in Greece.

A visit to the accelerator lab was field in during the week of August 23-27 to assist in the repair of the data acquisition system (DAQ) at the microbeam line and to perform initial steps in putting back in operation the *Petit Accelerateur pour l'Astro-physique* (PAPAP), 250 kV 1 mA p/D ion implanter, donated by France some years ago.

Both tasks were successfully completed. At the microbeam DAQ system, the fault was identified and corrected, while the operation of the PAPAP implanter was restored to the state of beam production. On the other hand, local team will require more efforts to achieve the beam currents according to specifications.

Van de Graaff Accelerator Laboratory, Centre for Nuclear Research Algiers (CRNA)

A status assessment mission was conducted at Centre de Recherche Nucléaire d'Alger (CRNA), Algiers Van de Graaff KN 3.75 accelerator under the national TC project ALG1019: Increasing National Analytical Capacities through Upgrading of Nuclear Analysis Laboratories.

Figure 8. Checking power supplies at the high voltage terminal of the KN Van de Graaff accelerator.

Four working days were spent with local accelerator staff to assess the facility status and assist in some corrective actions. A detailed plan of further corrections and upgrades was proposed and agreed with the aim to keep the existing accelerator in operational state and providing ion beams to the scientists. The laboratory has some plans to acquire a new accelerator in the new future.

References

[2] Multivariate analysis of PIXE + XRF and PIXE spectral images, J. Anal. At. Spectrom., 2021,36, 654-667, https://doi.org/10.1039/D0JA00529K

1.5 Neutron Science and Applications

NSIL is currently establishing a Neutron Science Facility (NSF) based on two compact neutron generators: Deuterium-Deuterium (DD), resulting in 2.45 MeV neutrons, and Deuterium-Tritium (DT), resulting in 14.1 MeV neutrons, with maximum source intensities up to 1×10^7 n/s and 3×10^8 n/s over 4π, respectively.

Refurbishment plans for M building extension

The NSIL's NSF has been installed in the M building, located in the north-east area of the IAEA Seibersdorf Laboratories Site. The southwestern wing of the building has been demolished. As illustrated in Figure 9, the north-eastern wing has been refurbished as a first phase of the refurbishment plan and now hosts the new NSF, consisting of its experimental area (M10), control room (M06A), main entrance area (M06B) and gamma spectroscopy room (M09A). The current Phase 2 consists of a refurbishment of the remaining rooms (see the same Figure 8) to keep them connected with the existing infrastructure regarding water, sewer, electrical power, fire alarm and heating.

The fully refurbished M building will contain one dedicated hands-on-training room (by merging M05 & M06), mainly dedicated for Non-Destructive Testing (NDT) using active interrogation, flow-rig and other lab-scale radiotracer experiments. The second training room (M09) will be adjusted as needed to serve as a space for meetings, lecturing as well as a workspace for fellows/interns. The project is also integrating additional premises (M07 & M08), for the storage of large pieces of equipment and training in industrial NDT by using X-ray radiography technique, respectively. The refurbishment project also includes the accommodation of about 170 m^2 outdoors area/platform (after the demolishment of the southwestern wing of the building) for training and testing of portable radiation instrumentation.

According to the updated plan, the M building refurbishment (Phase 2) should be finalised by the end of summer 2022.

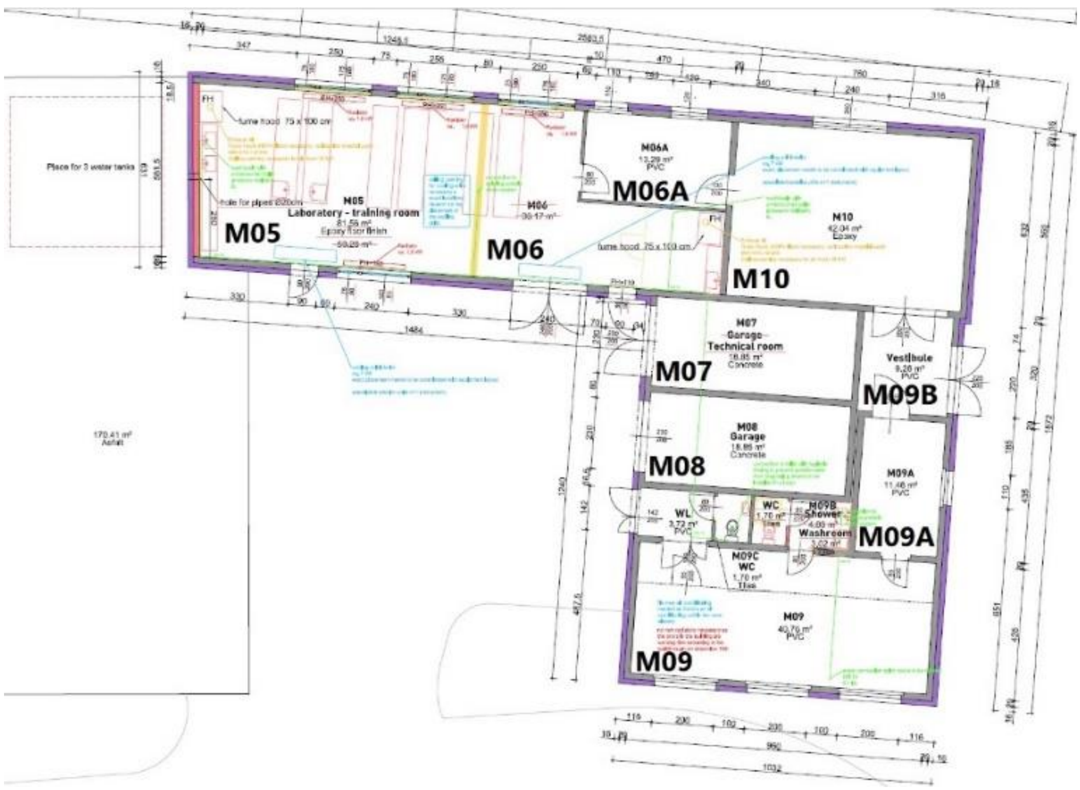


Figure 9. Floor plan refurbishment of M building for the NSF and ancillary experiments/applications, with a total surface of 250 m^2.

P385 DD neutron generator and its OHM

The DD P-385 neutron generator (see Figure 10) is a commercially available compact sealed tube. The device can operate at high voltage between 40 to 130 kV and with a beam current between 20 and 70 µA producing 2.45 MeV neutrons through the D(d,n)3He reaction.

Figure 10: The Thermo-Scientific P-385 DD generator with its neutron emission tube and a control unit.

It can be operated in continuous mode or in pulse mode with frequencies from 250 Hz to 20 kHz and adjustable duty cycle. The generator tube is 70 cm long and has a diameter of 10.2 cm. The emission point is located at 12 cm from the front end of the tube. The tube is connected to the control unit which is remotely controlled from the control room.

The Operation Housing Module (OHM, see Figure 11, [3]) of the DD generator is composed of a 30 cm thick high-density polyethylene (HDPE). A 10 cm diameter aperture, the so-called beam port, can be opened on one side of the OHM. The centre line of the aperture is positioned such that it intersects the neutron source location.

The beam stop is an inseparable part of the DD OHM and is composed of a 25 cm thick HDPE board, 64×55 cm on the side facing the beam port and 10 cm thick walls on the four sides around the neutron beam.

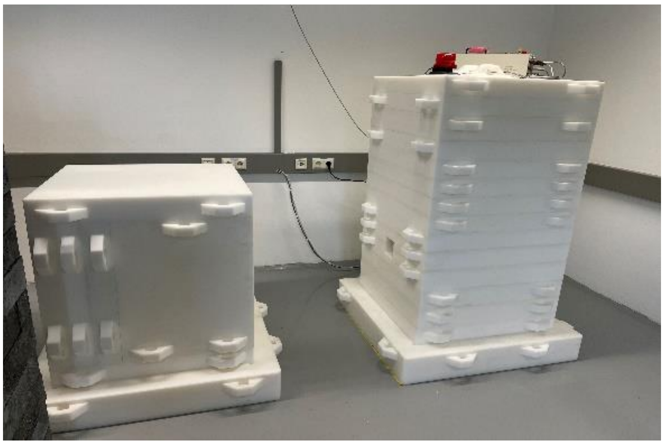


Figure 11: The OHM of the DD neutron generator (right) with the beam stop (left).

Commissioning of the DD generator at the NSF

The commissioning [4] included assembling of the polyethylene shielding and the beam stop, setting up of the DD neutron generator, the remote training on its use (provided online by generator provider Thermo Fisher Scientific), the safety interlock system checks (performed in cooperation with G4Steam who were responsible for the system installation), the radiation monitoring of the facility (performed by Division of Radiation, Transport and Waste Safety (NSRW)), and the testing of the operating parameters of the DD generator.

The safety interlock system checks consisted of confirming that each part of the interlock system can provide the required safety functions (typically to trip or disable operation of neutron generator) and the corresponding information.

Most of the tests did not require any neutron production, while a few of them required low neutron output operation to check the tripping ability once the safety signal was sent.

The radiation monitoring of neutron and gamma dose rates included monitoring inside and outside M10 at three levels of the neutron generator output (at about 10 %, 50 %, and 100 % of nominal neutron source intensity). Monitoring has been performed both with closed and opened beam port.

The radiation monitoring confirmed ambient dose equivalent rates below the required value of 1 µSv/h outside the controlled area when the DD neutron generator is operating.

Inside the controlled area, a non-negligible contribution to the ambient dose equivalent rate was found in low energy X-rays, peaking around 70 keV and originating from the neutron generator tube itself, close to the ion source. Although, M10 room is not accessible during operation of the generator, this radiation was practically eliminated by covering the tube head with a 2 mm thick lead sheet.

Figure 12: Dose rate monitoring performed by NSRW outside M building with DD neutron generator in operation.

Finally, the operating parameters of the DD neutron generator have been tested and confirmed. Neutron generator output has been estimated both by neutron activation analysis technique using golden foil and by using the ELSE He-3 thermal neutron detector (see Figure 13).

