Evaluation Panel: EXACT SCIENCES - Physics

Panel Members

Peter Butler (Chair)	University of Liverpool, United Kingdom
Deborah O'Connell	University of York, United Kingdom
Farvah Nazila Mahmoudi	CERN, Switzerland
Giampaolo Pisano	University of Cardiff, United Kingdom
Hanns-Ulrich Habermeier	Max Plank Institute for Solid State Research, Germany
Konstantinos Kokkotas	University of Tübingen, Germany
Paul Soler	University of Glasgow, United Kingdom
Rolf Allenspach	IBM Research Division, Zurich Research Laboratory, Switzerland
Tulkki Jukka	Aalto University, Finland
Zaher Salman	Paul Scherrer Institut, Switzerland

R&D Units

Centro de Astrofísica e Gravitação (CENTRA)	Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento (IST-ID)
Centro de Ciências e Tecnologias Nucleares (C2TN)	Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento (IST-ID)
Centro de Física da Universidade de Coimbra (CFisUC)	Universidade de Coimbra (UC)
Centro de Física das Universidades do Minho e do Porto (CF-UM-UP)	Universidade do Minho (UM)
Centro de Física e Engenharia de Materiais Avançados (CeFEMA)	Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento (IST-ID)
Centro de Física e Investigação Tecnológica (CEFITEC)	NOVA.ID.FCT - Associação para a Inovação e Desenvolvimento da FCT (NOVA.ID.FCT/FCTUNL/UNL)
Centro de Física Teórica de Particulas (CFTP)	Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento (IST-ID)
Centro de Física Teórica e Computacional da Universidade de Lisboa (CFTC)	FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências (Fciências.ID)
Centro de Investigação em Ciências Geo-Espaciais (CICGE)	Faculdade de Ciências da Universidade do Porto (FCUP/UP)
Instituto de Astrofísica e Ciências do Espaço (IA)	FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências (Fciências.ID)
Instituto de Biofísica e Engenharia Biomédica (IBEB)	FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências (Fciências.ID)
Instituto de Física de Materiais Avançados, Nanotecnologia e Fotónica - Universidade do Porto (IFIMUP)	Faculdade de Ciências da Universidade do Porto (FCUP/UP)
Instituto de Plasmas e Fusão Nuclear (IPFN)	Instituto Superior Técnico (IST/ULisboa)
Laboratório de Instrumentação e Física Experimental de Partículas (LIP)	Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Laboratório de Instrumentação, Engenharia Biomédica e Física da Radiação (LIBPhys)	Universidade de Coimbra (UC)

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Astrofísica e Gravitação (CENTRA)
Coordinator: José Pizarro de Sande e Lemos
Integrated PhD Researchers: 33

Overall Quality Grade: EXCELLENT
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 5
(B) Merit of the team of Integrated Researchers: 5
(C) Appropriateness of objectives, strategy, plan of activities and organization: 5

Base Funding for (2020-2023): 586 K€
Recommended Programmatic Support
PhD Fellowships: 5
Programmatic Funding: 337 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The CENTRA is a centre of excellence in astrophysics and gravitational research. It hosts top scientists and some of them are world leaders in their field. The institute attracts young scientists from all over the world. The Unit works in three research areas: Gravitation (GRIT), Cosmos and stars (COSTAR), Scientific and space instrumentation and modelling (SIM). The Unit is contributing to the advancement of research areas such as black holes, gravitational waves, dark matter and supernovae.

The output of the Unit is of the highest order, with publications in the most prestigious scientific journals (Nature, Physical Review Letters, Astronomy and Astrophysics, etc.). Some of them had large resonance (Gaia release, Kilonova & Gravitational Waves). The number of papers published in 2013-17 is outstanding: more than 400 with 3000 citations and the highest number of papers/author in the field in Portugal. Given the number of Integrated Researchers of the Unit (33), the productivity and associated quality is remarkable.

The CENTRA main contributions are:
1) Fundamental science in gravitational wave physics and black holes: it is one of the few centres dealing with numerical relativity and leaders in testing General Relativity via the study of BH dynamics. These studies led to journal covers, invited reviews and media interviews.
2) Implementation and development instrumentation: this activity has found applications in well-known international projects such as ESO, ELT and Gaia (for which CENTRA is the national leader).
3) Dark matter search: innovative studies to evaluate the effect of dark matter on the structure of the Sun.
4) Organisation of the Gravitation Portuguese and international community: Co-founders of the Portuguese Society for Relativity and Gravitation, Chair of the GWverse network (a COST consortium of 26 countries), organisation of the international conference to celebrate 100 years from Eddington observations, chairing of the scientific committee of the most important conference on relativity, gravitation and cosmology (July 2019).

The CENTRA is very active in advanced training: in addition to the doctoral programs, CENTRA organised 7 national/international schools, and two summer schools for UG and Grad students, and also training for students in outreach. The outreach programme is rich, including public events, press releases, website interaction with public, media and popular science articles, a dedicated youtube channel (10000 student contacts), the famous 3D Gaia map on news. The Unit shares its 480 CPU PC Cluster facility, which is used worldwide.

Members of the Unit are key people in the Portuguese/international astronomical community: Portuguese delegate ESO, president Portuguese Astronomical Society, Academic co-coordinator Portuguese Space Agency and Chair on Journal of A&A. The CENTRA has an international working environment where 12 out of 17 researchers come from different nations. The CENTRA also hosts the unique theoretical physics ERC in Portugal. During the 2013-17 period, the Unit managed to secure non-FCT funds via national and international contracts covering 30% of the total budget.

The 2017 report of the External Advisory Board was extremely positive. The EAB stated that CENTRA is a centre of excellence in astrophysics and gravitation, a reference centre in Portugal, and a highly competitive international centre. They emphasised the outstanding research output, with works which have been influential in the field, and the sharing of software (available online) and facilities (PC cluster).

The plan of activities for the 2018-22 period includes:

A) Scientific objectives: i) Fundamental physics with Gravitational Waves and Black Holes; ii) Numerical relativity; iii) Stars and Dark Matter; iv) Acceleration of the Universe;
B) Leadership in projects and major collaborations: i) The Gaia mission; ii) GRAVITY and the Galactic Centre; iii) Next generation flagship missions; iv) LISA.

The Unit aims at maintaining excellence, having more leading roles, more international partnerships/networking and to keep the outreach activities at the current high levels. However, given to its growth, the Unit lacks a Project Manager and indeed this position has been requested now.

The Doctoral programme requires a total of 16 new PhD fellowships for the period 2018-22. The request for new IRs is 4 (for 3 years, funded at 85%). The budget request to FCT for 2018-22 is 72% of the total. The expected 28% non-FCT funds are realistic given the previous record (30%). The justification of resources is very detailed.

The Unit research team shows vision, by realising the importance for research centres to revise their programs and strategies following the recent discoveries which are now connecting previously detached fields and communities (e.g. electromagnetic and gravitational waves).

The team proves to be innovative, by working on novel observational techniques (for Black Holes, Neutron Stars, Supernovae and BH event horizons), by developing numerical General Relativity techniques to study fundamental physics processes (such as Hawking radiation, BH entropy and stellar collapse). These are extremely important tools at the forefront of the field, involving also mathematicians.

The team works on interesting alternative areas such as the study of the star motion in the Gaia survey to detect gravitational waves, the study of the Sun to put constraints on dark matter/energy and the study of systematic errors in cosmology by observing the polarisation of Supernova host galaxies.

The team has expertise in instrumentation, software and observation techniques, so putting CENTRA in a very strong position compared to other centres. The manufacturing of instrumentation involves also Portuguese companies.

The Panel noted that the number of PhD students has increased from 10 in 2013 to 18 in 2017, in contrast to the national tendency; the number of young researchers with contracts increased from 30 to 33. The proposal has a request for 16 PhD Fellowships and 4 new researchers. Given that the the limited budget for these positions in this FCT Program, the Panel can recommend that only 5 PhD Fellowships and 1 new researcher position be awarded. The Panel also recommends 202k€ for non-staff costs. Priority within the base funding should be given to the hiring of a project manager and two engineers.

The PhD student fellowships should be applied as follows:
PhD Program in Physics (IST – University of Lisbon): 2 PhD fellowships
PhD Program in Physics Engineering (Faculdade de Ciências of Lisbon): 1 PhD fellowship
PhD Program in Physics Engineering (Faculdade de Engenharia, University of Porto): 1 PhD fellowship

The priority order of the new researcher to be hired is: 1) CMS group; 2) Phenomenology group.

The Programmatic Funding should be partially used for support to ELT-METIS project to share supplementary costs for instrumentation that will be manufactured by Portuguese companies, and support for participation to ELT/Gaia consortium meetings and ESO headquarter trips.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Ciências e Tecnologias Nucleares (C2TN)
Coordinator: José Pedro Miragaia Trancoso Vaz
Integrated PhD Researchers: 75

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 1125 K€
Recommended Programmatic Support
PhD Fellowships: 5
Programmatic Funding: 409 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
This Center, of 75 integrated PhDs, is an interdisciplinary R&D Unit of IST, established in 2013, that strives to promote radiation for science and society. It is a large organisation that provides radiation and nuclear services for the Portuguese government, industries and cultural institutions. We note that senior staff are members of Evaluation Panels of proposals submitted to HORIZON 2020 Calls for projects, are members of the Editorial Board of international journals and provide the national liaison officer of Portugal for IAEA. As expected for a R&D Unit of this size, C2TN is engaged in advanced training at Master and PhD levels, with a large doctoral program.

The Unit tackles a wide variety of societal challenges and contemporary applications from healthcare and radiation exposure assessment to cultural heritage and cybersecurity. As a consequence, this is the type of R&D Unit that is essential in Portuguese government. The Unit has a wide range of expertise in: PET, SPECT and TRT; radioanalytical, dosimetry and metrology techniques; gamma and alpha spectroscopy and various ion beam based analytical techniques, including PIXE; molecular synthesis. It has several specialized laboratories e.g. for handling radioisotopes, clean rooms, for archeological dating, spectrometers for condensed matter and nuclear physics, electron linac and Van de Graaff accelerators.

C2TN brings together researchers from diverse fields in physics, chemistry, biology, etc. with a common interest in techniques based on nuclear methods. As such, there is great potential for synergies at least on the technical side. There may be some opportunities of collaborations also on the science side, for example, by exploring applications of different techniques on the same problem. Some of the groups seem to carry out dedicated and innovative research and some of the groups seem to be service providers for the general scientific community. In other words, it seems like some groups are more reactive than proactive in setting their own research agenda.

Highlights of research which has societal impact include: investigation of large uranium-based molecules for storage and processing of information; characterization of specific radiopharmaceuticals for cancer treatment, such as DNA damage caused by 99mTc; measurements and simulations for radiation protection and dosimetry; development of instruments for neutron and alpha-particle detection; and monitoring air quality using nuclear analytical techniques.

In certain fields C2TN is leading internationally, e.g. in the field of emission channeling for material studies the work on technologically relevant semiconductors and doping effects is quite powerful and unique. The uranium based single molecule magnets research is also potentially very interesting.

The Unit has publications in a very wide range of journals of international standing covering several fields – the sample publications are in high impact (mostly > 4) journals. In many cases the papers have a decent number of citations.

The members of C2TN are active internationally, being involved in collaborations at CERN (ISOLDE, n-TOF and MEDICIS), IAEA as well as other European projects. For these collaborations the Unit has made substantial contributions, e.g. using radioactive probes at ISOLDE (CERN). They are also pursuing collaborations with biotech companies to investigate

potential applications for their research in this field. In addition, they offer services to industrial partners using technologies based on ionizing radiation.

