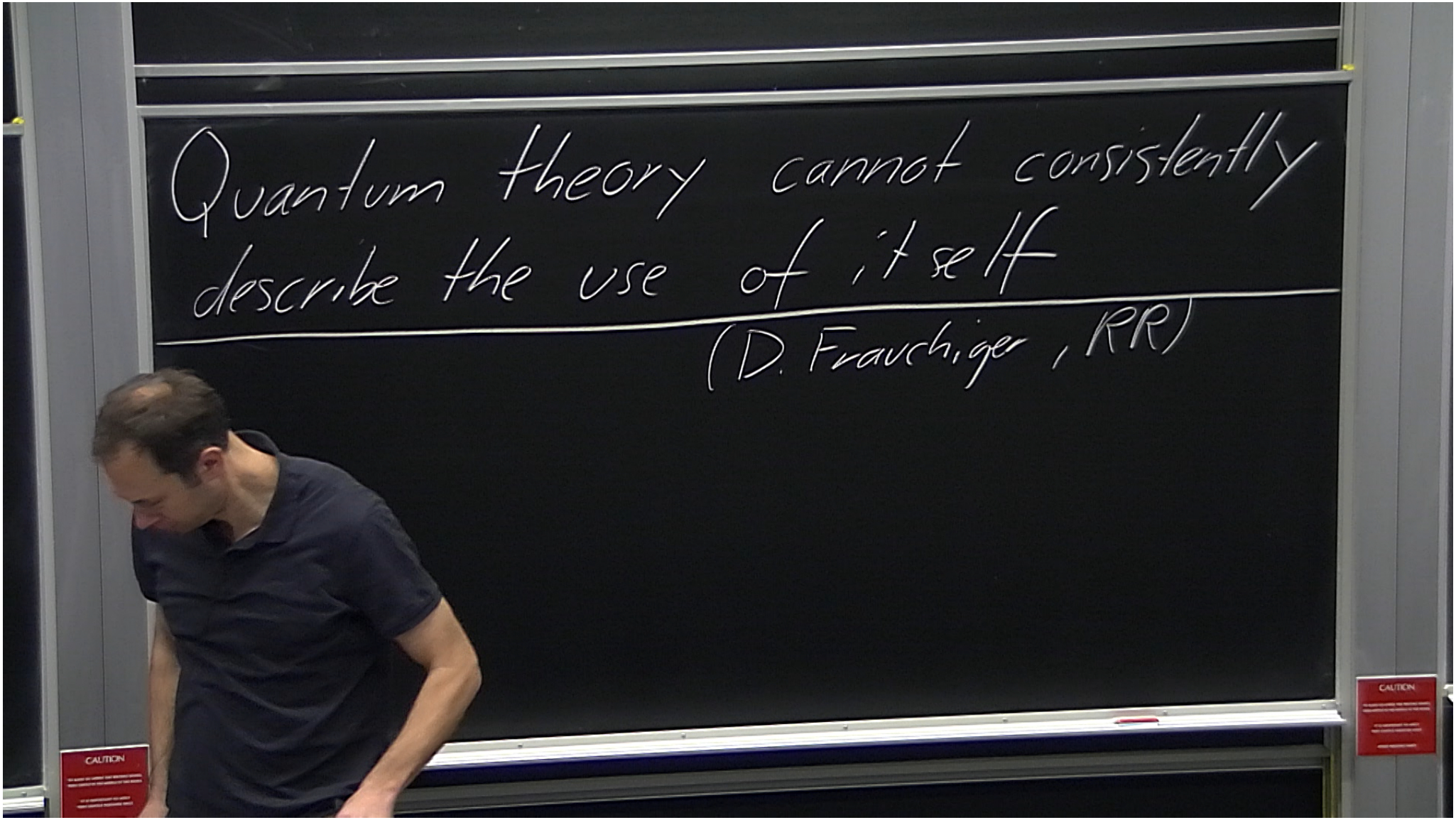
Title: Quantum theory cannot consistently describe the use of itself

Date: Apr 05, 2018 10:30 AM

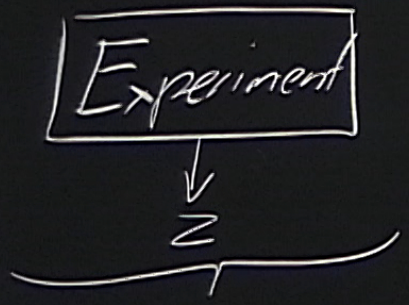
URL: http://pirsa.org/18040085

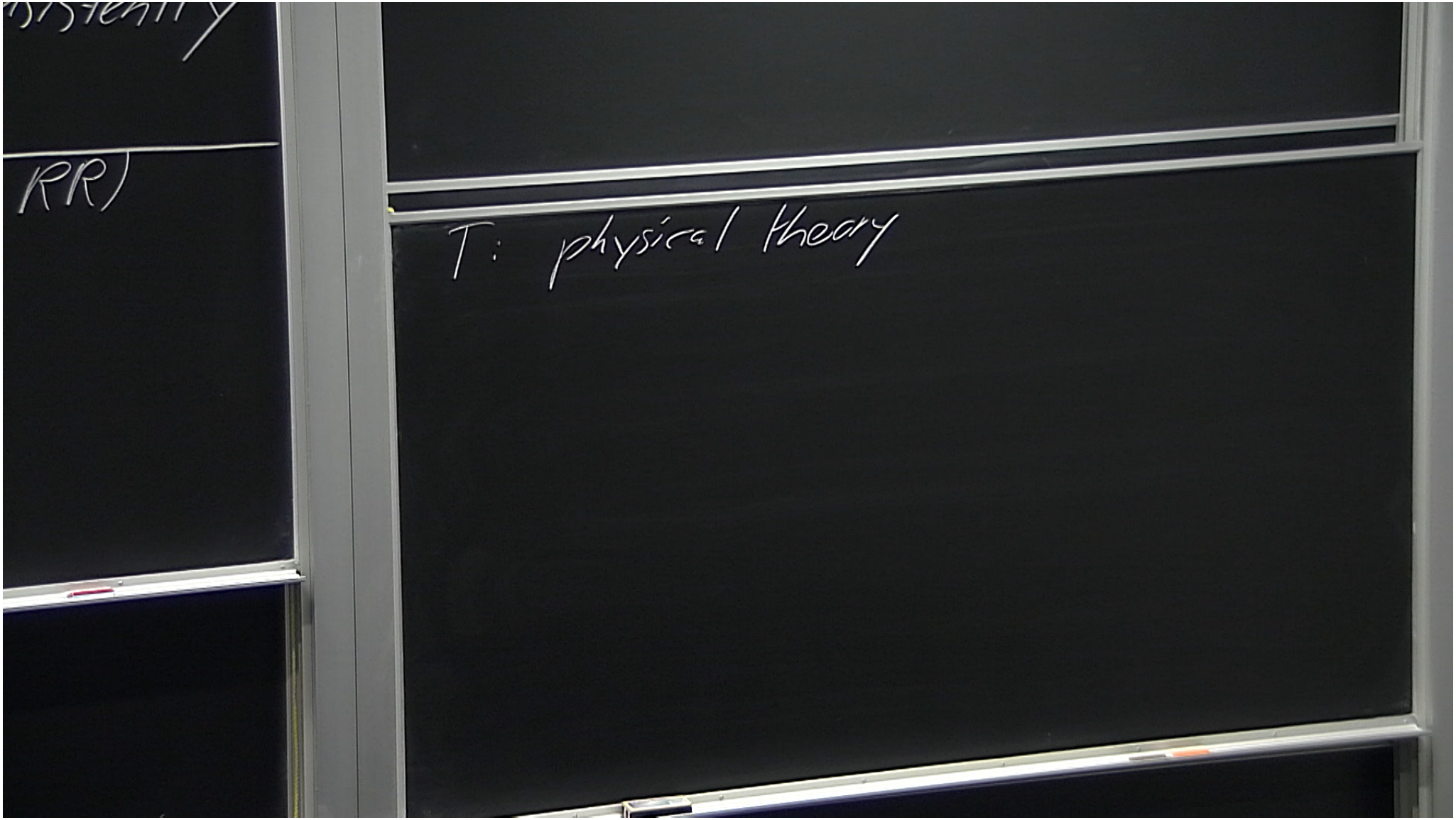
Abstract:

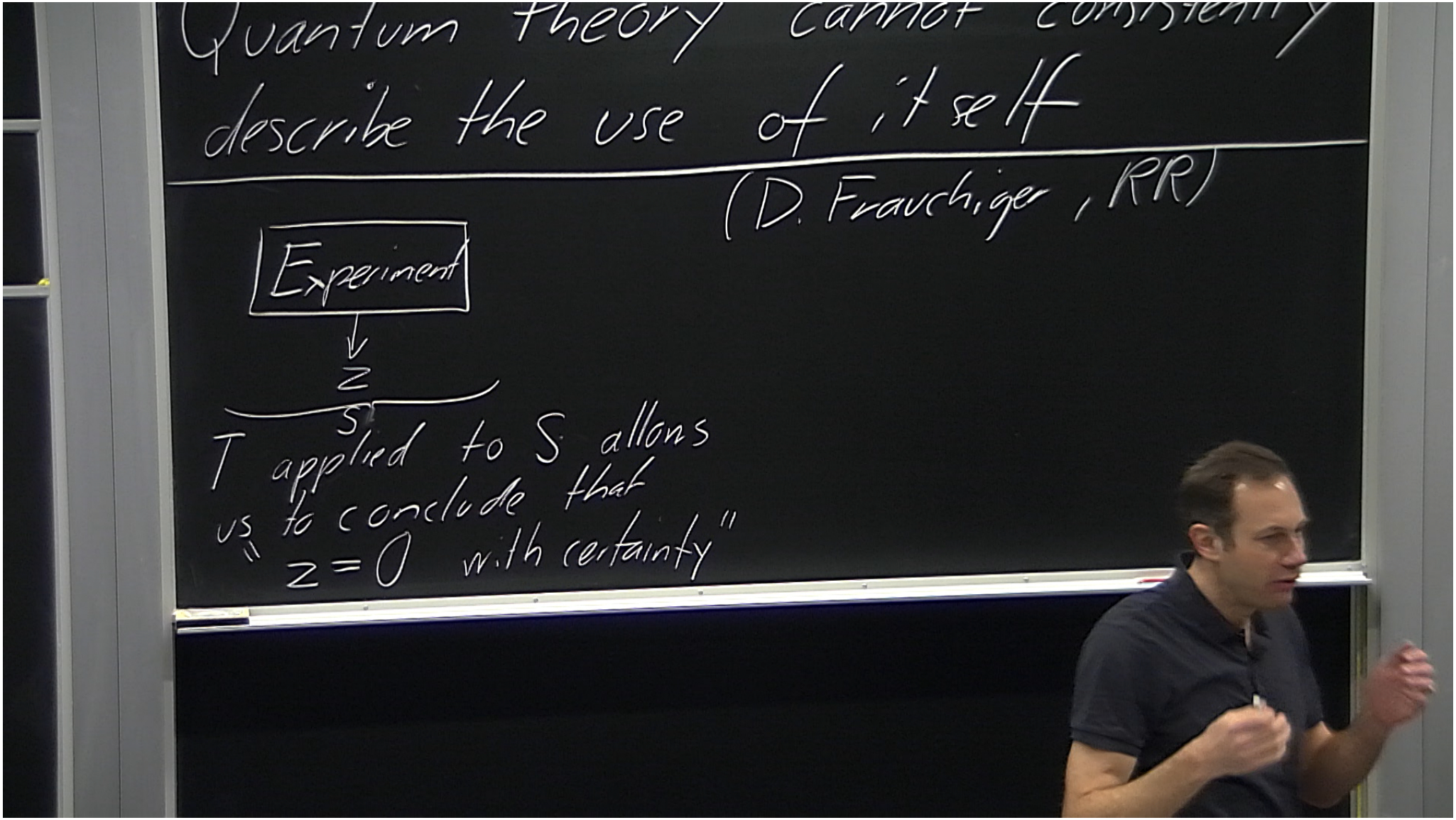

Quantum theory cannot consistently
describe the use of itself
(D. Frauchiger, RR)
CAUTION
CAUTION

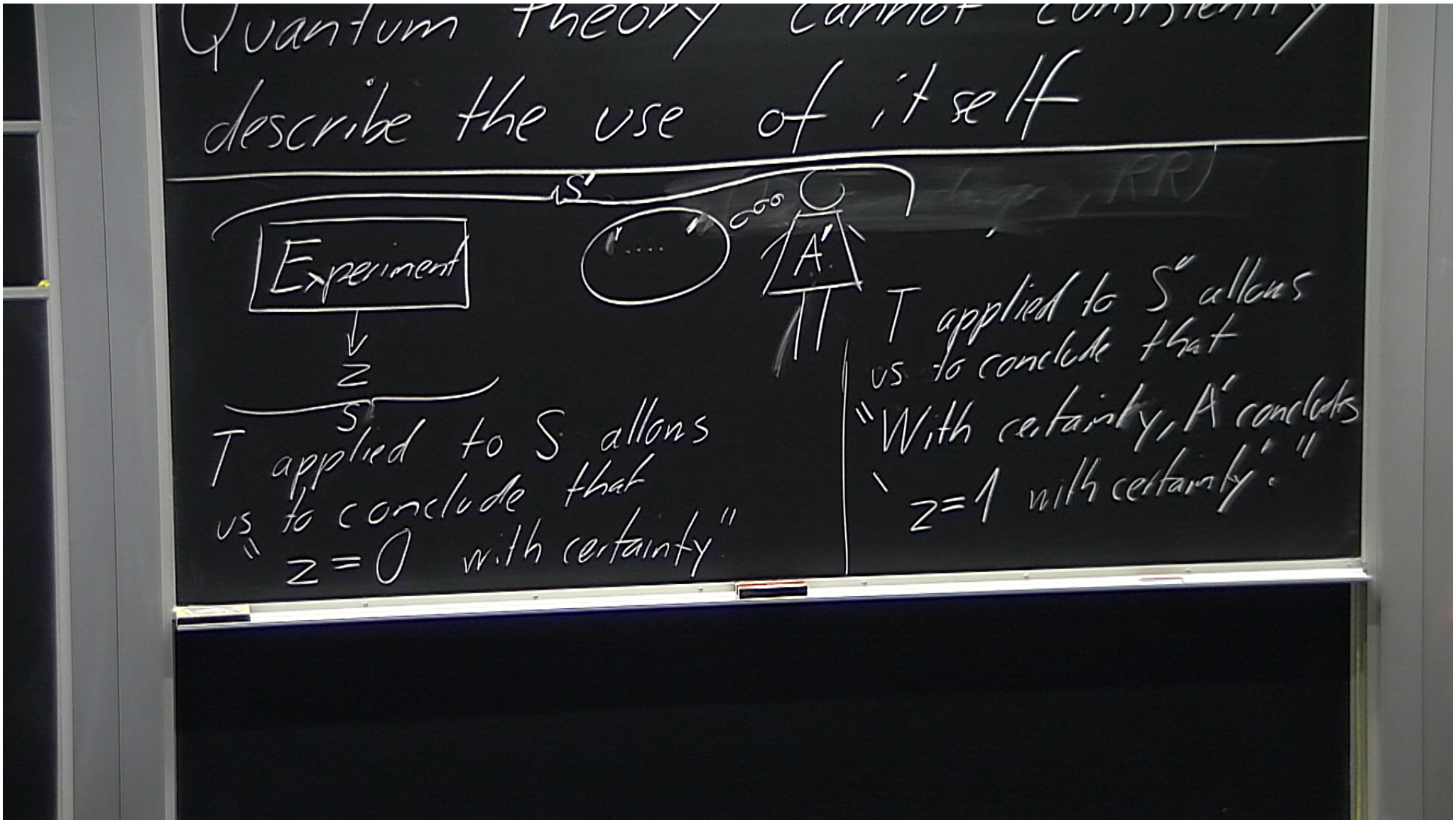
Quantum theory cannot consistently describe the use of, itself

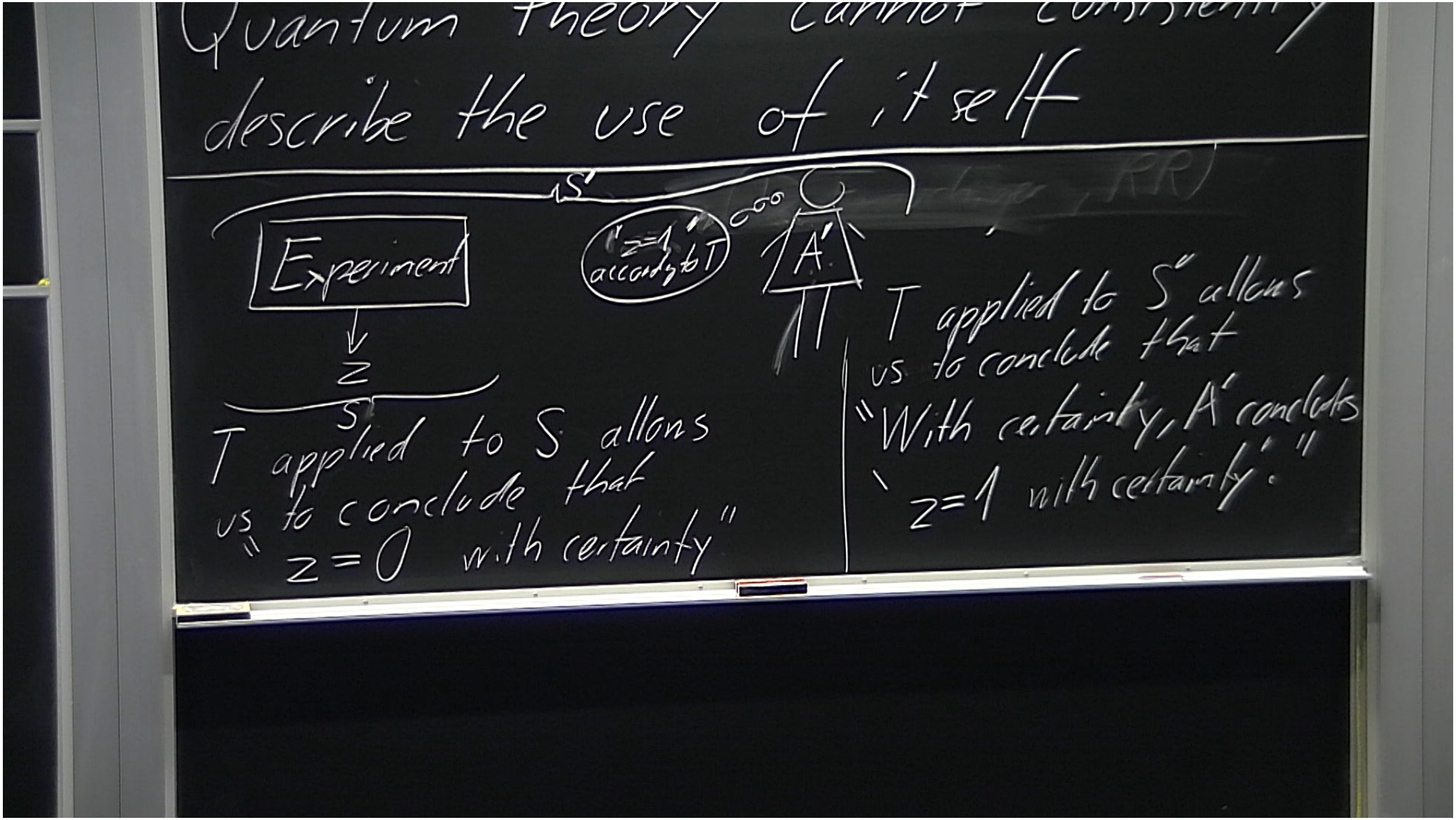
(D. Frauchiger, RR)



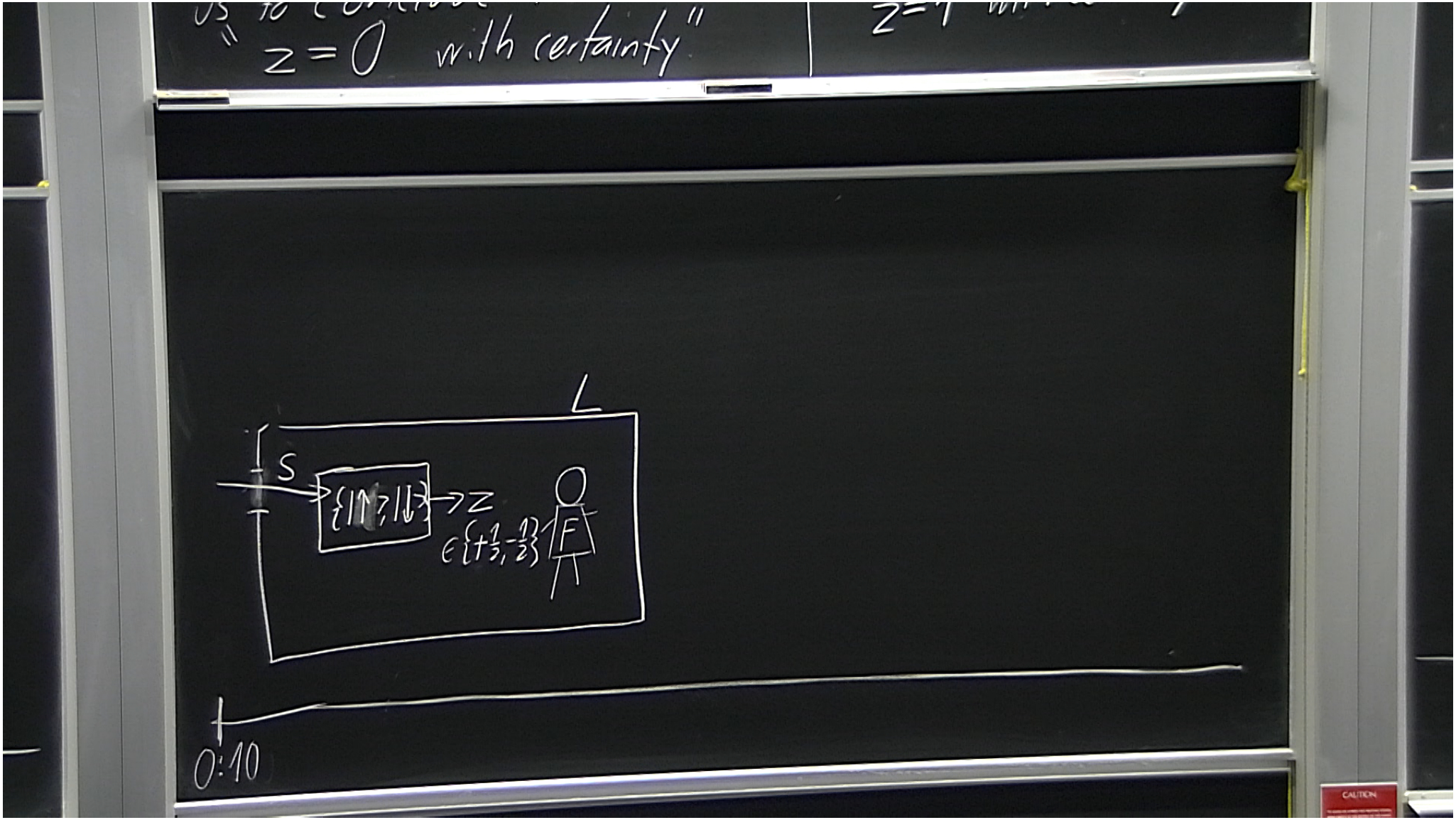

RR)
T: physical theory

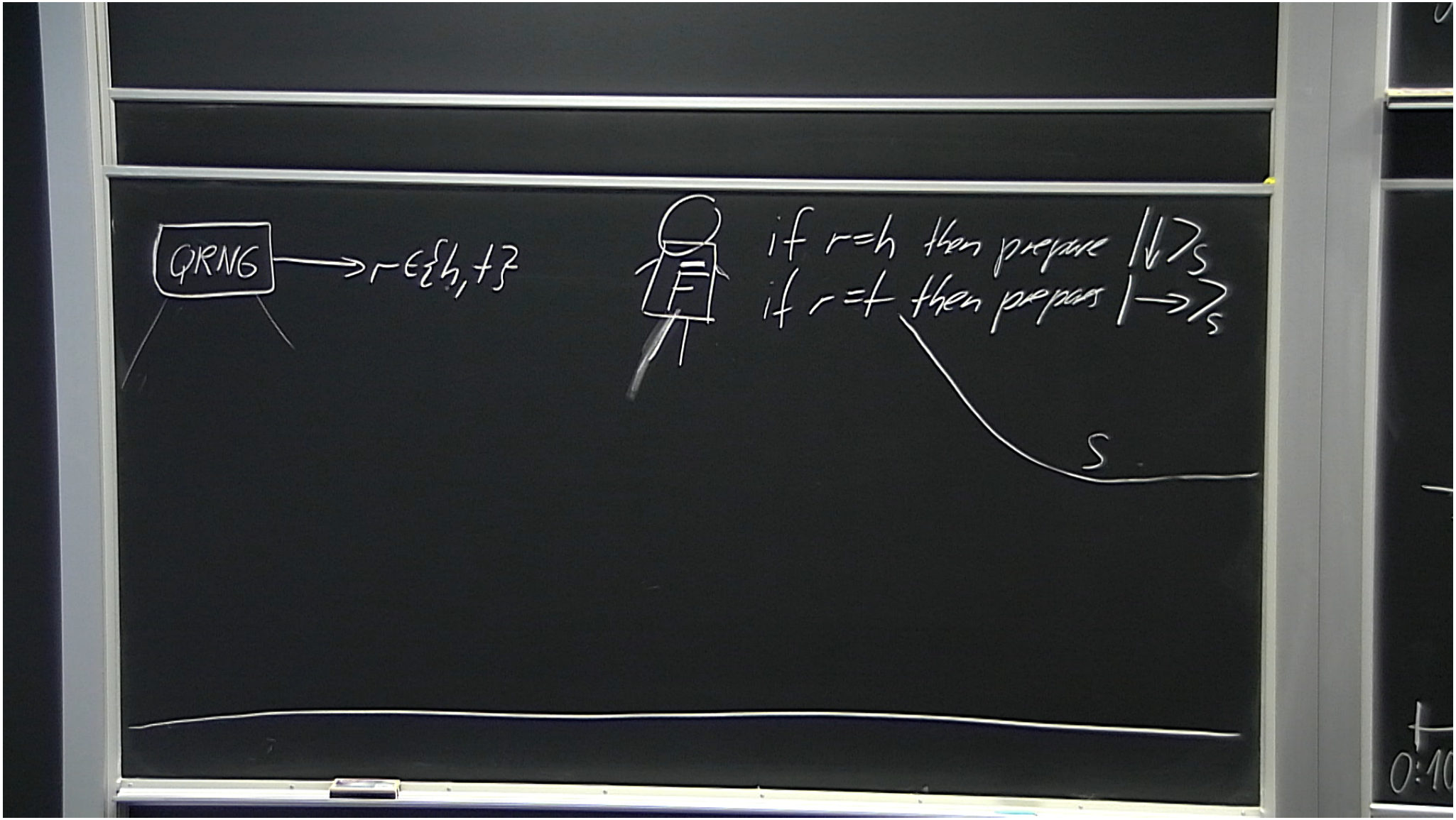

Quantum theory cannot consistently
describe the use of, itself
(D. Frauchiger, RR)
Experiment
z
S
T applied to S allows
us to conclude that
z = 0 with certainty"

