PHYSICS @EPFL 2019

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CONTENTS 2019

FRONT COVER
Multicolor 3D image of a protein complex reconstructed from 2D super-resolution microscopy images.

LETTER FROM THE DIRECTOR

Dear Reader,

A warm welcome to the Institute of Physics (IPHYS) at the Faculty of Basic Sciences at EPFL. This brochure lists our key figures and facts in research, teaching, and technology transfer of the year 2018. Let me point out a few outstanding achievements and academic promotions of our members. We congratulate Frédéric Courbin on his ERC Advanced Grant, Christoph Galland and Suliana Manley on their ERC Consolidator Grants, as well as Henrik Rønnow and Gabriel Aeppli on their ERC Synergy Grant. Christian Theiler has received an SNSF Eccellenza Grant and Fabrizio Carbone was promoted Associate Professor. Pascale Jablonka and Philippe Spätig were promoted to Adjunct Professor, and Christopher Mudry to external Adjunct Professor.

We are very happy that Lesya Shchutska will join us from April 2019 on as Assistant Professor Tenure Track in the field of Particle Physics. We cordially welcome Anna Fontcuberta i Morral (Materials Science), who is now co-affiliated to our Institute, and Peter Maurer who joined us with his SNSF Fellowship.

The number of students in Physics, but also overall at EPFL, continues to increase. This year Nicolas Grandjean took over from Jean-Philippe Ansermet as head of the Physics Section. We are very grateful to Jean-Philippe for his 12 years of duty. We are also proud of our students who have won this year's International Physics Tournament, many thanks also to the colleagues who accompanied them on their way to this success. The Doctoral School of Physics is now headed by Frédéric Mila and we very much thank Vincenzo Savona for his effort as head in the past. Teaching distinctions were awarded to Vincenzo Savona, Frédéric Mila, and Antonio Gentile.

We are looking forward to another exciting year with Faculty nominations to come in condensed matter physics, quantum science and technology, and accelerator physics. I wish you a good reading and thank Blandine Jérôme for putting together this newsletter.

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LESYA SHCHUTSKA HUNTS FOR NEW PARTICLES

Lesya Shchutska has been appointed Assistant Professor Tenure Track of High Energy Physics. She will start at EPFL on April 1st.

Lesya Shchutska knew that she wanted to do research in physics since she was 10 years old, and that she wanted to do particle physics in her last year of high school at the age of 15. After a bachelor and a master within the LHCb experiment group led by Prof. Andrey Golutvin at Moscow's Institute for Theoretical and Experimental Physics, she worked during her PhD on developing a new detector for a balloon-borne experiment, graduating from EPFL in the group of Prof. Tatsuya Nakada in 2012. "After that," explains Lesya Shchutska, "I pursued my curiosity for new physics searches, and especially for dark matter particle searches, by joining the CMS experiment at the Large Hadron Collider (LHC), and concentrating my research on looking for Supersymmetric particles decaying to leptonic final states." In addition, she worked on the R&D for the future fixed target facility at CERN – SHiP (Search for Hidden Particles).

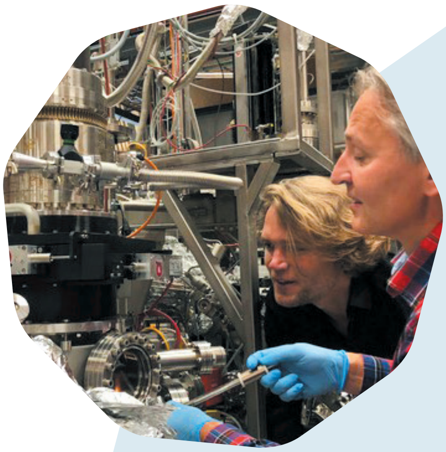
Lesya Shchutska's main research interest lies in a future discovery of new particles, as e.g. dark matter nature, the sizeable matter-antimatter asymmetry and the neutrino masses are not predicted by the standard model of particle physics. One of the most elegant and compelling extensions of the standard model was proposed by Prof. Mikhail Shaposhnikov at EPFL. This theory already inspired the design of a new facility at CERN (SHiP), and led many experimentalists to hunt for heavy neutrinos – invisible and noninteracting siblings of very light standard model neutrinos. With a recently awarded ERC Starting Grant, Lesya Shchutska is now looking for the signs of these particles in the huge dataset delivered by the LHC.

"When joining IPHYS," says Lesya Shchutska, "I will profit from the opportunity to do my research with the LHCb experiment at CERN." LHCb might be seeing a difference in interactions of the three families of charged leptons. If confirmed, this will be the first sign of physics beyond the standard model at the LHC. The LHCb detector also provides means to look for long-lived heavy neutrinos produced in the decays of b mesons, a task almost impossible in the other experiments. She will also work on the upgrade of the Scintillator fiber tracker for LHCb that should enable LHCb operation on the High-Luminosity LHC.

Searching for invisible and noninteracting neutrinos

Lesya Shchutska is also very involved in teaching and outreach programs. She uses all available opportunities to talk about her work at CERN and to pass on a passion for research to students of all levels. "Teaching and outreach in sciences are of vital importance since they ensure the continuity of keeping and developing the scientific knowledge," says Lesya Shchutska. "I would like to take full advantage of the opportunity that the position at EPFL offers to access a new audience and to motivate young people to try a career in science."

"My time at EPFL will allow me to both (re)establish myself in the new collaboration and to grow as a high-energy experimental physicist by expanding my area of expertise," adds Lesya Shchutska. "Collaborative environment, bright students, and even close location to CERN are a unique combination, which is impossible to find in any other place. And with the tantalizing hints we see and with the expectations we have from analyzing LHC data in the near future, the best outcome would be new particles discovery which will turn once more our understanding of nature."



CONTROLLING MAGNETIC SPIN WITH ELECTRIC FIELDS

EPFL physicists have found a way to reverse electron spins using electric fields for the first time, paving the way for programmable spintronics technologies.

Spintronics is a field of physics that studies the spin of electrons, an intrinsic type of magnetism that many elementary particles have. The field of spintronics has given rise to technological concepts of "spintronic devices", which would run on electron spins, rather than their charge, used by traditional electronics.

Magneto-electric coupling at the basis of programmable semiconductor-based spintronics

In order to build programmable spintronic devices we first need to be able to manipulate spins in certain materials. So far, this has been done with magnetic fields, which are not easy to integrate into everyday applications.

In a new set of experiments, an international team of physicists led by Hugo Dil at EPFL has now demonstrated the ability to control what is called "the spin landscape" using electric fields. They accomplished this in a new class of materials based on germanium telluride (GeTe), which is the simplest ferroelectric material operating at room temperature.

The scientists used a technique called spin- and angle-resolved photoemission spectroscopy (SARPES), which can measure the spin of electrons, and has been perfected by Dil's lab. By combining SARPES with the possibility to apply an electric field, the physicists demonstrate electrostatic spin manipulation in ferroelectric α-GeTe and multiferroic (GeMn)Te.

In addition, the scientists were able to follow the spins' switching pathway in detail. In (GeMn)Te, the perpendicular spin component switches due to electric-field-induced magnetization reversal. This provides firm evidence of magneto-electric coupling, which opens up the possibility of programmable semiconductor-based spintronics.

"Our previous work showed that magnetic fields can control spins in these materials," says Dil. "And now we have shown that spin manipulation is also possible using electric fields. Our experimental findings open up a promising path to only use electric fields in a spintronics device, strongly reducing the energy consumption."

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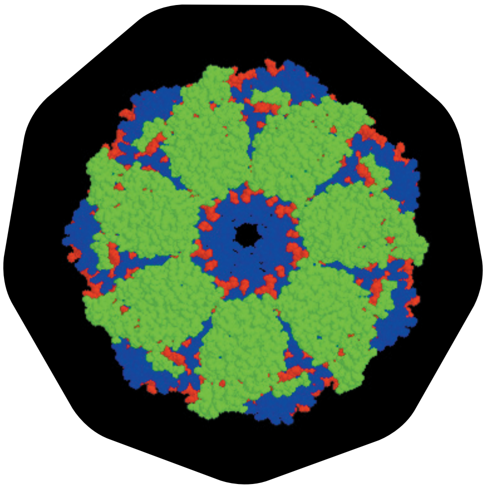

CHAPERONES CAN HOLD PROTEINS IN NON-EQUILIBRIUM STATES

Chaperones are specialized proteins in the cell that help other proteins to reach their functional 3D shapes, which correspond to the states preferred at thermodynamic equilibrium. But a new study by EPFL, UNIL and INSERM (France) scientists shows that chaperones can also maintain proteins in non-equilibrium states, potentially altering their fate.

After translation, proteins must fold to their functional 3D shape and keep it while under attack by various perturbations: external stress such as temperature changes, wrong interactions with other proteins in the cell, and even deleterious mutations. To ensure that proteins stay functional, the cell uses a particular class of proteins, the chaperones. These are present in all organisms and are among the most abundant proteins in cells, emphasizing how crucial they are to sustain life.

The current view is that the functional 3D shape of a protein is also its most thermodynamically stable state, and that chaperones help proteins reaching this state by preventing them from aggregating and by allowing them to escape so-called "kinetic traps" – points where the protein may get "stuck" in a non-functional state. And to do all this, chaperones need energy, which in the cell comes in the form of adenosine triphosphate, or ATP.

The labs of Paolo De Los Rios at EPFL and Pierre Goloubinoff at UNIL, in collaboration with Alessandro Barducci (INSERM – Montpellier), have now shown that the energy from ATP is used by chaperones to actively maintain the proteins they are working on in a non-equilibrium but transiently stable version of the functional form, even under conditions upon which the functional form should not be thermodynamically stable.

"What we found is that chaperones can actively repair and revert the proteins they act upon in a non-equilibrium steady-state," says De Los Rios. "In this state, the proteins are in their native state even if, from an equilibrium thermodynamics perspective, they should not."

The researchers combined theoretical and experimental approaches to prove that chaperones are molecular motors, capable of performing work and extending the stability range of proteins. The results may challenge parts of the prevalent view that evolution has designed amino acid sequences so that the functional state of the protein they belong to is thermodynamically optimal.

Even thermodynamically sub-optimal proteins might be able to reach their functional form

"In the presence of chaperones, even thermodynamically sub-optimal proteins might be able to reach their functional form, facilitating evolution in its endless exploration of chemical possibilities," says De Los Rios.

