Quantum Gate Synthesis
- SQUANDER -

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Project recap

- SQUANDER package
  - An optimization based quantum compiler
- Variation Quantum Eigensolver (VQE) algorithm
  - hybrid quantum classical algorithm [1]
  - approximate the E_{ground} of a system [2]
  - parametrized quantum circuit
  - iterative minimization based on classical method

Project recap

Optimization methods

- SQUANDER built-in optimizers (**gradient-based**)
  - ADAM - *Adaptive Moment Estimation*
  - BFGS - *Broyden–Fletcher–Goldfarb–Shanno*
  - Cosine strategy
  - Gradient descend
  - Gradient descend with parameter shift rule
- Other optimizers (**gradient-free**) from **SciPy** package
  - Nelder - Mead
  - Powell
  - Cobyla

Written codes

A forked version of SQUANDER on github.com/menkobalazs/SMC-Lab-SQUANDER

- `Heisenberg_VQE.py` (modified):
  - Added argument parser for flexible execution.
  - Modified the `config` variable.
  - Implemented result-saving and logging.
  - Introduced SciPy's `minimize` with *Nelder-Mead*, *Powell*, and *Cobyla*.
  - Added random parameter initialization.
- `explore_simulations.py`: Generates figures from results.
- `run_simulations.sh`: Runs simulations in a `screen` session.

Results with $N_{qubit} = 10$

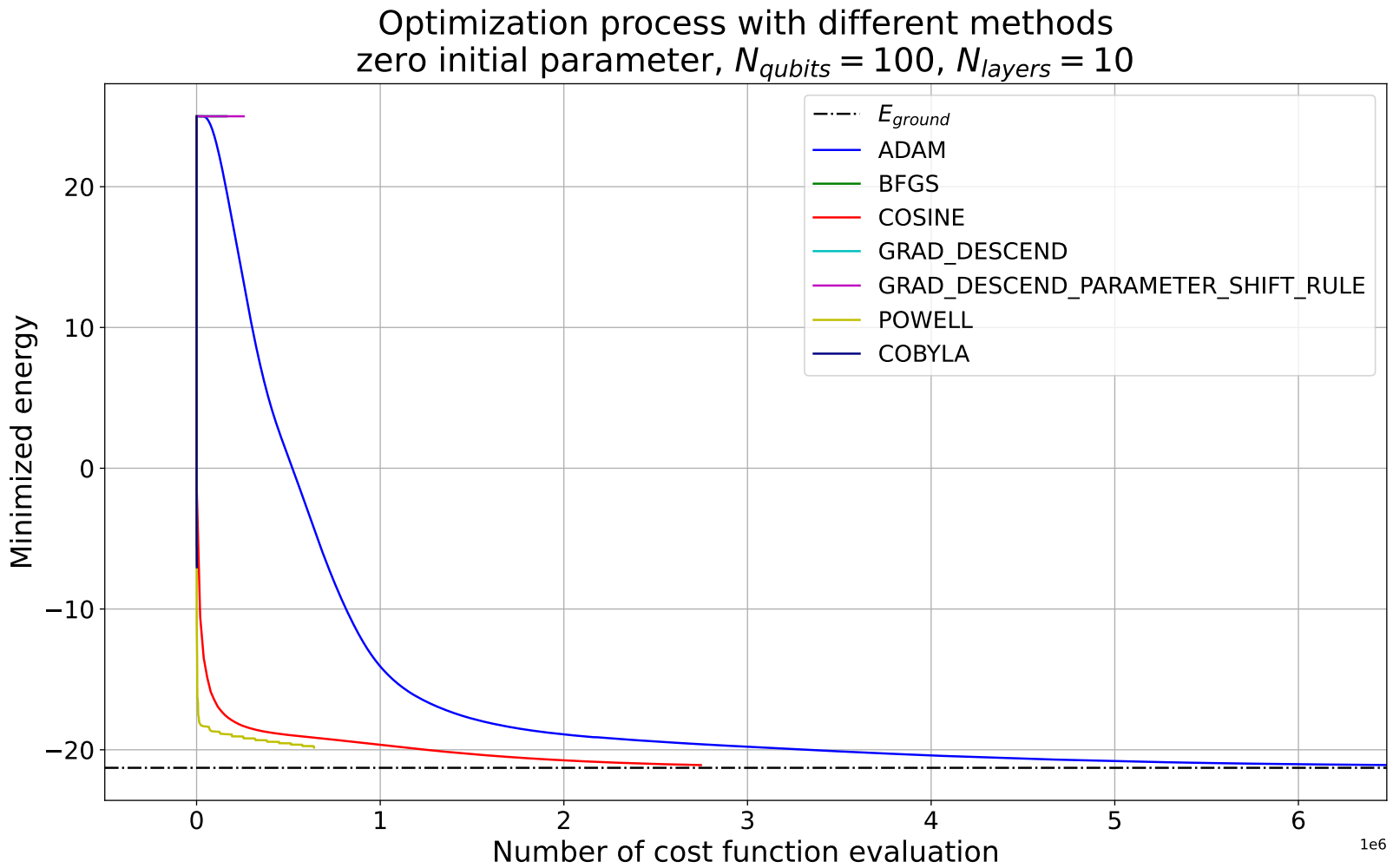

Figure 1: Minimization of cost function with zero initial parameters.

