

Institution: King's College London

Unit of Assessment: 9 Physics

1. Unit context and structure, research and impact strategy**1.1. Overview**

The Department of Physics at King's has a rich heritage and tradition of interdisciplinarity. Our vision is to engage in high quality impactful research, to promote a culture of enquiry and collaboration, and to deliver on the **King's Vision 2029** with research to inform and innovate.

The last REF period has seen substantial growth, with increases across all research demographics (Fig. 1). The number of research groups has grown from three to five, and we have benefited from significant investment in new research infrastructure. We have increased grant income, with the quality of our research highlighted by 7 ERC grants, among many other individual awards as detailed later. The size of the department is now such that we have critical mass to study physics at all scales, from subatomic particles to single atoms, to cells, and up to the scale of the entire universe.

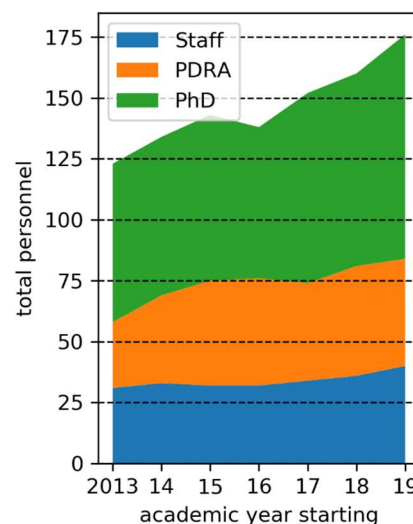


Figure 1 Growth of King's Physics.

We have also taken huge steps in Equality, Diversity and Inclusion since 2014, recognised through **JUNO Champion** status and an **Athena Swan Silver** award. The number of female academics has doubled from 10% to 21%. Efforts in this area will remain at the core of our plans to further strengthen our vibrant, international and diverse working environment; we attribute our success to our shared vision in recruiting talented early career staff and fostering them within an environment where groups work together to support each other's continued development.

1.2. Structure

King's Physics sits in the Faculty of Natural, Mathematical & Engineering Sciences (**NMES**) (see REF5a §1.1). The Department has undergone significant structural changes since 2014: the administrative structure has been streamlined with clear role descriptors and a workload model introduced to capture staff effort and reward research activity. The Research Strategy Committee (Head of Department (HoD), Deputy Head (Research), Vice Dean (Research) and Heads of Groups) has been overhauled, with a clear statement on remit, responsibilities and strategic vision. A Management Team (DMT), comprising HoD, Deputy Heads for Research and Education, the Leads for Diversity and Enterprise & Engagement, and the Departmental Manager, has oversight of departmental activities and is able to prioritise and balance research with other activities. This structure allows the department to function efficiently, giving staff more time to focus on their research commitments. Despite the diversity of fields in our **five research groups (Fig.2)** there are wide-ranging collaborative links between groups, evidenced by publications and ongoing research projects. Each Research Group has a Head, whose responsibility is to lead the group in terms of research strategy and management of members, to make the group cohesive and inclusive, and to support members in applying for grants and maximising their potential. This support structure fosters a discipline-specific environment for early career researchers to benefit from the experience of more senior members, and for staff to peer-mentor and support each other.

The Department forms the core of wider integrated physics-related research activities across the University, with ties to the other NMES departments and to physics research embedded in interdisciplinary research divisions within the Health Faculties of King's College London, including joint appointments (*Garcia-Manyes, Spillane*) with the Randall Centre for Cell & Molecular Biophysics. Of the 39 staff submitted to REF2021, one member of staff is submitted with UoA5 (Biological Sciences) and two with UoA12 (Engineering), reflecting the interdisciplinary ethos of the Department of Physics, with the remainder submitted to UoA9.

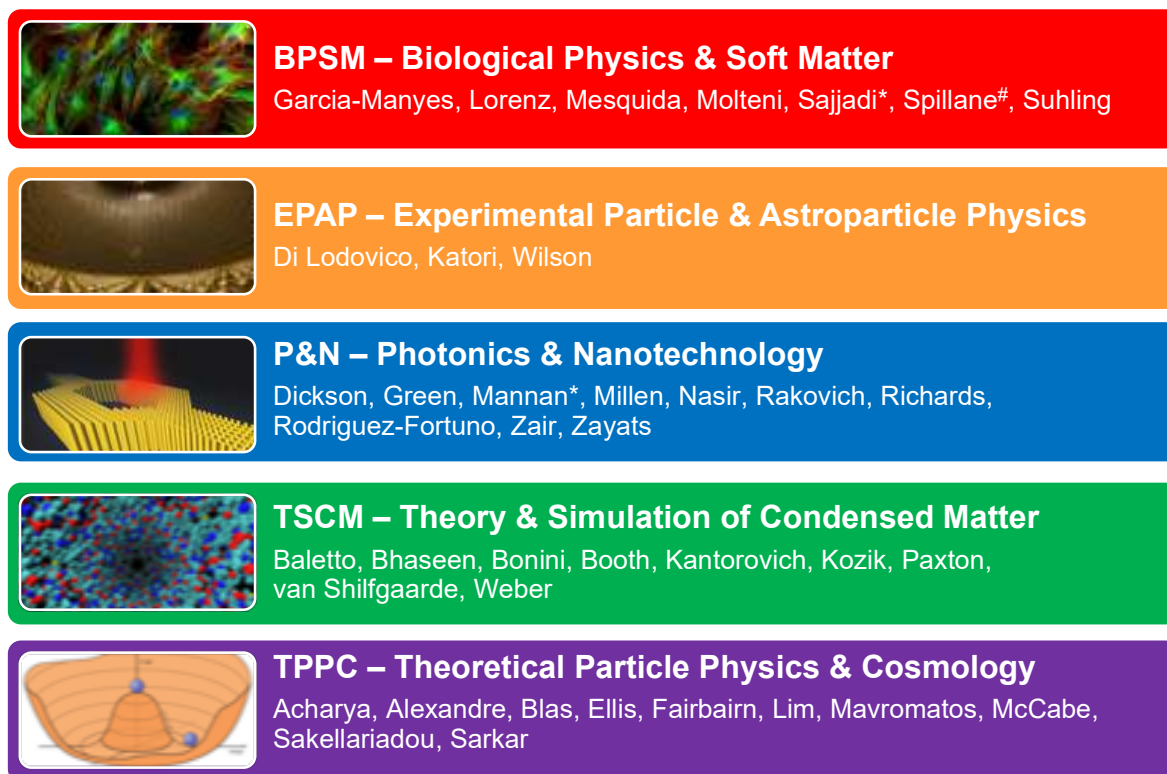


Figure 2. King's Physics **Research Groups** (# submission to UoA5 and * submission to UoA12)

1.3. Research Strategy

Our aim is to deliver internationally excellent research in our distinctive research areas, growing research capacity and constantly seeking to capitalise on new opportunities.

Our strategy to meet this goal is to recruit outstanding researchers, to enhance our research base, and allow our Groups to reach their full potential. We will continue to expand in our areas of excellence, aiming to grow the department by 30% as we meet the King's Vision 2029, which has as a core ambition the strategic growth of Science and Technology, supported through substantial investment (REF5a §2.4).

1.3.1. Evidence of Success

As an indicator of the credibility of our goals, we have met and exceeded our previous aims, presented in REF2014:

- *“Further growth to consolidate the strong research environment that has been established in the Department and ensure sufficient scale to respond to new challenges.”*

Response: We have increased staff numbers by 29%, our research funding has proportionally increased, and the number of prestigious grants has risen (§3.1). Development of a supportive research culture is recognised by a Juno Champion award. There has been a significant expansion

in High Performance Computing (HPC) capability (§3.3) and £6M investment in new experimental laboratories and equipment (§3.2).

The creation of the EPAP Group in 2019 demonstrated the University's commitment to the growth of Physics. The motivation for this strategic development was the creation of a world-class experimental activity in an area related to the strong TPPC group and involved in large science collaborations, hitherto missing in the Department, as well as to grow experimental research for a better theory-experiment balance.

- *"Further development of the Theoretical Particle Physics and Cosmology Group as a leading centre for particle phenomenology to meet the need for such research with the flow of data from the LHC, the Planck satellite and many astroparticle experiments now underway."*

Response: We have gone beyond this objective with the creation of the EPAP Group, while new TPPC appointments *McCabe* and *Blas* consolidate our links with phenomenology; their presence at KCL marks us out as a leading dark matter research group in the UK. The award of an Ernest Rutherford Research Fellowship to *David Marsh* (from April 2021) and the appointment of *Ruth Gregory* (from January 2021) as Head of Department further strengthens particle cosmology and gravitation research.

