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## OPERATION AND EXPLOITATION OF RPI

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### Annual Activity Report 2013

#### UNIT: Reactors and Nuclear Safety

#### TEAM

| Name                         | Category                            | R&D (%) |
|------------------------------|-------------------------------------|---------|
| José Gonçalves Marques       | Principal Researcher (Habilitation) | 100%    |
| Nuno Barradas                | Principal Researcher (Habilitation) | 100%    |
| António Nazaré Falcão        | Principal Researcher                | 100%    |
| Andreas Kling                | Auxiliary Researcher (Habilitation) | 100%    |
| Ana Cristina Palma Fernandes | Auxiliary Researcher (FCT)          | 100%    |
| Ana Rita Lopes Ramos Wahl    | Auxiliary Researcher                | 100%    |
| Daniel Beasley               | Auxiliary Researcher (Ciência)      | 100%    |
| Marco Stanojev Pereira       | Auxiliary Researcher (Ciência)      | 100%    |
| Thomas A. Girard             | Auxiliary Researcher (U. Lisboa)    | 50%     |
| Joana Santos                 | Graduated Technician                | 100%    |
| André Rodrigues              | Assistant Technician                | --      |
| Francisco Barreira Gomes     | Assistant Technician                | --      |
| Joaquim António Ribeiro      | Assistant Technician                | --      |
| José Carlos Roxo             | Assistant Technician                | --      |
| Maria Teresa Fernandes       | Assistant Technician                | --      |
| Nuno Serrote                 | Assistant Technician                | --      |
| Rodolfo Pombo                | Assistant Technician                | --      |
| Rogério Santos               | Assistant Technician                | --      |

#### OBJECTIVES

The main objective of the Operation and Exploitation of the Portuguese Research Reactor (OE/RPI) is to be able 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 work of the team ensures that the reactor is available around 200 days per year on a routine basis.

The RPI is prepared to handle a large number of long irradiations in positions close to the reactor core, with thermal neutron fluxes as high as  $2.5E13$  n/cm<sup>2</sup>/s. Short irradiations, of the order of a few seconds, are also supported for the cases when the isotopes under study have a very short half-life. The RPI also supports neutron tomography and irradiation of electronic components and systems in two dedicated beam lines.

Besides the tasks that are essential for the operation of the RPI, the researchers of the OE/RPI are involved in several activities, from which we highlight:

- Optimization of the neutron radiography setup through installation of a new CCD camera and a detailed study of solid state nuclear track detectors for image recording.
- Improvements to existing irradiation infrastructures, to provide a better support to users and install new analytical techniques.
- Development and test of superheated droplet detectors and their use in dark matter search within the SIMPLE project. The main objectives were to develop and test a prototype detector for Phase III and to refine the analysis of the Phase II of data taking in the LSBB tunnel in Rustrel, France.

- Development and expertise in deterministic and Monte Carlo calculations for the RPI, in particular neutronics, also including safety analyses, thermohydraulics and others. Simulation tools for ion beam interactions are also developed.

Public visits to the RPI are an important part of our work. One of our objectives is to host at least 50 visits per year, continuing to maintain the RPI as the most visited infrastructure of the Campus.

## MAIN ACHIEVEMENTS

A total of 497 irradiations were performed in the RPI in 2013, corresponding to 1131 h of reactor time. The main users of the RPI are described in Table 1. The largest sustained activity supported by the RPI is neutron activation analysis (NAA) in the URSN and UCQR Research Units, which accounts for approximately 50% of the use of the reactor.

| User                                   | Area                   | % Time |
|--|------------------------|--------|
| CTN-URSN                               | Dosimetry              | 5.5    |
|  | NAA                    | 33.9   |
|  | Neutron Damage Studies | 0.3    |
|  | Tomography             | 16.2   |
|  | Education and Training | 0.3    |
| CTN-UCQR                               | NAA                    | 12.1   |
|  | Neutron Damage Studies | 0.4    |
|  | Isotope Production     | 0.2    |
| Centro de Física Nuclear, Univ. Lisboa | Isotope Production     | 19.2   |
| IVIA, Spain                            | Neutron Damage Studies | 0.5    |
| IFCA, Spain                            | Neutron Damage Studies | 0.5    |
| IMB-CNM, Spain                         | Detector Development   | 1.0    |
| U. Heidelberg, Germany                 | Dating                 | 9.9    |

Table 1: Main users of the RPI in 2013

Solid state nuclear track detectors (SSNTD) have been used for charged particle detection for several decades. Their use for thermal neutron radiography requires a suitable converter screen typically using natural Boron as a neutron to charged particle converter. The  $\alpha$  and  ${}^7\text{Li}$  particles released from the nuclear reaction  ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$  induce damages in the molecular structure of the detector, which are visible only by electron microscopes. However, after chemical etching, the damages are enlarged thousands of times, becoming cone-shaped tracks and forming an image which is visible by naked eye. Traditionally, an image obtained with a SSNTD exhibits a very low contrast and this has been its main disadvantage. Significant progress was made to recording and digitizing images at the RPI using an enriched boron-10 converter and a low cost flatbed scanner, reducing the cost for installation of the technique and enabling a significant reduction on the optimum neutron fluence required to obtain a neutron image. Fig. 1 shows a neutron radiography of a gas lighter using the new setup.

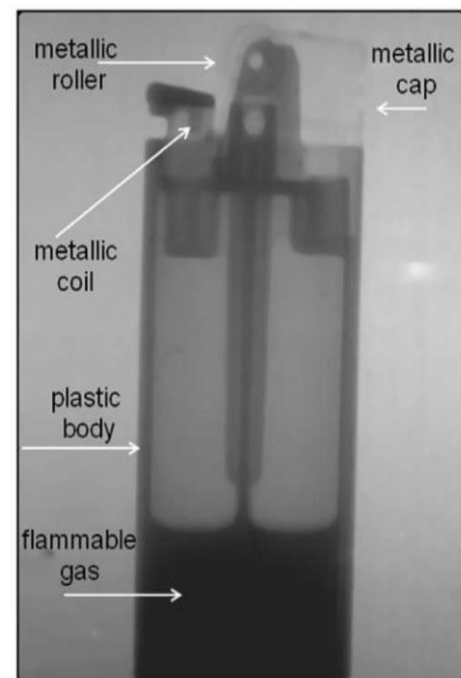


Fig 1: Neutron radiography of a gas lighter. The image was recorded using a CR-39 solid state nuclear track detector and digitized using a HP4370 scanner.

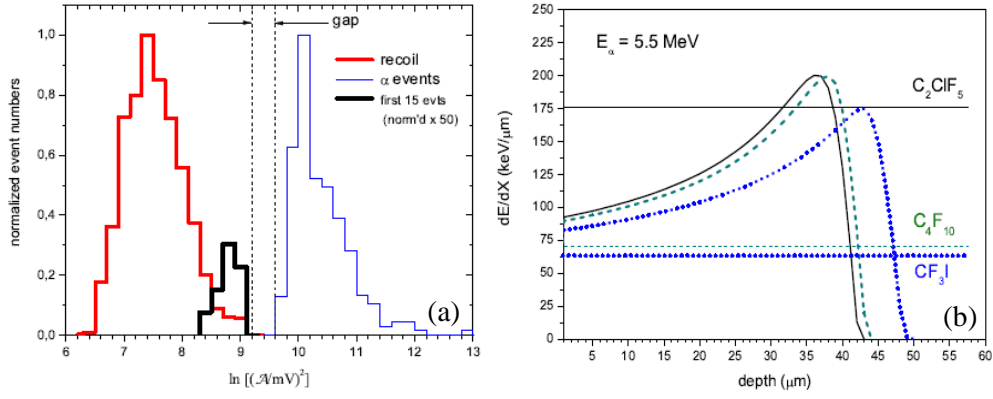


Fig. 2: (a) Distribution of  $\text{Ln}(\mathcal{A})$  ( $\mathcal{A}$ , signal amplitude) of  $\alpha$  and neutron events in SIMPLE SDDs ; (b) LET for 5.5 MeV  $\alpha$ 's in  $\text{C}_2\text{ClF}_5$  (solid),  $\text{C}_4\text{F}_{10}$  (dashed) and  $\text{CF}_3\text{I}$  (blue dotted) as a function of penetration depth. The lines indicate the  $\alpha$ 's critical LET ( $\text{LET}_c$ ) in the different liquids.