Results with $N_{qubit} = 10$

Zoomed figure.

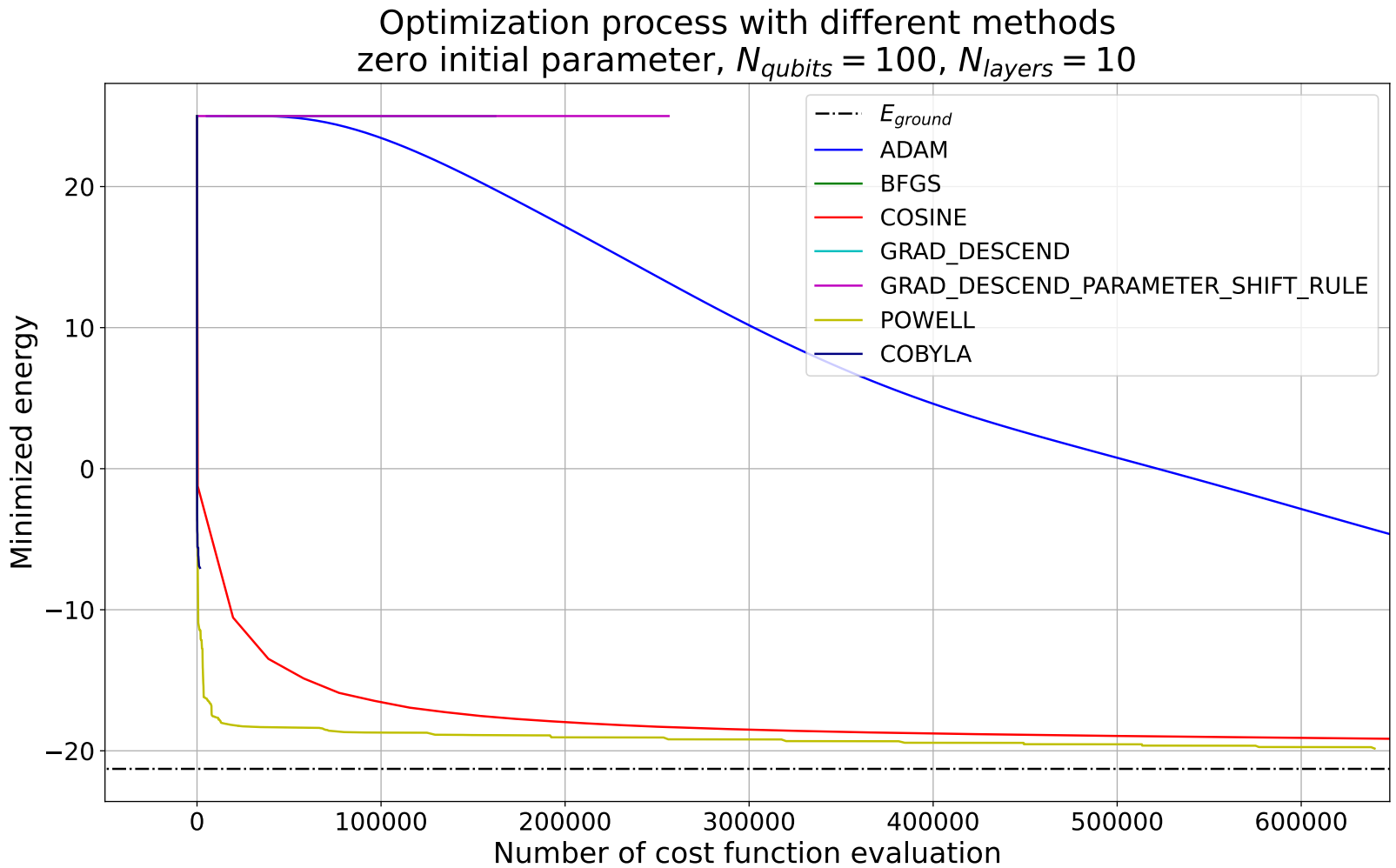

Figure 2: Minimization of cost function with zero initial parameters.

