Benchmarking with Repetition Codes

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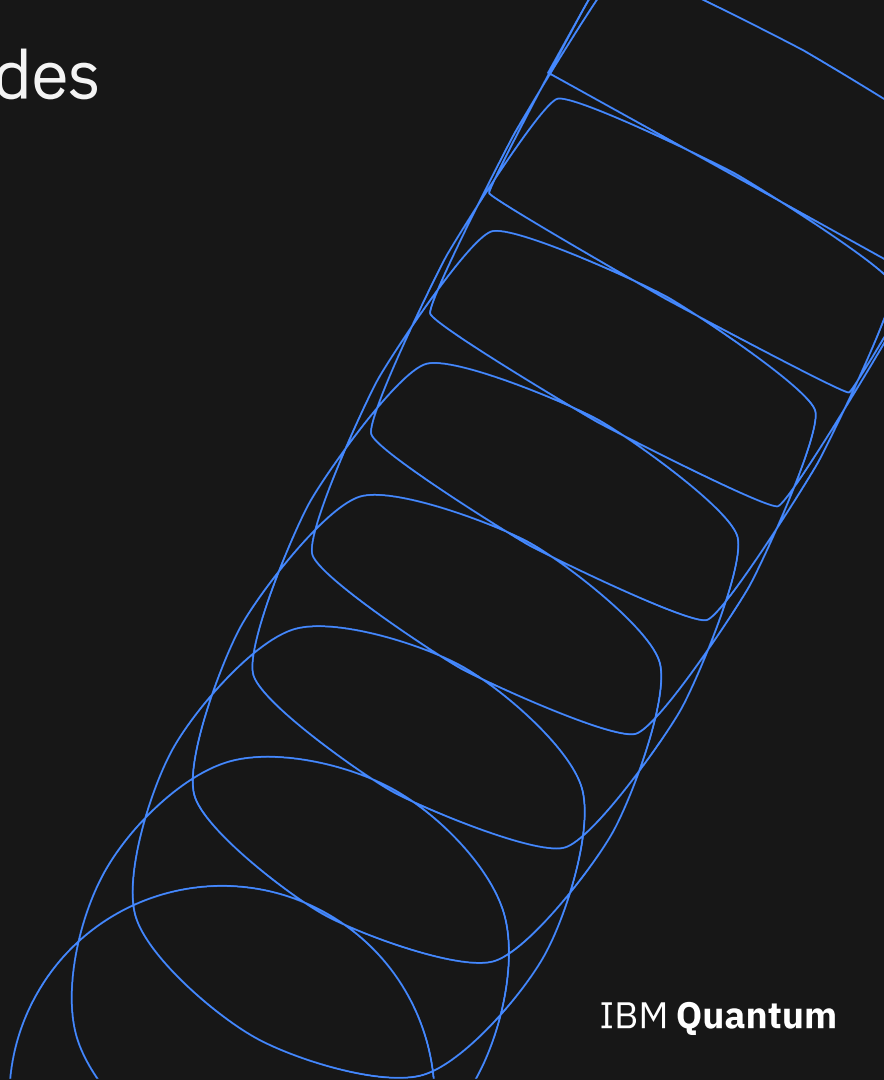

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Subproject A5: Quantum Error Correction

