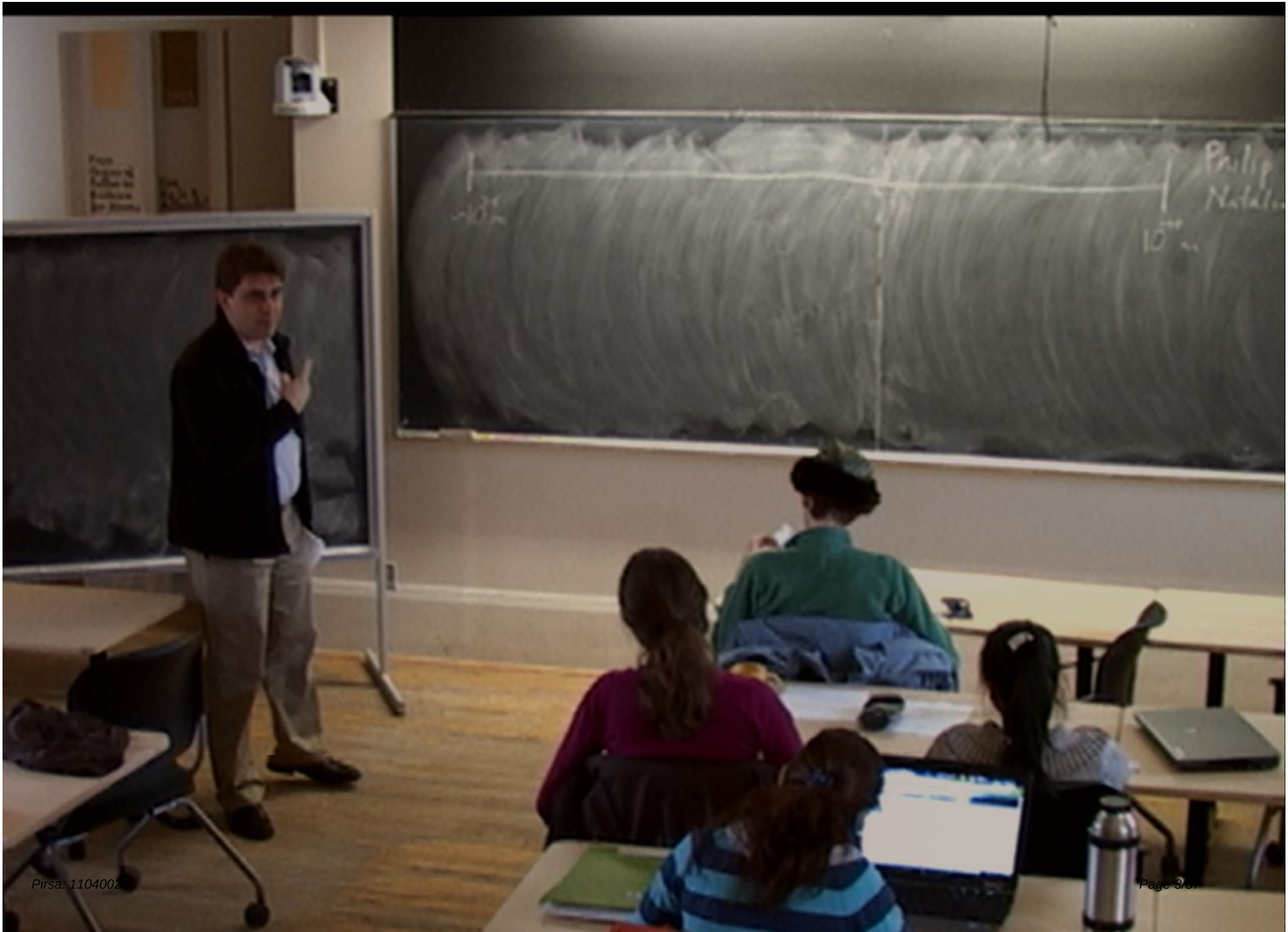
Title: Explorations in Particle Theory - Lecture 1