- *"Restructuring of the Experimental Biophysics & Nanotechnology Group, and new appointments, leading to the creation of two new groups."*

Response: To support the growth of experimental research the previous Experimental Biophysics & Nanotechnology group was restructured as envisaged to create two groups:

- *Photonics & Nanotechnology* (P&N) with a focus on nanophotonics, metamaterials and functional nanomaterials, enhanced through the arrival of *Green* and *Rakovich*, and development into the areas of ultrafast photonics (*Zair*) and (quantum) opto-mechanics (*Millen*), and further strengthened through the appointment of *Rodríguez-Fortuño* in theoretical nano-optics.
- *Biological Physics and Soft Matter* (BPSM), with the transfer of *Lorenz* and *Molteni* from the TSCM Group bringing expertise in molecular simulation of biological systems, and the appointment of *Spillane* and *Elosegui-Artola* (joining April 2021) to build on strengths in mechanobiology.

Core strategic principles of the department have been the development of:

- **Partnerships**, in particular with neighbouring London institutions (see §4.1.1 and Fig. 5 for further details). The development of the BPSM Group has strengthened our partnership with the **Francis Crick Institute** (REF5a §1.5) including the appointment of *García-Manyes* (Head of BPSM Group) and *Elosegui-Artola* as Crick Group Leaders. The combined strength of the P&N, BPSM and TSCM Groups were instrumental in King's accession to the **London Centre for Nanotechnology (LCN)** in 2018. Our partnership in the London **Thomas Young Centre (TYC)** for Theory & Simulation for Materials & Molecules has been strengthened through the Tier 2 MMM HPC Hub (see §3.3) and the **JC Maxwell Node of CECAM** (Centre Européen de Calcul Atomique et Moléculaire) was renewed in 2016 and again in 2020. During the REF period King's Physics has led the creation of the London Institute for Advanced Light Technologies (**London Light**) with Imperial and UCL, a collaborative environment for new and emerging areas of photonics. The EPAP and TPPC groups recently joined the **NExT Institute** for particle phenomenology, while the new EPAP Group brought a leading role in the international **Hyper-Kamiokande** experiment.
- **Interdisciplinary research.** The BPSM and P&N Groups have enjoyed numerous successful collaborations with researchers in the King's Health Faculties (REF5a §1.1). *Green* returned to the Physics Department from secondment (2011-2014) in the School of Biomedical Engineering

& Imaging Sciences (BMEIS), supporting the development of nanoparticles for medical imaging. Collaborations throughout the University have been strengthened further through the development of interdisciplinary Centres for Doctoral Training (CDTs), **CANES** (Cross-Disciplinary Approaches to Non-Equilibrium Systems) EPSRC CDT, led jointly with the Department of Mathematics, and the **BiPAS** (Biological Physics Across the Scales) CDT, led by the BPSM Group, both providing interdisciplinary doctoral training involving supervisors from across King's College London.

1.3.2. Future Objectives

(1) Strategic growth of King's Physics for sustainable research excellence:

Supported through King's Vision 2029, we will continue the successful growth of the Physics Department, to ensure a critical mass for the vitality and sustainability of our work, to embrace opportunities, address the global challenges of the future, and to further develop interdisciplinary research. An overarching objective is to continue to grow experimental activity, ensuring a healthy balance between theoretical, computational and experimental physics, underpinned by the further development of new research laboratory space. Initial priorities include: further appointments to the BPSM Group, building on connections with the extensive biomedical research in the King's Health Faculties and our partnership with the Francis Crick Institute; the growth of the EPAP Group to ensure a critical mass for sustainable excellence and to exploit new opportunities in this vibrant area of experimental research. The Deputy Head (Research) will work with a new Departmental Impact coordinator and the Faculty Enterprise & Engagement team to realise our goals of increased grant income and engagement with impact.

(2) A strong and supportive Research Culture:

King's Physics strives to create a culture for research in which all researchers are motivated and supported to produce research of the highest quality.

We already place **equality, diversity and inclusion** at the core of our activities and are committed to further progress, maintaining our status as a Juno Champion, with a goal of Athena SWAN Gold. Promoting a healthy work-life balance and inclusiveness at all levels fosters a more open research culture that enables deeper and more impactful research. The Departmental Management Team will ensure an ongoing balance of strategic need across departmental activities, embedding quality time, vital for the delivery of impactful research, at the core of management decisions.

The Department recognises that one of the immediate challenges in the wake of the pandemic is to bring research focus back into balance. A Research Focus Plan will include away days and an emphasis on mentoring.

We will strengthen **training and mentoring** of researchers at all career stages, supporting career development and progression to ensure all can realise their full potential. The next generation of researchers lie at the heart of our research culture, thus building on the successes of the CANES and BiPAS CDTs we will develop new doctoral training programmes across all Research Groups.

A strong research culture is underpinned by the highest standards of **Research Integrity**, promoted by a Faculty Research Integrity Champion, with a Physics Research Integrity Advisor (*Dickson*) leading training and providing a visible point of contact for researchers.

We are committed to the promotion of **Open Research**, as the cornerstone of reproducible science, guided by the King's Open Access policy (REF5a §2.3). King's Research Portal is our institutional repository, providing open access to the full text of research outputs, while King's Library supports research data management, including long term storage and public access for research datasets.

King's Physics actively pursues the development of community code, shared through GitHub and dedicated websites.

(3) Research Excellence through Partnership and Collaboration:

- Within the Department there exists an open and supportive environment for the development of research between Groups, which we will continue to encourage, assisting coherent bids for larger research grants.
- Within King's we will strengthen our focus on the development of interdisciplinary research to address major challenges, both with other Departments within the NMES Faculty, addressing the 'Connected Disciplines' priority of the Faculty's 5-year plan, and with other Faculties, in particular those in the Health Sciences, the King's Together programme supporting development of new collaborations.
- We will deepen our regional partnerships which together enable a local critical mass of world-class research, including the LCN, TYC, London Light, NExT and the Crick, and develop further our international strategic partnerships (see §4.1).

1.4. Research Groups: Status and Future Plans

- **Biological Physics and Soft Matter (BSPM)** investigates the physical phenomena underpinning many of the most challenging questions in biology today, with expertise ranging from computational biology to biophotonics to mechanobiology. Future Strategy: Establish UK leadership in the fields of bio-interfaces and mechanobiology both experimentally and computationally. To support the growth of this research area, recruitment of a Lecturer and Reader is underway (paused by COVID-19).
- **Experimental Particle and Astroparticle Physics (EPAP)** focuses on understanding the fundamental properties of the neutrino and facilitating the emerging field of neutrino astronomy. Future Strategy: Continue high profile research in current and future neutrino facilities and expand in the astroparticle physics area including dark matter detection strategies.
- **Photonics and Nanotechnology (P&N)** develops and applies advanced photonics and novel nanomaterials to address modern challenges in photonic and quantum technologies, material science, sensing, imaging and clean energy. Future Strategy: Strengthen theoretical capability alongside the Group's leading research in nanophotonics, nanomaterials and quantum systems.
- **Theoretical Particle Physics & Cosmology (TPPC)** pursues a strategy of, and has leading expertise in, integrated studies of particle physics, cosmology, astroparticle physics and gravitation. Future Strategy: Maintain leadership in particle phenomenology and further strengthen research into gravitation, especially via our involvement in LIGO, LISA and AION.
- **Theory and Simulation of Condensed Matter (TSCM)** tackles many-body physics with broad applications in materials science, nanotechnology and superconductivity, including applications of machine learning. Future Strategy: Maintain strengths in strongly correlated systems both in and out of equilibrium and expand into new directions, particularly quantum computation.

Many natural **synergies between the research groups** have emerged, both through research challenges bridging fields, and through joint membership of facilities, organizations and international initiatives (Fig. 3). Interactions between Groups are facilitated through internal colloquia, shared teaching and departmental away days. It is vital to constantly refresh our research priorities in order to benefit from new initiatives or collaborative opportunities.

