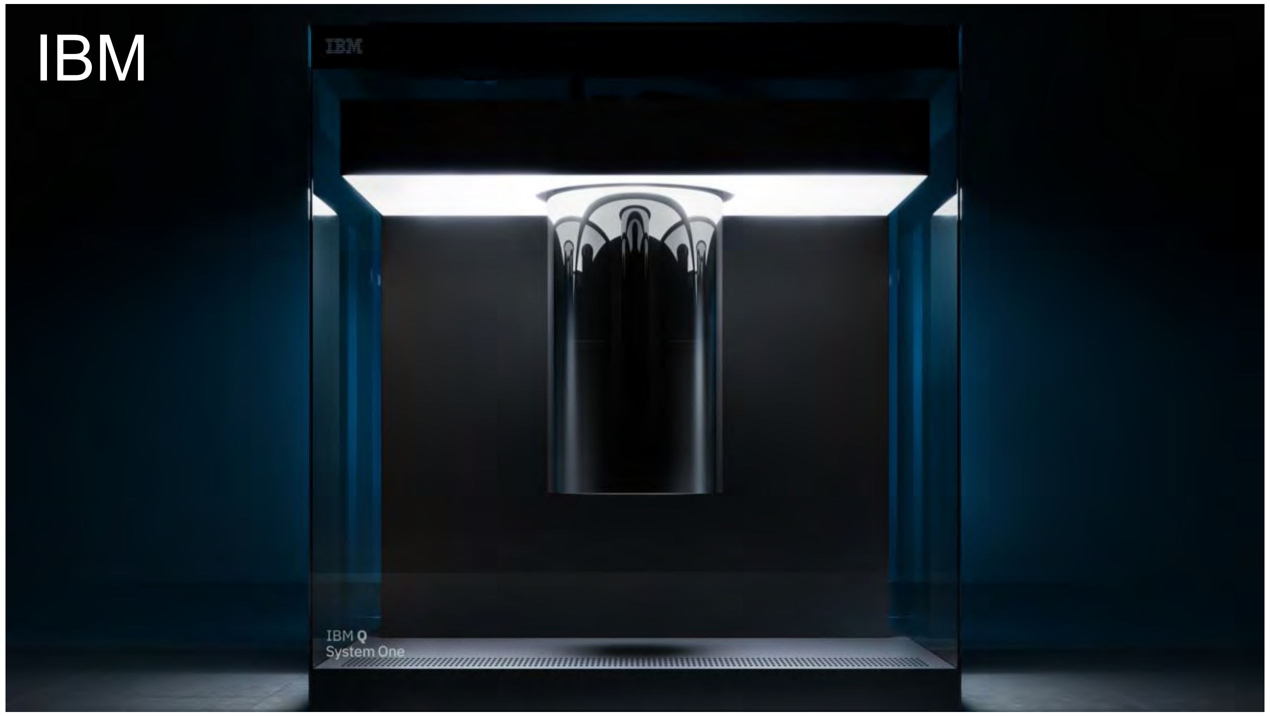
Quantum Computing: Quo Vadis?

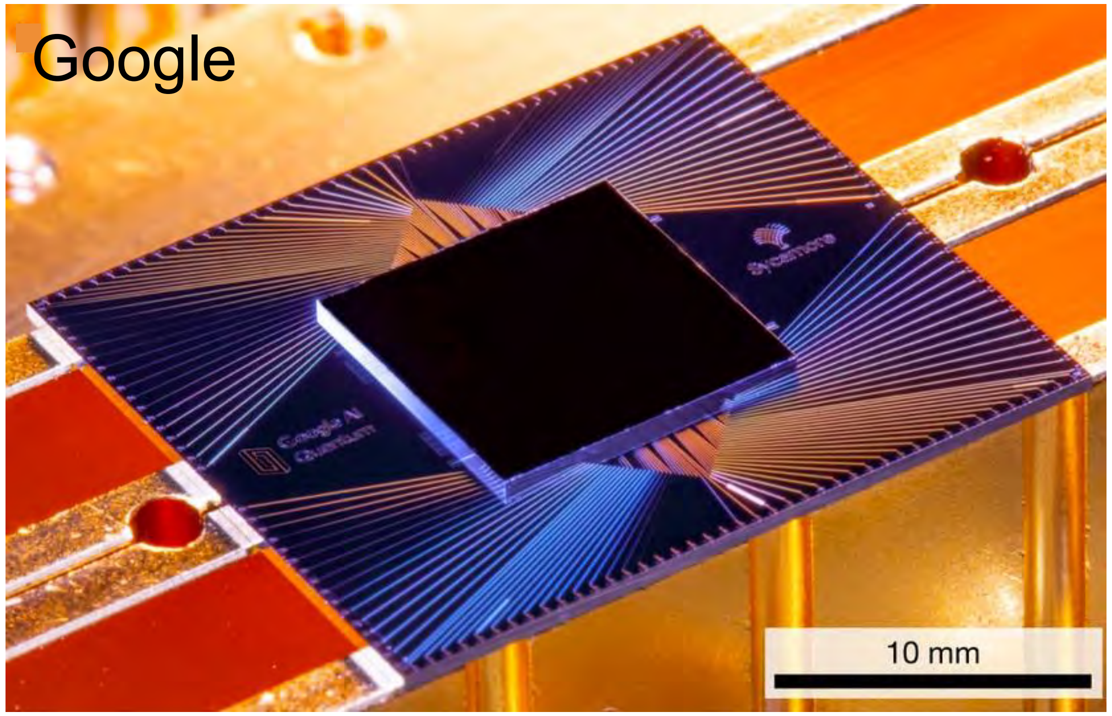
David DiVincenzo
Jülich

Quantum Computing in the NISQ era

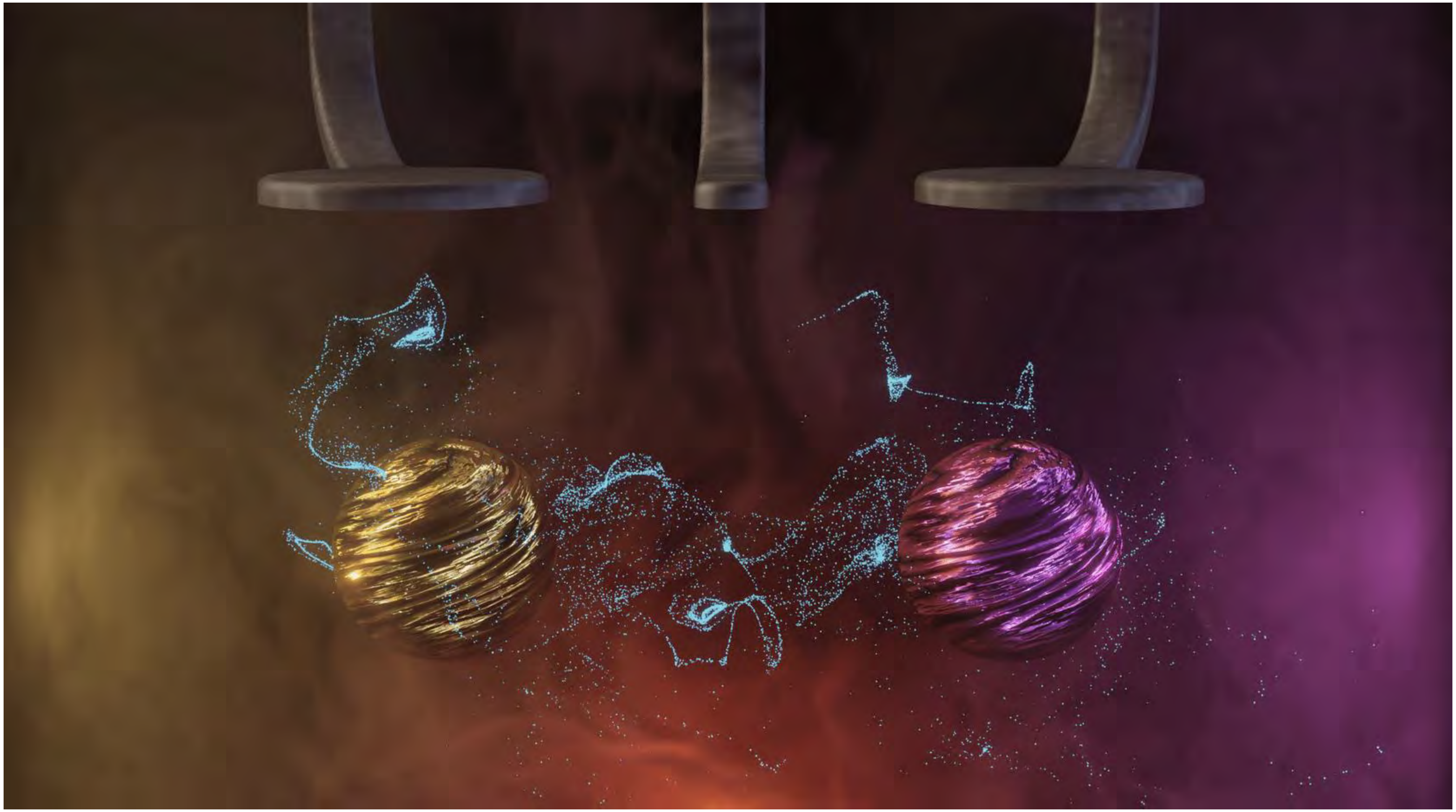
Noisy intermediate scale quantum devices

Still in an experimental era with devices with a small number of high-quality qubits



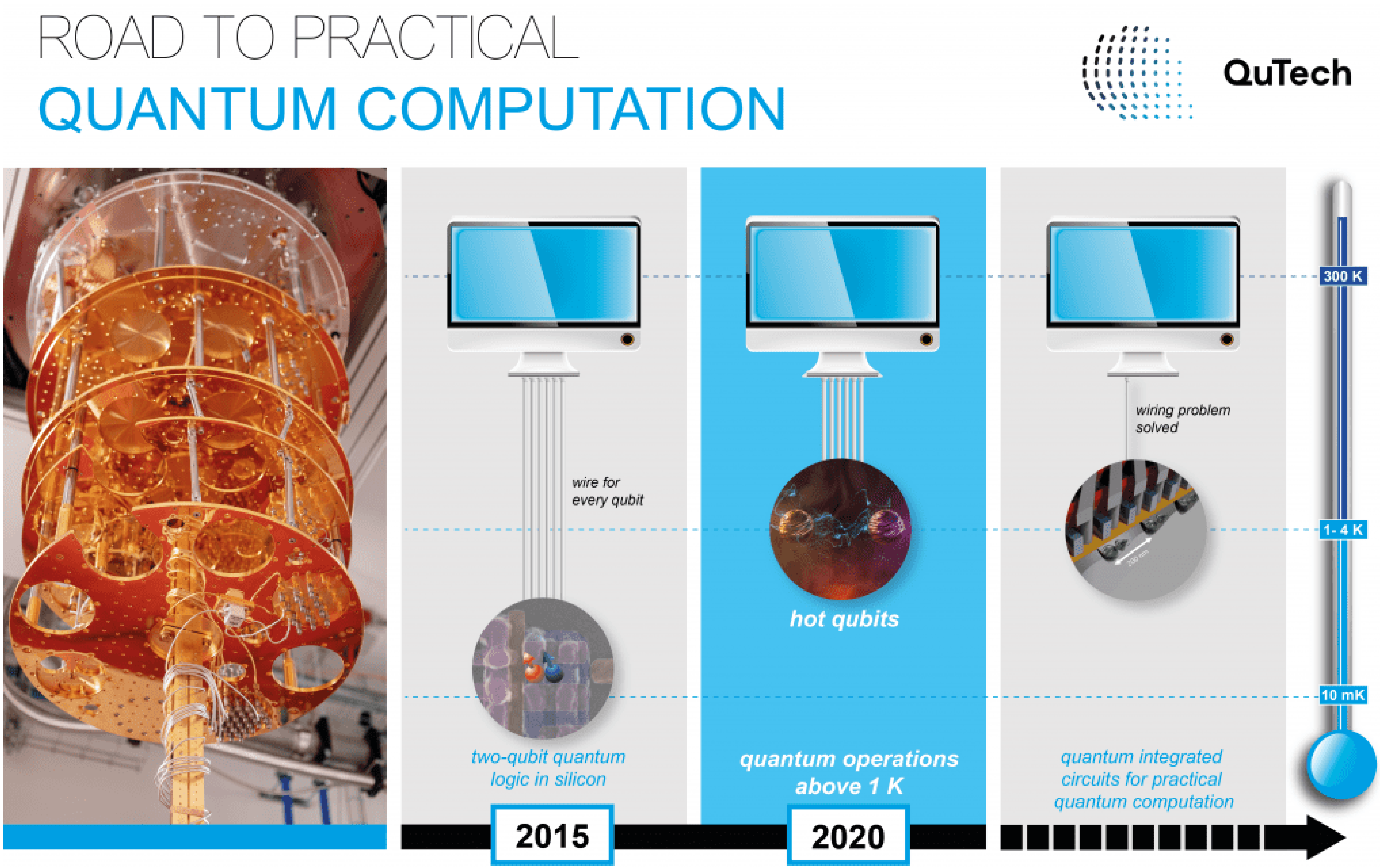


Spin qubits – artist's view

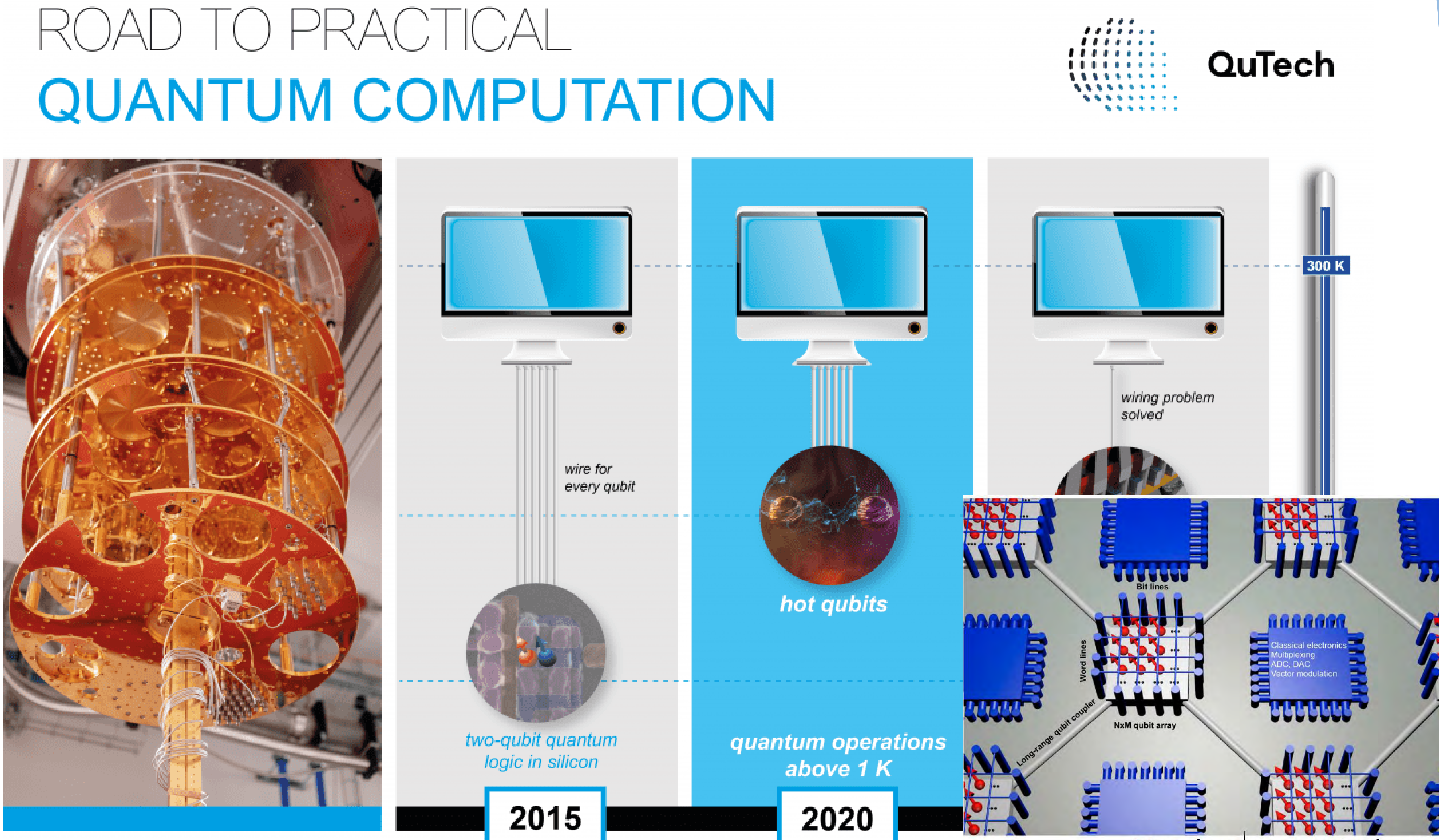


© Simon Trebst

Roadmap for spin qubits



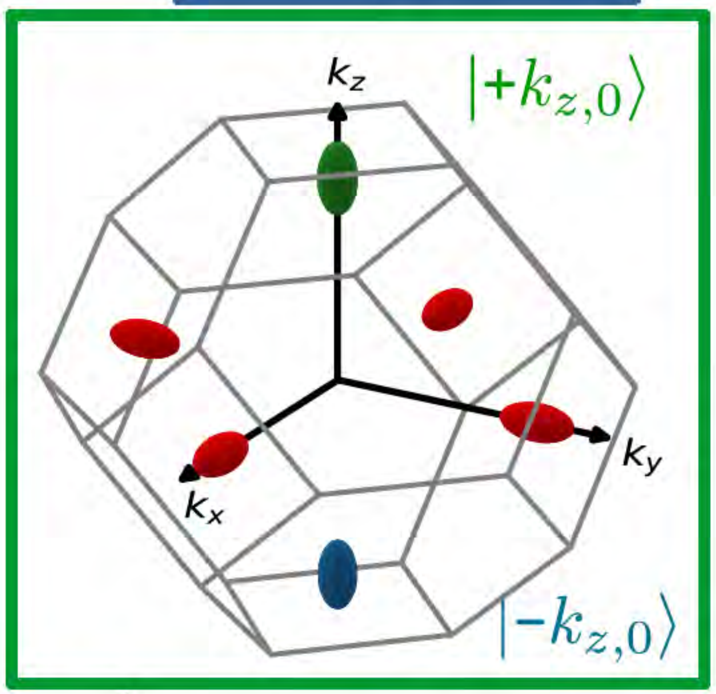
Roadmap for spin qubits



Vandersypen et al., npj Quantum Information 2017

Rich physics of moveable quantum dots

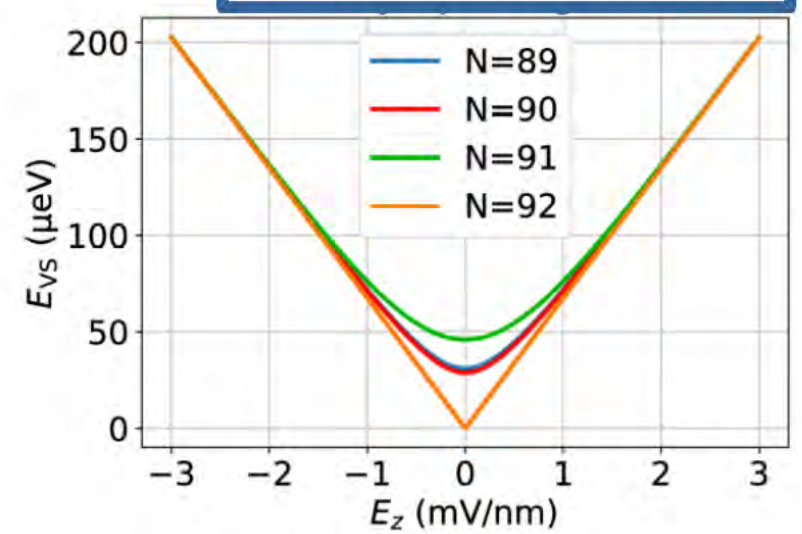
Valley state



$$|\mathrm{e_v}\rangle = \frac{1}{\sqrt{2}}\left(|+k_{z,0}\rangle + e^{i\varphi_\mathrm{v}}|-k_{z,0}\rangle\right)$$

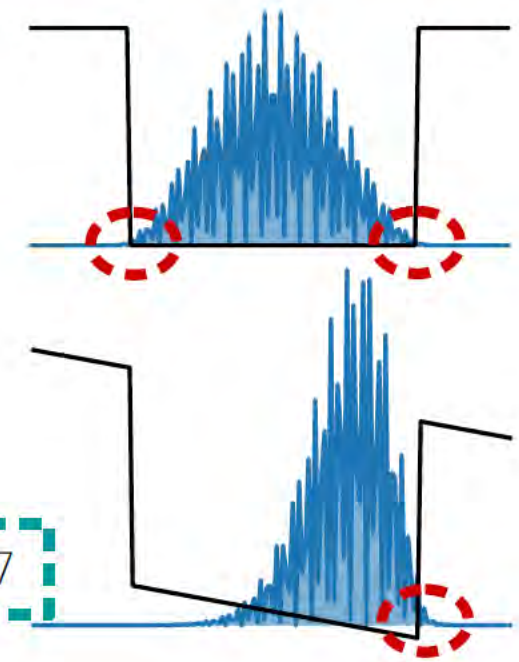
$$|\mathrm{o_v}\rangle = \frac{1}{\sqrt{2}}\left(|+k_{z,0}\rangle - e^{i\varphi_\mathrm{v}}|-k_{z,0}\rangle\right)$$

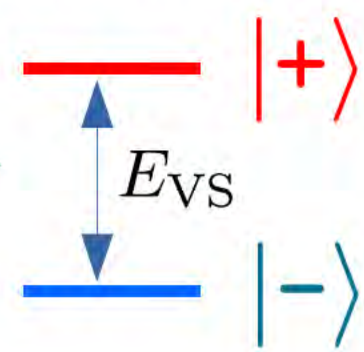
Valley Splitting



Valley-States in QW: Friesen et al., PRB 2007

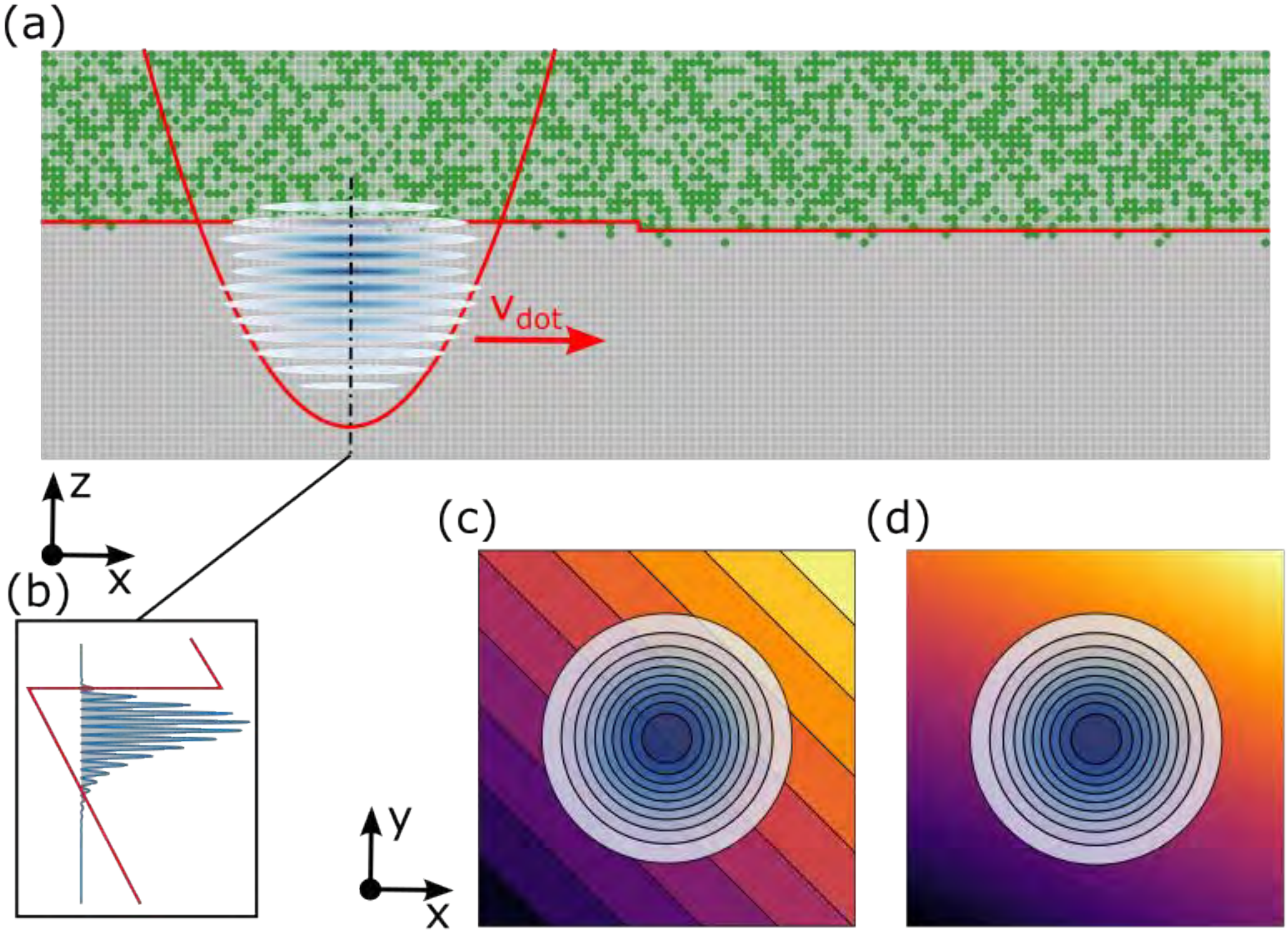
SiGe Si SiGe



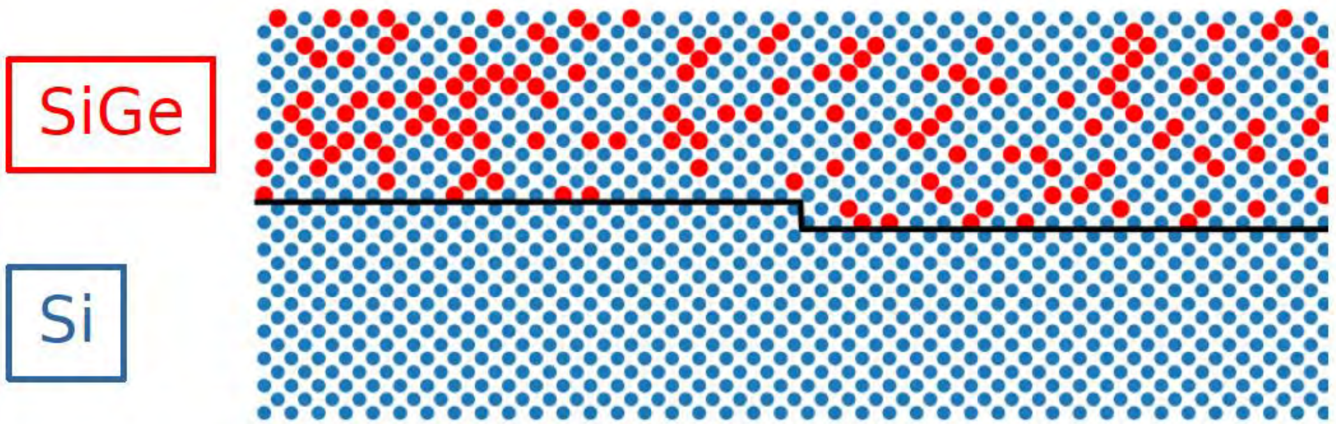


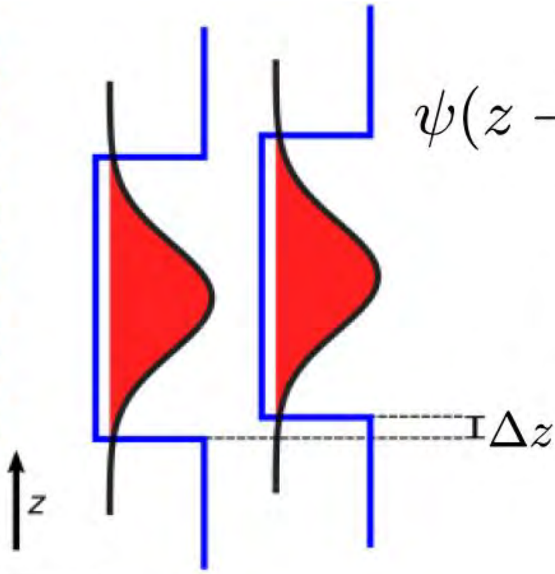
$$\hat{H}_v = \frac{E_{VS}}{2}\hat{\tau}(\varphi_\mathrm{v})$$