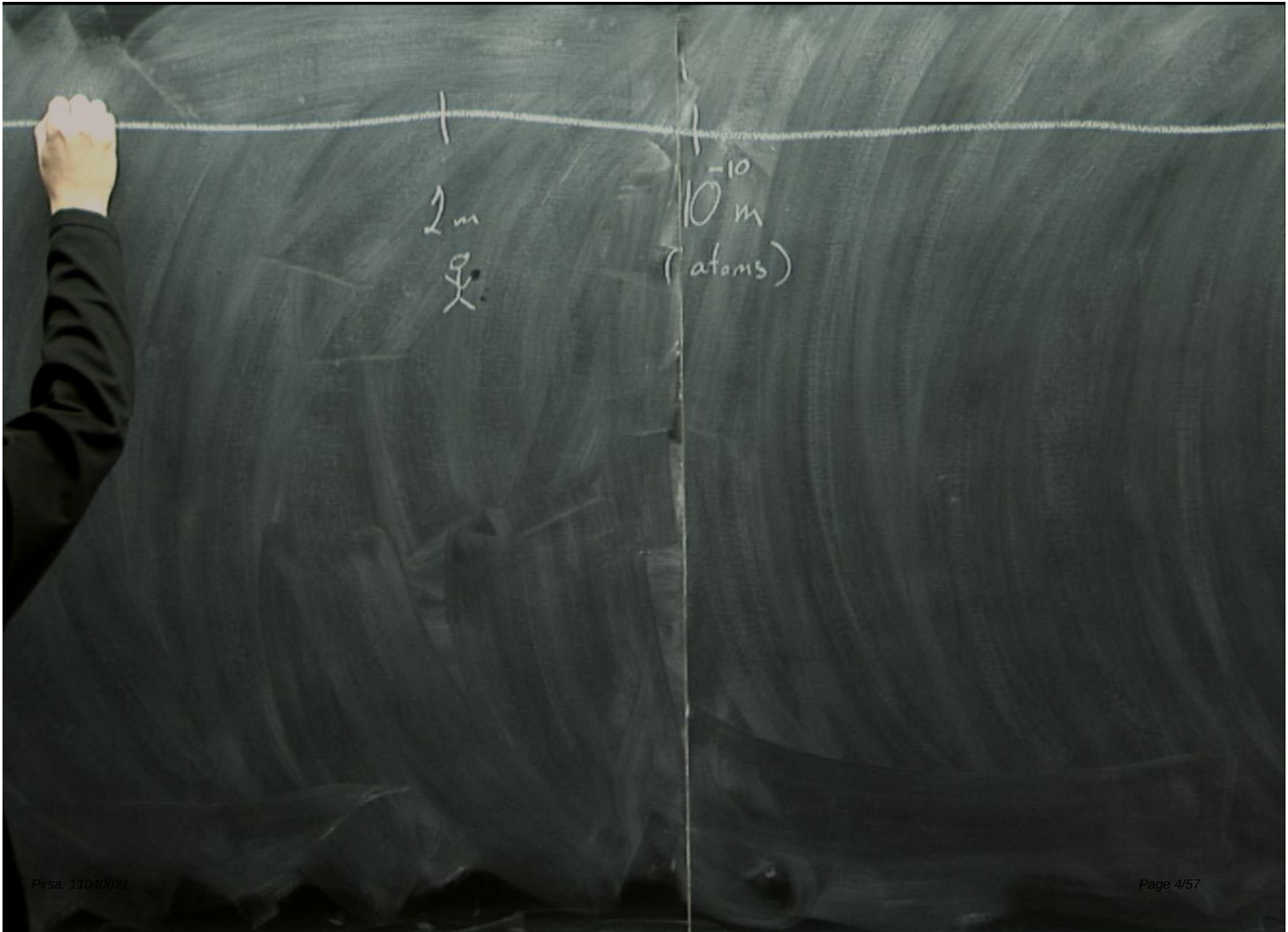
Date: Apr 04, 2011 10:15 AM

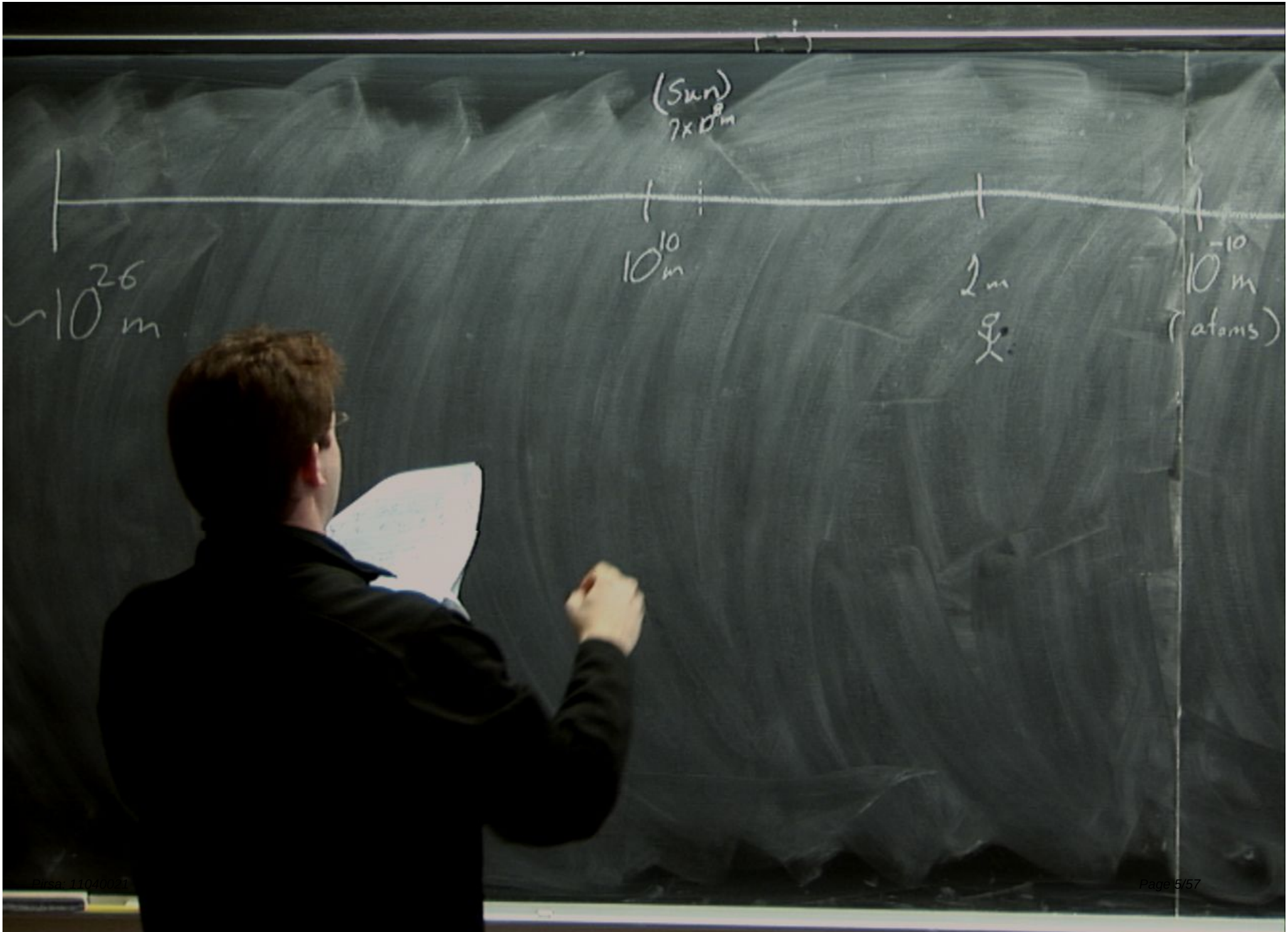
URL: http://pirsa.org/11040021

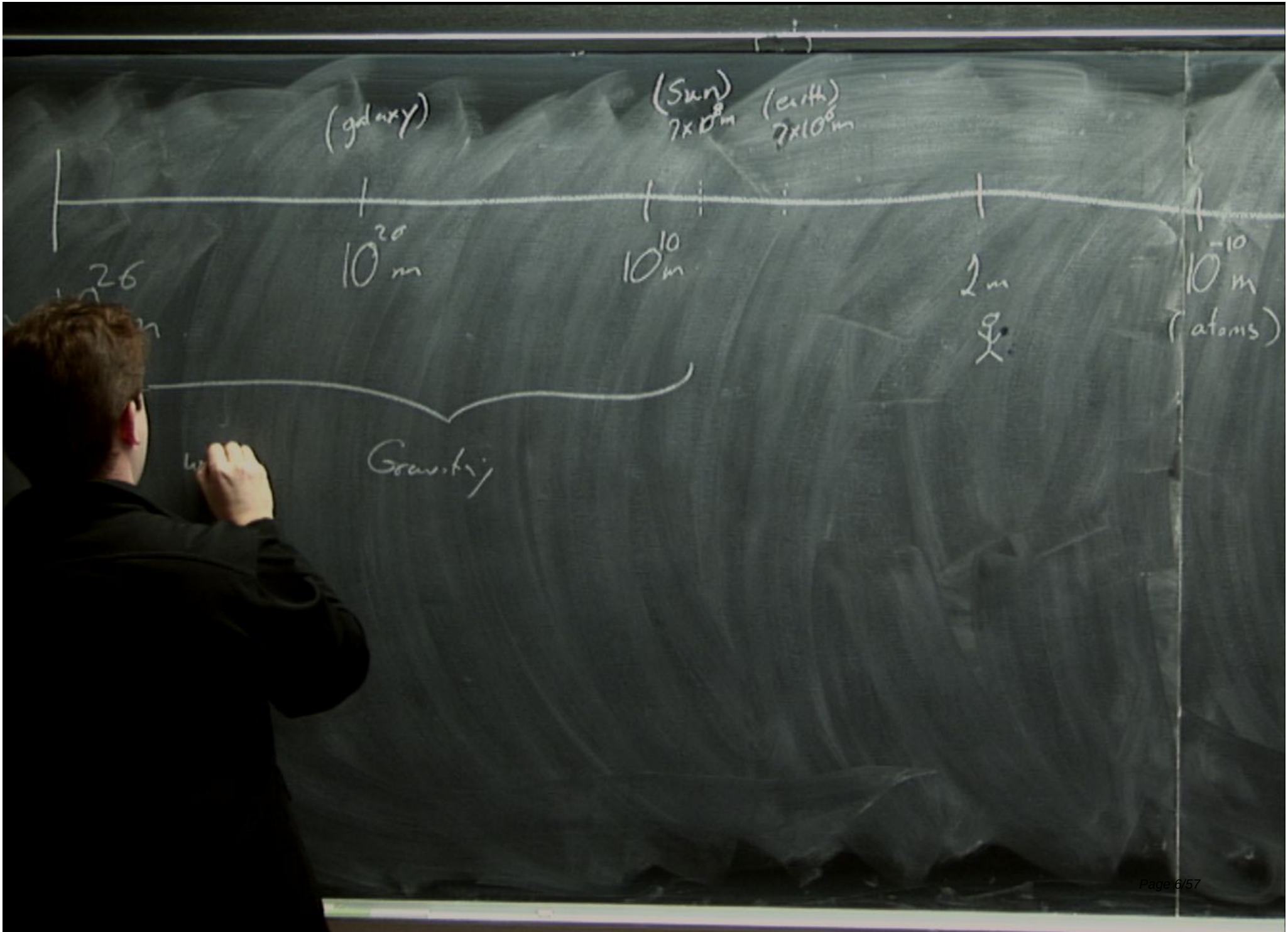
Abstract:

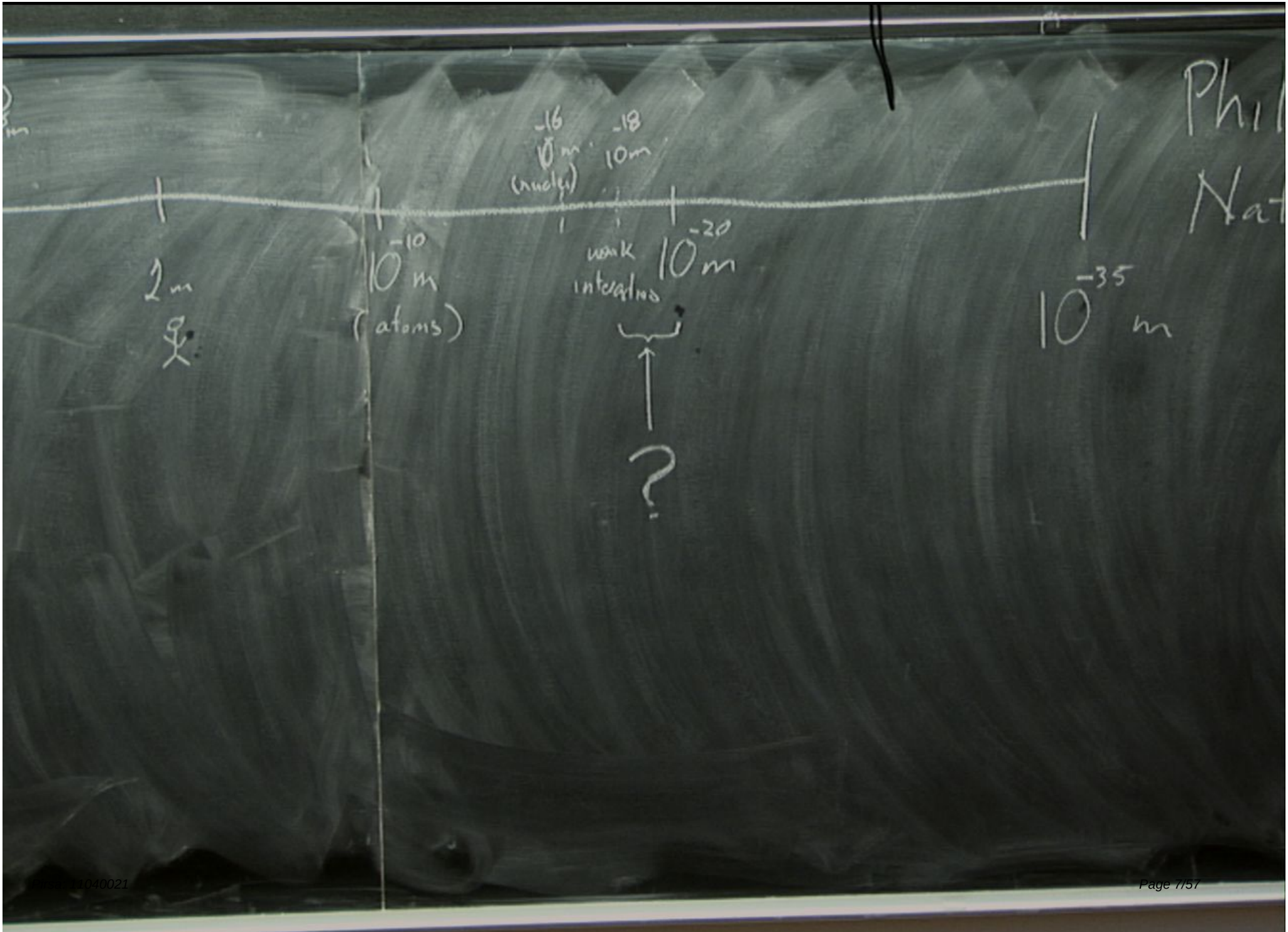

perimeter scholars
international

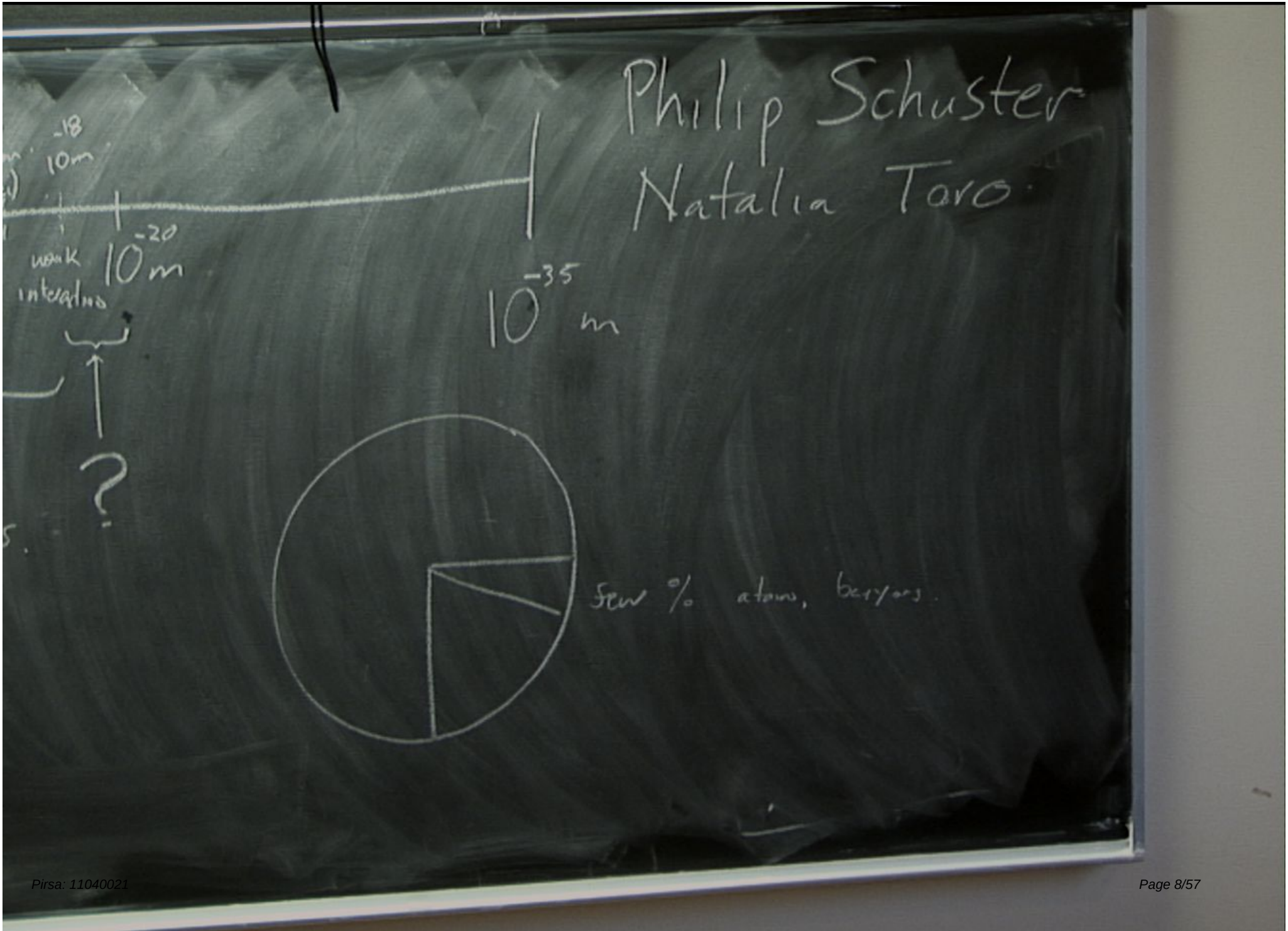


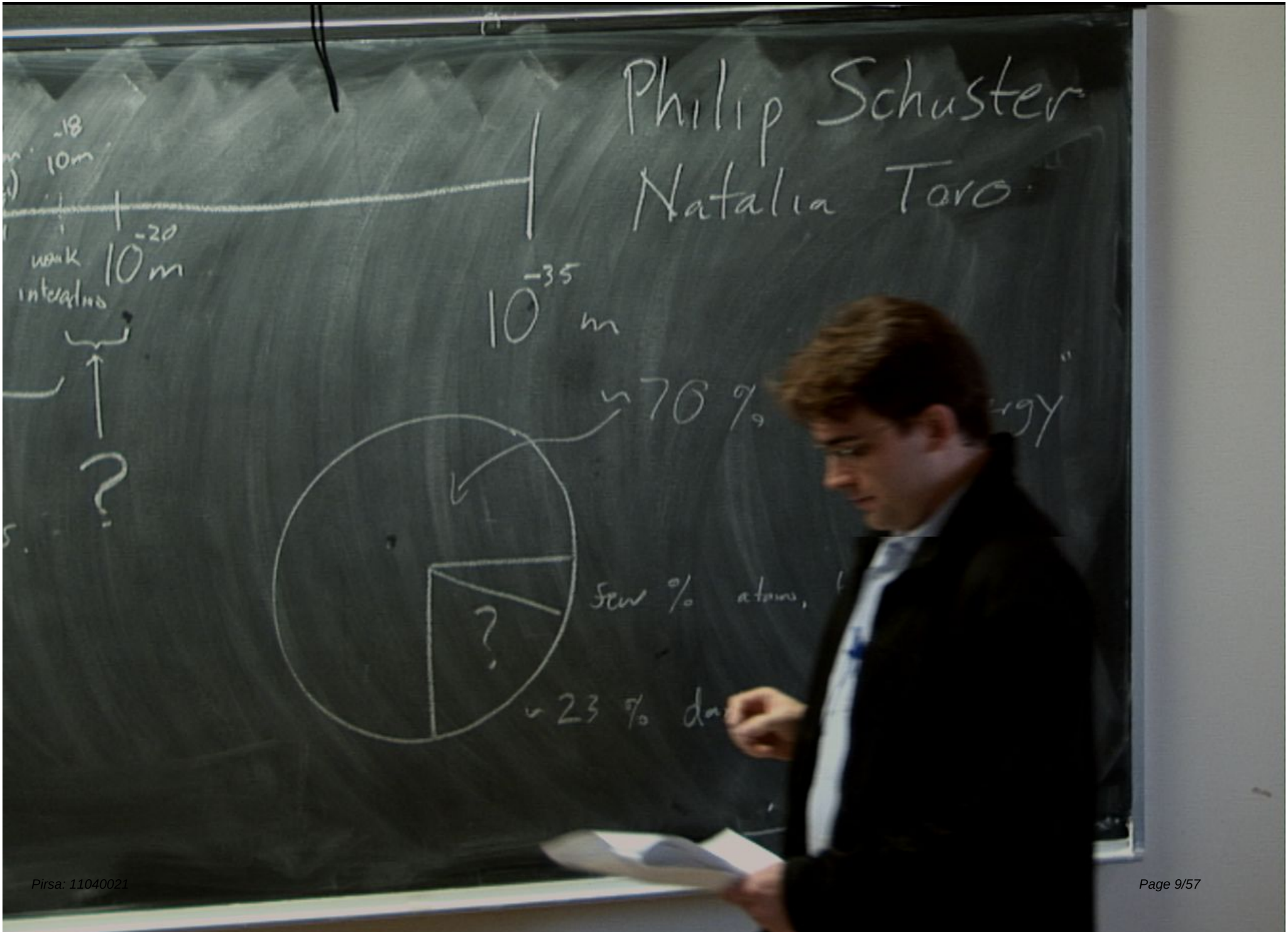

1
1
1 m
10^{-10} m
(atoms)