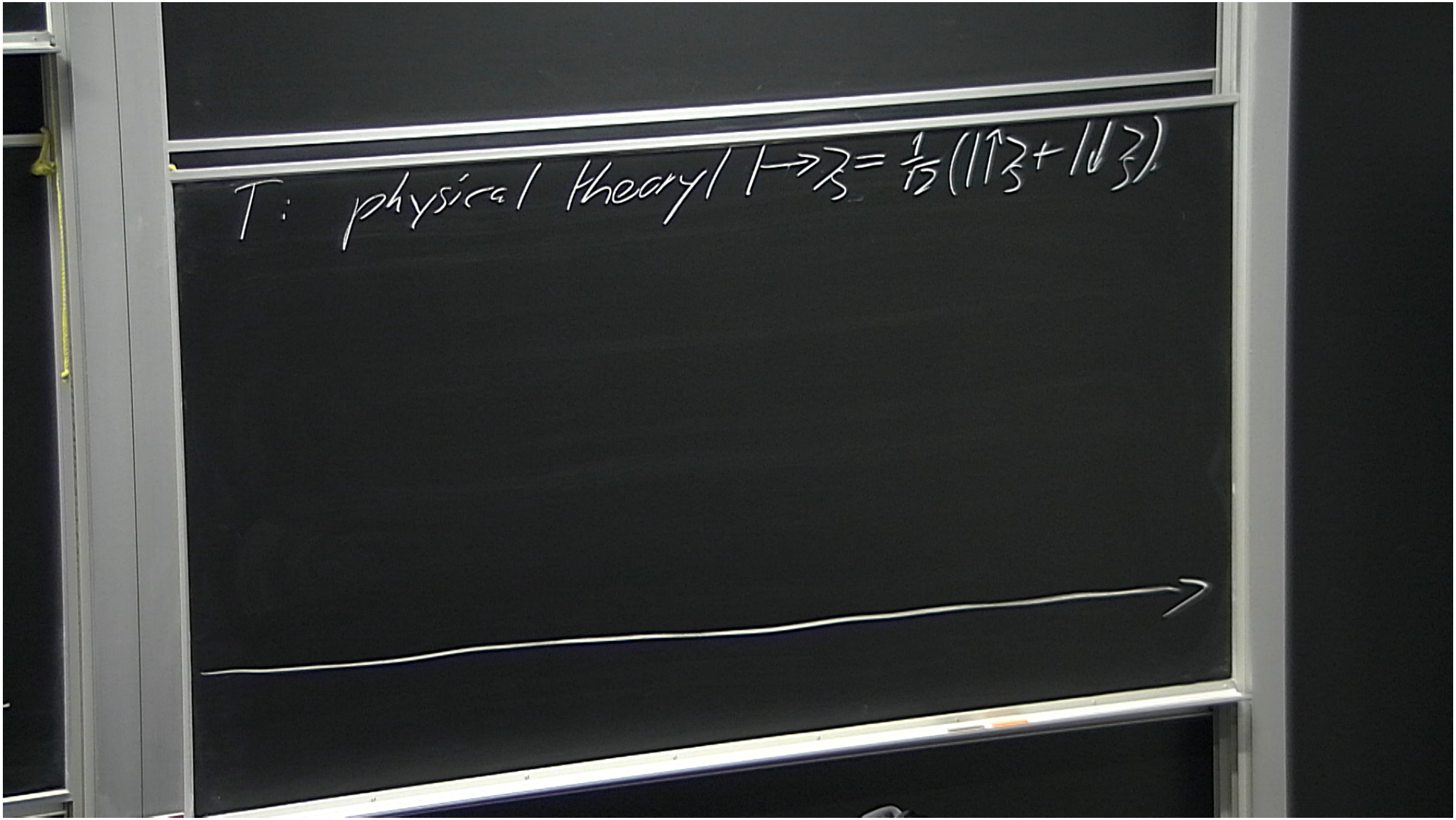

Quantum theory cannot consistently
describe the use of itself
S'
Experiment
z
S
T applied to S allows
us to conclude that
z=0 with certainty"
A'
T applied to S" allows
us to conclude that
"With certainty, A' concludes
z=1 with certainty"

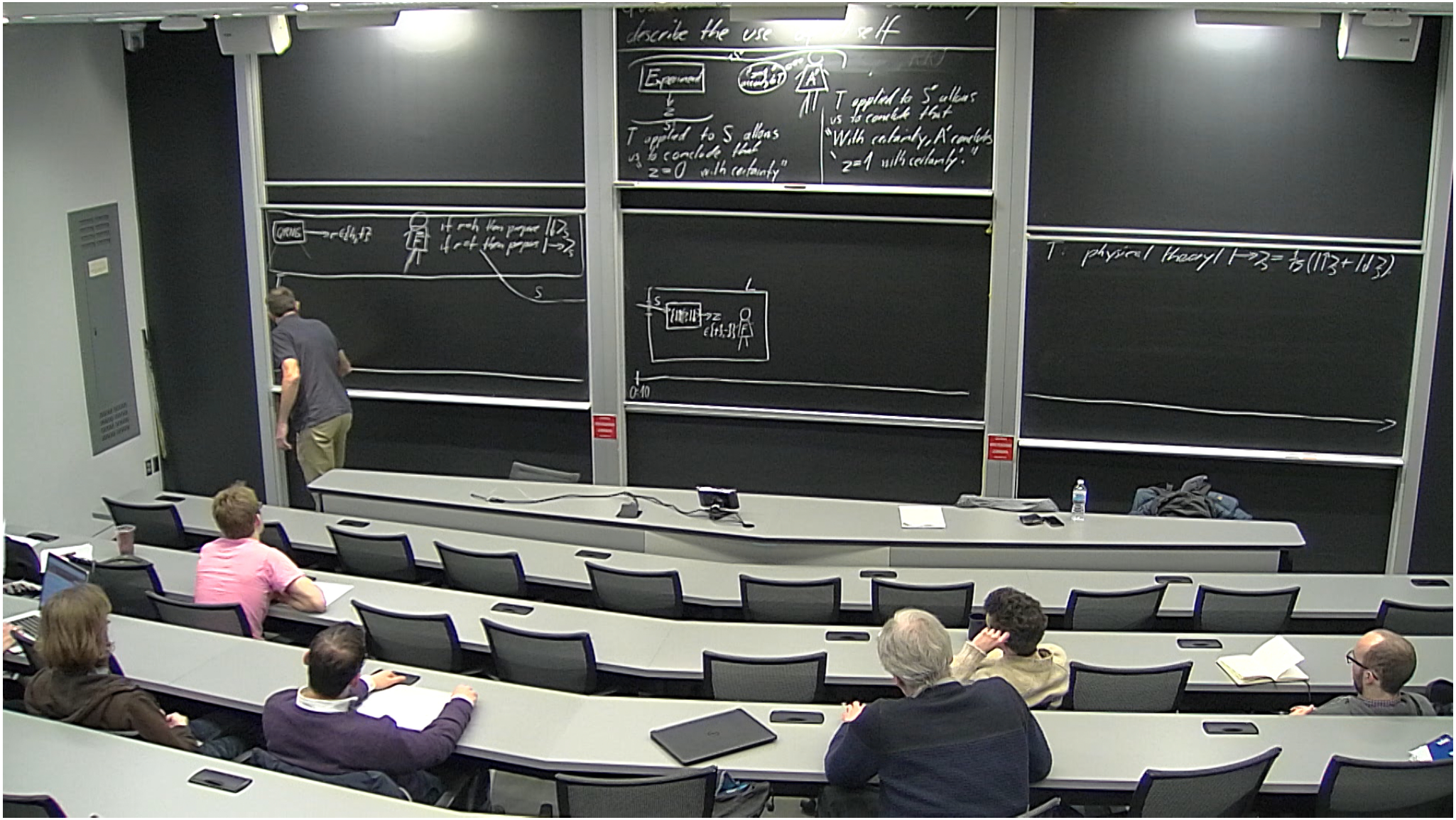

Quantum theory cannot consistently
describe the use of itself
S'
Experiment
z
S
"z=1" according to T
A'
T applied to S allows us to conclude that "With certainty, A' concludes z=1 with certainty."
T applied to S allows us to conclude that z=0 with certainty"

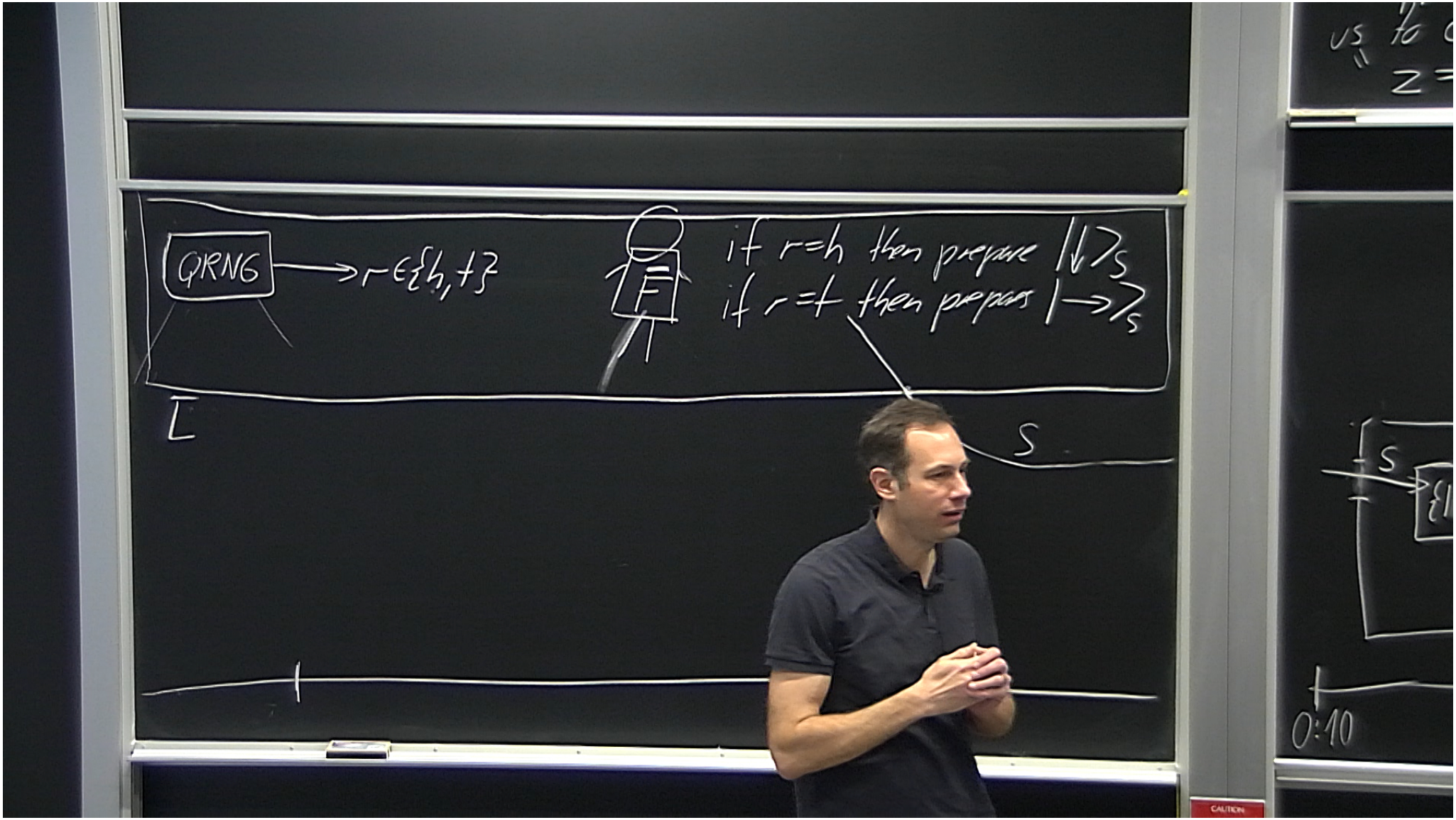

describe the use
Experiment
T applied to S allows us to conclude that z=0 with certainty"
T applied to S allows us to conclude that "With certainty, A" corresponds to z=1 with certainty."
T: physical theory