Rich physics of moveable quantum dots



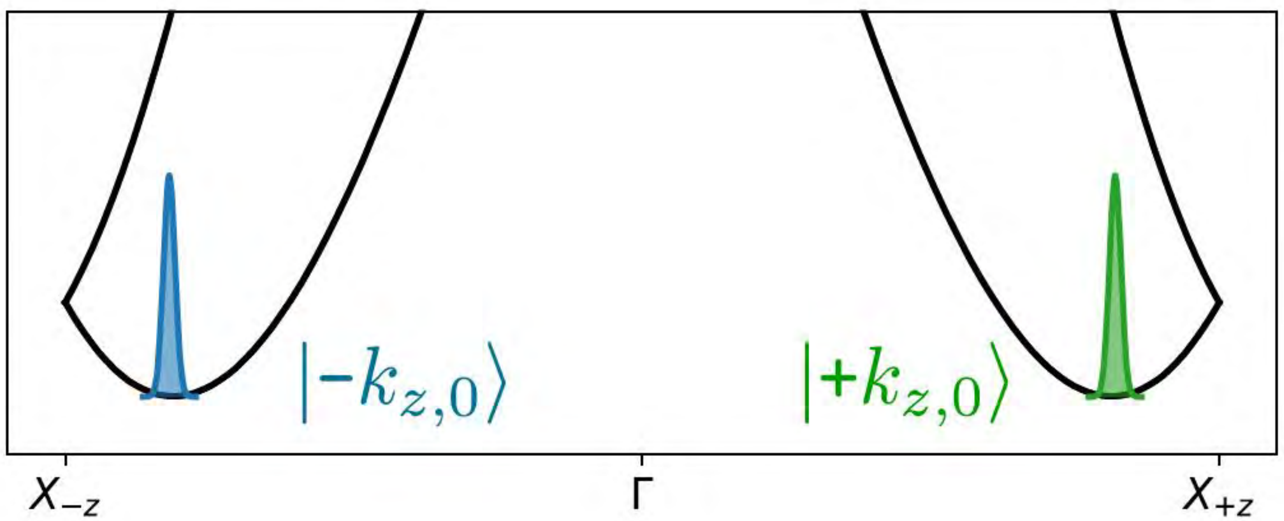
Rich physics of moveable quantum dots

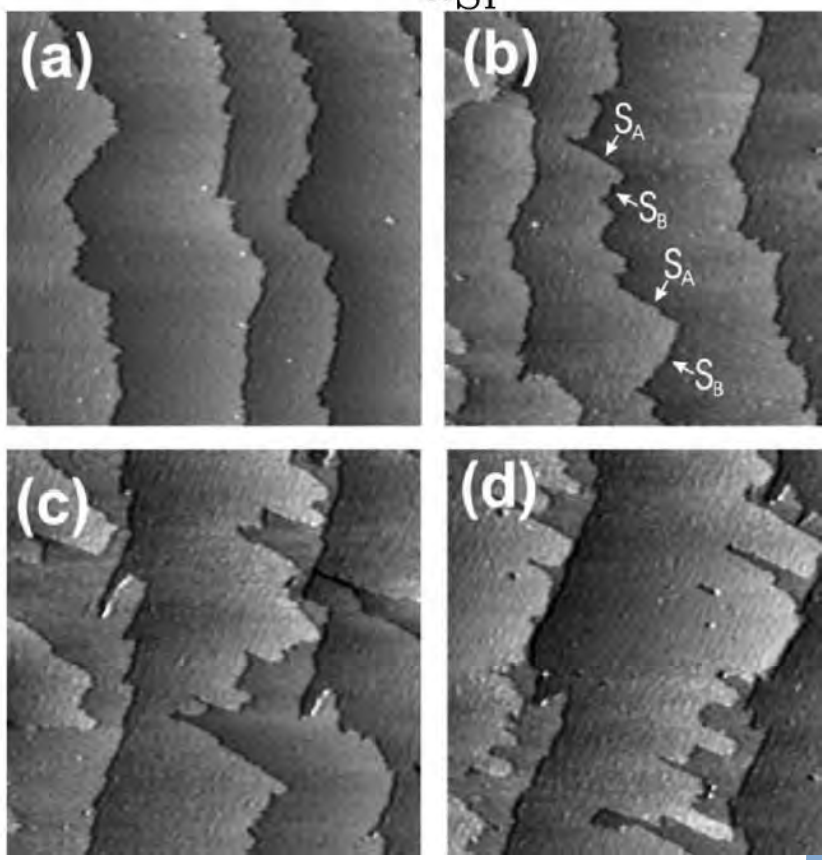




$$\psi(z-\Delta z) \circ\!\!-\!\!\bullet \; \Psi(k_z)e^{ik_z \Delta z}$$

$$\Delta\varphi_{\mathrm{v}} = 2 \cdot 0.85 \frac{2\pi}{a_{\mathrm{Si}}} \Delta z$$





Quantum Computing in the NISQ era

Noisy intermediate scale quantum devices

A experimental pivot from of a **few pristine qubits** to the realization of circuit architectures of **50-100 qubits** but tolerating a significant level of **imperfections.**

Article

Quantum supremacy using a programmable superconducting processor

https://doi.org/10.1038/s41586-019-1666-5

Received: 22 July 2019

Accepted: 20 September 2019

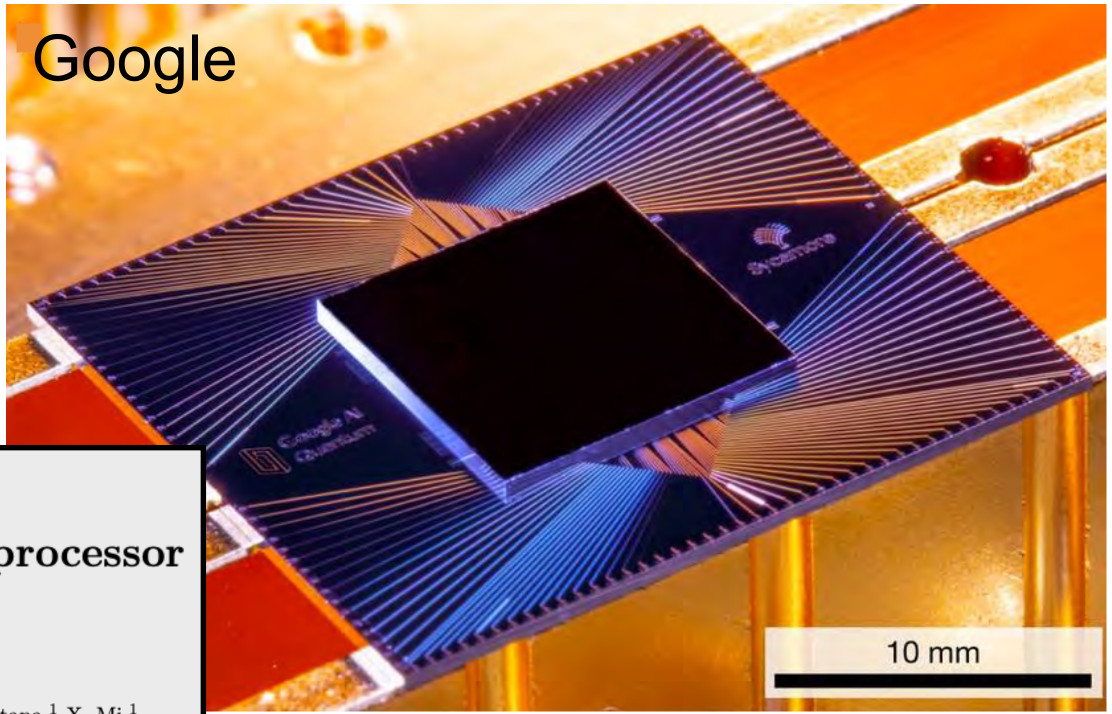
Published online: 23 October 2019

Frank Arute[1], Kunal Arya[1], Ryan Babbush[1], Dave Bacon[1], Joseph C. Bardin[1,2], Rami Barends[1], Rupak Biswas[3], Sergio Boixo[1], Fernando G. S. L. Brandao[1,4], David A. Buell[1], Brian Burkett[1], Yu Chen[1], Zijun Chen[1], Ben Chiaro[5], Roberto Collins[1], William Courtney[1], Andrew Dunsworth[1], Edward Farhi[1], Brooks Foxen[1,5], Austin Fowler[1], Craig Gidney[1], Marissa Giustina[1], Rob Graff[1], Keith Guerin[1], Steve Habegger[1], Matthew P. Harrigan[1], Michael J. Hartmann[1,6], Alan Ho[1], Markus Hoffmann[1], Trent Huang[1], Travis S. Humble[7], Sergei V. Isakov[1], Evan Jeffrey[1],

Realizing topologically ordered states on a quantum processor

arXiv:2104.01180v1

K. J. Satzinger,[1] Y. Liu,[2,3] A. Smith,[2,4,5] C. Knapp,[6,7] M. Newman,[1] C. Jones,[1] Z. Chen,[1] C. Quintana,[1] X. Mi,[1] A. Dunsworth,[1] C. Gidney,[1] I. Aleiner,[1] F. Arute,[1] K. Arya,[1] J. Atalaya,[1] R. Babbush,[1] J. C. Bardin,[1,8] R. Barends,[1] J. Basso,[1] A. Bengtsson,[1] A. Bilmes,[1] M. Broughton,[1] B. B. Buckley,[1] D. A. Buell,[1] B. Burkett,[1] N. Bushnell,[1] B. Chiaro,[1] R. Collins,[1] W. Courtney,[1] S. Demura,[1] A. R. Derk,[1] D. Eppens,[1] C. Erickson,[1] E. Farhi,[1] L. Foaro,[9] A. G. Fowler,[1] B. Foxen,[1] M. Giustina,[1] A. Greene,[10,1] J. A. Gross,[1] M. P. Harrigan,[1] S. D. Harrington,[1] J. Hilton,[1] S. Hong,[1] T. Huang,[1] W. J. Huggins,[1] L. B. Ioffe,[1] S. V. Isakov,[1] E. Jeffrey,[1] Z. Jiang,[1] D. Kafri,[1] K. Kechedzhi,[1] T. Khattar,[1] S. Kim,[1] P. V. Klimov,[1] A.N. Korotkov,[1] F. Kostritsa,[1] D. Landhuis,[1] P. Laptev,[1] A. Locharla,[1] E. Lucero,[1] O. Martin,[1] J. R. McClean,[1] M. McEwen,[1,11] K. C. Miao,[1] M. Mohseni,[1] S. Montazeri,[1] W. Mruczkiewicz,[1] J. Mutus,[1] O. Naaman,[1] M. Neeley,[1] C. Neill,[1] M. Y. Niu,[1] T. E. O'Brien,[1] A. Opremcak,[1] B. Pató,[1] A. Petukhov,[1] N. C. Rubin,[1] D. Sank,[1] V. Shvarts,[1] D. Strain,[1] M. Szalay,[1] B. Villalonga,[1] T. C. White,[1] Z. Yao,[1] P. Yeh,[1] J. Yoo,[1] A. Zalcman,[1] H. Neven,[1] S. Boixo,[1] A. Megrant,[1] Y. Chen,[1] J. Kelly,[1] V. Smelyanskiy,[1] A. Kitaev,[1,6,7] M. Knap,[2,3,12] F. Pollmann,[2,3] and P. Roushan[1]



All with **superconducting qubits.**

Quantum Computing in the NISQ era

Noisy intermediate scale quantum devices

A experimental pivot from of a **few pristine qu**
of **50-100 qubits** but tolerating a significant le

Article

Quantum supremacy using a programmable superconducting processor

https://doi.org/10.1038/s41586-019-1666-5
Received: 22 July 2019
Accepted: 20 September 2019
Published online: 23 October 2019

Frank Arute[1], Kunal Arya[1], Ryan Babbush[1], Dave Bacon[1], Joseph C. Bardin[1,2], Rami Barends[1], Rupak Biswas[3], Sergio Boixo[1], Fernando G. S. L. Brandao[1,4], David A. Buell[1], Brian Burkett[1], Yu Chen[1], Zijun Chen[1], Ben Chiaro[5], Roberto Collins[1], William Courtney[1], Andrew Dunsworth[1], Edward Farhi[1], Brooks Foxen[1,5], Austin Fowler[1], Craig Gidney[1], Marissa Giustina[1], Rob Graff[1], Keith Guerin[1], Steve Habegger[1], Matthew P. Harrigan[1], Michael J. Hartmann[1,6], Alan Ho[1], Markus Hoffmann[1], Trent Huang[1], Travis S. Humble[7], Sergei V. Isakov[1], Evan Jeffrey[1]

Realizing topologically ordered states on a quant

arXiv:2104.01180v1

K. J. Satzinger,[1] Y. Liu,[2,3] A. Smith,[2,4,5] C. Knapp,[6,7] M. Newman,[1] C. Jones,[1] Z. Chen,
A. Dunsworth,[1] C. Gidney,[1] I. Aleiner,[1] F. Arute,[1] K. Arya,[1] J. Atalaya,[1] R. Babbush,
Barends,[1] J. Basso,[1] A. Bengtsson,[1] A. Bilmes,[1] M. Broughton,[1] B. B. Buckley,[1] D. A.
Bushnell,[1] B. Chiaro,[1] R. Collins,[1] W. Courtney,[1] S. Demura,[1] A. R. Derk,[1] D. Eppens,[1]
L. Foaro,[9] A. G. Fowler,[1] B. Foxen,[1] M. Giustina,[1] A. Greene,[10,1] J. A. Gross,[1] M.
Harrington,[1] J. Hilton,[1] S. Hong,[1] T. Huang,[1] W. J. Huggins,[1] L. B. Ioffe,[1] S. V. Isakov,[1]
Kafri,[1] K. Kechedzhi,[1] T. Khattar,[1] S. Kim,[1] P. V. Klimov,[1] A.N. Korotkov,[1] F. Kostri
Laptev,[1] A. Locharla,[1] E. Lucero,[1] O. Martin,[1] J. R. McClean,[1] M. McEwen,[1,11] K. C.
Montazeri,[1] W. Mruczkiewicz,[1] J. Mutus,[1] O. Naaman,[1] M. Neeley,[1] C. Neill,[1] M. Y.
A. Opremcak,[1] B. Pató,[1] A. Petukhov,[1] N. C. Rubin,[1] D. Sank,[1] V. Shvarts,[1] D. Strain, M. Szalay, B.
Villalonga,[1] T. C. White,[1] Z. Yao,[1] P. Yeh,[1] J. Yoo,[1] A. Zalcman,[1] H. Neven,[1] S. Boixo,[1] A. Megrant,[1]
Y. Chen,[1] J. Kelly,[1] V. Smelyanskiy,[1] A. Kitaev,[1,6,7] M. Knap,[2,3,12] F. Pollmann,[2,3] and P. Roushan[1]

THE QUANTUM DAILY

News · Exclusives · Jobs Board · Solutio

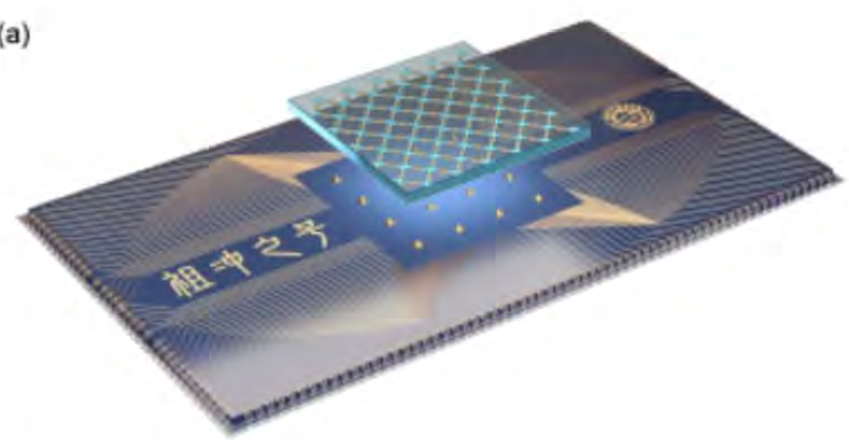
QUANTUM COMPUTING RESEARCH AND TECH

China's Superconducting Quantum Computer Sets Quantum Supremacy Milestone

By **Matt Swayne** June 30, 2021

Facebook · Twitter · Linkedin · Email

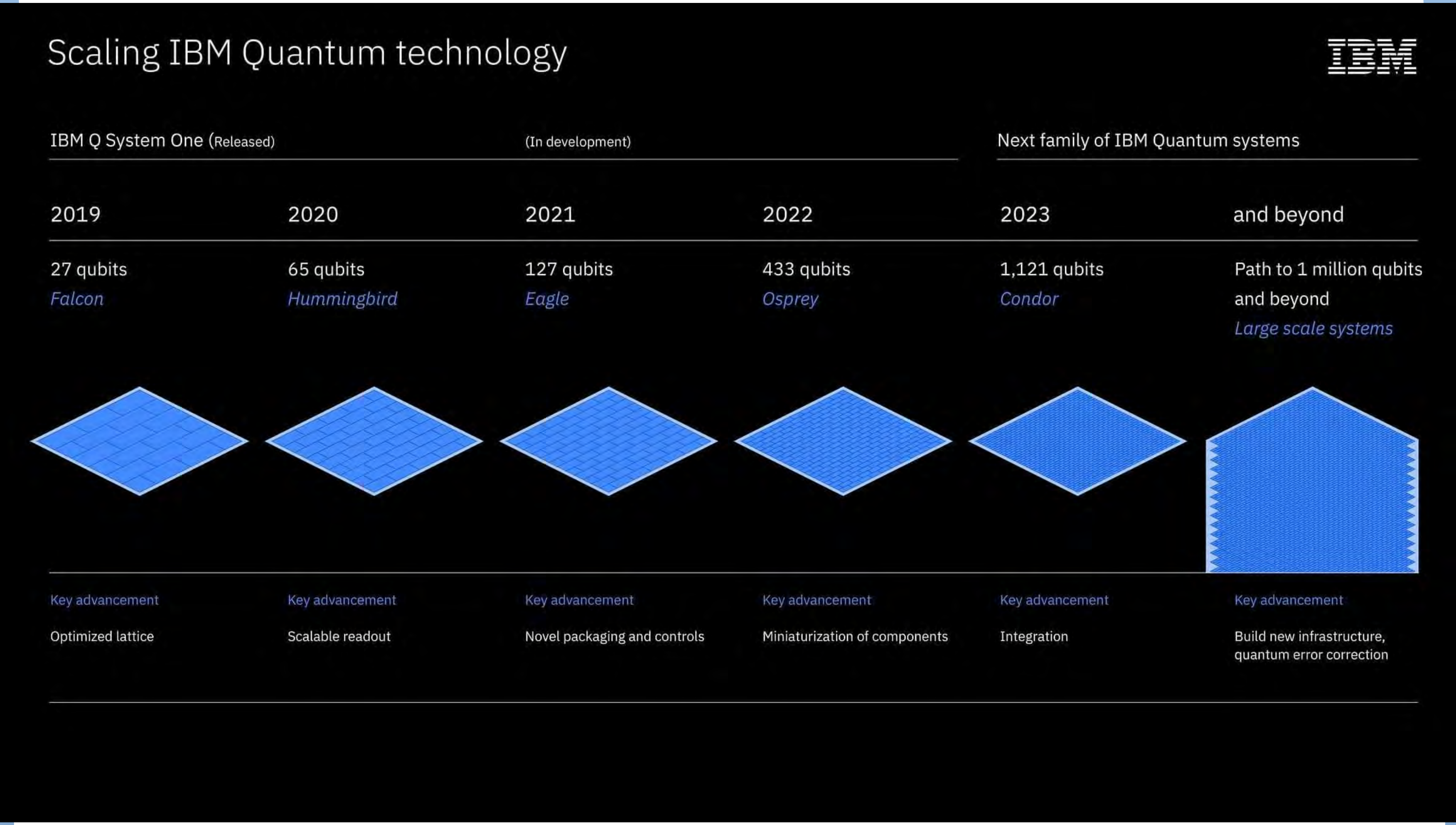
(a)



(b)

superconducting qubits.

