

Title: Disentangling quantum systems: a new perspective in computational quantum physics

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Abstract:

Disentangling quantum systems: a new perspective in Computational Quantum Physics

PIquDoS

Perimeter Institute, February 2nd 2005

Guifre Vidal - Institute for Quantum Information -
CALTECH

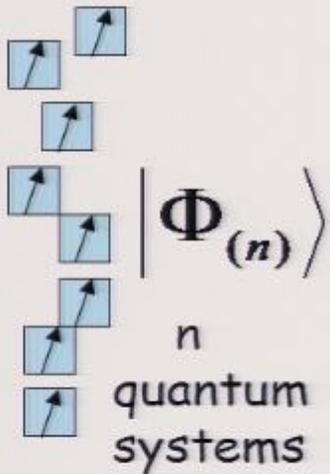
Outline

- 1) Simulation of Quantum Systems.
- 2) Efficient Decomposition vs Efficient Simulation.
- 3) Disentangling Quantum Systems.
- 4) Summary of Recent Progress
- 5) Conclusions

1 - Simulation of Quantum Systems

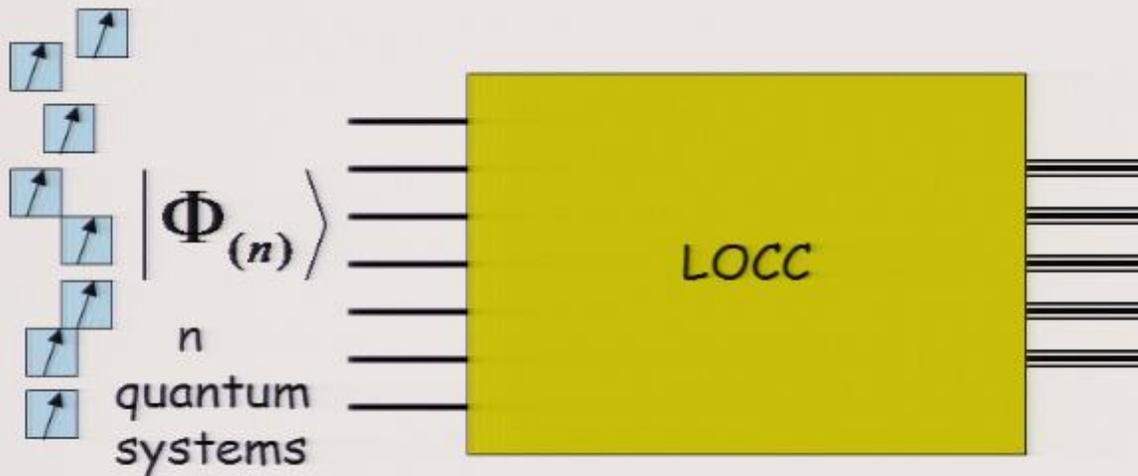
1 - Simulation of Quantum Systems

experimental setting: many-body state $|\Phi_{(n)}\rangle$



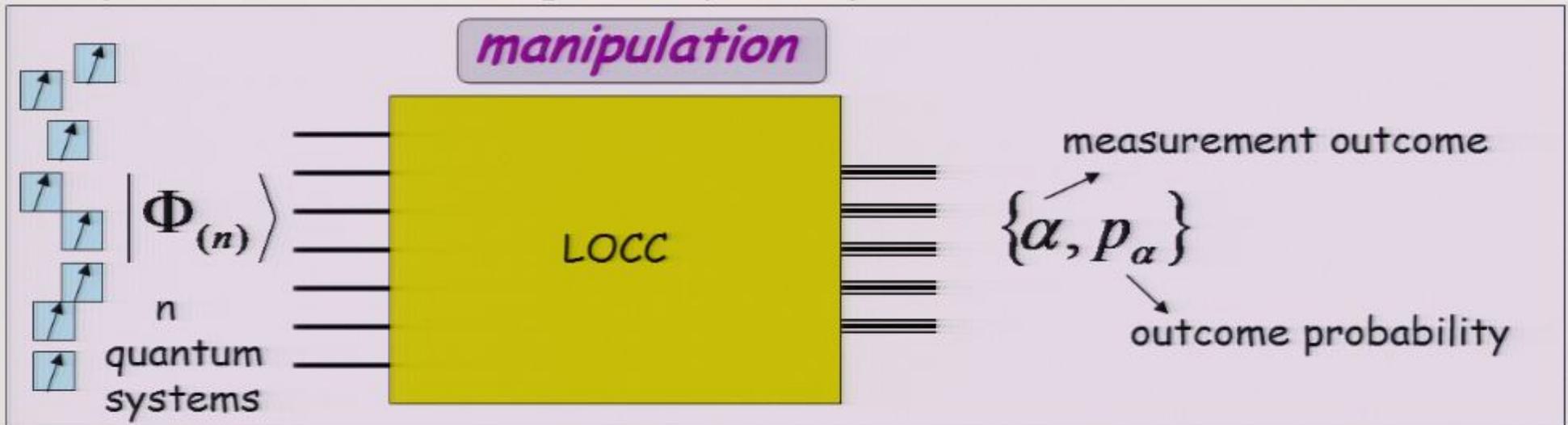
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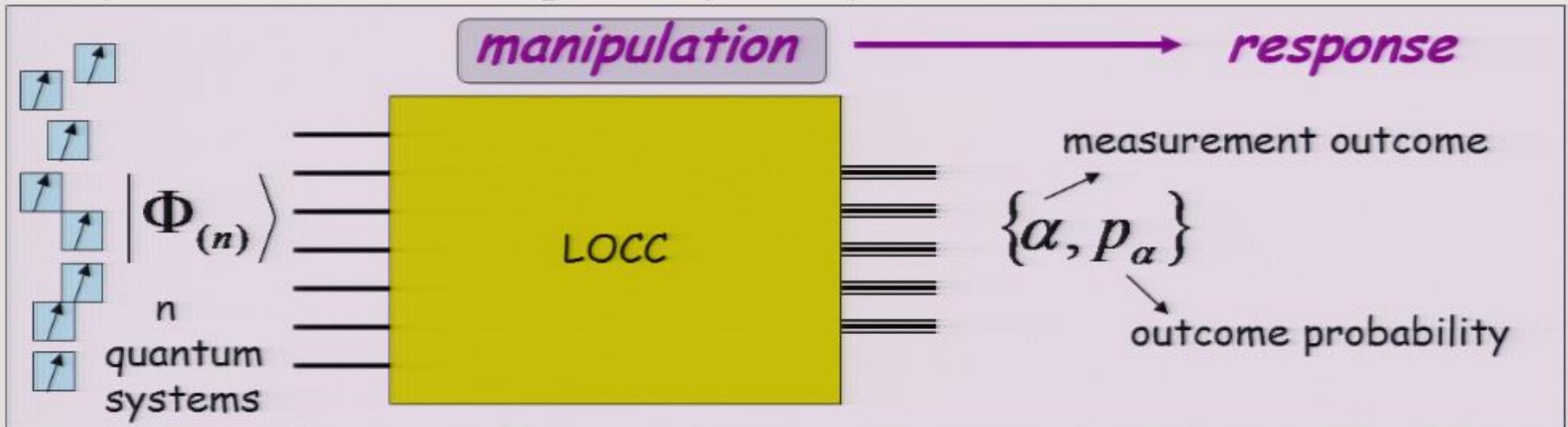
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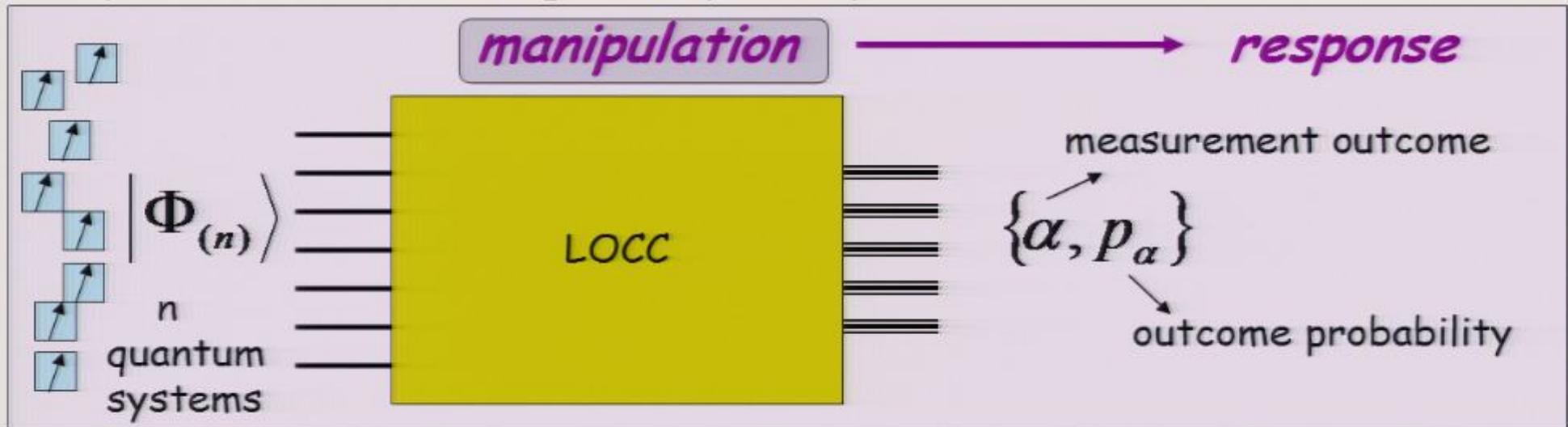
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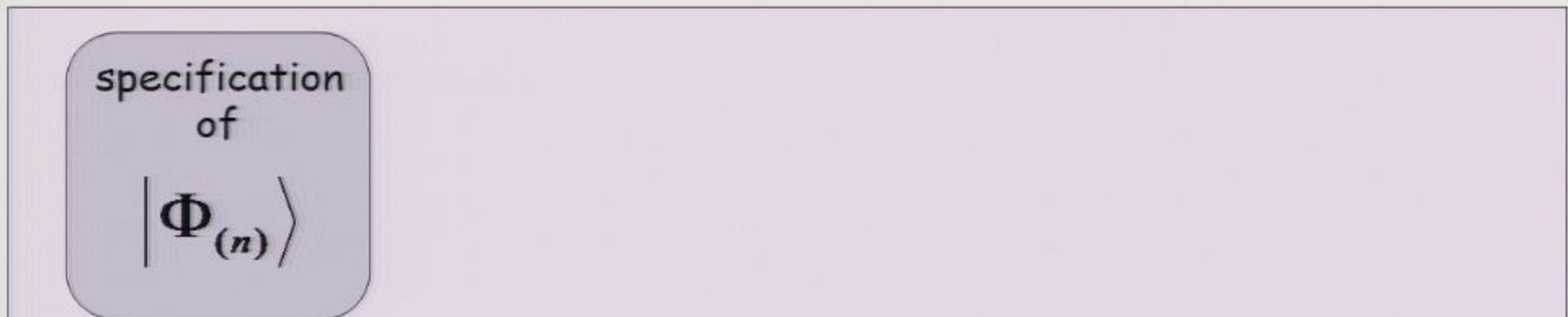
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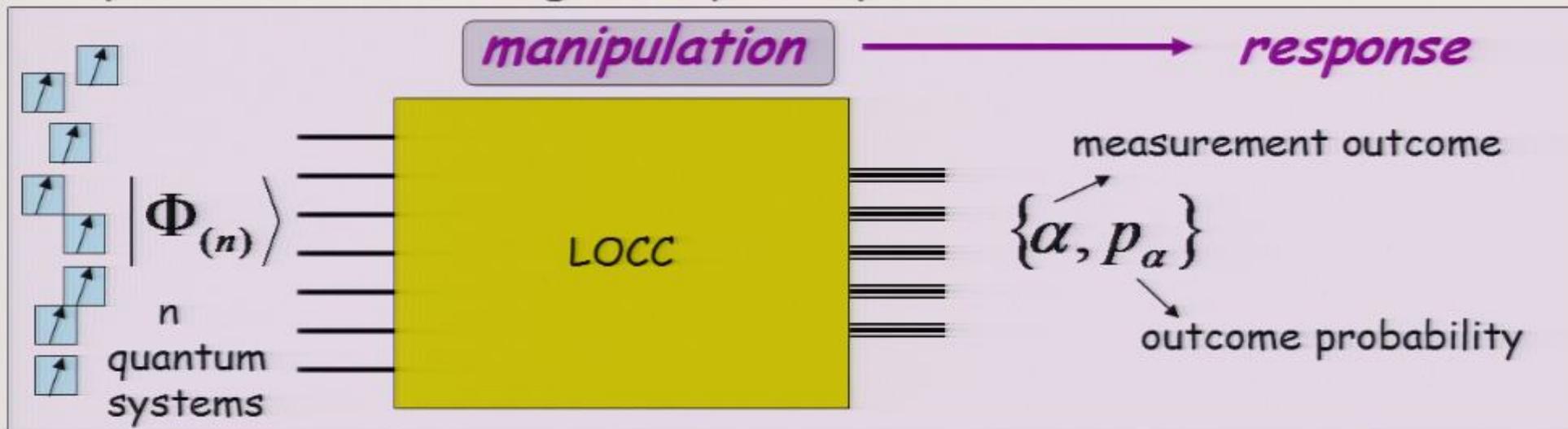


