Witness My Entanglement!

Team 17

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iQuHACK 2026 • IQM Challenge

Goal
Convince a curmudgeon that:

- Entanglement must be present (a proof, not vibes)
- Across qualitatively distinct state families
- While pushing qubit count as far as hardware allows

What we built and why it convinces a skeptic

A practical entanglement-certification pipeline tuned for IQM hardware:

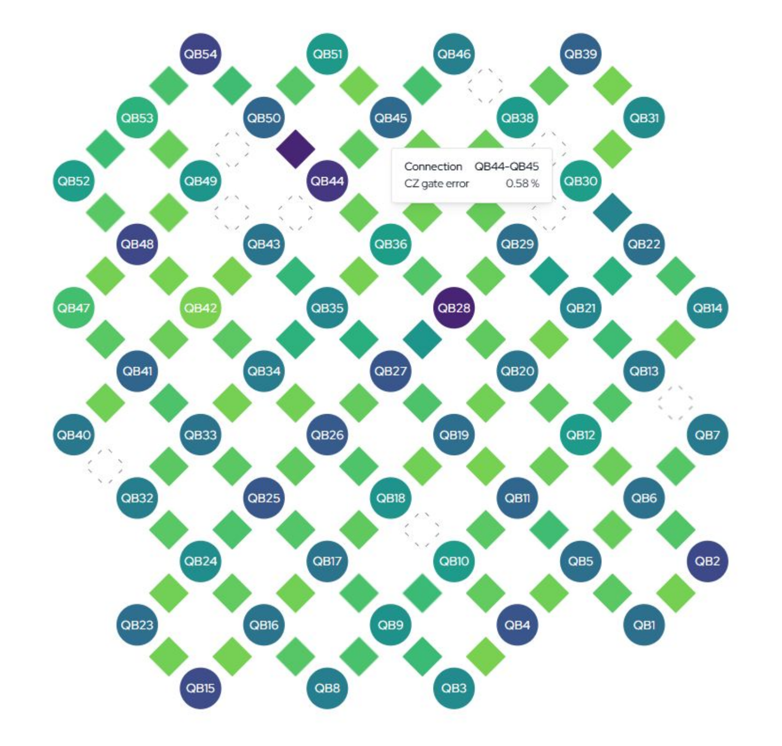
- Low-overhead witnesses (few measurement settings) for multipartite states
- 4 state families: GHZ, M, GC, IQP
- Hardware-aware mapping: choose qubits/edges using calibration data (CZ + readout)
- Scaling diagnostics: when proof fails, identify the dominant bottleneck experimentally

Largest proven entanglement (repo results)
25 qubits with 58% fidelity

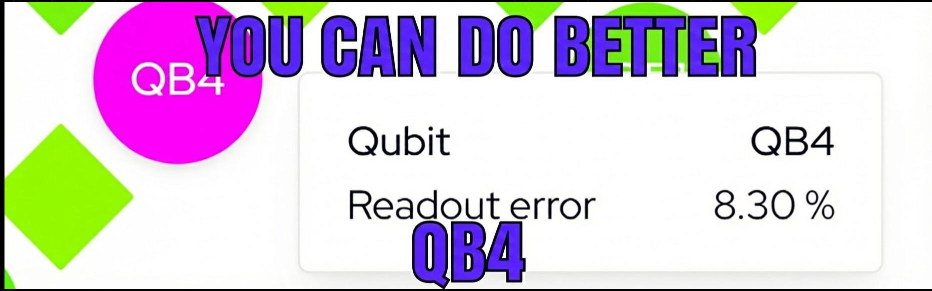
Distinct state families demonstrated
GHZ + M + GC + IQP

Scalability
50 qubits ????

