

Infraestrutura
Nacional de
Computação
Distribuída

2023 Activities Report

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EXECUTIVE SUMMARY

In 2023, INCD continued to support a wide range of scientific users from multiple research domains fulfilling its mission of supporting advanced computing for research and innovation at national and international level. Since 2022, the infrastructure is operating as a formal member of the National Advanced Computing Network (RNCA) of the Portuguese Foundation for Science and Technology (FCT). In this regard, in 2023, INCD supported computational projects from the third edition of the call for advanced computing projects (CPCA) organised by FCT, providing processing time, data storage and user support for high performance computing and cloud computing applications. INCD also participated in the preparation of the fourth CPCA call whose projects will be executed in 2024. In addition, INCD also supported a range of other projects, communities and services of national and international relevance.

Overall, in 2023, INCD delivered more than 40,380,000 processing hours to the research community supporting 133 projects that produced 111 peer reviewed publications. In addition, the capacity delivered by the infrastructure enabled the completion of 11 PhD thesis and 49 MSc thesis. A considerable number of ongoing thesis was also supported.

The collaboration in international distributed computing infrastructures continued with participation at international level in EGI, IBERGRID and supporting the Portuguese participation in the CERN LHC experiments through the participation in the Worldwide LHC Computing Grid (WLCG). In the context of these infrastructures, INCD delivered 16,790,311 processing hours supporting both cloud computing and high throughput applications.

Concerning the infrastructure centres, the decommissioning of the INCD centre in Riba-de-Ave was finalised in the first quarter of 2023, and a small fraction of this capacity was migrated to Lisbon. Meanwhile, the deployment of a new centre in the north of the country in Vila Real at University of Trás-os-montes e Alto Douro (UTAD) continued. This centre was inaugurated in November of 2023 and began delivering High Performance Computing capacity complementing the INCD centre in Lisbon. The gap of almost one year between the decommissioning of Riba-de-Ave and the commissioning of Vila Real has limited the capacity available during the year.

Regarding European projects, the participation in EGI-ACE and C-Scale finished successfully. In the C-Scale project, INCD demonstrated the integration of earth observation applications exploiting federated data and computing infrastructure services for Copernicus. In the EGI-ACE project, INCD acted as a service provider of cloud computing and high performance computing supporting applications in artificial intelligence, biodiversity and coastal engineering in the framework of the European Open Science Cloud (EOSC). The European project iMagine continued in 2023, with the INCD participation focused on the provisioning of cloud capacity for image processing in marine and freshwater science. A joint project with Google for the redistribution of cloud capacity for research via INCD started in the framework of EOSC. A new activity towards the creation of a data space for agricultural data also started in collaboration with organisations from the area.

Already in 2024, INCD applied and supported different applications to the FCT tenure programme, aiming at permanent positions for researchers, in partnership with the University of Trás os Montes e Alto Douro, LNEC and LIP.

The INCD associates, following a request by FCT, decided to work towards the evolution of the association towards the future Nacional Centre for Advanced Computing, with a wider scope and structure of associates. A working group to propose the governance model and the required changes in the INCD bylaws was established. This will be a major change for INCD, but also an opportunity to leverage and expand the current projects and infrastructure.

1. FEEDBACK FROM THE INTERNATIONAL ADVISORY COMMITTEE

The INCD Board of Directors handed over to the members of the AC the Activities Report of 2023 on July 4th 2024, in preparation for the annual meeting on July 10th. The committee would like to thank the INCD management for the excellent preparation of the report and presentation. Being informed about the activities of the last year, the focus of the meeting was to provide feedback and advice on the future plans and evolution of the infrastructure.

INCD is providing primary computing and data services that span from Cloud, High Throughput, to High Performance computing. The experience in large scale data management reflects as well in the multiple choice of options available to end-users: from cloud storage, to classical file storage, or long term storage. The know-how of INCD reflects in the provision of added-value services integrating latest IT technologies, such as containerization, federated HTC and HPC, deployment of Virtual Research Environment,, distributed data management, data protection, scientific portals and gateways, etc.

The report also transmits the effort that the INCD team makes to properly allocate resources that match the needs to a large variety of usage scenarios. This is a differentiating aspect of INCD with respect to other more conventional infrastructures based on just one type of service model.

Regarding upgrades of the infrastructure, during 2023 a substantial increase of capacity was installed at the new center at the University of Trás os montes e Alto Douro (UTAD), which entered into operation in November, reflecting from there on in the accounting numbers. It needs to be noted that INCD is acting, via FCCN, as a vector to deploy advanced network infrastructures across the country, focusing as well on areas in which the investment on advanced IT networks has been so far low. Such investments in distributed and networked infrastructures are key to articulate the territory and foster economic development and wealth.

INCD is integrated in the relevant European networks to provide resources in the framework of IBERGRID and EGI. It supports the delivery of the Portuguese quota to WLCG for CERN ATLAS and CMS experiments. The expertise in managing services and data infrastructure is also reflected at the national level in Portugal by the work to deploy a national catch-all data repository to support the Open Science strategy of FCT in alignment with EOSC.

INCD innovation activities take place in the context of the EU framework programs. Highlights of 2023 are the projects EGI-ACE, C-SCALE, EOSC-Synergy and iMagine. INCD has been provisioning cloud computing services to support biodiversity and coastal modeling in the project EGI-ACE. In the project iMagine, INCD supports with resources the provision of image datasets, and offers AI-empowered high-performance image analysis tools to enable processing and analysis in marine and freshwater science. In the framework of the EU project C-Scale, INCD worked in piloting federated access to HPC resources, supporting the integration and hosting of two earth observation cloud services and worked in the caching of satellite images data from Copernicus. INCD

provides cloud capacity for the Software Quality Assurance as a Service platform (SQAaaS) that was developed in the EOSC-Synergy project by LIP, IFCA/CSIC and UPV.

INCD has also explored the joint usage of commercial and in-house cloud services in cooperation with Google. Teaming with Google, INCD was awarded OCRE credits in 2023, receiving half a million Euro, in a competing proposal at European level. INCD proposed the usage of Google cloud in conjunction with its own cloud service enabling the INCD cloud to burst into Google for higher capacity and additional capabilities. INCD developed an architecture to enable movement of projects between the Google cloud and INCD. This is a very interesting development, with a huge innovation potential that needs to be supported.

The usage numbers continue to be impressive: very diverse user communities, fully allocated resources (~ 40 Millions of core hours), a threefold increase in the number of supported projects over the last years. The usual KPIs in terms of publications, presentations to conferences, PhD and Master thesis are very high compared to even larger peer infrastructures in other countries.

These numbers constitute a proof of the efficiency in the management of the available computing resources. Exceptionally high is the number of PhD and Master thesis being supported, with the long-term impact that implies. The number of PhD/Master's has increased steadily in the past few years, meaning that the infrastructure has reached a level of maturity which is appreciated to develop and execute advanced research projects.

The annual report makes it clear in terms of accounting and scientific impact the broad variety of scientific cases that are served by INCD. Particularly impressive is the fact that 65 different organizations, centers, infrastructures and research units have used INCD services in 2023. Supporting such a large number of users, from different areas is a massive undertaking. Given the exceptional KPIs, the perception of the AC is that the current team providing the support is extremely dedicated.

It needs to be stressed that providing such specialized support is expensive in terms of human resources. The necessity for such expertise is the differentiating factor with respect to other more generic infrastructures offering just one type of service model. The deployment of a stable backbone technical team at INCD is therefore a key step towards the stabilization of the exceptional KPIs presented in the past and recent years.

The hiring of a PhD position funded by FCT under the programme for Institutional Scientific Employment Stimulus has been an improvement in 2023, and constitutes a move in the right direction. The FCT tenure programme can be a source of improvement as well in the course of 2024 if the applications are successful.

The AC wishes to remark the potential of INCD to enable innovation at the frontier of the available technologies. Providing access to cutting-edge hybrid technologies, which for instance combine the potential of fast networks, flexible data acquisition, and event-driven computing, is key to support the requirements of the world of IoT. In the current context of massive data generation and processing, support to data-driven decision making will be a differentiating factor of clear societal interest for the

Portuguese public sector policies in many areas. INCD has an evident potential to impact and to transfer knowledge to society.

The summary of recommendations reads as follows:

1. Given the diversity of the user constituency, and variety of the service portfolio, the creation of a sustainable group of INCD personnel dedicated to technical user support has become mandatory. The AC understands that the challenges behind this recommendation go beyond the powers of the INCD Board of Directors (budgetary, availability of personnel in the labor market, etc.). Highlighting the innovation potential of INCD, their impact at the societal level, and the relevance of the KPIs reached could act as a catalyst and also an argument for the creation of more positions.

2. The KPIs presented (#projects and #institutions supported, #publications) are excellent. They should be made visible in the online channels, eg. webpage of INCD.

3. A new activity, that identifies and reflects on possible opportunities related to the potential INCD participation to the new EU programme, should be started. This would have the benefit that INCD can better anticipate and exploit its know-how and resources when considering its participation in new EU initiatives.

4. A suggestion is to better highlight and promote state of the art solutions developed within INCD, such as the transparent connection to Google Compute Cloud to provision extra resources. Again, this would reinforce the INCD standing and reputation toward both old and prospective collaborations.

5. A suggestion is to better promote INCD-imparted training courses, also beyond the EuroCC courses mentioned in the provided activity report. In fact, the training area has the potential to serve as a very meaningful promotion and possibly sustainability conduit for INCD.

6. A suggestion is to give full publicity to a list of topics for potential MD thesis work. This would open the possibility to recruit, naturally after a selection, external students who would help INCD in creating, maintaining or evolving innovative projects. Clearly this needs to be weighed against the additional workload that this would put on INCD staff.

7. The AC notes that the construction of the “National Center for Advanced Computing” is a significant step forward. A suggestion is to define and promote a related governance model in national and international places. A related suggestion is that this national center should not exclude the participation of private entities, as either contributors or users.

Isabel Campos Plasencia (Spanish National Research Council - CSIC)
Davide Salomoni (Italian National Center of Research in HPC - ICSC)

2. INTRODUCTION

Infraestrutura Nacional de Computação Distribuída (INCD) provides state-of-the-art advanced computing and data-oriented services to the Portuguese research and academic community. INCD supports research across all scientific and technological domains. Internationalisation is a key aspect of the INCD activities both through the participation in European projects, and by linking with international digital infrastructures and initiatives such as EGI[1], IBERGRID[2], WLCG[3] and EOSC[4].

The INCD association (*Associação INCD*) was created in 2015 in the framework of the Portuguese roadmap of research infrastructures funded by *Fundação para a Ciência e a Tecnologia* (FCT)[5]. The INCD association has as core goals performing research, development, promotion and international articulation of advanced computing activities, as well as the development and operation of the INCD infrastructure.

Since 2022, the INCD infrastructure operates in the framework of *Rede Nacional de Computação Avançada (RNCA)*[6], a Portuguese collaborative network that joins computing centres and expertise in high performance computing, high throughput computing and cloud computing for research and innovation. RNCA is coordinated by FCT that manages the access to the computing resources through the national calls for advanced computing projects (CPCA)[7], in which INCD is a provider of High Performance Computing (HPC) and cloud computing resources. In 2023, INCD supported projects from the third call for advanced computing projects, as well as projects, communities and services of national and international relevance.

3. ORGANISATIONAL STRUCTURE

The INCD organisational structure depicted in Figure 1 provides national and international strategic coordination, ensuring liaison with users and their participation in scientific projects as well as interface with other generic and thematic infrastructures.

The general assembly represents the member organisations, namely *Laboratório Nacional de Engenharia Civil* (LNEC)[8], *Laboratório de Instrumentação e Física Experimental de Partículas* (LIP)[9] and FCT. The directorate is responsible for the management of the association and is composed of three directors appointed by the members of the INCD association. The audit committee oversees the financial reporting, related internal controls and compliance. The advisory board provides strategic advice, critical thinking and analysis of the activities and plans. Security is

[1] https://www.egi.eu/
[2] https://www.ibergrid.eu/
[3] https://wlcg.web.cern.ch/
[4] https://open-science-cloud.ec.europa.eu/
[5] https://www.fct.pt/en/
[6] https://rnca.fccn.pt/en/
[7] https://rnca.fccn.pt/en/projetos/
[8] https://www.lnec.pt/en/
[9] https://www.lip.pt/?lang=en

transversal and is represented as an intermediate element of the organisational structure by the security officer. The technical coordinator manages the daily technical activities including the development and operation of the infrastructure.

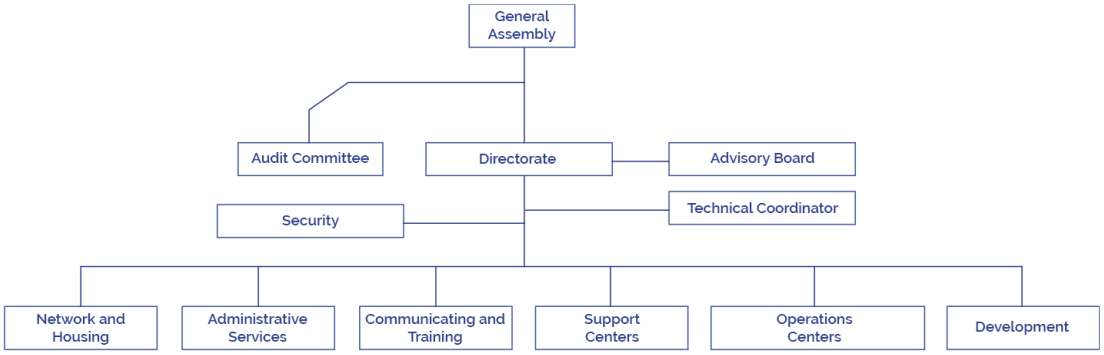

Figure 1: INCD organisational structure.

The technical areas that make the organisational structure include:

Administrative Services: provide technical and administrative support, including management of human and material resources, finances and projects.

Network and Housing: ensures provision of network connectivity and housing of equipment in data centres.

Communication and Training: improves the awareness about INCD and its services, manages relations with the users, manages the organisation of events, presence in web and social networks; as well as creation of training materials and events.

Support Centres: provide user support, consulting and knowledge transfer. They also participate in coordination, management and policy activities and liaise with other digital and thematic infrastructures.

Operational Centres: manage and provide the computing and data services provided by INCD, they are associated with data centre facilities. They manage the services, ensuring their availability and proper operation.

Development: ensures continuous improvement of the computing and data services. The development area is responsible for the evolution and modernisation of the infrastructure services.

The technical activities are performed mainly by staff from the member organisations (LIP, LNEC and FCT via FCT-FCCN[10]) complemented by staff from the INCD association.

[10] https://www.fccn.pt/en/

4. HUMAN RESOURCES

In 2023, INCD was backed by a technical team that included twelve LIP researchers, engineers, technicians and communications personnel that contributed to INCD, complemented by one engineer, one auxiliary researcher and one administrative assistant hired by the INCD association. The auxiliary researcher hired by INCD in 2023 was contracted in the framework of a PhD position funded by FCT under the programme for Institutional Scientific Employment Stimulus[11]. The team is further complemented with contributions from staff of FCT-FCCN and LNEC.

The coordination of the technical activities and related personnel is performed by the INCD technical coordinator, which is also the coordinator of the LIP computing group that performs most INCD technical activities. In 2023, INCD also started to prepare a set of joint applications together with its associates and partner universities, aimed at contracting researchers under the FCT tenure programme[12]. If successful these applications will enable a reinforcement of the human resources for research and innovation as well as strengthening of the collaboration with universities.

5. THE INFRASTRUCTURE SERVICES AND ARCHITECTURE

The INCD infrastructure comprises operational centres in several regions where the hardware is hosted and from which the services are delivered. The centres are distributed across several geographical locations, providing resiliency, exploiting existing resources and promoting partnerships with research and education organisations in the country. The hosting of the operational centres and their network interconnection is performed in close collaboration with the Portuguese National Research and Education Network (RCTS)[13] managed by FCT-FCCN. In particular, INCD leverages the RCTS housing service and RCTS Plus[14] private network service. The housing in data centres and the network connectivity constitute the foundation layers upon which the INCD architecture is built.