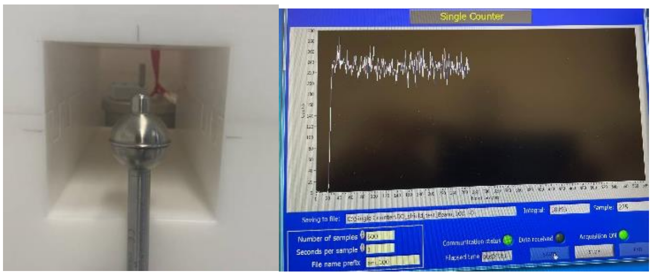


Figure 13: ELSE He-3 neutron detector in front of the open beam port of DD neutron generatgor over-head shielding (left). First neutrons observed at NSIL's NSF through the response of He-3 detector.

Both experimental techniques were confronted with Monte Carlo simulations, what showed acceptable agreement among the results [3, 4].

Further measurements were performed including the dependence of neutron output on high voltage and beam current, stability of operation, and the emission rate of the generator operated in continuous and pulsing modes. These measurements were carried our using the same ELSE He-3 neutron detector.

The DD neutron generator has been already put into nominal operation and service. Activities to establish the training program have started targeting to host the first training course in the fourth quarter of 2022.

First tests of the DT Neutron Generator

The Deuterium-Tritium (DT) sealed tube neutron generator (Figure 14), the source of 14 MeV neutrons with nominal maximum output of 3×10^8 n/s, was donated to NSIL a few years ago by The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

Figure 14. DT neutron generator.

During last few months, the NSF reached the stage of being able to start initial testing of the DT neutron generator. As the neutron generator was not in use for almost three years, the tests had to be conducted with special care and longer duration; specifically, a procedure of pumping and conditioning was followed to bring the generator to proper state regarding internal vacuum and high voltage holding capability.

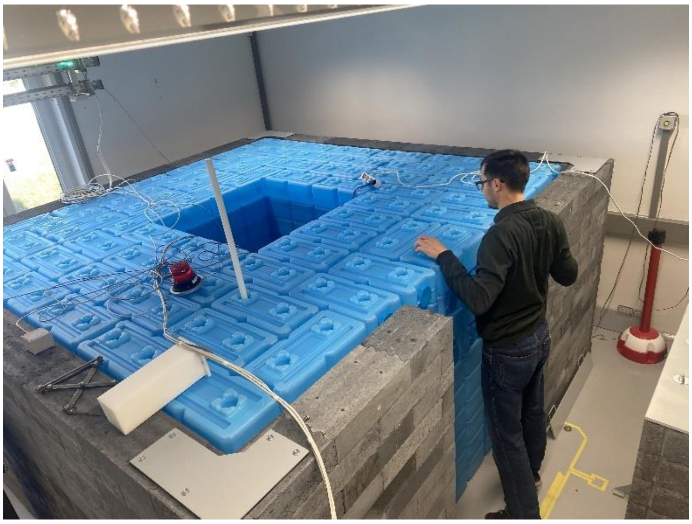


Figure 15. Combined heavy concrete and water shielding for the DT generator, placed inside the central cavity.

After successful finalization of conditioning procedure, initial neutron activation of thin metal foils measurements indicated the neutron output intensity in the range of 10^8 n/s over 4π, can be achieved. Preliminary radiation monitoring also confirmed that ambient dose equivalent rates are below the required value of 1 µSv/h outside the controlled area when the DT neutron generator is operating at this intensity.

Further test measurements will be required before the formal commissioning of this DT can be scheduled and performed in Q1 2022.

Progress in commissioning a Dual Neutron/X-ray Radiography and Tomography facility.

In the previous issue of the newsletter, a detailed description of the good imaging capability of the NSIL X-ray Radiography/Tomography system was published. In this issue, demonstration and optimization of the neutron radiography system using respectively thermal and fast neutrons is reported.

The maximum neutron yield of the DD generator is about 5×10^6 n s^{-1}. According to the Monte Carlo calculations, the thermal neutron flux is estimated to be of the order of 60 n cm^{-2} s^{-1} at the output of the beam port, and it is much lower than the recommended neutron flux to perform thermal neutron radiography. To increase the thermal neutron flux at the position of the imaging plane, a portion of the beam port from 10 cm×10 cm to 16 cm×14 cm was enlarged, so the imaging plane was moved closer to the neutron source. With the new optimized configuration, the thermal neutron flux at the imaging plane was increased nearly by a factor of 5 (to about 300 n cm^{-2} s^{-1}) - still relatively low for a typical thermal neutron radiography.

The thermal neutron radiography experiment setup at NSIL's NSF and the tested objects are shown in Figure 16. The extension part (inside the beam port) of the digital camera system was covered with a Cadmium sheet to avoid thermal neutrons background from the back of the imaging plane. The test objects included one lead cylinder can, filled with water, and a lead sheet with two cadmium bars inside positioned in “L”-shape.

Figure 16: Theexperiment setup of the thermal neutron radiography system (left), and the tested objects in the beam port (right).

During the experiment, the DD generator operated at steady continuous mode at its full nominal output (70 µA of current and 130 kV of high voltage). The CCD camera of the imaging system was operated at -20 °C. The exposure time setting was set for 2 hours. The resulting image we obtained as illustrated in Figure 17.

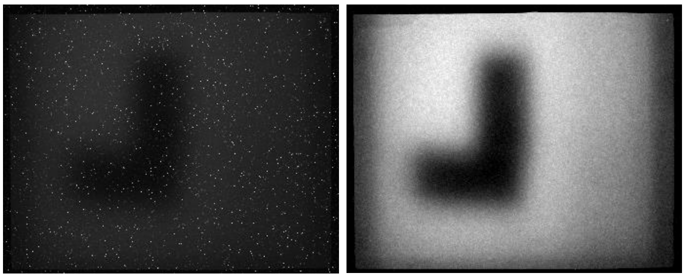


Figure 17: The original raw image provided by thermal neutron radiography system (left) together with the optimized image using ImageJ software (right).

By looking into the raw data one can distinguish only vaguely the “L”- shape of the cadmium bars inside the lead sheet. However, after removing spot noise and adjusting the contrast using the software *ImageJ*, a better visualisation of the cadmium bars is obtained. On the other hand, one can barely observe the shadow of the lead can, filled with water.

Fast neutron radiography experiments were also performed by keeping exactly the same configuration as described above and only exchanging the thermal neutron scintillator with the fast neutron scintillator. According to the Monte Carlo the fast neutron flux at the imaging plane position was expected to be of the order of 1200 n cm^{-2} s^{-1}. Figure 18 depicts the inspected objects we used and the optimized image.

From the two described experiments, we can conclude that we successfully demonstrated the feasibility of the neutron radiography experiment even with a relatively weak thermal and fast neutron fluxes of respectively ~300n cm^{-2} s^{-1} and 1200 n cm^{-2} s^{-1}. These experiments have proven that DD neutron generator will be beneficial to demonstrate neutron radiography capabilities for educational purposes.

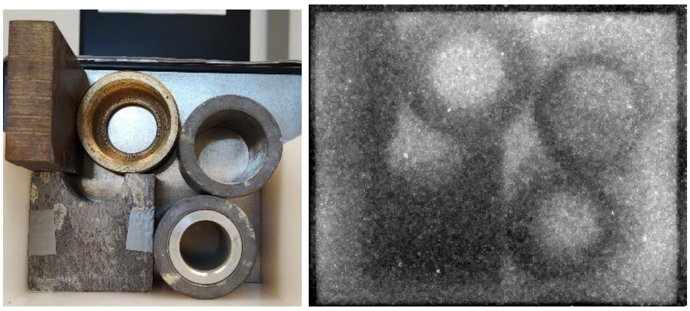


Figure 18: The tested objects were as follows : three hollow cylinders (made from lead, alloy and lead-alimimum layers) and two bricks (made from lead and iron) (left); the optimized fast neutron radiography image (right)

After commissioning of the DT neutron generator, better quality neutron radiography images may be expected due to much high neutron fluxes available in this particular case.

References

[3] Safety Analysis Report for commissioning and operation of the DD and DT neutron generators at the Neutron Science Facility, NA-NSF-2021-09

[4] Commissioning report for the DD neutron generator at Neutron Science Facility of Nuclear Science and Instrumentation Laboratory

1.6 Support to Radiation Technology experiments

New Online Course in the IAEA’s CLP4NET

For an auspicious online industrial and environmental processes diagnosis, troubleshooting and optimization using radiotracers and sealed source techniques, supporting and promoting sustainability of national capabilities are of crucial importance. These techniques have been widely used, as a unique non-invasive diagnostic tool in various complex processes to improve product quality, save energy and reduce pollution release.

During the COVID19 pandemic, partial-lockdown restrictions were in place at NSIL Seibersdorf laboratories. Nevertheless, the collaborative efforts with the support from the IAEA TC department has resulted in the development and production of an online training materials suitable to conduct virtual training workshops or as self-learning modules relevant to radiation technology experiments. Four such pre-recorded demonstration videos have been realised, with brief descriptions provided below and available through IAEA’s CLP4NET system.

Indeed, it was of high importance to keep supporting Member States with capacity building and capabilities enhancement during that very critical period characterized by tough travel restrictions and unavailability of hands-on-training courses due to pandemic restrictions.

(1) Radiation Safety Considerations. Outlining Safety instructions for handling properly radioactive material before carrying out any operation using radioactive tracers is one of the main objectives of the IAEA. Detailed information on radiation protection procedures is illustrated in the first video of this online training material to emphasise safety common guidelines as wearing appropriate protective clothing and dosimeters, planning to minimize radioactivity handling time, using an appropriate radiation shielding, self-monitoring on a regular basis and regular radiation surveys of work area for contamination control during and after completion of work.

(2) Elution Procedure of the 99Mo-99mTc Generator for Industrial and Environment Applications. The IAEA program aims to enhance the expertise and capability of IAEA Member States in deploying radioisotopes generators for industrial applications to meet national needs as well as to assimilate new developments in radiotracers use for diagnostics in industrial and environmental processes and optimization of applications. Since over 70 % of industrial radiotracers investigations are still performed with the 99mTc isotope - driven mainly by the easy availability - the focus of the second video of this training material was on describing meticulously all steps for performing safely the elution of the 99Mo-99mTc generator prior to its industrial and environmental applications.

