Title: How Fundamental is the Uncertainty Principle?

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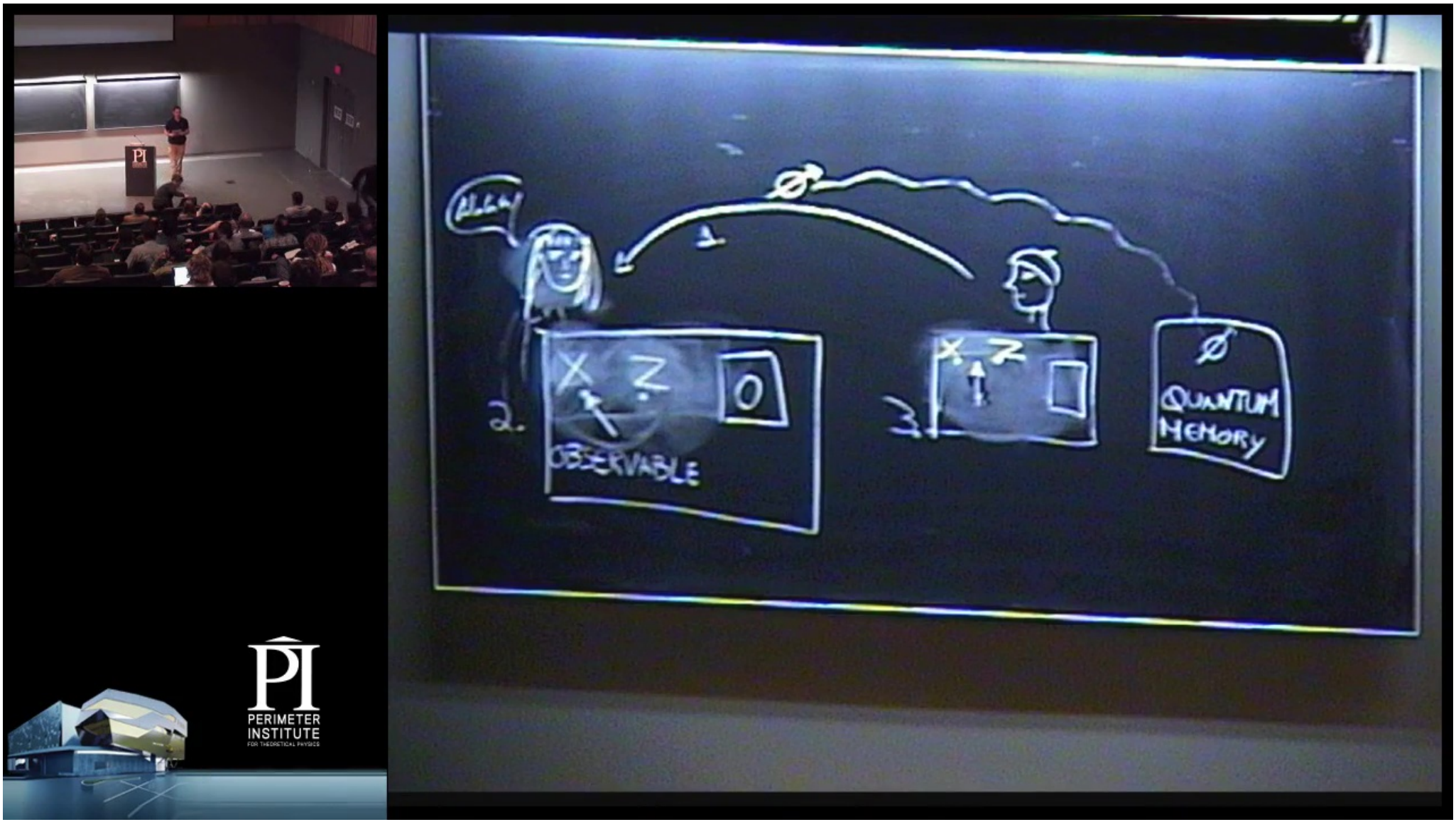
Abstract: According to quantum theory, it is impossible to prepare the state of a system such that the outcome of any projective measurement on the system can be predicted with certainty. This limitation of predictive power, which is known as the uncertainty principle, is one of the main distinguishing properties of quantum theory when compared to classical theories. In this talk, I will discuss the implications of this principle to foundational questions. In particular, I