ANNUAL REPORT 2020

Scientific and Technical Activities

Laboratório de Aceleradores e Tecnologias de Radiação (LATR)

Laboratory of Accelerators and Radiation Technologies
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Cover Photo: Coronavirus and UTR Facility.

Date: July 2021

Foreword

Laboratory of Accelerators and Radiation Technologies (Laboratório de Aceleradores e Tecnologias de Radiação, LATR) is a Laboratory of Technological Development (LDT) of Instituto Superior Técnico (IST) conducting services and research activities in the area of charged particle beams and radiation technologies.

Among the major equipment, it hosts a 2.5 MV Van de Graaff Accelerator with an Ion Microprobe end-station, a 3 MV Tandem Accelerator with a micro-AMS system and a 210 kV High Flux Ion Implanter as well as a semi-industrial ^{60}Co gamma radiation Unit.

Around these devices different groups of users develop their activities, from research to industrial applications (as it is the case of irradiation services performed at the ^{60}Co source), focused on areas related with Material Science, Environment, Health and Biomedical Sciences and Conservation and Cultural Heritage.

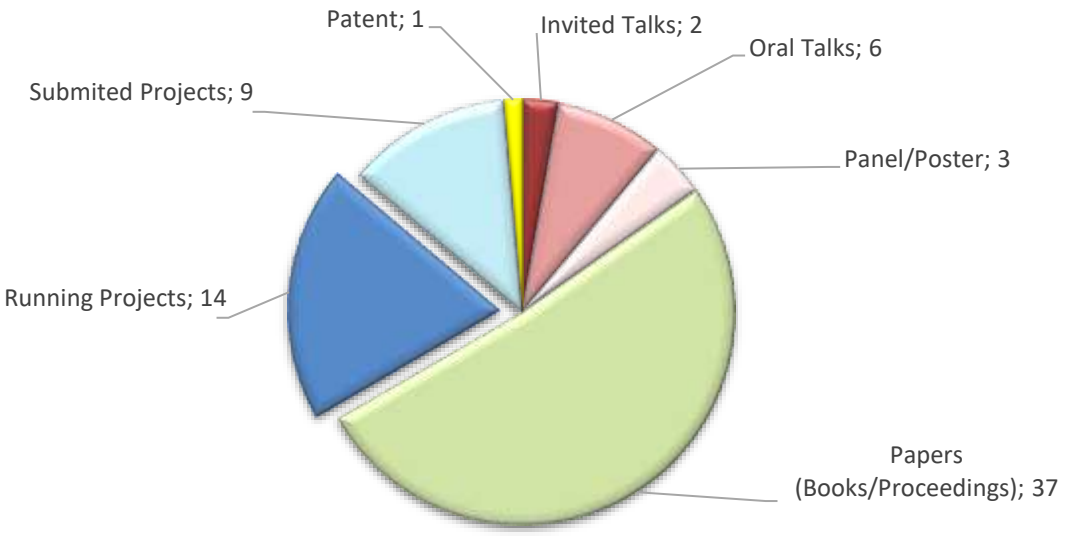
These broad ranges of applications promote and attract strategic collaborations with several institutions and universities, both national and international. Alongside these activities, strong emphasis is continuously put on postgraduate teaching and training, by actively enrolling graduate students in research activities, leading to masters and doctoral theses.

In 2020, facing SARS-CoV-2 (COVID-19) restrictions, LATR operated below 50 percent of normal capacity. Even though, it was still possible to pursue some research activities and services for the Industry and Health Units helping on the national effort to combat the Pandemic.

All the LATR members belong to the Department of Engineering and Nuclear Sciences (Departamento de Engenharia e Ciências Nucleares, DECN) and during 2020 gave their contribution for the outputs on R&D and technical services highlighted in the next pages.

LATR in Numbers

R&D 2020

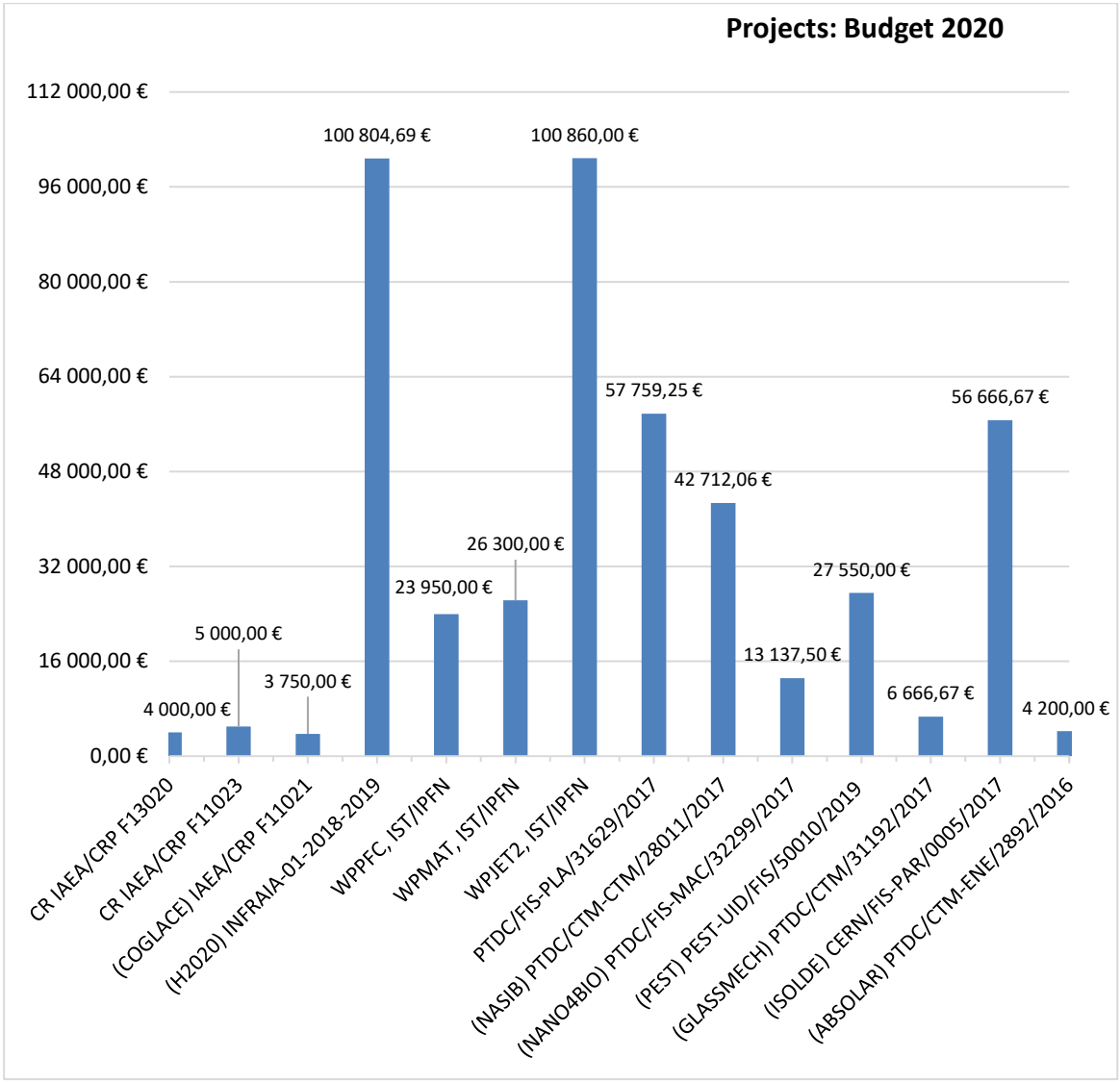


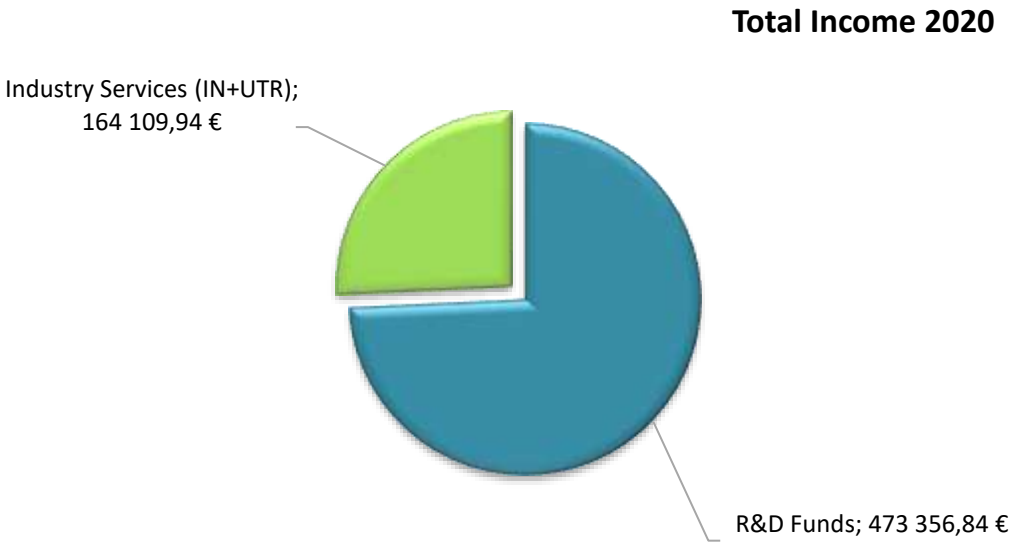
Running Projects 2020

€ 473.356,84

Education 2020

MSc Theses 2.


Projects: Budget 2020
112 000,00 €
96 000,00 €
80 000,00 €
64 000,00 €
48 000,00 €
32 000,00 €
16 000,00 €
0,00 €
4 000,00 €
5 000,00 €
3 750,00 €
100 804,69 €
23 950,00 €
26 300,00 €
100 860,00 €
57 759,25 €
42 712,06 €
13 137,50 €
27 550,00 €
6 666,67 €
56 666,67 €
4 200,00 €
CR IAEA/CRP F13020
CR IAEA/CRP F11023
(COGLACE) IAEA/CRP F11021
(H2020) INFRAIA-01-2018-2019
WPPFC, IST/IPFN
WPMAT, IST/IPFN
WPJET2, IST/IPFN
PTDC/FIS-PLA/31629/2017
(NASIB) PTDC/CTM-CTM/28011/2017
(NANO4BIO) PTDC/FIS-MAC/32299/2017
(PEST) PEST-UID/FIS/50010/2019
(GLASSMECH) PTDC/CTM/31192/2017
(ISOLDE) CERN/FIS-PAR/0005/2017
(ABSOLAR) PTDC/CTM-ENE/2892/2016


Total Income 2020
Industry Services (IN+UTR); 164 109,94 €
R&D Funds; 473 356,84 €

RESEARCH
&
DEVELOPMENT

Ion Beam Applications

R&D | ION BEAM LABORATORY

The research and development activities at the Ion Beam Laboratory of LATR in the last years were focused on four large areas.

A major activity is running under the ***European Fusion Programme***, where the unique experimental set-up installed in the laboratory allowed the measurement of full tiles from the JET Reactor. We are the unique laboratory in the world offering this possibility, producing significant scientific outputs for the fusion programme. The results have been acknowledge by the International Community and evaluated in terms of high quality and impact.

Other important activity, well recognized among our peers by the relevance and novelty of the results, is the ***Study and Development of Wide Band Gap Nanostructures and New Detection Systems***. This work is integrated in the *Joint Research Activities of the RADIATE Project* (http://www.ctn.tecnico.ulisboa.pt/ipfn/PROJ-WBGM.html) where IST (LATR) plays an important role. In 2020 it was approved new funding allowing LATR to offer Transnational Access to Ion Beam Techniques by external users.

A third activity with a strong societal impact is the application of ***Ion Beam Technologies in Biomedicine, Cultural Heritage and Conservation and Restoration***. The laboratory has a long-standing collaboration with the Department of Conservation and Restoration from FCT-UNL focused on the study of historical glazed tiles, glasses and stained glasses among other cultural objects.

Finally, the members and collaborators of LATR are involved on the ***Development and Installation of New Equipment and Techniques*** to keep the laboratory equipped with *State of the Art technology on its field*.

