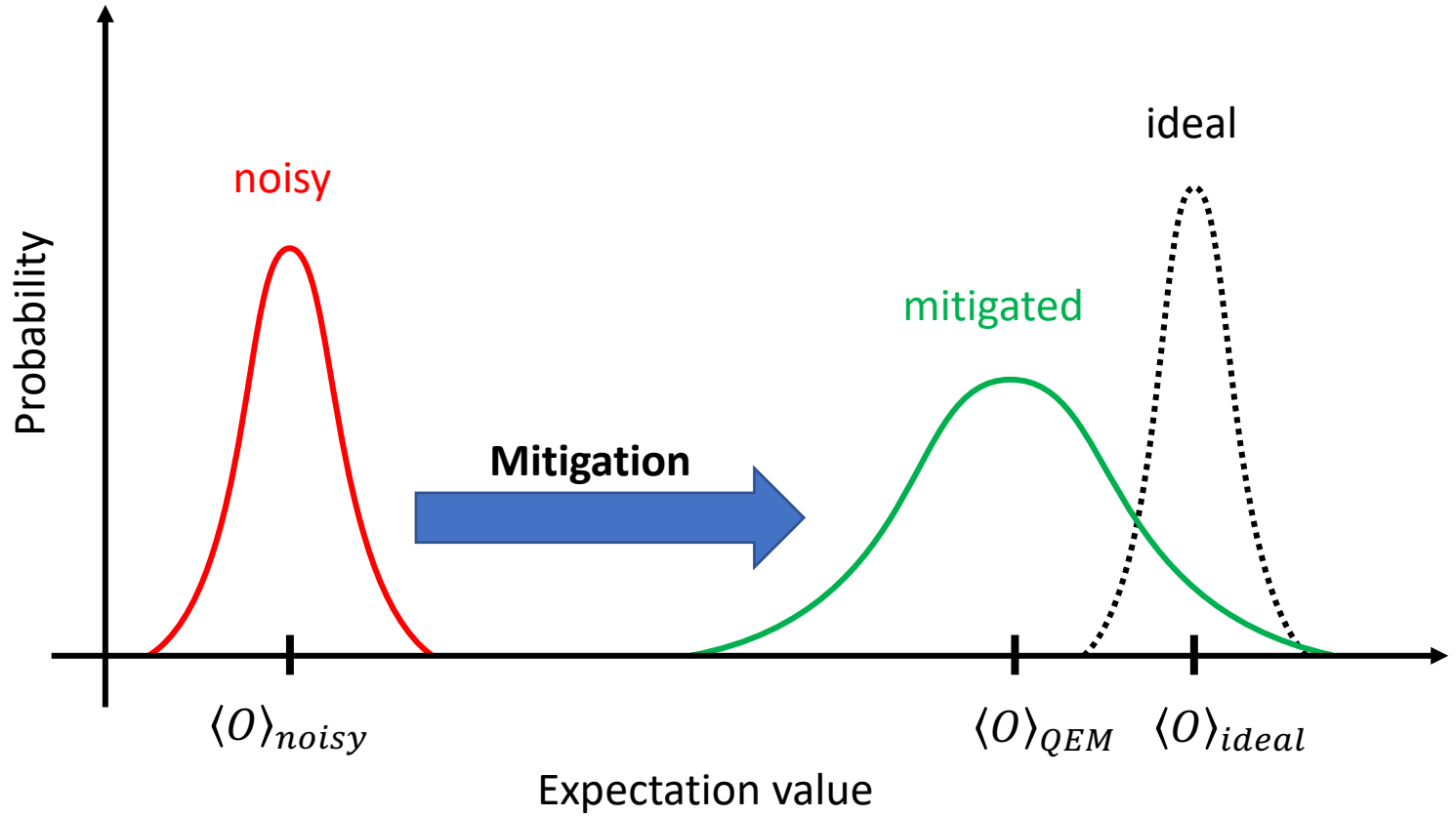
Issue #33: Implementation of GSE

Idea of Quantum Error Mitigation

→ Recover clean expectation value via **classical postprocessing**.



Purification-based method

Subspace Expansion
[McClean et al.,
Nature Communication, 2020]

Exponential Error Suppression
[Koczor, PRX, 2021] /
Virtual Distillation
[Huggins et al, PRX, 2021]

Zero-noise Extrapolation
[Temme et al., PRL, 2017]

QEM for coherent error

QEM for stochastic error

Generalized Subspace Expansion
[Yoshioka et al., PRL, 2022]

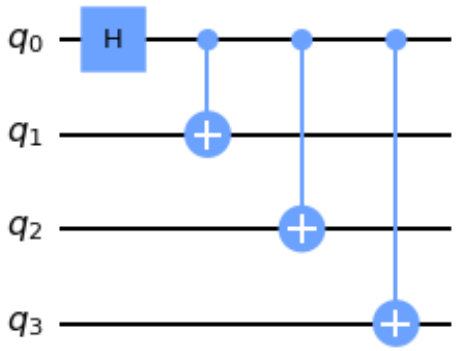
- Generalization of error-agnostic QEM methods → wide applications
- QEM for both coherent/algorithmic error and stochastic error