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Graduation Day

Every first week of October takes place the Master's degree graduation day, the so-called Magistrale, which honored 1,043 students this year. They were warmly applauded by their parents, friends, professors, a crowd of about 3,000 people under the roof of the Swiss Tech Convention Center. Among them, a distinguished group of 57 students received a degree in physics, a passport for a rich professional life!

The Graduation Day, on Saturday October 6th, closes a long journey for EPFL's students after 5 years - sometimes more - of hard working, discovering, learning, and finally getting their Master degree. The ceremony was honored by distinguished guests such as Daniel Borel, co-founder of Logitech and EPFL's alumni, and Guy Parmelin, Federal Councilor. EPFL's President Martin Vetterli first delivered a congratulatory message to the students concluding by "never forget, you are responsible for our planet". The Award ceremony featured the third highest Master's grade average going to Lubomir Bures, a physics student with 5.96 out of 6. Another important award is the Golden Polysphère, recognizing the best teacher, that was handed out this year to Antonio Gentile from the Physics Section (see p. 15). The general ceremony ended with an allocution by the Federal Councilor Guy Parmelin recalling that "science is a form of personal commitment to bettering the community."

In the afternoon, the students split by sections and meet together with parents, families, friends, and teachers. This year, 57 Master degrees (37 in physics, 17 in physics engineering, and 3 in nuclear engineering) were handed out by Prof. Jean-Philippe Ansermet, the former director of the Physics section. This was a very emotional moment after 12 years spent as the head of the section. His strong commitment to the management of the physics teaching was acknowledged by the new section director, Prof. Nicolas Grandjean and highlighted by a warm applause from the audience. There were also two special distinctions: Elodie Savary was awarded the merit prize, which recognizes an extraordinary education path, and Gabriele D'Aversa the Haussman prize, which rewards an outstanding Master thesis (see p. 22). The ceremony was also enlightened by a couple of inspiring speeches delivered by Prof. Jan Hesthaven, the Dean of the School of Basic Sciences, and Mr. Moussa Dialo, EPFL Physics alumni (1997). Finally, one should keep in mind that behind the physics diploma is a team of teachers, technicians, and administrative staff who are fully dedicated to teaching, as does Prof. Vincenzo Savona who was handed out the best teacher award of the Physics Section (see p. 15). The Graduation Day is obviously a special day for our Master students. The door suddenly opens on unknown and limitless territories. Hopefully, the physics education they received at EPFL will always be an outstanding landmark.

Fabrizio Carbone reveals ultrafast phenomena at the nanometer scale

Fabrizio Carbone was named Associate Professor of Physics as of 1st of August.

Fabrizio joined Physics at EPFL in 2009, after a PhD at the University of Geneva and a postdoc at Caltech. There, working with Ahmed Zewail, 1999 Chemistry Nobel laureate, he demonstrated the first fs-resolved electron energy loss spectroscopy experiments in a transmission electron microscope, a technique that enabled several new explorations of solids, nanostructures and molecules.

In his laboratory (LUMES), Fabrizio Carbone implemented a state-of-the-art apparatus capable of pushing the resolution limits of time-resolved electron microscopy to the nanometer, attosecond, and milli-electronvolt space, time and energy scale. Thanks to this instrument, his group made several breakthroughs, for instance demonstrating the ability of light pulses to write and erase topological magnetic patterns called skyrmions and monitor their ensuing dynamical evolution. He and his group were also able to map and control plasmonic near fields in nanostructures and use their interaction with free electrons to coherently manipulate their wavefunction down to the attosecond scale.

Fabrizio Carbone was awarded the 2016 Latsis University prize, an ERC Starting Grant in 2010 and an ERC Consolidator Grant in 2017. The latter will enable a significant development of the ultrafast electron microscope with the aim of manipulating individual charges and spins in materials and nanostructures with light and electron pulses.

DETECTING THE BIRTH AND DEATH OF A PHONON

EPFL physicists have developed a new technique to probe elementary quantum excitations of atomic vibrations inside a diamond crystal under ambient conditions. The technique uses ultra-short laser pulses and detectors sensitive to single photons.

Phonons are discrete units of vibrational energy predicted by quantum mechanics that correspond to collective oscillations of atoms inside a molecule or a crystal. When such vibrations are produced by light interacting with a material, the vibrational energy can be transferred back and forth between individual phonons and individual packets of light energy, the photons. This process is called the Raman effect.

In a new study, the group of Christophe Galland has developed a technique to measure, in real time and at room-temperature, the creation and destruction of individual phonons, opening up exciting possibilities in various fields such as spectroscopy and quantum technologies.

The technique uses ultra-short laser pulses, which are bursts of light that last for less than 10^{-13} second. First, one such pulse is shot onto a diamond crystal to excite a single phonon inside. When this happens, a partner photon is created at a new wavelength through the Raman effect, which is observed with a specialized detector, heralding the success of the preparation step.

Second, to interrogate the crystal and probe the newly created phonon, the scientists fire another laser pulse into the diamond. Thanks to another detector, they now record photons that have reabsorbed the energy of the vibration. These photons are witnesses that the phonon was still alive, meaning that the crystal was still vibrating with exactly the same energy.

This is in strong contradiction with our intuition: we are used to seeing vibrating objects progressively lose their energy over time, like a guitar string whose sound fades away. But in quantum mechanics this is “all or nothing”: the crystal either vibrates with a specific energy or it is in its resting state; there is no state allowed in between. The decay of the phonon over time is therefore observed as a decrease of the probability of finding it in the excited state instead of having jumped down to the rest state.

We just need to watch very fast

Through this approach, the scientists could reconstruct the birth and death of a single phonon by analyzing the output of the two photon detectors. The new technique can be applied to many different types of materials, from bulk crystals down to single molecules. It can also be refined to create more exotic vibrational quantum states, such as entangled states where energy is “delocalized” over two vibrational modes. And all this can be performed in ambient conditions, highlighting that exotic quantum phenomena may occur in our daily life – we just need to watch very fast.

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Frédéric Courbin receives an ERC Advanced Grant

Frédéric Courbin, adjunct professor at the Laboratory of Astrophysics (LASTRO), has received a European Research Council Advanced Grant for 2018.

The ERC Advanced Grants are given each year to established, leading principal investigators to provide long-term funding for *"ground-breaking, high-risk"* research projects in any field. Frédéric Courbin was awarded such a grant for his project *"COSMICLENS: Cosmology with Strong Gravitational Lensing"*.

Measuring cosmological distances has revolutionized our understanding of the Universe, and is still doing so! Early work in the 1920s led to the discovery of the expansion of the Universe. More precise distance measurements in the 90s with type-Ia supernovae revealed that this expansion is accelerating, with crucial consequences in cosmology and physics. However, the unexpected discovery of the *accelerated* expansion now poses new challenges and questions. Is the acceleration due to some repulsive form of dark energy? To Einstein's cosmological constant? Do we need to consider new physics? Answering these fundamental questions requires a reliable measurement of the Hubble parameter, H_0, the prime parameter in the distance ladder: this is precisely the goal of COSMICLENS using the time delay method in strongly lensed quasars.

The time delay method exploits well-known physics on galaxy-scales. It is one of the very few techniques, maybe the only one, that can yield H_0 to better than 2% using a single methodology. It involves no calibration, and is truly independent of any other cosmological probe. Capitalizing on the successful pathfinders COSMOGRAIL, led by Frédéric Courbin at EPFL and H0LiCOW led by Sherry Suyu at MPA-Garching, the goal is to fully exploit time delays with an observational, modeling and technical boost, organized in 2 phases.

Phase I will secure H_0 to 2% using the current chain of analysis, with feasible enhancements beyond the current state-of-the-art. This will confirm or refute the tension seen between H_0 values with different cosmological probes (CMB, BAO, Cepheids and Supernovae). Phase II targets 1% precision, improving the Figure of Merit of Stage-IV cosmological surveys (Euclid, LSST) by 40%.

The work is organized around 4 main axes that can potentially transform the field within the next 5 years by 1- implementing the first high-cadence photometric monitoring of lensed quasars to measure 50 new time delays, 2- providing new flexible non-parametric lens models based on sparse regularization of the reconstructed source and lens mass/light distributions, 3- providing a modular end-to-end simulation framework to mock lensed systems from hydro-simulations and to evaluate in detail the impact model degeneracies on H_0, 4- discovering new suitable lensed quasars in current surveys.

Anna Fontcuberta i Morral: nanowires to harvest energy

Anna Fontcuberta i Morral, associate professor at the Institute of Materials Science and Technology, is co-affiliated to the Institute of Physics since February 2018.

Anna Fontcuberta i Morral obtained her PhD at the Ecole Polytechnique in Paris in 2001. After a postdoctoral stay at the California Institute of Technology, she obtained a permanent CNRS researcher position at the Ecole Polytechnique in 2003. Thanks to a Marie Curie Excellence Grant, she became a Team Leader at the Technical University of Munich from 2005 to 2010. In 2008, she was appointed Assistant Professor Tenure Track at the Institute of Materials of EPFL and promoted to Associate Professor in 2014. She was awarded an ERC Consolidator Grant in 2015.

The research of Anna Fontcuberta i Morral focuses on the synthesis of novel semiconductor nanowires and the study of their properties. Her laboratory is well-known for innovations in wires involving hetero-structures interfacing p- and n-doped regions, which are of interest for solar cells. Specifically when these regions are radially arranged, the high surface-to-volume ratio of the wire is beneficial. This also holds for applications in sensors and nano-photonics.

Pascale Jablonka: stars reveal the history of the Universe

Pascale Jablonka was named as Adjunct Professor as of December 2018.

Pascale Jablonka obtained her PhD in Astrophysics and Space Techniques in 1991 from the University of Paris VII. For three years she was a postdoc successively at the University of Paris XI and the European Observatory of Munich. She has held researcher positions at the Paris Observatory (CNRS) and the University of Geneva before joining EPFL in 2009 as a scientific collaborator. She obtained the title of CNRS Directrice de Recherche in 2012.

Pascale Jablonka is an internationally recognized scientist in the field of astrophysics and cosmology, focusing on the formation and evolution of galaxies. She combines multi-wavelength observations with chemo-dynamical numerical simulations.

Pascale Jablonka seeks to understand the formation and properties of the first stars and galaxies in the Universe. To this end, she is leading several programs targeting the halo of our Galaxy and its satellites. She observationally characterizes and subsequently models in detail the chemical and dynamical evolution of dwarf galaxies, which are the best analogues to the primordial galactic systems. This allows to shed light on the physical processes linked to star formation, and on the nature and distribution of dark matter. Finally, Pascale Jablonka is known for her contribution to our understanding of the growth of the cosmic web, by unveiling the properties of void, filament and cluster galaxies.

