

PNW PLSE

Programming Abstractions for Quantum Computing

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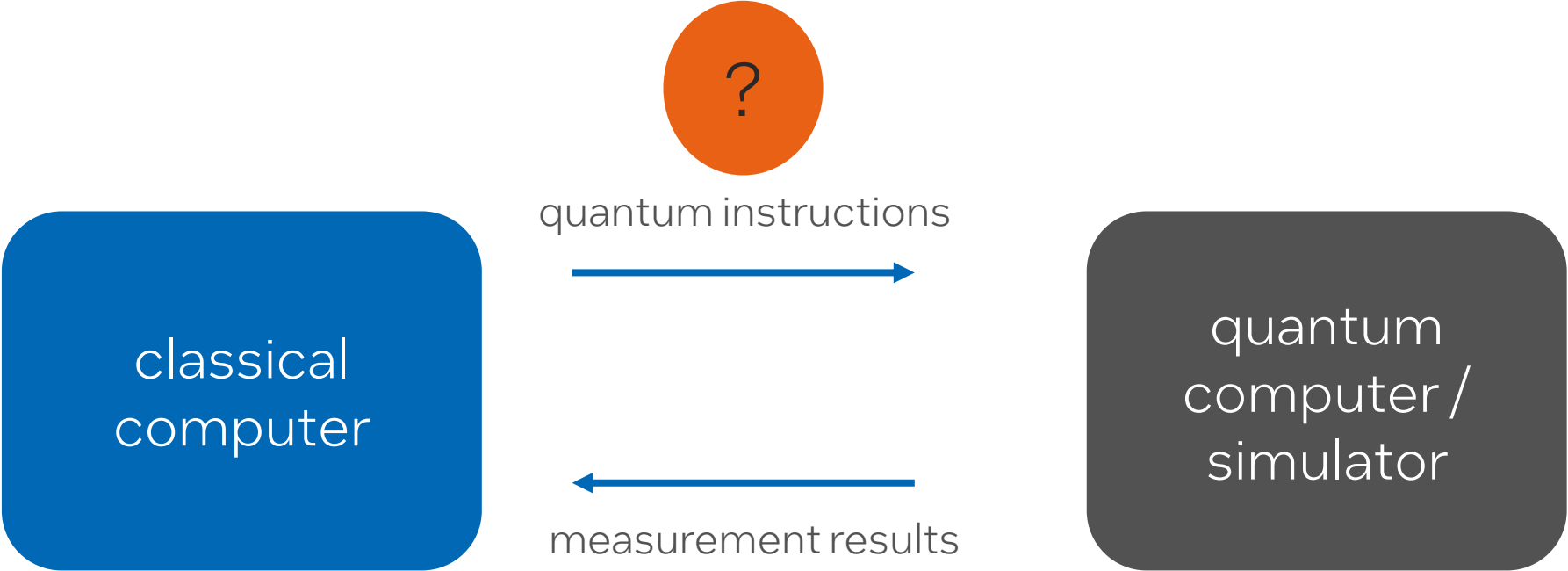
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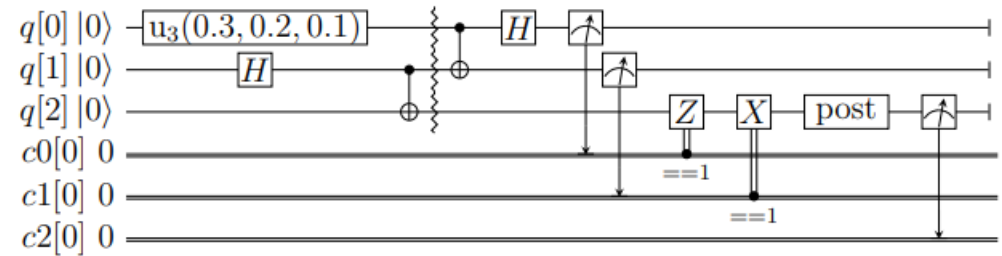
Quantum Computing as a Co-processor



