

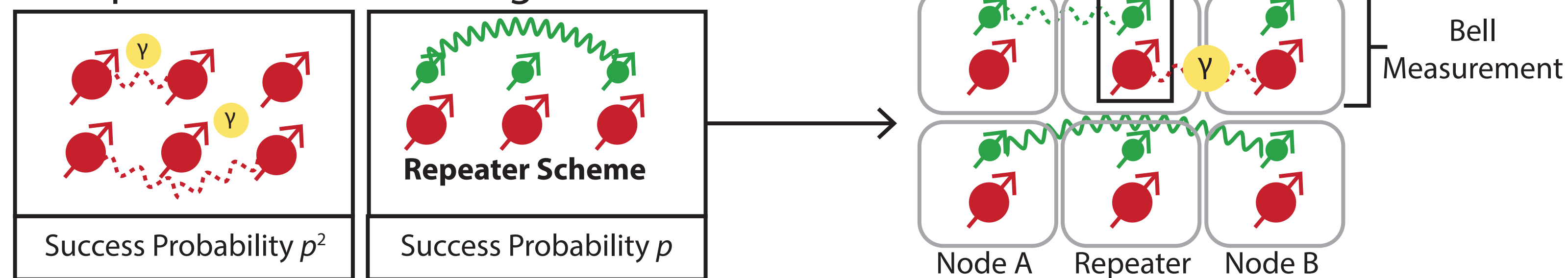
Quantum Repeaters for Quantum Networks

Towards a Long-Range Quantum Internet

Quantum networks can distribute entanglement over long distances

Applications: Quantum Key Distribution, Distributed Quantum Computing, and Nonlocal Sensing

A high-fidelity long-lived quantum memory in a quantum repeater node is needed to overcome exponential photon loss over long networks

