Nuclear Instruments and Methods

José Salgado

The strategy of the group involves activities in the following lines:

1. Modelling of radiation fields, calculation of neutron physic parameters, measurement of neutron cross-sections;
2. Design of electronic instrumentation for nuclear applications;
3. Application of electrical discharges in materials and environmental areas;
4. Technical assistance in nuclear instrumentation.

Modelling of radiation fields, calculation of neutron physic parameters

The presence of a sample in the neutron field of a nuclear reactor creates a perturbation of the local neutron fluxes. In general, the interpretation of the sample activation due to thermal and epithermal neutrons requires the knowledge of two corrective parameters: the thermal neutron self-shielding factor, G_{th}, and the resonance neutron self-shielding factor, G_{res}. Thermal neutron self-shielding factors in different materials (Al, Au, Cd, Co, Cu, Eu, Gd, In, Ir, Mo, Ni, Pt, Pb, Rh, Sc, Sm and Ta) and different geometries (foils, wires, spheres and) have been calculated by using the MCNP code.

It was shown that an adimensional variable, *z*, can be introduced ($z=\Sigma_t(E_{res}).x.(\Sigma_a/\Sigma_t)^{0.85}$), which converts the dependence of the resonance self-shielding factor on physical and nuclear parameters into a universal curve, valid for all materials.

Monte Carlo calculations have been carried out in the field of the projects n-TOF POCTI-49557/FNU/2002 and Preliminary design of an Accelerator Driven System- PDS-XADS_FIS-2001-00089, which will be reported elsewhere in this Progress Report.

Measurement of neutron cross-sections

There is also participation in the campaigns for the measurement of cross-sections in the TOF spectrometer installed at the CERN. This activity will be reported elsewhere in this Progress Report.

Design of electronic instrumentation

Some electronic modules have been designed and produced for the neutron spectrometers installed at the RPI.

The Group participates in the construction of a set of voltage dividers for a barium fluoride calorimeter for the CERN TOF spectrometer.

Electrical Discharges on Environment and Material Processing Applications

Cold plasmas have a significant impact in material processing and environment applications. The activity on this area has been divided between numerical simulation and experimental research.

Numerical modeling: Comparison of different methods for the solution of the electron Boltzmann equation. Extension of a code to solve the electron Boltzmann equation and a chemical kinetics library to include photon-electron collisions. Application of a simulated annealing method to the optimization of electron collision cross sections. Development of a model to simulate the plasma plume obtained in laser ablation of graphite.

Experimental Work: Characterisation of the pulses obtained in a dielectric barrier discharge system. Simultaneous measurement of the light emission in the UV-visible range and the mass spectra obtained in laser ablation of graphite.

Instrumentation and Technical Assistance

The main objectives are the development of equipment for internal groups, fabrication of equipment for specific applications and assistance to industrial companies and scientific institutions as well as technical consulting.

The technical assistance takes mainly the forms of specialized consultant engineering advice, installation of nuclear gauges, including calibration maintenance and repair and recharging of gauges with imported radioactive sources.

Co-operation with other institutions

The Group is involved in the following collaborations:

1. n_TOF collaboration, a consortium of 40 laboratories in Europe and USA;
2. Accelerator Driven System (PDS-XADS – FIS5-2001-00089;
3. Department of Automation and Electric Engineering, Instituto Superior de Engenharia de Lisboa;
4. Sociedade Ponto Verde
5. Research Laboratory for Materials and Environmental Chemistry, CRC, Hungarian Academy of Sciences;
6. Institute of Fluid-Flow Machinery, Poland.

Nuclear Instruments and Methods

Research Team

Researchers

- J. SALGADO, Coord. Researcher, Group Leader (85%)
- F. G. CARVALHO, Coord. Researcher (15%)
- J. MANTEIGAS, Auxiliary Researcher (70%)
- I. F. GONÇALVES, Auxiliary Researcher (100%)
- J. NEVES, Auxiliary Researcher (80%)
- C. CRUZ, Auxiliary Researcher (80%)
- N. PINHÃO, Auxiliary Researcher (100%)

Students

- T.L.P. SANTOS, last year student, Mathematics degree, FCT/UNL
- S.R.P.V. ILDEFONSO, last year student, Mathematics degree, FCT/UNL

Technical Personnel

- T. JESUS
- N. INÁCIO

Funding (€)

Research Projects:	1.460,00
Services:	17.847,90
Total:	**19.307,90**

Publications

Books:	0
Journals:	1 and 4 in press
Proceedings:	2
Conf. Communications:	3
Other publications:	0
Theses:	0
Graduation	2