Quantum Circuits

circuit
description
language
(e.g. python)

```
// quantum teleportation example
OPENQASM 2.0;
include "qelib1.inc";
qreg q[3];
creg c0[1];
creg c1[1];
creg c2[1];
// optional post-rotation for state tomography
gate post q { }
u3(0.3,0.2,0.1) q[0];
h q[1];
cx q[1],q[2];
barrier q;
cx q[0],q[1];
h q[0];
measure q[0] -> c0[0];
measure q[1] -> c1[0];
if(c0==1) z q[2];
if(c1==1) x q[2];
post q[2];
measure q[2] -> c2[0];
```



classical
computer

quantum instructions

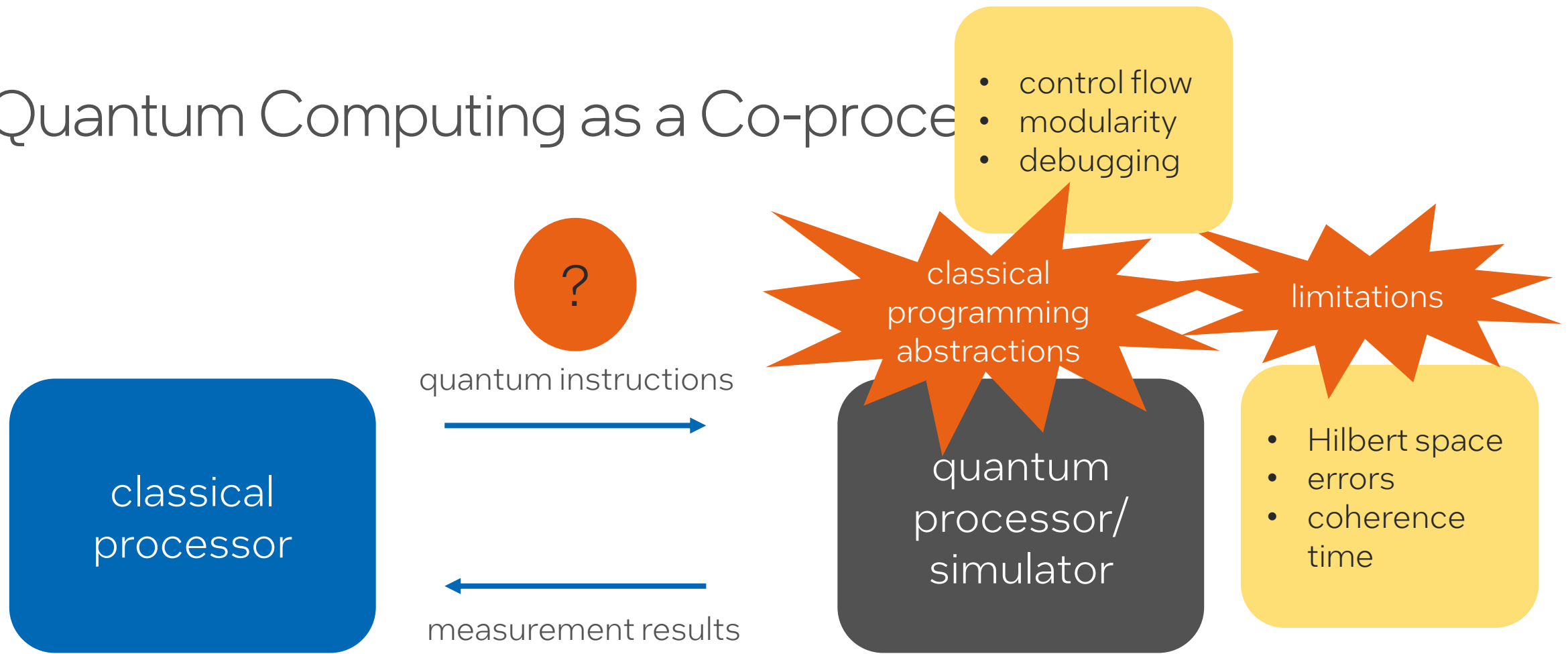


quantum
computer

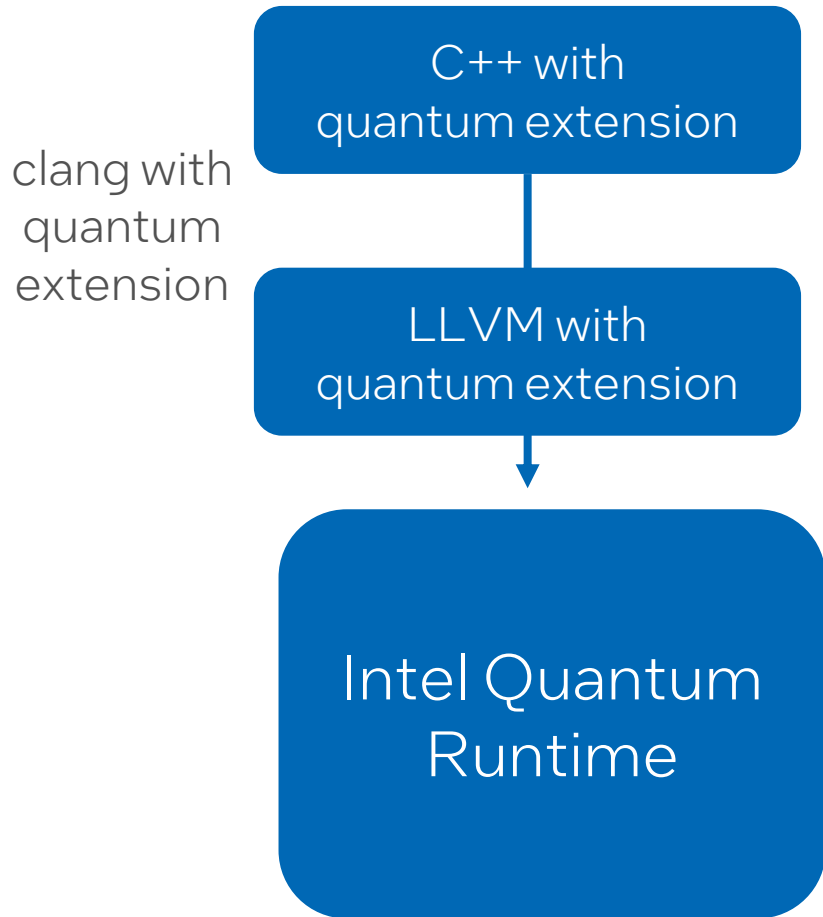
