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

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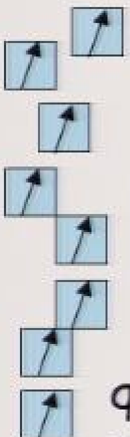
experimental setting: many-body state $\left|\Phi_{(n)}\right\rangle$



$\left|\Phi_{(n)}\right\rangle$

n
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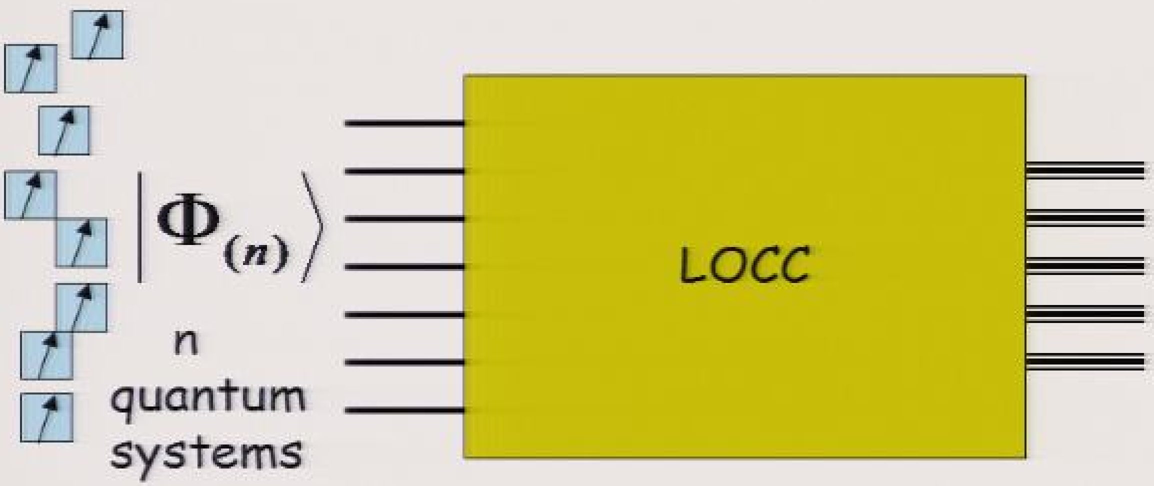

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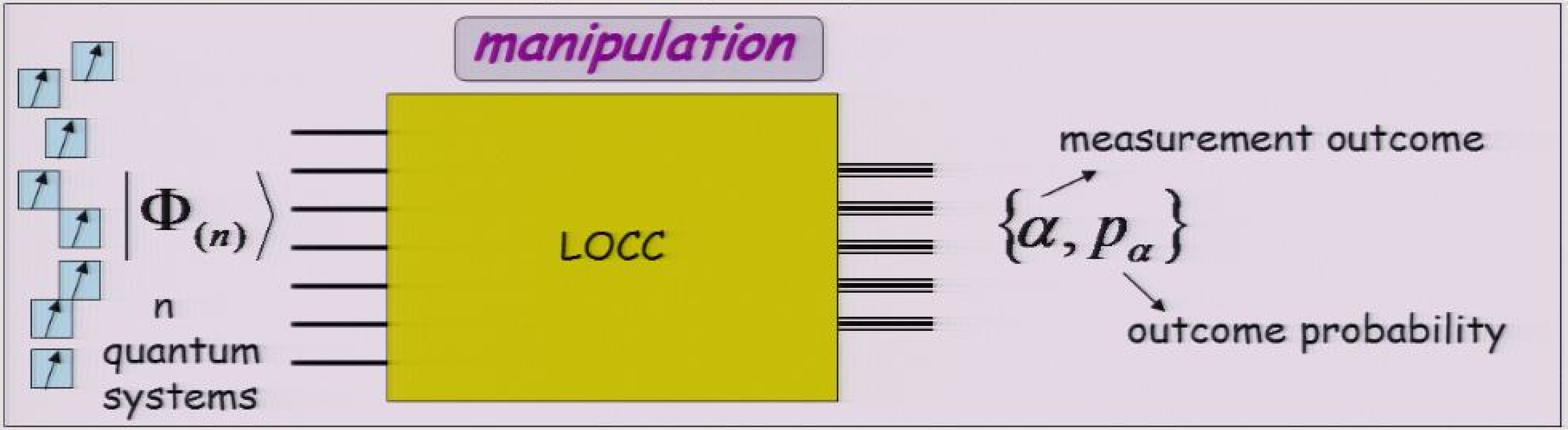

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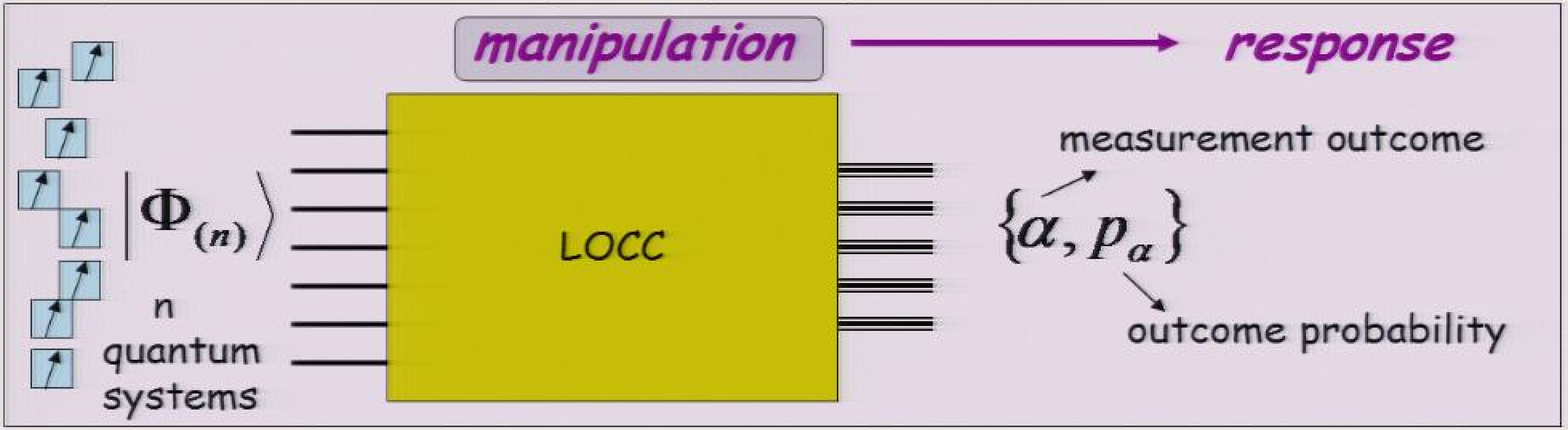

$$\{\alpha, p_\alpha\}$$

classical simulation of $\left|\Phi_{(n)}\right\rangle$

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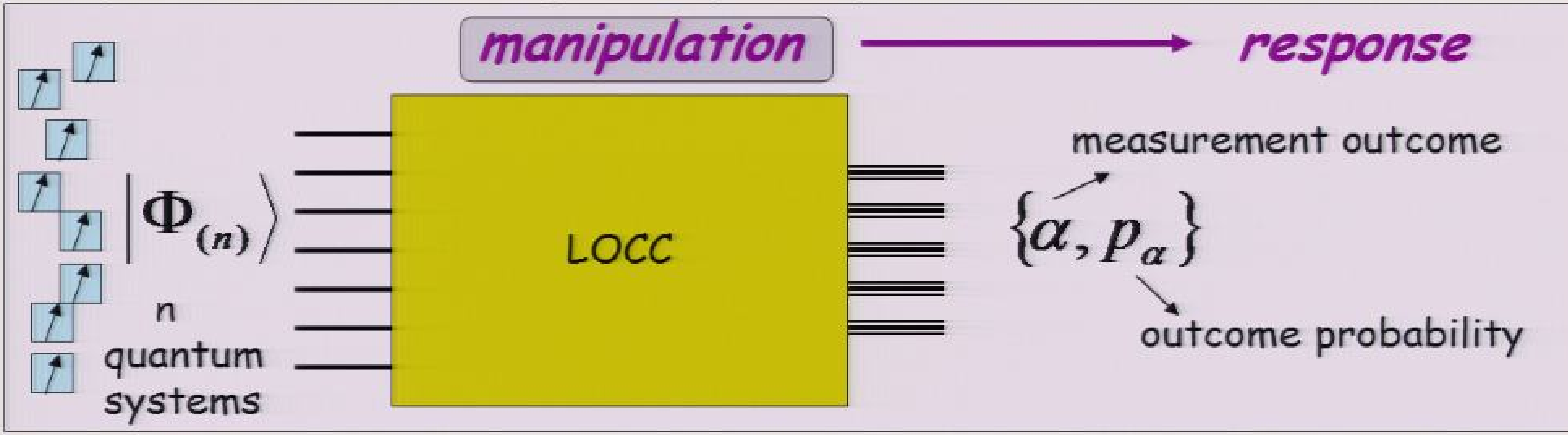

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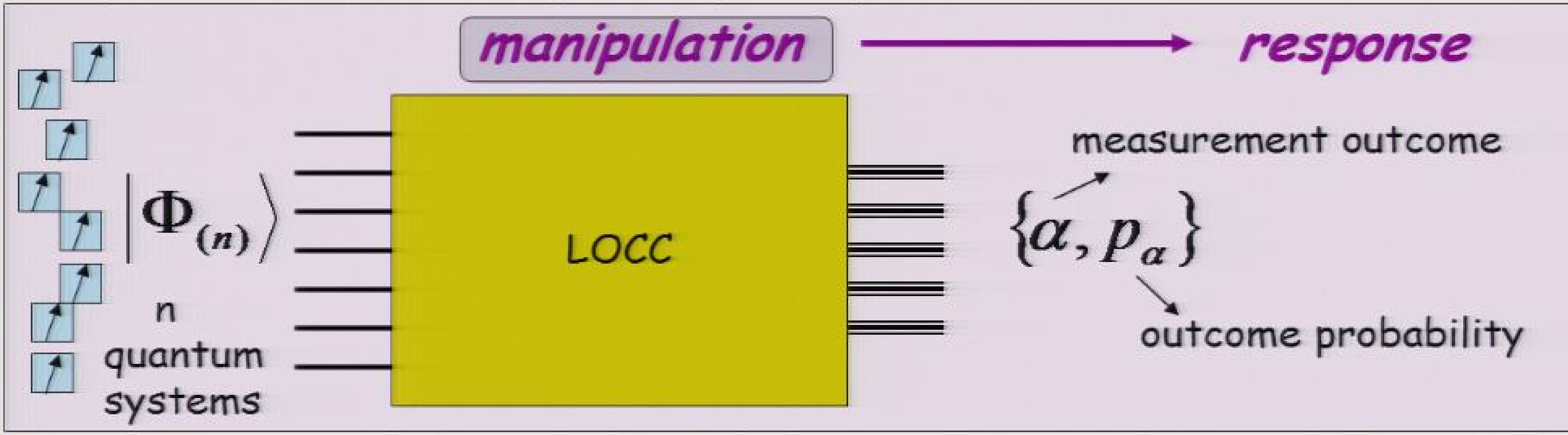

classical simulation of $|\Phi_{(n)}\rangle$

specification of $|\Phi_{(n)}\rangle$ + *classical computation*

experimental setting: many-body evolution

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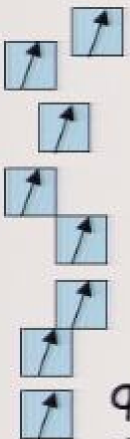

