Dosimetry and Radiobiology

Pedro Vaz and Octávia Monteiro Gil

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

In order to address the multidisciplinary, cross-cutting leading-edge scientific and technical issues in dosimetry and radiobiology, the synergies of the competences held by the GDR researchers and technicians were further strengthened.

Researchers and students 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;
- In R&D projects funded by the Portuguese Foundation for Science and Technology
- In the activities of EURADOS Working Groups.

Computational Dosimetry: the existing competence in Monte Carlo modelling and 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. Expertise in the manipulation of voxel phantoms was consolidated during this period.

Medical applications of ionizing radiation: Collaborative links with hospitals were fostered. Activities related to the dose assessment and computational modelling of medical radiological equipments were undertaken, namely in Mammography, Computorized Tomography (CT) and in Fluoro-CT. Research activities and studies in Nuclear Medicine in external radiotherapy and in brachytherapy were pursued.

ITN led a Portuguese consortium of institutions that gathered data to assess the exposure of the Portuguese population to ionizing radiation in the framework of the medical applications. The frequency of the most commonly performed exams and the associated dosimetric characterization was performed in the framework of the DoseDataMed II project.

Biological Dosimetry and Radiobiology: the expertise and competences in several radiobiology and bio-dosimetric techniques namely Comet assay dicentrics, micronuclei, and γ-H2AX and, were further strengthened.

The dose-response curves for dicentrics and micronuclei assay, using gamma radiation for the Portuguese population were finalized.

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 definition of a strategic research agenda for the low dose research in Europe.

Internal Dosimetry: the expertise in the manipulation of biokinetic models and in internal dosimetry studies was consolidated during the period.

Technical Services

A Task Force was created to respond to the high number of requests of radiological safety assessments mainly from Nuclear Medicine and radiotherapy installations but also from cargo x-ray scanners and industrial applications of accelerators.

The GDR continued to operate its individual dosimetry and monitoring services.

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 Masters and Ph.D. theses. Several technicians and students 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.)
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A.D. OLIVEIRA, Aux.
J. ALVES, Aux.
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P. TELES, Aux.
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Admin & Techn. Personnel

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A. BELCHIOR, Ph.D. student, FCT grant
A.C. ANTUNES, FCT grant
C. BORGES, Ph.D. student, FCT grant
C. CARRAPIÇO, Ph.D. student, FCT grant
C. FIGUEIRA, FCT grant
J. BENTO, FCT grant
M.N. PEREIRA, ITN grant
R.F. LUIS, Ph.D. student, FCT grant
R. SARMENTO, Ph.D. student, FCT grant
S. BARROS, Ph.D. student, FCT grant
V. MARTINS, FCT grant

Construction of a dose response curve for dicentric chromosomes

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

A dose response curve, for dicentric chromosomes, was developed at ITN using the chromosomal aberrations assay. This curve is an important tool, in biological dosimetry, allowing the estimation of dose in cases of accidental exposure to ionizing radiation where, often, no knowledge of the physical dose exists. The dose response curve was obtained studying *in vitro* irradiated samples of 16 healthy, non-smoker individuals, from both genders, in the 20 to 60 years age range. Samples of peripheral blood lymphocytes were irradiated, using a ^{60}Co source from LMRI. For each individual and dose studied, a total of 200 metaphases were scored. A total of 22,395 metaphase spreads were analyzed. The dose response calibration curve was constructed and statistical analysis was performed using the Chromosome Aberration Calculation Software (CABAS, v.2). The validation of the dose response curve was already done.

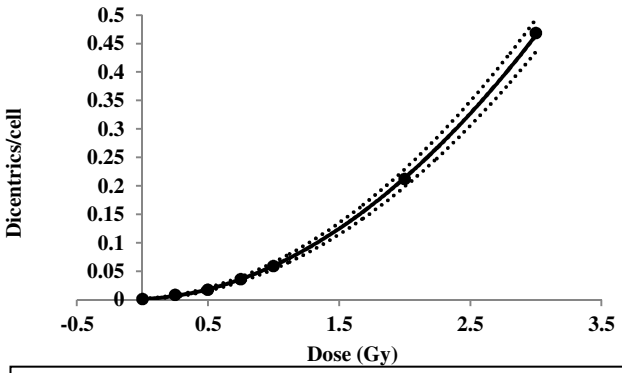


Fig. 1 Dose response curve for γ-rays. The solid line represents the fitted dose-response curve obtain using CABAS software. The observed frequencies of dicentrics per cell are represented by •. The 95% confidence intervals are represented by dotted lines.

