
NUCLEAR METHODS AND INSTRUMENTATION

Annual Activity Report 2013

UNIT: Physics and Accelerators

TEAM

Name	Category	R&D
João Manteigas	Auxiliary Researcher	100%
Isabel Gonçalves	Auxiliary Researcher	100%
José Neves	Auxiliary Researcher	100%
Nuno Pinhão	Auxiliary Researcher	100%
Tiago Jesus	Assistant Technician	100%
André Janeco	PhD Student IST	100%
Sílvia Barros	PhD Student IST	100%
Piménio Ferreira	Master Student FCUL	100%
Ana Moura	Research Project Fellow	90%

OBJECTIVES

The strategy of the group involves activities in the following lines: modelling of radiation fields, calculation of neutron physic parameters, measurement of neutron cross-sections, modelling and applications of gas discharges, design of equipment and software for nuclear applications and data analysis, consulting and technical assistance.

Modelling of radiation fields, calculation of neutron physic parameters

Monte Carlo calculations have been carried in the framework of the n_TOF Collaboration (ITN participation on the n_TOF-Ph2 experiment at CERN).

Measurement of neutron cross-sections

The analysis of the data for cross-section measurement taken, in the TOF spectrometer installed at the CERN, was carried out.

Modelling and application of gas discharges

The work in this area has covered three problems: a) the study of plasmas for dry reforming of methane, using mixtures of methane and carbon dioxide, diluted in helium. The final goal is to develop an energy efficient process for the production of *Syngas* or higher hydrocarbons. From middle of the year this work was conducted in the framework of project PTDC/FIS-PLA/2135/2012; b) the extension of a numerical code for the solution of the electron Boltzmann equation and based on the density gradient approximation, to other type of collision processes and optimization of the code for multi-core processors; and c) preliminary work on the application of dielectric barrier discharge to the treatment of liquids effluents.

Instrumentation and technical assistance

The main objectives are the development of equipment for CTN Groups, manufacture of equipment for specific applications and assistance to industrial companies and scientific institutions as well as technical consulting. The technical assistance takes mainly the form of specialised consultant engineering advice, installation of nuclear gauges, including calibration maintenance, repair and recharging of gauges with imported radioactive sources. The group has continued providing maintenance and repairing services of HPGe detectors.

MAIN ACHIEVEMENTS

Participation on n_TOF Experiment (phase 2) at CERN

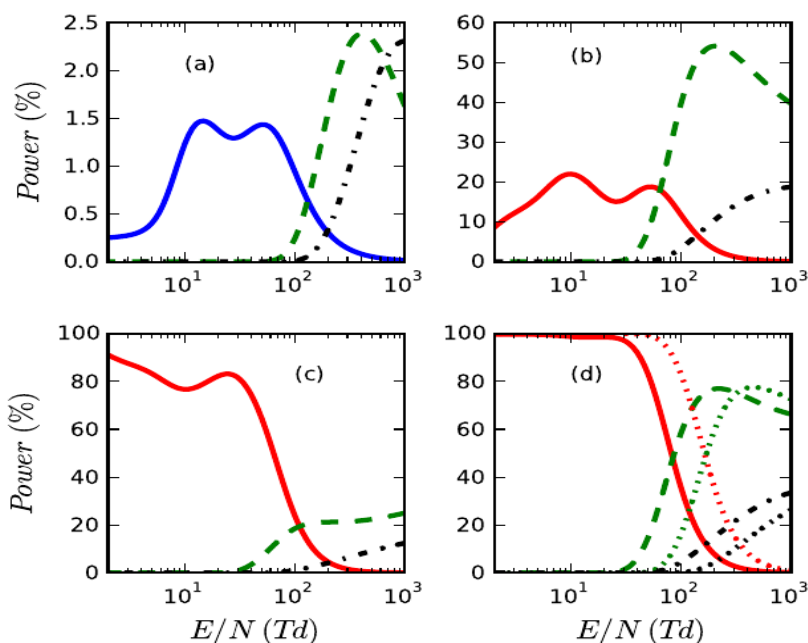
A complete and precise knowledge of cross sections for neutron induced processes is required for multiple applications such as the design of ADS and EA systems for the transmutation of nuclear waste and energy production, radioisotope production for medical and industrial applications and Astrophysics, Nuclear Physics and Nuclear Technology.