Results with $N_{qubit} = 10$

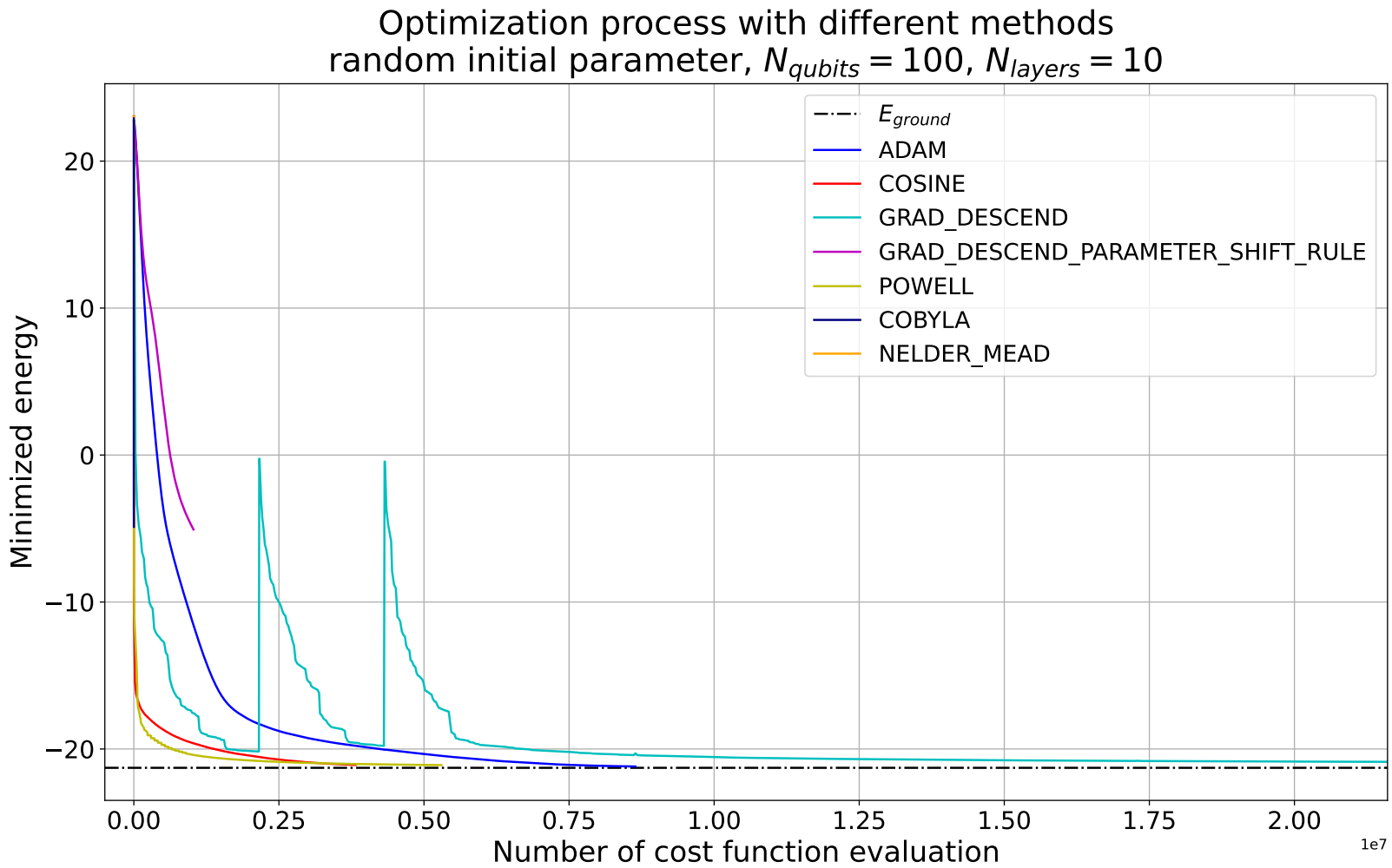

Figure 3: Minimization of cost function with random initial parameters.

Results with $N_{qubit} = 10$

Zoomed figure.