Within the SIMPLE project, significant progress was made in the understanding of particle discrimination using superheated droplet detectors. Three experiments use the superheated liquid technique: PICASSO, COUPP and SIMPLE, albeit with different molecules, respectively,  $\text{C}_4\text{F}_{10}$  (R-610),  $\text{CF}_3\text{I}$  (R-131I) and  $\text{C}_2\text{ClF}_5$  (R-115). Only SIMPLE reported a clear separation between neutron- and  $\alpha$ -induced events. Fig 2 (b) shows that an  $\alpha$  achieves  $\text{LET} > \text{LET}_c$  only between 32-40  $\mu\text{m}$  of liquid penetration:  $r \leq 16 \mu\text{m}$  constitutes a lower size cut-off to the droplet participation. Below the size cut-off droplets cannot contribute to bubble nucleation since the  $\alpha$  transits the droplet without achieving  $\text{LET}_c$  and thus the amplitude distribution of  $\alpha$  events shown in Fig. 2(a) presents a sharp lower edge, originating the observed separation.

Expertise in experimental determination of reactor parameters such as neutron fluxes must be matched by expertise in simulation tools. A wealth of RPI data collected for the fresh core was used to validate and benchmark different simulation approaches. The results of the stochastic code MCNP obtained at the RPI were compared with the results obtained with the stochastic code TRIPOLI and with the deterministic code system XSDRN/CITATION, utilized in the Greek Research Reactor (GRR-1). The neutron fluence rate in RPI was computed using each numerical approach with changed approximations. Two different nuclear data libraries were tested, i.e., ENDF/B-VI versus JEFF3.1, as well as two different ways of source definition, i.e., ‘‘point sources’’, placed in the center of each fuel cell, versus a ‘‘distributed source’’, where each fuel volume was considered as a neutron source. The deterministic code system XSDRN/CITATION was tested with respect to the definition of the transverse leakages associated to each one-dimensional, user-defined core zone, as analyzed by the XSDRN code in order to provide the zone equivalent cross sections. Thermal, epithermal and fast neutron fluence rates were computed and compared to activation foil measurements, as well as to corresponding MCNP results obtained at the RPI. The comparisons were performed in representative core positions, including standard fuel assemblies, dummy (non-fuelled) assemblies, beryllium reflectors and free grid positions close to the core.

$^{13}\text{C}$  is an important isotope in fusion research, with high relevance in ITER experiments. The tungsten-carbon alloy is used in some plasma-facing components, namely the divertor, and a carbon wall has also been used in some experiments. During operation, there is formation of tungsten carbides and also of carbon films, accompanied by erosion and redeposition of material. These processes are critical for the retention of hydrogen isotopes by the wall materials.  $^{13}\text{C}$  is used in these studies as an ideal tracer to study these processes, by injecting it in the plasma. Its determination with Elastic Backscattering requires accurate scattering cross sections, which were not previously available. We used a thin film method with Bayesian inference data analysis to determine the  $^{13}\text{C}(p,p)^{13}\text{C}$  cross section in the energy range 0.8 - 2.43 MeV, at scattering angles  $140^\circ$  and  $160^\circ$ . The accuracy of the results was also determined, including all sources of error. The cross section determined at  $140^\circ$  was benchmarked at energies around the 1.462 MeV resonance. The new data presented were then used, together with previously existing data from the literature, to perform an evaluation of the  $^{13}\text{C}(p,p)^{13}\text{C}$  cross section.

## RELEVANT PAPERS

- M. Ribeiro Gomes, F. Gatti, A. Nucciotti, P. Manfrinetti, M. Galeazzi, E. Alves, D. Bagliani, N. Barradas, S. Basak, M. Biasotti, E. Ferri, A. Kling, G. Pizzigoni, K. Prasai, J. Rocha, Status of the MARE Experiment, IEEE Trans. Appl. Superconductivity 23 (2013) 2101204, doi: 10.1109/TASC.2013.2249180
- M. Felizardo, T. Morlat, J.G. Marques, A.R. Ramos, T.A. Girard, A.C. Fernandes, A. Kling, I. Lázaro, R.C. Martins, J. Puibasset, Fabrication and Response of High Concentration SIMPLE, Superheated Droplet Detectors with Different Liquids, Astropart. Phys. 49 (2013) 28-43, doi: 10.1016/j.astropartphys.2013.08.006
- A.C. Fernandes, T.A. Girard, M. Felizardo, J.G. Marques, A.R. Ramos, A. Kling, T. Morlat, J. Puibasset, L. Lázaro, Superheated Liquids and the Search for Astroparticle Dark Matter, Chapter 4 in “Recent Developments in Dark Matter Research”, N. Kinjo and A. Nakajima (eds.), Nova Publishers, Hauppauge, NY, 2013, ISBN 978-1-62948-011-4 (e-book), ISBN 978-1-62948-010-7 (hardcover) pp. 131-170
- J. Demeulemeester, D. Smeets, C. M. Comrie, N.P. Barradas, A. Vieira, C. Van Bockstael, C. Detavernier, K. Temst, A. Vantomme, On the Growth Kinetics of Ni(Pt) Silicide Thin Films, J. Appl. Phys. 113 (2013) 163504, doi: 10.1063/1.4802738
- N.P. Barradas, N. Catarino, E. Alves, I. Bogdanović Radović, A. F. Gurbich, Measurement and Evaluation of the  $^{13}\text{C}(p,p)^{13}\text{C}$  Cross Section in the Energy Range 0.8-2.4 MeV, Nucl. Instrum. Methods Phys. Res. B 316 (2013) 81-87, doi: 10.1016/j.nimb.2013.08.041.

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## RESEARCHERS TEAM

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**NAME:** José Joaquim Gonçalves Marques

**CATEGORY:** Principal Research (Habilitation)

**IST-ID:** 5367

## ACTIVITIES

| N°    | Activity Description              | R&D (%) |
|-------|-----------------------------------|---------|
| 1     | Management                        | 70      |
| 2     | Participation on project SIMPLE   | 10      |
| 3     | Participation on project RADIARTE | 10      |
| 4     | Training Activities               | 10      |
| Total |                                   | 100     |

## WORK SUMMARY

| N° | Work Summary and Main Achievements  |
|----|---|
| 1  | a) Vice-President of Installation Commission of IST/ITN (until 31/10/2013); Member of the Management Board of CTN (since 01/11/2013).<br>b) Manager of the Portuguese Research Reactor and coordinator of the research Unit on Reactors and Nuclear Safety; coordinator of the Nuclear Engineering and Techniques group of C <sup>2</sup> TN since its creation in July 2013.<br>c) Vice-President of the Portuguese Physical Society.  |
| 2  | SIMPLE (Superheated Instrument for Massive ParticLe Experiments) is an experiment search for direct evidence of dark matter. It is located in a cavern 500 m deep in the Laboratoire Souterrain à Bas Bruit (LSBB) near Apt in southern France. The experiment is predominantly sensitive to spin-dependent interactions of weakly interacting massive particles (or WIMPs). Phase II of data acquisition ended in 2012, resulting in new and improved exclusion plots. Significant progress was made in the understanding of |

|   |  |
|---|--|
|   | neutron/alpha discrimination in superheated droplet detectors using different freons. A first prototype detector for Phase III was developed at CTN and is currently being improved. These activities were supported project PTDC/FIS/121130/2010.   |
| 3 | The neutron tomography setup installed in the RPI has been used to study conservation problems of ancient tiles within the framework of project PTDC/HIS-HEC/101756/2008 “Diagnosis, Decontamination and Conservation of Cultural Heritage: Neutrons and Ionizing Radiation in Artwork (RADIART)”. The first signs of CCD damage due to scattered neutrons became visible during 2013, after 4 years of use. This prompted a search for alternatives for image recording and digitizing as well as for less expensive CCD cameras. It was shown that the CR-39 solid state neutron track detector is a viable alternative for neutron radiography at the RPI and the images can be digitized with high quality using flatbed scanners with minimal modifications to standard procedures. The search for alternative cameras was done with the assistance of “Atik Cameras”, a Portuguese manufacturer of cameras for astronomy and resulted in the successful qualification of a camera for use in neutron radiography at the RPI. |
| 4 | Lecturer of two courses at the Faculty for Sciences of the University of Lisbon and at IST. Supervisor of one M.Sc. thesis (completed) and of one Ph.D. thesis (ongoing).  |