Considering the aspects mentioned above, the Panel was initially surprised to see that in the 2013-17 period the unit had not been very successful in attracting a significant contribution from industry and other international sources compared to that obtained from FCT (around 14% only). The number of research contracts with international bodies slightly increased whereas the one with national public/private entities almost halved. However, the Panel was pleased to see that funding from external sources had significantly increased since the proposal was submitted, and in the period 2013-2018 funding from outside the FCT (mostly from EU projects) has increased to 40% of the total.

Concerning the next period 2019-22 the plans build on existing strengths and includes many applied topics giving good potential for societal impact in the future. The details of these plans were however rather vague, and would have benefitted from more concrete examples and areas of excellence.

The general themes of advanced materials, radiopharmaceuticals and earth systems and cultural heritage showed areas where nuclear science has applications, without going into details. Also, the proposal mentioned the plan to move activities into security, space and defense, but again there were not many details here. The one exciting area that was mentioned in passing is a new hadron therapy facility; there are not many of these in Europe; so, if C2TN can provide such a facility, it would be really internationally leading.

At a first glance it seems that the research activities in the Unit are incoherent and artificially brought together. However, at the heart of these activities is the common use of nuclear methods/techniques. It is not very obvious how the different groups contribute to each other. The application mentions synergies, but no clear examples were given. Some examples were provided during the site visit, e.g. in detector developments and use of shared facilities. The Panel considers this to be satisfactory, but recommends to actively promote further opportunities for collaboration by creating shared PhD positions between the different groups.

The strengths of the research plans are that they embrace an attempt to create synergy between the 5 groups by merging them in 3 main projects; the plans include prominent roles for serving the society, the environment and the cultural heritage; and the intention to renew the personnel. The latter will respond to a major threat to the Unit, as the average age of the personnel is high and most of the permanent research staff will approach retirement age in 5 years time. Arguably, the intention of the Unit to expand into new areas of research (exploiting applications of their skills), while laudable in principle, in practice may have too many goals, beyond the capability of the personnel.

The Panel noted that the number of PhD students has dropped from 38 in 2013 to 32 in 2017, with a large drop to 21 in the current year; the number of young researchers with contracts is currently 11. The proposal has a request for 40 PhD Fellowships and 25 new researchers. Given the limitations of this FCT Program in these positions, the Panel recommends the award of 5 PhD student fellowships and 1 new researcher position.

The Panel anticipates that the Unit will compensate its need of more PhD student fellowships, new researchers and non-staff costs through future calls for individual fellowships and projects.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física da Universidade de Coimbra (CFisUC)
Coordinator: Maria Constanca Mendes Pinheiro da Providencia Santarem e Costa
Integrated PhD Researchers: 40

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 3
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 593 K€
Recommended Programmatic Support
PhD Fellowships: 3
Programmatic Funding: 305 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The CFisUC encompasses physics research at the University of Coimbra and carries out research, teaching and a noticeable outreach program. This old university has a long history of Physics and is divided into their natural strands: nuclear astrophysics, theoretical particle physics, condensed matter physics, chemical physics and biological physics. CFisUC research efforts are supported by 40 integrated researchers; 19 PhD students are spread over all fields of research of the Center (including outreach).

CFisUC follows a very well-planned outreach program which is designed for education and training of young scientists, but it also reaches out approaching and guiding pupils in schools and promoting science to the general public. Noticeable activities include the "Quark" Physics Olympiad training program, Summer Schools for high-school students and science teaching (Rómulo) and History of Sciences.

Members of CFisUC have been involved in various international networking activities (COST actions 1304, 15128, 15214, 15213, 16214) and H2020 projects, in which played leading role, and participate to ETSF (European Theoretical Spectroscopy Facility). At the same time, they participated in varied national research efforts and had leading roles in a number of FCT PhD programs (IDPASC, ChemMat, DAEPHYS).

CFisUC key and associated researchers supervised during 2013-17 47 MSc and 14 PhD students. Many of the students were supervised by members of the TWG groups.

The CFisUC members organized a number of summer schools and workshops

The research efforts of the CFisUC depend, in most of the cases, on computational resources which led the Unit initiative to play significant role in organizing the HPC efforts in UC (Navigator computer cluster) at national level and participating in major European efforts (PRACE). The Panel values high this activity of CFisUC.

It is noticeable the increase in funding via research projects in the last two years.

All integrated researchers publish in internationally competitive journals such as Phys Rev, Phys Lett, Computational Biology. Publications in Nature or Science or PRL have not been reported. The research output of the key integrated researchers (nuclear CVs) varies quite a lot. There are no exceptional cases, i.e. highly cited researchers or with major high-profile grants, fellowships or prizes, e.g. ERC grants.

CFisUC strategic plan for the period 2018-2022 is organized in 4 working groups (WG) which are, in the Panel opinion, loosely connected even though there is a noticeable effort (key researchers of the various WGs are involved in the research and supervision efforts of other groups) for improving synergism wherever it is possible.

The WG1 (Hadron Physics and Fundamental Interactions) includes 14 integrated researches has a lot of potential based on its track record but also due the recent discovery of gravitational waves which brought in the scientific forefront the research on neutron star equation of state, a field in which the group had significant impact in the last two decades.

The WG2 (Multifunctional Materials) includes 12 Integrated Researchers focusing on multifunctional magnetic materials, magnetoelectric phenomena, optimization of thin-film solar cells and in collaboration with C2TN study topological insulators and superconductor materials. The group has a very good track record and potential for attracting funding from European and private sources.

The WG3 (Chemical and Applied Condensed Matter Physics) includes 12 Integrated Researchers. The research projects of WG3 are related to society challenges such as clean energy via the development and characterization of materials for storing H or capturing CO. Their techniques are based on muon spin spectroscopy (muSR), in which they have a very good track record. There is potential for synergy with industry, but there was not any funding reported yet.

The WG4 (Soft and Biological Matter) is a relatively newly formed research group comprising 6 Integrated Researchers. Its research focus is the study of human tissues and vessels and their alterations with application to diabetes, cancer research. The findings can be applied to medicine and biology and there is potential for synergetic projects with other groups in UC, as well as at national and international level.

The Panel observed that the productivity, the international recognition, the potential and the prospects of the four working groups is varyed, as well as their research prospects. Furthermore, the quality of the researchers within the working groups is also varyed.

The Panel valued very high the well-organized effort of transferring the research knowledge to the society via three "Transfer Working Groups" (TWG), focusing on Outreach (TWG1), World Heritage (TWG2) and Physics for Industry (TWG3). TWG1 and TWG2 have significant contributions and prospects. The TWG3 efforts have not been materialized till now.

A very interesting and promising development is the hiring of a new professor in Exo-Planet research. Even though the field is not close to the existing ones in CFisUC, we anticipate that bridges can be set. Furthermore, collaborations with the Institute of Astrophysics and Space Science (Porto-Lisbon) should be sought.

The plans of CFisUC are very promising, but the wide range of activities and the broad range of research interests within the individual groups is not a very strong asset. The groups should focus on a few projects on which they have the leading expertise.

The WG1 should aim at building bridges with the IST groups related to gravitational wave research in order to foster the national effort in this extremely dynamical field. The Working Groups 2, 3, 4 should aim at links with industry in order to increase their funding and the dissemination of their research results.

The Panel noted that the number of PhD students has increased from 20 in 2013 to 30 in 2017, in contrast to the national tendency; the number of young researchers with contracts decreased from 60 to 48. The proposal has a request for 24 PhD Fellowships and 8 new researchers. Given the limitations of this FCT Program in this regard, the Panel recommends the award of 3 PhD Fellowships and 1 new researcher position.

The allocation of PhD student fellowships should be:
Doctoral Program in Biomedical Engineering: 1 PhD fellowship;
Doctoral Program in Physics (WG2): 1 PhD fellowship;
Doctoral Program in Physical Engineering: 1 PhD fellowship.

The Panel recommends that part of Programmatic Funding be used in hiring 1 new Junior PhD Researcher in Neutron Star Equation of State (WG1) and to cover costs of participation in international networks, in particular in PRACE.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física das Universidades do Minho e do Porto (CF-UM-UP)
Coordinator: Mikhail Vasilevskiy
Integrated PhD Researchers: 86

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 1275 K€
Recommended Programmatic Support
PhD Fellowships: 8
Programmatic Funding: 647 K€, including for 2 (Junior) New PhD Researchers Contracts.

Justification, Comments and Recommendations
The CF-UM-UP is one of the largest R&D Units in Physics, with 86 Integrated PhD Researchers. It has the intention of being a R&D Unit with a multi-disciplinary scientific activity in the fields of Pure and Applied Physics and adjacent areas. The Unit consists of two parts, the Centre of Physics of the University of Minho (CFUM) and the Centro de Física do Porto (CFP), and comprises researchers based at three sites of the two universities. The parts based in Porto and at UM are regarded to be complementary and help each other to perform high quality research, both fundamental and applied. In general, CF-UM-UP aims to provide infrastructure and the underlying conditions for competitive research and collaboration between university research and industry, with a special emphasis on serving the needs of Northern Portugal.

The research at the Centre is carried out in the fields of Theoretical High Energy Physics, Condensed Matter and Materials Physics (both theoretical and experimental), Materials Fabrication and Applications, Optics, Advanced Computations, Biophysics, Optometry and Vision Sciences, with about 15% of theoretical research and modelling and the rest of experimental research and development activities.

It is presently organised in four strategic research lines, three of which are based at Minho (1-3) and one in Porto.

The Lines based in the University of Minho span research in:
– Optometry and Vision Sciences (Line 1);
– Physics of new quantum and low-dimensional materials (theory, modelling and experimental research), Optics, Photonics and Photochemistry, Biophysics (Line 2); it also includes a number of Applied Mathematicians;
– Materials Science and Engineering (Line 3); it also includes development activities and fabrication via a couple of spin-off companies.

The Research Line in Porto (Line 4) investigates topics in Condensed Matter Physics as well as Cosmology and High Energy Physics. Field-theoretical methods are the “glue” between the seemingly very diverse topics.

The Unit claims there arestrong connections in applications between the different lines, but, beyond some joint projects and co-supervisions of students, these connections are not so obvious.

Line 1 (Optometry and Vision Sciences) covers visual optics modelling and adaptive optics systems to measure and correct in real-time optical aberrations in the human eye. Here, international partnership with research centers in Singapore, Canada, USA and the United Kingdom could be established.

Line 2 acts on a broad field of new quantum materials, Photonics and Photochemistry, with the flagship of Graphene Plasmonics. One of the world pioneers in the field is the leader (N Peres), and is involved in the EU Graphene Flagship.

Line 3 deals with polymer based magnetoelectric materials led by S. Lanceros-Mendes with research work ranging from basic understanding of the phenomena to the development of sensors and energy harvesting devices. Here, international recognition is well established.

Line 4 is located in Porto, certainly giving problems for the close cooperation between lines 1-3 and 4.

The scientific work of the reporting period is on a high level, in several cases also internationally, in particular the work on Graphene Plasmonics and the work of the theory group in Porto.

There are some 30 research laboratories. Being part of the transversal UM Laboratory for Materials Characterisation Services, CF-UM-UP is well equipped with facilities for materials growth and characterisation and optical spectroscopies, including time resolved techniques. However, there is a rather limited support by 1 engineer and 3 technicians at Minho where the experimental work is located. Since the type of laboratories is rather diversified, from thin film deposition to optometry, running 30 research laboratories with such a limited support of technicians/engineers implies substantial technical work from Master and PhD students.