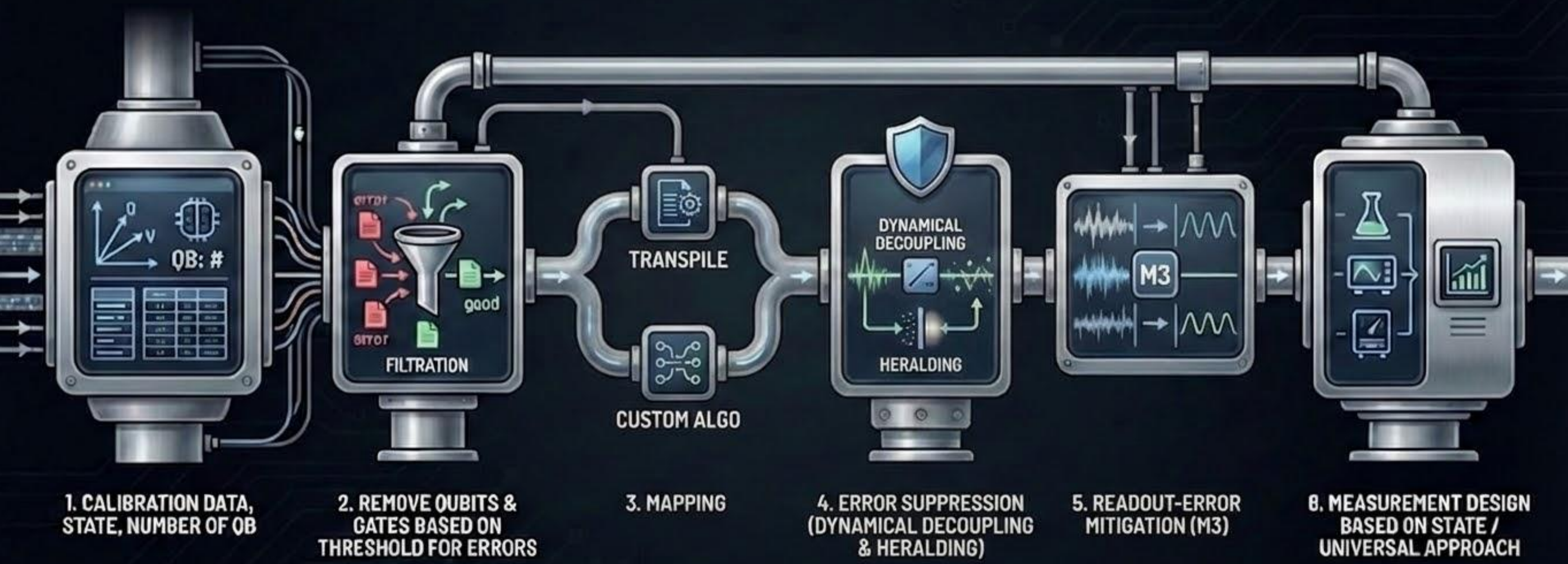
Hardware



- Read-out rate
- CZ gate fidelity
- Number qubits (Emerald)
- No access to IQM Pulla



