Mid-circuit measurement on $^{171}Yb^{+}$ using the *omg* architecture

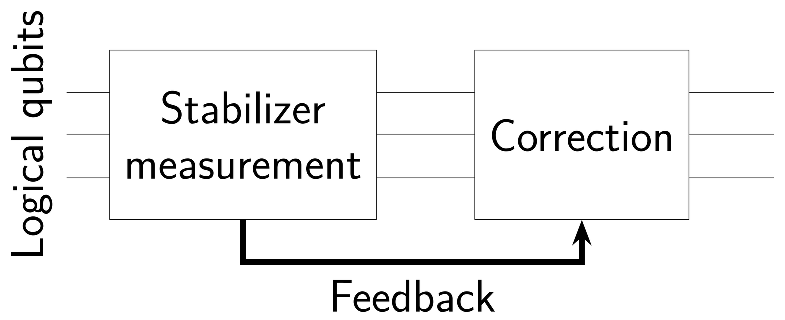
Yichao Yu[1], Keqin Yan[1], Debopriyo Biswas[1], Vivian Zhang[1], Bahaa Harraz[1], Marko Cetina[1], Crystal Noel[1], Alexander Kozhanov[1], Christopher R Monroe[1]

[1]Duke Quantum Center, Duke University

Mid-circuit measurement and the *omg* architecture

Mid-circuit measurement

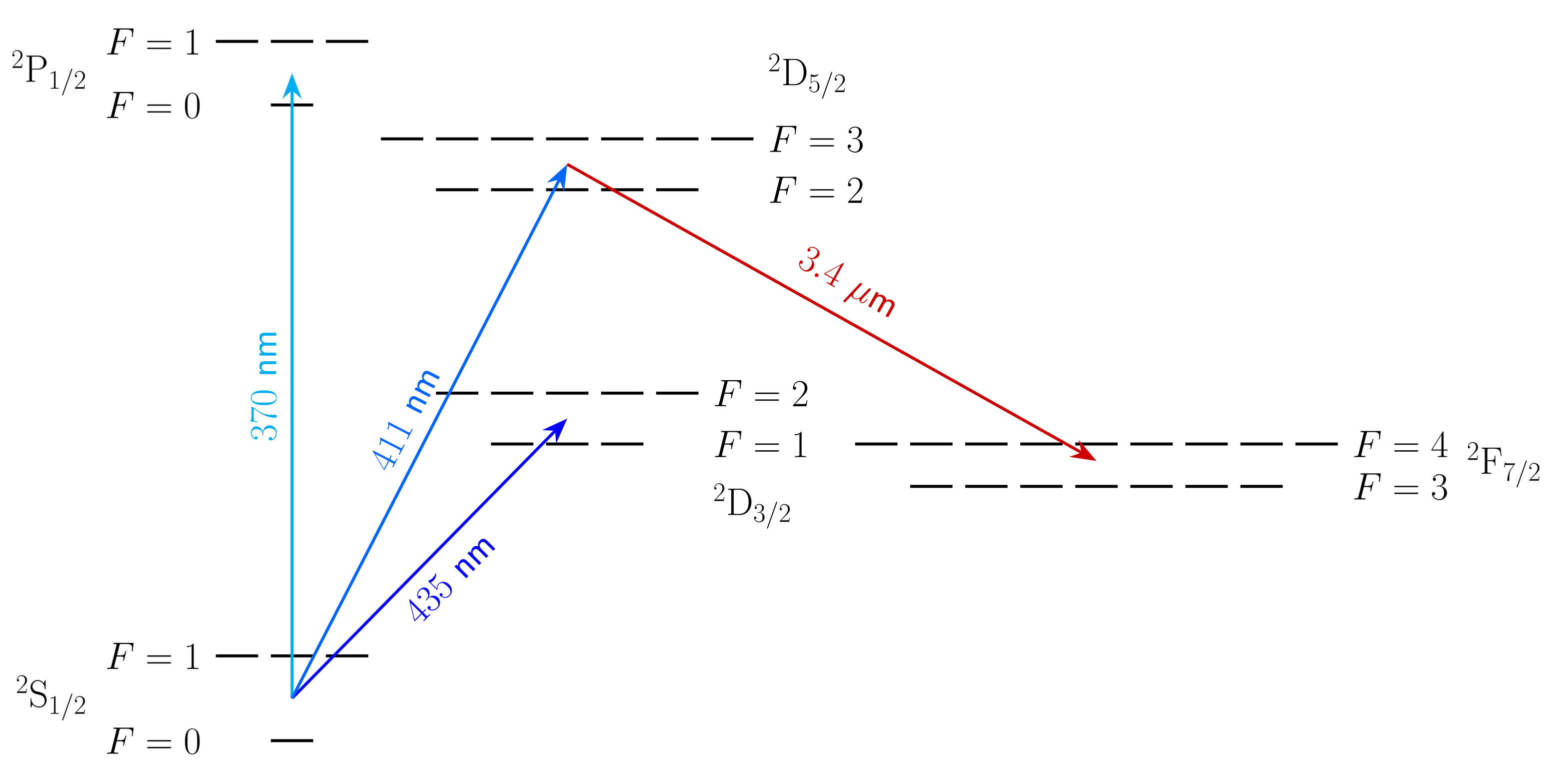
- Required for multiple rounds of error correction
- Partial readout without perturbing the rest of the system



