ANNUAL REPORT 2011

TECHNOLOGICAL AND NUCLEAR INSTITUTE

INSTITUTO SUPERIOR TÉCNICO

Indíce

itn

The ITN

As part of its activities ITN explores and places at the service of outside community specialized scientific equipments and infrastructures which are used as nodes in specialized research networks.

The Technological and Nuclear Institute (ITN – Instituto Tecnológico e Nuclear) was, until its integration, in 2012, in the Instituto Superior Técnico from the Technical University of Lisbon, a State Laboratory depending from the Portuguese Ministry of Science, Technology and Higher Education, endowed with scientific, administrative and financial autonomy.

The primary driving force of the ITN activities is to play a strategic role in research, advanced training, technical cooperation and services to the community with emphasis for activities related with the applications of nuclear sciences and technology, and in the areas of radiological protection and nuclear safety, aiming at increasing its role as a national and international reference laboratory. As part of its activities ITN explores and places at the service of outside community specialized scientific equipments and infrastructures which are used as nodes in specialized research networks.

The present document, in addition to a summary of the annual report 2011, highlights the main areas of activity of the Institute and displays the infrastructures that it operates and makes available to the community.

Historical Note

The construction of the first LFEN buildings and laboratories started in 1957 in terrains acquired by JEN in the previous year (September de 1956) near Sacavém.

The origins of Instituto Tecnológico e Nuclear, ITN (Nuclear and Technological Institute) can be traced back to the Laboratório de Física e Engenharia Nuclear-LFEN, which was established, in December 1955, by the Junta de Energia Nuclear, JEN (Nuclear Energy Board) created the previous year under the direct dependence of the Prime-Minister of Portugal (Decree-Law 9580, of 29th March 1954). The mission of LFEN was the development of research activities related to peaceful applications of nuclear energy. LFEN was the first, and for long time sole, large scale scientific investment of Portugal.

The construction of the first LFEN buildings and laboratories started in 1957 in terrains acquired by JEN in the previous year (September 1956) near Sacavém. Among the main pieces of equipment of this new Laboratory there were two particle accelerators – one 2 MeV van de Graaff and one 0.6 MeV Cockroft-Walton – which arrived in Portugal at the end of the Summer of 1957 and a 1 MW swimming-pool type nuclear research reactor, ordered in 3rd July 1957, to AMF Atomics Inc., which become operational on 25 April 1960. Both the first accelerator and the reactor, after considerable modernization and upgrades, remain today as two main infrastructures still in service at ITN.

In 1958 it was also started the building of a pilot-plant for the production of metallic uranium which become finally in operational in 1960 and that regularly produced metallic uranium and uranium fuel compounds until 1972.

On 1st October 1979 JEN was terminated and LFEN was integrated on the newly created Laboratório Nacional de Engenharia e Tecnologia Industrial - LNETI (National Laboratory for Engineering and Industrial Technology) under the authority of the ministry of Industry. In October 1992, LNETI became the Instituto Nacional de Engenharia e Tecnologia Industrial - INETI (National Institute for Engineering and Industrial Technology). In spite of the reorganization and relocation of some groups in other departments, both under LNETI and INETI, the previous activities of LFEN in the field of nuclear science and technology continued to be carried out at Sacavém campus by Instituto de Ciências e Engenharia Nucleares, ICEN (Nuclear Sciences and Engineering Institute) one of the institutes of the new Laboratory.

The Instituto Tecnológico e Nuclear, corresponding to previous ICEN, was established in 1994 as an autonomous institution, under the authority of Ministry of Planning and Land Administration (Decree-Law 324-A/94, of 30th December). One year later, ITN was integrated within the Ministry of Science and Technology (Decree-Law 296-A/95, of 17th November). In October 1998 ITN integrated additional personnel services and competences, in its newly established Department of Radiological Protection and Nuclear Safety (Protection and Radiological Safety Unit, since 2008). Until the decision of integration of ITN at IST-Instituto Superior Técnico of the Technical University of Lisbon, taken by the government in the end of 2011, ITN remained as an autonomous institution under the authority of the Ministry of Science, Technology and Higher Education.

Foreword

This brochure contains a general presentation of ITN, and its main achievements during 2011 and it is an introduction to the detailed report of activities that is attached in a CD.

The year of 2011 was the last one of ITN as an autonomous institution under the authority of the Ministry of Science, Technology and Higher Education, which after May 2011 became the Ministry of Education and Science. In fact in 2012 ITN became fully integrated in IST of the Technical University of Lisbon, according to a decision of the new Government, announced in the end of 2011.

This brochure contains a general presentation of ITN, and its main achievements during 2011 and it is an introduction to the detailed report of activities that is attached in a CD. There, following the structure of previous annual reports, the research activity of ITN is presented in a more extensive and detailed way considering each research unit and the scientific output is grouped under the different areas of activity.

The year of 2011 was dominated not only by the worsening of the economic crisis, with severe budgetary restraints, but also at the administration level by the retirement of former ITN Directive Board President, Professor Montalvão e Silva on 1st July, and later on the decision of the new Government, announced in the end of September, to integrate ITN at IST of the Technical University of Lisbon. As a consequence of this decision, which however did not became effective before the end of 2011, and due to the financial limitations, all planned investments were cancelled and management decisions were limited to ensure conditions to pursuit basic or contracted activities, with expenditures being kept to the minimum essential.

In spite of these very unfavourable conditions, the scientific output of ITN did not decreased significantly and, more significantly, did not deviate from the quality standards of the ITN work in previous years. This was only possible due to the high motivation of ITN staff, which with strong dedication pursued their mission and duties, maintaining the tradition of excellence of this institution, namely maintaining and operating relevant scientific infrastructures to the benefit of the scientific community. The ITN infrastructures and laboratories, in many cases unique at the national level, are presented in this brochure and we hope the ITN integration in the University will enable a more efficient use of them for advanced training and education purposes.

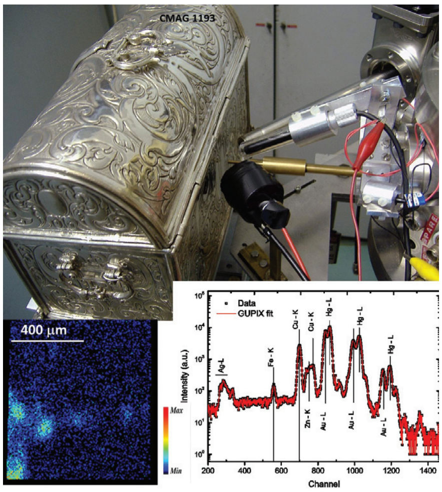
Manuel Leite de Almeida
ITN Acting President until February 2012

Physics and Accelerators

Mission and Competences | Main Achievements

Mission and Competences

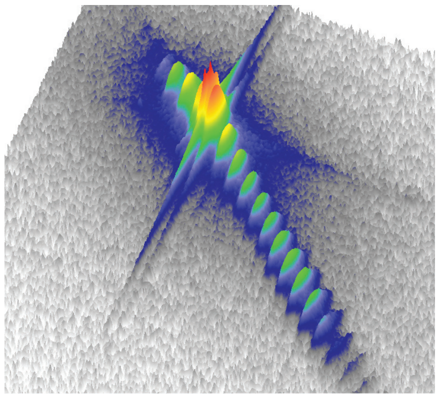
- R&D of advanced materials, processes and technologies for applications to Industry, Biomedicine, Environment and Cultural Heritage using radiation techniques, in particular ion beam and ionizing radiation based techniques;
- Maintain and upgrade the research infrastructures and equipment making them available to the scientific community.
- Disseminate knowledge and promote advanced learning in the areas of expertise;
- Offer specialized services, consultancy and technical assistance to the industry in areas using nuclear and radiation techniques;
- Development of equipment using ionizing radiation for industry and research;



Silver chest (CMAG 1193, c.XVI-XVII), Au composition distribution and X-ray spectrum.

Main Achievements

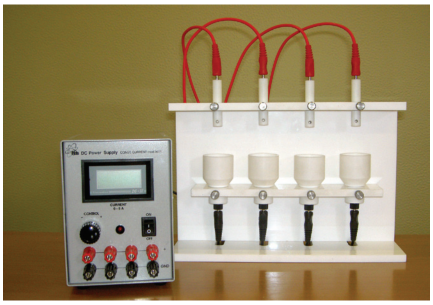
- Optical doping of wide bandgap semiconductor hetero-/nanostructures for applications in optoelectronics and spintronics by ion beams.
- Ion beam processing and characterization of advanced materials for applications in extreme working conditions (plasma facing materials) including, e.g. Fusion reactors.
- Precise assessment of Arsenic site location in Germanium using ^{73}As emission channelling at CERN.



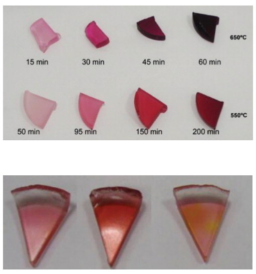
Reciprocal space map of a SiGe alloy multilayer.

- Cultural heritage objects (stained glasses, tiles, sacred objects, coins, etc.) studies to assess manufacturing processes, provenance and date artifacts.
- Nuclear microscopy of environmental and biological materials: toxicology of iron deposition in skin established as an indicator for human disorders.
- Elemental characterization and speciation obtained from high resolution X-ray energy dispersive spectrum data (PIXE).
- In-situ studies of nano-particles formation and structural characterization of low dimensional semiconductor systems using X-ray diffraction methods.
- Preparation and characterization of hybrid Organic/Inorganic materials prepared by gamma irradiation for biomedical applications.
- Contaminants distribution measured by microprobe techniques in PE-based grafted films produced by gamma irradiation to assess its biocompatibility.
- Development of methodologies of Radiation Technologies (gamma rays and electrons), for the improvement of new products [e.g. biomaterials, pharmaceutical products, gold ruby glass] and new processes [e.g. wastewater treatment, new materials for art, food conservation].