will consider the hypothesis that the uncertainty principle, rather than (only) telling us something about reality, may be seen as a manifestation of the limitations of our (classical) methods used to describe reality.


1.
2.
3.
X
Z
OBSERVABLE
QUANTUM
MEMORY
PERIMETER
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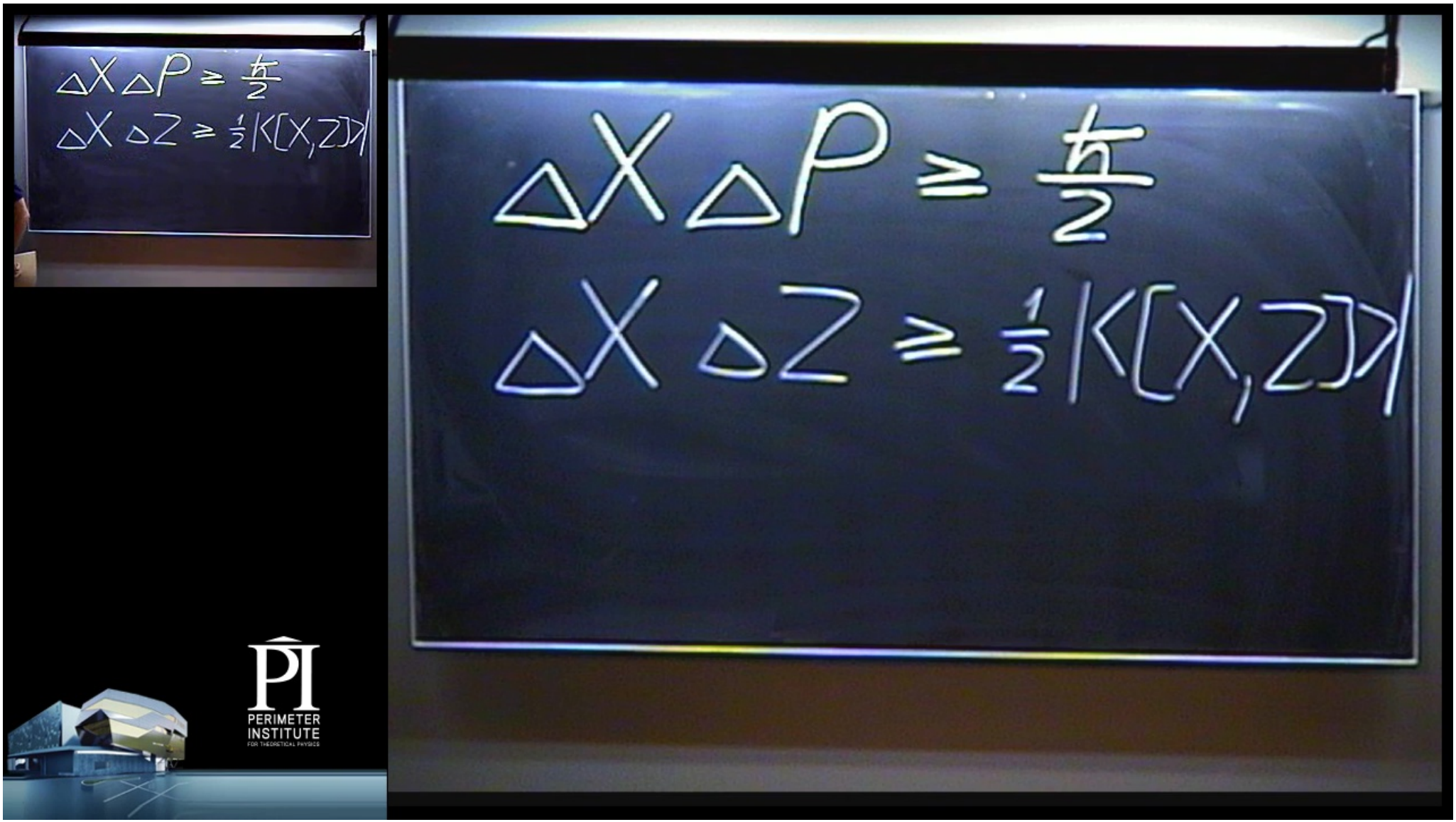
$\Delta X \Delta P \geq \frac{\hbar}{2}$
$\Delta X \Delta Z \geq \frac{1}{2} |\langle [X,Z] \rangle|$
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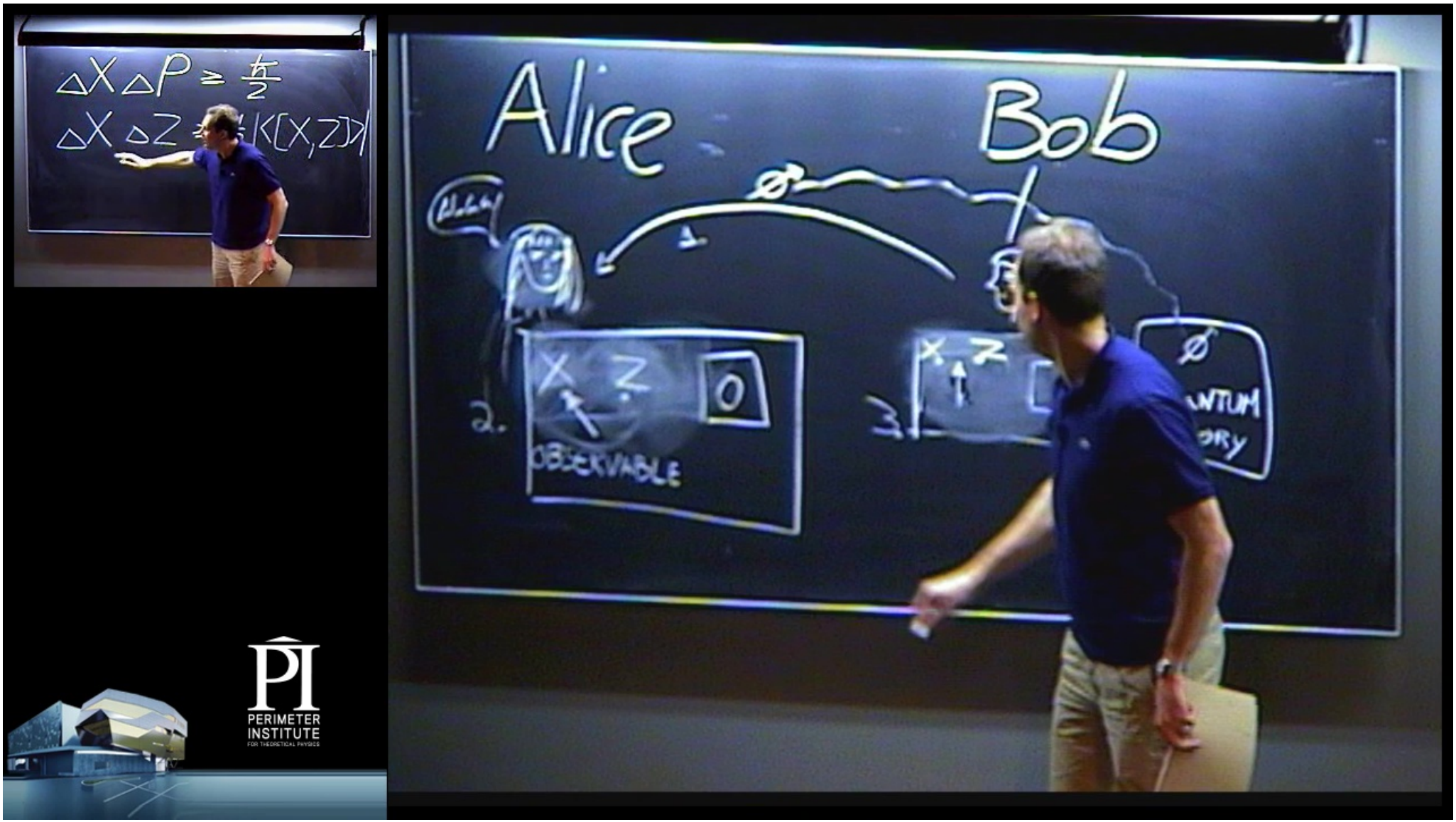
Alice
Bob
OBSERVABLE
PERIMETER