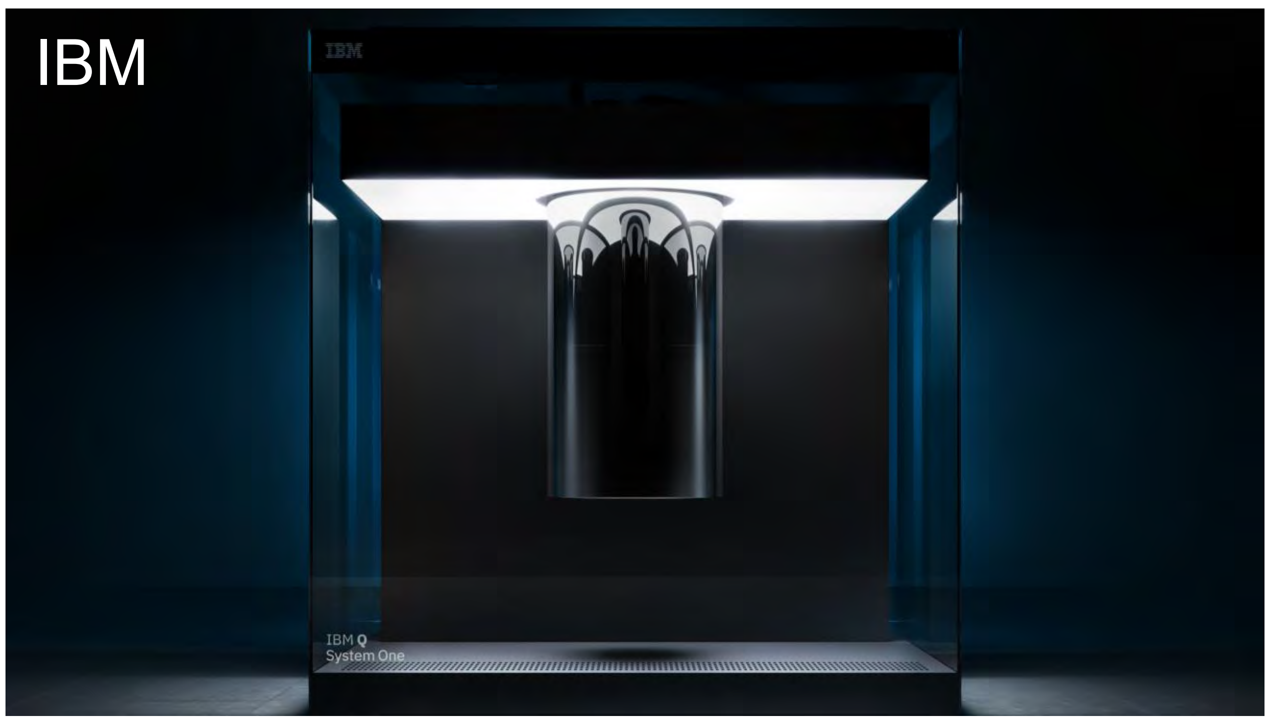
Quantum Computing Beyond the NISQ Era

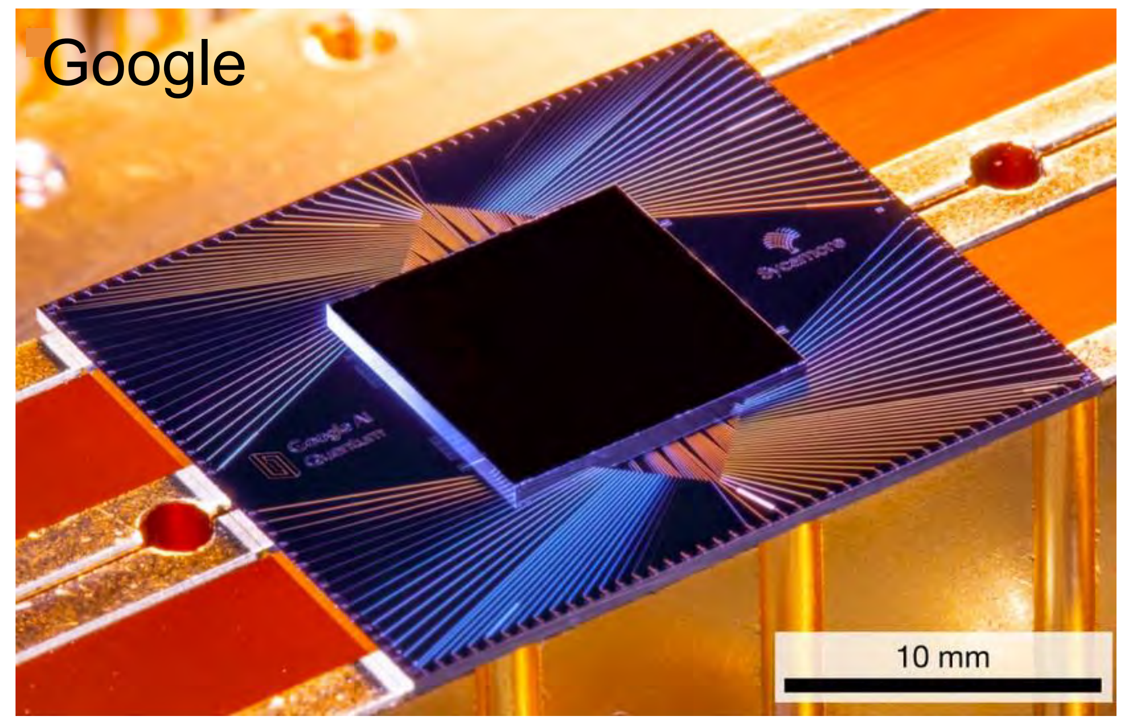


Quantum Computing in the NISQ era

Noisy intermediate scale quantum devices

A experimental pivot from of a **few pristine qubits** to the realization of circuit architectures of **50-100 qubits** but tolerating a significant level of **imperfections.**



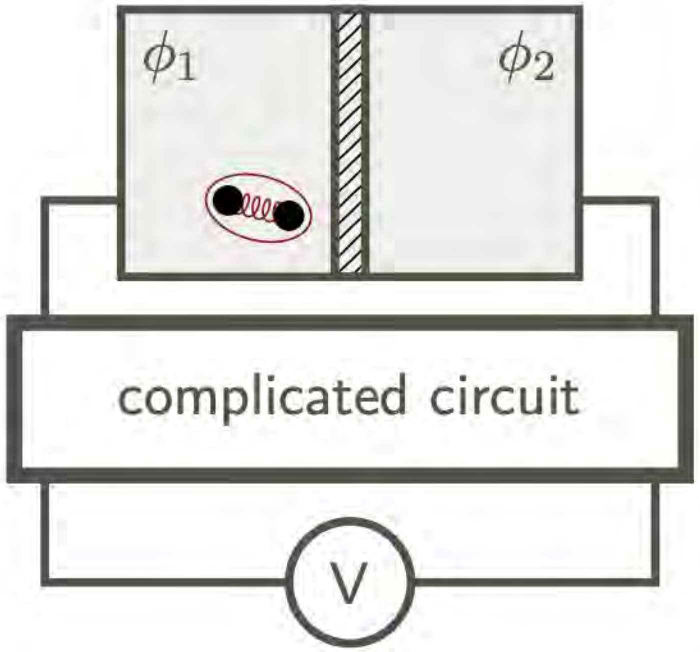


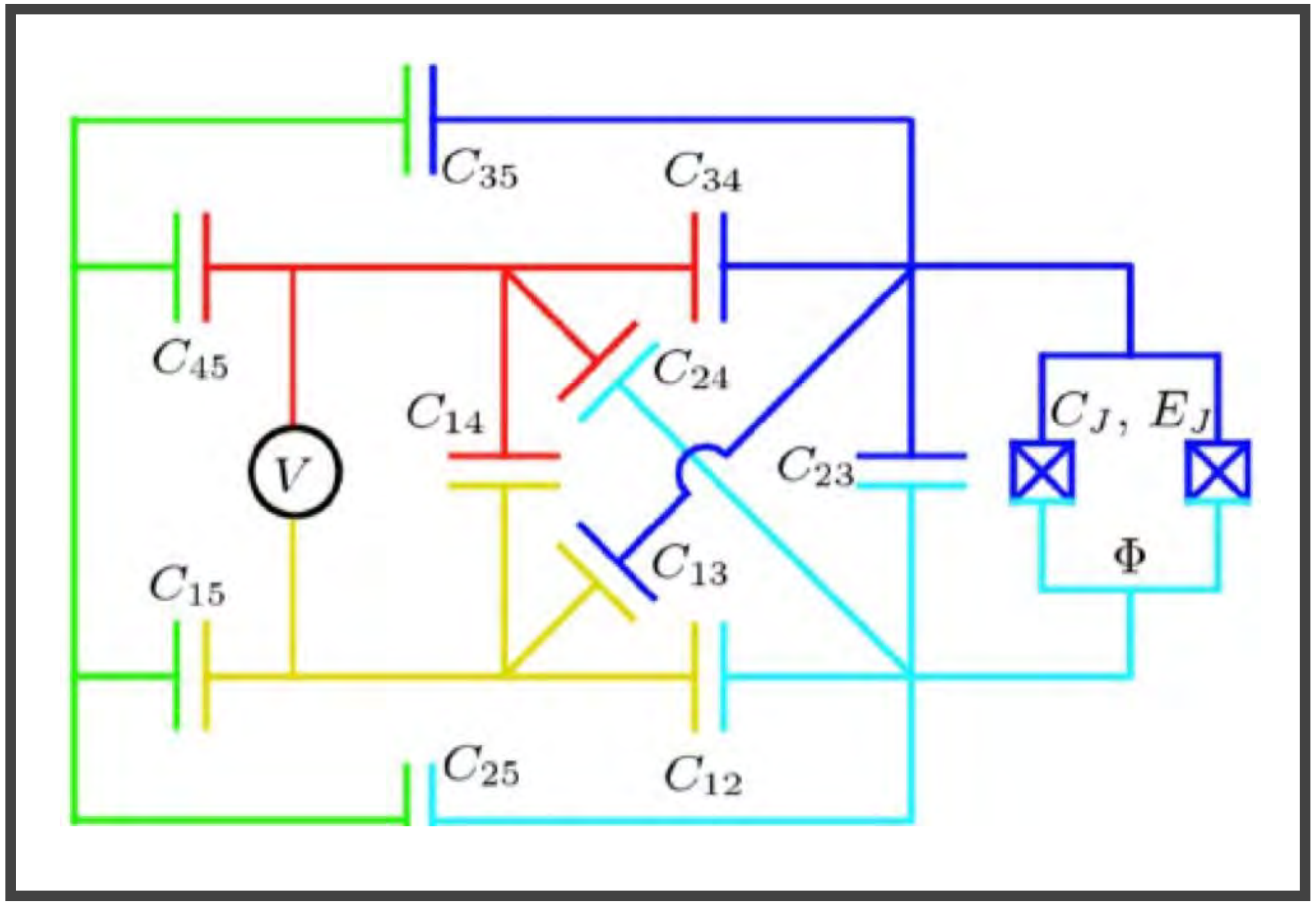
Both, IBM & Google, use superconducting charge qubits: **the transmon**

transmons

the transmon qubit

$$\hat{H}_{ST} = 4E_C(\hat{n} - n_g)^2 - E_J \cos\hat{\phi}$$



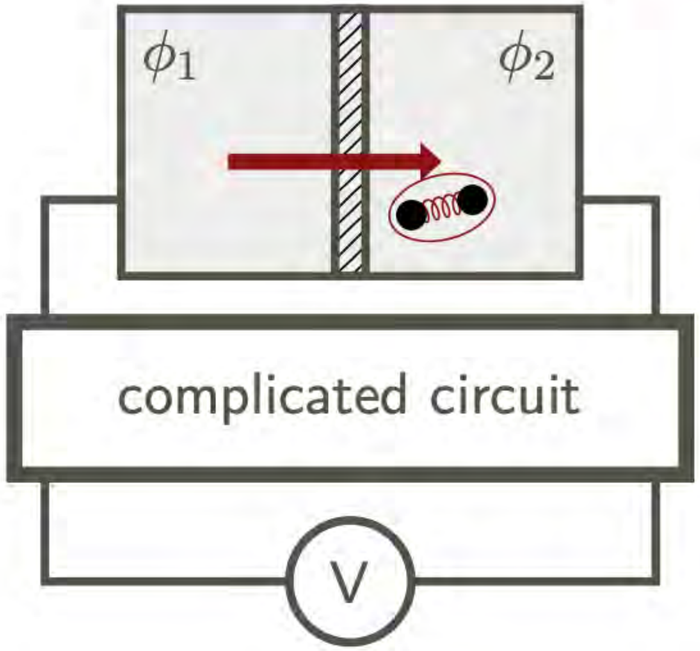


J. Koch et al., Phys. Rev. A (2007)

the transmon qubit

$$\hat{H}_{ST} = 4E_C\,(\hat{n} - n_g)^2 - E_J \;\cos\hat{\phi}$$

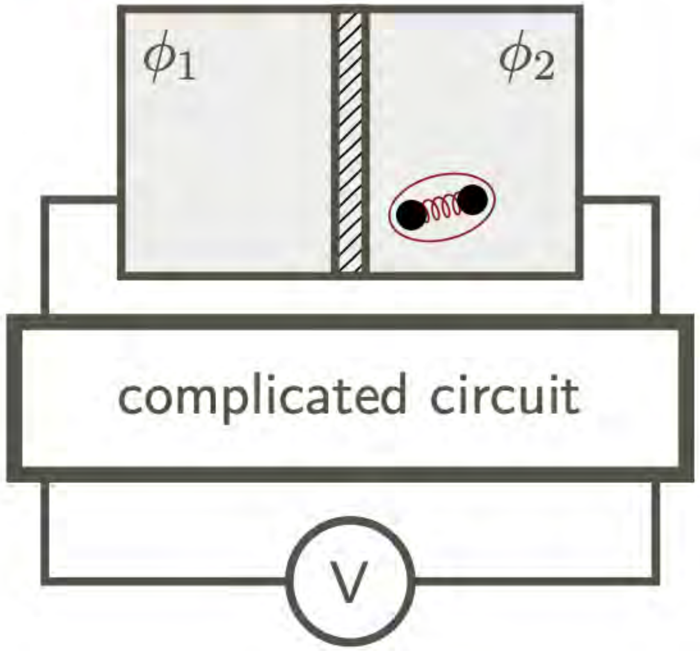
Josephson tunneling



the transmon qubit

$$\hat{H}_{ST} = 4E_C\,(\hat{n} - n_g)^2 - E_J\,\cos\hat{\phi}$$

charging energy

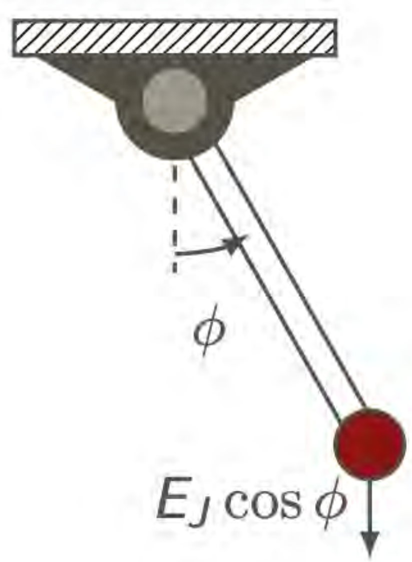


charge insensitive

cooper pair box

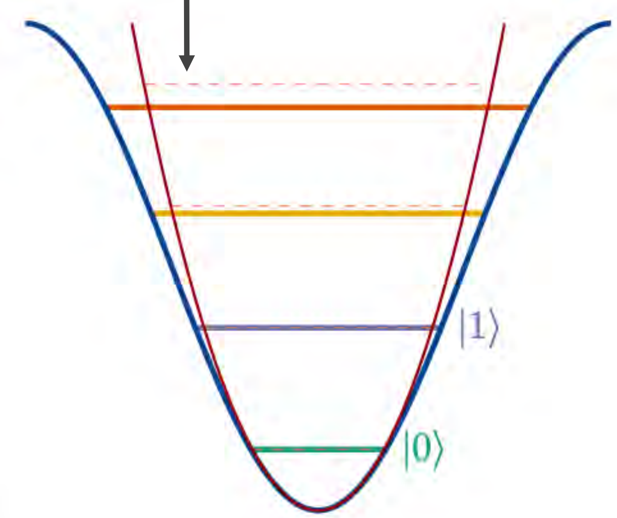
the transmon qubit

$$\hat{H}_{ST} = 4E_C\,(\hat{n} - n_g)^2 - E_J\ \cos\hat{\phi}$$



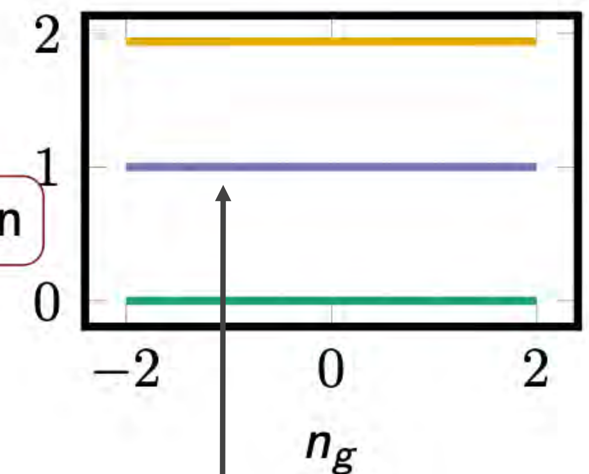
level spacings converge **algebraically** to equidistance

Anharmonicity



$E_J/E_C = 50$

Charge dispersion



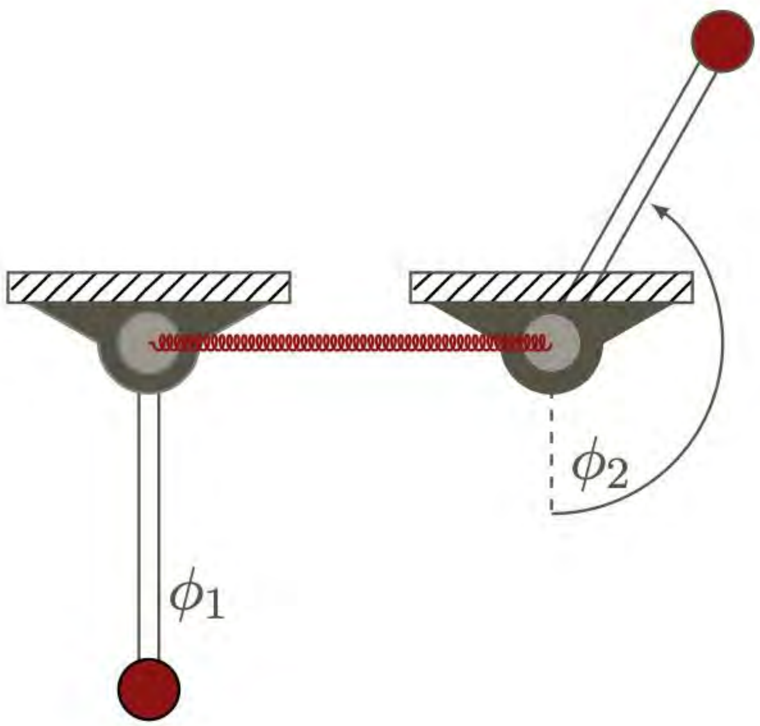
charge sensitivity decays **exponentially**

charge insensitive

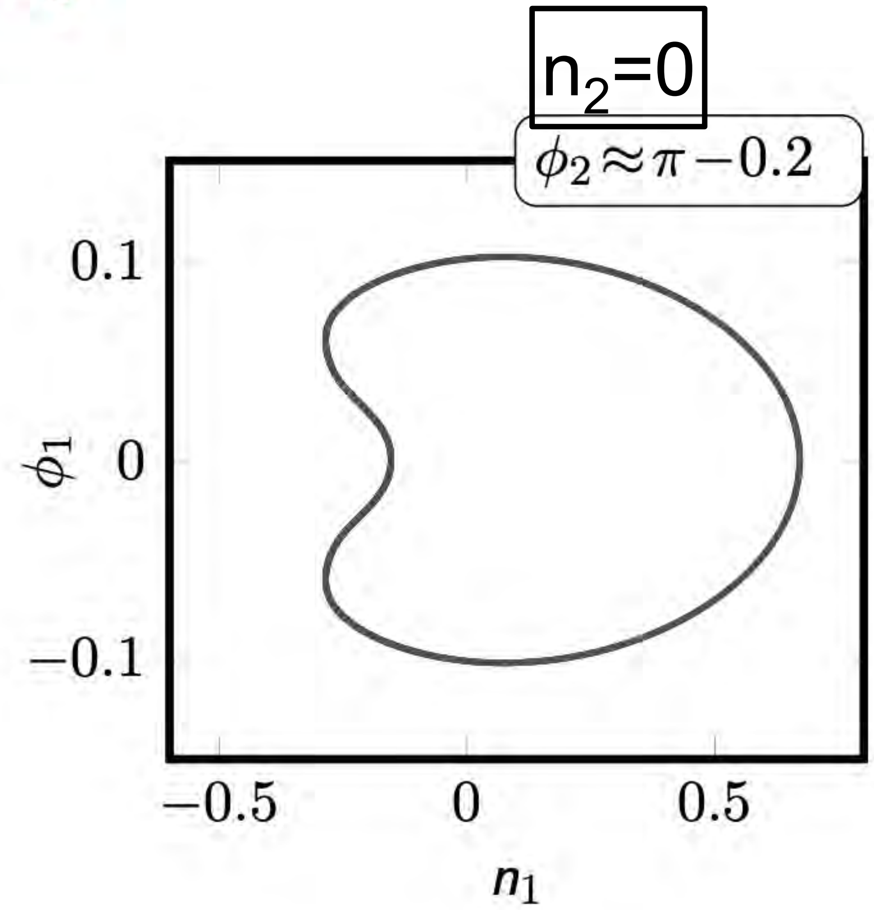
cooper pair box

classical transmon dynamics

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

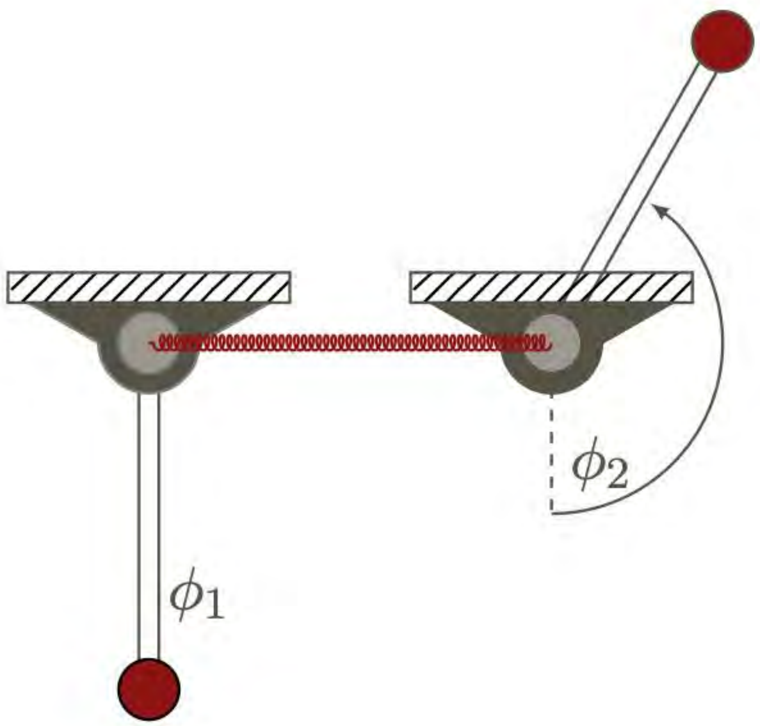


2 Transmons

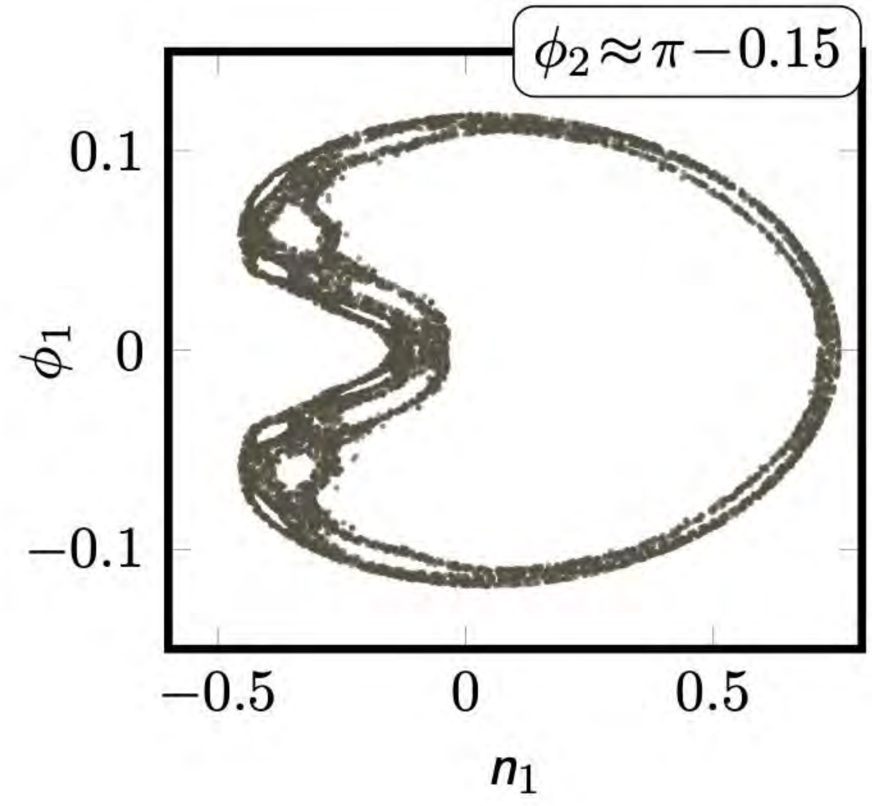


NB: “Actual” coupler is not a spring; rather, the angular momenta are coupled to one another (no easy mechanical analog?).
“Spring” is correct in small-oscillation case (with rotating-wave approximation)

