Title: 12/13 PSI - Found Quantum Mechanics Lecture 8

Date: Jan 16, 2013 11:30 AM

URL: http://pirsa.org/13010075

Abstract:

Classical statistical theory

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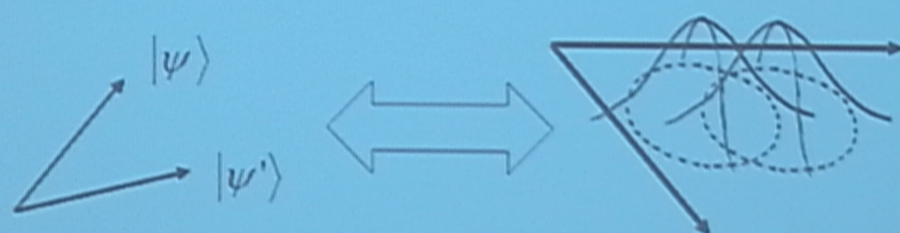
fundamental restriction on statistical distributions

$\Downarrow$

A large part of quantum theory

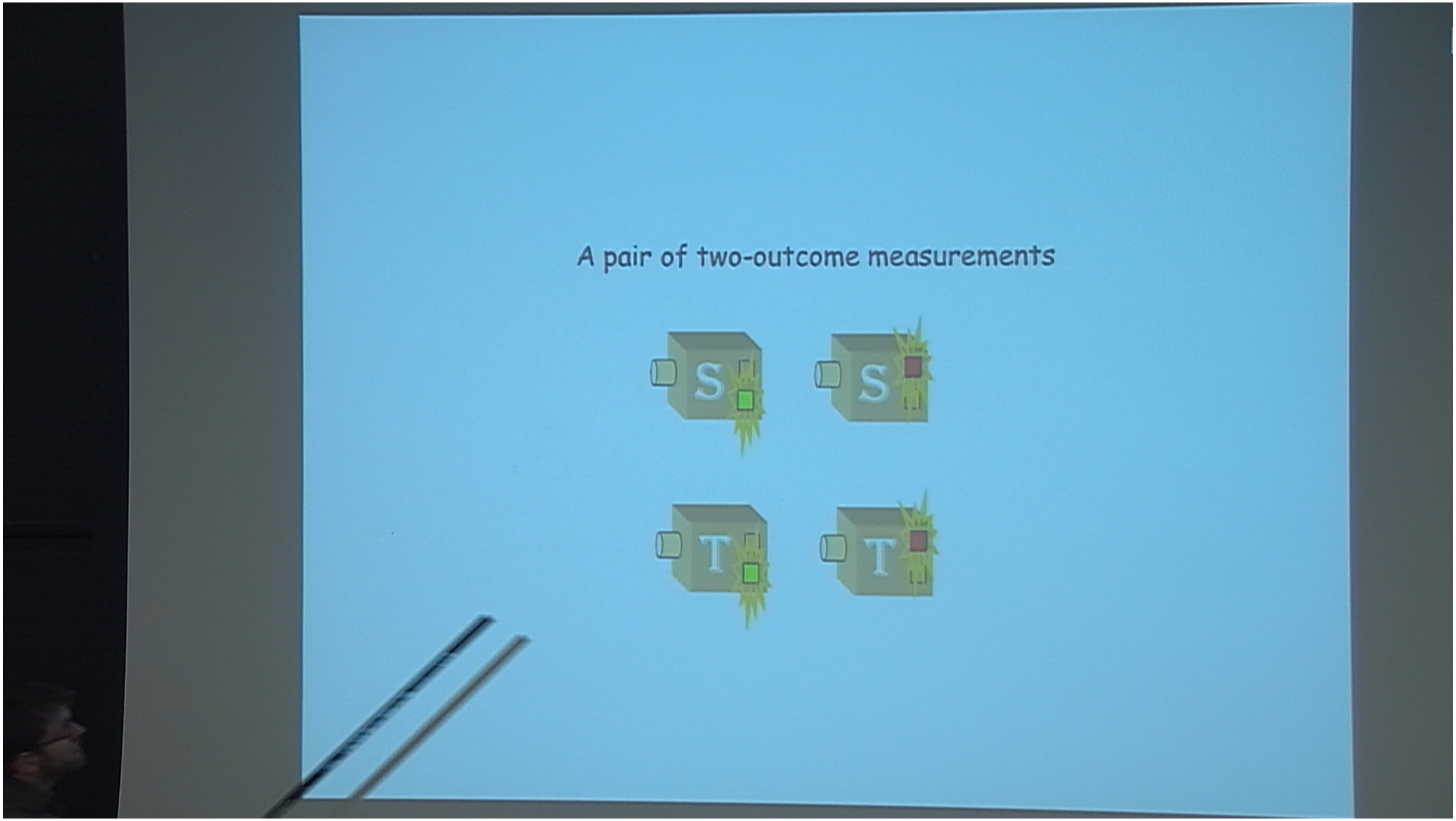
In the sense of reproducing the operational predictions

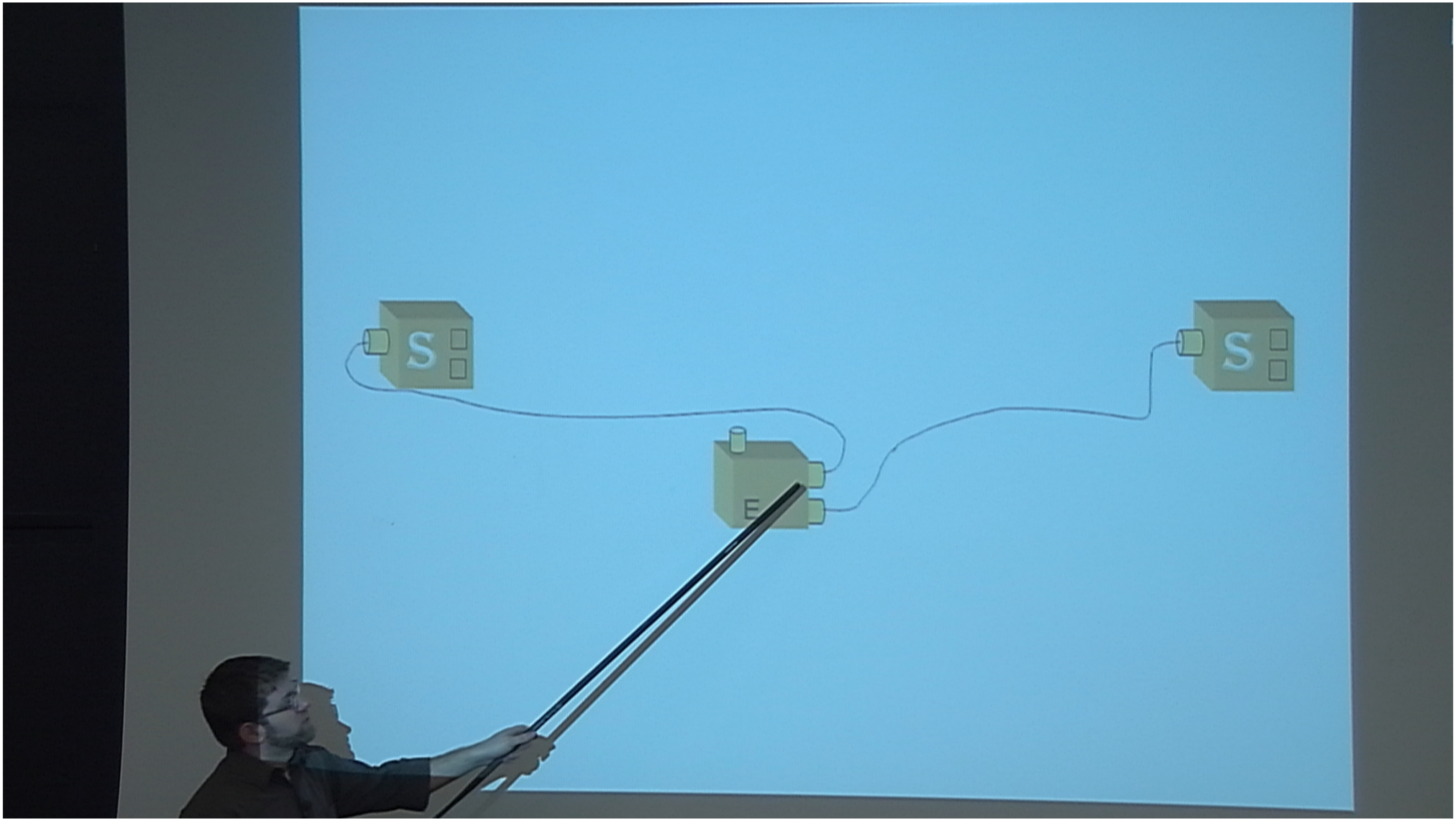
We obtain a ψ-epistemic hidden variable model of a large part of quantum theory

