STRATEGIC PLAN 2021-2024

Institut de Física d'Altes Energies (IFAE)

Submited to IFAE's Governing Board, July 2021

Edifici C, Universitat Autònoma de Barcelona (UAB). 08193 Bellaterra (Barcelona)

OUTLINE

1. INTRODUCTION

IFAE's Strategic Plan 2021-2024 is based upon the Strategic Plan submitted to the 2020 call of the Severo Ochoa Excellence Program (SO2020) in February 2021.

IFAE's research program for 2021-2024 builds on the coherence and strengths of the existing research lines, on strategic investments in infrastructure, and on a clear scientific vision in deciding new research lines. In 2017, IFAE initiated a thorough exploration of new technological and scientific research lines. As a result of a process that stretched over a year, the institute decided to open two new research lines in the fields of Gravitational Waves (GW) and Quantum Computing Technologies (QCT). The line on GW astronomy will bring us to the new frontier in Fundamental Physics, while the line on QCT will expand our Applied Physics portfolio towards quantum technologies.

That important exercise included the consideration of the strengths of IFAE and the opportunities we want to seize to improve them, while trying to correct some of our weaknesses and fight against possible threats.

1.1 SWOT analysis

IFAE's main STRENGTHS are summarized as follows:

- The very high quality of the scientific and technical personnel, due to the high-standard selection protocols and the center's scientific program attractiveness. IFAE has managed to attract many world-class scientists through the ICREA program, including the current director and the PI of this proposal. IFAE is an attractive institute for foreign talent, which improves the quality of research at IFAE. The quality of its personnel allowed IFAE to position itself as a key contributor in some of the strongest scientific collaborations worldwide. IFAE's senior researchers hold highly visible posts in leading international collaborations, and are also members of very relevant international committees.

- IFAE has a strong technical-services group that includes a core group of highly capable, motivated engineers and technicians under permanent contracts. In addition, IFAE has a set of infrastructures that constitute a landmark in our country, particularly the instrumentation related to microelectronic device assembly in our clean rooms, which together with our three ASIC-design engineers provide a unique opportunity for high competitiveness. This has been further strengthened by the recent addition of the novel QCT infrastructure, unique in Spain.

- IFAE has a crucial presence in PIC, the most important scientific data center for high-throughput computing in Spain, and one of only seven LHC Tier-1 centers in Europe, and which is now an integral part of a Spanish distributed ICTS (singular scientifical-technical infrastructure) devoted to data science.

The current WEAKNESSES are:

- For a long time now, IFAE has been suffering from a poor space allocation. Currently, IFAE personnel are scattered around three buildings, none is which owned by IFAE. One of them is a poor-quality prefab building.

- For a long time, IFAE has also suffered from lack of sufficient administrative support, particularly at the scientific level. Every year the administrative burden increases, due to new cumbersome regulations from most funding agencies.

- IFAE is still afflicted by the lack of young staff. The situation has been partially alleviated with the recent incorporation of two Ramón y Cajal researchers in the Cosmology and QCT areas, and a senior Beatriz Galindo researcher who will join UAB and IFAE's Theory Division in summer 2021. More actions are needed to rejuvenate an ageing scientific staff.

Current OPPORTUNITIES include:

- Excellence programs (SO, COFUND, ERC, ICREA) provide the opportunity to attract young talent at all levels (tenure-tracks, postdocs and PhD students).

- The investment on the Technical Division during the last decade gives IFAE the opportunity to increase its portfolio of applicable research, and increase the chances to draw on Horizon Europe funds and also maximize industrial returns.

- BIST provides IFAE with an exceptional opportunity to establish multidisciplinary collaborations.

- PIC provides a distinctive opportunity for IFAE to jump into the blooming world of big data, particularly in astronomy, but also in biosciences, where we can leverage our collaboration with BIST leading institutes in that field.

- The presence of groups at IFAE involved in gravitational waves, gamma rays and observational cosmology experiments place IFAE in a privileged position to fully exploit the nascent field of multi-messenger astronomy.

- The presence at IFAE of a unique QCT infrastructure in Spain provides the opportunity to have a significant impact in the forthcoming quantum revolution.

Finally, the currcurrent THREATS are listed:

- Since 2010, IFAE has suffered from only marginal increases in its base funding and the decrease in the budget of Spanish competitive calls. The 2018 evaluation from CERCA, after giving to IFAE the highest qualification, pointed to a certain underlying fragility in IFAE's financials, since 75% of its budget depends on competitive funds, and recommended to further diversify its funding sources. Despite some progress in that direction, most funding alternatives prioritize a more applied research profile.

- Most of our research lines do not match very well with the most important EU funding programs. Not only Horizon Europe is mostly focused on applied research, but also the personal grant schemes like ERC hardly fit with our work in large experimental collaborations.

- In spite of the boost in our administrative structure, the ever-increasing bureaucratic pressure on project management and justification hampers and unduly slows down the efficiency in the operation of our center.

IFAE's enormous potential to keep doing leading research at the frontier of fundamental physics and technology is clear from its strengths and opportunities. The risks we need to mitigate are related to funding, including the difficulty to tap into European funding programs.

1.2 Key issues

Following the previous analysis, a scientific strategic vision emerged, designed to mitigate some of the weaknesses mentioned above while taking advantage of our strengths and some of the opportunities. A detailed discussion is presented in Section 2. The more salient points are listed next:

- IFAE shall reinforce its current research lines, which will continue to be extremely relevant in the next 5-10 years. In these lines, IFAE participates in top experiments delivering key scientific results, and we will strive to enhance our leadership position in their scientific exploitation.

- The ATLAS experiment enters a crucial phase in the construction of the upgraded detector in preparation for the High Luminosity LHC period. It is in IFAE's core mission to guarantee, with strategic actions and the necessary technical support and infrastructure, a successful and timely completion of the upgrade project.

- Special actions are targeted to reinforce the newly opened research line on Gravitational Waves (GW), consolidating IFAE's hardware upgrade program for Virgo, and fostering a multimessenger culture at IFAE.

- Special actions are foreseen to strengthen the Theory Division, with the aim to preserve its excellence in the long term and to increase its competitiveness in the general field of Astroparticle Physics, including Cosmology and GW.

- Special actions are proposed to consolidate the new QCT research line in IFAE, bringing it to the forefront of the European efforts in the field, and facilitating synergies with other top-level research centers in Spain.

- Special actions are proposed to increase the capabilities of our very productive Medical Physics research line, preserving its excellence in the long run, and facilitating the exploration of new ideas, nowadays limited by lack of time and sufficient personnel.

In the next Section, this scientific vision will be cast in a list of specific goals and actions.

2. SCIENTIFIC AND STRATEGIC GOALS LINKED TO THE SCIENTIFIC ACTIVITIES OF THE CENTRE, FEASIBILITY AND MONITORING PLAN

IFAE's structure, with its administrative flexibility and strong role of the director, encourages robust and coherent strategic planning of scientific and technological activities. This structure and our commitment to excellence have allowed us to make bold choices in our research lines to enhance IFAE leadership in the international scene. IFAE's internal management structure served it well during the last years: no change is deemed necessary at this time.