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Daniel Miller

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University of Basel

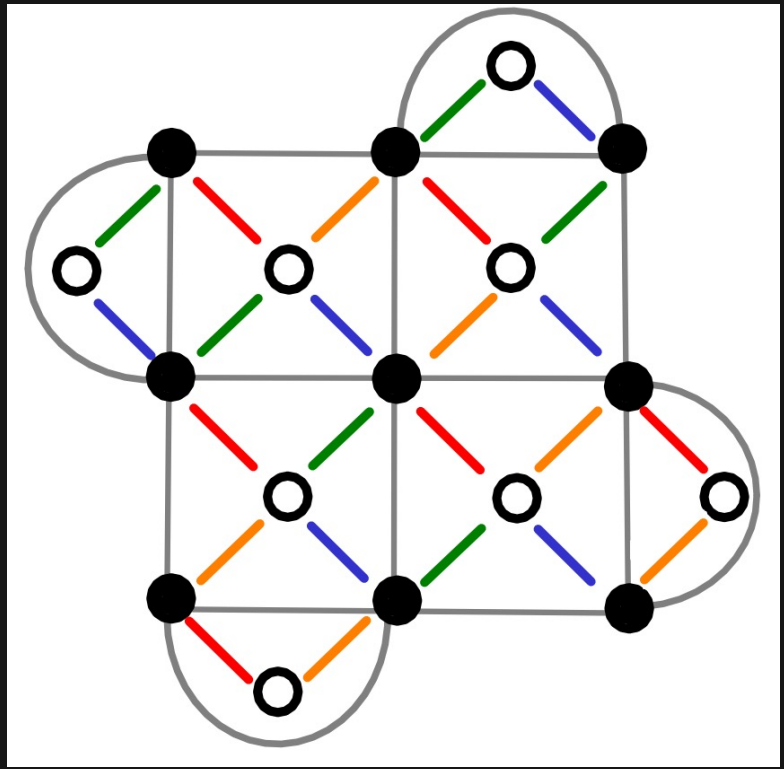
- Milestones
  - Propose proof-of-principle experiments for ~5 qubits
  - Propose demonstration of a logical qubit for ~20 qubits
  - Plan scalable QEC for 100+ qubits

How good is a quantum device?

- A FTQC is basically a QEC machine
- Algorithms are minor changes to QEC scheme

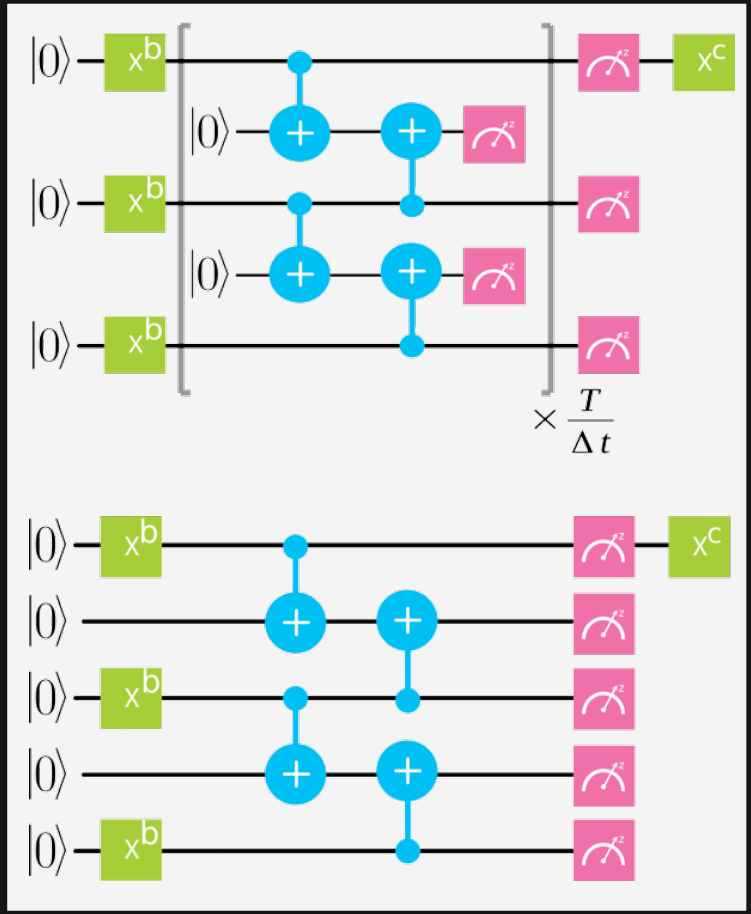
- So how well can a device do QEC?