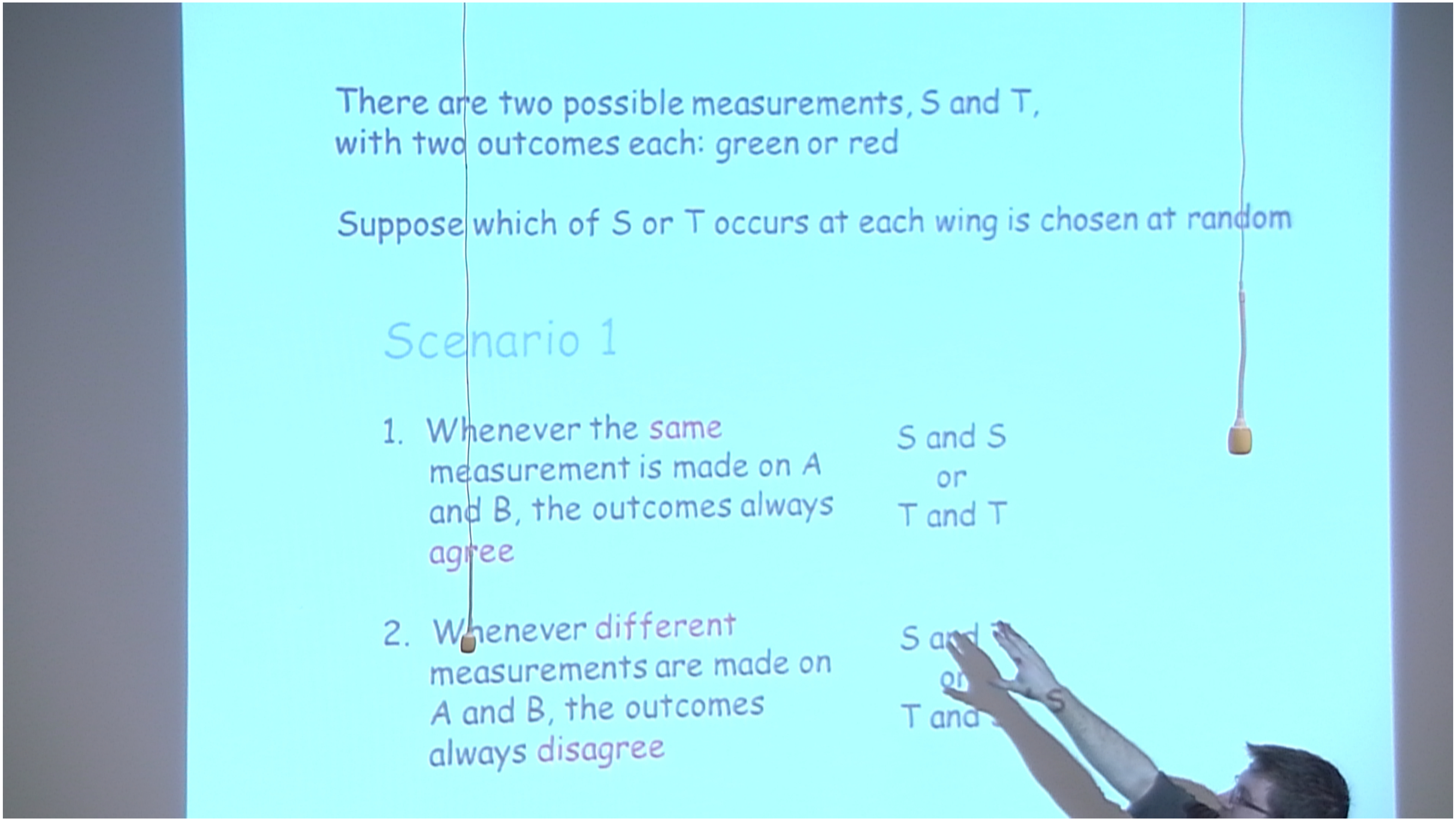


Categorizing quantum phenomena

Those arising in a restricted statistical classical theory	Those not arising in a restricted statistical classical theory
Noncommutativity	Bell inequality violations
Entanglement	Contextuality
Ambiguity of mixtures	Computational speed-up
EPR Steering	Certain aspects of items on the left
Collapse	Others...
Coherent superposition	
Teleportation	
No cloning	
Others...	
Type 1 Nonclassicality	**Type 2 Nonclassicality**


A pair of two-outcome measurements
S
S
T
T


S
S
E


There are two possible measurements, S and T,
with two outcomes each: green or red
Suppose which of S or T occurs at each wing is chosen at random
Scenario 1
1. Whenever the same measurement is made on A and B, the outcomes always agree
S and S
or
T and T
2. Whenever different measurements are made on A and B, the outcomes always disagree
S an
T and

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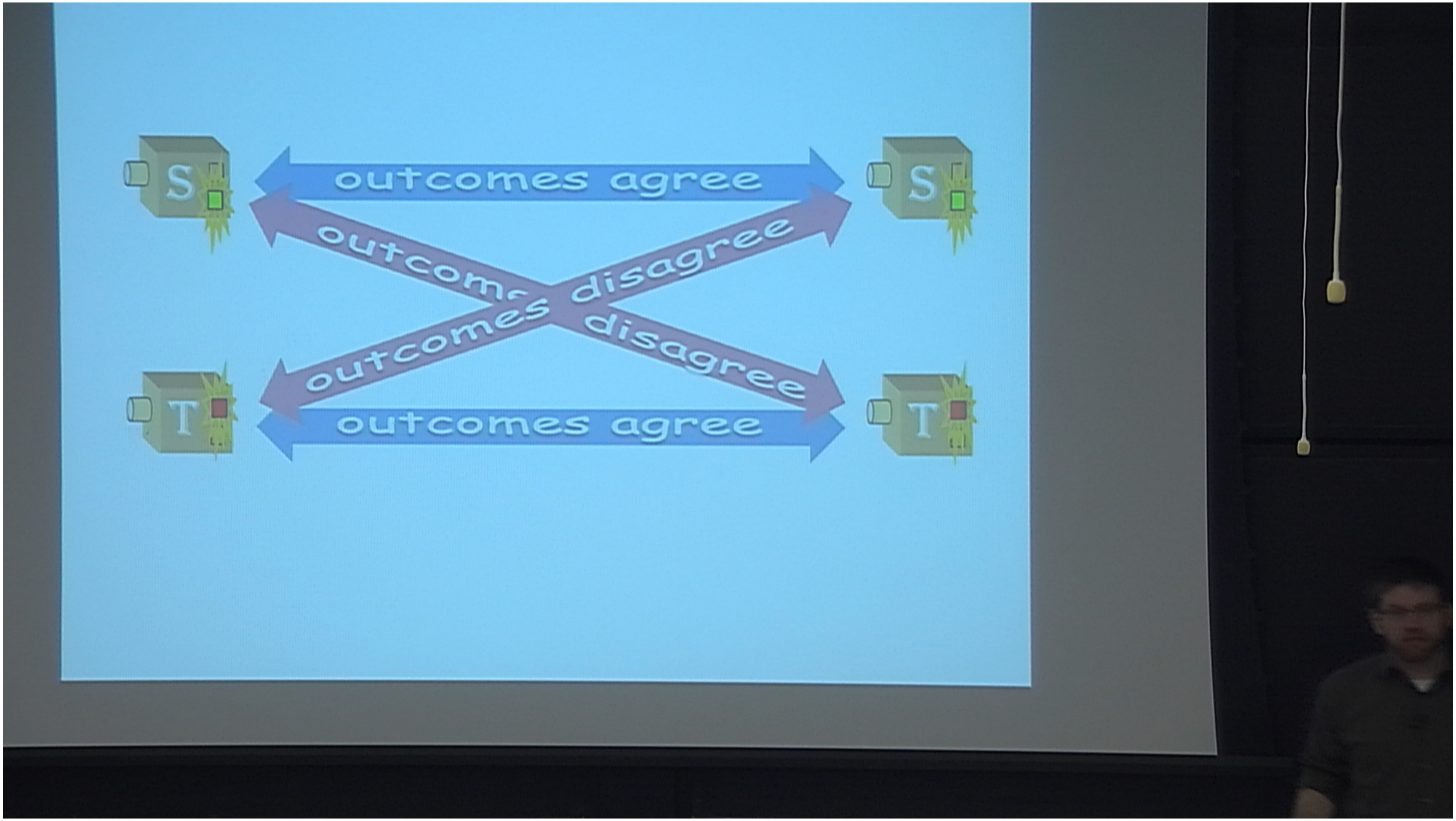
   or
   T and S

