Generation of stretched single qubit gates for Richardson error extrapolation

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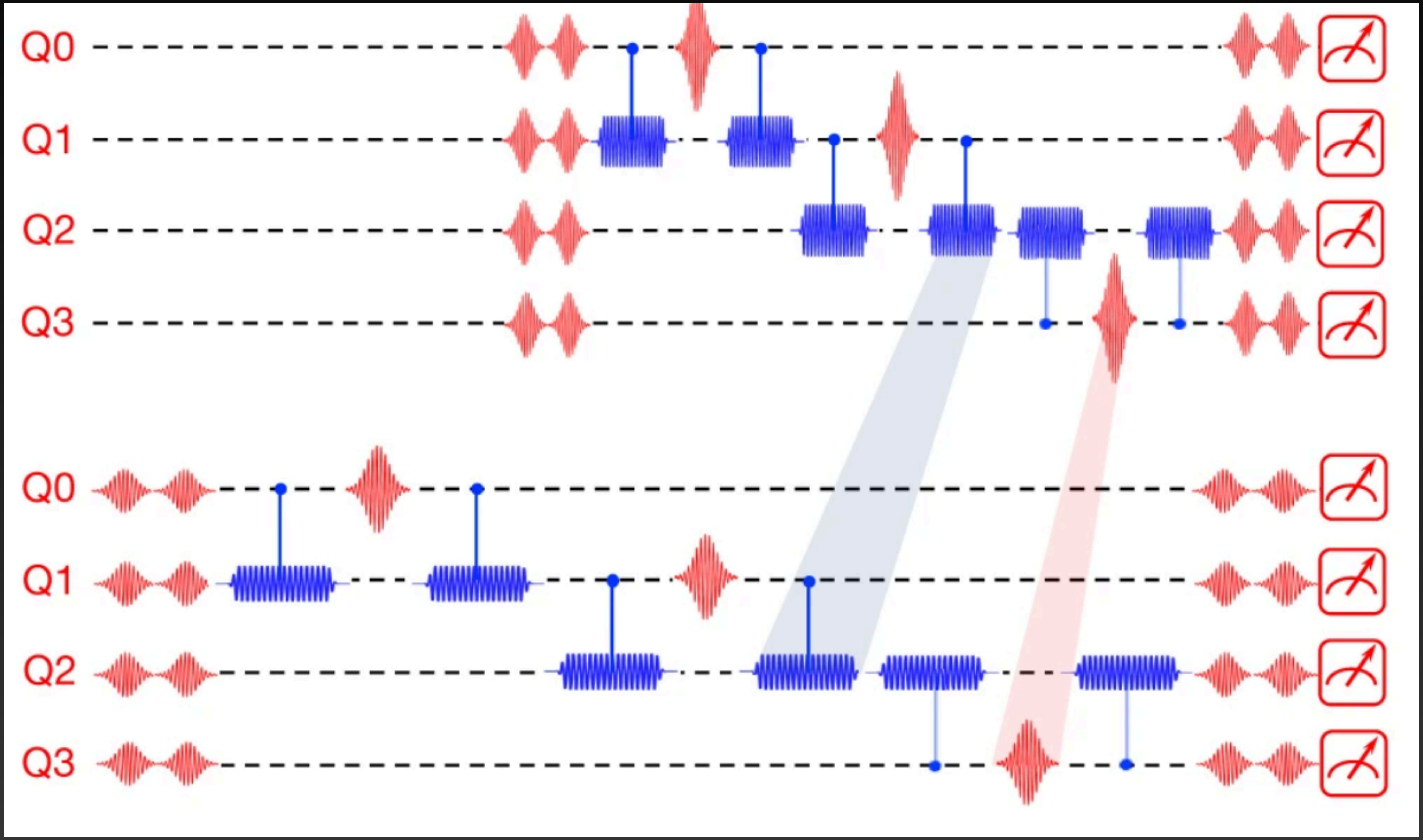
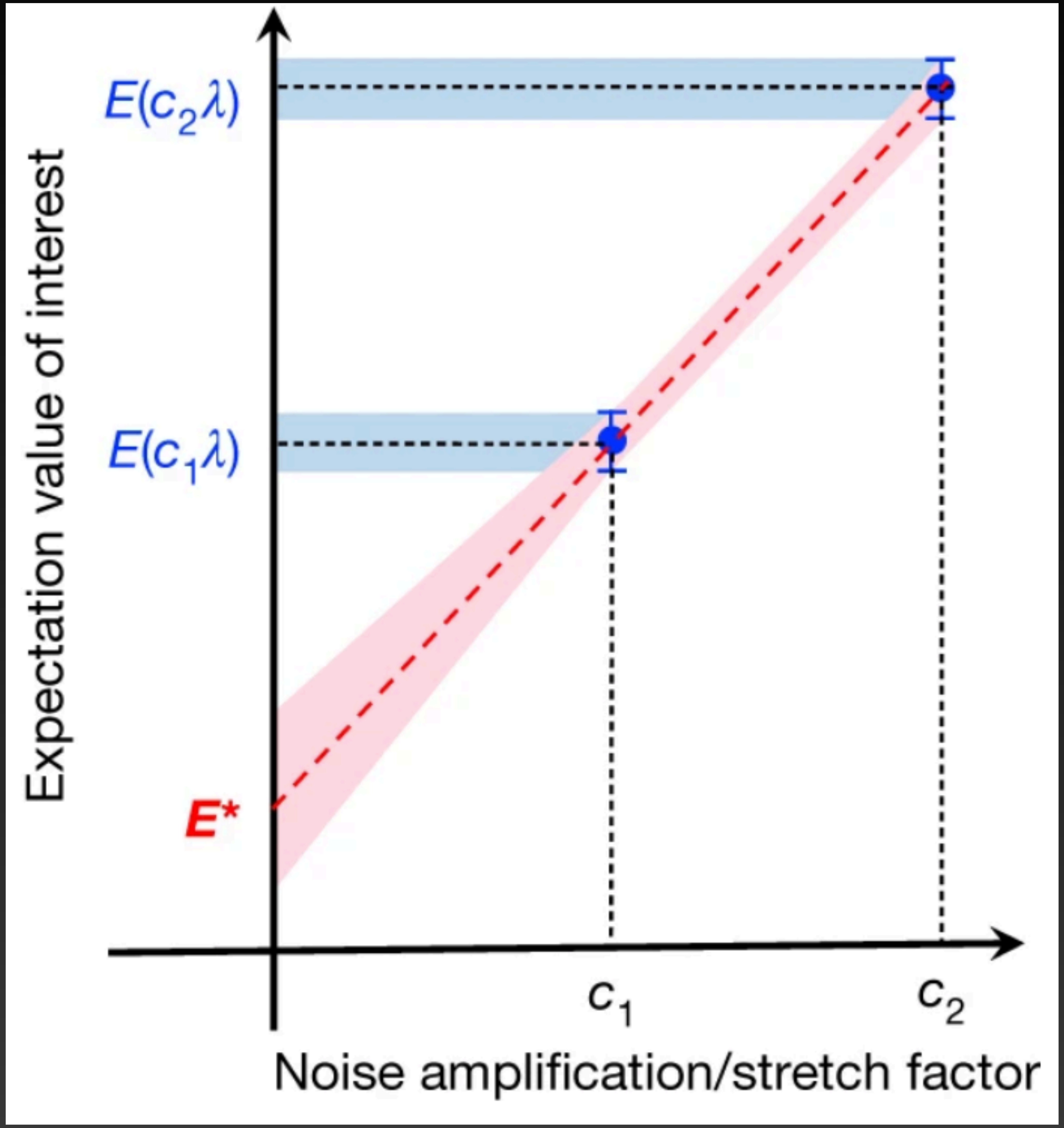
Error Mitigation Method