The n_TOF Collaboration has been carrying out experimental campaigns at the neutron time of flight spectrometer at CERN, using the CERN/PS accelerator complex. In this facility, a 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/cm²/pulse is available to perform cross section measurements in the detectors station located 185 m downstream. IST/ITN team is involved in collaboration with INFN-Bari and CEA-Saclay in the analysis of the data recorded during 2004 and from 2009, as well as the feasibility studies associated to the construction of the second experimental area. In this way we concluded the analysis of the data on neutron capture on U-233, taken using the BaF2 calorimeter, and data taken during 2009 and 2010 using the BaF2 calorimeter and the C6D6 detectors for the neutron capture cross-sections of Fe and Ni isotopes.

Plasma dry reforming of methane and carbon dioxide

In the framework of project PTDC/FIS-PLA/2135/2012 the production of *Syngas* (a H₂+CO) mixture with helium in a dielectric barrier discharge reactor is under way. This study involves both experimental and modeling work. The experimental work-plan includes the study of the effect of the gas temperature on conversion and selectivity, using an AC power supply, on selected mixtures. In 2013 the following sub-tasks were completed or are in the final stage: a) Project and numerical modeling of a reactor; acquisition of raw materials and experimental equipment; development of the data acquisition and control modules for this experiment; construction of the reactor. In 2013 the study of the electron kinetics in He/CH₄/CO₂ mixtures at room temperature, and including the effect of products (H₂ and CO) was also completed. In particular this study enlightened the role of helium on these discharges.

A code to study the electron kinetics based on the density gradients representation



Fractional electron power losses per type of process and gas as a function of the reduced electric field. (a) Helium, (b) CO, (c) CH₄, (d) total mixture. blue - elastic collisions, red - vibrational excitation, green - electronic excitation, black - ionization.

A code to solve the electron Boltzmann equation for an electron swarm in a constant electric field was extended to include a) electron-electron collisions; b) the treatment of the electron-vibrational processes in polyatomic gases based on the harmonic approximation; c) multi-step excitation and ionization; d) the treatment of rotational levels in gases with orto- and para- modes (e.g. H₂); e) cross section defined by

analytical functions. Finally the main algorithm was adapted to take advantage of parallel processing in the present multi-core processors.

Application of dielectric barrier discharge to the treatment of liquids effluents

An experimental system based on a dielectric barrier discharge over a liquid was developed to study the degradation of hemoglobin in liquid effluents. This problem is relevant to the treatment of effluents from slaughter houses. The results will be compared with previous results obtained with gamma radiation.

Consulting, design and technical assistance

The main purposes of the project were accomplished. By request from internal groups and external customers, several electronic equipment and prototypes were designed (or upgraded) and manufactured. Additionally, substantial work related to technical maintenance, calibration and quality control of different nuclear instruments and equipment was carried out. A number of consulting services in the field of engineering of radiation was provided too.

In 2013, the project achieved a total income of about € 14.894,85 from Portuguese (Portucel, Soporcel, Arsenal do Alfeite, Cimpor and Siderurgia Nacional, etc.) and foreign clients (France and Ireland).

RELEVANT PAPERS

- C. Lederer et al (n_TOF collaboration), Neutron Capture Cross Section of Unstable ^{63}Ni : Implications for Stellar Nucleosynthesis, *Phys. Rev. Lett.* 110, 022501 (2013).
- G. Tagliente et al (n_TOF collaboration), The $^{93}\text{Zr}(n,\gamma)$ reaction up to 8 keV neutron energy, *Phys. Rev. C* 87, 014622 (2013).
- C. Weiss et al (n_TOF collaboration), A new CVD diamond mosaic-detector for (n, a) cross-section measurements at the n_TOF experiment at CERN, *Nuclear Instruments and Methods in Physics Research A* 732 (2013) 190–194.
- C. Guerrero et al (n_TOF collaboration), Performance of the neutron time-of-flight facility n TOF at CERN, *Eur. Phys. J. A* (2013) 49: 27.
- M. Barbagallo et al (n_TOF collaboration), High-accuracy determination of the neutron flux at n TOF, *Eur. Phys. J. A* (2013) 49:156.