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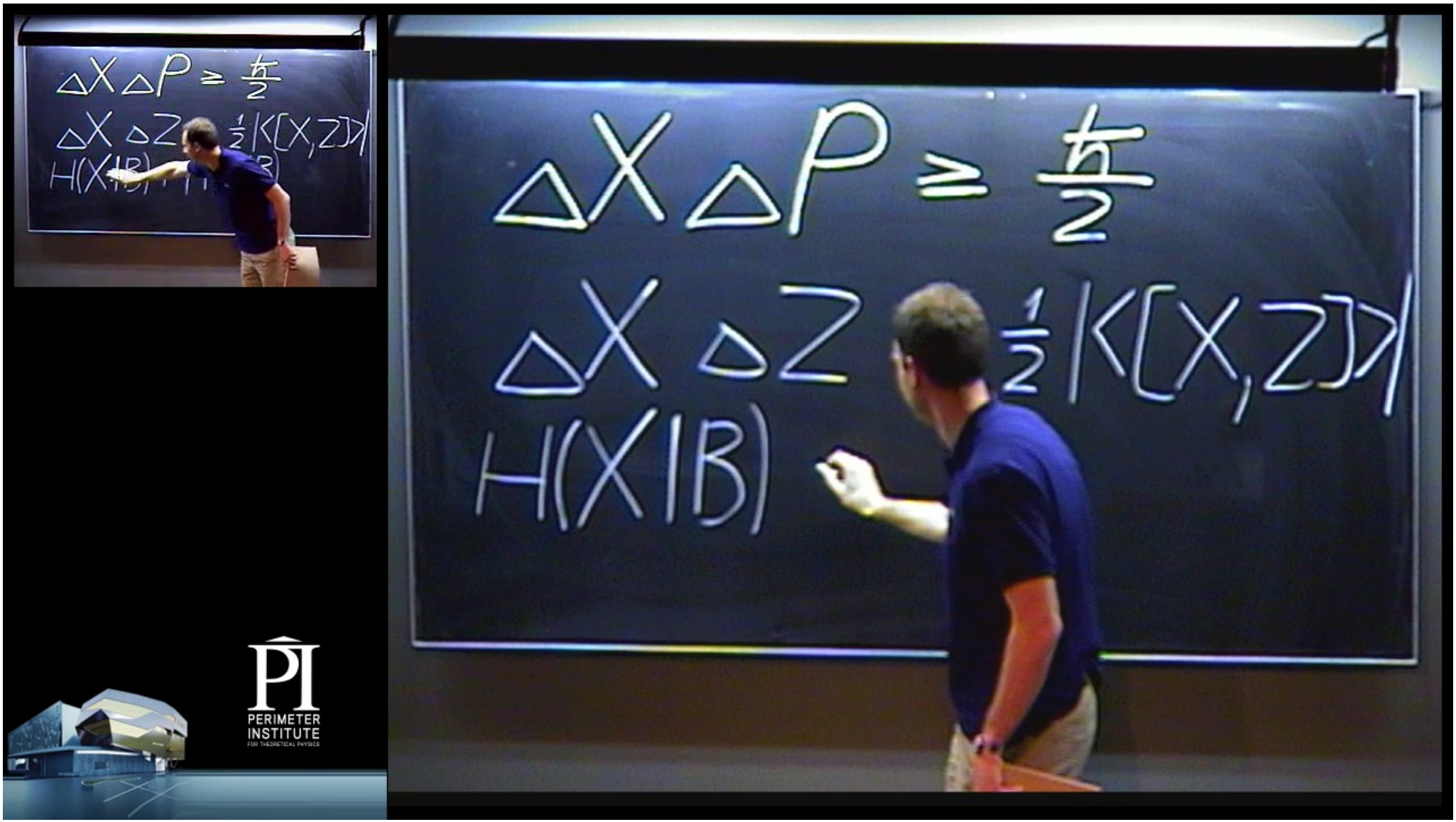
ΔX ΔP ≥ ħ/2
ΔX ΔZ ≥ 1/2 |⟨[X,Z]⟩|
H(X|B)
PERIMETER
INSTITUTE
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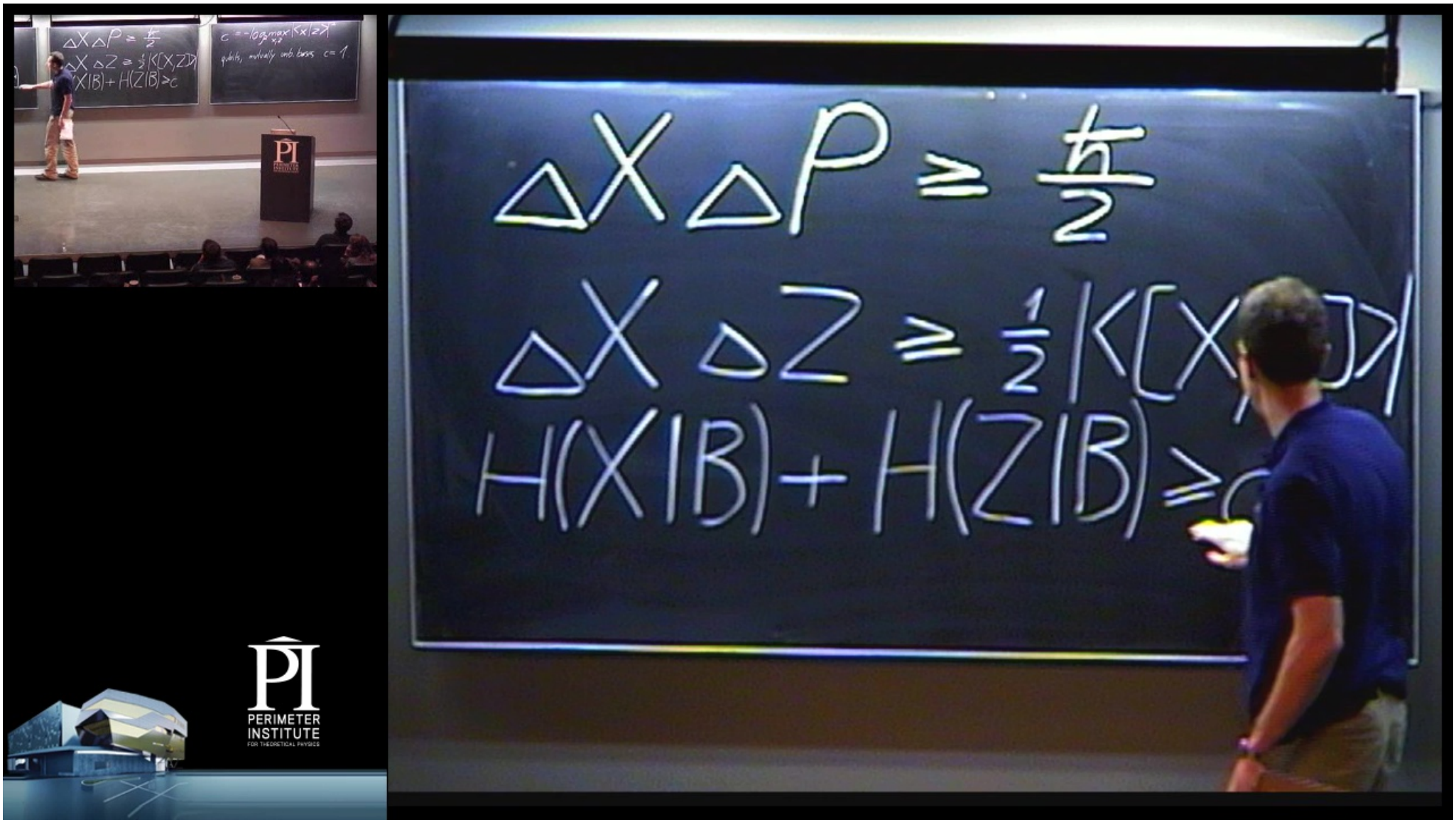
ΔX ΔP ≥ ħ/2
ΔX ΔZ ≥ 1/2 |⟨[X,Z]⟩|
H(X|B) + H(Z|B) ≥ c
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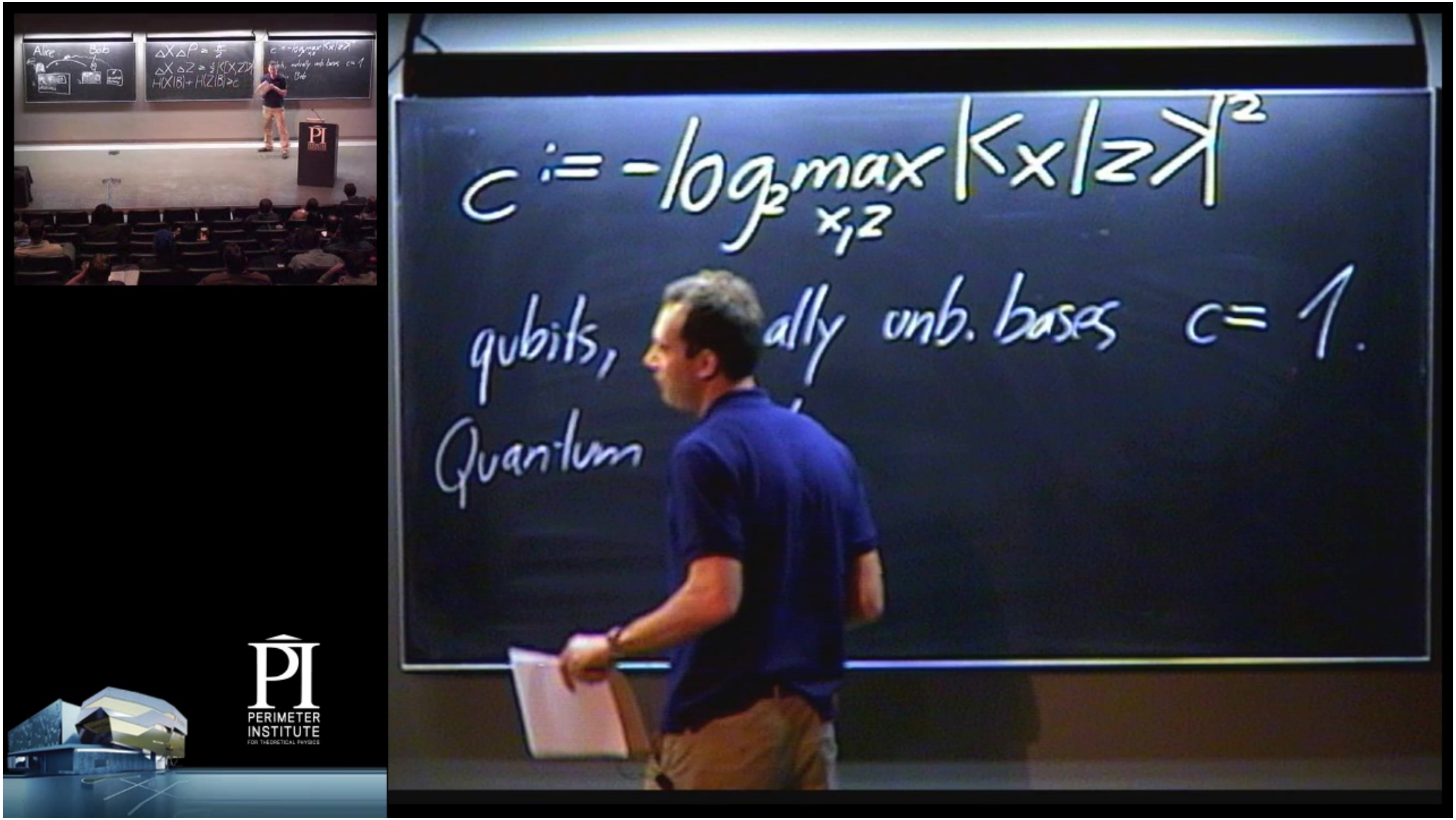
c := -log2 max |<x|z>|^2
x,z
qubits,
ally
unb. bases
c = 1.
Quantum
PERIMETER
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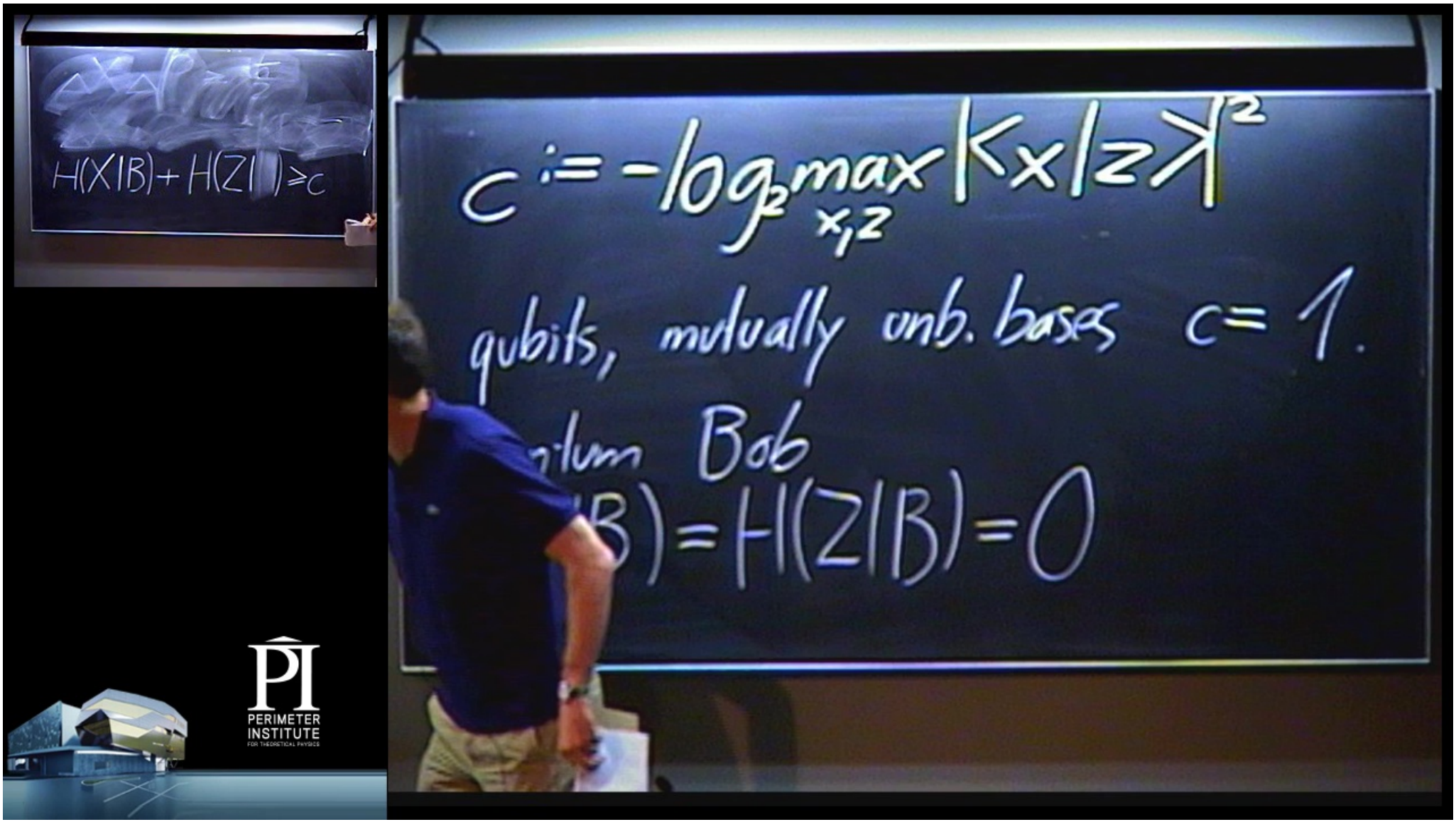
H(X|B)+H(Z|
≥c
c := -log₂ max |⟨x|z⟩|²
x,z
qubits, mutually unb. bases c = 1.