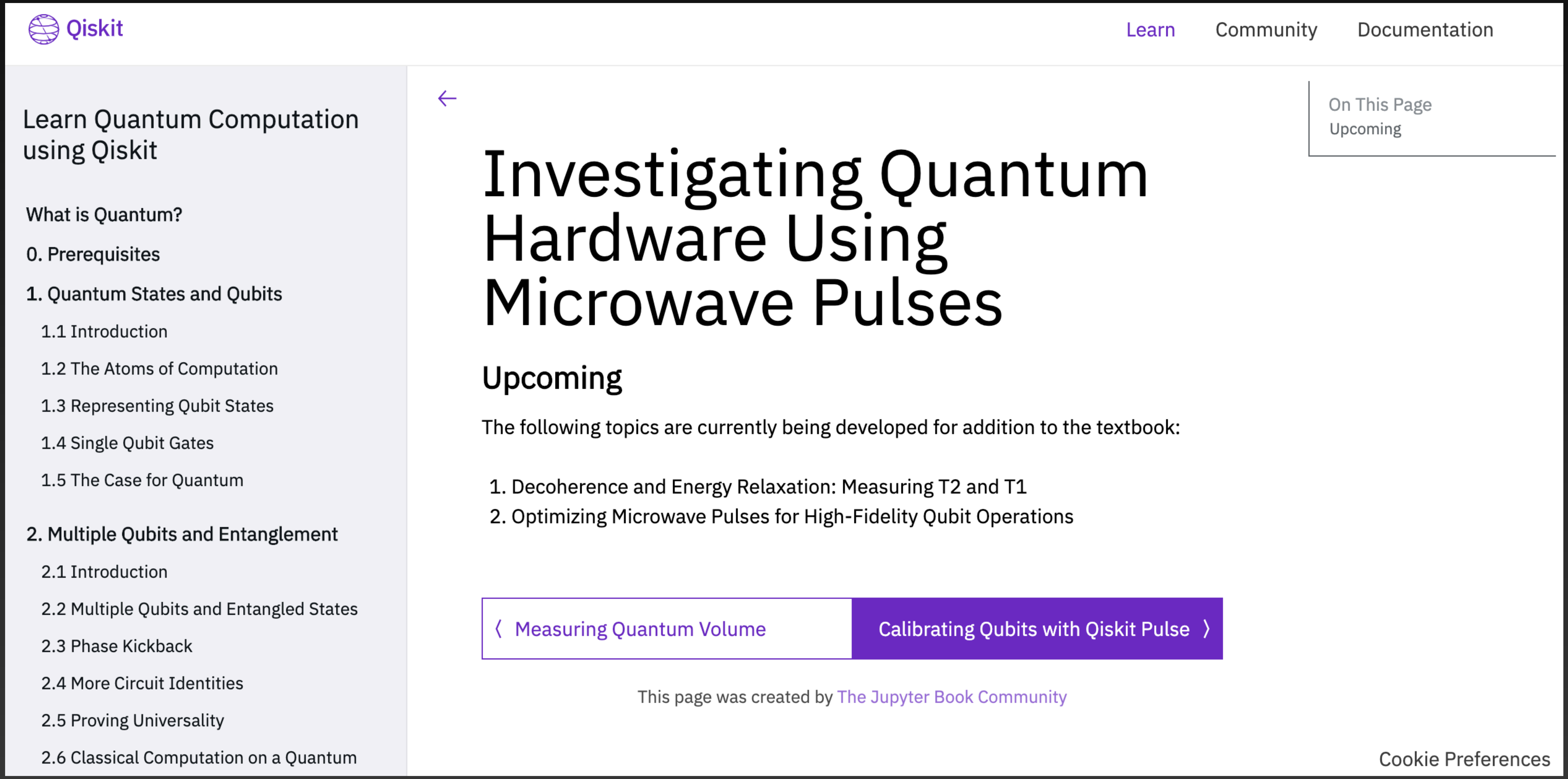


Error Mitigation Method



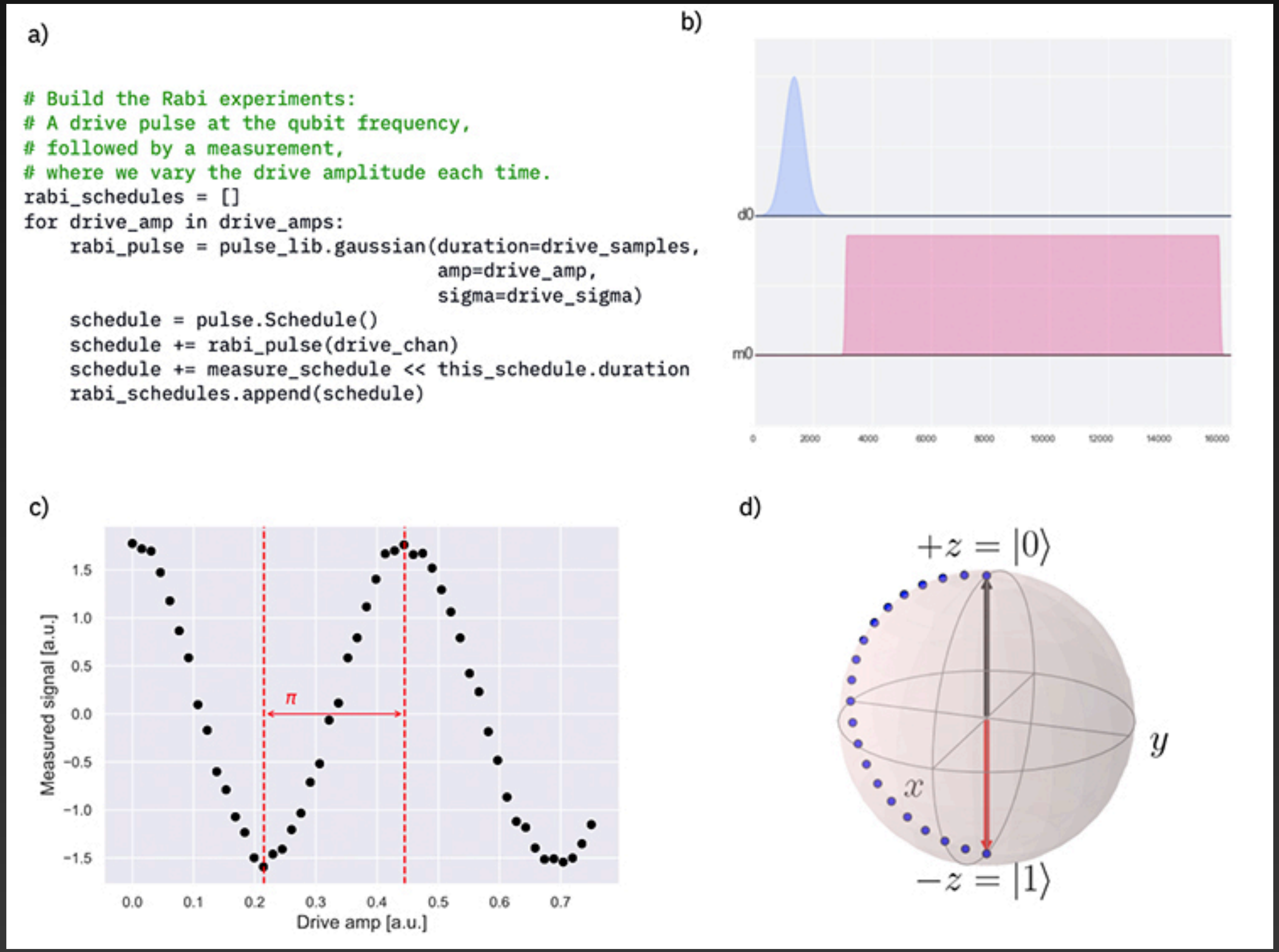
Work Flow

Calibrating Qubits with Qiskit Pulse

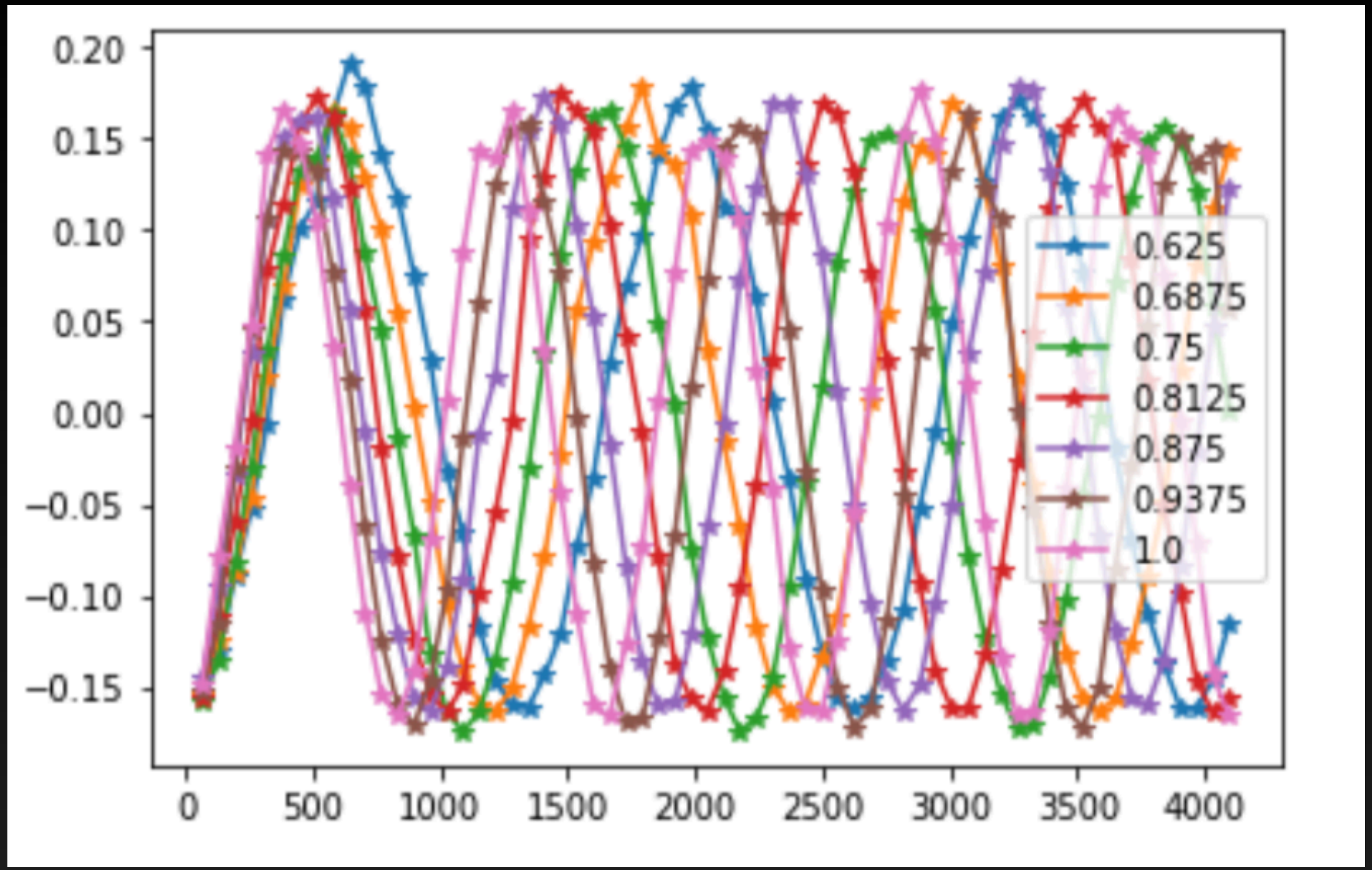