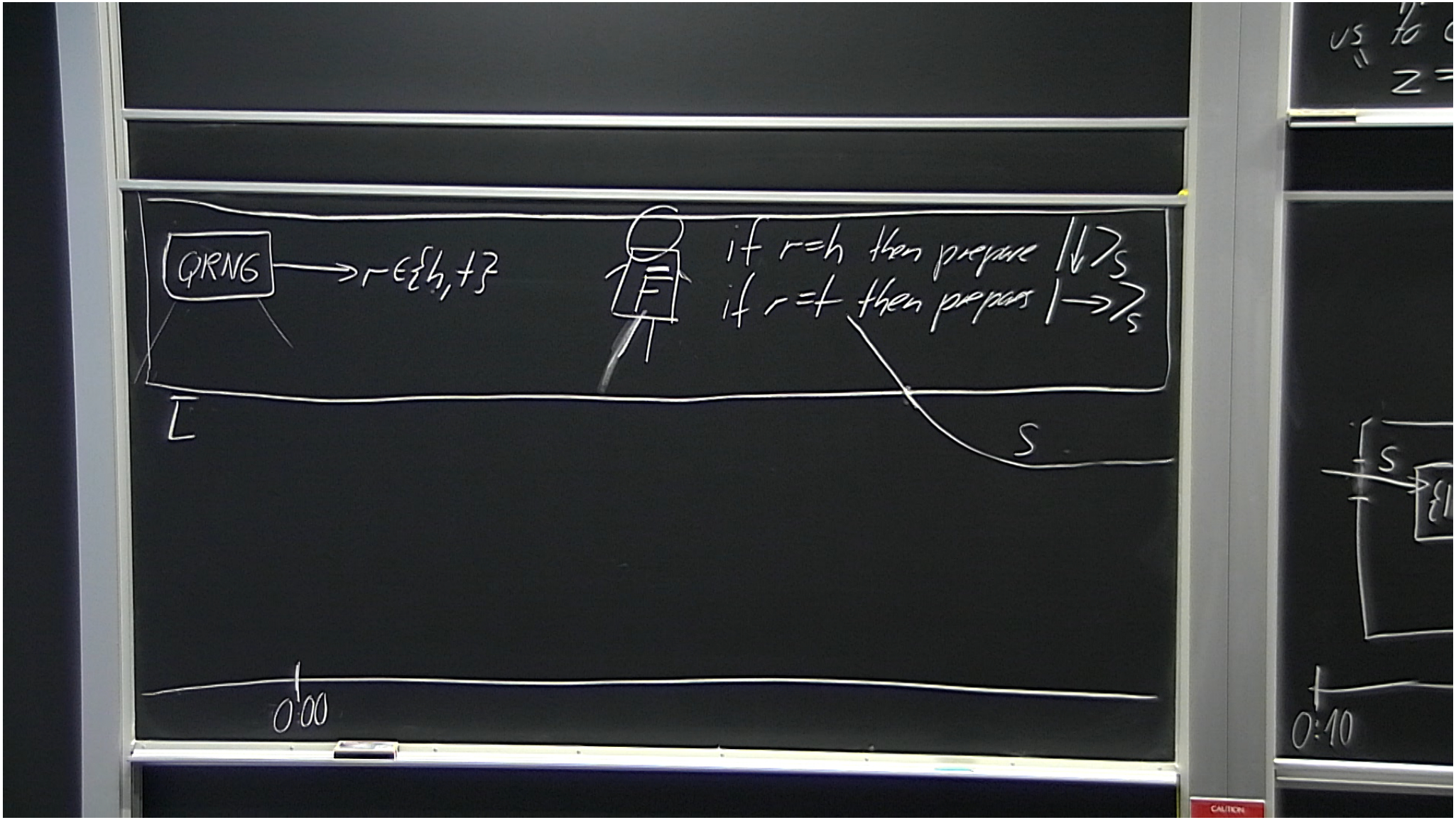

z=0 with certainty"
L
S
Z
F
0:10

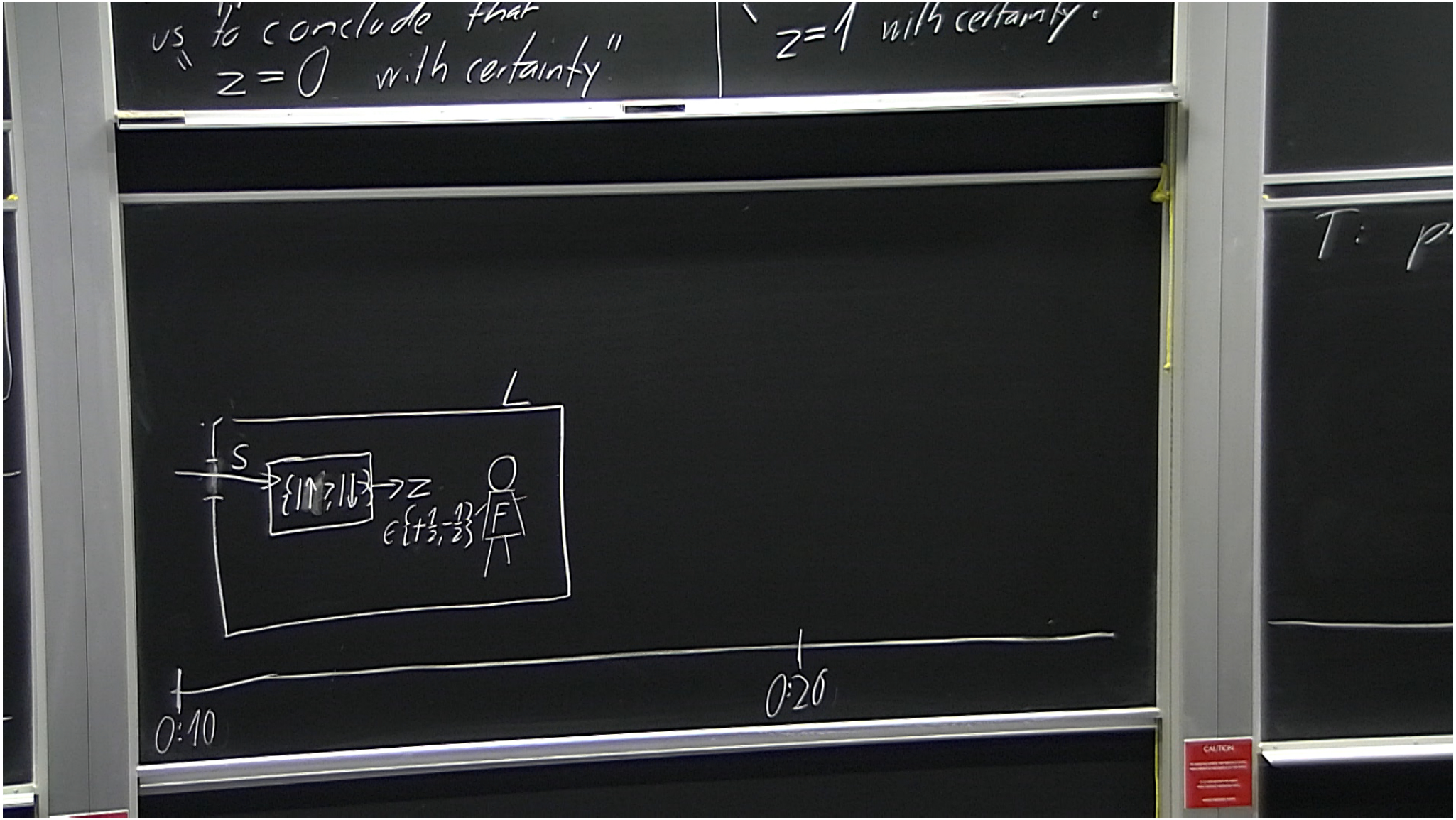

QRNG
r ∈ {h, t}
if r=h then prepare |+⟩_S
if r=t then prepare |−⟩_S
S

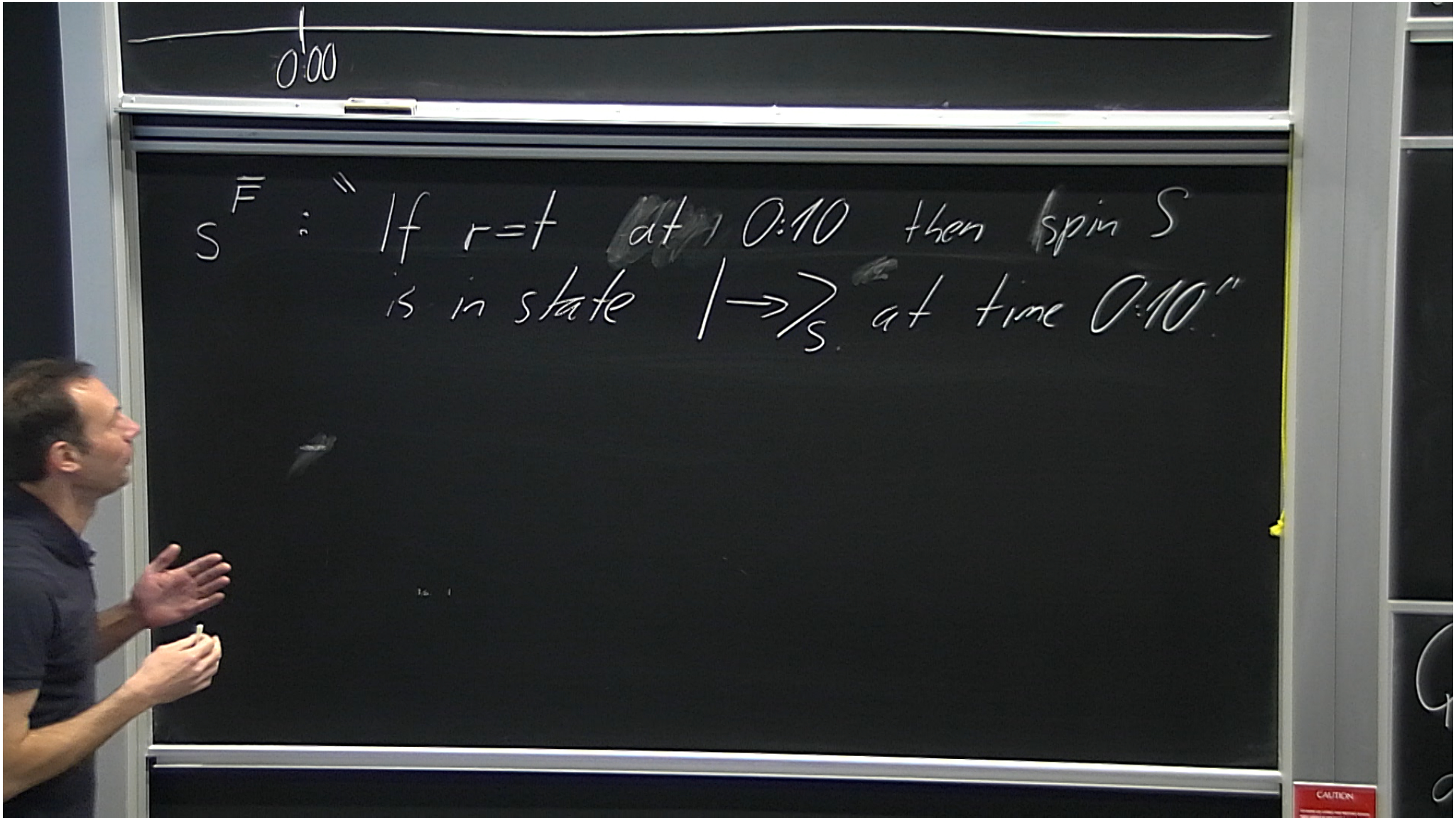

T: physical theory

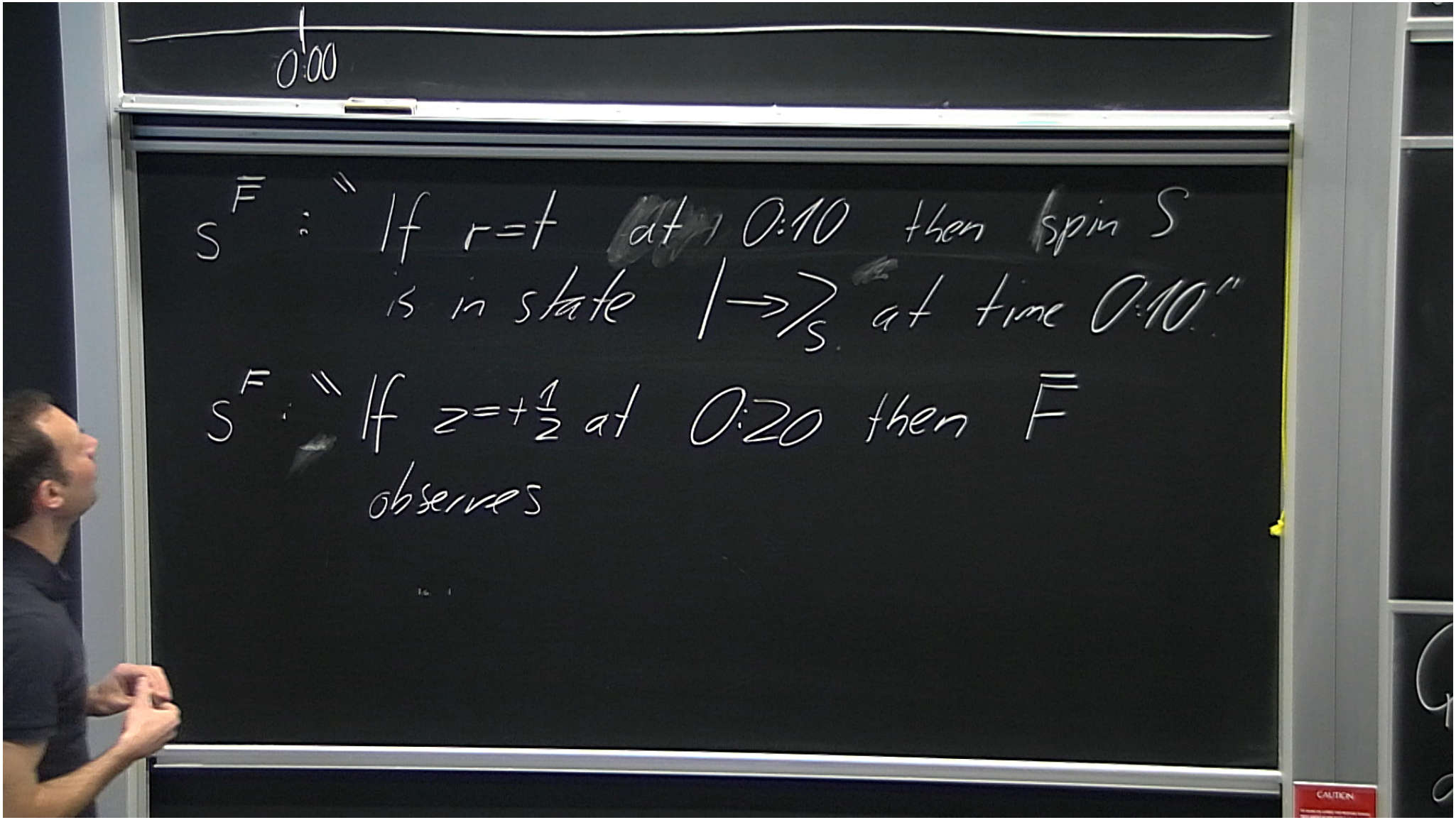

describe the use
Experiment
T applied to S allows us to conclude that "With certainty, A" concludes "z=1 with certainty."
T applied to S allows us to conclude that z=0 with certainty"
T: physical theory

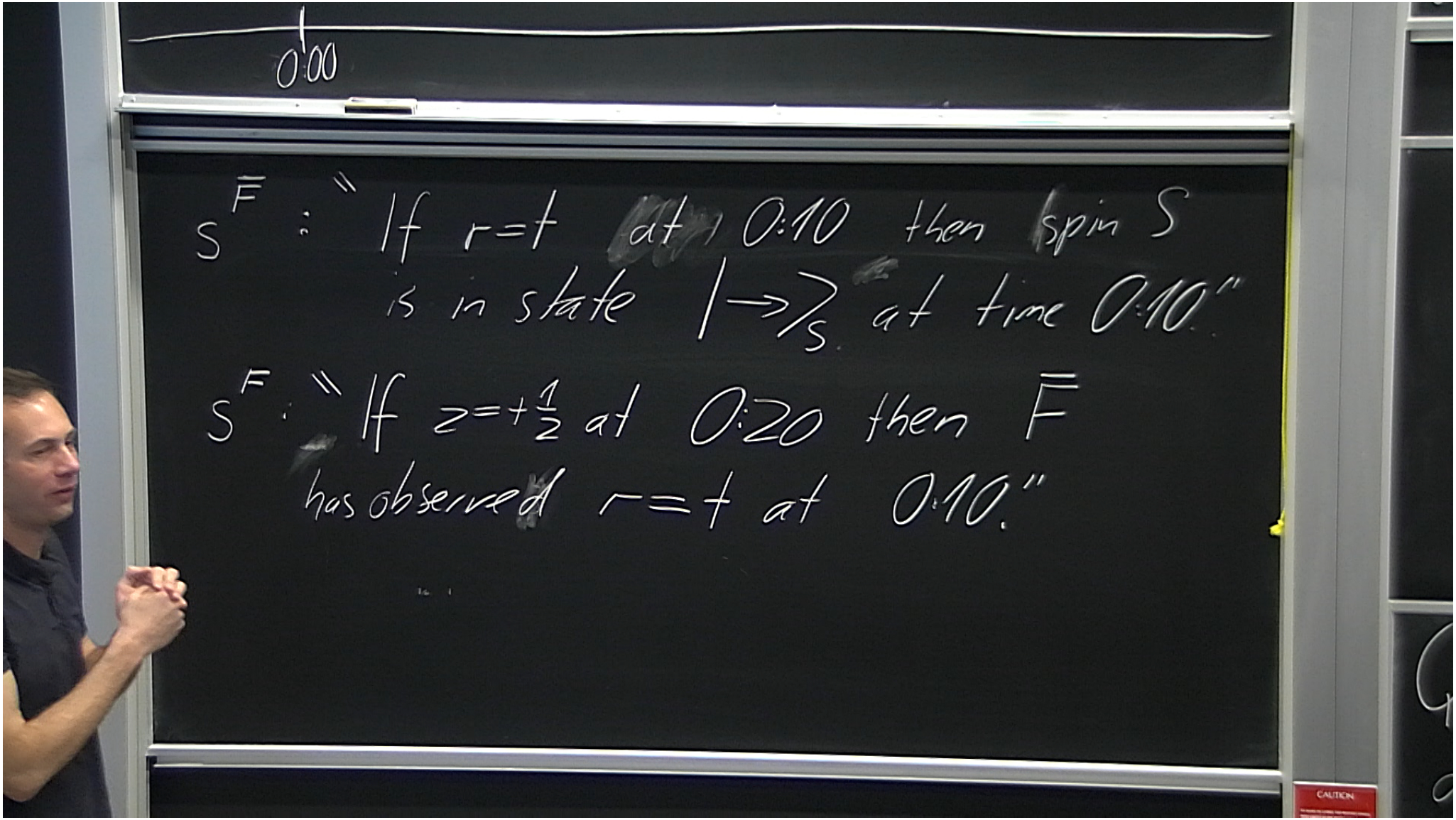

QRNG
r ∈ {h, t}
if r=h then prepare
if r=t then prepare
L
S
0:10

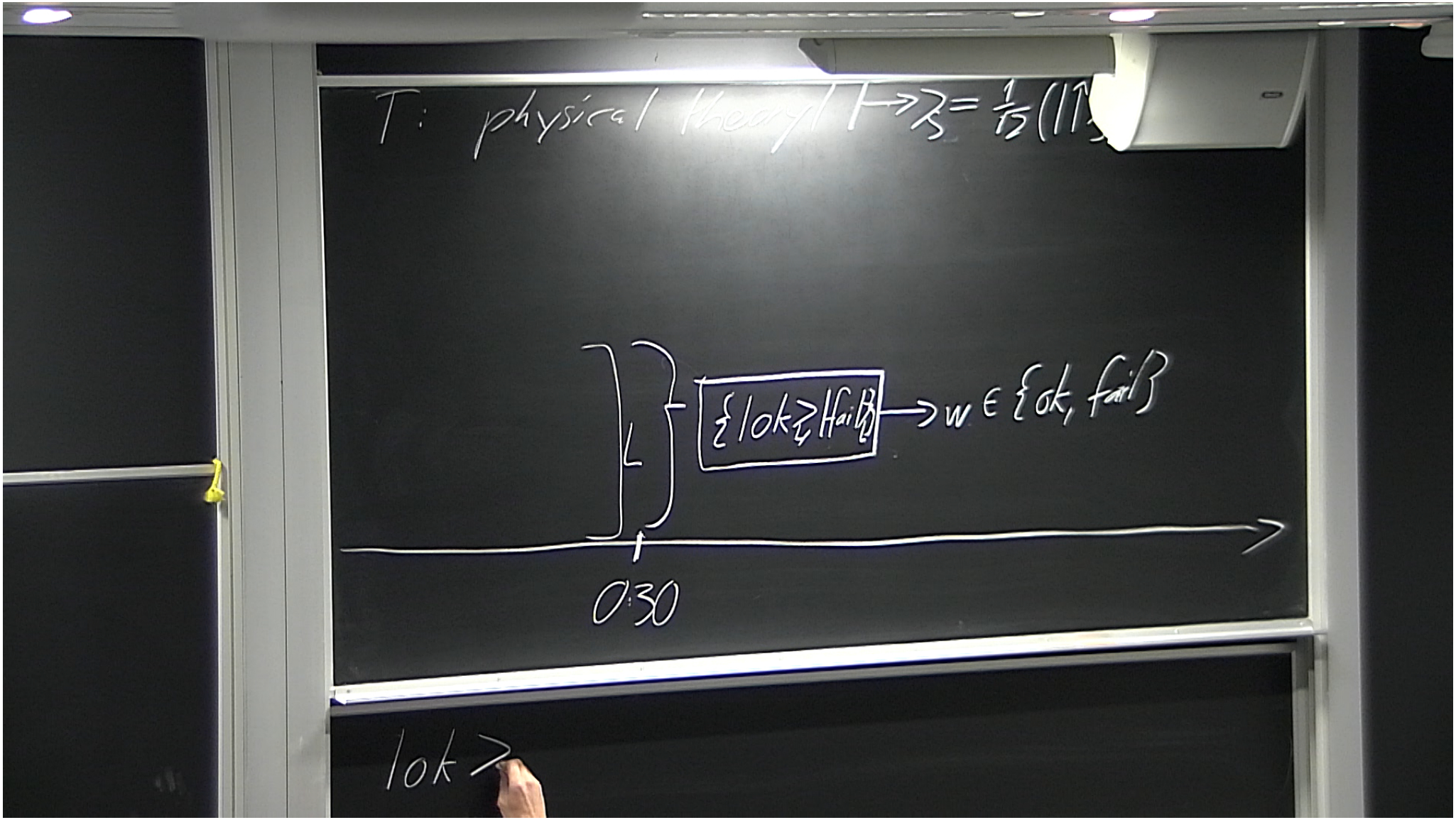

QRNG
r ∈ {h, t}
if r=h then prepare
if r=t then prepare
L
S
0:00
0:10

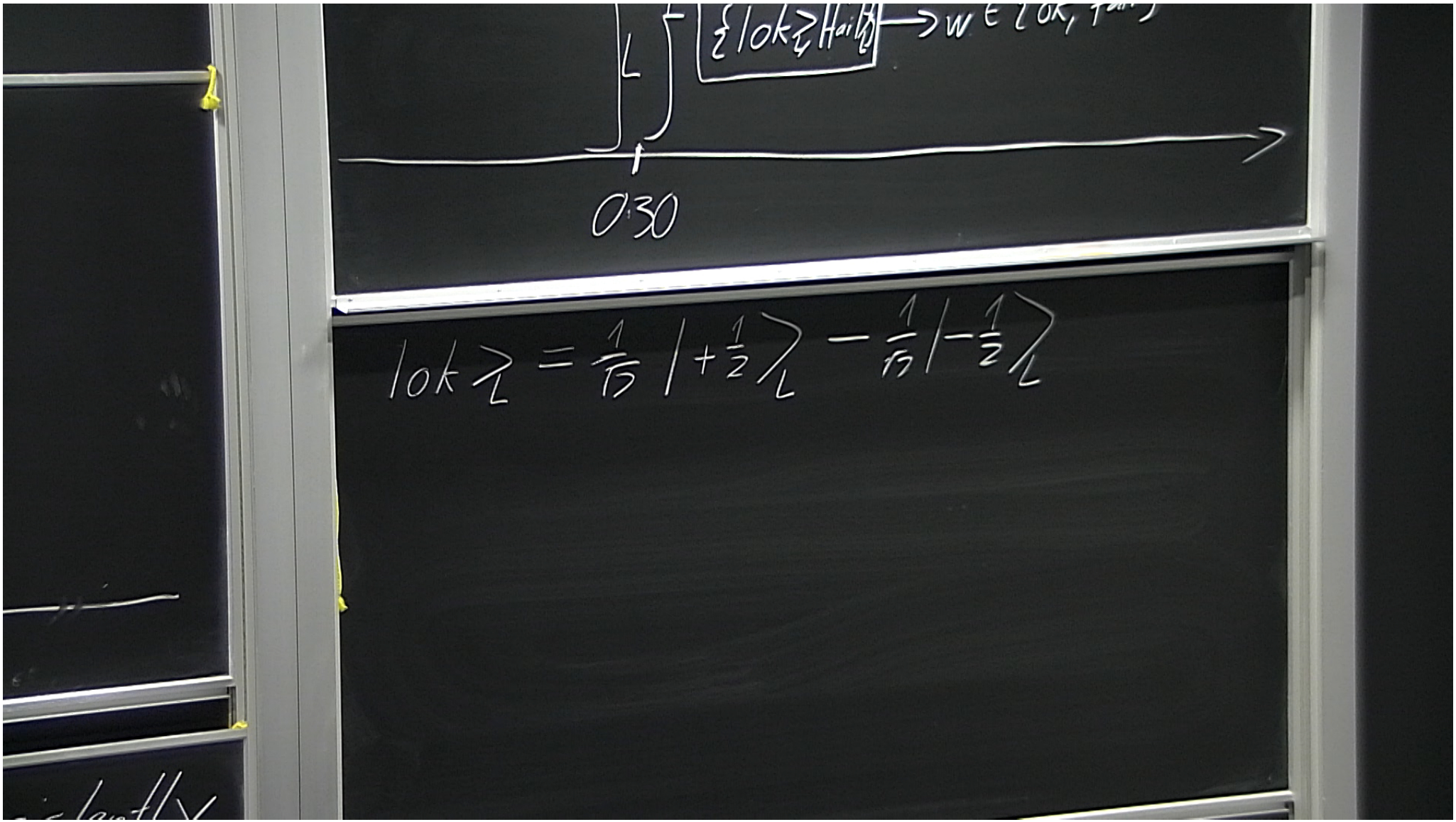

us
to conclude that
z=0 with certainty"
z=1 with certainty.
T: p
L
S
F
0:10
0:20

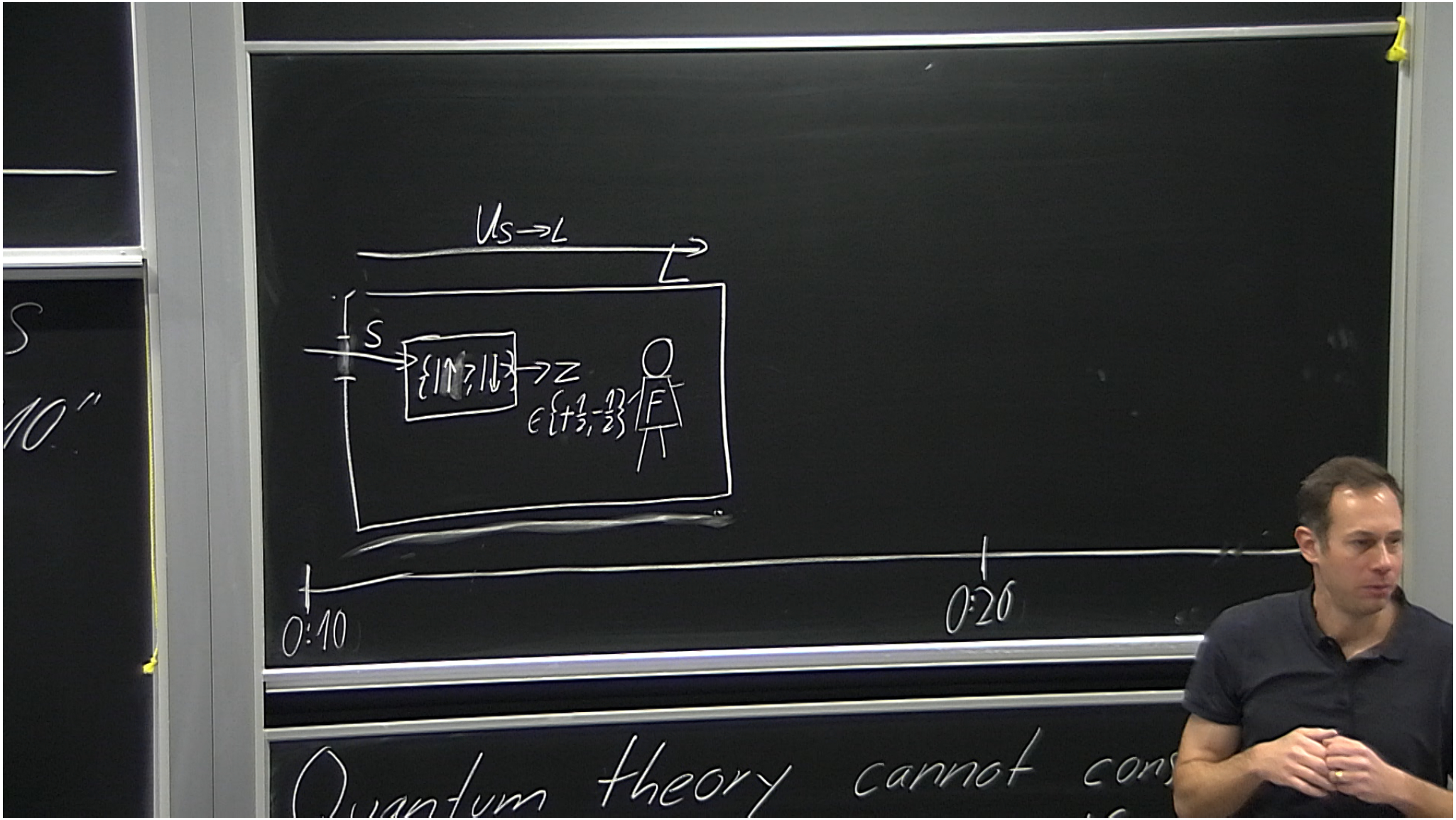

0:00
S^F : " If r=t at 0:10 then spin S is in state $|\rightarrow\rangle_S$ at time 0:10"
CAUTION

