Tsim: A Fast Universal Simulator for Quantum Error Correction

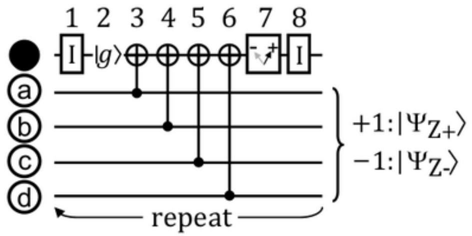
JUNE 2026

Rafael Haenel, Roger Luo, Chen Zhao

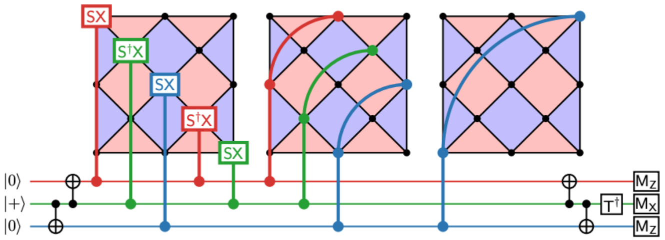
github.com/QuEraComputing/tsim • arXiv: 2604.01059

Requirements of simulating QEC protocols

Circuit to simulate: QEC gadgets

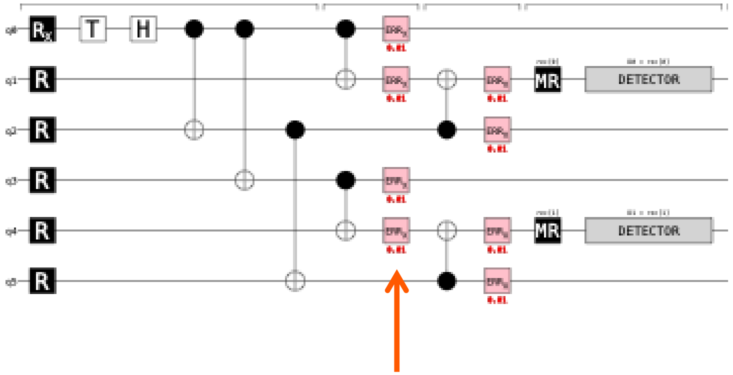


Clifford (quantum memory)



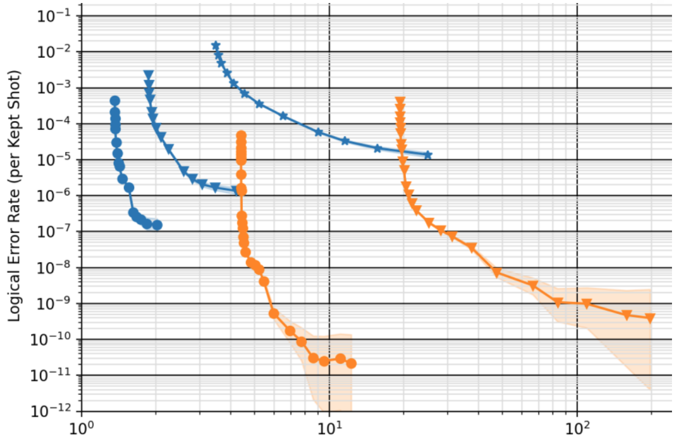
Low-magic (magic state cultivation)

Output of the simulation: measurements from noisy circuits



Pauli Errors

Extensive Monte Carlo sampling



Need trillions of shots to explore the 1e-12 logical error rate regime

Gidney 2019; figures from Fowler et al. 2012, Sahay et al. 2025, and Gidney et al. 2024

Tsim

Circuit to simulate: QEC gadgets

Low-magic circuits

Stabilizer rank decomposition

Bravyi et al. arXiv:1808.00128
Kissinger, Wetering arXiv:2109.01076
Qassim et al. arXiv:2106.07740

