Avoiding barren plateaus via transferability of smooth solutions in Hamiltonian Variational Ansatz

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OUTLINE

- **Variational Quantum Algorithms and Barren Plateaus**
- **QAOA-inspired ansatz**
- **Pattern of optimal parameters**
- **Solution transferability**
- **Avoiding Barren Plateaus**

Variational Quantum Algorithms

- Leading **NISQ strategy**

- The problem is encoded in **minimising a cost function**

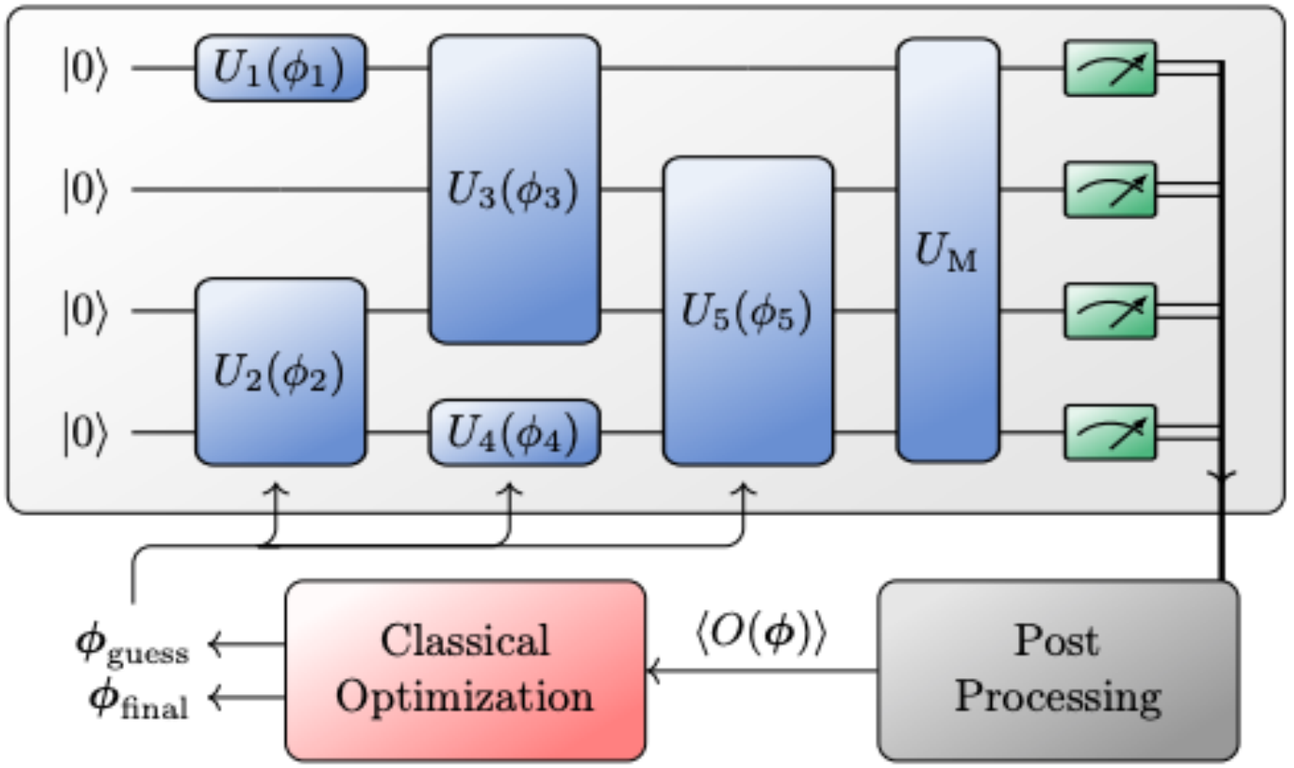
(e.g. finding Ground state of an Hamiltonian) — **(e.g. Hamiltonian expectation value)**

- The **main steps** are:

1. State preparation using a **parameterized circuit**
2. **Measurement** process
3. Classical **optimization**

MAIN DIFFICULTIES:

