Resetting uncontrolled quantum systems

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MN, arXiv:1710.02470

I invented a time-warping device, ask me how!

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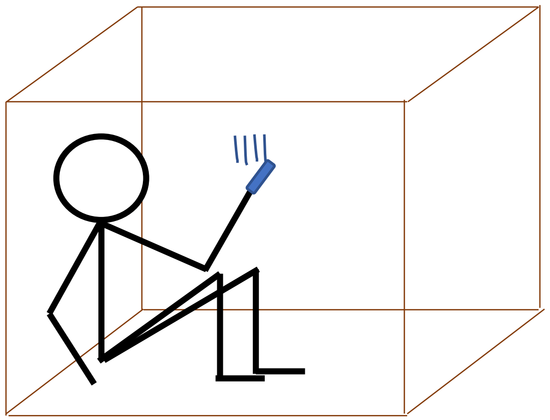
Time-warp

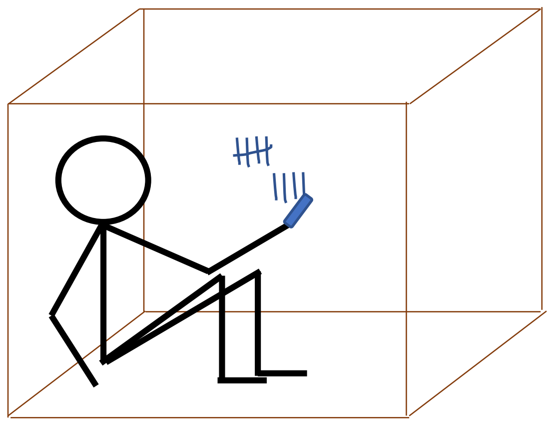
**noun | \ ˈtīm ˈwȯrp **

Definition of TIME-WARP

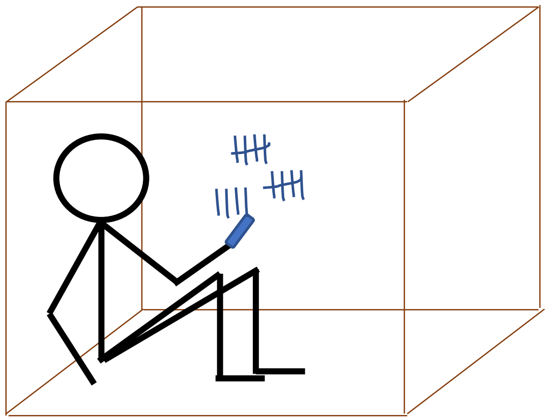
1. an anomaly, discontinuity, or suspension held to occur in the progress of time



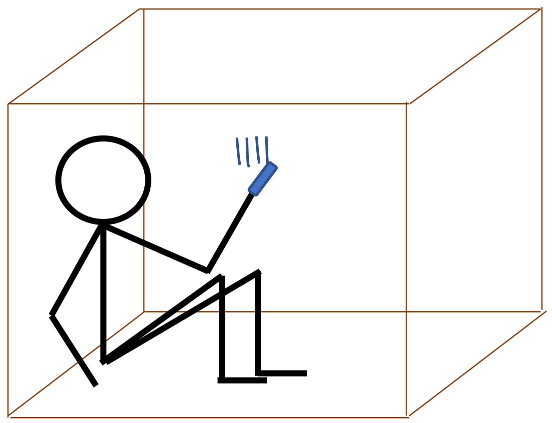
$t = 0$



$t = 1$ hour



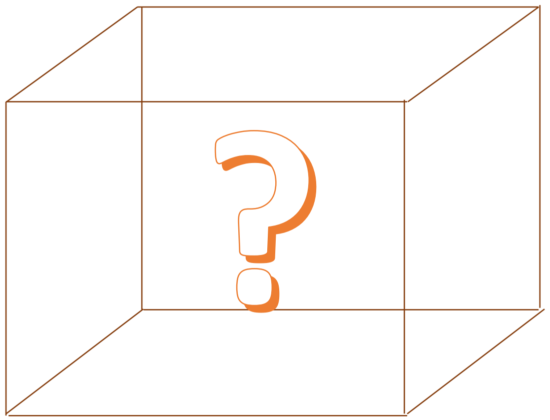
$t = 2$ hours



$t = 0$

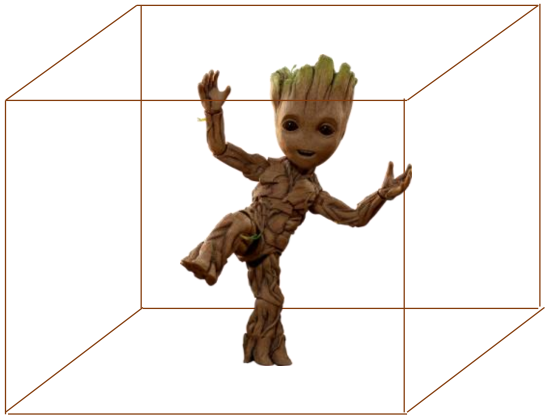
Time warp for two hours

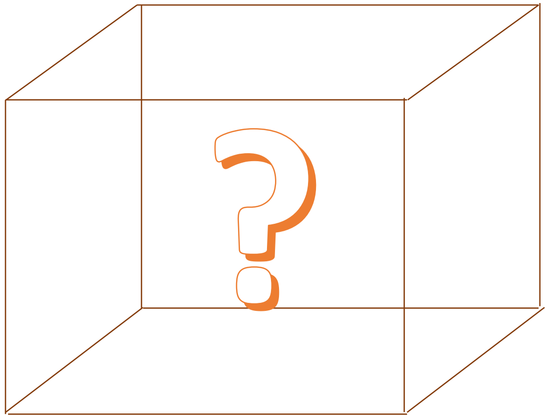
What should we find in the box if we are to claim a time warp experience?



t = 2 hours

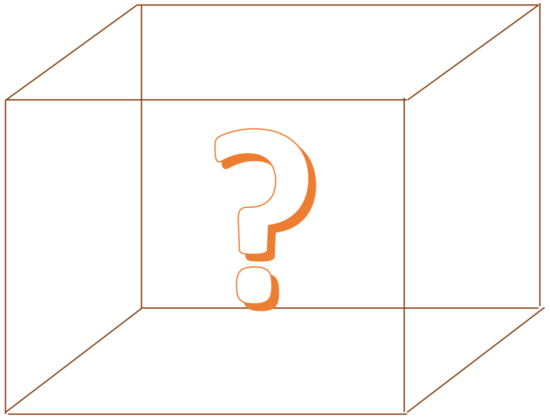
Not expected





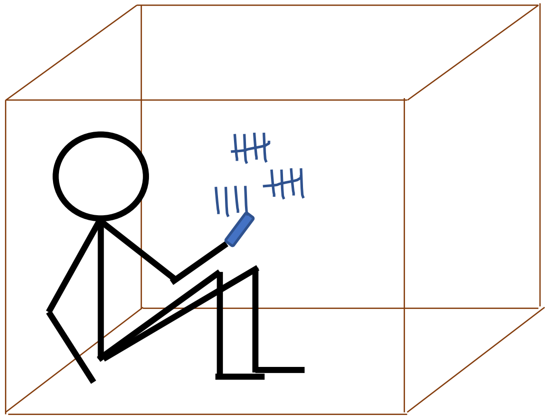
$t = 2$ hours

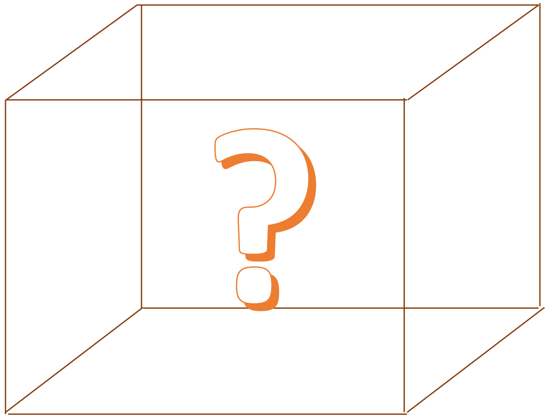
Not expected



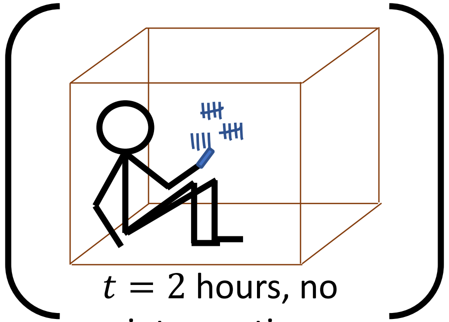
t = 2 hours

Not expected



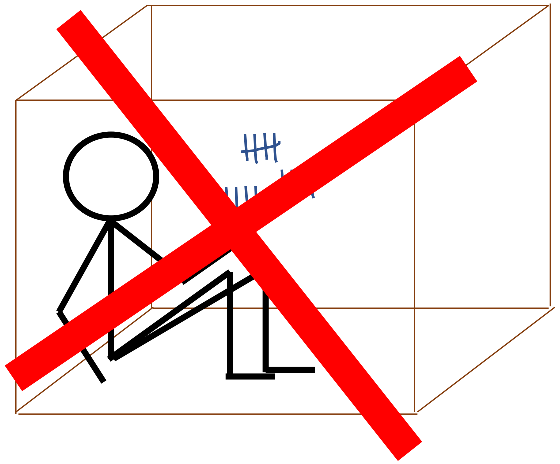


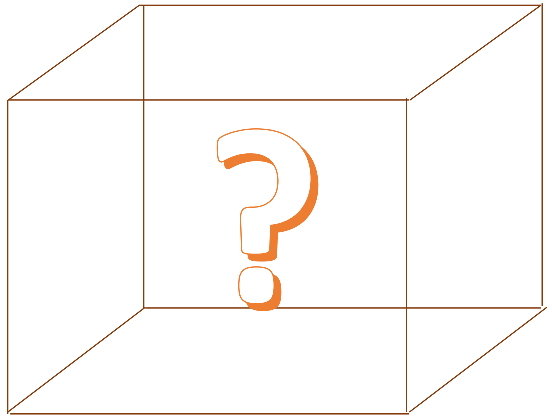
$t = 2$ hours



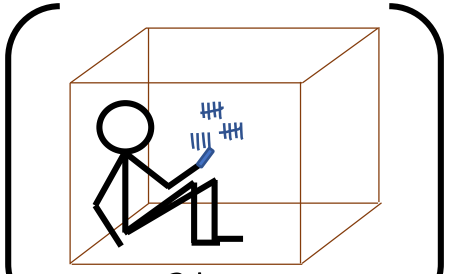
$t = 2$ hours, no intervention

Not expected



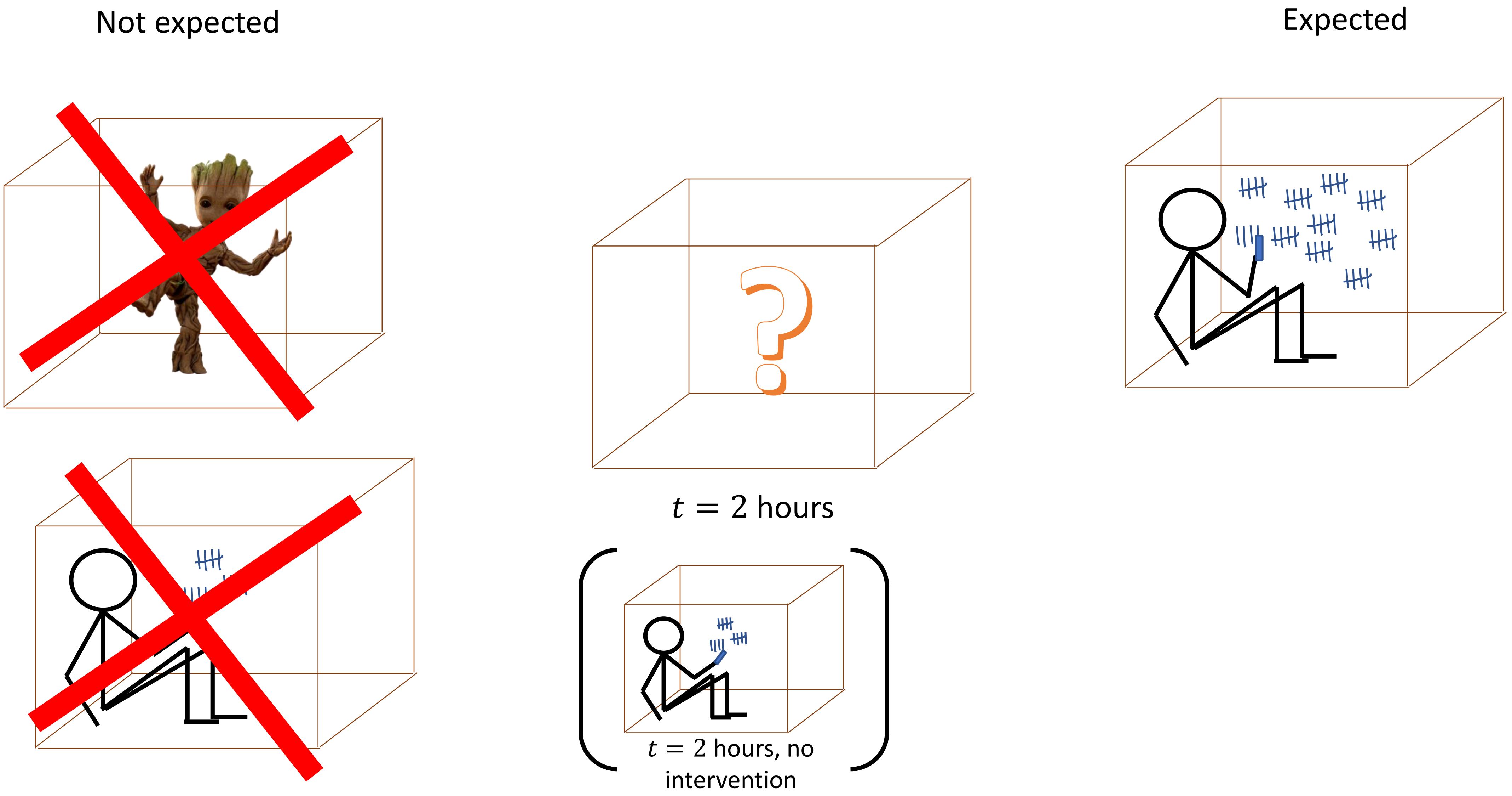


t = 2 hours

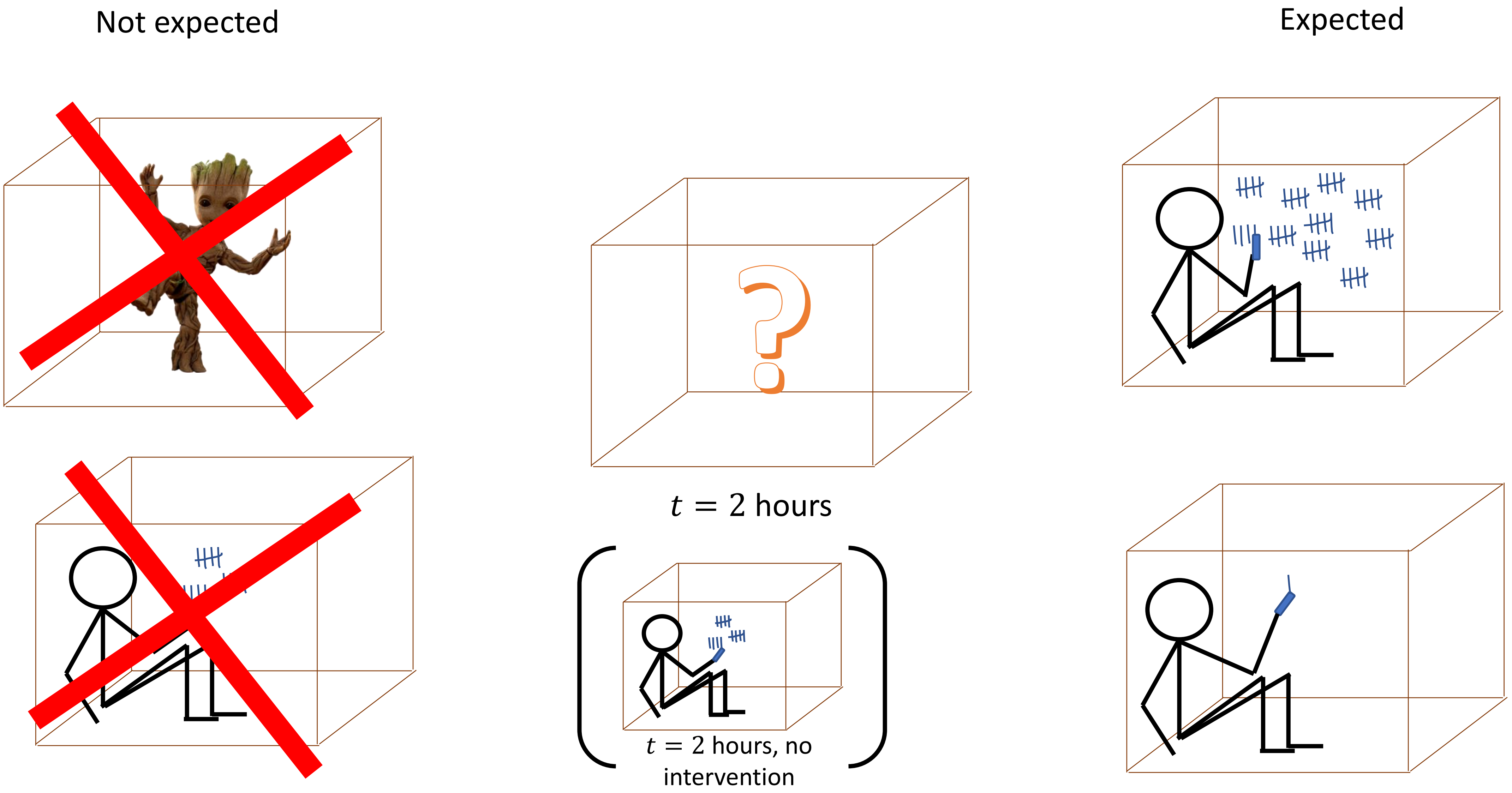


t = 2 hours, no intervention

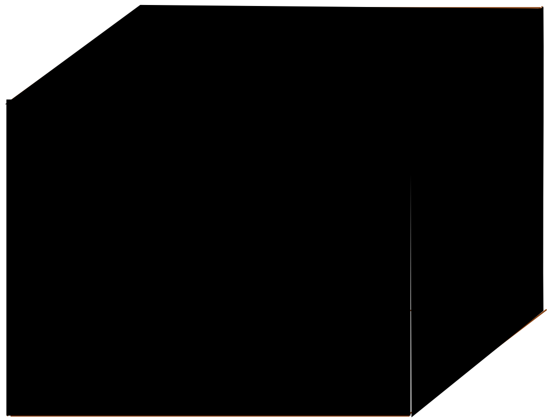
Expected



Not expected
Expected
t = 2 hours
t = 2 hours, no intervention

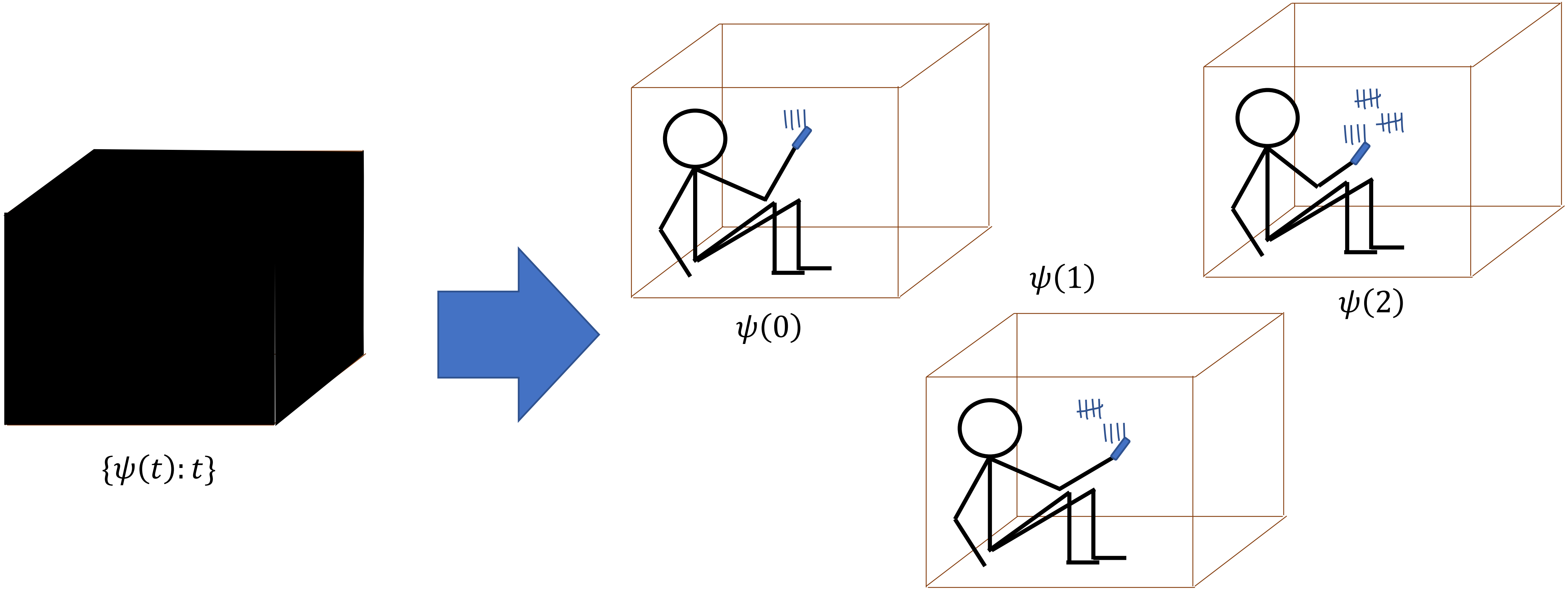

Not expected
Expected
$t = 2$ hours
$t = 2$ hours, no intervention

Time warp: operational definition



$\{\psi(t): t\}$

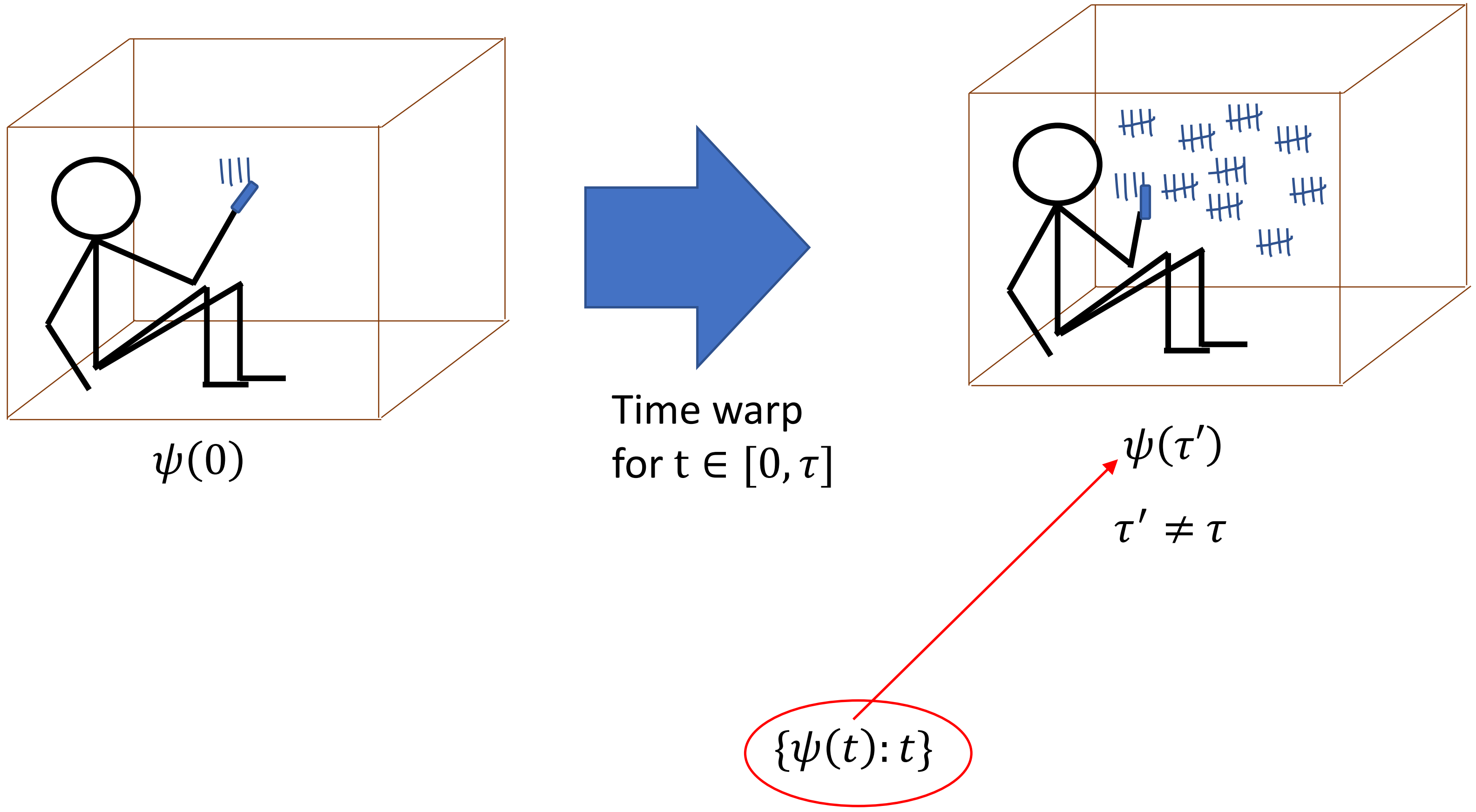
Time warp: operational definition



Time warp: operational definition

Time warp protocol for t $\in [0, \tau]$

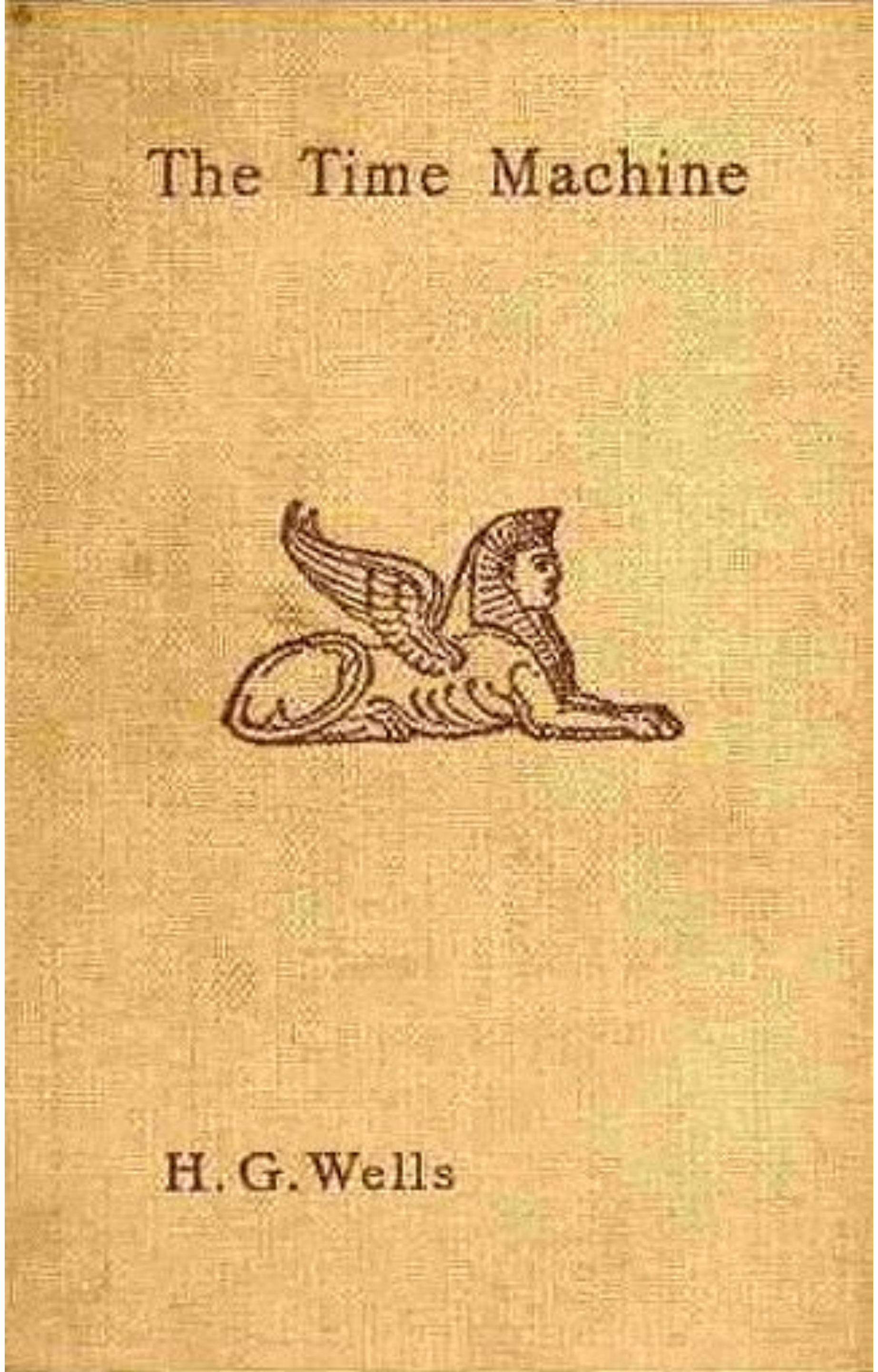
Time warp: operational definition



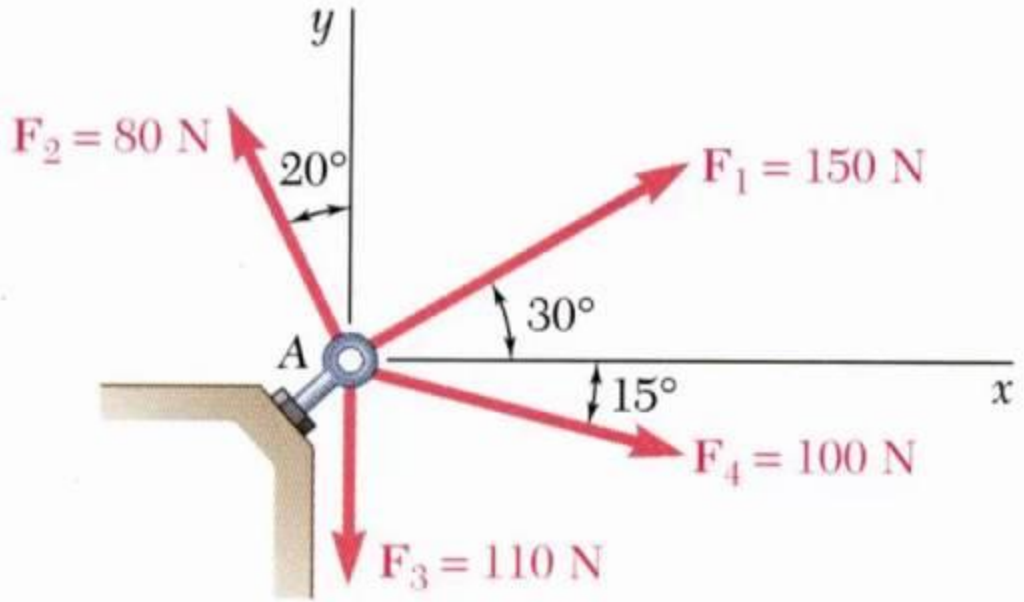

A brief history of time warp

King Raivata and
princess Revati
(400BC?)

Peter Damian
(1007-1072)



(first edition in 1895)

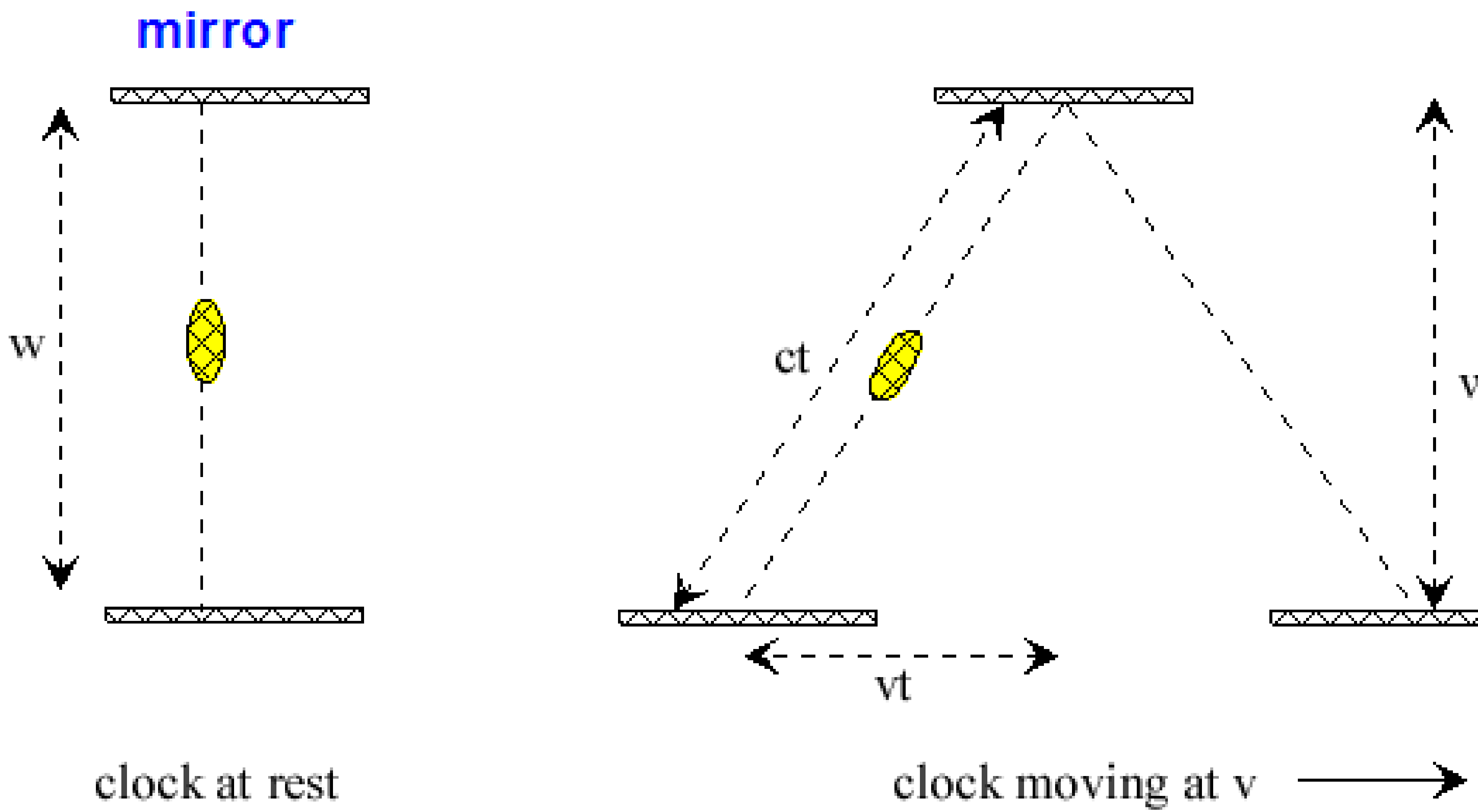


Four forces act on bolt *A* as shown. Determine the resultant of the force on the bolt.

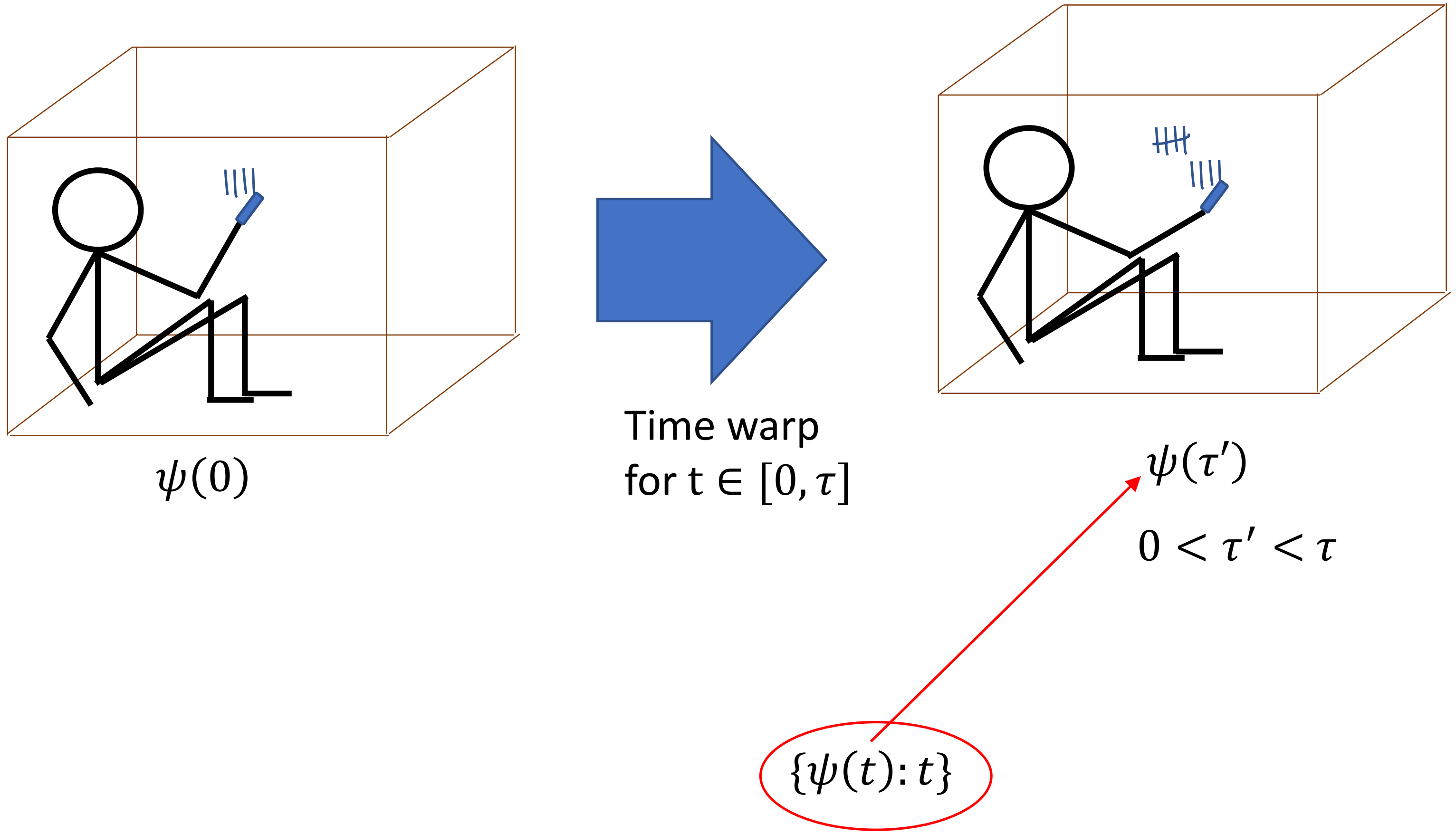
- Resolve each force into rectangular components.
- Determine the components of the resultant by adding the corresponding force components.
- Calculate the magnitude and direction of the resultant.