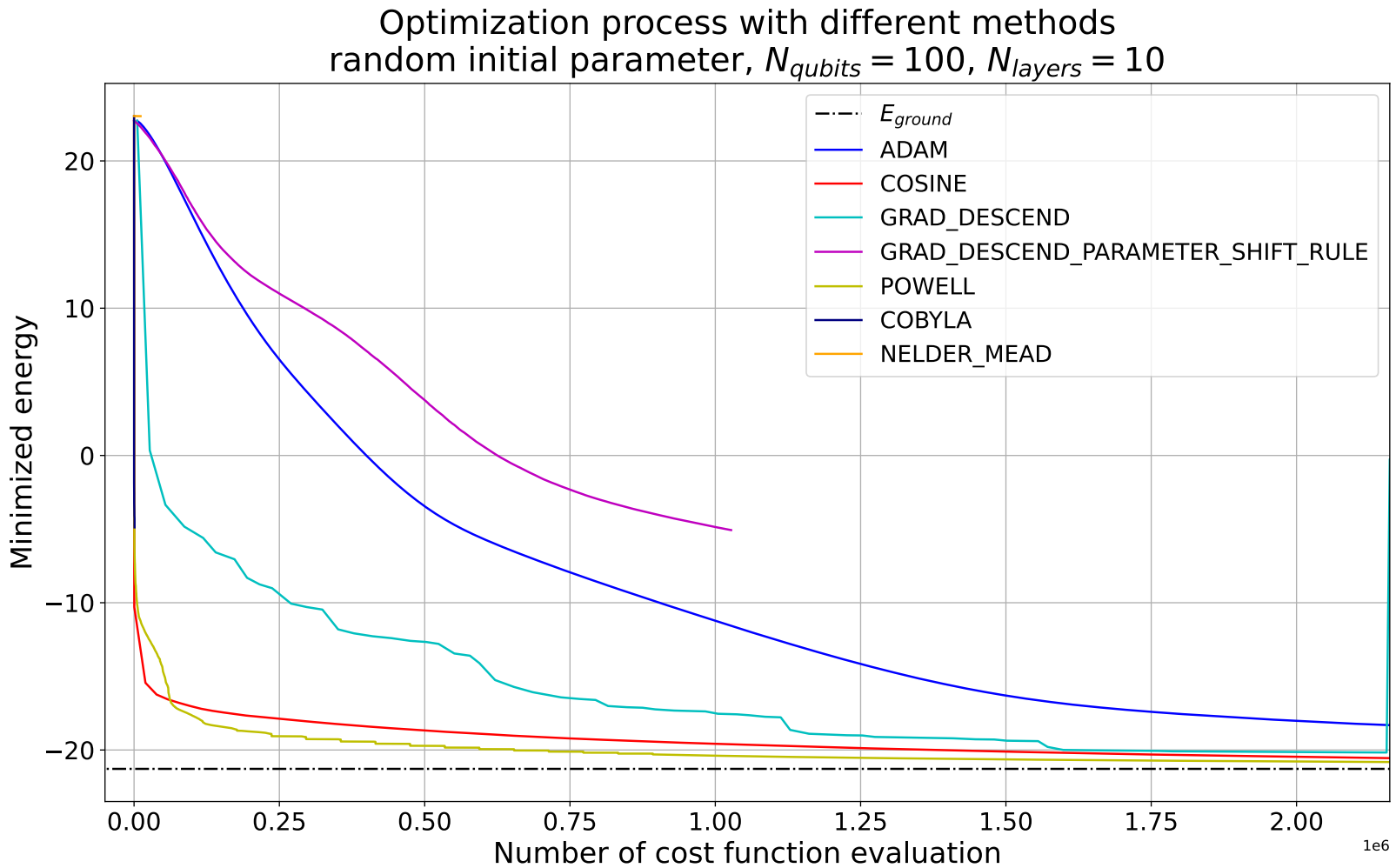

Figure 4: Minimization of cost function with random initial parameters.