FUNDS

Description	Reference	Timeframe	2013
Project AEECMP	PTDC/FIS-PLA/2135/2012	Jan 2013/Dec 2014	15.407,40 €
CERN n_TOF Experiments (phase 2)	CERN/FP/123602/2011	Apr 2012/Set 2014	30.000,00 €
Services	ITN/CR – 4402 + IST/CR - 4064	Sales 2012	39.739,50 €
Total			85.146,90 €

INTERNATIONALIZATION

- CIEMAT, Spain.
- Comenius Univ., Dept. of Experimental Physics, Bratislava, Slovakia.
- Leibniz Institute for Plasma Science and Technology, Greifswald, Germany.
- n_TOF collaboration, a consortium of several laboratories in Europe, USA and Japan.
- Research Institute for Solid State Physics and Optics, Budapest, Hungary.

RESEARCHERS TEAM

NAME: João António Borges Manteigas

CATEGORY: Auxiliary Researcher

IST-ID: 25362

ACTIVITIES

Nº	Activity Description	R&D (%)
1	Management activities	35
2	Consulting, design and technical in the field of engineering applications of radiation and radioisotopes. Total Invoice: 14.894,85 €.	45
3	PCT Project: “ <i>Increasing the Energy Efficiency of Plasma Conversion of Methane</i> ” (PTDC/FIS-PLA/2135/2012). Starting date: 01-01-2013. Approved: € 102.716,00.	15
4	PCT Project: “ <i>ARIAS - Application of Ionizing Radiation for a Sustainable Environment</i> ” (RECI/AAG-TEC/0400/2012). Starting date: 01-01-2013. Approved, € 499.469,00.	5
Total		100

WORK SUMMARY

Nº	Work Summary and Main Achievements
1	<p>Coordinator of the “<i>Nuclear Methods and Instrumentation</i>” group:</p> <ul style="list-style-type: none"> Line of activity: development of methods, techniques and instrumentation using ionizing radiation for applications in industry and research. <p>Coordination of the subgroup “<i>Nuclear Instrumentation – Services</i>”:</p> <ul style="list-style-type: none"> Line of activity: supply of equipment brand IST and specialized services, including technical assistance and consultancy. <p>Coordinator of the Activities Plan for 2013;</p> <p>Collaboration in the preparation of the:</p> <ul style="list-style-type: none"> Activity Report of the do IST 2012 (flyer); Activity Report of the IST/UFA 2012; Co-ordination of the establishment of new research group to integrate C²TN; Collaboration in the regulation of the C²TN;
2	<p>Quality control of manufacturing process of small series of equipment, brand CTN/IST.</p> <p><i>Examples:</i></p> <ul style="list-style-type: none"> “Laboratory Equipment for the Determination of Radioactive Element Traces by Electrodeposition” (standard), 4 cell Electrodeposition Set; “RADX100”/Pocket Radiation Dosimeter; “T6C M-CS Multi Micro-Current Source”. <p>Consulting, design, installation, repair and maintenance of nuclear equipment for enterprises and sale of equipment brand CTN/IST to domestic and foreign customer:</p> <ul style="list-style-type: none"> <i>Total Invoice: 14.894,85 € (see annex).</i> <p>Maintenance of electronic equipment.</p>
3	<p>An automated system intended to manage and monitoring the Dielectric Barrier Discharge Reactor high voltage value, according the temperature inside chamber (20°-600° C) was designed and produced. In addition, the system allows the simultaneous control of two commercial devices; two mass flow meters brand EL-Flow®, through a personal computer.</p>
4	<p>LINAC – Linear Particle Accelerator</p> <p>In order to fix/recuperate the LINAC, technical support and some recovery works were carried out. Example: The repairing of the two electromagnetic electron beam collimators.</p>

INTERNAL REPORTS / SERVICES

- J.B. Manteigas, J. Neves, N. Pinhão, Technical Assistance in the Field of Engineering Applications of Radiation and Radioisotopes, UFA/CTN/IST 2012.

NAME: Isabel Maria Ferro Pereira Gonçalves

CATEGORY: Auxiliary Research

IST-ID: 5361

ACTIVITIES

Nº	Activity Description	R&D (%)
1	Participation of ITN in the n_TOF ph2 experiment at CERN	50
2	Cooperation with CERN - Optimization studies of the ISOLDE targets and design of HIE-ISOLDE	30
3	ANDES (Accurate Nuclear Data for nuclear Energy Sustainability)	20
Total		100