measurement results



Quantum Computing as a Co-processor

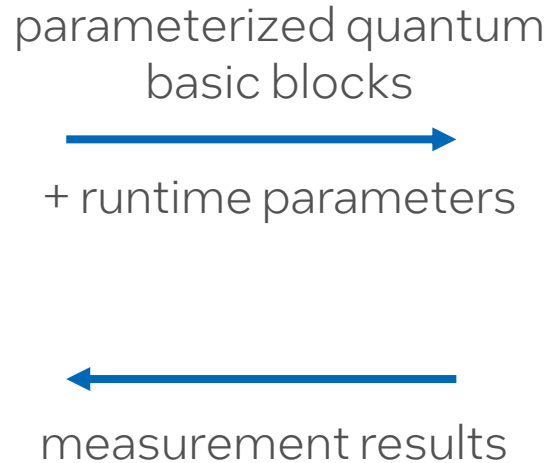


Intel Quantum SDK



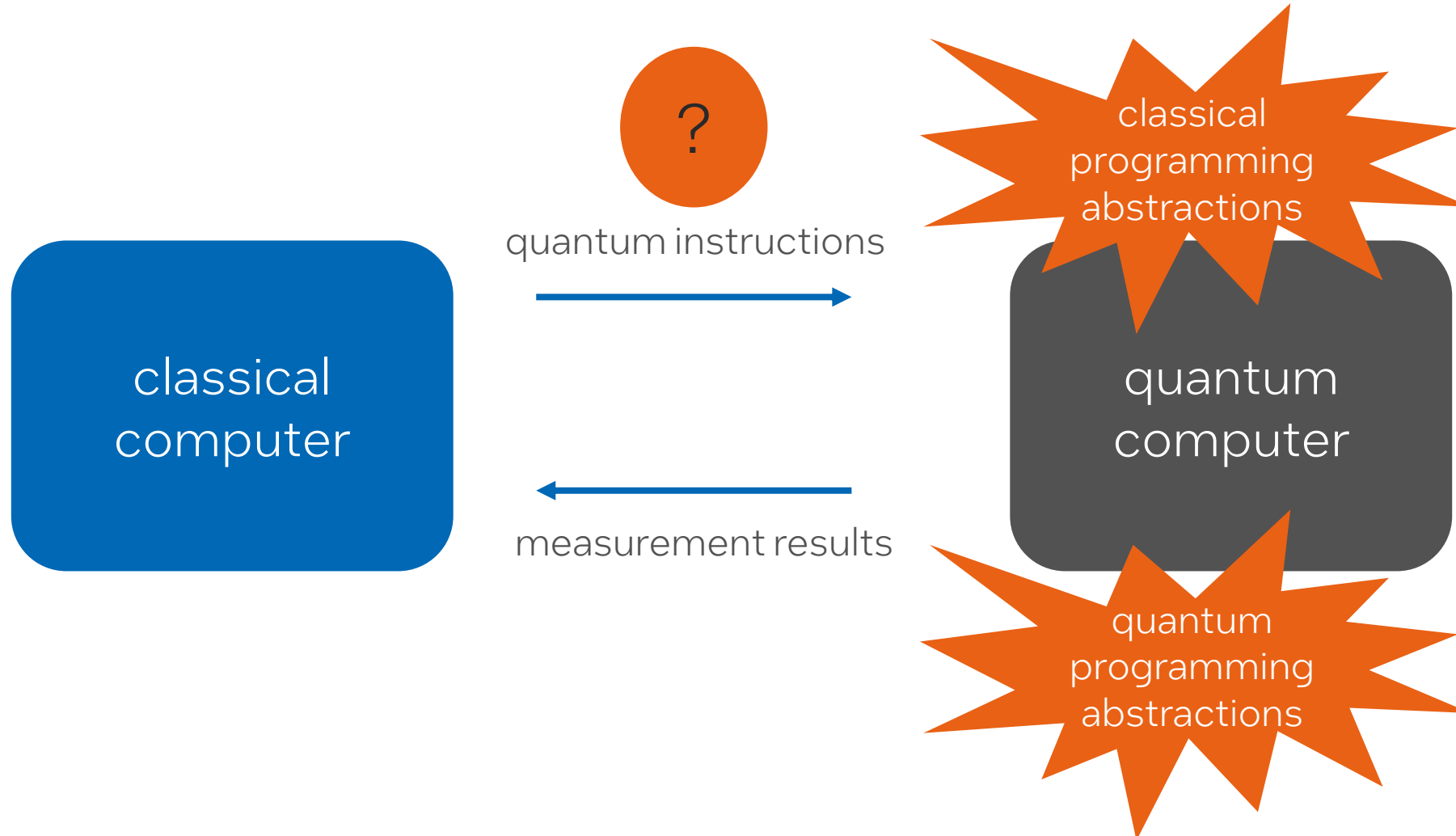
developer.intel.com/quantumsdk

```
quantum_kernel void ghz_total_qubits() {  
    for (int i = 0; i < total_qubits; i++) {  
        PrepZ(qubit_register[i]);  
    }  
  
    H(qubit_register[0]);  
  
    for (int i = 0; i < total_qubits - 1; i++) {  
        CNOT(qubit_register[i], qubit_register[i + 1]);  
    }  
}
```



Intel Quantum Simulator / Hardware

Quantum Computing as a Co-processor



PCOAST: A Pauli-based IR

PCOAST: A Pauli-based Quantum Circuit Optimization Framework

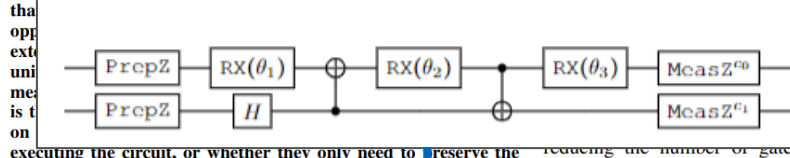
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Optimization at the Interface of Unitary and Non-unitary Quantum Operations in PCOAST

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Abstract—This paper presents the Pauli-based Circuit Optimization, Analysis, and Synthesis Toolchain (PCOAST), a framework for quantum circuit optimizations based on the commutative properties of Pauli strings. Prior work has demonstrated