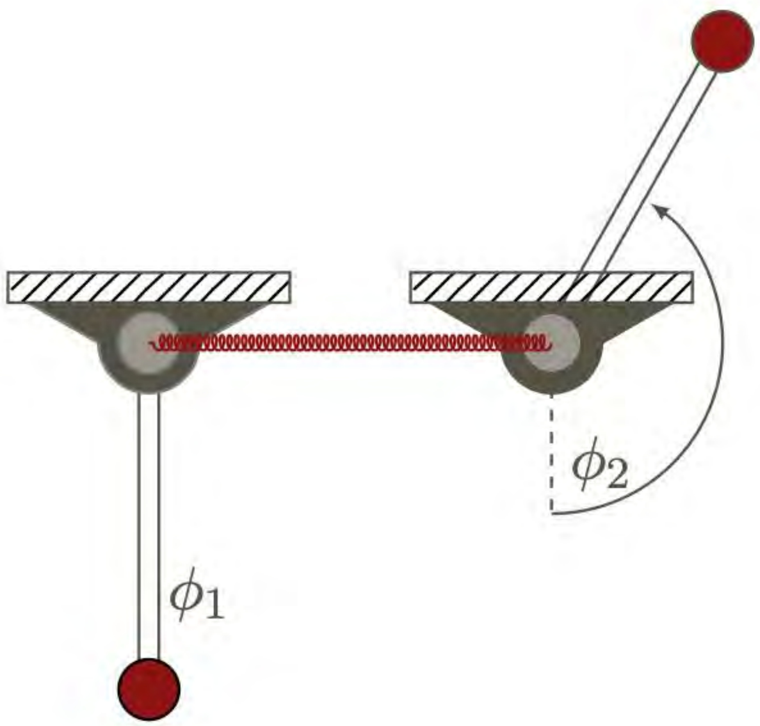
classical transmon dynamics



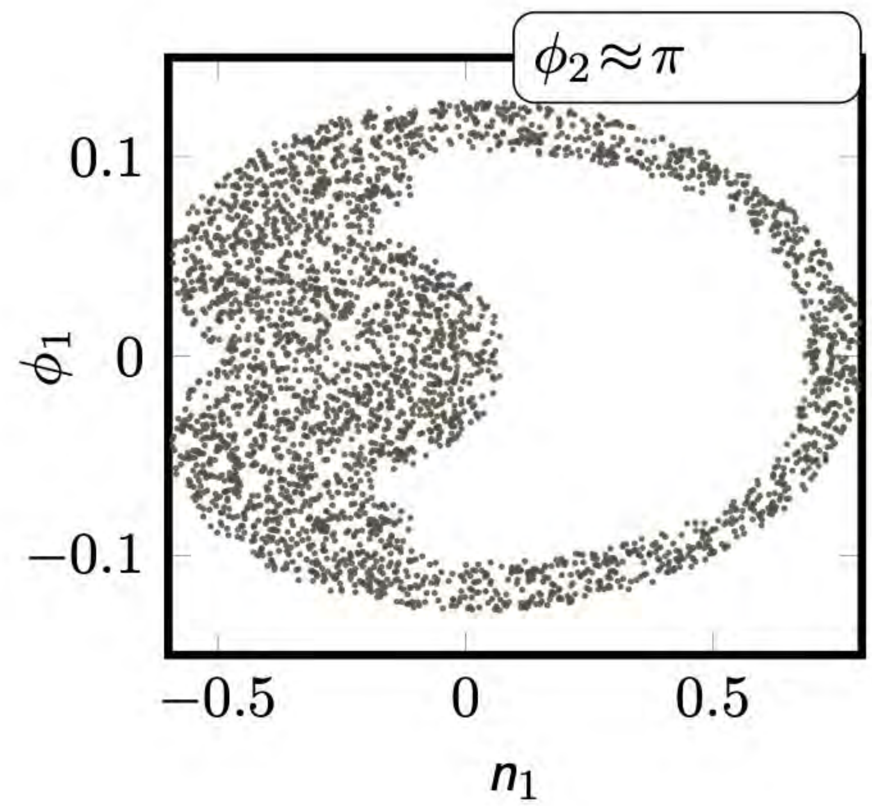
2 Transmons



classical transmon dynamics



2 Transmons

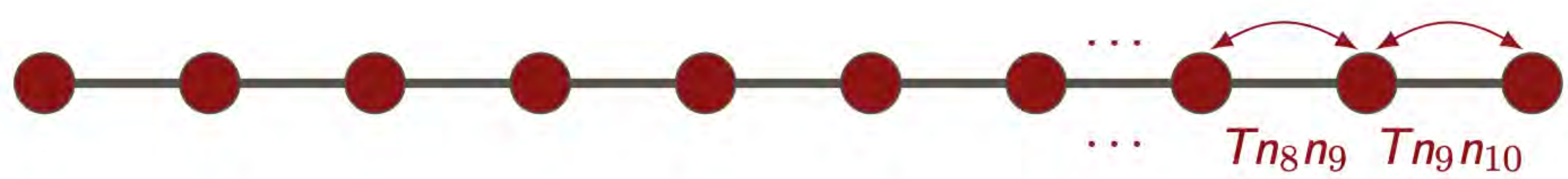


Dynamics exhibits CLASSICAL CHAOS

interacting transmons

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

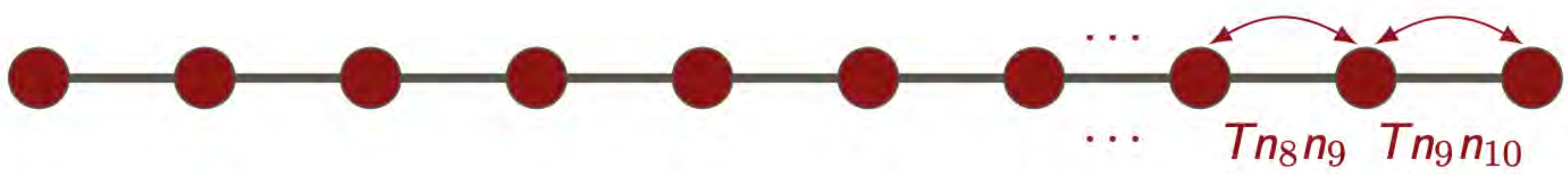


relevant **energy scales**

interacting transmons

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling



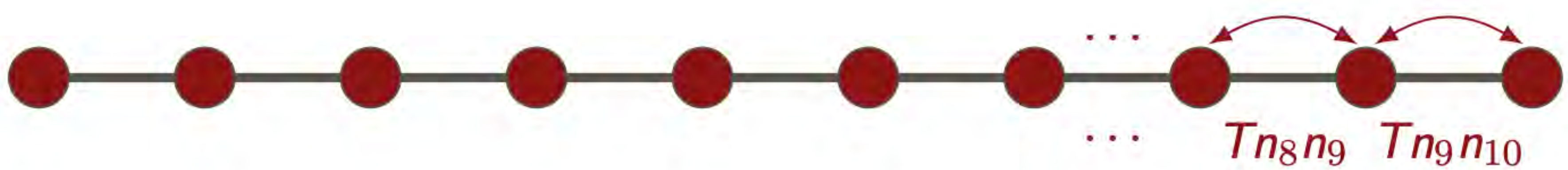
relevant **energy scales**

interacting transmons

Not temperature, but coupling

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling



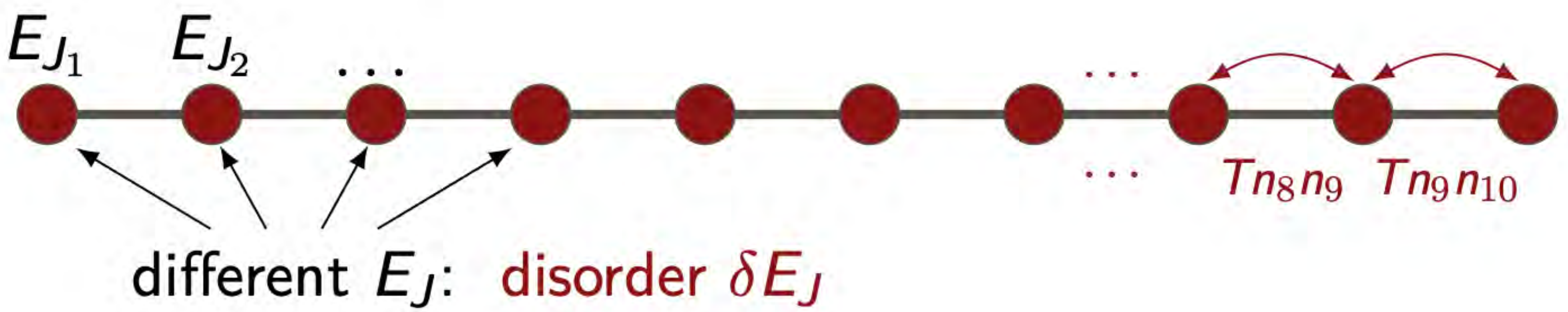
relevant **energy scales**

temperature

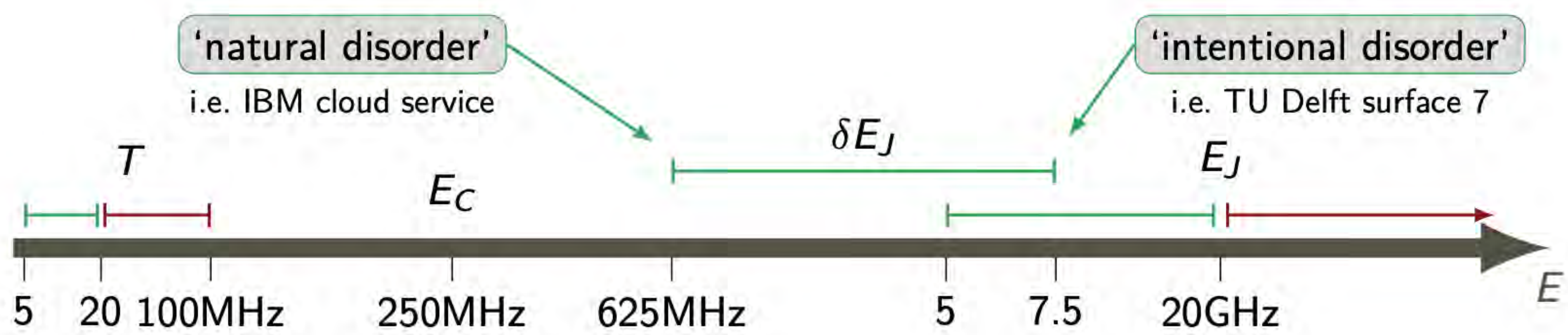
interacting transmons

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling



relevant **energy scales**

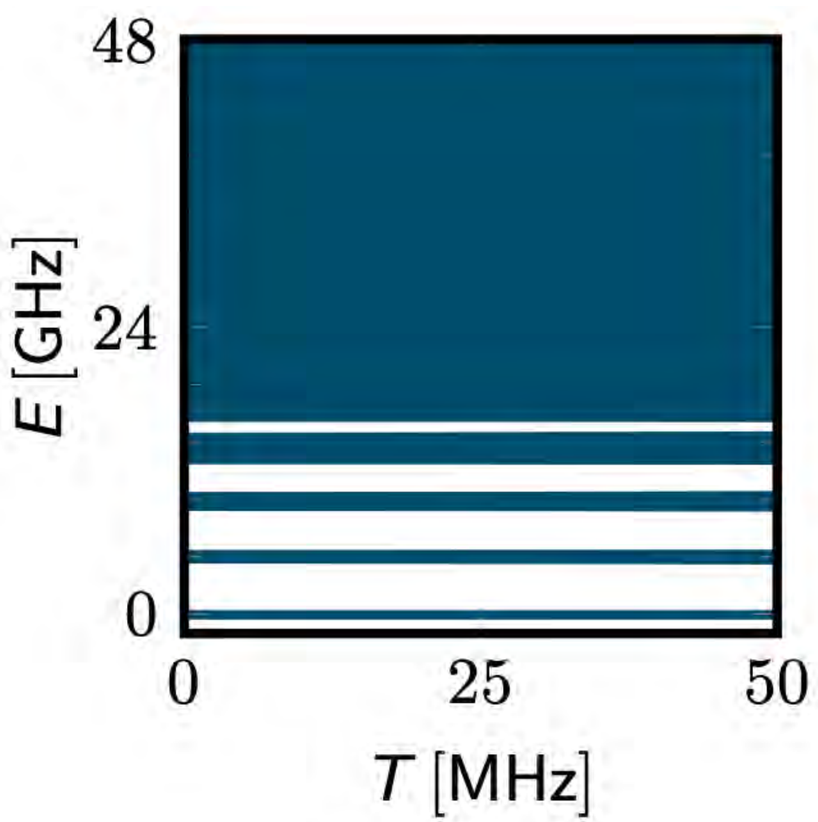


energy spectra – spaghetti plots

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

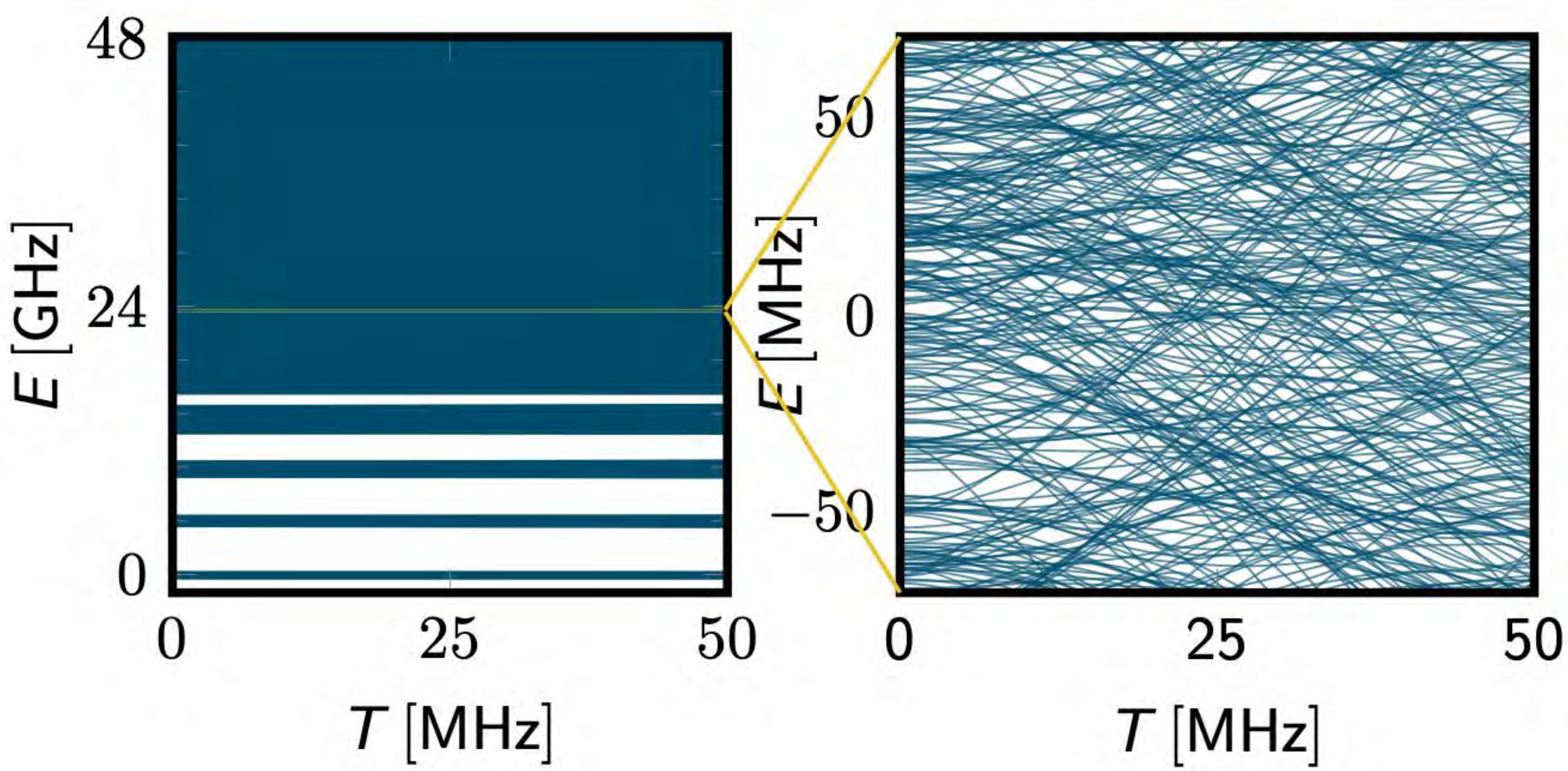
T≠0
(finite coupling)



energy spectra – spaghetti plots

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$ Capacitive coupling

$T \neq 0$
(finite coupling)

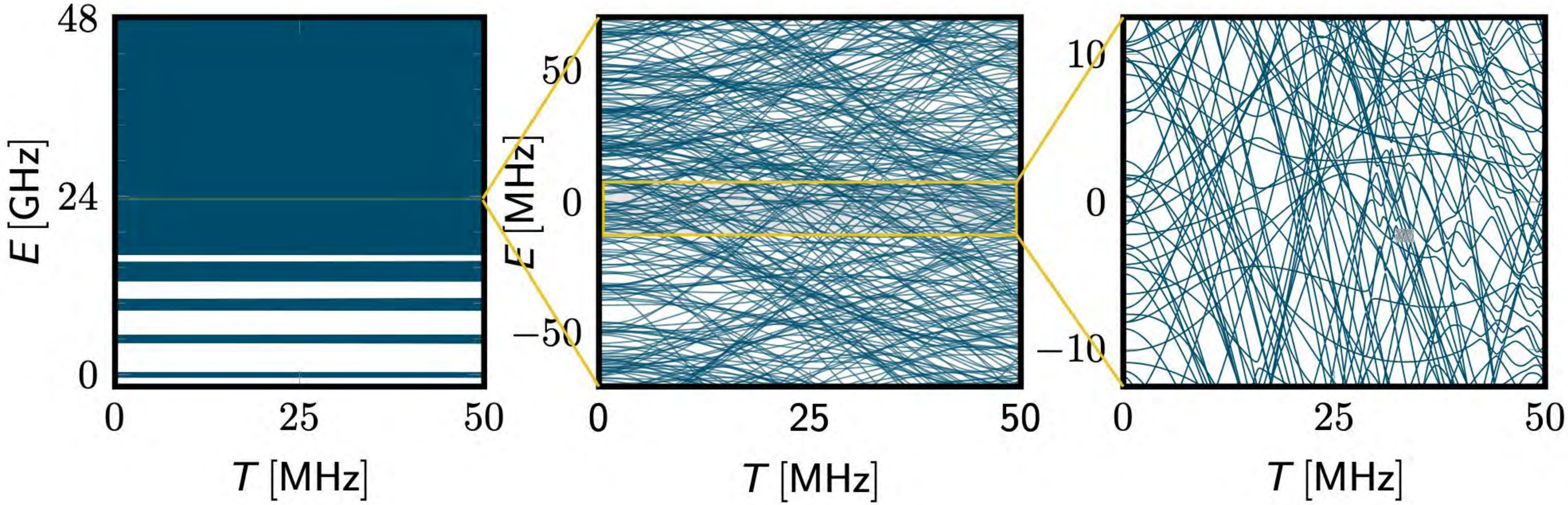


energy spectra – spaghetti plots

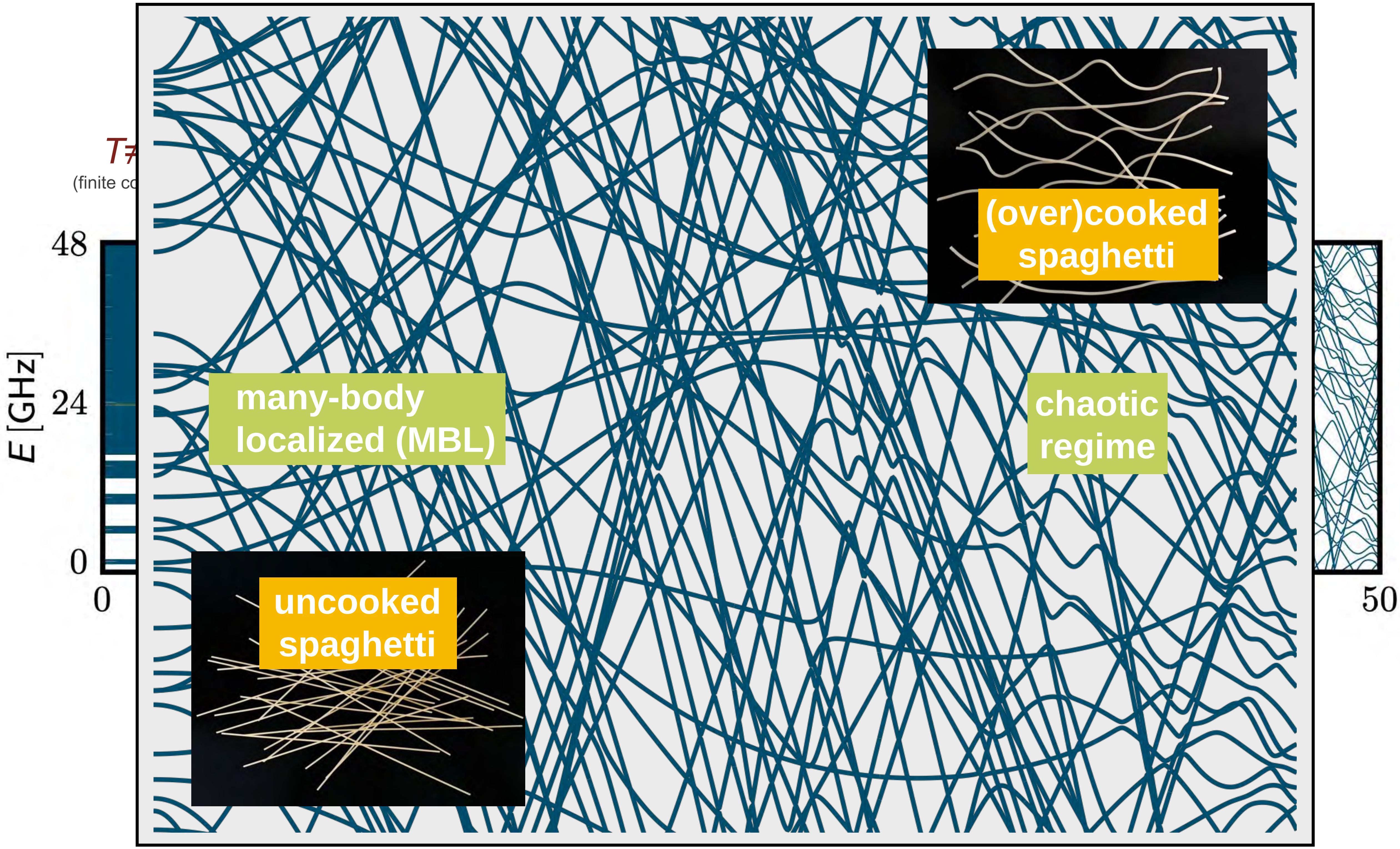
$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

T≠0
(finite coupling)



energy spectra – spaghetti plots

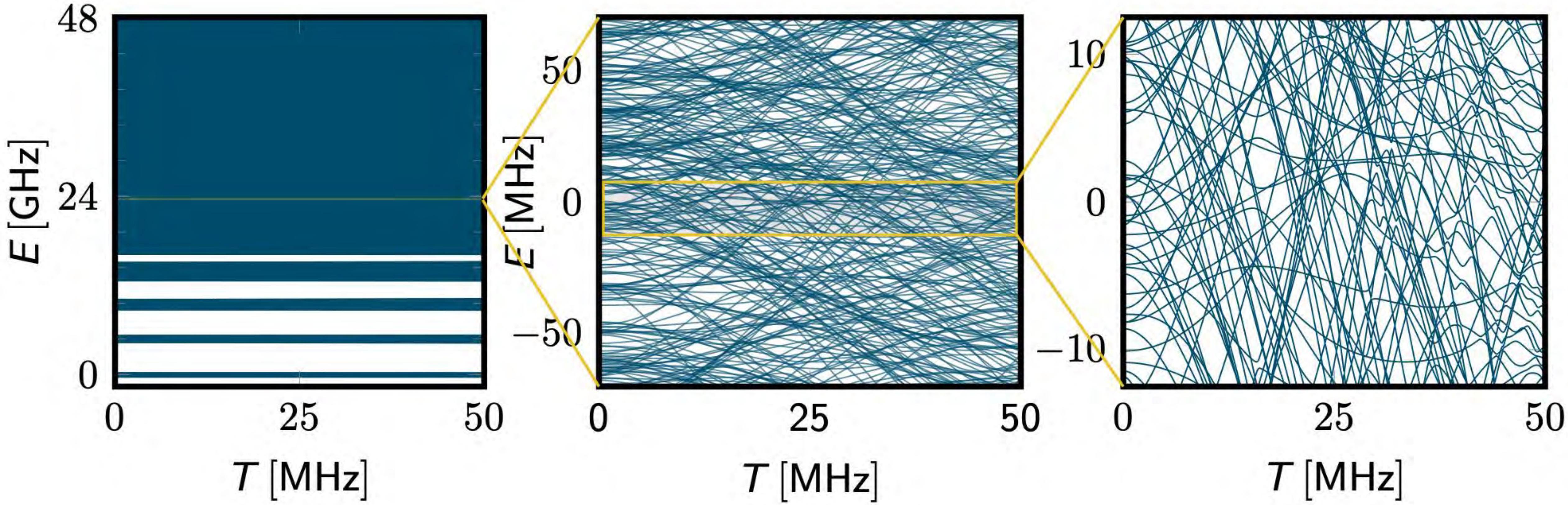


energy spectra – spaghetti plots

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

T≠0
(finite coupling)



Some **key questions**:
Signatures of chaos? What do we have to look for? Computational states for $T > 0$?

computational states

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i \; + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

SORRY, TWO DIFFERENT n's:
-Cooper pair charge operator
-excitation number

T=0
(no coupling)

Product states $|\psi\rangle = |n_1, n_2, \ldots\rangle$ with total excitation number $n = \sum_i n_i$.

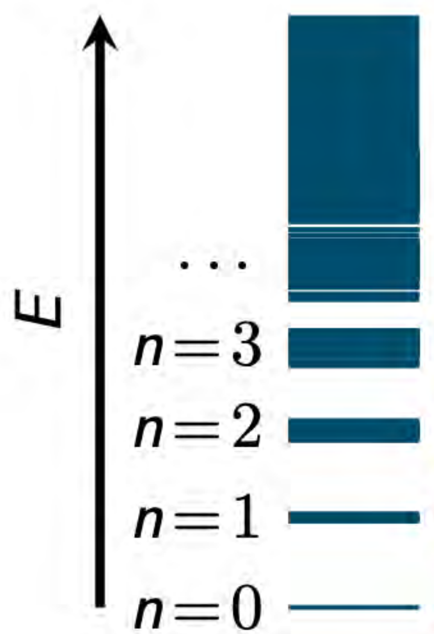
computational states

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{<i,j>} n_i n_j$$

Capacitive coupling

T=0
(no coupling)

Product states $|\psi\rangle = |n_1, n_2, \ldots\rangle$ with total excitation number $n = \sum_i n_i$.