Bob
B) = H(Z|B) = 0
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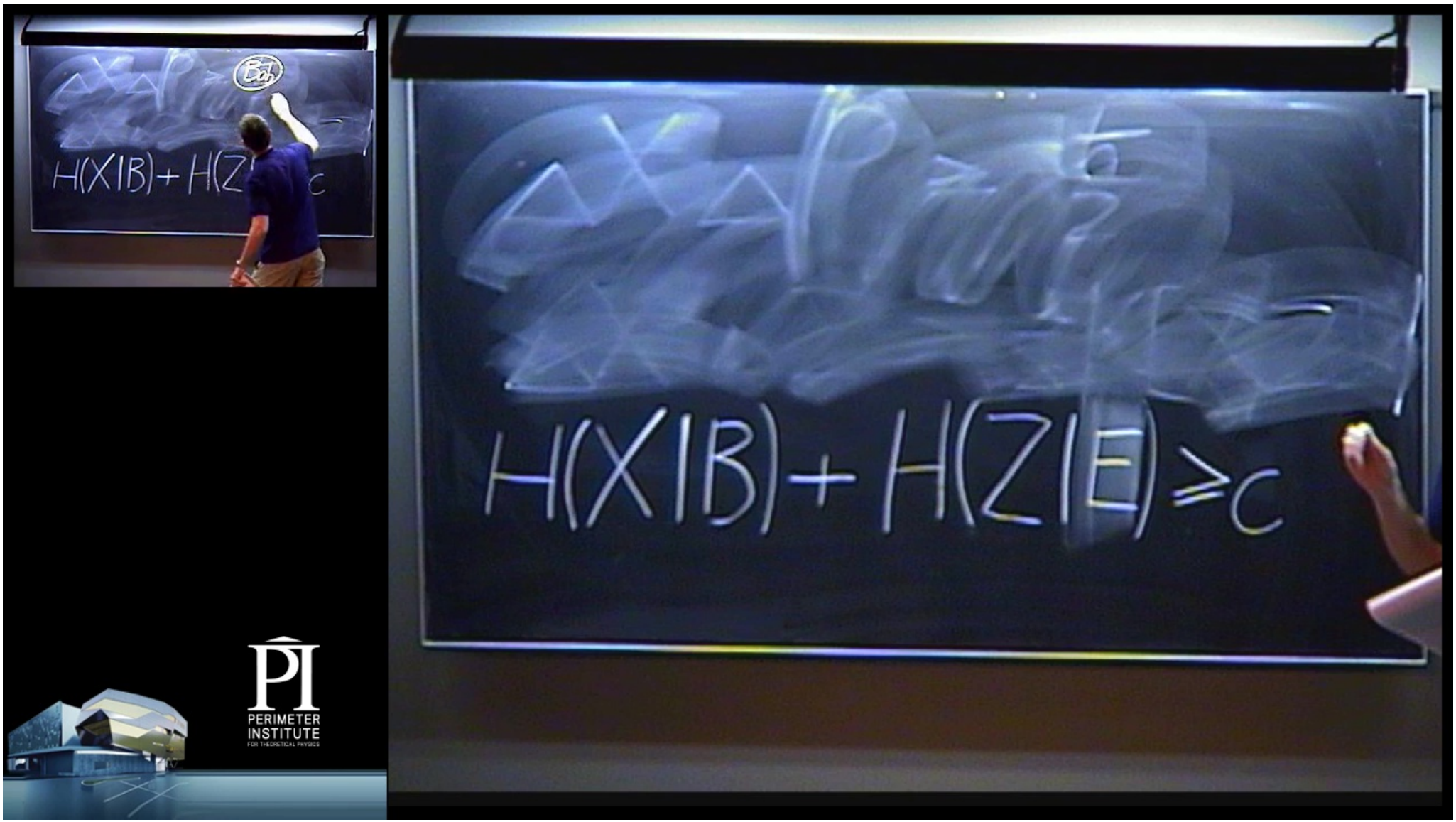
H(X|B)+H(Z|E)≥c
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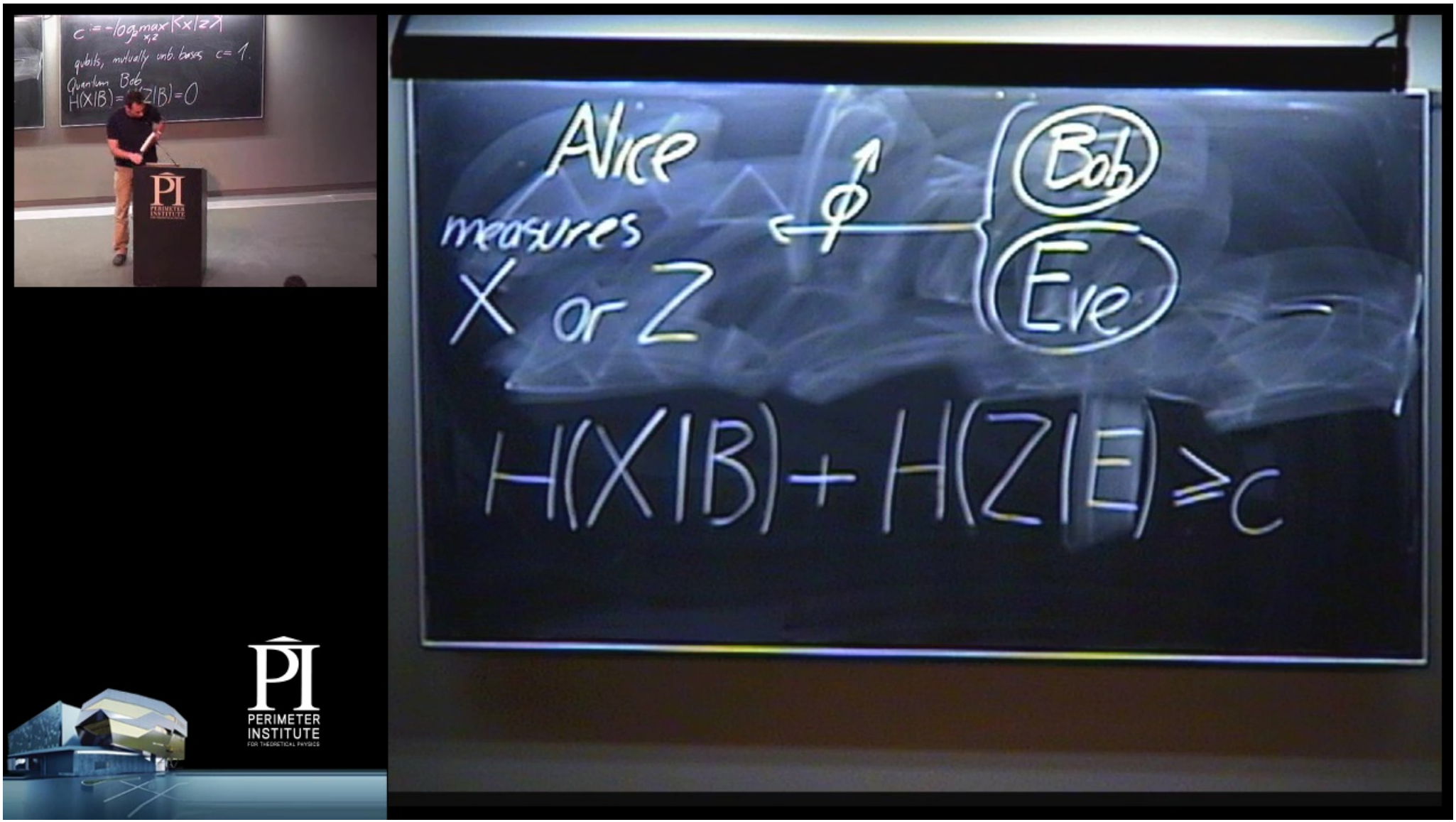
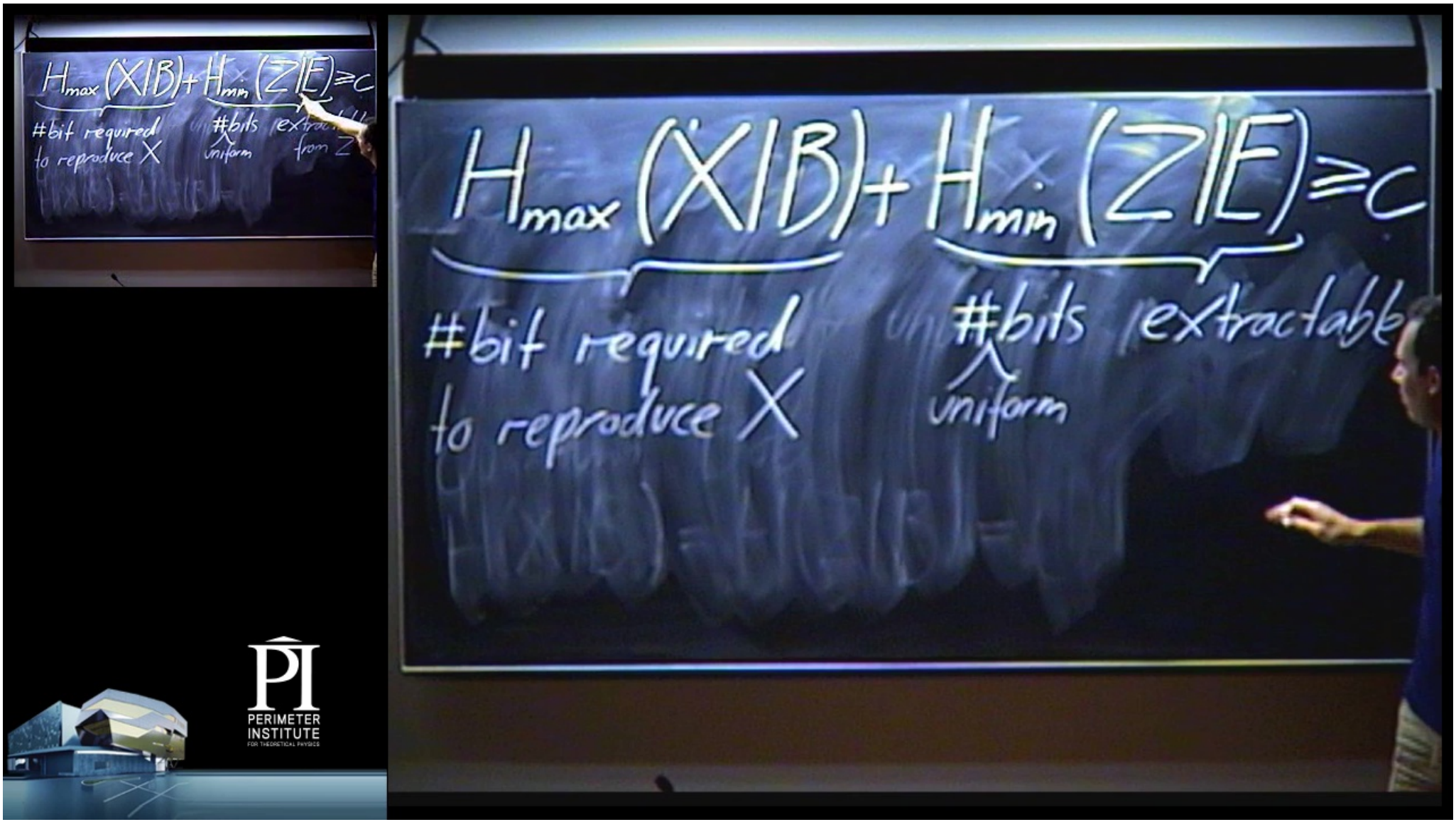

Alice
measures
X or Z
Bob
Eve
H(X|B)+H(Z|E)≥c


$H_{max}(X|B) + H_{min}(Z|E) \geq c$
#bit required to reproduce X
#bits uniform extractable from Z