Universal pipeline



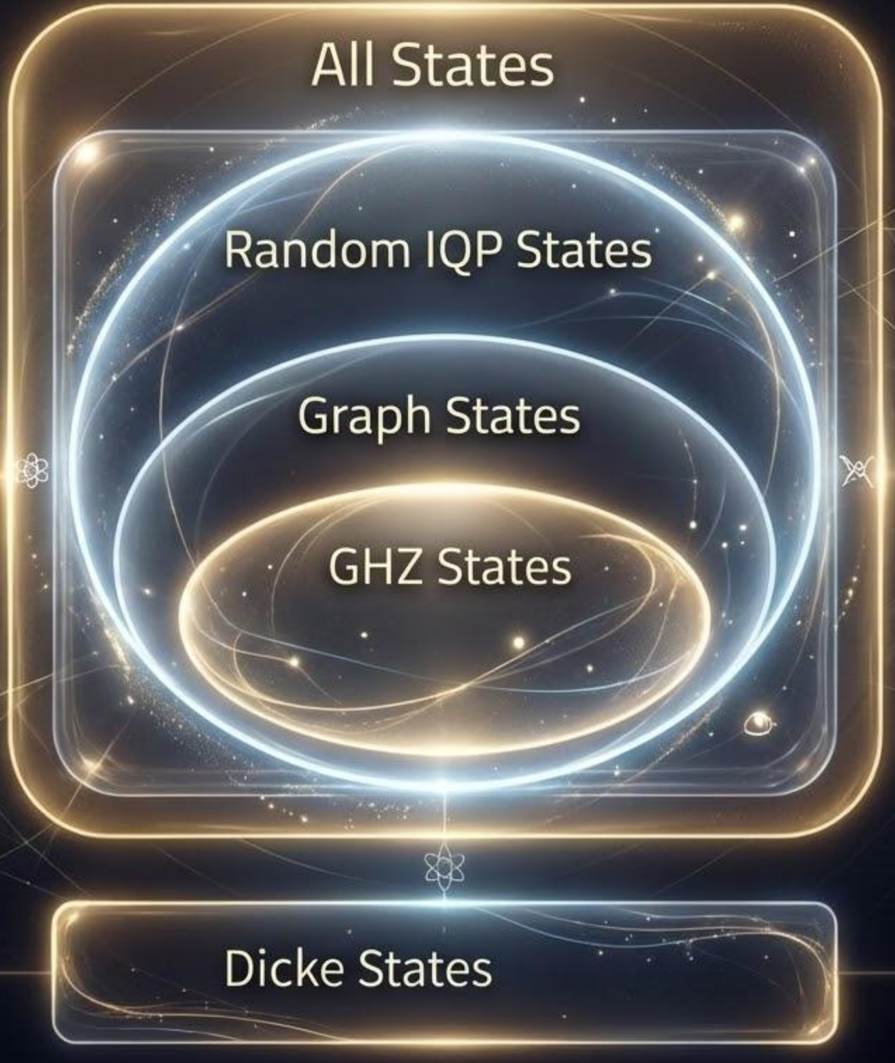
Noise-Aware Qubit Mapping*

Method	How it works	F(raw)	F(filtered)
Naive transpile (v=3)	Qiskit auto-routing, no calibration data	0.41	0.52
Topology DFS / BFS	DFS / BFS by degree, noise-unaware	0.41	0.52
Greedy noise-aware	DFS by F_CZ * F_RO, multi-start	0.37	0.53
ILP optimal	Global optimization (log-fidelity), HiGHS solver	0.38	0.48

* map a 25-qubit linear GHZ chain onto 54-qubit IQM Emerald to maximize fidelity

Different states

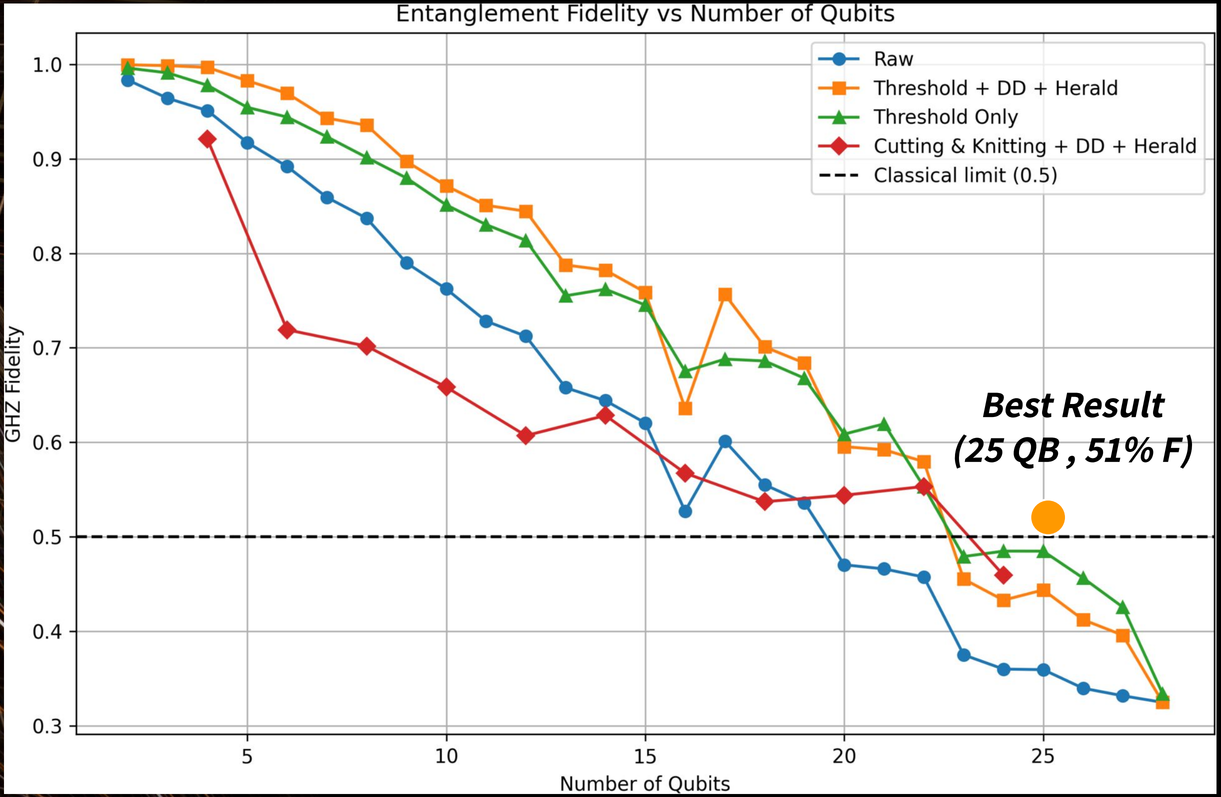
GENERALIZED GME STATE!!!!!