2.1 Global strategy

In order to properly assess the impact and consequences of the proposed strategic plan 2021-2024, it is worth stating the overall strategic goals of the Severo Ochoa (SO) 2020 research program presented here:

1. The main strategic goal is to continue enhancing the research capabilities of IFAE and the international competitiveness and leadership of its different research lines. This applies to the three main facets of IFAE's research: theory, analysis of experimental data, and instrumentation design and construction. This goal determines most of the personnel and infrastructure actions described elsewhere. In particular, IFAE opened in 2019 two new research lines on Gravitational Wave astronomy and Quantum Computing Technology, keeping the institute at the forefront of the research on fundamental physics and enlarging its applied physics portfolio towards quantum technologies. Both new research lines were wholeheartedly endorsed by IFAE's External Scientific Board in its last meeting in late 2019. The consolidation and further enhancement of these two lines motivate several of the SO2020 actions.

2. The second strategic goal is to further leverage our large expertise in cutting-edge instrumentation for state-of-the-art experiments in particle physics and astronomy to generate knowledge and technology useful to other research areas closer to more immediate societal challenges, taking particular advantage of our relationship with other BIST centers that work in areas such as photonics, nanotechnology or biosciences.

Some of the main tools to achieve the goals are described in the training and recruiting plan (Section 3). Attracting leading researchers to IFAE, at all stages of development, is a crucial ingredient of our plan. The SO2020 is instrumental in this regard. Thanks to our own post-doctoral programs financed or co-financed with IFAE's SO2012 and SO2016 funds and to the talented PhD and Junior Leader programs put together by La Caixa Foundation in conjunction with the SO program, we have been able to bring to IFAE excellent young scientists that have had a very high impact in the research of the institute.

As pointed out in Section 1, IFAE is still suffering from the lack of young staff: for instance, almost all its staff has aged above the limit to apply to ERC Consolidator grants. To try to mitigate this, in Section 3, we describe a program to hire, with SO2020 funds, two outstanding young (typically in their mid 30s) scientists who would be offered tenure-track positions with the expectation that after 3-4 years at IFAE, they could apply to ICREA positions. These researchers should be of high-enough caliber to apply to ERC Starting/Consolidator grants with a significant chance of success, which would guarantee a tenure position.

One of the two positions mentioned above will be for a theorist. The Theory Division of IFAE, which has been considered one of the best in Europe, recently lost several researchers who received offers from other leading European institutions with which it was impossible to compete in terms of salaries, and more important, available research funds. This new hire, who will be offered substantial start-up funds, will rejuvenate the Theory Division, solidifying its leading position, while strengthening the general area of astroparticle physics, including cosmology and gravitational wave astronomy. A first step took place recently, with Prof. Diego Blas joining UAB, and IFAE's Theory Division, with a senior Beatriz Galindo position.

The second position will be devoted to instrumentation and applied physics, in the broad area of medical applications with pixel detectors, in which IFAE has already achieved a recognized leadership position. The hiring of an excellent instrumentist will enhance and rejuvenate IFAE's applied physics group, preserving its excellence in the long term. She/he will have freedom to start her/his own research lines, and will be encouraged to develop, starting from high-energy physics technologies, new ideas and techniques that may have more immediate applications to society at large. The SO2020 will also help preserve the current IFAE capabilities in the operation of the landmark clean-room instrumentation by highly specialized technical personnel. Altogether, this links directly to our second main goal stated above. IFAE has recently created three spin-off companies: Baretek (Barcelona Detector Technologies), a company dedicated to the development of silicon píxel detector technologies for security and medical applications; Deep Detection S.L., with funding from the Mobile World Capital foundation, which offers high-speed X-ray cameras with several energy levels for on-line monitoring in production inspection mode; and Qilimanjaro Quantum Tech S.L., which represents our bridge to industry in quantum computing applications, and has already secured over 4 M€ in funding.

The acquisition of new key research infrastructure is a pillar of the SO2020 plan serving both main goals above. Most notably, the SO2020 investment plan will enable IFAE to become a key developer of superconducting quantum computing technology, complementing in this way its leadership in quantum annealing at the European level. Other strategic investments on new clean-room instrumentation for microelectronics, to complement our existing infrastructure for pixel sensors, and a new enhanced optical laboratory will contribute to the current activities for the upgrade of several experiments IFAE is involved in (notably ATLAS and Virgo), placing the institute in a privileged position for the design and development of new detectors for future generation experiments. In perfect synergy, the new instrumentation will enhance also the technical capabilities relevant for R&D on new devices for medical applications. Finally, the SO2020 will be instrumental to leverage emerging co-funding opportunities to acquire new strategic infrastructure and, for example, update the data storage facilities at PIC, thus consolidating its role as a member of the newly created Spanish distributed infrastructure for data management.

The SO2020 plan includes a seed-money program, similar to that already in place in our previous SO actions, with the aim to support new innovative ideas that often need to be kick-started with the institutes own funds, before they can attract competitive funding, particularly if they are proposed by young researchers, with limited track record. As in the past, grants will be awarded on a competitive basis among the proposals received internally, and priority will be given to early-career scientists whenever possible.

Additionally, the SO2020 plan promotes the organisation of top-level scientific workshops, and supports an extended visiting program at IFAE to stimulate scientific exchange at the highest level.

2.2 Specific goals

The global S02020 strategy described above is further detailed in the following specific goals:

1) To strengthen the Theory Division.

2) To further enhance our leadership position in the ongoing large international projects in which IFAE is involved (ATLAS, MAGIC, CTA, T2K, DES, DESI, PAUS, Euclid, LSST, Virgo), maximizing their scientific returns.

3) To reinforce and consolidate the new research line on Gravitational Waves, leveraging our expertise in detector construction and data analysis, promoting a multimessenger culture at IFAE and establishing a highly visible position in the R&D towards the key instrumentation for the future.

4) To participate vigorously in the development and construction of near-future large international projects, reaching leadership positions in the ATLAS high-luminosity upgrade, CTA, T2K-II and Advanced Virgo, and to be a main actor in the design of the next generation of experiments.

5) To expand our activities in the area of instrumentation, leveraging our expertise in instrumentation for cutting-edge experiments in fundamental physics and astrophysics to develop applications to other areas, with particular emphasis on medical imaging, following IFAE's recognized track record in this area.

6) To consolidate and further enhance the activities related to Quantum Computing Technology, bringing IFAE to the forefront of the European efforts in the field and increasing the existing collaborations with other local centers like the BSC and ICFO.

7) To further improve our programs for training of young scientists (PhD students and post-docs) in order to attract to IFAE the best young researchers in our areas.

8) To take advantage of our alliance with the other centers in BIST to keep broadening our research towards more transversal, multidisciplinary projects.