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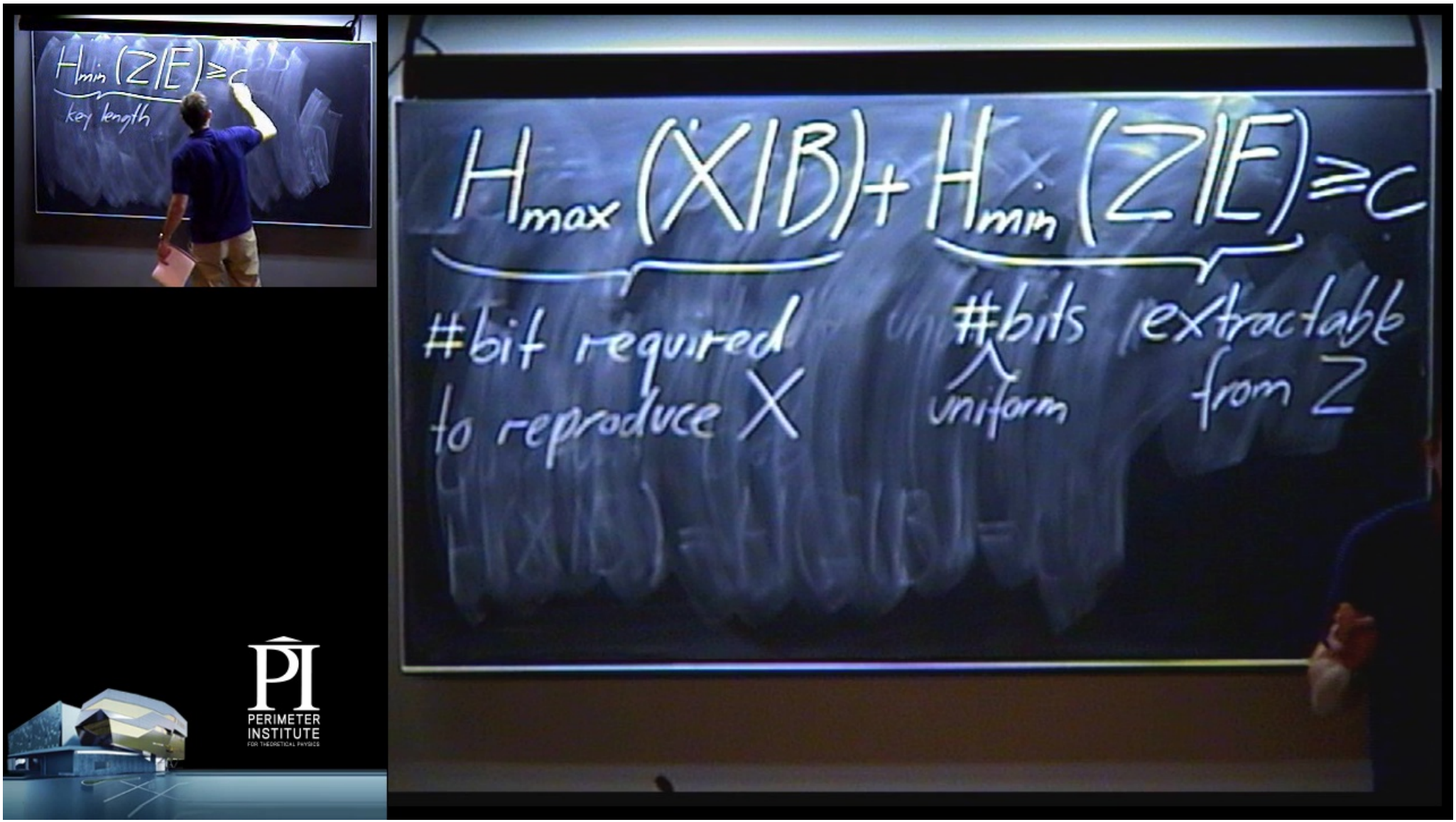
$H_{min}(Z|E) \geq c$
key length
$H_{max}(X|B) + H_{min}(Z|E) \geq c$
#bit required to reproduce X
#bits uniform extractable from Z
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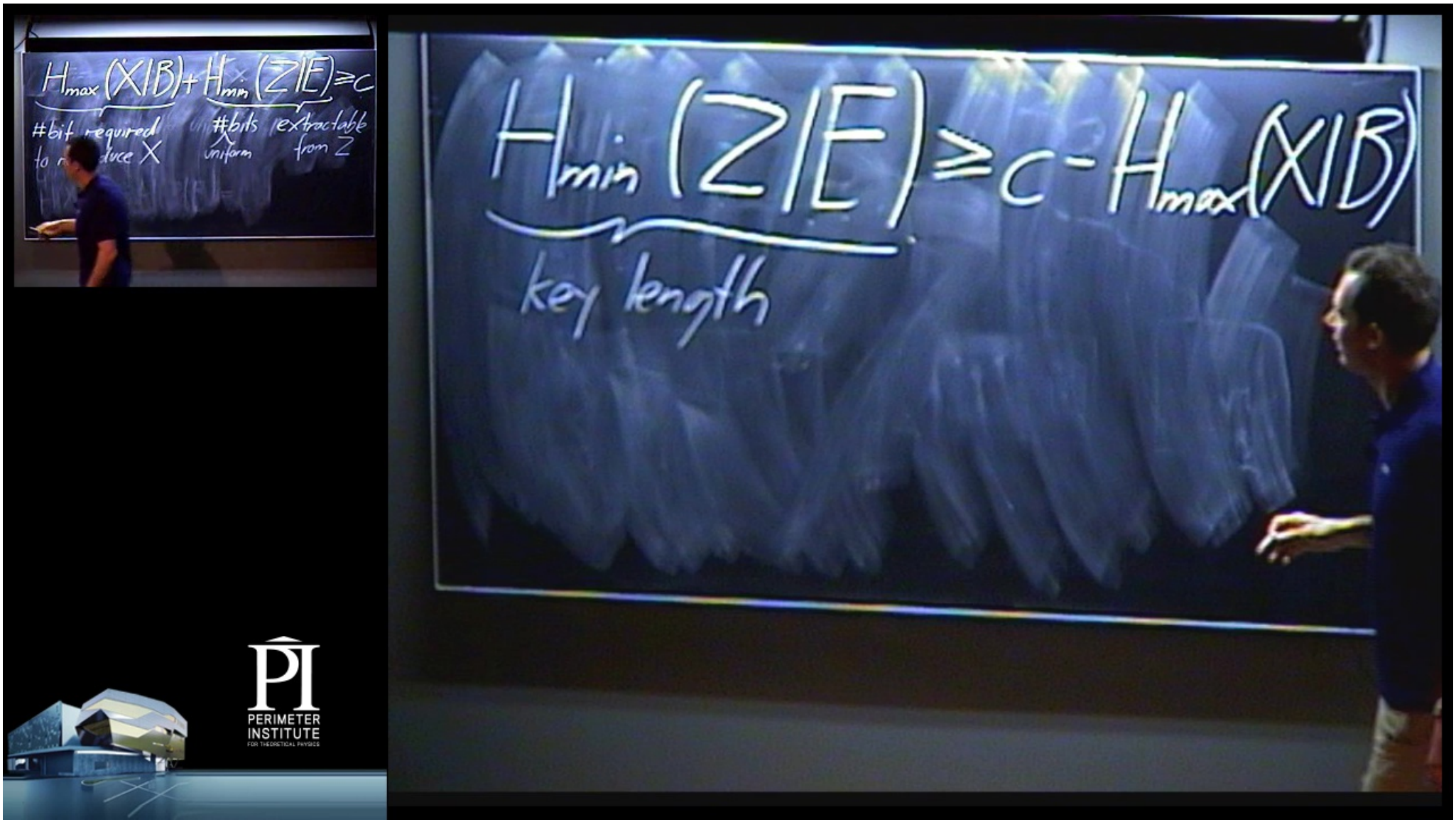
$H_{max}(X|B) + H_{min}(Z|E) \geq c$
#bits required
#bits uniform
extractable from Z
$H_{min}(Z|E) \geq c - H_{max}(X|B)$
key length