CALIFORNIA

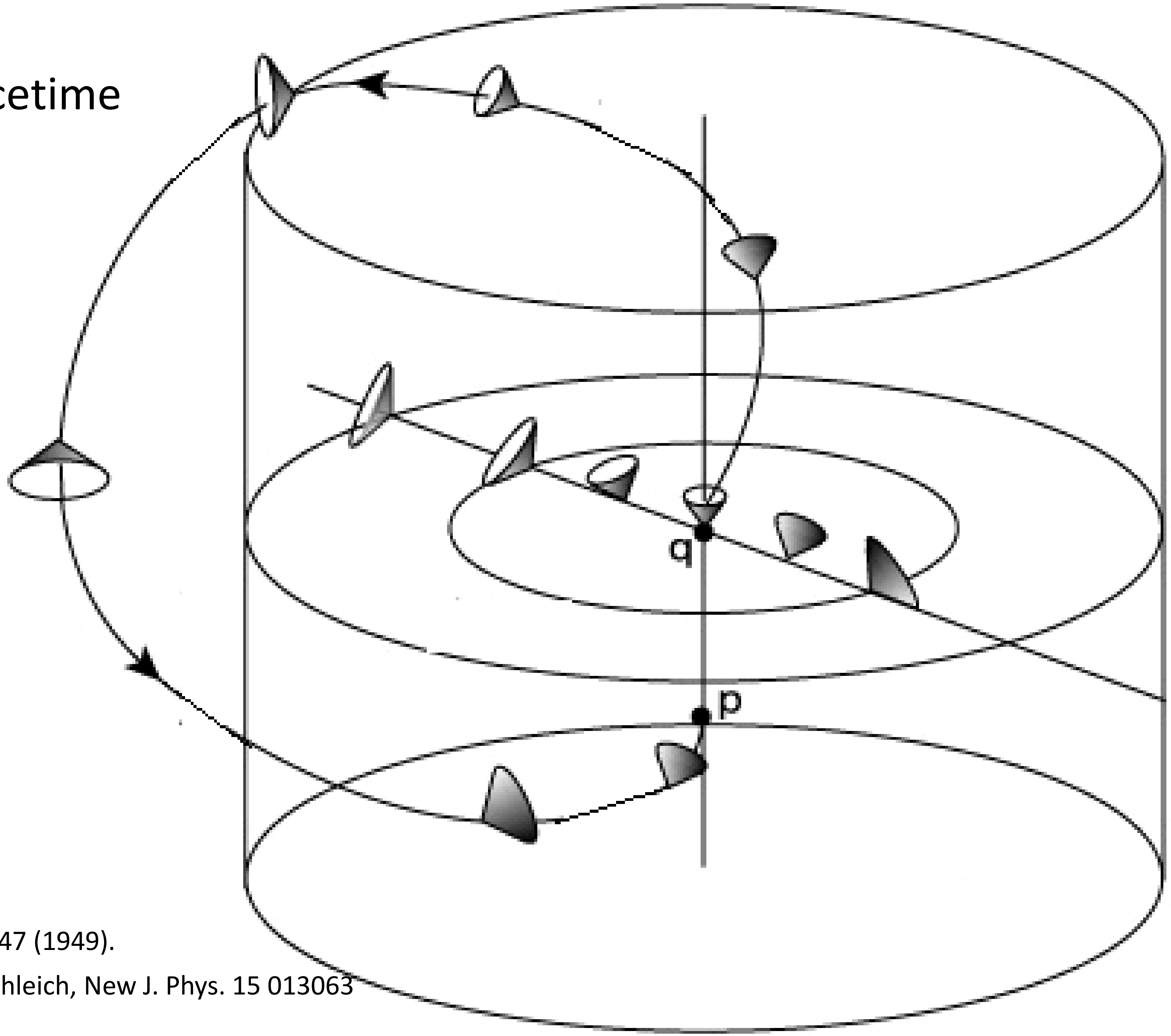
Warping time physically


mirror
w
ct
w
vt
clock at rest
clock moving at v

Time warp in special relativity



Gödel spacetime



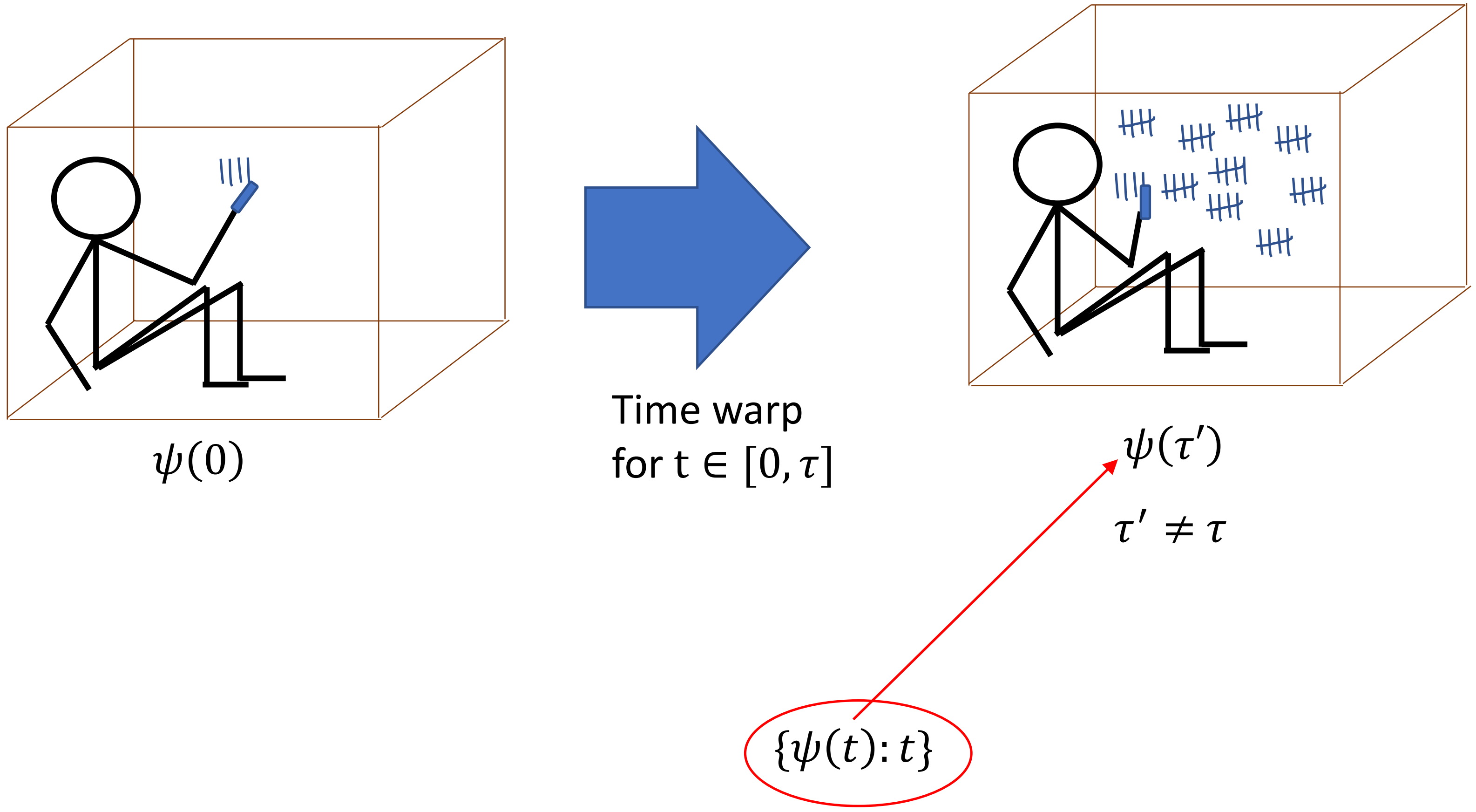
K. Gödel, *Rev. Mod. Phys.* **21** 447 (1949).

M. Buser, E. Kajari and W. P. Schleich, New J. Phys. 15 013063 (2013).

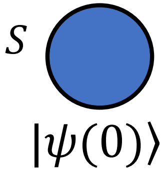
Time travel with wormholes

K. Thorne, Black Holes and Time Warps: Einstein's Outrageous Legacy, Commonwealth Fund Book Program (1994).

Time warp with time machines



The time translator

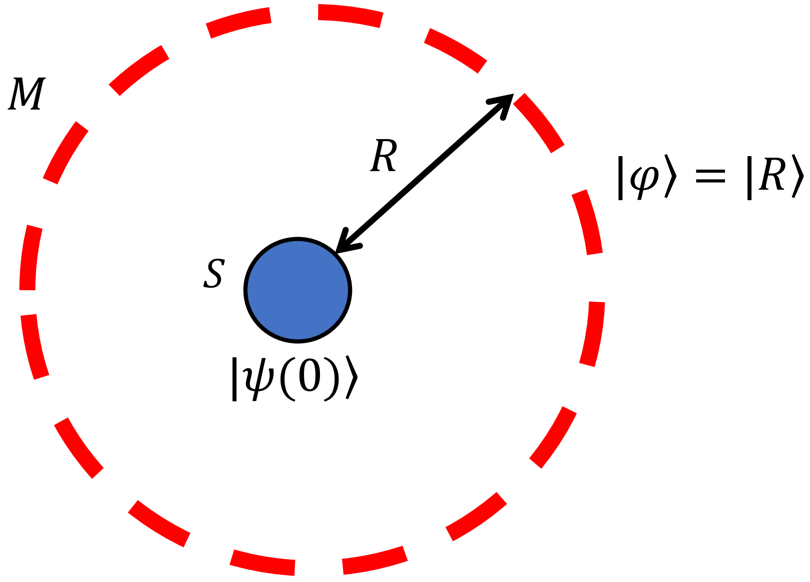


Evolution after time T

$$e^{-iH_0T}|\psi(0)\rangle$$

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

The time translator

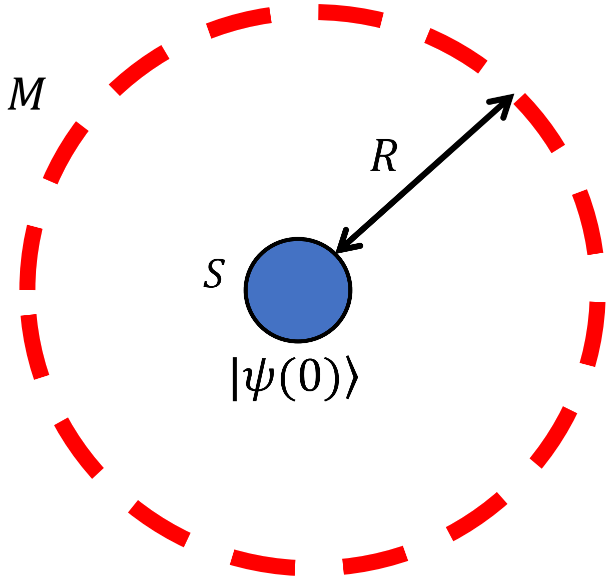


Evolution after time T

$$e^{-iH_0\gamma_R T}|\psi(0)\rangle|R\rangle$$

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

The time translator



$$\gamma_R = \sqrt{1 - \frac{2GM}{Rc^2}}$$

Evolution after time T

$$e^{-iH_0\gamma_R T}|\psi(0)\rangle|R\rangle$$

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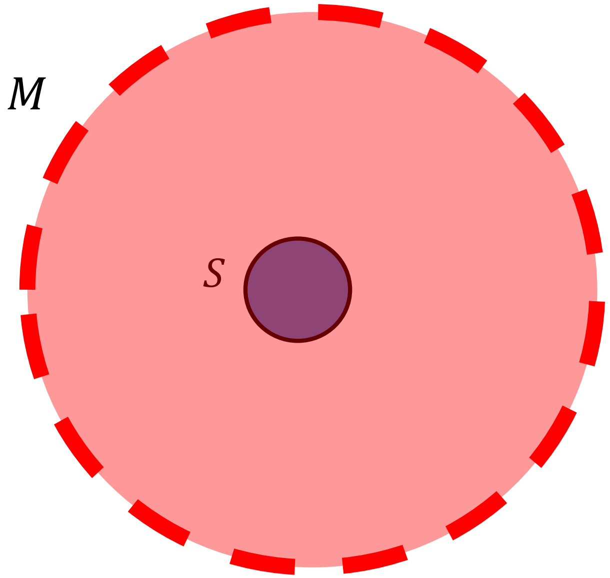

$$|\varphi\rangle = \sum_R c_R\, |R\rangle$$

Evolution after time T

$$\sum_R c_R\, e^{-iH_0\gamma_R T}|\psi(0)\rangle|R\rangle$$

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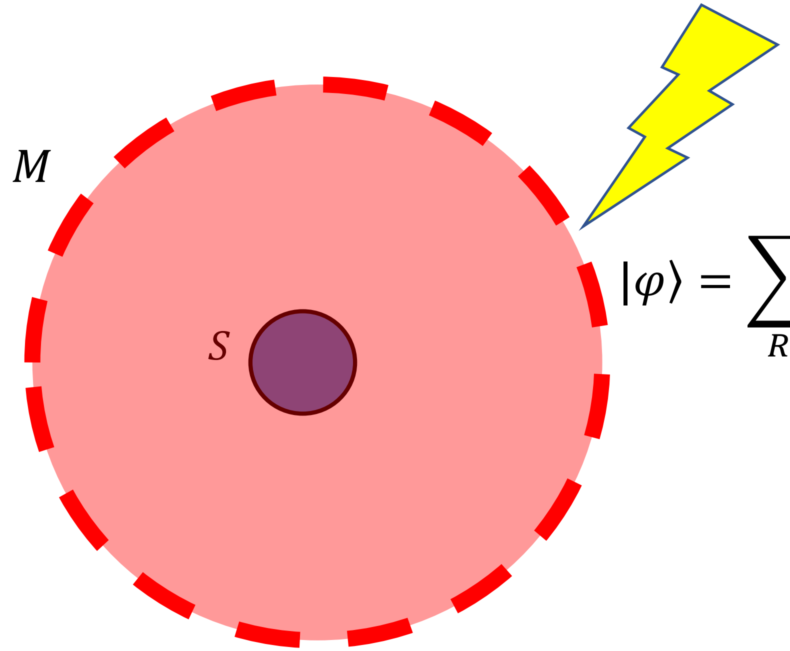

Measurement $\sum_R |R\rangle$

$$|\varphi\rangle = \sum_R c_R\,|R\rangle$$

Evolution after time T

$$\sum_R c_R\, e^{-iH_0\gamma_R T}|\psi(0)\rangle|R\rangle$$

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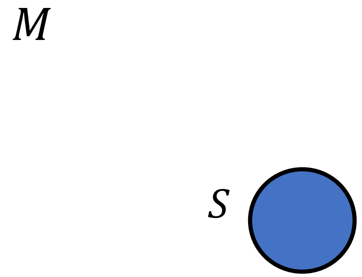
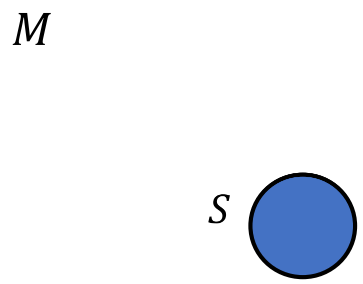


Evolution after time T

$$\sum_R c_R \, e^{-iH_0 \gamma_R T} |\psi(0)\rangle$$

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

The time translator

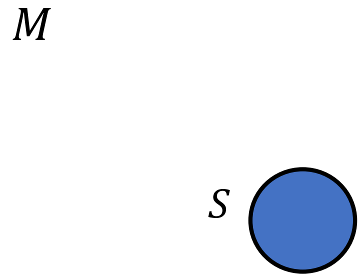


Evolution after time $\mathrm{T} \ll 1$

$$\sum_R c_R \, e^{-iH_0\gamma_R T}|\psi(0)\rangle \approx e^{-iH_0\alpha T}|\psi(0)\rangle$$

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

The time translator



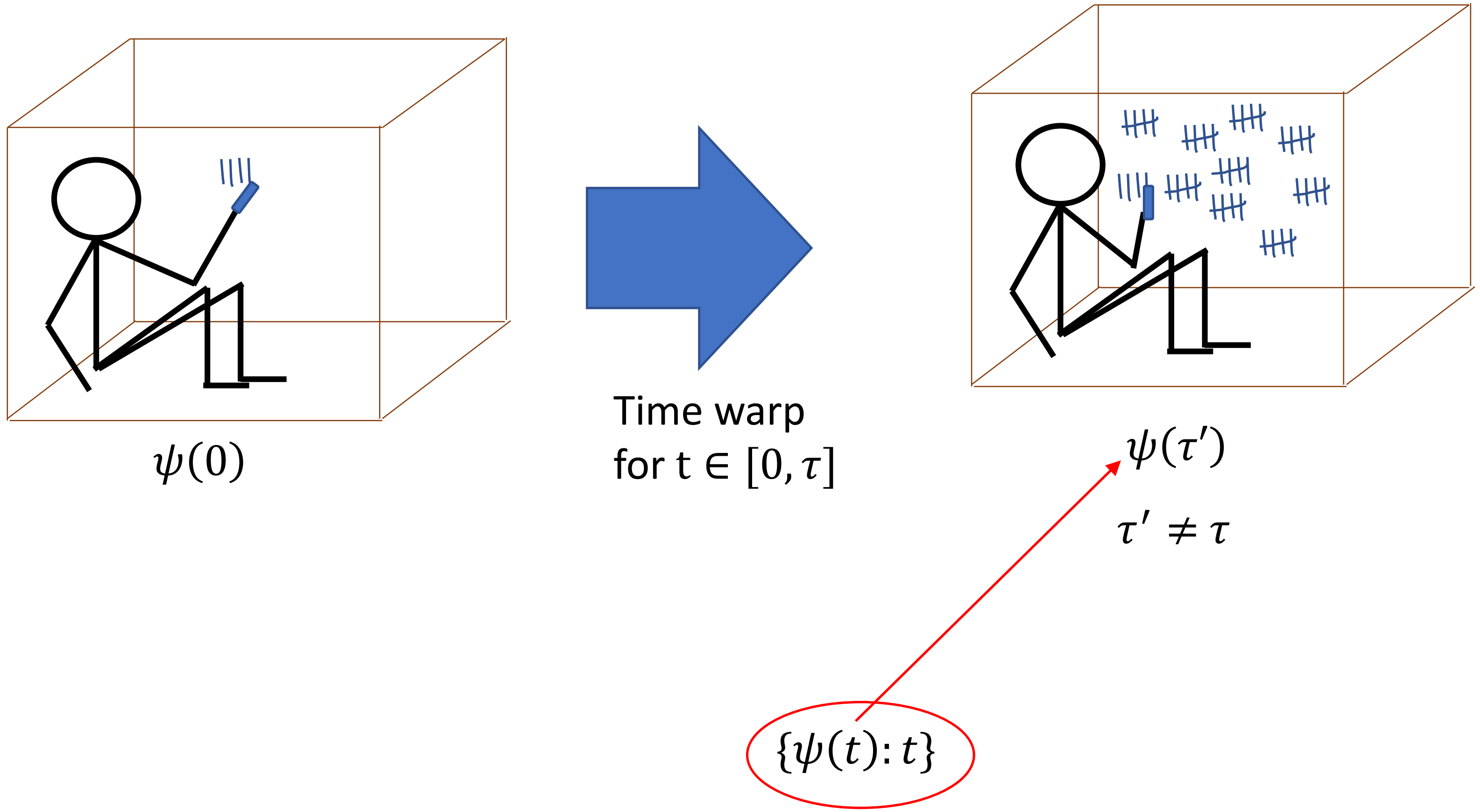
Interesting cases $\begin{cases} \alpha \gg 1 \\ \alpha \leq 0 \end{cases}$

Evolution after time $\mathrm{T} \ll 1$

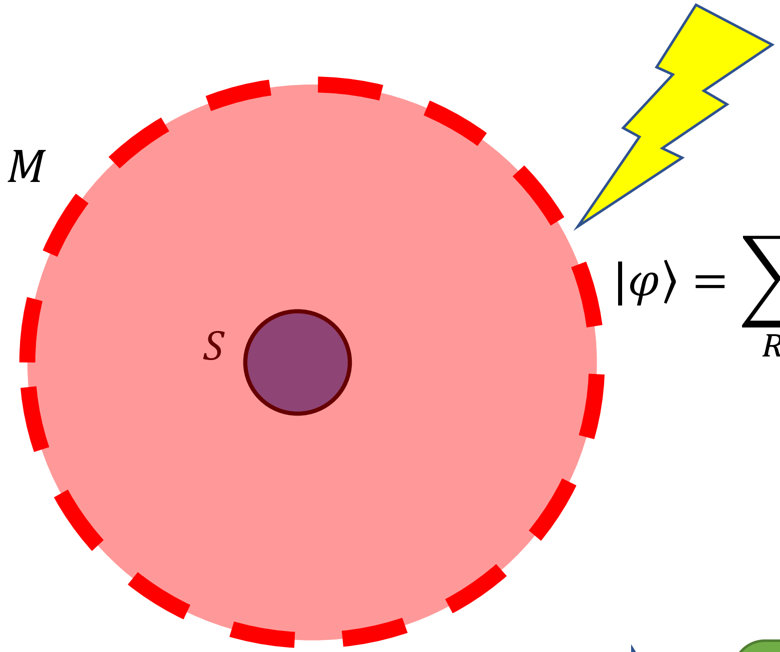
$$\sum_R c_R \, e^{-iH_0 \gamma_R T} |\psi(0)\rangle \approx e^{-iH_0 \alpha T} |\psi(0)\rangle$$

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

Time warp with the time translator



The time translator



Measurement $\sum_R |R\rangle$

$$|\varphi\rangle = \sum_R c_R\,|R\rangle$$

$$\sum_R c_R\, e^{-iH_0\gamma_R T}|\psi(0)\rangle \approx e^{-iH_0\alpha T}|\psi(0)\rangle$$

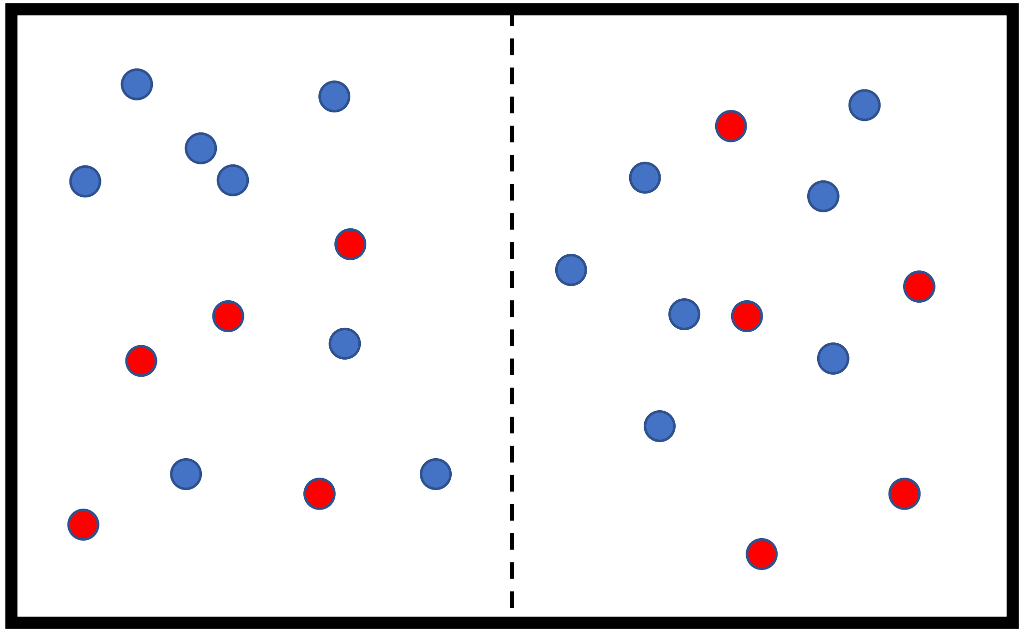
Problem: astronomically small probability of postselection

Y. Aharonov, J. Anandan, S. Popescu and L. Vaidman Phys. Rev. Lett. 64, 2965 (1990).

“The time translator has the same chances of succeeding as I have of delocalizing and relocalizing somewhere else”

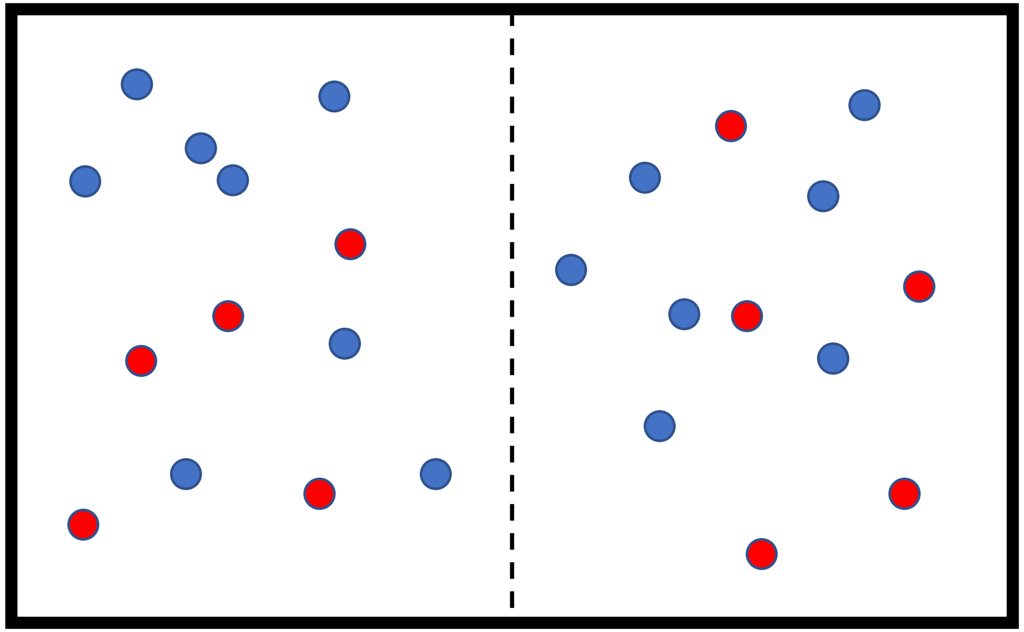
L. Vaidman

Time warp, the lame way



$\psi(0)$

Time warp, the lame way



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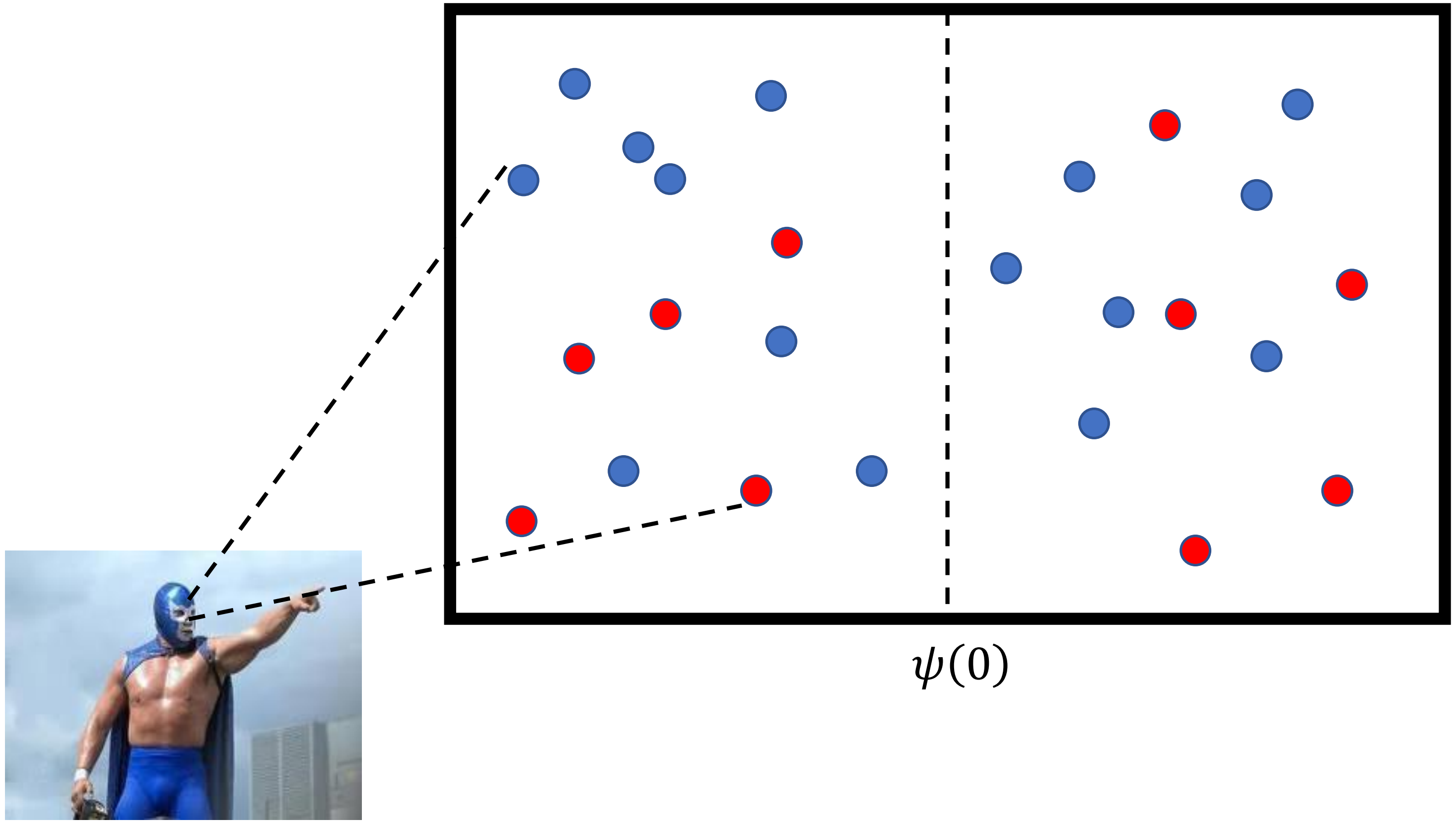

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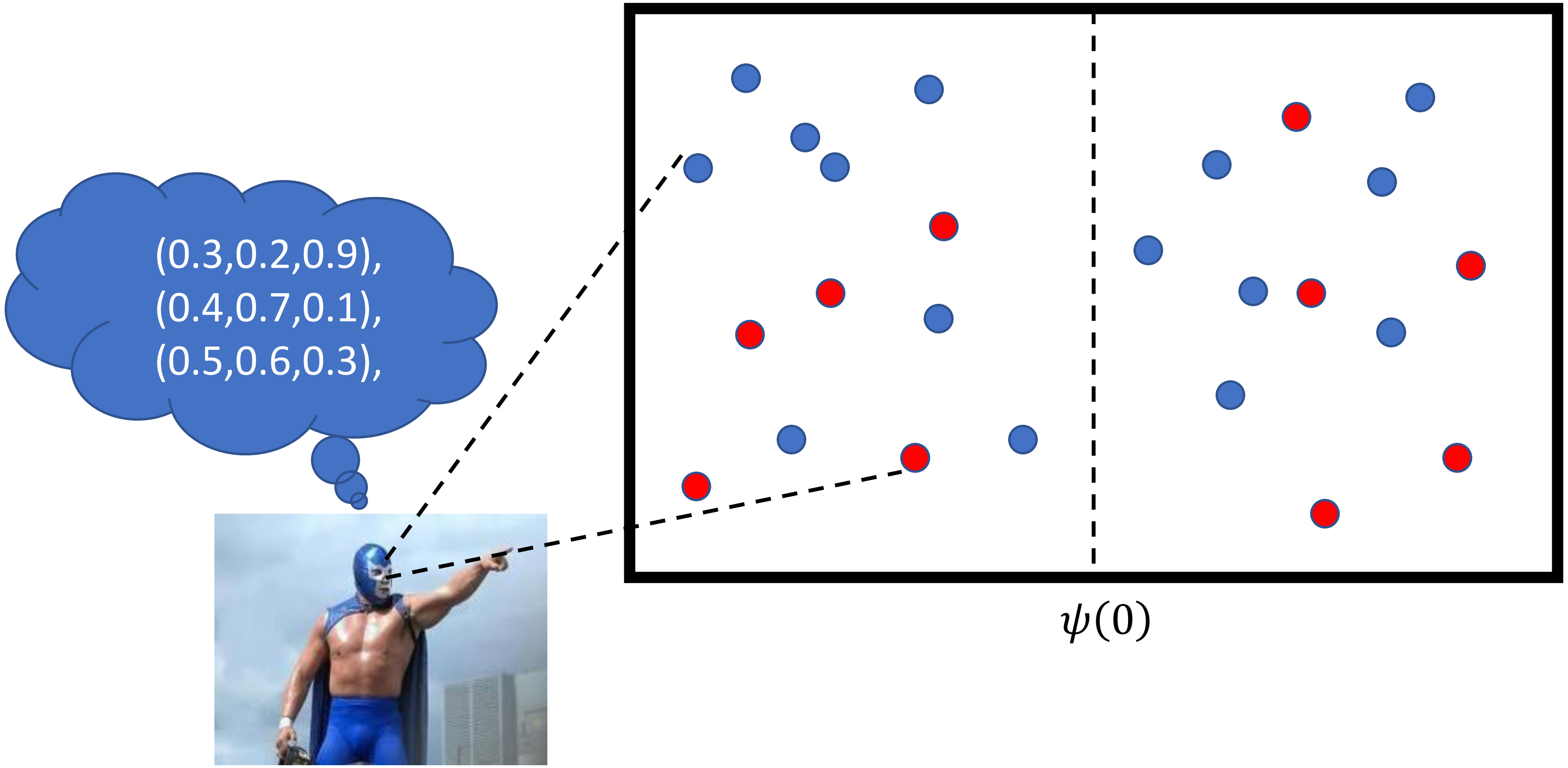
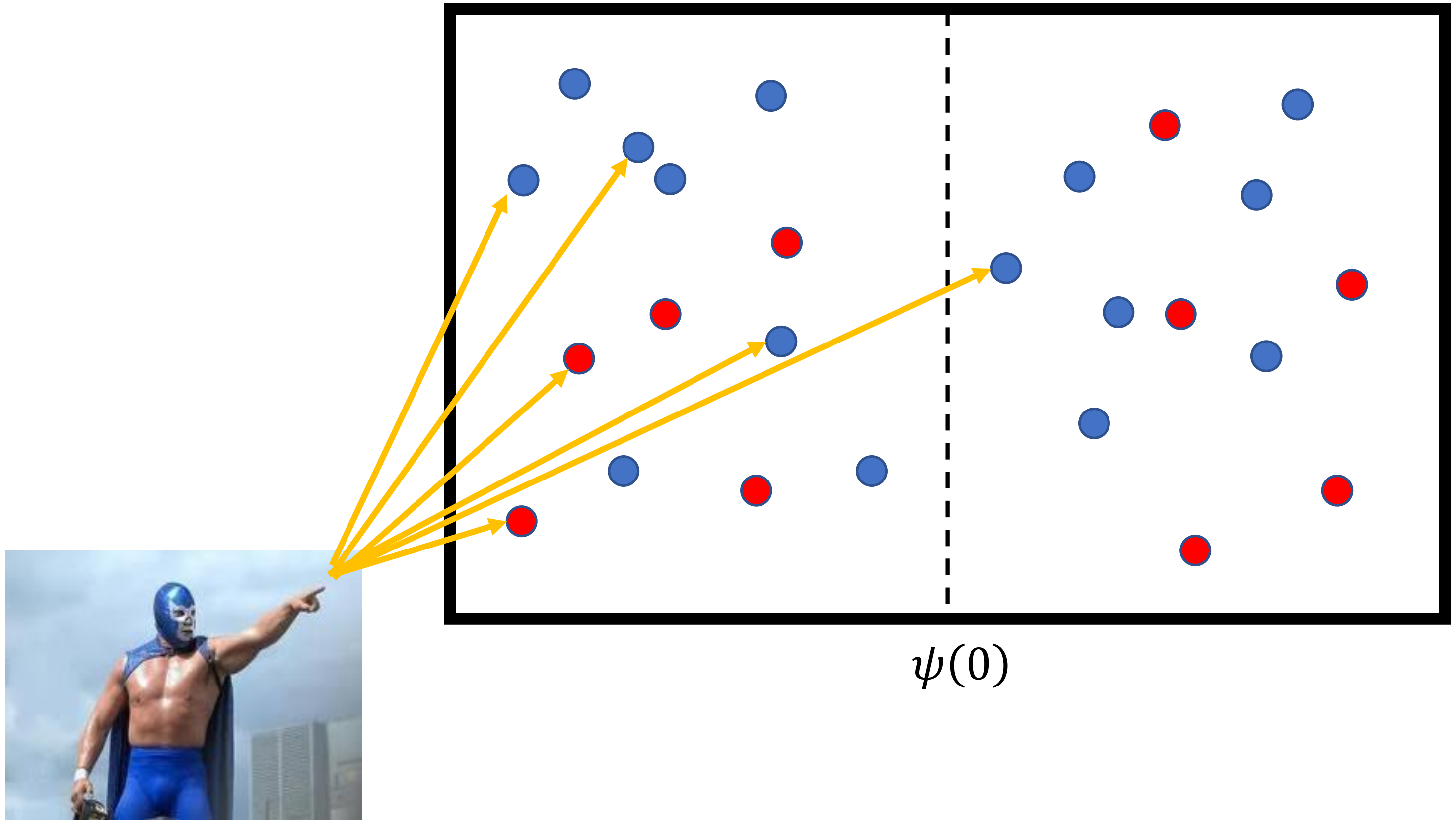
Time warp, the lame way