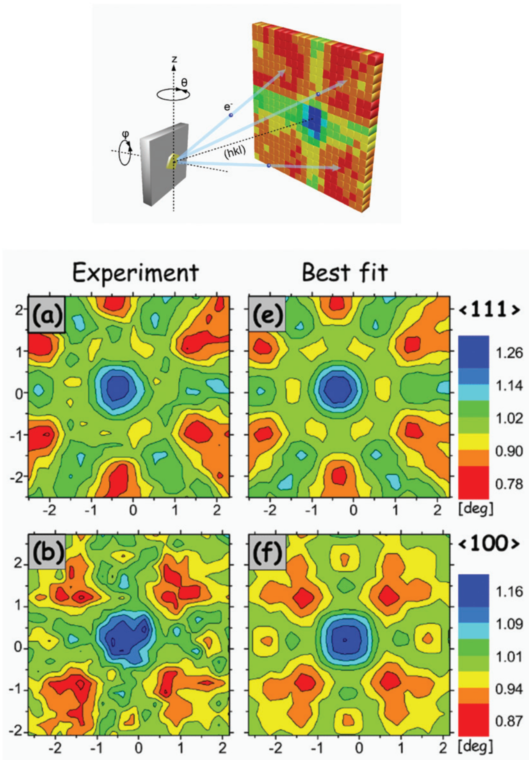
- **Developments in Nuclear Instruments and Methods for laboratory and industrial applications:**
  - modeling of radiation fields and equipment design;
  - determination of nuclear data;
  - development and application of plasma at atmospheric pressure for scientific and industrial purposes;
  - software development for control and data analysis;
  - design of electronic and nuclear instrumentation.



Laboratory equipment for determination of radioactive element traces by electrodeposition.



Gold ruby glass using gamma irradiation.



Emission patterns of conversion electrons from ^{73}As implanted a single crystal of Ge measured with a 2-dimensional position-sensitive CERN detector.

Chemical and Radio-pharmaceutical Sciences

Objectives | Main areas of expertise | Achievements

Objectives

Develop research and expertise, and support network in the synthesis and characterization of inactive and radioactive compounds, cultural materials, geological and biogenic materials, and hydrological resources. Our activities focus on Radipharmaceutical, Nuclear, Materials, Earth and Environmental Sciences, Catalysis, Cultural and Natural Heritage applications.

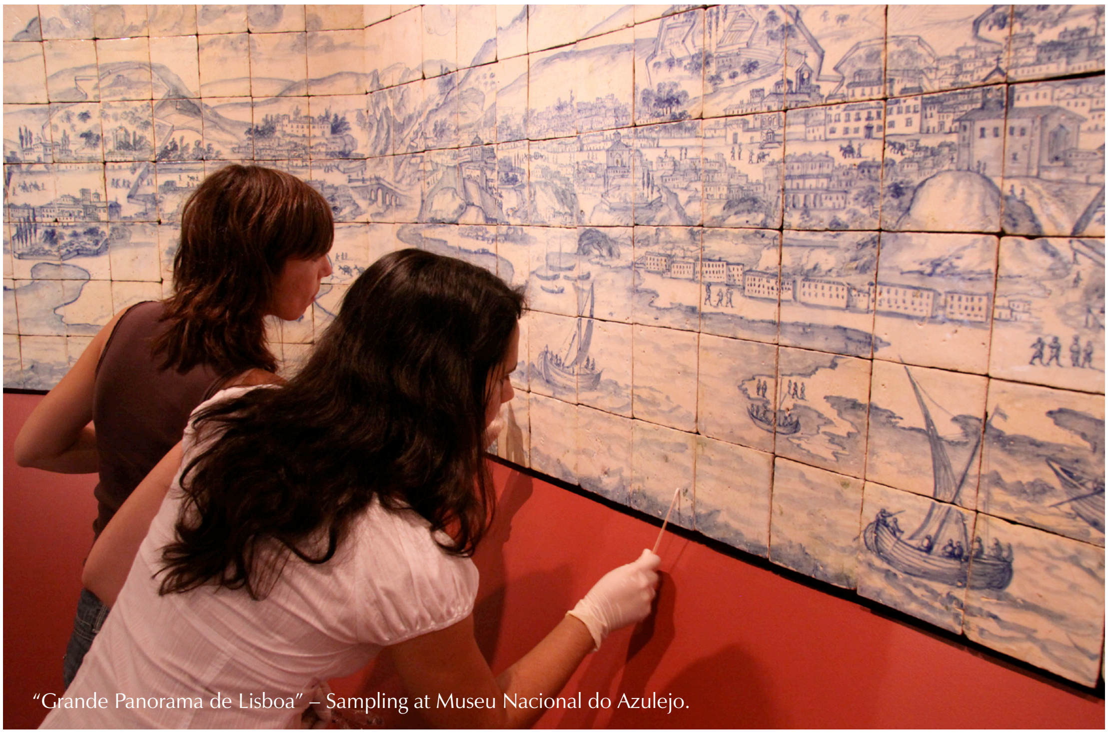
Research groups: (i) Applied Geochemistry & Luminescence on Cultural Heritage; (ii) Environmental and Analytical Chemistry; (iii) Inorganic and Organometallic Chemistry; (iv) Radiopharmaceutical Sciences; and (v) Solid State.

Main areas of expertise

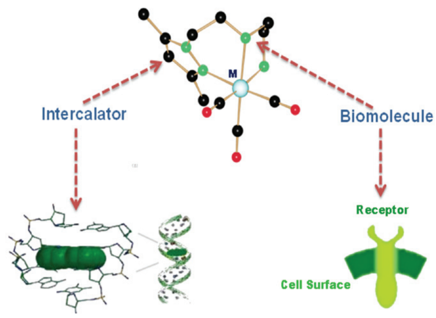
- **Radiochemistry**
- **Lanthanide and actinide chemistry**
- **Radiopharmaceutical Chemistry**
- **Molecular Materials**
- **Solid State Chemistry and Intermetallics**
- **Geochemistry**
- **Nuclear and related methods for chemical characterization:**
    - neutron activation analysis, X-ray fluorescence, Mössbauer spectroscopy, Elemental and molecular Mass spectrometry (ICPMS, FTICR-MS ,ESIMS… Isotope analysis- IR-MS).
- **Low temperature and high magnetic field solid state characterisation techniques (electrical transport and magneto transport, magnetisation AC susceptibility, …)**
- **Luminescence dating and dosimetry.**
- **Radiocarbon dating**

Achievements

- **Degradation processes and the assessment of consolidant impregnation efficiency in Portuguese glazed tiles have been addressed by using Neutrons and Ionizing Radiation, providing a significant aid to the development of strategies for conservation or restoration:**
    - Biodeterioration of the tile panel "Grande Panorama de Lisboa" (Lisbon before the 1755 Earthquake).
    - Chemical and mineralogical patterns of ceramic body and glaze of treated and non-treated tiles.
- **Environmental changes in the Portuguese coastal area- Minho estuary, studied by organic geochemical approaches, showing:**
    - Signature during the Little Ice Age in organic matter, reaching a maximum, primarily derived from terrestrial sources.
    - Alternations in the C/N and $\delta^{13}C$ values through the 18th and 19th centuries, associated with alternating severe droughts and intensive precipitation periods.



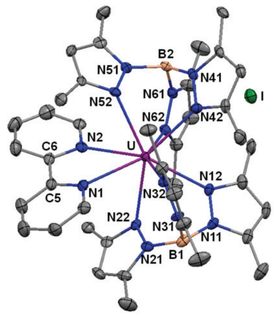
"Grande Panorama de Lisboa" – Sampling at Museu Nacional do Azulejo.

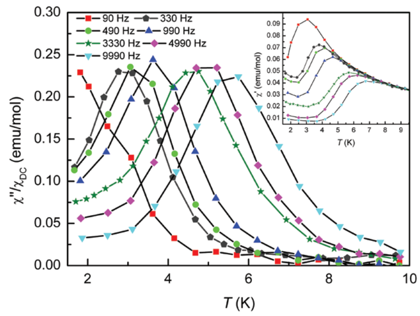


Trifunctional tricarbonyl metal (M=Re,^{99m}Tc) complexes.

- **New multifunctional Re(I)/99mTc(I) tricarbonyl frameworks for cell-specific nuclear targeting:**
  - Were developed the first 99mTc-based frameworks bearing DNA intercalators and bombesin analogues that combine specific cell targeting with nuclear internalization, a crucial issue in the potential usefulness of 99mTc in Auger therapy.
- **Single molecule magnetic (SMM) behaviour was discovered in a Uranium mononuclear complex, the first cationic one. A comparison of the only two other U based examples known, made possible to establish important magnetic-structural correlations.**

- **Mass spectrometry studies lead to a new way of accessing the size/effective charge of trivalent lanthanide and actinide species in the gas phase.**





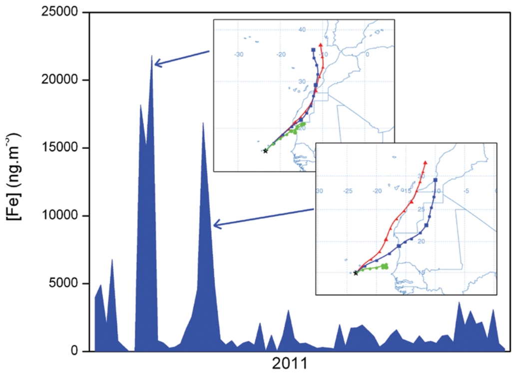
Single molecule magnet behaviour in uranium mononuclear ion.

