CQC Technical Workshop 2024

Digital Twin and Characterization Experiments

Dennis Willsch, JSC
Sebastian Schulz, JSC

[Hannes Lagemann, JSC]
[David Rabanus, JSC]
[Alejandro Montanez-Barrera, JSC]

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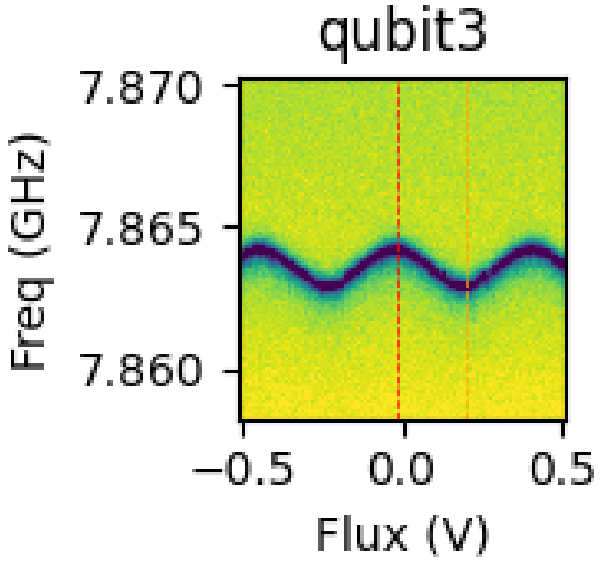

Resonator Spectroscopy

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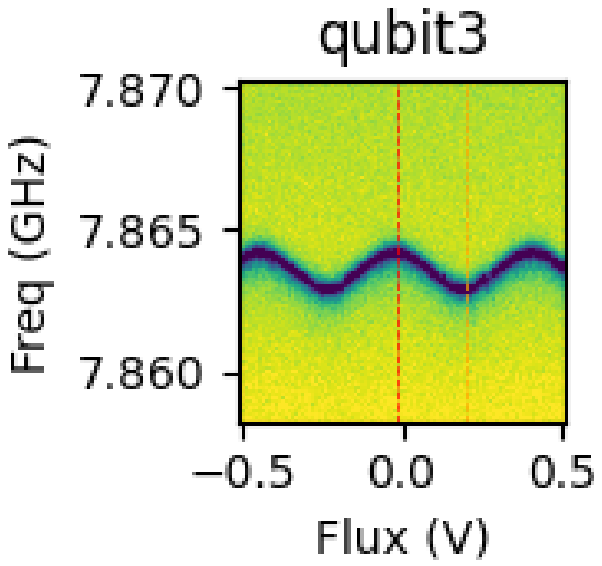

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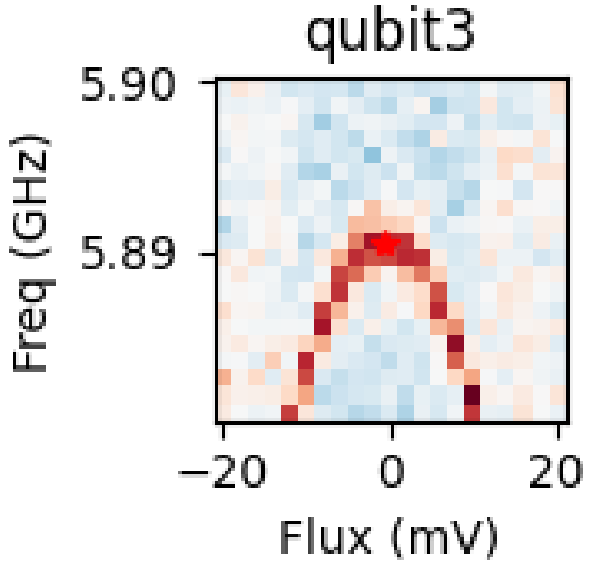

Qubit Spectroscopy

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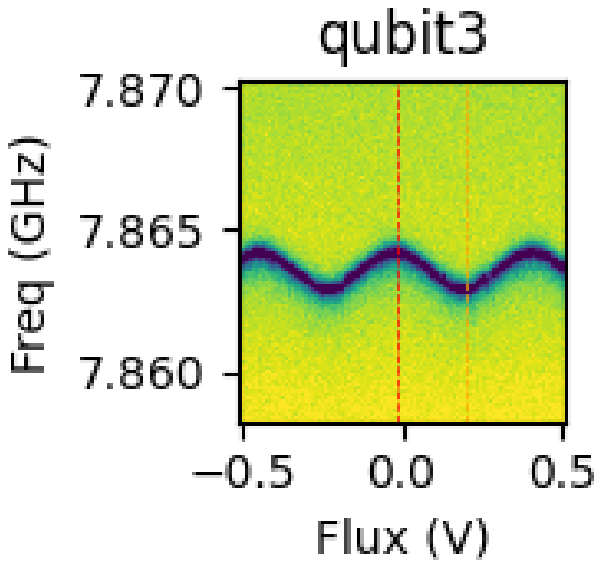
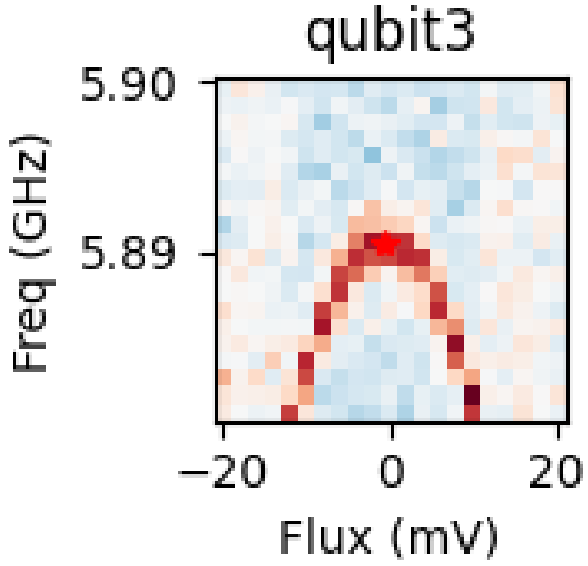


Resonator Spectroscopy



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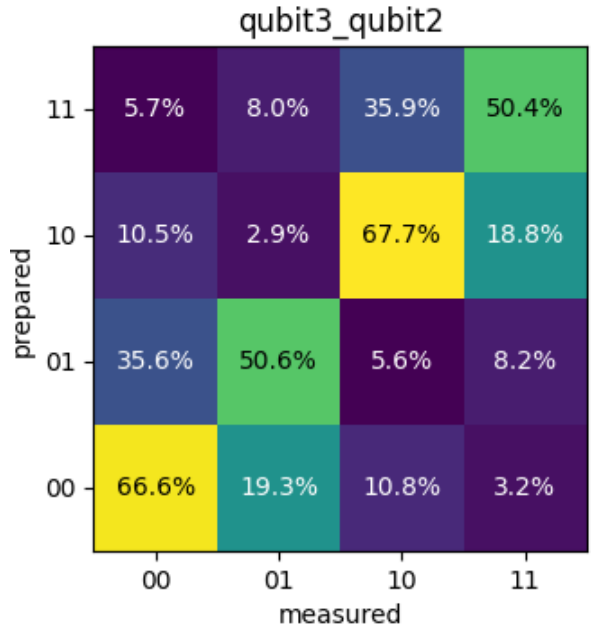

Two-Qubit State Preparation

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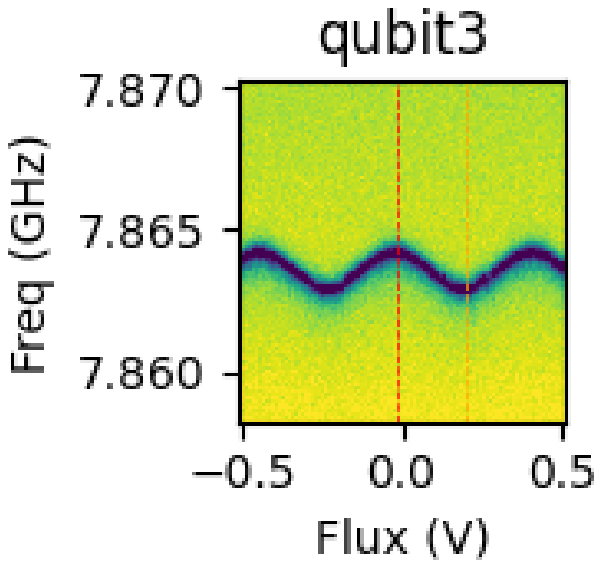

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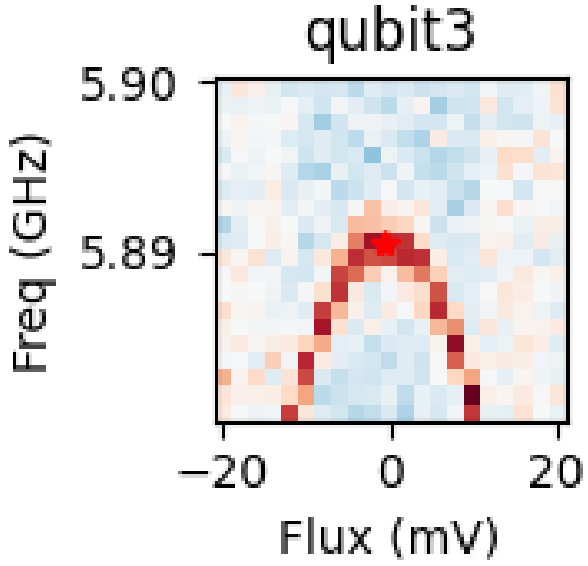

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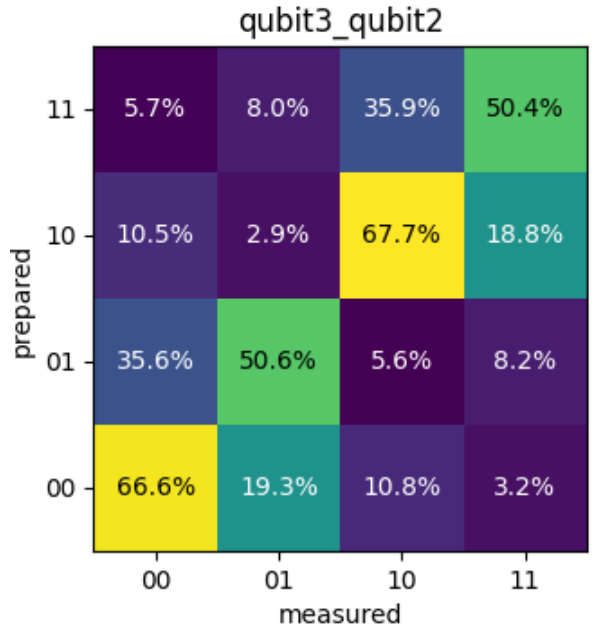
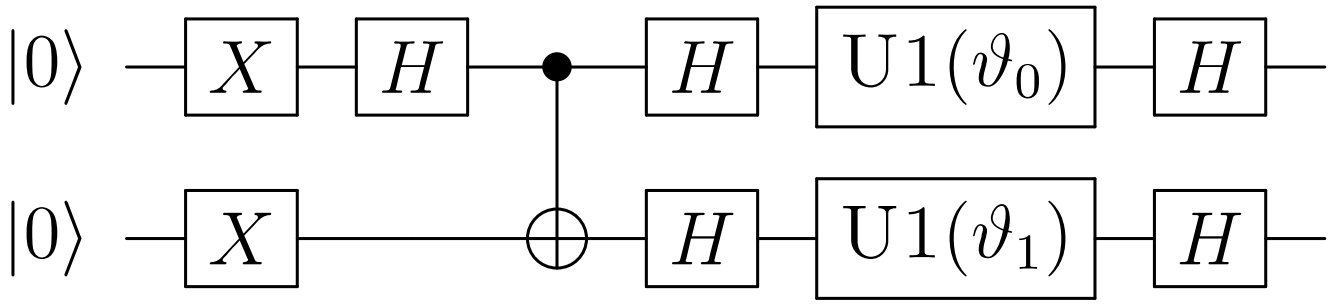


Two-Qubit State Preparation

→ Spectroscopy experiments are crucial to find good model parameters for Digital Twin Simulations (see later)

Characterization of the Singlet State



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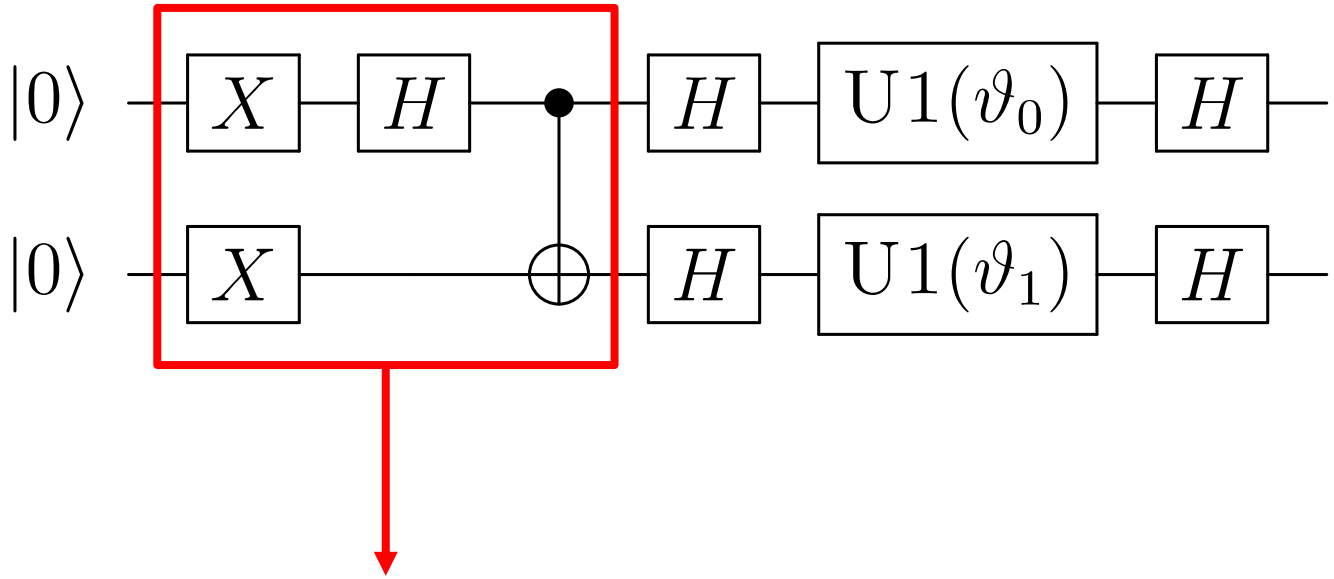

Creates the Singlet State

$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$$

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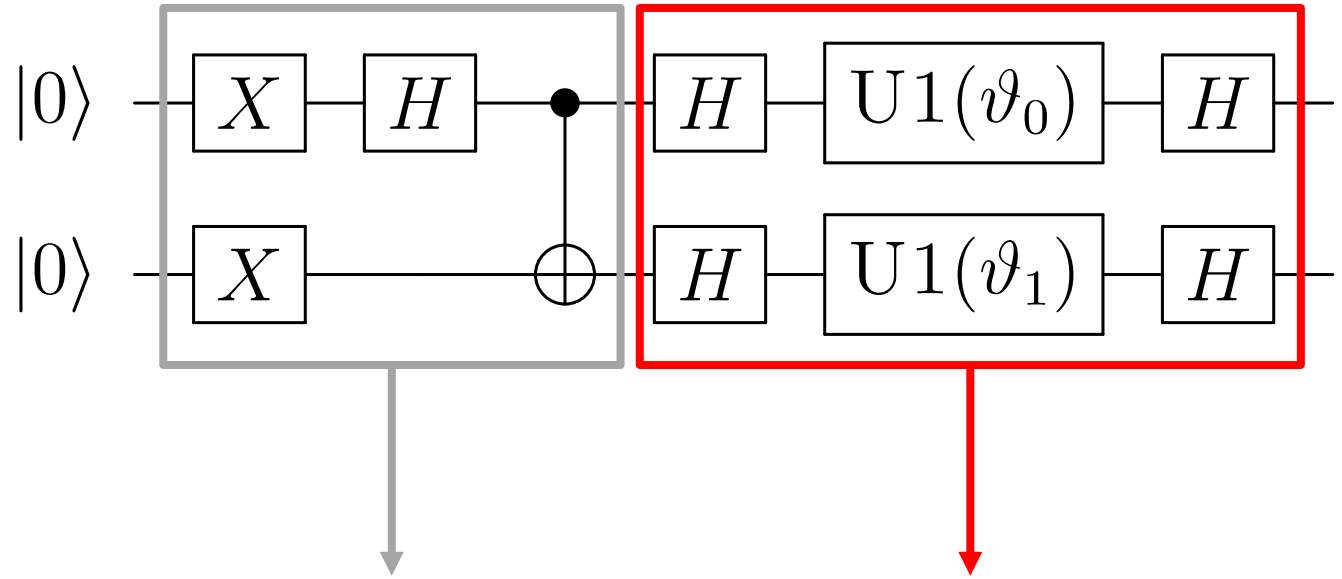

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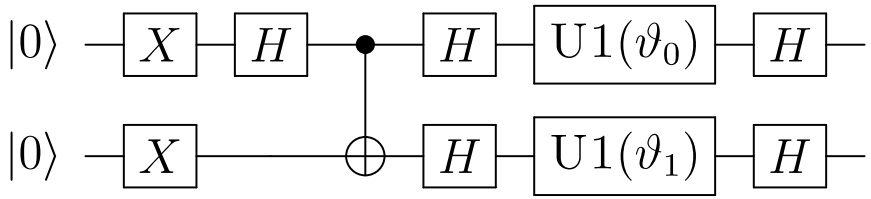
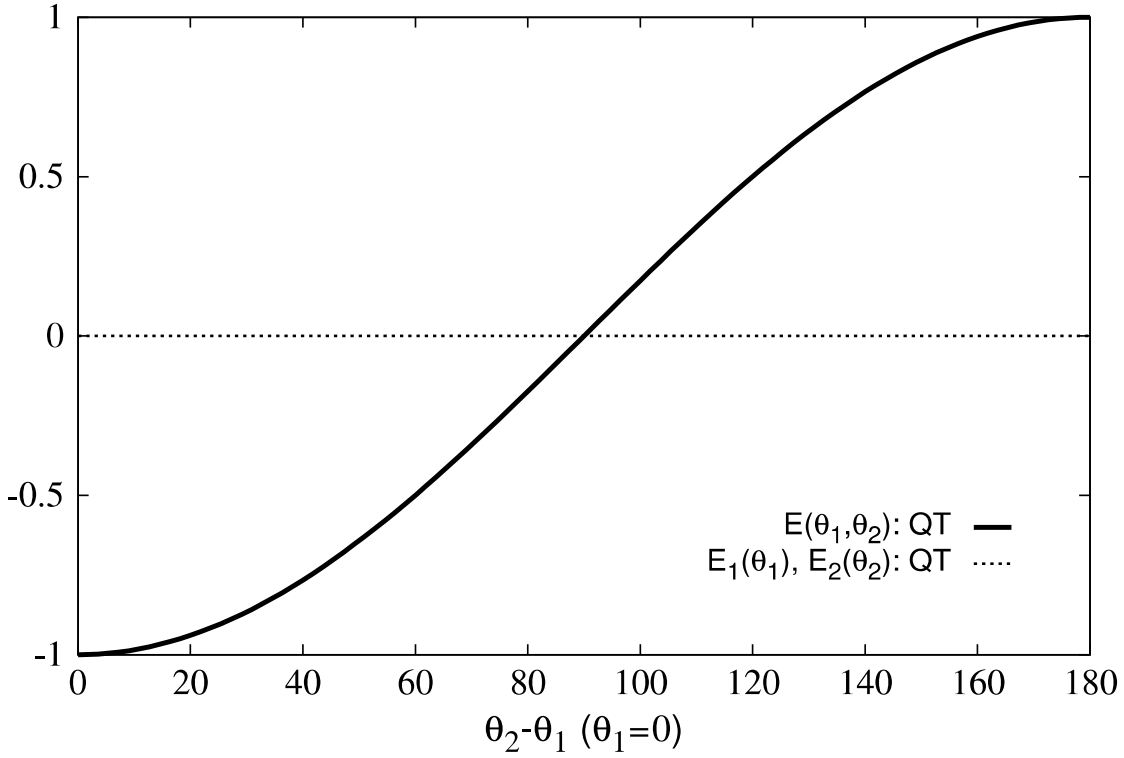
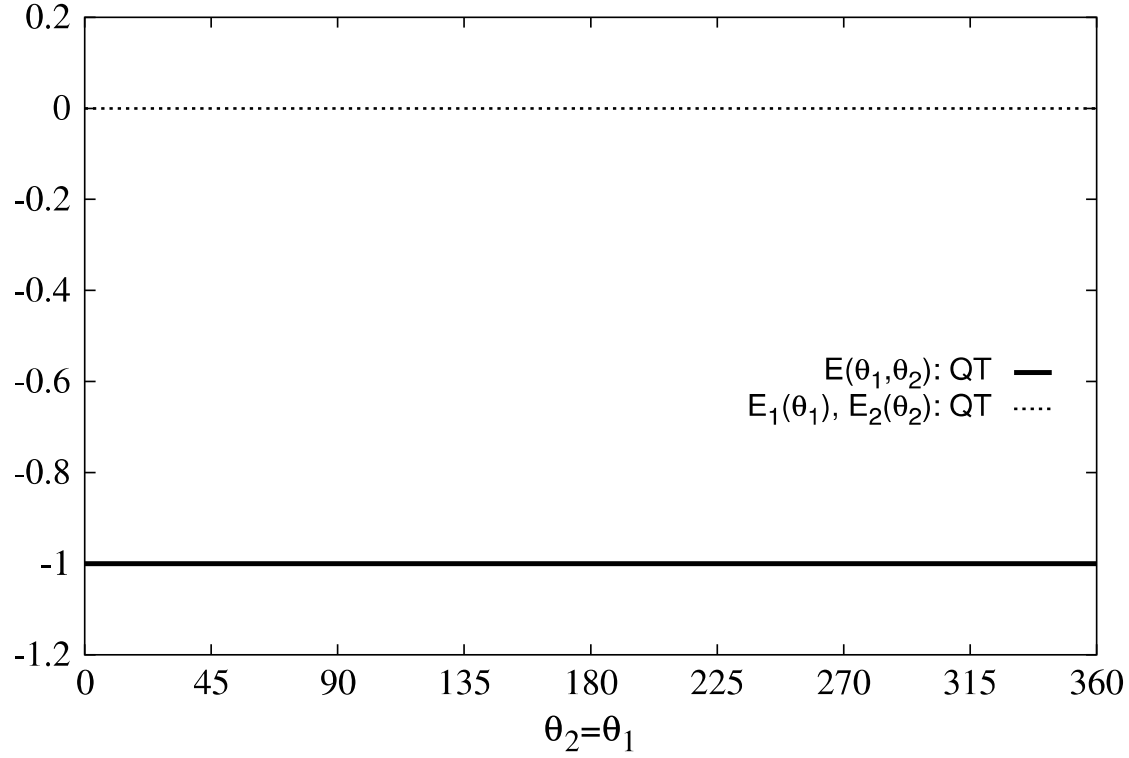
Measurement of Correlations

Characterization of the Singlet State







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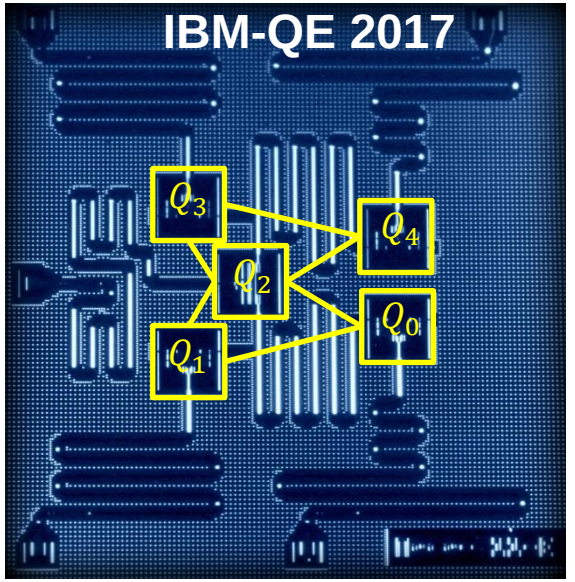

