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HEZKUNTZA SAILA DEPARTAMENTO DE EDUCACIÓN

BASQUE EXCELLENCE RESEARCH CENTRES

2022-2025 PROGRAM

DIRECTION FOR RESEARCH
VICE-MINISTRY OF UNIVERSITIES AND RESEARCH

Ekintza Plana | Plan de Acción | Action Plan

Zentroa | Centro | Centre

(bcam)
basque center for applied mathematics

3. Strategic Plan for 2022-2025

3.1. Research Programme(s)

This section should include (Max. 7 pages):
Main research objective(s) and description of the research activities, projects, lines deployed to meet that/those objective(s). Outcomes foreseen: publications, patents… Social impact of the research programmes to be developed.

The present Research Programme is addressed to the consolidation of the current research areas, generation of new research lines and the expansion of BCAM research teams' size and quality as well as its scientific outcome. This Programme also aims to increase the participation on competitive public projects at regional, national and international level. We will increase the number of publications in peer-review journals both in mathematics and mathematical methods to industry, life and social sciences. We will also keep increasing the publications in the first decile and first quartile.

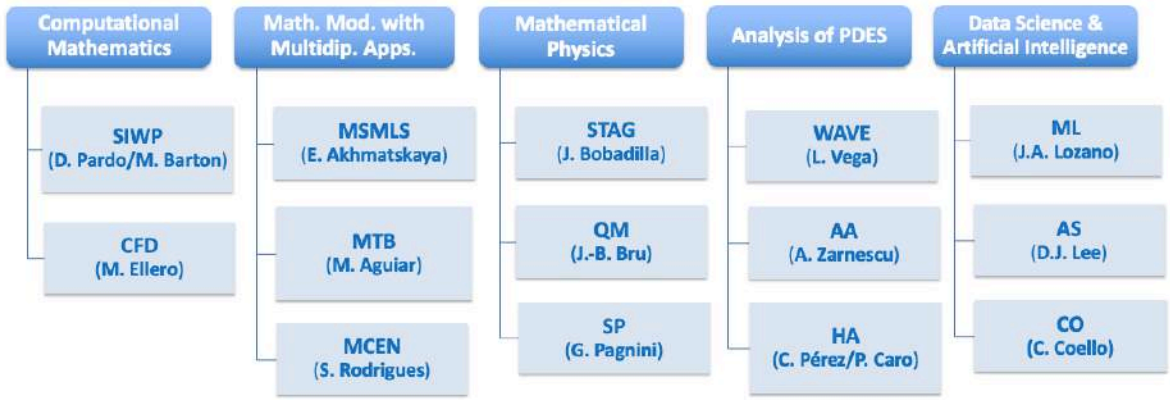


Figure 39. BCAM research area, lines and group leader

New generated knowledge transfer to industry and society is the key potential impact of BCAM's Research Programme. The objective is to transfer the obtained research results to sectors such as telecommunications, health, transport, energy and aeronautics, including local, national and international entities. The novelty, relevance, potential impact objectives and expected outcomes of the BCAM Programme are based on the different research areas:

AREA: COMPUTATIONAL MATHEMATICS (CM)

SIMULATION OF WAVE PROPAGATION (SIWP)

Goals and objectives: The ultimate scientific goal of MATHDES group is to bring a significant mathematical contribution to the resolution of real-life problems. Our key objectives are: expand the already initiated high-impact works on numerical methods, including Deep Learning (DL) algorithms, for partial differential equations; modeling of manufacturing technologies (CNC machining, 3D printing); transfer this mathematical knowledge to the industry; train new researchers in the area.

Novelty and potential Impact: With the experience and know-how acquired in the past five years in DL algorithms, our group - composed of world-class scientists with complementary expertise in applied mathematics, deep learning, and high-performance computing - will contribute to the consolidation of this powerful tool for a number of real life problems. We will also contribute to a better mathematical understanding of DL algorithms. We expect our work to have a major impact on the emerging technologies and the wellbeing of the society, because it addresses relevant problems, such as the exploitation of renewable energies, the reduction of CO_2 footprint, and the structural health of civil infrastructures, to name a few. Another thread of our research focuses on modeling of manufacturing processes (CNC machining, 3D printing, inspection path-planning) where our mathematical models make the process more accurate and/or faster, consequently making the whole manufacturing pipeline better and/or cheaper.

Programme description: In order to reach the aforementioned objectives, we will undertake the following actions:

- Increase the number of Q1 and D1 publications (we expect an increase of at least 20%)

- Apply to at least four European projects (we expect to obtain at least two of them);
- initiate at least a new research topic on Deep Data-Driven computing for solving equations complemented with data;
- Maintain and enhance alliances with top research institutions worldwide (we expect to include in our further applications to European Projects at least two Universities from Latin America);
- Explore new industrial markets and promote periodic meetings with potential partners
- Enhance new industrial collaborations that can further benefit from our ongoing projects (e.g. with results of ADAM^2, we will approach prosthesis manufacturers).

CFD MODELLING AND SIMULATION (CFDMS)

The research goals for the next phase are centred around the following scientific themes:

(1) Continuum Flow and Multiscale Simulation of Complex Fluids: In the past three years we have developed a number of mesoscopic particle models for both, complex suspensions and polymeric materials, which describe in details the coupling between hydrodynamics and microstructure in these complex systems. These models are usually applied under simple viscometric conditions, i.e. uniform shear flow, to extract rheological properites (viscosity, normal stresses, viscoelastic moduli etc.). The objective of the next phase is to extend these techniques to more complex flows, i.e "moving from rheology towards the fluid mechanics of complex fluids".

In order to achieve this goal, the mesoscopic models need to be extended and suitably generalized on larger spatial-temporal scales and for heterogenous flow conditions. In the context of suspension exhibiting discontinuous shear thickening (DST) behaviour, we will develop and implement novel continuum partial differential equations into Lagrangian meshless discretization techniques (e.g. Smoothed Particle Hydrodynamics) and study the DST liquid behaviour under complex flow conditions such as free-surface flows or expansion/contraction geometries. This work will benefit from the new collaboration with Dr. R. Seto, an expert in the area of DST models (currently BCAM Visiting Fellow) and also with Dr. B. Sandnes in Swansea Univ. where real experiments will be performed (a PhD co-supervision is currently ongoing).

Highly connected with this topic is the possibility to bypass the choice of approximate constitutive relations for DST fluids, whose validity is not always guaranteed. Therefore, we want to develop a multiscale model-free technique which, by synchronous coupling of simulations on different scales, allows to incorporate the relevant flow physics implicitly.

We will generalize the well-known Heterogeneous Multiscale method (HMM) to a full Lagrangian case. The new technique could be applied in a wide range of complex systems including complex hemodynamics. In particular, within the framework of the Marie Curie framework (Individual fellowships), a member of our CFD group in BCAM (N. Moreno) will actively work on multiscale simulations of thrombogenesis and its impact on the the viscoeastic rheological and flow properties of blood.

(2) Particle-models of magnetic particles suspended in liquids and interacting with external fields: This specific research objective is connected to the the recently awarded coordinated project of the Spanish State Research Agency (together with UNED, UAM, CSIC and IMDEA and acronym 'THEXP'). In particular, the BCAM subproject (Compu-Nano-Hydr) will be centred around the theme of nano-hydrodynamics-assisted soft matter experiments by addressing methodological challenges and practical questions. The focus will be on magnetic nano-assembly, frictional dynamics, lubrication and interfacial film dynamics, hydrodynamics-resolved simulations of magnetic nanoparticles dynamics and aggregation under the action of an alternated magnetic field.

(3) Machine Learning for CFD: We will explore new ways to apply machine learning techniques to the area of computational fluid dyamics. This could proceed along multiple routes. From one side, we want to explore the possibility to develop new reduced order model of compex fluids (i.e. polymeric liquids, melts) by using data-driven constituive relations, i.e. entirely learnt from microscopic simulations. On the other hand, in collaboration with Dr. Roberto Santana (Computer Science Department UPV/EHU) we will interact with the BMW group (Munich) to apply Physics-Informed Neural Network techniques to rationalize CFD simulation data (this is a general topic of a PhD co-supervision with BMW planned for the next years).

AREA: MATHEMATICAL MODELLING WITH MULTIDISCIPLINARY APPLICATIONS (M3A)

MODELLING AND SIMULATION IN LIFE AND MATERIAL SCIENCES (MSLMS)

Novelty and potential impact: Our goal is to identify the needs, priorities and challenges in the applications under study, and extend, tune and apply the recently developed by us mathematical tools as well as propose the novel methods in order to address those problems. Following our previously defined strategy, we will focus on such areas of public interest as health, energy, materials and quantum science, working closely with the experts and practitioners in those areas. **Progamme description:**

Health: ***Tracking the development of resistance to anti-cancer therapy through mathematical modelling -*** development and implementation of a probabilistic framework for the integration of heterogeneous types of data sets (clinical and omics data) for more effective classification of genes linked to resistance of patients to breast cancer endocrine therapy (with bioGUNE, MTB (BCAM), **GNIA**)

Advanced real-time modelling of epidemiological and hospital admission evolution due to COVID-19 - proposing and implementing a parallelization strategy for in-house software HaiCS for its better adaptation to advanced epidemiological models (with AS (BCAM), UPV/EHU, CAPV, OSI)

Coarse grained continuum descriptions of agent based models in mathematical biology – derivation of kinetic and aggregation-diffusion models via cell automation lattice approximation or mean-field limits with applications ranging from cell sorting in neural crest models to computational neuroscience synchronization for mammal navigation paths (with Oxford University).

Energy: ***Optimization of battery materials -*** optimization of transport in composite electrolyte materials; design of novel Perovskite-like materials of the type Li/Na-Fe-Cl as cathodes for Li-/Na-ion batteries; probabilistic screening of advanced energy materials**;** numerical integrators for Quantum problems and Monte Carlo simulations**;** ML-driven atomistic simulations for energy (with **IConMSAM** and **GNIA**).

Predictive modelling of microbiome - development of a new approach based on Bayesian Inference and Machine Learning concepts for modelling, design and engineering of a microorganism for the production of biofuels and bioproducts from lignin (to be implemented in Biodesign) (with Berkeley Lab).

Materials: ***Modelling of hydrogen diffusion and trapping in different types of steel microstructures –*** applying latest in-house optimization tools to derivation of atomistic force fields for simulation of the hydrogen mobility in steel lattice and across grain boundaries (with Tecnalia, UPV/EHU).

Intelligent design of multi-phase polymers- designing a systematic approach for inferring existence and level of a scale separation in the population balance models for latex particle morphology formation (with AA (BCAM), QuInST,POLIMI).

Quantum Science: ***Quantum measurements*** - application of the Feynman's approach to the analysis of the extended Wigner's friend scenario (EWFS) (with QuInST, CNRS).

Chemical reaction mechanism – development of novel methods for understanding chemical reactivity: complex angular momentum analysis of differential and integral cross sections (with QuInST, Manchester U.).

MATHEMATICAL AND THEORETICAL BIOLOGY (MTB)

Novelty and potential impact. New challenges areanticipated for the coming years with the MTB research line becoming a reference for excellence science in biomathematics in Europe. We aim to bridge mathematics and other life science disciplines, building the capacity of researchers to use practical and relevant real life information during mathematical modelling development and data analysis. With a strong mathematical component, we are committed to public health preparedness and infectious diseases outbreaks responses. We will continue our research efforts to strength public health capacity for detecting, identifying and addressing likely infectious diseases epidemics.

Programme description. MTB will work in collaboration with other BCAM lines and external institutions such as the Basque Health Department, Osakidetza Basque Health Service, Basque Centre for Climate Change BC3 Basque (BC3) and the Instituto Vasco de Investigaciones Agrarias (NEIKER) as well as collaboraborating with many international researchers from different fields and countries. Eventual industry collaboration is anticipated. Scientific events organization, including outreach activities and courses will take place strengthening and broadering networking and gaining international visibility.

Research proposal. With a strong mathematical component and a timely application to the current sanitary situation we are living in now.

- Public Health Epidemiology: focused on basic and applied aspects of host, pathogen, and environmental factors that influence disease emergence, transmission and spread, epidemiological models will be formulated

to describe the transmission of the disease and to predict future outbreaks. Models will be developed to be used as guiding tools, helping to better understand the interactions between pathogens and human hosts, taking into consideration the host immune components involved in the progression of the disease, including but not limited to i) modeling animal-to-human spillover dynamics; ii) modeling SARS-CoV-2, Influenza Like Illness (ILIs) and other human coronavirus dynamics, iii) modeling neglected tropical diseases and iii) understanding the climatic impact and social behaviour on disease transmissibility and control.

Population dynamics and methodological topics in natural sciences and mathematics: By developing stochastic spatially extended systems, questions (and not limited to) to be answered are: When will the emergence of a new pathogen become a pandemic threat? Which is the role of spatial dynamics in the spread and control of infectious diseases? How does critical fluctuations influence the disease dynamics? What is the role of imported disease cases across geographical boundaries and how it triggers the outbreak of new infection clusters? Which are the sizes and features of those clusters and what are the thresholds towards a pandemic scenario? What is the influence of population heterogeneity on the overall disease dynamics? What are the model limitations and which is the best way to model and optimize the effects of different control measures such as lockdown, social distance, non-pharmaceutical interventions and vaccination? Research activities will include bio-statistics methods for model comparison and parameter estimation of chaotic systems.

MATHEMATICAL, COMPUTATIONAL AND EXPERIMENTAL NEUROSCIENCE (MCEN)

Programme description: MCEN will build upon its recent research trajectory but it has also identified three key novel research directions, which are:

(1) To develop Intelligent deep-brain stimulators for Epilepsy. Presently there are no deep-brain stimulators for epilepsy due to the difficulty of predicting the onset of epilepsy. Moreover, since it is an intermittent disease then a continuous input may disrupt other brain processes. As part of a PhD project we will develop a novel closed-loop mathematical control method to track stability boundaries of neuronal states that lead to epileptic states. We will first undertake this research for in-vitro experiments (Fig.36:A) and subsequently for in-vivo experiments in collaboration with Achucarro Center (Fig.36:B). However, aspects of the in-vivo experiments will be carried out in parallel with the in-vitro experiments since it will calibrate the in-vivo experiments, collect data and develop novel data methods based on Topological data analysis.

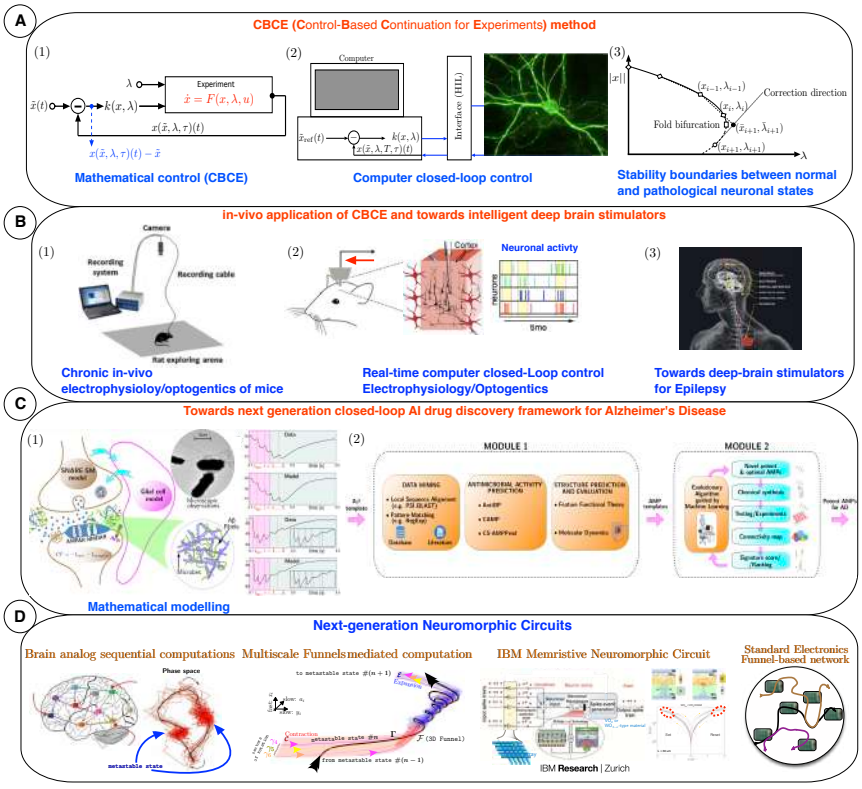


Figure 40. Analog circuits that are sensitive to stimuli yet robust to noise and with computing capabilities that supersedes computers

(2) To develop novel closed-loop computational-experimental platform to screen for new drugs with high-therapeutic efficacy against Alzheimer's Disease (see Fig.36:C). This will be driven by mathematical modelling, as well as, by combining machine-learning, Topological data analysis, PDEs, graph theory and molecular simulations which together will screen for drugs. The synthesized drugs will be tested in mini-brains (based on human pluripotent cells) and ranked. The best drug candidates will be further optimized in closed-loop.