- **Noise**
- **Non-convex** optimization
- Flat landscape (a.k.a. **Barren Plateaus**)



VQAs scheme [Bittel et al., PRL (2021)]

Barren Plateaus

High circuit expressibility

→

Exponential vanishing gradients with number of qubits N

(Barren Plateaus definition)

[McClean et al., Nat. Comm. (2018)]
[Holmes et al., PRX Q. (2022)]

↓

Estimation accuracy at least exponential

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Exp. number of measurements needed

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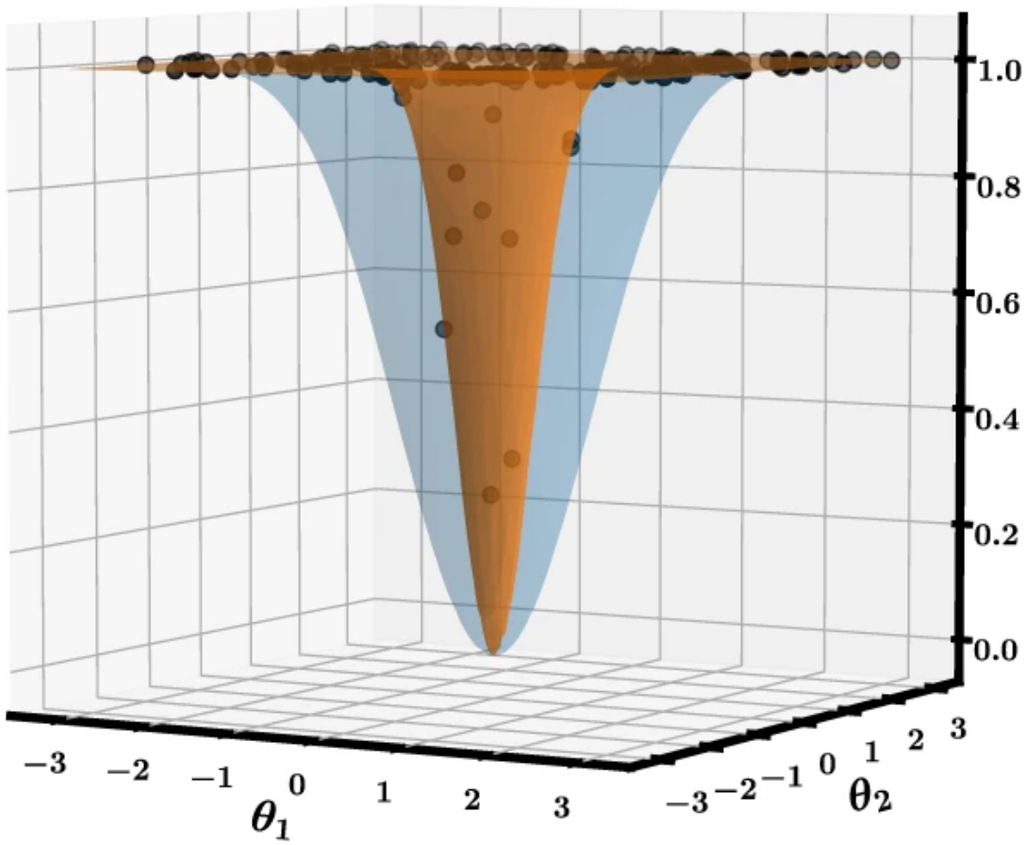
☠ **Serious problem for VQAs** ☠



Orange (blue) landscape N = 24
(N = 4) qubits. [Cerezo et al.,Nature(2021)]

Problem-inspired Ansatz

$$|\psi(\boldsymbol{\gamma})\rangle = \prod_{m=1}^{P} e^{-i\gamma_{m,M}H_M}\cdots e^{-i\gamma_{m,1}H_1}\,|\psi_0\rangle$$

The problem **Hamiltonian** is a **linear combination of these generators**

Easy-to-prepare state

These are **symmetry-preserving** ansatz, known as **Hamiltonian Variational Ansatz** (generalisation of QAOA)

