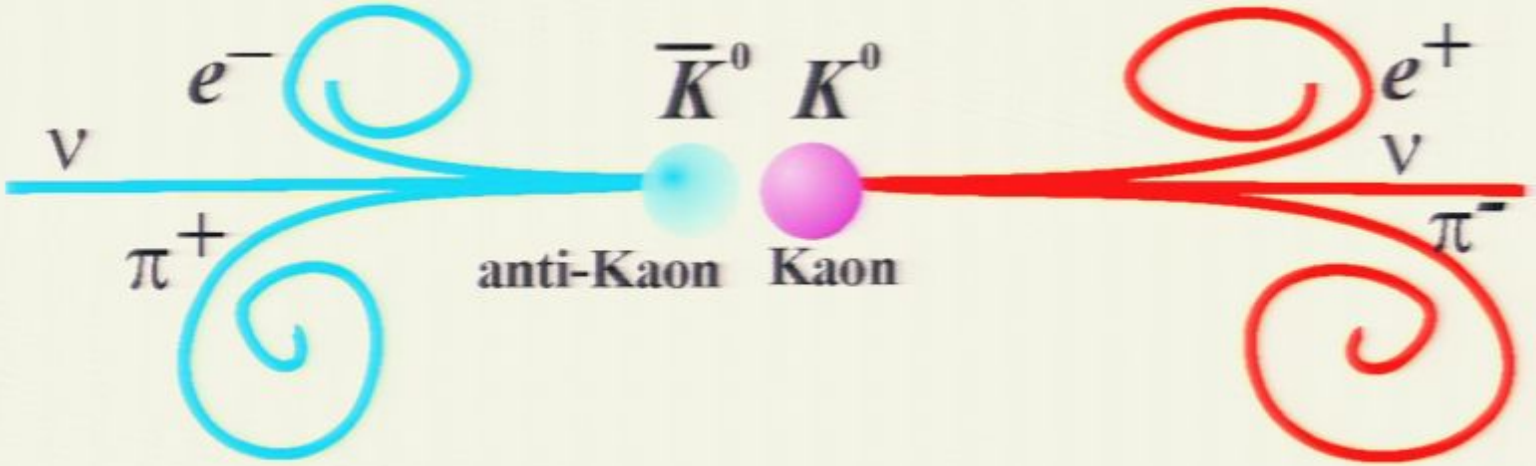
Title: Origin of the anthropocentric flow of time?

Date: Sep 29, 2008 05:00 PM

URL: http://pirsa.org/08090077

Abstract: The underlying motivation for rejecting Everett\'s many-worlds interpretation of quantum mechanics and instead exploring single-world interpretations is to make physical theory concordant with human experience. From this perspective, the wave function collapse and Bohm-de Broglie interpretations are anthropocentric in origin. But this does not lessen their importance. Indeed accounting for our human experience of the physical world is a key element of any physical theory. This is no less true for the theory of time where accounting for the anthropocentric notion of a unidirectional flow of time is a challenge. In this talk we examine a peculiar time asymmetry that may shed some light on this problem.The matter-antimatter arrow of time, which is associated with the weak force in neutral Kaon decay, has been an enigma for 40 years. While other arrows (cosmological, electromagnetic, thermodynamic and psychological) have been linked together, the matter-antimatter arrow stands alone. It is often regarded as having a negligible effect on time in our daily lives. The main reason for this view appears to be the relatively small violation of the Charge-Parity conjugation invariance (CP) involved. However the smallness of the violation is not necessarily an obstacle to the manifestation of macroscopic effects. For example, a small difference in a quantum-state fidelity for a single particle leads to a difference which grows exponentially with the number of particles. So provided sufficient numbers of particles are involved such a violation could yield significant effects.We examine the effect of the violation of CP invariance on the dynamics of a large system such as the universe. Provided the CPT theorem holds, the CP violation is equivalent to a violation of time reversal invariance (T). We impose the constraint that the violation should equivalent in both directions of time (past and future) with respect to the present. This implies that if H is the Hamiltonian for one direction of time, then THT the Hamiltonian for the opposite direction. We will see that any given quantum state a> that represents the present of our part of the universe is closer to its evolved state a+> in the future compared to its retro evolved state a-> in the past. In other words, our present state is more likely to be extended (slightly) into the future than the past. We will see that the end result is a never-ending extension of the present into the future. Moreover for a collection of a million neutral kaons, the fidelity between the present state and a slightly future-evolved state is a billion times larger than the fidelity between the present and an equivalent retro-evolved state. In this context, the seemingly insignificant kaons appear to be responsible for our anthropocentric view of moving through time.

Physical origin of our perception of time?



Joan Vaccaro
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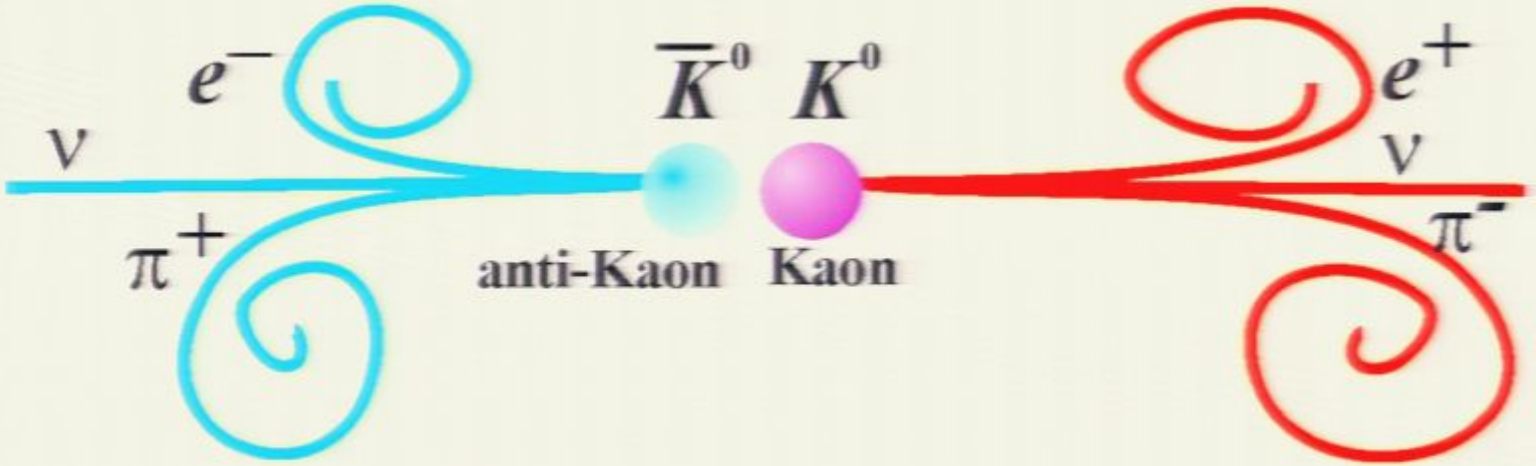

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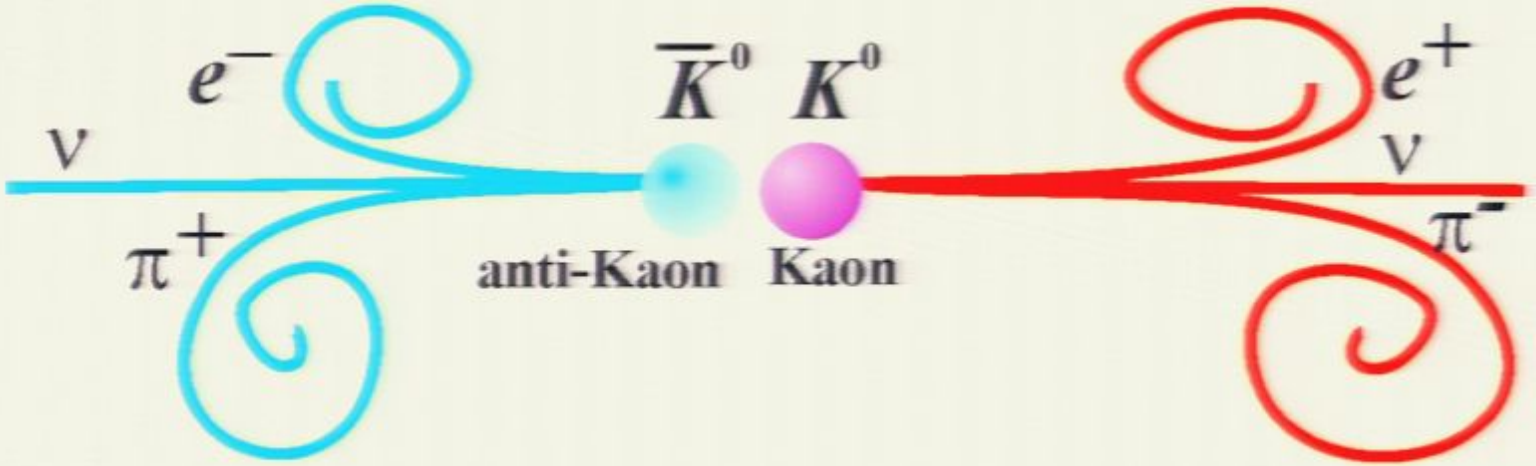

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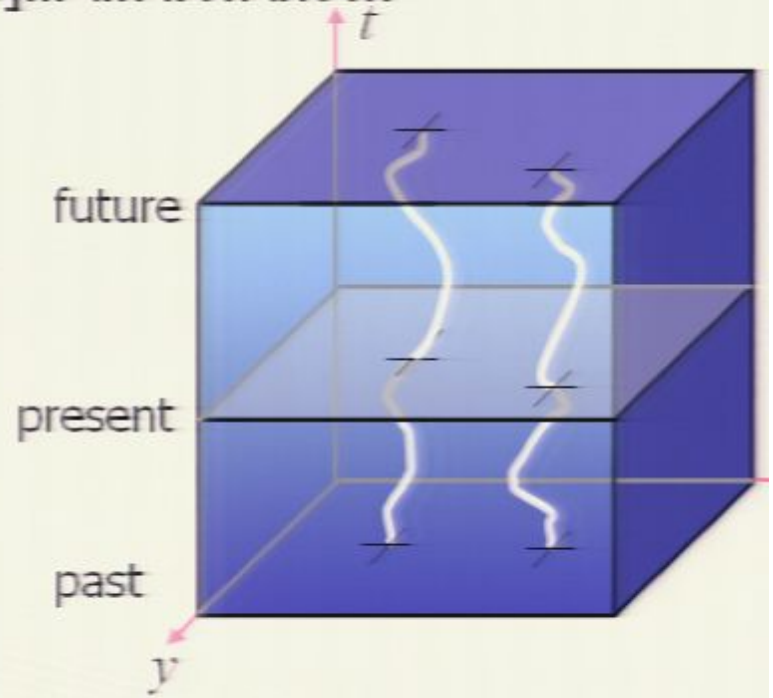
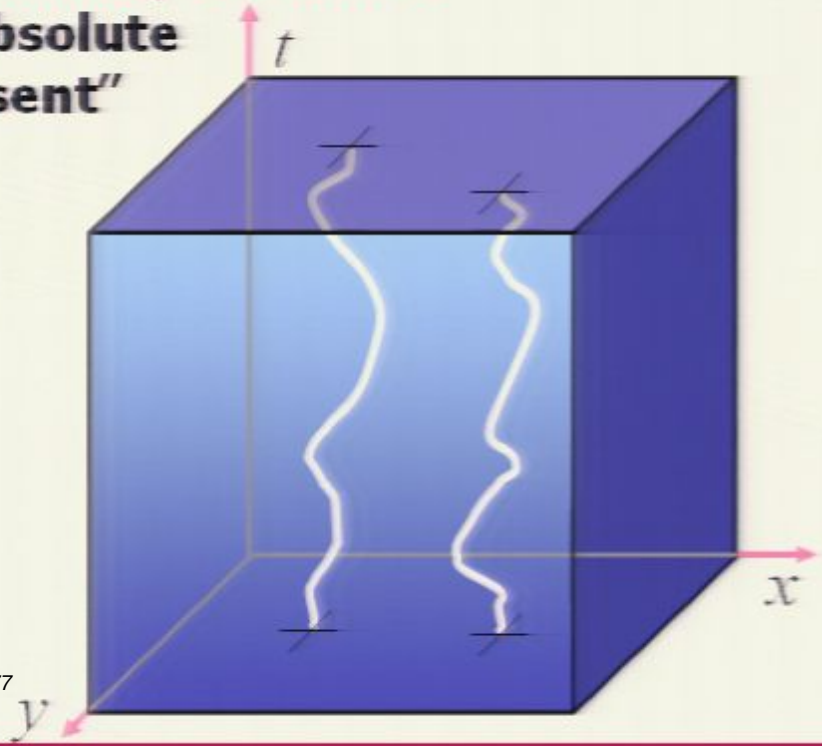
Introduction

Block Universe

William James (1842-1910)
determinism – "the future has no ambiguous possibilities"..."the whole is"...[like]..."an iron block"



Special Relativity (1905)
simultaneity is relative
no absolute "present"



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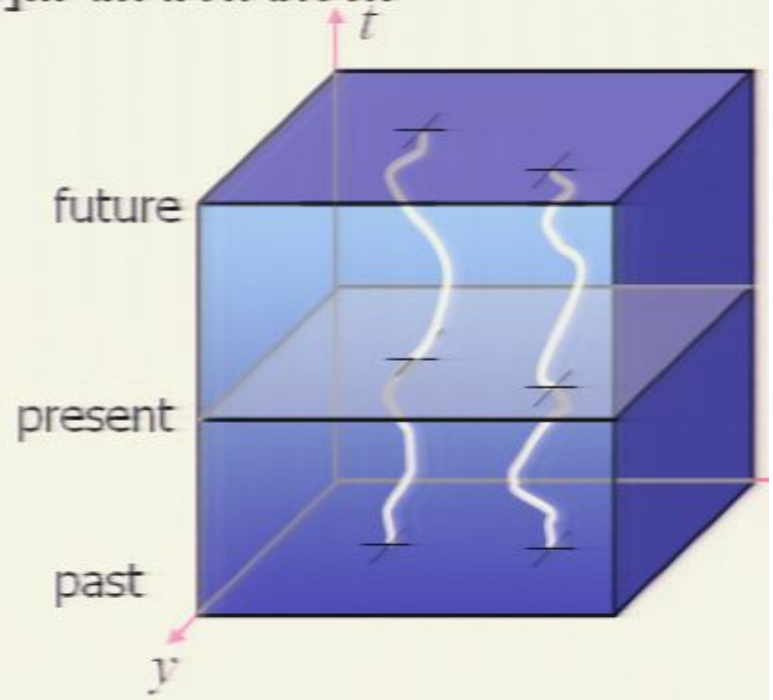

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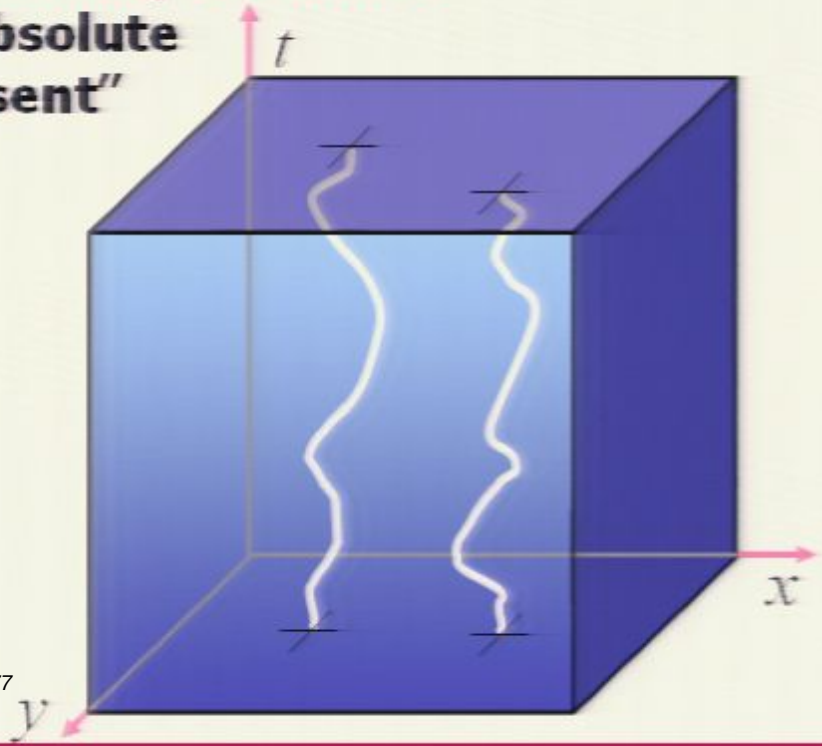

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Framework for a Physical Theory

- needs to be **free of anthropocentricism** – Huw Price
- but it must also **give an explanation** of our human experience (of a single quantum world, of our perception of time ...)

Subjectivity of perception of time

- The **"present" in time** is like **"here" is space.**
  "here" and "now" are not special in Physics
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Compare with the illusion of a single quantum world

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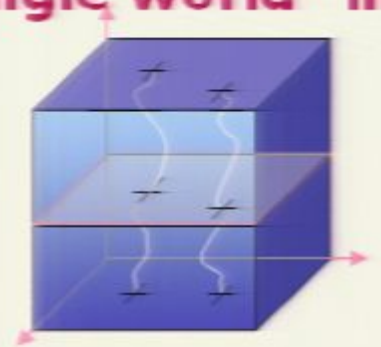

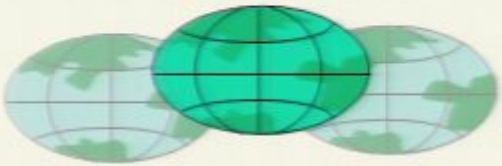

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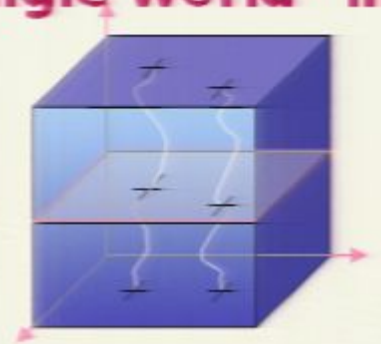

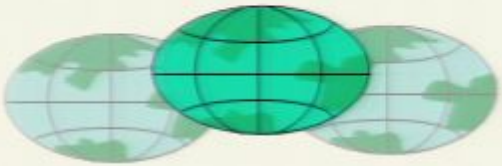

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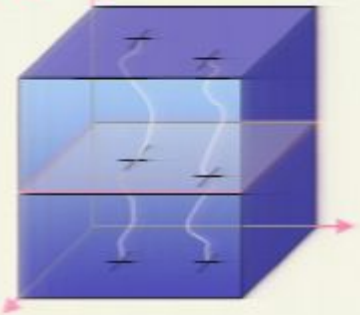

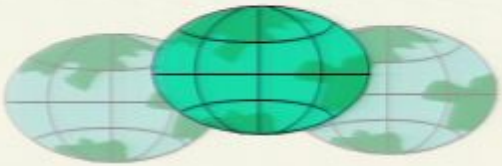

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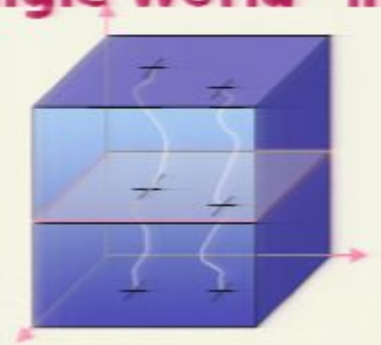

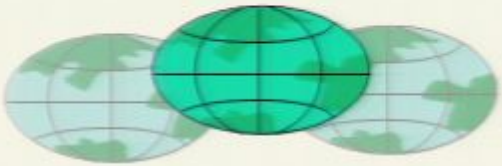

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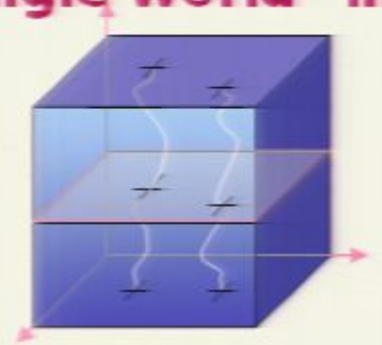

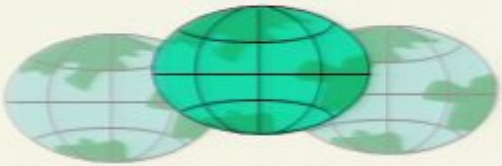

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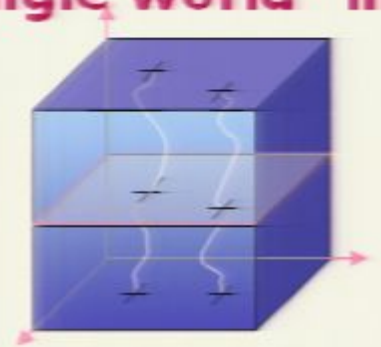

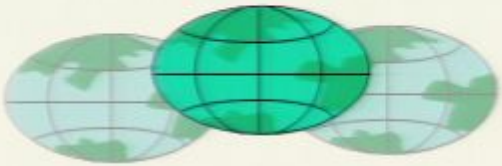

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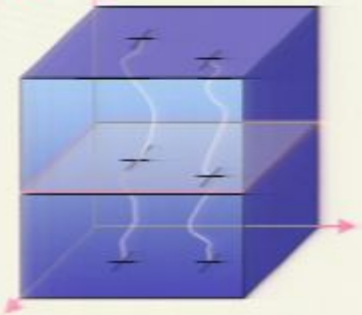

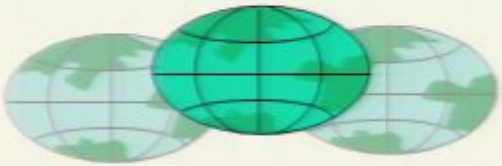

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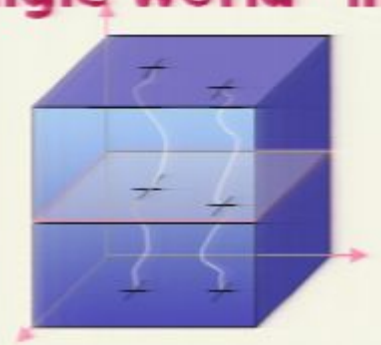

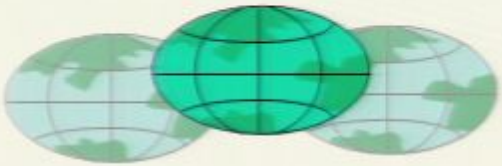

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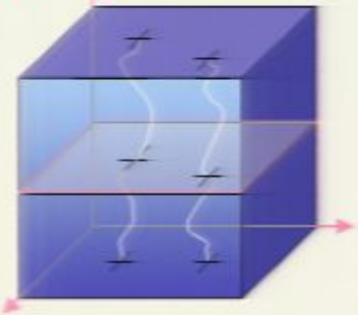

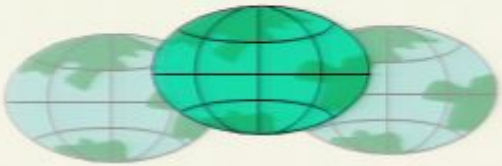

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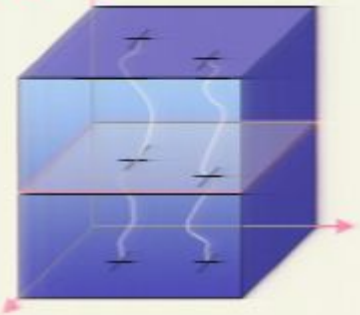

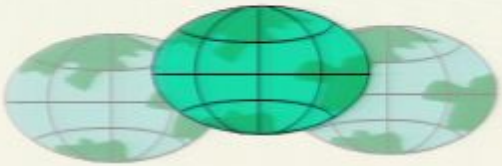

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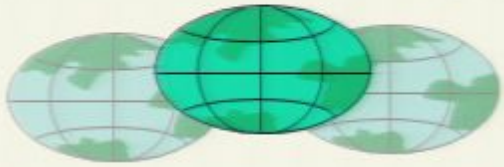
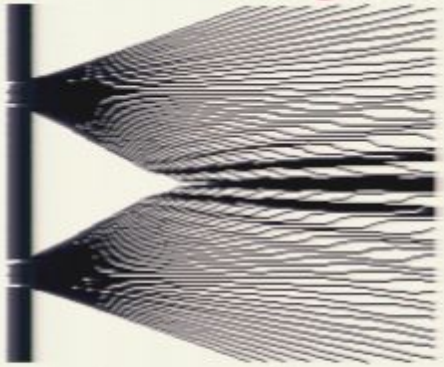
Bohmian mechanics

- Realistic explanation of a **single quantum world**
  i.e. this gives Bohmian mechanics an **anthropocentric basis**





there's nothing wrong with studying Bohmian mechanics *(& no need to meet out the back...)*

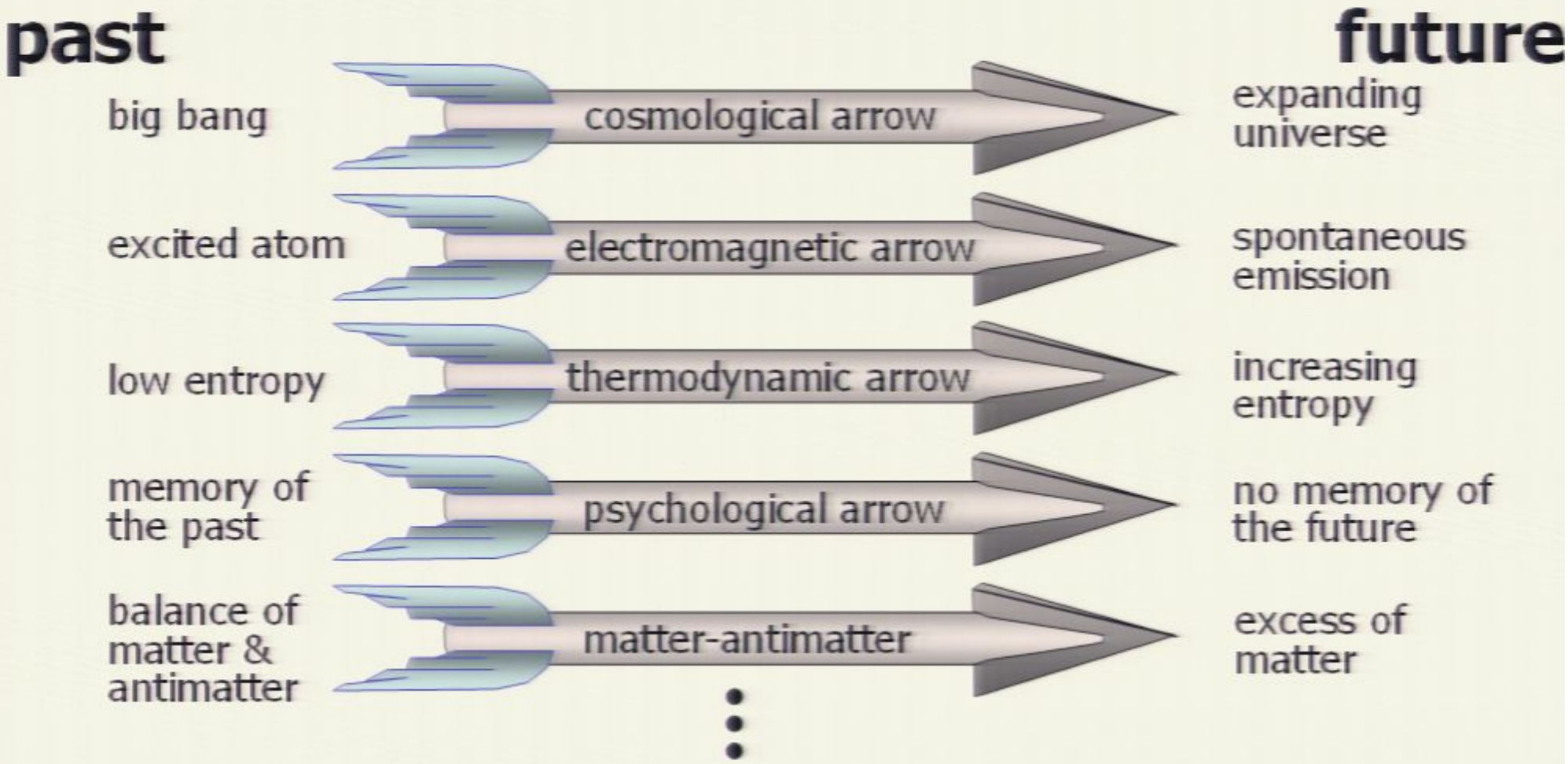
this is my justification for studying the physical origin of perception of time i.e. the illusion that

past ← present ← future

is a continuous (connected) sequence

Arrows of time

- Emerge from *phenomenological* time asymmetric dynamics



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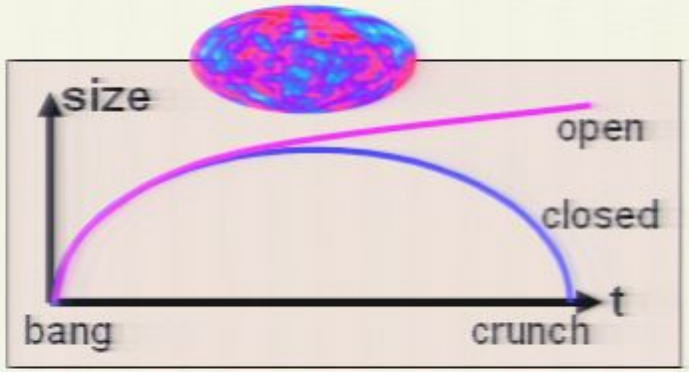
  - **(i)** special **boundary conditions**, or
  - **(ii)** time asymmetric **dynamics & Hamiltonian**

(i) Asymmetric Boundary Conditions:



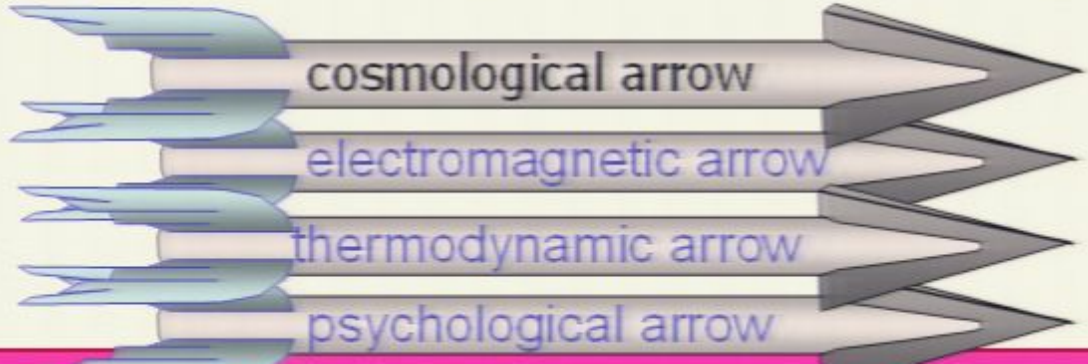
cosmological model with initial condition that drives expansion → time asymmetry

basis of cosmological arrow

retarded radiation is dominant in expanding universe } basis of electromagnetic arrow

Pegg, Nature phys. Sci. 243 143 (1973)

Related arrows:



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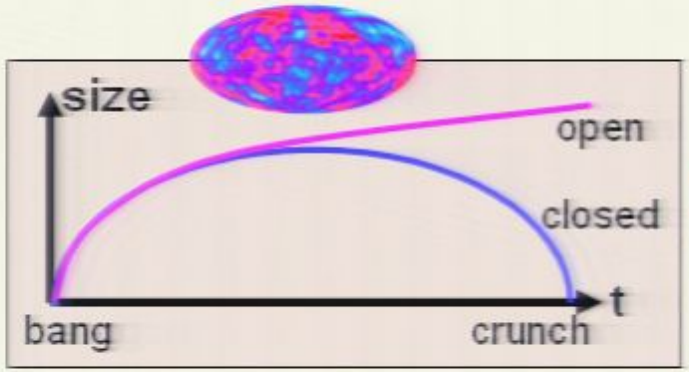

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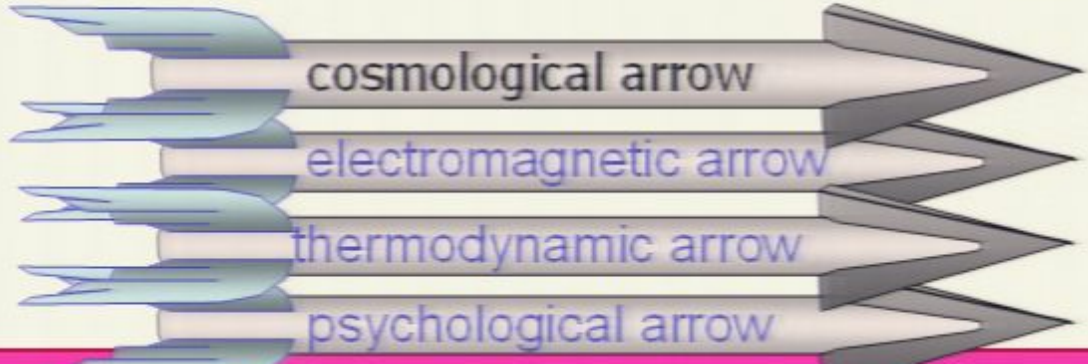

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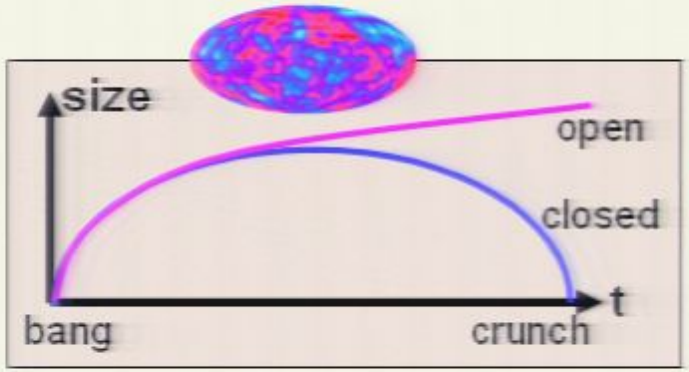

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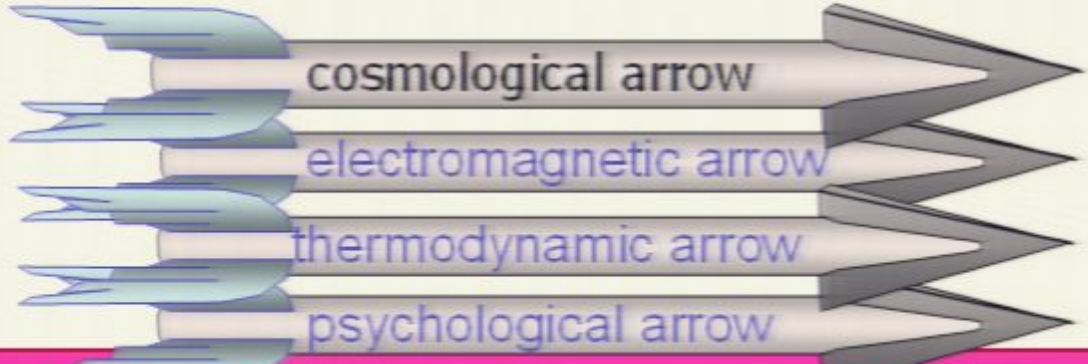

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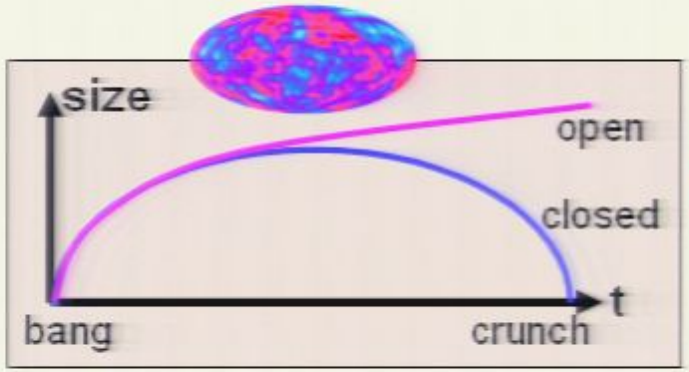

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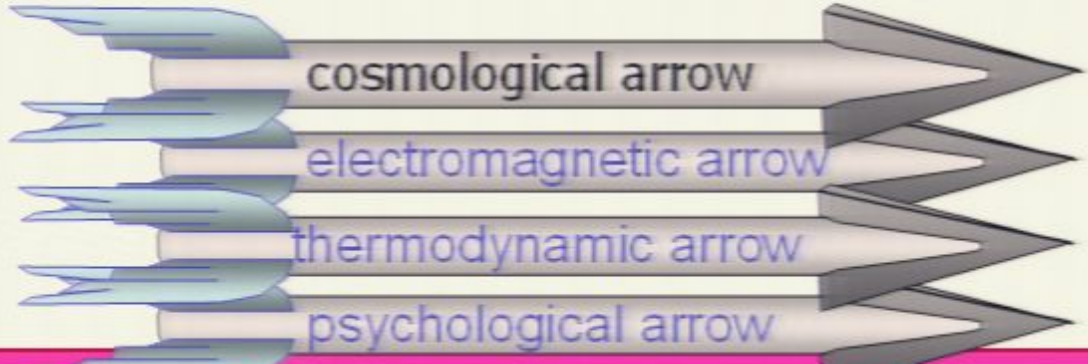

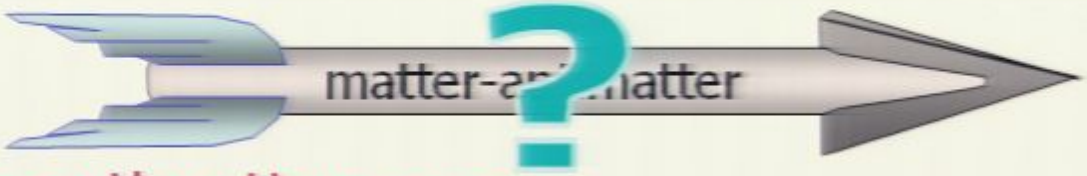

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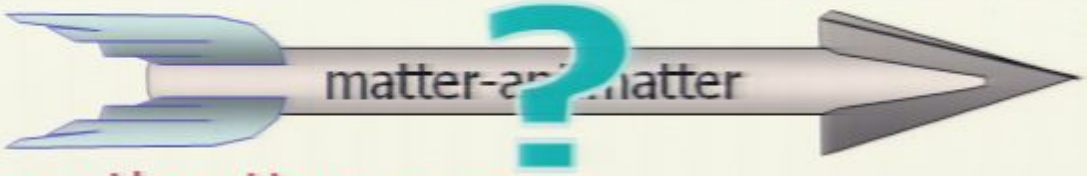