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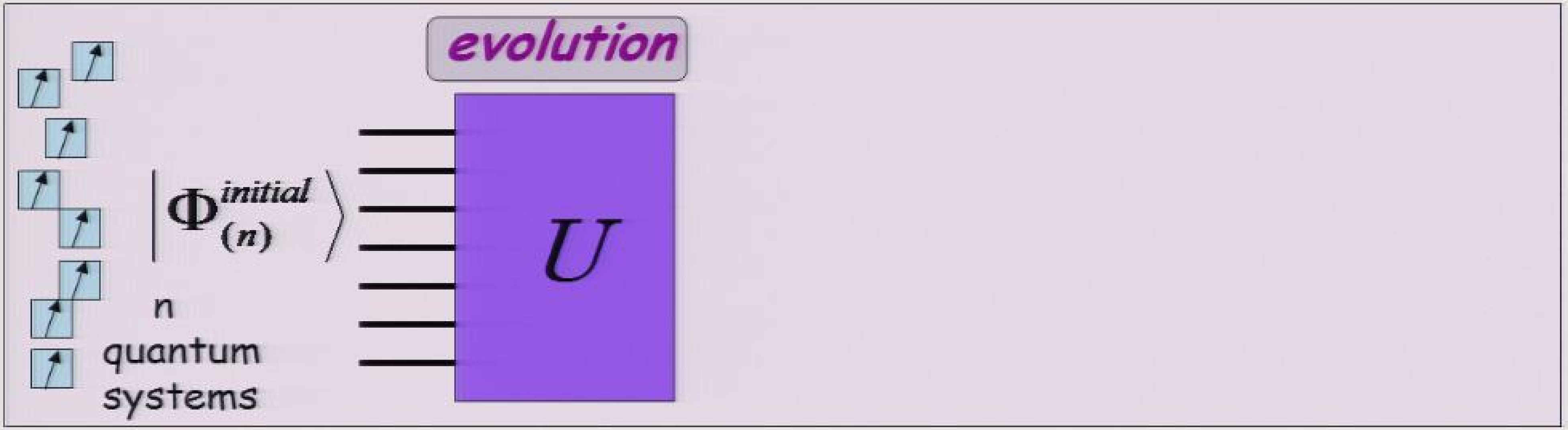

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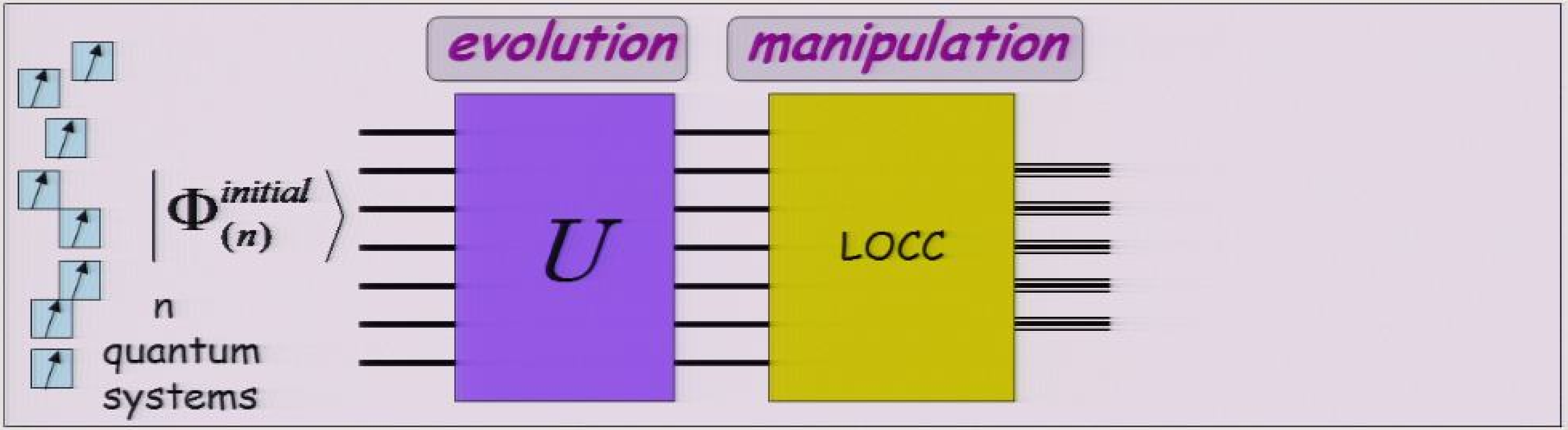

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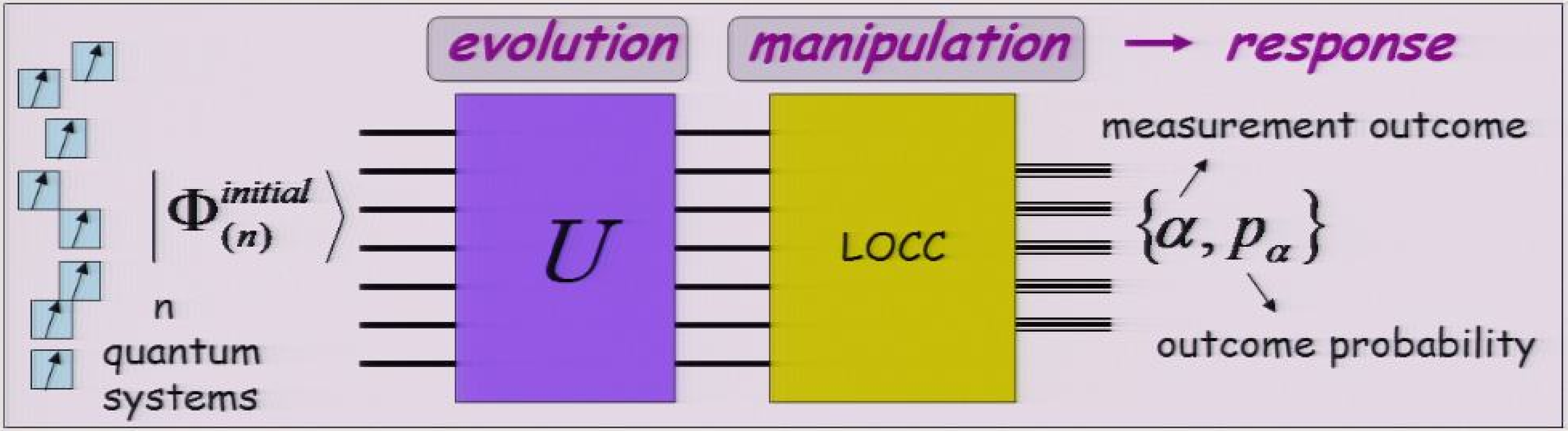

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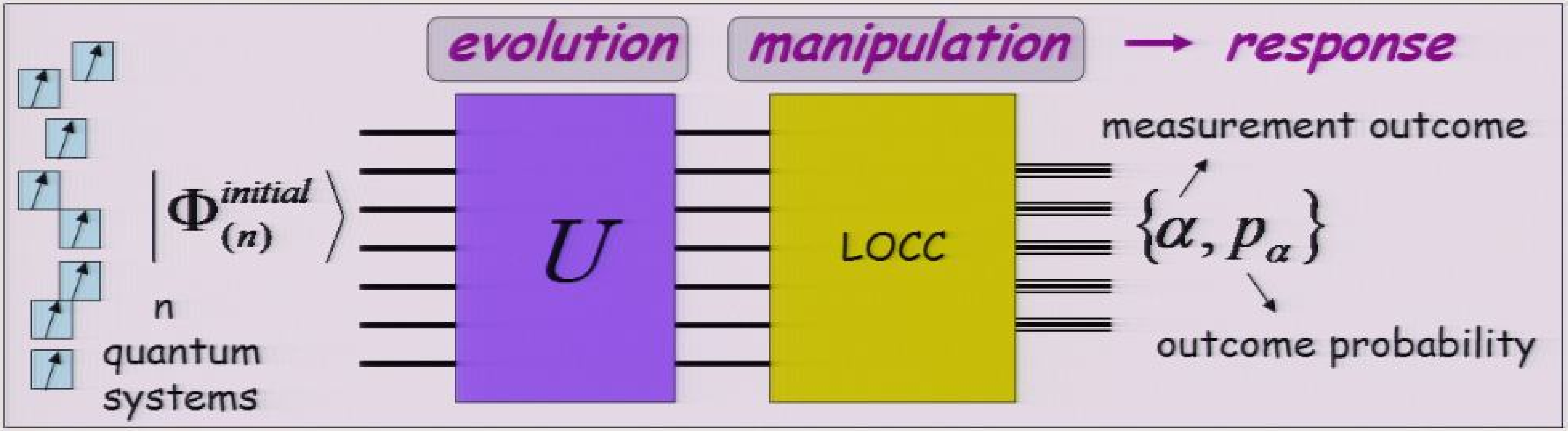

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specification of

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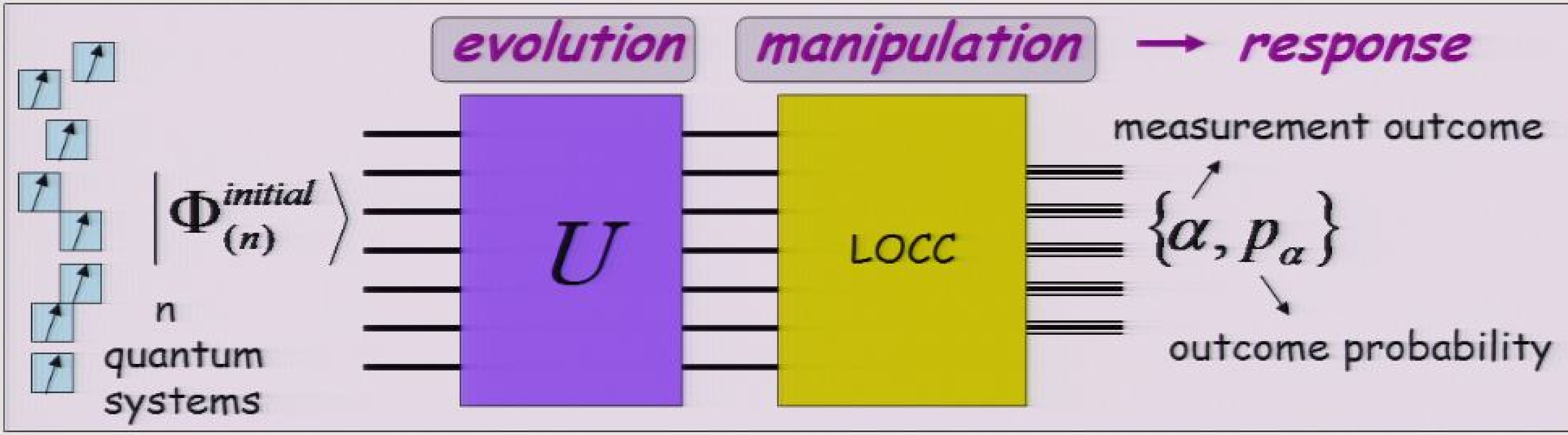

classical simulation of evolution U starting from $\left|\Phi^{initial}_{(n)}\right\rangle$

specification of $\left|\Phi^{initial}_{(n)}\right\rangle$, U + ***classical computation***

- Why do we want to simulate quantum systems ?