WORK SUMMARY

Nº	Work Summary and Main Achievements
1	<p>A complete and precise knowledge of cross sections for neutron induced processes is required for multiple applications such as the design of ADS and EA systems for the transmutation of nuclear waste and energy production, radioisotope production for medical and industrial applications and Astrophysics, Nuclear Physics and Nuclear Technology.</p> <p>The n_TOF Collaboration has been carrying out experimental campaigns at the neutron time of flight spectrometer at CERN, using the CERN/PS accelerator complex. In this facility, a 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/cm²/pulse is available to perform cross section measurements in the detectors station located 185 m downstream. IST/ITN team is involved in collaboration with INFN-Bari and CEA-Saclay in the analysis of the data recorded during 2004 and from 2009, as well as the feasibility studies associated to the construction of the second experimental area. In this way we concluded the analysis of the data on neutron capture on U-233, taken using the BaF2 calorimeter, and data taken during 2009 and 2010 using the BaF2 calorimeter and the C6D6 detectors for the neutron capture cross-sections of Fe and Ni isotopes.</p>
2	<p>The production of Radioactive Ion Beams (RIBs) is of great importance for scientific studies in the fields of Nuclear Physics and Astrophysics, for Materials Science studies and also for Medicine.</p> <p>One of the most important installations worldwide for the production of Radioactive Ion Beams (RIB), using the ISOL (Isotope Separation On-Line) method is the ISOLDE facility at CERN, where more than 1000 radioactive isotopes have been produced. These isotopes are currently produced at ISOLDE following the bombardment of various primary targets with a pulsed proton beam of energy 1.4 GeV and intensity 2 μA. Most of these isotopes can be accelerated in the REX-ISOLDE facility to energies up to 2.8 MeV/u.</p> <p>In this project, the IST/ITN group aims at the continuation of the on-going collaboration with CERN in the optimization of the target systems at ISOLDE – computational activities as well as of design and tests of prototypes, and in Radiological Protection and Shielding studies of the future facility HIE-ISOLDE (“upgrade” of the existing installation for higher proton beam energy and intensity) – computational activities of shielding design and experimental validation through measurements.</p>
3	<p>The participation of the IST/ITN team consisted on the determination of the capture neutron cross sections for ²³⁸U and ²⁴¹Am and the fission cross sections for ²⁴⁰Pu and ²⁴²Pu, using the TOF spectrometer at CERN.</p>

PUBLICATIONS

Papers

- S. Barros et al, Dosimetric assessment and characterisation of the neutron field around a Howitzer container using a Bonner sphere spectrometer, Monte Carlo simulations and the NSDann and NSDUAZ unfolding codes, *Radiat Prot Dosimetry* (2013) 154 (3): 346-355.
- C. Lederer et al (n_TOF collaboration), Neutron Capture Cross Section of Unstable ^{63}Ni : Implications for Stellar Nucleosynthesis, *Phys. Rev. Lett.* 110, 022501 (2013).
- G. Tagliente et al (n_TOF collaboration), The $^{93}\text{Zr}(n,\gamma)$ reaction up to 8 keV neutron energy, *Phys. Rev. C* 87, 014622 (2013) .
- Y. Romanets et al, Radiation protection, radiation safety and radiation shielding assessment of HIE-ISOLDE, *Radiat Prot Dosimetry* (2013) 155 (3): 351-363.
- C. Weiss et al (n_TOF collaboration), A new CVD diamond mosaic-detector for (n, a) cross-section measurements at the n_TOF experiment at CERN, *Nuclear Instruments and Methods in Physics Research A* 732 (2013) 190–194.
- C. Guerrero et al (n_TOF collaboration), Performance of the neutron time-of-flight facility n TOF at CERN, *Eur. Phys. J. A* (2013) 49: 27
- M. Barbagallo et al (n_TOF collaboration), High-accuracy determination of the neutron flux at n TOF, *Eur. Phys. J. A* (2013) 49:156.

Conference Proceedings

- C. Lederer et al (n_TOF collaboration), Experiments with neutron beams for the astrophysical s process Proceedings of the conference Nuclear Physics in Astrophysics, Lisbon, May 2013
- Plompen et al, ANDES measurements for advanced reactor systems, ND2013 proceedings
- E. Leal-Cidoncha et al (n_TOF collaboration), Study of the $^{234}\text{U}(n,f)$ fission fragment angular distribution at the CERN n_TOF facility, ERINDA Workshop, Oct 2013