- We need to
  - Check proposals for large-scale QC are compatible
  - See if few-qubit devices can do the basics



How well can a device do QEC?

- We need to at least test the standard methodology
  - Encode bit values
  - Detect errors using stabilizer measurements
  - Correct during decoding
- Simplest way is using the repetition code
- Not fully quantum, but:
  - Can be done with 5 qubits or more
  - Very flexible on connectivity



Repetition code experiments

- Simplest approach
  - Look at logical error vs code distance
  - See if decay is the required exponential
- But not good for small devices
  - Few data points
- And not good for large devices
  - Exponential scaling

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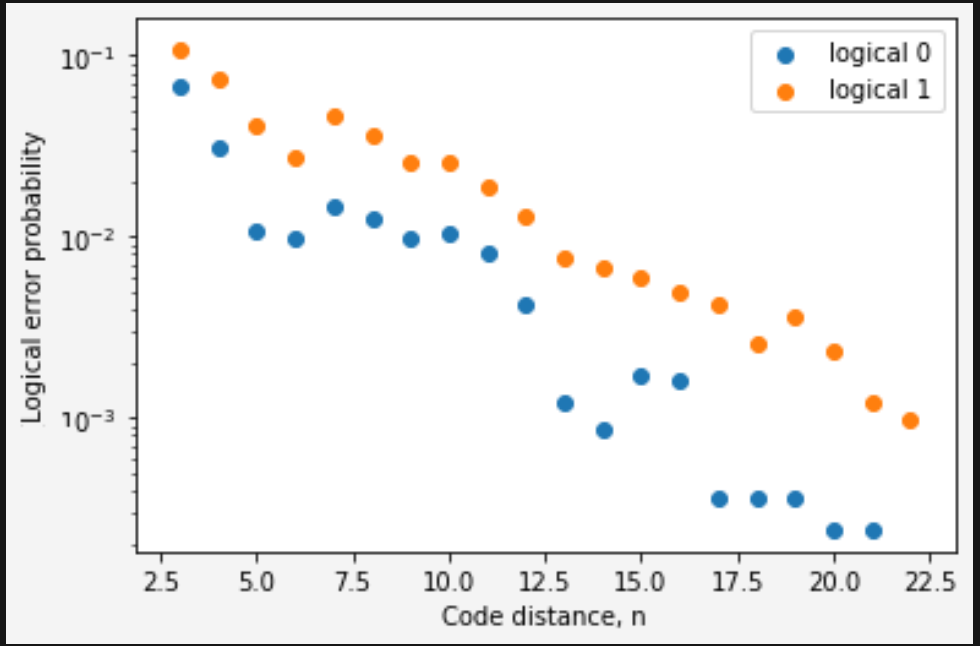
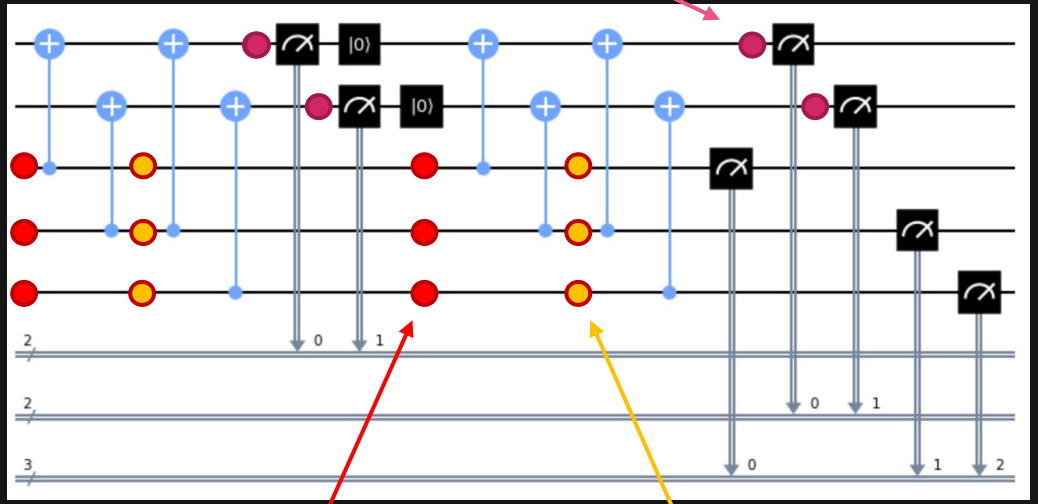


