# Analog Quantum Learning for Quantum Simulation

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Quantum machine learning, a flagship application for near-term quantum devices, leverages the variational principle to optimize quantum circuit parameters. Despite its potential, the application of variational quantum circuits encounters several obstacles. First, the limited coherent time of quantum devices only allows shallow circuits or short-time quantum evolution, and it subsequently constrains the expressibility of the quantum ansatz. The second challenge involves the measurement of the objective function or gradients in the experiments, potentially demanding an excessive number of measurements. Finally, not all physical hardware can rapidly and reliably execute arbitrary single and two-qubit gates.

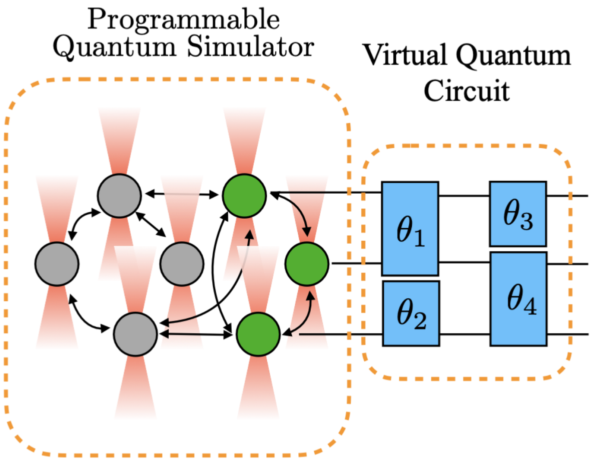


Figure 1: The concept of hybrid quantum circuits, a paradigm where programmable quantum simulators interact with virtual quantum circuits

In this talk, I aim to present prospective solutions to address these challenges with Programmable Quantum Simulators (PQSs).To augment expressibility, we introduce the concept of hybrid quantum circuits, a paradigm where programmable quantum simulators interact with virtual quantum circuits. These virtual circuits can be efficiently simulated on classical computers. I will show how this approach significantly enhances the performance of PQSs for quantum chemistry simulation at both zero and finite temperatures. Furthermore, I will discuss the recent progress in classical shadow tomography with locally scrambling quantum dynamics. This advancement allows us to read out many properties of quantum systems with very few measurements. Our findings provide valuable insights to overcome the current limitation of quantum machine learning and quantum simulation.