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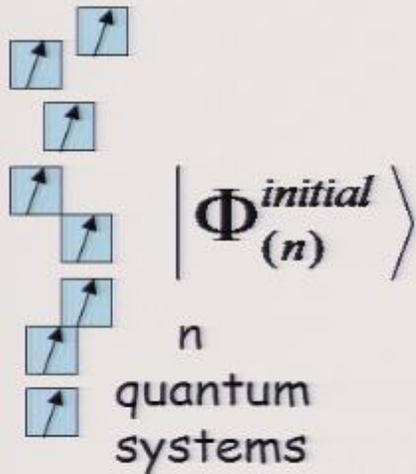


experimental setting: many-body evolution

$$|\Phi_{(n)}^{final}\rangle = U |\Phi_{(n)}^{initial}\rangle$$

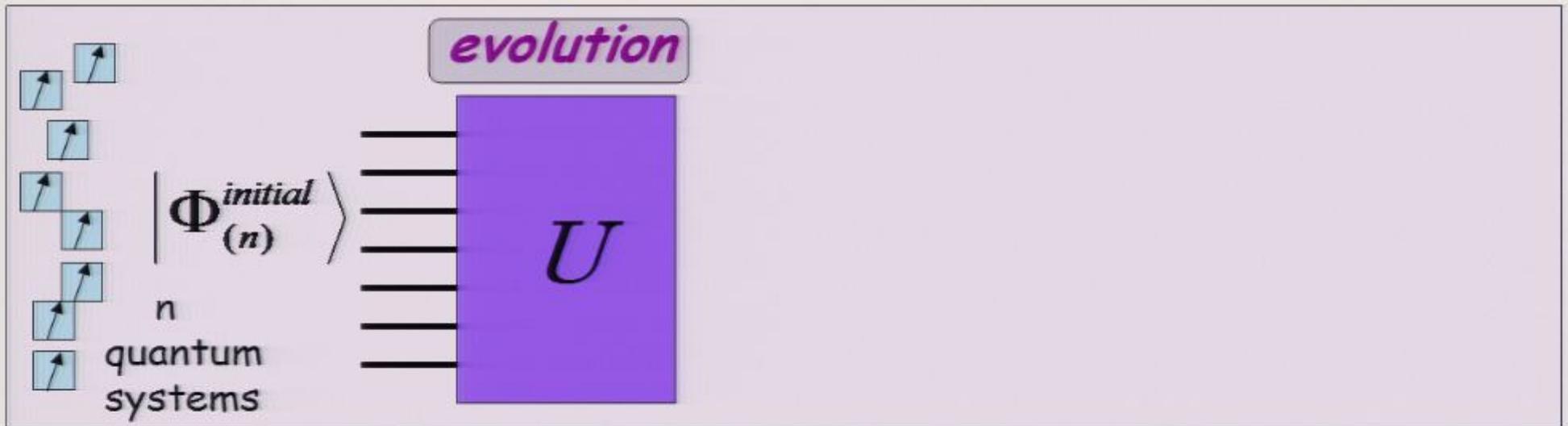
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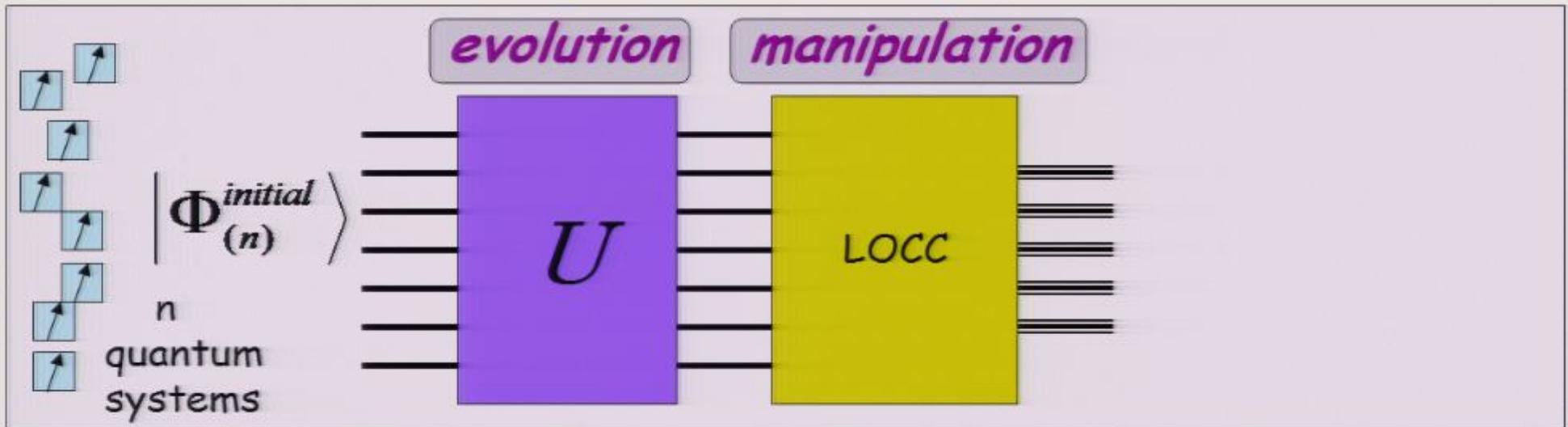
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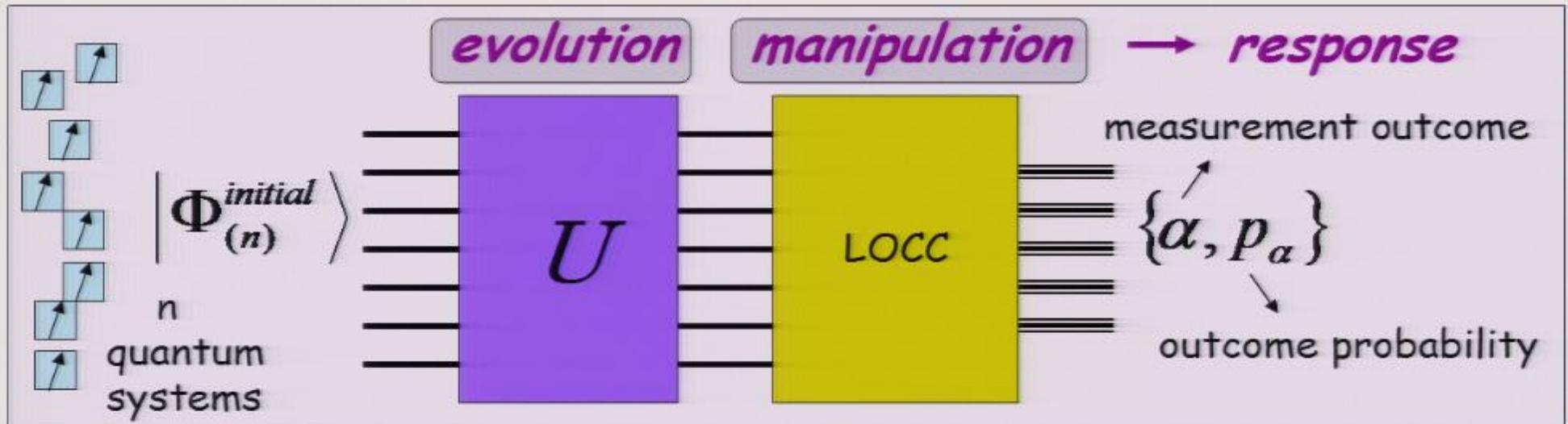
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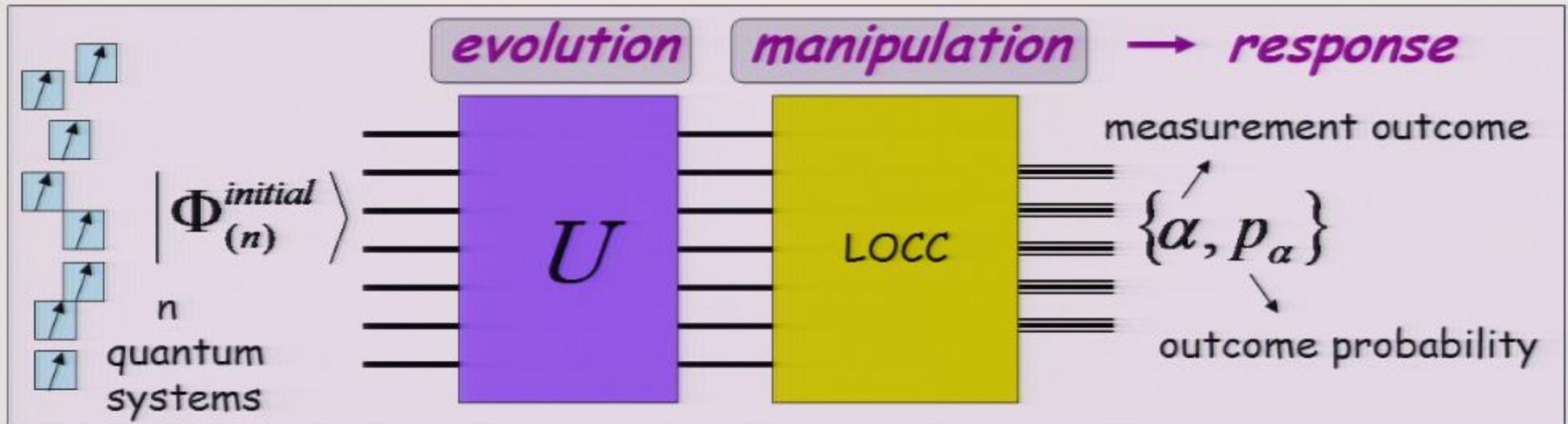
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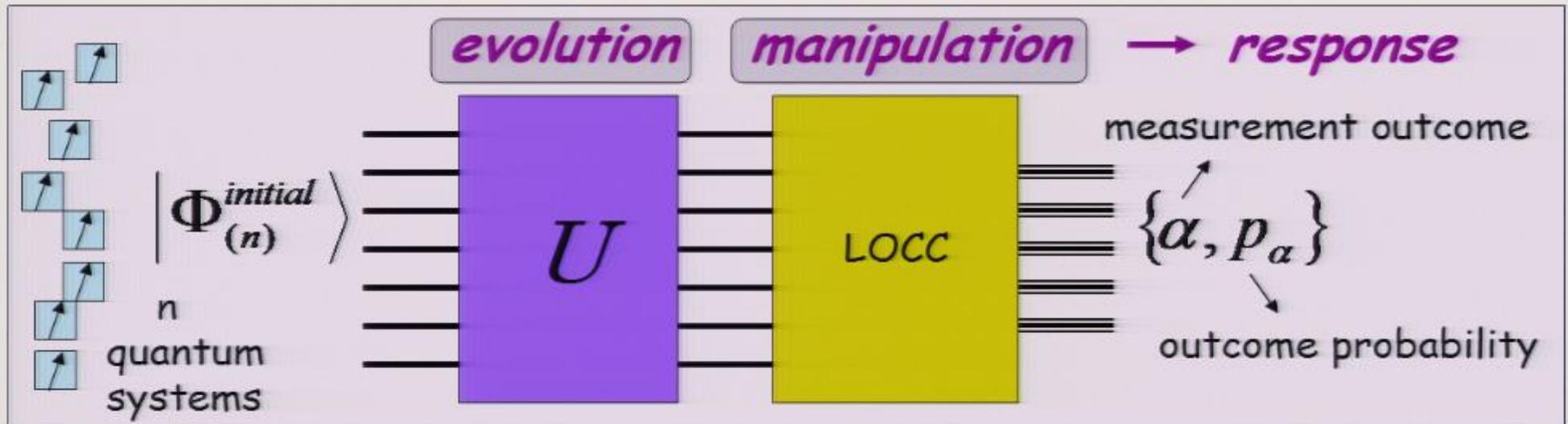


classical simulation of evolution U starting from $|\Phi_{(n)}^{initial}\rangle$

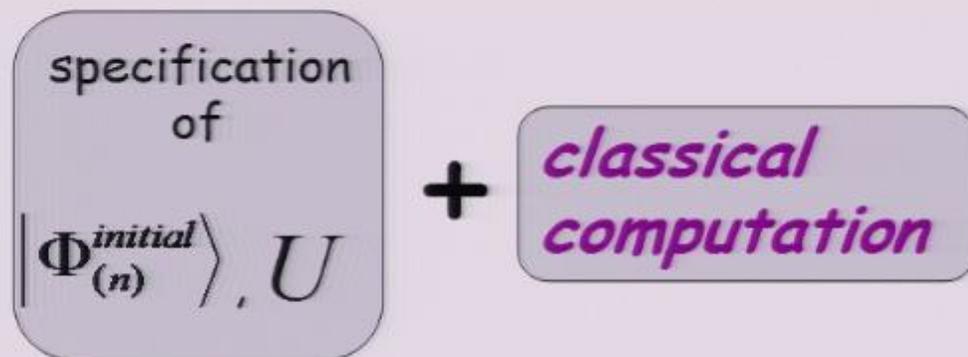
specification
of
 $|\Phi_{(n)}^{initial}\rangle, U$