Dose response curve using cytokinesis-blocked micronucleus assay –Study on Portuguese population

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

We continued the development of the work that will lead us to the implementation of a dose-response curve for the Portuguese population using the cytokinesis-blocked micronucleus (CBMN) assay. The establishment of another endpoint, in biological dosimetry is of utmost importance. Moreover, is the first time that this kind of study is done in Portugal, namely in ITN. The study will be undertaken in 16 healthy donors without smoking habits, being the subjects, from both genders, distributed in four groups from 20 to 60 years. For this work, the samples of peripheral blood were irradiated at LMRI with 0.25, 0.50, 0.75, 1.00, 2.00, 3.00 Gy air kerma, using a ^{60}Co source. Until now, a set of 105,000 binucleated cells were analyzed in terms of micronuclei frequency. Figure 1 shows a clear dose dependent increase and a larger intervariability between individuals at higher doses. Our future work will focus on the calculation of calibration curve parameters and its validation.

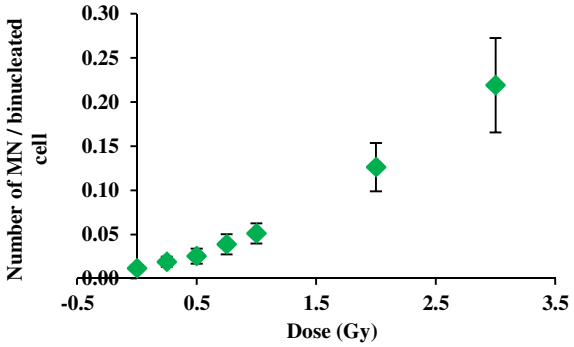


Fig. 1 Distribution of micronuclei per binucleated cell in function of dose, considering 15 donors (105,000 binucleated cells scored).

Implementation and optimization of γ-H2AX assay using peripheral blood human lymphocytes

O. Monteiro Gil, A.C. Antunes, V. Martins, A.S. Rodrigues[1]

DNA double-strand breaks (DSB) are a high cytotoxic form of DNA damage and, if not correctly repaired, can initiate genomic instability, chromosome aberrations and may eventually lead to cancer. Exposure to ionizing radiation induces DSB that can be quantified by the detection of the phosphorylated form of H2AX histone in the vicinity of a DSB (green spot), being the number of foci proportional to the damage induced. γ-H2AX is a very important bioindicator for biodosimetry. For this reason, we are implementing γ-H2AX assay at ITN, with the help and knowledge of the Genetic Department of UNL. Our objective is to implement a dose-response curve.

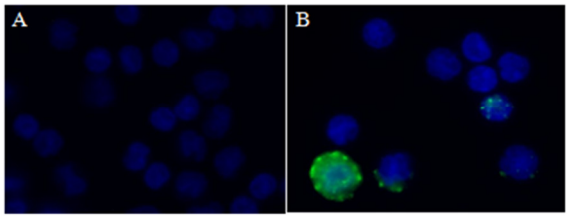


Fig. 1 Foci of γ-H2AX. (A) Cells with no radiation exposure, (B) Cells exposed *in vitro* to 2 Gy.

[1] Genetic Dep. UNL

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

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

The major adverse consequences of radiation exposures are attributed to DNA damage in irradiated cells that have not been correctly restored by metabolic repair processes. However, this has been challenged by observations in which effects of ionizing radiation arise in non-irradiated cells.

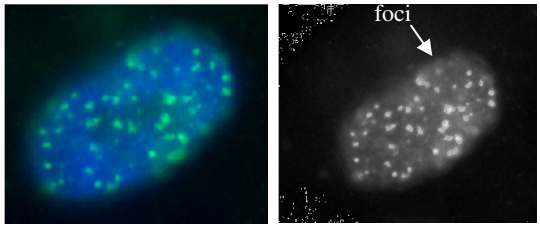


Fig. 1 Foci of γ-H2AX. This cell was exposed to 100 mGy of α-radiation.