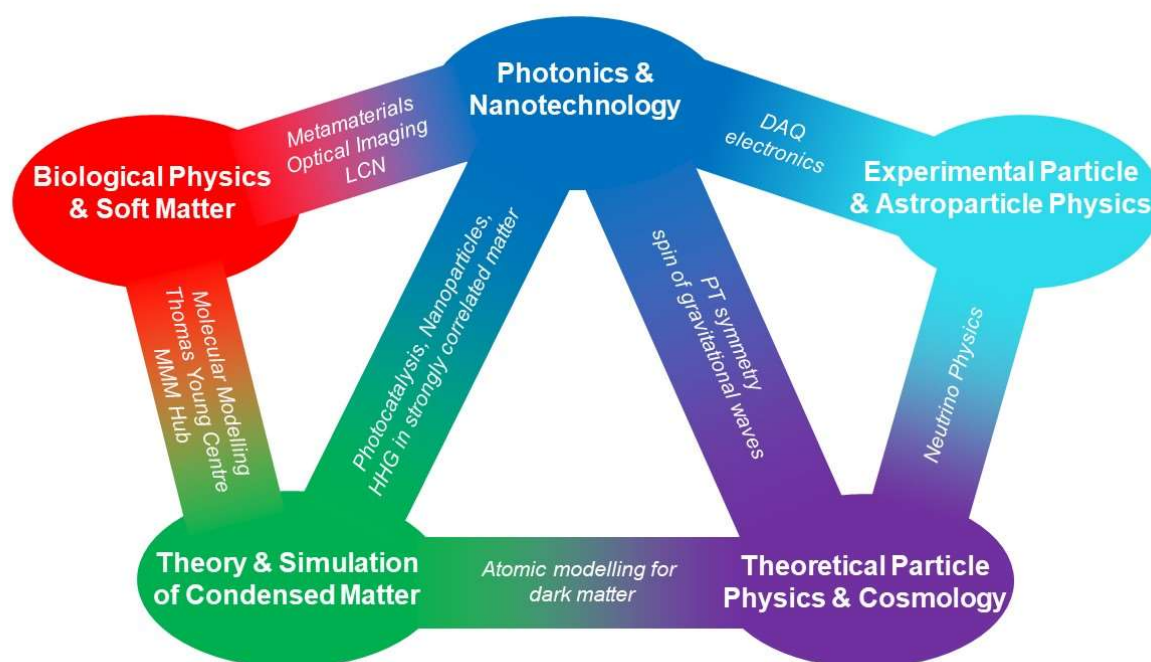


Figure 3. Examples of some collaborative activity between Groups

1.5. Enabling Impact

King's Physics research has led to health, economic, cultural, social and educational impact, with our approach to enable impact highlighted below. We take advantage of funding such as the University's EPSRC Impact Acceleration Award (IAA), and the King's Innovation Institutes (REF5a §4.5) to facilitate delivery of research impact. Our interdisciplinary research starts the journey to impact in health through our strong connections within the University as lead of King's Health Partners Academic Health Science Centre (REF5a §1.5). The Faculty has established an *Enterprise & Engagement Committee* to encourage and enable opportunities for the development of impact and develop an enterprise-driven culture. The Physics Lead for Enterprise & Engagement (*Mesquida*) links Departmental and Faculty activities, allowing us to share opportunities, best practice and achievements and a *Business Advisory Board* has been established to inform our strategic thinking.

1.5.1. Partnership & Collaboration with Industry and Commercialisation:

Since 2014 we have enjoyed many collaborations with industrial and government partners (See §4). These partnerships were strengthened through **secondments**, both outgoing, such as a Royal Society Industry Fellowship (*Nasir*), and incoming, with visiting scientists embedded at King's (AWE, QinetiQ). CASE conversion of research council DTP studentships (e.g. Rolls-Royce) and the EPSRC IAA (e.g. Photek) were used to seed new collaborations with industry partners.

The development of new industry partnerships is supported by a *Faculty Industry Liaison Manager*, who provides strategy oversight and project management of partnership and innovation initiatives, and the University's *Industry Partnership Team* which enables new partnerships, shapes collaboration models, closes agreements and manages long-term relationships. Activities associated with commercialisation and Intellectual Property are supported by a dedicated *IP & Licensing Manager* for the Faculty.

1.5.2. Interdisciplinarity:

Collaborations at the life sciences interface enable both new biological insight and development of new techniques for application in biomedical research, in turn leading to impact in healthcare. This is highlighted through our **impact case study** on improvements to cancer treatment and patient outcomes using novel fluorescence lifetime imaging microscopy, developed through collaborative biophotonics research between Physics, the Randall Centre and the Comprehensive Cancer Centre at King's.

1.5.3. Outreach and Public Engagement:

Impact in the form of outreach is embedded within King's Physics, enabling the engagement of a wide range of audiences with our research. These activities vary from the organisation and delivery of international summer schools in developing countries (see **impact case study**), to appearances in national media as well as the more regular programs of talks to public audiences and schools and exhibitions as science festivals. The interaction of science with art provides new opportunities to ignite creativity and discovery and we have engaged with a number of collaborations with artists and curation of exhibitions, including events organised by London Light and enabled through the King's Artist in Residence programme, and the Dark Matter season at London's Science Gallery at King's (see **impact case study**).

2. People**2.1 Staffing Strategy and Recruitment**

Strategic investment by King's College London in the development of Science and Technology has enabled King's Physics to deliver its strategic ambition for further growth (§1.3), by recruiting outstanding researchers to consolidate areas of research excellence and ensure sufficient scale to respond to new challenges. There has been a significant increase in the number of staff, both academic and postdoctoral, and students (Fig.1). In the REF period King's Physics made 12 appointments (including 5 female staff) to academic posts with responsibility for research: 7 as Lecturer, 1 as Senior Lecturer, 2 as Reader and 2 Professors. All academic staff are on open-ended contracts. Our focus on the recruitment of outstanding early career academics ensures we are able to maintain a balanced demographic profile and enable future succession planning from within the Department. To promote international collaboration, two staff combine their King's post with positions in leading international centres: Acharya (ICTP Trieste), van Schilfgaarde (US National Renewable Energy Laboratory NREL). New appointed staff are from CERN, GRAPPA (Amsterdam), Vienna, the Crick, Cambridge, Durham, Imperial and QMUL. In the same period three academic staff left, while we bore the untimely passing of our valued colleague Alessandro de Vita.

Our strategy to develop a distinct interdisciplinary research profile, and to develop our partnerships, has been pursued through new joint appointments with the Randall Centre for Cell & Molecular Biophysics (*Spillane*) and with the Francis Crick Institute (*Elosegui-Artola*, joining April 2021). Our partnerships with the London Centre for Nanotechnology, London Light and the Thomas Young Centre, and associated opportunities for technology impact, have been supported through new academic appointments in photonics and nanotechnology (*Millen*, *Rakovich*, *Rodríguez-Fortuño*, *Zair*), and in strong electron correlations (*Booth*). The targeted development of particle physics and cosmology has been supported through appointment of *Blas*, *McCabe* and *Gregory* (joined Jan 2021) and establishment of the EPAP Group (*Di Lodovico*, *Wilson*, *Katori*). Appointment of new staff with experimental programmes has also proceeded hand-in-hand with refurbishment programmes to create high quality new laboratory space in which their research can flourish.

Recruitment follows best EDI practice, with advertising material and job descriptions reviewed and updated by the Department EDI team to encourage diverse applicant pools. Essential requirements of all academic appointments are: an outstanding research track record and strong independent research vision; fit with the research priorities of the group and awareness of impact; suitability for teaching. Academics from other groups, students and postdocs are encouraged to attend the interview presentation and contribute feedback to the panel. To promote the recruitment of outstanding early career researchers to King's, a Faculty policy was developed for proleptic appointment to an open-ended position on completion of a personal fellowship, including a full academic appointment process to ensure equality and rigour, with 3 such staff appointed in King's Physics: Royal Society University Research Fellows (URFs) *Booth* and *Rakovich*, and Ernest Rutherford Fellow *McCabe*.

2.2. Staff support and Development

King's Physics has put in place a range of initiatives and mechanisms (detailed below) to ensure that *all* researchers obtain the support and development they need such that their time at King's is valuable, whether they remain within King's or move on with their skills enriched. The Department Research Committee provides a forum for discussion of practical research issues, for example access to training, travel and consumables for PhD students and postdocs, computing and laboratory issues.

2.2.1. Workload Model

All academic staff in King's Physics are involved in research, education and administration, with departmental duties allocated by the HoD according to a Transparent **Workload Allocation Model**, capturing assigned duties, research grant management, contributions to impact, the academic field and beyond. Allowance is made for **Reduced Workload** for early career staff, for staff returning from extended leave (e.g. parental leave or sickness), and in recognising the research commitments of staff who have secured fellowships or other major individual research awards.

2.2.2. Support for early career academic staff

King's Physics is committed to the support of new academic staff to realise their potential to develop into successful academics and leading researchers.

Start-up: All new academic staff are provided with funding to enable them to establish a strong independent research programme, including equipment budgets, an assigned PhD studentship in the first year of appointment, and for experimentalists, dedicated newly refurbished laboratory space (see §3.2). £1.01M of start-up funding for equipment, consumables and research staff has been provided to new physics staff over the REF period, with the level of support dependent on need.