TEAM

Name	Category	Affiliation
Eduardo Alves	Full Researcher (LATR)	DECN/IPFN
Katharina Lorenz	Senior Researcher (LATR)	DECN/INESC-MN
Rui Silva	Senior Researcher (LATR)	DECN/IPFN
Carlos Cruz	Auxiliary Researcher (LATR)	DECN/IPFN
Luís Alves	Auxiliary Researcher (LATR)	DECN/C^{2}TN
Rodrigo Mateus	Auxiliary Researcher (Collaborator)	DECN/IPFN
Victoria Corregidor	Auxiliary Researcher (Collaborator)	DECN/C^{2}TN
Hélio Luís	Researcher (Collaborator)	IPFN/DL57 Contract
Marta Dias	Researcher (Collaborator)	IPFN/DL57 Contract
Marco Peres	Researcher (Collaborator)	IPFN/DL57 Contract
Norberto Catarino	Researcher (Collaborator)	IPFN/Project Contract
Sérgio Magalhães	Researcher (Collaborator)	IPFN/DL57 Contract
Przemyslaw Adam Jozwik	Researcher (Collaborator)	IPFN/Project Contract
Chamseddine Bouhafs	RADIATE Postdoctoral Scholarship	IPFN
Daniela Pereira	PhD Scholarship	INESC-MN
Miguel C. Sequeira	PhD Scholarship	IPFN
Dirkjan Verheij	PhD Scholarship	IPFN
Ana Maria Ferreira Ribeiro	MSc Student	IPFN
Ricardo Jorge Clemente Martins	PhD, Research Grant	IPFN
Jorge Rocha	Graduated Technician	DECN/LATR
Ana Faria, Secretary, Income/Logistics	Graduated Technician	DECN/LATR
Teresa Pires, Web Designer/Logistics	Graduated Technician	DECN
Joana Filipa Tomé Flora	Technician Grant (accelerators)	LATR

Plasma wall interactions in JET ITER Like Wall

N. Catarino, C. Cruz, R. Silva, E. Alves

ITER Like Wall of JET gave the possibility to study most of the plasma wall interactions relevant to establish the operating conditions for the International Thermonuclear Experimental Reactor (ITER). Evaluation of material migration, erosion/deposition and fuel retention processes have been used to validate theoretical models and provide the relevant figures to design a safe reactor. During the last two years, we measured a large number of components and passive diagnostics removed from JET to get the necessary data to model the interactions. Moreover, we also used some mixed coatings produced in laboratory to study fuel trapping and mixing mechanism. JET had completed three operating periods, ILW1, ILW2 and ILW3, giving an opportunity to make comparisons between tiles exposed to different plasma regimes and compare tiles exposed for all the three periods, ILW1-3 (2011-2016).

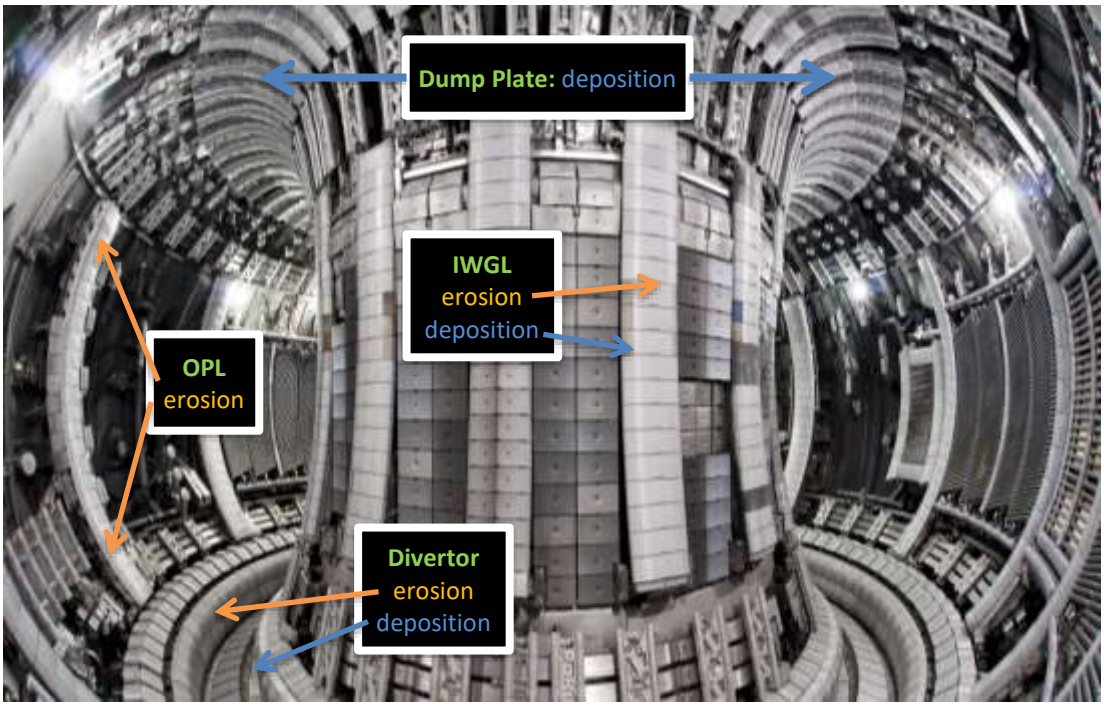


Figure 1: JET vessel indicating the regions where the major plasma wall interactions occur.

Our results give updated fuel inventories and provide comparisons of individual mid-plane limiter tiles exposed during ILW1, ILW2, ILW3 with ones exposed throughout the full operation, ILW1-3. For example, results for D concentration in deposits at the ends of the mid-plane IWGL tile are of the order of 0.1-1 x 10^{18} D/cm^2 for tiles exposed in individual campaign, whereas results from a tile exposed for all campaigns show D concentrations at least a factor of three higher. This indicates continuous accumulation of fuel in deposits, with no release due to heating. In the central eroded region, exposed to highest heat flux, retention values remain low for all tiles analysed.

Analysis of IBA data from ILW1, ILW2, ILW3 along the inner and outer wall limiters extending poloidally show the complex fuel retention and erosion/deposition pattern from the top to the bottom of the vessel, fig.1. Most interaction occurs in the central region, which correlates with the heat flux patterns seen from infra-red cameras.

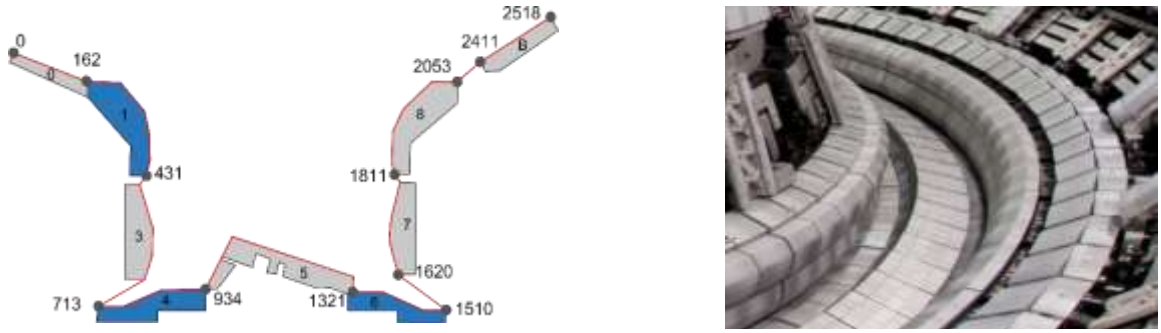


Figure 2: Schema of divertor tiles of JET chamber shown in the righ panel.

In addition, divertor tiles, fig.2, reveal a similar deposition patterns after each individual campaign. The cumulative results after the three campaigns show a major deposition of Be and D on top of tile 1. Shadowed areas of tile 4 reveal the presence of different impurities (C and O) as well as Be and D. A detailed overview of all the results can be found in the contributions presented at conferences and published in reference journals.

Liquid metal walls for plasma reactors (LMwalls)

R. Mateus, N. Catarino

This is a research activity supported by a FCT grant. Lithium-Tin (Li-Sn) alloys with low Li contents are being developed to be used as protective coatings of tungsten plasma-facing-components (W PFC). In this sense, W PFC´s (in the project, pure W meshes) were wetted by the alloys in the liquid state. Afterwards, the wetted samples will be irradiated in ISTTOK tokamak. The irradiation effects as well as the deuterium retention and the protective behaviour of a liquid Li-Sn cover in the W material will be investigated. Since Li materials react fast with air, the samples before and after irradiation in ISTTOK are transported either in vacuum or under an argon atmosphere. Some of the related work was reported and published in scientific journals and proceedings.

The activity was delayed in 2020 by the pandemic.

Figure 1: Experimental mounting for IBA analysis.

Development of mixed-material reference coating for fusion studies

R. Mateus, R. Silva, E. Alves

Several beryllium-based (Be-based) and tungsten-based (W-based) coatings, most of them co-deposited with deuterium (2H, D) were produced on W or Mo plates, respectively, by High Power Impulse Magnetron Sputtering (HiPIMS) at IAP Bucharest (Romenia), under a wide range of temperatures, from room temperature up to 400 ºC.

Some coatings were co-deposited under a regime temperature mimicking the environment in the Joint European Torus tokamak discharges (JET-like pulses), or in W plates having distinct average roughness.

The deposition parameters were tuned to obtain nominal D contents of 5 at.% and 10 at.% and nominal thicknesses of 5 μm. Ion beam analytical techniques, namely Rutherford backscattering spectrometry (RBS), elastic backscattering spectrometry (EBS) and nuclear reaction analysis (NRA) were used to investigate the role of carbon (C), nitrogen (N), oxygen (O) and neon (Ne) contents in the retention mechanisms of D, fig.1.

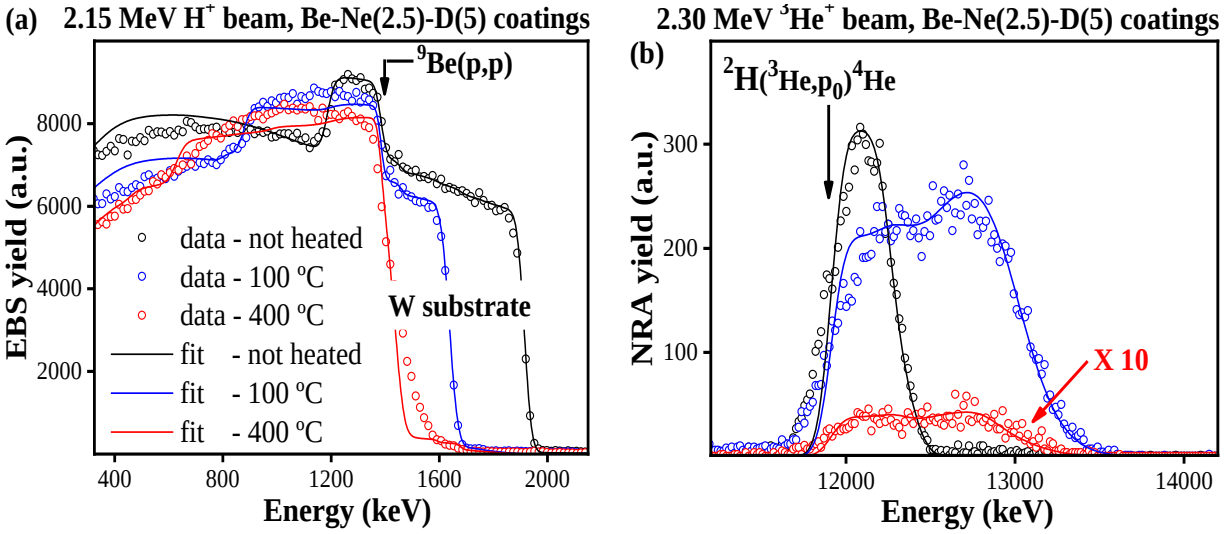


Figure 1: Example with the analysis of **Be+Ne(2.5)+D(5)** coatings: EBS analysis with 2.15 MeV H^+ ion beams (a) and NRA analysis with a 2.30 MeV $^3H^+$ ion beam (b).

High entropy alloys and thermal barriers for fusion nuclear reactors

M. Dias, R. Martins, S. Magalhães

The activities during this period were focused on the development of thermal barriers for nuclear fusion following two approaches: (i) thermal barriers materials made of refractory metals CrNbTaVW and (ii) production of Cu and W based high entropy alloys.

CrNbTaVW equiatomic high entropy alloys have been devised for thermal barriers between the plasma-facing tungsten tiles and the copper-based heat sink in the first wall of fusion nuclear reactors.