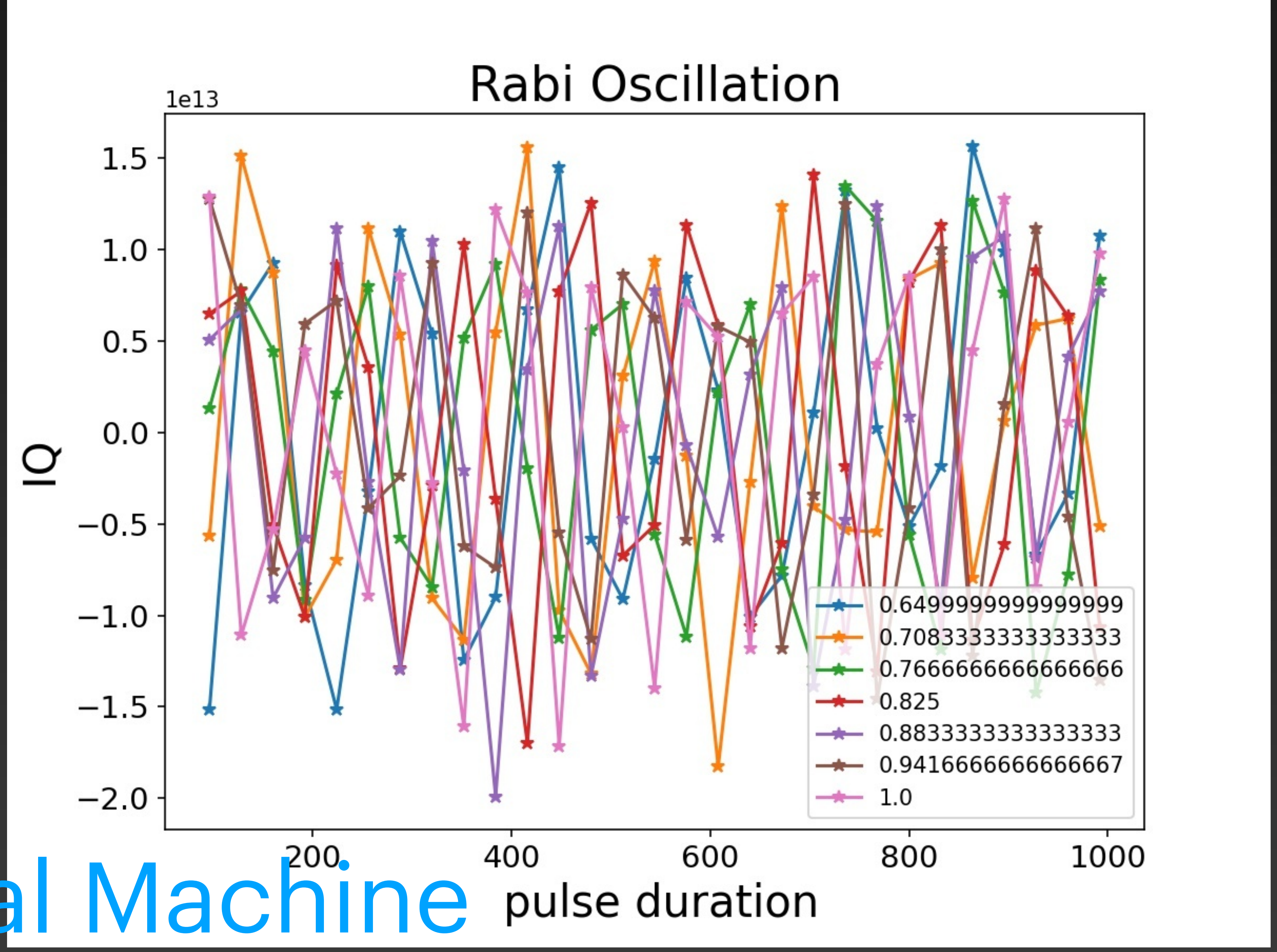
Work Flow

Check Linearity



Simulation



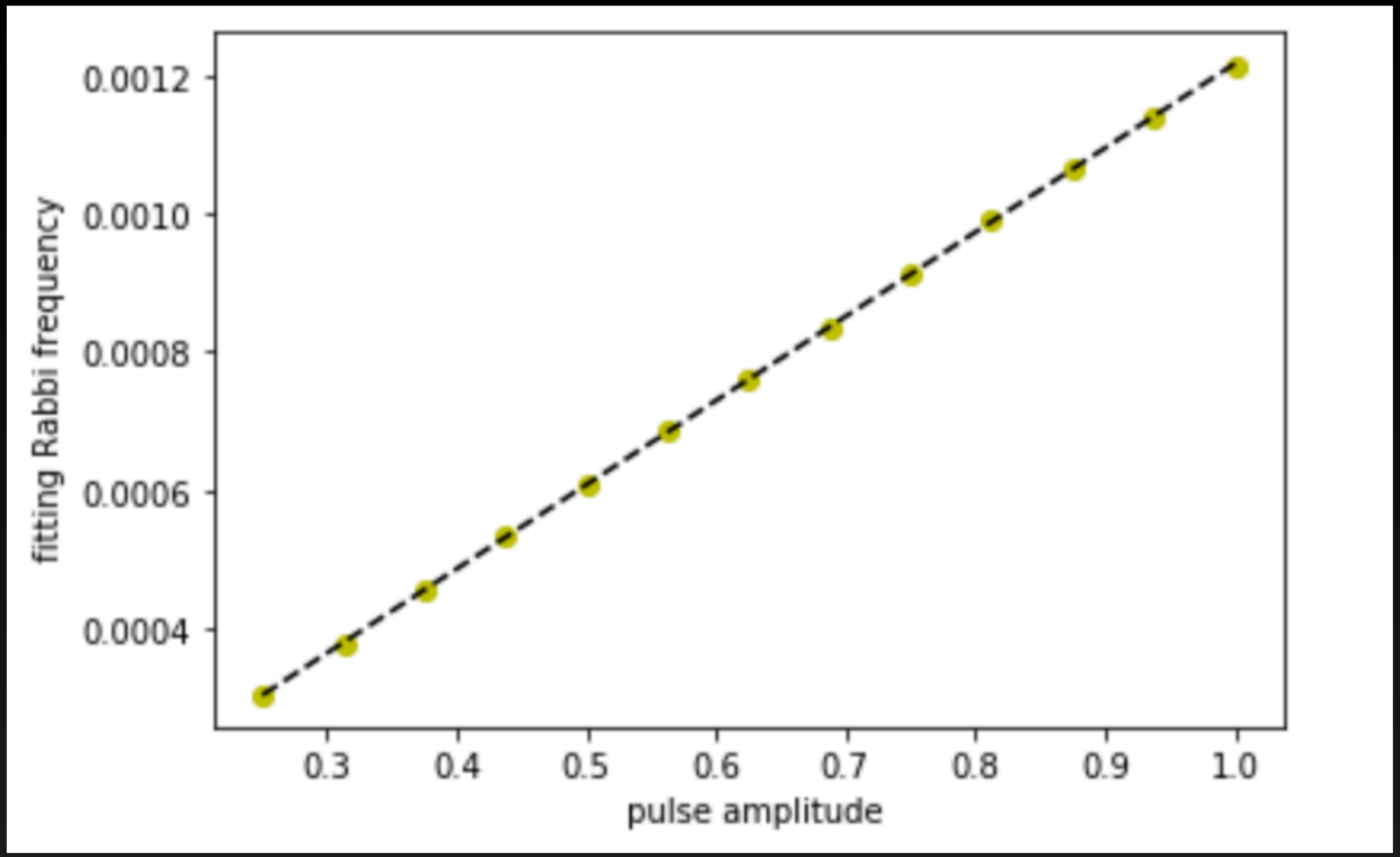


On real Machine

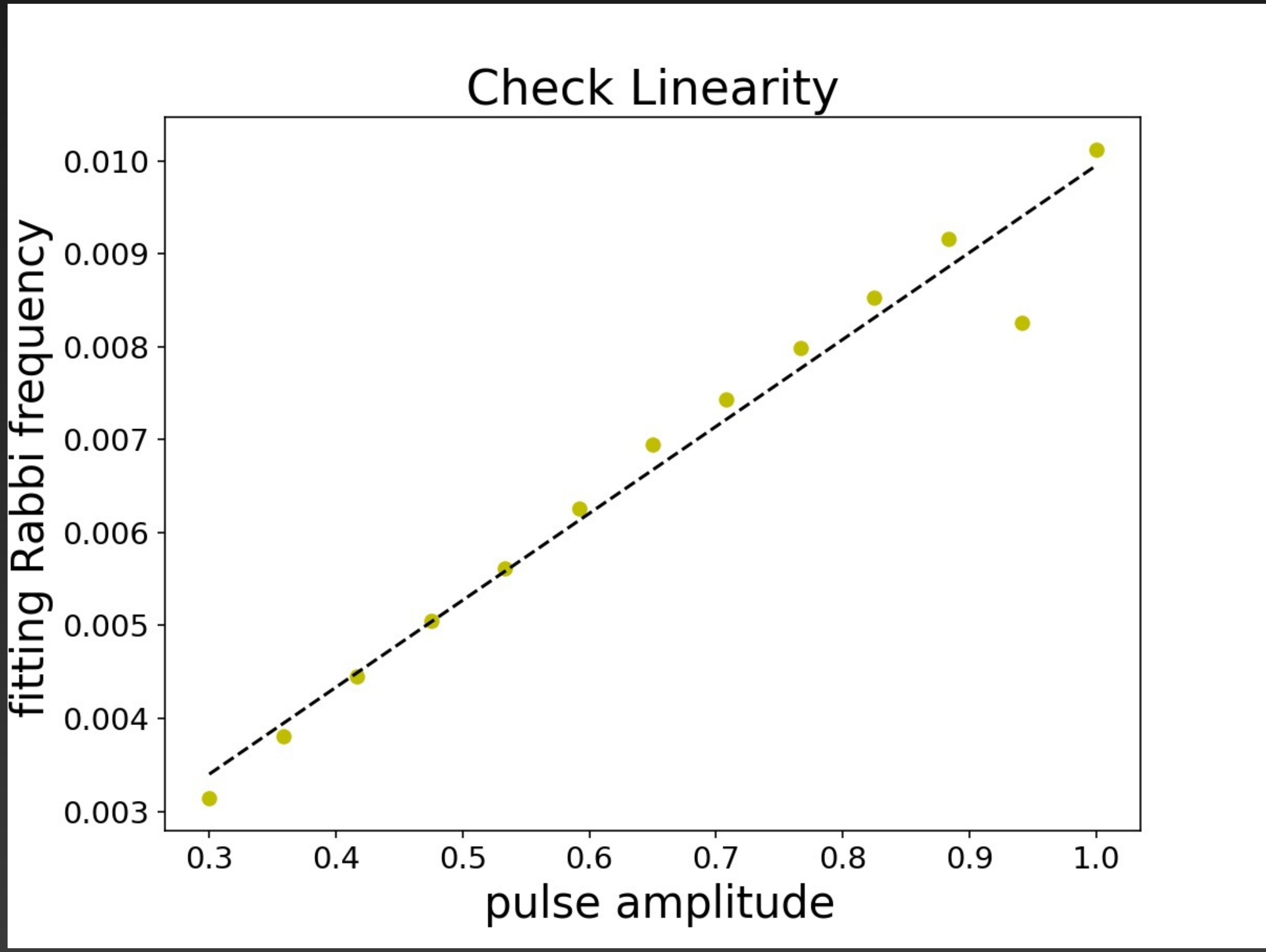
Work Flow