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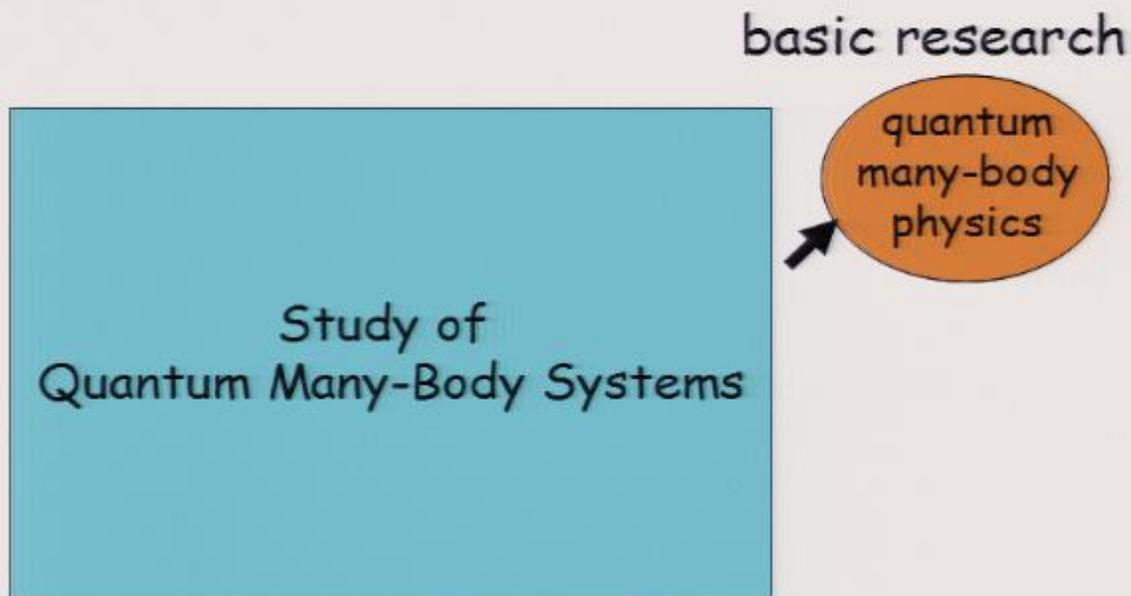


- Why do we want to simulate quantum systems ?

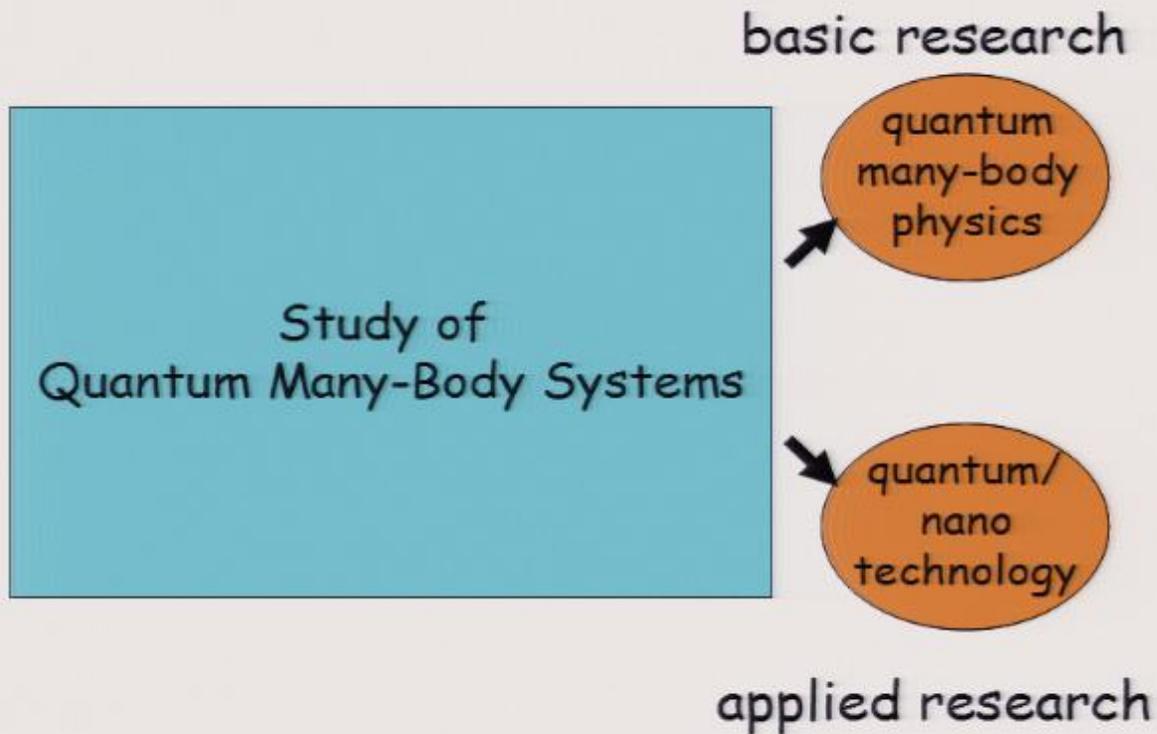
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Study of
Quantum Many-Body Systems