## PUBLICATIONS

- A.C. Fernandes, T.A. Girard, M. Felizardo, J.G. Marques, A.R. Ramos, A. Kling, T. Morlat, J. Puibasset, Superheated Liquids and the Search for Astroparticle Dark Matter, Chapter 2 in: *Recent Developments in Dark Matter Research*, N. Kinjo, A. Nakajima (Eds.), (Nova Science Publishers: Hauppauge NY, 2013, ISBN 978-1-62948-011-4) pp. 131-170.
- M. Felizardo, T. Morlat, J.G. Marques, A.R. Ramos, T.A. Girard, A.C. Fernandes, A. Kling, I. Lázaro, R.C. Martins, J. Puibasset, Fabrication and response of high concentration SIMPLE superheated droplet detectors with different liquids, *Astroparticle Physics*, 49, 28-43 (2013), doi: 10.1016/j.astropartphys.2013.08.006.

## EDUCATION

- Supervisor and Jury member, M.Sc. Thesis, *Acidente de Fukushima: Análise Crítica*, Sara Silva Pinto Wahnon, Dep. Phys. IST, concluded 17/10/2013.
- Lecturer, Técnicas Nucleares, M.Sc. degree on Physical Engineering, Faculdade de Ciências, Universidade de Lisboa, 2nd semester 2012/2013.
- Lecturer, Energia Nuclear, M.Sc. degree on Technological Physical Engineering and MIT doctoral programme, IST, 2nd semester 2012/2013.

## PROJECTS

- *Real Time Wide Area Radiation Surveillance System (REWARD)*, FP7-SEC-2011.1.5-1, Contract 284845. Leading Institution: CSIC, IST/ITN Coordinators: P. Vaz, J.G. Marques (10%).

## CONFERENCE ORGANIZATION / COMMITTEES

- Member, Programme Committee of the 16th International Topic Meeting on Research Reactor Fuel Management (RRFM), Saint Petersburg, 21 - 25 April 2013.
- Liaison Officer, International Nuclear Information System (INIS), IAEA.
- Member, Euratom Article 37 Group of Experts, European Commission.
- Member, Consultative Committee Euratom-Fission (CCE-FISSION), European Commission.
- Member, Advisory Committee of the Euratom Supply Agency, European Commission.
- Member, Working Group, European Atomic Energy Society.
- Member, Research Reactor Operators Group, European Atomic Energy Society.

## FUNDS

| Project/Service  | Reference   | Timeframe       | 2013                |
|--|---|-----------------|---------------------|
| Tomografia com microsonda nuclear com discriminação em profundidade - Tomo3D   | PTDC/FIS/115089/2009<br>(D.G. Beasley: Participant)                   |                 | 9.245,98<br>(UFA)   |
| Real Time Wide Area Radiation Surveillance System (REWARD)   | FP7-SEC-2011.1.5-1, Contract 284845 (J.G. Marques, co-coordinator)    | 12/2011-11/2014 | See UPSR            |
| Diagnosis, Decontamination and Conservation of Cultural Heritage: Neutrons and Ionizing Radiation in Artwork (RADIART) | PTDC/HIS-HEC/101756/2008<br>(J.G. Marques, M. Stanojev: Participants) | 01/2010-06/2013 | 23.509,44<br>(UCQR) |
| Neutrino mass direct determination: Portuguese contribution to MARE  | PTDC/FIS/116719/2010<br>(A. Kling, N.P. Barradas: Participants)       | 01/2012-12-2013 | 3.500,00            |

## INTERNATIONALIZATION

- Argonne National Laboratory, USA, Reduced Enrichment for Research and Test Reactors
- Consejo Superior de Investigaciones Científicas, Barcelona, Spain, Radiation effects
- Humboldt University Berlin, Germany, Argon-Argon dating
- Institute for Particle and Nuclear Physics, Hungary, Accuracy of Rutherford backscattering
- Instituto de Pesquisas Energéticas e Nucleares, Brasil, Neutron tomography
- Instituto Valenciano de Investigaciones Agrarias, Spain, Radiation-induced mutations
- ISOLDE Collaboration, CERN, Switzerland, Optimization of targets
- Katholieke University Leuven, Bélgica, Artificial neural networks for data analysis
- Mediterranean Research Reactor Network (IAEA), Research reactor network
- South Africa's National Research Foundation, Evaluation of research programmes
- Ruđer Bošković Institute, Croatia, Electronic stopping powers of materials
- Universidade de Lisboa, Portugal, Dark matter search
- Universidade de Lisboa, Portugal, Direct neutrino mass determination
- Università degli Studi di Milano, Italy, Detectors for low-energy radioactive decays
- Università di Genova, Italy, Detectors for low-energy radioactive decays
- Universitat Politècnica de València, Spain, Hosting of ERASMUS MSc student
- University of Heidelberg, Germany, Argon-Argon dating
- University of Miami, USA, Development of advanced data analysis for cryogenic detectors
- University of Santiago de Compostela, Spain, Radiation effects
- University of Surrey, England, Development of software for ion beam analysis

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**NAME: Nuno Pessoa Barradas**

CATEGORIA: Principal researcher (Habilitation)

IST-ID: 25378

## ACTIVITIES

| Nº | Activity Description                                    | R&D (%) |
|----|---|---------|
| 1  | RPI supervision   | 15      |
| 2  | Calculations for the RPI                                | 10      |
| 3  | Receiving visits to CTN and RPI                         | 2       |
| 4  | Participation in collective bodies of scientific nature | 10      |
| 5  | IBA development and data analysis                       | 5       |

|       |  |     |
|-------|--|-----|
| 6     | SPIRIT: Support of Public and Industrial Research Using Ion Beam Technology  | 10  |
| 7     | Bandgap engineering of III-nitride quantum wells for efficient green light emitting diodes.                                      | 15  |
| 8     | Free-charge carrier properties and doping mechanisms of InN-based materials - PTDC/FIS/100448/2008                               | 3   |
| 9     | Neutrino mass direct determination: Portuguese contribution to MARE - PTDC/FIS/116719/2010                                       | 20  |
| 10    | Material transport and erosion/deposition in the JET torus   | 5   |
| 11    | Analysis of mirrors exposed in JET-ILW and procurement of mirrors for exposure in JET 2014 campaigns: First mirror test for ITER | 5   |
| Total |  | 100 |

