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Quantum Computing in Practice: Navigating Simulation and Optimization on the Path to Quantum Advantage

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Abstract

The commercial and scientific momentum behind quantum computing is accelerating rapidly, yet a critical gap remains between theoretical promise and practical implementation. This talk bridges that gap through some of the hands-on projects spanning quantum simulation and combinatorial optimization, implemented on real quantum software frameworks including Intel Quantum SDK, Eviden myQLM, PennyLane, and Qiskit.

We begin by motivating the two most tractable near-term application domains - simulation and optimization, through current industry trends, before examining concrete implementations: a GAN-accelerated surrogate simulator for neutrino interactions in the INO-ICAL particle physics detector; a quantum-accelerated Quantum Monte Carlo workflow for correlated electron systems, developed in collaboration with Intel and presented at ISC 2025; a QAOA-based solution to the flight-gate assignment problem, developed in industry collaboration with Atos-Eviden; and a hardware-aware Variational Quantum Eigensolver (VQE).

The talk concludes with honest lessons from implementing these algorithms on real platforms, the theory-hardware gap, and why hybrid classical-quantum workflows remain the practical frontier. Attendees will leave with a grounded understanding of where quantum advantage is being engineered today, and what it actually takes to get there. “