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Study of
Quantum Many-Body Systems

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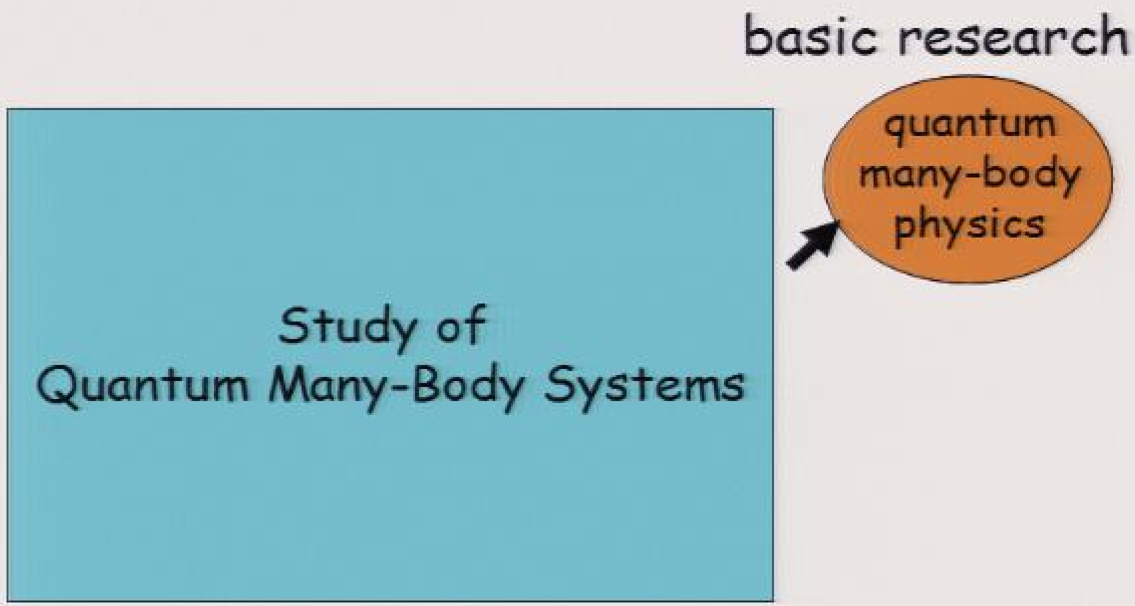

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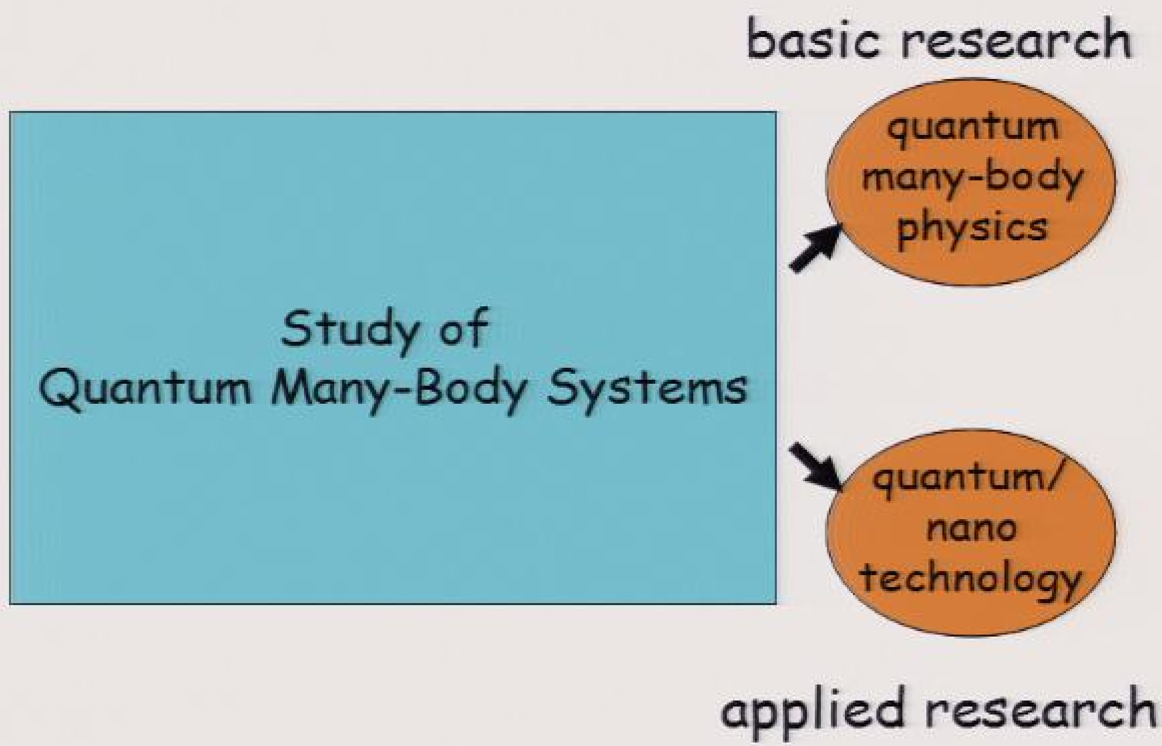

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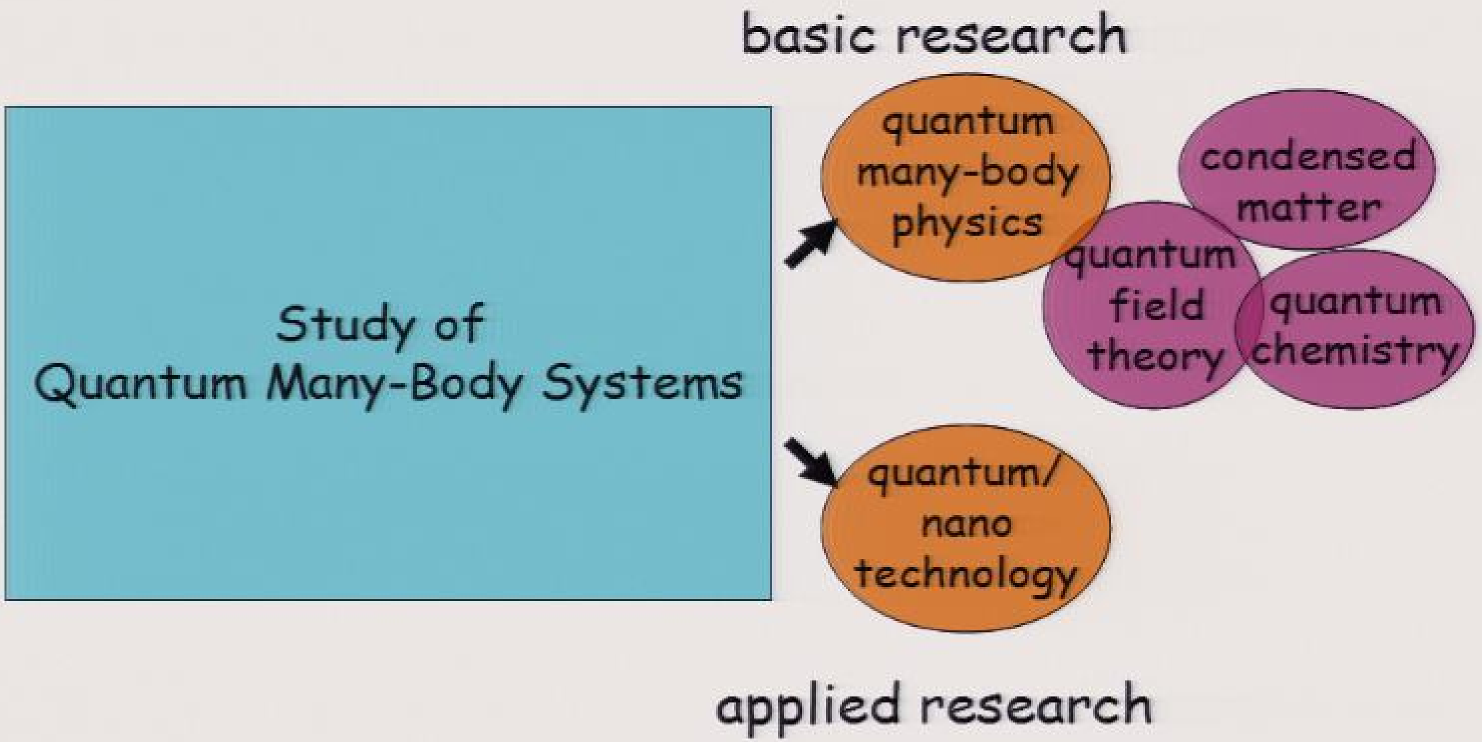