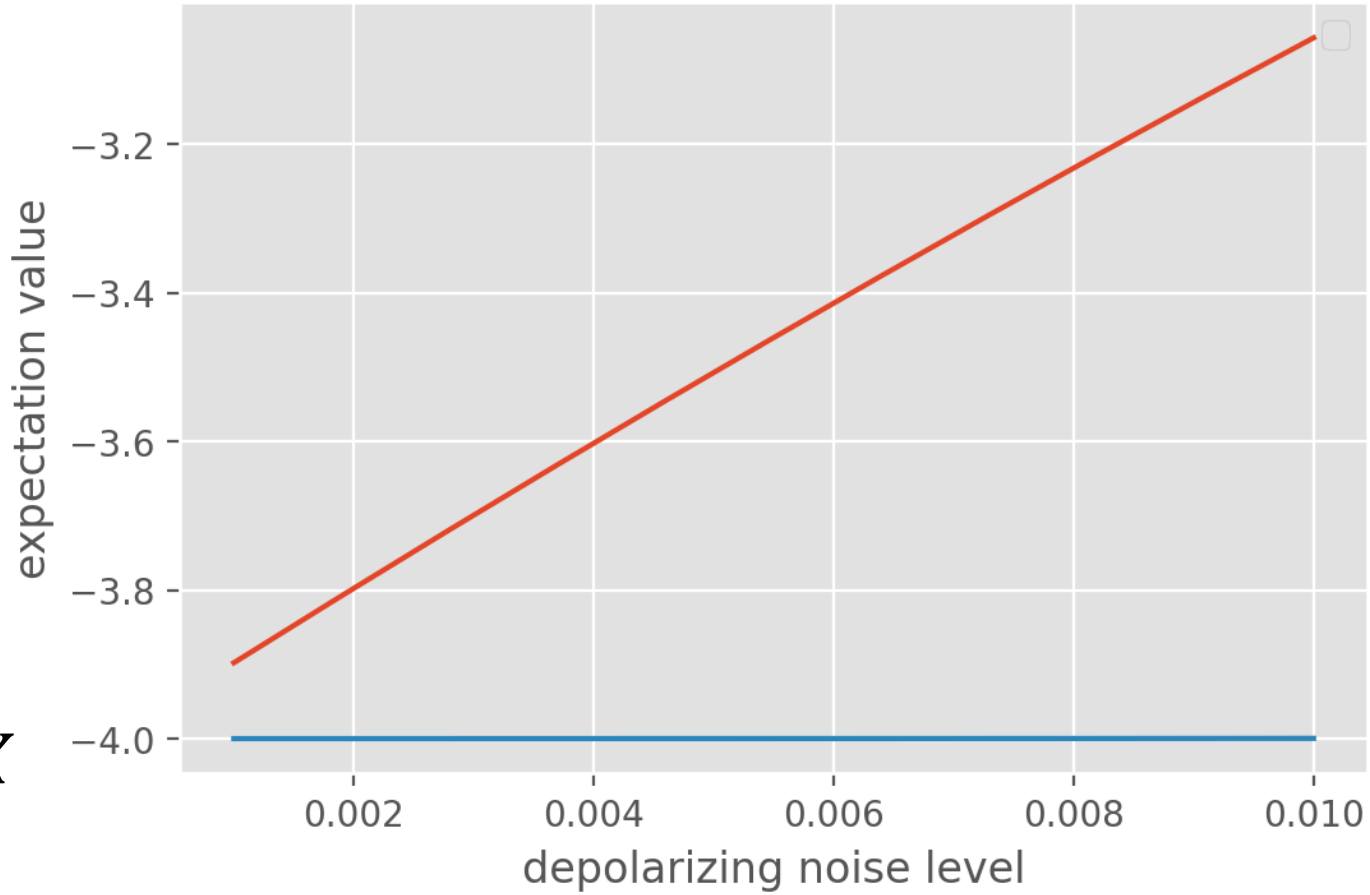
One of the strong tools for near-term quantum computation!!