Workload reduction: All new academic appointments have protected teaching and administrative loads during their probation, usually three years. This creates extra time for building up independent research, establishing a laboratory for experimentalists, guiding first PhD students and developing first research proposals.

Mentoring and training: Every new member of staff is supported formally through mentoring, while experienced staff across groups dedicate time to advising and helping new colleagues. The probation process offers a mechanism to discuss, set and review objectives periodically with their probation mentor, to ensure staff build their skills and research profile to promote a smooth transition to being confirmed in post.

2.2.3. Staff Development

King's Physics enables the development of staff through research support, training, mentoring, reviews and promotion. We engage proactively with King's comprehensive programme of professional development training, with a wide range of training courses available to staff. The Department also supports staff through nomination to university-provided training programmes such as the Leading Researchers Programme (Owen 2017, Lorenz 2018, Fairbairn 2019) which provides targeted development to enable accelerated career progression. Ongoing mentoring is provided by Heads of group and a regular lunch where non-professorial staff meet with the HoD to discuss and explore issues that affect them helps identify where support is required.

The University's annual performance development review (PDR) is designed to ensure that progress is maintained, with necessary support identified and provided. The process provides an opportunity to reflect on successes and difficulties, identify individual training needs and objectives for the year ahead, and discuss longer-term career plans and aspirations, including promotions. Importantly, the PDR enables identification of annual research objectives – publications, grant submissions and impact development. The PDR feeds back into the recognition-pay process and allows the HoD to recognise successes and difficulties, informing workload allocation.

2.3. Support for Research and Impact

2.3.1. Research Grant Development

Departmental processes to support grant development and writing include internal peer review panels and mock interviews. Peer review is bespoke for each group, with Heads of Group providing oversight, and monitored by the Deputy Head (Research), with best practice shared between groups.

The Faculty professional services team supporting research has grown from one Research Officer to a team of seven full-time, research-focused staff, with a Senior Research Officer embedded in the Department, and a dedicated PhD-qualified Research Development Manager (previously an EPSRC portfolio manager) from the University Research Strategy & Development team (REF5a §4.3), to support the development of funding applications, provide academic staff training and act as a source of expertise. The Faculty's "NMES20" programme supports the development of highly competitive grant applications through a structured cohort-based programme for eligible PIs in the Faculty each year. The Network of Fellows brings together current and recent holders of research fellowships and holders of major awards from across the Faculty, providing a forum for the development of activities to further the advance of network members, and to inspire, support and act as a source of advice for all academic colleagues.

A Research Overhead Incentive Scheme returns a portion of research overhead to Principal Investigators, with facility for financial year roll-over, to provide flexibility for research costs not met by funders and those incurred beyond grant end, to enable bridging funding for research staff and to initiate new activities. King's Undergraduate Research Fellowships provide funding for around six summer internships every year with the dual aim of integrating research and teaching, and helping academics explore new ideas for future proposals.

2.3.2. Research Partnerships and Networks

Our partnerships with the London Centre for Nanotechnology, Thomas Young Centre, London Light, NExT and Crick provide a strong interdisciplinary and collaborative environment for academic and research staff and PGRs. These partnerships bring together leading international researchers to speak at a range of workshops, lectures, networking meetings and more, showcasing latest developments and providing opportunities to discuss research, develop collaborations and build

networks. A more extensive network of support for King's Physics researchers is presented through our membership of national and international networks and collaborations (§4.1).

2.3.3. Support for Impact

The EPSRC IAA has been employed to develop a culture for impact across all Departments in the Faculty, including impact training for researchers, and one-to-one support for researchers developing projects for IAA funding; research staff are eligible to be PIs on IAA grants, in support of their development to independence.

Monthly *Encouraging Enterprise* webinars, delivered by King's specialists and external experts, foster an Enterprise & Engagement ecosystem within the Faculty. These provide an opportunity for our community to learn, share ideas and enable a step-change in how we more actively work with Industry and other external stakeholders in the public, policy and business domains.

2.4. Support and Development of Postdoctoral Researchers

Our Research Fellows and Postdoctoral Research Associates (PDRAs) lie at the heart of the Department's research environment, with numbers increasing from 27 to 44 over the REF period. Research staff are invited to Staff Meetings, ensuring they are fully included within the King's Physics community and exposed to the full range of academic issues considered within the Department.

The Physics **Postdoc Tutor** (*Blas*) ensures smooth progress for PDRAs by developing policy, monitoring progress and providing pastoral support and careers advice where necessary. The Tutor is expected to be familiar with appropriate university procedures and reporting mechanisms, for example on bullying and harassment. The postdoc tutor and two physics PDRAs attend the Faculty Research Staff Committee, which serves as a forum to exchange ideas and best practice across departments.

The Physics **Postdoc Forum**, chaired by the HoD, provides an arena for PDRAs to express their views, raise issues, and contribute ideas on how to improve the research environment for Early Career Researchers. The forum also provides a space for external guests to lead discussions on such topics as careers development or fellowship applications.

Research Staff Development: King's Physics is committed to delivering the principles of the UK Concordat to Support the Career Development of Researchers. The University's commitment to the Concordat is recognised by the European Commission's HR Excellence in Research Award which King's has held since 2012, recently renewing it for 2020-22. PDRAs have access to a wide range of training to enhance their skills and career prospects, with the Centre for Research Staff Development (CRSD, REF5a §3.3) providing university-level professional development support for research staff to achieve their potential. Research staff are supported in the development of externally funded personal fellowship applications, while the competitive King's Prize Fellowships (REF5a §3.3) support the transition to research independence (awarded to *Rhys*, 2019)

King's Physics is committed to aligning its practices with that of the Concordat by not only providing the relevant training for researchers, but also for supervisors and line managers. For example, staff received unconscious bias training in 2019 and had diversity and inclusion training at an away day in January 2020.

2.5. Training and Support of Postgraduate Research (PGR) students

Studentship funding: Most PGR students are fully funded by a variety of studentships administered by the Department, with all studentships externally advertised. Faculty-funded PhD studentships are a constant source of support for King's Physics and have contributed more than £2.2M over the REF

period. External sources of funding include EPSRC, BBSRC and STFC DTPs, EPSRC CANES and Medical Imaging CDTs, the Royal Society, ERC, charities and others. Other sources include University international studentships, the King's/Crick joint programme and the King's-China Scholarship Council Programme (4 *pa* since 2018). Research groups have access to funds to enable PGR students to attend training and research conferences.

Recruitment: All prospective PGR students are interviewed by a panel of at least two academic staff following university best practice. Measures adopted through our Athena Swan Action Plan on student recruitment have led to a marked increase in female PhD students during the REF period (Fig. 4).

Progression: To ensure oversight of the satisfactory development of their PhD programmes, research students have a 6-monthly progress review involving feedback from the supervision team, a training needs analysis, and agreement of objectives for the next period, signed-off by the physics postgraduate tutor. Major progress assessments also occur between 9 and 18 months (MPhil-to-PhD upgrade), based on a technical report and viva with a panel to ensure the PhD project is on track for successful completion. The Department Research Committee receives updates on PhD completion statistics, including breakdowns by group and student gender.

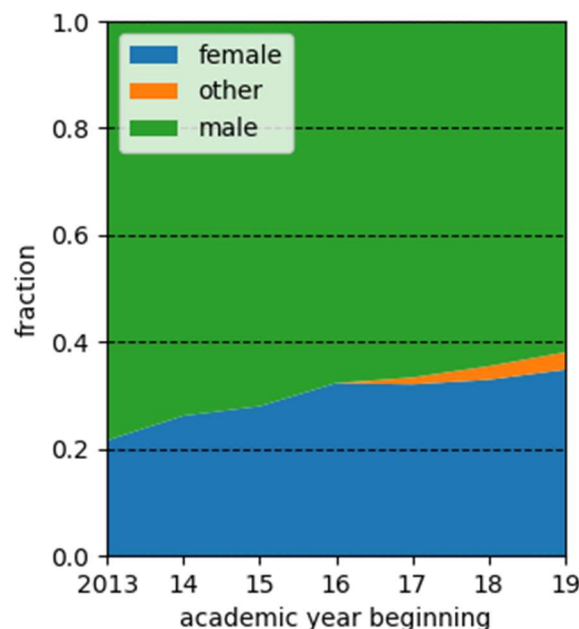


Figure 4. PhD student gender ratio

Postgraduate Tutor and Staff-Student Liaison Committee (SSLC): In addition to their supervision team, research students can raise issues with the Departmental Postgraduate Research SSLC, chaired by the Postgraduate Tutor (*Kozik*) who also acts as a contact for individual students.