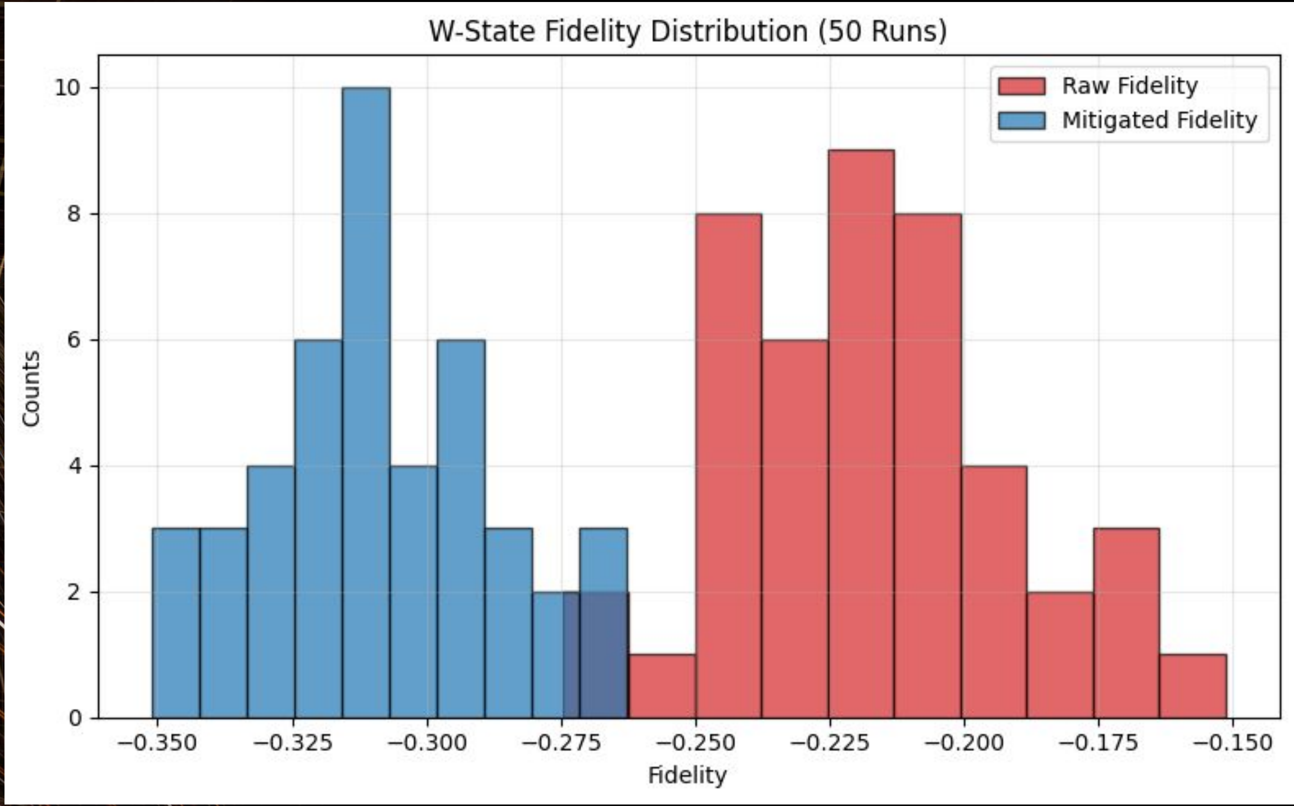
Different states

GHZ	Graph Circuit	IQP	Dicke (W State)
Bell-type inequality violation (e.g. Mermin / CHSH family for GHZ-type correlations)	Standard graph-state (stabilizer) witness: stabilizer expectations or graph-state fidelity exceeding separable bound	Randomly generated circuit with witness for all graphs in family	Fidelity witness implemented in code: $F = P(0^{\otimes N}), \quad \langle W \rangle = \frac{1}{2}\frac{N}{N-1} - F, \quad \langle W \rangle < 0$
25 Qubits Entangled!!!	6 Qubits	15 Qubits	3 Qubits

Results - GHZ Scaling



Results - W State



Approach: IQP Stabilizer Witness

1) Prepare an IQP state

- Run on a connected hardware subgraph (e.g., 15-qubit chain on Emerald)