Figure 2 shows the INCD architecture. The primary services delivered by INCD encompass high performance computing (HPC), high throughput computing (HTC) and cloud computing complemented by data oriented services. The primary services sit immediately above the housing and network layers. Each of these primary services can be used either directly by the end-users or indirectly through other higher level services meant to provide additional capabilities. This hierarchy of services includes federated access to the computing and data resources, integration in international computing infrastructures, added-value services for computing and data processing, and virtual research environments for specific disciplines or communities. Depending on their requirements and level of expertise, the users can choose which services and which layer of access is the most suitable for them. Common to all layers of the

[11] https://www.fct.pt/en/financiamento/programas-de-financiamento/emprego-cientifico/emprego-cientifico-institucional/
[12] https://www.fct.pt/en/concursos/fct-tenure-1-edicao
[13] https://www.fccn.pt/a-fccn/rede-rcts-rede-ciencia-tecnologia-e-sociedade/
[14] https://www.fccn.pt/en/areas-tecnologicas/conectividade/rcts-plus/

architecture are transversal activities such as security, training, interoperability, support, collaboration, innovation and development. These transversal activities are designed to assist the users in selecting, co-developing and exploiting the INCD capabilities.

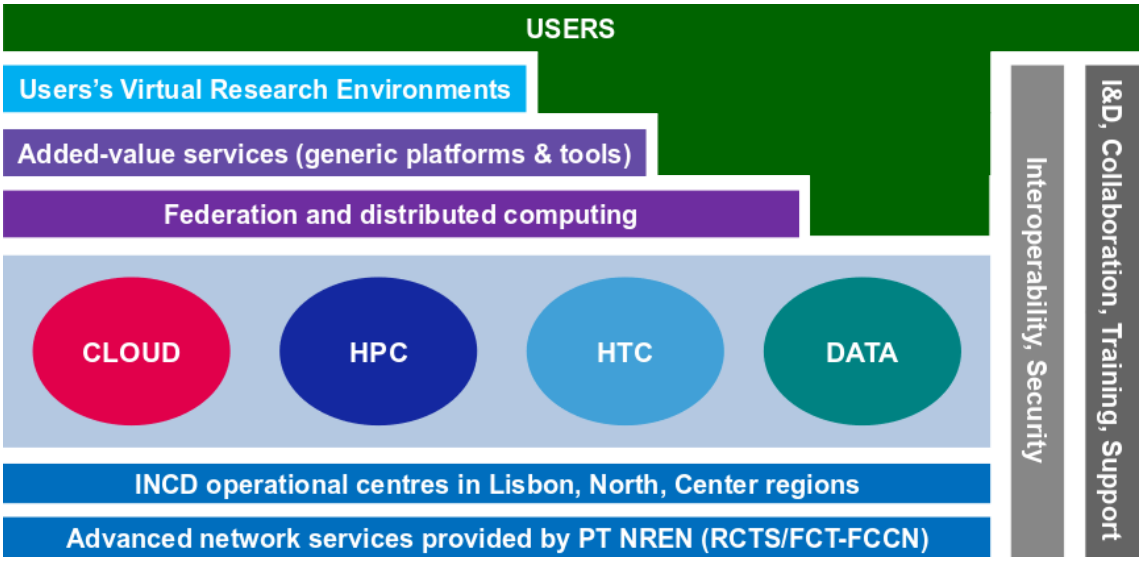

Figure 2: INCD high level architecture.

6. OPERATIONAL CENTRES

The main centre is located in the Lisbon region (INCD-A). This centre was established in the context of the former National Grid Initiative in 2009 and is housed at the Sala-Grid data centre in the campus of the National Civil Engineering Laboratory (LNEC) in Lisbon. The data centre is managed by FCT-FCCN, while the INCD computing equipment and services are managed mainly by LIP staff. This centre is complemented by tape based storage for data protection housed at the LIP data centre in Lisbon (INCD-L).

An initial centre in the North region (INCD-B) was established in 2019 and began being decommissioned at the end of 2022. The centre was hosted at a commercial data centre in Riba-de-Ave sharing capacity from part of a previous generation of the Stampede supercomputer donated by TACC[15] to FCT (this machine was named BOB). A small fraction of this system (*mini-BOB*) was transferred to Lisbon in the beginning of 2023. Meanwhile, a new INCD centre (INCD-D) began to be deployed in the North region at University of Trás-os-montes e Alto Douro (UTAD) in Vila Real. The centre is managed by staff from LIP and INCD, while the hosting is supervised by FCT-FCCN.

The INCD centre in Coimbra (INCD-C) was established by LIP in the context of the former National Grid Initiative, and is located at the Physics department of the University of Coimbra. This centre provides tape based storage for data protection.

[15] https://tacc.utexas.edu/

7. INFRASTRUCTURE UPGRADES

The set up of the new INCD-D centre in the North in Vila Real at UTAD continued along the year. Several improvements of the power and cooling in the university data centre delayed the commissioning of the services. The centre was finally inaugurated in November of 2023 when it began delivering HPC, HTC and Lustre services. This HPC/HTC computing cluster has been denominated Cirrus-D.

The INCD-D centre has a total capacity of about 5000 CPU cores AMD Epyc 7643 with a total of 27 TB of RAM, the online storage includes 1344 TB of storage capacity for Lustre. All systems are interconnected by Infiniband HDR 200 Gbps and Ethernet with 10 Gbps and 25 Gbps connections. The centre also has 2880 TB of storage capacity for Ceph and Openstack services (Stratus-D) whose installation also began in 2023, becoming available for production already in 2024. The INCD-D centre is designed to support HPC, HTC and cloud services.

A partition of the mini-BOB machine that was transferred to Lisbon was assigned by FCT to INCD and was reinstalled from scratch. Another partition was assigned to the Minho Advanced Computer Centre (MACC). The Lustre storage and the Infiniband network for both partitions was set up and operated by INCD.

8. INFRASTRUCTURE NETWORK

To interconnect the several centres INCD has established a private wide area network using the advanced network services provided by FCT-FCCN. The network topology is depicted in Figure 3.

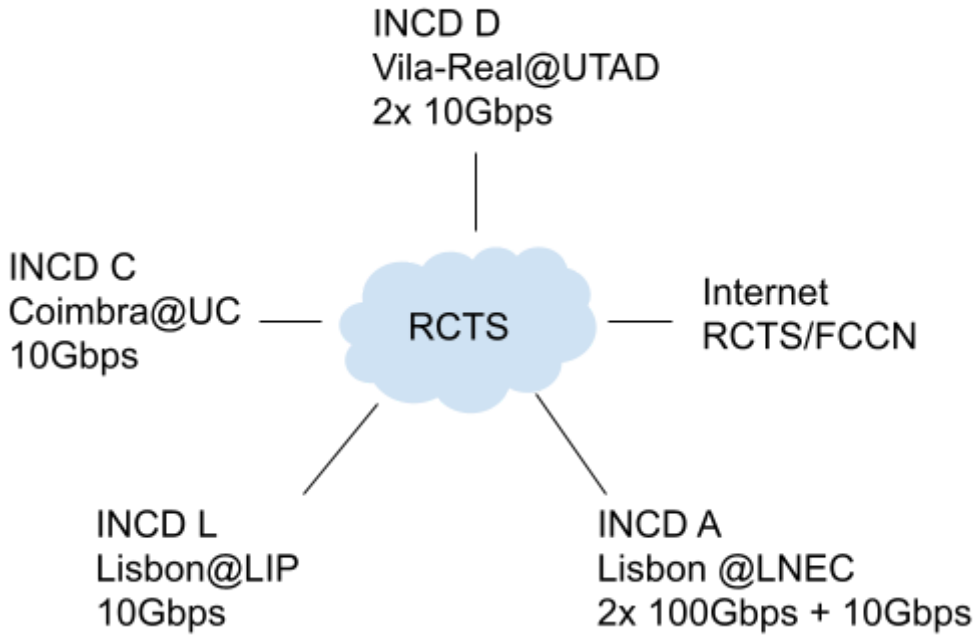

Figure 3: INCD network connectivity.

The centres are interconnected via an Ethernet Layer 2 network, which is built upon the RCTS Plus service provided by FCT-FCCN and is connected to the backbone of the national academic network RCTS also operated by FCT-FCCN. All centres have 10 Gbps links with the exception of the INCD largest centre in Lisbon at the LNEC campus, which is connected both at 100 Gbps for production and 10 Gbps for backup.

The process to establish a second connection of 100 Gbps in Lisbon for the Large Hadron Collider Open Network Environment (LHCONE) started in 2023. This connection became operational already in 2024. The LHCONE is a private network that provides optimised connectivity for computing centres in the Worldwide LHC Computing Grid (WLCG) such as the Portuguese WLCG Tier-2 operated by INCD in partnership with LIP.

9. INFRASTRUCTURE SERVICES

The catalogue of the services provided in 2023 is summarised in Table 1. The primary services are the generic building blocks that constitute the core of the INCD infrastructure, while the secondary services include specific services that are largely built upon the primary services.

Areas	Primary services	Secondary services
Computing	High Performance Computing	Large memory servers Accelerated computing Federated cloud computing Federated HTC/HPC Containerised computing Scientific portals and gateways Value-added services
	High Throughput Computing	
	Cloud Computing	
Data	Cloud Storage	Data repositories Long term storage Data protection Distributed RO filesystem Federated file storage
	File Storage	
	Tape Storage	
Knowledge	Software development	Integration of software & services Software quality assurance Physical resources Virtual resources Training and consultancy Online documentation
	Managed services	
	Support and Documentation	

Table 1: INCD services catalogue

9.1. PRIMARY COMPUTING SERVICES

The primary services encompass the main computing services namely High Performance Computing, High Throughput Computing and Cloud Computing. These services are further described in the following subsections.

Cloud Computing

The INCD cloud computing service (named *Stratus*) is an infrastructure-as-a-service (IaaS) cloud that enables access to virtual machines on-demand. The cloud service is built-on the Openstack cloud management framework, while the virtualisation uses the Kernel-based Virtual Machine (KVM)[16] hypervisor. The cloud computing service is complemented by the INCD cloud storage service that provides block and object storage to the Openstack cloud. In 2023, the cloud computing service was provided by the *Stratus-A*[17] service hosted at the INCD operational centre in Lisbon. In 2023 the service delivered 18,907,013 vCPU hours of processing time, and the service achieved a capacity of 3072 vCPUs cores. The capacity of the cloud service was slightly improved by adding computing nodes freed by the upgrade of the Lisbon HPC cluster. The deployment of a second Openstack installation at the Vila Real operational centre began and the service became operational already in 2024. This new installation with 2000 vCPUs will improve the overall resilience of the INCD cloud offering and will provide new capabilities. The cloud service was complemented with capacity delivered under a joint project with the Google cloud.

High Throughput Computing

The High Throughput Computing (HTC) service is optimised for the execution of large numbers of individual tasks either single threaded or multi-threaded, targeting massively computational and data intensive applications. Differently from the HPC workloads where the running processes need to communicate with low latency, the HTC computing processes are individual tasks that can be executed separately. For higher efficiency, the HTC and HPC services share the same Slurm batch systems. In 2023 the HTC service delivered 12,193,349 hours of processing time, mainly supported by partitions of the *Cirrus-A*[18] cluster in Lisbon. The service is composed of heterogeneous nodes both Intel Xeon and AMD Epyc interconnected via a high performance Ethernet network. The service relies on a Lustre[19] file-system optimised for high-throughput workloads provided by the INCD file storage service. In 2023 the service achieved a capacity of approximately 4236 CPU cores.

[16] https://linux-kvm.org/
[17] https://stratus.ncg.ingrid.pt/
[18] cirrus.a.incd.pt
[19] https://www.lustre.org/

High Performance Computing

The High Performance Computing (HPC) service is optimised for the execution of parallel computing workloads that require inter-process communication across computing nodes with low latency. This service is particularly suitable for MPI applications. In 2023, the service delivered 8,979,647 hours of processing time, backed by the *Cirrus-A* cluster in Lisbon. The *Cirrus-A* cluster features computing nodes equipped with AMD Epyc processors installed at the end of 2022. The cluster is equipped with an Infiniband network. The storage system is a Lustre file system optimised for parallel workloads provided by the INCD file storage service. In 2023 the service had a capacity of approximately 2320 CPU cores. A major effort was placed in the migration of the HPC service from CentOS 7 to AlmaLinux 8, including the set up of the software environment encompassing the compilation of HPC libraries and applications for this Linux distribution. The older compute nodes running CentOS 7 were removed from the HPC service and reused to reinforce other INCD services. A small partition of the mini-BOB transferred from Riba-de-Ave was integrated in the HPC service.

The total available capacity of the HPC service during the year was affected by the decommissioning of the Riba-de-Ave centre. A new cluster, *Cirrus-D*[20] in Vila Real, was inaugurated and started to operate in November of 2023. This new cluster has a capacity of about 4000 CPUs for the delivery of the HPC and HTC services.

9.2. PRIMARY DATA SERVICES

The primary data services encompass the main data storage services namely Cloud Storage, File Storage and Tape Storage, upon which other secondary data services are provided.

Cloud Storage

The INCD cloud storage service provides access to object and block storage. The service is oriented to provide robust scalable storage for cloud applications. The storage service is closely related to the INCD cloud computing service and is based on the Ceph[21] data storage system. The block storage service provides volumes for the cloud virtual machines, while the object storage service enables data to be stored as objects, therefore providing higher horizontal scalability than conventional data storage on file-systems. The object storage component of the service can also be used independently from the cloud computing service. Through its application programming interface (API), that includes support for S3[22] and SWIFT[23], the object storage can be easily and safely accessed remotely. In 2023, the cloud storage service supported by the INCD centre in Lisbon provided 1431 Terabytes*month (equivalent to an average

[20] ui.d.incd.pt
[21] https://ceph.com
[22] https://docs.aws.amazon.com/AmazonS3/latest/API/Welcome.html
[23] https://wiki.openstack.org/wiki/Swift

usage of 119 TB per month over the year), and the service had a total usable capacity of approximately 400 Terabytes including the Ceph triple redundancy (1.2 Petabytes of raw capacity). The deployment of a new Ceph storage system with 1 Petabyte of usable capacity (3 Petabytes of raw capacity) began in Vila Real and became operational in production in 2024.

File Storage

The file storage service provides access to POSIX read-write file systems that are mainly based on Lustre. This service is used in conjunction with the HPC and HTC services. In special cases the service can also be provided using other technical solutions such as NFS. The file storage service can also be used independently from the HPC and HTC services via secondary services such as the federated storage. This service is meant to support applications that rely on conventional file systems and is especially suited for storage and processing of large files. The file storage service provides the data storage backend for the HPC and HTC services. Following the decommissioning of the centre in Riba-de-Ave, in 2023 the service was supported only by the INCD centre in Lisbon with a usable capacity of about 2 Petabytes. Several old servers have been decommissioned and the total capacity has been consolidated. The deployment of a Lustre file system in Vila Real with a usable capacity of 1.2 petabytes was implemented to support the new *Cirrus-D* cluster and became available in November of 2023.

Tape Storage

Contrary to other services in the INCD catalogue, the tape storage service is a service internal to INCD that is not directly accessible to end-users. This service provides the backbone for other secondary services such as data protection and long-term storage, providing reliable yet cost-effective storage capacity for infrequently accessed data using LTO tape libraries. The service is provided by tape libraries in Lisbon and Coimbra with a total capacity of up to 20 Petabytes.

9.3. PRIMARY KNOWLEDGE SERVICES

The primary knowledge services category includes software development, managed services and support. Included in the support is the technical documentation for the services. These are services that leverage and share the INCD experience and competences. They are meant to support the exploitation of the computing and data services, but can also be used separately.

