Title: Foundations and Interpretation of Quantum Theory - Lecture 17

Date: Mar 18, 2010 02:30 PM

URL: http://pirsa.org/10030024

Abstract:

The Many-Worlds Interpretation
Lev Vaidman

A tale of a single world universe

Quantum states of all macroscopic objects are
Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

$$\Rightarrow\quad \rho(\vec{r})$$

$\rho(\vec{r})$ **of a cat!**

experience $\overset{\textbf{TRIVIAL}}{\Longleftrightarrow}$ $\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$

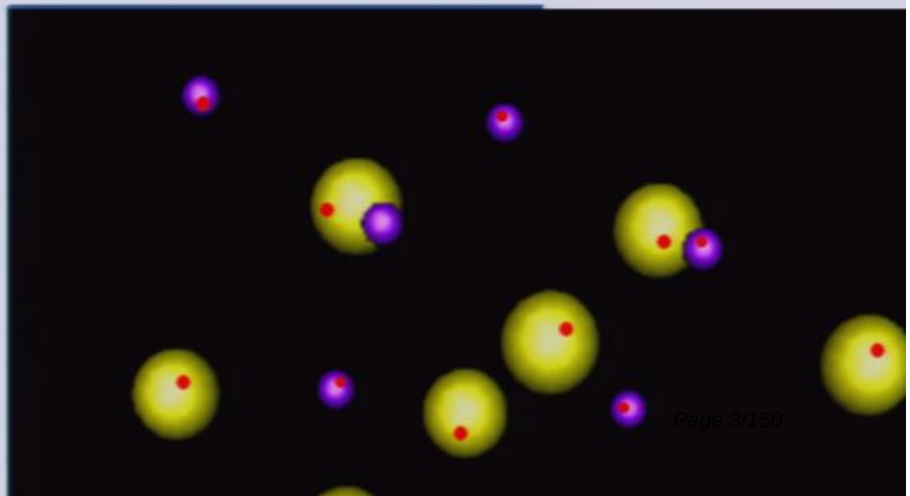
Almost the same as in

Textbook collapse

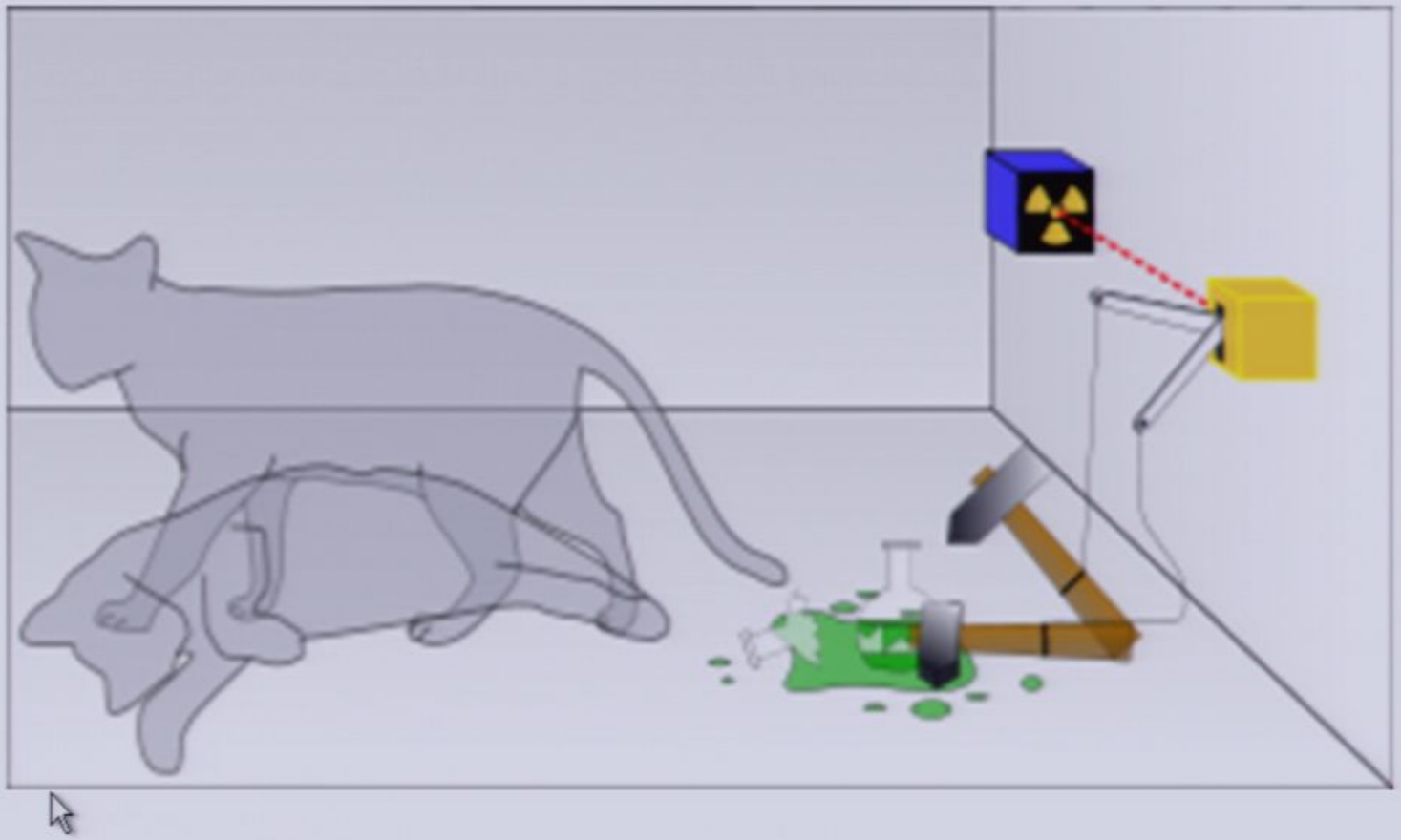
GRW-Pearle Collapse (mass density)

Bohmian trajectories

Laplacian Determinism



Two worlds universe



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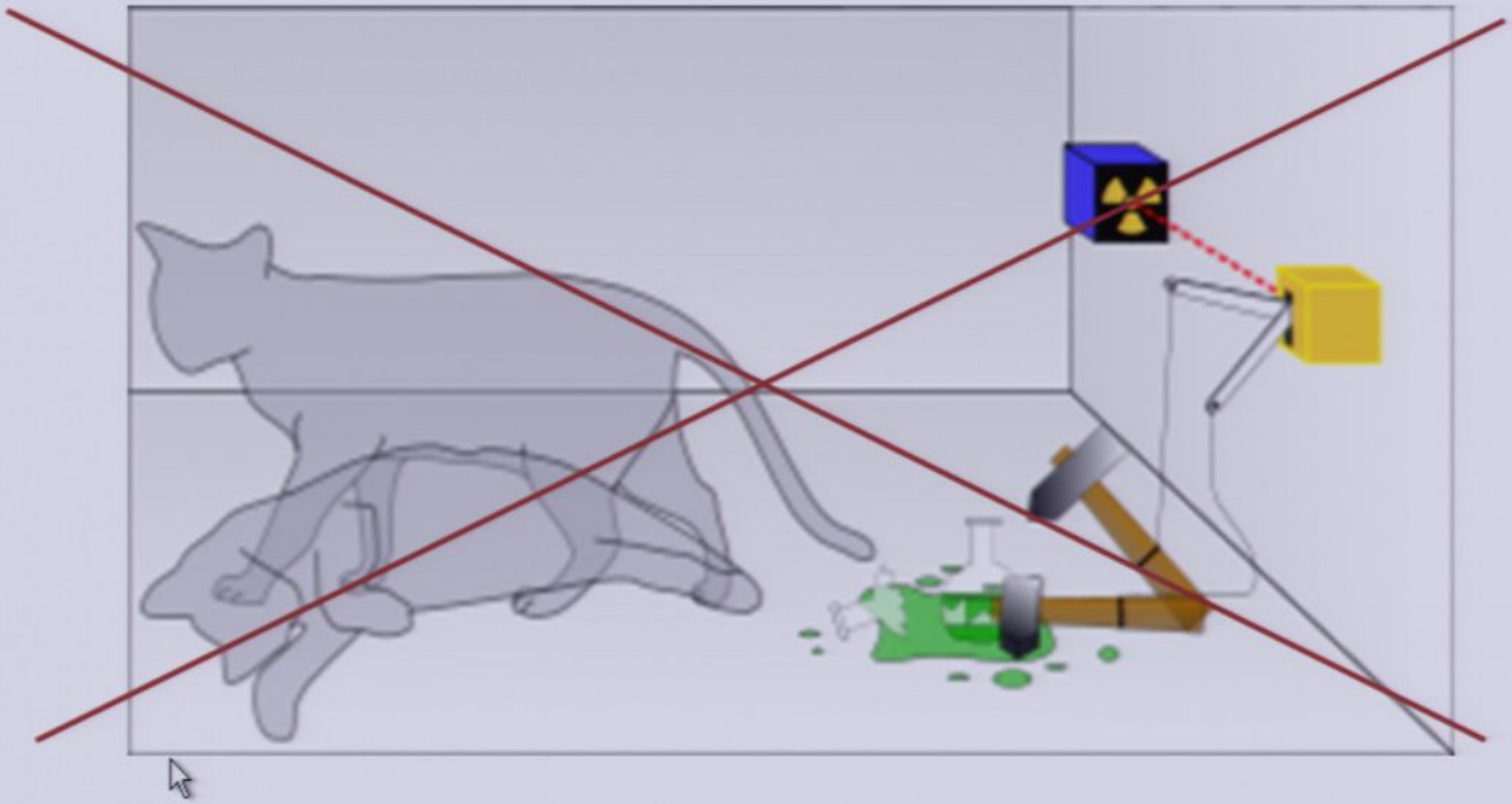
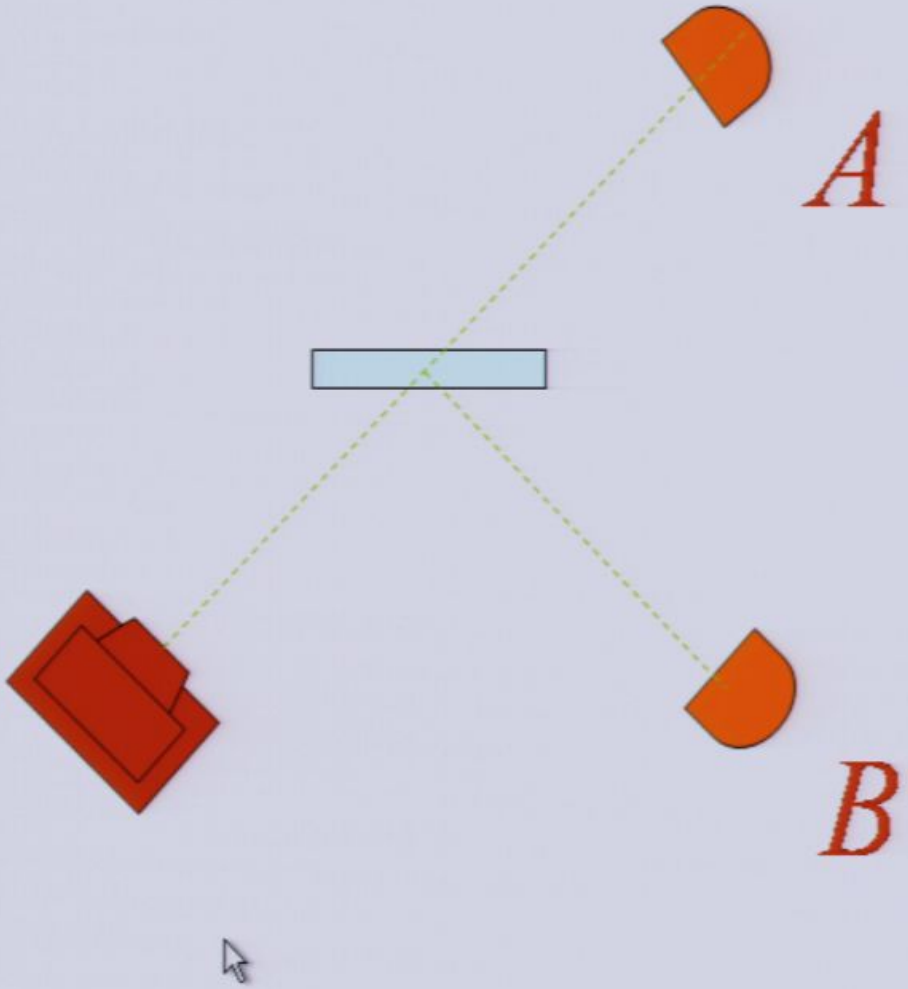


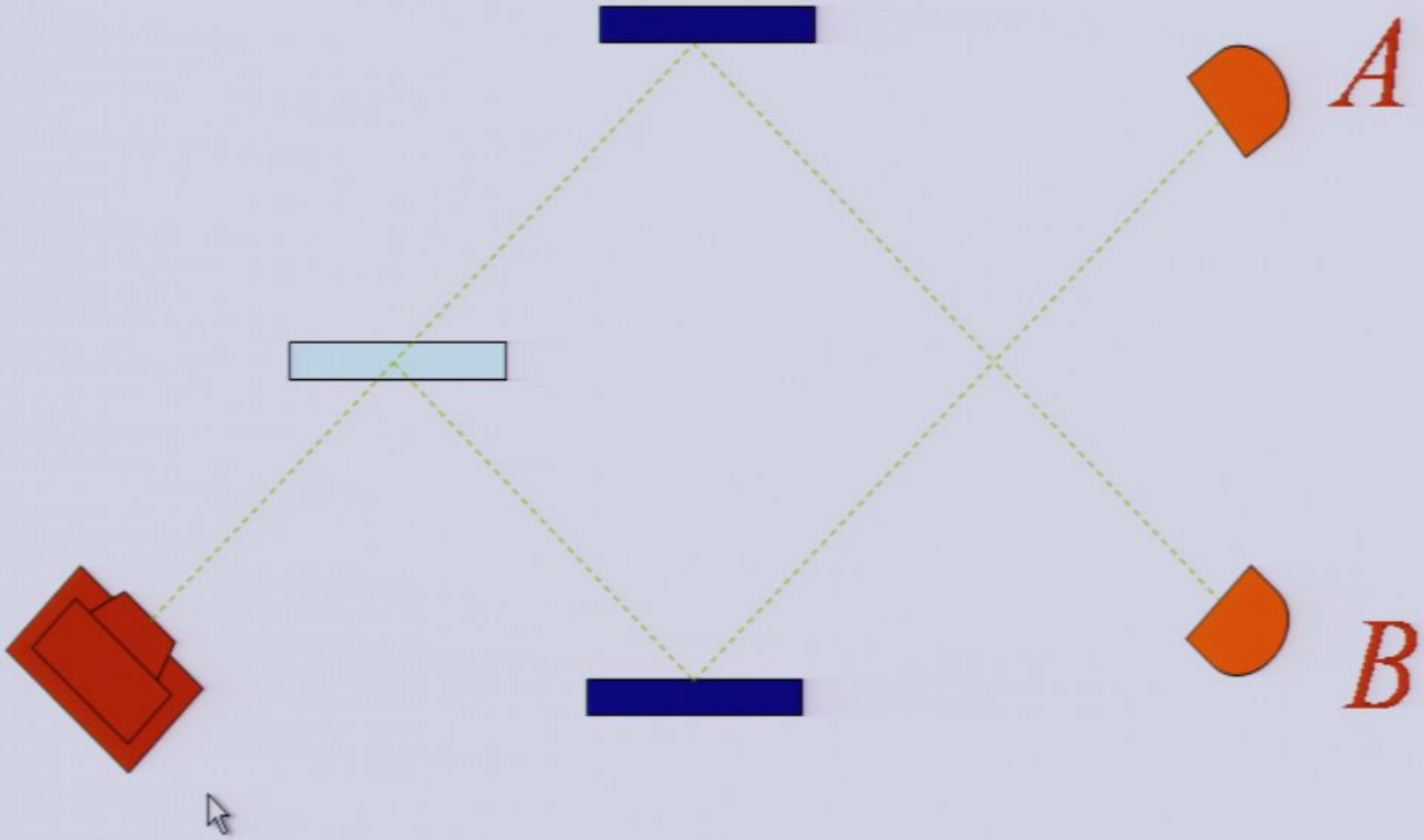
This is a multiple worlds universe

Two worlds universe



Two worlds universe

One world does not disturb the other



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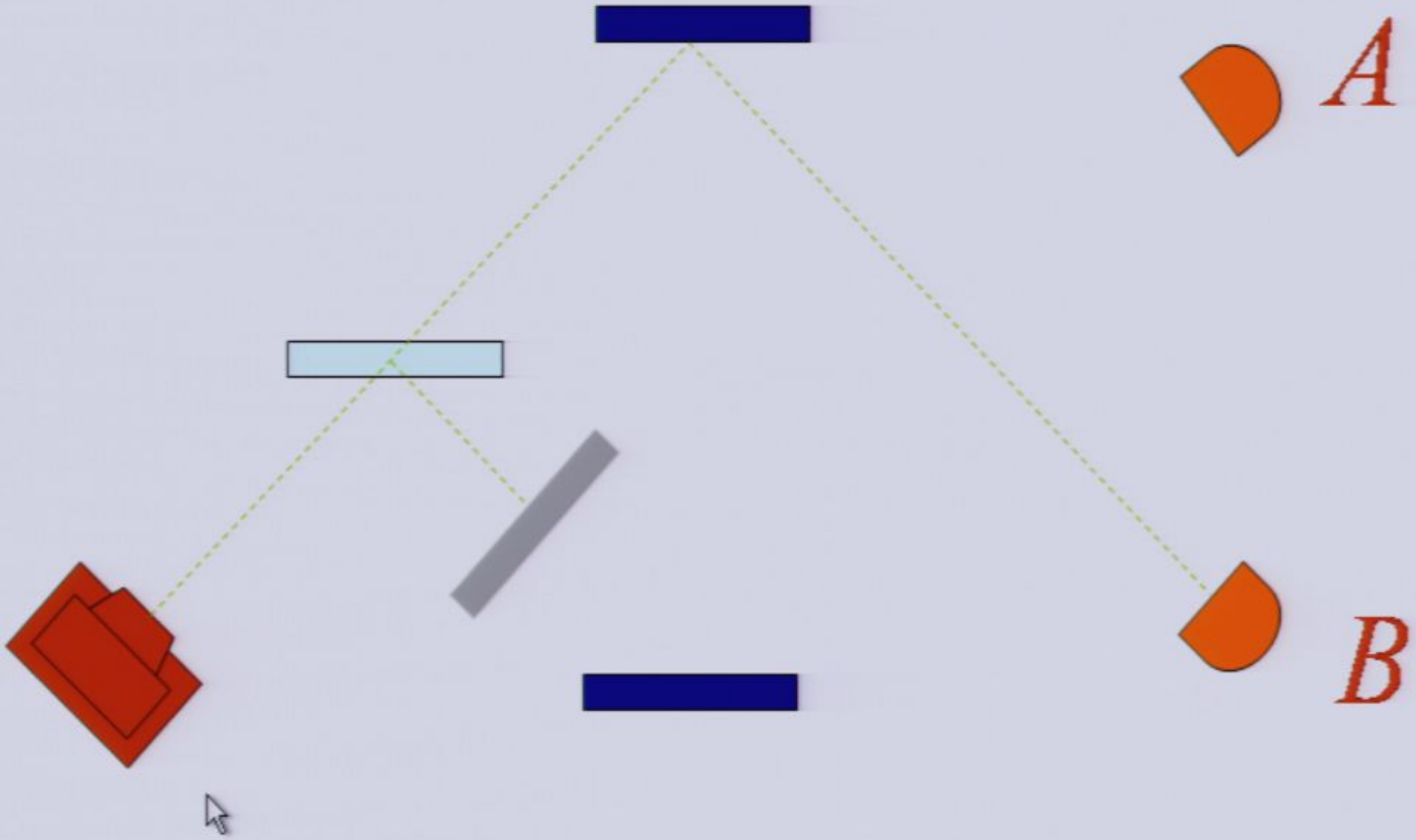

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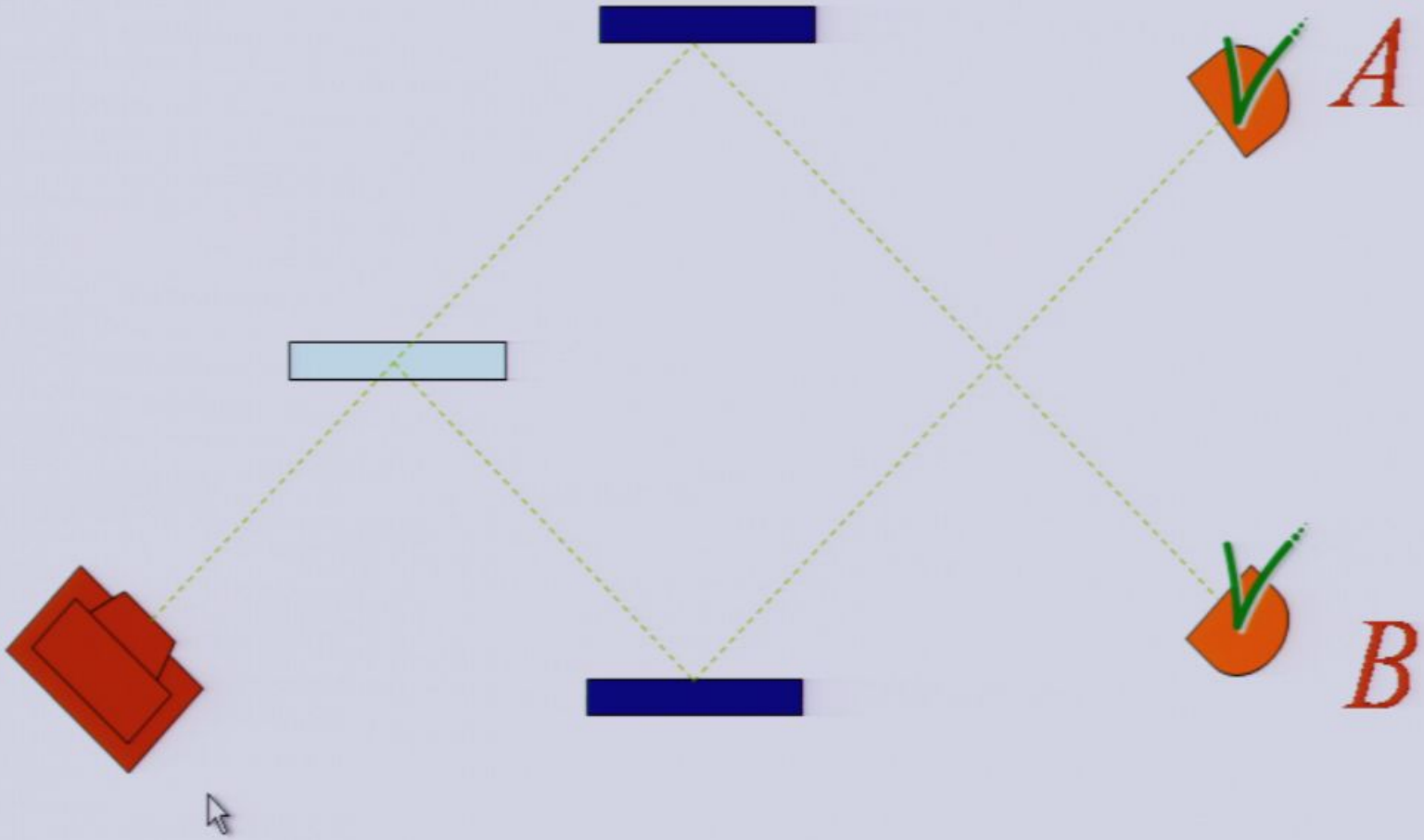

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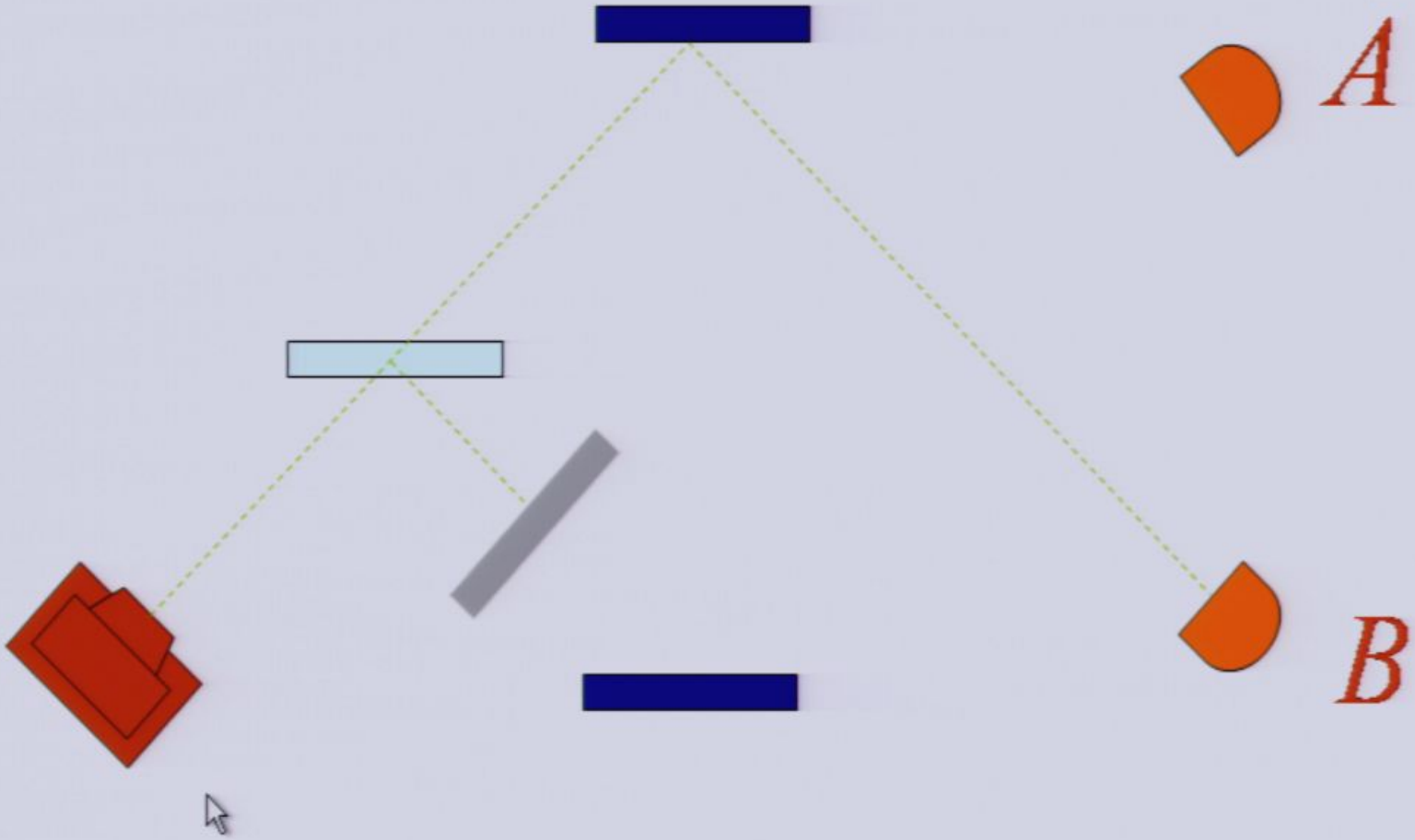

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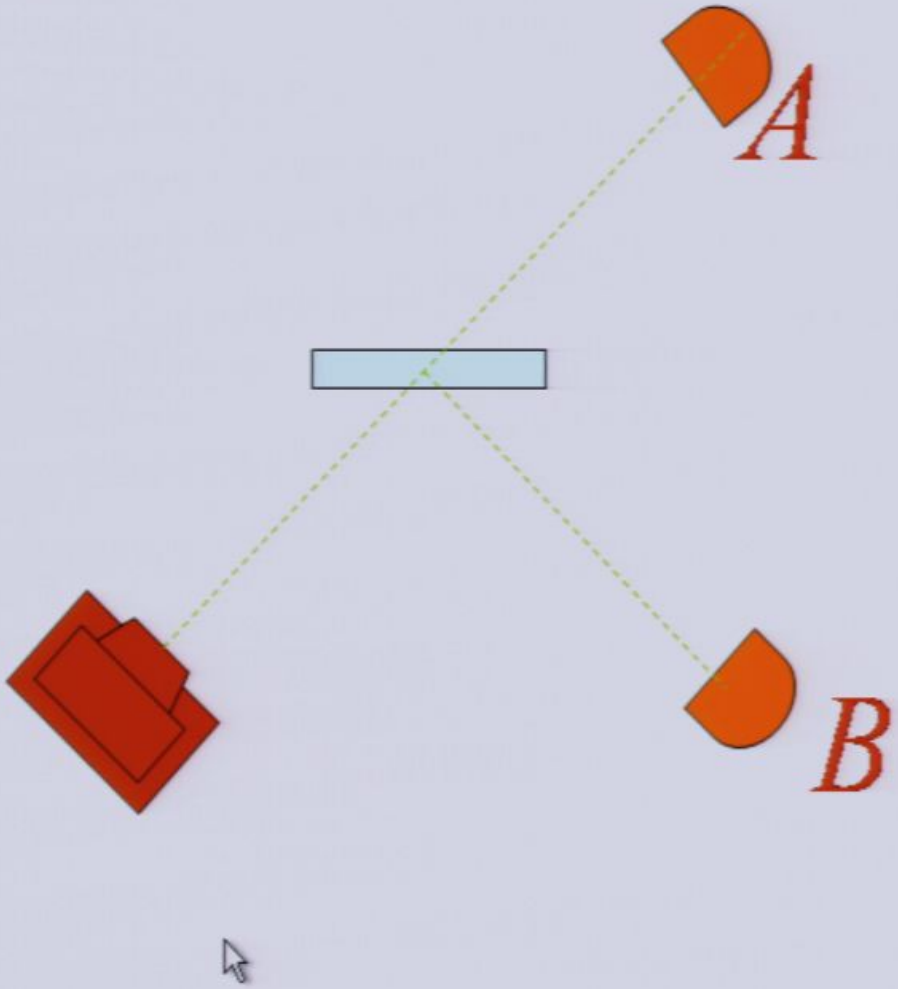
Preferred basis: $\{|A\rangle, |B\rangle\}$ **or** $\left\{\frac{|A\rangle + |B\rangle}{\sqrt{2}}, \frac{|A\rangle - |B\rangle}{\sqrt{2}}\right\} \equiv \{|+\rangle, |-\rangle\}$



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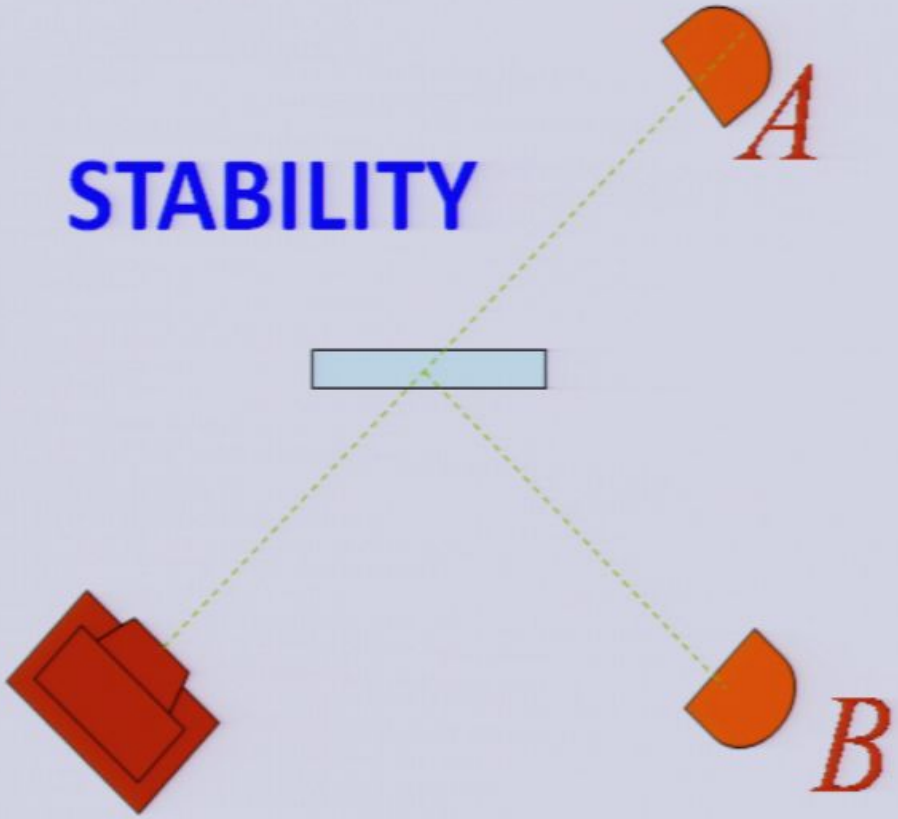