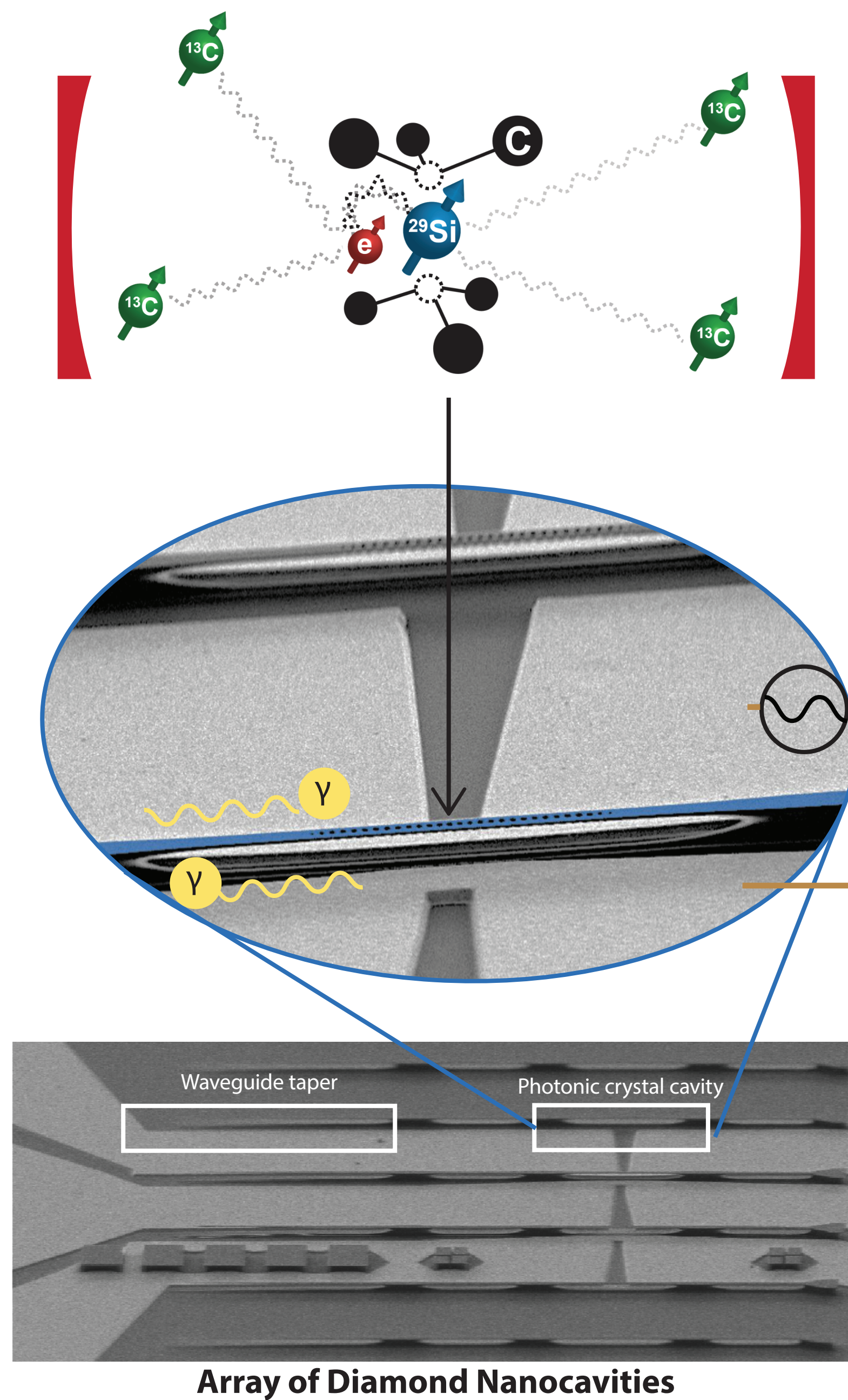


Requirements:

- Efficient, high-fidelity, spin-photon interface capable of multi-qubit gates
- Memory qubit needs to store quantum state for $1/p$ entanglement attempts

