# FEATURE DESIGN FOR QUANTUM CIRCUITS VIA CLASSICAL SHADOWS

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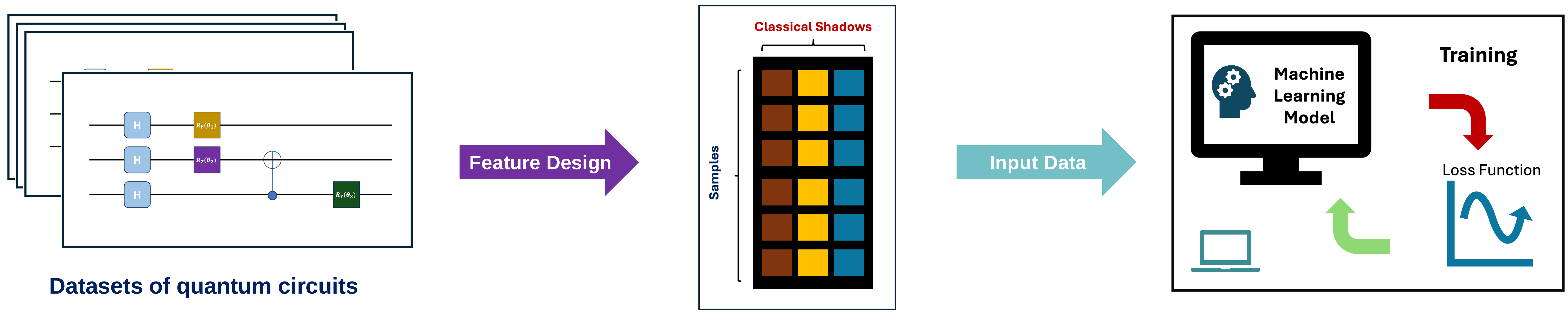
2nd Workshop in Machine Learning for Quantum Technologies – Erlangen, 2024

## MACHINE LEARNING TO APPROXIMATE HARD-TO-COMPUTE PROPERTIES OF QUANTUM CIRCUITS



Random and structured circuits

## CLASSICAL SHADOWS

The protocol of *classical shadows* [1] provides classical representations of quantum states based on **randomized measurements**.

Given a state $\rho$, classical shadows allow to predict $M$ linear functions of $\rho$, in the form $Tr(\rho O_i)$, up to an additive error $\epsilon$. They are **efficient** in the sample complexity:

$$N = \mathcal{O}\left(\frac{\log(M)\max_i \|O_i\|_{shadow}}{\epsilon^2}\right)$$

$N$: Size of the classical shadow

## MAGIC

The *magic*, or *nonstabilizerness*, of a quantum state $|\psi\rangle$ measures the amount of non-Clifford resources required to prepare it. Magic is a key measure in the study of **quantum advantage**.