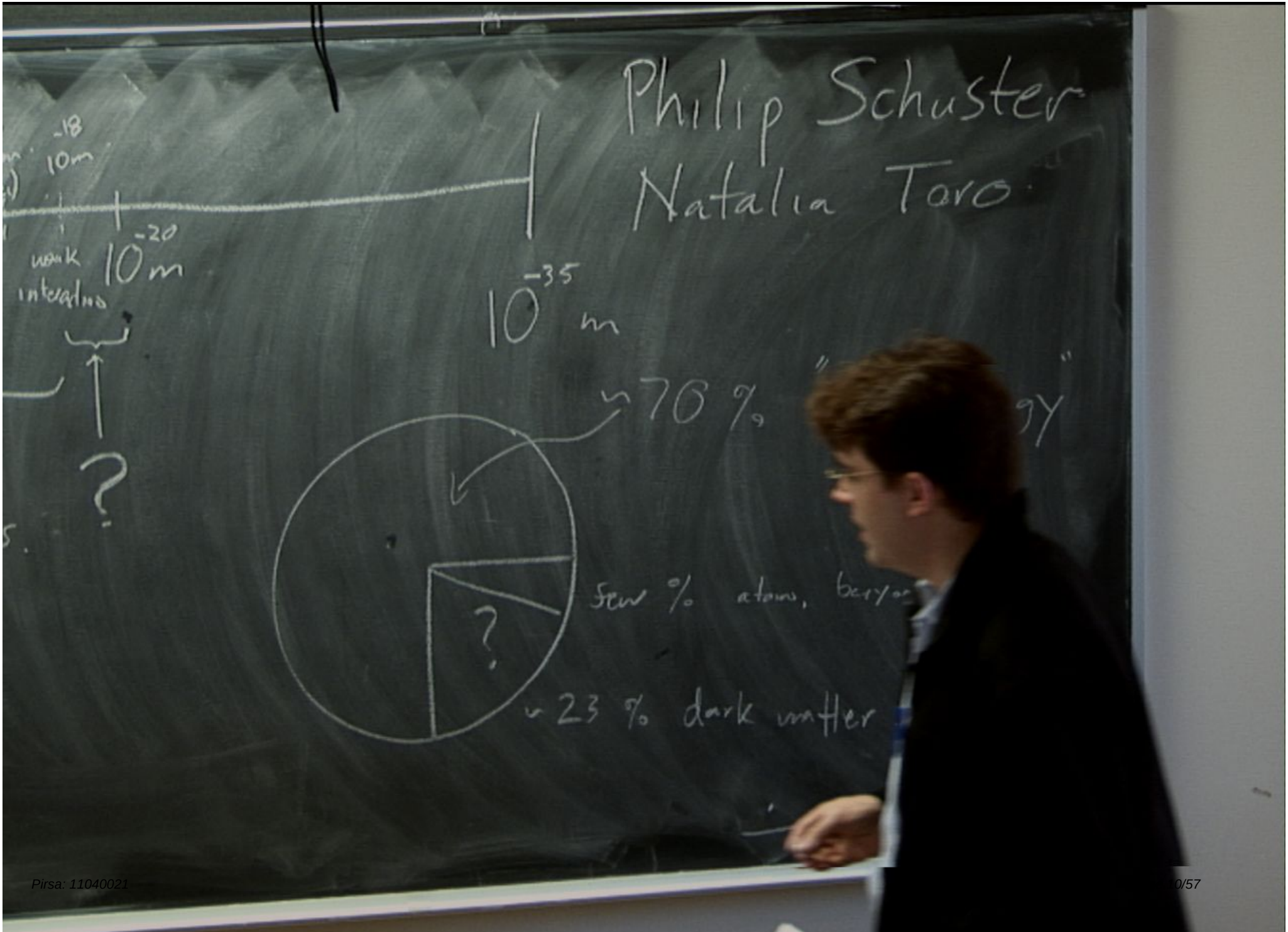

(Sun)
7×10^8 m
10^{10} m
2 m
10^{-10} m
(atoms)
$\sim 10^{26}$ m

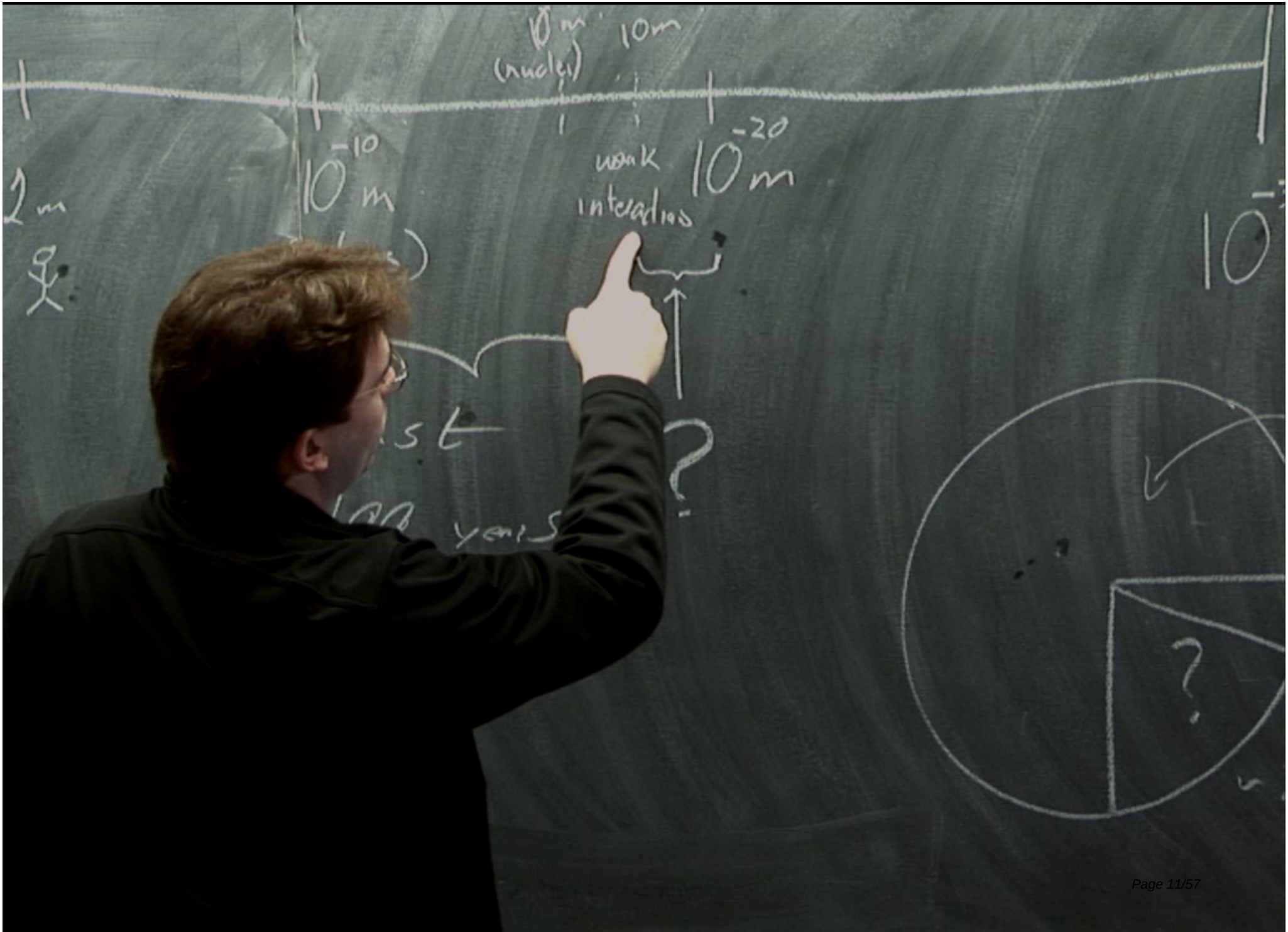

(galaxy)
(Sun)
7×10^8 m
(earth)
7×10^6 m
10^{20} m
10^{10} m
1 m
10^{-10} m
(atoms)
Gravity

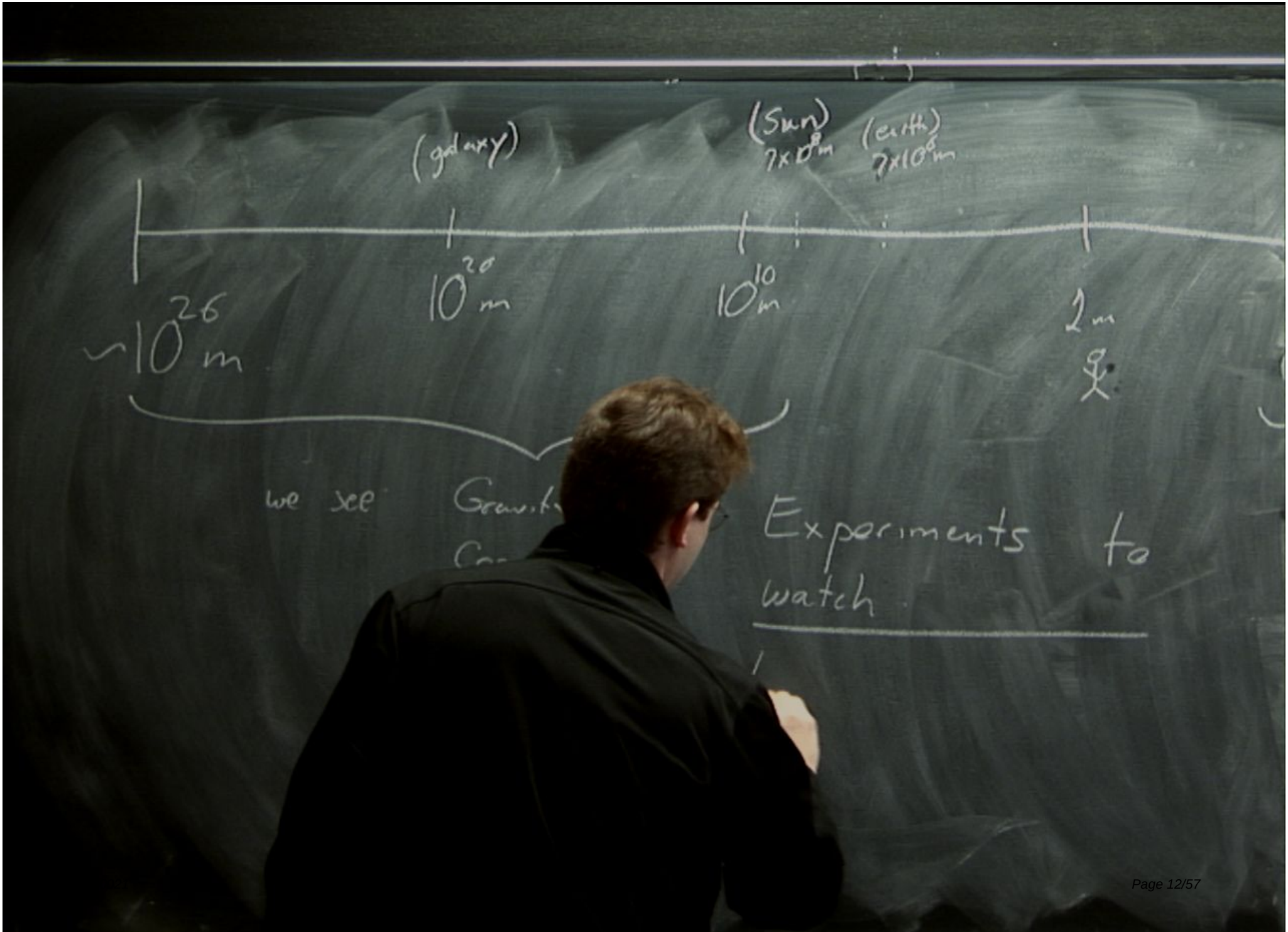

Phil
Nat
2 m
10^{-10} m
(atoms)
10^{-16} m
(nuclei)
10^{-18} m
10^{-20} m
weak interaction
10^{-35} m
?

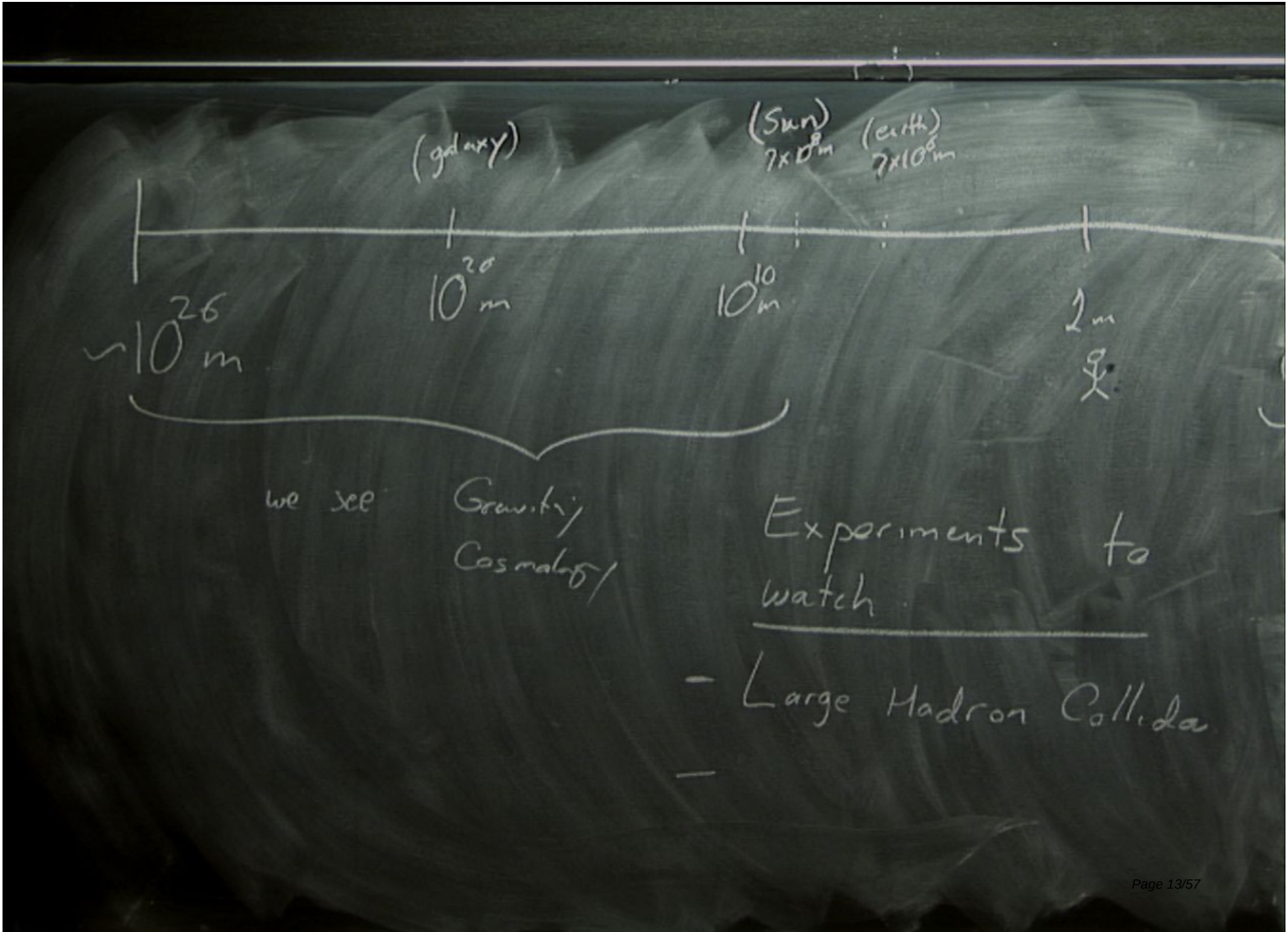

Philip Schuster
Natalia Toro
10^{-18} m
10^{-20} m
weak interactions
10^{-35} m
?
few % atoms, baryons