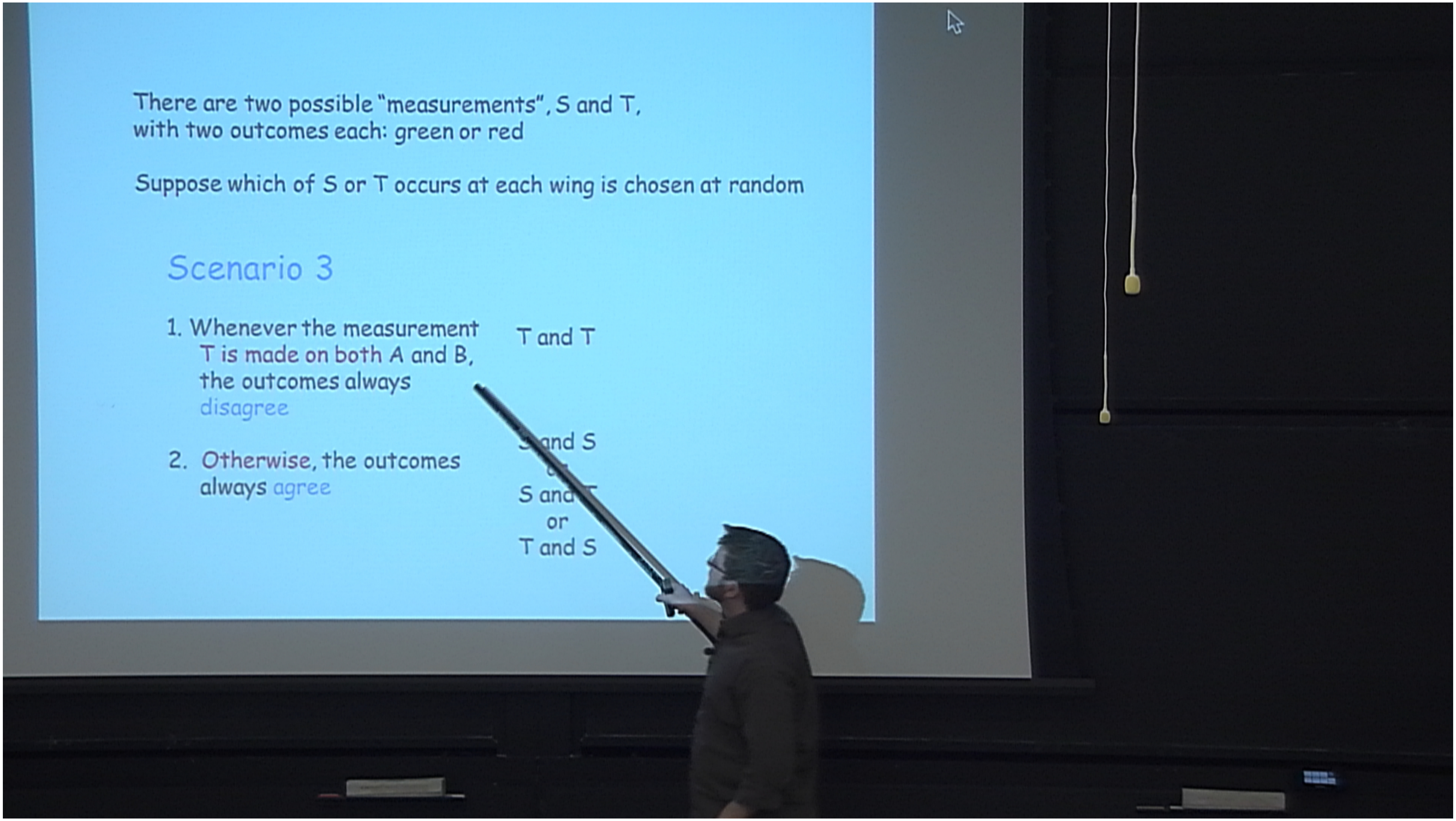

S
S
T
T
outcomes agree
outcomes disagree
outcomes disagree
outcomes agree

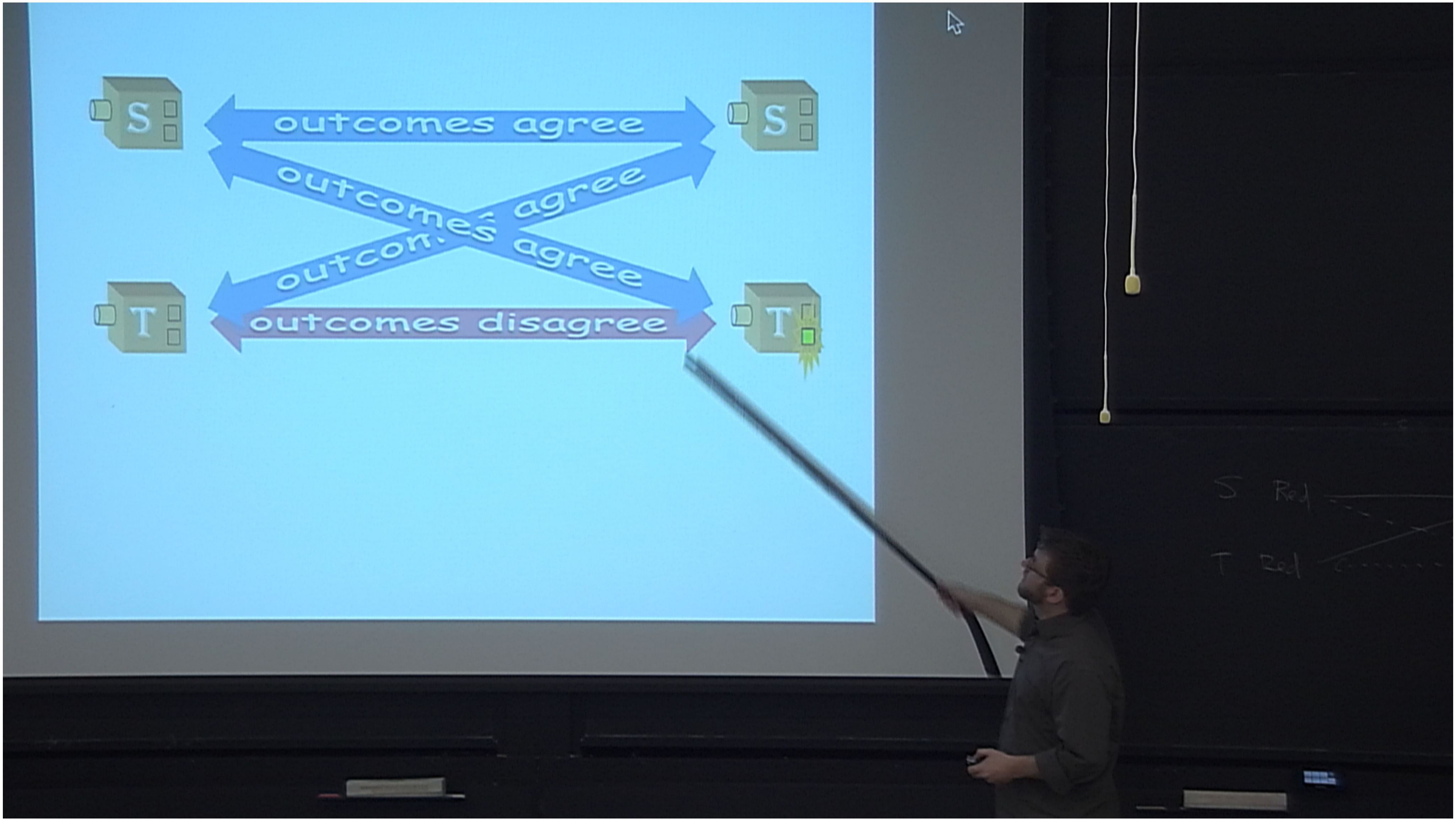
There are two possible measurements, S and T, with two outcomes each: green or red