Output of the simulation: measurements from noisy circuits

Pauli noise

Parametric ZX diagrams

Sutcliffe, Kissinger arXiv:2403.06777

Extensive Monte Carlo sampling

Millions to trillions of shots

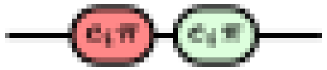
Parallelism

Measurement 

Trace 

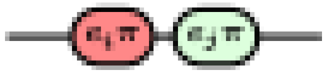
X_ERROR =

Y_ERROR =

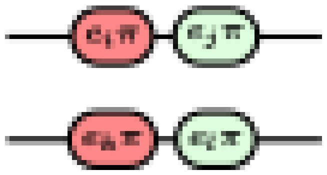


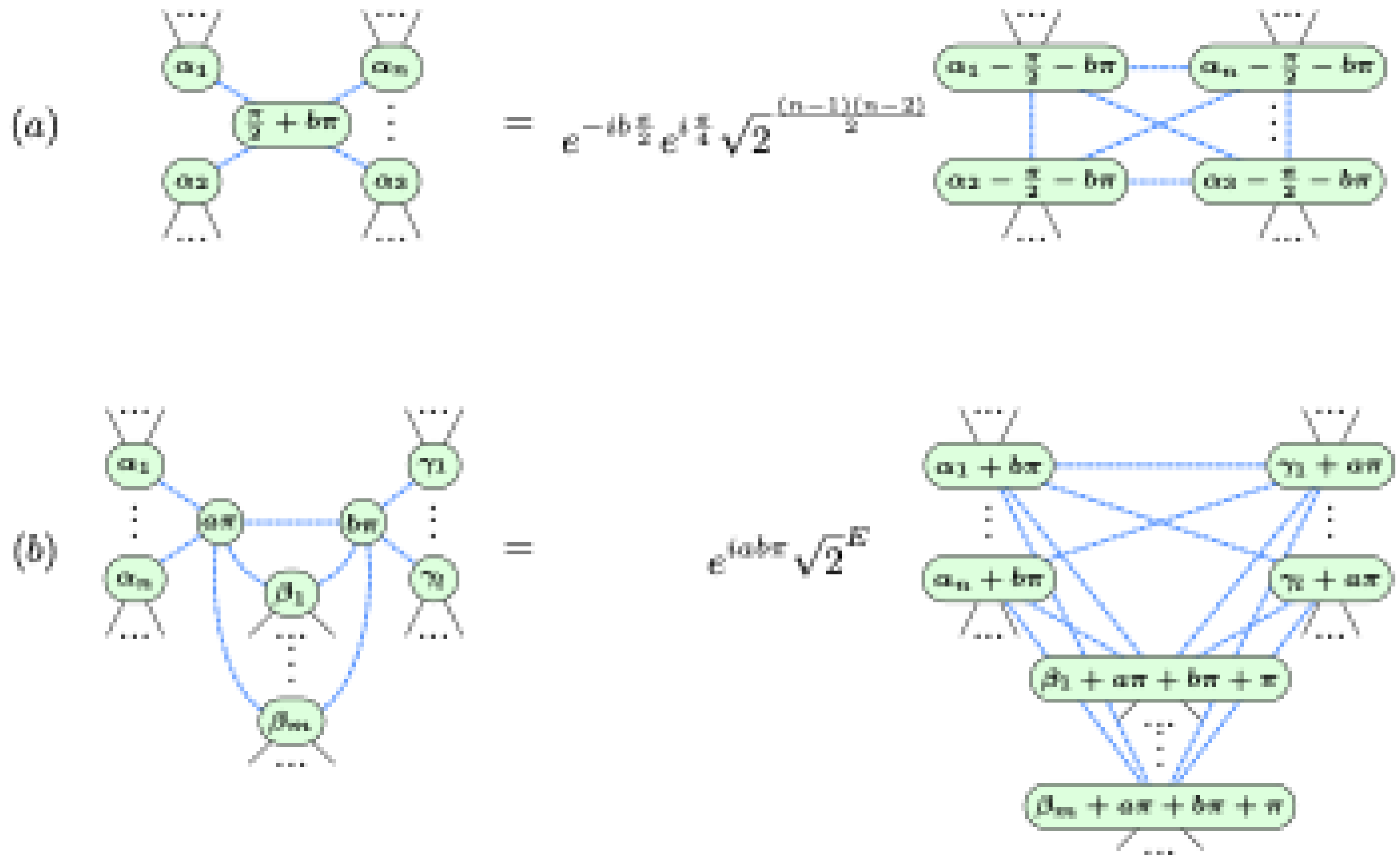
Z_ERROR =

PAULI_CHANNEL_1 =



PAULI_CHANNEL_2 =

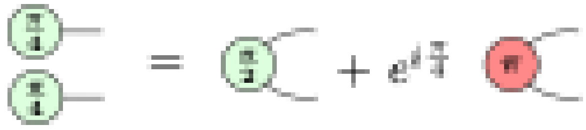



(a)
α_1
α_n
$\frac{\pi}{2} + b\pi$
α_2
α_3
$=$
$e^{-ib\frac{\pi}{2}} e^{i\frac{\pi}{4}} \sqrt{2}^{\frac{(n-1)(n-2)}{2}}$
$\alpha_1 - \frac{\pi}{2} - b\pi$
$\alpha_n - \frac{\pi}{2} - b\pi$
$\alpha_2 - \frac{\pi}{2} - b\pi$
$\alpha_3 - \frac{\pi}{2} - b\pi$
(b)
α_1
α_n
$a\pi$
$b\pi$
γ_1
γ_l
β_1
β_m
$=$
$e^{iab\pi} \sqrt{2}^{E}$
$\alpha_1 + b\pi$
$\gamma_1 + a\pi$
$\alpha_n + b\pi$
$\gamma_l + a\pi$
$\beta_1 + a\pi + b\pi + \pi$
$\beta_m + a\pi + b\pi + \pi$