We analyzed:

$$H_{\mathrm{XYZ}} = \sum_{j=1}^{N}\left(X_jX_{j+1} + \Delta_Y Y_jY_{j+1} + \Delta_Z Z_jZ_{j+1}\right)$$

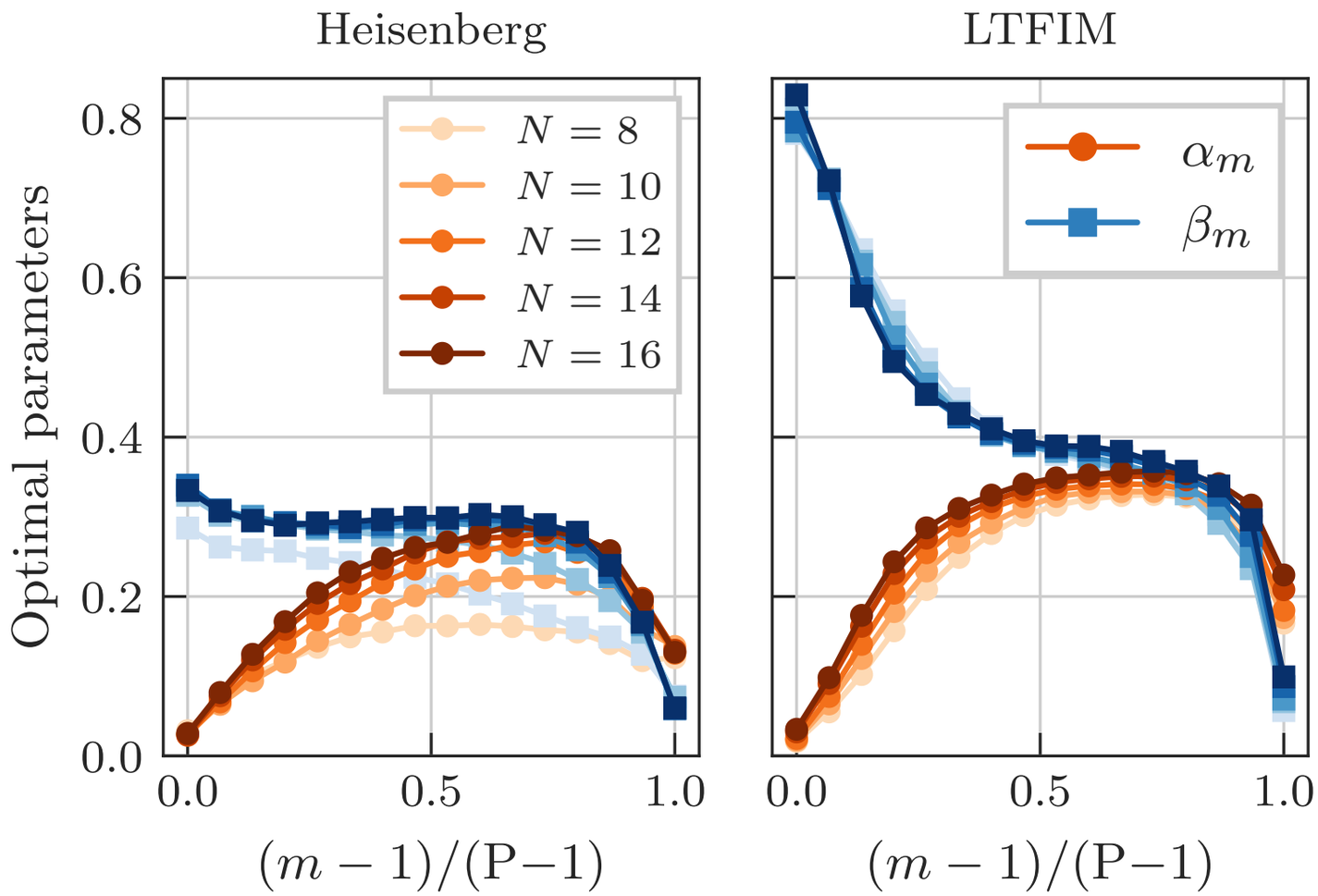
$$H_{\mathrm{LTFIM}} = \sum_{j=1}^{N} Z_jZ_{j+1} - g_x\sum_{j=1}^{N} X_j - g_z\sum_{j=1}^{N} Z_j$$