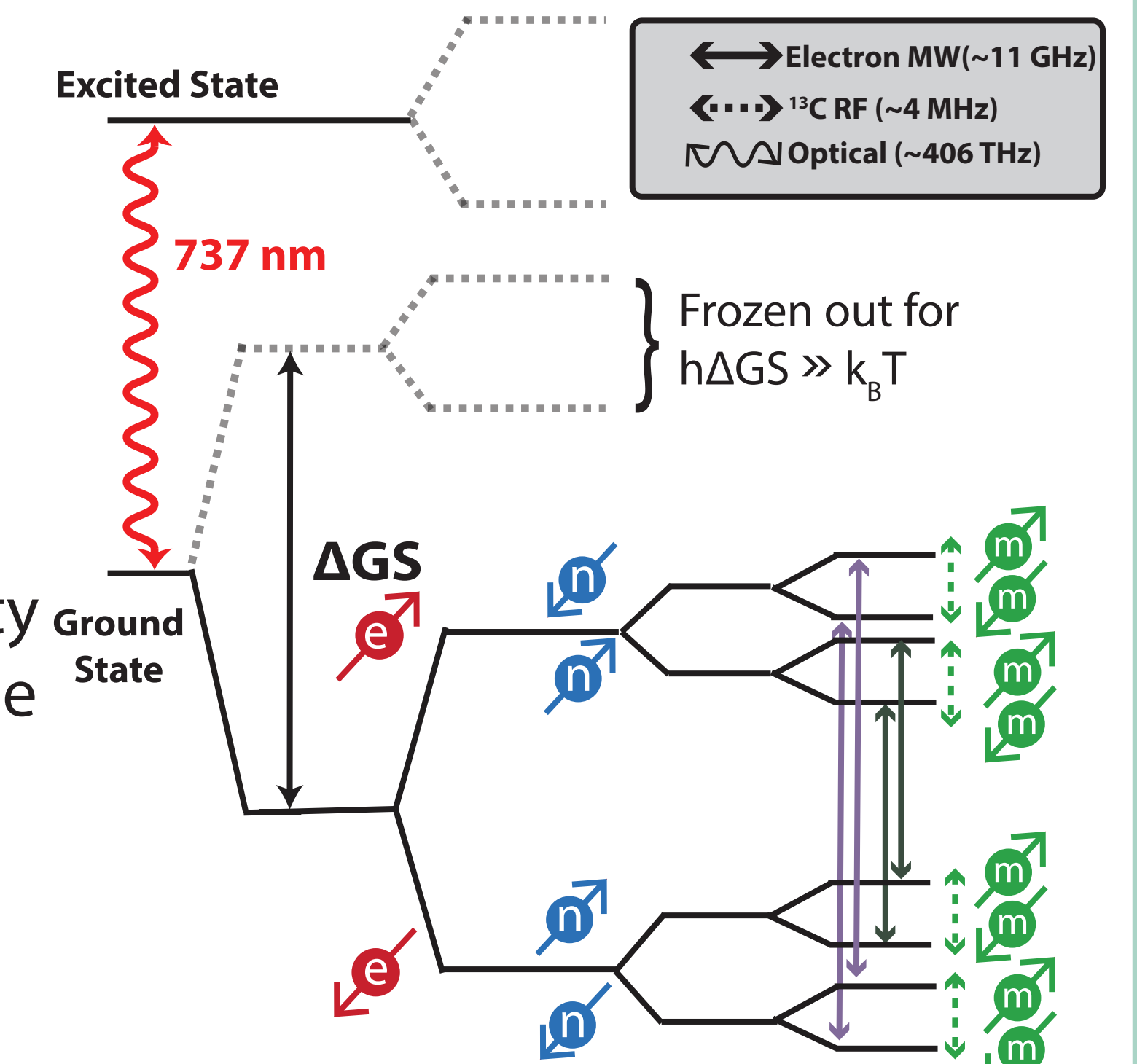
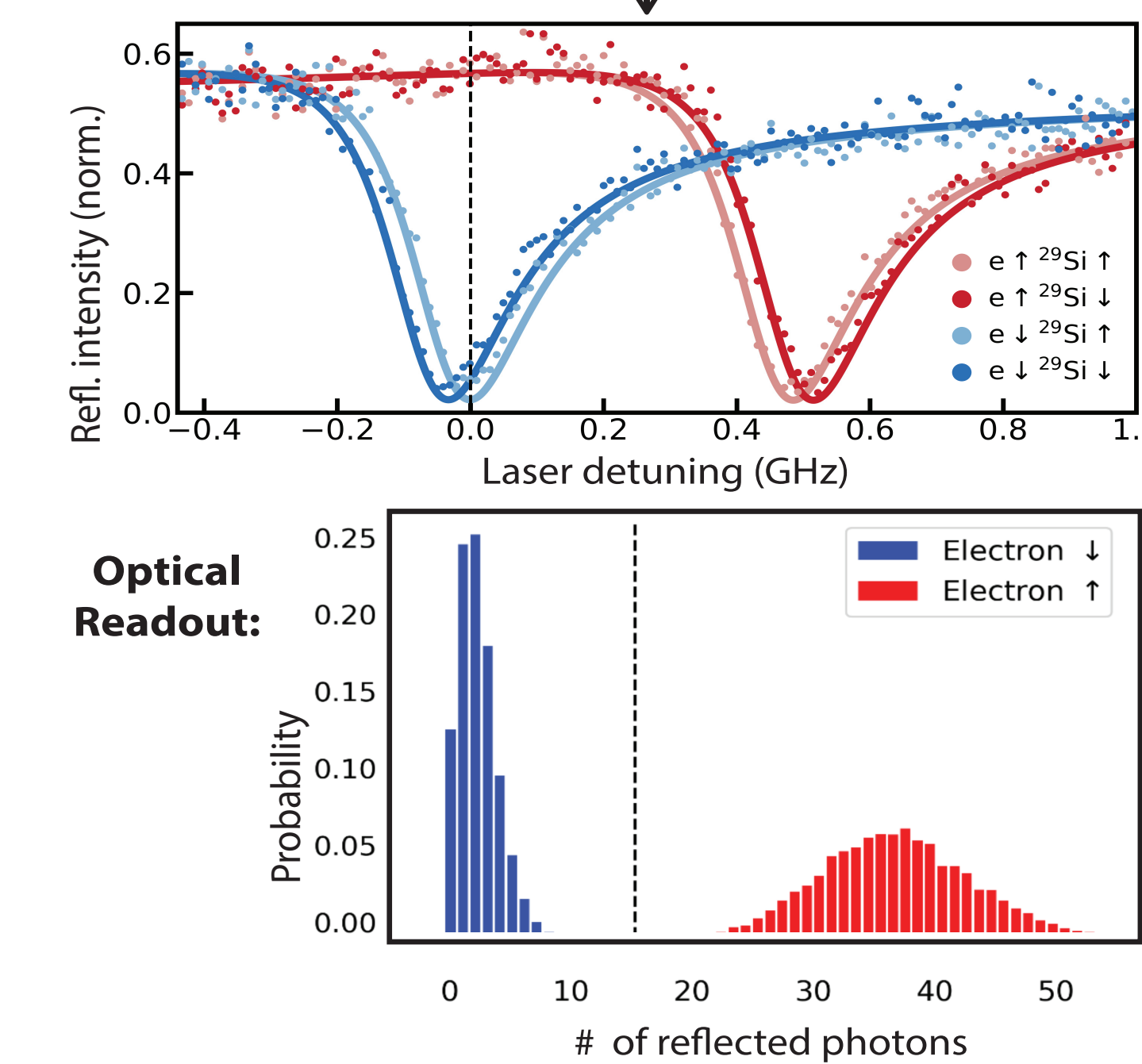
We show control of ¹³C spins with silicon-vacancy centers as long-lived quantum memories with quantum repeaters applications, demonstrating their high-fidelity spin-photon interface and coherence robustness against repeated entanglement attempts