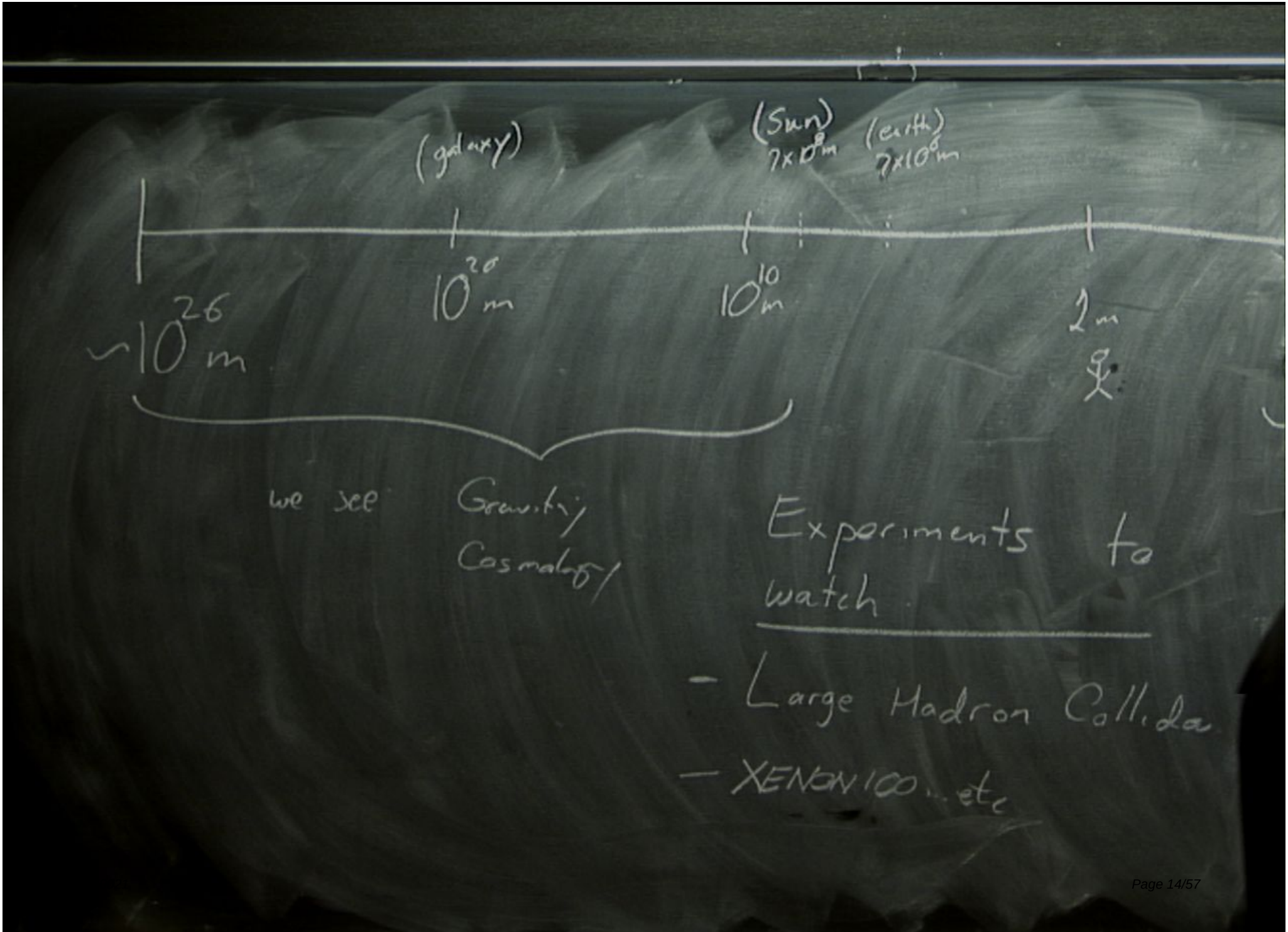

Philip Schuster
Natalia Toro
-18
10m
-20
10 m
weak
interaction
10^-35 m
70 %
few %
23 %
?
?

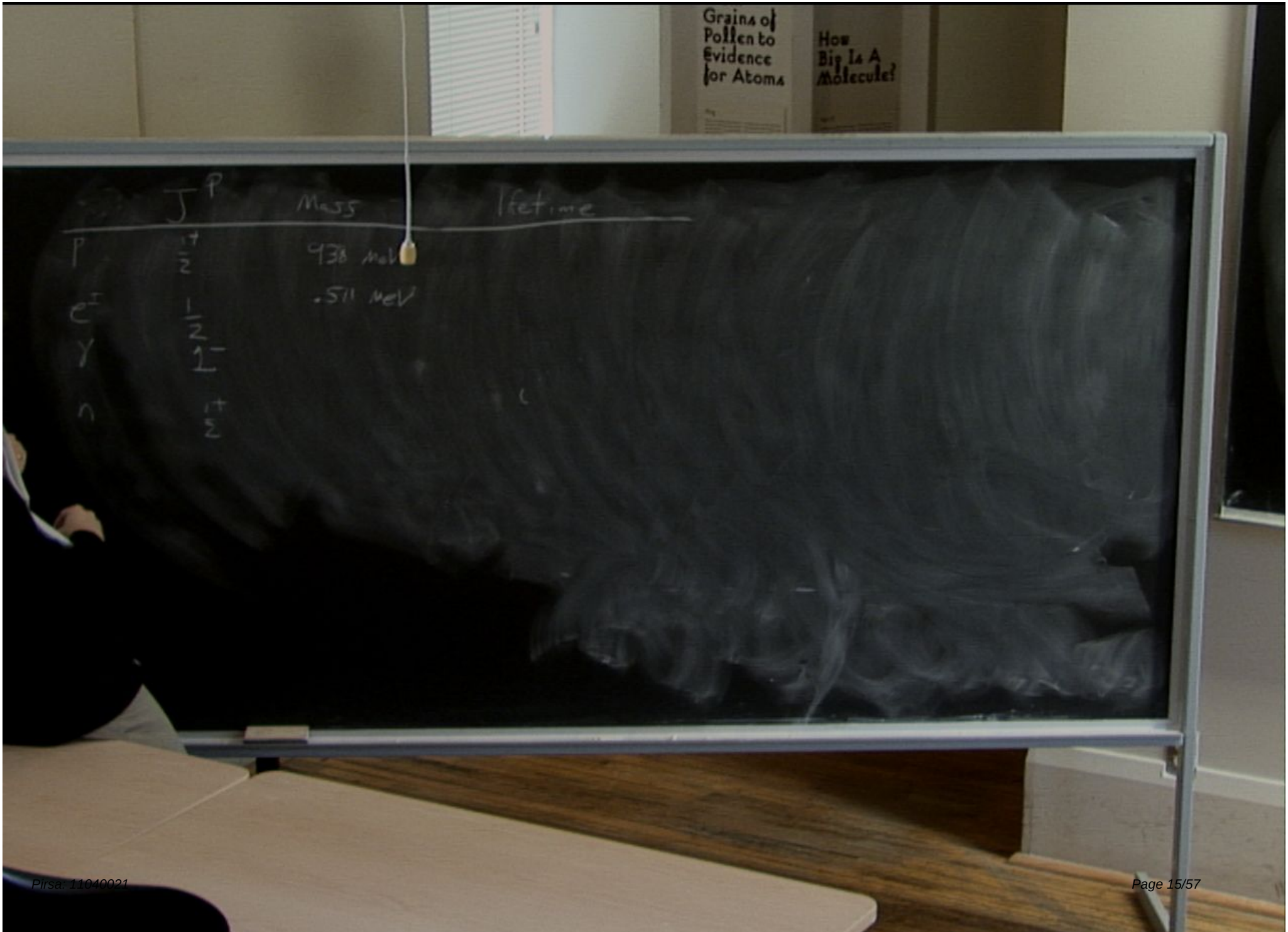

Philip Schuster
Natalia Toro
10^{-18} m
10^{-20} m
weak interaction
10^{-35} m
?
70 %
?
few % atoms, baryo
~23 % dark matter

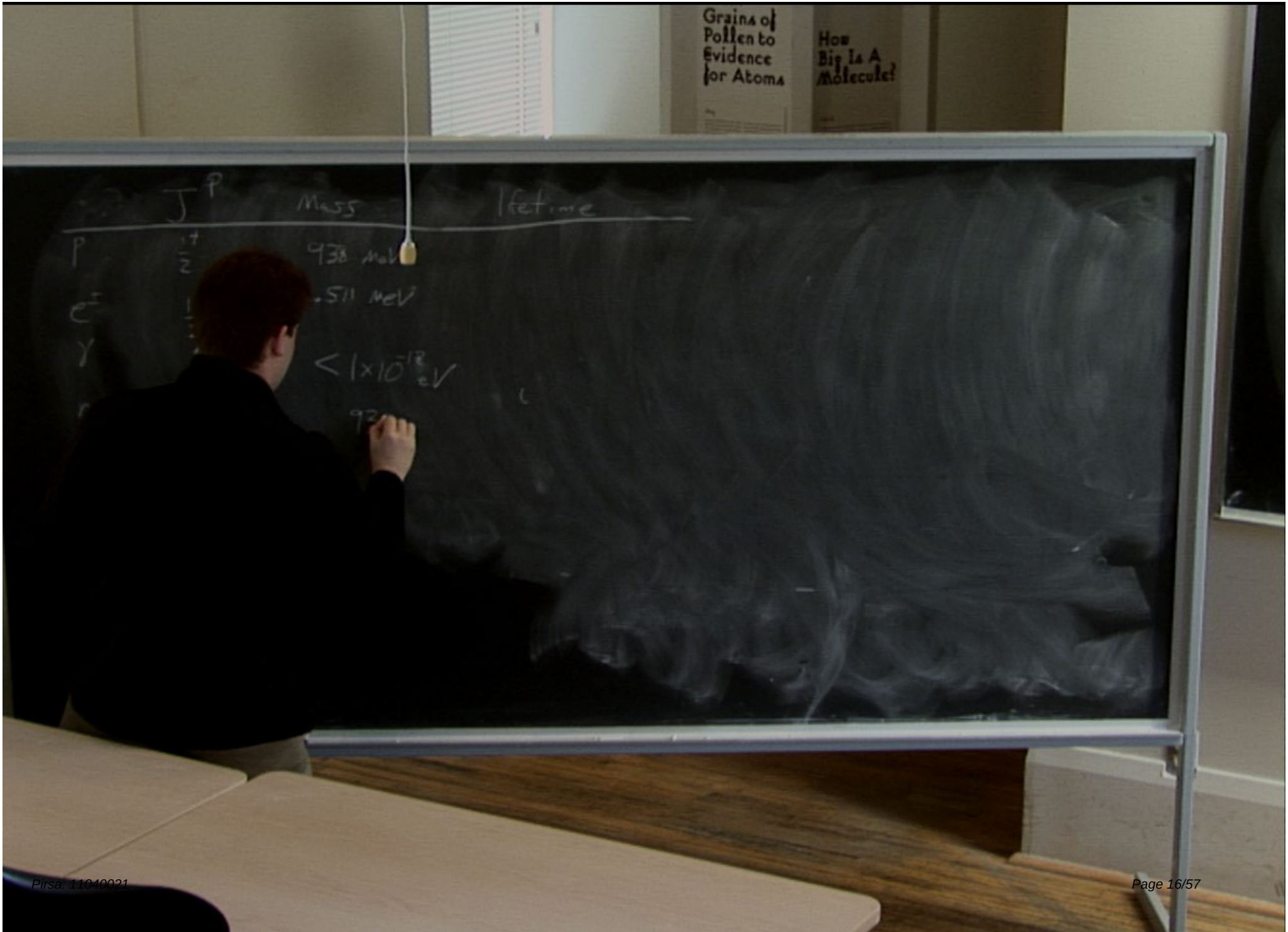

10m
(nuclei)
10^{-10} m
10^{-20} m
weak
interactions
?
?