(3) To develop next-generation neuromorphic analog circuits inspired by our recent theoretical findings on brain computation. The aim is to implement analog circuits that are sensitive to stimuli yet robust to noise and with computing capabilities that supersedes computers (see Fig.36:D).
Novelty and potential impact: The aforementioned projects are novel and will lead to long-term scientific, health and technological impact: 1. Deep-brain stimulators for epilepsy is non-existent and patients that do not respond to anti-epileptic drugs will benefit from this technology; 2. Drugs that cure Alzheimer's Disease is non-existent. The World-health-organisation has declared the urgency of finding such drugs within the decade 2020-2030; 3. Novel analog circuit that replicate brain computations will enable the development of new Artificial Intelligence that approximates Brain Intelligence. This will feed future smart technologies including robotic systems.

AREA: MATHEMATICAL PHYSICS (MP)

QUANTUM MECHANICS (QM)

Novelty and potential impact: Only a few results on interacting fermion systems are available, because of the lack of efficient mathematical methods to deal with interactions. The algebraic formulation has been important and fruitful for the mathematical foundations of quantum statistical mechanics in the last century. However, excluding a relatively limited amount of papers (see e.g., the theory of quantum spin systems), almost none of the modern mathematical approaches to quantum many-body problems really use the algebraic formulation of quantum statistical mechanics, in an essential way. The algebraic view point is however more general than the Hilbert-space approach (cf. the Rosenberg theorem).
A first important specificity of our approach, as compared to most of the current research projects on the non-relativistic quantum many-body theory, is the systematic use of the algebraic formulation of quantum mechanics to state mathematical problems related to this physical theory. Last but not least, we are going to establish a pivotal bridge between algebraic methods and innovative constructive methods of quantum field theory and statistical mechanics, in order to obtain a new general theory of (weakly) interacting fermions.
This theory will then be used as a springboard, by making conceivable the mathematical analysis of interaction effects on many-fermion systems, like in fermionic transport or quantum information theory. It will therefore be an important outcome with important scientific impact in both Physics and Mathematics.
Programme description:
Primary objective: In contrast with traditional strategies, we aim at combining the algebraic approach to quantum many-body problems with the development of new constructive methods of quantum field theory and statistical mechanics. In doing so, we expect to obtain a mathematically rigorous theory of weakly interacting fermion systems at equilibrium that can be applicable in multiple scenarios.
Secondary objectives: Applications of results of the primary objective to quantum transport with three possible objectives: emergence of resistivity from interparticle interactions, macroscopic effects at nanoscales, many-body localization, mathematical control of Rényi relative entropy (cf. quantum information theory), etc.

STATISTICAL PHYSICS (SP)

At the origin of power-law distributions. Ubiquity of power-laws is criticized because of limitations in data acquisitions and lacks in generative mechanisms, from which a dualism arises: Are power-laws generated by large variability in the internal configuration of the system? Or are generated by large variability among experimental system's replicae?

(1) Novelty. The aim is to state a criterion to reply to these questions.

(2) Novelty. The diffusive limit for random walks is attained at large-time and large-space limits that are "too much large" for applied purposes. Unexpected and important behaviors emerge during an asymptotic intermediate regime. A key feature lays in the asymptotic expansion of the characteristic function of the jumps' distribution through, which are or are not alternating series, this opens the way to a relation between fractional diffusion and the Riemann zeta function.
With U. Potsdam (Germany), Hugo Steinhaus Center (Poland), and U. La Sapienza (Italy). At BCAM: synergies with the RLs CFD-MS and MMB.
Predicting the arrival of the unpredictable. Deriving a Lorenz-type chaotic system from a prototypical reaction-diffusion equation for predicting the transition to chaos in wildfire propagation. Development of a stochastic dynamic prediction theory for ensemble forecasting of wildfire propagation, this last is not a merely application of an existing

technique in weather prediction because, in meteorology, it refers to the evolution of dynamical observable while, in wildifres, it refers to the evolution of surfaces.

(3) Novelty. A systematic analysis, of the reasons to transition to chaos, leads to establish a quantitative ranking-of-risk that allows for setting an alternative method for real-time risk assessment.

(4) Novelty. Development from scratch of stochastic processes for geometrical figures.

With USAL, U. Cantabria, CIMA (Italy) and a Spanish network and a European consortium that already worked for proposals' submission. Knowledge transfer is expected as software routine for operational code for fire simulations.

SINGULARITY THEORY AND ALGEBRAIC GEOMETRY (STAG)

Novelty and potential impact: Singularity Theory is in a continuous dialogue with the main developments in Algebraic Geometry and Topology. In this sense: Floer thoretic methods are very recently finding appropriate counterparts in the Algebraic Geometry and Singularity Theory (our team has already contributed in this direction), and its investigation will be probably central in the next years and open new directions to tackle classical questions. Lipschitz Geometry is one of the most rapidly developing areas in current Singularity Theory; the higher dimensional aspects of the complex case are largely unexplored, and apropriate Algebro-Topological tools are being currently constructed; Lipschitz Geometry is highly intertwined with non-arquimedean and model theoretic methods, and progress in this connection would impact greatly Singularity Theory. The main novelties that we introduced to our interests and toolkit recently are:

(1) Floer theoretic methods to study degenerations. We aim to prove the conjecture linking Floer Homology and contact loci, and explore possible generalizations relations contact and symplectic topology to invariants of the arc space of a singularity. This connects arc spaces (one of the main areas of expertise of the PI) with Floer Homology, which is recently pervading Singularity Theory.

(2) The further development of an Algebraic Topology capturing metric and Lipschitz phenomena of singularities. In particular he heads to results in the direction of analogues of Whitehead Theorem, with applications to the Lipschitz Normally Embedding problem, to an asymptotic Lefschetz fixed point theorem. A globalization of MD Homology will be studied (at the moment the theory is only constructed for germs and degenerations). The Lipschitz study of 1 parameter complex degenerations and Milnor fibrations will be addressed. In this sense prominent examples are degenerations of Calabi-Yau manifolds, whose metric geometry may shed some light towards the Strominger-Yau-Zaslow problem. Possible analogs and generalizations to the non-arquimedean word will be explored, speciphically concerning MD-Homology, the Lipschitz study of germs and Milnor fibration.

(3) Characteristic classes of singular varieties, where our results for L-classes can be continued to the study of an even stronger conjecture. Also, we plan to pursue the study of Milnor classes of non-complete intersections, largely untouched by now.

(4) The study of singularities via their Cohen-Macaulay modules and matrix factorizations will be continued.

(5) Minimal Model Program in birational geometry is nowadays developed well enough to yield very interesting applications in several problems connecting equisingularity with simultaneous resolution.

(6) A 3-years senior postdoc (I. Smirnov) funded by a La Caixa Junior Leader Grant, which is expert in characteristic p methods and connections with Commutative Algebra, will join the group in November 2021, together with a junior postdoc for 2 years. I expect this interaction to influence our research.

AREA: ANALYSIS OF PARTIAL DIFERENTIAL EQUATIONS (APDE)

LINEAR AND NON-LINEAR WAVES (WAVE)

Novelty and potential impact: The recent results obtained under the ERC HADE grant raise two main questions: (a) The Vortex Filament Equation (VFE) is a good model to describe some turbulent flows, as the non-circular jets generated by nozzles with a polygonal shape; (b) To prove the optimality of the sphere for the MIT Bag Model of quark confinement is reduced to solve some variational problems associated to non-local elliptic systems; The achievement of (a) will suppose a breakthrough in the understanding of turbulence. As for (b) it is a fundamental question of non-relativistic quantum mechanics.

Programme description: Regarding (a):

(1) We will construct quasi-invariant measures for solutions of VFE in collaboration with R. Lucà and N. Tzvetkov using techniques of Statistical Mechanics.

(2) In parallel, we want to further explore the deterministic track to construct the solution for the VFE for a regular polygon. At the level of the curvature and torsion, i.e. using the so called Hasimoto Transformation that links VFE with Non-Linear Schrödinger equation, this question has been recently settled in arXiv:2107.01934. The obtained solutions can be integrated using the Frenet equations at rational times (De La hoz -Vega; J. Non-linear Science, 2018). Our objectives are the integration at irrational times and to prove that the solution fits in the framework of weak solutions of Jerrard-Smets (ARMA, 2017).
(3) We will prove that the trajectories followed by any of the corners of a regular polygon exhibit the properties of multifractality and intermittency already showed for Riemann's non-differentiable function. As a consequence they verify the so-called Frisch-Parisi conjecture. We will also rigorously prove the unbounded growth of the amplitudes of the Fourier coefficients showed in the numerical experiments in 2018. We will complement these results with (i) physical experiments done in collaboration with the group of W. Irvine (U. of Chicago, USA), and (ii) numerical experiments of the so-called reconnection phenomena done in collaboration with the group of J. Nordstrom (U. of Linköping, Sweden), which shows many similarities with VFE.
Regarding (b): This is a completely new line of research that links classical Complex and Harmonic Analysis questions as the Hardy space and the Cauchy operator on Lipschitz curves, spectral properties of the Dirac operator with singular perturbations, and variational questions of non-local operators. For this objective we will collaborate with J. Serra through the recently created BCAM lab in Analysis and PDEs.

APPLIED ANALYSIS (AA)

Novelty and potential impact: We will set the basis for several new directions in the study of liquid crystals and their interactions, setting a solid starting point that will certainly generate many subsequent development. We will addresses key issues in the physics and engineering of liquid crystals, that need a solid theoretical foundation in order to advance. It is expected that the various tasks of the project will have a significant scientific impact. This will be manifested mathematically, physically and technologically.
Firstly, mathematically, we will be developing new techniques to deal with inverse and optimisation problems in homogenisation, free boundary problems with nonlocal constraints, min-max nonlinear vectorial problems with nonlocal terms and qualitative aspects of vectorial minimal solutions of systems of PDEs. On the numerical side we will develop a framework for addressing problems relevant to PDE models, particularly those in materials science, by using machine learning techniques.
From a physical point of view this will contribute to developing new approaches, with experimental relevance. Firstly we will provide methods for designing new, general, types of surface energies through boundary rugosity manipulations. Secondly, using homogenized colloidal mixtures, we will be devising a way of generating liquid crystal materials with apriori given behavior in terms of spatial variations. Thirdly, we will be able to create surfaces which possess certain uniform refraction properties, relevant to the creation of lens-like devices
Programme description: Most of the mathematical studies of liquid crystals have been focused on defects. These have been considered in the simplest possible setting, namely defects inside of the material, which are not particularly general from a physical point of view. The main aim of the proposed programme is to attack problems that look into the next level of complexity, involving interactions between nematic liquid crystals and: (i) Surfaces (at the boundary of the sample or of colloids, that is inserted particles much larger than the LC molecules). (ii) Other materials (such as water and air, in particular droplets characterized by free boundaries). (iii) Fields (electric, mangetic and light).
In our programme we will focus on the defect structures related to the presence of interactions, while also considering specific qualitative aspects that can be described by the models such as the shape of the free boundaries, the form and design of surface energies, the anisotropic effects generated by fields and various specific scaling regimes.

HARMONIC ANALYSIS (HA)

In the research line of HA, our goals will concern the study of the following topics: Directional Rubio de Francia square function; Weighted inequalities in several contexts; Maximal operators on spaces of functions with extra regularity; Fourier restriction theory; Discrete harmonic analysis and non-commutative theory; Homogeneous and non-homogeneous harmonic analysis; Degenerate Poincaré-Sobolev inequalities: the self-improving property; Degenerate elliptic theory; Analysis of InvPro in anisotropic media; Quantum Hamiltonian from the knowledge of

states of wave functions.
The main themes enlisted above are very central in current research in HA and partial differential equations. We believe that, overall, the scientific goals lie on the threshold of current technology and knowledge and thus, successful outcomes will not only attract significant attention in their own right, but also establish novel methods of development in the corresponding areas. We are planning to carry out the objectives in collaboration with researchers at UPV/EHU (L. Fanelli, A. Fernández-Bertolin, I. Parissis) and collaborators from national and international centres.
Programme description: (1) We will push the research on versions of directional maximal and square operators towards multiscale and vector field versions, in an attempt to get results closer to the so-called Stein and Zygmund conjetures. We will also work on the construction of a satisfactory theory of maximal operators in the context of the infinite dimensional torus, with an ultimate aim of connecting with results from Dirichlet series. (2) A novelty is the connection with the regularity theory of degenerate elliptic. Although this line of research goes back to the work of De Giorgi and Moser our point of view is more attached to the work of Fabes-Kenig-Serapioni (FKS) in the 80's where it is shown the central role is played by Poincaré-Sobolev inequalities with weights. Very recently part of the (HA) team has developed a theory that improves the results obtained by FKS and showing the connection with other central topics from Harmonic Analysis such as BMO. (3) On the other hand, one of the main goals for this period will be to analyse InvPro in anisotropic media. This question has important technical difficulties due to the impossibility of encoding the inhomogeneity of media in lower-order perturbations of constant-coefficient operators. Another important goal will consist of determining quantum Hamiltonians from the knowledge of initial and final states of wave functions. This InvPro is connected with a unique continuation problem analysed by Luis Vega and collaborators. (4) In collaboration with Renato Lucà, we will consider a problem of magnetic reconnection in the context of magnetohydrodynamics (MHD). MHD describes the magnetic properties and behaviour of electrically conducting fluids as plasma and liquid metals.

AREA: DATA SCIENCE & ARTIFICIAL INTELLIGENCE (DS&AI)

MACHINE LEARNING (ML)

For the next period we will pursue several scientific goals. These goals can be globally summarize as follows:

- **Development of methods for temporal problems.** This research line is a continuation of the research lines from the previous period. Our goal is to combine the knowledge gained on the time series mining objective together with the statistical machine learning line and be able to develop methods for dealing with different problems within the wide area of time series: streaming, novelty detection, time series streaming, etc. The use of techniques derived from statistical machine learning will equip the methods with theoretical guarantees.
- **Development of techniques for supervised classification with general training data.** This research line aims to develop learning techniques that can handle different types of training data in a unified manner using a minimax approach. The general goal is to obtain learning algorithms that are able to balance cost vs accuracy trade-offs of training stages, and seamlessly aggregate ensembles of training samples with assorted types and qualities.
- **Distributed learning of probabilistic models.** This is a new research line focused on a decentralized and collaborative learning of machine learning models. This line will develop procedures that will allow a distributed and parallelized learning of models in both variables and instances spaces. Consequently, the learning methods that will be proposed in this line of research will improve computational efficiency, data privacy, as well as the accessibility to machine learning-based solution with respect to distributed methods based on a central server.

For all the aforementioned goals, we plan to implement software tools freely providing these algorithms to the research community. In some case we will protect our developments by means of patents and intellectual property measures.

APPLIED STATISTICS (AS)

For 2022-2025, our research efforts will be focused on the development of new statistical methods in the framework of semiparametric regression to tackle several challenging statistical problems with a particular interest in applications in different fields such as Health and Medicine, Sports Science and Climate Change. The general objectives are grouped in the three pillars:

1) **Statistical methodology.** Semi-parametric regression methods are the unified framework for lots of statistical modelling approaches (from generalized additive models to (non)-linear mixed-effects, longitudinal and correlated data to survival analysis with frailty, non-exponential families, spatial and spatio-temporal modelling and or Bayesian inference).
2) **Computational aspects.** The implementation of new methodological advances in Open Source software has dramatically increased in the last few years. This tendency contributes to the important impact of shortening the time from the development of new statistical advances to their application. Nowadays, reproducible research is becoming a standard in high-impact journals to provide the scientific community with the statistical tools to evaluate new statistical methodologies. Hence, software development plays thus a fundamental role in knowledge and technology transfer;
3) **Multidisciplinary collaborations and research transfer.** The AS research team is formed by a group of applied statisticians and mathematicians with a solid theoretical background with experience in health, clinical practice and environmental modelling also with a solid background in programming and the development of statistical software.

The group will put its efforts in increasing its critical mass by attracting competitive candidates for Juan de la Cierva, Ramón y Cajal grants or Ikerbasque fellows or other grants such as MSCA or Junior Leader La Caixa.
In terms of scientific publications, most of our publications are in the Q1 of the "Statistics and Probability" category and some others in other multidisciplinary areas. For the next, period considering the ongoing collaborations with Health Institutions, and the high-quality PhD students in the group, high-impact publications in applied journals will be expected to show the multifaceted nature of the research team. The research project led by the group leader in the National Research Plan (PID2020-115882RB-I00) will be the cornerstone of the research developed in by the group but not restricted to it.