Some relief comes from the collaboration with the Iberian International Nanotechnology Laboratory (INL) located nearby, representing an important extension of the research capabilities. The INL is modern and very well equipped at the international standard. Some students are trained there and sometimes CFUM can have access to INL facilities, within co-supervisions or joint projects. More than this, two INL groups are led and were created by CFUM integrated members (UM staff), also Associate Members of the INL, one experimental and one theoretical. The group working in graphene is the only Portuguese group included in the EU Graphene Flagship. Another facet of the collaboration with the INL is the joint venture named QuantaLab, a research structure dedicated to Quantum Technologies and Quantum Materials. Several CFUM members belong to it. The QuantaLab develops efforts on creation of synergies between researchers who are somehow related to new Quantum Information Technologies, in terms of either software or hardware. It organises thematic meetings and belongs to the IBM-Q network.

Furthermore, there is a large collaboration project between the University of Minho and Bosch, funded by the National Innovation Agency, beyond the participating entities themselves. It is dedicated to autonomous driving and within this project CFUM is contributing to research, development and testing of new optical detection and measurement systems (LiDAR). It involves a considerable number of CFUM staff members, contracted researchers, fellows and students. Quite importantly, this project allows CF-UM to purchase some equipment, which the Panel expects to remain in the Centre after the end of the project.

From the theory side there is an involvement of the CFP in the Simons Foundation Network, encompassing 17 PI's spread over 7 countries in North America and Europe with a total of 17.5 million for 7 years (about $1 million to UP) enabling the financing of 3 Post-Docs and 2 PhD students at UP.

The CF-UM-UP shows a rather substantial scientific production. In 2018, the total number of published journal papers (including conference articles) was 188, a ≈20% increase compared to the previous year.

4 international patents have been granted and 57 invited talks have been delivered at international conferences. 45 Master theses have been accomplished and 7 PhDs have been granted. The visibility of the Unit is ensured by the involvement of the members of the Unit in the organisation of international conferences and workshops. The Annual International Congress on Optometry and Vision Science, Braga, since 2006 may serve as an example. In the last years it counts with more than 500 participants and is entirely organised by the CFUM members of the Research Line 1.

Based on the rather succesful work during the period 2013-2017, the plan for the future is mainly the continuation of the work along the 4 research lines. Each group has a coordinator who is in charge of both, the scientific as well as the financial matters. The researchers – the young PhD students as well – are rather motivated albeit being well aware of financial constraints the Unit is envisaging. Therefore, the presentation by Prof. M Vasilievskiy concluded with the statement:
» Strength: The strongest points of the Centre are related to its interdisciplinary character. There are several researchers working actively at frontiers between Physics and other disciplines, such as Optometry, Molecular and Cell Biology, Engineering of new sensors, functional (e.g. photo-catalytic) surfaces, and systems for energy applications.
» Weakness: Several research facilities are not up to date and possibilities of their upgrading are very limited. The last serious upgrade of the scientific park of the Centre took place in 2006 (part of the National Re-equipment Program 2004). Since then, only occasional acquisitions have been possible.

» Opportunities: Increasing number of candidates to the UM and UP courses in Physics (BSc and MSc in Physics and Master in Engineering Physics) in the last years.
» Threats: Funding and timings incompatible with the dynamics of internationally competitive scientific research. With the overwhelming priority to “earn money”, the scientific research can be biased towards solely applied projects.
The Panel members do share this opinion.

The Unit has a substantially large number of projects/activities. It is highly recommended to reduce the topics to the most rewarding ones. The Unit is internationally highly regarded in some select areas, but not in others. Due to the limited money allocated in total by FCT, applying for external grants such as EU ERC is highly desirable.

The Panel recommends that the new PhD Researcher to be hired be allocated to the University of Minho, in order to strengthen collaboration between theory and experiment. The Programmatic Funding should also be partially used to fund engineering and/or technical support.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física e Engenharia de Materiais Avançados (CeFEMA)
Coordinator: Pedro José Oliveira Sebastião
Integrated PhD Researchers: 46

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 683 K€
Recommended Programmatic Support
PhD Fellowships: 4
Programmatic Funding: 436 K€, including for 2 (Junior) New PhD Researchers Contracts.

Justification, Comments and Recommendations
The CeFEMA combines research groups in fundamental as well as applied physics in the fields of condensed matter physics, materials science and engineering. The idea behind the formation of this R&D Unit is combining theoretical and experimental research to achieve better understanding and possibly "design" power for new functional materials. In principle, this is a great idea which is used frequently nowadays to enhance the impact of scientific research. The primary research topics that the Unit is pursuing are far from equilibrium materials and processes, functional materials, soft matter and graphene and low dimensional materials. The research activities builds upon existing expertise in theoretical physics, complex fluids, NMR and surfaces, laser assisted synthesis and processing, nanostructured materials, membranes and chemical/electrochemical processes.

The Unit benefits from two important facilities which are part of the national network research facilities; the Microlab for electron microscopy the nuclear magnetic resonance (NMR) laboratory which is an international leader in fast field cycling NMR technology.

The Unit is scientifically productive with a good level of publication record in a diverse range of topics. Some of the publications are very well cited which is a good indicator of the international relevance of the research in CeFEMA. The Unit is also quite successful in attracting international and private funding which accounted for about 25% of the total budget in the period 2012-2017. In addition, CeFEMA has filed for three international patents, one of which resulted in a start-up company for safe and controlled freezing of biopharmaceuticals. The key Integrated Researchers are all good, though with a large variation in their level. Most importantly, the two young key researchers, who are currently leading the theory efforts and research in energy related advanced materials are very promising.

The Panel finds that the research directions related to design and synthesis of new membranes, associated with biological functions, have the potential for a clear and direct societal impact. The same holds for the research in advanced materials for energy conversion and storage. In the field of condensed matter physics, the Unit is targeting very topical subjects, e.g. topological phases of matter and transition metal dichacogenides. Success in these fields could help to enhance the Unit international visibility. However, to achieve an impact in this particular field and in general condensed matter physics, the Unit should strengthen the synergies between theory and experiments. The Unit seems to be thinking seriously in this direction, but no concrete evidence of such effort was immediately visible. A good starting point would be a new PhD Researcher position between the theory group and one of the experimental groups within CeFEMA.

The outreach activities in CeFEMA are aimed at increasing science awareness in schools, both in Portugal and abroad, e.g. Timor, Cabo Verde and Mozambique. This international perspective of the outreach activities is quite unique and should be encouraged. Nevertheless, given the nature of some research performed in the Unit, there may be some additional avenues to explore in order to enhance its visibility.

The objectives and plans of the Unit are very well thought and suited for the capabilities of the CeFEMA. However, these objectives are very diverse and cover a broad range of topics:

(1) Topological phases of matter (theory, maybe experiment?);
(2) Nanostructured fluids and soft matter (experimental NMR);
(3) Non-equilibrium matter and processes (theory, no experimental component);
(4) Energy conversion and storage (experiment, no theoretical component);
(5) Advanced materials micro and nanofabrication (experiment, material/film synthesis);
(6) Artificial organs (experiment and engineering);
(7) Physics of information and quantum technologies (new, theory, computational and experimental with international teams)

These topics reflect the fields and interests of the Integrated Researchers. Nevertheless, given the limited funds and manpower available in CeFEMA, this is very ambitious, and may be hard to achieve while maintaining a high standard of scientific output in all involved fields. The Panel recommends that CeFEMA narrows down its focus to few strategic/important fields, those with highest chances for success and better opportunities for international visibility.

The Unit requests funding for 36 PhD fellowships, i.e. an average of 8 PhDs/year. This is reasonable considering the number of Integrated Researchers (less than one PhD per researcher) and the declining number of PhD students over the last few years. Additional funding is requested for six PhD researchers, one to work on topological phases, one for advanced materials, one artificial organs, one quantum technologies (NV centers), and two for energy conversion and storage. All positions are well justified, though the quantum technologies position implies diverging into yet another field of research, which may not be a good idea at this stage.

From the Panel discussions with the team of CeFEMA and the site visit, it seems that one of their key researchers, who is leading the research in the field of energy conversion and storage, does not have a permanent (or tenure track) position. This uncertainty poses a major risk for the future of CeFEMA in this highly productive and successful research line. Therefore, it should be considered a priority for allocation of funds.

When it comes to the requests of equipment funding, things become much more complicated. The existing equipment available at CeFEMA is mostly old but still functioning. This is the case of the NMR and electron microscopy laboratories. For these laboratories, funding for maintenance is important and needed, but we do not think that enhancements in these are needed for the evolution of future directions in CeFEMA. We recommend that the funding be directed towards enhancing primary future research directions, in particular, those built around advanced materials for energy conversion and storage and as well as artificial organs.

The Panel noted that the number of PhD students has dropped from 21 in 2013 to 10 in 2017. The proposal has a request for 36 PhD Fellowships and 6 new researchers. Given the limitations of this FCT Program in this respect, the Panel recommends that 4 Fellowships and 2 new PhD Researchers positions be awarded.

There are two members of the Unit that can be considered critical for two major fields that the Unit deals with, namely advanced materials for energy conversion and storage and as well as artificial organs. The Panel recommends that each one of these fields be allocated with one of the new PhD fellowships awarded. A third PhD fellowship should be allocated within the theory group to strengthen the newly appointed assistant professor; the Panel recommends that this particular research will aim to boost the collaboration between the theory group and one of the other experimental groups. The Panel has no specific recommendation for the 4th PhD fellowship.

As mentioned before, it is important to allocate a longer term contract to two researchers in the fields:
- Energy conversion and storage,
- Artificial organs.

The Panel recommends to strengthen three of the core fields of research in the Unit, in particular those involving new and young researchers to boost their future productivity and establish their international visibility.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física e Investigação Tecnológica (CEFITEC)
Coordinator: Paulo Manuel Assis Loureiro Limão-Vieira
Integrated PhD Researchers: 17

Overall Quality Grade: GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 3
(B) Merit of the team of Integrated Researchers: 3
(C) Appropriateness of objectives, strategy, plan of activities and organization: 3

Base Funding for (2020-2023): 211 K€
Recommended Programmatic Support
PhD Fellowships: 1
Programmatic Funding: 55 K€.

Justification, Comments and Recommendations
The CEFITEC was established in 1994 within Universidade NOVA de Lisboa, School of Science and Technology (FCT NOVA), gathering consolidated scientific and technological know-how right at the intersection of fundamental, applied and technological physics, with the main purpose to create an academic hub of reference. It is one of the few R&D Units that has an "inverted" pyramid, in the sense that a small fraction of fundamental research is complemented by an extended range of applications and an even wider technology development. The Unit expertise is highly interdisciplinary, from physics engineering to chemistry, biomedical engineering and even pharmaceutical know-how.

The CEFITEC intends to play a key role in applied physics (mainly applied molecular physics and technology), vacuum science & technology, and instrumentation. Albeit being a small unit with 17 Integrated PhD Researchers only, the Unit runs 4 full equipped laboratories on Surface Science and Vacuum Technology, Molecular Physics, Plasmas and Applications, Functional Molecular Systems and Solar Pumped Lasers. Additionally CEFITEC has commitments related to Biophysics and Biomedical Engineering.

The research at CEFITEC focuses mainly at the applied level, aiming at gaining comprehensive knowledge at the atomic and molecular level on a huge variety ranging from secondary electron emission from surfaces, detailed characterization of functional molecular systems based on organic and biomolecules for the development of organic devices and biomimicry of membranes and rudimentary cells, to coatings ageing produce.