Results with $N_{qubit} = 14$

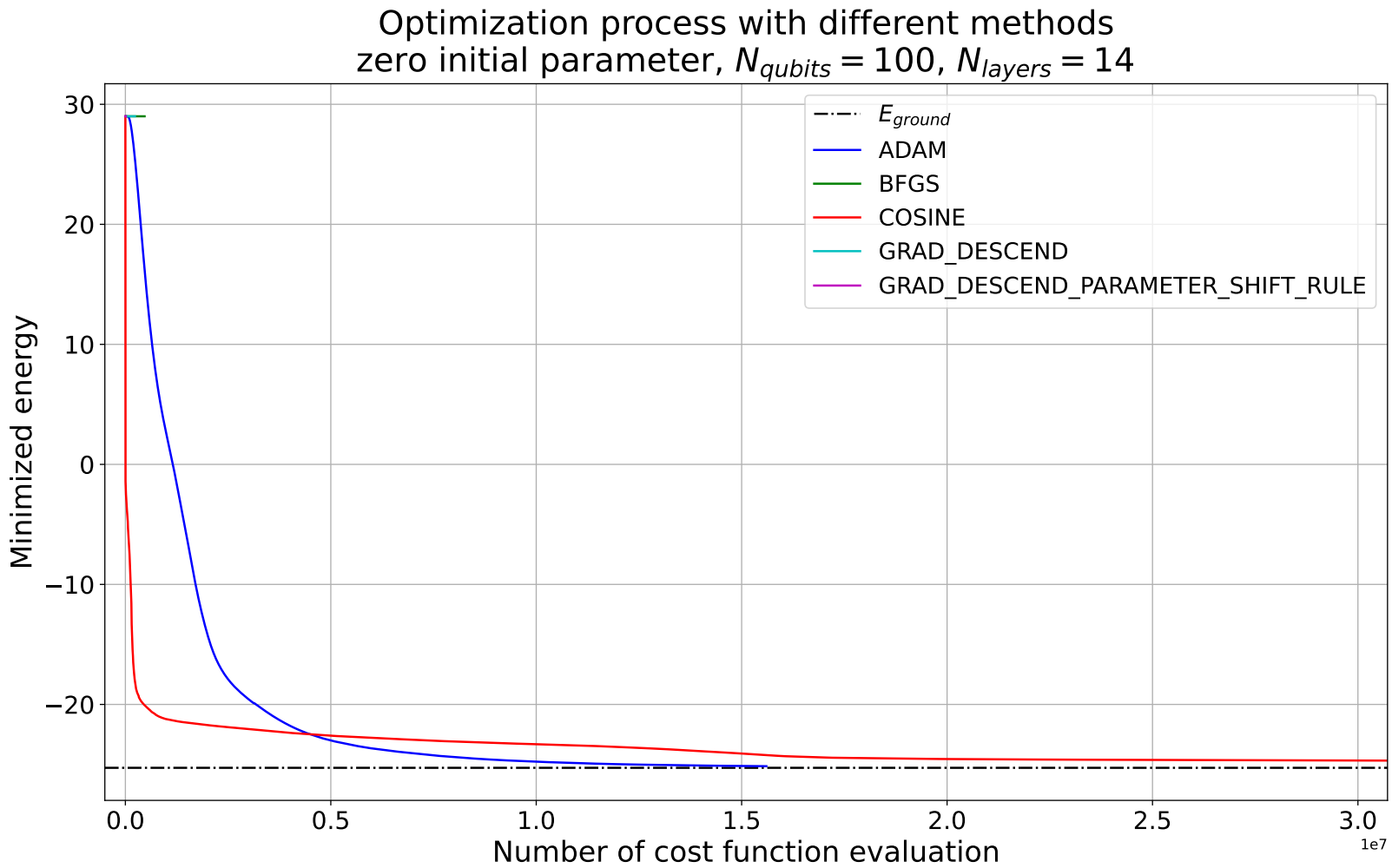

Figure 5: Minimization of cost function with zero initial parameters.

Results with $N_{qubit} = 14$

Zoomed figure.

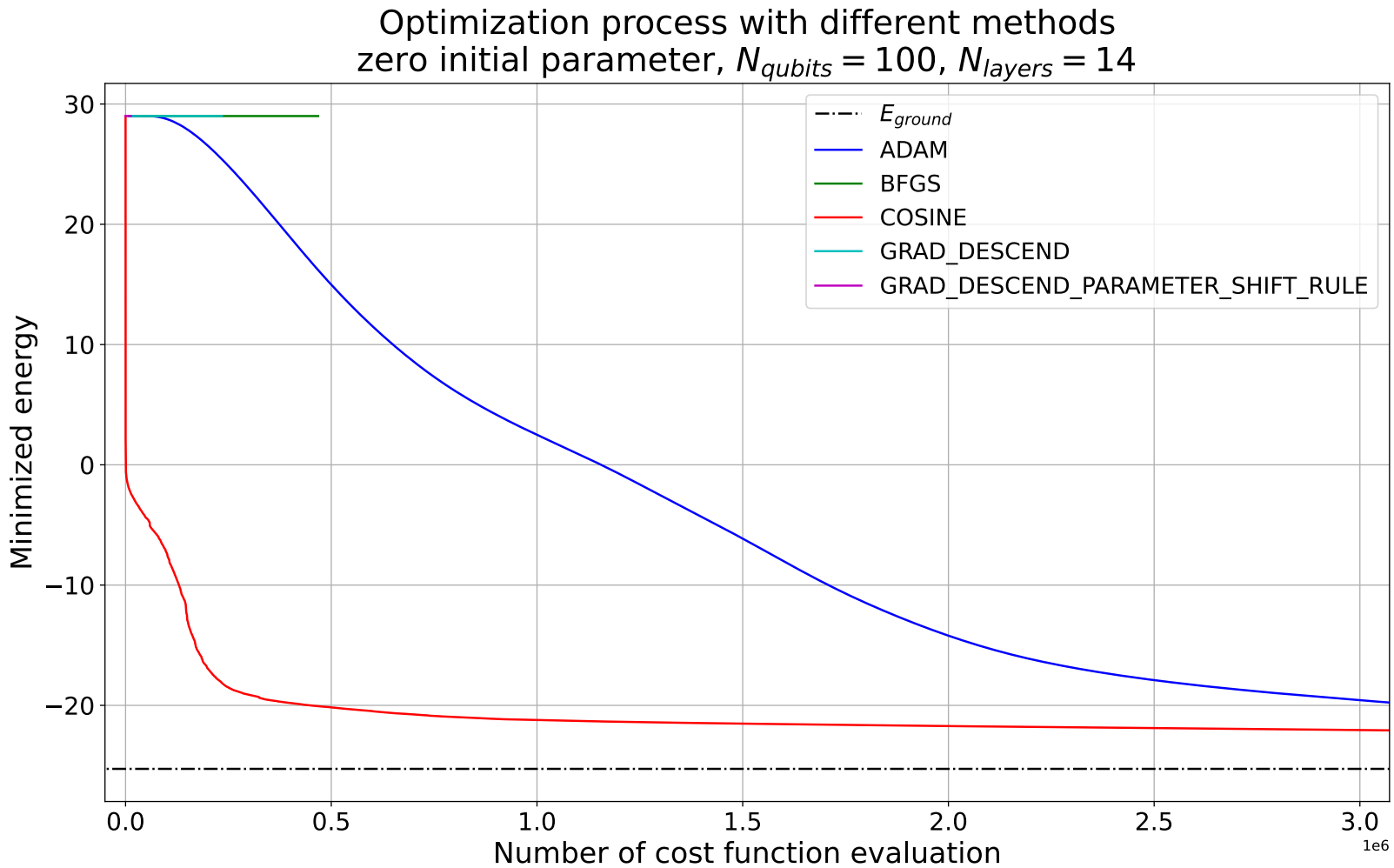

Figure 6: Minimization of cost function with zero initial parameters.