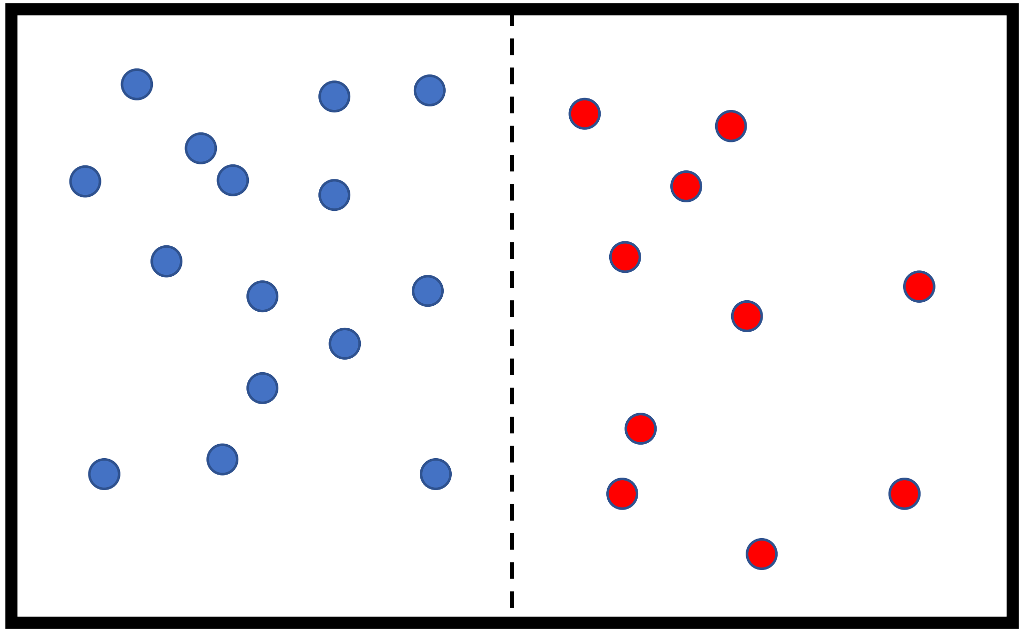


Time warp, the lame way

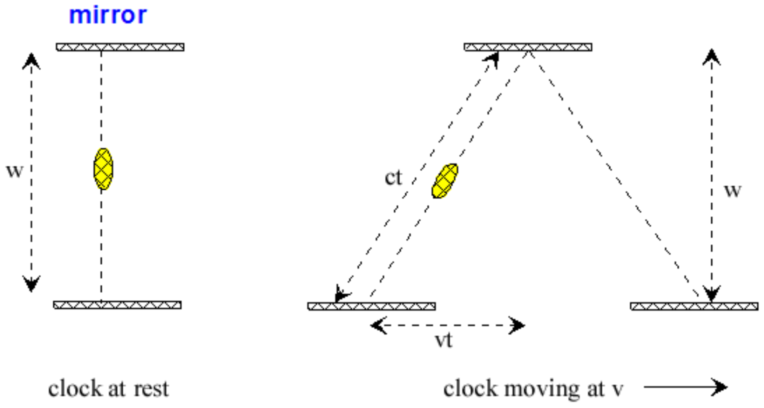


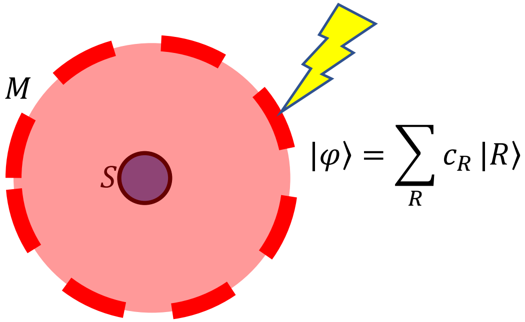
$\psi(0)$

Time warp, the lame way

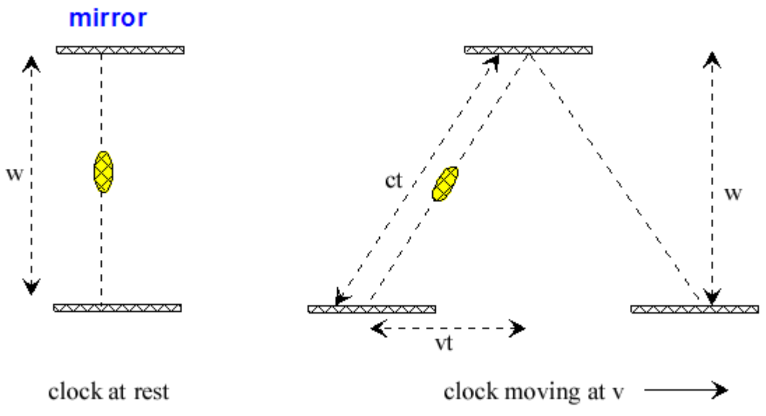


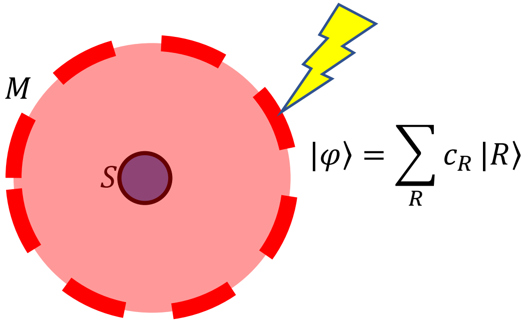
$\psi(-5732)$





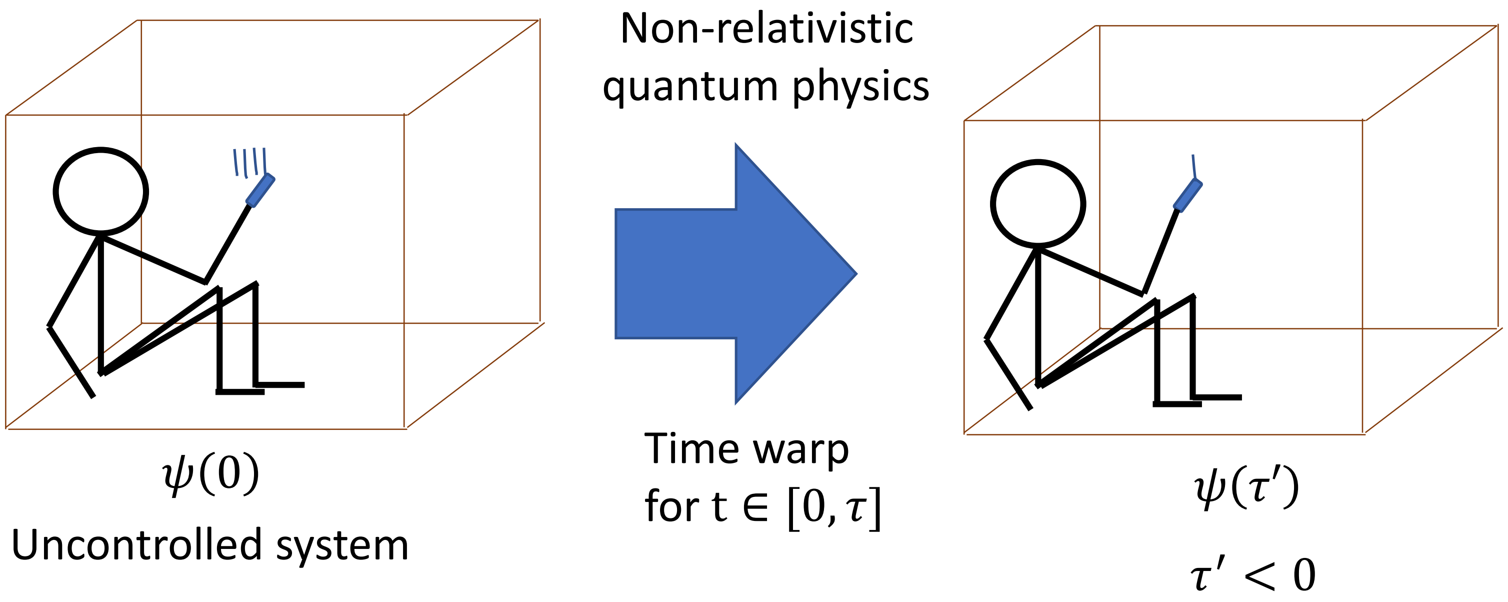
These proposals <u>do not require control or knowledge of the physical system</u> that we influence



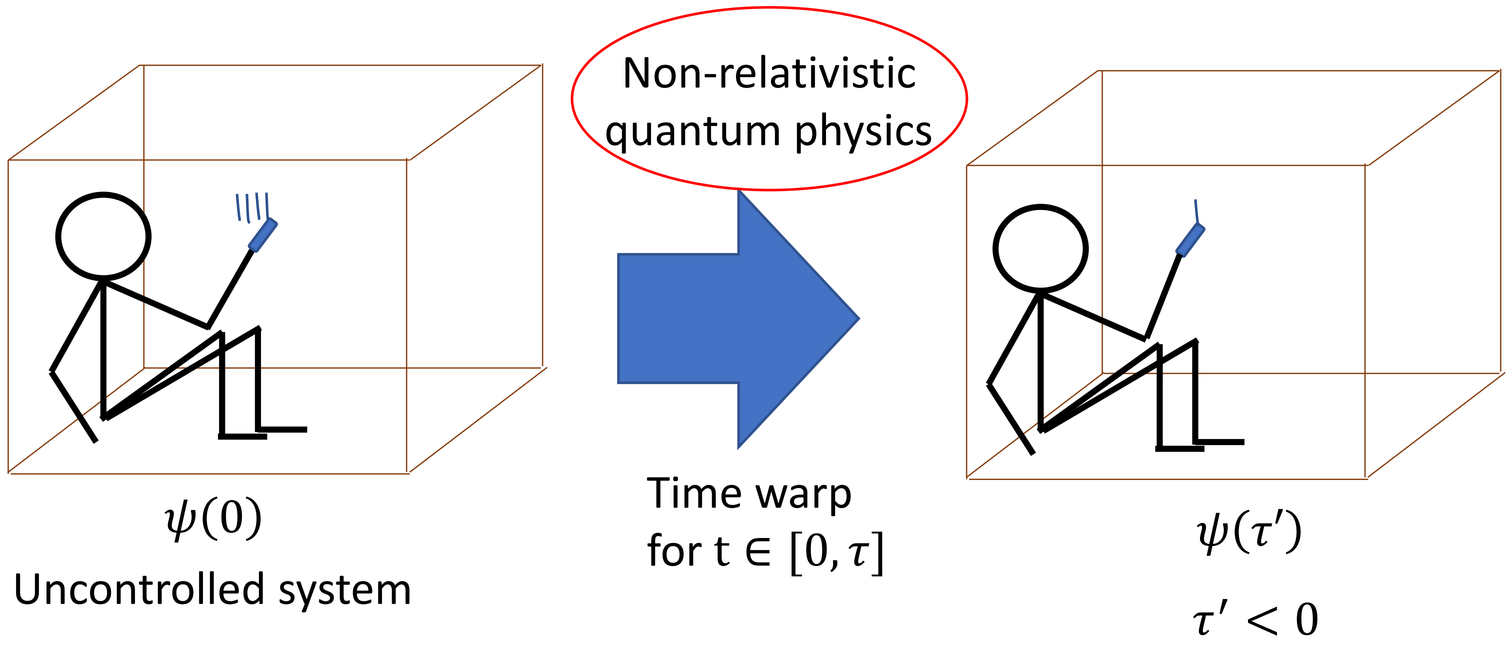


All interesting proposals to achieve time warp rely on <u>special or general relativity</u>

Main result

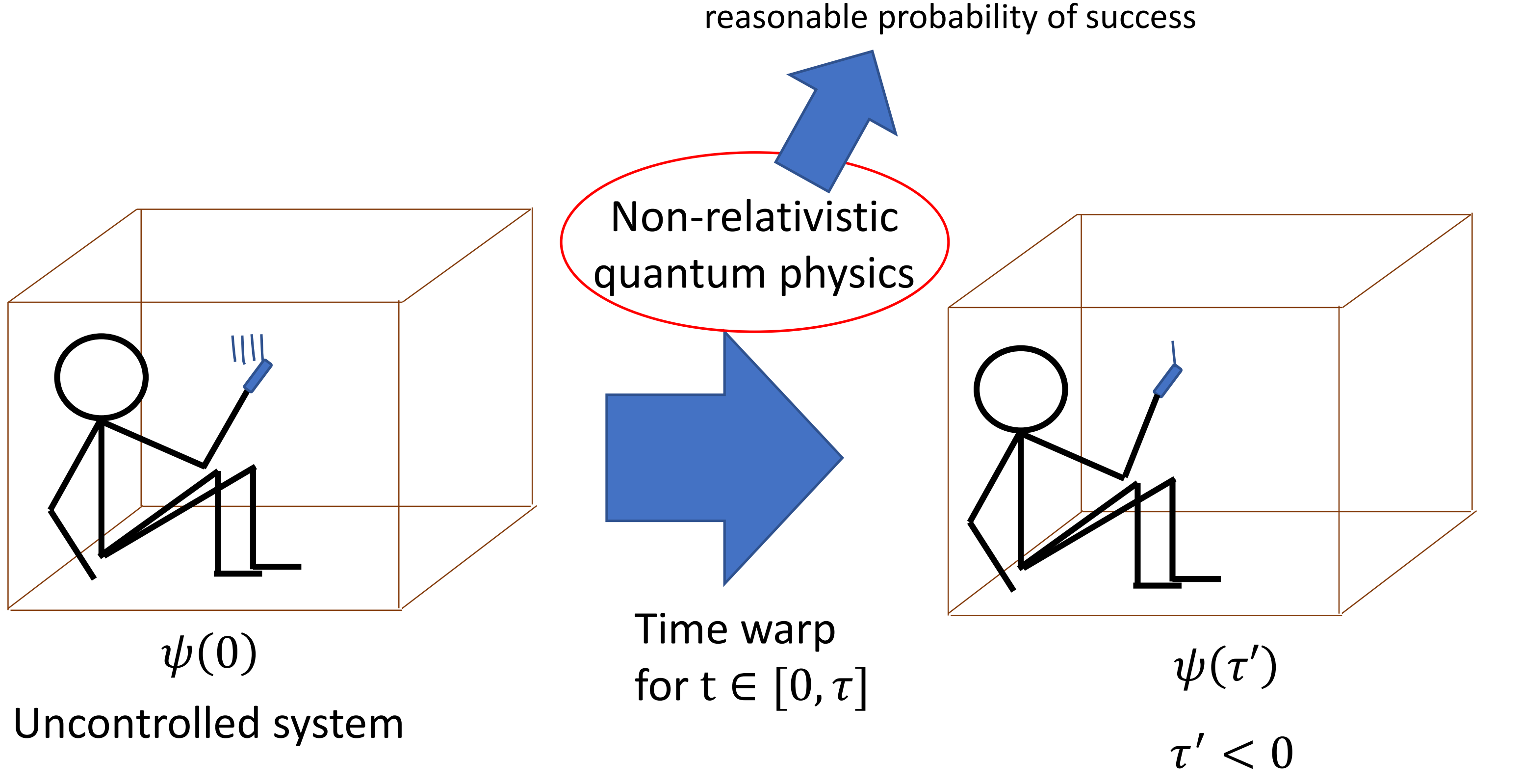

Non-relativistic
quantum physics
$\psi(0)$
Uncontrolled system
Time warp
for $t \in [0, \tau]$
$\psi(\tau')$
$\tau' < 0$

Main result



Non-relativistic quantum physics
$\psi(0)$
Uncontrolled system
Time warp for t ∈ $[0, \tau]$
$\psi(\tau')$
$\tau' < 0$

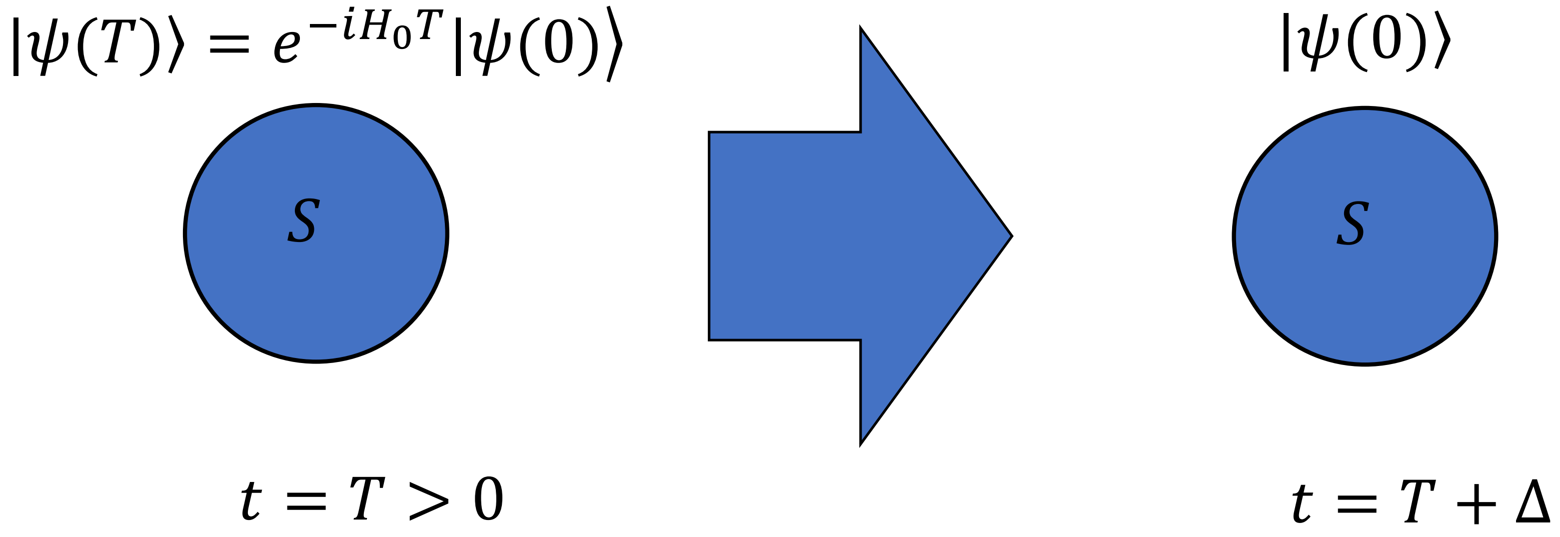
Main result



reasonable probability of success
Non-relativistic quantum physics
$\psi(0)$
Uncontrolled system
Time warp for $t \in [0, \tau]$
$\psi(\tau')$
$\tau' < 0$

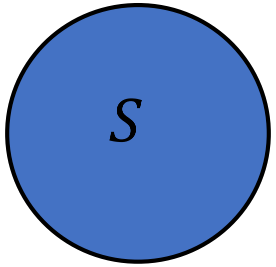
Scenario

Goal



Obvious solution

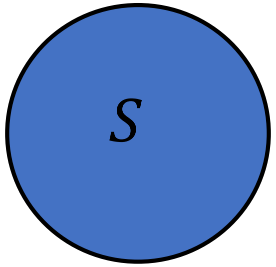
$$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$$



$$|\psi(0)\rangle = e^{+iH_0T}|\psi(T)\rangle$$

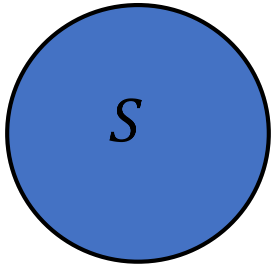
Obvious solution

$$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$$

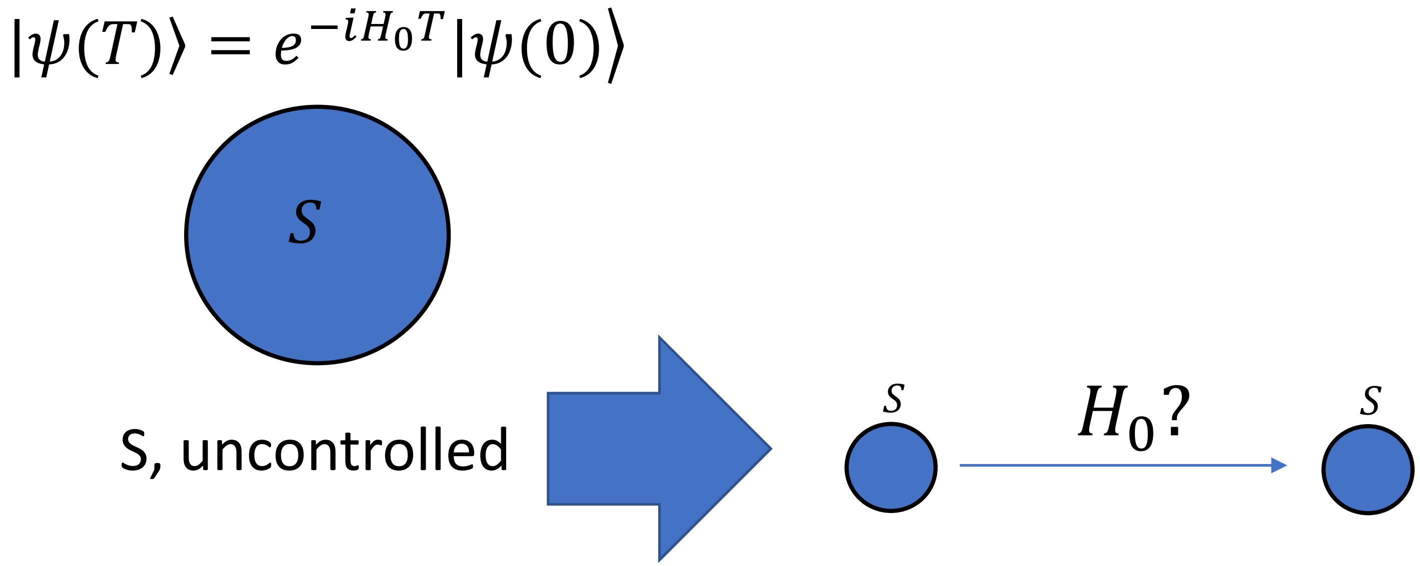


$$|\psi(0)\rangle = e^{+iH_0T}|\psi(T)\rangle$$

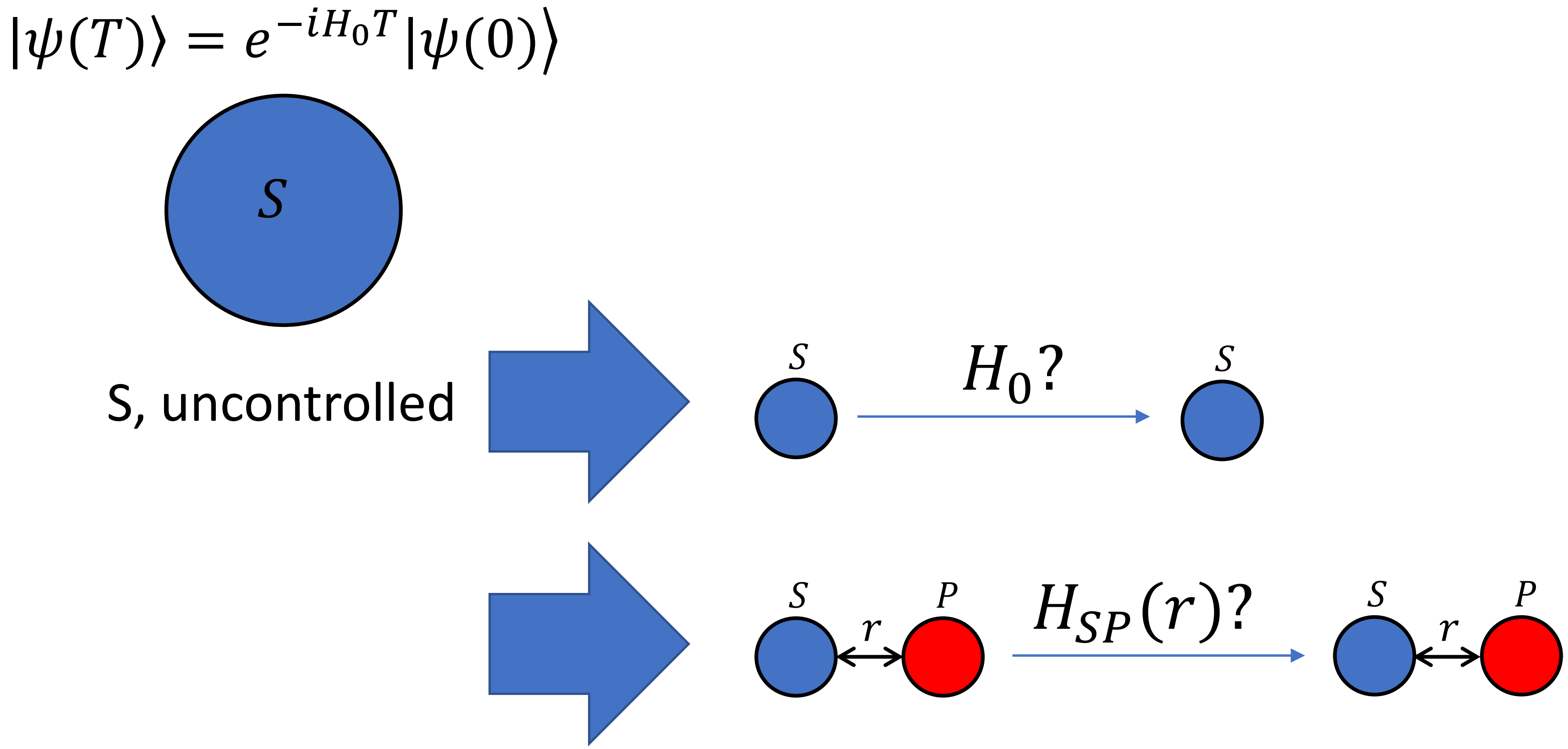
$$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$$



S, uncontrolled



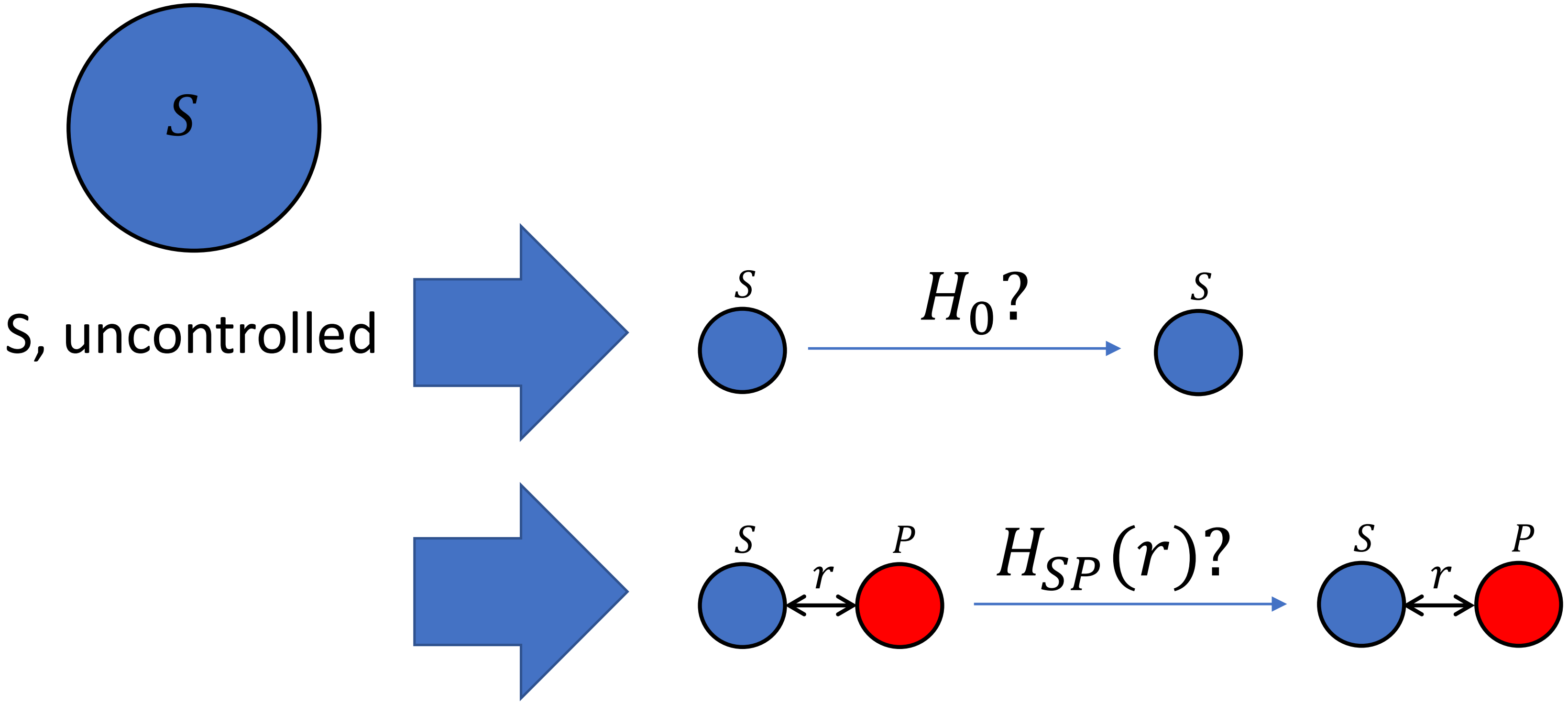
$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$
S
S, uncontrolled
S
H_0?
S

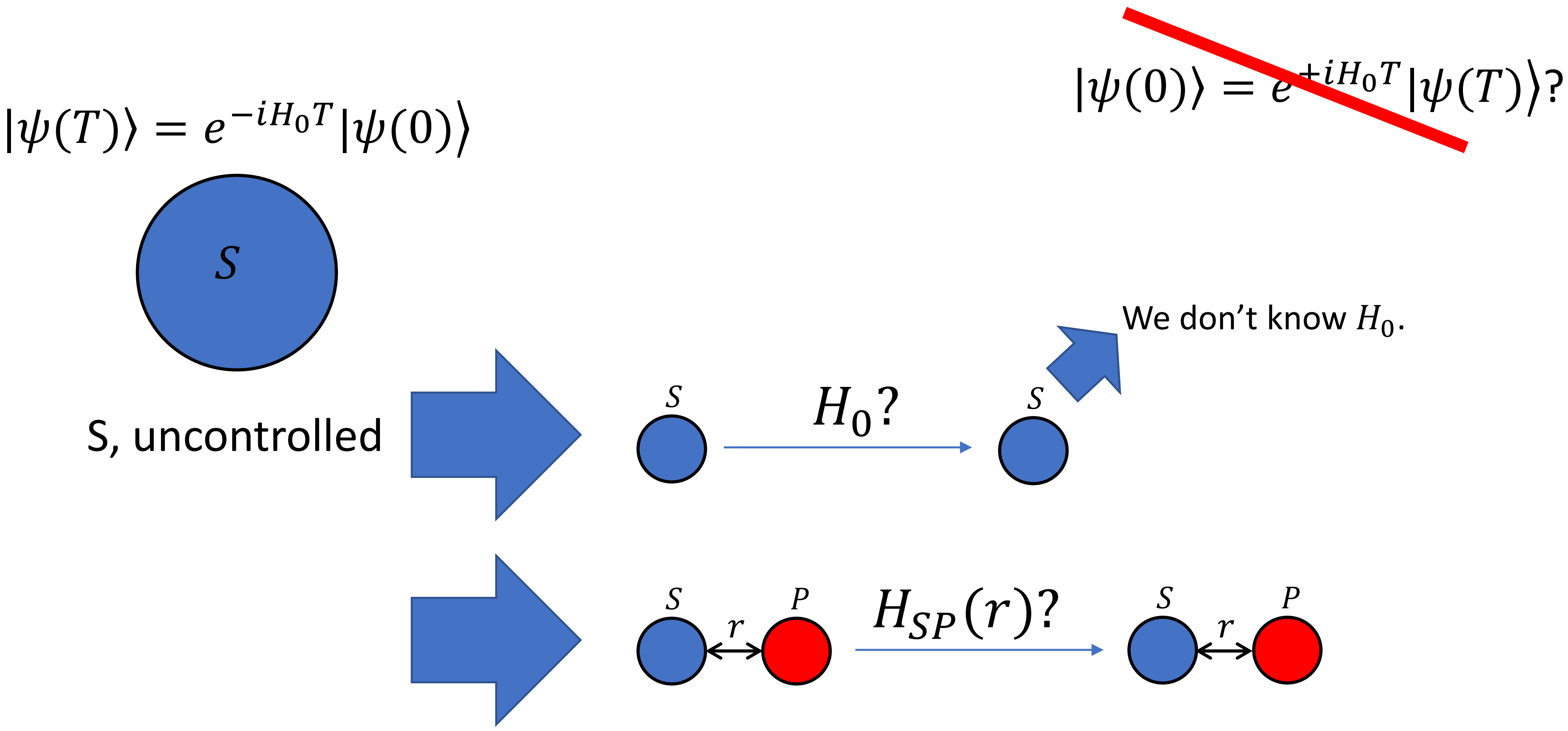


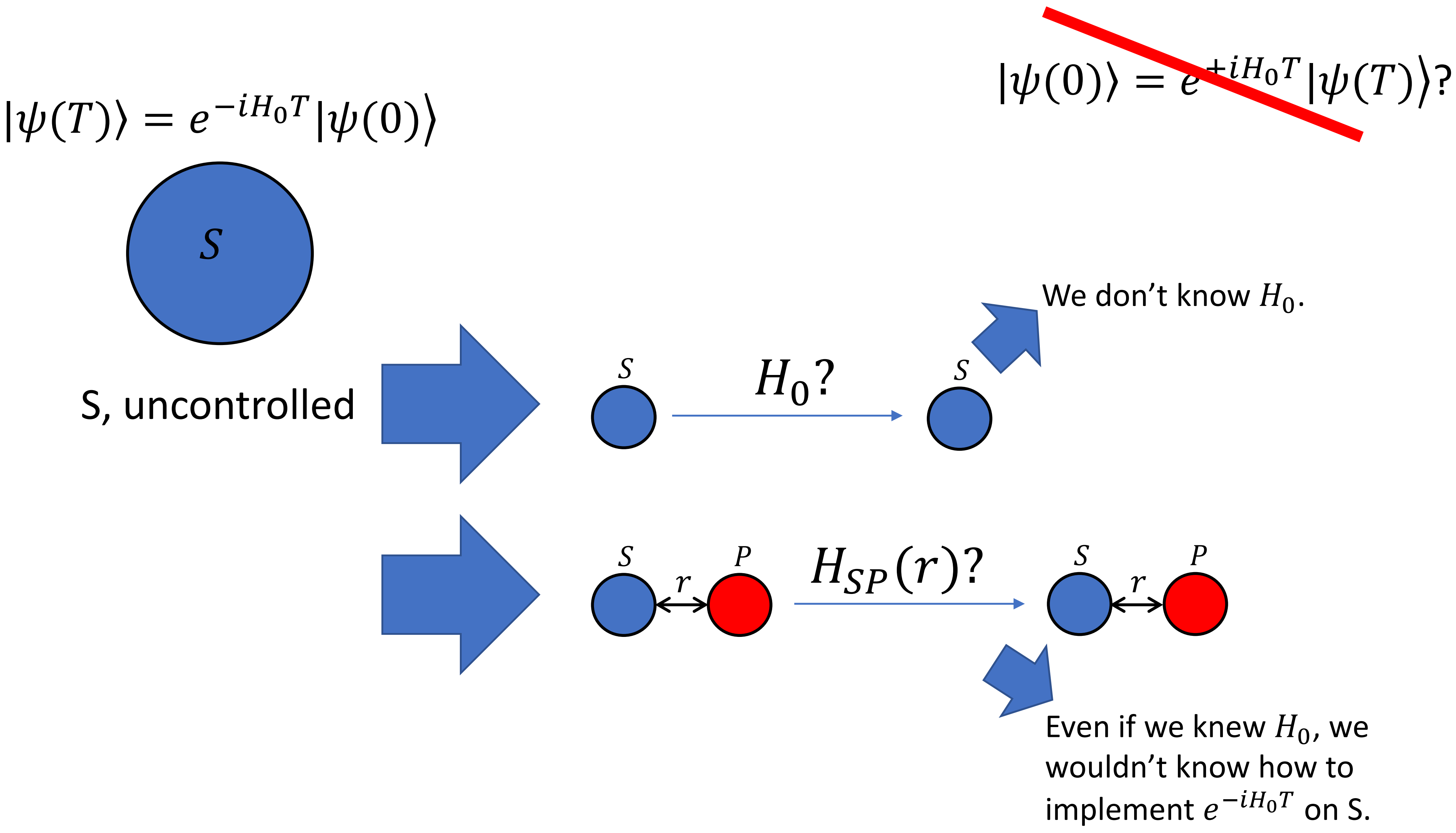
$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$
S
S, uncontrolled
S
H_0?
S
S
r
P
$H_{SP}(r)$?
S
r
P

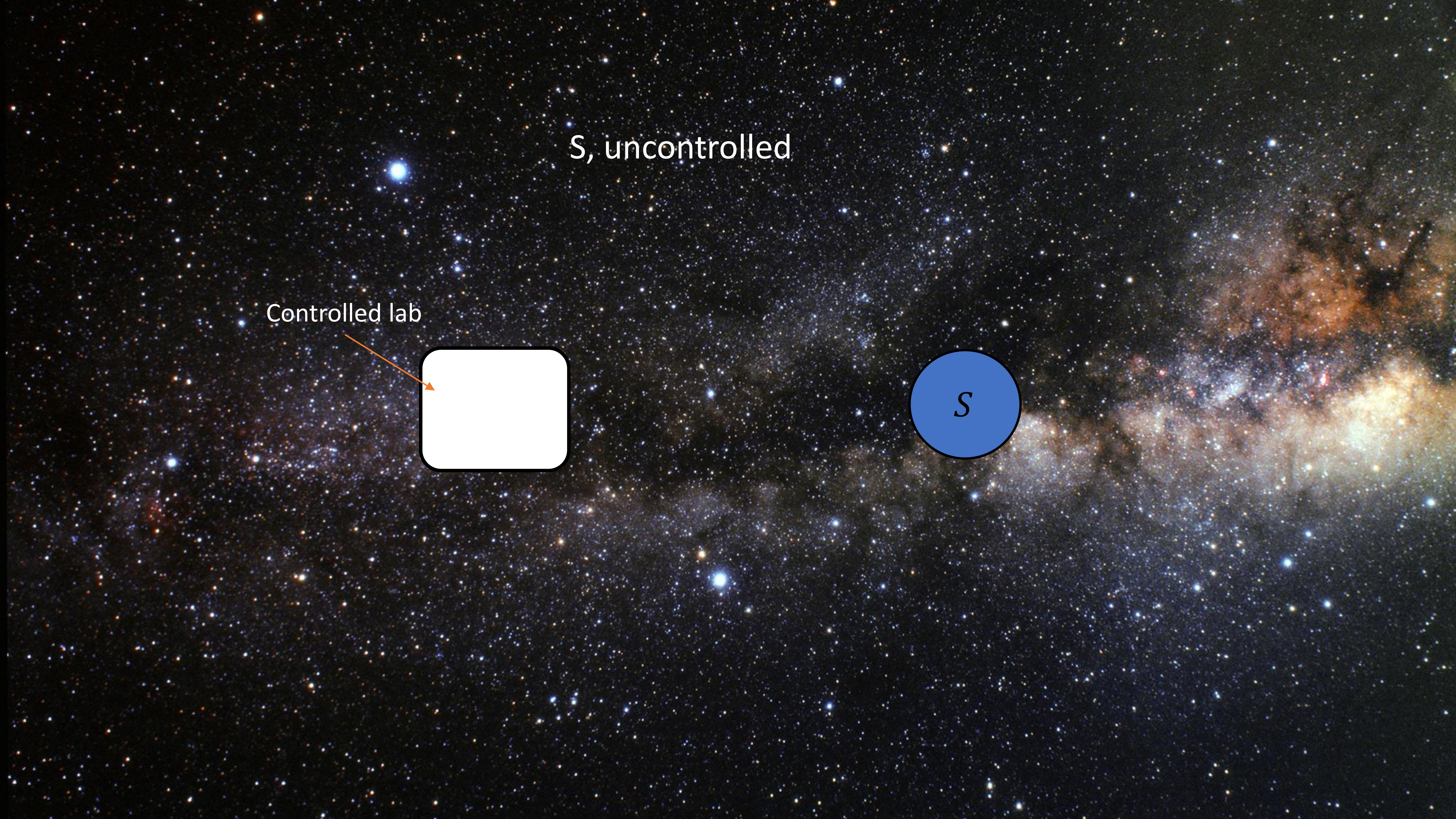
$$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$$

$$|\psi(0)\rangle = e^{+iH_0T}|\psi(T)\rangle?$$

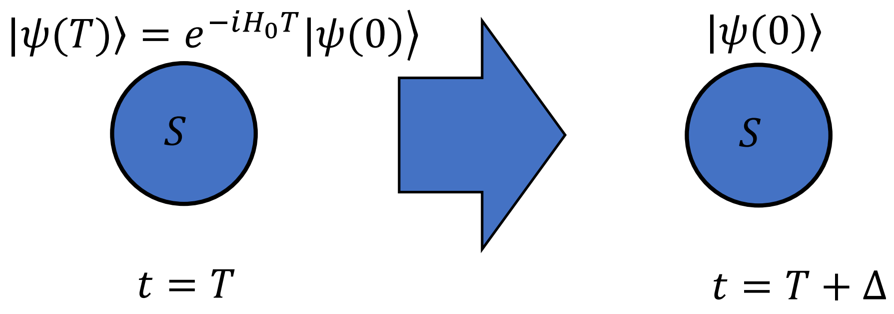



$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$
$|\psi(0)\rangle = e^{+iH_0T}|\psi(T)\rangle$?
S
S, uncontrolled
S
H_0?
S
We don't know H_0.
S
r
P
$H_{SP}(r)$?
S
r
P


$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$
$|\psi(0)\rangle = e^{+iH_0T}|\psi(T)\rangle$?
S
S, uncontrolled
S
H_0?
S
We don't know H_0.
S
r
P
$H_{SP}(r)$?
S
r
P
Even if we knew H_0, we wouldn't know how to implement e^{-iH_0T} on S.