The unit has a wide spread field of expertise such as:

1. Surface functionalization – functional manganite thin films (ABO3-based) with excellent photocatalytic performance under visible irradiation. This work was carried out with a magnetron cathode prototype specially constructed to support powder targets, which was assembled at CEFITEC. Additionally, CEFITEC is purchasing the fiber optics and manufacured the front mirror for the LIP project for CERN.
2. UV radiation effect on DNA – the damage at molecular level caused by UV in the 3.5 to 8.0 eV range was studied on DNA thin films.
3. Site selective bond excision of molecules – the achievement of electron-induced site- and bond-specific dissociation in electron transfer experiments.
4. Solar laser efficiency improvement – the group achieved a record-high solar laser collection efficiency of 1.5W/m2 in multimode and 7.9W/m2 in fundamental mode regimes, as highlighted in both 2016 Laser Focus World and Renewable Energy Global Innovations
5. Thermal desorption of contaminants from cork – CEFITEC succeed in developing a technology to mitigate the problem of cork taint in wine. A laboratorial prototype was built to validate the process in whole natural cork stoppers and then cork manufacturers were invited to validate the technology, which they did.
6. In sum, these achievements show the research team capability to tackle scientific and/or technological challenges. The strength of the Unit is seen in some excellent work in the Surface Science section.

Given the small size of the unit (17 Integrated Researchers with a PhD), the publication output is good, even when not considering the large number of publications related to CERN/ATLAS. One of the research highlights of the past funding period is the work on selective bond cleavage in DNAs, published in PRL in 2013.

The number of PhD students in the Unit is very healthy.

The individual objectives and plans of the Center are suited for the capabilities of CEFITEC with their expertise in Surface Science & Vacuum Technology as well as Molecular Physics & Technology. The organization consists of 4 Laboratories. A remarkable specialty of CEFITEC is Metrovac, the service provider in the area of low-pressure topics (calibration of vacuum gauges and leak detectors).

The labs are equipped with a variety of relevant experimental techniques, ranging from TOF-SIMS to vacuum metrology. The scientific objectives pursued within the laboratories are very diverse. Even if they deserve special attention such as: Surface supported nanoclusters and Nanocatalysis, Surface reactions, Surface tailoring and ultrathin film growth, Analysis of biological materials by surface analysis techniques, Permeability evaluation and gas confinement, Vacuum and ultra-low flow calibration just to name some from the Surface Science and Vacuum Metrology Lab, they consist in isolated clusters with little or no synergy between them.

The CEFITEC is regarding societal relevance of its research highly, and in particular how this fits to topics relevant for Portugal. The showcase example is the insight provided into cork. Here, a serendipitous discovery at CEFITEC was developed into a remarkable piece of technological insight into a long-standing problem of the industry. CEFITEC should be credited to have recognized the relevance and to have secured patent protection.

Another example concerns the work on solar pumped lasers. The concept of solar pumped lasers is not new and was also not invented at CEFITEC. However, CEFITEC is steadily making progress in the key figures that characterize these lasers. Extrapolating into the future, one could imagine that such lasers might become reasonable laser sources in select off-grid applications. It must be expected, though, that In case electrical power is available, standard laser sources will not be replaced by solar pumped lasers because of its lower efficiency. A well thought-through plan for a realistic niche application would be welcome.

The plan for the next funding period should be sharpened, so that the limited resources are used to the best extent possible. At present, the plan covers 6 Goals (state-of-the-art training, Technology Transfer , Attracting new talents, Keep producing impact on EU scientific communities, Generating impact on public, professional and governmental opinion, focus on funding and networking opportunities), whereas scientific topics are not listed beyond the techniques of the 4 main Laboratories. The Panel invites the Unit to boldly think about possible future success topics similar to the cork project, that ideally fulfilled the requirement of societal needs and likewise could be accomplished with modest experimental effort. It is foreseeable that the challenges of the cork topic will be resolved in the next funding period, and then a follow-up project is needed. What could be a materials issue with similar traits as the cork project? A weakness on the other hand is the apparent lack of synergy between the different activities in the laboratories which can be overcome by some restructuring plans and an improved cohesion in seminars for the whole unit.

Given the modest funding that FCT can provide, alternative funding sources, such as from the EU, should be actively sought.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física Teórica de Particulas (CFTP)
Coordinator: Jorge Manuel Rodrigues Crispim Romão
Integrated PhD Researchers: 18

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 5
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 270 K€
Recommended Programmatic Support
PhD Fellowships: 3
Programmatic Funding: 175 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The Center for Theoretical Particle Physics (CFTP) is the leading theoretical particle and nuclear physics R&D Unit in Portugal. It is well known internationally and had significant contribution in the field. The Unit consisted of 18 integrated researchers and 3 PhD students at the time of the proposal (2017). It currently has (June 2019) 12 permanent staff, 7 postdocs and early career researchers, and 5 PhD students. This is a group with very active members, with excellent scientific records, and with active participation in international conferences and events.

It has very good international visibility, in terms of collaborations, organization of events, and responsibilities. Members of CFTP have been session co-conveners at ICHEP 2014 and ICHEP 2018, the foremost international conferences in High Energy Physics. CFTP also organizes other international scientific meetings and conferences in many locations around the world, where leading researchers attend due to their international reputation, the most notable of which is a series of workshops on multi-Higgs models. They hold leadership of a COST action, and one member is on the High Energy Particle Physics Division Board of the European Physical Society (EPS).

Members of the group collaborate with experimental particle physicists from Portugal (LIP) and the rest of the world (for example, at CERN, JLAB, FAIR, ...). Unit members also participate (and lead) international networks. It is vital for this internationally competitive Unit to continue to thrive and to carry out theoretical and phenomenological research in particle physics, to complement the mainly experimental programme being carried out by LIP. They have very good student training and do some outreach activities in Portugal and abroad. Internally, they have mixed collaborations between more senior researchers, postdocs and students, making the students actively involved in the research projects from the very beginning. The group is very successful in attracting the best students in Portugal (4 out of 16 national individual FCT fellowships in Physics chose to go to CFTP).

The research team has a high reputation. In particular, some of their activities in Higgs physics and CP violation are at the forefront of the international activities in the field, which continue coherently their pioneering work in the past. They also have a strong team in hadron physics and a burgeoning group in theoretical neutrino physics. The group has developed certain areas of exceptional quality, such as:

1) Development of multi-Higgs models to probe the structure of the vacuum. This area of research has attracted more than 1500 citations in a series of papers led by CFTP personnel (Physics Reports 516 (2012) 1-102 has 1477 citations according to INSPIRE-HEP).
2) Multi-Higgs models with non-vanishing flavour changing neutral currents (FCNC), such as the Branco-Grimus-Lavoura (BGL) model developed at CFTP.
3) Flavour symmetries to address the flavour anomalies of LHCb and the exploration of the symmetry groups that could be responsible for discrete flavour symmetries.
4) Hadron physics: non-perturbative QCD theories to address hadron spectroscopy observed at experimental facilities, such as JLAB and HADES.

There is extensive evidence of international quality in the number of papers published by the CFTP in the past four years. During this time, the institute has published 161 highly cited papers in high-quality leading international journals (28 papers achieved more than 28 citations over the four-year period). This is a high-quality output.

Multi-Higgs models received, by far, the largest number of citations, followed by the areas of flavour symmetries and hadron physics. Members of CFTP are very well known in their area of research and have been renowned members of the international community. For example, three leading members of CFTP wrote one of the definitive text-books on CP violation, which is used by researchers of CP violations from all around the world, and one member has written a modern text book on neutrino physics (with a colleague at IFIC Valencia), published in 2015. Members of CFTP have also been responsible for writing other more general Physics undergraduate textbooks in the Portuguese language, sold widely in Portugal, and a popular science book on Nuclear Physics, with well-known authors from the UK.

The group has been very successful at establishing international collaborations and training the next generation of young theoretical physicists. For this reason, it is very important to continue to fund this unique Center in Portugal, as a national Center of Excellence.

The objectives of the group are very clear and well laid out. The main strategy is focused around international excellence and recruitment of the best possible candidates for available faculty and researcher positions. The areas for future research are well motivated, based on the experience of the group. The clear strategy of pursuing discrete symmetry groups to describe the 'Flavour Problem', including the structure of the neutrino sector, was well motivated during the question and answer session of the visit. Being able to predict the parameters of the PMNS matrix and CP violation in neutrinos, coupled to theories of leptogenesis to describe the matter-antimatter asymmetry of the universe, is an area of great scrutiny in theoretical particle physics, and is showing great promise in the group.

The Panel encourages CFTP to reinforce its collaboration with experimental groups, in particular with LIP and to extend the current collaboration on neutrino physics to other research topics of common relevance for both Units. The joint collaboration/projects of CFTP with other groups in Portugal (Lisbon and Coimbra in particular) are also very welcome.

In summary, CFTP is committed to theoretical particle physics, with evidence of international leadership and engagement in international programmes and a clear motivation for the resources sought, to achieve training of the next generation of theoretical particle physicists and to enable a slow regeneration of the permanent faculty members, especially due to the age profile of these researchers.

Within the limited resources of this FCT Program, the Panel recommends the allocation of Programmatic Funding equivalent to hiring one Junior PhD Researchers to two such positions with 50% co-funding from IST to start to regenerate the age profile of CFTP, and 3 PhD student fellowships to carry out excellent training in theoretical particle physics in an internationally competitive research environment. A small part of the Programmatic Funding can also be used for costs of participation in European networks.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Física Teórica e Computacional da Universidade de Lisboa (CFTC)
Coordinator: Margarida Maria Telo da Gama
Integrated PhD Researchers: 13

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 188 K€
Recommended Programmatic Support
PhD Fellowships: 3
Programmatic Funding: 155 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The CFTC is a leading national R&D Unit with only 13 integrated PhDs, which is well recognized nationally and internationally and performs high level research, both qualitatively and quantitatively. The focus of its research is on theoretical and computational physics, with emphasis in the areas of soft condensed matter, non-linear dynamics and particle physics. Its research is highly relevant and paves the way for new technologies in materials science and non-linear optics.

The Unit maintains strong links with many international centers of relevant research and over the years achieved funding for these collaborations. The CFTC has long lasting collaborations with top international experts and this elevates the quality of its research, leading in an impressive number of publications in top journals.

Many young scientists emerged from CFTC and this is an added value to the society, to industry and to academia.

The three main research streams of the group are:
- Collective properties (dynamics of non-equilibrium and out-of-equilibrium soft matter systems);
- nonlinear waves in non-Hermitian optics, quantum gases, and microcavities;
- particle physics (extensions of the Standard Model).

The work on intrinsic order in liquid crystals and the work on the theory of nonlinear systems with PT symmetry-breaking has appeared in high-impact journals.

The CFTC, in spite of its small size, has a highly productive research program with a very good publication record and a high number of citations. The Unit, while focusing on theoretical and computational physics, maintains very strong international and national collaborations with experimental groups. This is a very positive aspect of the research in this Unit. They are also fully aware of the available possibilities to attract international as well as national funding and utilize these opportunities very well.

The Unit members have distinctive contributions which are acknowledged internationally. Two staff members received research prizes from the University of Lisbon in 2017. Another remarkable feature of the Unit is its success in attracting international visitors (professors and sabbatical stays). The CFTC has organized several international workshops and conferences and the members of CFTC are also invited regularly to international workshops and conferences. The group also provides a Panel Chair for ERC, and a subgroup convener for CERN (on Neutral Extended Scalars).