Software Development

Development of software to expand the INCD offering such as new tools and services, or co-development of specific software in partnership with user communities. The service includes both development of new services and software as well as porting of software to be used at INCD. The service is often provided in the framework of projects joining INCD with user communities, or as part of the support provided to new projects and user communities. In 2023, included in this service INCD performed software developments and customisations for several of its services. INCD also contributed to the development of open source software such as the udocker tool for containerisation used in several projects.

Managed Services

This support service is oriented to the management of virtual or physical resources integrated in INCD. The virtual resources can be virtual machines, containers or other types of resources that can be instantiated using the INCD services, and whose management can be fully or partially delegated to INCD. The physical resources can include private hardware that is housed at INCD under agreed conditions. A key condition for the physical resources is that they are integrated and shared via the INCD primary services (e.g. cloud, HPC, HTC or data storage services). This allows the users to become free of the burden of managing hardware resources, while simultaneously benefiting from the combined capacity of these resources together with the INCD capacity, capabilities, scalability and connectivity. Examples of this service in 2023 include the delivery of the managed Lustre installation for the mini Bob machine used by MACC, the management of hardware integrated in the INCD cloud for the GBIF national node, the management of VMs for many different user communities and the management of the Portuguese Tier-2 in the Worldwide LHC Computing Grid.

Support and Documentation

This service aims at supporting the usage of the INCD services through documentation and support. Most of the documentation is provided online and is continuously improved and enlarged based on the perceived user difficulties and feedback from the INCD helpdesk. Direct support is provided through the INCD helpdesk via email, complemented with remote conferencing. The implementation of a new trouble ticket system based on Zammad[24] started and is expected to replace the current RT system in 2024. In 2023, the INCD helpdesk received 548 user support requests via the trouble ticketing system. The development of a new portal for the internal management of projects and users has started, including a new database for collection of usage and key performance indicators.

[24] https://zammad.com

9.4. SECONDARY SERVICES

The secondary services category includes a wide range of services that are built upon the primary computing, data and knowledge services complementing them with additional capabilities.

Large memory computing

The large memory computing service is aimed at computational tasks with large memory requirements. The service takes advantage of the HPC, HTC and cloud services, and provides access to a set of compute nodes with larger RAM capacity that can be accessed through batch partitions associated with the HPC and HTC services or via the cloud service. The maximum RAM capacity is limited to 512GB in Lisbon and 1TB in Vila Real. This service targets multithreaded shared memory applications with large memory requirements such as genome data processing and other *big data* applications. The large memory service in Vila Real became fully operational in November of 2023 providing access to machines with 1TB of RAM.

Accelerated computing

The accelerated computing service provides access to compute nodes equipped with specialised hardware e.g. GPUs. The service is suitable for machine learning, artificial intelligence applications and other GPU enabled applications. The accelerated computing service is supported in Lisbon via the *Cirrus-A* cluster (HPC and HTC) and *Stratus-A* cloud. The range of supported GPUs includes NVIDIA A100, V100 and T4 for production and older NVIDIA GPUs mainly for development and educational purposes. The service provided more than 52,900 GPU computing hours.

Federated cloud computing

Access to cloud computing resources federated in the EGI and IBERGRID infrastructures interconnecting cloud computing services and cloud data storage at international level. The INCD cloud service itself is federated into the EGI and IBERGRID international infrastructures. Through the federated cloud service, INCD provides cloud capacity from its own cloud service *Stratus*-A in Lisbon and assists users in gaining access to additional cloud capacity integrated in the EGI and IBERGRID federations. The service is mainly oriented at supporting international research activities that benefit from the access to shared computing resources at international level for added capacity and resiliency. In 2023 the service provided 6,615,354 hours of elapsed time. A second installation of this service is expected to become available in Vila Real in 2024 using the *Stratus-D* cloud service.

Federated HTC and HPC

Access to the EGI, IBERGRID and WLCG distributed computing infrastructures, interconnecting computing clusters at international level. The INCD main computing services HTC and HPC are federated in the EGI and IBERGRID international infrastructures. Through the federated computing service, INCD can provide HTC and HPC capacity from its own computing services and/or assist users into accessing additional capacity integrated in the EGI federation. The service is mainly oriented at supporting research activities that benefit from the access to shared computing at international level. In 2023 the federated HTC and HPC service was delivered by the *Cirrus-A* cluster in Lisbon. The service provided 10,174,957 hours of federated computing time. A second installation of the federated HTC and HPC service is expected to become available in 2024 exploiting capacity from the *Cirrus-D* cluster at the Vila Real centre.

Containerised computing

The containerised computing service provides support for execution and orchestration of Linux containers for services and applications. The service enables portability, reproducibility and preservation of applications together with their computing environments. The service is meant to support execution of simple or complex containerised services and applications. This service relies on the HPC, HTC and cloud services enabling execution of Linux containers using different types of container execution runtimes. Some of the supported tools include udocker, Docker, Singularity/Apptainer and orchestrators like Docker Swarm and Kubernetes among others. The development of a bare metal Kubernetes service independent from other services was started. This new Kubernetes will support multi-tenancy and is expected to become operational in 2024.

Scientific portals and gateways

This service supports the deployment, operation and access to scientific gateways and portals. These are community oriented services delivered on top of the INCD cloud and/or in combination with other INCD data or compute services. Examples of such services include R-Studio, Jupyter notebooks, Galaxy portals and domain specific solutions for simulation and data analysis. These services are deployed on-demand for each community that requires them.

Value-added services

Provisioning of a wide range of generic services mainly delivered through the INCD cloud that target specific yet common requirements of the research and academic community both at the organisation and team level. Examples of such services include Sync & Share services, databases, agenda & meeting organisation, web servers, load balancers, proxies, among others. The range of services is flexible and is managed according to the demand.

Data repositories

INCD continued collaborating with FCT-FCCN and LIP in the deployment and evaluation of a catchall data repository tailored to the Portuguese research community. The data repositories service is oriented to support open science requirements concerning open access to research data by supporting digital data repositories for specific communities. The service is based on the Dataverse open source research data repository software. The effort was mainly focused on benchmarking and improving the performance and resiliency of the service. The piloting phase of the service performed in cooperation with selected user communities started in the last quarter of 2023 and is ongoing.

A new activity started in the framework of the Portuguese participation in the European partnership of *Agriculture of Data*. In this context, INCD is collaborating with several public entities related with agriculture or that provide information relevant for agriculture, aiming at piloting different use cases exploiting data from multiple origins with a particular focus on satellite images from Copernicus Sentinel-1 and Sentinel-2. This activity aims to establish the basis for a future data space dedicated to agriculture.

Long-term storage

This service is aimed at long-term data storage of infrequently accessed data. The service is mainly delivered using tape library based storage, but can also be provided via on-line data storage depending on the nature, size and data access patterns. This service is supported by INCD through the LIP managed data centres in Lisbon and Coimbra.

Data protection

The data protection service is aimed at data backups to protect against data loss and support data recovery. The service is delivered using tape library based storage. This service is supported by INCD through the LIP managed data centres in Lisbon and Coimbra.

Distributed read-only filesystem

The distributed read-only file system service is meant to share immutable files across the INCD centres regardless of their geographic location. The service can be used to make user specific software environments available across the INCD infrastructure. The service is based on the CernVM-FS (CVMFS)[25], a scalable POSIX read-only file system. The service is mainly meant for sharing of software and smaller read only files in a reliable way, enabling an homogeneous computing environment across the INCD centres. The service features a stratum 0 and 1 in Lisbon and stratum 2 at the other centres. In 2023, the service had a maximum capacity of 2 Terabytes of storage. A new stratum 2 instance was deployed in Vila Real to support the new HPC and HTC services.

Federated file storage

The federated storage service enables remote access to the INCD File Storage service. Is based on several middleware services that provide high performance secure access to the Lustre file system. The middleware services include StoRM and XRootD, through which multiple data transfer protocols are supported including gridftp, WebDAV and XRootD. The federated file storage service is integrated with the EGI, IBERGRID and WLCG international infrastructures. In 2023 the service was supported by the INCD centre in Lisbon with a capacity of about 1.4 Petabyte of storage.

Training and consultancy

Complementing the core support and documentation activities, INCD also provides different types of training, either generic such as induction and assistance for new users or specific to address advanced usage topics or targeting specific communities. Consultancy and technology transfer are also part of these activities.

Integration of software and services

The integration of software and services is a support service aimed at facilitating the integration of generic, thematic or community specific software to take advantage of the INCD services. This is a human resources intensive service that is subjected to the availability of experts that work closely with the users providing guidance and accelerating the process of software co-development and integration. This service is oriented to both cloud services to be hosted at INCD and integration of HTC and HPC applications. This service also includes the integration at the federation level in order to take advantage of international infrastructures and initiatives like EGI, IBERGRID and EOSC to provide higher capacity, scalability and enable sharing of software, data and computing resources. In 2023, this activity was developed mainly in the context of

[25] https://cernvm.cern.ch

some CPCA projects and also in the European projects EGI-ACE, C-Scale and iMagine. In the framework of the Portuguese participation in the European partnership of *Agriculture of Data* a set of applications was also identified for integration.

Software quality assurance

With this service, INCD aims to support software development and the adoption of software quality best practices. The service builds upon the SQAaaS platform developed by IBERGRID in the EOSC-Synergy project to enable on-demand creation of CI/CD pipelines making quality verification and validation easily accessible to researchers and software developers. Besides the SQAaaS other services such as CI/CD and software source code repositories are also provided. A GitLab service for INCD users was made available as part of the software development and quality assurance framework.

INCD also supported the hosting of the software repositories for the Unified Middleware Distribution (UMD) and Cloud Middleware Distribution (CMD) as well as for IGTF trust anchors. Hence providing a key service for the international distributed computing community. These repositories are also a key component of the EGI quality assurance process for the UMD and CMD distributions provided by Portugal and Spain in the context of IBERGRID.

10.INFRASTRUCTURE MANAGEMENT AND OPERATIONS

The infrastructure management and operations is split mainly across the centres in Lisbon and Minho working tightly in the development and management of the infrastructure, participation in projects and user support.

The improvement of the infrastructure has been a continuous effort and in 2023 included both multiple software improvements and hardware reorganisations. In this context, the retirement of old computing and storage equipment continued, with the corresponding capacity being either consolidated or replaced using equipment either purchased in the public tender of 2022, donated or provided by the INCD partner organisations.

Several software improvements were introduced. In particular, a transition from CentOS to AlmaLinux and in certain cases Ubuntu was started inline with the RHEL 7 end-of-life scheduled for June of 2024. All new equipment and upgrades are now targeting AlmaLinux 8 or 9 for the HPC, HTC and Lustre based services, while the Openstack and Ceph based services are moving to Ubuntu. Correspondingly a large effort was placed in creating and optimising the HPC and HTC software environments for AlmaLinux.

The migration of part of the Bob machine from Riba-de-Ave to Lisbon finished in the first quarter of 2023, the installation of the network and Lustre storage was performed

by the Lisbon team, while the migration of other INCD hardware from Riba-de-Ave to Vila Real was performed by the Minho team. The mini-Bob partition assigned to INCD in Lisbon was also fully reinstalled with AlmaLinux. Older compute nodes from the CentOS 7 HPC service were decommissioned and reallocated to other services.

The improvement of the HTC partition of the Lisbon cluster with hardware from the ATLAS experiment donated by CERN continued in 2023. The deployment of the new HPC and HTC cluster in Vila Real was completed and started to operate in November of 2023. In Coimbra a complete reorganisation of the local infrastructure including network and services is in progress.

11.FEDERATION ACTIVITIES IN EGI, IBERGRID AND WLCG

The participation of INCD as a provider in the international digital infrastructures IBERGRID (ibergrid.eu) and EGI (egi.eu) continued as a key aspect of the INCD strategy to support international projects and research communities. The three main computing services provided by INCD (cloud, HTC and HPC) are integrated in IBERGRID, and through the Iberian infrastructure they are also integrated in the wider federations, therefore enabling the sharing of compute and data resources to support international research. The high energy physics collaborations, such as the ATLAS and CMS experiments at the CERN Large Hadron Collider (LHC), are examples of research communities supported through this approach. Other examples include: the Portuguese node of the Global Biodiversity Information Facility (GBIF) in the framework of the Lifewatch, thematic services developed by LNEC in the scope of EOSC such as OPENCoastS and Worsica, among others. In 2023, INCD delivered more than 10,174,957 HTC/HPC federated computing hours and 6,615,354 federated cloud computing hours supporting research projects and communities of national interest in the scope of the IBERGRID and EGI federations. The federation in IBERGRID and EGI of the new computing and storage services available in Vila Real is also being prepared.

INCD provides the computing and data storage capacity for the Portuguese Tier-2 facility that supports the national participation in the ATLAS and CMS experiments at the CERN LHC. The Tier-2 is operated under the MoU for the Collaboration in the Deployment and Exploitation of the Worldwide LHC Computing Grid (WLCG) signed by the Portuguese government. Under this MoU, Portugal contributes to its share of the LHC computing costs through the delivery of computing and data capacity to the CERN experiments, supporting both global simulation and data processing for the experiments, and data analysis by Portuguese researchers. The WLCG is the world's largest thematic distributed computing infrastructure. The WLCG sits on top of the computing and storage capacity delivered by the computing facilities such as the Portuguese Tier-2 that are federated in either EGI (European Grid Infrastructure), OSG (Open Science Grid), or NeIC (Nordic e-Infrastructure Collaboration). In 2023, the process to connect the Tier-2 to the LHCONE private network started. The internal network that serves the Tier-2 was reorganised and a new virtual routing domain was established for the LHC experiments. The IPv6 connectivity for internal WLCG virtual networks was set up. Upgrades of several middleware services also took place

including support for authentication with tokens.

In 2023, the WLCG Tier-2 consumed 162,641,224 HEPSCORE23 normalised hours fulfilling the yearly pledged capacity. However, the Tier-2 capacity is largely below the necessity and the participation in the upcoming High Luminosity LHC with its huge computing and data requirements will be unfeasible without major upgrades.

INCD is hosting the EGI software repositories for the Unified Middleware Distribution (UMD), Cloud Middleware Distribution (CMD) and Certification Authorities for the International Grid Trust Federation (IGTF). These repositories support the distribution at global level of all middleware for the EGI federation and related digital infrastructures including the Worldwide LHC Computing Grid. This activity is conducted in the context of a tender for the EGI software management awarded to IBERGRID. In this context INCD also participated in the development of the new repositories in partnership with LIP. The new repositories are part of a complete reorganisation of the EGI software management and quality assurance process, and are now in production.

Also in the scope of the IBERGRID collaboration, INCD contributed to the organisation of the 12th edition of the IBERGRID conference[26]. The IBERGRID 2023 conference took place at the *Centro de Ciencias de Benasque Pedro Pascual* in September 2023 and was focused on topics related with the development, integration, quality and adoption of services, applications and digital twins to support cutting-edge research.

12.EUROPEAN OPEN SCIENCE CLOUD and EUROPEAN PROJECTS

Bridging with the IBERGRID and EGI activities, INCD participated in several activities related to the European Open Science Cloud (EOSC), both through participation in projects and by supporting thematic services in the framework of EOSC. Among others INCD is supporting in EOSC the coastal modelling service OPENCoastS[27] and water detection service WorSiCa[28]. These thematic services were developed by LNEC in collaboration with LIP and are housed at INCD. INCD also provides cloud capacity for the Software Quality Assurance as a Service platform (SQAaaS)[29] that was developed in the EOSC-Synergy[30] project by LIP, IFCA/CSIC and UPV.

The EOSC projects EGI-ACE and C-Scale finished in April and September of 2023 respectively. In EGI-ACE, the work of INCD was focused on providing cloud computing services to support applications in biodiversity, coastal modelling and machine learning. INCD also worked in piloting federated access to HPC resources. In C-Scale, the work of INCD was focused on the integration of earth observation services exploring data from Copernicus using the EGI infrastructure. INCD supported the integration and hosting of two earth observation cloud services and worked in the caching of satellite images.