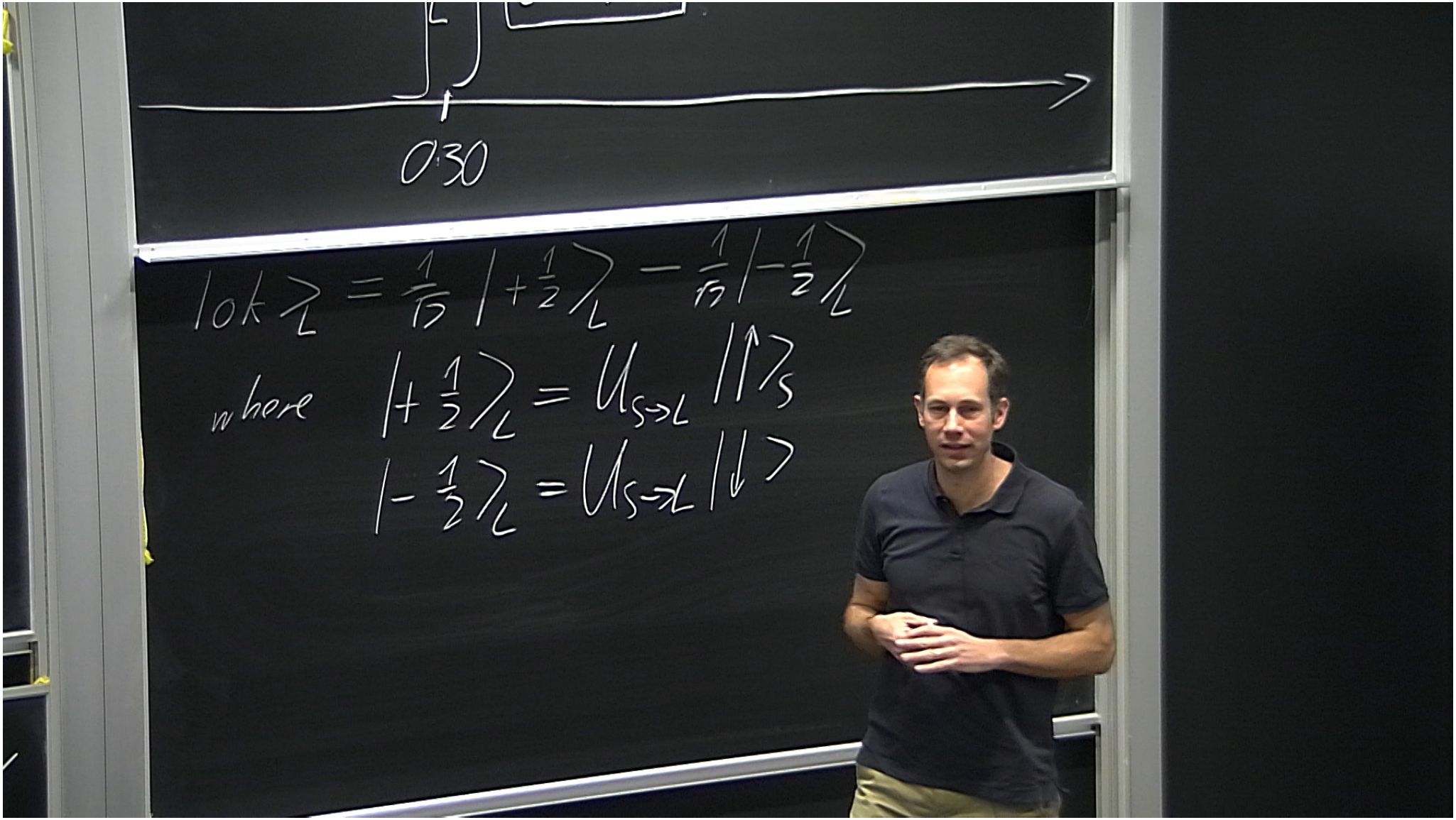

0:00
S^F: "If $r=t$ at 0:10 then spin S is in state $|\rightarrow\rangle_S$ at time 0:10"
S^F: "If $z=+\frac{1}{2}$ at 0:20 then F observes
CAUTION

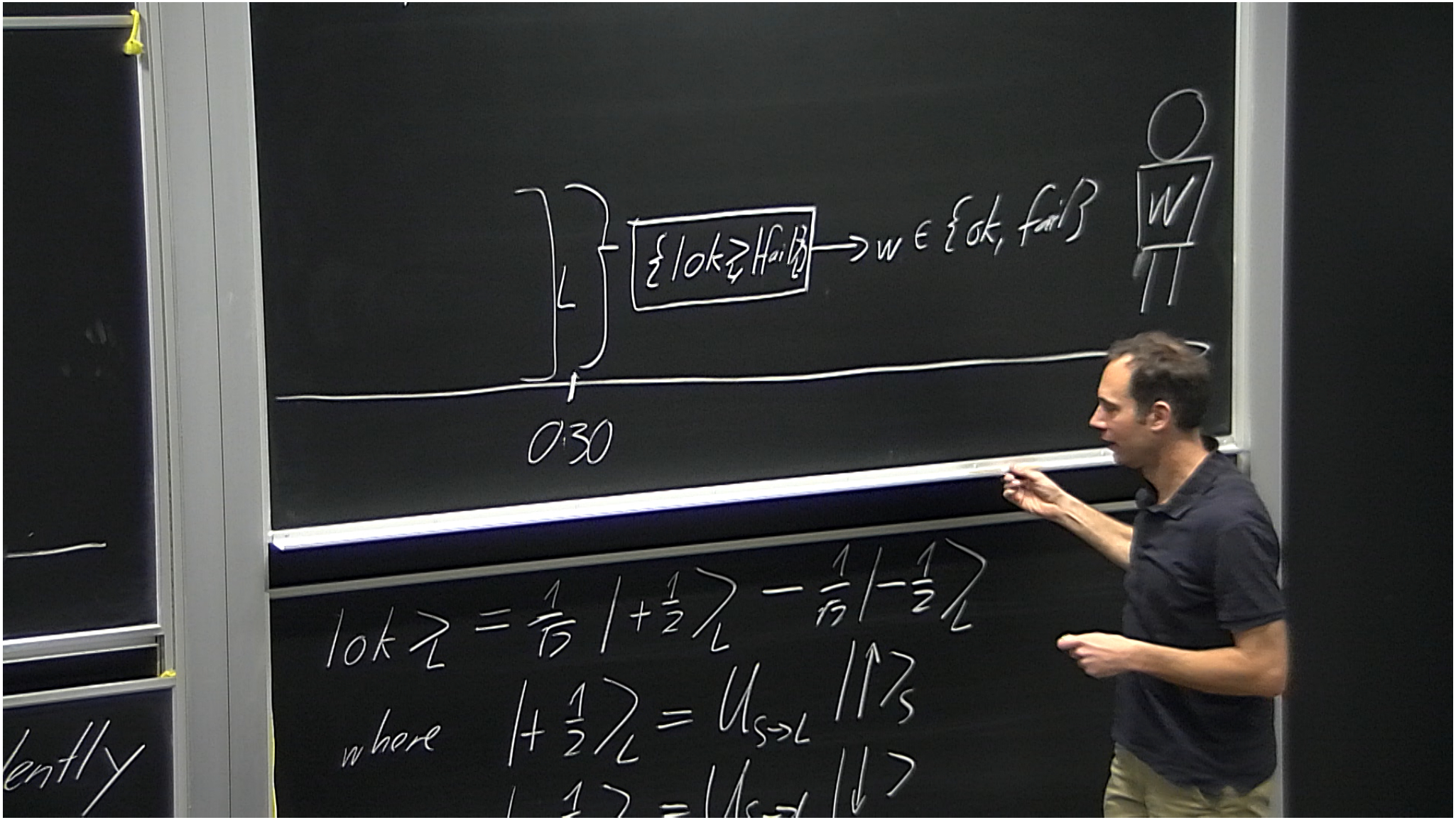

0:00
$S^{\bar{F}}$: "If $r=+$ at 0:10 then spin S is in state $|\rightarrow\rangle_S$ at time 0:10."
S^{F}: "If $z=+\frac{1}{2}$ at 0:20 then $\bar{F}$ has observed $r=+$ at 0:10."
CAUTION

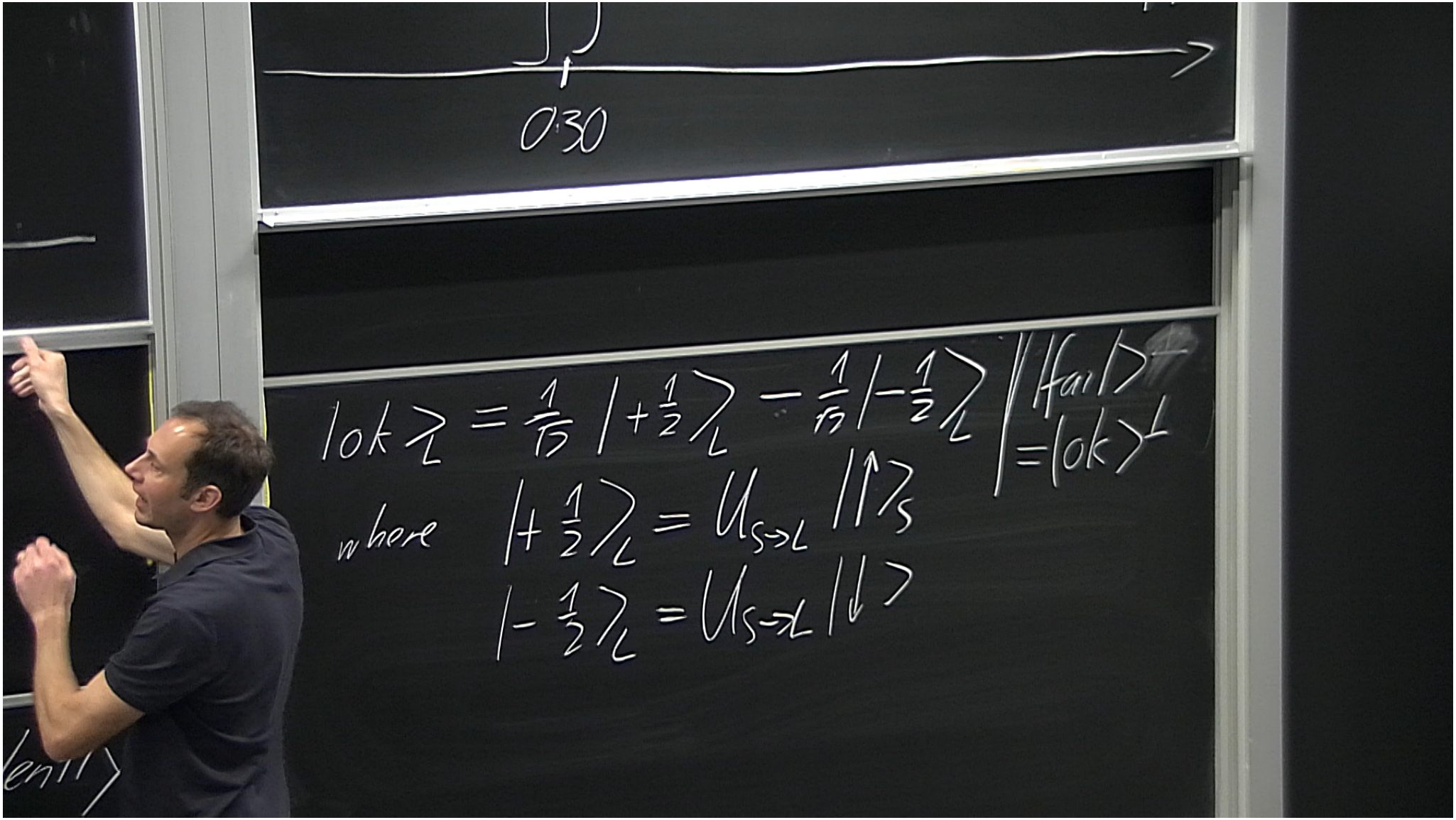

T: physical theory
0:30
|ok⟩

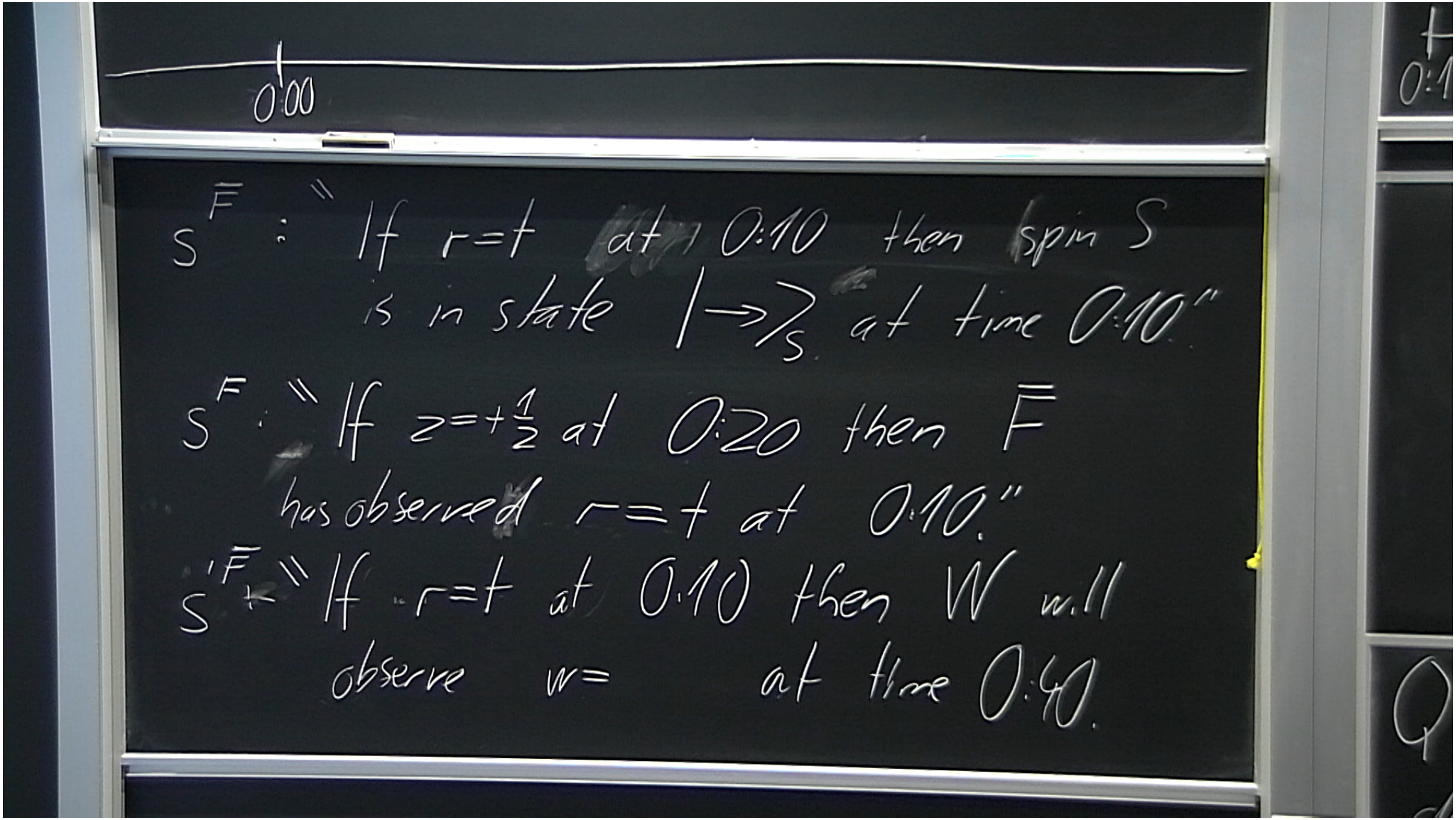

0:30
$|0k_z\rangle = \frac{1}{\sqrt{3}}|+\frac{1}{2}\rangle_L - \frac{1}{\sqrt{3}}|-\frac{1}{2}\rangle_L$

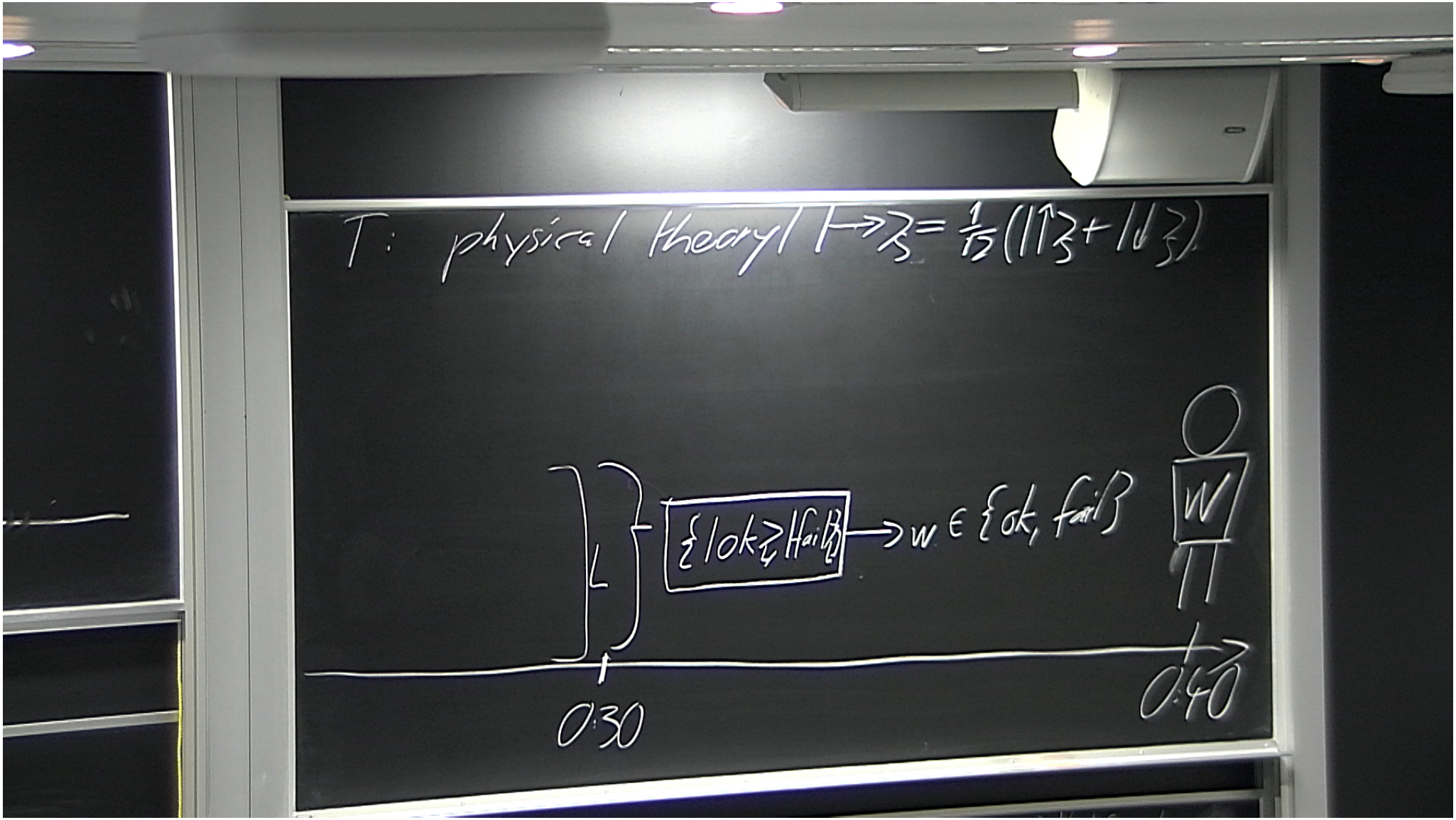

$U_{S\to L}$
S
$\{|1\rangle,|0\rangle\}\to Z$
$\in\{+\frac{1}{2},-\frac{1}{2}\}$
F
0:10
0:20
Quantum theory cannot

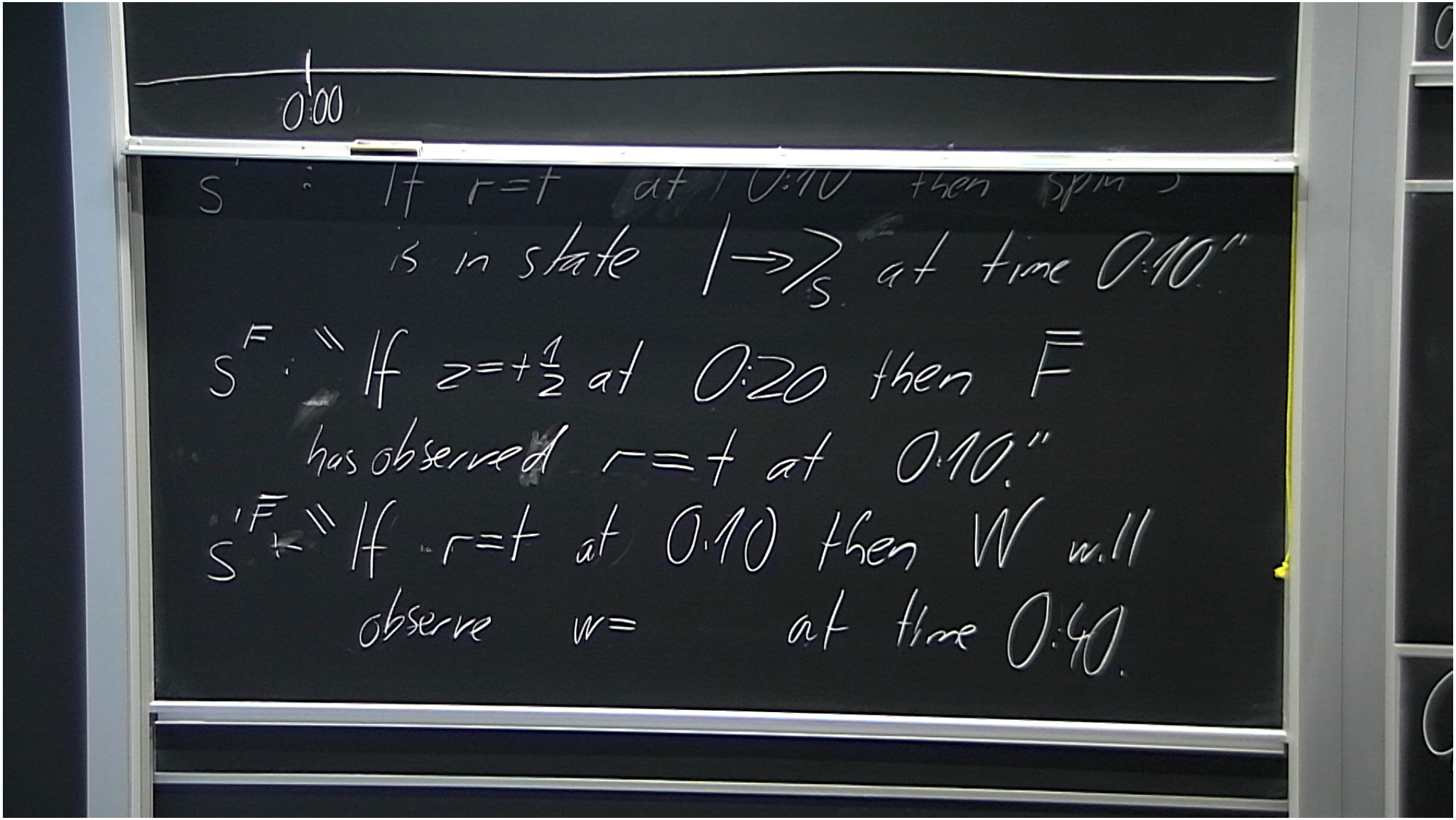

0:30
$|0k\rangle_L = \frac{1}{\sqrt{2}}|+\frac{1}{2}\rangle_L - \frac{1}{\sqrt{2}}|-\frac{1}{2}\rangle_L$
where $|+\frac{1}{2}\rangle_L = U_{S\to L}|\uparrow\rangle_S$
$|-\frac{1}{2}\rangle_L = U_{S\to L}|\downarrow\rangle$