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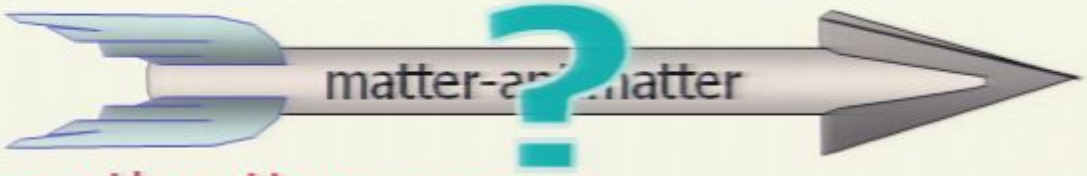

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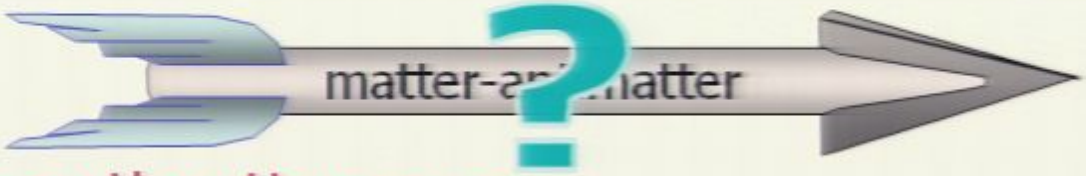

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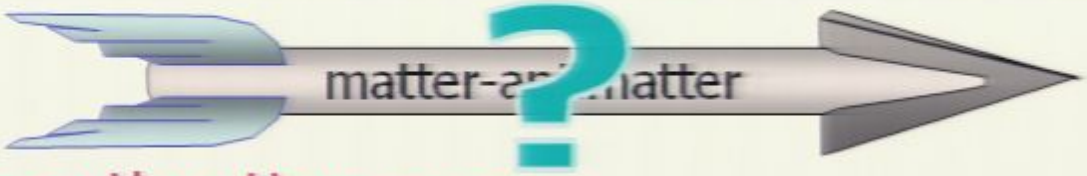

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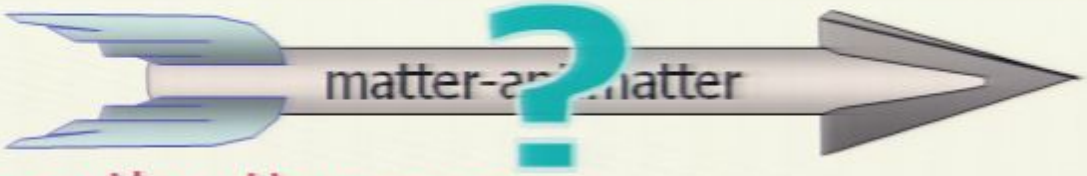

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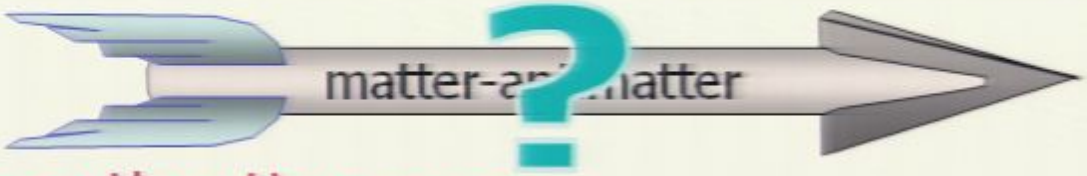

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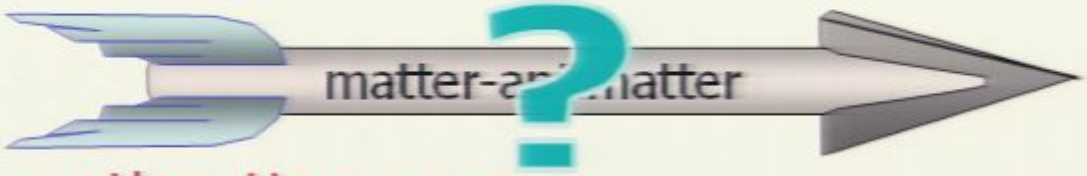

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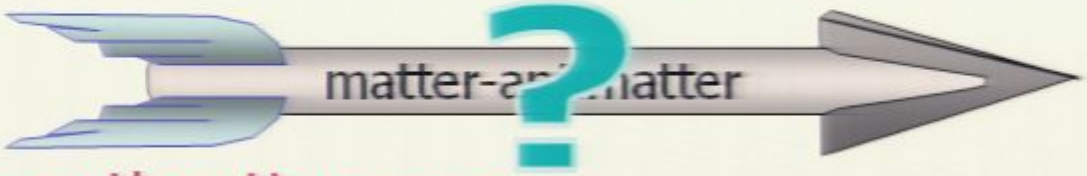

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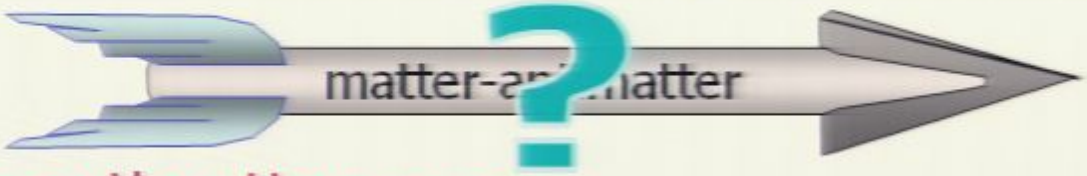

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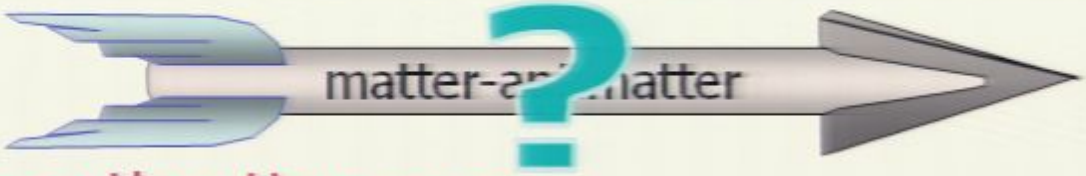

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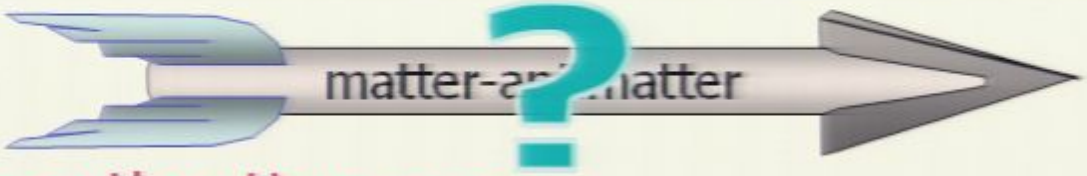

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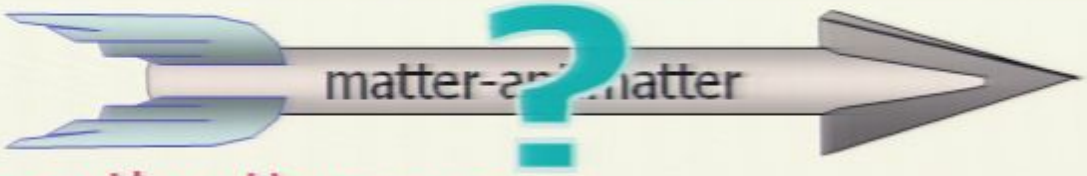

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Rest of talk

Violation of Time Reversal Invariance

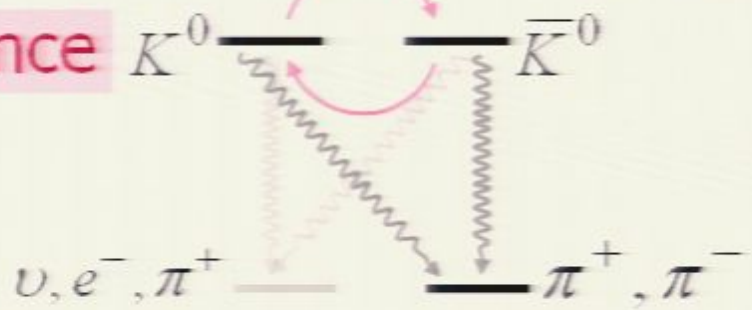
- what does the violation mean without an external time?
- how can a time asymmetric Hamiltonian be incorporated in an unbiased way?

The "Present" State with Past & Future

- use other time asymmetric systems as a guide
- present state has overlap with both future and past states

Mesons - T non-invariance

- physical parameters



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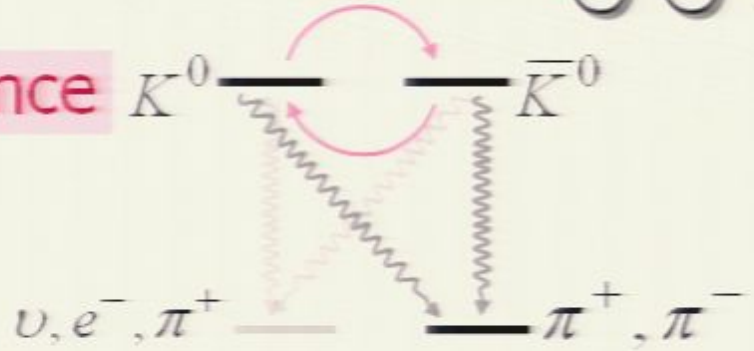
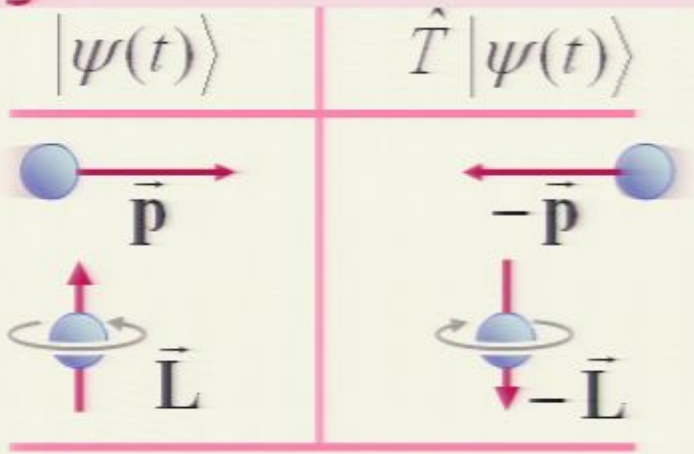
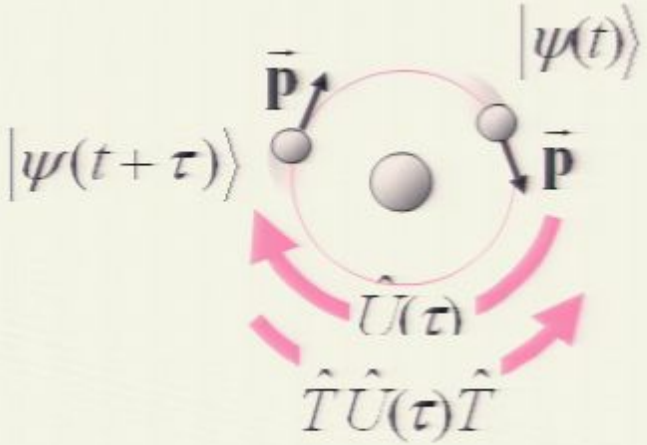


Violation of time reversal (T) invariance

Wigner's *motional* time reversal





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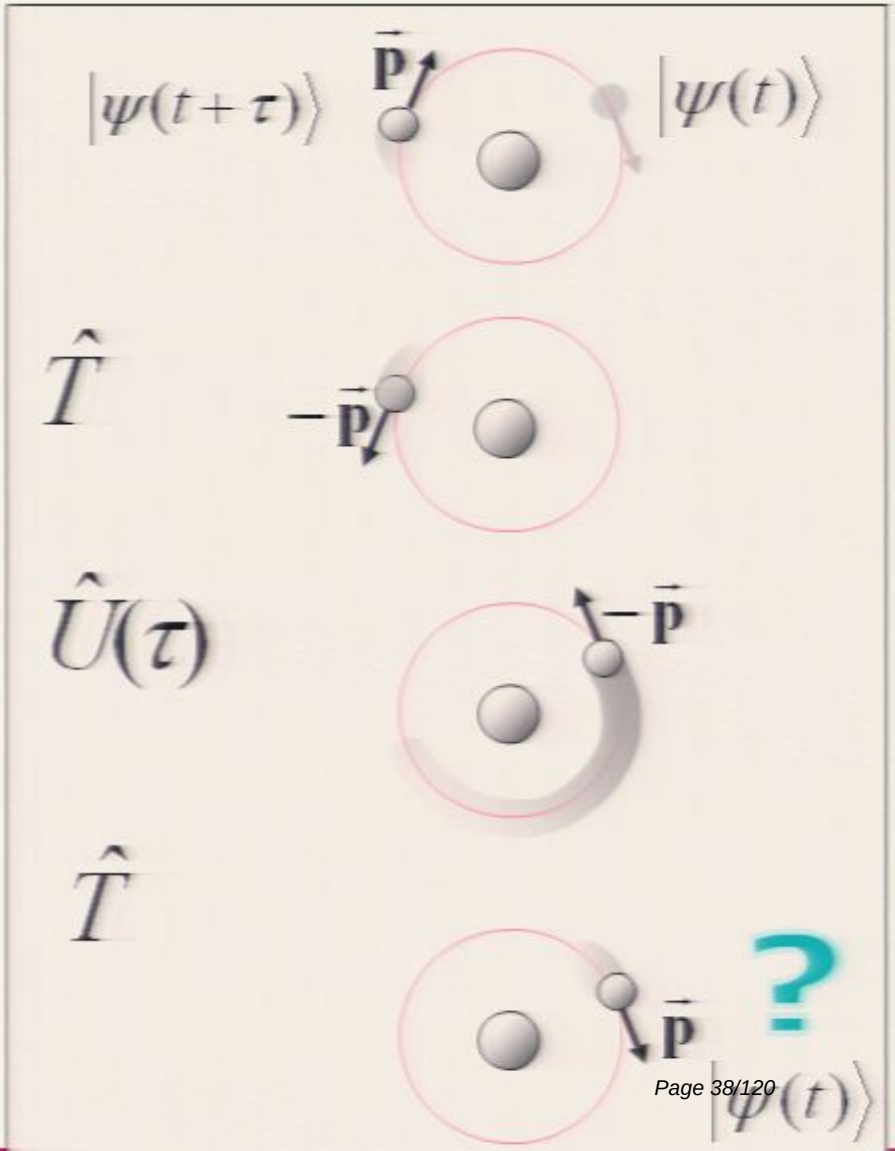

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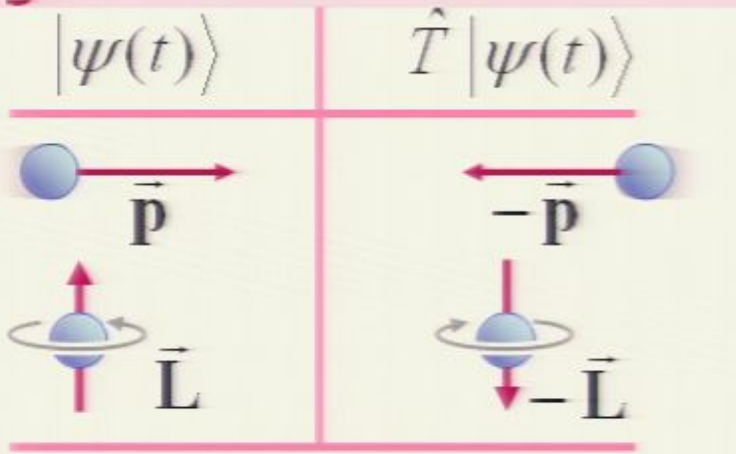

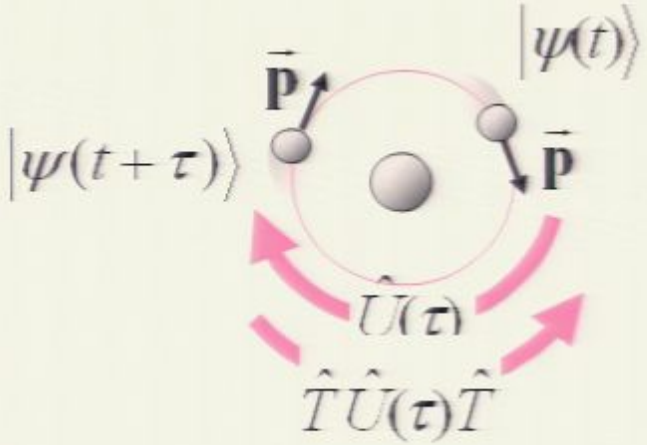

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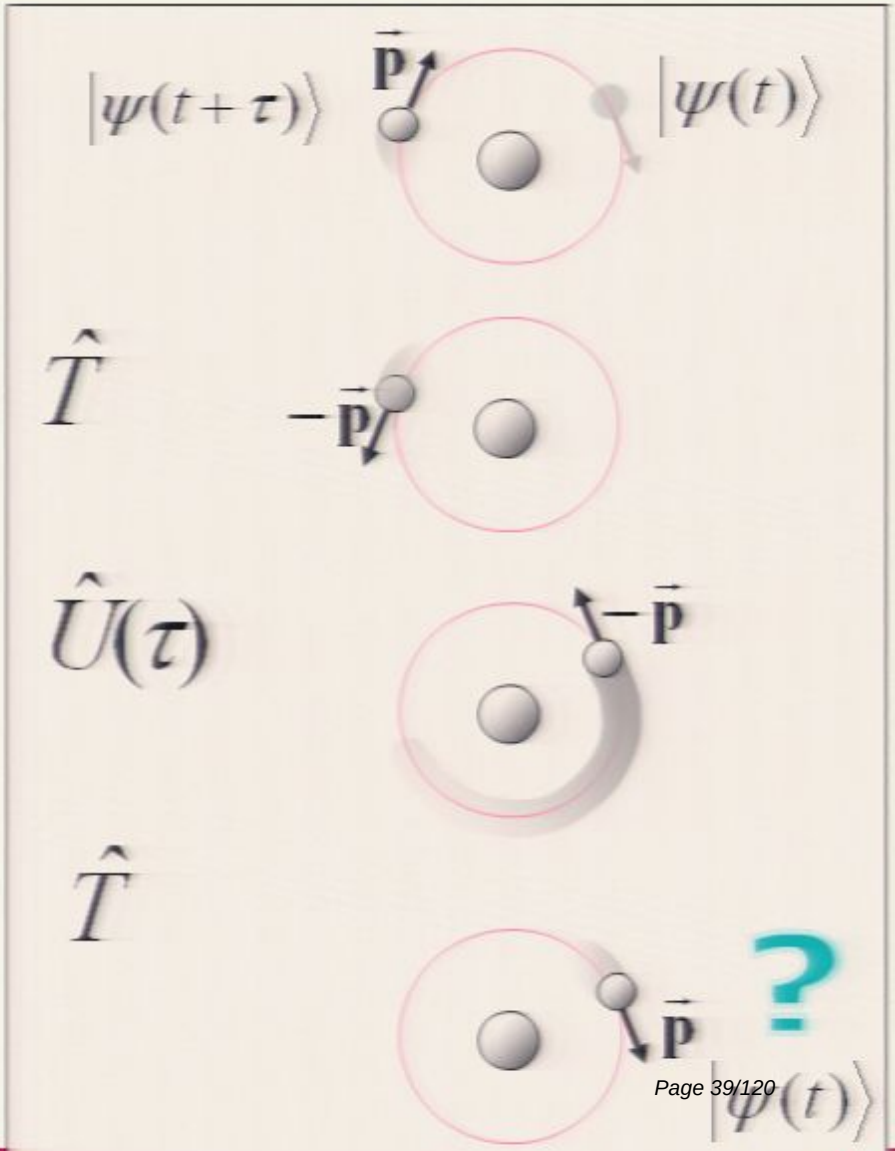

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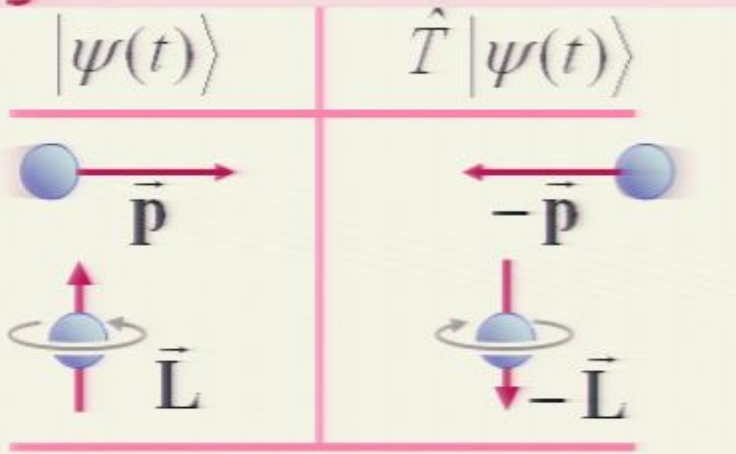

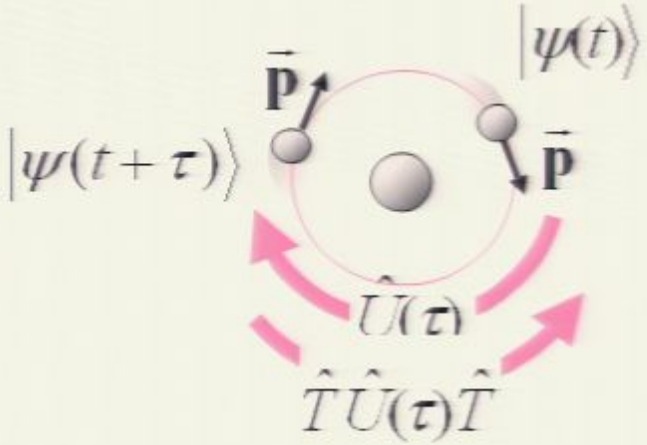

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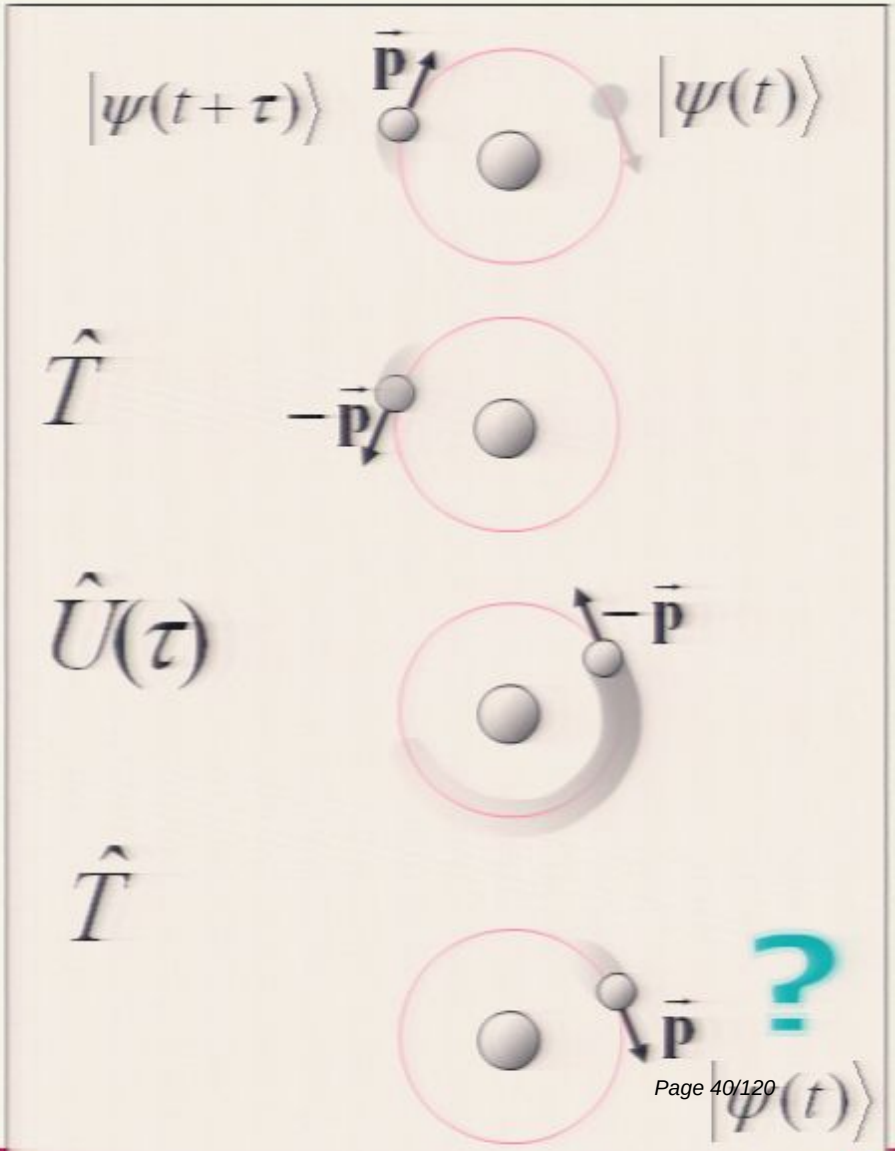

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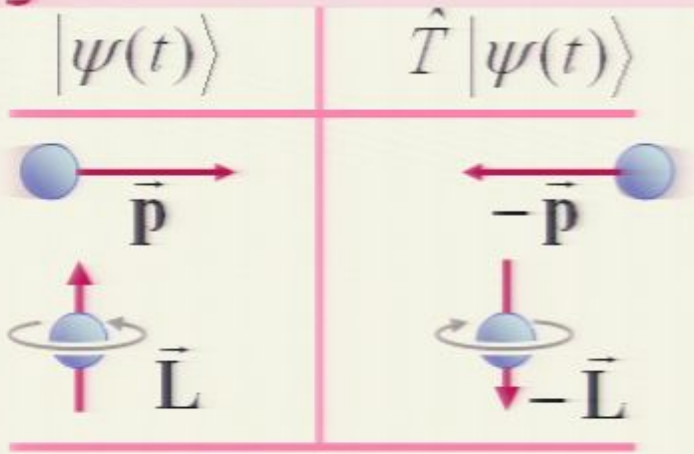

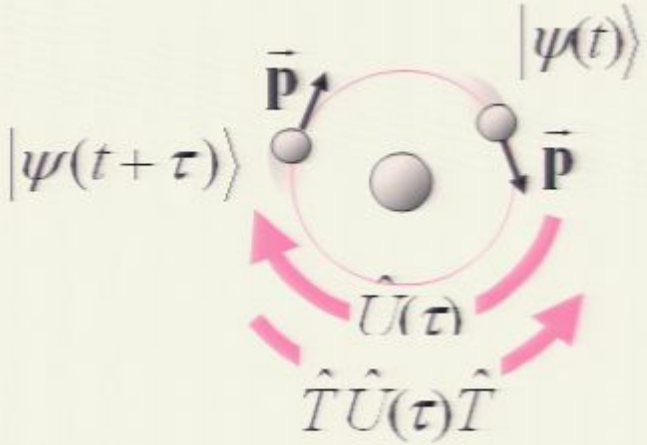

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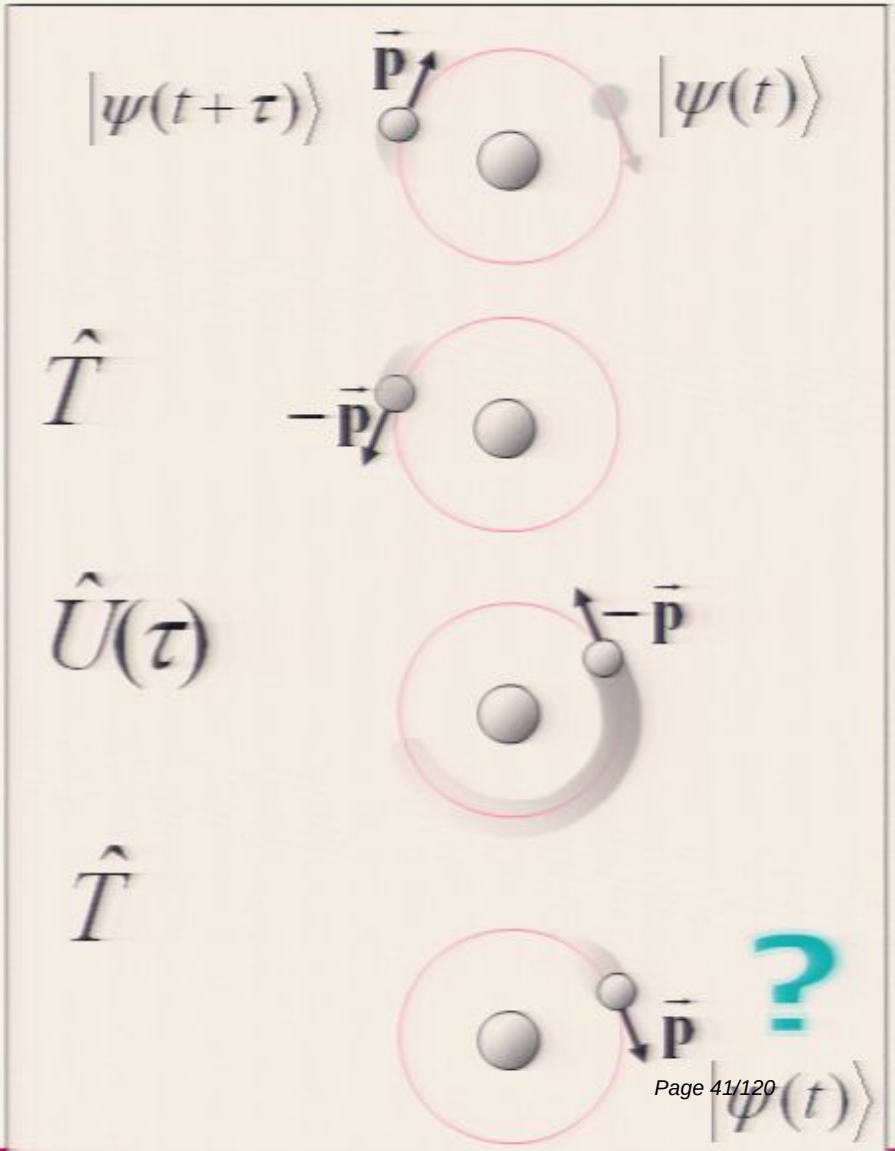

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i.e. $\hat{T}\hat{H}\hat{T} = \hat{H}$

CPT theorem

C = charge conjugation
P = parity inversion
T = time reversal

particle $\leftrightarrow$ antiparticle

$x \leftrightarrow -x$
$y \leftrightarrow -y$
$z \leftrightarrow -z$

$\mathbf{p} \leftrightarrow -\mathbf{p}$
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$\hat{C}\hat{P}\hat{T} = \hat{1}$ and so $\hat{C}\hat{P} = \hat{T}$

- Discovery of CP invariance violation in 1964 in K^0 meson decay.
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P = parity inversion
T = time reversal

particle $\leftrightarrow$ antiparticle

$x \leftrightarrow -x$
$y \leftrightarrow -y$
$z \leftrightarrow -z$

$\mathbf{p} \leftrightarrow -\mathbf{p}$
$\mathbf{L} \leftrightarrow -\mathbf{L}$

$\hat{C}\hat{P}\hat{T} = \hat{1}$ and so $\hat{C}\hat{P} = \hat{T}$

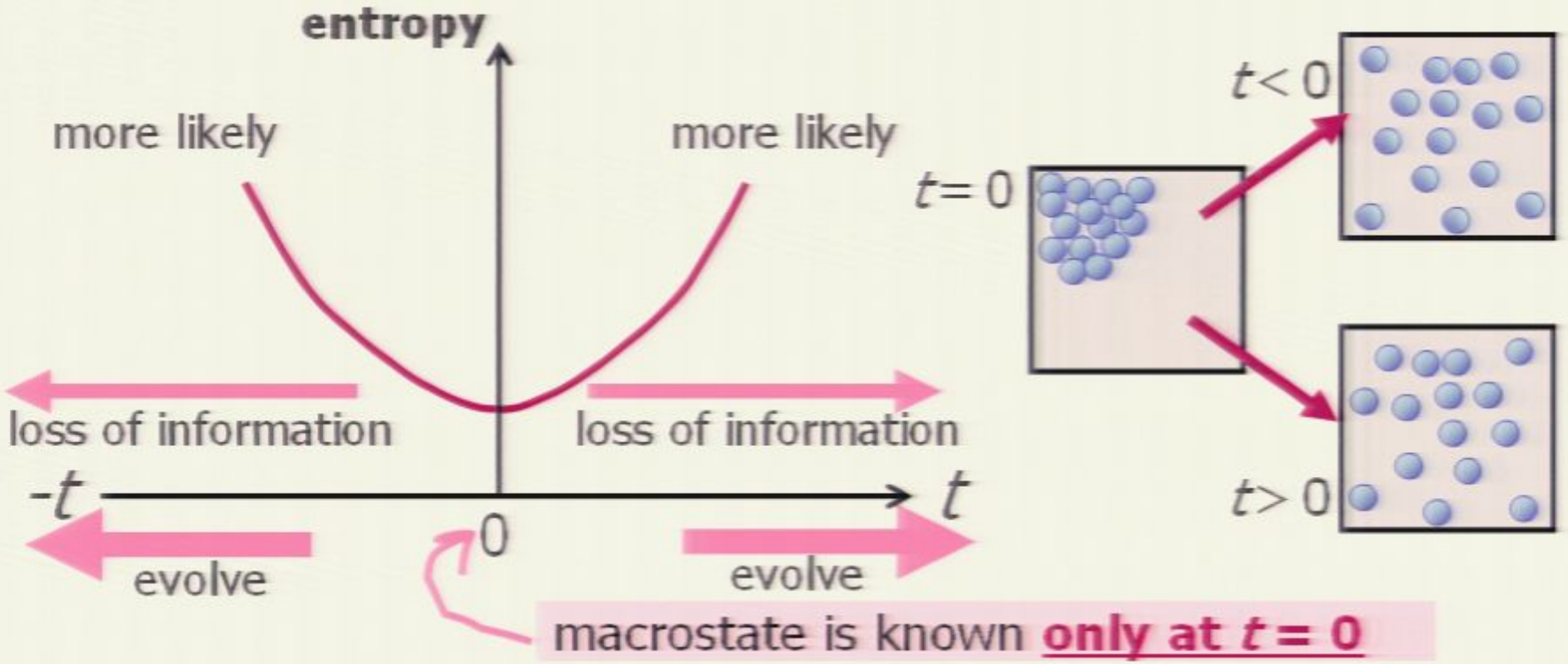
- Discovery of CP invariance violation in 1964 in K^0 meson decay.
  - implies T invariance violated (more details about Kaons later)
- CPT invariance implies that the **Hamiltonian is Hermitian**

Irreversible systems under time reversal

- **Consider a gas whose macrostate is known only at $t = 0$**

  gas is in an **unlikely** macrostate at $t = 0$,

  entropy increases with t and $-t$.