For the next five years, CFTC has a well-elaborated plan along 3 directions, evolving but also extending present approaches, focusing on consolidating researchers, promoting collaborations and attracting more external funding. It aims to maintain a very high level of research, consolidating its international recognition and national leadership in soft condensed matter and non-linear dynamics, as well as its position in particle physics. This will be achieved by attracting new staff members and increasing the number of students. They plan to pursue three main research streams mentioned

above. This will benefit from new collaborations with the University of Lorraine (France) and Virginia Tech (US), as well as institutes in Brazil. CFTC plans also to participate in different mobility programs.

Scientifically, the strategy plan seems to be very well thought with respect to the direction of research. The prominent track record of the scientists guarantees in principle the successful completion of the promised work.

The current organization of the Unit is without groups, to promote internal collaborations and synergies. This structure of management is relatively flat and welcome, in particular for such a small R&D Unit.

CFTC has received 960 KEUR from FCT during 2013-2017. The Unit is competitive and deserves further support. The ratio of PhD students to permanent researchers is very small (0.3) and should be increased.

The Panel encourages CFTC to reinforce its fruitful collaboration with experimental groups and also with other theoretical centers in Portugal and elsewhere.

In summary, CFTC is a small R&D Unit of theoretical physics, yet an effective R&D Unit of national importance and good evidence of international visibility, performing high quality research in condensed matter, non-linear dynamics and particle physics.

Within the limited resources of this FCT Program, the Panel recommends the allocation of Programmatic Funding to contribute to hiring 1 PhD Researcher, and of 3 PhD student fellowships. The Unit has not specified any non-staff costs, but they discussed their need for a cluster upgrade. The awarded Programmatic Funding can be partially used for this purpose.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Centro de Investigação em Ciências Geo-Espaciais (CICGE)
Coordinator: Dalmiro Jorge Filipe Maia
Integrated PhD Researchers: 10

Overall Quality Grade: GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 3
(B) Merit of the team of Integrated Researchers: 3
(C) Appropriateness of objectives, strategy, plan of activities and organization: 3

Base Funding for (2020-2023): 124 K€
Recommended Programmatic Support
Programmatic Funding: 54 K€.

Justification, Comments and Recommendations
The CICGE is participating in two infrastructures: ENGAGE-SKA and C4G. The former supports the Portuguese participation in the Square Kilometre Array (SKA), the latter is the Portuguese counterpart of EPOS (European Plate Observing System), dedicated to space-based observations of Earth systems. Following the 2013 evaluation, FCT cut the funding to CICGE and recovery resources were made available only in 2017. As a consequence, the External Advisory Board was suspended and there is no report available. In the 2013-17 period the non-FCT funds added up to 27% of the planned total budget. The number of PhD students in 2017 was very low (2) but this was related to the funding cuts.

The main contributions in 2013-17 are: 1) Helping to build the ENGAGE-SKA infrastructure; 2) D. Maia becoming Co-I in the ASPIICS experiment on the ESA PROBA3 mission to measure solar parameters; 3) Being part of the SKA Telescope Manager Consortium; 4) Development and patenting of a fire monitoring and real-time detection system; 5) Production of a New Atlas of Amphibians and Reptiles in Europe. The main publications in 2013-17 are published in refereed journals apart from a conference proceeding. They are quite detailed studies ranging from instrumentation for a satellite, science with the Square Kilometre Array, to studies of biogeography of amphibians. Other relevant contributions include: 1) The development and patenting of a high resolution scanner for road digitalization and automatic identification animal casualties caused by vehicles (stand-alone low-cost system); 2) The participation in many other projects (Life LINES, FCT-Roadkill, FIRE-C-Bus, FFAS and LUNA); 3) The participation in the foundation of Portuguese Herpetological Association. The organisational structure of the Unit includes many different bodies and roles even if it comprises only of 20 integrated researchers and 2 PhD students.

Concerning the 2018-22 period, the Unit has different objectives related to the two research divisions:

1) Space Situational Awareness (SSA): The SSA objectives are: i) Promote Portuguese participation SKA (ENGAGE-SKA); ii) Deploy instrumentation; iii) Exploitation data from space missions (Proba3/ASPIICS).
2) Earth Observations (EO): The EO objectives are: i) Studies of the impact of human activity on ecosystems combining in-situ measurements with remote sensing observations; ii) Studies of hazard prevention and mitigation. There are also plans for national and international outreach (in Mozambique). The above plans and objectives seem vague. While the report has articulated some of the areas that this Unit will carry out, there is very little scientific motivation for this work.

The budget requested from FCT is to support activities that are not in the scope of the currently approved non-FCT projects. The overall budget request is very small (€78k, out of an overall budget of €1381k) with all programmatic funding to support the Portuguese participation in EPOS (by covering part of the membership fees) and the rest to cover travel, participation in committee meetings and science working groups, to support the external advisory group and for consumables and small equipment. There are no requests for new PhD researchers or PhD student fellowships.

The R&D Unit is quite diversified with four laboratories working in different areas, from radio-astronomy to biology. It is stated that the Unit is a 'loose federation' of these labs. It is unclear whether or not this type of organisation/resource-sharing represents the structure aimed by FCT for these Units.

From the report, the 2018-22 objectives do not seem to be greatly different from what was planned to be achieved in the previous years, but this could be justified by the funds-cut in the period 2015-16. The specific contributions to the SKA were not clearly articulated in the report, but these were clarified during the visit. The CICGE team are the main developers and 'scrum master' for the telescope manager, the software for the telescope operation, monitoring and control system of the SKA. The deployment of instrumentation for ground-based solar radio-astronomy (with a small 5m radio-telescope) and for observation of near-Earth objects (optical telescope) seems to be of secondary importance, with much lower potential impact. There was no information about the scientific goals of the solar radio spectrograph and what scientific questions it would attempt to answer.

Within the EO division, the studies of the 'impact of human activity in ecosystems' and 'hazard prevention and mitigation' seem to involve three labs: the Spatial Biology, the ISMAI and the National Risk Assessment laboratories. However it is unclear how these loosely connected labs are meant to interact with each other and work together. There is no clear planning associated to these studies.

Apart from the involvement with SKA, other researchers seem to have national relevance, rather than have a highly visible international profile and do not seem to be well integrated in international structures.

This unit is coordinating the Portuguese contribution to the Square Kilometre Array (SKA) through ENGAGE-SKA, which is the only Portuguese infrastructure dedicated to radio-astronomy. SKA represents the future of radio-astronomy and it also provides links with Portuguese industry (via the SKA Telescope Manager Consortium).

In a different area, it is remarkably important the participation of D. Maia as Co-I in PROBA3, which is an innovative ESA space mission consisting of two satellites flying in formation to form a 150 m long solar coronagraph to study the Sun faint corona.

The most significant development in the EO area seems to be a patented fire monitoring and real-time detection system, which has the potential to provide emergency services with information on fire propagation and early warning. This could have societal impact, especially for Portugal.

The release of the 'New Atlas of Amphibians and Reptiles in Europe' is cited 222 times in Google Scholar, implying the ongoing internationalisation of the CICGE biology lab. The team has also patented another system for the detection of animal casualties.

The budget request is extremely low – a tiny fraction of other FCT applications. The expected external non-FCT funds are 94% of the overall budget, which is unique across all the FCT R&D Units applications. The Unit seems to be self-sustaining and is asking for small support on items that cannot be funded elsewhere.

The Unit carries forward important studies on the impact of human activity in ecosystems. Many targets (within both SSA and EO) are aimed to strengthen Portugal development and in line with Portugal Espaço 2030 strategy. The Unit is involved in national and international outreach, the latter by promoting space science in Mozambique, a partner in SKA. In this country, by its own initiative, CICGE organises annual schools in Astronomy.

The loose federation of four labs could be considered a weak point, but the interaction between the groups was actually very strong and different examples were provided. In any case, the Unit seems to require a more structured management. The competitiveness of the ground-based solar radio-astronomy observations complements other observations rather than being unique. A new laboratory, the Agri-Lab, was established in 2018 with the goal to support innovative research for sustainable agricultural practices and to improve food security.

The CICGE participated in two proposals directly linked to its areas of interest: ENGAGE-SKA and C4G. Both were approved by the international evaluating teams, and ENGAGE-SKA is now CICGE major source of funding (€1M available for 2017-2020). The Portuguese Minister of Science Technology and Higher Education signed the SKA International Treaty in March 2019 and Portugal is now a founding member of the SKA project, in part due to CICGE contribution.

The FCT funding made available from 2017 to present, via the Strategic Plan (recovery), was of the order of €40k. These funds covered less than 6% of the overall budget of the Unit for this period (~€708k). The funds covered 30% of the mission expenses, 4.5% of the equipment and no human resources. Any Strategic Plan budget awarded for the period 2020-2022 will be used mostly to provide funds for travelling, since other sources of funding will be available to cover the needs for the remaining items. The projects providing the major contributions to funding, from January 2017 to present, are: LifeLines (€74.6k), ENGAGE-SKA (€396.1k), FFAS (€51.5k).

The funding situation at CICGE is stable and will potentially improve for the period 2020-2022. SKA offers a major opportunity and has already been used to build an engineering team that could lead to a sustainable funding model. The team remains small, yet the participation in national scientific infrastructures alleviates that particular issue since it provides a large team of collaborators and the sharing of resources. Given that the industry-related projects and the participation in the SKA consortia cover human resources costs, the human resources budget in ENGAGE-SKA can be used to hire researchers to strengthen the science teams.

In conclusion, CICGE is requesting a small budget to fund activities from 2020-2022 not covered by other funding bodies. The Unit requests funds to cover networking for SKA and ASPIICS meetings. We estimate that this funding should cover approximately 12 trips for 3 people, at €1.5k each trip = €54k.

The panel encourages the Unit to kick off collaborations with other national R&D Units working in the area of Astrophysics, and in particular with the Institute of Astrophysics and Space Sciences in Porto which is nearby. Co-supervising students can help in starting such collaborations.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Instituto de Astrofísica e Ciências do Espaço (IA)
Coordinator: José Manuel Lourenço Coutinho Afonso
Integrated PhD Researchers: 61

Overall Quality Grade: EXCELLENT
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 5
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 1056 K€
Recommended Programmatic Support
PhD Fellowships: 6
Programmatic Funding: 585 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The IA is the main astronomical institute of the country. It resulted from the merging of the astronomical Institutes of Lisbon and Porto. Its research personnel include 70 integrated researchers (1/3 is university staff and the rest on research contracts or fellowships) it is worth mentioning the high degree of internationalization, since 40% of them are not Portuguese. Its research focuses in modern topics of Astrophysics and Space Science. It participates in most major international efforts of ESA and ESO and acquires a team of experienced researchers working on instrumentation.

The IA is a model of an organization that is seeking to optimize its output and impact given its limited scale and resources. This is to be applauded. It has usefully done this by focusing on a small number (5) of key themes. This is an excellent strategy and one which has the potential to reap internationally significant rewards. It allows for the possibility to enter large collaborations by delivering a key capability where IA researchers have a large enough critical mass, and it shows to the external community an understanding by the institute of the need to properly resource collaborative participation, where it is important to maintain external credibility and deliver to, for example, international entities like ESO on time and to specification.

The Integrated Researchers are typically of high scientific quality, in specific areas the research is competitive at international level and can reach the level of major European institutes. IA members participate in many international scientific projects as members, co-PIs and even PIs (ESPRESSO, CHEOPS, HIRES@ELT, PLATO, MOONS@ELT, CoROT, Kepler, MOONS@VLT, MOSAIC@ELT, Euclid, eLISA). It is worth mentioning that the current Secretary of the IAU (the most important astronomical society) is member of IA.