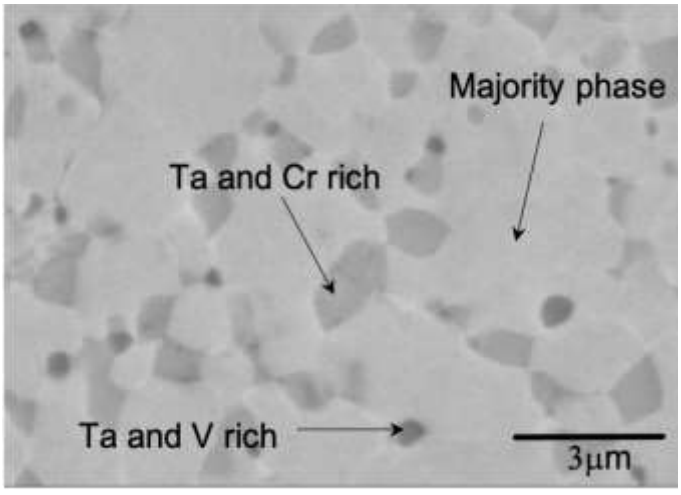


Figure 1: SEM image of the CrNbTaVW sample.

These novel materials were prepared by ball milling and consolidated by *Upgrade Field Assisted Sintering Technology* at 1873 K under a pressure of 90 MPa.

Structural properties together with electrical, magnetic and mechanical behaviours of these samples were evaluated. After 2 hours of milling the sample, evidence the formation of a bcc-type structure with a minor fraction of WC. The X-ray analysis of the consolidated material suggests that the alloy can be described as two different bcc-type structures with different lattice parameters.

Moreover, the microstructure observations revealed the presence of a majority phase with an equiatomic composition of the elements together with two minor phases. The alloy is endowed with an electrical resistivity typical of an high entropy alloy along with an antiferromagnetic behaviour.

Mechanical properties of the CrNbTaVW system, fig.1, were assessed in the fields of hardness, elastic modulus and flexural strength. The high entropy alloy reaches an elastic modulus of 328 GPa, with a room temperature ultimate flexural strength of 293 MPa and a transgranular fracture mechanism. WTaTiFeCu in an equiatomic proportion was ball milled in a tungsten carbide container using ethanol as a process control agent. However, the XRD results indicate the formation of Ta hydride and a big contamination of WC. The optimization is now an on-going process.

Ion solid interaction in wide bandgap semiconductors and sensor development

D.R. Pereira, D. Verheij, M. C. Sequeira, M. Peres, D. Nd. Faye, P. Jozwik, S. Magalhães, L. C. Alves, C. Cruz, J.G. Marques, E. Alves, C. Díaz-Guerra, F. Djurabekova, K. Nordlund, N. Ben Sedrine, T. Monteiro, M. R. Correia, S. Cardoso, P.P. Freitas, C. Durand, J. Eymery, J. Fernandes, K. Lorenz

Within the projects NASIB and RADIATE, in collaboration with the Universities of Aveiro, Complutense Madrid and Helsinki, CEA Grenoble and INESC-MN, we are studying the effects of ion irradiation on wide bandgap semiconductors such as GaN, MoO_3 and Ga_2O_3. Understanding ion-solid interactions in semiconductors is important to develop device-processing techniques based on ion implantation as well as to understand the performance of different semiconductors in radiation environments such as space. Figure 1 shows the strain and static Debye Waller factor extracted from X-ray diffraction (XRD) patterns of oxygen implanted MoO_3. Careful fitting of the experimental curves allows the estimation of the uncertainties in these parameters [1]. Activities on understanding swift heavy ion irradiation of III-nitrides have continued. Furthermore, GaN microwires were processed into single-wire devices by depositing metallic contacts on their extremities (fig. 2). These devices showed efficient detection of UV light and energetic protons [2].

[1] D. R. Pereira et al., NIMB 478 (2020) 290–296.
[2] D. Verheij et al., EPJ Web of Conferences 233 (2020) 05001.

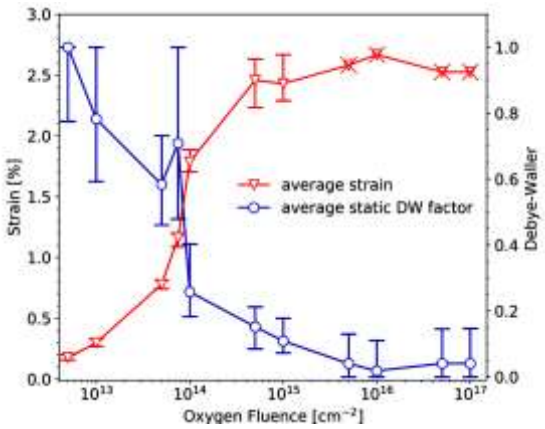


Figure 1: Strain and static Debye Waller factor extracted from XRD curves of oxygen implanted MoO_3.

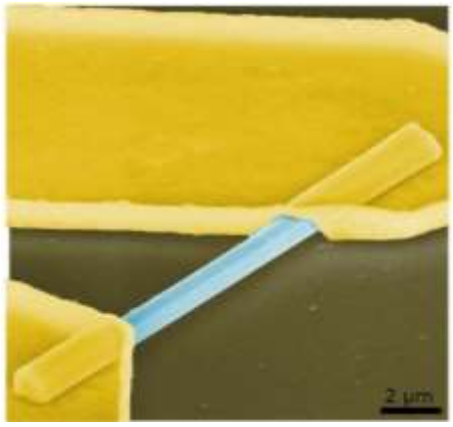


Figure 2: SEM image of a GaN microwire radiation sensor.

Self-powered proton detectors based on GaN core-shell p-n microwires

D. Verheij, M. Peres, S. Cardoso, L. C. Alves, E. Alves, C. Durand, J. Eymery, J. Fernandes, K. Lorenz

GaN and related III-nitride semiconductors are considered for the next generation of high power and high frequency electronics. Furthermore, these semiconductors revealed extraordinary thermal, chemical and radiation resistance making them ideally suited for applications in extreme environments such as space.

The same properties are also interesting for the development of particle detectors and radiation sensors. Moreover, the wide bandgap allows the incorporation of optically active dopants and defects, interesting for quantum applications such as single photon emitters and quantum sensors.

If the radiation sensor is embedded in the semiconductor matrix (a so-called active substrate), it allows the detection of implanted ions in real time.

In the joined research activity Detectors and Electronics (WP21), the Radiate consortium investigates novel wide bandgap materials such as diamond, Ga_2O_3, and GaN as radiation sensors. Here, we report on the fabrication and characterisation of radiation sensors based on GaN core/shell p-n junction microwires. With their small size, high resistance to radiation and high crystalline quality, GaN microwires constitute highly interesting building blocks for radiation-hard devices. Through microfabrication steps, single-wire devices were processed with leakage currents as low as 1 pA in reverse bias.

A scanning electron microscopy image of such a device is shown in fig. 1. Irradiation with both UV light and protons results in photo/ionocurrent signals several orders of magnitude above the dark current and response times below 30 ms. Fig. 2 shows transient measurements of the ionocurrent induced by 2 MeV proton irradiation for different biases. Interestingly, the device works in photovoltaic mode without any externally applied bias and it shows good resistance to radiation.

Self-powered particle detectors have the potential to offer exceptional flexibility and compactness in applications where size limits and low power consumption are key requisites. *https://doi.org/10.1063/5.0045050*

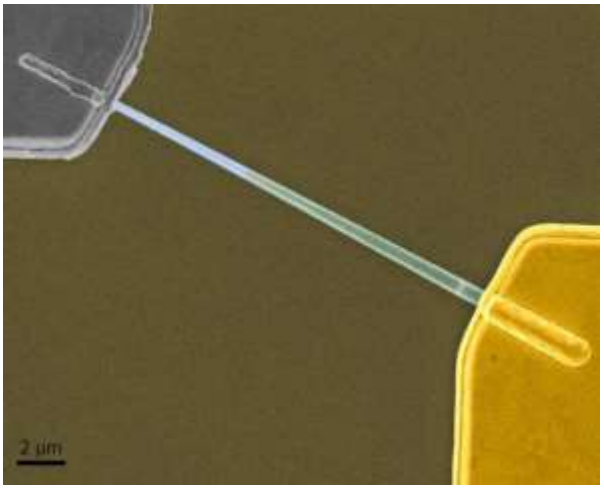


Figure 1: Scanning electron microscopy image of a single p-n-junction microwire device.

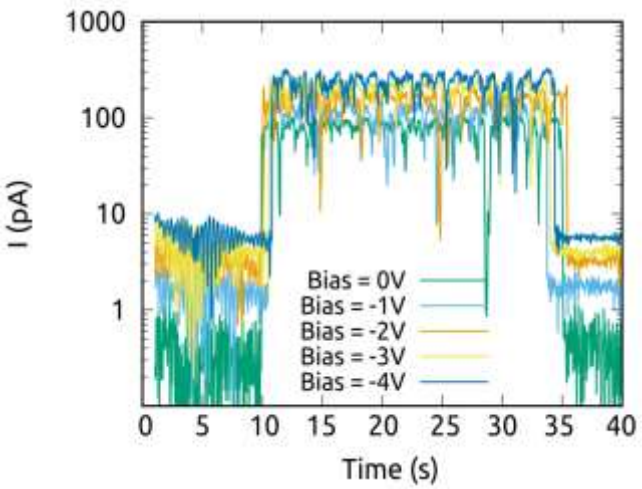


Figure 2: Transient ionocurrent measurements for irradiation with 2 MeV protons for different applied biases.

Microbeam research based activities

L.C. Alves[1,2,3], V. Corregidor[1], R.C. da Silva[2,3,4], M. Vilarigues[5], I. Coutinho[5], M Bandiera[5], S. Coentro[5], J.C. Cruz[6], M.A. Barreiros[7], P. Salomé[8], T. Pinheiro[3,9], F. Marujo[1,3], M. Fortunato[10], T. Peña3,[10], M. Peres [2,4], K. Lorenz[2,3,11], D. Verheij[11], N. Catarino[2,4], C. Cruz [2,3,4], E. Alves,[2,3,4], S. Cardoso[11]

Research work was performed under national and international funded research contracts or under collaboration with internal and external group members.

Figure1: Golden silver plate characterization using the external proton beam.

Most relevant applications included ion beam characterization of advanced materials and functional devices (Ga_2O_3; GaN; perovskites and CIGS solar cells) together with archaeological/historical samples (glass, stained glass grisailles, glazed tiles and metallic artefacts) fig.1, biology/biomedicine studies using new drugs containing Cu or Au nanoparticles for cancer therapy, and advanced materials for fusion reactors. The microprobe, tomography automatization system was improved and a motorized x,y external beam sample holder stage was implemented together with the development of a DLL capable of stage positioning while integrated with the script file capabilities of the DAQ3 microprobe software control for automatic data acquisition.

[1] *C2TN, Instituto Superior Técnico, Universidade de Lisboa, E.N. 10, (km 139,7) 2695-066 Bobadela LRS, Portugal*
[2] *LATR, Instituto Superior Técnico, Universidade de Lisboa, E.N. 10, (km 139,7) 2695-066 Bobadela LRS, Portugal*
[3] *DECN, Instituto Superior Técnico, Universidade de Lisboa, E.N. 10, (km 139,7) 2695-066 Bobadela LRS, Portugal*
[4] *IPFN, Instituto Superior Técnico, Universidade de Lisboa, E.N. 10, (km 139,7) 2695-066 Bobadela LRS, Portugal*
[5] *VICARTE, Glass and Ceramics for the Arts, FCT-UNL, Monte da Caparica, Portugal*
[6] *LIBPhys, FCT-UNL, Monte da Caparica, Portugal*
[7] *LNEG/UER, Estrada do Paço do Lumiar, 22, 1649-038 Lisboa, Portugal*
[8] *INL, 4715-330 Braga, Portugal*
[9] *IBB, Instituto Superior Técnico, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal*
[10] *Dept. Física, Instituto Superior Técnico, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal*
[11] *INESC-MN and IN, Rua Alves Redol 9,1000-029 Lisboa, Portugal*

IBA techniques for paper characterization

B. Brandão, M. Ribeiro Mota Padeira Nunes and T. Ferreria, V. Corregidor, L.C. Alves

The external ion-beam setup was used to study different type of paper support and iron-gall ink in collaboration with Portuguese Universities. B. Brandão, for U. Nova de Lisboa, used the set-up to stablish the S content in papers treated with nano- and micro-cellulose to consolidate historical documents.

The work developed was part of her Master thesis entitled "*Nano e Micro Celulose como Material de Consolidação e Reforço de Papel*". On the other hand, M. Ribeiro Mota Padeira Nunes and T. Ferreria, from Evora University, used the proton beam (in vacuum mode) to study the ink composition of fragments from a book written in the first half of the 17th century by the Jesuit Father António Pessoa. Results show different ink composition, indicating the use of different inks along the book.