Check Linearity

Simulation



On real Machine

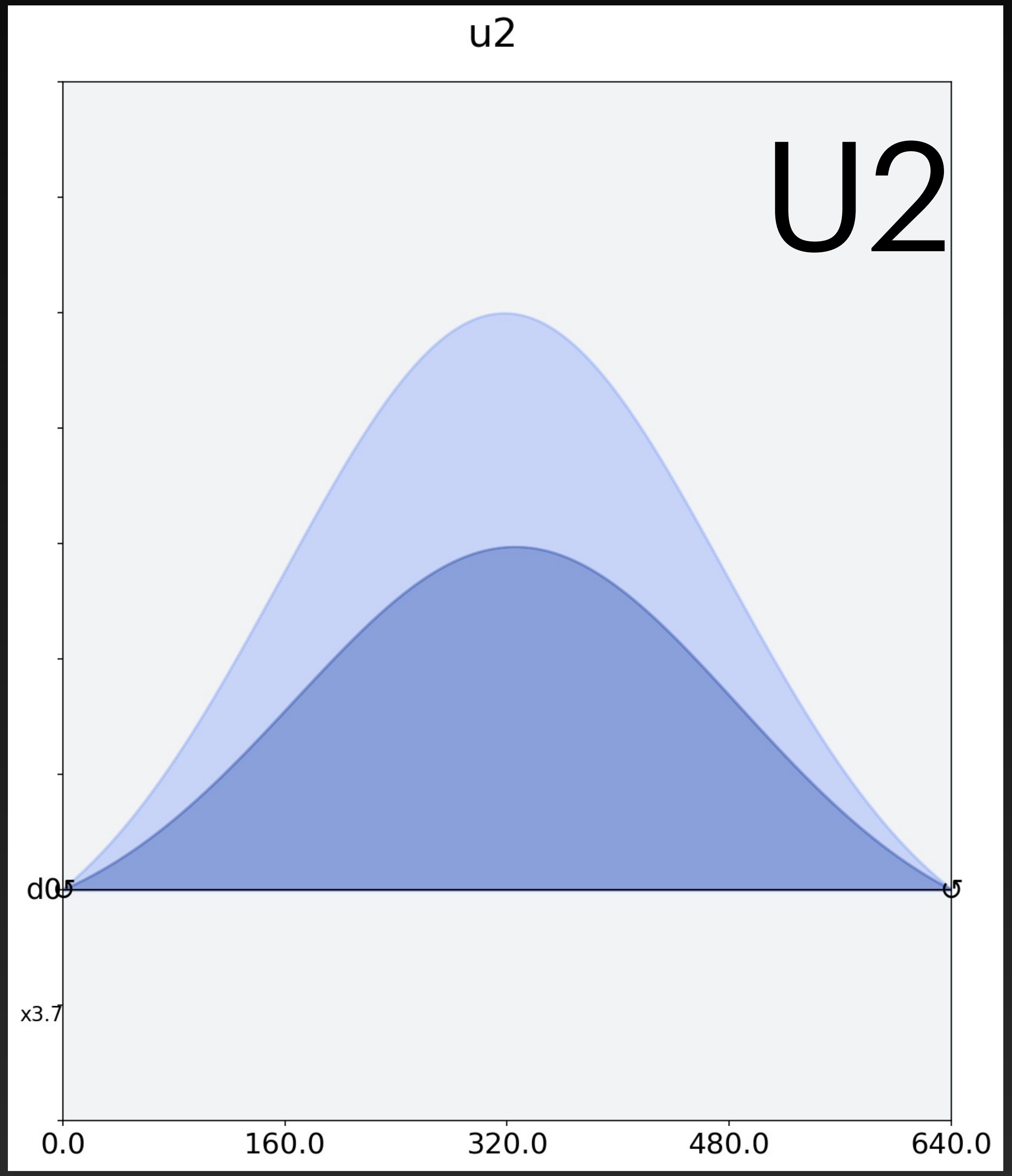


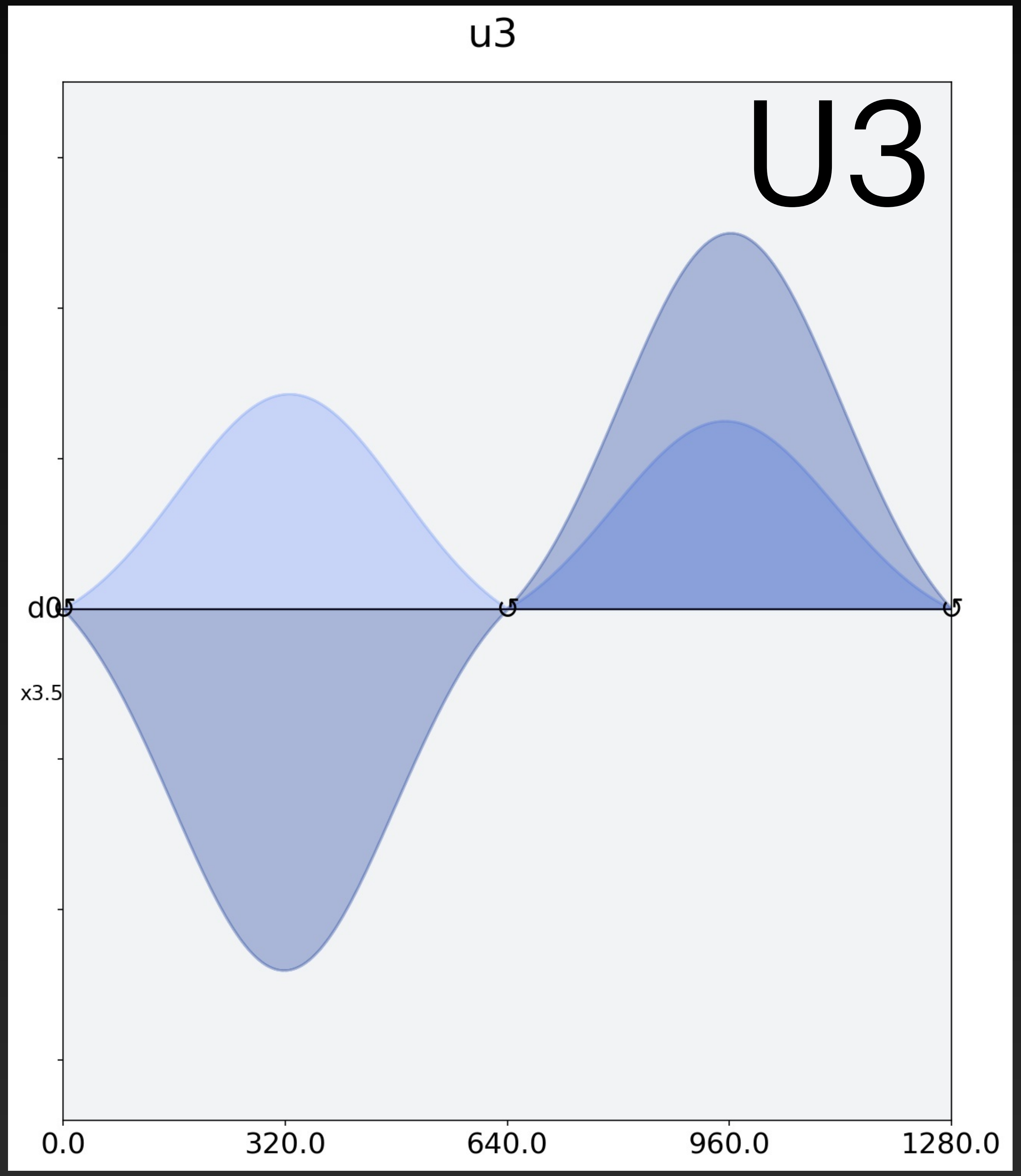
Work Flow

Check Linearity

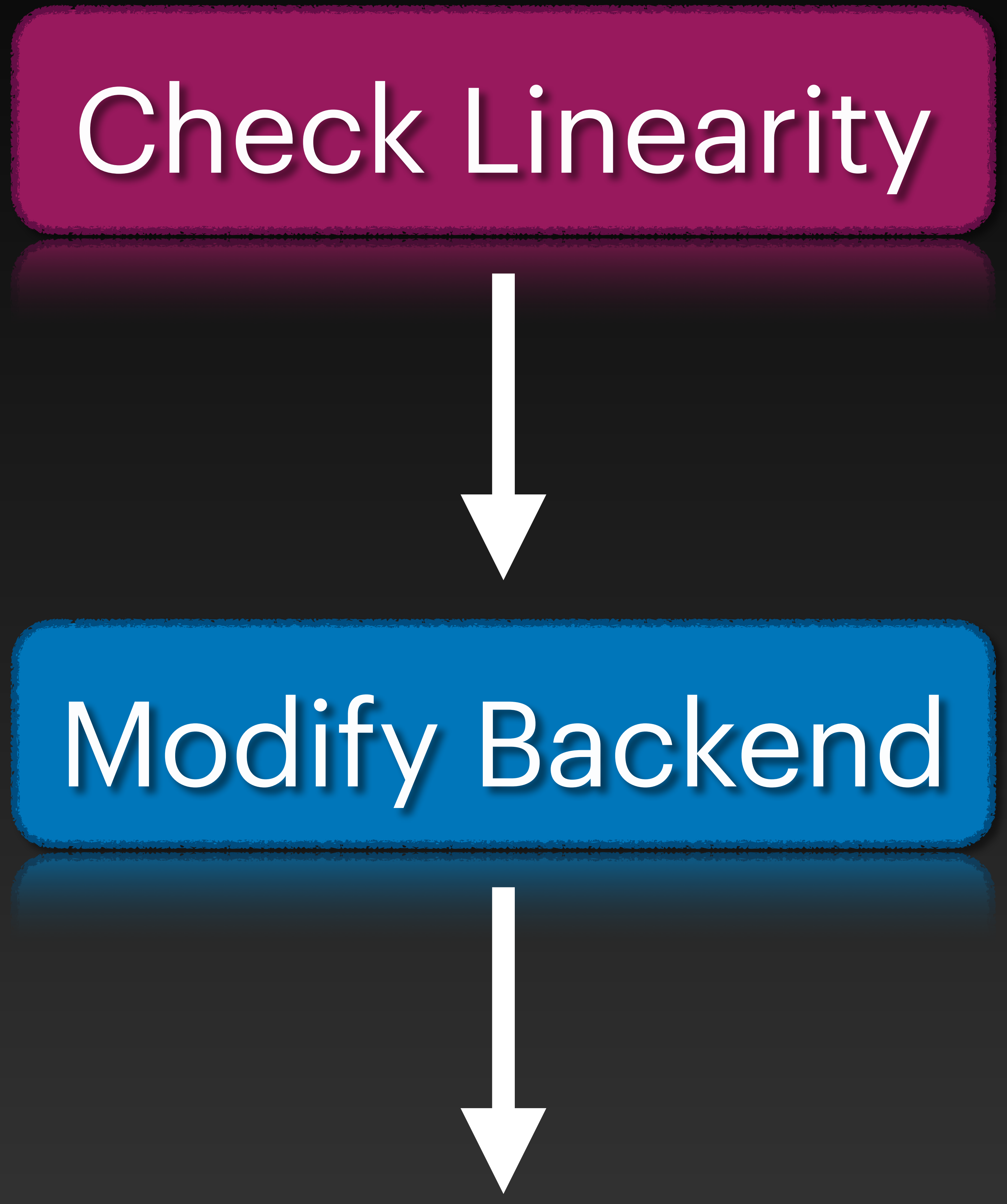