Results with $N_{qubit} = 14$

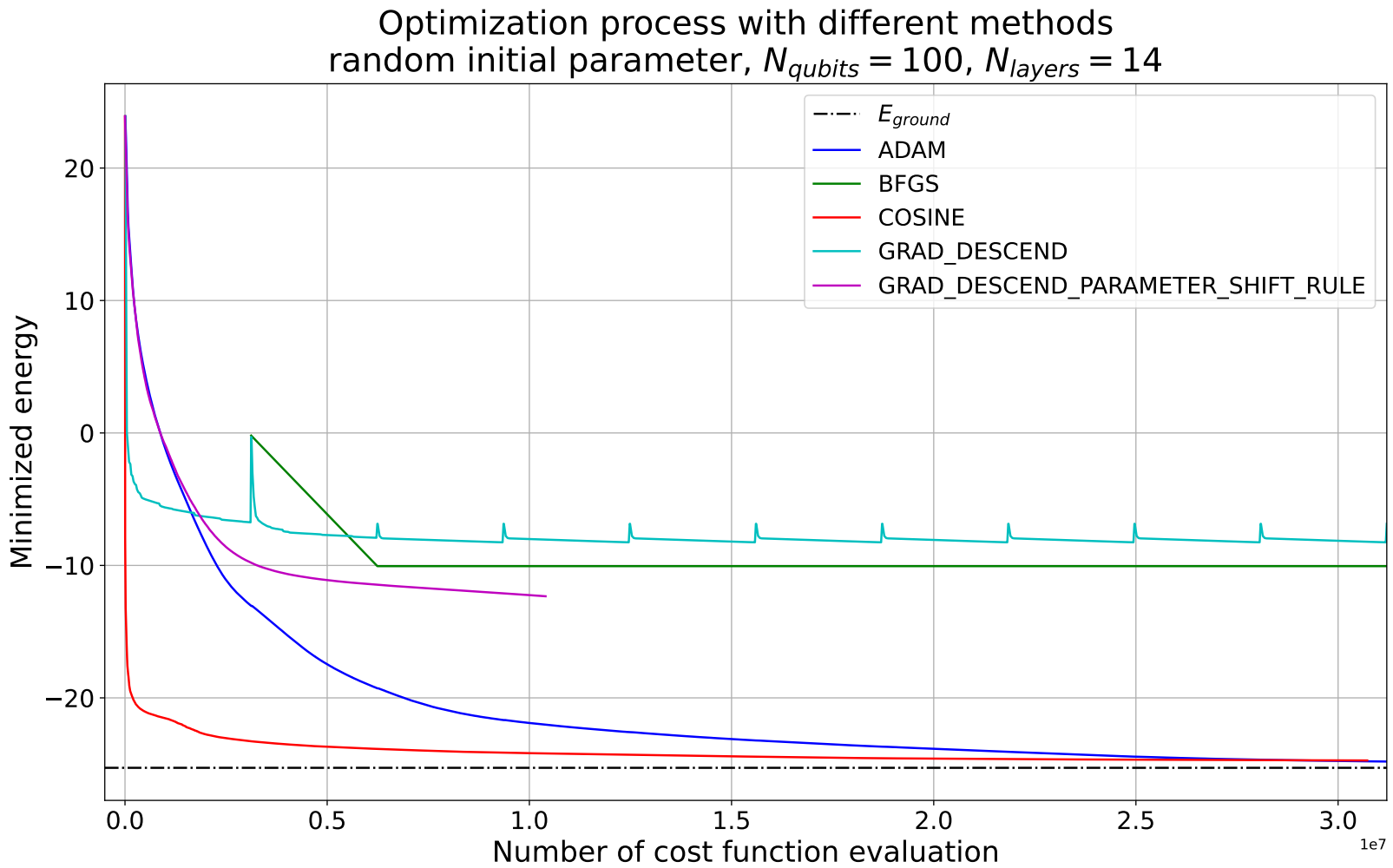

Figure 7: Minimization of cost function with random initial parameters.

Results with $N_{qubit} = 14$

Zoomed figure.