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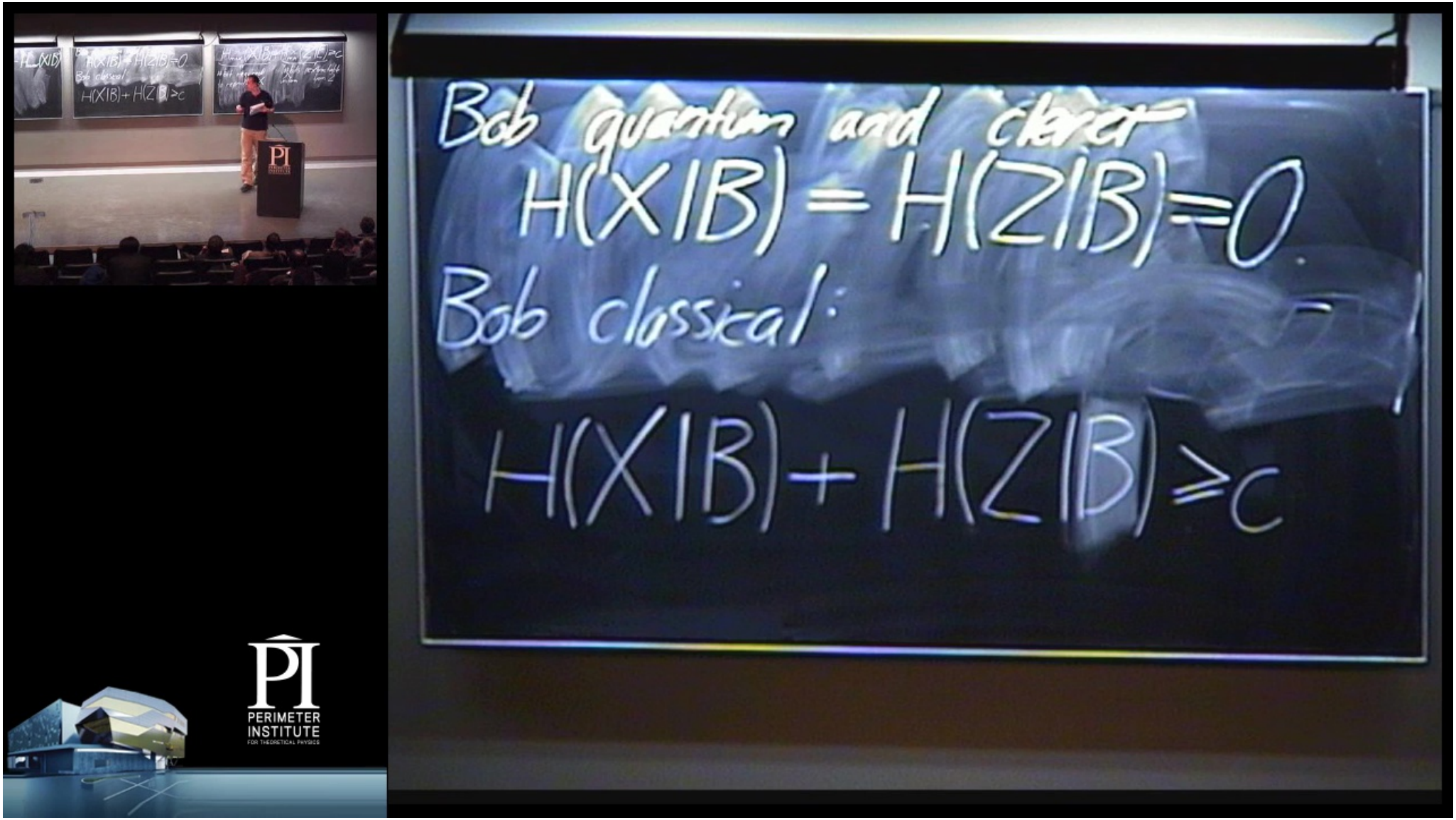
Bob quantum and classical
H(X|B) = H(Z|B) = 0
Bob classical:
H(X|B) + H(Z|B) ≥ c
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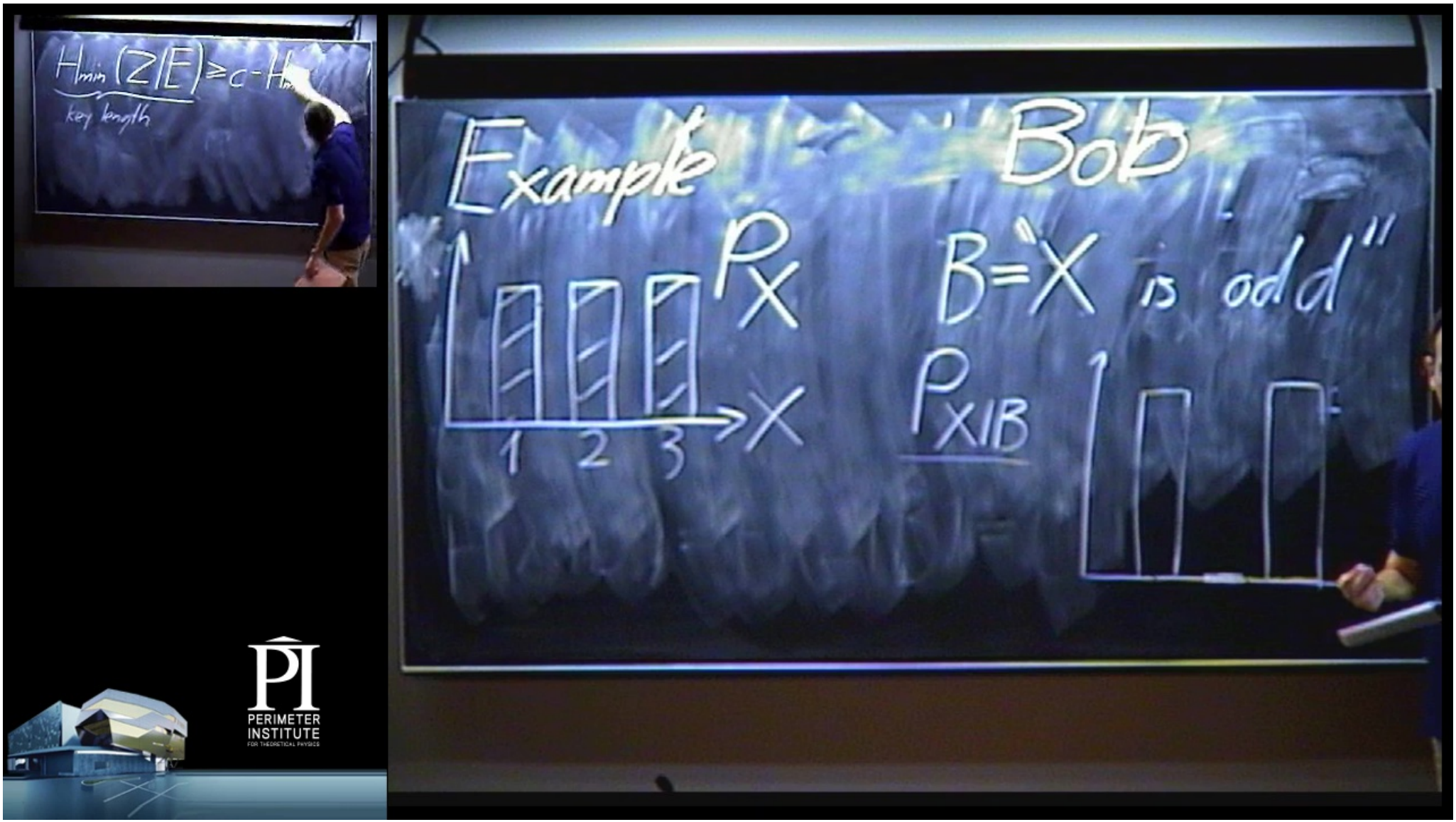
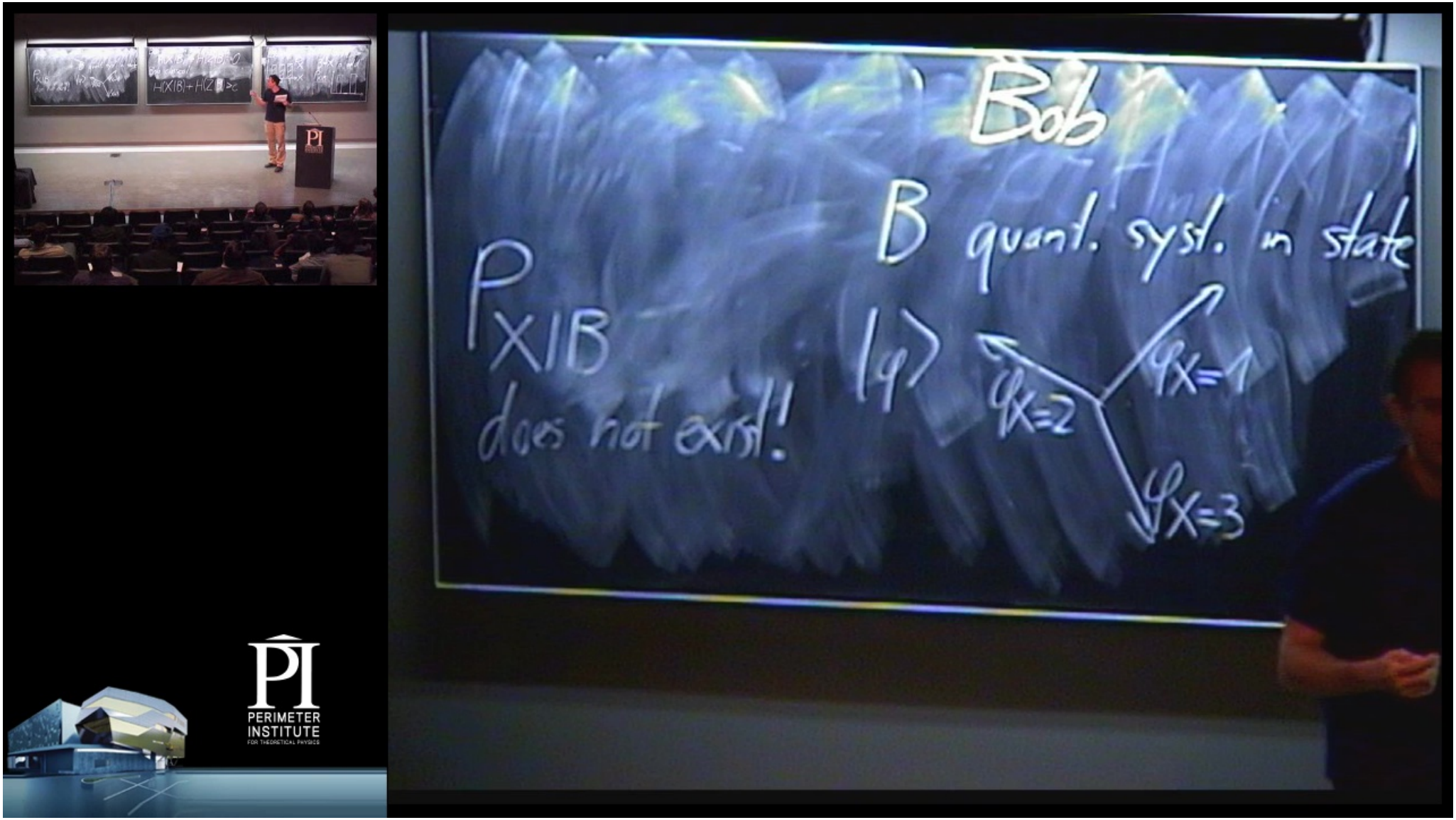

Hmin (Z|E) ≥ c - H
key length
Example
Bob
Px
1 2 3
X
B = "X is odd"
PX|B


Bob
B quant. syst. in state
$P_{X|B}$
does not exist!