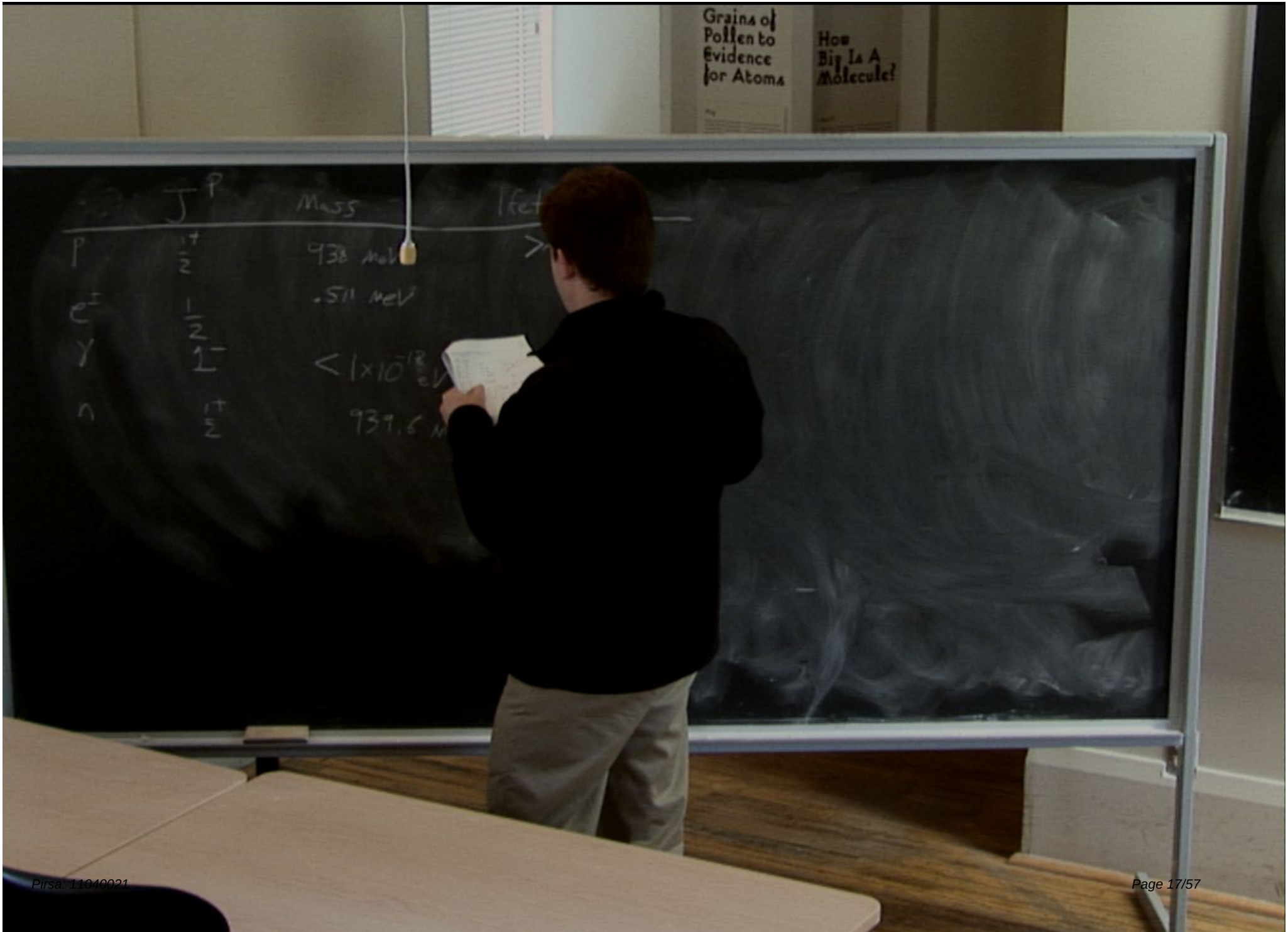

(galaxy)
(Sun)
7×10^8 m
(earth)
7×10^6 m
10^{20} m
10^{10} m
1 m
$\sim 10^{26}$ m
we see
Experiments to watch

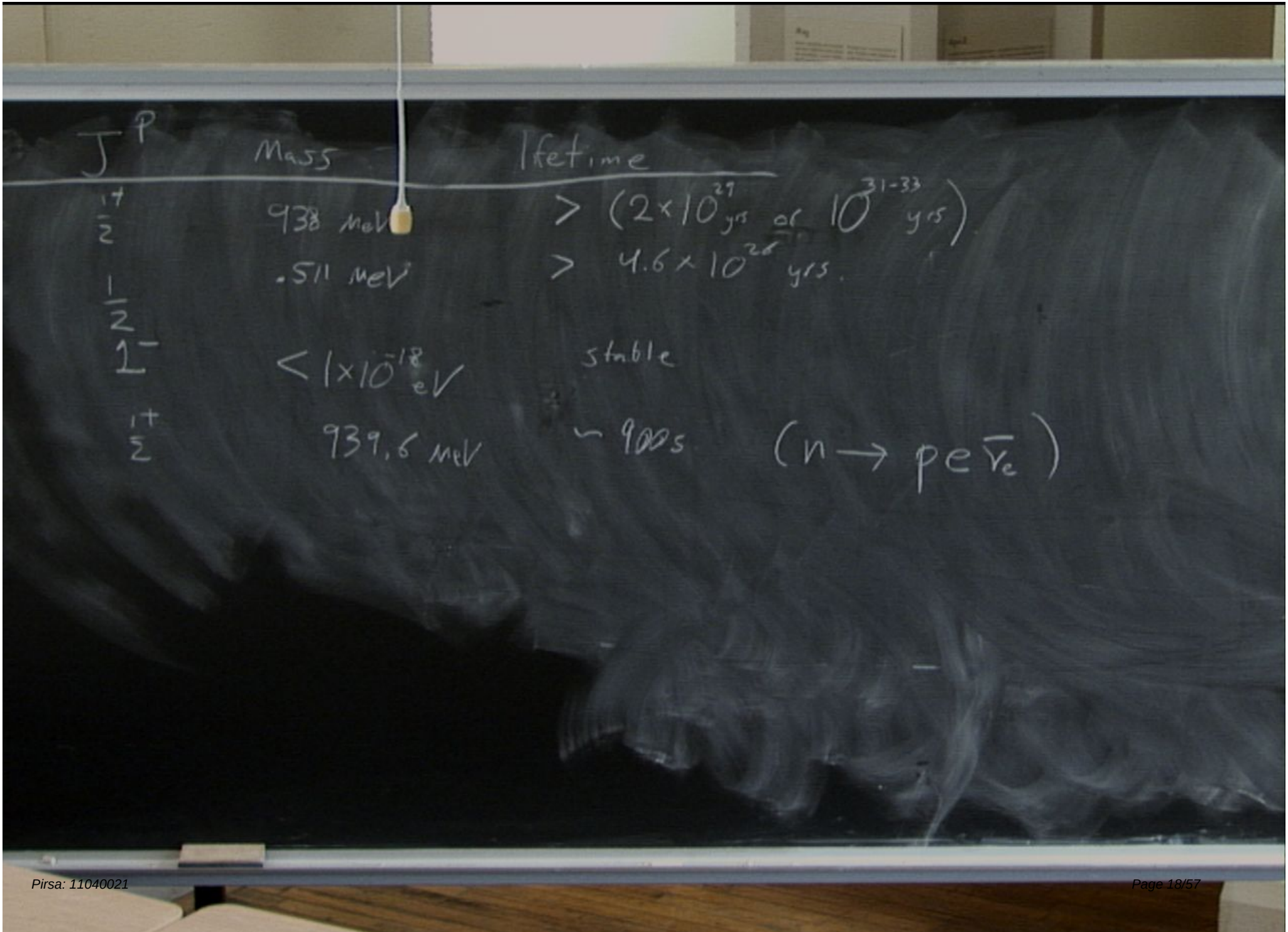

(galaxy)
(Sun)
7×10^8 m
(earth)
7×10^6 m
10^{20} m
10^{10} m
$\sim 10^{26}$ m
1 m
we see Gravity/Cosmology/
Experiments to watch
- Large Hadron Collider
-

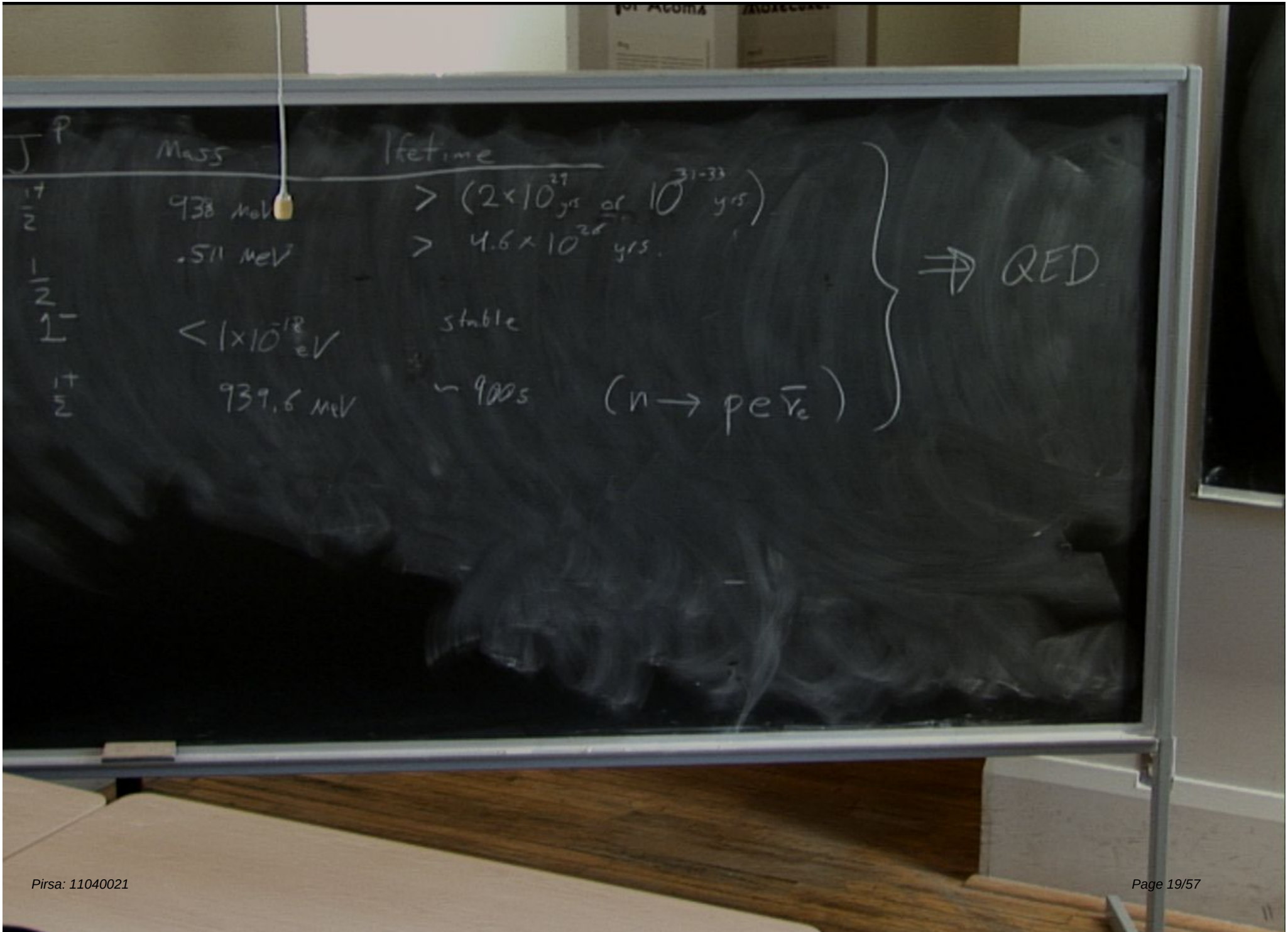

(galaxy)
(Sun)
7×10^8 m
(earth)
7×10^6 m
10^{20} m
10^{10} m
$\sim 10^{26}$ m
2 m
we see
Gravity
Cosmology
Experiments to watch
- Large Hadron Collider
- XENON100 ... etc