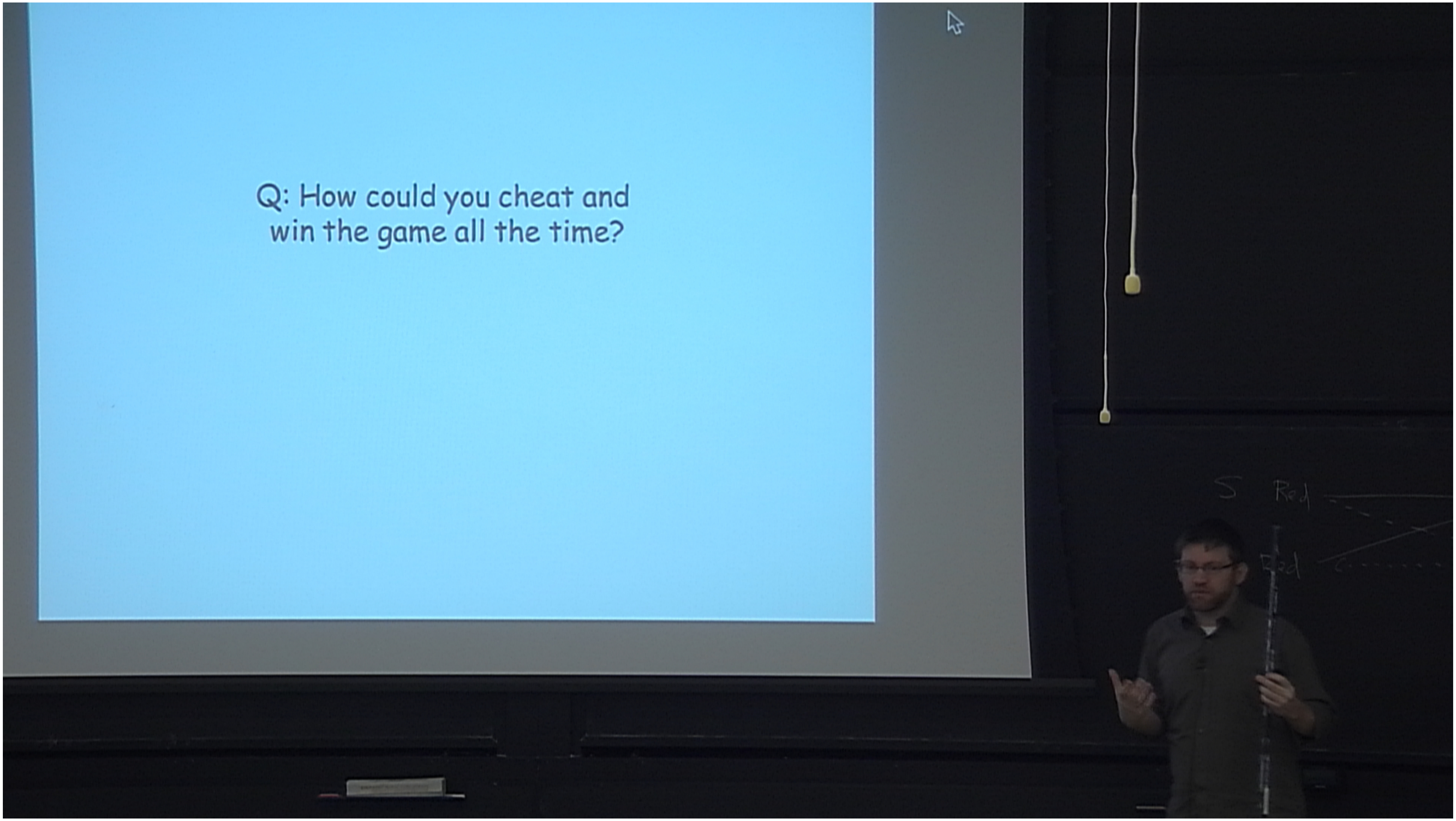
Suppose which of S or T occurs at each wing is chosen at random