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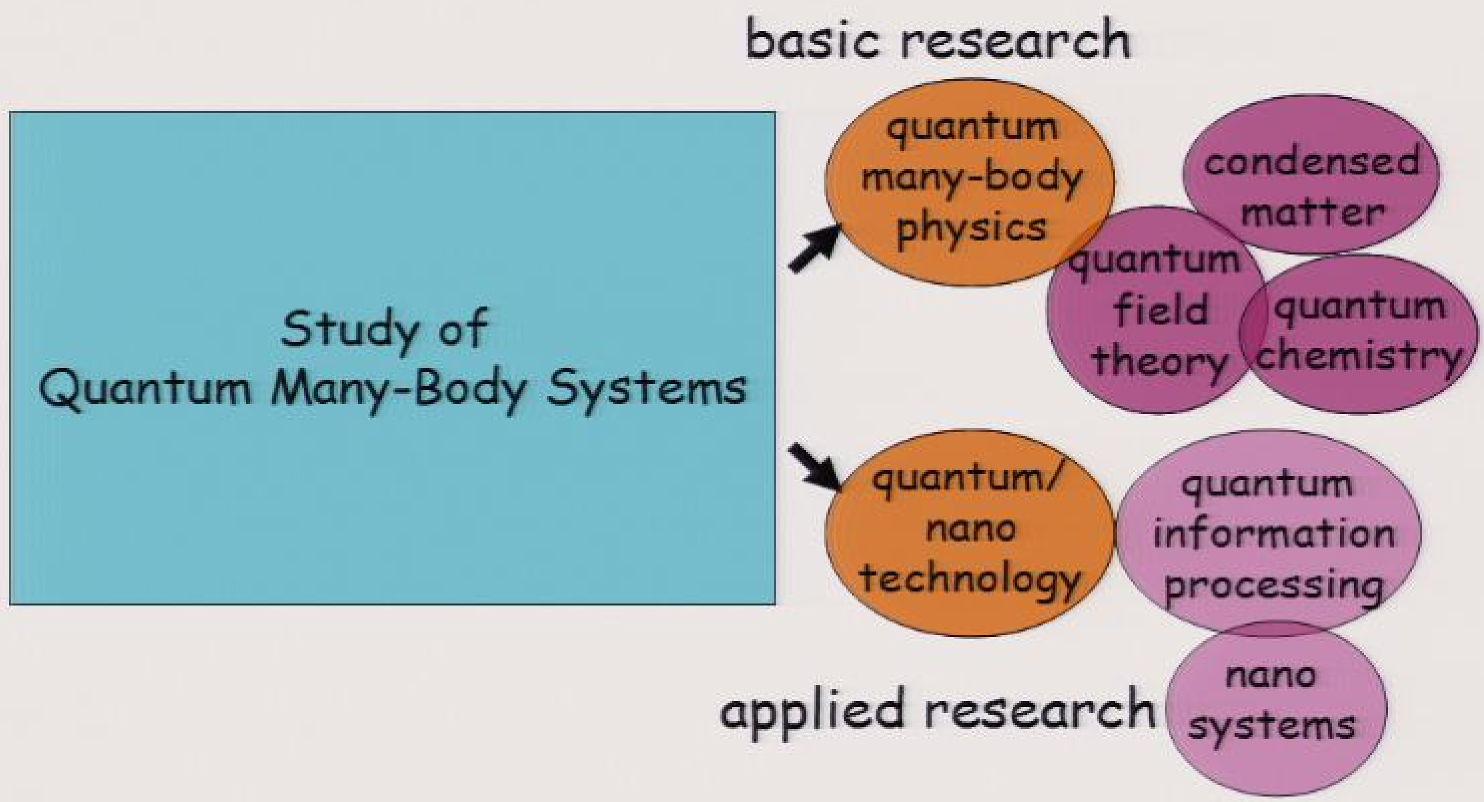

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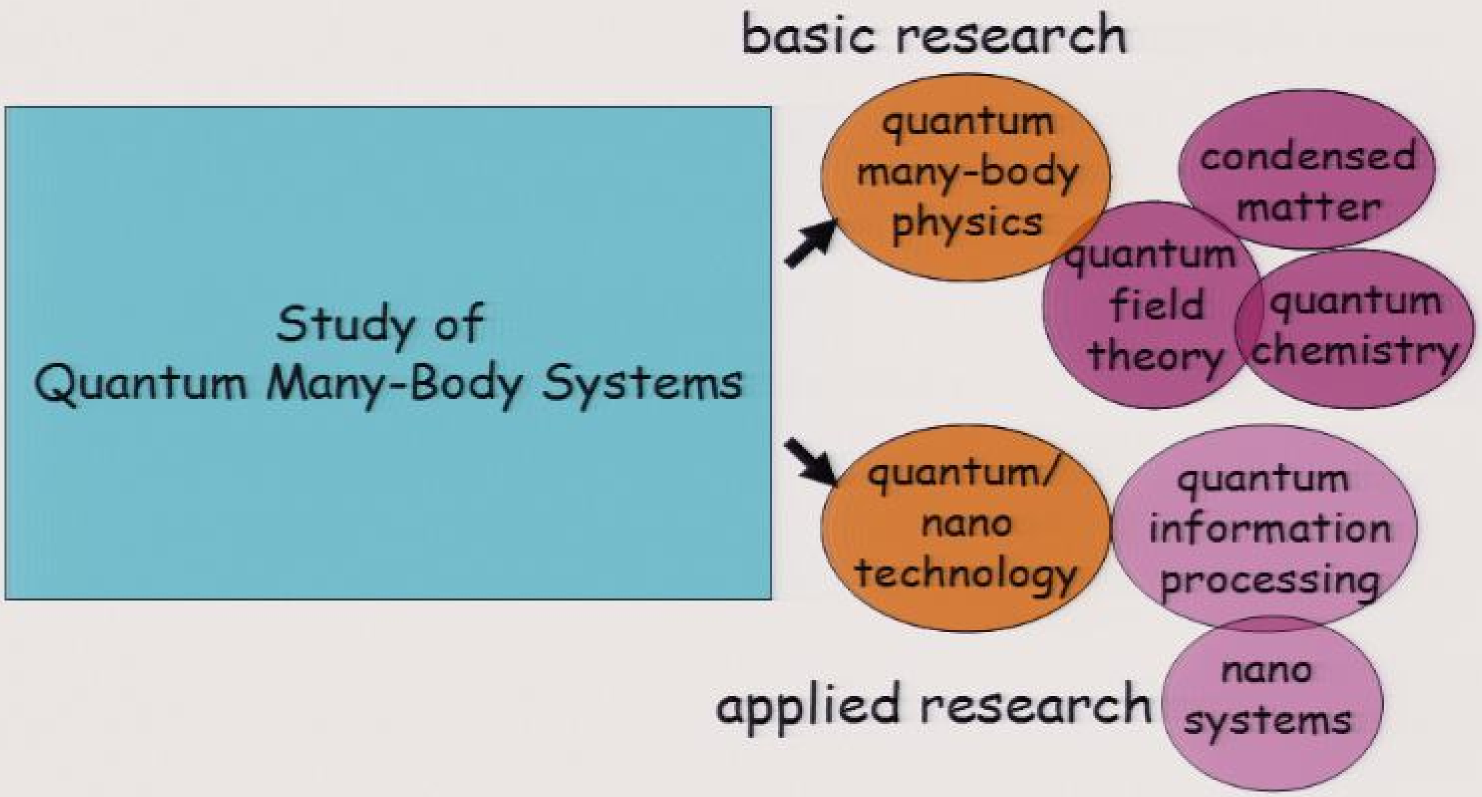

Some simulation algorithms are known [quantum montecarlo, density functional theory, density matrix renormalization group, …] but they only apply to very specific situations.

straightforward classical simulation

$$\dim H_n = 2^n$$

dimension of Hilbert space is exponentially large in n

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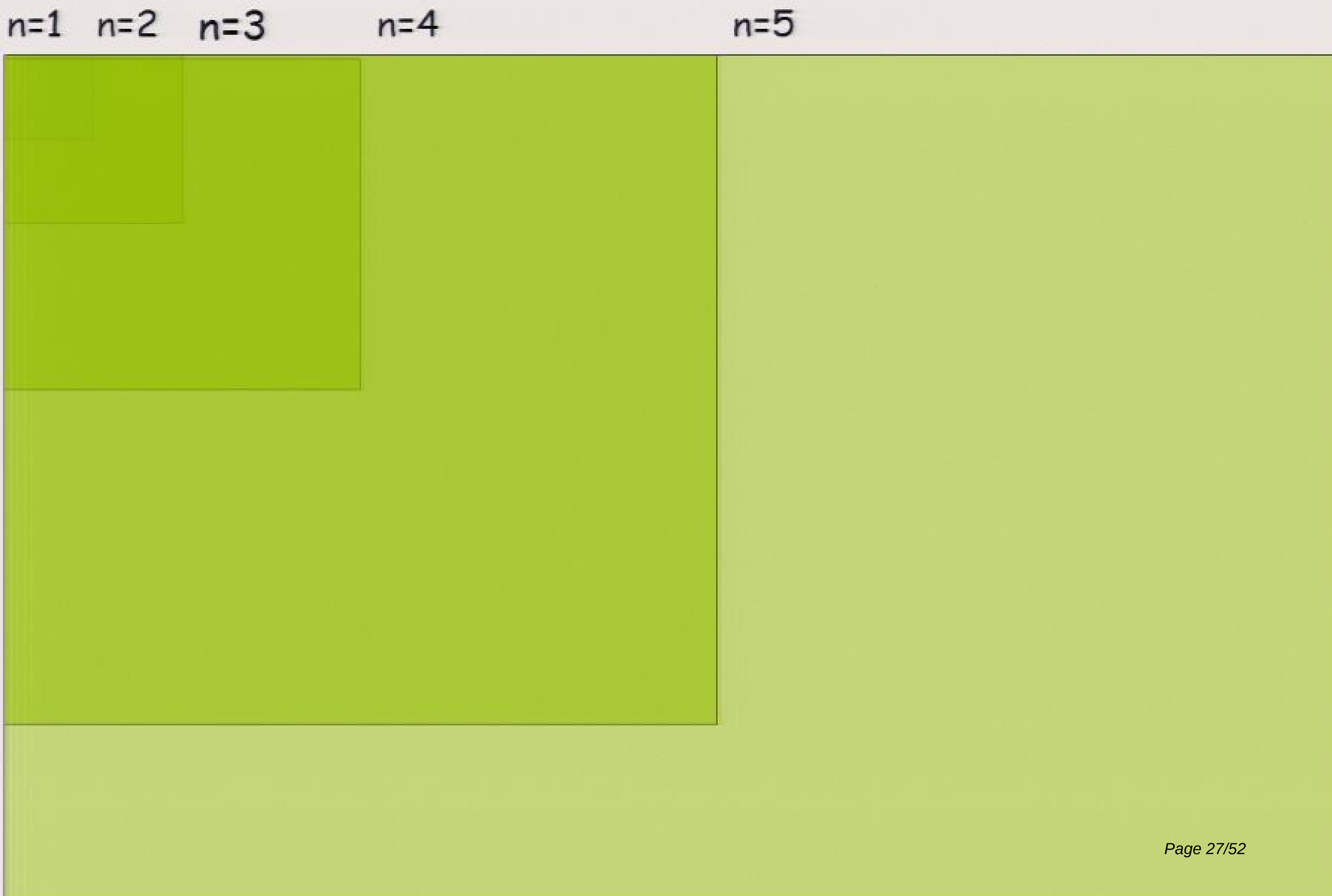