Calculation of thermal and resonance neutron self-shielding factors in foils, wires, spheres and cylinders

Isabel F. Gonçalves, José Salgado, Eduardo Martinho*

Objectives

The presence of a sample in the neutron field of a nuclear reactor creates a perturbation of the local neutron fluxes. In general, the interpretation of the sample activation due to thermal and epithermal neutrons requires the knowledge of two corrective parameters: the thermal neutron self-shielding factor, G_{th}, and the resonance neutron self-shielding factor, G_{res}. This work deals with *(a)* the calculation of G_{th} and G_{res} in foils, wires, spheres and cylinders, *(b)* the description of these parameters by means of two universal curves on the basis of a dimensionless variable which includes the physical, nuclear and geometrical properties of the sample.

Results

The self-shielding factors depend on the geometrical, physical and nuclear properties of the material as well as on the typical dimension of the sample, as is shown in Figure 1 for G_{th} for wires. Similar results were obtained for foils, spheres and cylinders and for the resonance self-shielding factor.

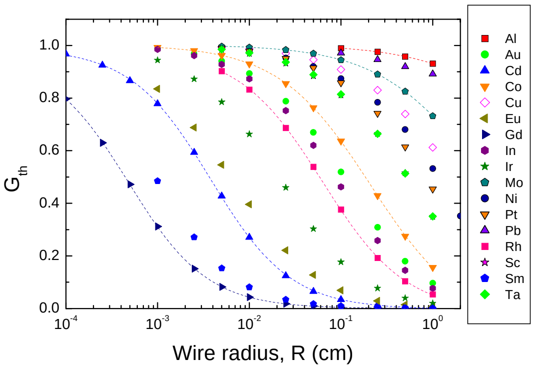

Figure 1 – Thermal neutron self-shielding factor for wires as a function of the wire radius.

The self-shielding factors were calculated using the MCNP code.

The analysis of the results also shows that two universal curves can be fitted to the calculated $G_{th}(z)$ and $G_{res}(z)$ values, where z is a dimensionless variable that takes into account the physical, nuclear and geometrical properties of the samples [1-4].

Figure 2 shows the universal curve for the thermal self-shielding factor, valid for spheres, wires, foils and cylinders.

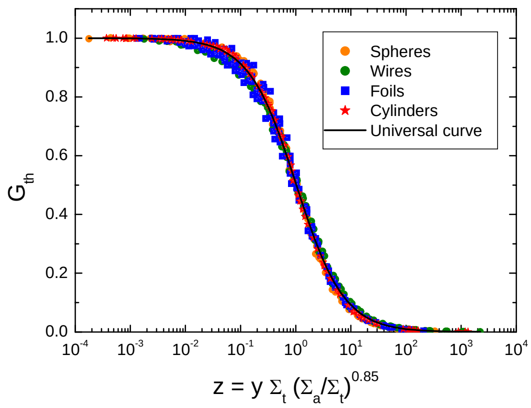

Figure 2 – Universal curve of G_{th} as a function of the dimensionless variable $z = y.\Sigma_t.(\Sigma_a/\Sigma_t)^{0.85}$ where y=1.5 t for foils; y=2.0 R for wires; y=1.6 $rh/(r+h)$ for cylinders; and $y=R$ for spheres

Comparison of this curve with experimental and calculated values obtained from the literature shows a good agreement.

Published, accepted or in press work

1. E. Martinho, J. Salgado, I.F. Gonçalves, Universal curve of the thermal neutron self-shielding factor in foils, wires, spheres and cylinders, *Journal of Radioanalytical and Nuclear Chemistry* (submited).
2. I.F. Gonçalves, E. Martinho, J. Salgado, Thermal neutron self-shielding factor in foils: a universal curve, International Conference on Research Reactor Utilization, Safety, Decommissioning, Fuel and Waste Management, 10-14 November 2003, Santiago, Chile, IAEA-CN.
3. J. Salgado, I. F. Gonçalves, E. Martinho, Development of a unique curve for thermal neutron self-shielding factor in spherical scattering materials, *Nuclear Science and Engineering* (accepted).
4. J. Salgado, E. Martinho, I. F. Gonçalves, Methodology for calculation of neutron self-shielding factors of a group of isolated resonances, Journal of Radioanalytical *and Nuclear Chemistry* (in press).

* Reactor Sector, Retired Researcher.

