

Generation of stretched single qubit gates for Richardson error extrapolation

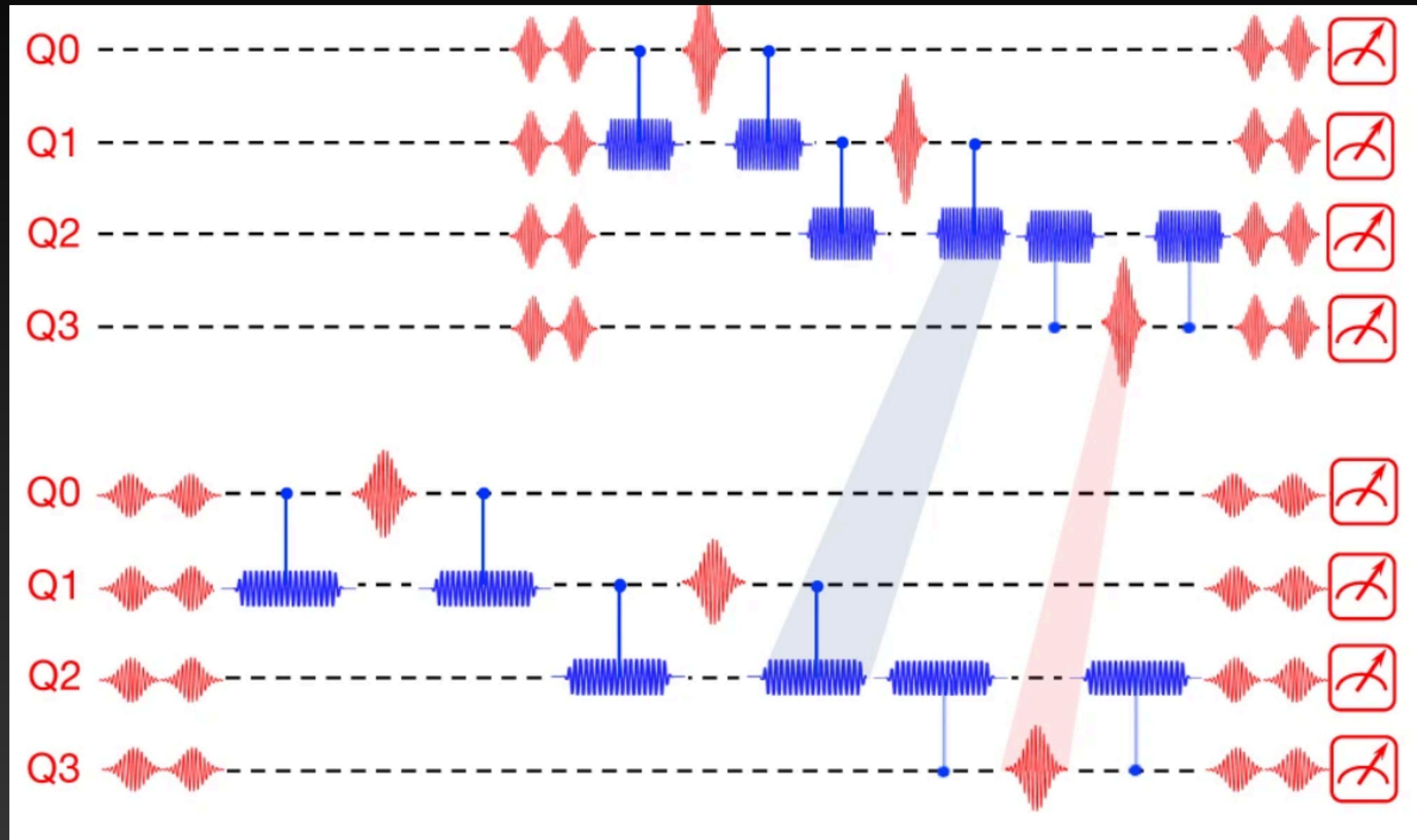
Instructor:
Mr. Kanazawa

Team Member:

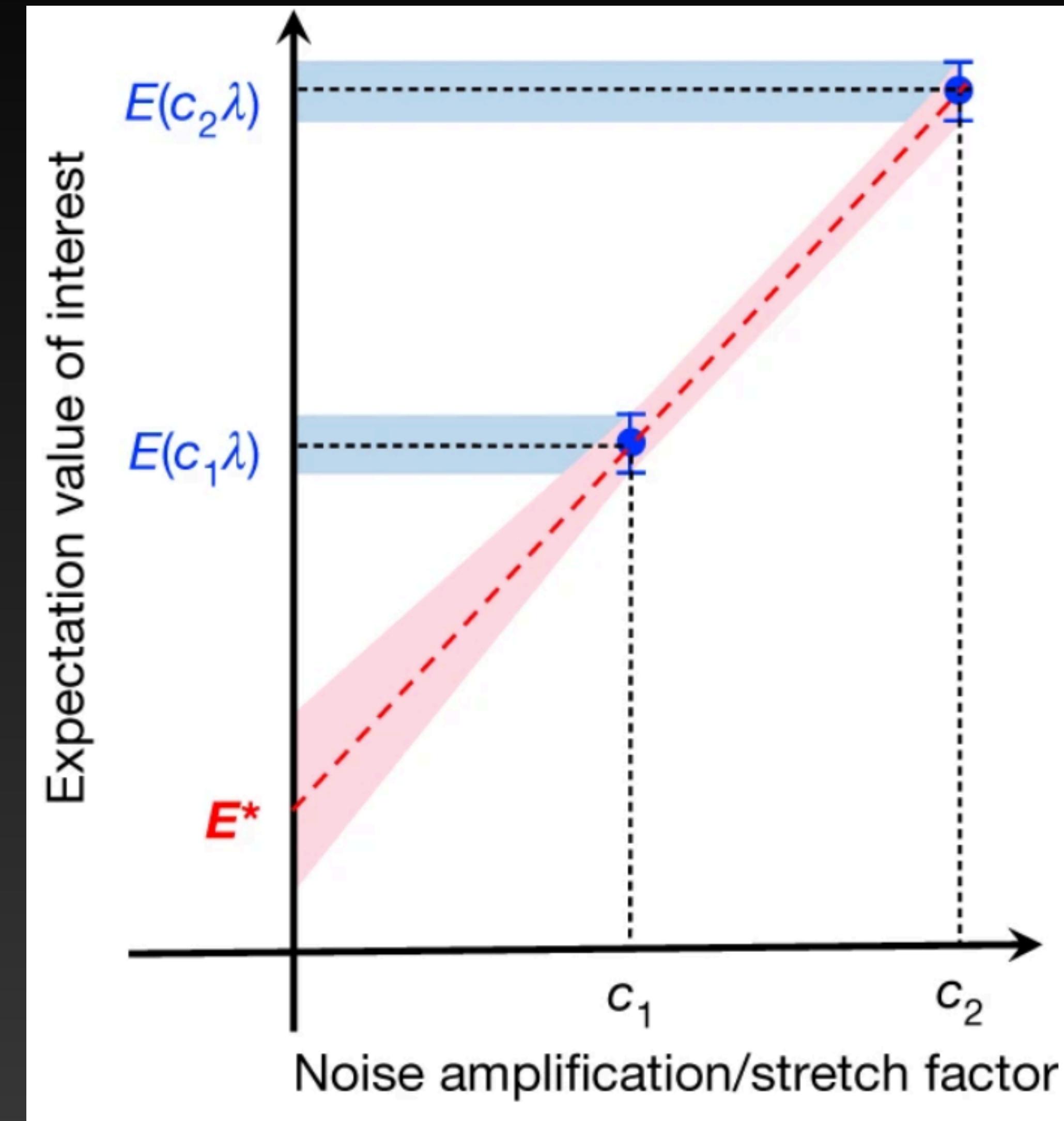
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Error Mitigation Method



Error Mitigation Method



Work Flow

Calibrating Qubits with Qiskit Pulse

The screenshot shows a web page from the Qiskit Learn website. The top navigation bar includes the Qiskit logo, a back arrow, and links for Learn, Community, and Documentation. On the left, a sidebar lists chapters and sub-chapters for "Learn Quantum Computation using Qiskit". The main content area features a large title "Investigating Quantum Hardware Using Microwave Pulses" with a "Upcoming" section below it. A sidebar on the right contains "On This Page" and "Upcoming" sections. At the bottom, there are navigation arrows between "Measuring Quantum Volume" and "Calibrating Qubits with Qiskit Pulse", along with a footer note about the page's creation by The Jupyter Book Community and a "Cookie Preferences" link.