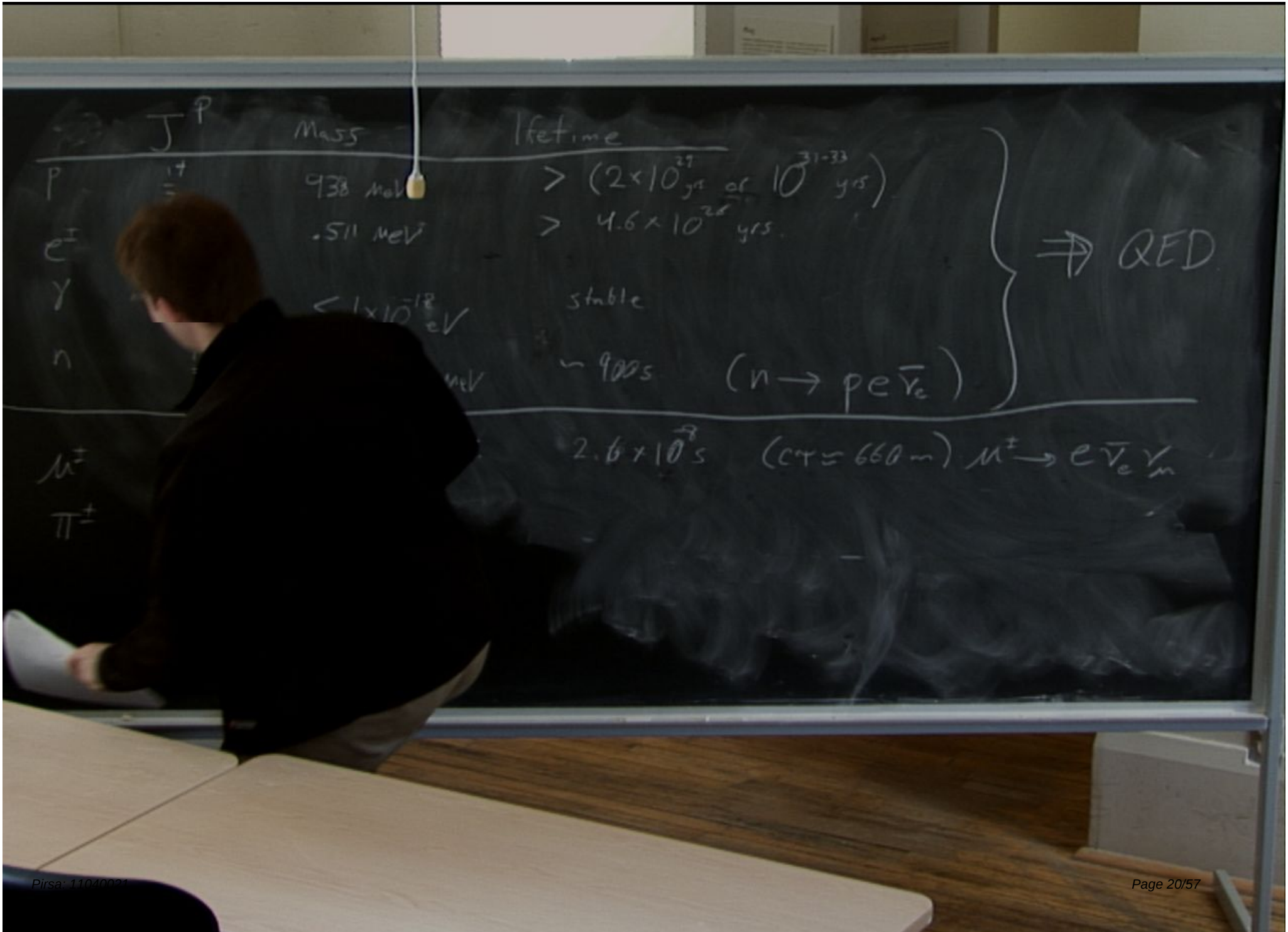

Grains of Pollen to Evidence for Atoms
How Big Is A Molecule?
J^P
Mass
lifetime
p
1/2+
938 MeV
e⁻
1/2
.511 MeV
γ
1⁻
n
1/2+

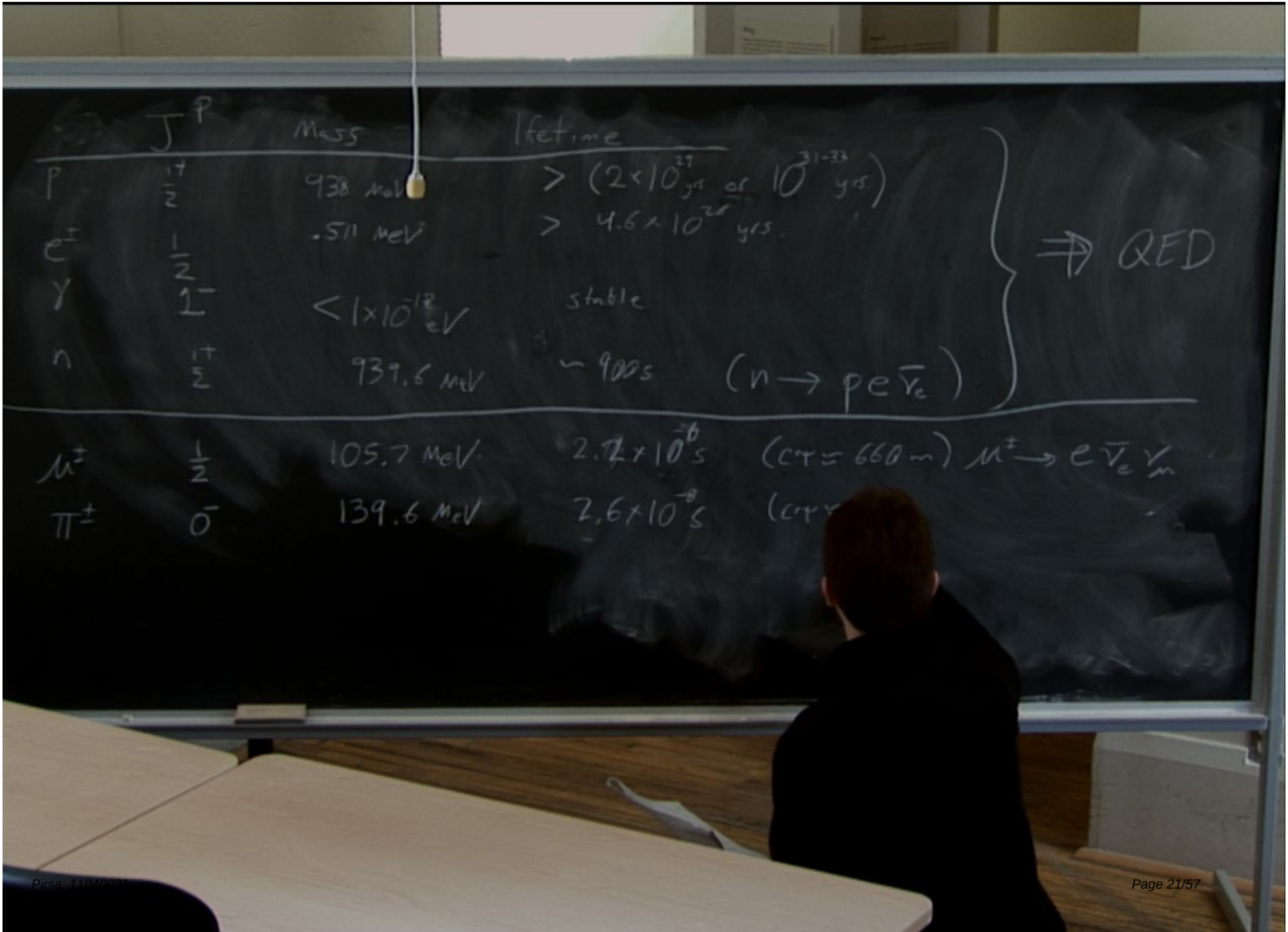

Grains of Pollen to Evidence for Atoms
How Big Is A Molecule?
J^P
Mass
lifetime
938 MeV
.511 MeV
< 1×10^-18 eV