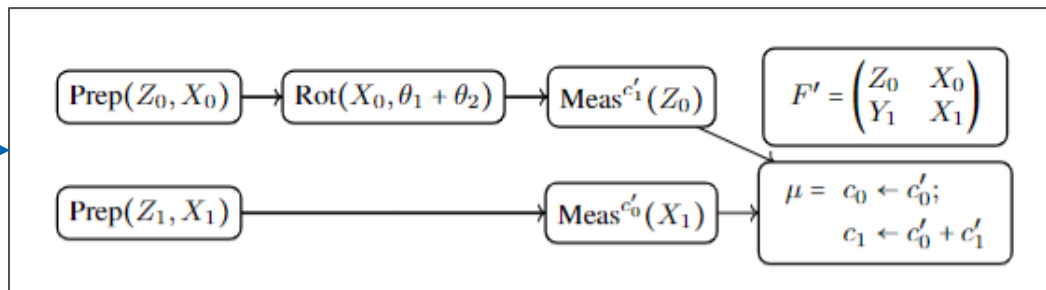
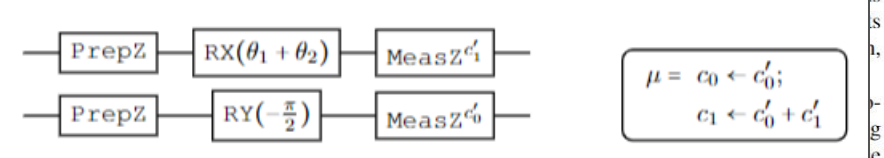
of the fact that unitary circuits can be decomposed into Clifford gates (generated by the Hadamard gate H , the phase gate S and the controlled-not gate CNOT); and non-Clifford gates $\text{Rot}(P, \theta) = e^{-i\theta/2P}$, where P is X , Y , or Z . Because Cliffords conjugation, it is possible to non-Clifford Pauli rotations $\text{Rot}(UPU^\dagger, \theta)$. Doing these rotations can be merged, reducing the number of gates required in the final circuit,



that the number of gates required to execute the circuit, or whether they only need to reserve the

Abstract—The Pauli-based Circuit Optimization, Analysis and Synthesis Toolchain (PCOAST) is a framework for optimizing quantum circuit to a Pauli-based representation as well as metadata which look to optimize the unitary and non-unitary operations.

nodes. Second, PCOAST introduces a customizable greedy



In submission

PCOAST: A Pauli-based IR

Hamiltonian Simulation

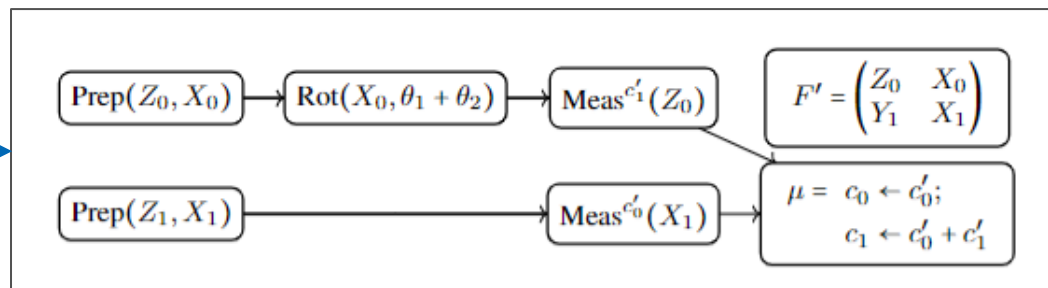
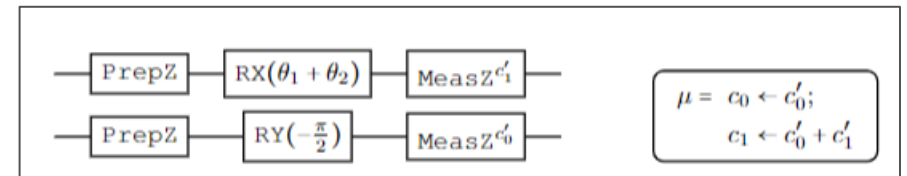
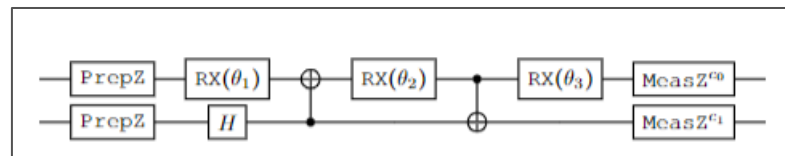
$$H = \theta_0 Z_0 Z_1 + \theta_{12} Z_1 Z_2 + \theta_{23} Z_2 Z_3 + \theta_{03} Z_0 Z_3 + \theta_{all} Z_0 Z_1 Z_2 Z_3$$

Schmitz, Albert T., et al. "Graph optimization perspective for low-depth Trotter-Suzuki decomposition." *arXiv preprint arXiv:2103.08602* (2021).

Quantum Kernel Expressions

```
OExpr multiCtrlU(OExpr U, qbit* qs, cbit* xs) {
    return control(qs, "|111>", U)
        + map(MeasZ, qs, xs);
}
```

Matsuura, Anne, Albert Schmitz, and Jennifer Paykin. "A Functional Approach to the Modular Construction of Quantum Logic." *Bulletin of the American Physical Society* (2023).



