Dosimetry and Radiobiology Group

Pedro Vaz and Octávia Monteiro Gil

The synergies of the competences held by the Dosimetry and Radiobiology Group (GDR) researchers and technicians were further strengthened, in order to address and to respond in a more efficient way to the multidisciplinary, cross-cutting leading-edge scientific and technical issues in Dosimetry and Radiobiology, including low dose radiation research.

The main components of activity of the GDR are Individual Dosimetry, Computational Dosimetry, Internal Dosimetry, Biological Dosimetry, Radiobiology and Radiological Safety Assessment of installations.

The competences in several radiobiology and bio-dosimetric techniques namely dicentrics, micronuclei, γ-H2AX and COMET assays, were strengthened The existing competence in Computational Dosimetry, (in Monte Carlo simulations) was deployed in support of radiological protection, dosimetry and shielding assessment studies of nuclear technology facilities, of radiological installations, and of the modelling of medical radiological equipments and of HPGe-based detection systems, including the Whole Body Counter operated by the GDR. Biokinetic models and Internal Dosimetry studies were undertaken.

Researchers and fellows from the GDR have:

- Participated in R&D projects conducted and submitted by international consortia, in the E.U. 7th Framework Programmes or in collaboration with CERN;
- Submitted research projects to the Portuguese Foundation for the Science and Technology;
- Participated in the activities of EURADOS WGs.

Medical applications of ionizing radiation

The GDR researchers participated in the preparation and submission of R&D projects to the E.U. 7th Framework Programme and to the Portuguese Foundation for the Science and Technology (FCT). Collaborative links with hospitals and clinics were fostered. Activities related to the dose assessment and computational modelling of medical radiological equipments were undertaken, namely in mammography, in Computed Tomography (CT) and in Fluoro-CT.

Low dose radiation research

The occupational or environmental exposure to low radiation doses and the medical exposures to ionizing radiation for diagnostic or therapy purposes are currently very hot scientific- and regulatory- related topics and issues. Major findings in the biological effects of radiation should allow to narrow the persisting uncertainties about the mechanisms of response of cells, tissues and biological systems in the range of low doses, what will pave the way for developments of the international system of Radiation Protection., The ITN participated as a full member in the activities of the EU-platform MELODI (Multidisciplinary European LOw Dose Initiative") namely in the drafting of a roadmap and a strategic research agenda for the low dose research in Europe.

Response to radiological emergencies and accidents

Activities initiated in recent years were pursued aiming at increasing the preparedness of response of the GDR in the context of retrospective dosimetry studies in radiological emergencies or following overexposures to ionizing radiation. The need to assess the doses and to reconstruct retrospectively the sequences leading to such situations (emergencies, overexposures), requires competences in areas such as Physical Dosimetry (measurements), Internal Dosimetry (modelling issues involving biokinetic models), Computational Dosimetry (Monte Carlo modelling and simulations) and Biological Dosimetry (using the aforementioned assays, amongst others).

Technical services

The GDR continued to operate its individual dosimetry and monitoring services and to perform the radiological safety assessment of radiological installations (radiotherapy installations and nuclear medicine services throughout the country). The radiological safety assessment of the X-ray scanners in operation in the Ports of Mozambique and Cape Verde was performed upon request of the local authorities.

The Central Dose Registry (CDR) for occupational exposure continued to collect and store on a quarterly basis the dosimetric data from the seven monitoring services and companies operating in Portugal.

Higher Education and Training

Several researchers maintained regular collaborations with Portuguese universities and higher education institutions, teaching Radiation Protection- and Dosimetry-related disciplines in the framework of Masters and post-graduation programmes and supervised several graduation, Masters and Ph.D. theses. Several technicians and fellows finished post-graduation diplomas and Masters thesis and participated in international training courses in radiation protection, dosimetry and radiobiology.

International and national representation activities

Researchers from the GDR acted as national representatives in Committees and Working Groups under the auspices of the EU, the IAEA and the OECD/NEA and assisted the Portuguese Government in the drafting of legislation and regulations.

Research team

Researchers
P. VAZ, Princ., (Agreg.)
M.A. NEVES, Princ.
J. ALVES, Aux.
O. MONTEIRO GIL, Aux
A. D. OLIVEIRA, Aux.
P. TELES, Aux.
S. di MARIA, Post-Doc

Technical and Admin. Personnel
T. ANTUNES
M. MARTINS (until Nov.)
M. SARAIVA
S. RANGEL
Y. ROMANETS

Fellows and Collaborators
A.C. ANTUNES
V. MARTINS
A. BELCHIOR
J. BENTO
C. BORGES
C. CARRAPIÇO
C. FIGUEIRA
R. F. LUIS
M.N. PEREIRA
S. BARROS
R. SARMENTO