9) To expand the reach of PIC, our LHC Tier-1, MAGIC and PAUS Tier-0, and one of the data centers for both CTA and Euclid, towards other projects in which IFAE is involved, such as Virgo and LSST, thus promoting PIC as an important centre in the field of multimessenger astronomy. Furthermore, we will exploit synergies with other BIST centres to leverage PIC's experience in data-intensive research.

10) To cautiously expand the Knowledge and Technology Transfer office (currently consisting of a single person), given the recent success in the creation of several spin-off companies, and in preparation for an enlarged applied physics portfolio.

2.3 Specific actions

In the following, we describe our specific action items for the period 2021-2024, and we relate them to each strategic goal mentioned above.

Theory Division

i) IFAE's theory group suffers from a low postdoc-to-senior ratio. Postdoctoral researchers being crucial to the production of quality science, we intend to allocate to the theory group a significant part of the post-doctoral researchers hired through the program described in Section 3.

ii) The theory group has recently suffered the departure towards other institutions of a few prominent researchers. To mitigate this loss, and to reinforce the competence in the area of astroparticle physics, including cosmology, gravitational waves and multimessenger phenomenology, we will use funds from the SO2020 award to hire

an excellent young astroparticle theorist, ready to fully interact with her/his IFAE observational colleagues in gravitational waves, gamma rays and cosmology. We will offer a 3-year tenure-track contract, with competitive salary and substantial research funds, with the expectation that the candidate will be able to compete for a Starting/Consolidator ERC grant and an ICREA position.

iii) The SO2020 award will contribute to strengthen the Theory Division by all other available means, including the Beatriz Galindo, Marie Curie, Ramón y Cajal, La Caixa Junior Leader, and ICREA calls. To this end, significant start-up funds will be made available with the aim of attracting excellent theorists to those programs.

iv) We plan to maintain a substantial number of short-term visiting theorists by devoting SO2020 funds to sponsor a series of workshops (1-2 per year) aimed at attracting a critical mass of international scientists. In addition, we intend to promote an extended-stay visiting program with the aim to attract leading scientists on sabbatical leave interested in IFAE.

v) While the scientific collaboration between the Theory and Experimental divisions has markedly increased in the last years, there is still room for improvement. To this end, we will keep promoting a joint theory/experiment PhD program, following recent initiatives in the area of GW and astroparticle physics.

Actions i), ii), iii) and iv) are coupled to specific goals 1) and 3), while iv) and v) are part of our strategy to attract the best young talent to IFAE (goal 7).

Hadron Collider Physics

i) The analysis of the Run 2, Run 3 and high-luminosity phases of the LHC will provide a stringent test of the Standard Model, further the picture of the Higgs sector, reaching high precision in many cases, and significantly extend the reach of searches for new physics. In the following five years, the activities will be focused on the completion of the Run 2 publications, the re-commissioning of the ATLAS detector in preparation of Run 3, followed by data taking, detector operations, and a prompt analysis of the Run 3 dataset. The SO2020 will provide the group with sufficient PhD students and postdocs to preserve the current leading position in several flagship analyses, within an extremely competitive ATLAS international environment.

ii) Given the effort invested and the success achieved, IFAE's contributions to the ATLAS upgrades for the high-luminosity run will naturally be centred around the pixel Phase-2 inner tracker upgrade and the HGTD construction. Although the core funding should come from elsewhere, the SO2020 shall play a strategic role in the ATLAS upgrade: in synergy with other initiatives at IFAE involving silicon sensors and microelectronics, the SO2020 will provide the means to upgrade the instrumentation in the clean rooms, including a new plasma cleaner, a new dispensing machine, and a new metrology machine, and also to strengthen the highly specialised technical support for pixel module production. In addition, the SO2020 will support the group with PhD students and postdocs.

iii) The 2020 update of the European strategy for particle physics has singled out an electron-positron Higgs factory as the highest- priority next collider, which could be

operating in the mid 2030s. IFAE has developed valuable expertise in emerging technologies that promise to underpin the next generation of experiments at colliders. In particular, DMAPS seems to be the technology of choice for future lepton colliders, and it can also be used for medical applications. The SO2020 will contribute to our ongoing R&D activity in this area.

Actions i) to iii) develop specific goals 2), 4), 5) and 7).

Gamma Ray Astronomy

i) The scientific exploitation of the MAGIC telescopes and the combined analysis of MAGIC and the first CTA telescopes in La Palma will remain a priority for the following 4-5 years, in the framework of a smooth transition from MAGIC to CTA, as the number of CTA telescopes installed in La Palma increases. In order to preserve the current leading position in the analysis of the MAGIC data, while maintaining and operating the MAGIC telescopes and participating in the commissioning of the different CTA telescopes in La Palma, the group will be supported by the SO2020 with PhD students and postdocs.

ii) IFAE, as part of the LST Consortium, will focus on the construction of the cameras for the three additional CTA-North Large-Size Telecopes (LST) before the end of 2022. Although the required funding comes from elsewhere, the significant investment on additional laboratory infrastructure already foreseen in other SO2020 actions will also help keep IFAE as a central institute in CTA.

iii) IFAE is preparing the integration of PIC as part of the CTA data center. The SO2020 grant will facilitate this initiative by helping upgrade the PIC storage infrastructure.

iv) IFAE is collaborating with the future China-led HERD experiment, a next generation satellite experiment for the study of high-energy cosmic- and gamma-rays, that will complement CTA. The IFAE group takes responsibility for assessing and optimizing the performance of the detector for gamma- ray astronomy and designing the corresponding trigger system. The SO2020 will facilitate and support this R&D initiative.

v) The Raman LIDAR built by IFAE in the framework of CTA for atmospheric monitoring for Cherenkov gamma-ray astronomy is now being proposed for more general applications related to weather monitoring, climate-change research, and disease propagation through aerosols. The SO2020 will support the related R&D activities.

Actions i) to iv) develop specific goals 2), 4), 7) and 9), while action v) is related to goal 8).

Neutrino Physics

i) The neutrino group at IFAE will focus on the full scientific exploitation of the T2K experiment in Japan, which continues to lead the field of long- baseline neutrino oscillations. At the same time, IFAE is playing a crucial role in the activities related to the upgrade of the ND280 near detector for T2K-II, mainly carried out in the framework of the CERN neutrino platform. ND280 will also be the initial near detector for the planned HyperK project in Japan. The SO2020 will support this effort

with the provision of PhD students and postdocs. Action i) is related to specific goals 2), 4) and 7).

