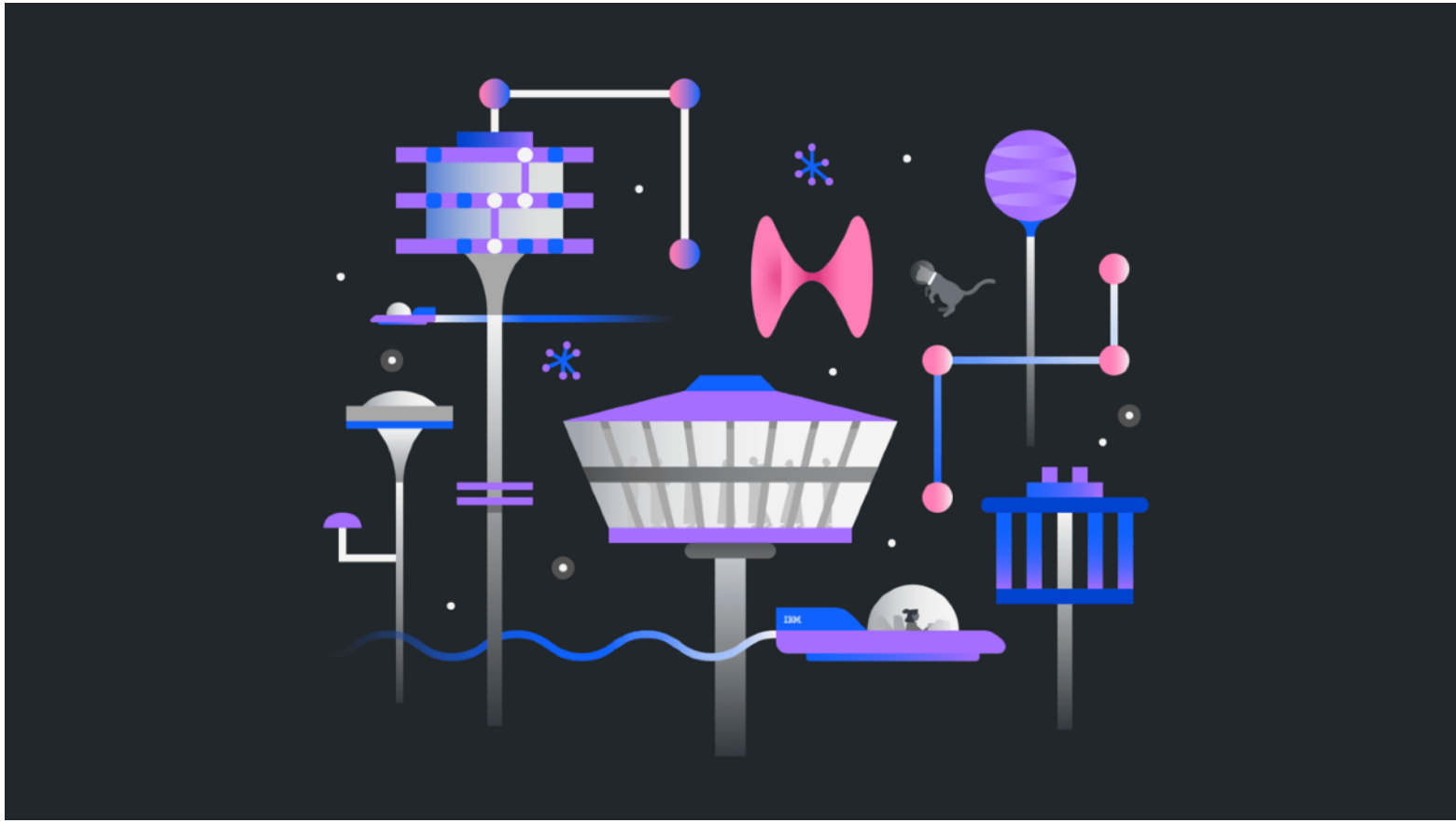
BasQ Qiskit Fall Fest 2024

Modeling dissipative dynamics on a quantum computer



Benjamin Tirado
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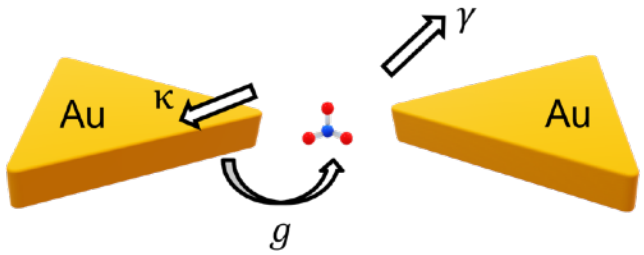
Supervisors

Universidad del País Vasco · Euskal Herriko Unibertsitatea
Centro de Física de Materiales · Materials Physics Center
Donostia International Physics Center
ikerbasque Basque Foundation for Science
CSIC · Consejo Superior de Investigaciones Científicas
BasQ Basque Quantum
QISKIT 2024 2024 FALL FEST

Introduction

Strong coupling



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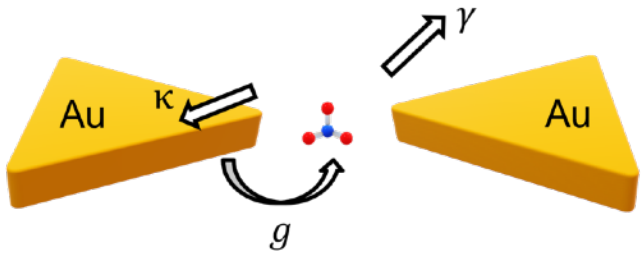

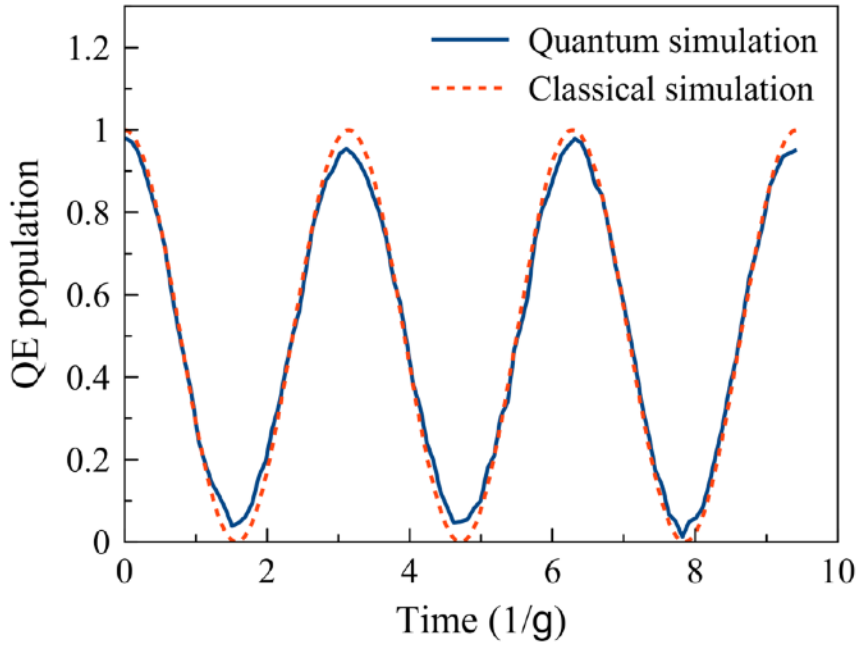

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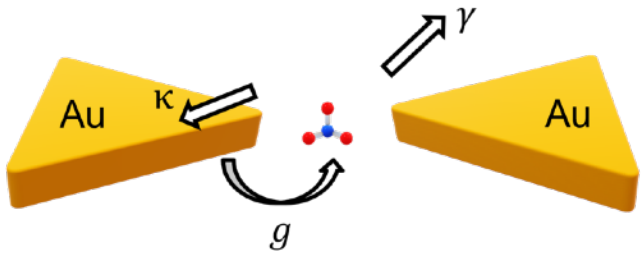

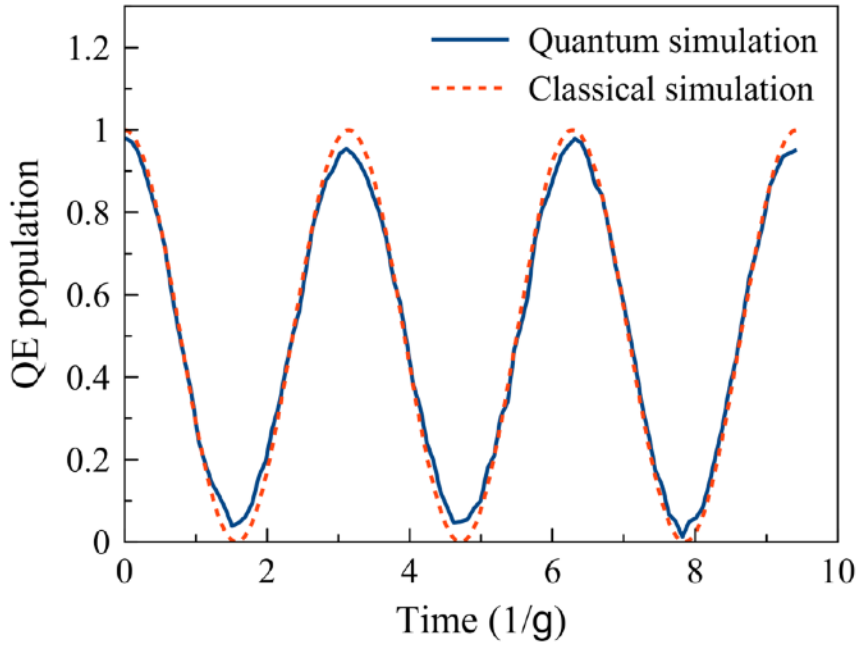

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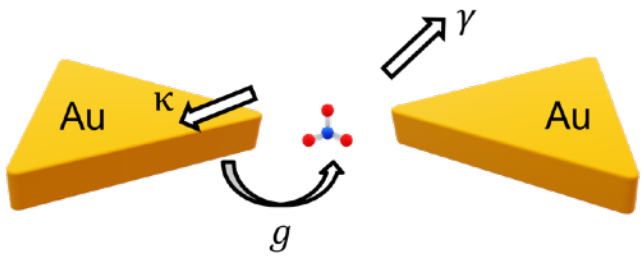

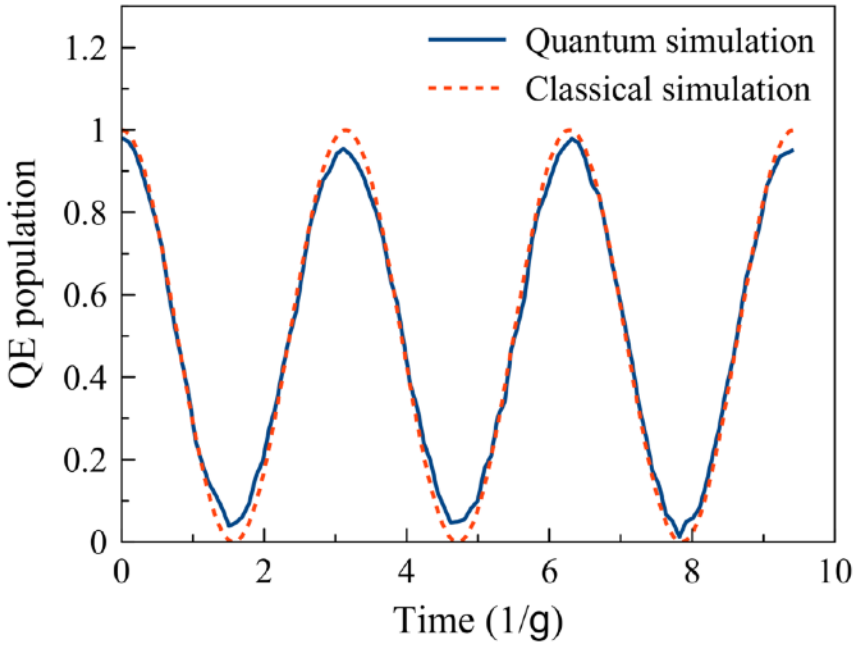

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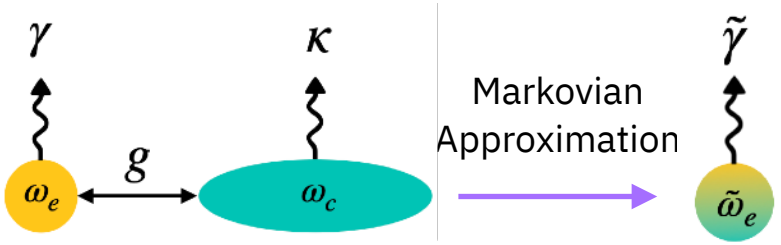
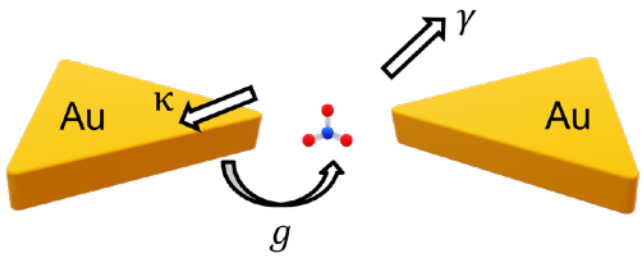
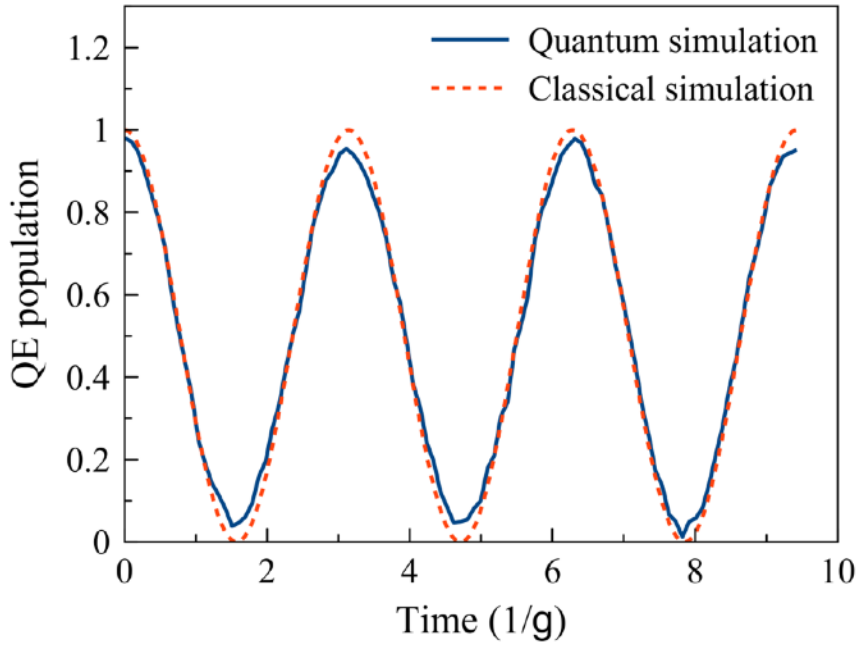


