Qiskit Advocates Mentorship Program

Bayesian Techniques for Randomized Benchmarking

Mentor: Shelly Garion, Research Staff Member at IBM Research Haifa, Qiskit Ignis core developer.

Mentees: Pierre Decoodt and SheshaShayee Raghunathan

Bayesian Techniques for Randomized Benchmarking

Plan:

1. Open a PR in qiskit-ignis with a Jupyter notebook describing Bayesian inference for standard RB
2. Further explore Bayesian methods for interleaved RB
3. Perform an RB experiment on a noisy simulator and quantum hardware, to demonstrate the Bayesian methods.

Bayesian Techniques for Randomized Benchmarking

Ground state population:

$GSP = A \cdot \alpha^m + B$

m: number of Clifford gates

Error per Clifford:

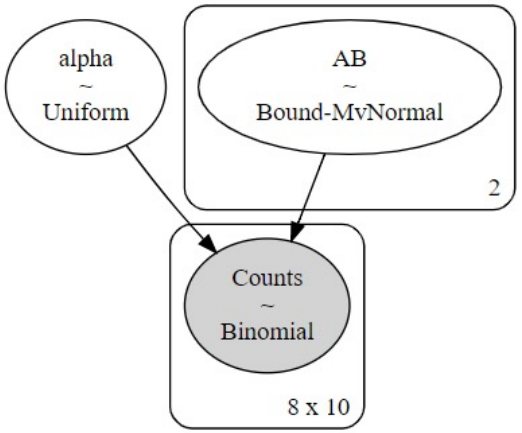
$EPC = \frac{2^n - 1}{2^n} \cdot (1 - \alpha)$

n: number of qubits

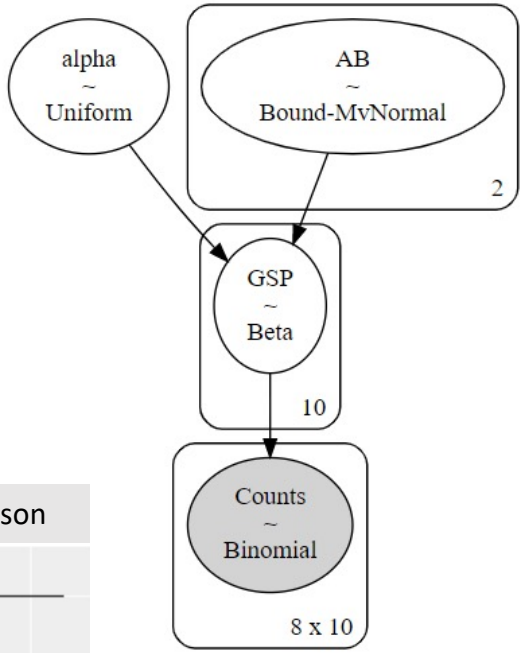
Number of experiments = $(c \cdot s) \cdot X$