[26] https://www.ibergrid.eu/2023-ibergrid-benasque/
[27] https://opencoasts.ncg.ingrid.pt
[28] http://worsica.lnec.pt
[29] https://sqaaas.eosc-synergy.eu/#/
[30] https://www.eosc-synergy.eu/technical-areas/quality/

The participation in the iMagine project continued in 2023. The project provides a selection of image datasets, AI-empowered high-performance image analysis tools to enable processing and analysis in marine and freshwater science.

Also in the context of the EOSC activities, INCD teaming with Google won an European procurement opened in the context of the EOSC-Future project for the distribution of commercial cloud services to European researchers, aimed at bridging the gap between commercial service providers and researchers through the EOSC ecosystem. The proposal from INCD with Google was submitted in December 2022 and was awarded at European level with OCRE credits in 2023, receiving half a million Euro. INCD proposed the usage of Google cloud in conjunction with its own cloud service enabling the INCD cloud to burst into Google for higher capacity and additional capabilities. In this context a closer collaboration with Google started and the INCD team received intensive training from Google. INCD developed an architecture to enable movement of projects between the Google cloud and INCD, and for bursting into the Google cloud particularly for Kubernetes applications.

13.RNCA AND HIGH PERFORMANCE COMPUTING ACTIVITIES

Within the scope of the national advanced computing network (RNCA), INCD together with its partners, continued to participate in activities aimed at establishing and developing the RNCA network (https://www.fccn.pt/computacao/rnca/). In this context INCD participated in the support to the FCT calls for advanced computing projects, through which FCT grants computing time for research projects. Namely, INCD participated in the third CPCA as an operations centre supporting 63 computing projects in several scientific domains including HPC, cloud and GPU computing. INCD also participated in the preparation of the fourth CPCA call and also in the technical evaluation of projects whose execution is meant to start in 2024.

Under the RNCA protocol, INCD has the responsibility of supporting research activities of strategic interest related with CERN and high energy physics while simultaneously supporting research projects in the context of FCT calls. In return, FCT is also contributing to the operational costs of INCD under conditions that are agreed annually. The yearly conditions for 2024 were therefore agreed and signed.

Under the agreement to support the *mini-BOB* in Lisbon, INCD managed the complete storage system that serves both the INCD and MACC partitions, as well as the Infiniband network. Part of the hardware that supports the storage system was also supplied by INCD.

INCD is supporting the activities of the Portuguese National High Performance Computing Competence Center (NCC) in the framework of the EuroCC2[31] project that started in January of 2023. In this regard, INCD collaborated with the LIP and FCT associates that are partners in the EuroCC project to support the dissemination, training and engagement of new users. INCD is also providing the housing to support

[31] https://eurocc.fccn.pt/en/

the Portuguese NCC web presence, and access resources to promote the adoption of HPC in the public sector.

14.OPEN SCIENCE AND RESEARCH DATA

INCD has been cooperating with FCT-FCCN and LIP to create a pilot catchall data repository for FCT based on the Harvard Dataverse[32] open source software. This FCT service aims at making research data openly available according to the open science values and FAIR principles. In 2023, this activity was significantly developed as part of a collaboration protocol with FCT-FCCN. INCD is housing development and piloting instances of the data repository for FCT-FCCN, and is assisting in the adaptation and deployment of the software to the national requirements. INCD is also assisting in performance profiling and optimization. Experimentation with several user communities has started. The production service will be coordinated by FCT-FCCN and will be named *Polen*[33].

In the C-Scale project that finished in September of 2023, INCD developed a cache service based on the OpenEO software to serve Copernicus satellite images for multiple earth observation applications that were integrated in the project. This activity promoted collaboration with other public organisations in the country, among these the participation in the European partnership of *Agriculture of Data*. Under the third CPCA call several entities related to the partnership have submitted a first project to explore the sharing of data and services using the INCD cloud. This project was approved by FCT and INCD is cooperating with these entities pursuing the concept of a data space for agriculture related data. Three different use cases have been established covering soil evapo-transpiration, identification of crops and cultivated areas, and sharing of different types of data.

15.USAGE METRICS

Overall in 2023 about 40,380,000 hours of processing time were delivered across all INCD services. Figure 4 shows the combined usage in processing hours of the INCD infrastructure since January of 2018. The usage includes the high performance computing, high throughput computing and cloud computing services, upon which other services are also built and delivered.

[32] https://dataverse.org/
[33] https://polen.fccn.pt/

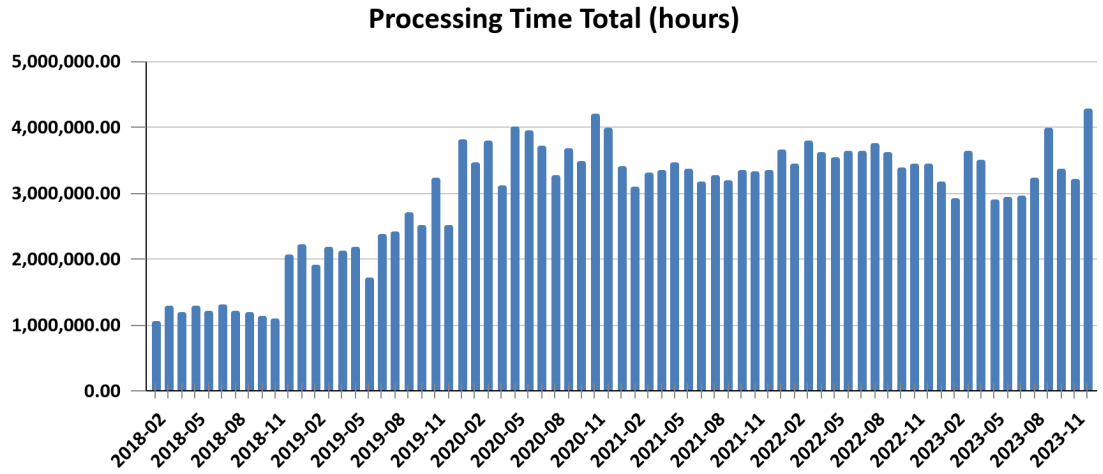

Figure 4: combined usage of all INCD services from January of 2018 to December of 2023.

Figure 5 shows the usage of the main INCD services since January of 2017 per centre and service. The figure shows the batch services supporting HPC and HTC both in Lisbon and in the North, and the cloud computing service also in Lisbon.

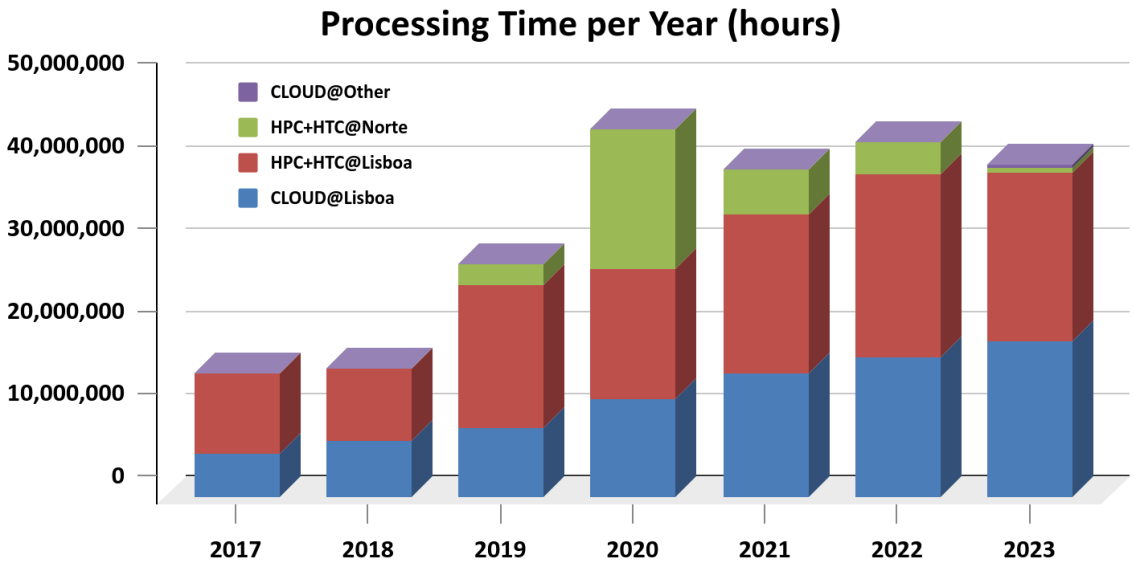

Figure 5: usage in hours of both HPC and HTC batch services from January of 2017 to December of 2023.

The HPC and HTC capacity delivered by the Lisbon centre amounted to 20,475,108 hours. In the north the HPC and HTC capacity delivered decreased significantly in 2023 with the decommissioning of the site in Riba-de-Ave. The improvement of the datacenter in Vila Real took longer than expected and began to deliver HPC capacity in November.

Following the trend of the previous years the cloud computing service in Lisbon had an increase in usage of 11%. Figure 6 shows the usage of the INCD cloud computing service provided by the Lisbon centre since January of 2017. In 2023 the service was used by 47 projects from 30 research units and organisations that consumed a total of 18,907,013 vCPU hours. In addition more than 300,000 processing hours were delivered by INCD using google cloud resources awarded in the framework of an European Open Science Cloud (EOSC) grant.

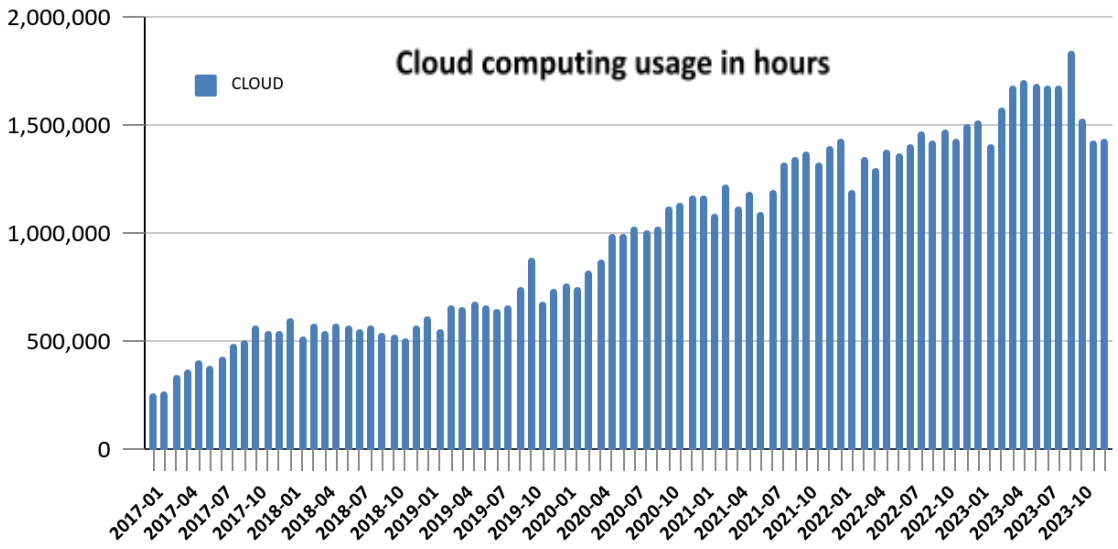

Figure 6: usage of the INCD cloud computing service from January 2017 to December of 2023.

In 2023, INCD supported a wide range of usage from infrastructures, research units and departments of universities from multiple scientific domains and geographic areas in the country. Section 16 contains the list of the supported entities. INCD supported 63 computing projects from the CPCA calls organised by FCT. INCD continued to support the Portuguese participation in CERN related experiments such as the ATLAS and CMS experiments at the CERN LHC. The Portuguese Tier-2 in the Worldwide LHC Computing Grid (WLCG) executed 741.737 processing jobs and delivered 162,641,224 HEPSCORE23 normalised processing hours. Table 2 shows the usage of the INCD primary computing services in 2023.

Services	Hours	Percentage
Cloud	**19,207,215**	**47 %**
HPC	**8,979,647**	**22 %**
HTC	**12,193,349**	**31 %**
Total	**40,380,211**	**100 %**

Table 2: summary of the services usage in 2023.

16.USERS AND PROJECTS

Table 3 shows the number of projects supported by INCD per year since 2017. In 2023, INCD supported a total of 133 research projects of which 63 were CPCA computing projects. In addition many projects were reported by CPCA users as being research projects that benefited from the CPCA computational resources.

Projects supported yearly	2017	2018	2019	2020	2021	2022	2023
Number of projects	61	57	65	122	123	114	133

Table 3: Projects supported yearly by INCD

Figure 7 shows the split of the projects supported in 2023 per scientific area. Physics was the area with the highest percentage of projects (20.3%), followed closely by biological sciences (16.8%), and Electrical, Electronic and Information engineering (14.7%) and Health sciences (11.9%), the remaining projects (36.3%) cover a wide range of scientific areas.

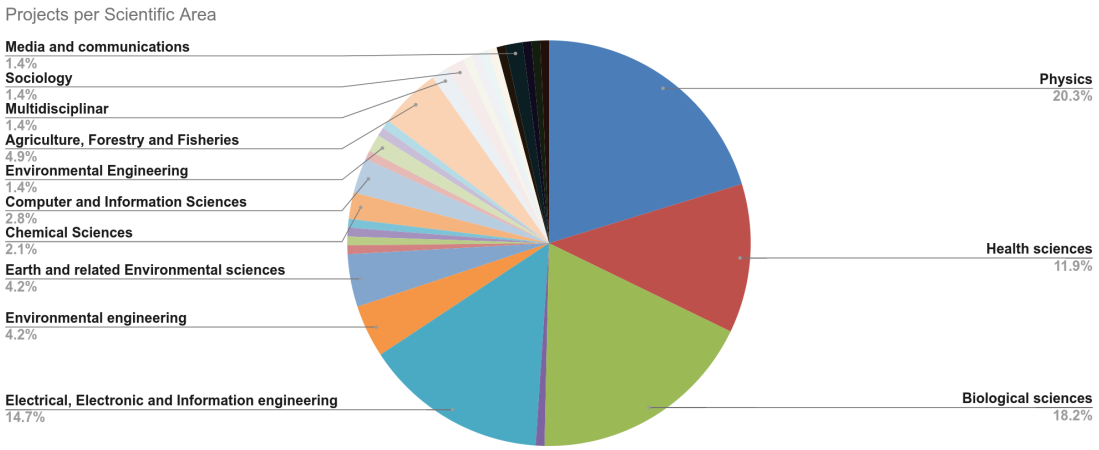

Figure 7: projects per scientific area in 2023.

Table 4 shows the list of the 65 different organisations, centres, infrastructures and research units that used INCD services in 2023.

