Title: Standard Model (Review) - Lecture 1

Date: Jan 02, 2012 09:00 AM

URL: http://pirsa.org/12010000

Abstract:


Standard Model & Quantum Field Theory
New Year
eeling Lucky today Dear Sages & Prophets


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Standard Model & Quantum Field Theory
Donoghue, Golowich, Holstein : Dynamics of the Standard Model
P. Ramond ; Journeys Beyond the Standard Model
M. Peskin : PSI Standard Ma lecture Notes.
S. Weinberg. QFT I & I


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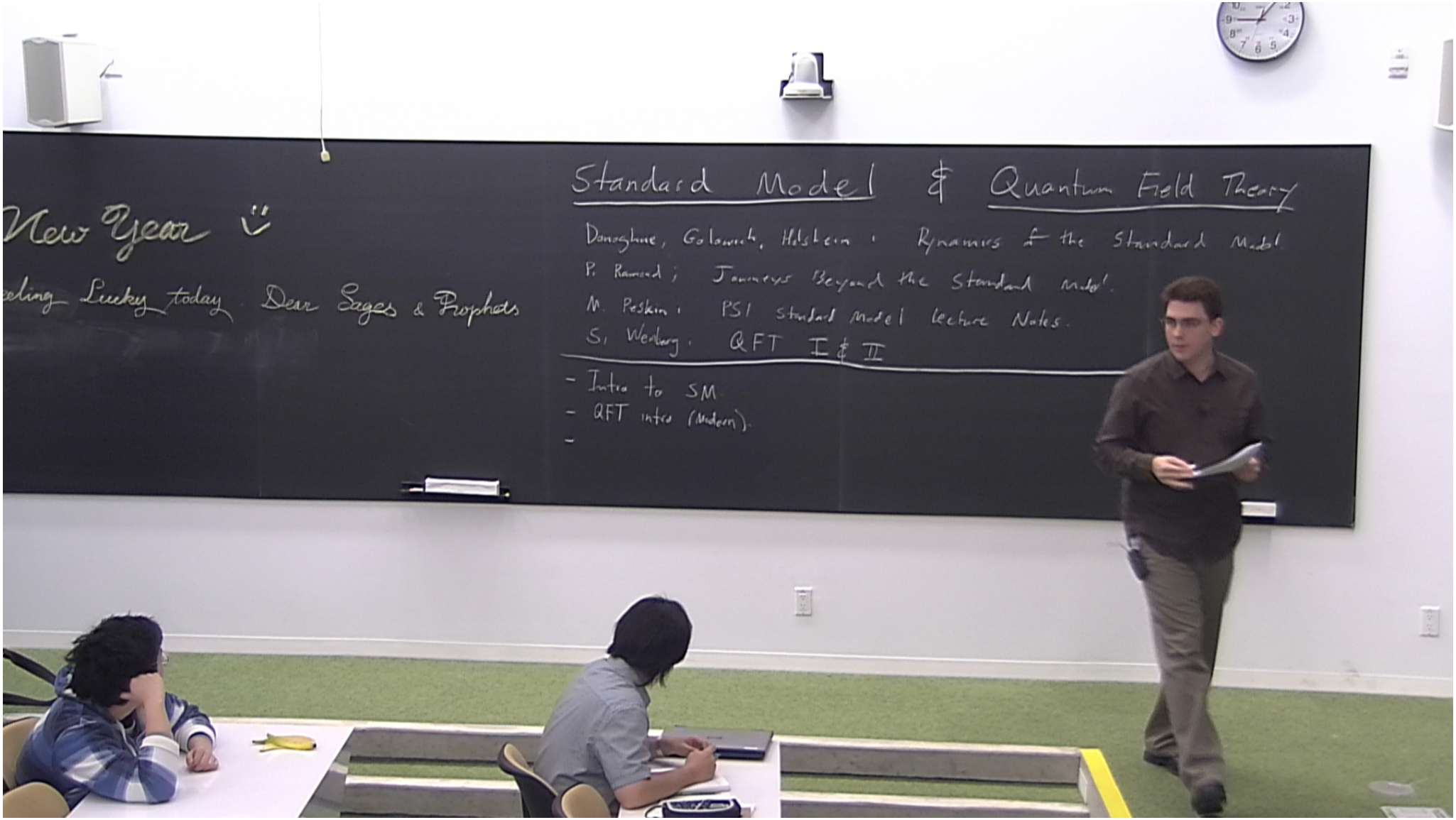
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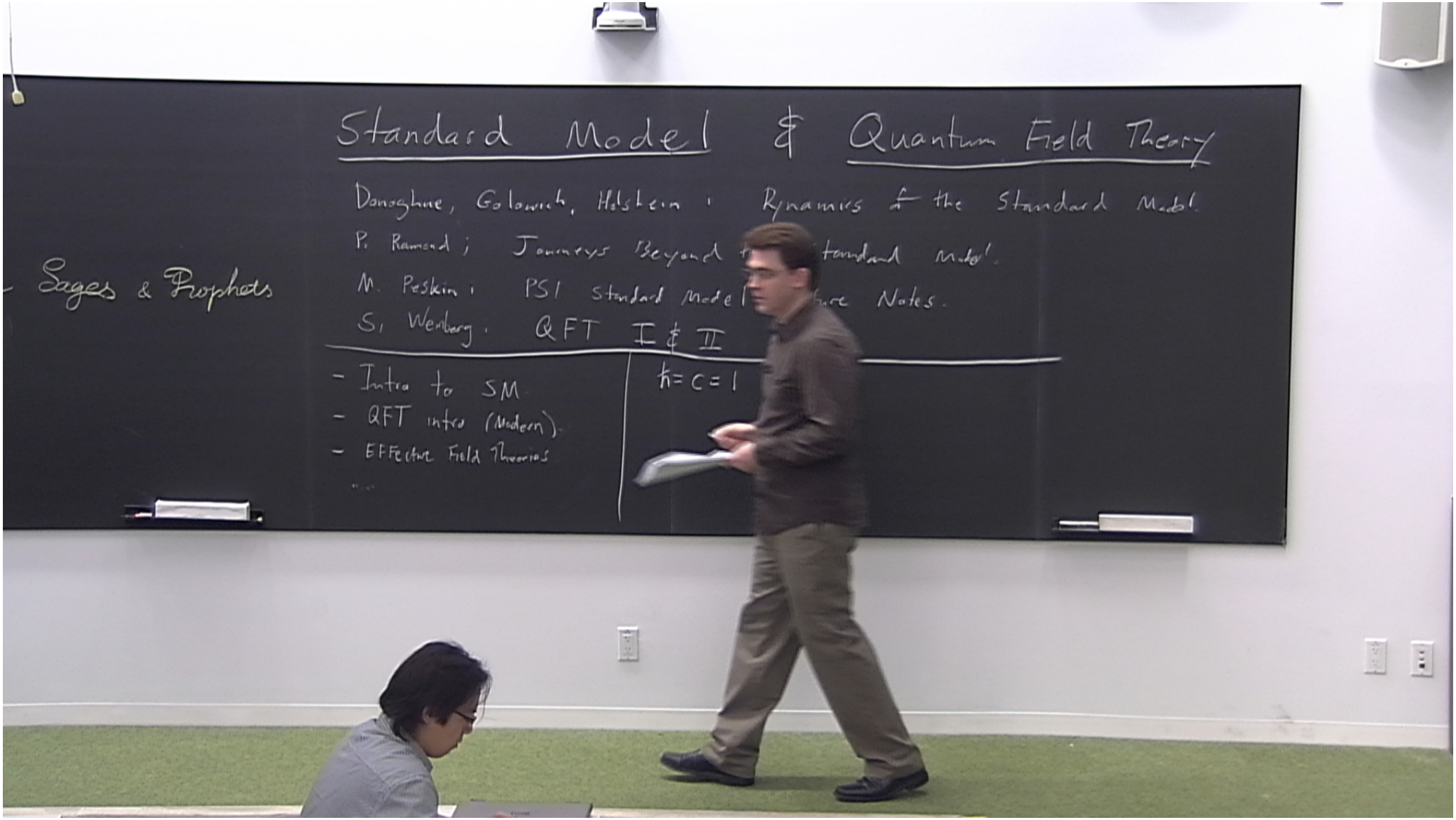
- Intro to SM
- QFT intro (Modern).
-


New Year
Standard Model & Quantum Field Theory
Dynamics of the Standard Model
Beyond the Standard Model
Lecture Notes.
- Intro to SM
- QFT intro (Modern)
- EFFective Field Theories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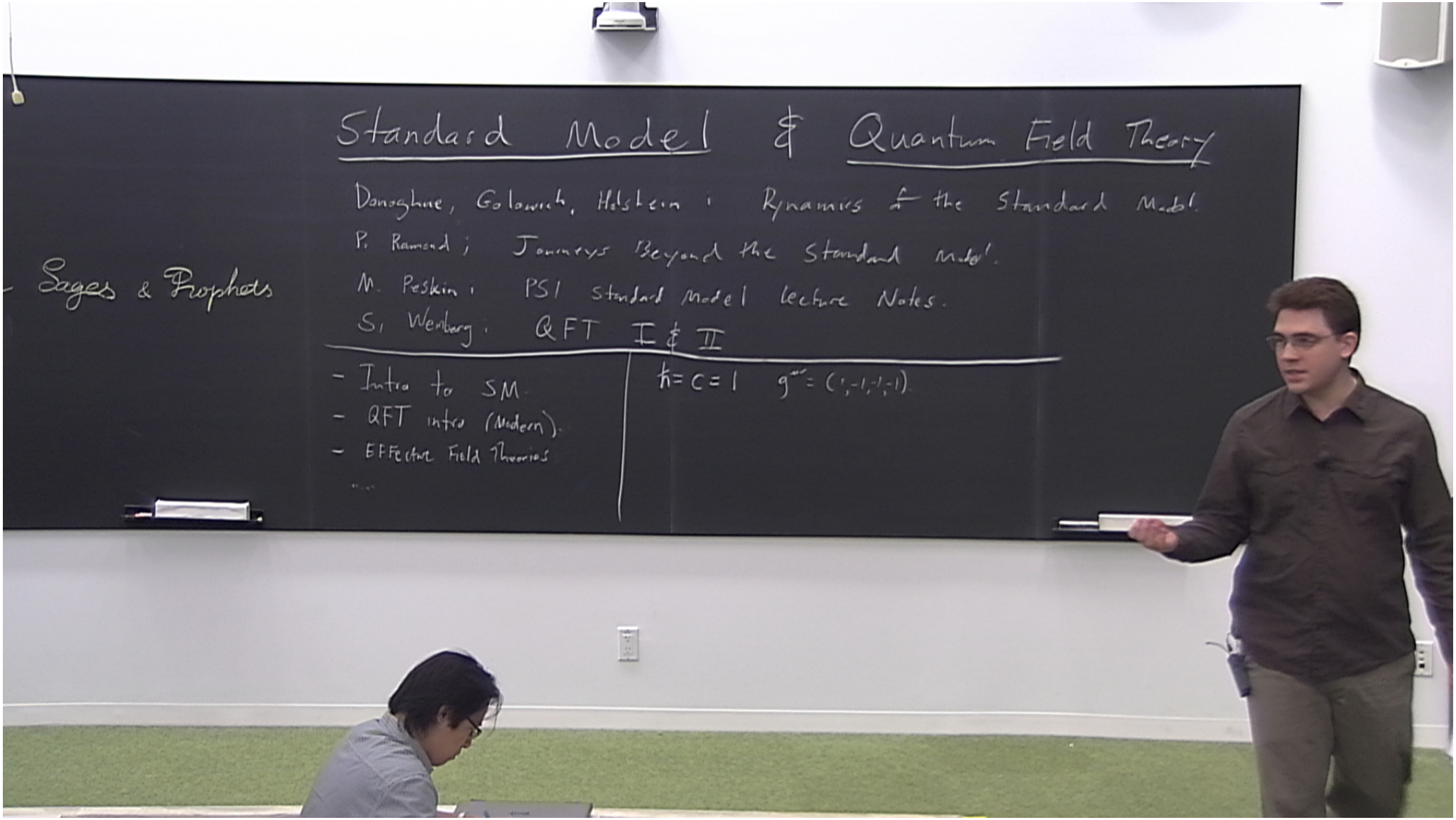
ħ = c = 1
Sages & Prophets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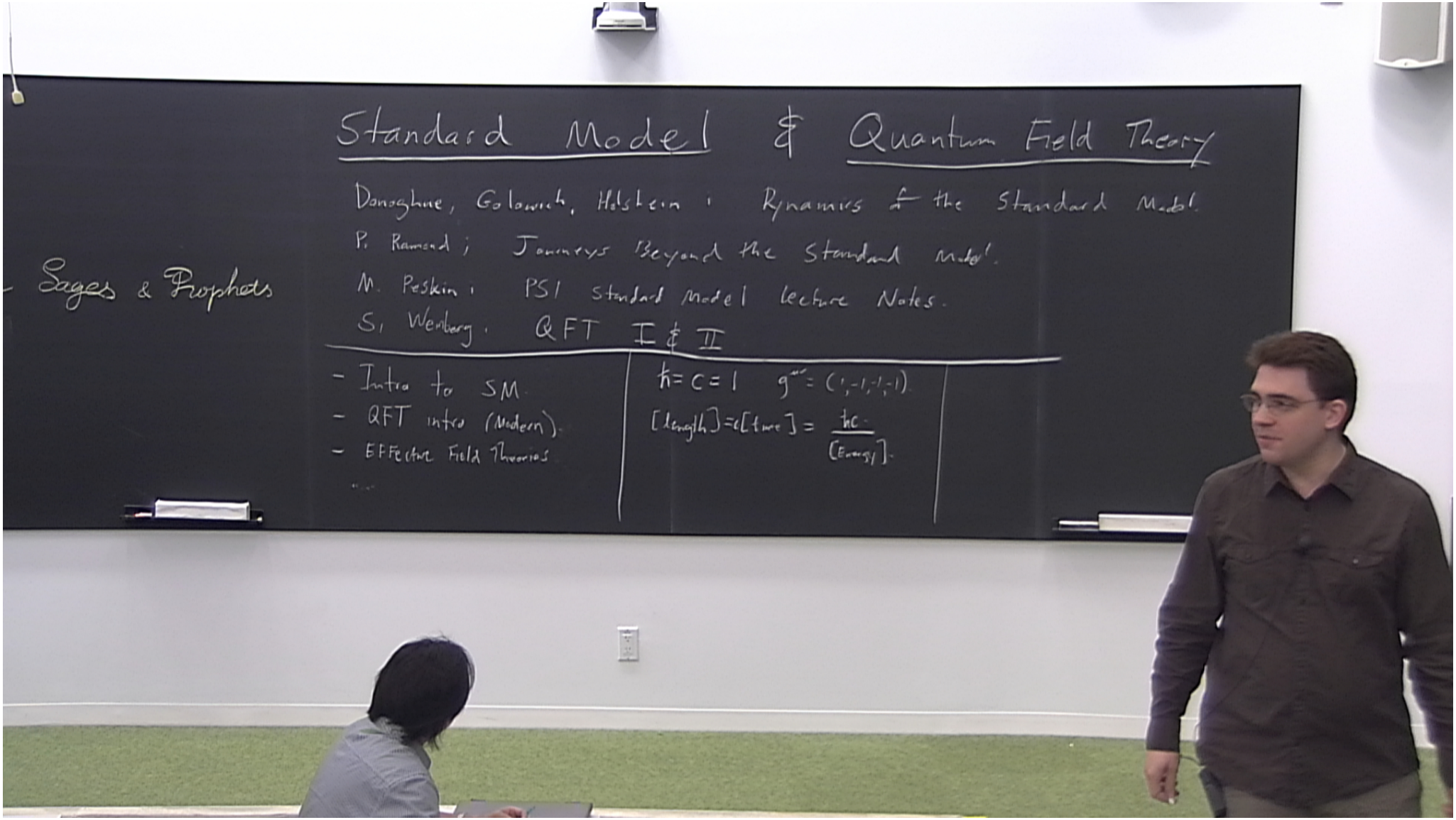
Sages & Prophets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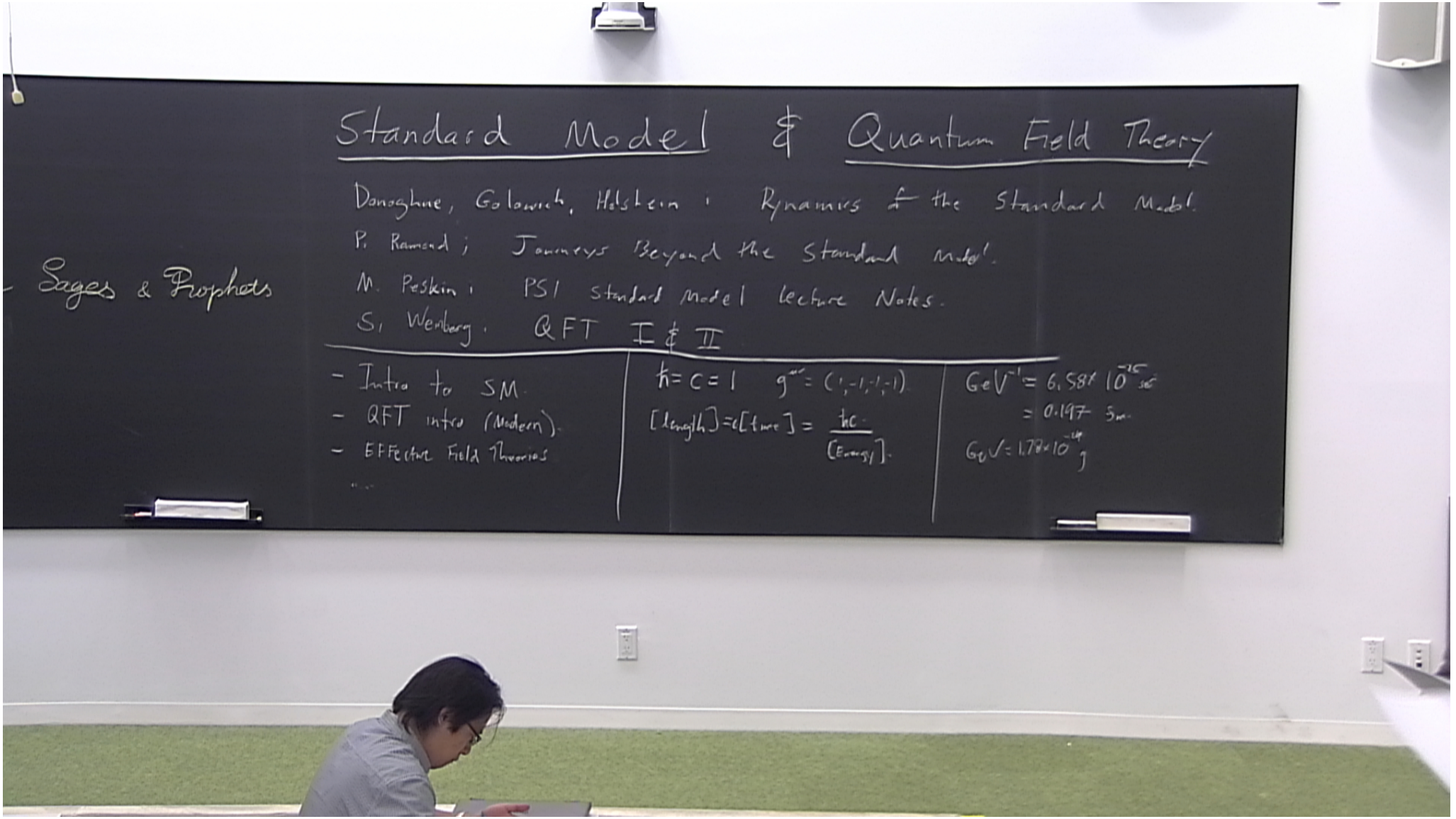
ħ = c = 1 $g^{\mu\nu} = (1,-1,-1,-1)$
[length] = c[time] = $\frac{\hbar c}{[\text{Energy}]}$
Sages & Prophets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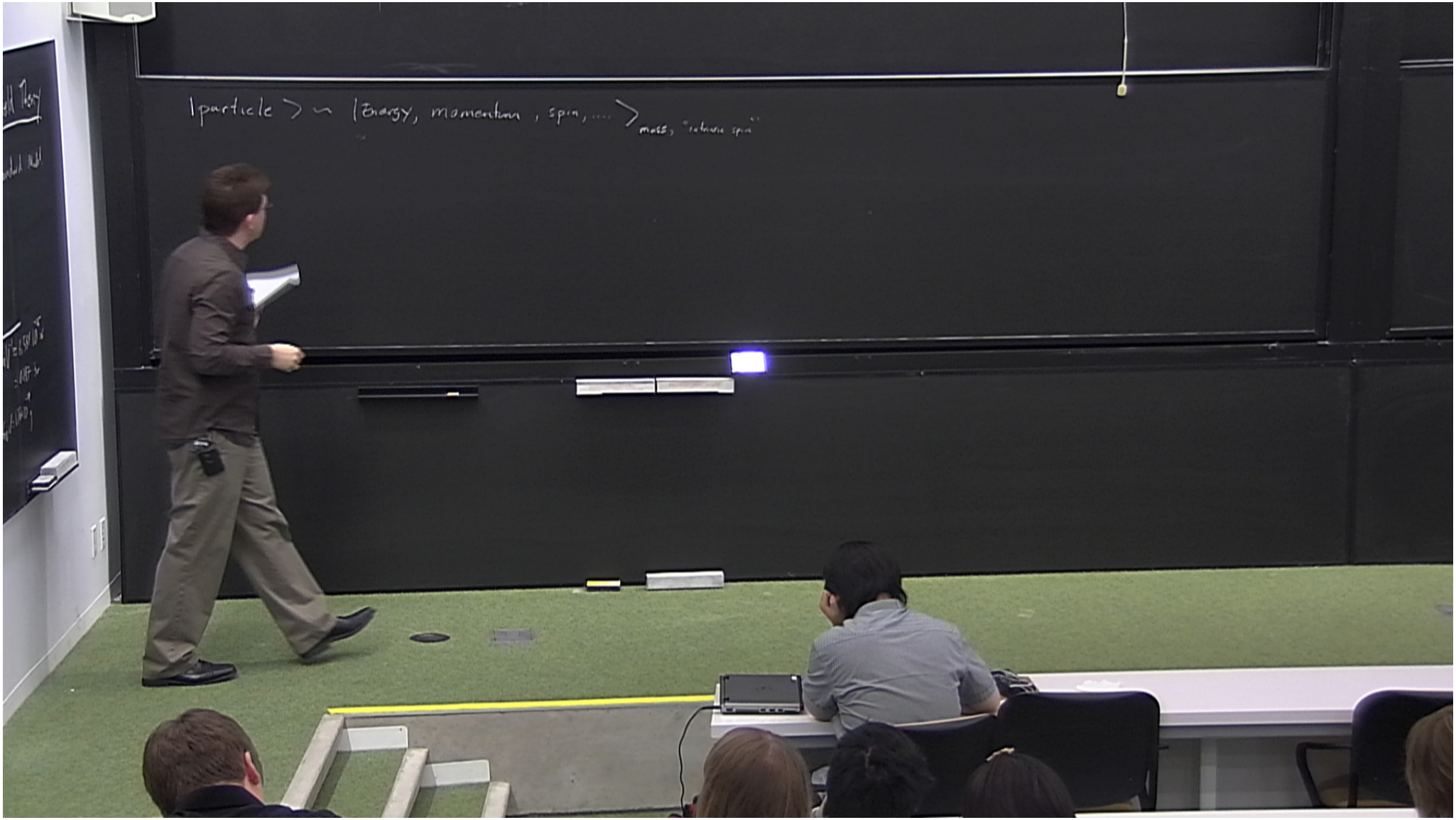
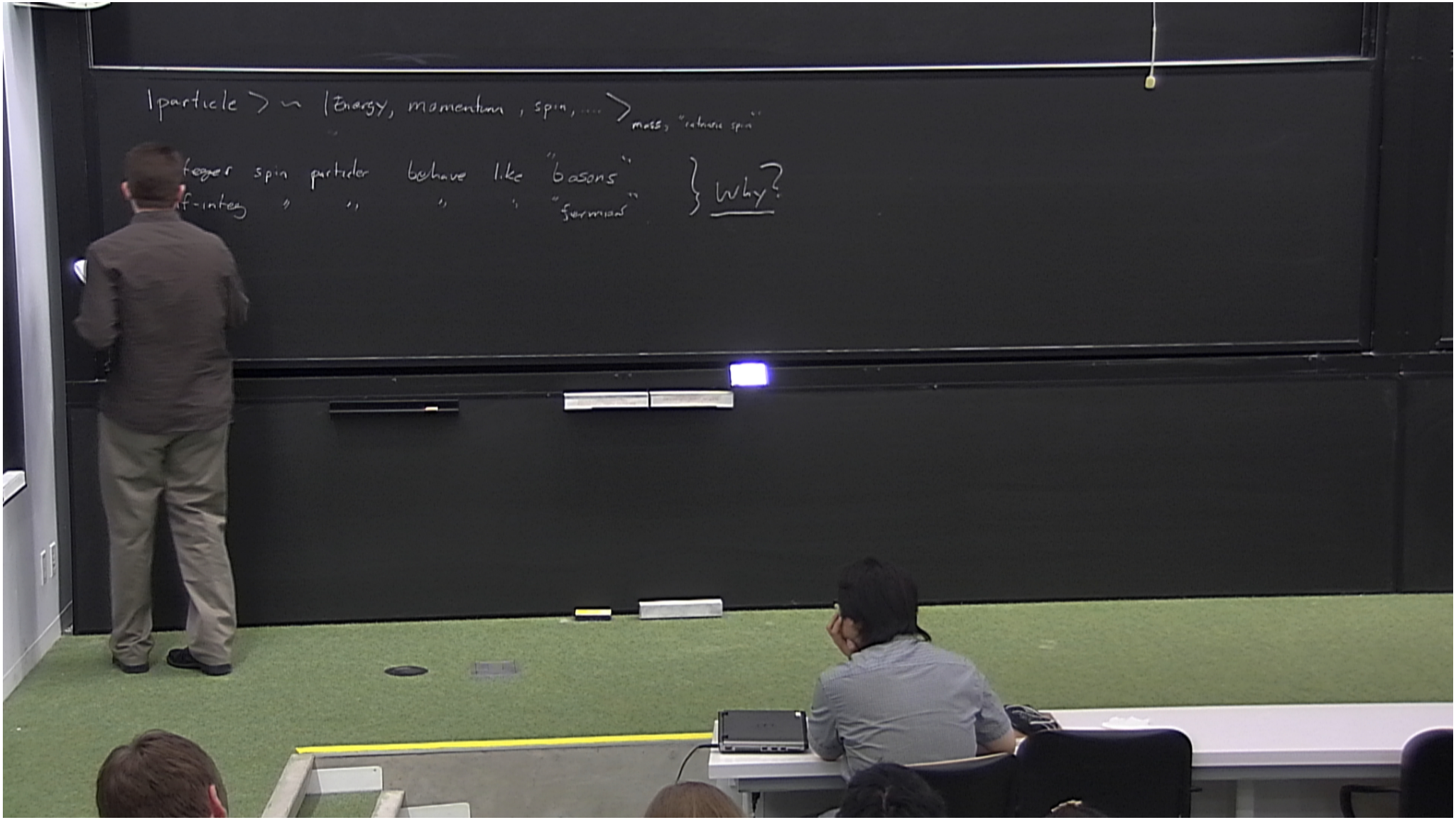
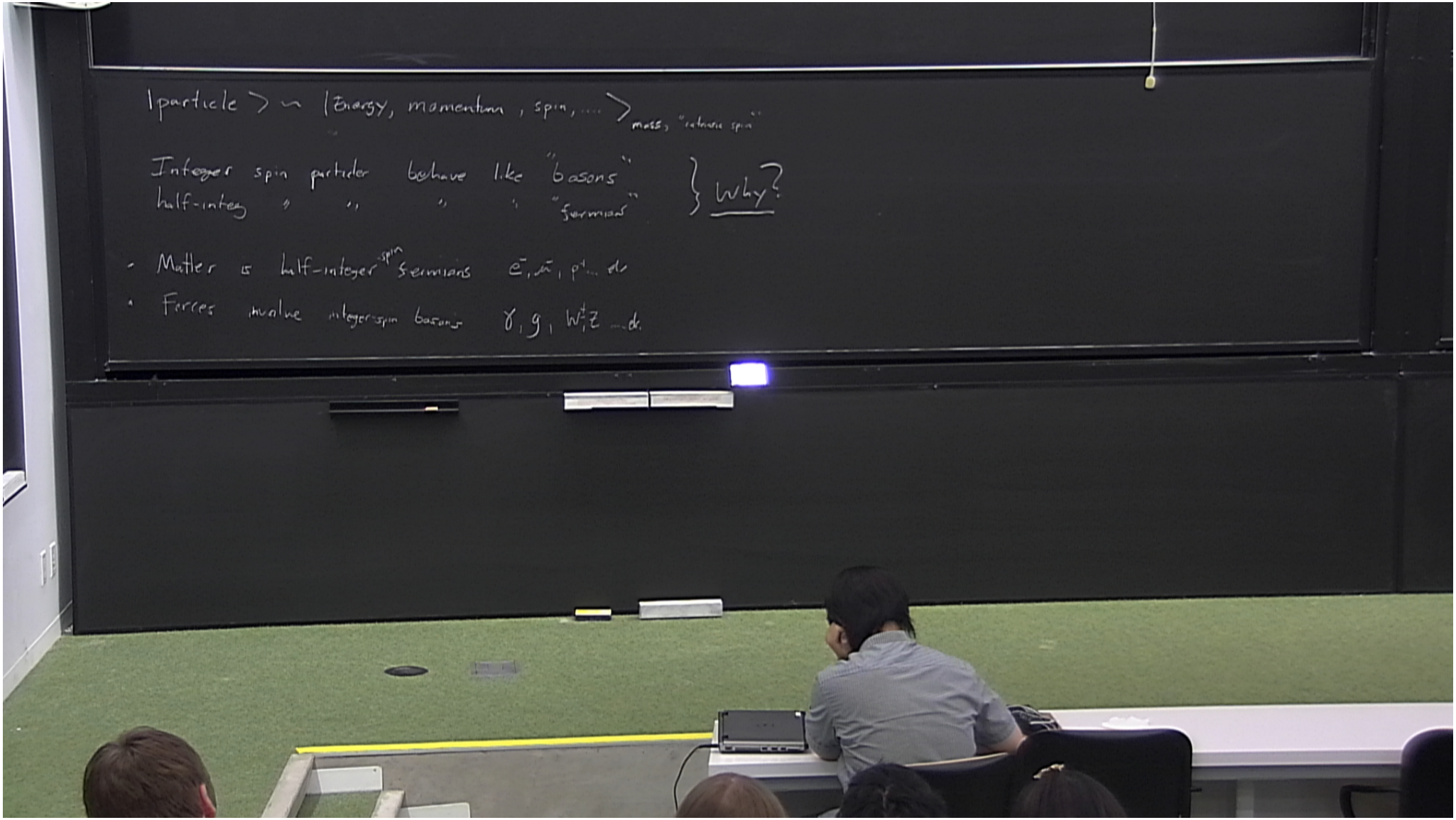
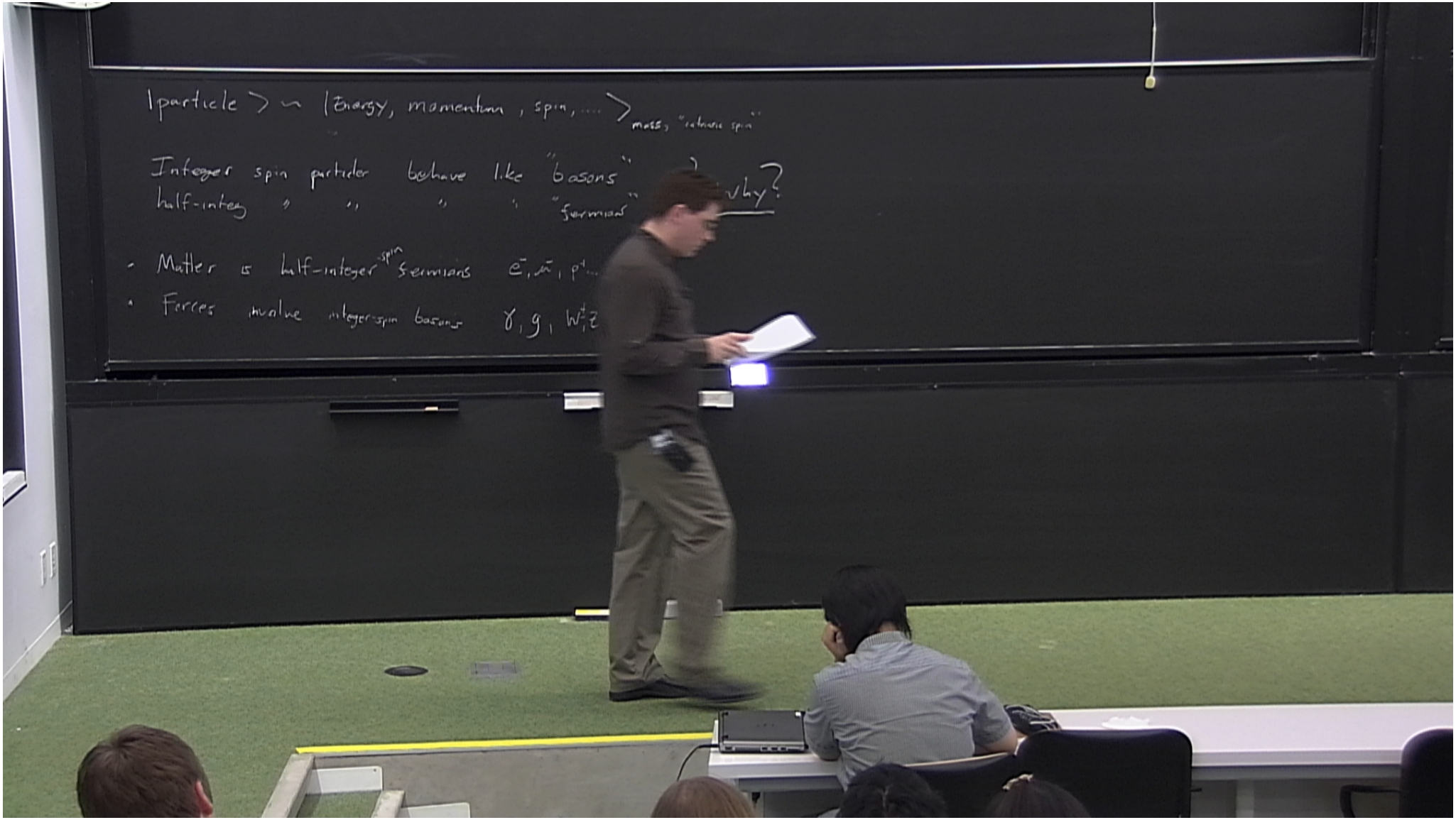
...
ħ = c = 1 g^μν = (1,-1,-1,-1)
[length] = c[time] = ħc / [Energy].
GeV^-1 = 6.58 × 10^-25 sec
= 0.197 fm.
GeV = 1.78 × 10^-24 g
Sages & Prophets