$|\varphi\rangle$
$\varphi_{X=1}$
$\varphi_{X=2}$
$\varphi_{X=3}$
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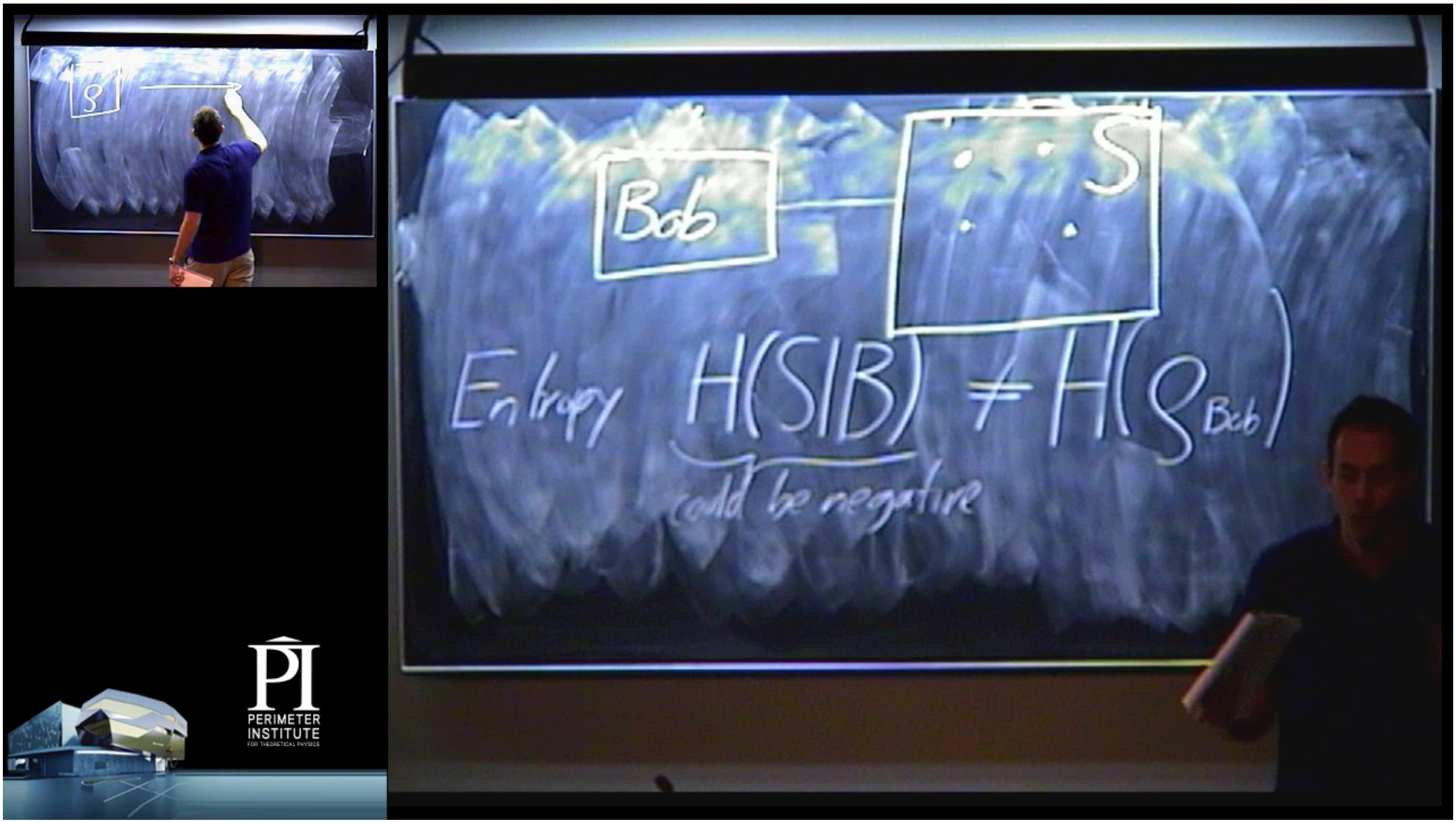
Bob
S
Entropy H(S|B) ≠ H(ρ_Bob)
could be negative
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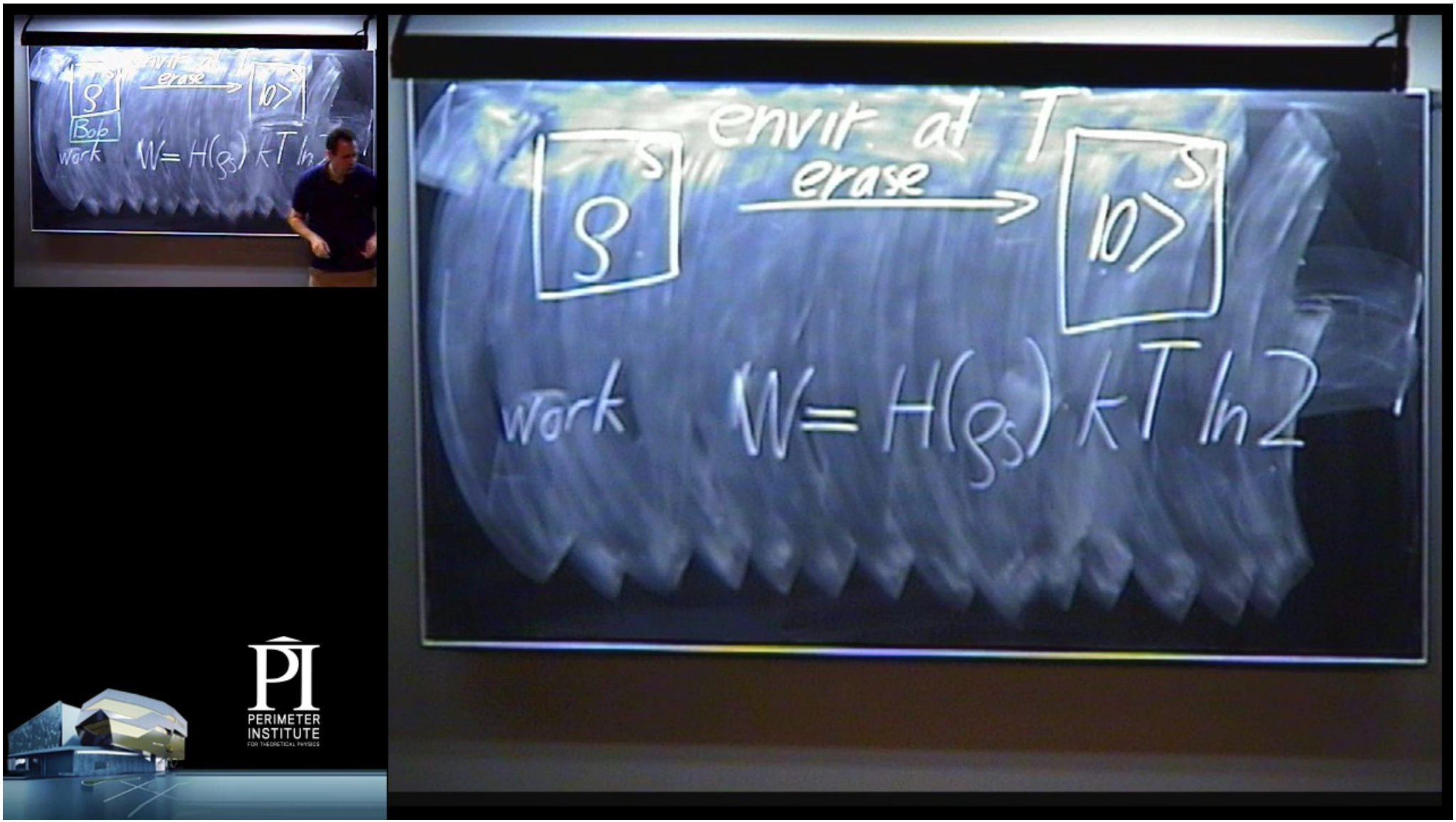
envir. at T
erase
ρ
s
|0⟩
s
work
W = H(ρs) kT ln2
Bob
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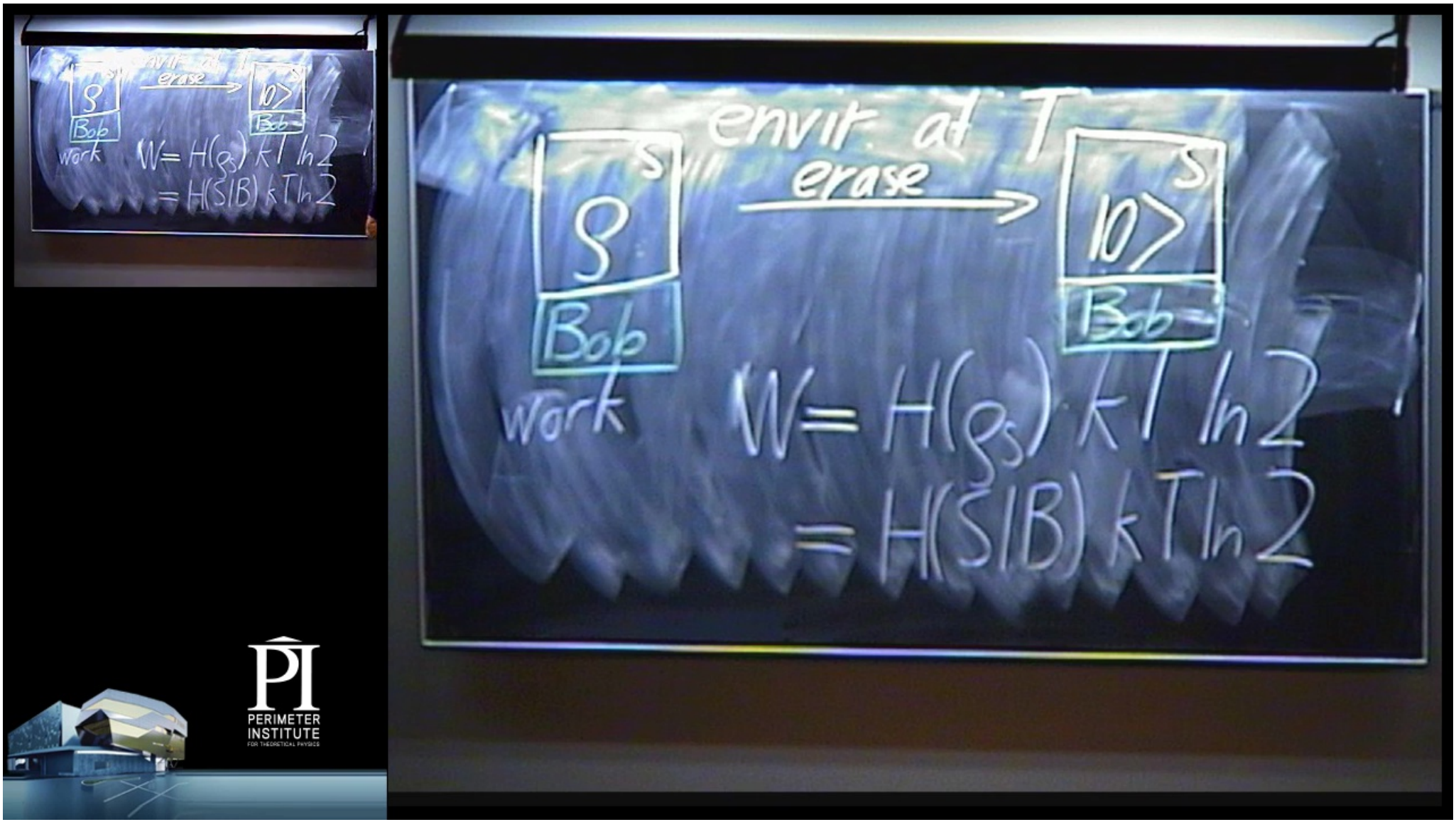
envir. at T
erase
ρ
S
Bob
work
|0>
S
Bob
W = H(ρ_S) kT ln 2
= H(S|B) kT ln 2

quantum information
and foundations of thermodynamics
workshop