Quantum emitter Plasmonic cavity

Introduction

Strong coupling





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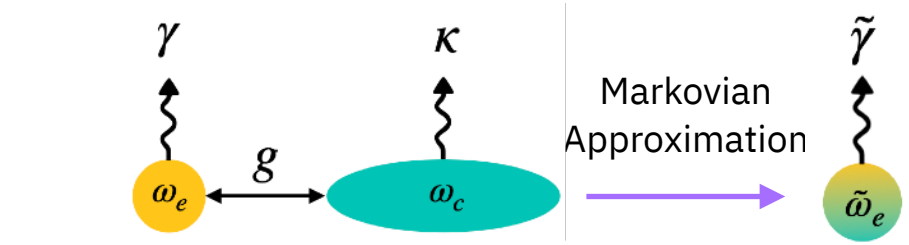

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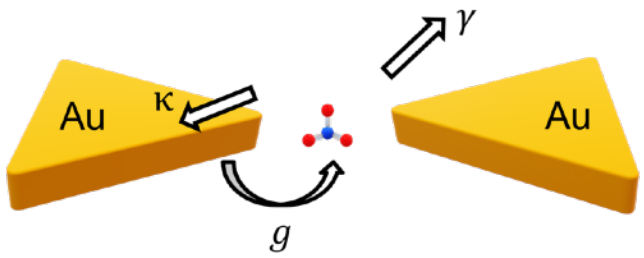

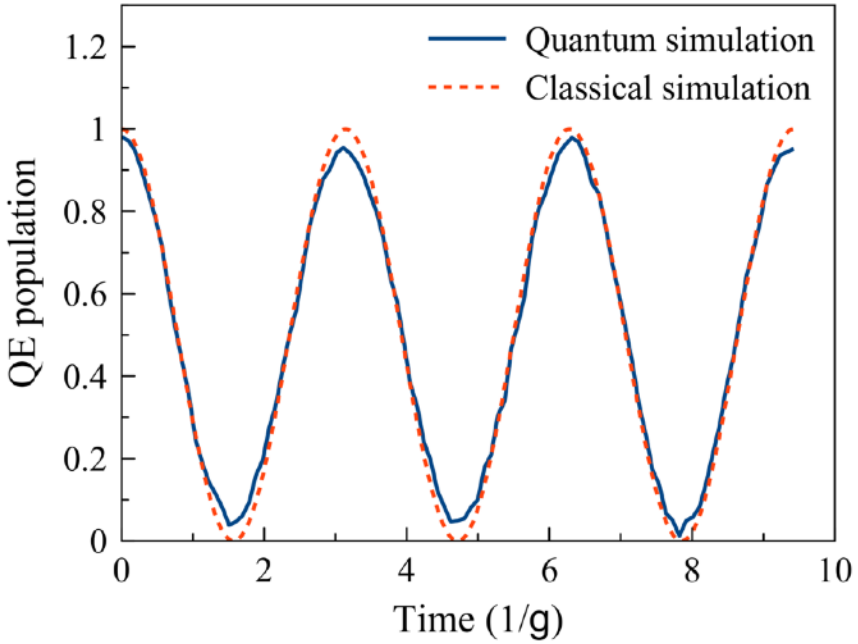

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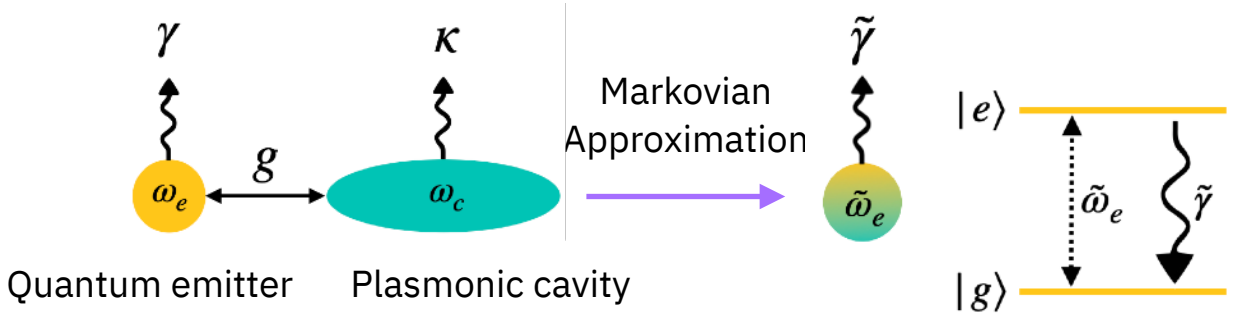

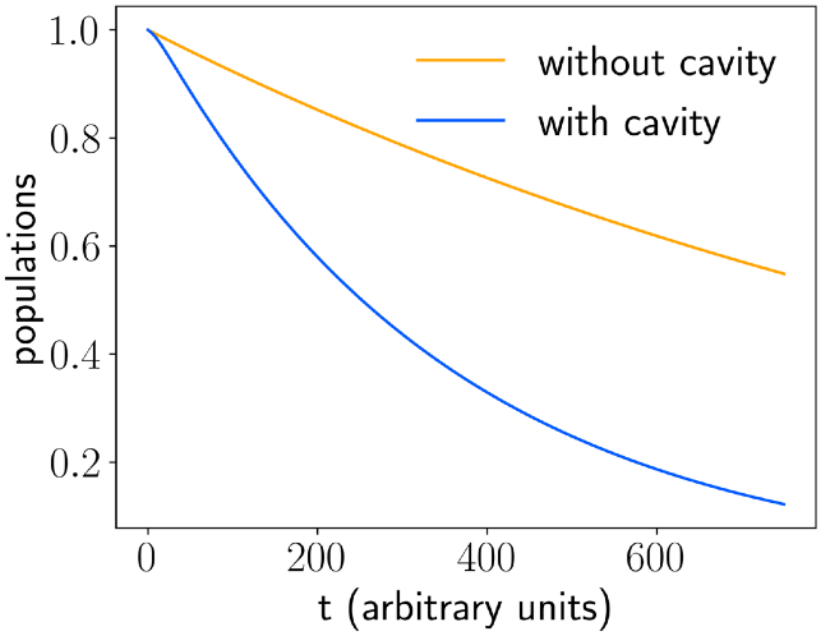

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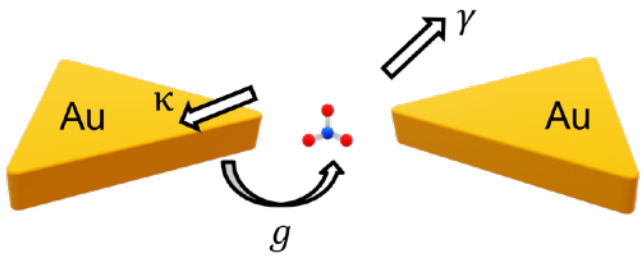
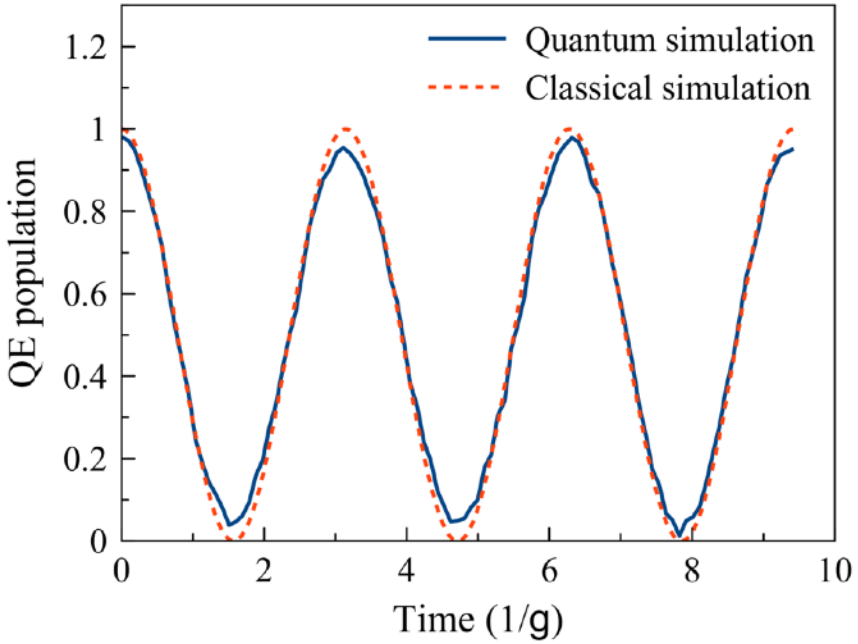
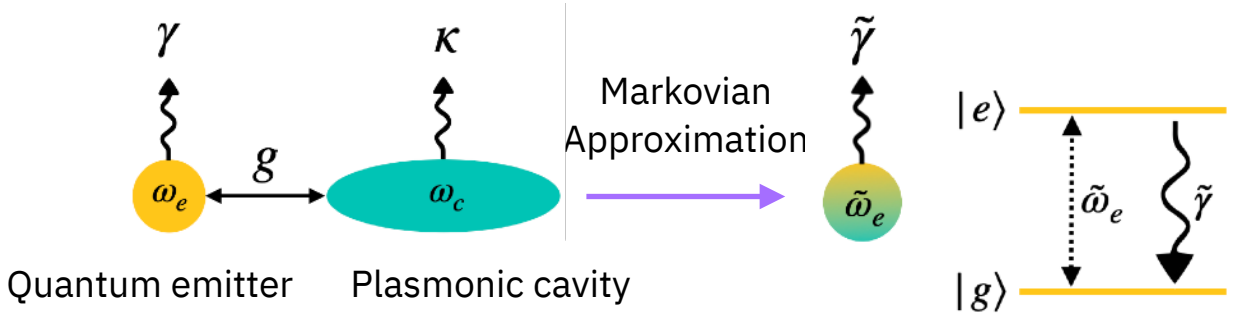
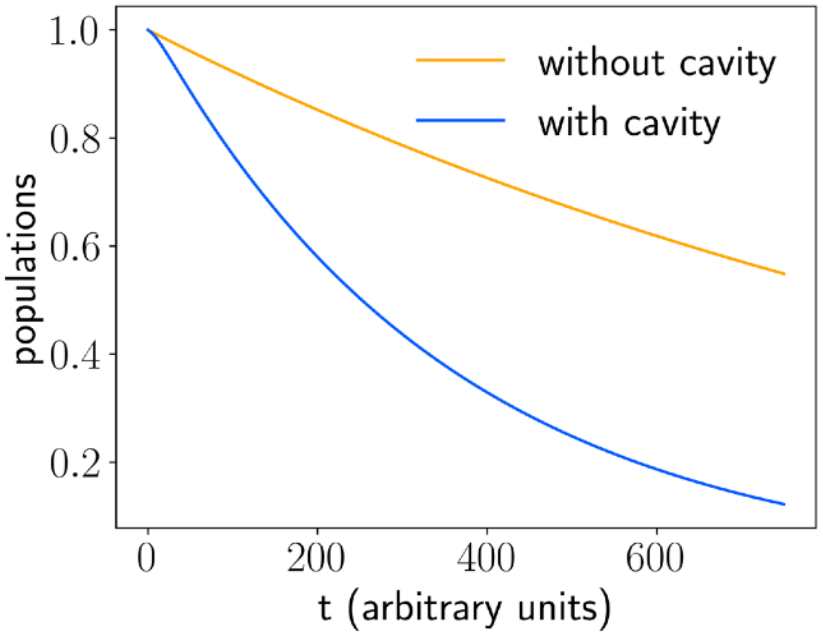




$$H = \omega_c a^\dagger a + \omega_e \sigma^\dagger \sigma + g(a^\dagger \sigma + a \sigma^\dagger)$$

Weak coupling





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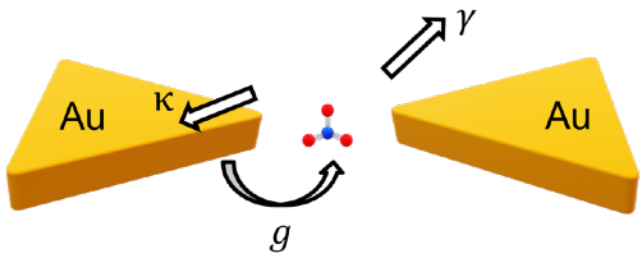

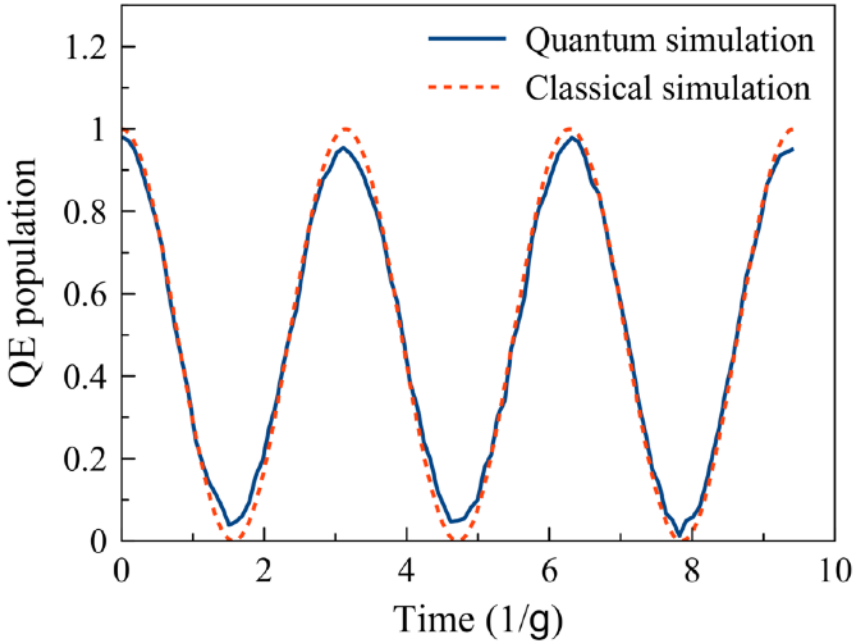

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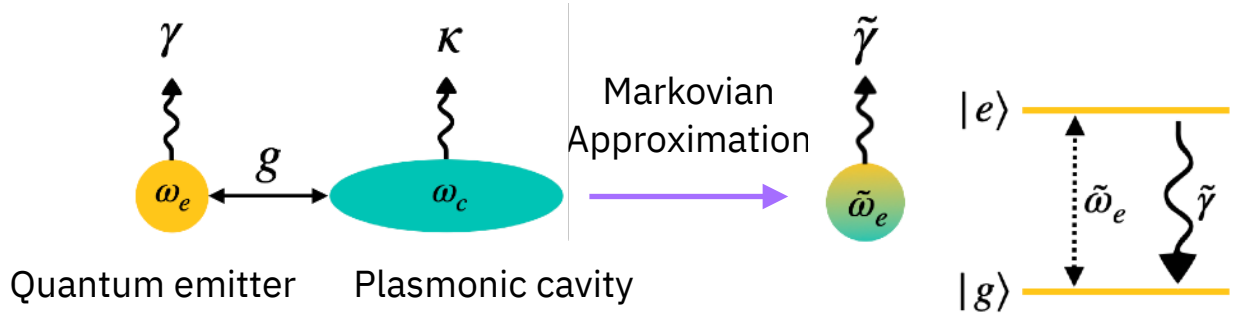