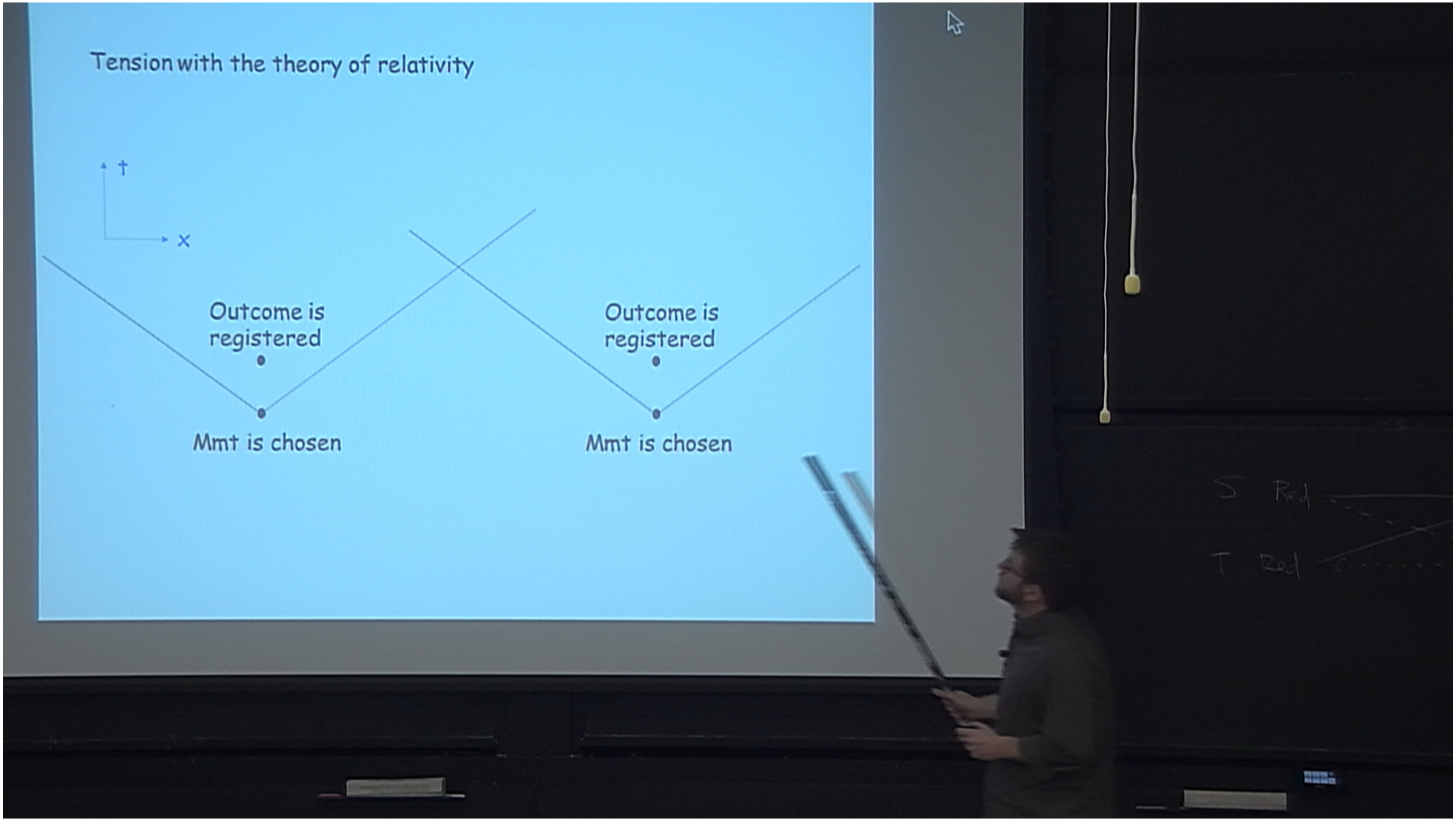
Scenario 2

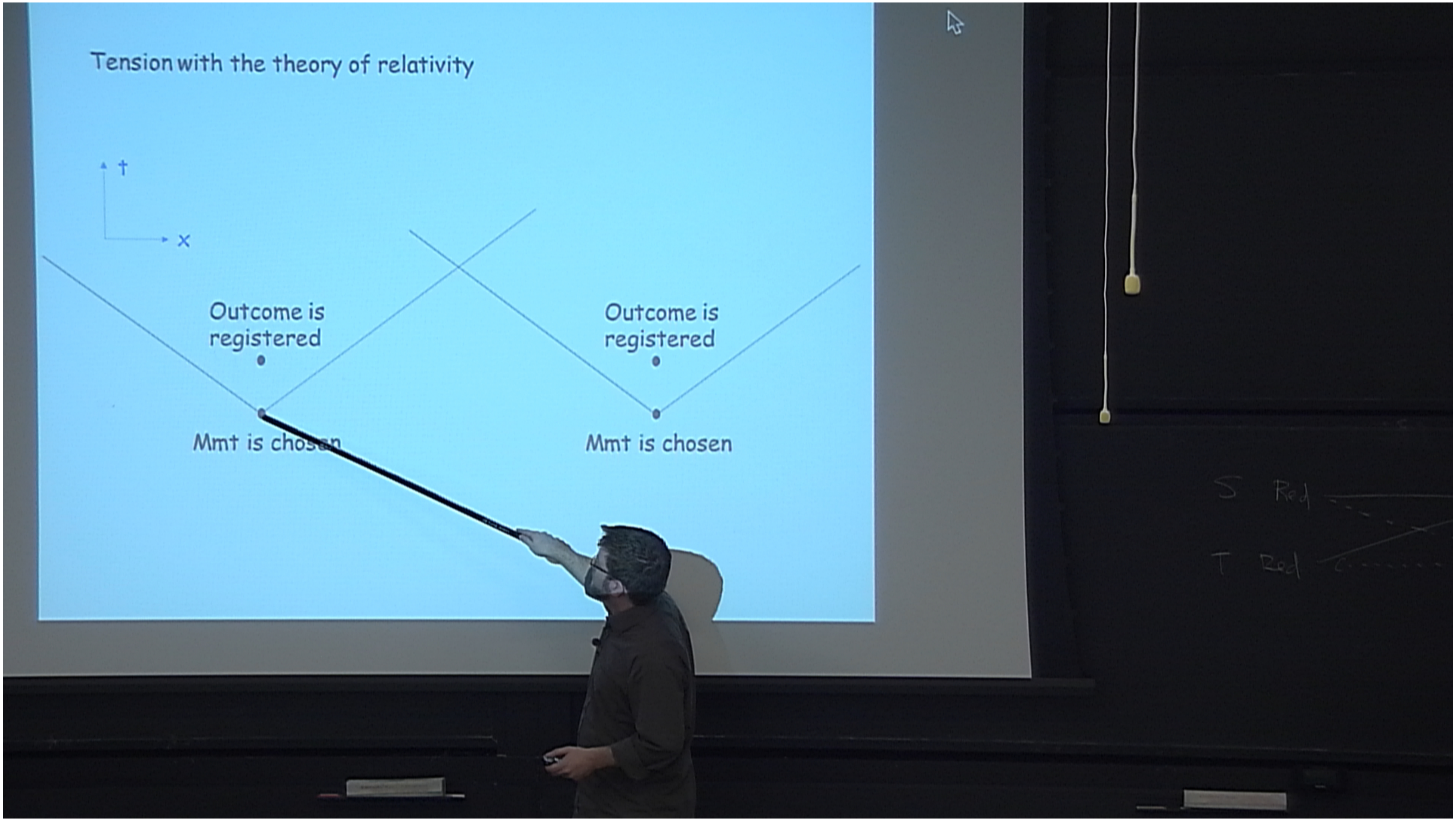
1. Whenever the same measurement is made on A and B, the outcomes always disagree	S and S or T and T
2. Whenever different measurements are made on A and B, the outcomes always agree	S and T or T and S


There are two possible "measurements", S and T,
with two outcomes each: green or red
Suppose which of S or T occurs at each wing is chosen at random
Scenario 3
1. Whenever the measurement T is made on both A and B, the outcomes always disagree
T and T
2. Otherwise, the outcomes always agree
and S
S and
or
T and S


S
S
outcomes agree
outcomes agree
outcomes agree
T
T
outcomes disagree
S Red
T Red


Q: How could you cheat and win the game all the time?


Tension with the theory of relativity
t
x
Outcome is registered
Mmt is chosen
Outcome is registered
Mmt is chosen
S Red
T Red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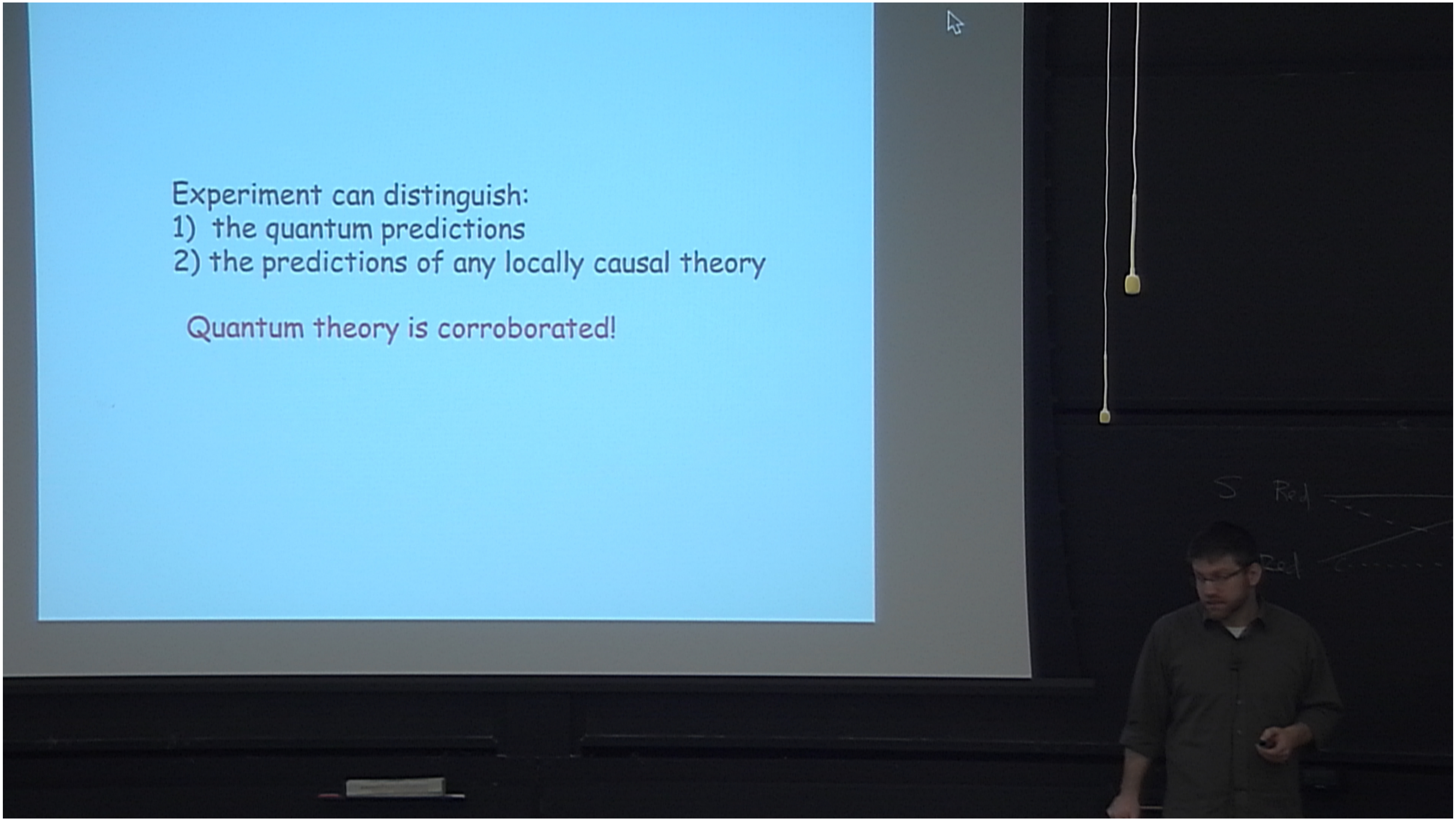
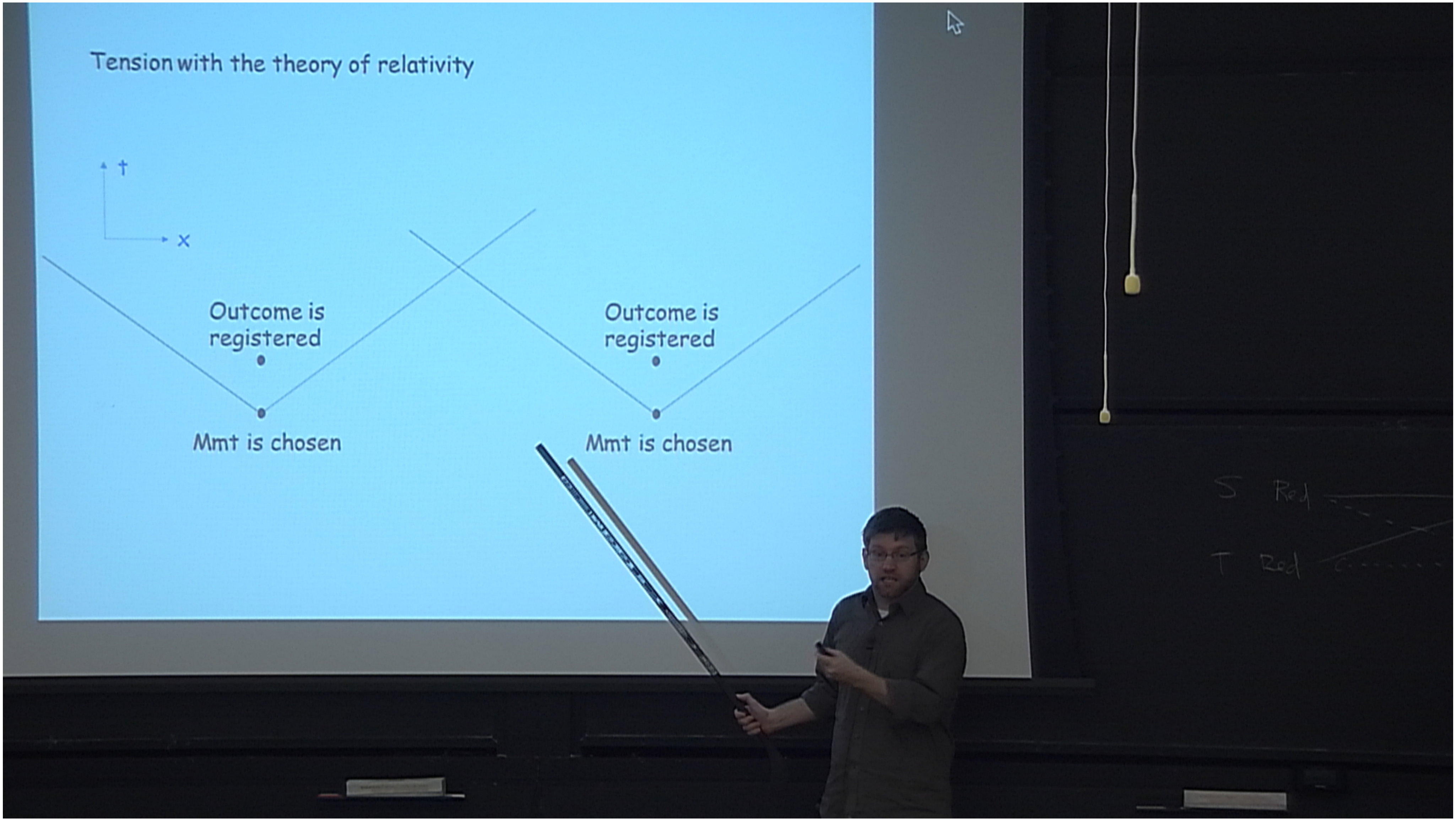