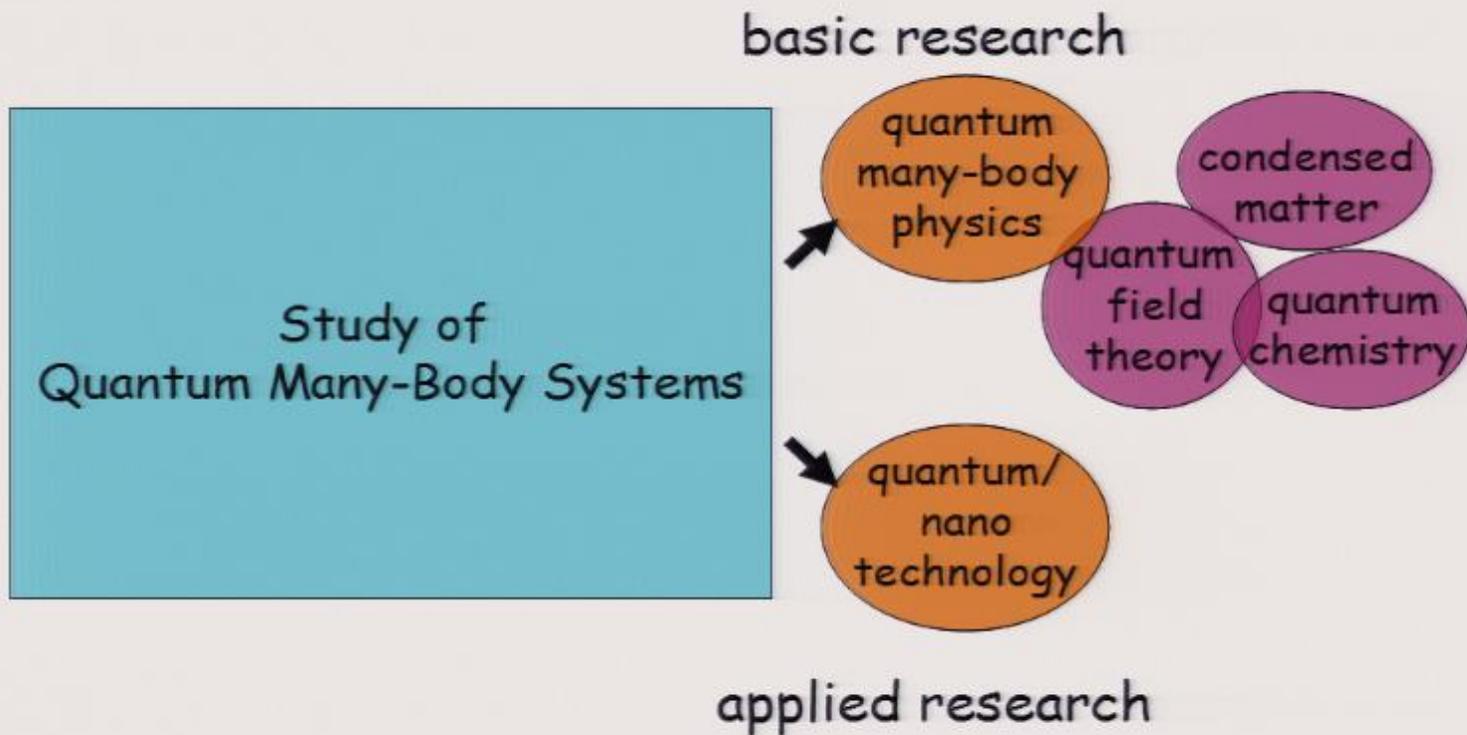
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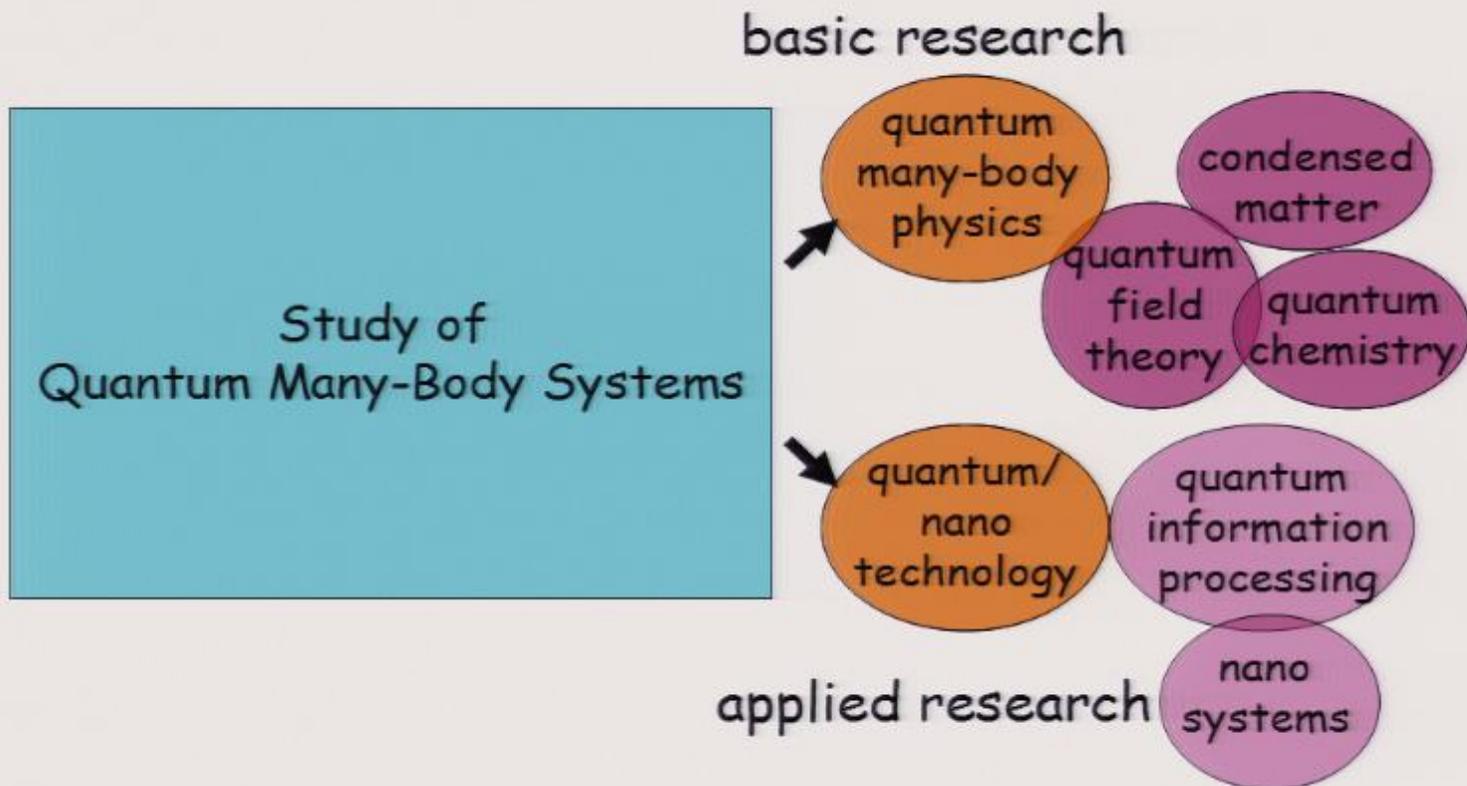
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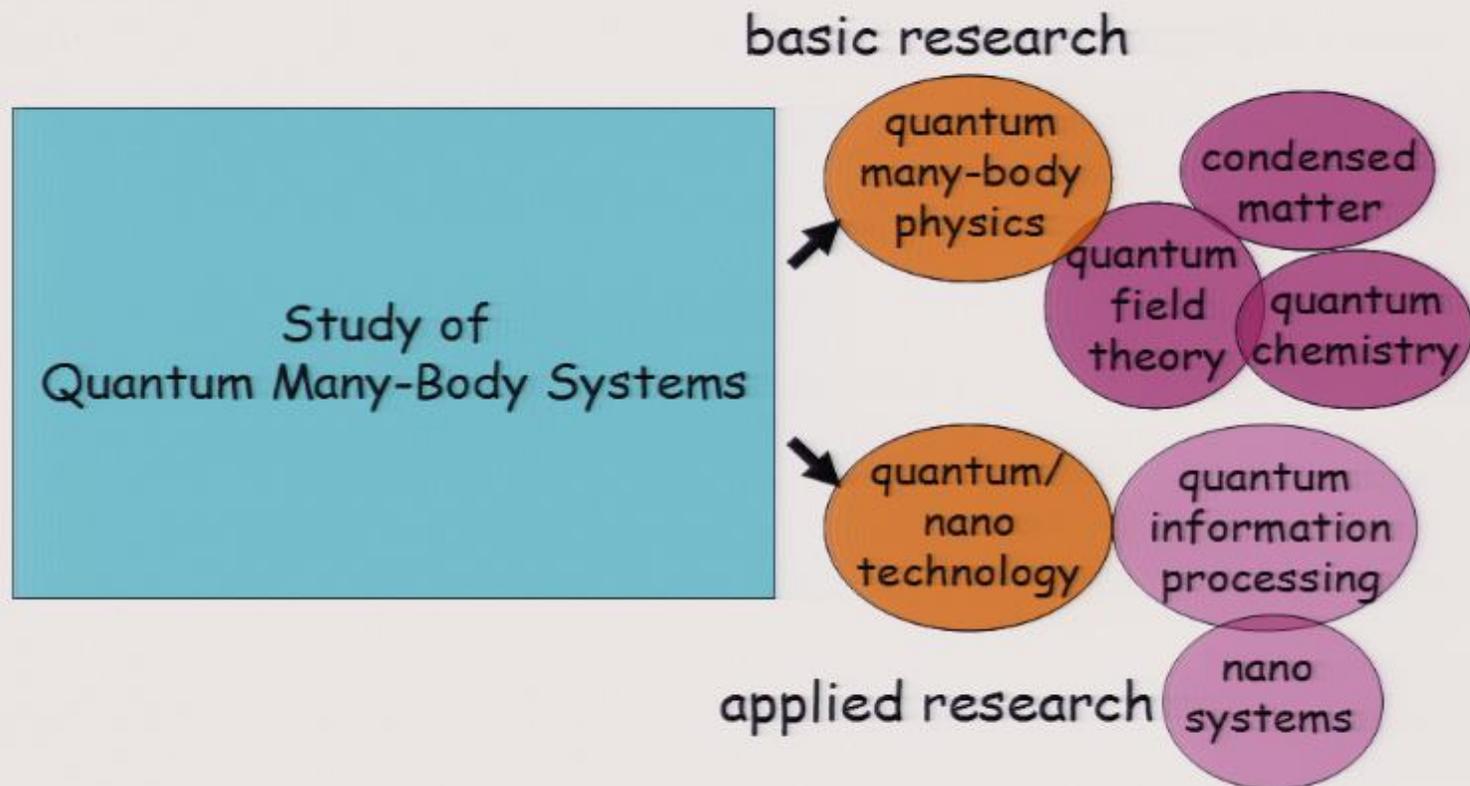
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Some simulation algorithms are known [quantum montecarlo, density functional theory, density matrix renormalization group, ...] but they **only apply to very specific situations.**

straightforward
classical simulation

$$\dim H_n = 2^n$$

dimension of Hilbert space is