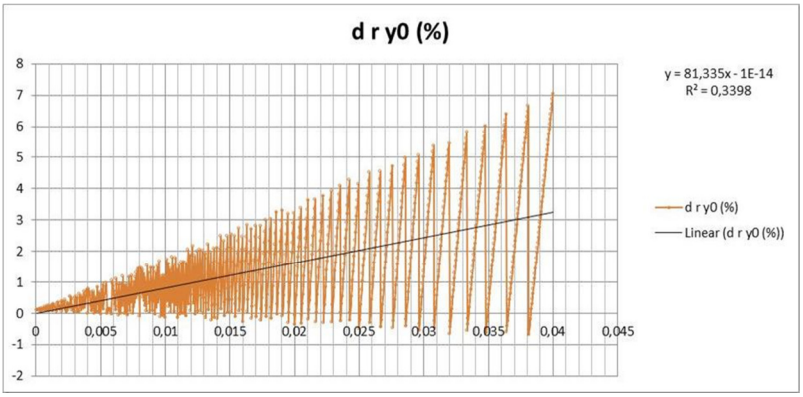
The main purpose of our studies was to evaluate the induction of untargeted effects by low doses of α-radiation depending on time and dose values. Our results suggest that lesions induced in cells are dependent of dose value, since the damage significantly decreases with decreasing dose values. They also suggest a time-dependent bystander response, as the cellular damage decrease after 5 days after irradiation when compared with cellular damage induced 2 days after irradiation. The quantification of the spatial and temporal distribution of the bystander response is also paramount. The aim of this on-going work is to evaluate the spatial distribution of the bystander signal in the cell monolayer, i.e., study how far the untargeted effects are induced in cells that are in the same culture but are not directly irradiated. These observations are relevant in terms of low dose exposition but also in terms of tumor delimitations for therapy. For this, we use the γ-H2AX technique, which allow us to study the cells exactly in the same place where they were irradiated.

[1] IBEB-Fac. Ciências, UL

BioKinModels – A computational tool to solve bio-kinetic models. New version 3.0

A.D. Oliveira

Technical details of the numerical implementation of the well-known ICRP Human Respiratory Tract model are under development in the BioKinModels format.
Numerical research and algorithm development concerned with time step and uncertainty estimation are under developed in the new BioKinModels version 3.0. These studies led to the algorithm OTS/TS Optimization of Time Step value version 1.0.



Uncertainty assessment of a portable NaI based detection system for thyroid monitoring

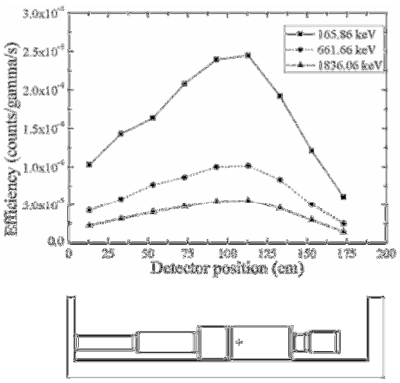
J. Bento, B. Martins[1,2], P. Teles, M. Neves, P. Colarinha[1], F. Alves[3], N. Teixeira[4], P. Vaz, M. Zankl[5]

Performance assessment and uncertainty evaluation were studied in a portable NaI based detection system. For the purpose, patients to whom ^{99m}Tc and ^{123}I marked radiopharmaceuticals were administered in the framework of Nuclear Medicine diagnostic procedures were monitored. The measured activities in the thyroid using the NaI detector were compared to the expected activities using the ICRP biokinetic models for radiopharmaceuticals. The state-of-the-art Monte Carlo program PENELOPE and two voxel phantoms (male and female) were used to evaluate the uncertainties influencing the thyroid monitoring. A computational parametric study was performed to quantify the influence of several parameters in the activity quantification (neck-detector distance, thyroid shape, thyroid size and overlying tissue thickness). The comparison between the measured and expected activities showed significant deviations (14% - 73%). The neck-detector distance proved to play an important role in measurement accuracy, since its 1 cm increase results in a 20% efficiency decrease. The comparison between the detector response using a physical phantom and the voxel phantoms reveals that the detection efficiency is lower for the voxel models: -25% for the male phantom and -7% for the female phantom. The variations in the thyroid volume and overlying tissue thickness evidenced an uncertainty of approximately 10% in the thyroid activity calculation.

[1] Hospital CUF Descobertas; [2]Medical Consult, SA, Portugal; [3]Escola Superior de Tecnologias da Saúde de Coimbra, Portugal;[4] Escola Superior de Tecnologias da Saúde de Lisboa, Portugal;[5]Helmholtz Zentrum München,Germany

Monte Carlo simulation of the WBC detector movement and efficiency using a BOMAB phantom