Qiskit

Learn Quantum Computation using Qiskit

What is Quantum?

0. Prerequisites

1. Quantum States and Qubits

- 1.1 Introduction
- 1.2 The Atoms of Computation
- 1.3 Representing Qubit States
- 1.4 Single Qubit Gates
- 1.5 The Case for Quantum

2. Multiple Qubits and Entanglement

- 2.1 Introduction
- 2.2 Multiple Qubits and Entangled States
- 2.3 Phase Kickback
- 2.4 More Circuit Identities
- 2.5 Proving Universality
- 2.6 Classical Computation on a Quantum

←

Investigating Quantum Hardware Using Microwave Pulses

Upcoming

The following topics are currently being developed for addition to the textbook:

1. Decoherence and Energy Relaxation: Measuring T2 and T1
2. Optimizing Microwave Pulses for High-Fidelity Qubit Operations

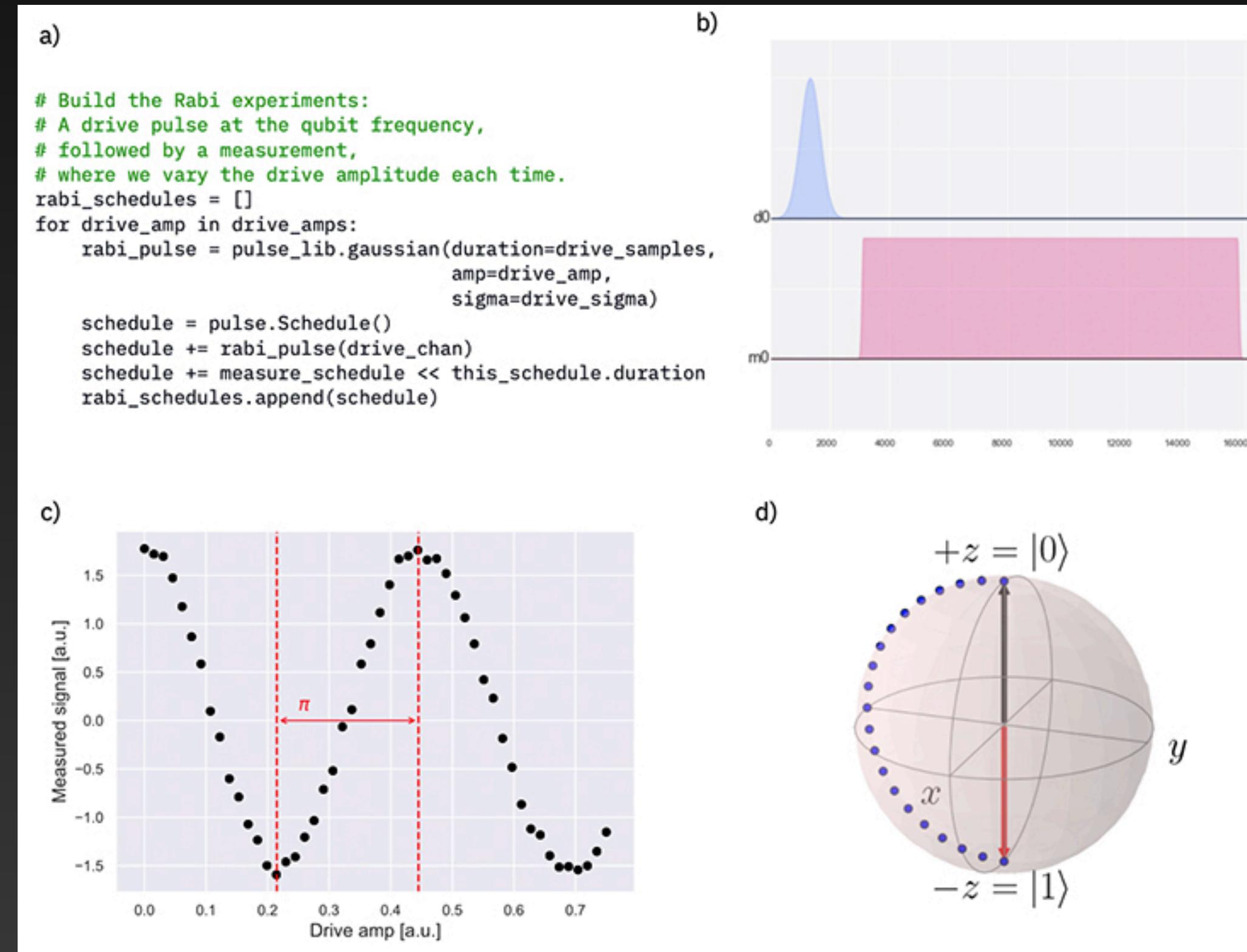
⟨ Measuring Quantum Volume Calibrating Qubits with Qiskit Pulse ⟩