Training: We have a continuing focus on ensuring students have the skills required to both perform and contextualise their research. The King's Centre for Doctoral Studies (REF5a §3.2) enhances standards for PhD supervision in the University, providing training for PGR students and supervisors across King's, with courses covering a wide variety of academic and transferrable skills. Training is a standing item on the agenda for the Departmental Research Committee (which has PhD student representation).

Each PGR student participates in research activities of the Group to which they are affiliated, including seminars, journal clubs and discussions with visitors, and are encouraged to attend the regular research seminars, lectures and events in the Department. The research groups form the immediate communities for PGR students, where they learn from others and are encouraged to discuss and present their own work and develop internal collaborations. PGR students in the same research group are normally co-located in the same office space to facilitate collaboration and peer support. Research students are regularly encouraged to present work at meetings, while our partnerships provide a strong enhanced environment for further subject-specific doctoral training (§4.1). For example, the Thomas Young Centre provides an unrivalled programme of training in material and molecular modelling, whilst the recent addition of the two particle groups (EPAP and TPPC) to the NExT Institute will further enhance doctoral training in this area.

Centres for Doctoral Training (CDTs): During the REF period, the Physics and Mathematics Departments co-led the EPSRC *Cross-Disciplinary Approaches to Non-Equilibrium Systems* (CANES) CDT. CANES has brought together over 50 supervisors from across King's, with students and staff benefitting from joint supervision in a multi-disciplinary environment with dedicated

computer and common rooms to build cohort cohesion. The CDT promotes student leadership, with successes including student-led workshops such as those on *Localisation in Quantum Systems* and *Quantitative Systems Biology*. Staff, students and industrial partners are brought together by the CANES Annual Retreat, and with partner engagement events.

Building on this success, the strong links at the life-science interface, within King's and with the Crick (§1.3.1 and Fig. 5), have facilitated the establishment of the CDT in *Biological Physics Across Scales* (BiPAS), a multi-disciplinary doctoral training programme funded by the Centre for Doctoral Studies and led by King's Physics.

2.6. Equality, Diversity and Inclusion (EDI)

Ensuring an inclusive and supportive working and learning environment is a key part of the Physics Department's EDI strategy, and core to King's Strategic Vision for 2029. In 2019 the Department of Physics was awarded **Juno Champion** status and an **Athena SWAN Silver** award, in recognition of its work to embed equality of opportunity in all areas of work and ensure that all members and prospective members of staff and students are treated solely on merit, ability and potential. Receipt of the Athena SWAN award coincided with the Faculty's Women in Science Week, an annual celebration of women working in STEM.

These awards reflect a deliberate and coordinated effort made by King's Physics over the REF period to embed all aspects of diversity and inclusion which, from 2015-2020, was led by *Peter Main* as HoD, bringing extensive insight from his leading role in the development of the Juno Programme while at the Institute of Physics. The work of *Main* on EDI in STEM education and recruitment was key to the establishment in 2019 of the **Gender Action** collaboration. The Department views these achievements not as the end of a journey, but rather as a springboard to further development and improvement, led by the Department Diversity Lead (*Zair*). Our Athena Swan action plan describes how we are advancing this, with oversight provided by the Department Equality & Diversity Committee (DEDC).

- Recruitment and application material have been reviewed to remove gendered language and appointment panels are chosen to reflect diversity in gender. All academic staff are required to attend Diversity Matters training.
- The diversity of speakers at events and seminars is monitored to ensure representative ratios and provide positive role models and behaviours.
- Flexible working hours are available for staff with circumstances such as caring responsibilities, with timetabled commitments scheduled accordingly. Seminars and meetings are scheduled during core hours of 10.00-16.00 to support staff with other commitments. Remote working on one or more days per week is common and staff can request a specific research day each week to be clear of other commitments.
- Fixed-term research staff are treated as permanent staff for PDR, training and career development. In particular, holders of personal research fellowships are considered on a par with academic staff, with the opportunity of a permanent academic post in areas of strategic priority (with appointment following a standard academic appointment's process).
- Staff are supported in research funding applications according to their individual circumstances. Care is taken to ensure panel diversity on all internal funding schemes, whether co-ordinated at Faculty or University level, with EDI assessment of funding outcomes.
- The University's Parents' & Carers' Fund and Carer's Career Development Fund provide financial support for staff to maintain research progress, including, e.g., conference attendance and other research travel for researchers with caring responsibilities (REF5a §3.4)

- Additional support is provided where needed – two examples are a member of staff who was provided with a postdoctoral researcher during a period where their young child had a prolonged illness and the case of a seriously ill colleague supported in their desire to continue research through reassignment of teaching workload to others.

More than a quarter of our staff (27%) do not identify as white and the department recognises the inequality experienced by BAME people. We are keen to address these issues and remove barriers for researchers from different backgrounds. Research Groups held discussion sessions in the light of the 2020 civil rights movements during which BAME colleagues shared their experiences. King's holds a Race Equality Charter Bronze Award, is a member of Stonewall Diversity Champions and the Business Disability Forum.

Selection of outputs for REF submission took place through internal Group peer review, providing the combined benefit of a structurally unbiased approach and better research understanding. The gender balance of authors of selected outputs was compared with the balance of the Department and no discrepancy was found.

2.7. Supporting researchers during the COVID-19 pandemic

Experimental research was particularly affected during lock-down, with a strong focus in early stages on re-opening research laboratories (which have operated continuously since June 2020) with safe-working practices in place. Furlough of research staff was adopted where possible to extend fixed-term contracts, with shortfall supported where required. The Department was effective in switching all communication online and staff meetings, group meetings, seminars and online coffee mornings provided support and sense of community. PGR students were offered laptops on loan if needed, the university extended PGR assessment deadlines, and funding extensions were available to UKRI and Faculty-funded studentships if research progress was affected by the pandemic.

3. Income, infrastructure and facilities

3.1. Research Funding

Research income has grown to a consistently higher level in this reporting period compared with the previous period. Fig. 4a shows the total annual research income to King's Physics (excluding CDT and other funding for PhD students). While the number of staff in the Department of Physics with

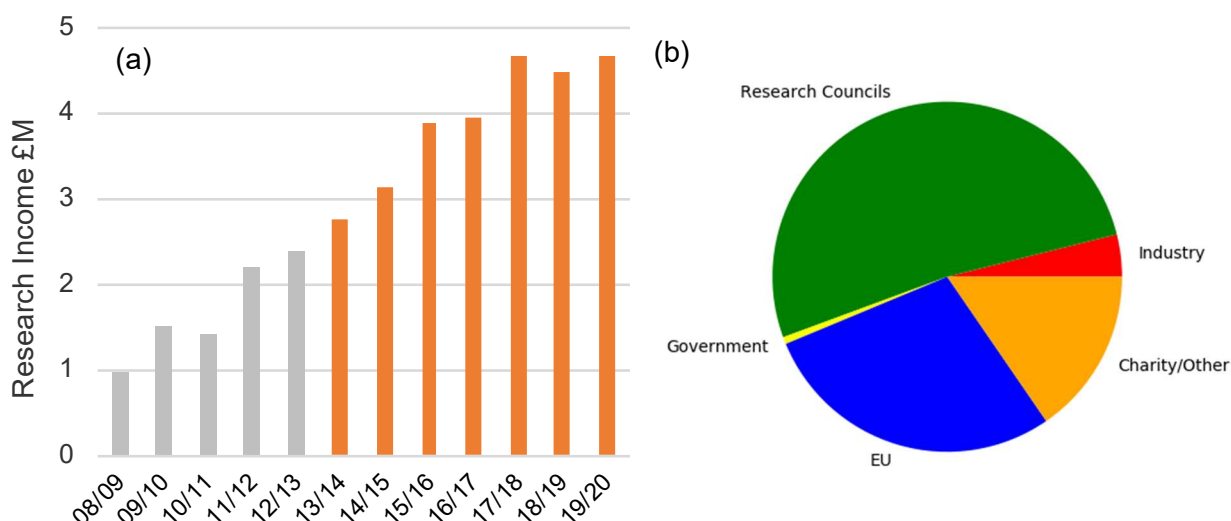


Figure 4. Research income by (a) academic year and (b) by funder type over REF period

significant responsibility for research has increased by 26% from 2012/13 to 2019/20, the annual income increased by 95%. This performance is within the context of the high number of early career academics appointed during the period.