Electrical Discharges on Environmental and Material Processing Applications

N.R. Pinhão, T.P. Santos[1], S.P.V. Ildefonso[1]

Objectives

The main objective of this project is the use of cold plasmas in applied fields. As research and development in this domain is heavily based on numerical modelling as well as on experimental work, one goal has been to establish a solid experience on numerical modeling. The development of self-consistent discharge models requires an accurate description of electron kinetics, through the solution of the Boltzmann equation, the evaluation of chemical kinetics and the transport of species in the plasma.

At the same time experimental equipment for handling gas mixtures, electric measurements and mass spectrometry has been installed in the framework of an experimental project.

Results

Numerical modelling

- The code-developed for the solution of the steady-state electron Boltzmann equation in cold plasmas has been extended to include photon-electron collisions.
- The chemical kinetics library previously developed has been extended to include photon-electron reactions; extended support for reactions with vibrational species; extended support for three-body reactions and a simplified syntax for the data input file.
- In the framework of an international cooperation, different representations of the electron energy distribution function, EEDF, and numerical methods have been compared for a pulsed Townsend discharge (see Figure).
- The study of optimization methods for automatic fitting of electron cross sections in gases has continued with the application of a simulated annealing algorithm and the study by Bayesian inference of the errors on the cross sections obtained.
- The modelling of the plasma plume obtained by laser ablation of graphite has progressed with the selection of carbon cross sections and the development of a chemical kinetics model.
- The simulation of a glow discharge in N_2 with a carbon cathode to the production of CN and CN_x thin films has been completed.

Experimental results

- Preliminary data has been obtained for the characterisation of the plasma plume produced on laser ablation of graphite by simultaneous measurement of the light emission in the UV-visible and mass spectra, both for positive and negative ions.
- Electrical measurements have been done on a dielectric discharge barrier system for gas cleaning.

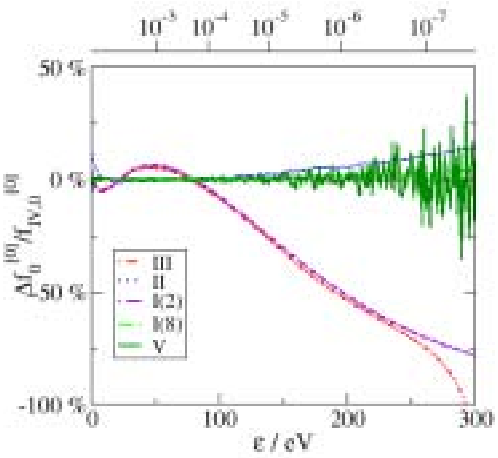

Figure - Relative error of the isotropic component of the EEDF in neon at 500 Td obtained by different techniques, taking the ITN results as reference.

Published, accepted or in press work

1. M.J. Pinheiro, B.F. Gordiets, N.R. Pinhão, Low Pressure Nitrogen Glow Discharge with Graphite Electrodes, *ISPC-16, Taormina, Italy, June 2003*.
2. A.G. Baptista, N.R. Pinhão, High Voltage Power Supply for Pollutants Treatment, *8th Portuguese-Spanish Congress on Electrical Engineering, Vilamoura, Portugal, July 2003*, (poster).
3. N.R. Pinhão, Z.Donkó, D. Loffhagen, E.A. Richley, M.J. Pinheiro, Comparison of Kinetic Calculation Techniques for a Pulsed Townsend Discharge, *GEC 2003, San Francisco, USA, October 2003*, (poster).

[1] Last year student, Mathematics degree, FCT/UNL

Final design of the ITN voltage divider for the TAC array

C. Cruz, J. Neves, P. Vaz, M. Heil[1], F. Käppeler[1], M. Mosconi[1], K. Wisshak[1]

[1] FzK – Forschungszentrum Karlsruhe, Germany

Objectives

The objective of this project is the construction of voltage dividers for calorimeter modules' photomultipliers. The photomultipliers will be associated to barium fluoride crystals for the CERN TOF spectrometer.

A new prototype has been designed, which presents some improvements.

Results

Two important improvements in the design of a new voltage divider for photomultipliers [1] are summarized below:

1) The range for adjusting the potential of the first focusing electrode (G1) was significantly extended as to allow for finding the real optimum of the pulse height and, hence, of the resolution. It was verified that the voltage divider (VD) is no longer affecting the energy resolution, which is completely determined by the respective photomultiplier (PM) and by the BaF_2 crystal. Fig. 1 shows an example of the measured spectrum for a $^{137}Cs/^{60}Co$ source.