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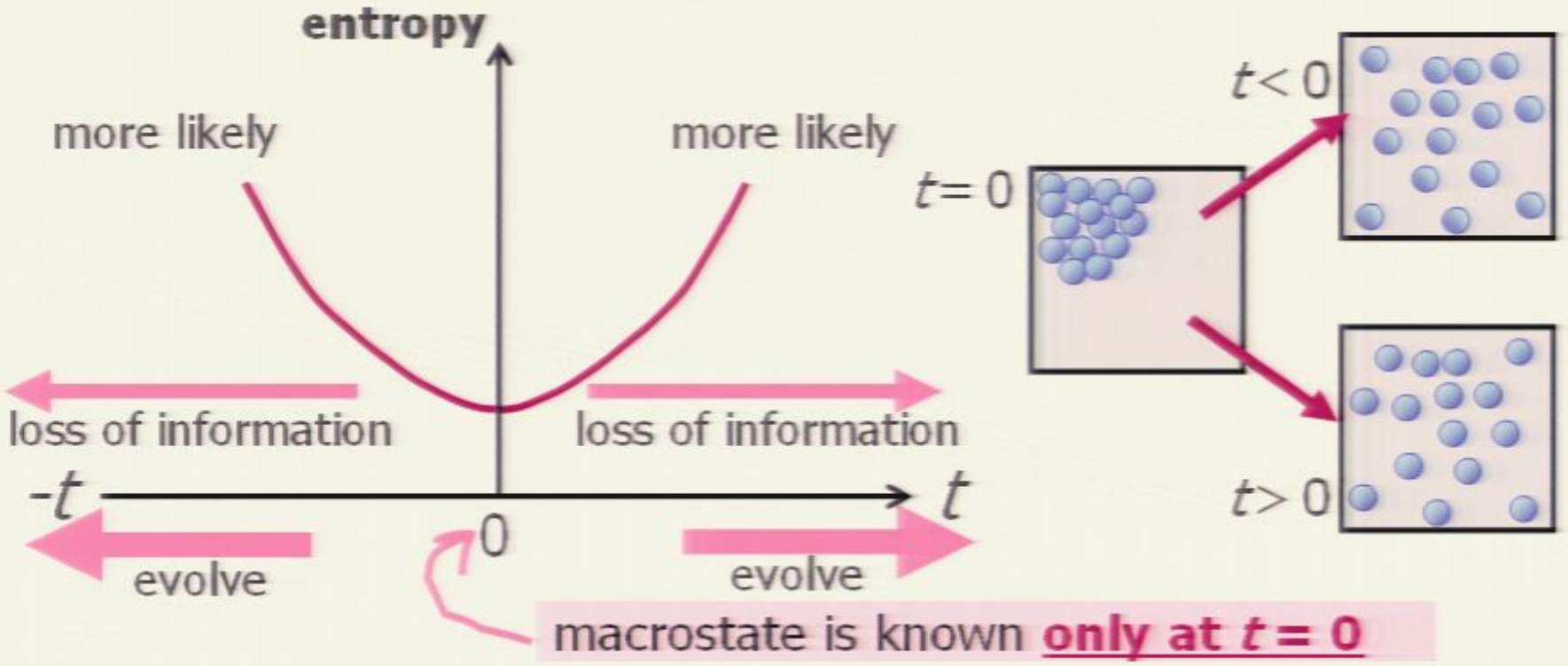

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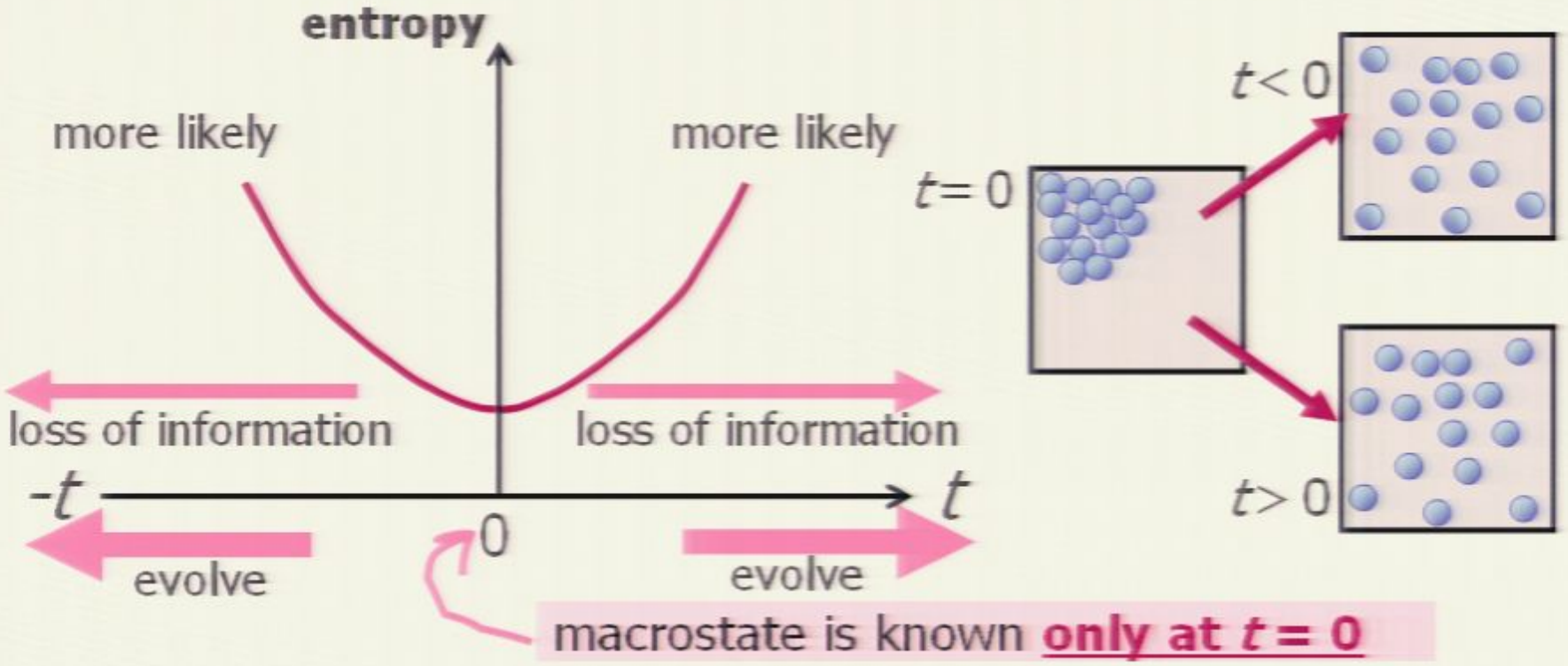

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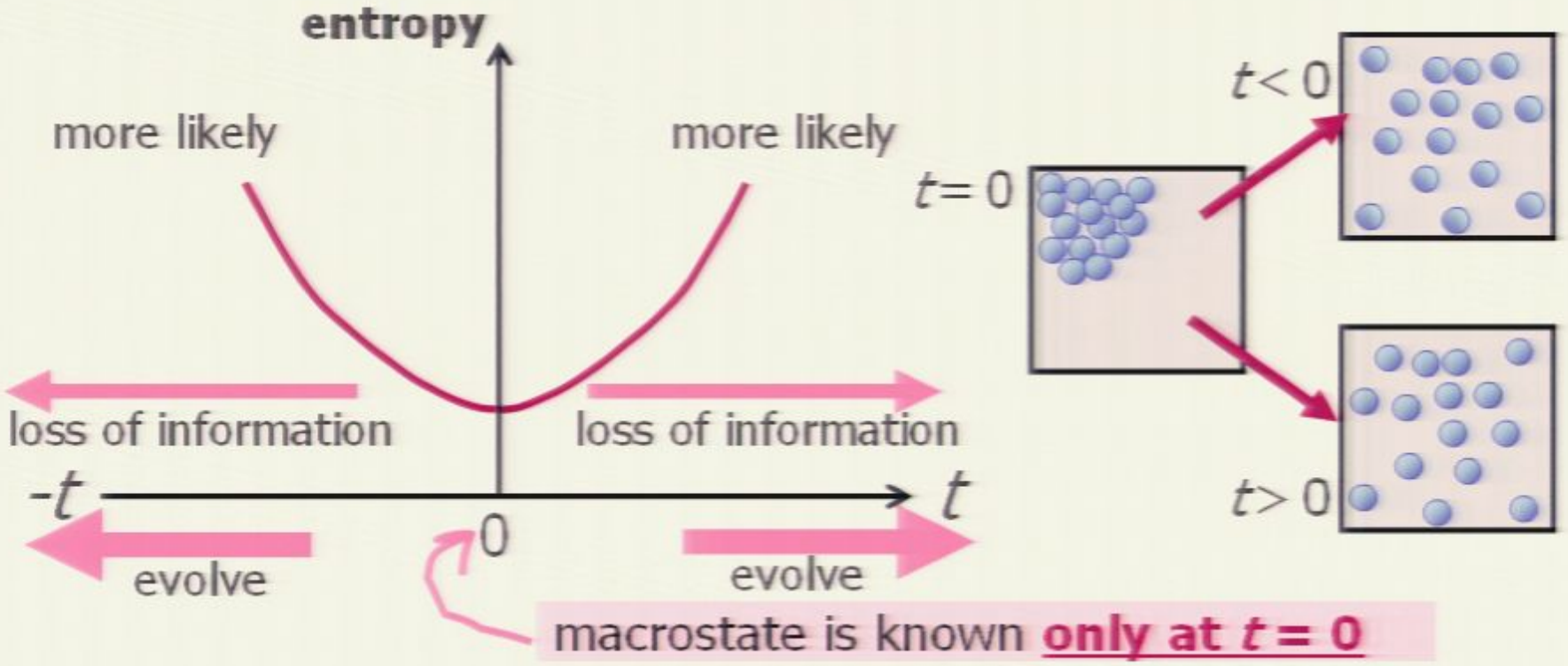

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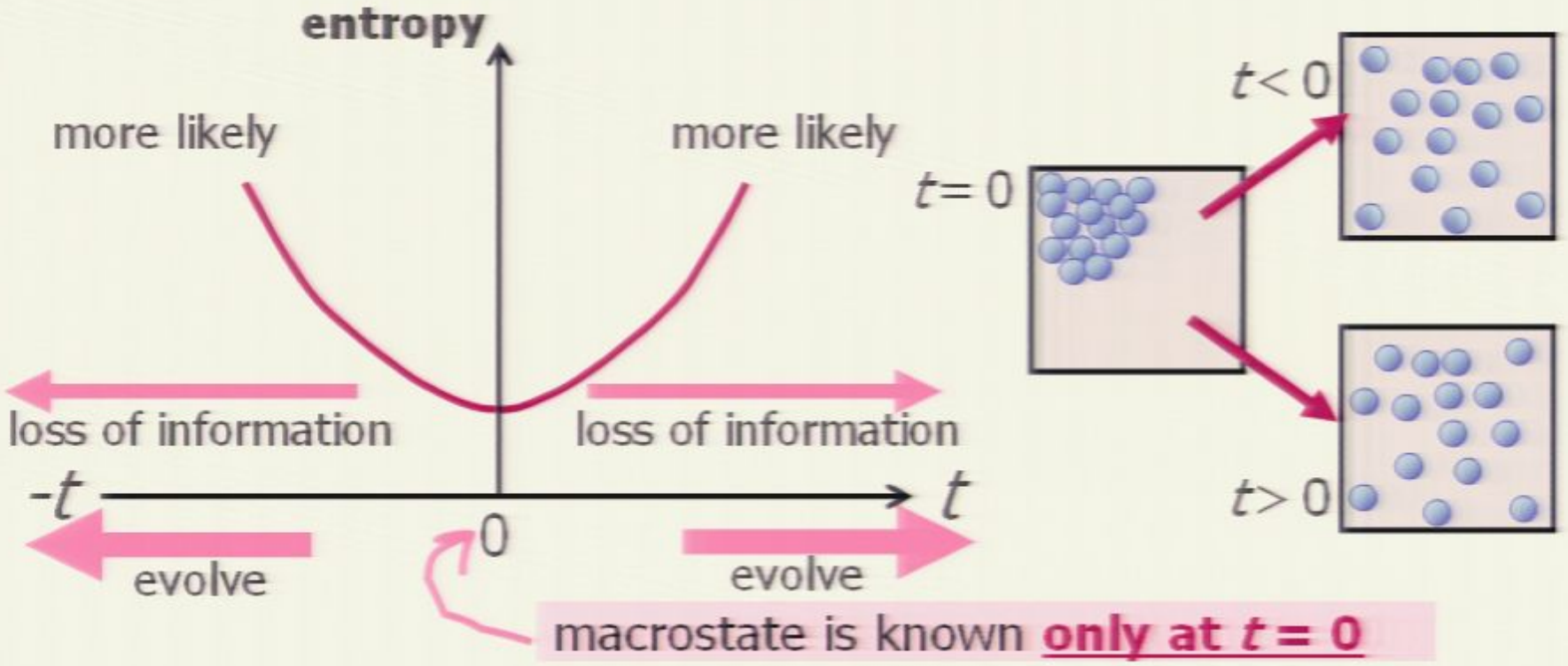

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- **Open quantum system under time reversal**

Stenholm & Jakob, Ann. Phys. 310, 106 (2004)

(damping into past) $\overset{\text{T reversal}}{\Longleftrightarrow}$ (damping into future)

$$\frac{\partial}{\partial t}\bar{\rho}(t) = \bar{\mathcal{L}}[\bar{\rho}(t)] \qquad \frac{\partial}{\partial t}\rho(t) = \mathcal{L}[\rho(t)]$$

$$\bar{\mathcal{L}} = -T\mathcal{L}T, \quad \bar{\rho} = T\rho T$$

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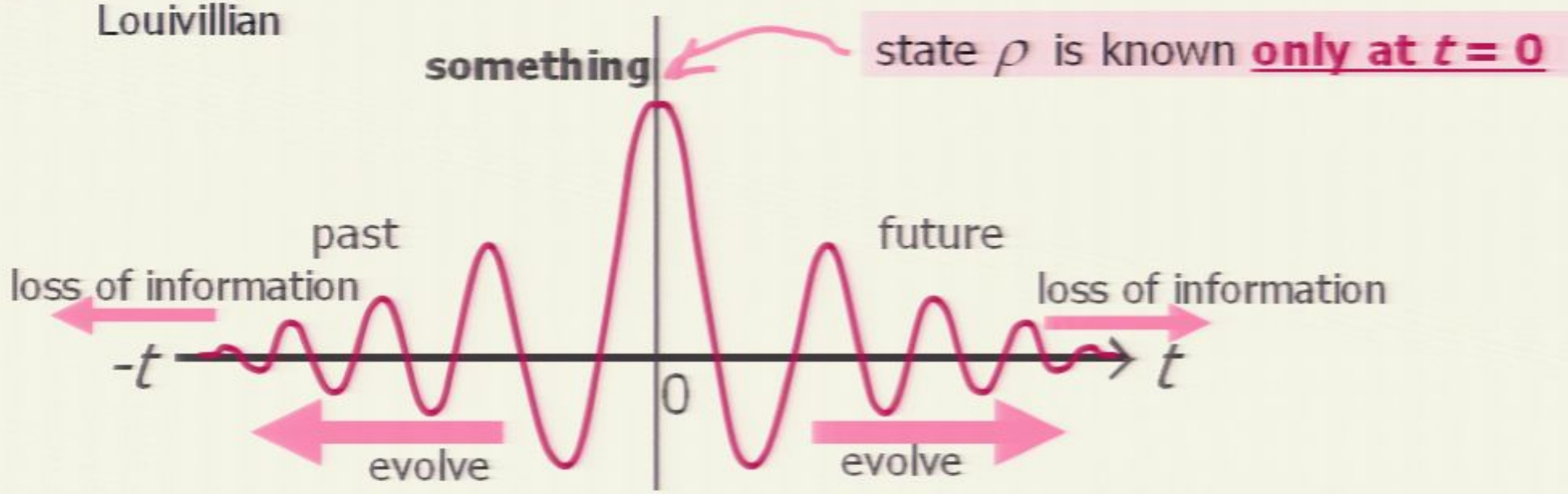

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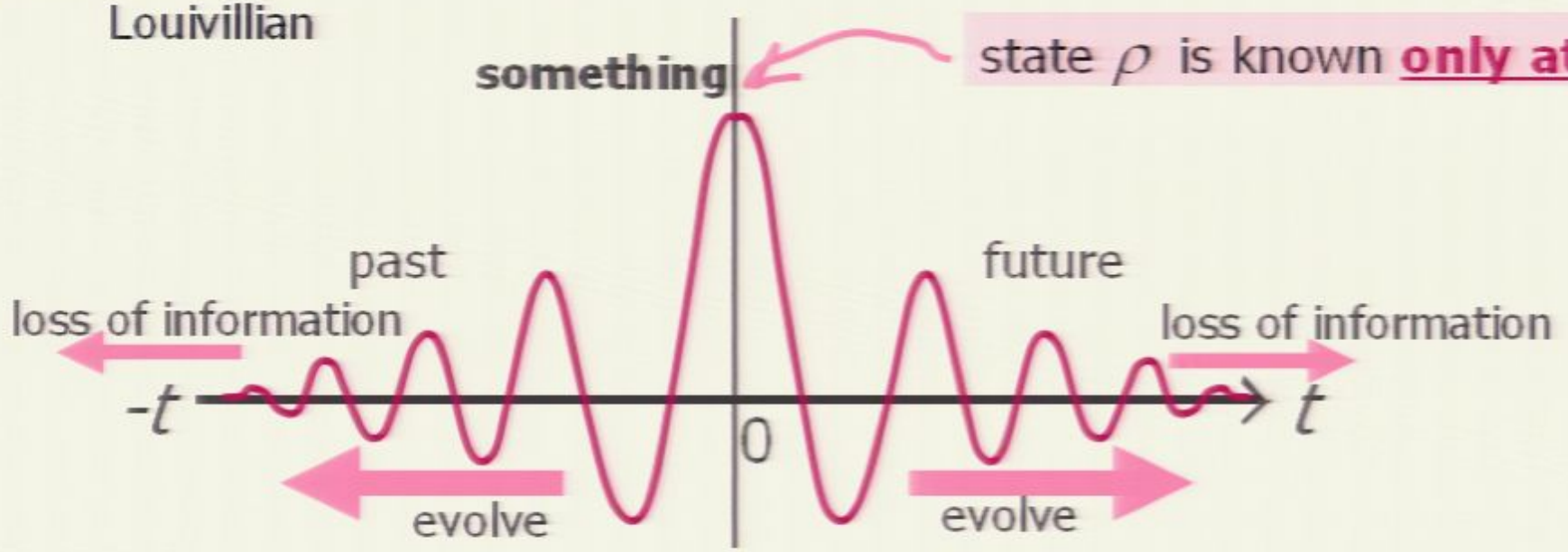

direction of evolution is the direction of information loss

T invariance violation in absence of external time

- Let the Universe be in state $|\Psi\rangle$ at some moment – the **"present"**
  NOTE: we have no info. about the history

Q? What is the unitary time evolution of $|\Psi\rangle$ in the absence of an external time parameter?

- **CP violation** indicates a **preferred direction** of time (like damping in open systems)
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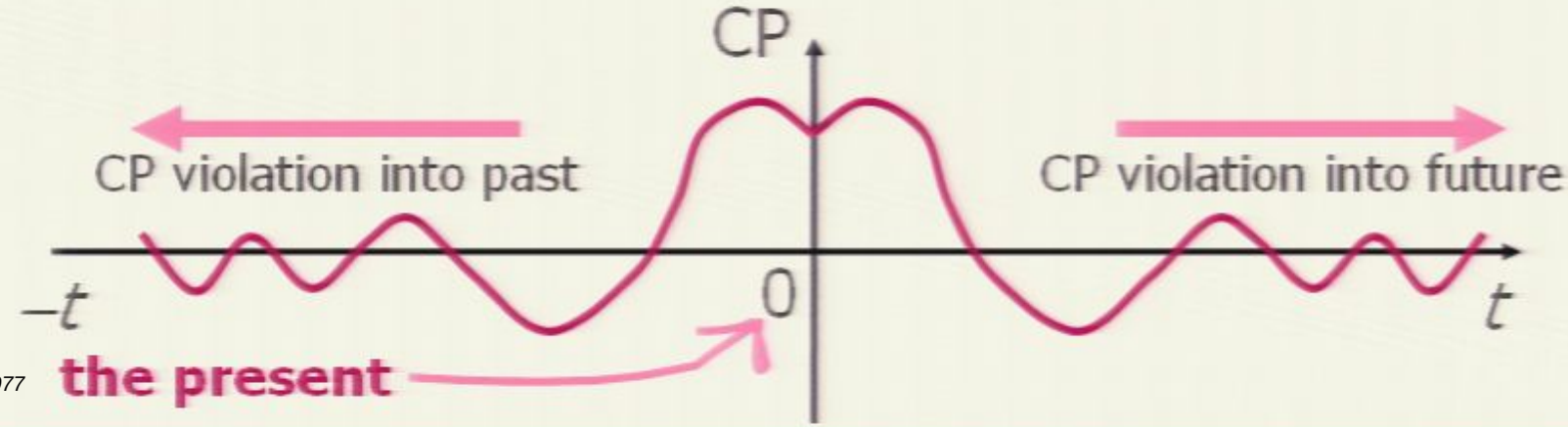

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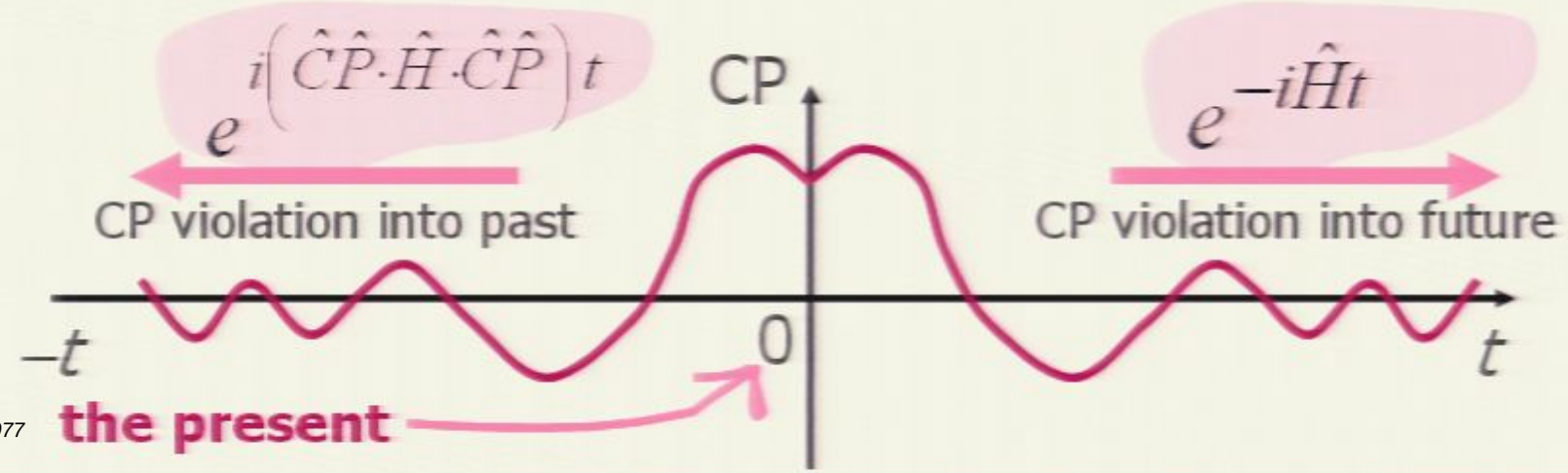

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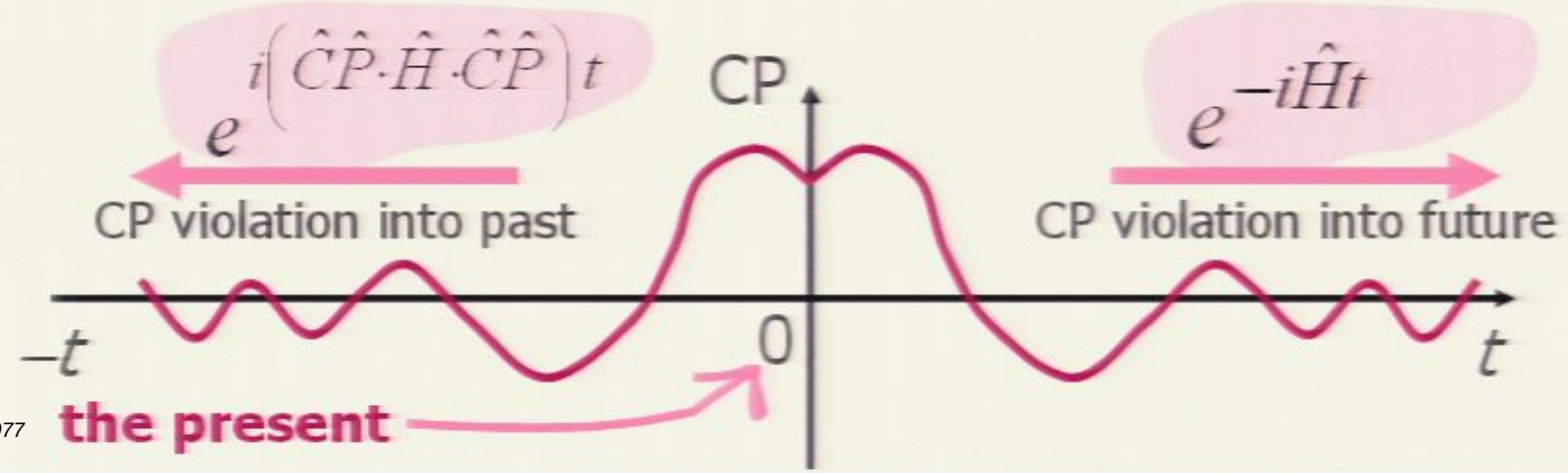

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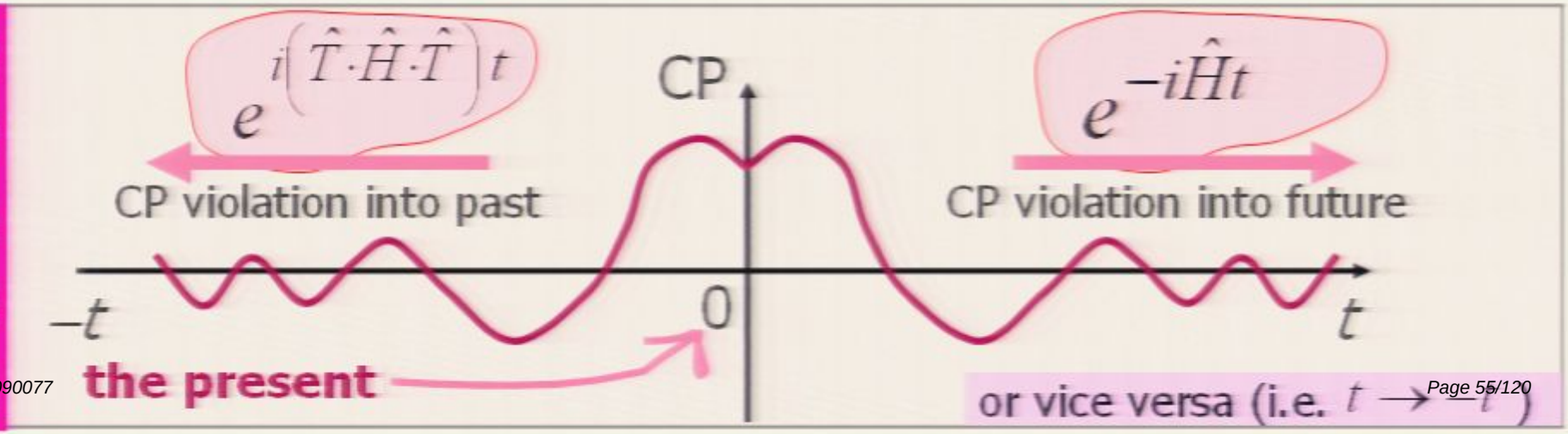

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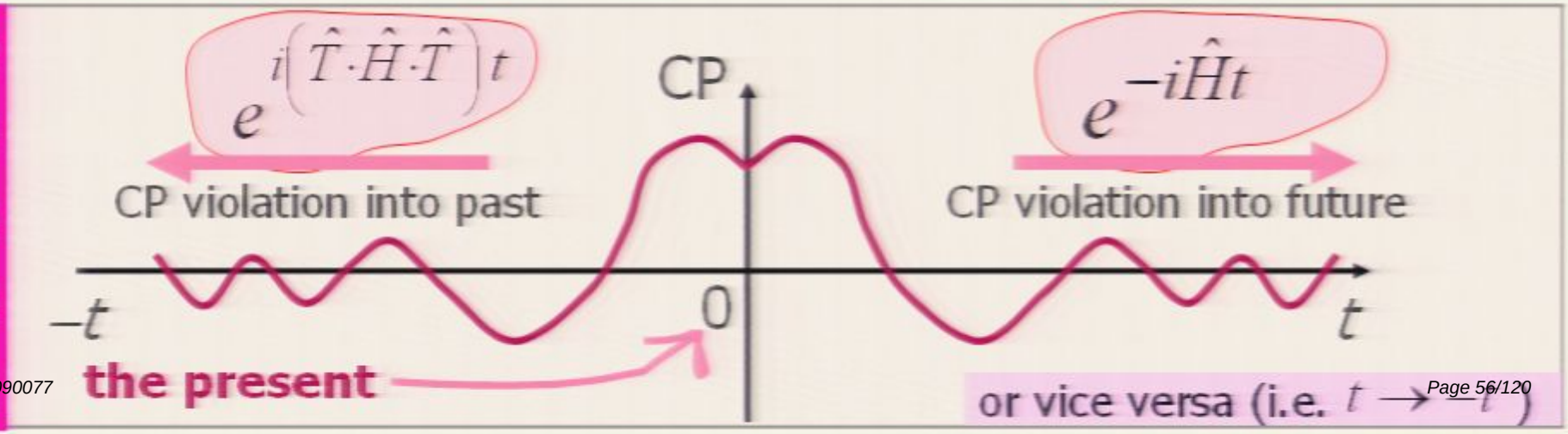

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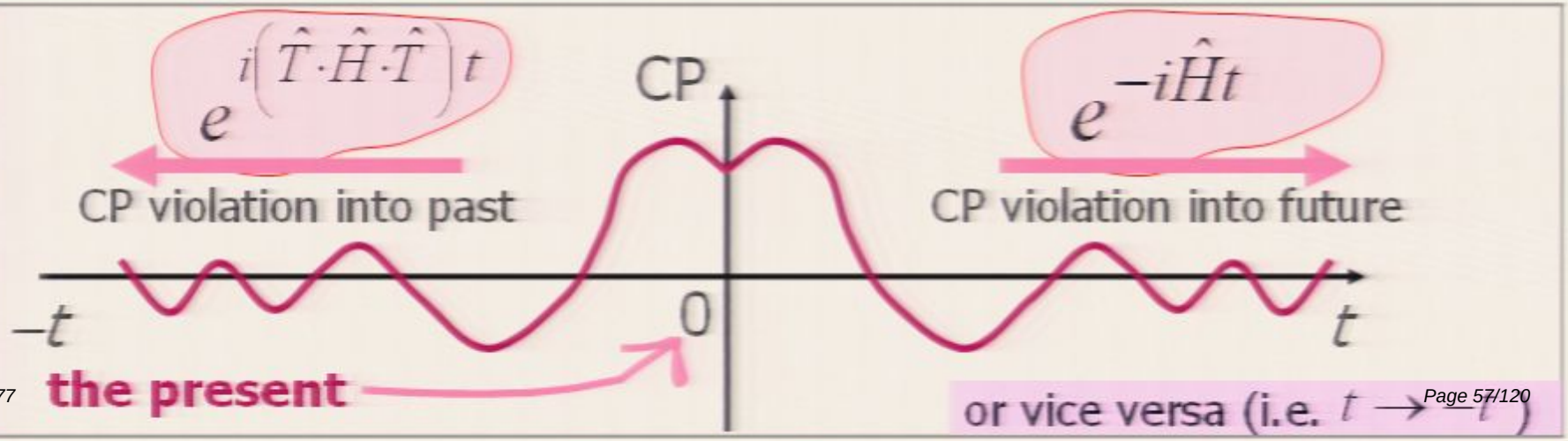

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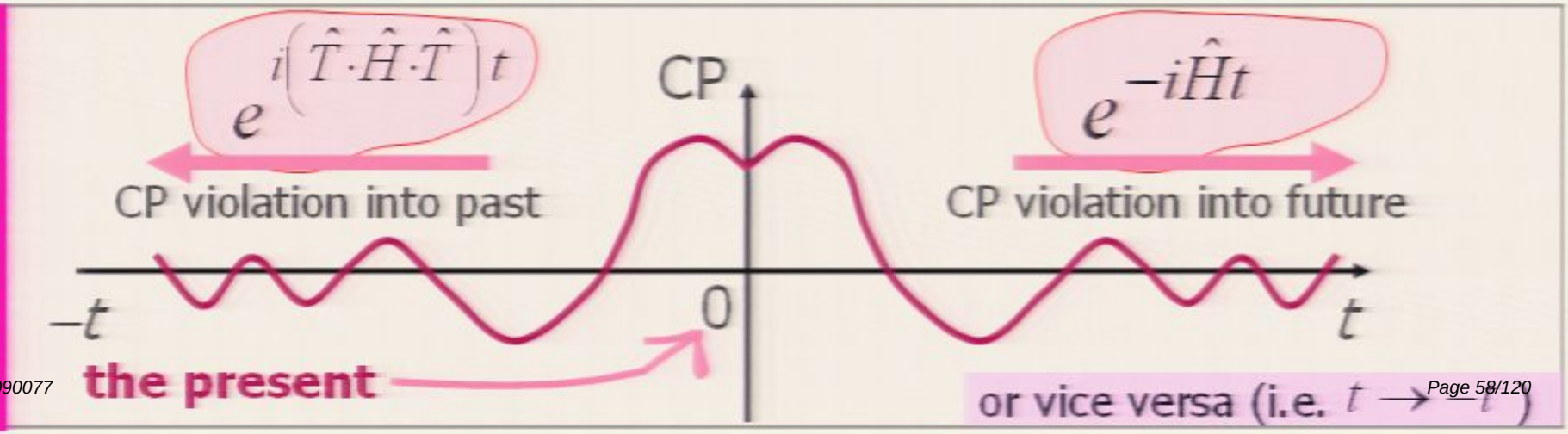

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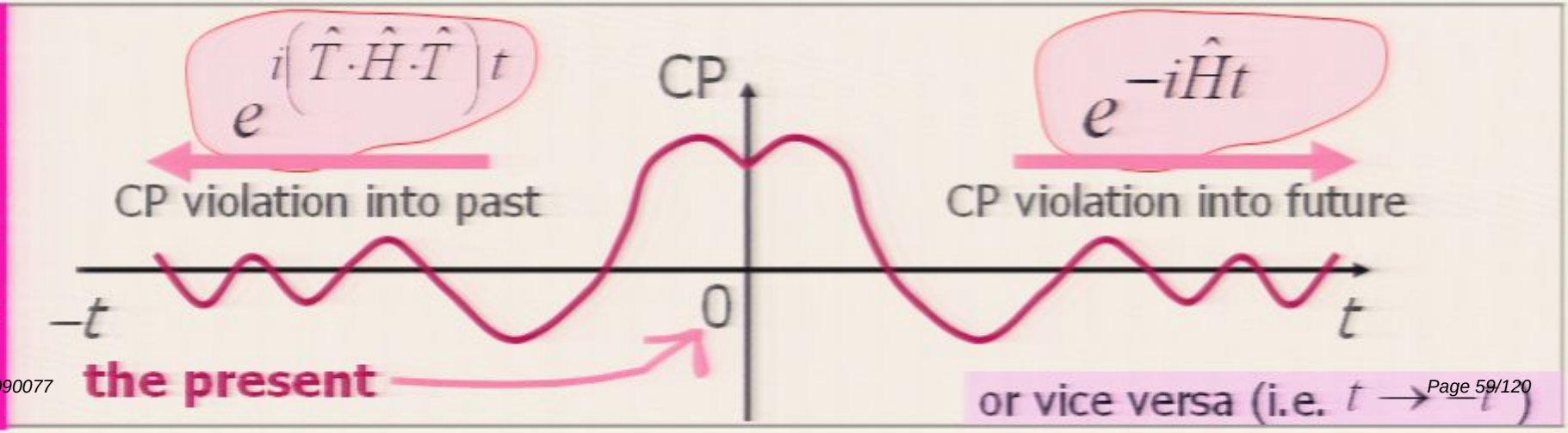

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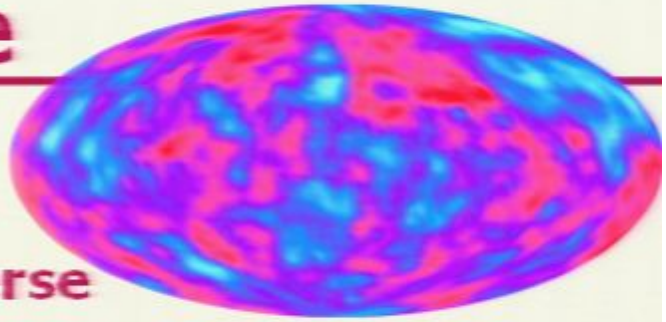


Canonical quantum gravity

- Wheeler-DeWitt equation for **closed Universe**
  minimal energy excitation requires it to be the **ground state**

$$\hat{H}\left|E_0\right\rangle = 0$$

David Pegg's formalism

Pegg, J.Phys. A 24 3031 (1991)

$$\left|E_0\right\rangle \propto \left|\phi_0\right\rangle + \left|\phi_1\right\rangle + \left|\phi_2\right\rangle + \cdots + \left|\phi_s\right\rangle$$

$e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$

History Vector
totality of physical reality

$$\left|\,\right\rangle\left|B_0\right\rangle + \left|\,\right\rangle\left|B_1\right\rangle + \left|\,\right\rangle\left|B_2\right\rangle + \cdots \left|\,\right\rangle\left|B_S\right\rangle$$

$e^{-iH_B\Delta}$

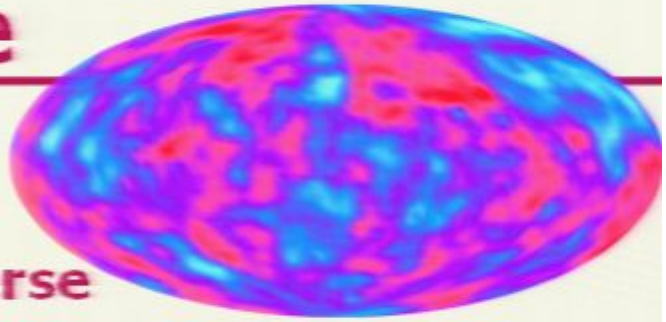
$\Delta t =$

C

B

M,J,Q

Past, Present & Future State



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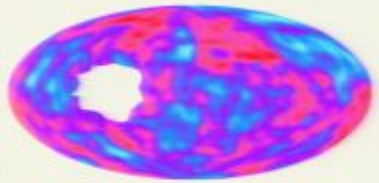
C

B



M,J,Q

$$\Delta t = \; -$$

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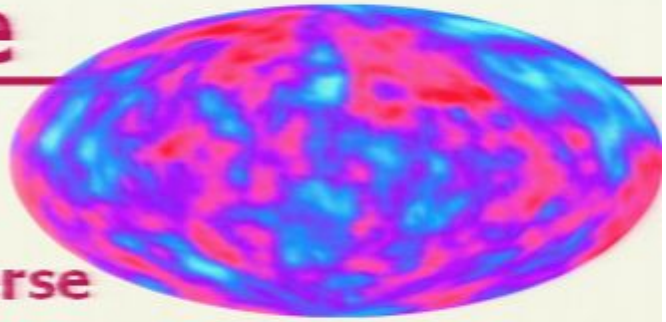

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$\Delta\hbar =$

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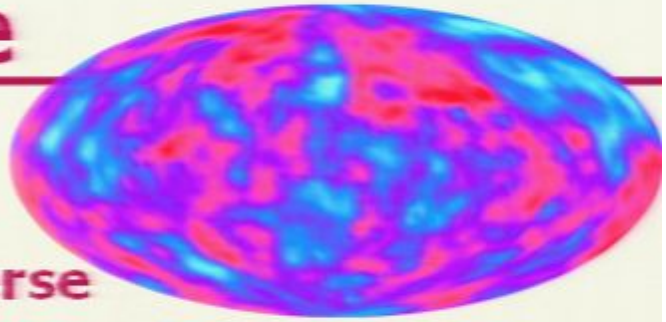

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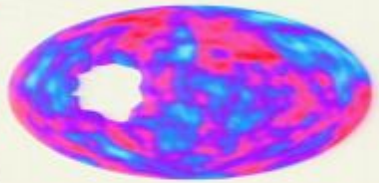