Reactors and Nuclear Safety Unit

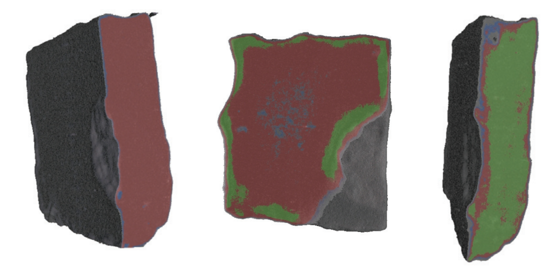
Mission and objectives | Main areas of expertise| Achievements in 2011

The main mission of the URSN is the operation of the Portuguese Research Reactor (RPI), in order to satisfy the users' needs while conducting all tasks with the assurance that the reactor is operated in a safe and reliable manner by a highly competent and motivated staff. The implementation of such objectives demands a variety of activities, some of which are repetitive in objective and variable in content, while others address specific aspects of the same end situation.

The Operation of the RPI is done according to national legislation and relevant international treaties. The URSN is also responsible for all practical arrangements regarding the implementation of several international duties of Portugal, such as the Additional Protocol for Safeguards, and representing the Portuguese Government and providing advice to Portuguese representatives in international Commissions and Working Groups under the umbrella of international institutions and organizations such as the European Commission and the IAEA.



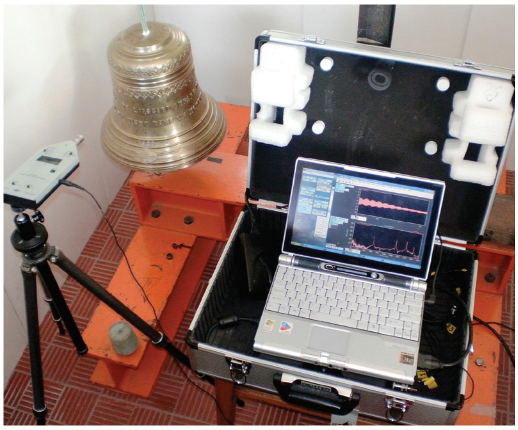
Fe concentrations measured in PM10 sampled in Cape Verde in 2011. Air masses backward trajectories associated with two Sahara dust events.



Fragment of glazed tile (16th century) from Museu Nacional do Azulejo: (a) untreated; (b) and (c) treated, different methods. Gray-surface; Red-ceramic body; Blue-voids; Green-resin.

(Left)
Field work performed for modal identification of the Mafra carillon bells.

(Right)
Laboratory apparatus used for developing experimental identification techniques and for testing bell-tuning methods.



The NANE group is dedicated to the study of the atmospheric dispersion of trace elements with the neutron activation analysis technique in the RPI. The group addresses, specifically, the development and application of nuclear techniques, source apportionment and tracking in the atmosphere, chemical speciation, uptake and release of chemical elements in biomonitoring and monitoring, as well as health linkage through epidemiology and nutrition studies.

The Applied Dynamics group does research in the areas of vibration and acoustic problems displayed by components of nuclear power plants, a key area in nuclear engineering. The same techniques are used to solve other problems, both of industrial and fundamental nature, outside the realm of power generation.

Main areas of expertise include:

- New methodologies for neutron and gamma dosimetry.
- Production of radioisotopes.
- Instrumentation for reactor monitoring and control.
- Radiation effects in materials and in electronic components.
- Vibratory and acoustic behaviour of mechanical components.
- Structural problems in power plants and other industrial facilities.
- Trace element analysis for biomonitoring and environmental studies.

Main achievements:

Neutron tomography demonstrated as abn efficient tool to inspect the internal structure of materials. Fluid penetration in ancient glazed tiles from the National Tile Museum was studied, to determine the efficiency of different methods of preservation of this cultural heritage.

Neutron Activation Analysis was used to perform a multi-elemental characterization of airborne particles sampled in Cape Verde, in order to assess the impact of Sahara desert dust for the global aerosol properties, human health and ecosystems.

Experimental and theoretical applied dynamics techniques were used to analyse the XVIII th century carillons of the Mafra basilica, a major work of the baroque in Europe, while new bell tuning techniques have been developed to deal with historical instruments.

Radiological Protection and Safety

Mission and objectives | Main areas of expertise | Achievements in 2011

Mission and objectives

The activities of the UPSR aim at i) the deployment of unique scientific and technical expertise, skills and competence in radiological protection in Portugal, ii) the fulfillment of the the Portuguese State duties and obligations in radiological protection and radiation safety and iii) the provision of scientific and technical support to the Portuguese Government in the execution of policies in radiological protection and in areas involving applications of ionizing radiations and radioisotopes. These activities encompass:

- Research and Development, with participation in FCT and EU FP7 EURATOM and EURAMET funded projects;
- Services in radiological protection and safety, radioactivity measurements, dosimetry and metrology of ionizing radiation, provided to stakeholders in the medical, industrial and military sectors;
- Fulfillment of legal obligations assigned to IST/ITN;
- Education and Training in radiological protection and safety, including teaching activities in undergraduate, post-graduation and Doctoral programmes and short-duration training courses;
- National & international representation, in Committees and Working Groups of the European Union, the IAEA, the OECD Nuclear Energy Agency, BIPM, OSPAR;
- Preparedness of response to radiological and nuclear accidents/emergencies, with the deployment of adequate scientific and technical expertise, techniques and equipment.

Main areas of expertise include:

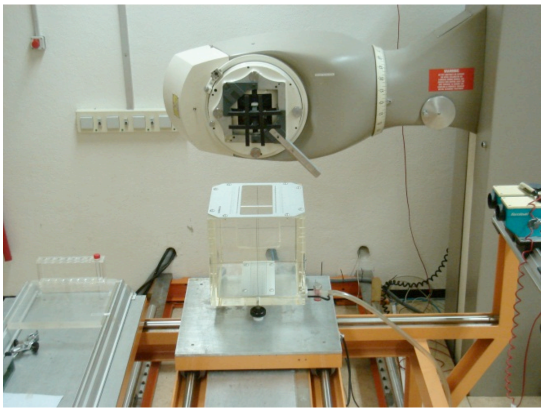
The main topical areas of expertise activities of the UPSR are associated to:

- Radioactive waste management;
- Monitoring and assessment of environmental radioactivity;
- Dosimetry and radiobiology;
- Metrology of ionizing radiation;
- Radioactivity measurements using different radioanalytical techniques;
- Occupational radiation protection;
- Radiological emergency response and intervention.

Achievements in 2011:

- Follow-up of the Fukushima accident and its radiological impact and consequences;
- Deployment of unique and high-level scientific and technical knowledge, skills and competences in radiological protection in Portugal;
- Assessment of the safe use of ionizing radiation in medical, industrial and research installations
- Individual monitoring of the exposure of workers to ionizing radiation;
- Environmental radiological monitoring nationwide;

- Analyses of the radioactivity contents of environmental (waters, foodstuffs, building materials, soils, aerosols, etc.) and biological samples;
- Assessment of indoor radon concentrations;
- Collection, segregation and interim disposal of radioactive waste from the medical, industrial and research uses of ionizing radiation;
- Authorization and licensing of radioactive sealed sources;
- Maintenance of the national standards for ionizing radiation;
- Calibration and metrological verification of radiation monitors and detectors;
- Maintenance and update of databases (on the exposure of workers to ionizing radiation, on radon concentration, on environmental radioactivity measurements).



Irradiation facility for calibration and metrological verification of radiation protection equipment.

HPGe detectors in the gamma spectrometry counting room.

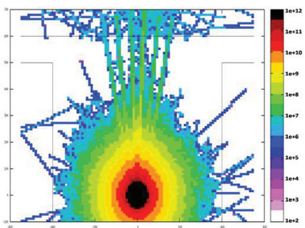


Fig.1

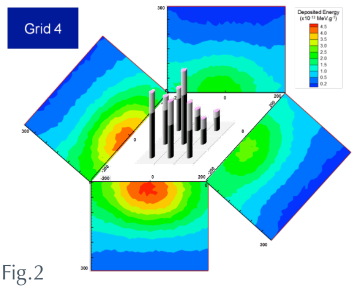


Fig.2

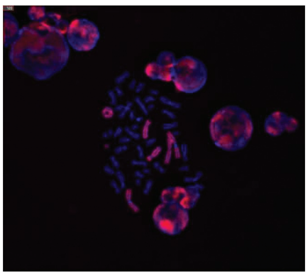


Fig.3

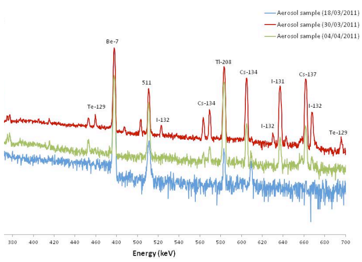


Fig.4

Fig.1
Radiation mapping around a spallation target (for nuclear technology applications)

Fig.2
Dose distribution in the radioactive waste storage facility

Fig.3
Chromosome observations using the FISH technique

Fig.4
Traces of the radionuclides released at Fukushima Daiichi measured at the ITN campus