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$$|A\rangle |R\rangle_{MD\,A} |R\rangle_{MD\,B} |R\rangle_{ENV}$$
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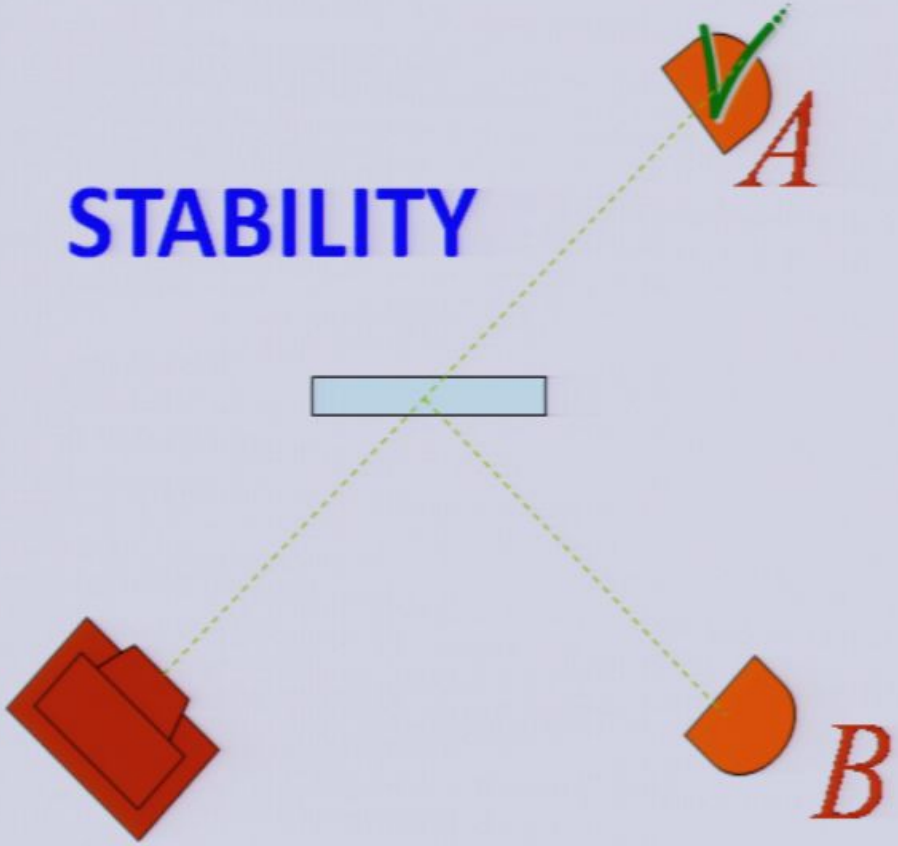

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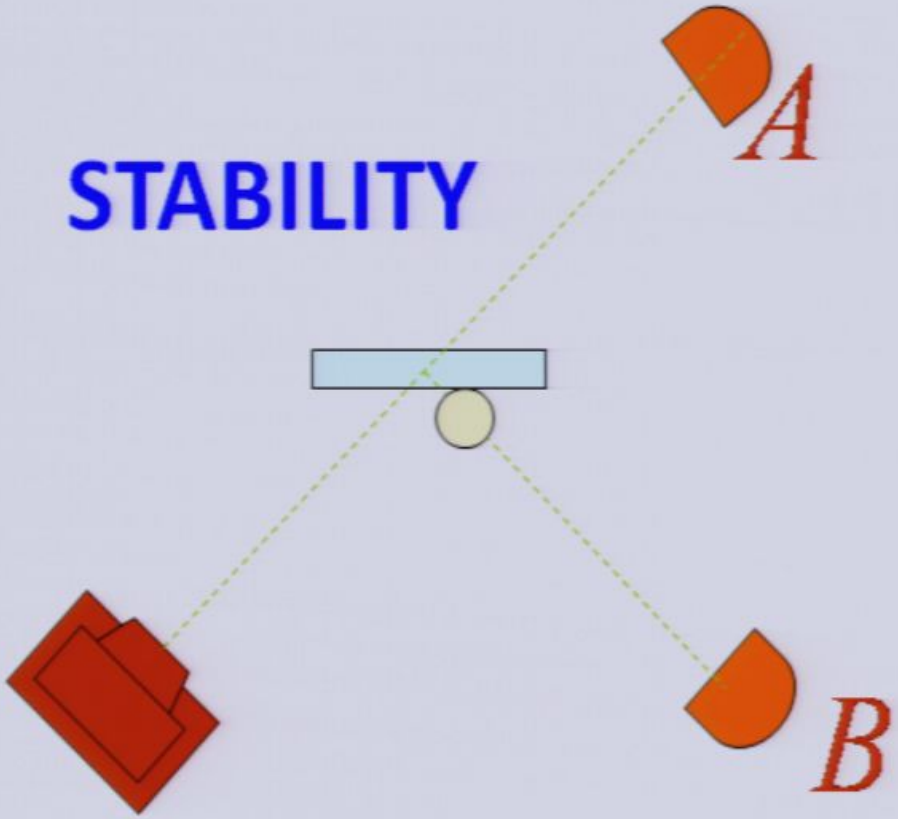

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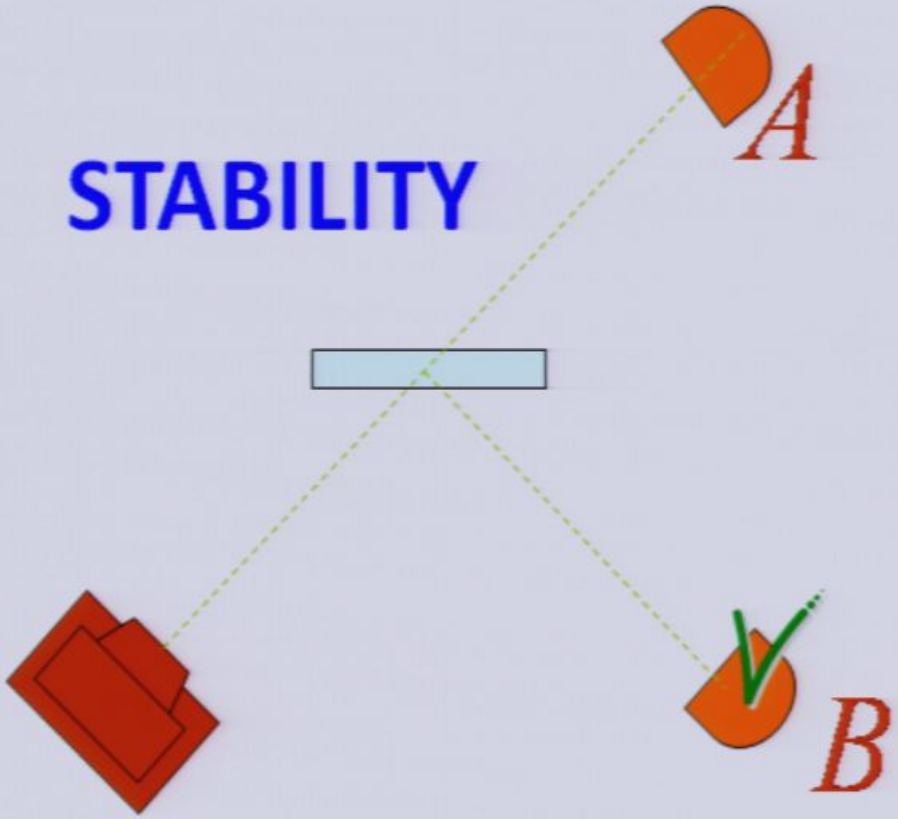

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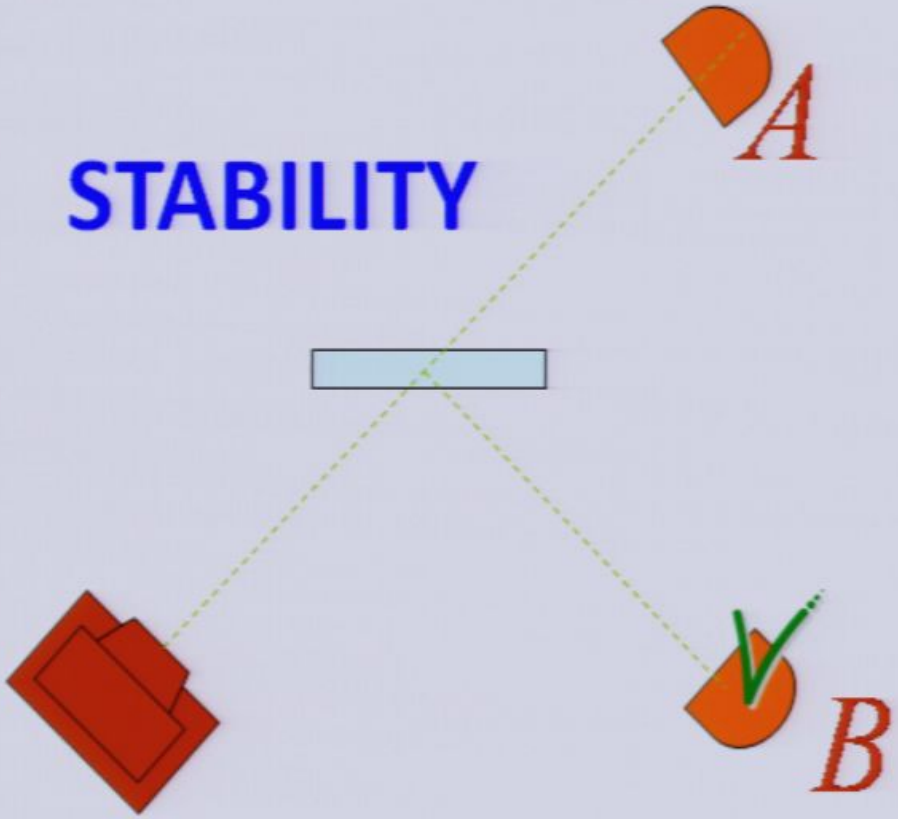

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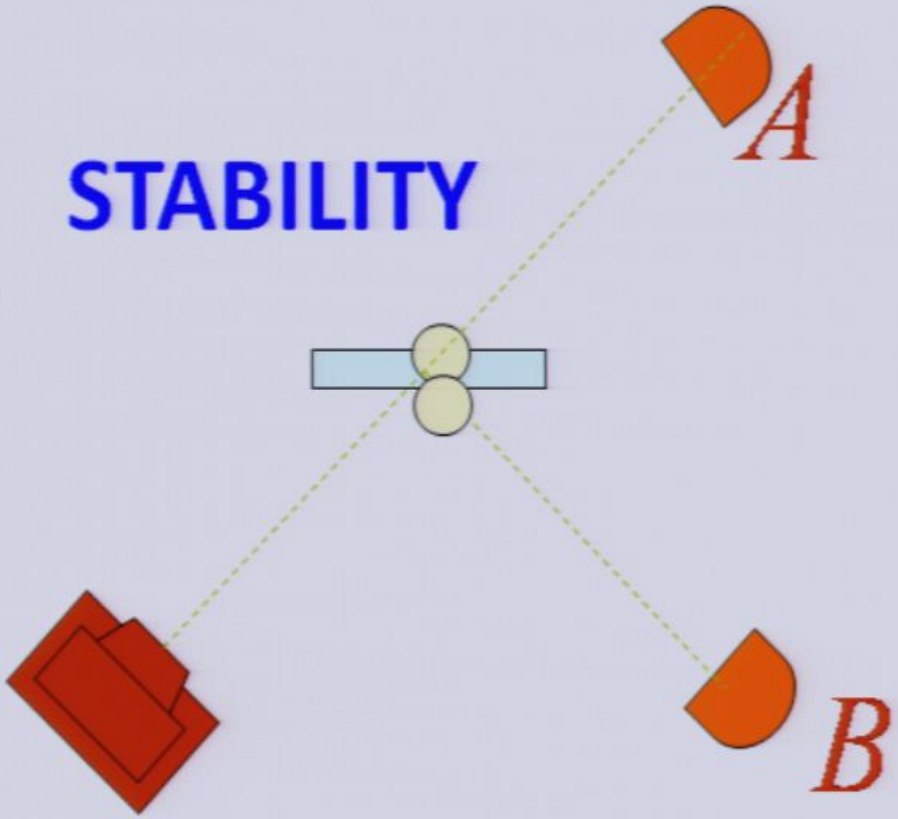

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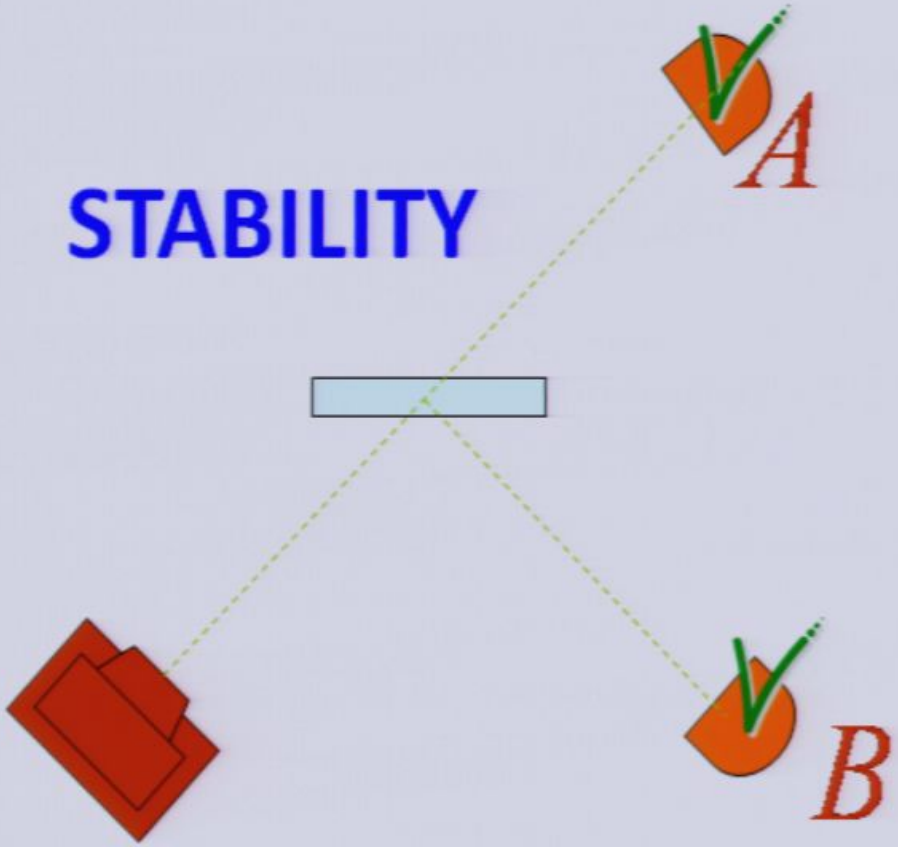

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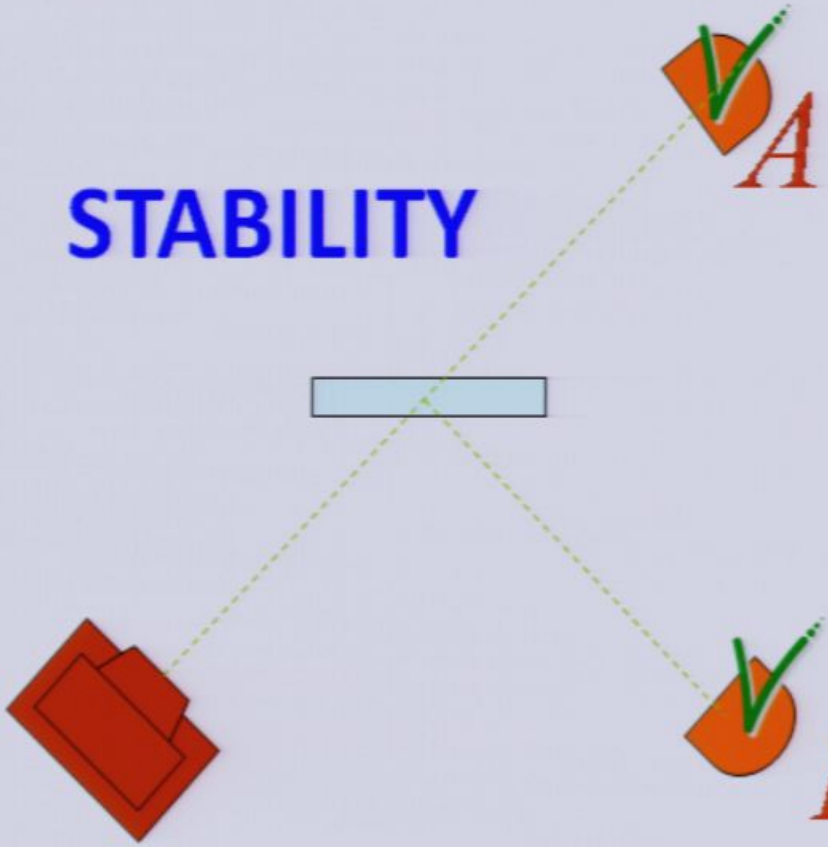

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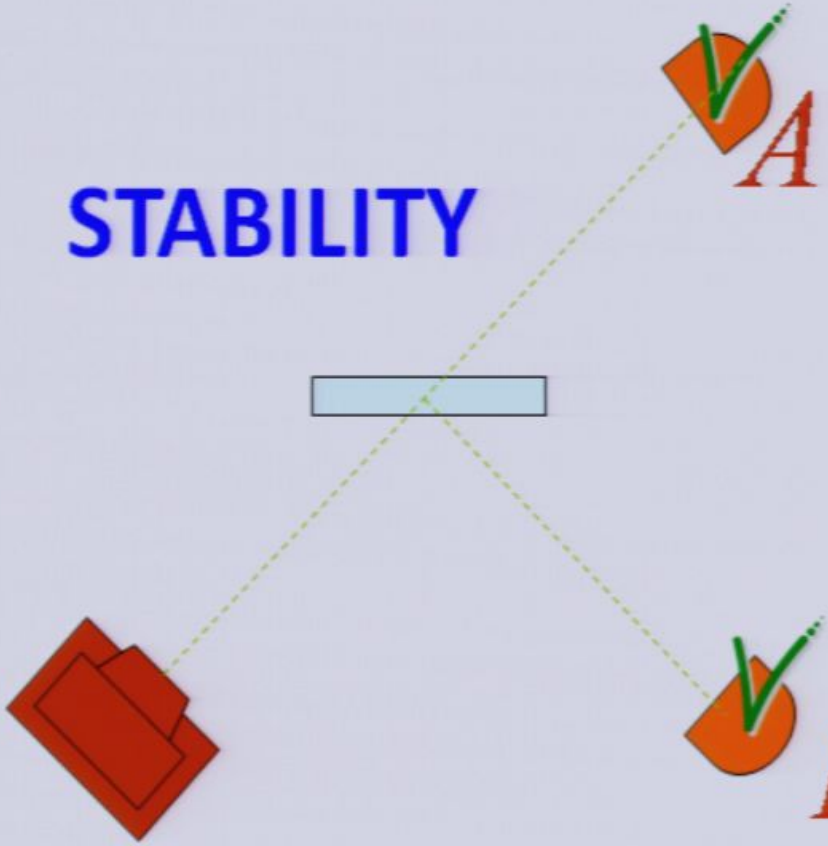

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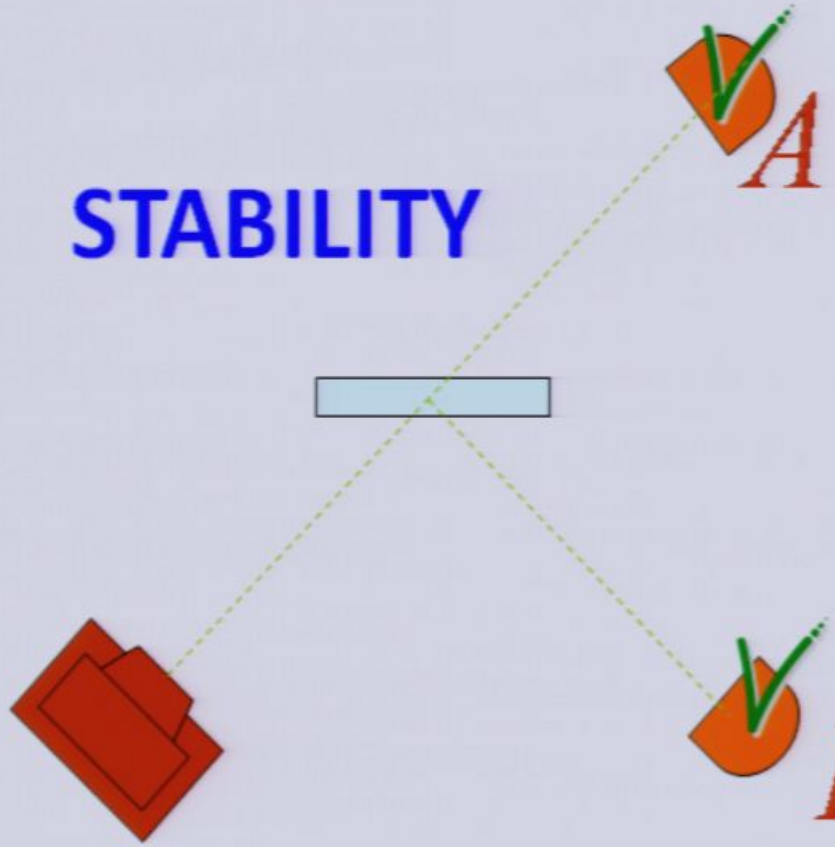

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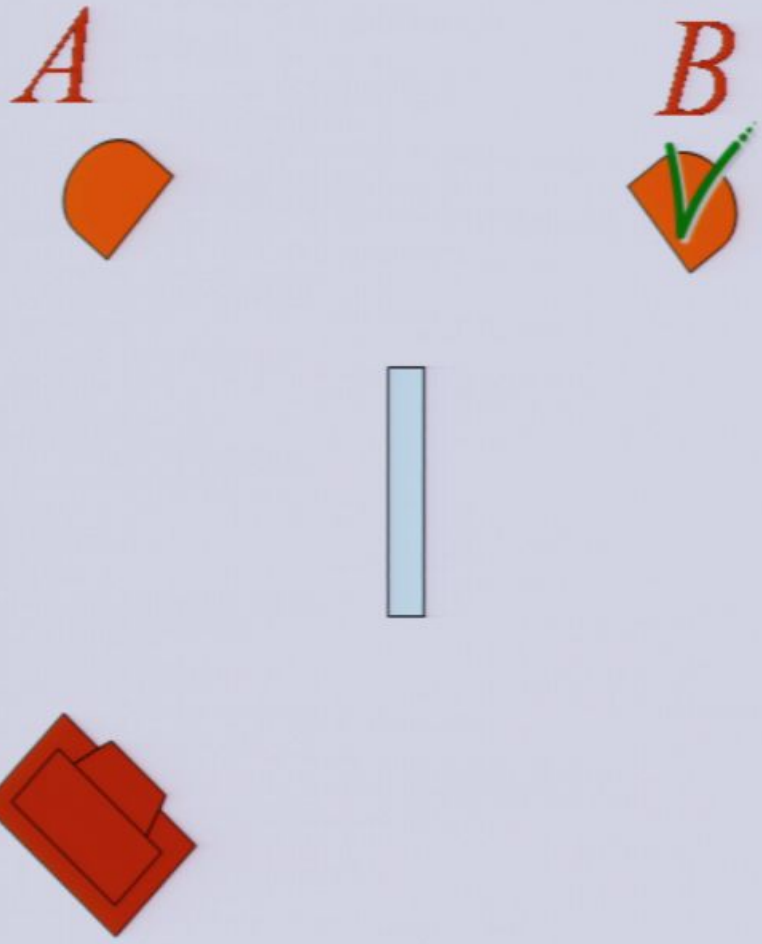
$$= |+\rangle \frac{|V\rangle_{MD\,A} |R\rangle_{MD\,B} |A\rangle_{ENV} + |R\rangle_{MD\,A} |V\rangle_{MD\,B} |B\rangle_{ENV}}{2} + |-\rangle \frac{|V\rangle_{MD\,A} |R\rangle_{MD\,B} |A\rangle_{ENV} - |R\rangle_{MD\,A} |V\rangle_{MD\,B} |B\rangle_{ENV}}{2}$$

What is "a world" in the many-worlds picture?

experience i $\Leftrightarrow$ world i $\Leftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$



$$\Psi_i = \psi_i^{OBJECT_1}\, \psi_i^{OBJECT_2} \ldots \psi_i^{OBJECT_K}\, \varphi_i^{REST}$$

ψ_i^{OBJECT} is a Localized Wave Packet for a period of time

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- "classical" macroscopic objects rapidly measured by the environment,

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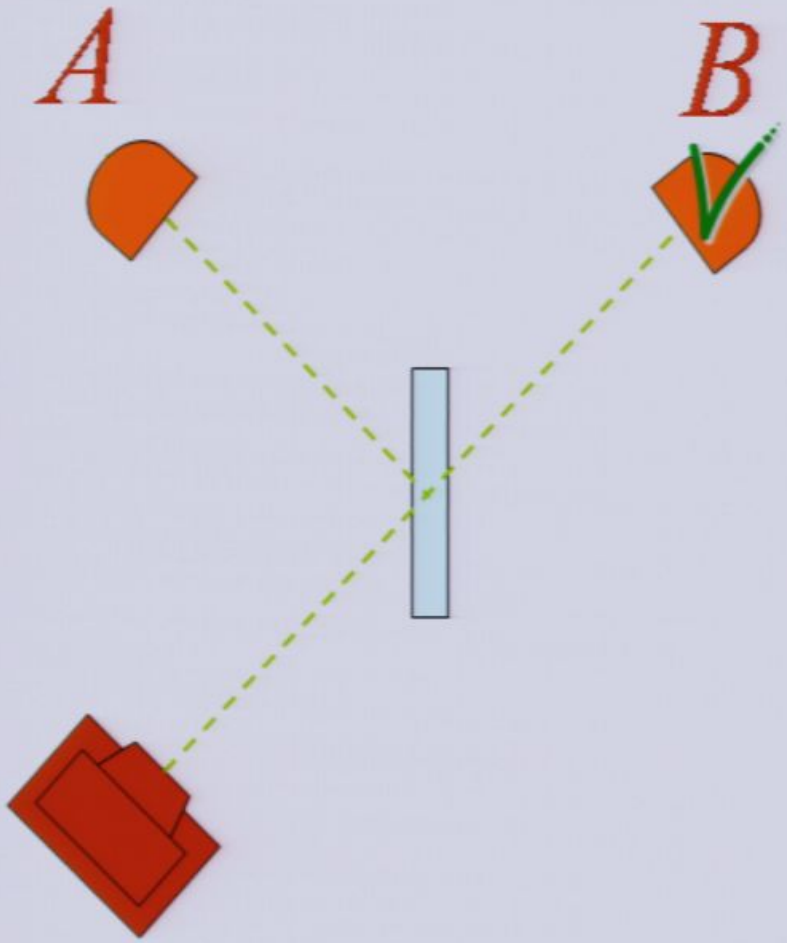

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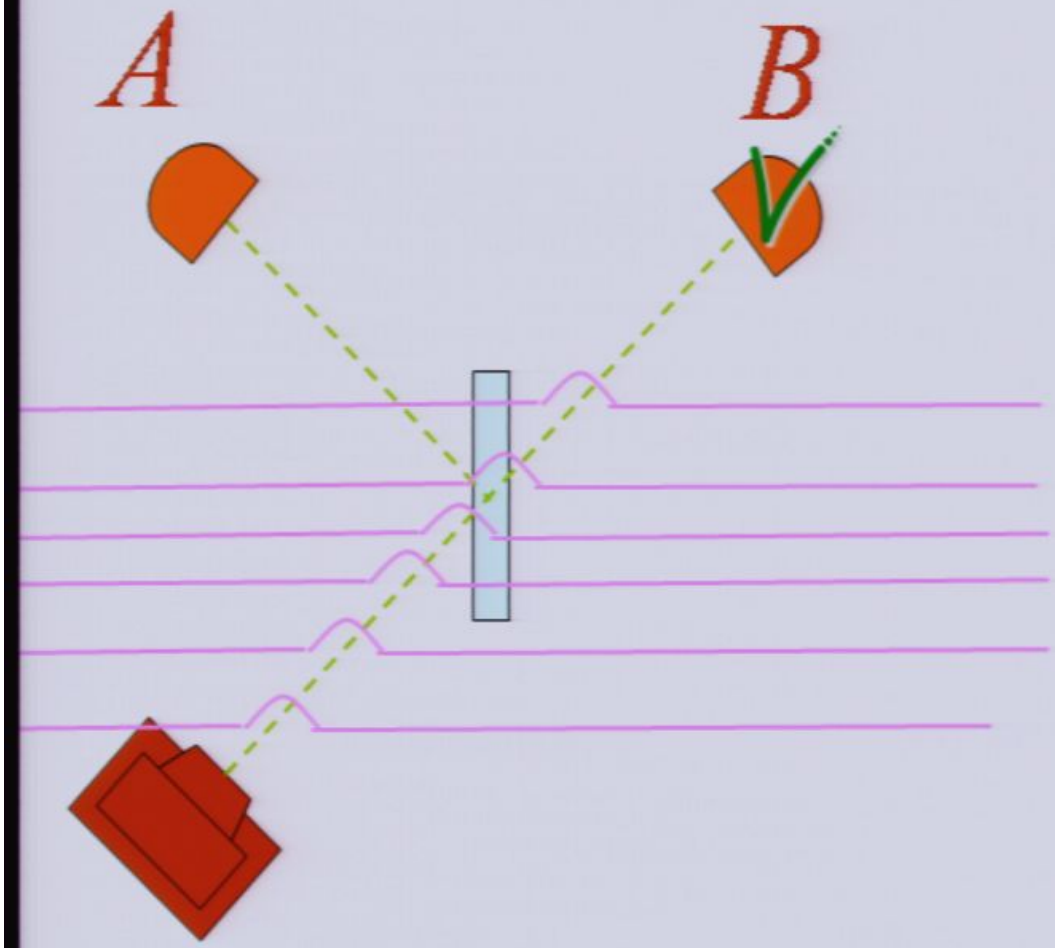

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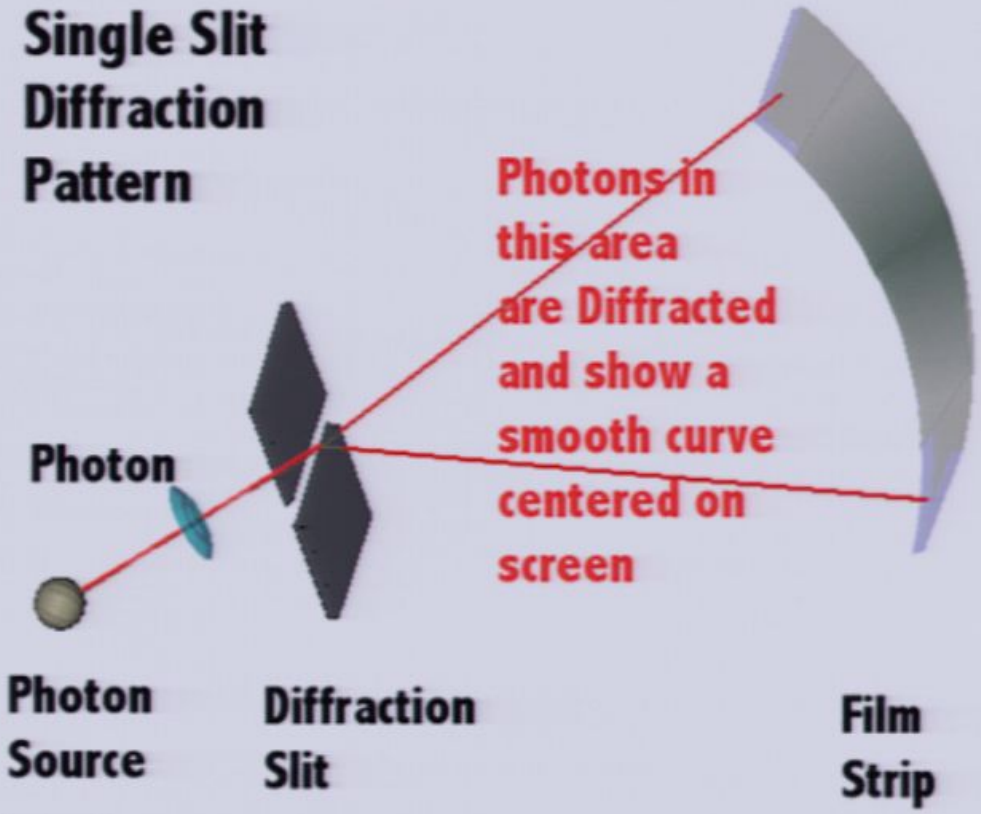
Many worlds universe