Experiment can distinguish:
1) the quantum predictions
2) the predictions of any locally causal theory
Quantum theory is corroborated!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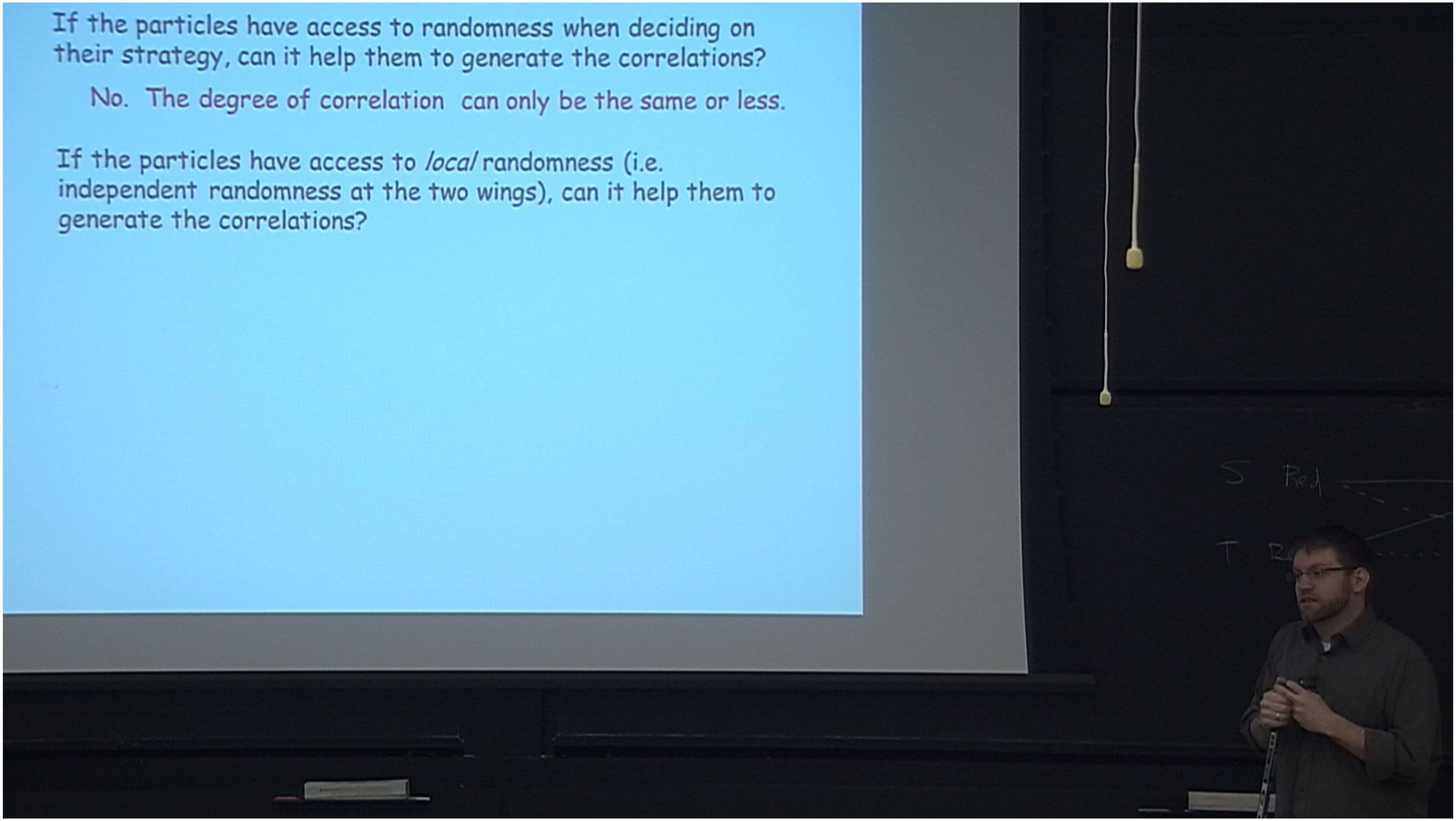
If the particles have access to randomness when deciding on their strategy, can it help them to generate the correlations?
No. The degree of correlation can only be the same or less.
If the particles have access to *local* randomness (i.e. independent randomness at the two wings), can it help them to generate the correlations?

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Yes. This is the detector loophole.

Is there a problem if the choice of measurement is made too early?

Yes. This is the locality loophole.