EDUCATION

- Supervisor of Ph. D. Thesis “Estudos de dosimetria e de espectrometria de neutrões para protecção radiológica, utilizando o espectrometro n_TOF no CERN”, by Silvia Barros, Instituto Superior Técnico, Universidade Técnica de Lisboa,
- Supervisor of Master Thesis “Caracterização Neutrónica e dosimetrica do alvo de espalação do espectrómetro de tempo de voo do CERN”, by Pimenio Ferreira, Faculdade de Ciências de Lisboa, Universidade de Lisboa,

PROJECTS

- *CERN/FP/123602/2011*, Participation of ITN in the n_TOF ph2 experiment at CERN, Coordinator: Isabel Gonçalves (50%).
 - *ANDES*, (Accurate Nuclear Data for nuclear Energy Sustainability), Euraton Seventh Framework Programme Grant agreement 249671. Leading Institution: CIEMAT, Madrid, Spain. IST/ITN Coordinator: Isabel Gonçalves (20%)
 - *CHANDA*, (Solving Challenges In Nuclear Data For The Safety Of European Nuclear Facilities), Proposal for FP7-Fission-2013. Leading Institution: CIEMAT, Madrid, Spain. IST/ITN Coordinator: Isabel Gonçalves (10%)
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NAME: José Luís de Sousa Neves

CATEGORY: Auxiliary Researcher

IST-ID: 5368

ACTIVITIES

Nº	Activity Description	R&D (%)
1	Consulting, Design & Technical Assistance in the Field of Engineering Applications of Radiation and Radioisotopes 2013 Total Income: €14.894,85	40
2	FCT project “Increasing the energy efficiency of plasma conversion of methane”, PTDC/FIS-PLA/2135/2012, (starting 2013-01-01); Total Funding: €102.716,00	40
3	FCT project “Application of Ionizing Radiation for a Sustainable Environment “, (Project ARIAS), RECI/AAG-TEC/0400/2012, (starting 2013-01-01); Total Funding: €499.469,00	15
4	Science divulgation and teaching activities	5
Total		100

WORK SUMMARY

Nº	Work Summary and Main Achievements
1	<p>The main purposes of the project are the Design and Manufacture of Electronic Equipment, the Consulting Activities in the field of engineering applications and Technical Assistance. By request from internal groups and external customers, several electronic equipment and prototypes were designed (or upgraded) and manufactured. Furthermore, several maintenance and repair work as well as some calibration and quality control actions, were carried out on diverse nuclear instruments and equipment.</p> <p><i>Some examples:</i></p> <ul style="list-style-type: none">• Repair work on the high-tech lab equipment “Automatic Luminescence Reader Controller”, brand Risoe, mod. DA-15, for the ETN Group / Luminescence Dating Laboratory was carried out.• “RADX100” (Pocket Radiation Dosimeter) – 3 such equipment were produced and several maintenance and calibrations actions were carried out by request from internal groups and external customers.• “T6C M-CS Multi Micro-Current Source” – 1 equipment was produced for export (France). The “T6C M-CS Multi Micro-Current Source” is a user friend lab-equipment which offers high linearity and accuracy over a wide range of currents. DC micro-currents are very helpful in I&D activities, namely in electrochemist, optoelectronic and electromagnetic studies and experiments.
2	An automated system intended to manage and monitoring the Dielectric Barrier Discharge Reactor high voltage value, according with the temperature inside chamber (20°C - 600°C) was designed and produced. In addition, the system allows the simultaneous control of two commercial devices - the Mass Flow Meters brand EL-Flow® - through a personal computer.
3	<p>Linear Particle accelerator, LINAC</p> <p>Linacs have many applications: they can generate X-rays and high energy electrons for medicinal purposes, serve as particle injectors for higher-energy accelerators, and are used directly to achieve the highest kinetic energy for light particles (electrons and positrons) for particle physics.</p> <p>Technical support and some recovery works were carried out in order to fix/recuperate the all accelerator. One example is:</p> <p>The repair work of two Electromagnetic Electron Beam Collimators.</p>
4	<p>“Ciência Viva” Programme: Neutron Detection Experiment</p> <p>The neutrons generated by an Am-Be source are moderated with water or other proper material;</p>

	<p>then the resulting low energy neutrons are detected within a Helium-3 filled gas proportional detector. The resulting charges from the detector are collected and amplified to measureable electrical pulses with the amplitudes proportional to the neutron energy.</p> <p>An Educational kit intended to Neutron Detection experiments using an oscilloscope was designed and realized. The kit consists of a neutron Am-Be source, a Helium-3 filled gas proportional detector and some electronic circuits, as the commercial polarizing high voltage device (about 1250 V), the low voltage power supply and a special designed amplifier/integrator circuit.</p> <p>This educational kit was presented for the first time in a Ciência Viva event organized by The Évora University.</p>
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INTERNAL REPORT/SERVICES