↓

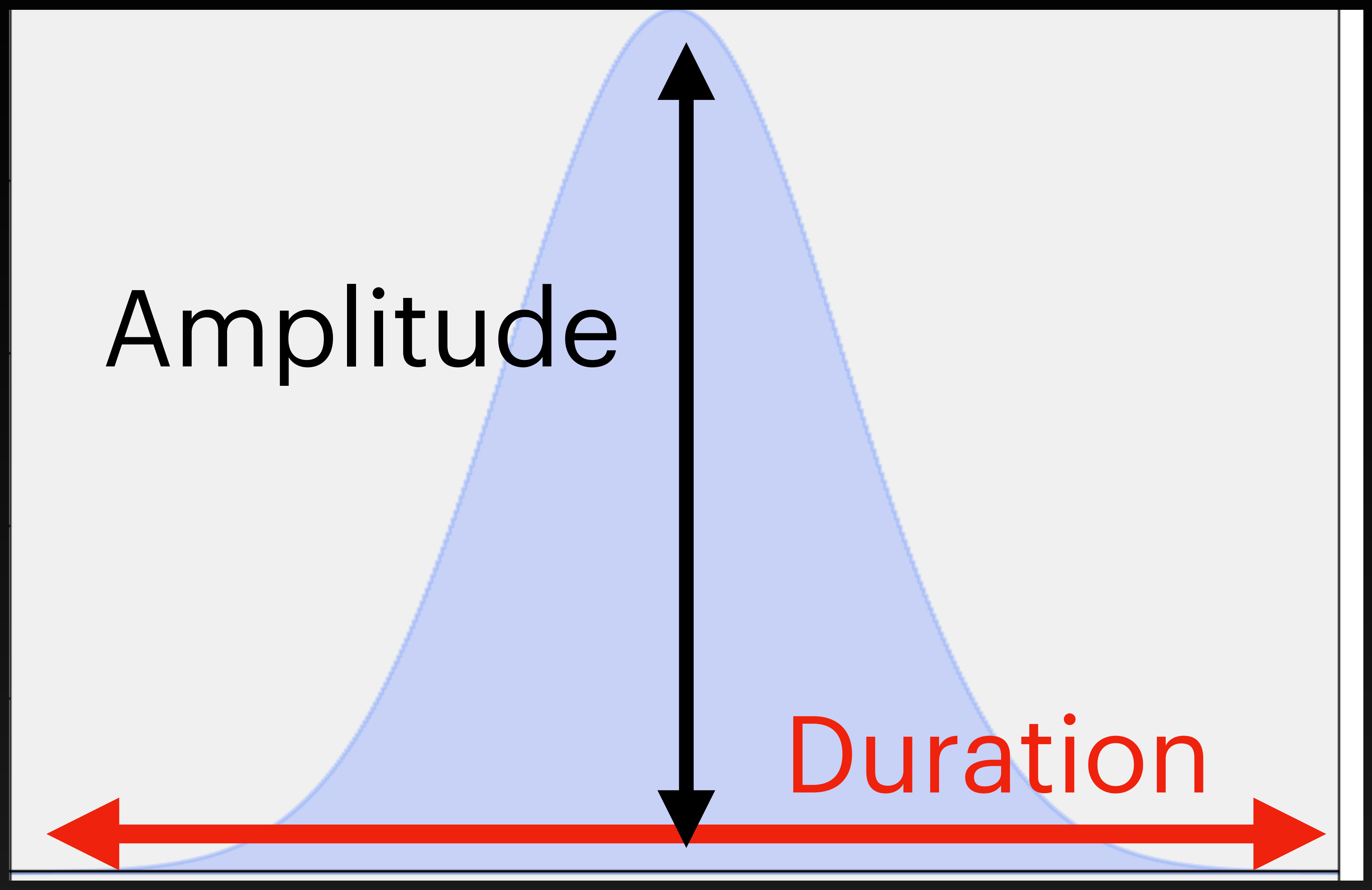
Modify Backend

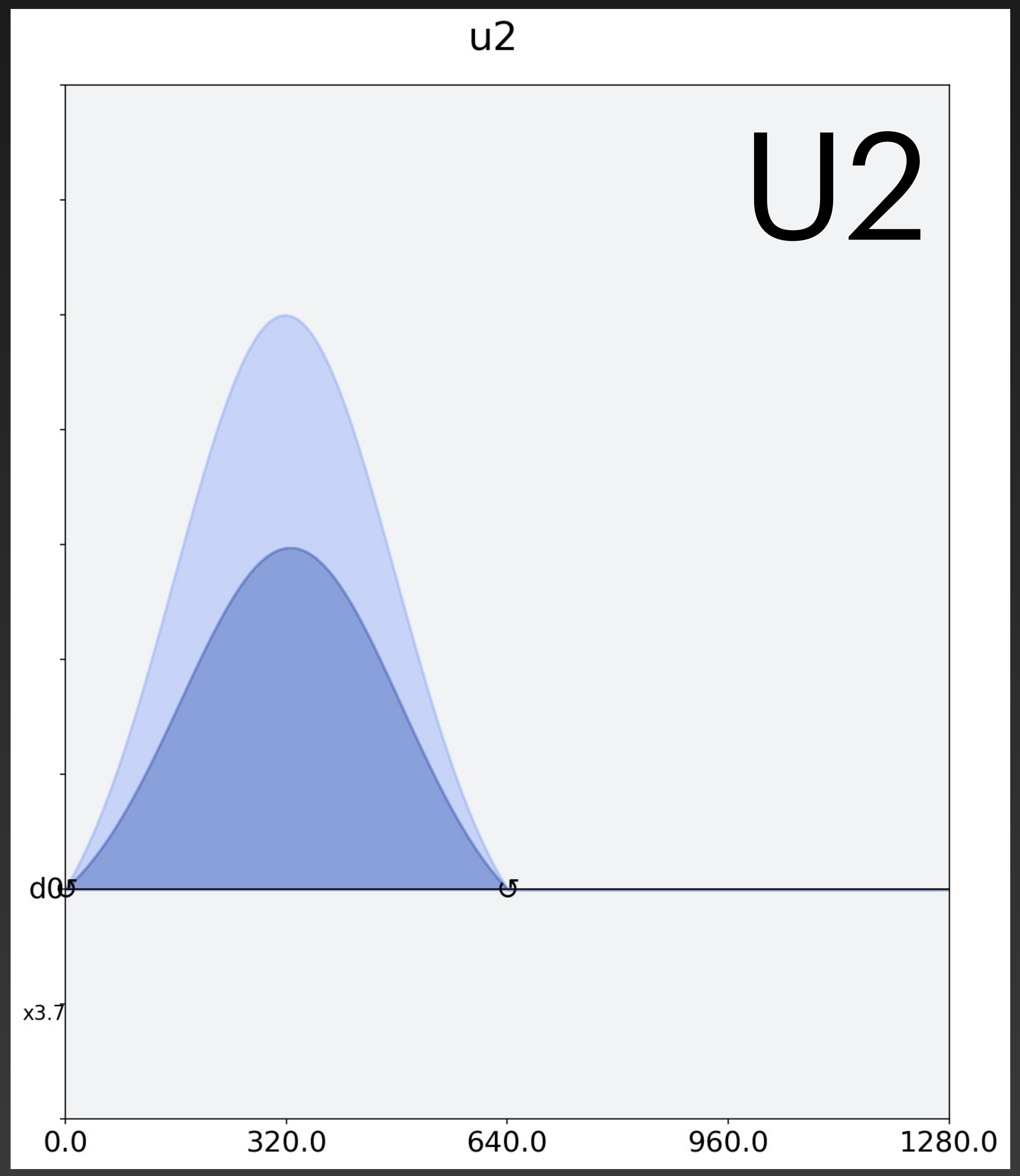


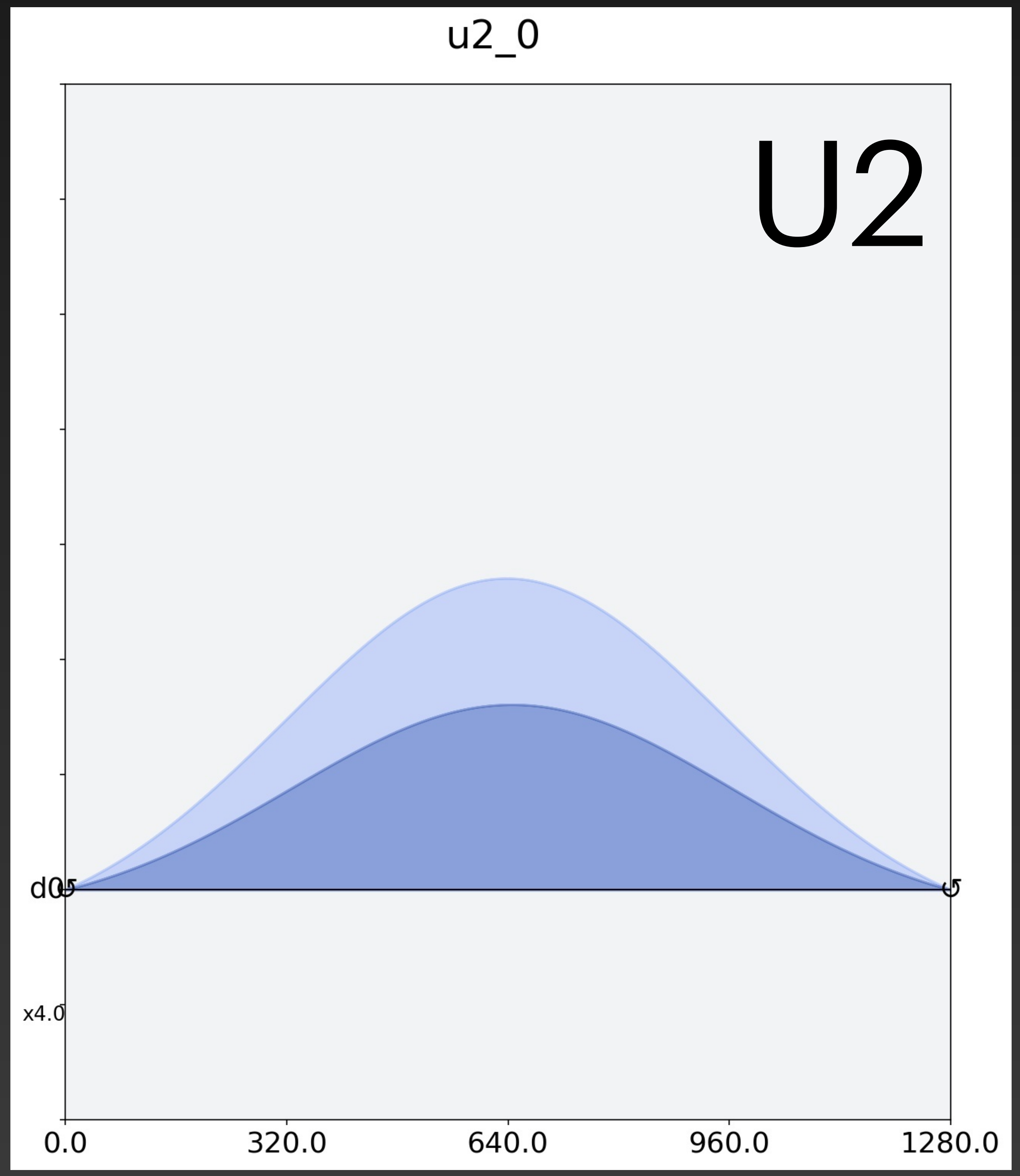


Work Flow


Check Linearity
Modify Backend


Amplitude