Implementation of a dose response curve for dicentric chromosomes

V. Martins, A. C. Antunes, O. Monteiro Gil

The development of a dose response curve, which can be applied to the Portuguese population in any radiological emergency, is being held at ITN. This work already began in the previous year. Until now, this kind of study was never done in Portugal. The *in vitro* dose response curve is being performed with a sample of 16 healthy, non-smoker individuals, from both genders and in the range of 20 to 60 years (two donors per gender and interval of age). To achieve this objective we have already irradiated samples of peripheral blood lymphocytes from 13 donors with doses from 0 to 3 Gy air kerma, using a ^{60}Co source locate at LMRI/ITN. Per dose and for each individual, 200 metaphases were scored by two independent scorers and an additional scorer was used for aberrant cells confirmation. Until now, a set of 18,200 metaphases with 46 chromosomes were analyzed. Dicentric chromosomes were the chosen endpoint, since they are almost exclusively induced by ionizing radiation, being the characteristic chromosomal aberration for radiation exposure. A clear dose-dependent increase in terms of dicentric chromosomes was observed for all donors and at the higher dose level a larger intervariability among individuals was seen (Figure 1).

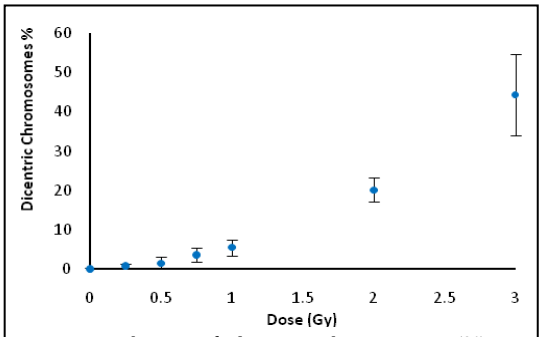


Fig.1 Distribution of dicentric chromosomes (%) in function of dose. Each point represents the average of 13 healthy donors (total of 18,200 metaphases scored).

Dose response curve using cytokinesis-blocked micronucleus assay

A. C. Antunes, V. Martins, O. Monteiro Gil

We have started the improvement of a dose response curve for biological dosimetry in case of radiation exposure, using the cytokinesis-blocked micronucleus (CBMN) assay. This is the first time that such study is undertaken for Portuguese individuals. The CBMN assay is an alternative method to the analysis of metaphases, because it is easier and allows faster evaluation of samples. Our study aims to evaluate the correlation among the different biomarkers, micronuclei and dicentrics, in order to propose the use of CBMN assay for a rapid triage in cases of malevolent acts or mass casualty situations, where rapid evaluation of biological effects induced by radiation exposure and dose estimation is mandatory. Whole blood samples of five healthy donors were irradiated *in vitro* with doses from 0-3 Gy air kerma, using a ^{60}Co source locate at LMRI/ITN. Per dose and for each individual a total of 1,000 binucleated cells were analyzed in terms of micronuclei frequency. Figure 1 shows a dose-dependent increase in the level of genetic damage induced by ionizing radiation, considering the five donors already studied. Future work will consider the study of more individuals in order to propose the CBMN assay for rapid radiation exposure screening purposes.

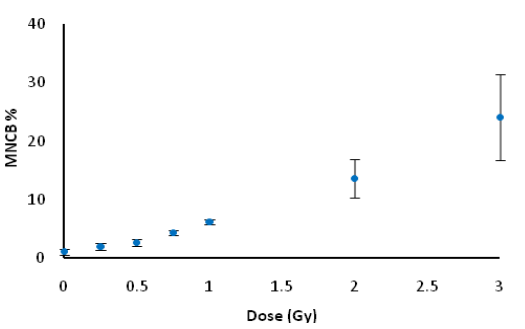


Fig. 1 Distribution of binucleated cells containing micronuclei (MNCB (%)) in function of dose, considering five donors (Total of 35,000 binucleated cells scored).

γ-H2AX-new technique implementation using peripheral blood human lymphocytes

O. Monteiro Gil, A. Sebastião Rodrigues[1]

We are implementing at ITN a new technique for detection of DNA lesion induced by ionizing radiation (IR) with the help and knowledge of Genetic Department of UNL. A DNA double-strand break (DSB) is a high cytotoxic form of DNA damage which, if not correctly repaired, can initiate genomic instability, chromosome aberrations and may eventually lead to cancer. Exposure to IR induced the phosphorylation of H2AX in the vicinity of a DSB (green spot), the greater the number of foci the greater the damage induced. This is a very important bioindicator to biological dosimetry.

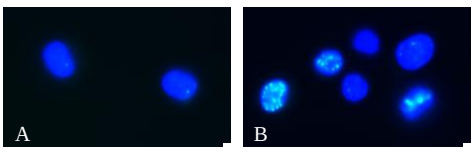


Fig. 1 Foci of γ-H2AX. (A) without exposition; (B) with exposition to the clastogenic agent. (A.S. Rodrigues, 2010)

[1] Genetic Department UNL

Radioprotective effects of manganese(III) porphyrins on the genotoxicity induced by low LET radiation (Co-60) in human lymphocytes

A.S. Fernandes[1], V. Martins, N.G Oliveira[1], O. Monteiro Gil

The aim of this on-going work is to study the influence of manganese(III) porphyrins with superoxide dismutase activity on the protection against the genotoxic effects induced by ionizing radiation (IR) as evaluated by the cytokinesis-blocked micronucleus assay.