The instrumentation part of IA activities (ISG) is equally strong and is involved in ground- and space-based projects of high profile related to most of the aforementioned international projects. Their recognition at international level played major role in getting a leading position in the preparation of the theoretical and technical part of the missions. The highlight of its activities is ESPRESSO, a high-resolution spectrograph for the VLT.

It is worth mentioning FADO, a publicly available, population spectral synthesis code to allow a better understanding of galaxy evolution since it is one more example demonstrating the internationally competitive research.

IA scientists obtained an ERC Starting Grant and several Marie Curie grants. They also received the Cosmology Buchalter Prize.

The activities of IA are organized in 5 “thematic lines” (TL), which are realized via 4 well planned major research groups (RG) in which synergism is achieved: RG1) is devoted to the study of the “Origin and evolution of Stars and Planets”,; RG2) to “Galaxies, Cosmology, and the Evolution of the Universe”; RG3) to “Instrumentation and Systems”; RG4) to Science Communication. They seem very well matched to the research infrastructure and resources available at IA.

The “exoplanet activities” of IA deserve the characterization of “excellent”, followed by the “galaxies” which can be characterized as “high-quality”, while all the rest should be characterized as “very-strong”, in partial agreement with the evaluation of the External Advisory Board.

The IA members are involved in the training of undergraduate students in Astronomy and Astrophysics and offer opportunities to them to be integrated from the very stage of their education in research projects. The IA fully managed a PhD network on space research through which 20 new PhD students were admitted in 2014-18. The average number of PhD students graduating every year during the last decade is 4-5 and about 9 MSc. It is noticeable that a significant part of them are non-Portuguese.

There is a large program of activities for the public outreach and cultural activities reaching on average 60,000 people/year. The Porto Planetarium is visited by 30,000 people/yr (70% schools). The IA outreach program brings Astronomy to 15 cities far from large urban centres, while the results of its research are advertised on media.

Overall, we are reasonably impressed by the merit of the team of integrated researchers as a whole. Many are involved in international projects, and it is obvious that they play important roles in these.

Evidence of scientific recognition, e.g. by being asked to edit or author reviews of modern topical areas in Physics/Astrophysics, was obvious, as was the excellence of the attention given to training the next generation of researchers and in explaining the merit of this work via the outreach program.

The publication rate of the IA researchers is quite good, even if not evenly distributed among them, and it is about 2.5 per year per scientist. Still the key scientists (nuclear CVs) have publication and citation numbers which meet high international standards. All publications are in high impact journals (ApJ, A&A, MNRAS, PRD) and it is worth pointing out the 6 Nature articles co-authored by IA members.

A strong asset of IA is the average age of its key researchers. Most of them will be active for the next two decades and this is an extra asset for the Institute and the Portuguese research in astronomy and astrophysics.

The IA in the previous FCT evaluation was ranked Excellent and it is considered the “most important research institution in the field in Portugal”, which is contributing to “one of the national research areas with the highest international impact”. The Panel believes that IA maintains this honorable title.

The planning of IA over the next 5 years is articulated clearly and cogently. The 4 Research Groups and the 5 Thematic Lines appear sensible and well matched to the research infrastructure and resources. Still it should be mentioned that all thematic lines are among the main priorities of top international institutes with significantly more human and funding resources. Thus, the research groups should invest their human and funding resources in those research projects in which they have and can maintain clear international leadership.

This thread is apparent, especially, in the instrumentation team which is extremely competent but at the same time suffers both from human and funding resources. Its involvement in free-flying satellites, high precision metrology, micro OEM systems and software pipelines are welcome. Still each one of these areas could require large resources, and so addressing how to invest in a subset of these is a critical question.

The Panel noted that the number of PhD students has increased from 19 in 2013 to 40 in 2017, in contrast to the national tendency; the number of young researchers with contracts descreased from 60 to 61. The proposal has a request for 24 PhD Fellowships and 8 new researchers. Within the limited resources of this FCT Program, the Panel recommends 6 PhD student Fellowships and 1 new PhD Researcher position be awarded. The Panel also recommends extra Programmatic Funding for non-staff costs, and that the Unit use it partially to cover the costs of external missions.

The allocation of the awarded PhD student fellowships should be as follows:
– Doctoral Degree in Astronomy or Physics Engineering (University of Porto): 3 PhD fellowships
– Doctoral Degree in Astronomy & Astrophysics or Physics Engineering (University of Lisbon): 3 PhD fellowships

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Instituto de Biofísica e Engenharia Biomédica (IBEB)
Coordinator: Pedro Miguel Dinis de Almeida
Integrated PhD Researchers: 15

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 218 K€
Recommended Programmatic Support
PhD Fellowships: 2
Programmatic Funding: 210 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The IBEB is a research institute in Biophysics and Biomedical engineering (the only Physics R&D Unit in the Lisbon area dedicated to this field) of the Faculty of Sciences of University of Lisbon. The IBEB is a relatively small R&D Unit; it has been hosting in the average 16 PhD level researchers and 13 PhD students. The FCT funding was about 0.5 MEUR for 2013-17. The IBEB transferred to the Physics Evaluation Panel (their initially requested Evaluation Panel was Biomedical Engineering and Bioengineering, but this possible Panel did not receive the established minimum number of 4 applications to function), at their request after being notified that its first choice Panel could not function.

Biophysics is one of the research fields, but actually IBEB is a cross disciplinary R&D Unit with its activities ranging from biophysics to ICT (signal analysis, big data, artificial intelligence), to biomedical engineering (imaging technologies, metrology) and to molecular medicine and clinical work. Therefore the figures of merit for the report period 2013-17 are rather different from Physics R&D Units, which has to be taken into account.

The mission of IBEB is to contribute to improved knowledge in Neuroscience and Oncology using physical, mathematical and engineering methods. The four main research areas are: (1) Medical imaging and diagnosis; (2) Brain connectivity and dynamics; (3) Cancer therapy and drug delivery; (4) Brain stimulation and neuro-rehabilitation. Research at IBEB includes collaboration of medical, academic and industrial institutions at national and international level. The IBEB is networked extensively trough the European Biomedical engineering and neuroscience community. The Unit application lists for 2013-17 two Horizon 2020 projects (STIPED and CAMELOT) and several ERC COST actions. In addition the report mentions several other international projects. The IBEB has been very successful in international fundraising.

As five main achievements in 2013-17 the Unit application mentions:
(1) MRI based Multi parameter differentiation of benign and malignant breast lesions;
(2) Progress in transcranical direct current stimulation (tDCS) in humans;
(3) Cancer treatment by laser activated functionalized nanoparticles has been shown to lead to reduced tumor volumes (by 80%) in mice models;
(4) Novel Co-60 based rotational therapy machines for radiosurgery and therapy leading to clinical benefits for lung and intra and extracranial tumors;
(5) A user friendly platform for the analysis of fMRI images developed at IBEB (in clinical trial) has been used to assist in preoperative mapping of tumors and epilepsy.

As the clinical partners, the report mentions Hospital da Cruz Vermelha and Centro Hospitalar Lisboa Norte, which are well known Portuguese hospitals.

The achievements have been published in international high-impact journals. The Unit application mentions an increase of the scientific impact in terms of publications from 10/yr before 2013 to 20/yr during 2013-17. There is however still place for improvement in the publication activity. It is important that staff members occupied with teaching and/or service duties can also find time for reporting their scientific work.

The IBEB is genuinely committed to Master and Graduate level teaching. Every year 40 new students are accepted in the Biomedical Engineering MSc program at FCUL, with most of them finishing their degree at IBEB. The IBEB is a key partner of the PhD Program of Biophysics and Biomedical engineering of the FCUL. Moreover, the IBEB has acted as a co-organizer in a yearly Biomedical Engineering workshop addressed to undergraduate and graduate students (with more than 150 participants/yr) and contributed to European networking of young researchers trough COST actions. The teaching effort will be continued for the application period of 2018-22. The teaching is also seen as a way to screen and recruit the smartest students to continue their studies in the IBEB PhD program. The IBEB has produced 12 PhD theses since 2013.

The Unit application devotes ample space to describing the societal impact and outreach of its activities. The IBEB organized the international PSMR2017 conference, which had more than 200 participants. The IBEB researchers have also been participating in the Science Committee meetings of the Portuguese National Parliament. The report lists 14 national and US patents and several spin-off enterprises from IBEB activities. The number of industrial contracts is impressive. The networking with enterprises will be enhanced in the application period by setting up an industrial/innovation committee to bring together researchers, managers and investors. An important part of this network are also the hospitals to which IBEB already has developed a trust-based relationship.

The development plan for 2018-22 is ambitious and realistically based on existing merits, resources and strengths of the Unit. The research mission is in development, consolidation and clinical implementation of solutions related to neurodegenerative diseases and cancer. The focus is in brain and breast. One of the highlights of the plan for 2018-22 is the development of a prototype for microwave imaging of the axillary lymph nodes with application to breast cancer diagnostic. This is, in international comparison, a highly ambitious research, engineering and clinical challenge. The development of new modalities for biomedical imaging fits well in the research profile of IBEB.

In sum, in the present evaluation of R&D Units by the Physics Evaluation Panel, IBEB is a special case. Its research mission is to start from cross disciplinary science and to develop over it systemic solutions for health technologies and clinical care in areas that are major health problems throughout Europe and worldwide. The R&D is carried out as a joint venture of physicists, engineers, biochemists and clinical experts. Thus, during the process there is a continued feedback from clinicians to guide the R&D. The pioneering approach of the IBEB has common points (although in a small scale) to the Stanford Biodesign program that binds medical, bioengineering and ICT research, and related education together with hospitals and startups and venture capital. The IBEB can be seen as a seed to similar growth in Portugal. A particular development point is to keep high priority also in the science impact. The cross disciplinary approach gives excellent possibility to this, as the IBEB staff has already demonstrated its capacity with publications in high impact international journals. The high science impact will also follow in the course of time, as the solutions for healthcare are adopted in clinical use. Therefore, the effort to increase publishing in high impact journals should not be a substitute for IBEB unique systemic research.

The IBEB budget plan for 2018-22 focuses in increasing the number of PhD students and of PhD Researchers, which is well motivated in the Unit application. It is important for FCT to understand that there is a real need for increasing PhD education in the research area of IBEB, which is directly linked to one of the most intensive growth areas of the global economy. During the site visit, the Panel was impressed by the enthusiastm and ambitious atmosphere of the average young staff. The IBEB has well-working premises and its research infrastructure is relevant for carrying out the planed research. The development plan is realistic and ambitious, and it is focused in the human resources. The Panel recommends that the requested 2 PhD student fellowships and 1 PhD Researcher contract be awarded to IBEB. The IBEB can presumably find funding from other sources for the modest instrumental costs. The goal of funding should be a steady modest growth during 2018-22, while keeping the present concise research field and the further strengthening of the IBEB unique cross-disciplinary research network, including startups, enterprises, hospitals and the medical school.

The Panel noted the researcher associated with the startup company NeuroPsyAl whose activity should be strongly supported.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Instituto de Física de Materiais Avançados, Nanotecnologia e Fotónica - Universidade do Porto (IFIMUP)
Coordinator: João Pedro Esteves de Araújo
Integrated PhD Researchers: 26

Overall Quality Grade: EXCELLENT
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 5
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 437 K€
Recommended Programmatic Support
PhD Fellowships: 5
Programmatic Funding: 435 K€, including for 1 (Junior) New PhD Researcher Contract.

