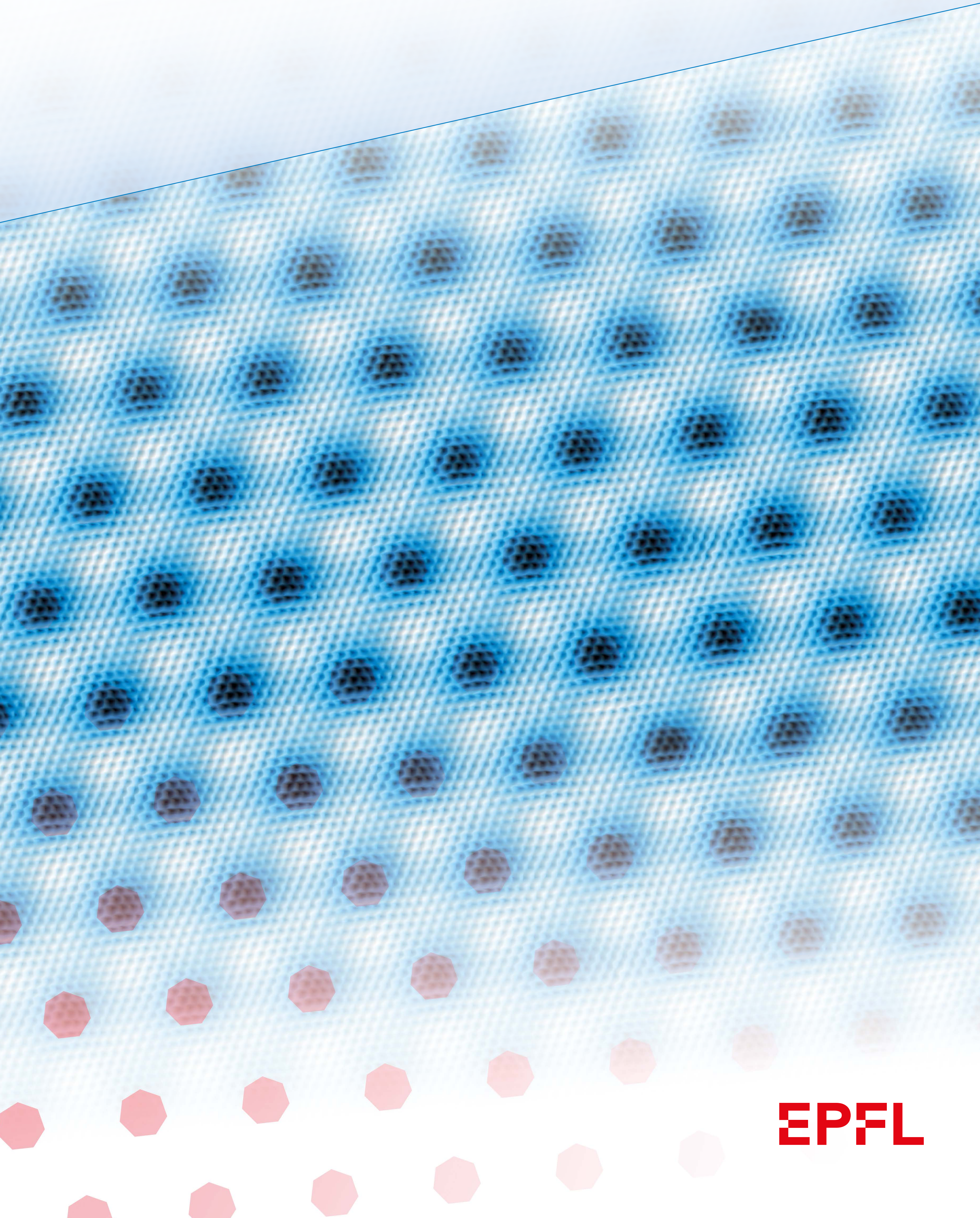
DOCTORAL
SCHOOL

# PHYSICS



EPFL

# “Nature’s imagination is so much greater than man’s, she’s never going to let us relax” Richard P. Feynman

Doctoral candidates in Physics at EPFL can team up with top ranking laboratories covering condensed matter, optics, biophysics, astrophysics, plasma, particle and theoretical physics. With its strong interdisciplinary character, the Doctoral Program in Physics is also a gateway towards advanced research in life science and engineering.