Henrik Rønnow and Gabriel Aeppli awarded an ERC Synergy Grant

Henrik Rønnow and Gabriel Aeppli have received a European Research Council Synergy Grant together with Nicola Spaldin and Alexander Balatsky in a collaboration between EPFL, PSI, ETHZ and Stockholm University.

Seeking to further our understanding of quantum properties of materials, these expert scientists have successfully secured an extraordinary €14 million Synergy Grant, administered by the European Research Council and one of the most prestigious awards for excellent European research projects.

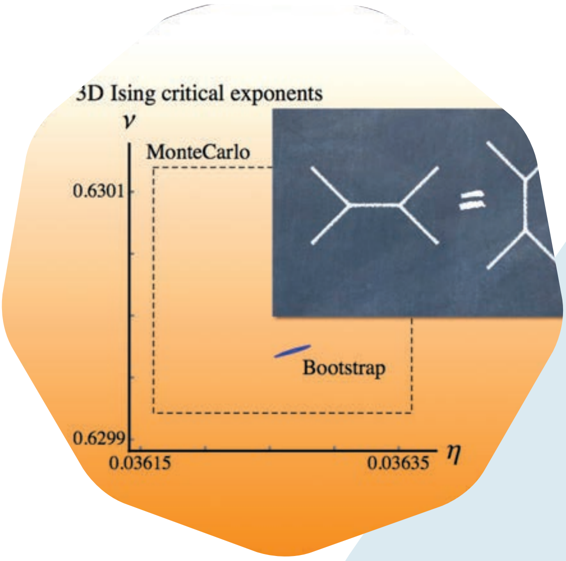
In this project entitled “Hidden, Entangled and Resonating Orders” (HERO), the scientists will join their respective expertise to look into “the heart of materials” to uncover new, “hidden” quantum properties in known materials, meaning properties that could not be seen by current methods or have perhaps been overlooked. They will also design new materials with useful quantum properties. Such new properties could be of use for data processing or storage in the future and thus become the backbone of future electronics, which need to be faster, smaller, and more energy efficient.

“Today’s silicon-based information technology still relies on principles which have been discovered around 70 years ago,” says Gabriel Aeppli, photon scientist at PSI and professor at EPFL. “This puts severe limits on what is possible, particularly where speed and energy efficiency are concerned. Therefore, we need to work on the next stage of the information revolution where we take more advantage of quantum effects.”

The four experts teaming up now will greatly advance the field: “Every time we sit together, we notice that we all come from very different angles but are often looking at the same thing,” says Henrik Rønnow, neutron scientist at EPFL’s Institute of Physics. “Already in the past, listening to the viewpoints of the other three has given me new ideas on how to better find the things I am searching. I am therefore very much looking forward to expanding this collaboration.”

Nicola Spaldin, theoretical chemist and material scientist at ETH Zurich, explains “hidden” phenomena by an analogy: “Imagine a large area composed of blue and yellow pixels. From a distance, it looks green; but when we look more closely, we discover additional information – in this case the way that the blue and yellow are arranged to make the green color – hidden from plain sight.” In the case of quantum phenomena, she explains, hidden properties are anything but trivial to find and require the advanced characterization tools of the large research facilities at PSI.

The team’s fourth scientist, Alexander Balatsky, is a theoretical physicist at Stockholm University. “We say that humanity has passed the stone age, the bronze age, the iron age, and is currently in the silicon age. What comes next will quite certainly be the quantum age – but which quantum material will it be?”



FROM BOILING WATER TO PION SCATTERING: THE BOOTSTRAP APPROACH TO FIELD THEORY

The conformal bootstrap is a powerful first principle approach to studying Conformal Field Theories. Building on their pioneering work in this area, EPFL theoretical physicists are exploring a wide variety of systems with this approach.

The majority of physical systems can exist in many distinct phases. Although we are all familiar with phases of water, even such a common example can display a peculiar behavior under special circumstances: at the critical point in the vapor-liquid transition, the length scale of correlations diverges and the system becomes scale-invariant. In a nutshell, the microscopic degrees of freedom organize cohesively at all scales in a state whose description defies perturbative approaches. However, in many cases these critical systems magically acquire, as an added bonus, invariance under position dependent dilatations, also known as conformal transformations. They can thus be described by the powerful formalism of Conformal Field Theory (CFT).

CFTs are ubiquitous in condensed matter and statistical physics, but also play a fundamental role in our modern understanding of particle physics. Indeed, quantum mechanics and relativity dictate that fundamental interactions must be described by some Quantum Field Theory (QFT), whose specific form we do not yet fully know. However, we do know that any QFT becomes a CFT in the limit of short (ultraviolet) or long (infrared) distances. Even more remarkably, CFT offers a glimpse into quantum gravity through the AdS/CFT correspondence, a powerful duality according to which space-time is not fundamental but instead emerges from quantum mechanics and symmetry.

Studying these often intricate CFTs, using only basic principles, like symmetry and quantum unitarity, has been a long-standing dream. Its implementation, called the conformal bootstrap, saw some success in two dimensions already in the 80's but only more recently was it fully realized in higher dimensions. This renaissance was made possible both by significant analytical progress in formulating the consistency equations and by the development of numerical techniques to find or constrain their solutions. This program was pioneered by the EPFL theory group [1].

Studying Conformal Field Theories using only basic principles

The first ten years of the bootstrap, reviewed in [2], have led to a number of groundbreaking results, including world record determinations of critical exponents and correlation functions in the Ising and O(N) models in three dimensions. More recently, the bootstrap philosophy has been applied to study generic QFTs. In this case, one imposes consistency conditions (like Lorentz invariance, causality and unitarity) on scattering amplitudes. This idea combined with bootstrap numerical methods has recently been used to study scattering of the lightest strongly interacting particle: the pion [3].

A synergy between the FSL lab, the LPTP lab and the group of Alessandro Vichi, is focused on exploring this uncharted territory, with the ambitious objective of unveiling new properties of strongly coupled systems and possibly discover new field theories.

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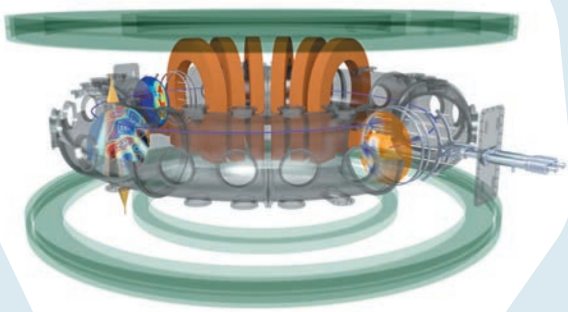

SCATTERING OF MM-WAVE BEAMS BY PLASMA TURBULENCE IN FUSION DEVICES

Physicists from the Swiss Plasma Center and their international colleagues have performed the first direct measurements of the scattering of millimetre-waves by turbulent plasmas, opening the way for modelling wave propagation in tokamaks.

In the next generation of fusion devices, high-power microwave sources at the electron cyclotron frequency will be essential for plasma operation. On the one hand, millimeter-waves (mm-waves) will be used to heat the electrons to temperatures close to 100 million degrees, necessary to achieve the fusion of deuterium and tritium nuclei, and, on the other hand, they will drive electron current, creating part of the magnetic field necessary for plasma confinement and stability. For example, in ITER, the largest tokamak device presently under construction in the South of France, up to 10 MW of microwave power will control the so-called neoclassical tearing modes, which are responsible for the degradation of the core confinement and hence of the device performance. For this purpose, a narrow mm-wave beam will be injected from the outside of the fusion device into the plasma to target specific regions with a surgical precision. However, when entering the plasma, the high-power beam will traverse a strongly turbulent plasma layer at the edge, which is characterized by large fluctuations of the electron density, scattering mm-waves and defocusing them as a blurring lens. This could result in a decrease of efficiency in the use of the microwaves, thus altering ITER operation and performance. A collaboration was initiated in the frame of the Enabling Research programme of EUROfusion to understand and predict how plasma turbulence will affect high-power mm-beams in ITER.

First direct measurements of mm-wave scattering by turbulent structures have been performed on the basic-plasma-physics device TORPEX and the TCV tokamak at the Swiss Plasma Center of EPFL. In TORPEX, a low-power mm-wave beam is launched through plasmas that feature turbulence similar to that observed at the edge of tokamaks. Using detailed measurements of the transmitted beam power combined with spatio-temporal imaging of the turbulent structures and full-wave numerical simulations, it was first demonstrated that small fluctuations of the electron density, which are associated with plasma turbulence, defocus the mm-wave beam, possibly resulting in beam spreading at larger densities. Similar experiments were conducted on the TCV tokamak by injecting from the top of the device microwave beams with hundreds of kW of power in conditions more relevant to ITER plasmas. Similar to TORPEX experiments, the turbulence at the edge of the tokamak was identified as being responsible for the fluctuations of the transmitted mm-wave beam power measured at the bottom of TCV.

Small fluctuations of the electron density defocus the mm-wave beam

These results represent an important test bed for validating numerical simulations and the theory of mm-wave propagation in fusion devices. Presently, a joint international effort is ongoing using state-of-the-art numerical codes to simulate plasma turbulence in TCV and to model the propagation of microwaves in its turbulent plasmas. This will allow laying the foundation of validated modelling of wave propagation in burning plasmas to reach predicting capabilities for ITER.

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European Research Council
Established by the European Commission

Christophe Galland receives an ERC Consolidator Grant

Christophe Galland, professeur boursier FNS, has received a European Research Council Consolidator Grant.

The purpose of Consolidator Grants from the European Research Council (ERC) is to strengthen independent and excellent new individual research teams that have been recently created. Christophe Galland was awarded the grant for his project entitled “Quantum Plasmomechanics with THz Phonons and Molecular Nano-junctions” (QTONE).

Christophe Galland’s research focuses on developing new optical techniques and nanostructures to measure and control the dynamics of internal vibrations in crystals and molecules, with a focus on revealing phenomena that can only be described by quantum mechanics. In both crystals and molecules, the links between atoms are not perfectly rigid; they rather behave like springs. As a result, molecules and crystals can internally vibrate, at the atomic level… And the typical frequency of these vibrations is about 10’000 times faster than the clock speed of a modern computer!