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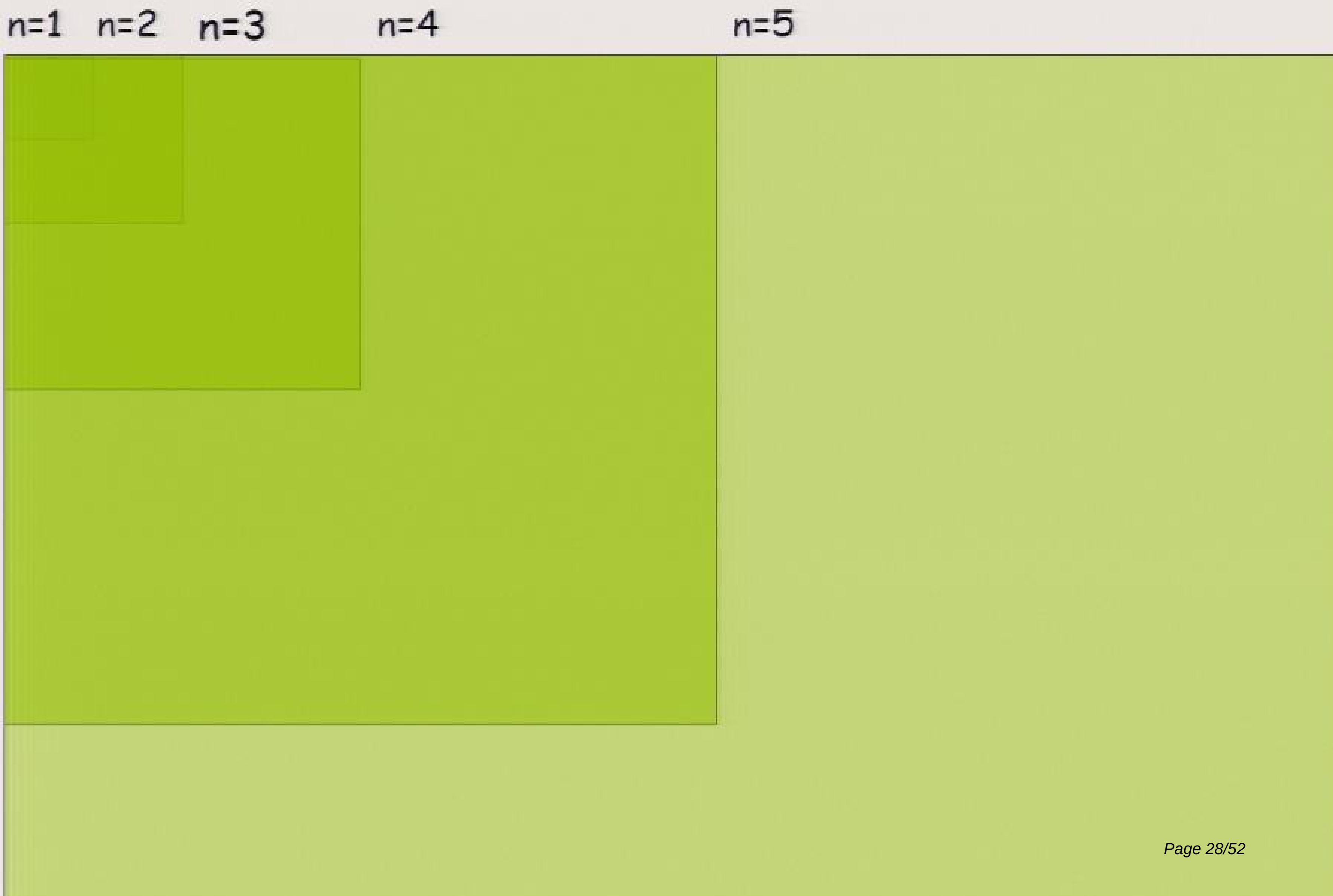

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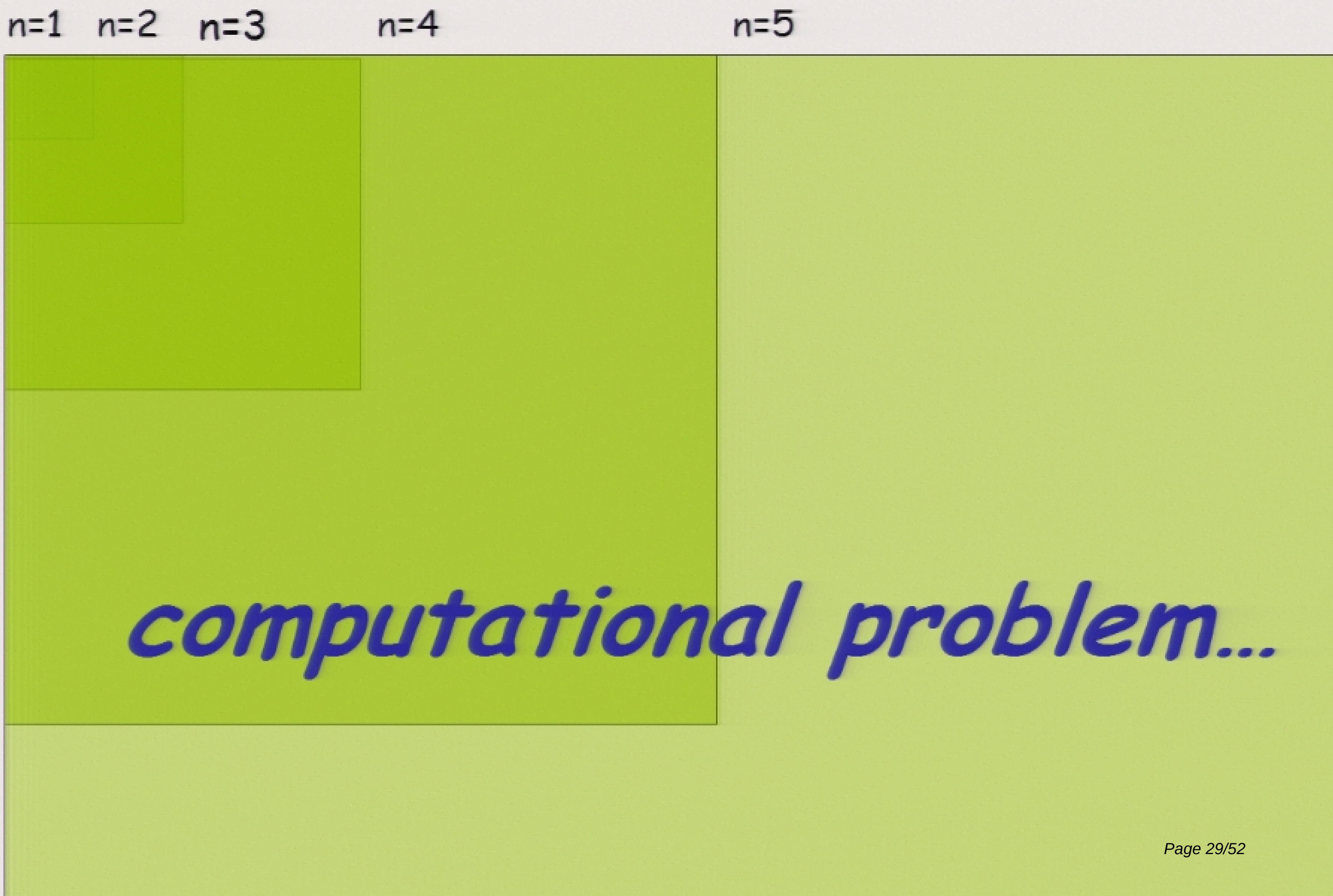

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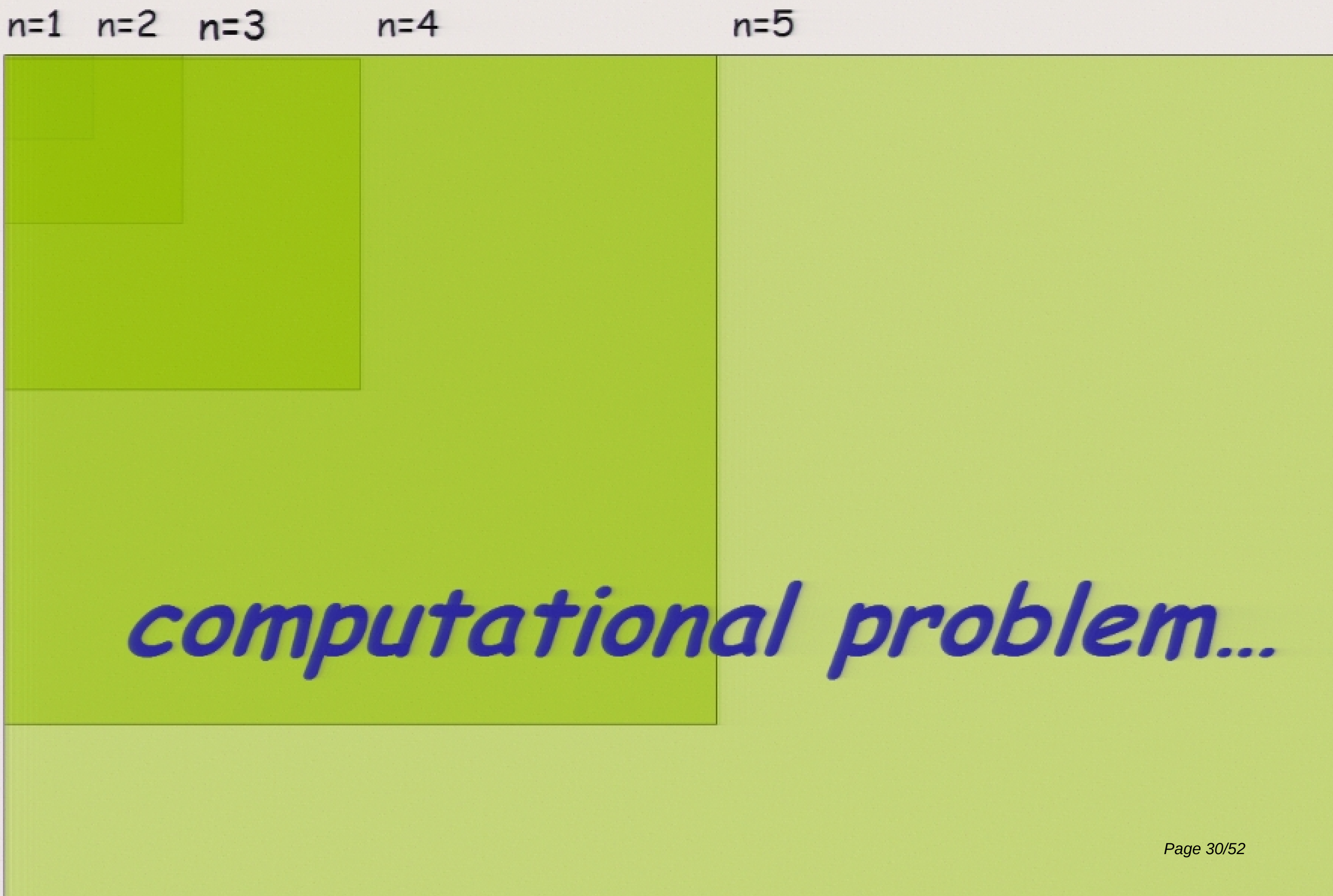

computational problem...