Our strategy for research funding reflects our research strategy outlined in Section 1: continue to appoint outstanding researchers, focussing on early careers researchers with a vision to become leaders of their field; increasing experimental activity; and extensive research grant development support (§2.3). **A quarter** of staff submitted to UoA9 have held one or more prestigious **personal fellowships or major investigator awards** since 2014. EU funding to King's Physics indicated in Fig. 4(b) is dominated by **European Research Council (ERC)** awards, spanning our Research Groups: 4 ERC starting grants (*Booth, Millen, Owen, Rodríguez-Fortuño*), 1 ERC consolidator grant (*Fairbairn*) and 3 ERC advanced grants (*Ellis, Zayats* – two awards). We also obtained 1 ERC Proof of Concept grant (*Millen*). In recognition of the research quality in biological physics, *Garcia-Manyes* has held an **EPSRC Early Career Fellowship**, a **Leverhulme Research Leadership Award** and a **Wellcome Trust Investigator Award**. In support of those starting their own research programmes, during the REF period King's Physics has held 3 **Royal Society URFs** (*Booth, Rakovich, Witek*) and an **STFC Ernest Rutherford Fellowship** (*McCabe*) with *Marsh* joining as an ERF in March 2021. *Zayats* and *Garcia-Manyes* have been awarded a Royal Society **Wolfson Research Merit Award** and **Wolfson Fellowship**, respectively. Prestigious early career fellowships have been secured by researchers on the pathway to independence, including a Royal Astronomical Society Fellowship (*Marsh*) and a Henry Wellcome Fellowship (*Beedle*).

In addition to standard grants from UKRI Research Councils, Leverhulme, Charities, US Funders and Industry (Fig. 4b), King's Physics had an active role in a number of major funded research consortia. King's led two **EPSRC Programme Grants** in plasmonics and metamaterials (PI *Zayats*): *Active Plasmonics* ([APLAS](#), £4.5M, £1.9M to King's), in collaboration with Imperial and QUB, followed by *Reactive Plasmonics* ([RPLAS](#), £4.8M, £2.4M to King's), with Imperial. In materials simulation King's Physics (PI *Paxton*) was a major partner in EPSRC Programme Grant *Hydrogen in metals* ([HEmS](#), *Paxton* and *de Vita*, £5.5M with Sheffield, Cambridge, Imperial, Lancaster, Oxford, £1.1M to King's). King's has participated in two prestigious international **Simons Foundation Collaborations**: on [The Many Electron Problem](#) (*van Schilfgaarde* and *Kozik*, £1.4M to King's) and on [Special Holonomy in Geometry, Analysis, and Physics](#) (*Acharya*, Physics and *Salamon*, Mathematics, £774k to King's).

An **STFC Consolidated Grant** in Particle Physics Theory is awarded jointly to the TPPC Group in Physics and the Theoretical Physics Group in Mathematics. The EPAP Group benefits from both STFC consolidated grants and experimental grants for projects when under construction (for example SNO+ and Hyper-Kamiokande). TPPC are core team members of two recently awarded **UKRI Quantum Technologies for Fundamental Physics** programmes.

Within King's, major funded projects and centres have underpinned our collaborative interdisciplinary partnerships within King's. These include the British Heart Foundation Centre of Research Excellence (£15M) and the BHF Research Excellence Award (£6M) (Physics co-I *Garcia-Manyes*) and the MRC Next Generation Light Microscopy Initiative (£1.6M, Physics co-Is *Owen* and *Suhling*).

3.2. Experimental Laboratories

Experimental research in King's Physics is accommodated by high quality laboratory space in the basements of King's Strand Campus. The Laboratories have the stringent vibration, noise and environmental control required for world-class research in many of our activities, particularly photonics and single-molecule force spectroscopy. These have been developed through a programme of investment in new laboratory space since 2010, with an **£5.5M** provided since 2014

for the creation of **new Physics Research Laboratories** to both accommodate growth of funded research and provide high quality laboratory space for new academic appointments:

- 80 m² new Clean Room facility (ISO7 with ISO5 areas), forming part of LCN facilities, including Plasma Enhanced Atomic Layer Deposition (PEALD);
- 295m² new photonics laboratories (nanophotonics, attosecond laser and optical levitation)
- 94m² new single-molecule biophysics laboratory space
- 60m² new laboratory space for EPAP group (completion delayed by COVID-19)

Further optical microscopy research laboratories for the BPSM Group are located in the Hodgkin Building of King's Guy's Campus (REF5a §1.3), adjacent to the **Nikon Imaging Centre** (REF5a §4.4) which provides a wide range of state-of-the-art optical imaging modalities. Optical microscopy laboratories in the Hodgkin (Wolfson Laboratory Refurbishment Award to King's Physics, completed December 2013), accommodate the King's **Microscopy Innovation Centre (MIC)**, which promotes the uptake of cutting-edge optical microscopy methods for biological imaging; the MIC management committee includes physics researchers *Ameer-Beg*, *Cox*, *Spillane* and *Suhling* from the Comprehensive Cancer Centre, Randall Centre and Physics Department in King's.

The **Strand Materials & Characterisation Facility** (REF5a §4.4) comprises the Department's core experimental facilities under the management of the facilities technician and overseen by a departmental steering committee (chaired by the Director of Research Labs), including AFM, FEG-SEM, cathodoluminescence, PEALD and thermal evaporation, UV-Vis and FTIR spectroscopy, ellipsometry, supported through an EPSRC [Equipment Award](#) (£804k) and a [Strategic Equipment Award](#) (£204k) in 2015. These facilities are available to researchers from other Departments in King's, LCN researchers, and external users.

Additional facilities include confocal and multiphoton microscopy, nonlinear, time-resolved, fluorescence and Raman spectroscopy, SNOM and dynamic light scattering, with **£466k** investment in new equipment since 2014 to support new appointments.

King's Physics also benefits from extensive electron microscopy within the King's **Centre for Ultrastructural Imaging** (REF5a §4.4, in partnership with JEOL). Since 2018, King's is a partner of the **London Centre for Nanotechnology**, and since 2011 King's Physics has enjoyed access to all Clean Room and dedicated nanofabrication facilities housed at UCL and Imperial.

The Physics **Director of Research Labs** (*Zayats*) ensures that Department Research labs run effectively and that there is sufficient quality provision to fulfil the Department research strategy. Experimental research is supported by a technical team which has grown by 50% since 2014 to 6 staff, including a Technical Service Manager, Safety Officer, Clean-Room Engineer, Facilities Technician and Electronics and Workshop support.

3.3. Computing Support

A range of local, regional national and international **HPC** platforms are available. A **Faculty Computing Support Team** of ca. 12 staff provides extensive support on computing provision for research, including HPC support. The Physics **Director of Computing Provision** (*van Schilfgaarde*) provides oversight of HPC delivery and ensures there is sufficient quality computing provision to accommodate research strategy, as well as ensuring access for students and staff with disabilities. *Lorenz* chairs the **Faculty Computing Committee** which has oversight of new Faculty investment for HPC, and other computing strategy.

Rosalind is the university-wide HPC cluster, supported and funded by the NMES Faculty in collaboration with King's IT and King's Health Partners' Biomedical Research Centres, with priority

for NMES researchers on Faculty-funded hardware; Physics researchers have been primary users. The cluster infrastructure is maintained and monitored by a third-party partner, enabling continuity of computational research during COVID-lockdown. Faculty investment in computing support during the REF period includes:

- 2013/14 £450k HPC cluster for use by NMES researchers: support for large parallel workloads with high core count nodes, Infiniband networking and Lustre filesystem.
- £100k investment in research storage and backup.
- 2018/19 £325k additional CPU and GPU capacity for large parallel workloads with OmniPath networking.
- £30k p.a. annual investment for infrastructure maintenance and renewal.

Gravity is available to NMES research groups that have purchased, through grants, hardware that is hosted in the facility, with a design that permits heterogeneity (varied CPU architectures, non-standard GPU configurations).

King's Physics is a key partner of the **Materials & Molecular Modelling (MMM) Tier-2 Hub**, established with **£8.5M** EPSRC funding in [2016](#), renewal [2020](#), enabled through the Thomas Young Centre and supported by King's through **£100k p.a.** contribution and a **Research Software Engineer** in King's Physics. The MMM Hub comprises two HPC facilities, Thomas (17,000 cores) and Young (23,040 cores). *Booth* and *Molteni* represent King's on the MMM Management Board.

Physics investigators been awarded more than 235M CPU hours on national and EU HPC facilities (Table 1), including time awarded through membership of the Materials Chemistry Consortium and UKCP Consortium.

King's has recently established a new University-wide e-Research function to provide a flexible research computing infrastructure for a wide range of computational workloads, underpinned by a £1M hardware refresh of Rosalind and a £800k Research Data Storage platform (online 2021).

HPC Facility	CPU hours
ARCHER (EPSRC)	97M
CIRRUS (EPSRC)	4M
PRACE (EU)	129M
DiRAC (STFC)	5M

Table 1. Competitively awarded CPU time.