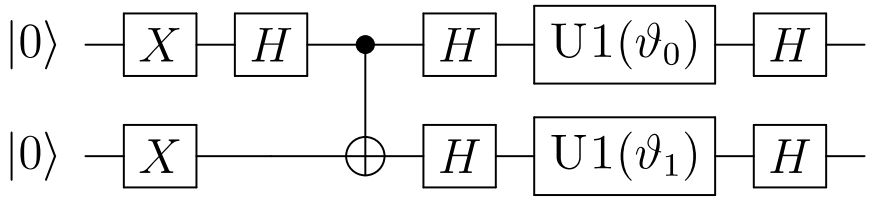

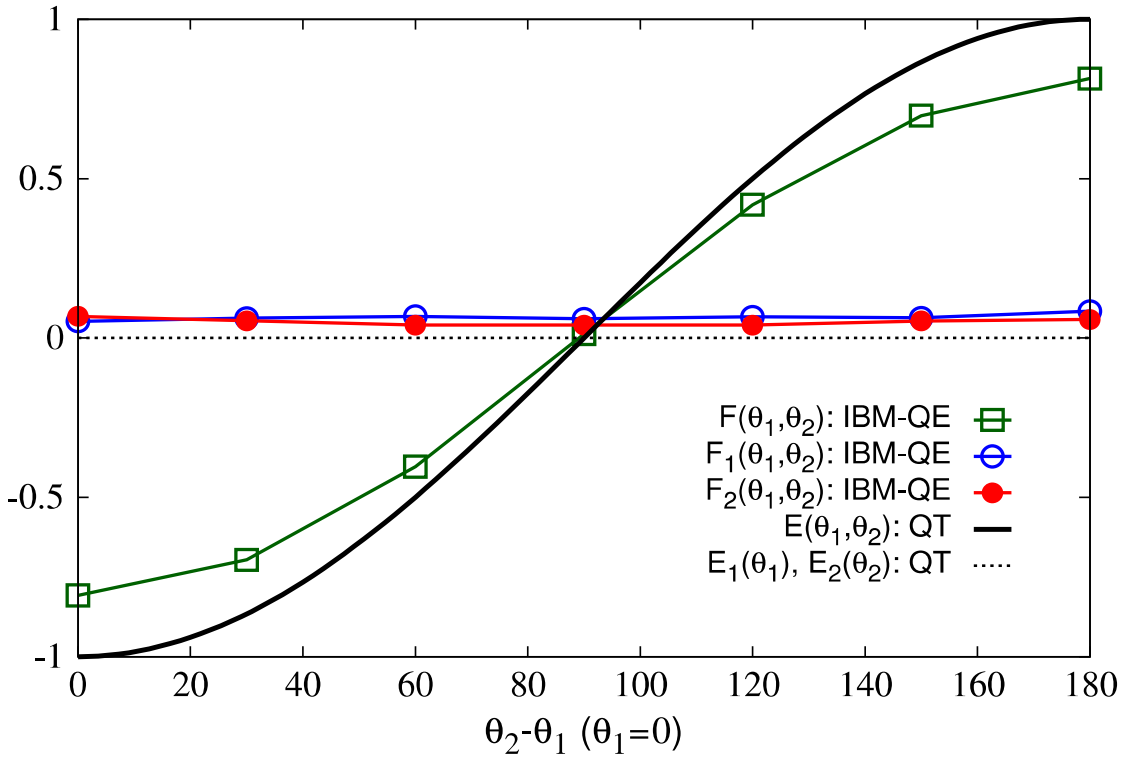

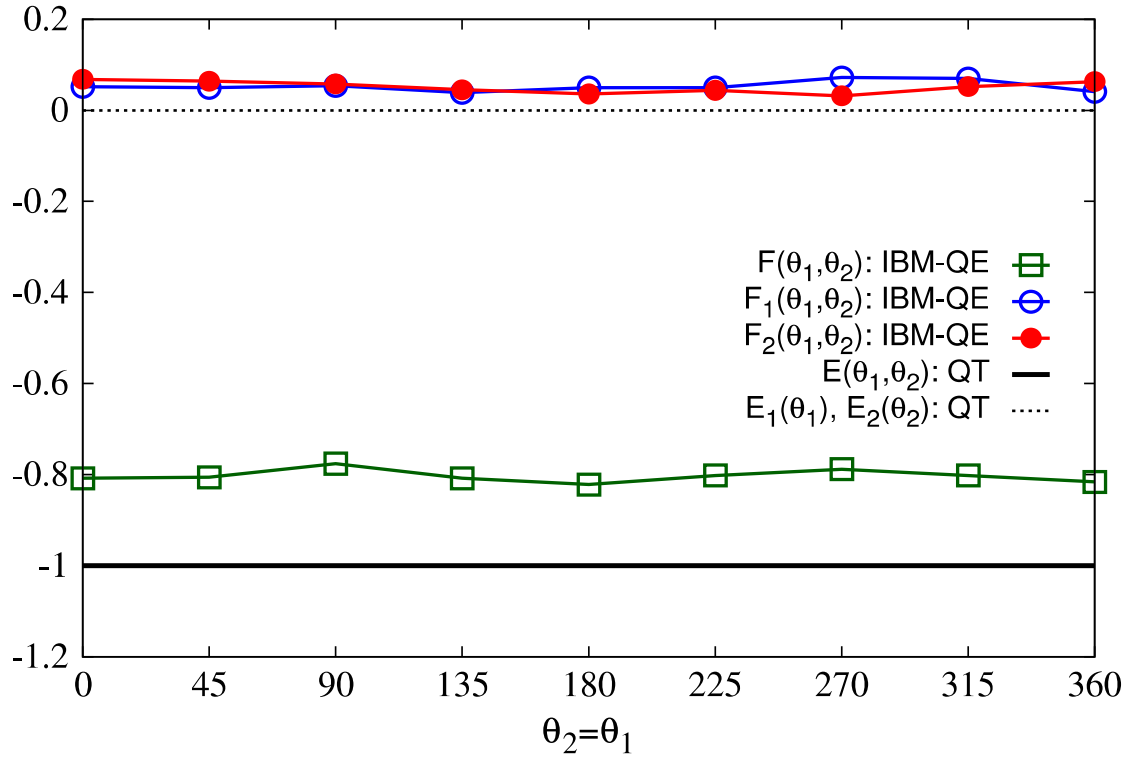

Michielsen et al., Comput. Phys. Commun. 220, 44 (2017)

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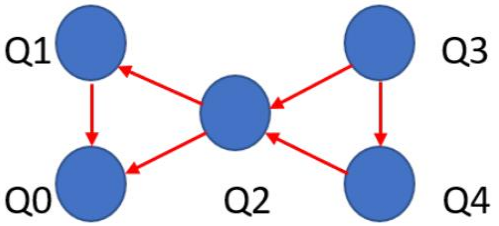
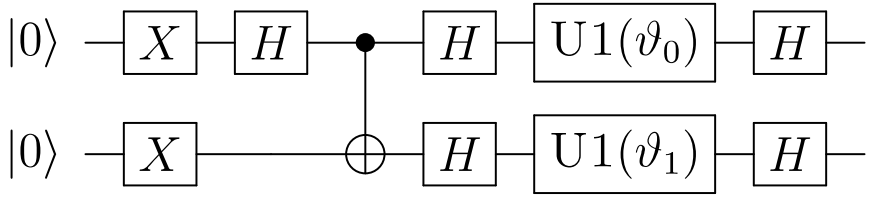
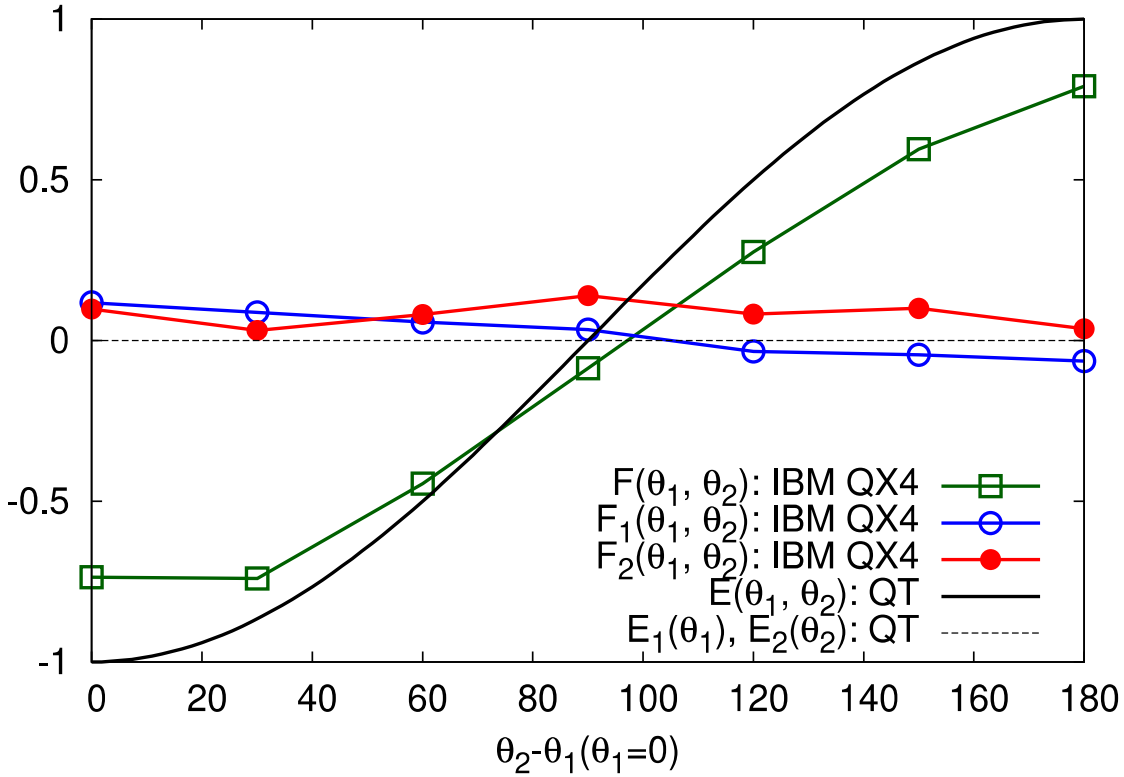
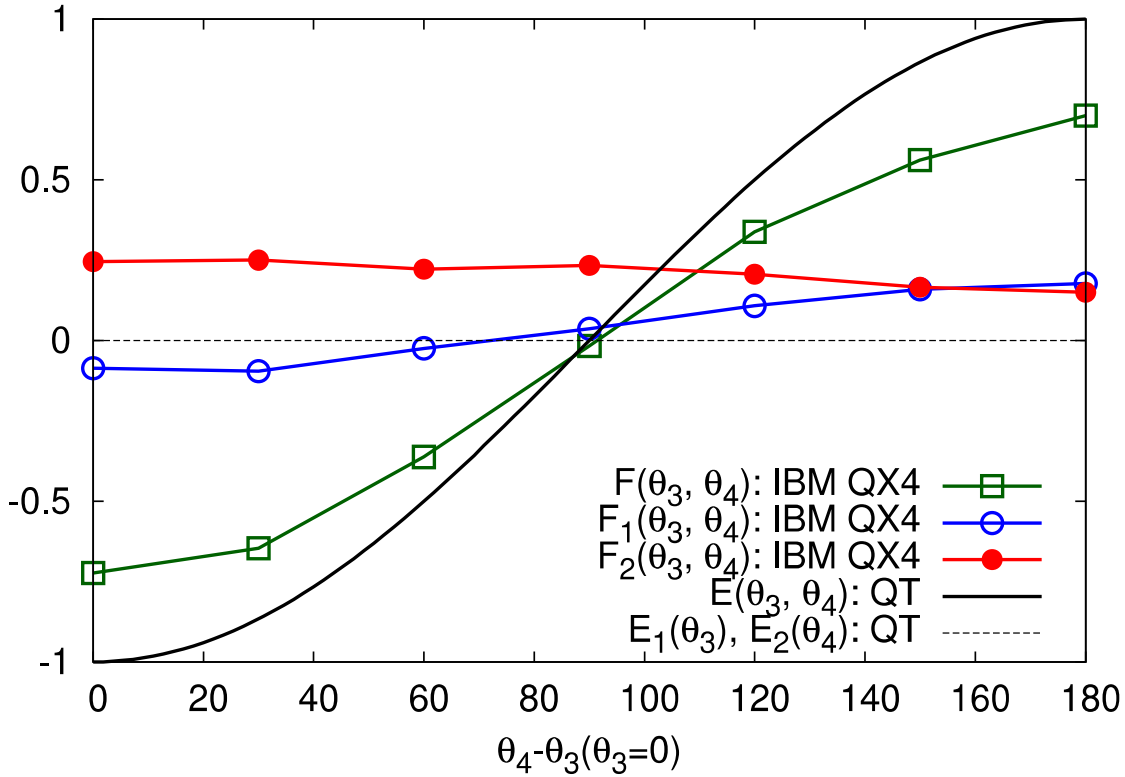


IBM QX4
2018







Michielsen et al., Adv. Parallel Comput. 34, 101 (2019)

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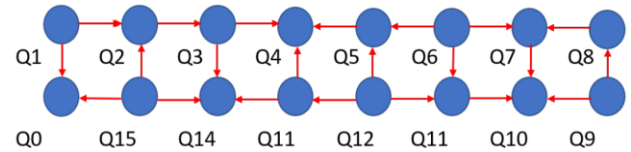
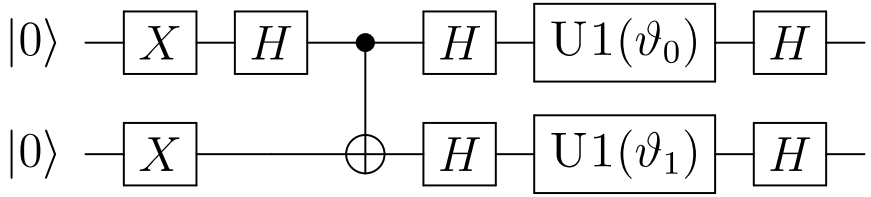
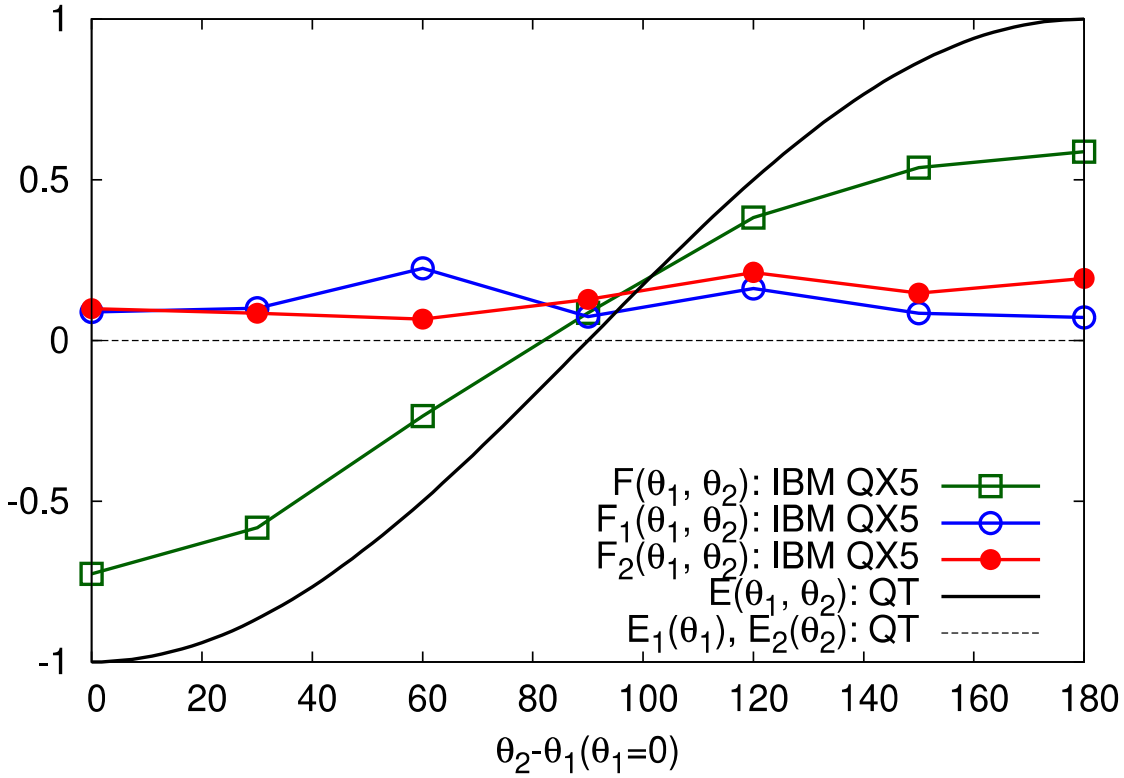
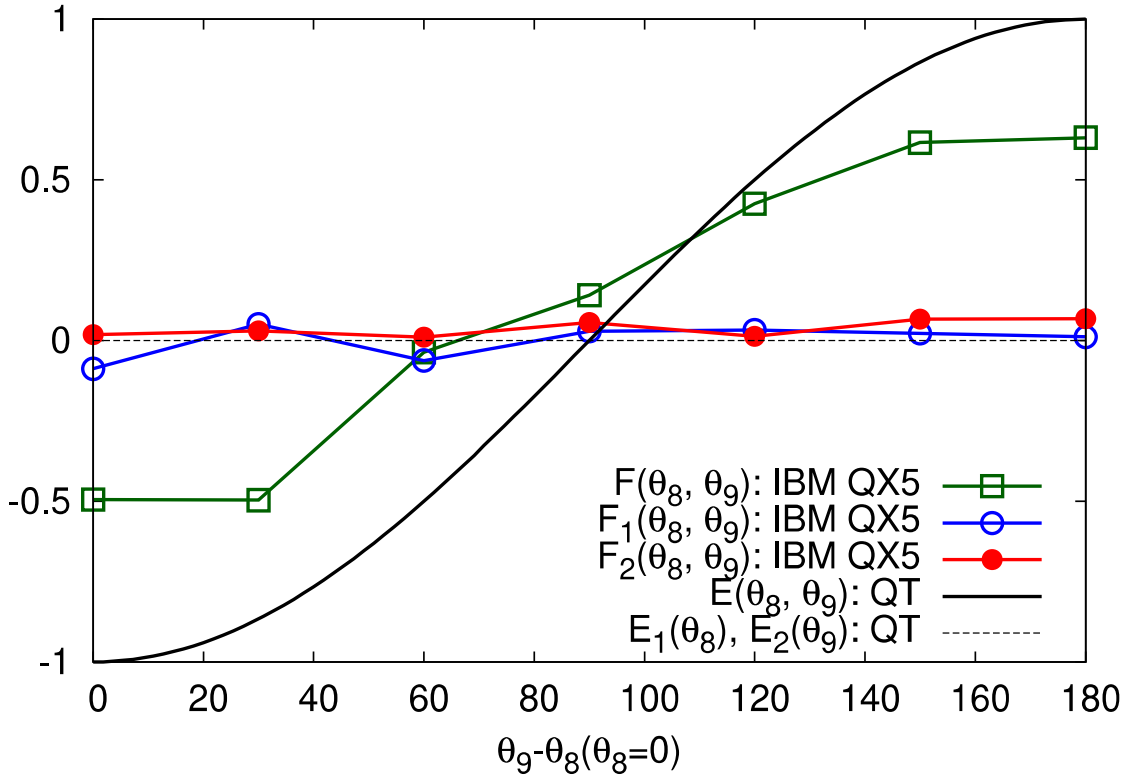


IBM QX5
2018







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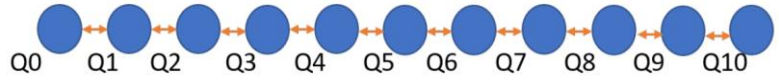

ALIBABA CAS
2018

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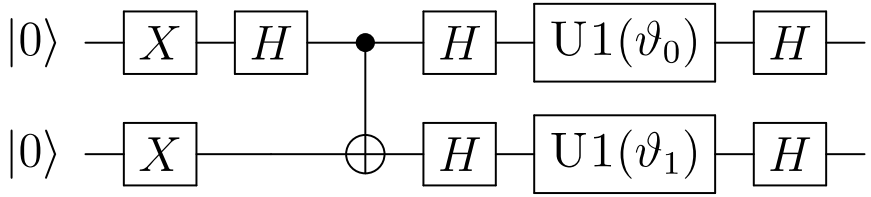

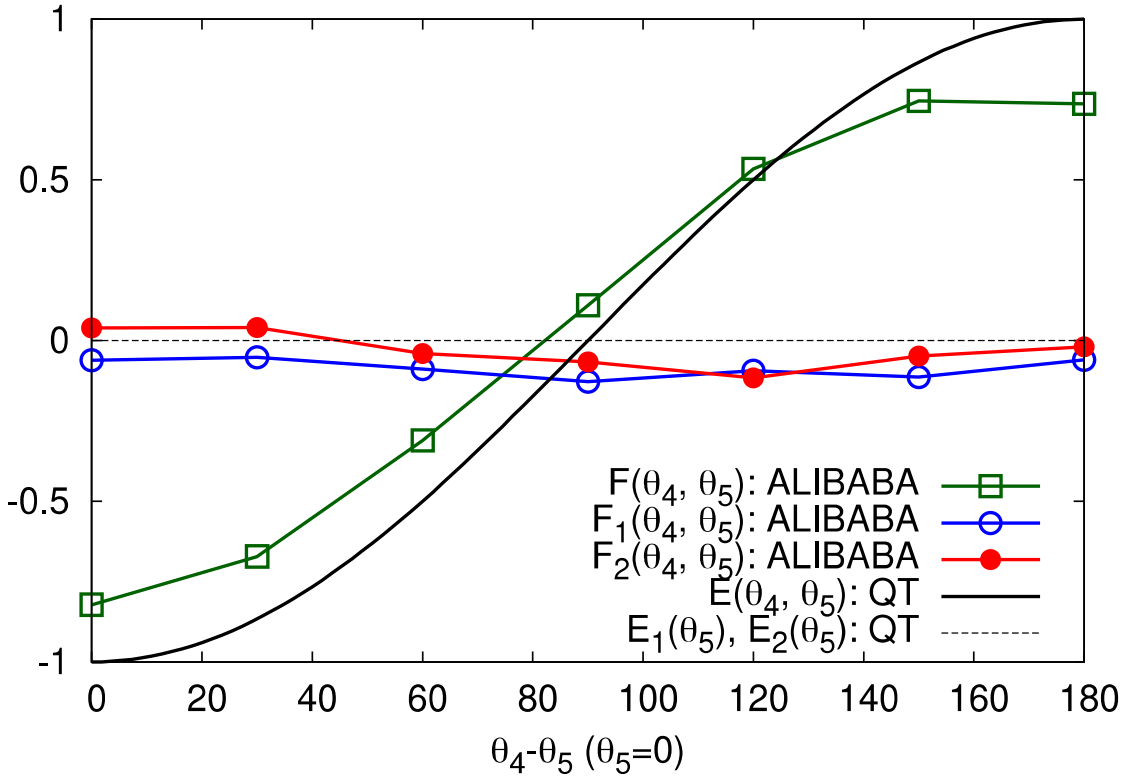

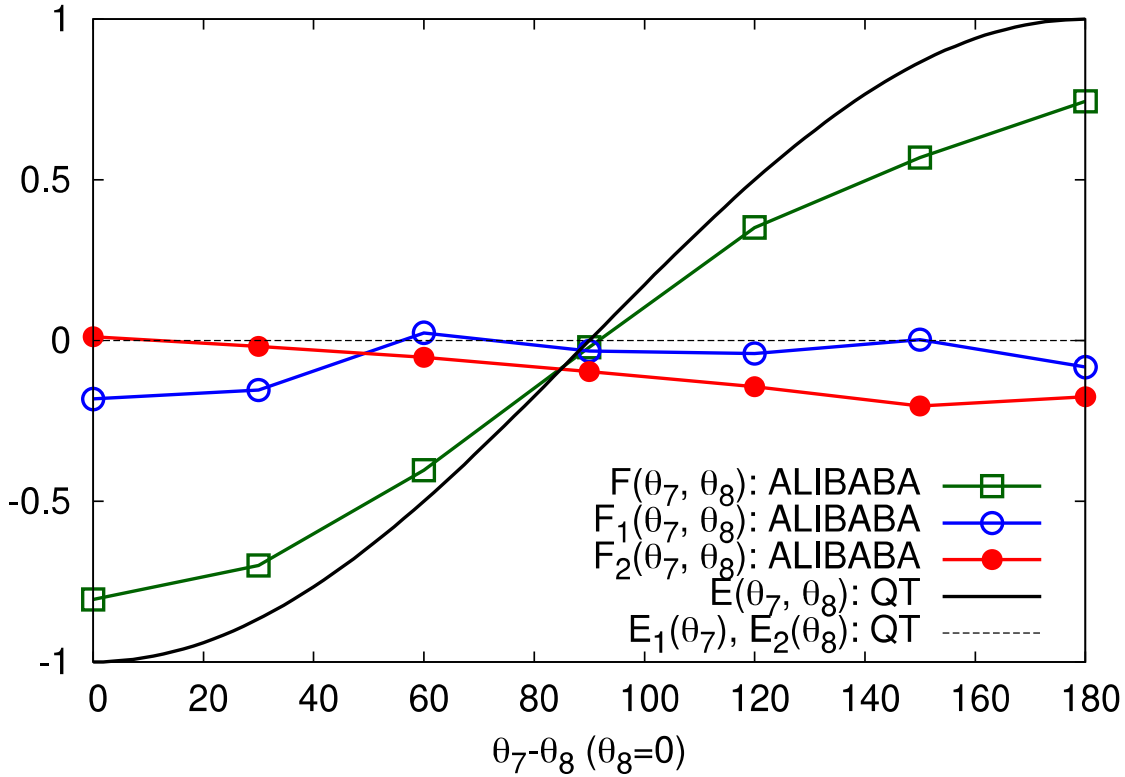

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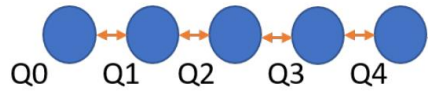
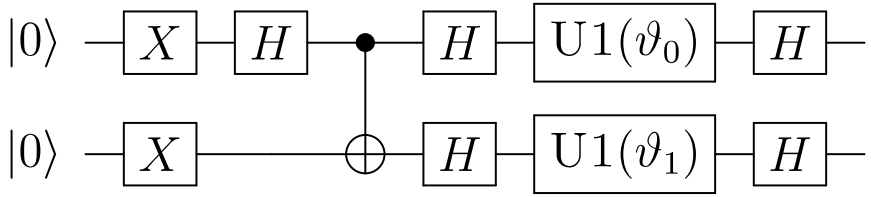
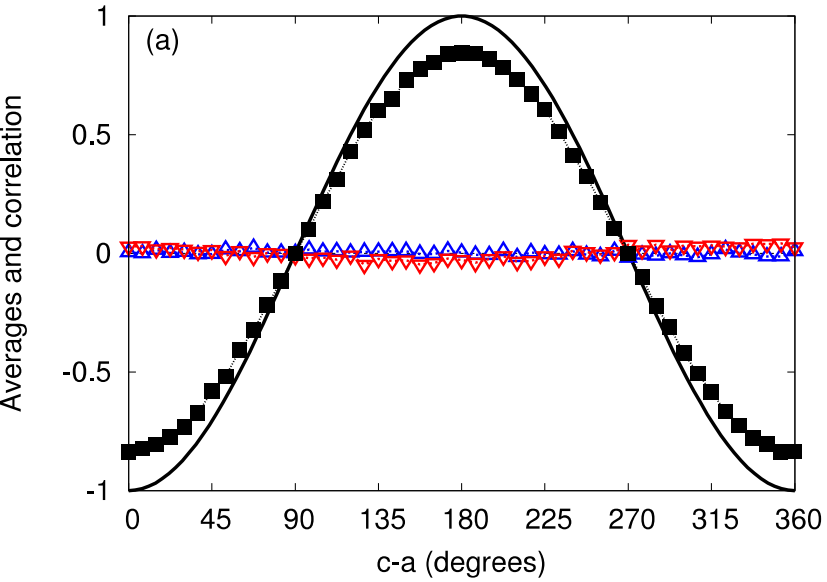