S, uncontrolled
Controlled lab
S

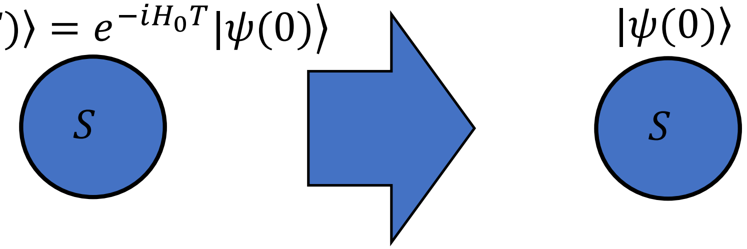
Resetting



MN, arXiv:1710.02470

Resetting

$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$ $|\psi(0)\rangle$

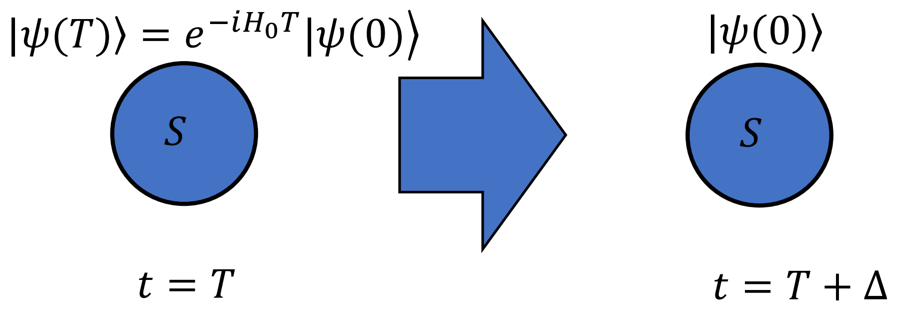


$t = T$ $t = T + \Delta$

Exact past state

MN, arXiv:1710.02470

Resetting



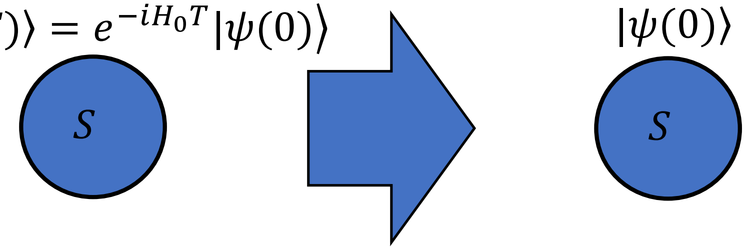
We ignore how S evolves (unitarily) by itself and with other quantum systems

We know $d_S = \dim(H_s)$

MN, arXiv:1710.02470

Resetting

$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$ $|\psi(0)\rangle$



$t = T$ $t = T + \Delta$

We ignore how S evolves (unitarily) by itself and with other quantum systems

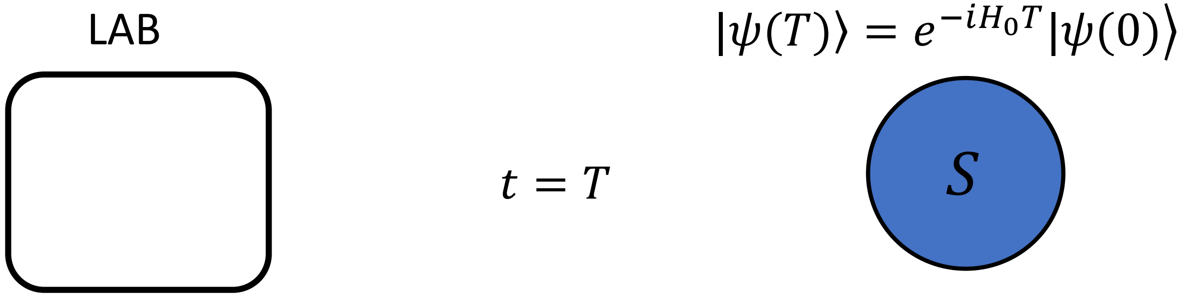
We know $d_S = \dim(H_s)$

Imposible if we drop any
of the two assumptions

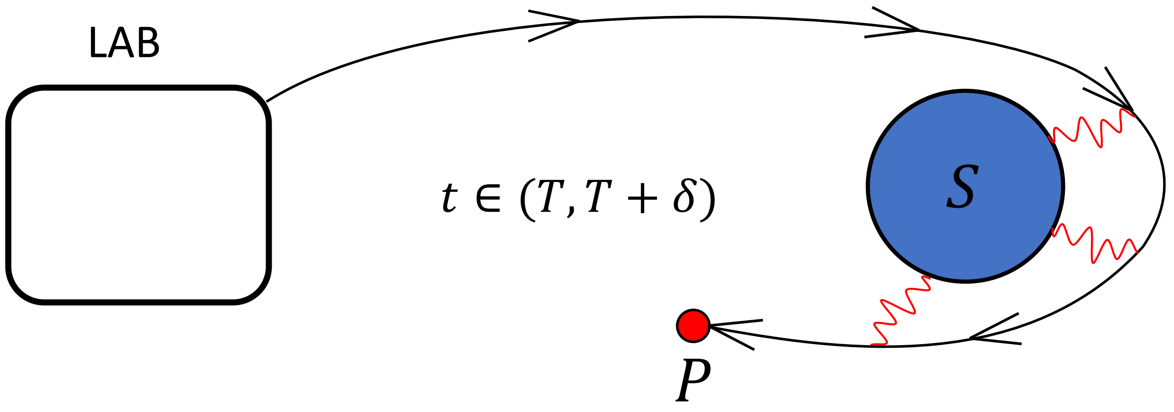
MN, arXiv:1710.02470

Sketch of a quantum resetting protocol

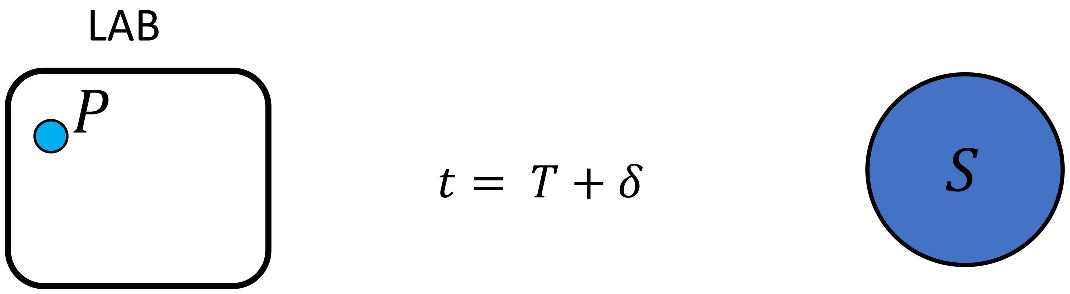
Initial conditions



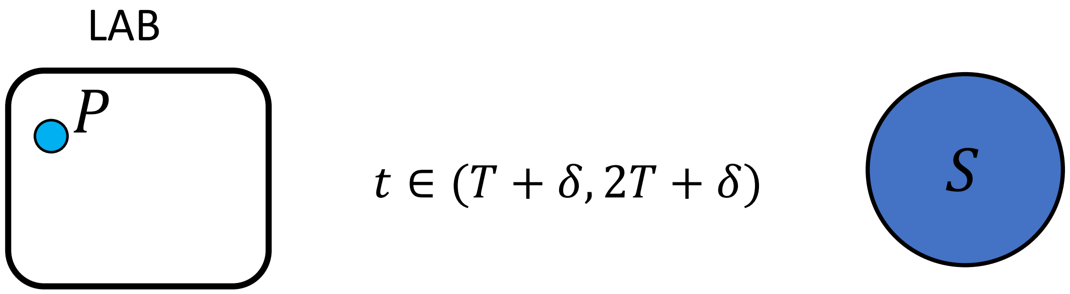
(a) Probe interaction



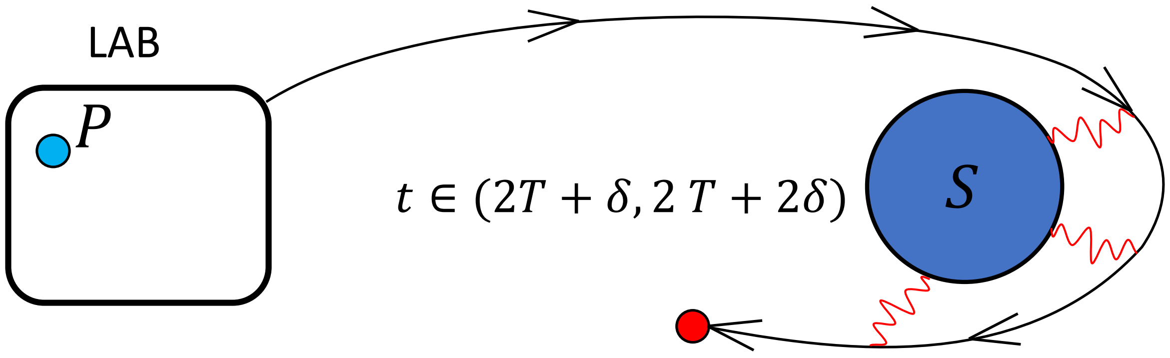
(a) Probe interaction



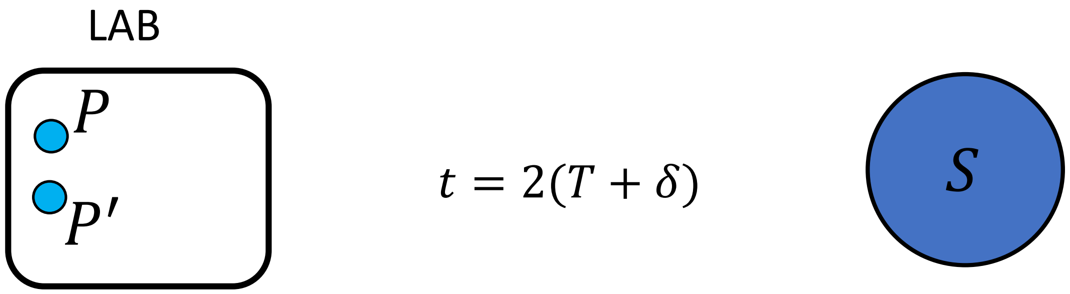
(b) Rest



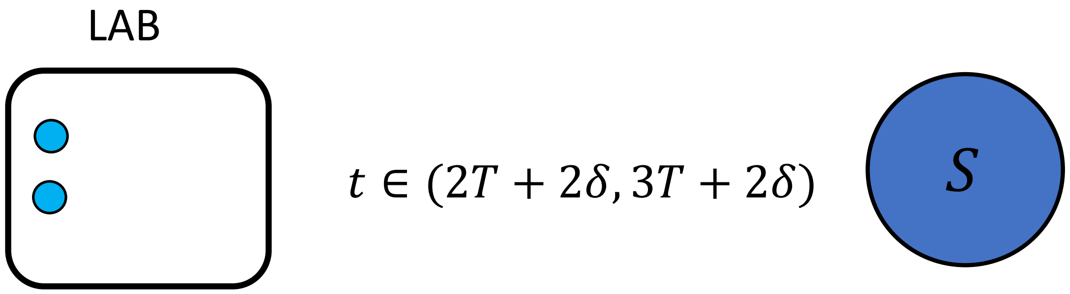
(a) Probe interaction



(a) Probe interaction

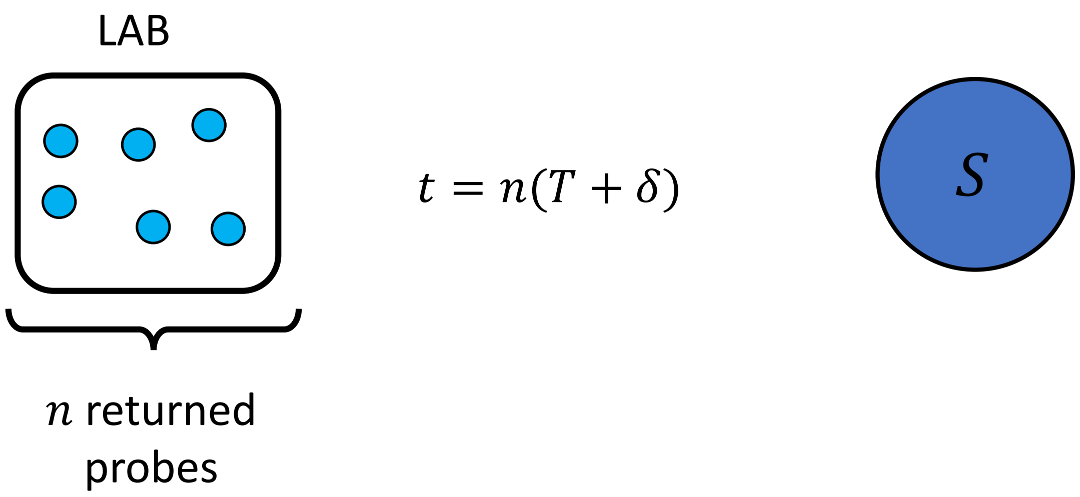


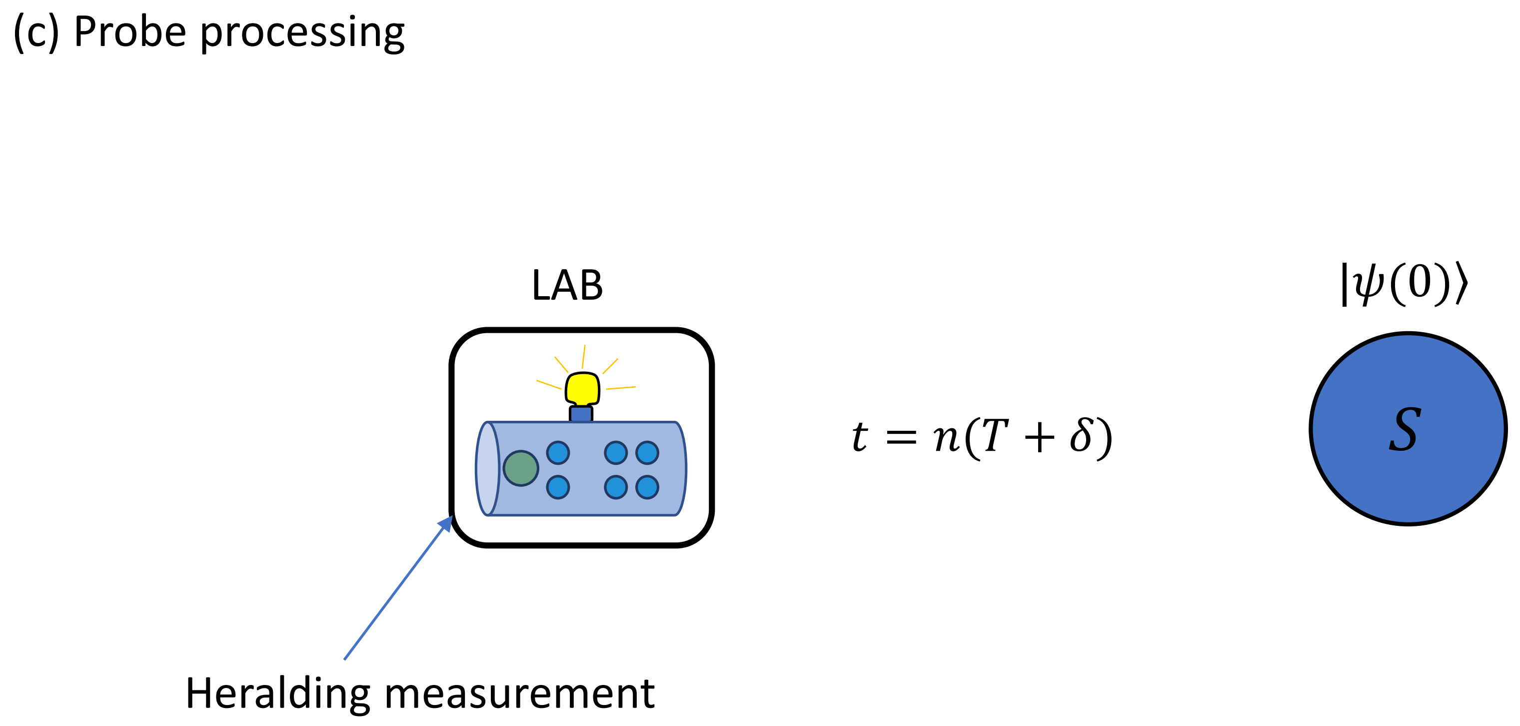
(b) Rest



⋮

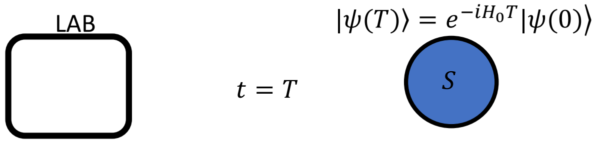
(a) Probe interaction



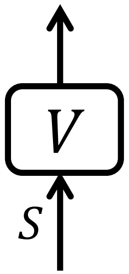

(c) Probe processing
LAB
$t = n(T + \delta)$
$|\psi(0)\rangle$
S
Heralding measurement