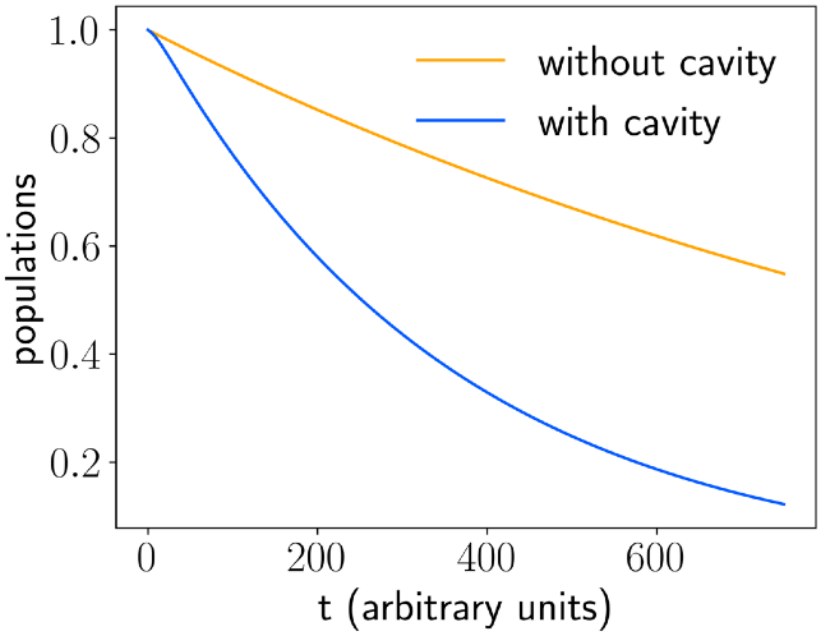

$$H_{eff} = \tilde{\omega}_e \sigma^\dagger \sigma$$

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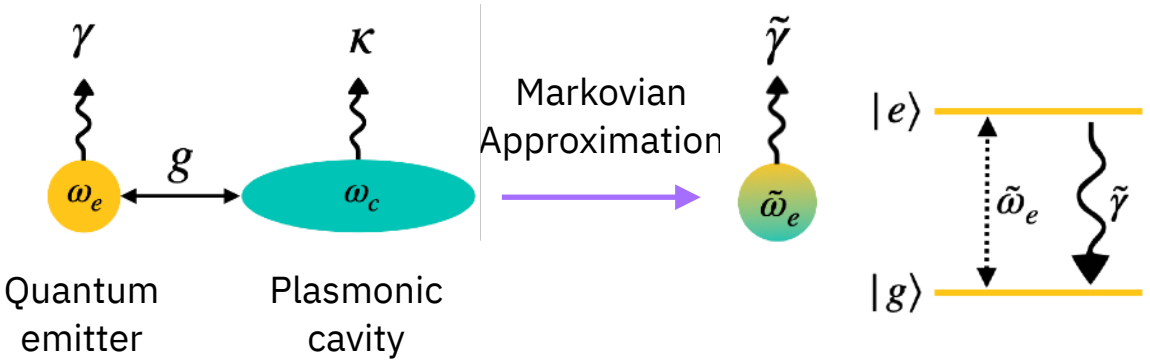
Weak coupling regime for one emitter



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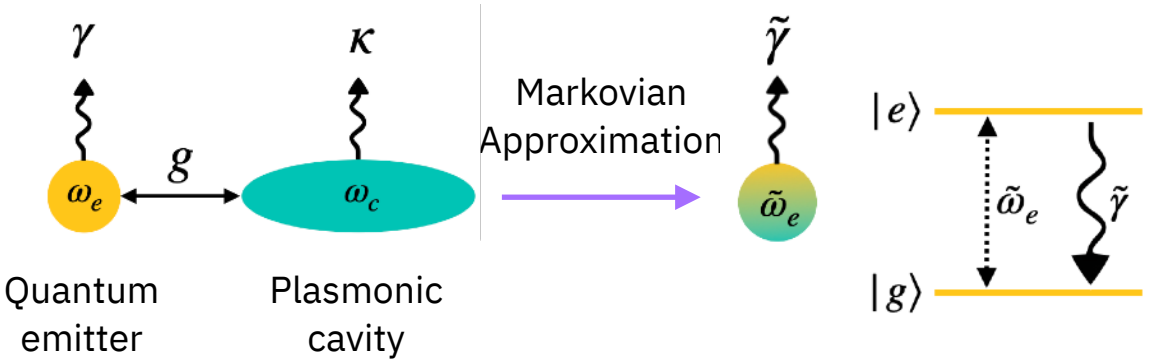

Main challenge: Modeling the dissipative process of the qubit

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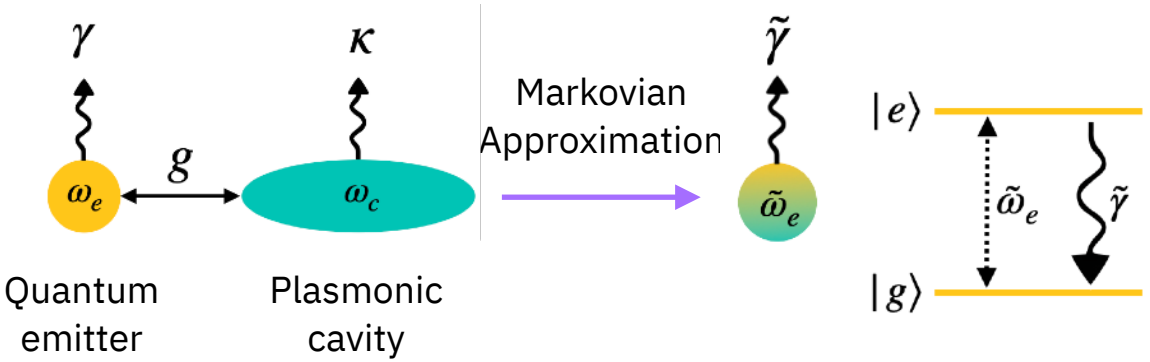

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$$\mathscr{D}[\rho] = \tilde{\gamma}\left(\sigma\rho\sigma^{\dagger} - \frac{1}{2}\left\{\sigma^{\dagger}\sigma, \rho\right\}\right)$$

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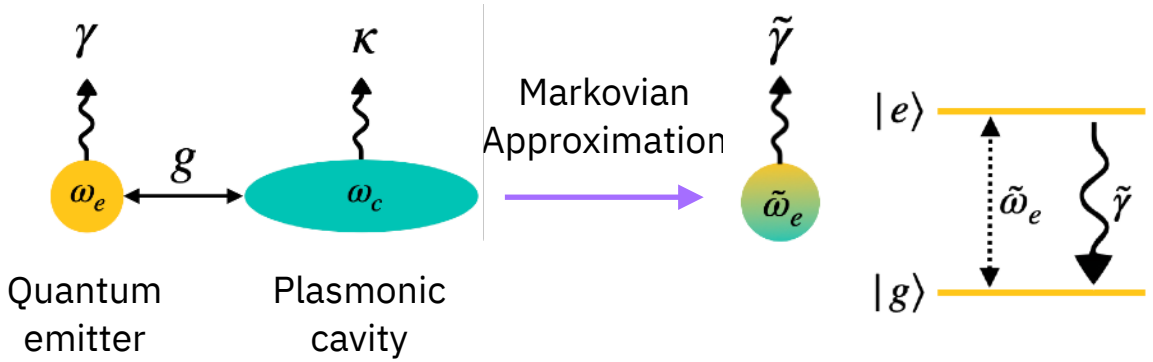

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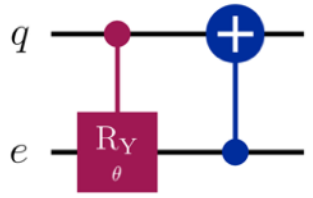
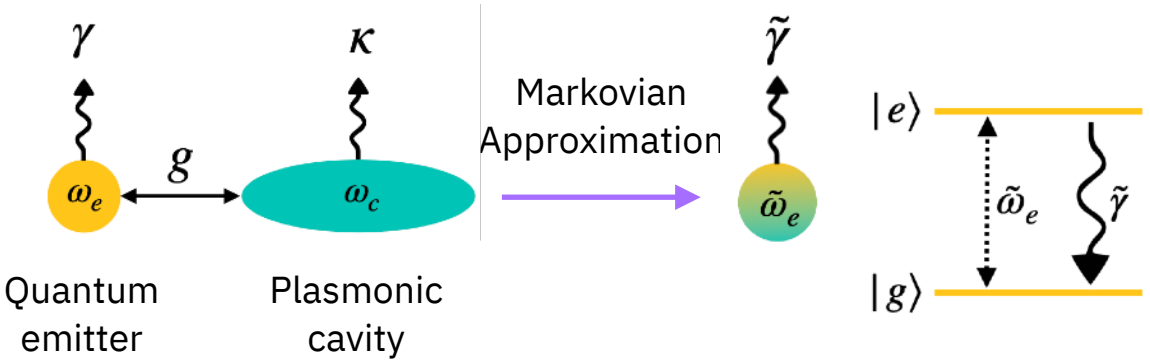


Amplitude damping channel

Weak coupling regime for one emitter



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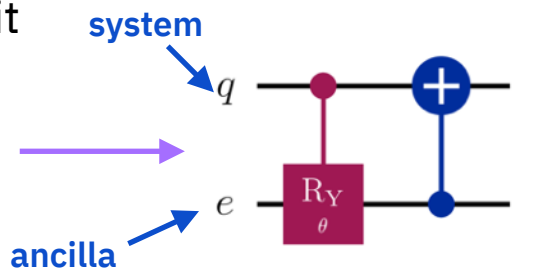

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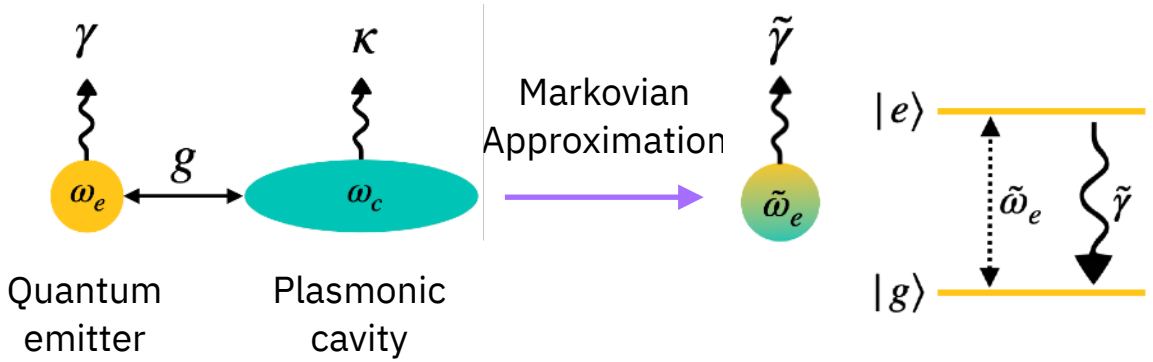

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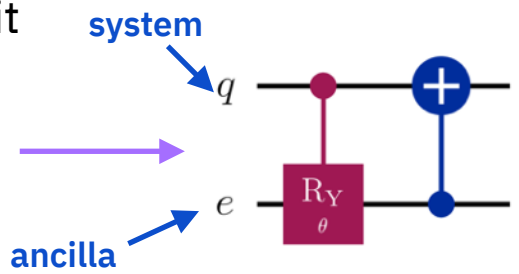
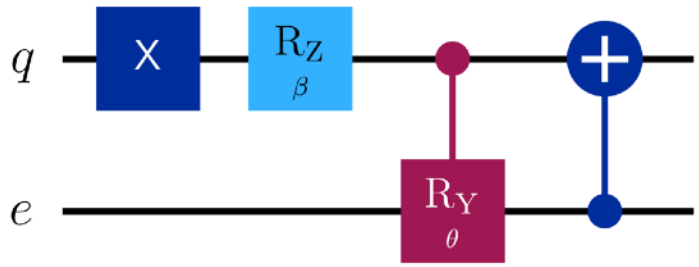


Amplitude damping channel

Total evolution (Hamiltonian and Lindbladian) for a single Trotter step:



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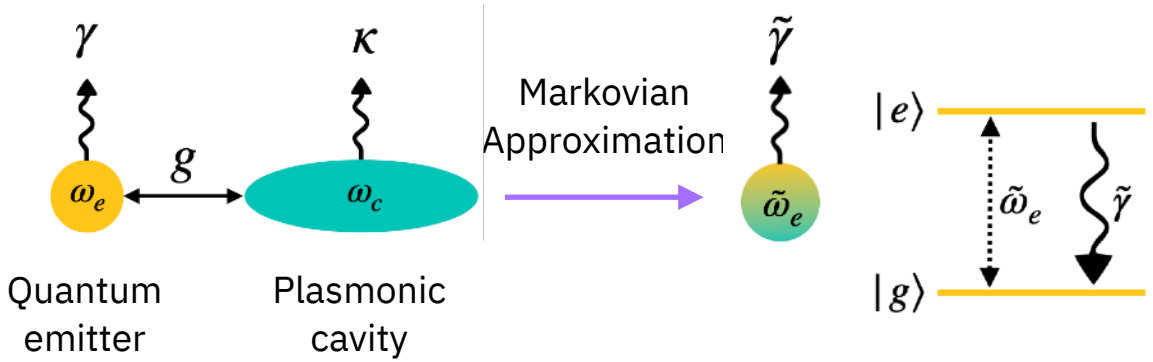