Although symmetry-ansatz, there can be Barren Plateaus

[Larocca et al., ArXiv (2021)]

Pattern in Optimal Parameters

$$(\alpha_1, \ldots, \alpha_P, \beta_1, \ldots, \beta_P,)$$

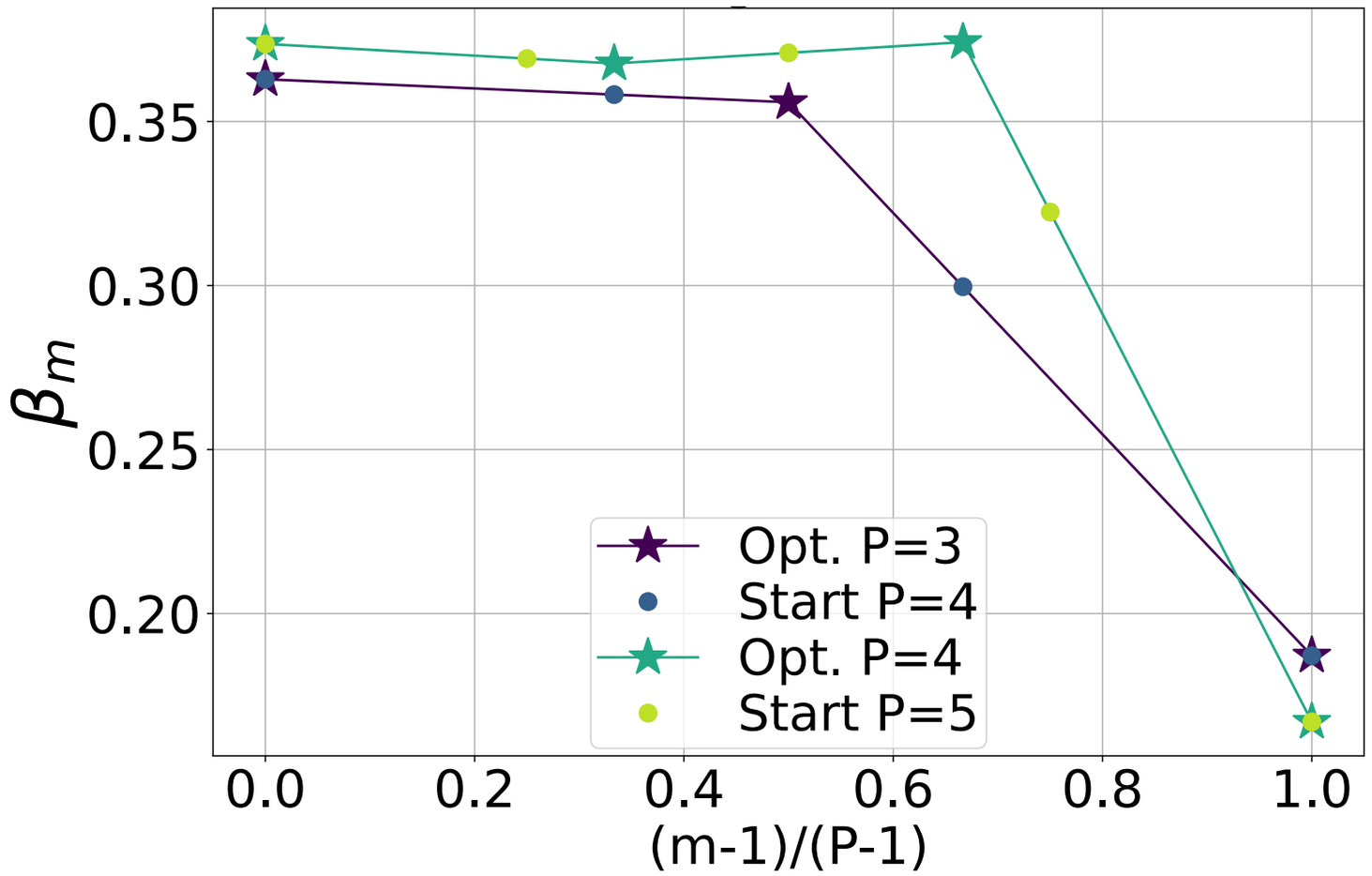


(Rescaled) index with which we labeled the parameters

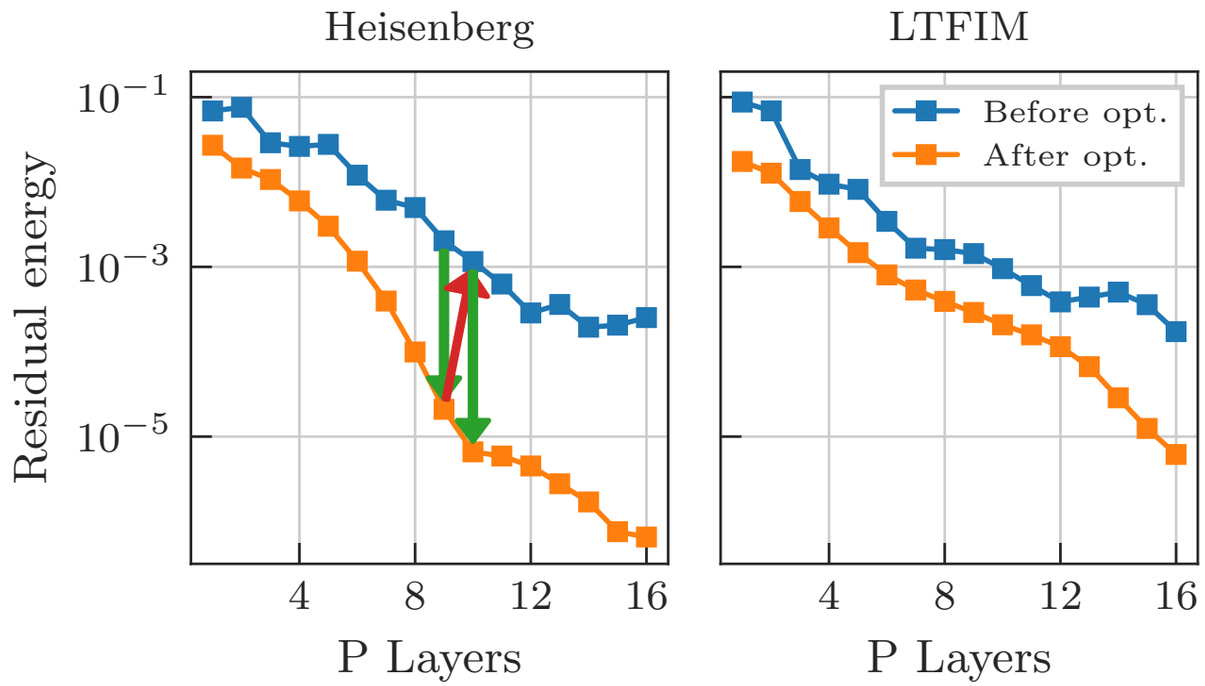
How can we find this pattern?