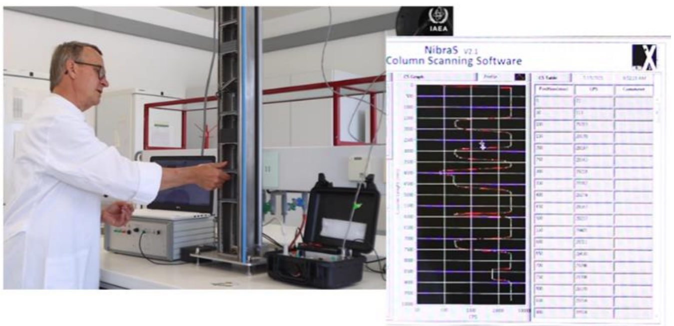


Figure 19: Gamma scanning demonstration of a distillation column model using X-ray generator and NibraS Data Acquisition Software.

(3) Gamma Scanning Methodology is the most widely applied non-intrusive and non-destructive sealed radioactive source technique for diagnosing and troubleshooting complex and multiphases processes, mainly petrochemical industries. It has been promoted by the IAEA for several years, giving examples of its use in industrial and environmental applications, and demonstrating how it can be applied to improve process efficiency and economic benefits. It consists of scanning trayed and packed columns, using appropriate sealed radioactive sources and related radiation detectors, to obtain density profiles and identify on-line problems such as damaged tray or packing, foaming, flooding, maldistribution, weeping, entrainment etc. The third video of this online course shows a recorded gamma scanning demonstration of a distillation column model using X-ray generator as an alternative to a sealed radioactive source to minimize any possible radiation exposure when working at laboratory conditions.

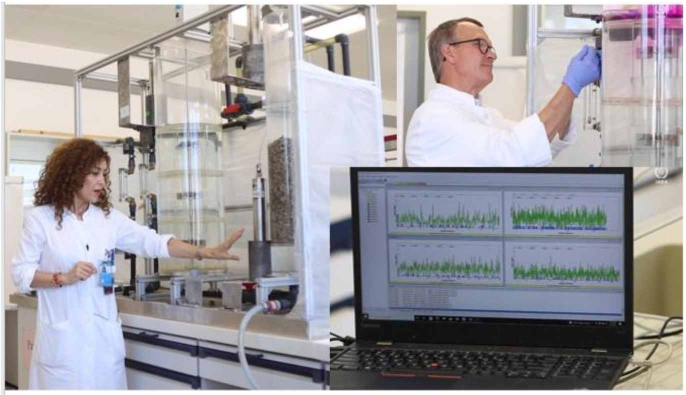


Figure 20: Radiotracer Methodology: Flow Rig setup, Radiotracer injection & RTD measurement using the newly developed Data Acquisition System (DAS) at NSIL laboratory.

(4) Radiotracer Methodology: Flow Rig Setup, Radiotracer Injection & Residence Time Distribution Measurements. The IAEA plays a major role in facilitating the transfer of radiotracer technology to Member Statesto optimize the performance of the various multiphase chemical process industries by increasing the understanding of these processes, identifying related malfunctions without requiring the shutdown, and assisting in the modelling of the key multiphase flow systems thus leading to high economic benefits. One of the available lab-scale methods for demonstrating the use of radiotracer for online measurement of the Residence Time Distribution (RTD) of a process material is by introducing a radiotracer to a water piping setup (called flow-rig system) that mimics the material's flow pattern. In the recorded exercise showed during the fourth video of the online course, a low activity of 99mTc radioisotope was injected into the water processing and NaI (Tl) detectors were calibrated and collimated to detect spectrum peaks at specific locations of the system. Then, the recently developed Data Acquisition System (DAS) at NSIL laboratory - which is the basic equipment for online radiotracer work - ensures collection, treatment, and visualization of the data.

1.7 NSIL Capacity Building Activities

NSIL has continuously developed new online training materials as alternative tools to counteract the negative impact of the remaining restrictions imposed by COVID-19 pandemic. Readers are advised to check the Nuclear Science and Instrumentation Portal for updates.

Online training materials

Since February 2021, the Nuclear Science and Instrumentation (NSI) Portal section on Training and the IAEA Open Learning Management system has incorporated new online materials.

Presently, thirteen new lectures were added on portable radiation detectors and in-situ techniques, as well as on X-ray spectrometry topics:

- UAV based radiological mapping of buildings
- Characterization on contamination and NORMs using portable high resolution identification devices
- XRF: fundamentals
- Instrumentation for XRF
- Statistics and detection limits in XRF
- Assessing distribution of elements using micro and confocal XRF
- Assessing 2D spatial distribution of elements using FFXRF
- Transportable XRF and XRD scanners to support characterization of cultural heritage
- Synchrotron techniques to support characterization of cultural heritage
- X-ray absorption spectroscopy in support of characterization of cultural heritage
- GEXRF for the analysis of layered materials
- PIXE analysis of cultural heritage objects
- SEM_EDS analysis of laminated altered layers in historical glass

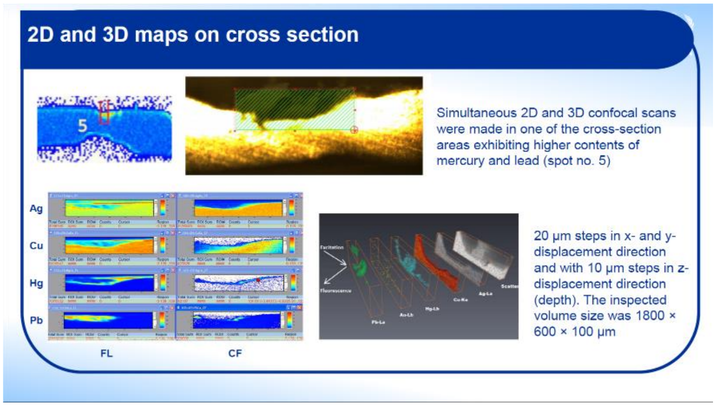


Figure 21: Example of one of the lectures available as MP4 movies recorded from MS PowerPoint presentations

Two additional practical demonstrations on XRF methods, recorded as videos are available from the NSI portal:

- Assessing distribution of elements using micro and confocal XRF
- Assessing 2D spatial distribution of elements using FFXRF

As a result of support provided by the Division of Technical Cooperation for Latin America and the Caribbean (TCLAC), two new e-learning materials on XRF and XRD techniques in the area of forensic investigations. These two new courses were added to the existing collection on Nuclear Analytical Techniques for Forensic Science, and the expanded collection was translated to Spanish.

The event was organized by the Division of Nuclear Fuel Cycle and Waste Technology in the Vienna International Centre and the IAEA Laboratories in Seibersdorf. Several lectures and practical exercises were provided by NSIL and the Terrestrial Environmental Laboratory (TEL), namely :

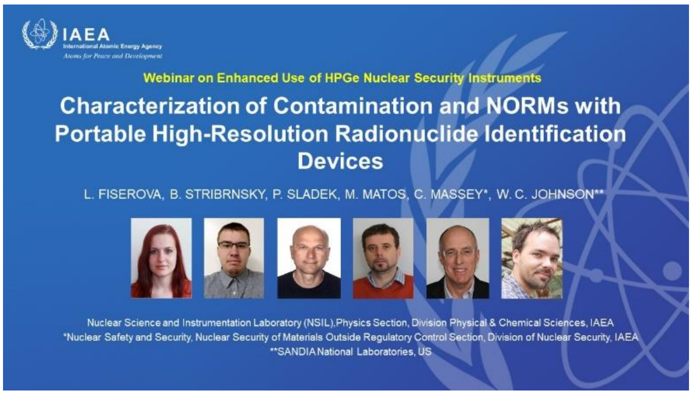
- Designing and implementing soil and vegetation sampling plans
- Radiological Mapping with Unmanned Aerial Vehicle (UAV) – NSIL Activities and Development
- Familiarisation, selection and use of radiological survey equipment
- Soil and vegetation sampling, packing and labelling
- Data visualization, spatial analysis and mapping using geo-statistic techniques and R-software.

The Workshop was attended by 19 participants (6 females) from 17 Member States.

Virtual Webinar on use of high-resolution gamma detectors for nuclear security tasks

17 November 2021.

This webinar on the Characterization of Contamination and NORMs with Portable High-Resolution Radionuclide Identification Devices was organized as part of cooperative activities between NSNS and NAPC. The objective of the webinar was to provide an overview of the approach for measurements of terrestrial contamination and characterization of NORMs using HPGe as one of typical instruments used for nuclear security applications. The Webinar targeted expert organizations, policy makers, and front-line organizations involved in the specification, procurement, and use of these types of instruments.



The webinar was attended by 193 participants (29 females) from 50 Member States.

Virtual Training Workshop on Accelerator Technology and Associated Instrumentation, Including Operation and Maintenance Aspects

22–26 November 2021.

A number of IAEA Member States are operating small and medium sized electrostatic accelerator facilities with a wide spectrum of technical expertise. Many of these facilities are facing difficulties in training new personnel and improving the knowledge and skills of more senior accelerator technicians, engineers and scientists. The need for training on accelerator technologies is evident and the IAEA is responding to such needs.

Due to Covid pandemic, a physical training in operation and maintenance of electrostatic accelerators was not possible to organize, therefore it was decided to organize the workshop virtually.

The objective of the virtual event was to discuss the issues during operation and maintenance of electrostatic accelerators and associated equipment and to deepen participants' knowledge in specific accelerator-related topics. The form of the meeting was a virtual roundtable with presentations, some with included recorded videos, from different laboratories followed by the discussions on presented issue.

The event was intended for young and experienced accelerator operators, engineers and scientists working at electrostatic accelerator facilities.

68 participants (8 females) attended this very successful event. One of the conclusions of the workshop was that it should continue to be organized in virtual form on annual basis, preferably as webinars. This will not abolish biannual physical hands-on-trainings in operation and maintenance of electrostatic accelerators.