## WORK SUMMARY

| N° | Work Summary and Main Achievements   |
|----|--|
| 1  | I am Deputy Supervisor of the RPI, replacing the Supervisor in her absences, around 1 to 2 months per year, due e.g. to holidays or missions. The competences of the Supervisor and Deputy Supervisor are defined in national legislation.   |
| 2  | I made calculations for the RPI, namely core neutronics and reactivity, fuel burnup, and calculation of safety limits, and evaporation of water from the reactor pool.   |
| 3  | I assisted 33 receptions and visits to IST/ITN and the reactor, from secondary schools, professional training, different professional bodies, and the general public. Each visit takes from 30 minutes to 1 hour. The main result is the promotion of the awareness of the science done at IST/ITN amongst the public, and in particular amongst secondary school students.  |
| 4  | I was member of the Scientific Commission of IST/ITN, representing the URSN, until September 2013. The SC had competences defined in the Regulation of IST/ITN, and has assisted the Installing Commission of IST/ITN in several matters. I am Vice-President of Centro de Ciências e Tecnologias Nucleares since September 2013.  |
| 5  | I collaborate in numerous grants of the LATR, analysing IBA data collected there. This work is particularly relevant because I am author of the most advanced code for IBA data analysis that allows to extract in an efficient manner information of superior quality. The variety of systems and samples analysed leads to the permanent development and improvement of the code. This work led to many joint publications with LATR. I also actively develop IBA, in particular in advanced models for analysis and simulation. |
| 6  | I am one of the members of the IST/ITN team involved in the European project SPIRIT (11 labs in 8 countries). In particular, I was the sole responsible in the entire Europe-wide project team for Milestone "19: Standards for IBA data format are established (KT14)", and the main contributor to Deliverable "39: New codes available to analyse data from new detectors and experimental set-ups (KT14)". This work led to several publications.  |
| 7  | I worked in the analysis of data from samples from this project.   |
| 8  | I worked in the analysis of data from samples from this project.   |
| 9  | I worked in the analysis of data from samples from this project.   |
| 10 | I worked in the analysis of IBA data from JET samples. In each experimental run of one week, many hundreds of spectra are collected with different IBA techniques. The data analysis is not trivial, both in the complexity of the data, and in the sheer amount of data, orders of magnitude larger than in usual applications. This work led to several publications.  |
| 11 | I worked in the analysis of IBA data from JET samples. In each experimental run of one week, many hundreds of spectra are collected with different IBA techniques. The data analysis is not trivial, both in the complexity of the data, and in the sheer amount of data, orders of magnitude larger than in usual applications. This work led to several publications.  |

## PUBLICATIONS

- Influence of stoichiometry and structure on the optical properties of AlN<sub>x</sub>O<sub>y</sub> films, J. Borges, N. P. Barradas, E. Alves, M. F. Beaufort, D. Eyidi, F. Vaz and L. Marques, *J. Phys. D: Appl. Phys.* 46 (2013) 015305 (11 p.)
- Electrical and photocatalytic behaviour of TaO<sub>x</sub>N<sub>y</sub> magnetron sputtered thin solid films, Daniel Cristea, Aurel Crisan, Nuno Barradas, Eduardo Alves, Pedro Costa, Senentxu Lanceros-Méndez, Luis Cunha, *Metalurgia International* 18 Issue 6 (2013) 61-64.
- Influence of composition, bonding characteristics and microstructure on the electrochemical and optical stability of AlO<sub>x</sub>N<sub>y</sub> thin films, J. Borges, C. Fonseca, N.P. Barradas, E. Alves, T. Girardeau, F. Paumier, F. Vaz, L. Marques, *Electrochimica Acta* 106 (2013) 23-34.
- Status of the MARE Experiment, M.R.Gomes, F. Gatti, A. Nucciotti, P. Manfrinetti, M. Galeazzi, E. Alves, D. Bagliani, N. Barradas, S. Basak, M. Biasotti, E. Ferri, A. Kling, G. Pizzigoni, K. Prasai, J. Rocha, *IEEE Transactions on Applied Superconductivity* 23 (2013) 2101204 ( p).
- On the growth kinetics of Ni(Pt) silicide thin films, J. Demeulemeester, D. Smeets, C. M. Comrie, N. P. Barradas, A. Vieira, C. Van Bockstael, C. Detavernier, K. Temst, and A. Vantomme, *J. Appl. Phys.* 113 (2013) 163504 (8 p).
- Local deposition of <sup>13</sup>C tracer in the JET MKII-HD divertor, Jari Likonen, M.I. Airila, J.P. Coad, A. Hakola, S. Koivuranta, E. Ahonen, E. Alves, N. Barradas, A. Widdowson, M. Rubel, S. Brezinsek, M. Groth, *J. Nuclear Materials* 438 (2013) S762-S765.
- On the formation of an interface amorphous layer in nanostructured ferroelectric Ba<sub>0.8</sub>Sr<sub>0.2</sub>TiO<sub>3</sub> thin films integrated on Pt–Si and its effect on the electrical properties, J.P.B. Silva, K.C. Sekhar, S.A.S. Rodrigues, M. Pereira, A. Parisini, E. Alves, N.P. Barradas, M.J.M. Gomes, *Applied Surface Science* 278 (2013) 136-141. DOI: 10.1016/j.apsusc.2012.11.161
- Properties Of Tantalum Oxynitride Thin Films Produced By Magnetron Sputtering: The Influence Of Processing Parameters, D. Cristea, D. Constantin, A. Crisan, C.S. Abreu, J.R. Gomes, N. Barradas, E. Alves, C. Moura, F. Vaz, L. Cunha, *Vacuum* 98 (2013) 63-69, doi: 10.1016/j.vacuum.2013.03.017.
- Influence of thermal annealing on structural and optical properties of Au:TiO<sub>2</sub> nanocomposite film, A. Marin, D. Munteanu, E. Alves, N.P. Barradas, L. Cunha, C. Moura, *J. Optoelectronics and Adv. Mat.* 15 (2013) 539-543.
- Influence of RF-sputtering power on formation of vertically stacked Si<sub>1-x</sub>G<sub>x</sub> nanocrystals between ultra-thin amorphous Al<sub>2</sub>O<sub>3</sub> layers: structural and photoluminescence properties, E. M. F. Vieira, J. Martín-Sánchez, M. A. Roldan, M. Varela, M. Buljan, S. Bernstorff, N. P. Barradas, N. Franco, M. R. Correia, A. G. Rolo, S. J. Pennycook, S. I. Molina, E. Alves, A. Chahboun and M. J. M. Gomes, *J. Phys. D: Appl. Phys.* 46 (2013) 385301 (10pp), doi:10.1088/0022-3727/46/38/385301
- Measurement and evaluation of the <sup>13</sup>C(p,p)<sup>13</sup>C cross section in the energy range 0.8-2.4 MeV, N.P. Barradas, N. Catarino, E. Alves, I. Bogdanović Radović, A. F. Gurbich, *Nucl. Instrum. Methods Phys. Res. B* 316 (2013) 81-87. doi: <http://dx.doi.org/10.1016/j.nimb.2013.08.041>
- TiAg<sub>x</sub> thin films for lower limb prosthesis pressure sensors: effect of composition and structural changes on the electrical and thermal response of the films, C. Lopes, C. Gonçalves, P. Pedrosa, F. Macedo, E. Alves, N.P. Barradas, N. Martin, C. Fonseca, F. Vaz, *Applied Surface Science* 285P (2013) 10-18. DOI: 10.1016/j.apsusc.2013.07.021
- Development of Tantalum oxynitride thin films produced by PVD: Study of Structural stability, D. Cristea, A. Crisan, N. Barradas, E. Alves, C. Moura, F. Vaz, L. Cunha, *Applied Surface Science* 285P (2013) 19-26. DOI: 10.1016/j.apsusc.2013.06.061
- Nanocomposite Ag:TiN thin films for dry biopotential electrodes, P. Pedrosa, D. Machado, C. Lopes, E. Alves, N.P. Barradas, N. Martin, F. Macedo, C. Fonseca, F. Vaz, *Applied Surface Science* 285P (2013) 40-48. DOI: 10.1016/j.apsusc.2013.07.154

## COMMUNICATIONS

- Seminar “Ion Beam Analysis - An introduction”, IST, 3 de June de 2013 (invited).
- Engenharia e Técnicas Nucleares, Workshop da Plataforma de Nanotecnologias e Engenharia de Materiais, CTN, 7 de June de 2013.