IBM Q Manila
2022

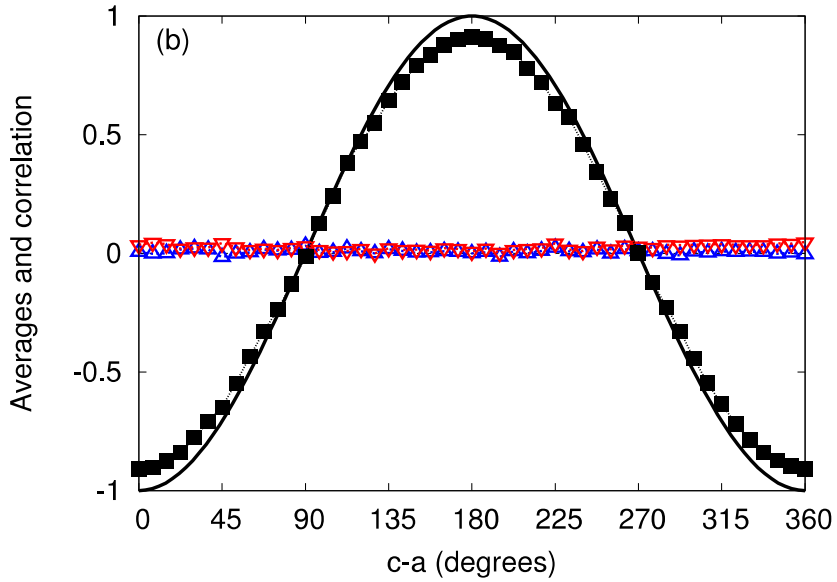
Characterization of the Singlet State



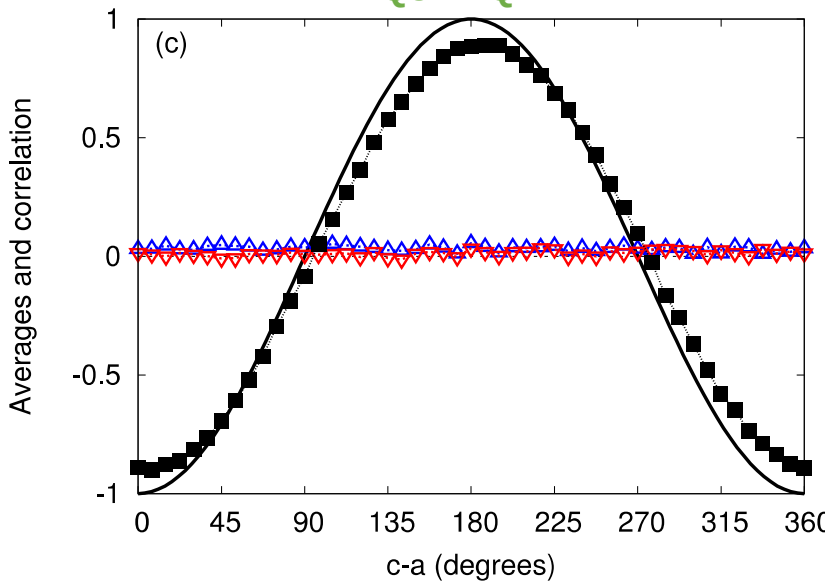
Q1 --- Q2



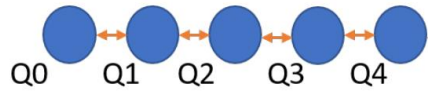
Q2 --- Q3



Q3 --- Q4



De Raedt et al., Ann. Phys. 453, 169314 (2023)



IBM Q Manila
2022

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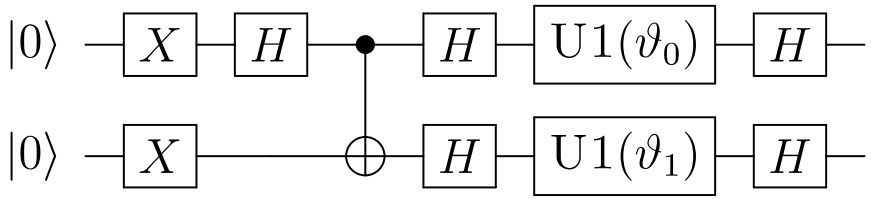

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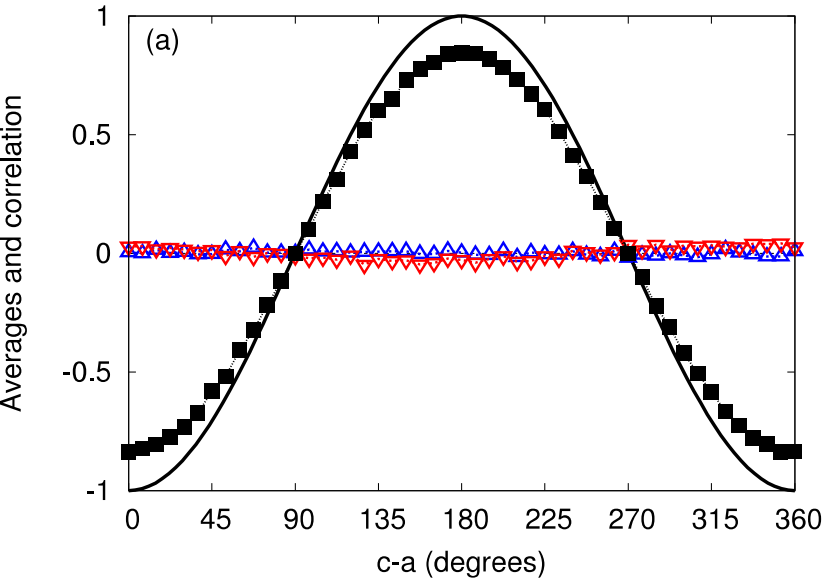
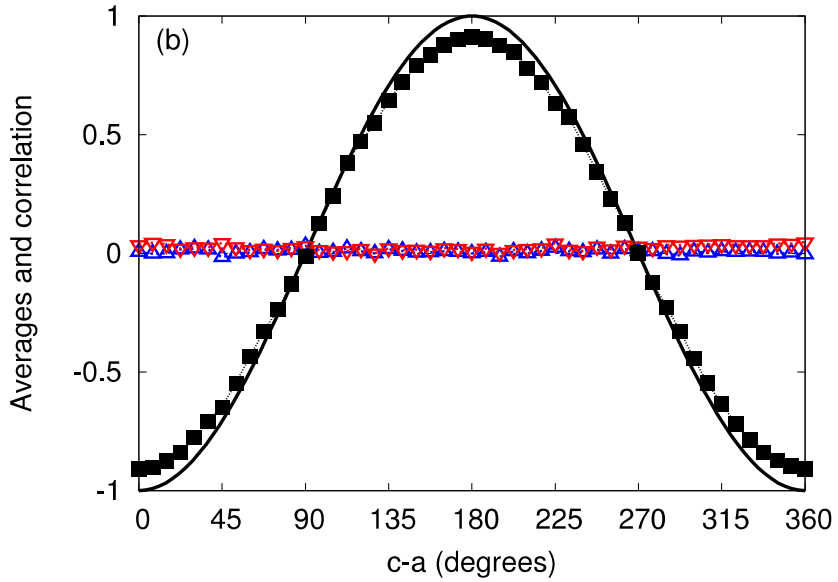
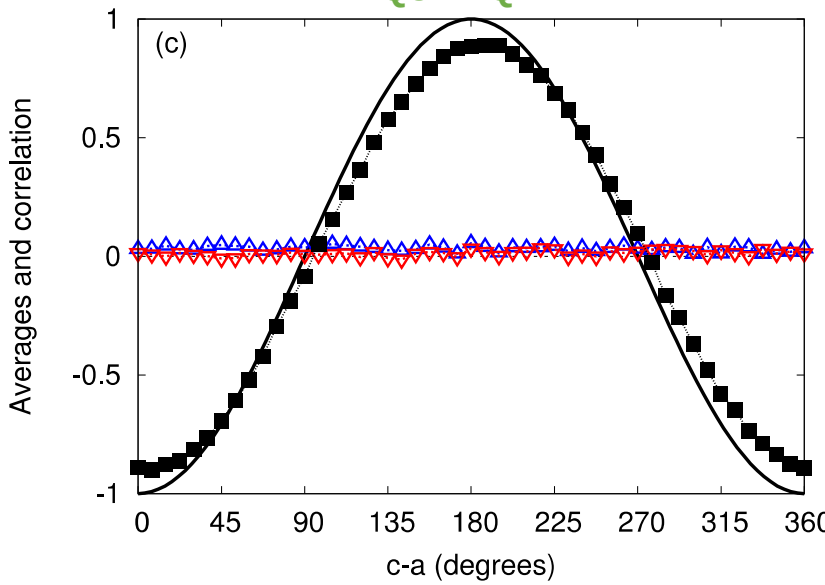


Q2 --- Q3



Q3 --- Q4



→ Very simple but informative experiment

We do have a node with preliminary results already → Discussion

De Raedt et al., Ann. Phys. 453, 169314 (2023)

Benchmark: Device Comparison

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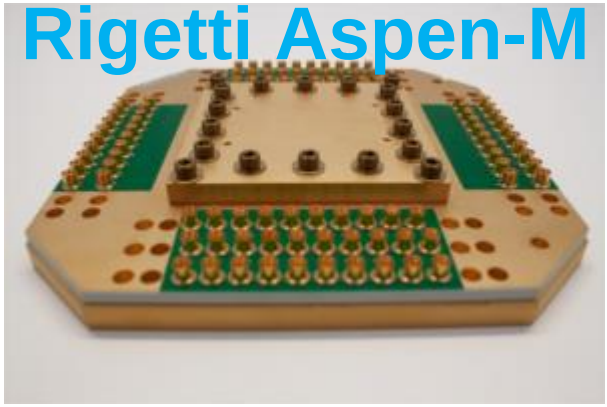

Montanez-Barrera et al., arXiv:2305.18757 (2023)

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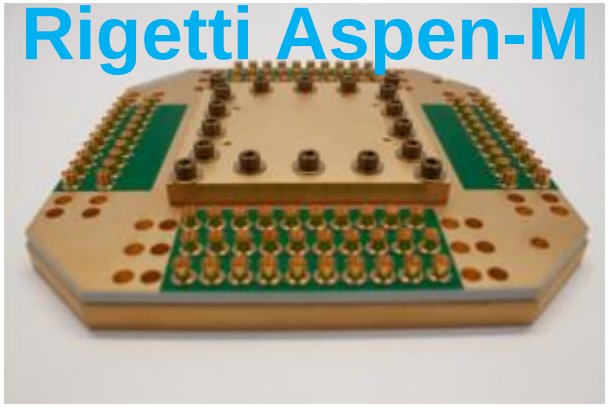

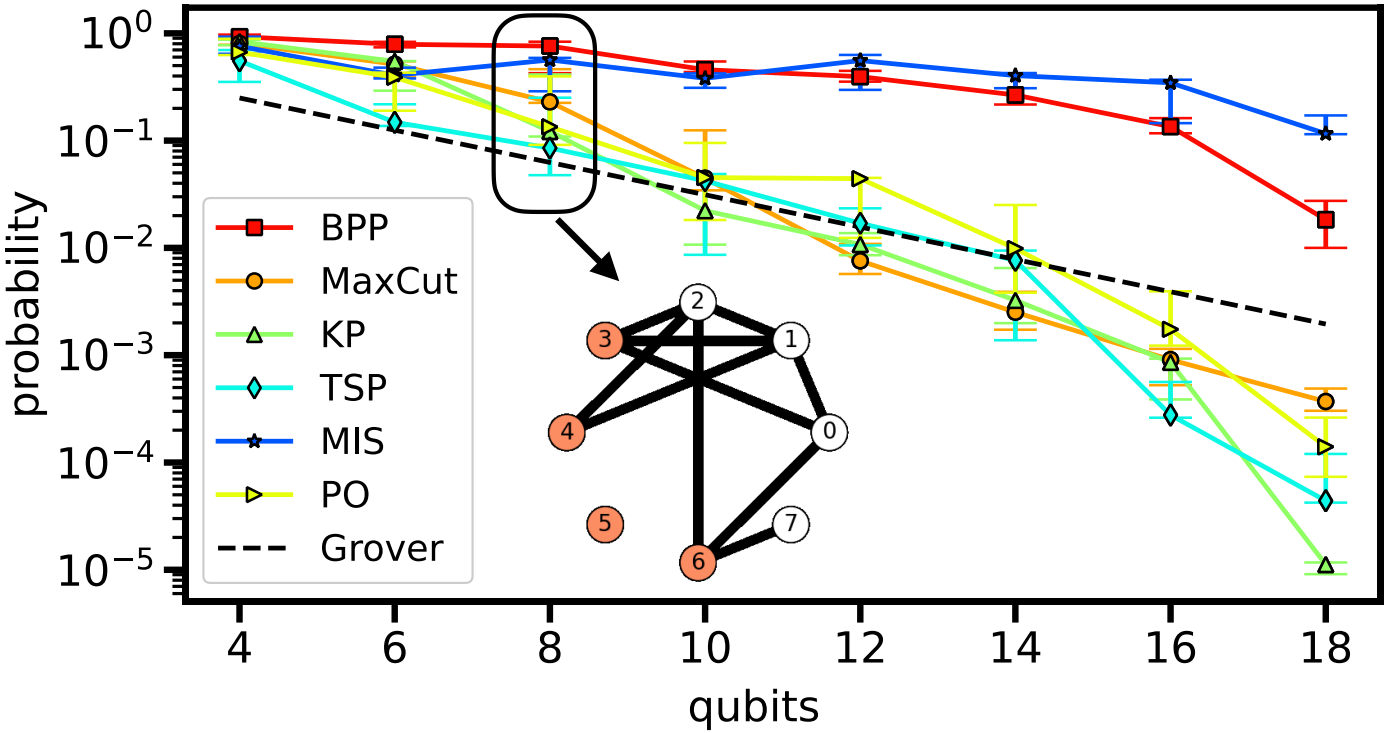

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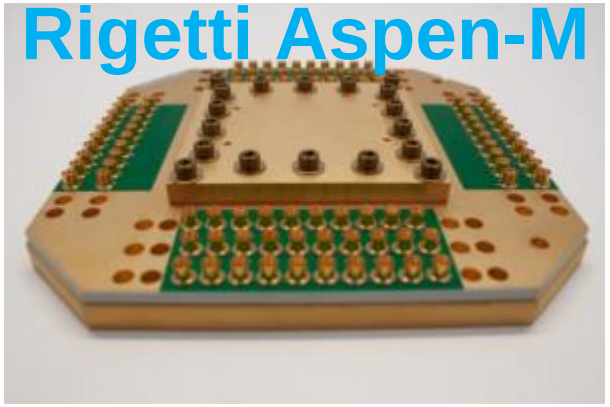

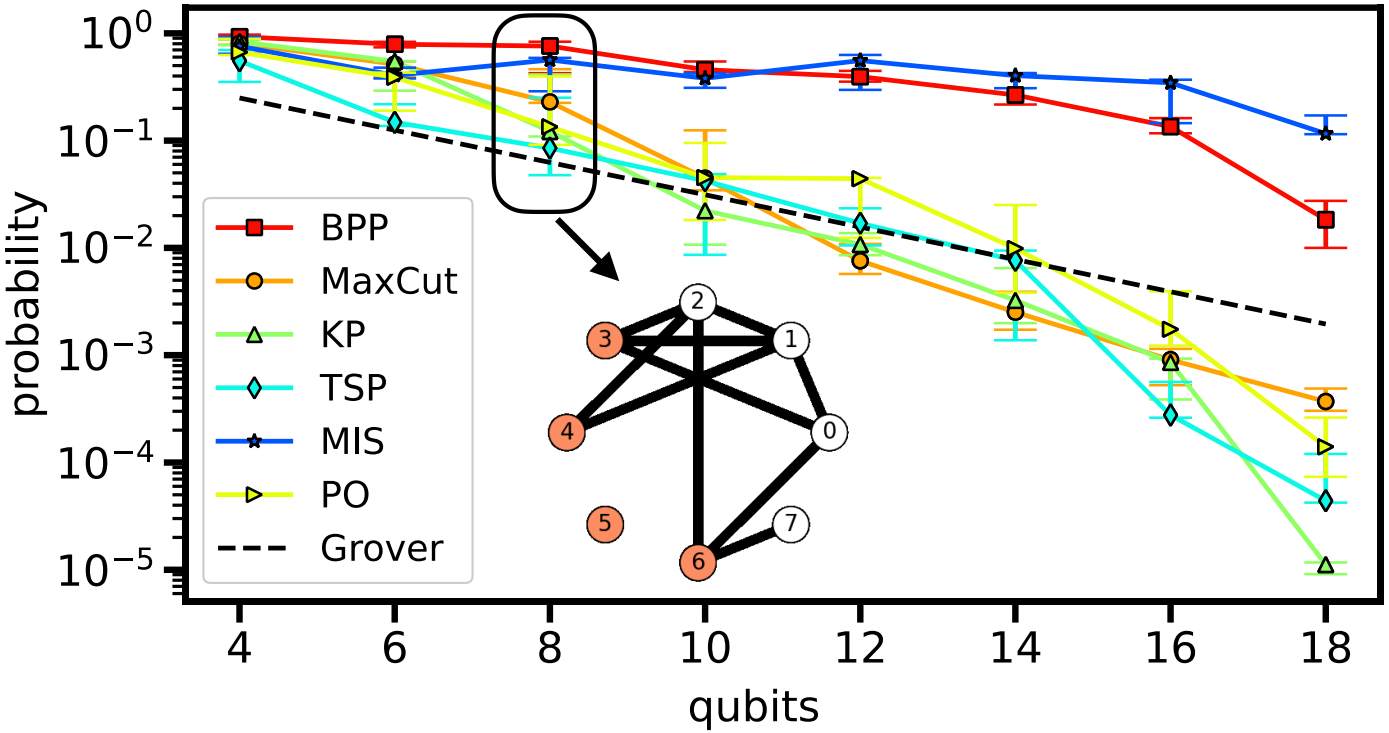

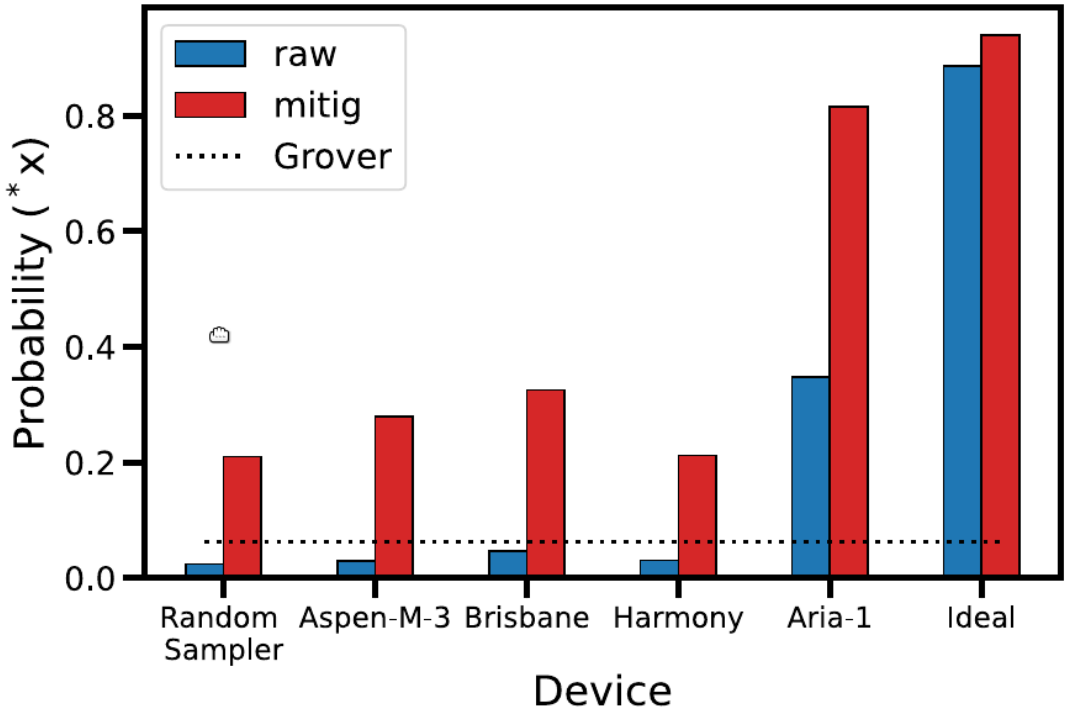

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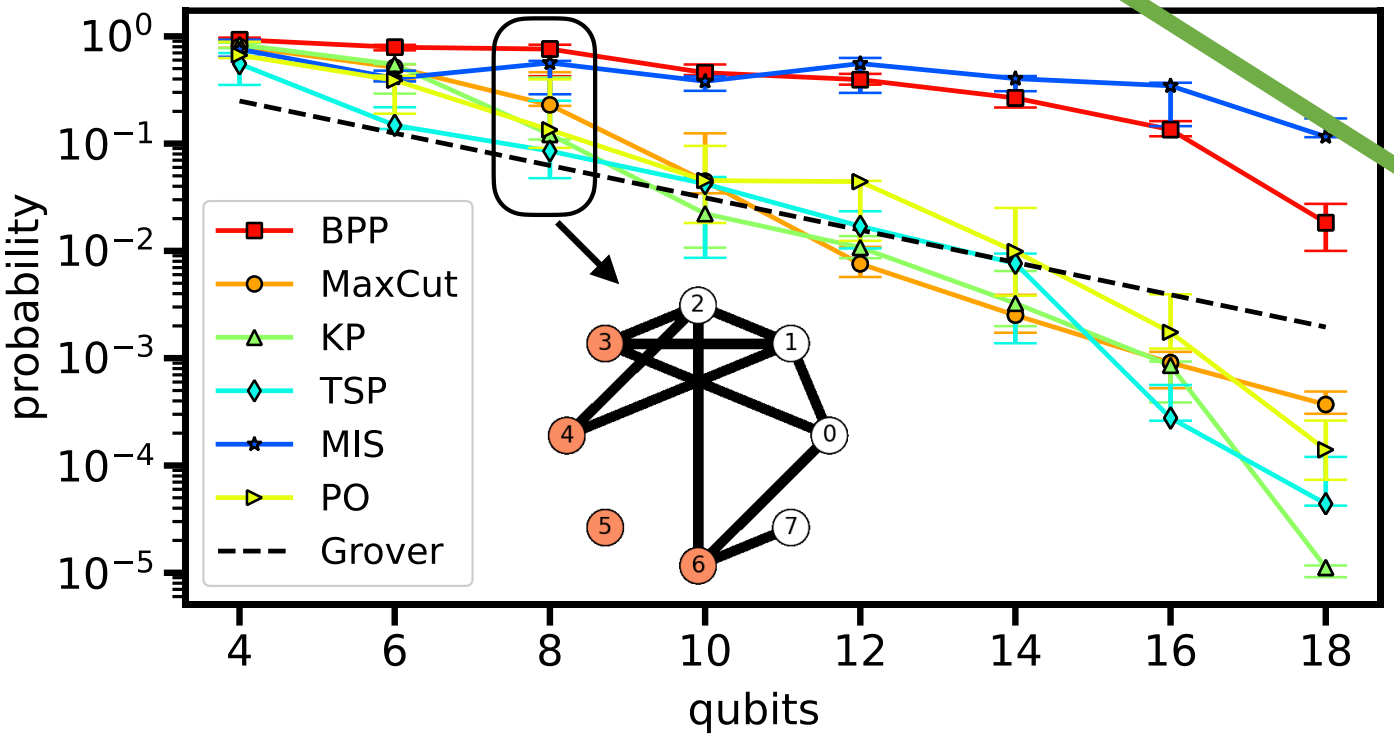