Algarve Biomedical Center Research Institute
Algarve Biomedical Center Research Institute (ABC Ri)
Associação BIOPOLIS
Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento - Centro de Recursos Naturais e Ambiente
Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento - Centro de Matemática Computacional e Estocástica
Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento - Instituto de Plasmas e Fusão Nuclear
Associação Laboratório Colaborativo para a Transformação Digital (DTx CoLab)
Associação para a Inovação e Desenvolvimento da FCT (NOVA.ID.FCT)
Associação para a Investigação e Desenvolvimento de Ciências (FCiências.ID)
Business Research Unit (BRU / ISCTE)
Católica Biomedical Research Centre (CBR)
Centro de Astrofísica da Universidade do Porto (CAUP)

Centro de Ciências do Mar e do Ambiente, (MARE-ARDITI - Pólo Madeira)

Centro de Ciências do Mar e do Ambiente (MARE - Pólo Lisboa)

Centro de Ciências do Mar e do Ambiente, (MAR - Pólo Évora)

Centro de Ecologia Evolução e Alterações Ambientais (cE3c)

Centro de Imagem Biomédica e Investigação Translacional (CIBIT)

Centro de Investigação em Ciências da Informação, Tecnologias e Arquitetura (ISCTE)

Centro de Investigação em Tecnologias e Serviços de Saúde (CINTESIS / UALG)

Centro de Matemática Computacional e Estocástica (Associação IST-ID)

Centro de Neurociências e Biologia Celular (CNC-UC / U.Coimbra)

Centro de Recursos Naturais e Ambiente (Associação IST-ID)

Concepção e Desenvolvimento de Sistemas de Informação (CDSI / ISCTE)

Departamento de Biologia da Universidade do Minho (U.Minho)

Departamento de Engenharia de Polímeros da Universidade do Minho (U.Minho)

Departamento de Engenharia Informática Instituto Superior Técnico (IST)

Departamento de Informática da Universidade do Minho (U.Minho)

Faculdade de Ciências da Universidade de Lisboa (FCUL)

Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa (FCT-UNL)

Faculdade de Ciências Sociais e Humanas (FCSH)

Faculdade Medicina Universidade Lisboa (FMUL)

Fundação para a Ciência e a Tecnologia - Unidade FCCN (FCT-FCCN)

Instituto de Astrofísica e Ciências do Espaço (IA)

Instituto de Biologia Experimental e Tecnológica (IBET)

Instituto de Biossistemas e Ciências Integrativas (BioISI)

Instituto de Ciências Sociais da Universidade de Lisboa (ICS)

Instituto de Engenharia de Sistemas e Computadores - ID (INESC-ID)

Instituto de Plasmas e Fusão Nuclear (Associação IST-ID)

Instituto de Telecomunicações (IT)

Instituto Nacional de Investigação Agrária e Veterinária, I.P. (INIAV)

Instituto Nacional de Saúde Doutor Ricardo Jorge (INSA)

Instituto Superior de Agronomia (ISA)

Instituto Superior de Engenharia de Coimbra (ISEC)

Instituto Superior de Engenharia de Lisboa (ISEL)

Instituto Superior de Engenharia do Porto (ISEP)

Instituto Superior Técnico, Universidade de Lisboa (IST)

Instituto Universitário de Ciências Psicológicas, Sociais e da Vida (ISPA)

Júnior Empresas do Instituto Superior Técnico (JUNITEC)

Laboratório de Física para Materiais e Tecnologias Emergentes (LaPMET)

Laboratório de Instrumentação e Física Experimental de Partículas (LIP)

Laboratório Ibérico Internacional de Nanotecnologias (INL)

Laboratório Nacional de Engenharia Civil (LNEC)

Nova School of Business and Economics (Nova SBE)

Portuguese Biological Data Network (BIODATA.PT)

Portuguese Coastal Monitoring Network (CoastNET)

Portuguese node of the Global Biodiversity Network (GBIF)

Sociedade Portuguesa de Botânica (SPBOTANICA)

Unidade de Ciências Biomoleculares Aplicadas (UCIBIO)

Universidade Aberta (U.Aberta)

Universidade da Madeira - Faculdade de Ciências Exatas e da Engenharia (UM)

Universidade da Madeira (UM)
Universidade de Aveiro (UA)
Universidade de Coimbra (UC)
Universidade de Trás-os-Montes e Alto Douro (UTAD)
Universidade do Algarve (UALG)

Table 4: organisations, infrastructures and research units that used INCD services in 2023

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17.PUBLICATIONS AND OTHER RESULTS

As a measure of the relevance and impact of INCD the figure 8 shows the evolution of the number of scientific results already published or approved for publication that benefited from the usage of the INCD services in 2023. The figures 8 and 9 contain the sum of all results including publications with peer review, publications in conference proceedings, conference posters, books, PhD thesis, MSc thesis, patents, published datasets and published software. The breakdown of the results per type is shown on Figure 9. The number of finished PhD thesis, MSc thesis and posters in conferences was the highest since 2017. The actual list of publications is provided in the appendix I.

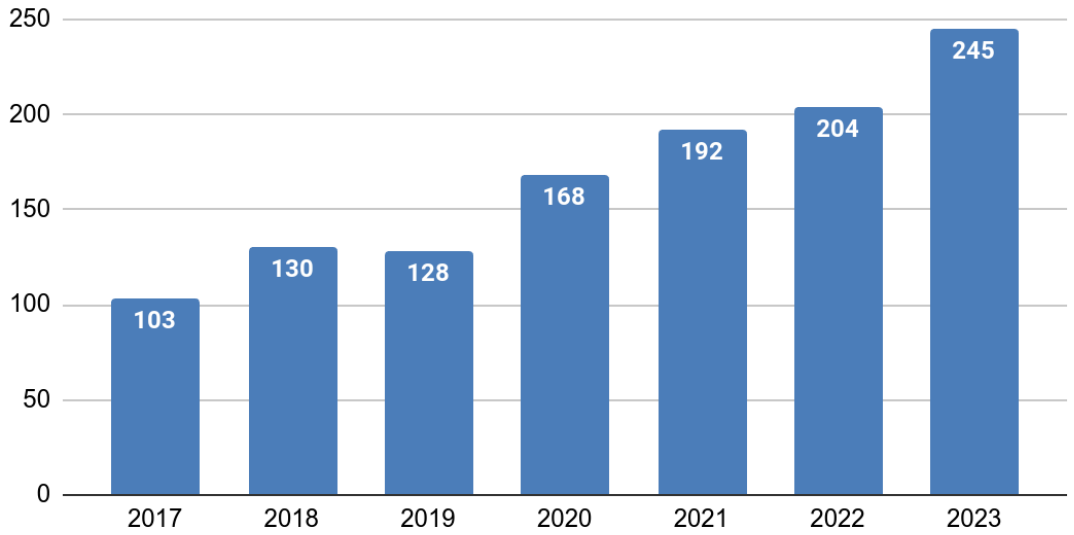

Figure 8: key results made possible by using INCD from 2017 to 2023.

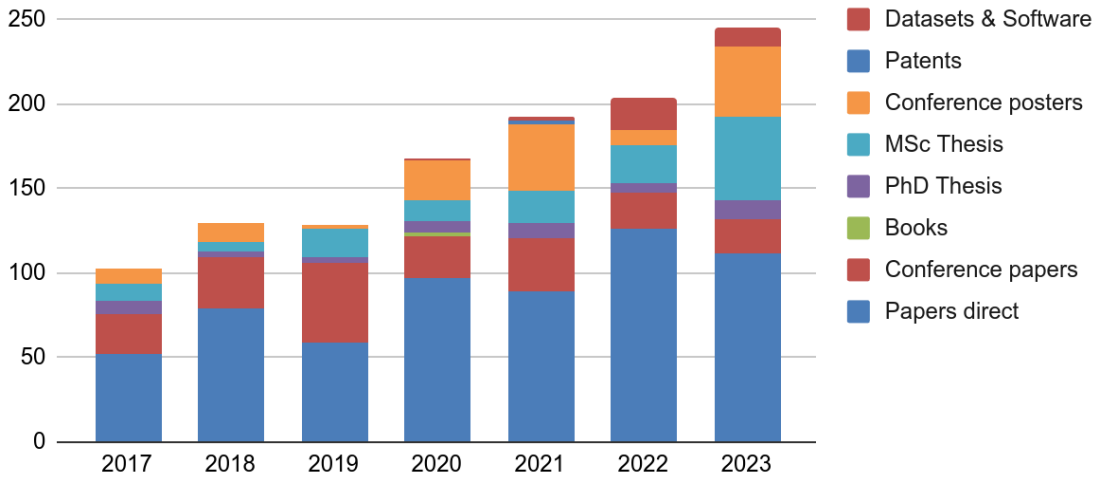

Figure 9: results per type from 2017 to 2023

Besides the publications, the results of 2023 also include 7 curated datasets and 6 software source code repositories. Regarding support to thesis 11 PhD and 49 MSc thesis were produced by the supported projects. In addition to these, INCD provided support to 72 PhD theses that are ongoing. The table 5 shows the complete set of results since 2017. Detailed information is available in the INCD wiki under the institutional information section[34].

	2017	2018	2019	2020	2021	2022	2023	Total
Papers direct	52	79	59	97	89	126	111	613
Proceedings	24	30	47	25	32	22	21	201
Books	0	0	0	2	0	0	0	2
PhD Thesis	8	4	3	7	9	5	11	47
MSc Thesis	10	5	17	12	19	23	49	135
Posters	9	12	2	24	39	8	42	136
Patents					2	1	0	3
Datasets & softw.				1	2	19	11	33

Table 5: results per type from 2017 to 2023

[34] https://wiki.incd.pt/shelves/incd-institutional-information

ANNEX I - PUBLICATIONS AND OTHER RESULTS

Publications produced with the support of INCD in 2023

- Gonçalves, M., Bernardo, C., Bernardino, M., & Soares, C. G. (2022). Climate change impacts on the wave energy in the Azores Islands. Trends in Renewable Energies Offshore, 43-51.
- CAMPOS, S., RODRIGO, A.P., MOUTINHO CABRAL, I. MENDES, V., MANADAS, B., D'AMBROSIO, M. & COSTA, P.M. (2023). An exploration of novel bioactives from the venomous marine annelid Glycera alba. Toxins, 15, 655 (doi: 10.3390/toxins15110655).
- Mixão, Verónica; Pinto, Miguel; Sobral, Daniel; Di Pasquale, Adriano et al. (2023) "ReporTree: a surveillance-oriented tool to strengthen the linkage between pathogen genetic clusters and epidemiological data". Genome Medicine 15: 43. http://dx.doi.org/10.1186/s13073-023-01196-1.
- Santos, João Dourado; Sobral, Daniel; Pinheiro, Miguel; Isidro, Joana et al. (2023) “INSaFLU-TELEVIR: an open web-based bioinformatics suite for viral metagenomic detection and routine genomic surveillance”. Research Square. https://doi.org/10.21203/rs.3.rs-3556988/v1.
- Substitution Models of Protein Evolution with Selection on Enzymatic Activity Ferreiro D., Khalil R., Sousa S.F., and Arenas M. Molecular Biology and Evolution 41 (2) (2024) Article | DOI: 10.1093/molbev/msae026
- Exploiting Locusta migratoria as a source of bioactive peptides with anti-fibrosis properties using an in silico approach Teixeira C.S.S., Biltes R., Villa C., Sousa S.F., Costa J., Ferreira I.M.P.L.V.O., and Mafra I. Food and Function 15 (2) pp.493-502 (2023) Article | DOI: 10.1039/d3fo04246d
- Crystal structures of Streptomyces tsukubaensis sigma factor SigG1 and anti-sigma RsfG Leite J.P., Lourenco F., Oliveira R., Sousa S.F., Mendes M.V., and Gales L. Journal of Structural Biology 215 (4) (2023) Article | DOI: 10.1016/j.jsb.2023.108038
- In silico identification of novel PqsD inhibitors: promising molecules for quorum sensing interference in Pseudomonas aeruginosa Vieira T.F., Cerqueira N.M.F.S.A., Simoes M., and Sousa S.F. Molecular Systems Design and Engineering 9 (1) pp.7-19 (2023) Article | DOI: 10.1039/d3me00107e
- Use of lysinated multiwalled carbon nanotubes with carbohydrate ligands as a doxorubicin nanocarrier: A molecular dynamics analysis Martins F.G., Thakur C.K., Karthikeyan C., Moorthy N.S.H.N., and Sousa S.F. Carbon Trends 12 (2023) Article | DOI: 10.1016/j.cartre.2023.100280
- Modulation of the functional interfaces between retroviral intasomes and the human nucleosome Mauro E., Lapaillerie D., Tumiotto C., Charlier C., Martins F., Sousa S.F., Metifiot M., Weigel P., Yamatsugu K., Kanai M., Munier-Lehmann H., Richetta C., Maisch M., Dutrieux J., Batisse J., Ruff M., Delelis O., Lesbats P., and Parissi V. mBio 14 (4) (2023) Article | DOI: 10.1128/mbio.01083-23
- An in silico approach to unveil peptides from Acheta domesticus with potential bioactivity against hypertension, diabetes, cardiac and pulmonary fibrosis Teixeira C.S.S., Villa C., Sousa S.F., Costa J., Ferreira I.M.P.L.V.O., and Mafra I. Food Research International 169 (2023) Article | DOI: 10.1016/j.foodres.2023.112847

- Structural, physicochemical and anticancer study of Zn complexes with pyridyl-based thiazolyl-hydrazones Araskov J.B., Maciejewska N., Olszewski M., Visnjevac A., Blagojevic V., Fernandes H.S., Sousa S.F., Puerta A., Padron J.M., Hollo B.B., Monge M., Rodriguez-Castillo M., Lopez-de-Luzuriaga J.M., Uguz O., Koca A., Todorovic T.R., and Filipovic N.R. Journal of Molecular Structure 1281 (2023) Article | DOI: 10.1016/j.molstruc.2023.135157
- TargIDe: a machine-learning workflow for target identification of molecules with antibiofilm activity against Pseudomonas aeruginosa Carneiro J., Magalhães R.P., de la Oliva Roque V.M., Simoes M., Pratas D., and Sousa S.F. Journal of Computer-Aided Molecular Design 37 (5-6) pp.265-278 (2023) Article | DOI: 10.1007/s10822-023-00505-5
- Susana Simões, Miguel Lino, Angela Barrera, Catarina Rebelo, Francesca Tomatis, Andreia Vilaça, Christopher Breunig, Andrea Neuner, João Peça, Ricardo González, Alexandra Carvalho, Stefan Stricker, and Lino Ferreira. 'Near-infrared light-activated formulation for the spatial controlled release of CRISPR-Cas9 ribonucleoprotein for brain gene editing', accepted in Angewandte Chemie.
- Ricardo D. González, Susana Simões, Lino Ferreira, and Alexandra T. P. Carvalho. 'Designing Cell Delivery Peptides and SARS-CoV-2-Targeting Small Interfering RNAs: A Comprehensive Bioinformatics Study with Generative Adversarial Network-Based Peptide Design and In Vitro Assays', Molecular Pharmaceutics, 2023, 20, 12, 6079–6089, doi:10.1021/acs.molpharmaceut.3c00444.
- Pedro R. Figueiredo, Ricardo D. González, and Alexandra T. P. Carvalho. 'Insights into the Degradation of Polymer–Drug Conjugates by an Overexpressed Enzyme in Cancer Cells', Journal of Medicinal Chemistry, doi: 10.1021/acs.jmedchem.2c01781.
- Teodoro, M. C., Conceição, E. M., Sinval, J., de Lourdes, M., & Neufeld, C. B. (2023). Adaptation, confirmatory factor analysis, and psychometric properties of the Brazilian version of the Repetitive Eating Questionnaire. International Journal of Eating Disorders. https://doi.org/10.1002/eat.23943
- Mixão, V., Pinto, M., Sobral, D. et al. ReporTree: a surveillance-oriented tool to strengthen the linkage between pathogen genetic clusters and epidemiological data. Genome Med 15, 43 (2023). https://doi.org/10.1186/s13073-023-01196-1
- João Dourado Santos, Daniel Sobral, Miguel Pinheiro et al. INSaFLU-TELEVIR: an open web-based bioinformatics suite for viral metagenomic detection and routine genomic surveillance, 07 November 2023, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-3556988/v1]
- Carvalho J., Faria R., Butlin R.K., Sousa V.C. (2023) poolHelper: An R package to help in designing Pool-Seq studies. Methods in Ecology and Evolution. https://doi.org/10.1111/2041-210X.14185
- Carvalho J., Morales H., Faria R., Butlin R.K., Sousa V.C. (2023) Integrating Pool-seq uncertainties into demographic inference. Molecular Ecology Resources, https://doi.org/10.1111/1755-0998.13834
- Casanova, J., Sinval, J., & Almeida, L. (2024). Éxito académico, compromiso y autoeficacia de los estudiantes universitarios de primer año: variables personales y desempeño del primer semestre. Anales de Psicología / Annals of Psychology, 40(1), 44–53. https://doi.org/10.6018/analesps.479151
- F.J.A.L. Cruz and J.P.B. Mota, "Partial Denaturation of Double-Stranded DNA on Pristine Graphene under Physiological-like Conditions", Liquids 2023, 3, 168.
- F.J.A.L. Cruz and J.P.B. Mota, "Structure and Thermodynamics of Empty Clathrate Hydrates bellow the Freezing Point of H2O", 14th Int. Chem. Bio. Eng. Conference, Bragança, Portugal, September 2023.