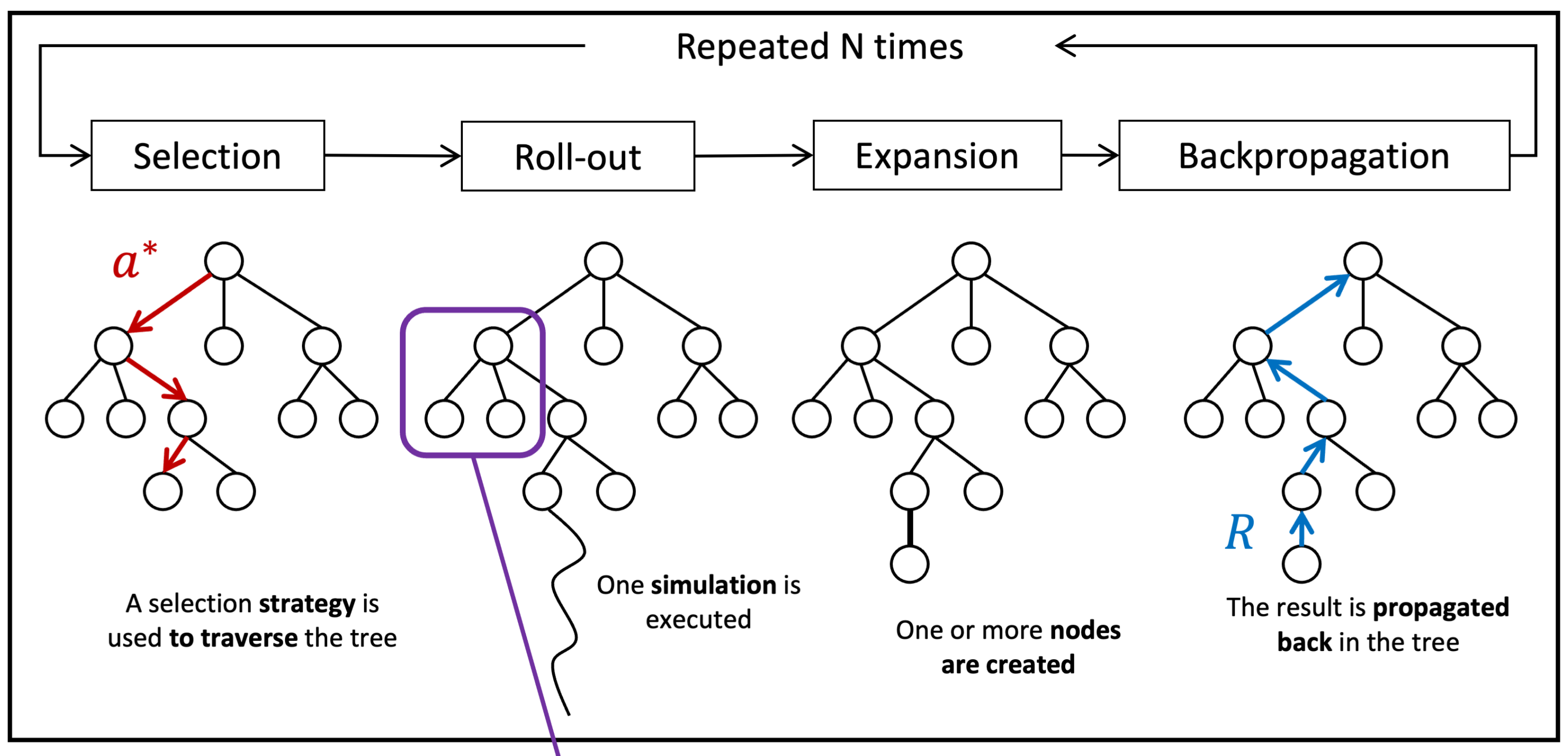
Example: **Stabilizer Rényi Entropy** [2]

Given a pure $n$-qubit state $|\psi\rangle$:

$$M_\alpha(|\psi\rangle) = \frac{1}{1-\alpha}\log\sum_{P\in\mathcal{P}_n}\Xi_P^\alpha(|\psi\rangle) - \log\ 2^n$$

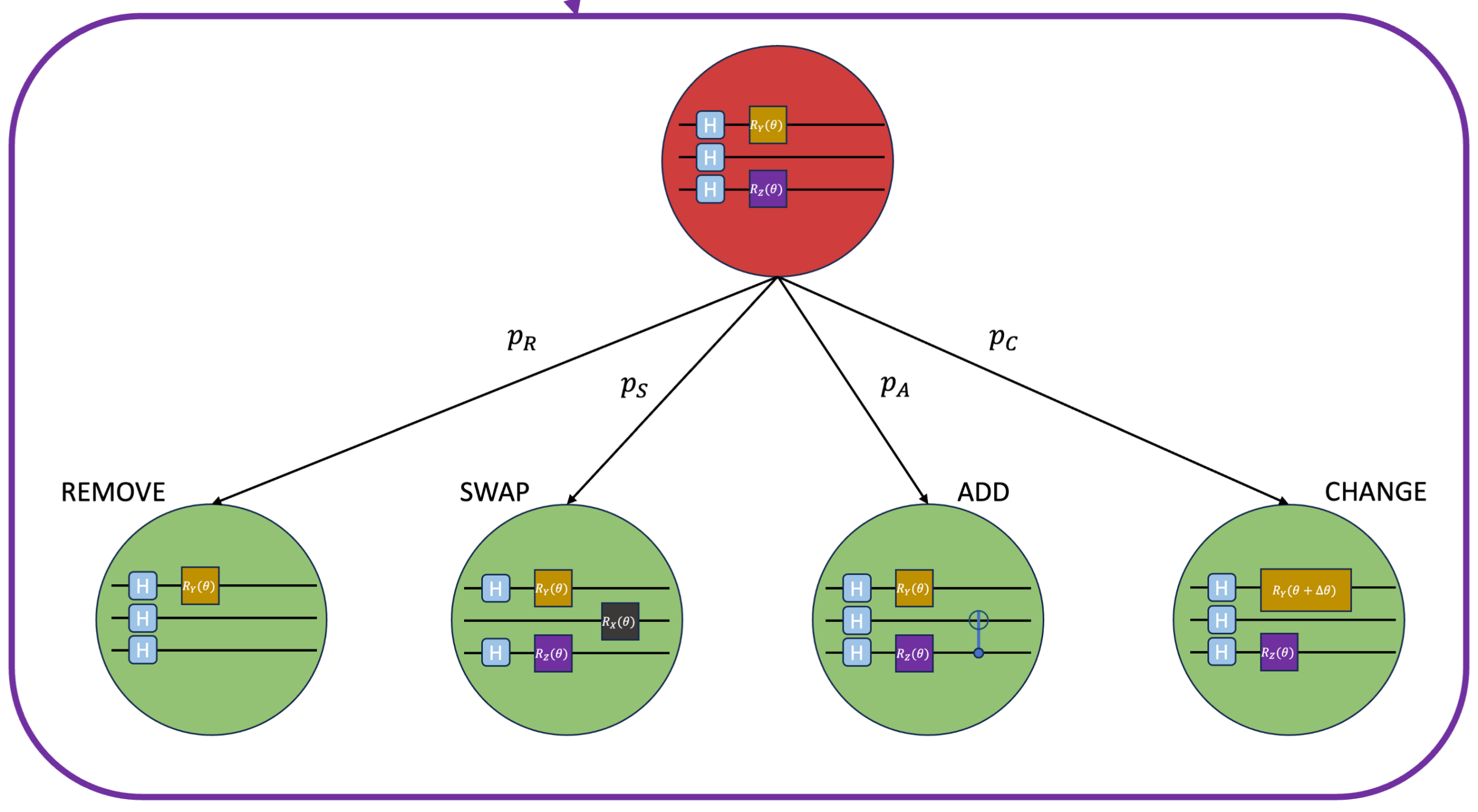
In general, the SRE is hard to compute as the number of Pauli strings grows exponentially.