Error profiling

- Full results can be used to estimate probabilities of each error
- Modelled by bit flips at each point in circuit
- Different flips caused by noise from different sources



Manila

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- We'll look at some work-in-progress results from a 5 qubit (superconducting) device

Qubit:

T1 (us)

Avg 144.29

min 127.1 max 178.96

Connection:

CNOT error

Avg 7.677e-3

min 5.905e-3 max 1.131e-2

Qubit	T1 (us)	T2 (us)	Frequency (GHz)	Anharmonicity (GHz)	Readout assignment
Q0	178.96	115.67	4.963	-0.34335	2.250e-2
Q1	131.99	65.41	4.838	-0.34621	2.810e-2
Q2	141.24	24.12	5.037	-0.34366	2.110e-2
Q3	142.16	70.28	4.951	-0.34355	1.720e-2
Q4	127.1	42.21	5.066	-0.34211	5.160e-2

Results from 20 rounds

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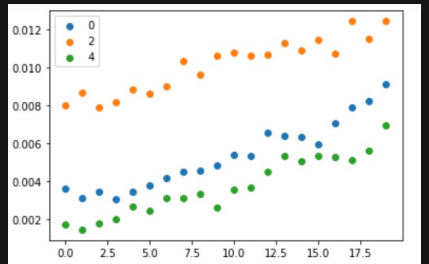
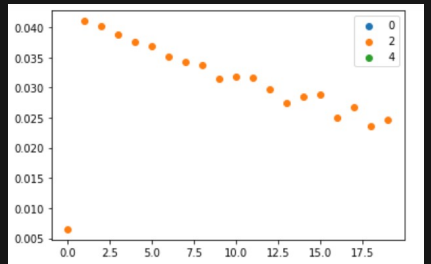
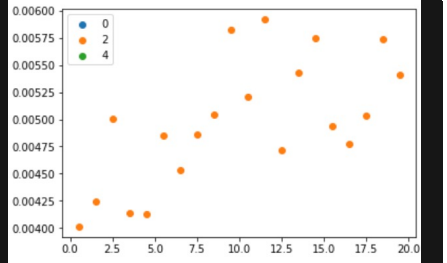
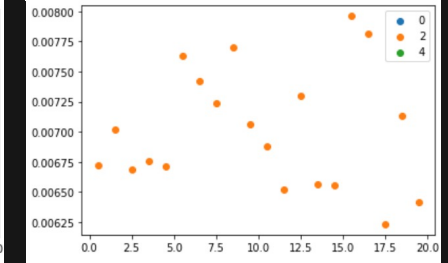
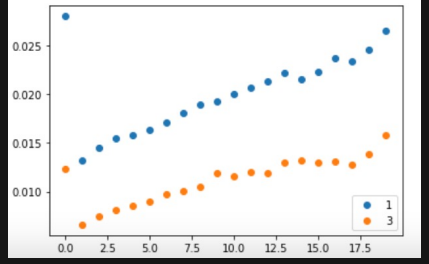
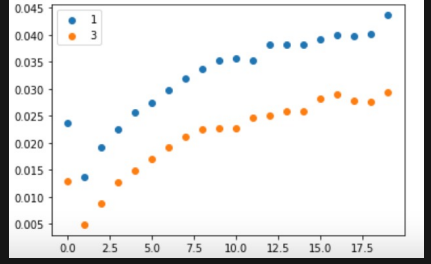
	0	1
Between syndrome measurement rounds (primarily relaxation)		
During syndrome measurement rounds (primarily cnot errors)		
Measurement		