2 - Efficient Decomposition vs Efficient Simulation

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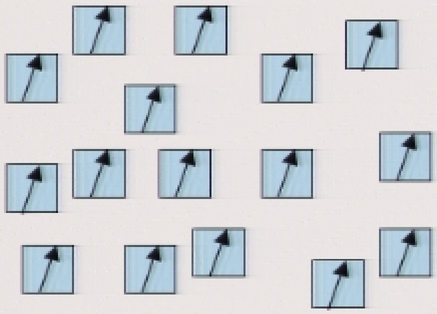

n quantum systems

generic state

$$\left|\Phi_{(n)}\right\rangle = \sum_{i_1 \cdots i_n} C_{i_1 \cdots i_n} \left|i_1\right\rangle \cdots \left|i_n\right\rangle$$

2^n

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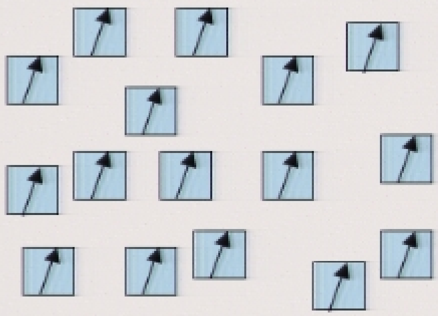

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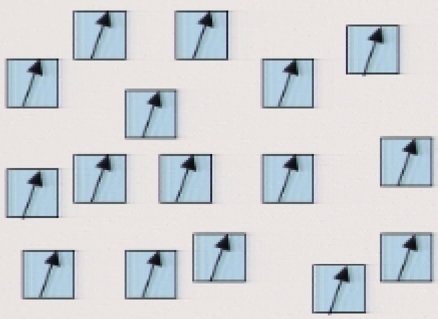

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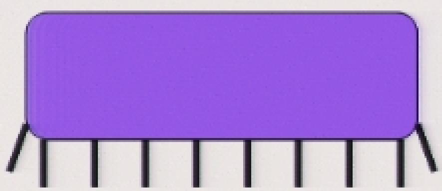

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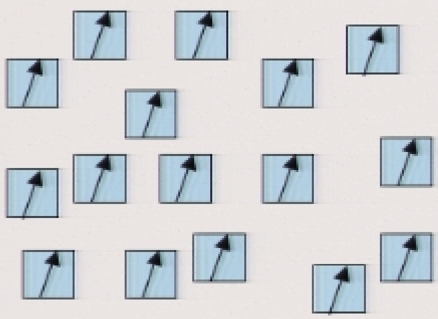

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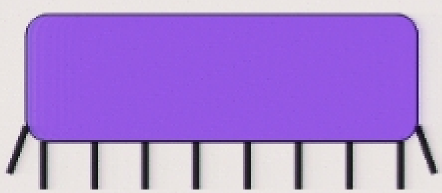

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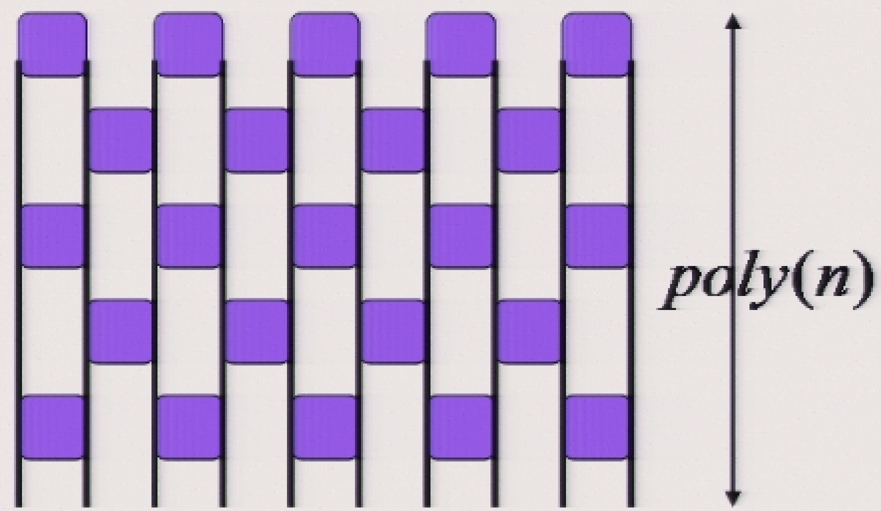

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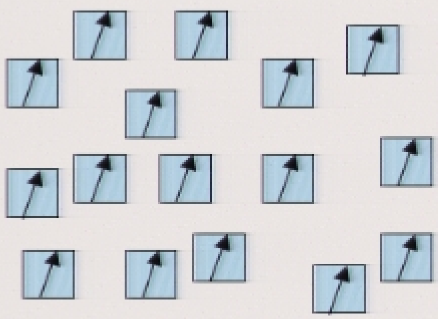

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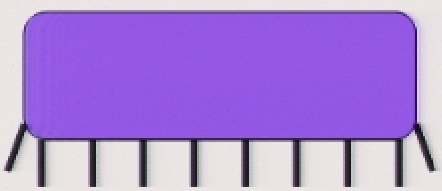

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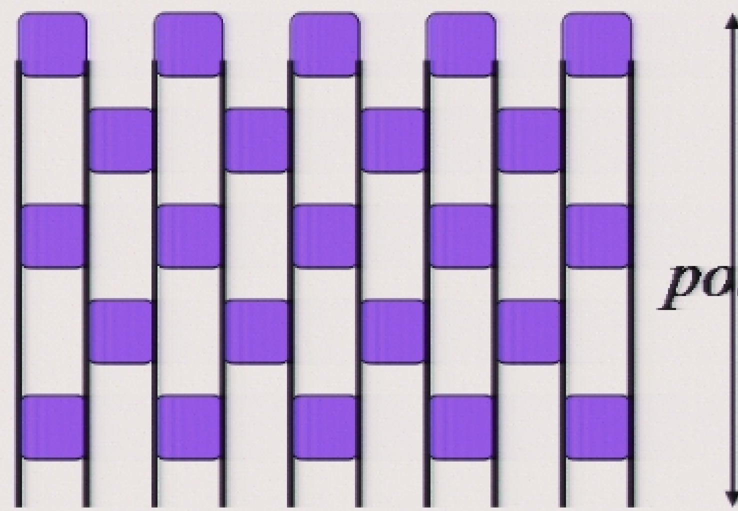
inefficient decomposition



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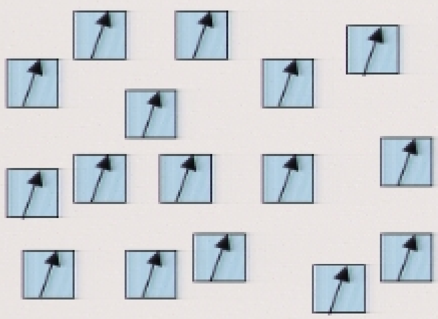

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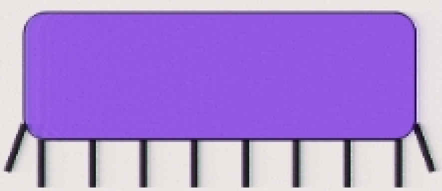

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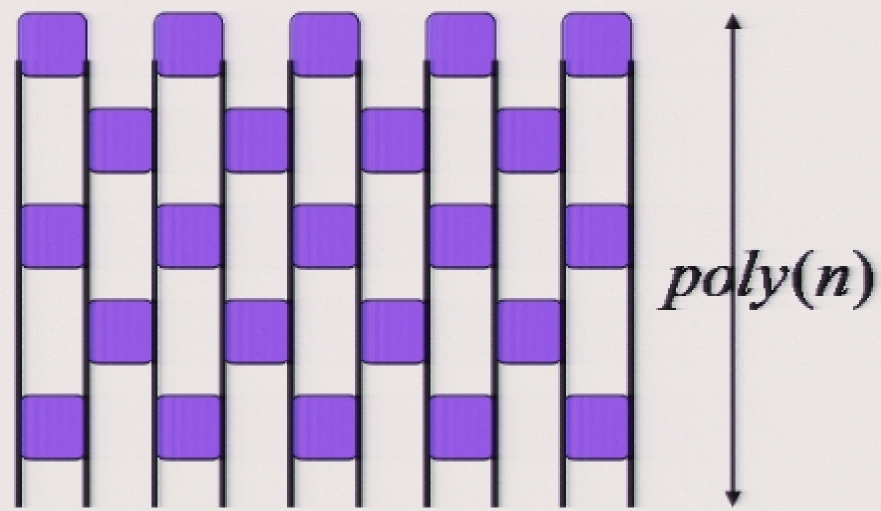

poly(n) parameters

efficient decomposition

Efficient decomposition

Efficient decomposition $\not\Longrightarrow$ Efficient simulation

Computation of a scalar product:

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

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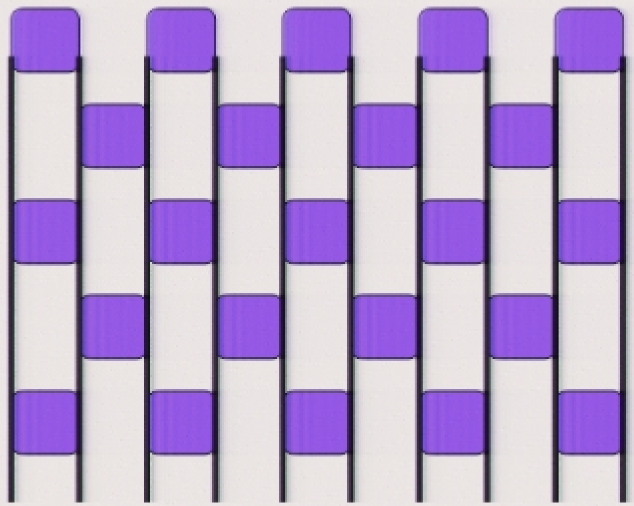