Observational Cosmology

i) The group will continue the successful science exploitation of DES until ~2023, and will contribute to the science with PAUCam, proving its capabilities as a medium-resolution redshift machine and focusing on synergistic opportunities with the preparation for, and scientific exploitation of, DESI, Euclid, and LSST.

ii) After helping build some of the apparatus that will explore the cosmic frontier in the next decade, the IFAE group is ready to start plunging into the scientific analysis of the copious data DESI, Euclid and LSST will deliver. The group will leverage its expertise in weak lensing and photometric redshifts, acquired in DES and PAUS, to have a high impact in Euclid and LSST, while the recent hiring of Dr. Andreu Font-Ribera will ensure IFAE's central role in the analysis of the Ly-alpha forest DESI data. For all this, the group should get adequate support in the form of PhD students and postdocs.

iii) Euclid and LSST data will be processed following a distributed computing model similar to that of LHC. PIC is one of the 9 Euclid Science Data Centers, focusing in holding Euclids massive cosmological simulations and is in the process of becoming an Independent Data Access Center for LSST, providing the ObjectLite catalog data to the LSST community using PIC's CosmoHub platform. The PIC upgrades proposed in this application will help it fulfill both goals.

iv) On the hardware front, IFAE will continue supporting PAUCam and the DESI GFAs for their future observations, and will seek opportunities to participate in R&D for infrared detectors for scientific use, profiting from the know-how and technical equipment acquired in the context of the ASTEROID project.

Actions i), ii) and iii) develop specific goals 2), 7) and 9), respectively, while iv) is related to goal 5).

Gravitational Waves

i) The group will continue the full scientific exploitation of LIGO/Virgo/KAGRA data, including the data from the next O4 and O5 observation periods, scheduled to start in 2022 and 2025. This will open wide the window of multimessenger astroparticle physics in IFAE, and will stimulate closer collaborations with a Theory Division reinforced in this general area. To this end, the group will receive support in the form of PhD students and postdocs, and will benefit from a strengthened theory group.

ii) The first IFAE instrumented baffle will be integrated in Virgo in 2021, as part of the phase I upgrade. Additional (much larger) baffles will instrument the area surrounding the main mirrors in 2024, as part of the phase II upgrade. IFAE is responsible for the maintenance and operations of the new instruments, and is expected to keep playing a central role in stray light control and background noise reduction as a whole, fundamental to achieve the design sensitivity. For all this, the group will receive adequate support in the form of PhD students and postdocs.

iii) The construction of large instrumented baffles for Virgo in such a delicate environment (surrounding the main test masses) is putting IFAE in a select list of European institutions capable of contributing significantly to the development of current and future ground-based gravitational wave detectors. To help in this regard, the SO2020 plan foresees a significant investment for upgrading the capabilities of IFAE workshops in the areas of metrology and optical setups. In particular, IFAE's optical room will be refurbished and enhanced with new equipment including more powerful lasers; an enlarged optical setup for the characterization of large surfaces in terms of reflectivity and scattering; a supercontinuum near-infrared lamp source; a dual-stage cold head for MWIR and LWIR detector characterisation; and a new touchless profilometer for precise roughness measurements. This strategic action has been designed in close connection with other research lines involving optical instrumentation at IFAE.

iv) In the following years IFAE will contribute to the design of the Einstein Telescope, as the European project for a third-generation ground-based interferometer.

Actions i), ii) and iii) develop specific goals 2), 3), 4) and 7), and iv) is related to goal 4).

Quantum Computing Technologies

i) The group has quickly become a reference in Europe in experimental quantum computation with annealing. By establishing key infrastructure for device processing, the SO2020 will permit IFAE to become a superconducting qubit technology developer, extending the group capabilities towards improving qubit properties, particularly longer coherence times to yield more stable quantum processors. New infrastructure includes a new sputtering system, a wet bench for chemical processing, optical lithography capabilities, a new vacuum oven, and a plasma chamber for substrate cleaning. This will add to the existing capacities already provided by SO2016 and through an agreement with our spin-off company Qilimanjaro.

ii) Increase the collaboration with Qilimanjaro to eventually provide scientists trained at IFAE to push device construction and deployment.

iii) Start a collaboration with deep underground laboratories like LSC-Canfranc for the operation of qubits in highly shielded environments to elucidate the fundamental mechanisms that lead to improved qubit coherence times, opening the possibility to use qubits as quantum sensors dedicated, for instance, to direct dark matter detection.

Actions i) to iii) develop specific goals 6), 7) and 8).

Instrumentation and Applied Physics

i) The small group at IFAE dedicated to medical applications is extremely productive and has a plethora of exciting research ideas that have led to a large number of international patents. Nevertheless, the group still suffers from lack of funding, research time (too often spent in applying for little start- up money for new ideas) and personnel. As a consequence, some of their ideas cannot be developed as desired. The SO2020 is intended to contribute in a major way to enhance the

capacity of the group and realise its full potential, facilitating the development of new ideas. To this end, SO2020 will provide a limited but consistent baseline funding to support their activities.

ii) In order to preserve the excellence of the group in the long term and increase the success rate of EU grants, we intend to hire a young scientist in the area of medical applications using funds from the SO2020 award. We will offer a 3-year tenure-track contract, with competitive salary and substantial start-up funding, with the expectation that the candidate will be able to compete for a Starting/Consolidator ERC grant and an ICREA position.

iii) As pointed out, the SO2020 award will allow for a selective upgrade of laboratory infrastructure serving several strategic research lines. In particular, a coherent plan is built around the investment foreseen in microelectronics equipment, crucial for the majority of our medical applications.

iv) IFAE will continue to promote R&D on new ideas on instrumentation for applied physics showing a clear potential to address concrete societal challenges, with particular attention to new collaborations with other BIST research centers.

v) To further facilitate KTT activities and bridge the gap between R&D and industrial product, the SO2020 will create its own Proof of Concept (PoC) program, allocating limited funds for one or two projects per year. Actions i) to v) develop specific goals 5) 8) and 10).

PIC Computing

i) The PIC computing center plays a central role in supporting the different research groups at IFAE. The excellent and highly reliable service provided by PIC opens the door for in-kind contributions in different experiments where IFAE is involved. Renewed effort has been put to expand PIC services towards other communities, with particular emphasis on life-science projects, leveraging PIC's extensive experience in data management and sophisticated data processing techniques, including machine learning. In collaboration with other BIST centers, PIC plans to build a bioimage repository and analysis facility for next generation Advanced Optical Microscopy (AOM). A world-class AOM hub exists within BIST, spearheaded by facilities and research groups at CRG, IBEC, ICFO and IRB, doing R&D at the forefront of this field. PIC will integrate in this hub and participate in interdisciplinary projects. PIC being one of the computing centers of the newly created Spanish infrastructure for data management, SO2020 will help PIC to upgrade its data storage infrastructure by co-funding initiatives based on ERDF infrastructure funds.

ii) The PIC computing center has been integrated in the LIGO/Virgo computing grid and is providing services to the collaboration in a continuous and substantial manner. Acting already as the computing center for a number of astroparticle physics and cosmology experiments, PIC is in a strategic position to become a reference hub for multimessenger data analysis. The SO2020 award will promote coordinated actions across research lines to make this goal a reality.

iii) The SO2020 award will facilitate the creation of a data-steward figure at PIC providing support for new projects on data management and data access following the FAIR guidelines.