J. Bento, S. Barros, P. Teles, M. Neves, I. Gonçalves, J.C., Pedro Vaz

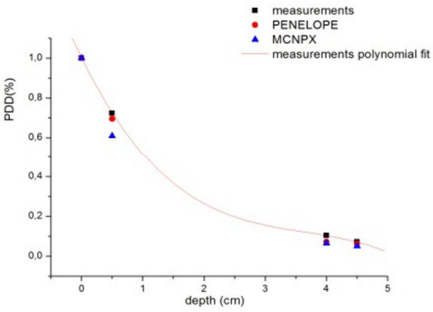


This work was performed as part of a new set of whole body counter (WBC) experimental calibrations using a BOMAB phantom, which improved the quality standards of this detection system. We performed a computational analysis of the WBC experimental calibration using two Monte Carlo simulation programmes: PENELOPE and MCNPX. Both the BOMAB phantom and the detection system were accurately implemented in the Monte Carlo codes. The WBC possesses a moving detector system, which poses a challenge for Monte Carlo simulations, as most codes only accept static configurations. The continuous detector movement was approximately described in the simulations by averaging several discrete positions of the detector throughout the movement. The computational efficiency values obtained with the two Monte Carlos codes have deviations of less than 3.2%, and the obtained deviations between experimental and computational efficiencies are less than 5%.

TLD measurements and Monte Carlo simulations for glandular dose and scatter fraction assessment in mammography: a comparative study

S. Di Maria, S. Barros, J. Bento, P. Teles, C. Figueira, M. Pereira, P. Vaz, G. Paulo[1]

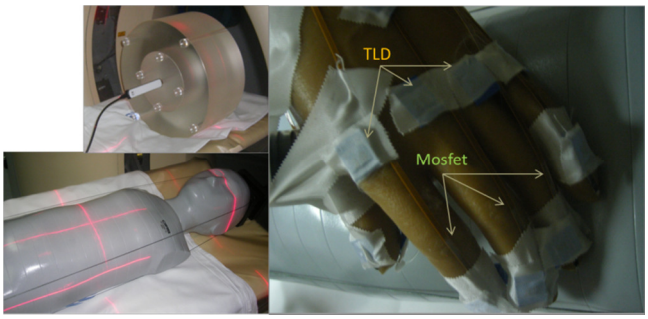
The main purpose of this study was to validate and compare Mean Glandular Dose (MGD) values obtained using Monte Carlo simulations with experimental values obtained from Entrance Surface Dose (ESD) and depth dose measurements performed in a Portuguese hospital mammography unit. ESD and depth dose were measured using ThermoLuminescent Dosimeters (TLDs), and a tissue equivalent mammography phantom recommended by the American College of Radiology (ACR). The good agreement between measurements and simulations (Percent Depth Dose) is shown in the figure. One of the results of this study was the dose variation inside the breast that goes from 12% to 230% of the total MGD (1.17 mGy in this case).



[1]Escola Superior de Tecnologia da Saúde de Coimbra

Extremity dose assessment in CT-Fluoroscopy, with measurements using a hand-phantom and Monte-Carlo simulations

P. Teles, F. Becker[1]*, S. Di Maria, C. Figueira, G. Paulo*[2]*, J. Santos*[2]*, P. Vaz*



In the framework of EURADOS work-group 12, dedicated to dose evaluation in extremities (hands) in CT-Fluoroscopy procedures in staff, we have performed a set of dosimetric measurements in a dedicated CT device in Hospital dos Covões (Coimbra) using a wax homemade hand-phantom, a pediatric RANDO phantom, and TLDs, MOSFETs, and PSDs in several positions around the hand-phantom, which was placed in two different positions to mimic the postural variability of the person performing the procedure. In order to create voxelised geometries of the experimental set-up for use in Monte-Carlo simulations, a number of CT scans was performed. Furthermore, a Monte-Carlo model of the CT device was implemented, which was validated by making use of CTDI measurements which were compared to the simulated Monte-Carlo values. A renormalization method was used to obtain directly dose in CTDI using Xu's method. In the future, we intend to use this model to perform simulations with the voxelised geometries and compare these results with the measurements. We intend to perform a detailed evaluation of dose distribution in the hands, as well as in the eye-lens, using this model.

[1]KIT – Germany;[2]Escola Superior da Tecnologia da Saúde de Coimbra

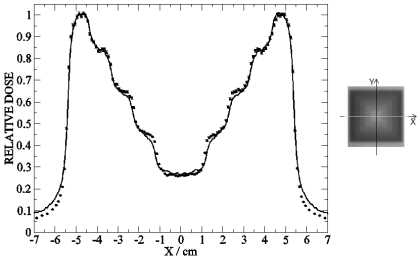
Monte Carlo modeling and simulations of the High Definition (HD120) micro MLC and validation against measurements for a 6 MV beam

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

The BEAMnrc® code was used to simulate the brand new micro multileaf collimator (HD120MLC) mounted on a Varian® Trilogy® linac, by developing a new component module (CM) named HDMLC CM.

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. Both the static and dynamic modes were implemented and validated.

The results were accepted and are to be published in Med Phys 39 (1) 2012, AIP ID: 048201MPH.