[1] CBT-iMed.UL /FFUL

Evaluation of the cytotoxicity induced by α radiation in an A549 cell line

A. Belchior, O. Monteiro Gil, P. Almeida[1], P. Vaz

The biological effects induced by α-radiation (^{210}Po), both direct and untargeted, in a human lung adenocarcinoma epithelial cell line (A549) were quantified with cytokinesis blocked micronuclei technique. The untargeted study includes; group I-irradiated cells (1Gy) cultured with fresh medium, group II-unirradiated cells cultured with irradiated medium previously filtered and group III-irradiated cells (1Gy) cultured after centrifugation with fresh medium. By direct exposure an increase in the number of cellular lesions as a consequence of increasing absorbed dose value is observed. At day 2 after cell irradiation, a more evident increase of the number of micronuclei (MN) per binucleated (BN) cell in group I was observed when compared to group III. Group II shows a clear increase in the frequency of MN when compared to the control. The delayed response of cells to radiation is similar to the early response. But, in Group II, the comparison of results obtained for delayed and earlier responses, one can notice an increase in the number of MN in the delayed response.

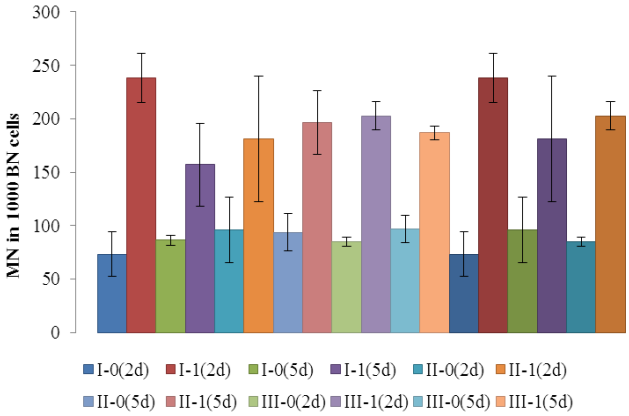


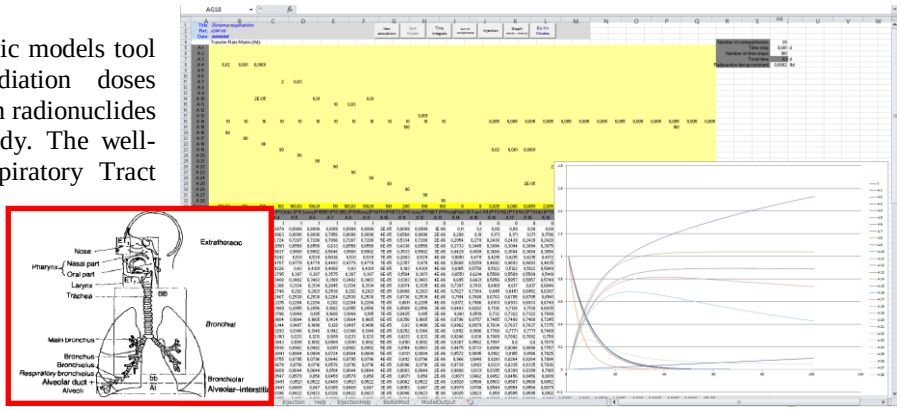
Fig 1 The controls are labeled as I-0, II-0, III-0 and the irradiated cultures as I-1, II-1, III-1. Early and delayed effects are labeled with 2d and 5d (2 and 5 days after exposure), respectively. Data represent the average of 3 independent experiments, ± S.E.M.

[1] IBEB-Fac. Ciências, UL

BioKinModels – Human respiratory tract

A.D. Oliveira

BioKinModel is a bio-kinetic models tool aiming to determine radiation doses received by individuals from radionuclides which enter the human body. The well-known ICRP Human Respiratory Tract model was implemented in the BioKinModels format.



Thyroid monitoring for assessment of I-125 contamination, using a NaI scintillator detection system

J. Bento, M. Neves, P. Teles

In addition to the WBC calibration, a portable detecting system using a NaI scintillator was also calibrated for thyroid measurements, using a PMMA phantom (RMC-II) and a I-125 source. Quality assurance of the equipment is performed recurrently. It is of major importance, as Iodine contamination cases are among the most common, thus improving ITN's emergency preparedness. This detecting system had a practical use in 2010, when five measurements had to be performed in relation to the suspicion of a possible accidental incorporation of I-125.