|particle> ~ |Energy, momentum, spin, ...>
mass, "intrinsic spin"


|particle> ~ |Energy, momentum, spin, ...>
mass, "rotation spin"
integer spin particles behave like "bosons"
"fermions"
Why?


|particle> ~ |Energy, momentum, spin, ...>
mass, "internal spin"
Integer spin particles behave like "bosons"
half-integer " " " "fermions"
} Why?
- Matter is half-integer spin fermions e⁻, ν̄, p⁺ ... etc
- Forces involve integer-spin bosons γ, g, W±, Z ... etc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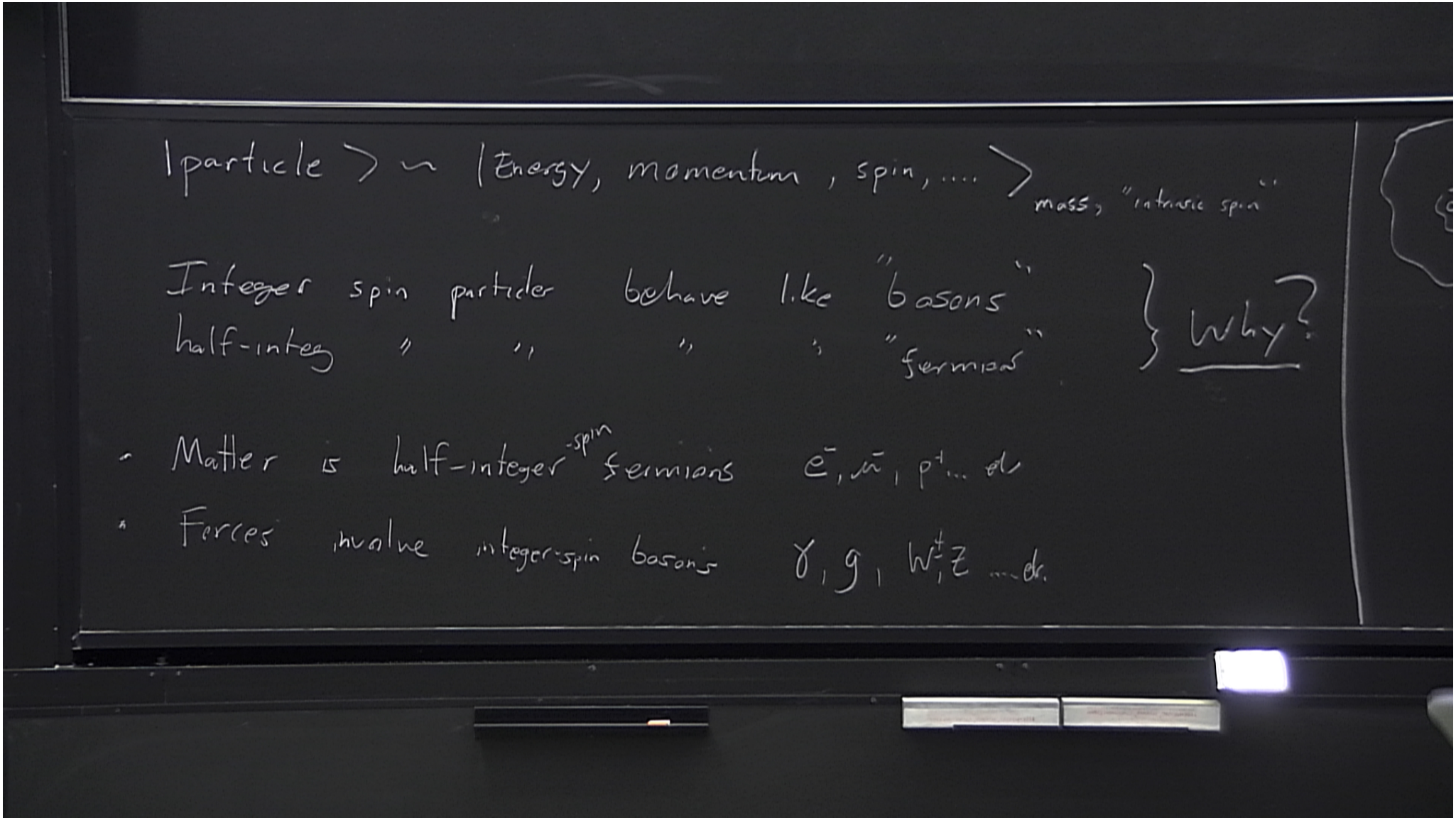
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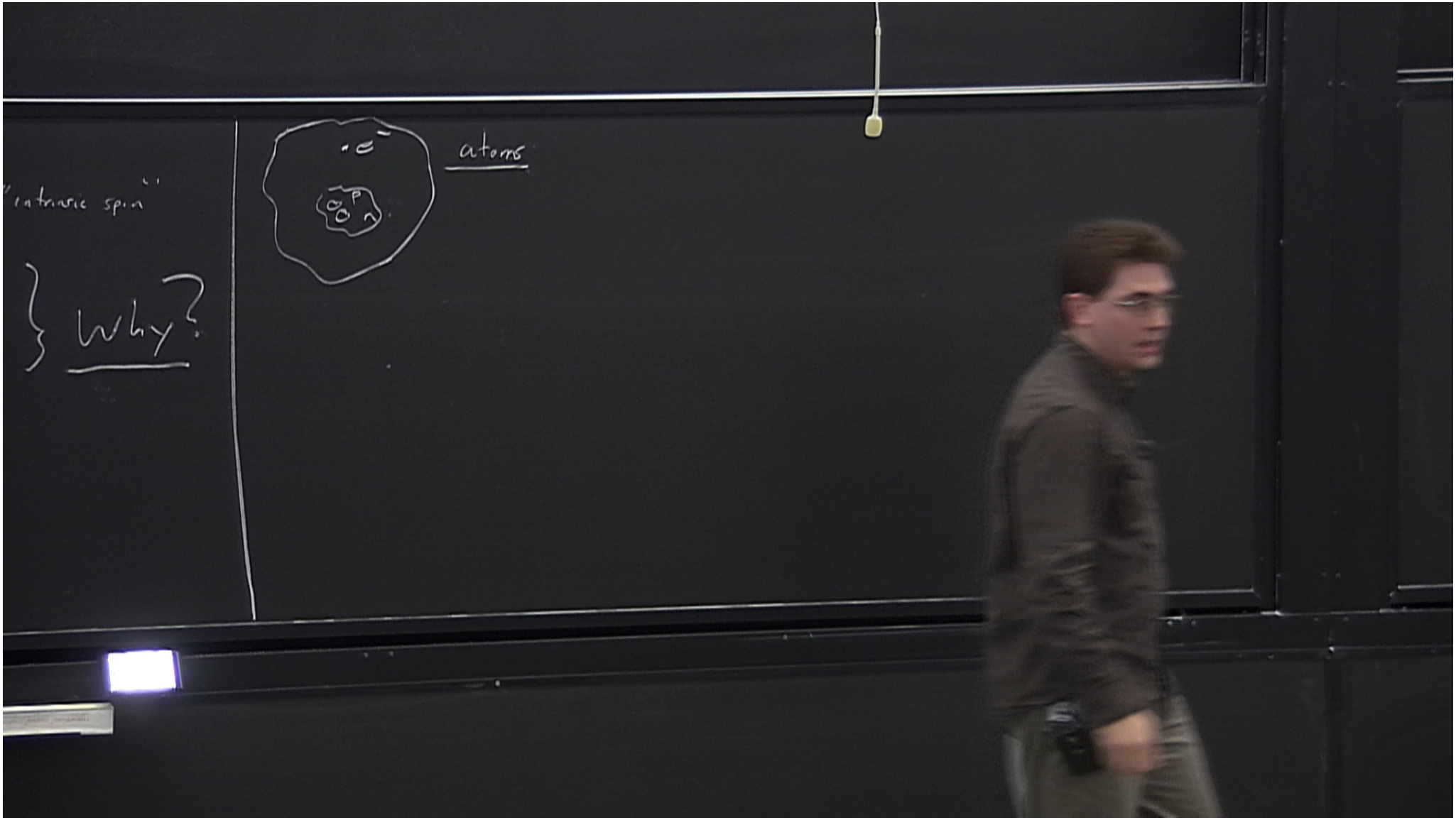
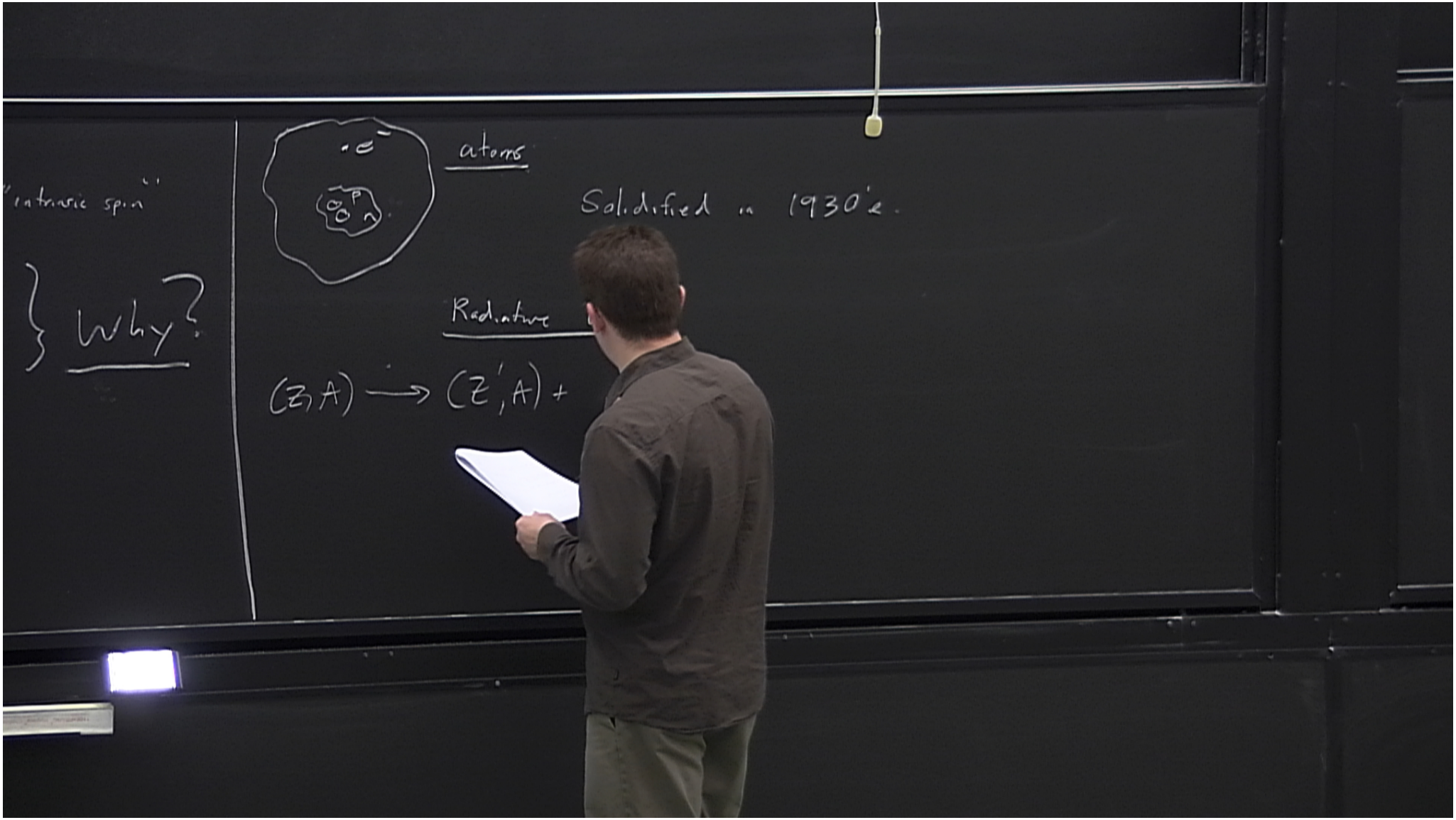
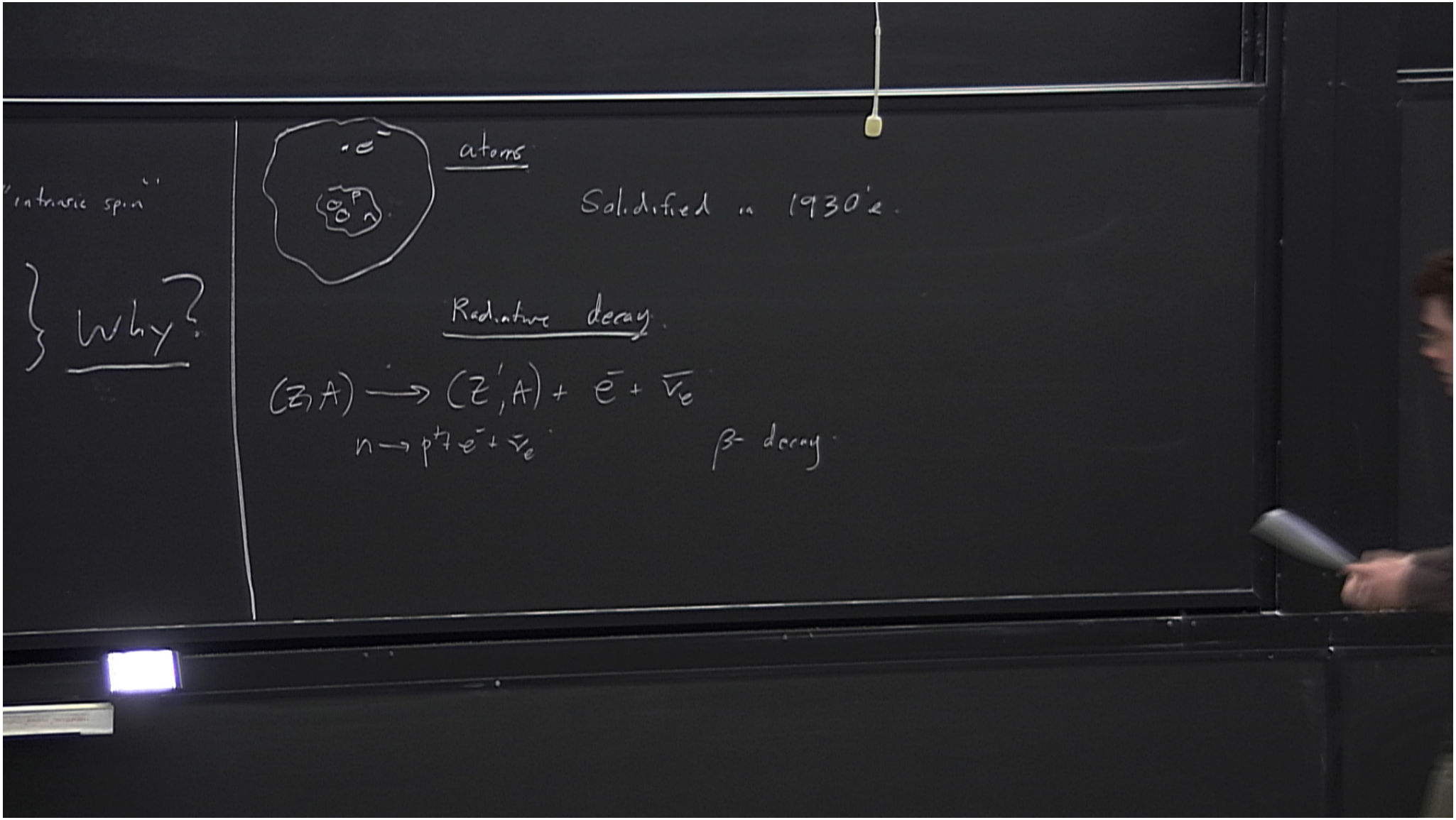