Results from 200 and 300 rounds

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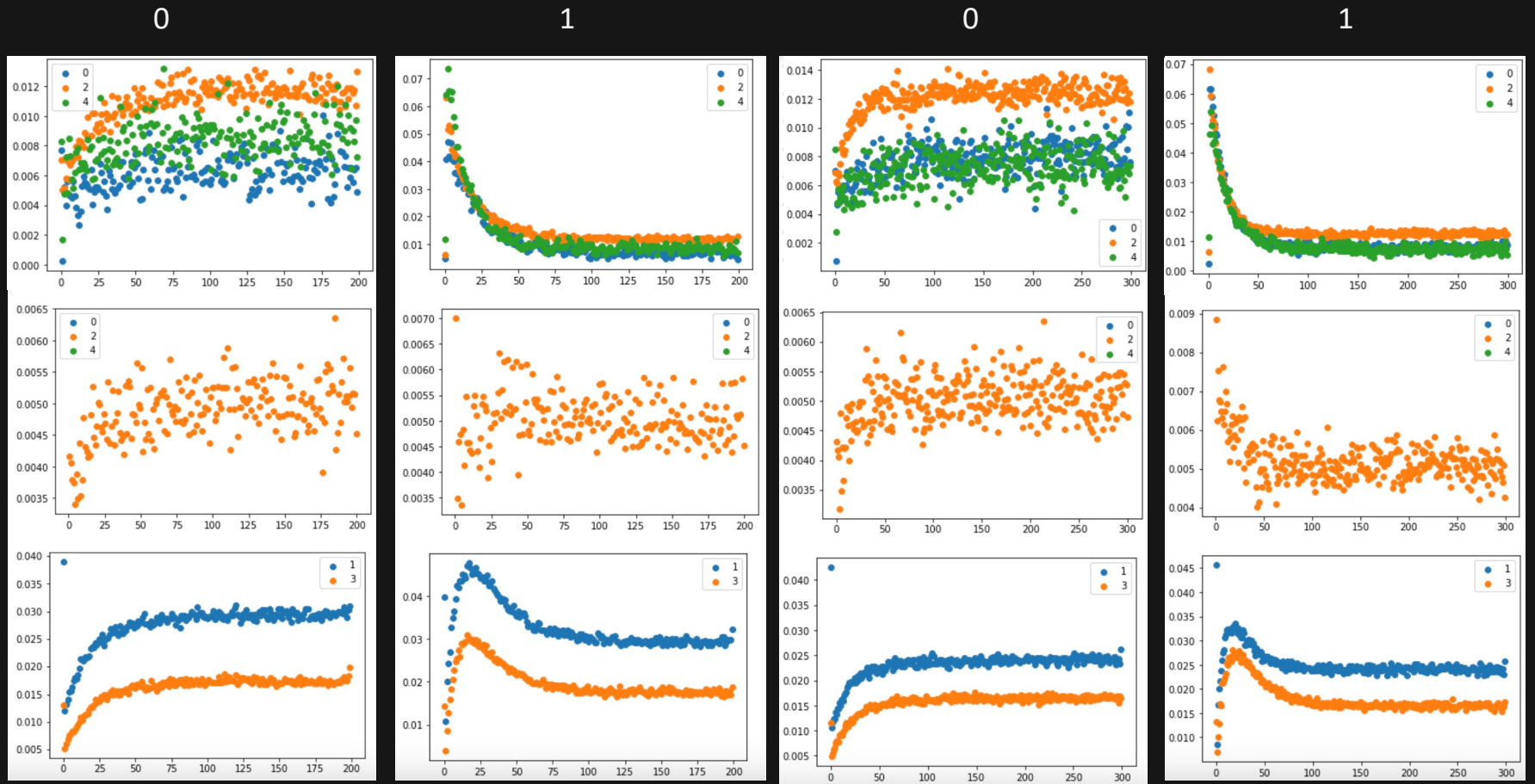