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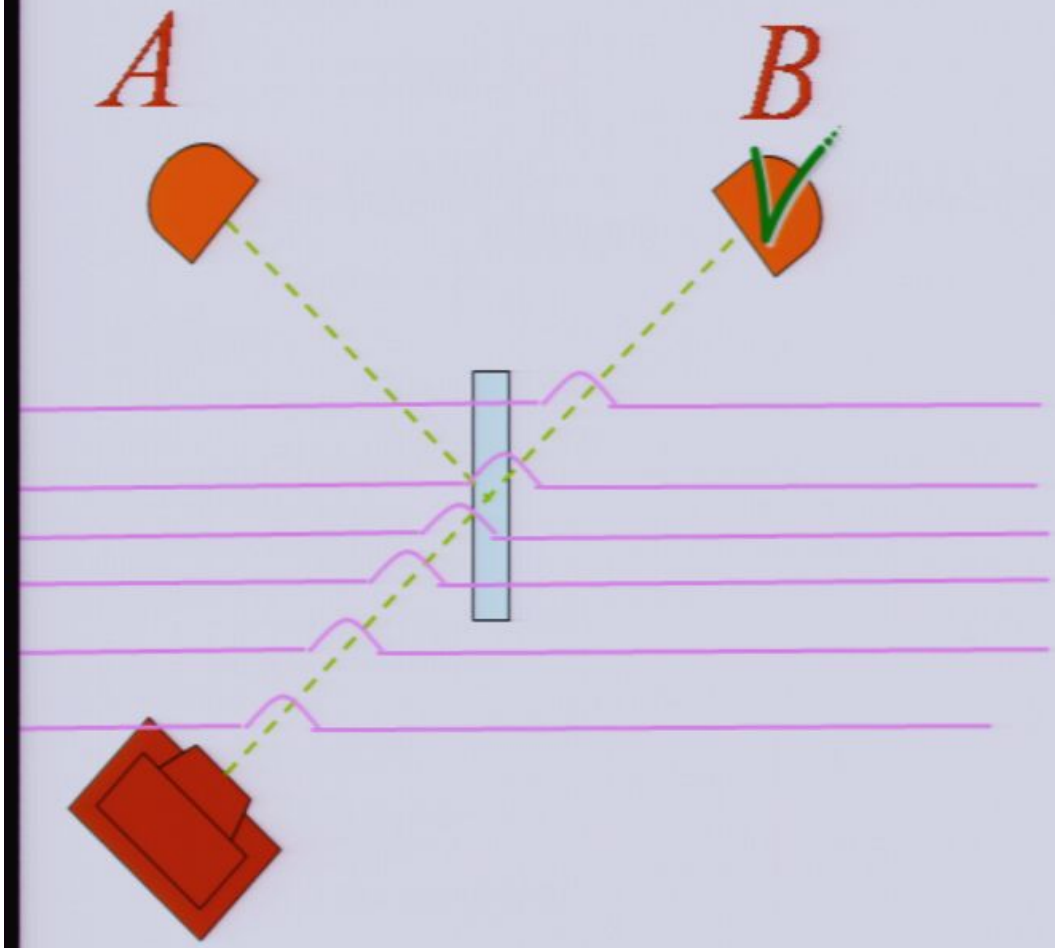

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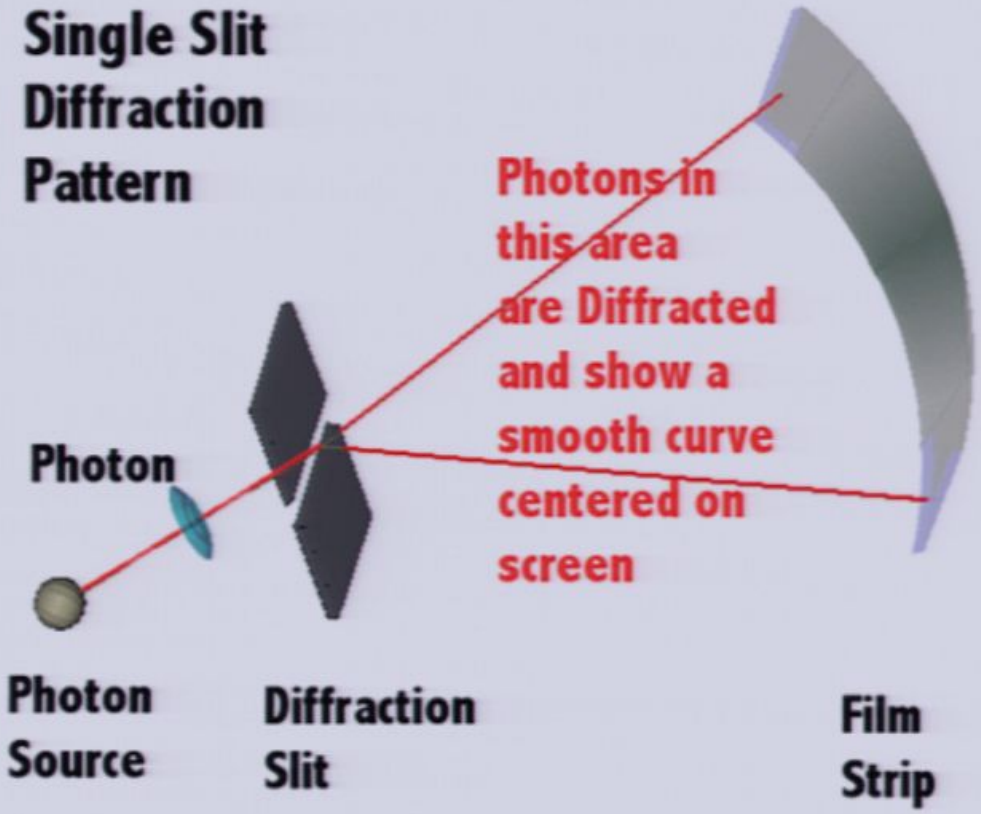

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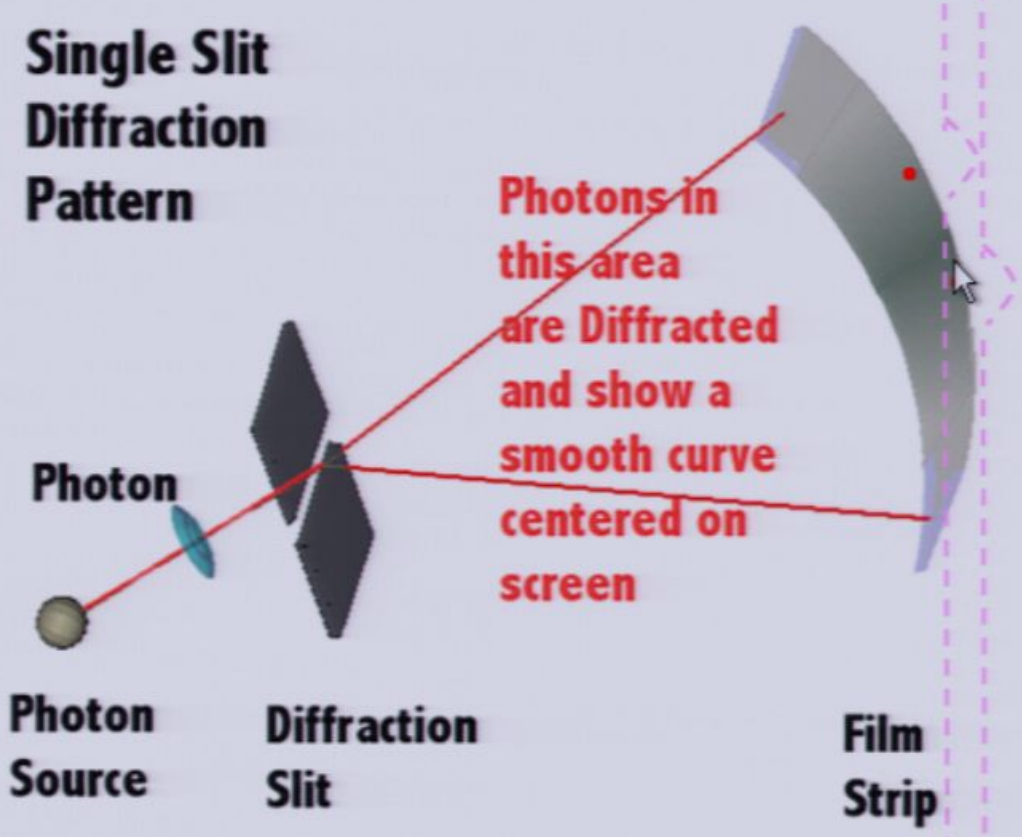

Locality and strength of the interaction to numerous particles ensure stability of all worlds

The tree of worlds

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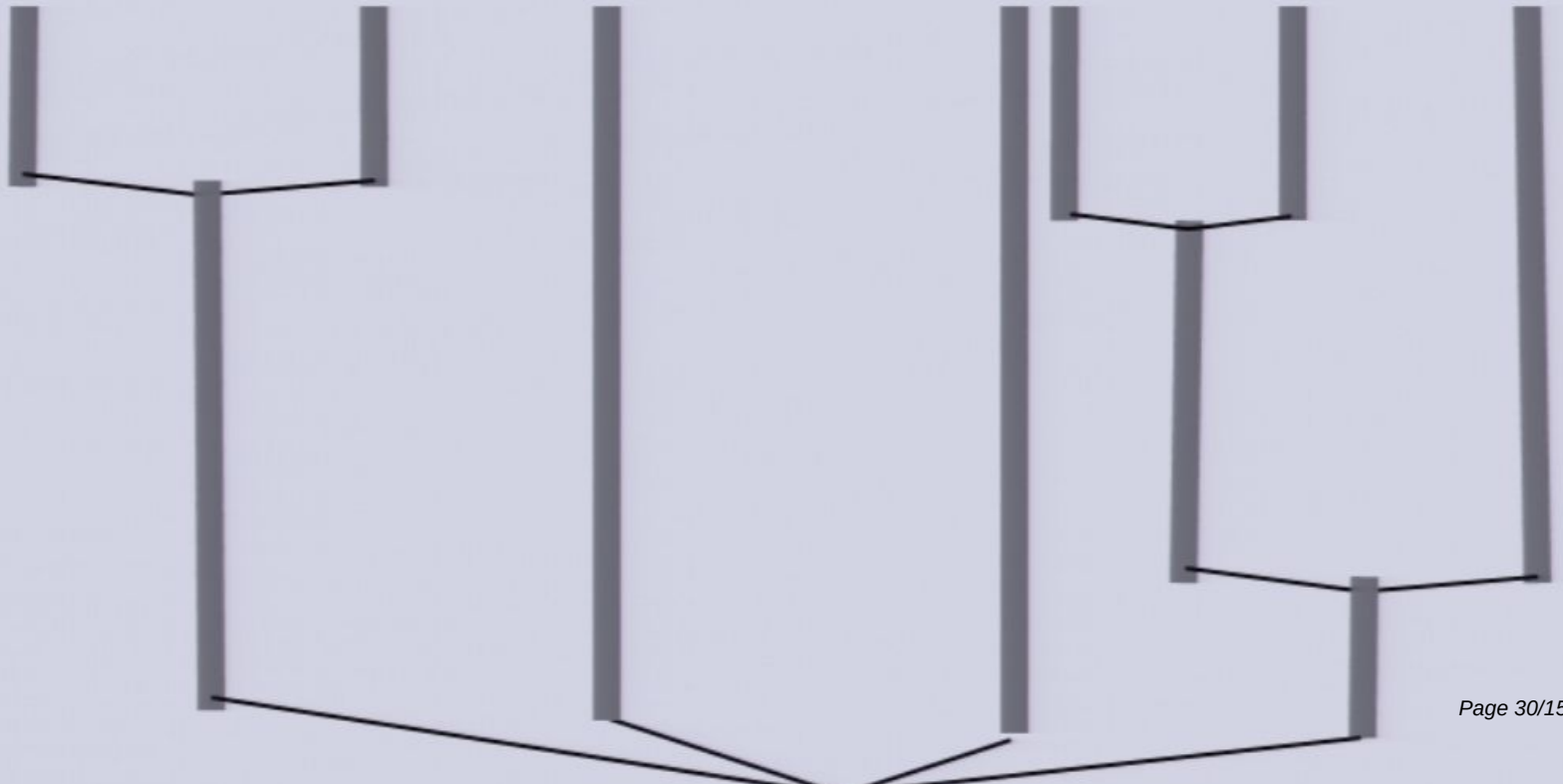

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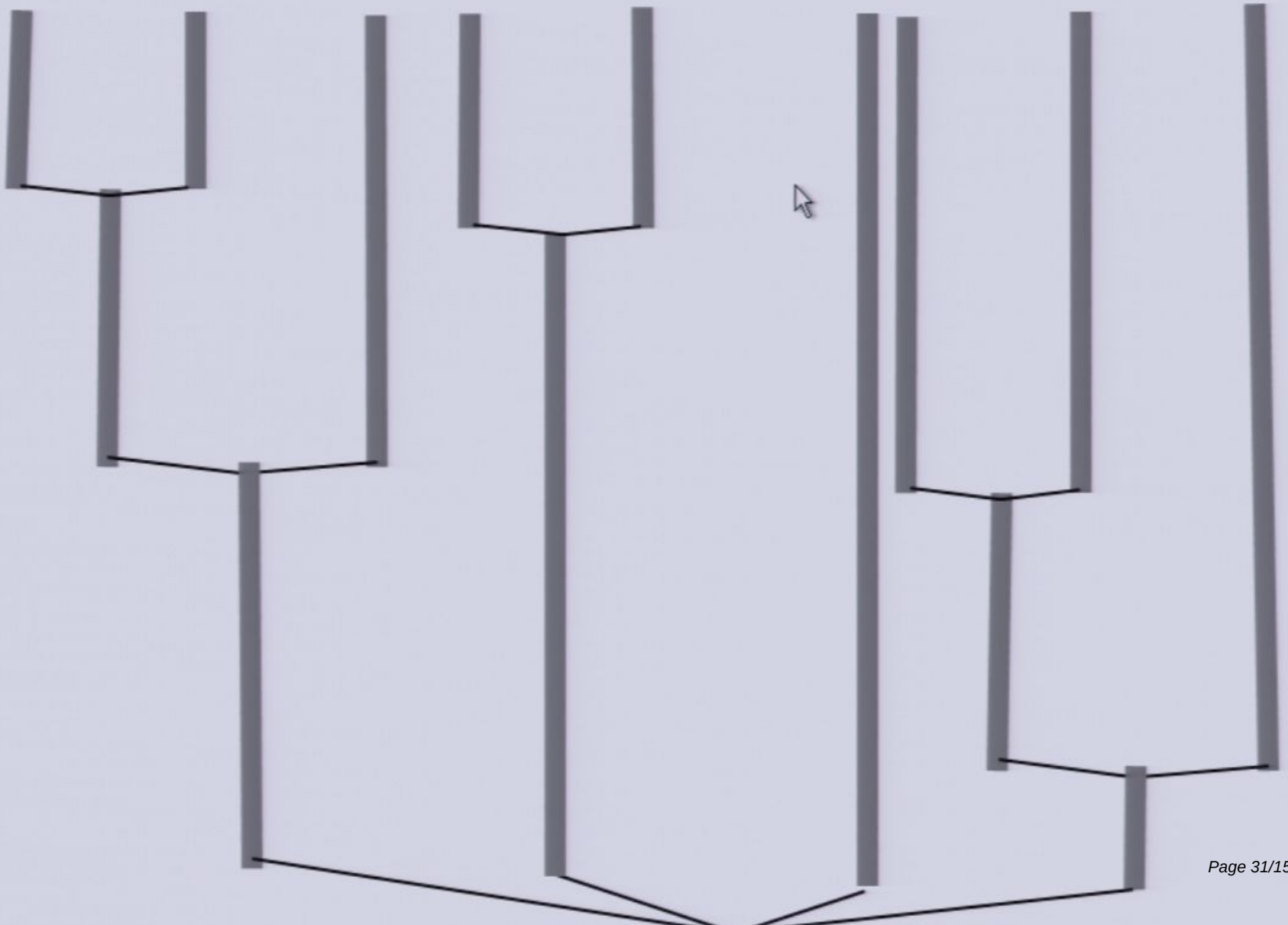
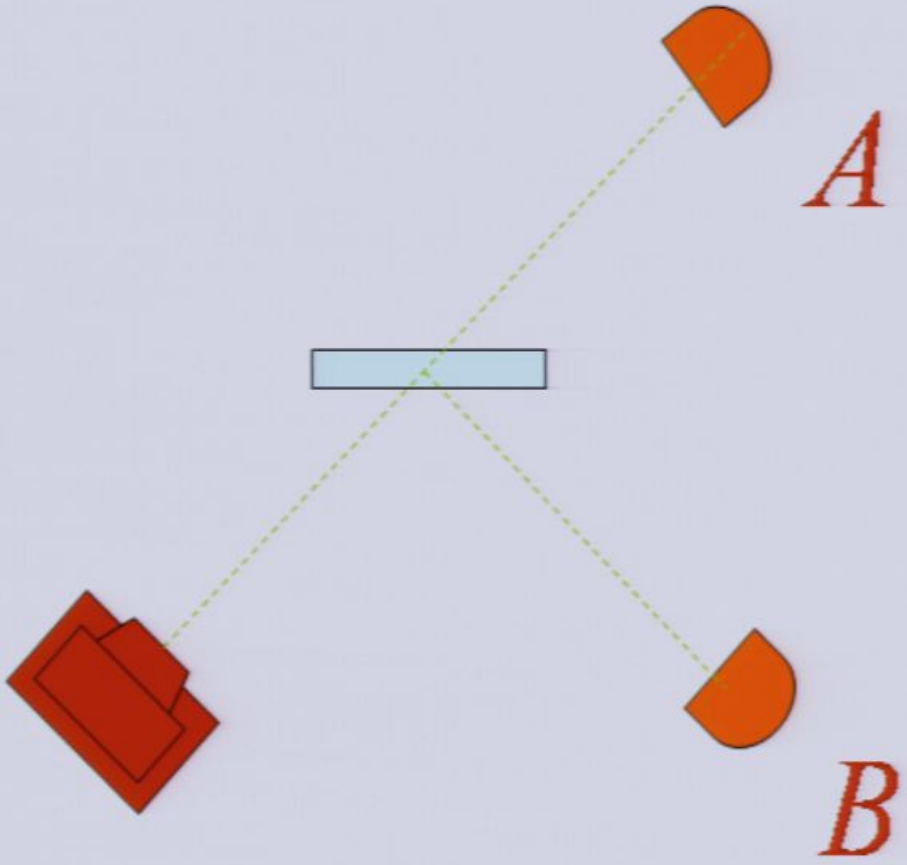


Test of the MWI



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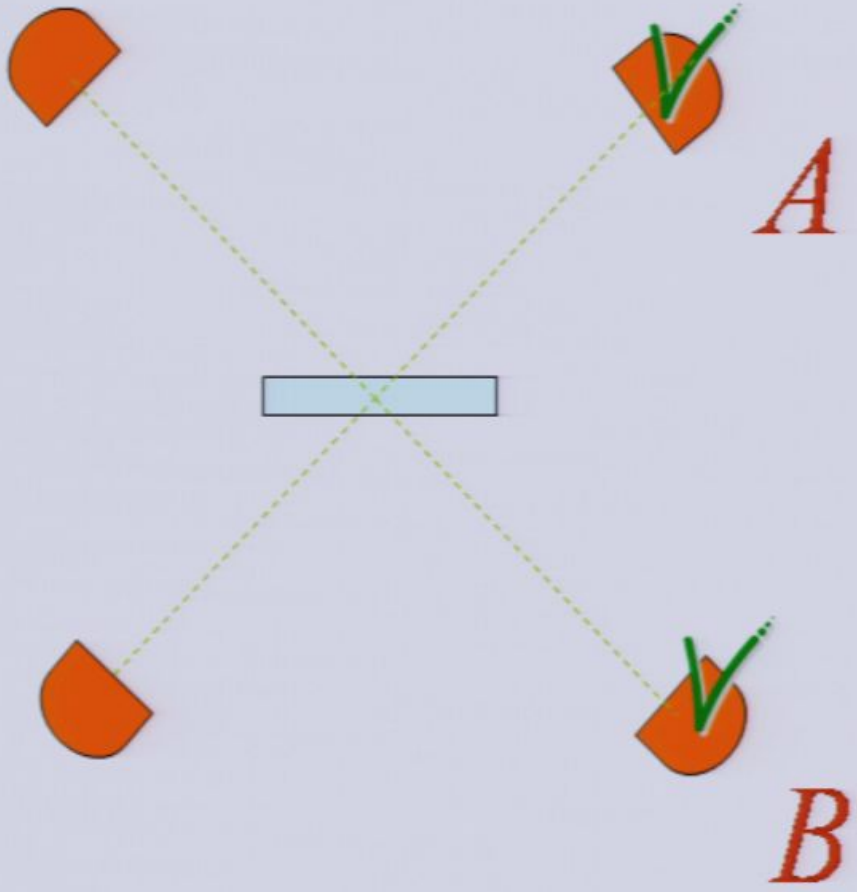

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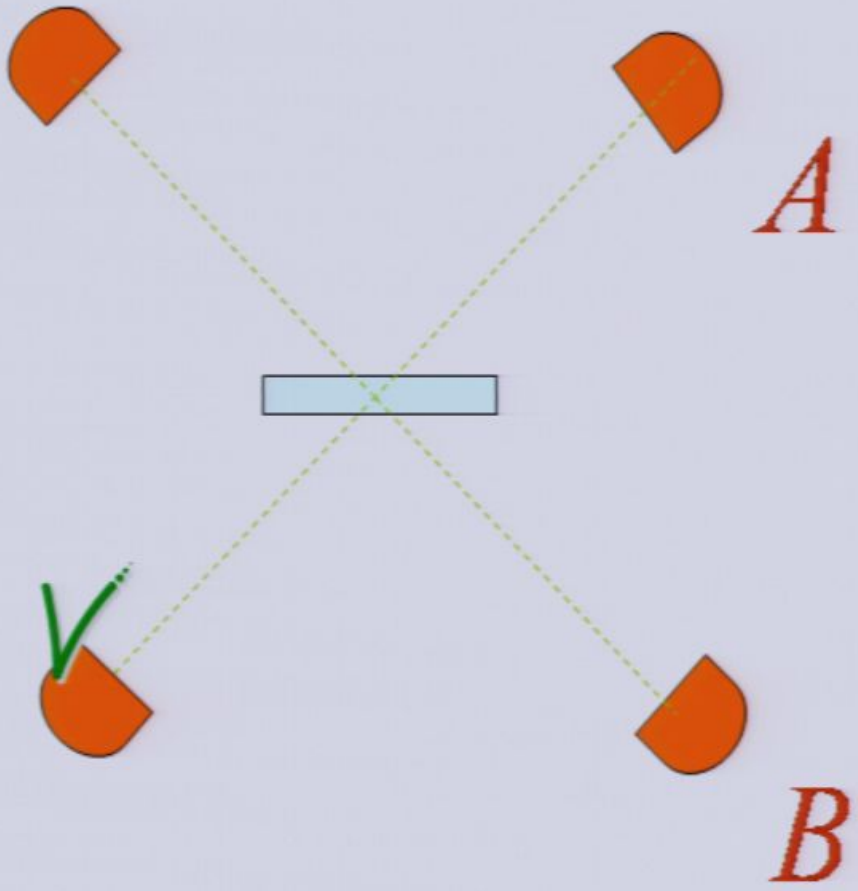

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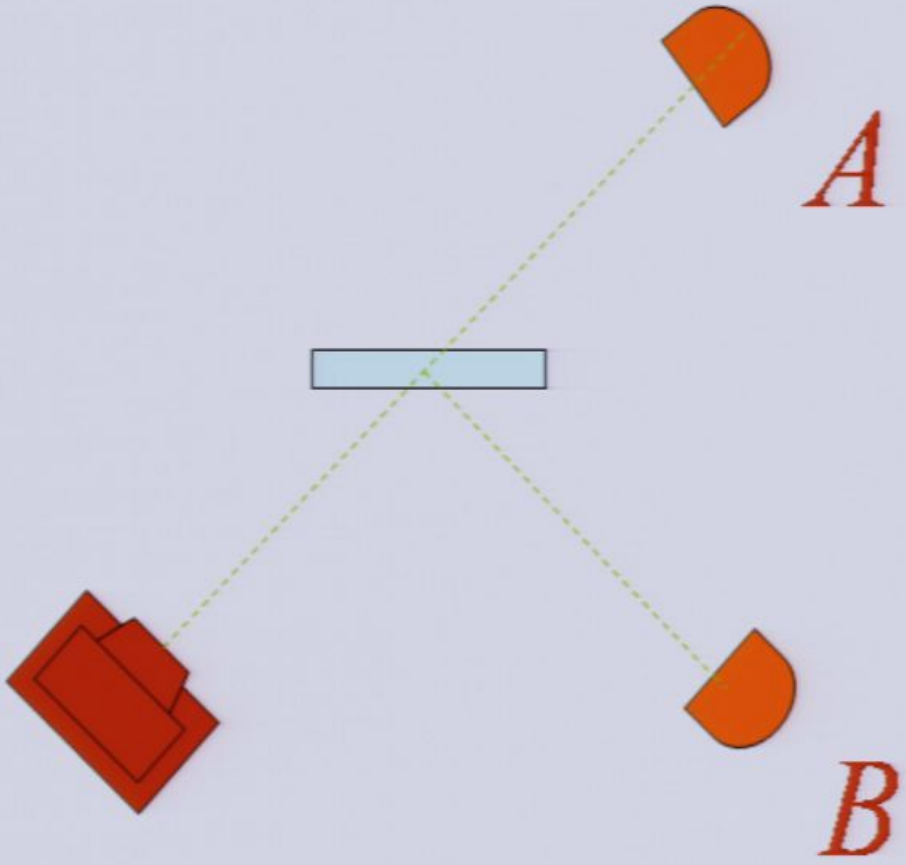

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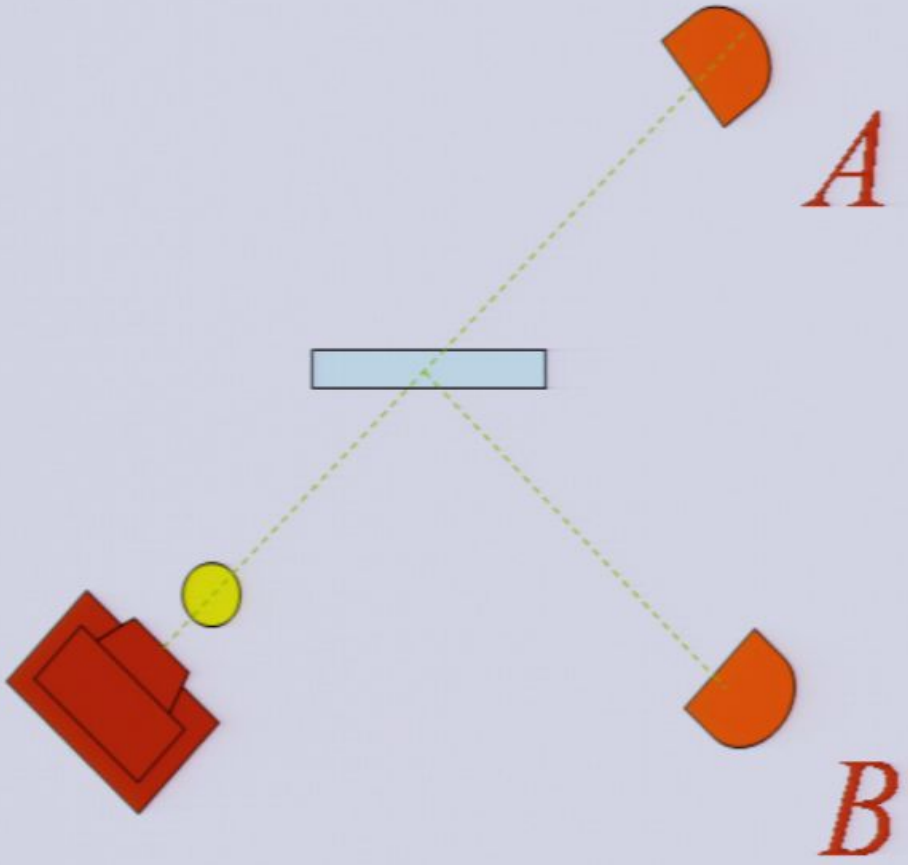

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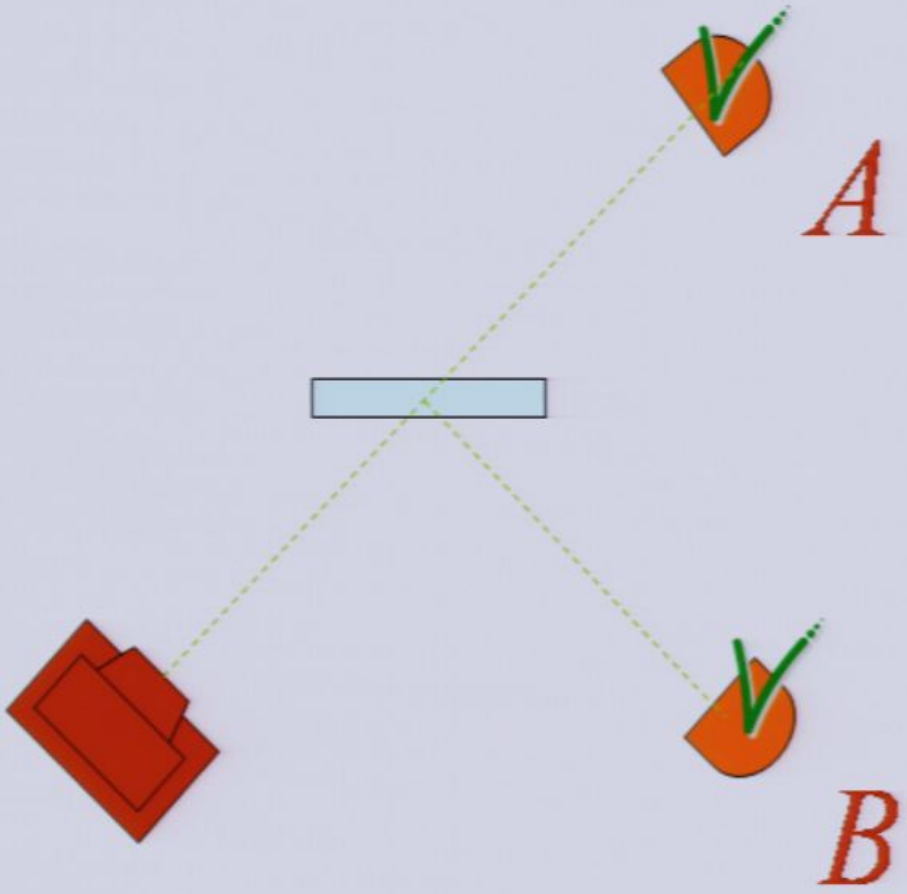

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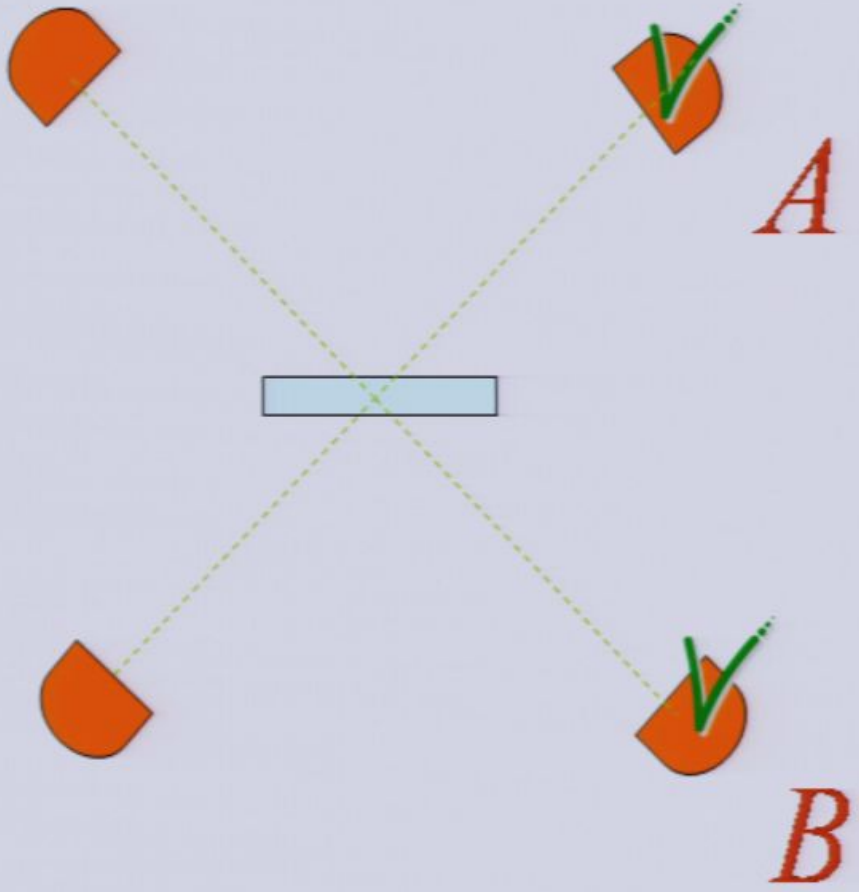