In vivo monitoring activities in internal dosimetry: recent calibrations using a BOMAB phantom

P. Teles, J. Bento, S. Barros, M. Neves, P Vaz

There have been remarkable improvements in the competences of UPSR in the framework of internal dosimetry activities. A new calibration of the whole body counter (WBC) was performed using a recently acquired BOMAB phantom, one of the industrial standard anthropomorphic phantoms used for these purposes. The WBC is now prepared to perform whole body scans and detect radionuclides emitting between 88 keV and 1836 keV, featuring low detection limits and acceptable minimum detectable activities. Along with the experimental calibration, Monte Carlo simulations were also performed, validating a computational model of the WBC and reproducing with good accuracy the measured detection efficiencies. In the future, this model will be extended to include mathematical and/or voxel phantoms that, in addition to being inexpensive will overcome the physical limitations of the experimental calibration.

Internal contamination assessment activities of Nuclear Medicine staff in Portugal

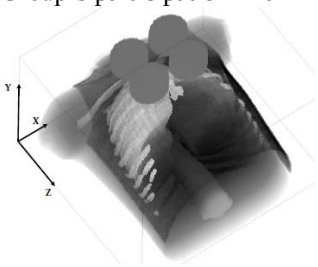
J. Bento, P. Teles, M. Neves

During 2010, a great effort was devoted to the assessment of the need to create and implement nationwide, a routine programme for internal monitoring of the Nuclear Medicine staff. This effort was put to practice by warning physicians and medical physicists against the risks of internal contamination in Nuclear Medicine, following the International Atomic Energy Agency (IAEA) guidelines, and disseminating ITN's competence in performing routine monitoring using the available equipment in our facilities. Several visits to key Nuclear Medicine services in hospitals in Lisbon, Porto and Coimbra, were undertaken, where insight into which are the most common practices in Nuclear Medicine, as well as which safety and protection measures are put in practice in these services was gained. Moreover, an assessment of the need for the internal monitoring of the Nuclear Medicine workers in the visited institutions was carried out using IAEA criteria, published in the safety guide RS-G-1.2. These criteria are based on the type and amount of radionuclides handled and on the protection and safety measures employed when handling them. A series of reports to the participating institutions is being prepared, as well as an article with the obtained results. The results of this study could lead to the implementation of a routine monitoring programme for nuclear medicine workers.

Participation in EURADOS activities related to internal dosimetry

J. Bento, P. Teles

Regarding the application of voxel phantoms in Monte Carlo simulations, expertise was acquired with the Group's participation in an EURADOS (WG-6 and WG-7) intercomparison exercise. This exercise involved the implementation of a voxel thoracic phantom, where the lungs were contaminated with enriched Uranium. The aim of the intercomparison was to simulate the response of a four HP-Germanium detector array to the several photopeaks emitted by the contaminated lungs. This activity involved the participation in the experimental measurements at the CIEMAT (Spain) and a two month internship at the IRSN (France), the two main institutions involved in this intercomparison. ITN's results were later compared with experimental data and were considered "accepted". To be noted also that ITN was the only institution to use the PENELOPE Monte Carlo program in the simulations.



EURADOS Working Group 2: Harmonization of individual monitoring in Europe

J.G. Alves, P. Ambrosi[1], D. Bartlett[2], L. Currivan[3], J.W. van Dijk[4], E. Fantuzzi[5], V. Kamenopoulou[6], A. McWhan[7], M. Figel[8], T. Grimbergen[9], A. Romero[10], H. Stadtmann[11]

The aim of this project is to disseminate previous activity carried out by EU-Trimer and the organization of regular intercomparison exercises groups, as well as to identify new activities for EURADOS WG2. WG2 collaborated in the organization of IM2010-European Conference on Individual Monitoring of Ionizing Radiation (347 registrations, 300 communications) being part of the scientific committee, chairing sessions and the refereeing process throughout 2010.

At IM2010 the document *Radiation Protection n. 160* authored by the EU-Trimer group and published by the European Commission was officially presented. Invited talks on the new technical recommendations and on the intercomparison exercises IC2008 and IC2009 were proffered at this conference as well as at the Solid State Dosimetry Conference held in Sydney in September. Talks on Radiation Protection 160 were also given at the ESOREX Symposium and at the RER/9/097 AIEA meeting in Vienna, both held in June.

The IC2009 on extremity dosimeters for photon and beta radiation fields was completed and the certificates presented to participants. IC2010 on whole-body dosimeters for photon fields was carried out and will end in February 2011.

[1] PTB, Germany; [2] formerly HPA, United Kingdom; [3] RPII, Ireland; [4] formerly NRG, Netherlands; [5] ENEA, Italy; [6] GAEC, Greece; [7] Babcock, UK; [8] HZM, Germany; [9] NRG, Netherlands; [10] CIEMAT, Spain; [11] Seibersdorf Laboratories, Austria.