- IBA of plasma facing materials, 21st International Conference on Ion Beam Analysis (IBA – 2013), Seattle, USA, 23-28 de June de 2013 (invited).
- Large scale total IBA, 11th European Conference on Accelerators in Applied Research and Technology (ECAART11), Namur, Belgium, 8-13 de September de 2013 (invited).
- Fundamentals of the IBA techniques: Theory (including depth profiling), Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Overview of PIXE, standard; high-resolution- and heavy-ion-PIXE, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Beyond single particle scattering off flat surfaces, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Pitfalls of IBA, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- NDF advanced capabilities, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Real time IBA and neural networks, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Computer exercise: Introduction to IBA simulation, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Computer exercise: Combined particle techniques: RBS, EBS, and ERDA, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Itália (invited).
- Computer exercise: Selected practical problems, Joint ICTP/IAEA Workshop on Advanced Ion Beam Techniques: Imaging and Characterisation with MeV Ions, 30 September - 4 October 2013, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy (invited).
- Determination of the  ${}^9\text{Be}(3\text{He},\pi){}^{11}\text{B}$  ( $i=0,1,2,3$ ) cross section in the energy range 0.7-2.5 MeV and application to analysis of fusion materials, IAEA Technical Meeting on "The application of microanalytical techniques based on nuclear spectrometry to the characterization of materials of importance for the nuclear power", 7-11 de October de 2013, Vienna, Austria.

## EDUCATION

- Arguing jury member, PhD of Master Ana Canaveira Gouveia Taborda, 16 de Abril de 2013, Universidade de Lisboa.
- Arguing jury member, M.Sc. of Graduated Luís de Souto Martins, 28 de November de 2013, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa.
- Responsible for project "Cultura científica no Agrupamento de Escolas Gil Vicente: parceria com o Clube de Ciência e com o IST", financed by the Programme "Pais com a Ciência" of Ciência Viva - Agência Nacional para a Cultura Científica e Tecnológica.

## COMMITTEES

- Member of International Committee of the International Conference on Ion Beam Analysis, since July 2013
-

**NAME: António Manuel da Silva de Nazareth Falcão**

CATEGORIA: Principal Researcher

IST-ID: 5345

## ACTIVITIES

| Nº    | Activity Description                  | R&D (%)  |
|-------|---------------------------------------|----------|
| 1     | Teaching                              | 10 (eq.) |
| 2     | Coordination of the Training Center   | 15       |
| 3     | Equipment development and use         | 35       |
| 4     | Hybrid glass-polymer systems research | 25       |
| 5     | Out-reaching science activities       | 10       |
| 6     | Other research related activities     | 5        |
| Total |                                       | 100      |

## WORK SUMMARY

| Nº | Work Summary and main Achievements   |
|----|--|
| 1  | <p><b>Teaching</b> – (activity performed since August in the framework of a protocol between the Higher School for Health Technology and IST);<br/>Invited Coordinator Professor at the Higher School for Health Technology coordinating and lecturing two courses on Biomechanics.</p>  |
| 2  | <p><b>Coordination of the Training Centre</b><br/>(activity maintained upon request of the Vice-President for the Management of CTN until September)<br/>On top of general management activity,<br/><i>Organization and coordination of education and training courses</i><br/>Three courses on radiation protection for professionals coordinating activities and/or operating equipment that make use or detect ionizing radiation.<br/><i>b-learning Course</i><br/>Conclusion of a demonstration prototype to be included in a radiation protection course including e-learning modules complemented by in-class practical sessions and examination.<br/>The work was carried out in collaboration with the company Unyleya, targets a broad public but is specially directed to professionals making use of ionizing radiation, and is meant to be made available in all Portuguese speaking countries.</p>   |
| 3  | <p><b>Equipment development and use</b><br/><b>Innovation in gamma-cell designing</b><br/>Preparation work to launch a project to construct a prototype of an innovative compact gamma irradiation equipment of the gamma-cell type (making use of interchangeable <math>^{60}\text{Co}</math> and <math>^{137}\text{Cs}</math> irradiation sources, allowing for a reproducible gamma flux in the sample chamber, for controlled irradiation environment, and in-line analysis of radiation produced gaseous components) was pursued.<br/>Following the expressed support of many institutions of the higher education tree as well as of the health sector national system, preliminary construction drawings and a demonstration video were produced to look for partners in a project to construct the prototype, the tasks and budget to execute the project.</p> <p><b>Reactivation of the irradiation facilities of IRIS</b><br/>After September, I became a member of the research group GREI, with the responsibility to coordinate the activity around the irradiation facilities included in IRIS (a <math>^{60}\text{Co}</math> source facility, and a LINAC that had been out of work for almost two years).<br/>The <math>^{60}\text{Co}</math> facility was repaired, and is presently in normal operation. It has been used in research work carried out by the members of LETAL and in a few preliminary tests aiming at using optical fibre in real-time dosimetry (collaboration with INESC, Porto).<br/>The recovery of the LINAC facility was started. It is a challenging job that was pursued on a step-by-step basis. By the end of 2013, the construction work of the protection and control room was concluded, the secondary cooling circuit was assessed, as well as the</p> |

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|   | vacuum system, the primary vacuum being re-established.  |
| 4 | <p><b>Hybrid glass-polymer systems and hybrid biomaterials research</b></p> <p>Synthesis and characterization of hybrid (MH) glass-polymer systems produced by gamma irradiation of the precursors (PDMS, TEOS, PrZr) with the addition of Ca and Sr</p> <p><i>Study of:</i></p> <p>(i) influence of the polymer molecular weight (range 4200 g/mol – 43500 g/mol) on the microstructure of the MH, specifically the size and fractal dimension of the oxide regions in systems 20 wt% PDMS - 73 wt% TEOS - 7 wt% PrZr;</p> <p>(ii) characterization of the effect of increasing catalyst content in size and porosity of the oxide microscopic domains.</p> <p>Using (Mw PDMS = 43500 g/mol), systems:</p> <p>33 wt% PDMS - (67-x)TEOs - xPrZr (x = 1, 2, 3 e 5 wt%)</p> <p>(25-x)PDMS - 75TEOS - xPrZr (x= 1.4, 2.9, 4.3 wt%)</p> <p>(50-x)PDMS - 50TEOS - xPrZr (x= 1.4, 2.9, 4.3, 5.7 wt%</p> <p>(iii) microstructural changes im MH prepared from precursors in weight percent composition (20wt%PDMS - 79wt%TEOS - 1wt% PrZr) followed by the addition of Calcium and strotium.</p> <p><i>overall results:</i></p> <p>based on data collected over the last few years, a model for the growth of the inorganic domains when PrZr is present</p> <p>1 article published, two articles submitted for publication and one communication</p> |
| 5 | <p><b>Out-reaching science activities</b></p> <p>Coordination of the programme of regular visits to the institution: 36 visits involving 1176 visitors (887 high school students, 211 university students and 78 other visitants), in the framework of which 8 talks were given.</p> <p>Talks on ionizing radiation and its applications were given under request.</p> <p>Participation in a science demonstration activity.</p>   |
| 6 | <p><b>Other research related activities</b></p> <p>On-going project collaboration and project proposal preparation collaboration:</p> <ul style="list-style-type: none"> <li>• <i>Application of Ionizing Radiation for a Sustainable Environment – ARIAS</i>; contract ref. FCT -RECI/AAG-TEC/0400/2012 (2013 – 2015). Total budget: 499.469 €, IST-ID budget: 499.469 €. Prime Contractor: IST-ID. Coordinator: F.M.A. Margaça (60%), in progress.</li> <li>• <i>Hybrid Materials for biomedical applications</i>, contract ref. FCT-PTDC/CTM/101115/2008 (2010-2013), Total budget: 125.000 €, IST-ID budget: 51.072 €. Prime Contractor: Univ. de Aveiro (I.M.M. Salvado), ITN Coordinator: F.M.A. Margaça (25%), concluded in 31<sup>st</sup> May 2013.</li> <li>• Participation in a proposal of an <i>European Network for Education and Training in Radiation Protection (ENETRAP III)</i>, which is reaching the final steps before clearance from the European Commission.</li> </ul>  |

## PUBLICATIONS

- Ferreira, L. M.; Leal, J. P.; Casimiro, M. H.; Cruz, C.; Lancastre, J. J. H.; Falcão, A. N. Evidence of structural order recovery in LDPE based copolymers prepared by gamma irradiation, *Radiation Physics and Chemistry*, Volume 94, p. 31-35. 10.1016/j.radphyschem.2013.06.031

## COMMUNICATIONS

- *Exploring the hybrid materials nanostructure by SANS*, F.M.A. Margaca, A.N. Falcão, J.J.H. Lancastre, I.M. Miranda Salvado, *BNC Users Meeting, Budapest, Hungary, November 15 (2013)*, Invited lecture.