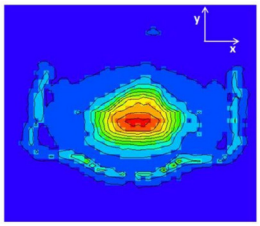
Dynamic MLC field of an inverse pyramid pattern: the continuous line corresponds to the film measurement; the full dots represent the Monte Carlo simulation results. The results were normalized to the maximum dose.

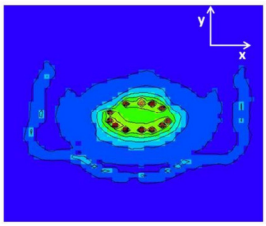
[1]Medicalconsult, SA; [2]Fac. of Medical Sciences, UNL; [3] UPSR; [4]Escola Superior de Tecnologia da Saúde de Lisboa

A dosimetric study of prostate brachytherapy using Monte-Carlo simulations, measurements, and a comparison with a treatment planning procedure

S. Barros, P. Teles, S. Cardoso[1], A. Faccure[2], L. da Rosa[3], M. Santos[3], P.P. Pereira Jr[4], P. Vaz, M. Zankl[5]

In order to study the uncertainties in the dose distribution delivered to the prostate in brachytherapy treatments,





different Monte-Carlo simulations were performed in the generic GOLEM voxel phantom. We have used a detailed computational model of the *Amersham 6711* ^{125}I seed, with the dosimetric parameters of which were previously determined under the guidelines of the *AAPM TG 64*. A careful analysis of the volume variation of the prostate, which swells after the seeds are inserted, the influence of using different seed arrangements, and the influence of interested effects, as well as of seed inter-spacing, since the seeds can migrate inside the prostate, was performed. Also, dosimetric measurements with the *Amersham 6711* source, using TLDs and a RW3 tissue equivalent phantom were performed and simulated, and the results compared. This was undertaken to increase the reliability of the Monte-Carlo simulations with a voxel phantom. Finally, we have also simulated a real treatment planning procedure with the GOLEM phantom. Variations of these parameters can lead to up to 30% changes in the total dose delivered to the prostate. Moreover, when compared to a real treatment planning dose estimation, our results are in between 14%-37% lower than those obtained with the real treatment planning.

[1]Univ. Federal do Rio de Janeiro, Brasil, [2]Comissão Nacional de Energia Nuclear, Brasil, [3]Inst. de Radioproteção e Dosimetria, Brasil,[4]Dosimetrika, Brasil, [5] Helmholtz Zentrum, München – German Research Center for Environmental Health

EURADOS Working Group 2: Harmonization of individual monitoring in Europe

J.G. Alves, P. Ambrosi[1], D. Bartlett[2], C. Cherestes[3], M.A. Chevalier[4], J.W. van Dijk[5], E. Fantuzzi[6], M. Figel[7], P. Gilvin[8], T. Grimbergen[9], E. Carinou[10], M. Lehtinen[11], A. McWhan[12], B. Obryk[13], A. Romero[14], F. Rossi[15], H. Stadtmann[16], B. Vekic[17]

The motivation of WG02 is to foster Harmonization of Individual Monitoring in Europe. Three main tasks are identified: the organization of regular self-sustained intercomparison (IC) exercises, the identification of problems and issues for the improvement of measurements, dose reporting and record keeping, and the dissemination of the activities.

The organization of regular IC exercises provide to individual monitoring services a method to show compliance with the ISO/IEC 17025 requirements, as accreditation in conformity to this standard is gradually becoming important in Europe. Two IC exercises are presently being prepared: IC2012ph and IC2012n, respectively, for whole body dosemeters for photon fields and for neutron dosemeters in mixed fields.

Under the improvement of measurements, dose reporting and record keeping, several issues requiring discussion and a harmonized approach were identified. A questionnaire is currently being prepared for distribution within the WG02 extended network.

The dissemination of WG02 activity is being addressed in several ways: presentations at workshops and conferences as well as the organization of a Training Course (TC). A TC on the implementation of RP 160 *European technical recommendations on for monitoring individuals occupationally exposed to external radiation* and from the lessons learned from IC exercises is currently being prepared and will probably take place next autumn, in Krakow (Poland).

1 PTB, Germany; 2 formerly HPA, UK; 3 Dozimed, Romania; 4 IRSN, France; 5 formerly NRG, Netherlands; 6 ENEA, Italy; 7 Helmholtz-Zentrum, Germany; 8 HPA, UK; 9 NRG, Netherlands; 10 GAEC, Greece; 11 STUK, Finland; 12 Babcock International, UK; 13 IFJ, Poland; 14 CIEMAT, Spain; 15 AOUC, Italy; 16 Seibersdorf Lab., Austria; 17 RBI, Croatia.