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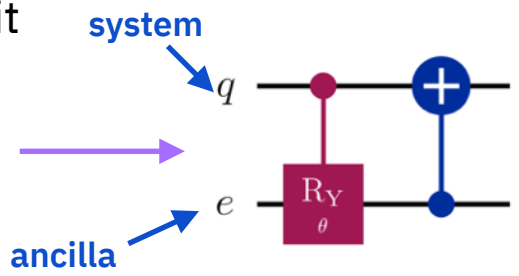

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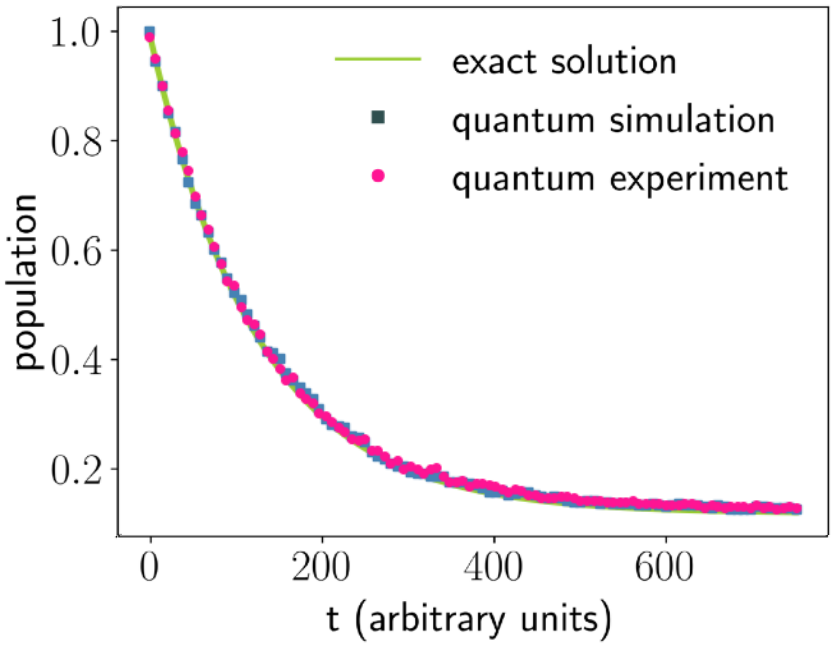
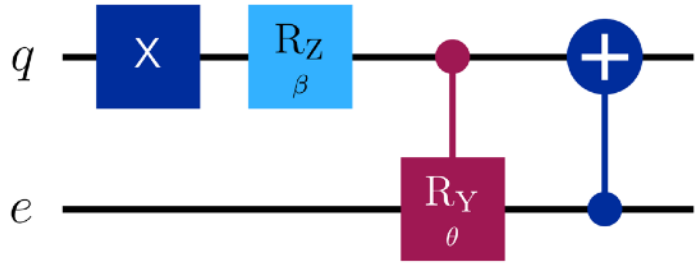


EstimatorV2

Total evolution (Hamiltonian and Lindbladian) for a single Trotter step:



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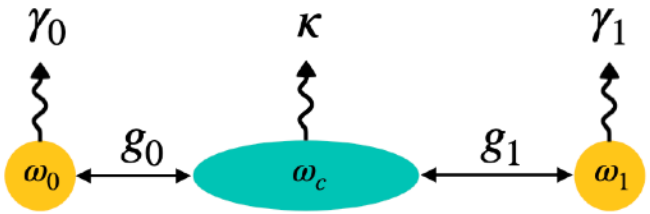
Weak coupling regime for two emitters

Adding **one more emitter**...



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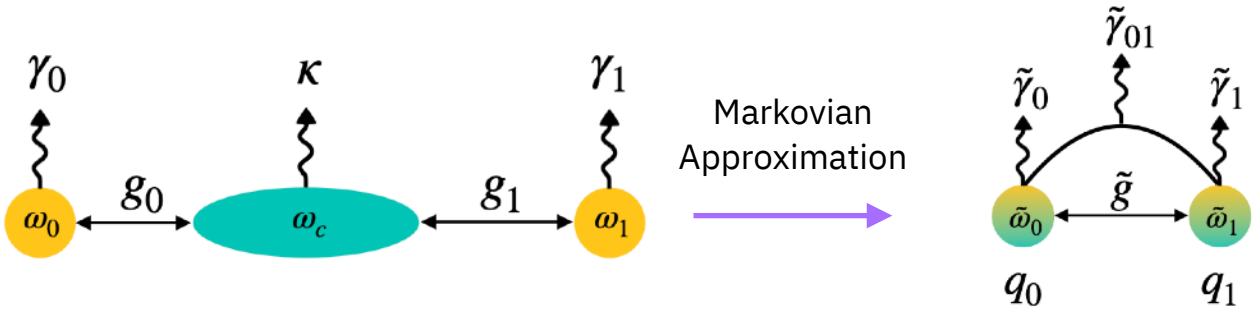

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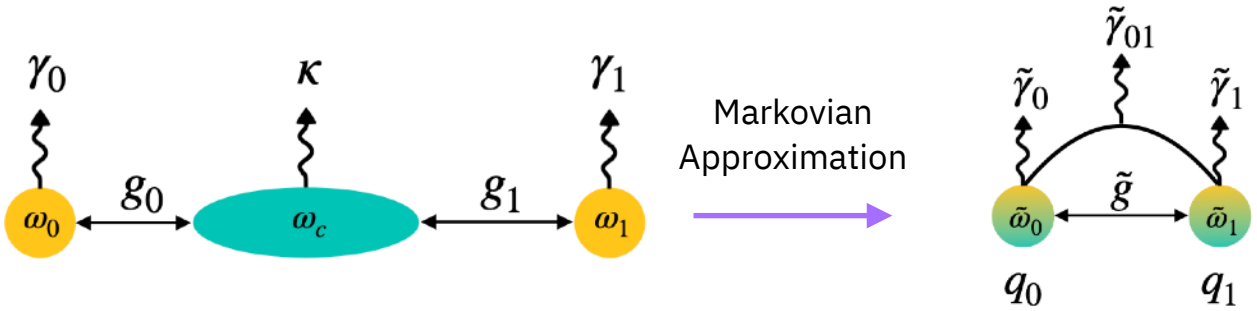
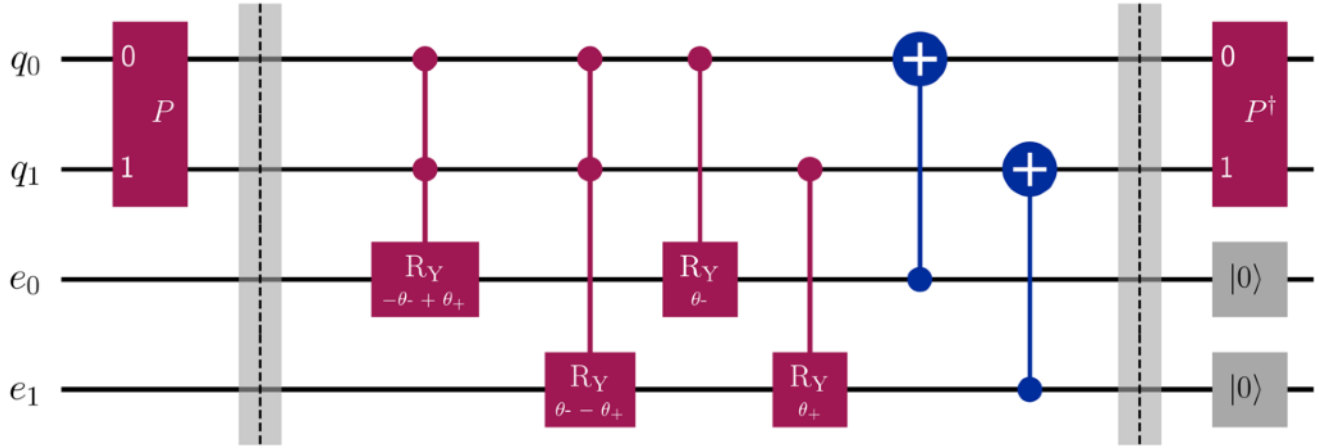


... makes the decay part of the circuit **more complex** (due to cross decay)...



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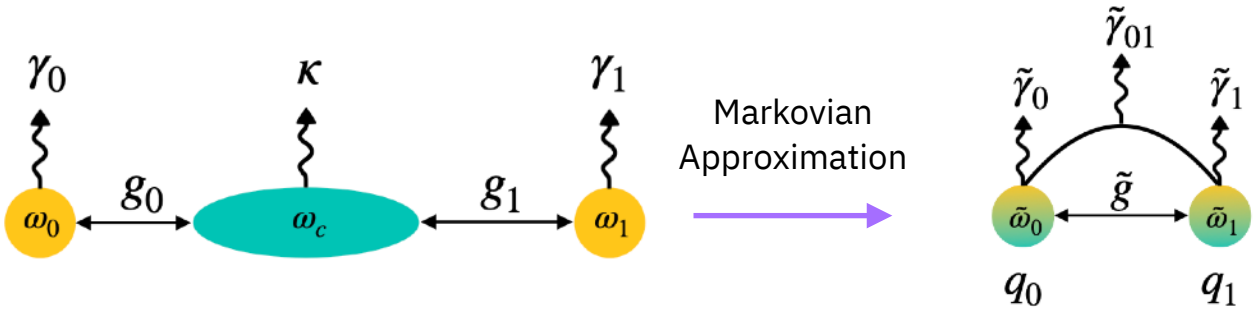

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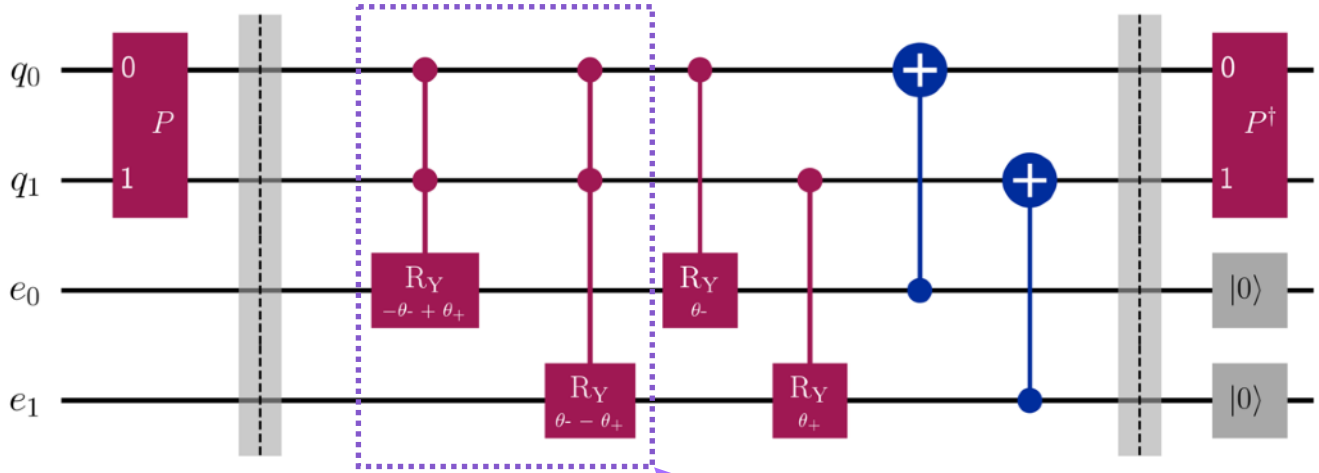

... as it includes t**hree-qubit gates**

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Weak coupling regime for two emitters

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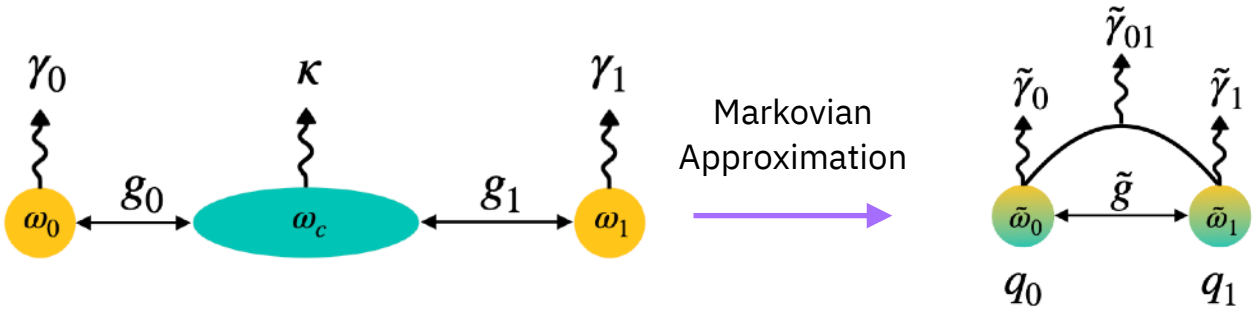

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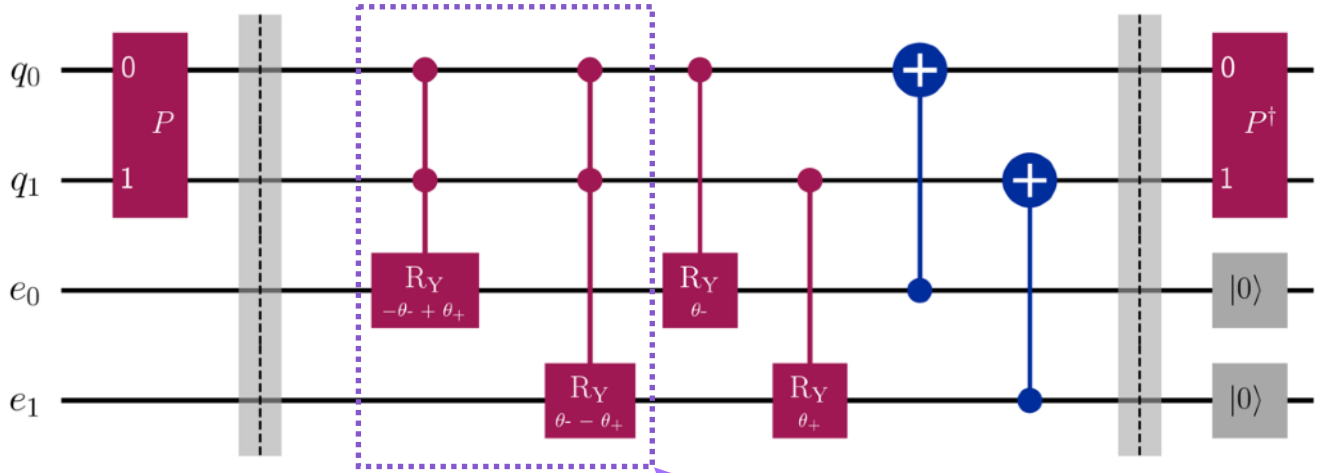