## EDUCATION

- Invited Coordinator Professor at the Higher School for Health Technology coordinating and lecturing two courses on Biomechanics.
- Courses coordinated and organized:
  - “*Conceitos Básicos de Protecção e Segurança Radiológica*”, 12h, AEPISA / ANAREPRE (Lisboa), Maio
  - “*Segurança Radiológica aplicada à Utilização de Gamadensímetros*”, 18h, Odebrecht Angola Projectos e Serviços, Lda., Setembro
- Other lectures and outreaching activities:
  - *Ionizing Radiation Physics* – Course Odebrecht, CTN, (September)
  - *Ionizing Radiation - biologic effects and their applications* – Vale de Cambra, (Março)
- Elaboration of a demonstration prototype of an e-learning course (*ionizing radiation physics and application to a density gauge*) to be included in a radiation protection course.
- Eight talks on *ionizing radiation applications* given at CTN.
- Ciência Viva – Participation in the event “Ciência na Rua, 2013” organized by Centro Ciência Viva de Estremoz – radiation physics experiments.

## COLLABORATIONS

- I.M. Miranda Salvado, Dept. Glass and Ceramics Eng., CICECO, University of Aveiro, Portugal, monthly visit, Collaboration research on hybrid materials for biomedical applications.
- J.C. Almeida, Dept. Glass and Ceramics Eng., CICECO, University of Aveiro, Portugal, every other month visit, to discuss results obtained in sol-gel prepared hybrid materials for biomedical applications.
- M.H.Casimiro, REQUIMTE, CQFB, Dep. Química, Fac. de Ciências e Tecnologia, Univ. Nova de Lisboa, weekly visit, Collaboration in research of new polymeric materials and their practical use.

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**NAME: Andreas Kling**

CATEGORY: Auxiliary Researcher (Habilitation)

IST-ID: 5353

## ACTIVITIES

| Nº    | Activity Description  | R&D (%) |
|-------|---|---------|
| 1     | Radioprotection at the Portuguese Research Reactor                                | 90      |
| 2     | Production of $^{163}\text{Ho}$ for the direct determination of the neutrino mass | 5       |
| 3     | Dark matter search experiment SIMPLE  | 5       |
| Total |   | 100     |

## WORK SUMMARY

| Nº | Work Summary and Main Achievements   |
|----|--|
| 1  | The function of a Responsible for the Radiological Protection of the LEN obliges to dedicate the vast majority of available time to the assurance and improvement of the radiological protection at the RPI complementing activities and services supplied by LPSR. Examples of routine tasks in this context are: 1) supervision of the work of the Radioprotection Technicians of RPI; 2) preparation of annual and semi-annual reports on |

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|   | <p>the radiological protection of the RPI with detailed analysis of all data collected manually and by automatic systems; 3) preparation, supervision and participation in the annual maintenance and calibration of the radiation protection systems; 4) substitution of the radiological protection technicians during absence, 5) preparation of the shipment of material irradiated at RPI etc.</p> <p>With regard to the improvement of the radiological control the focus in 2013 was on the revision and elaboration of the Safety Analysis Report (SAR), specifically the revisions of the Chapters 11 (Reactor Utilization), 12 (Operational Radiological Safety), 16 (Safety Analysis), 17 (Operational Limits and Conditions) and 20 (Internal Emergency Plan of RPI), the new regulation for the RPI and the Radiological Protection Plan for LEN to be delivered in December 2013 to the national regulatory body COMRSIN.</p>   |
| 2 | <p>The project PTDC/FIS/116719/2010 intends – as part of the MARE experiment – to determine the neutrino mass directly from the decay spectrum of the isotope <math>^{163}\text{Ho}</math>. This isotope has one of the lowest Q-values (2.15 keV) for electron capture known and is therefore an excellent candidate.</p> <p>Due to its long half-life (4570 y) the production of this isotope is a challenging task. After the successful production of a first lot of <math>\approx 20</math> kBq <math>^{163}\text{Ho}</math> in 2012 a second batch consisting of 41 mg erbium oxide (12.5 mg) enriched to 39.5% in <math>^{152}\text{Er}</math> has been irradiated for 200 hours at the RPI. Via the reaction <math>^{162}\text{Er}(n,\gamma)^{163}\text{Er} \rightarrow ^{163}\text{Ho}</math> the production of about 134 kBq of this isotope has been achieved. The radionuclide has been delivered to INFN in Genova for incorporation into cryogenic micro-calorimeters. Spectra with sufficient statistics for the detection of deviations in the spectrum endpoint are expected to be available in 2014.</p>                        |
| 3 | <p>In the dark matter search Project SIMPLE (Superheated Instrument for Massive Particle Experiments) the identification and suppression of background – mainly due to neutrons – has high priority. Therefore the characterization of possible neutron sources (mainly due to spontaneous fission of actinides and <math>\alpha,n</math> reactions) in construction and surrounding materials is crucial.</p> <p>Radioanalytical analyses of the materials used deliver activity values for a restricted number of <math>\alpha</math>-emitting radioisotopes of the natural decay chains (U, Th). However, for processed materials (e.g. steel, tap water) the detected chain radionuclides are no more in secular equilibrium. Therefore appropriate assumptions have to be derived on the activity concentrations of the remaining isotopes considering chemical and thermal properties of all isotopes of interest as well as the time that passed since processing.</p> <p>The results enabled to refine further the calculations on the expected neutron background leading to an improved agreement between observation and calculus.</p> |

## PUBLICATIONS

- M. Ribeiro Gomes, F. Gatti, A. Nucciotti, P. Manfrinetti, M. Galeazzi, E. Alves, D. Bagliani, N. Barradas, S. Basak, M. Biasotti, E. Ferri, A. Kling, G. Pizzigoni, K. Prasai, J. Rocha, Status of the MARE experiment, *IEEE Trans. Appl. Superconductivity* 23 (2013) Art. No. 2101204
- M. Felizardo, T. Morlat, J.G. Marques, A.R. Ramos, T.A. Girard, A.C. Fernandes, A. Kling, I. Lázaro, R.C. Martins, J. Puibasset, Fabrication and Response of High Concentration SIMPLE, Superheated Droplet Detectors with Different Liquids, *Astropart. Phys.* 49 (2013) 28-43
- A.C. Fernandes, T.A. Girard, M. Felizardo, J.G. Marques, A.R. Ramos, A. Kling, T. Morlat, J. Puibasset, L. Lázaro, Superheated Liquids and the Search for Astroparticle Dark Matter, Chapter 4 in *Recent Developments in Dark Matter Research*, N. Kinjo and A. Nakajima (eds.), Nova Publishers, Hauppauge, NY, 2013, ISBN 978-1-62948-011-4 (e-book), ISBN 978-1-62948-010-7 (hardcover) pp. 131-170

## COMMUNICATIONS

- Radiological Protection Plan of the Portuguese Research Reactor, A. Kling, *Workshop on Operational Radiation Protection for Research Reactors, 18 – 22 March 2013, IAEA Headquarters, Vienna.*

**NAME:** Ana Cristina Fidalgo Palma Fernandes  
**CATEGORY:** Auxiliary Researcher (Ciência 2007 / FCT Researcher)  
**IST-ID:** 5465

## ACTIVITIES

| Nº    | Designação da Atividade                     | R&D (%)* |
|-------|---|----------|
| 1     | Reactor dosimetry                           | 12 (29)  |
| 2     | Superheated liquid detectors                | 20 (48)  |
| 3     | Radiation dosimetry in medical applications | 10 (23)  |
| Total |   | 42 (100) |

\* From 1-Jan. to 30-April (Ciência 2007); from 1 to 12 Dec. (FCT researcher). Five months (42% year); values under parenthesis are for 1 year.