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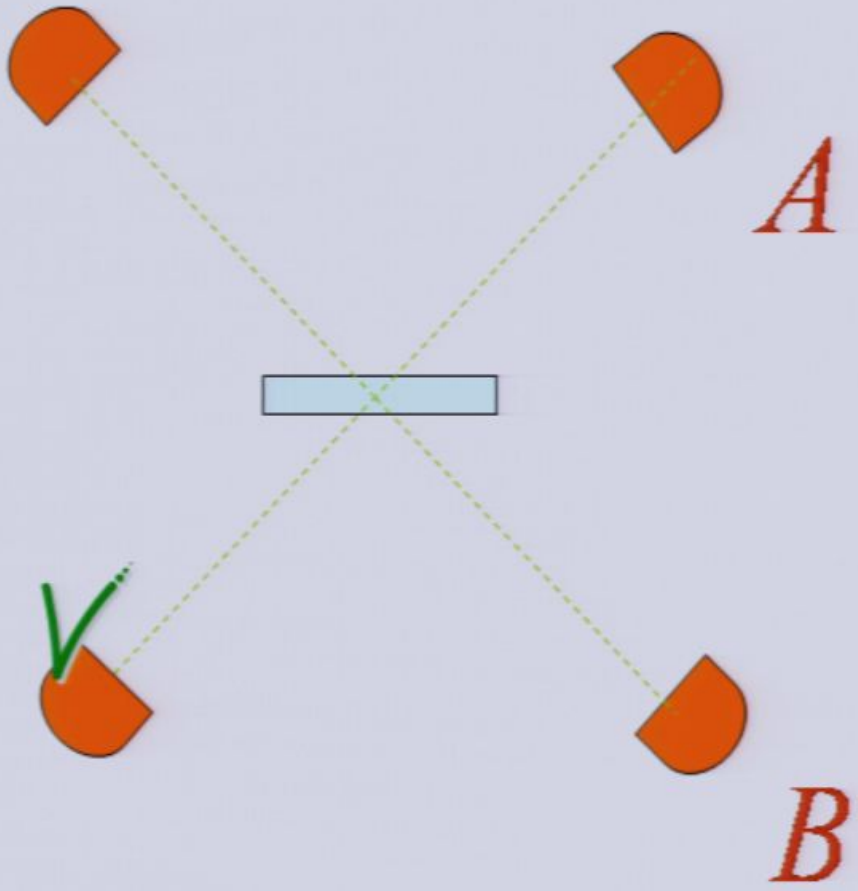
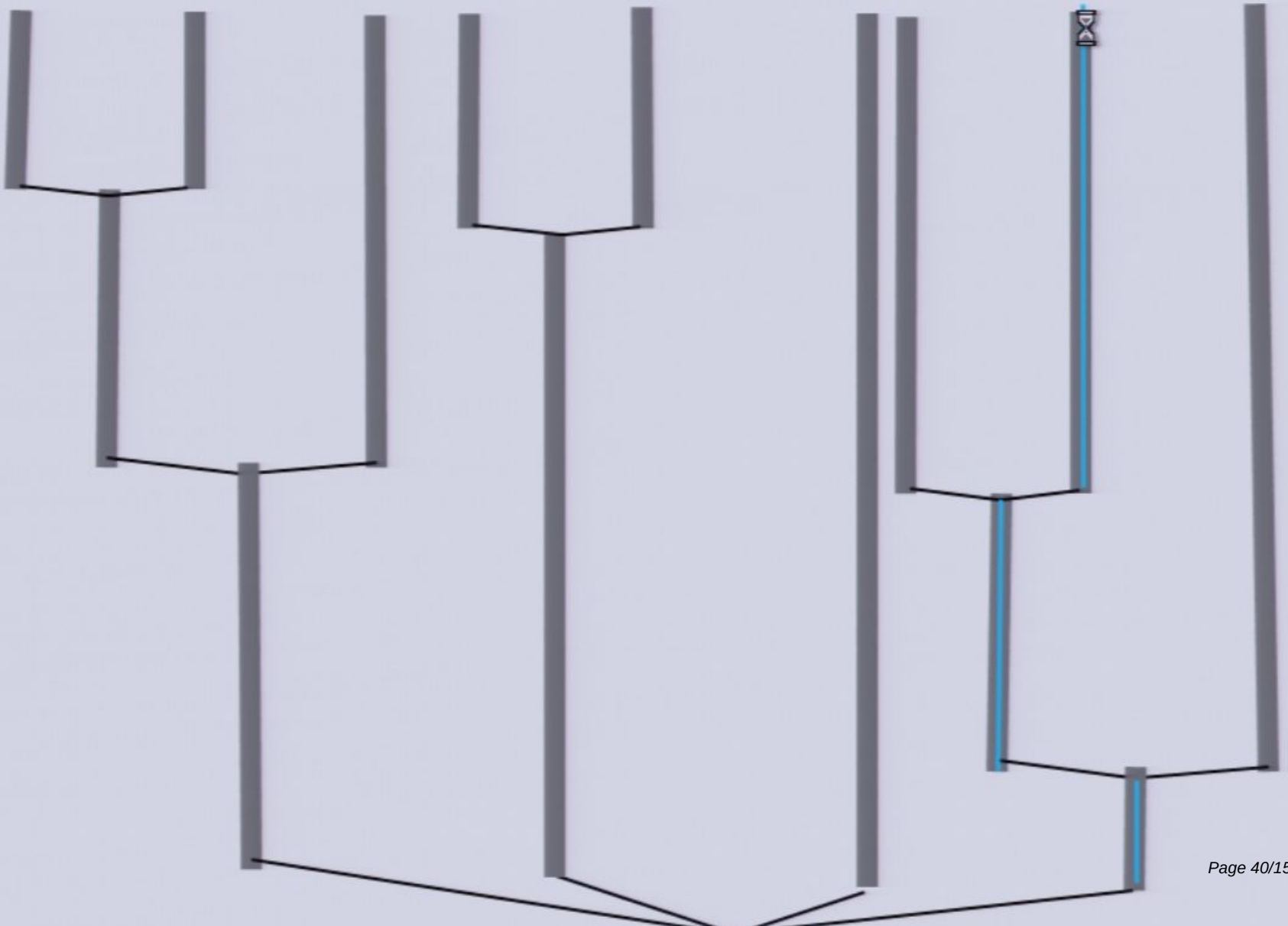


The tree of worlds



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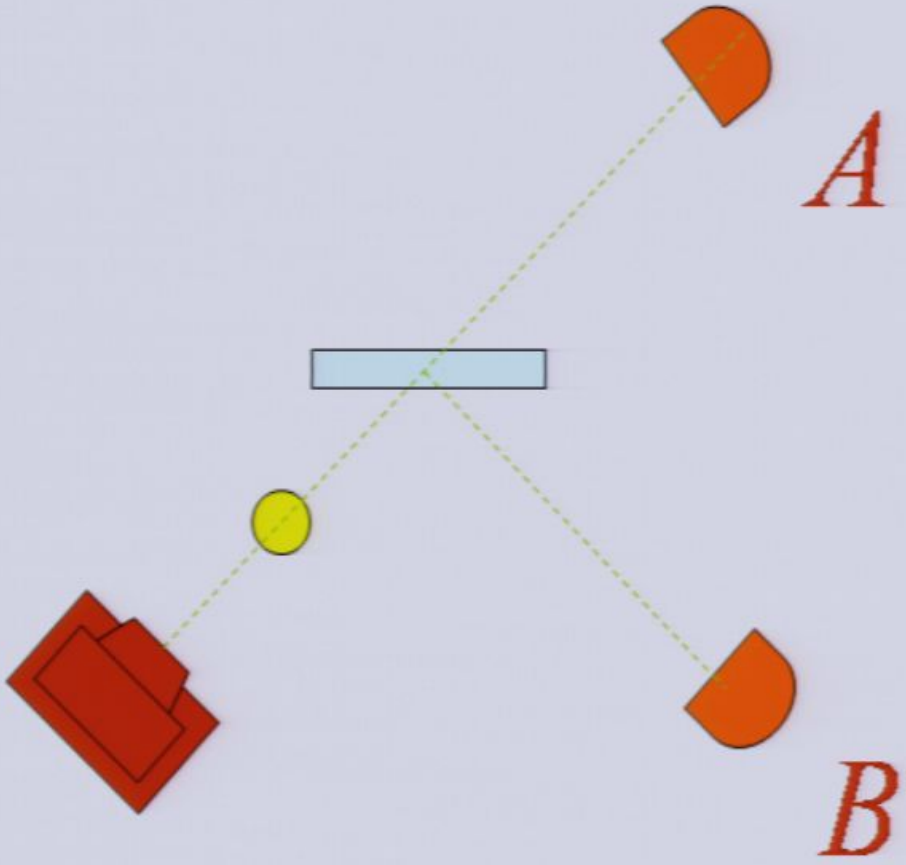

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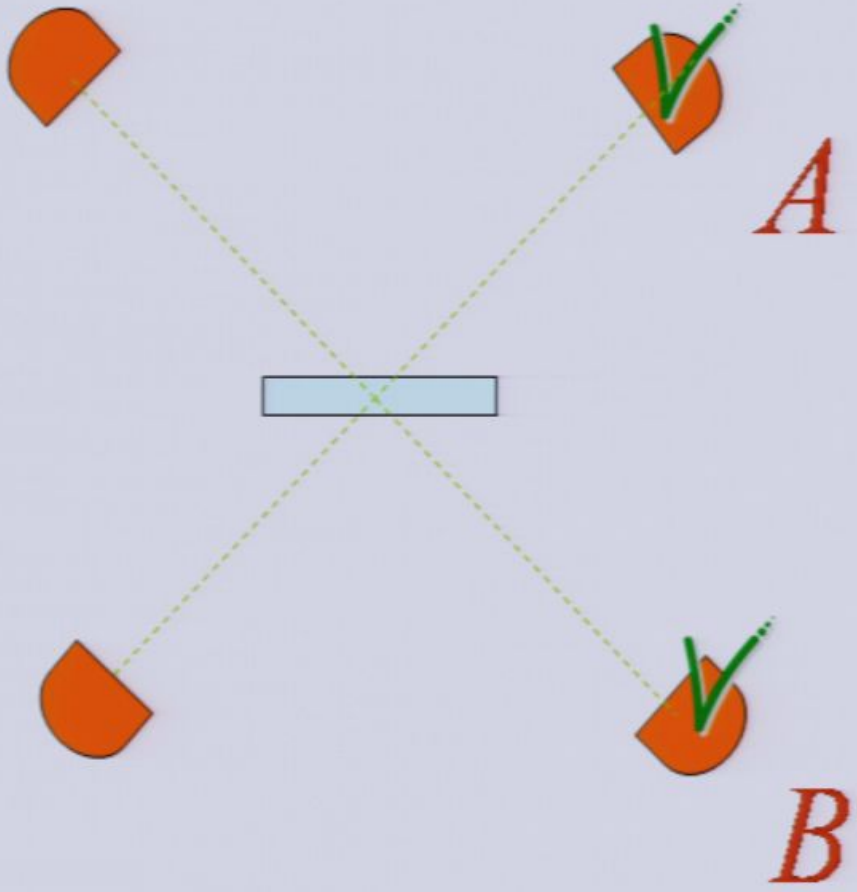
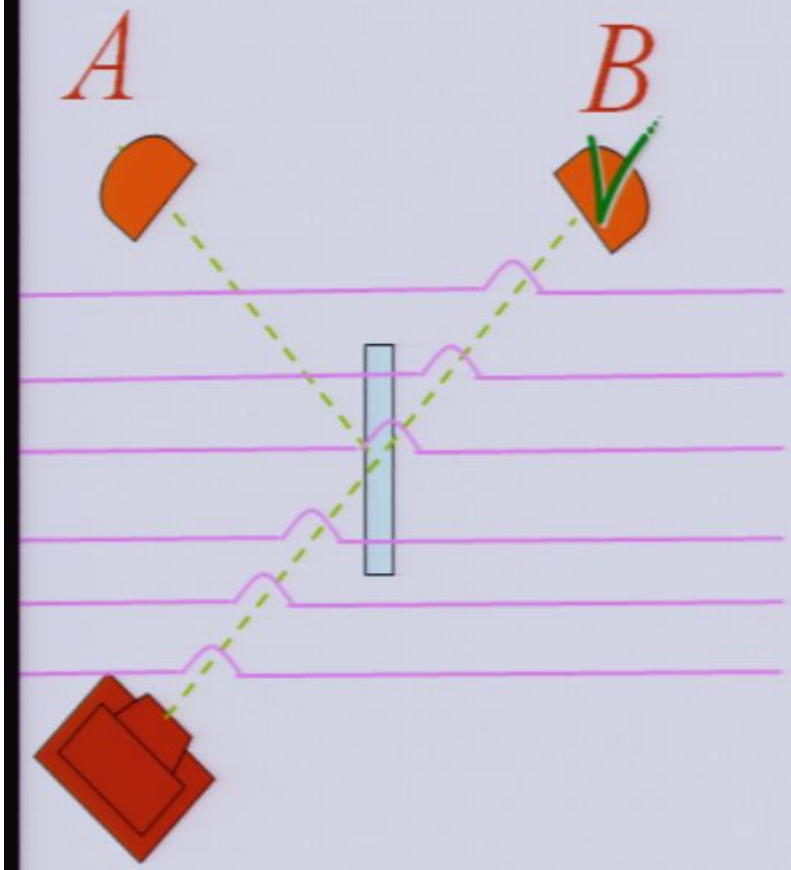
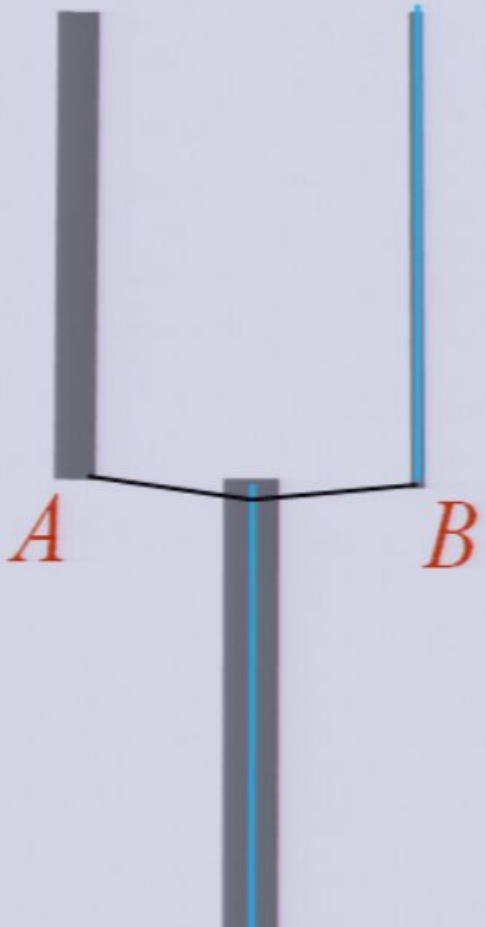


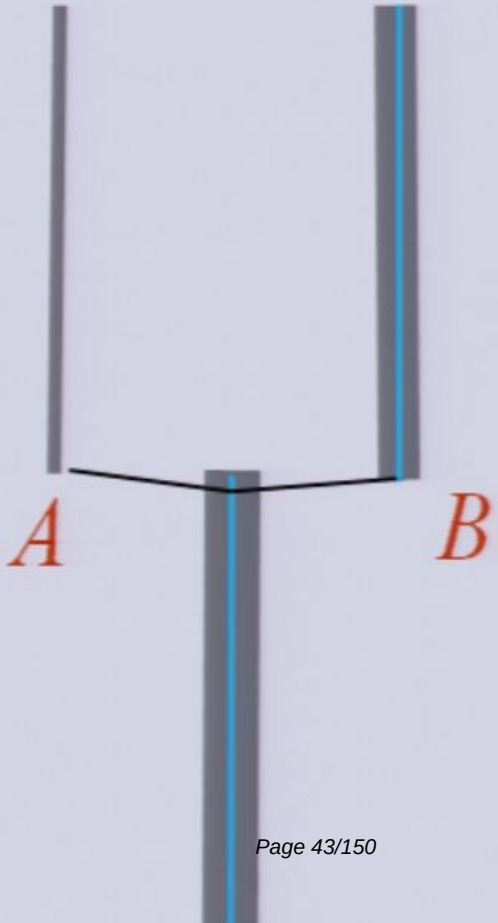
Do we experience amplitude?

$$|\Psi_i\rangle = \sqrt{\frac{3}{4}}|\Psi_A\rangle + \sqrt{\frac{1}{4}}|\Psi_B\rangle \quad ? \quad |\Psi_i\rangle = \sqrt{\frac{1}{4}}|\Psi_A\rangle + \sqrt{\frac{3}{4}}|\Psi_B\rangle$$



Experience world B ⟺ **Experience world B**





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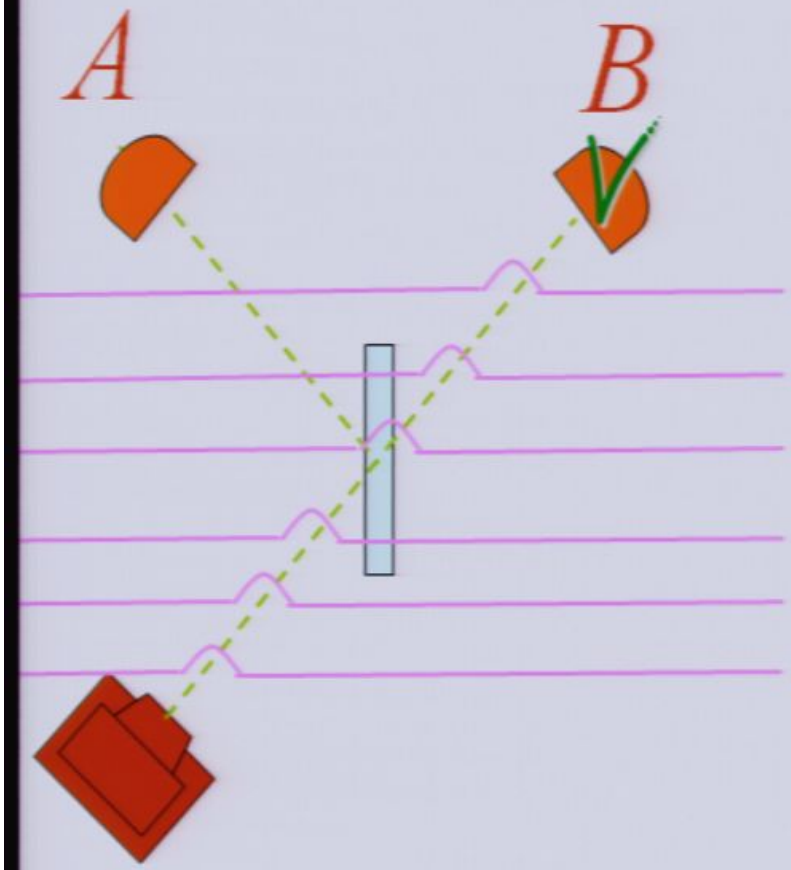

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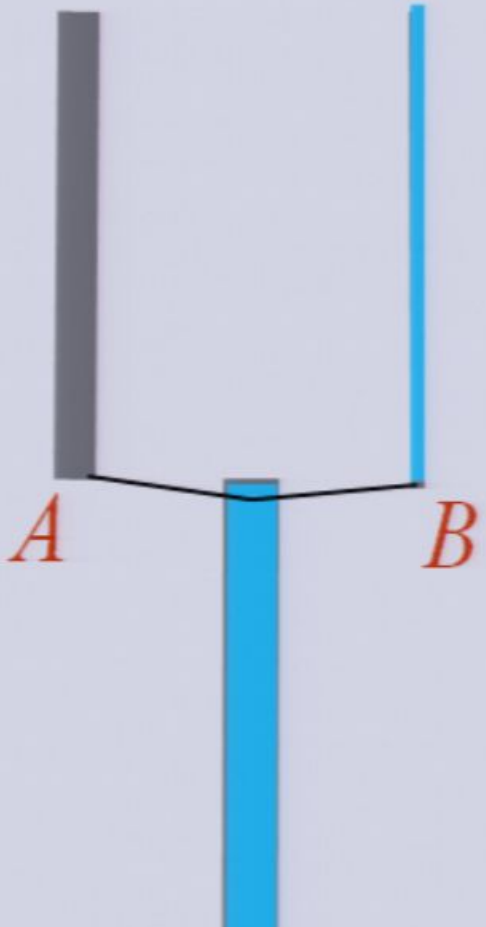

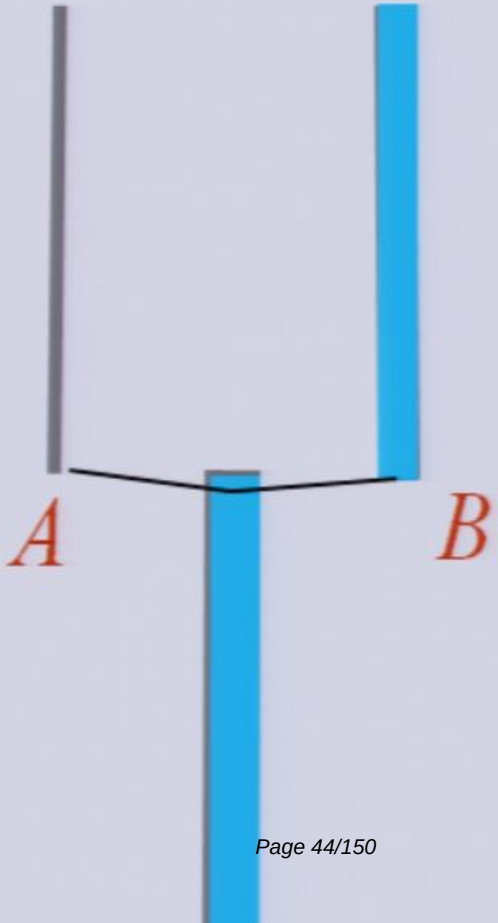

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Wikipedia

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Subjective probability

degrees of confidence, or credences, or "partial" beliefs of suitable agents.

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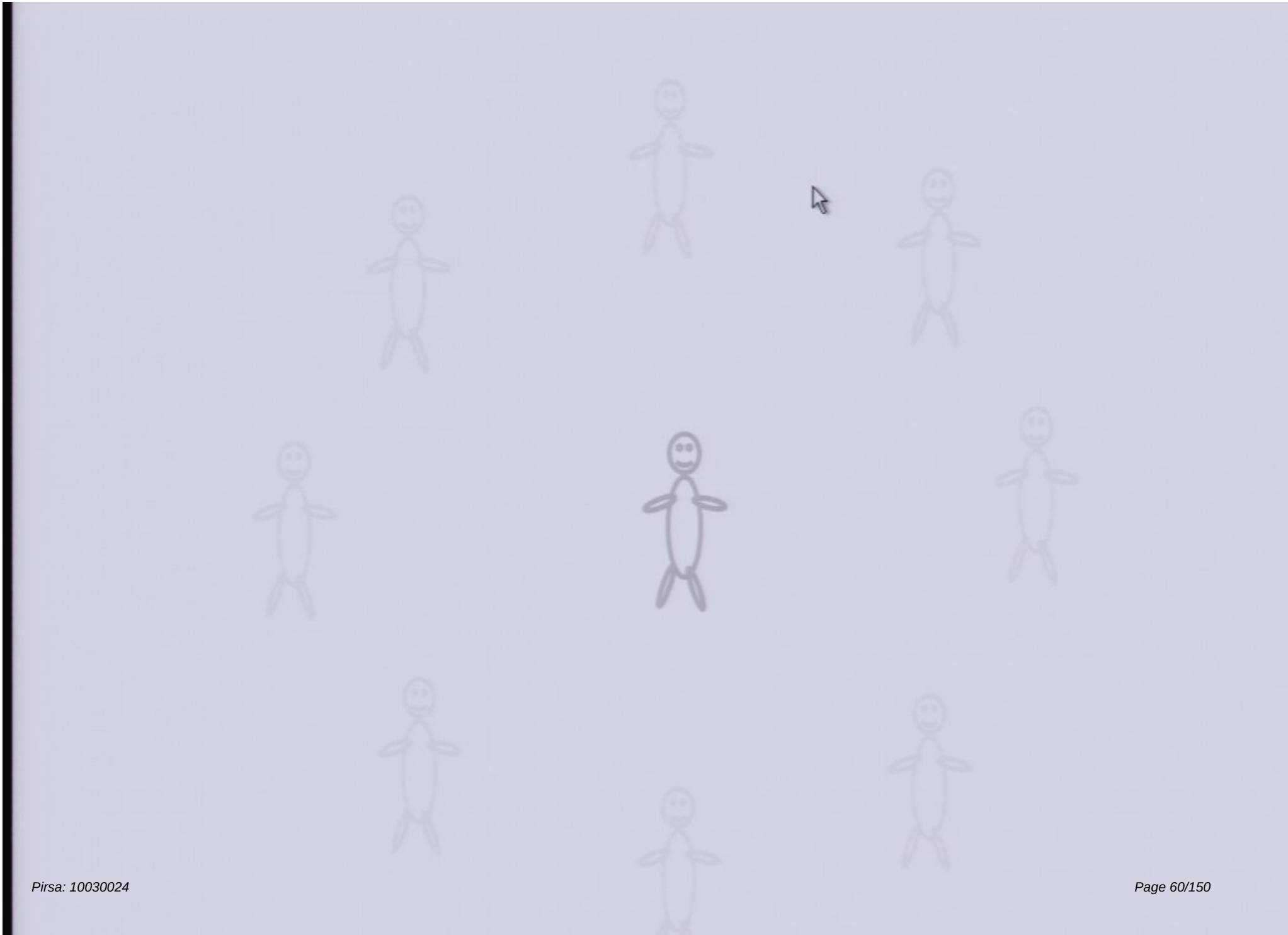
Classical Many Worlds