Duration


u2
U2
d0
x3.7
0.0
320.0
640.0
960.0
1280.0

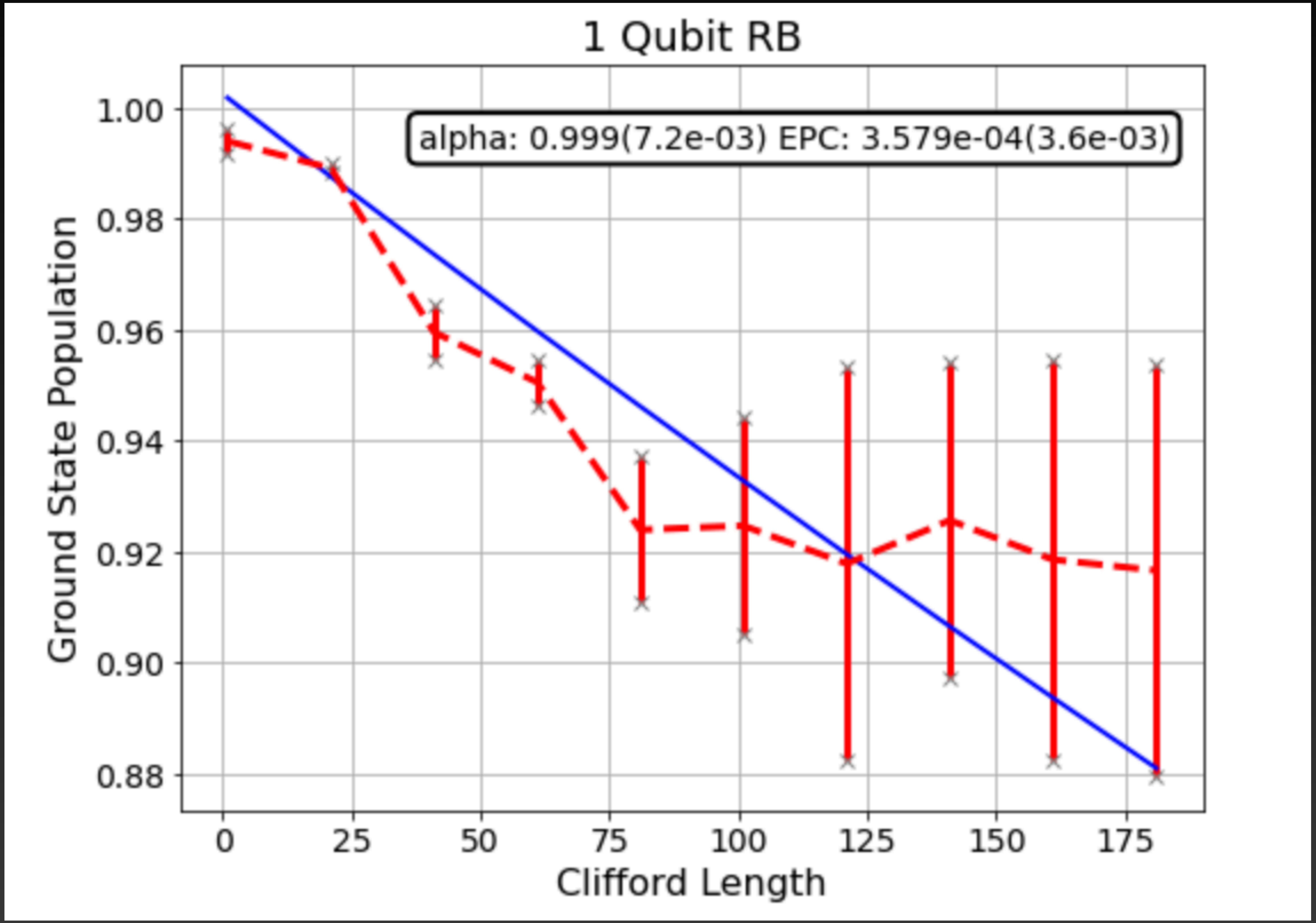

u2_0
U2
d0
x4.0
0.0
320.0
640.0
960.0
1280.0

Work Flow

Check Linearity

Modify Backend