omg architecture

- Combining ***O**ptical* ***M**etastable* and ***G**round* state qubits
- Protecting quantum information by converting between qubit types
- Faster than ion-shuttling

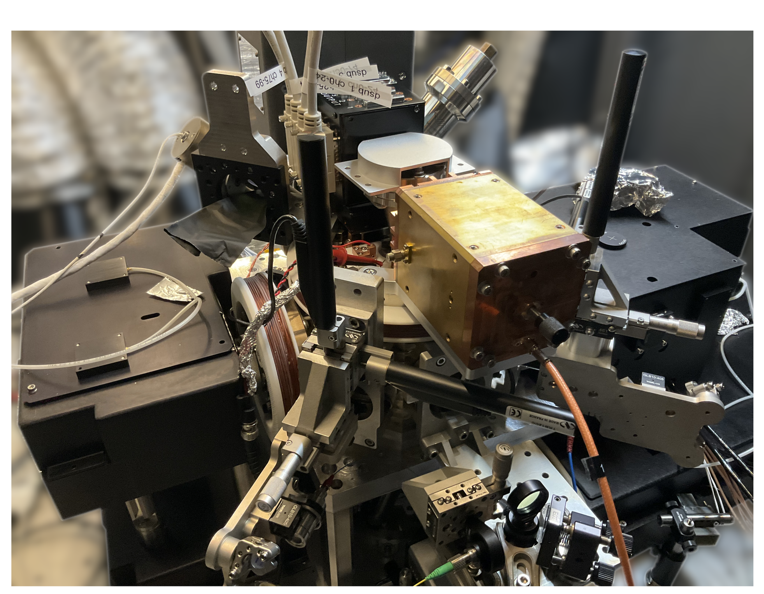
- Yb^{+}: $D_{3/2}$ (50 ms), $D_{5/2}$ (7 ms), $F_{7/2}$ (> 1 yr)
- Ba^{+}: $D_{3/2}$ (20 s), $D_{5/2}$ (30 s)
- ...



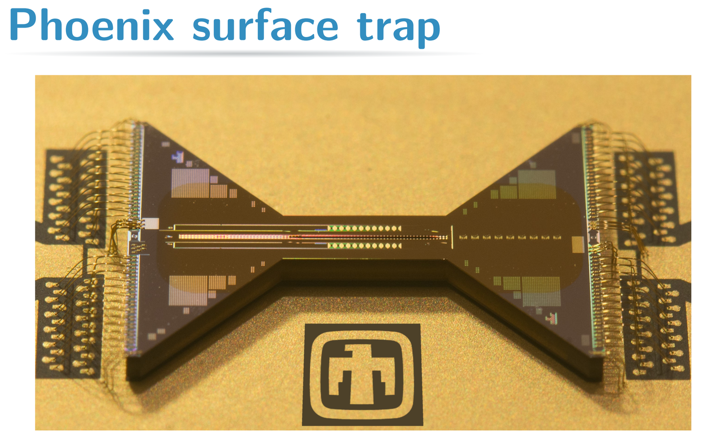
System

Optical control

- Global state preparation and detection with 370 nm
- Individually addressible Raman with 355 nm
- Global 435 nm for exciting to $D_{3/2}$ states
- (Planned) Global 411 nm and $3.4\ \mu m$ for accessing $D_{5/2}$ and $F_{7/2}$ states