4. Collaboration and contribution to the research base, economy and society

4.1. Partnerships & Collaborations

The development of research collaborations, networks and partnerships, both formal and informal, many interdisciplinary, lies at the heart of our research strategy (see Section 1.3).

4.1.1. National & International Research Partnerships

Our regional partnerships, summarised in Section 1.3 and Fig. 5, provide a strong framework for the development of successful research collaborations. The **London Centre for Nanotechnology** (co-Director *Zayats*) is a strategic partnership between King's, Imperial College London and UCL, strengthening collaboration within London, providing a platform for equipment sharing, and a forum for networking, joint lectures, and workshops. In biomedical science, the **Francis Crick Institute** was founded through partnership with King's, Imperial and UCL, enabling university researchers to bring physical sciences expertise to create new collaborations, through hosting of research at the Crick (*Garcia-Manyes*, *Elosegui-Artola*) and co-supervision of PhD students (*Lorenz*, *Garcia-Manyes*). Our partnership with Imperial, QMUL and UCL in the **Thomas Young Centre** (co-Director *Molteni*) provides a vibrant interdisciplinary and collaborative environment with an active programme of events and training for early career researchers. The TYC has brought new funding to King's

Physics with partners such as Argonne National Laboratory, EOARD and NPL, and enabled the award, and renewal, of the £8.5M MMM HPC Hub (see §3.3). The TPPC and EPAP Groups have recently joined the **NExT Institute** for *New connections between Experiment and Theory* (with Southampton, RHUL, QMUL, Sussex, RAL) and P&N led the creation (with Imperial and UCL) of the London Institute for Advanced Light Technologies (**London Light**, co-Director Zayats).

Our partnership with Cambridge, Imperial, Oxford and UCL of the **JC Maxwell Node** of **CECAM** (Node management committee *Molteni*) places King's Physics at the heart of European research in theoretical and computational condensed matter physics, chemistry, biology and materials science. The **transCampus** initiative between King's and Technische Universität Dresden (**TUD**, REF5a §1.5) has led to an MoU for the development of new collaborations in materials research between London and TUD. A collaboration on next generation solar cells was established within the **PLuS Alliance** University Network (King's, University of New South Wales and Arizona State University).

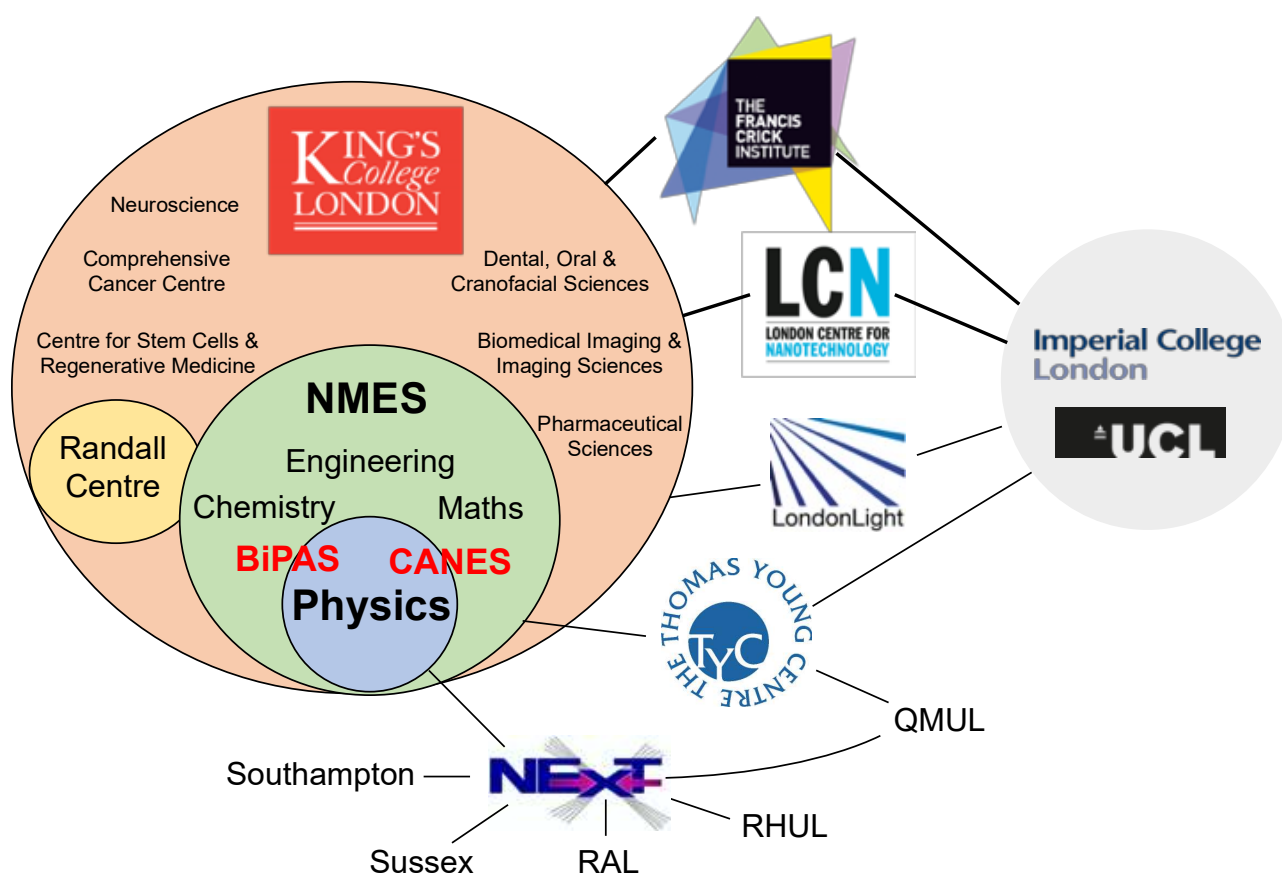


Figure 5. Primary interdisciplinary and regional research collaborations and partnerships.

4.1.2. International Experiments

Members of the EPAP Group are part of the **T2K**, **Superkamiokande**, **SNO+**, **MiniBoone**, **IceCube**, **IceCube-Gen2** and **ANNIE** international experimental neutrino collaborations, and have international leadership of the **Hyper-Kamiokande** experiment (*Di Lodovico* is joint spokesperson). During the REF period the Group contributed to new results in CP violation in the neutrino sector using the T2K experiment (near detector steering committee *Di Lodovico*). They are also investigating neutrinoless double beta decays with SNO+ (analysis coordinator *Wilson*). The Group has played a leading role in new papers from the IceCube experiment in probing beyond-the-Standard-Model physics. EPAP members have also made critical contributions to the Hyper-Kamiokande experiment which started construction in 2020.

TPPC Group members play leading roles in the **MoEDAL** experiment at CERN searching for exotic particles at the LHC (Physics coordinator *Mavromatos* & Theory coordinator *Ellis*) and are members of the **CTA**, **LIGO**, **LISA** (Chair of Dark Matter Package of the Science Interpretation working group: *Blas*), **Euclid**, **SKA**, and **Darkside** experiments. The Group are core team members of the *Atom Interferometer Observatory and Network* (**AION**, Head of publication board: *Ellis*).

4.1.3. Research networks & collaborations

King's Physics benefits from participation in a number of international research networks and collaborations. EPAP Group are members of the EU MSCA-RISE project *Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research* ([JENNIFER2](#), UK and WP3 lead *Di Lodovico*) and the international NuSTEC (Neutrino Scattering Theory Experiment) Collaboration (Board member *Katori*). In nanophotonics we have participated in the FORESEEN Consortium and associated FET-Open CSA *Nanoarchitectronics* (Steering Committee *Zayats*), and the Erasmus Mundus programme NANOPHI (Management Board *Zayats*), involving European and Asia-Pacific research groups. In ultrafast photonics *Zair* participates in the high repetition rate attosecond physics EU initiative at the Extreme Light Infrastructure (ELI-Alps) facility and is actively involved in the Laserlab Europe Consortium. In materials and molecular modelling, the TSCM and BPSM Groups have been active participants of the European Psi-k network (*Molteni* leads WG "Molecules, Biomolecules, Macromolecules"; *Booth* is a member of WG "non-perturbative many-body methods").

King's Physicists have participated in various EU COST Actions since 2014, and have been involved in a number of funded collaborative international research programmes, including two Simons Collaborations (§3.1), the *Novel Materials Discovery Laboratory* ([NoMaD](#)) EU Centre of Excellence and FET-OPEN *Mechanical control of biological function* ([MECHANO-CONTROL](#)).