To accurately describe these atomic oscillations, we have to abandon our classical intuition of a mass attached to a spring, whose position and velocity at any time after an impulsion can be precisely determined. Instead, it is fundamentally impossible to predict the exact positions of atoms in a vibrating molecule. The vibration can be excited only by absorbing a discrete amount of energy (a “quantum”), while the resulting excitation is associated with a continuous probability distribution for the position and velocity of the atoms (the “wavefunction”). In order to understand the inner working of matter, we must therefore recourse to “quantum mechanics”, a more fundamental theory than classical mechanics, which we use intuitively in our daily life to interact with moving, vibrating or rotating objects. New experimental tools must be developed – this is the realm of quantum science.

The goal of the new ERC-funded project is to use light to manipulate the quantum state of high-frequency internal vibrational modes. Extremely short laser pulses and ultra-sensitive, ultra-rapid detectors will be employed to create and detect individual quanta of vibration. Moreover, new nanostructures will be developed to focus light down to the molecular scale, thereby enabling a dramatic increase of its interaction with vibrations. With these new experiments, we hope to better understand how matter behaves in the quantum regime, and how we could use this non-classical behavior at our advantage to create new information technologies or sensing devices.

Christopher Mudry reveals the effects of disorder in quantum systems

Christopher Mudry was named external Adjunct Professor as of December 2018.

An ETHZ graduate, Christopher Mudry obtained his PhD from the University of Illinois at Urbana-Champaign in 1994. After postdocs at MIT and Harvard, he joined the Paul Scherrer Institute in 1999 as a researcher. In 2002 he became Senior Scientific Associate, and since 2009 he heads the Condensed Matter Theory Group. He was elected Fellow of the American Physical Society in 2011.

Christopher Mudry is one of the leading experts in quantum field theory applied to condensed matter and the author of a reference book on the subject. Developed in the framework of the relativistic generalization of quantum mechanics, quantum field theory has become the reference method for describing certain states of matter, including quantum phases in one dimension and quantum critical points. Christopher Mudry was one of the pioneers in using these methods to address the effects of disorder.

Christopher Mudry has also been a prominent actor in the emergence of the notion of topology in condensed matter. Topology is generally expressed by the existence of one or more properties that cannot be altered by local modifications. Christopher Mudry has in particular demonstrated that a new class of insulating materials, dubbed “fractional Chern insulators”, exhibit surface states protected from disorder by the topology of the underlying band structure and carry fractional charges.

PROMOTIONS

Philippe Spaetig: understanding the effects of irradiation on materials

Philippe Spaetig was named Adjunct Professor as of December 2018.

Philippe Spaetig obtained his PhD at the Institute of Atomic Engineering of EPFL in 1995. After a postdoctoral period at the Center for Research in Plasma Physics (CRPP, now Swiss Plasma Center), he spent two years at the University of California at Santa Barbara, before returning to the CRPP as a researcher. In 2008 he was named Senior Scientist (MER) at the Laboratory for Reactor Physics and Systems Behaviour of EPFL. Since 2013 he is Senior Scientist at the Laboratory for Nuclear Materials at the Paul Scherrer Institute (PSI).

Philippe Spaetig is a recognized scientist in the field of nuclear fusion reactors and in particular the relationship between microstructures and the mechanical properties of materials at high temperature. His main research topics are the aging and degradation of structural nuclear materials in clear water environments, the effects of irradiation on the evolution of mechanical properties of structural steels, and the development of tests on small or non-standard samples.

The activity of Philippe Spaetig is important for understanding the behavior of materials under neutron irradiation, which will play a major role in the licensing and commissioning of the future ITER and DEMO fusion facilities. His expertise is a major asset for the Swiss Plasma Center as part of the European research programs on fusion, EuroFusion and Fusion4Energy.

AWARDS

Suliana Manley receives an ERC Consolidator Grant

Suliana Manley, associate professor and head of the Laboratory of Experimental Biophysics, has received a European Research (ERC) Council Consolidator Grant.

ERC Consolidator Grants are given annually to researchers with 7-12 years of research experience after their PhD, as well as *"a scientific track record showing scientific talent and an excellent research proposal"*. Suliana Manley was awarded the grant for her project entitled "Revealing the adaptive internal organization and dynamics of bacteria and mitochondria" (Piko).

In her research, Suliana Manley combines super-resolution fluorescence imaging techniques with live cell imaging and single molecule tracking to determine how the dynamics of protein assembly are coordinated. "This project will take my group's research in new and exciting directions," says Suliana Manley. "We will develop smarter super-resolution microscopy that will allow our instruments to adapt to the samples they image, and use that feature to reveal the physical principles governing the tiny interiors of bacteria and mitochondria."

Bacterial cells appear less complex than our own cells - yet they are better able to survive harsh conditions. How they do this is not well understood, but there are clues that physical state transitions may be important. Bacteria faced with low nutrient conditions can enter a non-proliferating quiescent state in which their cytoplasm displays signatures reminiscent of the colloidal glass transition, with increasingly slow and heterogeneous diffusion. Simultaneously, evenly spaced, dense granules form. The complex state behavior of the bacterial cytoplasm is therefore important for their survival, but the *physical nature* of each of these processes is poorly understood.

Our own cells are typically tens of microns in size and contain mitochondria, which generate most of the ATP used for life. But little is known about the physical properties of the mitochondrial matrix, or how they are linked to energy production.

A major obstacle to elucidating the organization and dynamics of these systems is the relevant length scales, which lie below the diffraction limit. Furthermore, to observe and quantify their adaptive response, many cells must be measured. Our strategy to overcome both of these technical challenges is to develop *"smart microscopes" for multiplexed structured illumination and long-term molecular tracking,* capable of capturing the dynamics of thousands of cells or organelles in each experiment. These are broadly applicable to the quantitative study of nanoscale heterogeneous dynamics in living systems.

Earlier in the year, Suliana Manley was awarded a Medal for Innovation in Light Microscopy by the Royal Microscopy Society (RMS) *"for outstanding scientific achievements applying or developing new forms of light microscopy."*

Antonio Gentile awarded the Polysphère d'Or 2018

The Polysphère d'Or 2018 was awarded to Antonio Gentile of the Physics Section.

Every year, during the Graduation Ceremony, the students honour the best teacher of each faculty with a polysphere. The teacher who obtains the highest mark in the vote receives the Polysphère d'Or.

This year, the Polysphère d'Or has been awarded to Antonio Gentile, ET technician at the Physics Section and involved in the course "Introduction to construction technics" for 3rd year students in the Physics bachelor. Students learn in this course to design mechanical elements, to make them in the mechanical workshop, and to build electronic circuits. Antonio also supports all the practical work. In particular, he took part in the preparation of the team of students who won the International Physicists' Tournament last April in Moscow.

AWARDS

Vincenzo Savona awarded the Teacher Prize of the Physics Section

The Physics Section honours every year one teacher who has particularly excelled in this important mission. The trophy of the Teaching Prize 2018 was presented to Prof. Vincenzo Savona during the master's graduation ceremony.

The award recognizes the excellence of Vincenzo Savona's teaching in the course of Quantum Physics I and II. This course is at the heart of the training of physicists. The third year of this curriculum is considered by Physics students as an exciting and essential year, so much so that some of them give up a year of exchange to follow the training offered by the Physics Section.

Vincenzo Savona made this Quantum Physics course evolve in a remarkable way. The section has increased the volume of the course, following a redesign of the third year, which was largely promoted by Vincenzo Savona himself. The satisfaction of the students shows that he saw very well which changes were needed in the study plan. Thanks to the increase in the weekly workload of the Quantum Physics course, he was able to add advanced subjects in the second semester.

Vincenzo Savona has set up a class in Quantum Physics I and II unique in the scope of the subjects offered and their modernity. This is not a one-off effort, but a long-term work that has been built on the basis of the many commitments he has made in the teaching of physics.

AWARDS

Craie d'Or 2018 awarded to Frédéric Mila

The 3rd year Bachelor students in Physics have awarded the Craie d'Or of the best Bachelor Teacher to Frédéric Mila for his course in statistical physics.

Continuing the tradition initiated last year, 3rd year physics students presented the Craie d'Or to the Best Teacher in their bachelor curriculum, following the Practical Work III poster presentations on June 1st.

This year, the Craie d'Or was awarded to Frédéric Mila for his course in Statistical Physics (3rd year). He said he was very surprised to have received this award, considering what he had made his students endure. But he admits that he had great fun and that he was always eager to go to class. This enthusiasm was obviously communicative.

As one of the reasons for his ever-renewed enthusiasm for teaching, Frédéric Mila cites the fact that he has concentrated all his teaching during the fall semester. Thus, he can devote himself to it during that semester and focus on his research during the spring semester. This ensures him a good balance between teaching and research. According to the verdict of the students, this is very beneficial.

Oleg Yazyev wins the University Latsis Award

The award distinguishes Oleg Yazyev's work in the field of in silico materials discovery.

The award was given *"for his computer-based search for low-dimensional materials with novel electronic and transport properties. He has predicted a novel topological insulator phase in quasi-one-dimensional bismuth iodide, and a robust Weyl semimetal phase in molybdenum and tungsten diphosphides. Both predictions have been confirmed experimentally and created a field of intense research."*

Last decades have been marked by the discoveries of new paradigm-shifting classes of materials. Two notable examples are two-dimensional materials, made of atomically thin crystals, and topological materials, which emerged following the rigorous topological classification of the electronic band structures. Progress towards potential applications of this type of materials critically depends on discovering new materials of this kind. Oleg Yazyev and his laboratory tackle this challenge by performing computational, or in *silico*, materials discovery.

Early achievements are related to the structure and properties of disorder in graphene. These predictions received full experimental confirmation. More recently, Yazyev's laboratory has revealed a number of new topological insulators and semimetals with the high-throughput computational screening of known materials. The predicted topological properties of some of these materials have already been found experimentally.

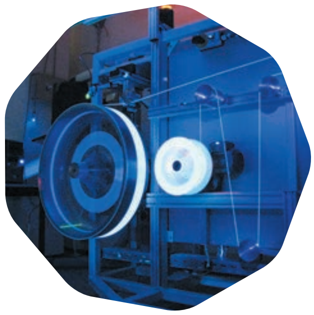
Christian Theiler receives two important grants

Christian Theiler, tenure-track assistant professor at the Swiss Plasma Center, was awarded an Eccellenza Grant from the SNSF and an Enabling Research Grant from the EUROfusion Consortium.