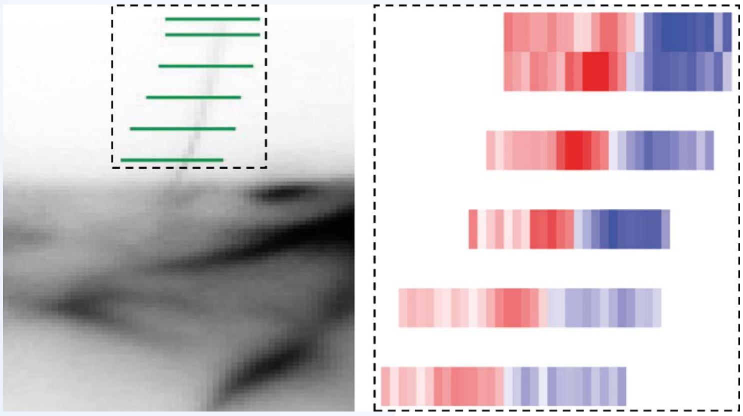
## From spin to time in photoemission

Photoemission is an important quantum process where electrons are emitted by a solid that is illuminated with UV light. The measurement of the properties of these electrons, such as their energy, momentum and spin polarization allows to reconstruct their behaviour inside the solid. This is the so-called spin- and angle-resolved photoemission spectroscopy (SARPES) technique.

However, it is not always possible to determine the electronic properties of the solid in its initial state, since the outcome of a measurement is influenced by the particular choice of parameters in the experiment, which is often a limitation.

Nevertheless, it is possible to exploit this fact in order to understand something about the process itself: in particular, to learn about the quasi-instantaneous time scale of the process by measuring the spin polarization. In fact different theories show how both spin polarization and time delay are related to a same quantity, namely the phase term of the photoemission matrix elements.

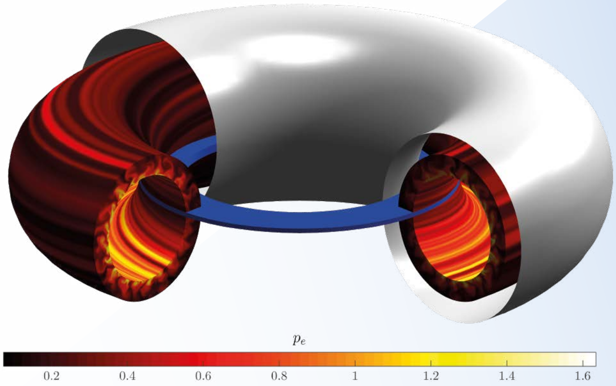
In my studies, I developed and explored the limits of the analytical model that allows to indirectly estimate the time scale from the measurement of the spin polarization, without explicit time resolution in the experiment. Furthermore, by performing SARPES experiments with synchrotron light from the Swiss Light Source I determined these time delays for two test samples: a copper single crystal and a high-temperature cuprate superconductor. The results are in the attosecond (10^-18 seconds) domain, which is the fundamental time scale at the atomic level.



In general, my work contributes to the understandings of the photoemission process and shows a new way to access such small time scales in quantum mechanics.

**Dr Mauro Fanciulli**
Spin Orbit Interaction Spectroscopy Group, Prof. Hugo Dil

# Verification and validation procedures in plasma physics




Providing a clean source of energy able to satisfy the unceasing growth of energy demand and to support the development of emerging economies represents one of the biggest challenges that humankind is facing today. One of the few possible solutions to this issue is represented by power plants based on nuclear fusion reactions, the same process that powers our Sun. This requires confining the fusion fuel at extremely high temperatures, of several million degrees, and creating a plasma in which fusion can occur.

The most promising concept for the realization of nuclear fusion power plants is the tokamak, a toroidal device which uses helicoidal magnetic fields to confine the hot plasma.

However, one of the greatest uncertainties in the success of the tokamak as a fusion reactor is related to our understanding of the plasma turbulent dynamics in the machine. Therefore, it is crucial to establish a validated predictive capability for the turbulent phenomena in magnetic fusion experiments and their consequences in present and future fusion devices.