Justification, Comments and Recommendations
The IFIMUP mission is to do fundamental studies in the physics of materials and to develop innovative experimental tools in selected areas that have the potential for technological applications. Based on the decade-long expertise of the leading scientists of the Institute, the topics are carefully chosen and were adapted over the years such that the topics are scientificantly challenging and, likewise, promise to be used, or are already used, outside research.

The scientific work in the reporting period is on a high level, in several cases also internationally. Examples include the ultrafast-laser work, both scientifically with the fs-control of currents in ferromagnets and technologically with: the creation of the Sphere Photonics startup; the highly cited template-assisted nanofabrication effort; and the recent more applied work in energy harvesting.

The level of international collaboration is high, substantially fostered by the unique experimental skills available within the Unit.

The key researchers are aware that patents can be a valuable asset in applied physics work, and hence they actively go for them and secure the valuable ideas (9 patents in the reporting period). The invention of the d-scan method and the corresponding creation and characterization of ultrashort laser pulses gives the Unit and the associated startup a competitive advantage also when compared with leading laser companies in selected applications.

The Unit has a good output of scientific articles (320 in the past period), given the small number of Integrated Researchers (17-25), it is aware that outreach is important to reach young talents at high schools (“Summer Physics School”), and it delivers services to several companies (mainly paid material characterization work).

The small team of Integrated Researchers is a dynamic group developing innovative ideas and novel approaches to material science, exploiting their strengths in this area. The key researchers are relatively young (all in their forties), but nevertheless respected figures in their respective areas of expertise, as shown by their publication lists, their external collaborations and joint projects (MIT, São Paulo, etc.), invitations to conferences and international Panels. Evidence was provided by the PhD students and young researchers that the Integrated Researchers create a vibrant atmosphere in the Unit in which collaboration between the groups flourishes and in which the professors care for the career of their group members. Group members have or had international responsibilities, e.g. in the European Physical Society or in EU or ERC Evaluation Panels. They received several prizes and awards, in particular for work related to the foundation of start-ups (ultrafast laser developments, Sphere Photonics, advanced materials for energy, iNanoEnergy), but also members at the start of their career were recognized, e.g. a PhD student who received the E-MRS award for work in energy-relevant materials. The number of completed PhD theses in the reporting period is 35, surpassing the number of Integrated Researchers by far (17-25 during the reporting period).

The plan to go forward is very well thought, thorough and describes the direction and methodology of the research. It evolves from the present, successful lines of research and presents experimental and technological challenges for which the team seems to be in a good position to succeed. A gradual transition away from “classical” materials is taking place, putting more emphasis on collective phenomena. In a strict sense, this cannot always be considered as “quantum” materials, which was chosen as the name of one of the thematic vectors, but this is a minor detail. In the “Advanced Energy Materials” vector, the Unit will try to exploit energy harvesting for very low energy sensing devices in Internet-of-Things applications, as being tested with companies presently. This might become an area with relevant societal impact. It is not obvious how much fundamental physics can be discovered in such projects, but the educational value for students who need to find jobs in industry later on is possibly high. In the “ultrafast laser” vector, the Unit puts its main emphasis on biomedicine, moving away from the successful magnetic investigation that was done in the past. The Panel had the reservation that medical expertise is needed for the foreseen projects. The University officials reported at the site visit that a new hire with expertise in this area is under way at Professor level, and that this person might likely join IFIMUP (although this is not guaranteed).

The Unit foresees to keep the light management structure they presently have, with short decision paths, to keep the Unit agile.

The Unit secured a large investment recently to broaden its technology and instrument base, by creating a new cleanroom in a public-private partnership (Porto University and INESC-Tec) and NECL. It is important to keep funding on a high-enough level to run the equipment (l-He, etc.). The Panel considers this to be more important than to hire an Auxiliary Researcher for becoming more successful in the attraction of external projects (EU, ERC).

The Unit plans to intensify its computational materials effort, by hiring an experienced Auxiliary Researcher to lead this effort. This will certainly be a strong asset. However, it will be hard to find a person with experience in all three directions.

In the application the Unit requests 24 PhD student Fellowships and support for 7 new PhD Researcher contracts. Given the limitations of this FCT Program, the Panel recommends 5 PhD student Fellowships and support for 1 new Researcher position be awarded. The Panel also recommends extra Programmatic Funding for operating expenses for the newly established NECL.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Instituto de Plasmas e Fusão Nuclear (IPFN)
Coordinator: Bruno Miguel Soares Gonçalves
Integrated PhD Researchers: 93

Overall Quality Grade: EXCELLENT
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 5
(B) Merit of the team of Integrated Researchers: 5
(C) Appropriateness of objectives, strategy, plan of activities and organization: 5

Base Funding for (2020-2023): 1674 K€
Recommended Programmatic Support
PhD Fellowships: 9
Programmatic Funding: 742 K€, including for 2 (Junior) New PhD Researchers Contracts.

Justification, Comments and Recommendations
The Institute for Plasmas and Nuclear Fusion (IPFN) is the leading national Centre for plasma and fusion research in Portugal. This relatively large size multidisciplinary centre addresses a broad portfolio of research activities in plasma science, including striving to harness clean fusion energy and electrically plasma-produced chemical fuels, pushing the fundamental frontiers of laser-drive quantum electro-dynamics and supporting future planetary missions, manufacturing of two-dimensional nanostructures and developing medical X-ray imaging. Stemming from societal and economic needs there are many opportunities for scientific and engineering growth in plasmas, of which IPFN is embracing. Ultra-short ultra-intense lasers are pushing the frontier of matter-radiation interaction, announcing a revolution in fundamental and structural biology with unprecedented resolution. The emerging international ITER programme promises new opportunities in tokamak science and technologies. Industrial applications of plasma technologies are continuously growing providing significant opportunities across many research areas; for example leveraging on a patent, IPFN are developing scale-up high-quality graphene production.

There is clear evidence of internationally leading activities in all research groups and themes across IPFN in the fields of magnetic confinement fusion, laser produced plasmas and low temperature plasmas. They actively participate in all related European activities and facilities, including JET, ITER, HIPER, ELI, ESA and FET. The IPFN provides a unique environment for world-class plasma research, and has excelled in growing to a critical mass of international competitiveness with many areas of world-leading expertise and recognition. There is also evidence of synergising competencies across IPFN, which will further boost international visibility and facilitate growth. A particularly noteworthy demonstration of synergies within the Unit are the activities between the VOXEL Laboratory and the Laboratory for Intense Lasers (L2I). They have high impact highly cited publications in this research area, e.g. in Nature Communications (2014), G. Lambert et al. this area offers particular promise for the Portuguese community going forward. As a whole, the Unit should consider taking more advantage of their critical mass and should seek to better exploit synergies between other research areas within the Unit.

The very strong involvement in European activities provides high visibility through established networks and involvement in various high profile publications. The Institute is very successful in attracting external funding, partially through leveraged Eurofusion funding, but also through multi-million Euro grants and contracts, including very high profile ERC grants in laser plasmas, the establishment of a local European Space Agency (ESA) facility for atmospheric reentry investigations (ESTHER), ITER contracts, H2020 Future Emerging Technology funding for medical imaging (VOXEL), and plasma synthesis of graphene (PEGASUS).

The publications produced by the unit are in highly cited journals, such as PRL, Nature Communications, Nature Physics and other internationally leading specialised journals such as Nuclear Fusion, Plasma Sources Science and Technology, and Plasma Physics and Controlled Fusion. The Unit is involved in international conferences organization, including for example the main European plasma physics conference (EPS) in 2015 and 2017. The Unit increasingly collaborates with industry and knowledge transfer programs (e.g. graphene patent and industrial contracts) and it is the leading training site for researchers in plasmas.

The Unit is involved in outreach activities: website, newsletters, articles, press releases, appearances in radio/TV, public exhibitions, seminars, and summer activities for high-school students and organisation of visits to IPFN labs. Particularly impressive are the use of virtual reality for data visualisation with both scientific and outreach endeavors, and also the clever targeting of secondary school teachers with their outreach activities as a way to effectively and sustainably reach younger generations.

The IPFN has successfully implemented the APPLAuSE PhD programme, featuring an innovative doctoral training programme at international level with over 25 students seconded to partner research institutions abroad, in the past 4 years. Alumni of this programme have developed successful careers in academy and industry.

During the 2013-17 period, non-FCT funds were a particularly large percentage of the total budget, approximately 60%, which is an excellent achievement. They have continuously secured funding from diverse sources, for example in the last 5 years: International R&D projects (about 4 M€/year total funding), a prestigious ERC Consolidated Grant of 2M€ for the project "InPairs", and several national projects.

The IPFN has a clear long term vision leveraging on its already world-leading expertise and competencies to tackle the important challenges highlighted above. This will see them continue to produce meaningful academic and societal impact and associated outputs. The team is well poised to take advantage of future opportunities both within IST and at international level. Internally, members of the IPFN preside over and sit on the IST Scientific Council, have positions within the IST Senate and the School Assembly, and are members of the Coordination Committee of the CTN. Numerous IPFN researchers are on various international advisory boards and councils. Hosting of several large research infra-structures (L2I, ISTTOK, ESTHER) along with smaller technological plasma experiments will enable further future collaborative opportunities and integration in the international and regional community.

The IPFN has recognised the challenge of attracting and retaining top researchers given the current national funding uncertainty. A significant future priority is reducing temporary contracts and they have made excellent commendable progress in tackling this by opening additional faculty and research positions co-funded by IPFN. These positions will be opened as international calls subjected only to scientific and technical excellence criteria.

The Unit has grown both in terms of the number of researchers and the PhD students, as well as in the number of national and international research funds that it managed to secure. The application of Programmatic funding should prioritize the stable increase in scientific employment, and their doctoral training programme.

The Panel recommends the Unit should prioritise the funding under the ‘Plasma Technologies and Intense Lasers’ theme and in addition carefully consider that any funds used in relation to contractual projects e.g. EUROfusion, closely aligns with the IPNF own research strategy.

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Coordinator: Mário João Martins Pimenta
Integrated PhD Researchers: 85

Overall Quality Grade: EXCELLENT
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 5
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 5

Base Funding for (2020-2023): 1547 K€
Recommended Programmatic Support
PhD Fellowships: 8
Programmatic Funding: 722 K€, including for 2 (Junior) New PhD Researchers Contracts.

Justification, Comments and Recommendations
The LIP is the leading Particle Physics R&D Unit in Portugal and contributes to many world-leading experiments at CERN and elsewhere. It consists of 85 Integrated Researchers with a PhD and 76 researchers without a PhD, of which 33 are students studying for their PhD (numbers from 2017, when the Unit application was written). The LIP has built important detector components for major experiments and has led important particle and nuclear physics analyses. The highlights of the group are their important contributions to both the ATLAS and CMS experiments at the Large Hadron Collider (LHC) at CERN, the ultra-high-energy cosmic ray experiment AUGER, dark matter searches at LUX and preparations for LZ, and neutrino physics, particularly in SNO and SNO+. Furthermore, their detector development team not only supplies instrumentation for leading particle physics experiments, but it also has significant impact in other areas of crucial importance to society, such as medical and health science applications.