Study of the effect of a proton beam in paintings

V. Corregidor, L.C. Alves

Figure 1: White pigment with linseed oil on glass during proton irradiation to induce visible defects (charge deposited 1mC).

The IBA techniques are considered as non-destructive techniques, if the right experimental conditions are used. These conditions are very dependent on the material under study.

In this work, the effect of the charge deposited by the proton beam on white pigment applied on canvas or glass substrate has been studied, fig.1.

For low deposited charge values (0.1 μC) no visual defects were observed, nevertheless for higher values (1 μC) the effect is quite dependent on the binder used (p.e. yolk egg). For 10 μC defects are clearly visible for all samples.

Isotopic depth profiling by Micro-AMS

H. Luís, E. Alves

The laboratory activities concerning AMS were affected by the lockdown. When laboratory work was resumed, focus was placed on the continuation of the development of the Micro-AMS capabilities, with the goal of performing deuterium depth profiles, having gained experience from the work previously performed with Pt profiles in Si samples.

Work was also developed in performing tests with the goal of using the capabilities of the Micro-AMS line for the production of stable, low intensity heavy ion beams, for the testing of detectors.

Parallel to the activities mentioned, W targets were measured to ascertain the capabilities of the system to measure trace W isotopes, fig.1.

Another work in progress is the determination of the impact of low intensity heavy ion beams on biological material. For this, student Maria Inês Guedes under my supervision developed a sample stage.

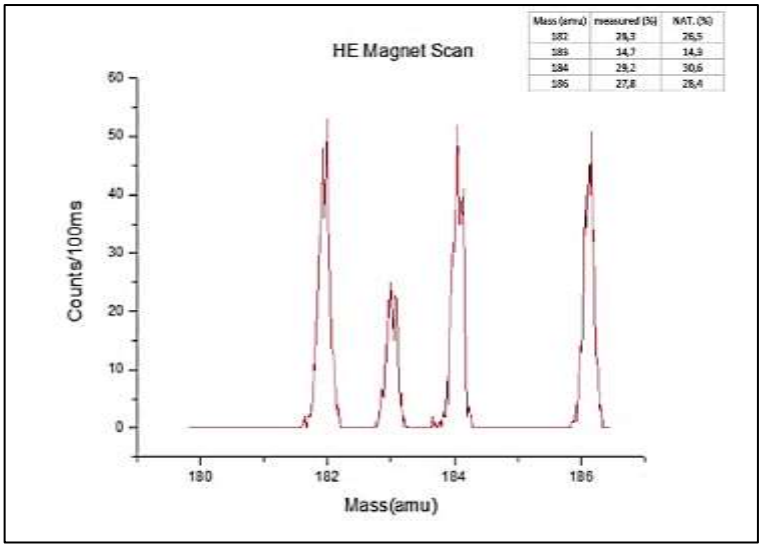


Figure 1: He Magnet Scan of tungsten isotopes in charge state 4+, from a pure tungsten target.

X-ray reflectivity software

S. Magalhães

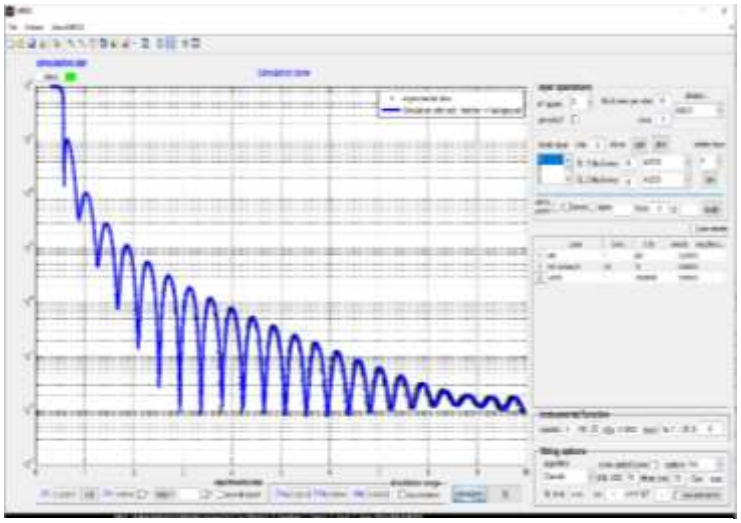


Figure 1: MROX simulation of a multilayer.

The software employs the principles of the dynamical theory of X-ray diffraction/reflection of several layered structures such as bulk materials, single layers, single quantum wells, quantum heterostructures and complex superlattices. Allow to simulate and fit different types of measurements of any implanted species. Simple to use, JET layers can be deleted, added, edited and crystalline-layered structure easy to obtain. Combined with the new developed code of X-ray diffraction simulations and fittings, MROX-XRR is a powerful tool to simulate and fit the effect of ion implantation into crystals, fig.1 Although, the MROX-XRR as software is still not published, the strong interest of the scientific community and especially collaborations with the University of Aveiro (Profs. N.A. Sobolev and M. Graça), enabled the publication of two research manuscripts in high-quality and high impact factors journals. Both MROX codes are available via www.mrox.eu website.

Creation and strengthening of laboratory resources

M. Peres, N. Catarino

During 2020, some effort was dedicated to install a new beam line coupled to the Tandem accelerator that will allow performing in-situ measurements of electrical and optical characterization during irradiation and implantation.

This new setup compared to the one developed and installed in the micro probe coupled to the Van de Graaff accelerator has a greater versatility and potential despite of a worse lateral resolution.

In the case of this setup, we are not limited to only protons and alpha particles but can use also heavy ion irradiation and at considerably higher energy.

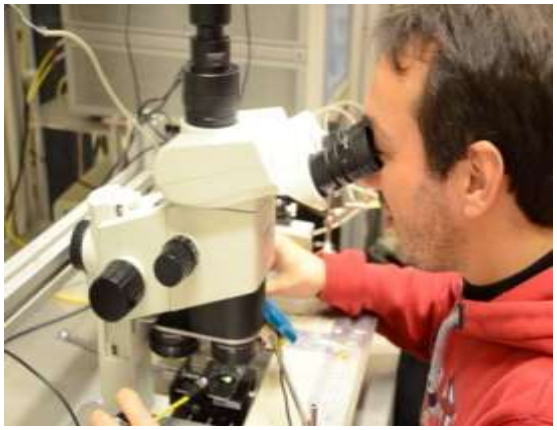


Figure 1: Optical observation of sample surface before analysis.

PUBLICATIONS
(Peer review journals)

Books (Book Chapters)

[1] P.Jozwik, L. Nowicki, R. Ratajczak, C. Mieszczynski, A. Stonert, A. Turos, K. Lorenz, E. Alves (2021): Advanced Monte Carlo simulations for ion-channeling studies of complex defects in crystals. In *Theory and simulation in physics for materials applications*. Ed. E. Levchenko, Y. Dappe, G. Ori, Springer Series in Materials Science, vol 296. Springer, Cham 2020. ISBN 978-3-030-37790-8.

Papers

[1] A.Baron-Wiechec, J.P. Coad, K. Heinola, M. Rubel, N.P. Barradas, E. Alves and JET Contributors, "Deposition in the tungsten divertor during the 2011–2016 campaigns in JET with ITER-like wall, *Physica Scripta* (T171) 014044, 2020. DOI: 10.1088/1402-4896/ab4df7.

[2] A.Al-Rjoub, L. Rebouta, N.F. Cunha, F.Fernandes, N.P. Barradas, & E. Alves (2020), "W/AlSiTiNx/SiAlTiO$_y$N$_x$/SiAlO$_x$ multilayered solar thermal selective absorber coating", *Solar Energy*, 207, 192-198. doi:10.1016/j.solener.2020.06.094. WOS:000575 902500003.

[3] A.C. Branco, R.Silva, T.Santos, H. Jorge, A.R. Rodrigues, R.Fernandes, S.Bandarra, , I.Barahona, A.P.A.Matos, K.Lorenz, M. Polido, R.Colaço, A.P.Serro & C.G. Figueiredo-Pina (2020), "Suitability of 3D printed pieces of nanocrystalline zirconia for dental applications", *Dental Materials*, 36(3), 442-455. doi:10.1016/j.dental.2020.01.006.WOS:000514844400014

[4] A.C. Branco, R. Silva, H. Jorge, T. Santos, K. Lorenz, M. Polido, R. Colaço, A. P. Serro, C.G. Figueiredo-Pina, "Tribological performance of the pair human teeth vs 3D printed zirconia: An in vitro chewing simulation study", *Journal of the mechanical behavior of biomedical materials*, 110, 103900 (2020). https://doi.org/10.1016/j.jmbbm.2020.103900

[5] A.Hakola, K Heinola, K Mizohata, J Likonen, C Lungu, C Porosnicu, E. Alves, R. Mateus, I.B. Radovic, Z. Siketic, V. Nemanic, M. Kumar, C. Pardanaud, P. Roubin and EUROfusion WP PFC Contributors (2020), "Effect of composition and surface characteristics on fuel retention in beryllium-containing co-deposited layers", *Physica Scripta*, Volume 2020 (T171), 014038. DOI: 10.1088/1402-4896/ab4be8

[6] A.Widdowson, S. Aleiferis, E. Alves, L. Avotina, A. Baron-Wiechec, N. Catarino, J.P. Coad, V. Corregidor, K. Heinola, I. Jepu, C. Makepeace and JET Contributors (2020), "Fuel inventory and material migration of JET main chamber plasma facing components compared over three operational periods", *Physica Scripta*, *Volume 2020 (T171),* 014051. ttps://doi.org/10.1088/1402-4896/ab5350.

[7] B.M.S.Teixeira, A.A.Timopheev, N.Cacoilo, L.Cuchet, J.Mondaud, J.R.Childress, Magalhães, S., E.Alves, & N.A. Sobolev (2020), "Ar^+ ion irradiation of magnetic tunnel junction multilayers: impact on the magnetic and electrical properties", *Journal of Physics D, 53(45), 455003*. doi:10.1088/1361-6463/aba38c. WOS:000563298700001.

[8] C.C.Montanari, P.A.Miranda, E.Alves, A.M.P.Mendez, D.M.Mitnik, J.E.Miraglia, R.Correa, J.Wachter, M.Aguilera, N.Catarino and R.C. da Silva (2020), " Stopping power of hydrogen in hafnium and the importance of relativistic 4f electrons", *Physical Review A*, 101(6), 062701. doi:10.1103/Phys RevA.101.062 701. WOS:000537136900013

[9] C.Lopes, C Gabor, D Cristea, R Costa, RP Domingues, MS Rodrigues, J. Borges, E.Alves, N.P.Barradas, D.Munteanu, F.Vaz, "Evolution of the mechanical properties of Ti-based intermetallic thin films doped with different metals to be used as biomedical devices", *Applied*

Surface Science, March 2020, Volume 505, 144617. https://doi.org /10. 1016/j.apsusc.2019.144617

[10] C.Machado, A.Machado, T.Palomar, L.C. Alves & M.Vilarigues, (2020), "Debitus grisailles for stained-glass conservation: an analytical study", *Conservar Patrimonio*, 34, 65-72. doi:10.14568/ cp2018067. WOS:000557918700006.

[11] C.Pardanaud, D.Dellasega, M.Passoni, C. Martin, P.Roubin, Y.Addab, C.Arnas, L.Couedel, M.Minissale, E.Salomon, G. Giacometti, A. Merlen, E. Bernard, R.Mateus, E.Alves, Z.Siketic, I.B.Radovic & A. Hakola, (2020), "Post-mortem analysis of tungsten plasma facing components in tokamaks: Raman microscopy measurements on compact, porous oxide and nitride films and nanoparticles", *Nuclear Fusion*, 60(8), 086004. doi:10.1088/1741-4326/ab9347. WOS:00054926 3400001.

[12] D.Cameron, K. P. O'Donnell, P. R. Edwards, M. Peres, K. Lorenz, M. J. Kappers, M. Bockowski, "Acceptor state anchoring in gallium nitride*", Appl. Phys. Lett.* 116 (2020) 102105. DOI: 10.1063/1.5142168

[13] D.I. Meira, R.P. Domingues, M.S. Rodrigues, E. Alves, N.P. Barradas, J. Borges, F. Vaz, "Thin films of Au-Al2O3 for plasmonic sensing", *Applied Surface Science*, Volume 500, January 2020, 144035. https://doi.org/10.1016/j.apsusc. 2019.144035

[14] D.R. Pereira, S. Magalhães, C. Díaz-Guerra, M. Peres, J.G. Correia, J.G. Marques, A.G. Silva, E. Alves, S. Cardoso, P.P. Freitas and K. Lorenz (2020), "Estimating the uncertainties of strain and damage analysis by X-ray diffraction in ion implanted MoO_3", *Nuclear Instruments & Methods in Physics Research B, 478, 290-296*, 118378. doi:10.1016/j.nimb.2020.07. 016. WOS:000564709900003.