1.6 Proficiency Tests Organized by NSIL

PTNATIAEA19: Analysis of clay and plant samples

The current exercise PTNATIAEA19, launched on 19 May 2021, as proficiency test (PT) materials includes a "clay sample" and a "plant sample" with well-established homogeneity and composition.

The test samples were shipped to the 101 registered participants by mid-August (the deadline was postponed by one month because of difficulties in delivering the samples due to the COVID-19 pandemic) and the closing date for submission of results was 31 January 2022.

The report preparation of results of the PT exercise is in progress and will be published through the PT website as usual.

2. Support to Technical Cooperation Projects

NSIL provides technical backstopping and support for more than 40 Technical Cooperation (TC) projects, particularly in "Capacity building, human resource development and knowledge management", "Marine, terrestrial and coastal environments", "Radioisotopes and radiation technology for industrial, health-care and environmental applications", "Accelerators" and "Nuclear Instrumentation". NSIL also supports other Technical Divisions within the IAEA in actions complimentary to their fields of expertise.

The restrictions imposed by COVID-19 pandemic have forced to find solutions to implement some of the activities in virtual mode. National and Regional Training Courses (RTCs) are one of the activities that can be used to implement this modality. Technical officers from the NSIL organized or supported several RTCs using MS Teams and Webex platforms.

RLA7023: Assessing Atmospheric Aerosol Components in Urban Areas to Improve Air Pollution and Climate Change Management (ARCAL CLIV)

RTC on remote sensing techniques
Virtual event, 5, 7, 12 and 14 October 2021

The regional project RLA7023 aims at reducing the impact of human activities on air quality deterioration, human health and climate change in countries of Latin America and the Caribbean. Elevated concentrations of airborne particulate matter (APM) contribute to early mortality, and therefore monitoring their concentrations and determining the sources of origin is of outmost relevance to address mitigation measures.

The objective of the RTC was to train participants on back-trajectory analysis and remote sensing techniques, allowing to identify events that might have happened elsewhere and due to long range transboundary transport of the air particulate matter be the cause of the observed increase in air pollution.

Lectures and practical demonstrations were provided by one expert from CNEA (Argentina) and two from University of Valladolid (Spain), and covered the following topics:

- Remote sensing fundamentals: gases and aerosols
- Satellite remote sensors: algorithms, images and data
- Air quality modelling and,
- Integrated management of aerosol event detection tools

The course was attended by 43 participants (17 females) from 13 Member States.

INT2020: Enhancing Capacity Building to Promote Successful Decommissioning and Environmental Remediation Projects

Training course on Environmental Remediation Site Characterization
Virtual event, 11 - 22 October 2021

The interregional project INT2020 aims at enhancing capacity building to promote successful decommissioning and environmental remediation projects. The training course was jointly organized by the Division of Nuclear Fuel Cycle and Waste Technology (NEFW) and the Division of Radiation, Transport and Waste Safety (NSRW) with the support experts from Canada, France, Germany, United Kingdom and United States of America. The topics included:

- Overview on the behaviour (fate and transport) of natural and artificial radionuclides involved in different contamination situations
- Regulatory aspects - aim of remediation: control of exposure
- Overview of detectors and measurement techniques used in site characterization
- Main concepts and approaches in the characterization of groundwater
- Site characterization in the scope of nuclear/radiological accident
- Characterization of nuclear sites
- Characterization of uranium mining sites
- Strategy of data acquisition + data visualization & modelling

NSIL assisted the event by providing lectures on the topics of radiation monitoring using portable detector and on in situ measurements and mapping to support radiological characterization of sites.

The course was attended by 31 participants from 19 Member States.

RLA1017: Applying Nuclear Analytical Techniques to Forensics for Analysing Firearms Crime Evidence

RTC on Nuclear Analytical Techniques for forensic analysis, including methods validation and quality assurance
Virtual event, 1 - 5 November 2021

Crime has been since many years, one of the main concerns of the population and the governments in Latin America and the Caribbean region. Many governments have enforced new legislation to combat the impunity of crimes through the development of clear, robust and conclusive criminal investigations, the compulsory requirement to base the process on the assessment of the evidence collected at the crime scene.

Nuclear and related analytic techniques (NATs) are a convenient tool to obtain a comprehensive micro-analytical characterization of forensic evidence. In general, NATs have a comparatively high sensitivity and require of minute amounts of samples. In many cases these techniques provide multi-elemental or multi-parametric results (e.g. elemental, mineralogy, structural, morphology, spatial distribution, among others), thus contributing to speed of the analysis and obtaining complimentary types of information. Several NATs are also non-destructive, thus allowing to preserve the scarce evidence for further analysis if requested.

The purpose of the RTC was to train participants on using nuclear and related analytic techniques for the characterization of forensic evidence, including:

- Neutron activation analysis (NAA)
- Scanning electron microscopy with X-ray microprobe (SEM-EDS)
- Vibrational spectroscopy techniques
- X-ray fluorescence (XRF) and X-ray diffraction (XRD)

The RTC was supported by lecturers from the Nuclear Analytical Laboratory International Centre for Environmental and Nuclear Sciences (Jamaica), the University of Alcala (Spain), The Service of Criminal Investigations of the Civil Guard (SECRIM, Spain), the Dep. of Geosciences, IDAEA-CSIC (Spain), the University of Girona (Spain) and the Central Laboratory of the Catalonian Police

(Spain). The attendants were 36 fellows (21 female) from 9 Member States participating in the project.

RAS1025: Enhancing the Capabilities of Radiocarbon Dating in Archaeological Applications (ARASIA)

RTC on Age Calculations, Isotope Fractionation, Data Interpretation and Bayesian Statistics of Radiocarbon Dates
Virtual event, 8-11 November 2021

All ARASIA countries are rich in archaeological patrimony. Large number of archaeological sites and excavations have unearthed remains dating thousands of years that belong to earlier civilization. Organic remains, such as bones, charcoal, seeds, etc., are the main findings that require absolute dating in order to better understand the past human history and to reconstruct early human occupation. Radiocarbon dating is a crucial tool for studying national cultural heritage and reconstructing ancient human history, however, most radiocarbon dating for artefacts is carried out in foreign laboratories with expensive cost.

The aim of this RTC was to strengthen the expertise in the field and assist Member States to improve the quality of their data, enhance capabilities in radiocarbon age calculation, correction, calibration, choice of adequate calibration curve, and application of Bayesian statistics to interpret data and define outliers.

Fourteen participants (7 females) from ARASIA Member States attended the RTC.

RER7012: Determining Long Term Time Trends of Air Pollution Source Tracers by Nuclear Techniques

RTC on Knowledge discovery on knowledge discovery on handling large datasets
Virtual event, 11-15 November 2020

To address the high level of air pollution in Europe, the regional project RER7012 has the objective to continue monitoring the concentration of atmospheric fine fraction of particles (PM2.5), to improve the accuracy of determining their elemental and chemical profiles and enhance the usefulness of the available data.

The identification of sources of pollution has been carried out so far using positive matrix factorisation (PMF). The project has gathered an extensive dataset, and due to the developments in big data handling and machine learning techniques, a RTC was organized to introduce the participants to several techniques, including:

- Machine learning for environmental data analysis
- Tree ensemble models
- Use of different software tools for handling large data sets

The RTC was supported by experts from Josef Stefan Institute (Ljubljana, Slovenia) and from the AGH University of Science and Technology (Krakow, Poland). The techniques were tested using one dataset provided by the Hungarian counterpart. The 14 participants (12 females) from 11 Member States positively evaluated the contribution of the course and committed to continue the research in the field, including several additional tests aimed at assessing the robustness of the machine learning techniques in different cases.

BAH7001: Enhancing Analytical Capabilities for Improved Environmental Monitoring

Task Force Meeting to Compile Results on Identification of Air Pollution Sources,
Virtual event, 20-30 October 2020

The national project BAH7001 is implemented with the aim of providing Bahrain with the technical capacities (equipment and expertise) to acquire and operate several radioanalytical methodologies aimed at the determination of major, minor and trace elements in seawater, drinking water, and environmental samples, thus helping to assess the impact of different activities releasing contaminants on the environment and the people of Bahrain.

Figure 22: A Liquid Scintillation Counter (LSC) and an Alpha Spectrometer with 8 measuring chambers to support Bahraini technical capabilities in measuring Alpha and Beta emitting radionuclides in water and environmental samples

An effective and integrated training program consisting of six (6) interlinked training packages is currently implemented to cover the following topics: sampling and pretreatment of environmental and norm samples, developing a sampling strategy and design of the field sampling, determination of alpha emitters by alpha spectrometry, liquid scintillation counting and determination of tritium in liquid samples, determination of gross alpha/beta and beta emitters (Pb-210, Ra isotopes, Sr-90, C-14) by LSC, and ISO/IEC 17025:2017 in radioanalytical laboratory. Depending on the nature and order of the training, some of these training packages are to be conducted online and others are to be performed physically as hands-on-training exercises, and with the direct assistance of two IAEA experts, at the Public Commission for the Protection of Marine Resources, Environment and Wildlife of Kingdom of Bahrain.

Such a consistent human resources capacity building program is promising Bahraini team to become a regional ISO-compatible centre employing radioanalytical techniques for determination of alpha, gross alpha/beta and beta emitters for monitoring of the terrestrial and marine environment.

3. Reports from NSIL Events

Training Workshop on Advanced X-ray Techniques for Characterization of Valuable Objects.

Virtual event, September 6 – 10, 2021

The workshop consisted of lectures and video demonstrations on advanced laboratory and large-scale facilities-based X-ray techniques for non-destructive characterization of valuable objects, including: Micro and Confocal X-ray Fluorescence (XRF), 2D scanners for XRF and x-ray Diffraction (XRD), Scanning Electron Microscopy with energy dispersive X-ray microprobe (SEM-EDS), Synchrotron-based XRF and X-ray Absorption (XAS) and Particle Induced x-ray Emission (PIXE).