Medical staff and patient dose assessment studies

J.G. Alves, M.F. Pereira[1], A.D. Oliveira, J.V. Cardoso, L.M. Santos, L.C. Freire[2], A. Pascoal[3], J.M. Santos[4], S. Sarmento[4]

The main objective of this line of activity is to carry out occupational and patient dose assessment studies in specific medical applications. ITN is partner in two research projects funded by *Fundação para a Ciência e a Tecnologia* (FCT) prepared under the framework of collaborations with *Universidade Católica Portuguesa* (PTDC/SAU-BEB/100745/2008 for mammography) and *Instituto Português de Oncologia do Porto* (PTDC/SAU-ENB/115792/2009 for fluoro-CT guided interventional procedures).
In the case of fluoro-CT guided procedures for lung biopsy collection the interventional radiologist is likely to be exposed to higher dose levels, particularly to the hands, upper and lower limbs. The dose assessment methodology was setup and gradually improved so that per-procedure results could be obtained. Ten previously characterized whole-body dosimeters as well as 11 extremity dosimeters inserted in casings in a special designed glove were used to estimate per-procedure dose distributions. Preliminary results were presented as communications (oral and a poster) at the IM2010-European Conference on Individual Monitoring of Ionizing Radiation and the corresponding papers were prepared and published in a journal. This work was considered of interest to the EURADOS Working Group 12 on European Medical Alara Network and is in progress.

[1] ITN Grant holder, PhD student; [2] Escola Superior de Tecnologia da Saúde de Lisboa; [3] Universidade Católica Portuguesa, Faculdade de Engenharia; [4] Instituto Português de Oncologia do Porto, Grupo de Física Médica.

Characterization of Occupational Exposure in Portugal in the period 2000 to 2008

J.G. Alves, M.B. Martins[1]

The aim of this work is the characterization of occupational exposure in Portugal in the period 2000 to 2008. Decree-Laws n. 165/2002, n. 167/2002 and n. 222/2008 entrust to ITN: (i) the creation and maintenance of a Central Dose Register (CDR) where the occupational exposure data of workers in Portugal are stored; and (ii) the publication of annual reports on the statistical analysis of data allowing the characterization of occupational exposure in the country.
The stored data consists of the identity of the worker, affiliation, periodic external dose evaluations in terms of the operational quantities $H_p(10)$ and $H_p(0.07)$ and the on information relative to the worker's facility field of activity and work practices. The facilities are organized in four fields of activity, namely conventional industry (12-13%), medicine (80-85%), research (3-7%) and mining (0-1%). Within each field of activity the ESOREX practice codes were used in the analysis and for international comparison.
The annual effective doses for the 2000 – 2008 period were analyzed, organized in three independent reports corresponding to 2000-2006, 2007 and 2008 and published by ITN. The analysis consisted in the distribution of the number of workers organized by dose intervals, on the determination of the annual average dose for the total monitored population and for the exposed workers, as well as on the calculation of the annual collective dose. The same parameters were also determined for each field of activity and for the ESOREX practices in each field of activity. Electronic versions of the reports are available from ITN's web page.

[1] Retired in October 2009

Monte Carlo simulations of a new micromultileaf collimator (MLC) High Definition 120 (HD120) implemented in a linac used in Radiotherapy

C. Borges [1,2,3], N. Teixeira [2,4], P. Vaz

After implementation and validation of the linear accelerator head of a Trilogy®, Varian® linear accelerator, up to the jaws, modeling of the brand new micro multileaf collimator HD120 was necessary.
The BEAMnrc® code was used to simulate this collimator. For implementation, the density and abutting gap of the MLC had to be determined.
Validations of the implementation were performed using ionometric (lateral and depth doses profiles) and photographic dosimetry (in a solid water phantom) of several open and irregular fields shaped by the MLC.

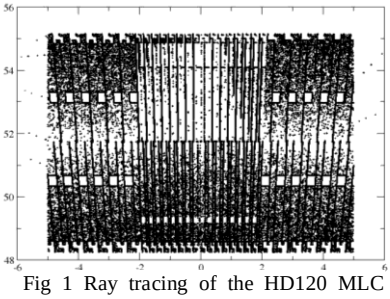


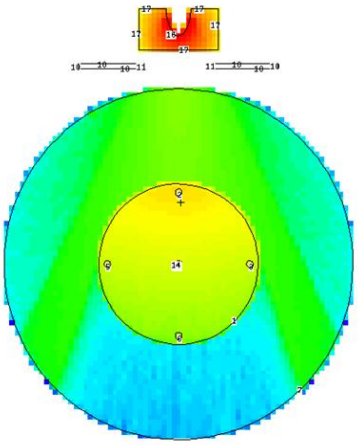
Fig 1 Ray tracing of the HD120 MLC simulated using the BEAMnrc code.