Silicon-Vacancy Centers: A Promising Platform for Quantum Repeaters

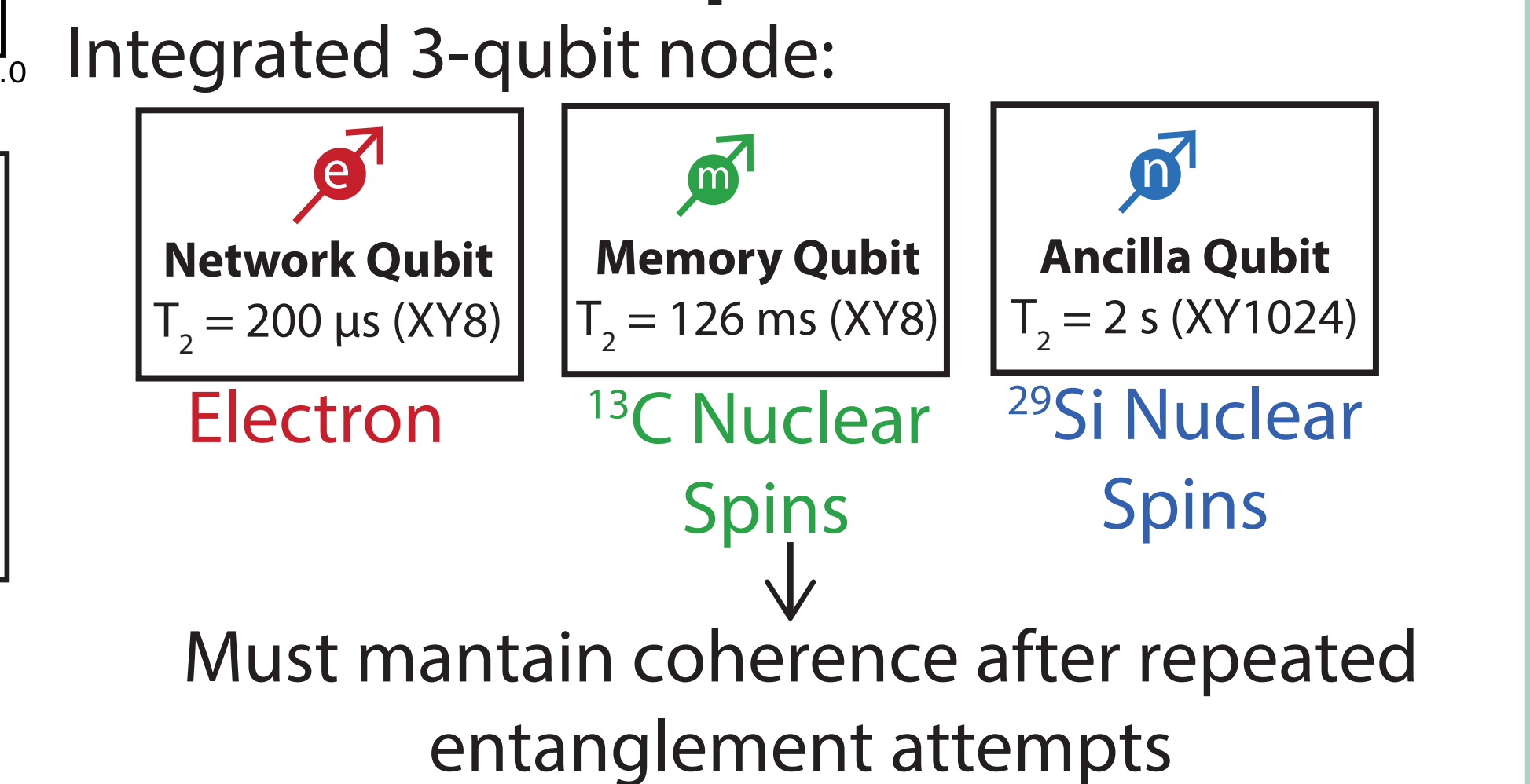


Nanophotonic Spin-Photon Interface

- SiVs are implanted in diamond nanophotonic cavities
- High collection efficiency (up to 90%) using tapered optical fiber
- On-chip MW and RF delivery to drive one- and two-qubit gates
- Cavity-enhanced contrast allows for high-fidelity ($F > 0.99$) optical readout and initialization of the electron at 737 nm