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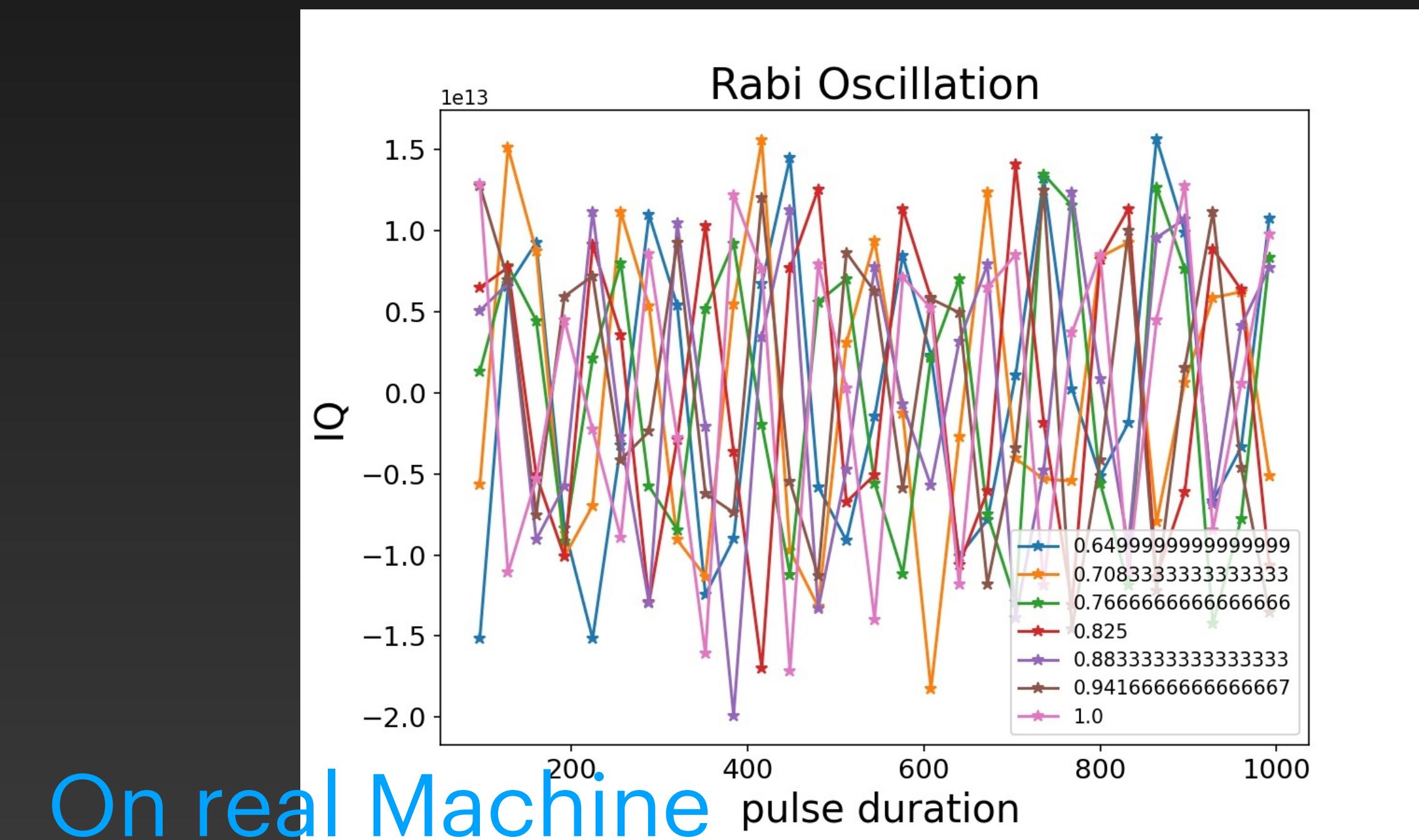
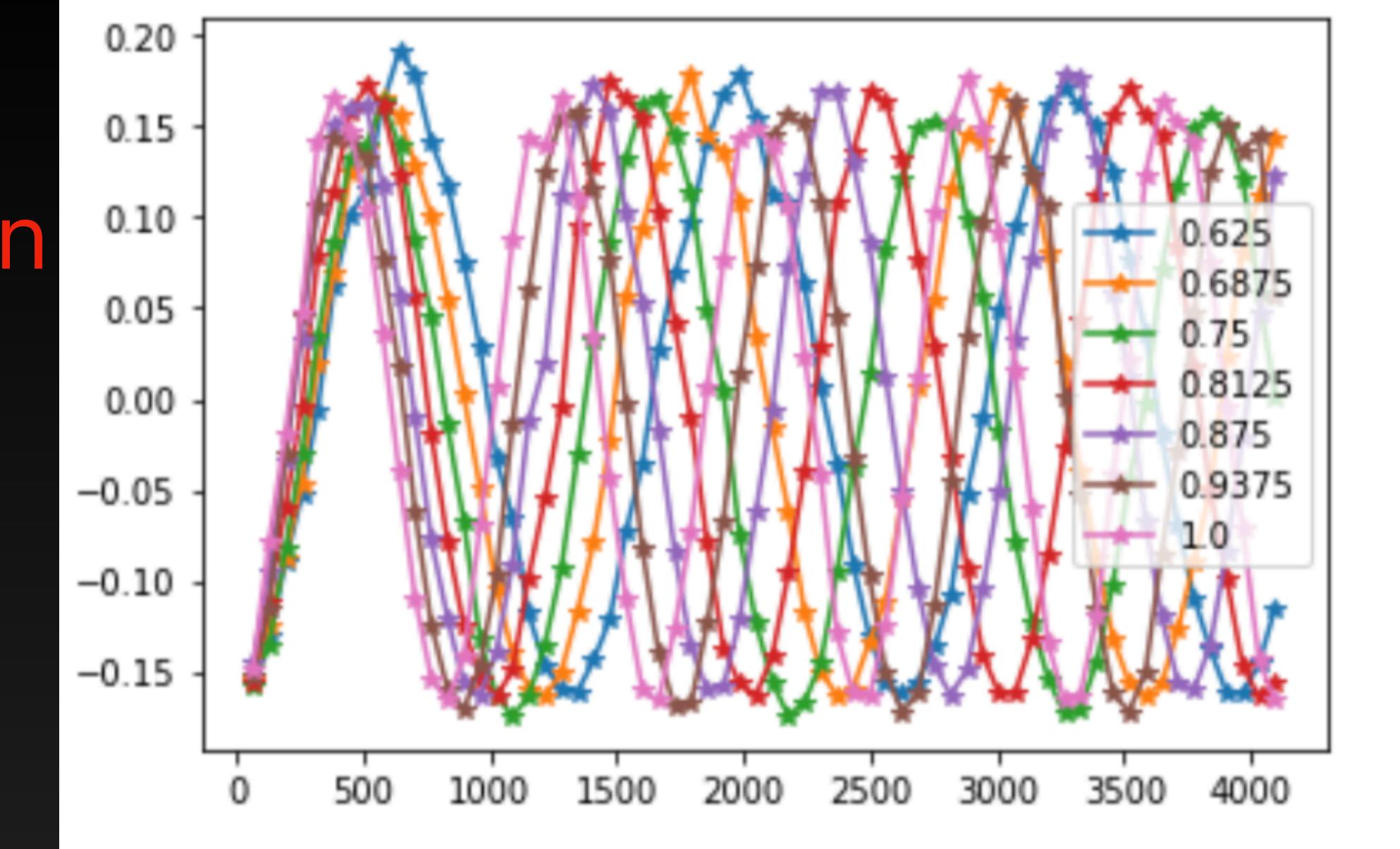
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Work