- J. Manteigas, J. Neves, Consulting, Design and Technical Assistance in the Field of Engineering Applications of Radiation and Radioisotopes, Technical report, UFA/CTN/IST, 2012

NAME: Nuno Rombert Pinhão

CATEGORY: Auxiliary Researcher

IST-ID: 25379

ACTIVITIES

Nº	Activity Description	R&D (%)
1	Project AEECMP: PTDC/FIS-PLA/2135/2012	50
2	Development of software for non-thermal plasmas modelling	25
3	Teaching	15
4	Science management activities	10
Total		100

WORK SUMMARY

Nº	Work Summary and Main Achievements
1	<p>This project focus on improving the energy efficiency of Syngas (a H₂, CO and CO₂ mixture which is a key intermediate in the chemical industry) production in non-thermal plasma reactors, using a dielectric barrier discharge (DBD) configuration and mixtures of CH₄ with other gases. The project has started in June and the following tasks have been completed or are under way:</p> <p>a) Project, construction and testing of a high temperature DBD reactor to study the study of the influence of gas temperature on methane conversion and products selectivity (completed);</p> <p>b) Development of a temperature controlled sinusoidal power supply and associated control software (completed);</p> <p>c) Study of the influence of the vibrationally excited population on dissociation and stepwise ionization in CH₄ mixtures;</p> <p>d) Modelling the chemical kinetics of plasma methane conversion;</p> <p>e) Development of a fast pulsed power supply.</p>
2	<p>A Boltzmann code based on the density gradients representation for the electron velocity distribution in gases has been extended to include:</p> <p>a) A Python interpreter allowing the reading of the electron cross section collision cross sections defined by an analytical function;</p> <p>b) The effect of vibrationally excited population in the collision term, with corresponding approximations for the cross sections of these levels;</p> <p>c) The effect of multi-step processes on the collision term;</p> <p>d) Improved debugging and reporting facilities and extended tests of model gases allowing to benchmark this code in comparison with others;</p> <p>e) An update of the main algorithm exploiting parallel processing in order to take advantage of current multi-core processors.</p>
3	Collaboration on teaching of a graduation course (“Mecânica e Ondas”) for the “Licenciatura em

	Eng. Informática e Comunicações"/IST, 2 nd semester. Co-responsible for the revision and development of exercise materials.
4	Member of "Assembleia de Escola" / IST

COMMUNICATIONS

- *Plasma-assisted conversion of methane and carbon dioxide: myths, challenges and opportunities*, N. Pinhão, A. Janeco, J. Branco, L. Redondo, V. Guerra, A. Moura, *5th Central European Symposium of Plasma Chemistry, Balatonalmádi, Hungary, 25-29 Aug (2013)*, Invited Talk.
- *Effect of small admixture of H₂O on the electron drift velocity in argon: experimental measurements and calculations* M. Kucera, D. Loffhagen, Z. Donko, N. Pinhao M. Stano, S. Matejcik, *XXXI International Conference on Physics of Ionized Gases, Granada, Spain, 14-19 July (2013)*, poster.
- *Electron kinetics in mixtures of CH₄, CO₂ and He, with formation of H₂ and CO: the effects of composition and vibrational temperature*, A. Janeco, N. Pinhão, V. Guerra, *XXXI International Conference on Physics of Ionized Gases, Granada, Spain, 14-19 July (2013)*, poster.

EDUCATION

- Course: "Mecânica e Ondas" for LEIC graduation: Problems classes. 2nd semester 2013.
- Jury membership: Miguel Ângelo Correia dos Santos, *Microwave Capillary Discharges in Helium at Atmospheric Pressure*, 2013. Master thesis
- Jury membership: André Filipe de Sousa Pinto, *Modelo Cinético da Ionosfera*, 2013. Master thesis.

PROJECTS

- *Increasing the energy efficiency of plasma conversion of methane*, FCT project, contract PTDC/FIS-PLA/2135/2012, IST/ITN Coordinator: N. Pinhão (60%)

FUNDS

- Project AEECMP, ref: PTDC/FIS-PLA/2135/2012. IST-ID Budget for 2013: 39.737,00 €, FCT granted in 2013: 15.407,40 €.