The lectures were provided by two specialists from NSIL and other experts from partner institutions, including the Kunsthistorsiches Museum (Vienna, Austria), the Laboratorio di Analisi Non Distruttive), IBAM-CNR (Catania, Italy), the University of Milano (Italy) and the Antwerp Maritime Academy (Belgium). Two specialists from Elettra Sincrotrone (Trieste, Italy) and one from the Ruđer Bošković Institute (Zagreb, Croatia) provided lectures as well.

The provided lectures were of excellent quality in content and methodological outline, and the answers provided to questions raised by the participants were very useful. Participants agreed that the objectives of this workshop were met and provided a positive feedback on different aspects of its organization and implementation, including suggestions for further improvements in the organization of this type of virtual events.

The Workshop was attended by 162 participants (76 females) from 43 IAEA Member States. The objectives of the workshop were communicated to TC relevant projects pursuing to support some of their needs for capacity building and not to duplicate efforts. TCLAC found the workshop relevant for the objectives of two regional projects (RLA1017 and RLA1019) and encouraged the participation of teams working in these projects (37 out of the 162 participants).

Although the implementation of the workshop as virtual event using MS Teams for such large number of participants was a challenge, it demonstrated that this alternative way to offer training was still efficient for most of the participants. However, it is advisable to keep the attendance at a smaller audience and probably focusing on countries within a similar time zone interval.

Consultancy Meeting to discuss on activities of ICTP-IAEA Joint Adaptive Research Projects

Seibersdorf, October 11 – 15, 2021

NSIL has successfully organized several events in cooperation with the ICTP Wireless Laboratory (T/ICT4D) and with the Multidisciplinary Laboratory (MLab) from Abdus Salaam International Centre for Theoretical Physics (ICTP). The T/ICT4D has long experience in implementing Long Distance Wireless Links, Wireless Sensor Networks for Development and Low-cost solutions for wireless links setup, whereas MLab focuses on R&D of scientific instrumentation based on modern technologies for experimental physics and on X-ray imaging and analysis for culture heritage conservation, among other fields of research and training.

Since 2020, an additional cooperation program was jointly developed to foster the implementation of Joint ICTP-IAEA Adaptive Research Projects. The Consultancy meeting was organized within this program, and the progress in implementation of the activities of three joint projects were discussed:

- Development of a compact radiation monitor and spectrometer based on FPGA technologies;
- Improvement of transportable units for XRF analysis of cultural heritage and;
- Access to, development and utilization of nuclear instrumentation and machine learning based methods

Training Workshop on Accelerator Technology and Associated Instrumentation, Including Operation and Maintenance Aspects

Virtual event, November 22 – 26, 2021

The purpose of the event was to provide hands-on training for young researchers and accelerator staff in different accelerator technologies as well as the associated operation and maintenance procedures.

The workshop was attended by 68 participants (6 females) from 23 Member States.

The workshop also resulted in exchange of information on the research infrastructure available among partners of the ongoing coordinated research project on Facilitating Experiments with Ion Beam Accelerators, and to review the progress to date and rectify problems identified during first several experiments.

Joint IAEA-ICTP School on Synchrotron Light Sources and their Applications

Virtual event (smr 3611), December 6 – 17, 2021

The IAEA-ICTP School was held virtually over two weeks, 4-hours per day. The event was co-sponsored and organized with the SESAME synchrotron in conjunction with the African Light source (AfLS), Lightsources for Africa, the Americas, Asia and Middle East project (LAAAMP), the European Synchrotron Research Facility (ESRF) and the Cyprus Institute, and its Agenda included a presentation was made by NSIL on “XRF Techniques for Materials and Life Sciences”.

The School was attended by 132 participants (38% female), 123 of which were from developing countries. 42% of the participants were from Africa, 42% from Asia and the remaining 16% from the rest of the world.

First Research Coordination Meeting of CRP G42008 “Facilitating Experiments with Ion Beam Accelerators”

Virtual event, December 6 – 10, 2021

The Coordinated Research Project (CRP) G42008 aims at facilitating researchers from countries not having ion beam analysis (IBA) accelerator facilities to perform experiments in such facilities abroad. The project started at the end of 2019 and is supporting travels of researchers to perform experiments at the ion beam facilities in the neighbouring countries. Unfortunately, the project was heavily affected by COVID-19 pandemic, restricting mobility of the researchers.

The first RCM for that CRP was held virtually to discuss status and possibilities to improve the project and overcome the issues due to pandemic. 26 participants from 24 countries presented their accelerator facilities and conducted and planned research through five days meeting. The status of implementation of the CRP can be summarized as follows (also see map in Figure 22):

- 11 ion beam accelerator centres (blue circles) are distributed in different areas of the world;
- 14 research teams (red circles) scheduled or already performed their experiments in the following areas: Agriculture (1), Archaeology (1), Biology (2), Ecology (5), Geology (1), Nuclear Physics (1), Solid State Physics (1).

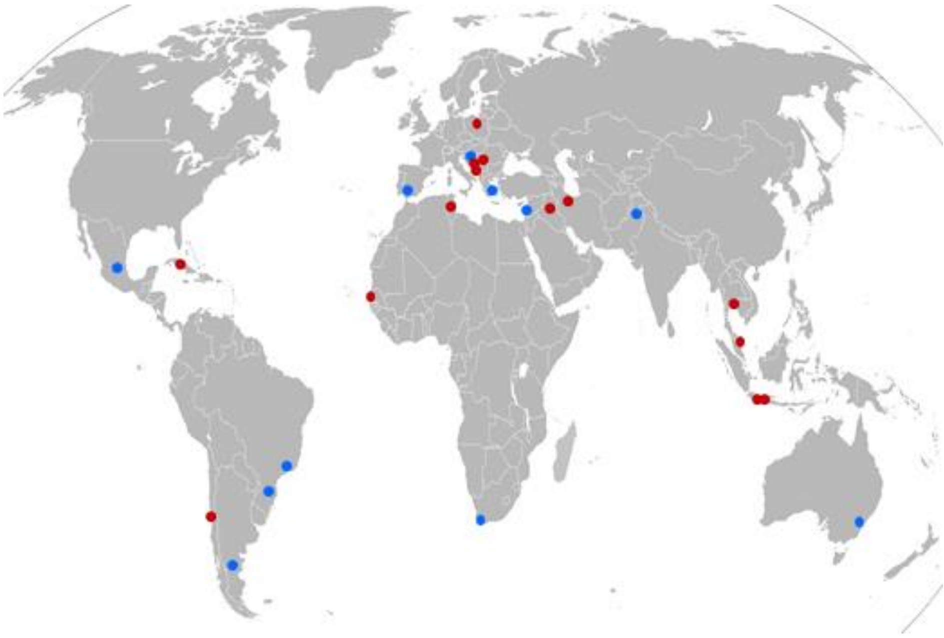


Figure 22: Geographical distribution of teams participating in CRP G42008: blue dots – supporting accelerator facilities, red dots – research teams accessing the facilities

4. Reports from Member States

Cuba

Laboratory Portrait:

Cienfuegos Centre for Environmental Studies

The Cienfuego's Centre for Environmental Studies (CEAC, Spanish acronym) is a research centre which belongs to the Agency of Nuclear Energy and Advanced Technologies (AENTA) of the Ministry of Science, Technology and Environment (CITMA). Since 2007 it has been recognized by the IAEA as a Regional Reference Centre for the application of nuclear techniques to the solution of Integrated Coastal Management problems.

CEAC facilities include an Environmental Laboratory which supports studies relevant to the identification of the sources, transport, fate and effect of pollutants in the environment, through the use of isotopic, nuclear and advanced techniques. The Environmental Laboratory is open to international scientific collaboration and its work goes beyond the borders, providing results compliant to the highest quality standards.

Strengthening of laboratory analytical capabilities with EDXRF technique

Thanks to technical cooperation with the IAEA, the laboratory capabilities have been strengthened with equipment and training for years. In 2017, with the support from the IAEA regional project RLA/7/020, the laboratory was equipped with an EPSILON 3XLE Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometer (Malvern Panalytical). Procedures are available for elemental characterization of biological material, atmospheric particulate matter (bulk atmospheric deposition and aerosol on filter samples), soil and marine sediments. The latter is accredited by the National Accreditation Body (ONARC) in compliance with the NC ISO/IEC 17025:2017 criteria, and the validity of analytical results are regularly demonstrated in proficiency tests involving the analysis of different environmental matrices coordinated by the IAEA laboratories and others.

To date, the EDXRF technique has enabled us to respond to government requests, scientific and technical services and research projects needs in the field of environmental pollution.

EDXRF application in pollution monitoring and geochronology studies in Cuban marine ecosystems using sediments.

Both freshwater and marine sediments are widely used as geo-marker for monitoring and identifying the possible sources since sediment can act as sink for the pollutants, providing valuable information on spatial and temporal changes in these inputs. To assess the risk of these contaminants, techniques are needed to evaluate their levels, so X-ray fluorescence (XRF) methods, due to its advantages: multi-elemental, non-destructive, do not need any sample preparation, and have good precision and accuracy, allow such evaluations to be carried out quickly and efficiently [1].

Cuba is a developing island country with a population of about 12 million inhabitants, of which about 10 % live in coastal areas. During the second half of the 20th century industrial development increased in Cuba, where mining, domestic non-treatment wastes, oil refining and thermoelectric industry (heavy oil combustion), as well as other more polluting industries had a potential impact on the coastal zone and its sediments. Therefore, several programs to monitor and assess the pollution on these impacted coastal sites have been performed using the capabilities installed in our EDXRF laboratory. As illustrated in Figure 1, spatial distribution of contamination has been assessed in: the coastline of the mining area of Santa Lucía (northwest), Cienfuegos Bay, where there has been an important development of harbour and industrial activity, oil refining and thermo-energy generation since the 1960s [2]; Guacanayabo Gulf, a site of important fishing activity and to which anthropic activities from different anthropic sources, among others [3].

Figure 1: Coastal sites of interest for sediment pollution studies

As a complementary support of the sediment geochronology studies, the laboratory has conducted analyses of sediment corer in other Cuban coastal areas impacted by industrial activity, over the past several years to better understanding the contamination history of each site. Those results are included in technical reports made to governmental groups for marine resource conservation and providing valuable information for the optimization of coastal zone management policies.