COMBINATORIAL OPTIMIZATION (CO)

For the next period we will pursue several scientific goals. These goals can be globally summarize as follows:

- Development of models that describe the location-allocation problem linked to Emergency Medical Services. This research line is a continuation of the research lines from the previous period. We will improve the modeling in two lines: on the one hand, incorporating stochastic times in the formulation and on the other hand, developing an input simulator based on the database provided by Osakidetza. Moreover, the simulations will be presented to the health professionals.
- Development of methods for stochastic optimization problems. Our goal is to combine the exact methods with the heuristics in order to solve large scale multistage mixed 0-1 problems as well as quadratic and quadratic constrained multistage problems.
- Optimization of renewable energy systems. The use of optimized Multi-Energy Systems, including renewables, combined heat and power units and energy storages, is proven to be effective in the reduction of fossil CO2 emissions. These systems can be efficiently operated to provide electricity, cooling and heating to energy districts and buildings. The model will determine the optimal renewable subsidy and carbon tax for multi-energy systems. This is a new research line focused on developing novel methodology for solving efficiently the previous model. It will be done in collaboration with the research group leader by Emanuele Martelli, from the University Politecnico di Milano (Italy).
- Large-scale multi-objective optimization. The focus will be on the development of new multi-objective evolutionary algorithms that can be used for large-scale problems (i.e., problems with 100 or more decision variables). These new algorithms will be compared with respect to state-of-the-art multi-objective evolutionary algorithms explicitly designed for large-scale problems using standard performance indicators from the area (i.e., hypervolume, inverted generational distance, s-energy, etc.).
- New hyperheuristic approaches for multi-objective optimization. Within this line, the idea is to design new schemes that combine different heuristics for multi-objective optimization in order to provide a more general multi-objective search engine. As part of these schemes, novel local search engines need to be designed as well.

For all the aforementioned goals, we plan to implement software tools freely providing these algorithms to the research community. In some cases, we will protect our developments by means of patents and intellectual property measures.

3.2. Research Groups

This section should include (Max. 3 pages):
Definition of research structure or organisation of the centre. Strategies and activities to support the attraction and retention of research talent. Expected evolution of the structure of personnel to achieve the strategic objectives of the centre.

A. RESEARCH STRUCTURE

As BCAM is a dynamic centre, in the framework of the stability of the research areas, there may be slight variations in the research lines so as to keep aligned with the most innovative research fields and current strategies like the recently launch IKUR. We will continue identifying emerging areas of research in Mathematical Sciences and foster new teams and research activities to carry them on.

The research structure will be also reinforced by putting special emphasis on i) the joint positions between research lines favouring the interconnection between the lines, ii) joint positions between Basque research centres in the framework of the IKUR strategy, iii) joint positions in the international joint research labs promoting the internationalization of the centres and finally iv) industrial PhDs in the framework of the knowledge transfer unit (KTU).

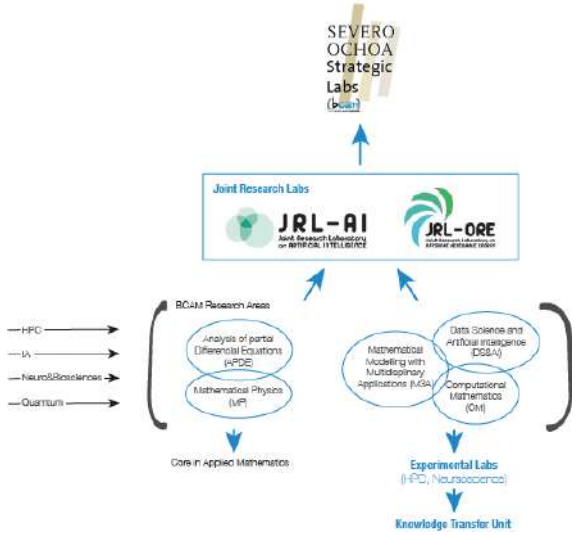


Figure 41. BCAM Research Structure 2022-2025

Regarding the organizational structure, each Research Area is coordinated by a **Senior Research Professor.** This profile matches with high level researchers with a significant seniority of more than 10 years. **Group Leaders** and **BCAM Researchers** lead the Research Lines. These profiles match with senior researchers with more than 4 years of research experience after getting the PhD degree in mathematics or related science. Proven capability of getting financing and leading and attracting a team of researchers and technicians is required. They must also have a good number and impact of publications, and meet international evaluation standards such as being eligible to achieve an ERC Starting and Consolidator grant. Each Research Line is composed by External Scientific Members, Junior Researchers, Post-Doctoral Fellows and PhD students, who also collaborate with the short-term personnel such as internships or visiting fellows and External Scientific Members. We will continue promoting joint positions and part time appointments of researchers that work on BCAM and some other institution part time (such as Tecnalia), since this allows us to establish more stable relationships.

B. PLAN AND ACTIONS TO ATTRACT AND RETAIN RESEARCHERS

In order to develop a suitable strategy for the period 2022-2025, key factors like the dynamic agenda of the Centre, the need to consolidate the research lines, interaction with other Basque research entities, international cooperation and the difficulties to attract strong and consolidated senior group leaders, need to be considered. As a result, we will continue with the **double strategy** of investing BERC funding to support a core team within each Research Area to keep the activities and extend them by incorporating new research lines following our fundamental principle

of mathematics in the service of society. Besides this basic funding, the Research Areas are encouraged to search for other sources of funding to recruit more people, according to their scientific plans. As stated before, the 2022-2025 period will be decisive in the consolidation of the research staff, so the BERC funding and the renewal of the Severo Ochoa will be critical at this point.

The researchers' **recruitment** is following the strategies planned through the **International Call for Researchers, Visiting Fellow Programme, and Internship Programme**. However, we plan to launch calls targeted to more specific profiles, trying to cover those needs identified by the research teams, following the corresponding scientific plans. This will allow us to concentrate energies and to be more efficient and move faster in a highly competitive market. In fact, in the period 2022-2025 BCAM we will continue developing our strategy to attract international talent, based on the following axes:

1. Strategy to recruit **PhD Students.** They must have an undergraduate degree in mathematics, engineering, computer science or related science. Additionally, a top academic background as undergraduate student and show and prove an interest in developing a challenging research topic shall be valued during recruitment, so that the candidates are eligible and can have access to competitive grants such as FPU from Spanish Ministry and grants from the Basque Government. As selecting strong candidates with high potential, who can cope with the challenge to finish a thesis is a key issue, we plan to make wide use of the **internship programme, summer schools and doc-course**, as a preliminary step. This will allow us to evaluate and check thoroughly the capabilities and attitudes of the candidates, before taking the decision to recruit them. Recently, we launched the **BCAM PhD Office,** as a resource to help our PhD students, and formed by the **BCAM PhD Committee**, to ensure the correct progress of the student during his/her thesis, and by **BCAM PhD Representative**, with the objective to represent the common problems that may be found by the PhD Students and acts as an intermediary between them and BCAM PhD Committee and BCAM administrative staff, as we described below in section 3.4.
2. Attracting **young researchers, with potential** to develop a promising career (by means of BERC funding in combination with **Ikerbasque** Fellow calls or other programmes such as **Juan de la Cierva, Ramon y Cajal, or Marie Curie**). This was a fruitful strategy during the last period. In the next period we aim to improve these achievements, and we are working on the strategy to generate synergies between our international calls and those Programmes in order to be more efficient.
3. Plan to recruit **Postdoctoral Fellows.** They must show a solid and coherent scientific track, having published a limited number of papers, but in top journals. Furthermore, the contribution and alignment with BCAM goals such as publications, SW code for simulations and modelling, etc., shall be especially valued for recruiting during the next period 2022-2025. Although the goal of hiring post-docs is to boost their career, so that they can benefit from a dynamic environment before they are getting permanent and/or good contracts in other international centres, promotion within BCAM is not excluded but is limited to exceptionally good candidates.
4. Collaboration with Ikerbasque to attract **Senior Research Professors**. Considering that BCAM is a young institution established in the Basque Country, the high competitiveness of the international talent attraction market, where the Spanish economy is a sign of uncertainty, and where the salaries and conditions we can offer are not higher than the average, it is difficult that BCAM can attract Group Leaders and Research Professors in the next period on its own. In this respect, one of the achievements of the last period has been to develop a more **coordinated strategy with Ikerbasque**, so that the scientific goals and needs identified at BCAM can be successfully integrated within Ikerbasque Calls and programmes. We should continue working on this in the next period.
5. **Policies on people management** issues and in particular in the main decisions of hiring new Group Leaders or appointing Ikerbasque Research Professors, will continue to be aligned and agreed upon with the BCAM selection Committee and our Scientific Committee.
6. **Strengthen strategy of Joint with industry Positions (with a special emphasis on industrial PhD students) and other research institutions in the Basque Country and Joint Research Labs**. Apart from the already running joint positions (BCAM-Tecnalia, BCAM-CICBiogune or BCAM-Illy) and industrial doctorates (ITP, Iberdrola, BBVA Data Analytics, and BMW) BCAM aims to launch new positions on different topics such as mathematical modelling applied to health, neuroscience, HPC, IA, quantum, etc.

Two key strategies for recruiting top quality researchers are the evolution and intensification of the international joint research labs and the part-time positions. The international joint research labs collaborative mechanisms open BCAM to access a broader scope of researchers, thanks to the synergies and complementary research capabilities that can be fostered in the framework of these labs. Researchers that have been trained in a prestigious research institution can find very attractive a program composed of two different centres including BCAM and where the supervisors are top researchers. Particularly, the newly created international research labs have promoted the hiring of post-docs in co-supervision with renown researchers from Oxford University or ETH Zurich. A second strategy is the promotion of part-time positions. Attracting full-time top researchers to the centre is very difficult as we have previously elaborated our salaries are not higher than average. In addition, very senior people have consolidated positions and they usually do not want to move. However, the possibility of having part-time researchers who can be in the centre between 3 to 6 months during the year is an achievable goal. In fact, we have started with this strategy with the hiring of Ikerbasque Prof. Carlos Coello, a worldwide leader in multi-objective optimization.

Regarding BCAM's strategy to retain talent, the strategy will be twofold:

1) **Strengthen the BCAM Career Development Plan** that was approved by the BCAM Steering Committee in 2016 with the support of the BERC Programme, Ikerbasque and other Basque and international entities.
2) Further develop the actions defined in our **Human Resources Management Action Plan** (described in 2.1.3) though the "Well-being at BCAM Programme", whose aim is improving BCAM working conditions and making BCAM the "best place to make research". During 2016 we have carried out our most recent "BCAM Survey" among researchers based on HR Logo principles, and we have started to put in place different activities such as budget information sharing, IT courses, team building activities, and funding opportunities seminars… In this area, BCAM is also actively collaborating with Bizkaia Talent so as to ease the integration of new researchers not only from the research point of view, but also from a personal perspective.
3) In 2021, BCAM has decided to start a **Mentoring Program** whose aim is to support the young researchers in their research career and to solve problems motivated by cultural change and scientific experience. The Mentoring Program has revealed to be helpful to reduce anxiety, improve academic performance and increase career satisfaction. Moreover, it also facilitates an easy adaptation into the different professional roles. This first year, the Mentors will be experienced researchers (at least 5 years of experience) working at BCAM, and Mentees will be PhD Students or researches with a PhD after 2015. Both Mentors and Mentees will be provided with all the tools to carry it out and will be able to develop both personal and professional skills.

C. EXPECTED EVOLUTION

While in the previous period 2019-2021 we expected a consolidation of the people in the centre, on the contrary we have experienced an important increase in the number of people reaching 125 researchers in June 2021 (see Figure 42). This increase is partially justified with the COVID pandemic that forced us to move some funds from other programs to recruiting. For the following period we expect that the number of people will decrease to 2019 levels. This number of researchers allows the lines to have a critical mass and at the same time is able to carry out the proposed scientific programme with guarantees. Of course, this will strongly depend on the renovation of the Severo Ochoa label and the success of the researchers in the different calls, particularly in Horizon 2020.

After a ramp-up period 2014-2017 where **the number of people researchers tripled**, most of the research lines have acquired a critical mass. In the period 2018-2021 this number also increased nearly a 50% thanks to the success in funding attraction and due to the exceptional situation derived from COVID-19. We expect this increased to be maintained in 2022, but the period 2023 to 2025 will be devoted to the consolidation of the research groups so as to reach a stable structure and to strengthen the most recent research lines and the experimental and knowledge transfer areas, with a special emphasis on the incorporation of new Top Senior Researchers and Joint Positions.

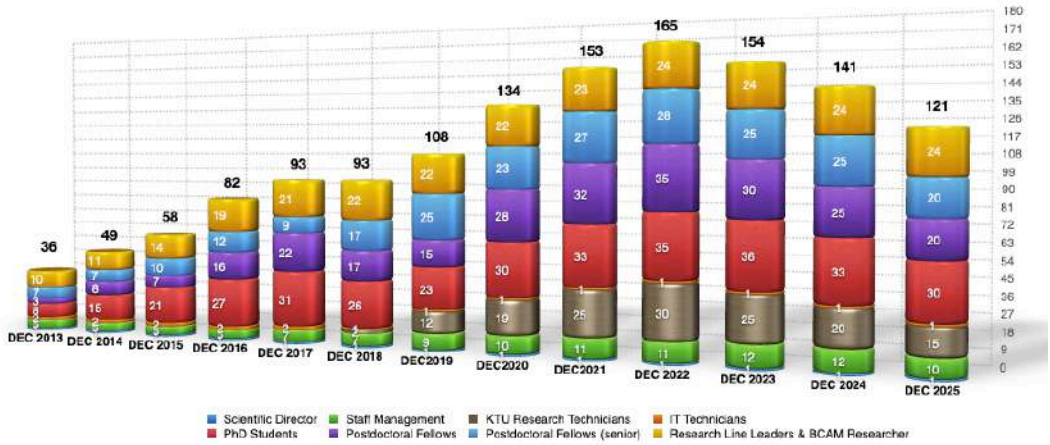


Figure 42. BCAM personnel evolution in period 2013-2025

Regarding Ikerbasque and senior researchers, BCAM currently has 5 full time and one part-time Ikerbasque Professors (IkP), 3 Ikerbasque Associate (IkA), and 5 Ikerbasque Fellows (IkF). Besides that, there are other 3 IkP, of the UPV/EHU that are temporarily at BCAM. We think that reaching a number of 15-16 Ikerbasque researchers (Professors, Associate and Fellows) on the horizon of 2025 is a reasonable number. As commented previously we expect that some of the new position could be part-time positions. This, together with 8-10 young researchers (i.e., either IkF or IkA) should be the stable structure of the centre at the end of the period.

Moreover, we want to give a step forward in our policy of joint positions and upgrade it to the level of Ikerbasque Professors. Experience shows that in this case, it is much more efficient if the researcher is part of the staff of the health institution. It is very easy to imagine a fluent and fruitful collaboration of the new researcher and BCAM. We plan to follow similar strategies during the near future as long as we receive excellent dossiers in areas that can, on the one hand enrich and complement our activities, and on the other help to give a solid, stable, and wide basis to the centre.

3.3 Internationalisation strategy

This section should include (Max. 3 pages):
Agreements and collaboration frameworks with international entities that help in the internationalisation of the centre. Highlight European and International projects/networks the centre aims to coordinate or take part in. Detail the research outputs expected for these collaborations: publications, patents, licences…
Visiting researchers, hosted or going abroad.
Specify the leadership and/or role of the centre on the activities to be developed.

A. INTERNATIONAL AGREEMENTS

For the period 2022-2025 one of our goals is to develop the international agreements signed during the previous period, carrying out actions according to an established work plan defined by a joint follow-up committee. Following the example of TRANSMATH Laboratory for Trans-border Cooperation with the University of Bordeaux, we will keep on identifying international potential partners to continue promoting **transnational initiatives in the field of mathematics and its applications**.

Besides the agreements and future applications for European Projects, the active participation and collaboration with other international teams is part of the strategy of every Research Area.

A second goal is to enhance and widen the collaboration inside the **Severo Ochoa joint research labs** by the incorporation of new researchers and particularly co-supervised post-docs and PhDs, and the joint participation in international research calls. A third goal is to open new research labs that can strength the collaboration network of BCAM in new research areas.