INTERP strategy

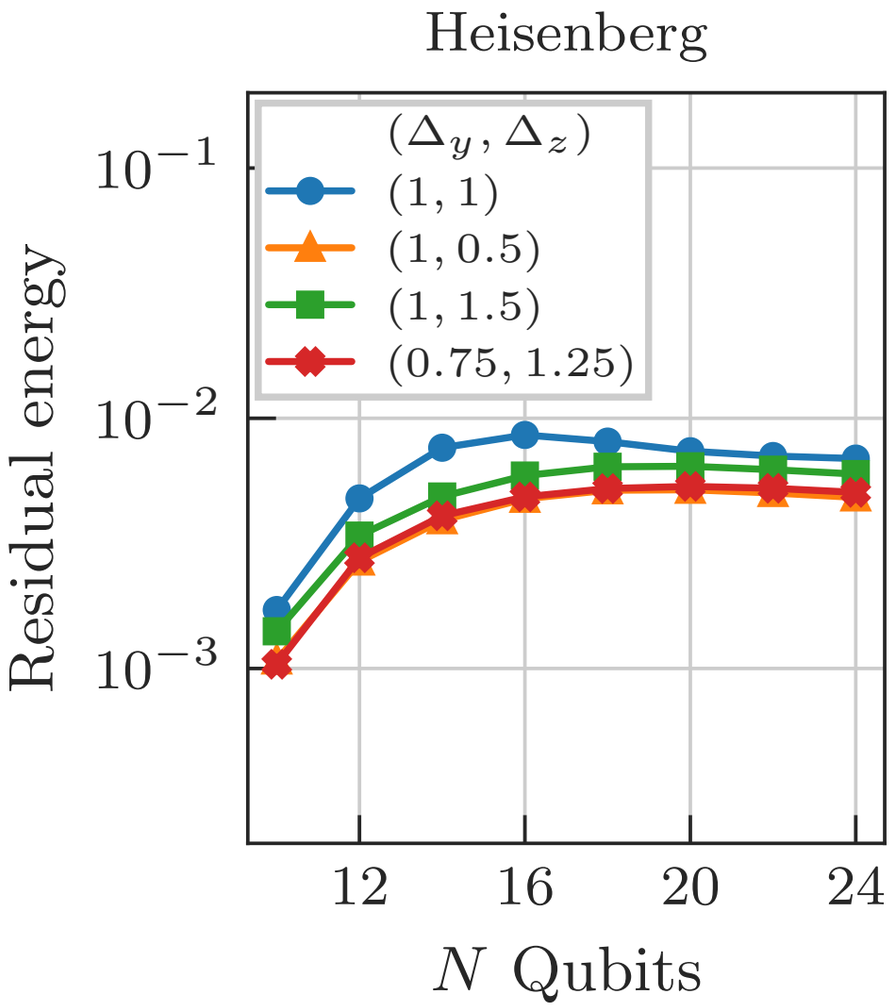
[Zhou et al., PRX. (2018)]