- Wang, S., Islam, H., Abdelwahab, H.S., Guedes Soares, C., 2024. Uncertainty analysis of CFD solver for predicting ship responses in head waves, in preparation.
- Gomes I., Galamba N., Protein Stability in a Natural Deep Eutectic Solvent: Preferential Hydration or Solvent Slaving?, J. Chem. Phys., 159, 235101, 2023 (URL: https://doi.org/10.1063/5.0177095)
- Neto V., Victor BL. , Galamba N., Cyclic Peptides as Aggregation Inhibitors for Sickle Cell Disease, J. Med. Chem., 66, 23, 16062–16074, 2023 (URL: https://doi.org/10.1021/acs.jmedchem.3c01484)
- Martins, G., Nascimento, C., Galamba, N., Mechanistic Insights into Polyphenols' Aggregation Inhibition of α-Synuclein and Related Peptides, ACS, Chem. Neurosci., 14, 10, 1905–1920, 2023 (URL: https://doi.org/10.1021/acschemneuro.3c00162)
- Monteiro, H., Paiva, A., Duarte, R.C., Galamba, N., On the not so anomalous water-induced structural transformations of choline chloride–urea (reline) deep eutectic system, Physical Chemistry Chemical Physics 25 (1), 439-454, 2023 (URL: https://doi.org/10.1039/D2CP04139A)
- Dias, A. M. G. C., Moreira, I. P., Lychko, I., Soares, C. L., Nurrito, A., Barbosa, A. J. M., Lutz-Bueno, V., Mezzenga, R., Carvalho, A. L., Pina, A. S. & Roque, A. C. A. (2023). Hierarchical self-assembly of a reflectin-derived peptide. Front. Chem., 11.
- Almeida, J., Palma, C., Félix, P.M., Brito, A.C. (2023). Long-term variation of dissolved metals and metalloid in the waters of an Atlantic mesotidal estuary (Sado Estuary, Portugal). Marine Pollution Bulletin, 188, 114615. HYPERLINK "https://doi.org/10.1016/j.marpolbul.2023.114615"https://doi.org/10.1016/j.marpolbul.2023.114615
- Brito, A.C., Pereira, H., Picado, A., Cruz, J., Cereja, R., Biguino, B., Chainho, P., Nascimento, A., Carvalho, F., Cabral, S., Santos, C., Palma, C., Borges, C:, Dias, J.M. (2023). Increased oyster aquaculture in the Sado Estuary: how to ensure ecosystem sustainability? Science of the Total Environment, 855, 158898.
- Favareto, L., Brotas, V., Rudorff, N., Zacarias, N., Tracana, A., Lamas, L., Nascimento, A., Ferreira, A., Gomes, M., Borges, C., Palma, C., Brito, A.C. (2023). Response of phytoplankton to coastal upwelling: the importance of temporal and spatial scales. Limnology and Oceanography, 68, 1376-1387. https://doi.org/10.1002/lno.12353
- Ferreira, A., Garrido, S., Costa, J.L., Teles-Machado, A., Brotas, V., Brito, A.C. (2023). What drives the recruitment of European sardine in Atlanto-Iberian waters (SW Europe)? Insights from a 22-year analysis. Science of the Total Environment, 881, 163421. HYPERLINK "https://doi.org/10.1016/j.scitotenv.2023.163421"https://doi.org/10.1016/j.scitotenv.2023.163421.
- Monteiro, R.M., Domingos, I., Almeida, P.R., Costa, J.L., Pereira, E., Belo, A.F., Portela, T., Telhado, A., & Quintella, B.R. Upstream movement of juvenile eels (Anguilla anguilla L.) in a southwestern European river. Environ Biol Fish 106, 1313–1325. https://doi.org/10.1007/s10641-023-01417-x
- França, S. Changes in the Functional Role of the Tejo Estuary (Portugal, Europe) According to Fish Ecological Guilds. Fishes 2023, 8, 545. https://doi.org/10.3390/fishes8110545
- João M. Miranda, Guilherme Osswald, Fernando A. Castro, Rui A. Rego, (2023). OpenFOAM validation for indoor ventilation applications, CILAMCE-2023, Proceedings of the XLIV Ibero-Latin-American Congress on Computational Methods in Engineering, ABMEC Porto, Portugal.
- Machine learning approach to the background reduction in singly charged cosmic-ray isotope measurements with AMS-02 E. Bueno, F. Barão, M. Vecchi NIMA (2023) 168644 10.1016/j.nima.2023.168644

- The ATLAS Experiment at the CERN Large Hadron Collider: A Description of the Detector Configuration for Run 3 ATLAS Collaboration (R. Pedro et al.) CERN-EP-2022-259 10.48550/arXiv.2305.16623
- Laser Calibration of the ATLAS Tile Calorimeter during LHC Run 2 R. Pedro, B. Pereira et al. JINST 18 (2023) 06, P06023 10.1088/1748-0221/18/06/P06023
- Search for pair-production of vector-like quarks in pp collision events at TeV with at least one leptonically decaying Z boson and a third-generation quark with the ATLAS detector ATLAS Collaboration (N. Castro, T. Vale et. al) Phys. Lett. B 843 (2023) 138019 10.1016/j.physletb.2023.138019
- Search for single production of vector-like T quarks decaying into Ht or Zt in pp collisions at root s=13 TeV with the ATLAS detector ATLAS Collaboration (N. Castro et al.) J. High Energy Phys. 8 (2023) 153 10.1007/JHEP08(2023)153
- Search for flavor-changing neutral-current couplings between the top quark and the Z boson with proton-proton collisions at √ s = 13 TeV with the ATLAS detector ATLAS Collaboration (N. Castro, A. Peixoto et al) Phys. Rev. D 108, 032019 10.1103/PhysRevD.108.032019
- Anomaly detection search for new resonances decaying into a Higgs boson and a generic new particle X in hadronic final states using s√=13 TeV pp collisions with the ATLAS detector ATLAS Collaboration (I. Ochoa et. al.) Phys. Rev. D 108 (2023) 052009 10.1103/PhysRevD.108.052009
- Luminosity determination in pp collisions at s√=13 TeV using the ATLAS detector at the LHC ATLAS Collaboration (R. Pedro et al.) Eur. Phys. J. C 83 (2023) 982 10.1140/epjc/s10052-023-11747-w
- Demonstrating Agreement between Radio and Fluorescence Measurements of the Depth of Maximum of Extensive Air Showers at the Pierre Auger Observatory The Pierre Auger Collaboration PRL (sibling of the PRD)
- Ground observations of a space laser for the assessment of its in-orbit performance The Pierre Auger Collaboration Optica
- Ultra high energy cosmic rays The intersection of the Cosmic and Energy Frontiers A. Coleman et al. (98 authors) Astropart Phys. 147 (2023) 102794 10.1016/j.astropartphys.2023.102819
- A Catalog of the Highest-Energy Cosmic Rays recorded during Phase I of Operation of the Pierre Auger Observatory Pierre Auger Collaboration (379 authors) Astrophysical Journal Supplement 264 (2023) 2, 50 10.3847/1538-4365/aca537
- Universality of the muon component of extensive air showers Lorenzo Cazon, Ruben Conceição and Felix Riehn JCAP03(2023)022 10.1088/1475-7516/2023/03/022
- Outdoor systems performance and upgrade L. Lopes et al., NIMA 1054, 168446, 2023 10.1016/j.nima.2023.168446
- Development of the CMS detector for the CERN LHC Run 3 CMS Collaboration arXiv:2309.05466, accepted for publication in the Journal of Instrumentation.
- Sub-25 ps timing measurements with 10 x 10 cm2 PICOSEC Micromegas detectors M. Gallinaro et al. Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 1046 (2023) 167687 10.1016/j.nima.2022.167687
- Towards robust PICOSEC Micromegas precise timing detectors M.Gallinaro et al. JINST 18 (2023) 07, C07018
- A large area 100-channel PICOSEC Micromegas detector with time resolution at the 20 ps level M.Gallinaro et al. JINST 18 (2023) 07, C070

- Search for top squarks in the four-body decay mode with single lepton final states in proton-proton collisions at root s=13 TeV CMS Collaboration (2373 authors) J. High Energy Phys. 6 (2023) 60 10.1007/JHEP06(2023)060
- Search for nonresonant Higgs boson pair production in final state with two bottom quarks and two tau leptons in proton-proton collisions at root s=13 TeV CMS Collaboration (2373 authors) Phys. Lett. B 842 (2023) 137531 10.1016/j.physletb.2022.137531
- Search for high-mass exclusive gammagamma->WW and gammagamma->ZZ production in proton-proton collisions at 13 TeV CMS and TOTEM Collaborations JHEP 07 (2023) 229
- Proton reconstruction with the CMS-TOTEM Precision Proton Spectrometer CMS and TOTEM Collaborations JINST 18 (2023) 09, P09009
- A next-generation liquid xenon observatory for dark matter and neutrino physics J. Aalbers et al. (599 authors) J. Phys. G-Nucl. Part. Phys. 50 (2023) 013001 10.1088/1361-6471/ac841a
- Energy resolution of the LZ detector for high-energy electronic recoils G. Pereira et al J. Instrum. 18 (2023) C04007 10.1088/1748-0221/18/04/C04007
- The MIGDAL experiment: Measuring a rare atomic process to aid the search for dark matter H. M. Araujo et al. (36 authors) Astropart Phys. 151 (2023) 102853 10.1016/j.astropartphys.2023.102853
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment J. Aalbers et al. (LUX-ZEPLIN Collaboration) Phys. Rev. Lett. 131 (2023) 041002 10.1103/PhysRevLett.131.041002
- Production and optical characterisation of blended Polyethylene Tethraplate (PET)/Polyethylene Naphtalate (PEN) scintillator samples P. Conde Muíño, J. A. Covas, A. Gomes, L. Gurriana, R. Machado, T. Martins, P. Mendes, R. Pedro, B. Pereira, A. J. Pontes, H. Wilkens arXiv:2312.14790
- Dual-Polarity Ion Drift Chamber: Experimental results with Xe-S mixtures A. Marques, D. Marques, N. Duarte, J. Teles, A. Cortez, A. Trindade, J. Escada, F. Santos, F. Borges Nucl. Inst. Met. A, Volume 1045, 1 January 2023, 167575 10.1016/j.nima.2022.167575
- A new experimental system for electron transverse diffusion measurements A. Trindade, J. Escada, J. Maia, R. Curado da Silva, F. Borges, A. Marques, F. Santos Nucl. Inst. Met. A, Volume 1045, 1 January 2023, 167603 10.1016/j.nima.2022.167603
- The new HADES ToF Forward Detector A. Blanco et al., NIMA 1050, 168182, 2023 10.1016/j.nima.2023.168182
- Evaluation of effective dose for gamma-rays of Terrestrial Gamma-ray Flashes in aviation: spectral- and atmosphere-effects J.M. Maia, R.M. Curado da Silva, Joana Mingacho Radiation Physics and Chemistry 215 (2024) 111332
- First results on FHM - a Floating Hole Multiplier V. Chepel, G.Martinez-Lema, A.Roy, A.Breskin J. Instrum. 18 (2023) P05013 10.1088/1748-0221/18/05/P05013
- Timing resistive plate chambers for thermal neutron detection with 3D position sensitivity L. M. S. Margato, G. Canezin, A. Morozov, A. Blanco, J. Saraiva, L. Lopes, P. Fonte L. M.S. Margato et al., Nuclear Instruments and Methods in Physics Research Section A, Volume 1052, July 2023, 168267 10.1016/j.nima.2023.168267
- Low-energy physics in neutrino LarTPCs S. Andringa et al. (34 authors) J. Phys. G-Nucl. Part. Phys. 50 (2023) 033001 10.1088/1361-6471/acad17
- Evidence of antineutrinos from distant reactors using pure water at SNO+ SNO+ Collaboration Phys. Rev. Lett. 130, 091801 (2023) 10.1103/PhysRevLett.130.091801
- Measurement of the total neutron cross section on argon in the 20 to 70 keV energy range S. Andringa, et al (ARTIE Collaboration) Phys. Rev. C 108, L011601 10.1103/PhysRevC.108.L011601

- Heavy Baryon Spectroscopy in a Quark-Diquark Approach A. Torcato, A. Arriaga, G. Eichmann, M. T. Peña Few-Body Sys. 64, 45 (2023) https://doi.org/10.1007/s00601-023-01826-9
- Intensity Ratio of Kβ/K$$\alpha$$ in Selected Elements from Mg to Cu, and the Chemical Effects of Cr K$$\alpha$$1,2 Diagram Lines and Cr Kβ/K$$\alpha$$ Intensity Ratio in Cr Compounds Y. Ito, T. Tochio, M. Yamashita, S. Fukushima, T. Shoji, K. Słabkowska, Ł. Syrocki , M. Polasik, J. P. Gomilsek, J. P. Marques, J. M. Sampaio, M. Guerra, J. Machado, J. P. Santos, A. Hamidani, A. Kahoul, P. Indelicato, and F. Parente Ito, Y.; Tochio, T.; Yamashita, M.; Fukushima, S.; Shoji, T.; Słabkowska, K.; Syrocki, Ł.; Polasik, M.; Gomilsek, J.P.; Marques, J.P.; et al. Intensity Ratio of Kβ/Kα in Selected Elements from Mg to Cu, and the Chemical Effects of Cr Kα1,2 Diagram Lines and Cr Kβ/Kα Intensity Ratio in Cr Compounds. Int. J. Mol. Sci. 2023, 24, 5570. https://doi.org/10.3390/ijms24065570 10.3390/ijms24065570
- Diverse mechanisms in proton knockout reactions from the Borromean nucleus 17Ne F. Wamers, C. Lehr, J. Marganiec-Galazka, et al. (62 authors) Eur. Phys. J. A 59, 154 (2023) 10.1140/epja/s10050-023-01063-y
- Suppression of Coulomb-nuclear interference in the near-barrier elastic scattering of 17Ne from 208Pb J. Díaz-Ovejas, I. Martel, D. Dell'Aquila, et al. (40 authors) Phys. Lett. B 843 (2023) 138007 10.1016/j.physletb.2023.138007
- Opacities of singly and doubly ionized neodymium and uranium for kilonova emission modeling A Flörs, R F Silva, J Deprince, H Carvajal Gallego, G Leck, L J Shingles, G Martínez-Pinedo, J M Sampaio, P Amaro, J P Marques, S Goriely, P Quinet, P Palmeri, M Godefroid Monthly Notices of the Royal Astronomical Society, Volume 524, Issue 2, September 2023, Pages 3083–3101 10.1093/mnras/stad2053
- The first PET glimpse of a proton FLASH beam F. Abouzahr, J.P. Cesar, P. Crespo, M.J. Gajda, Z. Hu , W. Kaye, K. Klein, A. Kuo, S. Majewski, O.R. Mawlawi, A. Morozov, A. Ojha, F. Poenisch, J.C. Polf, M. Proga, N. Sahoo, J. Seco, T. Takaoka, S. Tavernier, U. Titt, X. Wang, X.R. Zhu, K. Lang Phys. Med. Biol. 68 (2023) 125001 10.1088/1361-6560/acd29e
- Double J /$$\Psi$$ production in pion-nucleon scattering at COMPASS G.D. Alexeev et al. (COMPASS Coll.) Phys. Lett B 838 (2023) 137702 10.1016/j.physletb.2023.137702
- Jet substructure observables for jet quenching in Quark Gluon Plasma: a Machine Learning driven analysis Miguel Crispim Romão, José Guilherme Milhano, Marco van Leeuwen e-Print: 2304.07196 [hep-ph]
- The Forward Physics Facility at the High-Luminosity LHC J. L. Feng, F. Kling, M. H. Reno, et al. (including G. Chachamis) J.Phys.G 50 (2023) 3, 030501 10.1088/1361-6471/ac865e
- Medium-induced radiation with vacuum propagation in the pre-hydrodynamics phase Carlota Andres, Liliana Apolinário, Fabio Dominguez, Marcos Gonzalez Martinez, Carlos A. Salgado JHEP 03 (2023) 189 10.1007/JHEP03(2023)189
- Low-pT quarkonium polarization measurements: Challenges and opportunities Pietro Faccioli, Ilse Kraetschmer, Carlos Lourenco Phys. Lett. B 840 (2023) 137871 10.1016/j.physletb.2023.137871
- Dilepton decays of vector particles Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 1-37 10.1007/978-3-031-08876-6_1
- Particle Polarization in High Energy Physics An Introduction and Case Studies on Vector Particle Production at the LHC Preface Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) IX-XI
- Reference frames and transformations Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 39-83 10.1007/978-3-031-08876-6_2
- A frame-independent study of the angular distribution Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 85-120 10.1007/978-3-031-08876-6_3