B. INTERNATIONAL PROJECTS, NETWORKS AND SCIENTIFIC COLLABORATIONS
Below there is a summary of the most relevant collaborations to be further developed:

AREA: COMPUTATIONAL MATHEMATICS (CM)

SIMULATION OF WAVE PROPAGATION (SIWP)

- Our goal is to maintain and enhance, through the ongoing and future European and international Projects, the successful collaborations with the current academic partners worldwide, including Tecnalia, UPV/EHU, INRIA, EPFL, Technion, TU Vienna, KAUST, and Barcelona Supercomputing Center, and with a special focus on the Research Institutions in Latin America (see our new Latin American Network MATHDATA, www.mathdata.science).
- We also focus on alliances with former and new industrial agents, both in Spain (Repsol, Iberdrola, Petronor, etc.), and worldwide (Total in France, Weatherford in United Kingdom, The Consortium on Formation Evaluation at The University of Texas at Austin in USA). Another category of our industrial collaborations deals with multi-material manufacturing, in particular Hutchison (multimaterials), Stratasys (3D printing), and Trimek (metrology).

CFD MODELLING AND SIMULATION CFDMS

- We will consolidate our international network in the area of complex fluids. In particular with Delaware (Prof. Wagner) and Sydney U. (Prof. Tanner), as well as the newly started collaboration with Swansea U, (Prof. Sandnes) and Wenzhou Institute, U. of Chinese Academy of Sciences (Prof. Seto).
- Within the framework of the Marie Curie project we will initiate a collaboration with the Centre of Nanohealth (Dr. Curtis and Dr. Hawkins, Swansea U.) as well as Julich Forschungszentrum (Dr. Fedosov) on computational fluid dynamics of clotting processes. This international network (together with the local partners in the Basque Country - CICbiomagune and Biocruces) could lead to the formulation of new European projects within the next phase.
- We will try to consolidate our ongoing industrial collaborations with the Illy-caffe Italy on modelling and simulation of coffee extraction (Dr. Navarini) as well as with the BMW Group Munich, Germany (Dr. Gholami).

AREA: MATHEMATICAL MODELLING WITH MULTIDISCIPLINARY APPLICATIONS (M3A)

MODELLING AND SIMULATION IN LIFE AND MATERIAL SCIENCES (MSLMS)

We will apply all forms of collaboration with our international partners, implemented and practised in the past years:

- Maintaining the Lab headed by Oxford Prof. Jose A. Carrillo; leading and participating in international Consortiums; co-funding postdoctoral and PhD researchers; international affiliation of BCAM researchers; delivery of international courses; reviewing and moderating EU projects; applying for international grants; exchange of research visits; collaborative publications; software co-development; co-organising international events, etc. We plan to maintain collaboration with IConMSAM (St Andrews, Nottingham, Manchester, UK; Wilfrid Laurier, Canada; Queensland, AU; Shanghai, China; Antioquia, Colombia + 5 Basque centres), Berkeley Lab, USA; Oxford, UK; POLIMI, Italy; CNRS, France.

MATHEMATICAL AND THEORETICAL BIOLOGY (MTB)

- The group will put its efforts in increasing its critical mass by attracting competitive candidates thought competitive calls.
- The group will strengthen and broader the already existing scientific network through visiting activities, gaining international visibility and broad dissemination of the results during international scientific events.
- Scientific events organization (International conferences such as the DSABNS, symposium, workshops, summer schools, seminar series)
- Joint PhD/ Postdoctoral supervision

- Joint scientific proposals application within the EU Framework projects (ERC, MSCA)

MATHEMATICAL, COMPUTATIONAL AND EXPERIMENTAL NEUROSCIENCE (MCEN)

We will collaborate with an international group of researchers and industrial partners, where appropriate funding will be sought.

- Project 1 will be in partnership with Achucarro Neuroscience Centre and Inria. Although some local funds have been secured, we will target international grants (e.g. CURE - Citizens United for Research in Epilepsy).
- Project 2, involves several European and American partners, therefore European grants (e.g. ERC Synergy) and American grants (e.g. NIH) will be sought.
- Project 3 involves IBM, Inria and Ruhr University Bochum (Germany), and we will target EIC pathfinder open.

AREA: MATHEMATICAL PHYSICS (MP)

QUANTUM MECHANICS (QM)

- We aim at applying in the coming years for an Advanced ERC Grant to make the Quantum Mechanics group of BCAM in a new dimension in terms of reputation and size. To this end, the primary objective will be used as a stepping stone towards the success of such an application. Marie-Curie fellowships will also be considered.
- The application on an international grant in relation with the Brazilian agency FAPESP and the U. of São Paulo (USP) may also be a possibility, having in mind the strong scientific relationship between the group and the mathematical physics department of the USP.

STATISTICAL PHYSICS (SP)

- Through the research branch on wildfire propagation, the research line is part of a European consortium that applied at the last call European Green Deal with a technological project with TRL not less than 6. BCAM was supposed to lead a task. The project is not funded but the consortium has already to start to collaborate: presently we are writing a position paper based on the proposal. I expect that in the future a new proposal will be submitted by the consortium by re-modulating this one.
- The research branch on anomalous diffusion will be developed in collaboration with researchers, at least, from Germany, Poland and Italy.

SINGULARITY THEORY AND ALGEBRAIC GEOMETRY (STAG)

- The PI is a Member of the Meetings Committee of the European Mathematical Society, 2018-2021,
- Organizer of the Oberwolfach Workshop “Singularities”, 2021,
- Organizer of the Zoom Algebraic Geometry Seminar, and the coordinator of the Jean Morlet Semester “Singularity Thory from Modern Persectives”, comprising a Workshop, Research, School, 2 Research in Pairs, a Program of Invitations and a Conference: https://www.chairejeanmorlet.com/2021-2-bobadilla-pichon.html
- Keep stable cooperation with A. Nemethi (Renyi Institute) and N. Budur (KU Leuven), including 1 joint postdoc with Renyi Institute and 2 joint Ph.D. students with KU Leuven.
- More than 30 invitations to international conferences.
- The collaboration with N. Budur and A. Nemethi has already led to several (6) joint papers between their team members and BCAM team.

AREA: ANALYSIS OF PARTIAL DIFERENTIAL EQUATIONS (APDE)

LINEAR AND NON-LINEAR WAVES (WAVE)

In addition to current collaborators we plan to collaborate with T. Duyckaerts (U. Paris XIII), M. Lewin, P. Seré and M. Esteban (U. Dauphine, Paris), P. Jamming and D. Lannes (U. Bordeaux), F. Merle (IHES, Paris), N. Tzvetkov (U. Cergy-Pontoise, France); with J. Bernhdt (U. of Munich);with P. d'Ancona and L. Fanelli (U. La Sapienza) in Rome; with N. Visciglia (U. di Pisa); with S. Gutiérrez (U. of Birmingham); with E. Malinnikova (Stanford U.); with K. Nakanisi (U. Osaka) in Japan ; with H. Kubo (Hokkaido U.) in Sapporo, Japan; C. Kenig (U. of Chicago); G. Ponce (U. of California); E. Malinnikova (Stanford U.); A. Nahmod (U. of Massachusstes) in Amherst; J. Pipher (Institute for Computational and Experimental Research in Mathematics) in Providence RI; G. Staffilani (MIT) in Cambridge, USA; with B. Khesin, R. Jerrard, K. Sulem (Fields Inst.) Toronto, Canada; with F.Linares (IMPA) in Rio de Janeiro; with J. Angulo (U. Sao Paulo).

APPLIED ANALYSIS (AA)

- We will further aim to develop large-scale programmes involving members of the Applied Analysis group, that will emphasize the strength and international relevance of the research carried out in the analysis of complex materials.
- A. Zarnescu will co-organize (jointly with L. Nguyen, X. Lamy and A. Rueland) a trimester programme at the Hausdorff Institute in Bonn in the first half of 2023: Mathematics for Complex Materials https://www.him.uni-bonn.de/programs/future-programs/future-trimester-programs/complex-materials/description/

HARMONIC ANALYSIS (HA)

- To apply in the call of 2022 for a ITN project coordinated from BCAM. The topic will be at the interplay between HA and InvProb. The external points of the net are expected to be based at Finland with Lauri Oksanen, France with Yavar Kian, Germany with Angkana Rüland and Italy with Giovanni Alberti.

AREA: DATA SCIENCE & ARTIFICIAL INTELLIGENCE (DS&AI)

MACHINE LEARNING (ML)

- Strengthen our current collaboration with international partners. In this sense we plan to increase the organization of joint activities, analyse the options for co-supervising students and prepare and submit joint projects.
- We plan to ask, during this period for a FET Pathfinder project and also an ERC grant.
- We will also plan to reinforce our international position in relation with the Artificial Intelligence European network ELLIS. This is the network where our activity in the machine learning area matches the best.
- We will continue our fruitful collaboration with Prof. Moe Win from the Massachusetts Institute of Technology and Prof. Yuan Shen from Tsinghua University. In particular, we will continue publishing papers with those researchers and carrying out frequent visits to their universities. In addition, under the agreement signed with Tsinghua University we will receive one student from China in 2022 and two PhD students in the ML area at BCAM will carry out a research stay at Tsinghua before 2023.
- We will organize the workshop “Mathematics and Machine Learning, new interplays and opportunities” in which around 15 international and highly recognized researchers in the field with explore the rich relation between machine learning and classic fields of mathematics.

APPLIED STATISTICS (AS)

- For the next period, internationalization is one of the main goals of the group.
- The group has several collaborators at international levels based on individual contacts, but the aim is to establish stronger links with experts in the field and especially multidisciplinary collaborators to connect advanced research in Statistics with other scientific fields (current collaborators are based in the UK, Germany, France, Saudi Arabia or Chile). During 2022, Dr Sonali Das (University of Pretoria, South Africa) will visit BCAM AS research line under the Programme "Fundación Mujeres x Africa", to collaborate in topics related to Functional Data Analysis and Climate Change.
- In this direction, the group will seek potential research grants and networks with international Universities and Research Centres.
- The organization of the IWSM 2021 has attracted the attention of the scientific community in the field of statistical modeling to BCAM, as a young centre with great potential in general in field of Data Science.

COMBINATORIAL OPTIMIZATION (CO)

In this case we plan to carry out the following activities:

- We will start collaboration with the Politecnico di Milano (Italy) via the research group lead by Emanuele Martelli.
- We expect to collaborate with Maria Elena Bruni of the University of Calabria, Italy, in the research line of Emergency Services Location.
- It is expected to continue a collaboration with Dr. Qiuzhen Lin from Shenzhen University (in China), and with Prof. Ruhul Sarker from the University of New South Wales (in Australia).
- Continue our current leader positions in the IEEE such as: EiC of the IEEE Trans. on Evolutionary Computation and being part of other committees within the Computational Intelligence Society.

C. VISITING RESEARCHERS AND LEADERSHIP

BCAM has made it a priority the attracting and fostering potential of highly qualified researchers to work on fundamental aspects and applications of mathematics high quality, multidisciplinary and computational algorithms for the development of efficient new computational models, computer codes, and simulations. **BCAM mobility and training programmes** (Visiting Fellows, Internships & Visitors) are a clear example of actions that aim to foster internationalisation.

As part of internationalisation activities, BCAM not only fosters the incoming of students but also facilitates to make **visits to international research institutions**. In addition to the planned stays abroad of the senior researchers, many of the junior researchers at BCAM will apply for grants to visit international universities and/or excellence research centres. These grants are designed to strengthen the internationalization of scientific training and technical capacity by incorporating the awarded student into an outstanding research group for some months. Therefore, one of the main objectives of BCAM for the near future is to apply for Marie Curie actions within Horizon Europe framework through **MSCA Doctoral Networks, Staff Exchanges and COFUND** in order to develop our research plan in collaboration with institutions of member states and third countries. This type of programmes constitutes also an excellent platform to connect BCAM to the non-academic sector.

3.4 Training activities

This section should include (Max. 1 page):
Training activities for researchers and support staff in all the different career stages, designed to recruit, strengthen and retain the talent and personnel.

As a continuation of the activities described in section 2.4, we will continue in the framework of the HR logo training activities. On the one hand, training activities addressed for young researchers include internships, PhD students and postdoctoral trainees. On the other hand, training activities addressed for computational and soft skills, such us gender balance, mentoring and career stages, etc.

We will keep receiving students within the internship programme, spending short periods at BCAM, typically three months, in the framework of the training programmes they develop in their institutions of origin. Often,

this programme is a source of good future Ph. D. students at BCAM, since some of the best internships are recruited later.

In the same way, we will also continue within the PhD programme, participating mainly in the Mathematics and Statistics PhD Programme at UPV/EHU in Leioa, at the School of Engineering in Bilbao and the PhD programme in Computer Science at UPV/EHU in San Sebastián. Internally, we are strengthening the management structure of the PhD program at BCAM with the objective to support our PhD students in the management of their thesis, with the following actions: 1) We launched the BCAM PhD office, as a resource to help our PhD Students with the administrative issues, managed by the administrative staff. 2) We formalized the BCAM PhD Committee, led by Prof. Zarnescu and Prof. Vega, this committee is responsible for ensuring the correct progress of the student during his/her thesis. 3) We created the BCAM PhD Representative, with the objective to represent the common problems that may be found by the PhD Students, and acts as an intermediary between those students and the BCAM PhD Committee and BCAM administrative staff, currently led by Tamara Dancheva. 4) Recently we launched the annual report, with the objective to identify deviations that may affect the correct development of the thesis and definition of contingency actions; we are currently processing the information received. These actions will be revised in 2022 and will be improved, if needed. Finally, as a part of the reinforcement of the PhD program, we launched the "extra 3-months" programme so that all PhD grantees finalize the PhD project thesis, eligible to be co-funded by other grants and adaptable to "extra 6-months" in case of a 3-year contract.

In the framework of HR Logo, we recently launched a survey with the objective to gather feedback from PhD students regarding the management of the BCAM PhD Program or any other issue associated with the supervision of PhD students at BCAM, and this is the main result.

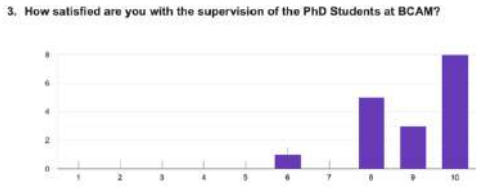


Figure 43. Satisfaction rate of the supervision of the PhD Students in BCAM

The postdoctoral market is by now quite dynamic. The limited number of permanent positions that Europe offers is pushing many young fellows to apply for postdoctoral positions. Furthermore, a postdoctoral period after the PhD Thesis and before getting into university duties, in the spirit of the American model, is suitable for a complete training and is better acknowledged. Profs. E. Akhmatsakaya and L. Vega are in charge of the BCAM Postdoc Committee.

We will continue the Mentoring Program, addressed to support our young researchers during the PhD thesis or postdoctoral trainees in their research career and to solve problems motivated by cultural change and scientific experience.

Apart from the activities for the predoctoral and postdoctoral positions, we will have different training activities that will help to encourage and reinforce the knowledge for our researches such us:

1. BCAM & UPV/EHU Courses are recognized by the UPV/EHU within the Master on Modelling and Research in Mathematics, Statistics and Computing.
2. BCAM also will collaborate in the Master in Offshore Renewable Energy.
3. BCAM Courses in Applied Mathematics for postgraduate students and researchers.
4. BCAM holds a series of training courses on advanced aspects of applied, computational and pure mathematics. They are mainly aimed at training master and doctoral students.
5. We will continue with the PhD Seminars organized by PhD Students from BCAM and UPV/EHU
6. Training through seminars, workshops and conferences: Training is complemented with the attendance to our regular activities that can be summarized as follows: (a) BCAM Postgraduate Courses, (b) Basque Colloquium on Mathematics and its Applications, (c) Seminars, (d) Weekly Seminar on Numerical Analysis, (e) Mathematics-Industry Workshops, (f) Workshops and Summer Schools, (g) Activity Groups and (h) Doctoral Student Seminars.
7. Transfer of Knowledge: BCAM will organise courses oriented to transfer knowledge in different topics of applied mathematics such as R courses, Machine Learning, and cybersecurity

Finally, as a part of the HR Logo actions, BCAM actively promotes training on non-scientific/technical skills, since it is beneficial not only for researchers and for administrative staff, but also for the centre as a whole. In this sense, BCAM is carrying out the Human Resources Management Improvement ("Wellbeing@BCAM") initiative and, as a part of it, there has been defined the BCAM Training Programme for the course 2021-2022 that will be yearly updated in the next period 2022-2025. This Training Programme will be composed by: Basque and Spanish

conversation classes, Gender Balance, Leadership, Effective Communication and Teamwork, Efficient Time Management, and Interpersonal Conflict Management.

3.5 Gender equality plan

This section should include (Max. 2 pages):
Include an analysis of the personnel of the centre, by gender and category. Define any measure intended to promote gender equality in the centre, including activities either organised or participated.