The Swiss National Foundation's Eccellenza Grants, offering project funds up to 1,5 MCHF over five years, aim at *"researchers in all disciplines who have recently been appointed as tenure-track assistant professors at a Swiss higher education institution."*

Christian Theiler's project is entitled *"Alternative divertors for improved tokamak operation"*. "In fusion devices, such as tokamaks," says Theiler, "the edge region of the magnetically confined plasma has to simultaneously assure good confinement of the core plasma and guarantee acceptable heat fluxes to the surrounding wall structures. We propose to use EPFL's Tokamak à Configuration Variable (TCV) to explore alternative magnetic geometries of the tokamak edge region, a promising path to develop a robust tokamak edge solution."

The aim of Enabling Research Grants is to provide *"a special path to bring new ideas and techniques into the programme in ways not easily achieved within the strongly goal-oriented main Work Packages."* Christian Theiler will lead a two-year collaborative research project entitled *"Towards a first-principles understanding of fluctuations and flows in the X-point region of tokamaks"* with an international team of 21 researchers.



New detector for LHCb experiment

The Large Hadron Collider beauty (LHCb) experiment at CERN is being updated to increase its potential to discover tiny signals of New Physics, beyond the Standard Model. The Laboratory of High Energy Physics (LPHE) participates in this activity, with a strong contribution from the mechanical and electronic workshops of the Cubotron.

A new particle detector consisting of 10,000 km of scintillating fibers is presently under construction. The LPHE has already produced about one third of the total number of the detector elements, or a total of 3900 km. The detector elements are fiber mats, composed of layers of fibers assembled by a winding machine. For this purpose, the machine shop realized multiple positioning templates, made many high-precision collages, and optical cuts with diamond burs.

In parallel, the electronic workshop has participated in the development of new solid-state photodetectors to capture the light produced by particles passing through the fibers (silicon photomultipliers with 128 channels, 125 µm each). In the construction phase, detailed quality controls on the various parts of the detector are mandatory.

The success of the project strongly depends on the expertise of both workshops, and in particular on the ability of engineers and technicians to work in the framework of a large international collaboration.

EPFL wins the International Physicists' Tournament

A team of students from EPFL won the 2018 International Physicists' Tournament in Moscow, beating the French and Brazilian teams in the final.

Sixteen teams from around the world gathered for a week in April at the Moscow Institute of Physics and Technology for the 10th annual International Physicists' Tournament. At the final, EPFL, representing Switzerland, edged out its rivals to win the tournament. EPFL's team was selected to represent Switzerland at a national competition held on campus last December. A Swiss team also won the competition in 2013.

For this tournament, the teams receive a series of physics problems several months prior to the competition. This year's challenges included: estimating the temperature of a liquid from the sound it makes when poured, determining the statistical distribution of sparks created by an angle grinder, and making a speaker without any moving parts. At EPFL, the third-year physics bachelor curriculum includes time to prepare for the tournament.

The teams have to come up with solutions, which they present at the competition and confront with those of the rival teams. An international panel of professional physicists evaluates the teams on the basis of their solutions and their critique of their rivals' work.

After an intense week, the six team members and their three accompaniers returned exhausted but thrilled and having learned a lot from the experience. Alberto Rolandi, EPFL's team captain: "I'd really like to thank our three coaches and my teammates for their great work throughout the semester and at the tournament. I'm also grateful to the technical staff in the physics labs for their support in both theoretical and practical matters."

The new EPFL team is already in full preparation for the 2019 edition of the competition. This year, Switzerland will be represented by a second team, namely from the University of Geneva. The two teams had a friendly fight on the Swiss National Selection that took place in December in Fribourg, where they were the only two teams competing.

The 2019 edition of the International Physicists' Tournament will take place at EPFL from April 21st till 26th. The Local Organization Committee, under the presidency of Jean-Philippe Ansermet and chaired by Evgenii Glushkov, includes many former IPT team members and coaches. We are looking forward to follow the performance of our students.

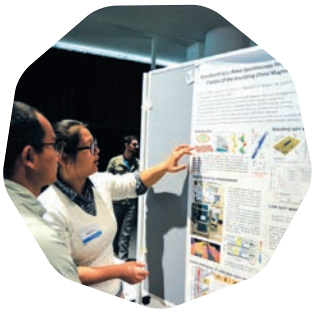
Frédéric Blanc, Arnaud Magrez, and Holger Reimerdes promoted MER

Frédéric Blanc, Arnaud Magrez, and Holger Reimerdes have been promoted Senior Scientists (MER).

Frédéric (Fred) Blanc is a member of EPFL's Laboratory of High Energy Physics and of the LHCb collaboration at CERN since 2007. He made crucial contributions to the LHCb tracking detectors and to flavor-physics analyses of the LHCb data. He teaches particle physics at the master level since 2010, and general physics since 2014.

Arnaud Magrez joined EPFL's Laboratory of Nanostructures and Novel Electronic Materials in 2003 as a scientist. From 2012 on, he took on the lead of the crystal growth and characterization facility. His research aims at the synthesis of novel crystalline materials with controlled size and morphology including low-dimensional systems such as carbon nanotubes and single crystalline monolayers. He teaches physics lab work to bachelor students and physics of novel materials at the master level.

Holger Reimerdes has a remarkably broad background in tokamak physics research, having worked extensively in various fields. Since joining the Swiss Plasma Center in 2010 he has become an internationally recognized expert in alternative divertor configurations. He is also the recipient of the 2016 Landau-Spitzer Award delivered jointly by the APS and EPS. He teaches plasma physics at the master and doctoral levels and is supervising several PhD students.



Physics Day 2018 even bigger than last year

Physics Day was organized by the PolyPhys association October 1^{st} 2018, in the Forum Rolex. The event consisted of a series of talks by invited speakers on various topics in physics, and a poster session. More than 150 students, postdocs, and professors attended the event.

Among the invited speakers were the charismatic Jeffrey Hangst, spokesperson of the CERN antihydrogen project, Eric Lutz with his quantum arrow of time, and Yiwen Chu, recently appointed at ETHZ, who spoke on the topic of quantum acoustics. João Penedones contributed with thought experiments in particle physics. The final event of the day was a keynote lecture by 2007 Nobel laureate Claude Cohen-Tannoudji. Vincenzo Savona, Christophe Galland, and Harald Brune chaired the talk sessions. The poster session attracted more than 30 posters, and the best three were awarded prizes.

Physics Day 2018 was a success, gathering a large audience of physics enthusiasts, and attracting world renowned speakers. The event was organized thanks to the generous support of the Doctoral Program in Physics, the Physics Section, as well as the EPS Young Minds project. Special thanks go to members of *Les Irrotationnels* and the International Physicists' Tournament organizing committee for their help.

A long mandate at the Physics Section

As of August 1^{st}, Nicolas Grandjean has taken the duty of Director of the Physics Section over from Jean-Philippe Ansermet, who reflects here on his 12 years of service.

When EPFL restructured into Schools in early 2000, the Physics Section was the gathering point of all physicists. This resulted in a renewed unity of Physics, built around teaching matters. The "REB" meeting ("Réunion des Enseignants de Base") for example allowed young and experienced teachers to share best practices. Our *extra muros* biennial meetings served to chart future strategies regarding both teaching and research.

Eight collaborators joined the section, which enjoys a staff of ten, during the time span of my three mandates. The stability of the section over a 12-year period has put us in a position of strength to create a 120-credit master that includes a highly successful semester of internships in industry or academic specializations; to clarify the teaching objectives and processes of our general physics courses; and to cooperate with the director of the preparatory year "CMS" in the creation of the now-running "MAN" (remedial 2^{nd} semester for 1^{st} year students in difficulty).

AUDIWEB is coming online soon: this website will showcase our fantastic collection of physics auditorium demonstrations. This spin-off from the MOOCs responds to requests made by teachers worldwide who wished to gain access to videos of our teaching material.

Watching students team up and tap into the many resources of our DLL (Discovery Learning Lab) in order to prepare for contests, such as the International Physicists' Tournaments, is a thrilling show of teaching in action. It was easy to insert these students' involvements into the stream of lab courses that runs through our undergraduate program. As senior scientists agreed to take part in our lab courses, the section has been able to supervise all of our students with the highest professionalism.

Our third year is such a success that some students are said to have given up on an exchange year, just to be able to follow our course offer. This is a great reward for all teachers who fine-tuned our curriculum, course volumes and objectives.

High school teachers are developing relationships with us and discovering the environment into which their students are going thanks to their teaming up for a semester with general physics teachers or attending summer training camps.

Time has come after these three mandates to hand over the baton to my colleague, Prof. Nicolas Grandjean. I wish him all the best in his new endeavor.


New Director heads the Doctoral Program in Physics

After heading the Doctoral Program in Physics for four years, Vincenzo Savona passed the torch on October 1st to Frédéric Mila, who presents here his view on the future.

First of all, I would like to thank my predecessor Vincenzo Savona for his action during the nearly four years he has spent as a director of the Doctoral Program in Physics. When I started on October 1st, 2018, I found a very well-organized program, and with his help and that of Anh Eymann, it has been very easy to step in.

As I see it, the main challenge of the Doctoral Program in Physics is to give our PhD students access to the advanced courses they need to complete their education. This relies in the first place on basic and specialized courses given by EPFL professors, and thanks to the action of my predecessors, there is already a broad offer in all fields.

Regarding basic courses, there is now a coherent offer of courses in high-energy physics that can also be followed by students during the semester of specialization of the second year of Master. This could serve as a model for other fields such as condensed matter or statistical/biophysics, and I hope that we will manage to increase the number of basic courses and have a coherent offer in all fields with the help of the new professors that will join IPHYS in the coming years.

This higher education also relies on advanced lectures by external experts to bring ideas from outside and open new perspectives. The end of the physics program of CUSO in 2016 calls for a replacement, and I have initiated a collaboration with our colleagues in Geneva to organize a series of advanced lectures in the Geneva Lake area. Attracting PhD candidates among the best in the world should also be a priority of the Doctoral Program in Physics. Proposing and advertising a coherent set of advanced lectures should also help promoting high level spontaneous applications.

The other very important challenge of the Doctoral Program in Physics is the well-being of our PhD students (and of their supervisors!). The mentoring system is a key instrument to detect problems early on, and I would like to take this opportunity to thank all the mentors who do not spare their time and energy to discuss with the PhD students they are following, and to help them whenever possible.

Finally, the fact that physics is now organized around three well-defined entities, the Institute of Physics, the Physics Section, and the Doctoral Program of Physics, is a great opportunity to fully synchronize our actions and cooperate on all aspects of the physics life on the EPFL campus. Let's try to use this opportunity to make physics as visible as it deserves to be!