exponentially large in n

straightforward
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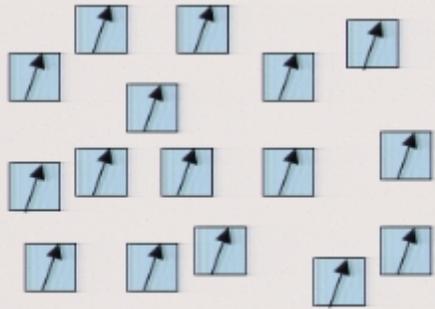
n quantum systems

generic state

$$|\Phi_{(n)}\rangle = \sum_{i_1 \dots i_n} C_{i_1 \dots i_n} |i_1\rangle \dots |i_n\rangle$$

2^n
parameters

2 - Efficient Decomposition vs Efficient Simulation



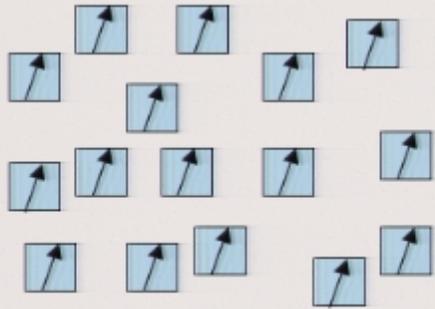
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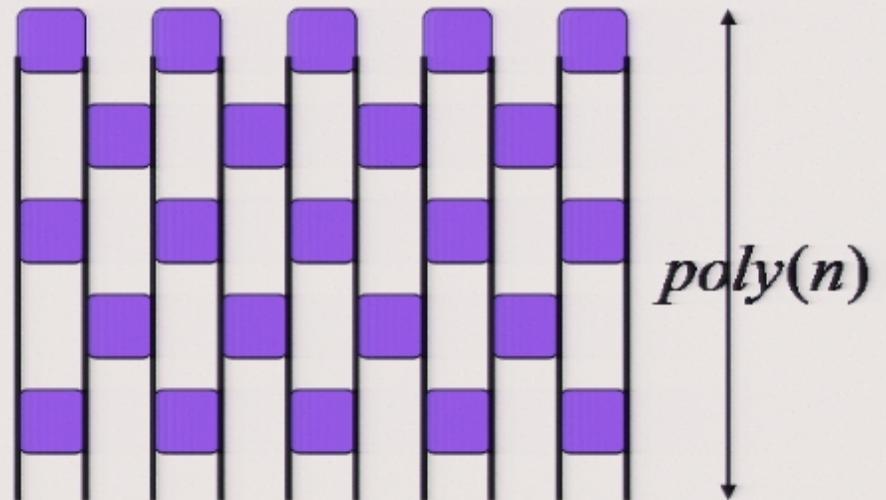
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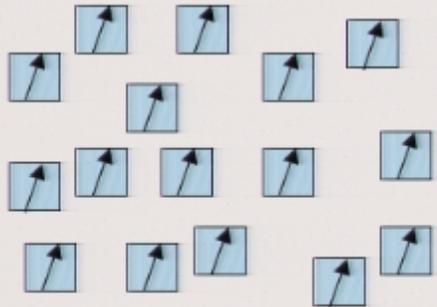