The publication of the report "Científicas en Cifras 2021" published by the Ministry of Science and Innovation, highlights several important points regarding the participation of women in the world of Research. The figures indicate that Spain currently has 95,000 female researchers, which represents 41% of the total research personnel. It is important to highlight that 56% are women in universities, however, in areas such as engineering and technology they represent 25.6% and only 13.9% are interested in science and technology.

The main problem, according to the report, is that in the research career, the low representation of women in the highest rank category (Grade A) continues to be outstanding, while there is gender balance in the other research categories (grades B, C and D). This indicates clear vertical gender segregation, also known as the "glass ceiling". Female researchers face various obstacles: conciliation, precariousness, mobility, gender bias and sexist environments. For this reason, many female researchers fall by the wayside as their research career progresses. Even so, it is important to highlight that in the Global Gender Gap Report ranking for 2021, Spain ranks 14th, compared to 27th place in 2017, which shows a notable improvement. There is progress in terms of decreasing the Gender Gap, but it is slow, and only equality policies will accelerate the changes. Attracting, retaining and supporting female talent in R&D is key to excellent, diverse and quality science.
This gap has also been present in BCAM over the last few years, and although the trend indicates that the female presence is very slightly equalizing, this presence does decrease throughout the research career.

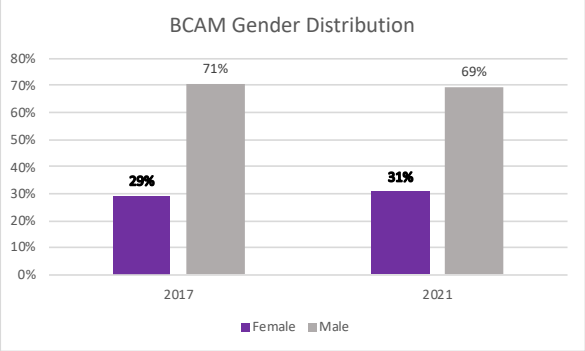


Figure 44. BCAM Gender Distribution years 2017 and 2021

Category	Female	Male	Total	Female %
STAFF	8	2	10	80%
PhD Student	13	20	33	39%
Postdoc Fellow	8	39	47	17%
BCAM Researcher	6	10	16	38%
Group Leader	1	7	8	13%
General Manager	1		1	100%
Scientific Director		1	1	0%
Total	37	78	115	32%

Table 11. BCAM gender distribution by category

To continue reducing the gap between women and men, the Equality Plan will be renewed for 3 years, as has been the case up to now. This equality plan will include strategic objectives and activities to be carried out to achieve these objectives.

Actions will continue to be taken to promote equality between women and men and to provide visibility, such as the following:

- MatEsElla Program: Initiative between the Spanish Royal Mathematical Society (RSME) and the Spanish Association of Executives and Advisors (EJE&CON) to promote scientific or entrepreneurial careers among women undergraduate or master's degree students in STEM discipline.
- 11F Initiative: Talks organized by the 11F platform, the Day of Women and Girl in science.
- Training courses: Courses given by external companies to promote and train researchers on the existing inequalities between men and women in research careers.
- EWM (European Women in Mathematics): international association of women working in the field of mathematics in Europe. This organization aims to promote the participation of European women in mathematics through different activities such as talks, conferences, mentorships... to strengthen the role of women in the field of mathematics.
- Commission for Equality in SOMMA Centres: The Severo Ochoa Centres and Maria de Maeztu Units, promote the Spanish Excellence in research. They are taking actions to encourage gender equality in which BCAM will continue collaborating.

3.6 Strategy for dissemination and transfer of knowledge, outreach activities

This section should include (Max. 2 pages):
Technology surveillance, knowledge transfer activities to be carried out. Include all the measures and actions intended to be implemented for research communication and dissemination, at a scientific level and to the general public. Detail the actions to be carried out.

A. KNOWLEDGE TRANSFER

BCAM is very active in a broad range of activities to support mutually beneficial collaborations between universities, businesses and the public sector. It is all about the transfer of tangible and intellectual property, expertise, learning and skills between academia and the non-academic community. For academics, knowledge transfer can be a way of gaining new perspectives on possible directions and approaches for research. Thus, for the period 2022-2025 we are planning to establish a **Knowledge Transfer Committee** at BCAM to address and monitor six different types of activities:

1. KT Partnerships to consolidate agreements with large companies that can sponsor activities at BCAM related to the industrial sector, health, technology, University and Public Administrations. National or international networks of Industrial Mathematics (EU-MATHS-IN, ECMI) could also fit here.
2. KT Innovation to provide advice and support for SMEs, start-ups and entrepreneurs. BCAM also supports the creation of new companies. Moreover, in this area a strategy will be defined to grant new patents and other IPR, such as software platforms/applications developed within the computational framework and their exploitation.
3. KT Dissemination to organize joint workshops with industry, events with schools and institutes, promote STEAM education, Pi Day activities, dissemination blogs, press publications, etc.
4. KT Labs to create new joint research labs and establish international BCAM classrooms with the aim of promoting the exchange of researchers, co-authored publications, co-supervised doctoral theses and the joint development of transfer activities with other technology centres and industry in general.
5. KT Training to offer BCAM courses for companies or research centres, and arrange industrial internships.
6. KT Unit to identify and complete successfully R&D projects with companies on demand.

See more details of BCAM strategy for transfer of knowledge activities in section 3.7.

B. DISSEMINATION ACTIVITIES

The main objective of the communication plan is to transmit the work of the centre. To do so, we will focus on communicating the work that researchers are doing and the results obtained and we will make an effort to show the good side of mathematics to the general public. In addition, we will emphasize Gender Balance, in order to promote STEM careers among girls and women.

Our targets audience of communication plan is divided into two groups: scientific public and general public. Furthermore, we can define these two groups by smaller ones to be able to target some of the actions more concretely, bearing in mind that not all actions are aimed at all groups:

SCIENTIFIC PUBLIC	**GENERAL PUBLIC**
Scientists and Researchers	Public Administration
STEM Students	Companies (final users)
Others Research Centres	Educational Centres (Schools, High Schools, etc.)
Specialized companies	Media (newspapers, journalists, etc.)
	Non-specialized people

In order to reach the audiences mentioned above, we will focus on dividing the actions into two groups: One-way exchange and Two-way exchange:

One-way exchange	**Two-ways exchange**
Centre website	Use of social media
Published news on the website	Scientific activities
Published interviews of researchers	Visits to the centre
Monthly Newsletters	Participation in scientific and dissemination events
Publications in media	
Centre Catalogue	

The aim of the BCAM communication plan in the next period is to continue promoting the activities divided into different targets:

1. Dissemination for scientific public: To show the work carried out at the centre and the results obtained, in order to attract talent and achieve collaborations with other research centres and companies.
    a. Specialized workshops, seminars and courses for researchers, to which we want to add a BCAM-Severo Ochoa course, with internationally recognized speakers
    b. Dissemination of different projects that are being carried out to attract talent to the centre using different social networking tools, such as, Twitter, LinkedIn and the BCAM News webpage.
    c. Joint dissemination activities, in order to create synergies between different research lines to show the joint work and to show that collaboration between different groups is necessary to carry out some research and that it allows widening the scope of it.
2. Dissemination for general public: Demonstrate what mathematics can be used for and go beyond the scientific field, and in this way inform about the projects that researchers are working on and their applications
    a. Interviews of BCAM researchers explaining their work to show what we do at BCAM.
    b. Social Media campaign “Without mathematics this could not exist”: To show how mathematics affects our environment and thus be able to relate it to different projects in which we work. In addition, we could collaborate with mathematicians who work specifically in dissemination.
    c. Problems competition for students to promote mathematics and relate those problems with BCAM projects.
    d. Participation in dissemination events, such as, Mathematics in everyday life, Pi Day activities and Pint of Science.
    e. Participated in activities for the promotion of scientific vocations, such as, First Lego League and Steam Sare initiatives.
3. Dissemination of Gender Balance: to promote women's careers in science and to raise awareness of the work of women scientists

a. Newsletter with information concerning the women in the centre
b. Talks from senior scientists to junior scientists and thus pass on the knowledge of the scientific world from experienced women to young women who are just starting.
c. Collaboration with Deusto University and University of Basque Country to prepare a "Gender Days" where, via different activities, scientist women will share their experience in science and motivate young women to join STEM careers.
d. Participation in activities to support women in science sucha as 11F, Inspira Steam and MatEsElla.

We want to consolidate our collaboration with the Chair of Scientific Culture of the UPV/EHU. This initiative has different sections with different purposes to raise knowledge about science reaching different audiences in different formats.
To conclude, BCAM's new website will be launched to develop the centre's communication and to renew the image of it. Apart from that, concerning the centre's dissemination material, a new catalogue is going to be drawn up to show the current scheme of Research Areas and the most recent achievements of the centre.

C. OPEN ACCESS
Finally, we must point out that BCAM is the first BERC centre that has set up (in 2016) an institutional repository compliant with Recolecta and the European Open Access publishing requirements (OpenAire) and we will continue in this way.
This repository is called BIRD - BCAM Institutional Repository Data and substitutes the previous system by which all publications were published at the BCAM webpage. We also adopted our institutional open-access policy, available at http://bit.ly/2zQHpRI, aligned with the Budapest Open Access Initiative, H2020 and the Spanish Act 14/2011. In 2021, we updated BIRD with two important tools: on the one hand with data repository and on the other hand, we synchronized BIRD with Scopus and all metadata will be automatically filled, reducing drastically the submission time.

3.7 Other activities

This section should include (Max. 3 pages):
Include any other activity to be developed during the period 2022-2025 that should be considered for the evaluation of the centre.

Apart from the activities already described in this section, it would be important to consider the following strategic actions for the next period 2022-2025:

Figure 45. BCAM's actions for the next period 2022-2025

A. EXPLORE FUTURE POTENTIAL FOR KNOWLEDGE TRANSFER & COLLABORATIONS

There are three research areas at BCAM (Computational Mathematics, Mathematical Modelling with Multidisciplinary Applications, and Data Science) that have the highest opportunities to transfer knowledge to society and which assume an important role of this responsibility. Nevertheless, for the period 2022-2025, we aim to give one step forward in this strategy, so, all research lines at BCAM have plans to carry out technology surveillance and knowledge transfer activities.

AREA: COMPUTATIONAL MATHEMATICS (CM)

SIMULATION OF WAVE PROPAGATION (SWIP)

We will participate in leading industrial events. We will organize periodic meetings with current and potential industrial partners to present our methods and results. These interactions will provide us with insights into what products may be commercially valuable and will generate a waiting audience for our products. We will explore new markets in Latin America, where we coordinate the H2020 MATHROCKS Project. We will also participate at top conferences, such as Siggraph, SPM, and GMP, and will organize at least one mini symposium with involvement from our industrial partners.

CFD MODELLING AND SIMULATION (CFDMS)

Besides more standard applications, we will explore the possibility to apply CFD to new technological areas.

- In particular, in connection to polymeric fluids and complex liquids, Leartiker could be a possible partner within the KTU.
- In the context of "pedestrian flow dynamics" we will explore the possibility to interact with the Athletic Football Club and Bilbao Basket.
- In connection to DST fluids for sport-protective applications, another possibility could be Spiuk. We will explore possible interests/links in this direction.

AREA: MATHEMATICAL MODELLING WITH MULTIDISCIPLINARY APPLICATIONS (M3A)

MODELLING AND SIMULATION IN LIFE AND MATERIAL SCIENCES (MSLMS)

We plan to implement the following actions: joint PhD and postdoctoral researchers with Basque and international entities; applications for external international, national and regional funding together with collaborators from our research networks; organization/participation of/in activities within MATH-IN, EU-MATHS-IN; (co-) development of open source software packages; providing access, training, and consultancy to potential external users (academic and industrial); and research visits exchange.

MATHEMATICAL AND THEORETICAL BIOLOGY (MTB)

Built on excellent research, an effective knowledge transfer with public health workers, including stakeholders, and external collaborators, will be achieved through practical, technical and personal skills development, via collaborative workshops, to promote a culture and environment where the work of modelers is clear, coherent and accurate enough to be implemented by the policymakers. Joint student supervision, project proposals and publications are anticipated.

MATHEMATICAL, COMPUTATIONAL AND EXPERIMENTAL NEUROSCIENCE (MCEN)

Project 1 (in partnership with Achucarro Neuroscience Centre and Inria) will transfer (in the short term 2022-2025) novel mathematical insights to in-vitro/in-vivo experiments. A final deep-brain stimulator is a long-term project for which interactions with clinicians will be crucial. Project 2 (long term), but in the short-term new mathematical methods will be transferred to drug discovery. Project 3 (involving IBM, Inria and Ruhr University Bochum) will transfer our mathematical insights to an industrial prototype (hopefully within 2022-2025).

AREA: MATHEMATICAL PHYSICS (MP)

QUANTUM MECHANICS (QM)

The Quantum Mechanics research line belongs to fundamental sciences and no direct reward in terms of economic benefits, well-being of population, technological development or productivity is expected. However, we are developing a new interdisciplinary research line between quantum mechanics and neurosciences. Therefore, we expect a significant transfer of knowledge between these research fields.

STATISTICAL PHYSICS (SP)

Knowledge transfer is expected from the collaboration with the European consortium on forest fires, see section 2.3. The activity will focus on providing a contribution based on statistical approaches to the development of platform for fire propagation. Moreover, the collaborations with the group SINUMCC, USAL, and with V. Egorova, University of Cantabria, are also expected to lead to deliverables for knowledge transfer through software routine for operation codes for fire simulation.

AREA: ANALYSIS OF PARTIAL DIFERENTIAL EQUATIONS (APDE)

LINEAR AND NON-LINEAR WAVES (WAVE)

We plan to do physical experiments in collaboration with the group of W. Irvine in U. of Chicago, USA. For funding this project, we will apply for a PoC (ERC) in the next call.

APPLIED ANALYSIS (AA)

The main aim in this direction will be to check the experimental relevance of the theoretical analysis resulting from the design studies previously developed.
The common feature of the analytical design studies is the presence of a small parameter in the mathematical models. Its physical interpretation is that of suitably small length scale.
The level of smallness can only be determined through experiments. We will focus on colloidal inclusions in a liquid crystal environment.

HARMONIC ANALYSIS (HA)

During the COVID-19 pandemic we have seen the need of establishing protocols to prevent the spreading of the virus SARS-CoV-2 virus in public rooms with infected individuals. Thus, we will propose and analyse a ventilation control problem consisting of ensuring that the concentration of a certain substance produced in a given place remains under a safe value by keeping an appropriate ventilation.

AREA: DATA SCIENCE & ARTIFICIAL INTELLIGENCE (DS&AI)

MACHINE LEARNING (ML)

In terms of transfer of knowledge, we plan to continue with the activities carried out in the previous period, where we combined the contribution to joint projects with technological centres, our participation in the Basque Cybersecurity Centre and the Basque Artificial Intelligence Center, and the supervision of industrial PhDs, together to address real industrial problems.

APPLIED STATISTICS (AS)

The research line in AS has contributed to the centre in several ways, including training courses, research projects with companies, and dissemination activities. The challenge for the next period is to promote industrial or joint PhD's with the existing collaborations with other research institutions.

COMBINATORIAL OPTIMIZATION (CO)

In terms of transfer of knowledge, we plan to continue with the activities carried out in the previous period trying to collaborate with different institutions in the solution of different optimization problems.

Finally, as part of the strategy in the period 2022-2025, we aim to carry out an internal process of rethinking the current concept of Knowledge Transfer at BCAM and the structure of the KTU.

B. PROMOTE SYNERGIES AMONG RESEARCH LINES

As explained along this proposal, one of the key aspects that make BCAM a reference centre in its field is the huge potential that can emerge of the interaction among its research lines. So, we will continue developing new strategies so as to generate these common research spaces.

C. PROMOTE JOINT RESEARCH LABS & “AULAS”

It is worth to point out that the promotion of joint research labs both with nearby and international institutions will be one of the axes of BCAM internationalization strategy. Other already launched initiatives such as the LTC TRANSMATH will also play an important role in this new period. Additionally, the creation of joint research spaces

for young students is also an important aspect of BCAM strategy, so we will continue exploring the creation of "University Aulas" not only at a local, but also national and international level, so as to foster BCAM training strategy.

D. CREATE A EUROPEAN PROJECTS OFFICE AT BCAM

BCAM administrative services are in continuous improvement, and among the actions identified for the next period, it is worth to point out that we aim to create a European projects office at BCAM that can answer researchers needs in this field and promote training.