Tobias Kippenberg wins ZEISS Research Award

Tobias J. Kippenberg is one of the two winners of the prestigious ZEISS Research Award for 2018.

The ZEISS Research Award, successor to the Carl Zeiss Research Award, is presented every two years and has been allocated prize money totaling 40,000 euros. The selected candidates should have already demonstrated outstanding achievements in the field of optics or photonics. Their work should offer major potential for gaining further knowledge and enabling practical applications. Many winners of the Carl Zeiss Research Award went on to obtain further awards and distinctions; four of them were even honored with the Nobel Prize.

Tobias Kippenberg directs the Laboratory of Photonics and Quantum Measurements. He is a pioneer in the field of cavity optomechanics and microresonator-based optical frequency combs. His research has demonstrated that, by using microresonators – which can confine light in an extremely small space and guide it – the faint forces exerted by light rays can be used to measure and cool down mechanical movements in the quantum regime. This means, for instance, that high-precision sensors can be developed to measure mechanical movements that are several orders of magnitude more precise than the currently available position sensors.

The other winner of the 2018 ZEISS award is Jean-Pierre Wolf, Professor at the Biophotonics Institute at the University of Geneva.

AWARDS

Harald Brune named Max Planck Fellow

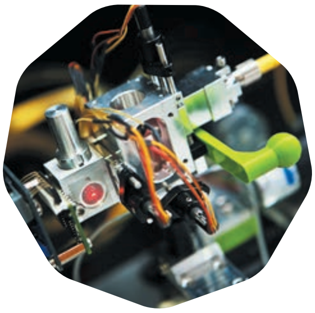
Harald Brune was named Max Planck Fellow at the Max Planck Institute for Solid State Research in Stuttgart as of November 1st 2018.

The Max Planck Fellow Programme promotes cooperation between outstanding University Professors and researchers from Max Planck Society. This award involves a grant for a 5-year project in collaboration with the hosting Max Planck Institute.

Together with the team of Klaus Kern and Christian Ast in Stuttgart, Harald Brune will investigate the nuclear spin moments in individual surface adsorbed lanthanide atoms. Due to better protection from the environment, the coherence time of nuclear spin states is known to be much longer than that of magnetic quantum states of electrons. The aim is to demonstrate the coherent control of single atom nuclear magnetic quantum states.

Earlier in the year, Harald Brune was distinguished as Technical University of Munich (TUM) Ambassador because he "gained international recognition with seminal contributions to nucleation and growth phenomena in metal epitaxy, and more recently developed a vigorous research line in the field of nanomagnetism. He is engaged in many international cooperations, documented by guest scientist activities and visiting professorships."

INNOVATION



Nano-motion detection for antibiotic testing

Resistell, a start-up created in 2017, develops a new diagnostic method to test bacteria for their susceptibility to antibiotics, without having to take days to grow these bacteria. This reduces the time for getting test results from days to minutes. Resistell has received, among other awards, the Swiss Nanotechnology Startup Award for the Best Nanotechnology Startup 2018.

The technology was originally developed by the Laboratory of Physics of Living Matter led by Prof. Giovanni Dietler and Dr. Sandor Kasas. It is based on the detection of the motion caused by living bacteria attached to Atomic Force Microscopy (AFM) cantilevers. Living bacteria cause oscillations of the cantilever, which can be detected by the device. This device is much simpler and cheaper than a commercial AFM, as only the deflection of the cantilever is measured.

When an antibiotic is added to which the bacteria are sensitive, the cantilever's vibrations return to the level of a sample without bacteria within minutes. However, if the bacteria are resistant to that particular antibiotic, the lever's vibrations persist. A custom-made software processes the signal and classifies the bacteria strain as susceptible or resistant to the antibiotic.

Bringing this new diagnostic tool on the market could help mitigate one of the biggest threats to global health. It is estimated that at least 700 000 people die every year from infections caused by antibiotic resistant bacteria and this number is expected to grow.

INSTRUMENTATION

Inauguration of AstroDome and new TELESTO telescope

On November 5th, 2018 took place the inauguration of AstroDome (Centre André Coliac) and of the new TELESTO telescope on the Observatory of Sauverny site.

Following an anonymous donation to the University of Geneva to help outreach in astronomy, the Department of Astronomy of the University of Geneva and the Laboratory of Astronomy of EPFL have renovated the dome on the Vaud-side of the Observatory of Sauverny site to develop "AstroDome" (Centre André Coliac). This unique place for astronomy in French-speaking Switzerland is now home to a new telescope and a control center.

The new 60 cm diameter telescope has been named TELESTO (for TELescope for Science, Teaching and Outreach). Telesto is also the name of a Greek mythology character and means "success". The control center, located "under" the telescope will drive TELESTO but also other telescopes such as the Swiss telescope Euler (1.2 m in diameter), which is on the site of ESO-Lasilla in Chile.

AstroDome will allow to share the beauties of the sky with the visitors of all ages coming to the Observatory of Sauverny, and to teach our students, mostly with practical work, the techniques for observing celestial objects that are used on the largest telescopes in Chile or in space. Finally, it will allow professional observations on larger telescopes controlled remotely.

IBM recognizes QST teaching

Having identified Quantum Science and Technology as a strategic area to be developed and reinforced, EPFL's Institute of Physics is plunging headlong into the field with two new faculty openings, a master course, and partnering with IBM and their cutting-edge quantum-computer platform. A team of students following these courses won the second Best Paper Award from IBM Q.

Harnessing the properties of quantum systems, the world is preparing to usher in technologies that seem to belong to mere science fiction, such as light-based quantum communications, unbreakable quantum cryptography, and quantum computers that run a million times faster than today's fastest supercomputers.

Europe has already heavily invested in Quantum Science and Technology (QST), with its FET Flagship on Quantum Technologies, while Switzerland runs its own, federally funded NCCR-QSIT project. Now, the Institute of Physics (IPHYS) is reinforcing its own QST efforts with two openings in this field.

In addition to its research efforts, EPFL's teaching in QST enjoys high visibility. Dr Marc-André Dupertuis from IPHYS, has been running a master course in quantum optics and quantum information since 2013. The course came to life through the efforts of Dupertuis and his assistant Clément Javerzac-Galy, and represents a major commitment by EPFL to establish itself as a leader in the future of QST.

This view is apparently shared by IBM, an industry pioneer in the field. In 2016, the tech giant launched "the IBM Quantum Experience (QX)", a cloud-based platform on which students and researchers can learn, research, and interact with a real quantum computer housed in an IBM Research lab through a simple internet connection and a browser. In 2017, IBM chose EPFL alongside MIT and the University of Waterloo to be one of the first institutions in the world to use its quantum computer for teaching.

As part of the QST teaching initiative, IBM made the QX platform available to master students taking Dupertuis' course. Using this platform, a team of bachelor and master students, led by Clément Javerzac-Galy, Marc-André Dupertuis and Nicolas Macris (IC), developed efficient algorithms for the generation of entangled quantum states, and demonstrated an implementation on the IBM quantum computer in an article that won the second Best Paper Award from IBM Q, given for highest-scientific impact papers by master, PhD student, or postdoctoral researcher.

Recognizing EPFL's effort in QST teaching, IBM also marked EPFL's access to QX with a lengthy tweet. "This shows that EPFL is already a top institution in the world for what concerns teaching in this domain," says Harald Brune, director of IPHYS.

The "Show" of the Physics Section

This year, more than a thousand children and their families had the chance to experience spectacular and fascinating physics experiments thanks to the EPFL Physics Show.

In partnership with the Science Outreach Department of EPFL, the Physics Section organized several shows in which spectacular experiments entertained the audience with various facets of the world of Physics. Lasting about an hour, this show took the public on a journey across mechanics, electricity, electromagnetism, and thermodynamics. It was full of flashes and bangs, with up to 30 experiments.

The following is a summary of the main events we organized or participated in this year. In June, 200 school children from the Canton of Jura and their families attended the "Science discovery" show; as in previous years, a similar event was set up for 800 children coming from the region around EPFL. On 7th and 8th of July, the Physics Section had a large booth at the "Night of Science" public event in Geneva. The theme of the booth was "time" and it was very successful; in just two days the total number of visitors reached 30,000. In November, the Physics Section took part in the "Scientastic" festival and created a virtual show on the physics of computers (bringing together about 1200 people). Finally, each year the Physics Section promotes its education curriculum to future EPFL students by presenting physics demonstrations, which illustrate the different research domains currently ongoing within the Institute of Physics.

Gilbert Hausmann Award attributed to Gabriele D'Aversa

Gabriele D'Aversa won the award for his master thesis entitled "Metasurface diffraction gratings for parallel polarization analysis and imaging: from vectorial diffraction and numerical optimization to a camera prototype". He performed his master project during an internship at Harvard University in the laboratory of Prof. Federico Capasso and was supervised from the EPFL side by Prof. Romuald Houdré.

The Gilbert Hausmann Award, supported by a donation by Mr Gilbert Hausmann, was founded in 2015 and rewards two graduates having completed an EPFL master project and one PhD student having completed an EPFL PhD thesis in the field of mechanical engineering, electricity or physics. The three prize-winning projects should stand out through their excellence, particularly in terms of originality and the prospects that they open.

In his master diploma work Gabriele D'Aversa demonstrated that he was able to master the theoretical aspects, the modelling and design as well as the optical measurements, up to the point of finally making a small prototype of an imaging camera with full polarization analysis. All these aspects are theoretically and experimentally complex. Not only this work is important and fundamental in the field of metasurface lenses, for which the group of Prof. Federico Capasso is worldwide leading, but it can also have an impact for real commercial applications such as imaging cameras with polarization analysis.

AWARDS

Mauro Fanciulli gets the Physics Doctoral Thesis Award

Mauro Fanciulli got the award for his thesis entitled "Spin polarization and attosecond time delay in photoemission from solids' supervised by Prof. Hugo Dil, professeur boursier SNSF.

In his thesis work, Mauro Fanciulli developed and applied a novel approach to determine the attosecond time scale of the photoemission process from the measured spin polarization. In contrast to other approaches in the time domain, the unique combination of theory and experiment employed by Mauro allows to extract the absolute, and not only relative, time delay. Furthermore, the method does not require ultrashort photon pulses or an external reference time and as such allows to "measure time without a clock". Mauro applied his method to plain copper and to the high temperature superconductor BSCCO, which yielded time scales of 26 and 85 attoseconds, respectively, indicating the possible influence of correlation effects on the process. The developed method can also be applied to other physical processes relying on the transition from an initial to a final state, such as tunneling. In a broader context Mauro's results open up a new research direction and yield a thrilling new insight in the fundamental time scale of quantum mechanical processes.