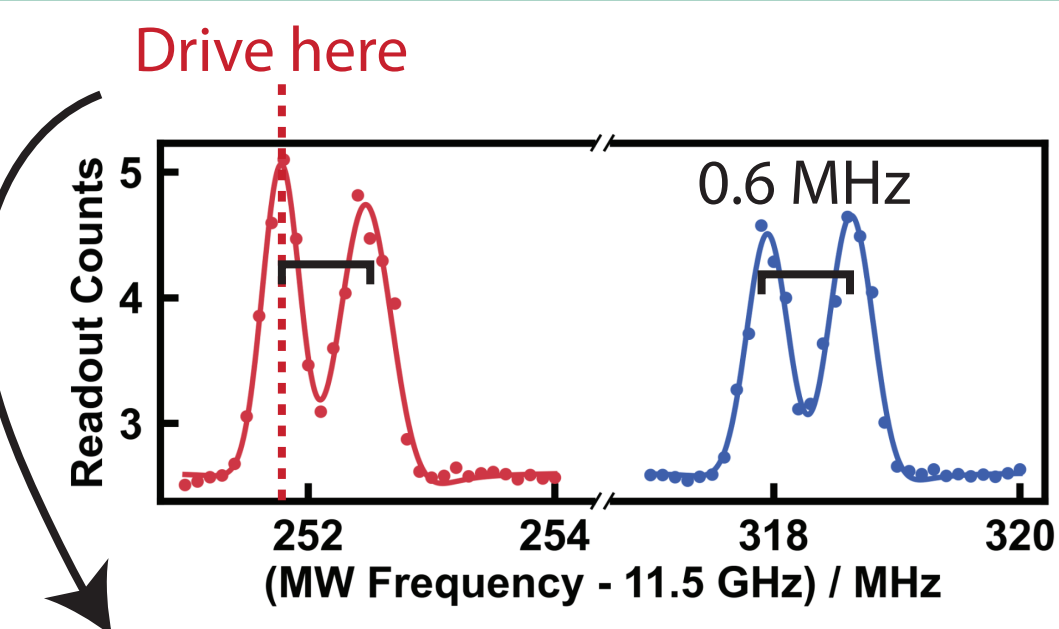
SiV Quantum Repeater Architecture



¹³C Spectroscopy

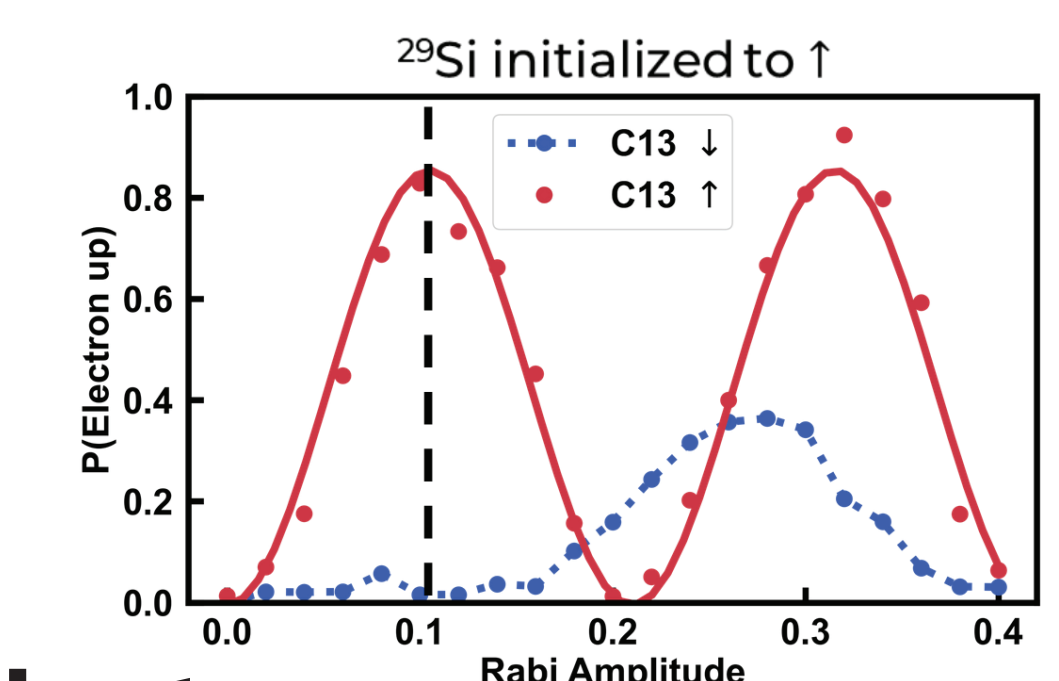
Electron - ¹³C Coupling

- Coupling to ¹³C leads to splitting in electron ODMR spectrum
 - Flips electron if both ²⁹Si and ¹³C are spin up
- $A_{||}/2\pi = 0.67 \text{ MHz}$