E. EXPLORE NEW RESEARCH COLLABORATIONS WITH BASQUE INSTITUTIONS IN THE FRAMEWORK OF THE IKUR STRATEGY

BCAM aims to become a key stakeholder in the implementation of the IKUR strategy due to the multiple interactions of its research with other centres. In fact, BCAM has already ongoing relationships with most of these centres, that aim to be further developed. Special emphasis will be given to the collaborations in the field of biosciences, due to the strategic Mathematical Modelling Applied to health project raised from the COVID-19 Basque Modelling Task Force.

F. REINFORCE BCAM EXPERIMENTAL LABS

The recently launched NEUROMATH Lab, together with the HPC Lab & the Artificial Intelligence and Cybersecurity Labs are one of the key tools so as to promote the research relationships of the most applied research lines at BCAM with other experimental centres, so in the next period 2022-2025 it is expected to reinforce those three labs by acquiring new equipment and required resources.

3.8 Time planning

This section should include (Max. 2 pages):
Time planning for the deployment of the strategies and activities

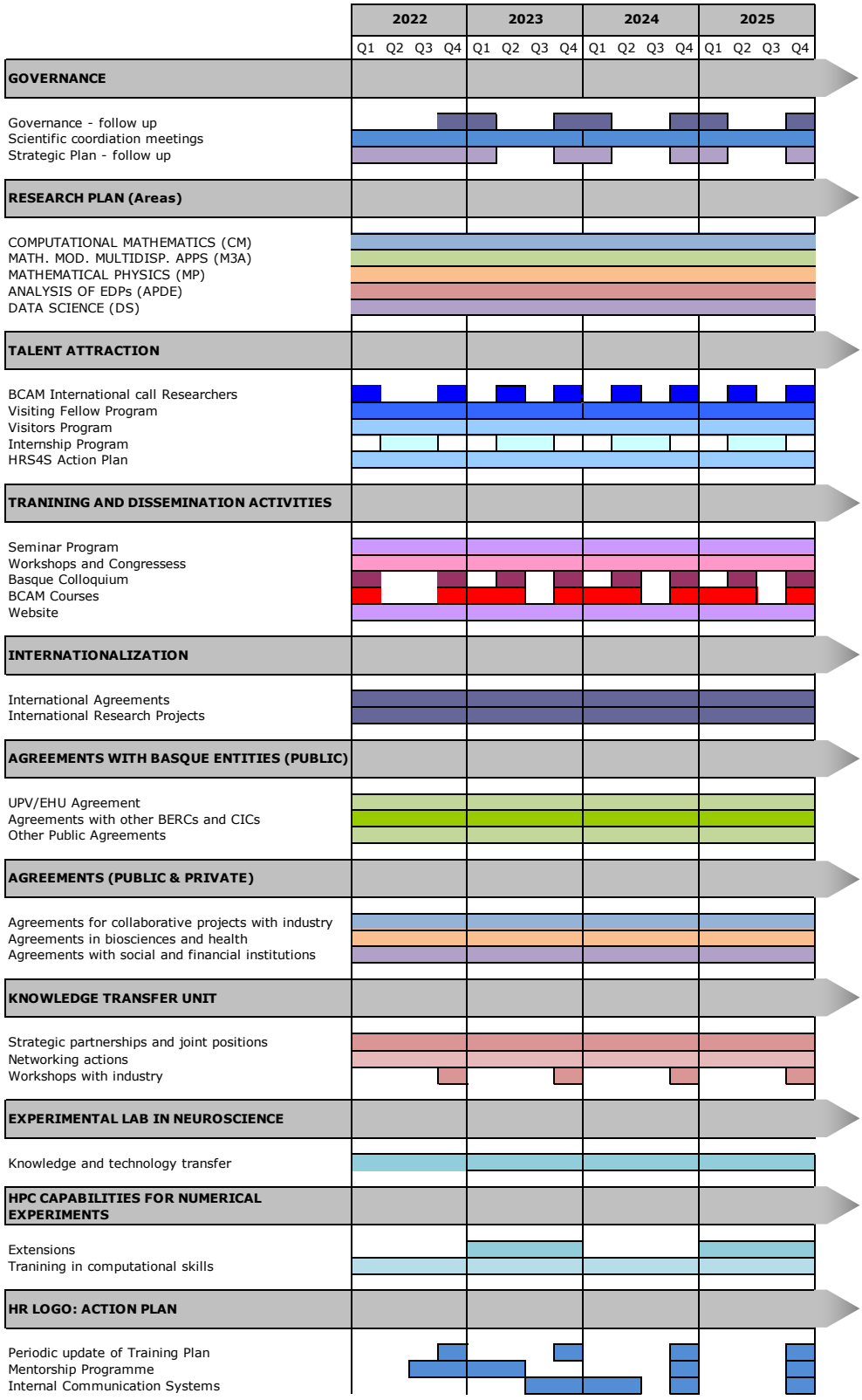


Figure 46. Time planning of the deployment of the strategies and activities

3.9 Financial planning: quantification and economic justification

3.9.1 Budget

This section should include (Max. 3 pages):
Include information on the budget foreseen for 2022-2025. All the expenses must be justified by means of a detailed description of its specific destination and a study of the financial sources expected to cover those expenses.
Include the table supplied in the Excel file.

BCAM's efforts to attract funding have been very successful in the last period, and the centre has managed to **increase its budget by 30% in the period 2018-2021.**The period 2022-2025 will be a **consolidation period for BCAM in which the growth rate will change its trend until a stable personnel and premises structure is achieved** (expected by the end of 2025). At this point, the support from the Basque Government through the BERC Program and other strategic initiatives such as IKUR, are very important to provide the required stability. We must point out that the budget for 2022-2025 is elaborated under the assumption that the Severo Ochoa accreditation BCAM must apply for in 2021 may not be successful, since it would be quite difficult to obtain this accreditation for the third time in a row.

So as to elaborate this budget, we have made the corresponding projections in the following concepts:

- **Personnel:** In this concept we must take into account the exceptional situation derived from COVID-19, which has significantly increased personnel resources in 2020-2021, since the funding initially aimed for BCAM Programs (visitors, trips, scientific activities, etc.) has been devoted to personnel resources. This trend will continue in 2022, but we expect the personnel cost to readapt to the BCAM cost structure from 2023 on. Additionally, the estimation of the cost corresponding to the personnel previewed evolution (described in section 3.2.C) is included, taking into account not only personnel hired by BCAM, but also the cofunding to institutions such as Ikerbasque and joint positions. The following table summarizes these costs and the trend evolution. It must be taken into account that so as to calculate the annual personnel costs the personnel is expressed in FTE (Full Time Equivalent), which is why the amounts are different from the personnel evolution table included in section 3.2.C that is expressed in terms of number of researchers by the end of the corresponding year:

						Personnel variation - baseline FTE 2021				Personnel costs evolution			
	2021	2022	2023	2024	2025	2022	2023	2024	2025	2022	2023	2024	2025
Scientific Director + PI	24	25	25	25	25	1	1	1	1	285.000 €	285.000 €	285.000 €	285.000 €
Postdoc (senior)	25	24	22	20	19	-1	-3	-5	-6	982.824 €	900.922 €	819.020 €	778.069 €
Postdoc (junior)	30	32	28	25	22	2	-2	-5	-8	1.225.888 €	1.072.652 €	957.725 €	842.798 €
PhD	31	33	31	31	30	2	0	0	-1	828.957 €	778.717 €	778.717 €	753.597 €
Administrative Staff & IT	11	11	12	12	10	0	1	1	-1	470.000 €	480.000 €	480.000 €	420.000 €
KTU Research Technicians	21	24	21	19	14	3	0	-2	-7	602.376 €	527.079 €	476.881 €	351.386 €
TOTAL	**142**	**149**	**139**	**132**	**120**	**7**	**-3**	**-10**	**-22**	**4.395.045 €**	**4.044.370 €**	**3.797.343 €**	**3.430.850 €**

Table 12. BCAM personnel costs

Figure 47. Personnel cost and trend evolution 2022-2025

- **Other costs:** In this concept we have projected current costs taking into account renting and maintenance costs of the new premises and the natural increase in BCAM Programmes and external services.
- **Investments:** In the next period we plan to continue making investments to improve BCAM capabilities so as to provide researchers the resources required to carry out excellence research, both in terms of premises and IT resources. Additionally, the equipment for the experimental laboratory on Neurosciences, as well as the required equipment to adapt BCAM HPC capabilities to the computational needs required for numerical experiments, is also considered. Regarding general IT infrastructure, the following expenses are previewed:

2022	2023	2024	2025
▪ New Secure Identity Tool ▪ New User Account Manager ▪ Storage Upgrade ▪ Upgrade HPC capabilities to the computational needs ▪ Maintenance Services ▪ Standard Equipment for Researchers	▪ Renewal of interconnection switches ▪ Renewal of Firewalls ▪ Maintenance Services ▪ Standard Equipment for Researchers	▪ Renewal of Wireless Infrastructure ▪ Maintenance Services ▪ Standard Equipment for Researchers	▪ Renewal of UPS service ▪ Upgrade to 10Gb Networking ▪ Maintenance Services ▪ Standard Equipment for Researchers

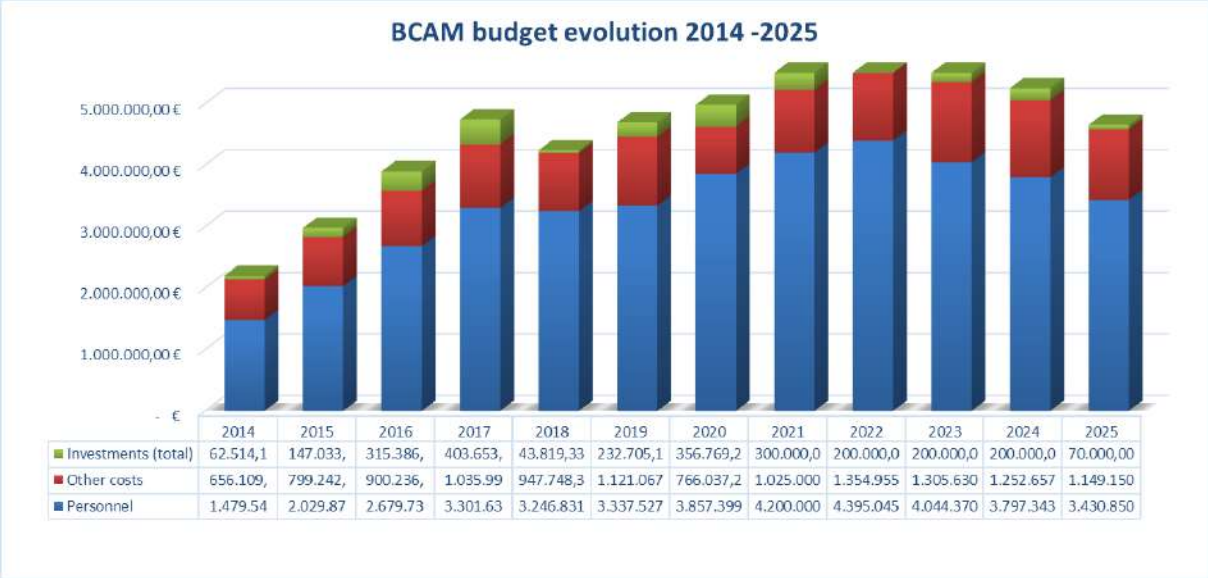
**Standard equipment includes laptop or workstation, external display and accessories.*

Taking into account the above details, the budget expected for the period 2022-2025 amounts to 21,4 M€, with the following annual cost distribution:

BUDGET	2022	%	2023	%	2024	%	2025	%	TOTAL 2022-2025	%
Personnel	4.395.045,00	73,87%	4.044.370,00	72,87%	3.797.343,00	72,33%	3.430.850,00	73,78%	**15.667.608,00**	**73,21%**
Other costs	1.354.955,00	22,77%	1.305.630,00	23,52%	1.252.657,00	23,86%	1.149.150,00	24,71%	**5.062.392,00**	**23,66%**
Investments (total)	200.000,00	3,36%	200.000,00	3,60%	200.000,00	3,81%	70.000,00	1,51%	**670.000,00**	**3,13%**
TOTAL BUDGET	**5.950.000,00**	**100,00%**	**5.550.000,00**	**100,00%**	**5.250.000,00**	**100,00%**	**4.650.000,00**	**100,00%**	**21.400.000,00**	**100,00%**

Table 13. BCAM annual cost distribution for period 2022-2025

As stated throughout this proposal, after a ramp-up period in which the BCAM budget has more than doubled, this 2022-2025 will be a consolidation period in which the budget growth rate will change its trend, until to reaching a stable structure expected by the end of the period. In summary, the budget evolution from 2014 to 2025 is shown below:



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investments (total)	62.514,1	147.033,	315.386,	403.653,	43.819,33	232.705,1	356.769,2	300.000,0	200.000,0	200.000,0	200.000,0	70.000,00
Other costs	656.109,	799.242,	900.236,	1.035.99	947.748,3	1.121.067	766.037,2	1.025.000	1.354.955	1.305.630	1.252.657	1.149.150
Personnel	1.479.54	2.029.87	2.679.73	3.301.63	3.246.831	3.337.527	3.857.399	4.200.000	4.395.045	4.044.370	3.797.343	3.430.850

Figure 48: BCAM budget evolution 2022-2025

3.9.2 Incomes

This section should include (Max. 3 pages):
Detail of all the financial sources expected to cover the budget foreseen for the period 2022-2025.
Justify the information provided and include the table supplied in the Excel file.

In the next period 2022-2025, incomes are expected to increase by approximately 10%. The distribution of expected incomes in the period 2022-2025 is shown in the following table:

INCOMES (BERC only)	2022	%	2023	%	2024	%	2025	%	TOTAL	%
PUBLIC FUNDING	**5.654.800,00**	**95,04%**	**5.286.000,00**	**95,24%**	**5.075.500,00**	**96,68%**	**4.498.000,00**	**96,73%**	**20.514.300,00**	**95,86%**
BERC programme	1.500.000,00	25,21%	1.500.000,00	27,03%	1.500.000,00	28,57%	1.500.000,00	32,26%	**6.000.000,00**	**28,04%**
UPV/EHU funding	0,00	0,00%	0,00	0,00%	0,00	0,00%	0,00	0,00%	**0,00**	**0,00%**
Other Basque funding	1.858.800,00	31,24%	1.931.000,00	34,79%	1.825.000,00	34,76%	1.580.000,00	33,98%	**7.194.800,00**	**33,62%**
CSIC funding	0,00	0,00%	0,00	0,00%	0,00	0,00%	0,00	0,00%	**0,00**	**0,00%**
Other Spanish funding	1.700.000,00	28,57%	1.104.500,00	19,90%	938.000,00	17,87%	829.000,00	17,83%	**4.571.500,00**	**21,36%**
EU & International funding	581.000,00	9,76%	710.500,00	12,80%	772.500,00	14,71%	569.000,00	12,24%	**2.633.000,00**	**12,30%**
Other funding	15.000,00	0,25%	40.000,00	0,72%	40.000,00	0,76%	20.000,00	0,43%	**115.000,00**	**0,54%**
PRIVATE FUNDING	**295.200,00**	**4,96%**	**264.000,00**	**4,76%**	**174.500,00**	**3,32%**	**152.000,00**	**3,27%**	**885.700,00**	**4,14%**
R+D contracts	20.000,00	0,34%	30.000,00	0,54%	30.000,00	0,57%	30.000,00	0,65%	**110.000,00**	**0,51%**
patronage	5.000,00	0,08%	5.000,00	0,09%	5.000,00	0,10%	5.000,00	0,11%	**20.000,00**	**0,09%**
donations	0,00	0,00%	0,00	0,00%	0,00	0,00%	0,00	0,00%	**0,00**	**0,00%**
returns via patents, licencing…	0,00	0,00%	0,00	0,00%	0,00	0,00%	0,00	0,00%	**0,00**	**0,00%**
other private funding (R&D grants from private foundations)	270.200,00	4,54%	229.000,00	4,13%	139.500,00	2,66%	117.000,00	2,52%	**755.700,00**	**3,53%**
TOTAL INCOME (must match total budget)	**5.950.000,00**	**100,00%**	**5.550.000,00**	**100,00%**	**5.250.000,00**	**100,00%**	**4.650.000,00**	**100,00%**	**21.400.000,00**	**100,00%**

Table 14. Distribution of expected incomes for period 2022-2025

The distribution of expected incomes by funding source in the period 2022-2025 is shown in the following figure:

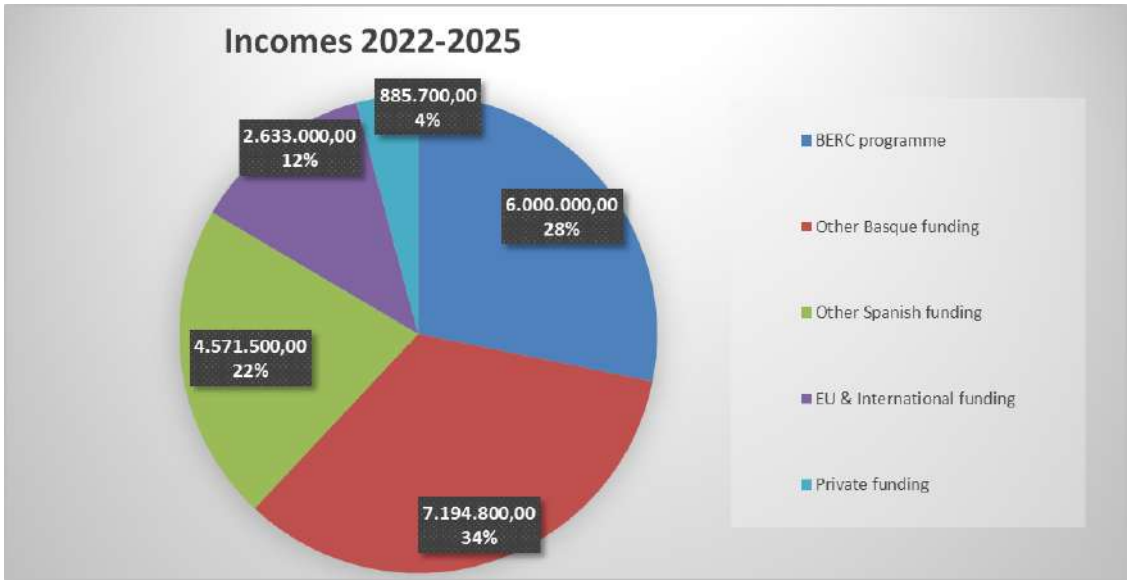


Figure 49. Distribution of expected incomes in the period 2022-2025

As it can be seen in the figure above, the contribution requested from the BERC Programme will slightly increase in percentage (from 25% to 28%) in relation to the last period due to the new dimension of the centre and the increase in the basal funding required. In the next period, aligned with the strategy described in the present proposal, we aim to continue seeking for funding from other regional, international and private sources, with a special emphasis on the Basque Government IKUR strategy, H2020 and private funding resources.