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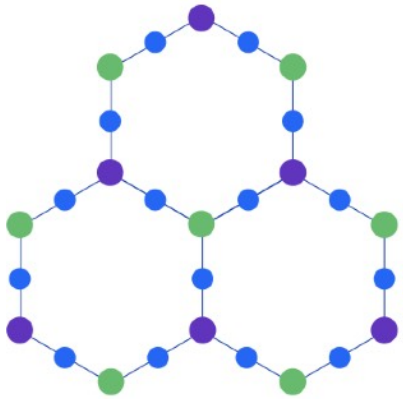
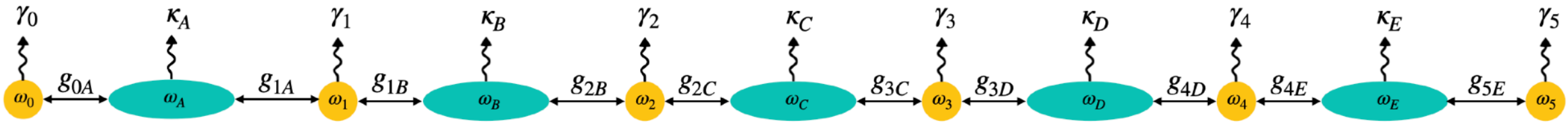
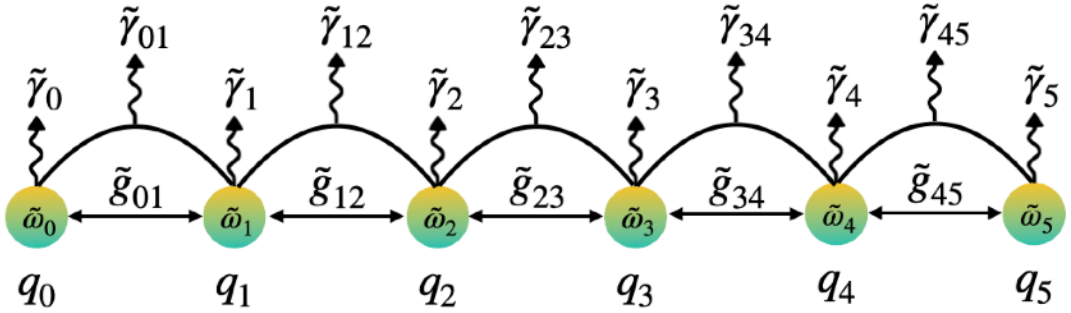


(Not well suited for the hardware **limited connectivity**)

Weak coupling regime for n emitters



Markovian Approximation



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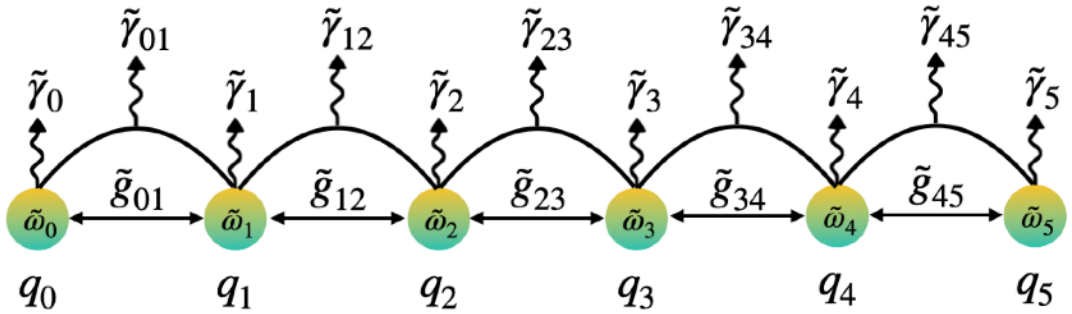

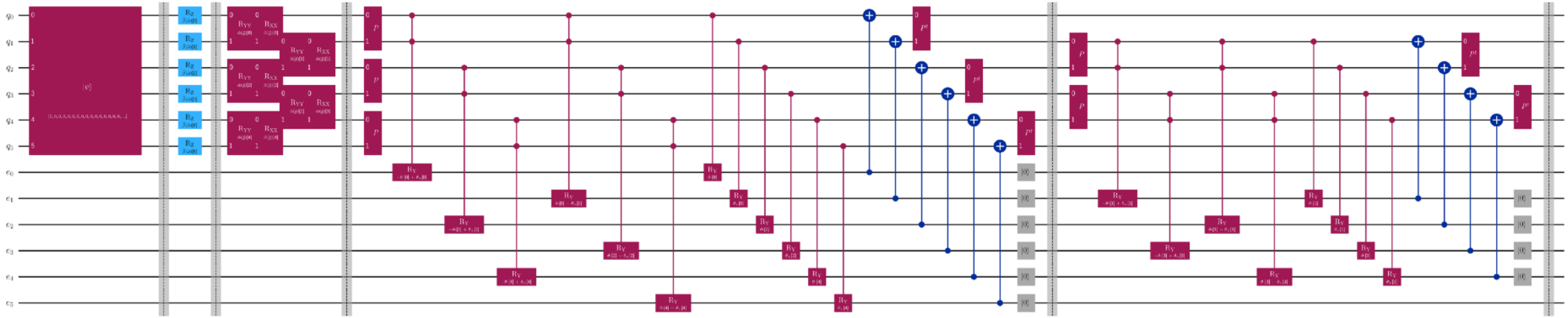

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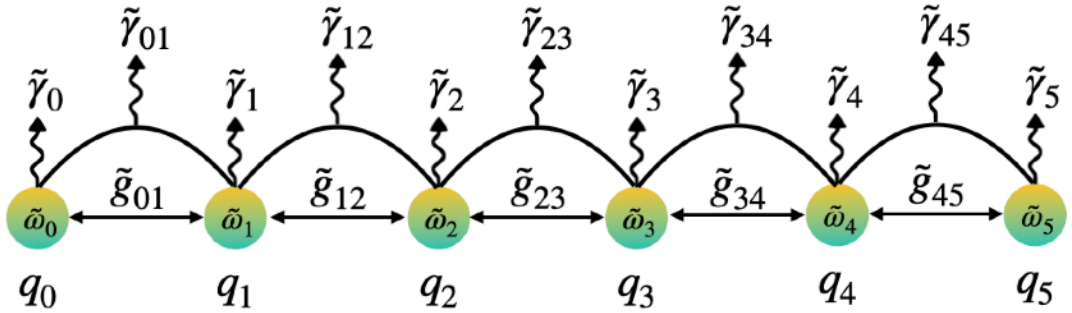
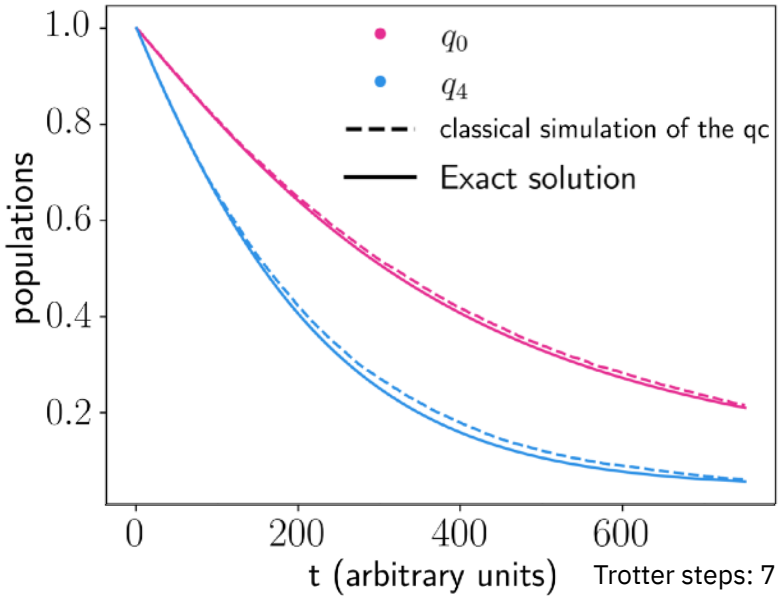
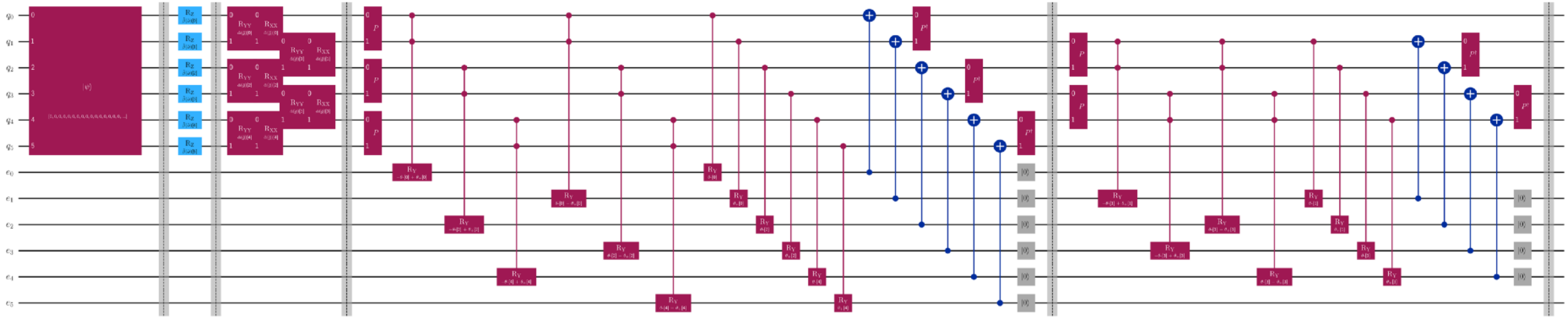




Trotter steps: 7



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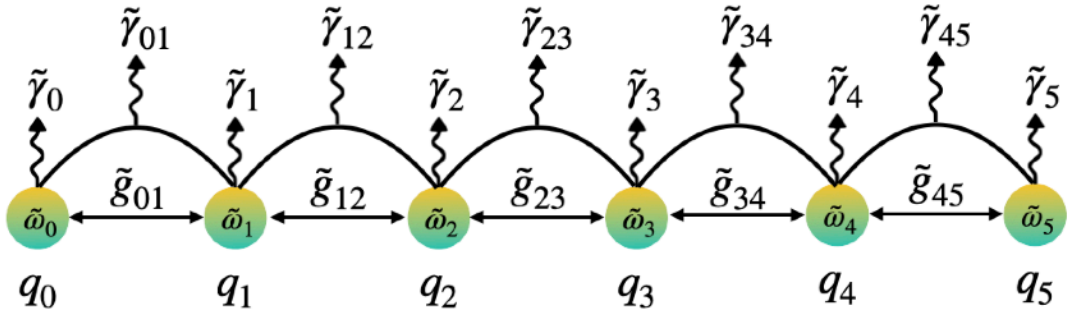

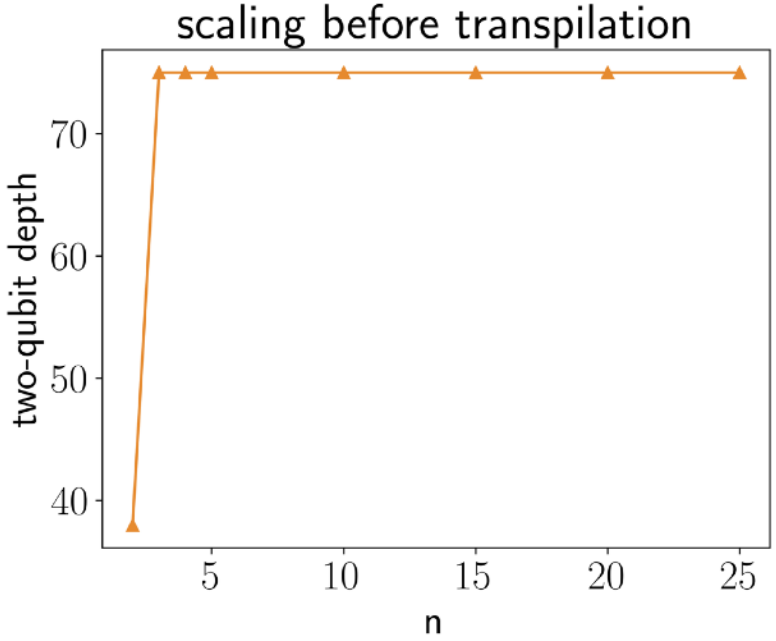

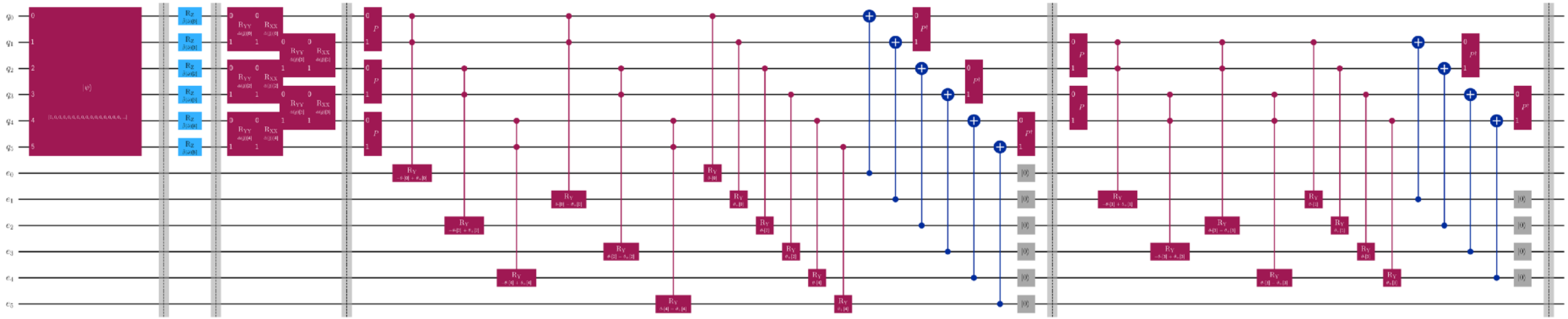

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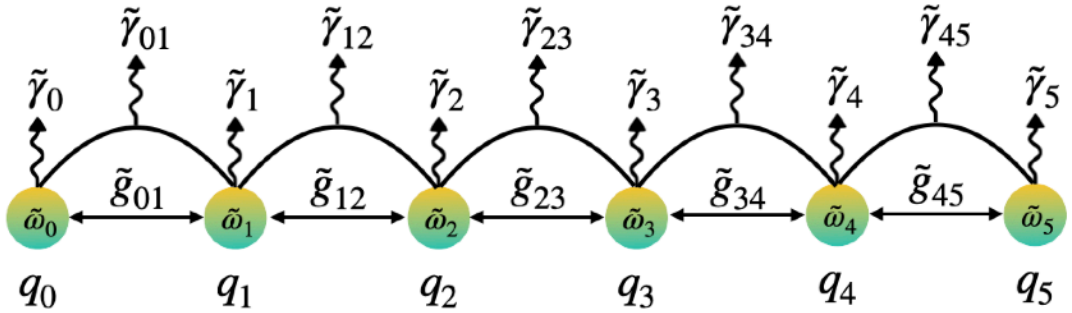