Rabi Driving

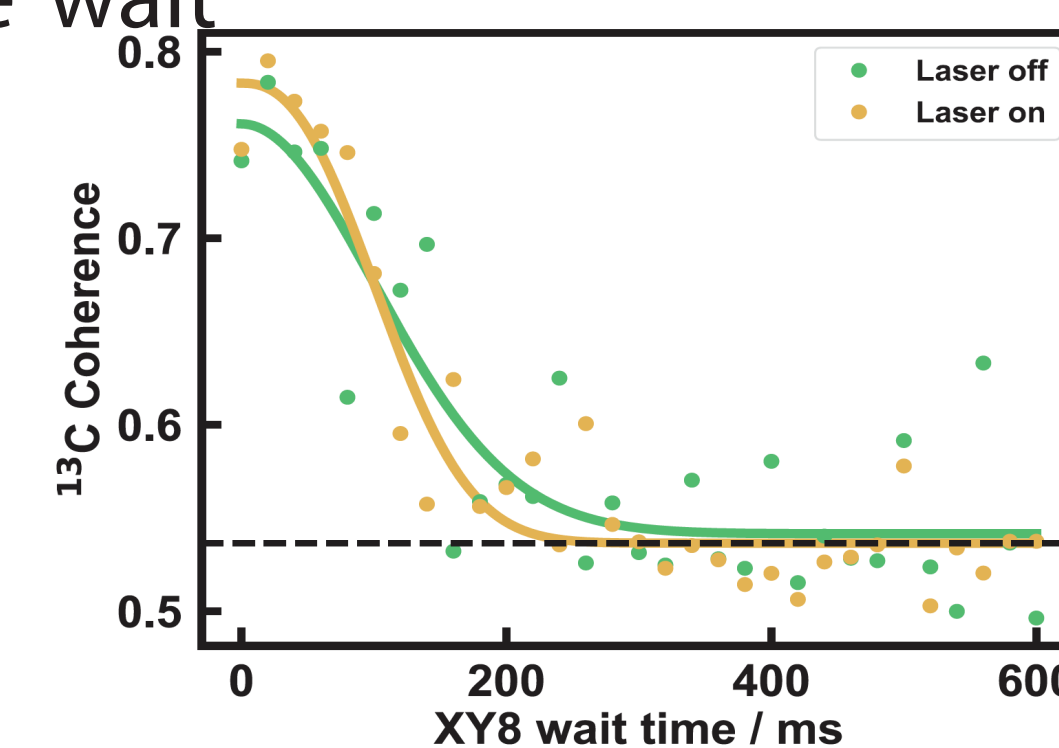
Driving on either peak gives an electron rotation conditioned on ¹³C spin state



Coherence Over Electron Readouts

XY8 coherence of the ¹³C with and without resonant optical excitation during the wait times