Flow

Check Linearity



Simulation



On real Machine

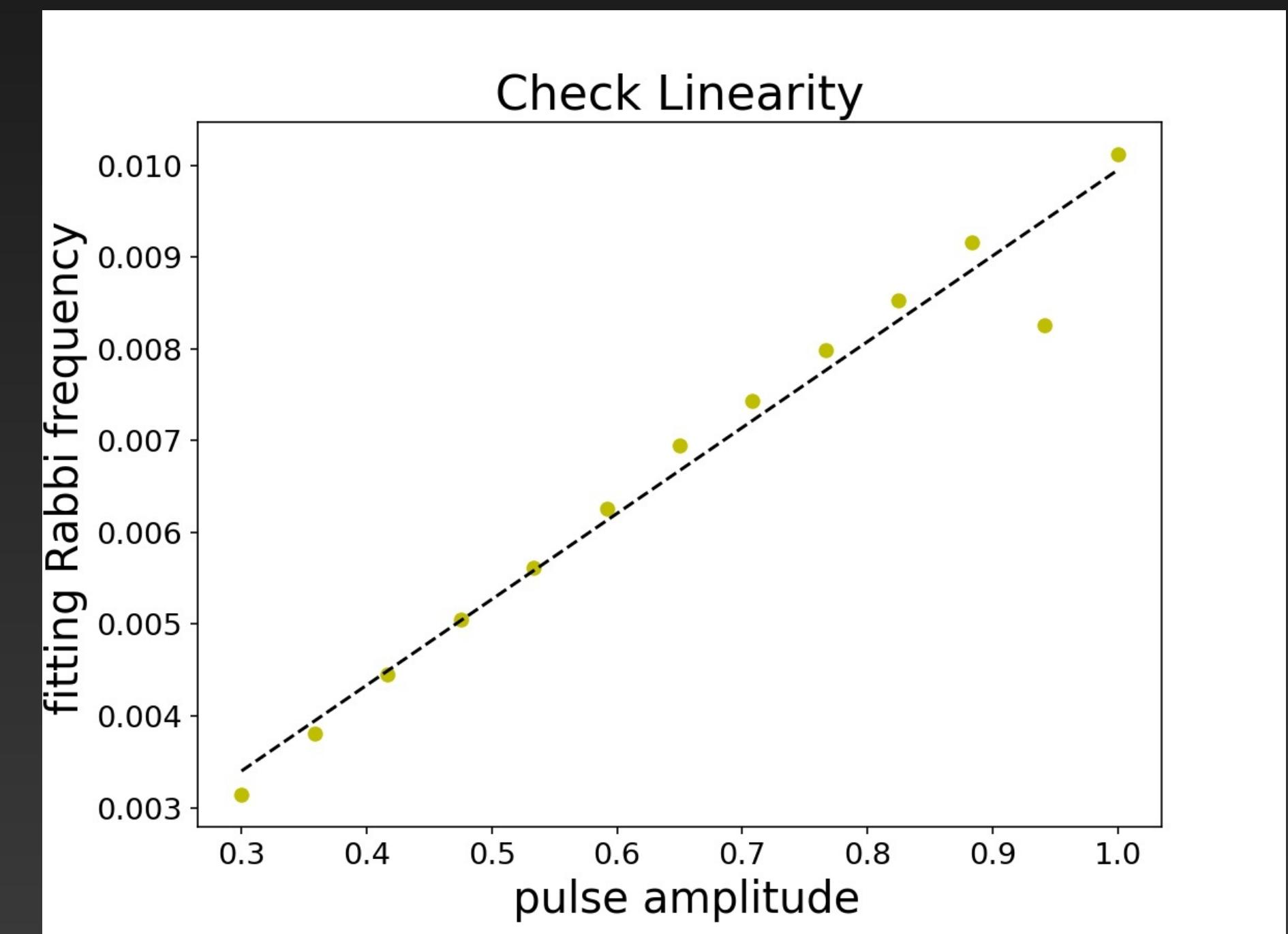
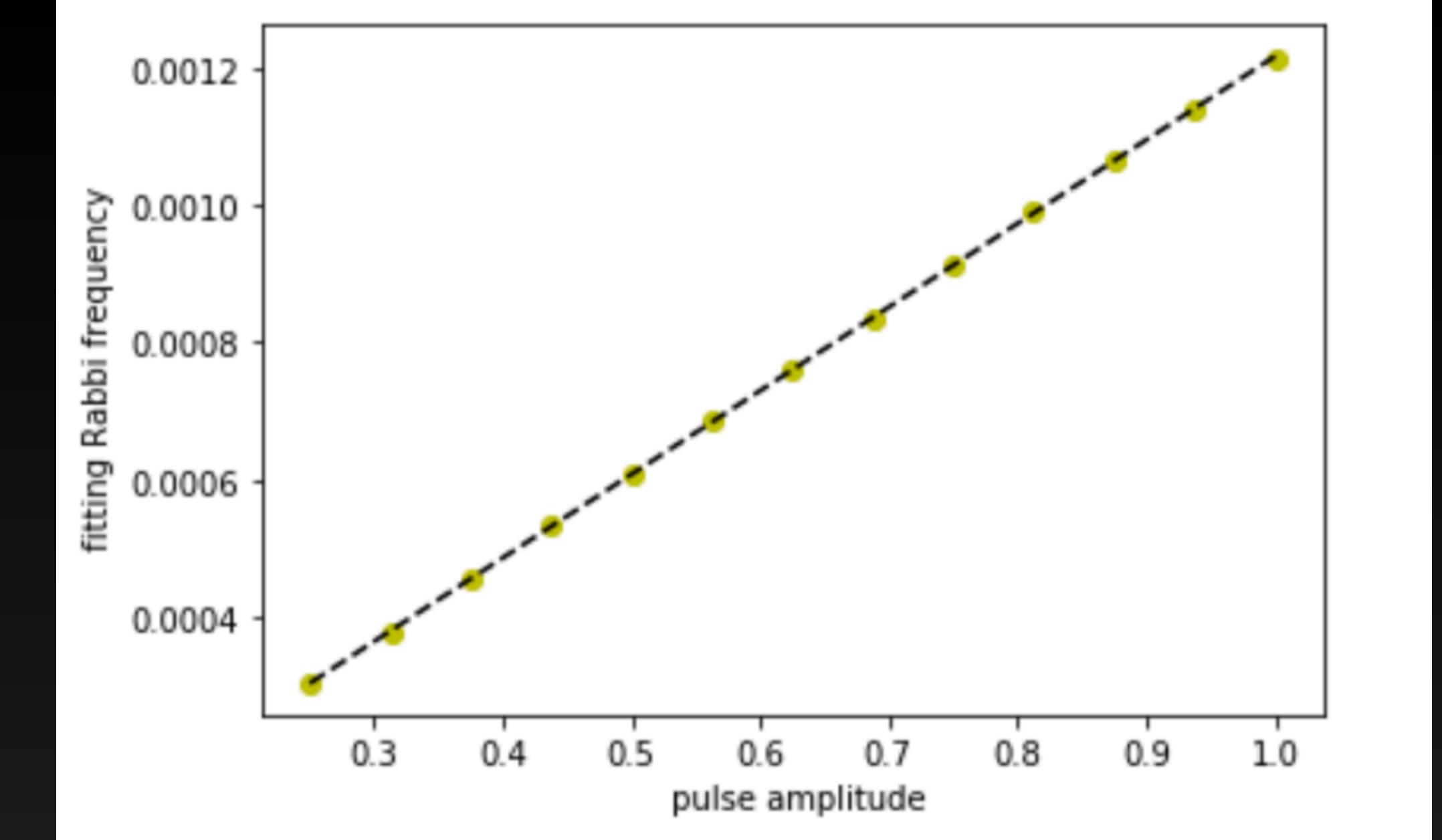
Work Flow