M,J,Q

$$\Delta t = \; -$$

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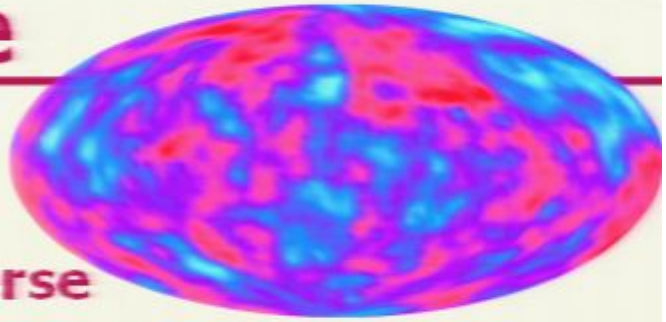

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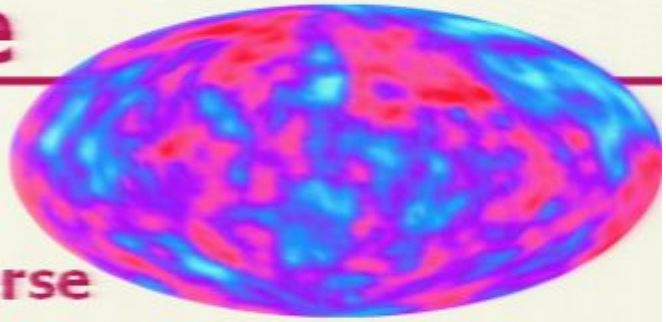

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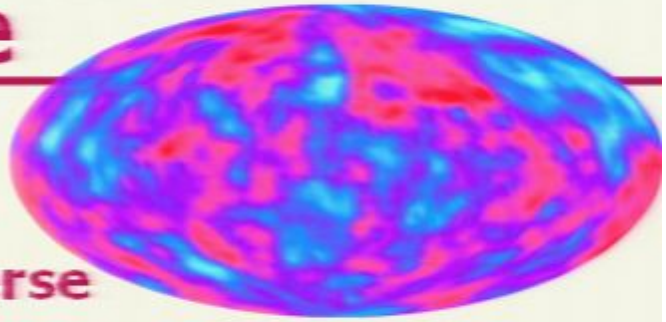

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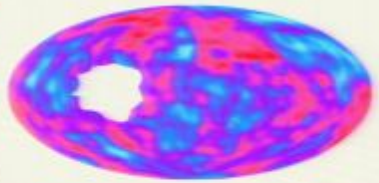

M,J,Q

$$\Delta t = \; -$$

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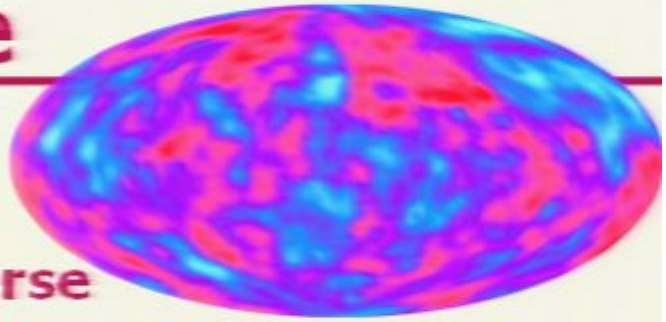

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History Vector
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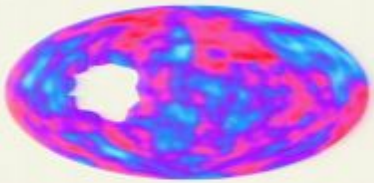
$\Delta t =$ clock − clock

C

B

M,J,Q



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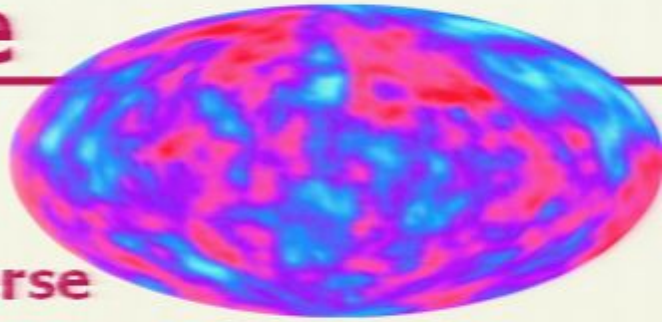

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$e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$ $e^{-i\hat{H}\Delta}$

History Vector
totality of physical reality

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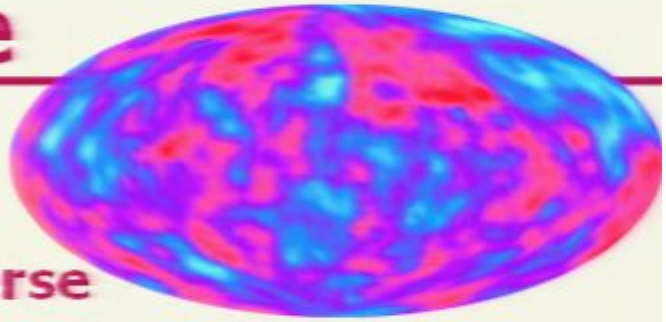
$$\Delta t = \;\; -$$

C B

Past, Present & Future State



Canonical quantum gravity

- Wheeler-DeWitt equation for **closed Universe**
  minimal energy excitation requires it to be the **ground state**

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C

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M,J,Q

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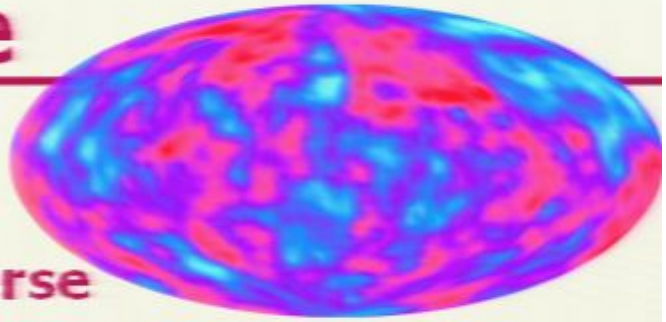

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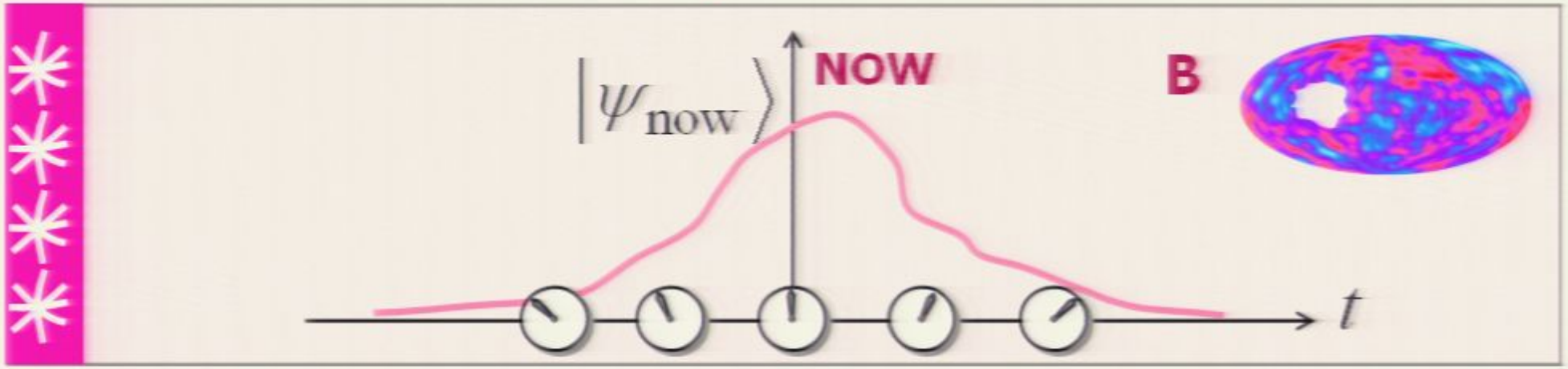

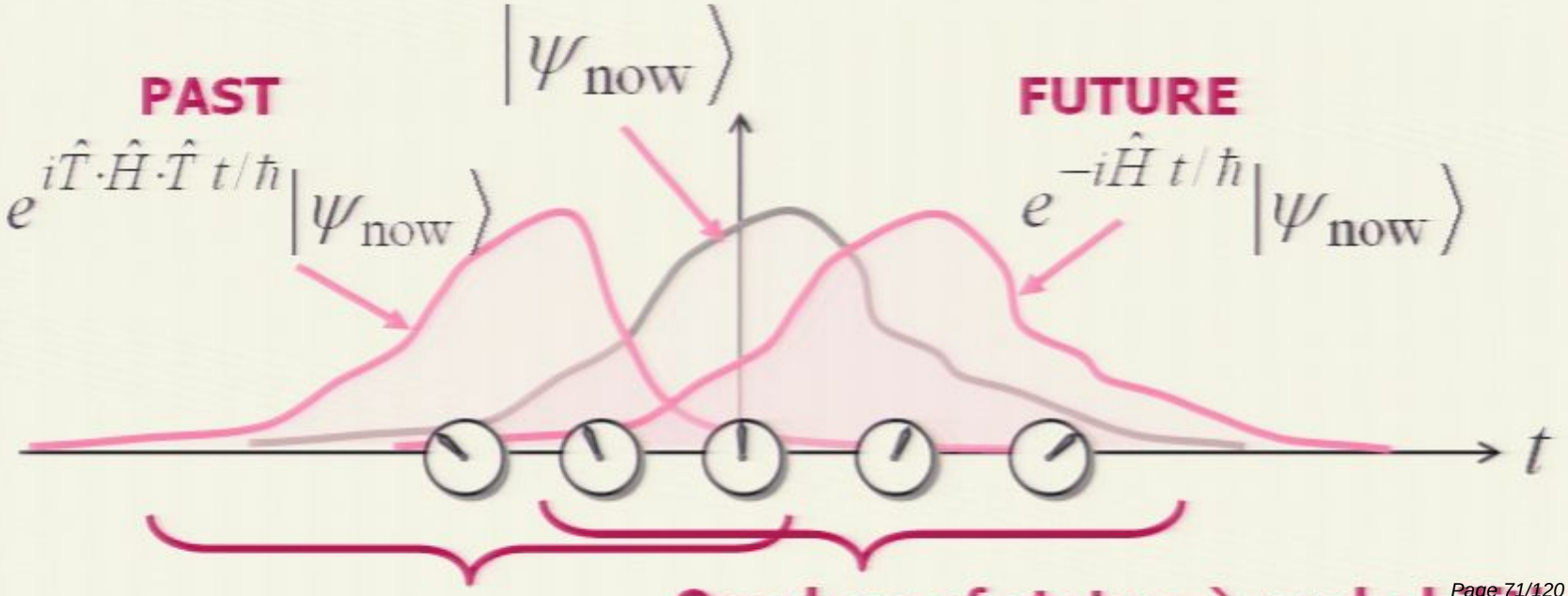

Overlaps of states → probabilities

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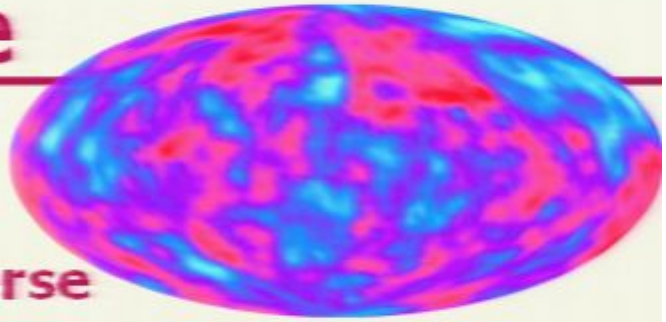

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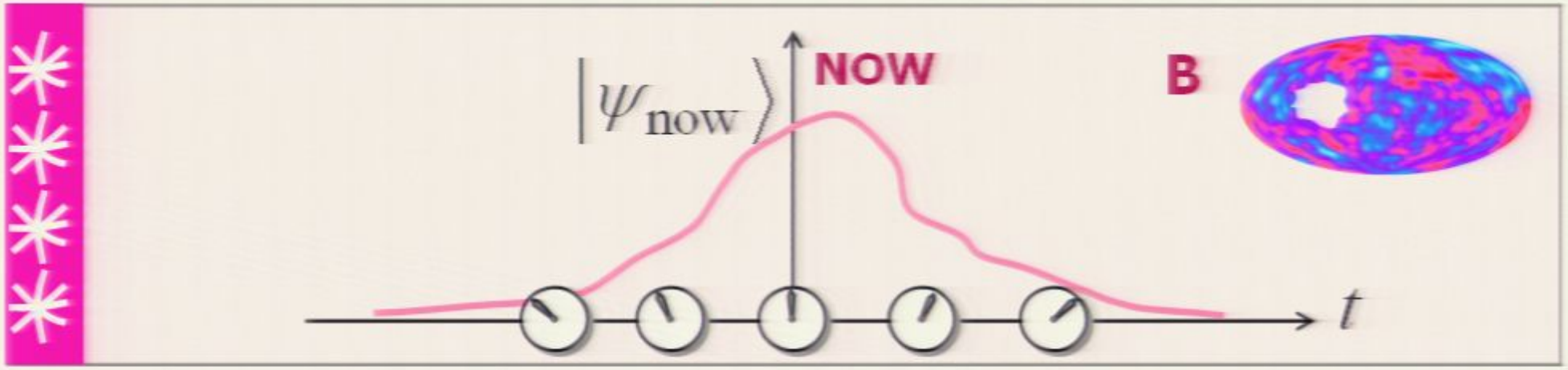

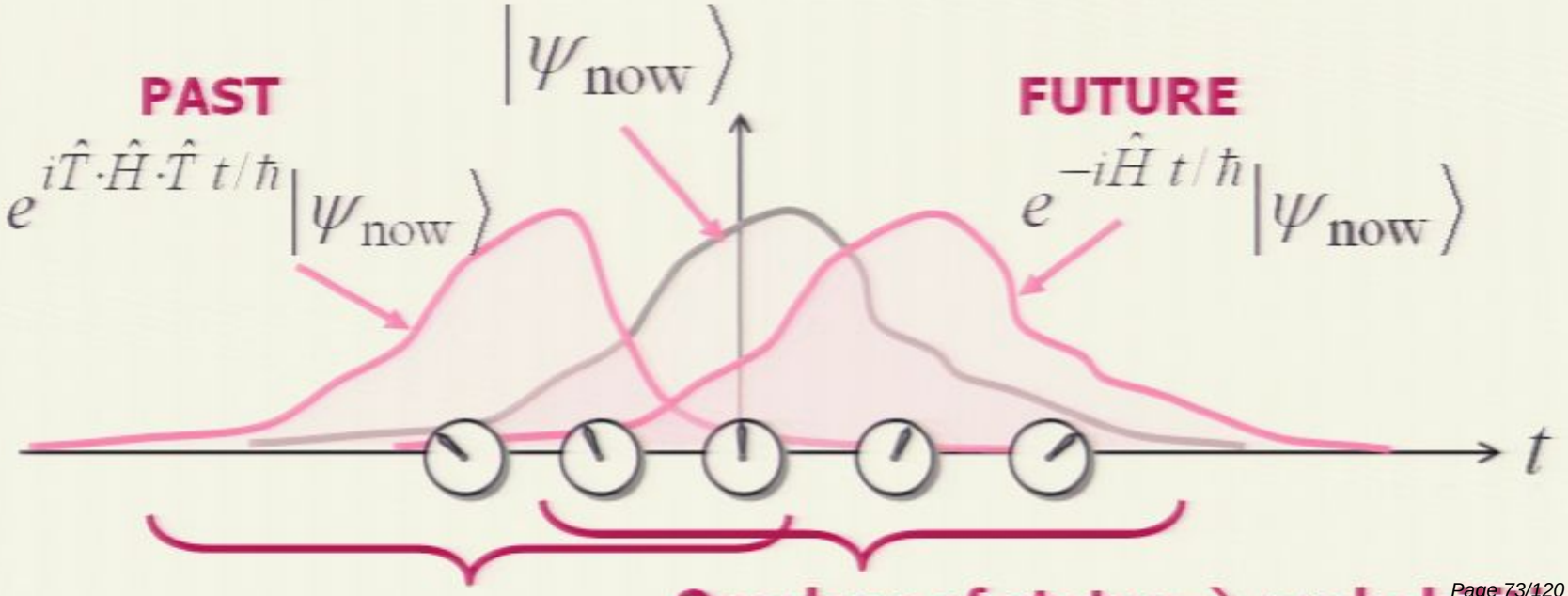

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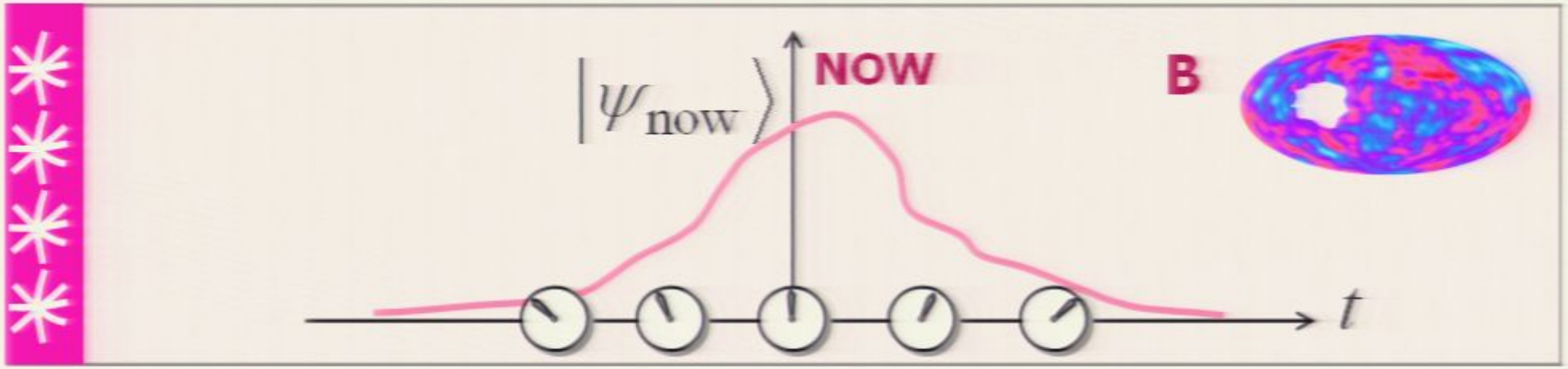

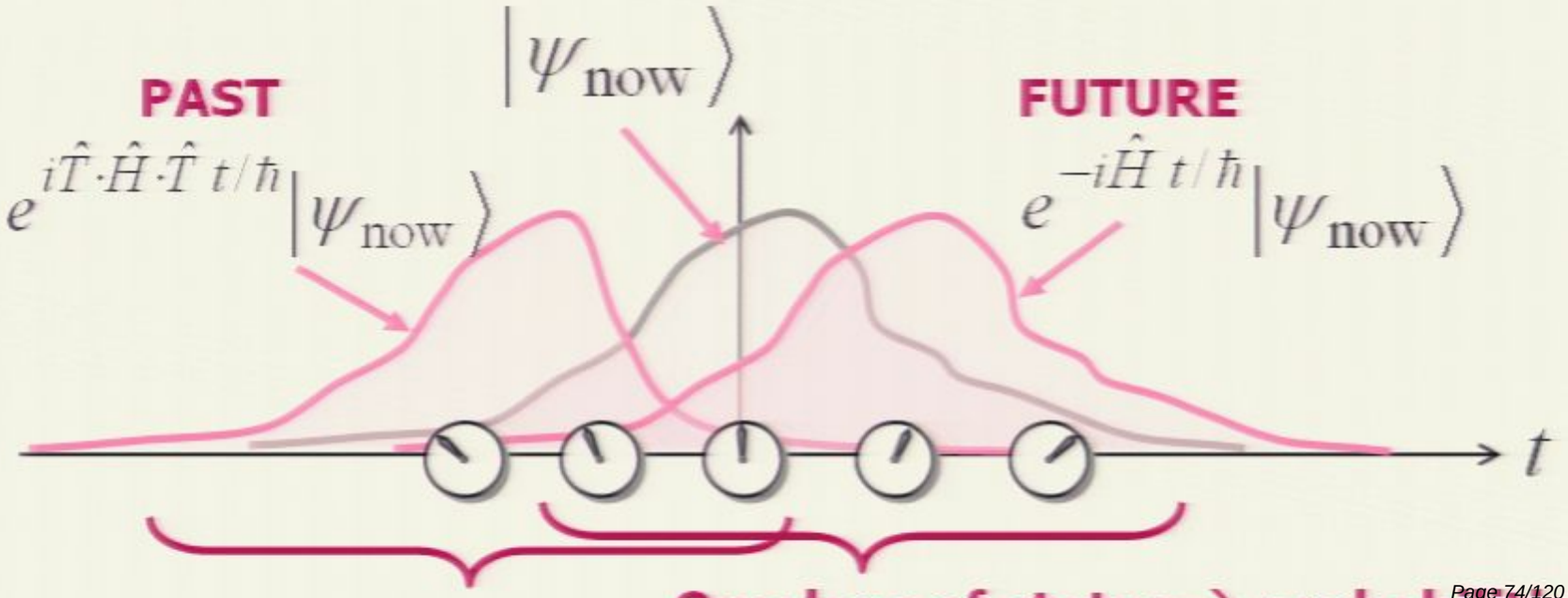

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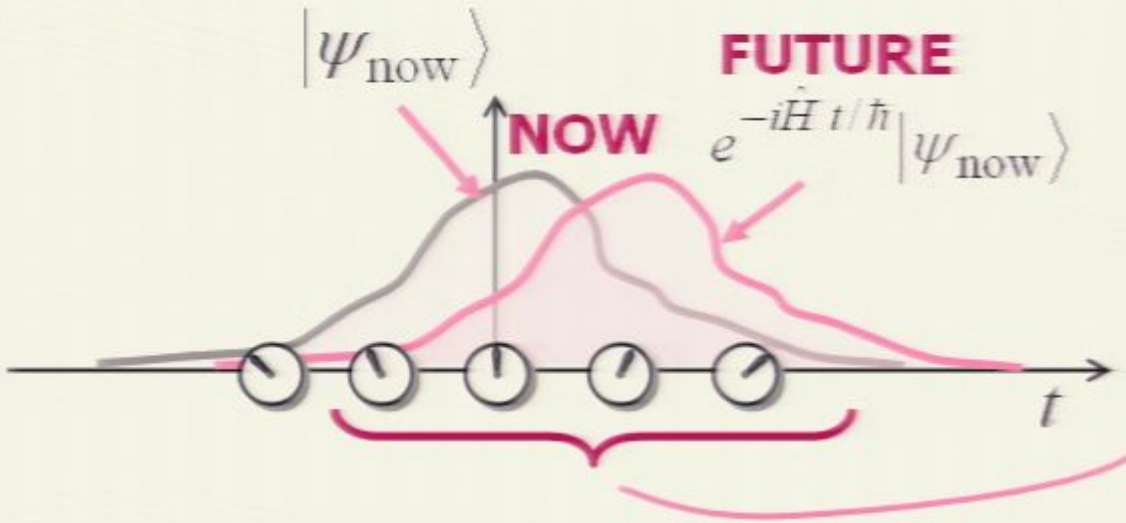

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= probability of **now** being in **future** state

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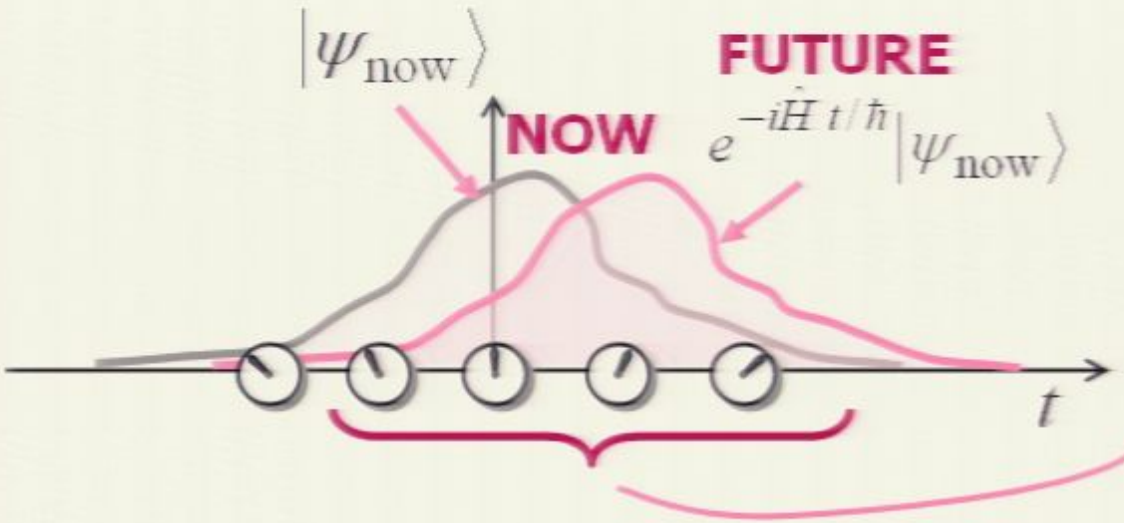

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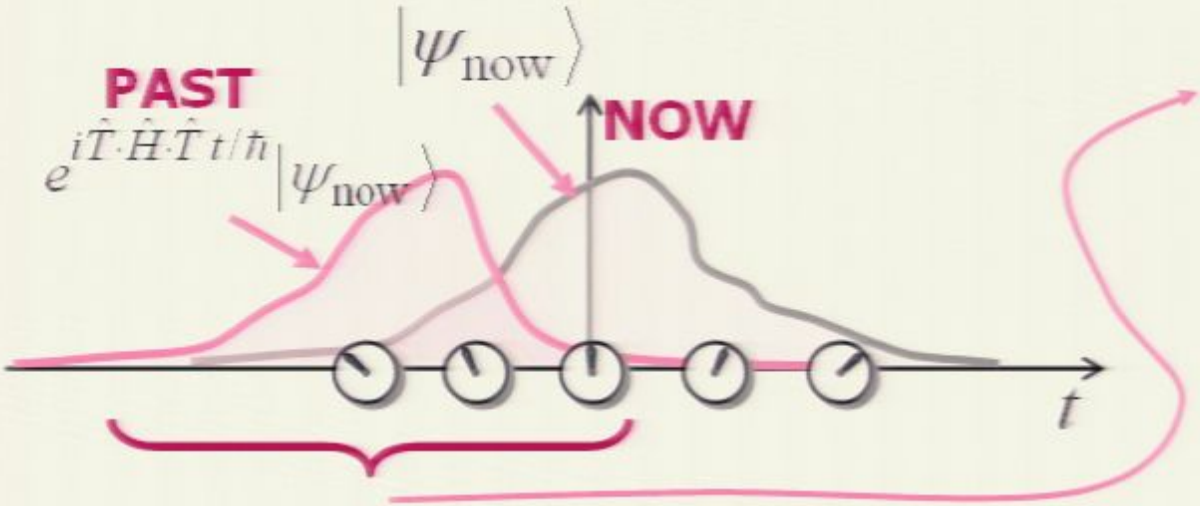

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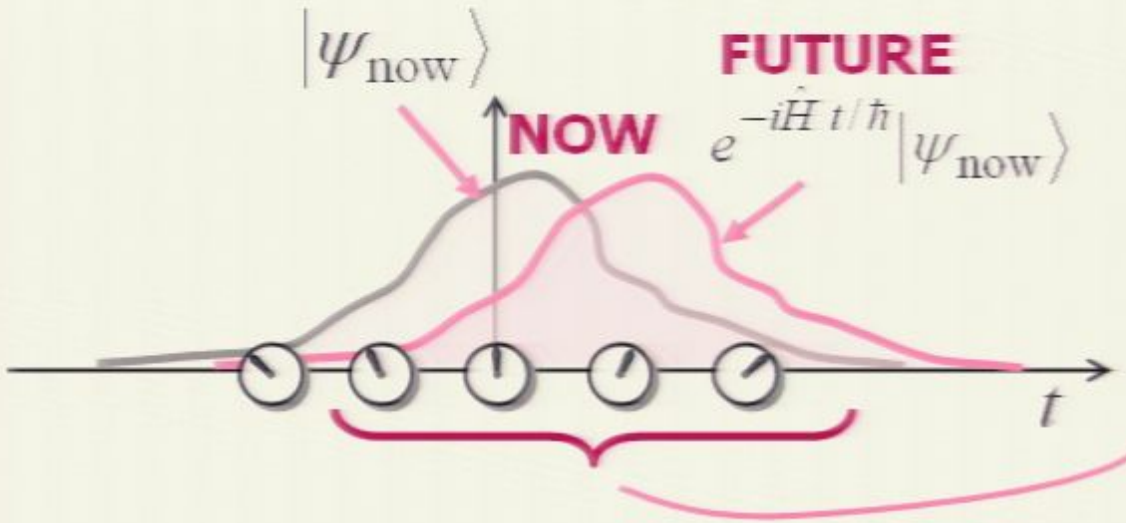

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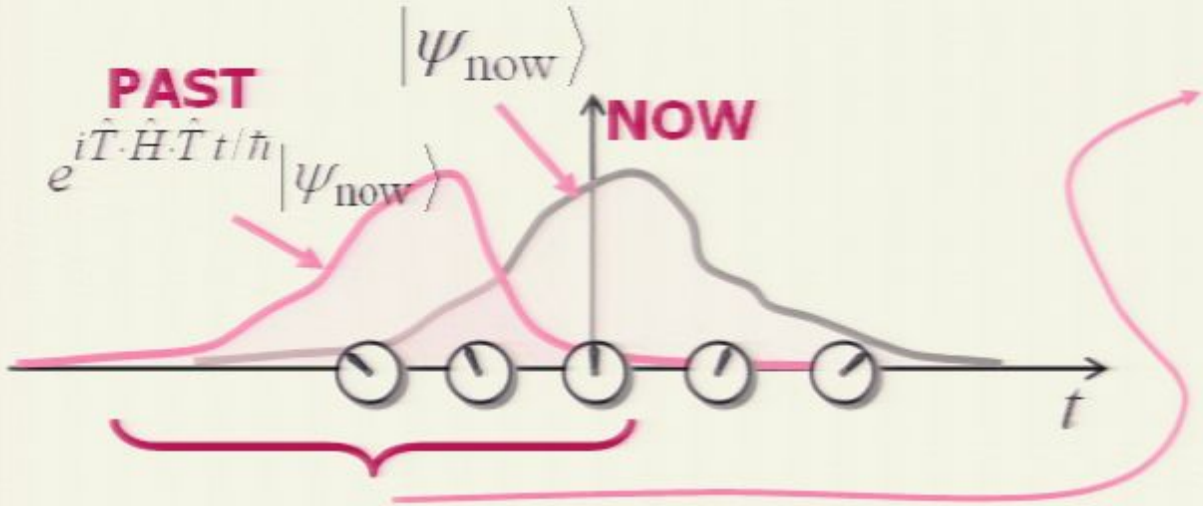

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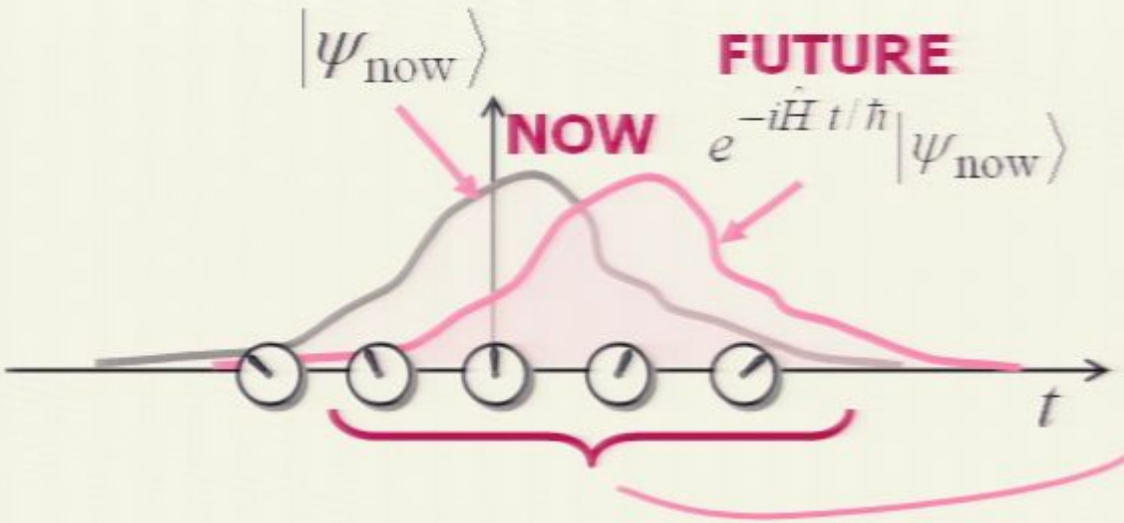

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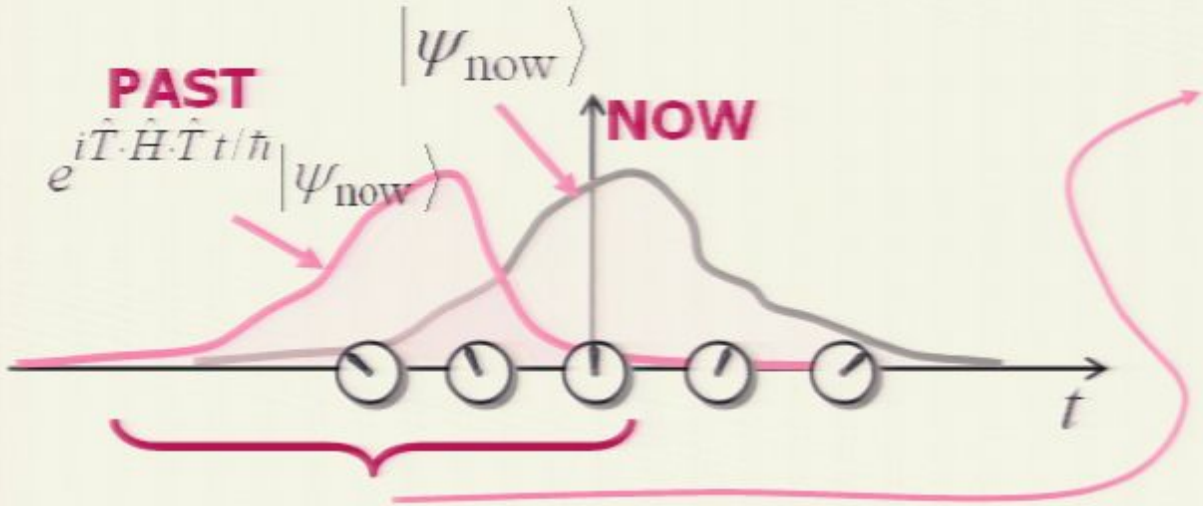

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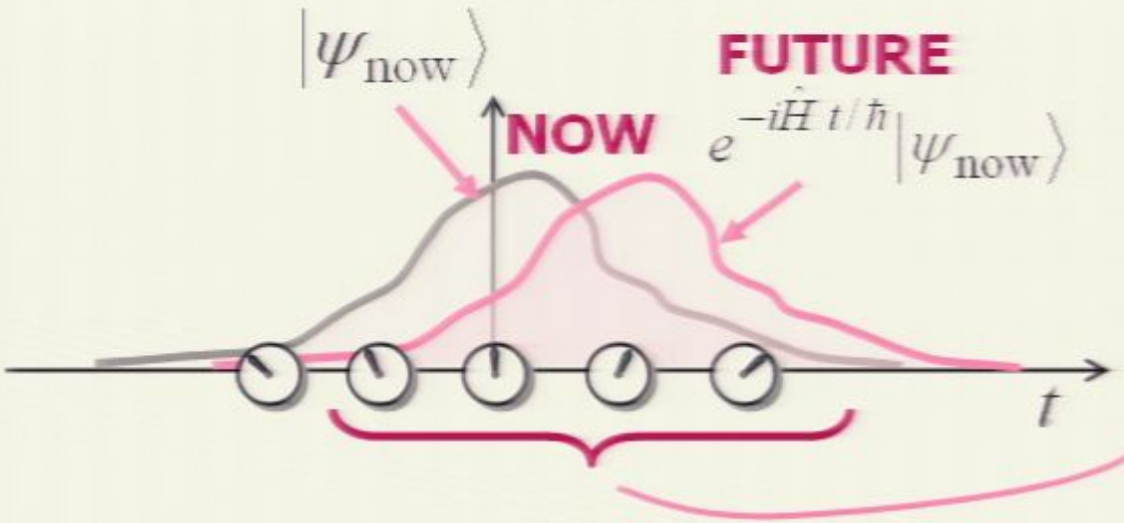

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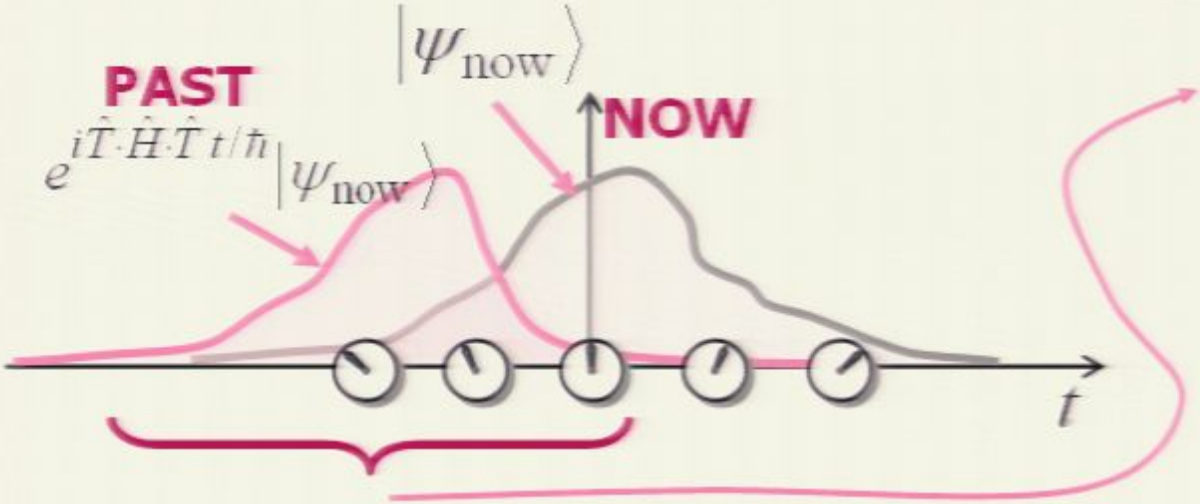