~1000 entanglement attempts possible!
~100 km maximum node distance

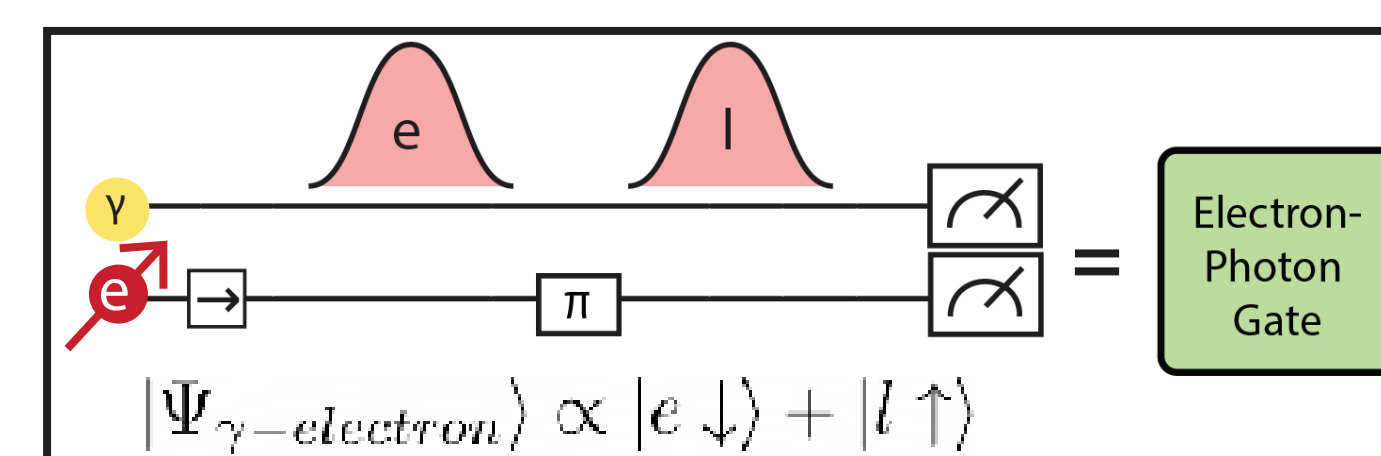


Building a Repeater Node with SiVs

Spin-Photon Entangling Gates

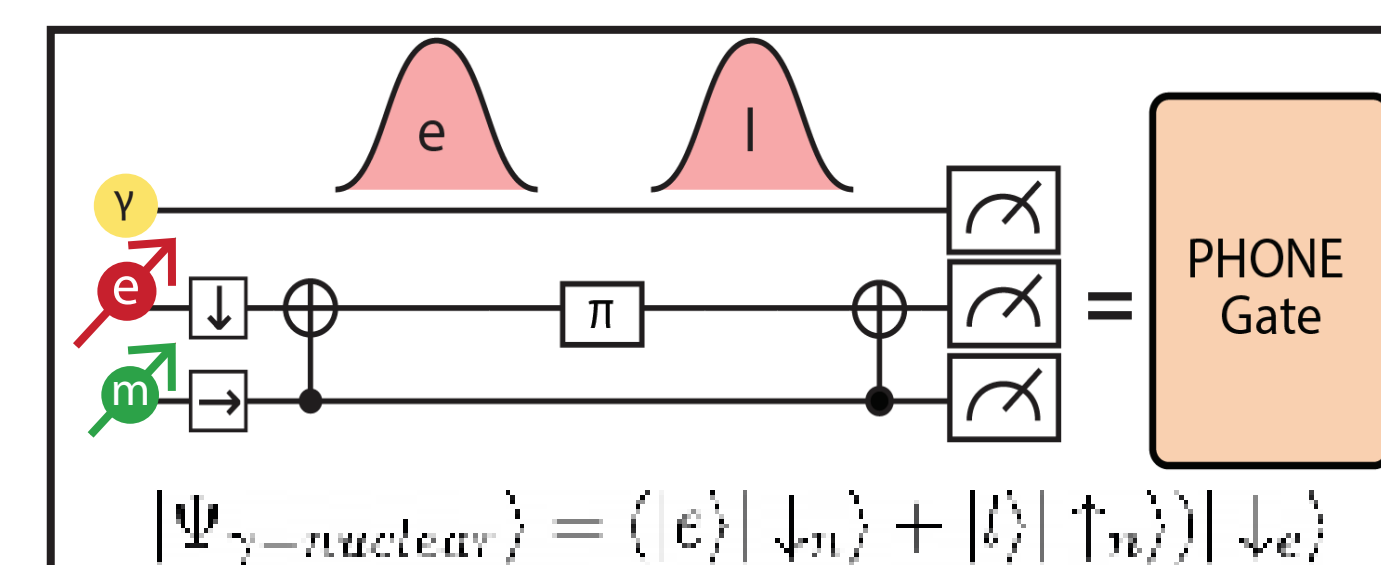
Electron-Photon Gate

- Time-bin encoding
- Heralded Bell state between electron and photon time-bin

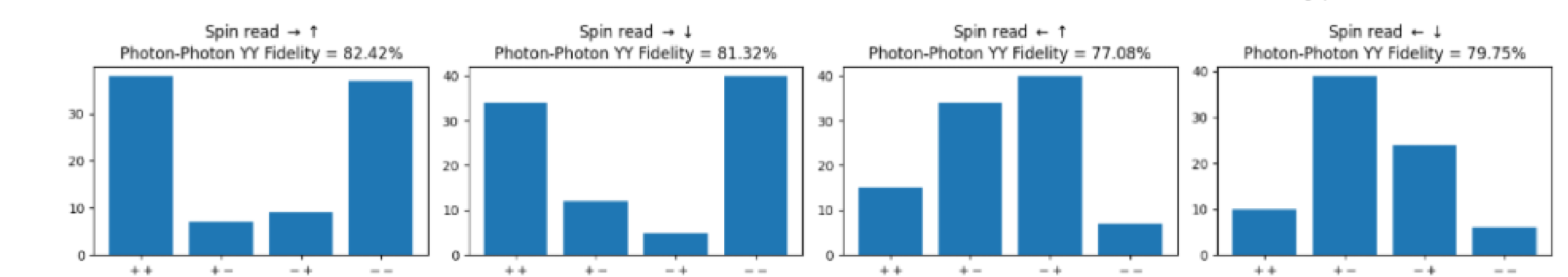
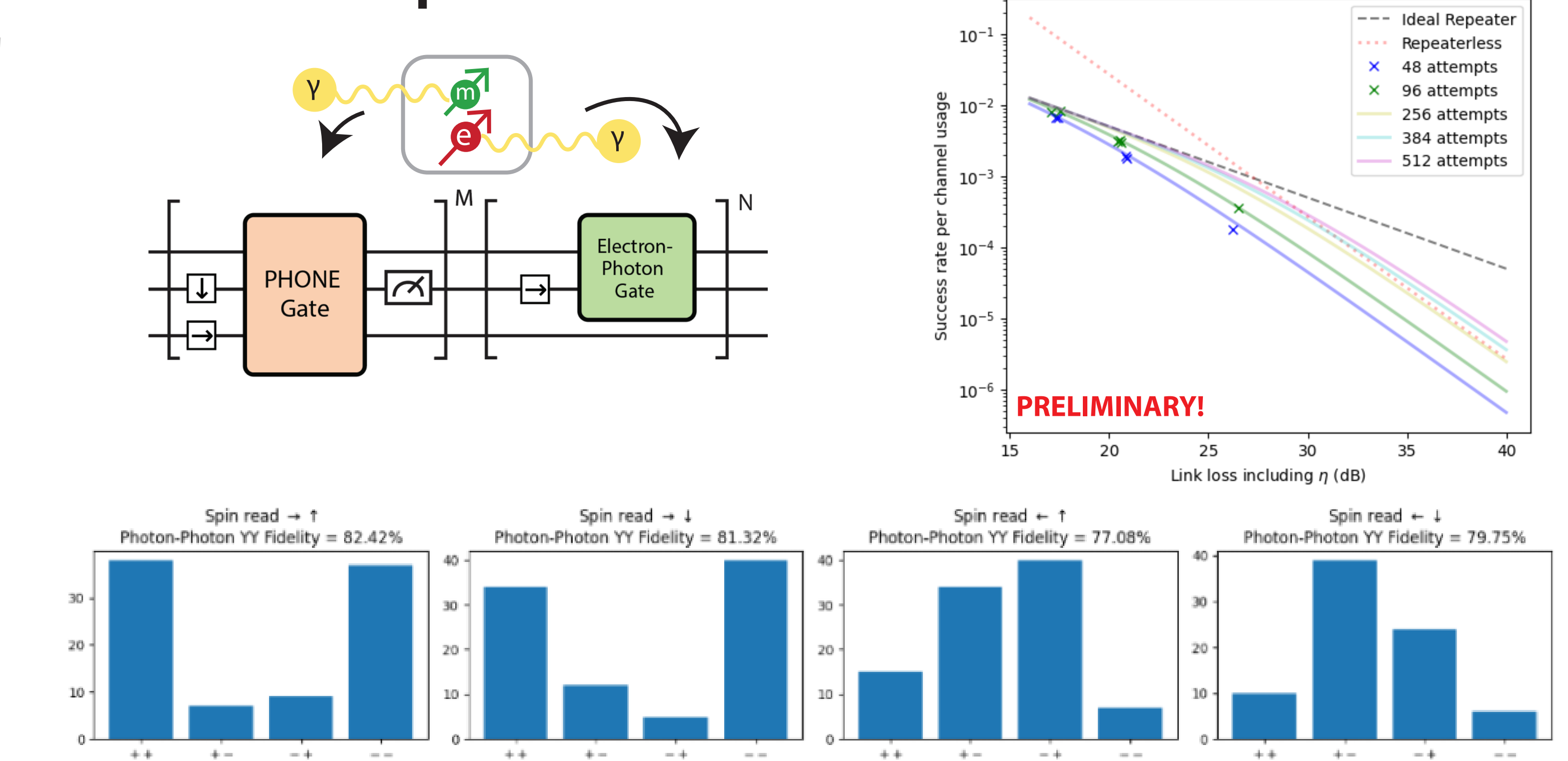


PHONE (Photon-Nucleus Entangling) Gate

Electron as flag qubit for error-detection



Electron-¹³C Repeater Protocol



Outlook

3 - Node Network with SiVs

Quantum repeater scheme can help create interesting 3-node states and procedures (purification, teleportation, etc)

Efficient Blind Quantum Computing

Gates can become deterministic with the addition of a robust memory

- Stas et al, arXiv:2509.09464 (2025).
- Wei et al, Science 388, 509-513 (2025).
- Knaut et al, Nature 629, 573-578 (2024).
- Stas et al, Science 378, 557 (2022).

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