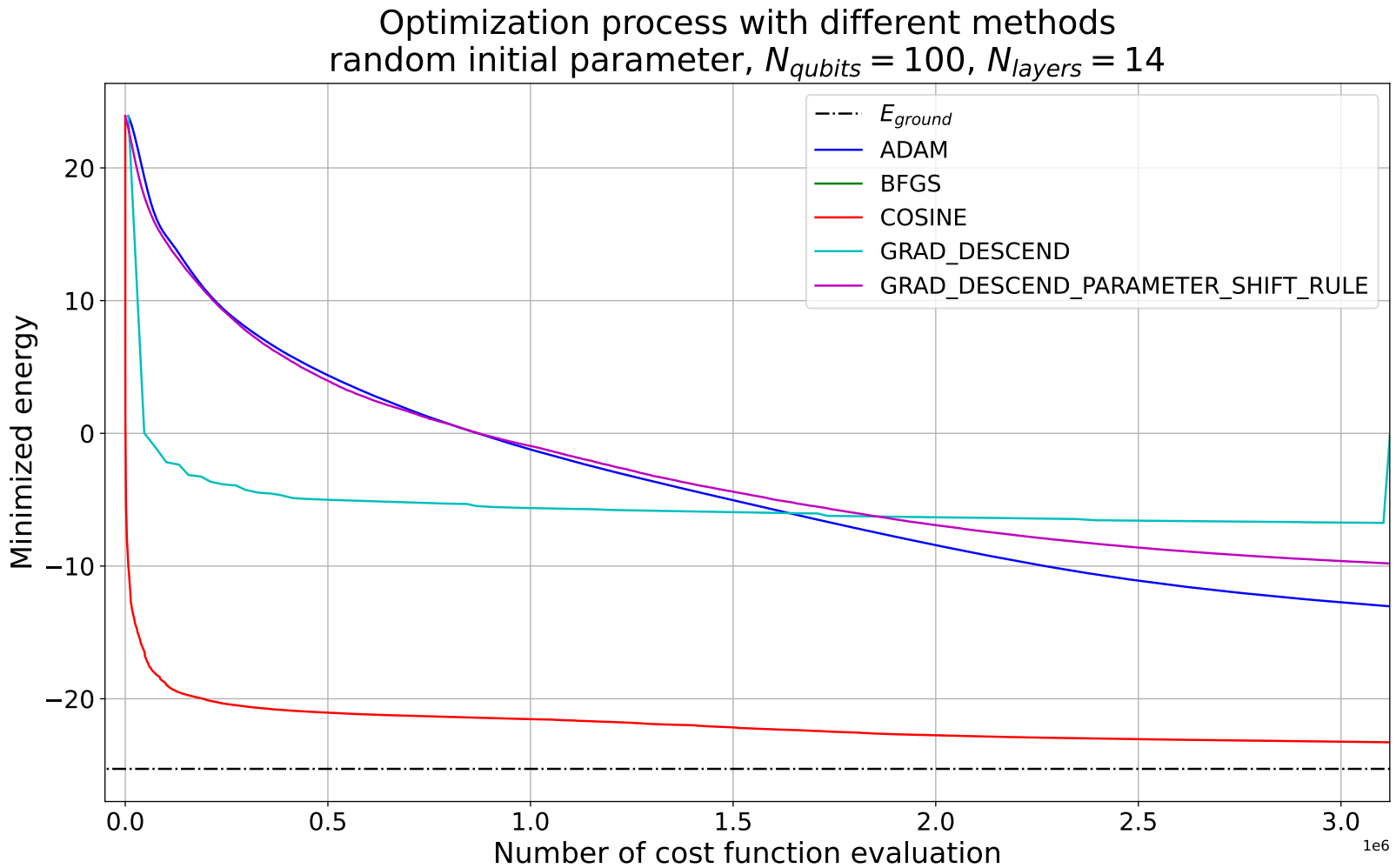

Figure 8: Minimization of cost function with random initial parameters.

Comparison with the article [3]*

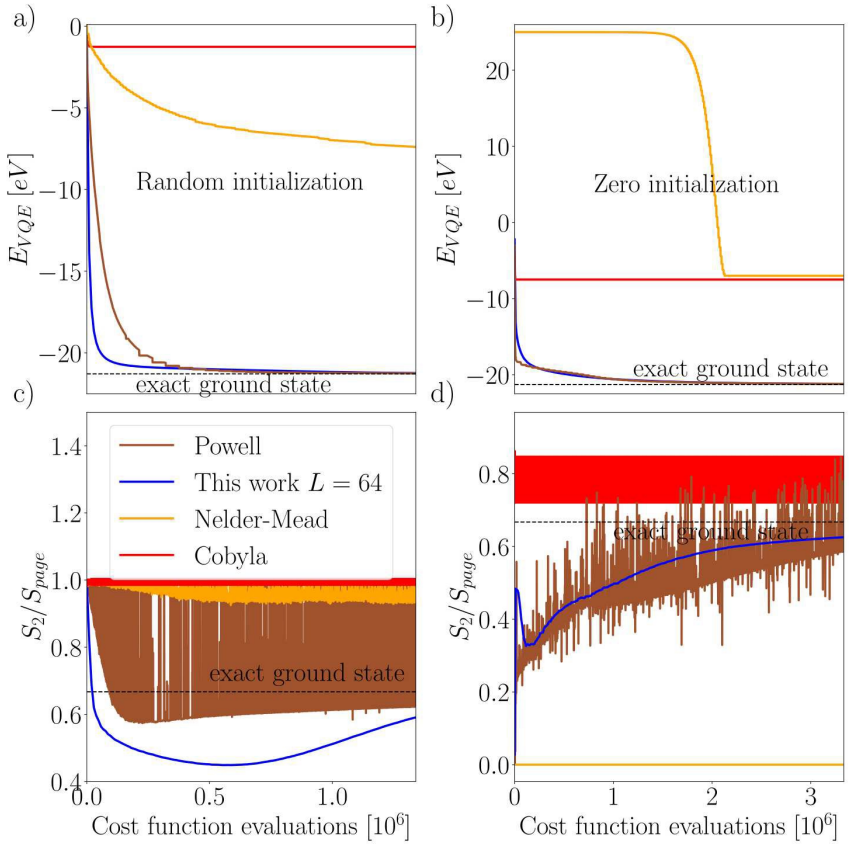

Figure 9: Fig. 8. from [3]