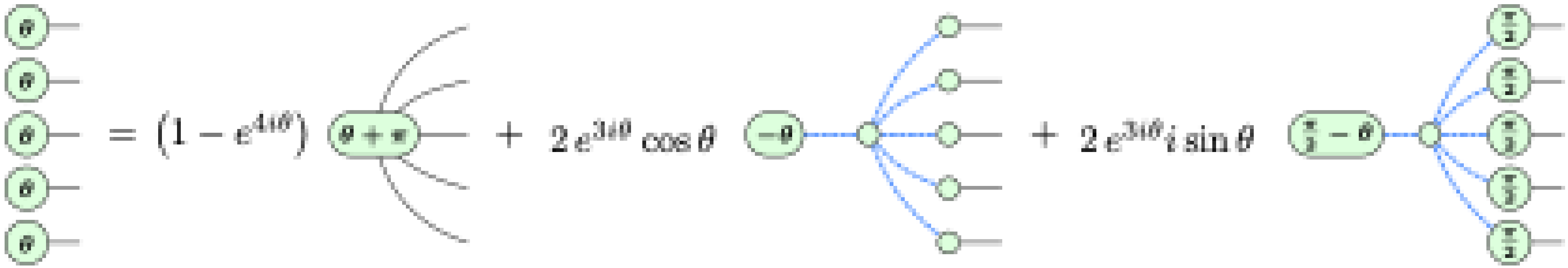
Stabilizer rank decomposition

T decomposition $\longrightarrow 2^{t}$

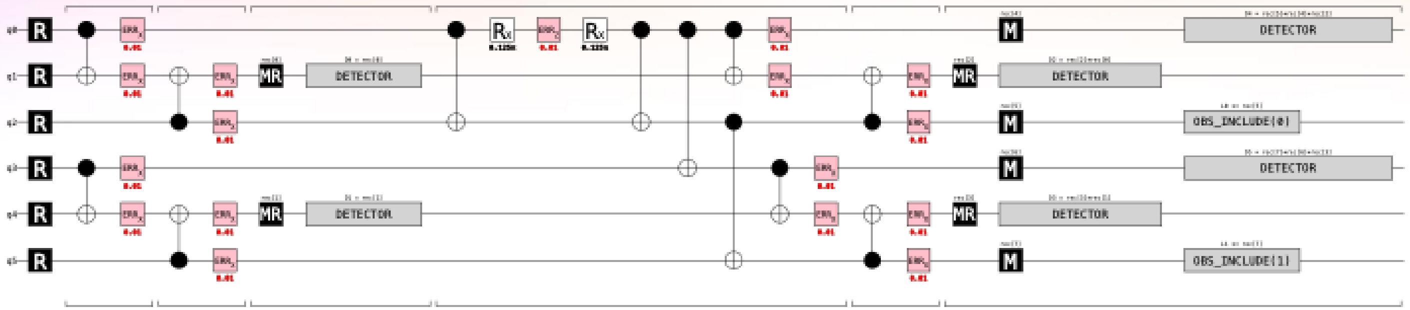
$\longrightarrow 2^{0.5t}$

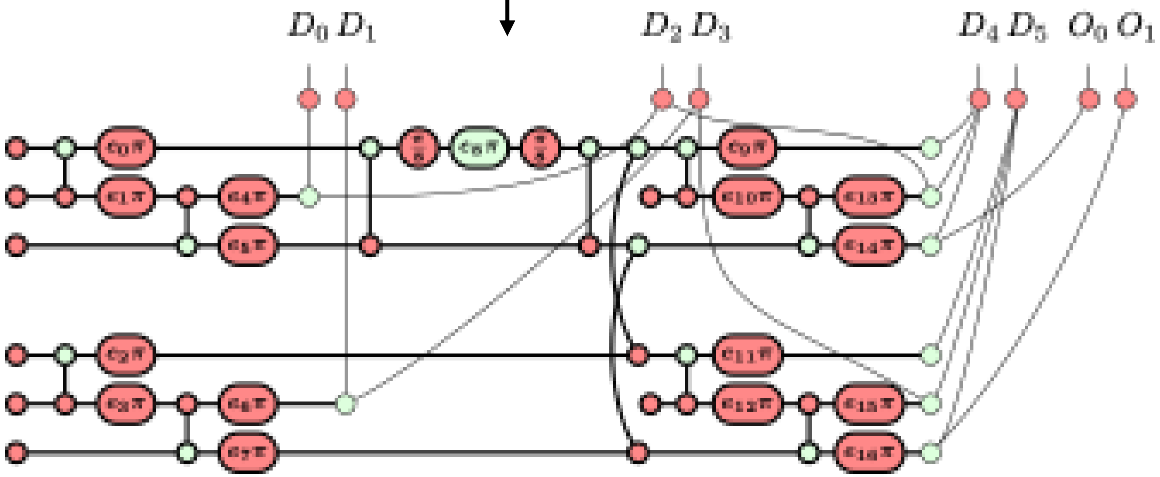


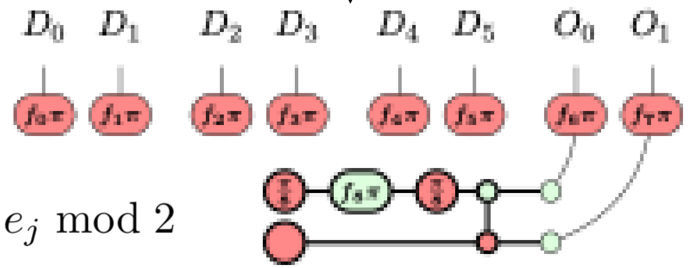
Magic Cat 5 decomposition $\longrightarrow 2^{0.396t}$



Bravyi et al. arXiv:1808.00128; Kissinger, Wetering arXiv:2109.01076; Qassim et al. arXiv:2106.07740; Codsi 2022; Sutcliffe 2025; Wan, Zhong arXiv:2509.08658