The actions i) to iii) develop specific goal 9).

2.4 Core and competitive funding

In summary, the SO2020 award will allow IFAE to remain at the forefront of Fundamental Physics and Astrophysics research and related state-of-the- art instrumentation over the next several years and to further boost a strong applied physics portfolio with a large KTT potential. In particular, the SO2020 award will be instrumental to accomplish different missions: to strengthen the Theory Division; to consolidate and enhance the two new research lines on gravitational waves and quantum computing technology; to increase the reach of the applied physics division; to maintain the international leadership in all the well-established physics research lines; and to reinforce the KTT office. This is clearly reflected in the way the SO2020 budget is allocated.

In terms of personnel, about 600 k€ of the SO2020 budget will be devoted to hiring two young leaders in the fields of theoretical physics and medical imaging, respectively, including a competitive salary and significant start-up research funds. A provision of about 1000 k€ is allocated for co-funding research grants for postdocs, and to facilitate the incorporation of outstanding PhD students to the research groups before fellowship calls become available. About 150 k€ will serve to support highly specialized clean-room technicians and to hire one junior person to reinforce the KTT office.

In terms of infrastructure, the SO2020 plan includes the investment of about 800 k€ in key new instrumentation for the clean rooms and optical laboratory, especially relevant for the applied physics, quantum computing technology and gravitational waves lines, but beneficial to the rest of IFAE's research. About 400 k€ will be devoted to support R&D on new instrumentation and promote KTT through a PoC program. A provision of about 290 k€ is intended to support PIC computing, co-funding the upgrade of the data storage system via infrastructure calls with ERDF funds and facilitating the creation of a data-steward figure.

Finally, about 200 k€ are intended to promote scientific exchange by supporting top-level workshop initiatives and an extended visitor program at IFAE.

An estimation of the expected annual funding for IFAE in the 2021-2024 period can be broken down as follows:

- Base funding from the Catalan government: 2.4 M€. This number takes into account the planned moderate increases during these years.
- Spanish competitive calls, excluding Severo Ochoa: 4.5 M€. Conservatively, this number assumes that IFAE will take a flat percentage of the planned increase in the overall Spanish science budget.
- EU competitive calls: 0.7 M€. Here, we have considered a 30% increase over the current numbers, based on the improved alignment of some of IFAE research lines with the Horizon Europe goals.
- Catalan competitive calls: 0.6 M€, presumed flat.

- Contracts and services: 0.13 M€, where we have considered a 20% increase, by, among other things, exploiting our relationship with our newly created spin-off companies.

So, the overall funding, excluding the Severo Ochoa grant, would come out to ~8.3 M€ per year.

Turning now to gender related matters, in 2016 the European Commission granted IFAE the HR Excellence in Research Award for its Human Resources Strategy and its action plan, which includes specific actions regarding training, recruiting, and mentoring of researchers. It also includes a gender-action plan. With the 2021-2024 SO plan, IFAE's Gender Committee will turn into an Equity, Diversity and Inclusion (EDI) Committee, which, while continuing to focus on gender issues, will also tackle the broader subjects of diversity, equity in the treatment of all employees, and inclusion of all sensitivities at IFAE.

During recent years, an effort has been put in place to monitor the ethics and scientific integrity at IFAE. The institute recently adhered to CERCA's code of good practices in research, and we have at our disposal the newly formed Catalan committee for scientific integrity, CIR-CAT, which provides advice and analysis and can ultimately intervene in case of conflict.

The figure of an Ombudsperson and the Gender Committee have been consolidated and related protocols and plans established. The actions taken have already proved to be useful, but more work is needed. Several actions are planned for the coming years. In particular, we intend to have regular workshops for thesis supervisors on good practices when interacting with their PhD students. The complementary workshops for PhD students are already in place. A document is in preparation with guidelines on how to communicate research results both at scientific and outreach level.

Here we present the tentative schedule. A fraction of the SO2020 actions involve recruiting, for which we will follow the established best practices, as in the past. These require relatively long lead times, from the advertisement of the positions to the arrival of the successful candidates to IFAE. For some of our research lines, strict deadlines have to be followed, in order to be in step with the worldwide market for, for instance, postdoctoral researchers in theory or cosmology. Some other actions involve the procurement of rather costly infrastructure items. The cumbersome rules that we must follow for these purchases preclude a rapid outcome. Finally, the other three main actions involve open internal calls for funding of workshops and extended-stay visitors, new R&D initiatives and PoC. These calls will remain open throughout the year. Taking all this into account, and assuming the outcome of the SO2020 application will be known by early fall 2021, the milestones for these actions can be established as:

- Fall 2022: First cohort of SO2020 PhD students arrive to IFAE.
- Fall 2022: First cohort of SO2020 post-docs arrive to IFAE.
- Fall 2022: Young Leader hires on theory and instrumentation areas arrive to IFAE.
- Fall 2023: Second cohort of SO2020 PhD students arrive at IFAE.
- Fall 2023: Second cohort of SO2020 post-docs arrive at IFAE.
- Spring 2022: New equipment for QCT at IFAE.
- Spring 2022: New microelectronics instrumentation at IFAE.

- Fall 2022: New optical laboratory infrastructure available at IFAE.
- Fall 2022: Updated storage facility at PIC.
- Fall 2022: New data-steward hire arriving to PIC.

For all the actions, the steering committee of the SO2020 award, formed by the Scientific Director and the 10 co-PIs (garantes) will monitor the timely fulfillment of the milestones. Monthly steering committee meetings will be held to determine whether small corrective actions are required in the execution of the grant, in view of unforeseen difficulties or in the presence of new emerging scientific and technological opportunities.

3. TRAINING AND RECRUITING STRATEGIC OBJECTIVES

In 2016, the European Commission granted IFAE the HR Excellence in Research Award for its Human Resources Strategy and its action plan, which includes specific actions regarding training, recruiting, and mentoring of researchers. It also includes a gender-action plan.

3.1 Training

The international nature of our research leads to many long-term stays of research of our scientific personnel at top-level international research centers such as CERN, JPARC, FNAL, DESY, EGO, ORM, etc. This is particularly true for our junior researchers, for whom it has an obvious high formative value. Stays in international laboratories and observatories will continue to be a core training activity for our young researchers. It is therefore fair to say that PhD students and, especially, post-docs are mostly trained on the job and by extended stays at the international laboratories where the experiments are. It is a tradition at IFAE that the PhD students in the experimental groups spend some time working on instrumentation projects before moving on to the data analyses that will constitute the bulk of their theses. In this way, we make sure that we produce well rounded scientists. This strategy will continue in 2021-2024.

In recent years, early-career scientists at IFAE have benefitted from a series of training workshops organized by BIST. These tend to focus on career development, leadership and KTT (for post-docs), and in talk-giving, CV-writing, paper-writing, etc. skills for PhD students. The workshops have been very well received and will continue.