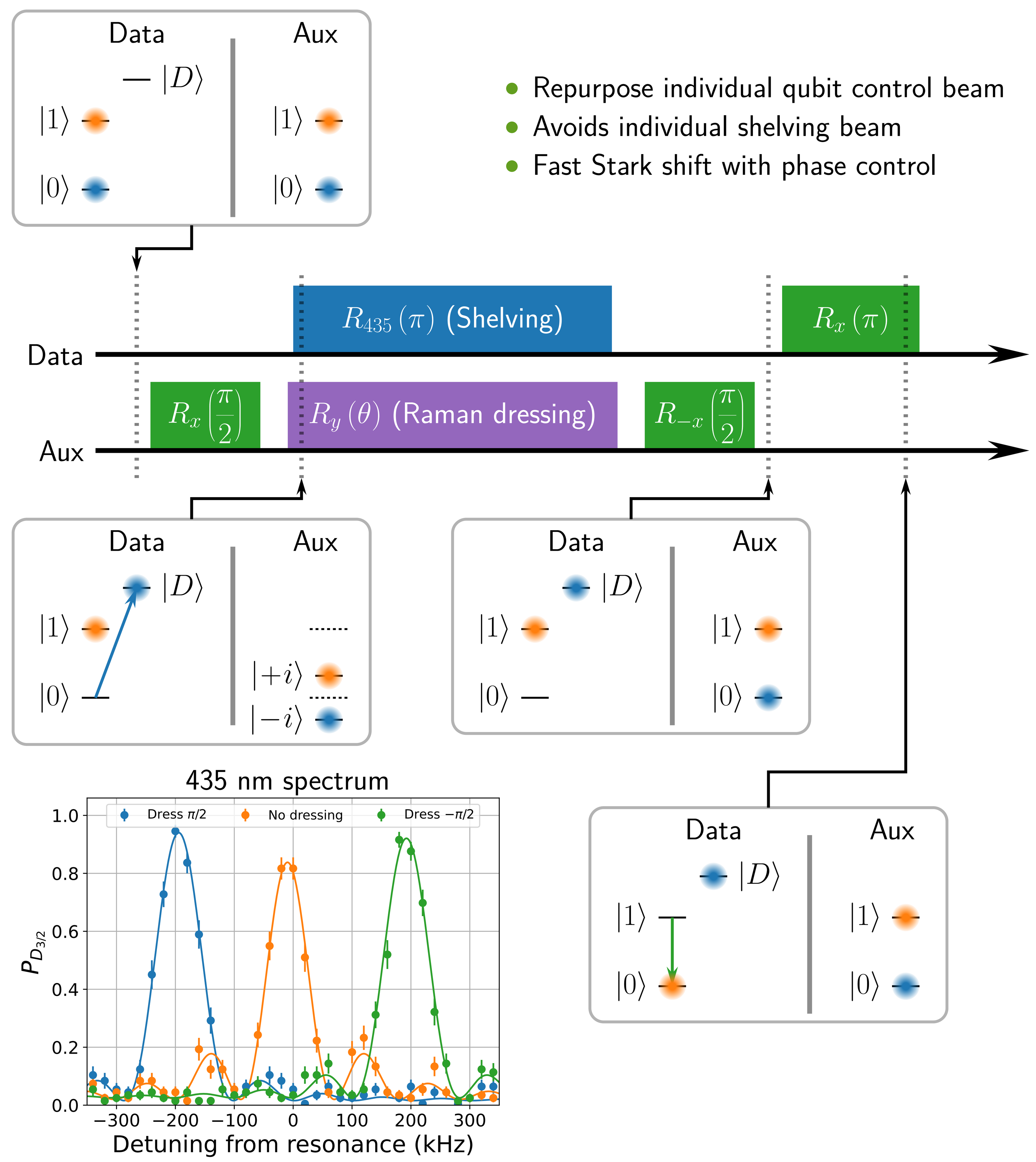
Phoenix surface trap



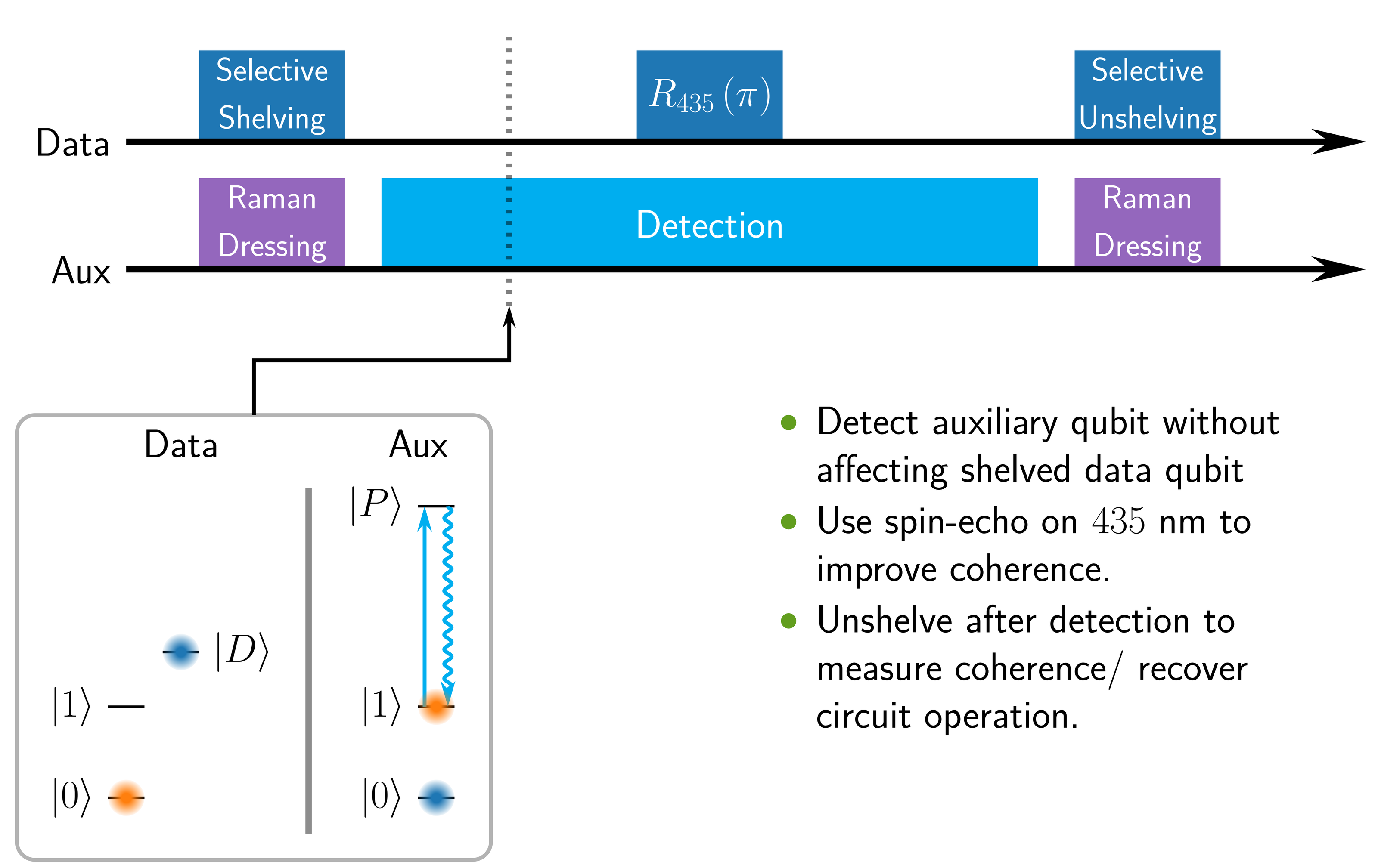
- Separate loading and quantum region
- Fine control of ion position
- Low heating rate

Selective shelving with Raman dressing

- Repurpose individual qubit control beam
- Avoids individual shelving beam