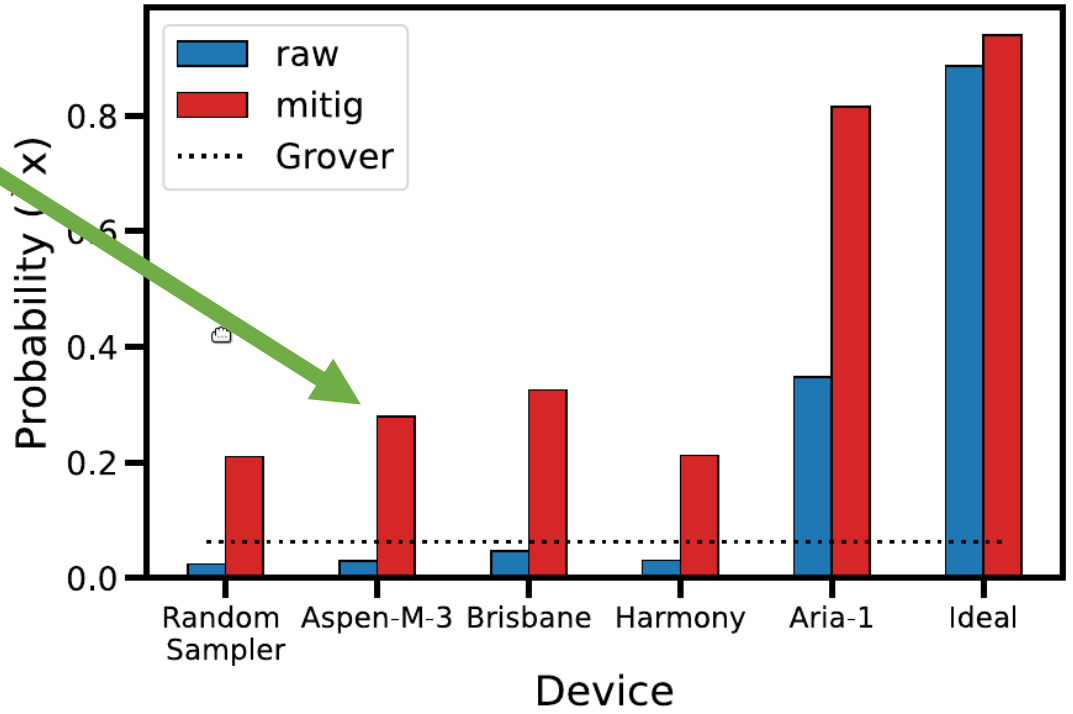

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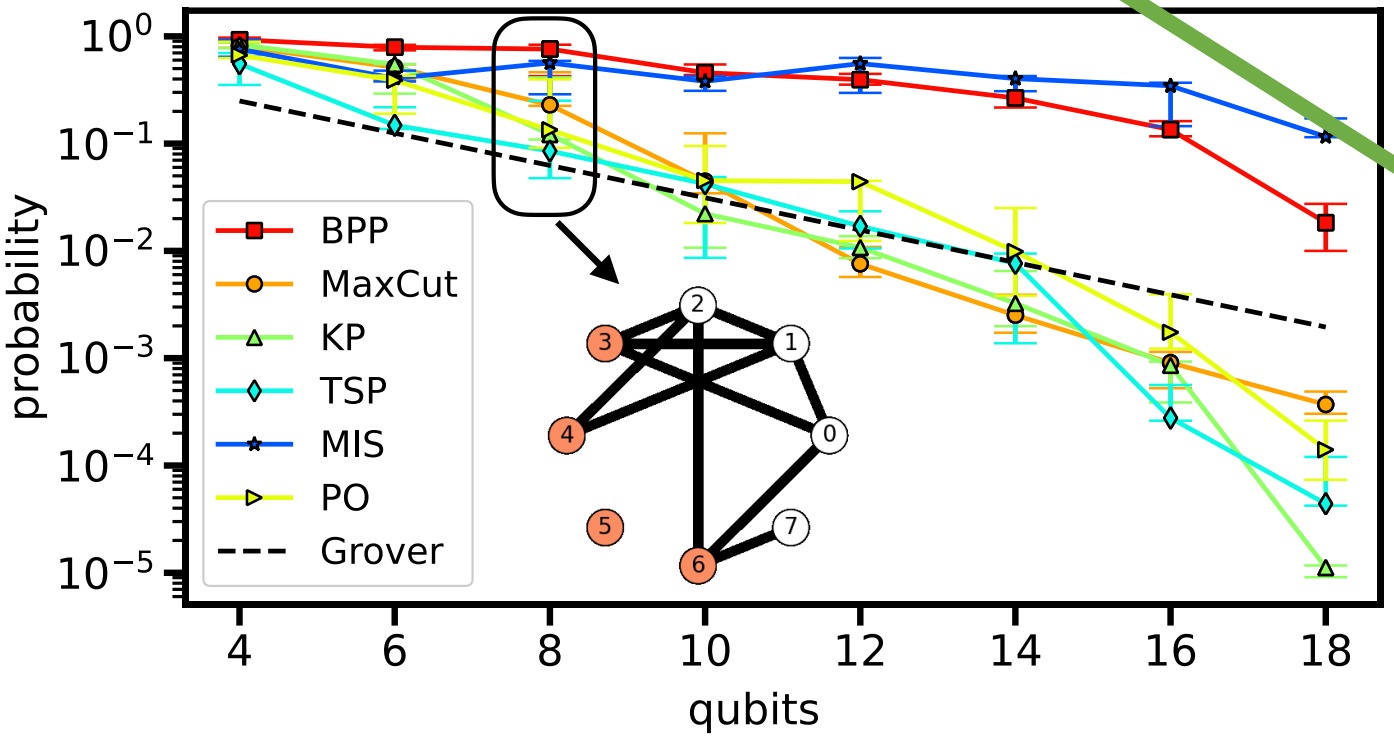

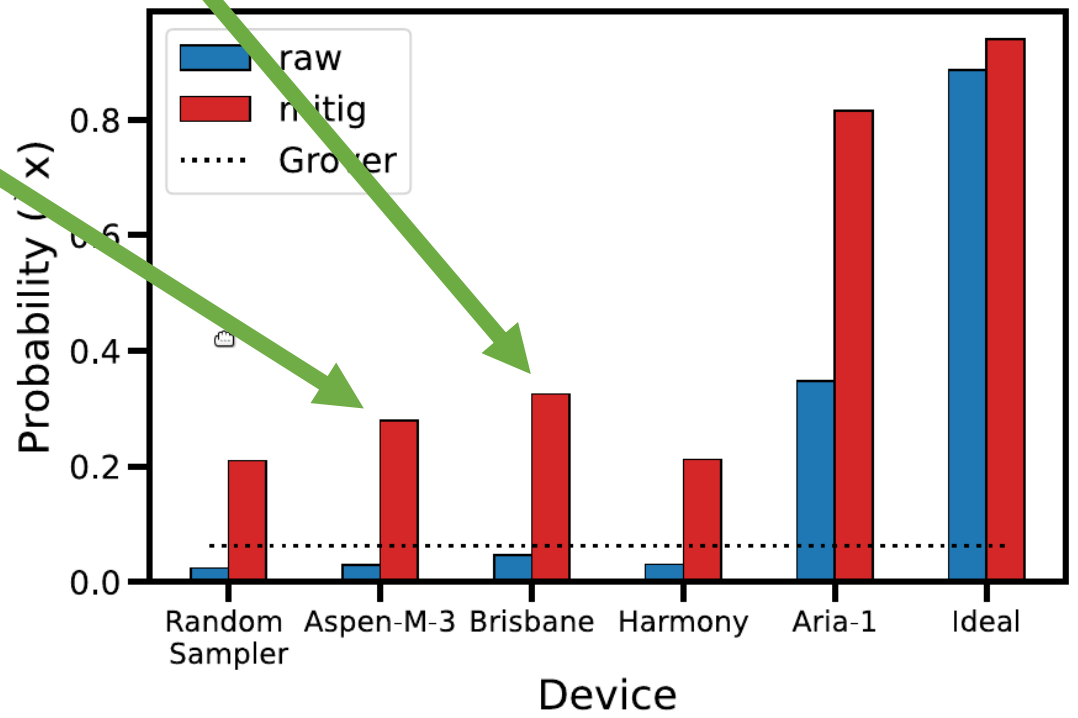

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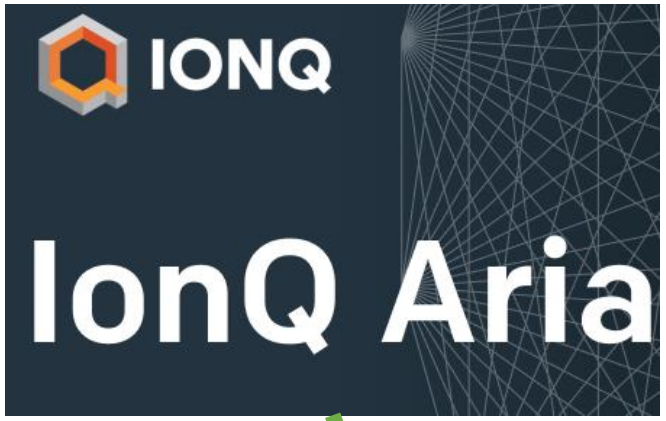

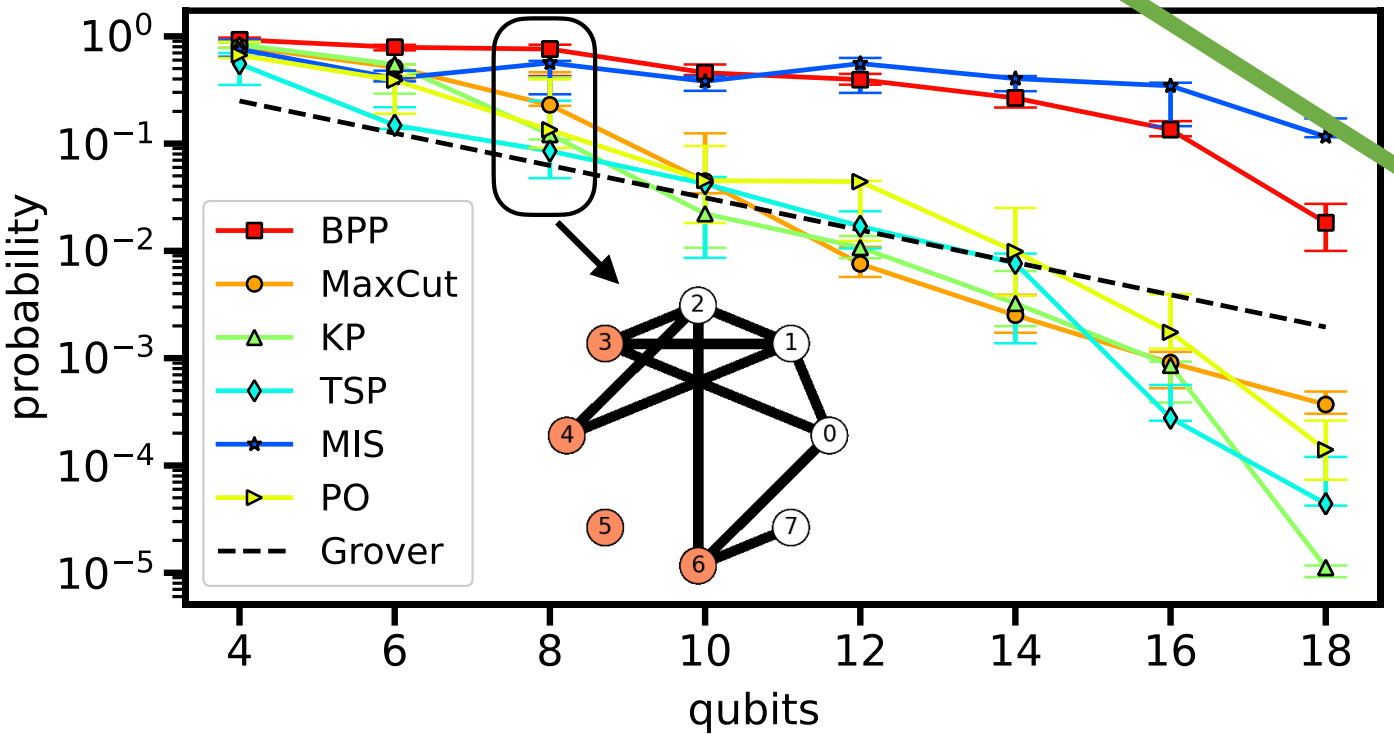

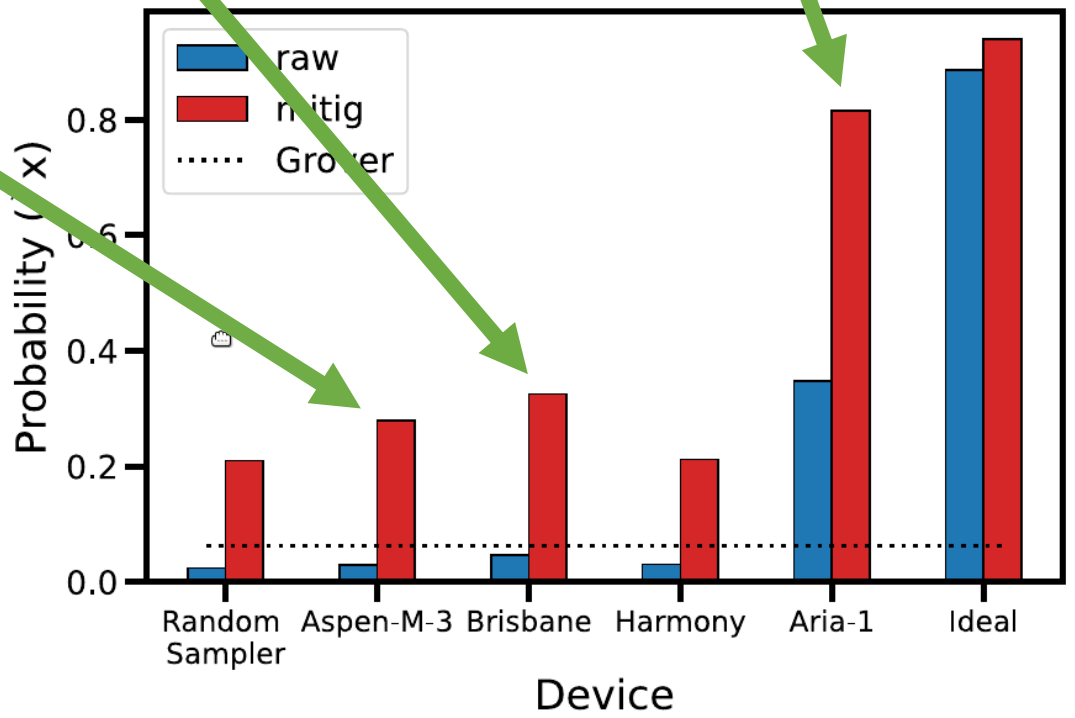

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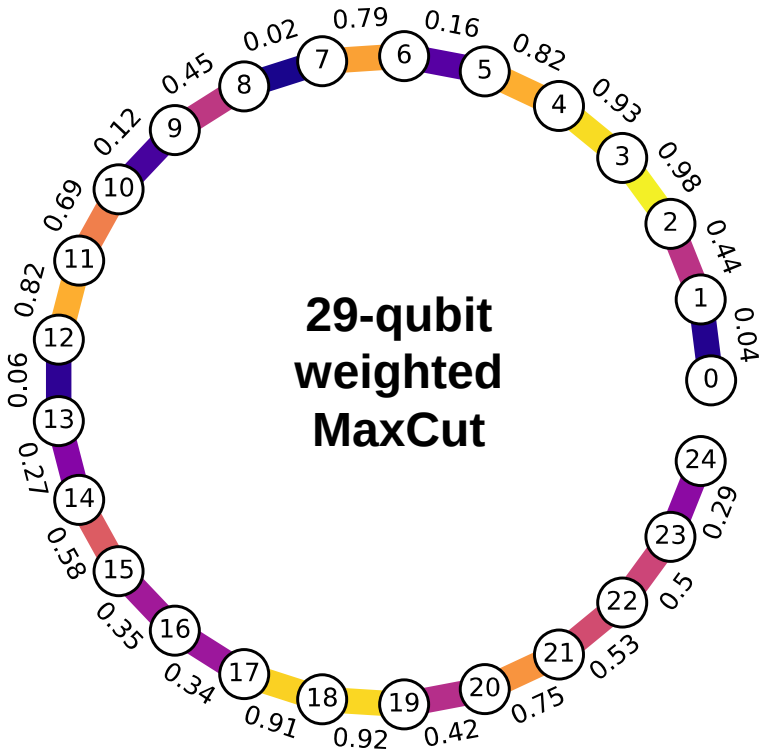
Benchmark: Device Comparison

Credit: Alejandro Montanez-Barrera (JSC)

Benchmark: Device Comparison



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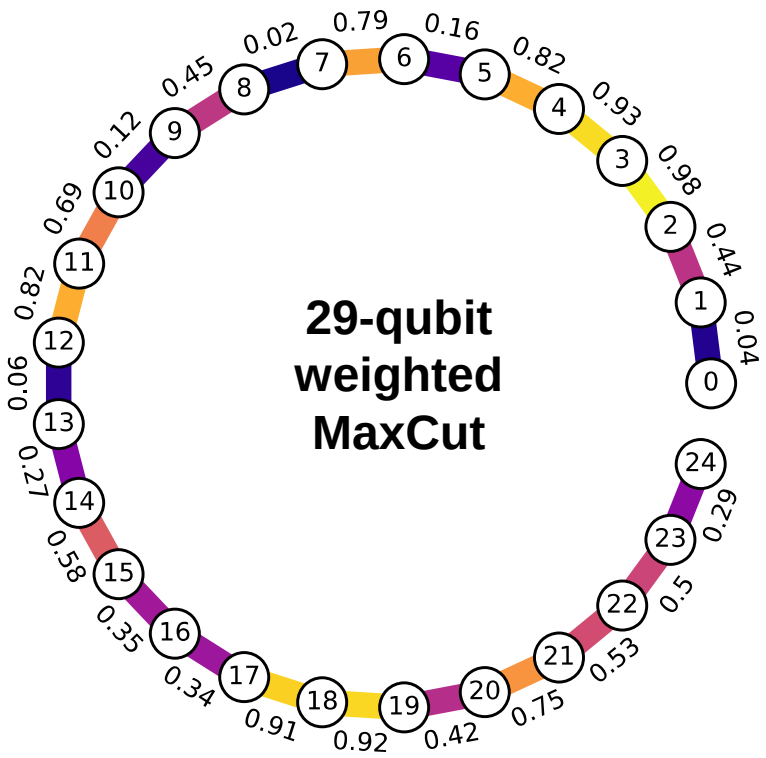

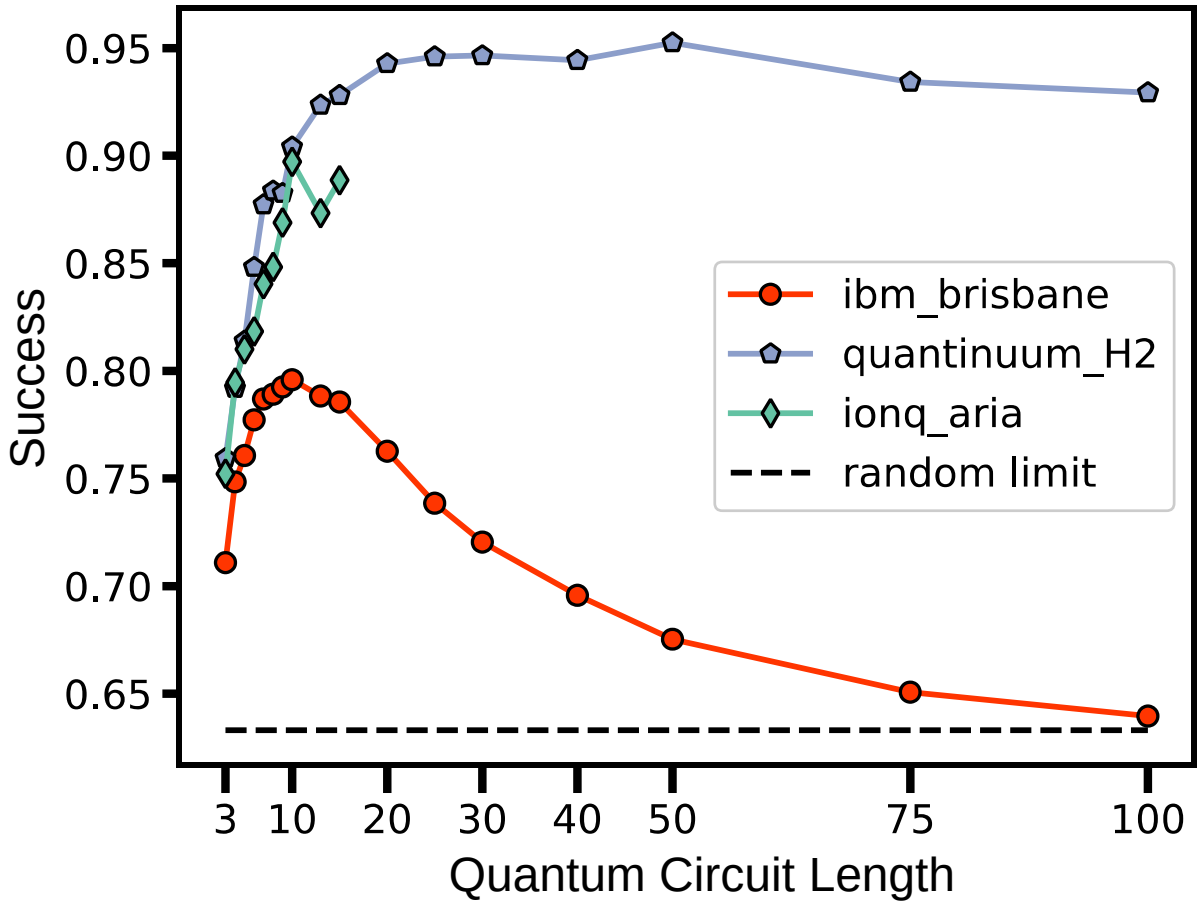

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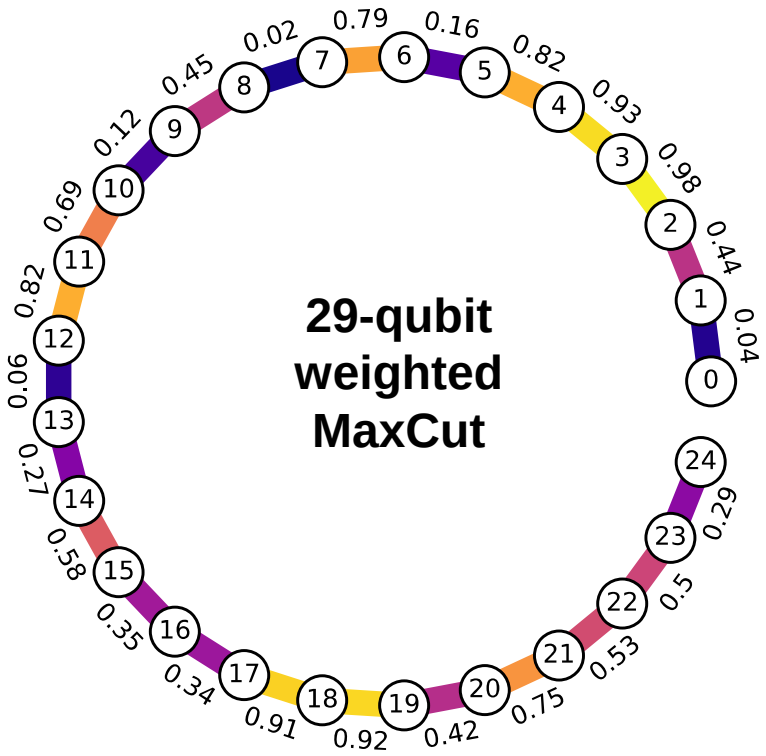