ETH Zurich
9th -12th August

organization
Renato Renner
Tony Short
Johan Åberg
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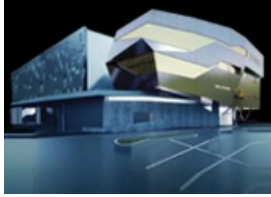

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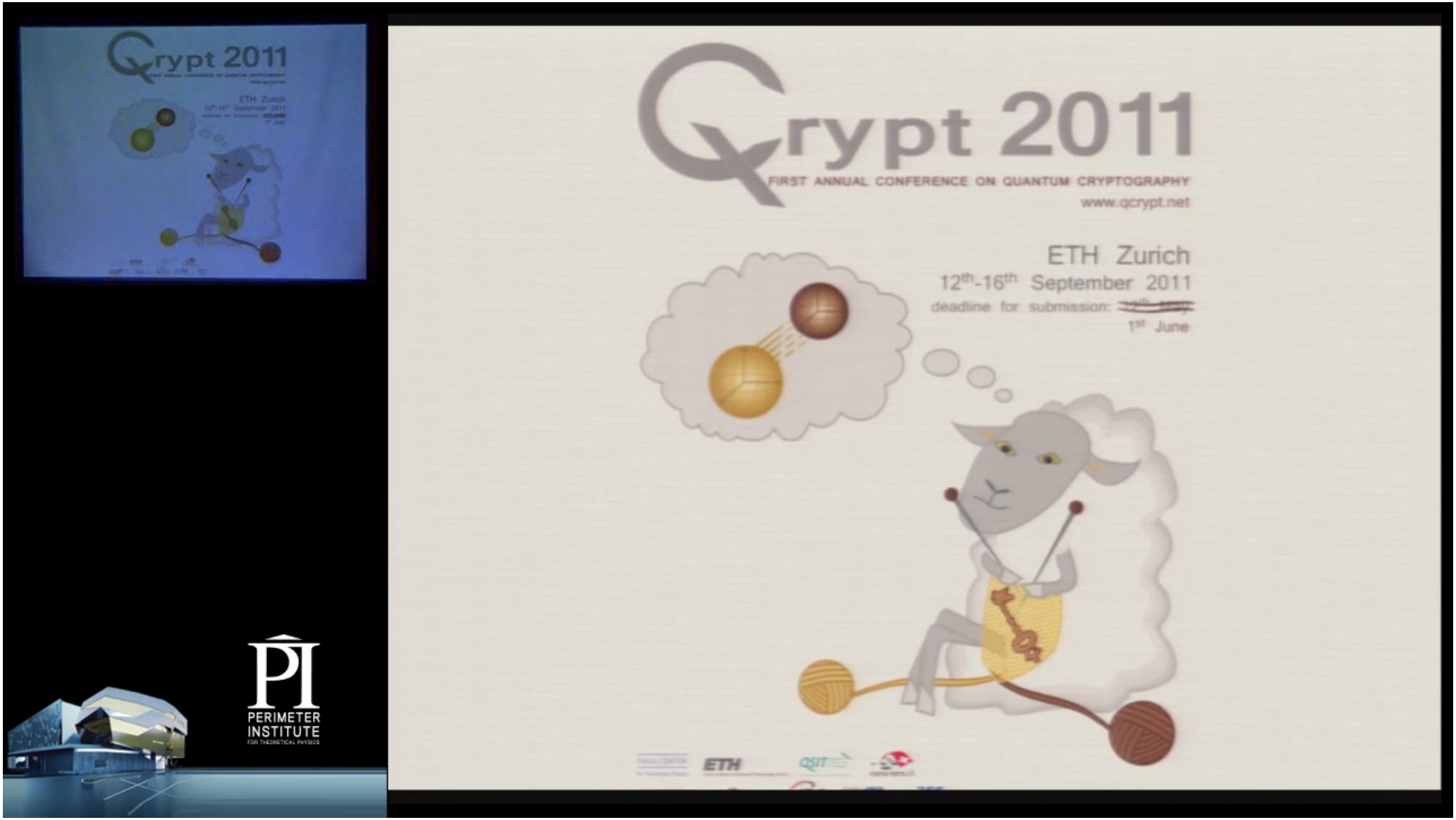
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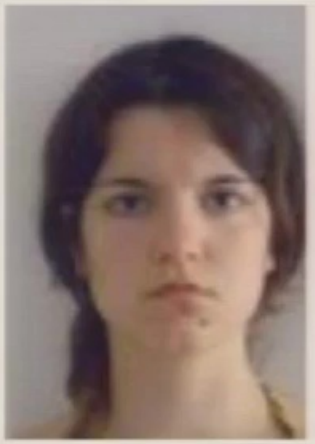

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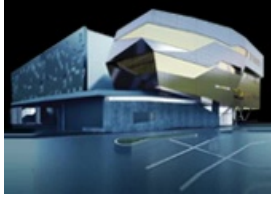

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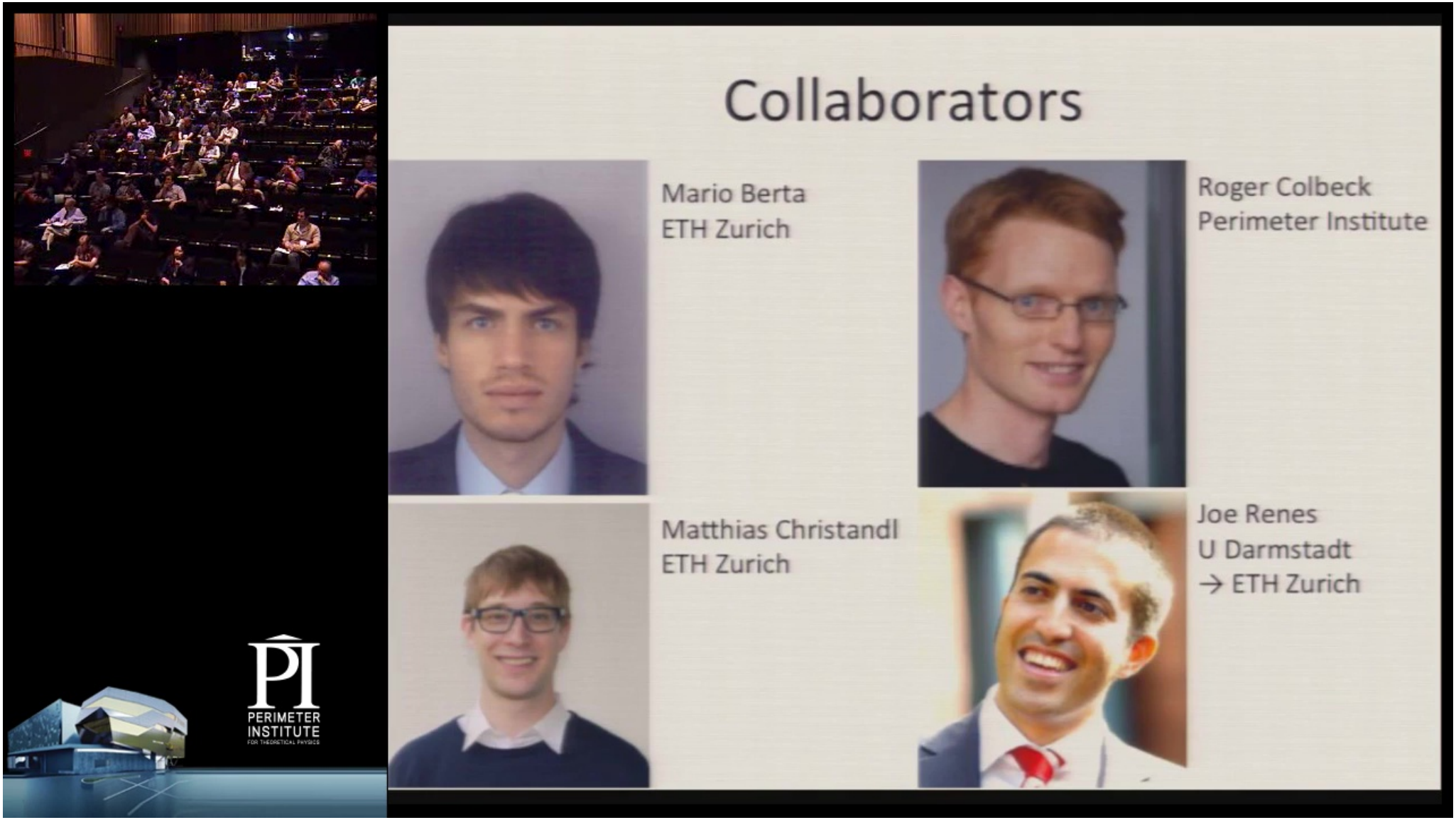
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