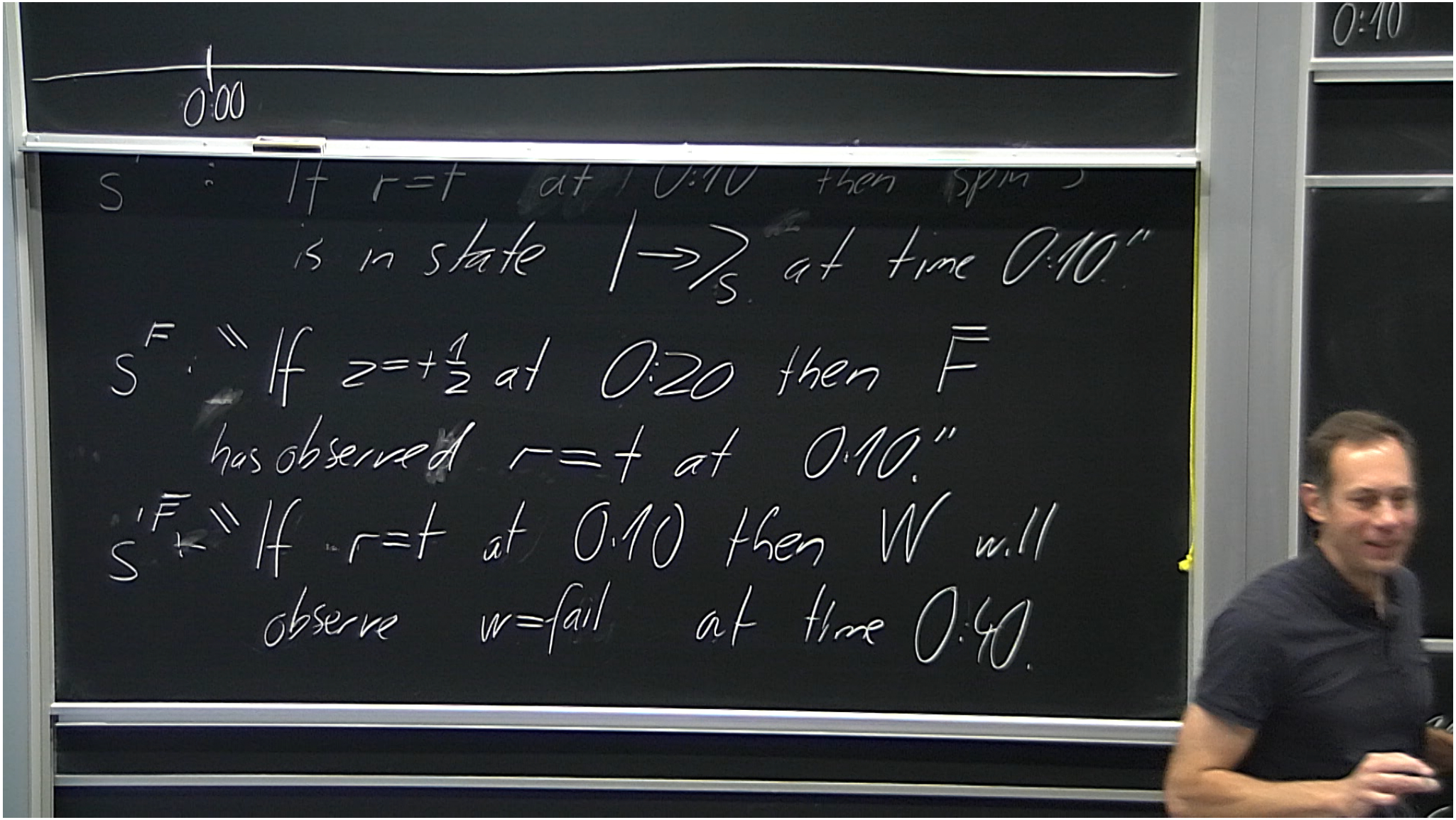

L
{|ok⟩, Fail}
w ∈ {ok, fail}
W
0:30
|ok⟩ = 1/√3 |+1/2⟩_L − 1/√3 |−1/2⟩_L
where |+1/2⟩_L = U_{S→L} |↑⟩_S
|−1/2⟩ = U_{S→L} |↓⟩
lently

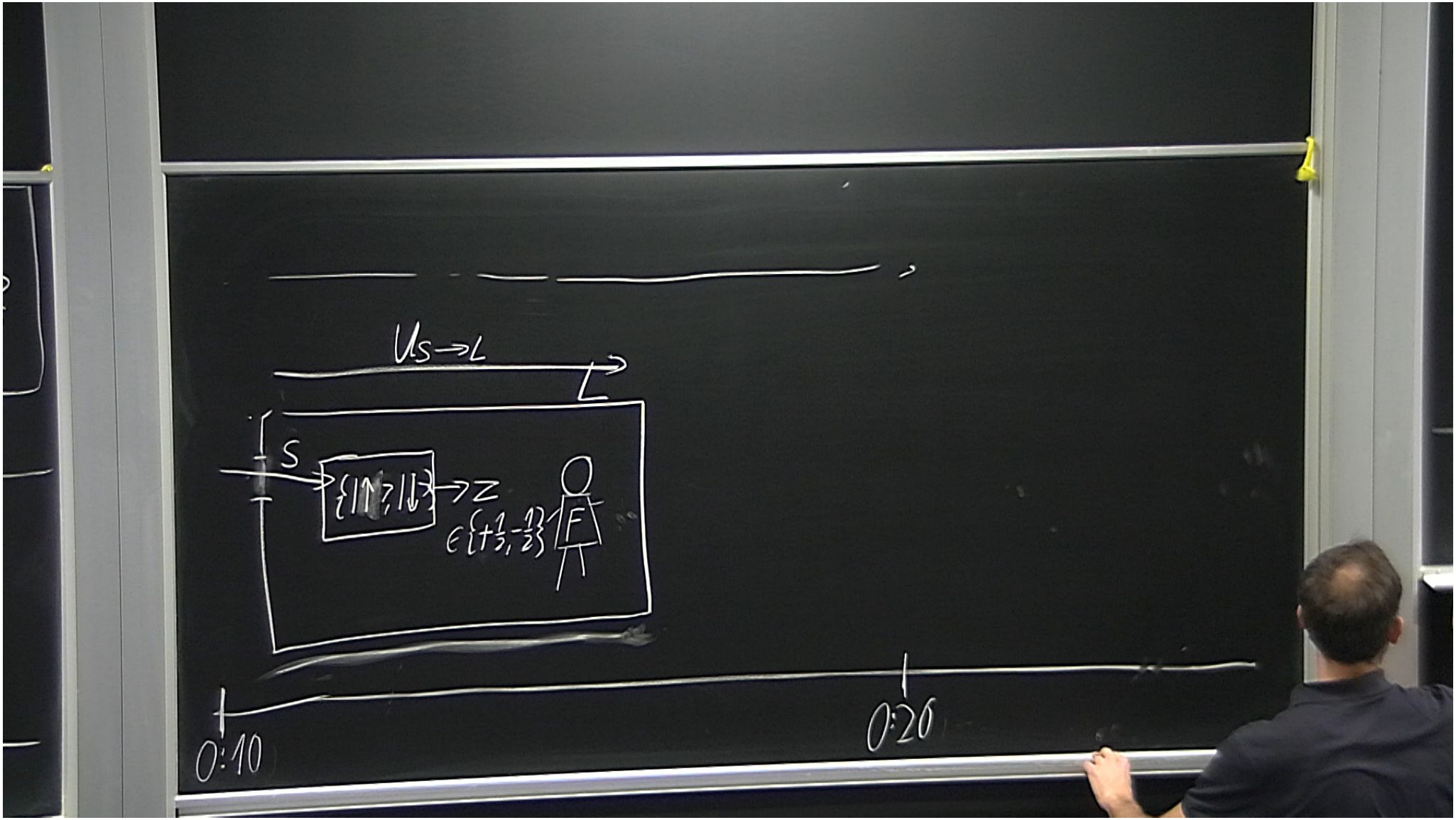

0:30
$|ok\rangle_L = \frac{1}{\sqrt{5}}|+\frac{1}{2}\rangle_L - \frac{1}{\sqrt{5}}|-\frac{1}{2}\rangle_L$
$|fail\rangle = |ok\rangle^\perp$
where $|+\frac{1}{2}\rangle_L = U_{S\to L}|\uparrow\rangle_S$
$|-\frac{1}{2}\rangle_L = U_{S\to L}|\downarrow\rangle$

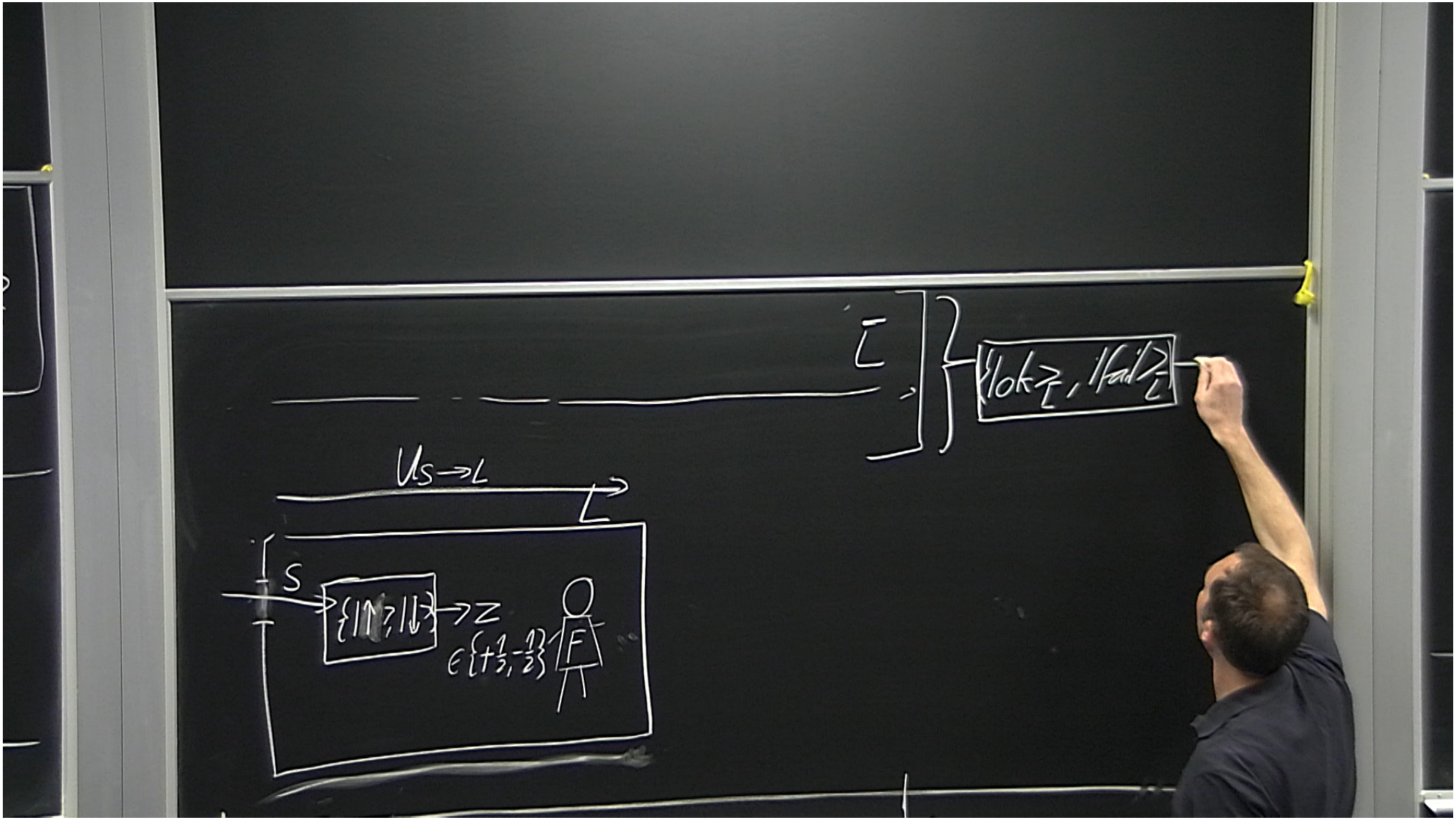

0:00
S^F: "If r=+ at 0:10 then spin S is in state $|\rightarrow\rangle_S$ at time 0:10"
S^F: "If z=+$\frac{1}{2}$ at 0:20 then $\bar{F}$ has observed r=+ at 0:10."
$S'^{\bar{F}}_+$ "If r=+ at 0:10 then W will observe w= at time 0:40.

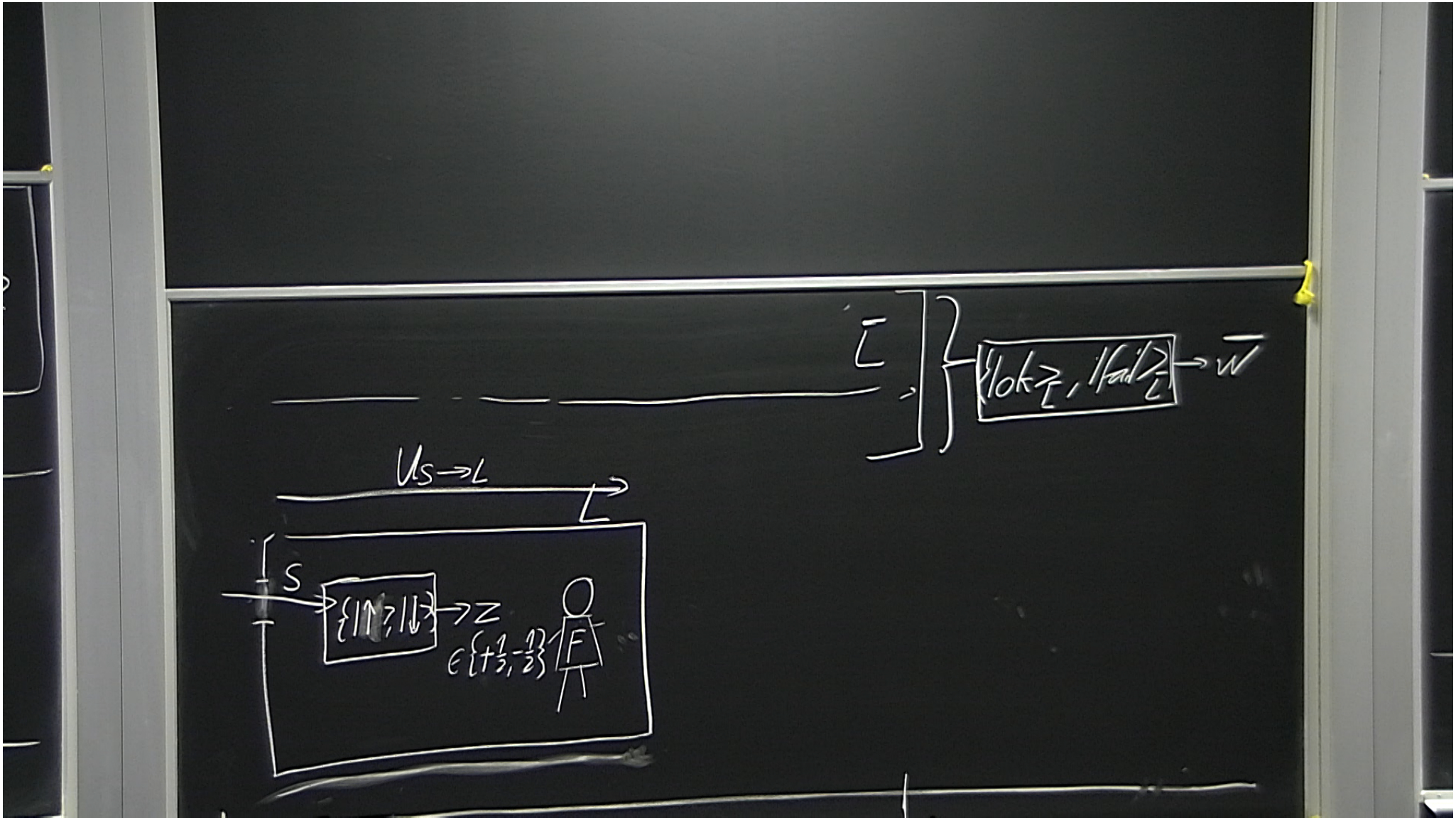

T: physical theory
L
{ok, fail}
w ∈ {ok, fail}
w
0:30
0:40

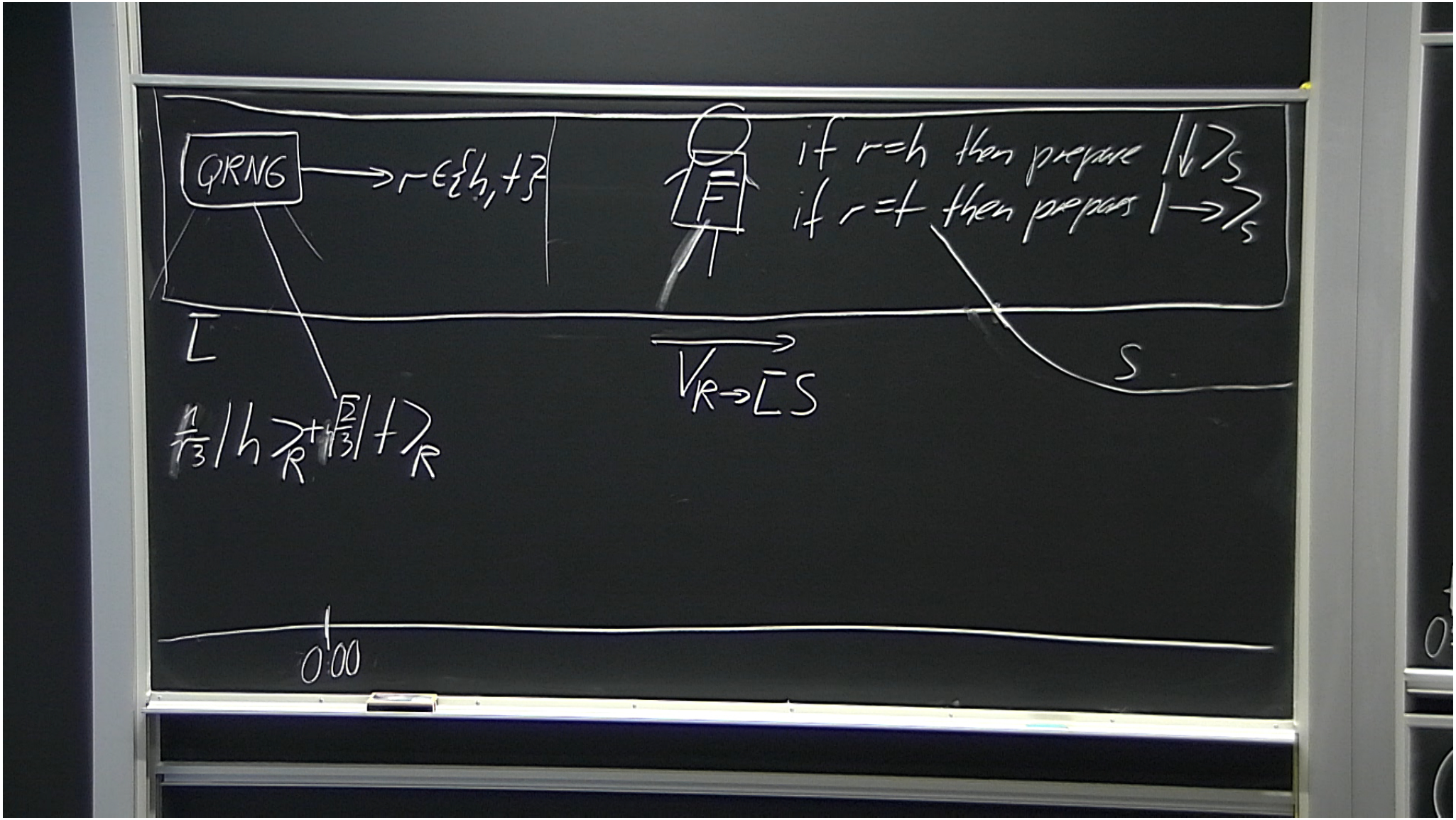

0:00
S : If r=t at 0:10 then spin S
is in state |→⟩S at time 0:10"
S^F : "If z=+1/2 at 0:20 then F
has observed r=t at 0:10."
S'F : "If r=t at 0:10 then W will
observe w= at time 0:40.

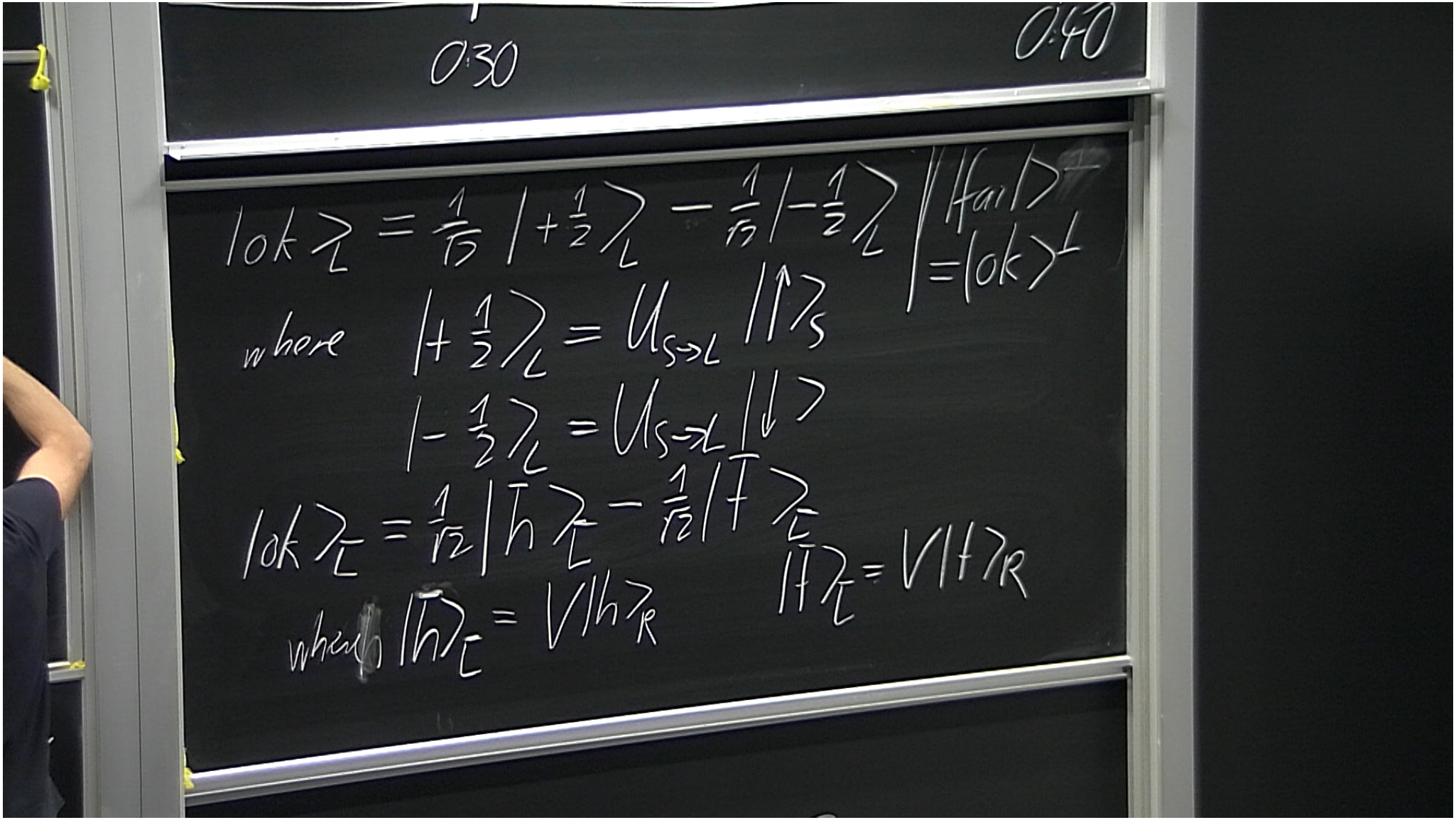

0:00
0:10
S' : If $r=+$ at 0:10 then spin S is in state $|\rightarrow\rangle_S$ at time 0:10"
S^F: "If $z=+\frac{1}{2}$ at 0:20 then F has observed $r=+$ at 0:10."
S'^F_+: "If $r=+$ at 0:10 then W will observe $w=$fail at time 0:40.