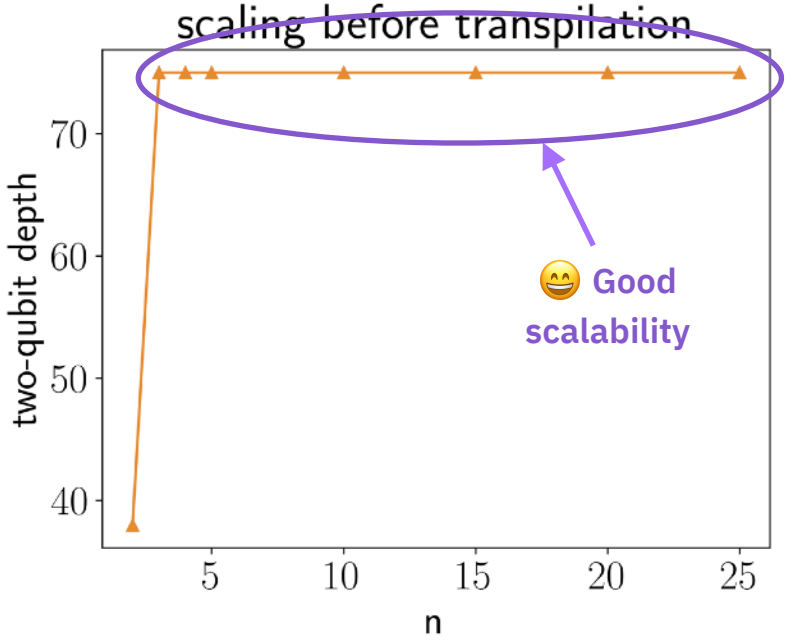

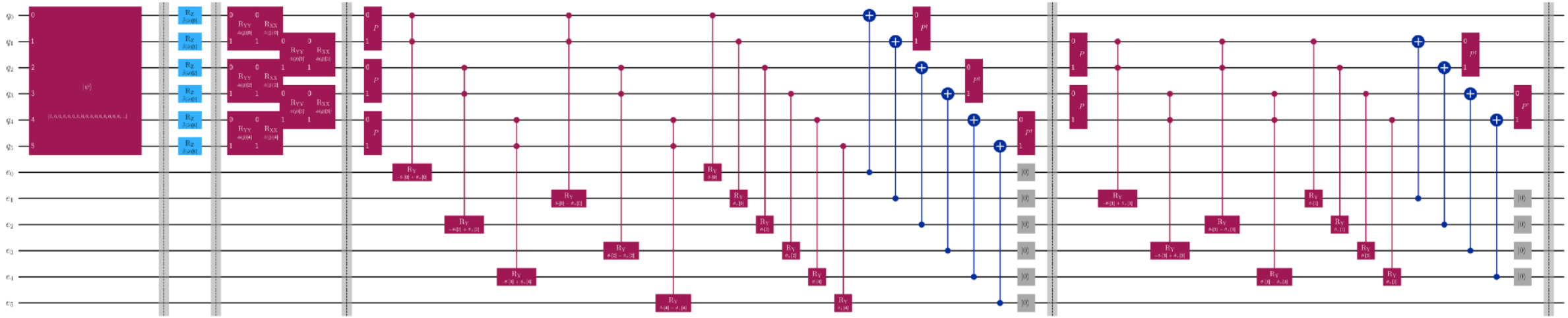

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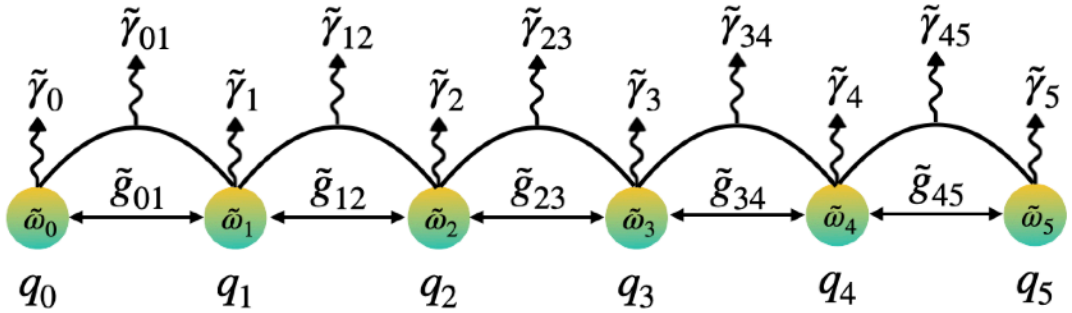
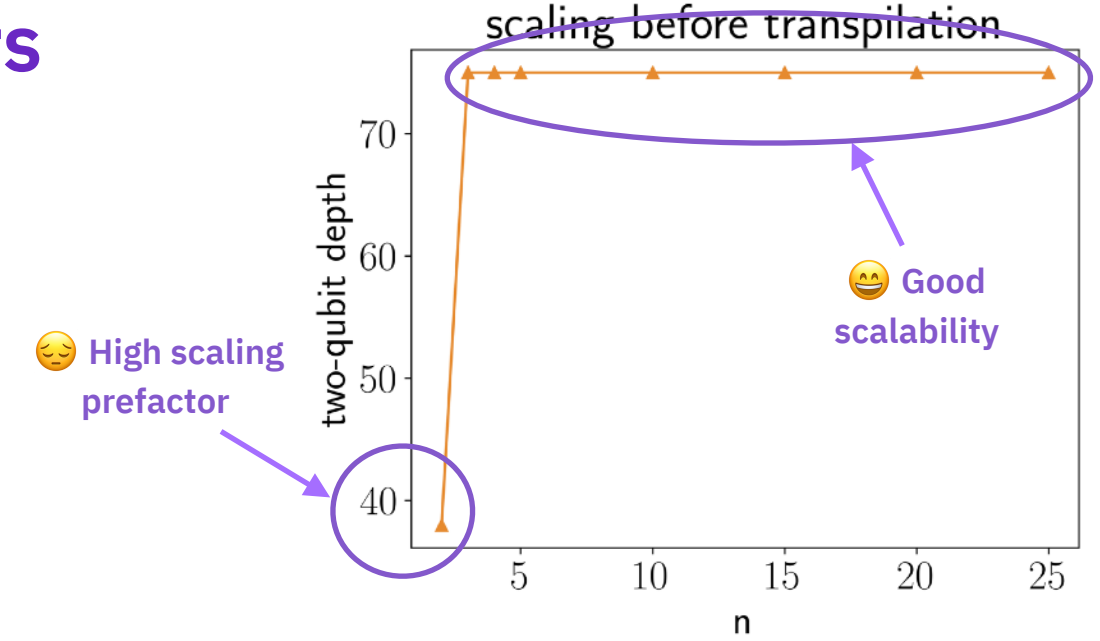
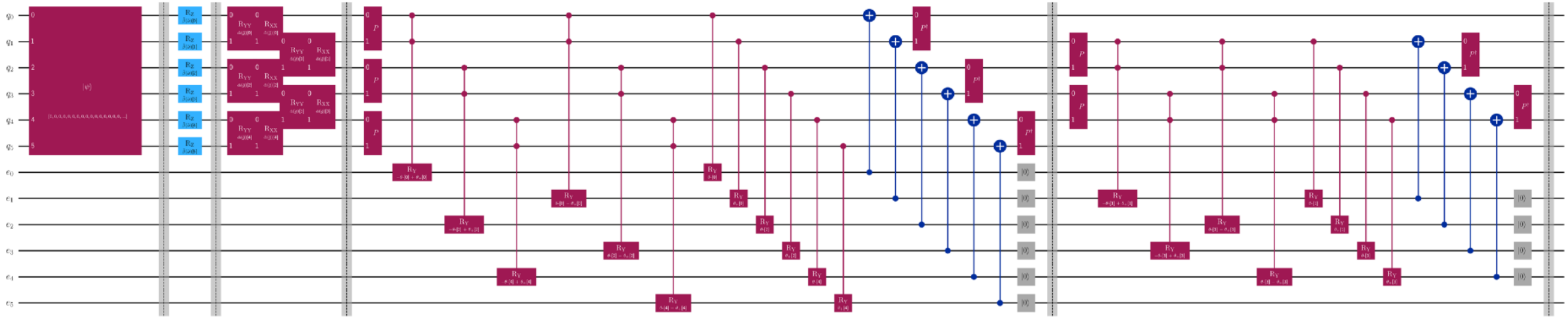
Weak coupling regime for n emitters







Reducing the core circuit depth using dynamic circuits (WIP)

Dynamic circuits: Make use of mid-circuit measurements to determine which gates to apply next.

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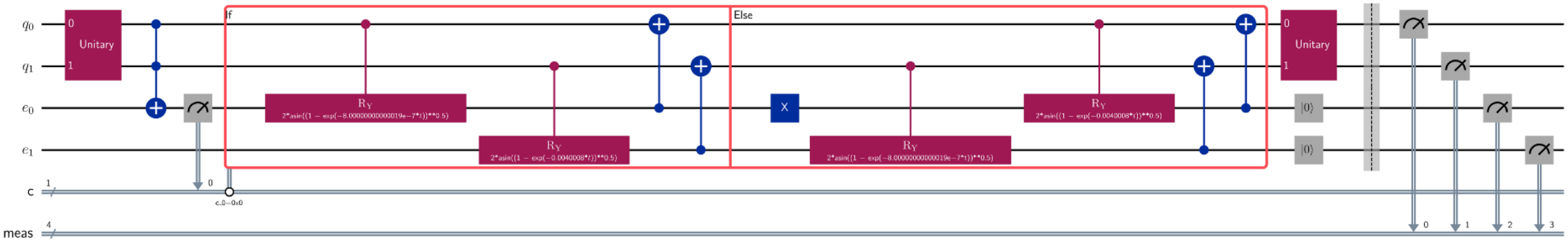

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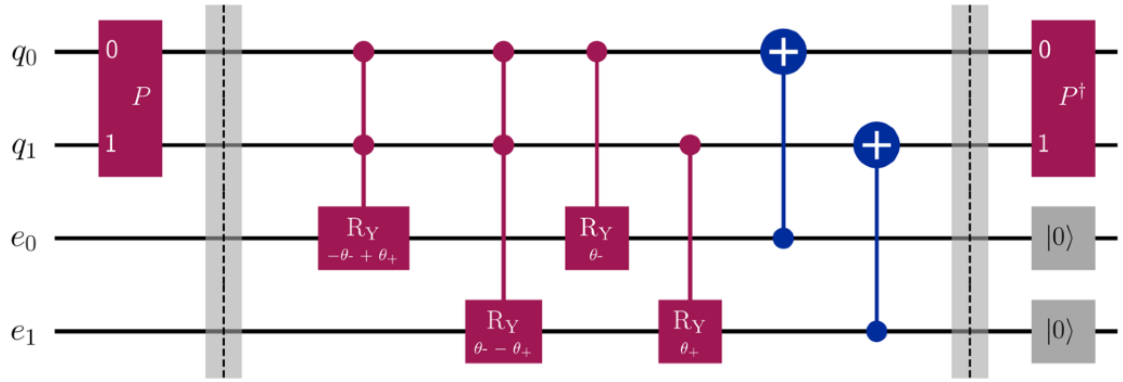
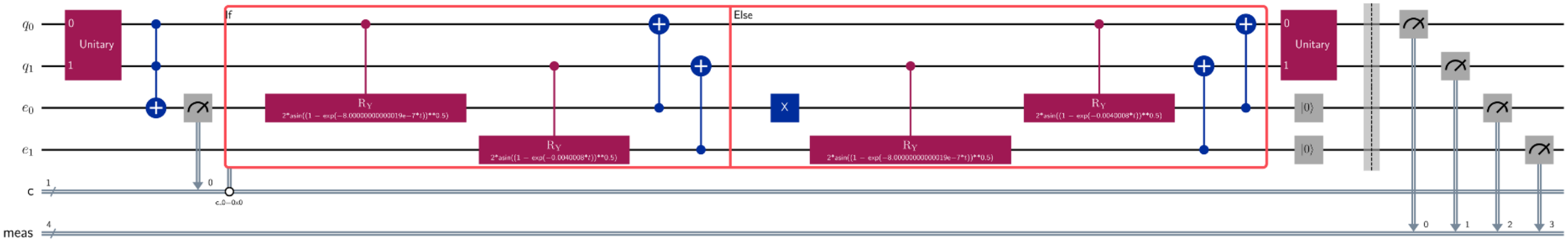
Reducing the core circuit depth using dynamic circuits (WIP)