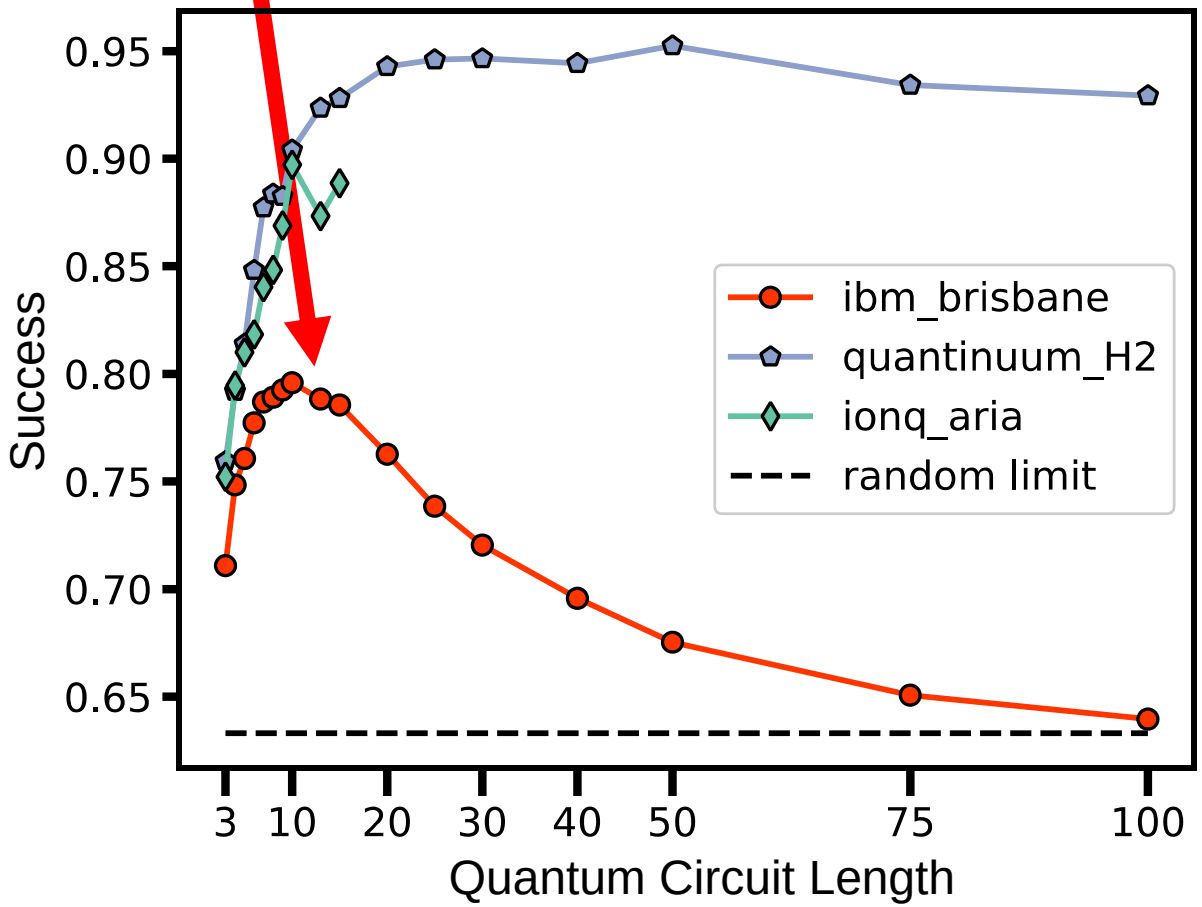

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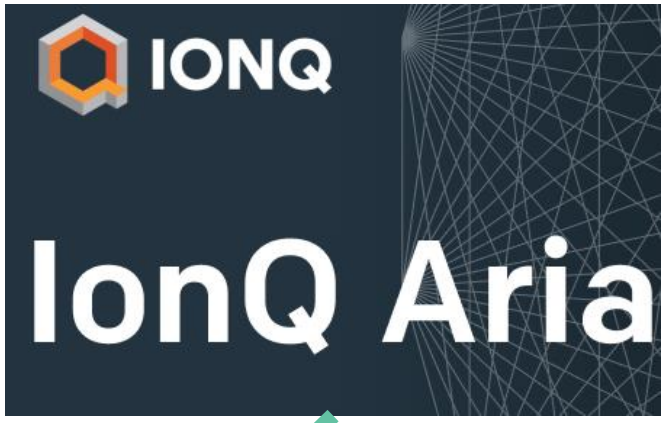

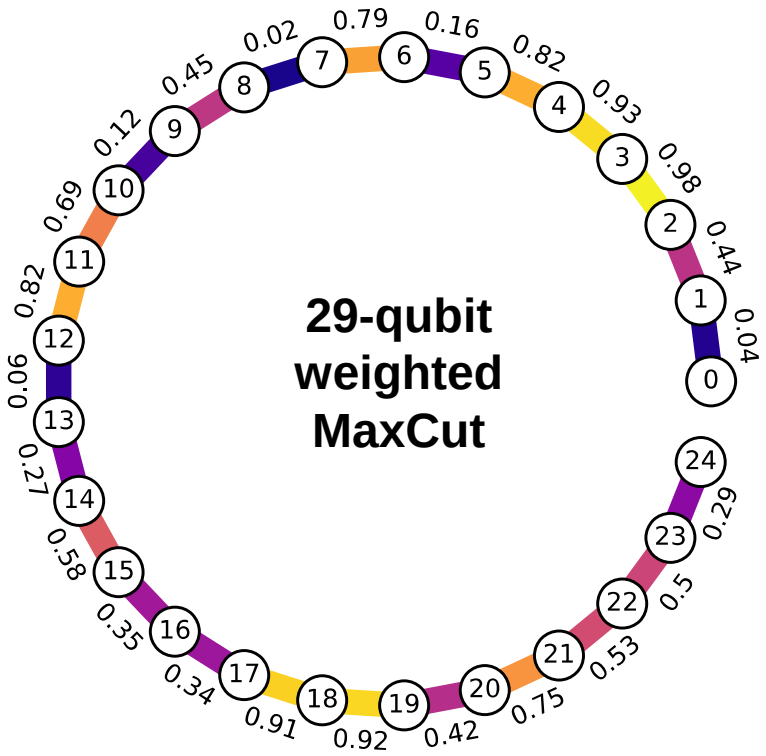

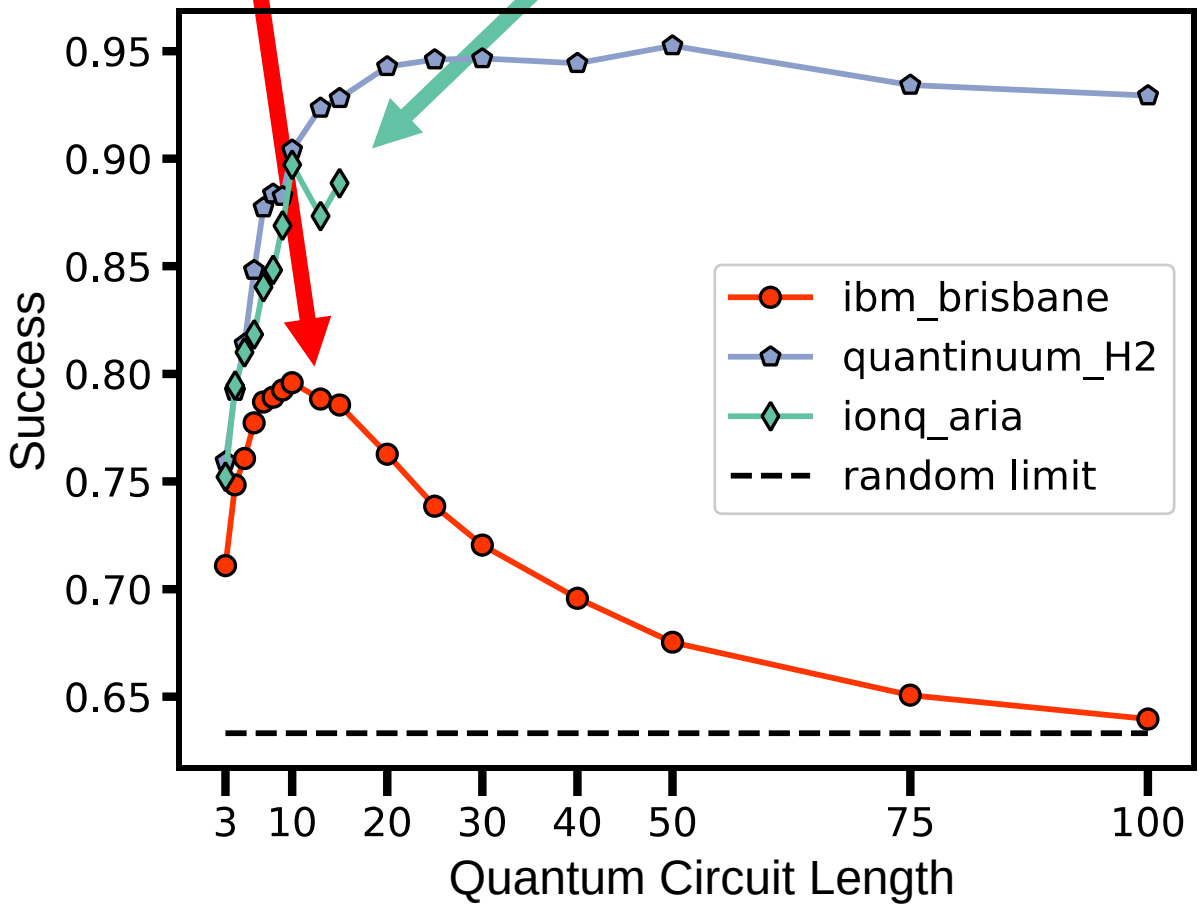

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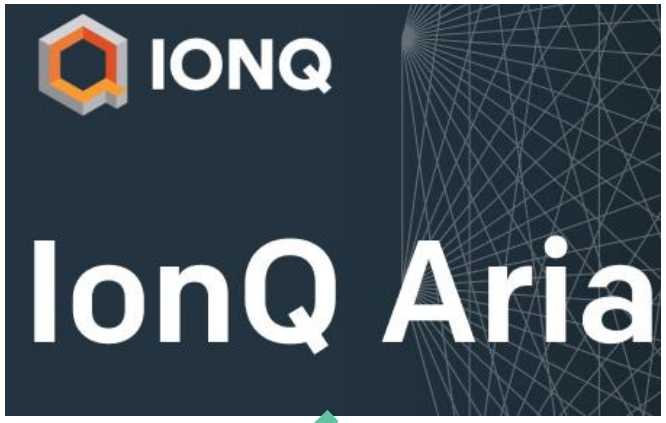

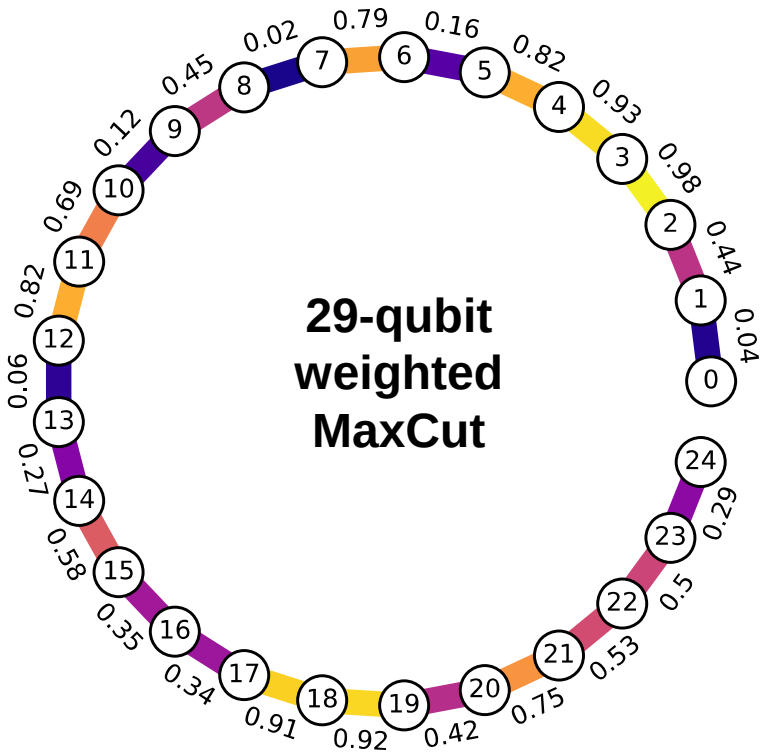

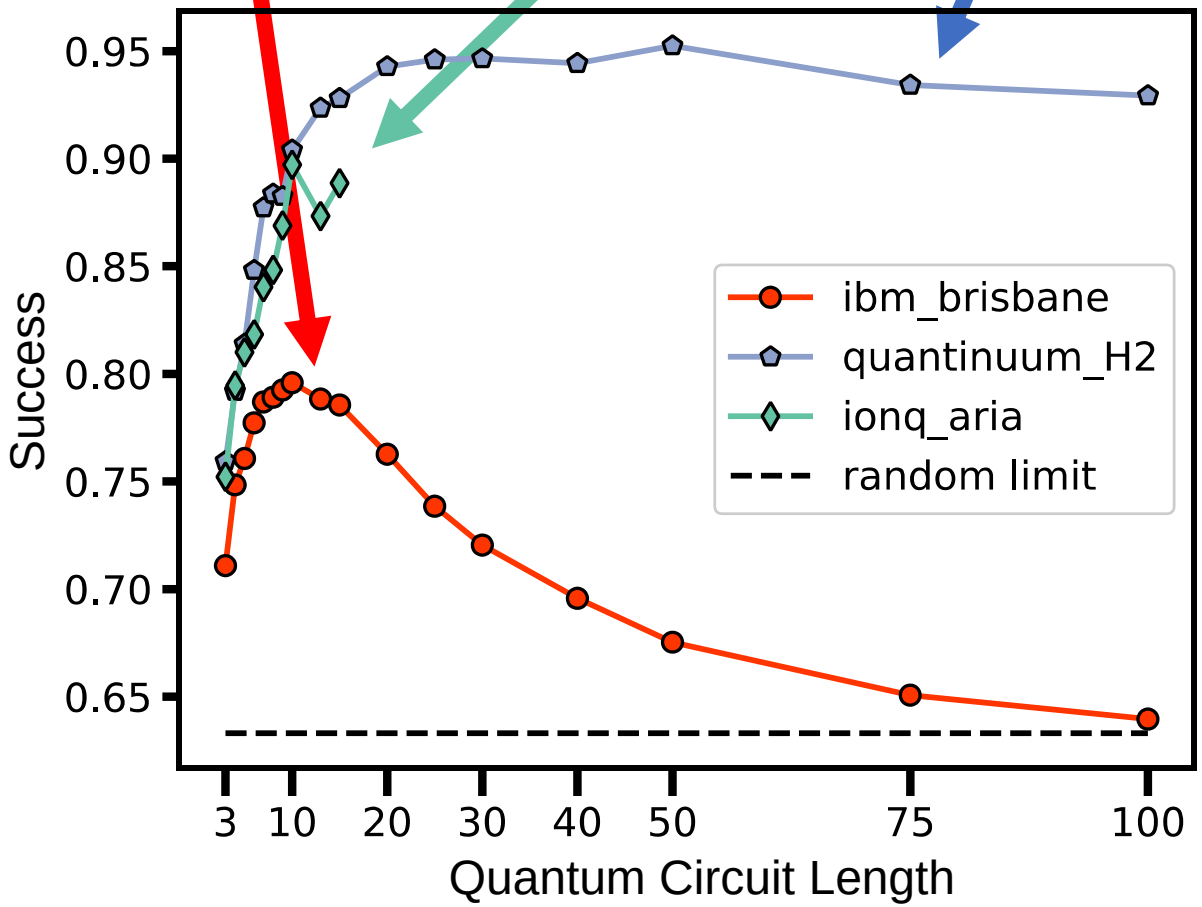

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Observation of Josephson Harmonics in Tunnel Junctions

nature physics

Article

https://doi.org/10.1038/s41567-024-02400-8

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Standard transmon model has been “wrong” for 15 years

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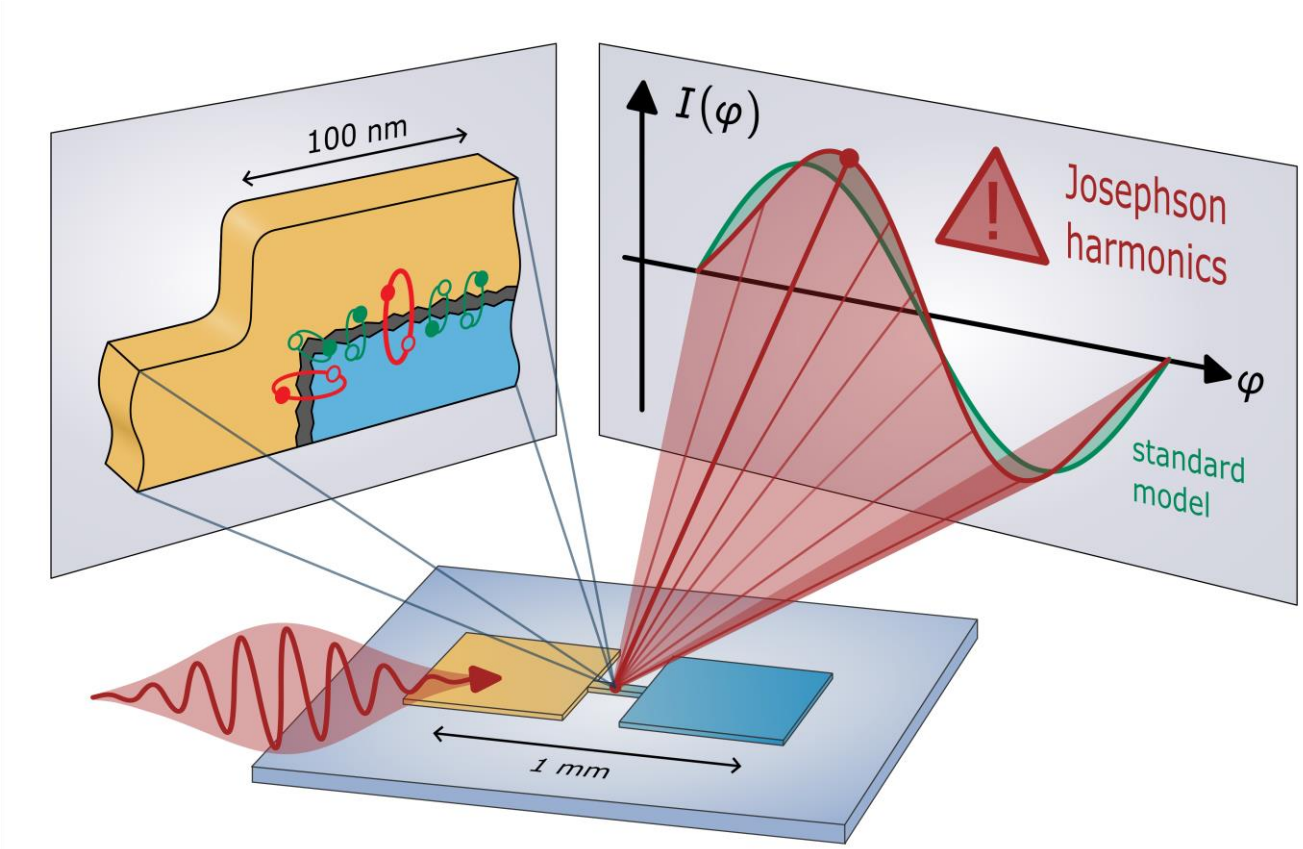

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Spectroscopy of Higher Levels

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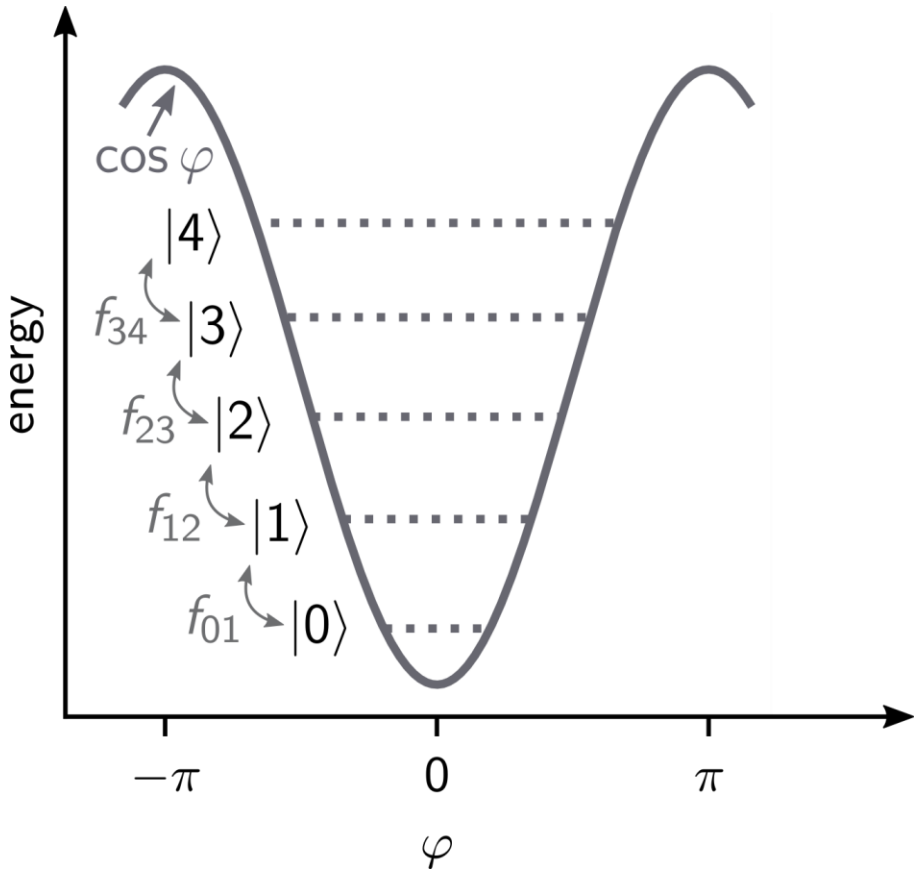
$$H = 4E_c n^2 - E_J \cos\varphi$$



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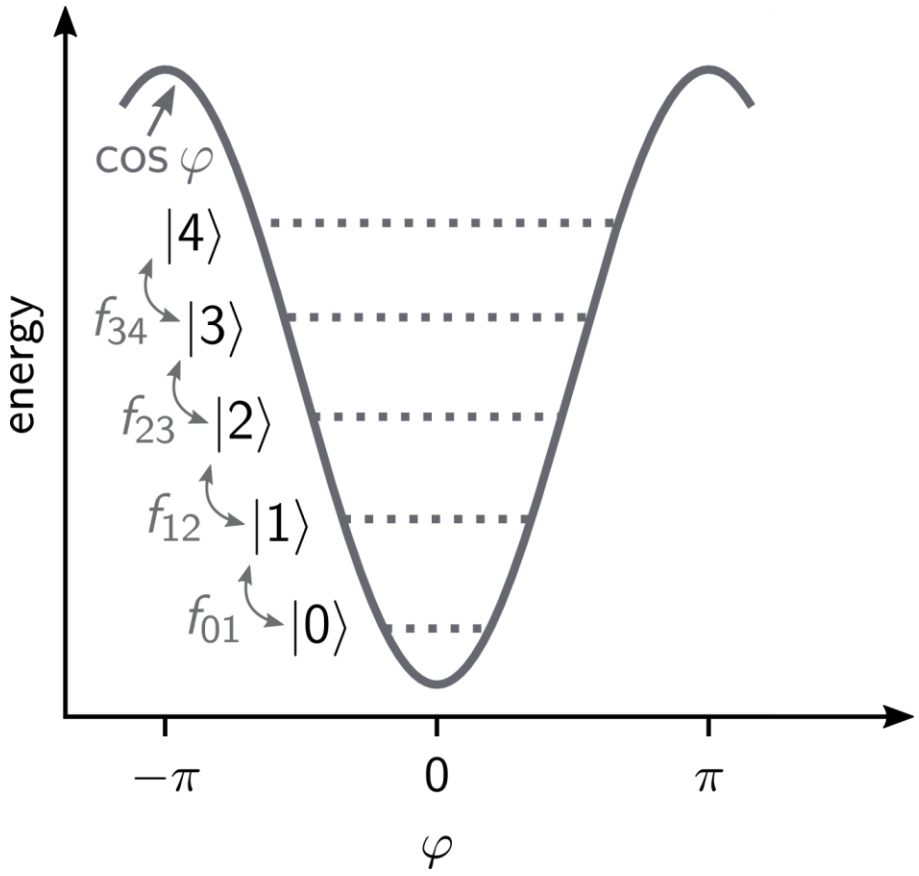