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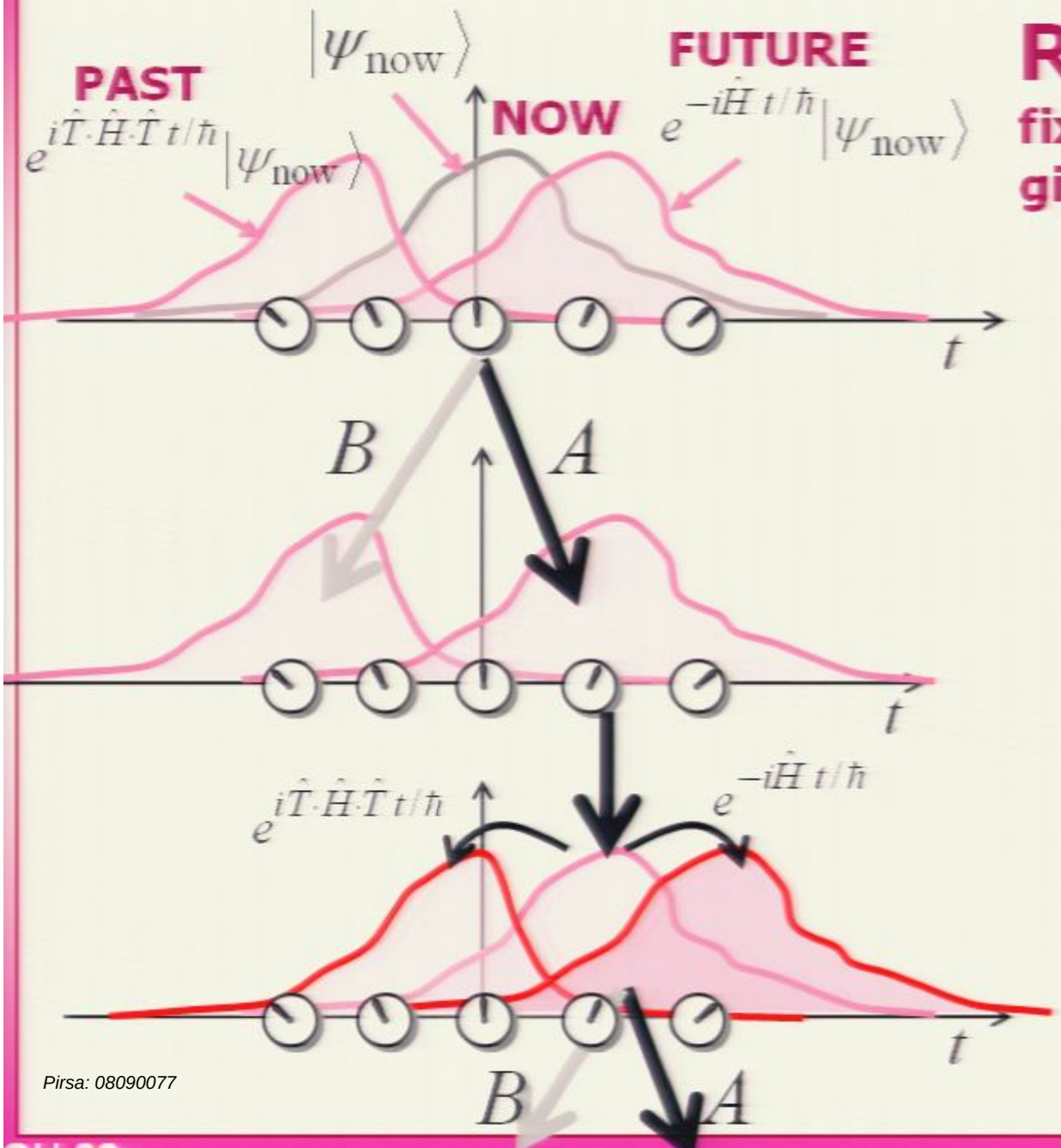
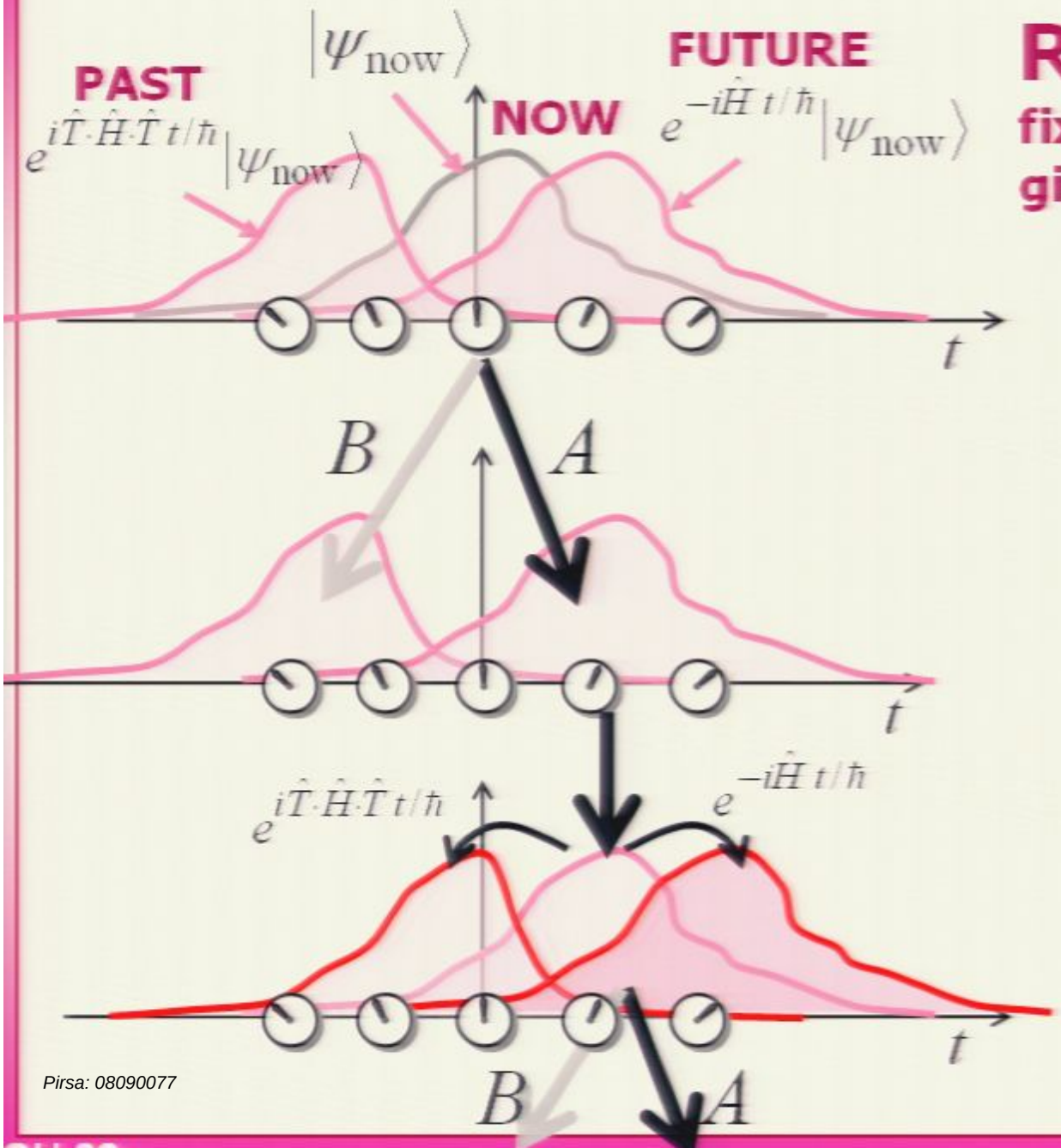


Ratchet effect

fixes quantum world

gives trajectories of states

Q? $\frac{A}{B}$



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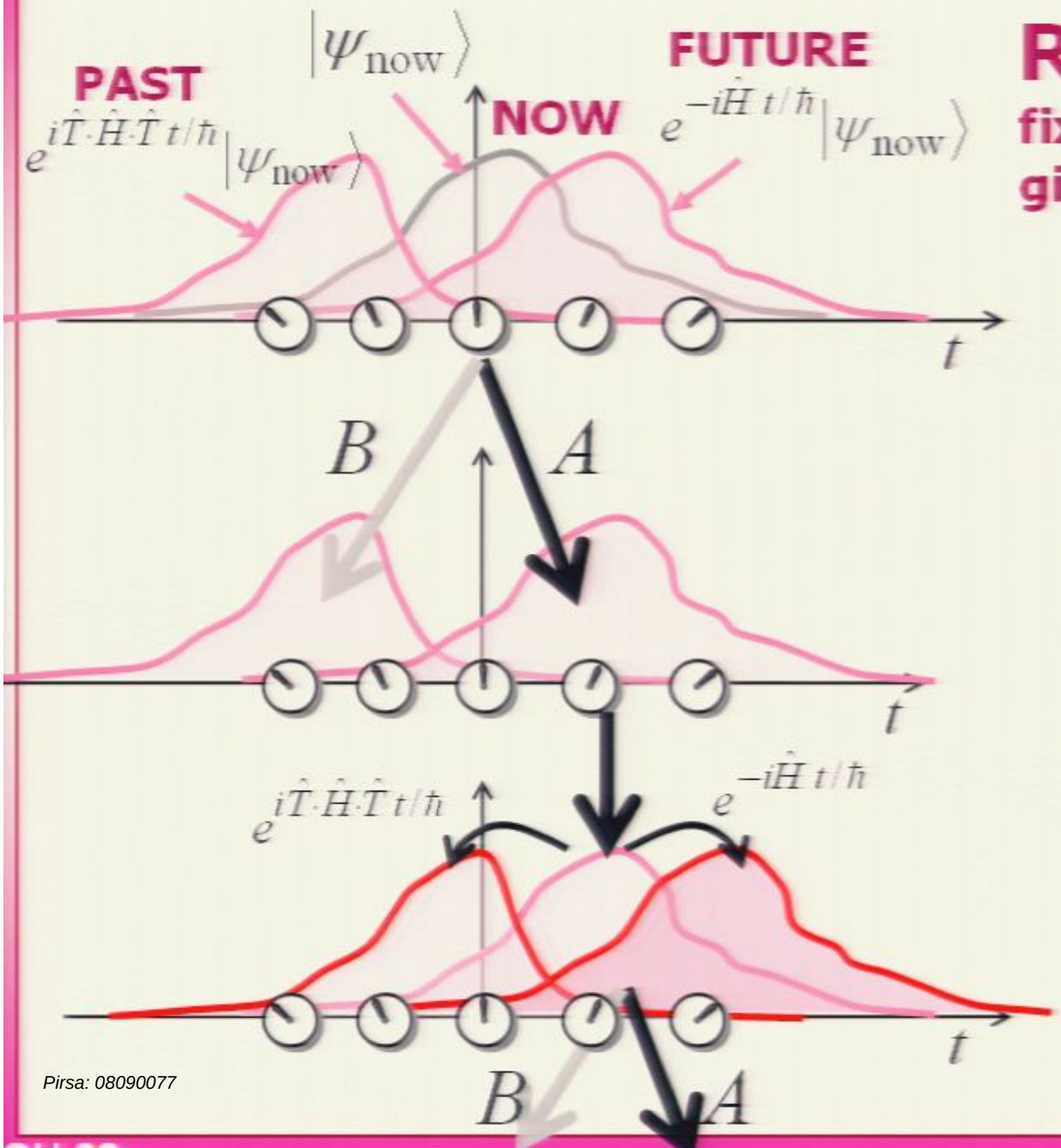

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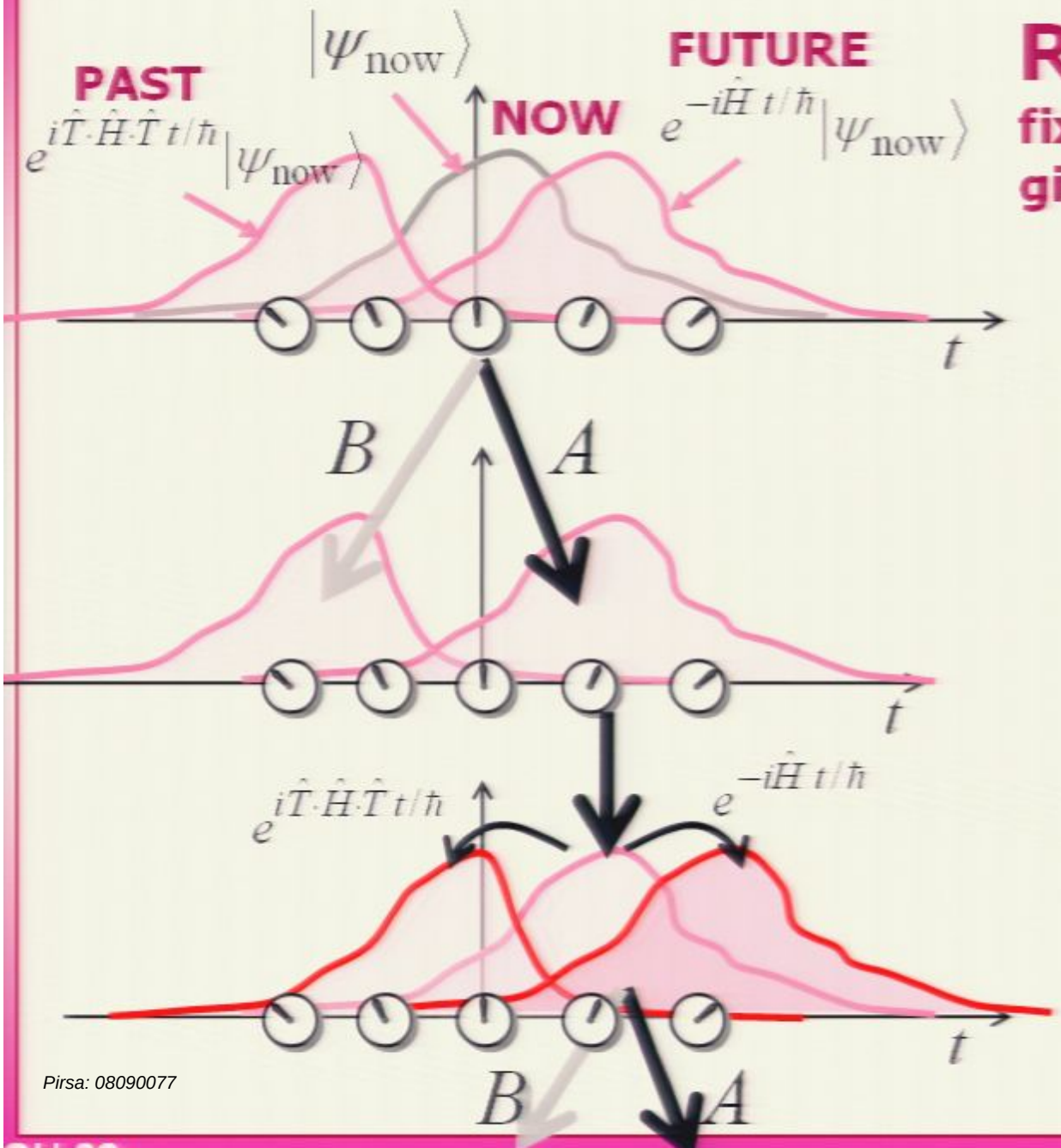

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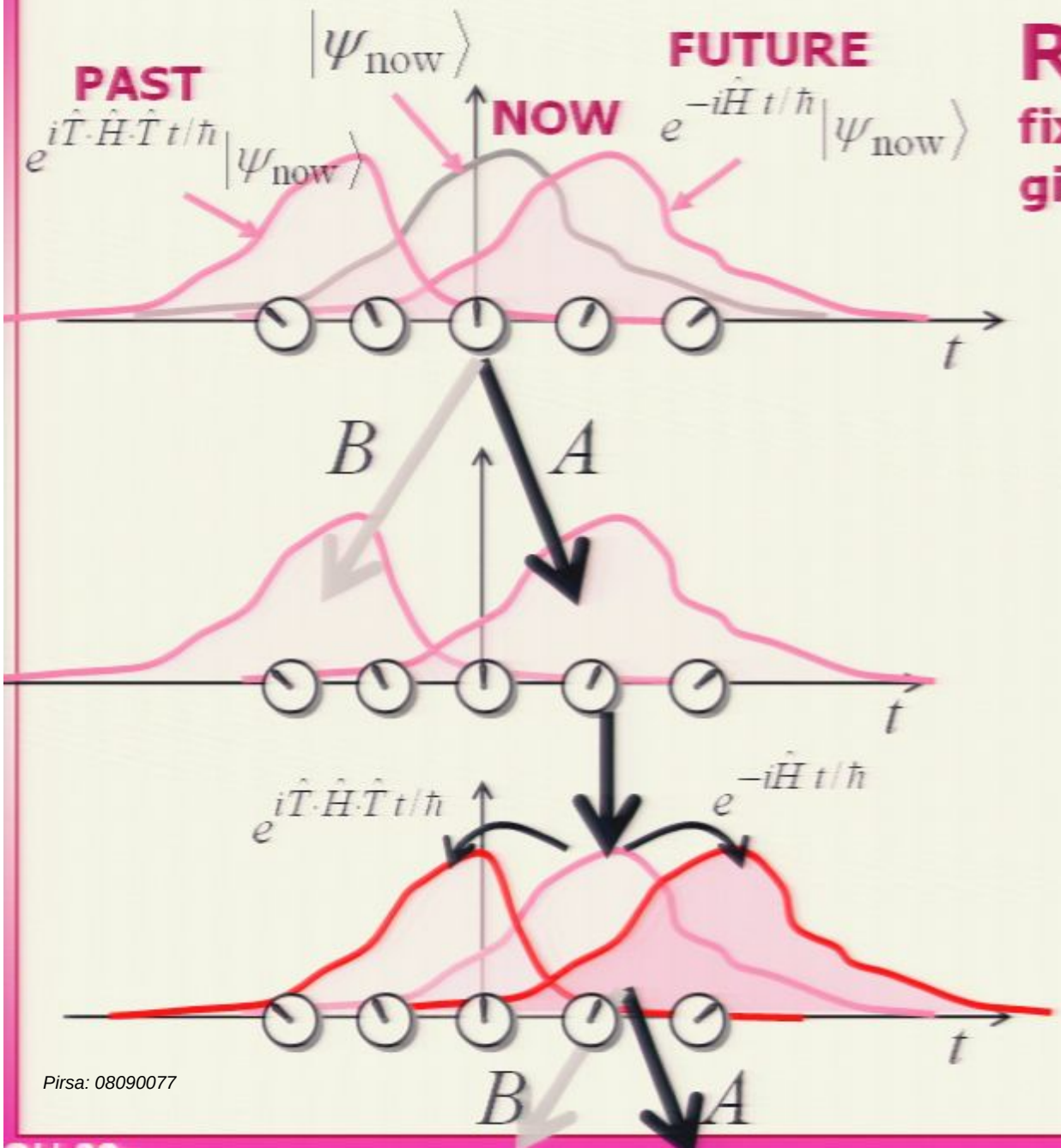

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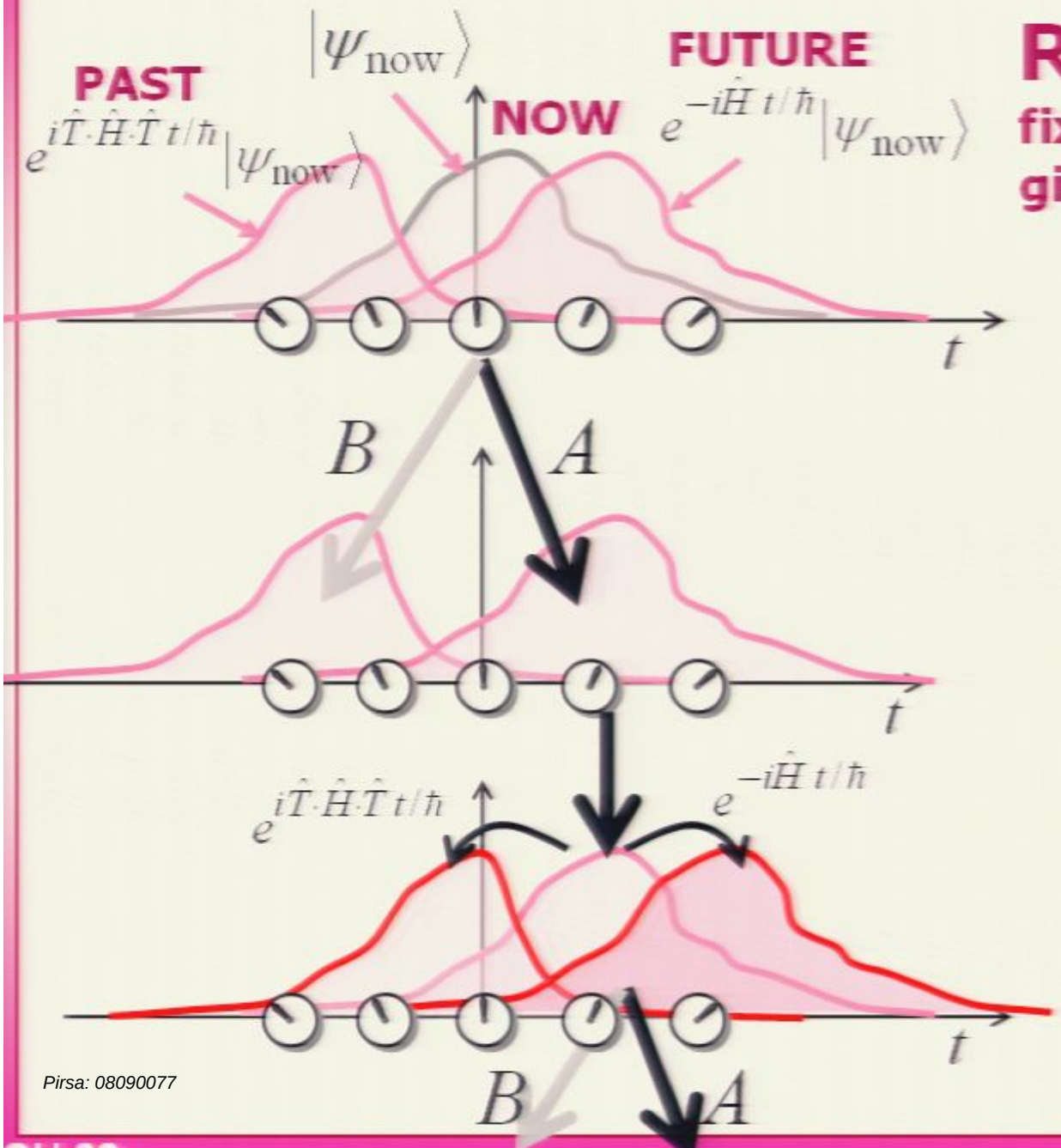

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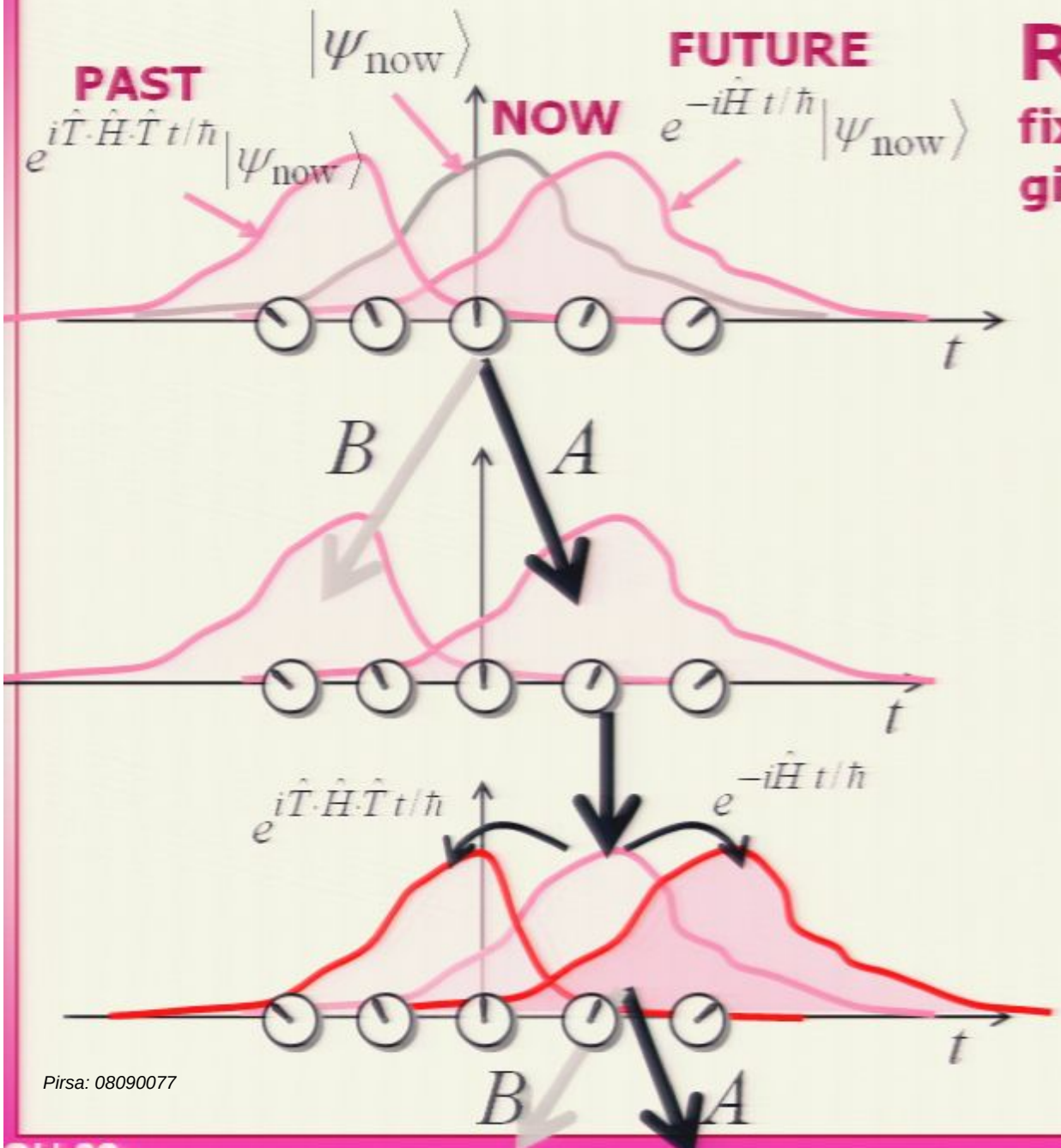

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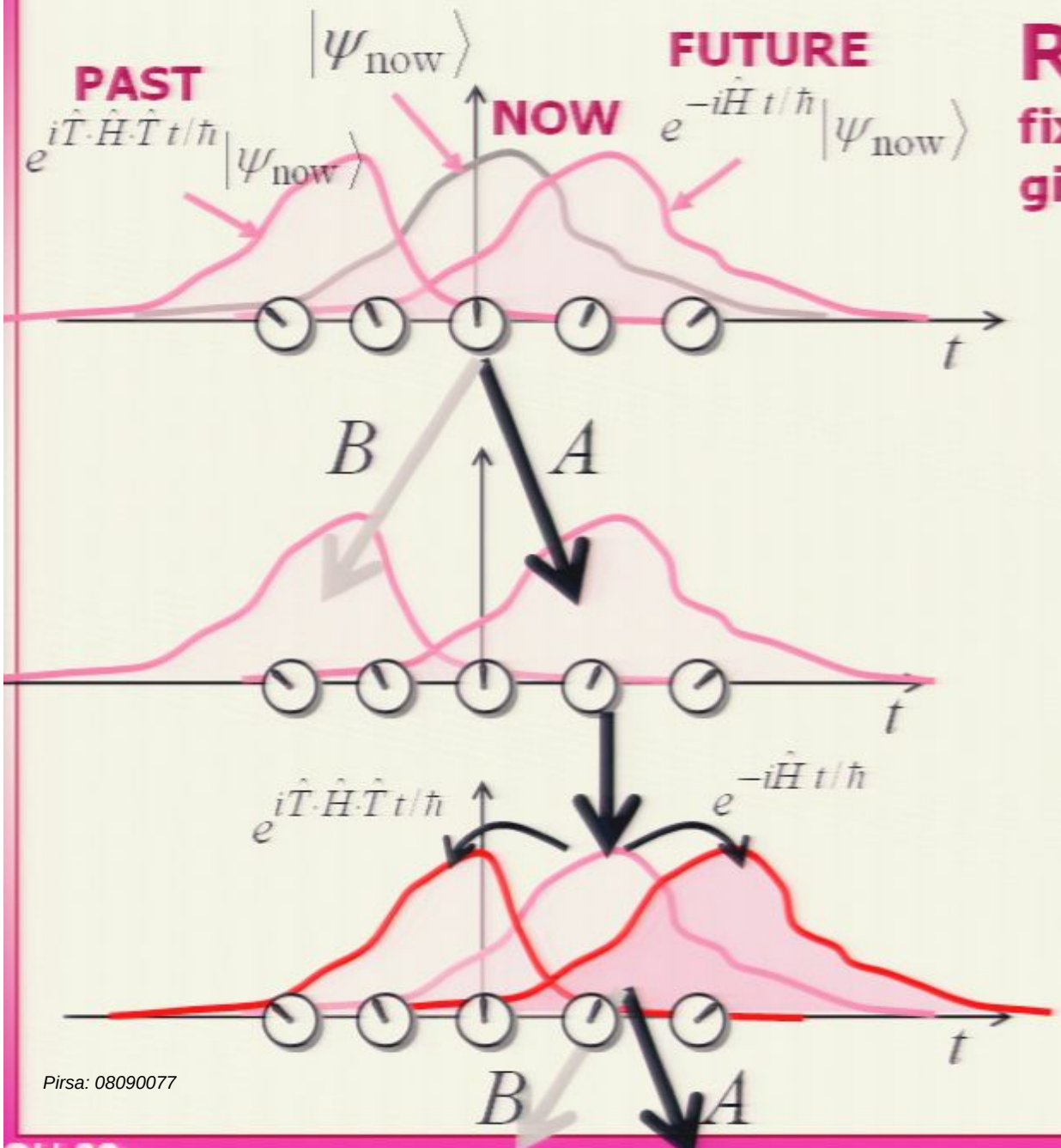

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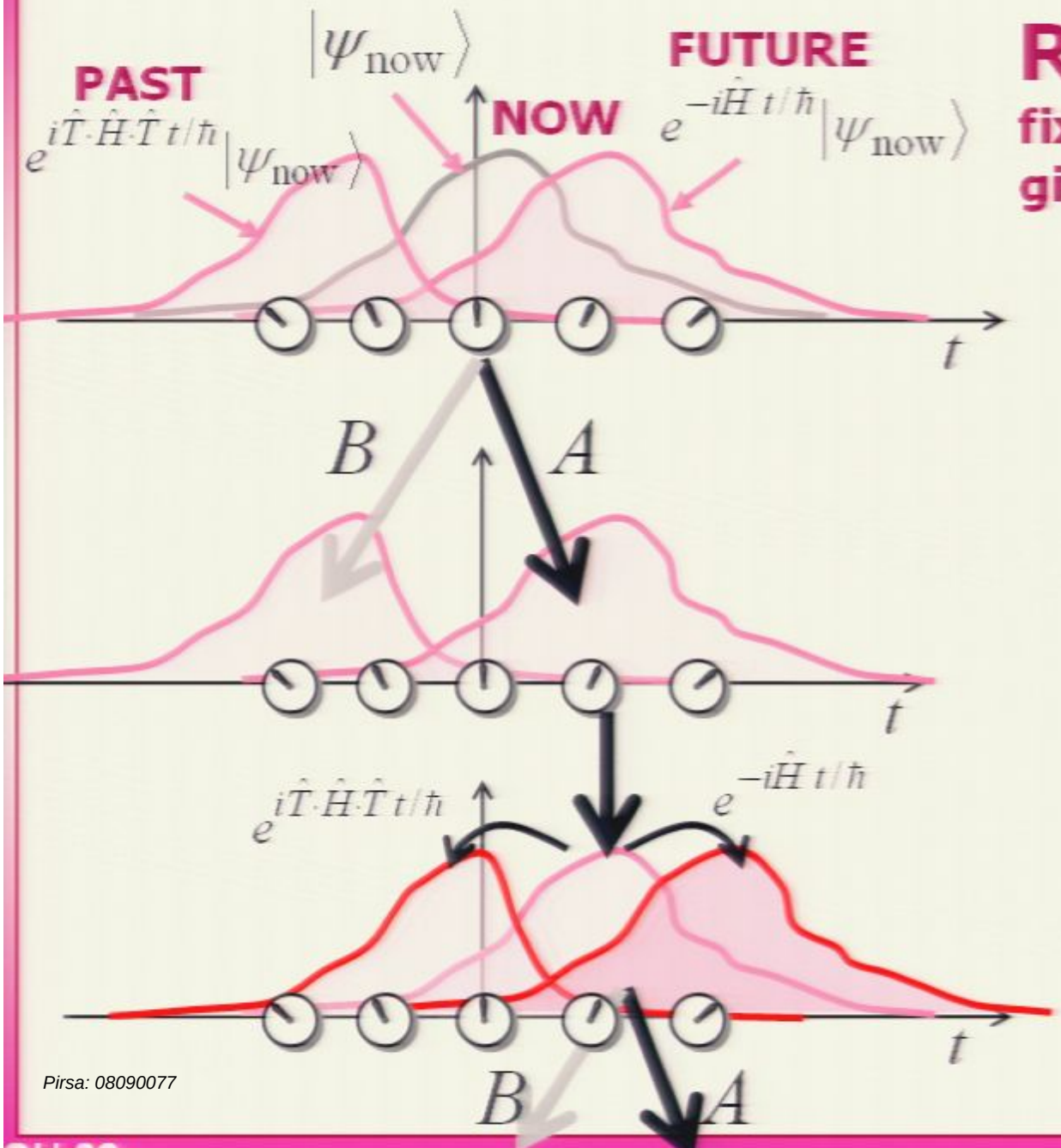

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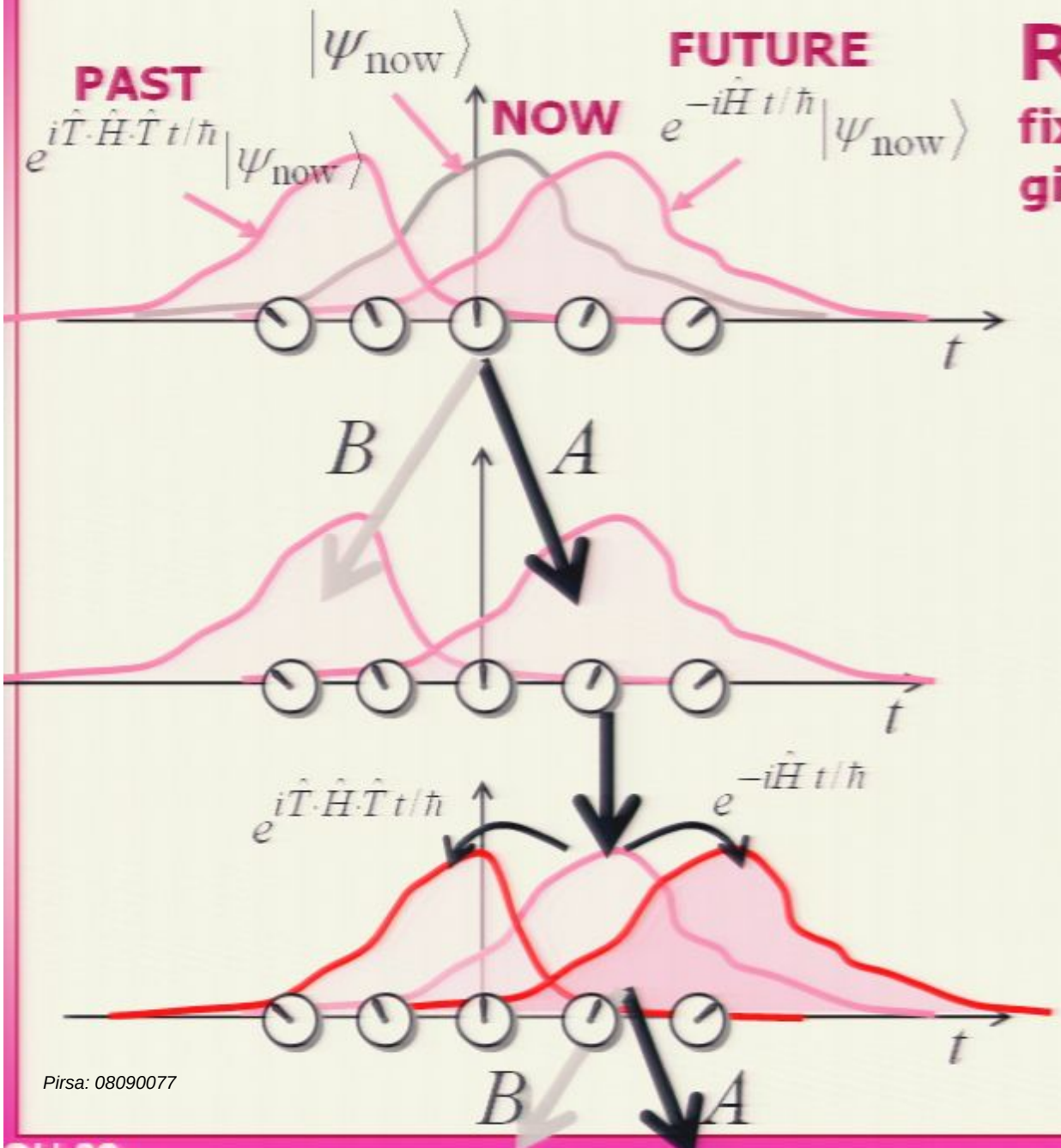