[15] J.Cruz, M. Manso, V. Corregidor, R.J.C. Silva, E. Figueiredo, M.L. Carvalho, L.C. Alves, "Surface analysis of corroded XV–XVI century copper coins by μ-XRF and μ-PIXE/μEBS self-consistent analysis, Materials Characterization", 161 (2020).10.1016/j.matchar. 2020.110170.

[16] K.Filintoglou, F. Pinakidou, J. Arvanitidis, D. Christofilos, E. C. Paloura, S. Ves, P. Kutza, Ph. Lorenz, P. Gerlach , E. Wendler, A. Undisz, M. Rettenmayr, O. Milchanin, F. F. Komarov, K. Lorenz, M. Katsikini, "Size control of GaN nanocrystals formed by ion implantation in thermally grown silicon dioxide", *J. Appl. Phys.* 127 (2020) 034302. DOI: 10.1063/1.5132604

[17] M.B. Costa, R. Mateus, M. Guedes, A.C. Ferro, "Mechanical Alloying in the Li-Sn system", *Materials Letters X* 6 (2020) 100045. https://doi.org/10.1016/j.mlblux.2020.100045

[18] M.Stachowicz, J.M. Sajkowski, S. Kryvyi, A. Pieniazek, A. Reszka, A.Wierzbicka, M.A. Pietrzyk, E. Przezdziecka, D. Jarosz, K. Gwóźdź, E. Placzek-Popko, E. Alves, S. Magalhães, A. Kozanecki, "Study of structural and optical properties of MBE grown nonpolar (10-10) ZnO/ZnMgO photonic structures", *Optical Materials*, Volume 100, February 2020, 109709. DOI: 10.1016/j.optmat.2020.109709

[19] M.Vilarigues, C.Machado, A. Machado, M. Costa, L.C. Alves, I.P. Cardoso & A. Ruivo (2020). "Grisailles: Reconstruction and characterization of historical recipes", *International Journal of Applied Glass Science*, 11, 756-773.doi:10.1111/ijag.15793. WOS:0005416509 00001.

[20] N.Catarino, A. Widdowson, A. Baron-Wiechec, J.P. Coad, K. Heinola, M. Rubel, N.P. Barradas, E. Alves and JET Contributors, "Deposition in the tungsten divertor during the 2011–2016 campaigns in JET with ITER-like wall", *Physica Scripta*, January 2020 (T171), 014044. DOI: 10.1088/1402-4896/ab4df7.

[21] N.Catarino, L.C. Alves, M.Dias, N.P. Barradas, S. van Til, M. Zmitko, E. Alves, "Oxidation behaviour of neutron irradiated Be pebbles", *Nuclear Materials and Energy* 23 (2020) art. nº 100748. https://doi.org/10.1016/j.nme.2020.100 748

[22] P.Dabas, R.C. da Silva, L.C. Alves, M. Vilarigues, T.S. Natarajan, "Thermal stability and ionic conduction characteristics of lithium germanate glasses", *Solid State Sciences*, 101 (2020) art. nº 106109. https://doi.org/10.1016/j.solidstatescien ces.2019.106109

[23] P.Jozwik, L. Nowicki, R. Ratajczak, C. Mieszczynski, A. Stonert, A. Turos, K. Lorenz, E. Alves, "Advanced Monte Carlo Simulations for Ion-Channeling Studies of Complex Defects in Crystals", *Theory and Simulation in Physics for Materials Applications*, February 2020, pp 133-160, DOI: 10.1007/978-3-030-37790-8_8

[24] P.Pereira-Silva, J. Borges, M.S. Rodrigues, J.C. Oliveira, E. Alves, N.P. Barradas, J.P. Dias, A. Cavaleiro, F. Vaz, "Nanocomposite Au-ZnO thin films: Influence of gold concentration and thermal annealing on the microstructure and plasmonic response", *Surface and Coatings Technology*, 385 (2020), 125379, https://doi.org/10.1016/j.surfcoat.2020.125379. WOS: 0005269 80900040.

[25] P.Quitério, A.Apolinário, D. Navas, S.Magalhães, E. Alves, A. Mendes, C.T. Sousa & J.P. Araújo, "Photoelectrochemical Water Splitting: Thermal Annealing Challenges on Hematite Nanowires", *Journal of Physical Chemistry C*, 124 (24) (2020) 12897-12911. doi:10.1021/ acs. jpcc.0c01259. WOS:000549942500004.

[26] P.Valério, I.P. Cardoso, M. Santiago, M.F. Araújo, L.C. Alves, M.A. Gonçalves, & R. Mataloto, "Microanalytical study of copper ores from the Chalcolithic settlement of Sao Pedro (Portugal): Copper production in the south-western", *Iberian Peninsula. Archaeometry*, 62 (2) (2020) 314-328. DOI:10.1111/arcm.12514. WOS:0004971693000 01.

[27] R.Mateus, M.B. Costa, L.C. Alves, M. Guedes, E. Alves, A.C. Ferro, "Lithium dilution in Li-Sn alloys", *Nucl. Mater. Energy* 25 (2020) 100783. https://doi.org/10.1016/j.nme.2020. 100783

[28] S.Coentro, L.C. Alves, J. Coll Conesa, T. Ferreira, J. Mirão, R.C. da Silva, R. Trindade, V.S.F. Muralha, "White on blue: A study on underglaze-decorated ceramic tiles from 15th-16th Century Valencian and Sevillian productions", *Journal of Archaeological Science: Reports* 30 (2020) 102254. https://doi.org/10.1016/j.jasrep.2020.102 254

[29] S.Pessanha, S.Silva, J.M. Silveira, I.Otel, H. Luis, V. Manteigas, A.P. Jesus, A. Mata, & M. Fonseca, "Evaluation of the effect of fluorinated tooth bleaching products using polarized Raman microscopy and particle induced gamma-ray emission", *Spectrochimica Acta Part A*, 236 (2020) 118378. doi:10.1016/j.saa.2020.118378. WOS:000538154800033.

[30] T.Morlat, A.C. Fernandes, M. Felizardo, A. Kling, T.A. Girard, J.G., F.P.Marques Carvalho & C.Cruz (2020). Response of Superheated Emulsion Detectors to low energy alpha irradiation. *Nuclear Instruments & Methods in Physics Research A*, 953, 163124. doi:10.1016/j.nima.2019.163124. WOS:000506419900069.

[31] V.Corregidor, A.L.António, L.C. Alves & S.C. Verde (2020), "Castanea sativa shells and fruits: Compositional analysis by proton induced X-ray emission". *Nuclear Instruments & Methods in Physics Research B*, 477, 98-103. doi:10.1016/j.nimb.2019.08.018. WOS:00054 2512300018.

[32] V.Corregidor, R. Dias, N. Catarino, C. Cruz, L.C. Alves & J. Cruz (2020), "Arduino-controlled Reflectance Transformation Imaging to the study of cultural heritage objects". *SN Applied Sciences*, 2 (9) 1586. doi: 10.1007/s42452-020-03343-4. WOS:00056383800000 3. Supplementary material.

[33] V.Nemanič, M. Žumer, C. Porosnicu, B. Butoi, E. Alves, R. Mateus (2020), "Deuterium inventory determination in beryllium and mixed beryllium-carbon layers doped with oxygen", *Fusion Engineering and Design*, 150, 111365. https://doi.org/10.1016/j.fusengdes. 2019.111365

[34] X.Biquard, E. G. Víllora, K. Shimamura, K. Lorenz, "XANES/EXAFS study of the Lu and Y incorporation in the single crystal $Tb_3Sc_2Al_3O_{12}$ Faraday rotator", *J. Appl. Phys.* 127 (2020) 115106. DOI: 10.1063/1.5145188

COMMUNICATIONS

Invited Talks

[1] E. Alves, "Radiation Technologies on Forensic Science", *TC Meeting on Advances in Radiation Processing: Emerging Applications and New Irradiation Facilities*, Vienna (Austria) February 6th, 2020 (invited).

[2] E. Alves, "Ion beam studies of plasma wall interactions on fusion devices", *Workshop on Radiation Effects of Materials and Devices (REMD-2020)*, Harbin (China), January 12-15th 2020 (invited).

Oral Talks

[1] D.P. Jozwik, M. Sequeira, S. Magalhães, D. Nd. Faye, E. Alves, C. Grygiel, C. Wetzel, K. Lorenz, "Study of the radiation damage in InGaN/GaN upon bombardment with Pb and Xe swift heavy ions", *Física 2020, 22ª Conferência Nacional de Física, 30º Encontro Ibérico para o Ensino da Física*, Lisbon, Portugal, September 2-5, (2020).

[2] D.R. Pereira, S. Magalhães, C. Díaz-Guerra, M. Peres, J. G. Correia, J. G. Marques, A. G. Silva, E. Alves, S. Cardoso, P. P. Freitas, K. Lorenz, "Tuning the electrical properties of α-MoO_3 lamellar crystals by de-fect creation during ion implantation", *Física 2020, 22ª Conferência Nacional de Física, 30º Encontro Ibérico para o Ensino da Física*, Lisbon, Portugal, September 2-5, (2020).

[3] E. Alves, "Deuterium and Metals in gaps of Beryllium", *Meeting on Ion Beam Analysis of Plasma-Facing Components from JET-ILW,* CTN-Bobadela, March 03-04th, 2020.

[4] M.Dias, F. Antão, P.A. Carvalho, J.B. Correia, E. Alves, HHFM 3.3.2.D2 "Thermal barriers materials made of Y2O3 reinforced Cu and CuCrZr. CuCrZr, Project Monitoring Meeting (zoom meeting), May 2020.

[5] M.Dias, F. Antão, P.A. Carvalho, J.B. Correia, E. Alves, HHFM 3.3.2.D2 "Thermal barriers materials made of Y2O3 reinforced Cu and CuCrZr. CuCrZr, Project Monitoring Meeting (zoom meeting), October 2020.

[6] V. Corregidor (2020). CARISMA - First Summer School of C2TN, CTN/IST, Bobadela. Topic: Nuclear Technologies in Archaeometry Studies, 8 – 10 September 2020.

Panel/Poster Presentation in Conferences

[1] A.Gomez-Moron, N. Schibille, L.C.Alves, A.B.Abad, P.Ortiz, M.Vilarigues & T. Palomar (2020). Characterization of glass tesserae from the Mosque of Cordoba. In: Science and Digital Technology for Cultural Heritage: Interdisciplinary Approach to Diagnosis, Vulnerability, Risk Assessment and Graphic Information Models, Pilar Ortiz Calderón, Francisco Pinto Puerto, Philip Verhagen, Andrés J. Prieto (Eds.). *Proceedings of the 4th International Congress Science and Technology for the Conservation of Cultural Heritage (TechnoHeritage 2019)*, March 26-30, 2019, Sevilla, Spain. CRC Press, pp. 258-262. ISBN 9780367363680. doi:10.1201/97804 29345470-48. WOS:000525578800048.

[2] D.Verheij, M.Peres, S. Cardoso, L.C. Alves, E. Alves, C. Durand, J. Eymery, J. Fernandes, K. Lorenz, "Sensores de radiação auto-alimentados baseados em microfios de nitreto de gálio", *Física 2020, 22ª Conferência Nacional de Física, 30º Encontro Ibérico para o Ensino da Física*, Lisbon, Portugal, September 2-5, (2020).

[3] M.Nunes, V. Corregidor, L.C. Alves, M.F. Olival, O. Sequeira, H. Maria Vilar, A. Manhita, A. Claro, T. Ferreira, Analytical investigation on the writing ink of Codex 99 from Manizola collection, *Analítica 2020: 10º Encontro da Divisão de Química Analítica - Lisboa, Portugal, 26-28 October, 2020.*

Conference Proceedings

[1] D.Verheij, M. Peres, S. Cardoso, L.C. Cerqueira Alves, E. Alves, C. Durand, J. Eymery, J. Fernandes, K. Lorenz, "Ion beam induced current analysis in GaN microwires", *2EPJ Web of Conferences 233*, 05001 (2020). https://doi.org/10.1051/ epjconf/202023305001.