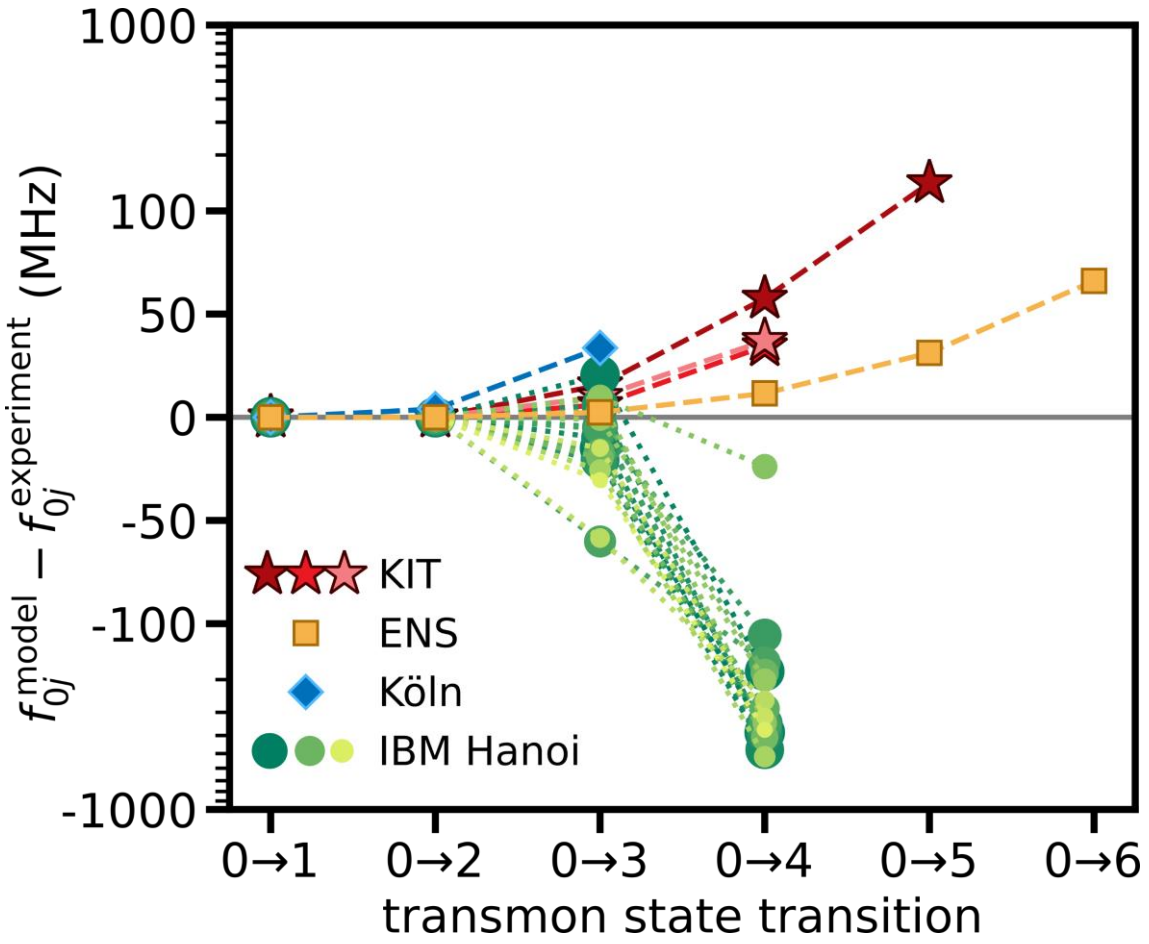

Willsch, Rieger, et al., Nat. Phys. (2024)

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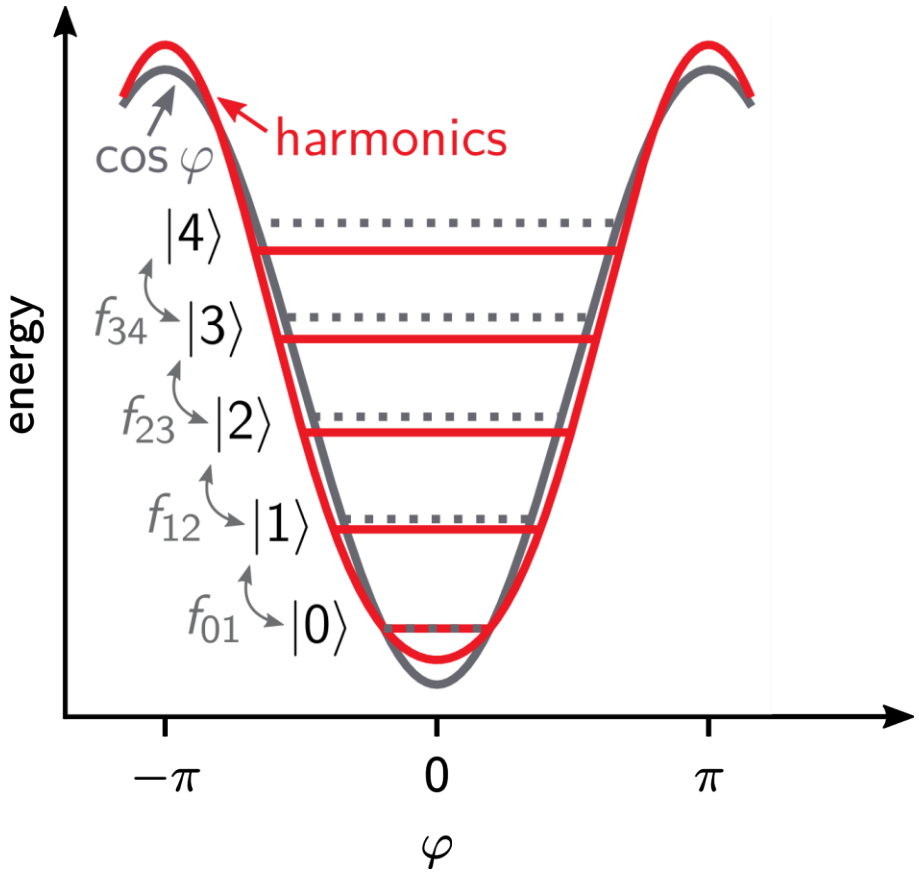

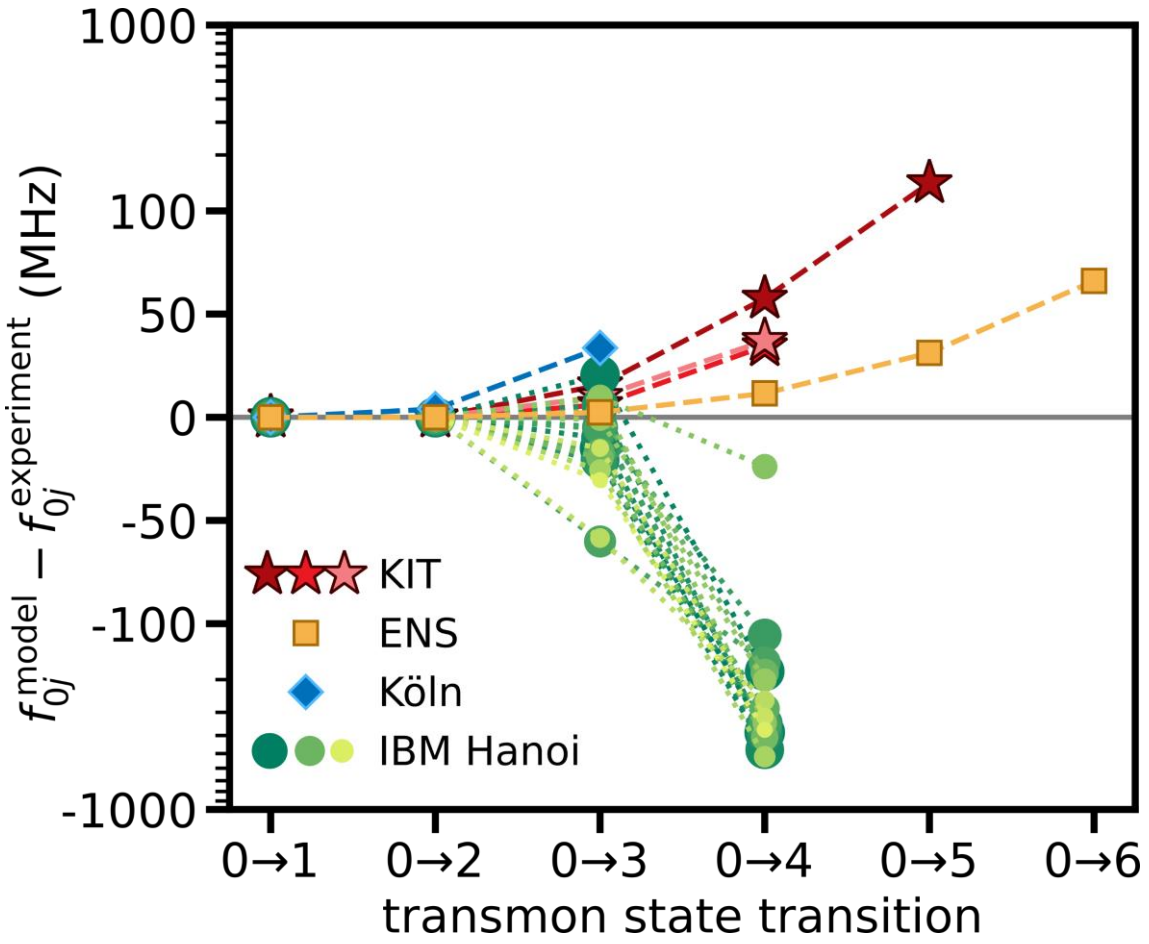

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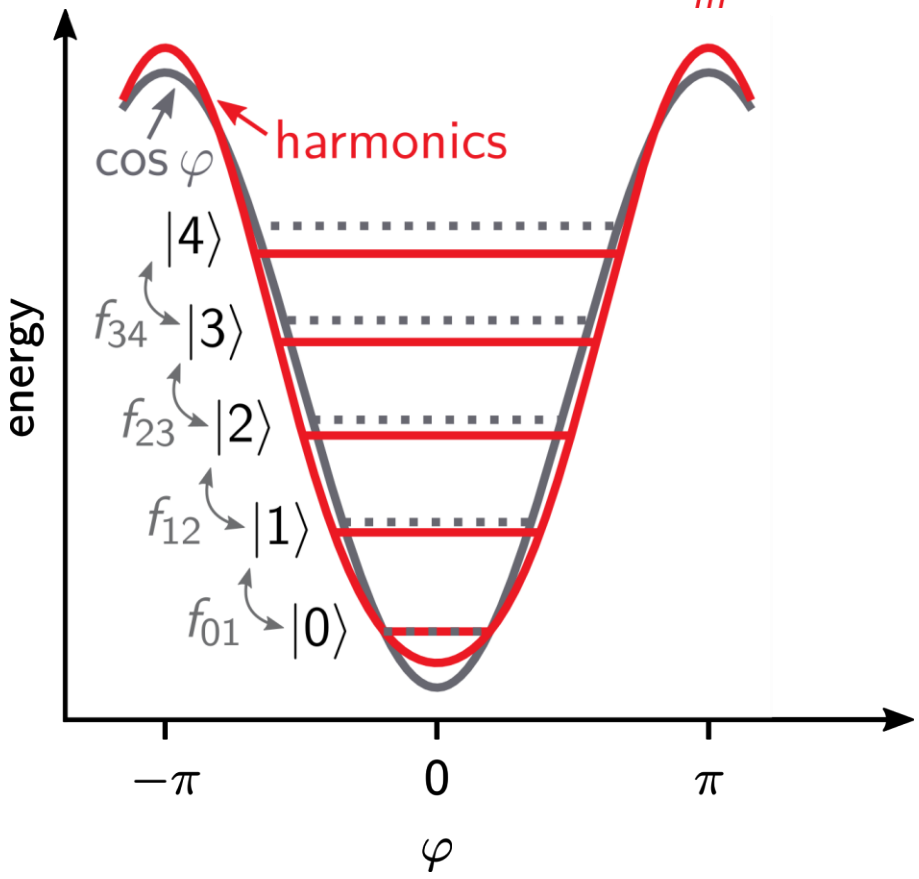

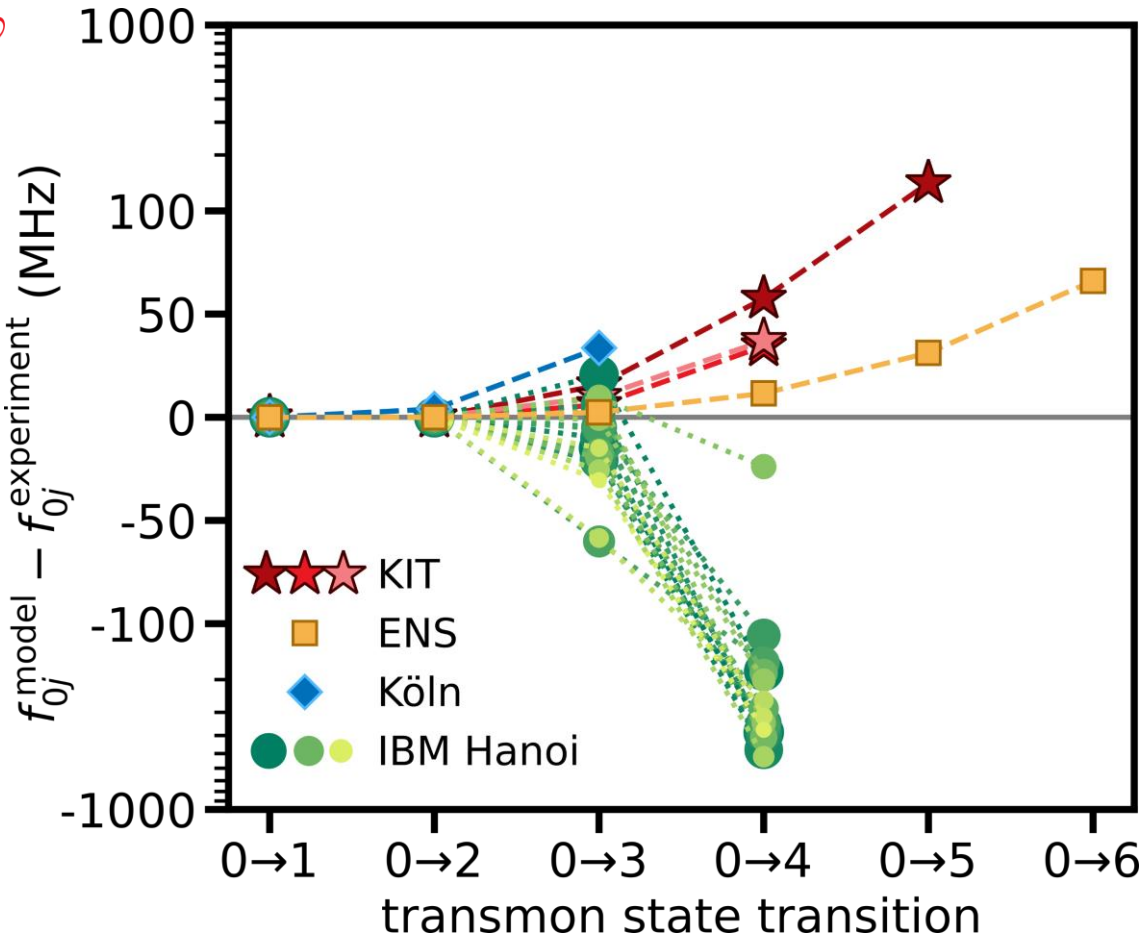

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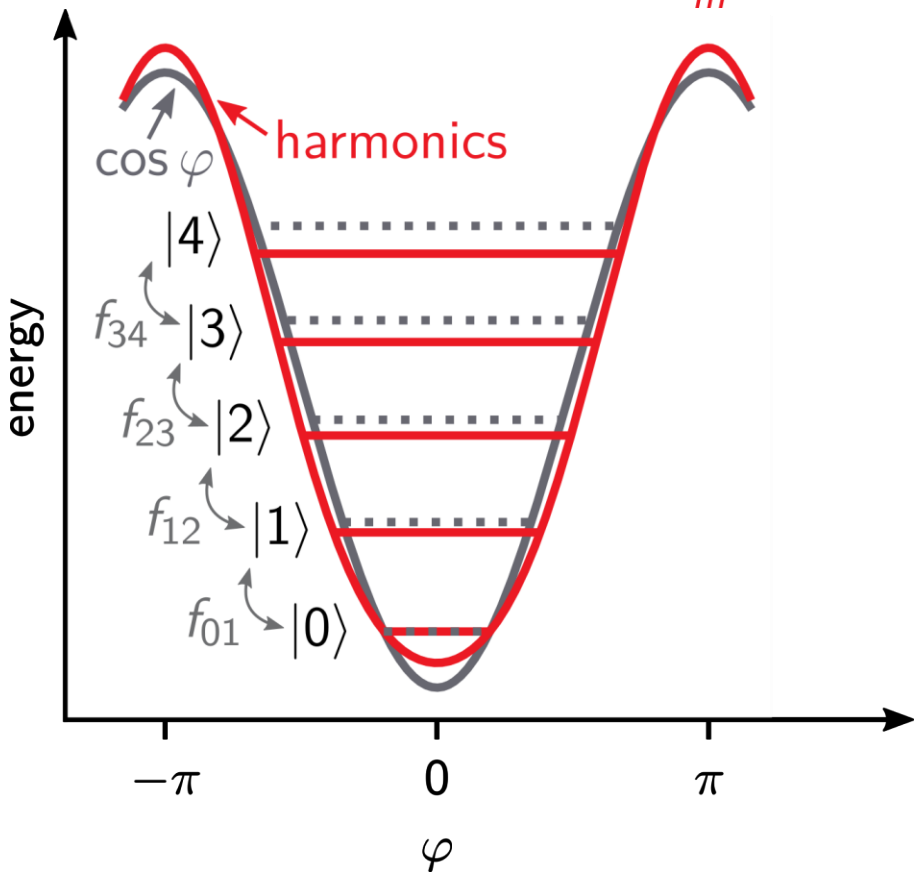

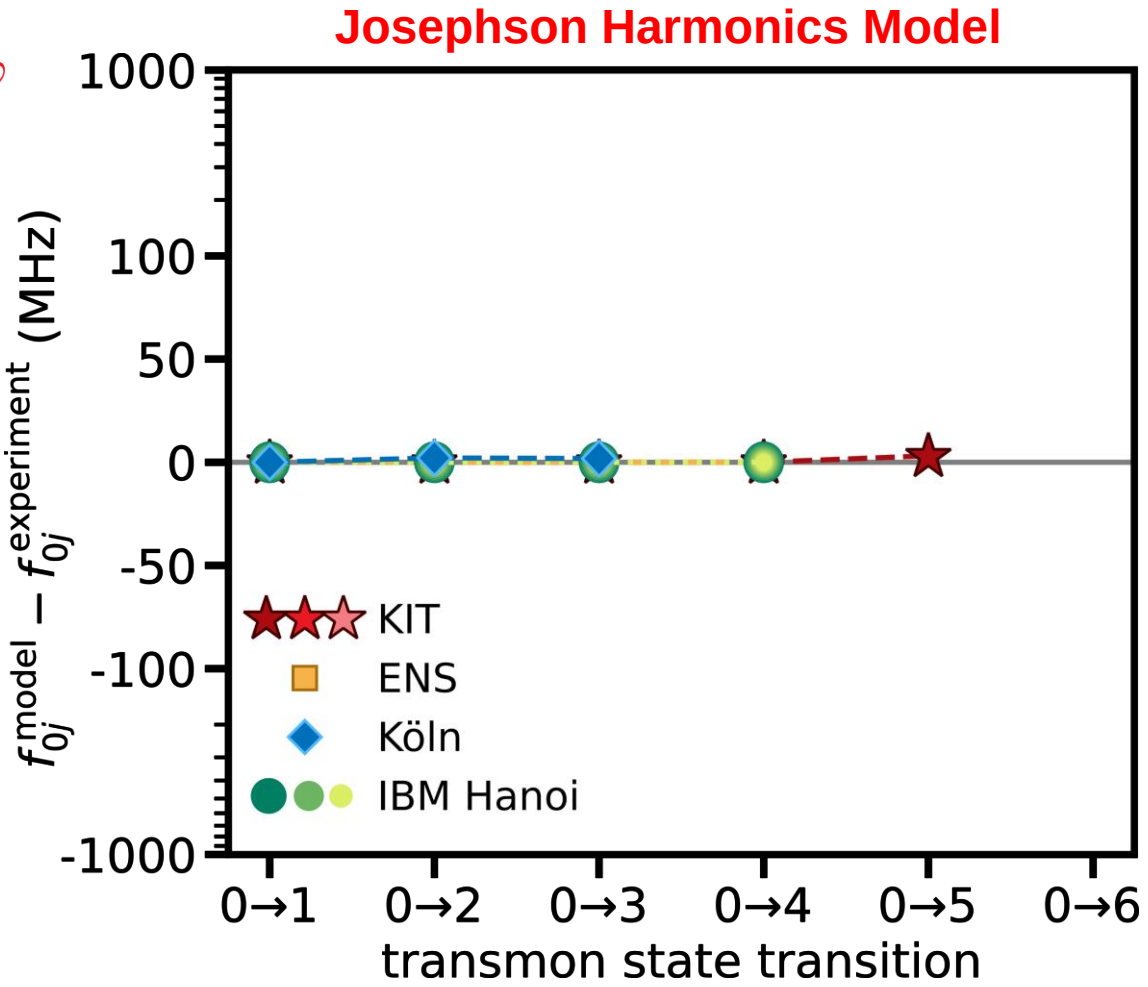

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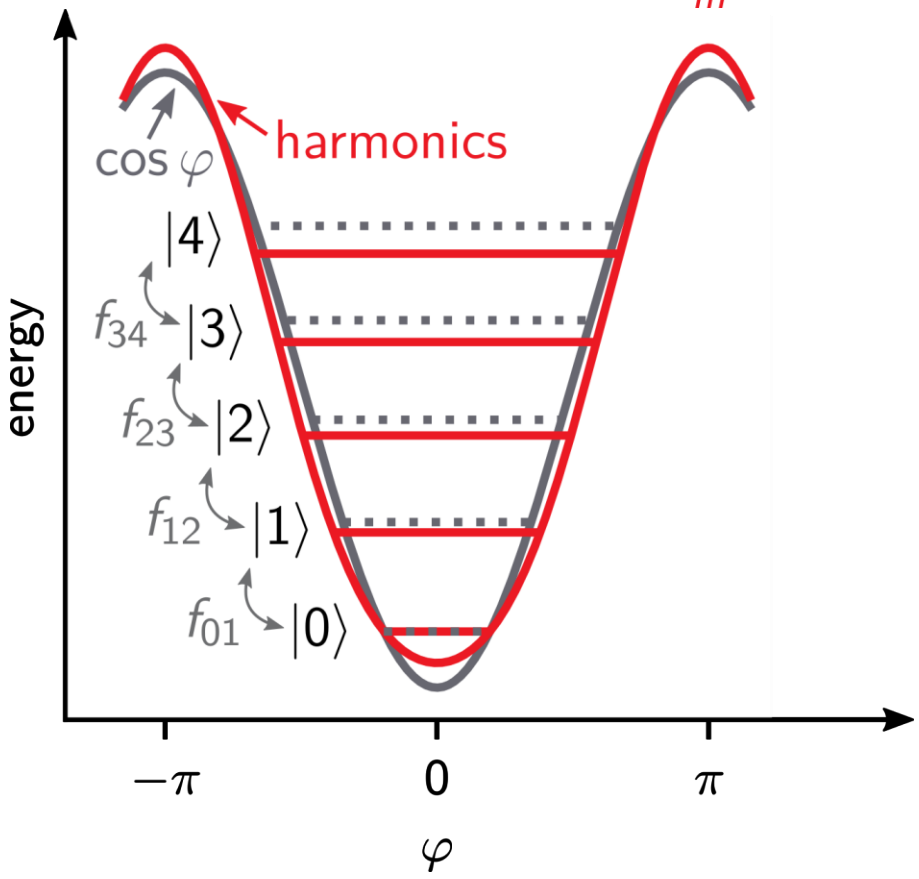
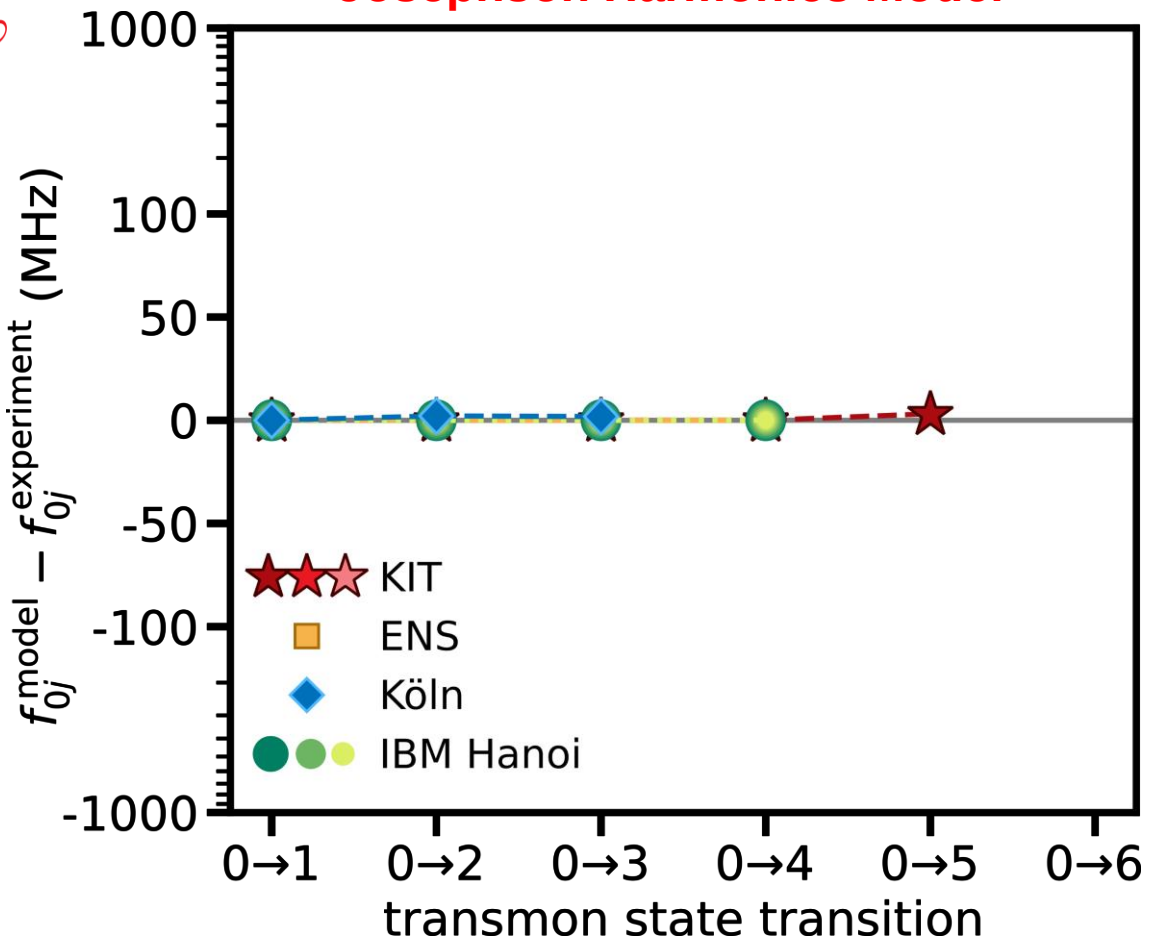