In the language of process diagrams

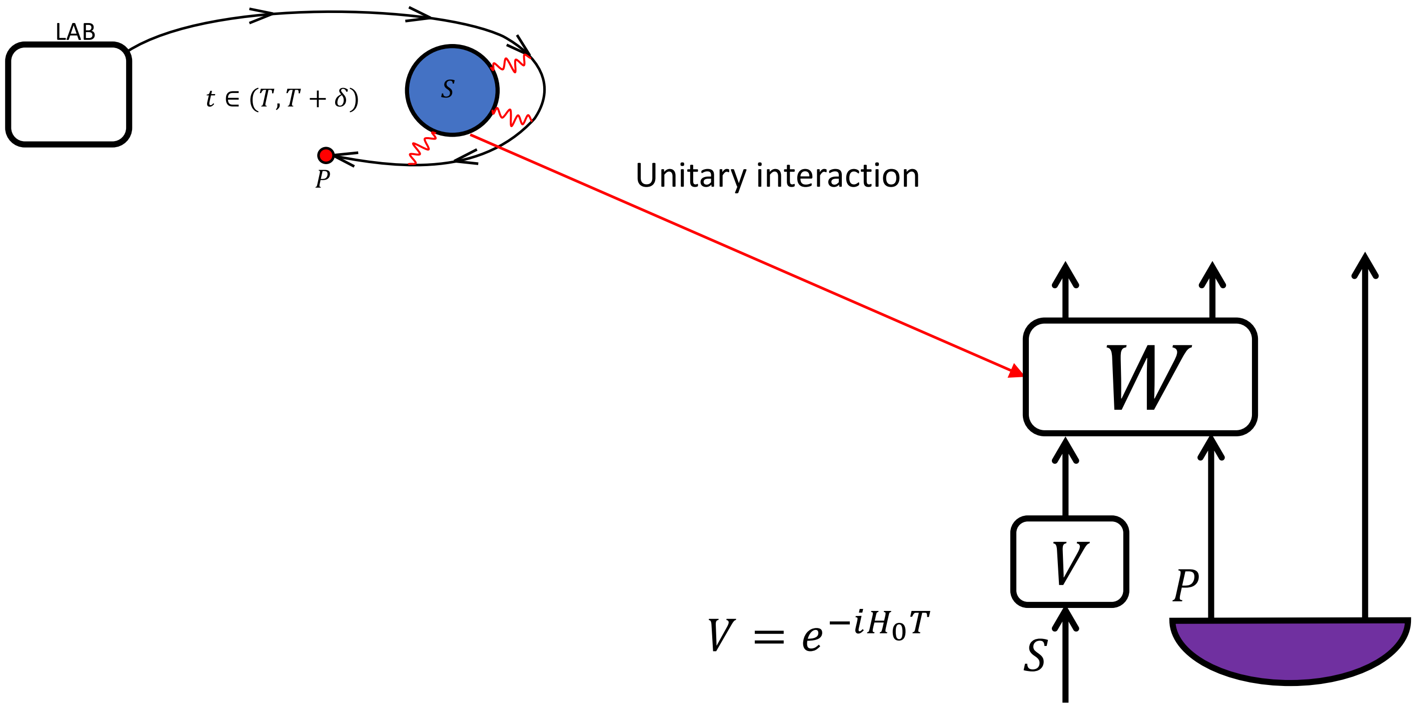
Initial conditions



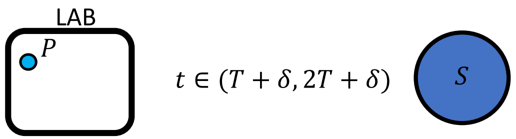
$$V = e^{-iH_0T}$$



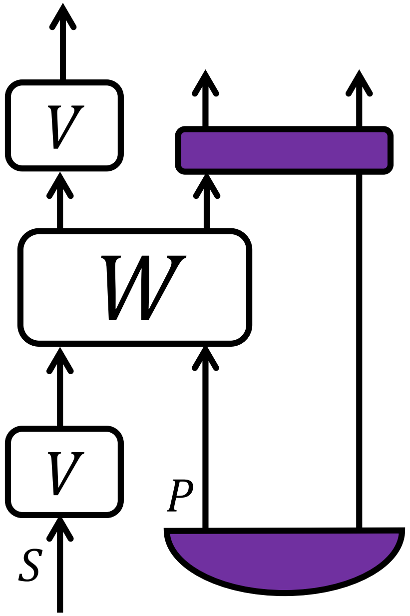
(a) Probe interaction



(b) Rest

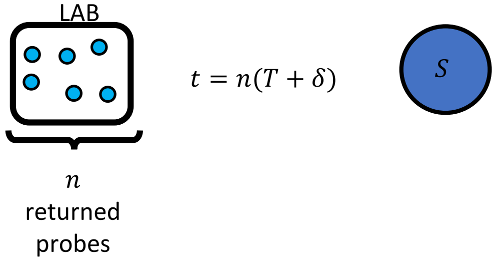


$$V = e^{-iH_0T}$$

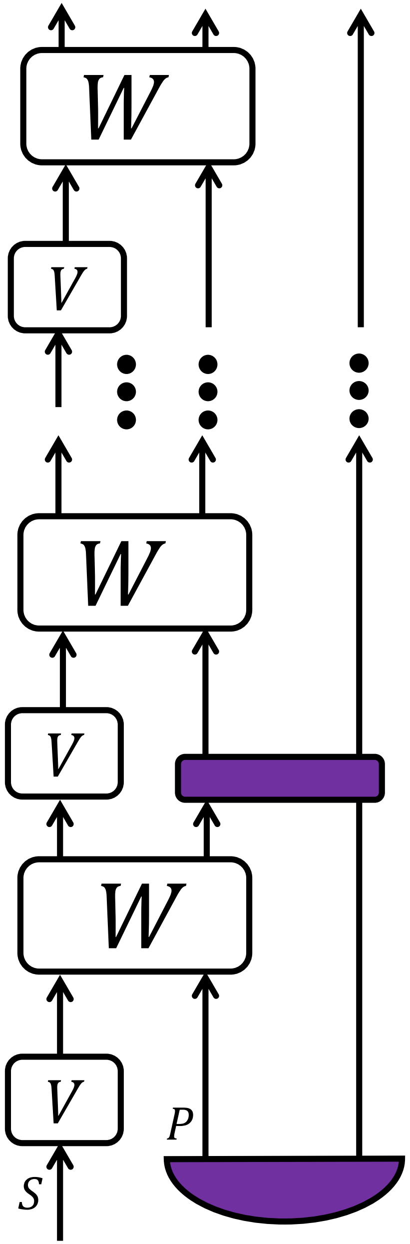


⋮

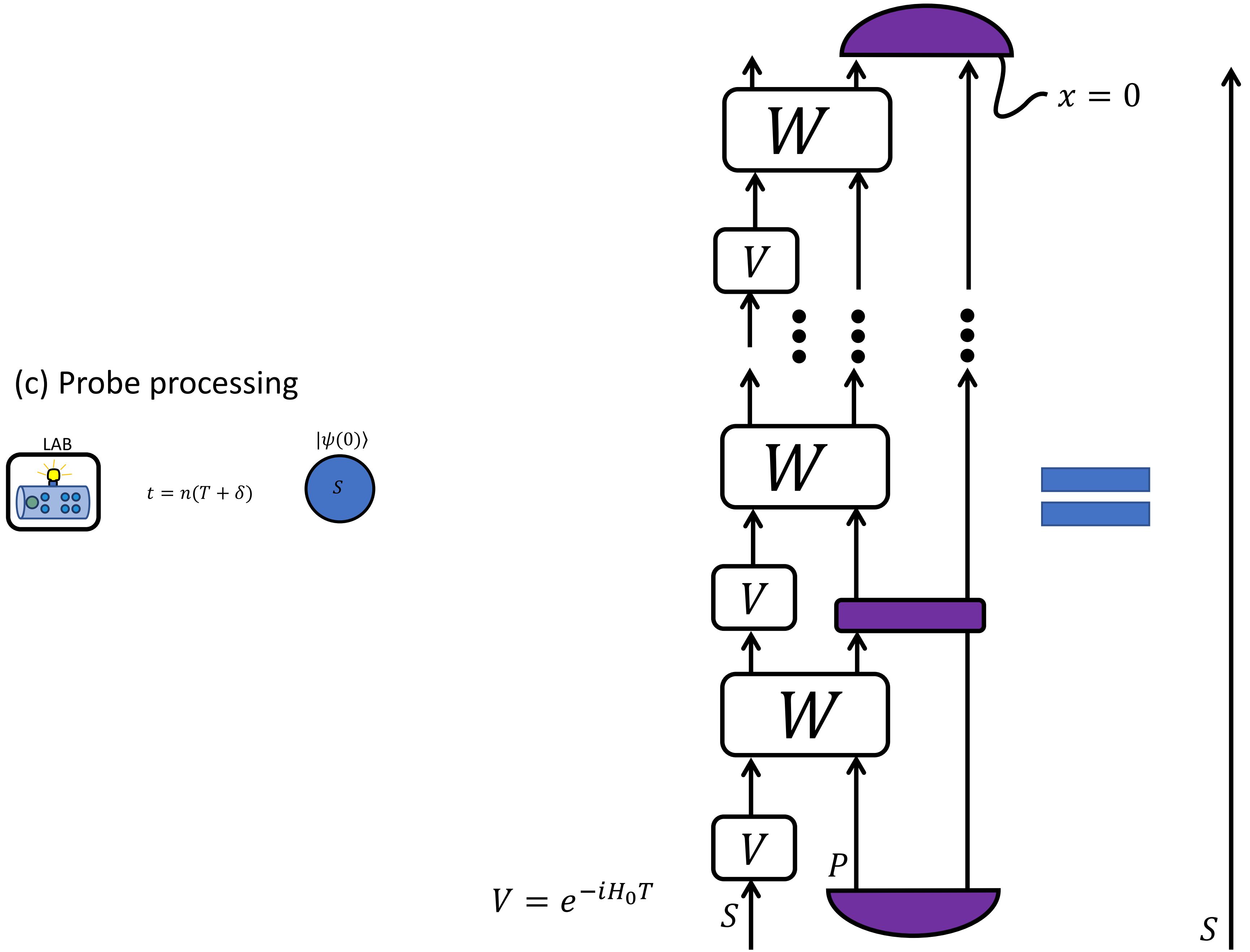
(a) Probe interaction

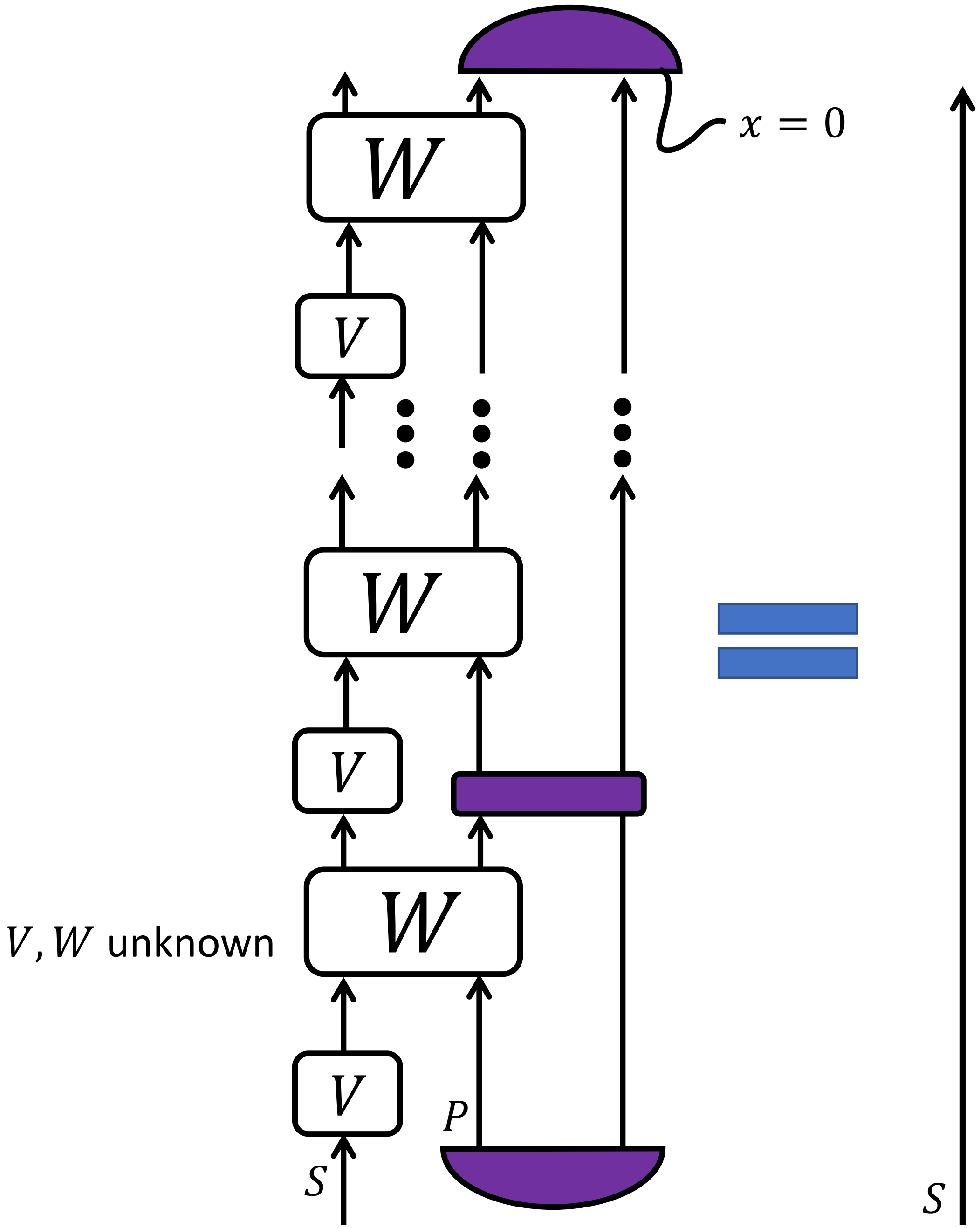


$$V = e^{-iH_0T}$$

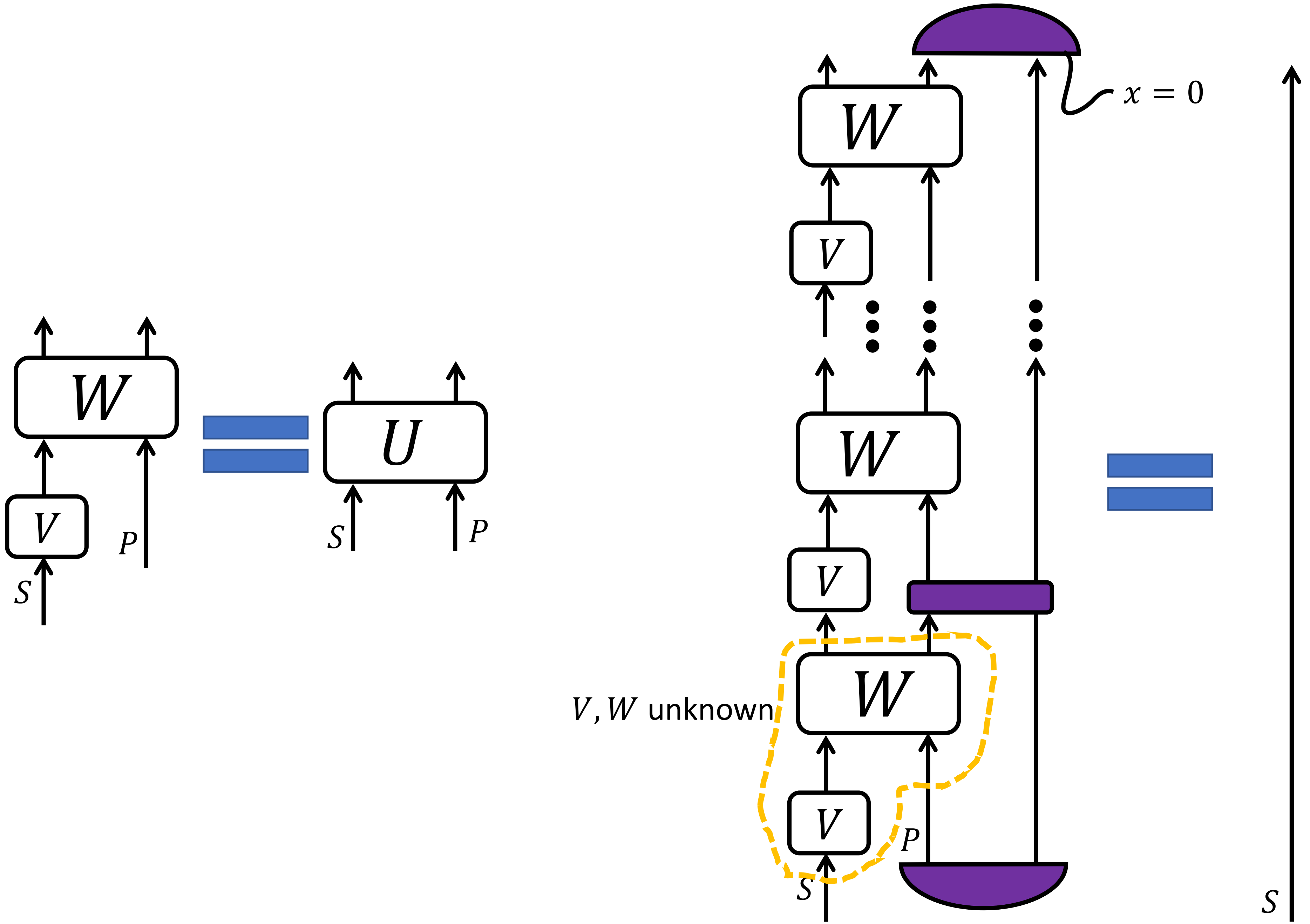


(c) Probe processing

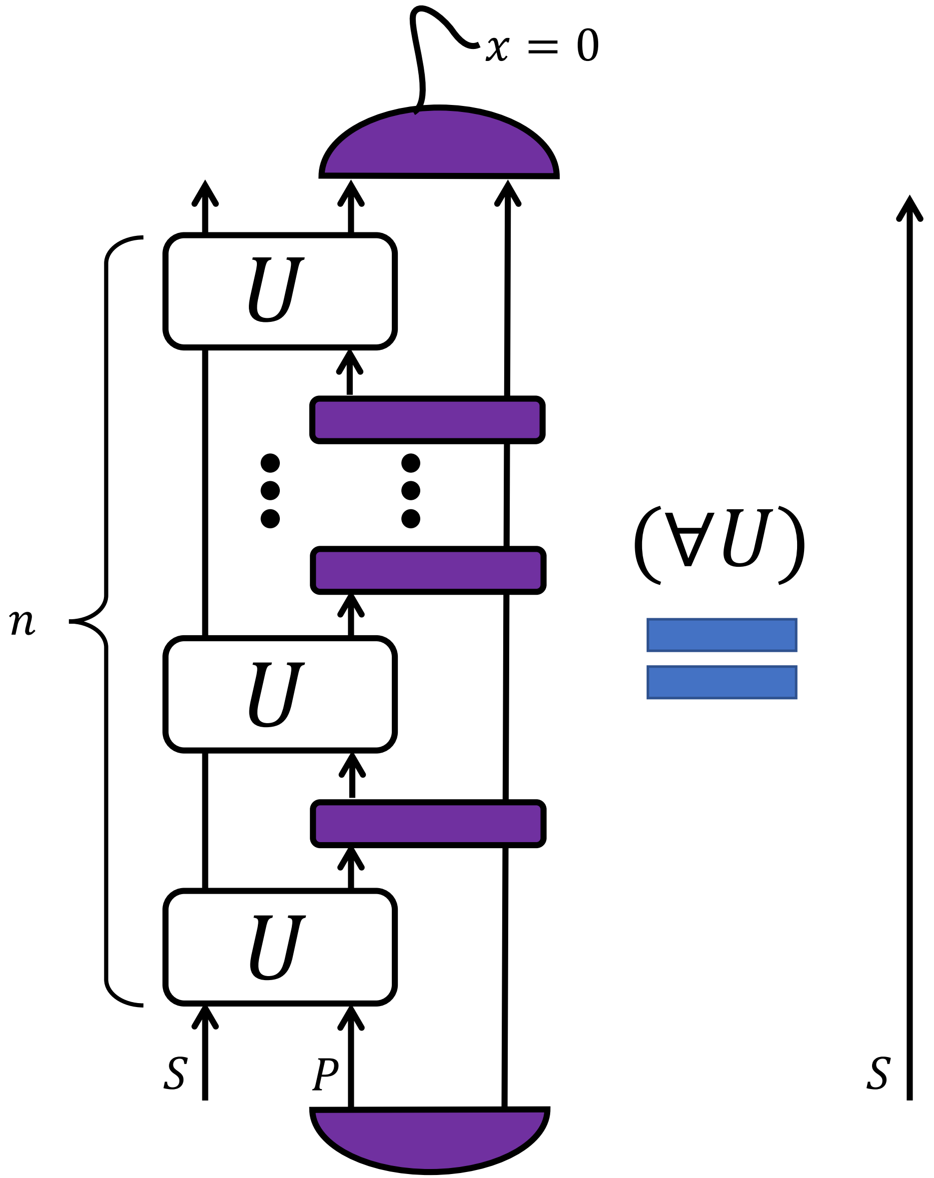




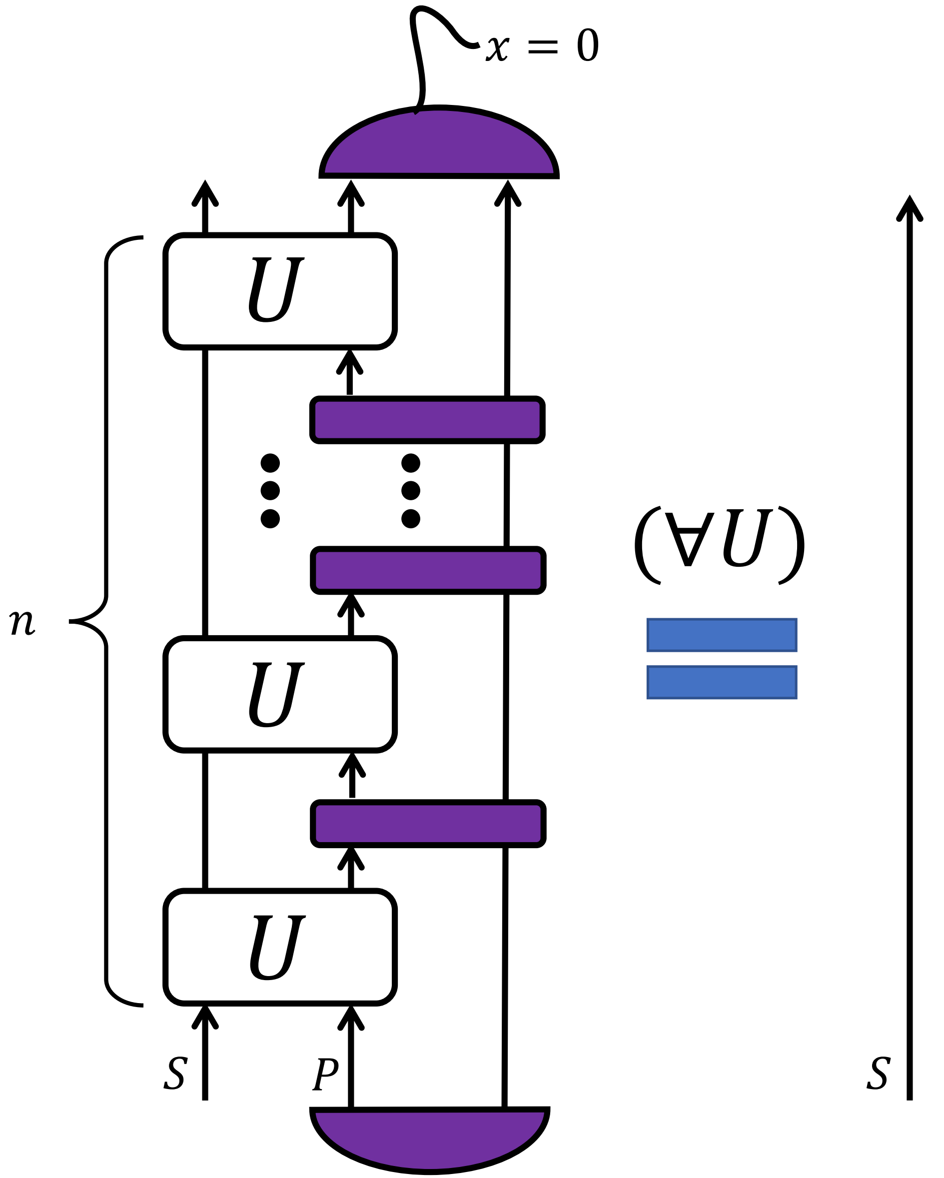
W
V
W
V
W
V
V, W unknown
S
P
$x = 0$
S


W
V
S
P
U
S
P
W
V
W
V
W
V
S
P
x = 0
V, W unknown
S

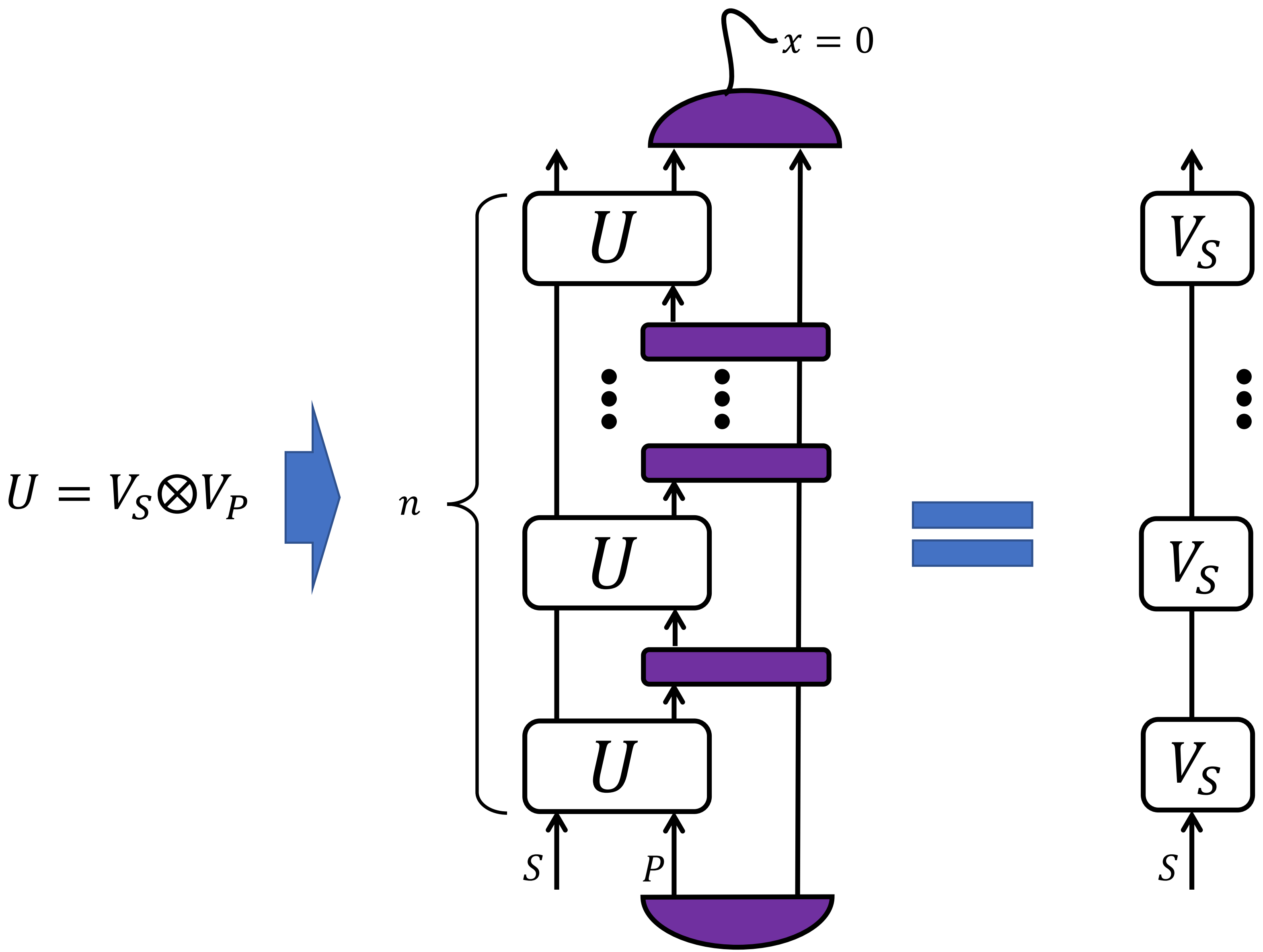
Quantum resetting protocol



Quantum resetting protocol



Desideratum: $P(x = 0|U) \neq 0$, for all U

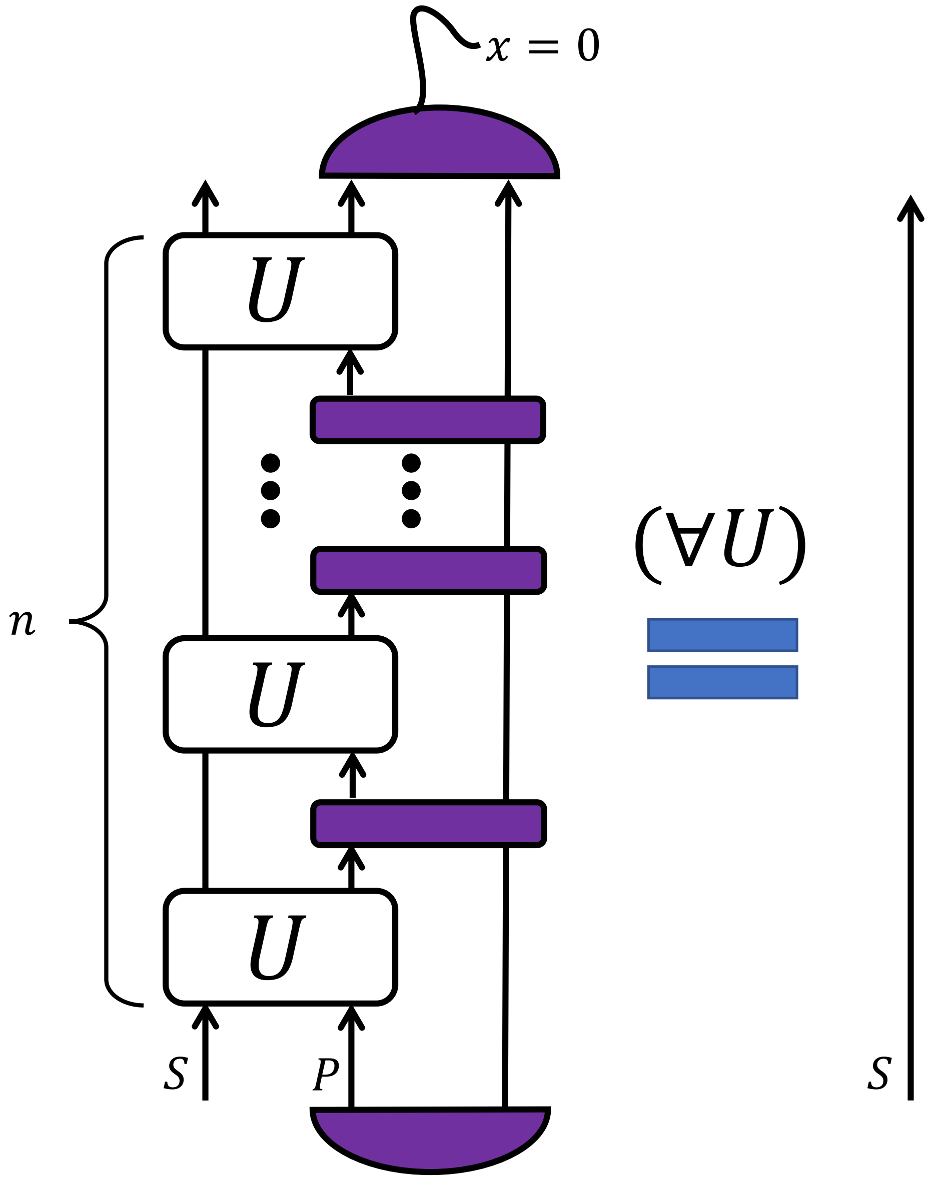


$U = V_S \otimes V_P$
$x = 0$
n
U
U
U
S
P
V_S
V_S
V_S
S

$$U = V_S \otimes V_P$$

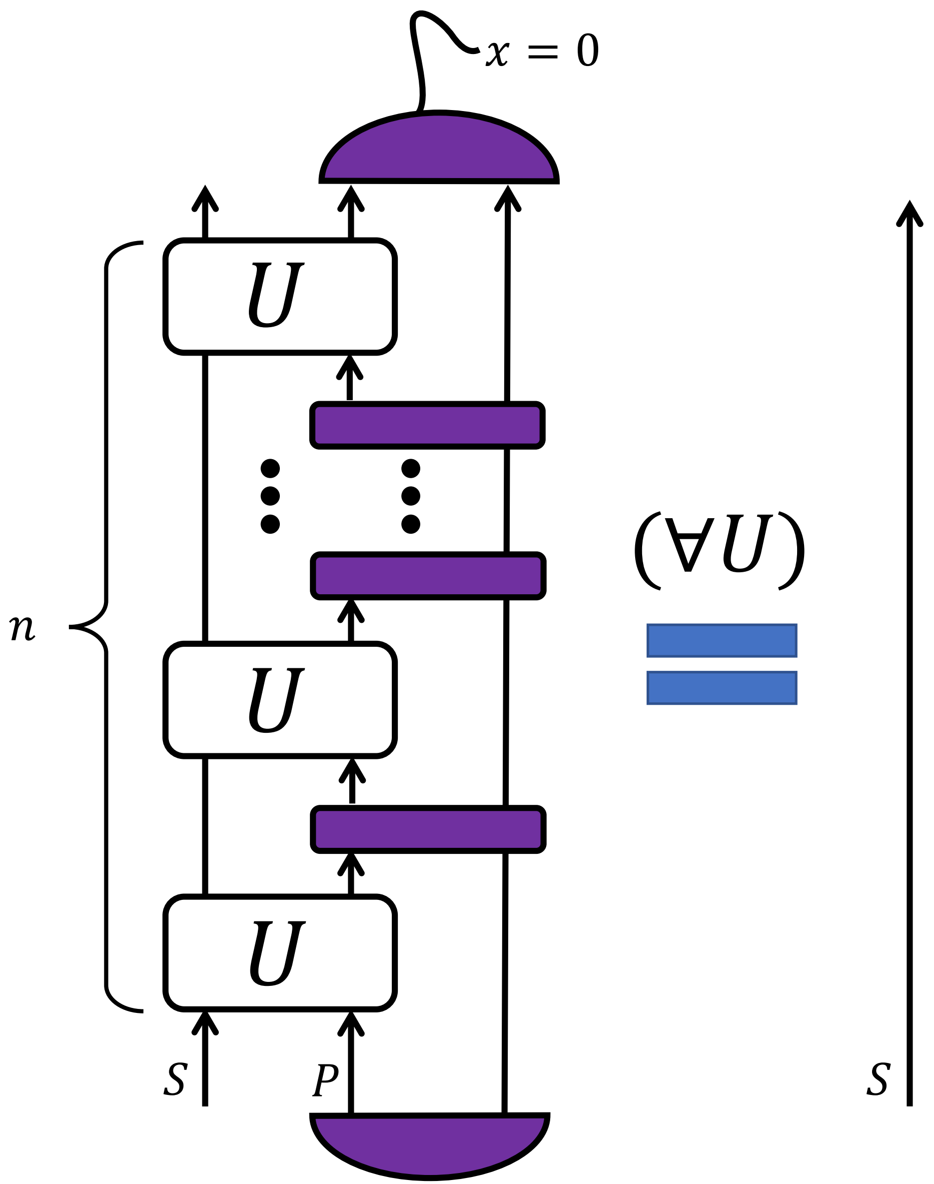
Resetting protocol will fail with probability 1

Quantum resetting protocol



Desideratum: $P(x = 0|U) \neq 0$, for all U

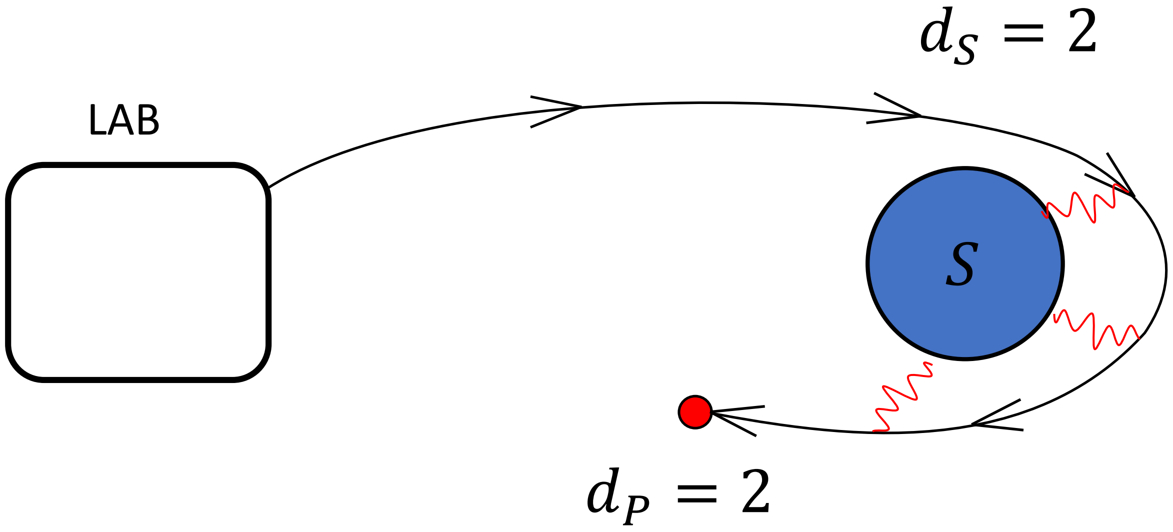
Quantum resetting protocol



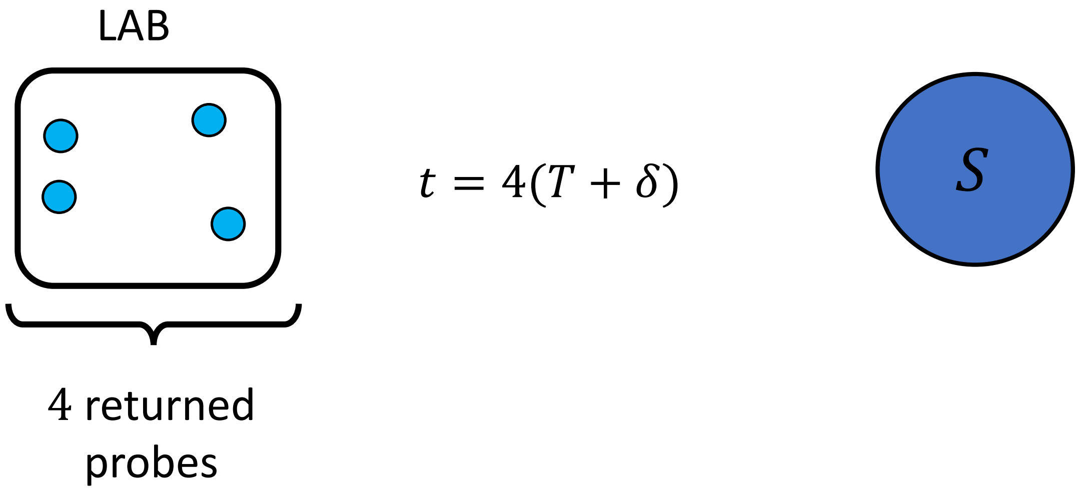
$P(x = 0|U) \neq 0$, except for a subset of unitaries of zero measure

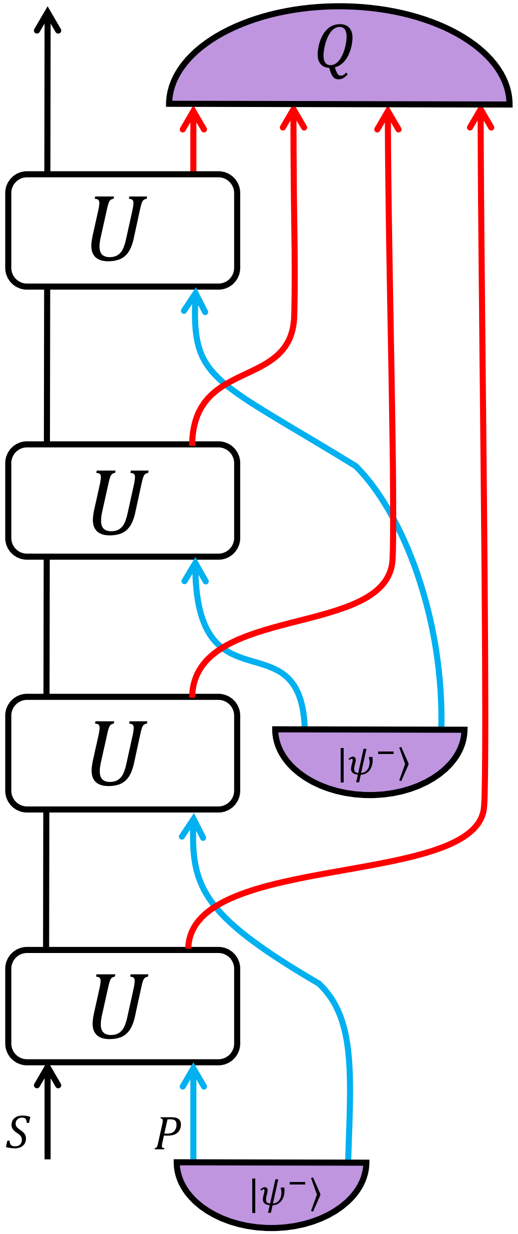
Do quantum resetting protocols exist?

Scenario

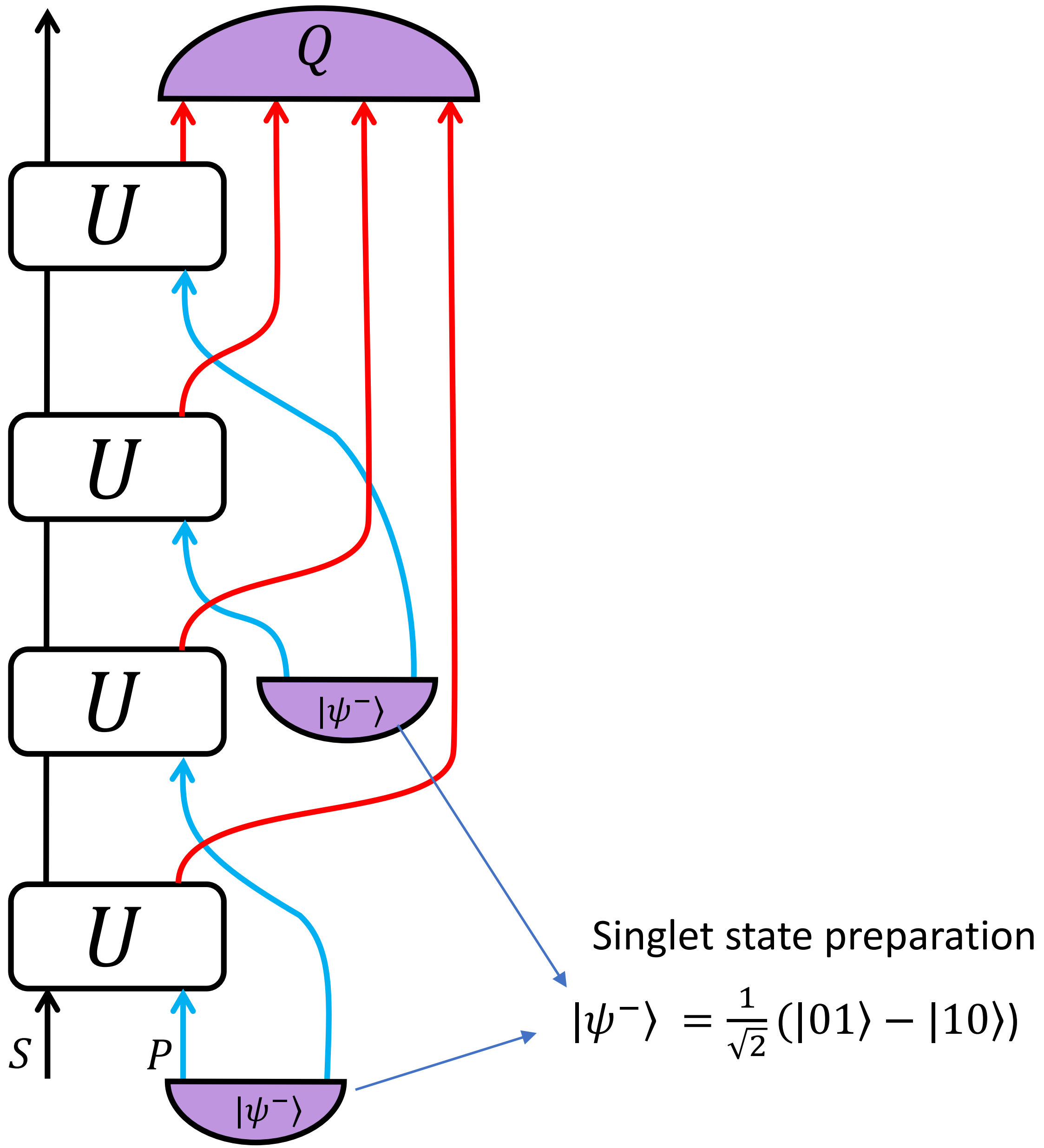


Scenario

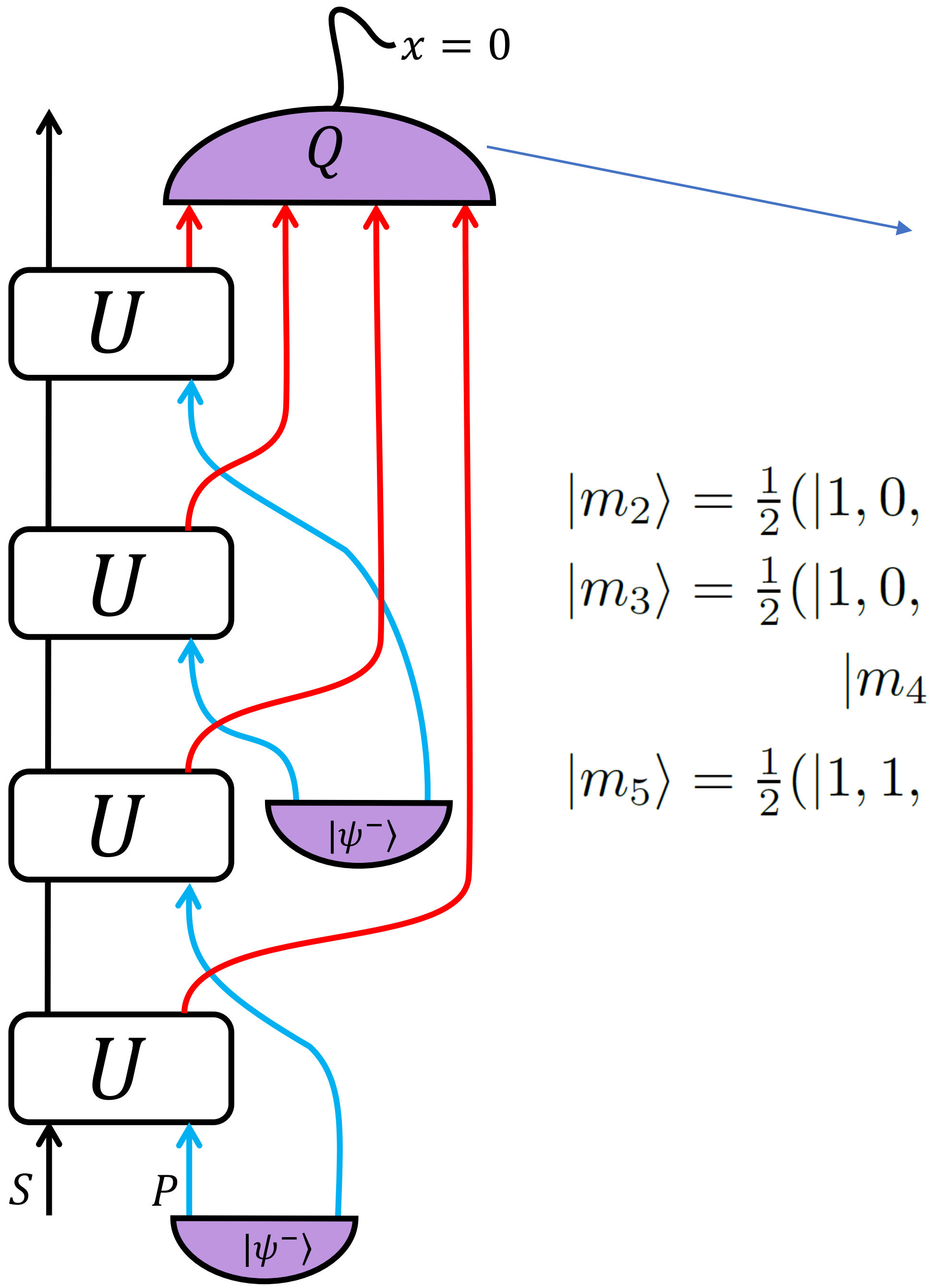




Q
U
U
U
U
|ψ⁻⟩
S
P
|ψ⁻⟩



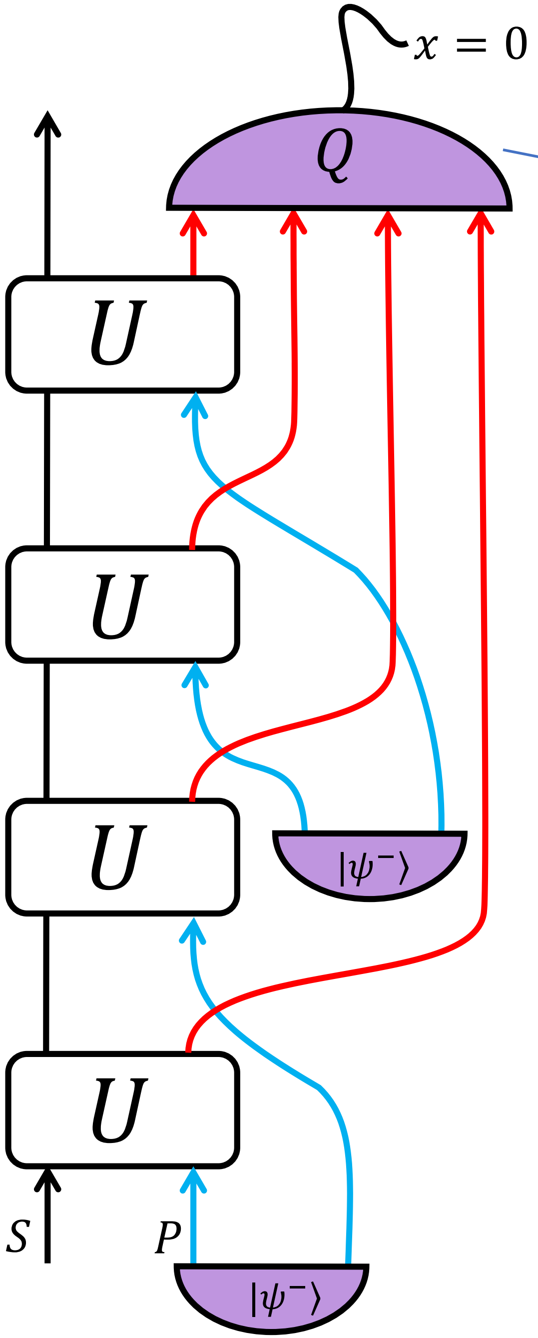
Q
U
U
U
U
|ψ⁻⟩
|ψ⁻⟩
S
P
Singlet state preparation
$|\psi^-\rangle = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$



Projection onto the space spanned by

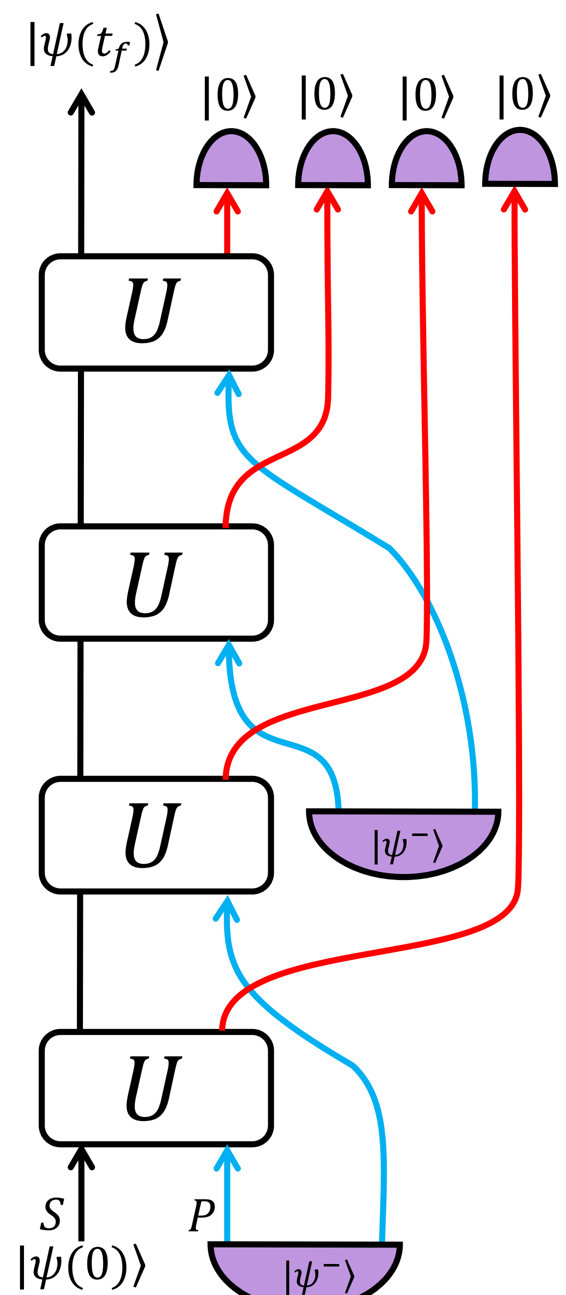
$$|m_1\rangle = |0,0,0,0\rangle,$$
$$|m_2\rangle = \frac{1}{2}(|1,0,0,0\rangle + |0,1,0,0\rangle + |0,0,1,0\rangle + |0,0,0,1\rangle),$$
$$|m_3\rangle = \frac{1}{2}(|1,0,1,0\rangle + |0,1,0,1\rangle + |1,0,0,1\rangle + |0,1,1,0\rangle),$$
$$|m_4\rangle = \frac{1}{\sqrt{2}}(|0,0,1,1\rangle + |1,1,0,0\rangle),$$
$$|m_5\rangle = \frac{1}{2}(|1,1,1,0\rangle + |0,1,1,1\rangle + |1,0,1,1\rangle + |1,1,0,1\rangle),$$
$$|m_6\rangle = |1,1,1,1\rangle$$

Why does this work?



Projection onto the space spanned by

$$|m_1\rangle = |0,0,0,0\rangle,$$
$$|m_2\rangle = \tfrac{1}{2}(|1,0,0,0\rangle + |0,1,0,0\rangle + |0,0,1,0\rangle + |0,0,0,1\rangle),$$
$$|m_3\rangle = \tfrac{1}{2}(|1,0,1,0\rangle + |0,1,0,1\rangle + |1,0,0,1\rangle + |0,1,1,0\rangle),$$
$$|m_4\rangle = \tfrac{1}{\sqrt{2}}(|0,0,1,1\rangle + |1,1,0,0\rangle),$$
$$|m_5\rangle = \tfrac{1}{2}(|1,1,1,0\rangle + |0,1,1,1\rangle + |1,0,1,1\rangle + |1,1,0,1\rangle),$$
$$|m_6\rangle = |1,1,1,1\rangle$$

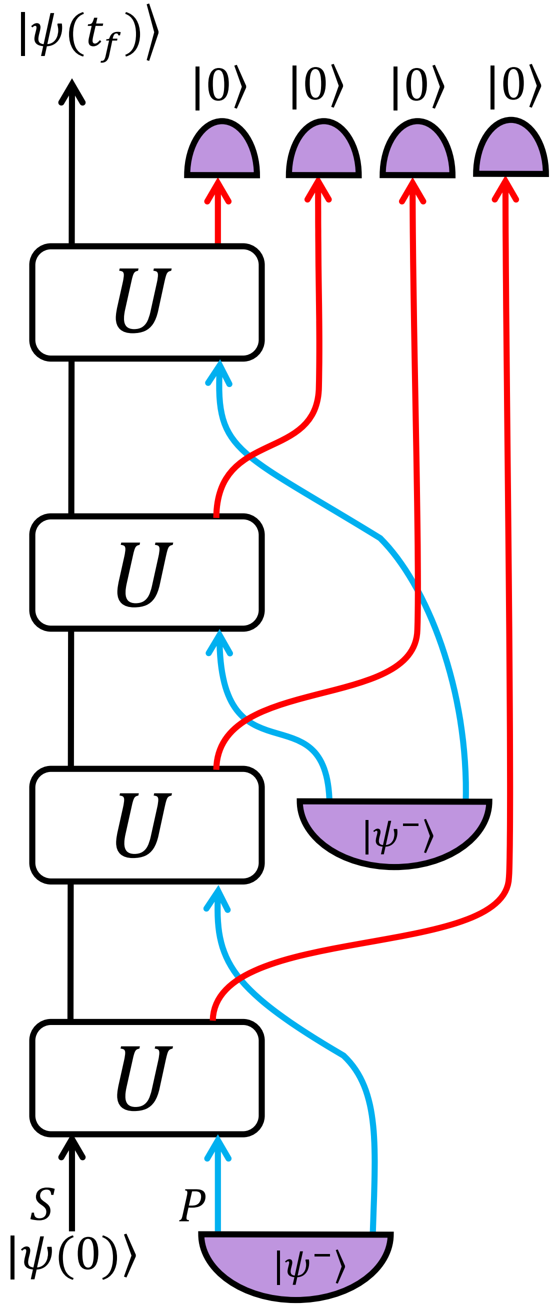


$|\psi(t_f)\rangle$
$|0\rangle$
$|0\rangle$
$|0\rangle$
$|0\rangle$
U
U
U
$|\psi^-\rangle$
U
S
P
$|\psi(0)\rangle$
$|\psi^-\rangle$

$$|\psi(t_f)\rangle = \frac{1}{2}[U_{0,0}, U_{0,1}]^2|\psi(0)\rangle$$

$$U_{ij} = (\mathbb{I}_S \otimes \langle i|_P) U (\mathbb{I}_S \otimes |j\rangle_P)$$

2x2 complex matrices



$A, B, 2 \times 2$ matrices

A, B, 2×2 matrices

$$[A, B] = \sum_{i=0,1,2,3} c_i \sigma_i$$

σ_i, Pauli matrices

A, B, 2×2 matrices

$$[A, B] = \sum_{i=0,1,2,3} c_i \sigma_i \qquad \mathrm{Tr}([A, B]) = 0 \Rightarrow c_0 = 0$$

σ_i, Pauli matrices

A, B, 2×2 matrices

$$[A, B] = \sum_{i=1,2,3} c_i \sigma_i$$

σ_i, Pauli matrices

A, B, 2×2 matrices

$$[A, B]^2 = \left(\sum_{i=1,2,3} c_i \sigma_i \right)^2 = \left(\sum_{i=1,2,3} c_i^2 \right) \mathbb{I}$$

σ_i, Pauli matrices

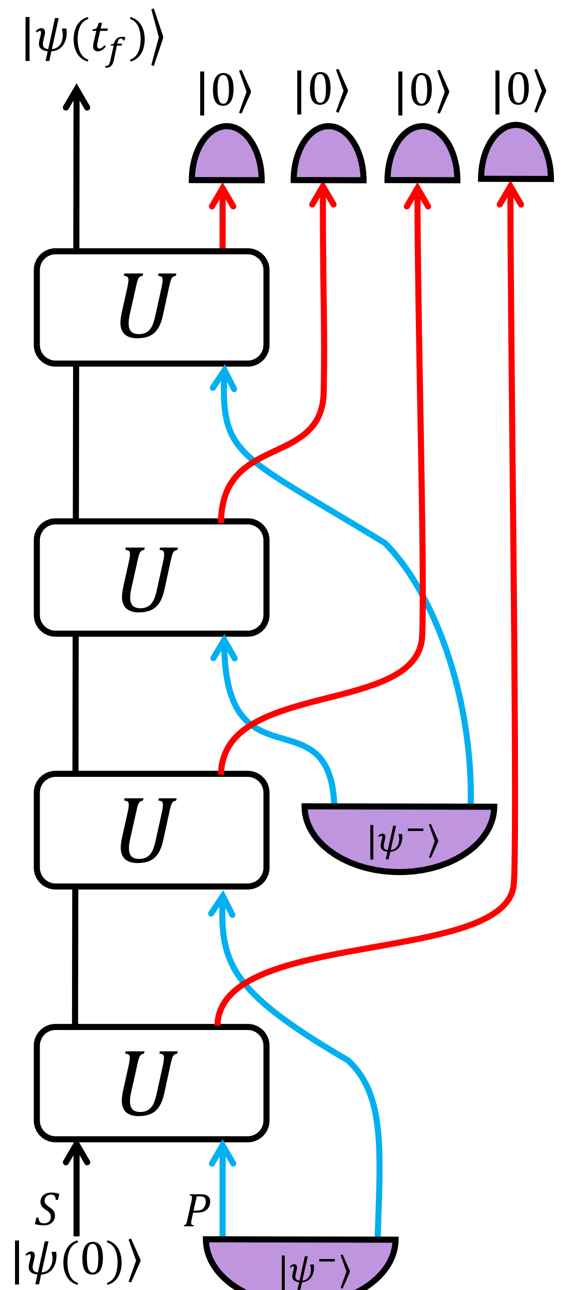
A, B, 2×2 matrices

Central polynomial for dimension 2

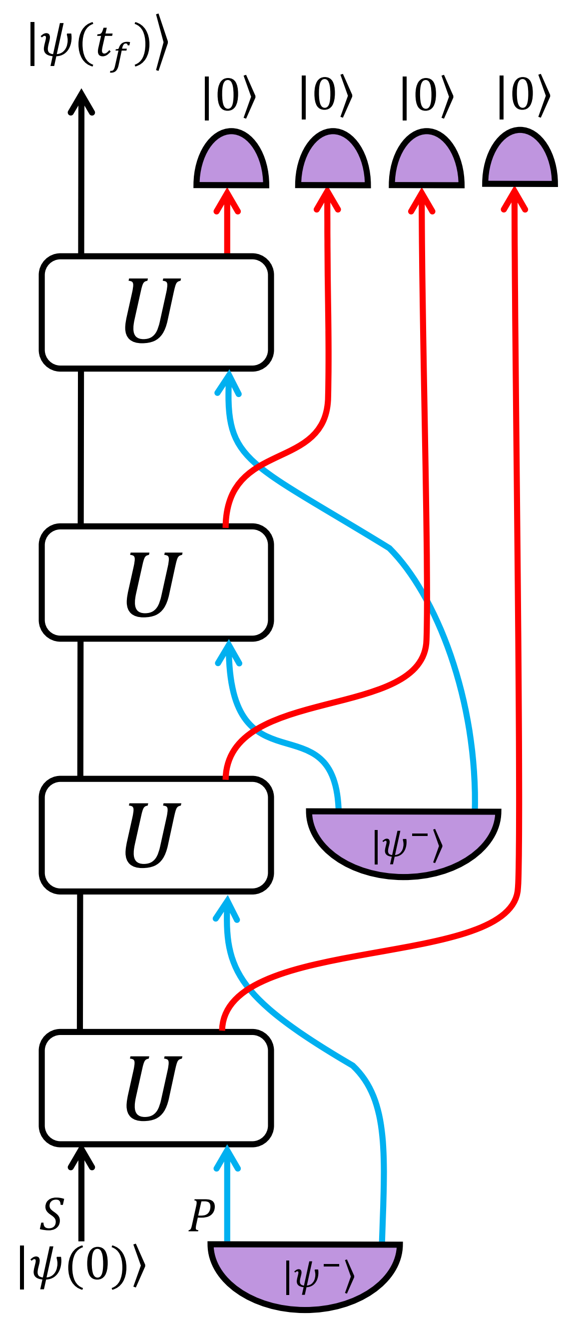
$$[A,B]^2 = \left(\sum_{i=1,2,3} c_i \sigma_i\right)^2 = \left(\sum_{i=1,2,3} c_i^2\right) \mathbb{I}$$

