INTERNSHIP PROPOSAL

Laboratory name: Compilation team, Firmware department, Alice & Bob CNRS identification code: N/A
Internship supervisors: JACINTO Hugo, GOUZIEN Élie
Web page: https://alice-bob.com
Internship location: Paris, France (primarily on-site, partial remote possible)
Duration: 6-month M2 research internship, starting January 2027

Thesis possibility after internship: YES Funding: YES

Co-design of magic state factories

In a context where magic state preparation dominates the space-time cost of fault-tolerant quantum algorithms, recent advances have substantially widened the factory design space: batched protocols producing several magic states per run [1, 2], compact protocols leveraging qubit recycling [3, 4], and "unfolded" distillation performed at the physical rather than the logical level, which exploits the noise bias of cat qubits [5, 6]. Because the repetition codes underlying Alice & Bob's architecture do not natively give access to the full Clifford group, the architecture must also distil Clifford resource states in addition to non-Clifford magic states [7]. Selecting the best factory is a highly multi-parameter optimisation problem, coupling spatial and temporal code distances, single- versus multi-output protocols, the degree of parallelism of the distillation circuit, the magic state injection scheme, the factory layout, and hardware connectivity constraints. The goal of this internship is to navigate this design space and identify the most resource-efficient factories for Alice & Bob's architecture, focusing first on magic state factories and possibly extending the resulting tools to Clifford state factories.

The intern will work closely with the Compilation and QEC teams to design, compile and optimise distillation factories for Alice & Bob's architecture, and may design new distillation protocols along the way. This work feeds directly into Alice & Bob's physical resource estimates for (early) fault-tolerant quantum computation.

[1] J. Haah and M. B. Hastings, Quantum **2**, 71 (2018), arXiv:1709.02832.
[2] S. Singh, C. Gidney, and C. Jones, arXiv:2606.28518 (2026).
[3] H. Jacinto, X. Valcarce, V. Barizien, É. Gouzien, and N. Sangouard, arXiv:2606.07734 (2026).
[4] V. Barizien, arXiv:2609.17044 (2026).
[5] D. Ruiz, J. Guillaud, C. Vuillot, and M. Mirrahimi, arXiv:2507.12511 (2025).
[6] V. Londe, arXiv:2605.06284 (2026).
[7] V. Barizien, H. Jacinto, and N. Sangouard, Phys. Rev. Lett. **136**, 030602 (2026), arXiv:2507.05408.

Keywords: quantum error correction, fault-tolerant quantum computing, magic state distillation, cat qubits, resource estimation
Techniques/methods: stabilizer formalism, quantum circuit compilation, combinatorial optimisation, numerical simulation of stabilizer circuits

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

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