Training of technical personnel will continue to be mostly on the job complemented with dedicated courses. Short stays at research centers like CERN or Fermilab help learn new techniques and developments. Occasionally, targeted training courses are held at IFAE for specific technical topics, or on more general topics such as Project Management. This will continue in 2021-2024.

IFAE will enhance its incoming mobility and strive to attract more visiting scientists, particularly to the Theory Division, by means of a series of long- term workshops (1-2 per year), aimed at attracting a critical mass of leading international scientists. Besides its direct training dimension, hosting high-impact conferences and workshops provides large visibility for IFAE and attracts first-class scientists from all over the world. This activity will be intensified in the future. Organizing colloquia and seminars by external researchers is another training activity that will continue.

Finally, our successful MSc program on High Energy Physics, Astrophysics and Cosmology will continue. Since 2017, it has been complemented by a new MSc in Multidisciplinary Research in Experimental Science put together by the seven BIST centers emphasizing laboratory work and learning by experience.

3.2 Recruiting

IFAE has always followed established international best practices for hiring scientific personnel, making good use of the freedom it enjoys in this regard, unlike other Spanish research institutions beset by numerous limiting bureaucratic rules and regulations.

One of the goals for the next four years is to attract a number of highly qualified students by offering a limited number of PhD grants with an internationally competitive salary. The candidates will be selected with our usual procedure based on grades, letters of recommendation, initiative, command of the English language and, for those passing the first cut, interviews.

Similarly, we want to continue the co-funding of high-level postdoctoral programs with an internationally competitive salary, with the goal of attracting high-caliber recent PhD recipients to IFAE. Candidates will be preselected based on their CV and letters of recommendation. Short-listed candidates will be invited to give a seminar at IFAE and will be extensively interviewed.

All research lines shall benefit from the PhD and postdoctoral programs just described, but there will be special consideration for three strategically very important lines: theory, applied physics, and the new gravitational waves line.

The relevance and role of IFAE's medical imaging area in our strategic plan 2021-2024 is analyzed elsewhere in this application. In 2021-2024 we want to boost its relevance by hiring a new tenure-track researcher in this field (details are given in Section 2). In turn, this will demand an increase in the number of post-docs and PhD students for this line.

The new research line on gravitational waves needs to expand with the help of high-quality PhD students and, particularly, post-docs, which will be co- funded with the SO grant.

IFAE's theory group has often been considered amongst the leading ones in Europe and is highly reputed worldwide. Our strategy is to strengthen their impact and visibility by ensuring, with the SO2020 award, the proper balance between senior scientists and early-career scientists (PhD students and postdocs), alleviating the chronically low postdoc-to-senior ratio in the group, a problem afflicting most other theory groups in Spain. For this reason, it is our purpose to allocate to the theory group a significant fraction of the postdoctoral researchers to be hired.

In the recent past, IFAE has been awarded three EU COFUND schemes, two of which are still running their course. In September 2020, IFAE, along with the other six SO research centers in BIST, submitted an H2020-MSCA-COFUND proposal to co-fund almost 100 postdoctoral positions, of which 10 will be for IFAE.

Hiring excellent permanent scientists is even more crucial than hiring early-career scientists. Because of the risks associated, hiring through a tenure- track mechanism is the preferred system in most leading universities and research centers in the world, since it affords a long period in which the institute and the candidate are able to gauge whether they are a good match. This is the system applied at IFAE. One of the most important strategic decisions in our SO2020 program is to open an

international search for two outstanding researchers, young but with substantial postdoctoral experience (typically 5-7 years after their PhD), to fill two tenure-track positions: one to reinforce the Theory Division, with a particular emphasis on astroparticle physics phenomenology, cosmology and gravitational waves; and another to enable a qualitative jump in our applied physics portfolio.

The positions will be advertised in the leading international job lists in our area, including CERN Courier, inspirehep, the AAS job list, etc. Two separate committees will be formed, with local as well as external top-level scientists. The selection will be made based on CV merits, letters of recommendation and, once a shortlist has been created, following a seminar and an exhaustive interview process at IFAE. Typically, we schedule short one-on-one interviews between each candidate and over 10 different IFAE researchers in several areas, and a longer interview with the members of the search committee. The understanding is that these researchers have to be of such a caliber as to have good chances to succeed in the ERC junior calls (Starting or Consolidator) and, eventually, in an ICREA call. Success on ICREA calls is very high for candidates holding an ERC grant. In any case, the usual comprehensive tenure evaluation will take place. Note that in this, as in our other actions, we will not relinquish to third parties the selection of our scientific personnel, since we will have selected these researchers in the first place.

3.3 Gender issues

Although the internal survey and analysis that led to IFAE's Human Resources Strategy concluded that IFAE does not discriminate its personnel on the basis of gender (or on any other ground: age, ethnic, national or social origin, religion or belief, sexual orientation, language, disability, political opinion or social or economic condition), the share of female researchers at IFAE remains low at 18.4%, though it rises to 25.2% for PhD students. This is fairly common in our field: looking at the ERC calls, women account for ~17% of applicants and ~15% of grantees in Physics and Engineering. In 2017 we launched a Gender Action Plan, aiming at: raising awareness about IFAE's gender policy among potential applicants; working towards improving gender balance among candidates; identifying and removing any potential gender bias in evaluation procedures; embedding gender awareness within all levels; and striving for gender balance among all relevant bodies, such as the external Scientific Advisory Committee. At the same time, we generated a protocol for dealing with, preventing, and eradicating workplace harassment, which explicitly includes sexual harassment and harassment because of gender or sexual orientation.

With the 2021-2024 plan, we want to enlarge the scope of the Gender committee to turn it into an Equity, Diversity and Inclusion (EDI) committee, which, while continuing to focus on gender issues, will also tackle the broader subjects of diversity, equity in the treatment of all employees, and inclusion of all sensitivities at IFAE.

3.4 Mentorship

The primary mentor of the PhD students at IFAE is their doctoral adviser, in most cases complemented by a UAB tutor. For post-doctoral researchers, it is the research group leader who acts as mentor. The mentors make sure that the career of young researchers is developing correctly, proposing training activities, making sure credit is given, looking for speaking opportunities at conferences and outreach events, and helping with the next career move to another institution.

Several collaborations we work in are currently setting up their own mentoring programs, pairing early-career scientists with senior researchers in different institutions. This can provide some redundancy and help achieve the career developments goals inside the collaboration.

4. INTERNATIONALIZATION

IFAE's experimental research in particle and astroparticle physics, including observational cosmology and gravitational waves, is carried out within large international collaborations, which involve many groups from several countries and include the top research institutions in the field. The work in applied physics and quantum computing technologies, as well as the theoretical work in all the above fields, are also highly internationalized.

Participation in Horizon Europe is extremely important for applied physics and quantum computing, but not as important to our core lines of particle and astroparticle physics, in which the typically multi-decade-long projects get their recurrent funding from national agencies. Participation in Cofund projects is very important for all lines in order to get high-quality postdocs.