2^n parameters



poly(n) parameters

2 - Efficient Decomposition vs Efficient Simulation



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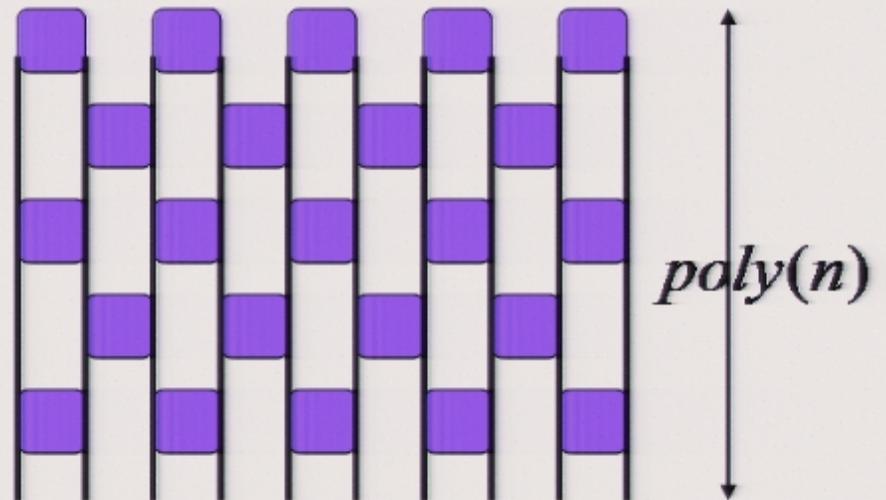
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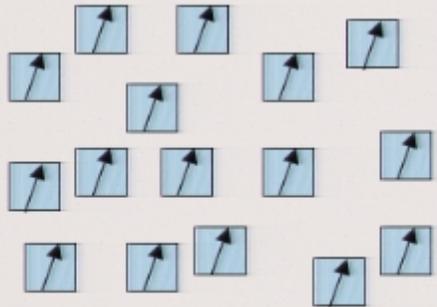
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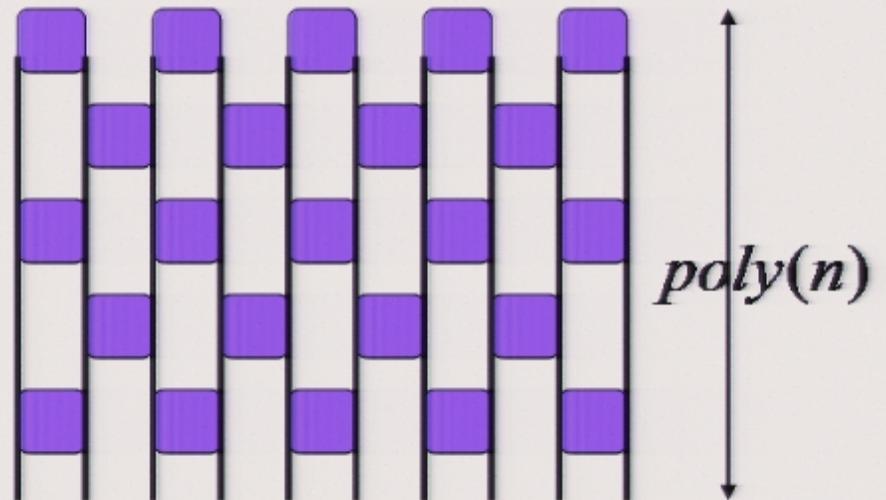
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Efficient decomposition

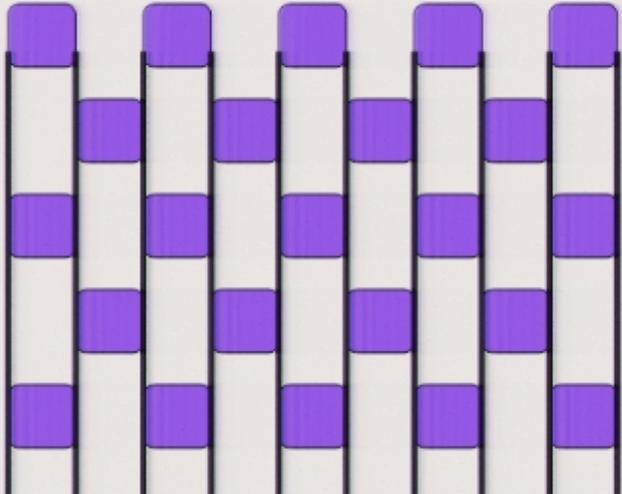
Efficient decomposition  Efficient simulation

Computation of a scalar product:

$$\langle \Phi_{(n)} | \Phi_{(n)} \rangle =$$

Efficient decomposition ~~→~~ Efficient simulation

Computation of a scalar product:

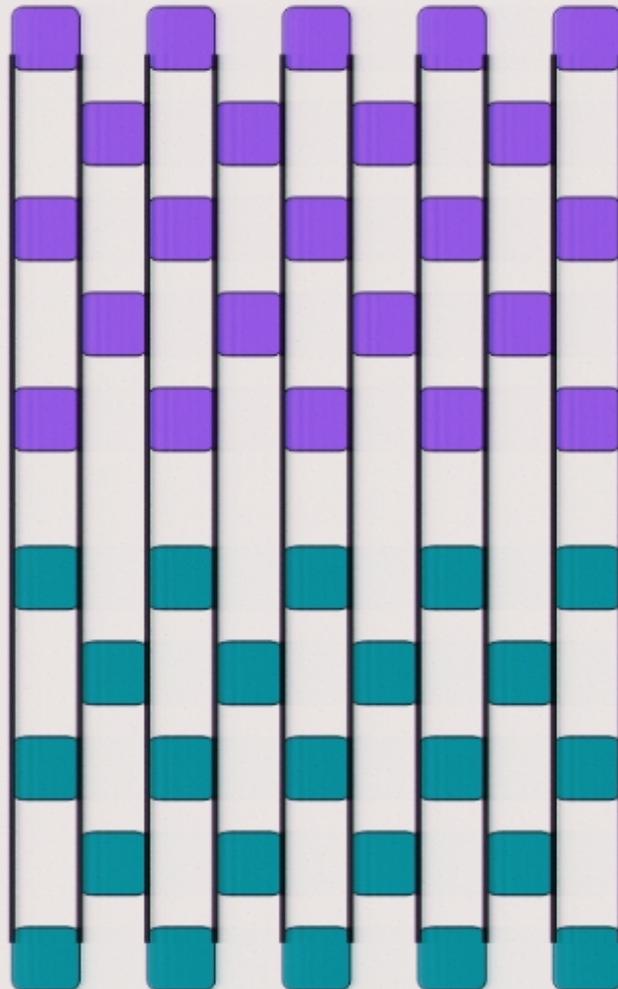
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The diagram shows a 5x5 grid of purple blocks. Each block is a small rectangle with a black outline. The blocks are arranged in five rows and five columns. The top row has five purple blocks. The second row has four purple blocks, starting from the second column. The third row has three purple blocks, starting from the second column. The fourth row has two purple blocks, starting from the second column. The fifth row has one purple block, in the second column. This pattern of blocks represents the computation of a scalar product, where the number of blocks in each row decreases from left to right, and the total number of blocks is 15.