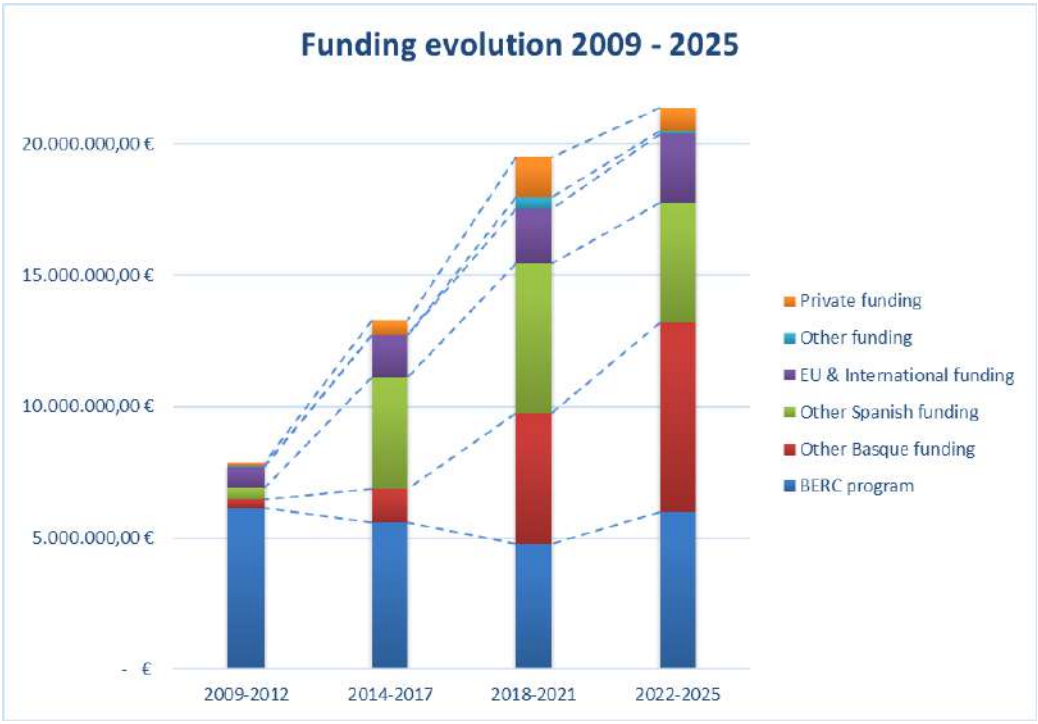


Figure 50. Funding evolution in period 2009-2025

The expected yearly incomes distribution for the next period is the following:

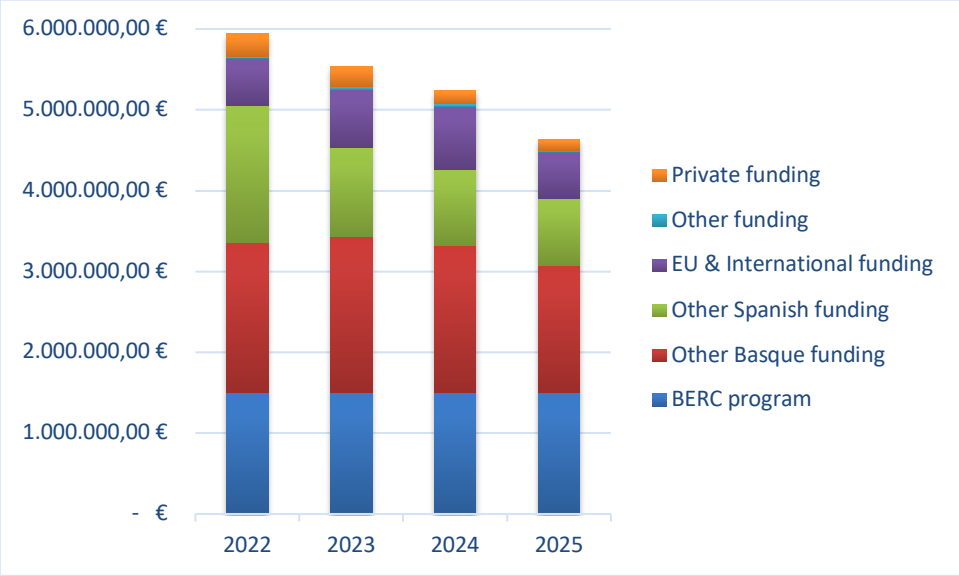


Figure 51. Distribution of yearly expected incomes in period 2022-2025

These funding resources come mainly from the following programs:

- **BERC program**
- **Other Basque funding**: BCAM has reinforced its position as a strategic partner for other BERCs, cooperative research centres and health institutions in the Basque Country, apart from the long-lasting strong relationship with the UPV/EHU. In this sense, BCAM is expected to have access to the following funding sources in the next period apart from the programs devoted to scientific equipment and hiring researchers:
    - Funding coming from the strategic programmes of the Research & Education Department of the Basque Government, such as the IKUR Programme, mainly devoted to the strategic projects on Mathematical Modelling Applied to Health and its contribution to the Neuroscience, HPC, AI, and Quantum areas. In fact, BCAM is strengthening its relationships with centres such as Achucarro or BCBL in Neurosciences; the relationship with DIPC and MPC in HPC and emerging research in Quantum; and with BC3 in Mathematical Modelling in relation to climate change models and changing distribution of vectors of diseases due to climate change, additionally to previous close relationships with Polymat. In the last period, BCAM has also promoted the relationship with health institutions under the BMTF (Basque Modelling Task Force) created to face the COVID-19 pandemic which counts on the support of the Basque Government with 1 million euros of funding expected for at least four years. Finally, BCAM is expected to reinforce its position as a strategic partner in the framework of Mathematical foundations of Data Science & Artificial Intelligence, which may lead to have access to additional funding sources in collaboration with other centres.
    - Funding coming from the collaboration with other Basque institutions (Cooperative research centres or technology centres) in programs such as ELKARTEK. Additionally, BCAM is the only BERC centre that takes part in the BCSC (Basque Cybersecurity Centre) and the BAIC (Basque Artificial Intelligence Center), that we aim may be a potential source for fundraising in the future. The centre also coordinates the LTC TRANSMATH Lab, that is supported by the Basque Government through Euskampus. Finally, the centre also counts on the support of the Biscay Regional Government for the development of the KTU (Knowledge Transfer Unit) through a program for assessing start-ups and small companies in mathematical modelling that may contribute to the development of their services. In this sense, it is expected that this collaboration may evolve in the framework of the Biscay entrepreneurship hub.

- **Other Spanish funding:** This funding is obtained through the calls of the Spanish state agency such as the National Plan, Ramón y Cajal, Juan de la Cierva, PhD grants, scientific equipment, etc. The current Severo Ochoa accreditation will last until June 2022, and in the current budget projection, it has been considered that it may not be obtained for the third time in a row due to the new strategies the Spanish government is developing in relation to that program.
- **EU & International funding:** BCAM takes part in several European projects in the different pillars of H2020 and is expected to continue fostering its participation in Horizon Europe, in calls such as ERC, FET-HPC, Marie Curie (individual fellowships, ITN, RISE), POCTEFA…
- **Other funding:** This funding comes from special activities organized by the centre such as congresses and other incomes.
- **Private funding:** The increase in this funding in the last period came mainly derived from the grants from La Caixa Foundation associated with the Severo Ochoa accreditation, but the centre is making strong efforts so as to increase its participation in other open programs from foundations such as Axa, Iberdrola… and developing strategic relationships though its KTU (Knowledge Transfer Unit) with private companies in the development of industrial doctorates and research projects development. It is expected to develop other strategic collaborations such as with the Iberdrola GSIH (Global Smartgrids Innovation Hub) or the potential synergies with Petronor Innovacion S.L. partner associated to BCAM.

3.9.3 Cost of renting of premises

This section should include (Max. 2 pages):
Please indicate the expenses expected in renting the premises or building for the period 2022-2025, and the justification of the evolution of these renting expenses for this period. Include documents (invoices) of the expenses in order to justify the cost and any comment or additional information that could be taken into consideration in this regard.
Justify the information provided and include the table supplied in the Excel file.

As indicated in section 1.4.3, due to the increase in the dimension of the centre, in September 2017 we started renting an office (150 m^2) in Mazarredo 16- Bilbao, with an annual cost of 22.326 € and in July 2021, an additional office was rented (180 m^2) next to that one, with an annual cost 26.790 €.

Figure 52. New premises rented in Mazarredo 16 (150 m2)

Finally, BCAM has access to office spaces in Leioa belonging to Ikerbasque, where the Neuromath Lab is located.

The expected cost of renting these premises in the period 2022-2025 is the following:

BUDGET (BERC only)	**2022**	**2023**	**2024**	**2025**	**TOTAL 2022-2025**
Cost of renting of facilities	49.200,00	50.184,00	51.187,68	52.211,43	**202.783,11**

The corresponding invoices to justify the expenses are included in section 1.4.3.

It also must be pointed out that BCAM's consolidation strategy in the period 2022-2025 and the promotion of strategic synergies may lead to additional space needs in centres such as the Biscay international Entrepreneurship Hub (in Bilbao) or promoting the centre's presence in the knowledge pole to be developed in Zorrotzaurre. This will be an issue to be discussed by the BCAM steering board in collaboration with institutions such as the Bilbao Town Hall.

3.9.4 Degree of lab-based practical work of the centre

This section should include (Max. 3 pages):
Please indicate the expenses expected for research-related tasks such as equipment, reagents, specific tools or similar, needed to carry out experiments, for the period 2022-2025.
Justify the information provided and include the table supplied in the Excel file.

In the period 2022-2025 the main expenses expected for research related tasks are aimed for the BCAM Neuromath Lab, the HPC Lab and general IT expenses:

1) Neuromath Lab

One of the mid- to long-term aims of the MCEN research programme is to develop intelligent closed-loop deep-brain stimulators for neurodegenerative diseases (e.g., epilepsy), and more generally, machine-brain interfaces to effectively communicate with the neural tissue. To advance, we will combine state-of-the-art neuroscientific technologies with novel mathematical and computational methods (CBCE - Control-Based Continuation for Experiments method) developed by the MCEN team leader in order to spatially and temporally dissect neural generators and simultaneously control neural activity. The envisaged experiments will combine electrophysiology (already available at MCEN) with optogenetics and calcium imaging (outlined in the requested budget: LASU, Prime BSI and Epi-fluorescence microscopy). The combination of these technologies provides two spatio-temporal neural tissue observables (i.e. electrical activity and calcium dynamic as a proxy of neural electrical activity). Moreover, it provides two actuators (i.e. electrical and light) enabling precise control of spatio-temporal dynamics of neural activity, however, via mediation of CBCE. Indeed, LASU allows to turn cell-type specific neural activity ON or OFF with millisecond precision, thus it enables to probe neural circuit function. The integration of LASU with calcium imaging allows the observation of cell-type specific neural circuit activity with cellular resolution using fluorescent indicators. The combination of electrophysiology, LASU, and calcium imaging provides a unique controlled experiment that allows to investigate the causal link between specific neuron activity, neural circuit dynamics and function (both in normal and pathological neural tissue states). Finally, by mediation of CBCE, we will be able to observe (via the two observables) the activity of neurons within the network and simultaneously control with precision cellular activity (via the two actuators). In other words, we will in closed-loop and real-time both 'read' and 'write' neural activity. To proceed with the experiments (numerous trials and developments are planned for the 4 years) we require consumables (outlined in the budget). These consumables will allow neuronal tissue preparation, incubation of the neural tissue and to prepare the electrodes with the appropriate chemical solutions. More precisely, these preparations will create artificial cerebro-spinal fluids (ACSF) that mimic the brain environment and provide electrodes effective for neural measurements. Subsequently, we will interface our CBCE method within the experimental setup. A key novelty is that the CBCE method develops a robust algorithm allowing for direct tracking of (un)stable neural states and their stability boundaries directly from noisy experimental data (indeed it is model-free). This means that it is possible to track stability boundaries between normal and pathological brain states (e.g., in epilepsy). Moreover, it provides a novel way to spatially and temporally dissect neural generators (and indeed neural function) in terms of feedback control signals. Furthermore, CBCE allows to couple (in real-time and bidirectionally) a neuron or neural tissue to a computer simulation of a critical component (e.g., model of ion-channel, neuron, neural circuit model), as well as, an external neuromorphic circuit (see budget). This latter feature

allows one to gain insight on the loss/gain of function of a neural tissue (e.g. hub neurons) or a critical component of a neuron (e.g. ion channel). This entire novel setup will be tested in various experimental settings, involving normal brain tissues and epileptic brain tissues (e.g. in-vitro neural tissue from pre-clinical mice model with Dravet Syndrome (DS)). To provide a sense of how powerful this setup is, we provide just one brief example of how we could gain insight into the gain/loss of function of abnormal ion sodium channels that lead to epilepsy in DS, which has been elusive to date. In this context, this pioneering research will resolve two key problems, namely heterogeneity and plasticity. Heterogeneity means that even if we could get a perfect model for an ion channel (i.e. the case in which we couple in real-time and bidirectionally a computer simulation to a neuron) then depending on the mix of other channels within the neuron we would not find the same electrical activity and possibly not even the same role on different cells. With CBCE we can add an imprecise channel of interest (i.e. computer simulation) and couple to actual cells that have all other channels intact and with CBCE method we can follow the stability boundaries of cellular dynamics. Plasticity means that if we block a channel (chemically), the cells can adapt to this new situation by regulating other channels. Thus, there is a chance of totally misinterpreting the role of a blocked channel. With our proposed extension we reintroduce the channel of interest and then by mediation of CBCE we proceed with changes in any model parameter of the channel (e.g. conductances, gating properties), which generates appropriate feedback control that precisely tracks the neural dynamics. Consequently, we gain more freedom in the parameters that we affect, but also, we can make small/quantitative changes in a continuous manner instead of a qualitative change that can provoke cell adaptation. Thus, we believe that we will be able for the first time to characterize the loss/gain of function of the abnormal sodium channels in DS and propose therapeutic directions to treat DS, which is a severe form of child epilepsy. More generally, our proposed technology will provide breakthroughs in the understanding of neural functions, neural computations and pathological neural activity. This will also lead (in the long-term) to advances in machine-brain interfaces to improve neural functions. The success of this project will lead to the technological transfer to other labs (nationally and internationally) leading to further scientific impact. Our primary aim, is to develop closed-loop deep-brain stimulators as an alternative clinical therapy to treat epilepsy.
So as to develop this research the following resources are expected:

a) Consumables for 4-year recurrent neuronal electrophysiology: 15K Euros

To perform neuronal electrophysiological experiments, we will need materials resources. These include chemicals, reactants, electrodes, recurrent carbogen and cylinder-tank and other lab resources. Specifically, these are:

1. Chemicals: A) Artificial cerebro-spinal fluid (ACSF) for neural tissue (pH=7.3-7.4/300-310 mOsm) containing in mM: (NMDG, 92); (NaHCO3, 30); (NaH2PO4, 1.25); (HEPES, 20); (D-glucose, 25); (Na Ascorbate, 5); (Na Pyruvate, 3); (Thiourea, 2); (KCl, 2.5); (MgSO4*7H2O, 10); (CaCl2, 0.5). B) ACSF for incubation and recording (pH=7.3-7.4/295-305 mOsm) containing in mM: (NaCl, 124); (NaHCO3, 26); (NaH2PO4, 1.25); (D-glucose, 10); (KCl, 3- 4.5); (MgSO4*7H2O,1); (CaCl2, 1.8 – 2). C) Intracell (intrapipette) solution (pH=7.3-7.4/295-315 mOsm) containing in mM: (K-gluconate,130); (NaCl, 5); (CaCl2, 0.3); (MgCl2, 2); (HEPES, 10); (Na2-ATP, 5); (Na-GTP, 0.4); (EGTA, 1); + 0.1 % biocytin. To establish the correct pH 1M NaOH and 37% HCl will be used.
2. Electrodes: A) 101R-2W Platinum/Iridium wire, 90 % Pt, 10% Ir. Length 10 ft (3 m), diameter 0,002 " (50 µm); B) Male pin connector, diameter 1.57 mm, 20 pcs/pack; C) Borosilicate glass capillaries with cut ends, with filament, o.d. 1.5 mm, i.d. 0.86 mm, length 10 cm, 100 pcs/pack D) Ag/AgCl pellet electrode, diameter 2 mm, length 4 mm, with 70 mm wire, E) PC-100 pipette puller, F) Extracellular electrodes.
3. Carbogen and cylinder tank: A) BLUE CO2 5%/O2 Bot-L 50/200, B) cylinder tank and tank fixation system.
4. Other support experimental resources: fluid transfer tubes, plastic pipettes, Tygon tubing, micro-spoons, micro scapel, micro blades, straight and curved tweezers, scissors, table microscope, mini digital 500 GR weigh machine, trays, thermometer, mixer, magnets, filtration paper, gloves, coil table support, drainer.

b) Neuromorphic circuits: 20K Euros

Analog neuromorphic network circuits to interface in closed-loop neural-tissue to test key hypotheses in machine-brain interfaces. This will enable us to replace some neurons with artificial circuits. Specifically, we estimate:

1. Specifically given that, one analog artificial neuron: 200 Euros, we will request a network of 100 analog artificial neurons: 15K Euros.
2. Associated electronic interfaces: 5K Euros.

c) Photo-stimulation device, Prime BSI express, epi-fluorescence unit: 142K Euros
Fluorescence/calcium imaging and optogenetic neuronal stimulation device. This includes:

1. Prime BSI express camera for calcium imaging: 28K Euros.
2. LASU - Laser Applied Stimulation and Uncaging system which is a fast, ultra-precise, galvo-controlled laser-based photo-stimulation. It allows spatial-temporal control of neural tissue: 100K Euros.
3. Epi-fluorescence microscopy: 14K Euros.

Total: 177K Euros

2) HPC Lab

In relation to the HPC Lab, BCAM has a long experience on the use of HPC computing infrastructure. Recently this use has been much increased with the use of deep learning. The fist main contribution in this area has to do with the adaptation and modification of general-purpose algorithms, such as Monte Carlo simulation or Bayesian inference, to fully use the computation platform. Secondly, we plan to design new algorithms that due to the powerful computations can provide new answers to problems posed in areas such as material science, computation chemistry or physical chemistry, etc. Yearly updates of the computational capabilities of the centre are expected so as to cover the increasing computational needs derived both from previously described BCAM research lines development and the collaboration with other institutions in fields such as Mathematical Modelling Applied to Health, Energy, Neurosciences or Advanced Manufacturing:

- As part of the BCAM strategic plan, in the last years we have fostered a research line in Mathematical & Computational Neurosciences that actively collaborates with Achucarro, Biocruces and UPV/EHU, and which has strong international collaborations with both academic and industry.
- We have launched in 2021 a very ambitious project with the support of the Department of Education in the field of Mathematical Modelling Applied to Health in which we promote synergies with many Basque institutions and seek for international projection.
- The BCAM MSO (Modelling Simulation and Optimization) scientific platform groups a wide range of research lines that make intensive use of HPC resources (and GPUs): such as CFD (with a joint research lab BCAM-UPV/EHU Tecnalia on offshore marine energy and a Transborder Laboratory for Mathematics and Its Applications - TRANSMATH), inversion, numerical analysis, application of HPC in the field of materials (polymers & soft matter – with Polymat, computational chemistry and Physical chemistry, multiscale simulations applied to materials and devices, these last ones in collaboration with DIPC and CICEnergigune) and optimization and simulation of manufacturing processes in collaboration with the LTC AENIGME (Aquitaine Euskadi Network In Green Manufacturing and Ecodesign) lead by Prof. Frank Girot.

The previewed expenses for research-related tasks for these experimental activities is shown in the following table:

BUDGET (BERC only)	**2022**	**2023**	**2024**	**2025**	**TOTAL 2022-2025**
Cost of the lab-based practical work	200000,00	200000,00	200000,00	70000,00	**670.000,00**
equipment - HPC Lab.	122000,00	60000,00	157000,00	50000,00	**389.000,00**
equipment - Neuromath Lab	48000,00	114000,00	10000,00	5000,00	**177.000,00**
reagents					**0,00**
specific tools -IT	30000,00	26000,00	33000,00	15000,00	**104.000,00**

Table 15. Previewed expenses for research-related tasks for the experimental activities

4 Indicators

This section should include the main indicators of the Excel file provided as template.

Scientific output

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Number of indexed articles and reviews published in the given year	123	167	151	*94*	535	130	130	125	120	505
Number of indexed articles Q1	102	139	129,996	*76*	112	107	108	105	101	105
% of indexed articles Q1	82,9%	83,2%	86,1%	*80,9%*	83,3%	82,3%	83,1%	84,0%	84,2%	83,4%
Number of indexed articles D1	55	70	73	*38*	59	56	56	55	54	55
% of indexed articles D1	44,7%	41,9%	48,3%	*40,4%*	43,8%	43,1%	43,1%	44,0%	45,0%	43,8%
Number of indexed articles C1	5	6	5	*6*	6	6	5	6	5	6
% of indexed articles C1	4,1%	3,6%	3,3%	*6,4%*	4,3%	4,6%	3,8%	4,8%	4,2%	4,4%
% of indexed articles by the Scientific Director	4,9%	4,8%	4,6%	*6%*	5%	5,0%	5,0%	5,0%	5,0%	5%
Number of international scientific co-publications	95	108	115	*61*	379	88	88	89	86	351
Number of public private co-publications	15	20	20	*8*	63	17	17	18	17	69
Number of citations during the given year of all indexed articles published by the centre, total					3969					5954
H index of the centre for the indexed articles published until the given year	29	35	40	*43*	37	43	44	46	47	45
M index of the centre for the indexed articles published until the given year	2,9	3,2	3,3	*3,1*	3,1	2,9	2,8	2,7	2,6	2,7
Number of books, book chapters and monographies published in the given year	17	2	2	*1*	22	1	3	2	3	9

Talent attraction and recruitment

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Basque programmes	4	3	4	6	4,25	5	6	4	8	5,75
BERC	1	0	0	0	0,25	0	1	1	1	0,75
Basque Government (non BERC)	3	3	3	3	3	2	2	1	3	2
UPV/EHU	0	0	1	1	0,5	1	1	0	2	1
Others (Basque or local)	0	0	0	2	0,5	2	2	2	2	2
Spanish programmes	27	30	29	28	28,5	29	27	25	18	24,75
Minister	20	21	23	23	21,75	24	21	18	11	18,5
Others	7	9	6	5	6,75	5	6	7	7	6,25
International programmes	3	2	3	2	2,5	2	2	2	4	2,5
Total PhD students	34	35	36	36	35,25	36	35	31	30	33
Basque programmes	17	26	32	26	25,25	30	40	36	31	34,25
BERC	5	5	5	4	4,75	7	9	11	13	40
Basque Government (non BERC)	12	21	26	21		22	30	24	17	93
UPV/EHU	0	0	0	0	0	0	0	0	0	0
Others (Basque or local)	0	0	1	1	0,5	1	1	1	1	4
Spanish programmes	24	21	19	21	21,25	21	6	5	2	34
Minister	23	19	15	18	18,75	18	3	2	1	24
Others	1	2	4	3	2,5	3	3	3	1	10
International programmes	8	11	11	5	8,75	6	6	6	6	24
Total postdoctoral researchers	49	58	62	52	55,25	57	52	47	39	48,75
Basque programmes	2	2	1	1	1,5	1	1	1	1	1
BERC	2	2	1	1	1,5	1	1	1	1	1
Basque Government (non BERC)	0	0	0	0		0	0	0	0	0
UPV/EHU	0	0	0	0	0	0	0	0	0	0
Others (Basque or local)	0	0	0	0	0	0	0	0	0	0
Spanish programmes	0	0	0	0	0	0	0	0	0	0
Minister	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0	0	0
International programmes	0	0	0	0	0	0	0	0	0	0
Total technicians	2	2	1	1	1,5	1	1	1	1	1
Total BERC Personnel	8	7	6	5	6,5	8	11	13	15	11,75
Ikerbasque Research Professors	8	8	8	8,25	8,0625	9,25	10,25	10,25	10,25	10
Ikerbasque Research Associates	1	1	3	3	2	3	4	6	7	5
Ikerbasque Research Fellows	3	6	5	6	5	5	5	3	3	4
Total Ikerbasque Personnel	12	15	16	17,25	15,0625	17,25	19,25	19,25	20,25	19

External funding (BERC centre only)

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
% of other Basque funding (different from BERC funding)	8,00%	27,26%	32,38%	*35,10%*	25,69%	31,24%	34,79%	34,76%	33,98%	33,69%
% of Spanish funding	48,72%	27,68%	30,75%	*28,51%*	33,92%	28,57%	19,90%	17,87%	17,83%	21,04%
% of international funding	12,73%	12,60%	12,83%	*10,00%*	12,04%	9,76%	12,80%	14,71%	12,24%	12,38%
% of external funding (total)	69%	68%	76%	74%	71,64%	70%	67%	67%	64%	68,02%

Patents, transfer of knowledge and outreach activities

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Requested patents, utility models	0	0	1	0	1	1	0	1	0	2
Licenced patents, utility models	0	0	0	0	0	0	0	0	1	1
Patents, utility models under exploitation	0	0	0	0	0	0	0	0	0	0
Creation of *spin-offs*	0	0	0	0	0	0	0	0	0	0
Agreements/contracts with public institutions	4	9	7	7	27	5	7	7	9	28
Agreements/contracts with private firms	9	11	8	3	31	7	7	6	5	25
Organized congresses at national level	1	2	1	1	5	1	1	2	2	6
Organized congresses at international level	1	3	4	5	13	2	2	4	5	13
Invited lectures at international scientific congresses	57	59	61	61	238	60	61	62	63	246
Events and outreach activities organized	81	71	30	46	228	30	70	73	73	246
High Level Policy oriented meetings (City Halls, Basque Government, Spanish Government, European Union…)	0	0	0	0	0	0	0	0	0	0
Activity in mass media (nº)	54	88	74	26	60,5	50	60	70	80	65
Activity in social networks (nº)	305861	768122	734766	231258	510002	600000	650000	700000	730000	670000
Visits hosted (general public, schools, associations…)	7	6	2	0	3,75	2	5	5	6	4,5

Training

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
On going	42	37	46	*52*	177	46	43	38	33	160
Finalized (national)	0	0	0	*0*	0	0	0	0	0	0
Finalized (international)	13	13	11	*5*	42	10	11	12	7	40
Industrial	0	0	0	*0*	0	0	0	1	1	2
PhD Thesis	55	50	57	57	219	56	54	51	41	200
On going	2	2	7	9	20	5	4	6	7	22
Finalized (national)	3	2	4	2	11	2	3	2	3	10
Finalized (international)	2	3	2	3	10	3	4	3	4	14
Master Thesis	7	7	13	14	41	10	11	11	8	46
PhD courses	55	50	57	*57*	219	56	54	51	41	202
Master courses	7	7	13	*14*	41	10	11	11	8	40
Advanced courses	55	50	57	*57*	219	56	54	51	41	202
Number of researchers participating in courses	117	107	127	128	479	122	119	113	90	444

Internationalization

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Participation in international networks	3	2	5	*4*	14	4	4	5	5	14
International agreements	11	8	7	*2*	28	7	7	8	8	30
International projects (requested)	16	21	27	*4*	68	8	12	15	12	47
International projects (obtained)	2	2	3	*2*	9	2	2	3	3	10
% of non Spanish PhD personnel in relation to total number of PhD personnel	61,02%	68,18%	68,66%	*69,64%*	66,87%	65,0%	66,0%	67,0%	68,0%	66,5%
% of non Spanish PhD students in relation to total number of PhD students	52,94%	60,00%	46,15%	*45,45%*	51,14%	45,0%	46,0%	47,0%	48,0%	46,5%
Number of researchers who are member of editorial boards of indexed research publications	7	8	8	*9*	8	10	10	11	11	10,5
Number of researchers who are member of editorial boards of indexed Q1 research publications	5	6	6	*7*	6	7	9	9	9	8,5
Requested ERC grants	1	5	4	*1*	11	2	3	3	3	11
Obtained ERC grants				*2*	2	0	0	1	1	2
Visiting researchers (number of researchers)	182	182	81	*0*	445	25	50	100	100	275
Visiting researchers (number of months of average stay)	0,25	0,25	0,25	*0*	0,1875	0,25	0,25	0,25	0,25	0,25
Nobel Laureates or Fields medal awardees assigned o contracted by the centre	0	0	0	*0*	0	0	0	0	0	0
International recognitions, awards	0	1	0	*3*	4	1	2	1	2	6

Public and private partnerships

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Number of projects in cooperation with research groups of Universities within the Basque University System	9	8	8	*8*	8,25	8	8	8	8	8
Number of projects in cooperation with research agents within the Basque Network of Science, Technology and Innovation (non-industrial)	19	25	24	*11*	19,75	20	20	16	15	17,75
Number of projects in cooperation with research agents within the Basque Network of Science, Technology and Innovation (industrial)	1	2	2	*1*	1,5	2	2	1	1	1,5

Gender equality

INDICATORS	OBTAINED RESULTS 2018-2021					PROPOSED INDICATORS 2022-2025				
	2018	2019	2020	2021	TOTAL / AVRG	2022	2023	2024	2025	TOTAL / AVRG
Scientific director	0	0	0	0	0	0	0	0	0	0
PI	3	4	4	4,25	3,8125	3,25	3,25	3,25	3,25	3,25
Permanent researchers (PI excluded)	0	0	0	0	0	0	1	1	1	0,75
Postdoctoral researchers	13	13	17	13	14	13	11	8	8	10
PhD students	11	14	13	13	12,75	12	12	11	10	11,25
Technical personnel	0	0	0	0	0	0	0	0	0	0
Management personnel	8	14	15	12	12,25	9	10	10	8	9,25
Others	12	14	23	18	16,75	8	5	6	3	5,5
Total number of women	47	59	72	60,25	59,5625	45,25	42,25	39,25	33,25	40
Scientific director	1	1	1	1	1	1	1	1	1	1
PI	16	13	13	12	13,5	14	15	15	15	14,75
Permanent researchers (PI excluded)	1	1	3	3	2	3	3	5	6	4,25
Postdoctoral researchers	39	51	50	45	46,25	49	46	42	36	43,25
PhD students	23	21	23	23	22,5	24	23	20	20	21,75
Technical personnel	2	2	1	1	1,5	1	1	1	1	1
Management personnel	1	1	1	1	1	1	1	1	1	1
Others	41	39	48	40	42	11	7	8	7	8,25
Total number of men	124	129	140	126	129,75	104	97	93	87	95,25
% of women in the centre	27,4854	31,383	33,9623	32,349	31,2949	30,3183	30,3411	29,6786	27,6507	29,4972
% of women related to senior researchers	14,2857	21,0526	19,0476	20,9877	18,8434	15,2941	18,2796	16,8317	16,1905	16,649
Activities related to promotion of gender equality (n.)	1	11	12	4	28	11	12	12	13	48