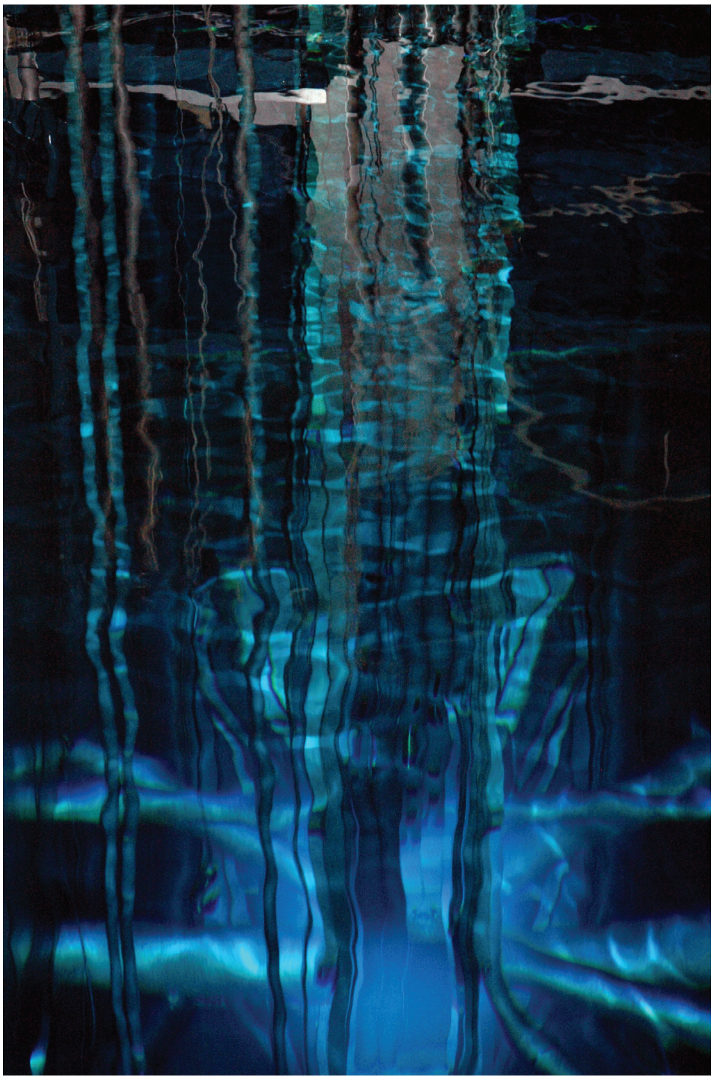
Facilities, equipments and techniques available at ITN

Research Reactor RPI | Ion Beam Laboratory | Low Temperatures and High Magnetic Field Characterization of Materials | Radioactivity Measurements | Manipulation and Characterization of Radioactive Compounds

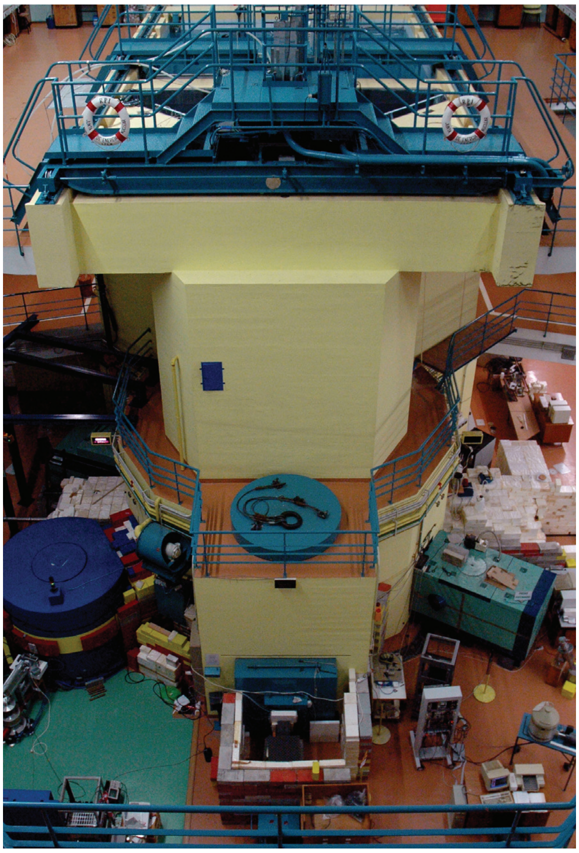
Research Reactor RPI

The RPI is an open core pool-type nuclear research reactor, 1 MW thermal power, light water cooled and moderated. As a multi-purpose research facility the reactor offers a number of specialized experimental devices to internal and external users, including:

- **Irradiation channels in the core grid** with a well characterized neutron flux, a system for preset time-irradiations up to one hour, followed by automatic transport and storage in shielded cells where irradiated samples can be safely handled, for radioisotope production, and other purposes.
- **A Thermal Column** with a highly thermalized neutron flux, and facilities for extracting fast, epithermal and thermal neutron beams for training and research.
- **A Gamma Irradiation Chamber** using the wide energy spectrum of gamma rays from spent fuel elements.
- **A Neutron Tomography Setup** with an image size 30 by 30 cm for research and industrial applications.
- **Neutron diffraction beam line** for training and research in materials science.
- **Neutron and gamma irradiation facilities, in internal and external positions, including pneumatical systems for fast irradiations.**



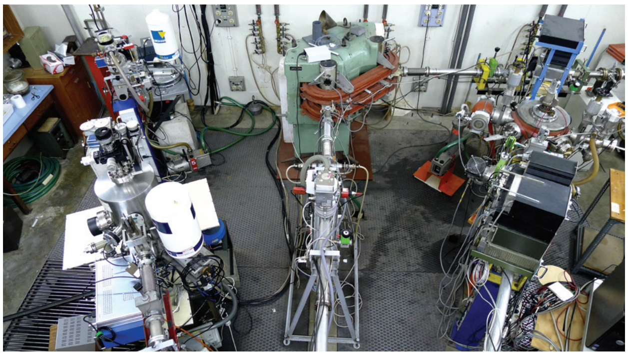
Inside-pool view of the RPI core at 1MW.



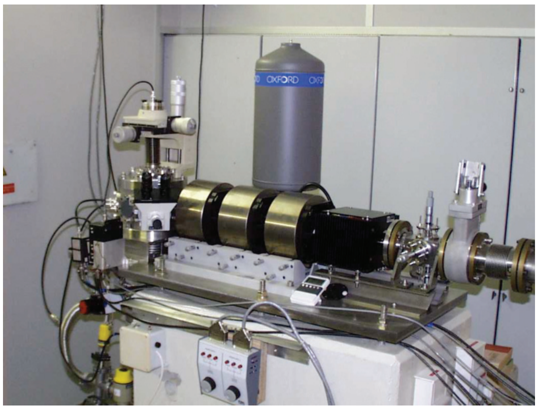
View of experiments installed in the reactor hall and of the reactor pool.

Closely associated with the reactor facility there are **Laboratories for Instrumental Neutron Activation Analysis**, enabling the measurement of trace element concentrations, with high accuracy and precision. The Laboratories are equipped with gamma-spectrometers, with coaxial Ge detectors and low energy photon detectors and automatic sample changers. Neutron Activation Analysis is mainly applied to environment, nutrition and epidemiology studies.

An Applied Dynamics Laboratory is installed in a dedicated hall annex to the Reactor building. Research in the vibratory and acoustic behaviour of mechanical components used in nuclear plants as well as in other industrial facilities is carried out in this Laboratory.



General view of ion implanter.

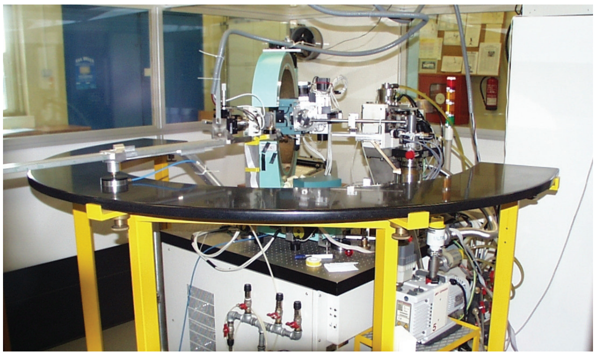


Nuclear microprobe end stage.

Ion Beam Laboratory. This is a multipurpose facility that comprises the following three large instruments at Sacavém:

- a 2.5 MV Van de Graaff accelerator with 3 dedicated beam lines for physics research and the characterization of elemental composition and structure of materials by using standard nuclear techniques, RBS, PIXE, ERDA, NRA, and Channelling and by using a nuclear microprobe with raster mapping by focused micro beams, 2-3 μm in cross dimension, using PIXE, RBS, IBIL, STIM and CSTIM techniques including an external beam extension.
- a 3.0 MV tandem accelerator equipped with a dedicated line for Accelerator Mass Spectrometry (AMS) for heavy isotope studies with micrometer resolution. This facility also offers to the users a complete set of ion beam techniques including a High Resolution High Energy PIXE end station using a EDS X-ray Microcalorimeter Spectrometer (XMS) capable of detecting X-rays between 1 keV and 20 keV.
- a 210 kV high flux ion implanter with semi-industrial implantation chamber for implanting stable ions, from −100 ºC up to 1000 ºC, for R&D purposes.
- Emission Channeling (EC) set-up on-line at the ISOLDE beam line, in CERN, equipped with a high-resolution goniometer and a fast electron detector. Two Perturbed Angular Correlations (PAC) 6-detector $\gamma-\gamma$ setups and one unique electron$-\gamma$ PAC spectrometer.