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Application of EDXRF in atmospheric pollution studies

Air pollutants, especially airborne particulate matter (APM), have been associated at urban and rural sites with several kinds of sources resulting in adverse health effects [4]. Characterization of PM components, including inorganic elements, is of primordial importance in proposing mechanisms for health effects and in source apportionment studies. One of the common techniques for the elemental characterization of aerosol samples is the XRF, due to well-known advantages [5]

Support to airborne particulate matter pollution monitoring

In 2020, as support to the ARCAL RLA7023 "Assessing Atmospheric Aerosol Components in Urban Areas to Improve Air Pollution and Climate Change Management", the EDXRF capabilities of CEAC were used to determinate the elemental composition of $PM_{2.5}$ samples from a monitoring program in a reference sampling site located at Havana city (Figure 2). Data generated was used to evaluate the Cuban air quality regulations, assess the impacts of fine particulate air pollution at local and regional scales, as well as for source apportionment using dispersion modelling and receptors model.

Project results were mainly directed to health and environmental authorities, to research centres linked to environmental impact studies and risk analysis to provide the basis for decision makers in the adoption of control strategies to reduce the impact of air pollution in urban areas.

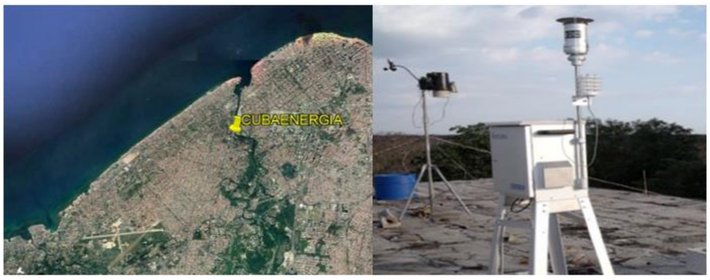

Figure 2: Monitoring of PM2.5 airborne samples in Havana. Reference sampling point (left), Low volume sampler Tecora (right)

Elemental characterization of air quality biomonitors in central region of Cuba

Since 2019, EDXRF capabilities have also been used to provide continuity and support studies on air quality in the City of Cienfuegos using the epiphytic plant *Tillandsia recurvata L.* as an air quality bio-monitor [6, 7]. Biomonitoring is a simple and relatively inexpensive tool for spatiotemporal surveys of environmental quality including air pollution. Although lichens are frequently used in temperate regions, *Tillandsia species* (Figure 3) are more appropriate to monitor atmospheric pollution in tropical areas. Using EDXRF we have analysed up to 24 elements in tissue samples of these plants, including specific tracers of anthropogenic pollution sources such as Zn, Cu, Pb, V and Ni. The results have facilitated the study of how contamination is distributed throughout the urban area of Cienfuegos, determining specific tracers of emissions from point sources of pollution, as well as identifying the main sources of pollution (road traffic emission, fossil fuel combustion sources and emissions associated with urban waste landfills, among others). These results are an important contribution to the studies of environmental pollution in urban areas in Cuba, due to the persistence of limitations in the country to monitor the air pollution by traditional methods, which generally require many resources and long periods of time.

Figure 3: Bio-monitor (Tillandsia recurvata L. species) used in air quality studies in Cienfuegos

International academic exchange and others research activities

As part of the research activity, academic exchanges have been developed between CEAC and the University of Vermont and Oberlin College (USA) for the study of soil erosion in watersheds and the impact of Cuban agriculture in recent years [8]. The characterization of the sediments of the studied basins in the western and central regions of Cuba has enriched the studies (Figure 4).

Figure 4: Sampling for soil erosion studies of watersheds in Cuba

Other activities implemented under national research programs where XRF plays an important role are: i) study of macronutrient and micronutrient levels related to food safety and nutritional value of plant foods; ii) mangrove sediments elemental composition in coastal and wetland areas; iii) soil pollutant composition of soil impacted by agricultural and industrial activities; among others.

Challenges ahead

Among main challenges and goals identified for the laboratory, one need to mention:

- Increase the visibility of our laboratory in the national, regional and international area, reporting results with the highest quality standards.
- Maintain the accreditation of the laboratory in compliance with NC ISO/IEC 17025:17.
- Involve the XRF techniques in high impact research for the solution of environmental problems.

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Spain

Laboratory Portrait:

Join Laboratory UdG + CSIC for X-ray Analytical Applications (LARX)

In recent years, the conceptual advancement on green analytical chemistry (GAC) has moved in parallel with efforts to incorporate new screening or quantitative low-cost analytical tools to solve analytical problems. In this sense, the role of solid-state techniques (such as XRF) that allow the non-invasive analysis (or with a minimum sample treatment) of solid samples cannot be neglected. The main activity of the LARX is to progress in sustainable analytical methods for the study of metals, metalloids and metallic nanoparticles in solid and liquid samples in many different fields making use of nuclear analytical techniques (NATs), see Figure 1.

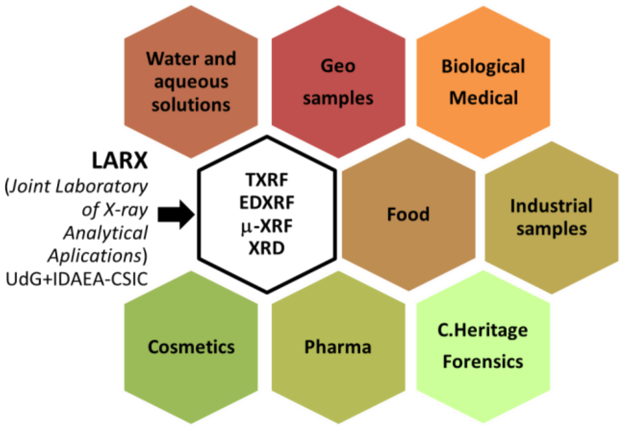

Figure 1: Fields of application of XRF and XRD in LARX

In the premises of LARX other atomic spectroscopic techniques (i.e, ICP-OES and ICP-MS) are also available to confirm and validate the results found with those based on XRF when required.

Below a summary of some of the most recent studies performed by the laboratory in biomedical, food and environmental fields are presented.

Application of TXRF and EDXRF for multielement determination in biological fluids and tissues

In most clinical studies it is of significance to know information about the multi-elemental composition of biological samples. Conventional analysis of this type of samples relies upon digestion followed by atomic spectrometry detection. This approach is essential for the quantification of ultra-trace elements while in other applications it could be of interest to have simpler analytical methods with multi-elemental capability but involving a minimum sample treatment, a lower amount of sample and reduced costs. One of the laboratory's recent research lines is focused on the development of simple and sustainable analytical methods involving an easy sample treatment (i.e, dilution, suspension) for the analysis of different types of biomedical samples. In cooperation with the Faculty of Pharmacy and Biochemistry (University of Zagreb, Croatia) the laboratory has demonstrated the usefulness of dilution and TXRF analysis for the quantitative determination of clinically relevant elements such as Fe, Cu and Zn in different types of human fluids including whole blood [1], plasma and serum [2] and seminal plasma [3].

Home-based collection protocols for clinical specimens are actively pursued as a means of improving life quality of patients. In this sense, dried blood spots (DBS) are proposed as a non-invasive and even self-administered alternative to sampling whole venous blood. In a recent study, performed in the frame of a scientific cooperation with the "Miguel Servet" hospital in Zaragoza (Spain), the laboratory has shown the potential of EDXRF for laboratory testing of DBS created from the deposition of several µL of blood onto a clinical paper [4]. Promising results were obtained for determination of electrolyte elements such as Cl and K that are often measured in either plasma or serum. The determination of Fe in DBS proved also to be useful, bearing in mind that from a clinical perspective, Fe status is normally assessed as either serum ferritin or by means of the total iron binding capacity test (see Figure 2).

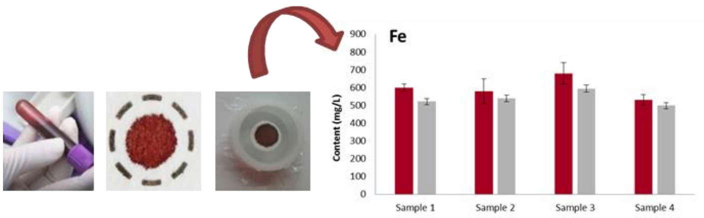

Figure 2: Results obtained for the determination of Fe in four blood samples using the DBS+EDXRF (red) and reference methods (grey).

Recently, it has been demonstrated that trace elements play also a leading role in the understanding of carcinogenesis. In this sense, the laboratory is working in the development of X-ray spectrometry methodologies for sustainable multi-elemental analysis of healthy and cancerous tissue analysis (i.e, liver, colon, heart, intestine, stomach, muscle, lung and bladder). This research is done in cooperation with the LIBPhys group of the Universidade de Lisboa (Portugal) and entails the combination of different analytical techniques including TXRF, µ-EDXRF and ICP-OES.

Foodstuff analysis by TXRF

Elemental composition of foodstuff is of significance for safety and nutritional purposes. The elemental and dynamic range of TXRF makes it particularly suited to the analysis of food, simultaneously determining trace level of contaminants and macro-/micro- nutrients. Moreover, this technique allows the determination of liquid and solid samples with minimum sample treatment. This could be really interesting in some type of food samples such as for example tea samples, since it is important to determine multielement composition of the original herb (solid sample) as well as the infusions (liquid sample). In the last years, the laboratory has developed several analytical TXRF methods for the multi-elemental analysis of different types of foodstuffs, including wine samples. In this sense, it was found that for routine and screening analysis of red and white wines, sample analysis can be directly performed depositing 10 µL of the internal standardized sample (using Ga as internal standard) on a quartz glass reflector for the later TXRF analysis [5]. The method has been recently applied in combination with chemometric tools to classify the origin and type of wine from different regions.