[2] M.B. Costa, R. Mateus, L. Cerqueira, M. Guedes, A. C. Ferro, "Production of Li-Sn Alloys by Reactive Milling for Nuclear Fusion Applications", *Euro PM2019 Conference, 2020,* ISBN**:** 978-189907251-4.

Other Seminars

[1] E. Alves, Master on Mining Engineering*: Energy: Challenges for the 21st Century*, IST, February 28th (2020).

[2] K. Lorenz, "Ion beams in III-nitride research: Doping, characterisation and radiation resistant electronics, *King Abdullah University of Science and Technology, Saudi Arabia*, Semi-talk Webinar, July 23, 2020, Thuwal, Saudi Arabia.

FUNDED PROJECTS

Running Projects

[1] *Analysis of materials for fusion applications under bombardment of D plasma streams, X-ray and neutrons*. **IAEA/CRP F13020 Coordinated Research Contract** (2020-2022): **IST Budget: €12.000,00** (€4.000,00/year); **Budget 2020: €4.000,00**. Prime Contractor: IST, Coordinator: E. Alves.

[2] *Development and Application of Ion Beam Techniques for Materials Irradiation and Characterization relevant to Fusion Technology*, **IAEA/CRP F11023 Coordinated Research Contract** (2020-2025). **IST Budget: €20,000 €** (€5.000,00/4 years); **Budget 2020: €5.000,00**. Prime contractor: IST. Coordinator: N. Catarino.

[3] *Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences* (COGLACE). **IAEA/CRP F11021 Coordinated Research Contract** (2017-2020): **IST Budget: €15.000,00** (€3.750,00/year); **Budget 2020: €3.750,00**. Prime contractor: IST: Coordinator: L.C. Alves.

[4] **INFRAIA-01-2018-2019 (H2020)**: *Research And Development with Ion Beams – Advancing Technology in Europe* (RADIATE). **IST Budget: €403.218,75; Budget 2020: €100.804,69.** Portuguese Coordinator: E. Alves.

[5] ITER PHYSICS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (**Work Package: PFC (Plasma Facing Components)**, IST/IPFN). *Preparation of efficient PFC operation for ITER and DEMO* (2015-2020). **IST Budget: €169.430,00**; **Budget 2020: €23.950,00**. IST Coordinator: R. Mateus & E. Alves.

[6] ITER PHYSICS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (**Work Package: MATERIALS**, IST/IPFN) (2015-2020). **IST Budget: €134.620,00**; **Budget 2020: €26.300,00**. IST Coordinator: M. Dias.

[7] JET PROJECTS WORK PROGRAMME 2014 & WORK PLAN 2014-2020 (**Work Package: JET2: PLASMA-FACING**, IST/IPFN*)* (2015-2020). **IST Budget: €590.710,00; Budget 2020: €100.860,00**. IST Coordinator: E. Alves.

[8] *Liquid metal walls for plasma reactors*, **PTDC/FIS-PLA/31629/2017** (October 2018-September 2021). Total Budget: € 231.037,00, **IST-ID Budget: €231.037,00; Budget 2020: 57.759,25**. Prime Contractor: IST-ID. Coordinator: R. Mateus.

[9] *Materials and Nuclear Physics Research with Radioactive Isotopes and Techniques, PORTUGAL AT ISOLDE:* **CERN/FIS-PAR/0005/2017** (2018-2020). Prime Contractor: Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento (IST-ID). **IST Budget: €170 000,00; Budget 2020: €56.666,67**. IST Coordinator: J. G. Correia (C^2TN); Team Member: P. Peres and K. Lorenz.

[10] *Materials Processing and Characterization* (PEST). PROJECTO ESTRATÉGICO: **PEST-UID/FIS/50010/2019** (2015-2020). **IST Budget: €198.800,00; Budget 2020: €27.550,00.** Group leader: E. Alves.

[11] *Nano-engineering of Wide Bandgap Semiconductors Using Ion Beams* (NASIB). **PTDC/CTM-CTM/28011/2017** (15-06-2018 to 14-06-2021):. Total Budget: € 223.623,25, **IST Budget: €170.848,25; Budget 2020: €42.712,06.** Prime Contractor: IST-ID, Coordinator: K. Lorenz

[12] *Plasmonic Nanoparticles for Bio-detection* (NANO4BIO). **PTDC/FIS-MAC/32299/2017** and POCI-01-0145-FEDER-032299 (2018-2021). Total: €230.083,17; UMinho: € 117.558,20; **IST Budget: €52.550,00**; **Budget 2020: €13.137,50.** IST Coordinator: E. Alves.

[13] *Solar Selective Absorber for High Temperature Applications* (ABSOLAR). **PTDC/CTM-ENE/2892/2016** (P2020): Total Budget: €100.548,00€, **IST Budget: €16.800,00; Budget 2020: €4.200,00**. IST Coordinator: E. Alves.

[14] *Surface Engineered Glass Ceramics with Improved Mechanical Properties* (GLASSMECH). **PTDC/CTM/31192/2017**. IST Budget: €237,288. **LATR Budget: €20.000,00; Budget 2020: €6.666,67**. IST Coordinator: L. Santos, Member, E. Alves.

Submitted Projects

[1] *3D-imaging by means of a nuclear microprobe (3D-NM),* **PTDC/FIS-OUT/7356/2020** (2021-2023). Prime Contractor: IST-ID, Institution, C^2TN, Country: Portugal (Coordinator: Victoria Corregidor). IST Coordinator (Victoria Corregidor).

[2] *Defect Engineered 2D Oxide Field Effect Transistors for efficient biosensing (DEOFET),* **PTDC/CTM-CTM/3553/2020** (2021-2024). Prime Contractor: INESC-MN, Portugal. Coordinator (Katharina Lorenz).

[3] *Market competitive chalcopyrite-perovskite Tandem Solar cells (TaSol),* **PTDC/FIS-MAC/3803/2020** (2021-2023). Prime Contractor: IST-ID, Institution, C2TN Country: Portugal (Coordinator: Luís Cerqueira). LATR Coordinator (Luís Cerqueira).

[4] *Nanodiamonds: optical and magnetic probes for bio/medical applications (RUSH4nano DIAMONDS),* "La Caixa" **HR20-00544** (2021-2023). Prime Contractor: Univ. de Aveiro, Institution, Dept Physics and I3N, Country: Portugal (Coordinator: Teresa Monteiro). IST Coordinator (Katharina Lorenz, LATR).

[5] *O MROX e as elevadas concentrações de impurezas em semicondutores dos grupos III (nitretos), II-VI (óxidos) e IV (silicetos),* **PTDC/CTM-CTM/0647/2021** (01-01-2022 to 31-12-2024). Prime Contractor: Instituto Superior Técnico, Instituto de Plasmas e Fusão Nuclear, Portugal. Coordinator: Sérgio Magalhães.

[6] *Radiation resistant ultra-thin CIGS solar cells for microsatellites (*PV4NewSpace), **FCT-PTDC/EME-REN/1147/2020** (2021-2023), Prime Contractor: Univ. de Aveiro, Institution: Physics Dept. Country: Portugal (Coordinator: Joaquim Leitão). IST Coordinator (Katharina Lorenz).

[7] *Study of Actinides on Environmental samples with AMS and Micro-AMS (ActAMS),* **PTDC/FIS-NUC/6920/2020** (2021-2023). Prime Contractor: Fundação para a Ciência e Tecnologia, Portugal (Coordinator: Hélio Fernandes Luís). IST Coordinator (Hélio Fernandes Luís).

[8] *Transístores de efeito de campo de óxidos 2D para biossensores eficientes,* **PTDC/CTM-CTM/3553/2020** (01-02-2021 to 31-01-2024). Prime Contrator: Instituto de Engenharia de Sistemas e Computadores - Microsistemas e Nanotecnologias (INESC MN). IST Coordinator: Katharina Lorenz (INESC MN).

[9] *W-based high entropy alloys as thermal barriers for nuclear fusion,* **PTDC/CTM-CTM/2484/2020** (01/01/2021 to 01/01/2024). Prime Contractor: IST, Portugal. Coordinator: Marta Dias.

PATENTS

[1] M. Peres K. Lorenz, J. Rocha & E. Alves, INVENTION PATENT NATIONAL Nº 117063 (2020). This invention is related to a process of producing thin Ga_2O_3 members with a well-defined sub micrometric thickness. This process is based on the use of ion beams for the production of defects in order to create a gradient of stresses that induce delamination, resulting in thin membranes. Patent reference: DP/01/2021/75535.

EDUCATION

MSc Theses

[1] H. Luís, Supervisor of **Kateline Marisa Dias**, MSc thesis "*Determinação da distribuição de flúor em esmalte dentário"* (Master in Engenharia Biomédica), FCT/UNL, Monte da Caparica, May 8, 2020.

[2] L.C. Alves, Supervisor of **Manuel Fortunato**, MSc thesis *"Optimização e execução experimental da técnica STIMT na microssonda nuclear do IST/CTN"* (Master in Engenharia Física Tecnológica), Instituto Superior Técnico, Universidade de Lisboa, Oct. 2020.

Classes/Teaching

[1] E. Alves, Doctoral Program APLAuSE, 2020.

[2] E. Alves, Invited Professor at Physics Department. Experimental Classes: "*Fisica Nuclear*", 2nd semester MEFT 2019/2020.

[3] E. Alves and R.C. Silva, Invited Professor at Physics Department. Experimental Module: "*LFEA - Laboratório de Física Experimental Avançada"* (MEFT - Mestrado Integrado em Engenharia Física Tecnológica

[4] K. Lorenz, Invited Professor at Physics Department. Disciplines: *"Caracterização Avançada de Materiais Funcionais (DEFT)", "Ciência dos Materiais para as Tecnologias Nucleares"* (MEFT, MEGE), *"Modulo experimental LFEA"* (MEFT), *"Módulo Energia Solar Fotovoltaica"* (MEGE, MEFT), *"Módulo Física e Tecnologia dos Semicondutores"* (MEFT), *"Módulo Nanotecnologias e Nanoelectrónica"* (MEFT), *"Módulo Métodos de Caracterização em Física de Estado Sólido"* (MEFT), Aulas práticas *"Mecânica e Ondas, Electromagnetismo e Óptica"* (MEEC), 2020.

[5] K. Lorenz, Invited Professor at Physics Department. Disciplines: "*Material Science for Nuclear Technologies"* and "*Photovoltaic Solar Energy"*, in the Curricular Plans for MSc Students on "Mestrado Bolonha em Engenharia e Gestão da Energia". Academic years: 2017/2018; 2018/2019; 2019/2020.

[6] K. Lorenz, Invited Professor at Physics Department. Disciplines: "*Photovoltaic Solar Energy"*, in the Curricular Plans for MSc students on "Mestrado Bolonha em Engenharia e Gestão da Energia", 2020.

[7] K. Lorenz, Invited Professor at Physics Department. Discipline: "*Advanced Characterisation of Functional Materials",* in the Curricular Plans for PhD Students on "Diploma de Estudos Avançados em Engenharia Física Tecnológica". Academic years: 2018/2019; 2019/2020.

[8] K. Lorenz, Invited Professor at Physics Department. Disciplines: "*Advanced Experimental Physics Laboratory";* "*Material Science for Nuclear Technologies";* "*Photovoltaic Solar Energy";* "*Nanotechnologies and Nanoelectronics"* and "*Physics and Technology of Semiconductors"*, in the Curricular Plans for MSc Students on "Mestrado Integrado em Engenharia Física". Academic years: 2018/2019; 2019/2020.

[9] M. Peres, Invited Professor at Physics Department. Theoretical and laboratory classes (20% of the total contact hours) at the Course Unit "*Physics and Technology of Semiconductors"* (MEFT 2020).

[10] M. Peres, Invited Professor at Physics Department. Supervision of two groups of students in the course unit *"LFEA - Laboratório de Fisica Experimental Avançada"* (MEFT - Mestrado Integrado em Engenharia Física Tecnológica). Students developed a mini-project doing experimental work in research units including a total of 4x4 hours of laboratory work at LATR, for each group (MEFT 2020).

[11] M. Peres, Invited Professor at Physics Department. Supervision of two Project of MEFT students within the Course Unit "*Introduction to Research developing projects of research based learning*". **Duarte Esteves**: "*Activation of the Cr3+ emission in Ga_2O_3 by proton irradiation"* (MEFT 2020).

[12] R. Mateus, Invited professor at Physics Department. Discipline: *"Mechanics and Waves, Laboratory classes",* diploma in LEIC-T, (first semester 2020/2021).

TRAINING COURSES

[1] H. Luís, Lecturer of "*Técnicas Nucleares: AMS*", training course on "Applied Nuclear Physics", Summer School, Monte da Caparica, Portugal, September 17, 2020.