## WORK SUMMARY

| Nº | Work Summary and Main Achievements  |
|----|---|
| 1  | <p>Two important areas of reactor dosimetry at the RPI were subject to comparison exercises:</p> <ul style="list-style-type: none"> <li>• Within a collaboration with the Greek Research Reactor, the validated MCNP model of the RPI core was involved in the evaluation of deterministic (CITATION) and stochastic (TRIPOLI) neutronics codes. A general agreement within 80% was obtained among the codes and measurements regarding thermal and epithermal fluence rates. A noticeable exception is the poor performance of TRIPOLI using distributed sources and in the calculation of fast neutron fluence rates, indicating the need for improvements in the source term.</li> <li>• A preliminary presentation of the round-robin results on foil activity measurements (10 foils, 8 institutions) promoted by the European Workgroup on Reactor Dosimetry, yielded maximum deviations of 1.2% and <math>\pm 5\%</math> for 80 measurements of mass and specific activity, respectively. Consistent systematic differences between some institutions are evident; potential correlations should be considered when measured neutron activation rates are used for plant dosimetry assessments.</li> </ul> <p>A collaboration with the CR group of C<sup>2</sup>TN and with University of Aveiro was initiated towards the evaluation of novel compounds for boron neutron capture therapy, via cell irradiations at the vertical access of the thermal column of RPI and corresponding dosimetry.</p> |
| 2  | <p>Superheated liquid detectors are used in the SIMPLE international collaboration for dark matter search. An improved neutron shielding configuration for the next phase of SIMPLE using bubble chambers for increased active mass was investigated through MCNP simulations. Radioassays of various materials employed in the detector fabrication were performed for this purpose. The results indicate the possibility of reducing the neutron background over 2 orders of magnitude through basic modifications relatively to the current configuration, namely (i) the use of purified water in the shield and (ii) the replacement of the PVC currently used in the detector prototype by a Cl-free material such as PE.</p> <p>The calculation of the neutron background signal in the superheated droplet detectors employed in the latest phase of SIMPLE is being improved through the inclusion of the recoil angular distribution and additional source contributions from the shield and instrumentation. This work aims to characterize as accurately as possible the background signal of the SDD for its application in low-level radiation metrology within the "Investigador FCT" contract.</p>  |
| 3  | <p>Intensity-Modulated Radiotherapy is a treatment modality planned for Centro Hospitalar Barreiro-Montijo which requires improved treatment plan algorithms to deal with the small radiation fields employed. The workplan for the commissioning of AAA for Eclipse according (mostly) to IAEA TECDOC-1583 was prepared and dose measurements in recommended configurations initiated for future comparison with corresponding calculations. In addition, the increased workload associated with IMRT motivated the re-</p>  |

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| evaluation of the radiation safety conditions for the exposed workers. |
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## PUBLICATIONS

- A.C. Fernandes, T.A. Girard, M. Felizardo, J.G. Marques, A.R. Ramos, A. Kling, T. Morlat, J. Puibasset, Superheated Liquids and the Search for Astroparticle Dark Matter, Chapter 2 in: *Recent Developments in Dark Matter Research*, N. Kinjo, A. Nakajima (Eds.), (Nova Science Publishers: Hauppauge NY, 2013), pp. 131-170. ISBN 978-1-62948-011-4
- P. Savva, M. Varvayanni, A.C. Fernandes, J.G. Marques, N. Catsaros, Comparing neutronics codes performance in analyzing a fresh-fuelled research reactor core, *Annals of Nuclear Energy*, 63, 731-741 (2013), doi: 10.1016/j.anucene.2013.08.036.
- M. Felizardo, T. Morlat, J.G. Marques, A.R. Ramos, T.A. Girard, A.C. Fernandes, A. Kling, I. Lázaro, R.C. Martins, J. Puibasset, Fabrication and response of high concentration SIMPLE superheated droplet detectors with different liquids, *Astroparticle Physics*, 49, 28-43 (2013), doi: 10.1016/j.astropartphys.2013.08.006.

## EDUCATION

- Jury, M.Sc. Thesis, *Using magnetic resonance images for planning treatments in external radiotherapy-validation procedures for "MRI-only"*, Ana Catarina Freire Moreira, Faculdade de Ciências, Universidade do Porto, 18 December 2013

## COLLABORATIONS

- Pinheiro, CHBM, Centro Hospitalar Barreiro Montijo, Portugal, 15 Feb - 30 Apr 2013, Commissioning of treatment planning algorithms for Intensity-Modulated Radiotherapy.

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**NAME: Ana Rita Lopes Ramos Wahl**

CATEGORY: Auxiliary Researcher

IST-ID: 5352

## ACTIVITIES

| Nº    | Activity description               | R&D (%) |
|-------|------------------------------------|---------|
| 1     | Gestão – Supervisora do RPI        | 80      |
| 2     | Participação na colaboração SIMPLE | 20      |
| Total |                                    | 100     |

## WORK SUMMARY

| Nº | Work Summary and Main Achievements  |
|----|---|
| 1  | <p>My main role in the Operation and Exploitation Group of URSN is to act as Reactor Supervisor of the Portuguese Research Reactor (RPI). The duties and responsibilities of the Supervisor are described in the <i>Despacho 10-A/MCT/96</i>, published in <i>Diário da República, II série</i>, nº 62 of March 13, 1996. The Supervisor ensures that the Reactor operates in accordance with the Operation Limits and Conditions (OLC) imposed by the licensing authority and with national legislation related to radiation protection and nuclear safety. My work in 2013 included:</p> <ol style="list-style-type: none"><li>a) Receiving, analysing and processing all irradiation requests for the Reactor. Irradiation requests are analysed in order to check compliance with the limits established in the OLC and with applicable Rules of Operation;</li><li>b) Daily management and supervision of the Reactor Operators' work, including: a) quality control of verifications and measurements related to maintenance procedures (daily, weekly and monthly) and Reactor start-up/shut-down procedures (daily); b) in case of lack of personnel, acting as Operator or Radiation Protection Technician, in</li></ol> |

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|   | <p>order to ensure proper functioning of the service and compliance with safety regulations;</p> <p>c) Development of procedures for routine and non-routine actions in the Reactor, including manipulation of experiments, instrument calibration, core interventions and emergency procedures. In 2013, in particular, a review of all routine safety related procedures was initiated to assess compliance with the recommendation set forth in the IAEA No. NS-G-4.4 Safety Guide (“Operational Limits and Conditions and Operating Procedures for Research Reactors”). The review process, which will span the 2013-2014 period, brings together the contributions of all members of the RPI’s Operation Team and is integral part of the groups’ technicians’ evaluation through SIADAP.</p> <p>d) Maintenance and verification of the records (paper and electronic) required by the OLC;</p> <p>e) Supervision of all preventive and curative maintenance in the Reactor, including programming of activities, acquisition of necessary equipment or materials, personal supervision of the work (when I am not doing it myself), final assessment of equipment performance after maintenance and writing of maintenance records and reports;</p> <p>f) Ensuring the continuous training of the Reactor Operators (specific annual retraining and on the job training).</p> <p>g) The last quarter of 2013 was occupied in finalizing the new version of the RPI’s Safety Analysis Report, a collaborative effort of the Operation and Exploitation Group. This work, initiated in 2006, was completed in 2013. The report is an integral part of RPI’s legal obligations set forth in Decree-Law 262/2012 and was submitted in December 2013 to the regulatory authority COMRSIN.</p> |
| 2 | <p>The SIMPLE (<i>Superheated Instrument for Massive ParticLe Experiments</i>) experiment is dedicated to the direct search for dark matter, in particular WIMPS (<i>Weekly Interacting Massive Particles</i>). In 2013 the activities were supported by the FCT funded project PTDC/FIS/121130/2010 (Phase III), which ended in 30/09/2013. Phase III started in 2012 and aimed at building a new prototype detector, with R&amp;D efforts concentrated at the RPI’s SIMPLE laboratory, to be deployed at LSBB (Laboratoire Souterrain á Bas Bruit, Rustrel-Pays d’ Apt. France). The prototype suffered several delays in construction due to lack of timely funding and the current prototype, as it stands in December 2013, still needs further development. In 2013 SIMPLE published one paper in Astroparticle Physics and had a full review of the Phase II results accepted for publication in Physical Review D.</p>   |

## PUBLICATIONS

- “Fabrication and response of high concentration SIMPLE superheated droplet detectors with different liquids”, M. Felizardo, T. Morlat, J.G. Marques, A.R. Ramos, TA Girard, A.C. Fernandes, A. Kling, I. Lázaro, R.C. Martins, J. Puibasset, for the SIMPLE Collaboration, *Astroparticle Physics* 49 (2013) 28–43. Times Cited: 0; DOI: 10.1016/j.astropartphys.2013.08.006.
- “ The SIMPLE Phase II Dark Matter Search”, M. Felizardo, TA Girard, T. Morlat, A.C. Fernandes, A.R. Ramos, J.G.Marques, A. Kling, J. Puibasset, M. Auguste, D. Boyer, A. Cavallou, J. Poupene, C. Sudre, H.S. Miley, R.F. Payne, F.P. Carvalho, M.I. Prudêncio, R. Marques, *Physical Review D*, *accepted for publication*.