In view of the increasing demand of methods that implicate less or no sample pretreatment for multi-elemental analysis of solid foodstuff sample the laboratory develops a simple analytical method for multi-elemental TXRF analysis of vegetal food samples (i.e., Cabbages, spinach, mushrooms, tomatoes, strawberries, seaweed). On the basis of our results, suspension of the powdered vegetal material proved to be feasible as sample treatment before the TXRF analysis. This procedure is faster than digestion and does not involve the use of dangerous reagents. Considering the accuracy levels that can be achieved suspension may be recommended as a standard procedure for this kind of samples [6].

Proper supply of nutrients to plants is mandatory for adequate crop production. Many strategies, such as soil fertilization and seed treatment have been proposed to this goal. Currently, plenty of studies in plant nutrition afford only a low mass of sample for analyses, which is not sufficient for most spectroscopic techniques, including conventional EDXRF. In this context, the laboratory developed a new EDXRF method for the determination of nutrients in mass-limited soybean plant tissues in which only 20 mg were needed for the analysis. The method was based on the preparation of a solid vegetal suspension with a subsequent deposition of 20 µL of the suspension on a 6 µm polypropylene film for the later EDXRF analysis. The use of synthetic aqueous cellulose multielemental standards using Triton X-100 surfactant at 1% to simulate the vegetal matrix appears to be an effective means to obtain reliable calibration curves over the range of each element to be determined [7].

Metal and inorganic species determination in water samples by EDXRF

In the last years, great concern has been raised about chemical pollution of water bodies. XRF can be used as a powerful technique to detect inorganic pollutants collected from water samples using an adequate extraction material [8]. Since 2008 one of the research activities of LARX has been focused on the development of preconcentration procedures using organic thin layers for the determination of tarce elements and inorganic species in different types of water samples (Figure 3).

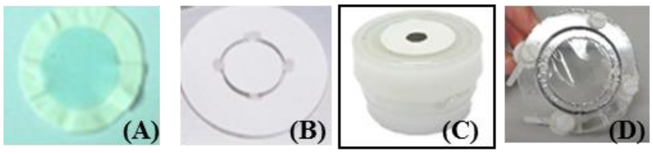

Figure 3: Organic thin layers used to preconcentrate metals and inorganic species previous its determination by EDXRF (A: commercial functionalized SPE disk, B: commercial filter paper retainer, C: laboratory designed nanomaterial membrane, D: laboratory designed polymer inclusion membrane, PIM)

Commercial filter paper retainers and functionalized solid-phase extraction disks have been used as suitable retainers for the determination of divalent cations (i.e., Ni2+, Cu2+, Zn2+, Pb2+, Cd2+, Fe2+) in waste and mining water samples. This approach can be also used for a fast and cost-effective screening and rapid monitoring of water composition in the field, if combined with portable XRF systems [9].

In the last years the laboratory also explored the design of novel focused-tunable absorbent materials to expand the applications of XRF in the field of water analysis. In this category it is important to highlight the potential of solid nano-adsorbents. Their large surface area, fast sorption kinetics and their low resistance to diffusion are features especially relevant in adsorption of both organic and inorganic species in complex samples. Carbon-based nanomaterials (i.e., Carbon nanotubes (CNTs), graphene, graphene oxide (GO)) are especially convenient to be used as solid sorbents in combination with XRF due to the fact that carbon atoms do not emit characteristic X-ray radiation in the spectrum region of interest. Moreover, due to the very small particle size of this type of nanomaterials, particle size effects can be neglected and the loaded materials with the analytes of interest can be directly analyzed by XRF without a previous elution step. Until now successful results have been obtained using raw and modified CNTs and GO for the determination of several metals [10], As(V)/As(III) and Se(IV)/Se(VI) species [11] in different type of water samples, including sea water.

Another possibility to collect the target pollutants from water samples is the use of polymer inclusion membranes (PIMs). PIMs are a type of functionalized membranes in which a suitable carrier is immobilized within the chains of a plasticized thermoplastic polymer. PIMs are easy to prepare, possess good mechanical properties and are versatile in terms of the target chemical species they can extract and transport. Moreover, membranes are ideal samples for analysis by XRF due to their organic thin layer nature and the possibility to directly analyze the loaded membrane without the presence of matrix effects. In a recent publication, a PIM made of cellulose triacetate (CTA) and the ionic liquid TOMATS was shown to effectively extract Hg (II) from different natural waters prior its quantification by XRF [12]. In this study, it was also demonstrated that the PIM-sorbent was a suitable medium to preserve the analyte for a 6-month period at room temperature. This finding opens the possibility to explore the use of PIMs also as a suitable medium to cope with stability problems of some analytes during sample storage.

Outlook

LARX has a long trajectory in the field of method development and samples characterization using X-ray based techniques. Various national and international research collaborations have been established with the academic society, R&D institutions and industrial companies. At present, the members of the LARX (Eva Marguí, Manuela Hidalgo and Ignasi Queralt) are in the management committee of the COST ACTION CA18130 created to coordinate the efforts to establish TXRF as a reference technique for reliable elemental analysis.

LARX members have also experience in the organization of international conferences and workshops related with X-ray spectrometry such as the International Conference on Total Reflection X-ray Fluorescence Analysis and Related methods (TXRF-2019) and the Theoretical and Practical XRF spectrometry workshop: instrumentation and applications (THEOPRAX) that is held biannually.

It is interesting to highlight that in the last years several graduate, PhD and postdoctoral students have joined our laboratory through short term scientific missions in order to be trained in the development of X-ray analytical methodologies for the monitoring of metals and metalloids in different type of samples. Therefore, we are always opened to scientific cooperation and new X-ray analytical methods applications.

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Sweden

Detector Group, European Spallation Source (ERIC)

The Detector Group of the European Spallation Source (ESS) [1], currently under construction in Lund, Sweden, is concluding its detector design effort and is about to enter the production phase. The main aim of the project is to assemble, install, commission and operate the detector systems for five neutron scattering instruments at ESS [2], serving the needs of reflectometry, spectrometry and diffractometry. This is the culmination of a 10-year effort to develop new detection technologies which are mature enough to address the challenging requirements in terms of counting rate, position resolution and large area coverage. In parallel, significant effort has been invested on simulation tools that accurately treat the transport of thermal neutrons in matter. A few glimpses of this effort are presented below.

The MultiBlade detector for neutron reflectometry at ESS

Implementation of reflectometry based techniques is one of the biggest challenges at ESS. With a proton accelerator power of 5 MW and energy of 2 GeV, the average incident neutron flux on the sample under investigation is expected to be of the order of 10^{10} n/s/cm^2. With samples reflecting a significant percentage of the incident beam (90%), it becomes apparent that this is also the order of magnitude of the neutron flux that the detector has to cope with high efficiency and without saturation.

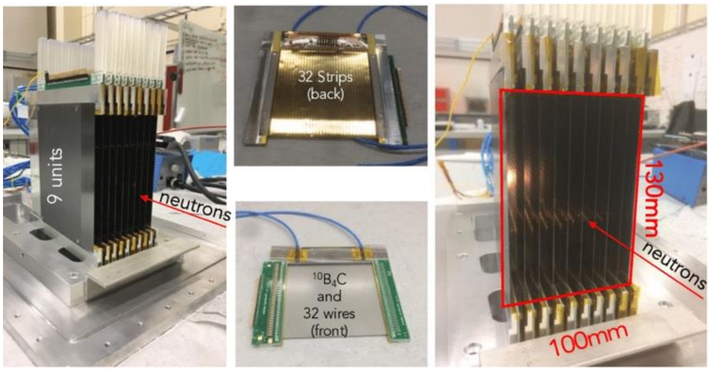

Figure 1: The MultiBlade detector and its building units (middle).

The MultiBlade detector [3, 4] is a ^{10}B-based MultiWire Proportional Counter (MWPC) technology, which utilises 7 μm-thin $^{10}B_4C$ films [5] coated on Ti substrates (Fig. 1). The enriched ^{10}B content converts the thermal neutrons to charged particles, which ionise the Ar/CO_2 counting gas mixture. The readout consists of wires and strips, perpendicular to each other. Reading out electrical signals in coincidence between wires and strips allows for the determination of the position where the neutron hit the detector with the required precision (0.5 mm x 2 mm). The fan-like geometry of the detector and the shallow incident angle (5°) of the neutrons on the converter layer enable the spread of the neutron beam over a large area, preventing pile-up effects and boost the detection efficiency of the detector up to 45% for 2.5 Å and 80% for colder neutrons.

Two MultiBlade detectors are about to be assembled for use in the ESTIA [6] and FREIA [7] reflectometers at ESS. A third module is already installed at the AMOR instrument at PSI, Switzerland and will serve the user program of the facility. A fourth detector is planned for the SONATA reflectometer at the PIK research reactor in Russia.

This detector design and others of similar design based around $^{10}B_4C$ thin films have, over the past decade, opened up new capabilities for future thermal neutron detection beyond the current state-of-the-art ^{3}He-based detectors. This will be a growing field in the coming years.

A Gd-based GEM detector for protein crystallography at ESS

The NMX (Neutron Macromolecular Diffractometer) [8] instrument at ESS is designed to provide the first time-stamped neutron data in the field of neutron macromolecular Laue diffraction, making possible the temporal separation of spatial overlaps in the diffractogram. To this end, it requires a spatial resolution of 200 μm. In order to push the detection efficiency higher than a few % that typical boron layers achieve, a neutron converter with a higher absorption cross section to ^{10}B was chosen, i.e. a single ^{nat}Gd layer supported on an Aluminium substrate. This enhances the detection efficiency to about 15% for thermal neutrons. The GEM (Gas Electron Multiplier) readout ensures high-rate capability (>>1 MHz/cm^2) and operational robustness. Three identical GdGEM [9] modules will be positioned in a few different arrangements around the sample position with the help of robotic arms (Figs. 2, 3). The various configurations exist to address the different unit cell dimensions and orientations of the sample.