[2] H. Luís, Supervisor of **Maria Inês Guedes** ("Mestrado Integrado em Engenharia Biomédica") in "Summer School: Applied Nuclear Physics", "*Desenvolvimento de um sistema de porta-amostras móvel para estudos de radioterapia",* FCT-UNL, September 1-October 30, 2020.

[3] N. Catarino, Supervisor of **António da Rocha Neves, André Luís Martins Lopo** and **Sara Lança Perdigão Santos**, at *"Estágio de Verão Ciência-Viva: fabricação de suportes de amostras com impressora 3d para feixes de iões"* (3 high school students), under IST/Ciência-Viva Collaboration, August 17-28, 2020.

[4] R. Mateus, Lecturer of "*Detectores de Radiação*", training course on "Física Nuclear Aplicada", Summer School, Monte da Caparica, Portugal, August-October, 2020.

[5] R. Mateus, Supervisor of **Mariana Meira Roxo** ("Mestrado Integrado em Engenharia Biomédica") in "Summer School: Applied Nuclear Physics", *"Quantificação de Li e B em*

vidros de borossilicatos (VICARTE-FCT/UNL): análises complementares por PIGE e NRA", September 1-October 30, FCT-UNL, 2020.

JURY MEMBERSHIP

[1] E. Alves, International recruitment of a **Professor Adjunto** in the disciplinary area of Nuclear Medicine, for the ESTeSL of the Polytechnic Institute of Lisbon, Notice 707/2019 (January 2020).

[2] E. Alves, International recruitment of a **Professor Coordenador**, Technical-Scientific Area of Medical Imaging and Radiotherapy, Notice 1090/2020, ESS/P.PORTO (March 2020).

[3] E. Alves, International recruitment of a **Investigador Principal**, in the scientific area of Nuclear Technologies and Radiological Protection, Department of Nuclear Engineering and Sciences of IST. Notice 500/2020 (March/July 2020).

[4] E. Alves, International recruitment of a **Professor Associado**, in the disciplinary area of Physical and Biomedical Engineering, FCT/UNL, Notice n.º 1664/2019 (June 2020).

[5] E. Alves, International recruitment of a **Professor Catedrático,** in the disciplinary area of Physics and Physical Engineering, Physics Department of FCT-UNL, Notice Nº 1666/2019, 31-12-2019 (October 2020).

EXTERNAL EVALUATER

[6] E. Alves, External evaluator of **Feng Liu** for promotion to "**Associate Professor**" with tenure at *Institute of Heavy Ion Physics, School of Physics at* Peking University (February 2020).

[7] E. Alves, Vogal, Qualification Recognition Jury for PhD Thesis of **Pooja Sharma** (Júri de Reconhecimento de Habilitações de "*Reconhecimento Específico - Doutoramento em Física",* January 31st 2020, Universidade de Coimbra.

AGGREGATION / HABILITATION

[1] E.Alves, Member of the jury of **Rui César do Espírito Santo Vilão**, Aggregation in Materials Condensed Matter Physics, FCT/Univ. Coimbra (20-21/07/2020).

[2] E.Alves, Member of the jury of **Katharina Lorenz** (2020). Aggregation in Technological Physics Engineering, Instituto Superior Técnico, Universidade de Lisboa (1-2 October 2020).

CONFERENCES ORGANIZATION

[1] E. Alves, Chair of the *EUROfusion JET2-IBA Meeting on "Ion Beam Analysis of Plasma-Facing Components from JET-ILW"*, CTN-Bobadela, April 17-18 2020.

[2] K. Lorenz, Member of the Scientific Committee of the *"Física 2020"*, Lisbon, Portugal, September 2-5, 2020.

TECHNICAL COMMITTEES

Eduardo Alves

[1] Member of the external "*Review Board Center for Integrated Nanotechnologies*", Sandia National Laboratories, Los Alamos, USA, since 2018.

[2] Elected Member of "*International Committee of the International Conference Series on Surface Modification of Materials by Ion Beams"*, since 2017.

[3] Member of "*Nuclear Physics European Coordination Committee, NuPECC"*. Portuguese Representative, since 2016.

[4] Member of *"Scientific Review Panel" of CERIC-ERIC*" (European Research Infrastructure Consortium), since 2016.

[5] Chair of "*International Programme Advisory Committee (iPAC)"*, CIMAP-CIRIL, Caen, since 2015.

[6] Deputy Director of *"Laboratório de Aceleradores e Tecnologias de Radiação",* since 2013.

[7] Member of the *"Executive Board of Instituto de Plasmas e Fusão Nuclear",* Group Leader of Materials Processing and Characterisation, since 2013.

[8] Member of *"Scientific Council of IST",* since 2012 (2º term.).

[9] Elected Member of "*International Committee of the International Conference Series on Ion Beam Modification of Materials"*, since 2006.

[10] Elected Member of *"International Committee of the International Conference Series on Radiation Effects in Insulators"*, since 2001.

Katharina Lorenz

[11] Member of the *"Advisory Editorial Board of Nuclear Instruments and Methods in Physics research, Section B: Beam Interactions with materials and Atoms"*, since 2019.

[12] Member of the*"EMIR Scientific Committee*", French National network of accelerators for irradiation and analysis of molecules and materials, since 2019.

[13] Member of the *"ISOLDE and Neutron Time-of-Flight Experiments Committee – INTC"*, CERN, Switzerland, since 2019.

[14] Member of the *"User Selection Panel at the Ion Beam Centre, Helmholtz-Zentrum Dresden-Rossendorf"*, Germany, since 2014.

[15] Member of the "*Panel of Reviewers of Beamtime Proposal at Centro de Micro-Análisis de Materiales, Madrid",* Spain, since 2011.

INTERNAL REPORTS

- Carlos Cruz, *Internal Emergency Plan for the LATR Accelerator, 2020.*
- Carlos Cruz, *Radiological Protection Plan - Physics Building (Accelerators), 2020.*

CAMPUS & COMMUNITY

Follow-up visits to the Ion Beam laboratory, as indicated below:

Description	Visits / Visitants 2020	
Secondary School	4	185
University	1	36
Other Visits	0	0
Sub-Total	**5**	**221**

COLLABORATIONS

In 2020, and despite the pandemic limitations, collaborations with some research units were active. Among the most important, we select the following:

- Two new international collaborations were put forward with both Prof. Adrian Kozanecki and Prof. Vittorianna Tasco, based on interchanging knowledge about the crystalline quality of the layers grown by the respective research groups.

The Polish group focuses its expertise in the growing of oxides; the Italian group focuses its expertise in the growing of nitride layers. While collaboration with the Italian group is formally recent (2021 FCT call of Projects), collaboration with the Polish group has been strengthened and has been active for some years (S. Magalhães).

Prof. Adrian Kozanecki and Dr. Marcin Stachowicz
Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

Prof. Vittorianna Tasco and Dr. David Tobaldi
CNR NANOTEC, Institute of Nanotechnology, Lecce, Italy

- A collaboration with Hamamatsu was established resulting on sharing of electronic equipment. As an example, in an experiment to be carried out in ESRF (from 9 to 14 June 2021 – already approved) Hamamatsu agreed to collaborate borrowing a photoluminescence system (M. Peres, 2020).
- **CFUM** (*Centro de Física da Universidade do Minho*):
  This is a very strong and important collaboration initiated in the nineties with Professors Luis Rebouta, Filipe Vaz and Luis Cunha. The number of common projects and papers co-authored put this collaboration among the more successful of all.
- **CQE** (*Centro de Química Estrutural, IST & FCUL*):
  The collaboration with two groups of the center have been active for a long time. The use of radiation technologies have been explored with the Biomedical Research Group of Professor Ana Paula Serro with excellent results. Particularly this year was very busy with the activities related with the pandemic.

  Furthermore, there are a long and consolidated collaboration with Professor Rui Almeida and Luis Santos with some FCT projects approved in the last years, including one in the last call.
- **I3N** *(Institute for Nanostructures, Nanomodelling and Nanofabrication)*:
  The collaboration with this Associated Laboratory is shared with CENIMAT (*Materials Research Center*) of Professor Elvira Fortunato from the new University of Lisbon and the Pole of Aveiro with the Group of Professor Teresa Monteiro of the Physics Department of the University of Aveiro. The results, during the last decades, both in terms of projects and publications are noticeable.
- **INESC-MN** (*INESC Microsystems and Nanotechnologies*):
  We have a collaboration with Professor Paulo Freitas since the earlier nineties which is still very active, currently under the leadership of Professor Susana Cardoso Equipment of both laboratories is being used in common research projects and student supervision.
- **LIBPhys** *(Laboratory for Instrumentation, Biomedical Engineering and Radiation Physics of the Physics Department of New University of Lisbon)*:
  The collaboration with researchers of LIBPhys dates back to the origin of our Laboratory. Professor Adelaide Jesus did her PhD in Atomic Physics at the former facilities of the ion beam laboratory and since then she and his collaborator Professor João Cruz use the accelerators for the experimental work of her group in nuclear physics.

- **VICARTE-NOVA** (*Department of Conservation and Restoration of the NOVA School of Science and Technology*):
  Collaborations with Márcia Vilarigues (Head of Department) and her group is relevant on the applications of ion beam microanalysis to study historical glazed tiles, glasses and stained glasses. This collaboration has a great societal interest and offer the possibility to explore the potential of ion beam technologies in the study of cultural heritage objects.
- **LIP** (*Laboratory of Instrumentation and Experimental Particle Physics*):
  The group of Professor Daniel Galaviz uses regularly the beam lines at LATR for research activities in the framework of international collaborations and projects.
- **CeFEMA** (*Center of Physics and Engineering of Advanced Materials, IST*):
  The collaboration was very strong with Professor Reinhard Schwarz and now after his retirement there is still some work shared with Professor Pedro Brogueira.

Other collaborations

- Alexandra Barreiros, Laboratório de Engenharia e Geologia (LNEG), "Ion beam microanalysis – perovskite solar cells", 2020.
- João Pedro Araújo, Paula Quitério, Universidade do Porto, "Ion beam analysis of hematite samples", 2019-2020.
- Joaquim Leitão, Universidade de Aveiro, "Ion beam analyses of several samples", November 16, 2020.

Nuclear Instrumentation and Gamma Irradiation

SERVICES

SECTOR 1 | Nuclear Instrumentation Services

TEAM

Name	Category	Activity/Competences
Eduardo Alves	Senior Researcher	Director
José Neves	Auxiliary Researcher	Electrical Engineer
Ana Faria	Graduated Technician	Income/Logistics
Teresa Pires*	Graduated Technician	Web Designer/Logistics*

**External collaboration (DECN).*

SERVICES

Unfortunately, at the beginning of 2020, Nuclear Instrumentation (IN) activity was compelled to stop all services related to Maintenance and Security Checks of Nuclear Instrumentation on industrial Plants, due to new legislation. *This highly profitable activity was guaranteed by a Technician working as operator at the irradiation facility (UTR) but due to limited human resources and competences to lead the licensing process to submit to the Portuguese Environment Agency (APA) became impossible to pursue these services.*

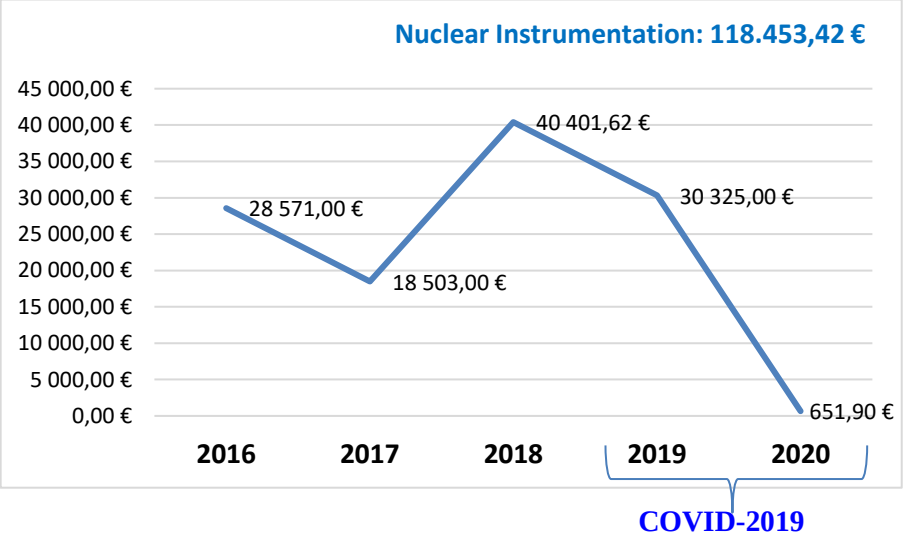
Since then, IN's activity was reduced to technical services under warranty support, for sold equipment (mainly RADX100 dosimeters), as below:

- Maintenance of six digital instrument **"RADX100"** (Personal Radiation Dosimeter), which were produced and sold to REPSOL Polímeros.