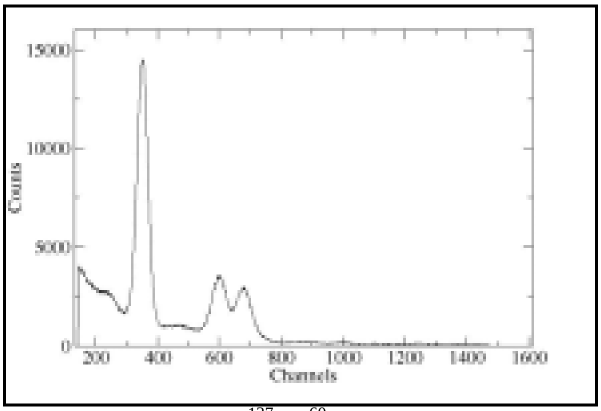

Fig. 1: Spectrum for a $^{137}Cs/^{60}Co$ source. An energy resolution of 11.1 % for the ^{137}Cs line at 662 keV was achieved

2) The bump on the tail of the pulses, which is obvious for the n_TOF flash as well as for signals produced by cosmic ray muons (Figs.2) has been understood as being due to feedback from the 6th dynode, which was electrically connected to the second focus electrode (G2) for obtaining the proper potential. This effect was eliminated by a second modification of the wiring circuit.

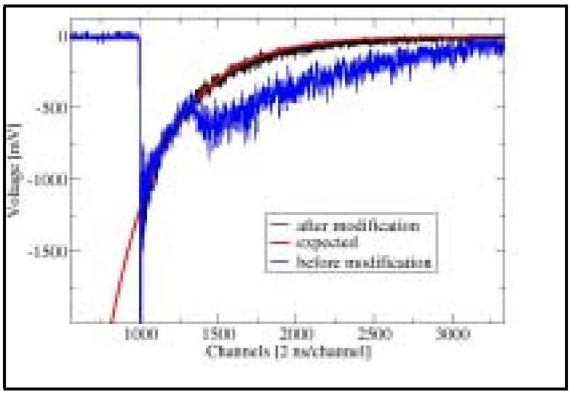

Fig. 3: The blue and the black signal show the response of the detector for a cosmic muon event before and after the modifications, respectively. With the new design we see no bump on the tail of the signal. The red line shows an exponential curve with the decay time of the scintillator.

3) As the result of the successful test measurements, it was agreed to freeze the present design and to adopt it for the TAC modules.

4) The final VD will have three adjustable voltages, for the focus electrodes G1 and G2 as well as for the first dynode D2. All three adjustments can be made externally via knobs on the rear side of the VD. These knobs will be designed such as to prevent accidental misadjustments. There will be also an internal cover plate to prevent light leaks through the VD towards the PM.

5) The VD will be equipped with 2 SHV connectors for the high voltage cables and 1 BNC connector for the anode signal.

Published, accepted or in press work

1. C. Cruz, J. Neves, P. Vaz M. Heil, F. Käppeler, M. Mosconi, K. Wisshak, Final design of the ITN voltage divider for the TAC array, Internal n_TOF Note (2003), to be submitted to NIMA.

Technical Assistance in the Field of Engineering Applications of Radiation and Radioisotopes

J. B. Manteigas, J. Neves, C. Cruz, N. Pinhão, F.G. Carvalho, J. Salgado

Objectives

The main objectives are the development of equipment for internal groups, fabrication of equipment for specific applications and assistance to industrial companies and scientific institutions as well as technical consulting.

Results

A summary of the more relevant work carried out is:

(i) Technical and scientific participation in the n-TOF (PS213) experiment at CERN.

(ii) Support in electronics for nuclear instrumentation (development and maintenance) to DPSR, Physics Sector, UTR and Reactor.

(iii) Technical and scientific collaboration in testing equipment for the "CERN Large Hadron Collider" under contract agreement between ITN and VELAN.

A summary of the more relevant services rendered in 2003 is presented below.