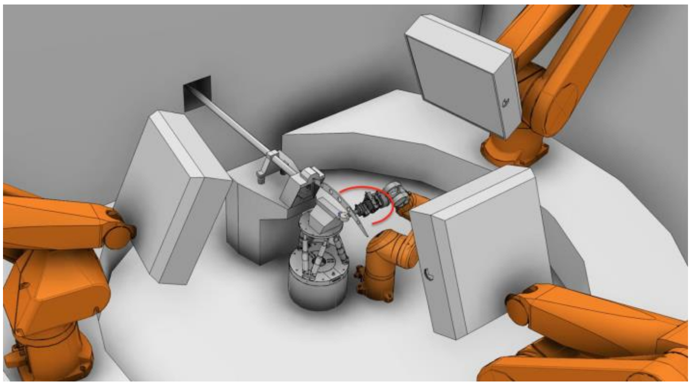

Figure 2: The GdGEM modules on the robotic arms of NMX.

The 0.4 mm pitch Copper readout is combined with the μTPC method [10], in order to achieve the required spatial resolution. The technique allows for 3D tracking of the conversion electrons with the aim of accurately locating the starting point of the electron track at the converter layer. Adaptations on the original algorithm have been implemented and successfully tested at neutron beam lines. A final detector test is planned with the entire electronics readout chain in 2022 before construction can begin.

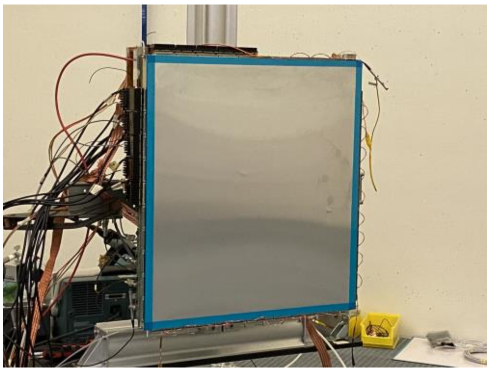

Figure 3: The GdGEM module (60 cm x 60 cm) during a source test at CERN.

NCrystal: a library for thermal neutron transport

NCrystal [11,12] is a library and associated tools which enables calculations for Monte Carlo simulations of thermal neutrons in crystals and other materials, supporting a range of physics including coherent, incoherent, elastic and inelastic scatterings in a wide range of materials, including crystal powders, mosaic single crystals, layered single crystals, amorphous solids, and liquids.

It was originally developed in order to support the detector design efforts and help understand the Bragg (coherent elastic) scattering effects in the polycrystalline materials of the detectors, e.g. Al, Ti, Cu. The difference between treating the neutron transport inside a crystal or using a free gas approximation can differ by up to an order of magnitude in terms of cross sections, leading to significant deviations in the modelling results.

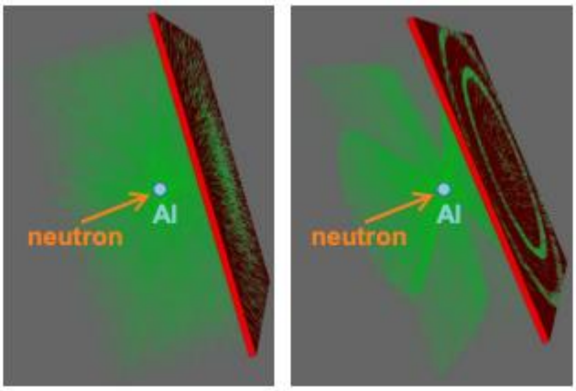

Figure 4: Scattered neutron particles on an Al sphere without and with NCrystal.

Meanwhile, the NCrystal library has been extended to include non-Bragg scattering effects, extending its capabilities enormously and broadening its scope to instrument design, as well as moderator design. Multi-phase materials, isotopic compositions, amorphous solid materials have been validated against data and made available to the community [14]. It also allows the user to create their own material compositions.

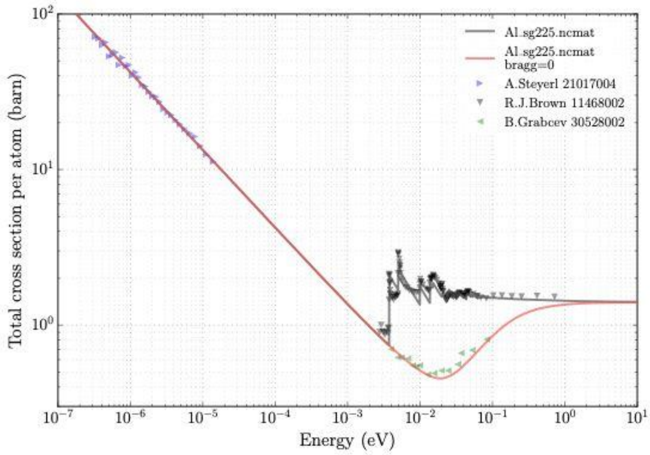

Figure 5: Total cross section for Aluminium as calculated by NCrystal as a function of neutron energy, against published data

Meanwhile, the NCrystal library has been extended to include non-Bragg scattering effects, extending its capabilities enormously and broadening its scope to instrument design, as well as moderator design. Multi-phase materials, isotopic compositions, amorphous solid materials have been validated against data and made available to the community [14]. It also allows the user to create their own material compositions.

Significant effort has been invested in factorising the software in ways that allow extensions, plugins and interfaces to be developed by other developers. NCrystal can already be used in conjunction with Geant4, McStas and ANTS2, and can generate ENDF data via NJOY and .ace files for MCNP [15]. Plugins for OpenMC, PHITS and MCNP are currently under development.

In addition to the NCrystal library, a framework of tools has been developed to simplify and extend the possibility to do full simulations of thermal neutron detectors and instruments [16, 17]. This includes a tool MCPL [18] which enables the effective interfacing of different Monte Carlo codes, which allows the best simulation tool to be used for each part of the problem,

Outlook

The efforts of the ESS Detector Group have yielded in development of new thermal neutron detection technologies to address the new challenging scientific requirements of the ESS source and the new instrument designs. Entering the new phase of the project, the production of these detectors will begin in the early months of 2022. The team is looking forward to seeing complete detector systems installed and commissioned at the ESS instruments.

Contributors

Kalliopi Kanaki on behalf of the ESS Detector Group

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Selected recent NSIL publications

- Transition metal chromophores in glass beads of the classical and Hellenistic period: Bonding environment and colouring role, F. Pinakidoua, M. Katsikini, E. C. Paloura; J. Osan; M. Czyzycki; A. Migliori; E. Palamara; N. Zacharias; A. G. Karydas, Spectrochimica acra Part B 171 (2020) 105928.
- Sources of sedimentary organic matter and assessment of heavy-metal levels in estuarine sediments after Fundao dam breach, J. P. Felizardo, M. C. Muniz, M. Vezzone, R. P. Cardoso, J. Wasserman, R. Padilla, A. Migliori, R. M. Anjos, Estuarine, Coastal and Shelf Science 261 (2021) 107507, https://doi.org/10.1016/j.ecss.2021.107507
- Bias-dependent displacement damage effects in a silicon avalanche photodiode, R. M. Zedric, S. S. Chirayath, C. M. Marianno, Y. Diawara, N. Skukan, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 507, 15 November 2021, Pages 42-45.
- Improved performance of neutron activation analysis laboratories by feedback workshops following interlaboratory comparison rounds, D. Ridikas, N. Pessoa Barradas, A. Migliori, A. Katukhov, P. Bode, Accreditation and Quality Assurance volume 26, Pages 157–164 (2021)

Selected recent Web stories

The IAEA regularly informs the media and public of its work through press releases, impact stories, videos and podcasts, as well as photo essays and statements of the IAEA Director General and senior staff. It also gives access to the many events it organizes, from conferences to technical meetings. The latest stories on NSIL results can be accessed from https://www.iaea.org/news and include:

- Now Available: New Drone Technology for Radiological Monitoring in Emergency Situations, Feb 1, 2021
- New IAEA Online Platform Offers E-Materials in Nuclear Instrumentation, Feb 26, 2021
- IAEA Conducts First Virtual Training on Using Ion Beam Techniques and Applications, Apr 7, 2021
- IAEA drone for emergencies, Apr. 15, 2021
- IAEA, South Africa’s iThemba Labs to work together in advancing accelerator-based science, Nov. 2021

Selected upcoming Events

- 16th Vienna Conference on Instrumentation VCI 2022 (Virtual event organized in cooperation with the International Atomic Energy Agency), Vienna, 21-25 Feb. 2022
- CN-301 the International Conference on Accelerators for Research and Sustainable Development: from good practices towards socioeconomic impact, 23 to 27 May 2022, Vienna, https://www.iaea.org/events/AccConf22
- Training Workshop on Synchrotron Technologies and Techniques and their Applications, Trieste, Italy, 23-27 May 2022
- Technical Meeting on the Use of Unmanned Aerial Vehicles for Radiation Detection and Surveillance, Brno, Czech Republic, 27 Jun. – 1 Jul. 2022.
- European conference on X-ray spectrometry EXRS-2022, 26 Jun. – 1 Jul. 2022, https://www.uantwerpen.be/en/conferences/exrs/
- Training Workshop on Method Validation and Quality Control in X-Ray Fluorescence Techniques, Seibersdorf, Austria, 5-9 Sep. 2022
- Technical Meeting on Advances in Nuclear Instrumentation and Novel Detector Systems Used at Ion Beam Facilities, Vienna, 3-6 Oct. 2022
- Training Workshop on the Safe Operation and Applications of Neutron Generators, Seibersdorf, Austria, 7-18 Nov. 2022
- Joint ICTP–IAEA Workshop on Advanced Solutions for Field Measurements, Trieste, Italy (dates to be defined, 3Q 2022)
- Training Workshop on the Operation and Maintenance of Electrostatic Accelerators and Associated Instrumentation, Cape Town, South Africa (dates to be defined, 4Q 2022)

Updated information on the Events organized by the NSIL is available on the IAEA Nuclear Science and Instrumentation Portal and also through the IAEA Meetings webpage.

Contributions to our Newsletter

Publication of materials for consideration in our Newsletter should be submitted in MS Word only.

Short article submissions should be no more than 800 words with up to 2 high quality figures/pictures (including captions) and, if needed, a maximum of 3 most relevant references.

Submissions for "Laboratory Portrait" articles, a new rubric in the Newsletter, should be no more than 1500 words with up to 4 figures/pictures and, if needed, a maximum of 10 most relevant references.

Impressum

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