Check Linearity



Simulation

On real Machine

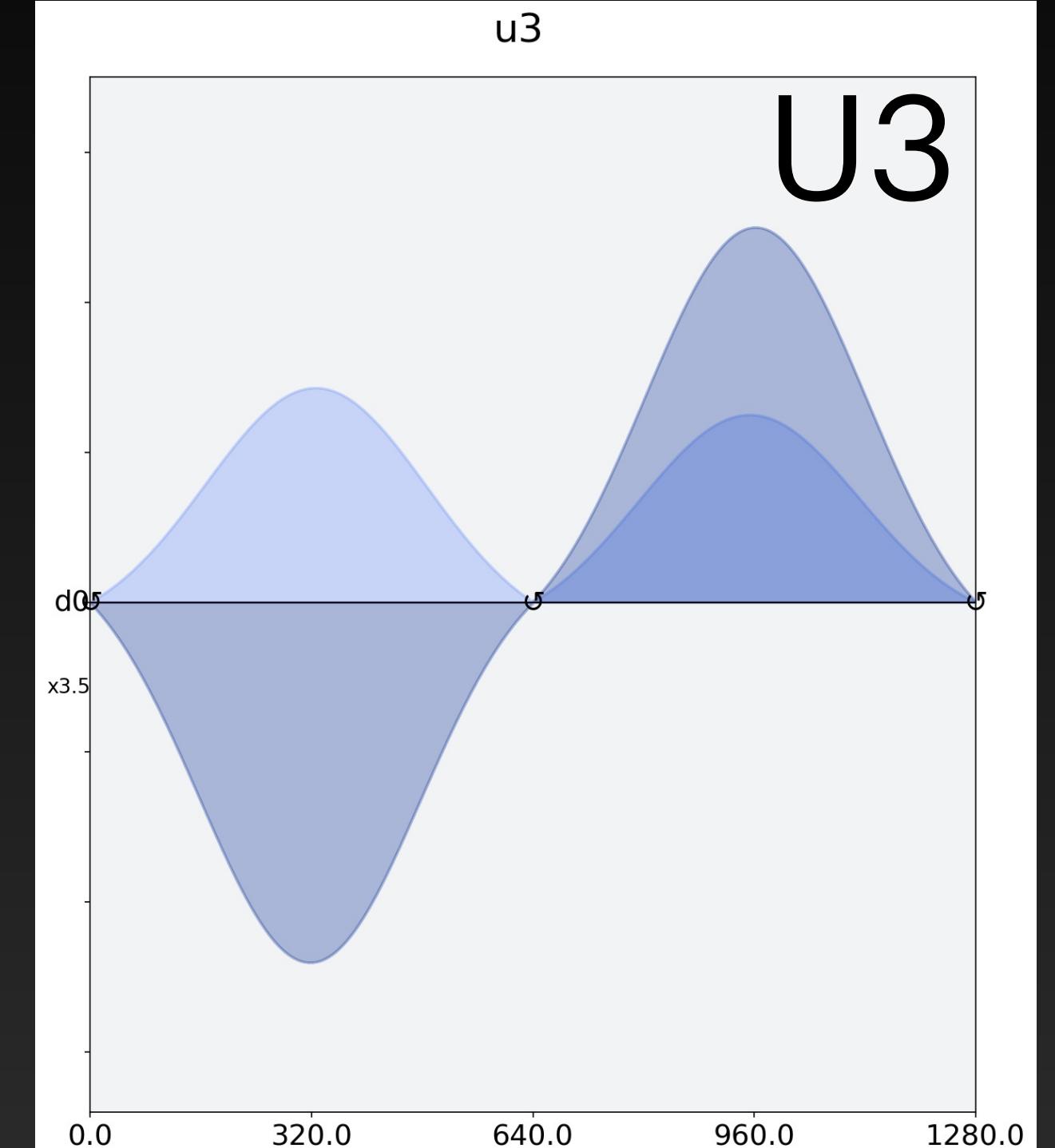
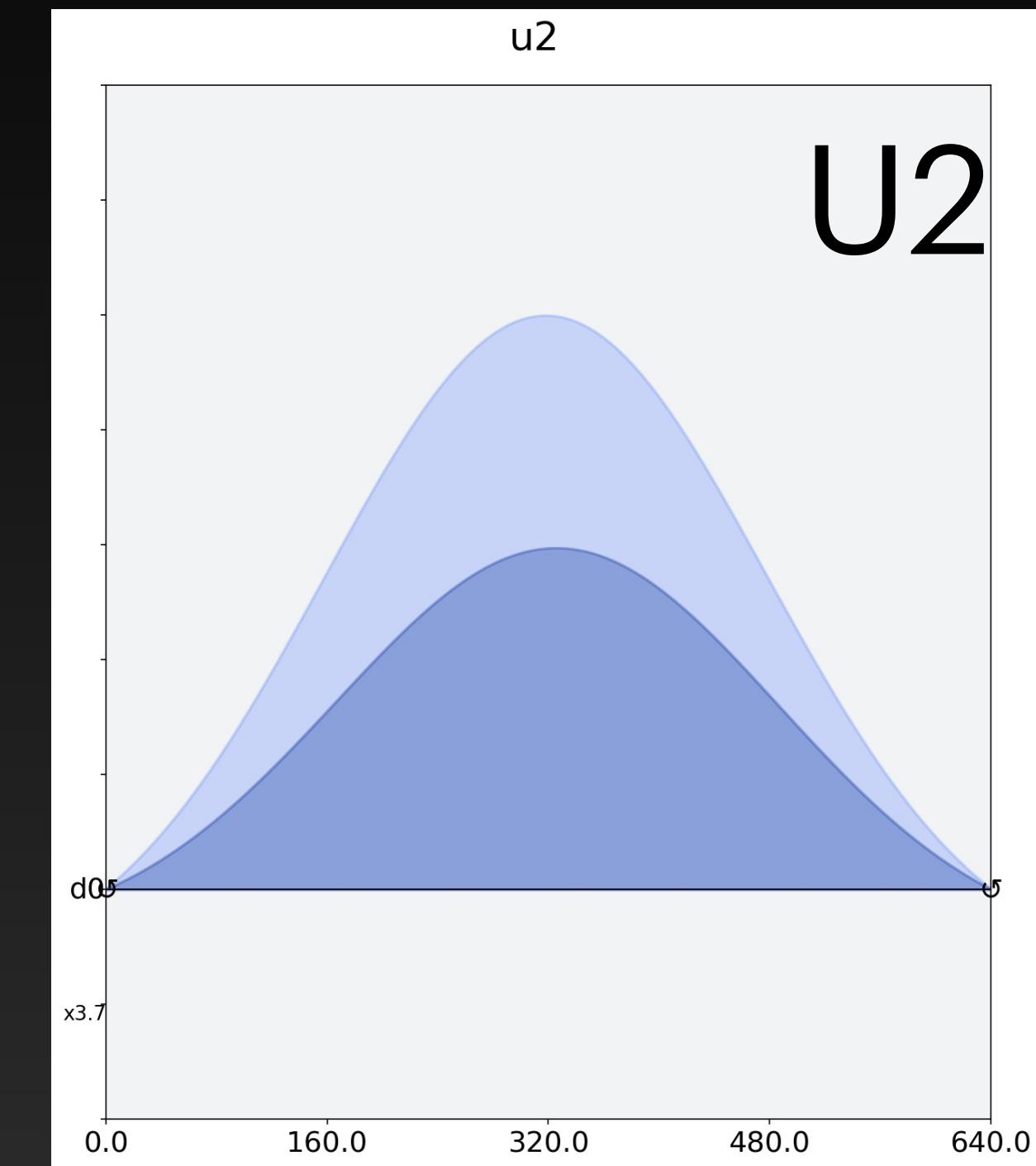