The international visibility and networking of the institute in each line is already very strong. We will reinforce and consolidate it participating strongly in Horizon Europe and improving our success in ERC grants, especially through our applied physics portfolio, and we will continue our successful participation in Cofund programs through the BIST and UAB-Sphere coordinated proposals. Here, we detail the strategic plan to reach these goals in each research line.

Theory Division

As already mentioned, IFAE's Theory Division has been regarded as one of the best in Europe. The Theory Divisions research is carried out on themes related to the Standard Model of particle physics, ideas Beyond the Standard Model, and issues of Astroparticle Physics and Cosmology. In all cases, this is carried out already in close collaboration with many prominent theorists from prestigious universities and laboratories around the world.

The strategic future goal is to maintain and enhance the excellence and the international impact of the group with the hiring of a high-level young scientist using SO funds, as well as further strengthening the connection with IFAE's Experimental Division and increasing the success rate for obtaining ERC grants. The SO grant will be crucial in giving support to the Theory Division for the hiring of excellent postdoctoral researchers and in maintaining a lively program of workshops and seminars.

Hadron Collider Physics

The activities of the ATLAS group are focused in the exploitation of CERN's Large Hadron Collider (LHC). In the physics analysis front, the group concentrates on the most relevant aspects of the LHC physics program, and it has established its leadership in very important research lines. The research is always carried out in intimate collaboration with scientists from many of the most prestigious institutions around the world. Several members of the group have occupied relevant coordinating position in physics working groups in ATLAS.

The SO2020 grant will allow further strengthening of the IFAE team and its presence at the central research lines in the experiment. Ultimately, this should translate into an increased visibility at the physics coordination level, with the aim of taking further top-level responsibilities within the experiment.

A strong contribution to the upgrade of the ATLAS detector constitutes a pillar of IFAE's research program in the experiment and part of the SO2020 strategy. The group is playing a central role in the design and construction of 3D-pixel sensors for the new ATLAS silicon tracker in preparation for the high-luminosity LHC period starting in 2027. In addition, IFAE is among the institutions leading the development of LGADs for the new High Granularity Timing Detector (HGTD) in ATLAS. Also, R&D on DMAPS technologies is performed in close collaboration with CERN, the ALBA synchrotron, and

other leading European institutions, in the framework of the AIDA2020 effort and similar initiatives. This is considered a strategic activity for the institute, and may facilitate IFAE's future access to Horizon Europe funds for technological developments, for which this SO grant is instrumental.

Neutrino Physics

IFAE scientists are crucial for the upgrade of the ND280 near detector for the T2K experiment in Japan, which will also become the near detector of the future HyperK experiment. The hardware activity is focused on the design and construction of the new TPC, within the CERN neutrino platform. The SO2020 actions will preserve this leading position with the provision of enough personnel.

Gamma Ray Astronomy

The SO2020 actions will facilitate that IFAE continues to play a central role in the CTA and MAGIC international projects, as well as the exploration of future involvements. Thanks to the essential role of IFAE scientists and engineers in the construction and integration of the CTA LST1 camera, a consortium led by IFAE has won the public international bid for the production of the cameras for the remaining three LSTs of CTA-North. It is strategic for IFAE, and part of the SO2020 mission, to maintain the leadership in CTA during the whole duration of the project, and to get further similar contracts using the technology and know-how developed in-house.

In addition, the team plans to keep its prominence in the physics exploitation of MAGIC and CTA instruments (currently the MAGIC spokesperson and the LST software coordinator are IFAE scientists). IFAE will continue its involvement in EU H2020 programs like the ASTERICS project, with the mission to address the challenges common to the various Astronomy ESFRI facilities (SKA, CTA, KM3Net, and E-ELT), and the ESCAPE initiative.

Finally, the institute will maintain its R&D effort in view of future CTA upgrades. It is already involved in the design of the HERD cosmic and gamma ray detector on board the upcoming Chinese space station, complementary to CTA, with the aim to further consolidate the presence of IFAE in space research initiatives, of strategic importance.

Observational Cosmology

IFAE's research program in observational cosmology will continue the exploitation of the DES and PAUS data, in the framework of excellent international collaborations. The international visibility in the analysis of the DES and PAUS data is very high already, and the goal for the immediate future is to maintain it and port it to the next generation of experiments. IFAE is part of the three leading next-generation dark-energy surveys: the ESA Euclid satellite mission, the US-led DESI spectroscopic experiment, and the DESC Collaboration of the LSST at the Vera Rubin Observatory. IFAE's plan on observational cosmology is ambitious, being on collaborations with some of the best institutions in the world, and relies to a significant extent on the availability of the necessary funds in this SO program, notably for post-docs and PhD students.

On the hardware front, IFAE is part of the H2020 ASTEROID project whose mission is to make Europe self-reliant on large infrared detectors for Earth and space missions. The technical equipment for characterization of these detectors opens the door to future possible international partnerships in this area.

Gravitational Waves

The IFAE group in Virgo is playing a central role in the construction of novel instrumented baffles to monitor the scattered light close to the main mirrors, with a large potential for improving the interferometer performance. This has placed IFAE in the select list of centers producing new instrumentation for GW interferometers and paves the way to have a leading position in the design of the next-generation interferometers, like the Einstein Telescope, in which IFAE is already part of the main coordination bodies. The SO actions, including both personnel and lab infrastructure, will be instrumental to consolidate a leadership position in this field. Strong collaborations have been put in place for instrumentation and physics analysis with some of the most relevant institutions in USA, Europe and Japan.

Quantum Computing Technologies

Pol Forn-Díaz, the PI of this research line, has already reached significant international visibility with the coordination of a FET-Open and an ERA-net projects. The existing efforts to build coherent quantum annealer prototypes will receive a significant boost from a qubit foundry located at IFAE, for which the SO2020 is instrumental. This will represent a qualitative jump in the positioning of the institute at the forefront of EU advancements in this technology and will facilitate future ERC grant applications on related subjects with a high chance for success.

Instrumentation and Applied Physics

The SO actions will contribute in a major way to preserve the excellence of the applied physics group, with the hiring of a new high-level young scientist targeting junior ERC grants in the near future, a significant investment in the lab, and the explicit support for R&D initiatives. The group maintains an active role in the CERN-led Medipix collaborations and it has been successful in obtaining funds from ATTRACT (H2020) calls. Ideas are in place for an ERC Synergy application, whenever the next call comes out. It is strategic for the institute to nurture the newly created spin-off companies and exploit the proliferation of ideas in collaboration with other BIST centers leading to new patents.

PIC Computing

The SO actions will contribute to maintain PIC as one of the leading high-throughput computing centers in Europe, one of the best performing Tier-1 LHC centers, and a reference for experiments in astroparticle physics, cosmology and gravitational waves. PIC is in a privileged position to become an international hub for multimessenger astronomy. As PIC is now one of the nodes of the Spanish infrastructure for data management, serving different communities including bioscience, the SO2020 grant will be an instrument for helping upgrade the PIC permanent storage infrastructure and promoting its participation in EU projects related to human health.