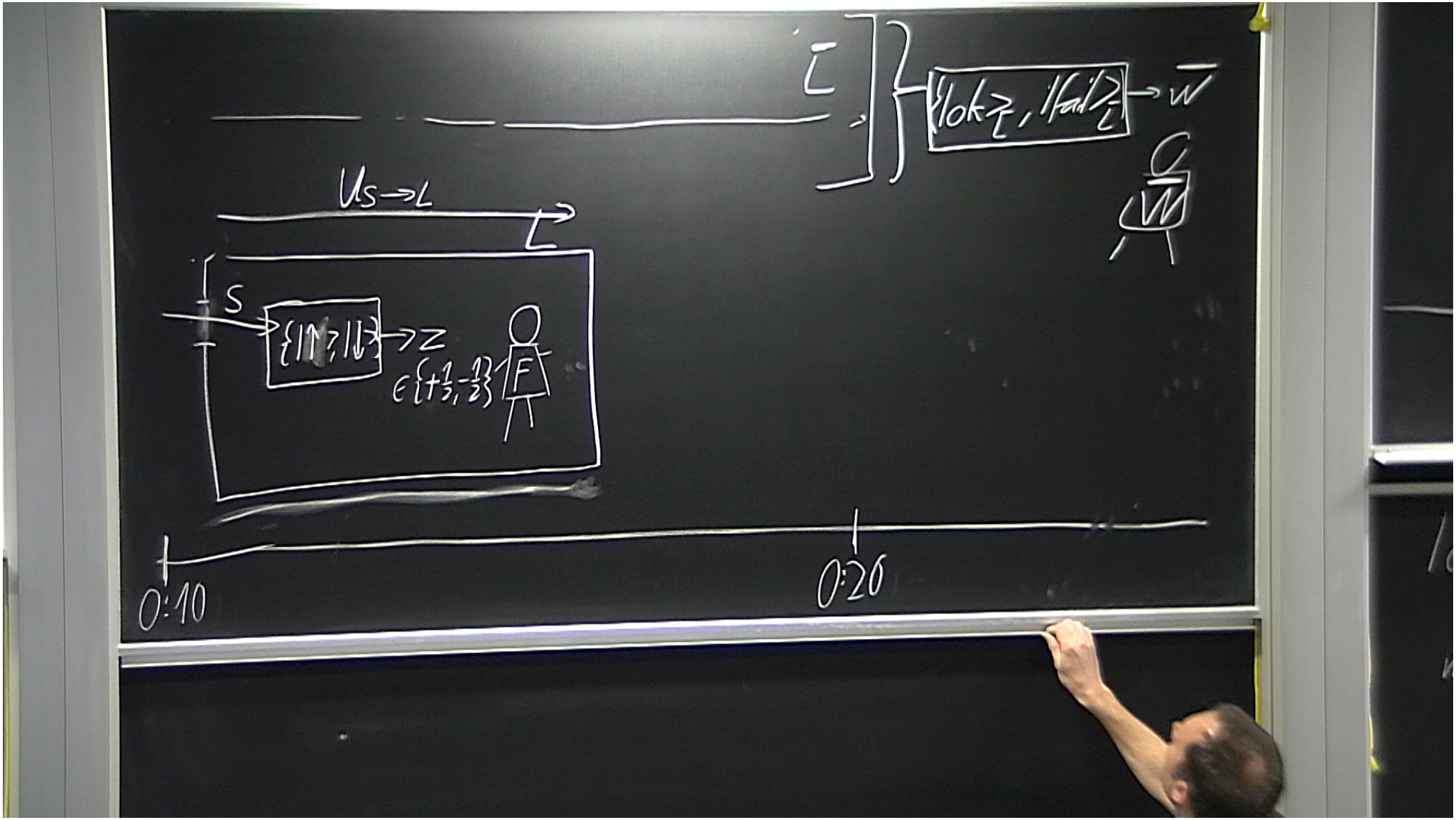

$U_{S \to L}$
L
S
$\{1\uparrow, 1\downarrow\} \to Z$
$\in \{+\frac{1}{2}, -\frac{1}{2}\}$
0:10
0:20

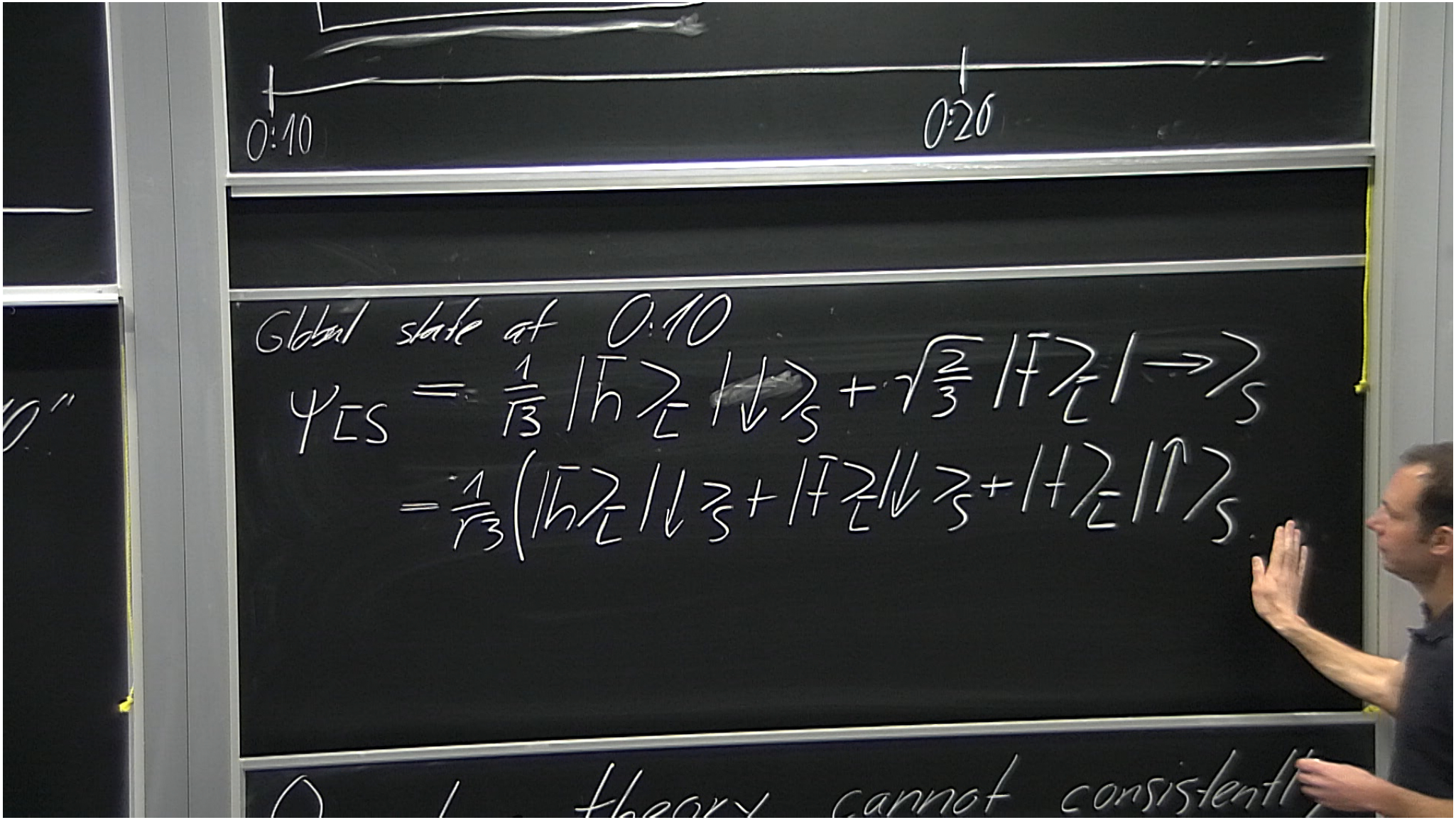

L
ok_L, fail_L
U_{S→L}
L
S
Z

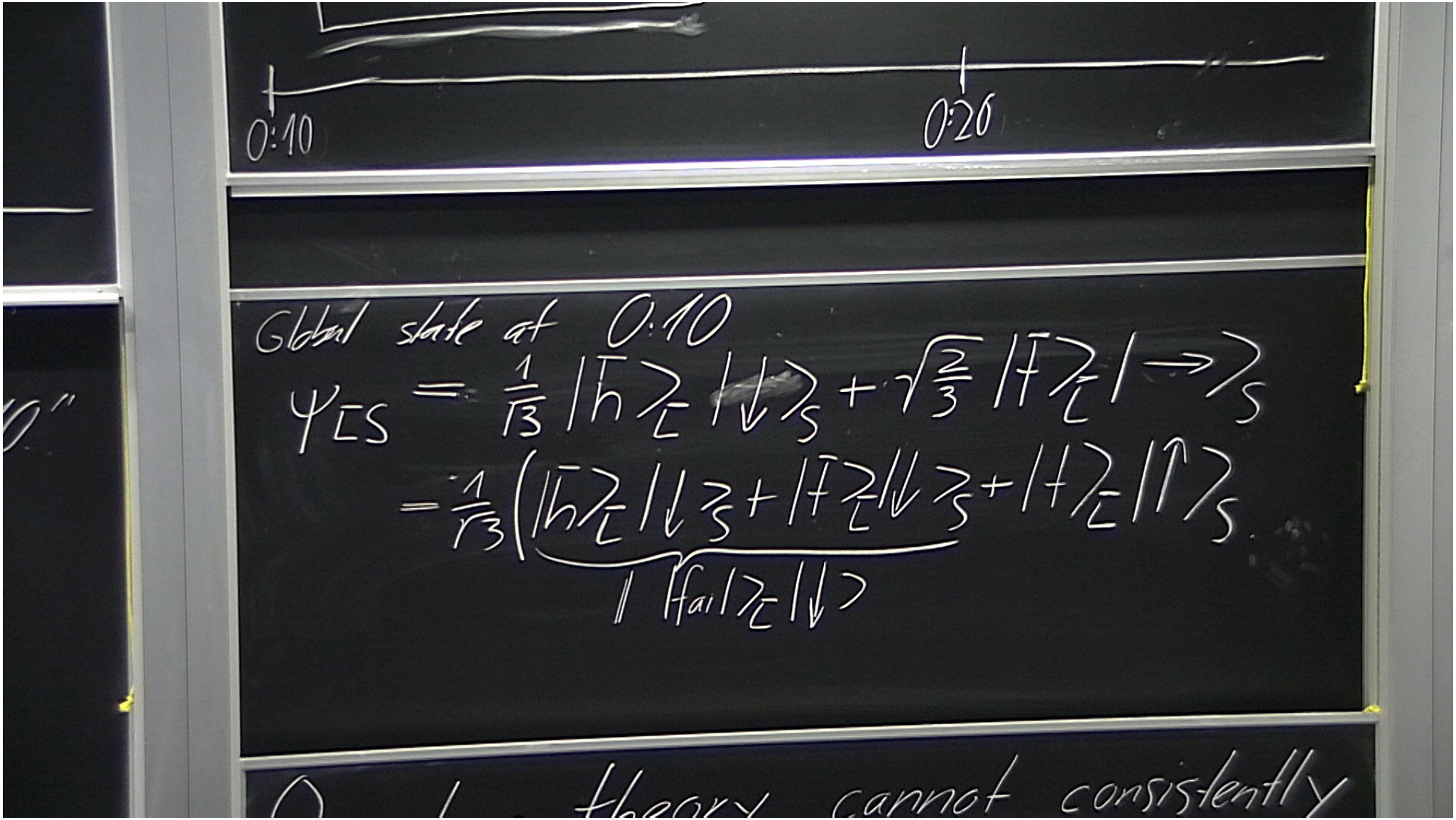

$U_{S \to L}$
L
S
Z
W

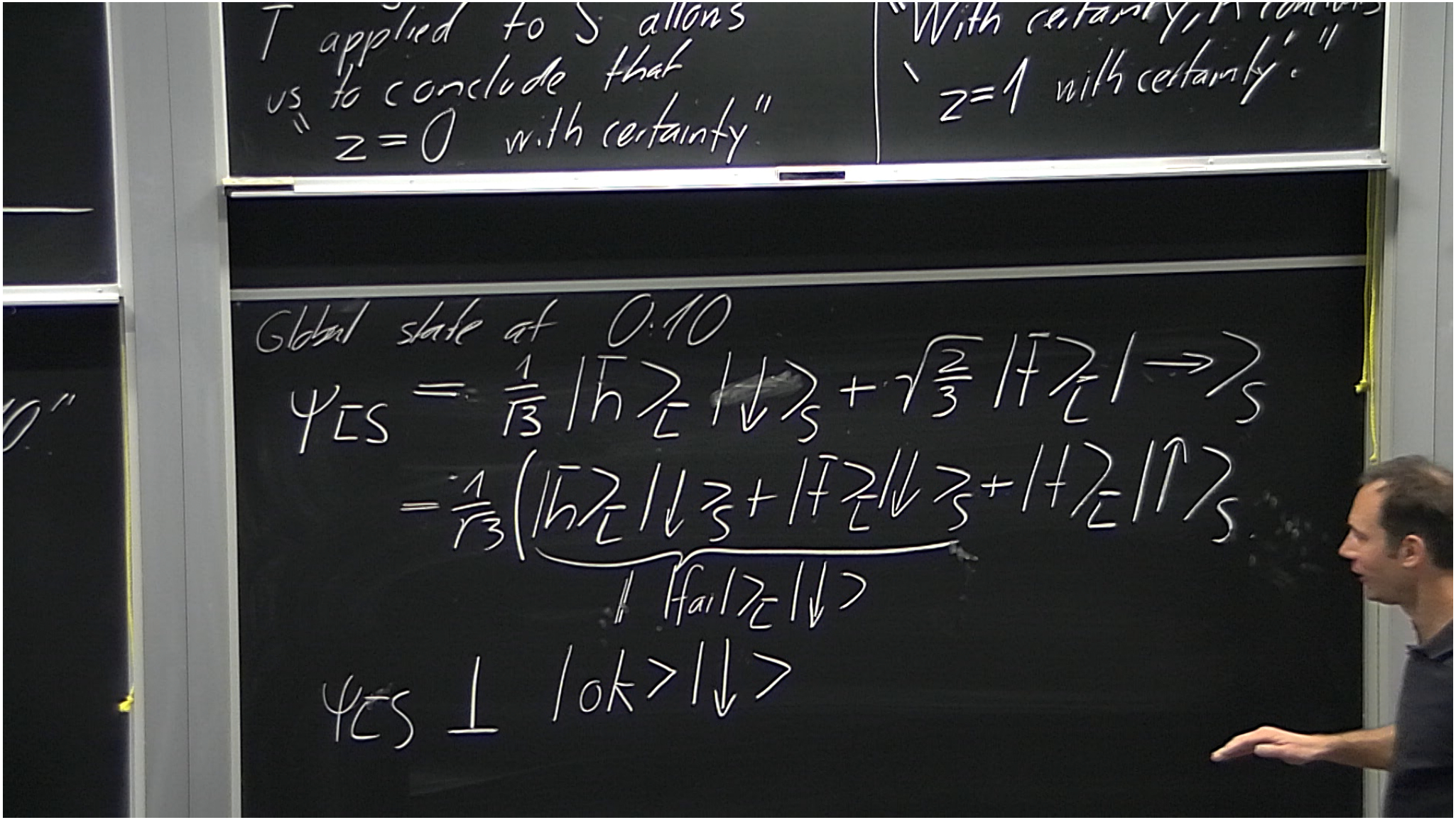

QRNG
r ∈ {h, t}
if r=h then prepare
if r=t then prepare
L
S
$V_{R\to LS}$
$\frac{1}{\sqrt{3}}|h\rangle_R + \frac{\sqrt{2}}{\sqrt{3}}|t\rangle_R$
0'00


0:30
0:40
|ok⟩_L = 1/√3 |+1/2⟩_L − 1/√3 |−1/2⟩_L
|fail⟩ = |ok⟩^⊥
where |+1/2⟩_L = U_{S→L} |↑⟩_S
|−1/2⟩_L = U_{S→L} |↓⟩
|ok⟩_L = 1/√2 |h⟩_L − 1/√2 |t⟩_L
where |h⟩_L = V|h⟩_R
|t⟩_L = V|t⟩_R


0:10
0:20


0:10
0:20
Global state at 0:10
$\Psi_{ES} = \frac{1}{\sqrt{3}}|\bar{h}\rangle_E|\Downarrow\rangle_S + \sqrt{\frac{2}{3}}|\bar{H}\rangle_E|\rightarrow\rangle_S$
$= \frac{1}{\sqrt{3}}\left(|\bar{h}\rangle_E|\Downarrow\rangle_S + |\bar{H}\rangle_E|\Downarrow\rangle_S + |\bar{H}\rangle_E|\uparrow\rangle_S\right.$
theory cannot consistent


0:10
0:20
Global state at 0:10
$\Psi_{LS} = \frac{1}{\sqrt{3}}|\bar{h}\rangle_L|\downarrow\rangle_S + \sqrt{\frac{2}{3}}|\bar{t}\rangle_L|\rightarrow\rangle_S$
$= \frac{1}{\sqrt{3}}\left(\underbrace{|\bar{h}\rangle_L|\downarrow\rangle_S + |\bar{t}\rangle_L|\downarrow\rangle_S}_{|\text{fail}\rangle_L|\downarrow\rangle} + |\bar{t}\rangle_L|\uparrow\rangle_S\right)$
theory cannot consistently


T applied to S allows
us to conclude that
"z=0 with certainty"
"With certainty,
z=1 with certainty."
Global state at 0:10
$\Psi_{ES} = \frac{1}{\sqrt{3}}|h\rangle_E|\downarrow\rangle_S + \sqrt{\frac{2}{3}}|t\rangle_E|\rightarrow\rangle_S$
$= \frac{1}{\sqrt{3}}(|h\rangle_E|\downarrow\rangle_S + |t\rangle_E|\downarrow\rangle_S + |t\rangle_E|\uparrow\rangle_S$
$|fail\rangle_E|\downarrow\rangle$
$\Psi_{ES} \perp |ok\rangle|\downarrow\rangle$

T applied to S allows us to conclude that $z=0$ with certainty"

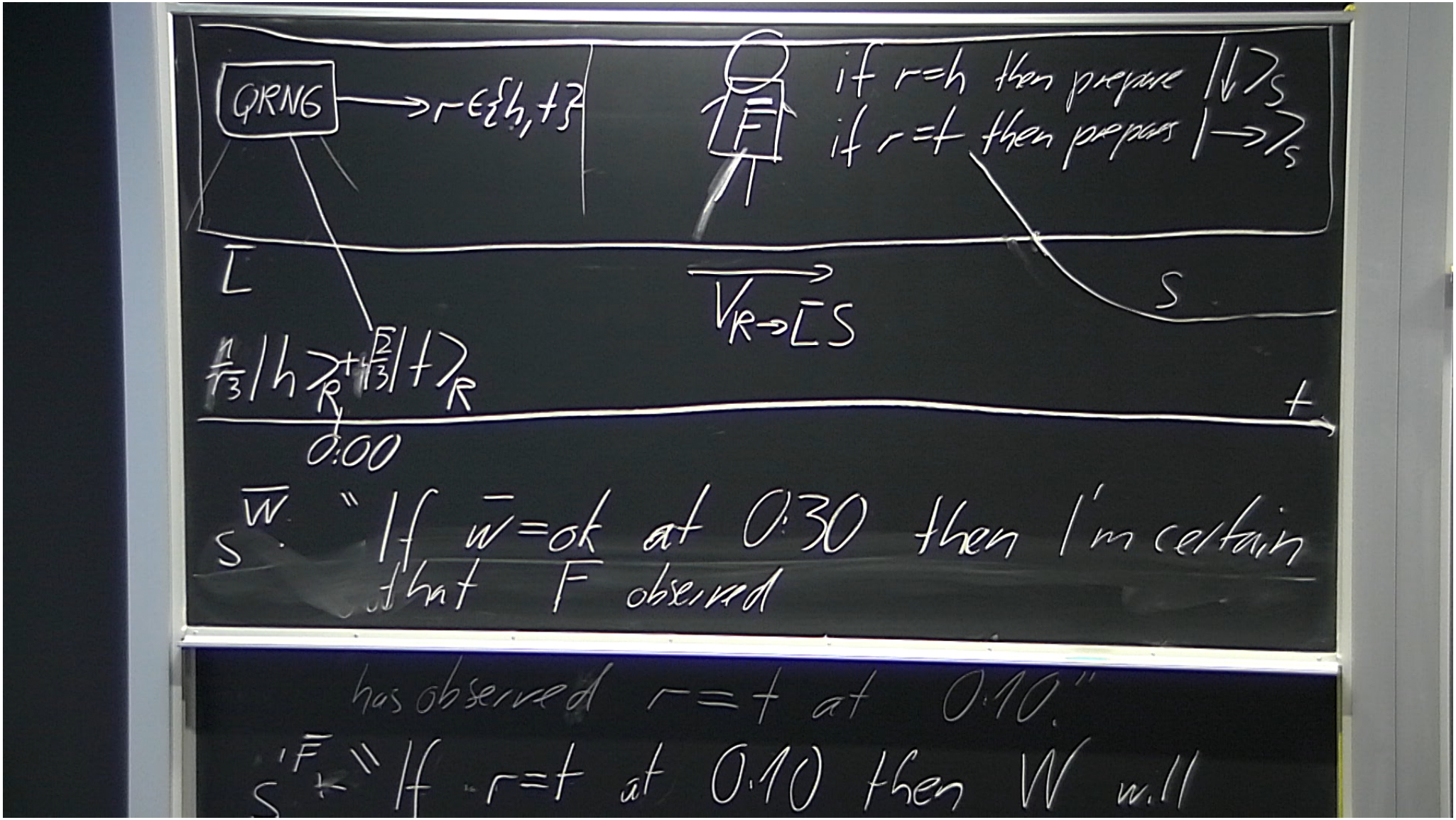
"With certainty, it [illegible] $z=1$ with certainty."