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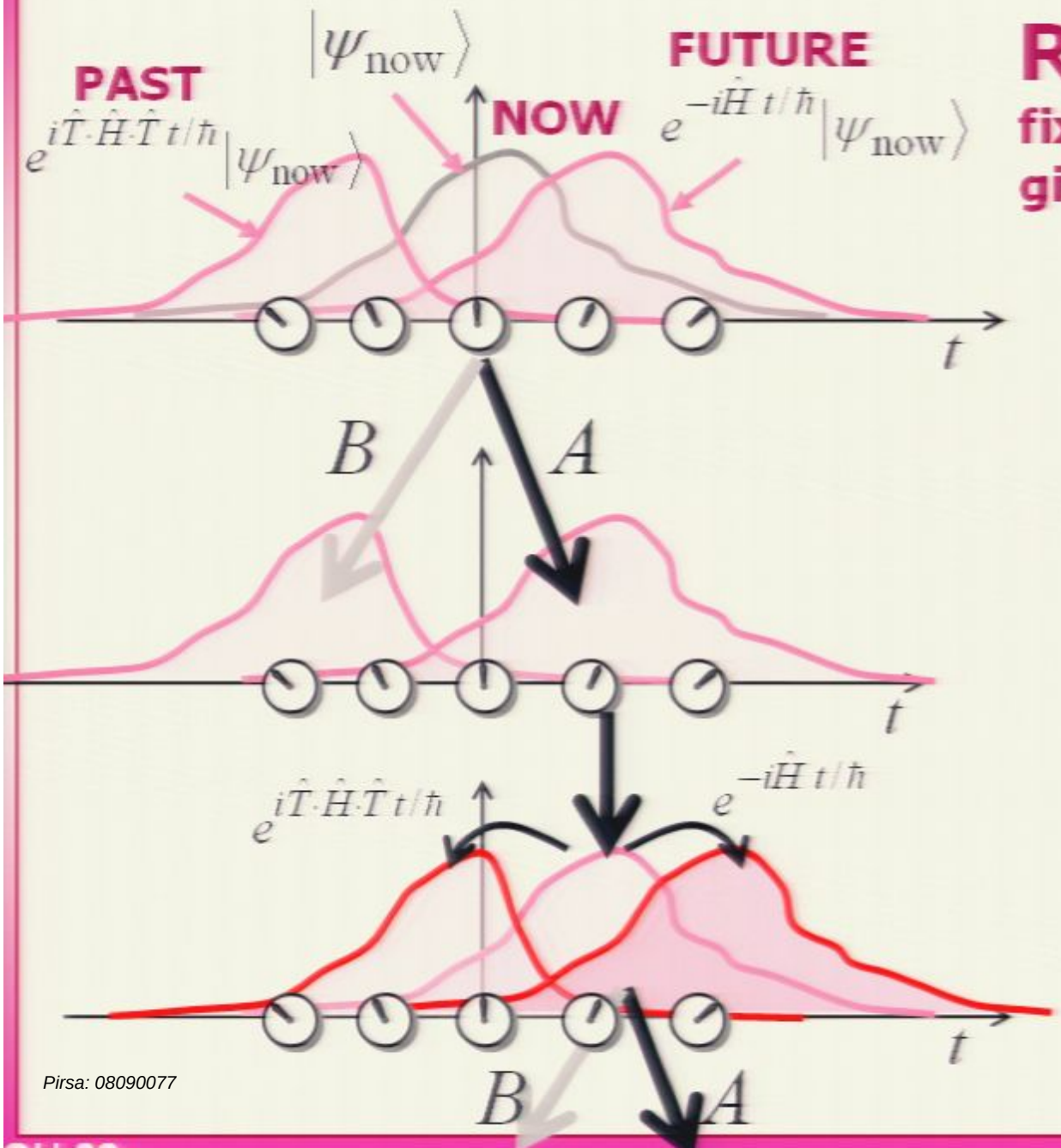

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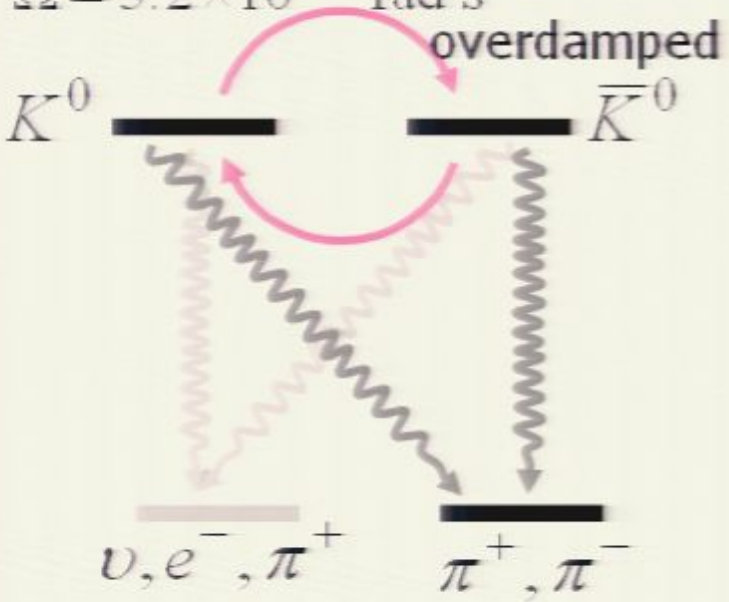
bare state picture

weak interaction

$\Omega = 5.2 \times 10^{10}$ rad s^{-1}

overdamped



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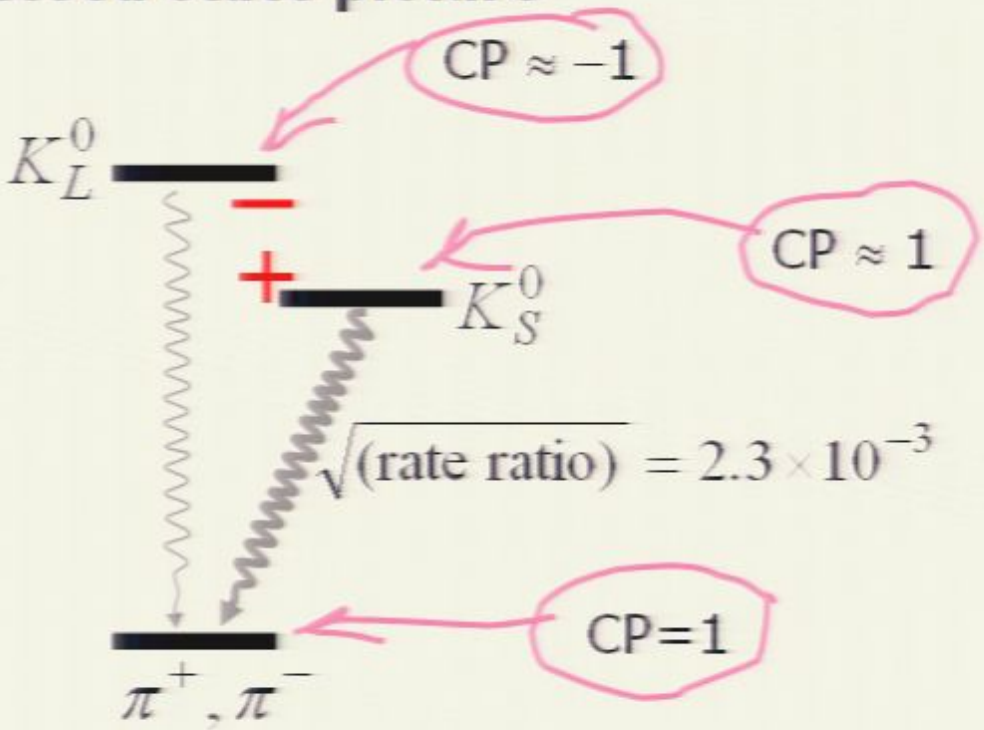
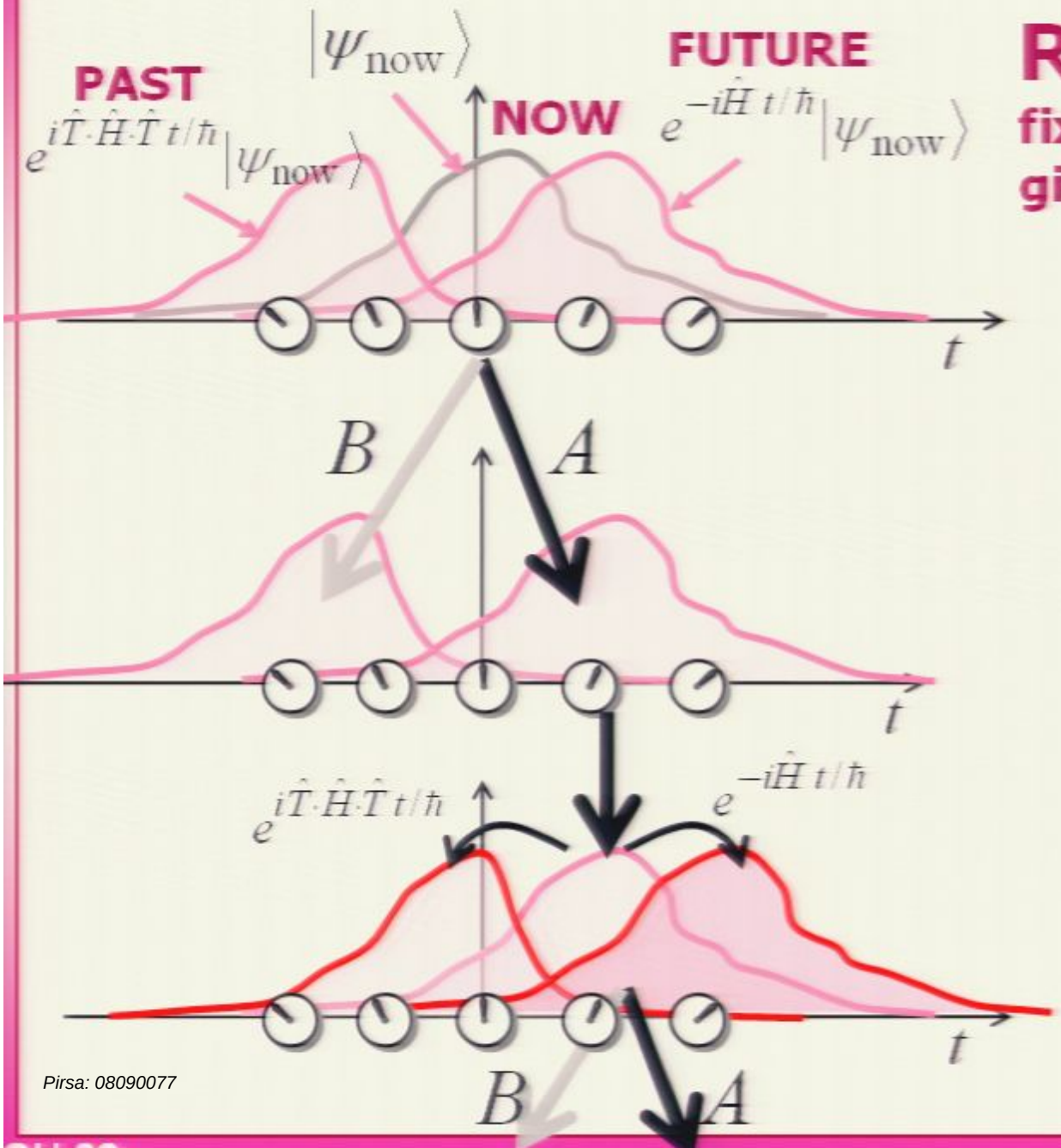


Cronin & Fitch, PRL 13 138 (1964)



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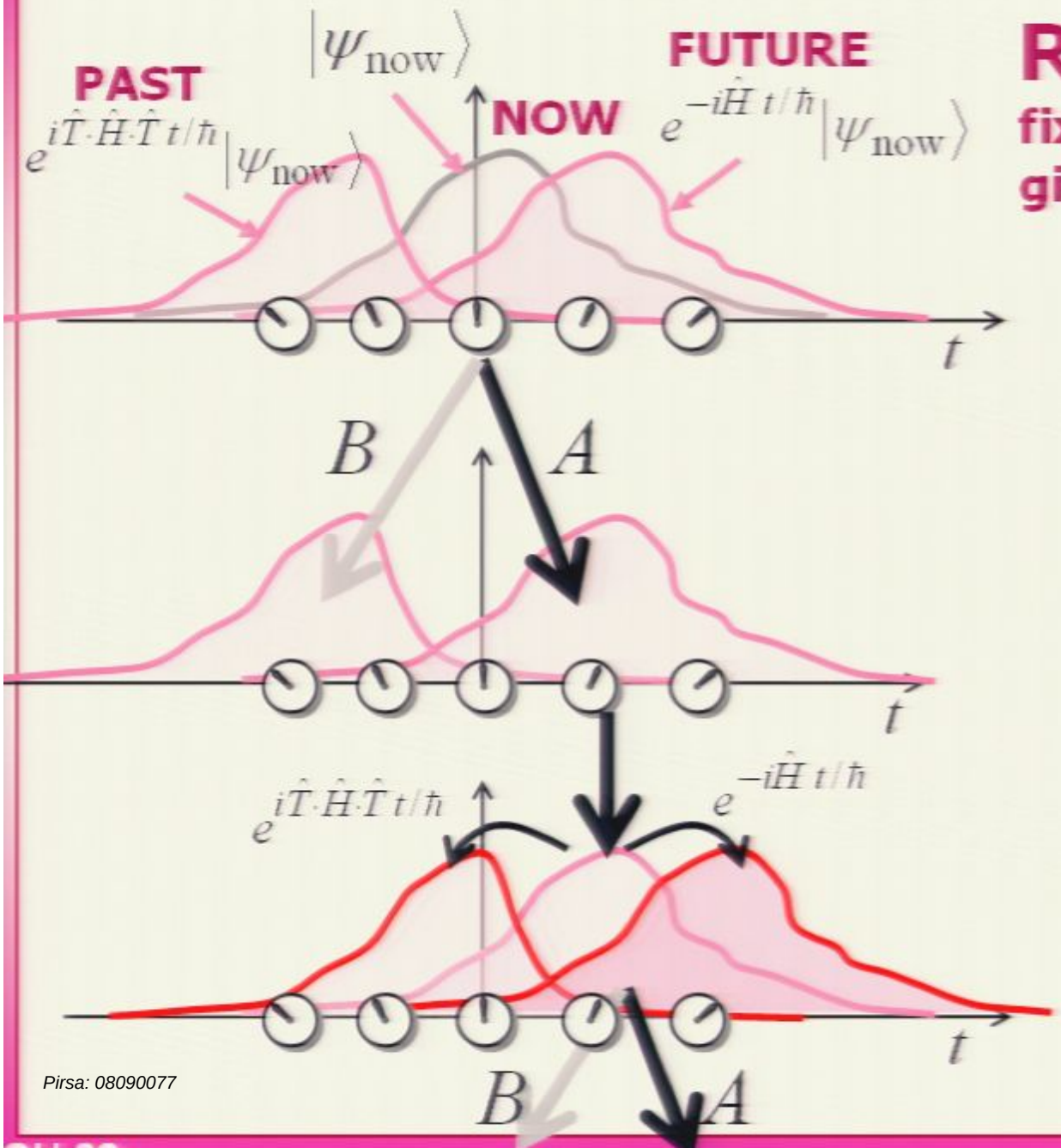

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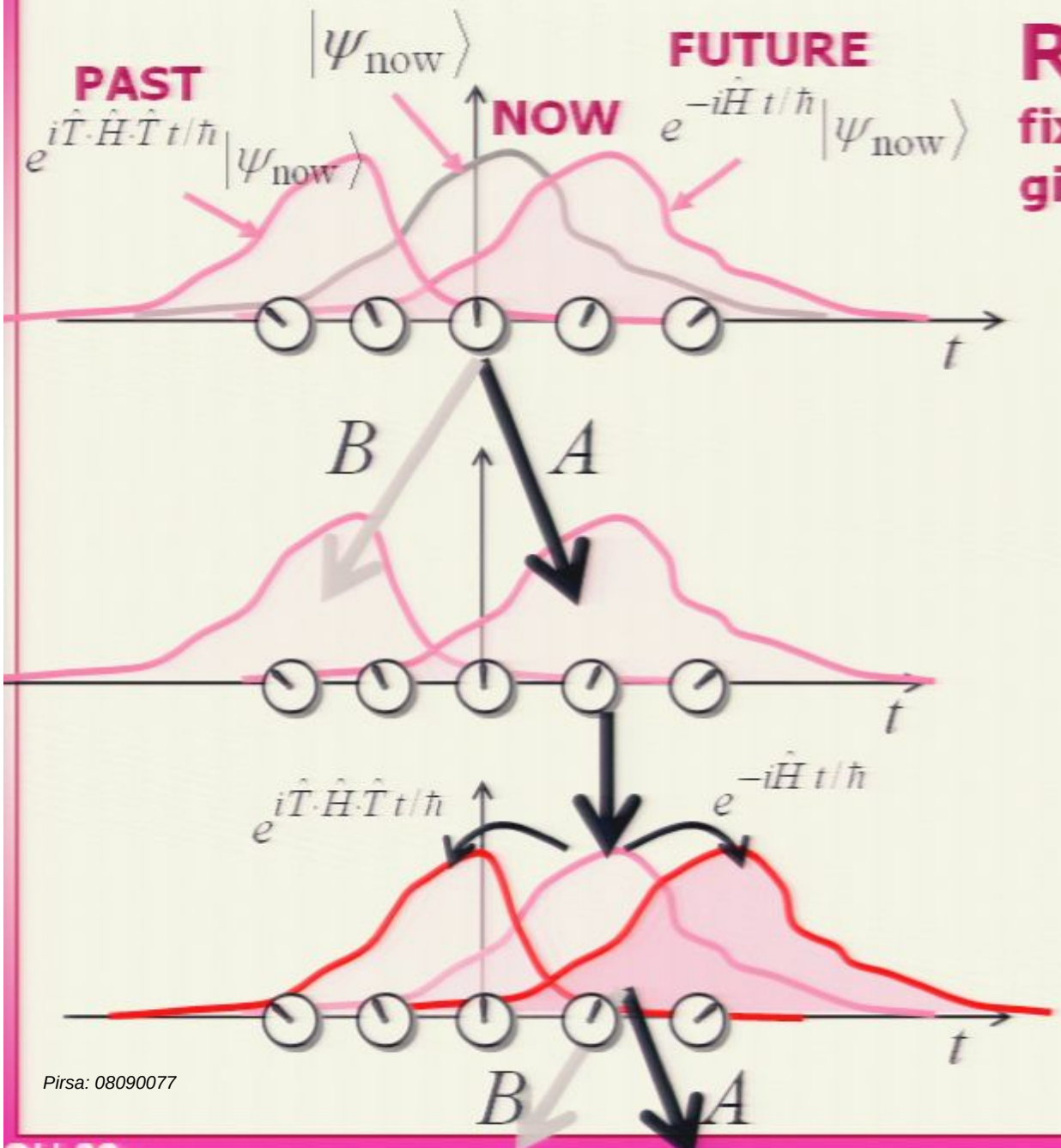

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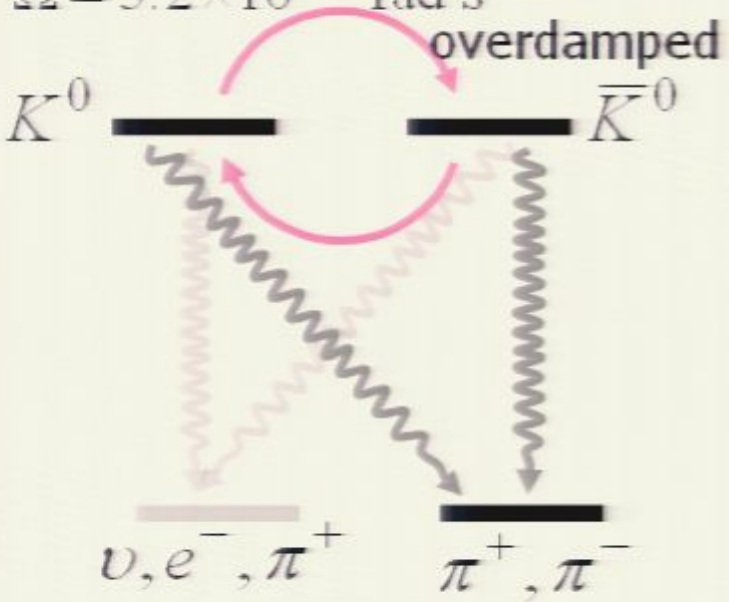

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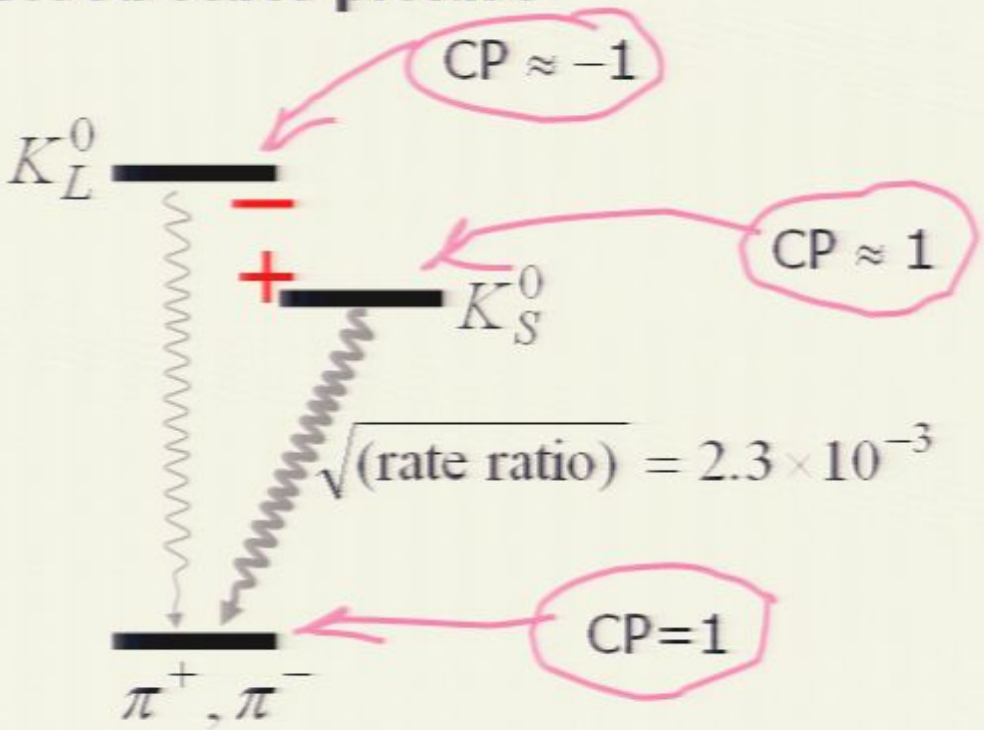

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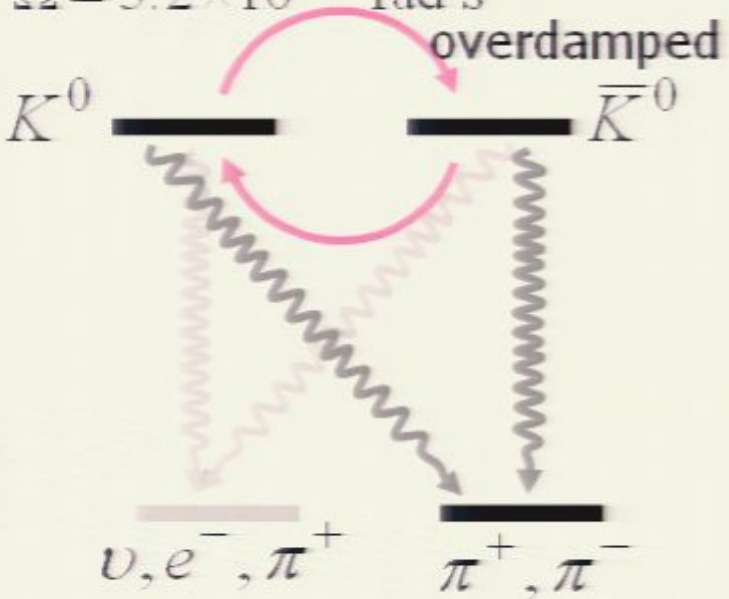

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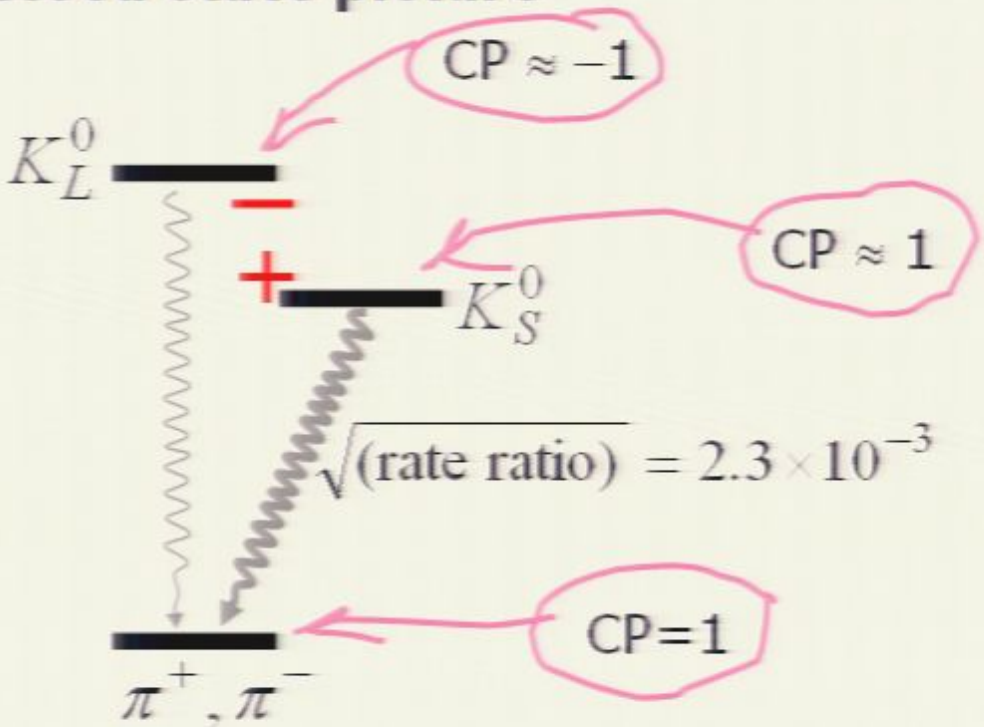

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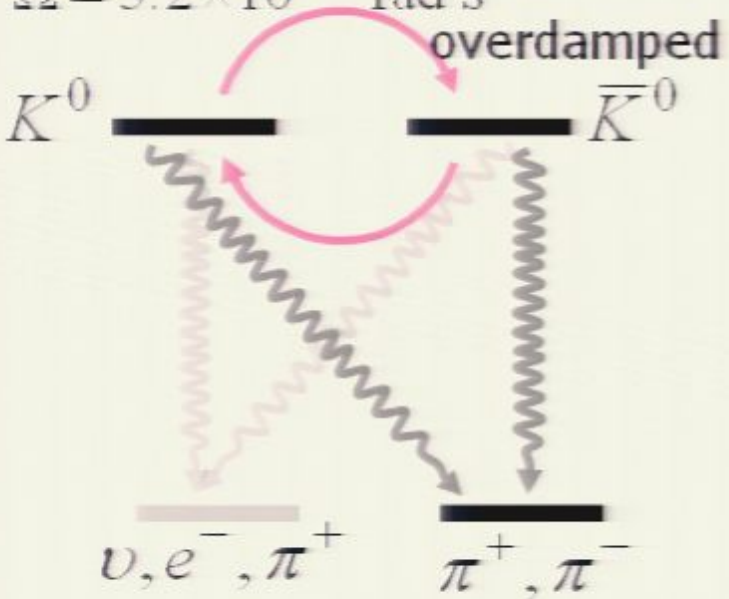
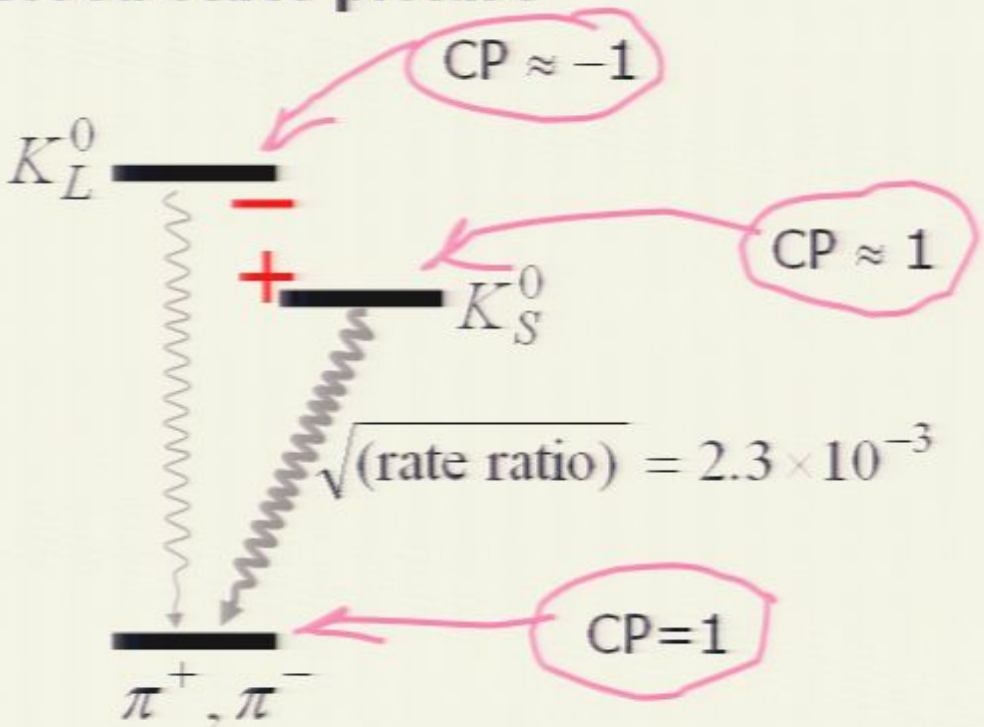


dressed state picture



Cronin & Fitch, PRL 13 138 (1964)

Mesons – neutral K mesons

Physical parameters

mass $m_{K^o} = m_{\overline{K}^o} = 498 \frac{\text{MeV}}{c^2}$ $(\approx \frac{1}{2} m_p)$

lifetimes $\tau_{K_S^0} = 9.0 \times 10^{-11}$ s (decay to all modes)

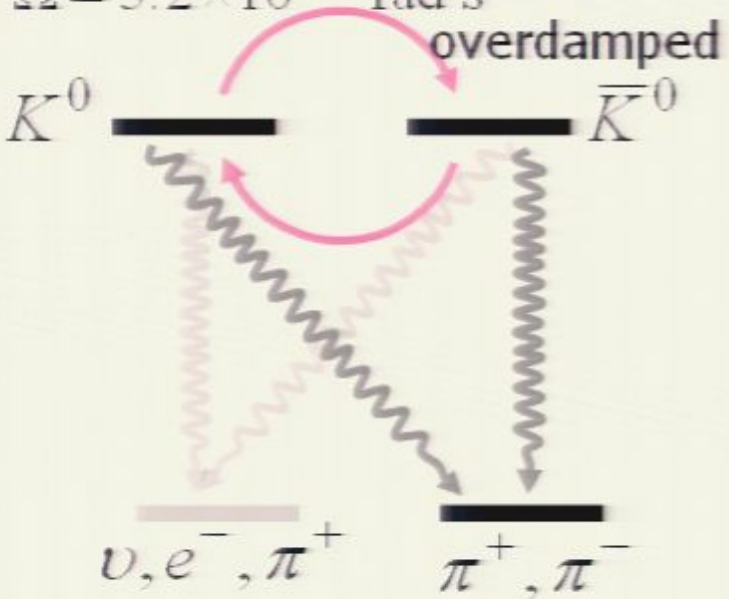
$\tau_{K_L^0} = 5.1 \times 10^{-8}$ s

bare state picture

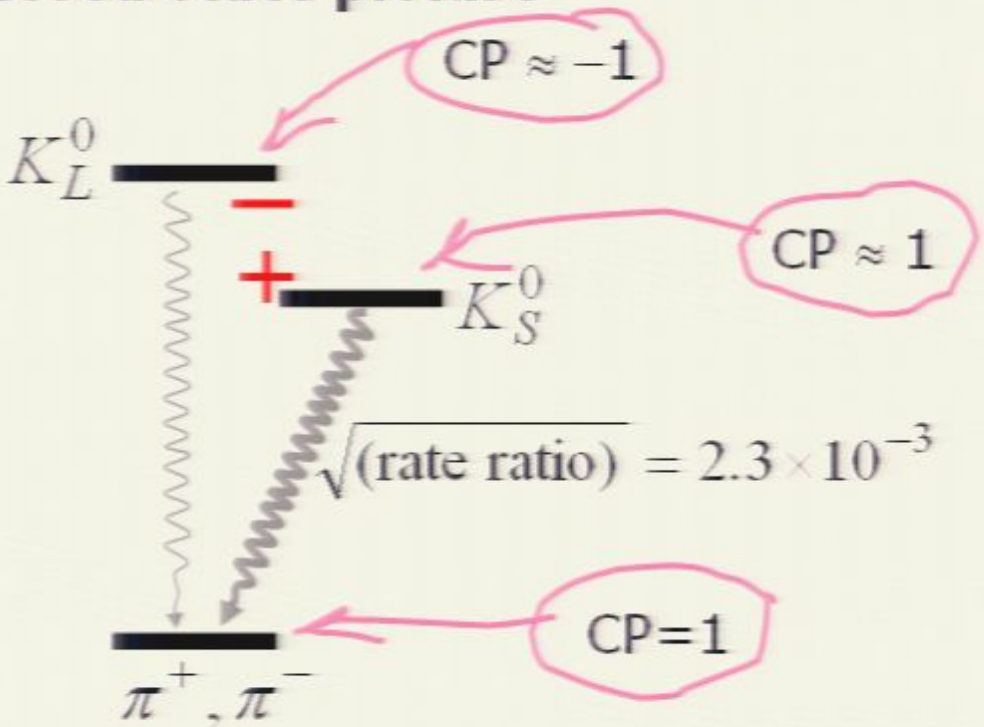
weak interaction

$\Omega = 5.2 \times 10^{10}$ rad s^{-1}

overdamped



dressed state picture



Cronin & Fitch, PRL 13 138 (1964)

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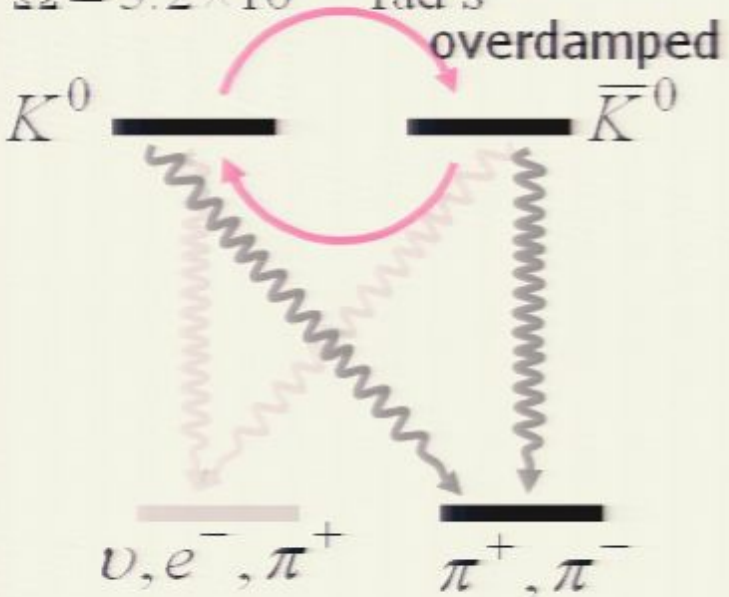
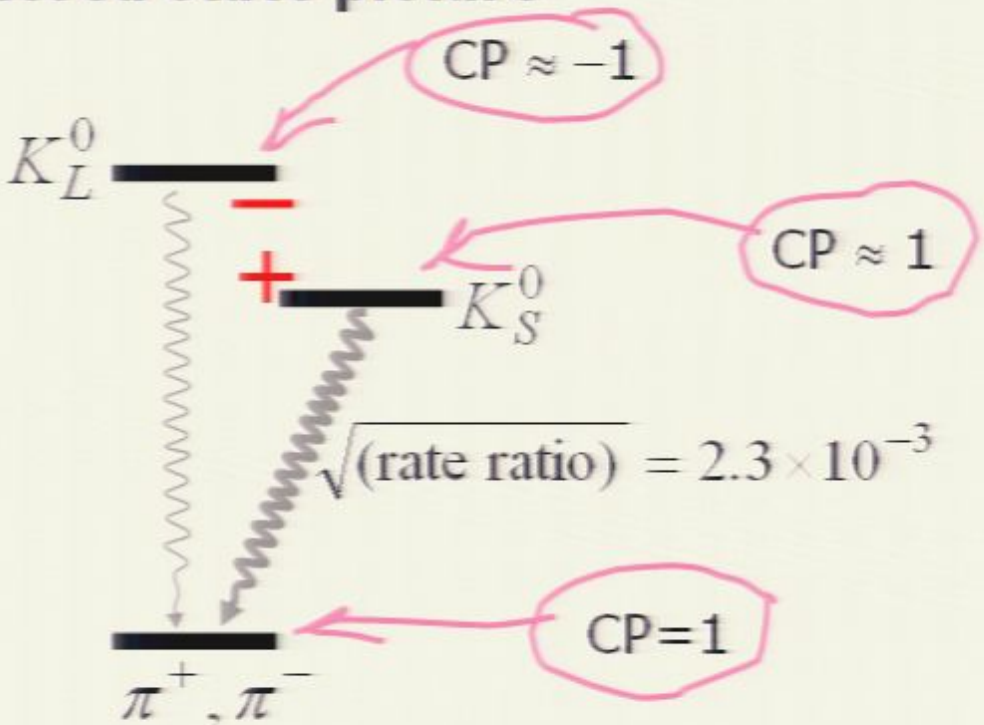


dressed state picture



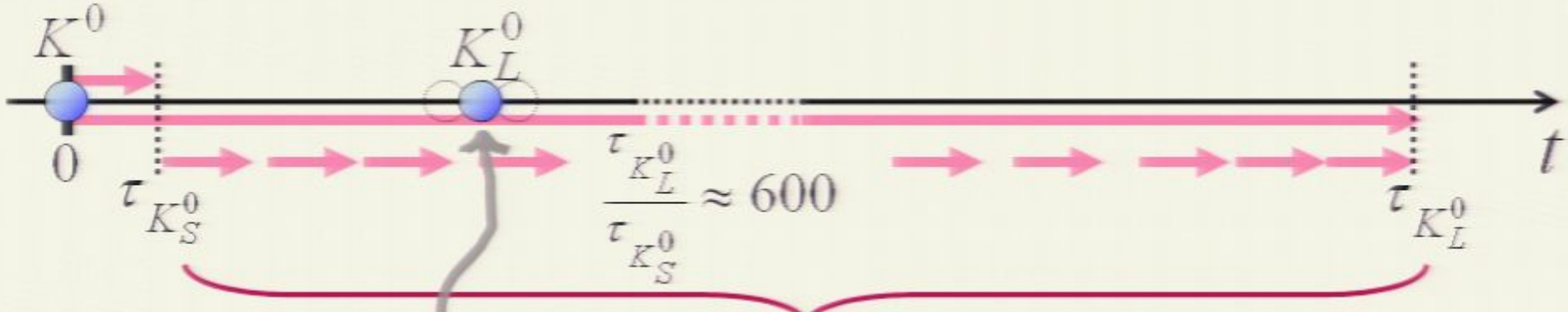
Cronin & Fitch, PRL 13 138 (1964)