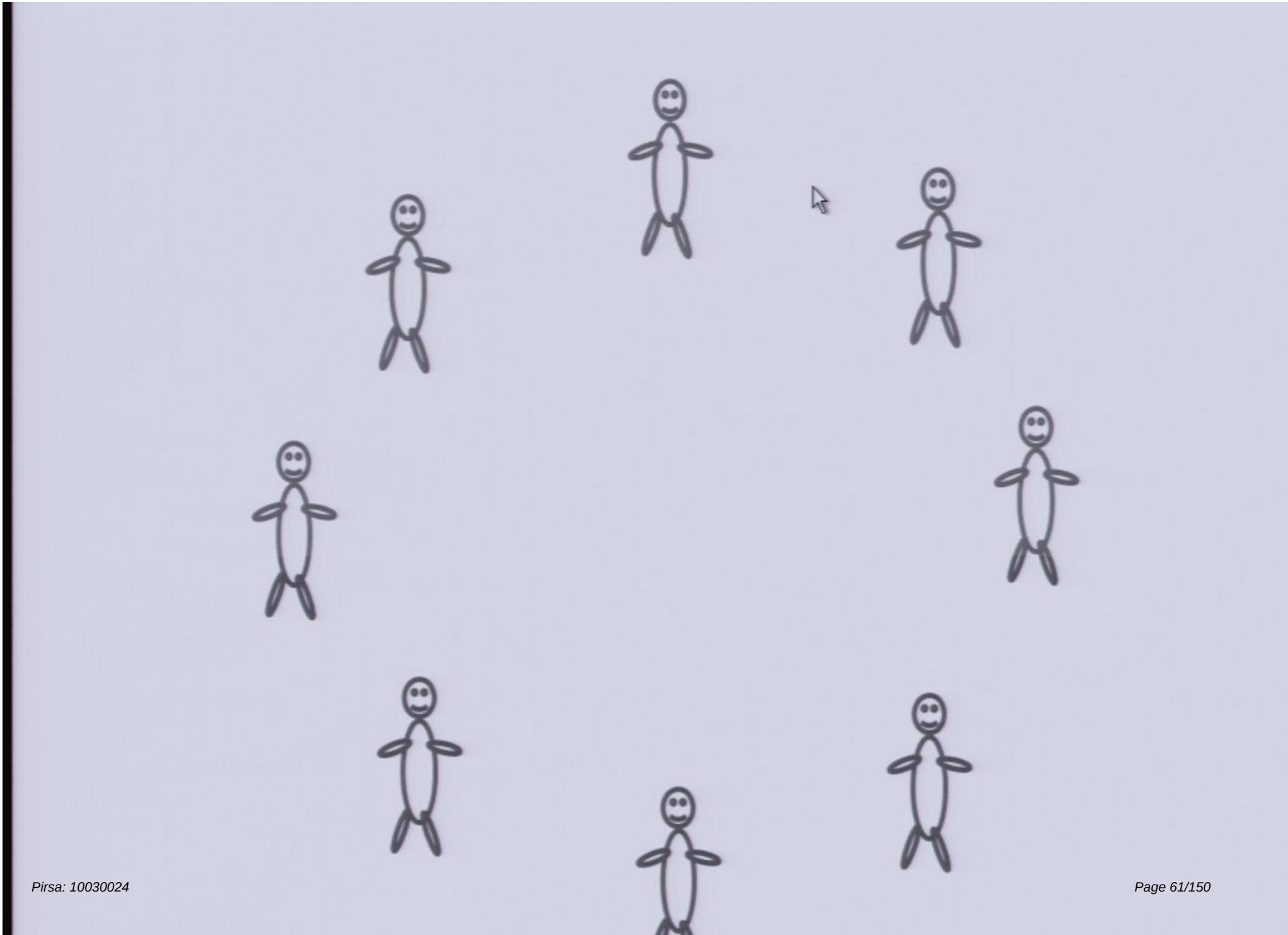
Teleportation

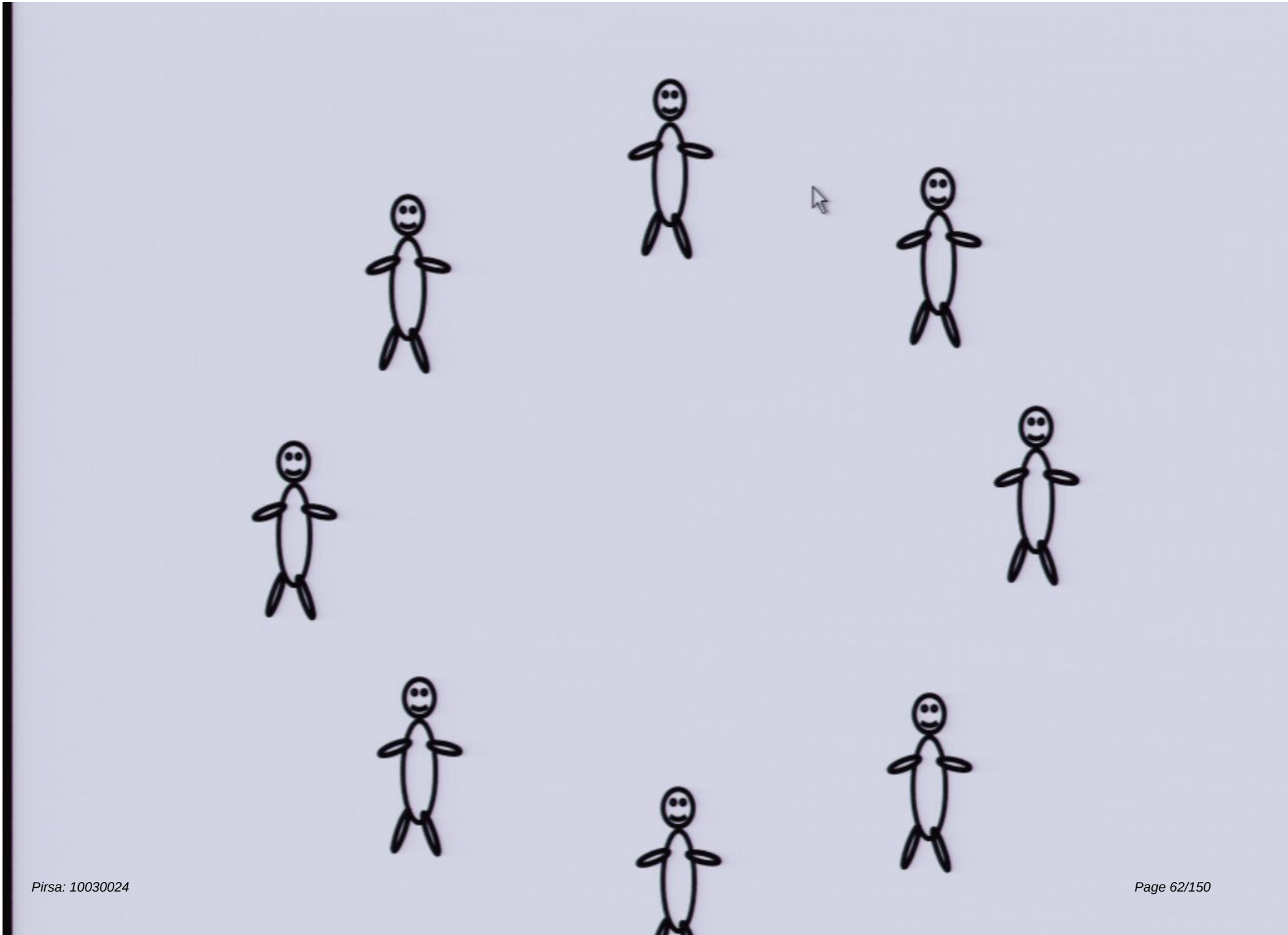
Teleportation

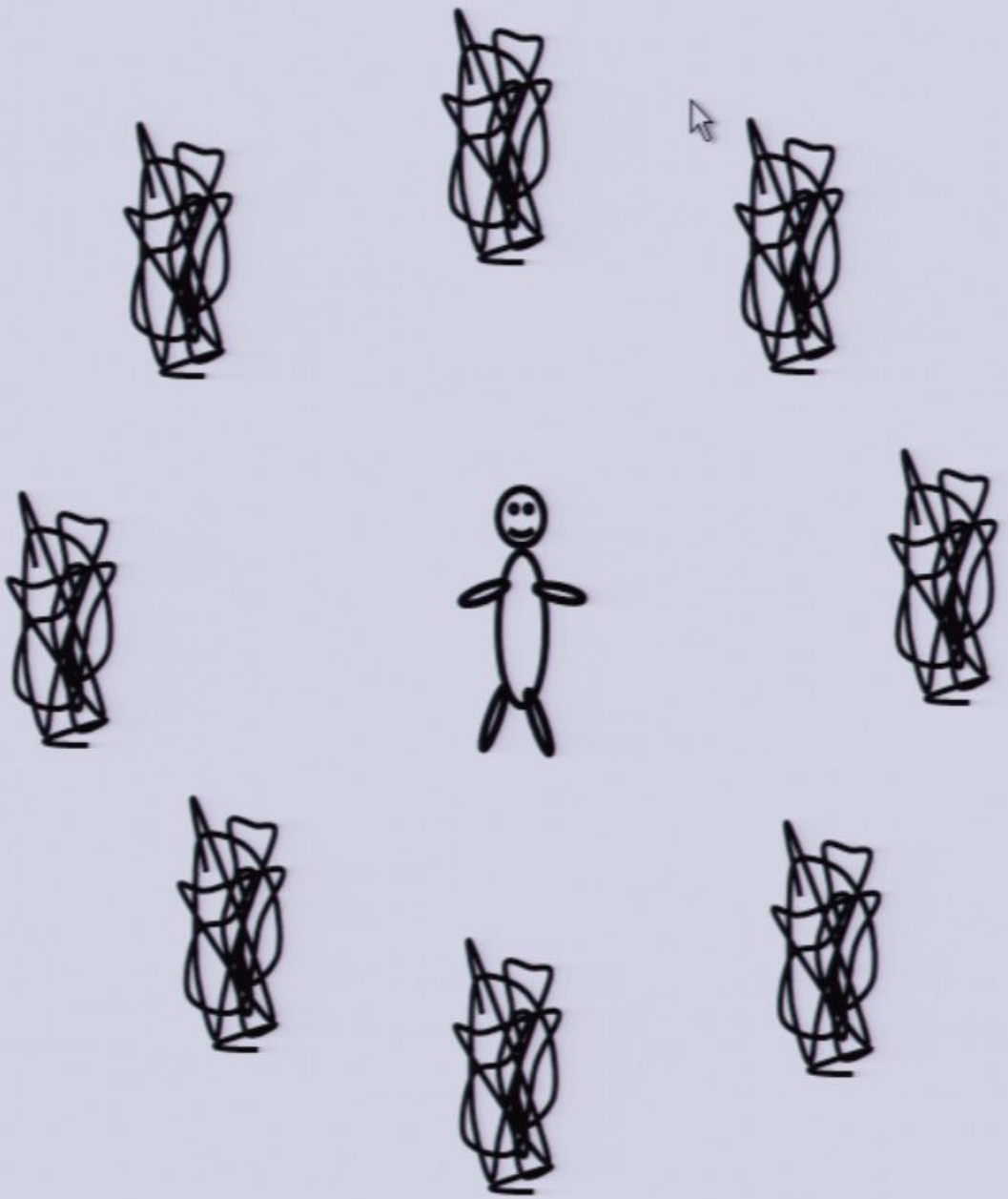
Classical teleportation

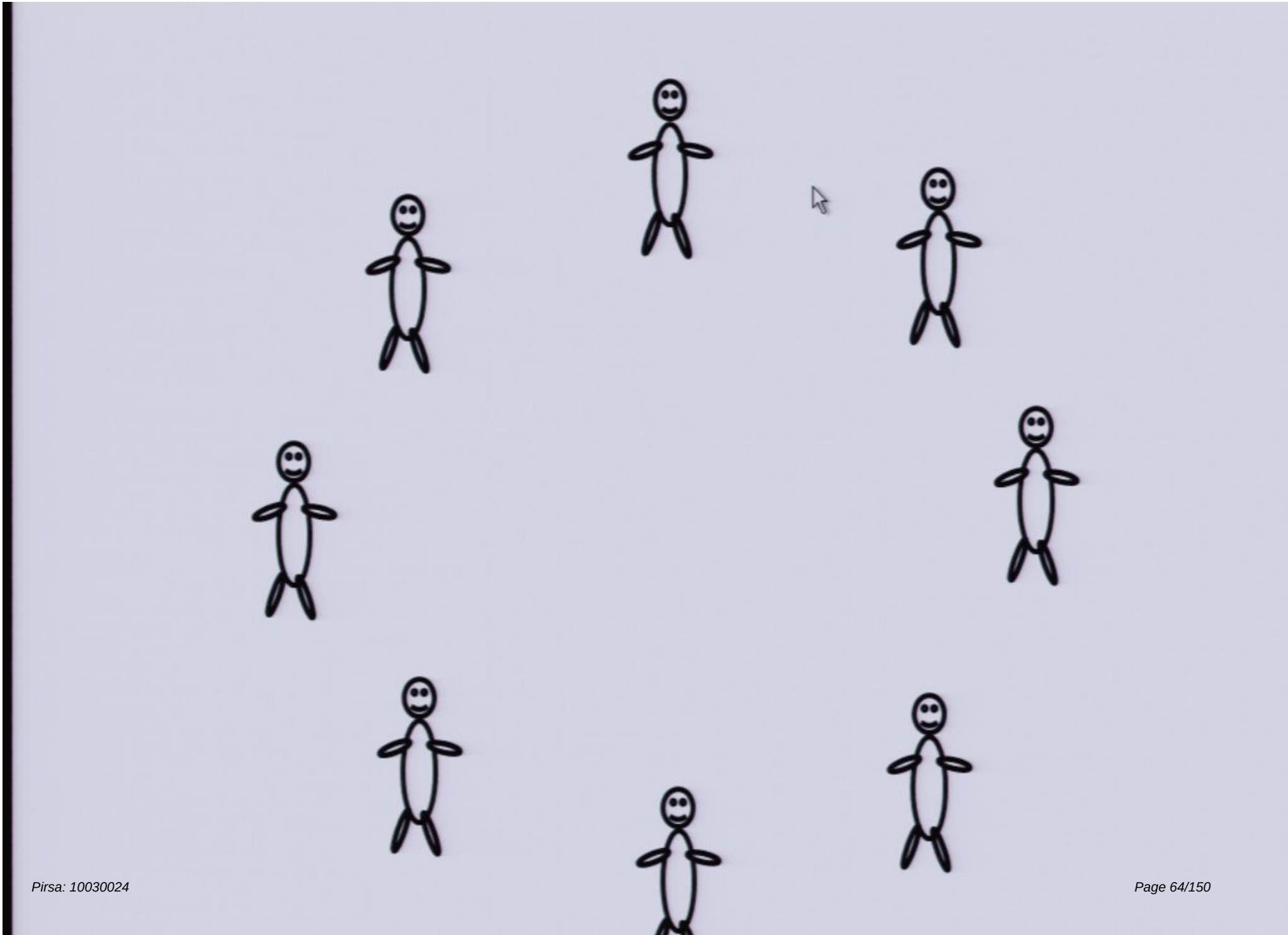
Classical teleportation

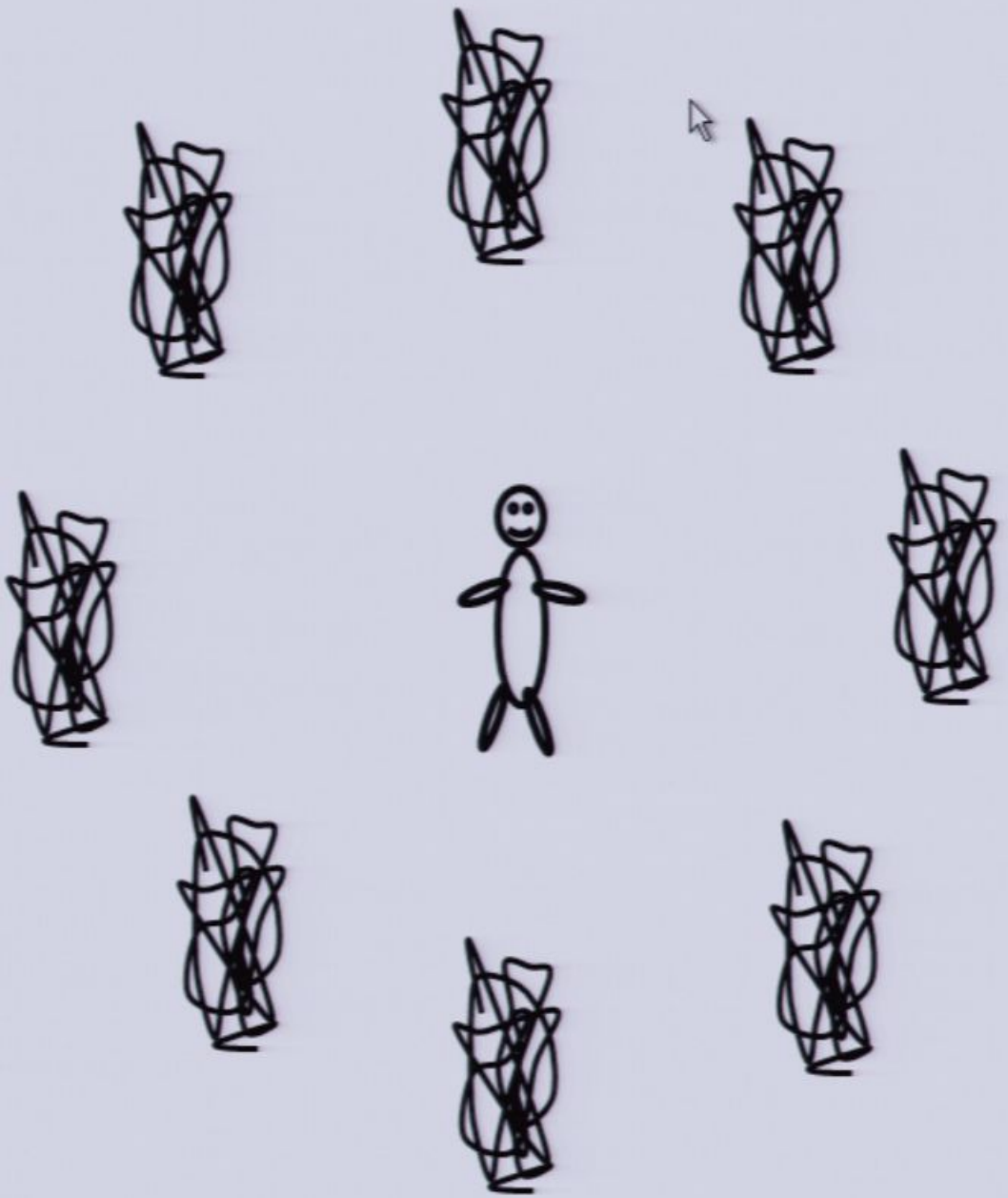


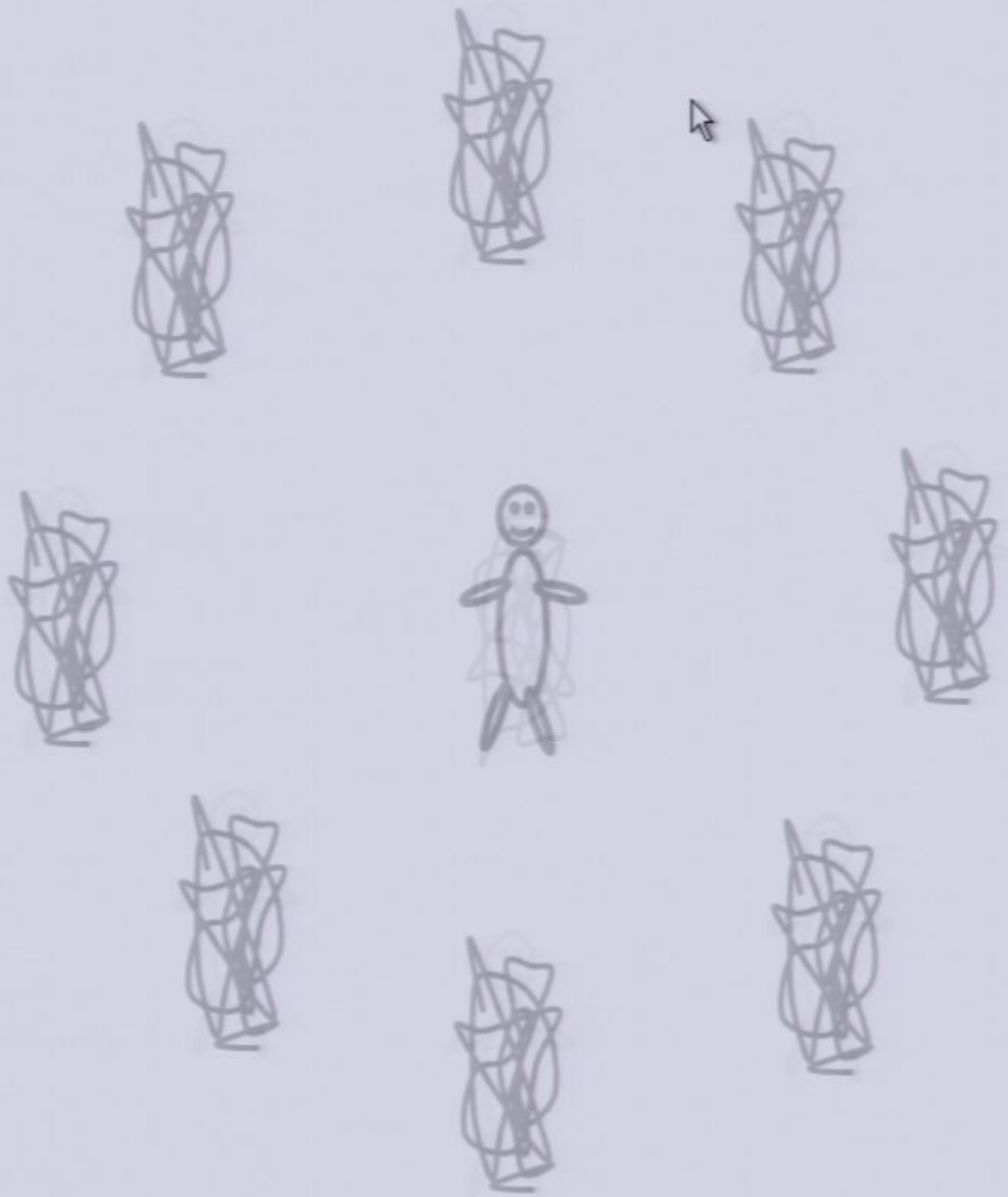


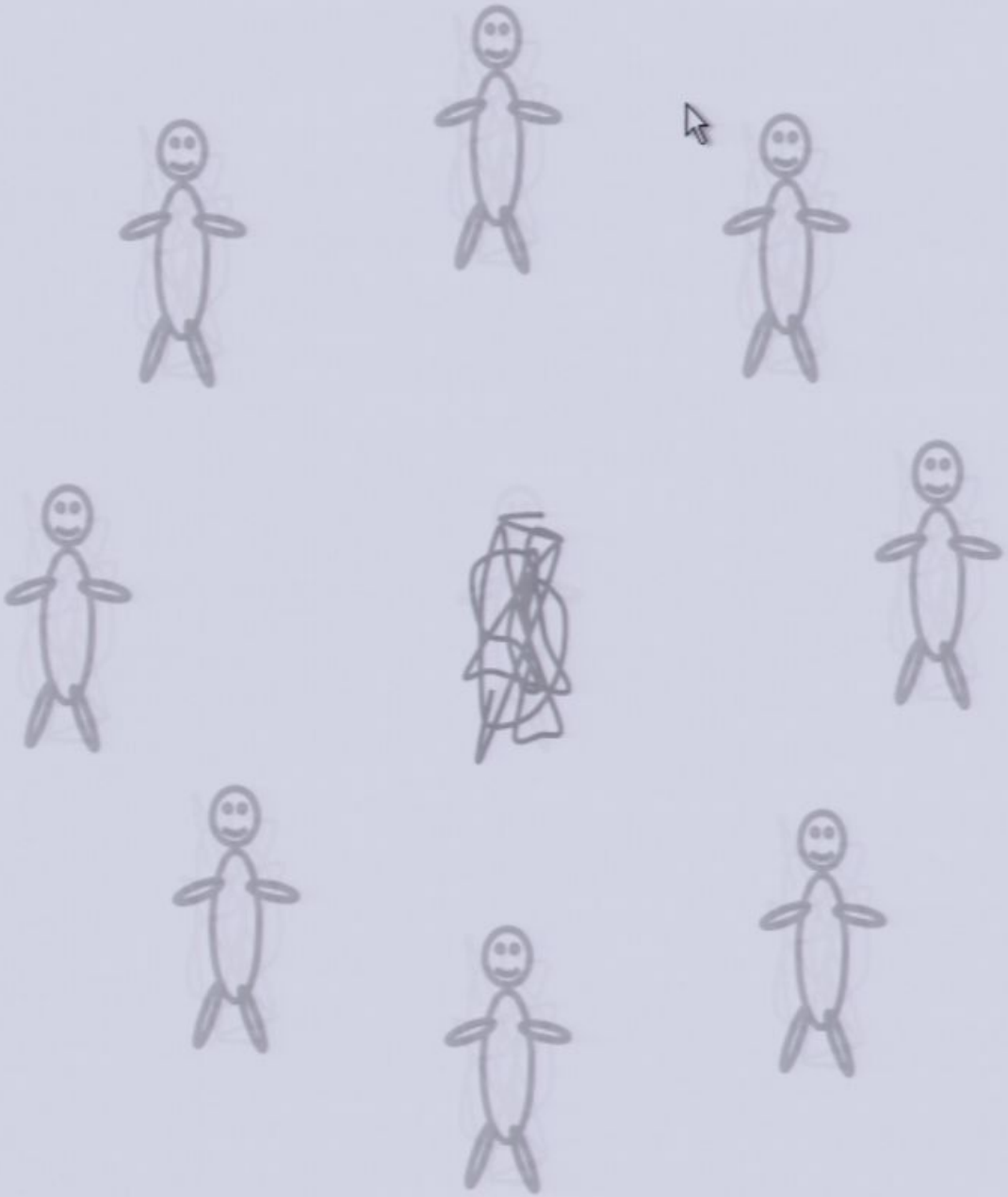


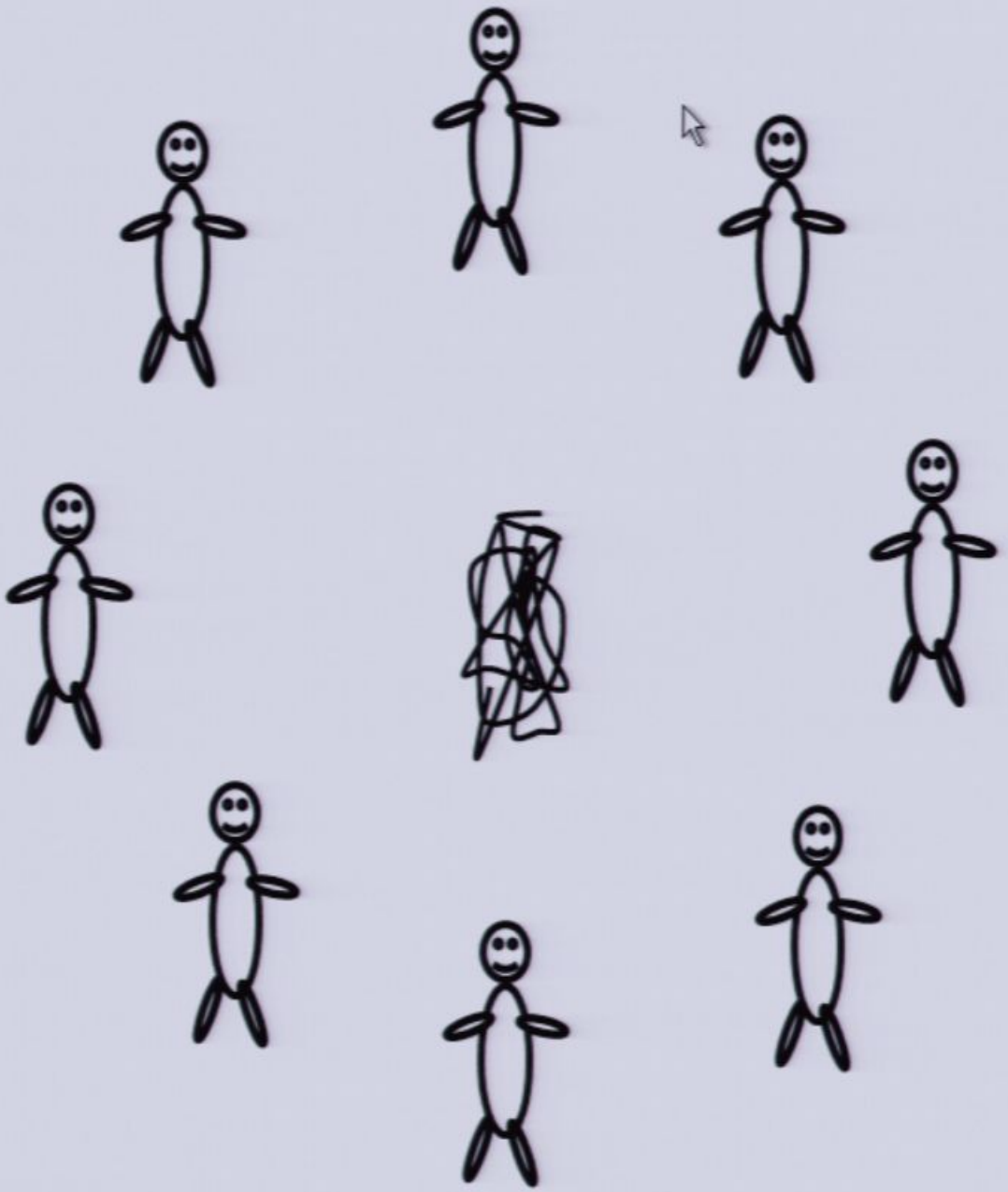


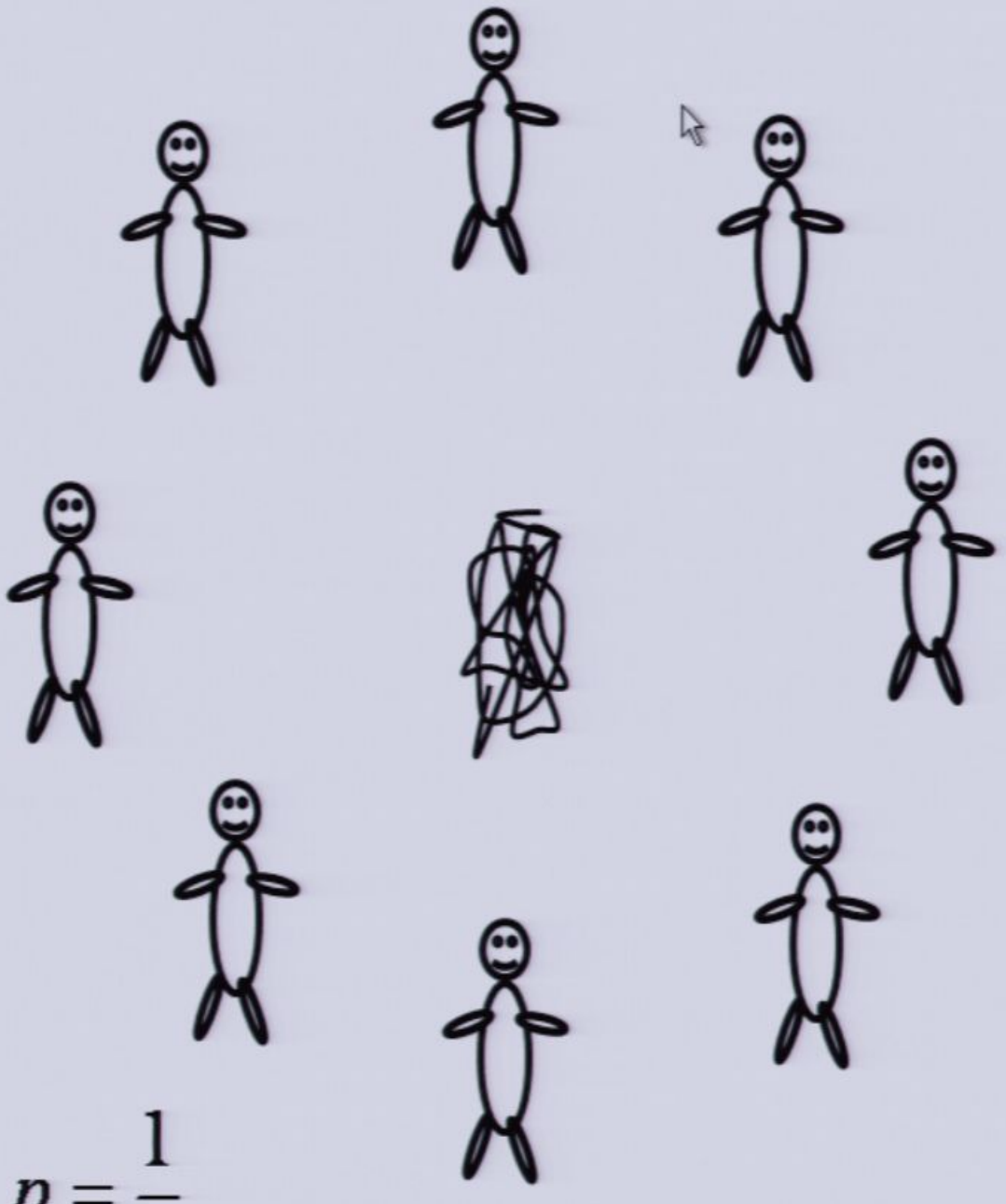






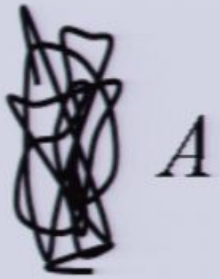






symmetry $\Rightarrow p = \frac{1}{-}$

Probability of something to happen – A or B?



A

B

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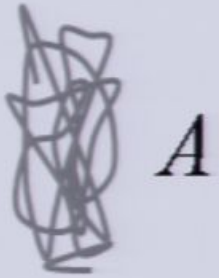

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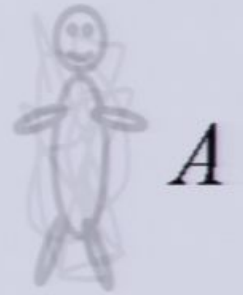

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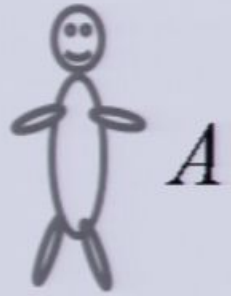

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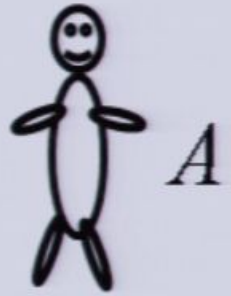

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Here: A and B

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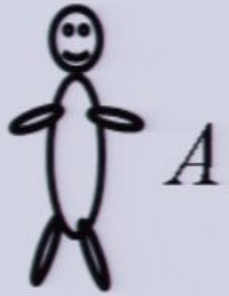

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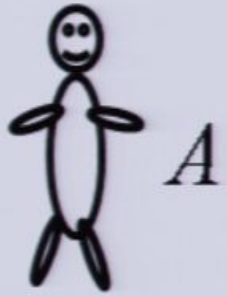

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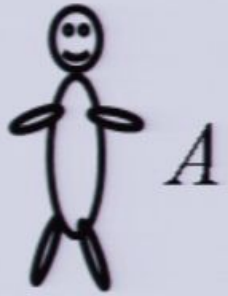

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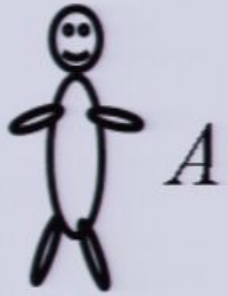

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Measure of existence: Can it be different from 0 and 1?

A

$\mu_A = 0$

$\mu = 1$

B

$\mu_B = 0$

Measure of existence: Can it be different from 0 and 1?

A

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B

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A

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Measure of existence: Can it be different from 0 and 1?

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$\mu_A = 5$

$\mu = 0$

B

$\mu_B = 3$

de Finnetti readiness to bet is proportional to the measure of existence

Probability Problems of the MWI of QM

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Probability given by the number of worlds yields wrong predictions

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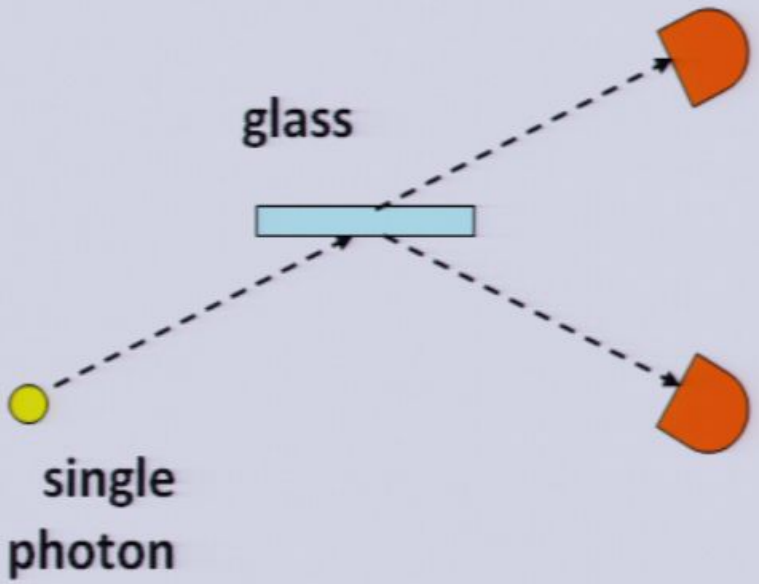

	Quantum probability	Numbers of worlds probability
A	0.9	0.5
B	0.1	0.5

$$|\Psi\rangle = \sqrt{0.9}\,|\Psi_A\rangle + \sqrt{0.1}\,|\Psi_B\rangle$$

Probability Problems

It seems that it is good to play Russian quantum roulette.

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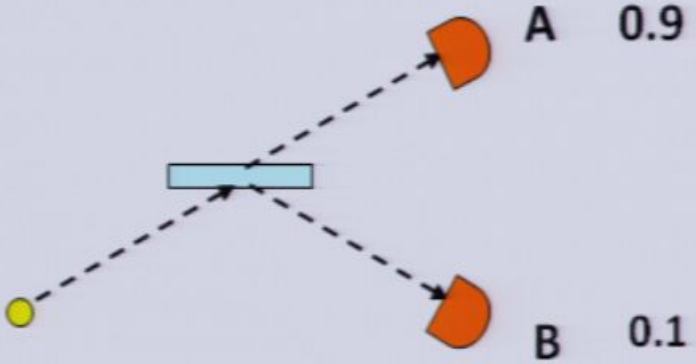

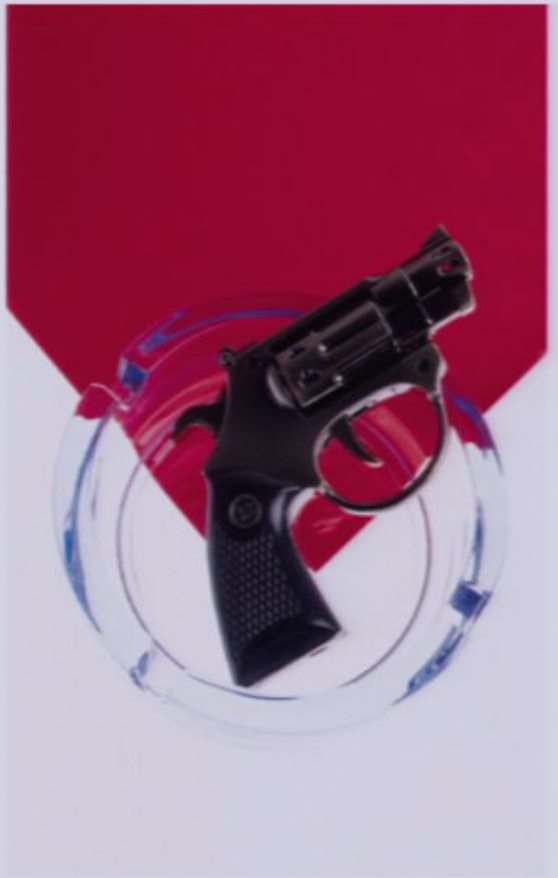

The Probability Problem

In the MWI there is no meaning for probability

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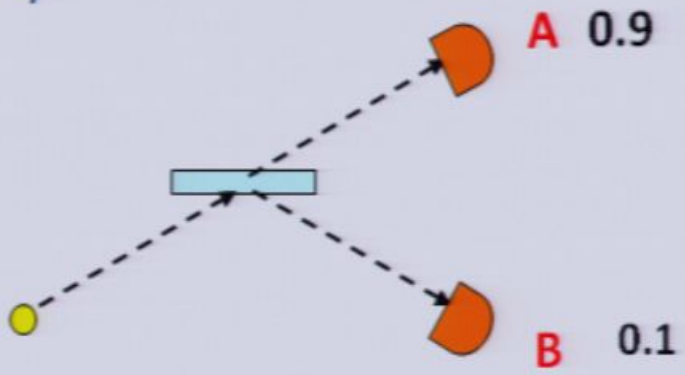
In the MWI there is no meaning for probability

There is no randomness and no ignorance

Probability of what?