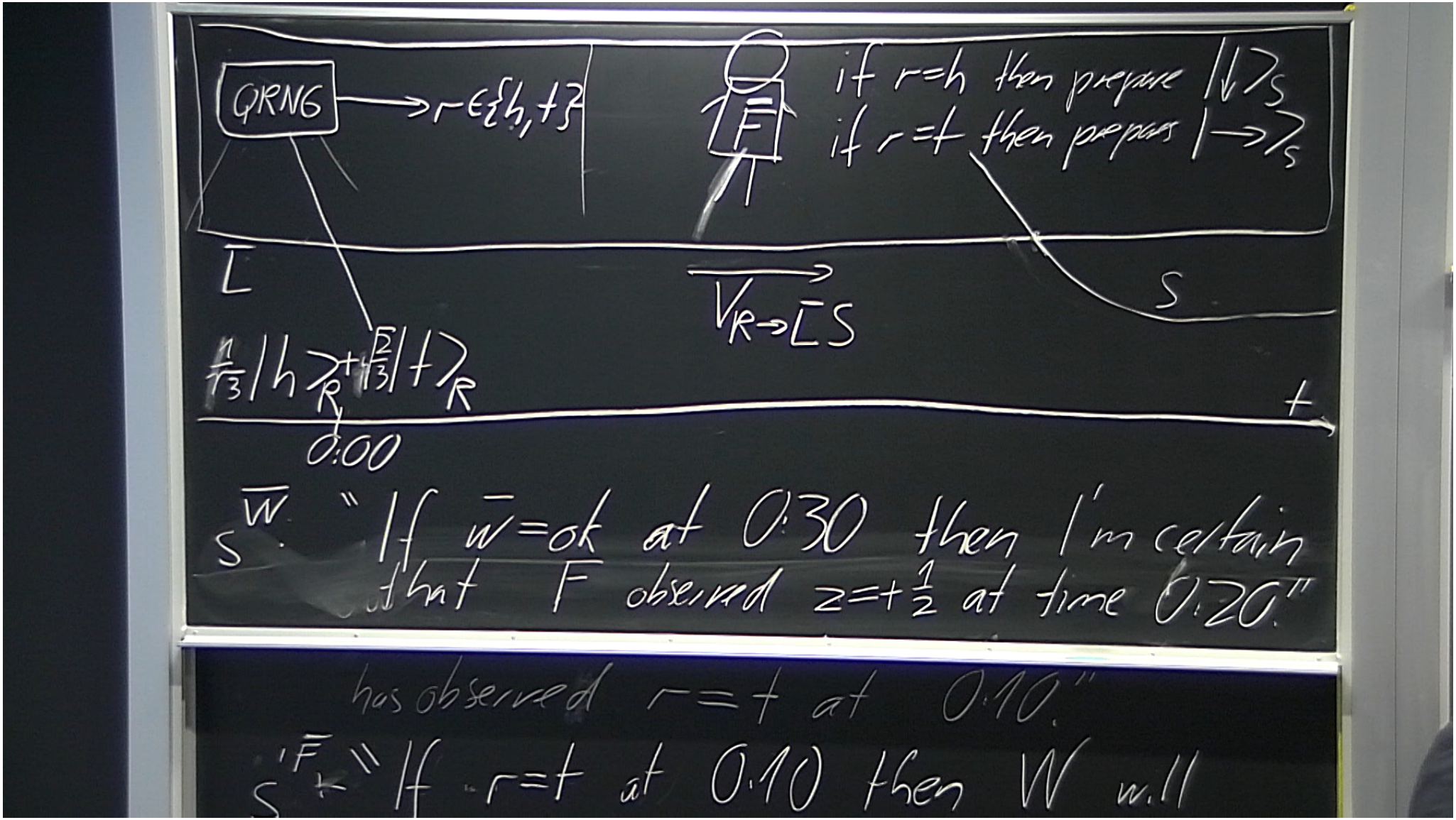
Global state at 0:10

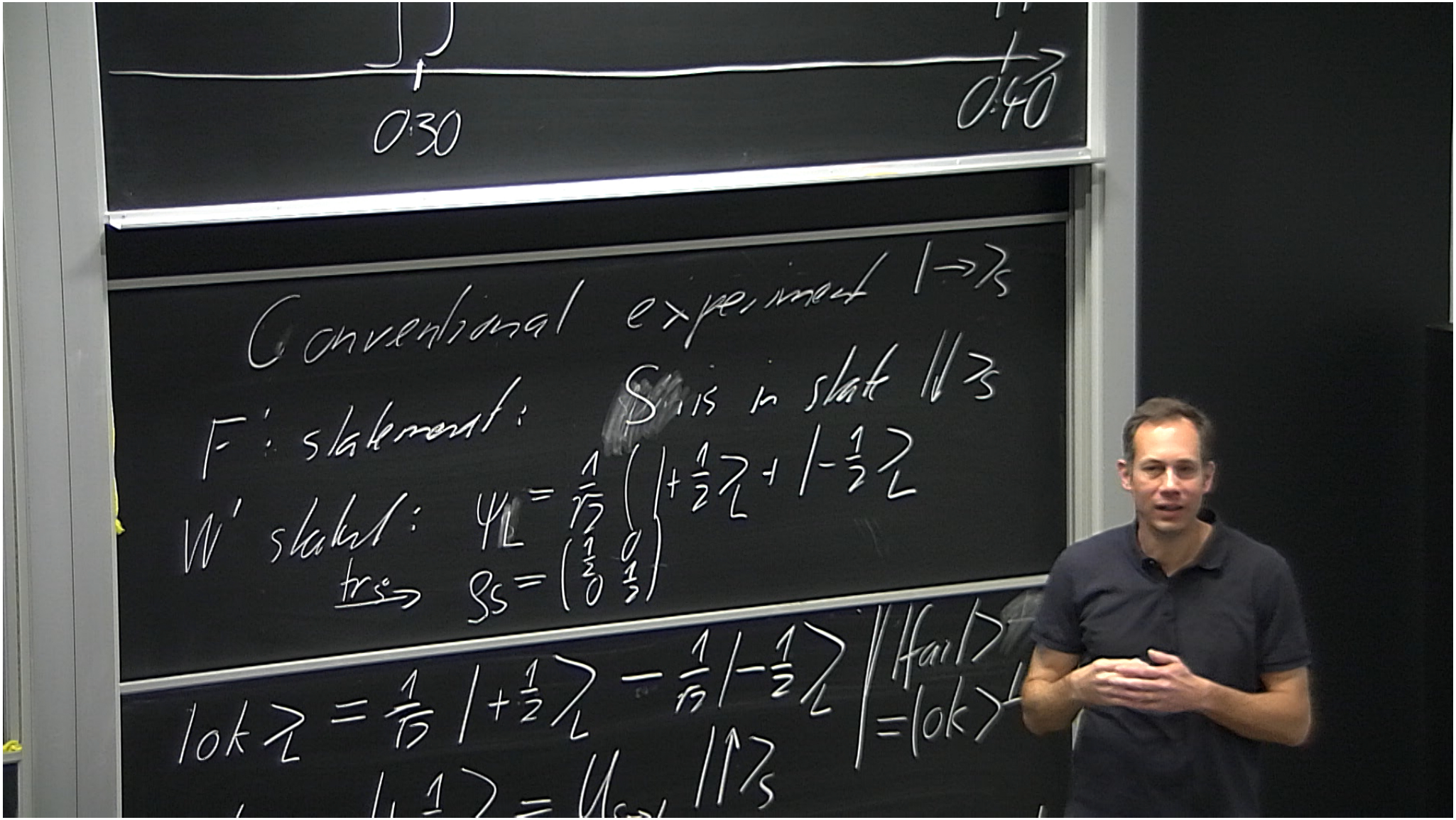
$$\Psi_{ES} = \frac{1}{\sqrt{3}} |h\rangle_E |\downarrow\rangle_S + \sqrt{\frac{2}{3}} |t\rangle_E |\rightarrow\rangle_S$$

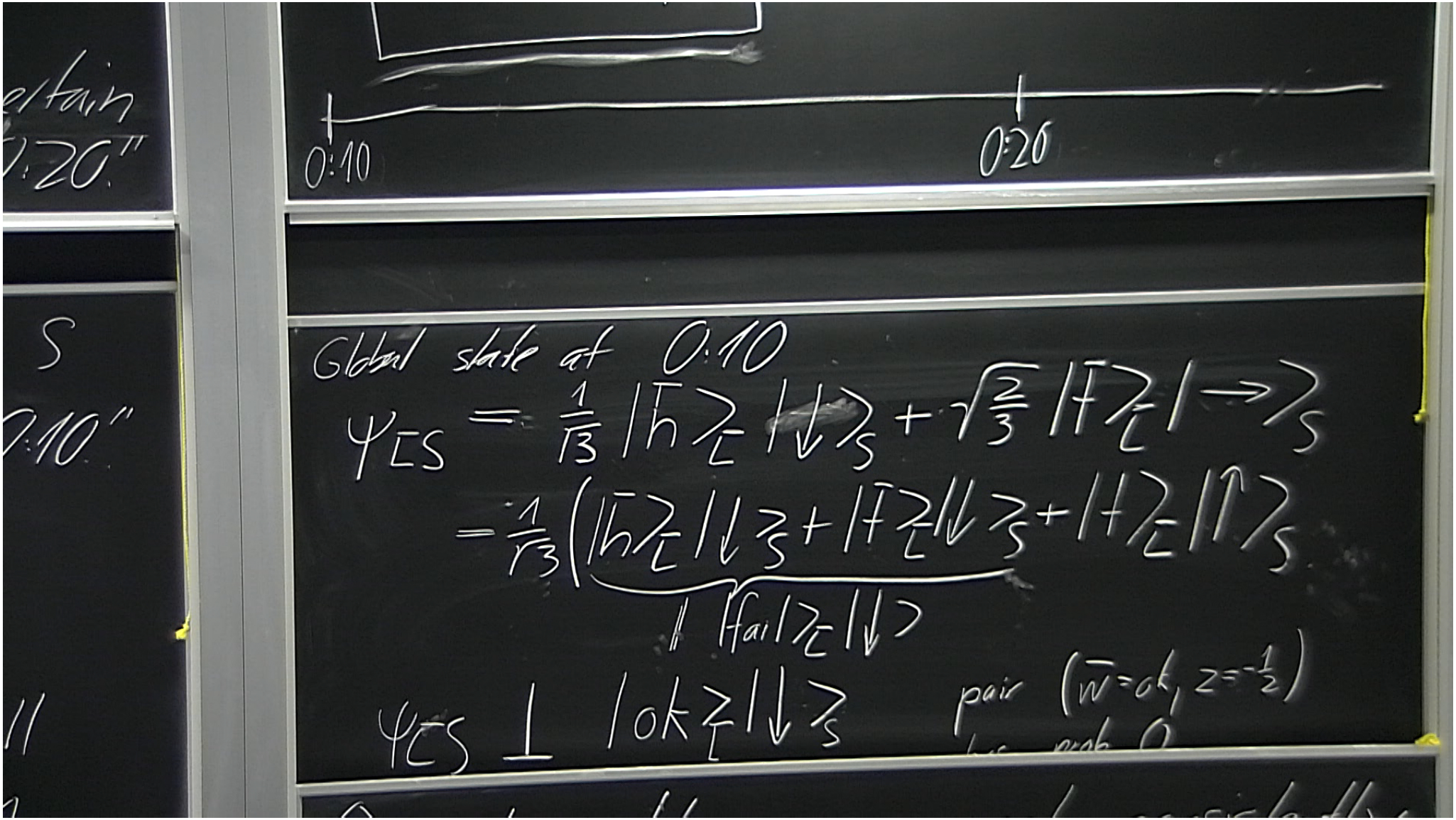
$$= \frac{1}{\sqrt{3}} \left(\underbrace{|h\rangle_E |\downarrow\rangle_S + |t\rangle_E |\downarrow\rangle_S}_{\propto |fail\rangle_E |\downarrow\rangle} + |t\rangle_E |\uparrow\rangle_S \right)$$

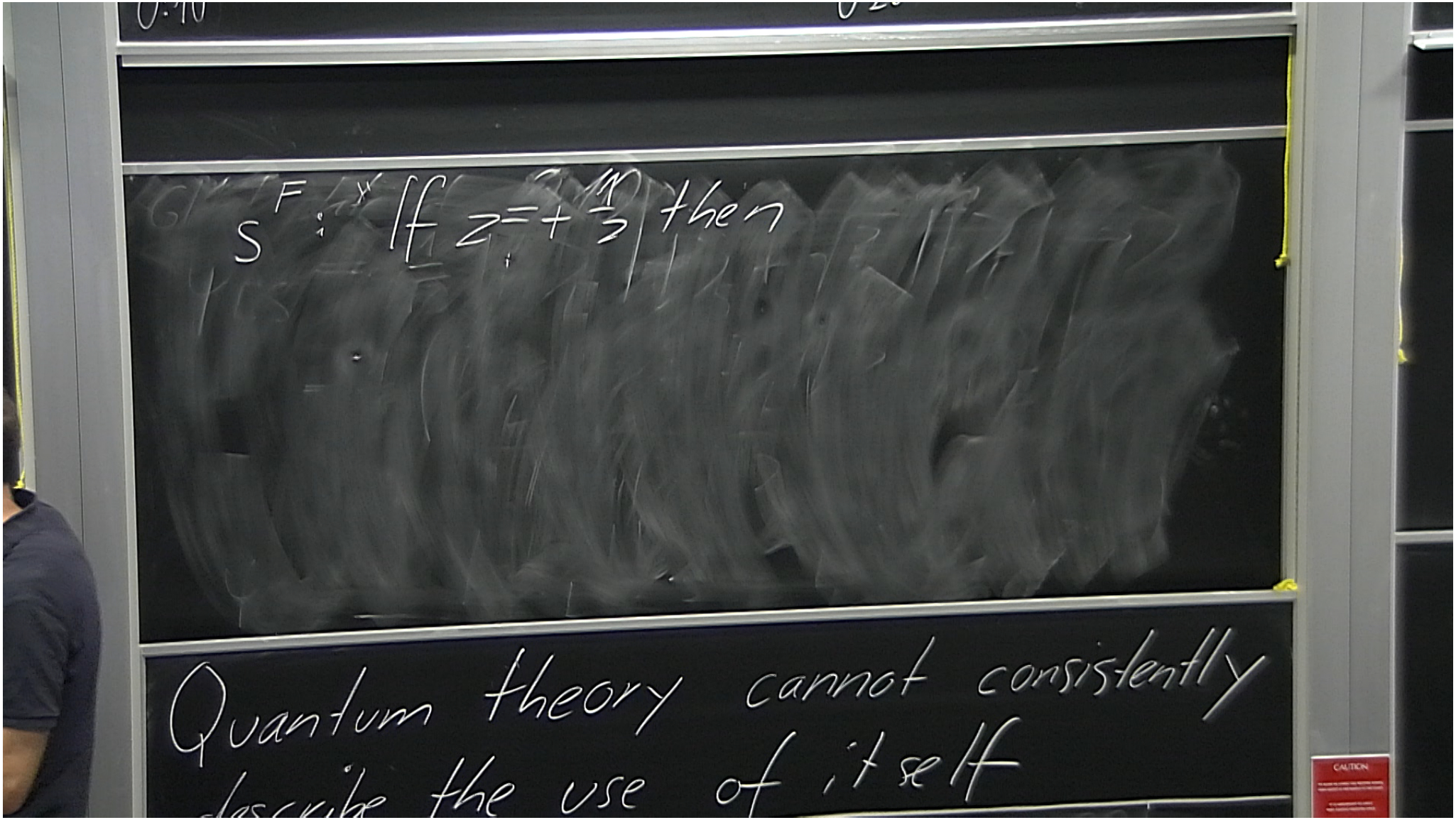
$\Psi_{ES} \perp |ok\rangle_E |\downarrow\rangle_S$ pair $(\bar{w}=ok, z=-\frac{1}{2})$ has prob. 0

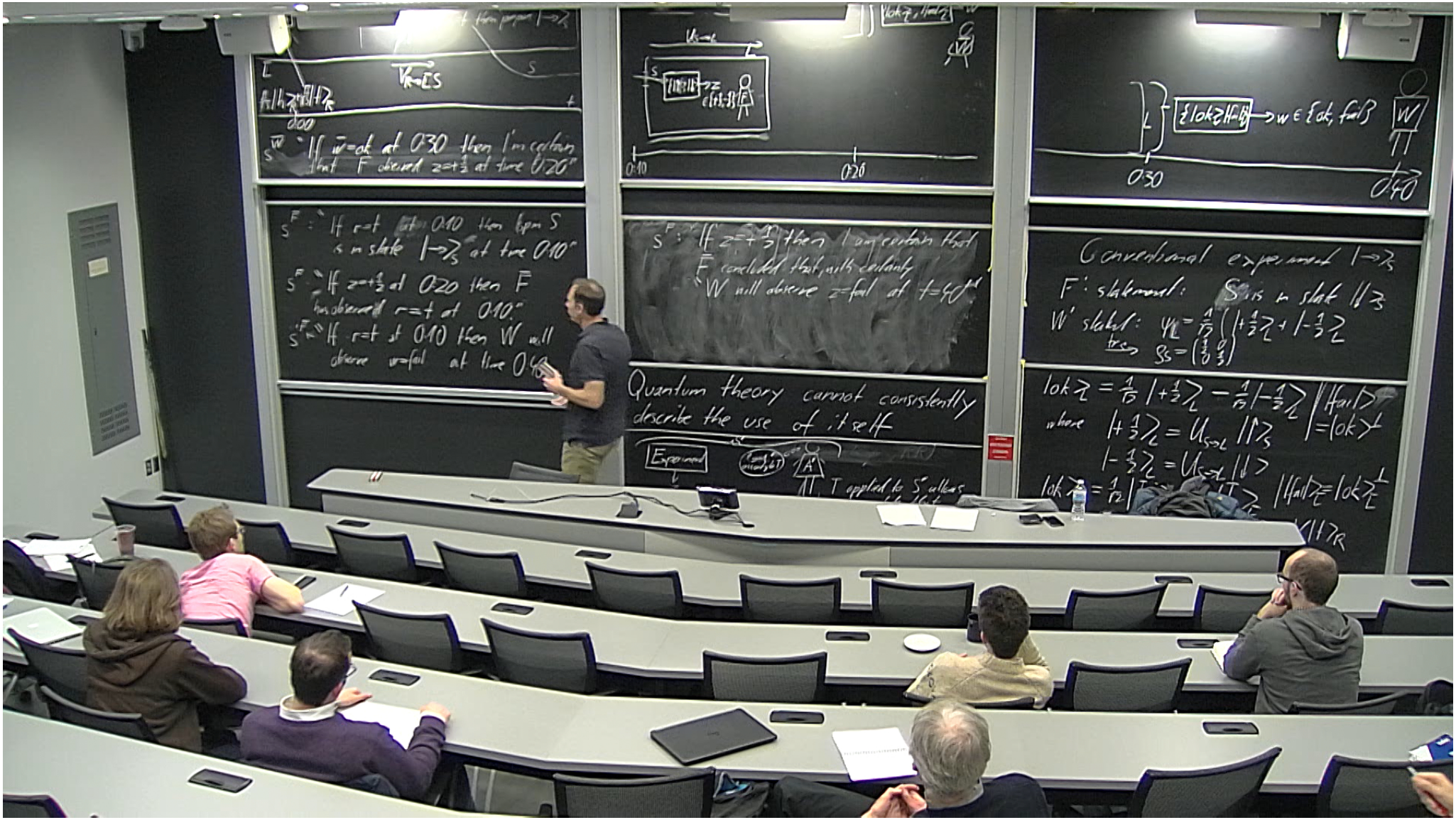

QRNG
r ∈ {h, t}
if r=h then prepare
if r=t then prepare
L
S
$V_{R \to \bar{L}S}$
$\frac{1}{\sqrt{3}}|h\rangle_R + \frac{\sqrt{2}}{\sqrt{3}}|t\rangle_R$
0:00
t
$S^{\bar{W}}$: "If $\bar{w}$=ok at 0:30 then I'm certain that F observed
has observed r=t at 0:10."
$S^{'F}_{+}$: "If r=t at 0:10 then W will

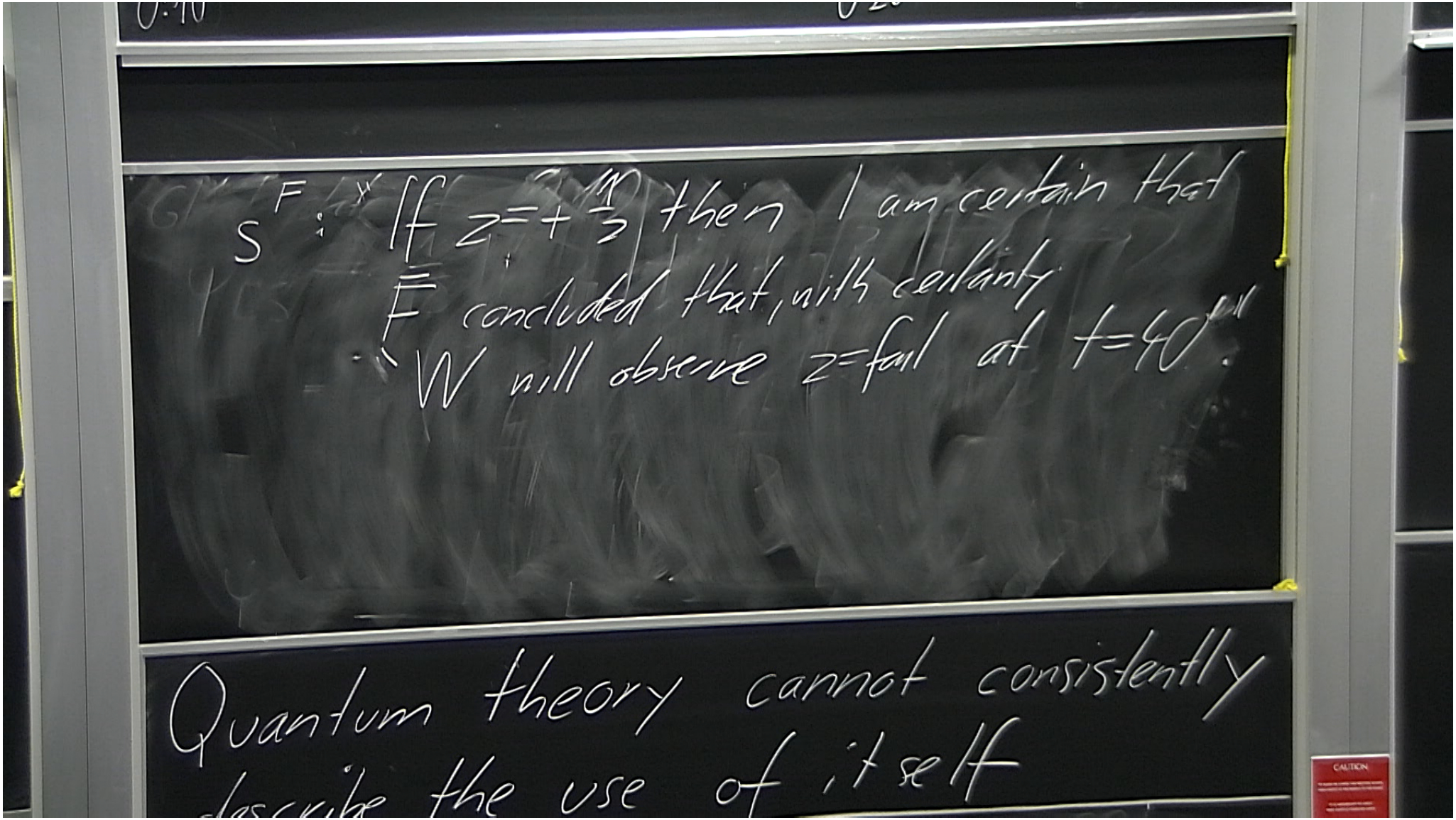

QRNG
r ∈ {h, t}
if r=h then prepare
if r=t then prepare
L
S
$V_{R \to LS}$
$\frac{1}{\sqrt{3}}|h\rangle_R + \frac{\sqrt{2}}{\sqrt{3}}|t\rangle_R$
0:00
t
$S^{\bar{W}}$: "If $\bar{w}$=ok at 0:30 then I'm certain that F observed $z=+\frac{1}{2}$ at time 0:20."
has observed r=t at 0:10."
$S^{\bar{F}_t}$: "If r=t at 0:10 then W will

