

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Institut de Physique Théorique, CEA Saclay

CNRS identification code: UMR 3681

Internship director's surname: Sangouard, Nicolas

e-mail: nicolas.sangouard@cea.fr

Phone number:

Web page: <https://quantum.paris/>

Internship location: CEA Saclay, l'Orme des Merisiers, Bâtiment 774

Thesis possibility after internship: YES, already

Funding: YES

If YES, which type of funding: EU

Identifying decoding failures in quantum error correction

Context. Quantum computers have the potential to outperform classical devices in tasks such as optimisation, cryptography, and quantum simulation. Recent experiments have even demonstrated a quantum advantage in controlled settings. However, these demonstrations typically involve artificial problems, and scaling quantum computers to solve real-world tasks remains extremely challenging.

Quantum error correction. The main obstacle is noise: qubits easily lose their quantum properties through interactions with the environment. To make large-scale quantum computation possible, errors must be detected and corrected using quantum error correction (QEC). In QEC, information is encoded across many qubits so that errors can be detected and corrected without disturbing the computation.

Scientific question. A crucial step in any QEC protocol is decoding, the process of interpreting measurement outcomes to decide the best correction. Efficient and accurate decoding is essential for QEC to work properly: a bad decoding strategy leads to a larger error rate. Developing better decoding strategies is therefore a central step towards practical quantum computers.

Project. In this project, we will focus on quantum low-density parity-check (LDPC) codes, a family of QEC codes with promising scalability properties. Their standard decoding algorithm, belief propagation (BP), is known to not be optimal for low physical error rates. The goal of the internship is to design and implement a method to identify the syndromes that are typically misclassified by BP. To successfully identify these syndromes, their decoding will be compared against an optimal, though computationally demanding, reference decoder. Ultimately, identifying the error patterns that are not well decoded could be used to improve the error rate of LDPC codes. The project will start with simple codes correcting a single type of error (appropriate for biased-noise qubits) and could later be extended to more general cases. The internship will involve a combination of analytical reasoning and numerical simulation.

Environment. The student will join Nicolas Sangouard's research group at the Institut de Physique Théorique (CEA Paris-Saclay) and work in close collaboration with Nicolas Sangouard, Kiara Hansenne (postdoctoral researcher), and Anthony Benois (PhD student). The internship will take place in a dynamic environment at the interface of quantum information theory and quantum technologies.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO

Quantum Physics: YES

Theoretical Physics: YES