## MAGIC-INFORMED QUANTUM ANSATZ SEARCH FOR VARIATIONAL QUANTUM ALGORITHMS



**Node → Quantum Circuit**

**Move → Modification of Quantum Circuit**



**Universal Gate Set** $= \{CX, R_X(\theta), R_Y(\theta), R_Z(\theta)\}$

- **Monte Carlo Tree Search** is employed to explore the space of parametrized quantum circuits ✓
- Machine Learning models are employed to **bias the search** towards magic states
- Machine Learning models are employed to support MCTS in the design of quantum circuits that **avoid *barren plateaus*.**

Domains of **Application**:

**Ground State Energy Estimation**

1. Hydrogen: $H_2$
2. Lithium Hydride: $LiH$
3. Water: $H_2O$

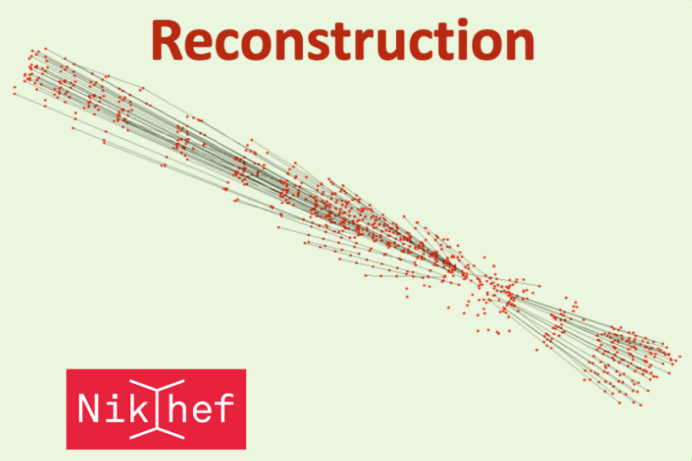
**Quantum Random Circuits**

Different sizes:

- Number of qubits
- Number of gates

**Systems of Linear Equations**

**Particle Track Reconstruction**



**Max Cut**

Sudoku

**REFERENCES**

**[1]** Huang, H. Y., Kueng, R., & Preskill, J. (2020). Predicting many properties of a quantum system from very few measurements. Nature Physics, 16(10), 1050-1057.

**[2]** Leone, L., Oliviero, S. F., & Hamma, A. (2022). Stabilizer rényi entropy. Physical Review Letters, 128(5), 050402.

**[3]** Sack, S. H., Medina, R. A., Michailidis, A. A., Kueng, R., & Serbyn, M. (2022). Avoiding barren plateaus using classical shadows. PRX Quantum, 3(2), 020365.

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