Efficient decomposition ~~→~~ Efficient simulation

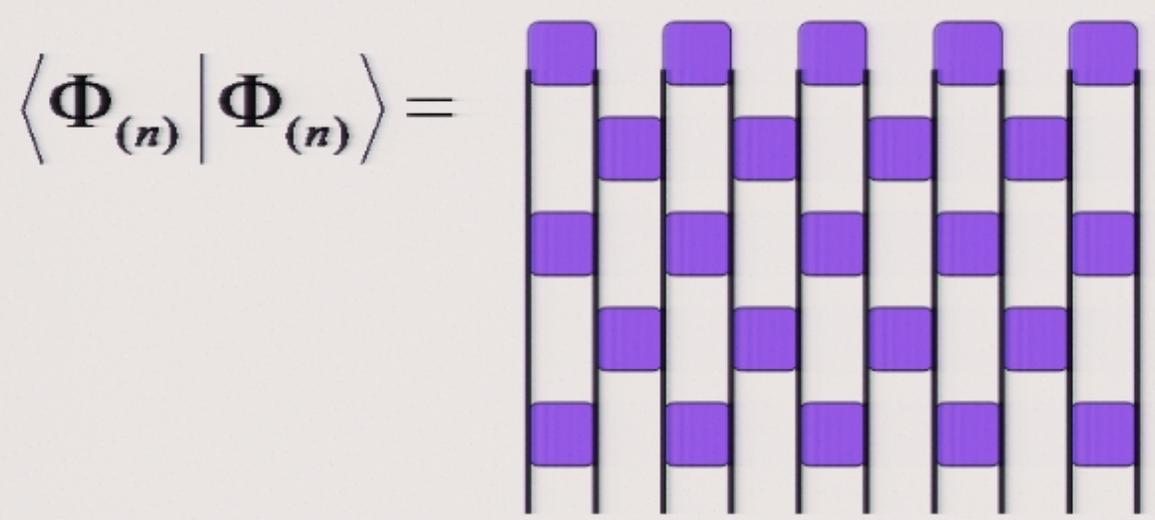
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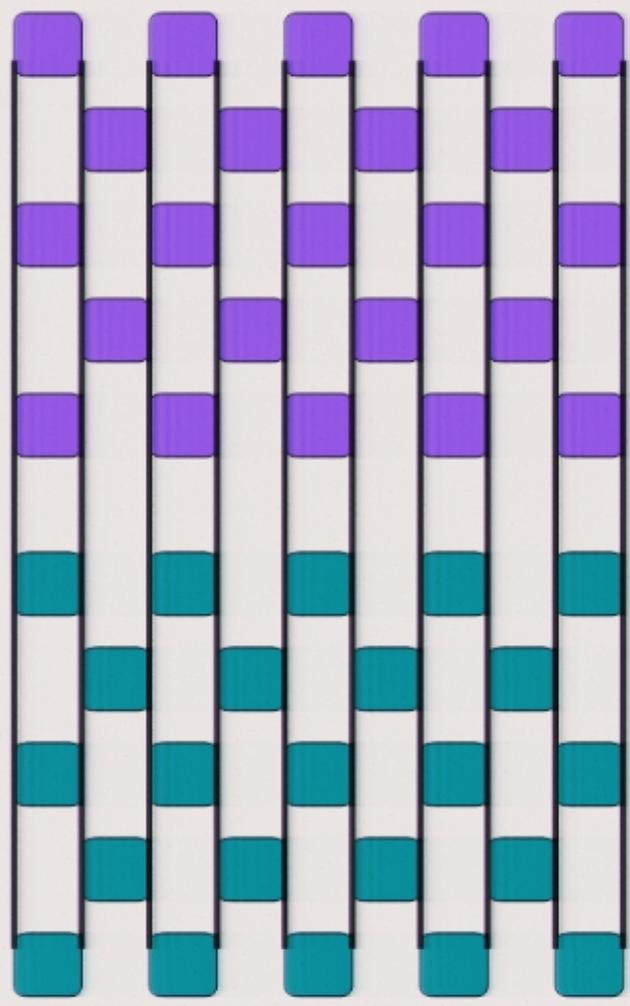
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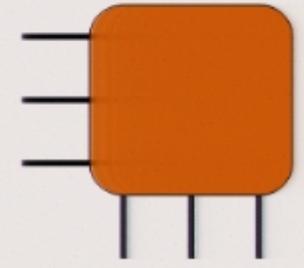
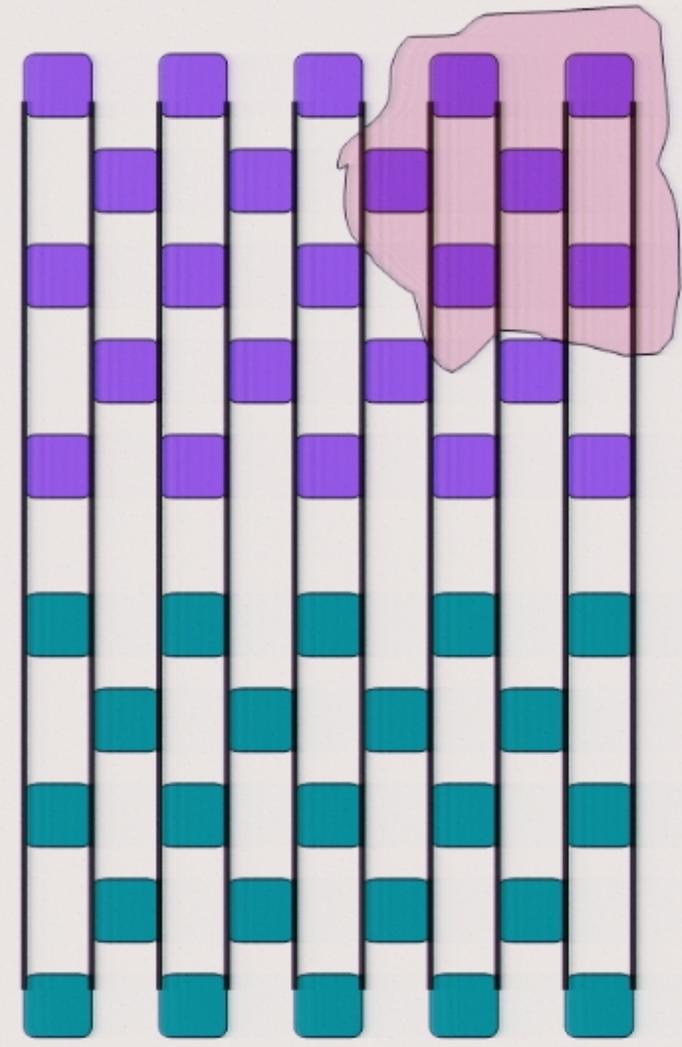
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Efficient decomposition $\not\rightarrow$ Efficient simulation

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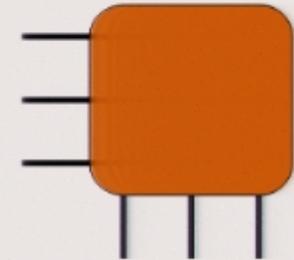
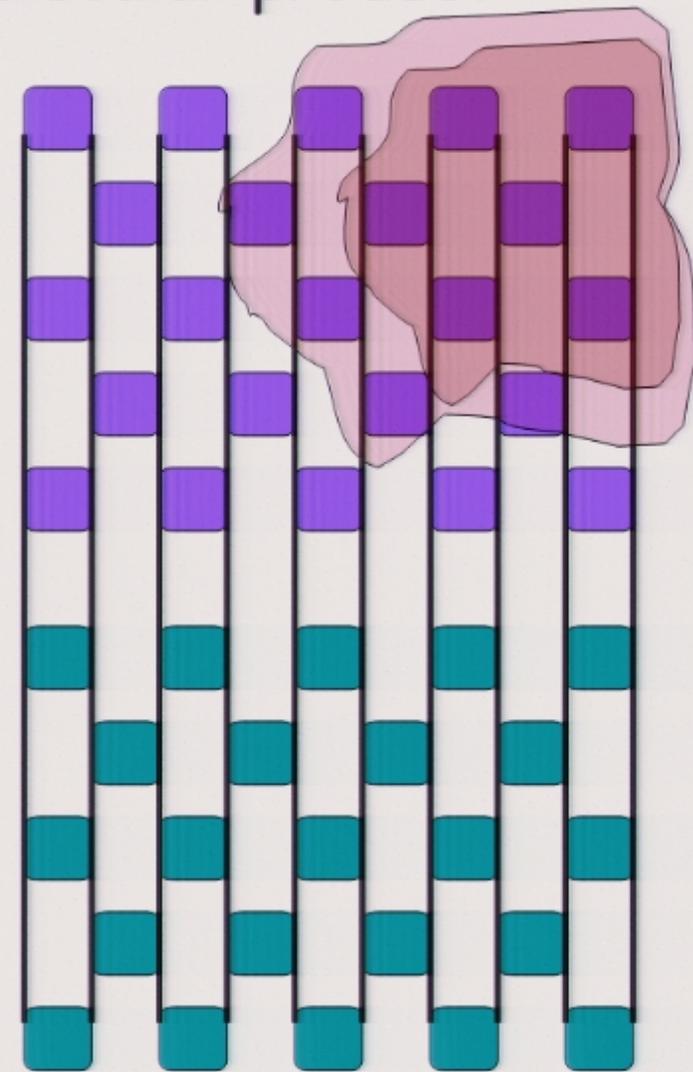
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Efficient decomposition \rightarrow Efficient simulation