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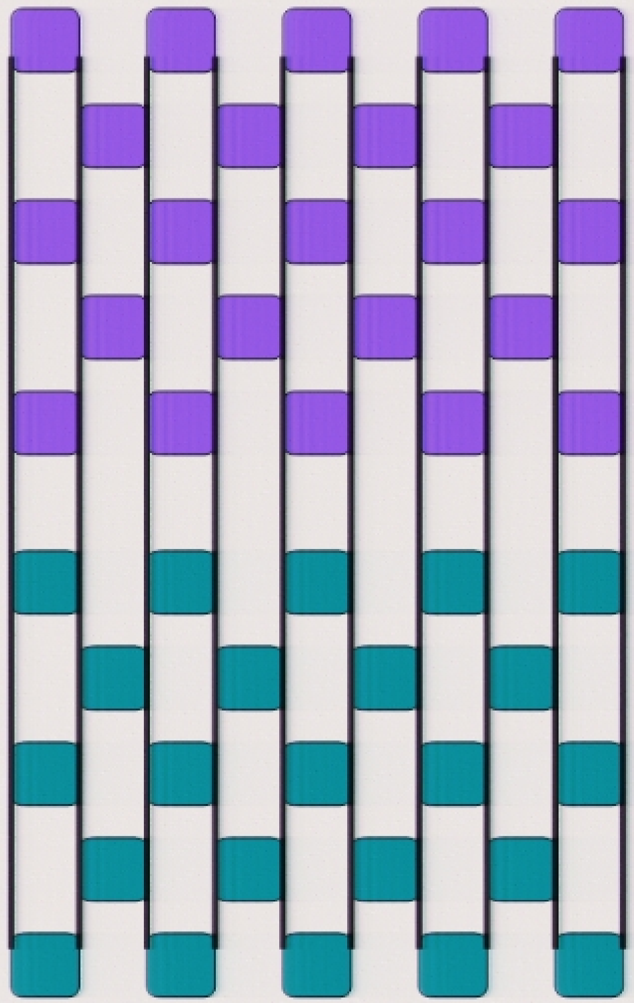

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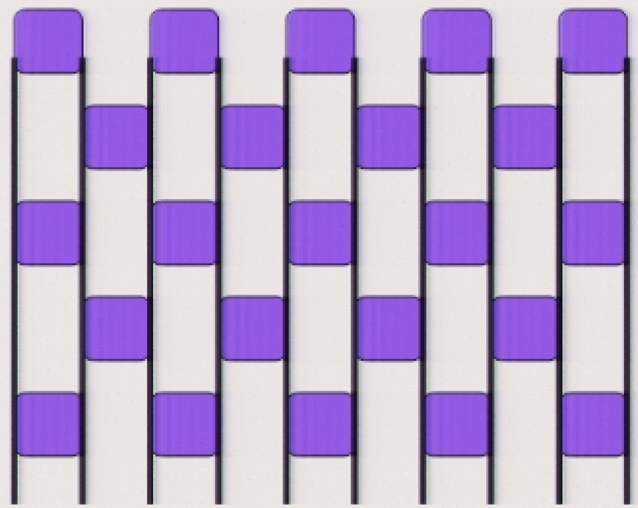

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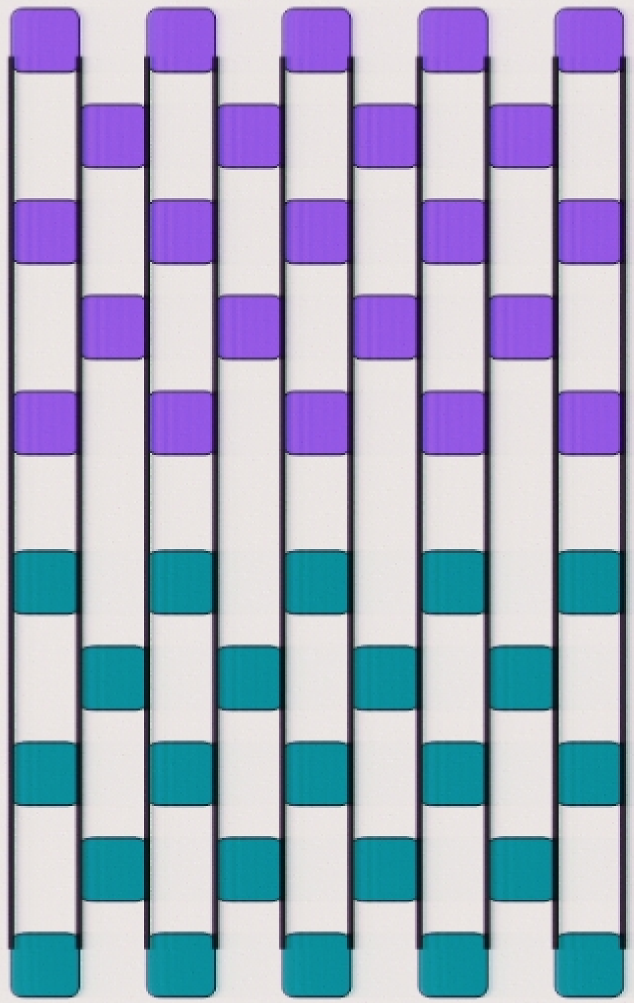

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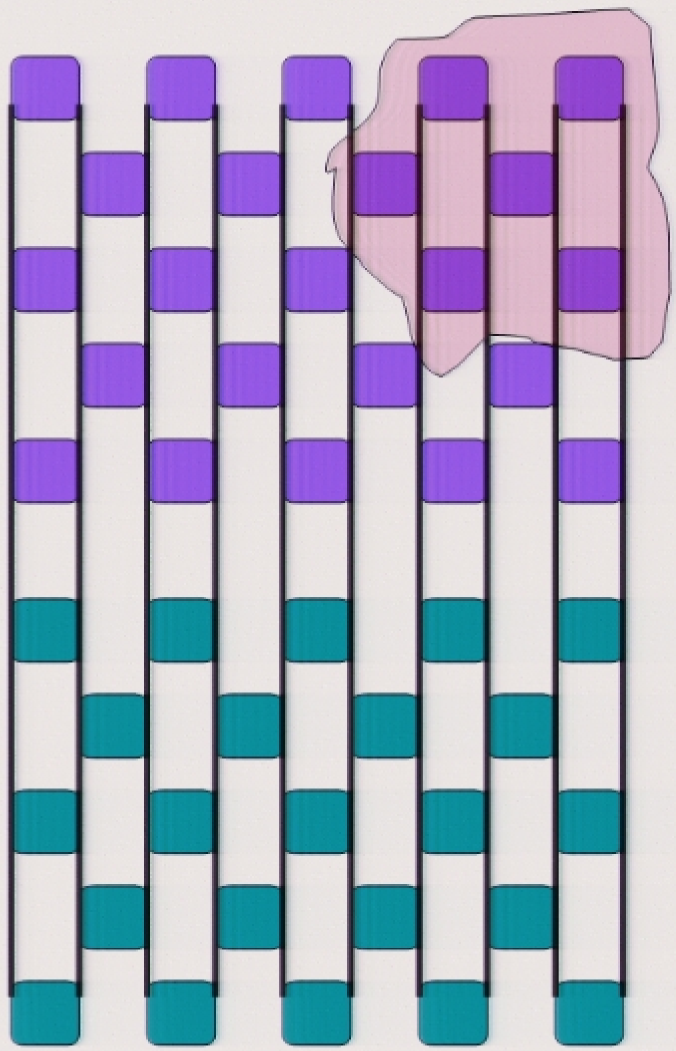

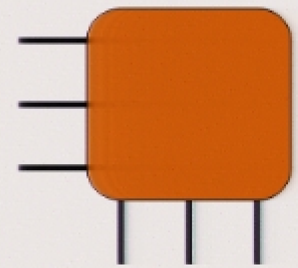

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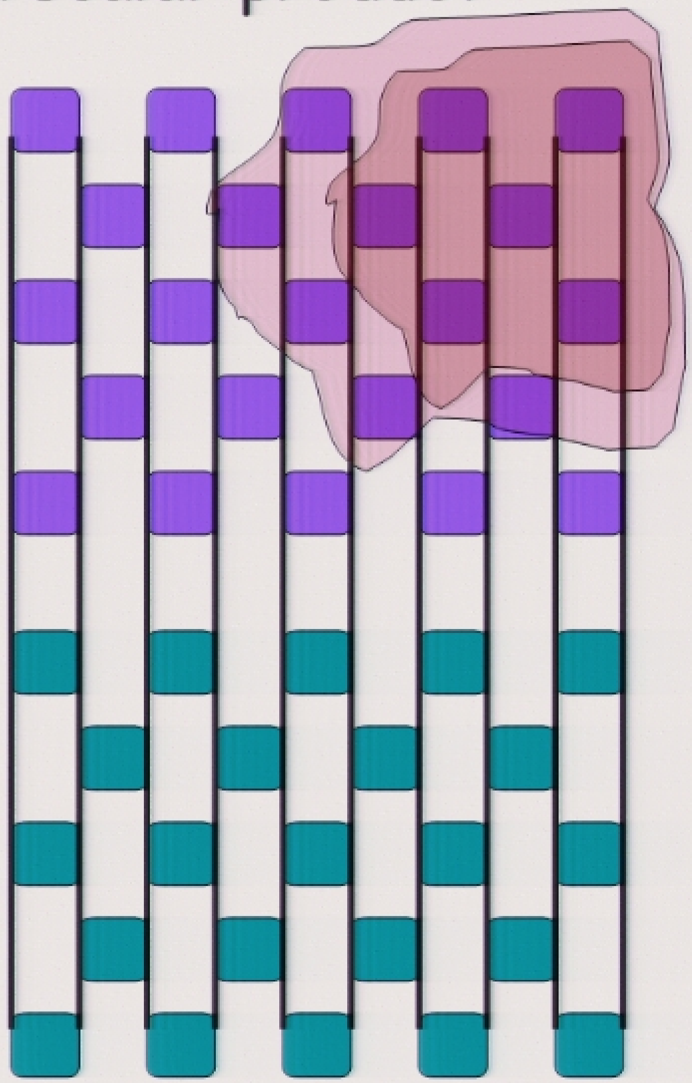