c : number of copies, s: number of seeds, X: number of tested m values

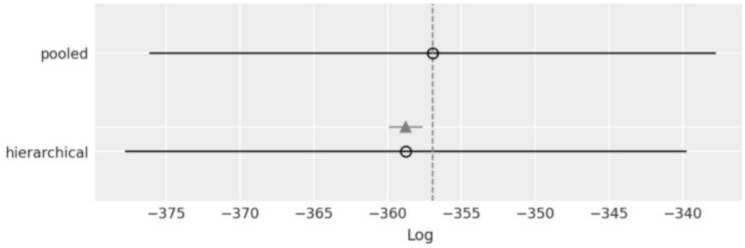
Pooled Model



Hierarchical Model

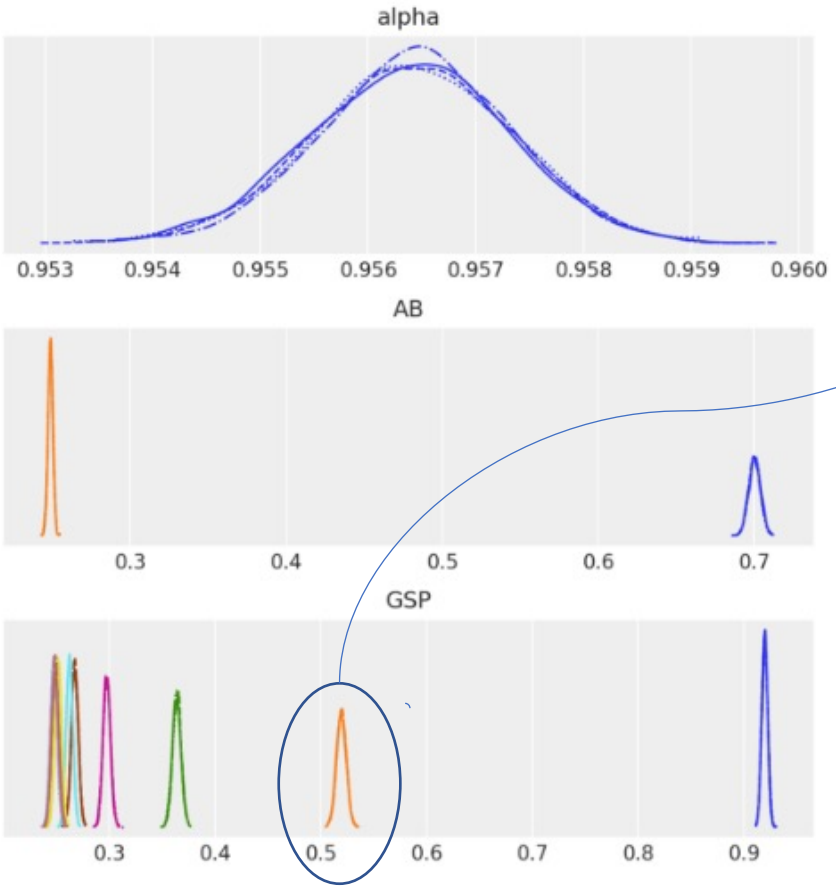


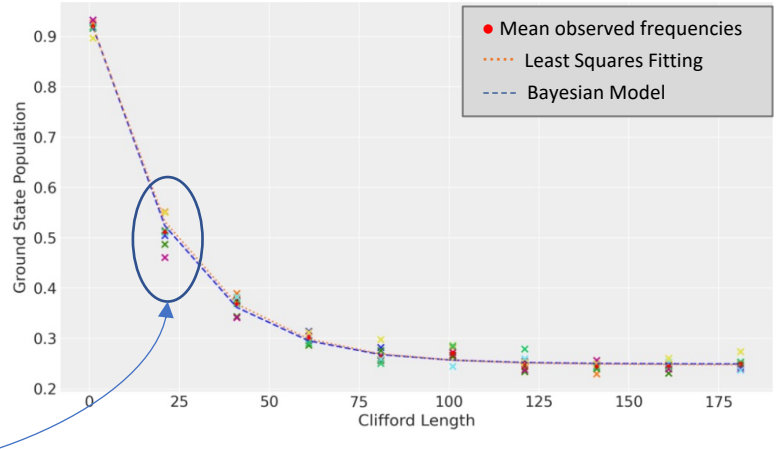
Leave-one-out Cross-validation comparison



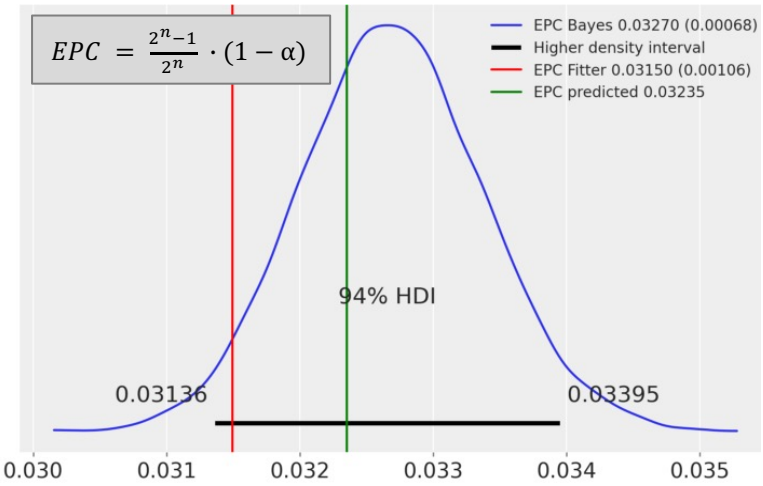
Bayesian Techniques for Randomized Benchmarking