σ_i, Pauli matrices

$$|\psi(t_f)\rangle = \frac{1}{2}[U_{0,0}, U_{0,1}]^2|\psi(0)\rangle$$



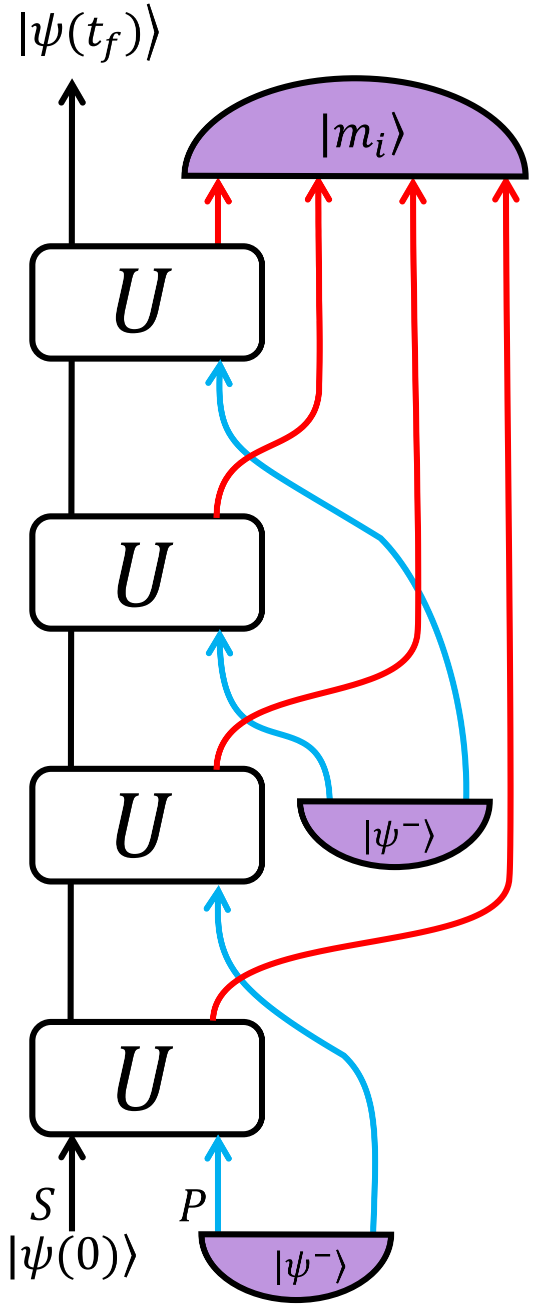
$$|\psi(t_f)\rangle = \frac{1}{2}[U_{0,0}, U_{0,1}]^2|\psi(0)\rangle \propto |\psi(0)\rangle$$

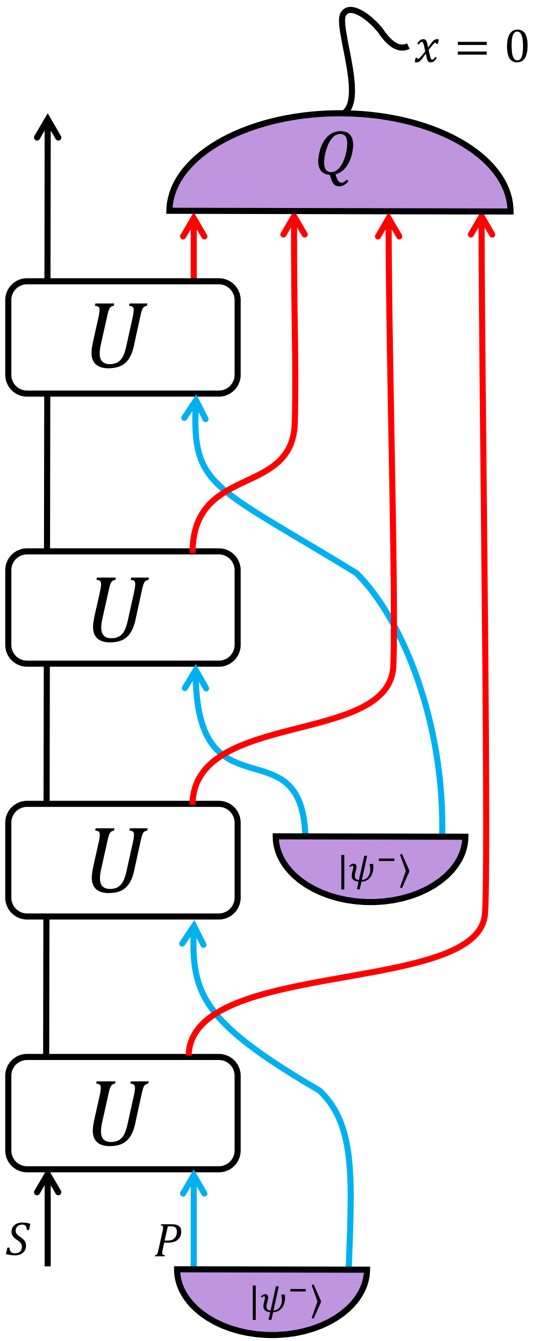


Similarly,

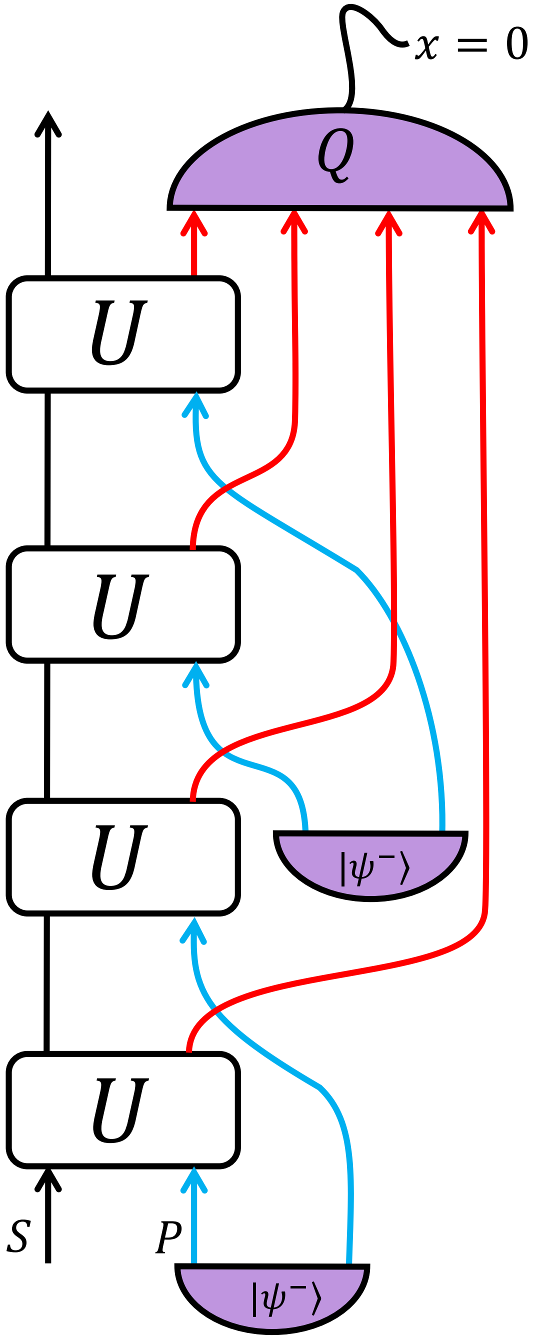
$$|\psi(t_f)\rangle \propto |\psi(0)\rangle$$

$$|m_1\rangle = |0,0,0,0\rangle,$$
$$|m_2\rangle = \tfrac{1}{2}(|1,0,0,0\rangle + |0,1,0,0\rangle + |0,0,1,0\rangle + |0,0,0,1\rangle),$$
$$|m_3\rangle = \tfrac{1}{2}(|1,0,1,0\rangle + |0,1,0,1\rangle + |1,0,0,1\rangle + |0,1,1,0\rangle),$$
$$|m_4\rangle = \tfrac{1}{\sqrt{2}}(|0,0,1,1\rangle + |1,1,0,0\rangle),$$
$$|m_5\rangle = \tfrac{1}{2}(|1,1,1,0\rangle + |0,1,1,1\rangle + |1,0,1,1\rangle + |1,1,0,1\rangle),$$
$$|m_6\rangle = |1,1,1,1\rangle$$



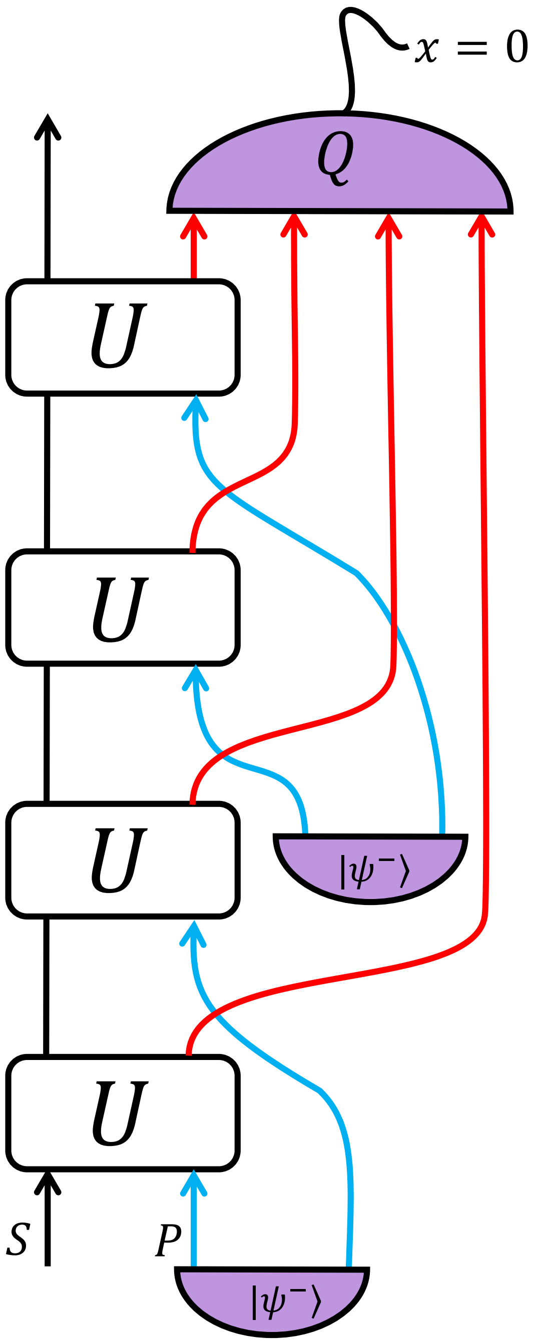


$$P(x = 0|U) \in [0, 1]$$



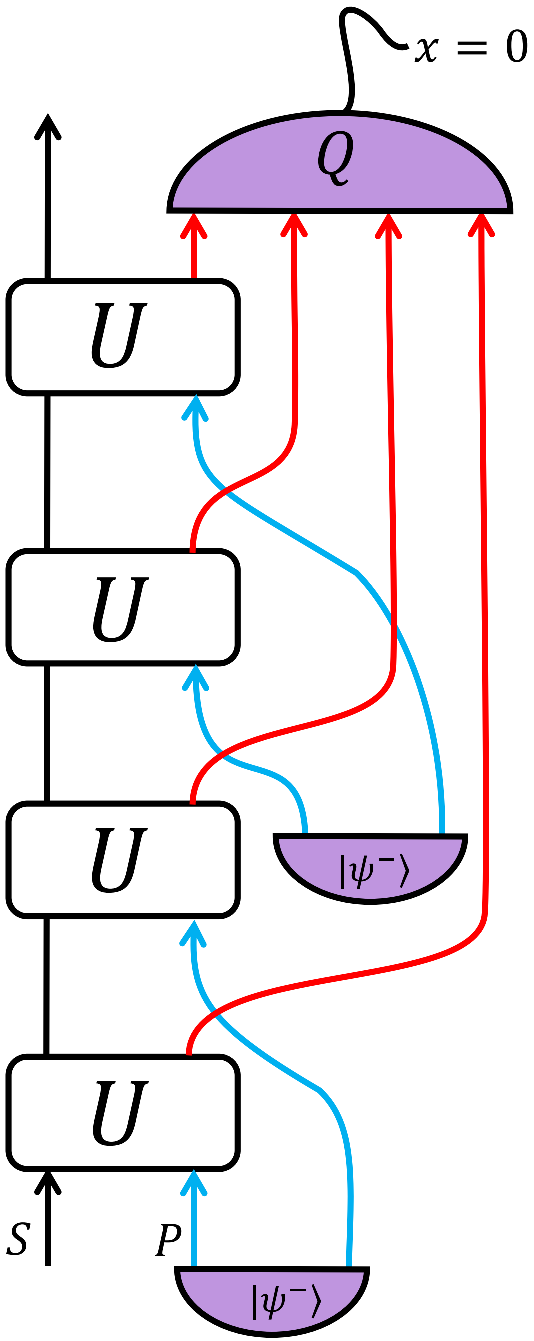
$$P(x = 0|U) \in [0, 1]$$

E.g.: $U = V_S \otimes V_P$



$$P(x = 0|U) \in [0, 1]$$

E.g.: $U = \frac{\sigma_x \otimes \sigma_z + i\sigma_y \otimes \sigma_x}{\sqrt{2}}$



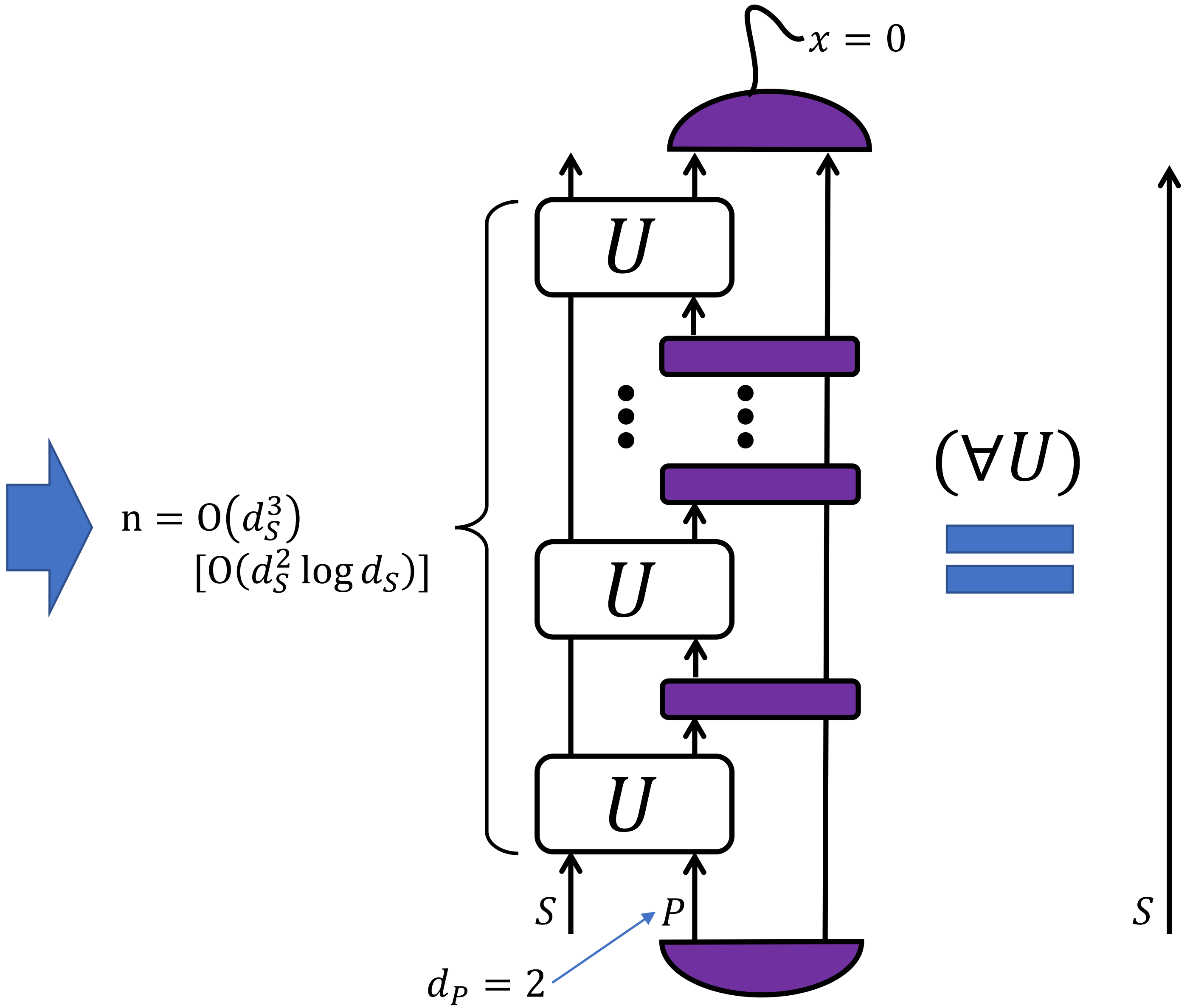
Average probability of success for completey unknown U

$$\int dU\, P(x = 0|U) \approx 0.2170$$

Generalization

MN, arXiv:1710.02470

For all d_S



$P(x = 0|U) \neq 0$, except for a subset of unitaries of zero measure

MN, arXiv:1710.02470

Characterization of all quantum resetting protocols (practical for n=4)

$$\begin{aligned} &\max \operatorname{tr}(M_0^T X(\rho)) \\ \text{s.t. } &\operatorname{supp}(M_0^T) \in \mathcal{H}^c, M_0, M_1 \geq 0 \\ &M_0 + M_1 = \mathbb{I}_{A_n^{out}} \otimes \Gamma^{(n)}, \\ &\operatorname{tr}_{I_k}(\Gamma^{(k)}) = \mathbb{I}_{O_{k-1}} \otimes \Gamma^{(k-1)}, \end{aligned}$$

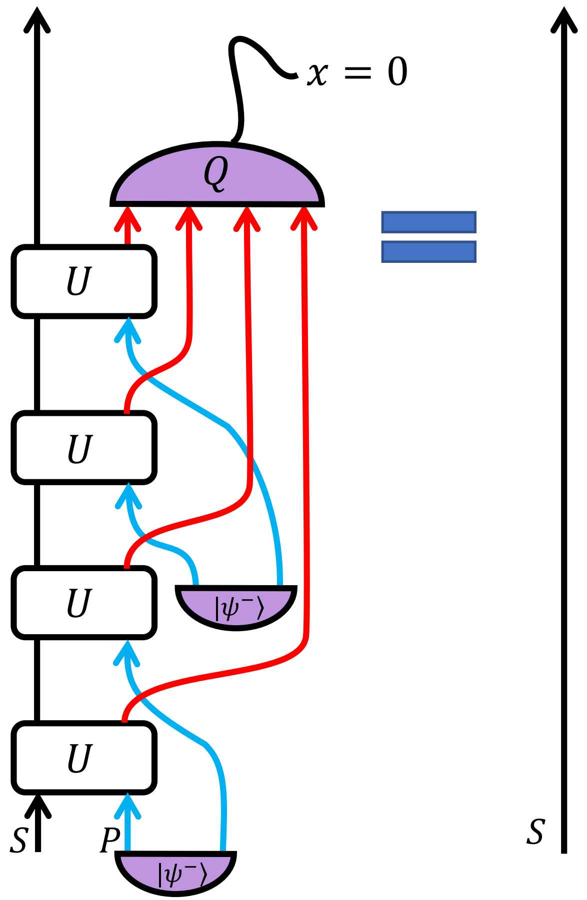
MN, arXiv:1710.02470

Heuristics to identify optimal strategies for high numbers of probes

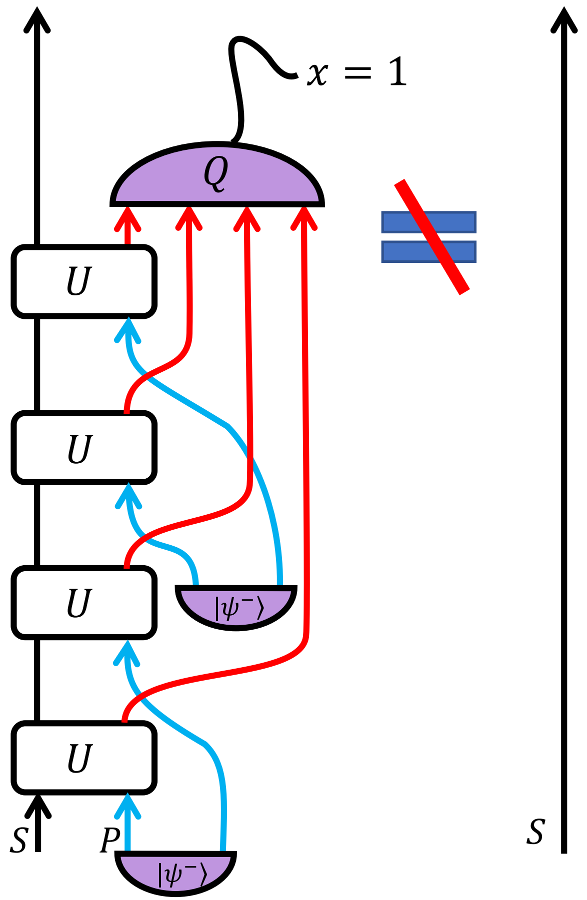
$\mathcal{W}_8, \widetilde{\mathcal{W}}_8,$ $n = 8, d_S = 2$

$\mathcal{W}_9$ $n = 9, d_S = 3$

What if the protocol fails?

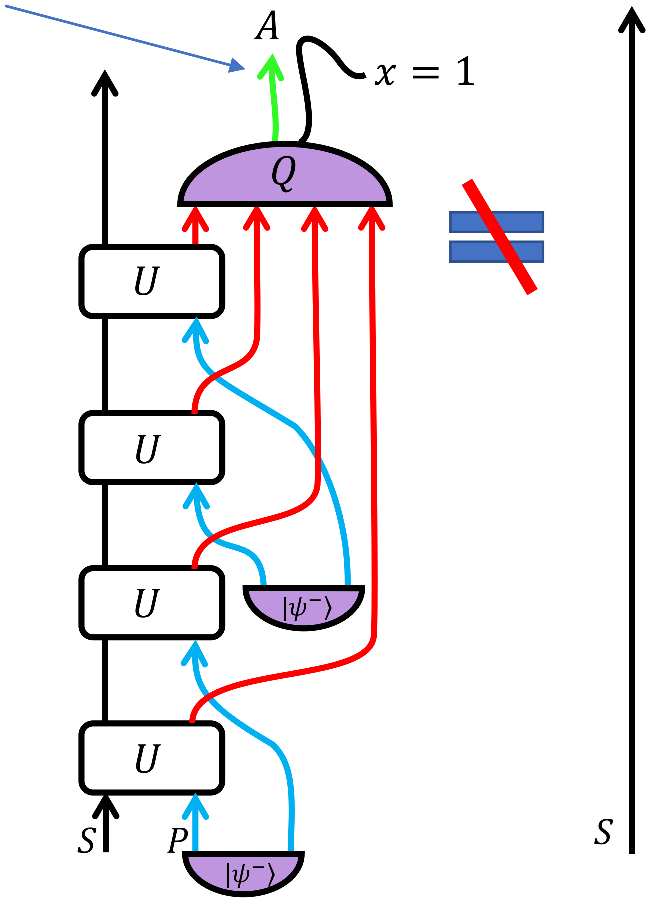


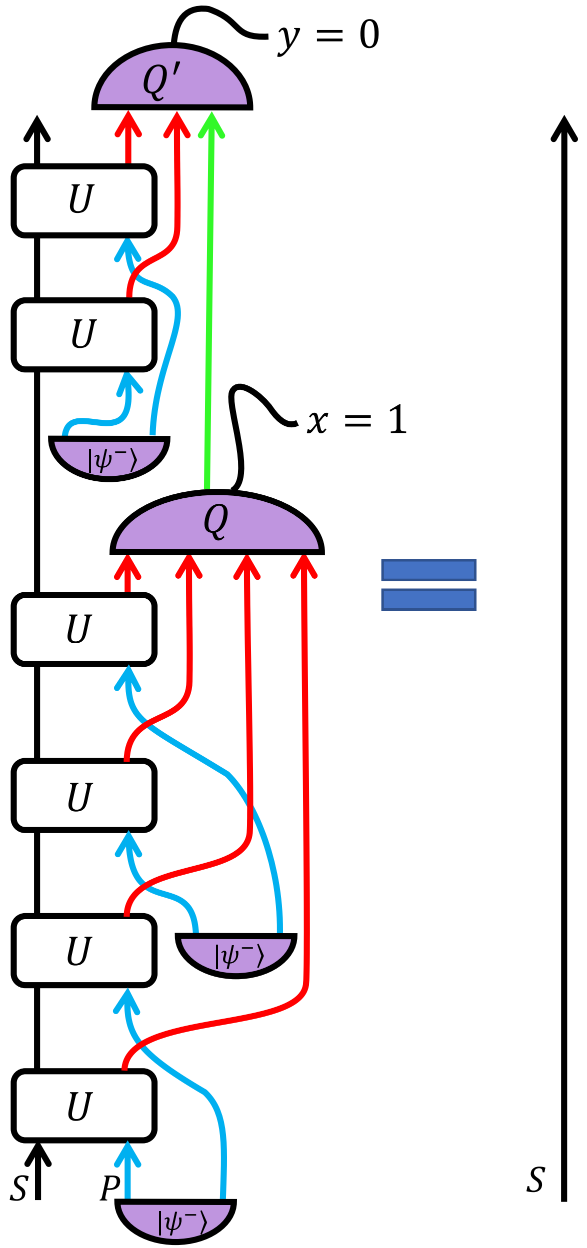
x = 0
Q
U
U
U
U
|ψ⁻⟩
|ψ⁻⟩
S
P
S



x = 1
Q
U
U
U
U
|ψ⁻⟩
|ψ⁻⟩
S
P
S

Suppose that the last measurement is a non-demolition one



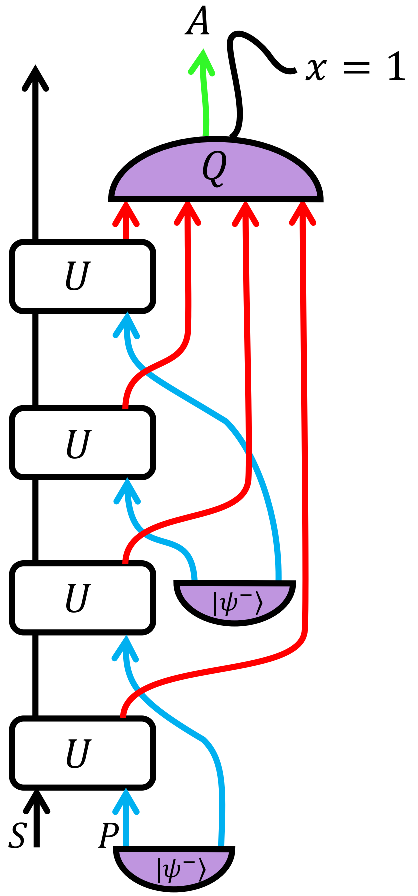


$y = 0$
Q'
U
U
$|\psi^-\rangle$
$x = 1$
Q
U
U
U
$|\psi^-\rangle$
U
S
P
$|\psi^-\rangle$
S

$$|\omega\rangle_{SA} = \sum_i f_i(U)\,|\psi\rangle_S|i\rangle_A$$

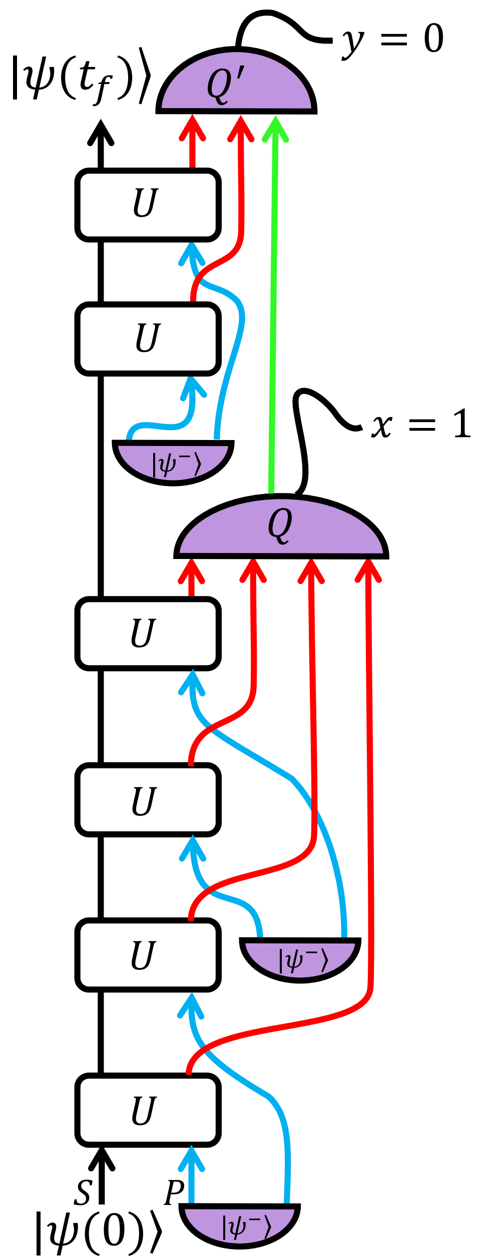
$f_i(U)$, non-central matrix polynomials of degree 4 on the variables

$$U_{ij} = (\mathbb{I}_S \otimes \langle i|_P)\,U\,(\mathbb{I}_S \otimes |j\rangle_P)$$



$$|\psi(t_f)\rangle_S = \sum_i g_i(U) f_i(U) \, |\psi(0)\rangle_S$$

$g_i(U)$, matrix polynomials of degree 2, such that $\sum_i g_i(U) f_i(U)$ is a central polynomial

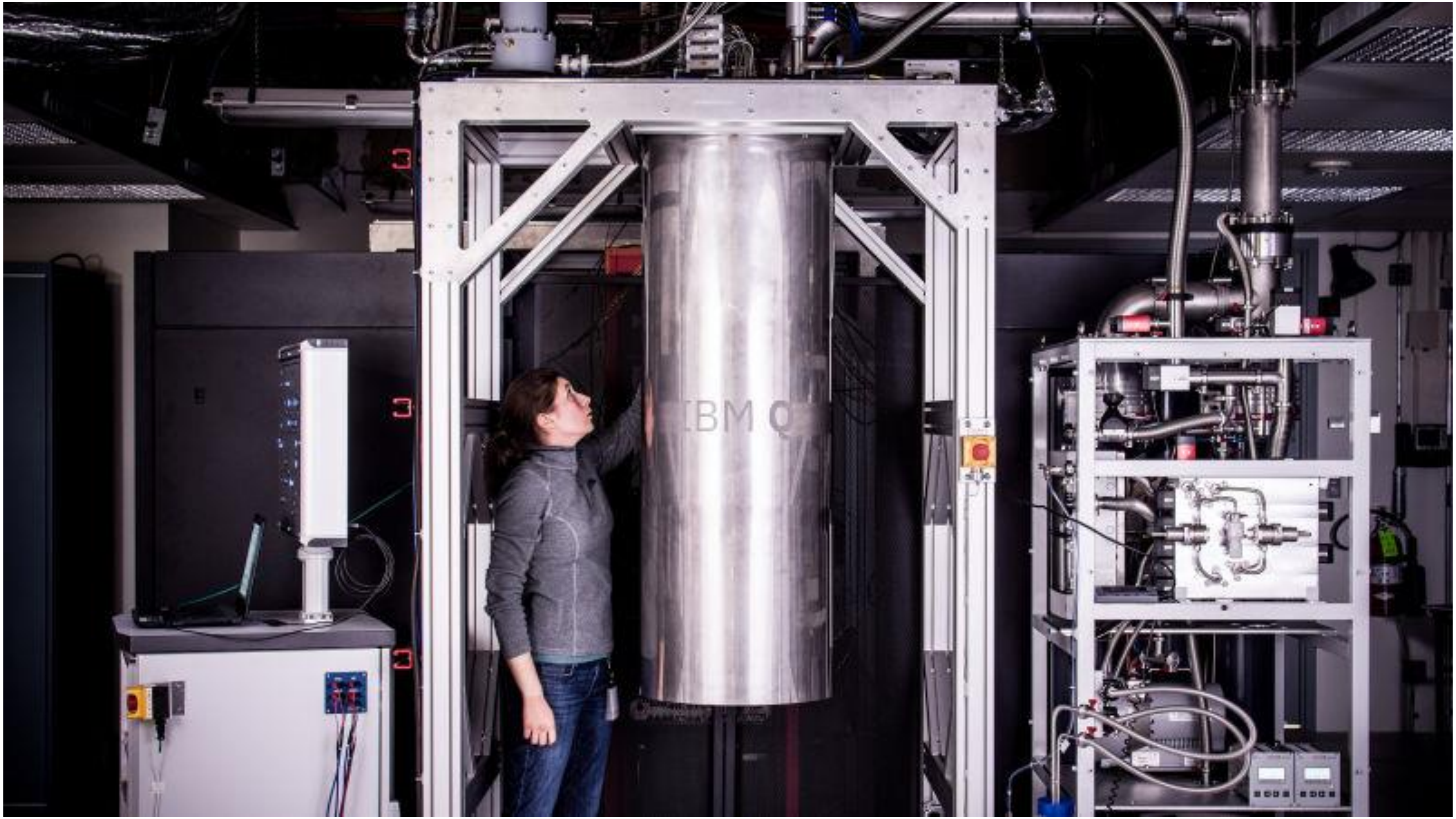


Undoing six possible failures

Average probability of success for completey unknown U

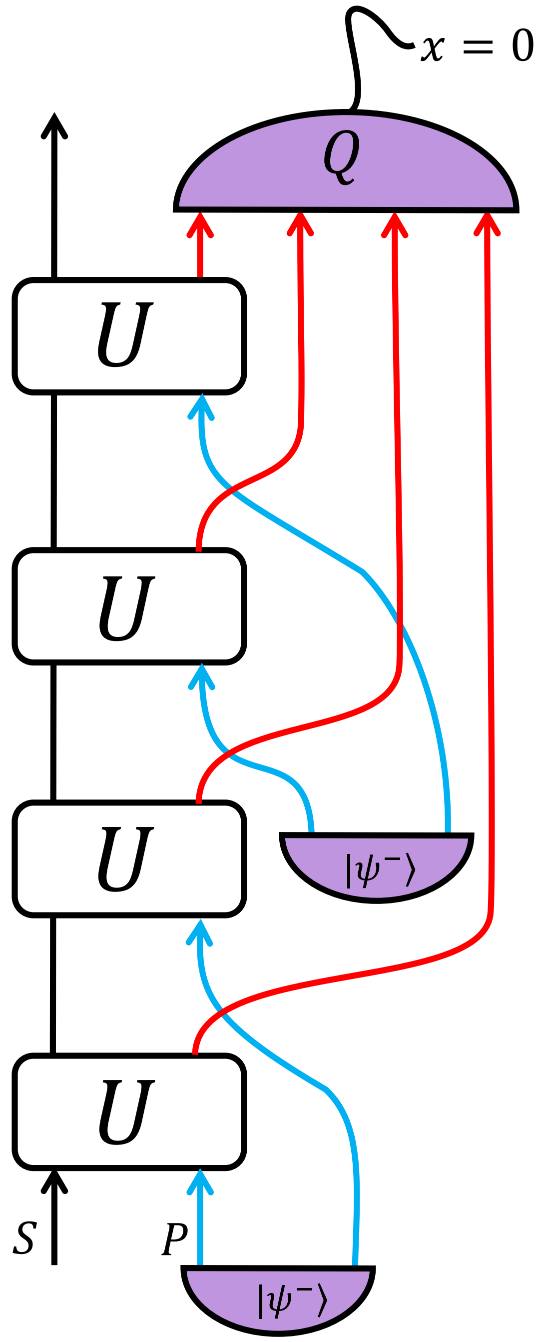
$$\int dU\, P(x=0|U) \approx 0.6585$$

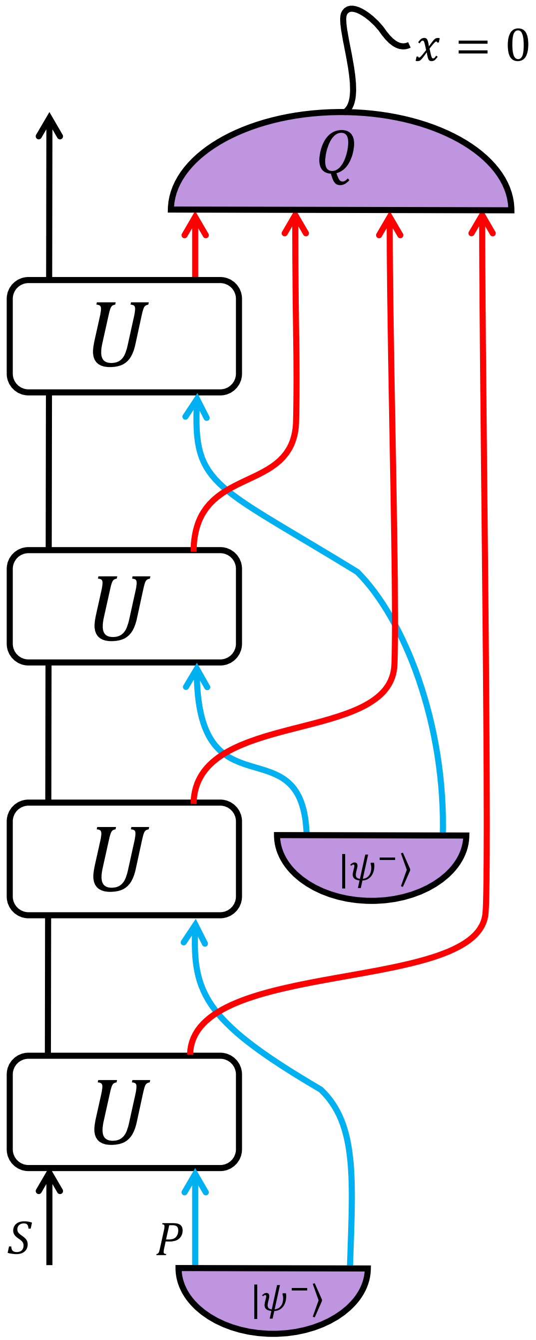
Experimental implementation?