intrinsic spin
Why?
atoms


"intrinsic spin"
Why?
atoms
Solidified in 1930's.
Radiative
(Z,A) → (Z',A) +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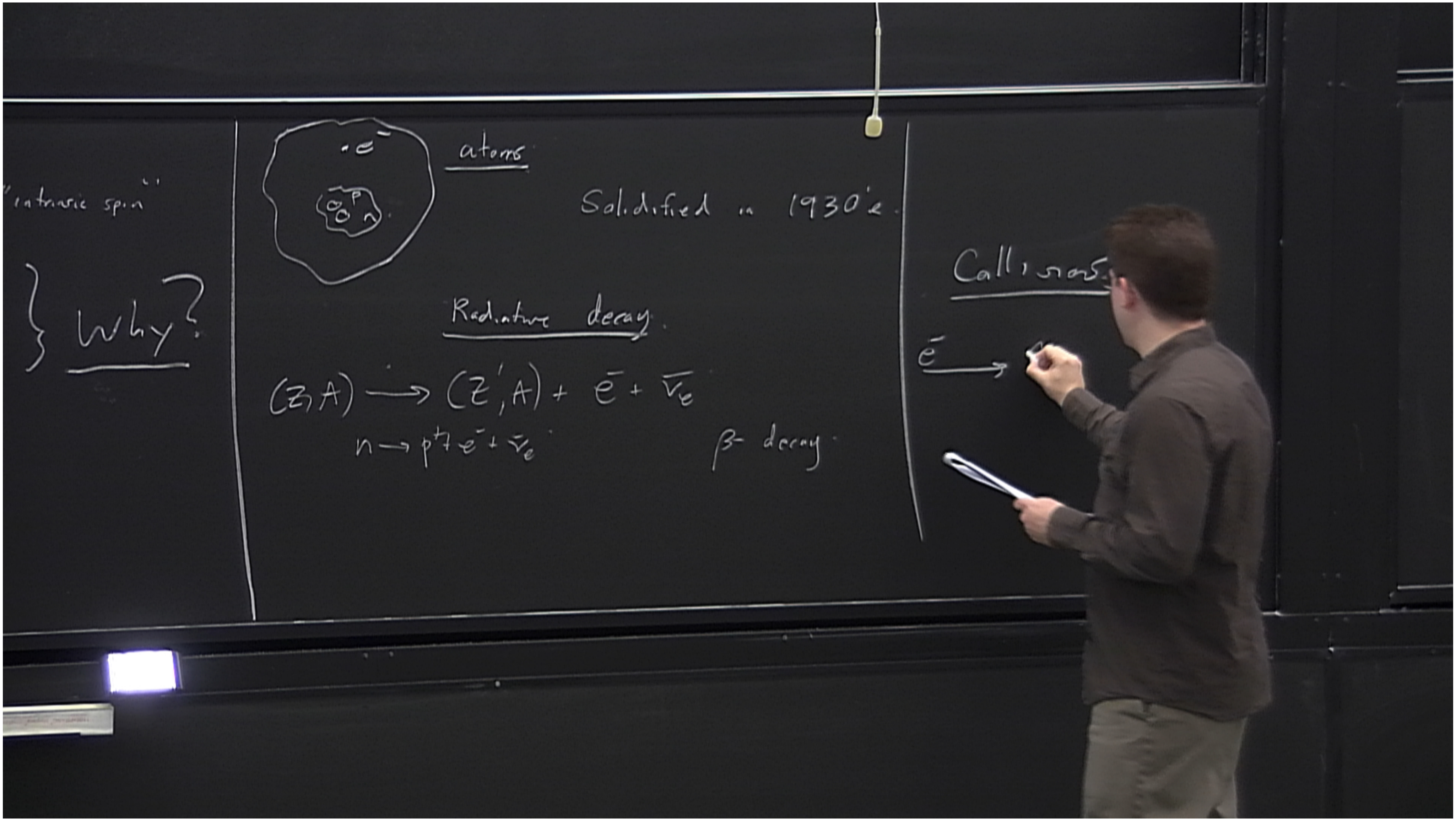
$(Z,A) \longrightarrow (Z',A) + e^- + \bar{\nu}_e$
$n \longrightarrow p^+ + e^- + \bar{\nu}_e$
β^- decay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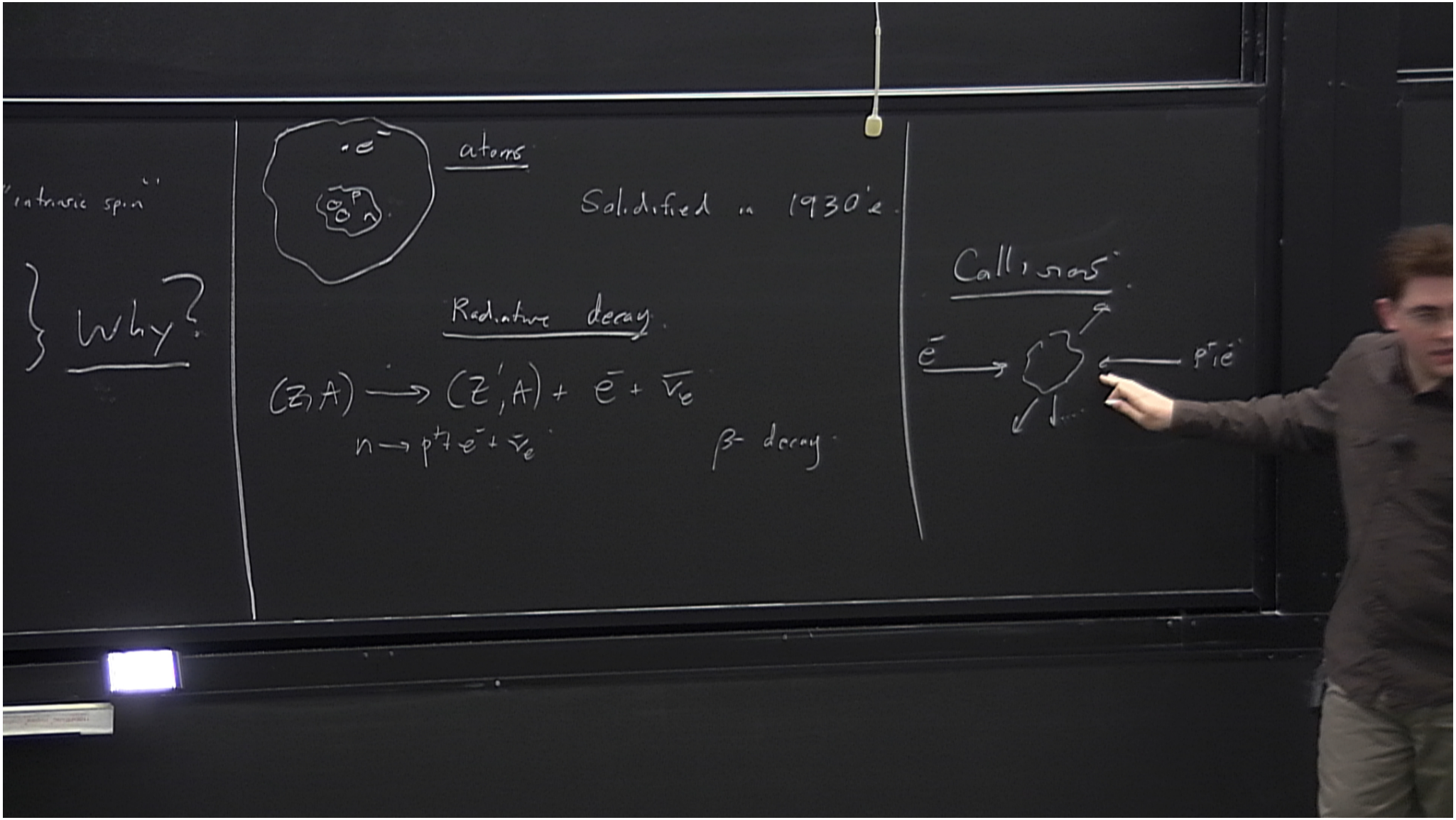
n ⟶ p⁺ + e⁻ + ν̄e
β- decay
Collisions
e⁻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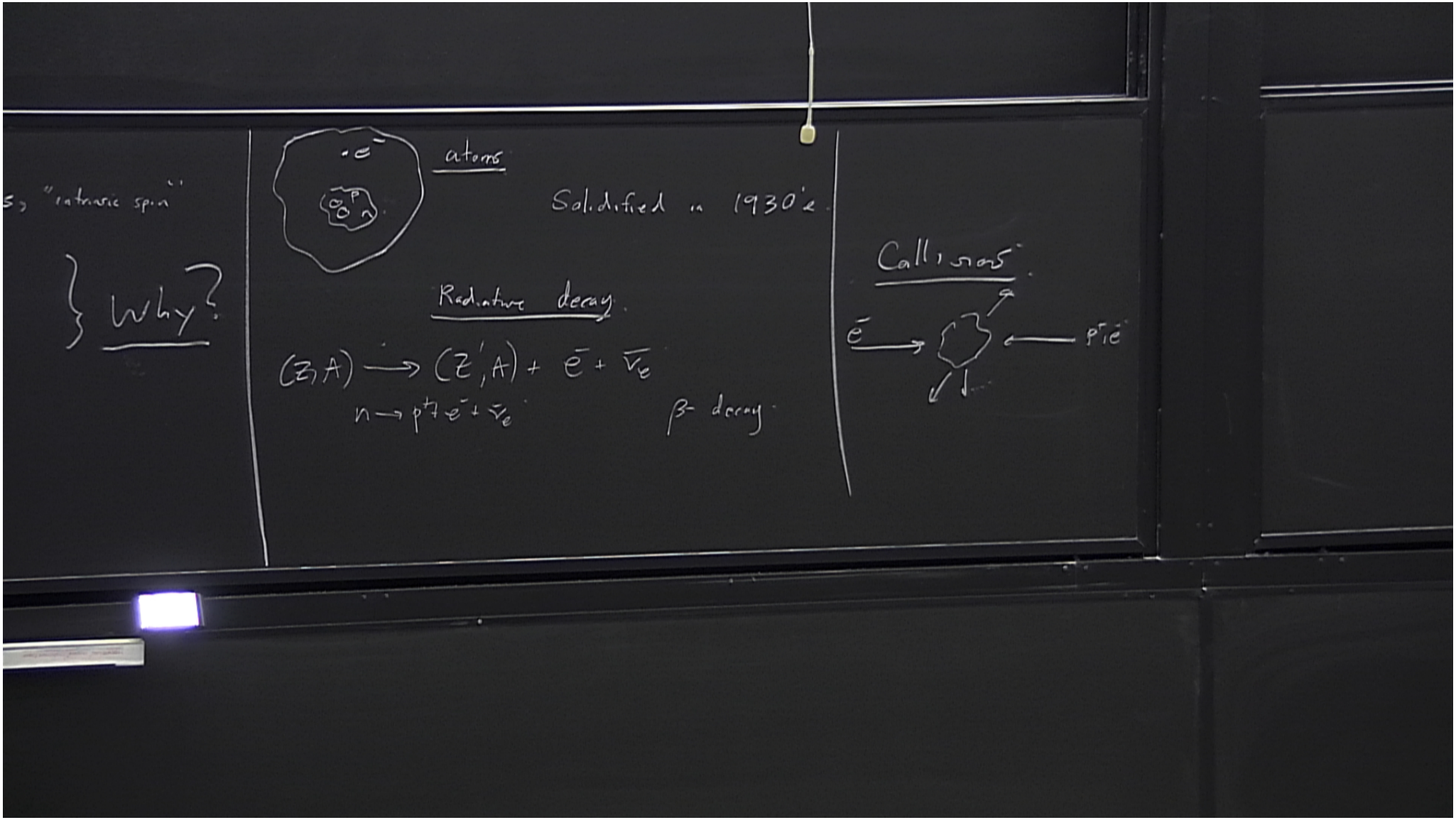
Collisions
$\bar{e}$
$p\bar{e}$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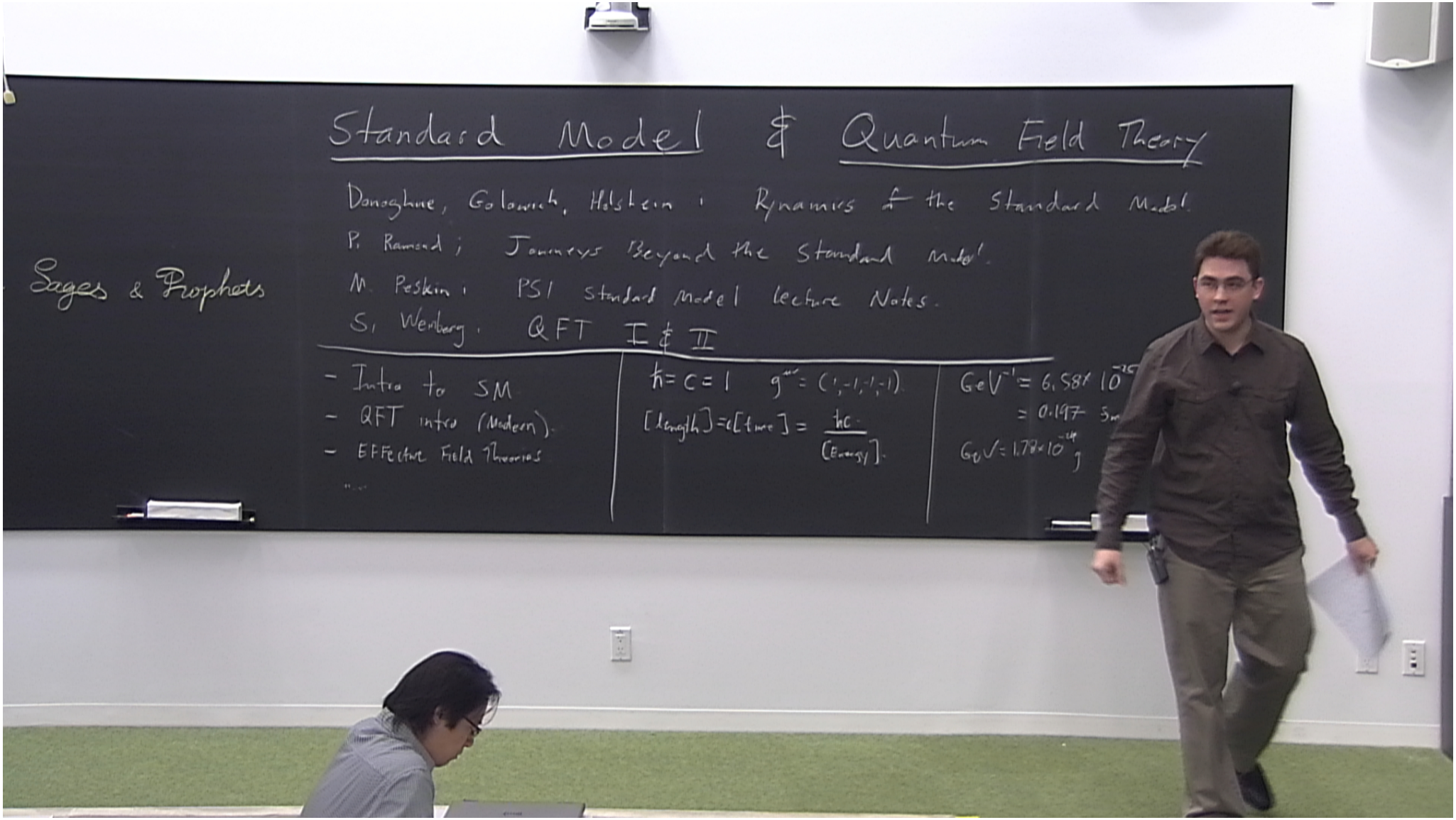
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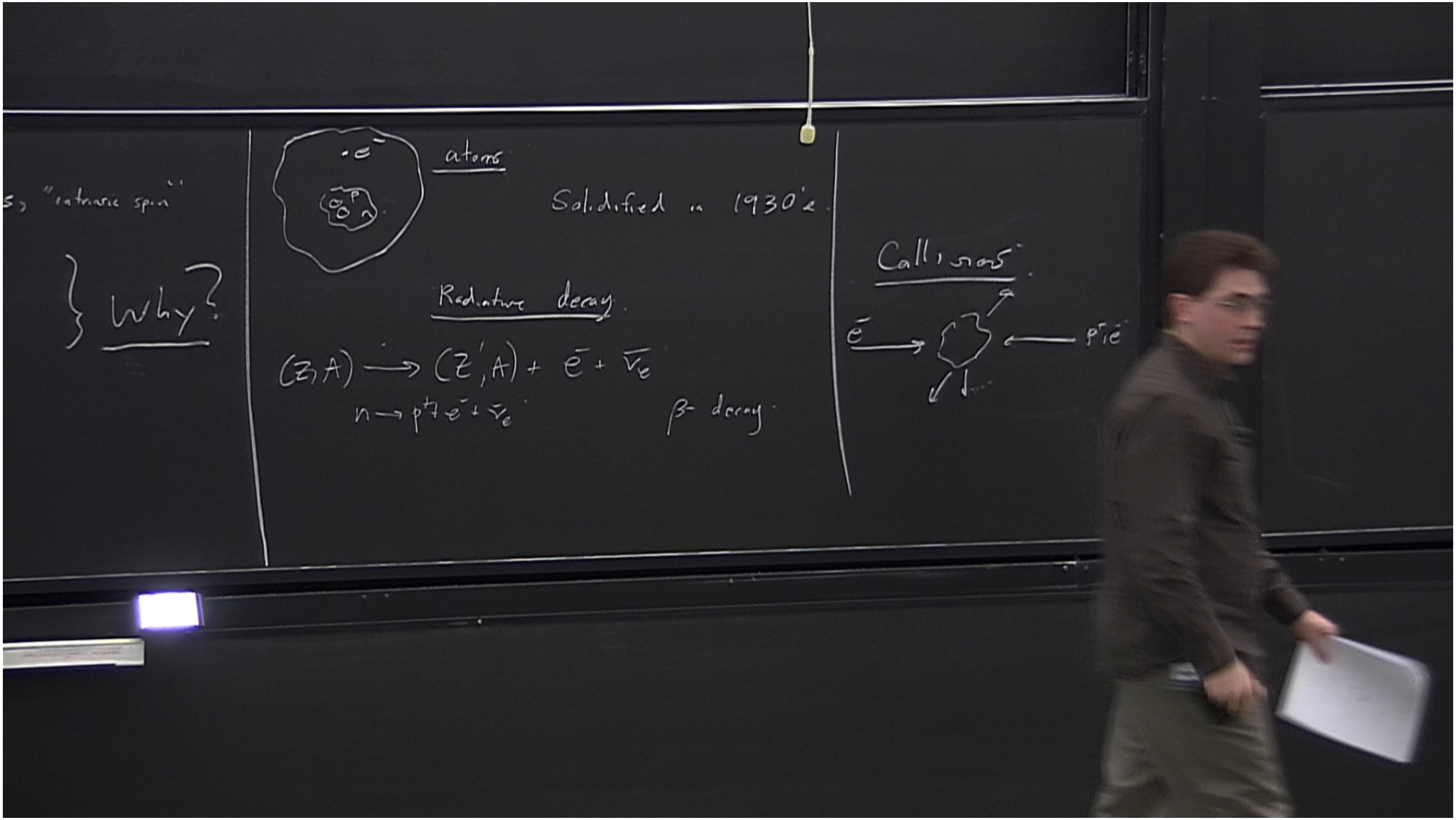
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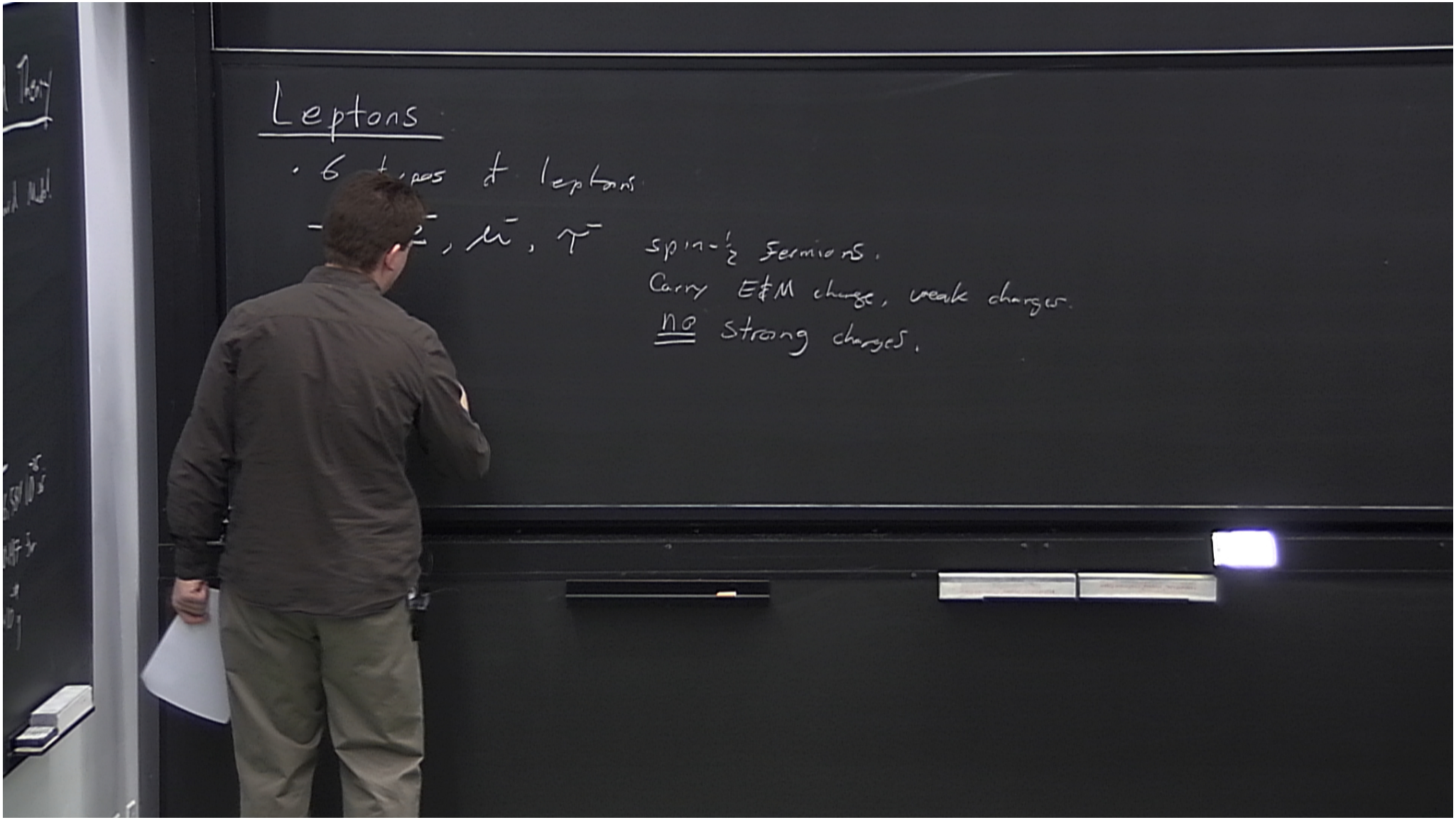
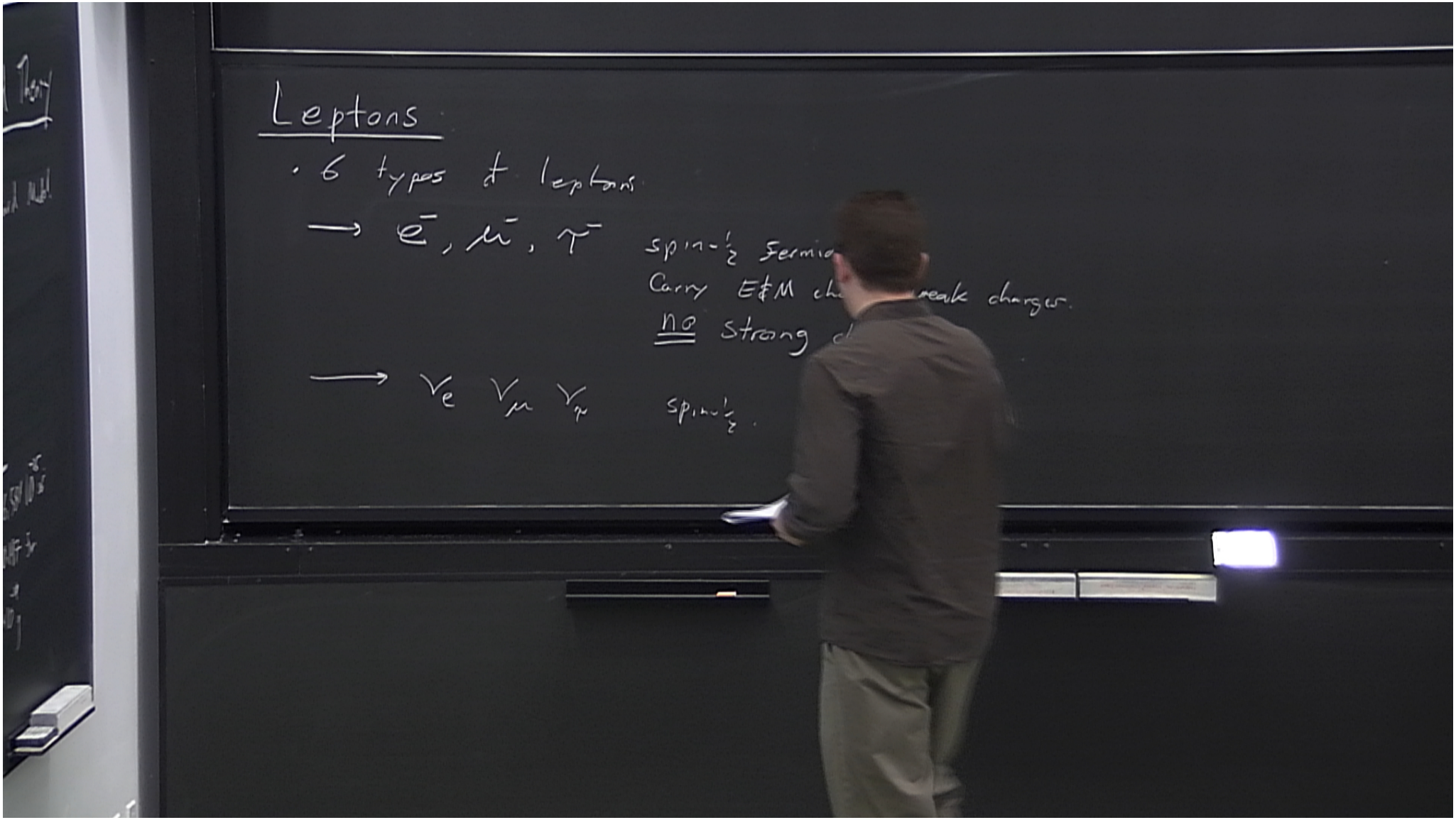
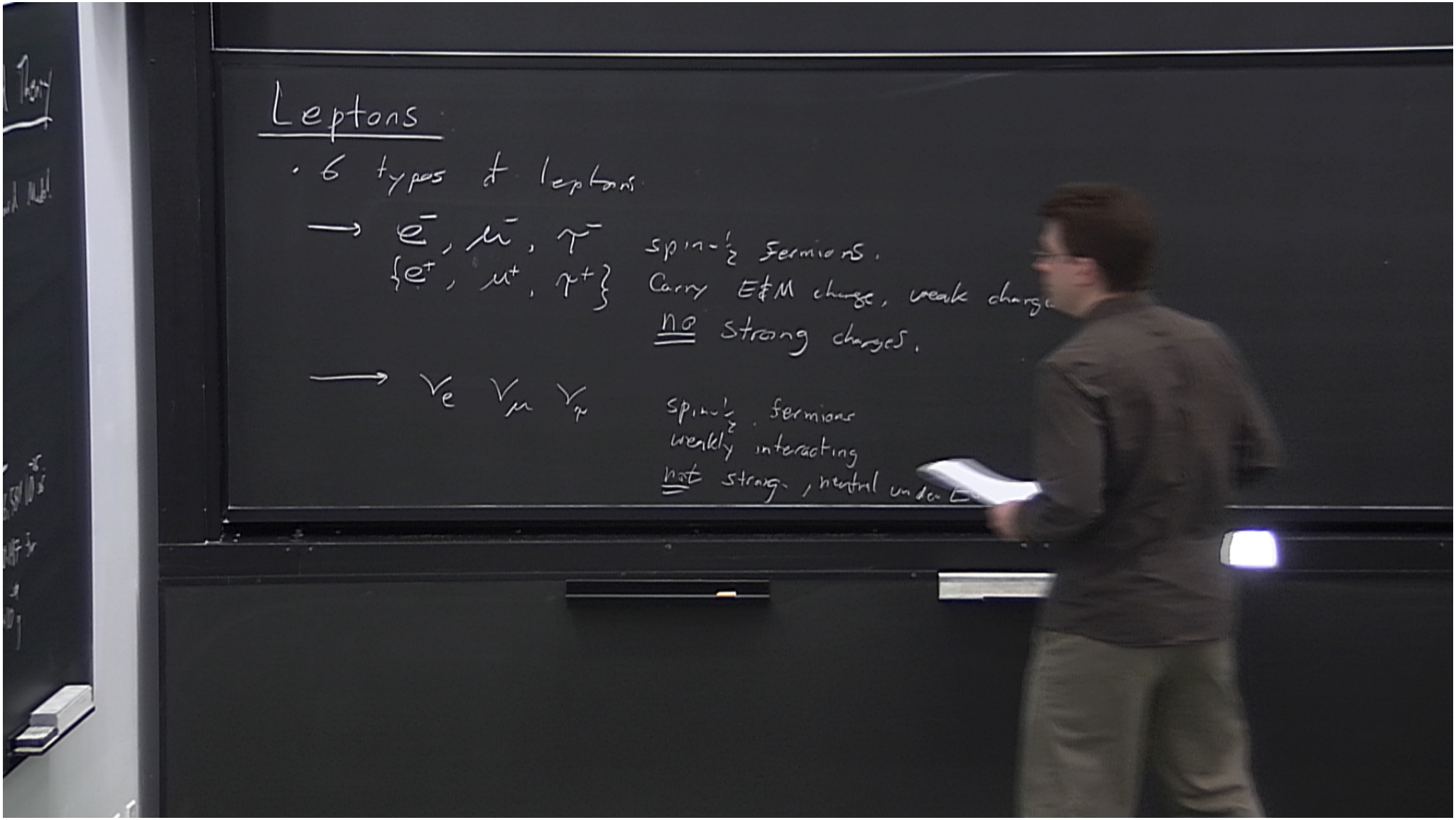
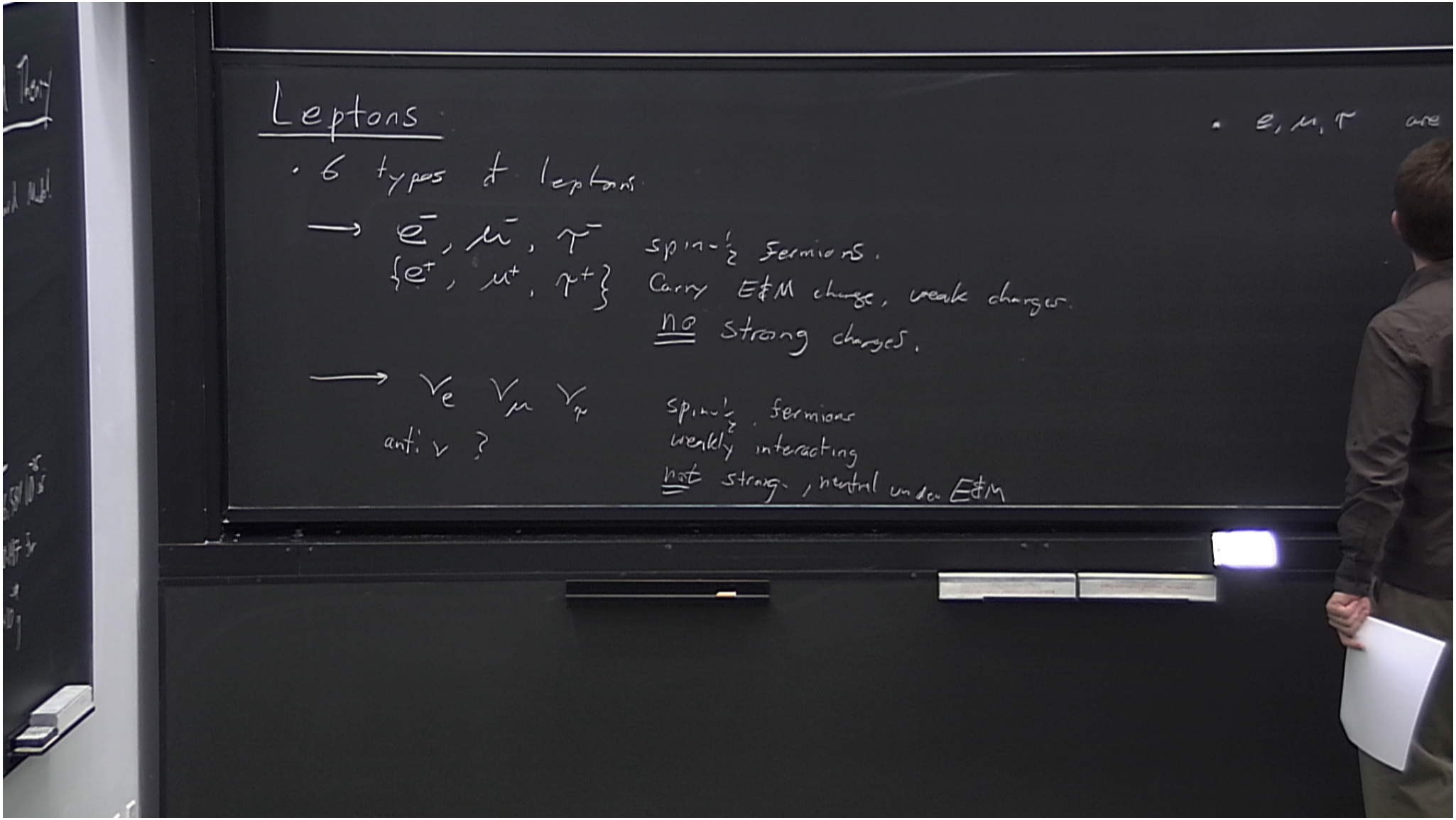
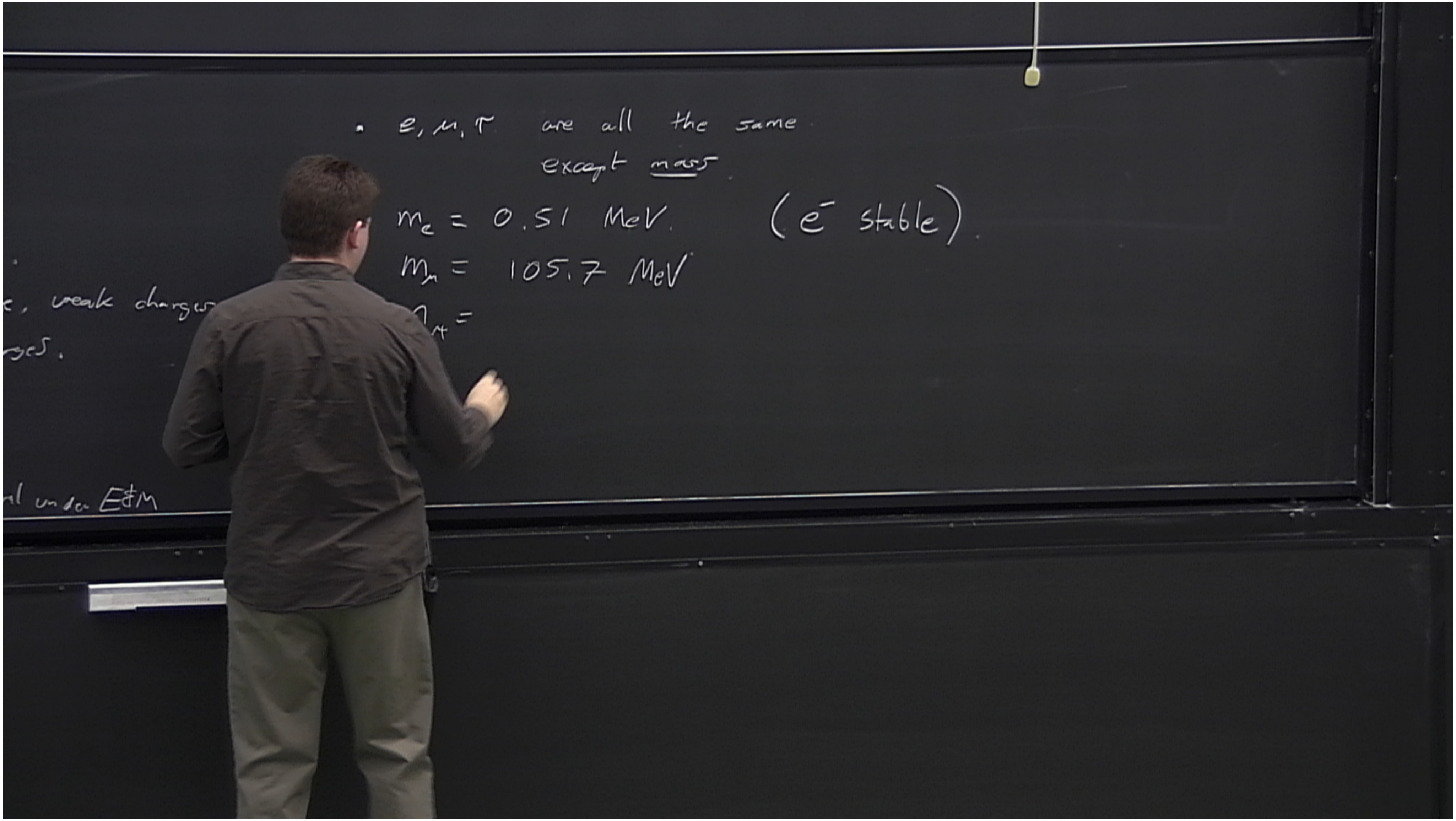

Leptons
spin-½ fermions.
Carry E&M charge, weak charges.
no strong charges.

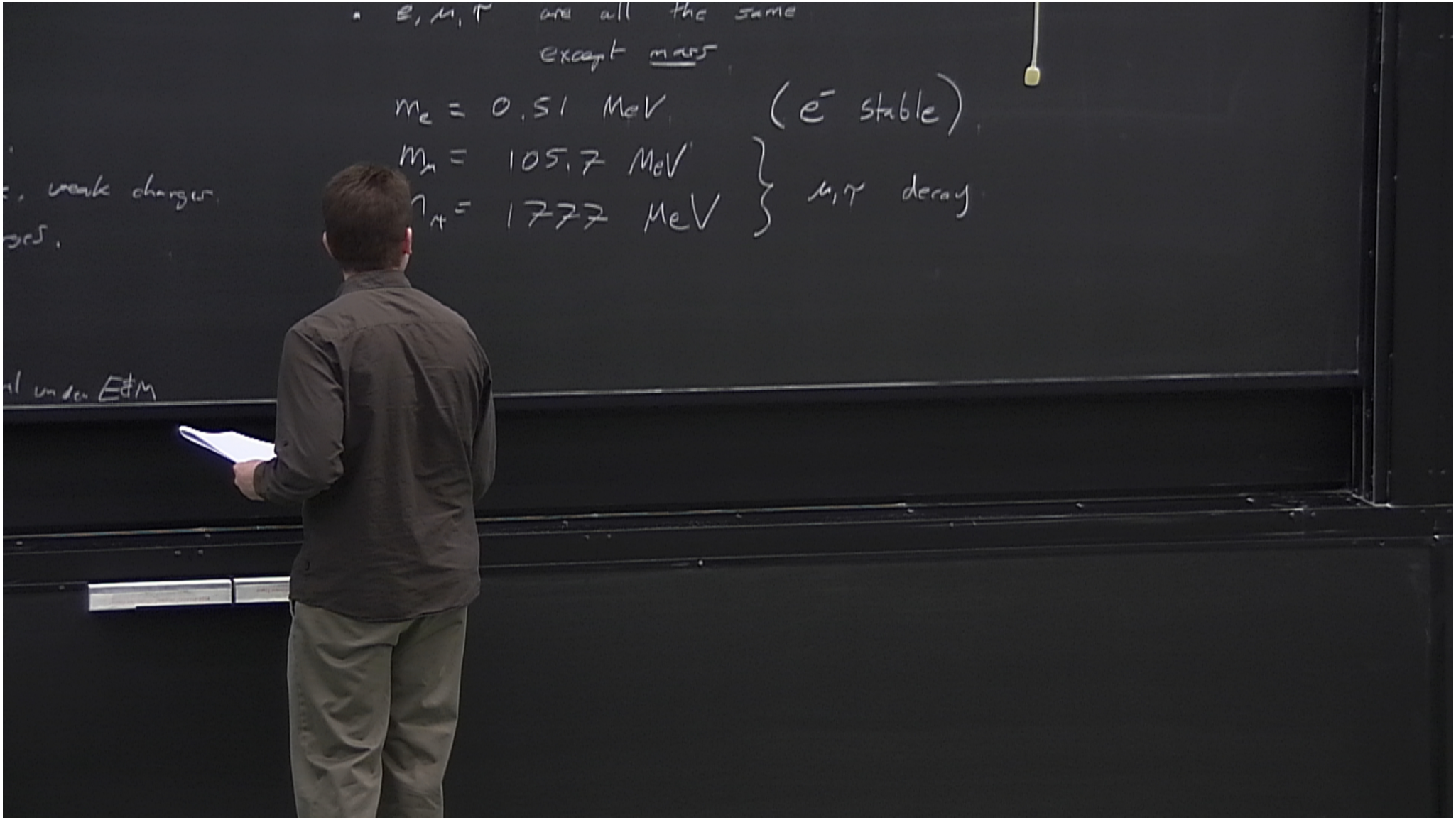

Leptons
· 6 types of leptons
→ e⁻, μ⁻, τ⁻
spin-½ Fermi
Carry E&M ch
weak charges.
no Strong c
→ νe νμ ντ
spin ½.