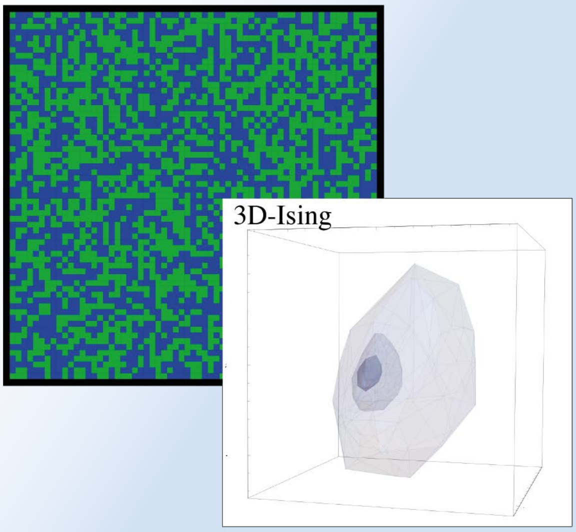
Because of the extremely complex plasma phenomena taking place in tokamaks, state-of-the-art simulation codes are needed to investigate the physics at play in these machines. My Ph.D. thesis and my current research activities enter in this context, giving an important contribution in addressing the two crucial questions “How can we ensure that plasma turbulence simulation codes are bug free?” and “How can we rigorously compare simulation results with experimental measurements?”. To this aim, I developed a rigorous verification and validation methodology and I applied it to plasma turbulence simulation codes, increasing significantly the reliability of the numerical tools that are used to study the physics at play in magnetic fusion devices. At the same time, I gave an important contribution in advancing our understanding of plasma turbulence, elucidating some of the mechanisms that govern the turbulent transport at the edge of fusion devices. One example is the study of the impact of the magnetic field shape on plasma turbulence, which provided useful information for the design of future fusion reactors.


**Dr Fabio Riva**
Swiss Plasma Center (Theory), Prof. Paolo Ricci


# Exploring Conformal Field Theories

Conformal field theories have been long known to describe the fascinating universal physics of scale invariant critical points. They describe continuous phase transitions in fluids, magnets, and numerous other materials. A prototypical example is boiling water at the critical pressure and temperature. In addition, conformal field theories sit at the centre of our modern understanding of quantum field theory, describing the asymptotic behaviour of quantum systems at infinitesimally small or large distances.

For decades it has been a dream to study these intricate strongly coupled theories non-perturbatively using only symmetries and other consistency conditions. This approach, which takes the name of Conformal Bootstrap, was extremely successful in two dimensions and has led to exact solutions, as in the case of the planar Ising model. On the other hand, conformal field theory was originally conceived in four and three dimensions, with applications to particle physics and critical phenomena in mind: after a few unfruitful attempts in dimensions higher than two, this ambitious task was dismissed and the conformal bootstrap remained dormant for over 40 years.




My PhD thesis introduced a completely new method to explore conformal field theories in any space-time dimension. I clarified how to analytically set up the consistency equations and developed numerical techniques for finding or constraining their solutions. These were based on complex optimisation algorithms, such as linear programming and semi-definite programming. The techniques I introduced allow to carve out the parameter space of a scale invariant system, and determine the allowed values of various observables.

In the subsequent years, these developments have led to a number of groundbreaking results, including world record determinations of critical exponents and correlation function coefficients in the Ising models in three dimensions. Today the conformal bootstrap is a well-established research field.


**Dr Alessandro Vichi**
Theoretical Particle Physics Laboratory, Prof. Riccardo Rattazzi

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Your master’s degree in physics or closely-related field is the requested academic degree for your PhD studies in physics. You will be admitted to the EPFL Doctoral Program in Physics once the following two independent conditions are met:

- you applied to the program, and were selected by the admission committee on the basis of the application documents;
- you found a thesis advisor associated with the doctoral program, in a research unit that decided, after an interview, to offer you a PhD student position to work on a specific research project.

Our PhD students complete their thesis in four years at most, participate in the teaching, and have a large freedom to define their own scientific training.

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