Work Flow

Check Linearity



Modify Backend

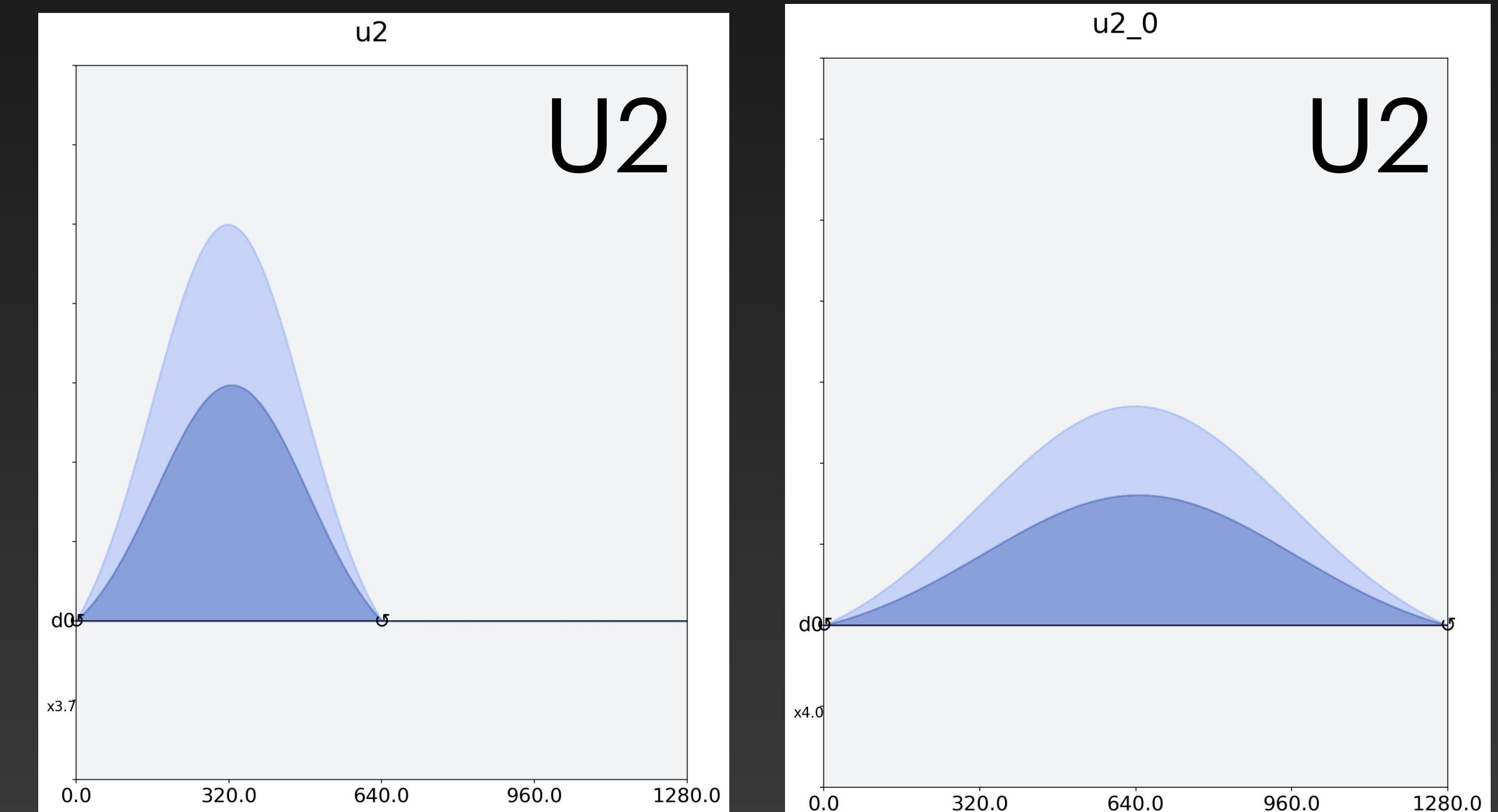
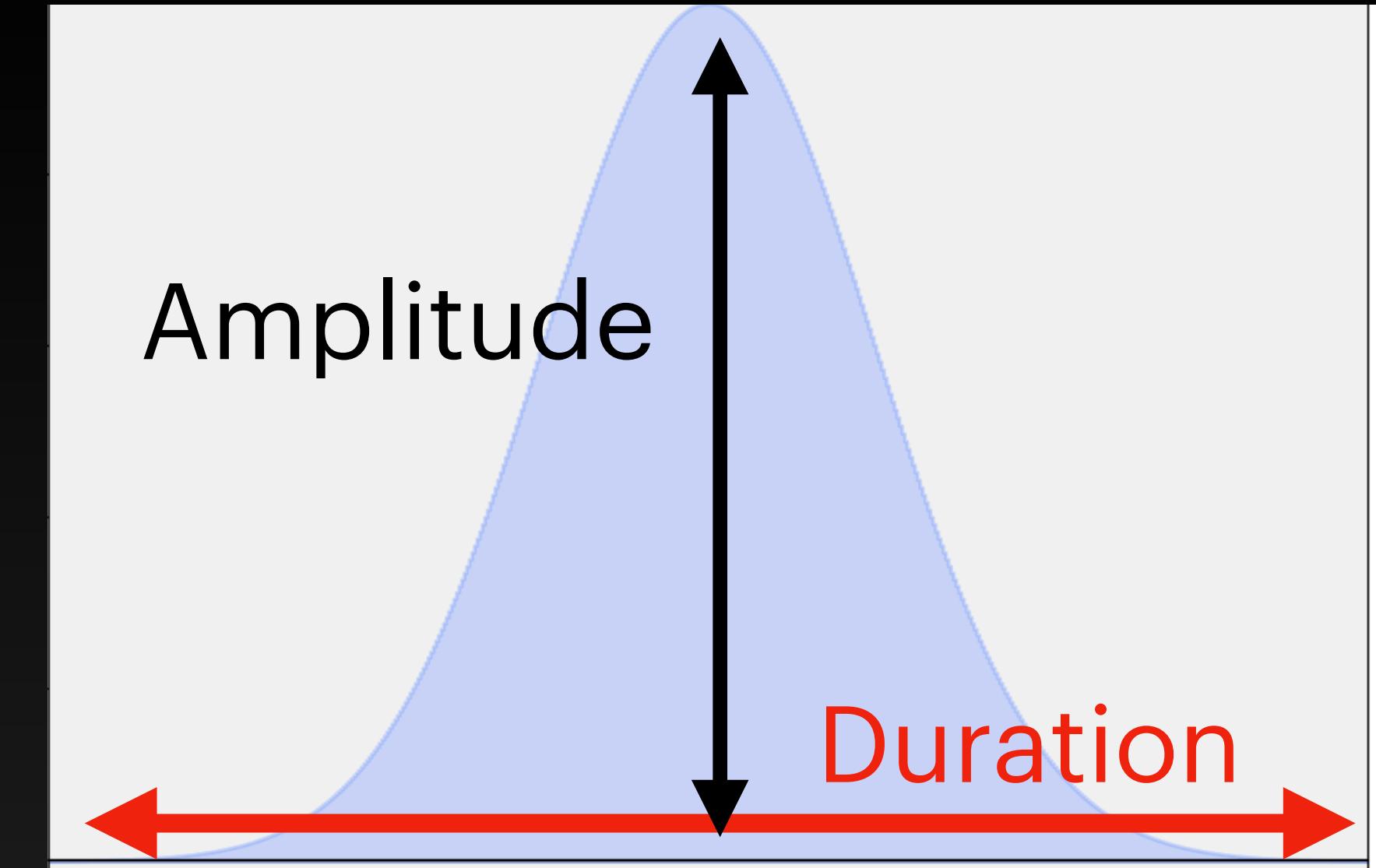