2) Define local stabilizers

For each qubit i:

```
Si = Zi × (X on all neighbors of i)
```

3) Measure $\langle S_i \rangle$ with basis rotations

- Target i: measure in Z (no change)
- Neighbors j: apply H, then measure (X-basis)
- From each bitstring: s = zi × (x on neighbors) ⟶ average over shots

4) Witness / certificate

```
avg<S> = mean_i <Si>
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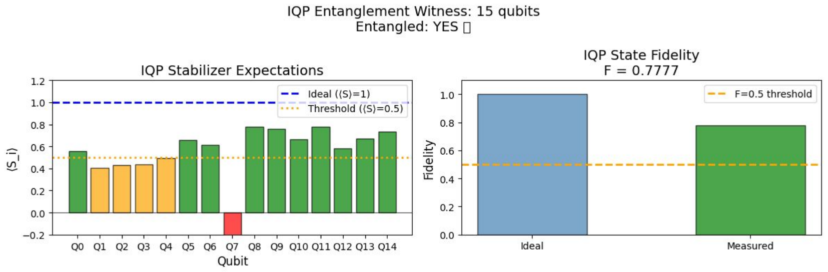
Entangled if avg<S> > 0.5 (witness W = 0.5 - avg<S> < 0)

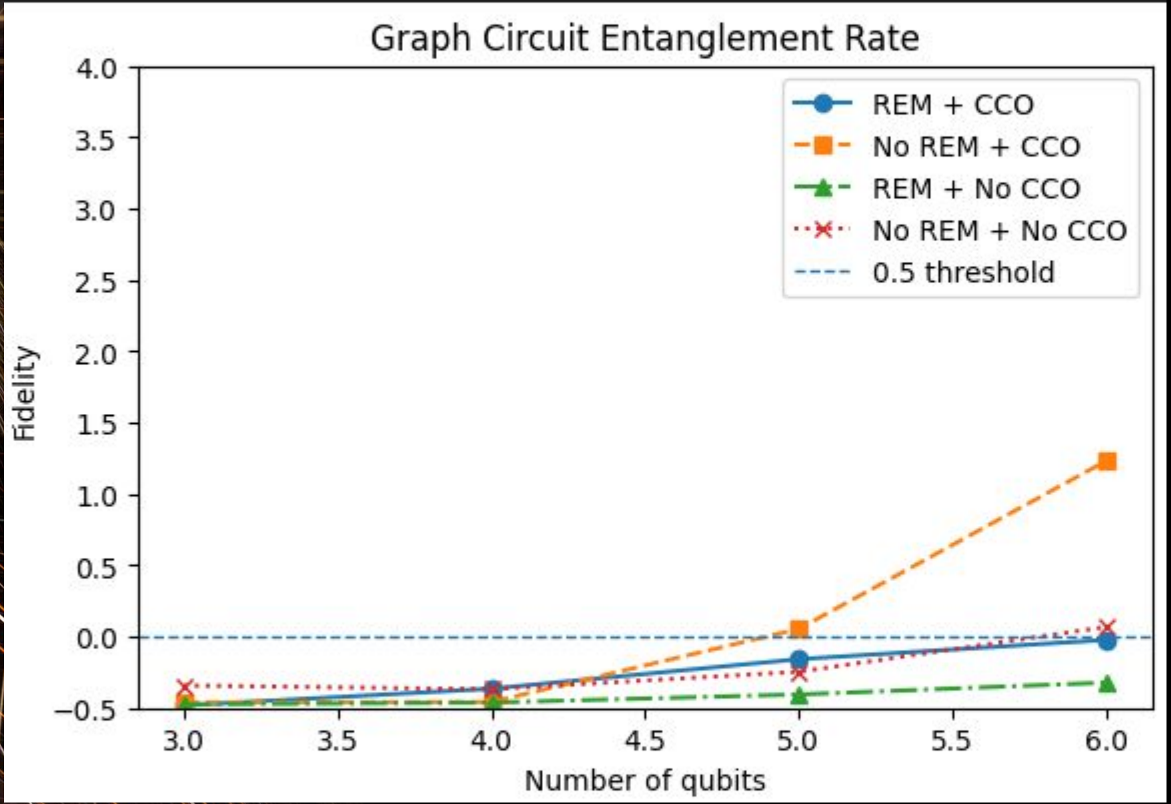
Fidelity proxy: F ~ (1 + avg<S>) / 2



Emerald (15 qubits): avg<S> = 0.555 ⟶ W = 0.5 - avg<S> < 0

Certified • O(n) circuits • Works across many IQP graphs (distinct states)

Graph Circuit



THANKS!

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