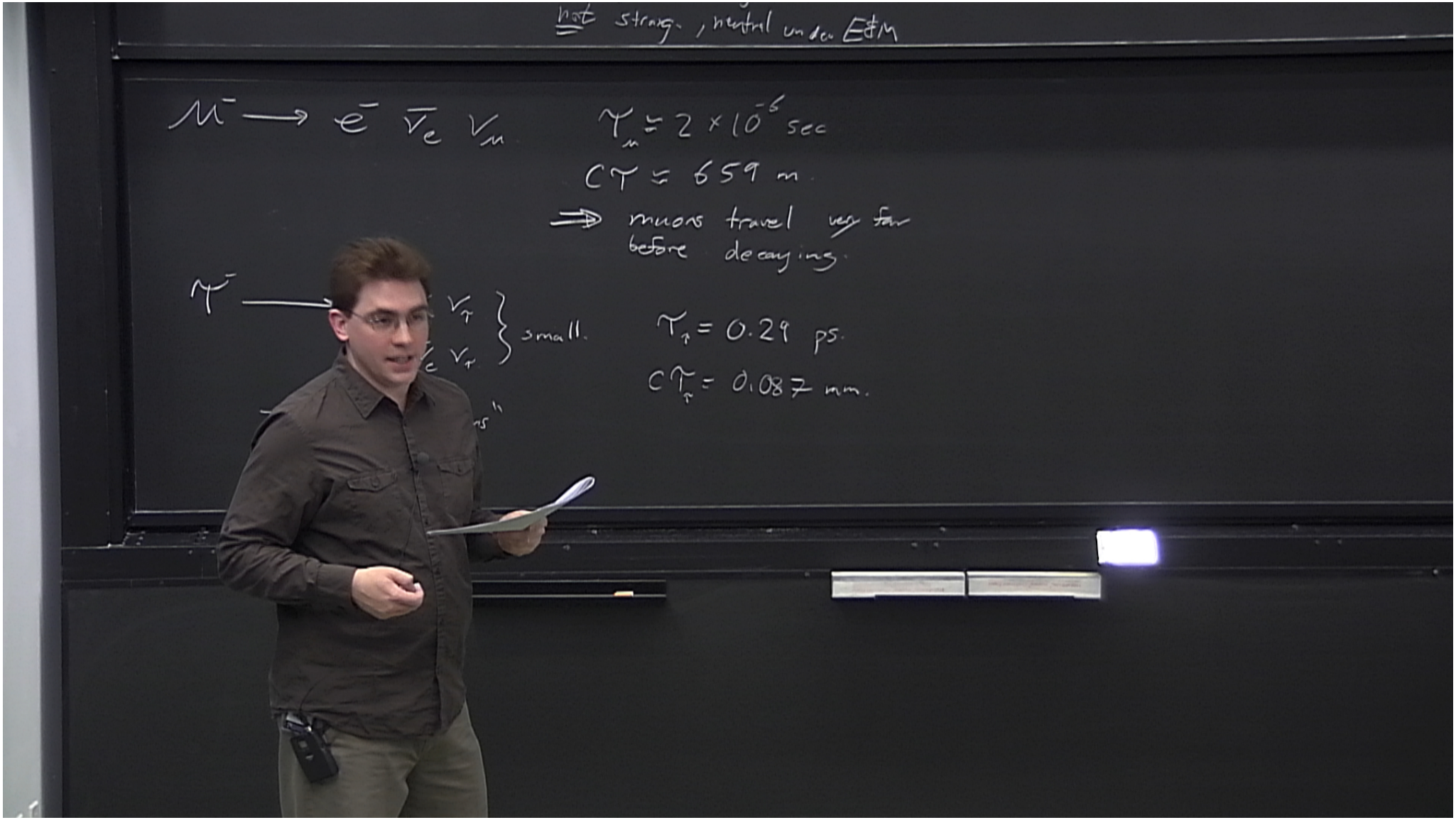

Leptons
· 6 types of leptons
→ e^-, μ^-, τ^-
{e^+, μ^+, τ^+}
spin-½ fermions.
Carry E&M charge, weak charge
no strong charges.
→ ν_e ν_μ ν_τ
spin-½ fermions
weakly interacting
not strong, neutral

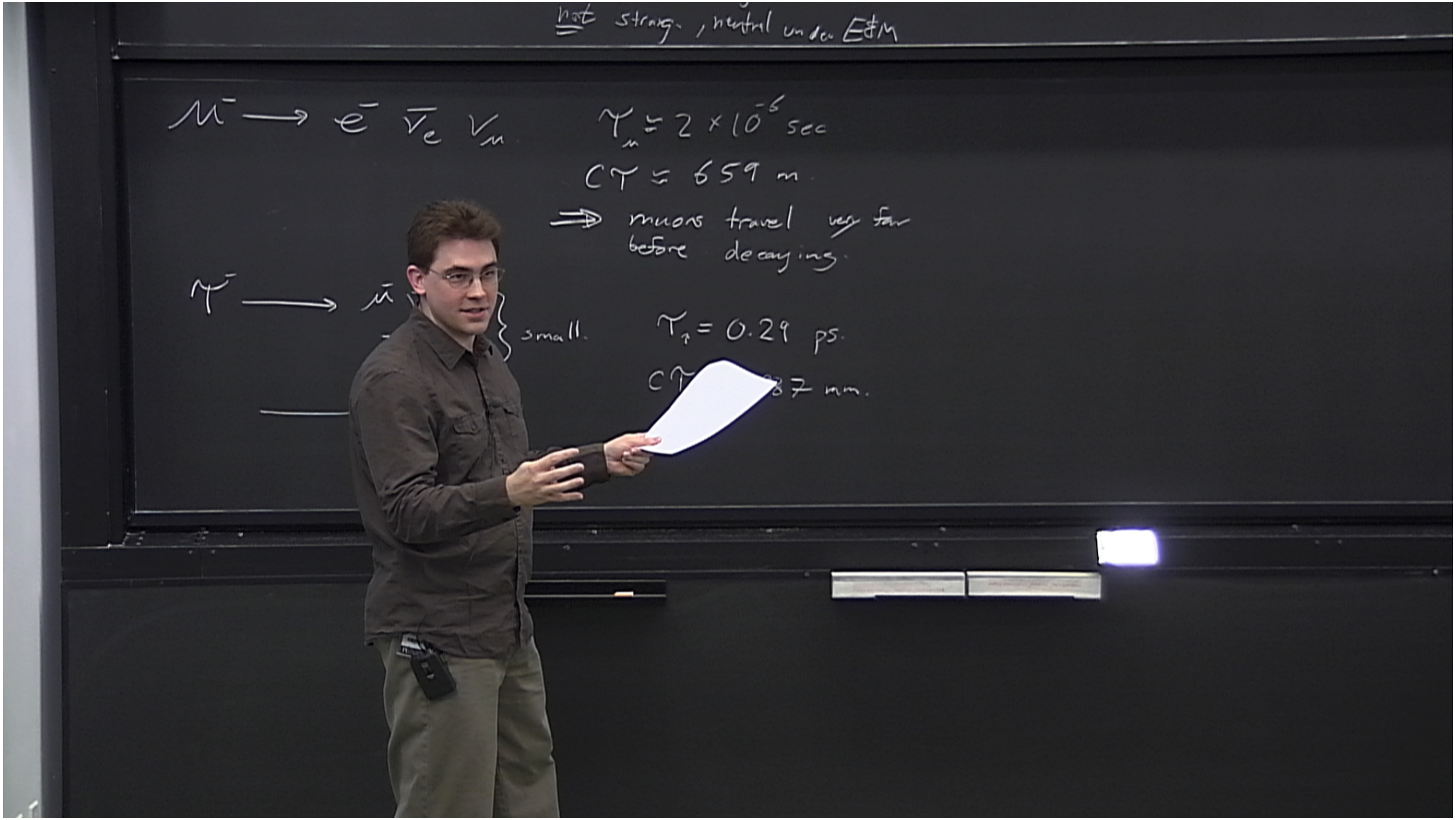

Leptons
• 6 types of leptons
→ e^-, μ^-, τ^-
{e^+, μ^+, τ^+}
spin-½ fermions.
Carry E&M charge, weak charges.
no strong charges.
→ ν_e ν_μ ν_τ
anti-ν ?
spin-½ fermions
weakly interacting
not strong, neutral under E&M
• e, μ, τ are



e, μ, τ are all the same
except mass
m_e = 0.51 MeV (e⁻ stable)
m_μ = 105.7 MeV
m_τ =


e, μ, τ are all the same
except mass
$m_e = 0.51$ MeV (e^- stable)
$m_\mu = 105.7$ MeV
$m_\tau = 1777$ MeV
μ, τ decay


not strong, neutral under E&M
$\mu^- \to e^- \bar{\nu}_e \nu_\mu$
$\tau_\mu \simeq 2 \times 10^{-6}$ sec
$c\tau \simeq 659$ m
$\Rightarrow$ muons travel very far before decaying.
τ^-
small.
$\tau_\tau = 0.29$ ps.
$c\tau_\tau \simeq 0.087$ mm.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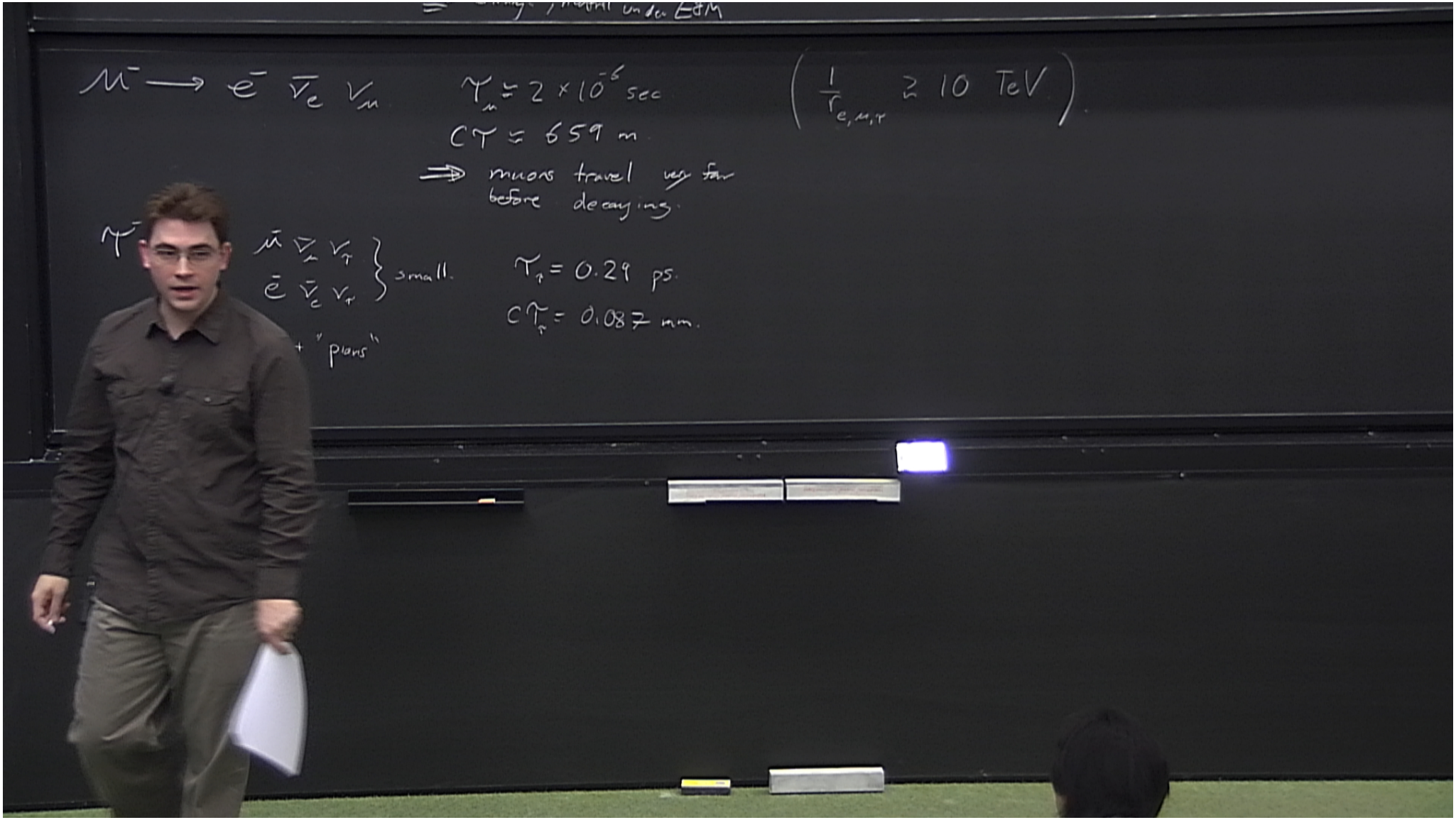
$\Rightarrow$ muons travel very far before decaying.
$\tau^- \longrightarrow \mu$
small.
$\tau_\tau = 0.29$ ps.
$c\tau$ 87 mm.


$\mu^- \to e^- \bar{\nu}_e \nu_\mu$
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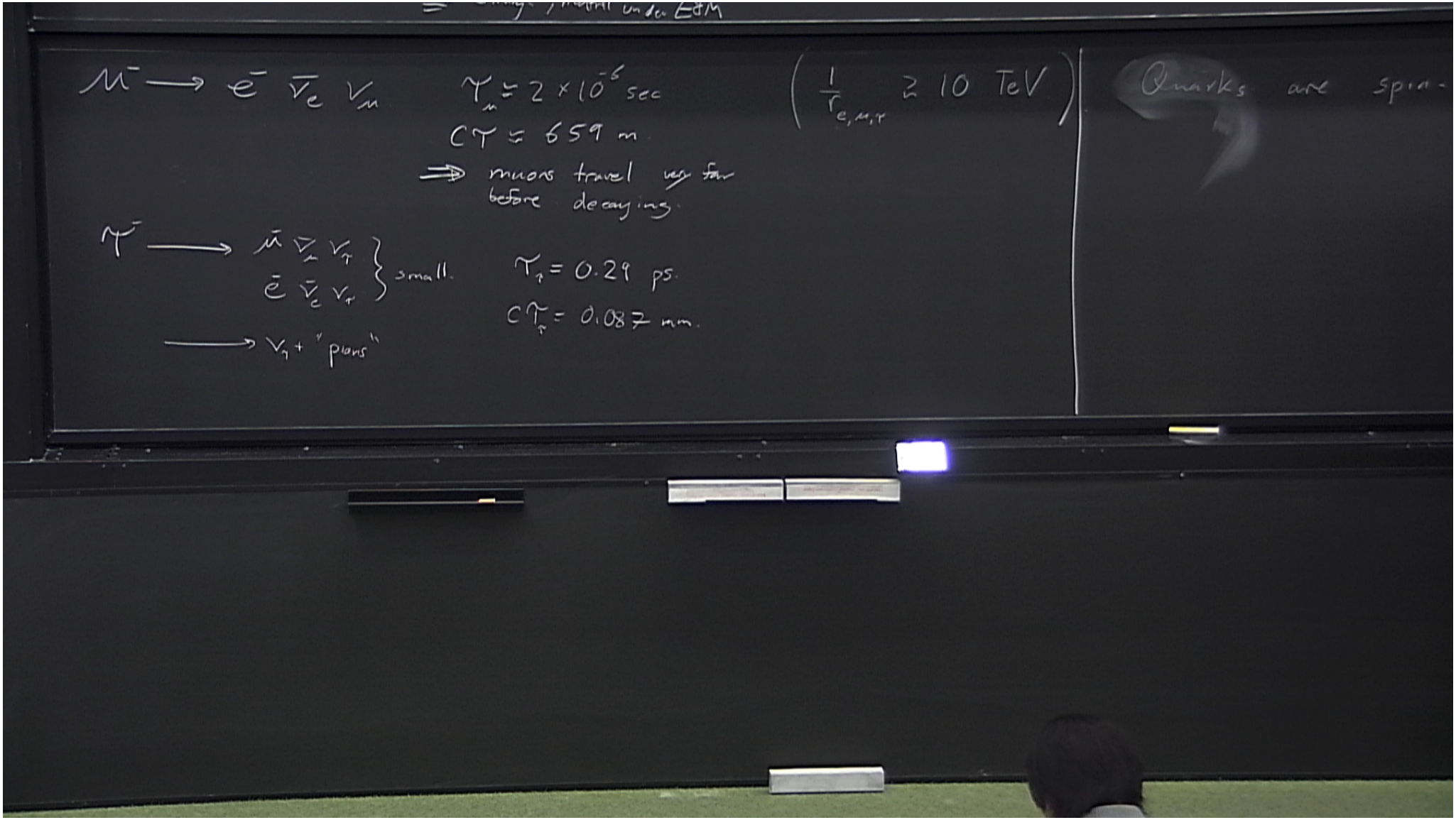
$\Rightarrow$ muons travel very far before decaying.
$\left(\frac{1}{r_{e,\mu,\tau}} \gtrsim 10 \text{ TeV}\right)$
τ^-
$\mu^- \bar{\nu}_\mu \nu_\tau$
$e^- \bar{\nu}_e \nu_\tau$
small.
$\tau_\tau = 0.29$ ps.
$c\tau_\tau = 0.087$ mm.
"plans"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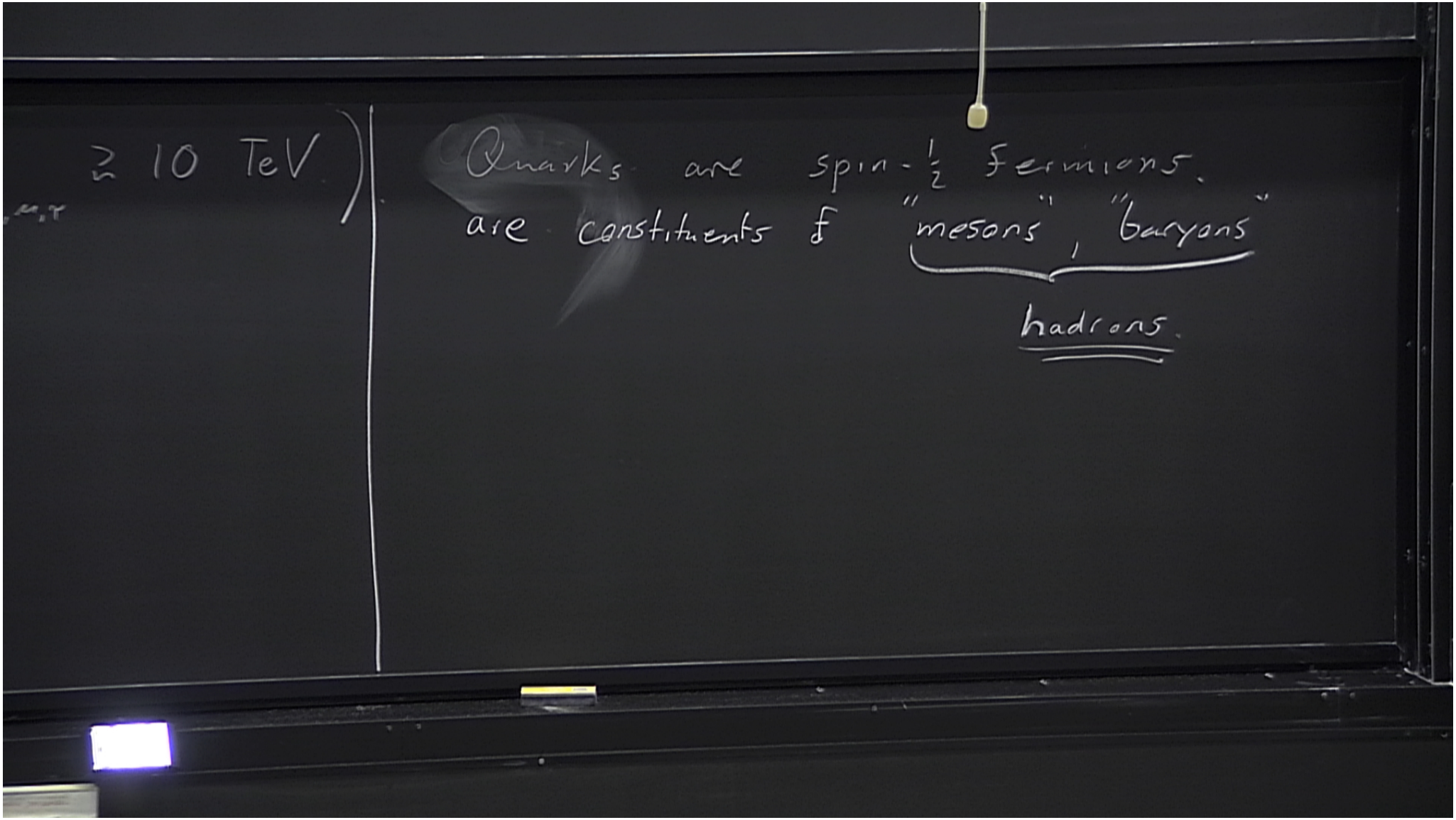
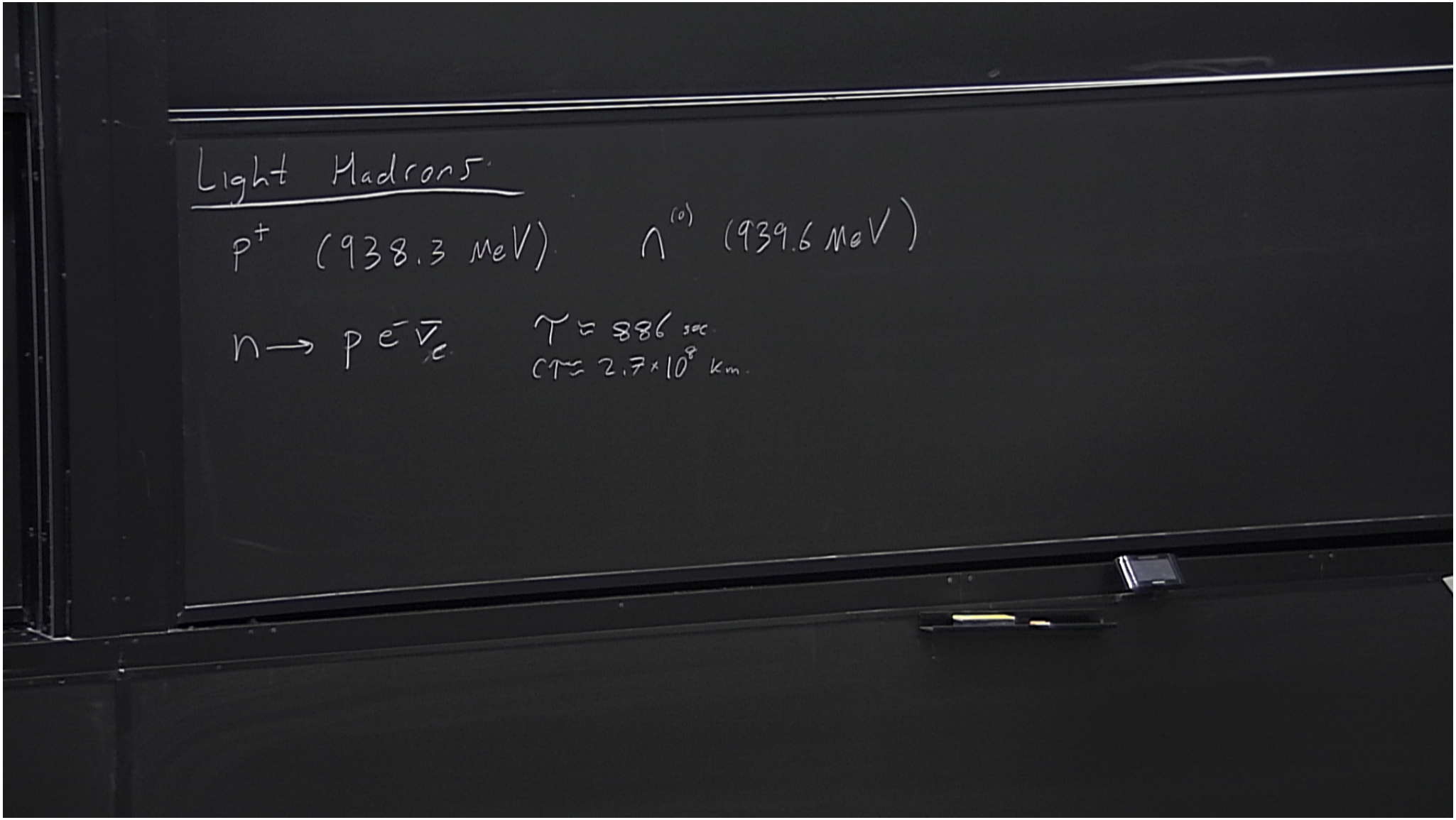
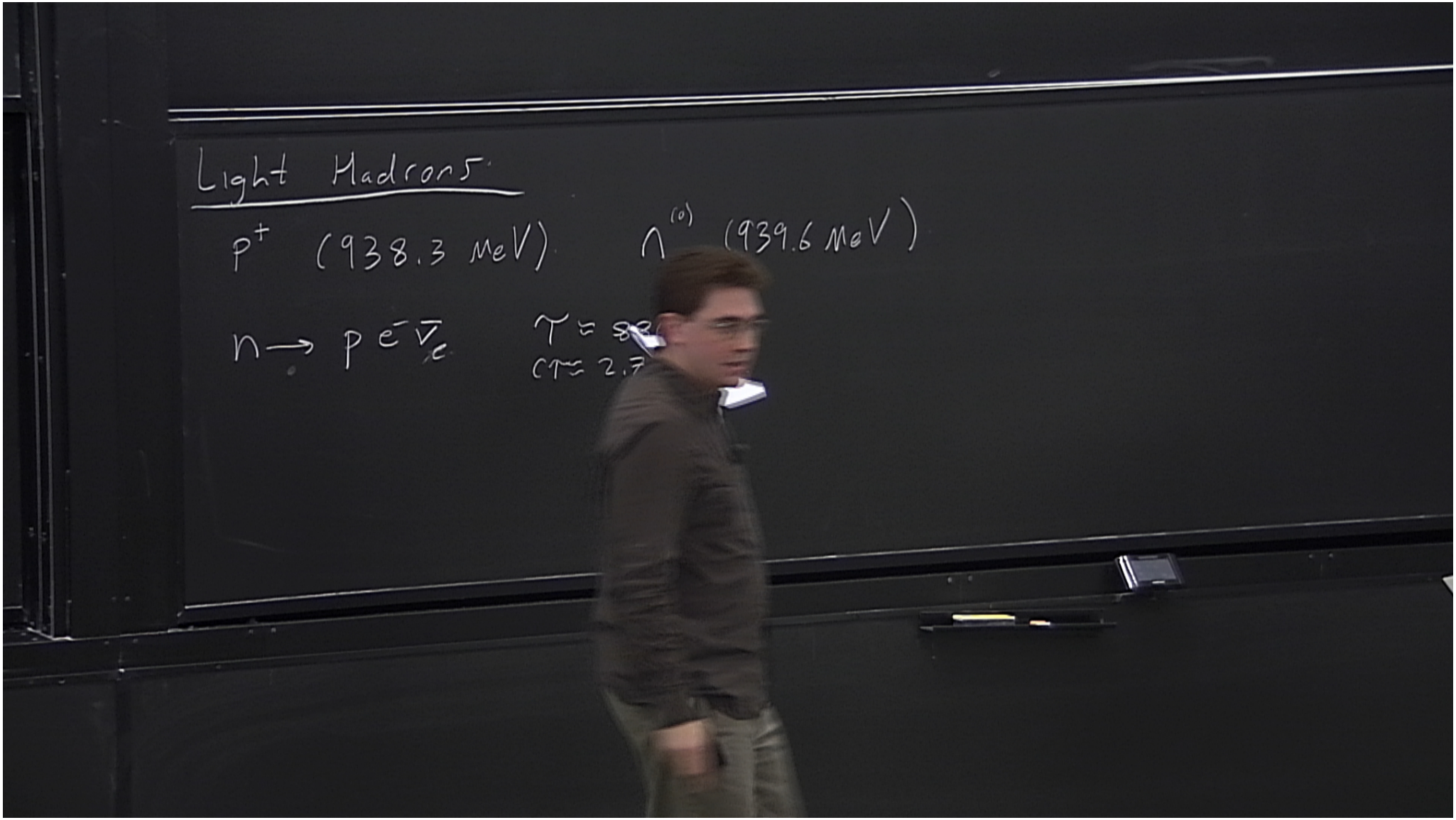
$\Rightarrow$ muons travel very far before decaying.
$\left(\frac{1}{r_{e,\mu,\tau}} \gtrsim 10 \text{ TeV}\right)$
Quarks are spin-
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$
$e^- \bar{\nu}_e \nu_\tau$
small.
$\tau_\tau = 0.29$ ps.
$c\tau_\tau = 0.087$ mm.
$\to \nu_\tau$ + "plans"


≥ 10 TeV
Quarks are spin-½ fermions.
are constituents of "mesons", "baryons"
hadrons.