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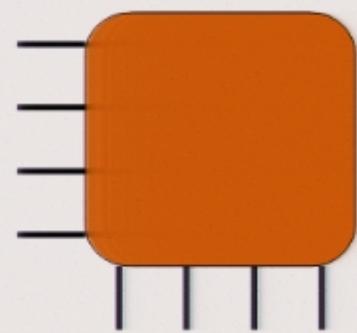
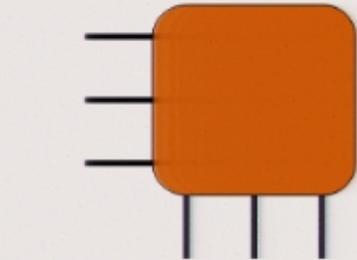
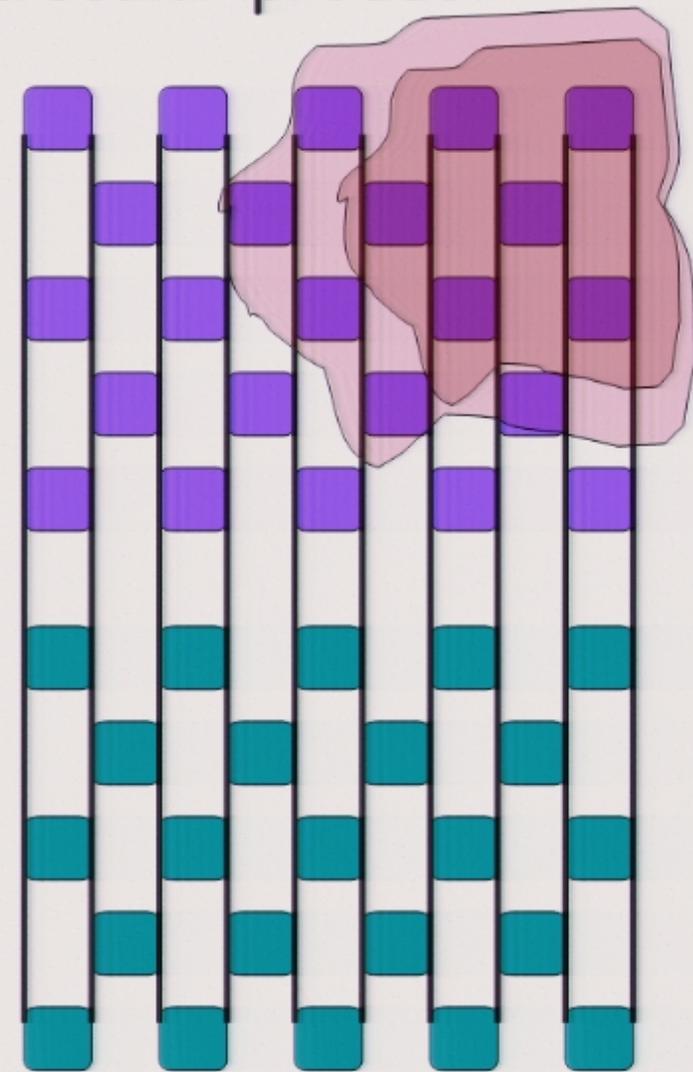
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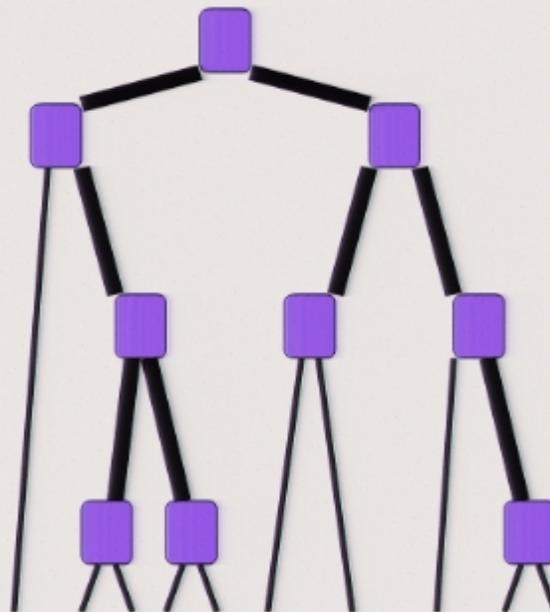
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Efficient decomposition
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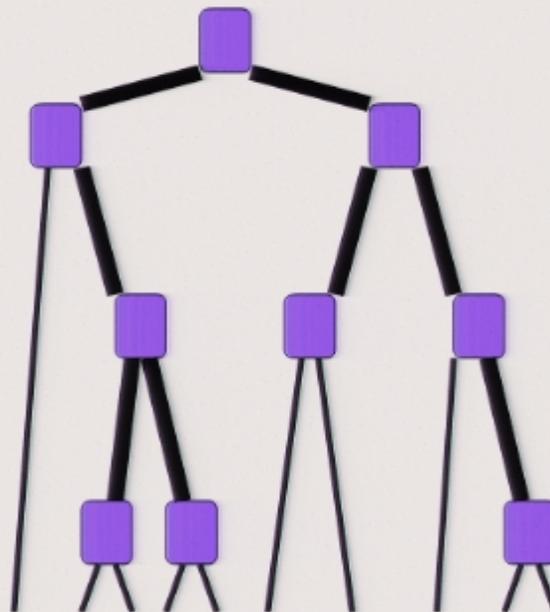
Efficient decomposition
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Example: Tree of small tensors

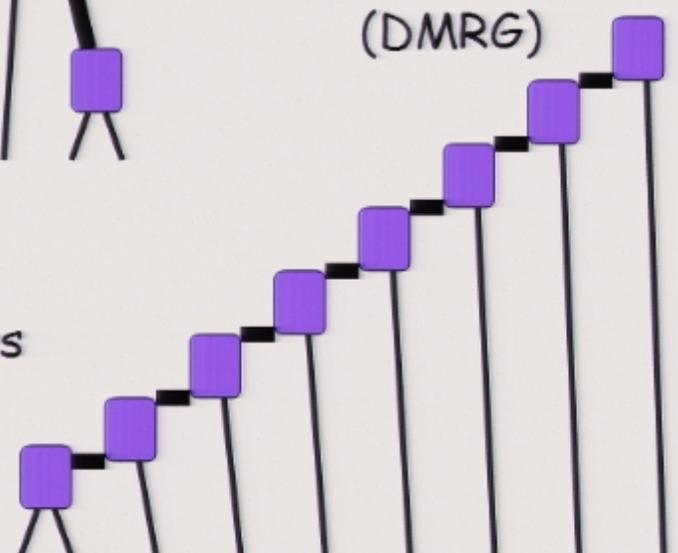
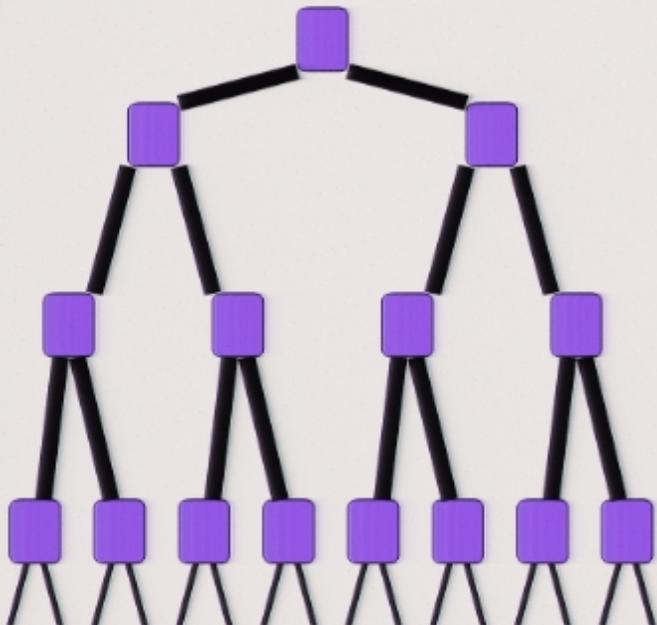


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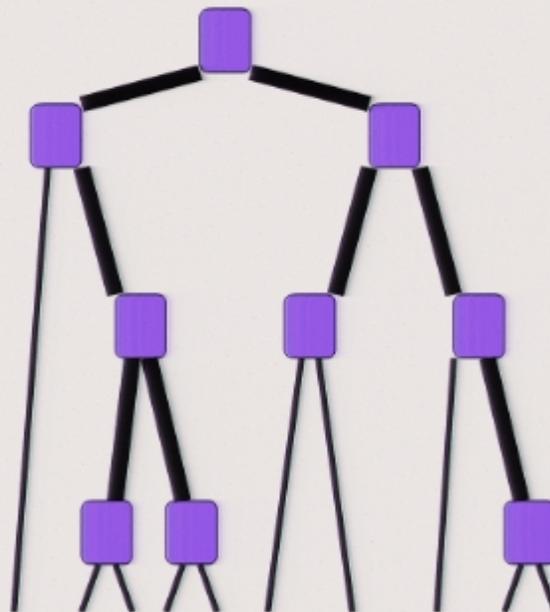


$O(n)$ parameters



Efficient decomposition
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Example: Tree of small tensors



$O(n)$ parameters

(DMRG)