Probability of something to happen – A or B? In MWI - A and B

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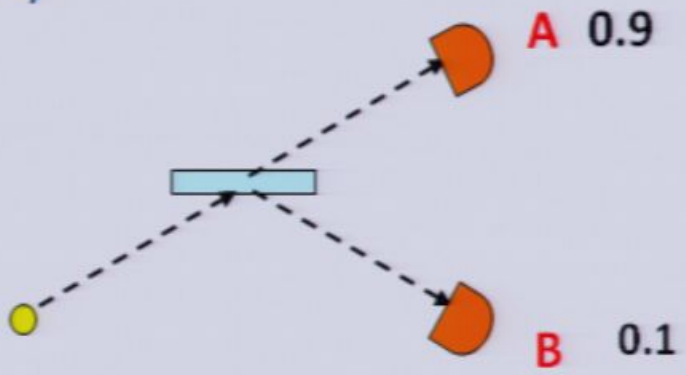

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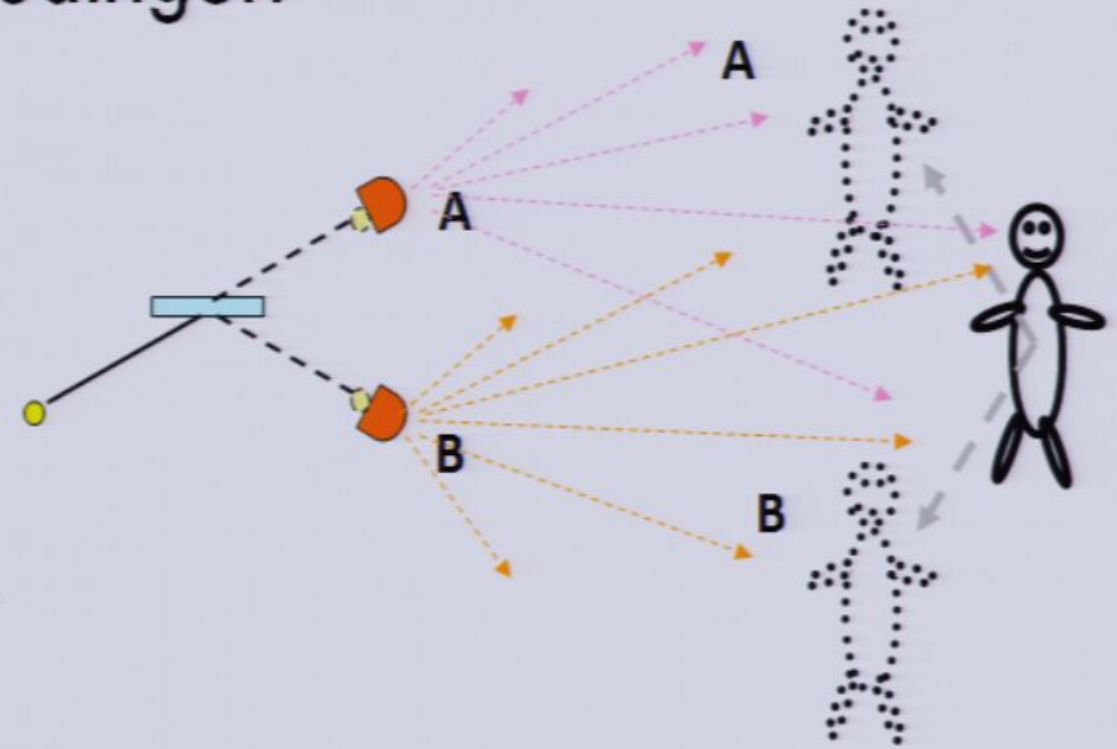
Textbook collapse, GRW – randomness probability

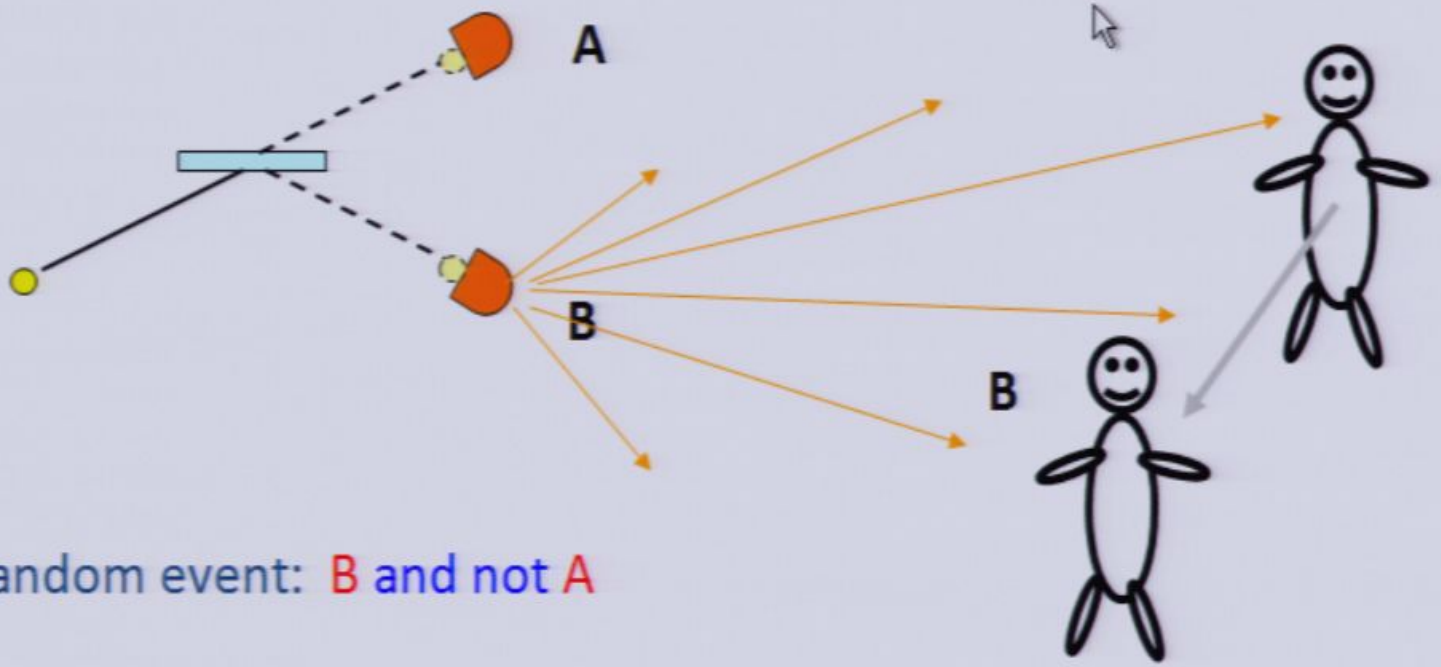
Add an Observer

Schrödinger:

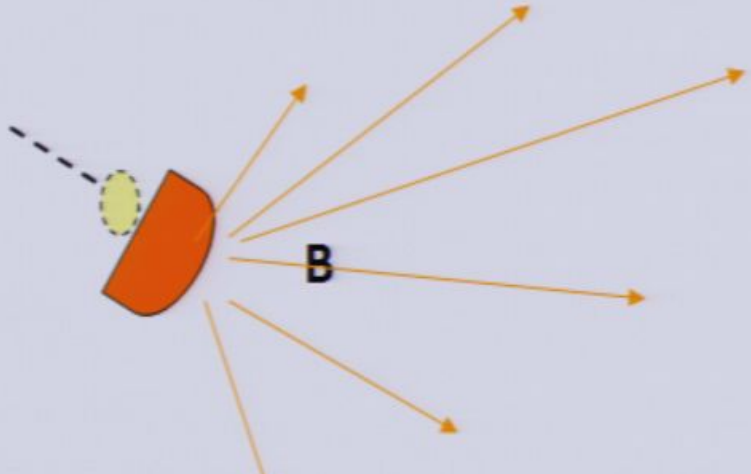


$$|\Psi\rangle \rightarrow \sqrt{0.9}\,|\Psi_A\rangle + \sqrt{0.1}\,|\Psi_B\rangle$$

Collapse

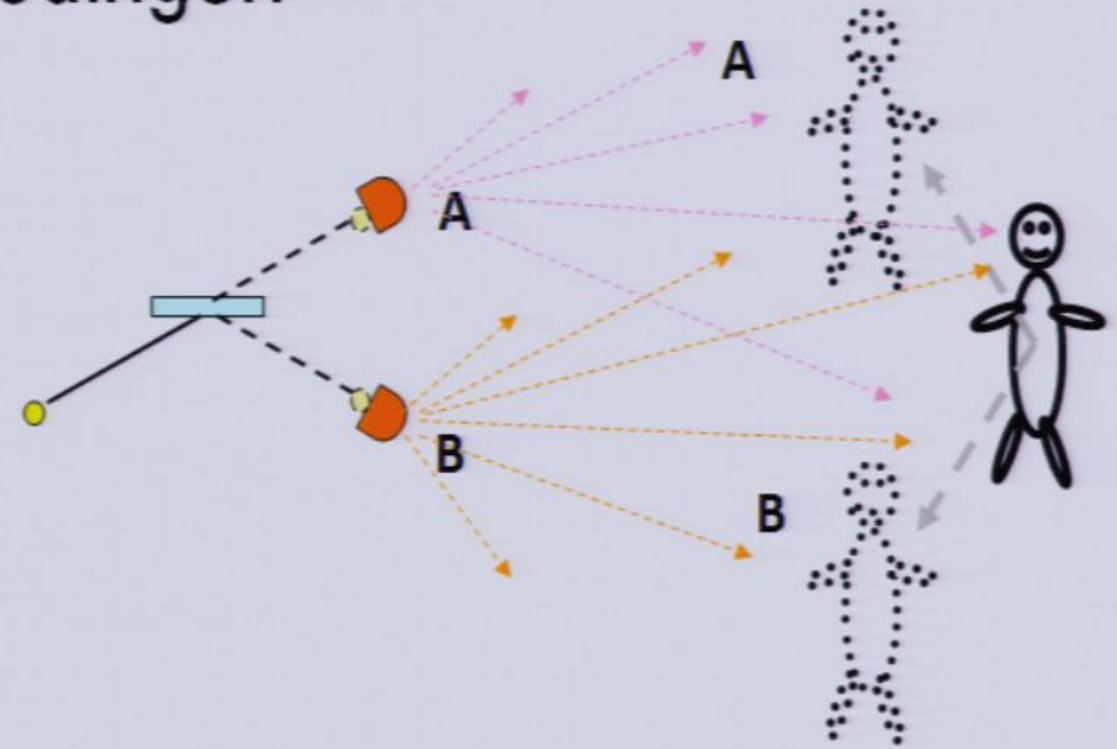


Random event: B and not A



Add an Observer

Schrödinger:



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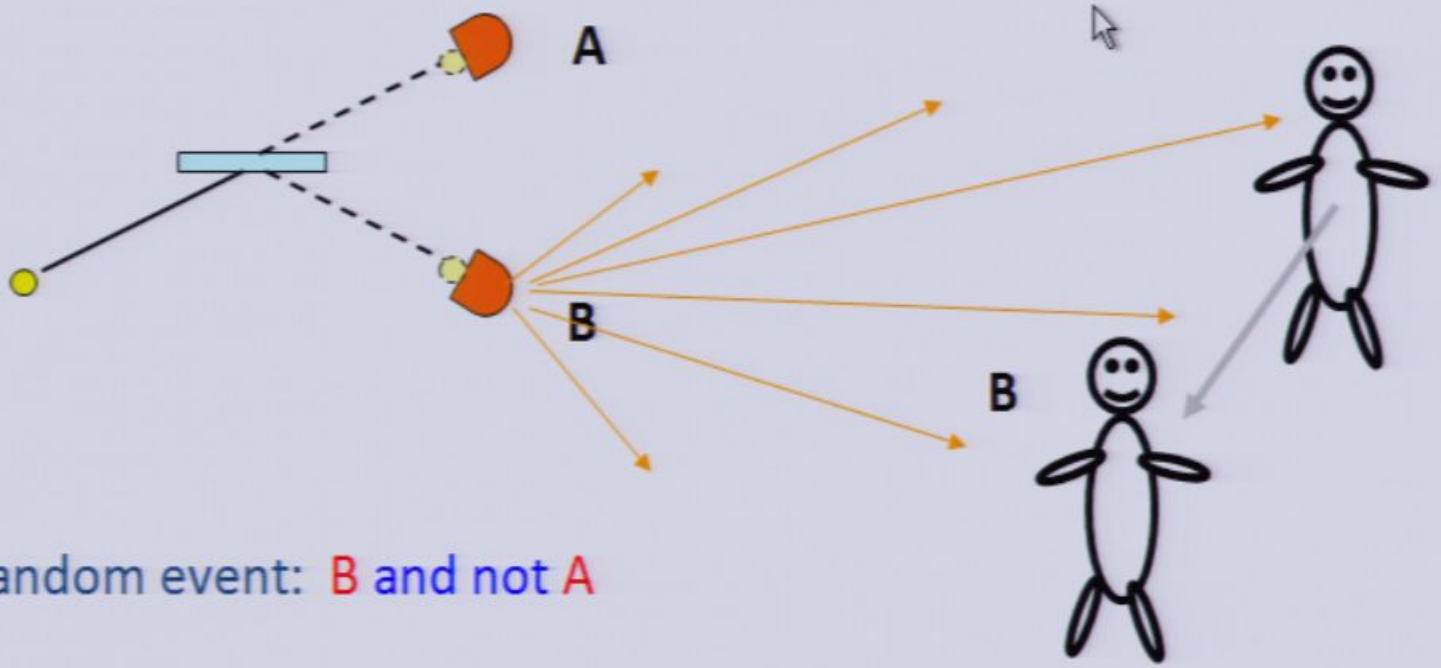

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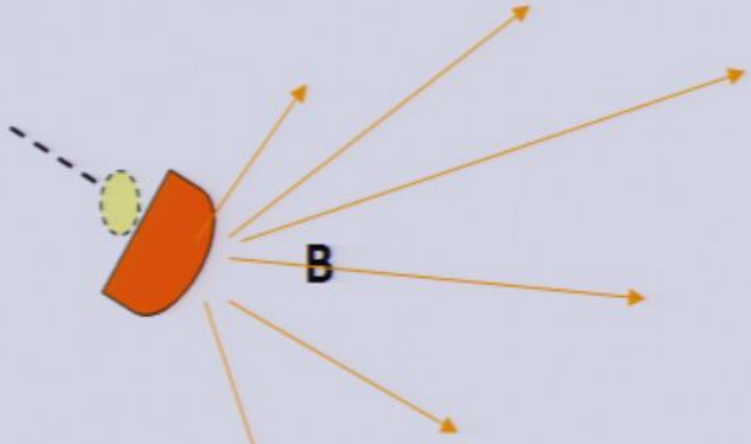
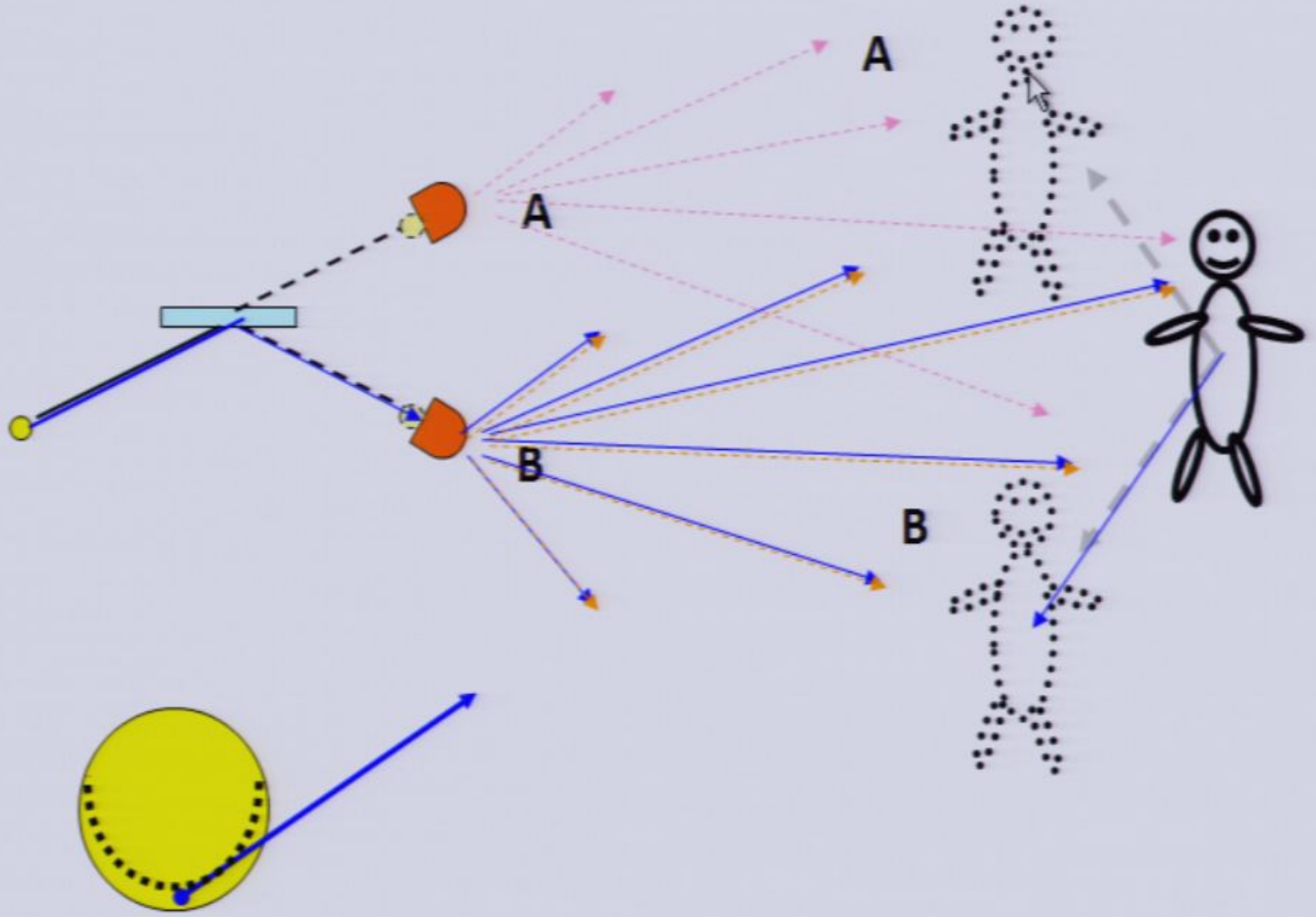
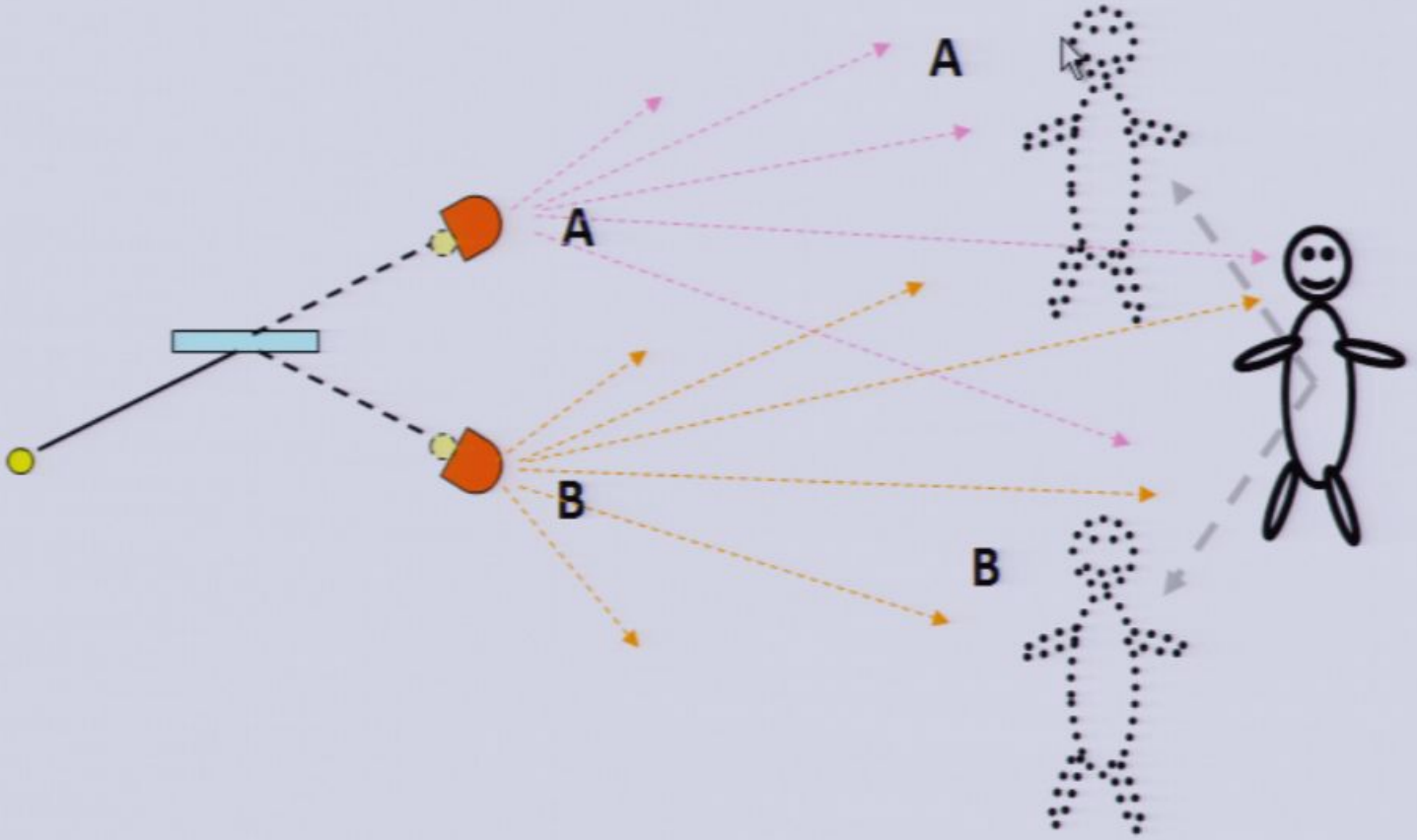


Bohmian Mechanics



Ignorance probability: the observer does not know the initial Bohmian position

Many Worlds (Schrödinger):



Probability of what?

Ignorant of what?

MWI: Give up probability

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Probability postulate is replaced by

Behavior Principle:

We should care about all our successive worlds in proportion to their measures of existence.

Measure of existence of world i: $\mu_i = |\langle \Psi_{UNIVERSE} | \Psi_{WORLD\,i} \rangle|^2 = |\alpha_i|^2$

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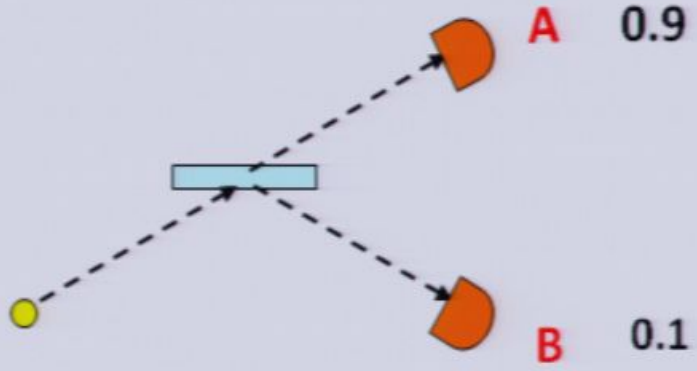
I should bet 1:9 Get 1 if A, pay 9 if B



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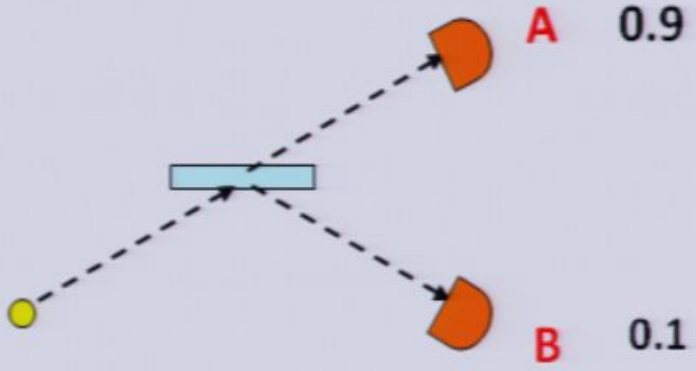

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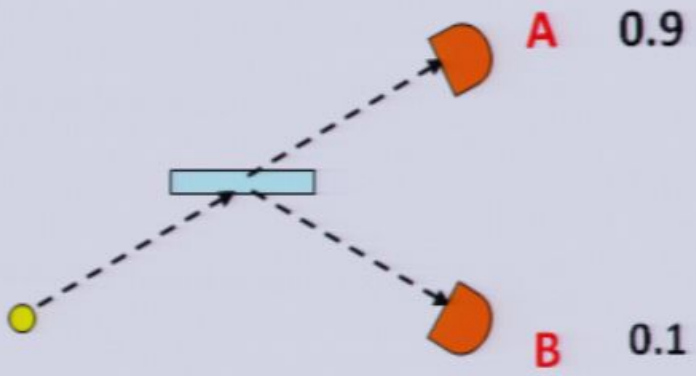

I should not play Russian quantum roulette

I should bet as if I have a concept of probability

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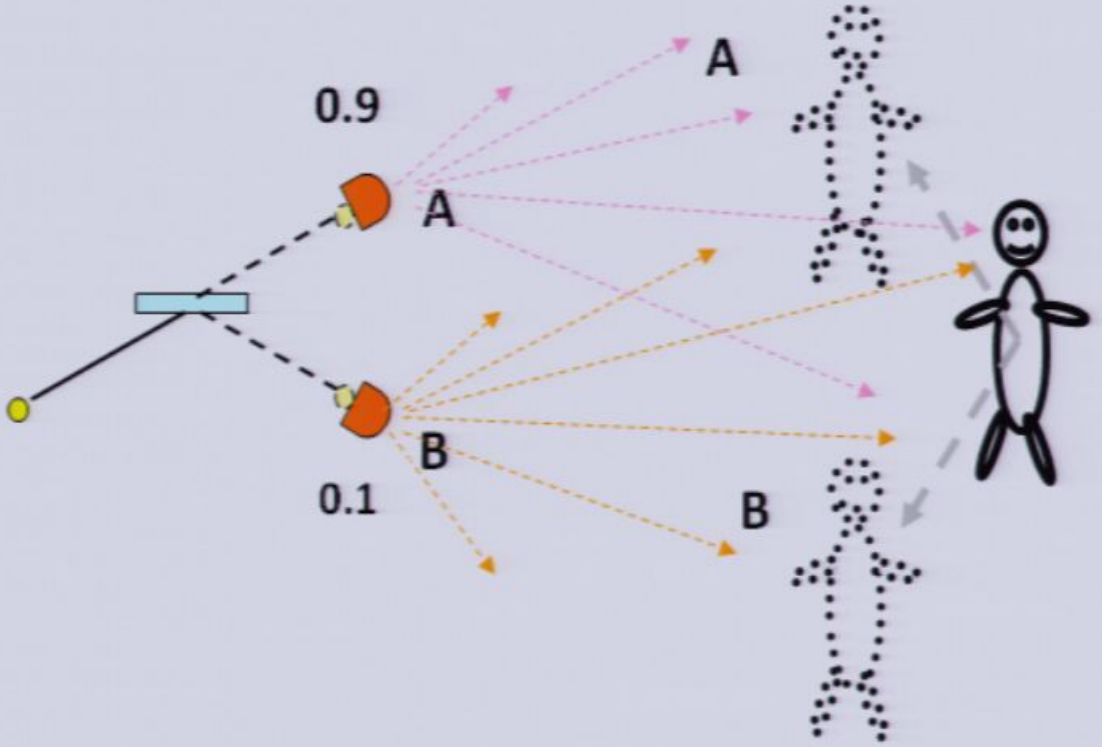
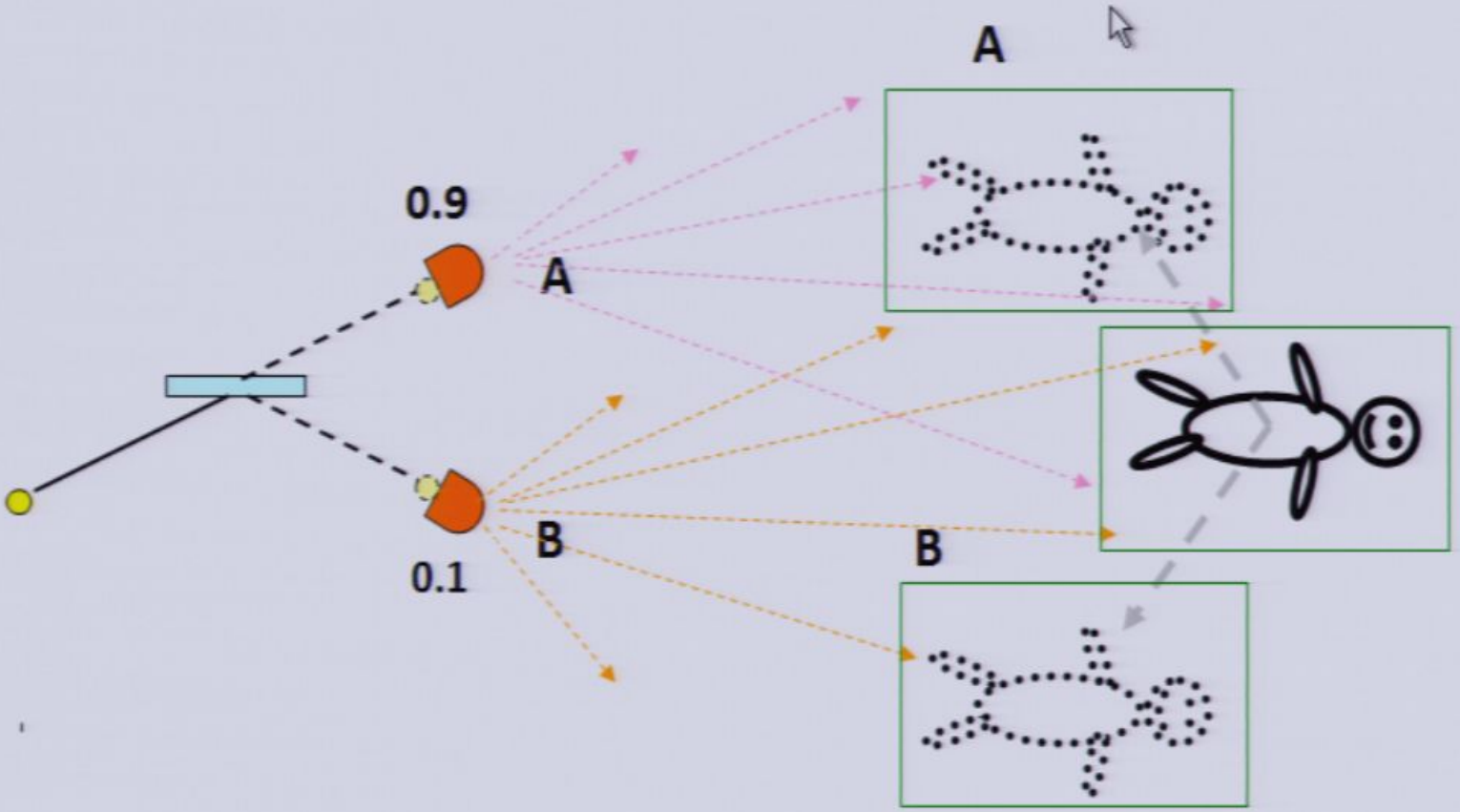
$\mu_i = |\alpha_i|^2$ as an ignorance probability measure