[1]Medicalconsult, SA; [2]Fac. of Medical Sciences, UNL; [3] UPSR; [4]Escola Superior de Tecnologia da Saúde de Lisboa

Measurements and calculation, using Monte Carlo simulations, of the doses in Computed Tomography (CT) exams

C. S. Figueira, R. Sarmento, P. Madeira[1], P. Vaz

The objectives of the work consisted in the modeling and simulation, using Monte Carlo methods, of a CT scanner and the associated irradiation conditions, namely the resulting radiation doses. In order to achieve these objectives, measurements using an appropriate phantom and associated radiation detection equipment were performed using a CT scanner in operation at an hospital, to validate the results obtained by Monte Carlo simulations. Some of the crucial modeling issues are the exact knowledge and accurate description of the geometry and constituent materials of the scanner gantry and multiple components (filters and collimators), the knowledge of the energy spectrum of the emitted X-radiation and the electron-to-X-ray conversion efficiency in the anode. In the almost complete absence of information provided by the equipment manufacturer, the uncertainties associated to the geometry, materials and radiation beam, translate into uncertainties affecting the Monte Carlo simulation results. In order to minimize discrepancies between computational (C) and experimental (E) results, sensitivity analysis studies were performed, varying some of the geometric parameters of the components. Using the trial-and-error method to iterate the geometry of one of the main components, it was possible to achieve an agreement between C and E results with less than 5% difference.



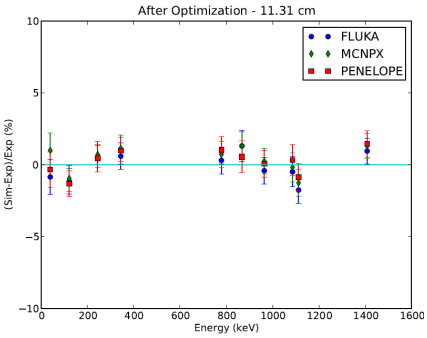
The dose distribution computed using Monte Carlo simulations, in the different components of the gantry, with a CT phantom in its center and the bowtie filter and collimators (outside the external circle) is displayed in the Figure.

[1] Serviço de Imagiologia, Centro Hospitalar Lisboa Central – Hospital de São José.

Modelling and understanding the behaviour of HPGe detectors

R. Luís, J. Bento, P. Nogueira, G. Carvalhal, L. Silva, M. Reis, P. Teles, P. Vaz

The existing competence in Monte Carlo simulations was deployed to address modelling issues of radiation detectors. A transversal activity involving the Measurement Laboratory (LM) and the Dosimetry and Radiobiology Group (GDR) was pursued, in order to gain further insight in the response of HPGe detectors (experimental and simulated detection efficiencies are shown in the picture), namely in the efficiency calibration and coincidence summing corrections, among others. Three different state-of-the-art Monte Carlo codes were used, namely FLUKA, MCNPX and PENELOPE. Of these activities resulted 1 article published in NIM A and a presentation at the most important international Conference on Monte Carlo methods applied to radiation physics and particle transport simulation (MC2010).



Optimization studies of the ISOLDE targets, at CERN

R. Luís, T. Stora[1], P. Vaz

The ISOLDE facility at CERN has been one of the premier radioactive ion beam facilities worldwide since it started operating in 1967. In the studied configuration, a 1.4 GeV pulsed proton beam hits a tungsten spallation target, generating intense neutron fluxes that induce fission in a UCx target. The first objective of this work was to predict the yields of neutron-rich isotopes of Zinc and Cadmium using the Monte Carlo code FLUKA. After validation with the experimental yields obtained at ISOLDE, an optimization of the targets configuration was undertaken, in order to reduce the contamination of the desired neutron-rich isotopes by proton-rich isobars. The Figure shows the improvement predicted for the contamination of Zinc isotopes by Rubidium isobars. For ^{80}Zn, an important nuclide for the Physics program at ISOLDE, there is an improvement in the ratio ^{80}Zn/^{80}Rb of the order of 20. A similar result was obtained for the ^{130}Cd/^{130}Cs ratio.

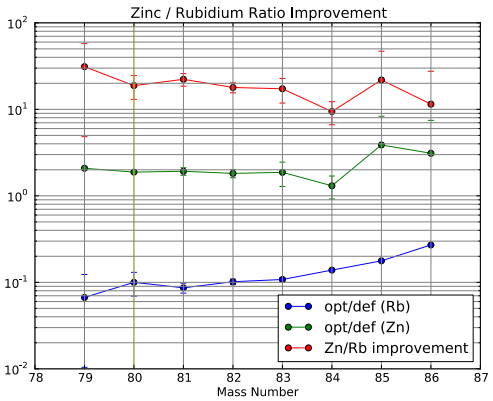


Fig 1 Zn / Rb ratio improvement.

[1] CERN-ISOLDE

Computational Dosimetry – Radiation Protection, Dosimetry and Shielding studies for the HIE-ISOLDE facility at CERN

Y. Romanets[1], V. Vlachoudis[2], AP. Bernardes[2], Y. Kadi[2], P. Vaz[1]

The High Intensity and Energy ISOLDE (HIE-ISOLDE) project is an upgrade of the existing ISOLDE facility, at CERN. After upgrade it is expected to raise the operational energy of the proton beam up to 2 GeV and intensity up to 4 μA. An increasing of the nominal parameters of the operation of the facility requires validation of existing geometry and shielding of the installation from the radioprotection and radiation safety point of view. The detailed study of the dose distribution (shown in the Figure), particle fluxes and activation calculation was performed in order to assess the radiation safety and radioprotection of the upgraded facility. On this work the state-of-the-art FLUKA Monte Carlo code was used.