$56 \times |1,1,1,\ldots\rangle$, $8 \times |3,0,\ldots\rangle, \ldots$

$28 \times |1,1,0,\ldots\rangle$, $8 \times |2,0,\ldots\rangle$

$8 \times |1,0,\ldots\rangle$

$|0,0,\ldots\rangle$

$\dim \mathcal{H}_{\text{cs}} \approx 3 \cdot 10^6$

computational subspace (8 transmons)

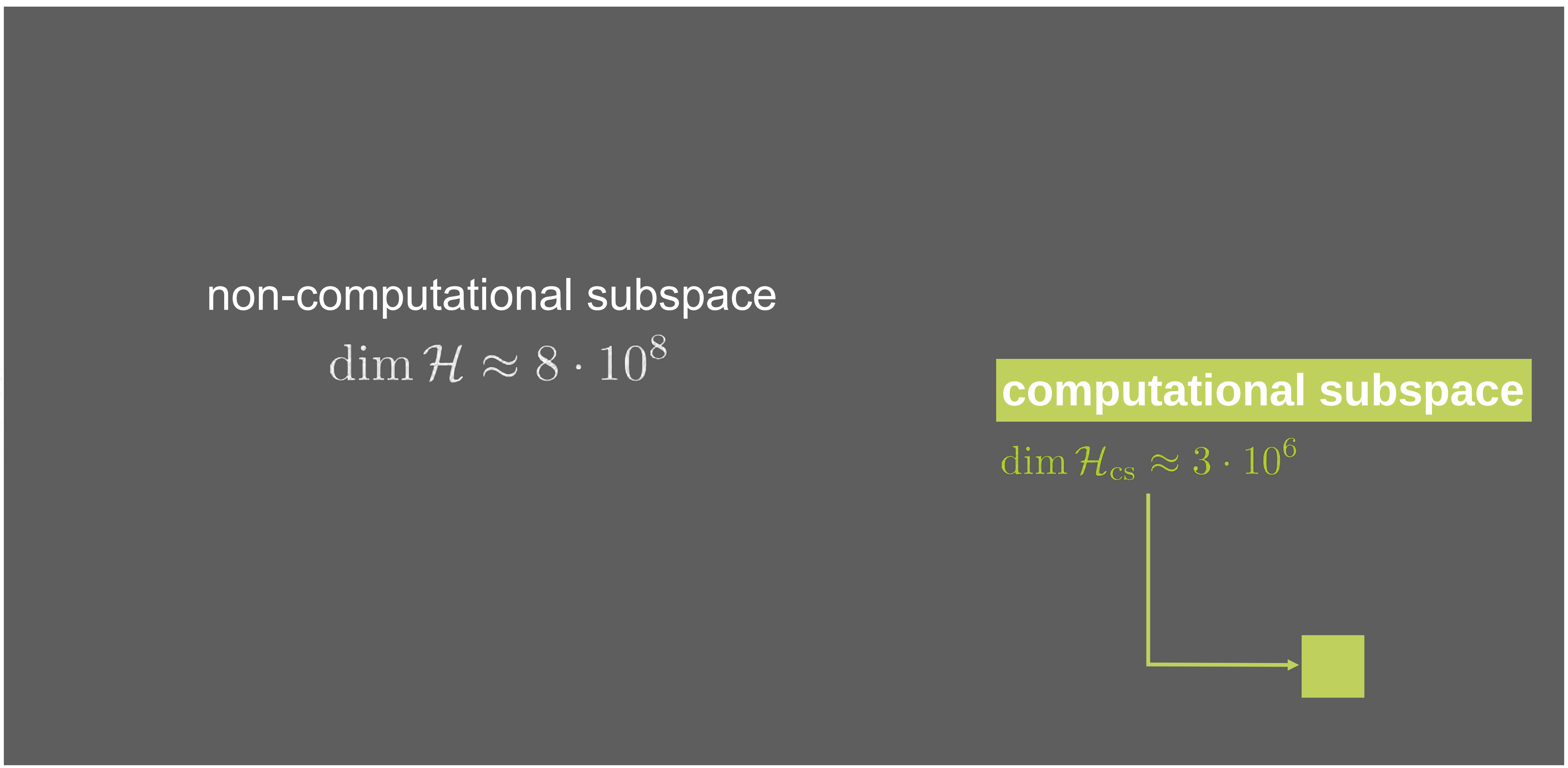
computational states

$$H = 4E_C \sum_i n_i^2 - \sum_i E_{J_i} \cos\phi_i + T \sum_{\langle i,j \rangle} n_i n_j$$

Capacitive coupling

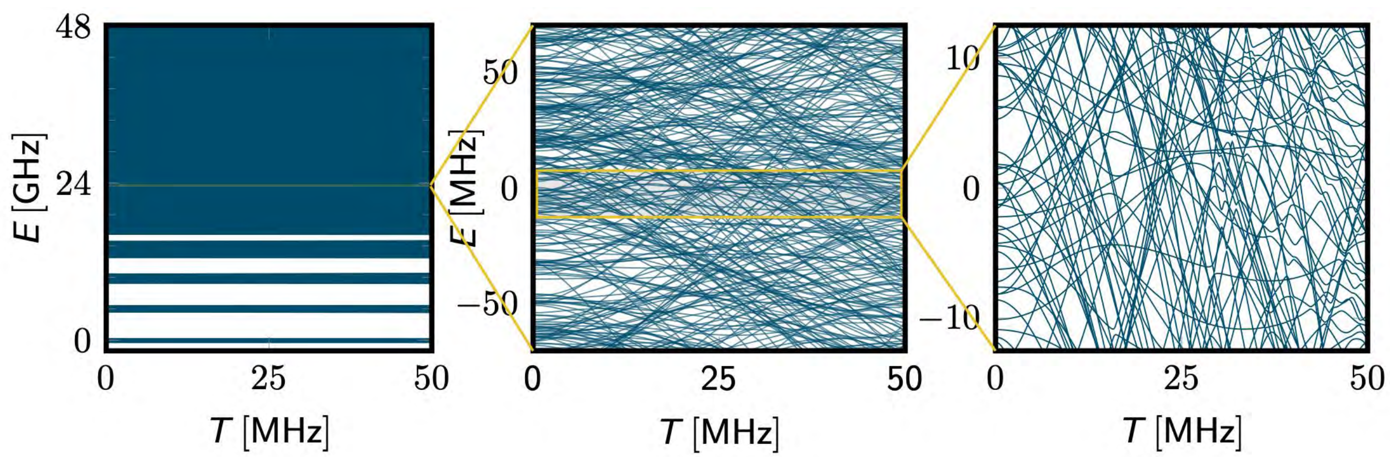
T=0
(no coupling)

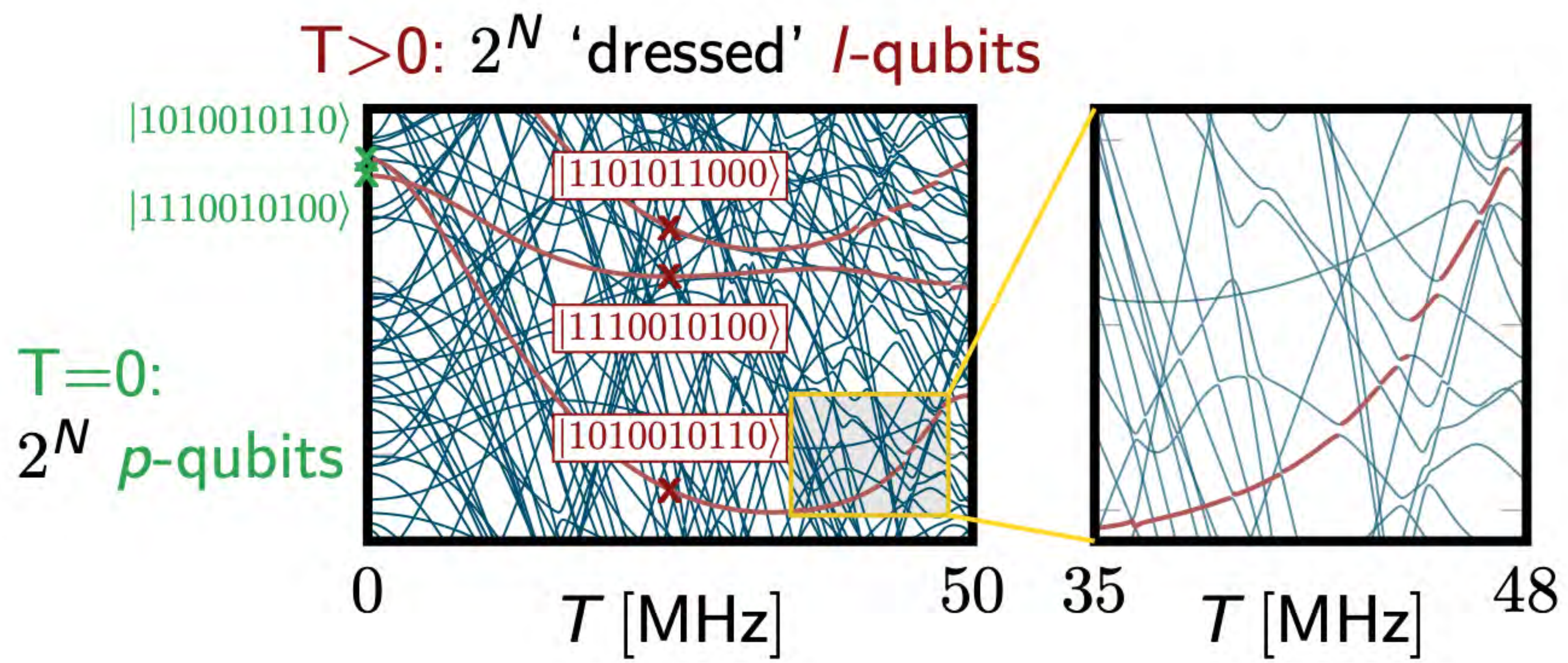
Product states $|\psi\rangle = |n_1, n_2, \ldots\rangle$ with total excitation number $n = \sum_i n_i$.



diagnostics

Finding the localized states that we want





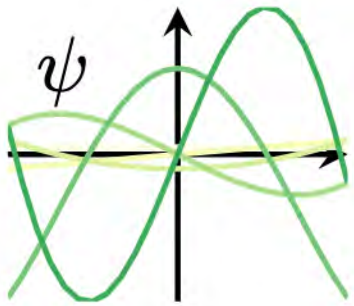
meet the team

Christoph also prepared many (LaTeX) originals for the slides of this talk.

diagnostic toolbox

spectral statistics

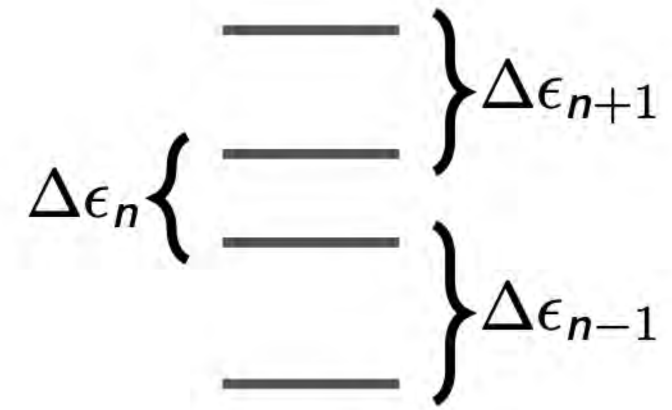
wavefunction statistics



Walsh transform

spectral statistics

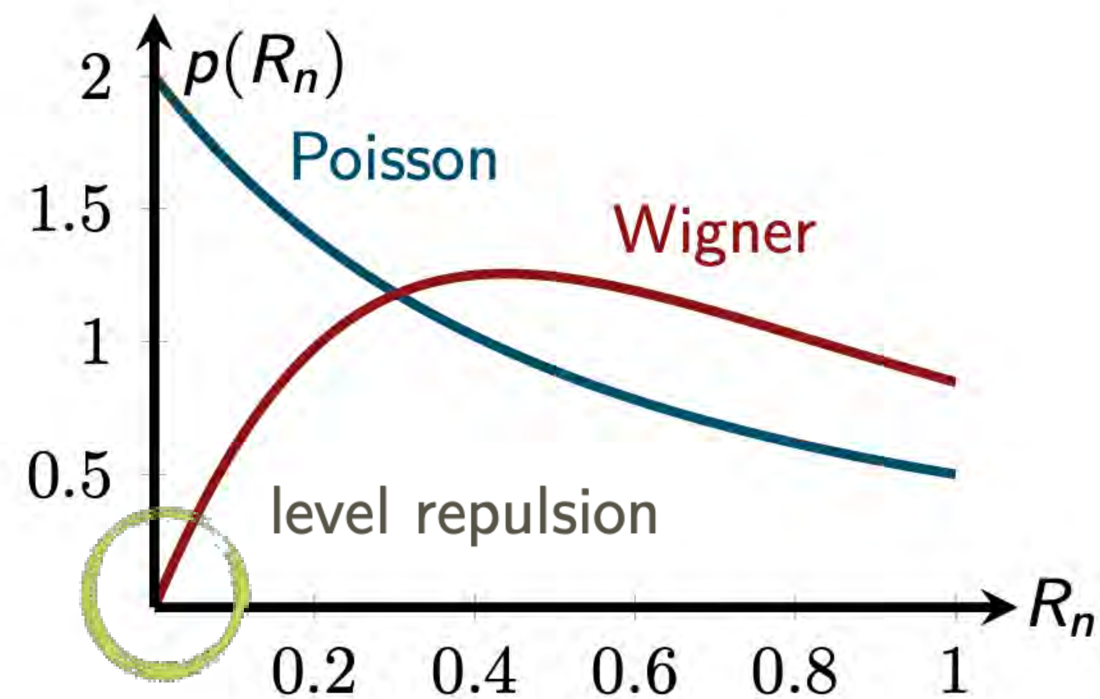
- Statistics for $r_n = \Delta\epsilon_{n+1}/\Delta\epsilon_n$, $R_n = \min(r_n, 1/r_n)$.
- MBL phase: **Poisson** statistics.
- Chaotic: GOE **Wigner-Dyson** statistics.



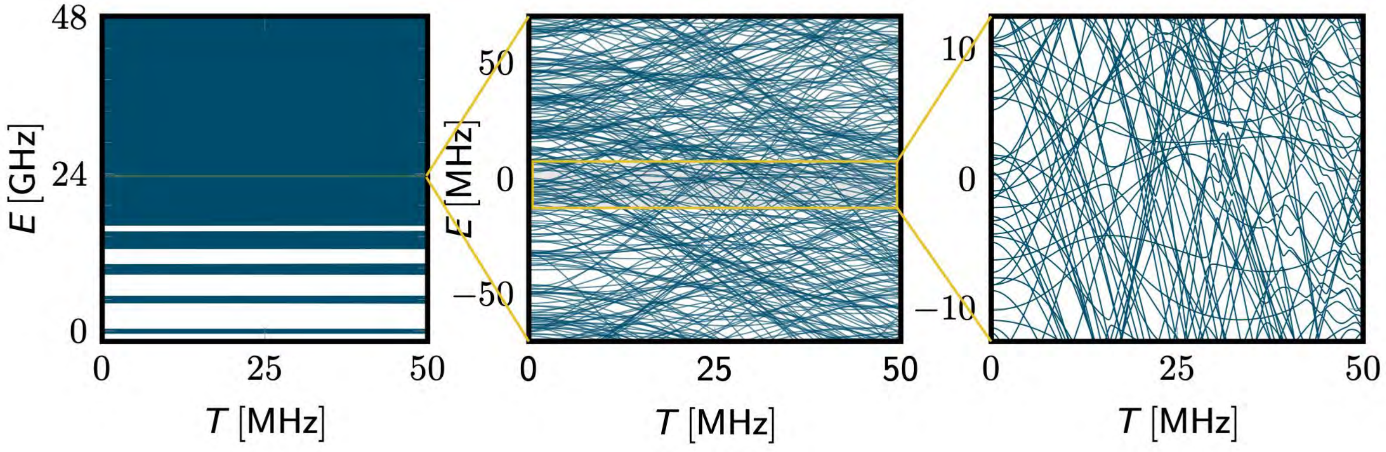
- Degree of agreement measured with **Kullback-Leibler divergence**:

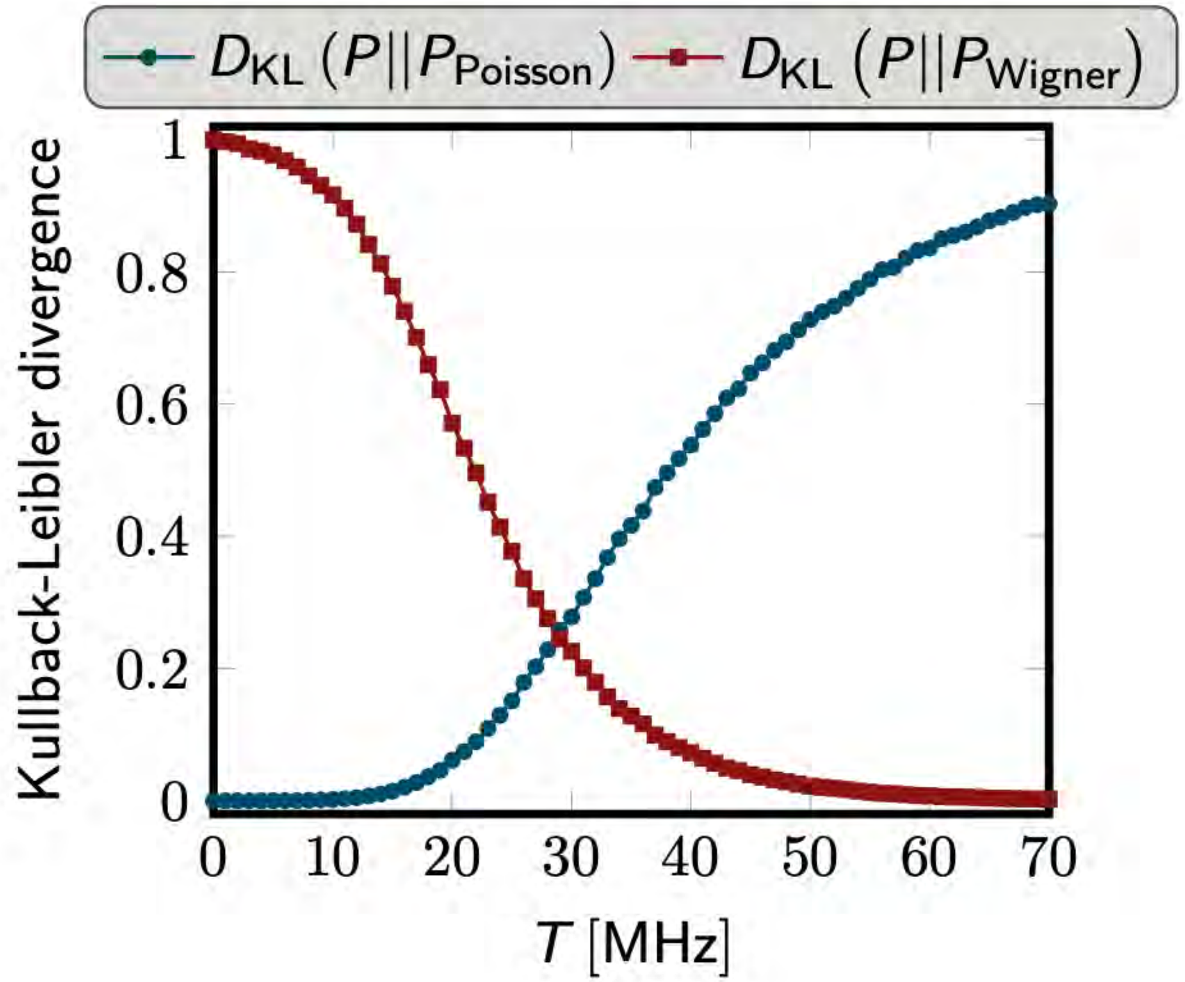
$$D_{\mathrm{KL}}(P||Q) = \sum_k p_k \log\left(\frac{p_k}{q_k}\right)$$

data (p_k) — theory (q_k)



