BRIEF DESCRIPTION FOR THE GENERAL PUBLIC

Quantum theory predicted phenomena such as superposition, entanglement or nonlocality that were later harnessed for fascinating applications: quantum cryptography, teleportation, computation, sensing, metrology, or, more recently, true randomness certification. None of these is achievable in the classical world. These novel and fascinating possibilities have attracted a lot of attention, which lead to the expansion of quantum theory to other fields such as information theory. Crucially, the theoretical studies were closely followed by the development of experimental methods, creating a platform for experimental verification of quantum-theoretical predictions. At the onset of 21st century, all these efforts give rise to novel commercial, industrial and technological applications of quantum features, such as quantum key distribution schemes or truly random number generators, developed by European or American companies such as *idQuantique*, or quantum simulators/annealers offered by *D-Wave Systems*.

One of the key features of quantum mechanics that is used in the design of these devices is randomness. Its existence in quantum theory proves that the laws of physics at the micro-scale dramatically depart from those at the macro-scale, and, at the same time, escape our intuition and the way we perceive Nature. Moreover, it is a primary resource for quantum cryptography, but also for other applications such as numerical simulations in various fields of research, such as biology or even gambling. For these reasons, quantum randomness has been recently an object of intensive studies both from qualitative and quantitative points of view. Until now, quantum randomness has been studied in various scenarios exhibiting nonclassical effects. However, most of them have concentrated on the simplest quantum systems – qubits, leaving higher-dimensional quantum systems largely unexplored.

The main aim of this project is to fill this gap. First, we will provide methods of randomness certification, considering two scenarios: semi-device-independent and device-independent. In the second scenario, we will also aim at answering a fundamental question, namely, what is the maximal amount of randomness that can be certified from entangled states of arbitrary local dimension and whether the algebraic bound of $2\log_2 d$ is in fact achievable. Quite surprisingly, this problem remains unsolved even for the simplest case of two qubits and is crucial for the possibility of full exploitation of randomness as a resource. However, scientific curiosity is an equally strong motivation for research on the properties quantum randomness, in addition to its practical applications because a better understanding of the nature of randomness in quantum mechanics will give us a better understanding of the foundations of this theory.