Laboratory for the Structural Characterization of Advanced Materials equipped with a unique multipurpose X-ray analytical facility, the Hotbird. The main equipments and facilities of the Hotbird Laboratory are a high resolution X-ray diffractometer, powered by a 18 kW rotating anode X-ray source, for phase identification, residual stress measurement, 2-d mapping of Bragg peaks, and reflectometry studies, up to 1100 ºC in situ.

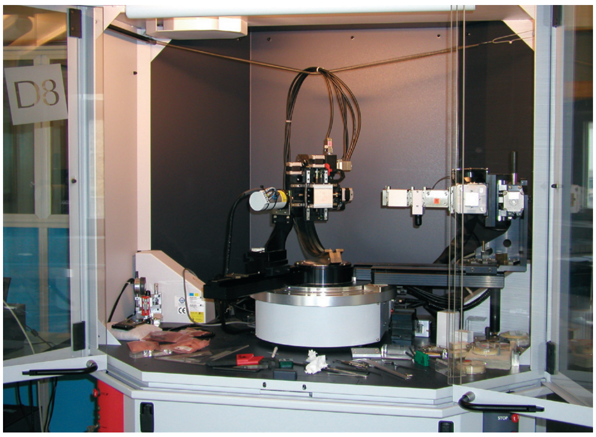


Overall view of the Hotbird X-ray diffractometer.

This lab is also equipped with a versatile high resolutionx-ray diffractometer, incorporating technological innovations such as a third generation Göbel Mirrors providing a parallel X-ray beam with highest flux density, a 0.001º goniometer resolution, and the Ultra GID component that allows the in-plane structural characterization. These unique features enables a rapid and accurate characterization of advanced semiconductors, thin films and nanostructured materials, allowing the user to easily switch between several materials research X-ray diffraction applications, including reflectometry, high-resolution diffraction, reciprocal space maps, grazing incidence diffraction and small angle X-ray scattering, as well as residual stress and texture.

X-ray diffraction Laboratory for structure analysis

This laboratory laboratories is equipped with a Single Crystal Diffractometer with a 4-circle goniometer, for the determination of crystal structures and structural characterization in organic, inorganic and organometallic chemistry research and with a PANanalytical X'pert modular diffractometer with basic module for powder analysis.



High resolution X-ray diffractometer.

Laboratory of X-ray Fluorescence Spectrometry equipped with one Kevex Delta XRF Analyst X-ray spectrometer for multielemental characterization by EDXRF. This facility allows the detection of elements from Na to U with high accuracy and reproducibility.

Mössbauer Spectroscopy Laboratory, equipped with two Mössbauer spectrometers, allowing for transmission or backscattering geometry. A continuous-flow liquid-He cryostat and a bath cryostat, with a superconducting split-pair magnet for studies in the temperature range 2-300 K, under magnetic fields up to 5 T are available. Conversion electron Mössbauer spectra of surface layers, thin films, multilayers, etc. may be obtained at room temperature. ^{57}Co, ^{151}Sm and ^{119m}Sn sources for ^{57}Fe, ^{151}Eu and ^{119}Sn spectroscopy are currently used.

Different **Chemical Synthesis Laboratories** allow the preparation of a wide range of special samples and compounds. They includes the Laboratory for the Synthesis of Molecular Materials and the Laboratory of High Temperature Synthesis and Crystal Growth. The first is capable of handling air sensitive compounds. The second features an induction furnace (for growing crystals by Czochralski, Bridgman or floating zone methods); arc furnaces and resistive furnaces (up to 1600 ºC); a precision cutting machine for small dimension samples; and a low damage spark erosion cutting unit.

Induction furnace.

Laboratories for Low Temperatures and High Magnetic Field Characterization of Materials

These laboratories can measure electrical transport properties, magnetization and AC magnetic susceptibility, as well as specific heat, in a wide range of conditions from very low temperatures (0.3 K) and under intense magnetic fields (up to 18 T). The main pieces of equipment available are cryostats with a 10 T and 18 T magnets with a 3He insert for magneto transport ; one Multipurpose Specific Heat and Magnetic Characterization System MagLab 2000, with a 12 T magnet; a Faraday Balance, with a 7 T magnet and a SQUID Magnetometer with 7 T magnet and a 3He insert. The operation of these cryogenic infrastructures is dependent on a He liquefaction plant, the only one operational in Portugal.

Helium Liquifaction Plant.

The Radiocarbon Dating Laboratory allows the dating of samples of a variety of materials including wood and other plant remains, charcoal, shells, bones, sediments, water samples (precipitated carbonates), peat, etc. by measurement of 14^{C} activity using Liquid Scintillation Counting (LSC).

The Tritium Dating Laboratory allows the determination of tritium concentrations in rain water, ground and surface water by LSC.

The Light Isoptopes Mass Spectrometry Laboratory is equipped with a SIRA 10 VG ISOGAS mass spectrometer allowing the measurement of isotopic ratios ($^{18}O/^{16}O$, $^{13}C/^{12}C$ and $^{2}H/^{1}H$) in solid, liquid and gas samples, for water resource studies, paleohydrology, paleoclimatology, paleoceanography and archaeometry.

Two Mass Spectrometry Laboratories
One is equipped with a Finnigan FT/MS 2001- DT high resolution mass spectrometer, allowing the study of the chemistry of ion-molecule systems in the gas phase. The other has a Bruker HCT quadrupole ion trap mass spectrometer with atmospheric pressure ionization sources appropriate to solution chemistry studies. These laboratories have been focused on studies of lanthanides and actinides and are members of the National Mass Spectrometry Network.

Fourier Transform Ion-cyclotron Mass Spectrometer.

Nuclear Magnetic Resonance Laboratory (NMR). This laboratory is equipped with a Unity Inova Varian 300 MHz multinuclear spectrometer with pulsed field gradient (PFG) probes to the study of molecular structures of organic and organometallic compounds.

Laboratories for Radioactive Compounds A range of dedicated facilities are operated for preparation, radiochemical characterization and in vivo evaluation of radioactive compounds and materials. They include perspex glove boxes; lead-wall remotely controlled hot cells; HPLC systems, radio-chromatographer, electrophoresis apparatus and animal facilities (normal and nude mice). An Actinide Chemistry Laboratory is dedicated to the manipulation of highly radioactive actinides.

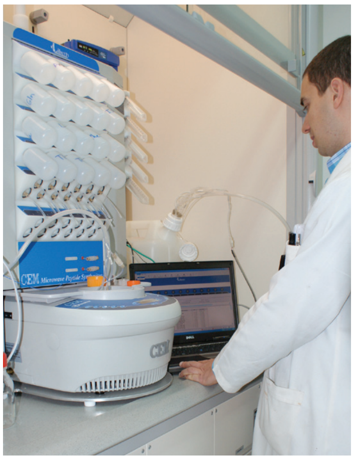
(Left)
Glove boxes and HPLC (Uv-gamma detection.

(Right)
Individual ventilated cages for mice housing.

Laboratories for Peptide Synthesis and Biochemical/Molecular Biology Studies allow the preparation, purification and characterization of biologically active molecules, namely peptides and peptide nucleic acids; identification/characterization of the biological mechanisms of action and cellular/molecular interactions of radioactive compounds useful for in vivo nuclear targeted molecular imaging and therapy.

(Left)
Automated Microwave Peptide Synthesizer.

(Right)
HPLC.

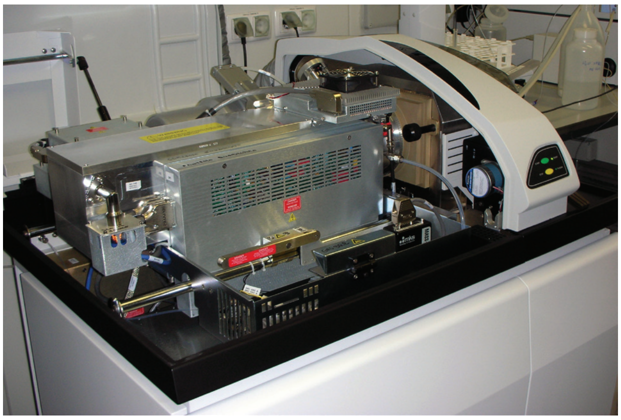


The Luminescence Dating Laboratory. This absolute dating method is based on a combination of retrospective dosimetry and environmental dosimetry, and evaluates the time since crystalline minerals were exposed to light or heat (examples: mineral grains of sand from sediment or a ceramic piece). Depending on the dosimetric properties of the signal and material being analysed, and the radioactivity of its environment, this method is able to date exposition to sunlight or heat between 0 years and >1 million years.

The Luminescence Dating Laboratory.

In the Laboratory of Catalysis, selected catalytic reactions, namely, the activation of pollutant C1 substrates such as CH_4 and CO_2, are under study on heterogeneous phase, using f-block elements as catalysts. Several reactor systems are available, including pressure reactors (autoclaves) and plug-flow type reactors (Pyrex and quartz) for measurements at atmospheric pressure. Facilities for safe manipulation of CO and techniques such as TPR and TPD for catalyst characterization are also installed. On-line GC analysis (TCD and FID) is the main technique used to follow the catalytic reactions.