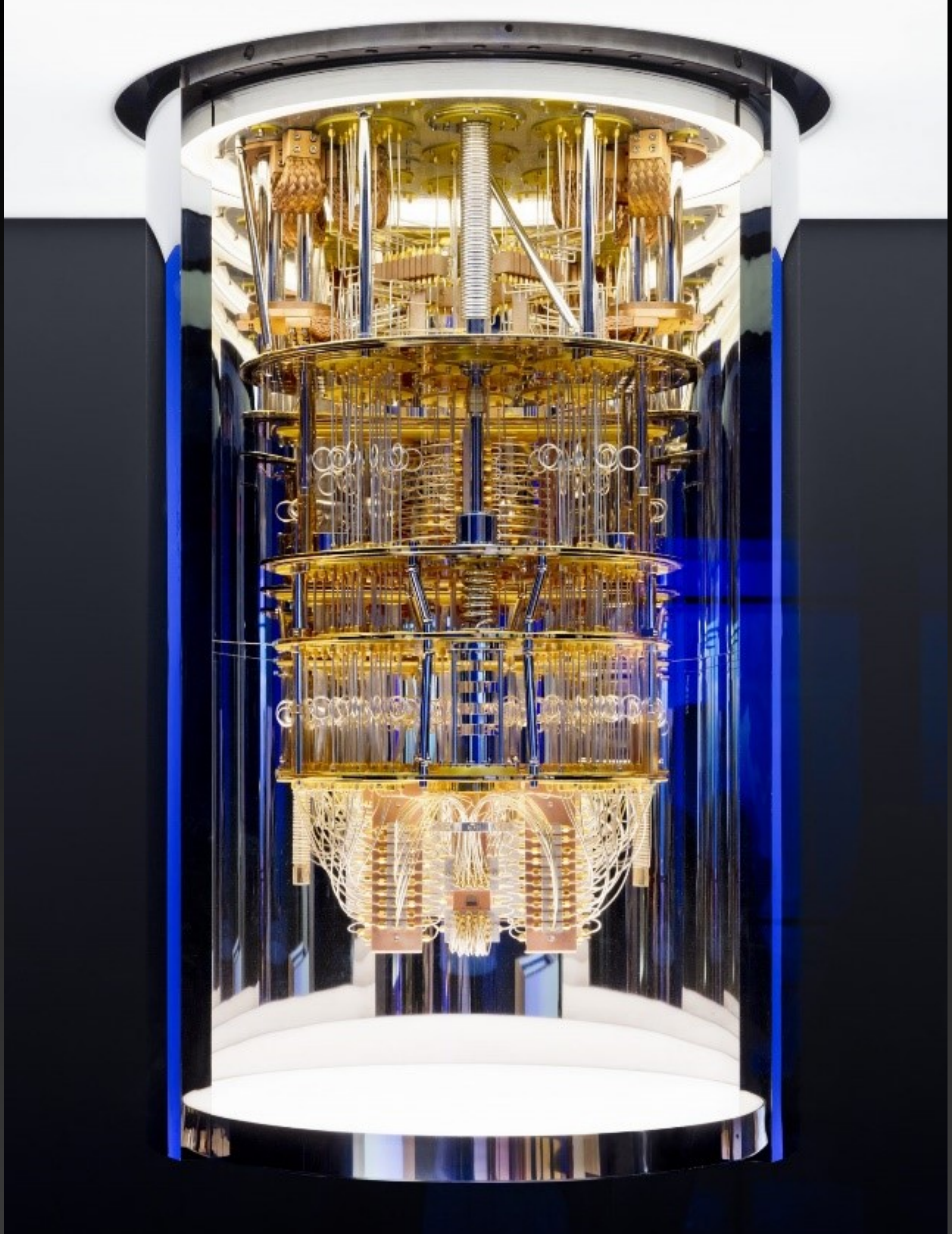
Randomized Benchmarking



Results

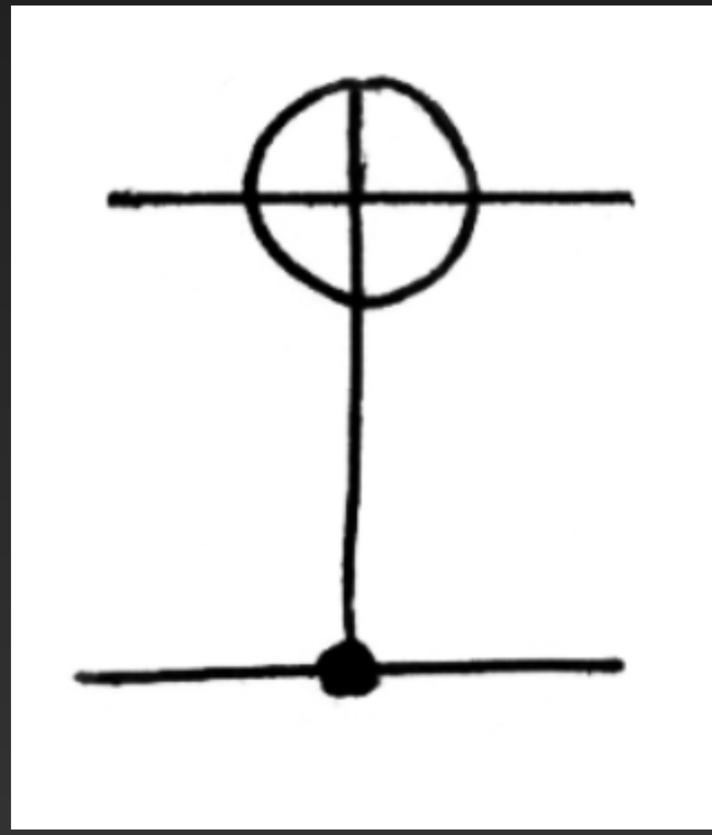
Usually up to ~200 Clifford length to measure single qubit gate fidelity owing to small error