Josephson Harmonics Model



→ **Spectroscopy experiments are crucial to find good model parameters (EJm)**

Willsch, Rieger, et al., Nat. Phys. (2024)

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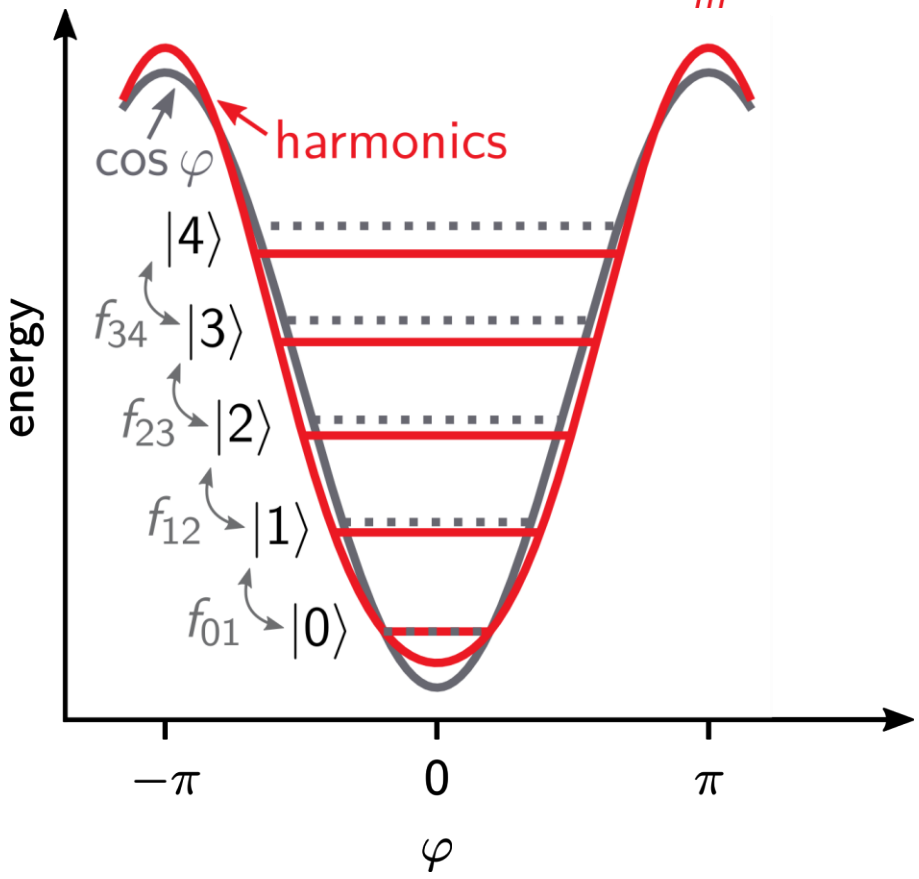

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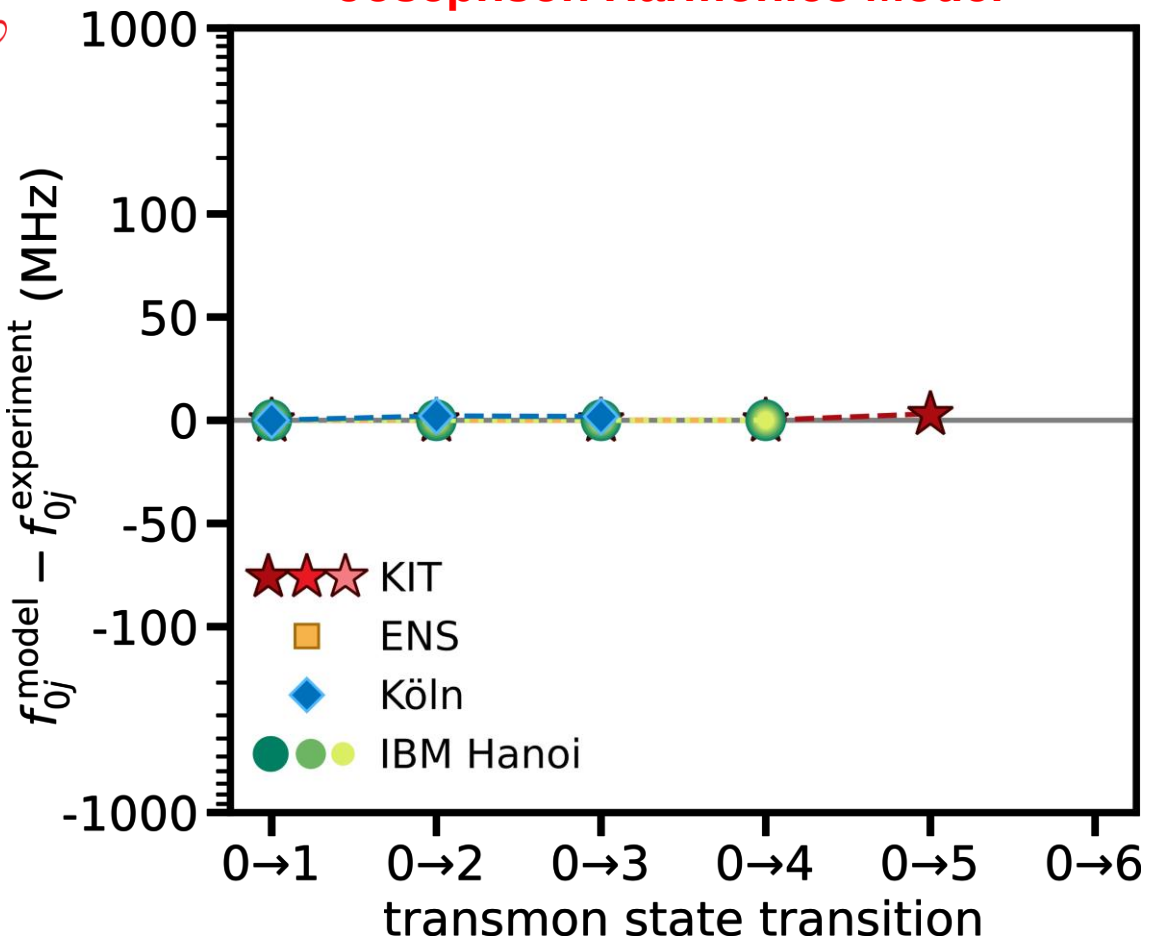

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Akiva: Nodes are ready for us to start

Willsch, Rieger, et al., Nat. Phys. (2024)

Charge Noise Characterization

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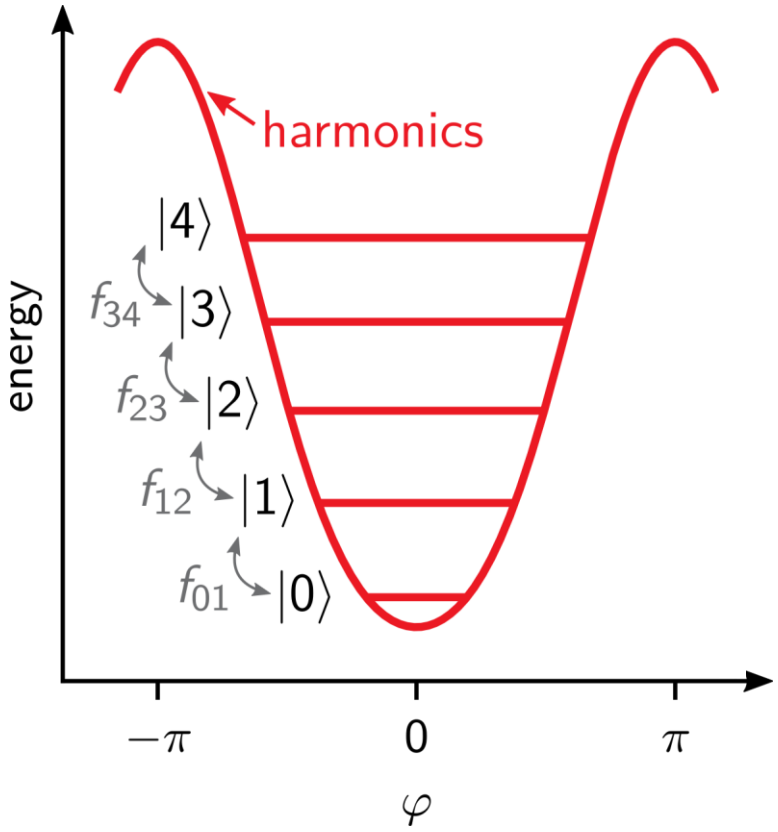

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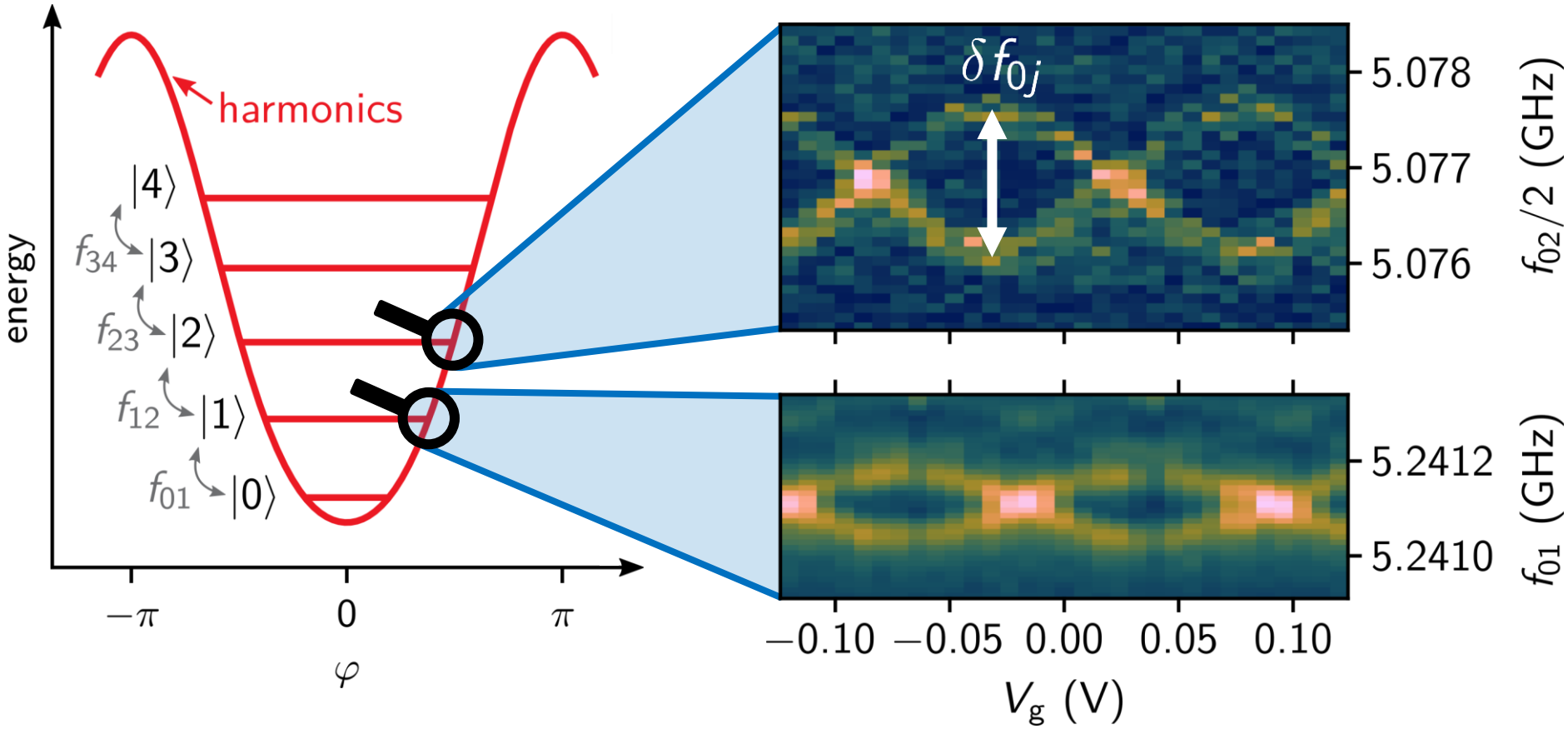

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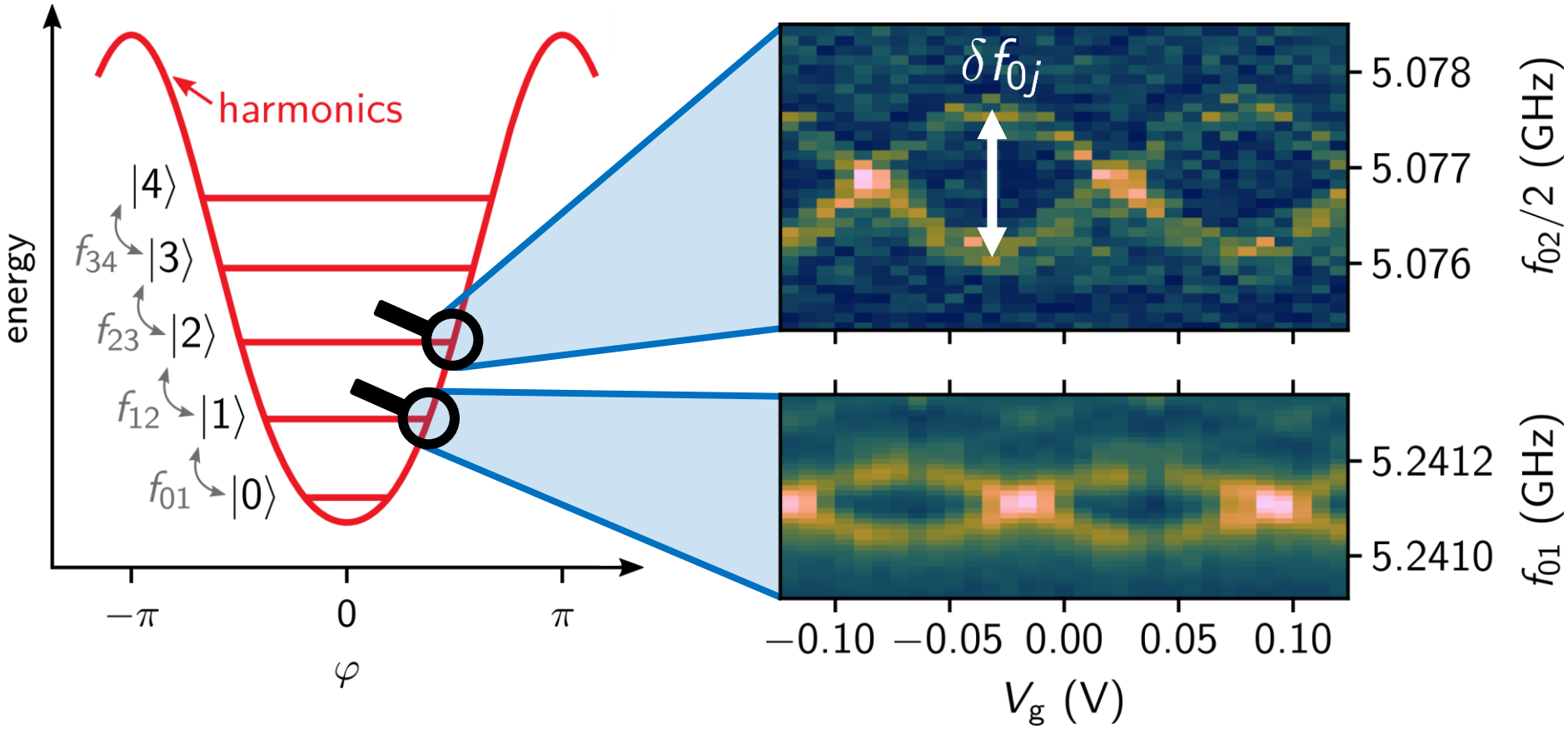

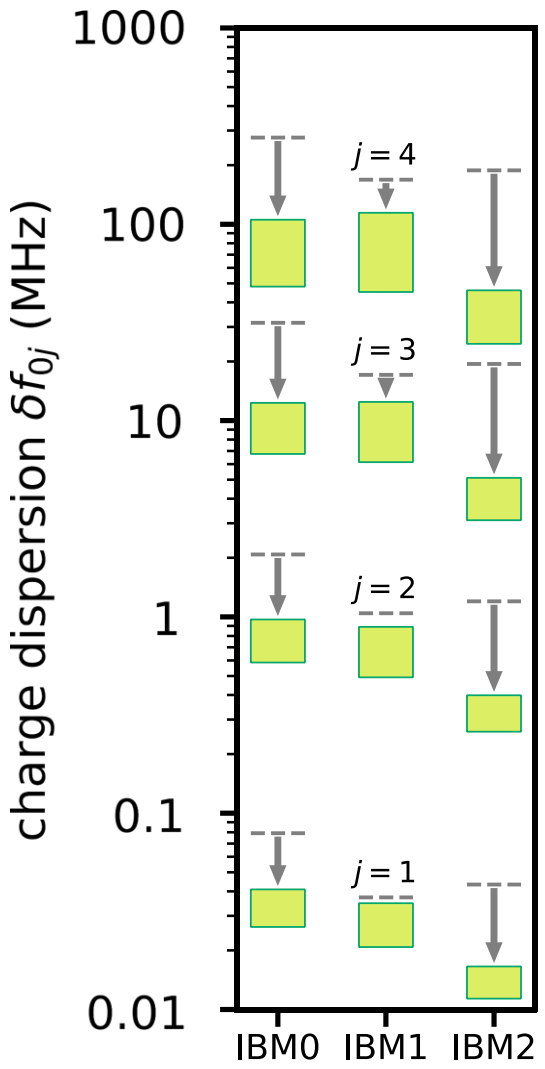

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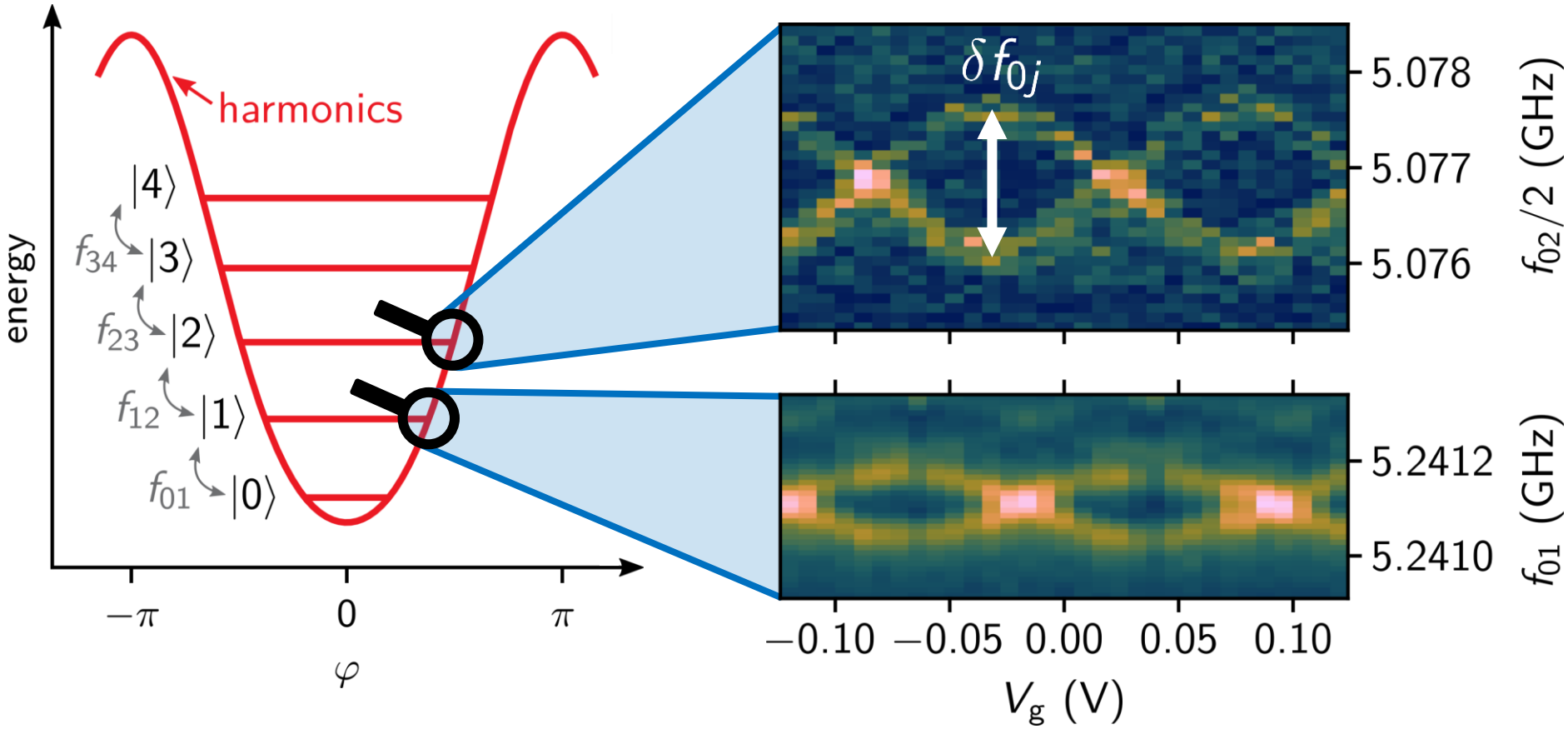