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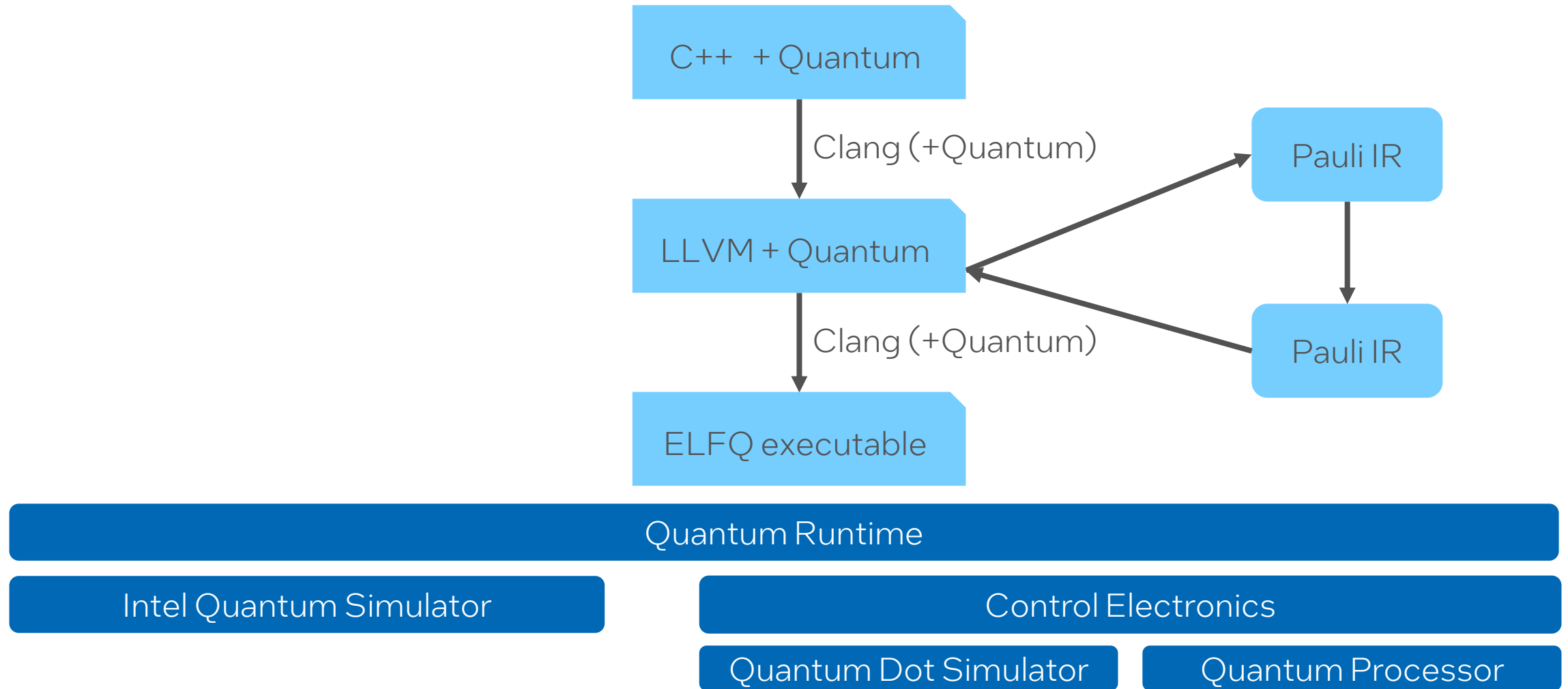
Intel Quantum SDK 1.0
developer.intel.com/quantum/sdk



Quantum Computing 101

- Qubits: $|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$, $|1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$
- Superposition: $\alpha|0\rangle + \beta|1\rangle = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$
 - $\alpha^2 + \beta^2 = 1$
- Unitary transformations $U \in \mathbb{C}^{2^n} \times \mathbb{C}^{2^n}$
 - $|\varphi\rangle \mapsto |U \cdot \varphi\rangle$
- Measurement:
 - $\text{meas} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{cases} |0\rangle & \text{w/ probability } \alpha^2 \\ |1\rangle & \text{w/ probability } \beta^2 \end{cases}$

Intel Quantum SDK Stack



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