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 $c_0 = 1 < c_1 < \ldots < c_n$, 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 $\rho^j_\lambda(T_j) = \rho_{c_j\lambda}(T)$, c.f. Eq. (33) as was discussed in section II. If we now measure the observable A on these states we obtain for $j = 0 \ldots n+1$ 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

$$\sum_{l=0}^{n} \gamma_j = 1$$
$$\sum_{j=0}^{n} \gamma_j \, c_j^k = 0 \quad \text{for } k = 1 \ldots n.$$

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

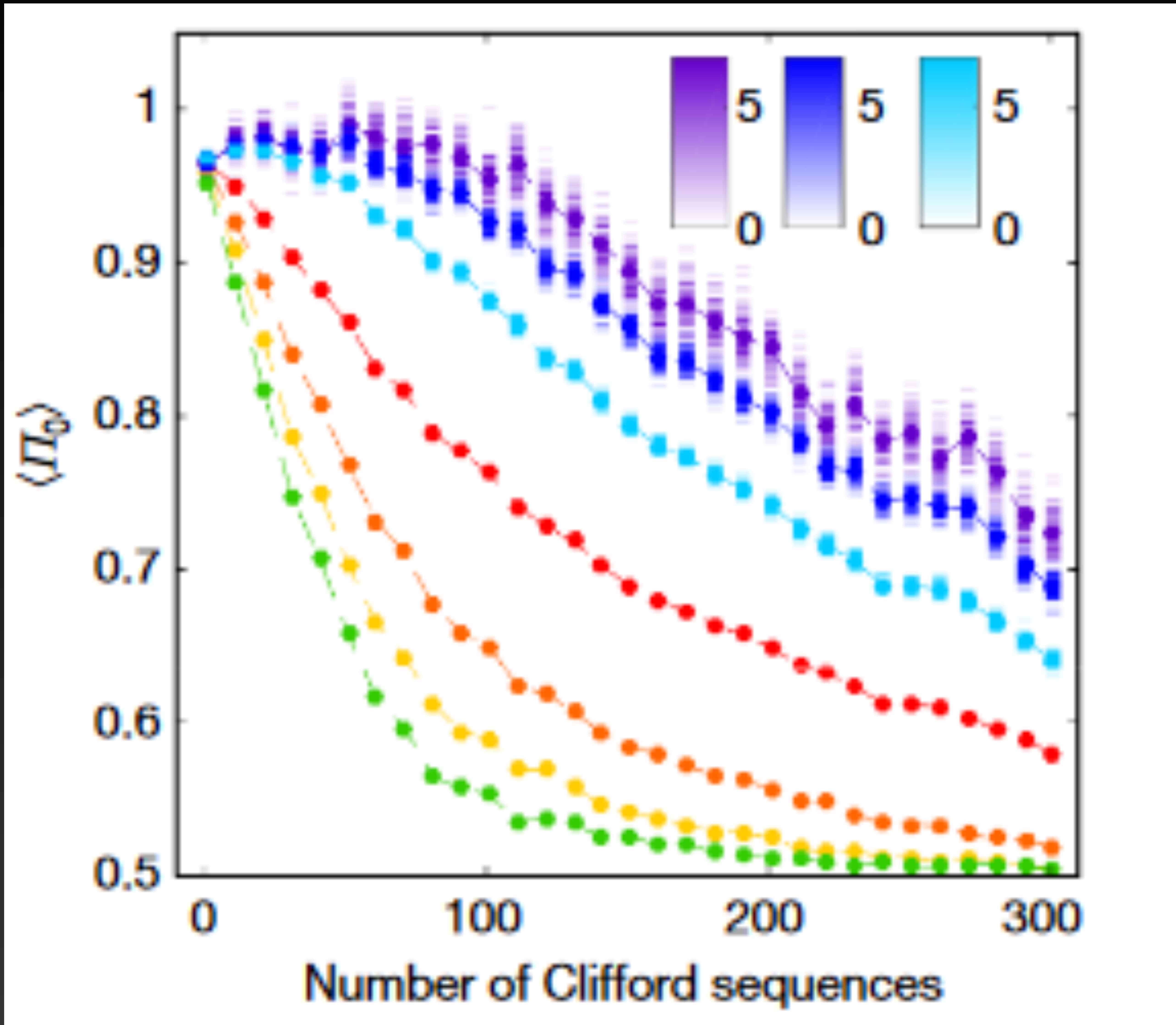
c=3

c=4

1st order extrapolation

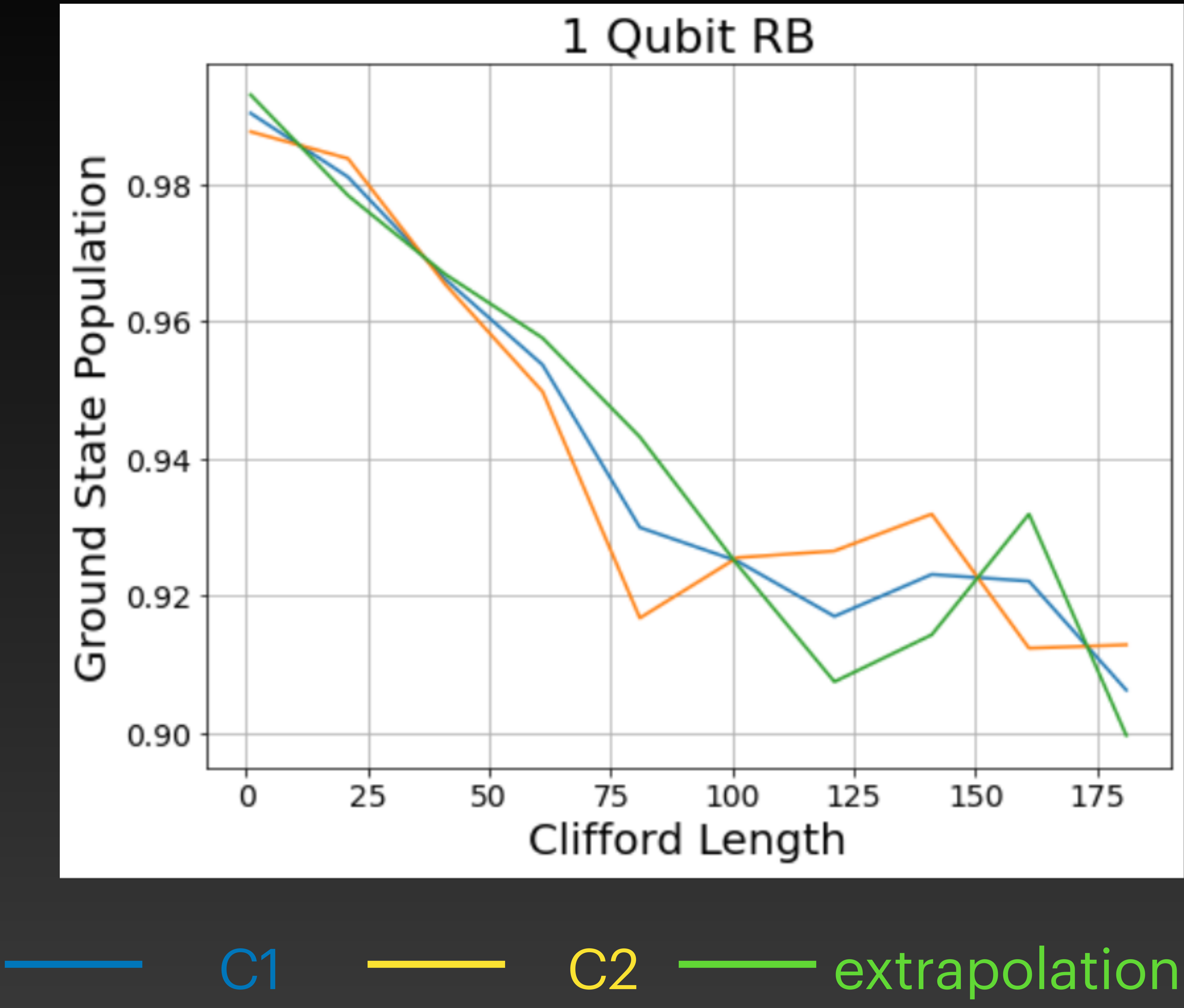
2nd order extrapolation

3rd order extrapolation



Fake Data

- Without changing the stretching constant



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