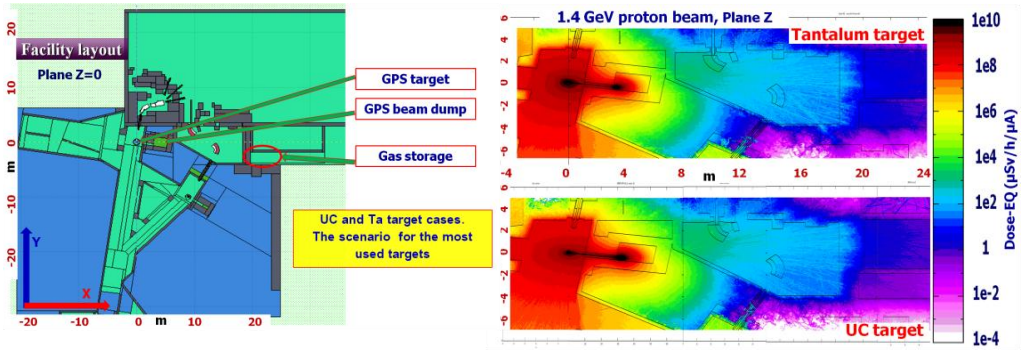


Fig 1 Layout of the ISOLDE facility (left) and Dose-Equivalent distribution for different spallation targets

[1] CERN-ISOLDE

EUROpean Research Programme for the TRANSmutation of High Level Nuclear Waste in an Accelerator Driven System (IP-EUROTRANS)

P. Vaz, I.F. Gonçalves, I. Paiva, R. Pires[1], Y. Romanets, P. Teles, R. Trindade

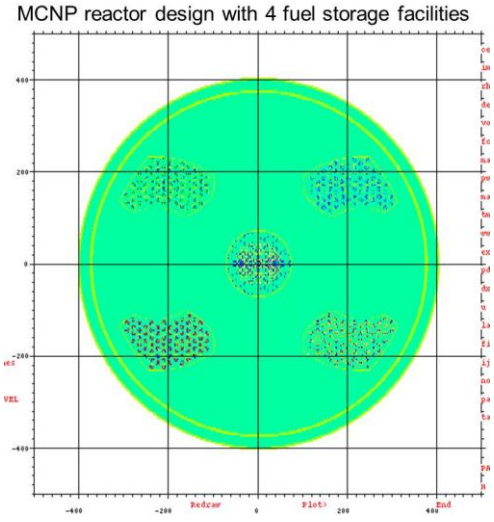
IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS (Accelerator Driven System) prototype dedicated to the transmutation of high-radiotoxicity and long-lived radioactive waste. During 2010, the Portuguese team, participated in the following domains:i) DM1-**DESIGN** – "*Development of a detailed design of XT-ADS and a conceptual design of the European Facility for Industrial Transmutation EFIT with heavy liquid metal cooling"* – participating in WP 1.2 ("Development and Assessment of XT-ADS and EFIT Designs") and WP 1.3 ("High Power Proton Accelerator Development"). DM2 – **ECATS** – *"Experiment on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket"*, participating in WP2.3 (The GUINEVERE project – Study of the reactivity monitoring methodology for an ADS in a modified lead VENUS reactor coupled to a modified continuous-beam GENEPI accelerator).

[1] Fac. de Engenharia / Univ. Católica Portuguesa

Central Design Team (CDT) for a Fast-Spectrum Transmutation Experimental Facility

S.Di Maria, P.Teles, P.Vaz

The project CDT is a European Union co-financed Collaborative Project in the 7th Framework Program EURATOM (Grant agreement nº: FP7-232527). The project aims to demonstrate an efficient transmutation of high level wastes and associated technology through a system working in subcritical and/or critical mode. The ITN team participates in the Work Package 2 entitled "*Design of the Fast Spectrum Transmutation Experimental Facility (FASTEF) in sub critical and critical mode*". In particular ITN is responsible for the neutronic assessment and criticality analysis in the fuel storage facilities both for radioprotection and damage material purposes. The studies undertaken consisted of Monte Carlo simulations using the program MCNPX. In the Figure, the layout of the four storage facilities of the facility is shown with the reactor core in the centrum.



ENETRAP-II: European Network for Education and Training in RAdiation Protection (Part-II)
P. Vaz

The project ENETRAP-II (Grant agreement number 232620) is a Coordination Action of the European Union in the 7th Framework Programme, in the context of the development of the Euratom Fission Training Schemes (EFTS) in all areas of Nuclear Fission and Radiation Protection.
ENETRAP-II aims at the development and implementation of a high-quality European standard for initial education and continuous professional development for Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs). The projects aims at developing a methodology for mutual recognition and setting up "reference" training schemes as an instrument to facilitate this mutual recognition, within the relevant regulatory framework. ITN participates in the: Work Package 3 entitled "Define requirements for RPO competencies and establish European guidance for RPO training", Work Package 4 entitled "Establish the reference standards for RPE training", Work Package 5 entitled "Develop and apply mechanisms for the evaluation of training material, events and providers", Work Package 8 entitled "Organise pilot sessions, test proposed methodologies and monitor the training scheme effectiveness", Work Package 10 entitled "Collaboration for building new innovative generations of specialists in radiation protection"