Light Hadrons
p^+ (938.3 MeV) $n^{(0)}$ (939.6 MeV)
$n \rightarrow p e^- \bar{\nu}_e$
$\tau \simeq 886$ sec
$c\tau \simeq 2.7 \times 10^8$ km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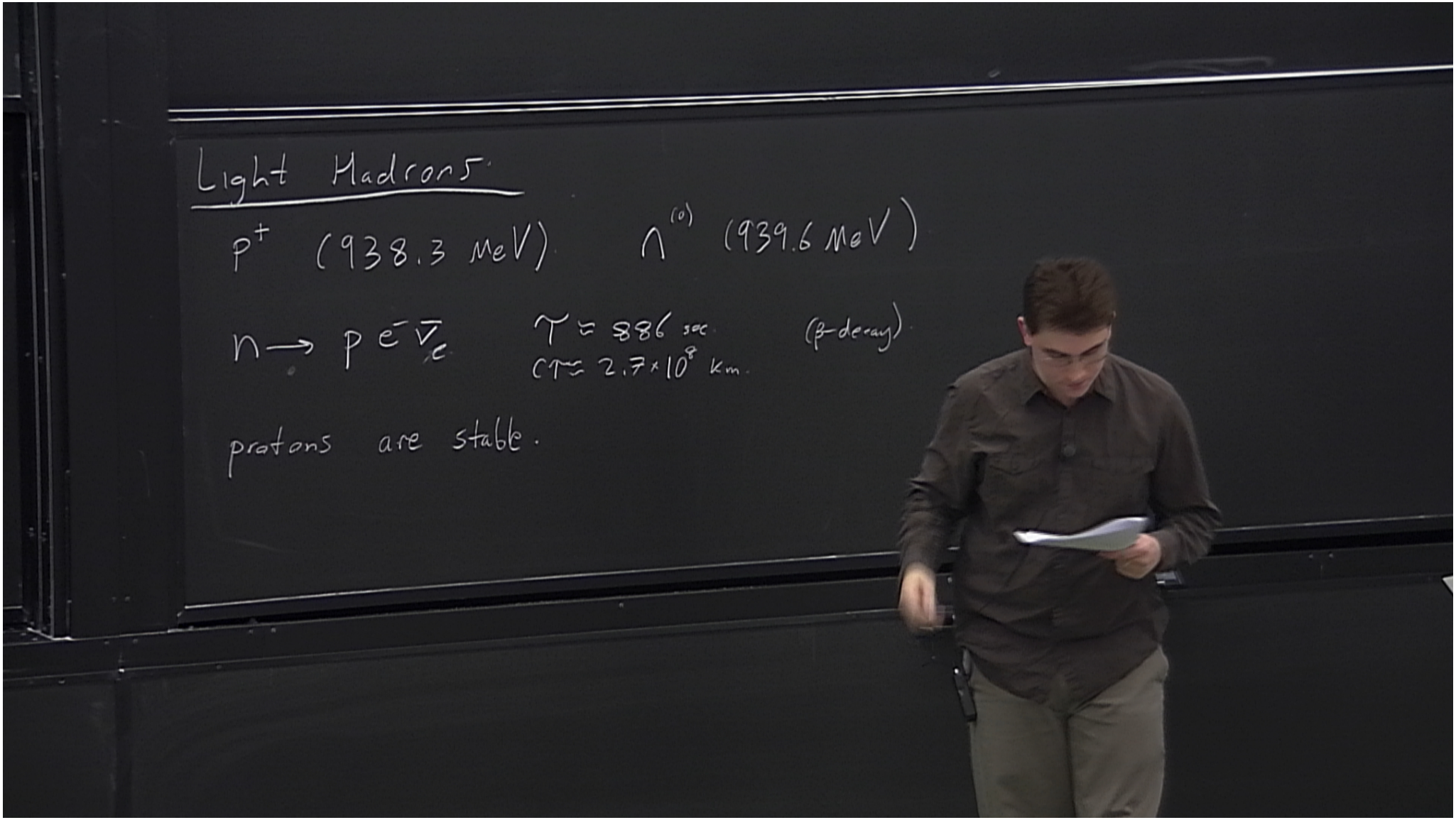
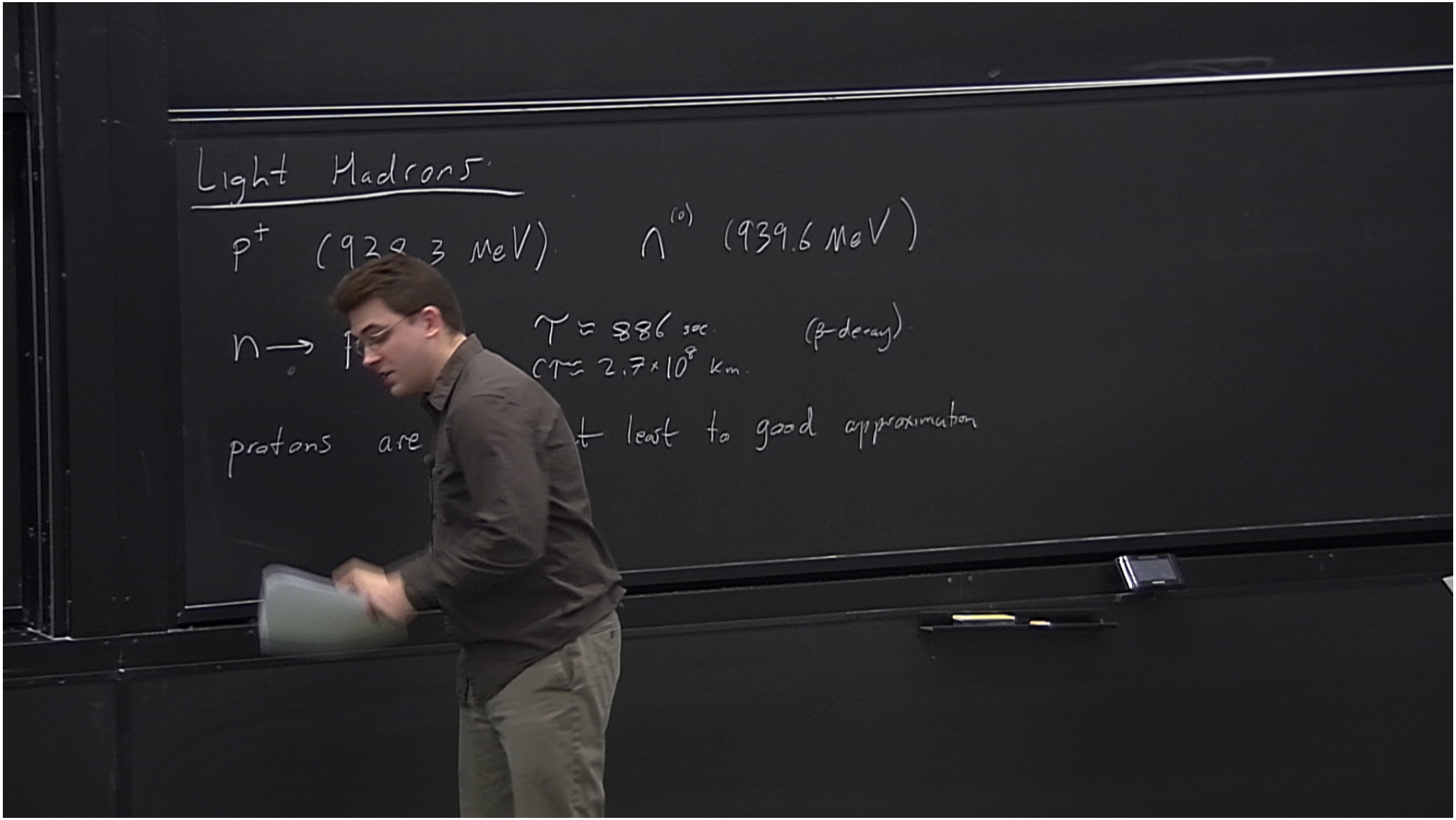
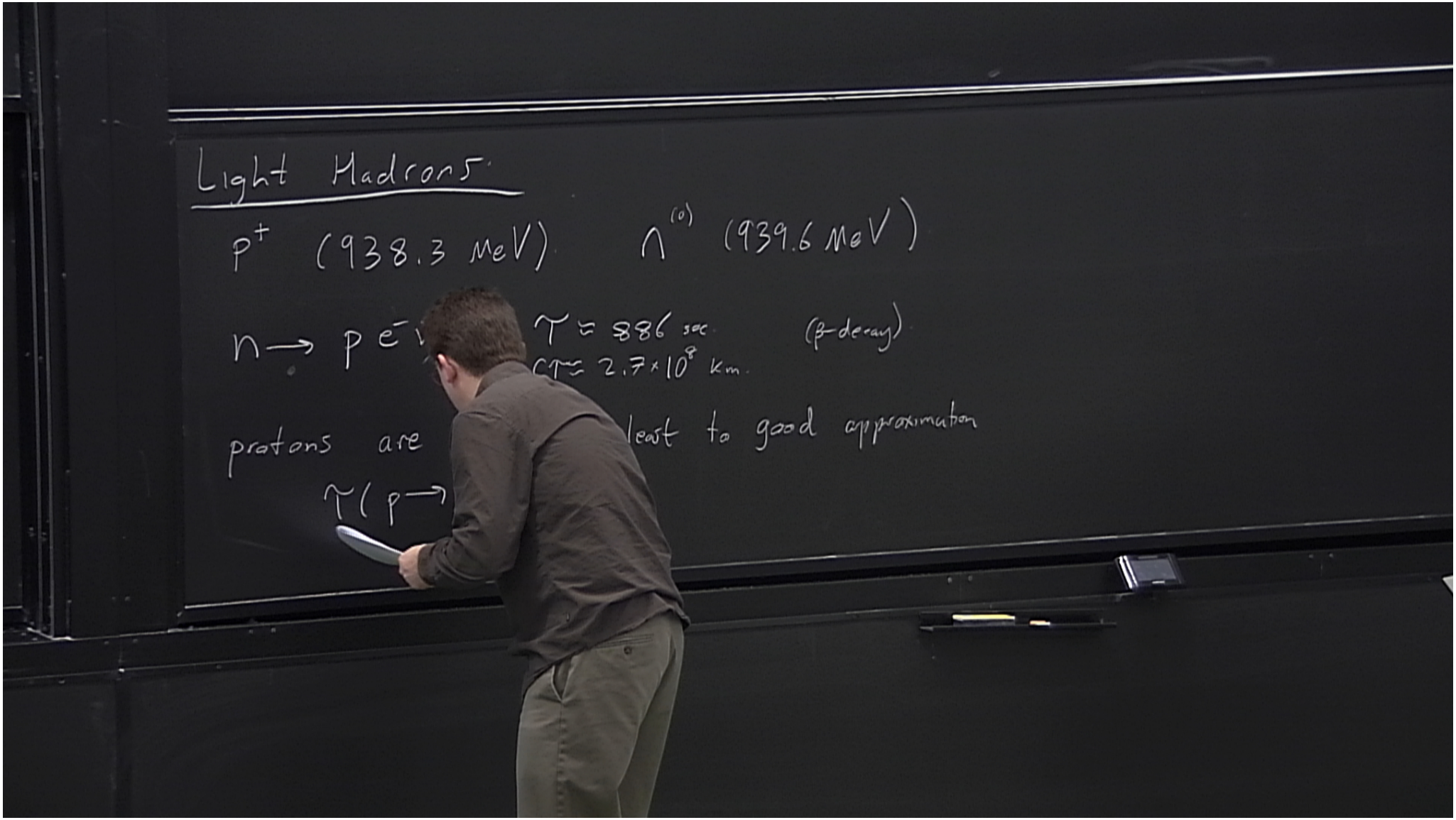

Light Hadrons
p^+ (938.3 MeV) $n^{(0)}$ (939.6 MeV)
$n \rightarrow p e^- \bar{\nu}_e$ $\tau \simeq 886$ sec (β-decay)
$c\tau \simeq 2.7 \times 10^8$ km
protons are stable.


Light Hadrons
p+ (938.3 MeV)
Λ(0) (939.6 MeV)
n →
τ ≈ 886 sec
(β-decay)
cτ ≈ 2.7 × 10^8 km
protons are
least to good approximation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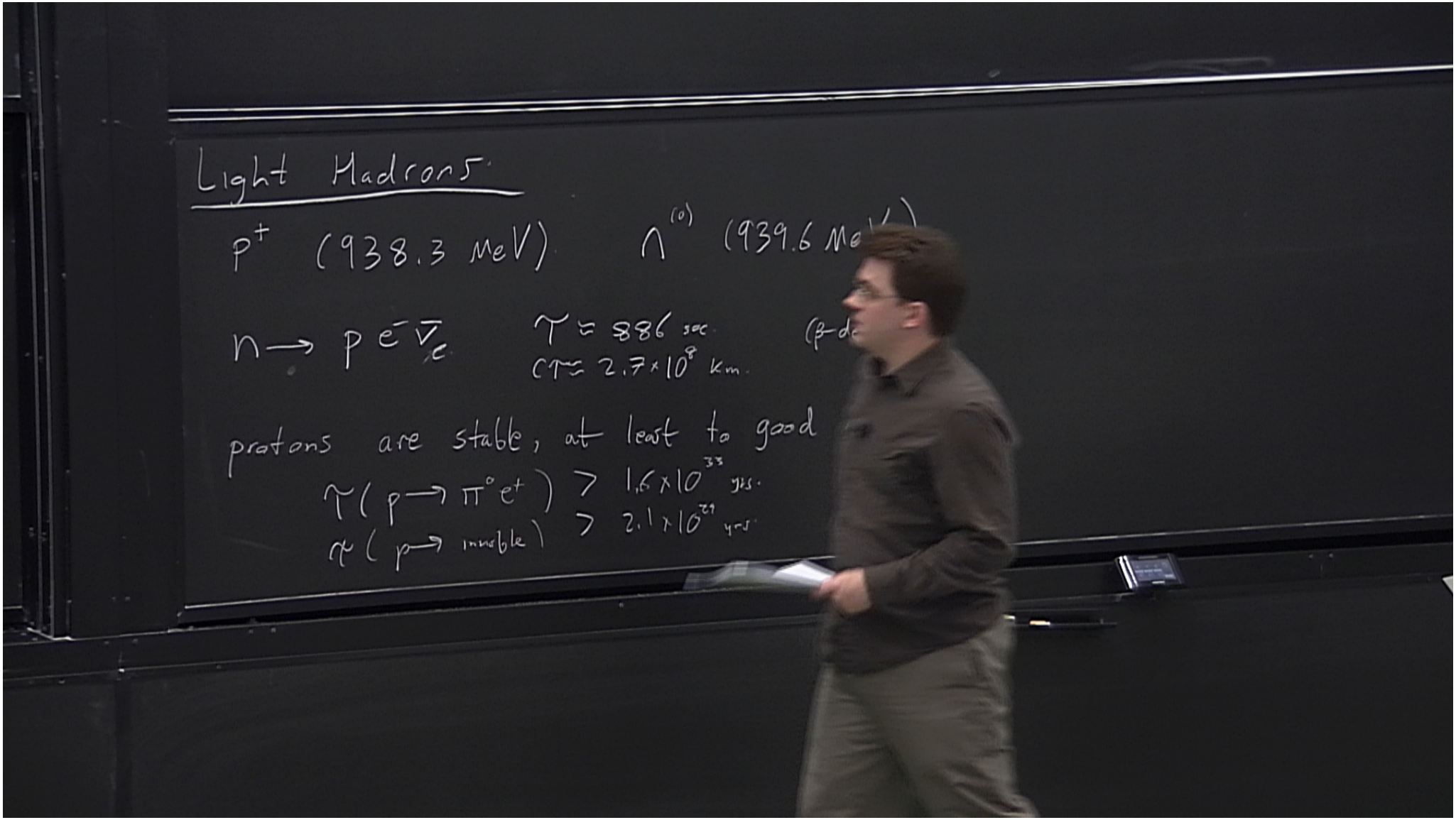
least to good approximation
τ(p →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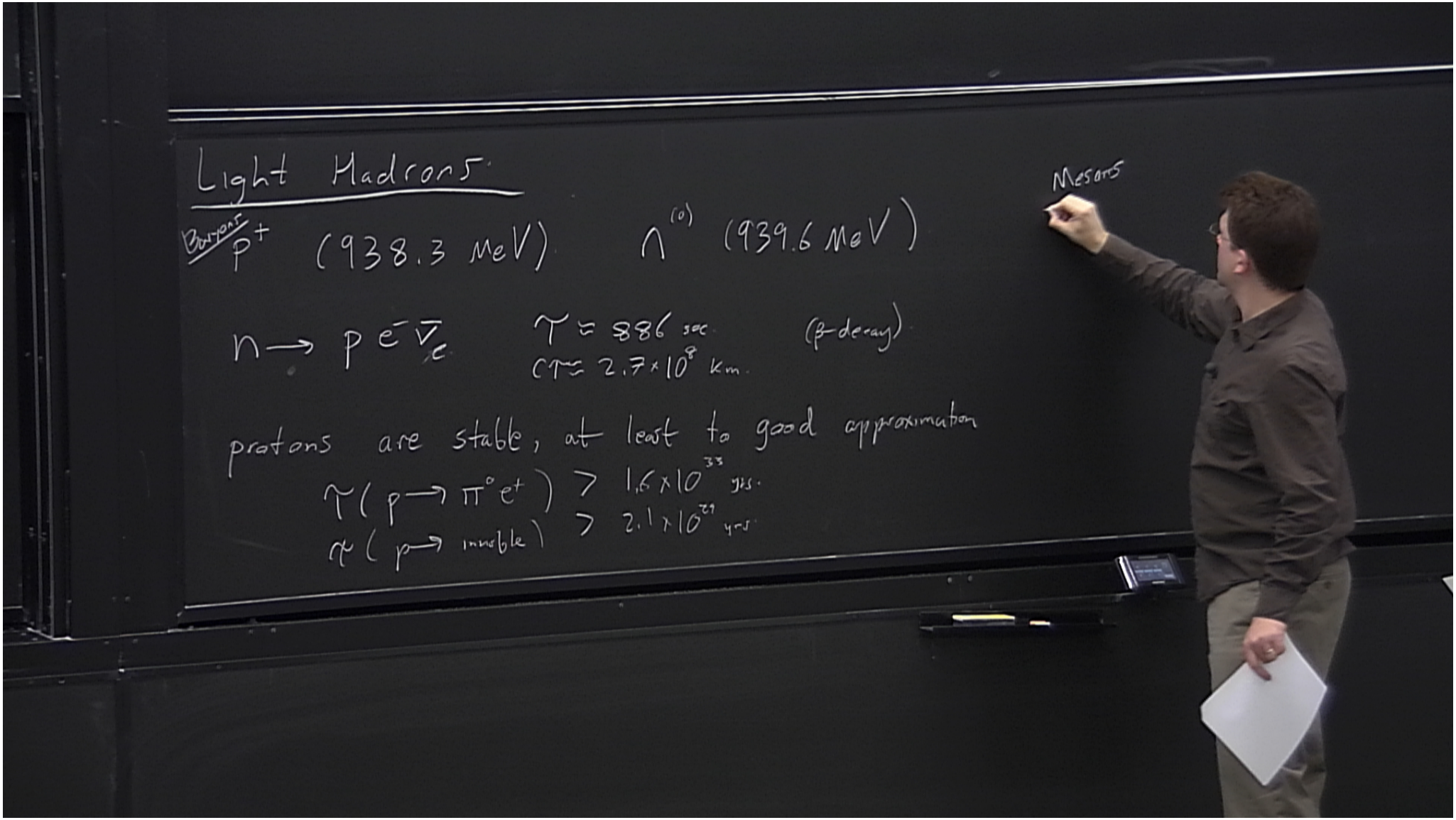
protons are stable, at least to good
$\tau(p \to \pi^0 e^+) > 1.6 \times 10^{33}$ yrs.
$\tau(p \to$ invisible$) > 2.1 \times 10^{29}$ yrs.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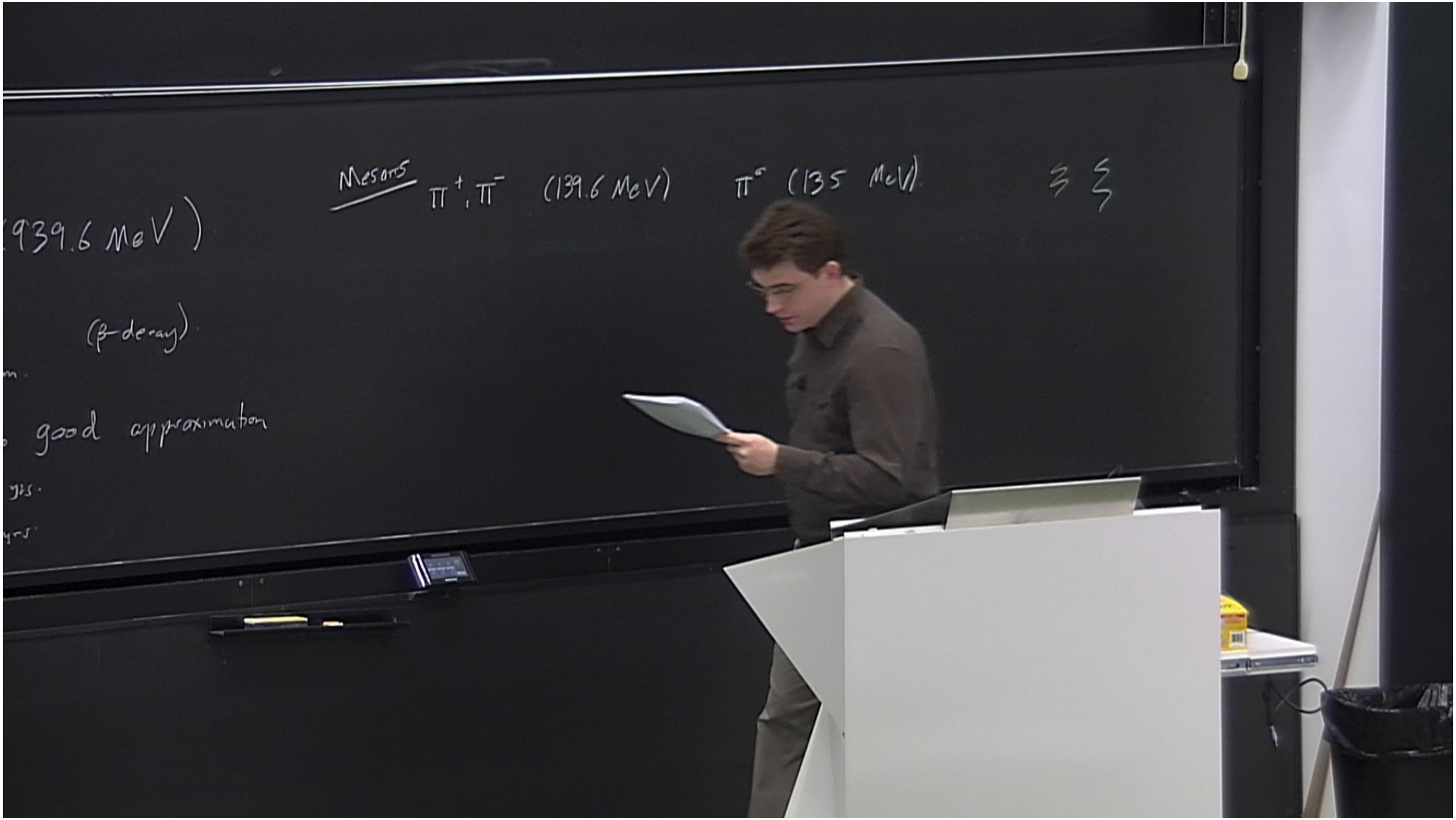
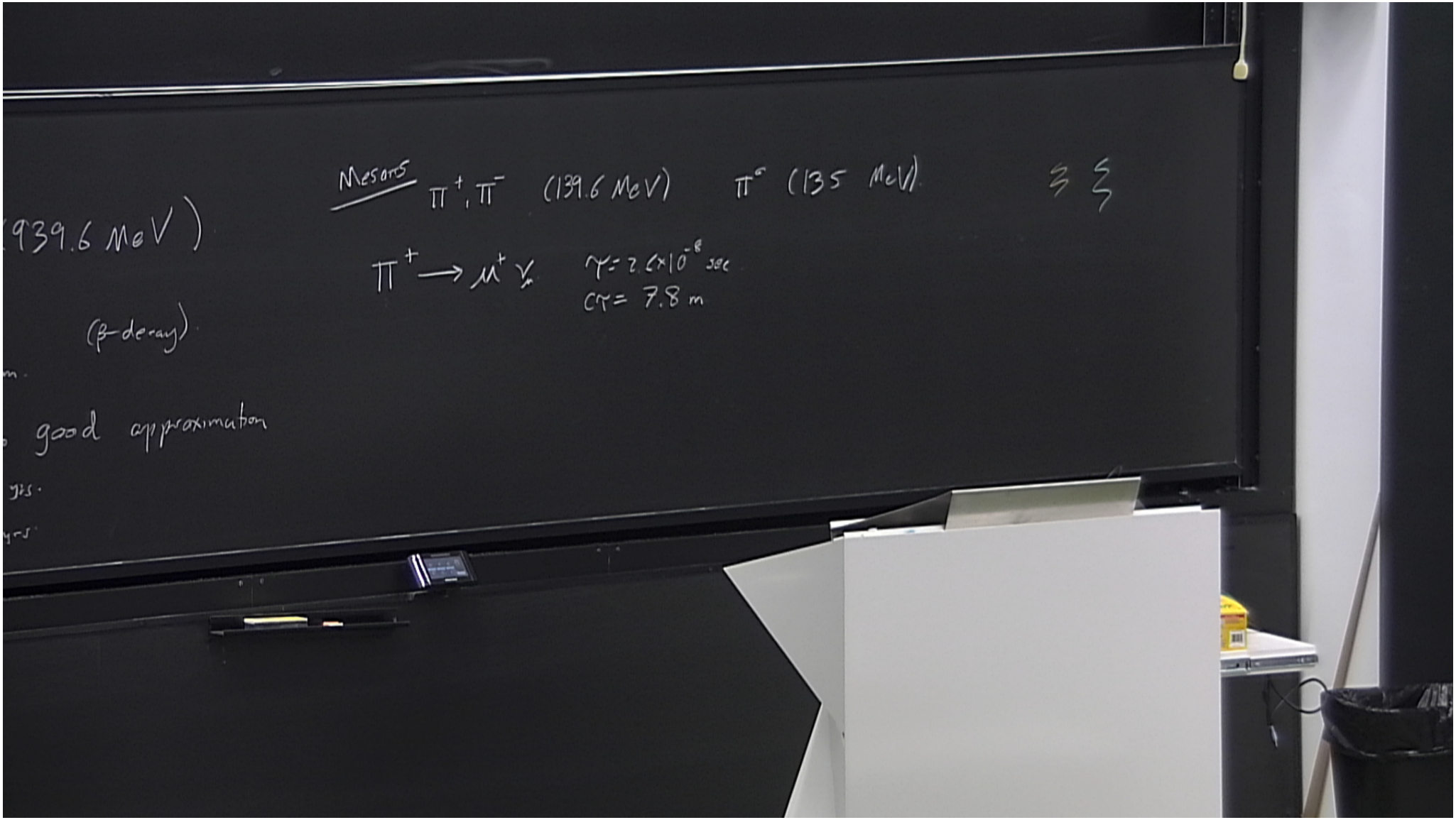
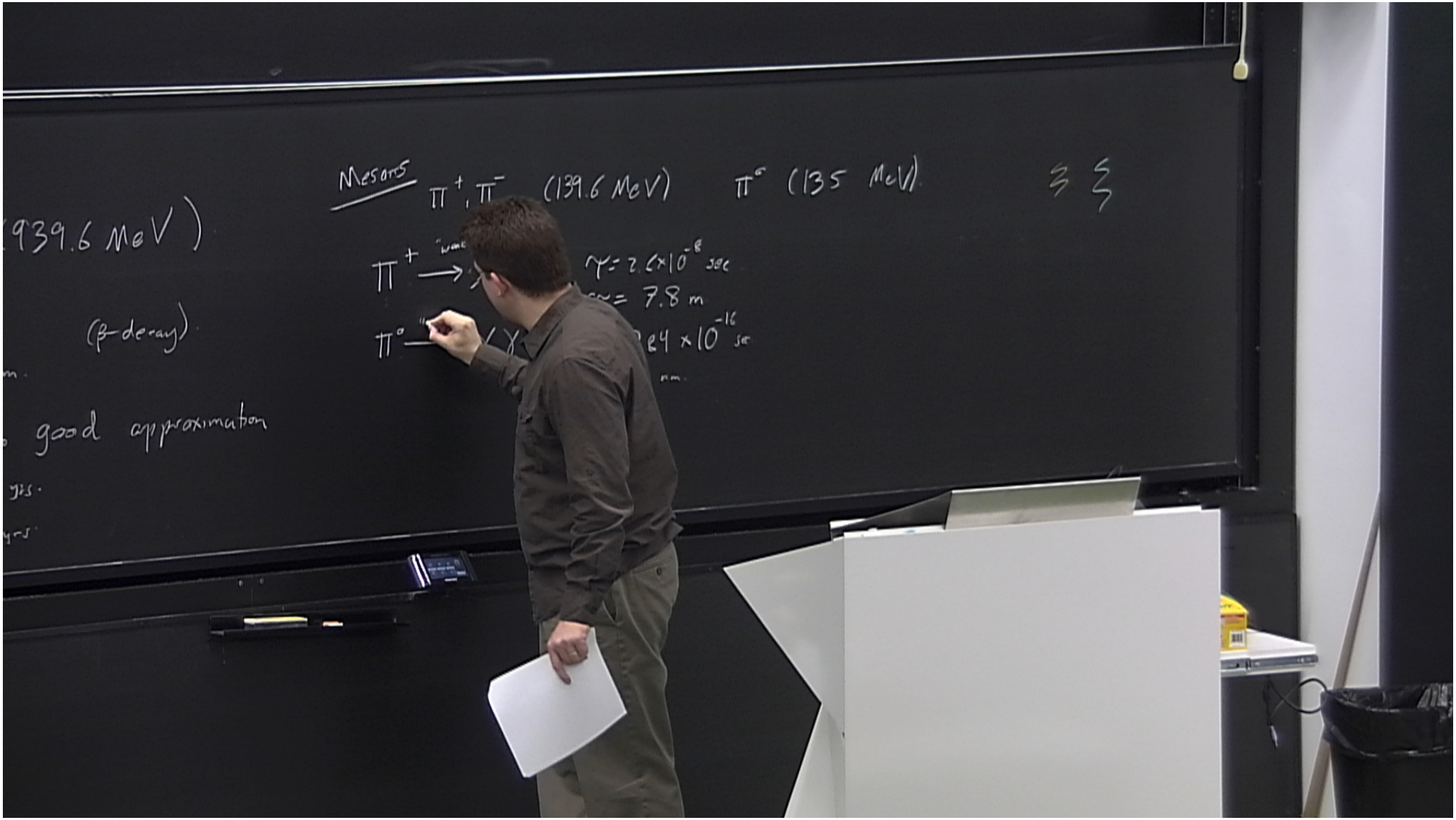
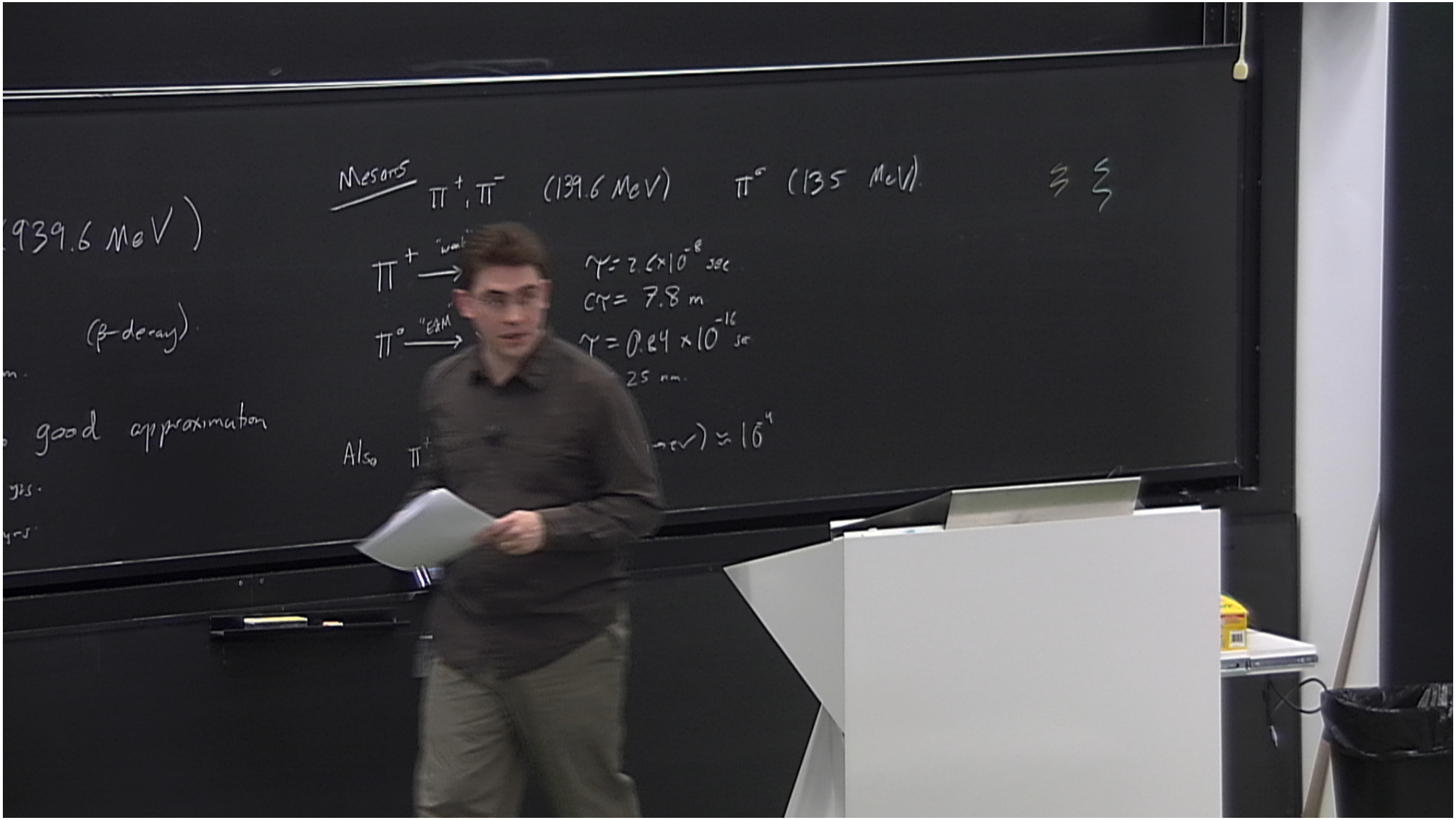
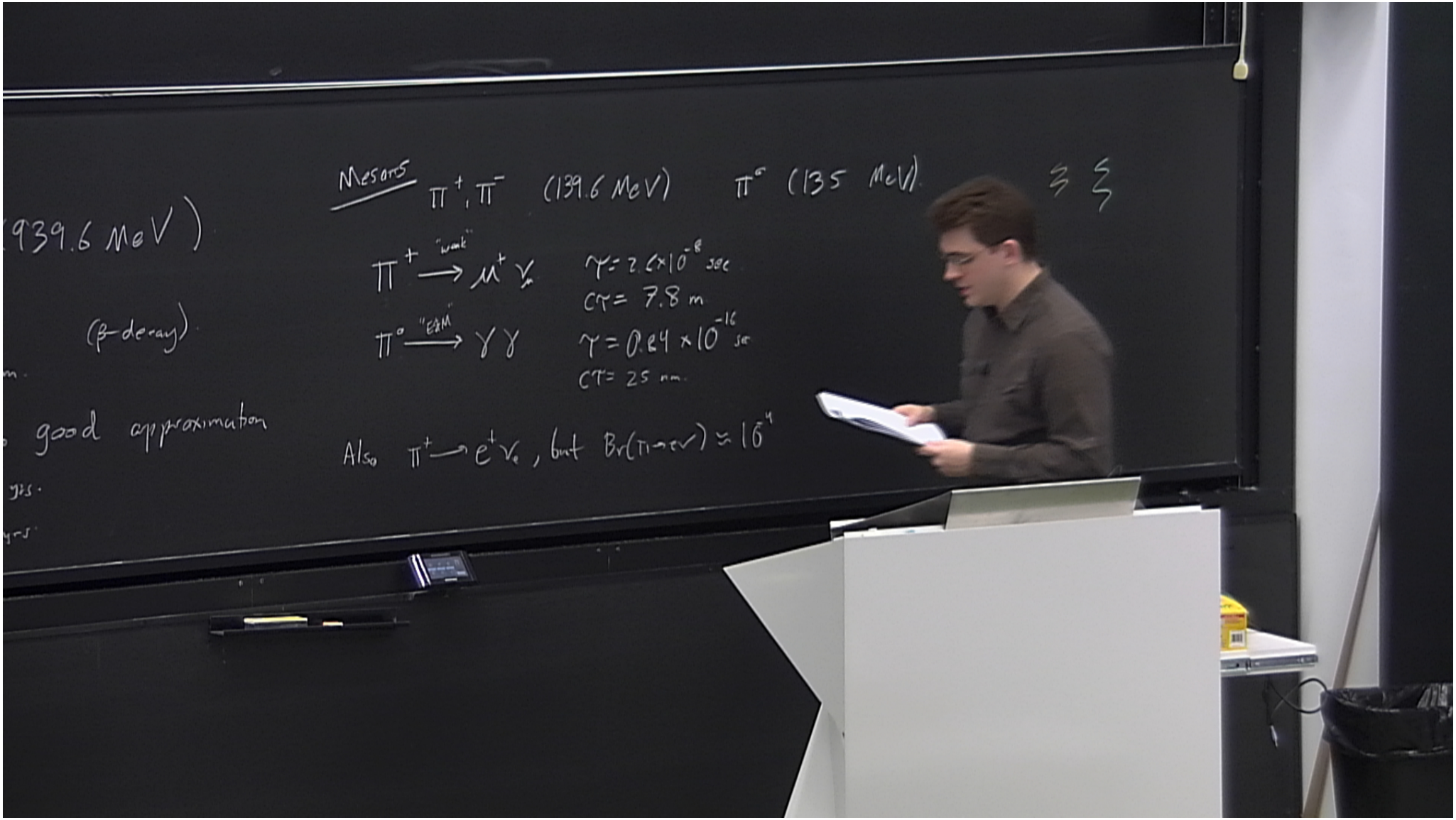
$c\tau \simeq 2.7 \times 10^8$ km
protons are stable, at least to good approximation
$\tau(p \rightarrow \pi^0 e^+) > 1.6 \times 10^{33}$ yrs.
$\tau(p \rightarrow$ invisible$) > 2.1 \times 10^{29}$ yrs.
Mesons