Medical staff and patient dose assessment studies

J.G. Alves, M.F. Pereira[1], A.D. Oliveira, J.V. Cardoso, L.M. Santos, A. Pascoal[2], S. Tecelão[3], J. Vaz[3], I. Arêde[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). A third collaboration with *Universidade Atlântica* for interventional procedures in angiography is also under way.

In the case of interventional procedures in angiography and in fluoro-CT guided procedures for lung biopsy collection, the team at the surgery room is likely to be exposed to higher dose levels, particularly to the hands, and the upper and lower limbs. The dose assessment methodology is based on the measurements of several dosemeter types. Ten whole-body dosemeters were distributed over the radiologist's body and a special glove was designed to hold 11 extremity dosemeters inserted in casings. Per-procedure dose distributions were obtained using this method and the first results (on fluoro-CT) were published. The work is still in progress and is considered of interest for the EURADOS Working Group 12 on European Medical Alara Network.

[1] ITN Grant holder and Ph.D. student; [2] Univ. Católica Portuguesa, Fac. Engenharia; [3] Univ. Atlântica; [4] Inst. Português de Oncologia do Porto, Grupo de Física Médica.

Optimization studies of the ISOLDE targets, at CERN

R. Luís, J. Marques, T. Stora[1], P. Vaz

The ISOLDE facility is one of the most important radioactive ion beam facilities worldwide. In its present 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 objective of this work is to propose an optimized target configuration which optimizes the production of neutron-rich isotopes, while reducing the contamination by proton-rich isobars. After several design iterations, a completely revised target configuration is now proposed, with the UCx target surrounding a thicker converter. Simulations with FLUKA and the cross section codes ABRABLA and TALYS clearly indicate that the new configuration will produce higher yields of neutron-rich isotopes while reducing the yields in the proton-rich side of the nuclear landscape. A prototype target system based on the new design will be built and operated at CERN during 2012, to test if the predicted improvements can be verified experimentally.

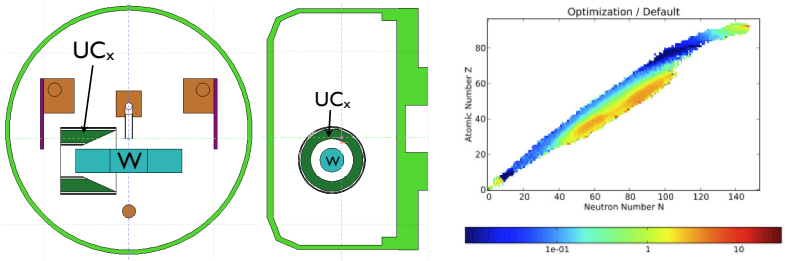


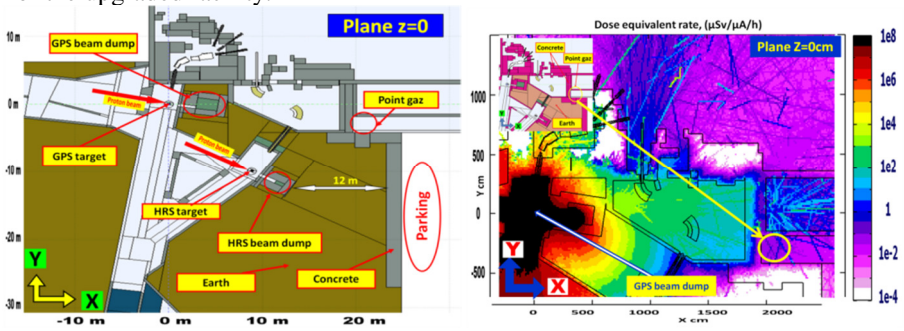
Fig (Left) Optimized targets configuration. (Right) Ratio optimized/default yields for all nuclides.

[1] CERN-ISOLDE

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

Y. Romanets, A.P. Bernardes[1], A. Dorsival[1], I. Gonçalves, Y. Kadi[1], P. Vaz, V. Vlachoudis[1], J. Vollaire[1]

The High Intensity and Energy ISOLDE (HIE-ISOLDE) project is an upgrade of the existing ISOLDE facility at CERN. The currently existing ISOLDE facility uses the proton beam with an energy of 1.4 GeV and an intensity currently limited to 2 μA. After upgrade (final stage) the HIE-ISOLDE facility is supposed to run at energy up to 2 GeV and intensity up to 4 μA. The foreseen upgrade imposes constrains, from the radiation protection and the radiation safety point of view and requires validation of existing geometry and shielding of the facility. The state-of-the-art Monte Carlo particle transport simulation program FLUKA are used to perform the computation of the dose rate distribution (shown in the Figure) and particle fluxes in order to assess the radiation safety and radioprotection of the upgraded facility.