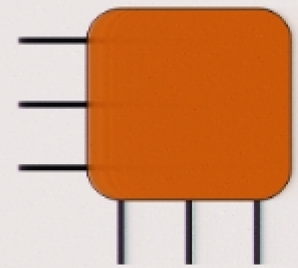

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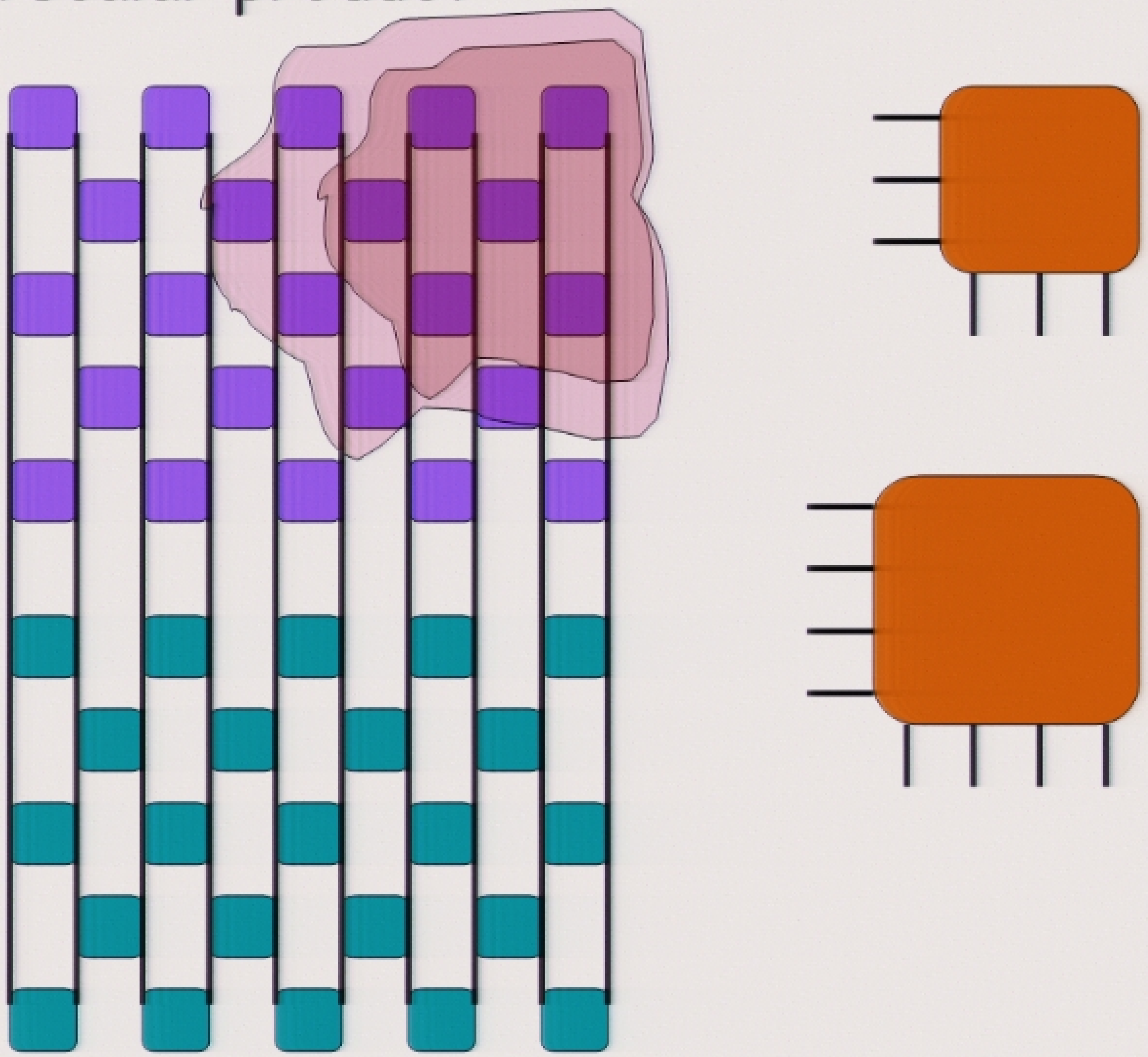

Efficient decomposition

and

Efficient simulation

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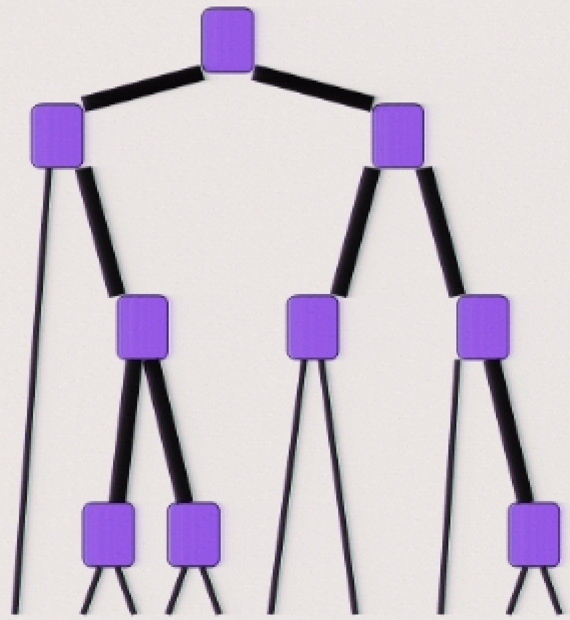
Example:

Tree of small tensors



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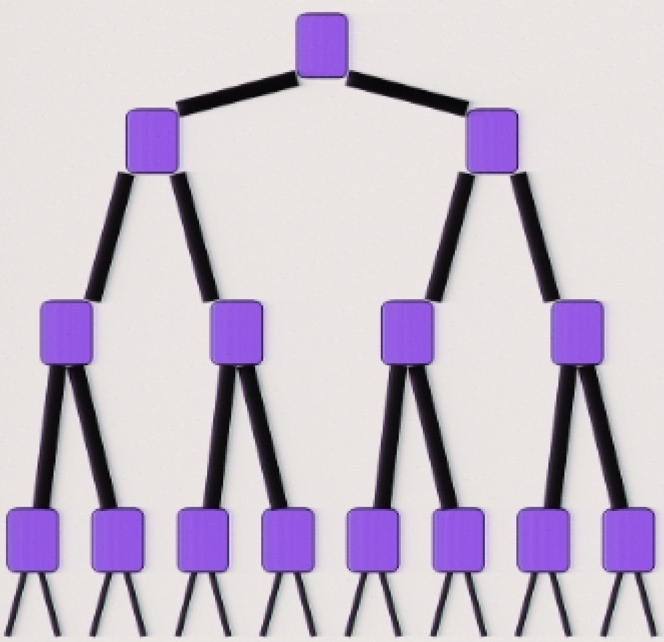
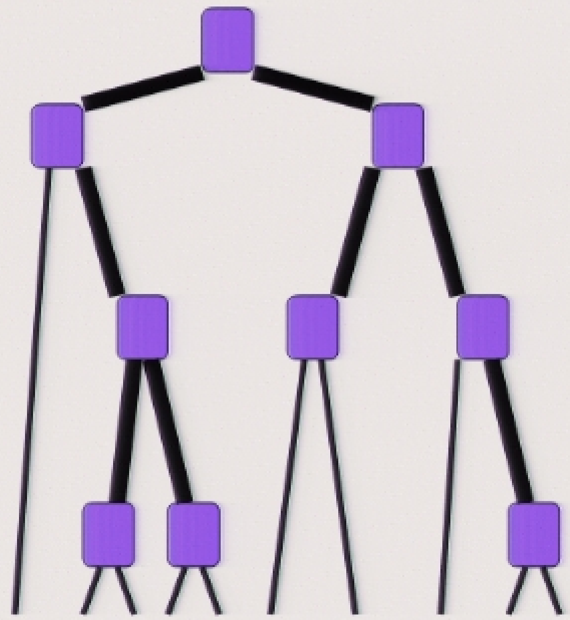
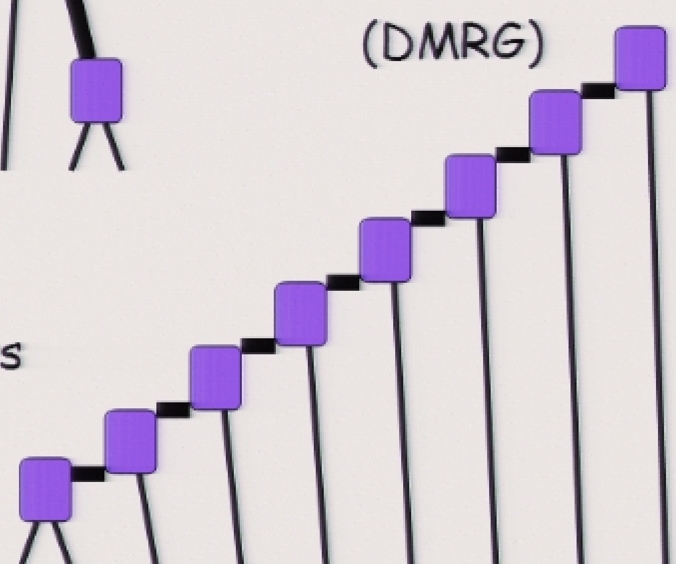




$O(n)$ parameters



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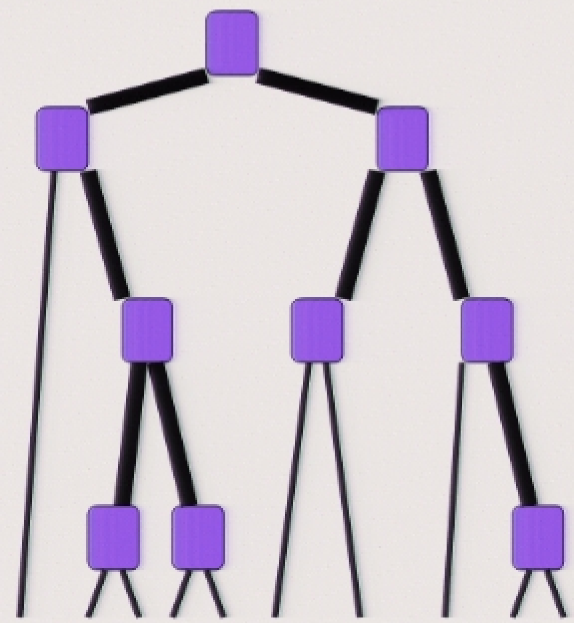

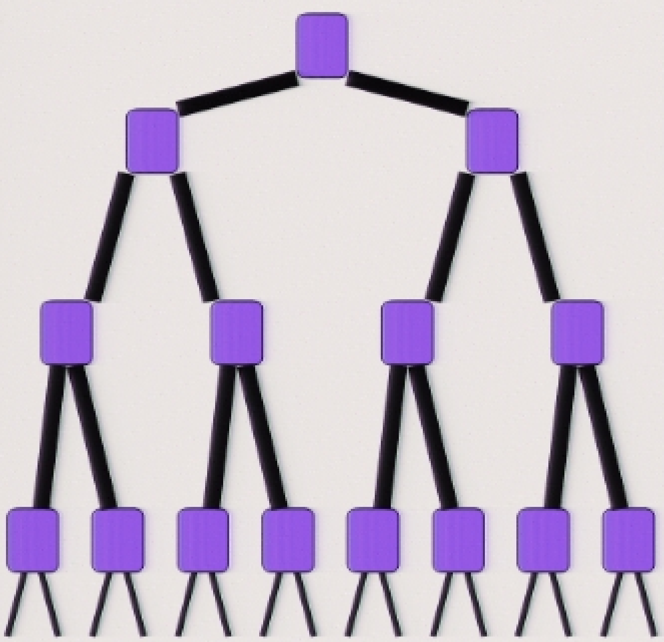

$O(n)$ parameters

(DMRG)