## COLLABORATIONS

- SIMPLE Collaboration, T. A. Girard, Nuclear Physics Centre of the University of Lisbon.
-



**NAME: Daniel Beasley**  
CATEGORY: Auxiliary Researcher  
IST-ID: 391

## ACTIVITIES

| Nº    | Activity Description                   | R&D (%) |
|-------|--|---------|
| 1     | Project: PTDC/FIS/115089/2009 – tomo3d | 20      |
| Total |  | 100     |

## WORK SUMMARY

| Nº | Work Summary and Main Achievements   |
|----|--|
| 1  | The tomographic reconstruction of biological specimens requires robust algorithms, able to deal with low density contrast and low element concentrations. GPU-accelerated reconstruction software, JPIXET, has been developed, which can significantly increase the speed of quantitative reconstruction of Proton Induced X-Ray Emission Tomography (PIXE-T) data. It has a user-friendly graphical user interface for pre-processing, data analysis and reconstruction of PIXE-T and Scanning Transmission Ion Microscopy Tomography (STIM-T). The reconstruction of PIXE-T data is performed using either an algorithm based on a GPU-accelerated version of the Maximum Likelihood Expectation Maximisation (MLEM) method or a GPU-accelerated version of the Discrete Image Space Reconstruction Algorithm (DISRA). The original DISRA, its accelerated version, and the MLEM algorithm, were compared for the reconstruction of a biological sample of <i>Caenorhabditis elegans</i> – a small worm. This sample was analysed at the microbeam line of the AIFIRA facility of CENBG, Bordeaux. |

## PUBLICATIONS

- D.G. Beasley, L.C. Alves, Ph. Barberet, S. Bourret, G. Deves, N. Gordillo, C. Habchi, Q. Letrequesser, A.C. Marques, H. Sez nec, R.C. Da Silva, A Comparison of Quantitative Reconstruction Techniques for PIXE-Tomography Analysis Applied to Biological Samples, *Accepted for publication Nuc. Inst. and Meth B* (2014).
- D.G. Beasley, A.C. Marques, L.C. Alves, R.C. da Silva, GPU-Accelerated Reconstruction of Proton Induced X-Ray Emission Tomography Data, *Radiation Physics and Chemistry* 95 (2014) 251-253.
- D.G. Beasley, A.C. Marques, L.C. Alves, R.C. da Silva, Fast Simulation of Proton Induced X-Ray Emission Tomography Using CUDA, *Nuc. Inst. and Meth B.* 306 (2013) 109-112.
- A.C. Marques, M.M.F.R. Fraga, P. Fonte, R. Ferreira Marques, D. Beasley, L.C. Alves, R.C. da Silva, New gas detector setup for on-axis STIM tomography experiments, *Nuc. Inst. and Meth B.* 306 (2013) 104-108.

## COMMUNICATIONS

- *A Comparison of Quantitative Reconstruction Techniques for PIXE-Tomography Analysis Applied to Biological Samples*, D.G. Beasley, L.C. Alves, Ph. Barberet, S. Bourret, G. Deves, N. Gordillo, C. Habchi, Q. Letrequesser, A.C. Marques, H. Sez nec, R.C. Da Silva, The 11th European Conference on Accelerators in Applied Research and Technology will be held in Namur, Belgium, Sep 8-13 (2013), oral presentation.

## PROJECTS

- *Combinação de tomografias MicroCT e PIXE para produção de modelos realistas para simulações de Monte Carlo de microdosimetria de neutrões*, EXPL/FIS-OPT/1793/2013, IST/ITN Coordinator: Daniel Beasley (50%)

## COLLABORATIONS

- Scientific Visit, Ion Beam lab, CENBG, University of Bordeaux, 25-27 March 2013, in scope of FCT project PTDC/FIS/115089/2009 – tomo3d.

**NAME: Marco Antonio Stanojev Pereira**

CATEGORY: Auxiliary Researcher

IST-ID: 5495

## ACTIVITIES

| Nº    | Activity Description   | R&D (%) |
|-------|--|---------|
| 1     | Implementation of the track-etch neutron radiography technique at the Portuguese Research Reactor. | 60      |
| 2     | Neutron tomography applied to studies in the archaeological and cultural heritage fields.          | 40      |
| Total |  | 100     |

## WORK SUMMARY

| Nº | Work Summary and Main Achievements  |
|----|---|
| 1  | The track-etch neutron radiography technique was recently implemented in a low flux thermal neutron port at the Portuguese Research Reactor. In this work we report significant improvements to recording and digitizing images, using an enriched boron converter, a CR-39 solid state nuclear track detector and a low cost flatbed scanner. The installed setup enables a significant reduction of the fluency required to obtain a neutron radiography image and has a spatial resolution of 62 µm. The quality of the obtained radiographic images makes this technique suitable for imaging purposes with low flux thermal neutron beams.   |
| 2  | Neutron imaging techniques are non-destructive tools that can help to understand the processes involved in manufacturing and restoration of cultural heritage artefacts. The interaction of neutrons with matter is markedly different from the interaction of other types of radiation, enhancing features where light elements are involved. Imaging of relative levels of neutron absorption is based on photography of scintillations produced in a ZnS screen doped with LiF, where Li is used as a neutron to charged particle converter. In this work were made analysis with neutron radiography and tomography at the Portuguese Research Reactor applied to the study and characterization of restorations with resin, absorption of natural oils, and water retention. |

## PUBLICATIONS

- R.M. Schoueri, C. Domienikan, F. de Toledo, M.L.G. Andrade, M.A. Stanojev Pereira, R. Pugliesi, The new facility for neutron tomography of IPEN-CNEN/SP and its potential to investigate hydrogenous substances, Applied Radiation and Isotopes, 84, 22-26 (2014) .
- F. Pugliesi, M.A. Stanojev Pereira, R. Pugliesi, M.S. Dias, The feasibility of the polycarbonate Durolon™ as a thermal neutron dosimeter, Applied Radiation and Isotopes, Available online 23 January 2014, doi.org/10.1016/j.apradiso.2014.01.009.
- M.A. Stanojev Pereira, R. Schoueri, C. Domienikan, F. de Toledo, M.L.G. Andrade, R. Pugliesi, The neutron tomography facility of IPEN-CNEN/SP and its potential to investigate ceramic objects from the Brazilian cultural heritage, Applied Radiation and Isotopes, 75, 6-10 (2013)
- M.A. Stanojev-Perreira, J.G. Marques, J.P. Santos, M.I. Prudêncio, C.I. Burbidge, Neutron imaging techniques applied to studies in the archaeological and cultural heritage fields, Mediterranean Archaeology and Archaeometry, 13.3, (2013) (in print)

## **COLLABORATIONS**

- R. Pugliesi, IPEN/CNEN-SP, Nuclear and Energy Research Institute, Brazil, 2012, Improvement of a neutron tomography system at the IPEN/CNEN-SP, April 2010 to April 2013.