The Doctoral School has also recognized the following doctorates with a special distinction: Nikolay Bykovskiy, Mauro Fanciulli, Doccio Malinverni and Anna Teplukhina.

AWARDS

Claudia Tambasco receives CHIPP Prize

Accelerator physicist Claudia Tambasco, working at the Particle Accelerator Physics Laboratory (LPAP), has been awarded the 2018 Swiss Institute of Particle Physics (CHIPP) Prize for research that has helped to improve the stability of proton beams in CERN's Large Hadron Collider (LHC).

The CHIPP Prize rewards annually the best PhD student in Experimental or Theoretical Particle Physics. It is the first time that the prize goes to the research and developments in accelerator physics. The jury honored Claudia Tambasco "for her decisive contributions to the understanding of Landau damping and beam-beam effects at the LHC with Beam-Transfer-Function measurements that led to a substantial increase in luminosity". Landau damping has been used since the start of the LHC operations to reduce losses caused by interactions between the proton beam and the surrounding vacuum pipe.

With Claudia Tambasco's thesis work under the supervision of Prof. Leonid Rivkin and Dr. Tatiana Pieloni, the impact of the beam-beam interactions has been measured for the first time in LHC using the Beam Transfer Function (BTF) method and results led to a proposal that increased the integrated luminosity in the LHC.

Dr Tambasco continues her research studying the Future Circular Collider (FCC) designs at the Swiss Accelerator Research and Technology (CHART) institute that provides the Swiss support for the future high-energy frontier projects at CERN.

AWARDS

Honorary Professors Martin and Schneider honored by foreign academies

Emeritus Professor Jean-Luc Martin received the Ernst Mach Honorary Medal for Merit in Physical Sciences from the Czech Academy of Sciences. On this occasion, a symposium on "Current trends in materials science" was organized in Prague. Professor Martin is well-known for his studies of the mechanical properties of various materials in terms of defect microstructures, using experimental techniques such as transmission and scanning electron microscopy and mechanical testing.

Emeritus Professor Wolf-Dieter Schneider got the Award of the 141st Committee of the Japan Society for the Promotion of Sciences *"for pioneering research work in nano-scale surface physics achieved by low-temperature scanning tunneling microscopy and spectroscopy"*. Professor Schneider has had a long and highly successful research career in surface physics and surface chemistry at the nanoscale, employing photoemission techniques and predominantly local scanning probe methods. Since his retirement in 2009, he is a scientific consultant at the Fritz-Haber-Institute of the Max-Planck-Society in Berlin.

INNOVATION

EPFL helps the International Cycling Union combat technological fraud

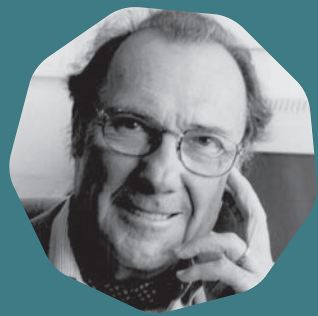
The Union Cycliste Internationale (UCI) has unveiled new X-ray methods to detect technological fraud in biking competitions. The Institute of Physics offered scientific and technological support to the project.

The possibility to hide performant motors in bicycles has led to a challenge for cycling as a sport. Since 2010 rumors have circulated of so-called technological fraud in professional bicycle races, but cyclists and fans alike deserve assurance that the outcomes of bicycle races are not influenced by mechanical doping.

To this end, the UCI revealed in Geneva an X-ray inspection unit designed to scan bicycles for hidden motors. EPFL's Institute of Physics and the University of Lausanne's Center of Research and Expertise in anti-Doping sciences assisted UCI in the realization. Initial X-ray tests were performed at EPFL, and the institute's expertise in radiation safety ensured a completely safe operation.

"One downside is that the machine is heavy (1500 kg), expensive, and that there is only one – which means that only the most important cycling races can be controlled," says EPFL's Professor Henrik Rønnow. "But this is only the beginning. By using a special X-ray source emitting only 50-nanosecond short pulses, our lab was able to design and construct a setup weighing less than 100 kg, which can be transported in a regular car. Each national cycling federation could have such a setup to ensure efficient controls at all levels."

IN MEMORIAM



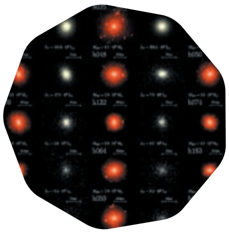
Professor Emeritus Philippe Choquard passed away

Professor Emeritus Philippe Choquard passed away on August 24th, 2018 at the age of 89.

Born in Porrentruy, Philippe Choquard graduated from ETHZ in theoretical physics in 1951 under the guidance of Wolfgang Pauli. Already in 1953, he obtained his PhD with Pauli, exploring new methods for Feynman's path integrals. In 1954, he entered Battelle, the newly founded research institute in Geneva. He became interested in various research problems, such as the study of thermal and transport properties of crystal lattices, the subject of his monograph "The Anharmonic Crystal" (1967).

In 1968, Philippe Choquard was appointed professor at EPUL, which became the EPFL a few months later. In 1969 he created the Laboratoire de Physique Théorique, promoting important research lines on statistical properties of lattices and mathematical models. He excelled in academic management: Dean of the Department of Physics (1969-70, 1981-82), President of the Swiss Physical Society (1978-79), member of the Executive Committee of the European Physical Society.

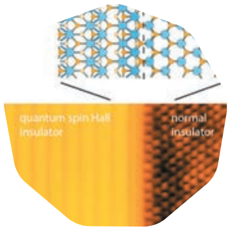
In the eighties, with his collaborators, Philippe Choquard became interested in the computer simulation of the equilibrium properties of Coulomb systems. He retired in 1996 but was scientifically very active, publishing numerous works till 2017. Philippe Choquard has achieved a remarkable scientific career, characterized by a strong commitment to EPFL and to the Physics community.



Studying dwarf galaxies to get the big picture

Researchers from the Laboratory of Astrophysics (LASTRO) have completed the fastidious task of analyzing 27 dwarf galaxies in detail, identifying the conditions under which they were formed and how they have since evolved. These small-scale galaxies are perfect for studying the mechanisms of new star formation and the very first steps in the creation of the universe. The LASTRO team found that the specific formation mechanism depends on the density of the galaxy's dark and baryonic matter.

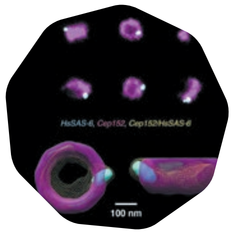
Y. Revaz & P. Jablonka, **Pushing back the limits: detailed properties of dwarf galaxies in a LCDM universe**, A&A **616**, A96 (2018). DOI: 10.1051/0004-6361/201832669



Observing topologically protected states

Materials exhibiting the quantum spin Hall effect host topologically protected one-dimensional helical edge states. However, control over the edges and associated edge states is hard to achieve in practice. An international team, with the theoretical support of Oleg Yazyev's lab, has demonstrated structurally well-defined boundaries in a fully accessible quantum spin Hall insulator by growing mixed-phase WSe_2 monolayers. These interfaces create opportunities both for studying the topologically protected boundary states and, potentially, for realizing practical devices based on them.

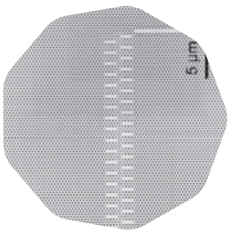
M.M. Ugeda *et al*, **Observation of topologically protected states at crystalline phase boundaries in single-layer WSe_2**, *Nat Comm* **9**, 3401 (2018). DOI: 10.1038/s41467-018-05672-w



Super-resolution microscopy builds multicolor 3D from 2D

A new technique developed by the lab of Suliana Manley overcomes the noise and color limitations of super-resolution microscopy by creating three-dimensional reconstructions from single-color, two-dimensional images of protein complexes. In collaboration with the lab of Pierre Gönczy (SV), the researchers tested the method on human centriole complexes that are crucial in helping the cell divide. They were able to uncover the 3D architecture of four proteins critical for centriolar assembly during organelle biogenesis.

C. Sieben *et al*, **Multicolor single particle reconstruction of protein complexes**, *Nat Methods* **15**, 777 (2018). DOI: 10.1038/s41592-018-0140-x



Slowing light down

Slow light propagation in nanostructured materials is a key component for realizing chip-integrated photonic devices controlling the relative phase of light and enhancing optical nonlinearities. EPFL physicists, together with an international team, have reported coupled-cavity-waveguides formed by photonic crystal cavities that were optimized using a genetic algorithm to achieve a record value of the group-index-bandwidth product.

Y. Lai *et al*, **Ultra-wide-band structural slow light**, *Sci Rep* **8**, 14311 (2018). DOI: 10.1038/s41598-018-33090-x

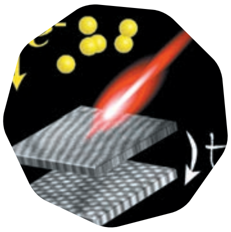
Knotted loops fall flat

Researchers from the Laboratory of Physics of Living Matter and their collaborators at the Universities of Lausanne and Warsaw have used knotted loops of metal beads to model knotted molecules, such as knotted DNA, and their motion through a viscous fluid. They found that while sedimenting, the loops reach a remarkably regular horizontal toroidal structure, with a number of intertwined loops, oscillating periodically around each other.

M. Gruziel *et al*, **Periodic Motion of Sedimenting Flexible Knots**, *Phys Rev Lett* **121**, 127801 (2018). DOI: 10.1103/PhysRevLett.121.127801

Fabio Donati receives the Max-Auwärter Award 2018

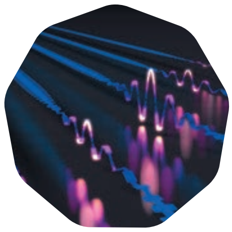
Fabio Donati has received the Max-Auwärter Award 2018 from the Austrian Physical Society for his work on magnetic remanence of single magnets. This work was performed while Fabio Donati was a postdoc in the Laboratory of Nanostructures at Surfaces of Prof. Harald Brune. Fabio Donati is now Research Professor at the Ewha Womans University in Seoul, Korea.