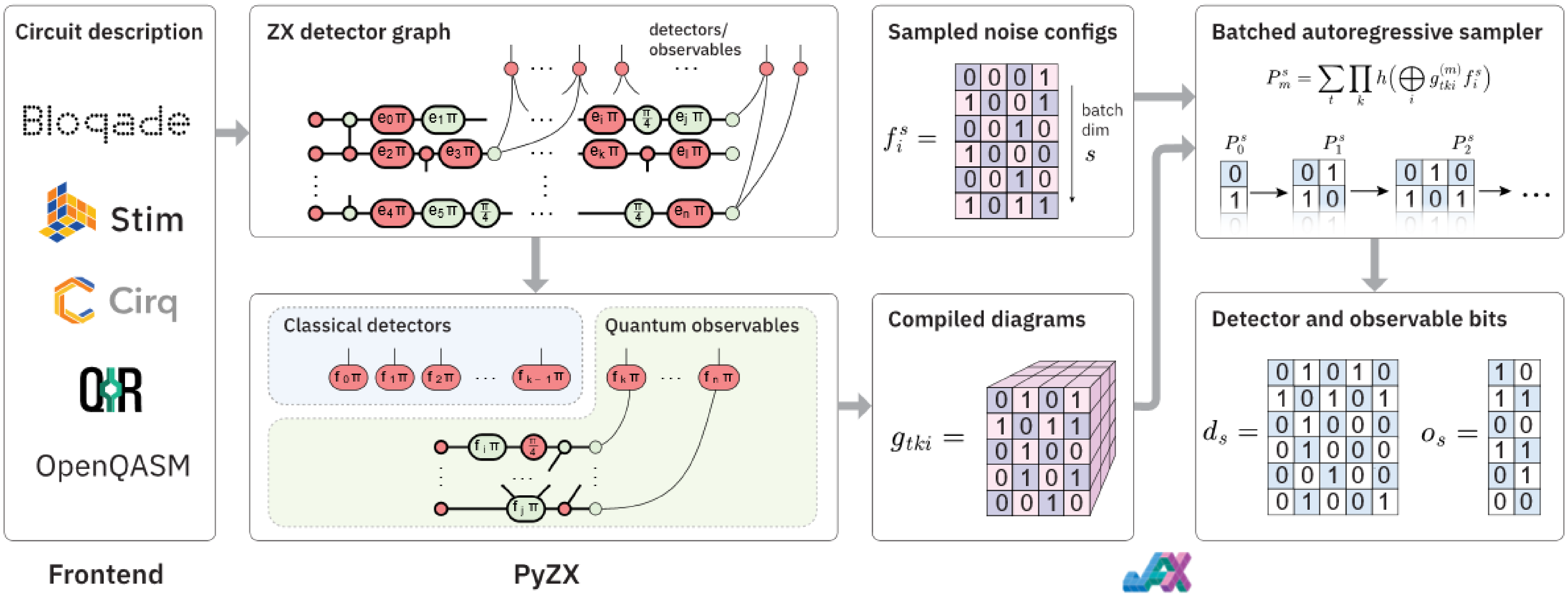






$$f_i = T_{ij} e_j \bmod 2$$

Tsim Overview

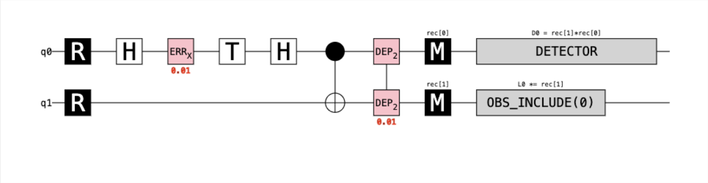


QuEra

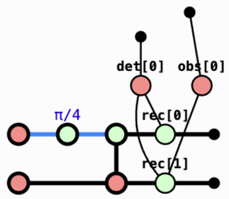
Demo

```
c = tsim.Circuit("""
    R 0 1
    H 0
    X_ERROR(0.01) 0
    T 0
    H 0
    CNOT 0 1
    DEPOLARIZE2(0.01) 0 1
    M 0 1
    DETECTOR rec[-1] rec[-2]
    OBSERVABLE_INCLUDE(0) rec[-1]
    """)
```
[12] ✓ 0.0s

```
c.diagram(height=150)
```
[13] ✓ 0.0s




```
c.diagram("pyzx");
```
[10]