IBM Q Experience

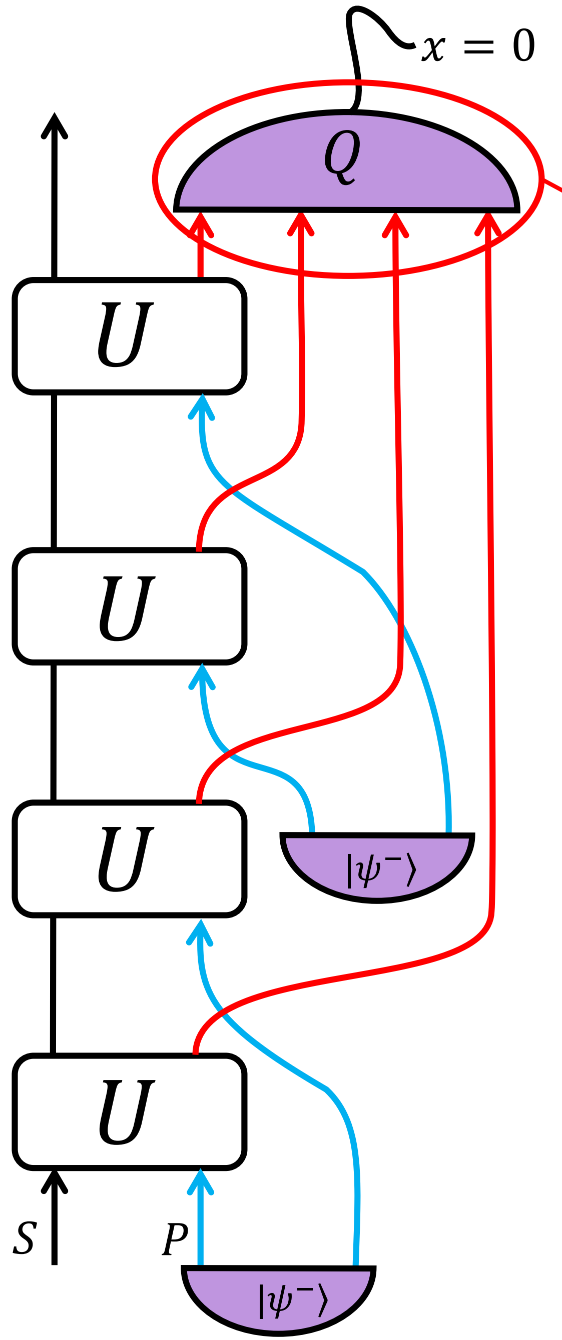
Experimental implementation: Prototype II



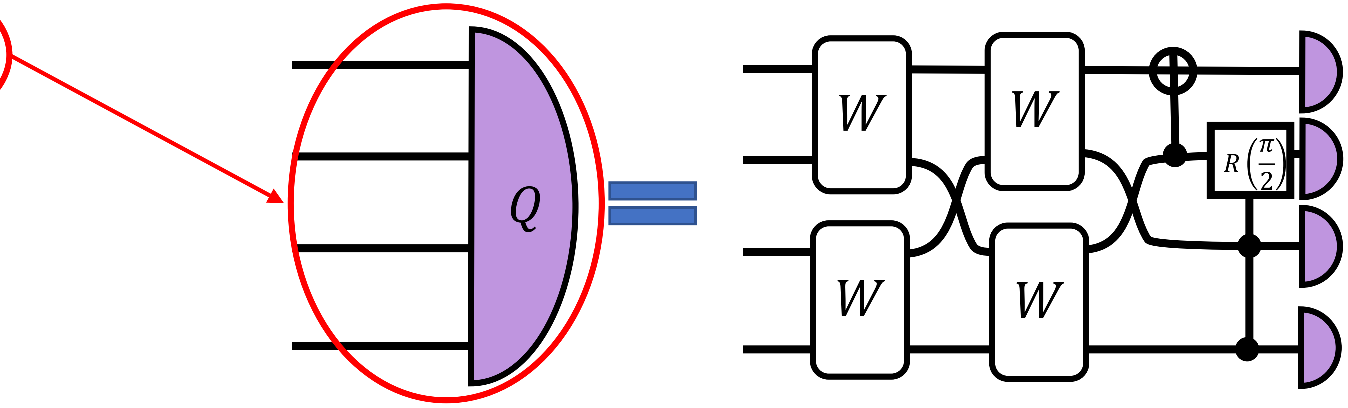


Experimental implementation: Prototype II

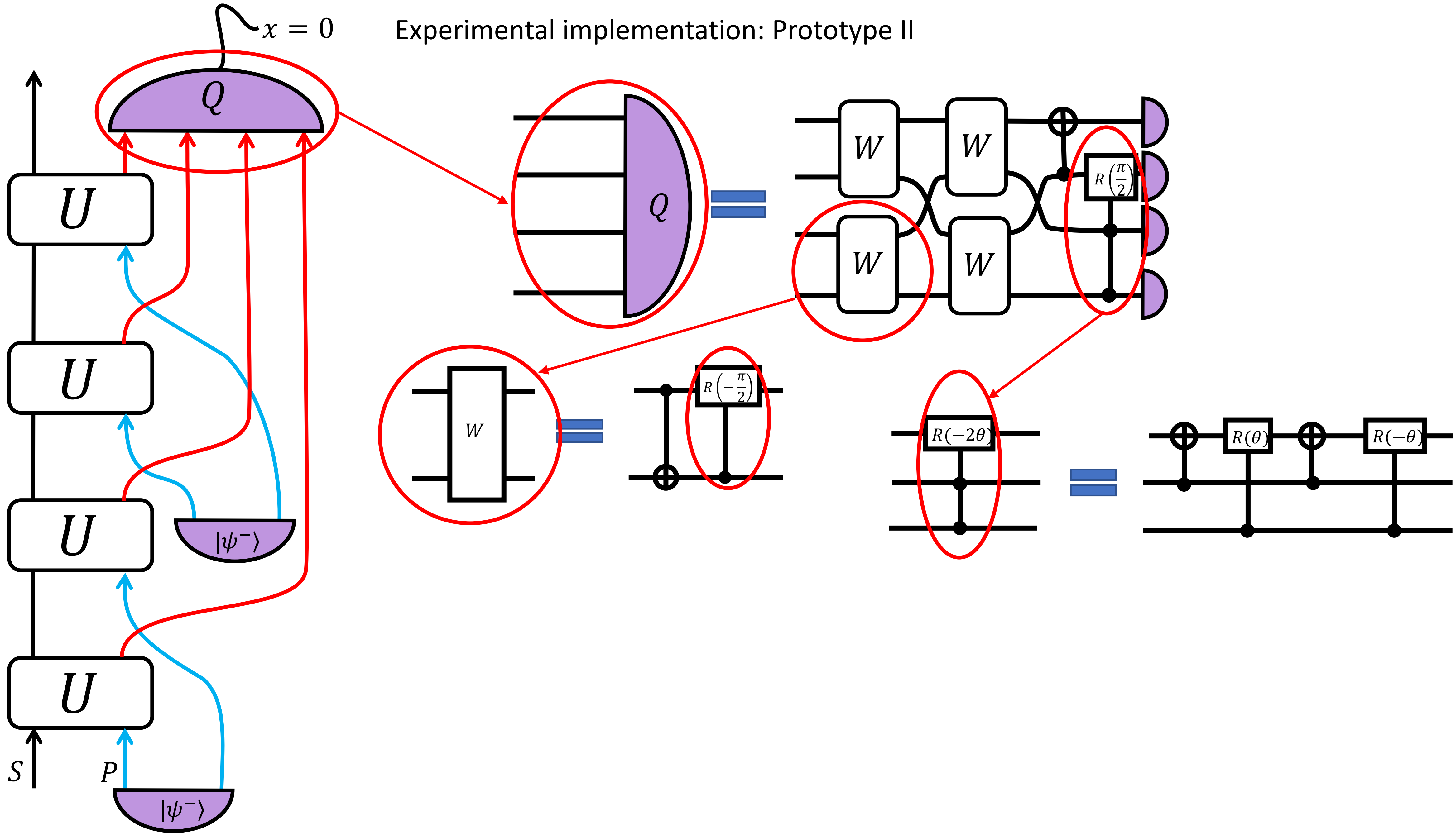
Implementation with single-qubit gates and CNOTS?



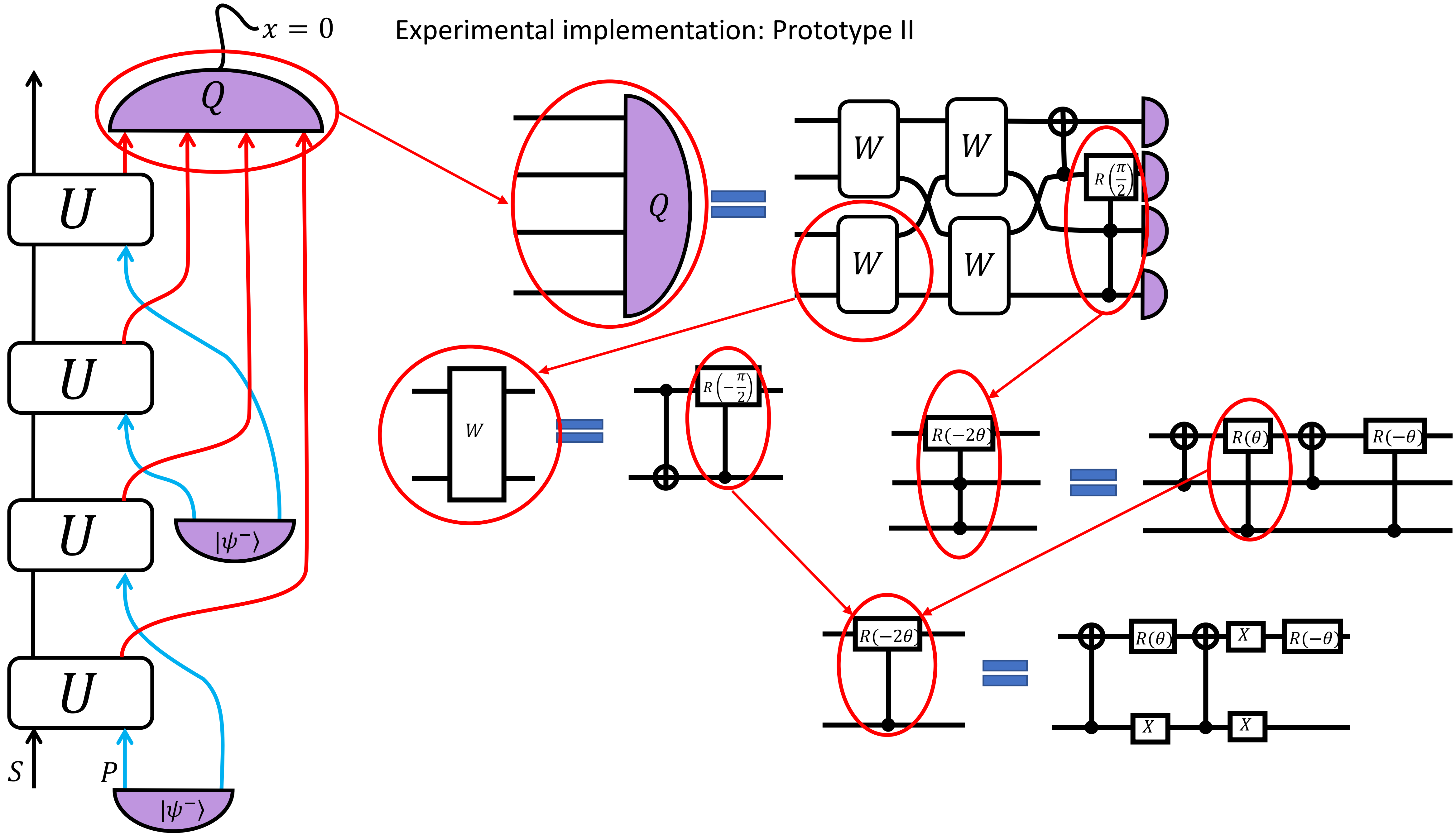
Experimental implementation: Prototype II



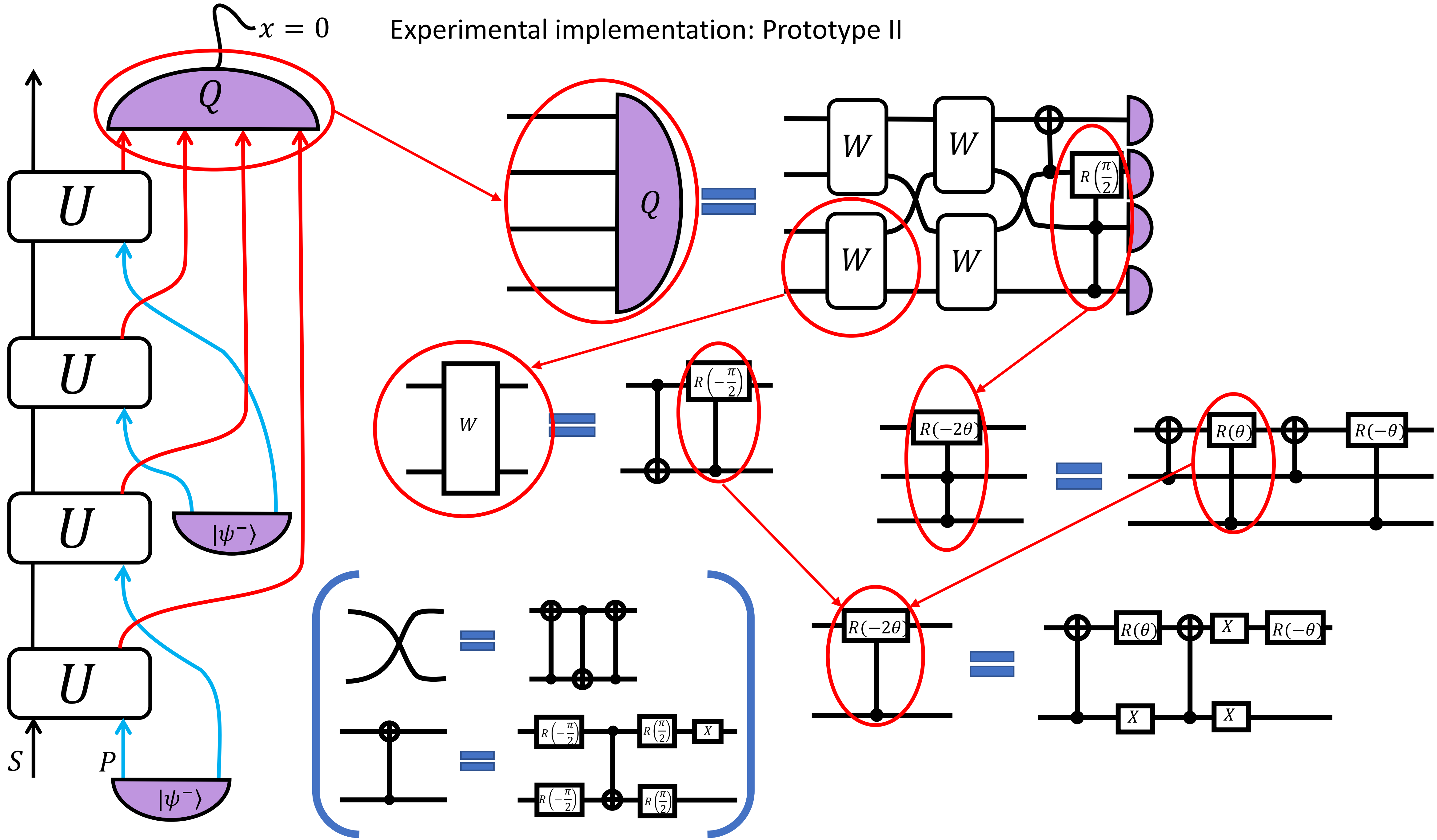
Experimental implementation: Prototype II

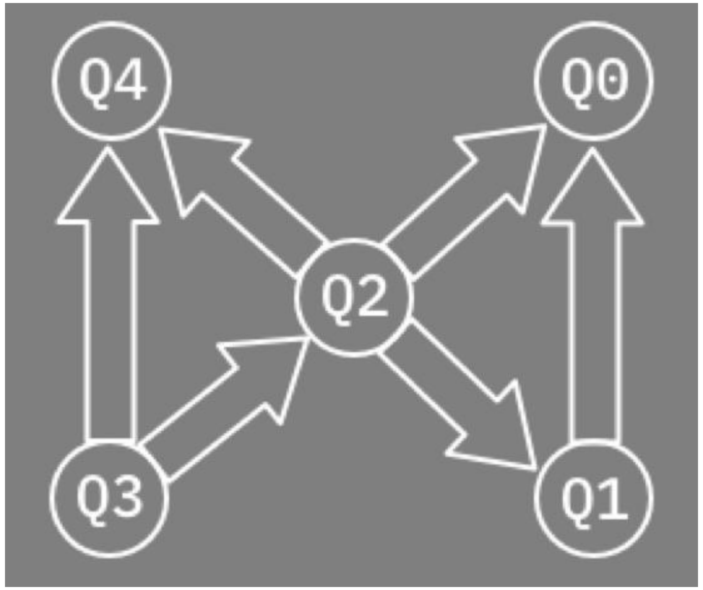


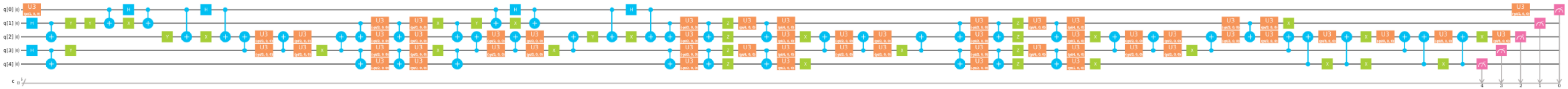
Experimental implementation: Prototype II



Experimental implementation: Prototype II

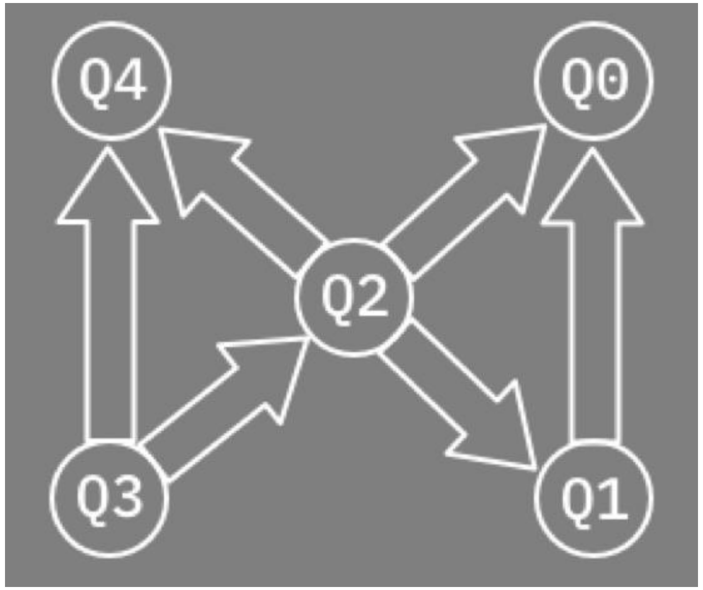


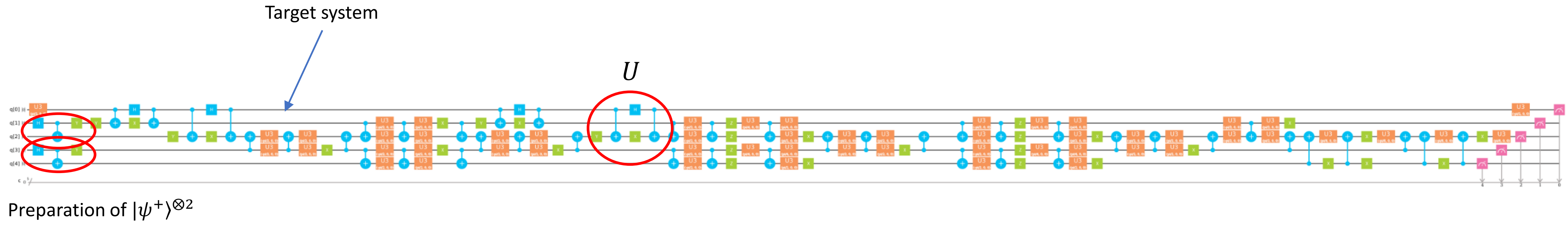




Largest circuit depth allowed!

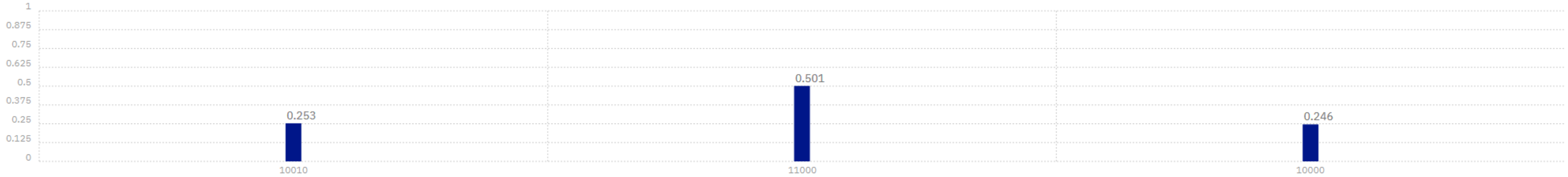
IBM QX4: Raven





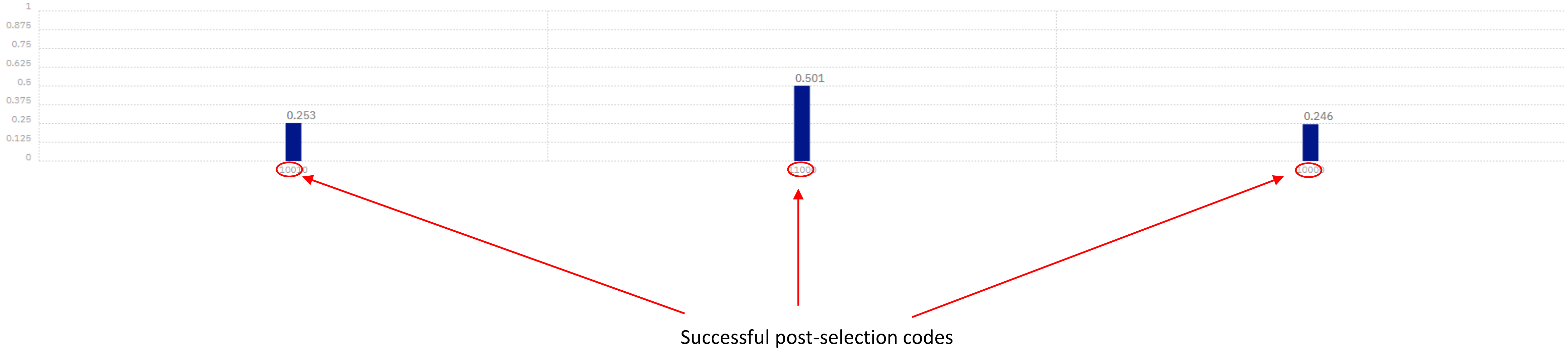
IBM QX4: Raven

Theoretical simulation



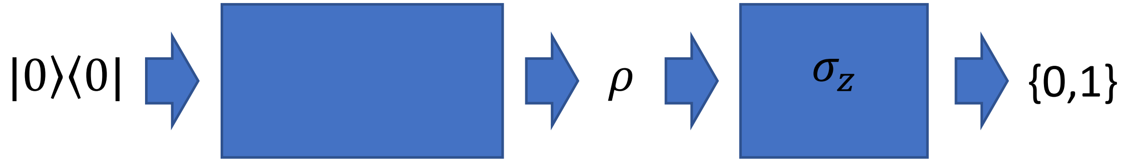
IBM QX4: Raven

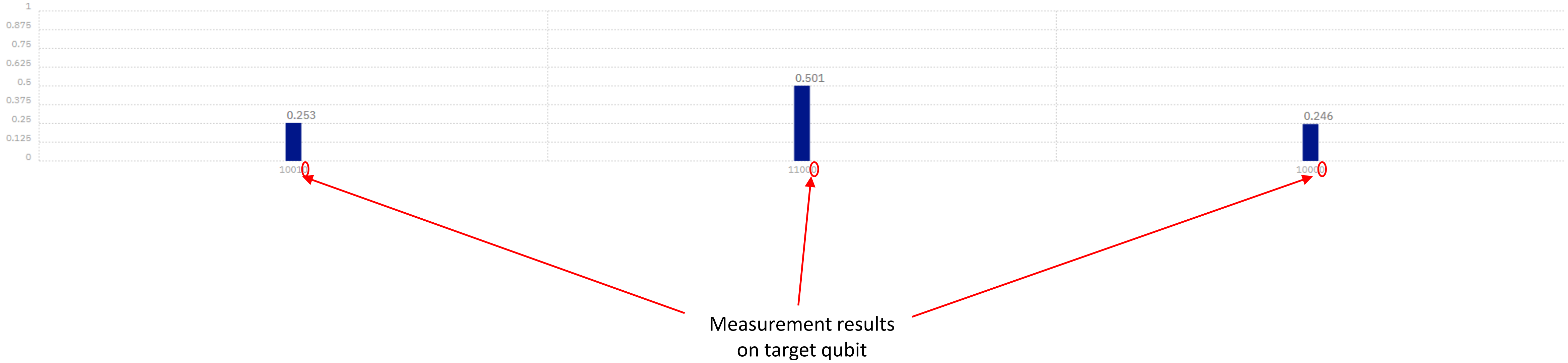
Theoretical simulation



IBM QX4: Raven

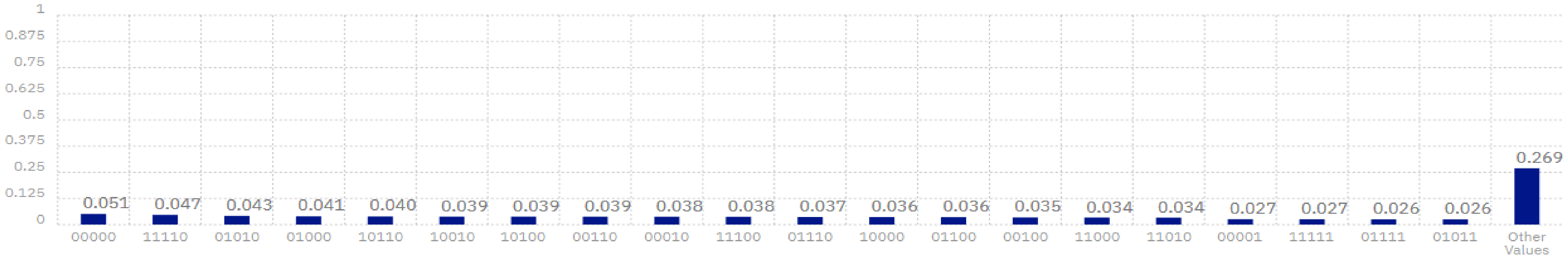
Theoretical simulation



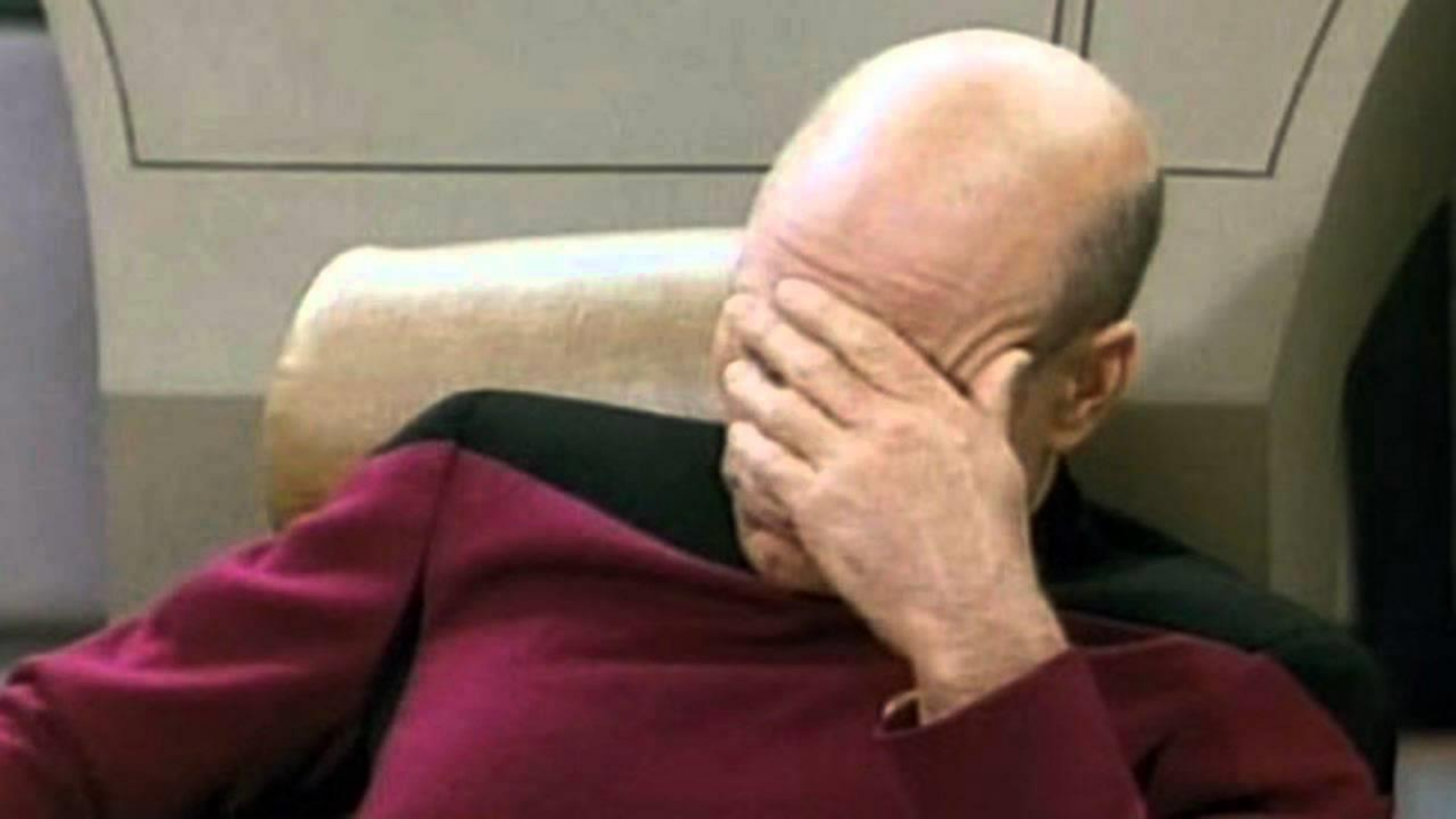


IBM QX4: Raven

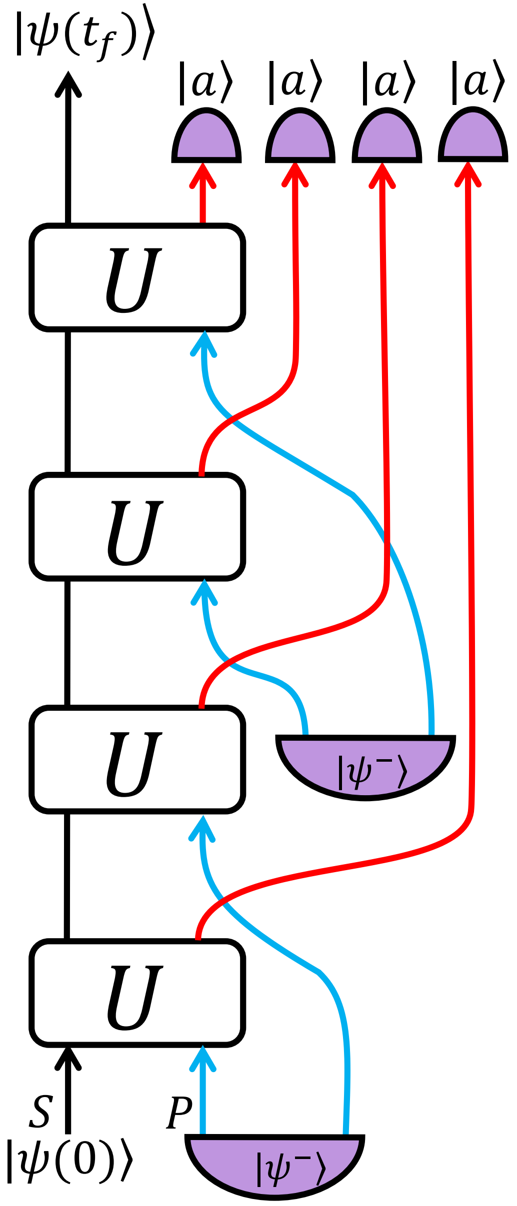
Crude reality

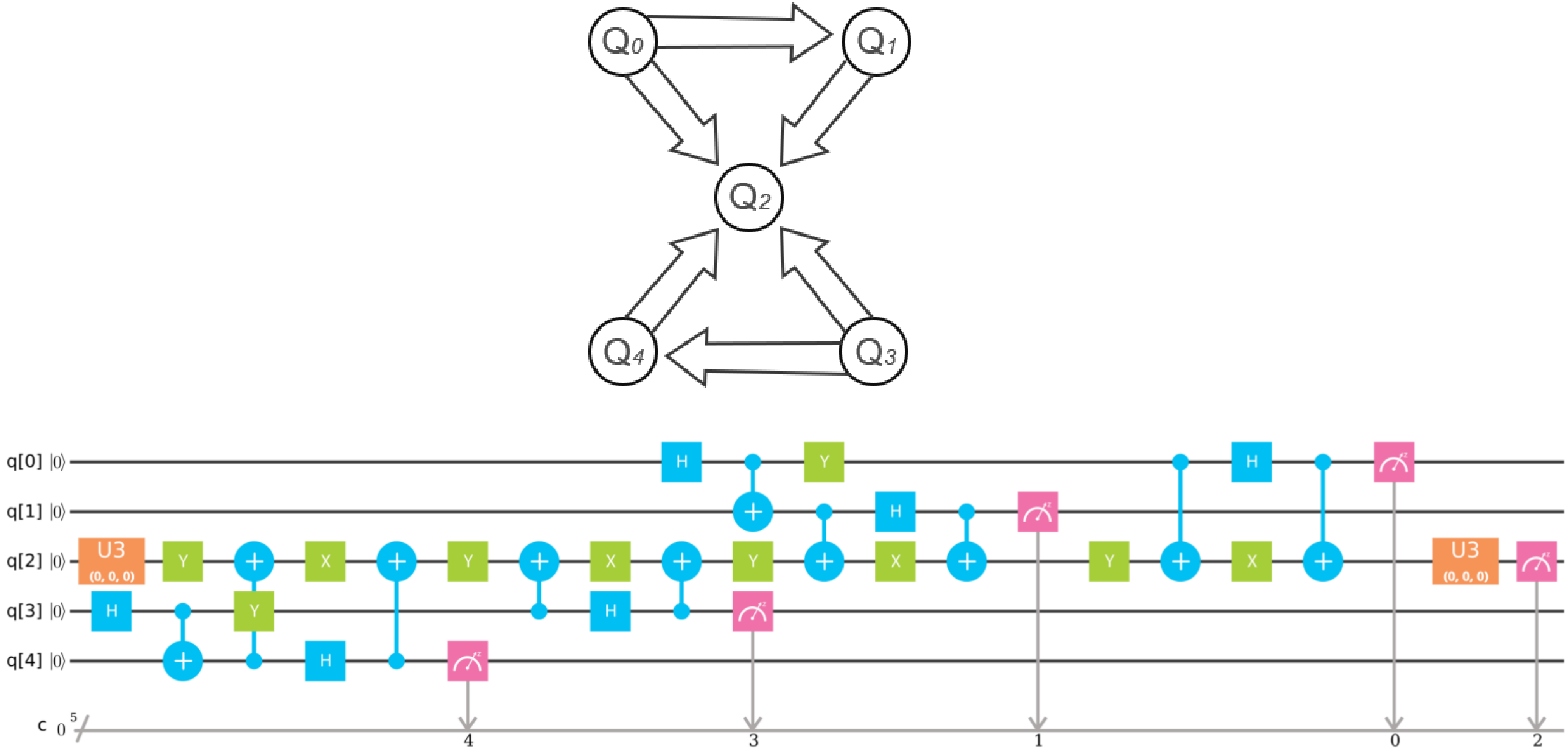


IBM QX4: Raven

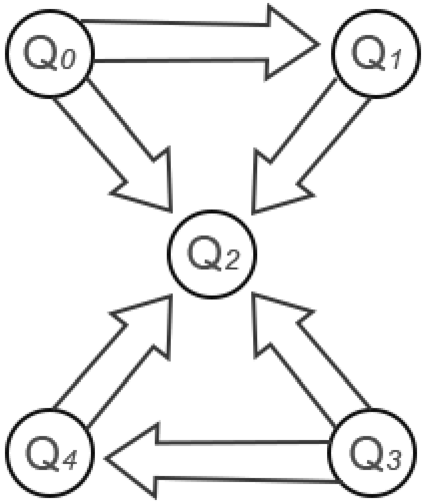


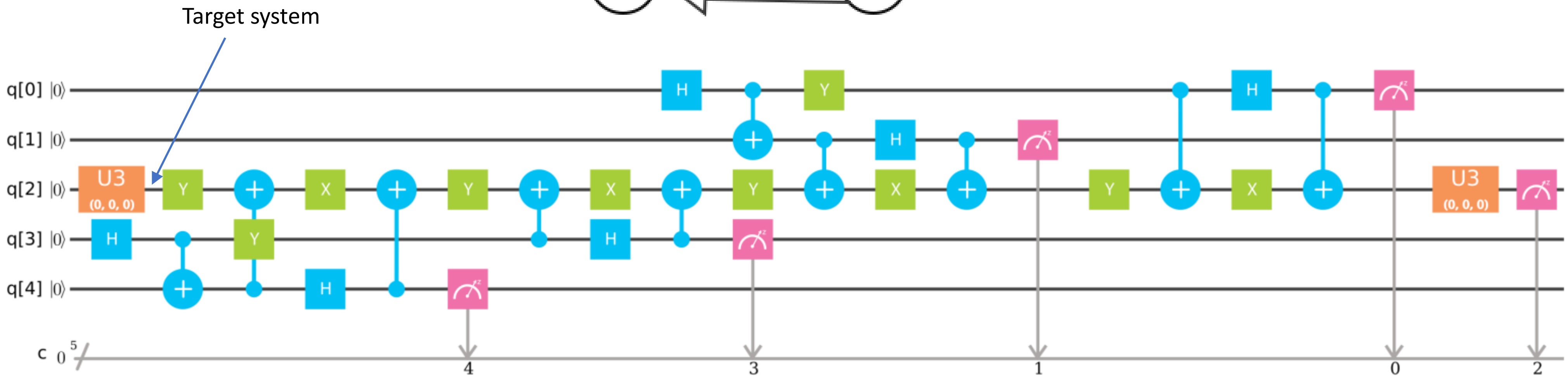
Experimental implementation: Prototype II