1) No superluminal signalling (independence of statistics at one wing on choice of measurement at the other)

2) The necessity of superluminal influences (dependence of particular outcomes at one wing on choice of measurement at the other)

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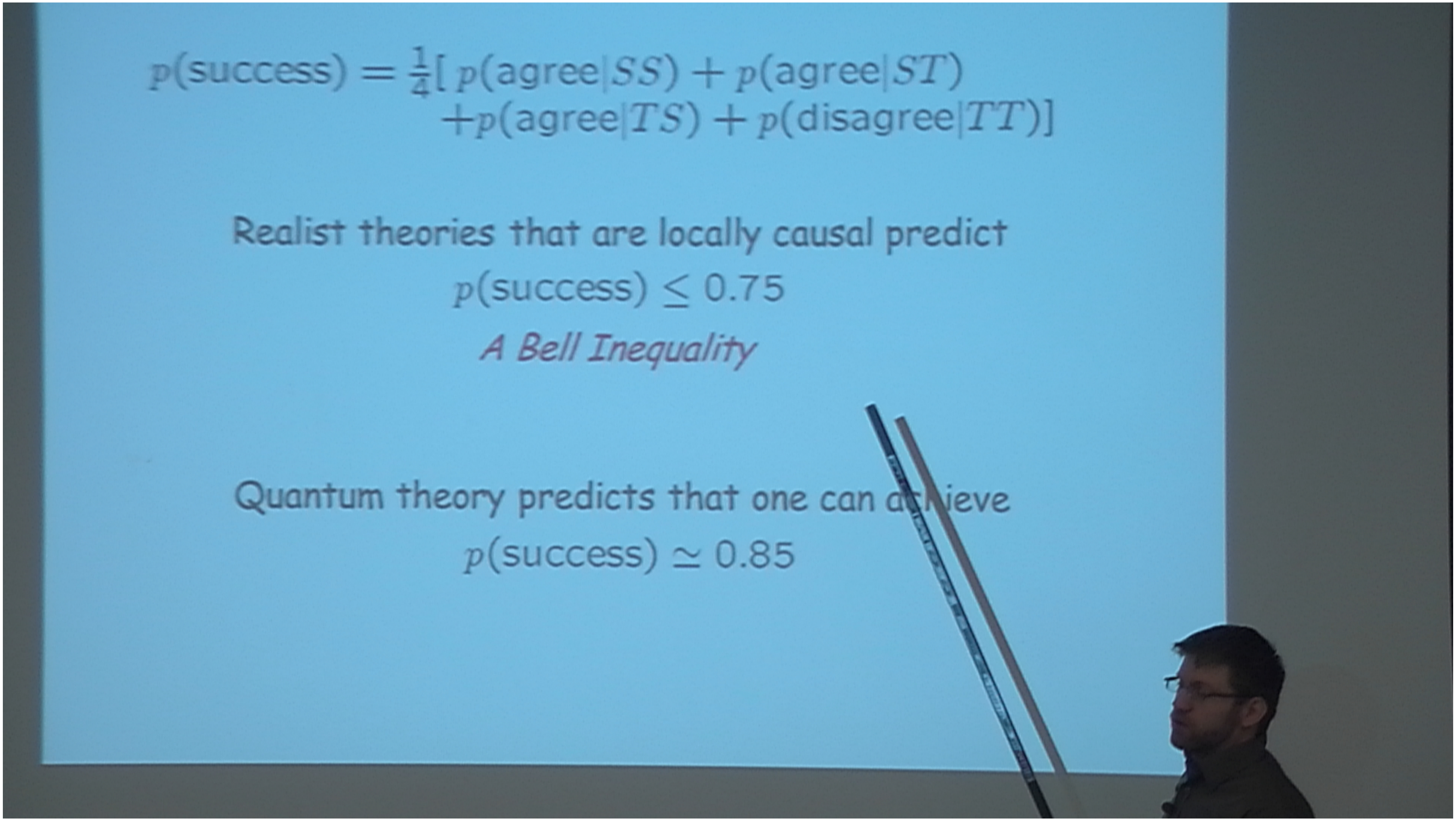
Realist theories that are locally causal predict

$$p(\text{success}) \leq 0.75$$

A Bell Inequality

Quantum theory predicts that one can achieve

$$p(\text{success}) \simeq 0.85$$


$p(\text{success}) = \frac{1}{4}[\,p(\text{agree}|SS) + p(\text{agree}|ST)$
$+p(\text{agree}|TS) + p(\text{disagree}|TT)]$
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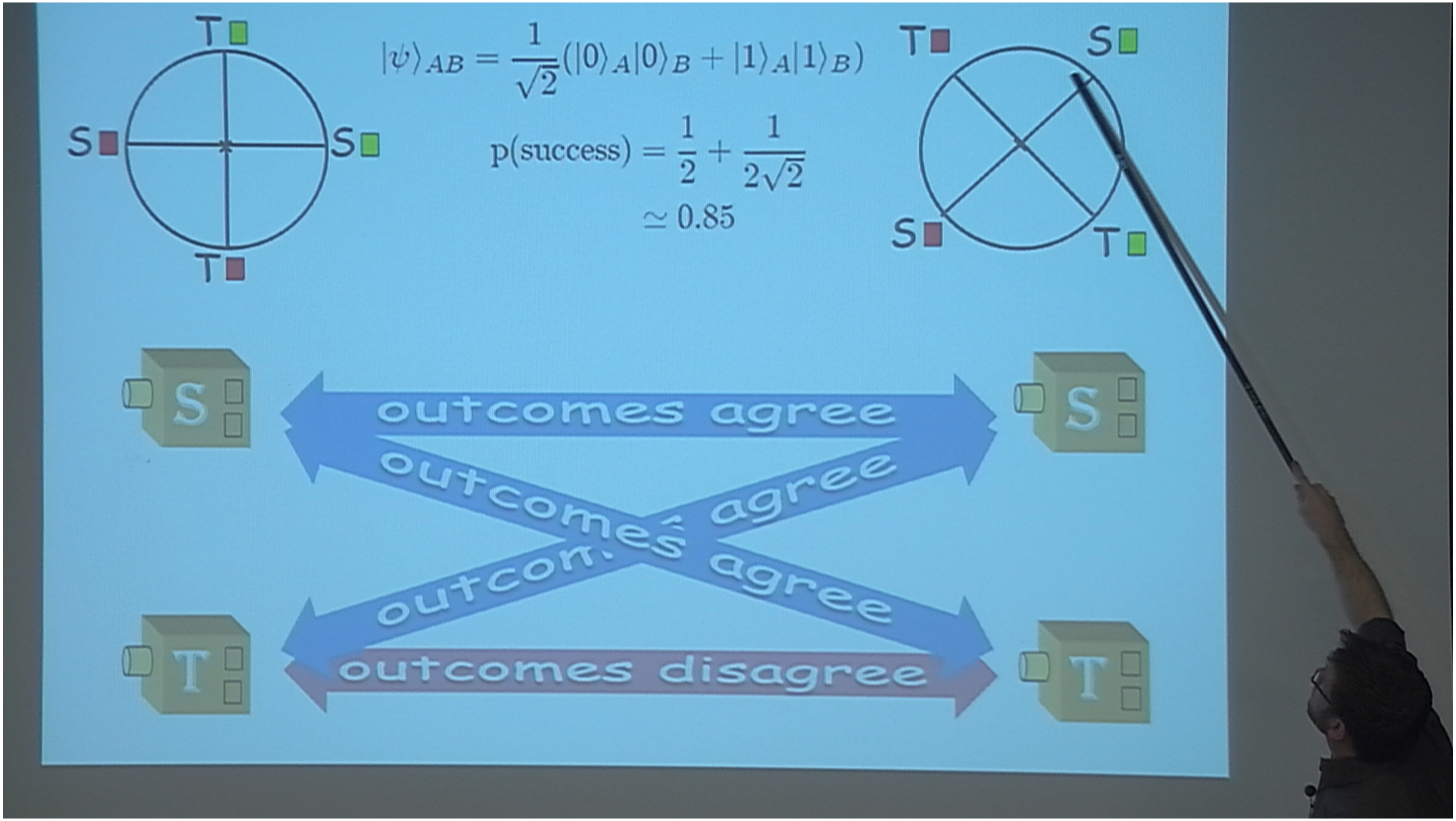
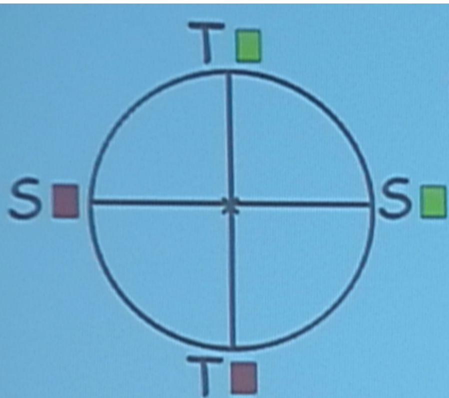
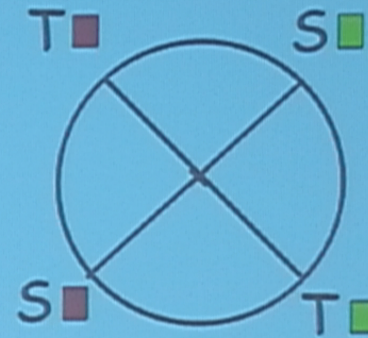