Participation of ITN in the n-TOF-Ph2 experiment (PS213) at CERN
I.F. Gonçalves, P. Vaz, C. Cruz[1], J. Neves[1], C. Carrapiço[2], R. Sarmento[2], L. Ferreira[1], L. Távora[3]

An experimental programme is being carried out since 2001 by the n-TOF Collaboration (a consortium of 40 laboratories in Europe, U.S.A. and Japan) at the neutron time of flight (TOF) facility at CERN, using the CERN/PS accelerator complex. A single proton pulse of $7 \cdot 10^{12}$ protons of 20 GeV impinges on a lead target every 2.4 seconds. After collimation, a neutron flux of the order of 10^5 neutrons/cm^2/pulse is available for cross section measurements in the detectors station located 185 m downstream the target area.
These cross-sections measurements are required in many applications such as the design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy production, radioisotope production for medical and industrial applications and many other subjects in Astrophysics, Nuclear Physics and Nuclear Technology. New or improved measurements of neutron cross-sections will also be very valuable for Radiation Shielding, Dosimetry and Monte Carlo Radiation Transport calculations. During 2010, the ITN team members in cooperation with researchers from CEA/Saclay and INFN/Bari, participated in: the analysis of the ^{233}U neutron capture data sets, the analysis of the ^{236}U neutron induced fission data sets, the data taking campaigns at CERN, the data analysis work is part of two on-going Ph.D. thesis. The ITN participation was undertaken in the framework of a project funded by the Portuguese Foundation for the Science and Technology (FCT).

[1] IST / Physics Department
[2] FCT Ph.D. student
[3] C. de Instrumentação / U. Coimbra

SERVICES

Individual and Environmental monitoring performed by ITN's individual monitoring service
J.G. Alves, M. Martins[1], M.F. Pereira[2], S. Rangel, M. Saraiva

The Individual Monitoring Service (IMS) for external exposure at ITN is based on a TLD system that consists of two 6600 Harshaw readers and on the whole body dosimeter Harshaw 8814 TL card and holder containing two LiF:Mg,Ti (TLD-100) elements for the evaluation of $H_p(10)$ and $H_p(0.07)$. In 2010, approximately 2,700 workers were monitored on a monthly basis. Following ITN's application to IPAC-*Instituto Português de Acreditação* for the accreditation of its laboratories according to the EN ISO/IEC 17025 standard, two technical audits took place at the IMS in 2010. The first one was performed by ISQ-*Instituto de Soldadura e Qualidade* and the second one by an IAEA-International Atomic Energy Agency appointed expert under project RER/0/021.
As a result of the overall production of the service directed for customers but also as support to research projects a total of five communications were presented at the IM2010-European Conference on Individual Monitoring of Ionizing Radiation. The laboratory took also part in the EURADOS 2010 Intercomparison of whole body dosimeters for photon fields.
Environmental monitoring for the assessment of the ambient dose equivalent $H^*(10)$ is performed at four sites at ITN *campus* (three evaluations per quarter) and at nine sites spread over the country on a quarterly basis. The results are used to compute the annual average dose equivalent rates for the monitored sites and are published in the National Radiological Environmental Monitoring programme annual report.

[1] Retired since 30th November; [2] ITN Grant holder, PhD student.

Risk and Safety Assessment

A.D. Oliveira, T. Antunes, A. Baptista, Y. Romanets, L. Portugal, R. Trindade, P. Vaz

At the end of 2009 it was introduced the "Document for the Safety Culture" (DCS) which suffer major improvements due to the collaborations of the staff of hospitals and clinics responding to the request of ITN for their active participation. The DCS is an ITN document, based in IAEA recommendations, European Directives and Portuguese legislation. Related with the DCS, it was introduced two important tools of safety assessment: a) a radiation protection program checklist and b) a radiation protection responsibilities checklist. The "responsibility checklist" aims to promote a higher level of commitment from hospital management bodies in what concerns safety culture, regular inside safety assessment and learning from experience. Several hospitals deserve a special mention due their very good commitment with the DCS, in arbitrary order: a) CIMC-Instituto CUF, Medicina Nuclear, Porto (DCS nº3/2010); b) Diaton, Medicina Nuclear, Viseu (DCS nº4/2010); and c) Hospital da Luz, Braquiterapia, Lisboa (DCS nº12/2010). One of the main problems founded was concerned with the responsibility structure and a lack of well-defined internal radiation protection rules. Several, radiotherapy, nuclear medicine and brachytherapy facilities are at the moment working in their DCS documents.

Another important activity, during 2010, in radiological assessment and training was developed in the CPLP countries Mozambique and Cape Verde, where 8 cargo container scanner facilities using LINACS where assessed from the point of view of radiation safety.