Work Flow

Check Linearity



Modify Backend



Work Flow

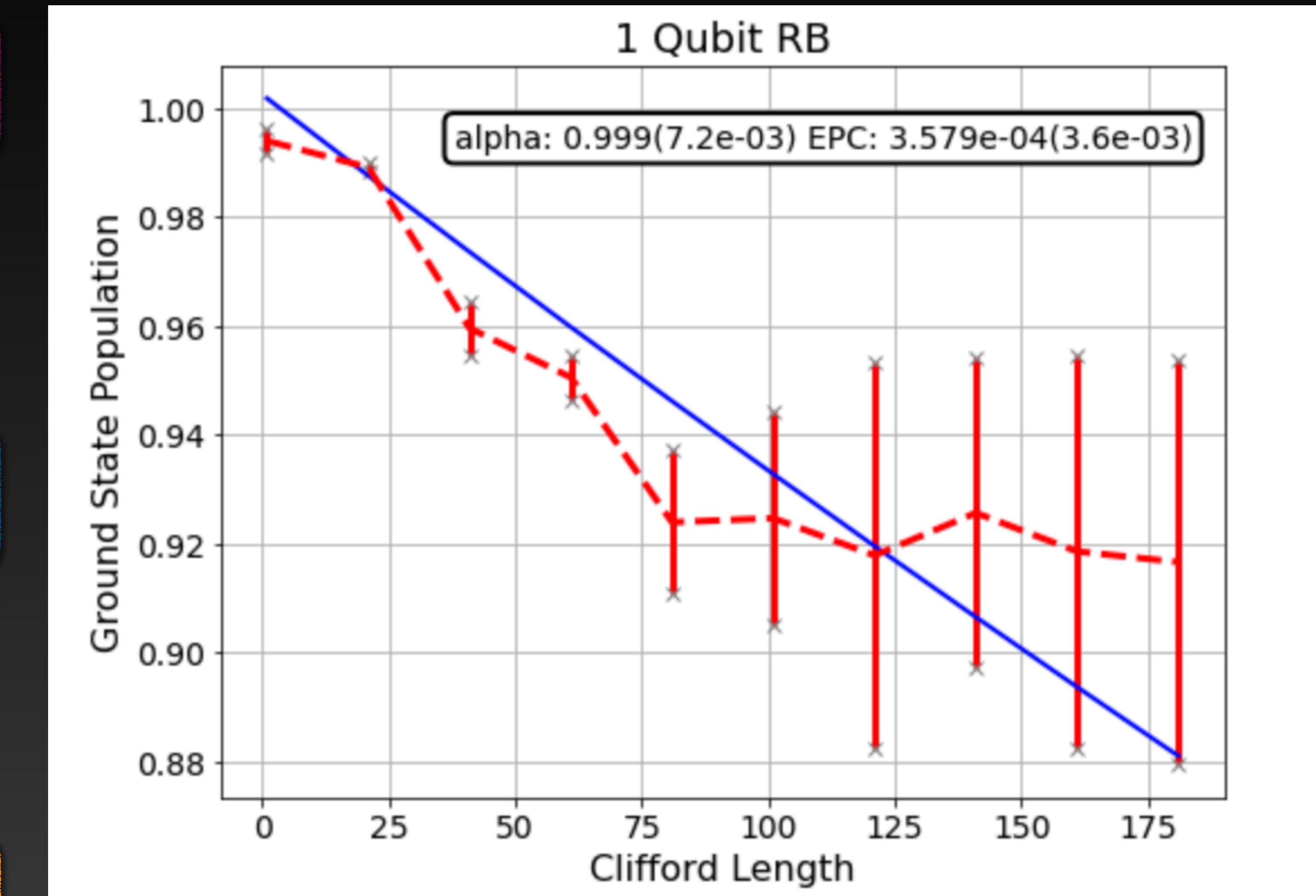
Check Linearity



Modify Backend

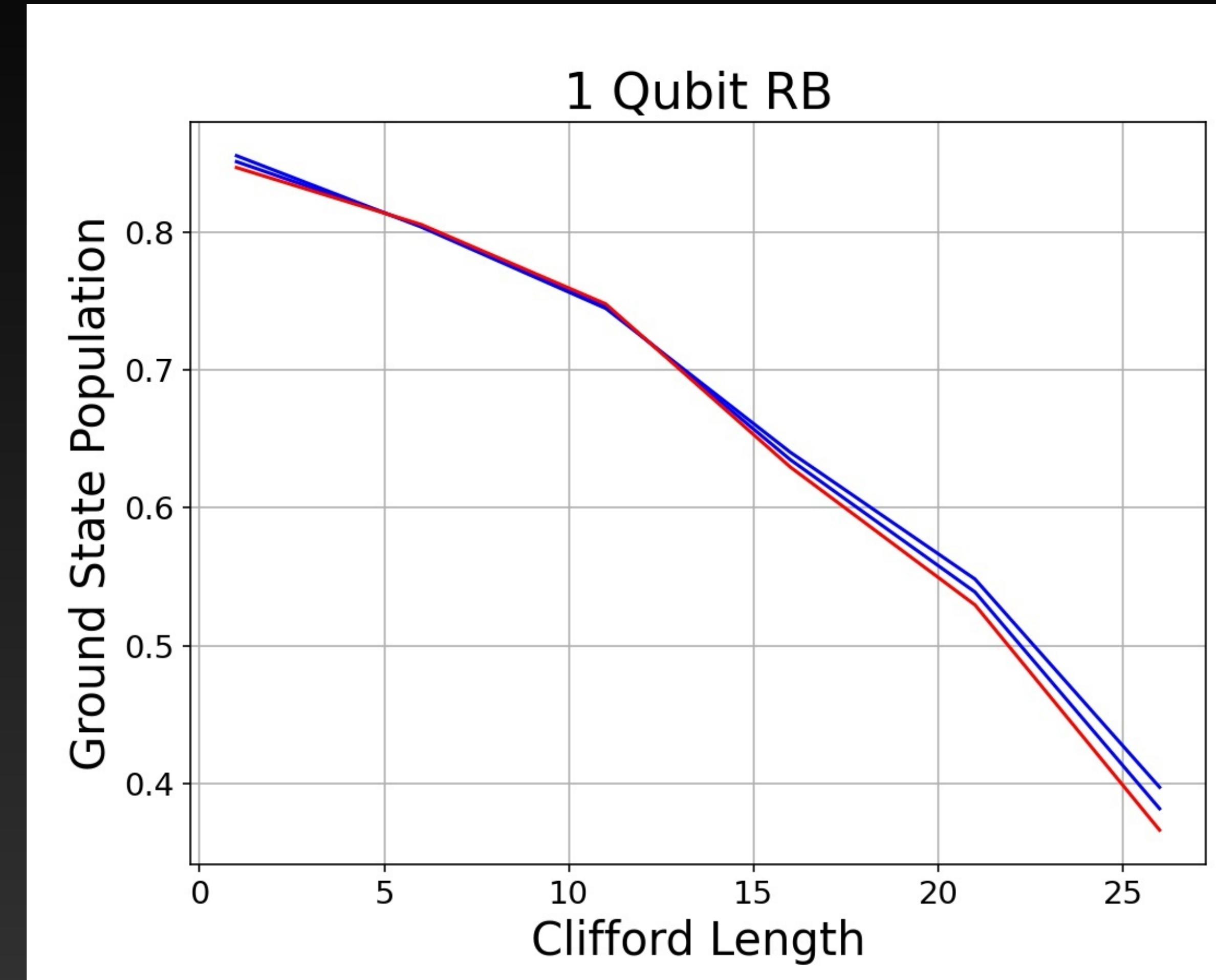


Randomized
Benchmarking



Results

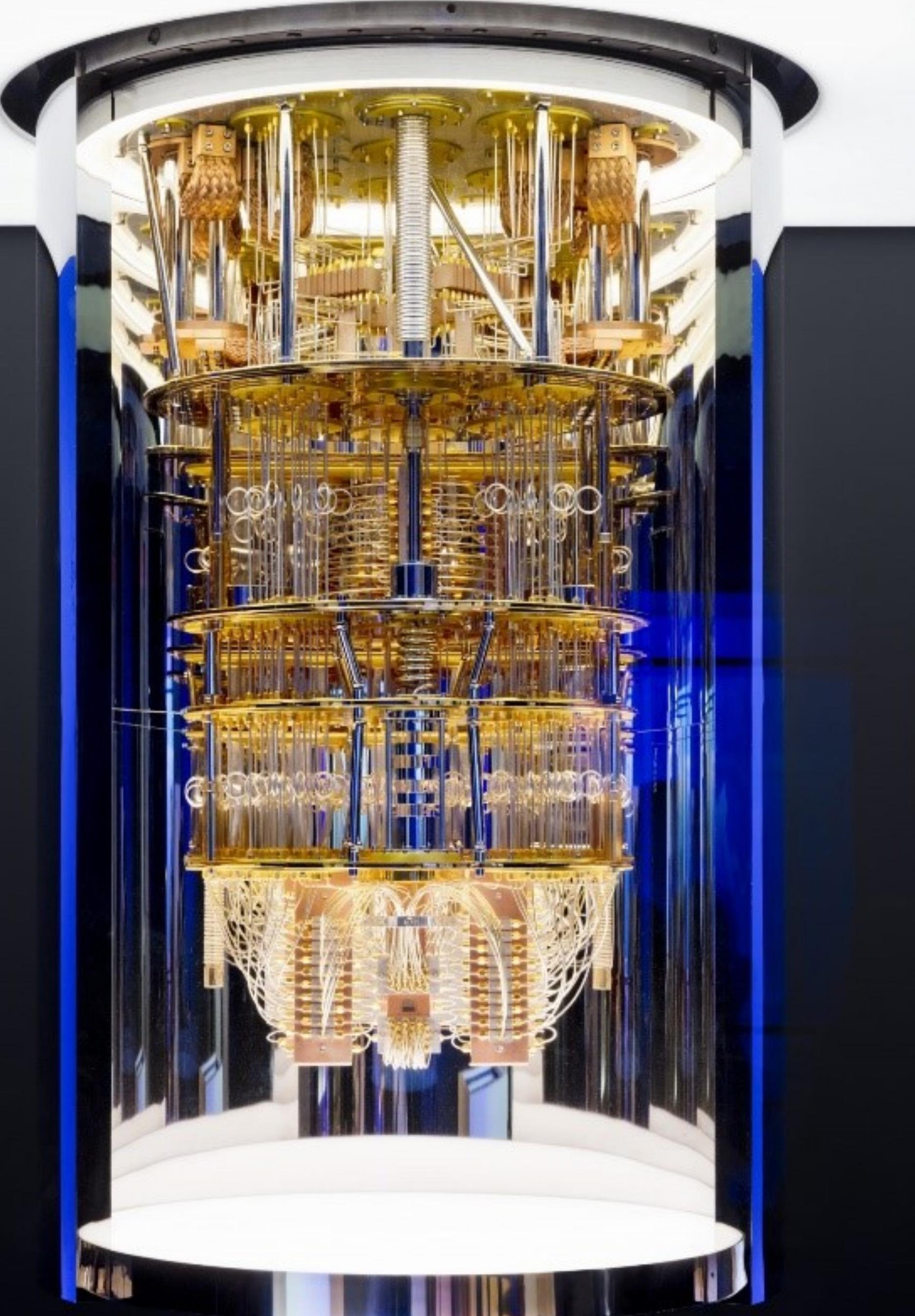
Usually up to ~200 Clifford length to measure single qubit gate fidelity owing to small error



— C1

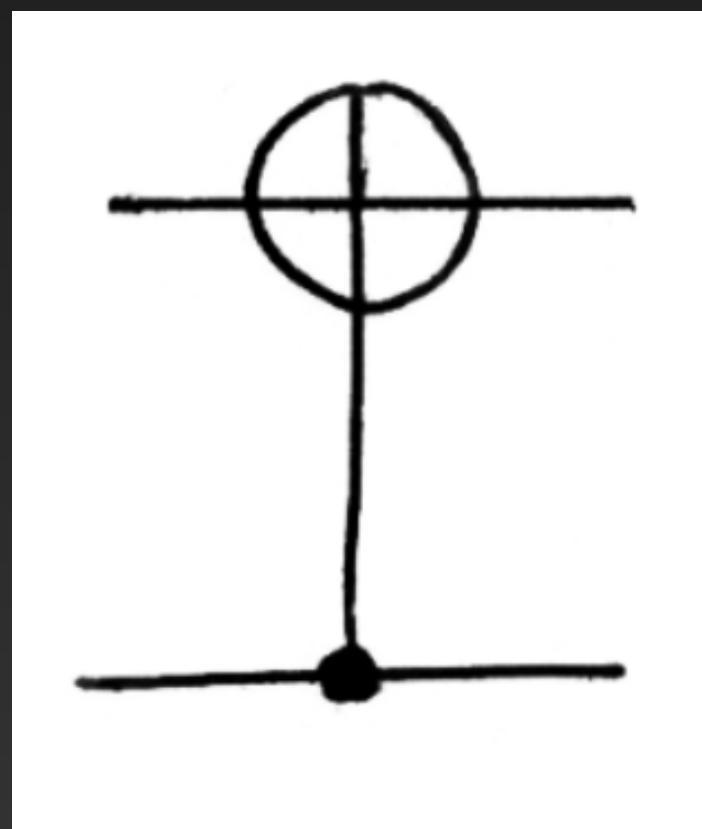
— C2

— extrapolation



Future Work

- Modify Two-qubit gate
(e.g CNOT)



Thank you for your
attention

Backup

Error bounds on the noise-free estimator

Let us now show that the protocol leads to the desired error bound on the estimated expectation value as claimed in the main text. Recall that we first choose a set of $n+1$ rescaling parameters $c_0 = 1 < c_1 < \dots < c_n$, to evolve with respect to the rescaled Hamiltonian $K^j(t)$ for time $T_j = c_j T$. As discussed in the previous section, this evolution leads to a state $\rho_\lambda^j(T_j) = \rho_{c_j \lambda}(T)$, c.f. Eq. (33) as was discussed in section II. If we now measure the observable A on these states we obtain for $j = 0 \dots n+1$ the estimates $\hat{E}_K(c_j \lambda) = E_K(c_j \lambda) + \delta_j$. Recall the set of equations for γ_j defined in [25] and given in the main text, which requires for the $\{c_j\}$ that