Original version





Dynamic circuit

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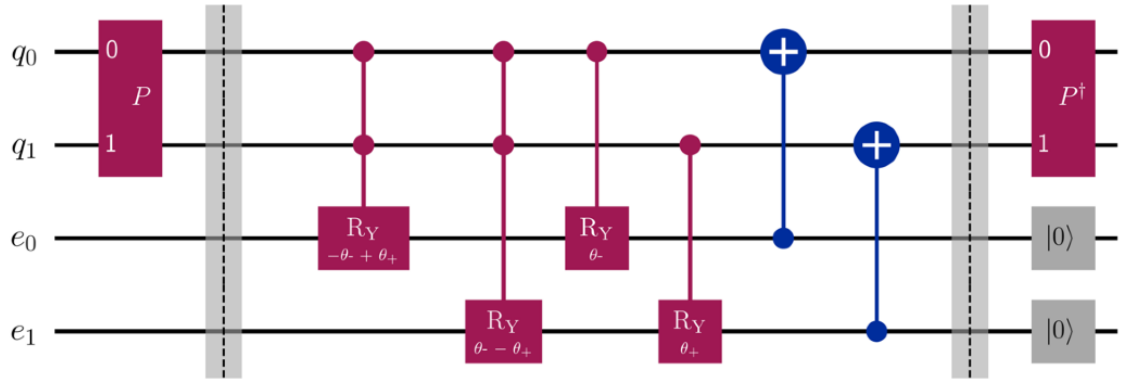
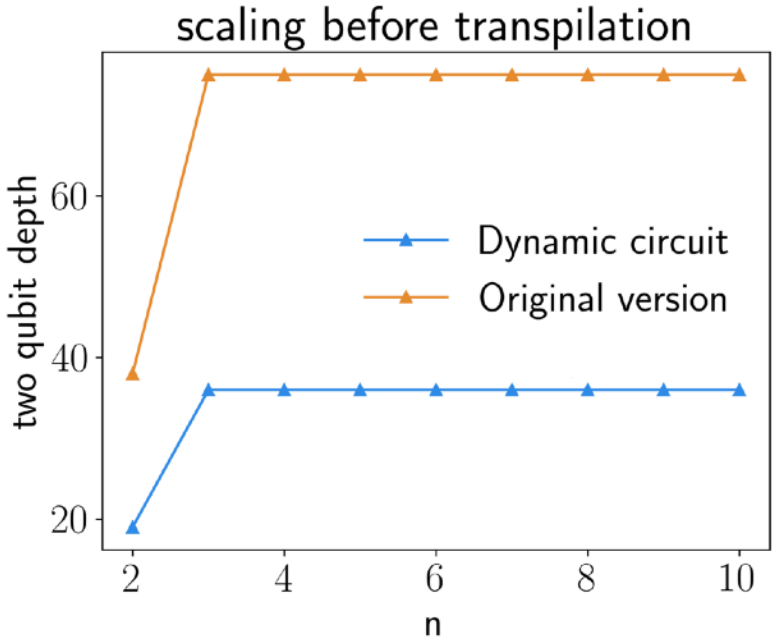
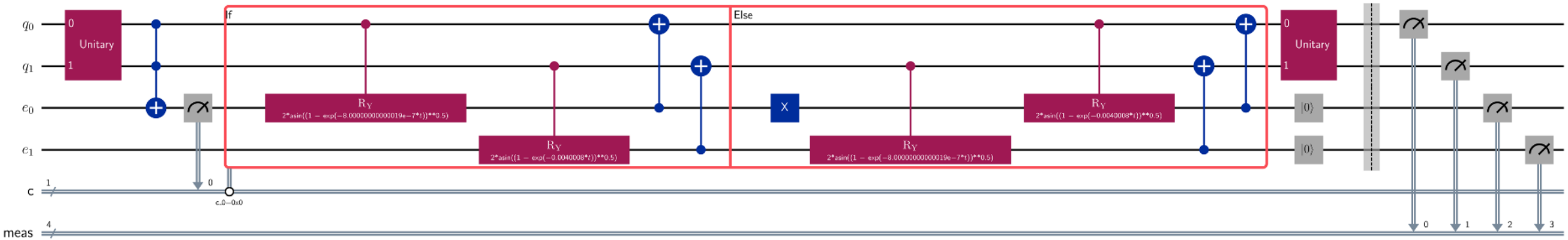
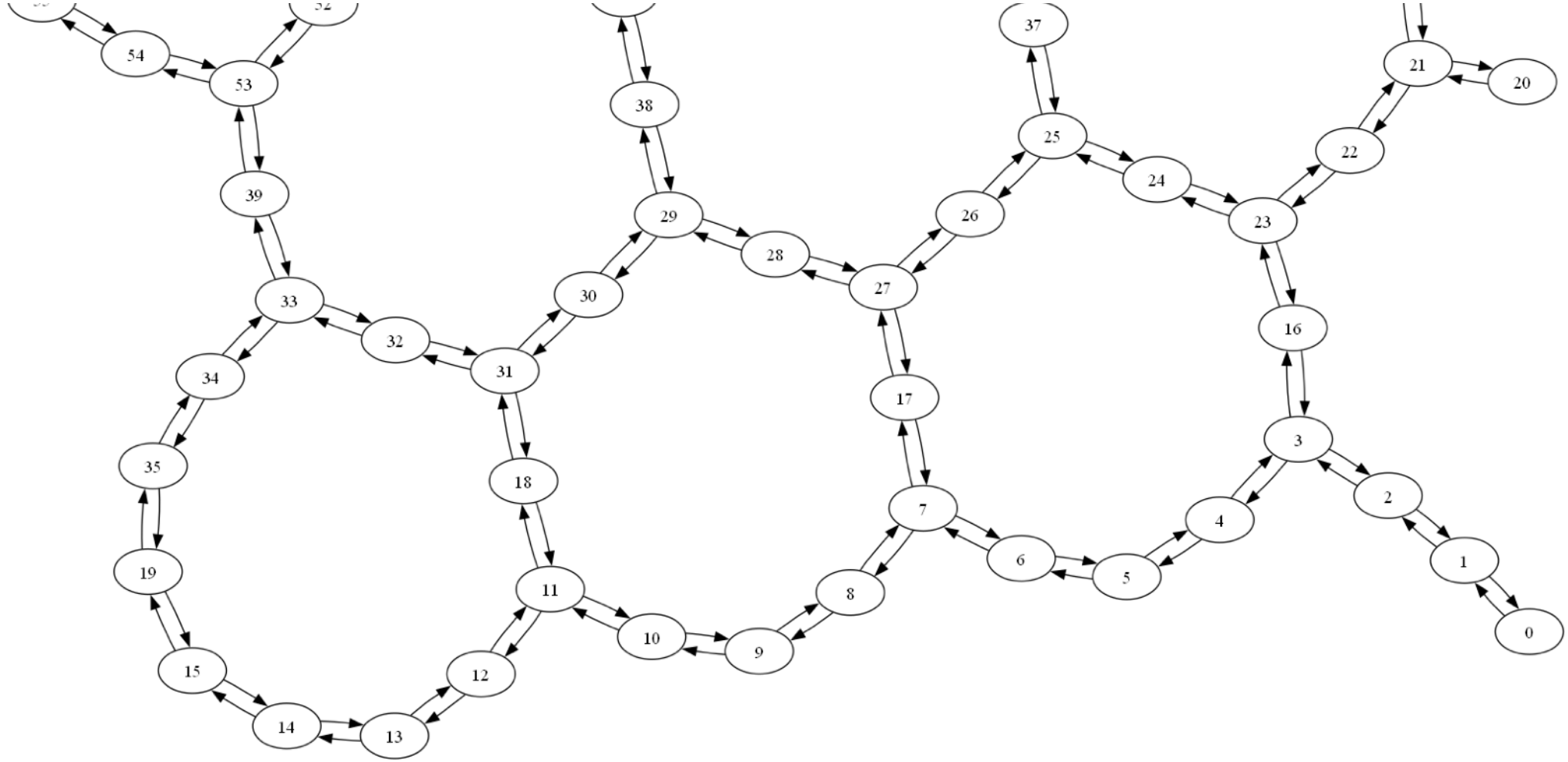






Dynamic circuit

Further improvements (I): tailored initial layout (WIP)



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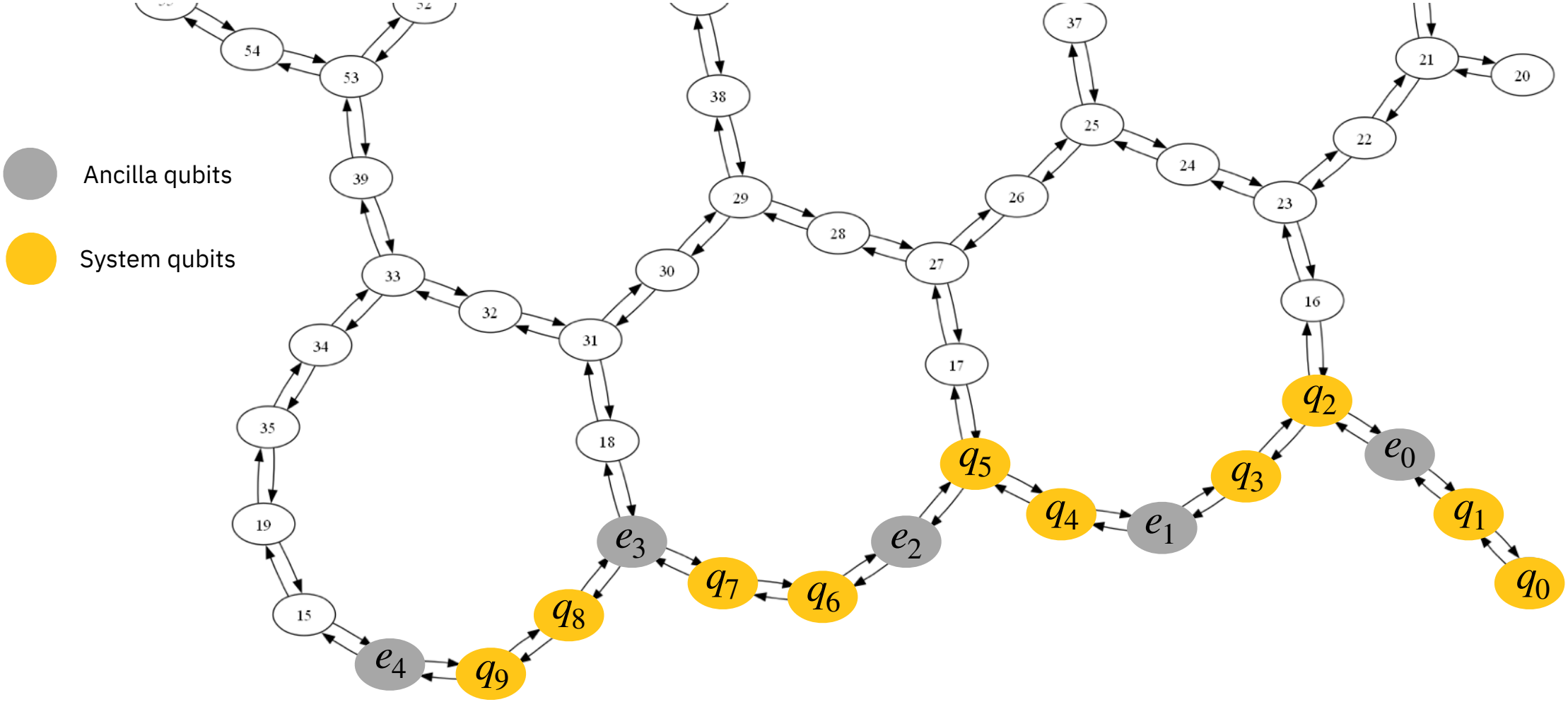
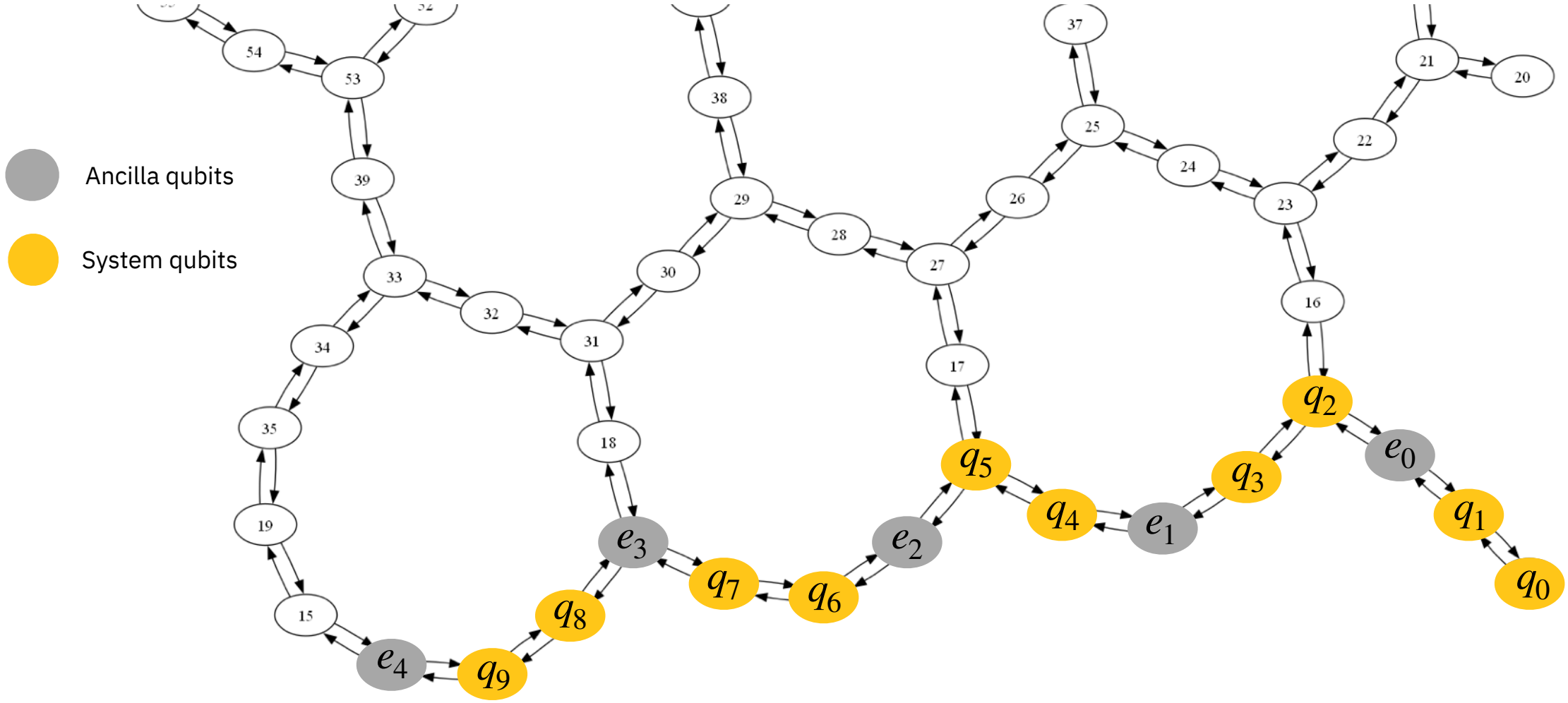


Further improvements (II): SWAP layering (WIP)