T
S
S
T
$|\psi\rangle_{AB} = \frac{1}{\sqrt{2}}(|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B)$
$\text{p(success)} = \frac{1}{2} + \frac{1}{2\sqrt{2}}$
$\simeq 0.85$
T
S
S
T
S
outcomes agree
S
outcomes agree
outcomes agree
T
outcomes disagree
T



$$|\psi\rangle_{AB} = \frac{1}{\sqrt{2}}(|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B)$$

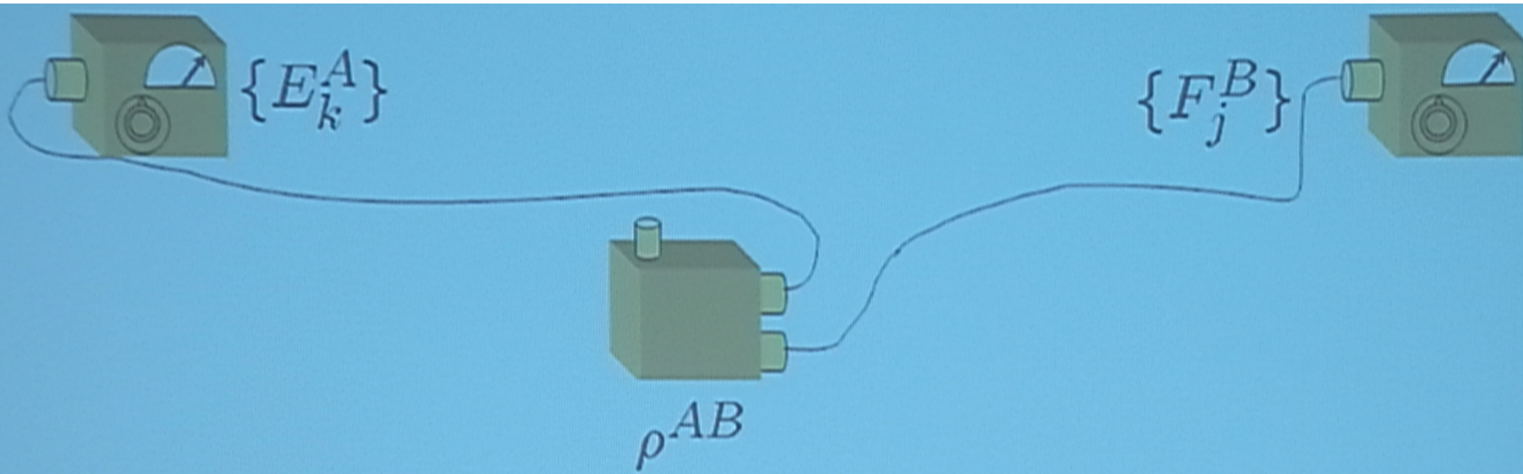
$$\text{p(success)} = \frac{1}{2} + \frac{1}{2\sqrt{2}}$$
$$\simeq 0.85$$



$$\begin{aligned}
{}_A\langle +\hat{n}|\psi\rangle_{AB} &= [\cos(\theta/2)\,{}_A\langle 0| + \sin(\theta/2)\,{}_A\langle 1|]\frac{1}{\sqrt{2}}(|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B) \\
&= \cos(\theta/2)|0\rangle_B + \sin(\theta/2)|1\rangle_B \\
&= |+\hat{n}\rangle_B
\end{aligned}$$

$$|\langle +\hat{n}|_A\langle +\hat{m}|_B|\psi\rangle_{AB}|^2 = |\langle +\hat{m}|+\hat{n}\rangle|^2 = \cos^2(\theta/2)$$

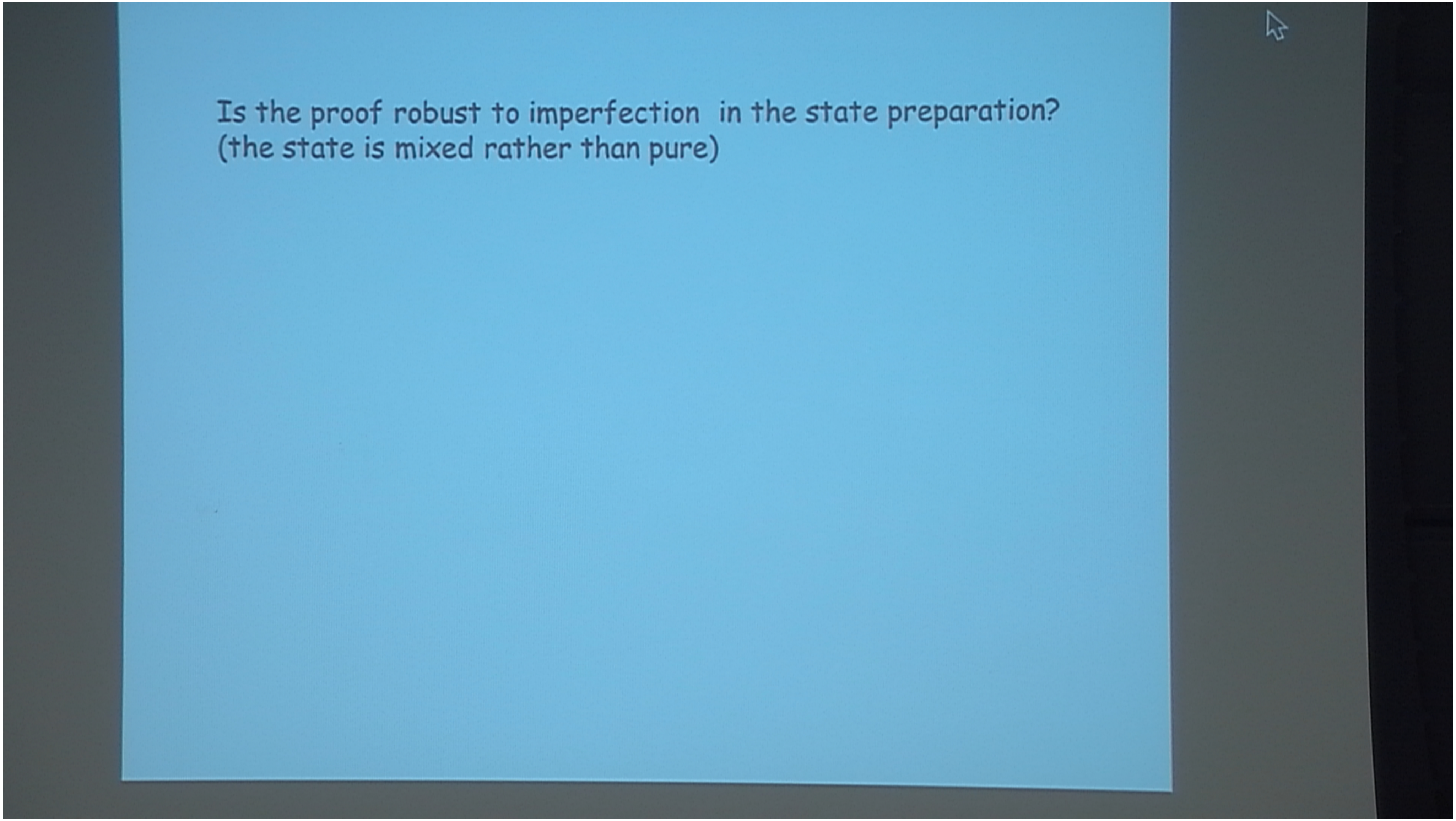
$$p(\text{agree}|SS) = p(\text{agree}|ST) = p(\text{agree}|TS) = p(\text{disagree}|TT)$$
$$= \cos^2(\pi/8) = \frac{1}{2} + \frac{1}{2\sqrt{2}}$$



$$
\begin{aligned}
p(j) &= \sum_k p(k,j) \\
&= \sum_k \mathrm{Tr}_{AB}[\,(E_k^A \otimes F_j^B)\ \rho^{AB}] \\
&= \mathrm{Tr}_{AB}[\,(I^A \otimes F_j^B)\ \rho^{AB}]
\end{aligned}
$$

Independent of choice of measurement at A

Note $[E_k^A \otimes I^B, I^A \otimes F_j^B] = 0$ for A and B space-like separated


Is the proof robust to imperfection in the state preparation?
(the state is mixed rather than pure)

Nonlocality in more depth

Nonlocality in more depth