Controlling skyrmions with lasers

A skyrmion is a collection of electron spins that look like a vortex in certain magnetic materials. They have attracted attention in particular for memory-storage technologies. Skyrmions can be rather stable and require very little energy for writing or erasing them. The labs of Fabrizio Carbone and Henrik M. Rønnow have now been able to write and erase stable skyrmions using laser pulses. The forming skyrmions were imaged with time-resolved cryogenic Lorentz electron microscopy, which can follow magnetic domain structures in real space and real time.

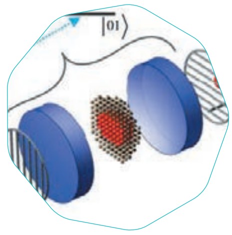
G. Berruto *et al*, **Laser-induced skyrmion writing and erasing in an ultrafast cryo-Lorentz transmission electron microscope**, *Phys Rev Lett* **12**, 117201 (2018). DOI: 10.1103/PhysRevLett.120.117201



"Good vibrations" in strained nanomechanics

High quality factor mechanical oscillators have applications both in practical sensing and fundamental science. Researchers in Tobias Kippenberg's laboratory have used insights from the semiconductor industry to reduce the dissipation in mechanical oscillators. The 7-mm long, 20-nm thick nanobeams were fabricated in the CMi and have mechanical quality factors of 800 million at room temperature—a world record. These devices will now be used to explore the limits of quantum measurements in room temperature experiments.

A. Ghadimi *et al*, **Elastic strain engineering for ultralow mechanical dissipation**, *Science* **360**, 6390 (2018). DOI: 10.1126/science.aar6939



Quantum interference opens up a new source for single photons

The predictions of Vincenzo Savona's lab for a new kind of single photon source have come to life in a recent collaboration with the universities of Leiden and Santa Barbara. The so-called unconventional photon blockade was experimentally realized with a semiconductor quantum dot embedded in a micropillar optical cavity. This is a promising and relatively easy method for quickly generating single photons, as it requires only weak interactions with the emitter to generate single photons.

H.J. Snijders *et al*, **Observation of the unconventional photon blockade**, *Phys Rev Lett* **121**, 043601 (2018). DOI: 10.1103/PhysRevLett.121.043601

Ambrogio Fasoli the new Chair of EUROfusion

Prof. Ambrogio Fasoli was recently elected as Chair of the General Assembly of EUROfusion, the European Consortium for the development of fusion energy. His nomination at the highest level in the fusion community in Europe constitutes not only a recognition of his competence and commitment, but also a proof of the prominent role that EPFL and Switzerland play in this field.

Magalí Lingenfelder included in RSC's "100 Women of Chemistry"

A paper by Magalí Lingenfelder, who leads the Max Planck-EPFL Nanolab, has been included in a collection of papers compiled by the Royal Society of Chemistry under the theme "Celebrating Excellence in Research: 100 Women of Chemistry".

Joël Mesot appointed new ETH President

The Federal Council has appointed Prof. Joël Mesot, Director of the Paul Scherrer Institute and part-time professor at the Institute of Physics, as the new President of ETH Zurich. He took office on January 1st 2019.

PHYSICS IN FIGURES

WORLD / EUROPE RANKINGS

13th / 5th
QS World University Rankings

29th / 9th
U.S. News

31st / 10th
Nanyang Technological University

45th / 19th
Academic Ranking of World Universities

FACULTY AND STAFF (in fte)

31.1
professors (chairs), of which 3 at SPC

135
scientific staff and lecturers

152
graduate students

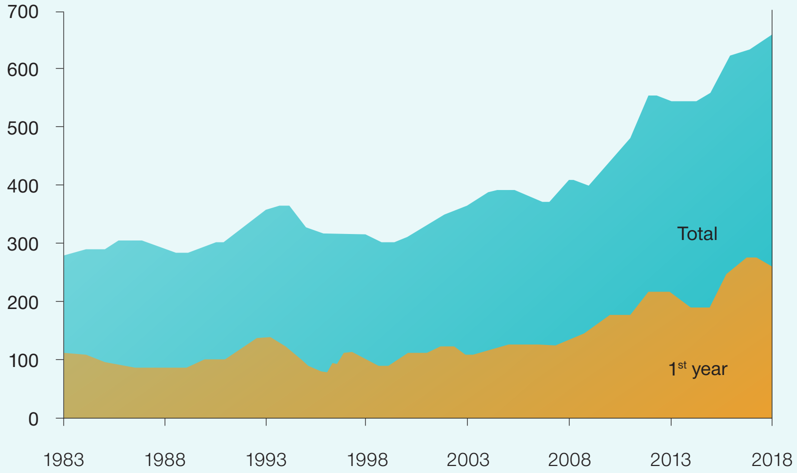
21
administrative staff

43
technical staff

TEACHING (year 2018)

92	bachelor degrees delivered
57	master degrees delivered
39	PhD degrees delivered
652	physics students
3441	other students receiving physics courses
3800	experiments demonstrated

NUMBER OF STUDENTS IN PHYSICS



RECORD BREAKING NUMBERS

20 meV
energy resolution in Dynamic Transmission Electron Microscopy (LUMES)

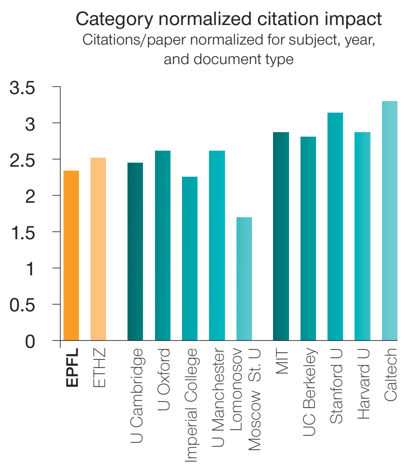
8x10^8
quality factor of mechanical resonator at room temperature (LPQM)

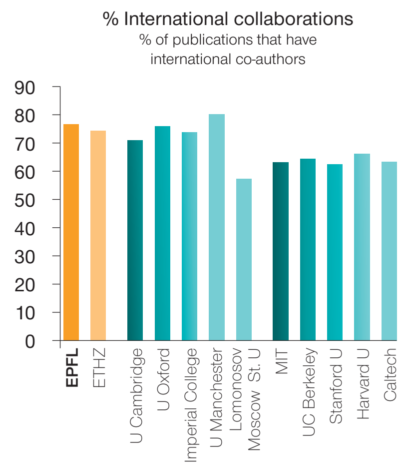
640
crystals of graphite in a new neutron spectrometer for investigating quantum materials (LQM)

35 K
maximum temperature for stable magnetic moment in single atom magnet (LNS)

2
ultra metal-poor stars without carbon enhancement in the Milky Way (LASTRO)

PUBLICATIONS 2012-2016 (InCites 28/01/2019)





TECH TRANSFER 2013-2018

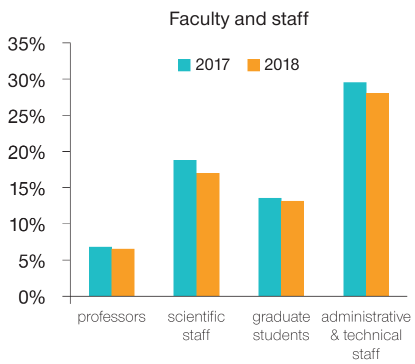
27
patent applications

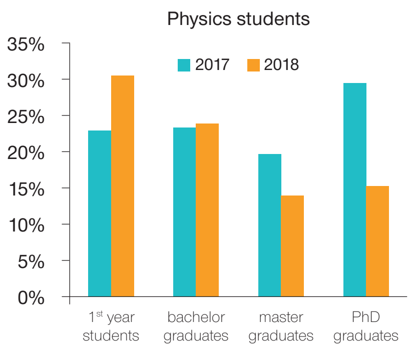
16
patents pending

6
patents granted

6
start-up companies created

PROPORTION OF WOMEN





EXTERNAL FUNDING

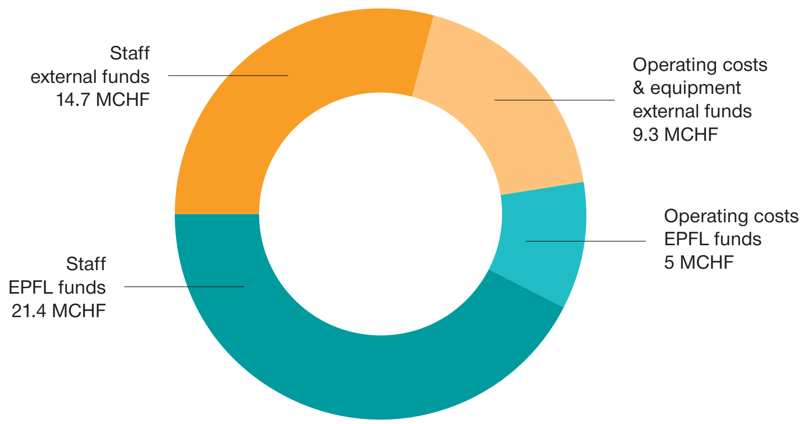
48%
external funding in total budget

8
ERC grants running

3
SNSF professorships

6
Ambizione grants running

FULL-YEAR IPHYS EXPENDITURE



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TEXT
Mediacom, Institute of Physics, Swiss Plasma Center, Physics Section and Doctoral Program in Physics, EPFL

DESIGN
cullycully.studio

PHOTOGRAPHY

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Multicolor 3D image of a protein complex reconstructed from 2D super-resolution microscopy images.
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Large Hadron Collider tunnel at CERN
© CERN

p. 5: Hugo Dil and Juraj Krempaský with the experimental set-up at the Paul Scherrer Institute
© Hugo Dil, EPFL

p. 6: A top-view of the GroES/GroEL bacterial chaperone complex model
© Wikipedia

p. 7: Graduating class of 2018
Elodie Savary receiving her diploma from Jean-Philippe Ansermet
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Frédéric Mila receiving the Craie d'Or
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Claudia Tambasco receiving the CHIPP Prize
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Wolf-Dieter Schneider
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Interface between the normal insulator and the quantum spin Hall insulator phases in WSe_2
© M.M. Ugeda et al 2018
Multicolor 3D model of human centrioles reconstructed from super-resolution micrographs
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Coupled-cavity-waveguide made of a photonic crystal cavity
© Antonio Badolato, University of Ottawa
A knotted loop of metal beads mimicking a knotted molecule
© Piotr Szymczak, University of Warsaw

p. 25: Formation of a skyrmion lattice triggered by a laser pulse
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Artist's rendition of vibrating nanostrings
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Principle of the unconventional photon blockade
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