The **HPLC/ICP-MS Laboratory** has an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) used in a wide range of research fields for multielemental analysis. With its low detection limits and ability to measure a large number of elements, this is a reference technique for trace element and isotopic ratio determinations in many fields including earth, environmental, life, materials and nuclear sciences. This ICP-MS is also coupled with a HPLC, with a collision/reaction cell, to reduce polyatomic interferences, being also an ideal elemental detection system for speciation analysis. The laboratory is installed in two clean rooms, one for the sample preparation and the other for the analytical measurements.



Inductively Coupled Plasma Mass Spectrometer.

The Laboratory for Radioactivity Measurements features a range of specialized equipments and facilities dedicated to the absolute measurement of alpha, beta and gamma activities in environmental samples:

- Alpha spectrometry systems: three EG&G Ortec OctêtePLUS alpha spectrometry workstations and nine EG&G Ortec 576A dual alpha spectrometers, for up to 40 simultaneous measurements.
- Gamma spectrometry systems: Canberra Multiport II multi-MCA with Ge(Li), HpGe and LEPS detectors.
- An automatic ultra-low background total alpha/beta counting system: Canberra XLB Tennelec 5.
- Liquid scintillation counting analyzers: Beckman LS 6500 and Packard Tri-Carb 3170 TR/SL

The Whole Body Counter and associated phantoms allows the assessment of the internal contamination (by ingestion, inhalation or other intake pathways) of radionuclides by individuals, following radiological or nuclear accidents.

The Metrological Laboratory of Ionizing Radiation, is a facility that hosts primary standards of X-rays, gamma and beta radiations and irradiation facilities for the calibration and metrological verification of radiation detection and survey instruments and equipment.

Metrological Laboratory of Ionizing Radiation and Radioactivity.

Whole Body Counter.

The Dosimetry and Radiobiology Laboratories deal with the determination of individual (external and internal) and environmental doses as well as the assessment of biological effects of ionizing radiation:

- The Whole Body Counter and associated phantoms, allows the assessment of the internal contamination (by ingestion, inhalation or other intake pathways) of radionuclides by individuals, following radiological or nuclear accidents.

A Radioactive Waste Interim Storage Facility is intended for the management of low-level radioactive waste

The Laboratory of Macromolecular Materials is dedicated to the manipulation and characterization of polymeric and hybrid materials processed by gamma irradiation. The laboratory is equipped with a unit for polymeric purification by discontinuous extraction a Differential Scanning Calorimeter (DSC) a Thermogravimetry unit (TGA) FTIR pectrometer, a mechanical testing machine and a hydraulic press (12 tons) with thermal mordents.

DSC and TGA thermal analysis equipment.

A Radioactive Waste Interim Storage Facility.

The Clean-Room Laboratory for Sample Processing is a Class-C (ISO 7) controlled area for the handling and preparation of samples meant for nuclear and nuclear related trace element analysis, equipped with a class-II type-A1 biohazard vertical laminar flow bench.

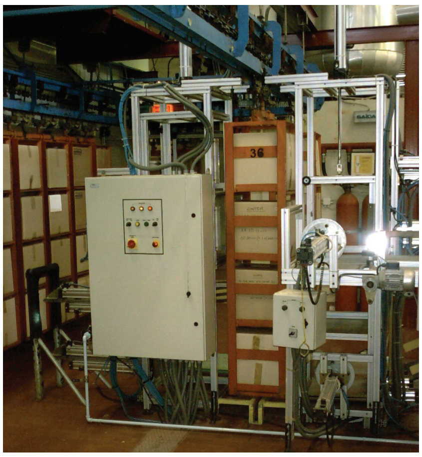
Several **Clean-Room Laboratories** support different activities in the area of microbiology and biological materials. These include A Class-C (ISO 7) area for the formulation of radiopharmaceutical preparations under sterile conditions and a Laboratory of Technological Assays in Clean Rooms (LETAL) featuring facilities in a cascade controlled areas (from ISO 8 to ISO 5) for microbiological and chemical analysis of the effects of ionizing radiation in products. This infrastructure is equipped with several laminar flow cabinets (vertical and horizontal) and analytical instruments (e.g. HPLC, UV-VIS spectrophotometer, TOC analyser).

Clean rooms for formulation of radiopharmaceuticals and microbiology.

The Microbiology Laboratory features facilities for the treatment and preparation of materials in a cascade controlled area, class-D (ISO 8), including a clean area, class-C (ISO 7), equipped with a class-II type-B2 biohazard laminar vertical flow bench (Baker) and a class-II type-A1 laminar horizontal flow bench (Bassaire).

The **Ionizing Radiations facility (IRIS)** is an infrastructure equipped with a 60Co gamma radiation source (Precisa 22) and a linear accelerator (6-12 MeV) that can function in both electron and photon (X-ray) beams modes.

The Radiation Technology Unit UTR is a semi-industrial facility with a cobalt-60 gamma source, providing irradiation services for a wide range of applications, namely the sterilisation of medical devices and pharmaceuticals, decontamination of raw materials, sludge and wastes. In the field of materials science R&D, the facility is currently used for the modification of the structure and properties of selected samples of materials.



Inside view of load control of UTR.

View of UTR.

Education and Training

In collaboration with the National Agency for the Popularization of Science – "Agência Ciência Viva", and during the summer holiday a one or two weeks hands-on training is offered to high school level students at the Institution's experimental facilities.

ITN takes advantage of the existing expertise and special skills of a qualified scientific and technical staff for the education and training of undergraduate and post-graduate students in different fields of science and engineering. Candidate applications are processed by the research groups involved and successful candidates are normally integrated in ongoing or new research projects. In most cases these newly-arrived trainees and co-workers are financed for a well-defined period of time by the National Science Foundation (FCT). Also post-docs of adequate scientific profile are engaged as fellows or under a contract to develop special projects whilst simultaneously gaining experience in certain research areas and in project management. As a rule the student work for a Master's or Doctor's degree.

ITN owns a number of specialized research infrastructures, equipments and services that are open to outside users in the framework of scientific collaborations, thus indirectly providing opportunities for education and training from which the higher education community takes advantage. In addition, a considerable number of researchers collaborate with higher education institutions lecturing classes, designing and implementing and coordinating specialized courses at the level of M. Sc., and supervising MSc and PhD students.

The Institution organizes short training courses in Radiation Physics, Radiological Protection and Radiation Safety, in special areas of interest to professionals (medical doctors, engineers, technicians, etc.) in radiological installations or operating radiation sources in the medical, industrial and engineering sectors and activities. Such courses are taught by certified staff members.

ITN gives special attention to the diffusion of scientific knowledge among the juvenile public including secondary school students and promotes regularly initiatives directed towards the general public. Schools are welcome to visit the Institution and such visits occur typically once per week.

In collaboration with the National Agency for the Popularization of Science – "Agência Ciência Viva", and during the summer holiday a one or two weeks hands-on training is offered to high school level students at the Institution's experimental facilities.

TRAINEES		
Year	**External**	**Internal**
2008	23	--
2009	81	--
2010	123	
2011	123	175

Environment and Cultural Heritage

Nuclear and related methods are important tools in Environmental studies and Cultural Heritage enhancement and preservation.

Environmental and archaeometrical studies carried out at ITN are largely based on the availability of several high sensitivity analytical techniques (instrumental neutron activation analysis, energy-dispersive X-ray fluorescence spectrometry, mass -spectrometry of light isotopes, radiocarbon (14C), luminescence and tritium dating, elastic backscattering, ion induced X-ray radiation and X-ray diffraction), many of them unique in Portugal, making ITN in this context, a key partner in many national and international research projects. Problems addressed aim at a better understanding of the evolution of man's technological skills and of the global environmental scenario, as well as the preservation of the Portuguese cultural heritage.

Studies of the biogeochemical cycles of elements and light isotopes in the atmosphere, and on the earth surface (water, sediments and soils) enable to establish the composition of the natural background and evaluate the anthropogenic contribution to the environment.

Air quality is assessed by identifying pollution emission sources and elements dispersion through the atmosphere by means of the elemental analysis of aerosols and selected biomonitors. The dynamics of the uptake and release of pollutants by industrial plants are studied.

Environmental changes that occurred during the Late Quaternary are identified by studying the stratigraphic structure of sedimentary deposits in estuaries of the main Iberian rivers, and coastal lagoons.

Palaeoenvironmental changes are investigated in different space and time scales up to the present, in order to establish evolution models and predict future changes in climate and landscape to support both geological and archaeological research.

The dynamics of groundwater systems, protection and development of water resources, climatic changes and the impacts of human populations on the environment have been studied by isotope hydrology.

Geochemistry, mineralogy, crystal chemistry, and microbiological studies are important in provenancing cultural assets, establishing production technologies, and for the optimization of conservation strategies.

Health and Life Sciences

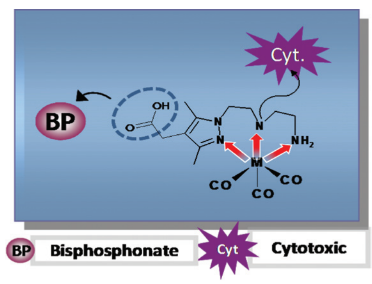
The research activities in the Life Sciences at ITN are carried out in close collaboration with the University, nationally and internationally, clinicians and industry.

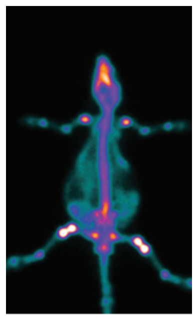
ITN, has a long standing tradition on the use of nuclear and radiation technologies in Health and Life Sciences addressing many of the global needs related to health care, ageing, food production, environment protection, and sustainable development. Expertise in radiation science and in the underlying physics, chemistry and biology, allows the development of new ways of exploiting microbiology, molecular biology and the design of innovative radioactive drugs for molecular imaging and targeted therapy, in close cooperation with universities, health research centers, hospitals and industrial partners.