- Meaning and interpretation of the frame-independent polarization Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 121-146 10.1007/978-3-031-08876-6_4
- Smearing effects in non-planar processes Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 147-172 10.1007/978-3-031-08876-6_5
- Polarization in cascade decays Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 173-242 10.1007/978-3-031-08876-6_6
- Two-body decay distributions beyond the dilepton case Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 243-281 10.1007/978-3-031-08876-6_7
- Alternative parametrization of the dilepton decay distribution Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 283-290
- Angular distributions of O -> i>V</igamma, with i>J</i(<iO</i) = J(V>)=1 and V -> l l |pigamma|pipi| ... Pietro Faccioli, Carlos Lourenco LECT NOTES PHYS 1002 (2023) 291-298
- Towards a muon collider Carlotta Accettura et al, including G. Chachamis, G. Da Molin, M.Gallinaro Eur.Phys.J.C 83 (2023) 9, 864 10.1140/epjc/s10052-023-11889-x
- Low projectile density contributions in the dilute-dense CGC framework for two-particle correlations Anderson Kendi Kohara, Cyrille Marquet, Víctor Vila JHEP 10 (2023) 159 10.1007/JHEP10(2023)159
- Field output correction factors of small static field for iba razor nanochamber Dalila Mateus, Carlo Greco and Luis Peralta Biomed. Phys. Eng. Express 10 015004 10.1088/2057-1976/ad0ae0
- Radioactivity in a bucket Luis Peralta Eur. J. Phys. 45 (2024) 015801 10.1088/1361-6404/ad0346
- Improving count rate capability of timing RPCs by increasing the detector working temperature A. Blanco et al. NIMA 1045, 167652, 2023 10.1016/j.nima.2022.167652
- A large-area MRPC detector for muon scattering tomography J. Saraiva et al. NIMA 1050, 168183, 2023 10.1016/j.nima.2023.168183
- An RPC-PET brain scanner demonstrator: First results Paulo Fonte et al NIMA 1051, 168236, 2023 10.1016/j.nima.2023.168236
- Resistive plate chambers for precise measurement of high-momentum protons in short range correlations at R3B M. Xarepe et al., NIM 1055, 168445, 2023 10.1016/j.nima.2023.168445
- Sealed (zero gas flow) resistive plate chambers Alberto Blanco, Paulo Fonte, Luis Lopes, Mario Pimenta Eur. Phys. J. Plus 138, 1021 (2023). 10.1140/epjp/s13360-023-04647-1
- Advances Towards a Large-Area, Ultra-Low-Gas-Consumption RPC Detector J. Saraiva, C. Alemparte, D. Belver, A. Blanco, J. Callon, J. Collazo, A. Iglesias, L. Lopes Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 1046 (2023) 167744 10.1016/j.nima.2022.167744
- Observation of collider muon neutrinos with the SND@LHC experiment SND@LHC Collaboration Phys. Rev. Lett. 131, 031802 10.1103/PhysRevLett.131.031802
- Exploring parameter spaces with artificial intelligence and machine learning black-box optimization algorithms Fernando Abreu de Souza, Miguel Crispim Romão, Nuno Castro, Mehraveh Nikjoo, Werner Porod Phys. Rev. D 107, 035004 10.1103/PhysRevD.107.035004
- Berry: A code for the differentiation of Bloch wavefunctions from DFT calculations Leander Reascos, Fábio Carneiro, André Pereira, Nuno Filipe Castro, Ricardo Mendes Ribeiro Computer Physics Communications 295 (2024) 108972 10.1016/j.cpc.2023.108972
- Fitting a Collider in a Quantum Computer: Tackling the Challenges of Quantum Machine Learning for Big Datasets Miguel Caçador Peixoto, Nuno Filipe Castro, Miguel Crispim Romão, Maria Gabriela Jordão Oliveira, Inês Ochoa Front. Artif. Intell. 6 (2023) 1268852 10.3389/frai.2023.1268852

- Intermediate levels of scientific knowledge are associated with overconfidence and negative attitudes towards science Simone Lackner, Frederico Francisco, Cristina Mendonça, André Mata and Joana Gonçalves-Sá Nat. Hum. Behav. 7 (2023) 1490-+ 10.1038/s41562-023-01677-8
- The effects of weather and mobility on respiratory viruses dynamics before and during the COVID-19 pandemic in the USA and Canada Irma Varela-Lasheras, Lília Perfeito, Sara Mesquita and Joana G Sá PLOS Digital Health 10.1371/journal.pdig.0000405
- The gamma/hadron discriminator LCm in realistic air shower array experiments R. Conceicao, P. J. Costa, L. Gibilisco, M. Pimenta, B. Tome Eur. Phys. J. C 83 (2023) 932 10.1140/epjc/s10052-023-12106-5

Publications in conference proceedings produced with the support of INCD in 2023

- An Earlier Experience Towards Optimizing Apache Spark Over Frontera Supercomputer. Bernardo, S., Ruhela, A., Cazes, J., Harrell, S.L., Gomes, J., High Performance Computing. ISC High Performance 2023. Lecture Notes in Computer Science, vol 13999. Springer, Cham. DOI: 10.1007/978-3-031-40843-4_29
- Prospects for VHE monitoring of Gamma-ray Bursts with SWGO. G. La Mura, U. Barres de Almeida, R. Conceição, A. de Angelis, F. Longo, M. Pimenta, E. Prandini, E. Ruiz-Velasco, B. Tomé, for the SWGO Collaboration, Proceedings of the Sixteenth Marcel Grossmann Meeting, World Scientific, DOI: 10.1142/9789811269776_0246
- Very high energy sky monitoring with the Southern Wide-field Gamma-ray Observatory. G. La Mura, U. Barres de Almeida and F. Longo, J. Phys.: Conf. Ser. 2429 012022, 12th Cosmic Ray International Seminar - CRIS 2022, DOI: 10.1088/1742-6596/2429/1/012022
- Very high energy sky monitoring with the Southern Widefield Gamma-ray Observatory, Giovanni La Mura, Ulisses Barres de Almeida and Francesco Longo, EPJ Web of Conferences 280, 01007 (2023), EPJ Web Conf. Volume 280, 2023, RICAP-22, 8th Roma International Conference on Astroparticle Physics, DOI: 10.1051/epjconf/202328001007
- Study of the 12C+16O fusion reaction in carbon burning via the Trojan Horse Method, A. A. Oliva, A. Tumino, N. Soic, et al., EPJ Web of Conferences 279, 11015 (2023), DOI: 10.1051/epjconf/202327911015
- Coulomb dissociation of 16O into 4He and 12C, L. T. Bott, K. Goebel, M. Heil, et al., EPJ Web of Conferences 279, 04003 (2023), DOI: 10.1051/epjconf/202327904003
- Monitoring of Solar Energetic Particles and Cosmic Rays with the RADEM instrument onboard the ESA JUICE mission, Patricia Gonçalves, Wojtek Hajdas, Marco Pinto, Andre Galli, and Olivier Witasse, EGU General Assembly 2023 Vienna, Austria, 24–28 Apr 2023, EGU23-14711, DOI: 10.5194/egusphere-egu23-14711
- Signature of Accidental Symmetry Breaking in Two-particle Correlations within the CGC, Anderson Kendi Kohara, Cyrille Marquet, Victor Vila, Acta Phys.Polon.Supp. 16 (2023) 5, 25, DOI: 10.5506/APhysPolBSupp.16.5-A25
- Experimental study of high-energy fission and quasi-fission dynamics with fusion-induced fission reactions at VAMOS++, D. Fernández, M. Caamaño, D. Ramos, et al., EPJ Web of Conferences 284, 04009 (2023), DOI: 10.1051/epjconf/202328404009
- Higgs Physics at a Muon Collider with detailed detector simulation, G. Da Molin et al.
- PoS ICHEP2022 (2022) 515, https://pos.sissa.it/414/515

- Resistive plate chambers for precise measurement of high-momentum protons in short range correlations at R3B, M. Xarepe, T. Aumann, A. Blanco, et al., Nucl. Instr. and Methods A 1055, 168445 (2023), DOI: 10.1016/j.nima.2023.168445
- LOOKING FORWARD: PHOTON-INDUCED PROCESSES WITH TAGGED PROTONS AT THE CMS EXPERIMENT, Michele Gallinaro, Acta Phys. Pol. B-Proc. Suppl. 16 (2023) 5-A12, DOI: 10.5506/APhysPolBSupp.16.5-A12
- Comprehensive investigation of fission yields by using spallation- and (p,2p)induced fission reactions in inverse kinematics, J.L. Rodríguez Sánchez, A. Graña-González, J. Benlliure, et al., EPJ WEB CONF 284 (2023) 04020, DOI: 10.1051/epjconf/202328404020
- Sibyll "star" : ad-hoc modifications for an improved description of muon data in extensive air showers, Felix Riehn, Ralph Engel, Anatoli Fedynitch, PoS ICRC2023 (2023) 429 - Proceedings of the 38th International Cosmic Ray Conference (ICRC2023), DOI: 10.22323/1.444.0429
- Gamma/hadron discrimination at PeV energies through the azimuthal fluctuations of air shower footprint at the ground, A. Bakalová, R. Conceição, L. Gibilisco, V. Novotný, M. Pimenta, B. Tomé, J. Vícha, PoS ICRC2023 (2023) 964, Proceedings of the 38th International Cosmic Ray Conference (ICRC2023), DOI: 10.22323/1.444.0964
- The muon measurements of Haverah Park and their connection to the muon puzzle, L.Cazon, H.P. Dembinski, G. Parente, F. Riehn, A.A. Watson, PoS ICRC2023 (2023) 431 - Proceedings of the 38th International Cosmic Ray Conference (ICRC2023), DOI: 10.22323/1.444.0431
- Study of b- and c-jets identification for Higgs coupling measurements at the Muon Collider, G. Da Molin, Nuovo Cim. C-Colloq. Commun. Phys. 46 (2023) 92, DOI: 10.1393/ncc/i2023-23092-y
- Accessing the forward region of the energy spectrum of leading neutral pions in ultra-high energy proton-air interactions, M.A. Martins, L. Cazon, R. Conceição and F. Riehn, PoS ICRC2023 (2023) 448 - Proceedings of the 38th International Cosmic Ray Conference (ICRC2023), DOI: 10.22323/1.444.0448
- A novel method to search for point sources of ultra-high energy neutral particles using spacetime information, M.A. Martins, L. Cazon,, R. Conceição,, J. Alvarez-Muñiz, and E. Zas, PoS ICRC2023 (2023) 451 - Proceedings of the 38th International Cosmic Ray Conference (ICRC2023), DOI: 10.22323/1.444.0451
- The Mercedes water-Cherenkov detector: a multi-PMT shallow tank design proposal for ground-based gamma-ray observatories, Ulisses Barres de Almeida, Pedro Assis, Pedro Brogueira, Ruben Conceição, Luis M. Domingues Mendes, Guilherme F. Franco, Lucio Gibilisco, Borja S. González, Luis F. Mendes, Mario Pimenta, Gizele L.P. Santos and Bernardo Tomé for the SWGO collaboration, Proceedings of the 38th International Cosmic Ray Conference, PoS ICRC2023 (2023) 601, DOI: 10.22323/1.444.0601
- Muon tomography with Resistive Plate Chambers for geological characterization, R. Sarmento et al., Nuclear Inst. and Methods in Physics Research, A 1060 (2024) 169031, DOI: 10.1016/j.nima.2023.169031

Conference posters produced with the support of INCD in 2023

- MOUTINHO CABRAL, I., MISSIONÁRIO, M., NUNES, M., MENDONÇA, V., FERNANDES, J., TRAVESSO, M., VINAGRE, C., MADEIRA, D., GROSSO, A.R., COSTA, P.M. & MADEIRA, C. (2023) How ocean warming is modulating marine host-parasite dynamics in the

Anthropocene: Evidence for higher parasite incidence and effects in non-warm adapted intertidal fish population. EcoSummit 2023, Gold Coast (Austrália), Junho de 2023.

- MADEIRA, C., MISSIONÁRIO, M., ALMEIDA, C., MOUTINHO CABRAL, I., NUNES, M., FERNANDES, J.F., TRAVESSO, M., ANTÓNIO, C., RODRIGUES, A.M., MENDONÇA, V., VINAGRE, C., GROSSO, A.R., COSTA, P.M., MADEIRA, D. (2023) Molecular and phenotypic plasticity of temperate gobies in response to ocean warming and marine heatwaves. Ciência 2023 - Encontro com a Ciência e Tecnologia em Portugal: Ciência e Oceano para Além do Horizonte.
- GONÇALVES C, MOUTINHO CABRAL I, RODRIGO AP, MADEIRA C, ALVES DE MATOS AP, GROSSO AR & COSTA PM (2023) Uncovering the potential of Cephalopoda and Polychaeta toxins for drug discovery. Ciência 2023 - Encontro com a Ciência e Tecnologia em Portugal: Ciência e Oceano para Além do Horizonte.
- Alpha-synuclein Structural Dynamics from Molecular Dynamics Simulations" at the BioISI Ciências Research and Innovation Week 2023;
- "Wild Type and Mutated α-synucleins' Structure from Coarse-Grained Molecular Dynamics Simulations" at the 2023 Coimbra 3D-Bioinfo-PT;
- Mixão, Verónica; Pinto, Miguel; Sobral, Daniel; Di Pasquale, Adriano; Gomes, João Paulo; Borges, Vitor. "ReporTree: a surveillance-oriented tool to strengthen the linkage between pathogen genetic clusters and epidemiological data". Applied Bioinformatics & Public Health Microbiology 2023
- Dourado Santos J, Sobral D, Pinheiro M, Isidro J, Bogaardt C, Pinto M, Prada JM, Horton DL, Gomes JP, TELEVIR Consortium, Borges V, INSaFLU-TELEVIR: an open web-based bioinformatics suite for viral metagenomic detection and routine genomic surveillance.Applied Bioinformatics & Public Health Microbiology 2023
- Sofia L. Mendes, Carla Sousa Santos, Philine G. D. Feulner, Vitor C. Sousa Multiple outcomes of hybridization in Iberian chubs inferred from whole genome data, 23-27 July 2023, Ferrara, Italy
- M. Furtado, I. Custódio, T. Pinheiro, R.C. da Silva, L.C. Alves, V. Corregidor, Artificial Neural Networks for high-resolution 3D imaging, ICNMTA 2022 Conference, September 11-16
- V. Corregidor, L.C. Alves, T. Pinheiro, R.C. da Silva, M. Furtado, Artificial Neural Networks and Ion Beams for 3D Imaging, International Conference on Accelerators for Research and Sustainable Development, IAEA, May 23-27 (2022)
- Iana Lychko Conference Poster Optimized production of reflectins and characterization of their reversible self-assembly 2023-12-09 PROTEIOS Microbiotec 2023, 7th-9th December 2023, Covilhã, Portugal
- Arménio Barbosa Meeting Poster Modeling studies of reflectin de novo peptide assembly 2023-04-05 5th National Physical Chemistry Meeting (15ENQF) and 4th Computational Chemistry Symposium, 4-5th April, 2023, Portugal
- Madeira C, Missionário M, Almeida C, Cabral IM, et al. (2023) Molecular and phenotypic plasticity of temperate gobies in response to ocean warming and marine heatwaves. Ciência 2023 - Encontro com a Ciência e Tecnologia em Portugal: Ciência e Oceano para Além do Horizonte, 5th-7th july, Aveiro, Portugal
- Cabral IM, Missionário M, Nunes M, […], Madeira C. (2023) How ocean warming is modulating marine host-parasite dynamics in the Anthropocene: Evidence for higher parasite incidence and effects in non-warm adapted intertidal fish population. EcoSummit 2023 - Building a sustainanble and desirable future: adapting to a changing land and seascape. 13th-17th june, Gold Coast, Australia
- M. Furtado, I. Custódio, T. Pinheiro, R.C. da Silva, L.C. Alves, V. Corregidor, Artificial Neural Networks for high-resolution 3D imaging, ICNMTA 2022 Conference, September 11-16