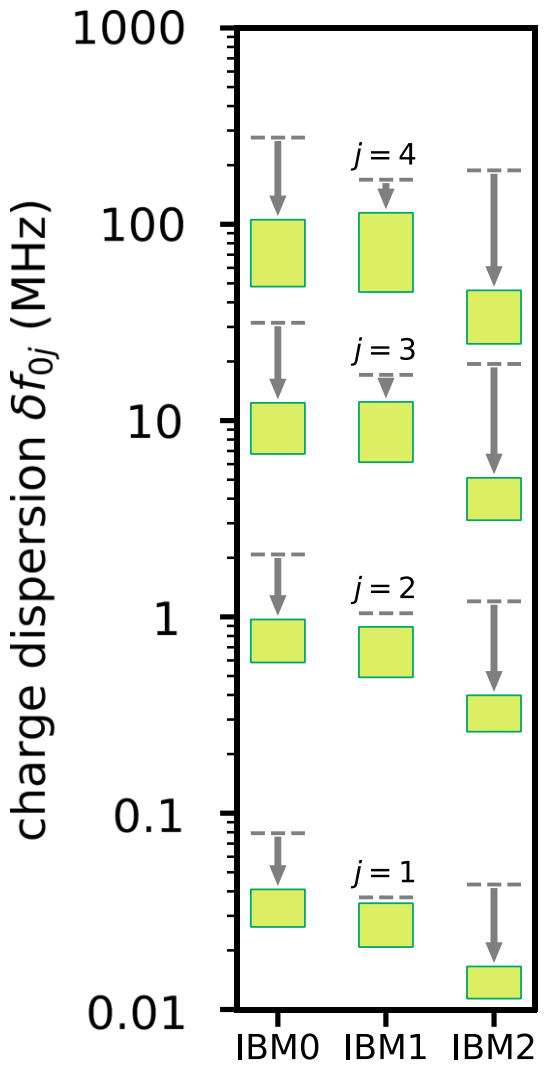

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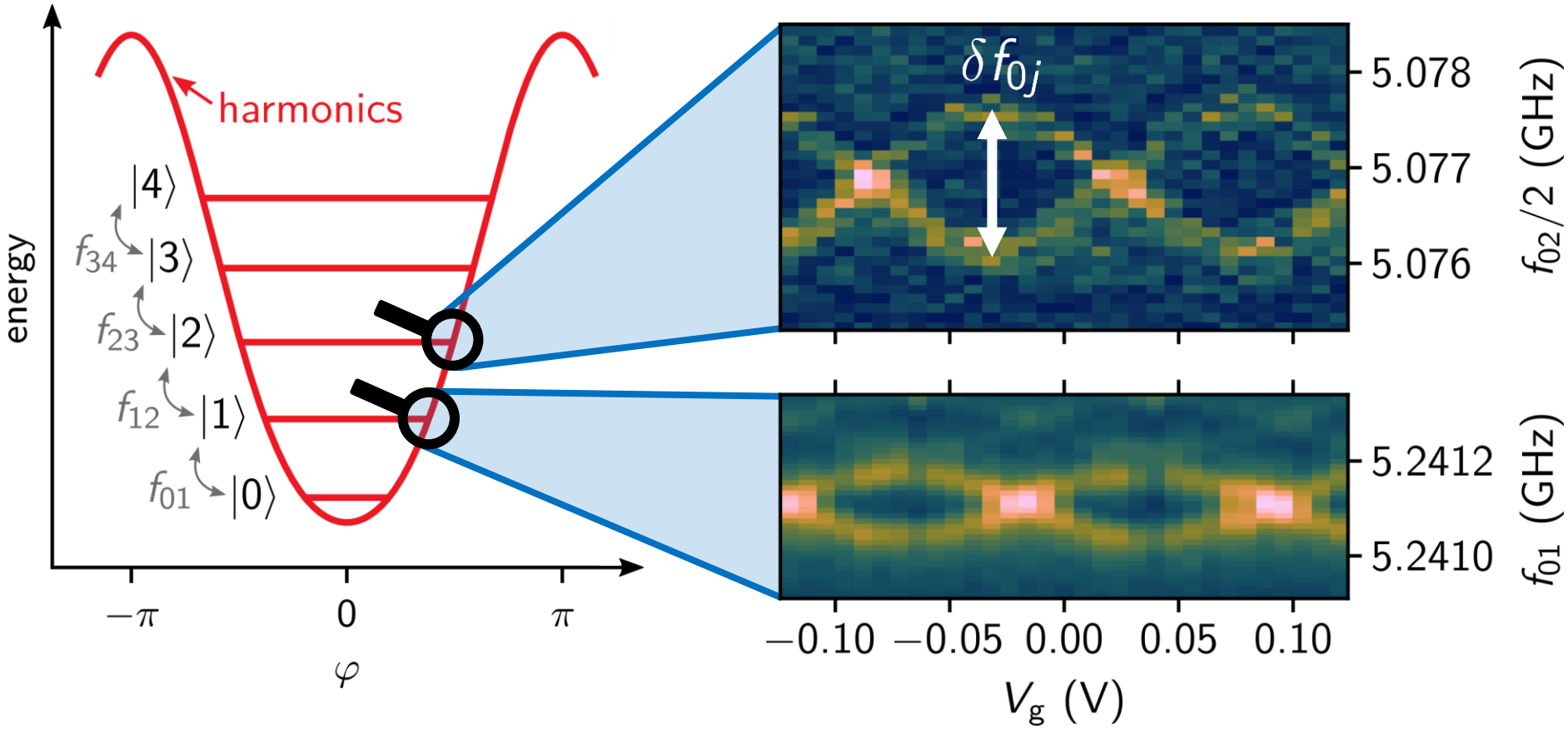

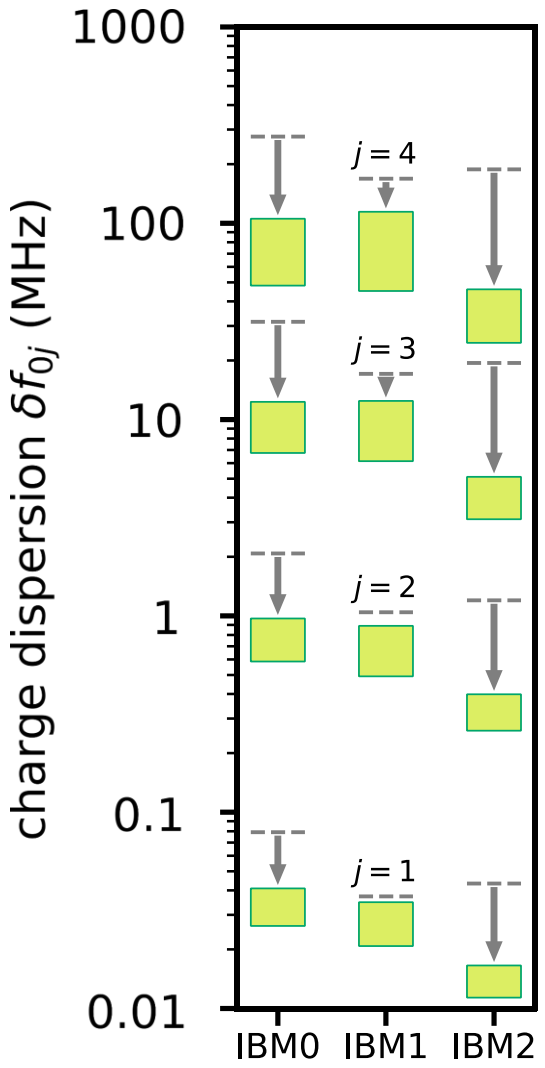

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David: We have some equipment that might help

Willsch, Rieger, et al., Nat. Phys. (2024)

Digital Twin Simulation: Example

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$$i\frac{\partial}{\partial t}|\Psi(t)\rangle = (H_{\mathrm{Tr}} + H_{\mathrm{Res}} + H_{\mathrm{Int}})|\Psi(t)\rangle$$

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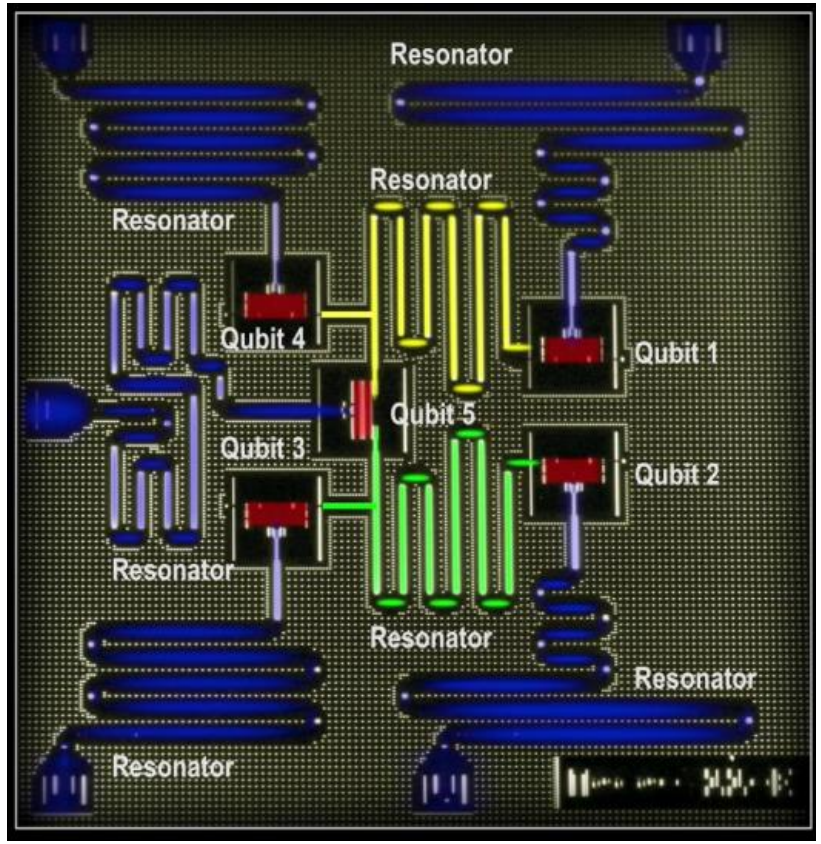

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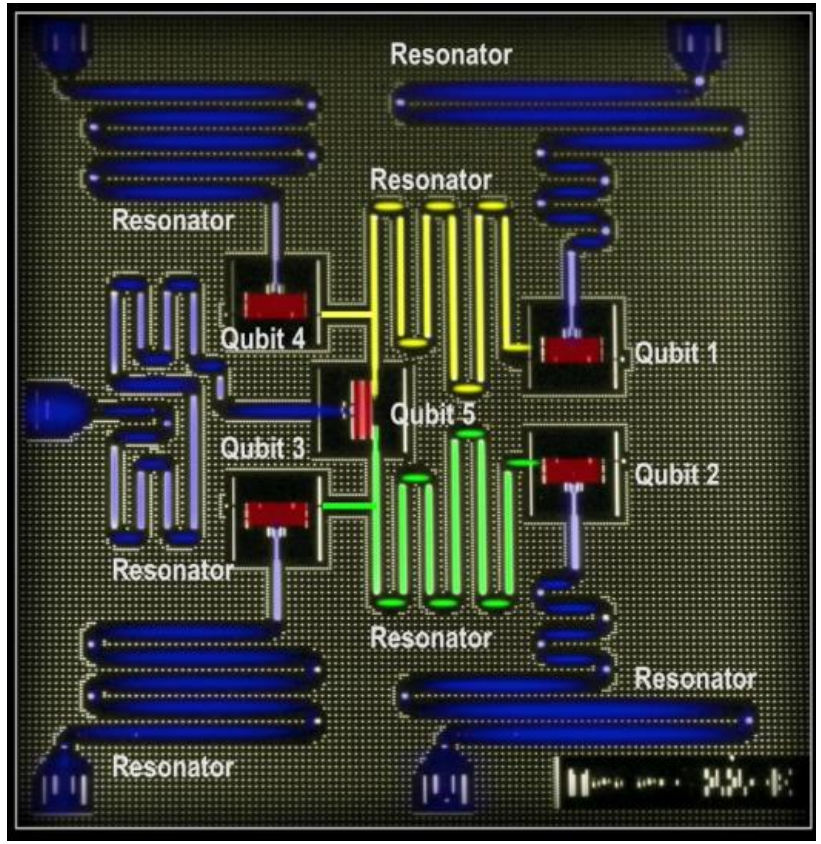
Device parameters and control pulses

State of the hardware at a certain point in time



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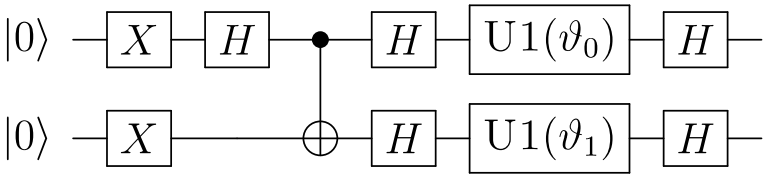

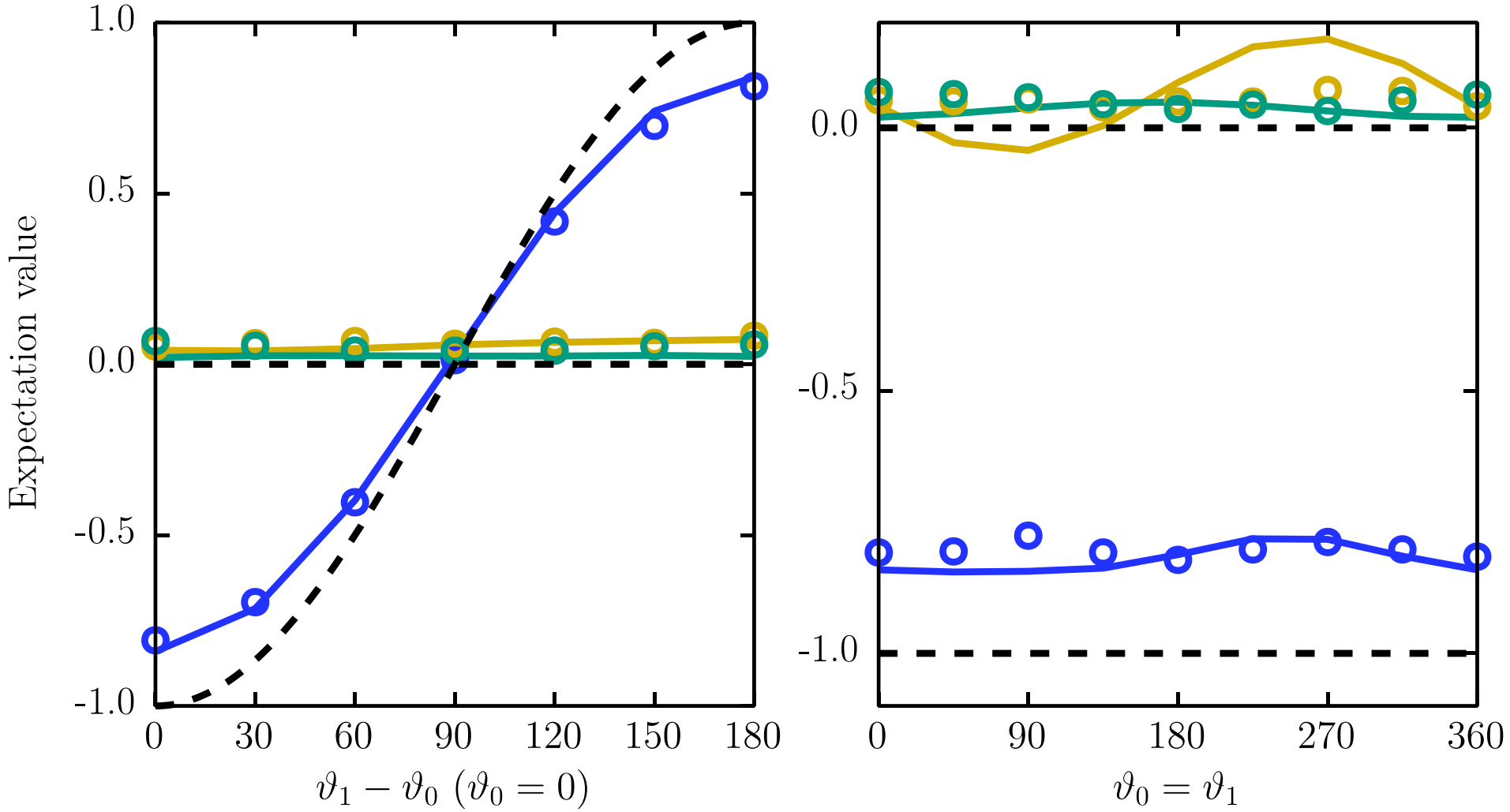

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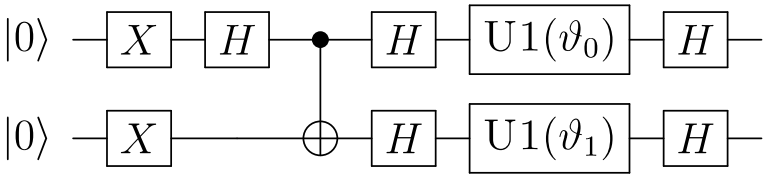

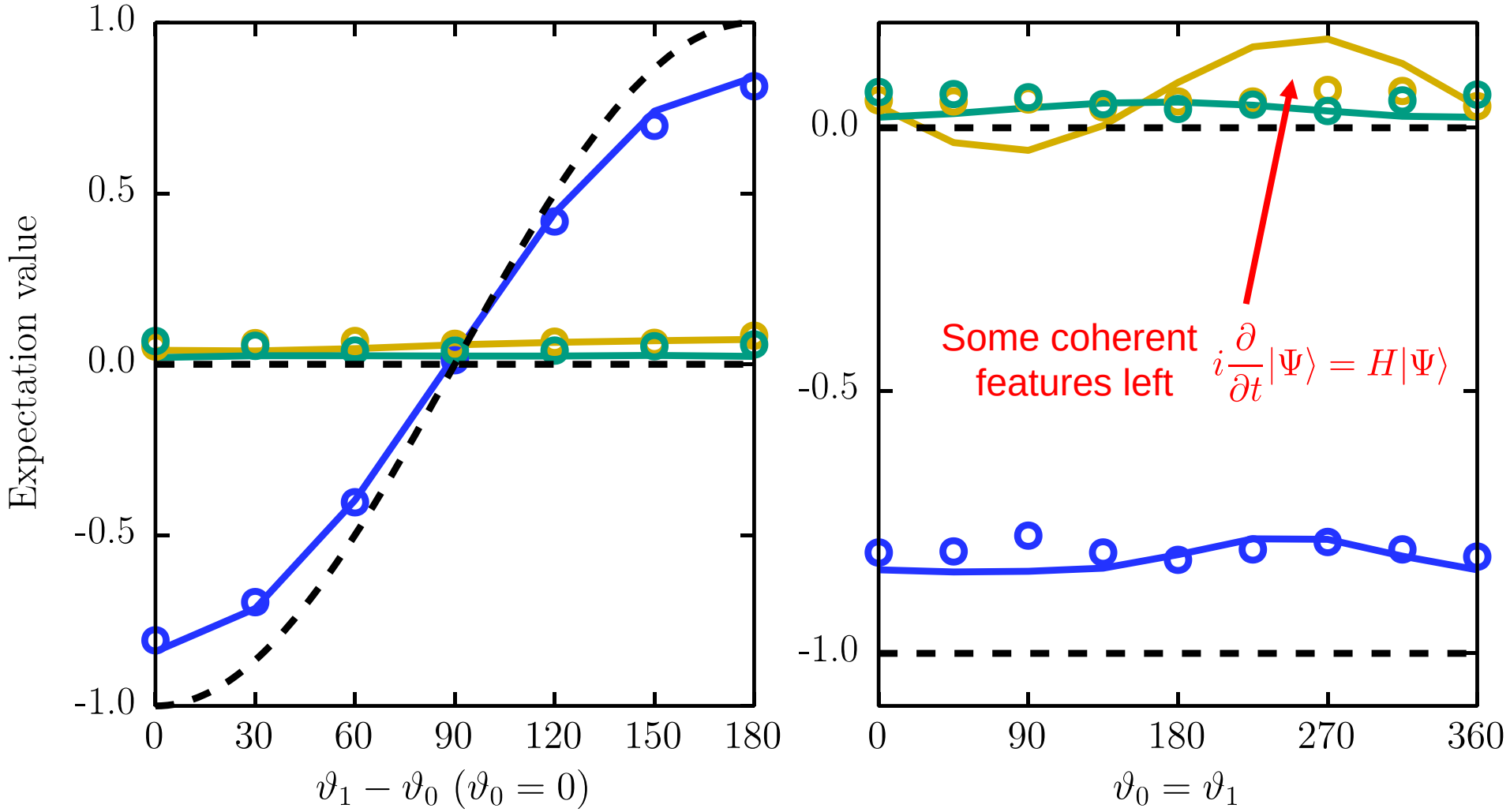

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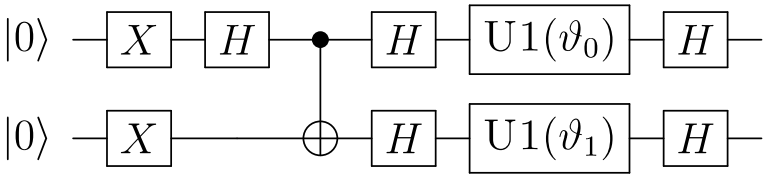

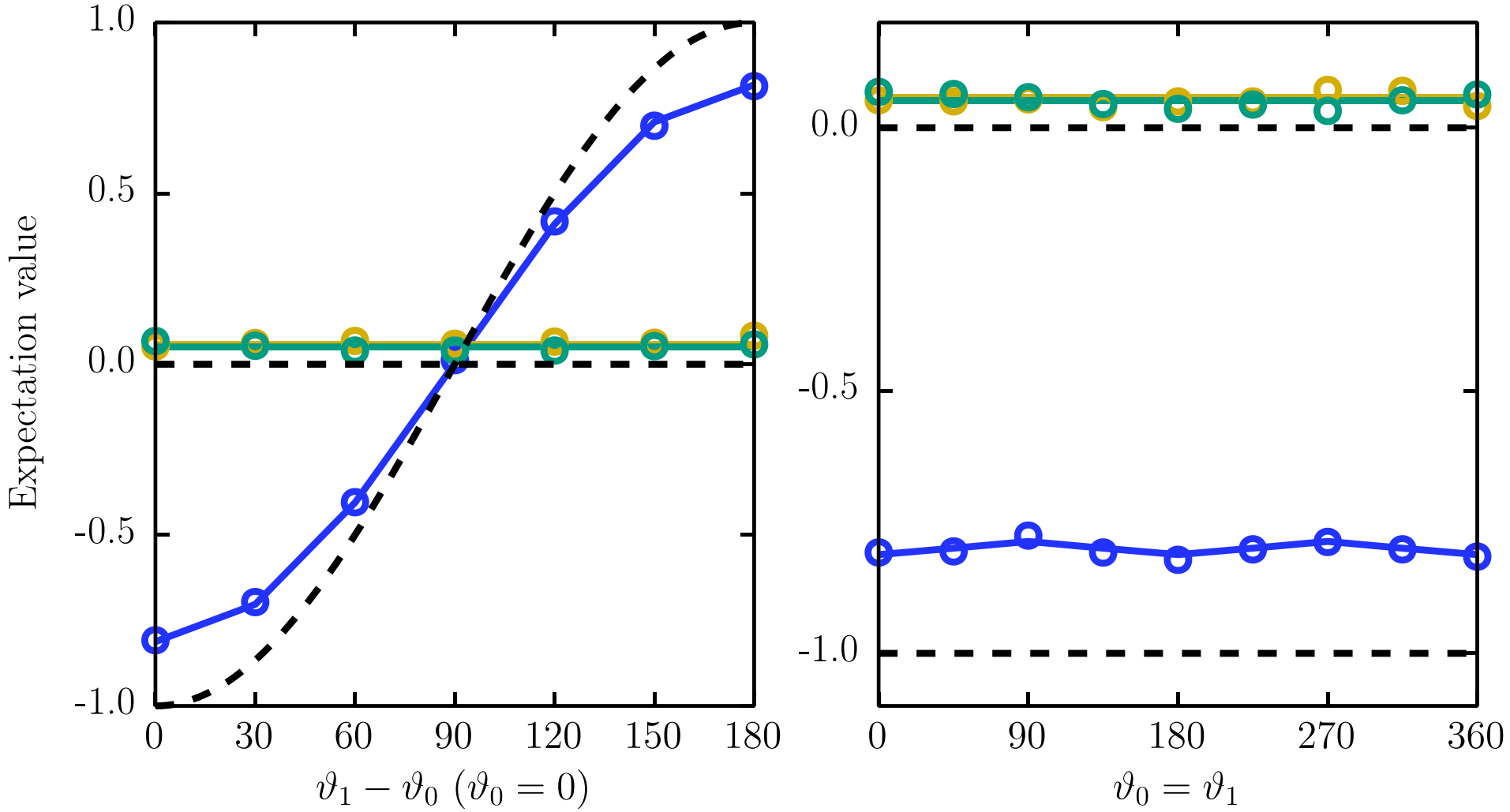

THANK YOU
FOR YOUR ATTENTION