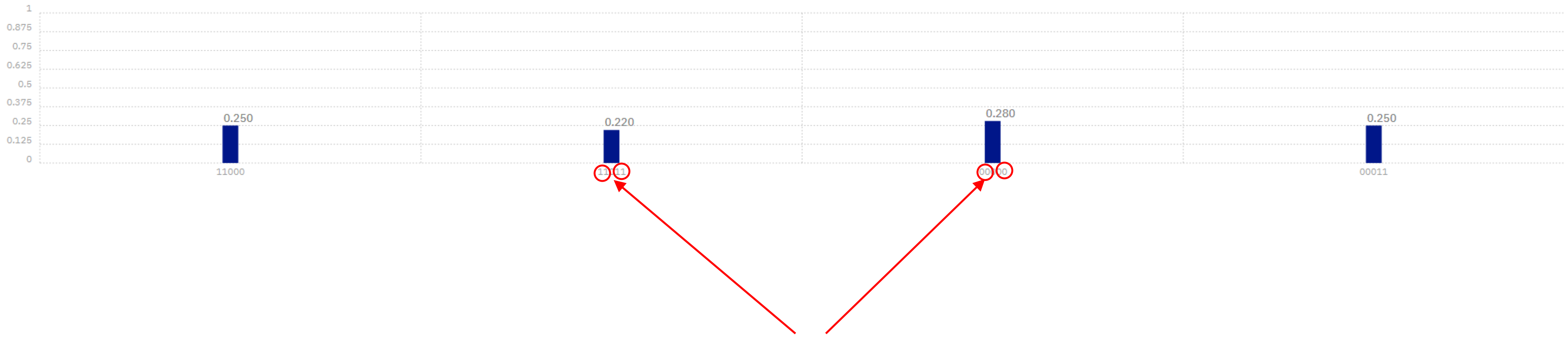
IBM QX2: Sparrow





IBM QX2: Sparrow

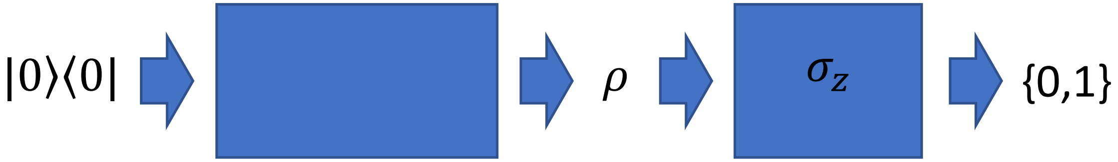
Theoretical simulation

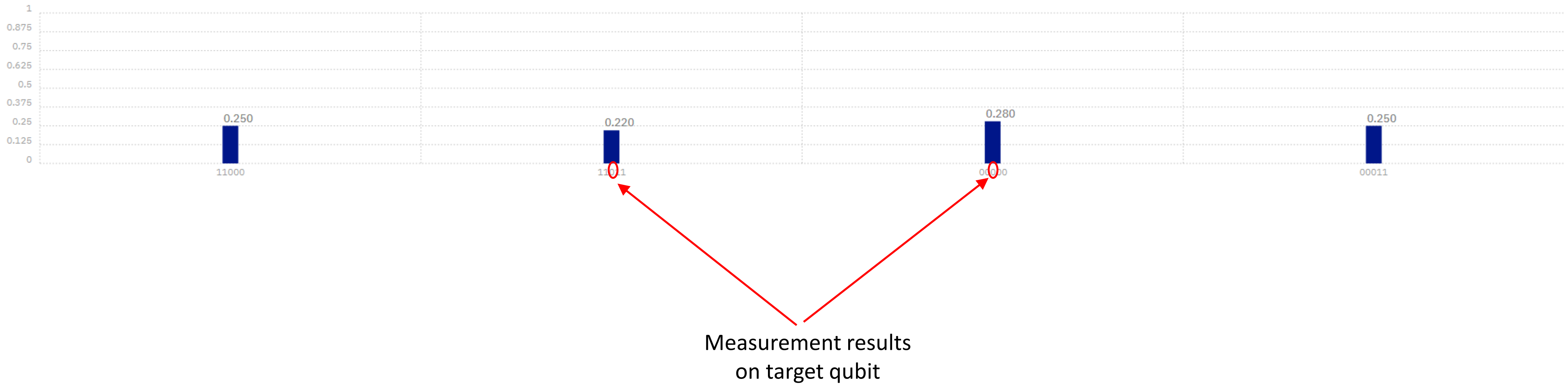


Successful post-selection codes

IBM QX2: Sparrow

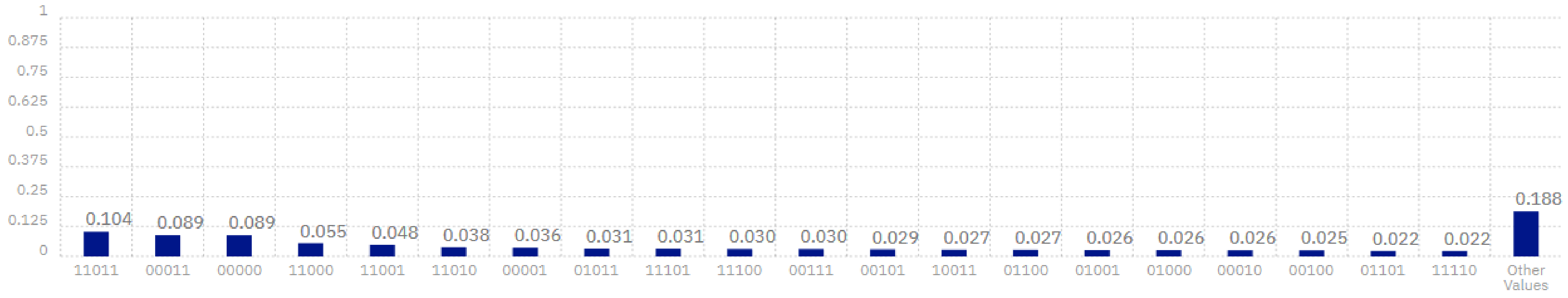
Theoretical simulation





IBM QX2: Sparrow

Crude reality

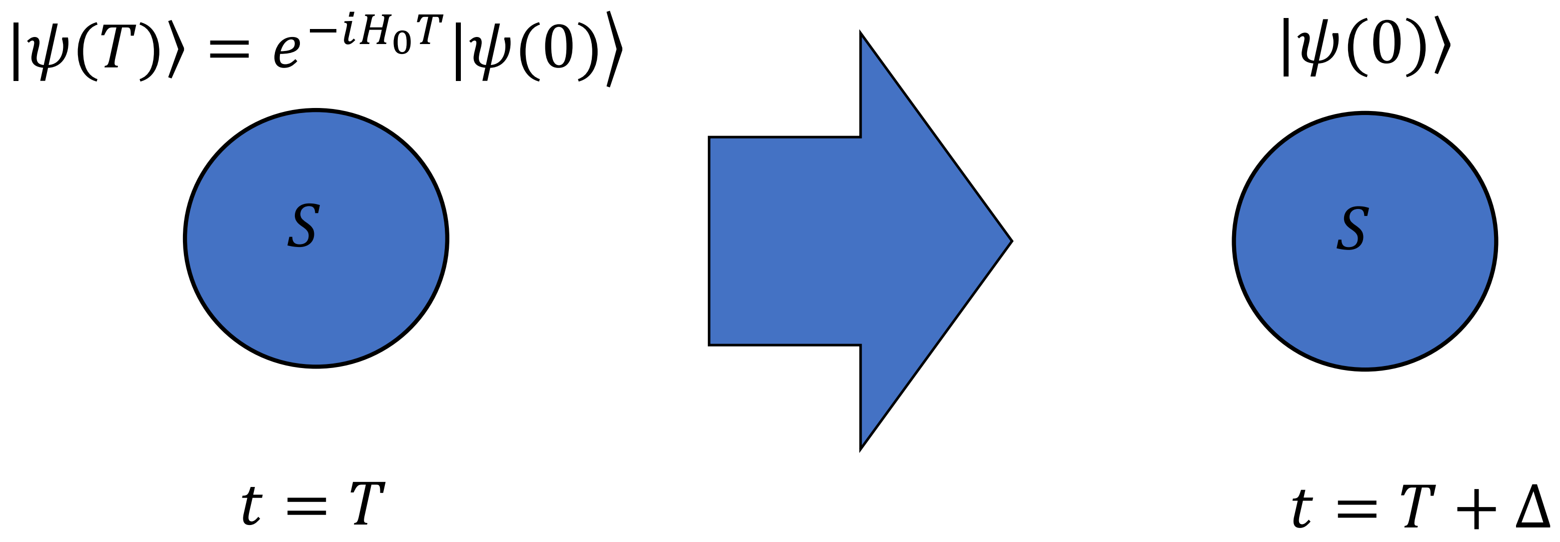


IBM QX2: Sparrow

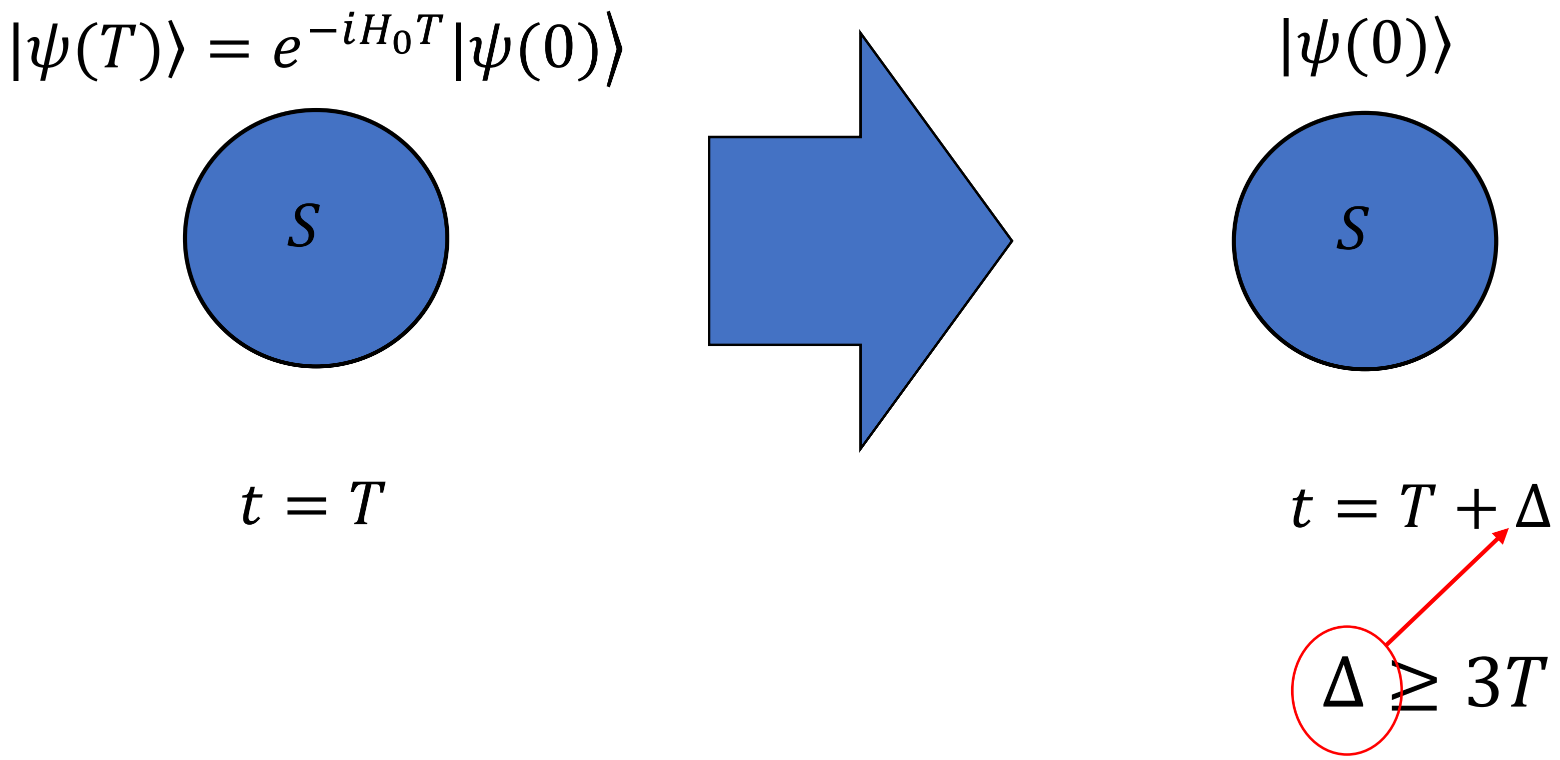
Conclusion

Do there exist protocols with average probability of success (with prior dU) arbitrarily close to 1?

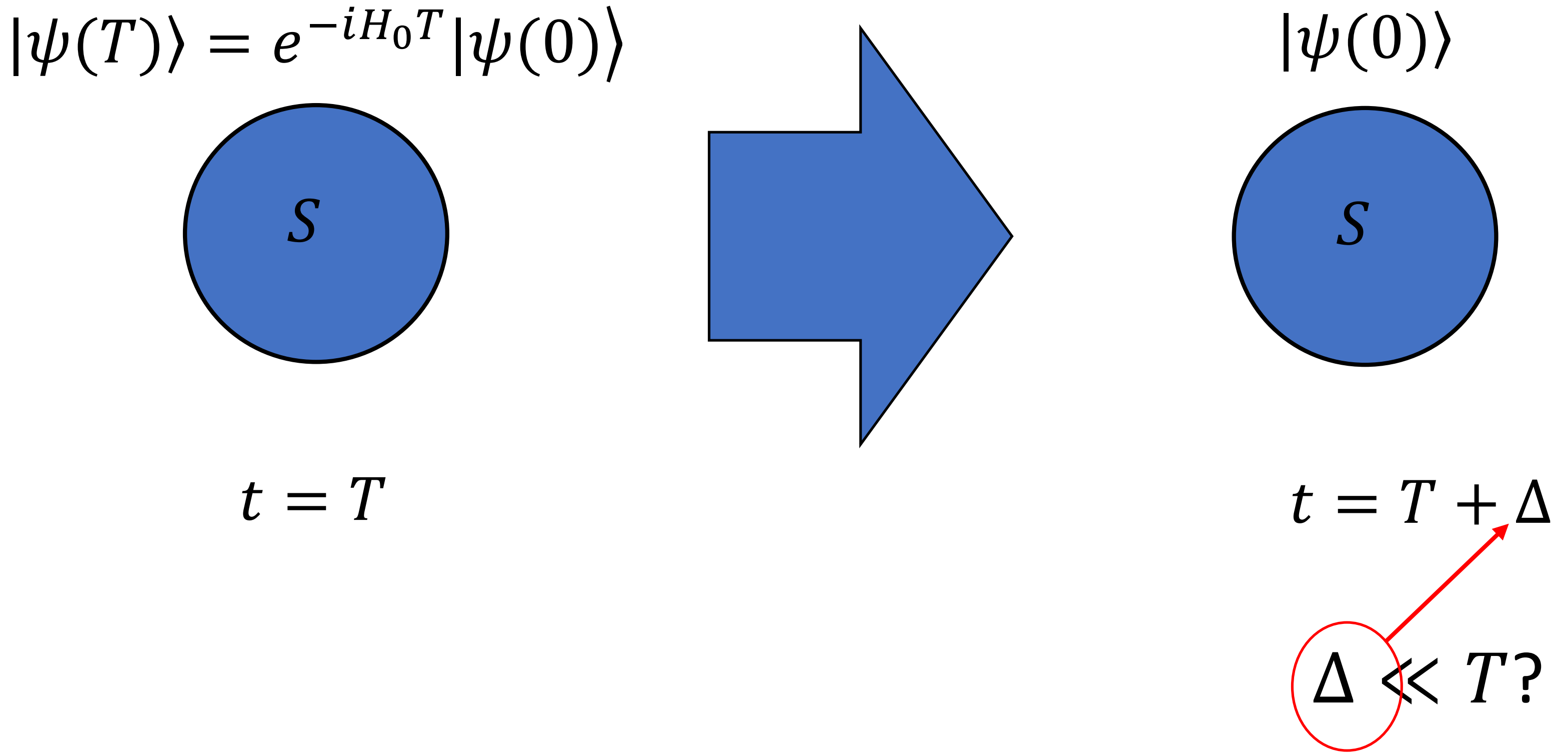
Can we shorten resetting protocols?



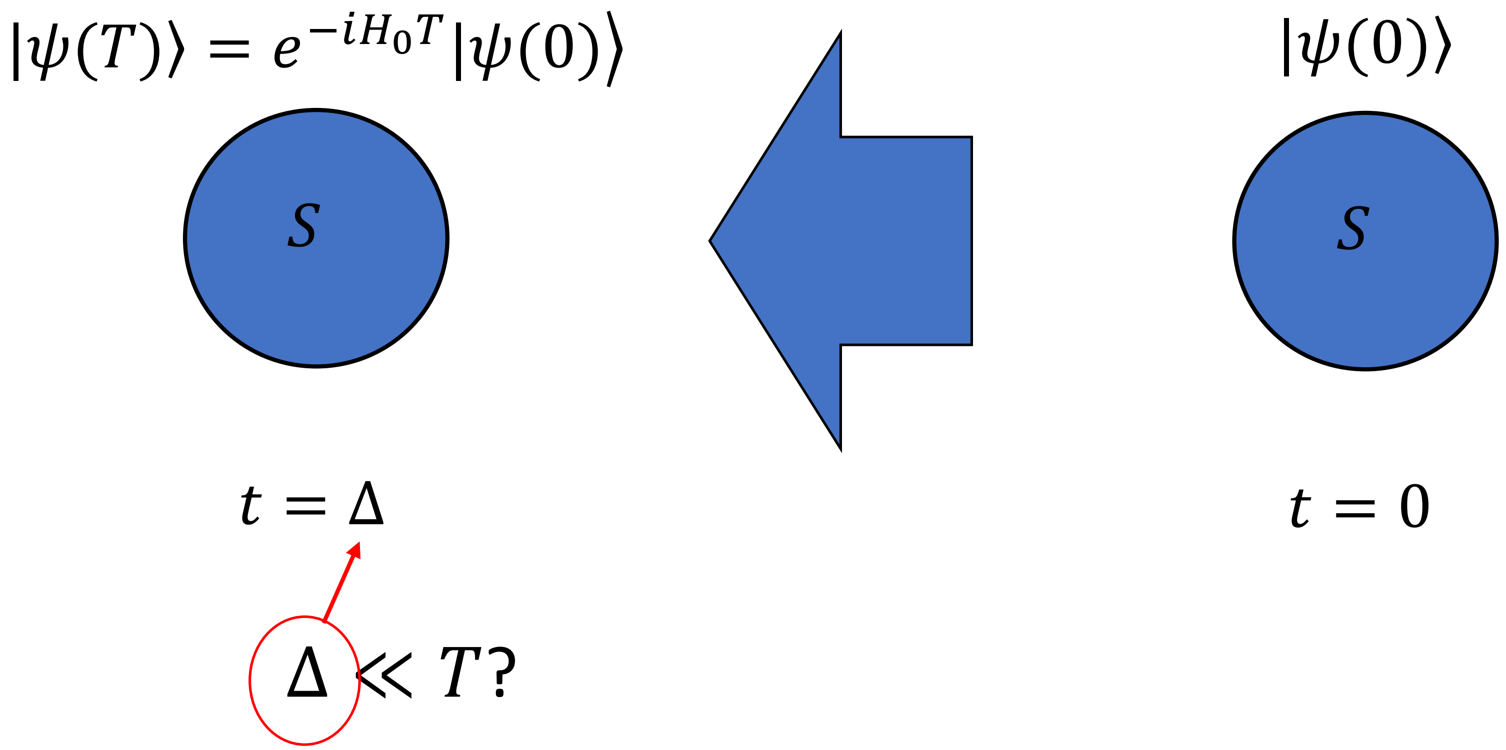
Can we shorten resetting protocols?



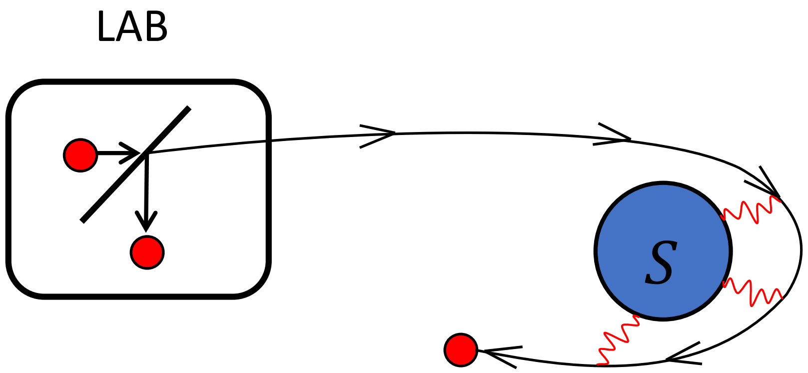
Can we shorten resetting protocols?



Can we fast-forward?

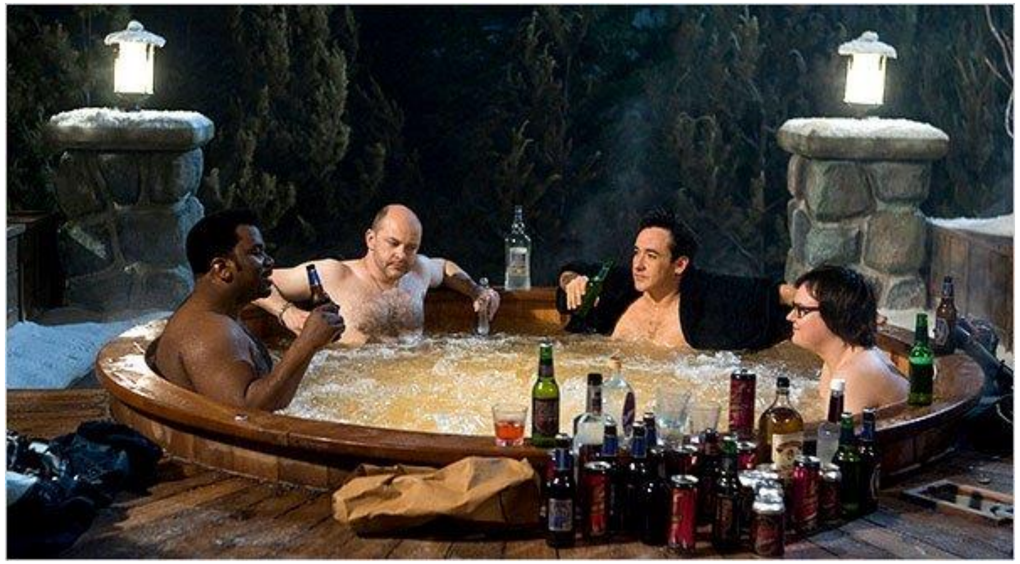


Can we shorten resetting protocols?/Can we fast-forward?



Hint: use which-path superpositions.

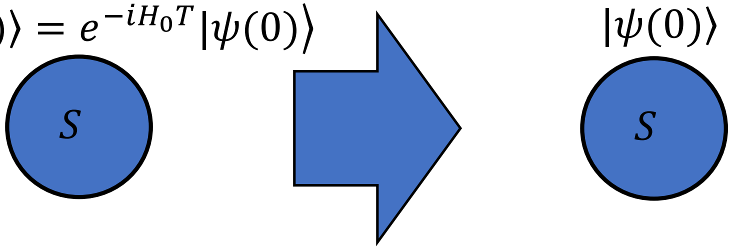
Simple experimental implementation?




Auto
Western Auto
TOWN
TO BE
CONCLUDED...

Refocusing

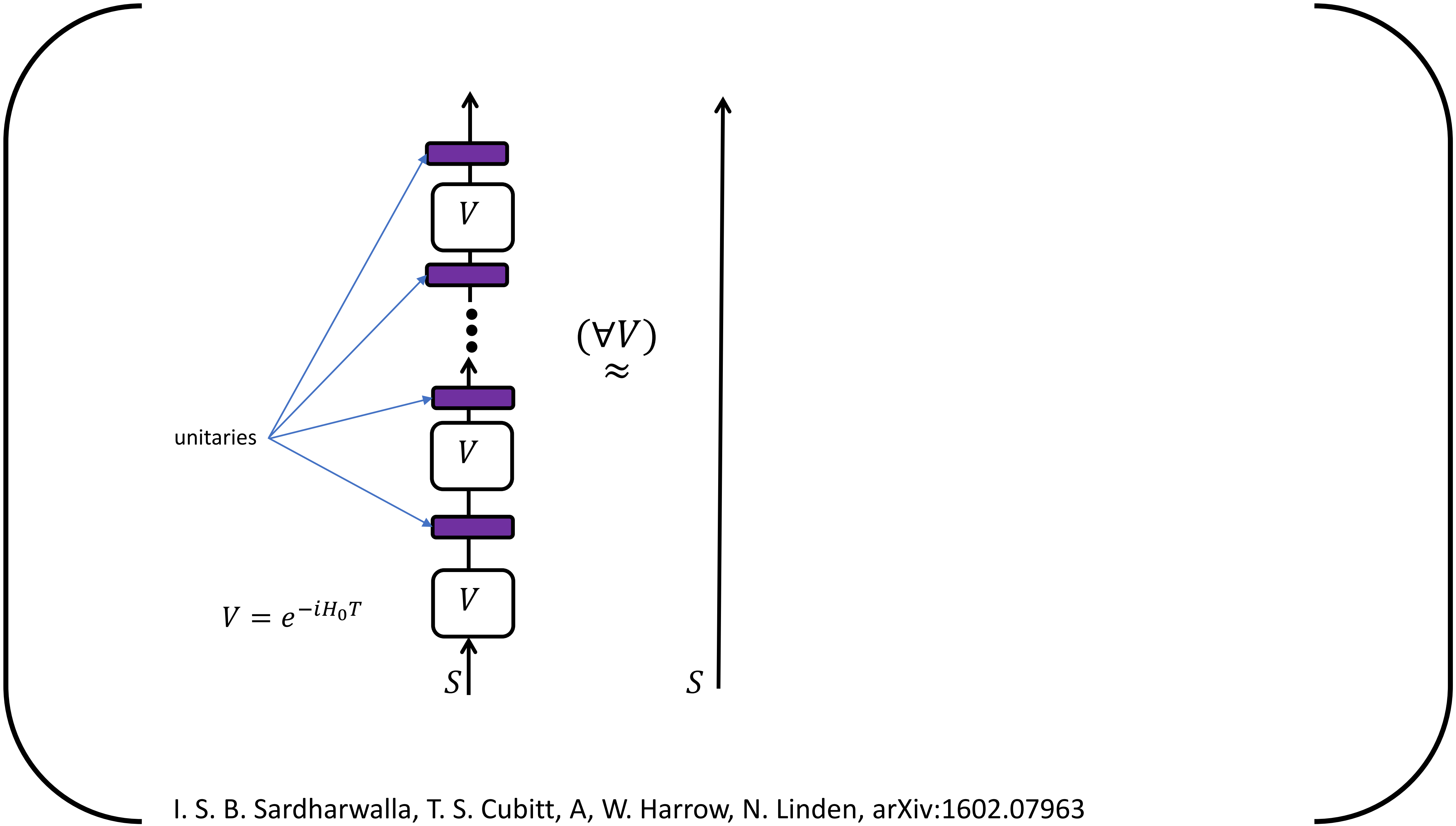
$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$ $|\psi(0)\rangle$



$t = T$ $t = T + \Delta$

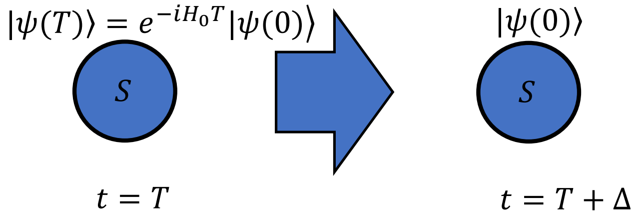
We ignore H_0, but any operation on S is allowed

I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963

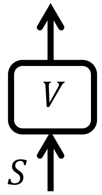


I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963

Refocusing (obvious solution)

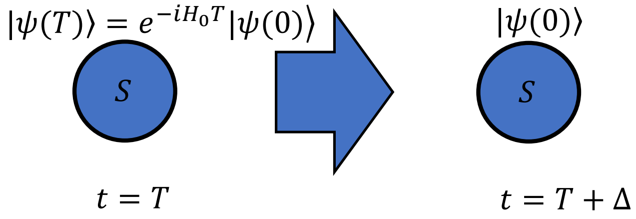


$V = e^{-iH_0T}$

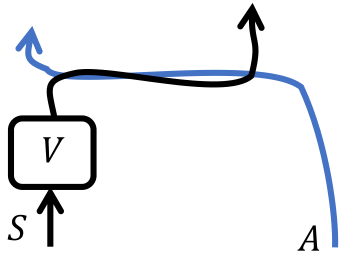


I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963

Refocusing (obvious solution)

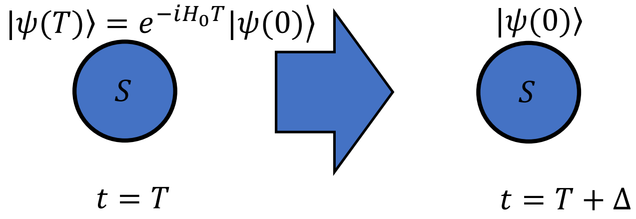


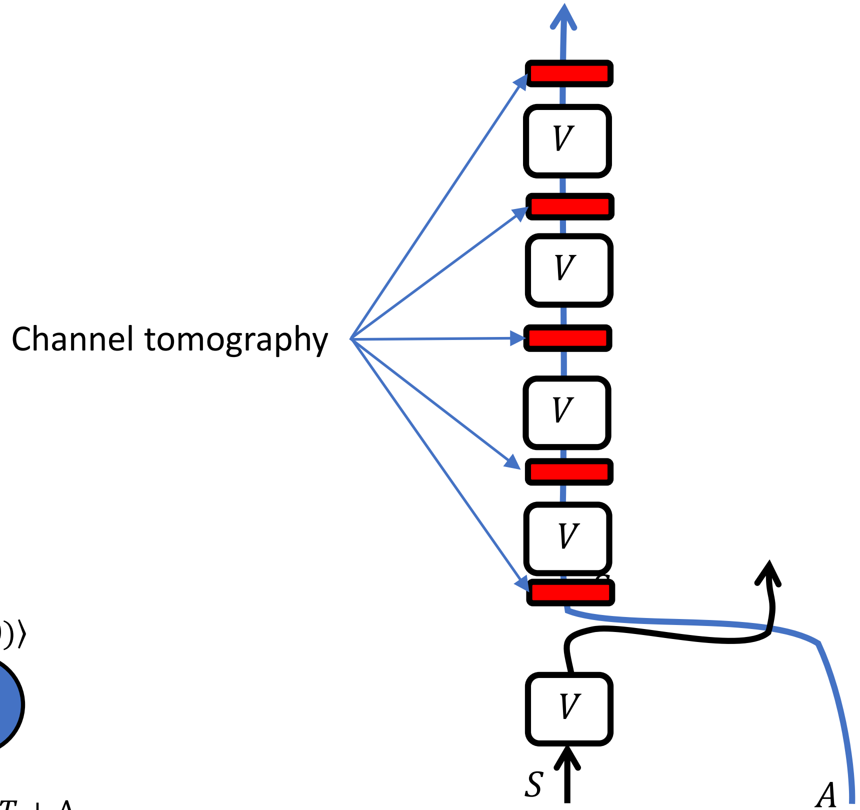
$$V = e^{-iH_0 T}$$



I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963

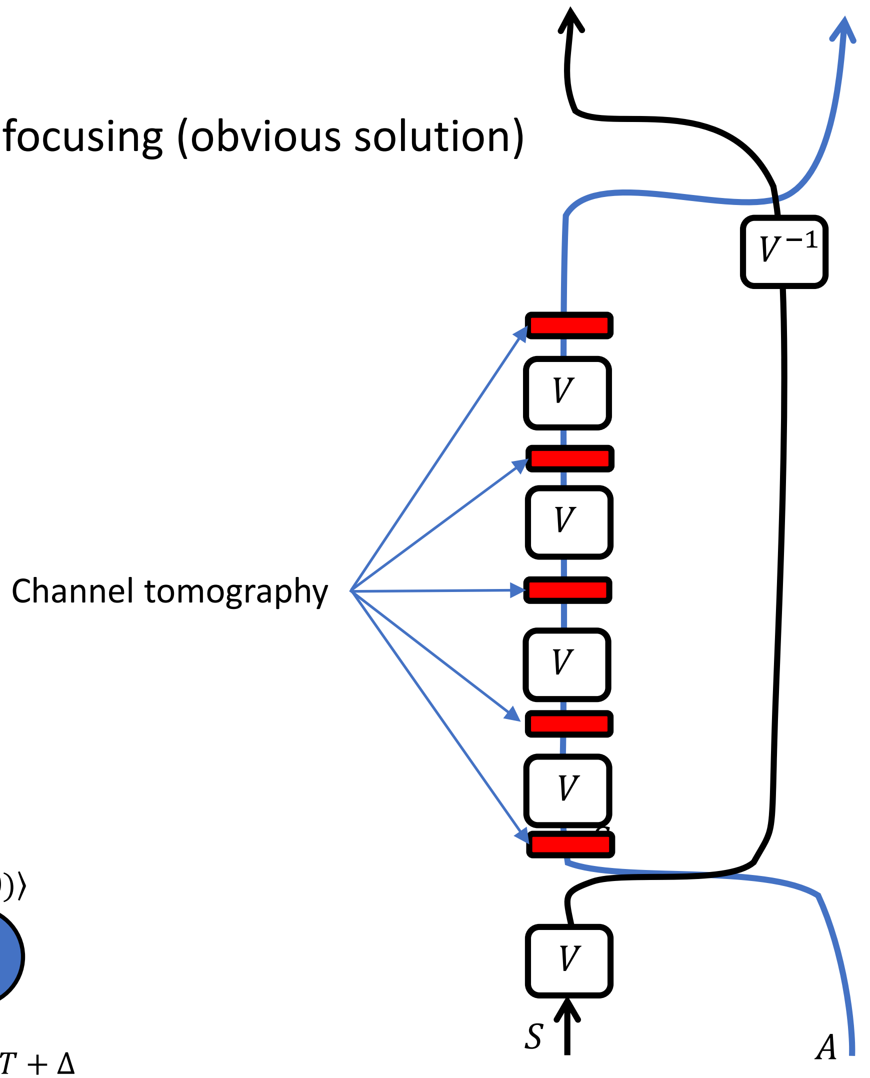
Refocusing (obvious solution)

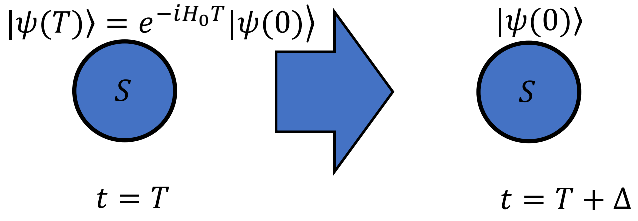




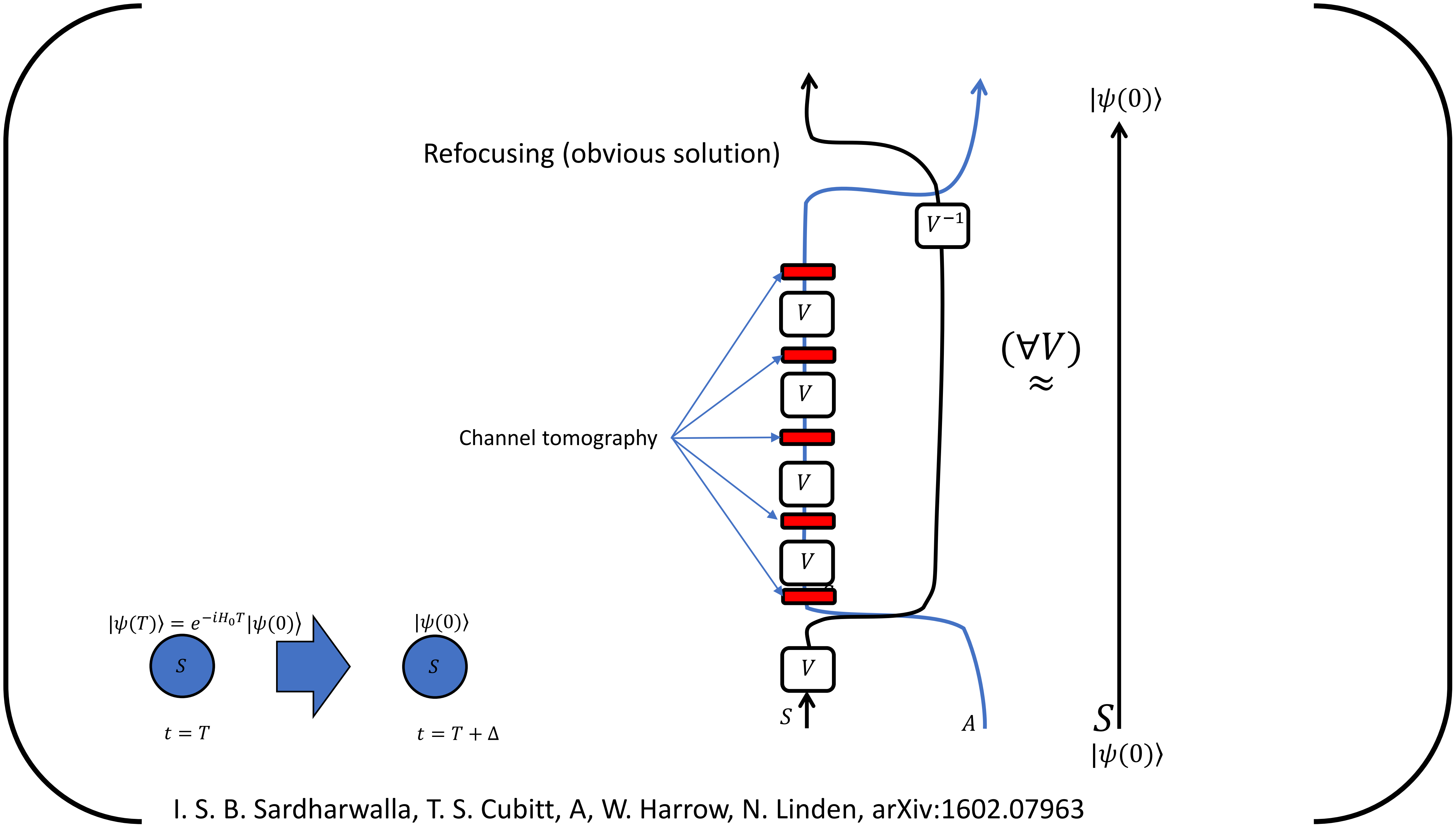
I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963

Refocusing (obvious solution)





I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963


Refocusing (obvious solution)
Channel tomography
$|\psi(T)\rangle = e^{-iH_0T}|\psi(0)\rangle$
S
$t = T$
$|\psi(0)\rangle$
S
$t = T + \Delta$
V
V
V
V
V
V^{-1}
S
A
$(\forall V)$
$\approx$
$|\psi(0)\rangle$
S
$|\psi(0)\rangle$
I. S. B. Sardharwalla, T. S. Cubitt, A, W. Harrow, N. Linden, arXiv:1602.07963