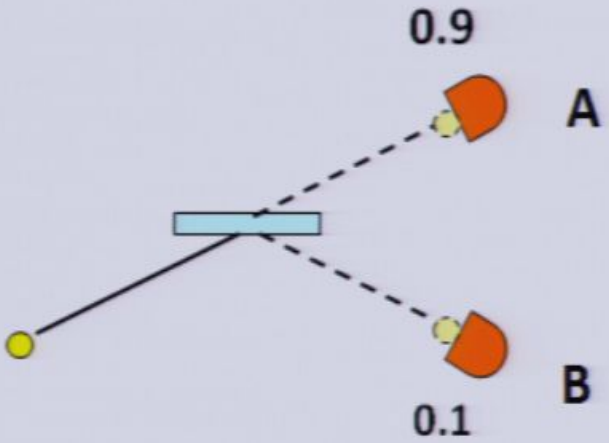


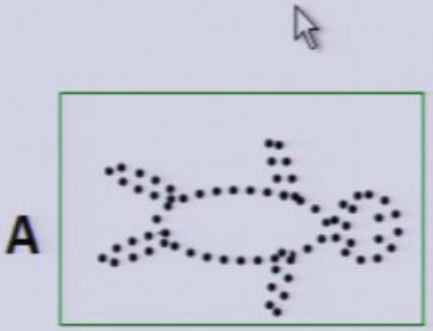
Sleeping Pill Experiment

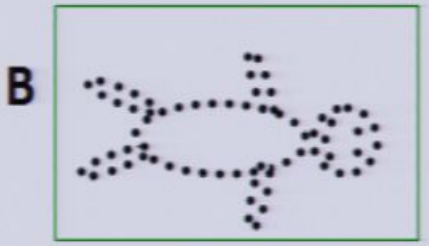
Vaidman (1998) ISPS

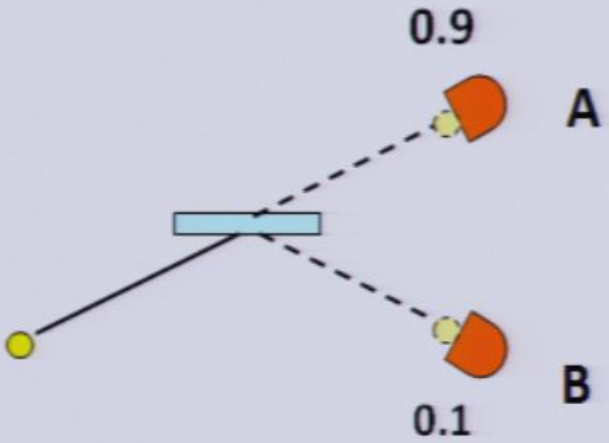


Ignorance probability of the descendants A and B


0.9
A
B
0.1


A


B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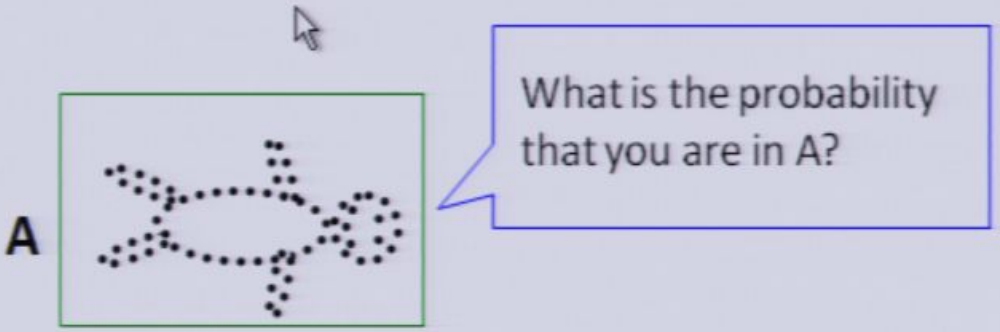
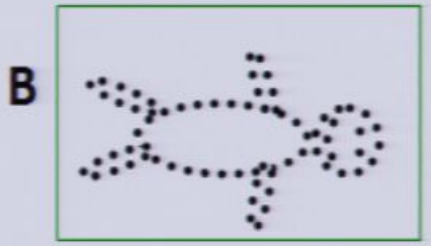
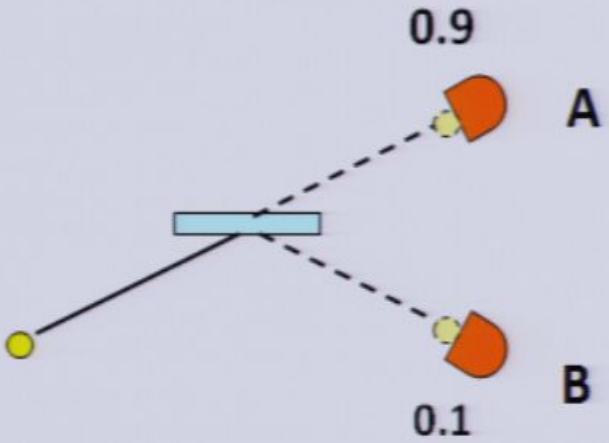
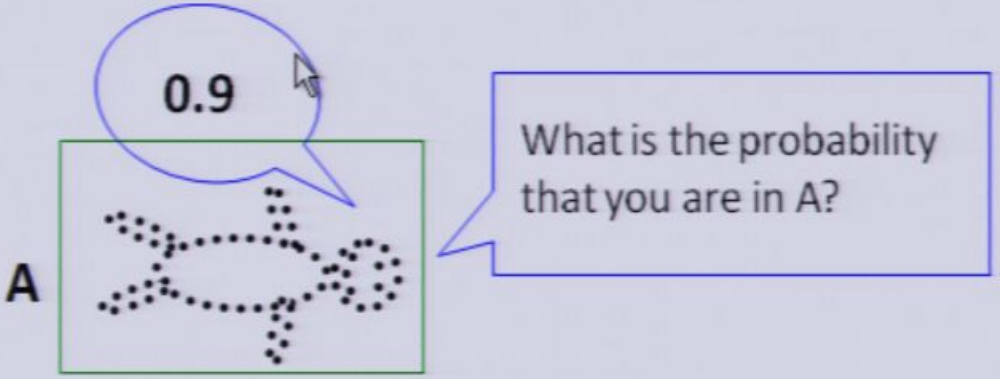

A
What is the probability that you are in A?


B


0.9
A
B
0.1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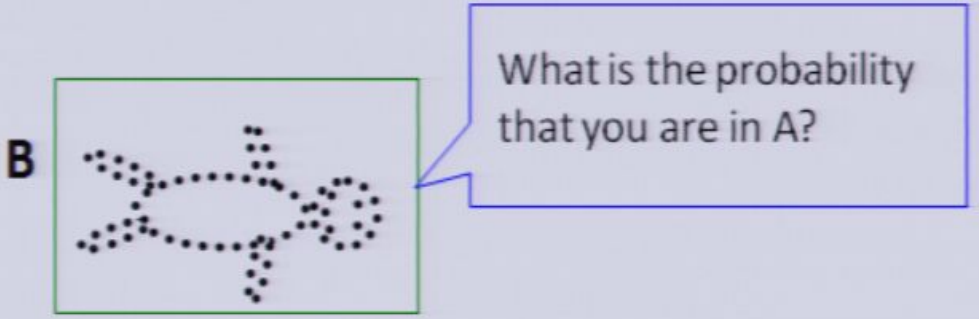
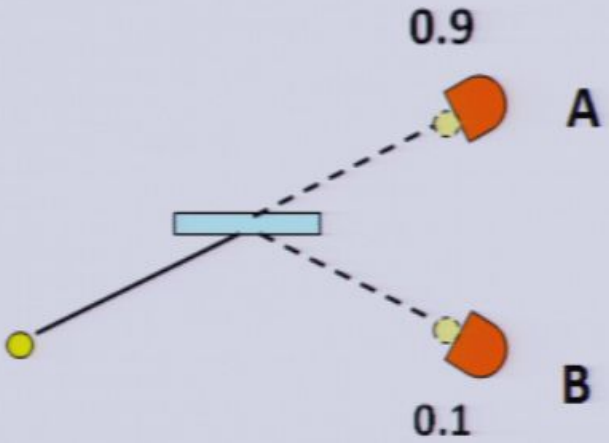
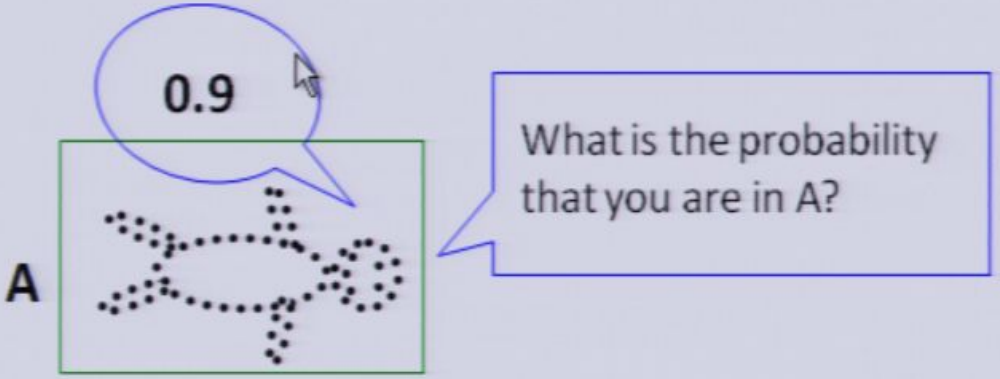
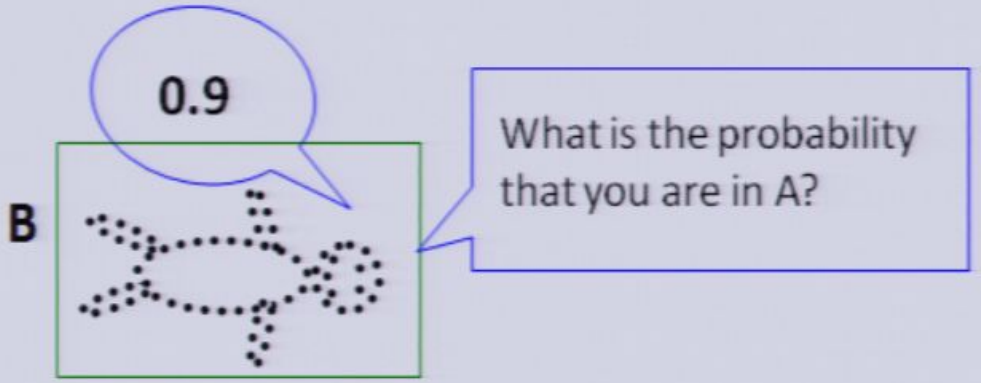
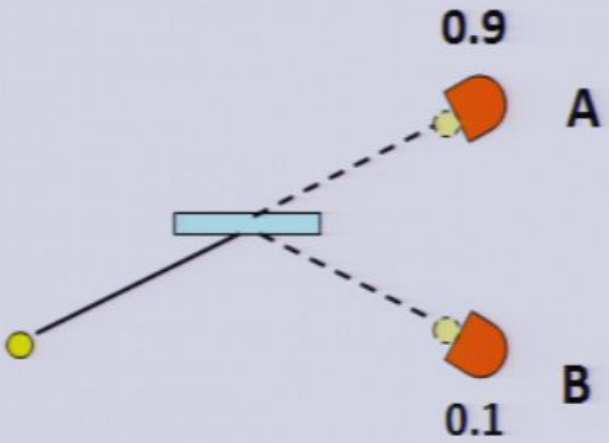

B
What is the probability that you are in A?

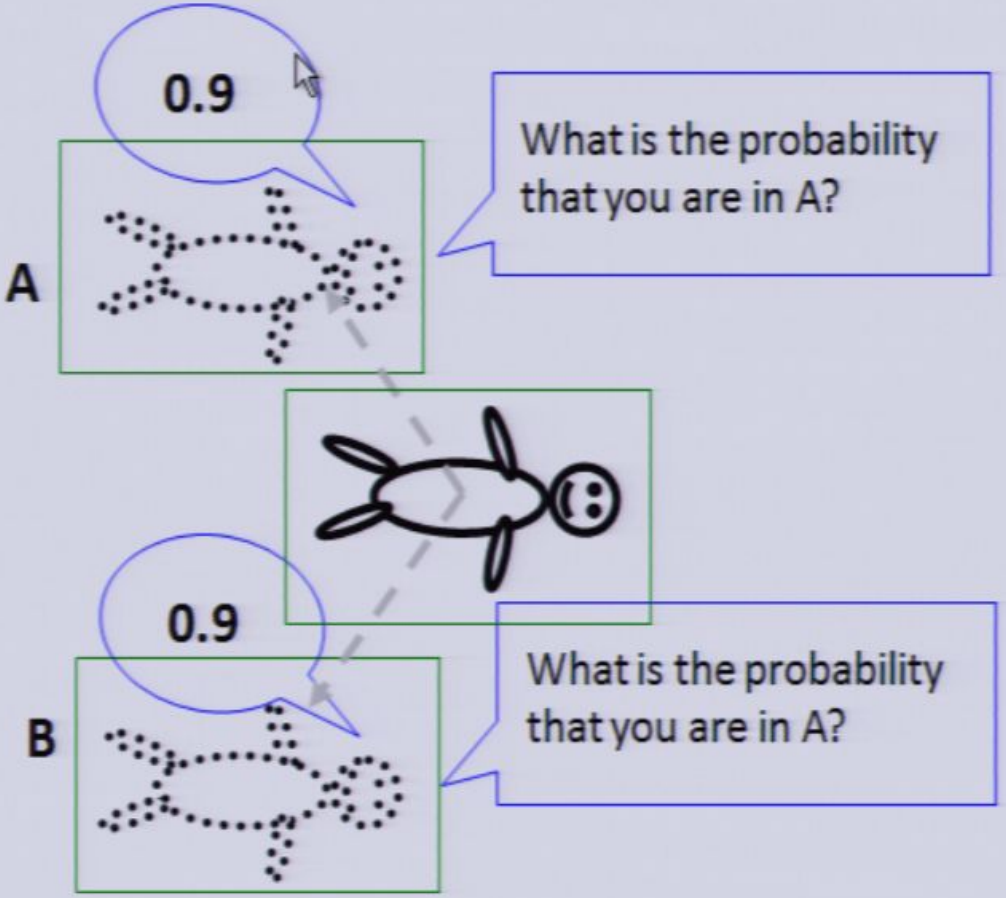






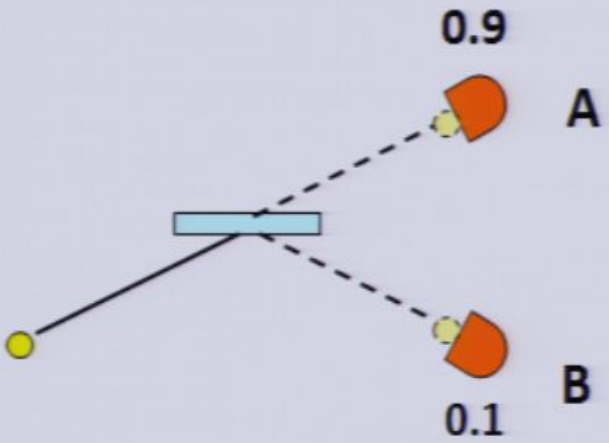
Only I_A and I_B can give this answer

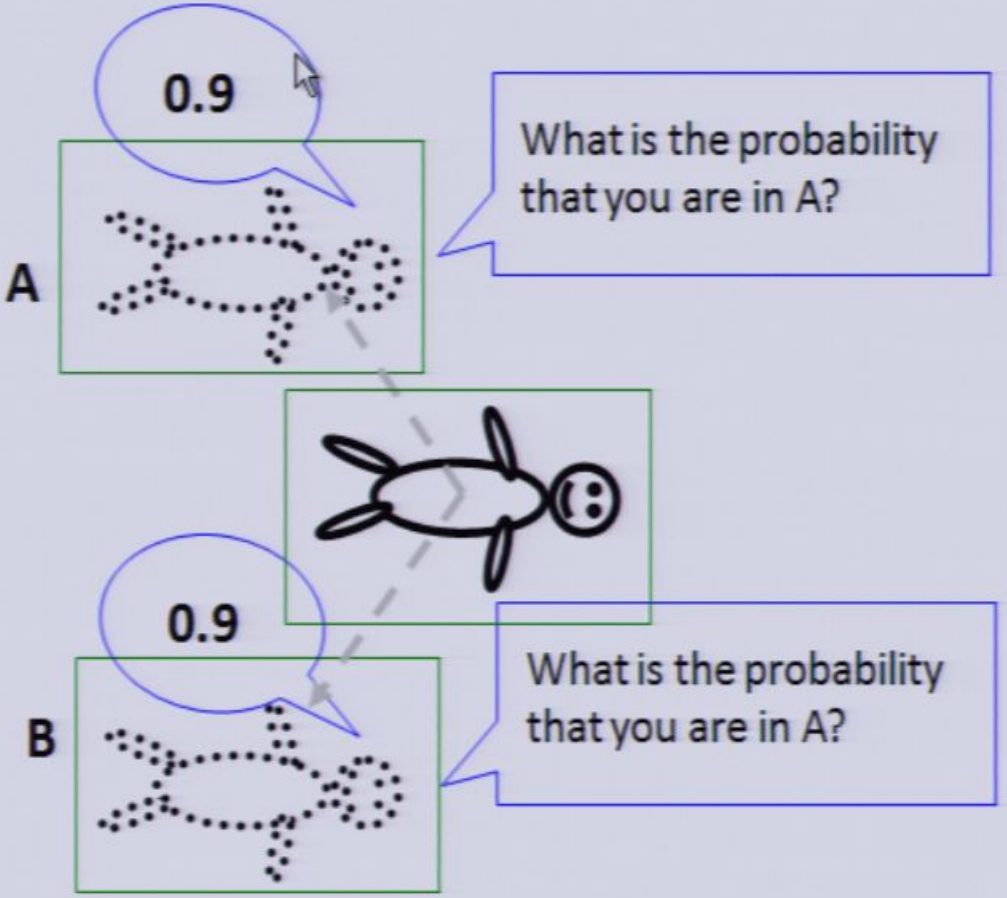




Since all the descendants yield the same answer we can relate it to me before the experiment. I put my bet for the descendants. They have probability. Thus, my bet is for a probabilistic event. This is the ignorance probability meaning of the measure of existence.

Is there a physical meaning of $\mu_i = |\alpha_i|^2$ of a present world?





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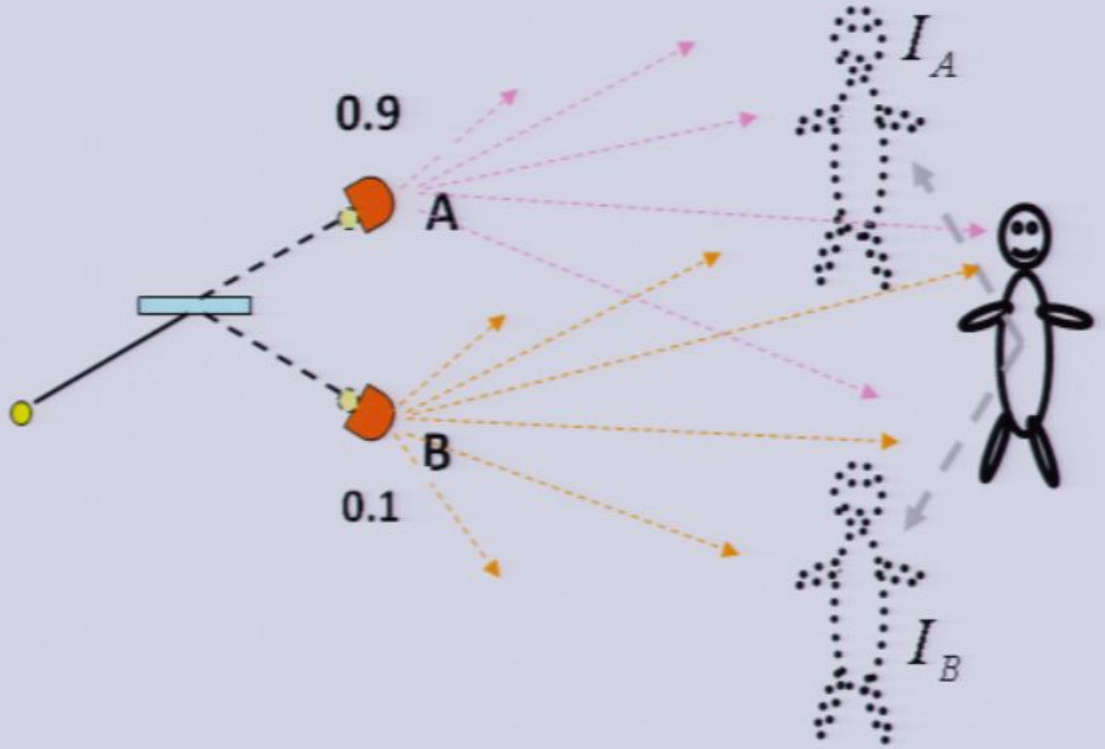
Should I_A behave differently than I_B because $\mu_A = 9\mu_B$?



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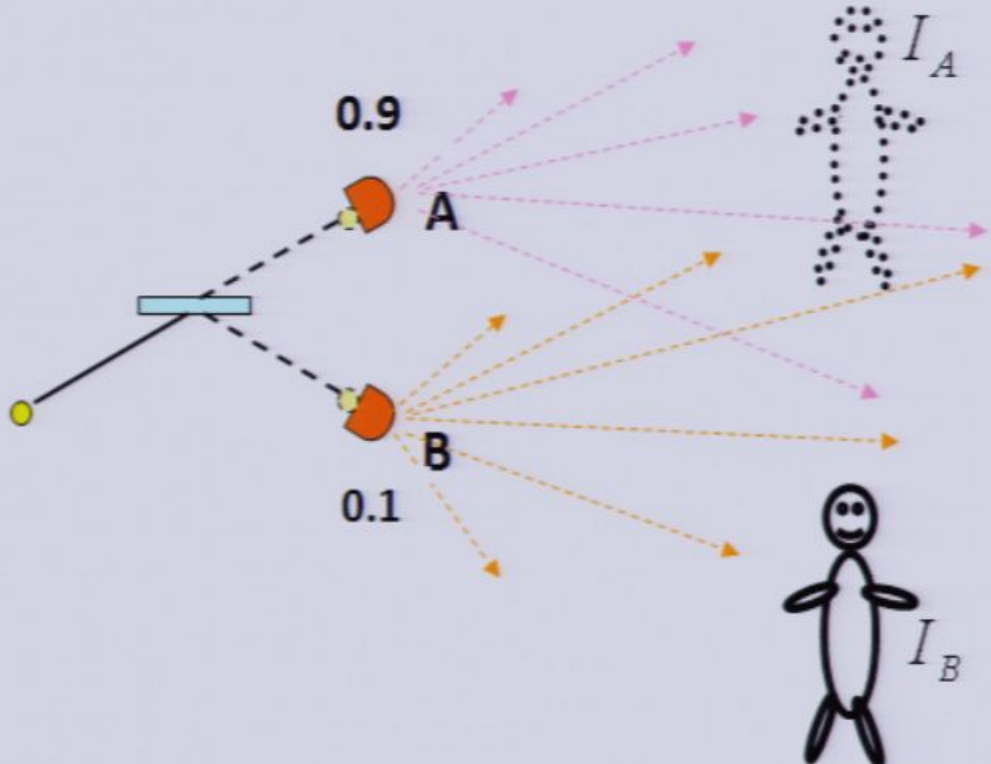

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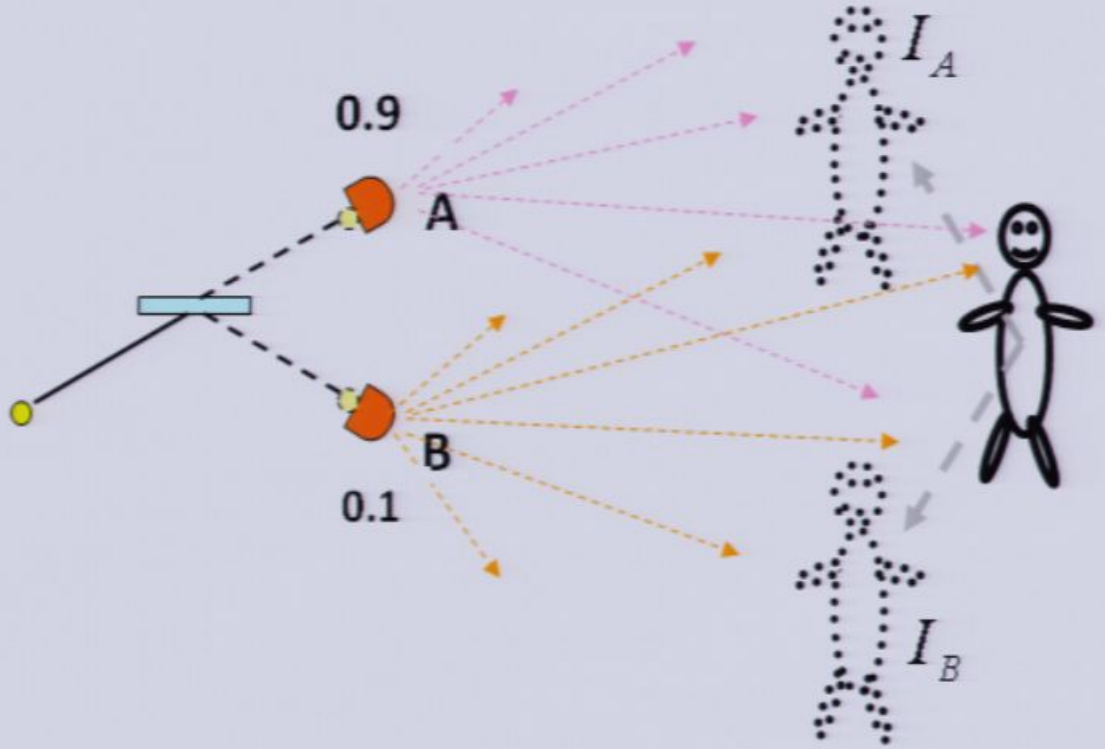

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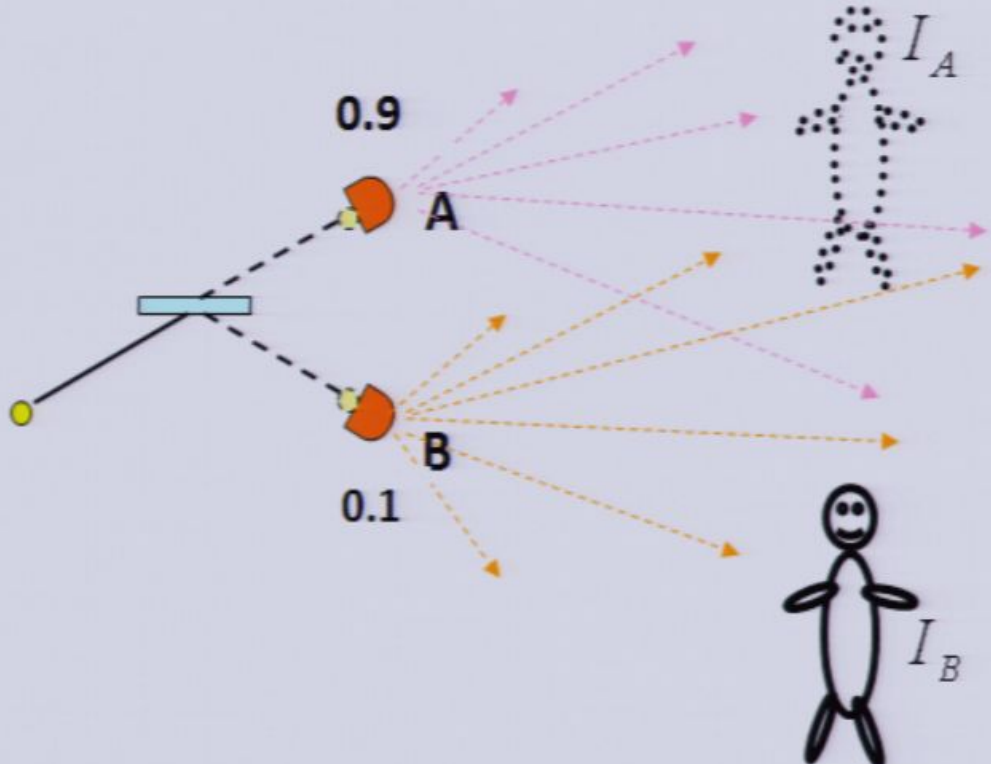

I am from another galaxy. Our technology is 10 million years ahead.

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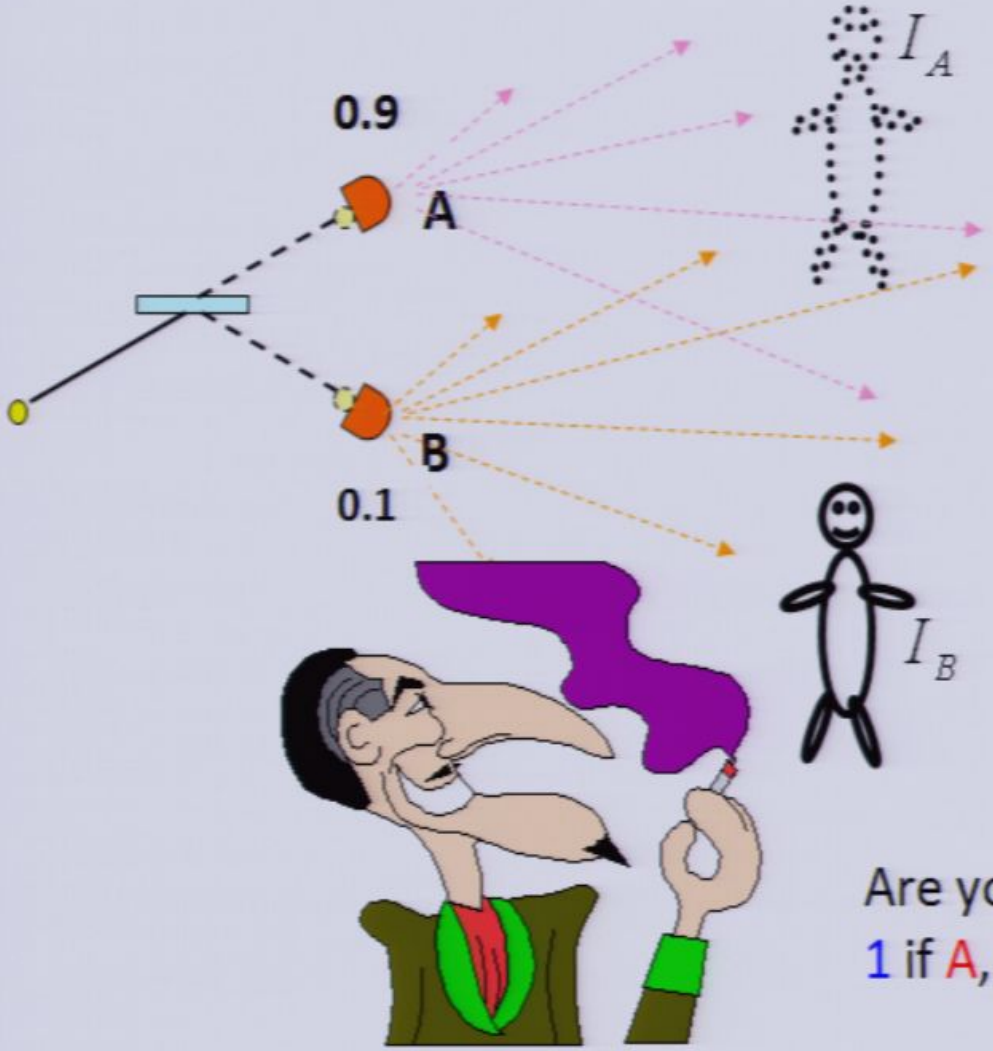
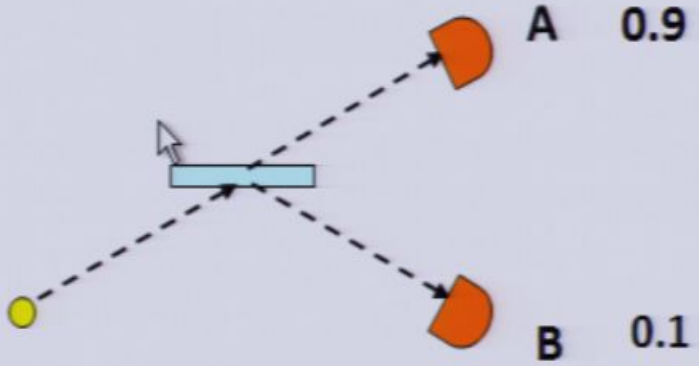
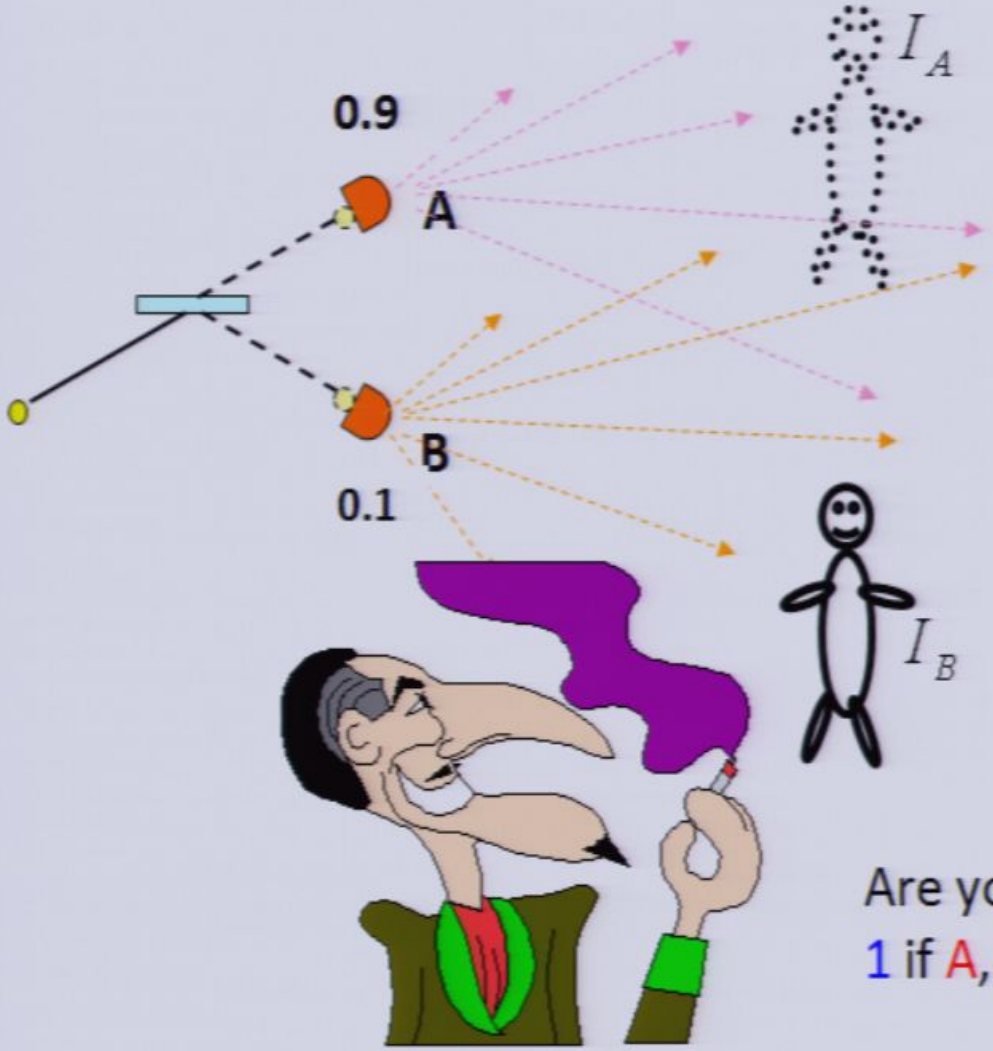
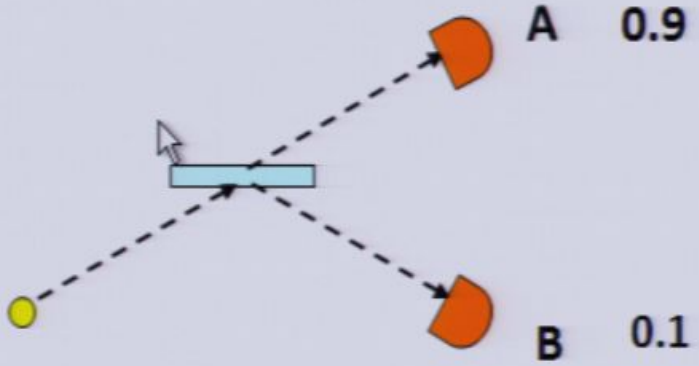
I like betting. Would you like to bet?