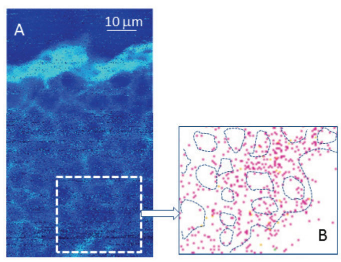
These activities are carried out in ITN, using facilities and know-how that are unique in the country, namely, the Ion-Beam Laboratory, Laboratories for Manipulation, Characterization in vitro and in vivo, and Biological Evaluation of Radioactive Compounds, the Gamma Radiation Facility and expertise on Radiopharmaceutical Chemistry, Solid Phase Peptide Synthesis, Bioconjugation and Drug Delivery Systems.

Topics being addressed include:

- Relationship between toxic elements in inhaled particles and the incidence of chronic respiratory diseases using the Ion-Beam techniques.
- Essential elements for the human body followed through human diet studies, including speciation, by neutron activation analysis.
- Epidemiological effects originating in the environment.
- Chemical analysis and cell and tissue morphology visualization at the micrometer and sub-micrometer level, using focused ion beams as sensitive probes.
- Control of the bioburden in pharmaceutical materials and end-products, medical devices, wastewater treatment and improvement of foodstuff quality, using the Gamma Radiation Facility.
- Development of new specific radiopharmaceuticals containing positron- or gamma- emitters for Nuclear Medicine Molecular Imaging or based on beta- or Auger-emitters for cancer therapy.
- Development of target-specific radiopharmaceuticals for cancer therapy, based on beta- or Auger- emitters.







Human skin of a patient with iron overload (A) and iron deposits in the extracellular space of epidermal cells (B).

Materials Science

A vast array of techniques for materials characterisation is available at ITN, providing fundamental information with national and international Universities, Health Research Centers, Hospitals and Industry.

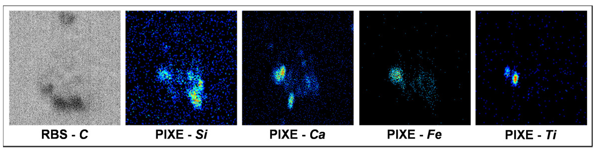
The long standing tradition of ITN in Materials Science and Technology, is based on unique infrastructure and experimental capabilities, which have attracted scientists, engineers, and research groups from all over Portugal and abroad.

Synthesis and modification of materials is achieved via chemical synthesis and ion implantation, or γ and neutron irradiation. Different methods of chemical synthesis are available in the fields of inorganic and organometallic chemistry, radiochemistry and solid state materials. Ion implantation is used to modify the near surface structure or to introduce dopants. Gamma and neutron irradiation are used for improving existing synthetic and natural polymers, and to create new materials.

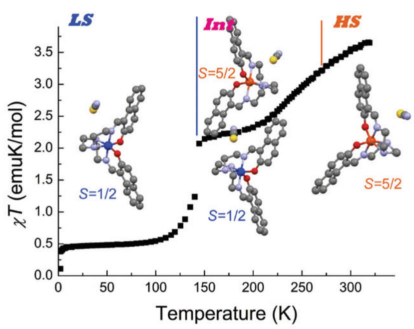
A vast array of techniques for materials characterisation is available at ITN, providing fundamental information with a high degree of complementarity. Chemical, structural, compositional, electric and magnetic properties can be measured.

The analytical techniques, which are unique and specific include ion backscattering, particle-induced X- and γ-ray emission, hydrogen-recoil detection, and nuclear reactions. Neutron beams are also available for neutron diffraction and scattering and high accuracy neutron activation analysis. α-, β-, and γ-spectrometry techniques are employed in a range of applications. X-ray diffraction and X-ray reflectometry are used for the study of thin films.

The Chemistry Department has a wide range of capabilities in the synthesis of new materials like intermetallics, oxides and molecular materials, and crystal growth, a special emphasis being placed on the design of multifunctional and nanostructural molecular materials with unconventional electrical and magnetic properties. ITN has unique facilities in Portugal for low temperatures and high magnetic field (0.3K-400K, up to 18T) characterisation of materials, as well as for Mössbauer spectroscopy.



(Mapas) Maps of Fig RBS (Carbon) and PIXE of impurities in a PE-g-HEMA film.



(SpinCO) Behavior of a Spin crossover hybrid material.

Nuclear Sciences and Radiological Protection

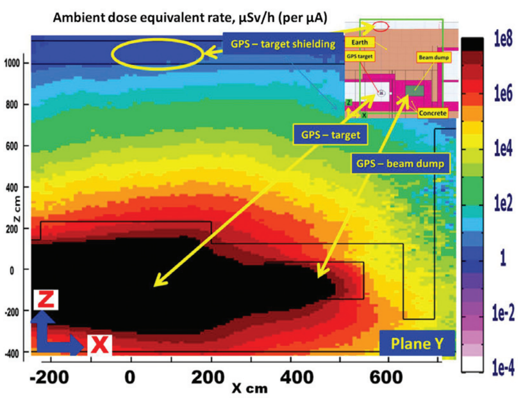
Nuclear Sciences and Radiological Protection have a longstanding tradition of research at ITN, that is unique in Portugal, often with support of the European Commission and the International Atomic Energy Agency.

Nuclear Sciences and Radiological Protection have a longstanding tradition of research at ITN that is unique in Portugal often with support of the European Commission and the International Atomic Energy Agency. Topics currently being dealt are:

- The operation of the Portuguese Research Reactor accompanied by work in nuclear engineering, (reactor calculations and safety analysis).
- Vibration and acoustic problems of components of nuclear (and conventional) power plants.
- Actinide chemistry; determination of key physicochemical properties of actinide species and study of new coordination environments for actinide/lanthanide separations.
- Transmutation of high-radiotoxicity radioactive waste.
- Assessment of radioactivity in the environmental compartments.
- Radiation physics, dosimetry, and radiation induced biological effects.

Radiological Protection is a specific mission of ITN and, alongside the research activities, a significant number of services to the community are offered in this field, namely:

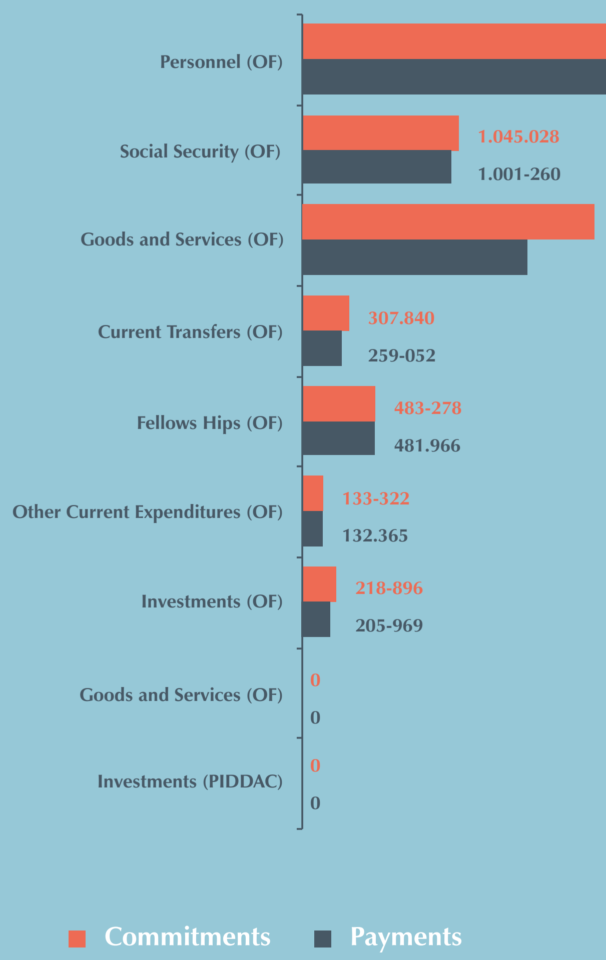
- Monitoring of environmental radioactivity,
- Verification and safety and risk assessment of facilities using radiations.
- Maintenance of the National Ionizing Radiation Standards and metrological calibration of radiation instruments.
- National environmental radioactivity monitoring with emphasis on the radiological characterization of contaminated sites and determination of indoor and outdoor radon concentrations.
- Assessment of doses received by the population due to different types of exposure to external radiation.
- Maintenance of the Central Dose Registry for Portugal (occupational exposure data collected since 1957).
- Management (monitoring, transport, segregation, conditioning and interim storage) of radioactive waste.
- Licensing of sealed sources.
- A authorization and control of the transportation of radioactive materials.
- Survey of nuclear vessels entering national ports.