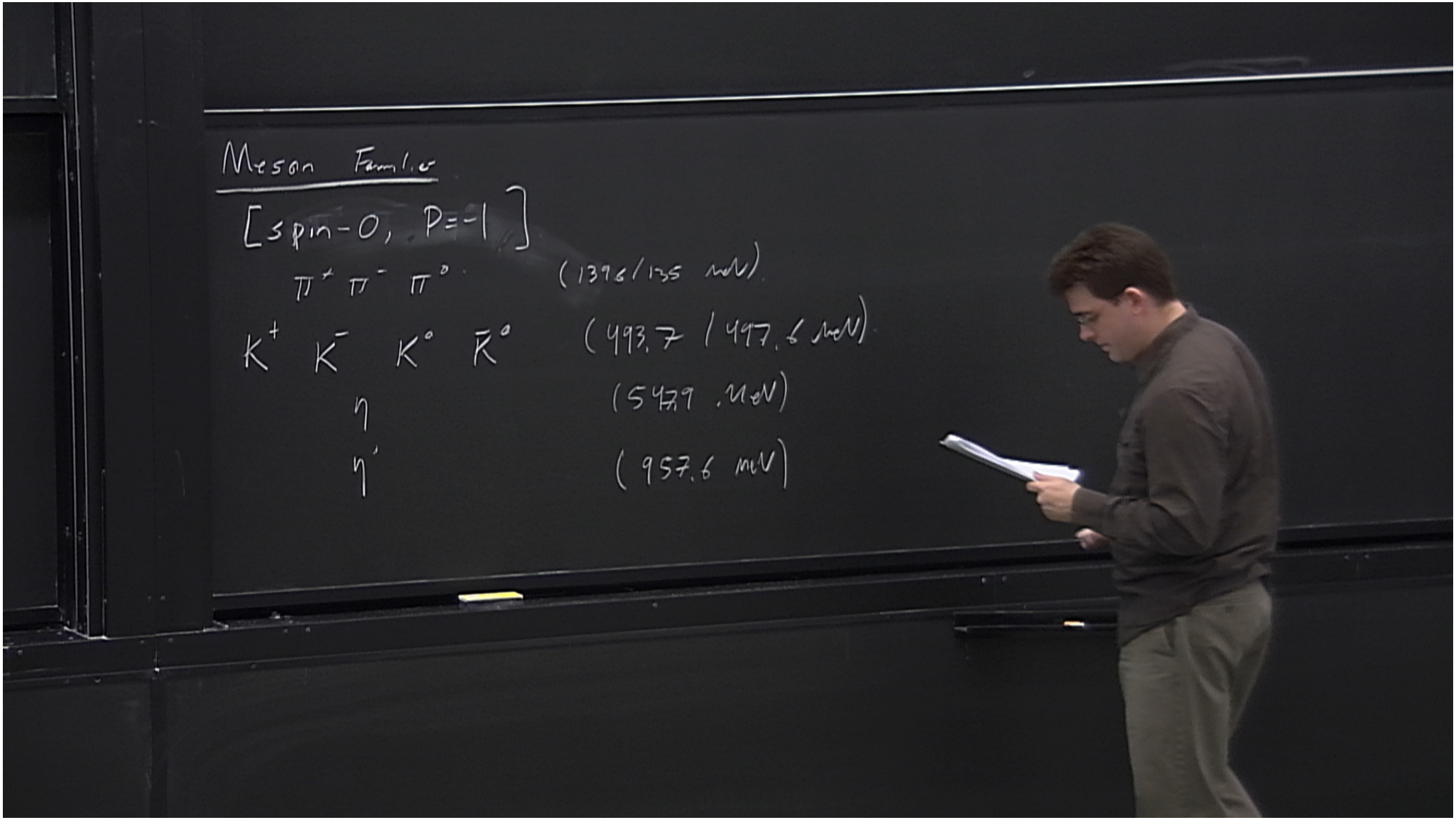

939.6 MeV)
Mesons
π^+, π^- (139.6 MeV)
π^0 (135 MeV)
(β-decay)
good approximation

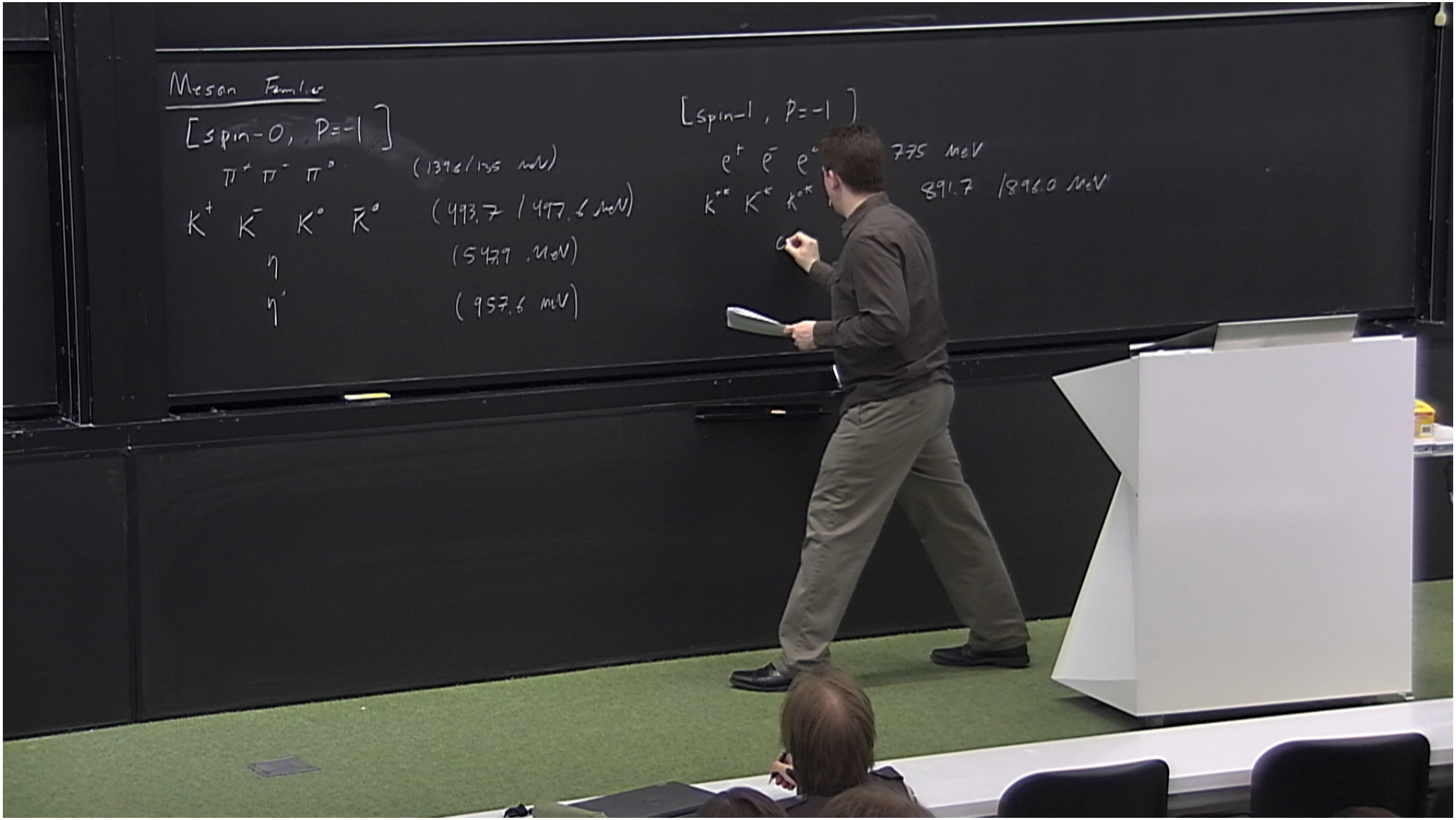

939.6 MeV)
(β-decay)
good approximation
Mesons
π+, π− (139.6 MeV)
π0 (135 MeV)
π+ → μ+ νμ
τ = 2.6×10−8 sec
cτ = 7.8 m

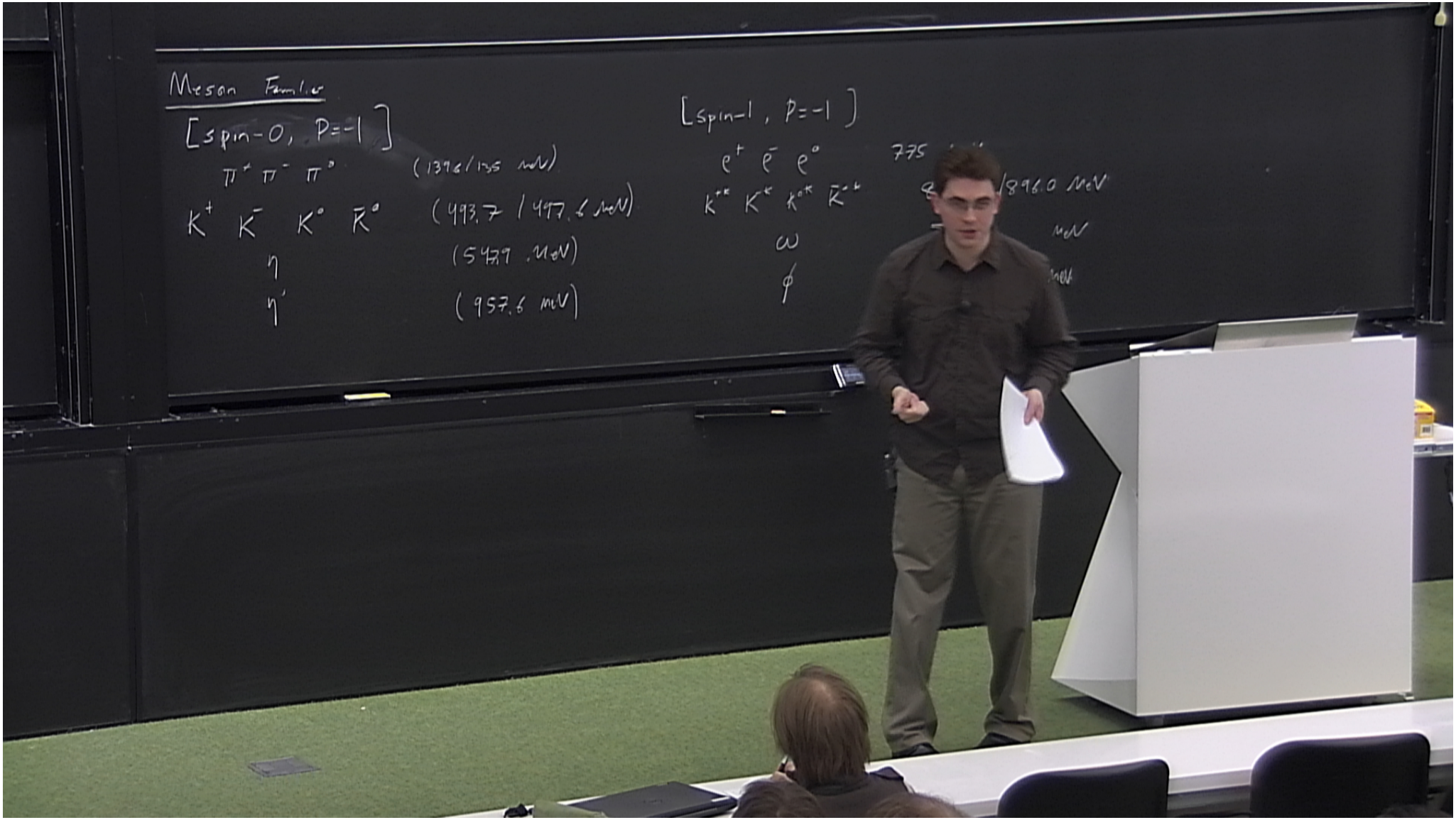

939.6 MeV)
(β-decay)
good approximation
Mesons
π+, π− (139.6 MeV)
π0 (135 MeV)
τ = 2.6×10^-8 sec
cτ = 7.8 m
8.4 ×10^-16 sec

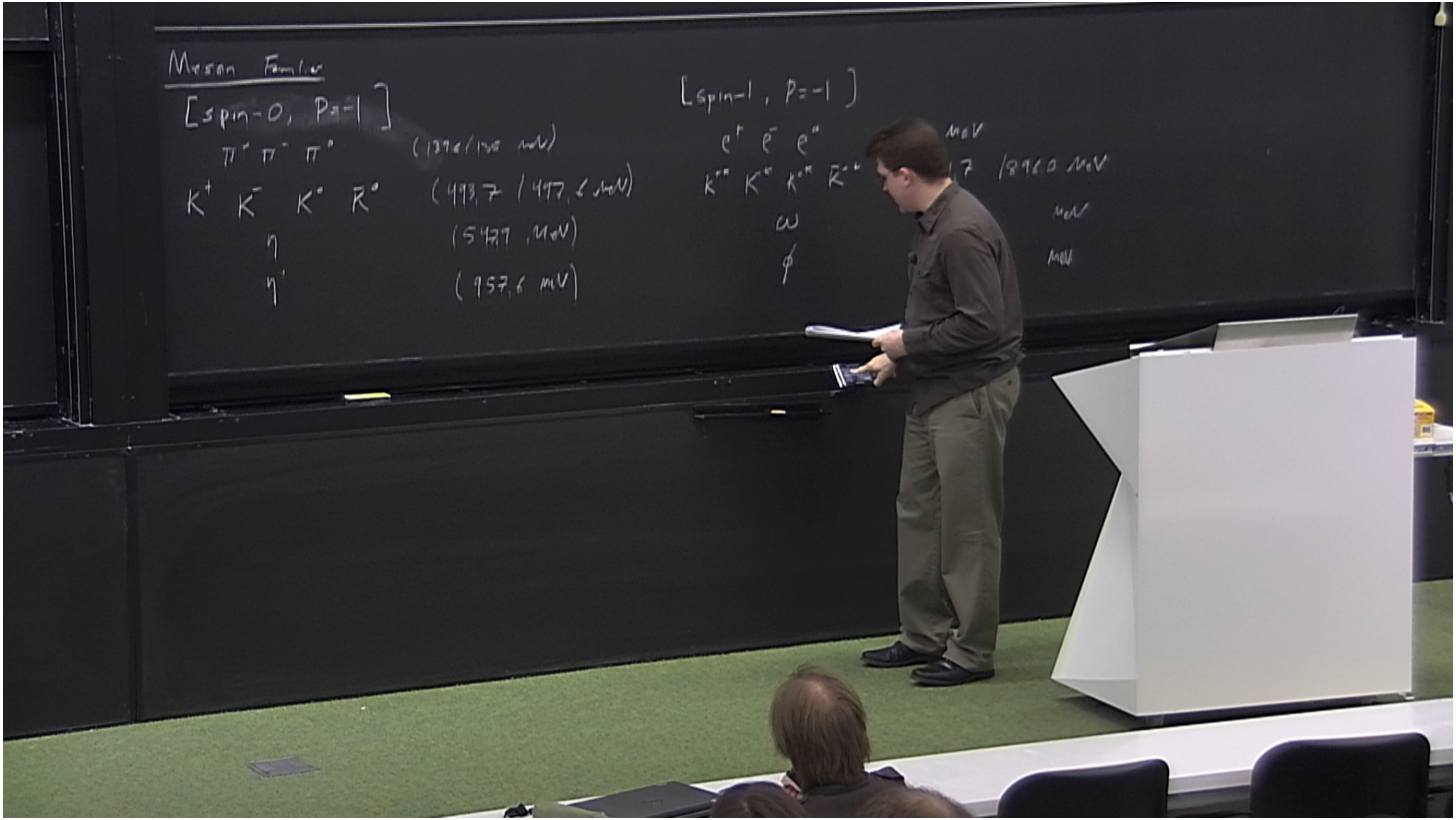

Mesons
π+, π− (139.6 MeV)
π0 (135 MeV)
939.6 MeV)
(β-decay)
good approximation
Also
τ = 2.6×10^-8 sec
cτ = 7.8 m
τ = 0.84×10^-16 sec
25 nm.

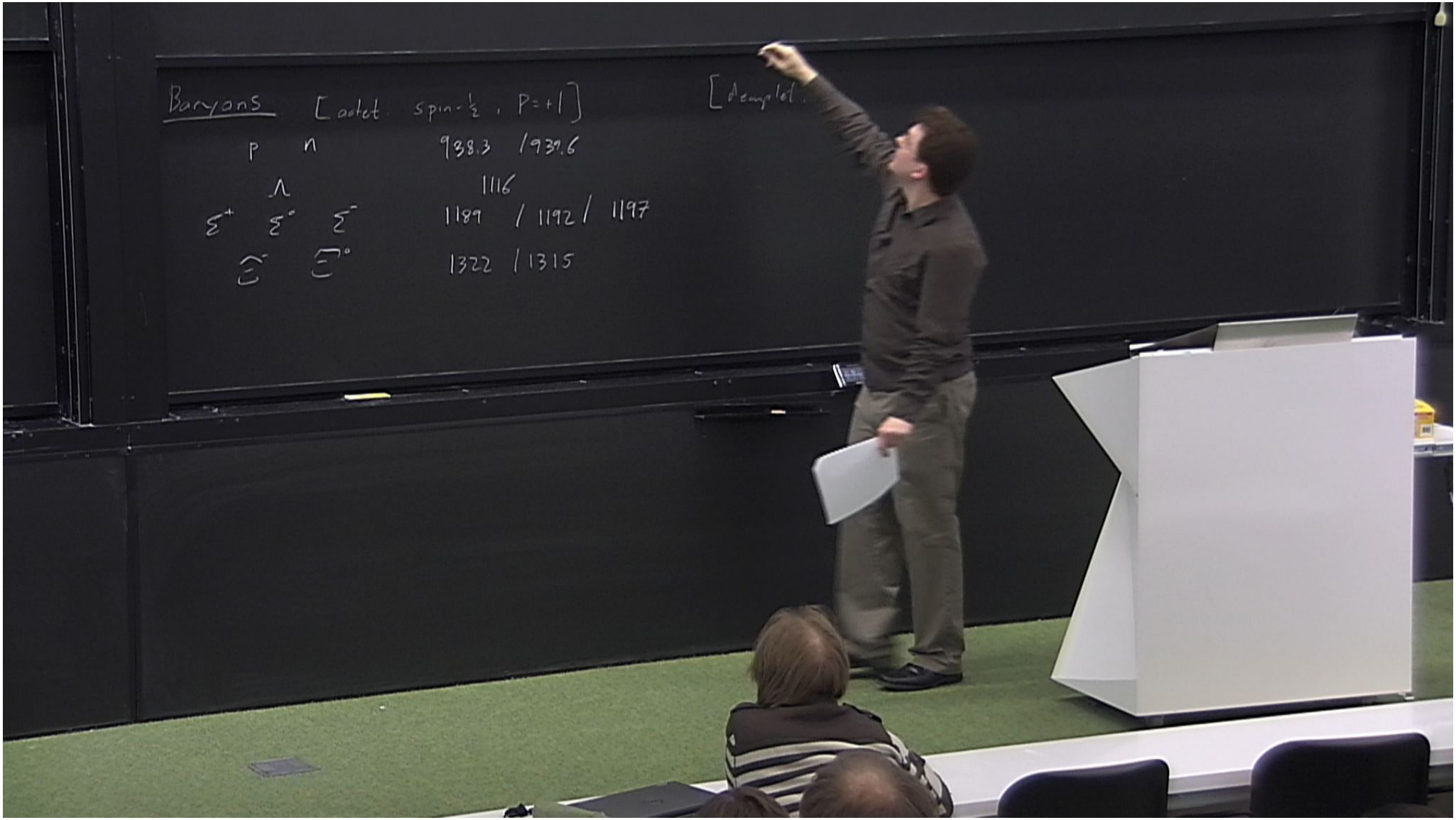

939.6 MeV)
(β-decay)
good approximation
Mesons
π+, π− (139.6 MeV)
π0 (135 MeV)
π+ "weak" → μ+ νμ
τ = 2.6×10−8 sec
cτ = 7.8 m
π0 "E&M" → γ γ
τ = 0.84 ×10−16 sec
cτ = 25 nm.
Also π+ → e+ νe, but Br(π → eν) ≈ 10−4

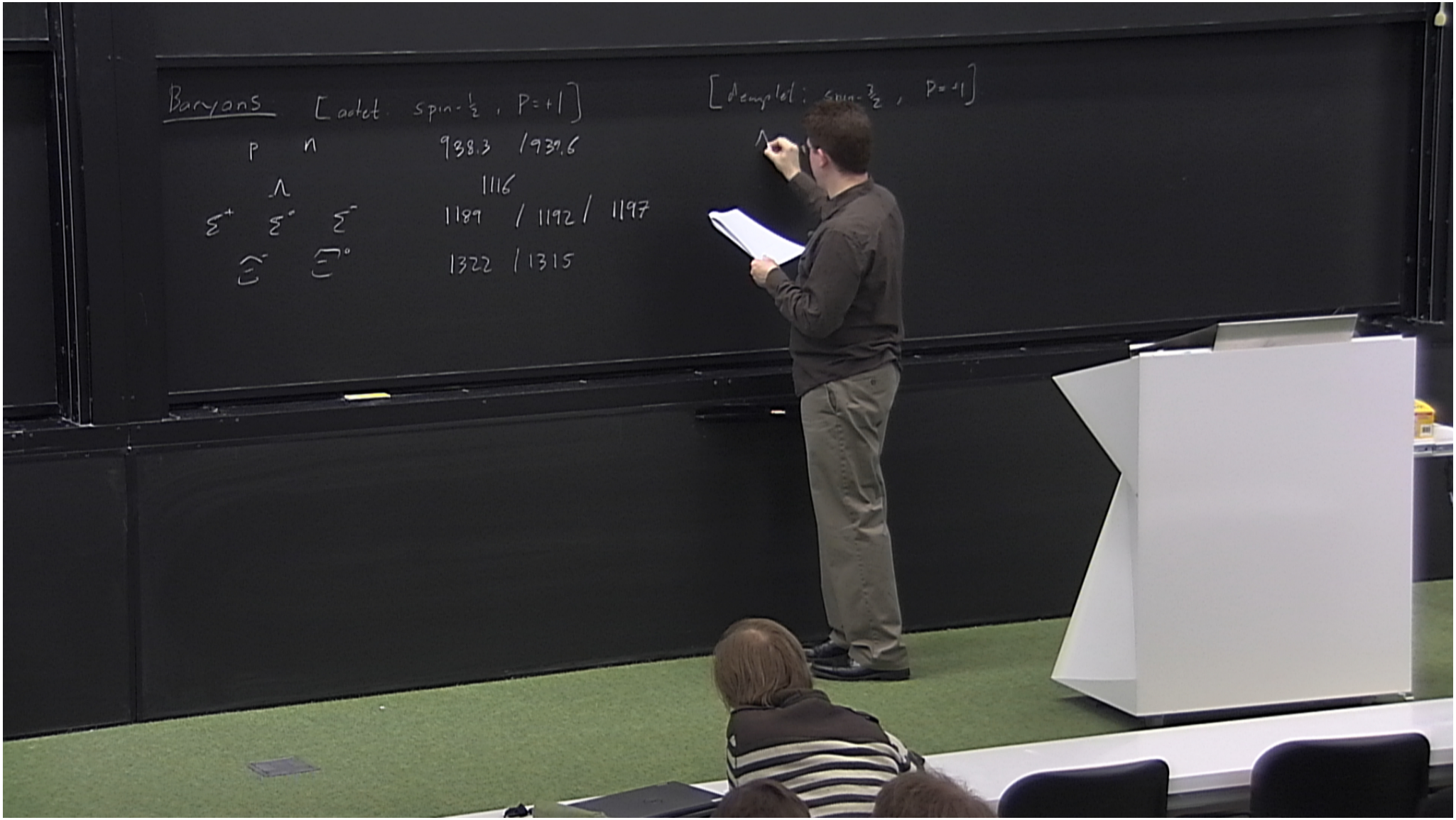

Meson Family
[spin-0, P=-1]
$\pi^+ \pi^- \pi^0$ (139.6/135 MeV)
$K^+ K^- K^0 \bar{K}^0$ (493.7 / 497.6 MeV)
η (547.9 MeV)
η' (957.6 MeV)