[1] CERN-ISOLDE

Participation of ITN in the FREYA project

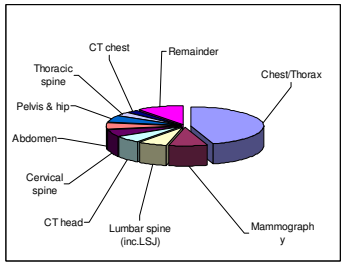
P. Vaz, S. Di Maria, P. Teles

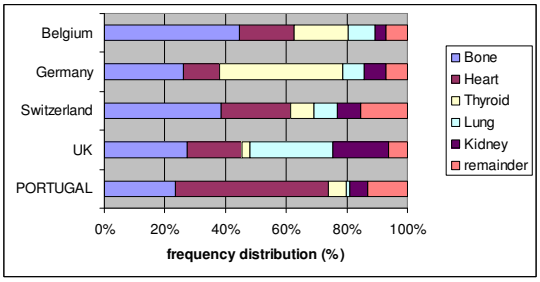
The project FREYA (Fast Reactor Experiments for hYbrid Applications) is a four-year (2011-2015, started in March 2011) European Union co-financed Collaborative Project in the 7th Framework Program. Building up on the former activities accomplished in the previous FPs, namely Muse in FP5 and EUROTRANS in FP6, it is proposed in the FREYA project to extend the investigations of the subcritical configurations for validation of the on-line reactivity monitoring methodology in ADS systems. FREYA intends to investigate the configurations with Keff= 0.99, 0.95 and the deep subcritical mode (0.85<Keff<0.95). The contribution of ITN (task leader) will be on neutronic Monte Carlo simulations aiming to the optimization of the measurements (like detector sensitivity simulations, criticality and delayed neutron fraction calculations).

Project Dose Datamed 2 – Portugal - Assessment of the exposure of the Portuguese population to ionizing radiation due to medical practices

P. Teles, P. Vaz and Dose Datamed 2 – Portugal consortium[1]

In the framework of the European Union sponsored Dose Datamed II project, we evaluated the exposure of the Portuguese population to ionizing radiation due to medical activities. We setup a multidisciplinary consortium, comprising representatives of research institutions, universities hospitals and other healthcare providers, administrative services of the National Healthcare System, professional associations, and outsourcing companies. We followed the guidelines provided by the RP 154 report. The estimated collective dose due to nuclear medicine(NM) exams is of 0.08 mSv/caput. Our data also show a high number of Cardiac exams (~50% of total) in NM performed in Portugal. The estimated collective dose for the TOP 20 exams (the 20 exams which contribute the most to the European collective dose) is of about 0.9 mSv/caput. There's a great prevalence of CT examinations, which account for 74% of the entire collective dose. The consortium intends to continue performing periodical evaluations of collective dose in the population due to medical practices.





[1]For further information about the members of this consortium please visit http://www.itn.pt/projs/ddm2-portugal/

Participation of ITN in the 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). An important issue regarding the MYRRHA/FASTEF nuclear reactor design is the in-vessel fuel storage facility, both for fresh and spent fuel. The model design and calculations were done with the state-of-art MCNPX Monte Carlo code. In particular a parametric study (see figure on the right) with the fuel assembly pitch on the multiplication factor (k_{eff}) was performed. The fuel assembly pitch was calculated in order to reach a k_{eff} value less than 0.95 for safety purposes. Moreover neutron flux, displacement per atom (*dpa*) and decay heat calculations were performed in order to fully characterize the four in-vessel fuel storage facilities.

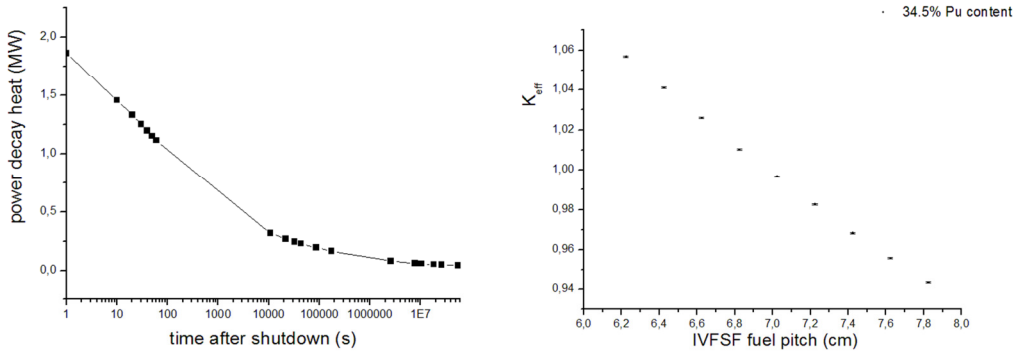


Fig. 1 **Left:** Power decay heat calculation performed for 68 Fuel Assemblies (33% Pu MOX fuel) with the ORIGEN program.
Right: parametric study that shows the Keff dependence by the IVFSF pitch (in the x-axis of the graph the half-pitch is shown).