5. EXPLOITATION AND DIFFUSION OF RESEARCH OUTCOMES

5.1 KTT

IFAE's Intellectual Property Rights (IPR) document covers IPR ownership management, protection processes and exploitation mechanisms. It includes an economic incentive for researchers: up to 50% of the returns from the IPR exploitation is assigned to its inventors. In 2020 the document was updated with a section related to the creation of spin-off companies.

Our Knowledge and Technology Transfer (KTT) plan is based on 3 main goals:

1) Consolidate the innovation and entrepreneurship training for researchers.

2) Improve the number of IFAE technologies reaching the market.

3) Promote the creation of companies based on IFAE technologies.

To achieve those goals, a list of milestones and concrete actions has been put together:

i) To engage 12-15 IFAE researchers and engineers in innovation training (11 did so in the last 4 years), IFAE will push the research staff to participate in seminars and courses addressed to promote entrepreneurship: Lean Launchpad OnCampus (MWCapital); UAB ideas; Health Entrepreneurship (Col·legi de Metges de Catalunya); From Science To Business (ESADE/BIST), etc. The goal is to analyze market opportunities for IFAE's research results and generate the corresponding business models, selecting the most promising new technologies to valorize.

ii) To stimulate the protection of inventions by filing 3-5 new priority patent applications (3 in the last 4 years), IFAE will implement regular meetings with the principal investigators to identify those technologies that involve novelty, inventive steps and industrial utility, by performing market research and patent analyses, and protect the research results with the most potential.

iii) To bring 2 new technologies from low to medium Technology Readiness Level (TRL) (1 brought to TRL 4-5 in the last 4 years) and to fill the gap between R&D outcomes and minimum viable products, IFAE will create its own proof of concept program: one or two innovation projects will be assigned ~20 k€ per year to validate their new ideas in the lab, in order to increase their TRL to enable applying to proof of concept calls and stimulate the interest of potential licensees and investors in IFAE technologies.

iv) To increase the exploitation of IPR up to 5-6 active licenses (3 licenses in the last 4 years), IFAE will establish strategic alliances with venture- building consultancies to support its technology licensing activities. The consulting companies will facilitate the contact with decision makers of the relevant players for each technology application and will give support in the license negotiation phase.

v) To push for creation of new spin-offs by presenting 3-4 entrepreneurship projects to accelerator programs (2 in the last 4 years). IFAE's technologies in medium TRLs will be presented to programs like BTTG-IESE, Empenta-ESADE, The Collider-MWCapital, where the business opportunity is validated by industrial mentors, the minimum viable product is developed and tested with corporate partners, and the first investment round is secured.

vi) To foster the growth of IFAE's spin-off companies reaching 3-4 active companies participated by IFAE (currently, 3 spin-offs), IFAE will promote the consolidation and growth of our spin-off companies through joint outreach activities (e.g. prototype showrooms), and synergies in networking actions with potential customers and investors.

Milestones and actions i) - ii), iii) - iv), and v) - vi) relate to goals 1), 2), and 3), respectively.

The KTT unit will set up periodical meetings with several of IFAE's technological partners in industry, acting as an industrial advisory board, including collaborators in the sectors with potential applications of IFAE's technologies: sensing and monitoring (e.g. IDNEO), medical diagnostics (e.g. LEITAT), data science (e.g. AIA), etc.

Turning now to knowledge diffusion, we divide the strategic activities in science education and outreach for the next 4 years into 3 categories.

5.2 Educational Activities

We plan to increase the scope of our educational portfolio, developing material for the new research lines. Gravitational Waves, in the broader context of multimessenger astronomy, and Quantum Computing are hot topics that attract the interest of the public. We will develop related educational activities to showcase the wide range of research lines at IFAE. The current educational programs (such as Bojos per la Física, Barcelona International Science Challenge, Physics Masterclasses, Cazadores de Rayos Gamma, Build the Universe Brick by Brick, Escolab & Talks in Schools, or Summer Fellowships at IFAE) will be maintained, adapted to the post-pandemic world.

A parallel line of work is the Centre Educatiu Singular Angeleta Ferrer, in which the BIST centres will participate in the development and execution of the science program of a new public high school in Barcelona whose mission is to promote STEM studies, particularly among female students. IFAE is involved in this project that will boost our collaboration with teachers and educators.

5.3 Outreach Events

We plan to strengthen our collaboration with institutions and festivals outside the science ecosystem (SONAR, etc.), to find new audiences and increase our reach. Beyond promoting talks given by IFAE researchers to schools and the general public, IFAE's outreach activities will focus in 2 aspects:

i) Interactive models that demonstrate IFAE technologies. We have created models for the quantum computing and retina projects and will develop new demonstrators for the BIOSPAD blood flow detector and the Virgo instrumented baffle, and will present them in fairs.

ii) Workshops for kids and families using Lego bricks, an excellent material to play with abstract concepts. We will expand the range of topics from particle physics to astrophysics and cosmology, to give a full overview of research at IFAE.

5.4 Corporate Communications & Press

Our new website will enable new developments to properly display the research performed at IFAE. A quarterly external newsletter targeted mainly to the local and international research ecosystem will be developed, and IFAE's social media presence will be increased. The main goal of the press activities remains an increased IFAE presence in the media through press releases.

IFAE ensures the open access of its publications by using the public arXiv.org repository for preprints, regardless of the fact that papers may be published in journals that may lie behind a paywall. This is common in the field and considered a good open-access practice. Also, in 2020, using the IMarina scientific information system, IFAE started adding its publications to the open-access Portal de la Recerca de Catalunya. IFAE is also involved in two other open science initiatives: the SOMMa Open Science and the CERCA Documentalists working groups.

In terms of open data, IFAE has pioneered with MAGIC the public release of high-level scientific products in standard astronomical formats (http://vobs.magic.pic.es/fits/), and developed a pilot project for the release of low-level data (http://opendata.magic.pic.es/), both hosted at PIC. IFAE is developing the MAGIC Data Legacy, which will contain all gamma-ray candidate events by MAGIC. As partners in the ESCAPE H2020 project, IFAE is developing the GammaHub platform, which will allow online data exploration, selection and analysis with multi-instrument gamma-ray data. PIC has also developed and hosts CosmoHub (https://cosmohub.pic.es), a platform for interactive data analysis of massive astronomical datasets. It offers 20 public datasets from DES, PAU, DESI, Gaia, etc. In the next years PIC will expand CosmoHub to include gamma-ray, neutrino and gravitational wave open data, becoming a hub for multi-messenger data analysis. Finally, three experiments in which IFAE participates offer their own open data platforms:

- LHC (http://opendata.cern.ch/): 2PB of public data.
- LIGO/Virgo (https://www.gw-openscience.org): alerts, analysis software.
- DES (https://des.ncsa.illinois.edu/releases/dr2): catalogues and images for 700M astronomical objects.