- Fast Stark shift with phase control



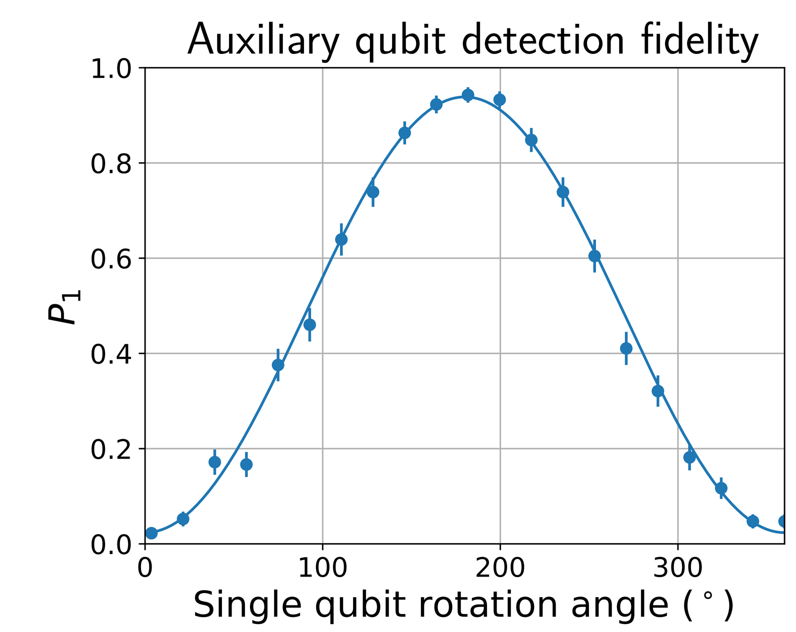
Mid circuit measurement with selective shelving



- Detect auxiliary qubit without affecting shelved data qubit
- Use spin-echo on 435 nm to improve coherence.
- Unshelve after detection to measure coherence/ recover circuit operation.