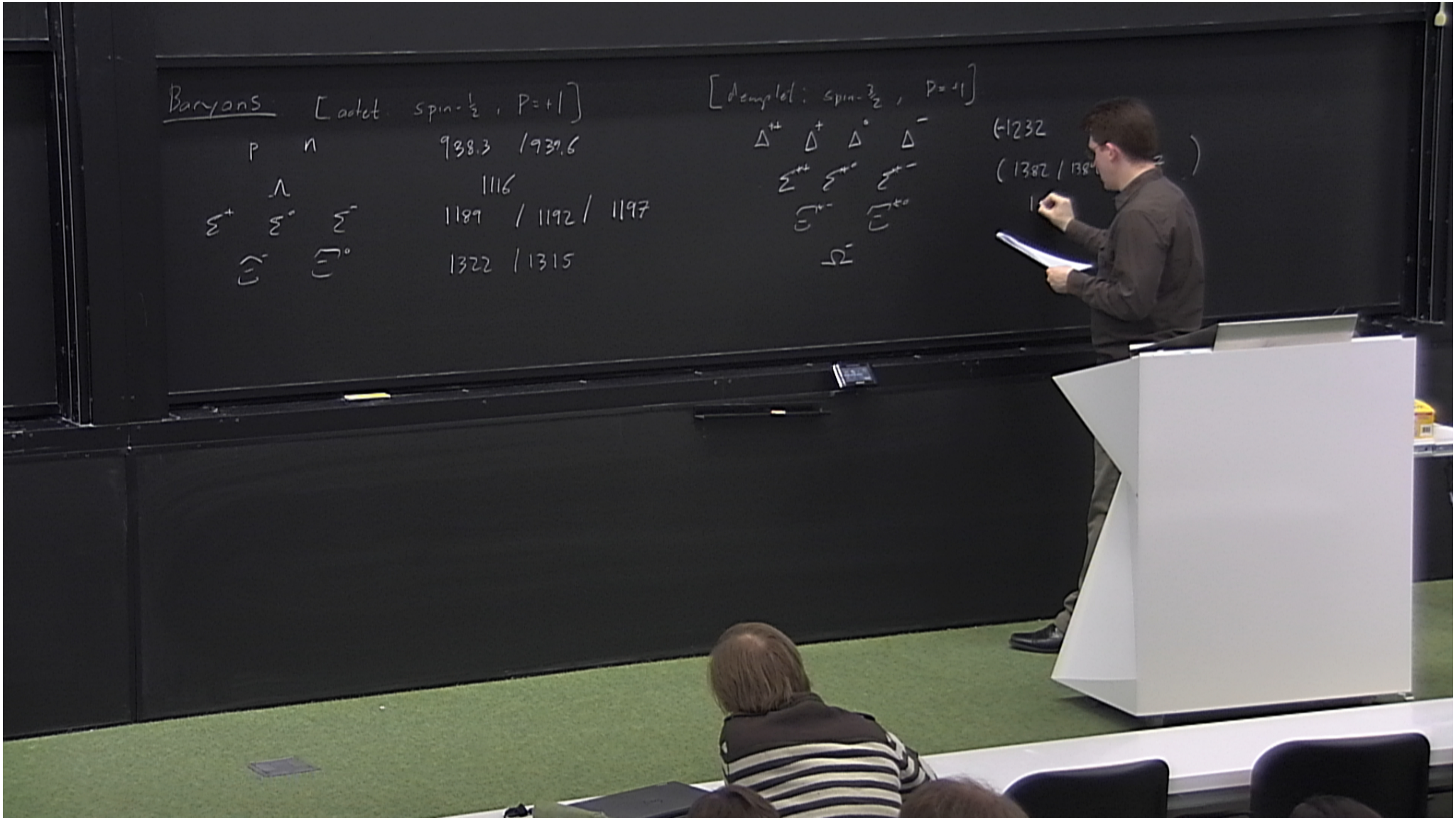

Meson Families
[spin-0, P=-1]
$\pi^+ \pi^- \pi^0$ (139.6/135 MeV)
$K^+ K^- K^0 \bar{K}^0$ (493.7 / 497.6 MeV)
η (547.9 MeV)
η' (957.6 MeV)
[spin-1, P=-1]
775 MeV
891.7 / 896.0 MeV

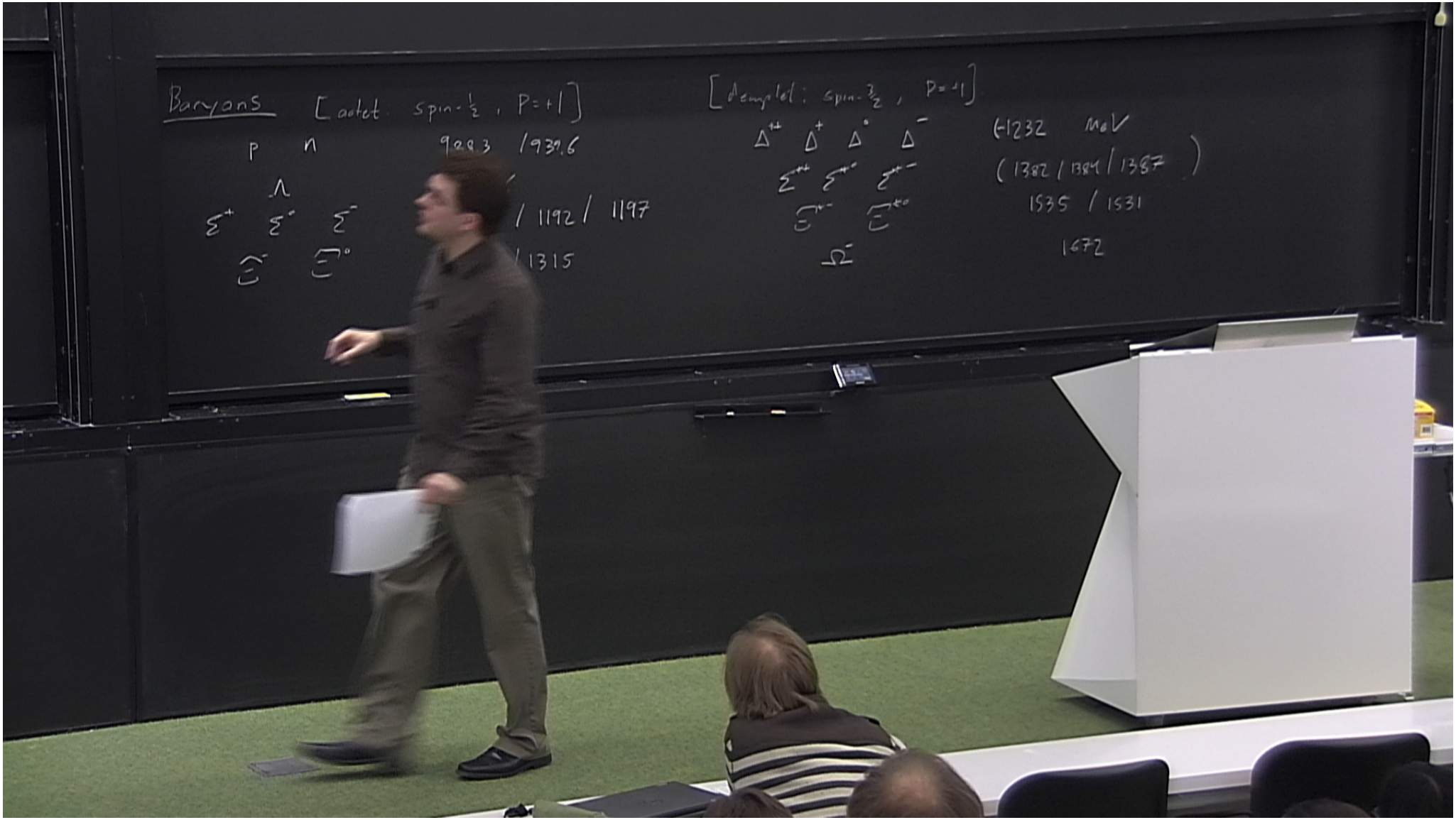

Meson Families
[spin-0, P=-1]
$\pi^+ \pi^- \pi^0$ (139.6/135 MeV)
$K^+ K^- K^0 \bar{K}^0$ (493.7 / 497.6 MeV)
η (547.9 MeV)
η' (957.6 MeV)
[spin-1, P=-1]
$\rho^+ \rho^- \rho^0$
$K^{*+} K^{*-} K^{*0} \bar{K}^{*0}$
ω
ϕ
775
896.0 MeV

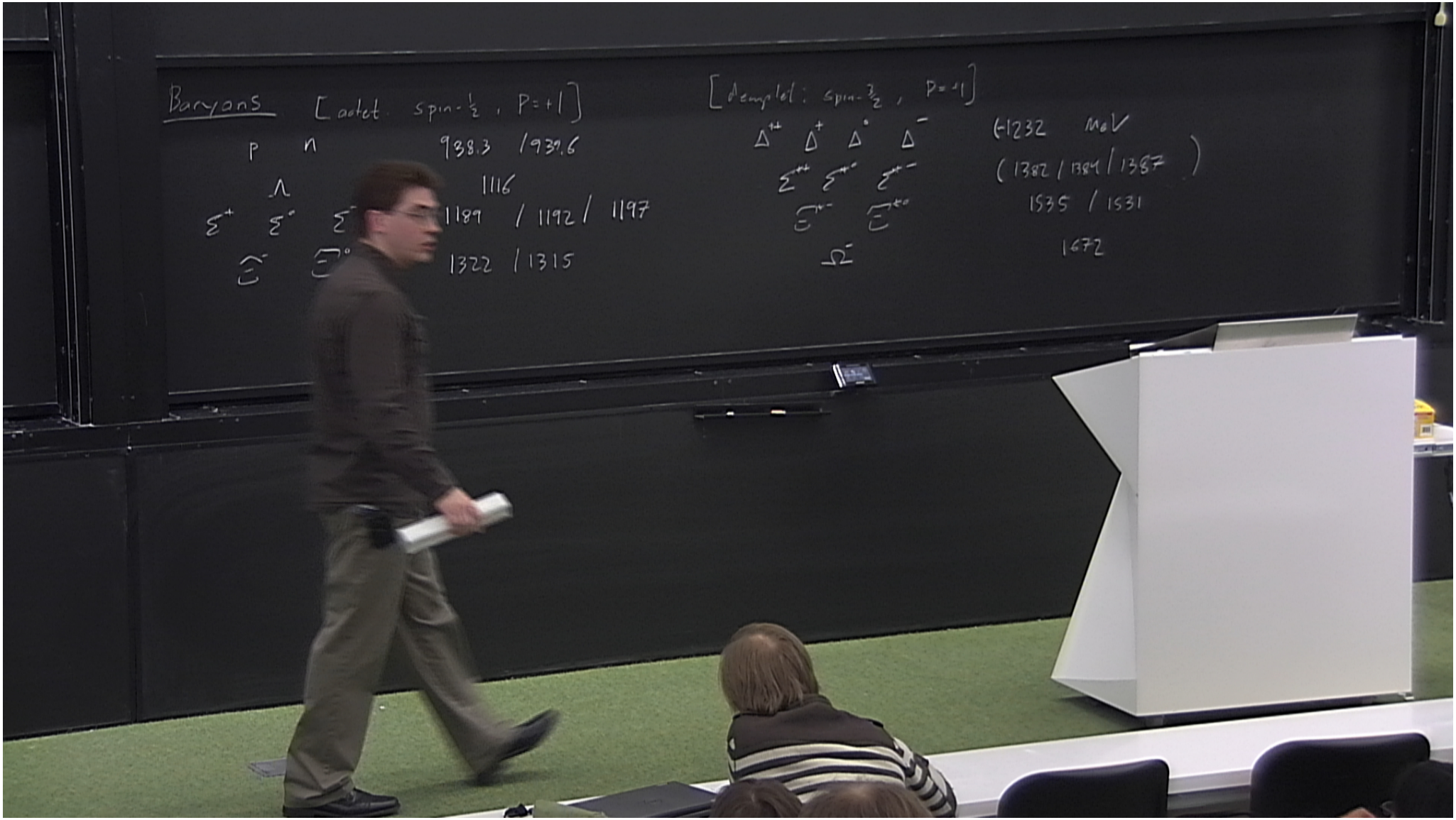

Meson Family
[spin-0, P=-1]
$\pi^+ \pi^- \pi^0$
$K^+ K^- K^0 \bar{K}^0$
η
η'
(139.6/135 MeV)
(493.7 / 497.6 MeV)
(547.7 MeV)
(957.6 MeV)
[spin-1, P=-1]
$e^+ e^- e^0$
$K^{*+} K^{*-} K^{*0} \bar{K}^{*0}$
ω
ϕ
MeV
1.7 /1960 MeV
MeV
MeV

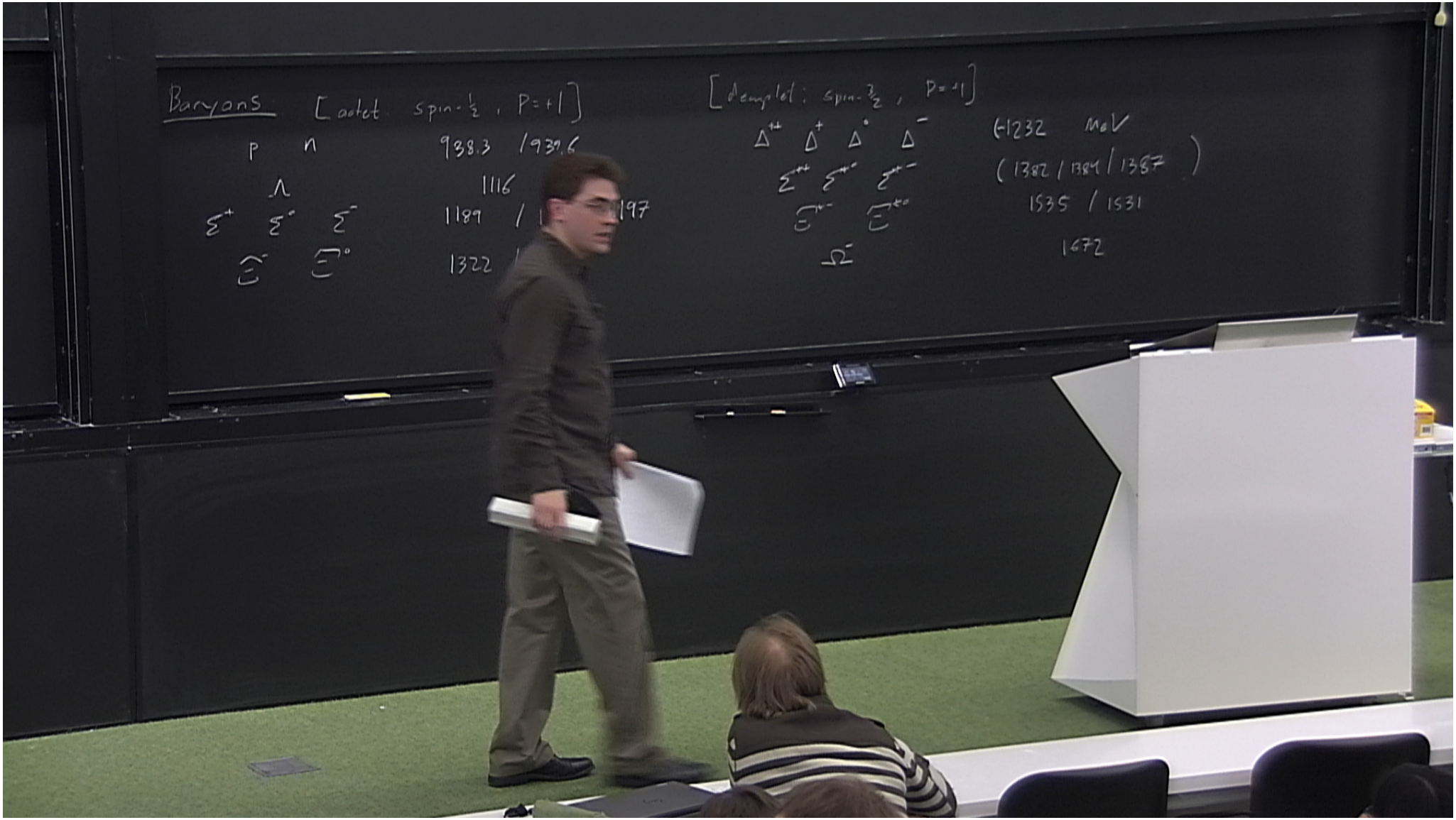

Baryons [octet spin-½, P=+1]
[decuplet
p n 938.3 / 939.6
Λ 1116
Σ+ Σ0 Σ− 1189 / 1192 / 1197
Ξ− Ξ0 1322 / 1315

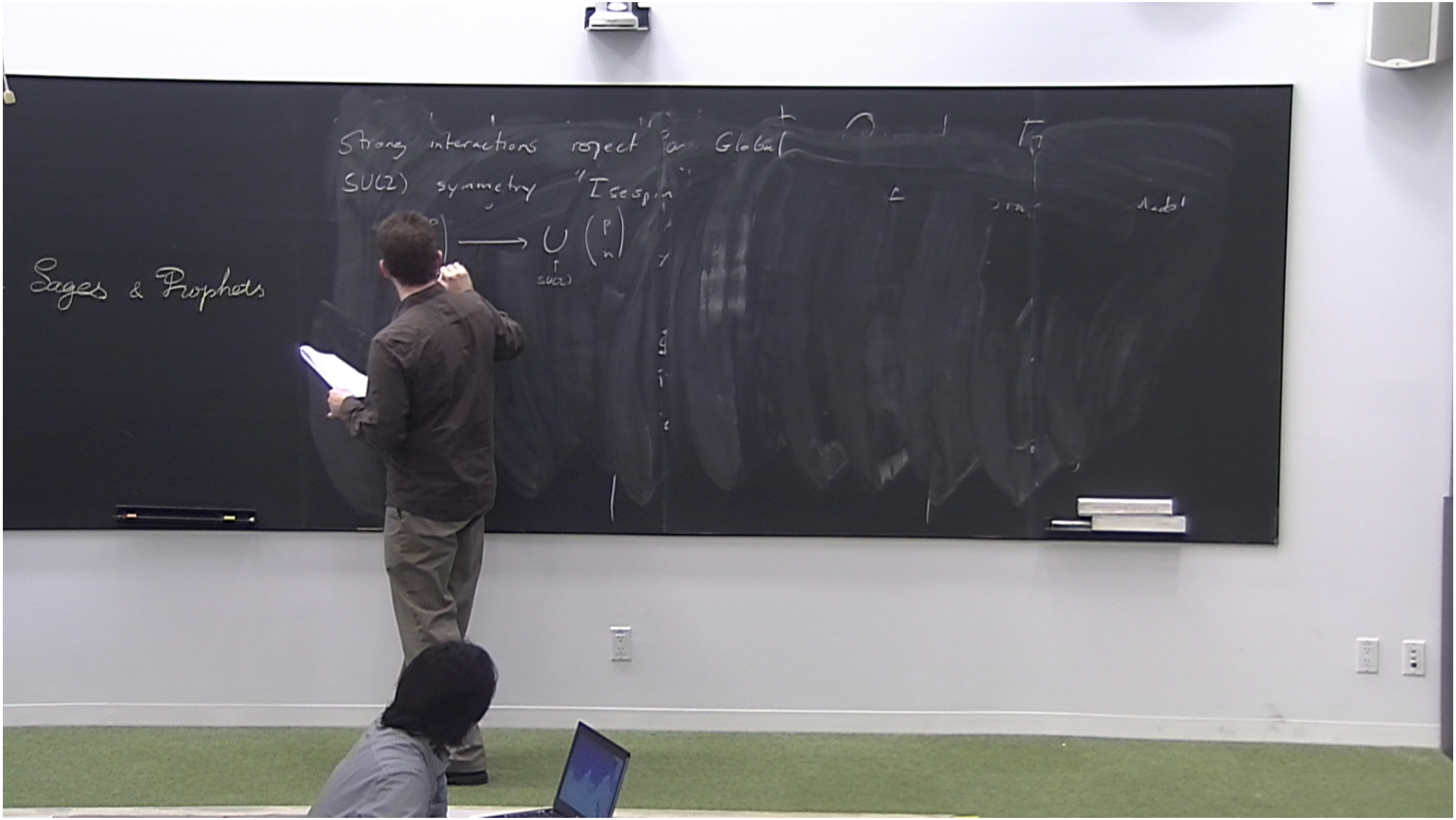

Baryons [octet spin-½, P=+1]
p n 938.3 / 939.6
Λ 1116
Σ+ Σ0 Σ- 1189 / 1192 / 1197
Ξ- Ξ0 1322 / 1315
[decuplet: spin-3/2, P=+1]

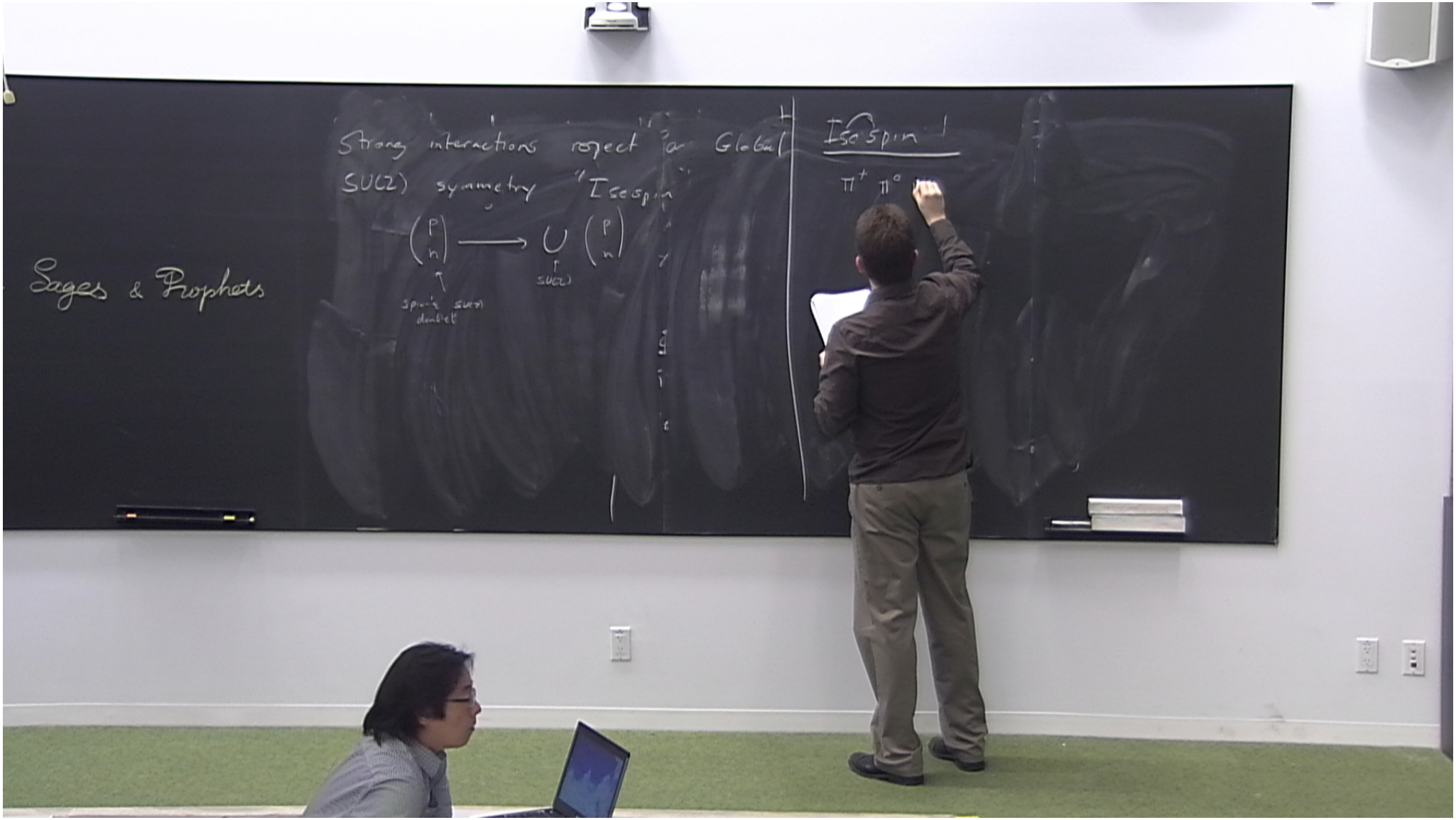

Baryons [octet spin-½, P=+1]
p n
938.3 / 939.6
Λ
1116
Σ+ Σ0 Σ−
1189 / 1192 / 1197
Ξ− Ξ0
1322 / 1315
[decuplet: spin-3/2, P=+1]
Δ++ Δ+ Δ0 Δ−
Σ*+ Σ*0 Σ*−
Ξ*− Ξ*0
Ω−
1232
(1382 / 138

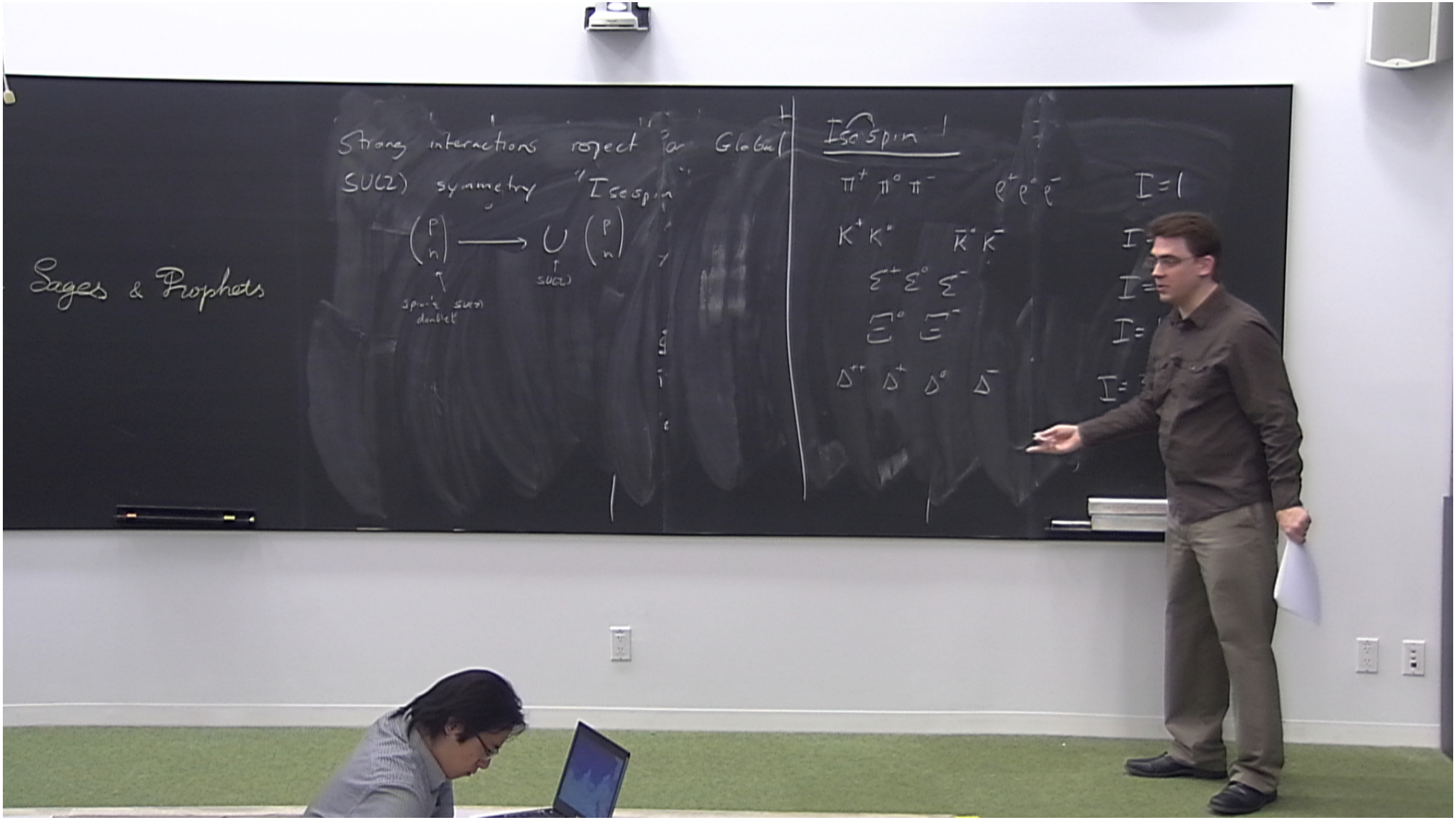

Baryons [octet spin-½, P=+1]
p n
Λ
Σ+ Σ0 Σ−
Ξ− Ξ0
939.6
1192 / 1197
1315
[decuplet: spin-3/2, P=+1]
Δ++ Δ+ Δ0 Δ−
Σ*+ Σ*0 Σ*−
Ξ*− Ξ*0
Ω−
1232 MeV
(1382 / 1384 / 1387)
1535 / 1531
1672