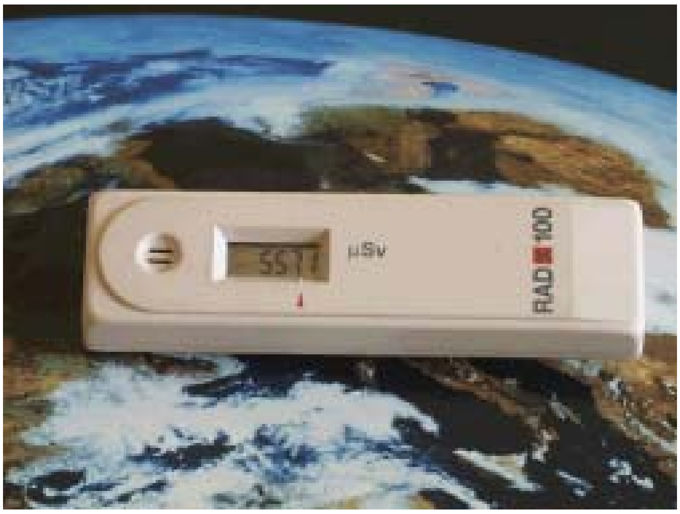

Figure: Lightweight personal Radiation Dosemeter, made in ITN

Summary of the more relevant services rendered in 2003

Activity	Quantity	Client	Price*(Eur)
Supply of plating electrode disks	500	ITN/DPRSN	300,00
Platinum electrodes	4	ITN/DPRSN	70,00
Laboratory equipment for the determination of radioactive element traces by electrodeposition	1	Gammadata (Suécia)	1150,00
Measuring and control of source activities	27	SOPORCEL	2300,00
Storage of radioactive sources	7	GALP Serviços, Porto	1414,00
Supply of RAD X 100 Dosemeters	1 7	PRONUCLEAR (H. Distrital Lamego) Arsenal do Alfeite	300,00 3500,00
Supply of technical *software*	1	RLMEC (Hungria)	903,33
Technical assistance to - RAD X 100	2 1 1 2	Arsenal do Alfeite ITN/Reactor ITN/UTR PRONUCLEAR	45,00 100,00 75,00 25,00
Technical assistance to - Source Containers	1 2 2	TECNISIS/Endress Hauser PORTUCEL/Cacia PORTUCEL/Tejo	475,00 1500,00 1000,00
Technical assistance to - Criogenic Valves	260	VELAN	6000,00
		Total Amount (EURO)	**19 157,33**

* PRICES DO NOT INCLUDE TAX (IVA)

Technical Assistance in the Field of Security Control

P. Marques, J. Manteigas, M. R. da Silva[1]

Objectives

The objective of this project is to provide technical and scientific collaboration in testing 400 cryogenic security valves for the “CERN Large Hadron Collider” under Contract agreement between ITN and VELAN Portuguesa – Valves constructor.

Results

The bodies of the valves are being tested according to the following procedures:

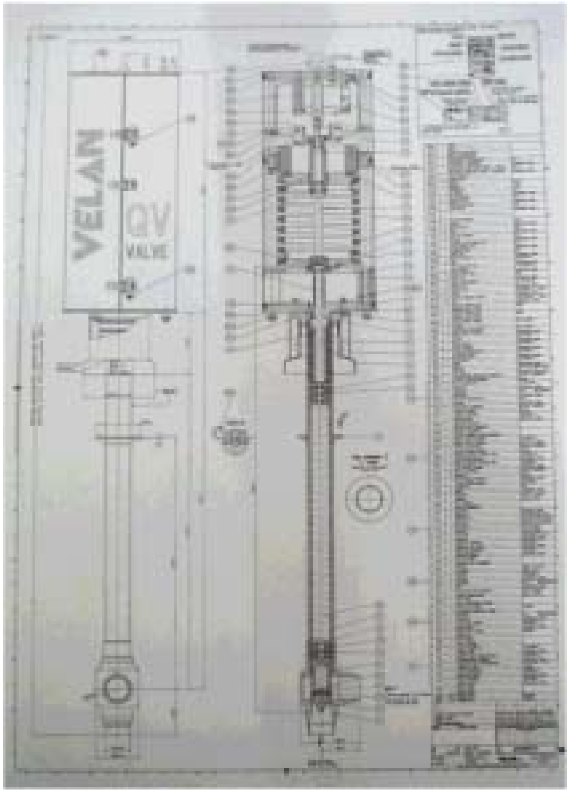

Figure 1 – Project of the valve

1. **Sub-zero treatment** – The body of the valve is submitted to a thermal shock with liquid nitrogen at a temperature of 77 K (- 156 ºC), during ten minutes.
2. **Helium leak detection –** The body of the valve is placed inside a vacuum chamber (10^{-4} mbar). A 20 bar helium pressure is then created inside the body. The body of the valve is tested with a helium leak detector at a leak rate of 10^{-9} mbar.l/s, during ten minutes.

Figure 2 – Stainless steel valve

This year 260 valves have been tested successfully so far.

Tests are carried out in a room that was adapted from a former “Cokcroft Accelerator”. This facility is now prepared to attend to future orders from clients of the industry, in order to perform tests of stanching in welding, using a high vacuum chamber.

[1] Centro de Física Nuclear da Universidade de Lisboa