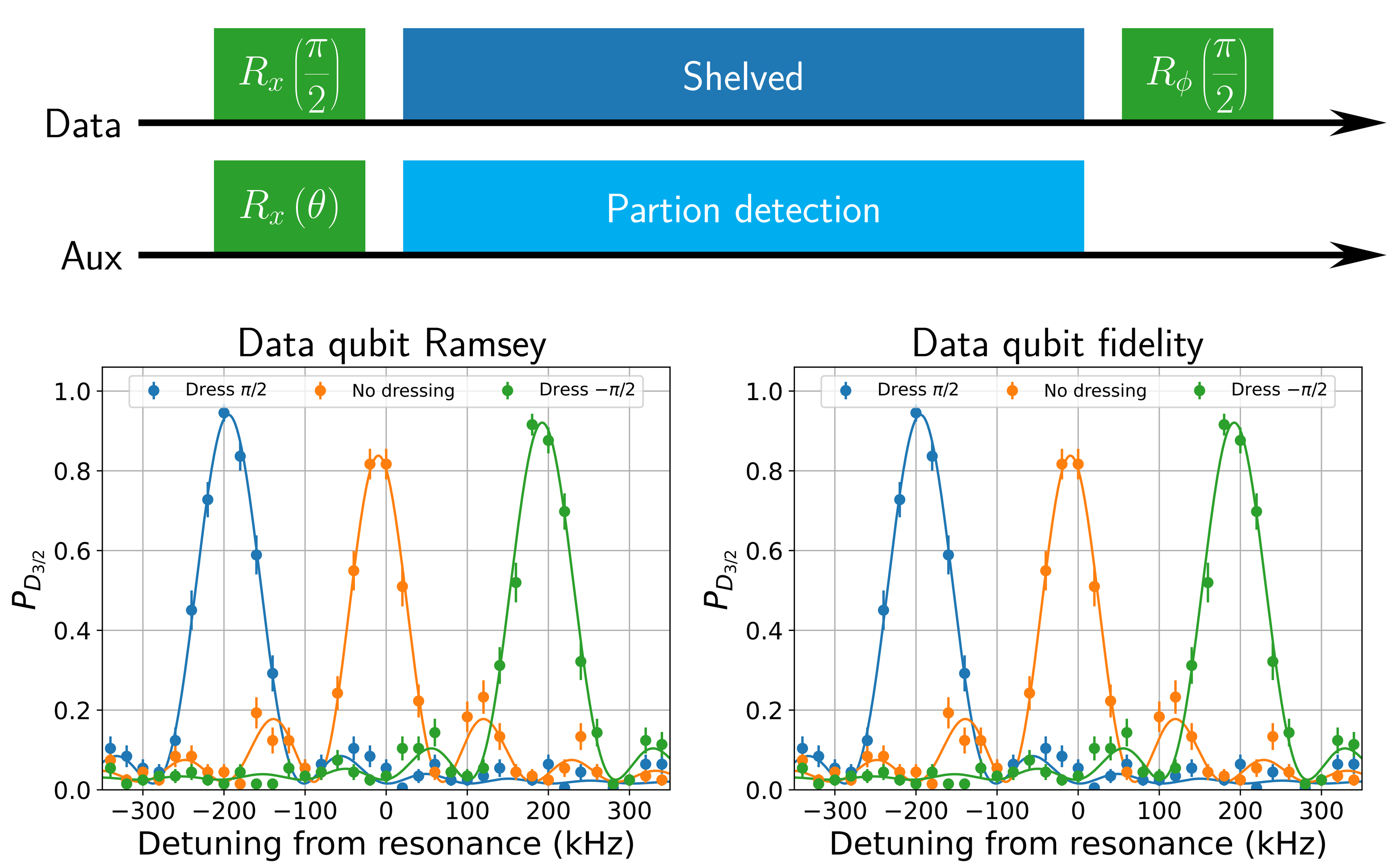
Preliminary results

Mid circuit measurement



- Detection time $130\ \mu m$
- Detection fidelity 92 %
- Limited by background and normal SPAM fidelity

Data qubit coherence



- Data qubit coherence 100%
- Limited by single qubit control
- Optical qubit coherence time
- Effect of re-scattering

Future works

- Improve dressing and shelving fidelity
- Shelve to longer lived $F_{7/2}$ state for better protection (Nature Physics vol. 18, 1058-1061 (2022))