$$GSP = A \cdot \alpha^m + B$$





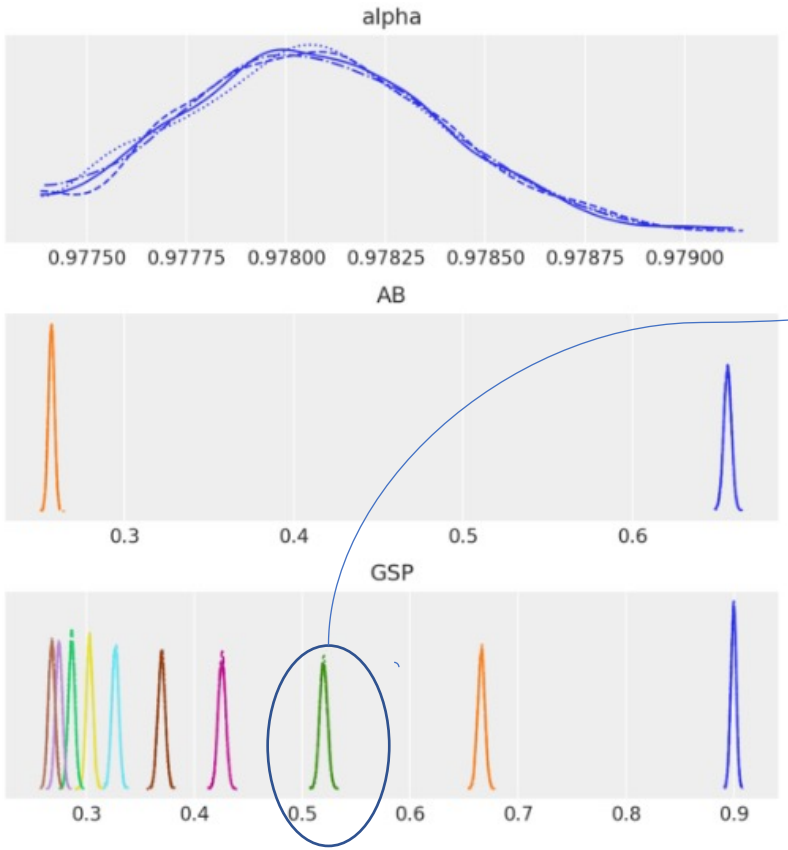
$$EPC = \frac{2^n - 1}{2^n} \cdot (1 - \alpha)$$

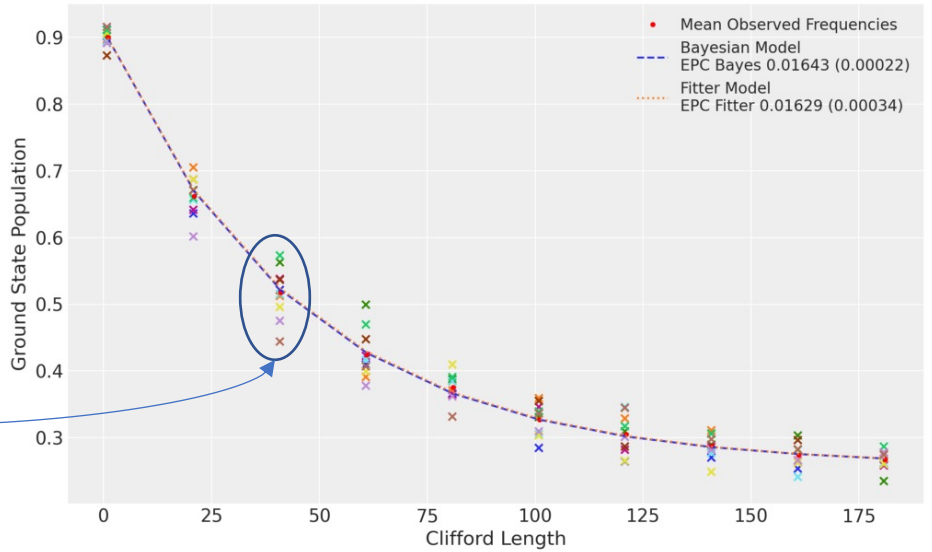


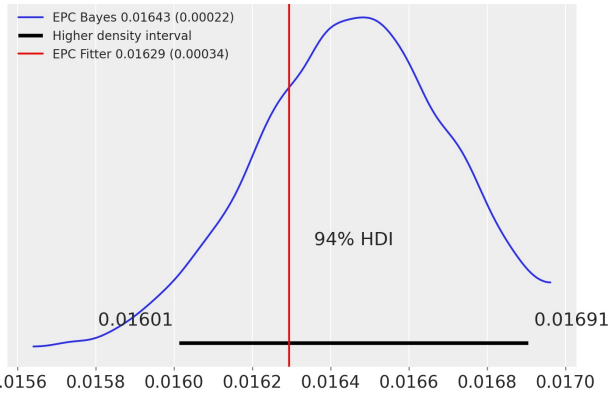
Depolarization Noise Simulation, 2-qubit RB, $s = 8,\ X = 10,\ c = 2^{10}$ shots
Hierarchical Bayesian Model, MCMC Algorithm: PyMC3 No-U-Turn Sampler

Bayesian Techniques for Randomized Benchmarking

$$GSP = A \cdot \alpha^m + B$$







Real device ibmq_lima, 2-qubit RB, $s = 10$, $X = 10$, $c = 2^{10}$ shots
Hierarchical Bayesian Model, MCMC Algorithm: PyMC3 No-U-Turn Sampler