Kullback-Leibler divergence

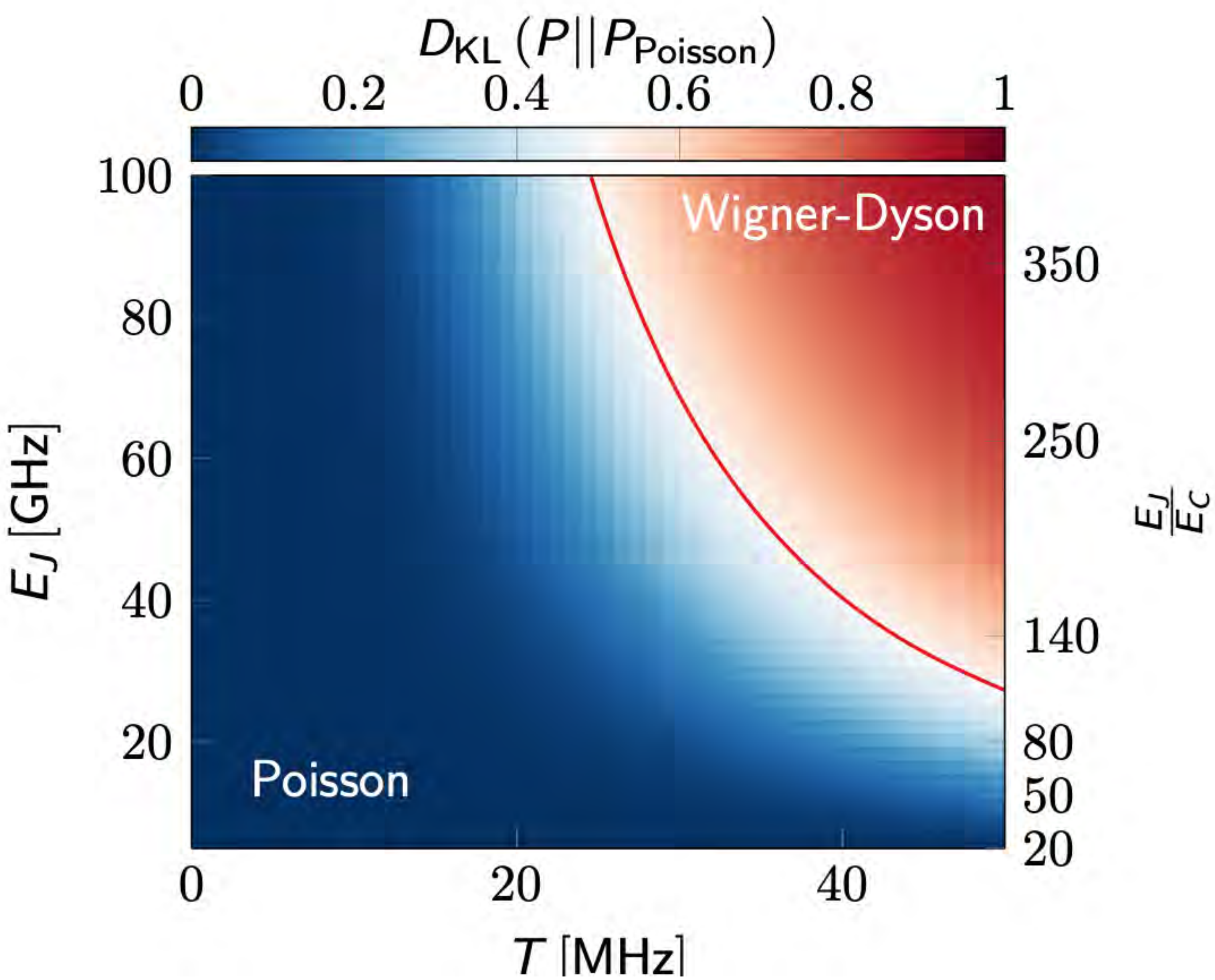




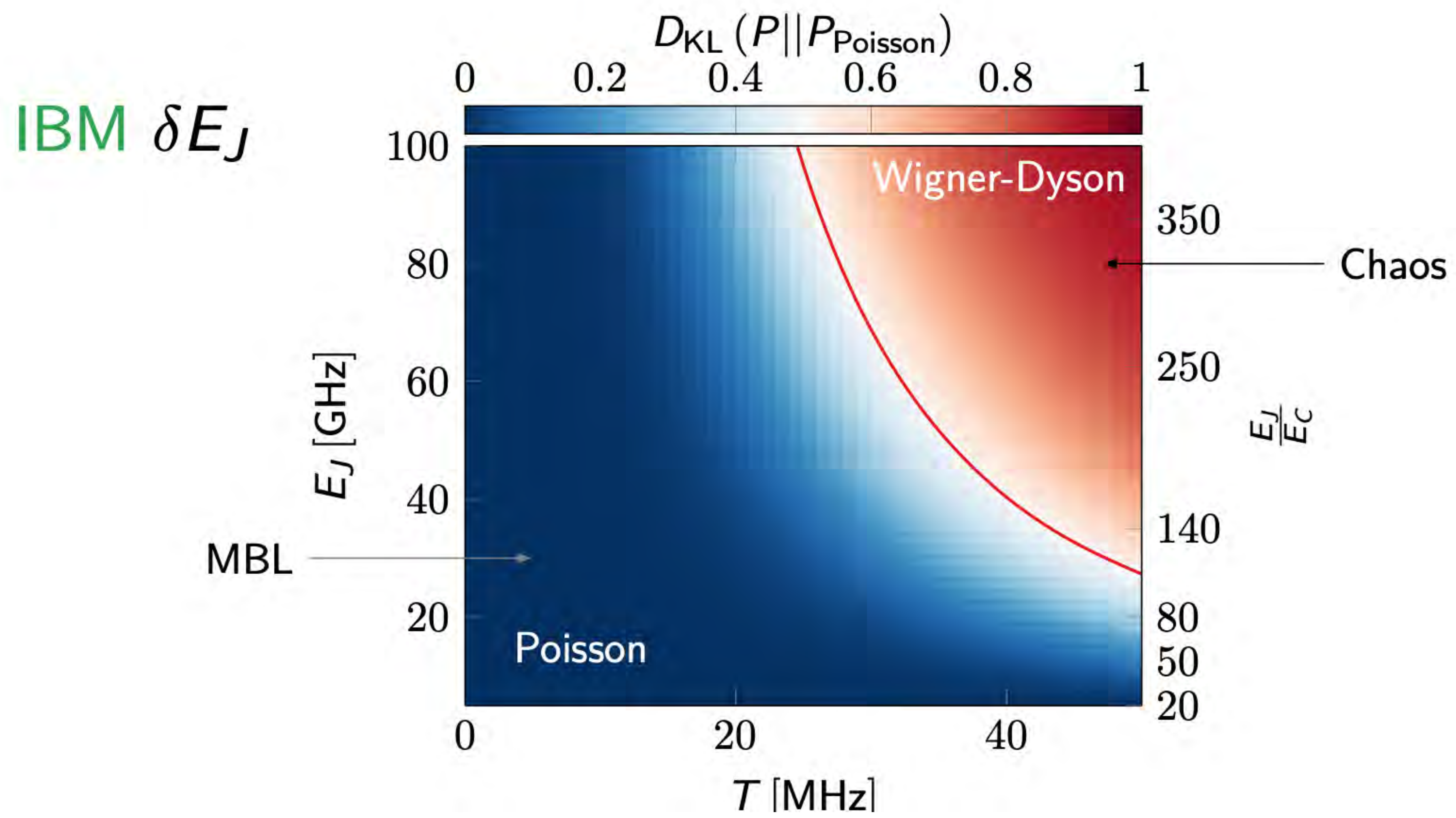
$E_J = 44$GHz
10 Transmons

phase diagram

IBM δE_J

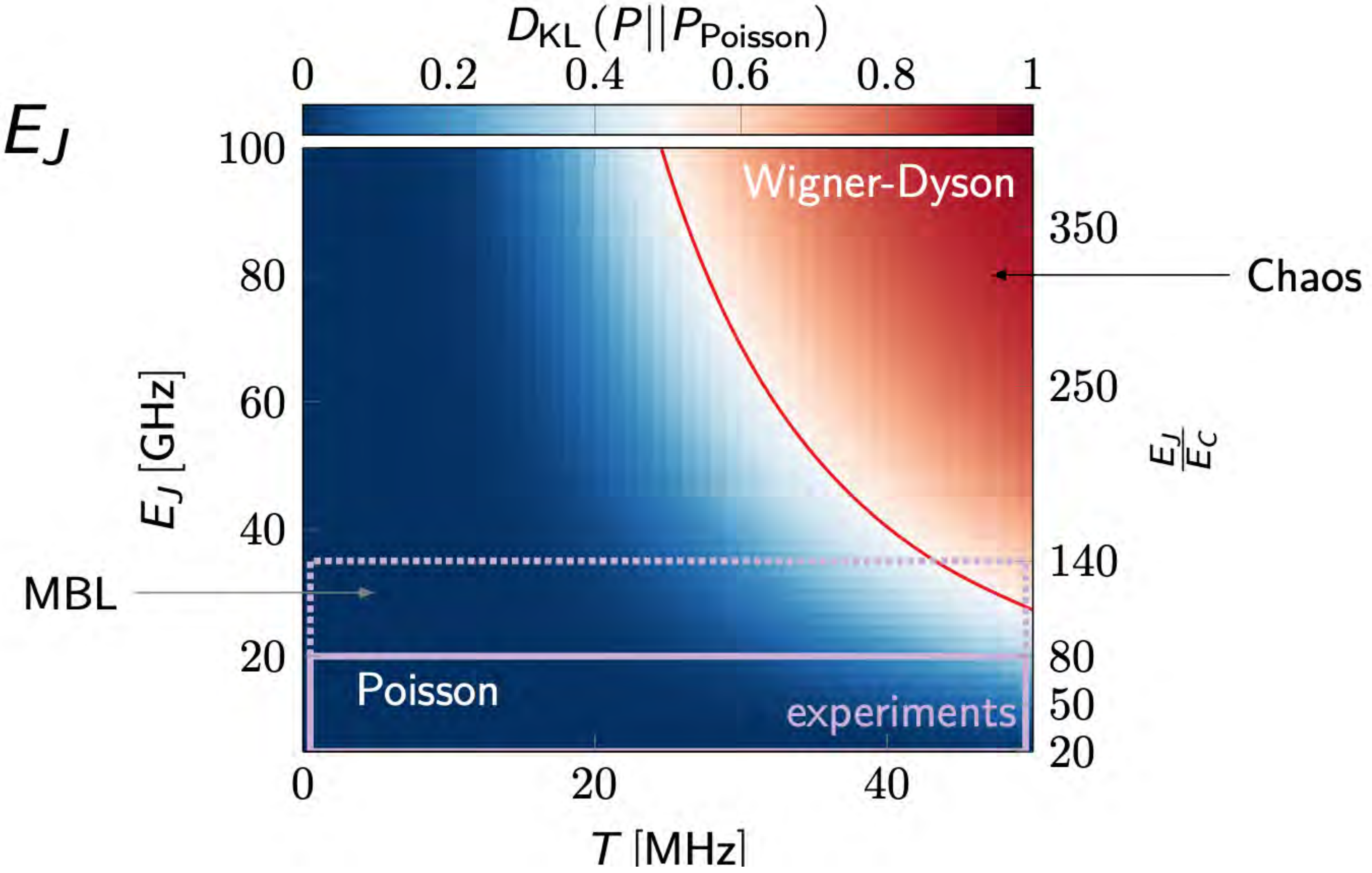


phase diagram



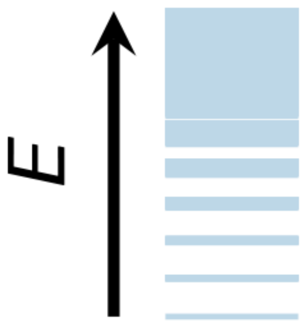
phase diagram

IBM δE_J

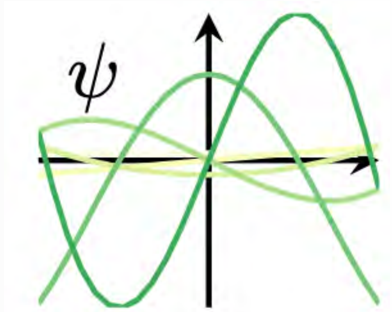


diagnostic toolbox

spectral statistics



wavefunction statistics

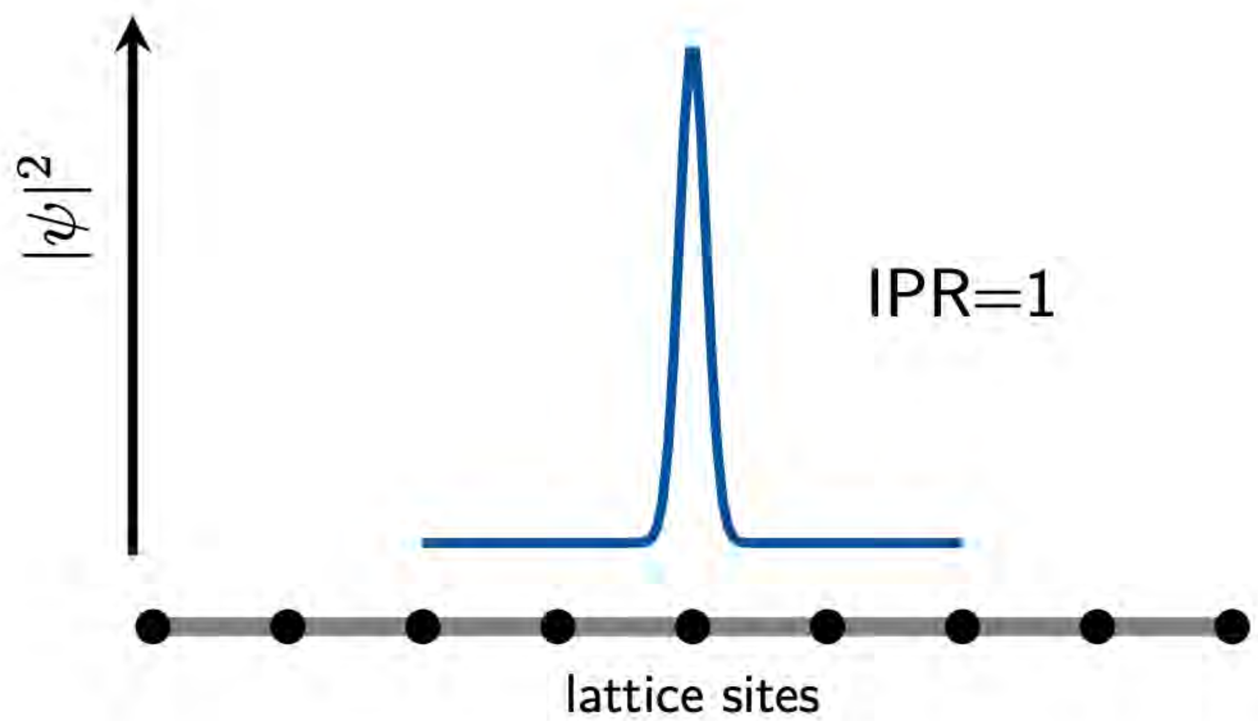


Walsh transform

inverse participation ratios

$$\text{IPR} = \int \mathrm{d}x |\langle x|\psi\rangle|^4$$

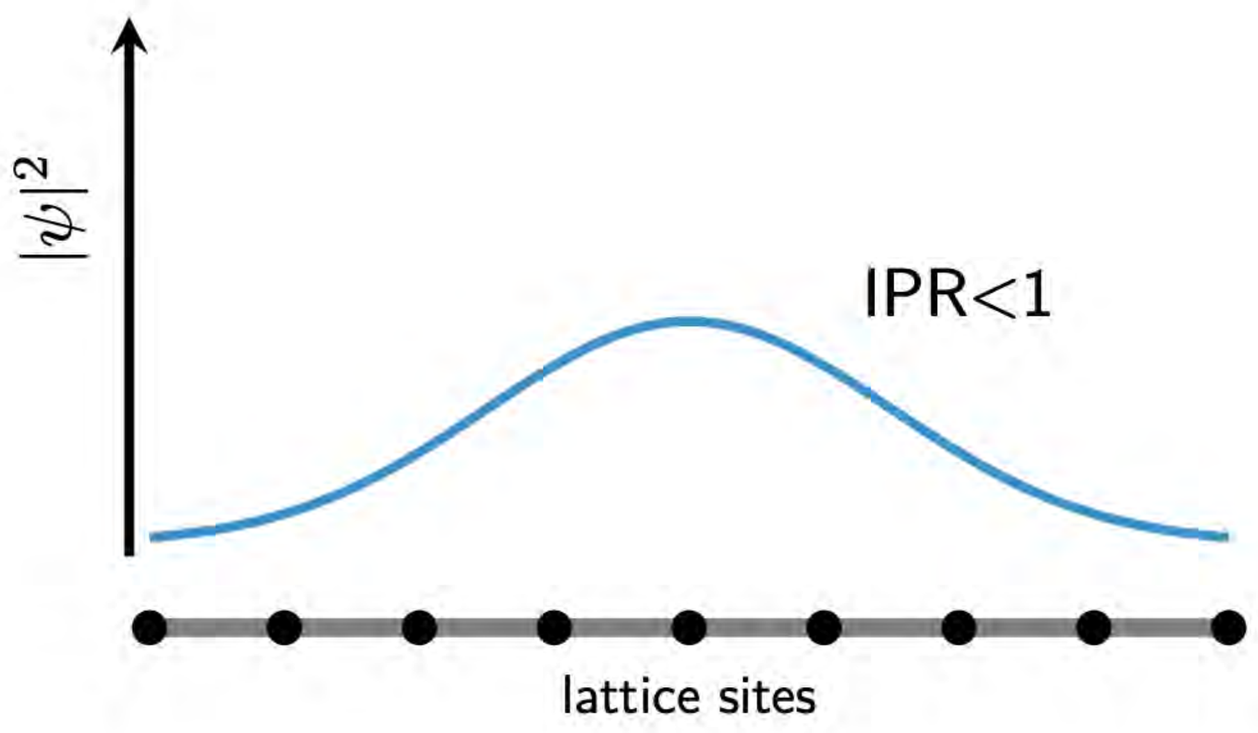
- IPR = 1: perfectly localized.



inverse participation ratios

$$\text{IPR} = \int dx |\langle x|\psi\rangle|^4$$

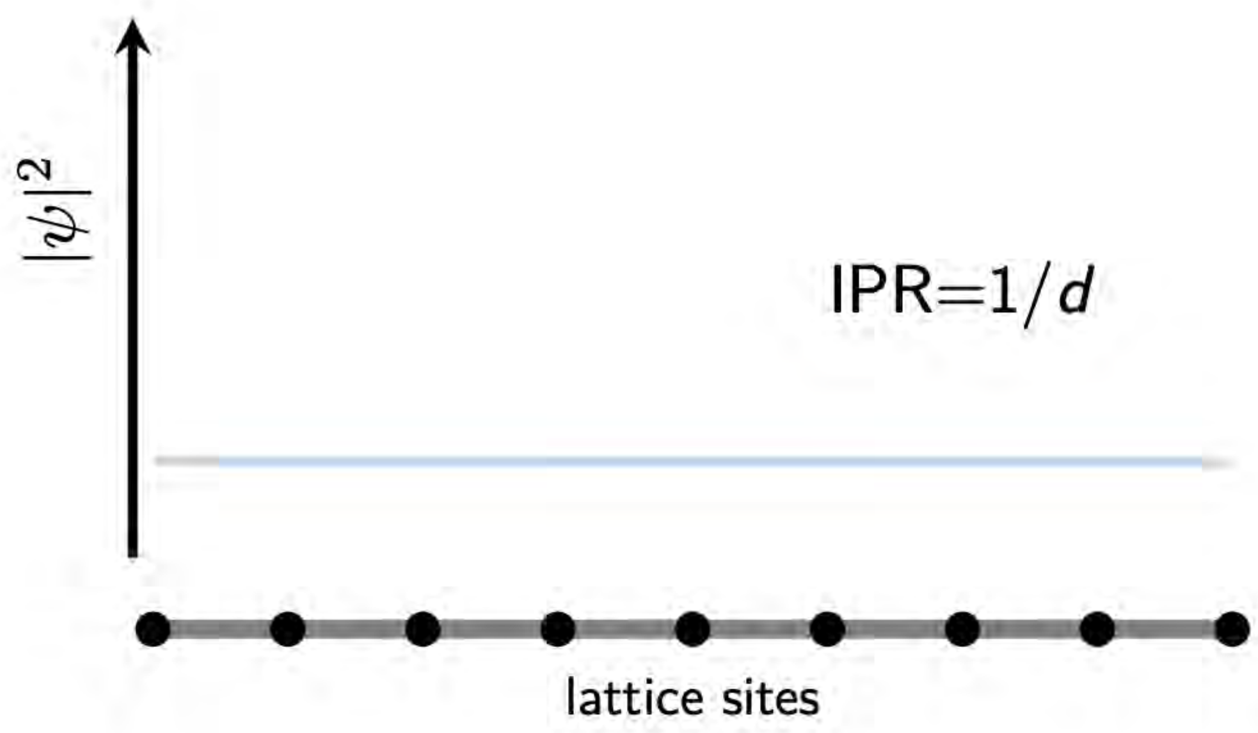
- IPR $= 1$: perfectly localized.



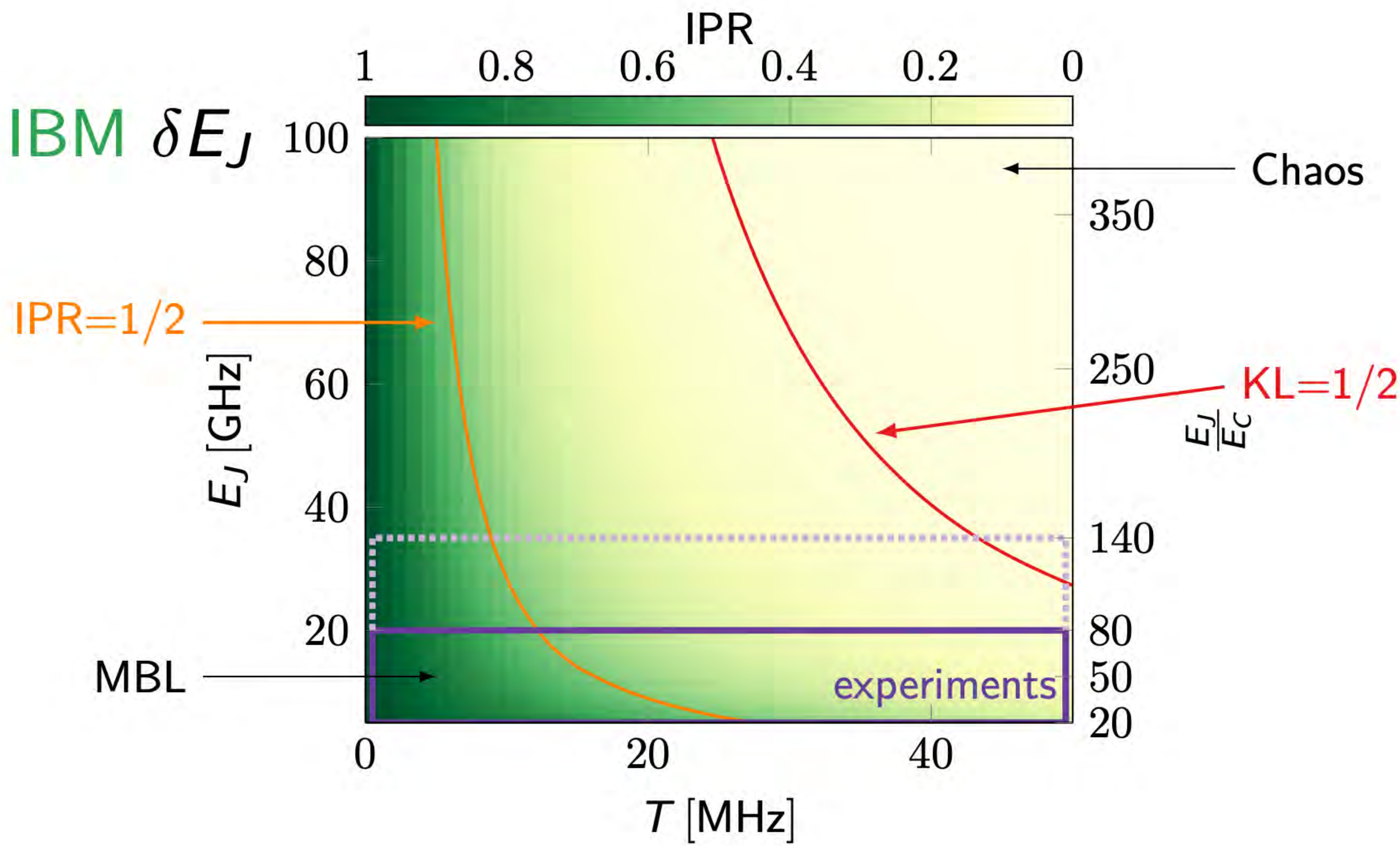
inverse participation ratios

$$\text{IPR} = \int dx |\langle x|\psi\rangle|^4$$

- $\text{IPR} = 1$: perfectly localized.
- $\text{IPR} = 1/d$: fully delocalized ($d = \dim \mathcal{H}$).



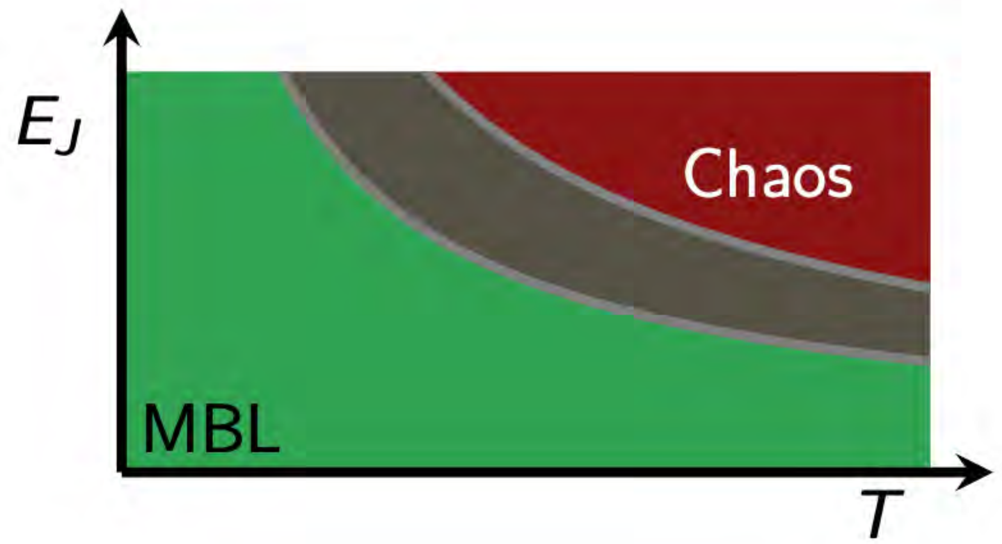
inverse participation ratios



Navigating the twilight zone

What we have learned so far …

… from **level statistics**

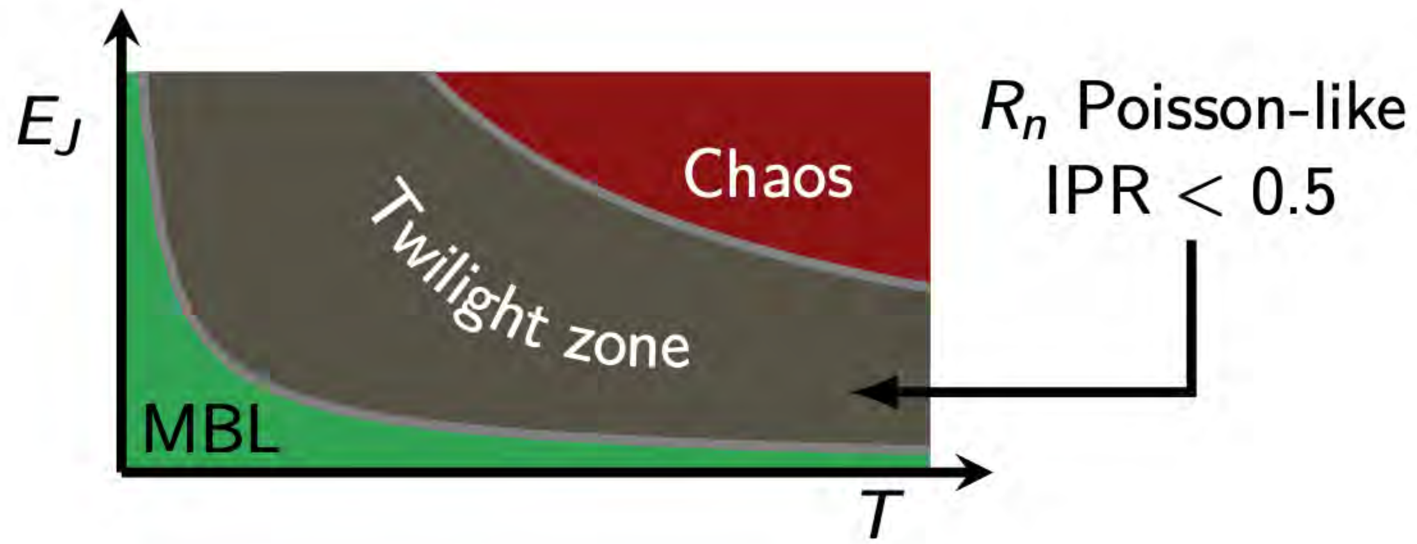


Navigating the twilight zone

What we have learned so far …

… from **level statistics**

… from **wave function statistics**

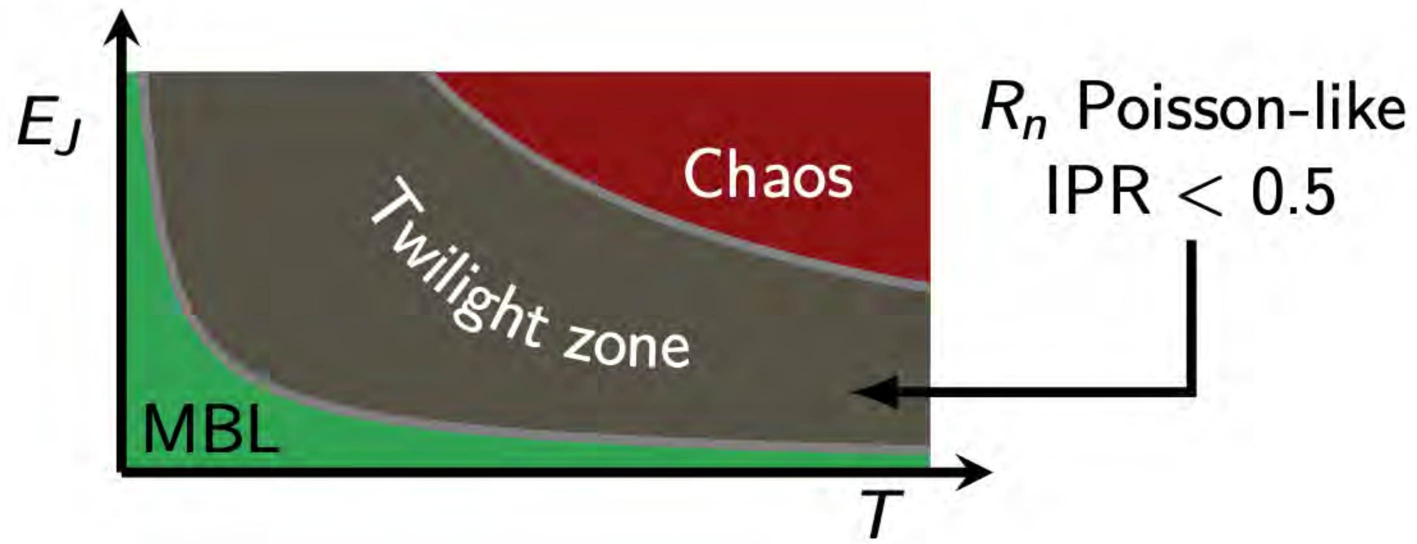


Navigating the twilight zone

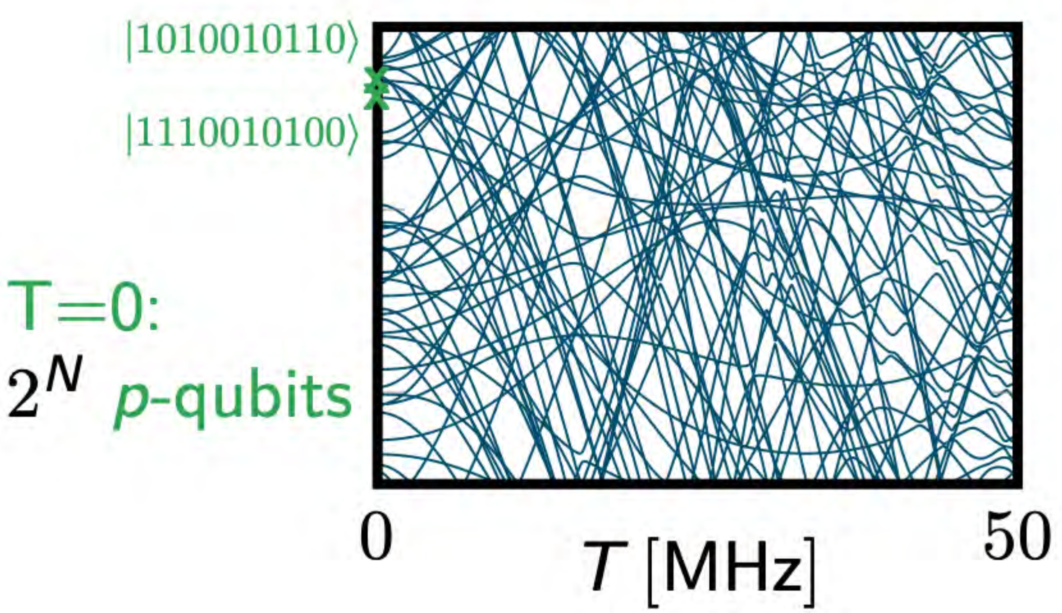
What we have learned so far …

… from **level statistics**

… from **wave function statistics**



… but what are the implications for the **computational subspace**?