Demonstration on Simulator

- red line: without any QEM
- blue line: with GSE

4-qubit GHZ





The ground state of

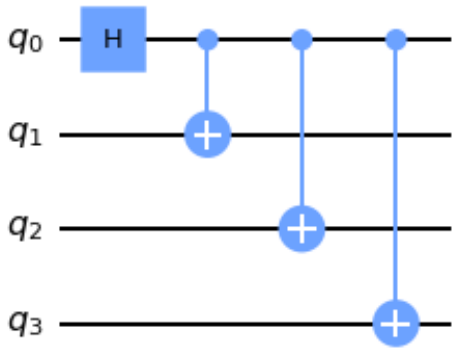
$$H = -ZZII - IZZI - IIZZ - XXXX$$

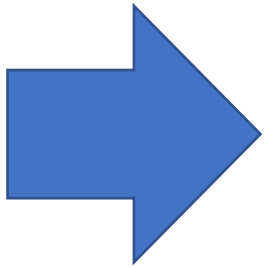
Ideal expectation value is

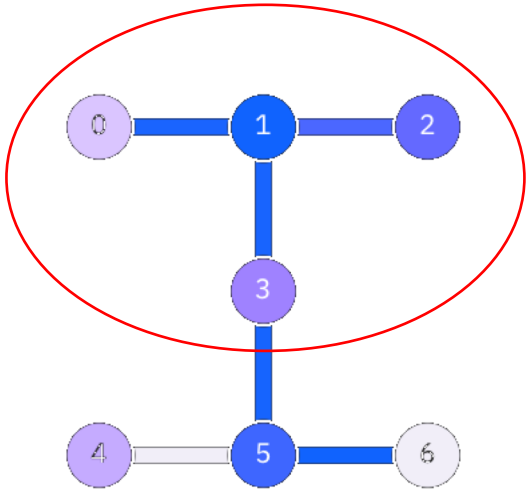
$$\langle GHZ|H|GHZ\rangle = -4.0$$

Demonstration on ibmq_jakarta

4-qubit GHZ







raw expval: -3.3853

mitigated expval: -3.2288

The ground state of

$$H = -ZZII - IZZI - IIZZ - XXXX$$

Ideal expectation value is

$$\langle GHZ|H|GHZ\rangle = -4.0$$

(System size might be too small
→ noise effect wins the mitigation effect)

Plan for Checkpoints 2 and 3

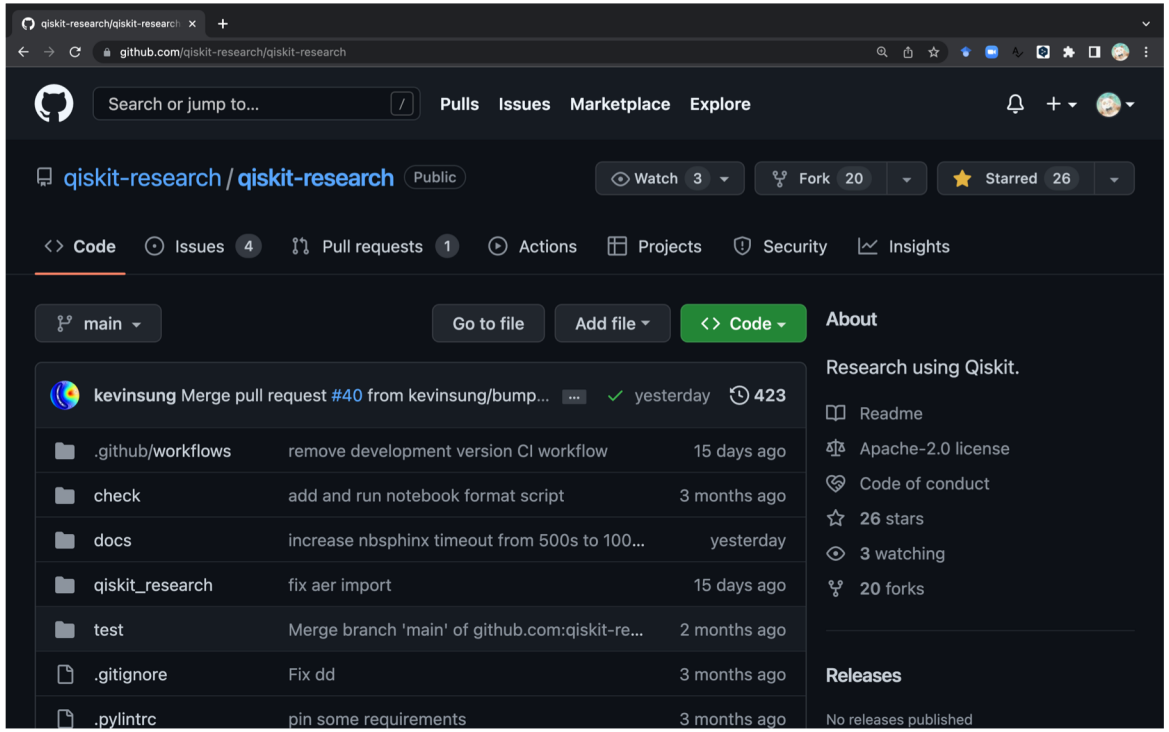
In October:

Apply GSE to the noisy result of VQE solver

- for the Ising model and other systems
- on IBM Quantum devices.

Generalize and refactor the implementation of GSE and its internal gadgets.

Deeply connected with the issue #3: implementation of virtual distillation

In November:

Add the demonstration and documentation of GSE to qiskit-research