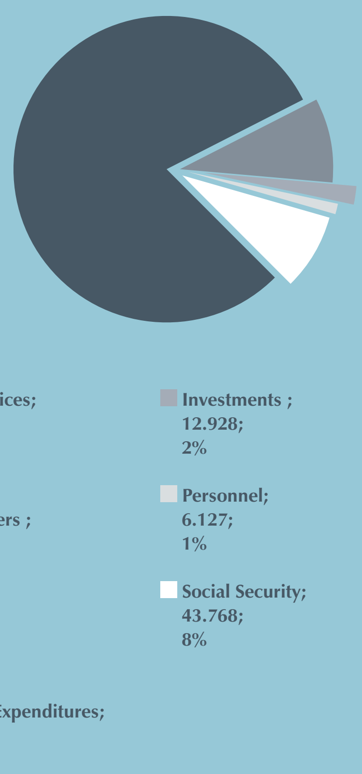
ITN in Numbers

Expenses | Income | Personnel | Publications

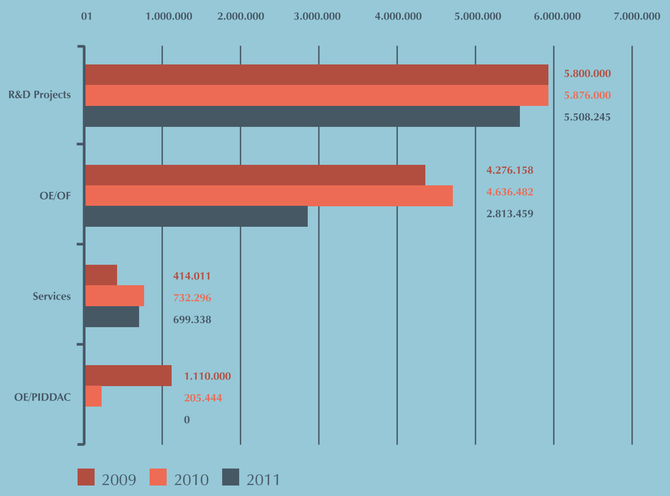
2011 Expenses



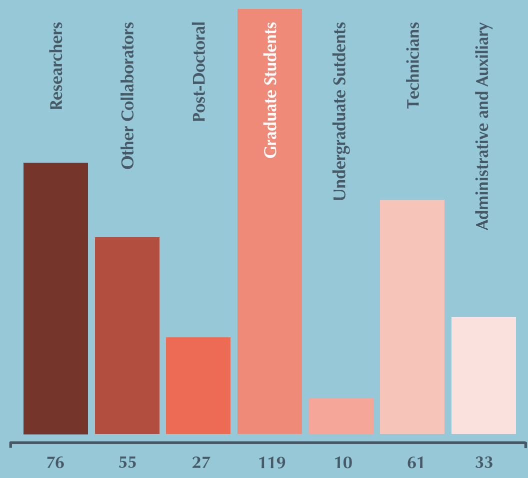
Unpaid Commitments



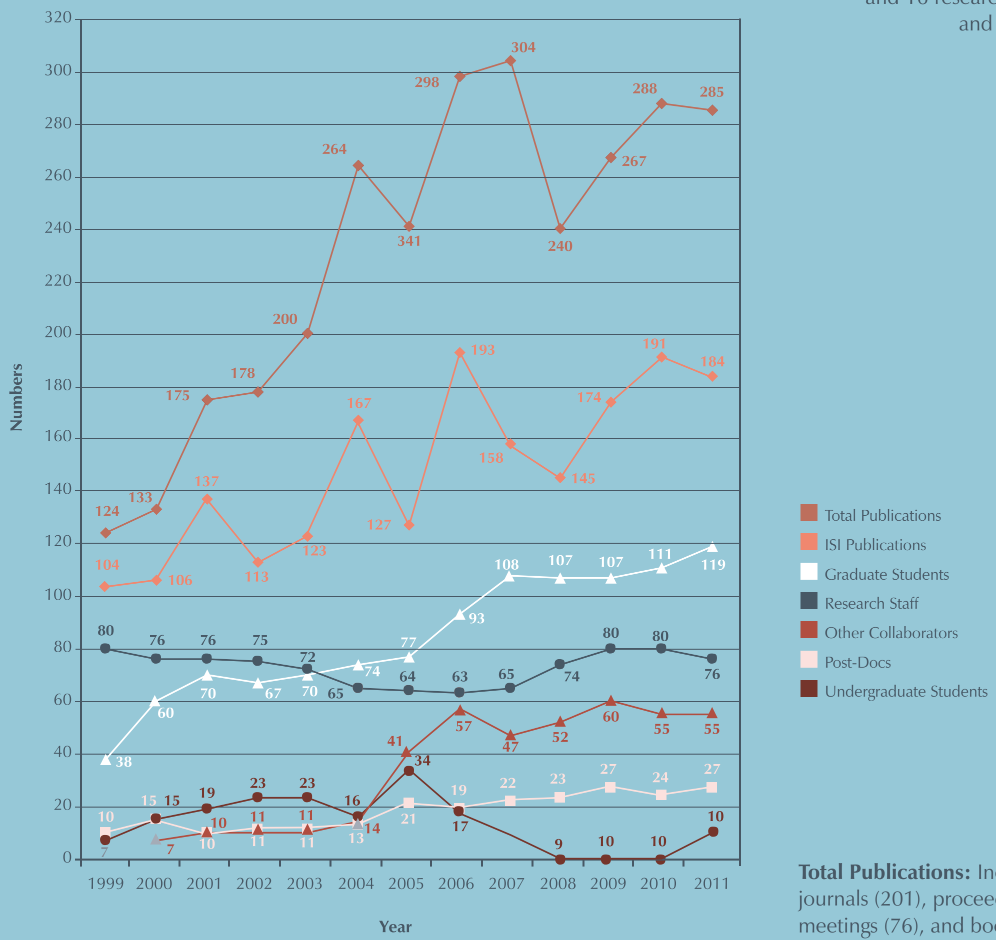
2009-2011 Income



Total Personnel - 381
(Permanent staff 165)

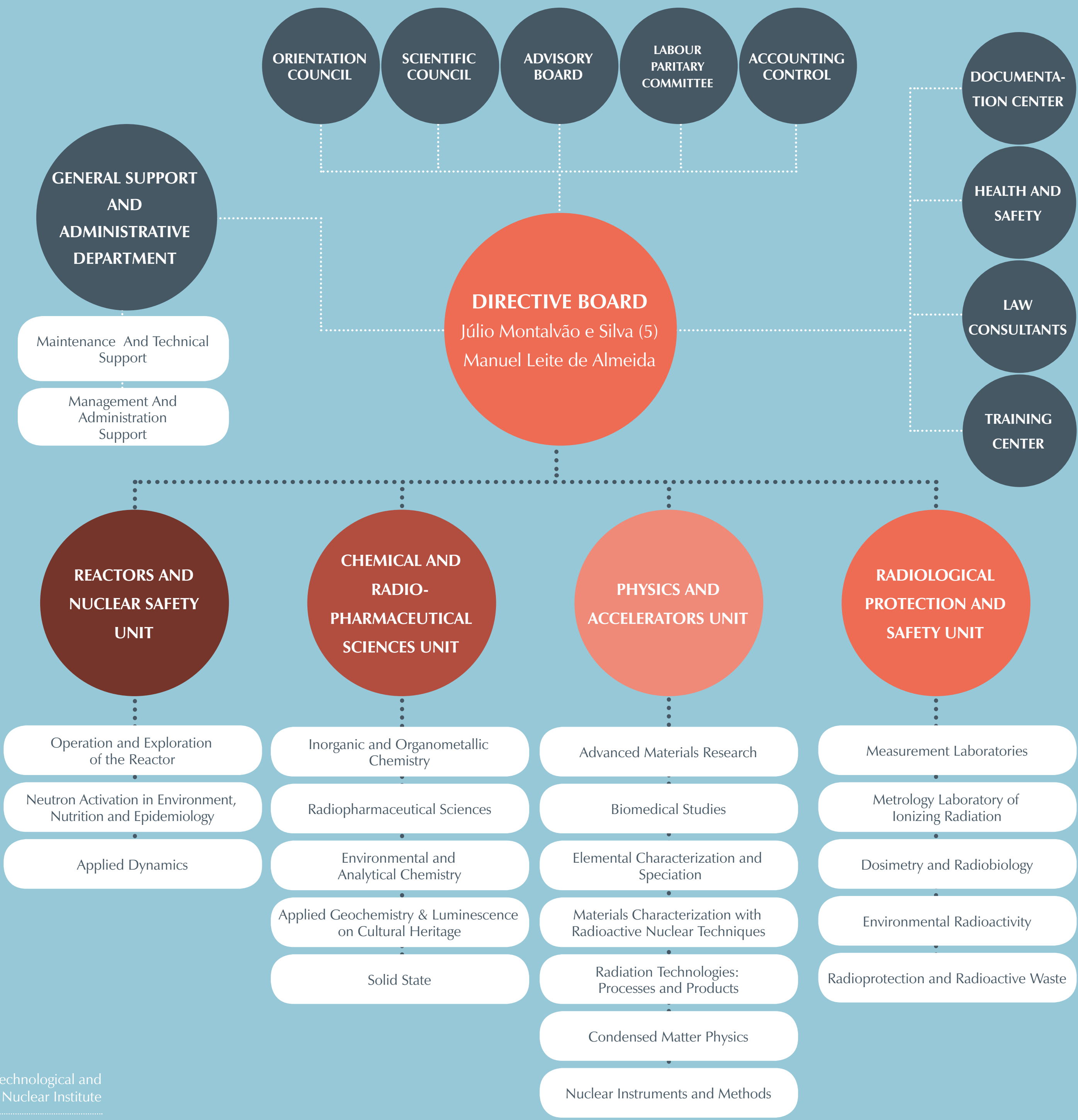


Staff: Research Staff as of December 31. Other collaborators include 39 professors from different universities and 16 researchers from other national and international institutions.



Total Publications: Includes international journals (201), proceedings of international meetings (76), and books/book chapters (8).

Organization



ITN Annual Report 2011

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