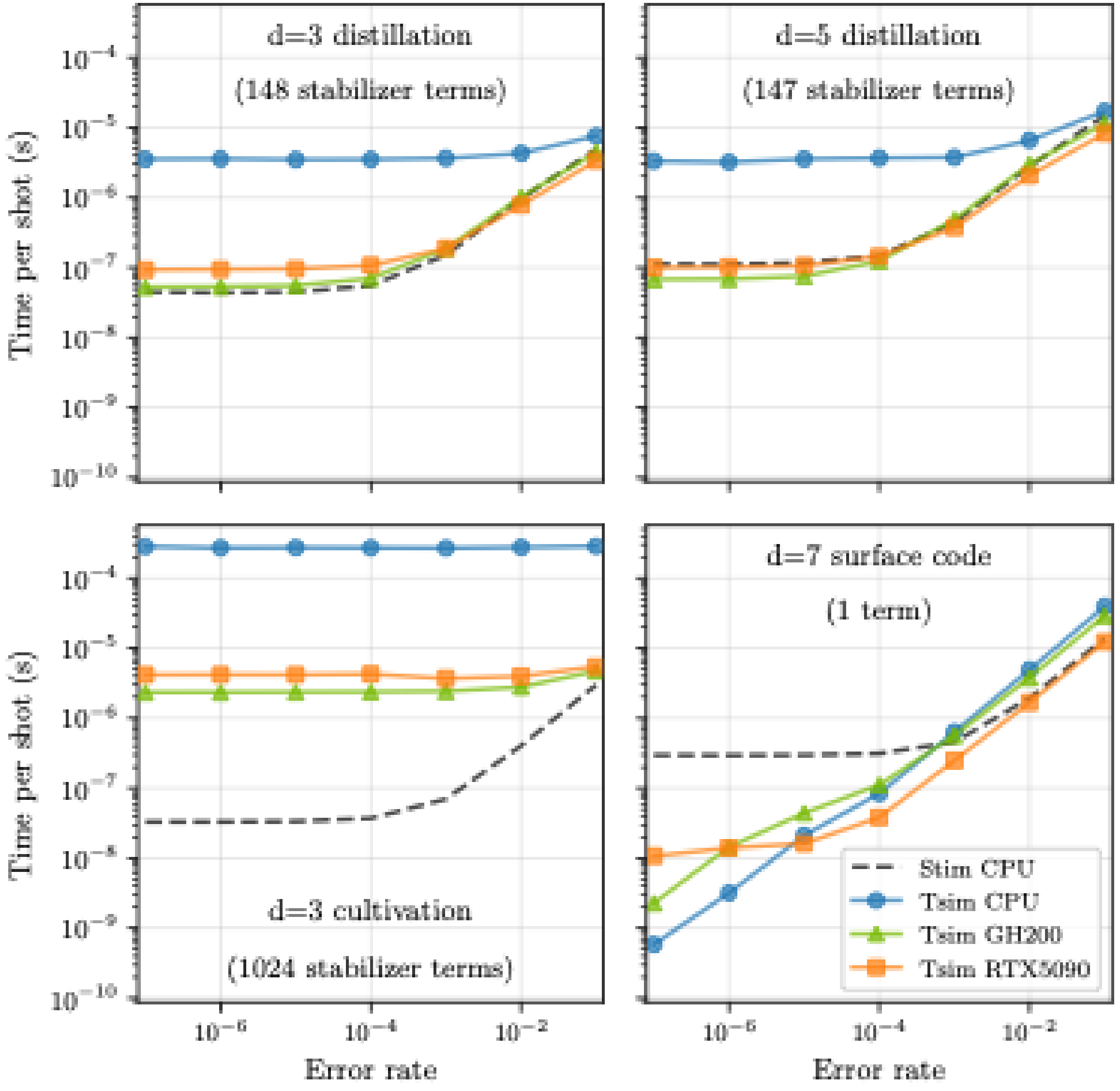

```
sampler = c.compile_sampler()
```
[14] ✓ 0.0s

```
sampler.sample(shots=100_000)
```
[16] ✓ 0.0s

```
array([[False, False],
       [ True,  True],
       [False, False],
       ...,
       [False, False],
       [False, False],
       [False, False]], shape=(100000, 2))
```

QuEra

Benchmarks



d=3 distillation
(148 stabilizer terms)
d=5 distillation
(147 stabilizer terms)
d=3 cultivation
(1024 stabilizer terms)
d=7 surface code
(1 term)
Time per shot (s)
Error rate
Stim CPU
Tsim CPU
Tsim GH200
Tsim RTX5090