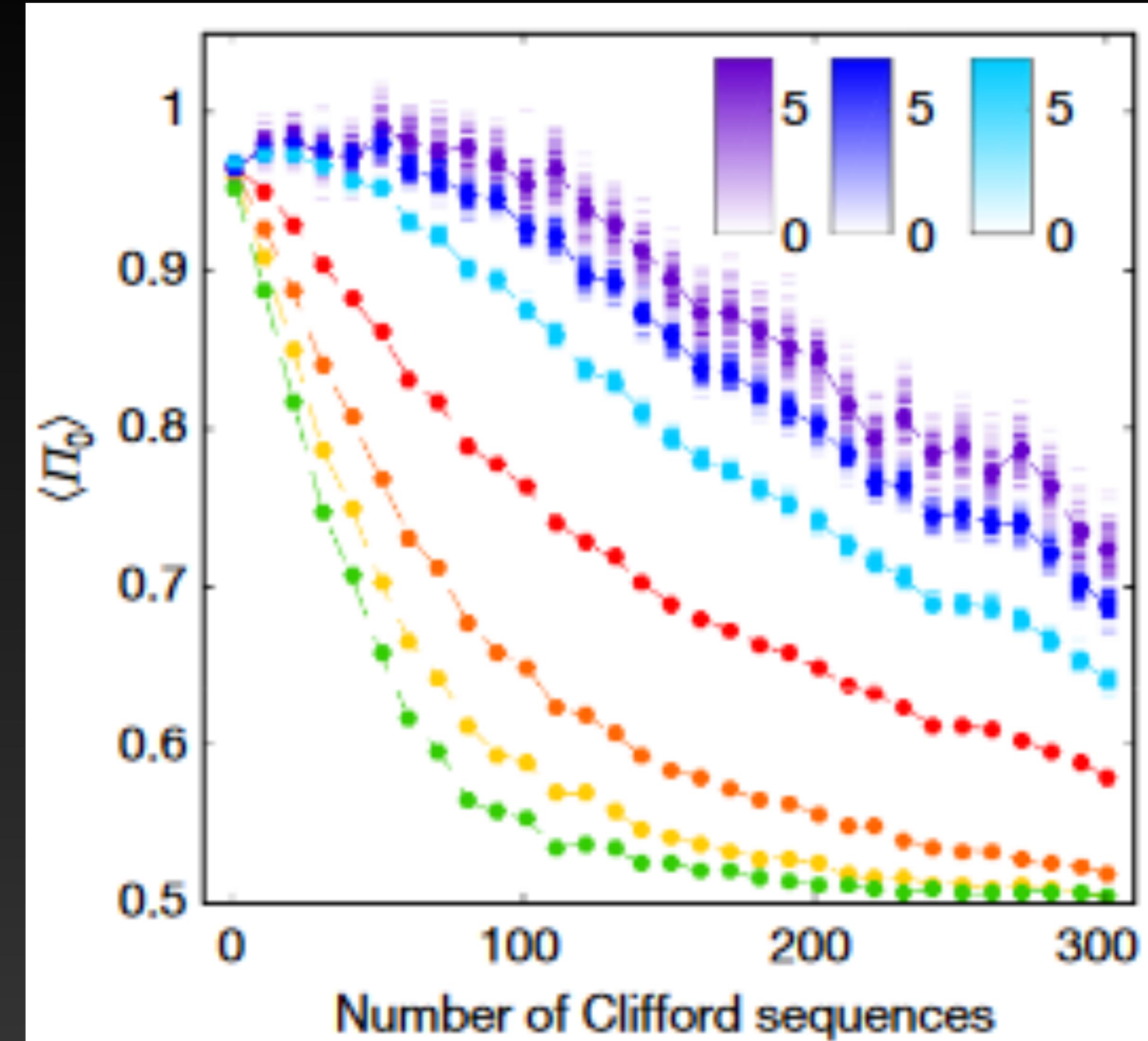
$$\begin{aligned}\sum_{l=0}^n \gamma_l &= 1 \\ \sum_{j=0}^n \gamma_j c_j^k &= 0 \quad \text{for } k = 1 \dots n.\end{aligned}$$

Now we observe that estimators $\hat{E}_K(c_j \lambda)$ can be expressed as

$$\hat{E}_K(c_j \lambda) = E^* + \sum_{k=1}^n a_k c_j^k \lambda^k + R(c_j \lambda, \mathcal{L}, T) + \delta_j$$

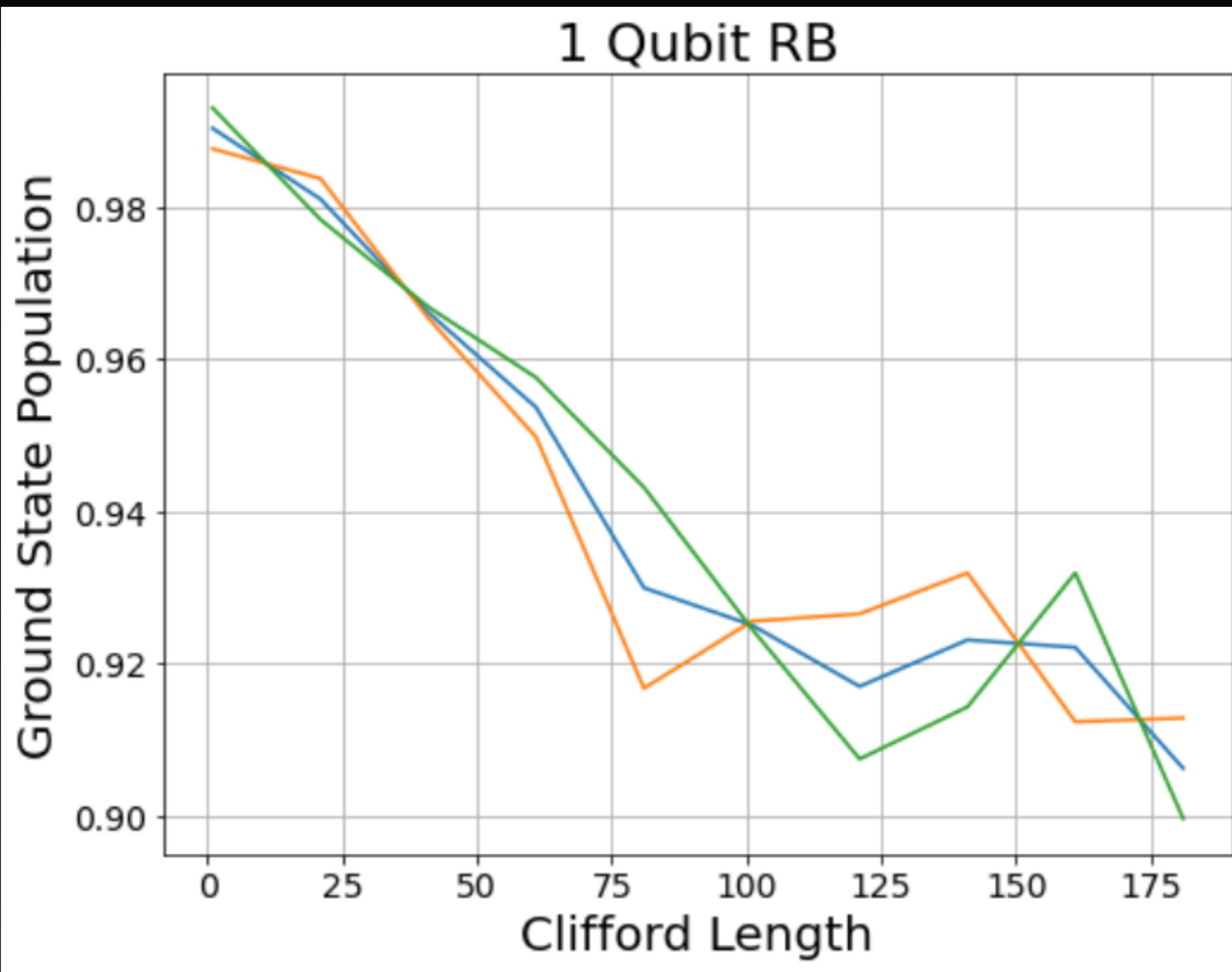
RB w.r.t different c

- C=1
- C=2
- C=3
- C=4
- 1st order extrapolation
- 2nd order extrapolation
- 3rd order extrapolation



Fake Data

- Without changing the stretching constant



—

C1

—

C2

—

extrapolation

Reference

[1] <http://www.nature.com/articles/s41586-019-1040-7>

[2] <http://arxiv.org/abs/2004.11205>

[3] Kristan Temme, Phys. RevL 119, 180509