Unitary model

Datta et al. PLA 130, 187 (1988)

$$\hat{U}_t \left| K^0 \right\rangle \approx \left| K_L^0 \right\rangle e^{-i\lambda_L t} + \left| \phi_L(t) \right\rangle$$

$$\left| K_{L,S}^0 \right\rangle \propto (1+\varepsilon)\left| K^0 \right\rangle \pm (1-\varepsilon)\left| \overline{K}^0 \right\rangle, \qquad \varepsilon = 2.3 \times 10^{-3}$$



$$\left| \psi_{\text{now}} \right\rangle \sim \left| \Psi(t) \right\rangle = \hat{U}_t \left| K^0 \right\rangle$$

$$e^{-i\hat{H}\,t/\hbar} \left| \psi_{\text{now}} \right\rangle \sim \hat{U}_\tau \left| \Psi(t) \right\rangle$$

$$e^{i\hat{T}\cdot\hat{H}\cdot\hat{T}\,t/\hbar} \left| \psi_{\text{now}} \right\rangle \sim \left(\hat{C}\hat{P} \cdot \hat{U}_\tau \cdot \hat{C}\hat{P} \right) \left| \Psi(t) \right\rangle$$

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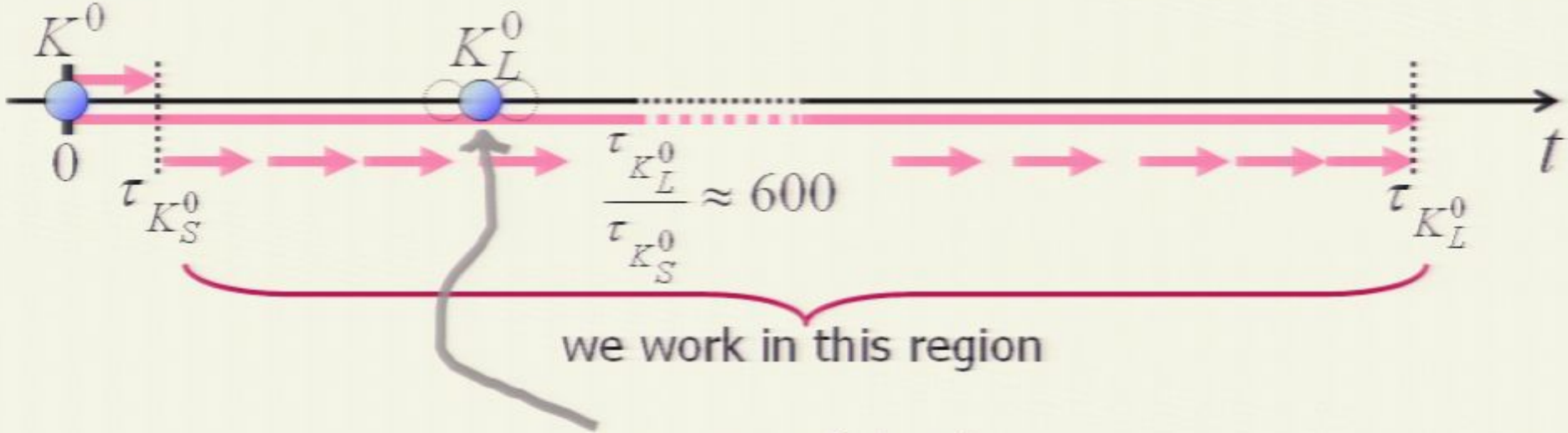

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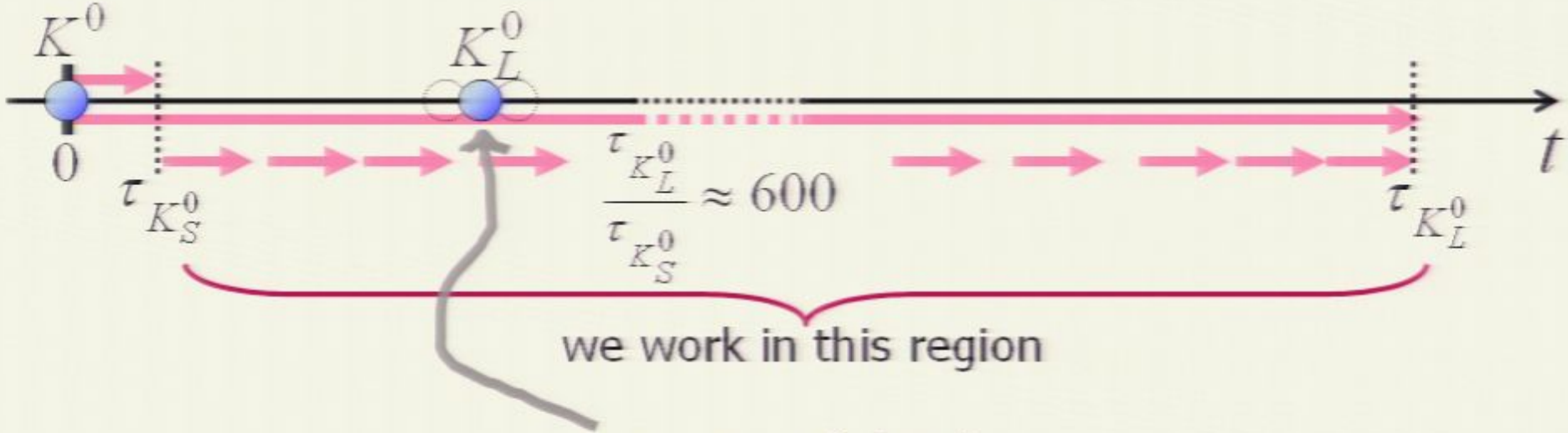

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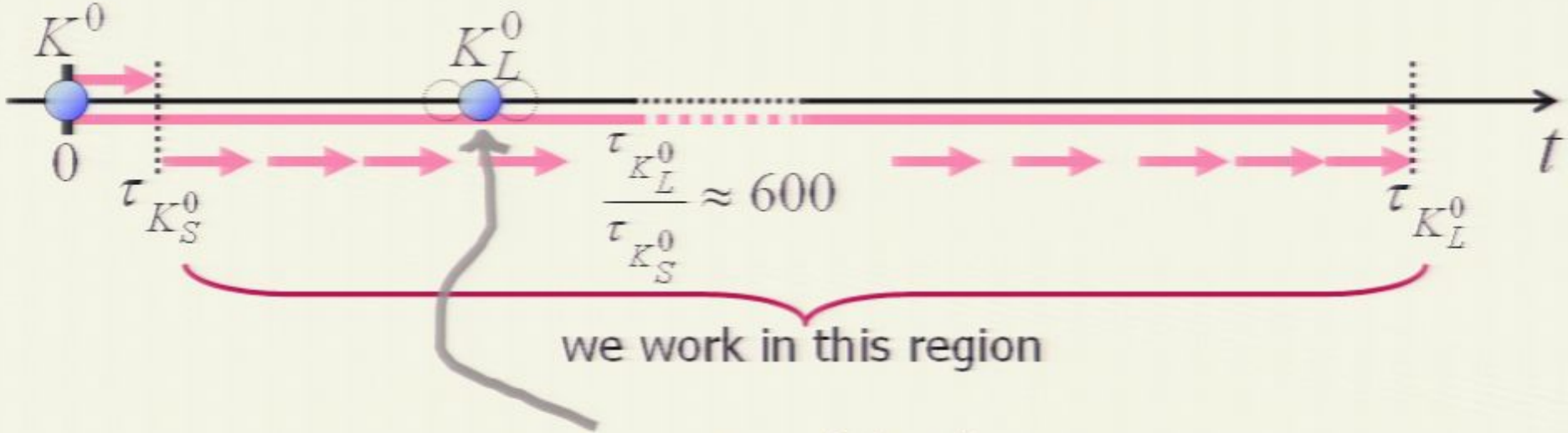

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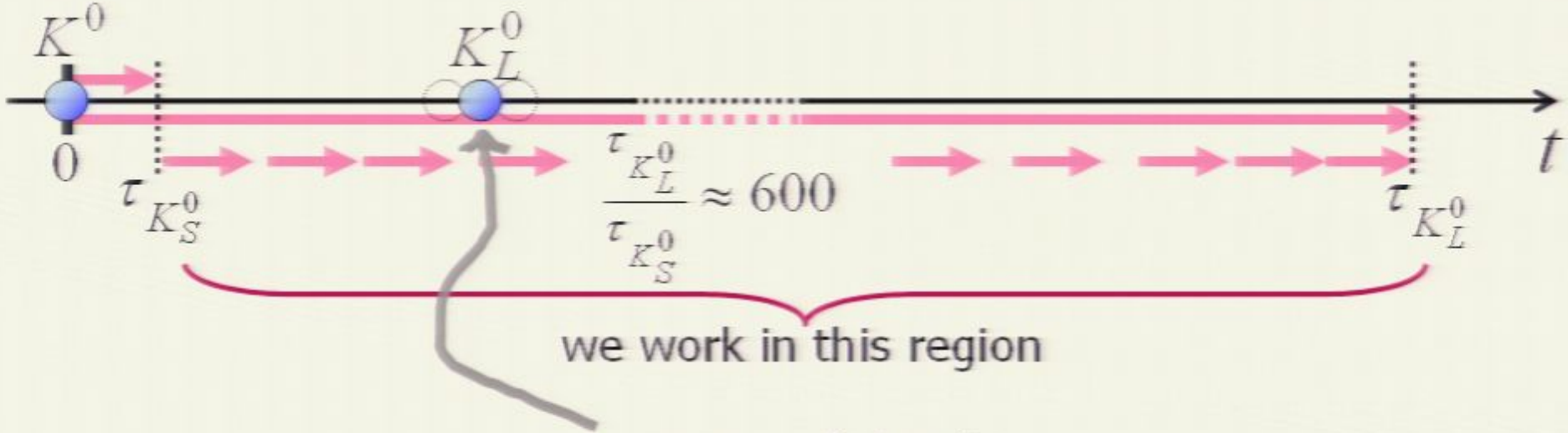

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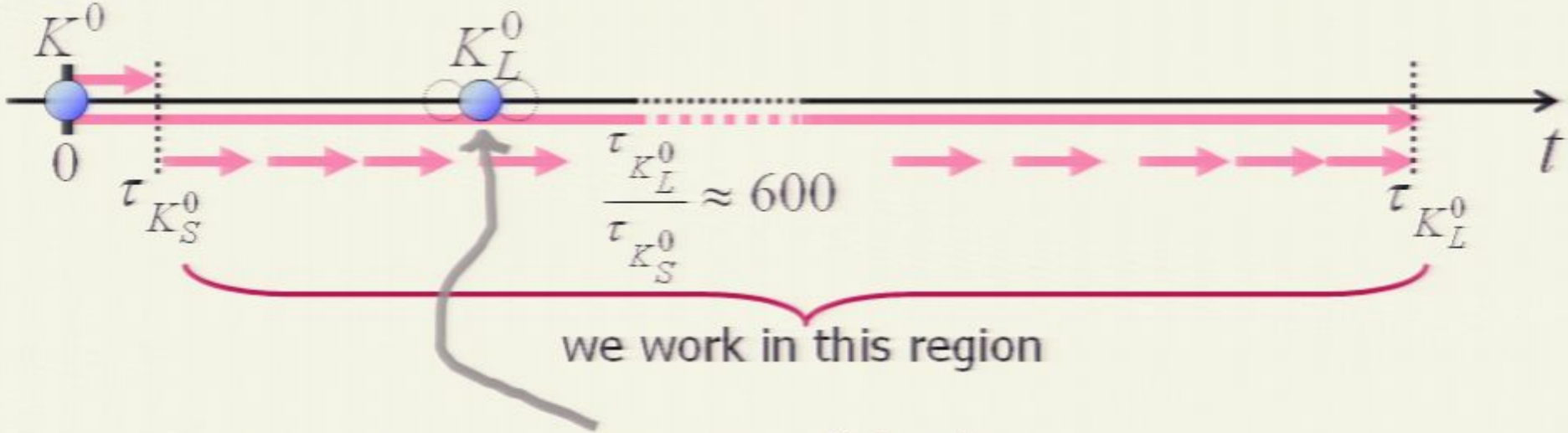

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Relative overlaps (fidelity)

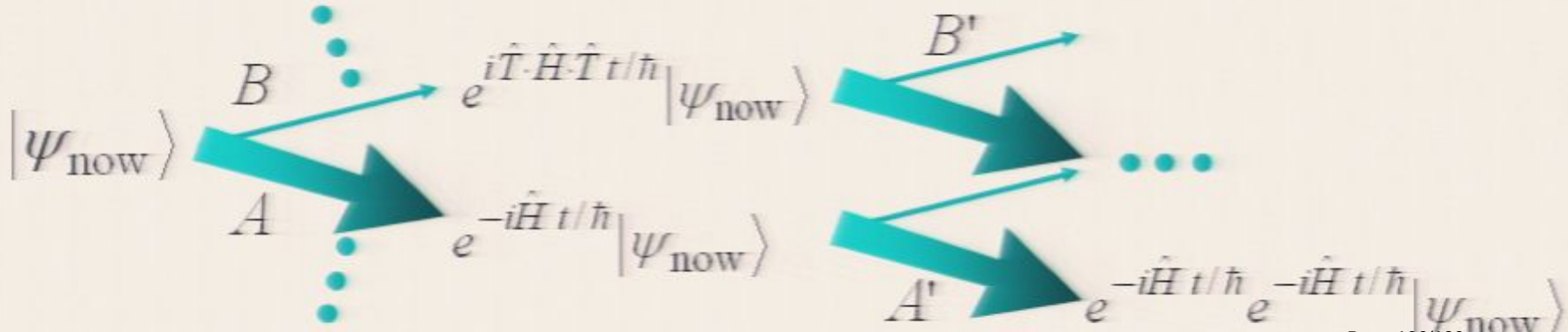
$$\frac{A}{B}=\frac{\left|\langle\psi_{\text{now}}|e^{i\hat{T}\cdot\hat{H}\cdot\hat{T}\,t/\hbar}|\psi_{\text{now}}\rangle\right|^2}{\left|\langle\psi_{\text{now}}|e^{-i\hat{H}\,t/\hbar}|\psi_{\text{now}}\rangle\right|^2}\sim\frac{\left|\langle\Psi(t)|\hat{U}_\tau|\Psi(t)\rangle\right|^2}{\left|\langle\Psi(t)|\hat{C}\hat{P}\cdot\hat{U}_\tau\cdot\hat{C}\hat{P}|\Psi(t)\rangle\right|^2}$$

$$=1-4|\varepsilon|^2\approx e^{-4|\varepsilon|^2}$$

$$|\varepsilon|=2.3\times10^{-3}$$

- For N such systems the relative fidelity scales as $e^{-4|\varepsilon|^2N}$

Ratchet effect



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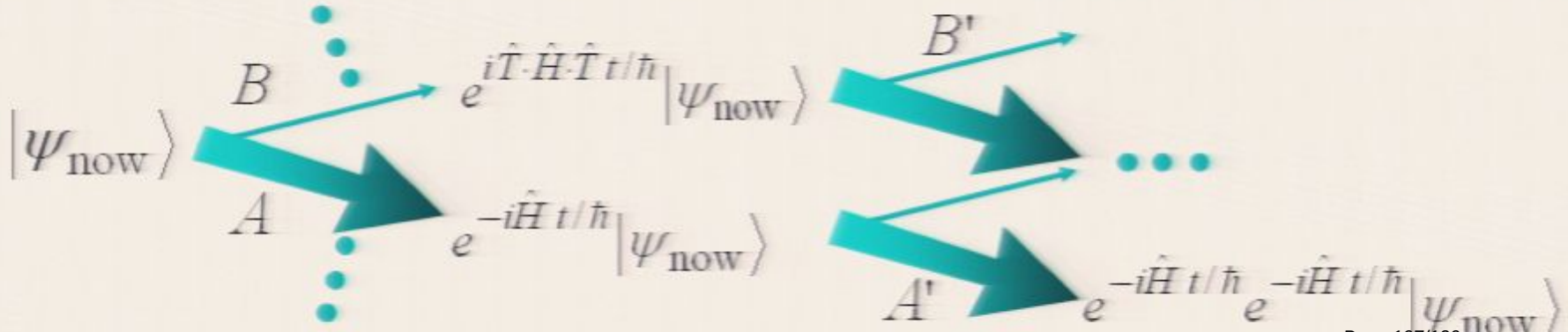
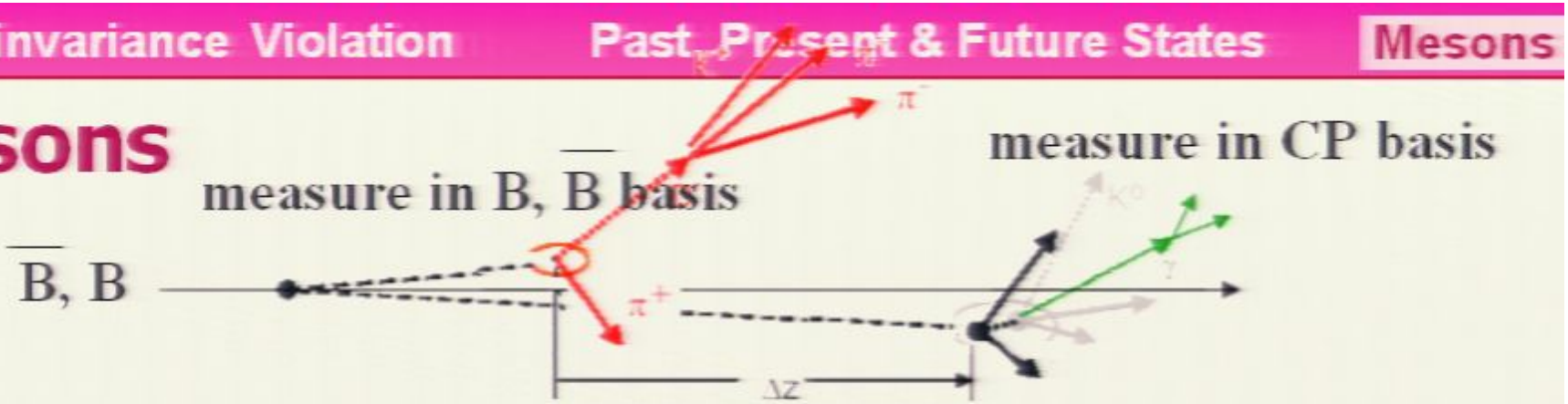
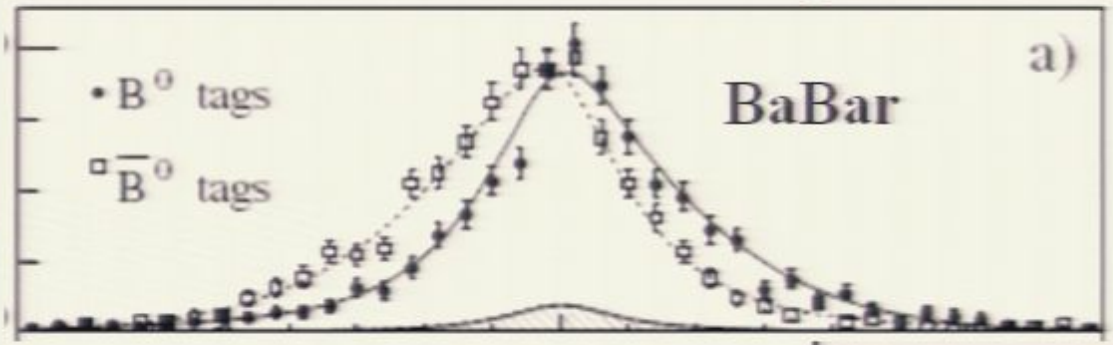
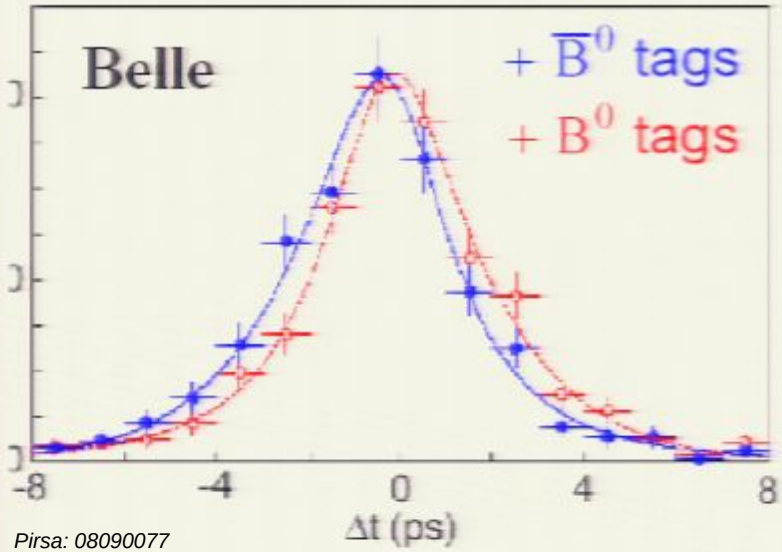
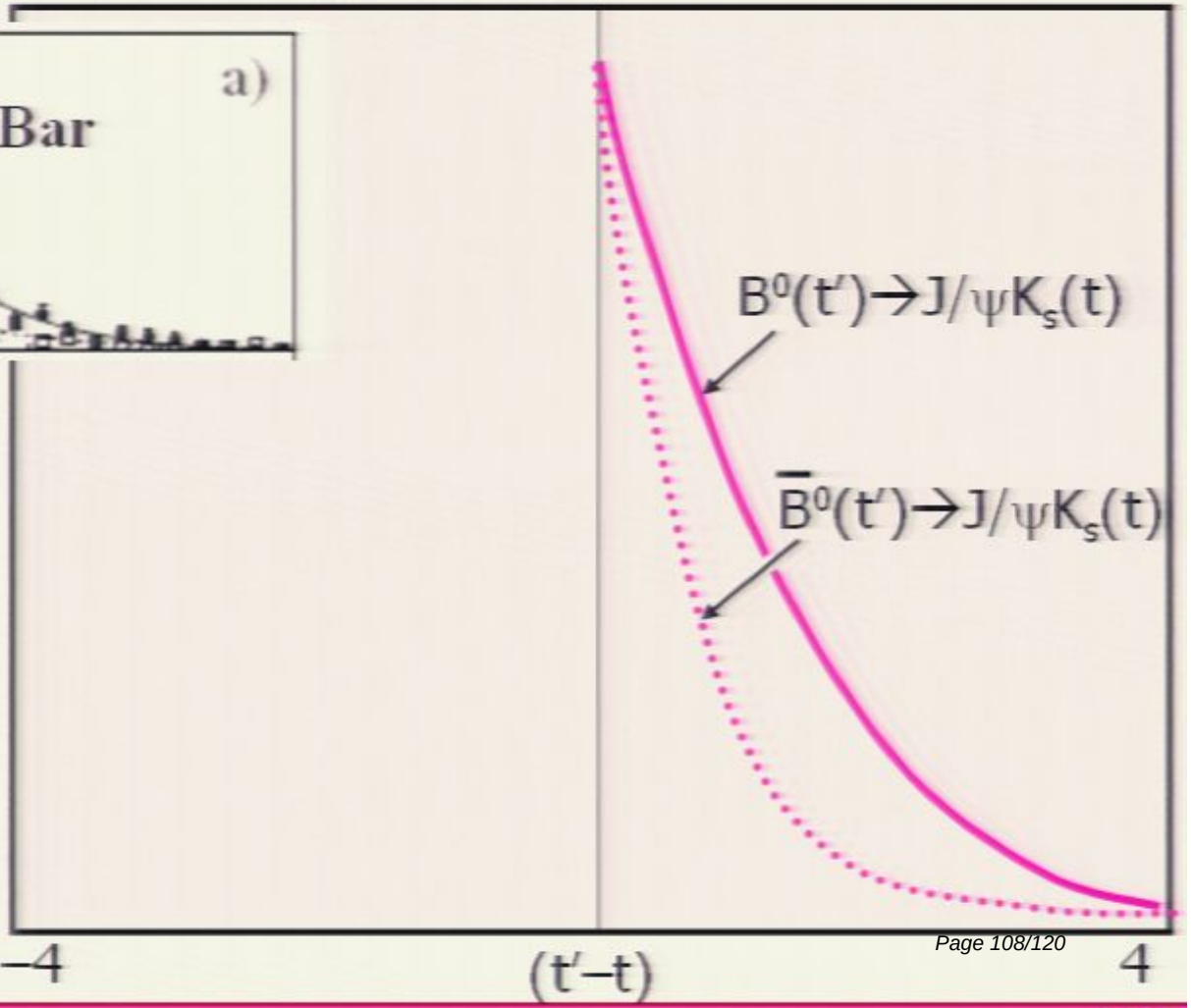


B mesons

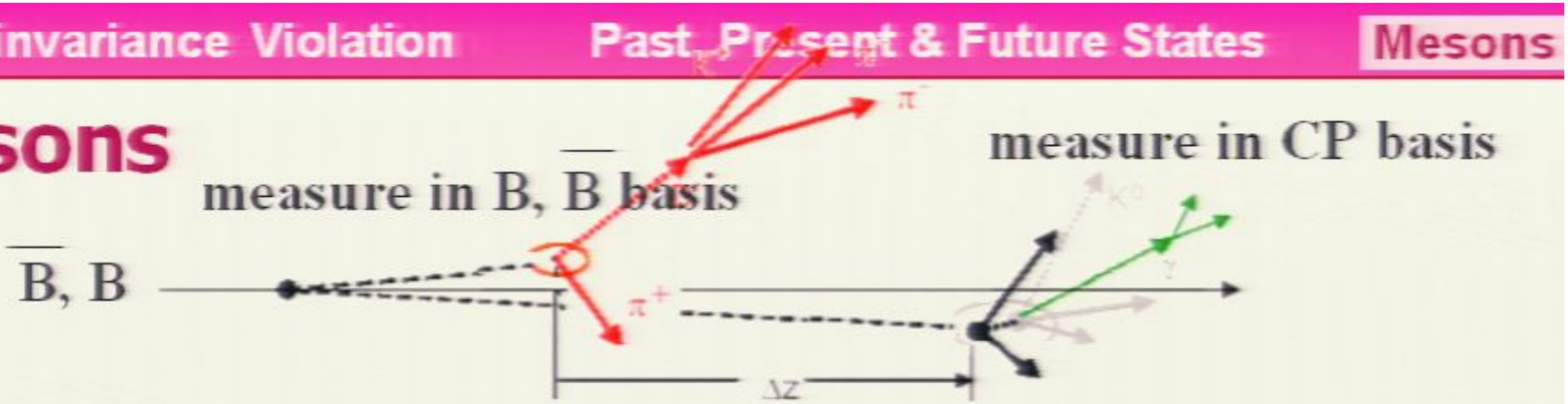

measure in B, $\overline{B}$ basis
measure in CP basis
$\overline{B}$, B
π^-
π^+
Δz

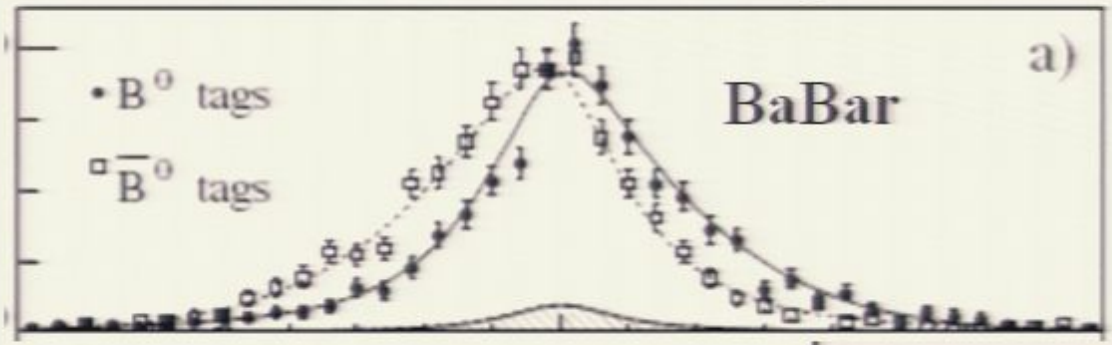

a)
BaBar
• B^0 tags
$\overline{B}^0$ tags

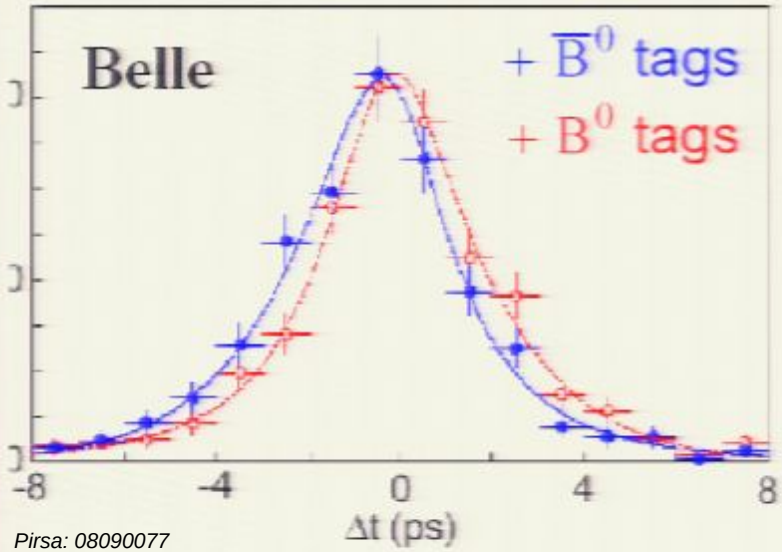

Belle
+ $\overline{B}^0$ tags
+ B^0 tags
-8
-4
0
4
8
Δt (ps)

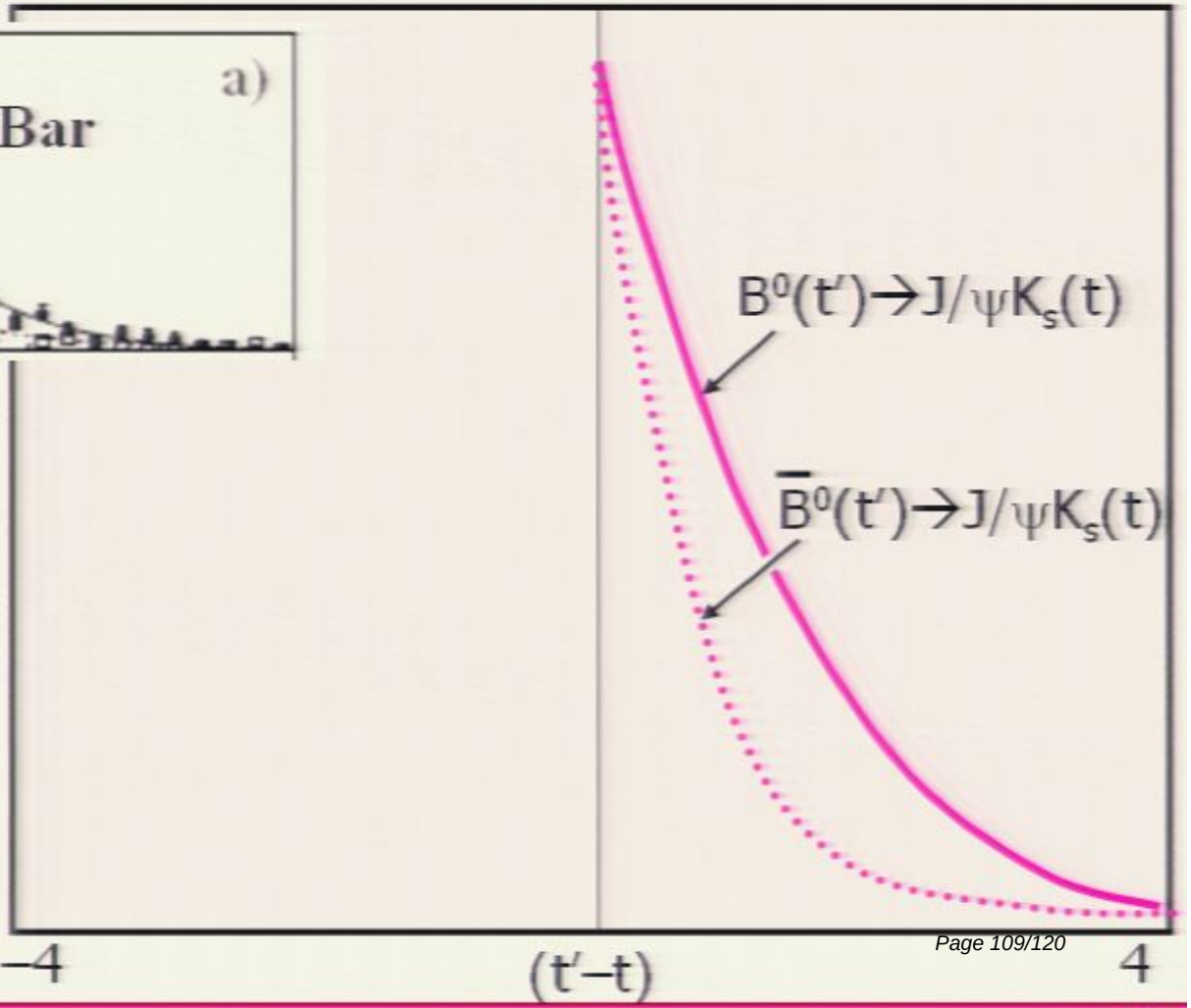

$B^0(t') \rightarrow J/\psi K_s(t)$
$\overline{B}^0(t') \rightarrow J/\psi K_s(t)$
−4
(t′−t)
4

B mesons

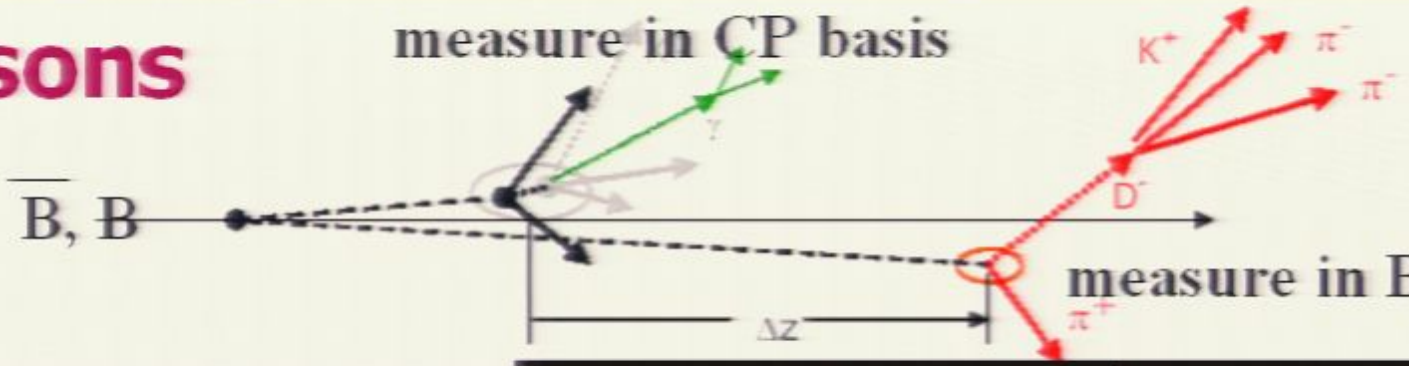

measure in B, $\overline{B}$ basis
measure in CP basis
$\overline{B}$, B
π^-
π^+
Δz

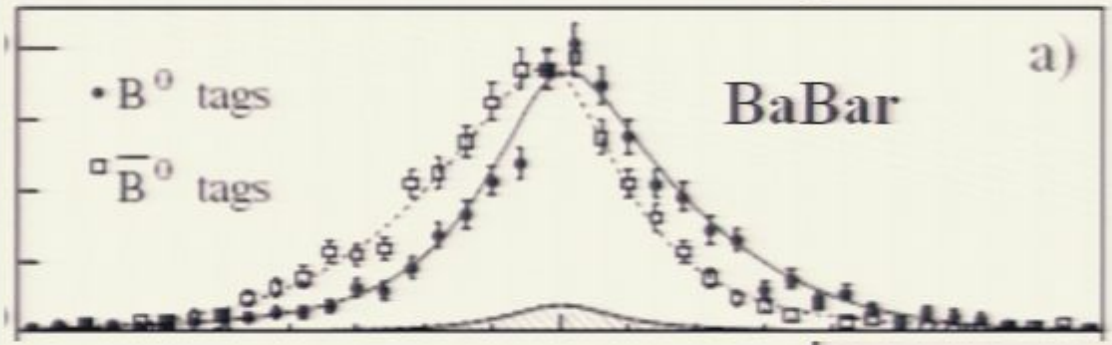

a)
BaBar
• B^0 tags
$\overline{B}^0$ tags

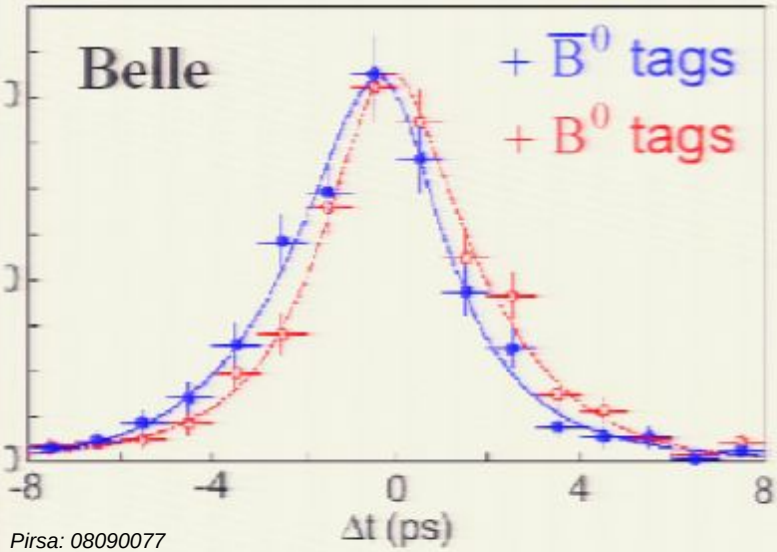

Belle
+ $\overline{B}^0$ tags
+ B^0 tags
-8
-4
0
4
8
Δt (ps)