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"

TRAining Schemes on Nuclear SAFEty culture (TRANSNUSAFE)
P. Vaz

Safety Culture is of paramount importance for the operation of nuclear and radiological installations. The objectives of the TRANUSAFE project, in the framework of the FP7-EURATOM are: i) to perform the assessment and to promote Safety Culture for the top managers of nuclear and radiological installations, such as nuclear power plants and nuclear installations, radiotherapy installations, facilities for the production of radioisotopes, among others and ii) study the mutual recognition and harmonization of good practices and behaviors associated to the development and effective implementation of the Safety Culture (Nuclear and Radiological). The study of the relationship between Safety Culture and the ALARA (As Low As Reasonably Achievable) principle deserves particular emphasis in the framework of TRASNUSAFE.
The TRANUSAFE project team includes representatives from the European ALARA network and the EUTERP platform, from universities, research institutions, regulatory bodies, industrial companies and hospitals. ITN is responsible for organizing a "pilot session" on the Safety Culture in the medical installations.
During the reporting period, ITN participate in Reflection Groups addressing the aforementioned topics. A questionnaire was prepared by the consortium and submitted to managers in hospitals, industrial companies, regulatory bodies and several other "stakeholders" in the EU member countries, including Portugal.

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).

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Services

Risk and Safety Assessment

A.D. Oliveira, T. Antunes, A. Baptista, Y. Romanets, P. Vaz

The "Document for the Safety Culture" (DCS), introduced in 2009 became a routine document used in the radiation safety assessment activities performed by ITN. Safety assessment of the cargo scanners of the Ports/marine harbors in Mozambique and Cape Verde were performed by ITN and led to the development of the DCS for non-medical applications. The DCS is a document jointly established by ITN and the responsibles of the radiological facilities, based in IAEA recommendations, European Directives and Portuguese legislation. Next it is shown a list of the radiation safety assessments concluded in 2011:

Facility	Type
IPOPFG	7 LINACs (external radiotherapy)
Centro Hospitalar Barreiro Montijo	1 LINAC (external radiotherapy)
Fundação Champalimaud	1 LINAC (external radiotherapy)
Dr. Júlio Teixeira / Hospital de Braga	1 LINAC (external radiotherapy)
Instituto CUF / Dr.Júlio Teixeira	1 Brachytherapy HDR
IPOLFG	1 Brachytherapy HDR
IPOPFG	1 Brachytherapy PDR
IPOPFG	1 Brachytherapy HDR
Hospital da Luz	1 Nuclear medicine
Hospital dos Lusíadas	1 Nuclear medicine
Kudumba Investments, Mozambique	5 cargo-scanners: marine harbors of Maputo, Beira and Nacala; railway in Matola and border with South Africa in Ressano Garcia
ENAPOR, Cape Verde	3 cargo-scanners: marine harbor of Praia, Mindelo and Palmeiras.
Sines	1 cargo-scanner, marine harbor

These services provided an income of more than 300 000 euros, corresponding to an average of 2 evaluations per month and a total of 46 reports, i.e. approximately 4 reports per month.

Individual and Environmental monitoring performed by ITN's individual monitoring service

J.G. Alves, M.F. Pereira[1]*, 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 dosemeter 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 2011, approximately 2,850 workers were monitored, 2,650 on a monthly basis and 200 workers on a quarterly basis.

Following the Fukushima nuclear power accident in Japan and upon the request of the Ministry for Foreign Affairs, ITN provided whole body dosemeters to the diplomatic staff at the Portuguese Embassy in Tokyo. Three measurement periods of two month duration each were performed and results showed that staff was not exposed to external gamma radiation.

Environmental monitoring for the assessment of the ambient dose equivalent $H^*(10)$ is performed at four sites at ITN *campus* 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.

Following ITN's application to IPAC-*Instituto Português de Acreditação* for the accreditation of its laboratories according to the EN ISO/IEC 17025 standard, the quality system was improved and the accreditation audit is due to take place in January 2012.

1 ITN Grant holder and Ph.D. student.