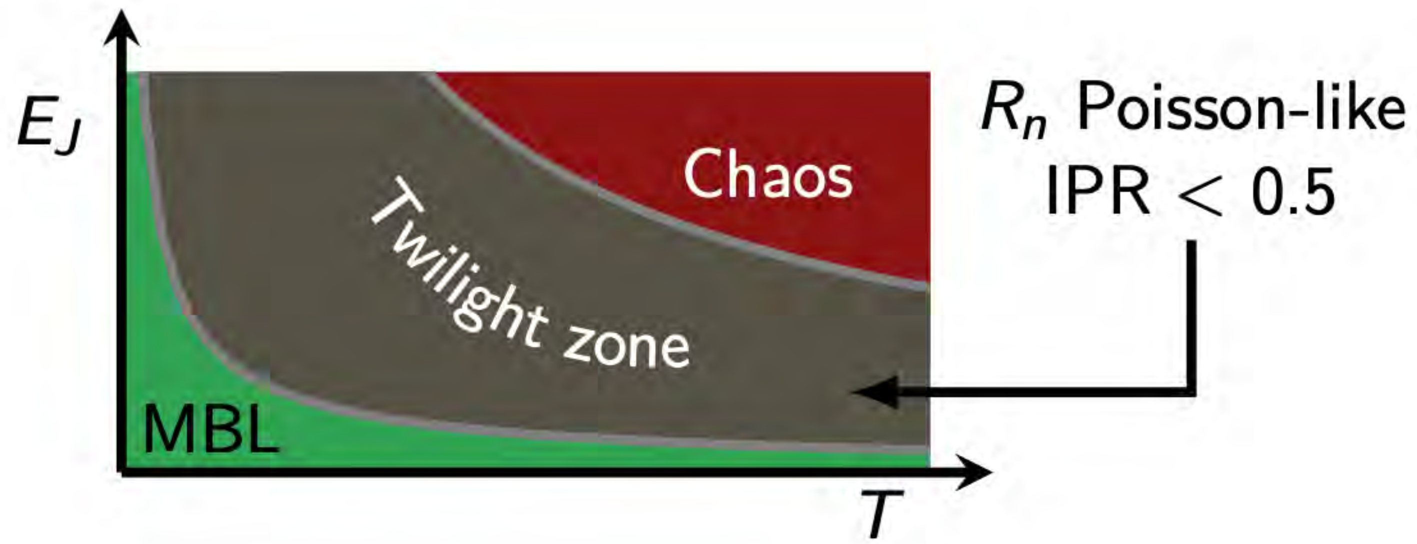


Navigating the twilight zone

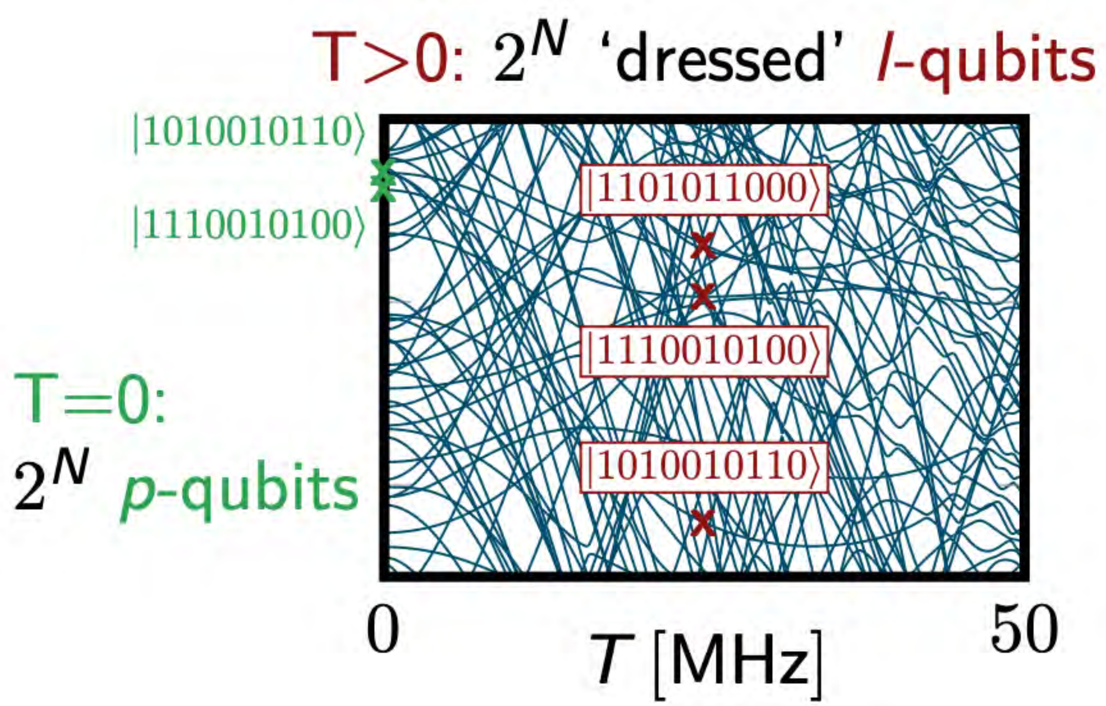
What we have learned so far …

… from **level statistics**

… from **wave function statistics**



… but what are the implications for the **computational subspace**?

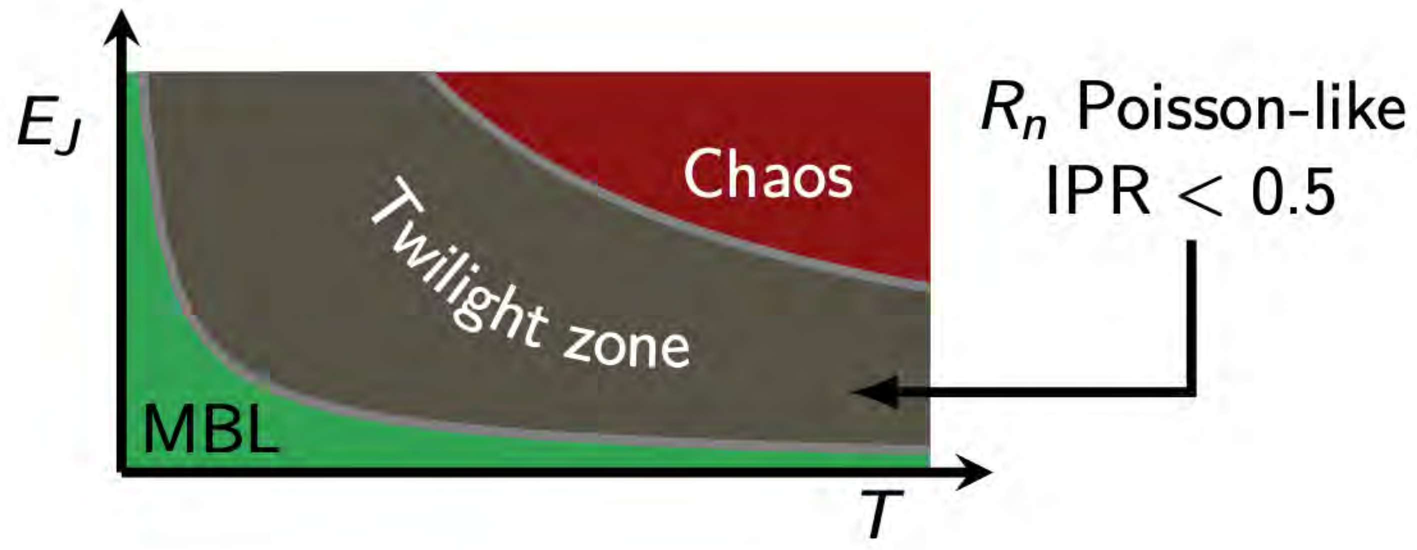


Navigating the twilight zone

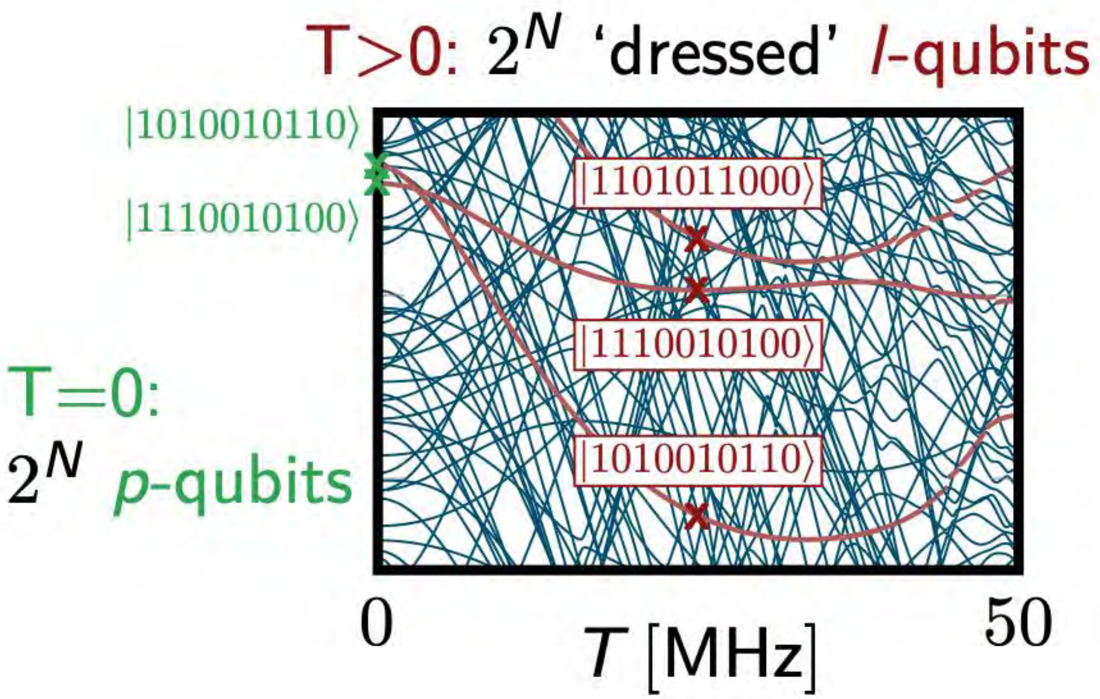
What we have learned so far …

… from **level statistics**

… from **wave function statistics**



… but what are the implications for the **computational subspace**?



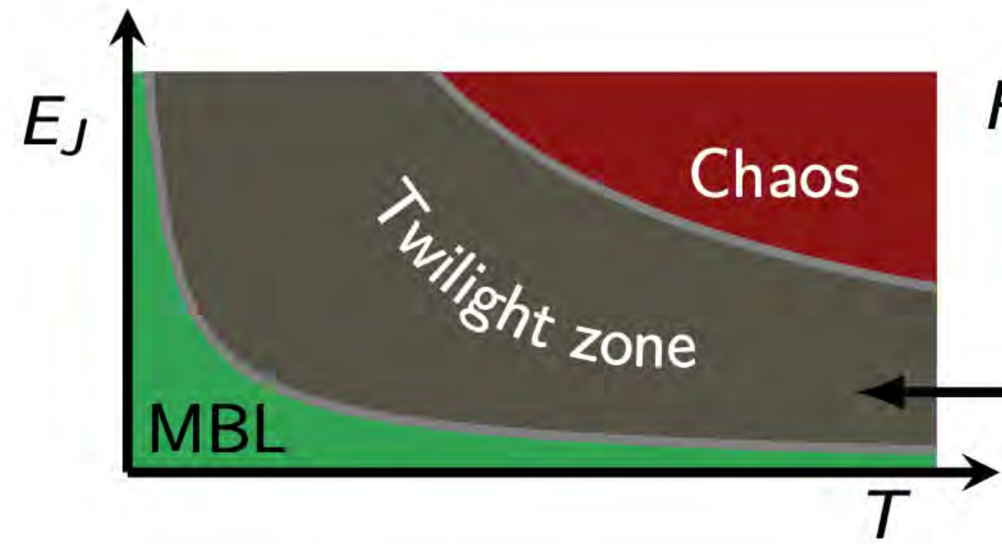
The l-qubit states are **intermingled** with a multitude of non-computational states

Navigating the twilight zone

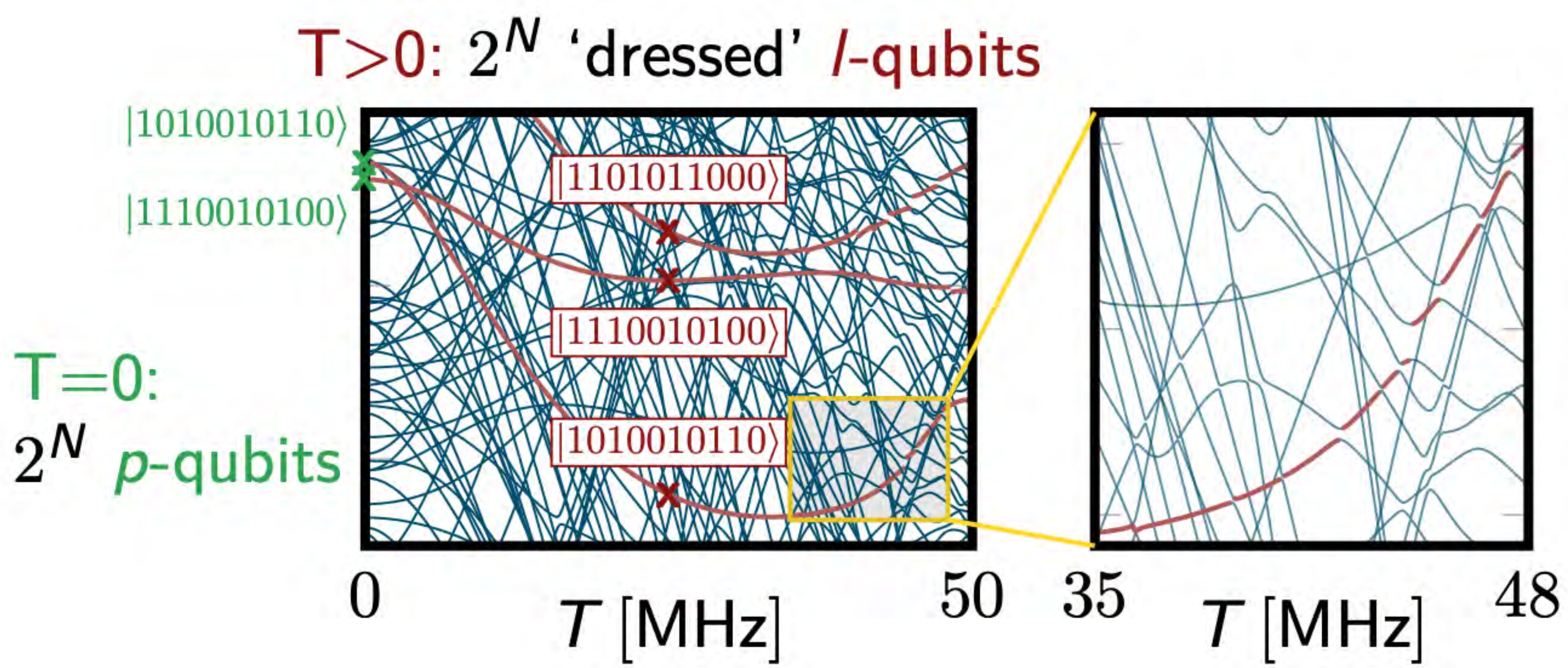
What we have learned so far …

… from **level statistics**

… from **wave function statistics**



… but what are the implications for the **computational subspace**?



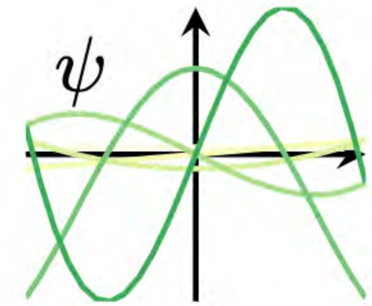
The l-qubit states are **intermingled** with a multitude of non-computational states

The l-qubit states become **coupled** amongst each other.

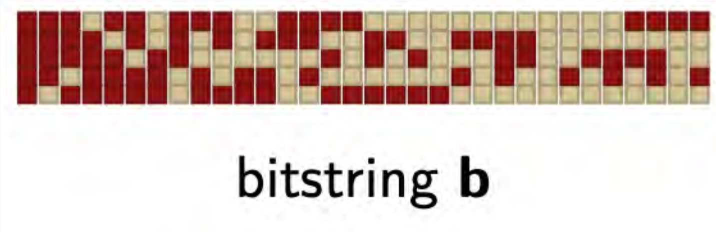
diagnostic toolbox

spectral statistics

wavefunction statistics



Walsh transform



l-qubit states

When working in the *l*-qubit basis we can recast our Hamiltonian into

$$H = \sum_i h_i \tau_i^z + \sum_{ij} J_{ij} \tau_i^z \tau_j^z + \sum_{ijk} K_{ijk} \tau_i^z \tau_j^z \tau_k^z + \cdots \quad = \sum_{\mathbf{b}} c_{\mathbf{b}} Z_1^{b_1} Z_2^{b_2} \ldots Z_N^{b_N}$$

τ - Hamiltonian of many-body localization

bit string representation

visualization

PHYSICAL REVIEW B **90**, 174202 (2014)

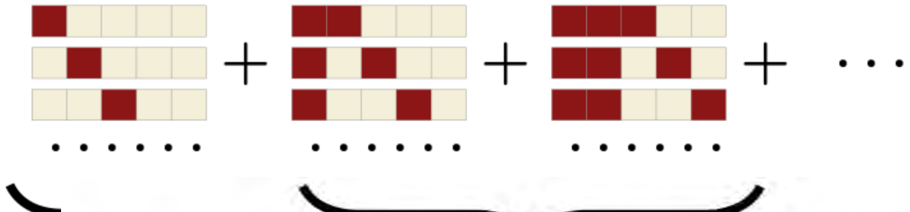
Phenomenology of fully many-body-localized systems

David A. Huse,[1] Rahul Nandkishore,[2] and Vadim Oganesyan[3,4]
[1]*Physics Department, Princeton University, Princeton, New Jersey 08544, USA*
[2]*Princeton Center for Theoretical Science, Princeton University, Princeton, New Jersey 08544, USA*
[3]*Department of Engineering Science and Physics, College of Staten Island, CUNY, Staten Island, New York 10314, USA*
[4]*Initiative for the Theoretical Sciences, The Graduate Center, CUNY, New York, New York 10016, USA*
(Received 27 August 2014; published 13 November 2014)

g. 01101: $c_{01101} Z_1^0 \, Z_2^1 \, Z_3^1 \, Z_4^0 \, Z_5^1 = K_{235} \, \tau_2 \, \tau_3 \, \tau_5$

ation : $c_{\mathbf{b}} \rightarrow$  $= K_{235} \, \tau_2 \, \tau_3 \, \tau_5$

$$H = \quad Z \quad + \quad ZZ \quad + \quad ZZZ \quad + \ldots$$



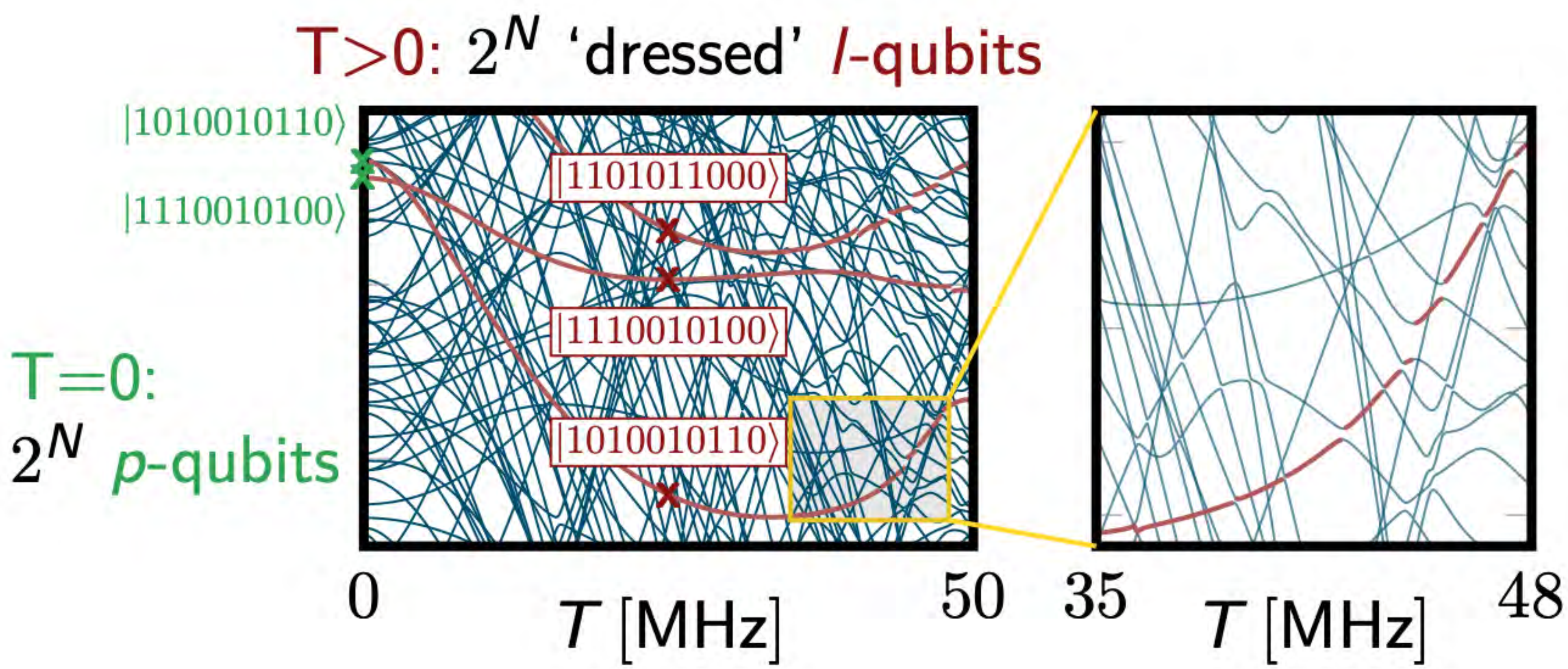
per Threshold for QC: $|c_{\mathbf{b}}| \lesssim 100$ kHz

PHYSICAL REVIEW LETTERS **125**, 200504 (2020)

Suppression of Unwanted *ZZ* Interactions in a Hybrid Two-Qubit System

Jaseung Ku,[1] Xuexin Xu,[2,3] Markus Brink,[4] David C. McKay,[4] Jared B. Hertzberg,[4]
Mohammad H. Ansari,[2,3] and B. L. T. Plourde[1,*]
[1]*Department of Physics, Syracuse University, Syracuse, New York 13244, USA*
[2]*Peter Grünberg Institute, Forschungszentrum Jülich, Jülich 52428, Germany*
[3]*Jülich-Aachen Research Alliance (JARA), Fundamentals of Future Information Technologies, Jülich 52428, Germany*
[4]*IBM Quantum, IBM T.J. Watson Research Center, Yorktown Heights, New York 10598, USA*
(Received 8 April 2020; accepted 2 September 2020; published 11 November 2020)