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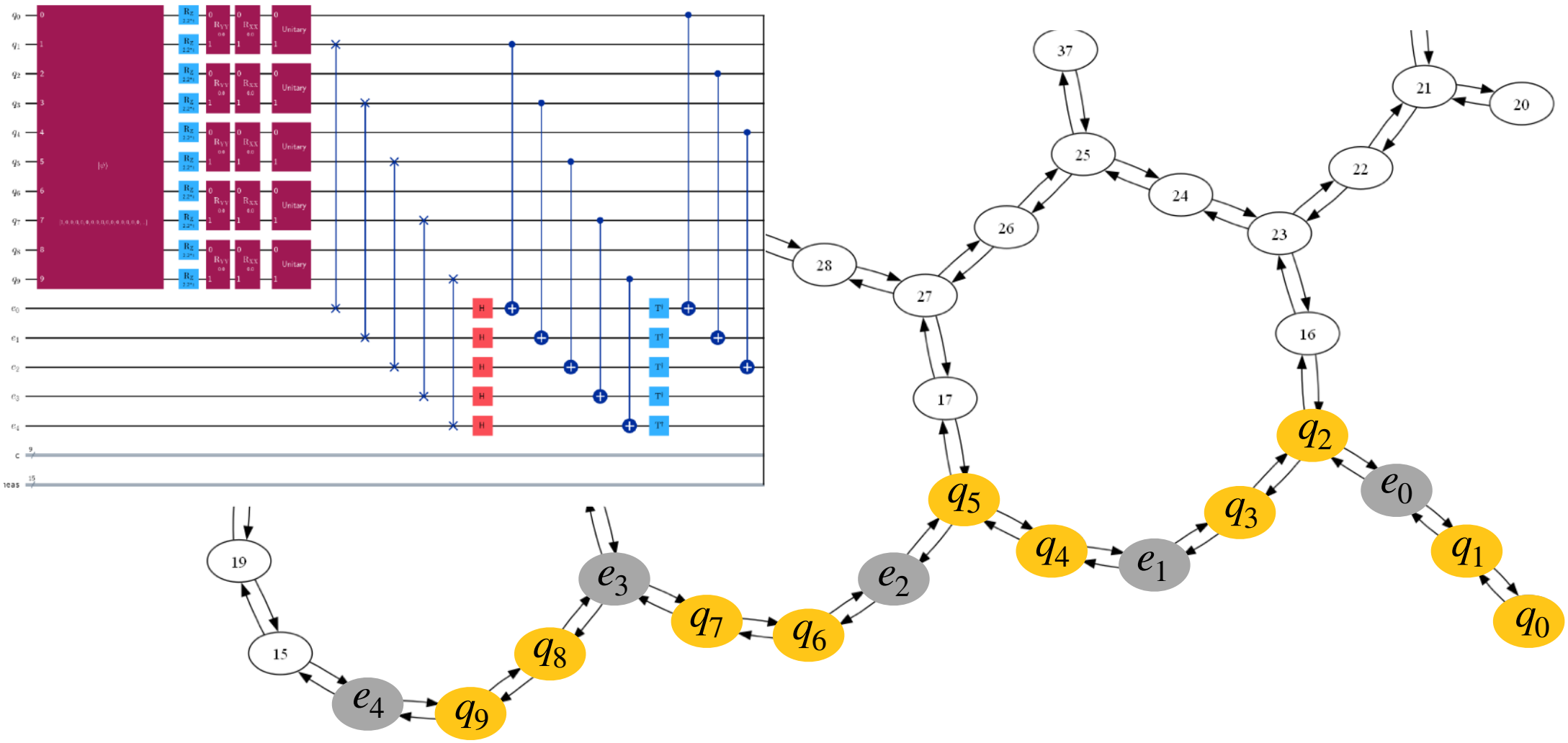

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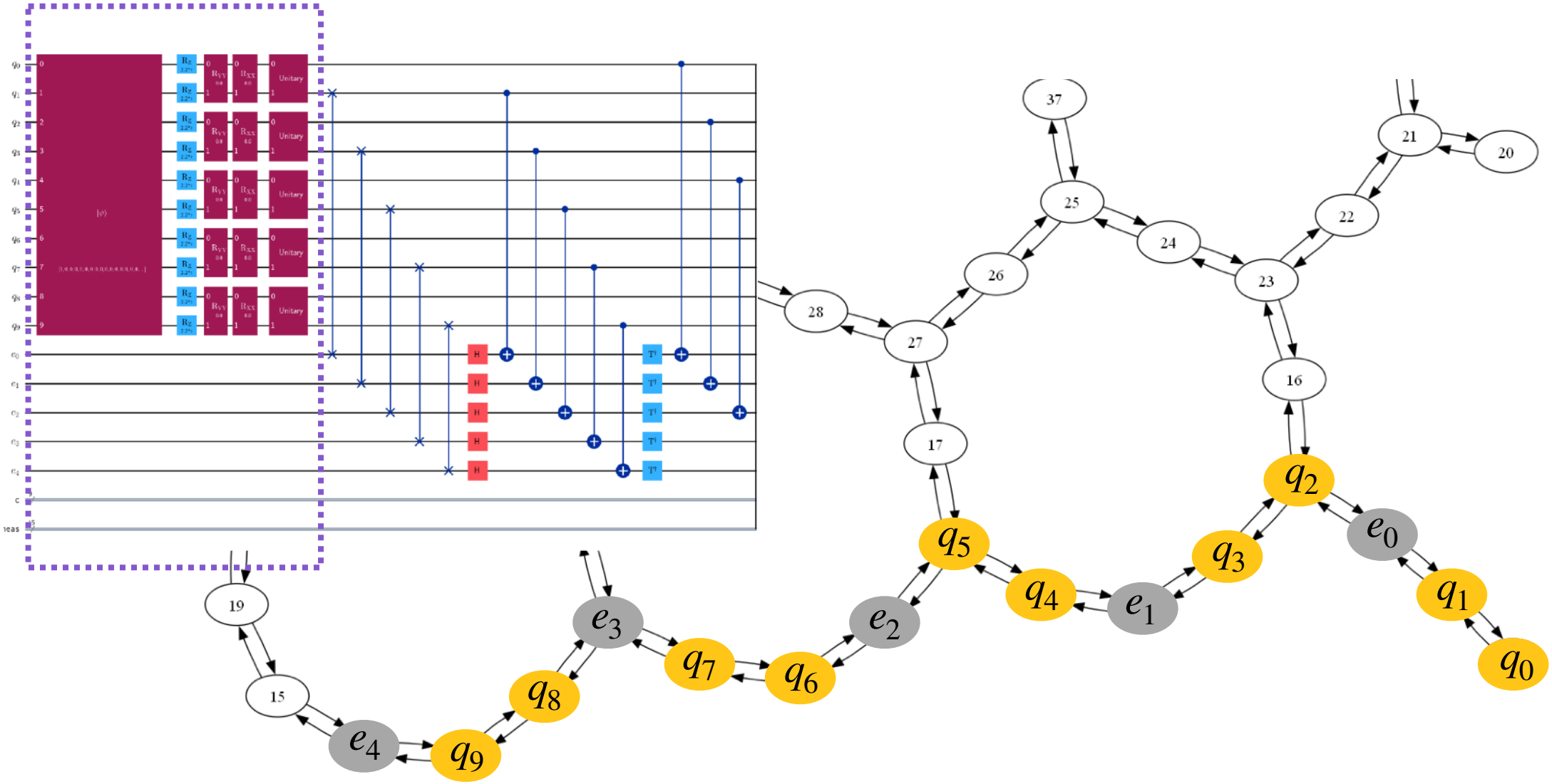

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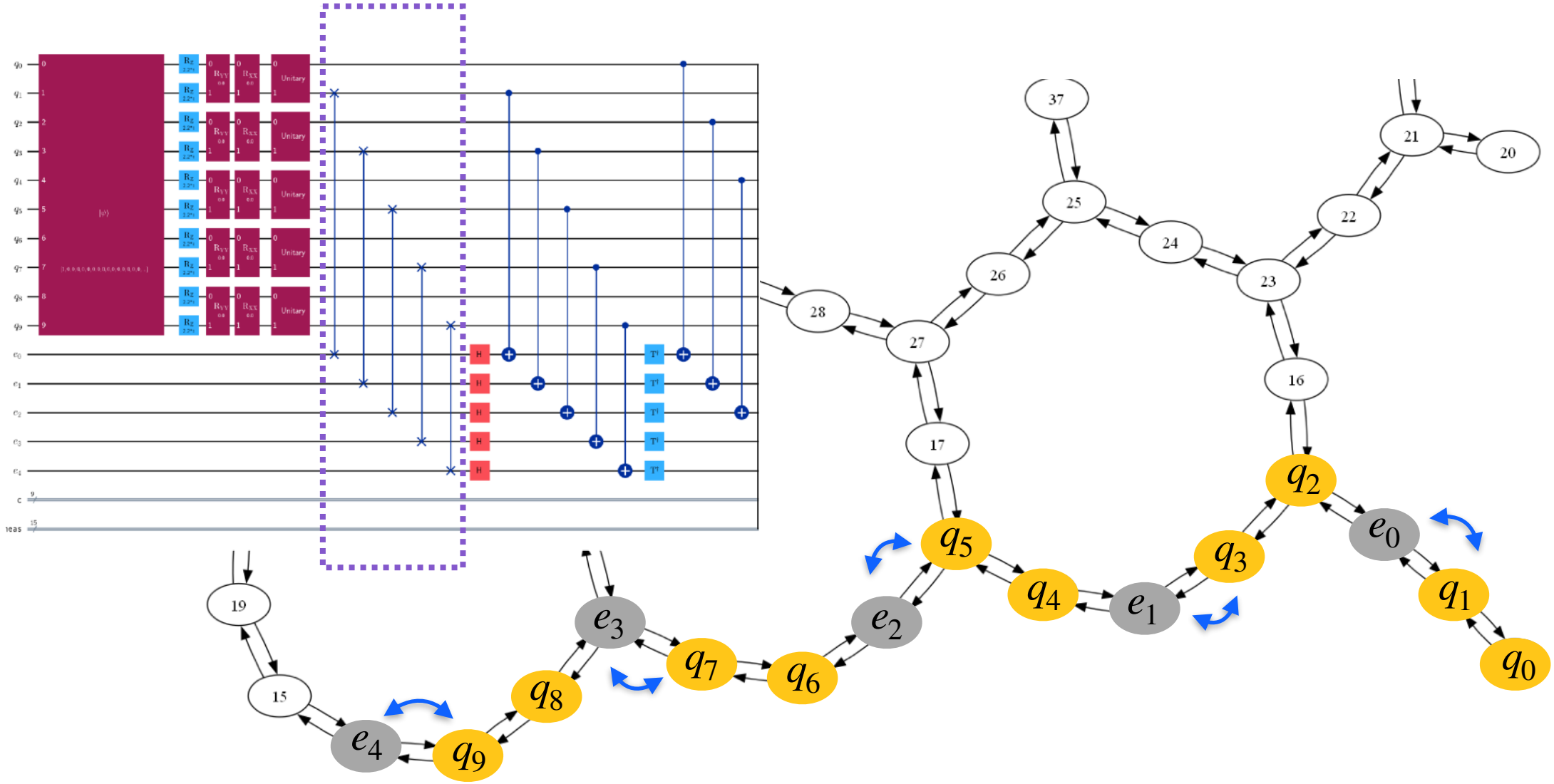

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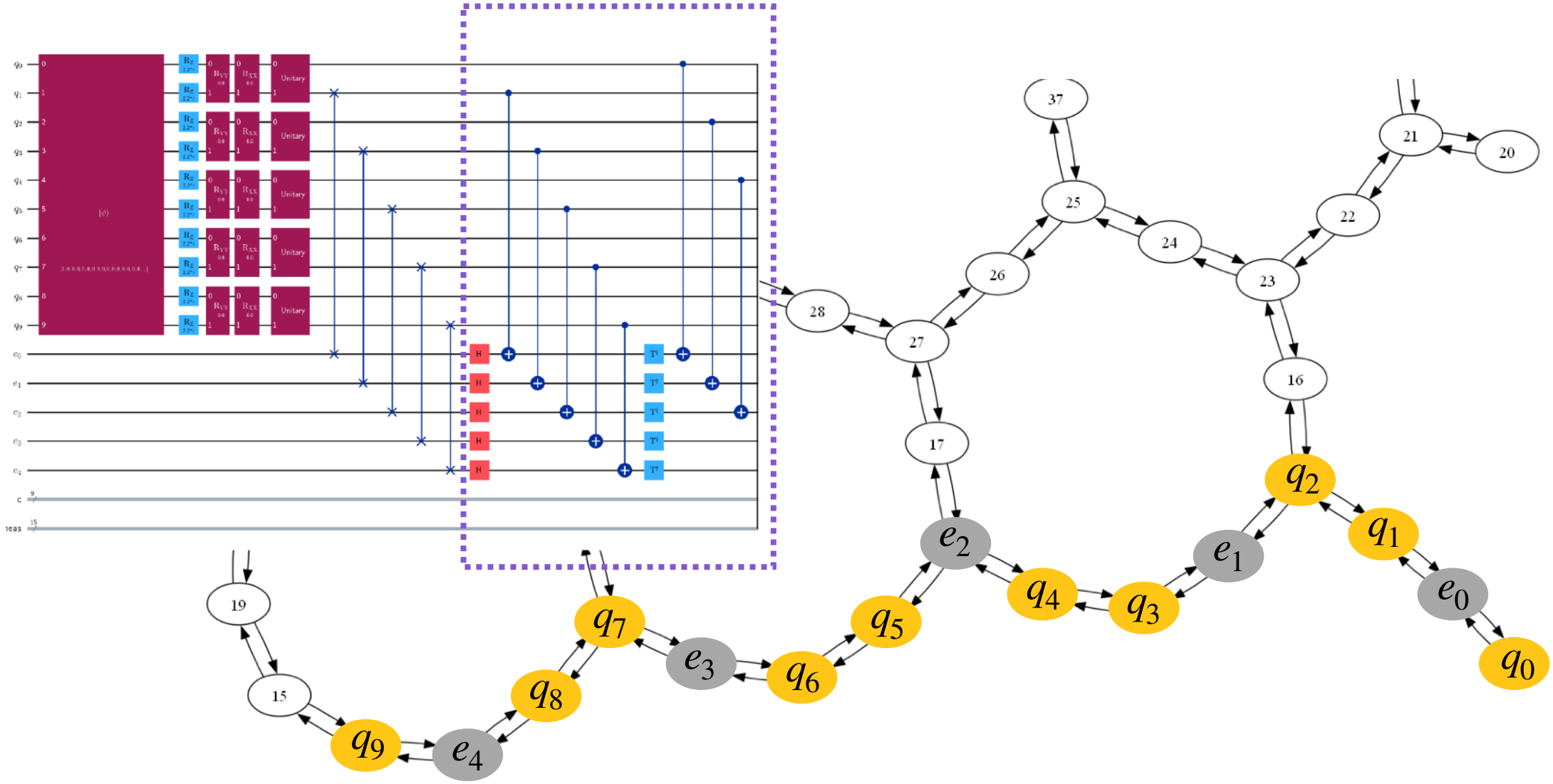

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Conclusions

Accurate modeling of the decay and cross-decay of multiple emitters

Core circuits are **still quite deep**

Good scalability with the number of emitters

Many techniques available for **further improvement**

Acknowledgements

- **Grant PID2022-139579NB-I00 Funded by MICIU/AEI/10.13039/501100011033/and by ERDF/EU**
- **Grant no. IT 1526-22 From the Basque Government for Consolidated Groups of the Basque University**

Thanks for your attention!