Warm-start for the optimization when you go from P→P+1

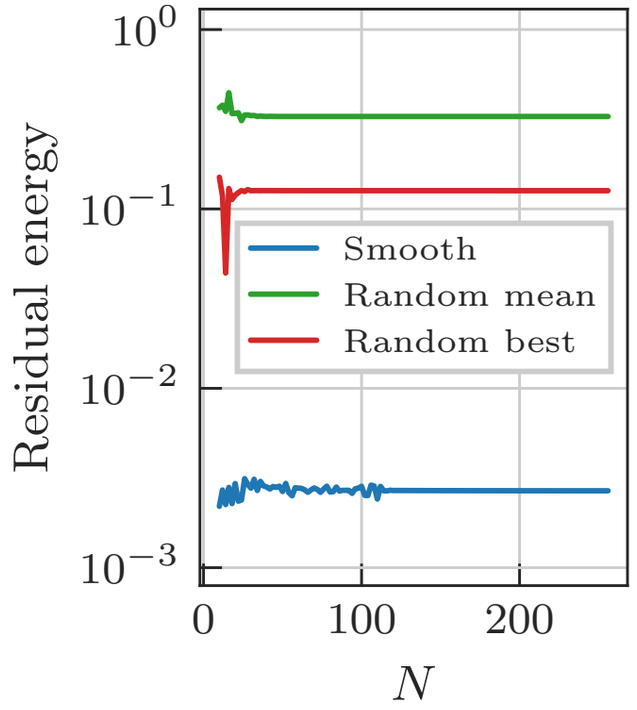


Transferability of solutions

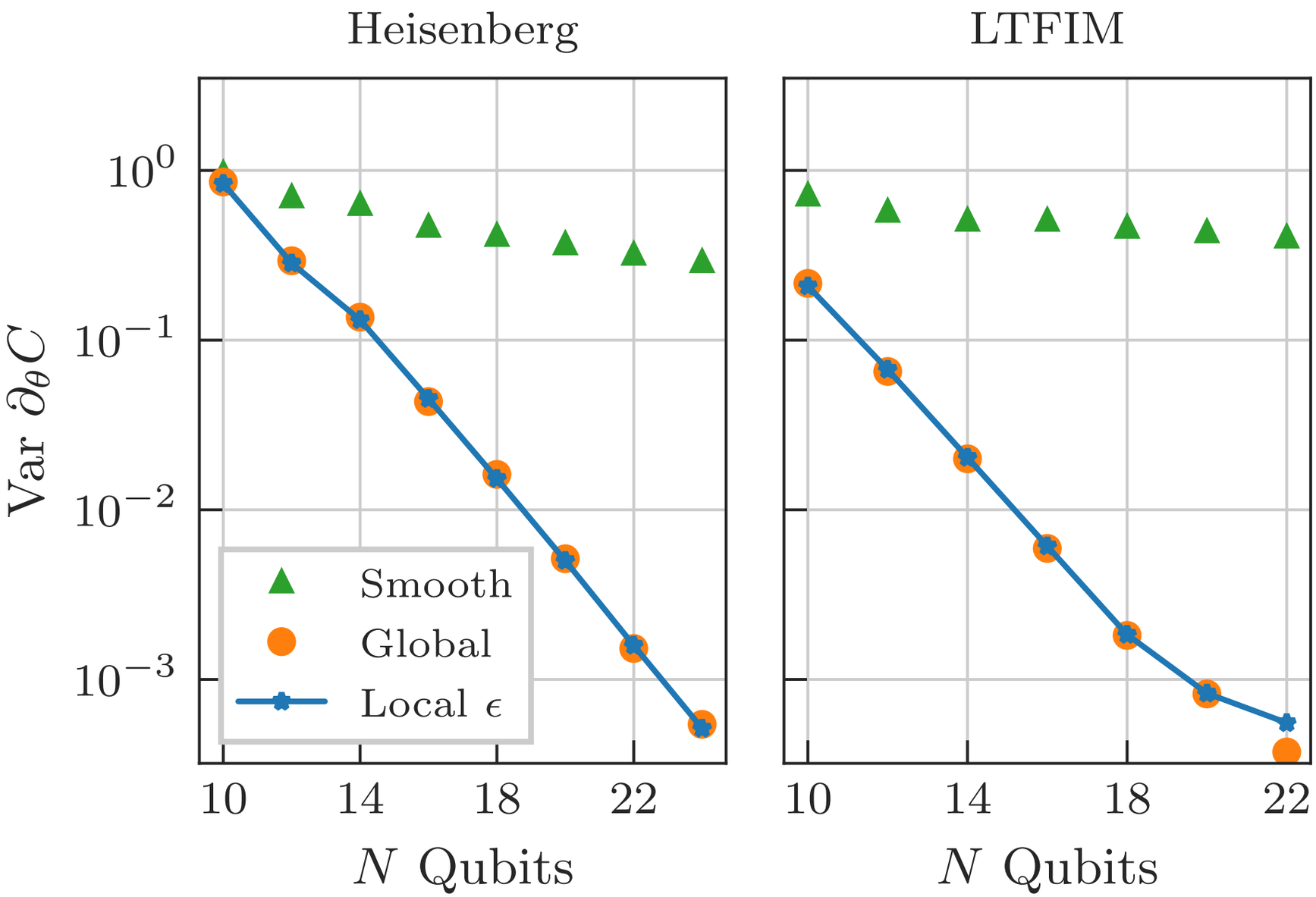


Warm-start when you go from $N_{GUESS} \rightarrow N_{TARGET}$

Transferability also for large-N (TFIM)



The warm-start allows to avoid the flat region



OPEN QUESTIONS

- 2D systems
- This helps avoiding bad local minima and BPs, but what about noise resilience?
- Analytical understanding (connection with Adiabatic QC?)

THANKS FOR YOUR ATTENTION!