Walsh transform



Reconstruction of the τ-Hamiltonian for finite coupling via a **Walsh transform**

$$\mathbf{b}_1 = 0000,\ E_{\mathbf{b}_1}$$
$$\mathbf{b}_2 = 0001,\ E_{\mathbf{b}_2}$$
$$\ldots$$
$$\mathbf{b}_4 = 1111,\ E_{\mathbf{b}_4}$$

Walsh transformation →

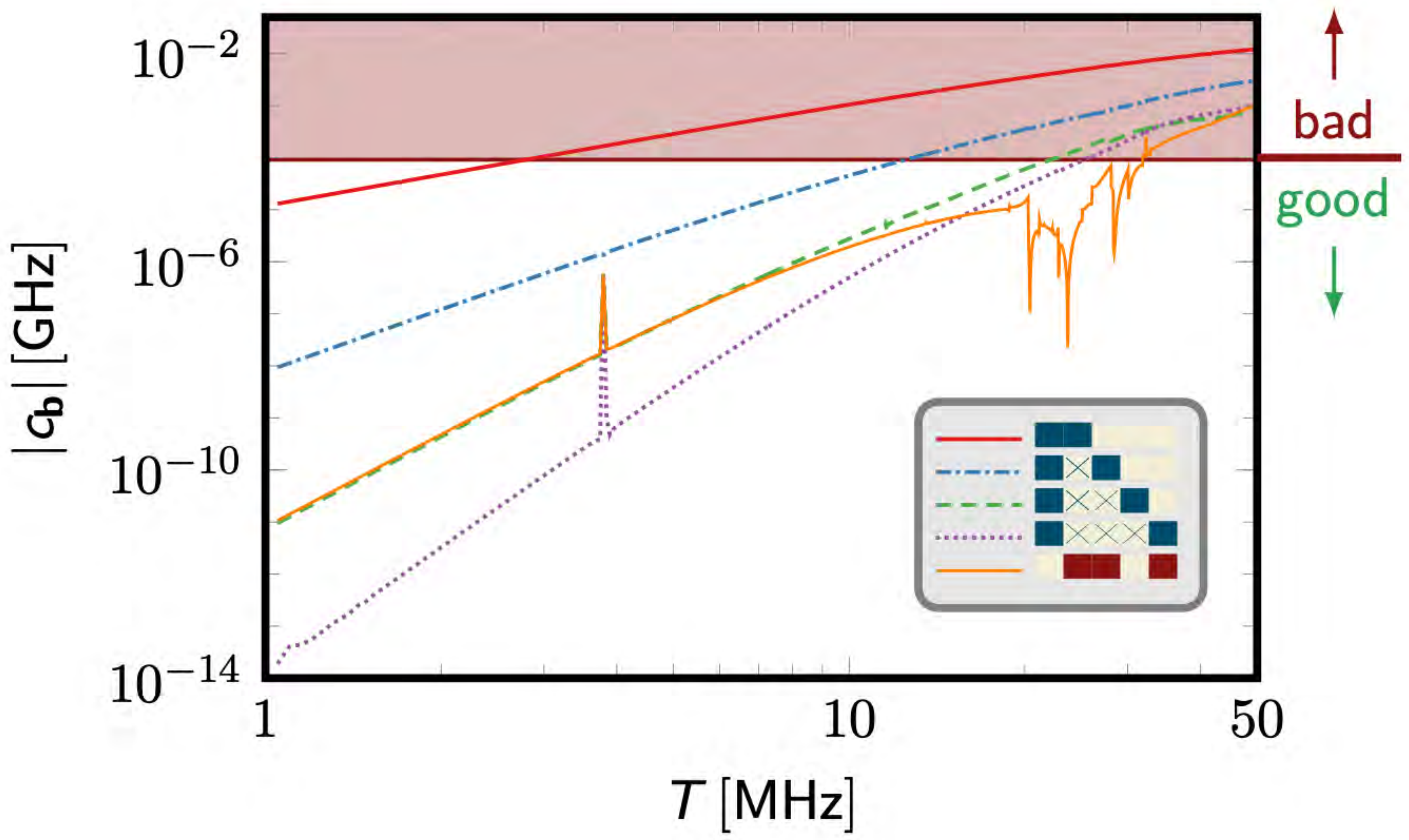
$$c_{\mathbf{b}} = \frac{1}{2^N} \sum_{\mathbf{b}'} (-1)^{\mathbf{b}\cdot\mathbf{b}'} E_{\mathbf{b}'}$$

$$H = \sum_{\mathbf{b}} c_{\mathbf{b}} Z_1^{b_1} Z_2^{b_2} \ldots Z_N^{b_N}$$

A discrete Fourier transform that extracts correlations between the *l*-qubits.

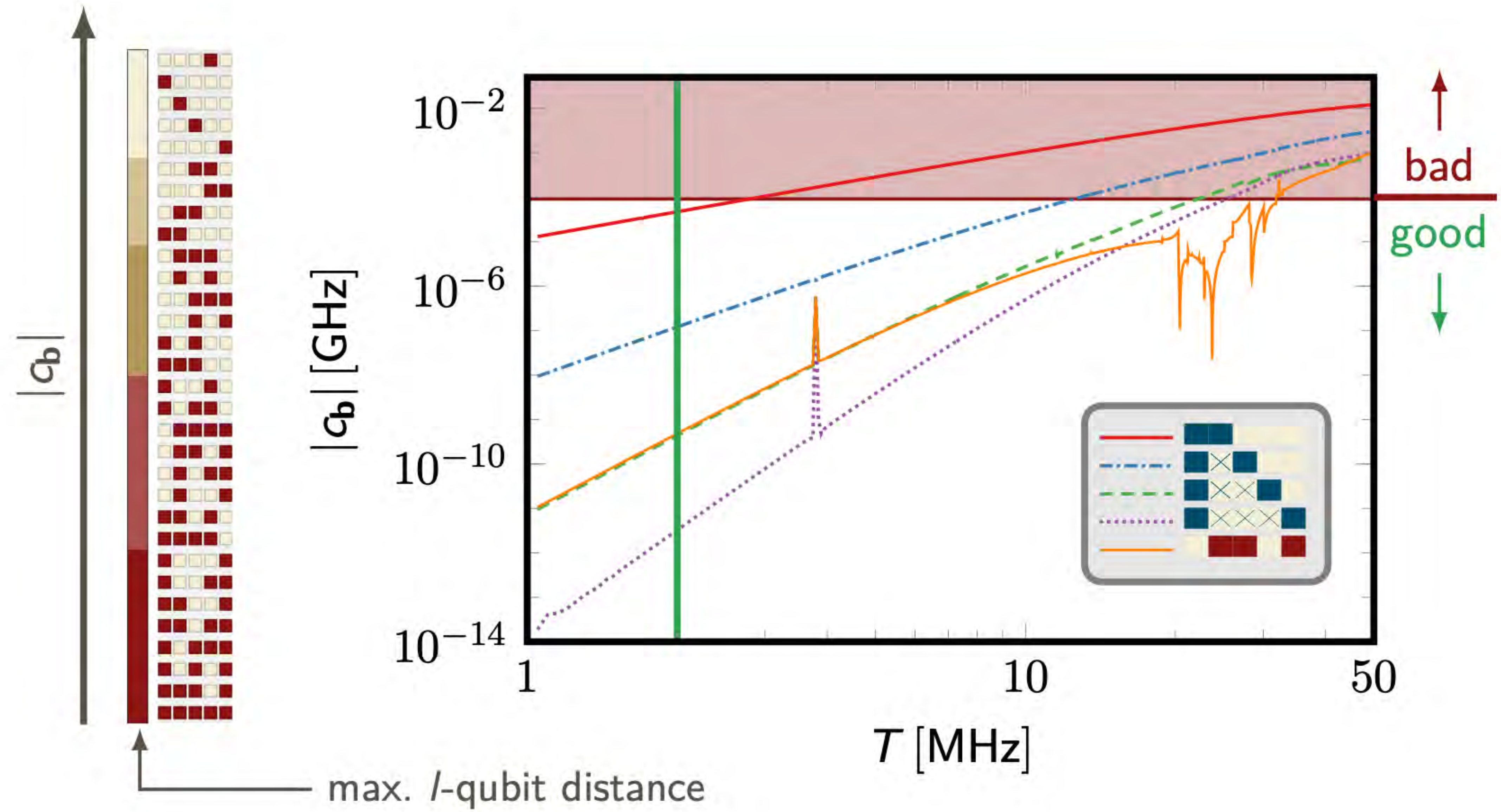
Walsh transform

IBM parameters



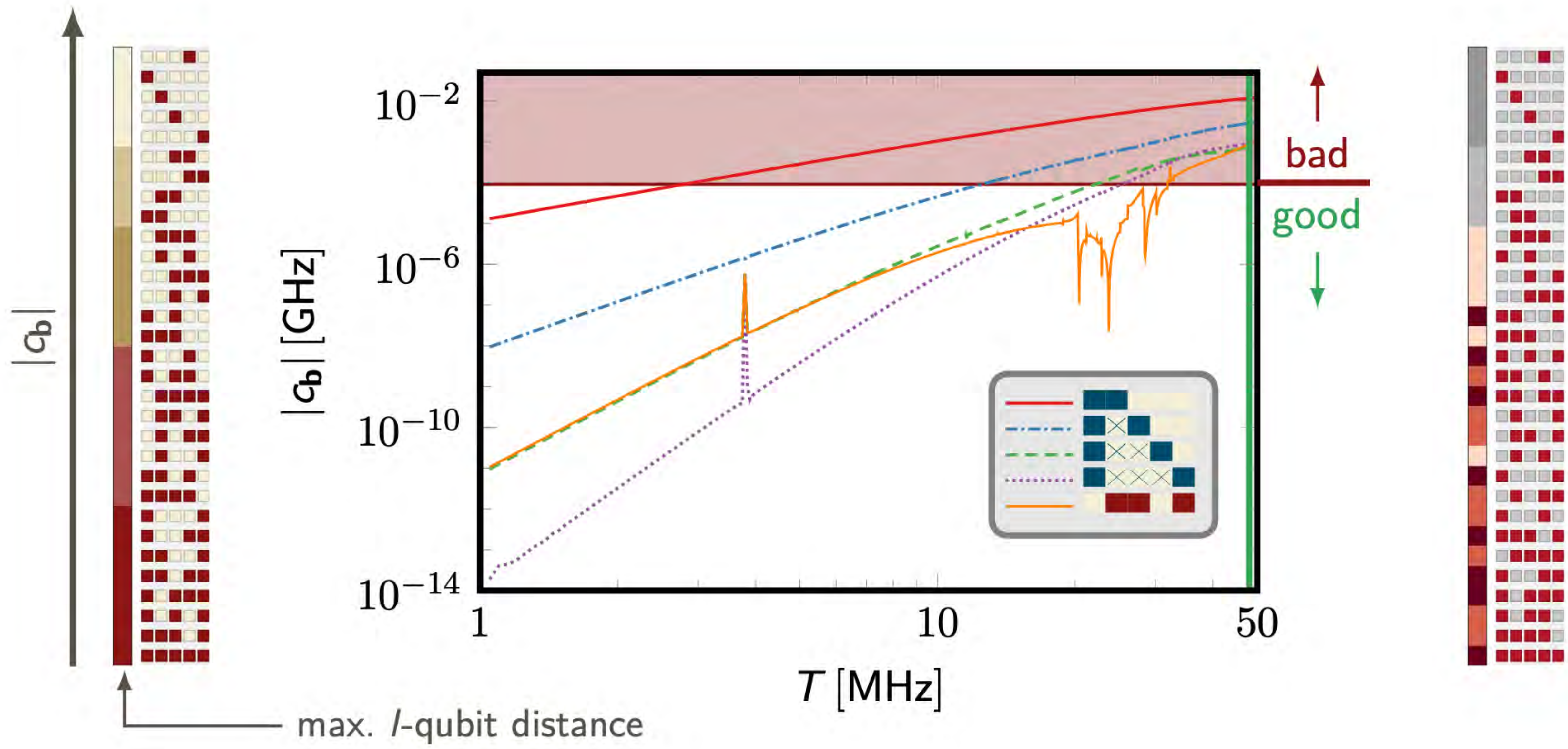
Walsh transform

IBM parameters



Walsh transform

IBM parameters

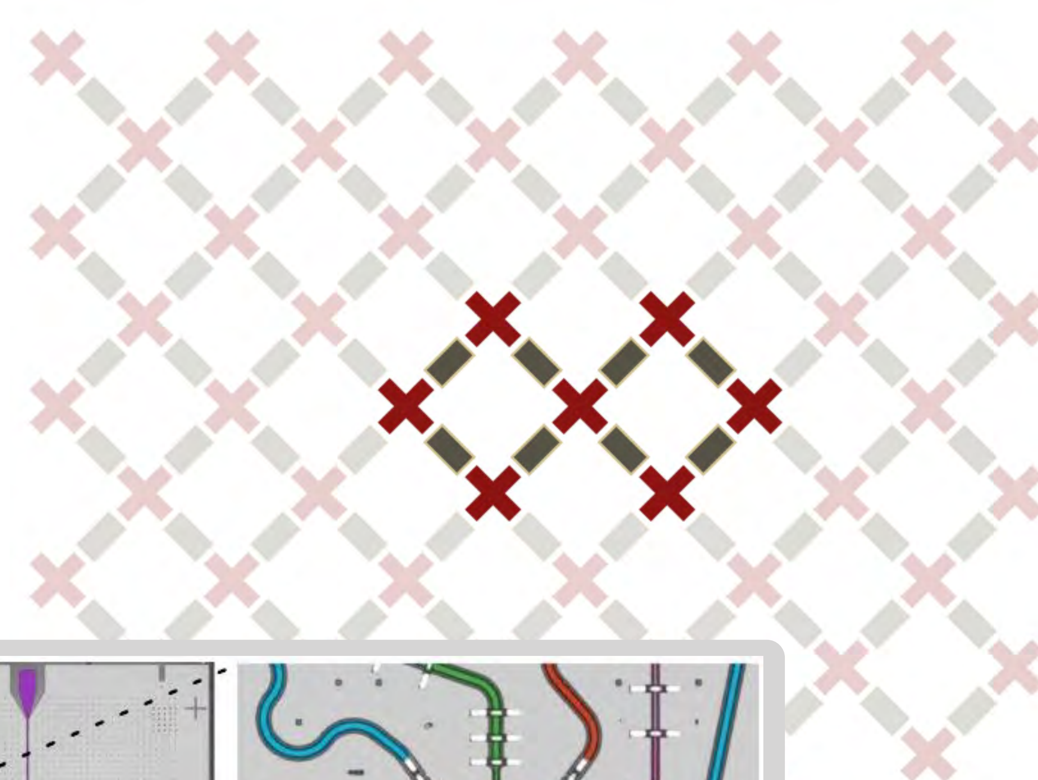


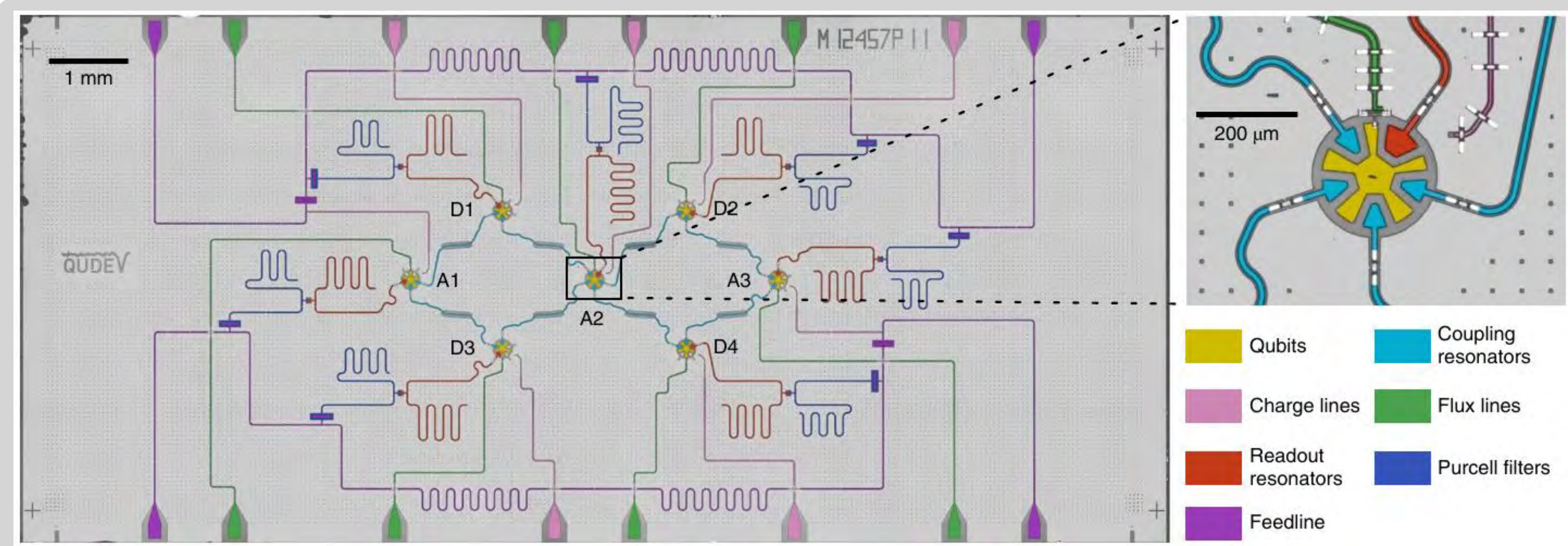
2d geometries

surface codes

Google's **sycamore processor**

surface 7





C. Andersen et al., Nature Physics (2020) disorder engineering

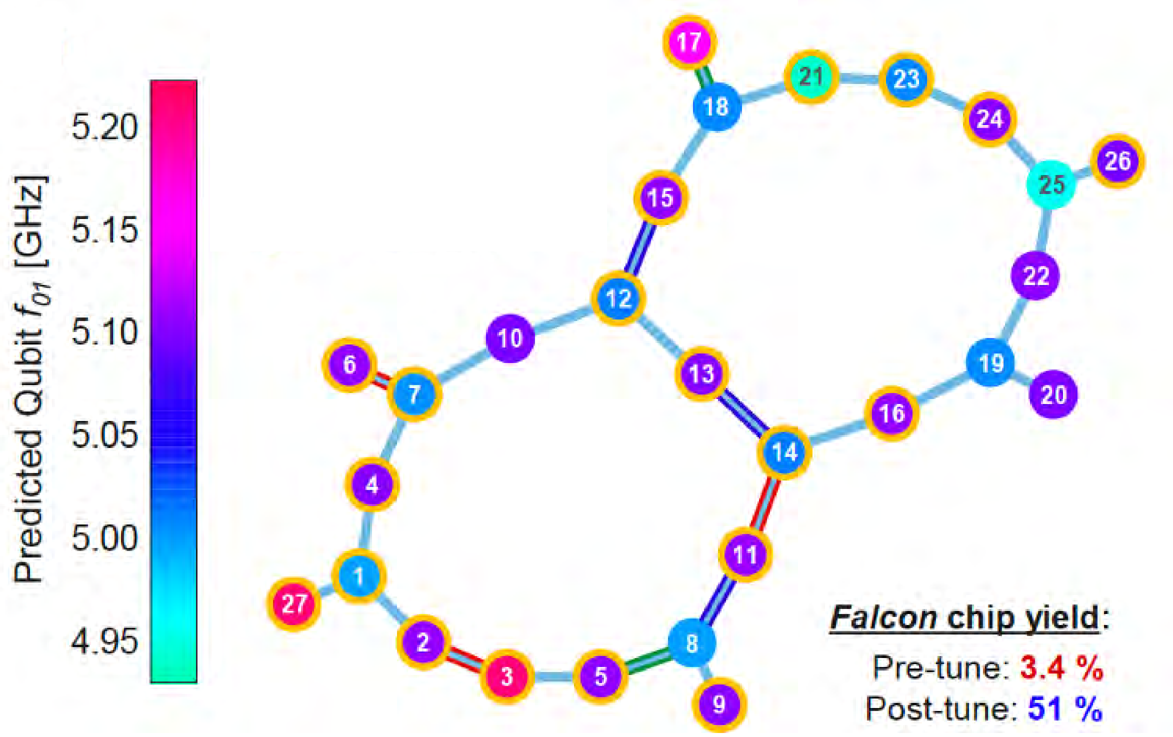
disorder engineering via laser annealing

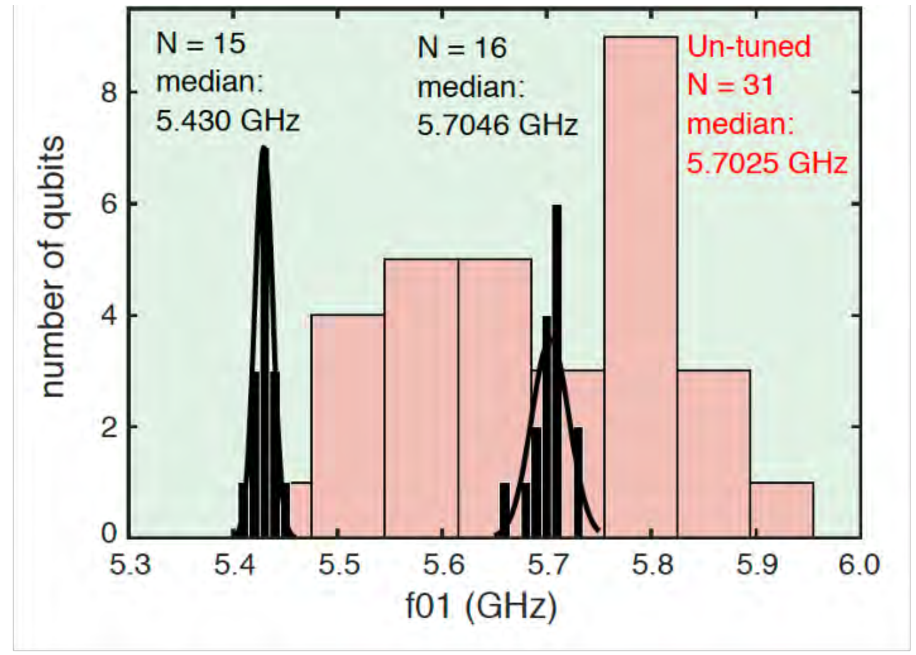
arXiv:2012.08475v1 [quant-ph] 15 Dec 2020

High-fidelity superconducting quantum processors via laser-annealing of transmon qubits

Eric J. Zhang, Srikanth Srinivasan, Neereja Sundaresan, Daniela F. Bogorin, Yves Martin, Jared B. Hertzberg, John Timmerwilke, Emily J. Pritchett, Jeng-Bang Yau, Cindy Wang, William Landers, Eric P. Lewandowski, Adinath Narasgond, Sami Rosenblatt, George A. Keefe, Isaac Lauer, Mary Beth Rothwell, Douglas T. McClure, Oliver E. Dial, Jason S. Orcutt, Markus Brink, Jerry M. Chow

IBM Quantum, IBM T. J. Watson Research Center, Yorktown Heights, NY 10598, USA





arXiv:2009.00781v4

Laser-annealing Josephson junctions for yielding scaled-up superconducting quantum processors.

Jared B. Hertzberg, Eric J. Zhang, Sami Rosenblatt, Easwar Magesan, John A. Smolin, Jeng-Bang Yau, Vivekananda P. Adiga, Martin Sandberg, Markus Brink, Jerry M. Chow, and Jason S. Orcutt

IBM Quantum, IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA

(Dated: September 16, 2020)

disorder engineering

staggered frequencies

sharper distributions

summary

Summary

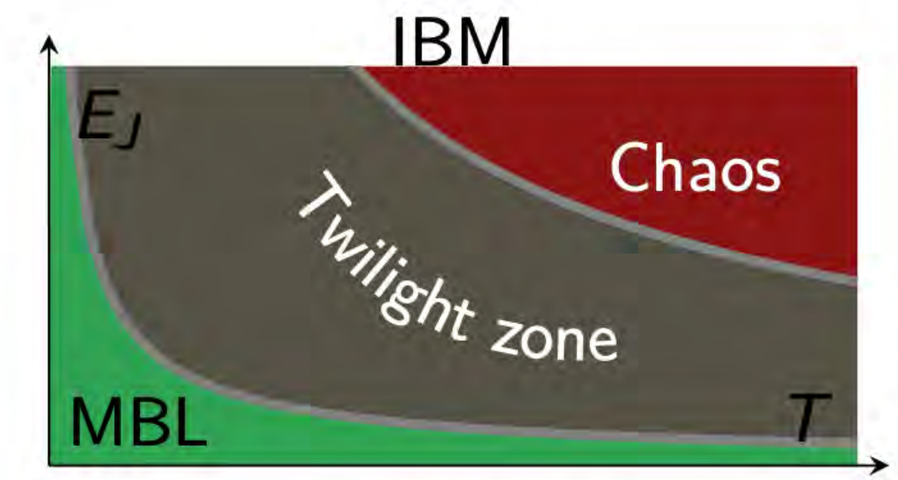
arXiv:2012.05923

Summary

- Transmon qubit architectures need to balance **intentional disorder** and **non-linear couplings** to stay away from an **MBL - chaos transition**.

- Some **current experimental setups** in fact lie dangerously close to chaos transition.

- Growing ***l*-bit correlations** additionally limit the experimental parameter range.



Outlook

Disorder engineering needs to explore more complex (fractal) staggering pattern.

- Dynamical **qubit operations** will need delicate stabilization.

Thanks!