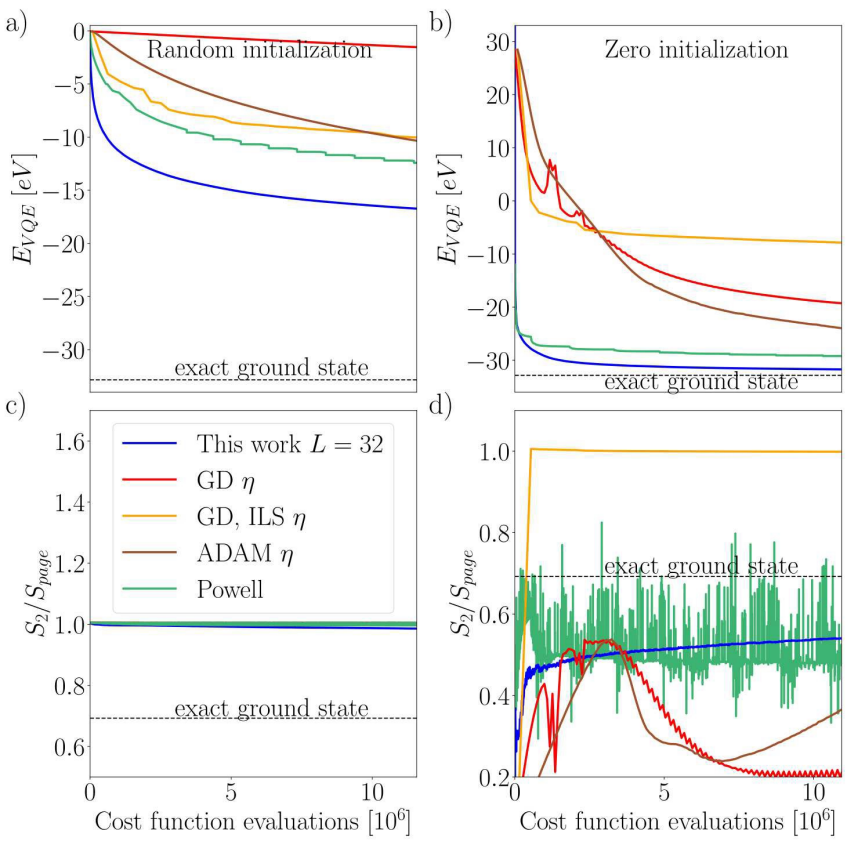

Figure 10: Fig. 9. from [3]

* *Line Search Strategy for Navigating through Barren Plateaus in Quantum Circuit Training*

My consent to the development

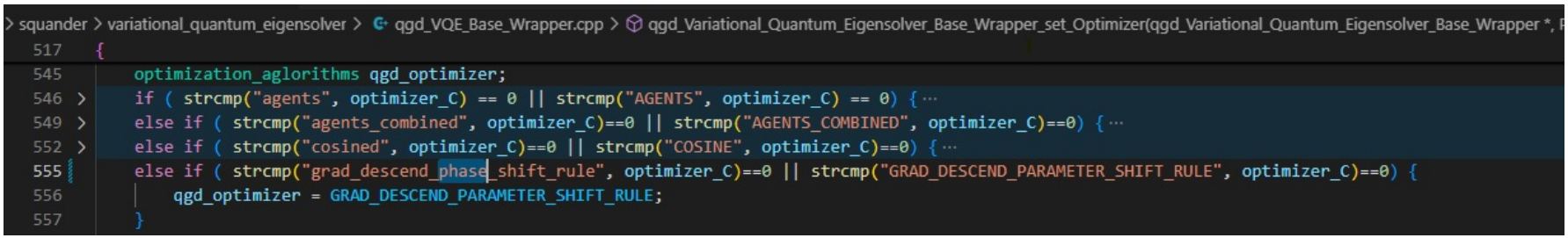

Figure 11: The issue in SQUANDER/qgd_VQE_Base_Wrapper.cpp file.

Further plans

- Search the reason of the peaks in *Gradient Descend* method.
- Create bar charts about the runtime of optimization process.

References

Jarrod R McClean, Jonathan Romero, Ryan Babbush, and Alán Aspuru-Guzik.
The theory of variational hybrid quantum-classical algorithms.
New Journal of Physics, 18(2):023023, 2016

Alberto Peruzzo, Jarrod McClean, Peter Shadbolt, Man-Hong Yung, Xiao-Qi Zhou, Peter J Love, Alán Aspuru-Guzik, and Jeremy L O'brien.
A variational eigenvalue solver on a photonic quantum processor.
Nature communications, 5(1):4213, 2014

Jakab Nádori, Gregory Morse, Zita Majnay-Takács, Zoltán Zimborás, and Péter Rakyta.
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