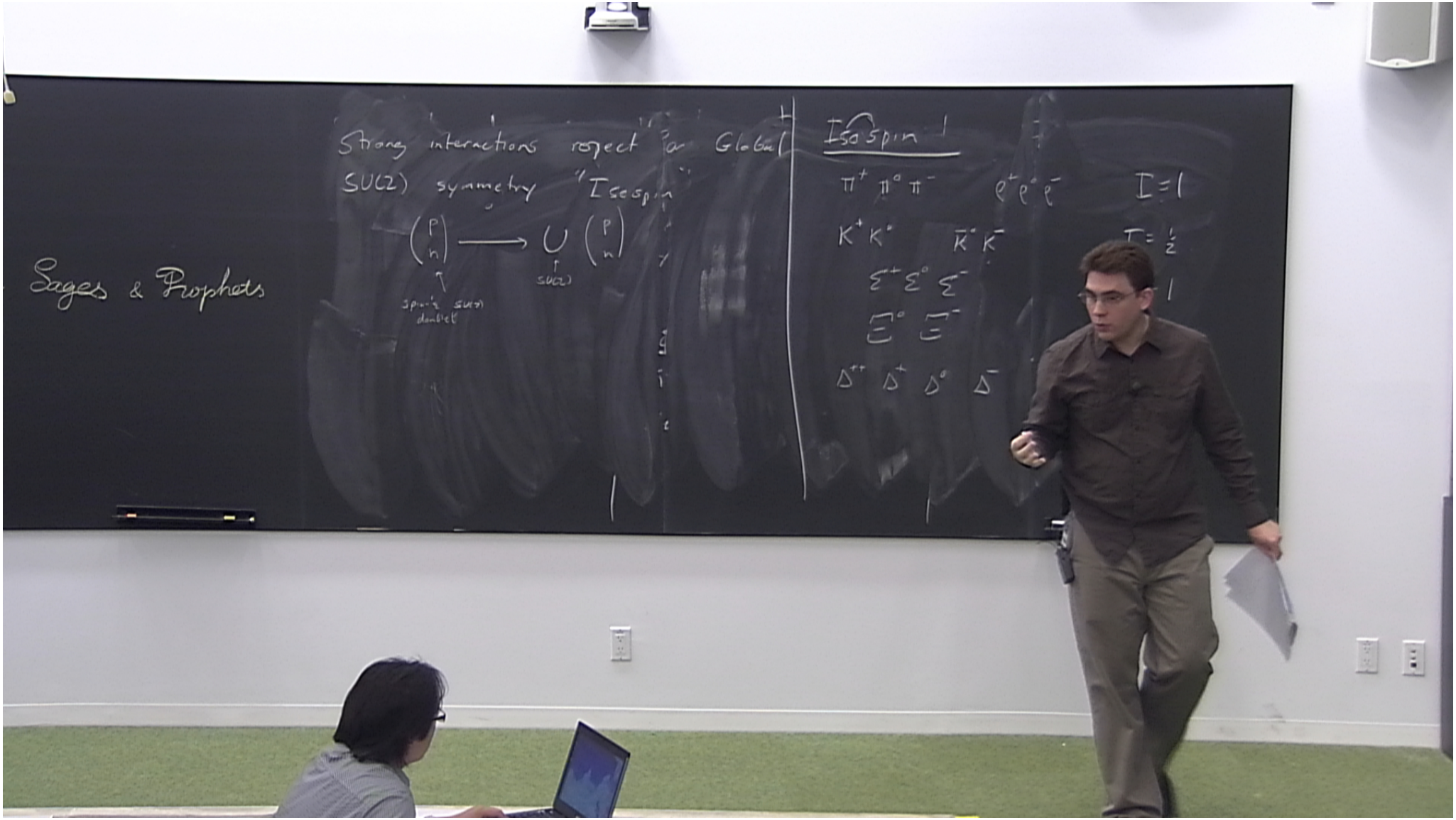

Baryons [octet spin-½, P=+1]
p n 938.3 / 939.6
Λ 1116
Σ+ Σ0 Σ− 1189 / 1192 / 1197
Ξ− Ξ0 1322 / 1315
[decuplet: spin-3/2, P=+1]
Δ++ Δ+ Δ0 Δ− +1232 MeV
Σ*+ Σ*0 Σ*− (1382 / 1384 / 1387)
Ξ*− Ξ*0 1535 / 1531
Ω− 1672

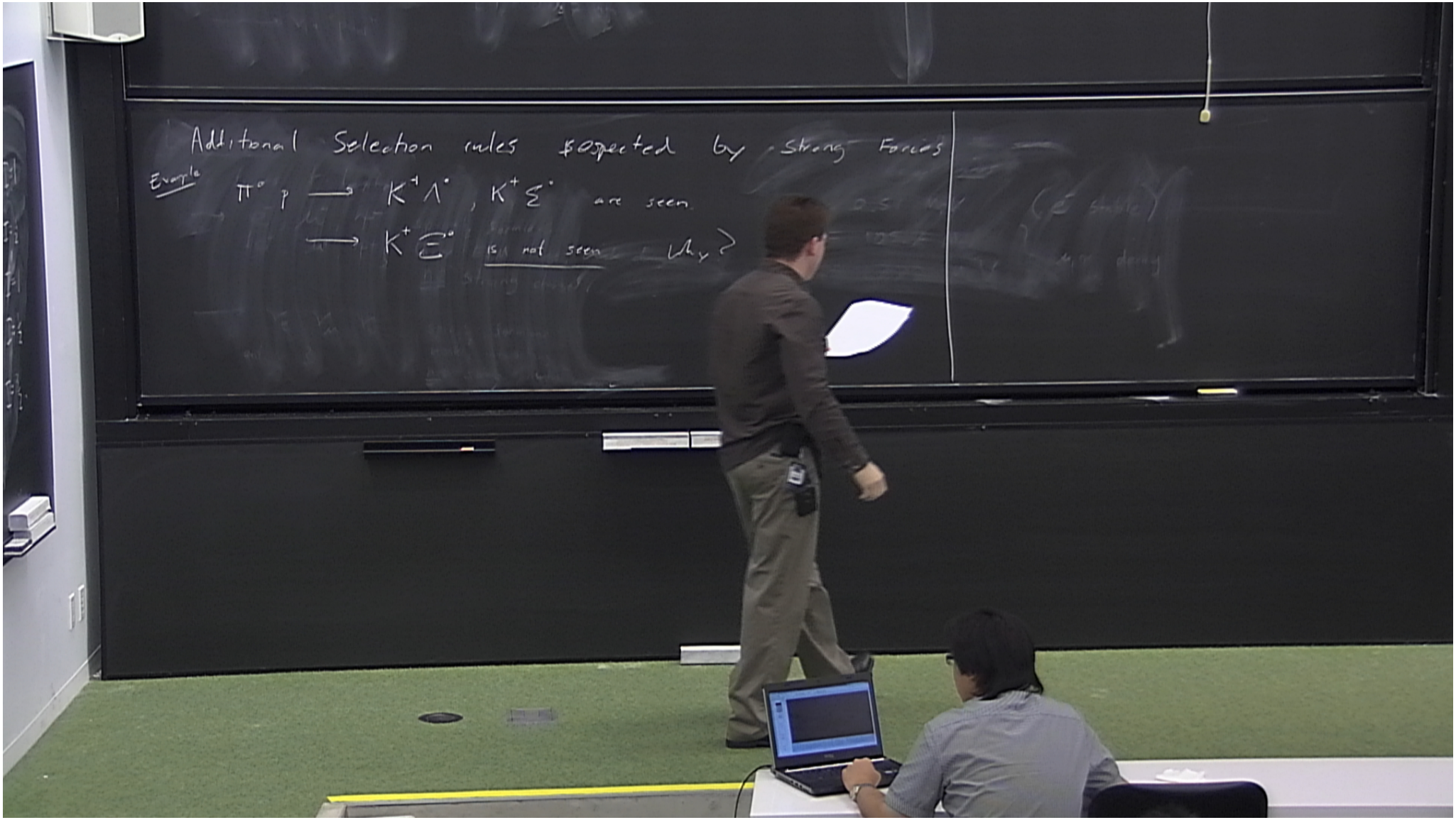

Baryons [octet spin-½, P=+1]
p n
938.3 / 939.6
Λ
1116
Σ+ Σ0 Σ−
1189 /
Ξ− Ξ0
1322
[decuplet: spin-3/2, P=+1]
Δ++ Δ+ Δ0 Δ−
1232 MeV
Σ*+ Σ*0 Σ*−
(1382 / 1384 / 1387)
Ξ*− Ξ*0
1535 / 1531
Ω−
1672

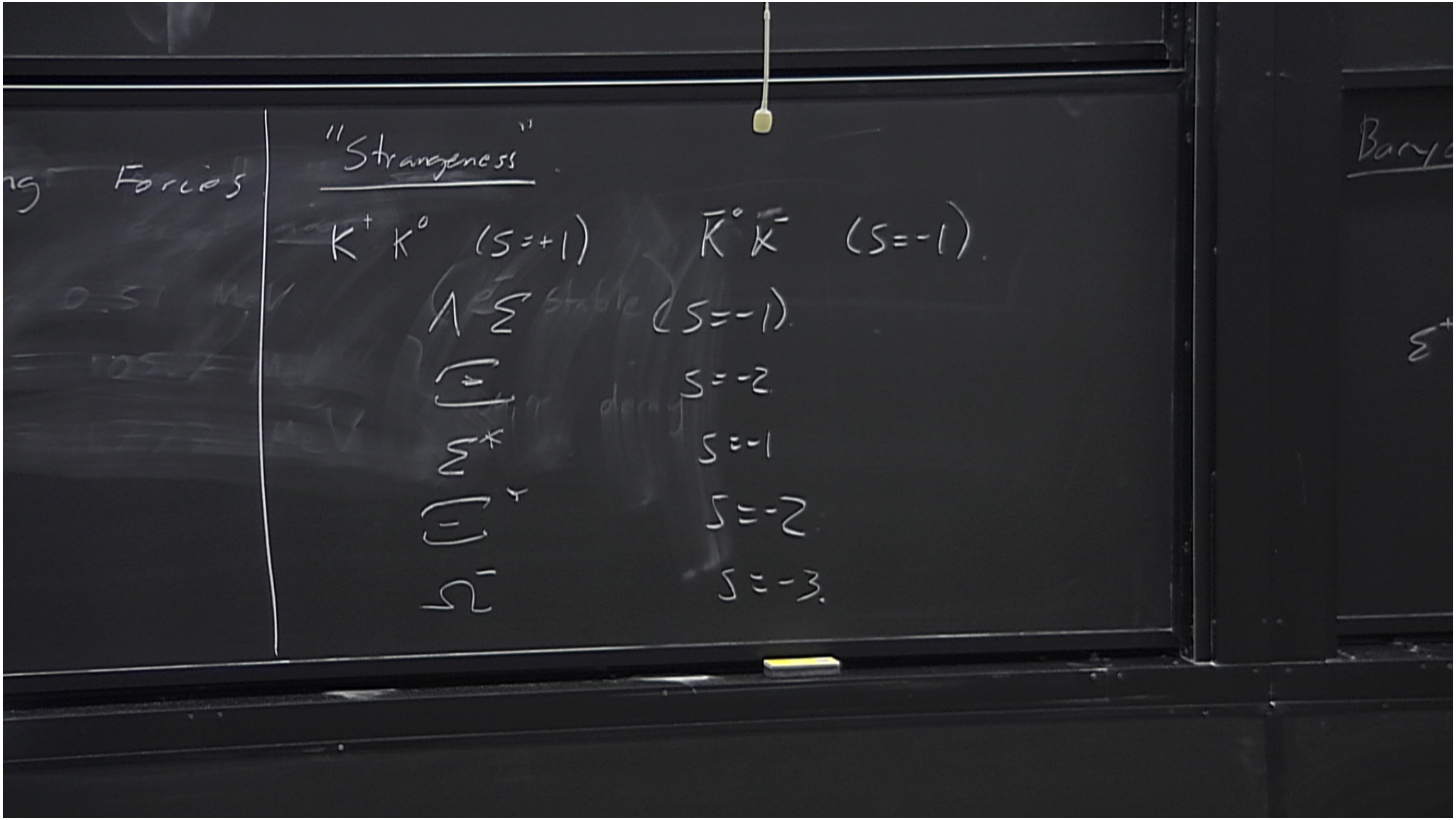

Strong interactions reject
SU(2) symmetry "Isospin
Sages & Prophets

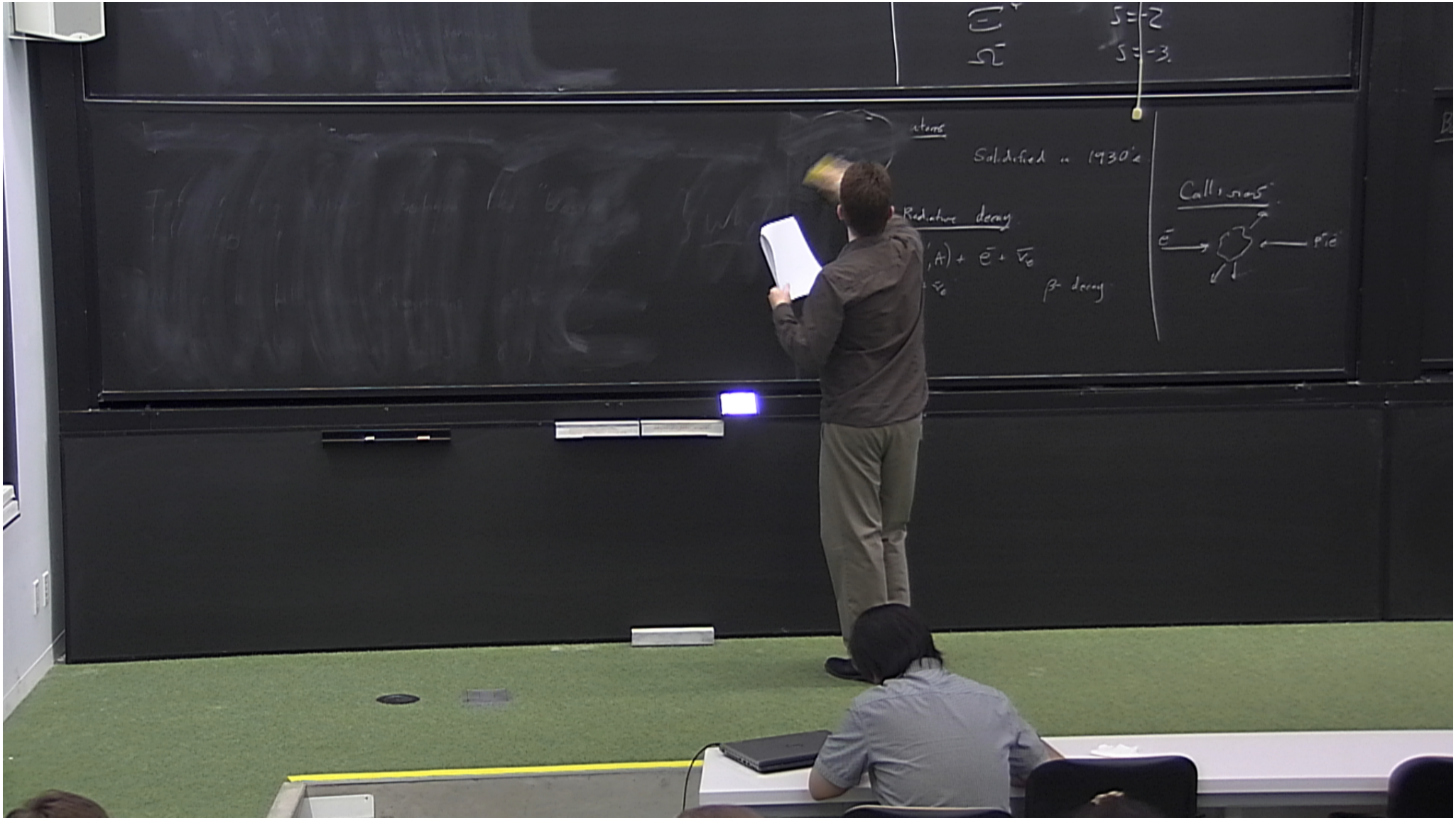

Strong interactions reject a Global
SU(2) symmetry "Isospin"
Isospin !
Sages & Prophets

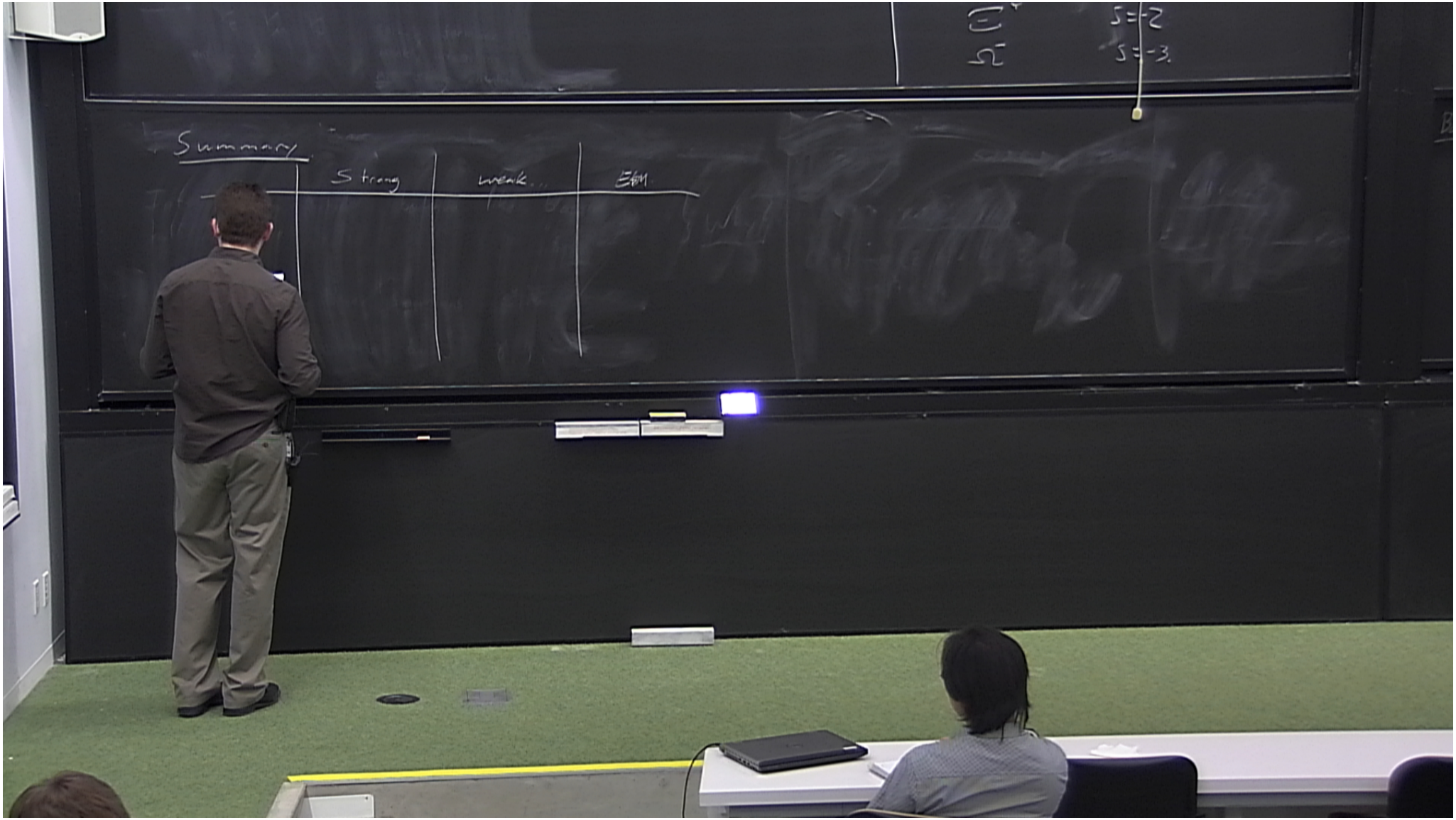

Strong interactions reject as Global
SU(2) symmetry "Isospin"
Isospin !
Sages & Prophets

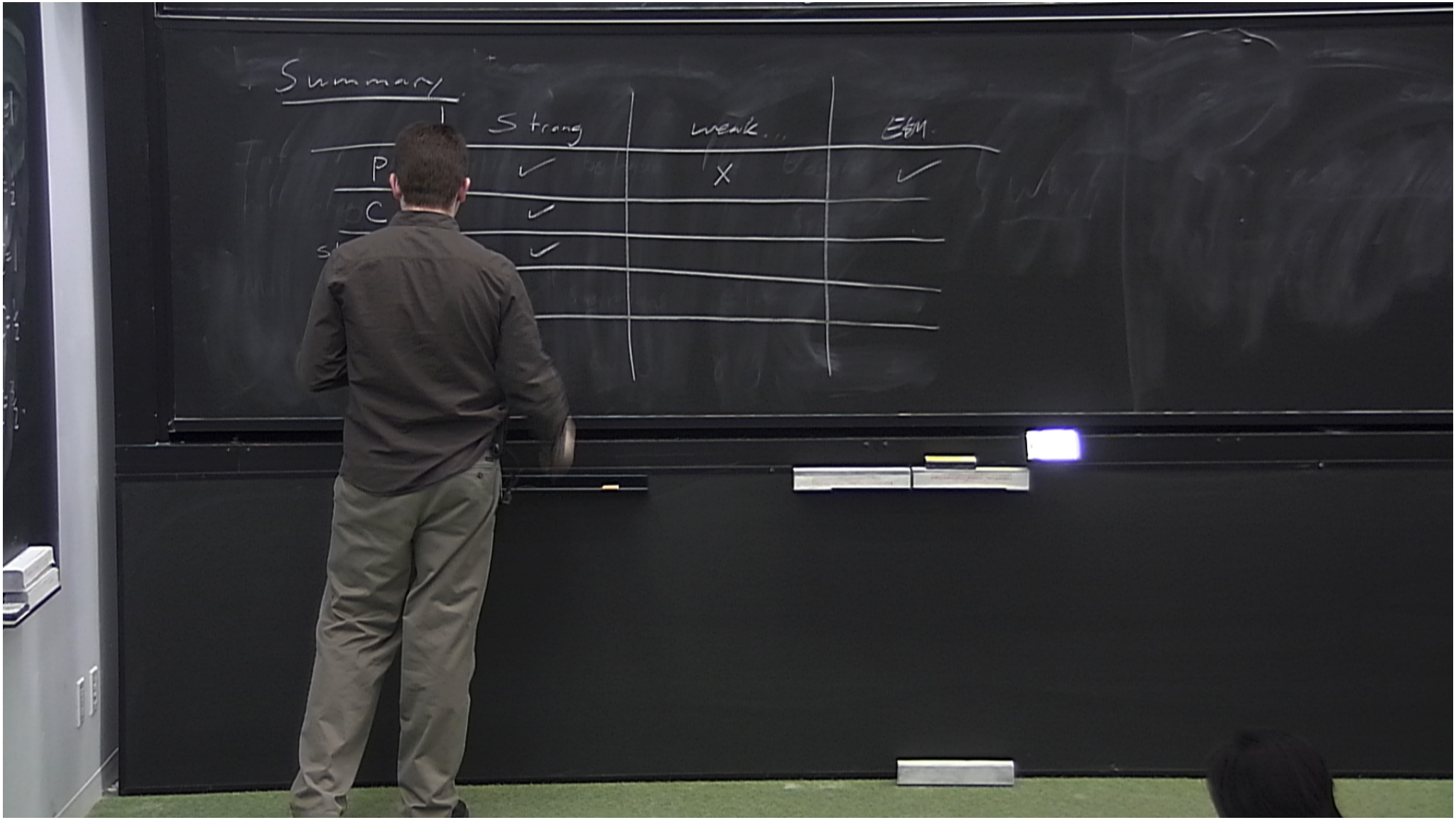

Sages & Prophets
Strong interactions reject as Global
SU(2) symmetry "Isospin"
Isospin !
I=1
I=½
1

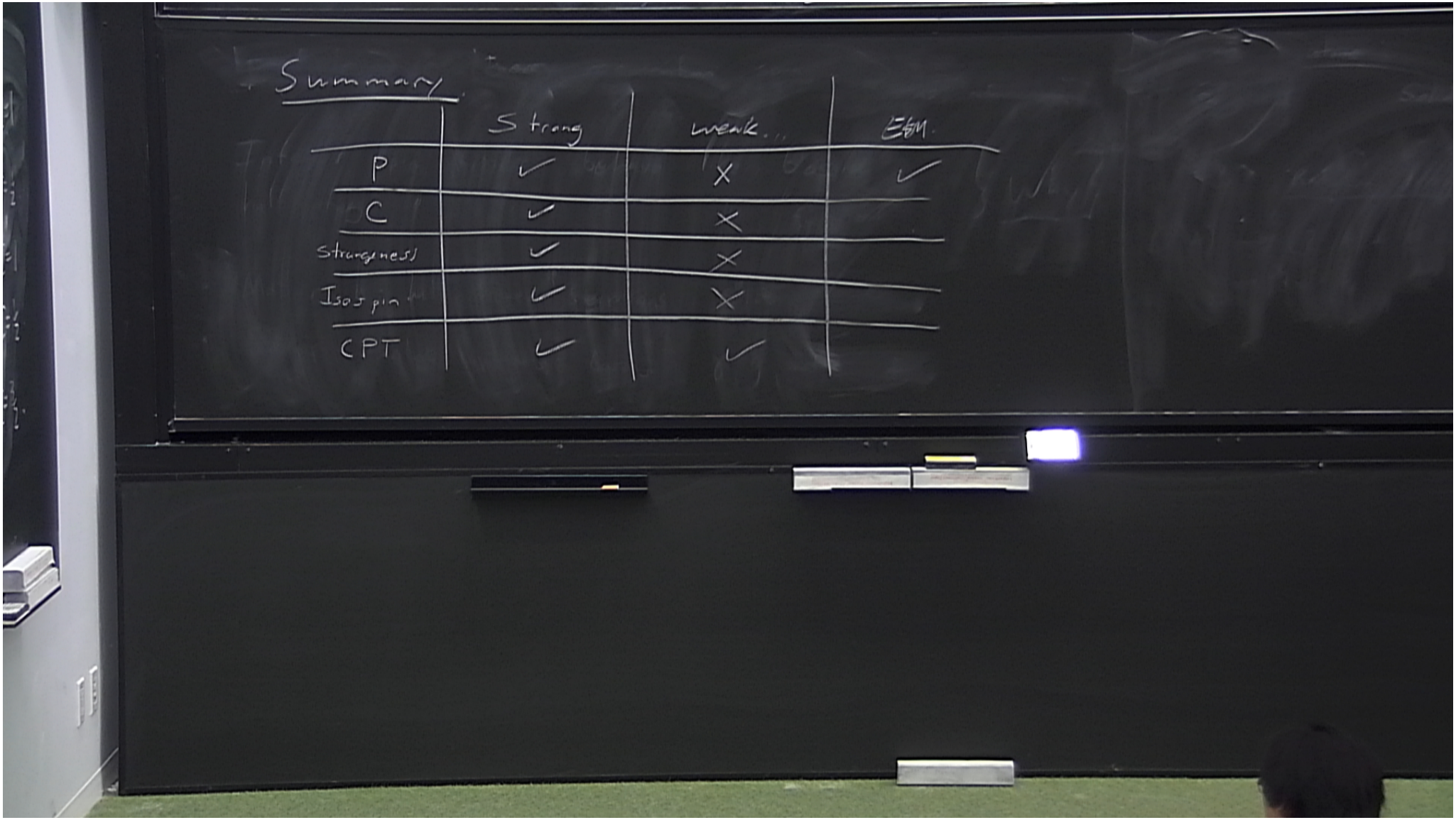

Additional Selection rules expected by Strong Forces
Example
$\pi^- p \longrightarrow K^+ \Lambda^0$, $K^+ \Sigma^-$ are seen
$\longrightarrow K^+ \Xi^-$ is not seen Why?

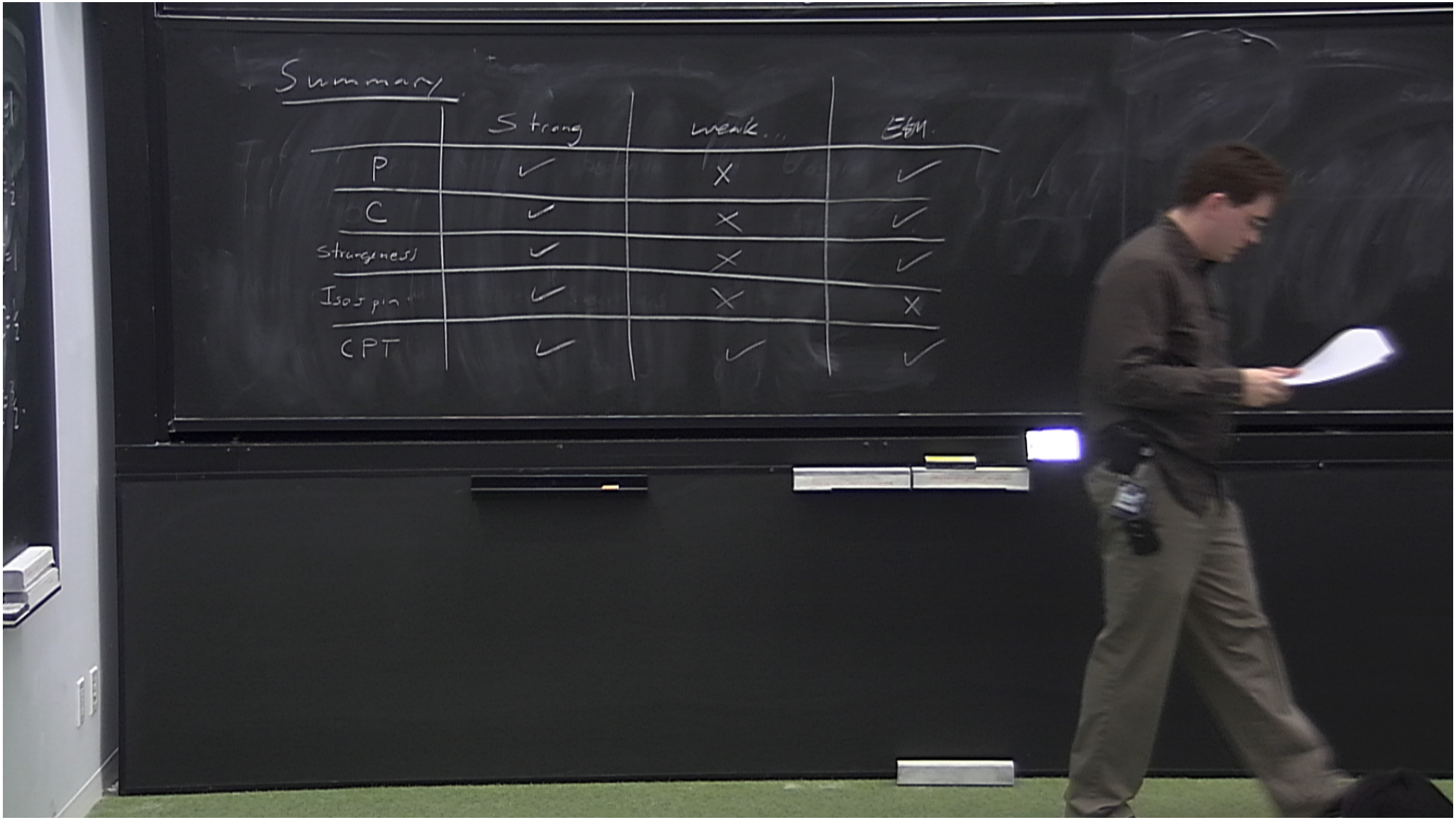

Forces
"Strangeness"
$K^+ K^0$ $(S=+1)$
$\bar{K}^0 K^-$ $(S=-1)$
$\Lambda\ \Sigma$ $(S=-1)$
Ξ $S=-2$
Σ^* $S=-1$
Ξ^* $S=-2$
Ω^- $S=-3$


Solidified in 1930's
Radiative decay
β- decay
Collisions


Summary
Strong
Weak
EM


Summary
Strong
Weak
EM
P
C


Summary
Strong
Weak
EM
P
C
Strangeness
Isospin
CPT


Summary
Strong
Weak
EM
P
C
Strangeness
Isospin
CPT