The department has also benefited from numerous national networks beyond those identified in §4.1.1., including CCP5 (Executive Committee: *Lorenz*), CCP9 (Project spokesperson: *Molteni*), the Materials Chemistry Consortium (Advisory Board: *Lorenz*), British Optomechanics Research Network (steering group: *Millen*), DMUK (Chair: *McCabe*) and co-leadership of EPSRC [NetworkPlus](#) on *Emergence and Physics Far From Equilibrium* (*Bhaseen*).

4.2. Engagement with research users and beneficiaries

4.2.1. Scientific Software Development

King's Physics have made extensive contributions through code development available to the community, enabling widespread adoption of developments pioneered at King's. Two highlights are:

- **Questaal**, led by *van Schilfgaarde*, is a suite of programs for electronic structure simulations, including advanced beyond-DFT electronic structure code. Questaal was an EPSRC [CCP9 flagship project](#) (with Daresbury, QUB) enabling the development of a community code, with regular workshops and online tutorials. Questaal now has approximately 300 registered users internationally.
- **GRChombo** (Collaboration co-founder *Lim*, with QMUL and Argonne National Laboratory) is a numerical relativity code with applications to cosmology and astrophysics with about 40 papers to date. The collaboration includes **Intel**, whose interest stems from GRChombo's pioneering use of their next generation MIC architecture, while the code is now used as a benchmark for the procurement of 4 UK Tier-1 HPC systems under the DiRAC-3 infrastructure upgrade.

4.2.2. Partnership & Collaboration with Industry

Wide-ranging engagement with industry and government partners has benefited the department through research funding, career development for early career researchers and new pathways to

impact. This has involved industry-funded projects, partnership on UKRI awards, secondments and through direct collaboration. Some examples include:

- **Microsoft**, using Questaal to help design its next-generation (JMRAM) superconducting computers able to run 100 times faster with 100 times less energy.
- The **Atomic Weapons Establishment** on materials at high pressure, supported by both industry and EPSRC funding and including a secondment into King's Physics.
- **Kennametal, European Thermodynamics, Johnson & Matthey** and **BIOVIA** with EPSRC and industry funding to design Eco-Friendly thermoelectric materials.
- Major steel companies and **Rolls-Royce** on atomistic modelling of alloys and metal corrosion.
- London-based SME **Rahko** on quantum machine learning, supported by InnovateUK funding.
- **DSTL** on metamaterials, resulting in a joint patent application.
- Various Photomultiplier tube companies (**ET enterprises, Hamamatsu, HZC**) to develop products for Hyper-Kamiokande.
- Instrumentation companies, such as **Photek** in microscopy innovation, and **Luigs & Neumann** and **Lumicks** for nanomanipulation of biological specimens.

4.3. IP and Commercialisation

Research by *Green* in King's Physics in 2010 demonstrated the use of conjugated polymer nanoparticles in imaging biology; the resulting patent (WO 2011039535) was licenced to **Stream Bio**, founded in 2015 to exploit this technology. Stream, which was awarded a **2018 Institute of Physics Business Award** for Outstanding Innovative Work on conjugated polymer development and commercialisation in the realm of medical diagnosis, has established a base within the UK High Value Manufacturing Catapult.

King's research since 2014 has led to a number of new patents, which we have supported with funding to advance these innovations on the pathway to impact (see §1.5). For example, development of metamaterial-based hydrogen sensors (WO/2014/184530: *Zayats, Dickson & Nasir*) has been supported through the EPSRC IAA to develop a proof of concept, followed by collaboration with **QinetiQ** on development and prototyping, with the collaboration supported by secondment of a QinetiQ researcher to King's Physics and a Royal Society Industrial fellowship (*Nasir*). This, and a novel emissive metamaterial device (patent WO/2018/134592), were showcased at the 2018 SPIE Photonics Europe Innovation Village and the KTN Metamaterials Showcase (Birmingham, 2019).

4.4. Outreach, Public Engagement and Contributions to Society

As described in Section 1.5, King's Physics is committed to engagement with diverse communities through our research. Most departmental staff are active in outreach, encompassing a wide range of activities. Important examples of our work are two of our impact case studies: the Dark Matter Season at Science Gallery London, and Schools in Developing Countries to widen participation in research. In addition to a large number of media interviews and the usual talks to school children, examples include:

- London Light has celebrated at King's the **international day of light** with exhibitions open to the public where the theme of light is explored through, side-by-side, artworks and photonics demonstrations.
- Regular participation by many staff in events around London for the public such as **Pint of Science, Science Gallery Lates**, and **Dark Matter Days** on Halloween, leading to public talks and YouTube videos.

- Destination STEMM: A Windsor fellowship programme providing mentoring for disadvantaged and minority race students hoping to study STEMM subjects at university.
- King's Physics researchers contributed to the **Royal Society Summer exhibition** in 2015 on monopoles, 2018 on photonics and 2019 on neutrinos.
- Science talks at festivals such as the **Secret Garden Party**, **Bloomsbury Festival**, **Hay-on-Wye** science & philosophy festival, the **New Scientist Science Festival**, **ArtBasel** festival, **Athens Science Festival** and short courses open to the public at the **Royal Institution**.

4.5. Wider influence and contributions

Grant/Fellowship Committees:

Many roles on funding panels include: **STFC Ernest Rutherford Fellowship** Panel (*Fairbairn* and *Wilson*); **STFC Particle Physics Theory** Panel (*Fairbairn*); **EPSRC Quantum technology Fellowship** Panel (*Zayats*), **Engineering Programme Grant** Panel (*Richards*), standard mode panels (*Dickson*, *Zair*); and **tier-2 HPC resource allocation** panel (*Booth*). *Garcia-Manyes* – **Wellcome Trust Investigator Award** panel. *Baletto* – **La Caixa Foundation** Postdoctoral Junior Leader Fellowship panel. *Di-Lodovico* was on the **EU ERC** Panel, the **Royal Society URF** panel and the **UKRI future leader fellowship** panel. 7 staff are members of the EPSRC College.

Membership of National and International Committees:

Important roles in professional organisations include: *Zayats* – **EPSRC Physical Sciences Strategic Advisory Team**. *McCabe* – **STFC Particle-Astrophysics Advisory** Panel. *Katori* – Chair of the **IoP Astroparticle Physics Group** and member of the **IoP High Energy Particle Physics Group** committee. *Sakellariadou* – Chair of the Gravitational Physics Division of the **European Physical Society**. *Baletto* – member of the **Royal Society of Chemistry Quantum Chemistry Group** committee. *Lorenz* has been treasurer of the **RSC/SCI Colloid and Interface Science Group**. *Richards* was Chair of the Standing Conference of Physics Professors (2013-2015, renamed **Heads of Physics Forum** during his term).

Steering groups/ advisors/ International Advisory Committees:

King's staff have held a variety of advisory roles at different labs and institutes. *Di-Lodovico* – **LHC experiments** and **Long Baseline Neutrino** Committees. *Ellis* – International Advisory Committee for the **Higgs Centre** (Edinburgh), **Kavli IPMU** (Tokyo) and the **T.D.Lee Institute** (Shanghai). *Ellis* is Chair of the IAC for the **Chinese Jinping Laboratory**. *Mavromatos* – Advisory Board of the **Stefan Meyer Institute** (Vienna). *Fairbairn* performed a periodic review of the **CNRS lab at Annecy** and *Ellis* at the **University of Sussex**. *Zayats* served on the Advisory Board of the **ASTAR Data Storage Institute** (Singapore) and on the panel for the **Future Horizons for Photonics Research- 2030 and Beyond Roadmap** (UK Photonics Leadership Group).

Prizes:

Scientific prizes won during the period of the REF include the **Royal Society Bakerian Lecture and Prize** (*Ellis*), **IoP Bates Prize** (*Millen*), **IoP Lawrence Bragg Gold Medal** (*Acharya*), the **Buchalter Cosmology Prize** (*Blas*), **Gold Award and Cavendish Medal for STEM for Britain** (PhD student *Caixeiro*), **IoP Jocelyn Bell Burnell Medal and Prize** (PhD student *Cornell*).

Other Honours:

Ellis was awarded three **honorary doctorates** and elected a **Fellow of the Indian National Science Academy**, elected **Fellow of the Estonian Academy** and **Honorary Fellow of the Institute of Physics**. *McCabe* & *Fairbairn* were awarded **IPPP-Durham associateships** while *Sakellariadou* was an Emmy Noether Fellow at the **Perimeter Institute**. *Garcia-Manyes* was made a Fellow of

the **Catalan Academy of Sciences** and a member of the **Faculty of 1000** in biological physics. These are in addition to the other fellowships and awards already mentioned in (§3.1).