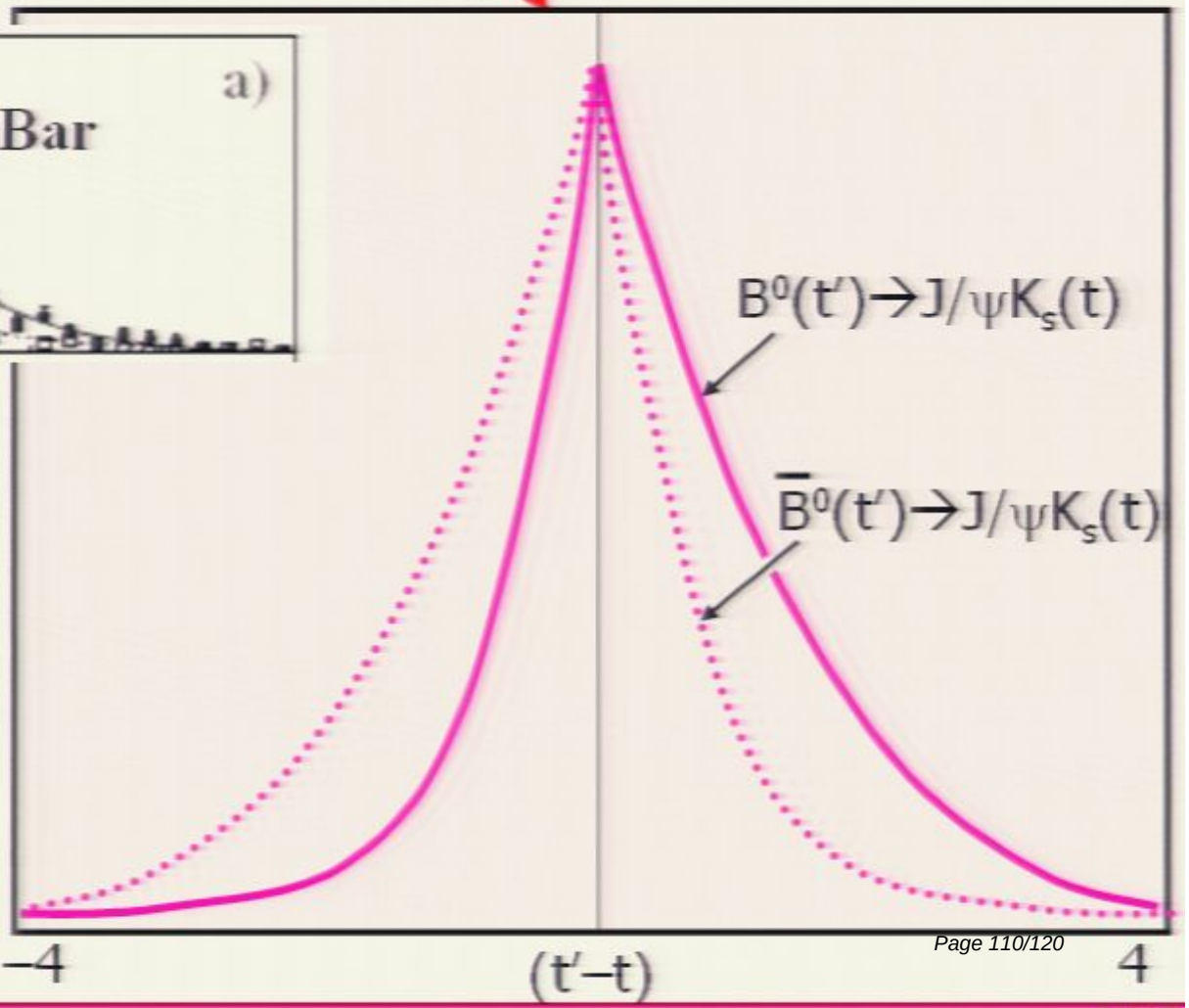

$B^0(t') \rightarrow J/\psi K_s(t)$
$\overline{B}^0(t') \rightarrow J/\psi K_s(t)$
−4
(t′−t)
4

B mesons


measure in CP basis
$\overline{B}$, B
K^+
π^-
π^-
D^-
measure in B, $\overline{B}$ basis
π^+
Δz


a)
BaBar
• B^0 tags
$\overline{B}^0$ tags


Belle
+ $\overline{B}^0$ tags
+ B^0 tags
-8
-4
0
4
8
Δt (ps)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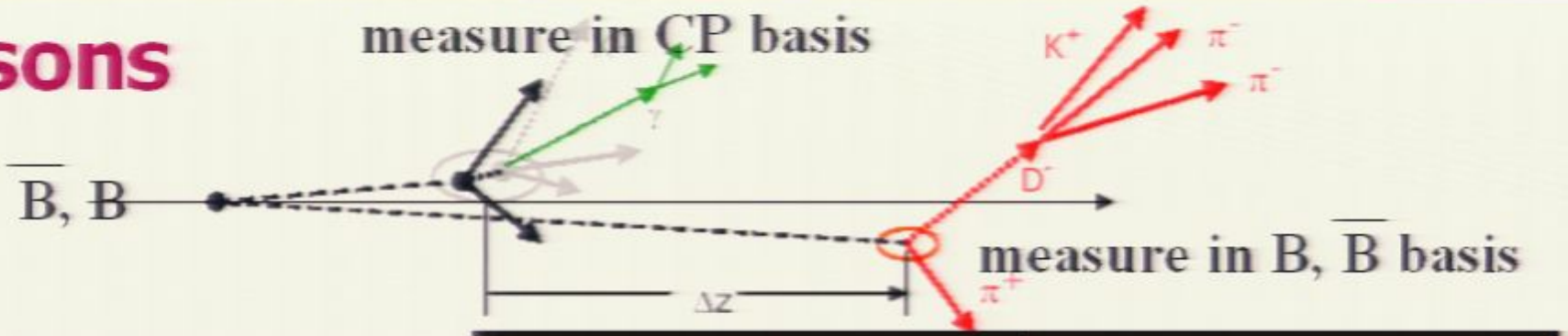
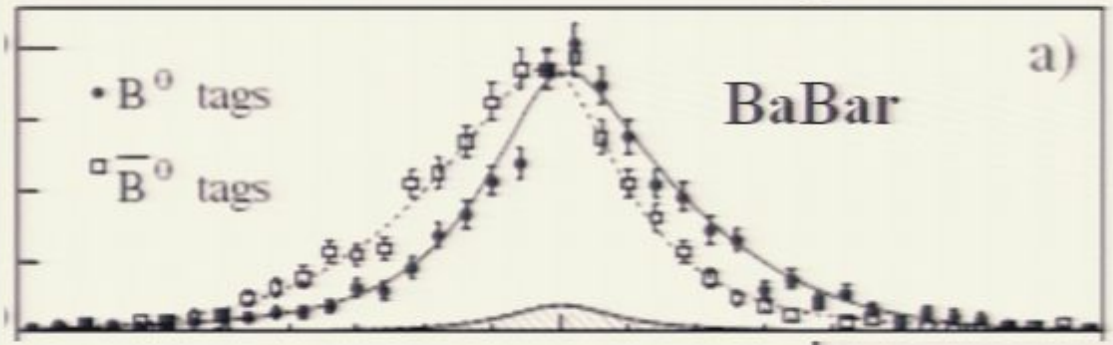
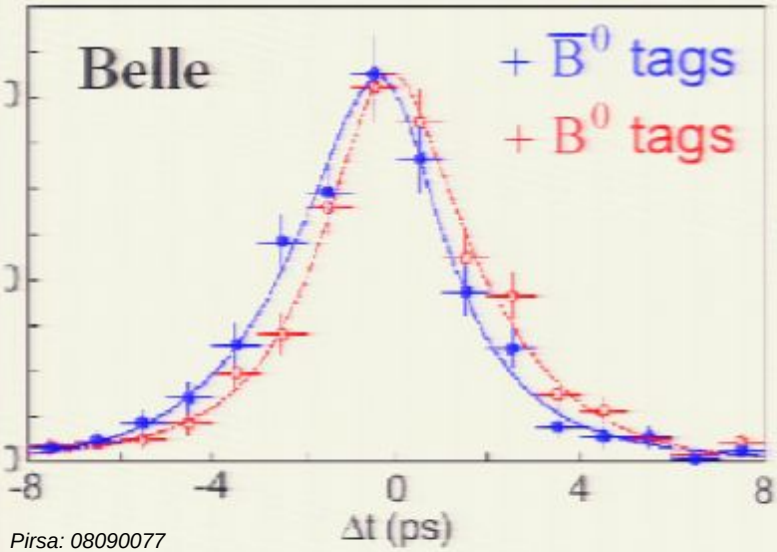
$\overline{B}^0(t') \rightarrow J/\psi K_s(t)$
−4
(t′−t)
4

B mesons


measure in CP basis
$\overline{B}$, B
K+
π-
π-
D-
γ
measure in B, $\overline{B}$ basis
π+
Δz


• B^0 tags
□ $\overline{B}^0$ tags
a)
BaBar


Belle
+ $\overline{B}^0$ tags
+ B^0 tags
-8
-4
0
4
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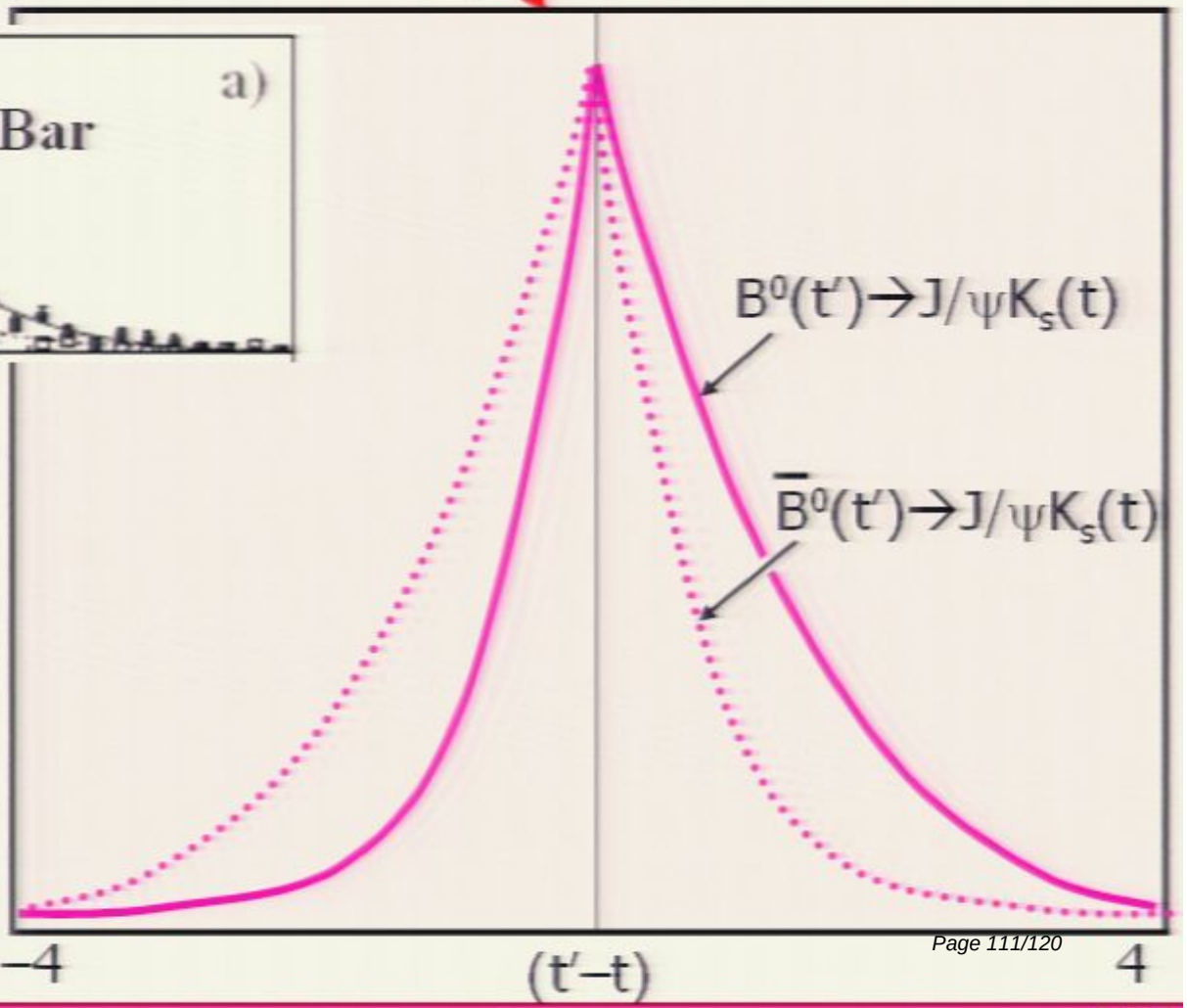
Δt (ps)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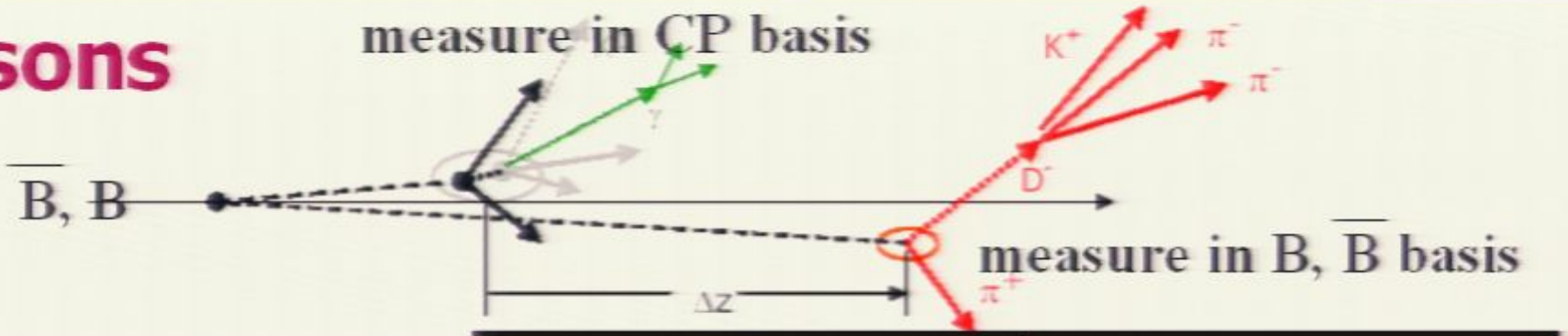
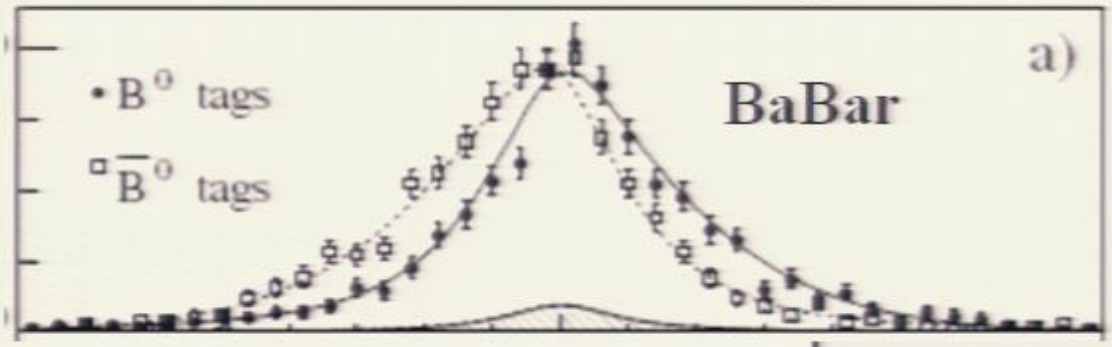
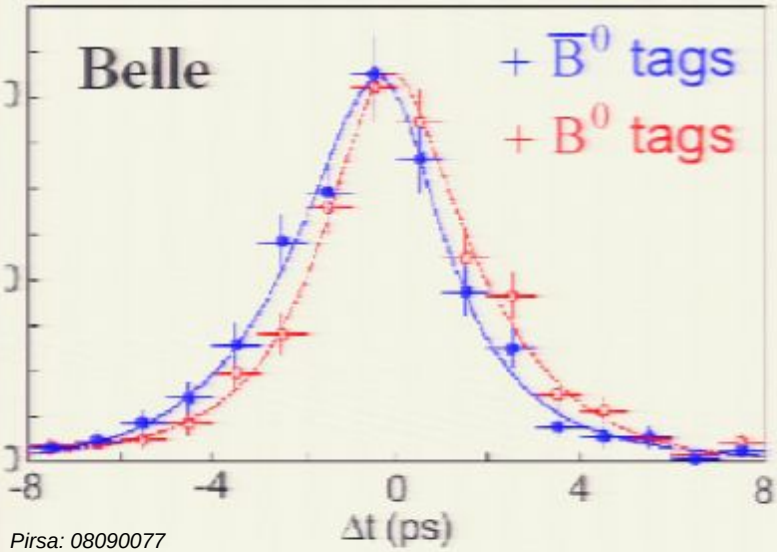
−4
(t′−t)
4

B mesons


measure in CP basis
$\overline{B}$, B
K^+
π^-
π^-
D^-
measure in B, $\overline{B}$ basis
π^+
Δz


a)
BaBar
• B^0 tags
□ $\overline{B}^0$ tags


Belle
+ $\overline{B}^0$ tags
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-8
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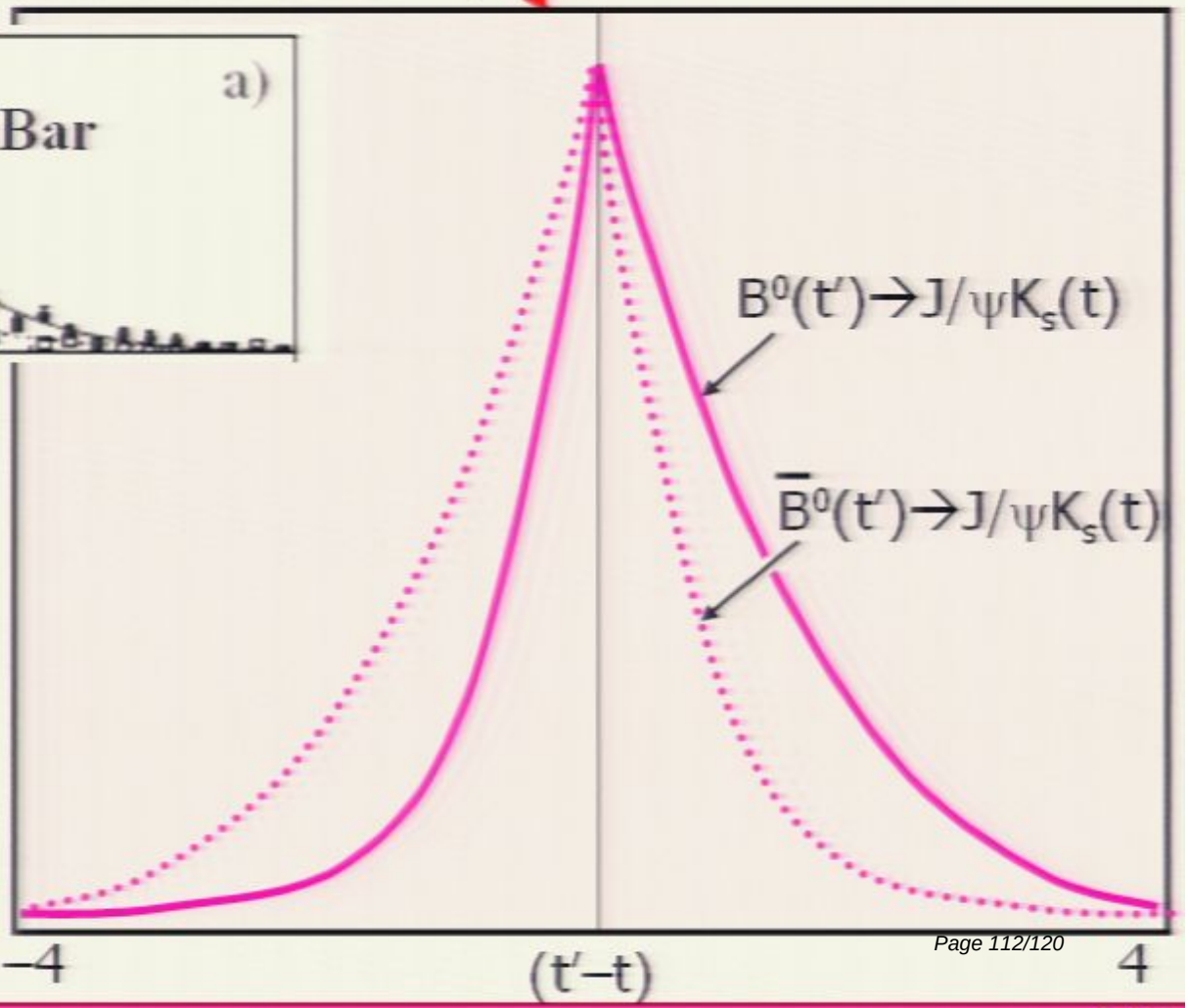
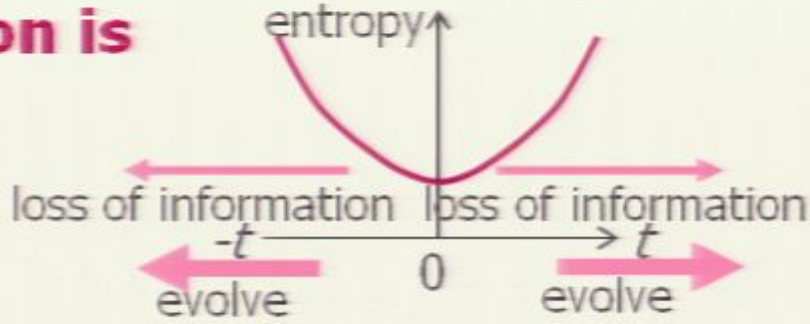

$B^0(t') \rightarrow J/\psi K_s(t)$
$\overline{B}^0(t') \rightarrow J/\psi K_s(t)$
−4
(t′−t)
4

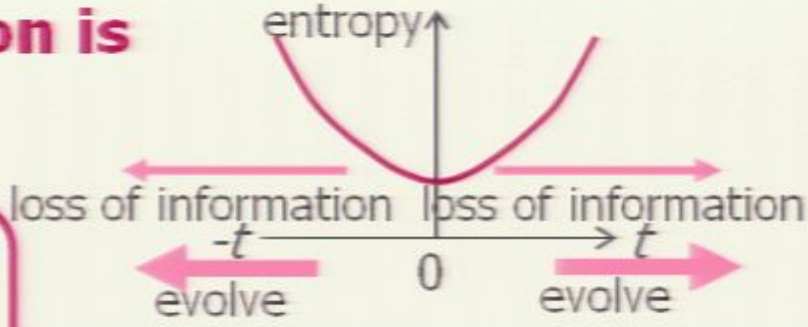
Summary

1. time direction is ambiguous

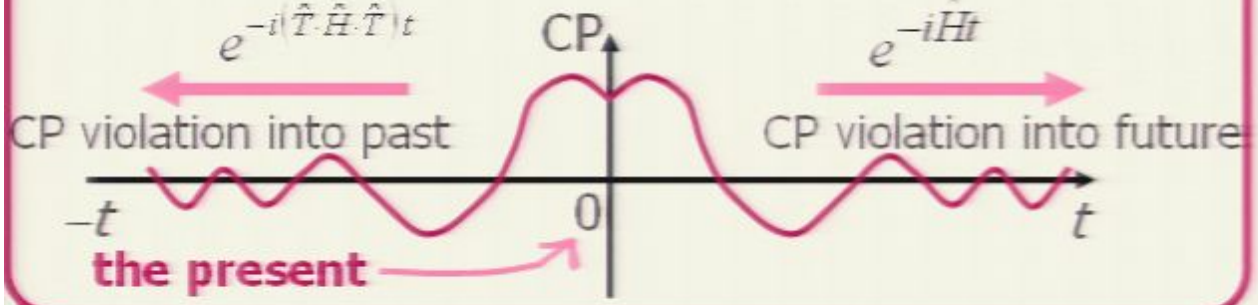


Summary

1. time direction is ambiguous

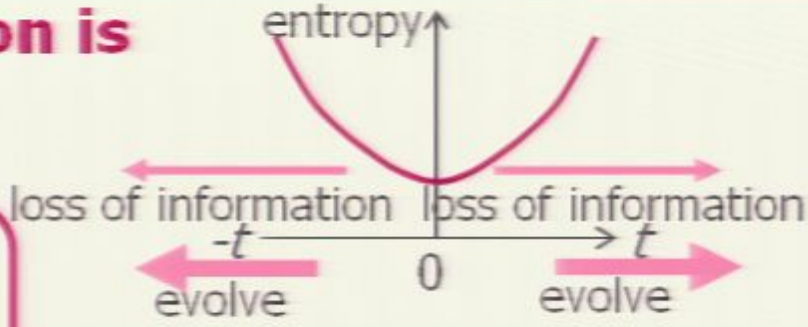


2. equal CP (=T) violation in both directions

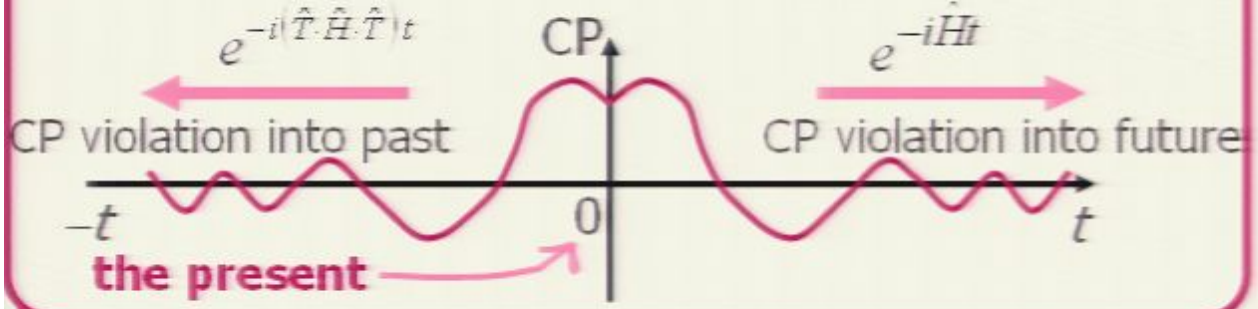


Summary

1. time direction is ambiguous

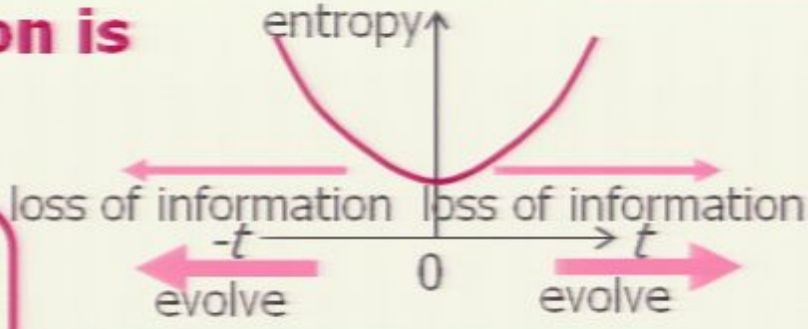


2. equal CP (=T) violation in both directions

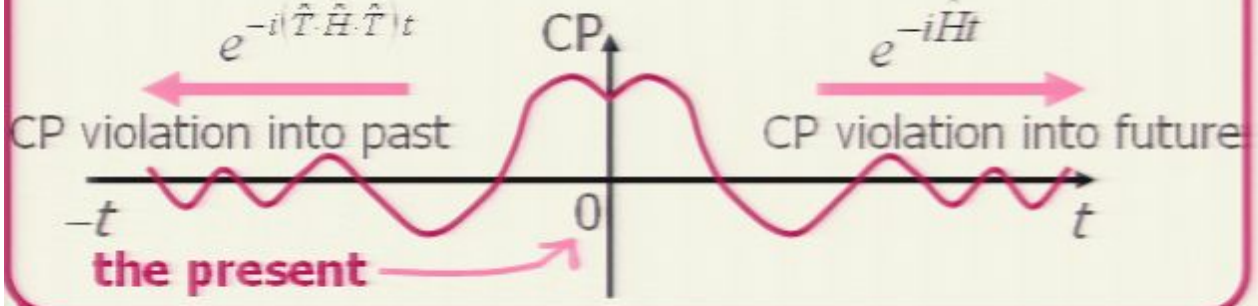


Summary

1. time direction is ambiguous

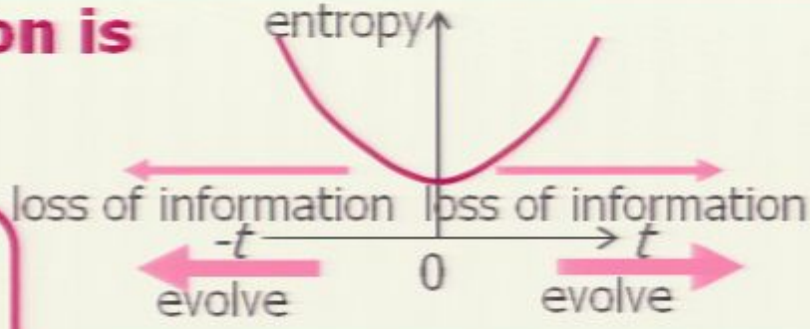


2. equal CP (=T) violation in both directions

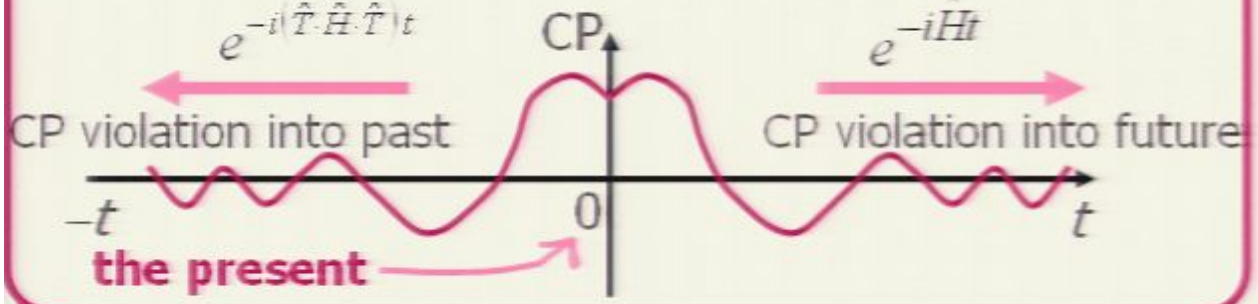


Summary

1. time direction is ambiguous

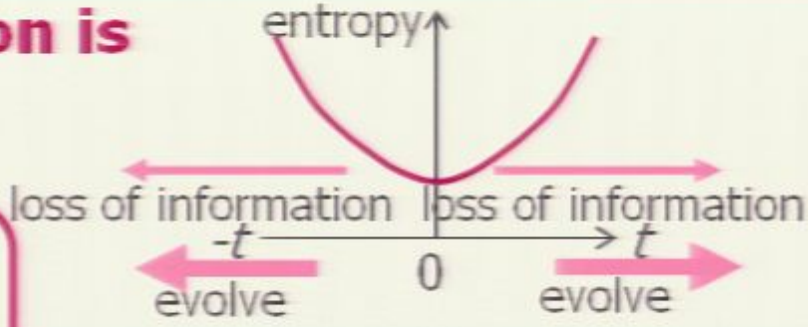


2. equal CP (=T) violation in both directions

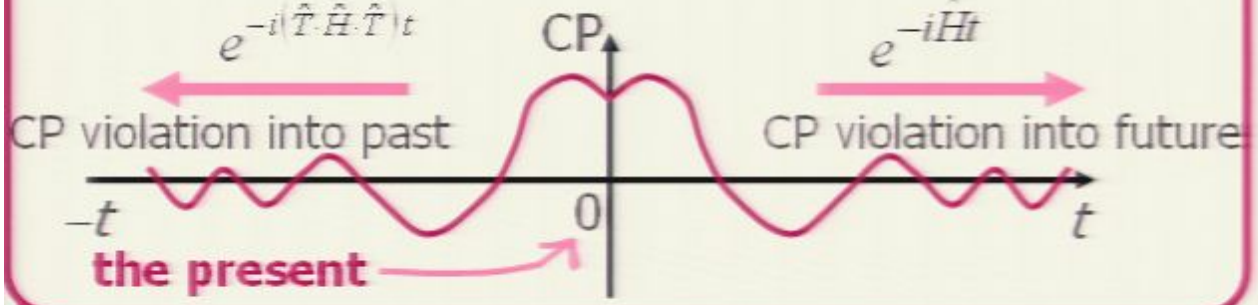


Summary

1. time direction is ambiguous

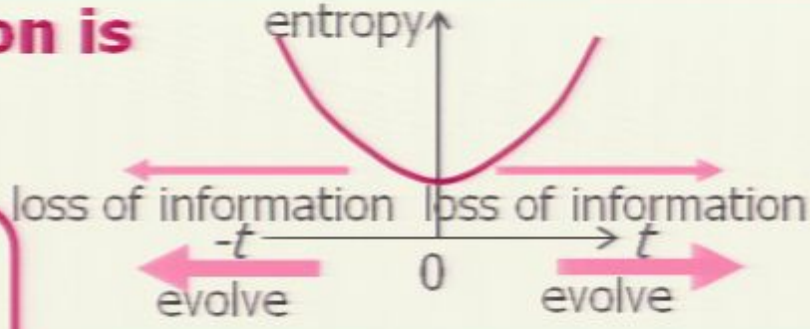


2. equal CP (=T) violation in both directions

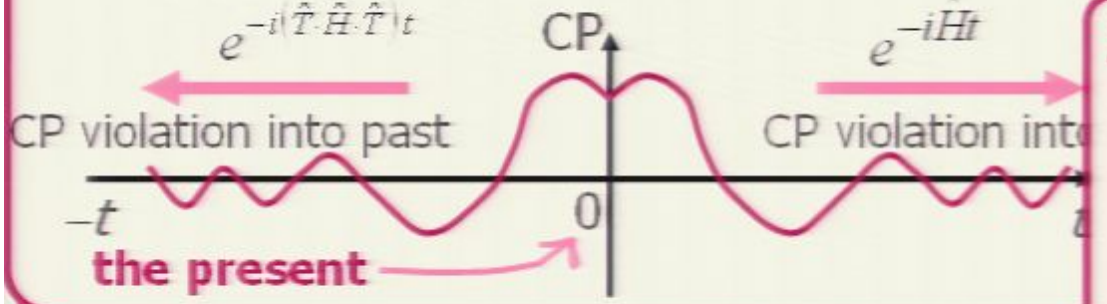


Summary

1. time direction is ambiguous



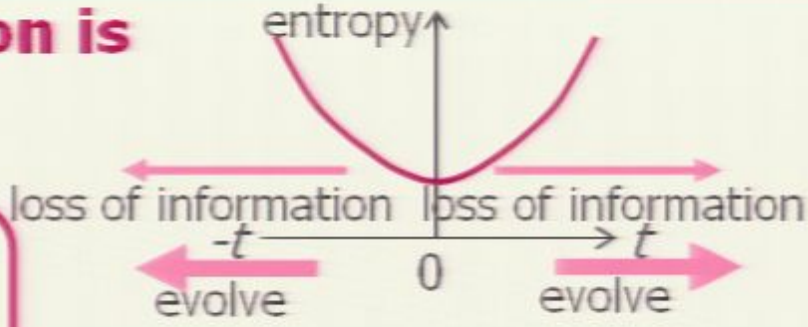
2. equal CP (=T) violation in both directions



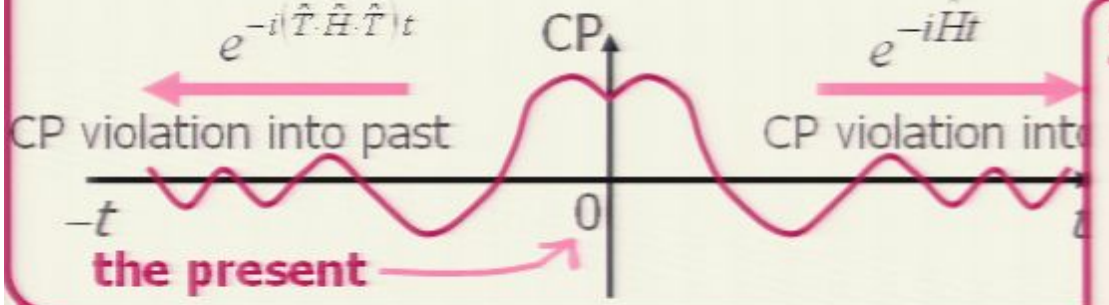
3. Overlaps: already partly in the future

Summary

1. time direction is ambiguous



2. equal CP (=T) violation in both directions



3. Overlaps: already partly in the future

4. Ratchet effect – progression of "nows"