Are you ready to bet 1:1 ? Get
1 if A, pay 1 if B





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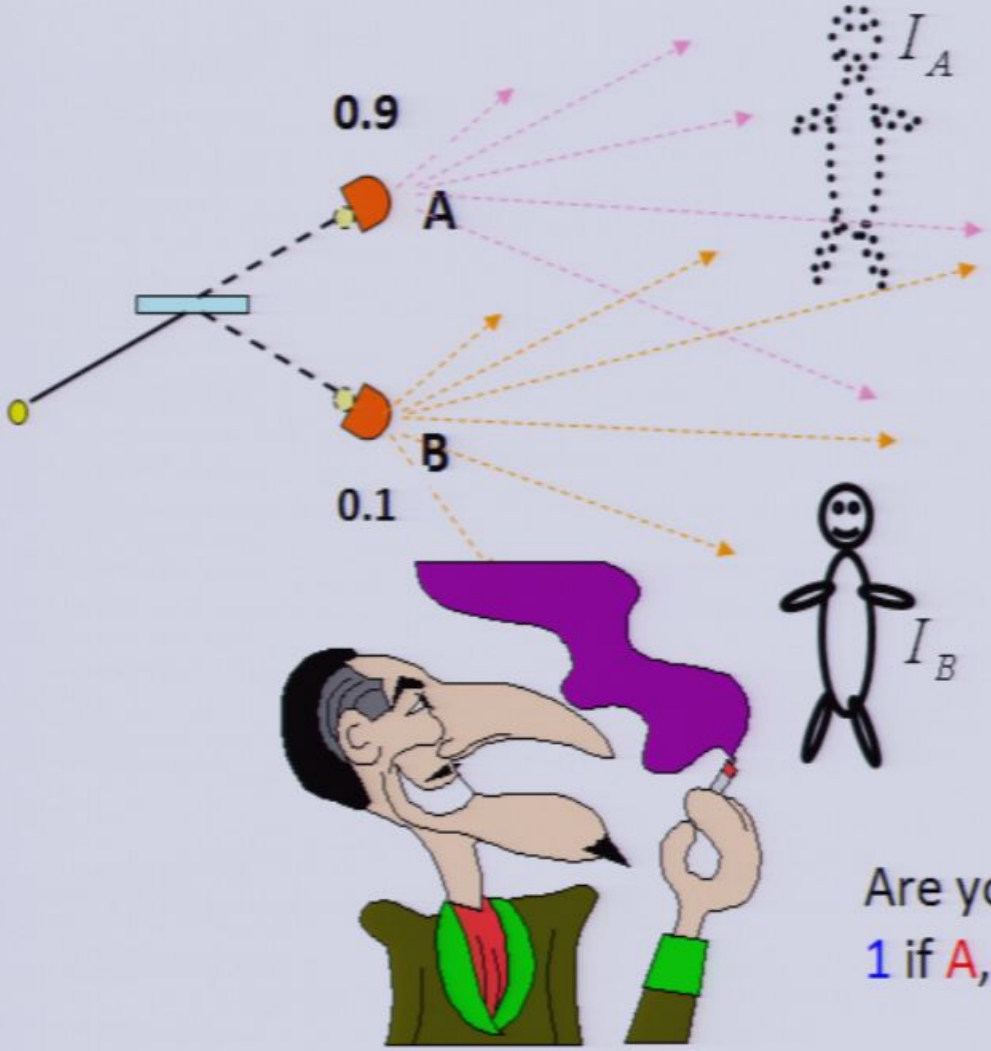
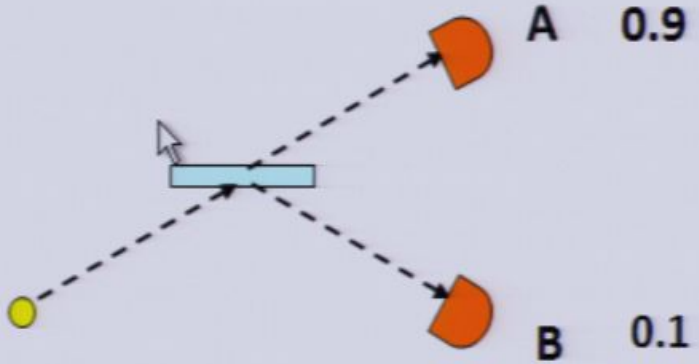
I_B should say no! The creature can always win.





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I_B should say no! The creature can always win.

I_A should say yes! I will have at least 6.4 :3.6 odds to win.

I can do to the neutron what the creature can do to me

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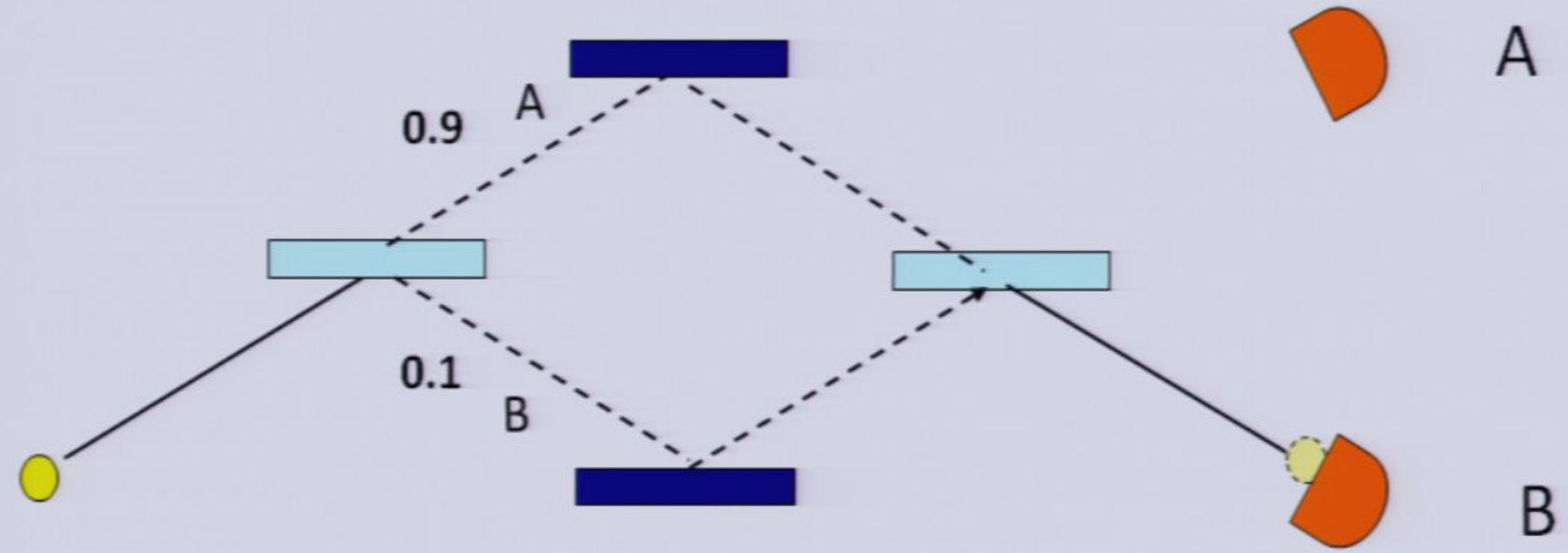
Neutron interferometer



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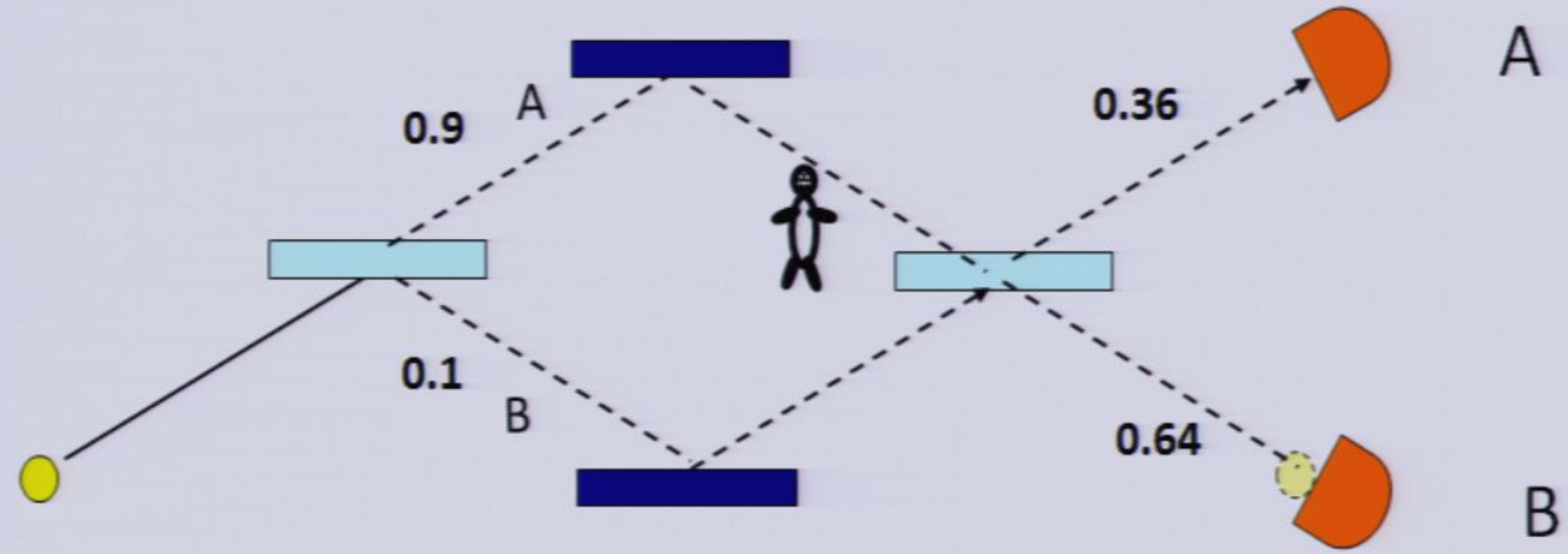

MWI+Decisison Theory $\Rightarrow$ $p=|\alpha_i|^2$

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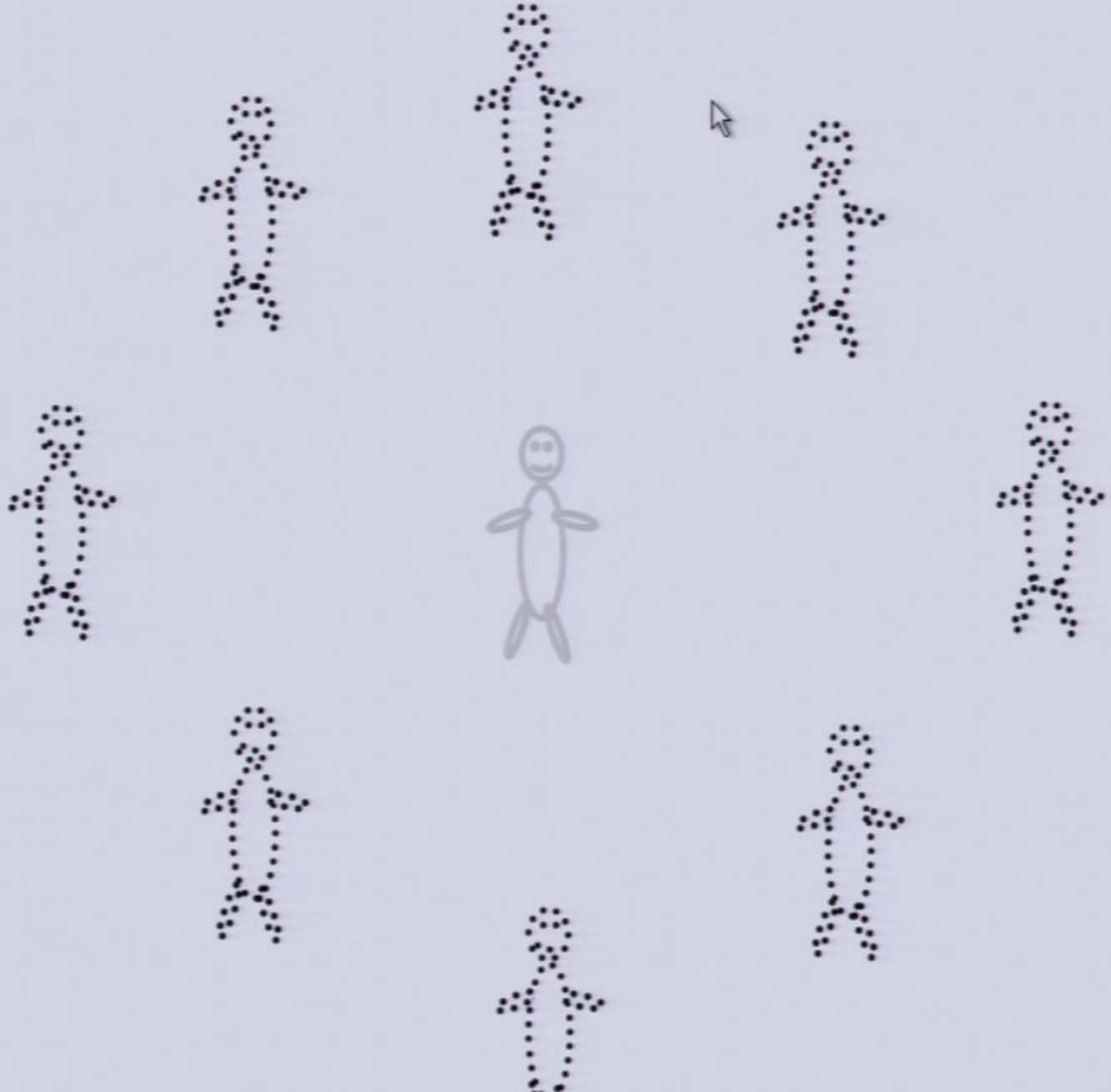

There is no "real" probability in the MWI

Probability of an event is replaced by measure of existence of the world with this event and probability postulate is replaced by "behavior principle"

Measure of existence of future worlds can be given a meaning as an ignorance probability of the descendents of the observer.

Measure of existence of a present world has a physical meaning as a measure of ability to interfere with parallel worlds

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Sleeping Beauty Controversy

Beaty, what is your credence for Tails?

Elga: 1/3 Lewis: 1/2

Tuesday

Monday

Fair coin ½ : ½

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Sleeping Beauty Quantumland

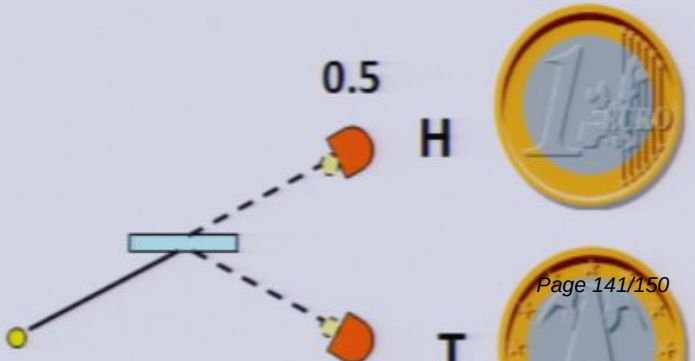
Beaty, what is your credence for Tails?

MWI: 1/3

Tuesday

Measure of existence of each world = ½

Monday



Quantum Fair coin ½ : ½

Interaction-free measurement

A. Elitzur and L. Vaidman
Found. Phys. **23**, 987 (1993) .

BOMB:

explodes when any particle "touches" it

interacts only through explosion

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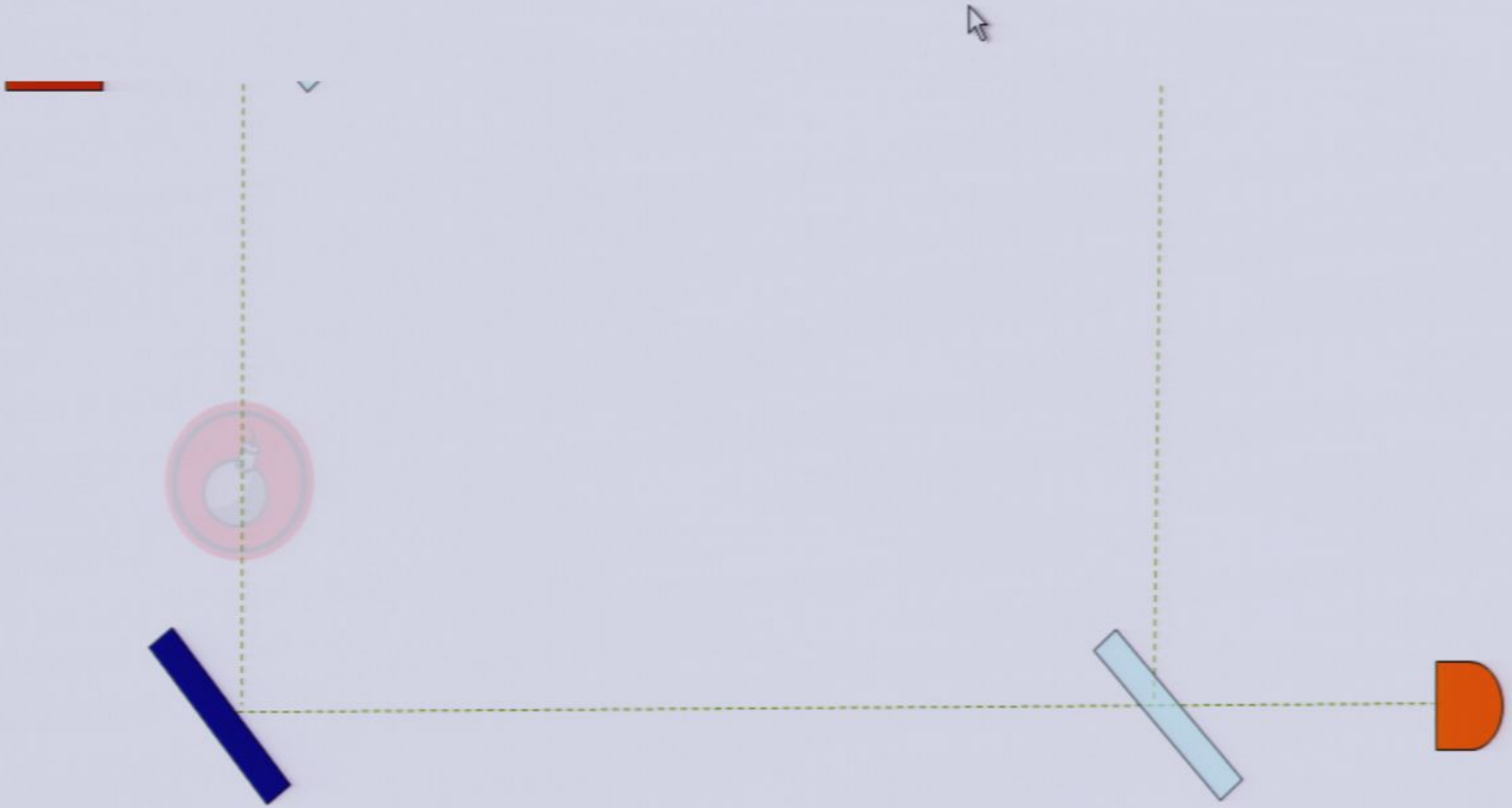

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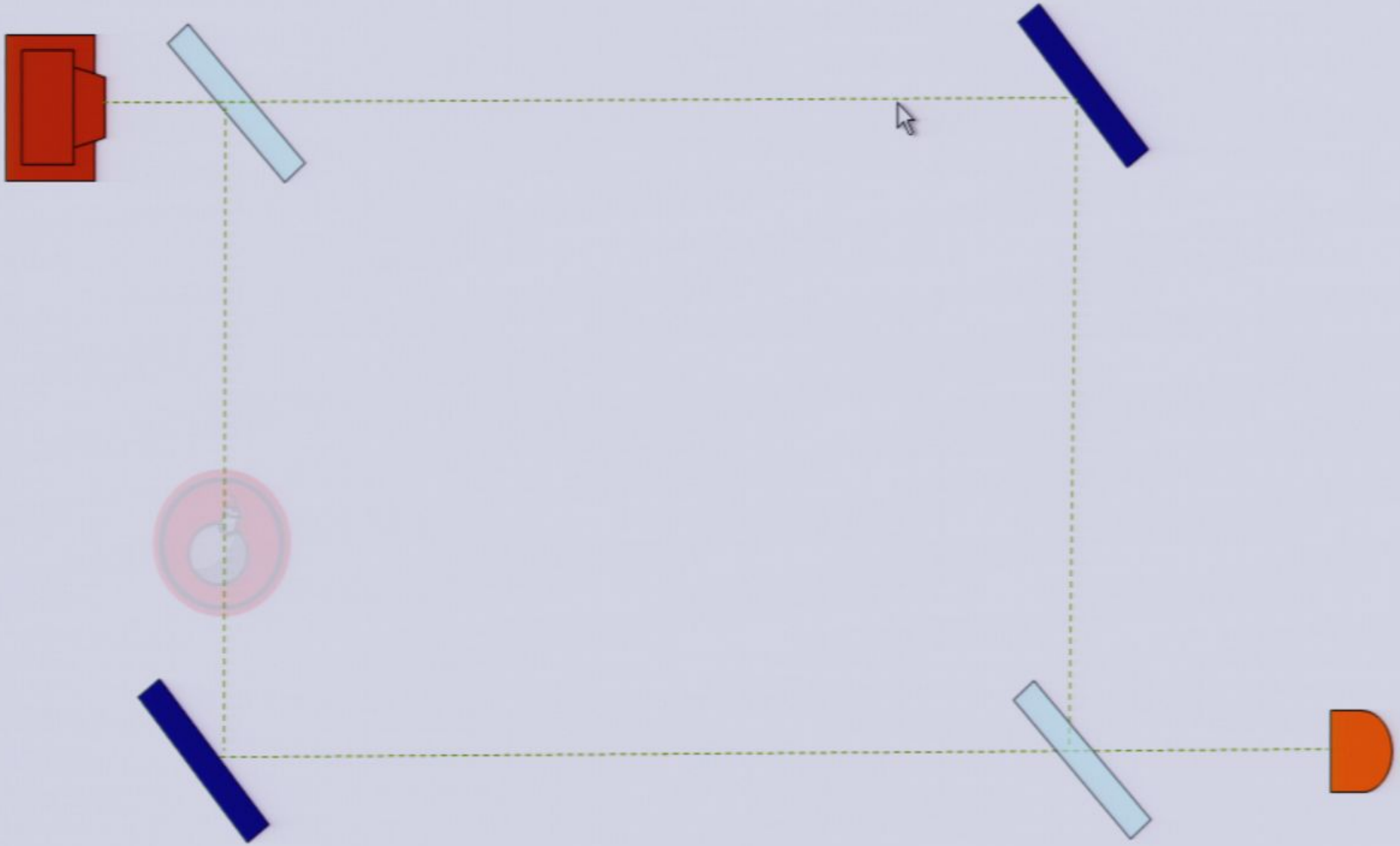
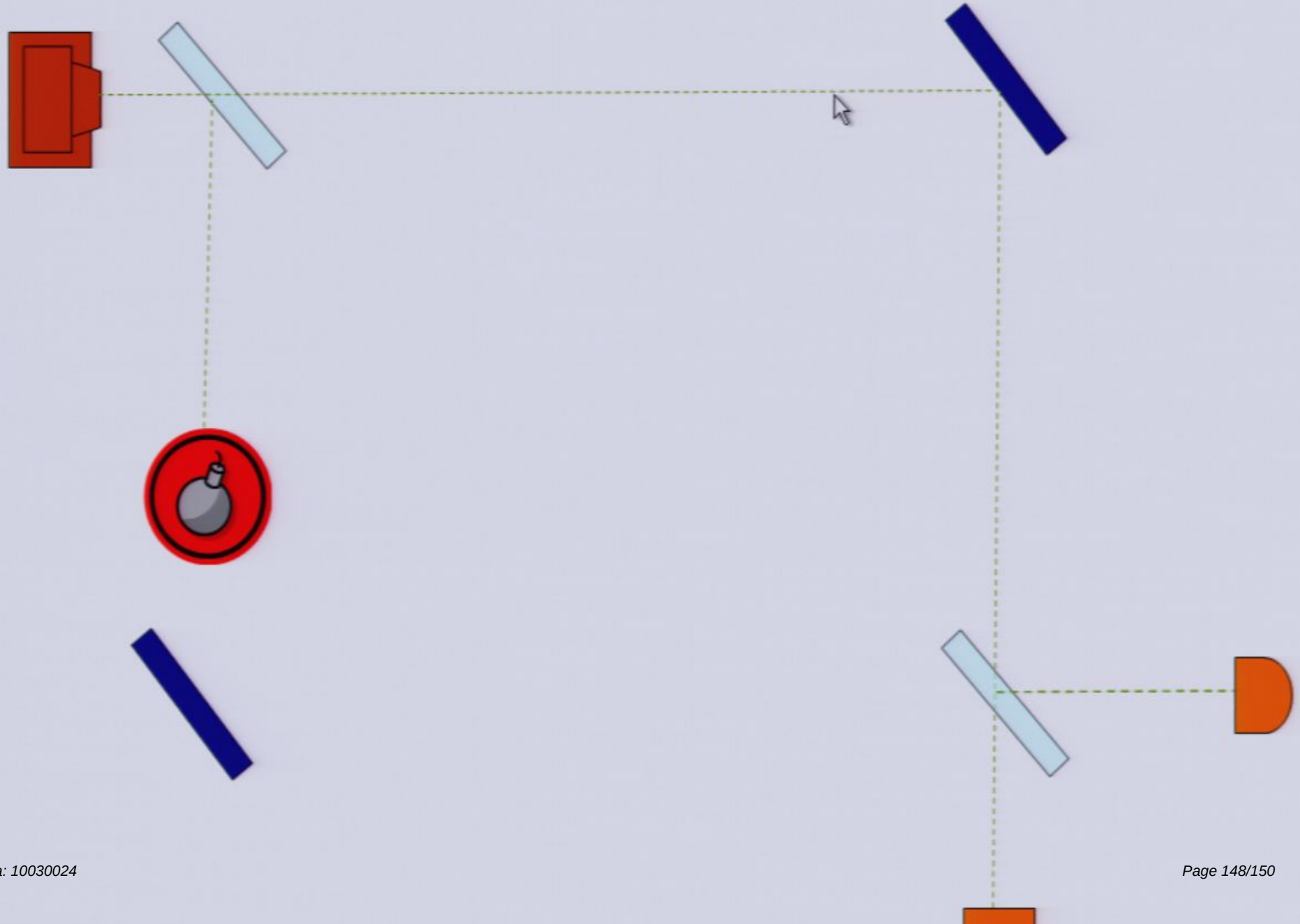


Interaction-free measurement



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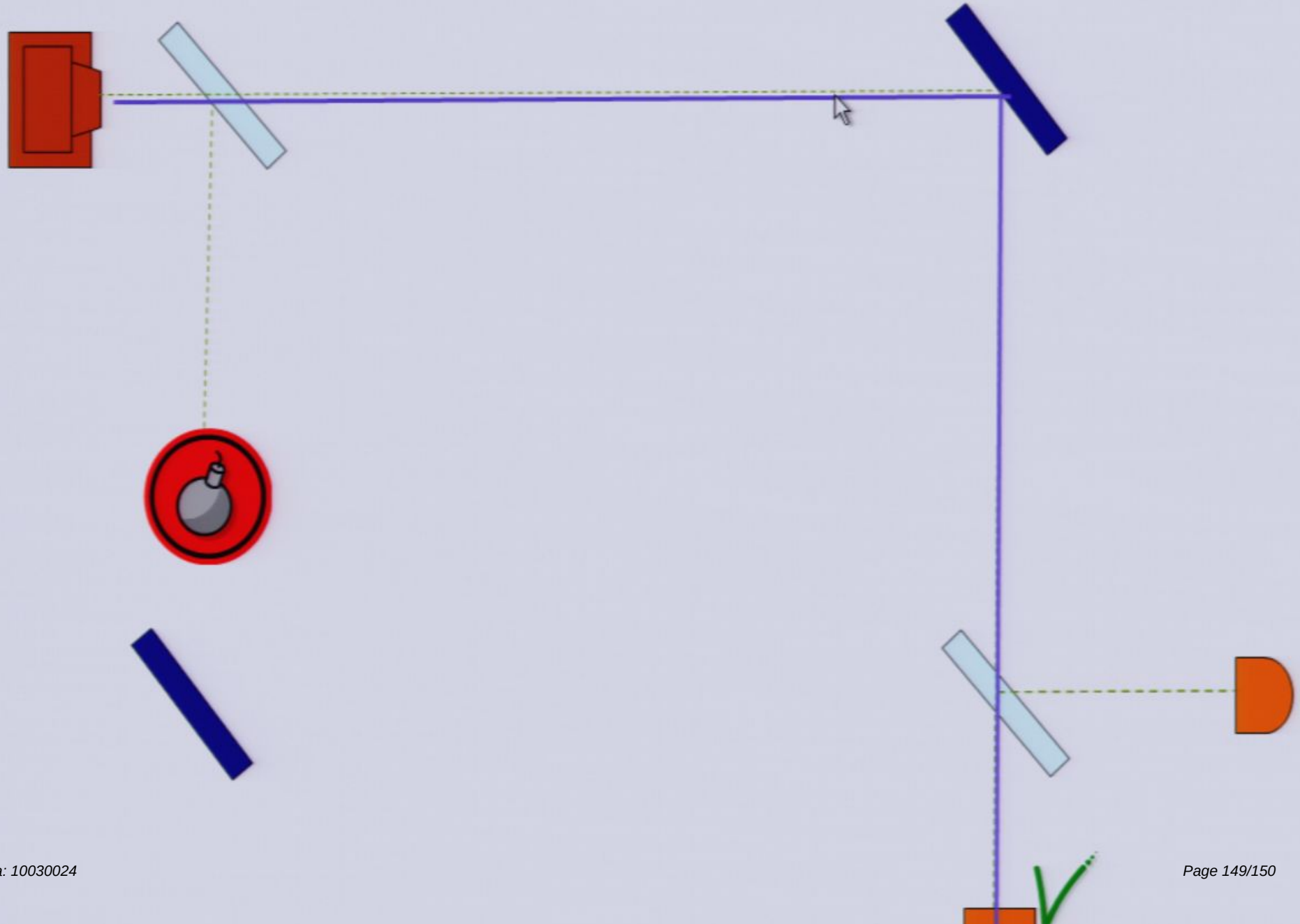

The Many-Worlds Interpretation is an approach to quantum mechanics according to which, in addition to the world we are aware of directly, there are many other similar worlds which exist in parallel at the same space and time. The existence of the other worlds makes it possible to remove randomness and action at a distance from quantum theory and thus from all physics.