- V. Corregidor, L.C. Alves, T. Pinheiro, R.C. da Silva, M. Furtado, Artificial Neural Networks and Ion Beams for 3D Imaging, International Conference on Accelerators for Research and Sustainable Development, IAEA, May 23-27 (2022)
- 2nd Annual Meeting of CIBIT: "Deciphering emotions in the human brain - a functional MRI exploration of music-induced emotions and their potential applications"; Alexandre Sayal, Inês Bernardino, Teresa Sousa, Miguel Castelo-Branco, Bruno Direito (2023)
- Luís Mendes, Gas Regeneration System for RPCs, LISHEP2023, UERJ, Rio de Janeiro, Brasil 2023-03-06
- Nuno Leonardo, New Era in Neutrino Physics at Colliders: construction and physics of SND@LHC experiment, LISHEP 2023, Rio de Janeiro, 2023-03-07
- Ricardo Silva, Improving opacity predictions through optimization of atomic data calculations, Atomic Processes in Plasmas (APIP) 2023, Vienna, Austria, 2023-05-16
- Ricardo Barrué, The ATLAS Trigger System, 11th Large Hadron Collider Physics Conference 2023, Belgrade, Serbia, 2023-05-23
- Nuno Fernandes, ATLAS Trigger and Data Acquisition Upgrades for the High-Luminosity LHC, 11th Large Hadron Collider Physics Conference 2023, Belgrade, Serbia, 2023-05-23
- Joana Antunes, Impact of Physical Parameters on GBM Survival Curves in Enhanced Radiotherapy with Gold Nanoparticles, 61th Annual Particle Therapy C0-Operative Group conference (PTCOG 61), Madrid, Spain, 2023-06-15
- Maria Giorgi, Proton minibem radiation therapy for cardiac radioablation: A proof of concept, 61th Annual Particle Therapy Co-Operative Group conference (PTCOG 61), Madrid, Spain, 2023-06-15
- Miguel Molina-Hernández, Radiolysis modeling of FLASH during a continuous beam irradiation, 61th Annual Particle Therapy C0-Operative Group conference (PTCOG 61), Madrid, Spain, 2023-06-15
- Joana Leitão, Proton Multi-Beam FLASH Radiotherapy: Combining FLAH and IMPT Applied to Meningioma Case, 61th Annual Particle Therapy Co-Operative Group conference (PTCOG 61), Madrid, Spain, 2023-06-15
- Ricardo Silva, An Atomic Data Optimization Method For Improved Kilonova Opacity Modeling, International Colloquium On Atomic Spectra And Oscillator Strengths For Astrophysical And Laboratory Plasmas (ASOS14), Paris, France, 2023-07-10
- Joana Gonçalves-Sá, Understanding COVID-19 pandemic trajectories: why changes in online behavior matter for now-casting, NetSci2023: International School and Conference on Network Science, Vienna, Austria, 2023-07-12
- Pedro Canatário Duarte, The diffusion of information in social media – How complex is it?, NetSci2023: International School and Conference on Network Science, Vienna, Austria, 2023-07-14
- Ana Luísa Carvalho, The ATLAS trigger system during Run 3, Lepton Photon Conference, Melbourne, Australia, 2023-07-17
- Felix Riehn, The muon measurements of Haverah Park and their connection to the muon puzzle, 38th International Cosmic Ray Conference (ICRC2023) - The Astroparticle Physics Conference, Nagoya, Japan and Online, 2023-07-27
- André Torcato, Heavy baryon spectroscopy in a quark-diquark approach, 25th European conference on few-body problems in physics (EFB25), Mainz, Germany, 2023-07-30
- Miguel Martins, Accessing the forward region of the energy spectrum of leading neutral pions in ultra-high energy proton-air interactions, The Astroparticle Physics Conference, ICRC 2023, Nagoya, Japan and Online, 2023-08-01

- Miguel Martins, A novel method to search for point sources of ultra-high energy neutral particles using spacetime information, The Astroparticle Physics Conference, ICRC 2023, Nagoya, Japan and Online, 2023-08-03
- Maura Teixeira, ATLAS Forward Proton Detector as a Tool for New Physics Searches, poster presentation at European School of High Energy Physics,Grenaa, Denmark 2023-09-11
- Patrícia Gonçalves, The Radiation Monitor onboard JUICE, Science opportunities during cruise Heliophysics in Europe, ESTEC, ESA, Noordwijk, The Netherlands, 2023-11-01
- BRAVER challenges students in radiation protection training in an international training, Higher Education with Impact Conference, Hasselt, Belgium, 2023-12-13
- CHERNE, an adaptative network focused on students, Higher Education with Impact Conference, Hasselt, Belgium, 2023-12-15
- Rodrigues, F.E.P., Darbre, T., Machuqueiro, M.: "In silico study of cationic peptide dendrimers as pH-dependent vectors for siRNA", 3D-BIOINFO-PT Annual Meeting, Coimbra, Portugal, Dez. 2023. (Poster)
- Rodrigues, F.E.P., Darbre, T., Machuqueiro, M.: "Investigating the pH-Dependent Structure of Cationic Peptide Dendrimers and Their Potential as siRNA Vectors: An In-Silico Study", 3rd Chem & Biochem Students Meeting, FCUL, Lisboa, Portugal, July 13, 2023. (Poster)
- Ricardo Silva, Improved Opacity Predictions of r-process Elements, Jornadas Doutorais do Departamento de Física 2023 Lisboa, Faculdade de Ciência da Faculdade de Lisboa, 2023-03-30
- Tomás Correia Sousa, CALIFA calibration with cosmic muons, Doctoral Congress of Engineering 2023, Faculdade de Engenharia da Universidade do Porto, 2023-06-16

PhD Thesis produced with the support of INCD in 2023

- Dr. Gonçalo Teixeira, "Olfaction inspired sensing using tailor-made proteins" , MIT Portugal Program of Bioengineering Systems, FCT NOVA, December 2023.
- Cereja, R. (2023). Phytoplankton in estuarine waters: assessment of temporal and spatial variability. Doutoramento Earth Systems, Faculdade de Ciências, Universidade de Lisboa.
- Rational development of new biocatalysts for the production of Parkinson Disease drugs Student: Juliana Rocha Programa Doutoral em Biomedicina (PhD) Universidade do Porto Faculdade de Medicina, Portugal 2018 – 2023 Defense: July 25 2023
- IST Miguel Orcinha Study of solar modulation effects on cosmic ray fluxes measured by the AMS experiment
- ATLAS, Pheno UC Susana Santos Study of the ttH production and Higgs couplings to Top quarks in the ATLAS experiment
- UC Alexandre Fonseca Trindade Study of noble gases mixtures characteristics as a detection medium
- DarkMatter UC Guilherme Pereira Data processing and Human Machine Interface for the monitoring and control system of LZ dark matter experiment
- FCUL Elisabet Galiana Analysis and simulation of (p,g) and PIGE low energy reactions: An ENSARRoot development
- IST Diogo de Bastos Search for the supersymmetric stop quark in the CMS experiment
- FCUL Dalila Mateus Estudos dosimétricos para SBRT/SRT de pequenas lesões do Cérebro
- IST Ana Luísa Carvalho Study of the CP properties of the Higgs coupling to top quarks with ATLAS at the LHC.

MSc Thesis produced with the support of INCD in 2023

- João Pedro Correia Mourão Miranda (2023) Simulação Numérica de Ventilação Instacionária em Espaços Interiores, ISEP.
- RODRIGO DE JESUS EUSÉBIO "Re-implementation of a data analysis pipeline for the genetic characterization of viral pathogens in the context of laboratory surveillance of viral outbreaks" Sep, 2023 Nova Medical School
- Marta Ferreira (2023) Genomics of adaptation to cadmium on a spatially heterogeneous environment. MSc Biologia Evolutiva e do Desenvolvimento. Faculdade de Ciências da Universidade de Lisboa.
- Catarina Gomes Ferreira, MitoProfiles: Cancer mitochondrial profiles in high metabolic rate organs, Mestrado em Bioinformática - Universidade do Minho;
- Jorge Fernando Pereira Sinval: Beyond the Accuracy of Clinical Reasoning: The Development of a New Instrument. Msc Faculdade de Medicina de Lisboa
- Ribeiro, A.R. Estudo da dinâmica de movimentos e comportamento migratório dos ecótipos anádromo e holobiótico de truta (Salmo trutta L.) no rio Mondego., Mestrado em Ecologia e Gestão Ambiental, Faculdade de Ciências, Universidade de Lisboa.78pp HYPERLINK "http://hdl.handle.net/10451/56922"http://hdl.handle.net/10451/56922
- Development of computational approaches for the identification of bioactive molecules present in databases of cyanobacterial compounds for therapeutic approaches in human diseases Student: Renato Soares (Main Supervisor: Dr. João Carneiro, CIIMAR; Other Supervisors: Diogo Pratas, Univ Aveiro) Mestrado: Bioinformatics and Computational Biology Faculdade de Ciências da Universidade do Porto, Portugal Defense: July 24th 2023
- Molecular Modelling of Natural Compounds Extracted from Plants as New Insecticide Agents Student: Maria Araújo Mestrado: Biofísica e Bionanosistemas Universidade do Minho, Portugal 2019/2022 Defense: April 23rd 2023
- Understanding the Molecular Basis Behind Congenital Disorders of Glycosylation Student: Tiago André Cunha Oliveira Mestrado: Biochemistry of Health Escola Superior de Saúde, Instituto Politécnico do Porto, Portugal 2023 Defense: November 22nd 2023
- Uminho Céu Neiva Advanced machine learning techniques in rare events research at the Large Hadron Collider
- FCUL João Afonso Jantarada Simulation of a p-process in a Supernova Explosion using the NucNet Tools framework. http://hdl.handle.net/10451/56730
- UC Patrícia Ferreira Machine Learning for Anomaly Detection in the Atlas Trigger at the LHC
- UC João Humberto Gomes Deep Learning in QCD Jets
- UC Sandro Saltão Optimisation of the vertical separation of multiple scatter events in the LZ detector with applications in the sensitivity to the $0\nu2\beta$ decay of Xe-136
- FCUL Catarina Pereira Performance of the TileCal High Voltage Upgrade System
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- FCUL Tomás Almeida Design of a phantom for radiobiology studies

- UMinho Pedro Chaves Probing Dark Matter with Higgs Bosons and Top Quarks
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- FCUL Tomás Correia Sousa Characterization of CsI(Tl) Crystals and Implementation of tools for the CALIFA calorimeter at FAIR http://hdl.handle.net/10451/59068
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- UC João Parente Development of Machine Learning Tools for the extraction of behavioral and physiological parameters of birds in their natural environment
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- FCTUC Giorgio Canezin A nRPC-4D neutron Detector Concept with Timing and Tridimensional Position Readout Capability
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- IST Simão Costa Probing quark hadronization with B mesons at the LHC http://cds.cern.ch/record/2883330?ln=en
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- IST Marco Leitão "QGP effects on Energy Correlators inside jets"
- IST Milton Freitas Measurement of the number of muons in high occupancy MARTA stations
- FCUL Edgar Sousa Study of dosimetry techniques applied to electron beams with high dose rate
- ISEL Maria João Borges Beam tests of a scintillation array detector for high-resolution dosimetry
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- FCUL Nuno Taborda Construção de um protótipo para o estudo da exalação de radão por materiais de construção
- FCUL Fábio do Carmo Cálculo de espetro de emissão de Auger para simulações de radioterapia sensibilizada com nanopartículas de ouro
- UC Maria Miguel Interlock electronics for the high Granularity Timing Detector od the ATLAS

Datasets produced with the support of INCD in 2023

- Martins, C., Carvalho, L.M., Moutinho Cabral, I., Saúde, L., Dreij, K., Costa, P.M. A mechanistic study on the interaction effects between legacy and pollutants of emerging concern: A case study with B[a]P and diclofenac. Accession number GSE232729 (under publication embargo)
- Gonçalves, C., Moutinho Cabral, I., Grosso, A.R, Costa, P.M. Transcriptome profiling of the posterior salivary gland of the cuttlefish Sepia officinalis. Accession number GSE251667 (under publication embargo)
- Mixão, Verónica; Brendebach, Holger; Pinto, Miguel; Sobral, Daniel; Gomes, João Paulo; Deneke, Carlus; Tausch, Simon; Borges, Vítor. Genome assemblies and respective wg/cgMLST profiles of a diverse dataset comprising 3,076 Campylobacter jejuni isolates. https://zenodo.org/record/7230105#.Y-ftJi0qJQI.
- Mixão, Verónica; Brendebach, Holger; Pinto, Miguel; Sobral, Daniel; Gomes, João Paulo; Deneke, Carlus; Tausch, Simon; Borges, Vítor. Genome assemblies and respective wg/cgMLST profiles of a diverse dataset comprising 1,999 Escherichia coli isolates. https://zenodo.org/record/7230102#.Y-fuTi0qJQI.
- Mixão, Verónica; Brendebach, Holger; Pinto, Miguel; Sobral, Daniel; Gomes, Joao Paulo; Deneke, Carlus; Tausch, Simon; Borges, Vítor. Genome assemblies and respective cgMLST profiles of a diverse dataset comprising 1,874 Listeria monocytogenes isolates. https://zenodo.org/record/7230003#.Y-fvCC0qJQI.
- Mixão, Verónica; Brendebach, Holger; Pinto, Miguel; Sobral, Daniel; Gomes, João Paulo; Deneke, Carlus; Tausch, Simon; Borges, Vítor. Genome assemblies and respective wg/cgMLST profiles of a diverse dataset comprising 1,434 Salmonella enterica isolates. https://zenodo.org/record/7230091#.Y-fvrC0qJQI
- Mixão, Verónica; Pinto, Miguel; Sobral, Daniel; Di Pasquale, Adriano; Gomes, João Paulo; Borges, Vítor. Multiple Sequence Alignment of a diverse dataset with 1788 Mycobacterium tuberculosis isolates. https://zenodo.org/doi/10.5281/zenodo.7772651

Software created with the support of INCD in 2023

- MitoCarta, depositado no GitHub (https://github.com/MitoProfiles/MitoCarta)
- Validation and benchmarking of ReporTree (a surveillance-oriented tool to strengthen the linkage between pathogen genetic clusters and epidemiological data) https://github.com/insapathogenomics/ReporTree
- Development of INSaFLU TELE-VIR platform https://github.com/INSaFLU/INSaFLU
- Development of INSaFLU Snakemake https://github.com/INSaFLU/insaflu_snakemake
- Development of udocker https://github.com/indigo-dc/udocker
- Development of SQAaaS https://sqaaas.eosc-synergy.eu/#/