These are some detailed highlights:

1) Building components of the Tile Calorimeter (TileCal) at ATLAS and its upgrade resulted in an ATLAS outstanding achievement award due to the quality and significance of the work for the collaboration. The Higgs analyses are the main areas of strength, including contributing to the discovery of Higgs decays to two vector bosons (H->WW) and the coupling to third generation quarks (Higgs decays to two beauty quarks H->bb, and associated Higgs production with a top-antitop pair ttH). They collaborate with theorists from CFTC on the ttH discovery channel.
2) The CMS group, while small in size, is really outstanding and world-class. A member of LIP was deputy spokesperson of the CMS collaboration at the time of the Higgs discovery, and has supplied physics working group co-conveners of the CMS Higgs Physics analysis, the Top Quark Physics analysis and the CMS B and Quarkonium Physics group. This is a remarkable achievement for such a small group, to be leading three of the most important physics analysis groups. Highlights include the flagship discovery channel of the Higgs decaying to two photons, which dominates the Higgs mass measurement, top decays to dileptons and the first observation of the Bs->mumu decay, which places severe constraints on Supersymmetry. Forward physics with CTTPS is another area of strength. They also work on the MIP timing detector for the upgrade, to reduce pileup in the High Luminosity LHC, and the CTPPS forward detector.
3) The phenomenology group is also of a very good quality, with top physics and heavy ions the areas of strength. There is collaboration with the experimental groups to define new variables in top-quark physics and development of new state-of-the-art Monte Carlo generators. The existence of a phenomenology group in a laboratory predominantly dedicated to experimental particle physics and instrumentation is very positive and should be encouraged.
4) The Partons and QCD (PQCD) group is small in size and is focussed on the COMPASS experiment at CERN, where they contributed to the monitoring and control system. The main physics highlights include measurements of polarisation in Drell-Yan processes and a future programme of deep-inelastic scattering at COMPASS.
5) The Low Energy Interactions (LEHRI) group is also small and focussed on work at GSI and FAIR in Germany. They have contributed to the construction of major pieces of hardware, such as the Restive Plate Chamber (RPC) wall for HADES and the CALIFA calorimeter for R3B. Dilepton production from Au+Au collisions in HADES is the physics highlight.

6) The cosmic ray group works on extremely high energy cosmic rays at the largest air-shower array in the world (AUGER) in Argentina and the AMS experiment at the international space station. For AUGER the group is supplying RPC modules to enhance the detection of muons in air showers and has confirmed a long-standing problem of a muon deficit in ultra-high-energy showers. For AMS, the group supplied the Ring Imaging Cherenkov (RICH) detector for particle identification and studies solar modulations of cosmic rays.
7) The neutrino physics group is involved in the Sudbury Neutrino Observatory (SNO, SNO+), in NEXT and DUNE. The group has an important responsibility for the calibration insertion system for SNO+, whose aim is to measure neutrino-less double beta decay in a high-mass tellurium sample. The NEXT experiment is also a double-beta decay experiment at the Canfranc laboratory, but using high-pressure gaseous xenon Time Projection Chamber (TPC) in the Spanish Pyrenees. The two experiments are complementary, since one is a high-mass experiment and the other is a high-precision experiment. These are both very important for the future of the field to determine whether neutrinos are their own antiparticle (Majorana particles) or not. The effort of LIP in the long-baseline neutrino experiment DUNE in the USA is still under negotiation, but it involves calibration systems and the protoDUNE prototype at CERN.
8) Dark matter is another of the area of strength with participation in ZEPLIN, LUX, LZ and future dark matter searches using liquid xenon with international collaboration. They have had leading roles (data analysis coordinator and reconstruction coordinator) for the LUX experiment that has set world-leading limits on Weakly Interacting Massive Particle (WIMP) dark matter candidates. The group also provides the manager of the LZ control system, which will be the foremost dark matter experiment, currently under construction.
9) The detector development group has world-leading expertise in resistive plate chambers, with exceptional timing and position resolution, and noble gas Time Projection Chamber technology (both liquid and gaseous xenon).
10) The health and biomedical applications group is an excellent example of impact of particle physics research and detector development in healthcare and imaging. There are clear synergies with the detector development group (many members are common to both) developing positron emission tomography, Ortho-CT, radiation therapy and dosimetry using particle physics detector techniques, that improve the performance of these important medical diagnostic and therapeutic instruments.
11) The applications for space exploration group uses particle physics detectors for radiation dosimetry in space, also in close synergy with the detector development group. Again this shows how particle physics detectors can be used in other areas of science.
12) The Computing group has been extremely successful at coordinating Grid and Cloud computing and High-Performance Computing in Portugal. They participate in international and EU-funded grid computing infrastructures, such as EGI (European Grid Initiative) and WLCG (World LHC Grid Computing), which supports the particle physics programme, but also has many applications outside of particle physics, with a large fraction of CPU time of these major national facilities devoted to other areas of science.

The plans of LIP for the future are all excellent, with an overall coordinating role of all particle physics in Portugal. This is essential to be able to have critical mass and to increase the visibility of Portuguese particle physics in large international collaborations. Applications of particle physics to society, such as medical, imaging, dosimetry and other areas of science, such as space, are also very strong, and LIP should be commended for this strategy. The LIP participates in 5 EU-funded ITN and COST actions, showing the internationalisation and networking of the group. The outreach and public understanding of science engagement programme by LIP is also excellent, increasing the visibility of particle physics in society. They organize an international Portuguese-speaking Teachers Education Programme, in collaboration with CERN, in which school teachers from many Portuguese speaking countries visit CERN and receive education and training on particle physics. Furthermore, LIP has strong collaboration with industry to enhance the technological capabilities of Portuguese industry and to encourage Portuguese industry to bid for CERN contracts. In summary, LIP is truly a Center of Excellence and should continue to lead particle physics research and innovation in Portugal.

The application LIP submitted requests 44 PhD student Fellowships and 18 new PhD Researchers contracts (10 would be physics-oriented and 8 would be instrumentation scientists). Despite the evidence of excellence shown by LIP, within the limited resources of this FCT Program, the Panel recommends the allocation of support for 2 new PhD Researchers contracts and 8 new PhD student fellowships.

The priority order of allocation of these resources is:
1) CMS group: one PhD researcher and one PhD student.
2) Phenomenology group: one PhD researcher and one PhD student, to work closely with the experimental groups.
3) ATLAS group: one PhD student;
4) Dark matter group: one PhD student, to exploit data from LUX and/or LZ and contribute to the LZ control system;
5) Neutrino group: one PhD student to work on SNO+;
6) Cosmic ray group: one PhD student to work on AUGER;

7) PQCD and LEHRI groups: one PhD student;
8) Detector development, health sciences and space sciences: 1 PhD student to work synergistically between the groups.

The awarded Programmatic Funding should also be used for some non-staff costs. The Panel recommends that these be partially applied for external missions (100k€) and to cover the cost of upgrading or purchasing equipment. The priority order of the equipment should be:
1) Detectors laboratory and clean room facility at LIP-Coimbra (200k€);
2) Electronics and scintillator laboratories in LIP-Lisboa (152k€).

Evaluation Panel: EXACT SCIENCES - Physics

R&D Unit: Laboratório de Instrumentação, Engenharia Biomédica e Física da Radiação (LIBPhys)
Coordinator: Joaquim Marques Ferreira dos Santos
Integrated PhD Researchers: 46

Overall Quality Grade: VERY GOOD
Evaluation Criteria Ratings
(A) Quality, merit, relevance and internationalization of the R&D activities of the Integrated Researchers in the R&D Unit Application: 4
(B) Merit of the team of Integrated Researchers: 4
(C) Appropriateness of objectives, strategy, plan of activities and organization: 4

Base Funding for (2020-2023): 645 K€
Recommended Programmatic Support
PhD Fellowships: 4
Programmatic Funding: 233 K€.

Justification, Comments and Recommendations
The Laboratory for Instrumentation, Biomedical Engineering and Radiation Physics (LIBPhys) is a medium size R&D Unit with a high national profile. The Unit, established in 2013 across the University of Lisbon, University Nova Lisbon and University of Coimbra, combines synergistic activities across multiple institutions. It was recognised that the Unit is very well integrated with a collaborative environment across the multiple sites.

The global strategy of the Unit is implemented along four thematic lines:
1) Fundamental parameters and metrology;
2) Cryogenics, electronics and radiation detection instrumentation;
3) Analytical techniques development and application;
4) Biomedical engineering.

The multidisciplinary activities are topical and address contemporary problems with significant promise for both industry application of societal and economic benefit along with academic impact. The team has expertise in atomic, molecular, and nuclear physics, electronic and industrial automation, instrumentation and signal processing with applications to analytical methods, radiation detection and biomedical engineering, offering an extensive spectrum of research activities.

There is already some evidence of international involvement, e.g. through its roles in NEXT and EXSA, including strong international collaborations with Germany, France, Switzerland and Japan. There is a strong emphasis on applied multi-disciplinary work, including collaborations with industries and local hospitals. This is really positive and provides the promise of good societal benefit.

The scientific output of the Unit is overall healthy (~660 papers and 46 PhD theses for over 55 PhD level researchers (28.6 FTE)), including a few in high impact journals and provisional patents. Citations for many individual publications remain low for the moment, which raises the question if this limits international visibility and impact of LIBPhys activities. There are significant knowledge and technology transfer activities involving not just the scientific community and industry, but also society through the development of specific equipment, techniques and methods. There are collaborations with private and public bodies (hospitals and clinics) and also activities involving museums and national archives having found applications in cultural heritage in collaboration with museums. In addition, there are a few scientific interactions within the R&D Unit itself.

During the past year the number of researchers has increased with the addition of four permanent positions plus at least one other imminent permanent position. This was very positively received and should boost the Unit and its outputs in the coming years. There are already indications of this positive impact on, for example, the increase in FCT project funding during 2018. The addition of a Professor position with a medical background is also welcomed and should help support the inter-disciplinary nature of the Unit.

It has been recognized by the Unit that non-FCT funding still remains low; this is surprising given the number of knowledge transfer activities the Unit is engaged with. Interactions with industry are very strong and the Unit also has a few spin-off companies, but the amount of funding coming as a direct contribution from industry is relatively low. It is recommended that the Unit considers if they are undercharging in their industrial contracts, with charging only 25% on company projects. The Unit is developing strategies to generally increase additional funding routes, including close networking with EU partners, and working with a dedicated office to help facilitate funding opportunities.

LIBPhys members have international presence on many international conference committees and have also been involved in journal editing. They should continue to enhance their international profile through these and other routes.

Diversity is relatively strong given the subject area, both at the more junior level at ~36% and similarly represented at more senior level on the executive committee. The Unit recognises the need to continue to enhance this and other diversity aspects across the Unit. The Panel welcomed the fact that there are a relatively high number of international joint PhDs particularly with European counterparts enhancing diversity and providing opportunities for their early career researchers. In addition, local training for example including the offer of relevant entrepreneurial skills courses and workshops is very good. The strong support provided to early career researchers in developing their independence was very evident and positively recognised by the Panel. In particular, we note the collaborative atmosphere and direct exchange of knowledge between PhD students and junior researchers, even between those based at different universities. The PhD programs also offer courses on soft skills, which are highly appreciated by the students.

What was less evident is the bigger picture vision of the Unit and, particularly, the uniqueness that the Unit has to offer. It is recommended the Unit considers how to improve its branding in this respect, so that it can position itself more competitively internationally.

The outreach activities of the Unit seem to be minimal, which is surprising given the diverse fields of research. The Panel recommends strengthening these activities among school children and the general public to enhance the national visibility of the Unit. The Panel also recommends intensifying efforts in enhancing the exposure of their unique technical developments and research in international conferences or even actively offering scientific seminars at national and international universities and institutions.

The application the Unit submitted requests 72 PhD student Fellowships and 40 new PhD Researchers. Within the limits of this FCT Program, the Panel recommends 4 PhD student Fellowships and no new Researcher position to be awarded. The Panel also recommends that Programmatic Funding be used to cover non-staff costs.