This activity will be also discontinued in 2021 due to the retirement of the Engineer responsible.

INCOME TRACK RECORD (2016-2020)

Amounts without VAT:



SECTOR 2 | Sterilization and Decontamination Services

Technological Unit for Radiosterilization (UTR), is a semi-industrial (demonstration) ^{60}Co plant where research and services are combined to demonstrate to the industry the great potential of radiation for sterilization and decontamination of products (https://www.tsf.pt/portugal/sociedade/eu-nao-tenho-vida-zaragatoas-raios-gama-e-testes-a-covid-13305150.html). The unit is certified ISO 9001:2015, since 2017.

The collaboration with Laboratory for Technological Tests in Clean Rooms (LETAL), provides an important set of services with a great technology transfer component in the field of ionizing radiation applications. The study and dose validation for decontamination and sterilization of new products offers to the industry the possibility of increasing the value of its products and in some cases crossing borders.

The unit serves a large number of companies operating in different fields like medical implants, pharmaceutical products, plants as well as flasks/bags among others.

Today SARS-CoV-2 pandemic raised major concerns worldwide about sterilization of products like Personal Protective Equipment (PPE) for health workers and materials used on kits for diagnostic. UTR played a role on this national effort (http://utr.ctn.tecnico.ulisboa.pt/index.html) working without time limitations to provide sterilized "Zaragatoas" for the kits produced at IST.

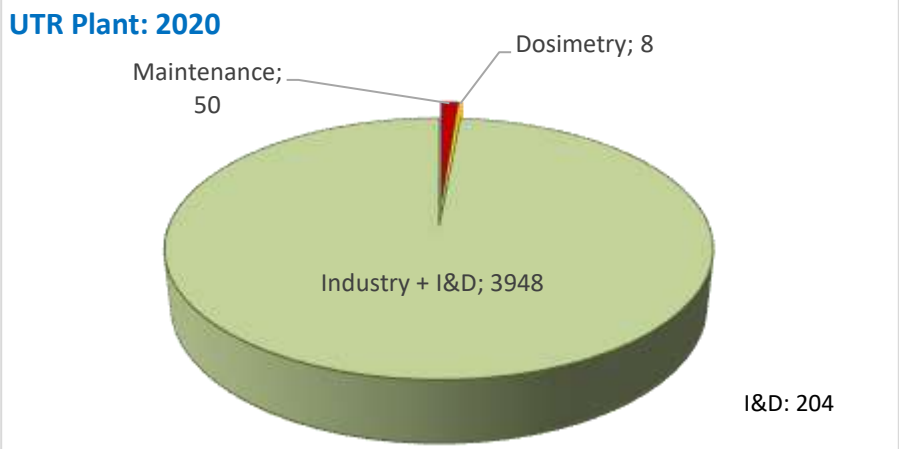
TEAM

Name	Category	Actvities/Competences
Eduardo Alves	Senior Researcher	Director
Paula Matos	Agro-food Engineer	Technical Director&Quality
Carlos Cruz	Auxiliary Researcher	Radiological Protection&Maintenance
Ana Faria	Graduated Technician	Income/Logistics
Teresa Pires	Graduated Technician	Web Designer/Logistics*
Nuno Inácio	Graduated Technician	Irradiator Operator Chief
Filomena Baptista	Assistant Technician	Irradiator Operator
Tiago Jesus	Assistant Technician	Irradiator Operator
Tiago Sena	Assistant Technician	Irradiator Operator

**External collaboration (DECN).*

WORKING HOURS

From March 18th to June 23rd and July 13th to August 21st, there were only one shift working.



INCOME TRACK RECORD

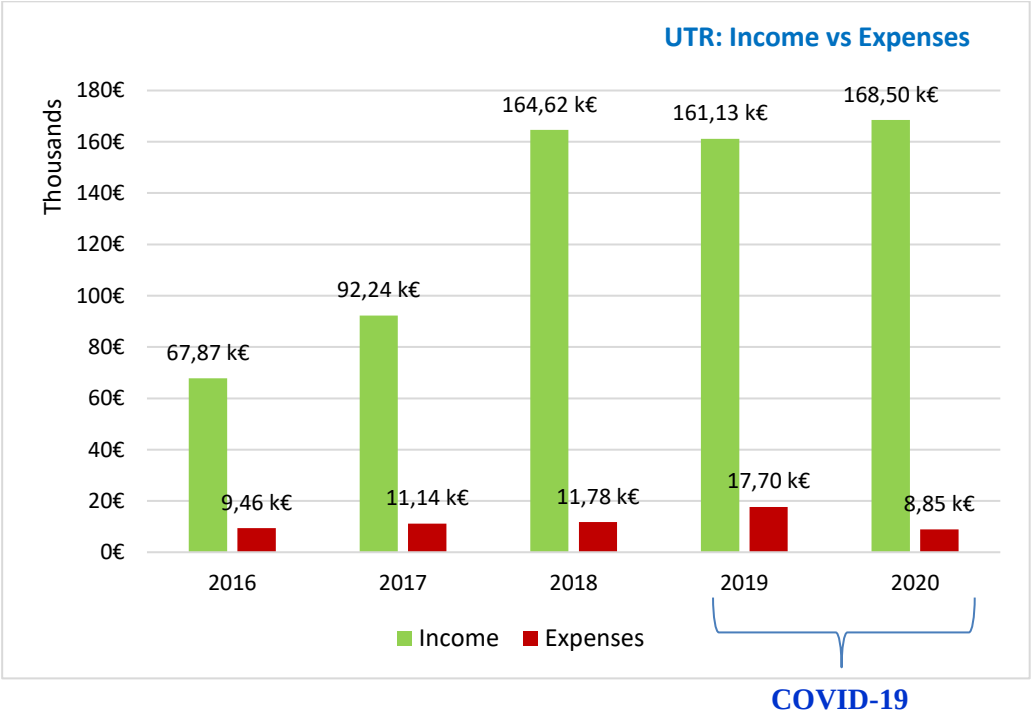
Previous Investments

In 2015 IST purchase a total activity of 135 kCi Co-60 (4995 GBq) by the amount of **€ 348.000** (three hundred forty eight thousand EUR) to the **Institute of Isotopes Co. Ltd** (IZOTOP). By contract the company was responsible for installation of the sources in the irradiator, which happen in January 2017.

Total Income/Expenses (2016-2020)

(Amounts without VAT):

UTR	Income	Expenses
2016	67 865,98 €	9 455,05 €
2017	92 238,88 €	11 144,50 €
2018	164 620,70 €	11 775,13 €
2019	161 126,52 €	17 699,30 €
2020	168 497,96 €	8 851,63 €
Total	**654 350,04 €**	**58 925,61 €**



CLIENTS in 2020

- ALFARROXO TRADING (Pine bark)
- ARAN EUROPE S.L. (Spain)
- ATRAL-CIPAN
- 3B's RESEARCH GROUP (UMINHO)
- BORGSTENA TEXTILE, PT
- EDOL
- HOVIONE
- IST (COVID-19)
- IST-ID (COVID-19)
- IST Research Activities
- IDRUSTENT (Syringes)
- INEB (U. PORTO, Hydrogel)
- LABESFAL
- LABIALFARMA
- LABINOX
- LECIFARMA
- PRODEC (InEye)
- PROGRESSOPLASTE
- SN TÊXTIL
- SOL DE DIAL
- SOCIEDADE ARTISTICA, LDA
- VYGON

ACTIVITY HIGHLIGHTS

1. Covid-19 – Covid Kit Consortium

A consortium of Instituto Superior Técnico Técnico, Algarve Biomedical Center (ABC), Hidrofer and Logoplaste was created to produce kits to diagnose Covid. The ceremony took place on 23rd April 2020 at IST/CTN campus and was attended by the consortium members and by the Minister of Science, Technology and Higher Education, Manuel Heitor, the Minister of Labour, Solidarity and Social Security, Ana Mendes Godinho, and the Minister for Territorial Cohesion, Ana Abrunhosa.

The president of Técnico, Professor Rogério Colaço, stressed the importance of this partnership that "*allowed us to combine knowledge and skills to produce these kits in sufficient quantity to meet country's needs*". "*We hope to export these kits wherever needed as soon as possible*".

Swabs are essential for Covid-19 screening and Portugal was importing this material in order to be able to do the tests. Now there is a product 100% made in Portugal that combines science and national companies to face the current public health emergency.

UTR was responsible for the sterilization of all the "Zaragatoas" used in the kits produced by the consortium

Source:
http://utr.ctn.tecnico.ulisboa.pt/pg_media_projetos.html

2. Sterelization of Health Equipment: STEReoEPI Project

UTR was also involved in a FCT funded project to develop a new method for sterilizing Personal Protective Equipment (PPE). The project entitled **"Gamma sterilization and reuse of PPE"** got a €39,808 funding from FCT - 2nd Edition of "RESEARCH 4 COVID-19" and was led by Professor Ana Paula Serro.

Although most PPE are disposable, many can be safely reused if they are sterilised and maintain adequate performance. Reuse of PPE can have an enormous impact on environment protection and economy of health care services".

Personal Protective Equipment (PPE) has become part of our lives and at UTR we sterilized several types of materials and PPE to determine their integrity after several sterilization cycles. Once developed, the sterilization model can be transferred to healthcare units. The first results were very promising.

Source:
https://tecnico.ulisboa.pt/pt/noticias/cientistas-do-tecnico-desenvolvem-novo-processo-de-esterilizacao-de-equipamentos-de-protecao-individual/

3. CANNABIS Project

During 2020, cannabis farms cover several km^2 of land from north to south of continual area of Portugal. The business flourish all over the country and nearly all the companies contacted UTR to study the possibility to use gamma radiation to process their products. We received the visit of some companies to discuss the capabilities of the unit to process large quantities of the dry product and packing requirements.

However, due the psychotropic effects of the product it is mandatory to be licensed by INFARMED since the decontamination is considered a step in the production process. We submitted a licensing application for the decontamination of cannabis with gamma radiation but it became clear after two meetings with the INFARMED group that our request for the cannabis decontamination service was not compatible with commercial processing.

Unfortunately and despite the huge interest of the industry, UTR resources are insufficient to prepare such a complex process necessary to obtain the licensing and, in parallel, get the GMP (Good Manufacturing Practices) recognition required to commercialise the products irradiated in the Unit inside the European market.

CAMPUS & COMMUNITY

Due to the mandatory confinement resulting from the Covid-19 epidemic, 2020 was an atypical year, with no study visits to the campus allowed after March. Follow-up visits to the UTR, as indicated below:

Description	Visits / Visitants 2020	
Secondary School	1	69
University	0	0
*Other Visits	1	1
Auditors	3	6
Sub-Total	**5**	**76**

**Other Visits:*

- Client: VF Pharmaceuticals, July 10, 2020 (1).

Internal Auditory:

- CTN/LPSR – Assess the degree of compliance of the Management System according to the normative framework NP EN ISO 9001: 2015. **Luis Santos** and **Ana Amaral**, 03/11/2020.

External Auditory:

- TÜV Rheinland – Quality Management System Certification: Renewal of certification for the Norma ISO 9001:2015. **Herminio Henrique**, 30/11/2020.
- HIKMA - Client: to ensure quality and acceptable compliance status to applicable GMP regulations of the targeted site in regards to the irradiation of Lactose (**Ana Paula Gageiro** e **Anabela Supico**). UTR, 13/10/2020.

Concluding Remarks

A decision on the future of irradiation services at IST must be taken very soon.

The activity will be below 100 kCi in 2021 approaching the limit value (approx. 60 kCi) for supplying services to the industry requiring doses above 10 kGy.

To support the decision, an open discussion with current users and other stakeholders which have revealed intentions to use the technology (such as cannabis industry) should be promoted.

From the experience acquired during the last years, it is clear that the Unit cannot operate according the public rules if it is intended to work for the Industry and make some revenue.

To continue the operation satisfying the orders of the current list of clients, the Unit should be reloaded with at least the same activity of Co-60 as in 2017, and this will be much more costly since there are no more space for new sources in the irradiator and some of the older ones must be removed.

In any case, as an act of responsibility, it is important to inform our clients in advance about the near future of the Unit!

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