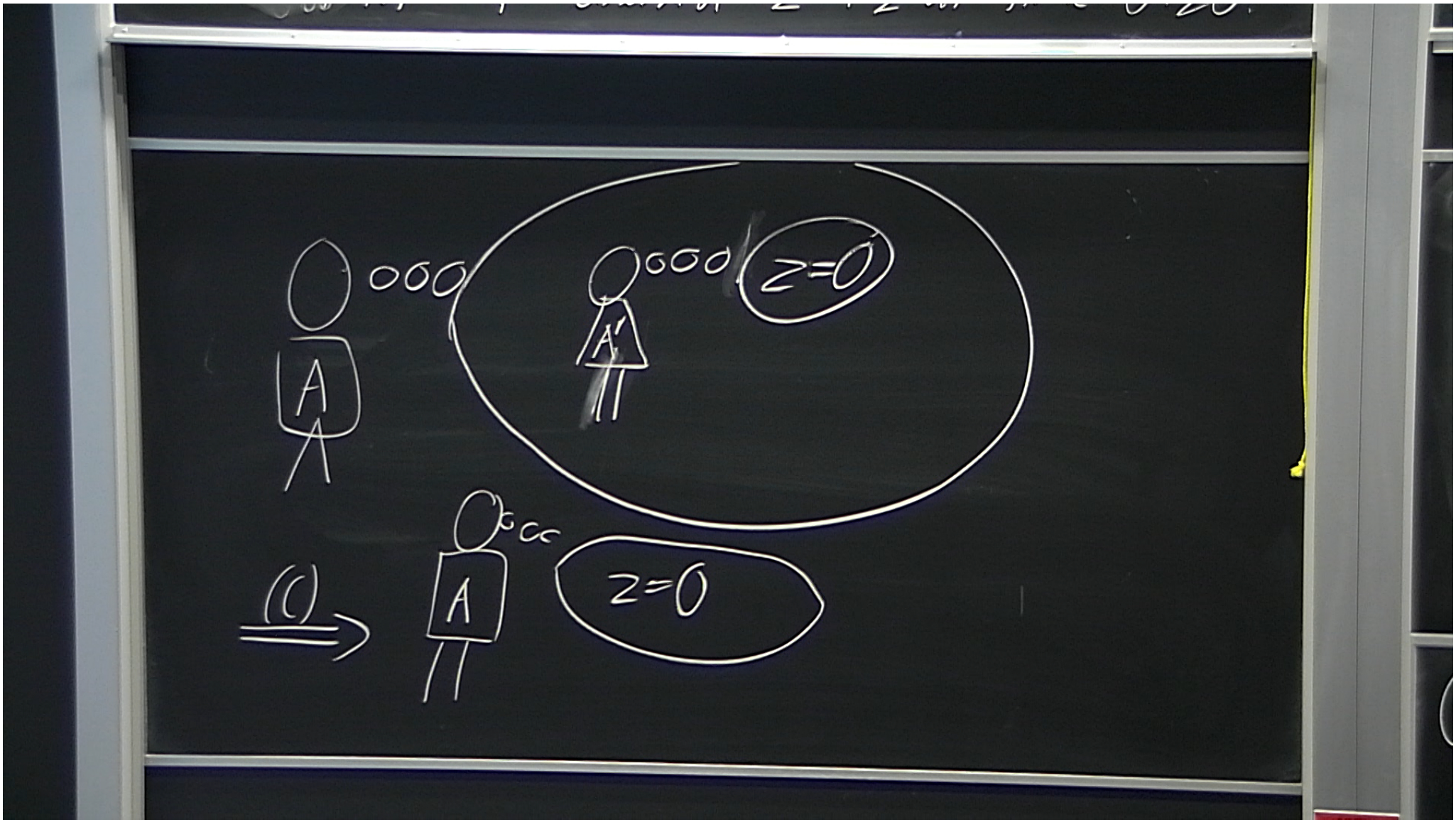

0:30
0:40
Conventional experiment
F: statement:
W' stakel:
tr

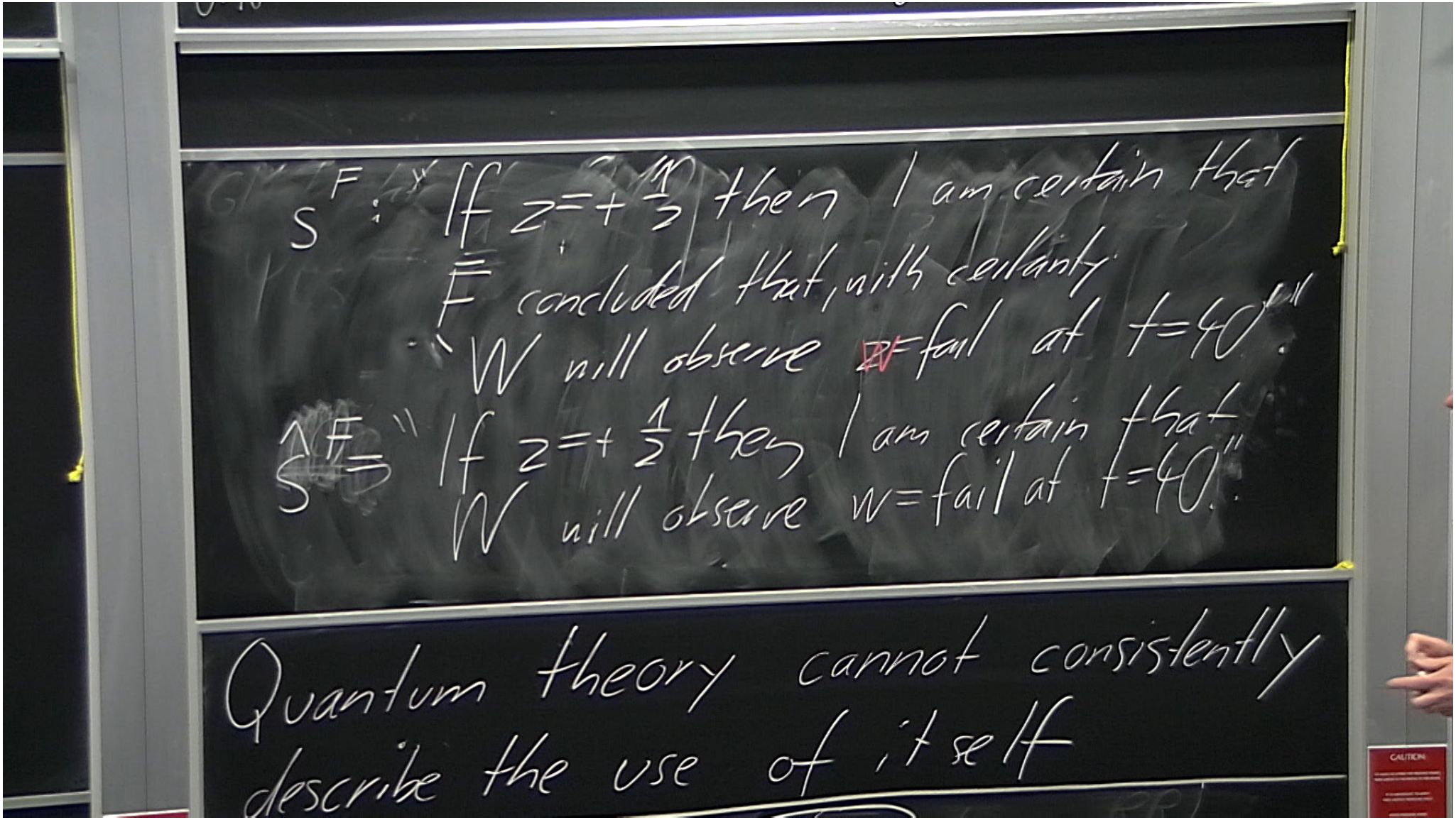

0:10
0:20
Global state at 0:10
$\Psi_{ES} = \frac{1}{\sqrt{3}}|\bar{h}_E\rangle|\downarrow\rangle_S + \sqrt{\frac{2}{3}}|\bar{t}_E\rangle|\rightarrow\rangle_S$
$= \frac{1}{\sqrt{3}}(\underbrace{|\bar{h}_E\rangle|\downarrow\rangle_S + |\bar{t}_E\rangle|\downarrow\rangle_S}_{|\text{fail}_E\rangle|\downarrow\rangle} + |\bar{t}_E\rangle|\uparrow\rangle_S$
$\Psi_{ES} \perp |ok_E\rangle|\downarrow\rangle_S$
pair $(\bar{w}=ok, z=-\frac{1}{2})$


S^F: If $z = +\frac{1}{2}$ then
Quantum theory cannot consistently
describe the use of itself


Quantum theory cannot consistently describe the use of itself
Experiment
Conventional experiment
F: statement:
W' statement:
where

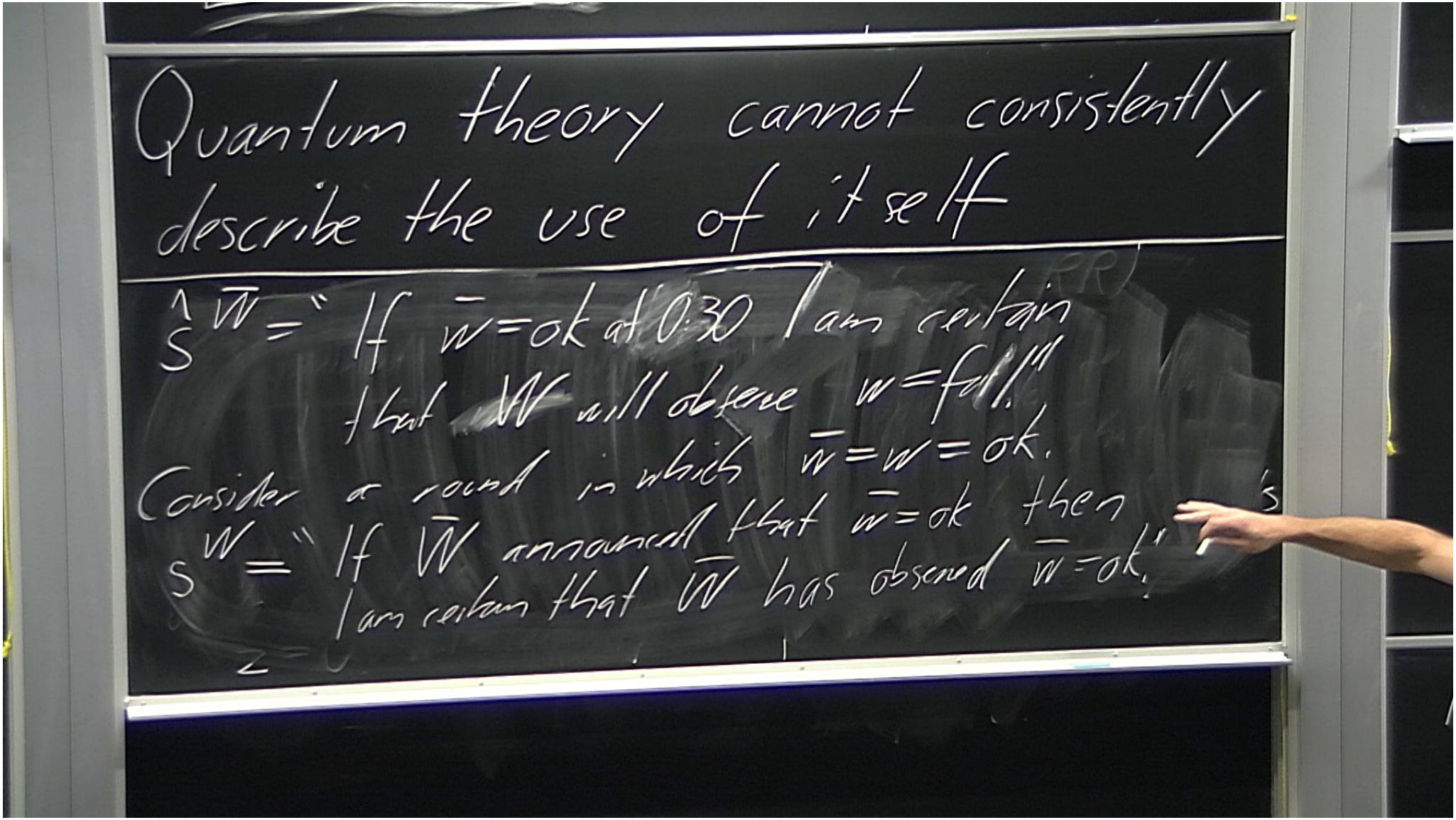

S^{F}: If $z = +\frac{11}{2}$ then I am certain that
F concluded that, with certainty
W will observe z=fail at t=40.
Quantum theory cannot consistently
describe the use of, itself

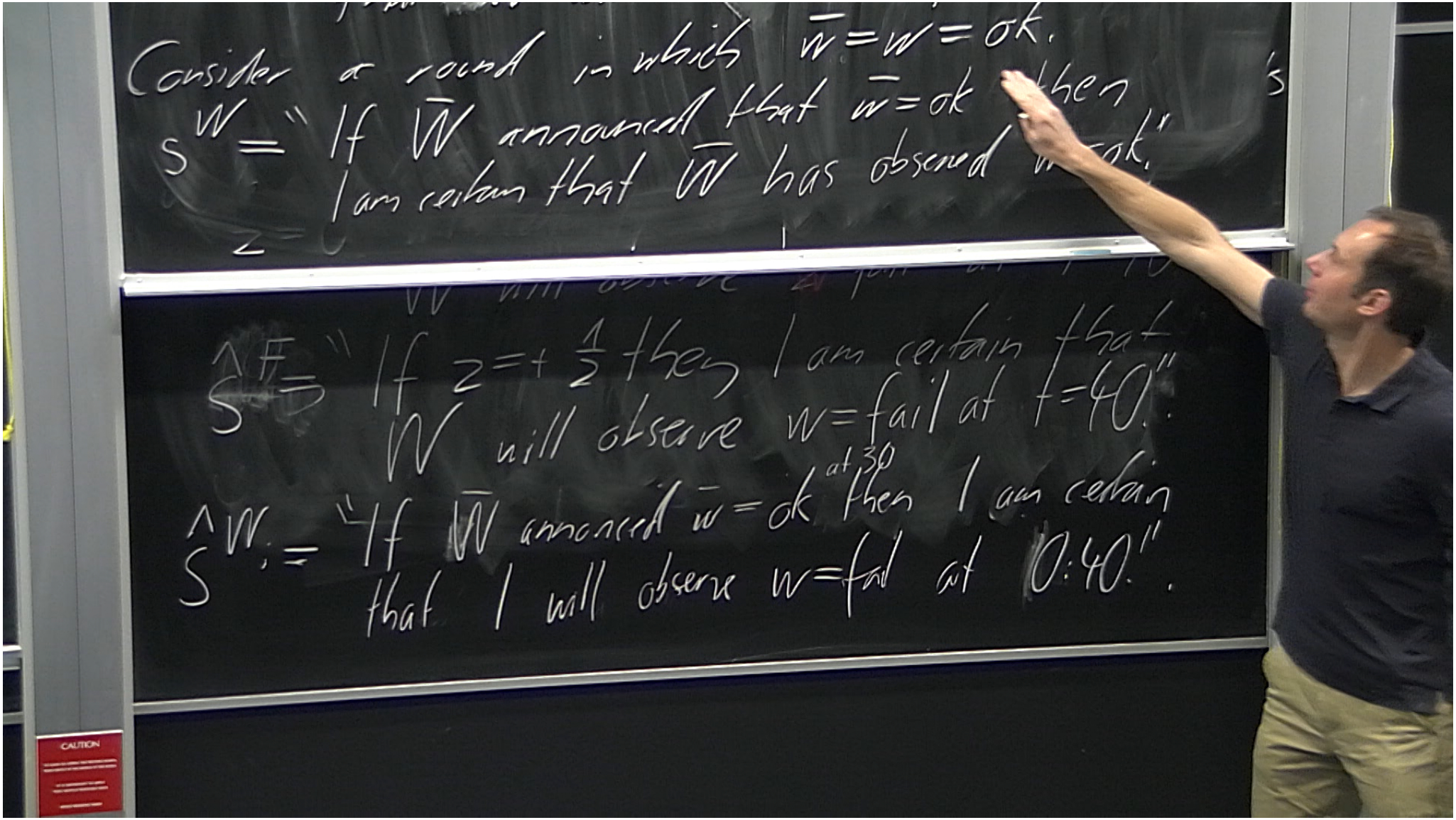

A
A'
z=0
A
z=0

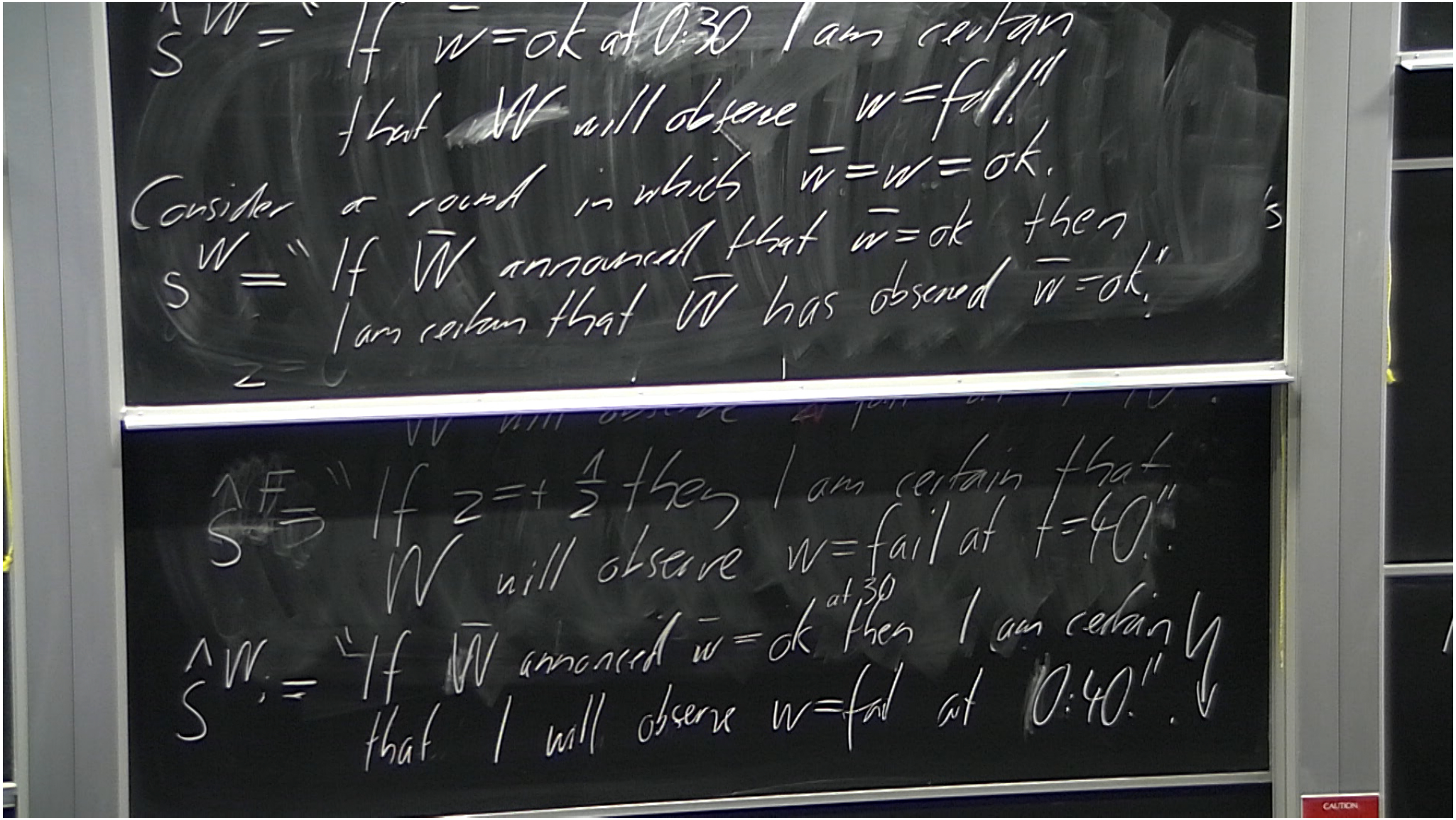

S^F: "If $z=+\frac{1}{2}$ then I am certain that
F concluded that, with certainty
"W will observe F fail at t=40."
$S^{\hat{F}}$ = "If $z=+\frac{1}{2}$ then I am certain that
W will observe W=fail at t=40."
Quantum theory cannot consistently
describe the use of, itself

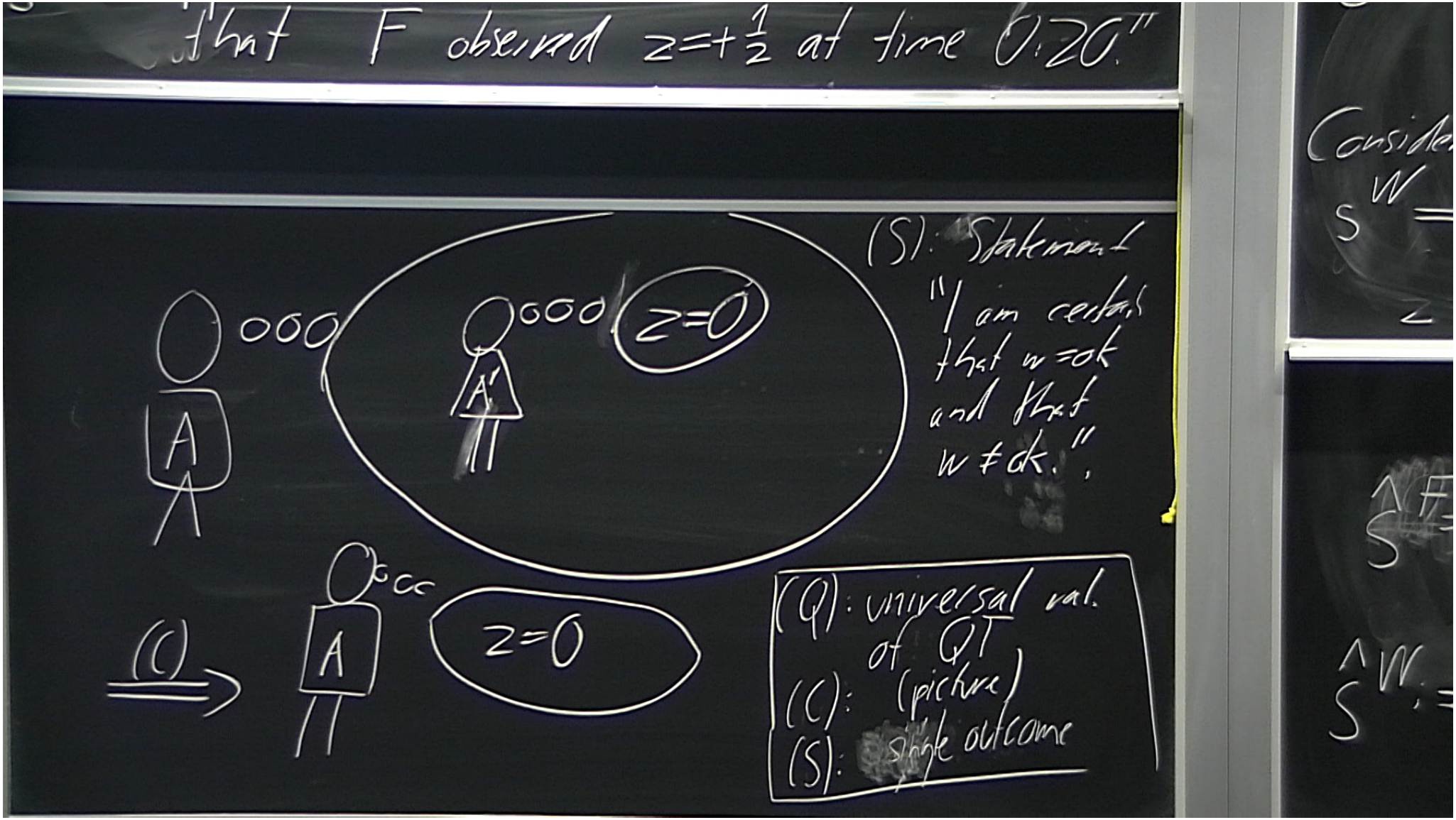
Quantum theory cannot consistently describe the use of itself

$\hat{S}$ $\hat{W}$ = " If $\bar{w}$ = ok at 0:30 I am certain that $\hat{W}$ will observe w = fail!"


Quantum theory cannot consistently describe the use of itself
$\hat{S}^{\bar{W}}$ = " If $\bar{w}$ = ok at 0:30 I am certain that $\bar{W}$ will observe w = fail!"
Consider a round in which $\bar{w} = w$ = ok.
S^{W} = " If $\bar{W}$ announced that $\bar{w}$ = ok then I am certain that $\bar{W}$ has observed $\bar{w}$ = ok!"


Consider a round in which $\bar{w} = w = ok$.
S^W = "If $\bar{W}$ announced that $\bar{w} = ok$ then I am certain that $\bar{W}$ has observed $w = ok$."
S^F = "If $z = +\frac{1}{2}$ then I am certain that W will observe $w = fail$ at $t = 40$."
$S^{W,30}$ = "If $\bar{W}$ announced $\bar{w} = ok$ at 30 then I am certain that I will observe $w = fail$ at 10:40."


$S^{\hat{W}}$ = "If $\bar{w}$ = ok at 0:30 I am certain that $\hat{W}$ will observe w = fail!"
Consider a round in which $\bar{w} = w$ = ok.
$S^{\bar{W}}$ = "If $\bar{W}$ announced that $\bar{w}$ = ok then I am certain that $\bar{W}$ has observed $\bar{w}$ = ok."
$z = \frac{1}{2}$
$S^{\hat{F}}$ = "If $z = +\frac{1}{2}$ then I am certain that $\hat{W}$ will observe w = fail at t = 40."
$S^{\hat{W}_i}$ = "If $\bar{W}$ announced $\bar{w}$ = ok at 30 then I am certain that I will observe w = fail at 10:40."


that F observed $z=+\frac{1}{2}$ at time 0:20."
A
A'
z=0
(S): Statement
"I am certain that w=ok and that w≠ok."
A
z=0
(Q)
(Q): universal val. of QT
(C): (picture)
(S): single outcome