Understanding Manila (so far)

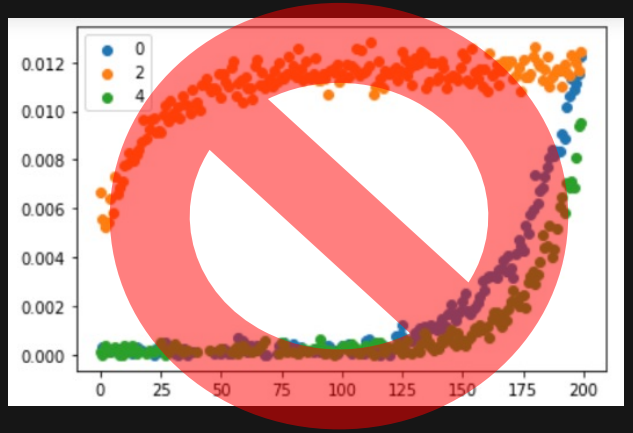
- Results show good agreement to benchmarking
  - CNOT error rates
  - Measurement error rates

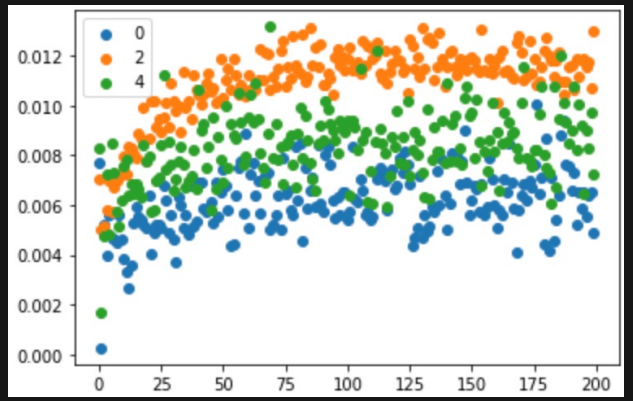
~~- Nevertheless, there are mysteries still to be solved~~

~~- Uptick of relaxation errors at end (no matter how many rounds are run)~~

~~- Is it my bug, or somewhere else?~~

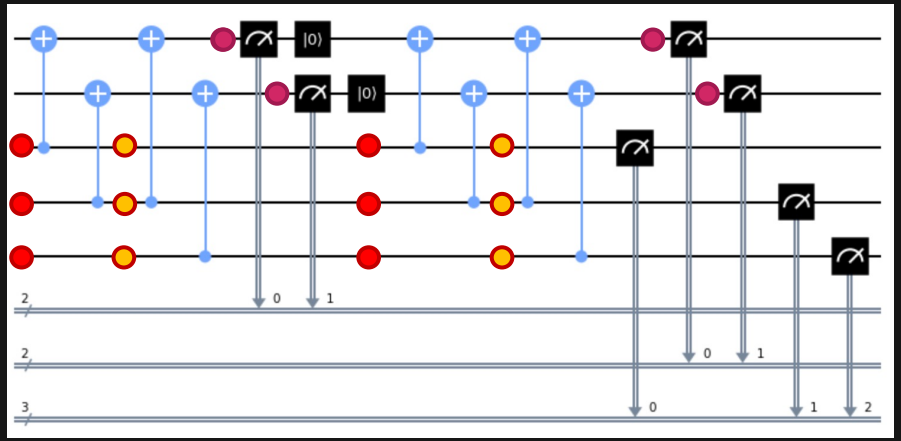
- The above mystery was solved
  - It was my bug!





Conclusions

- We ran a simple complex circuit
  - Dense with entangling gates and measurements
  - Easy to understand the output
- Results tell us about noise throughout the circuit
- Agrees with benchmarking, but still mysteries to solve
- **Give us 5 qubits and we'll do it for you too!**



Thanks for your attention

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