n_g - number of gates
n_t - number of non-Cliffords
n_q - number of qubits

$O(n_g + n_t^2 2^{2 \cdot 0.396 n_t})$

$O(n_g n_q + n_t 2^{\max(n_t, n_q)})$ $\quad$ $O(n_g)$

Circuit	Qubits	Ops	Non-Cliff	$k_{\max}$	Clifft	Stim	Tsim
Pure Clifford							
Surface code $d = 7, r = 7$	118	4667	0	0	2.2M	**20.1M**	13.9M*
Near-Clifford: Magic State							
Cultivation $d = 3$	15	676	29	4	**10.4M**	–	0.5M†
Cultivation $d = 5$	42	4379	91	10	**314.4k**	–	DNC
Distillation	85	1163	10	5	**1.5M**	–	**1.5M**†
Near-Clifford: Coherent Noise							
Surface code $d = 3, r = 1$	26	173	65	5	19.4M	–	**5.9B***
Surface code $d = 3, r = 3$	26	415	195	8	**1.7M**	–	DNC
Surface code $d = 5, r = 1$	64	533	209	13	133.1k	–	**1.6B***
Surface code $d = 5, r = 5$	64	2073	1045	24	**0.7**	–	DNC

*MacBook Pro M4
†NVIDIA GH200

Clifft: Fast Exact Simulation of Near-Clifford Quantum Circuits, 2026, B. A. Chase, arXiv:2604.27058

README | Contributing | Apache-2.0 license

docs latest | coverage 97% | arXiv 2403.06777
Like Tsim? Leave a star 110

Tsim

A GPU-accelerated quantum circuit sampler based on ZX-calculus stabilizer rank decomposition. Tsim feels just like Stim, but supports non-Clifford gates.

Installation

Install with pip:

```
pip install bloqade-tsim
```

Or with uv:

```
uv add bloqade-tsim
```

If your machine has a GPU, use:

```
pip install "bloqade-tsim[cuda13]"
```

tsim

Get started › tsim

Quick start

An introductory tutorial is available **here**. For many existing scripts, replacing `stim` with `tsim` should just work. tsim mirrors the Stim API and supports all Stim instructions.

Additionally, tsim supports the instructions `T`, `T_DAG`, `R_Z`, `R_X`, `R_Y`, and `U3`.

```
import tsim

c = tsim.Circuit(
    """
    RX 0
    R 1
    T 0
    PAULI_CHANNEL_1(0.1, 0.1, 0.2) 0 1
    H 0
    CNOT 0 1
    DEPOLARIZE2(0.01) 0 1
    M 0 1
    DETECTOR rec[-1] rec[-2]
    """
)

detector_sampler = c.compile_detector_sampler()
samples = detector_sampler.sample(shots=100)
```

ppvm

PART OF THE BLOQADE SDK · V0.1

ppvm

Fast Pauli propagation and generalized stabilizer-tableau simulation for noisy quantum circuits — built to scale with the programs you actually run on QuEra's neutral-atom hardware.

RUST 2024 PYTHON ≥ 3.10 SOURCE github.com/QuEraComputing/ppvm

Quick Start → Developer Guide → API Reference →

PAULI PROPAGATION | GENERALIZED TABLEAU | tableau_ghz.py · tested

```
from ppvm import GeneralizedTableau

tab = GeneralizedTableau(n_qubits=2, seed=0)
tab.h(0)
tab.cnot(0, 1)

r0 = tab.measure(0)
r1 = tab.measure(1)

print(f"qubit 0: {r0}, qubit 1: {r1}")  # → qubit 0: 1, qubit 1: 1
print("correlated:", r0 == r1)  # → correlated: True
```

The generalized tableau evolves the state forwards and samples measurement outcomes. GHZ correlations fall out of two single-qubit measurements.

github.com/QuEraComputing/tsim

https://tsim.mintlify.app/

github.com/QuEraComputing/ppvm

QuEra

Tsim: Fast Universal Simulator for Quantum Error Correction (2026) arXiv: 2604.01059

75 open positions

All Departments

All Locations

Search

- All Locations
- Albuquerque, NM, USA
- Boston, MA USA
- Boston, MA, USA
- Harwell, England, UK
- Harwell, UK
- Providence, RI
- Toronto, Ontario, Canada
- Tsukuba, Japan

2026 QuEra Career Fair Event

Finance

Information Technology

Laser Systems

Photonics

Product Management - Program Management

QEC and Architecture

QPU Hardware Engineering