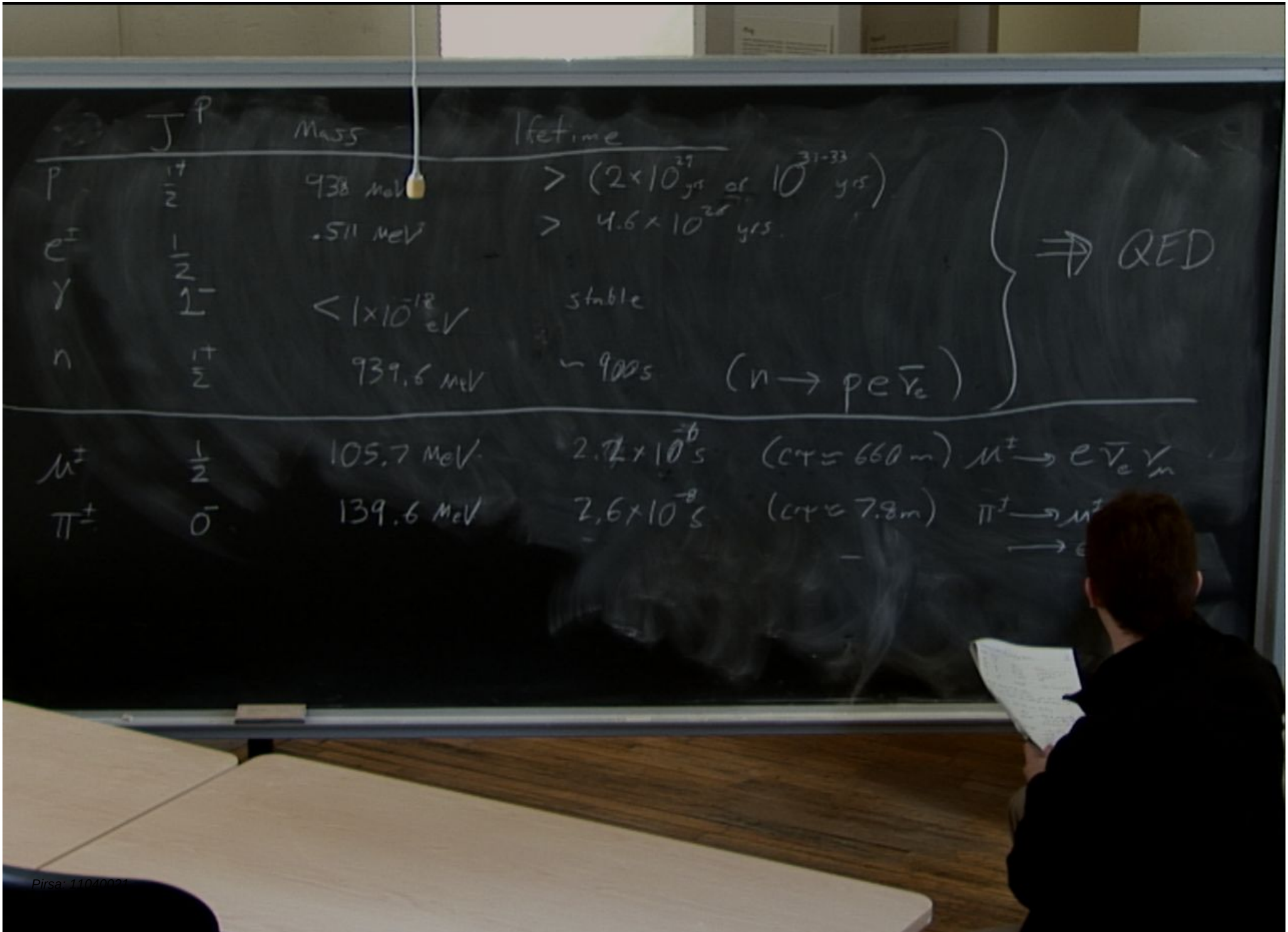

Grains of Pollen to Evidence for Atoms
How Big Is A Molecule?
J^P
Mass
938 MeV
.511 MeV
939.6 M

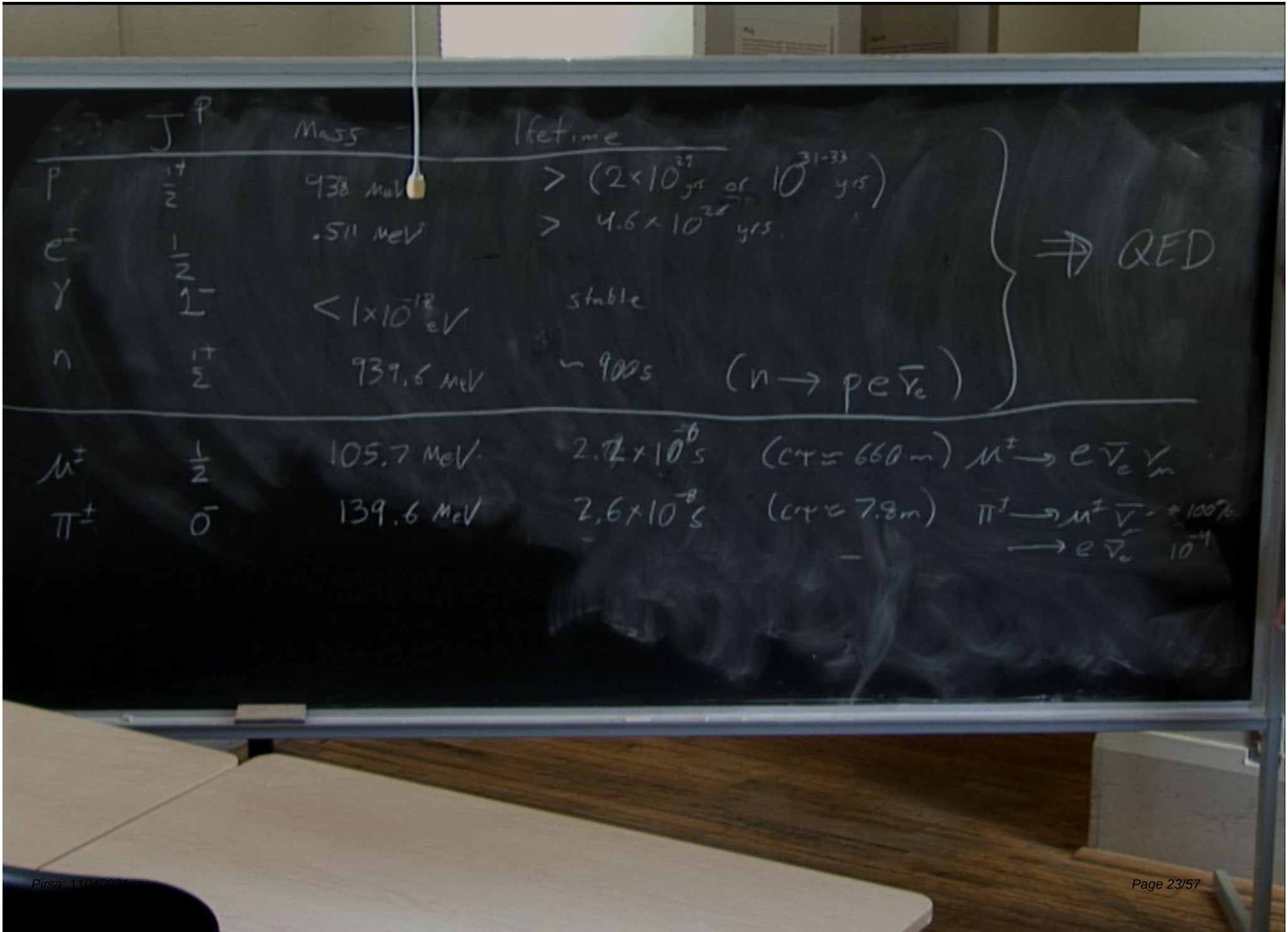

J^P
Mass
lifetime
1+/2
938 MeV
> (2×10^29 yrs or 10^31-33 yrs)
.511 MeV
> 4.6×10^26 yrs.
1/2
1−
< 1×10^-18 eV
stable
1+/2
939.6 MeV
~ 900s
(n → p e ν̄e)

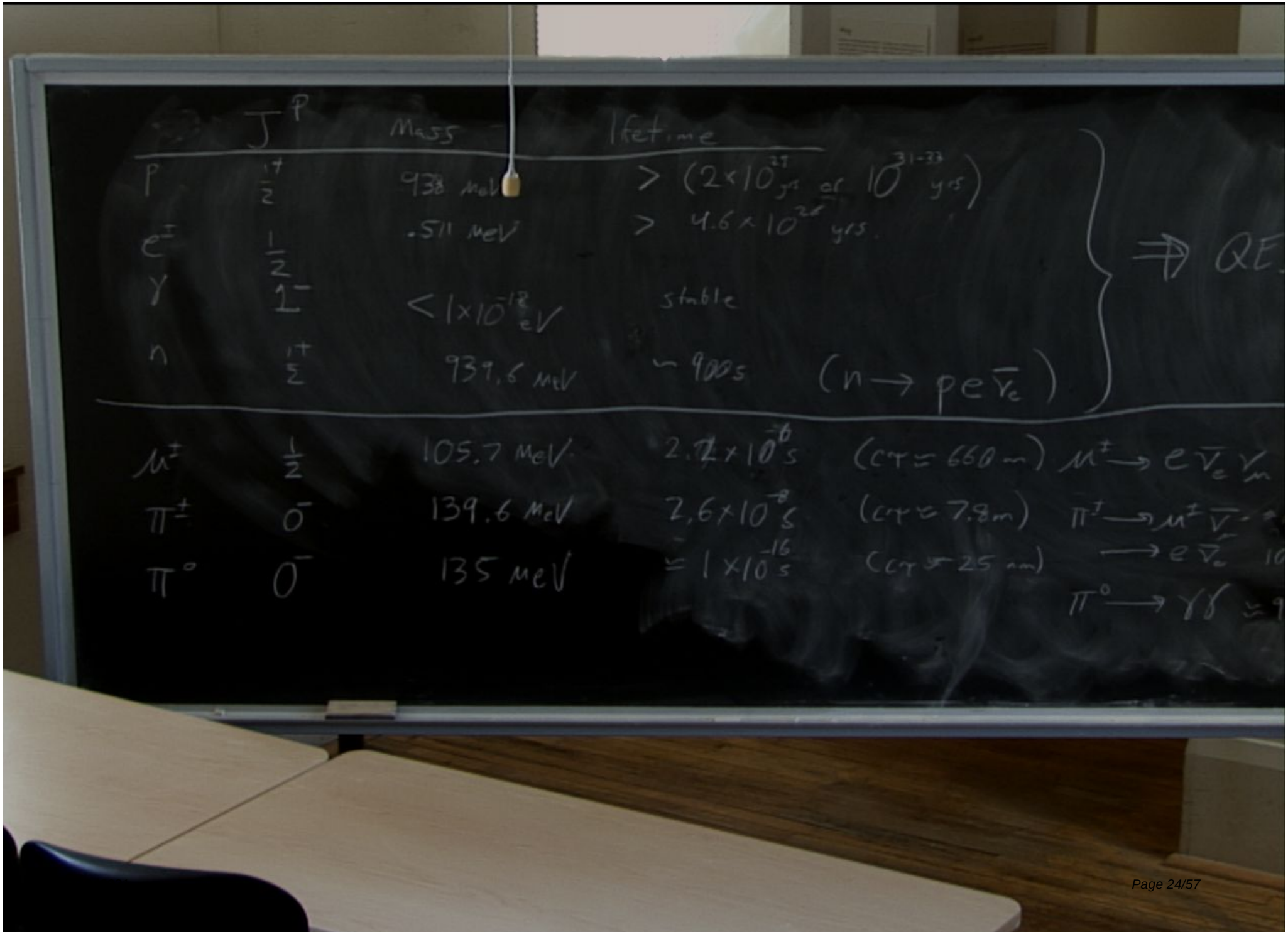

J^P
Mass
lifetime
1/2+
938 MeV
> (2×10^29 yrs or 10^31-33 yrs)
.511 MeV
> 4.6×10^26 yrs.
1/2
1−
< 1×10^-18 eV
stable
1/2+
939.6 MeV
~ 900s
(n → p e ν̄e)
⇒ QED


J^P
Mass
lifetime
938 MeV
> (2×10^27 yrs or 10^31-33 yrs)
.511 MeV
> 4.6×10^26 yrs.
stable
~ 900s (n → pe ν̄e)
⇒ QED
2.6×10^-8 s (cτ = 660 m) μ± → e ν̄e νμ

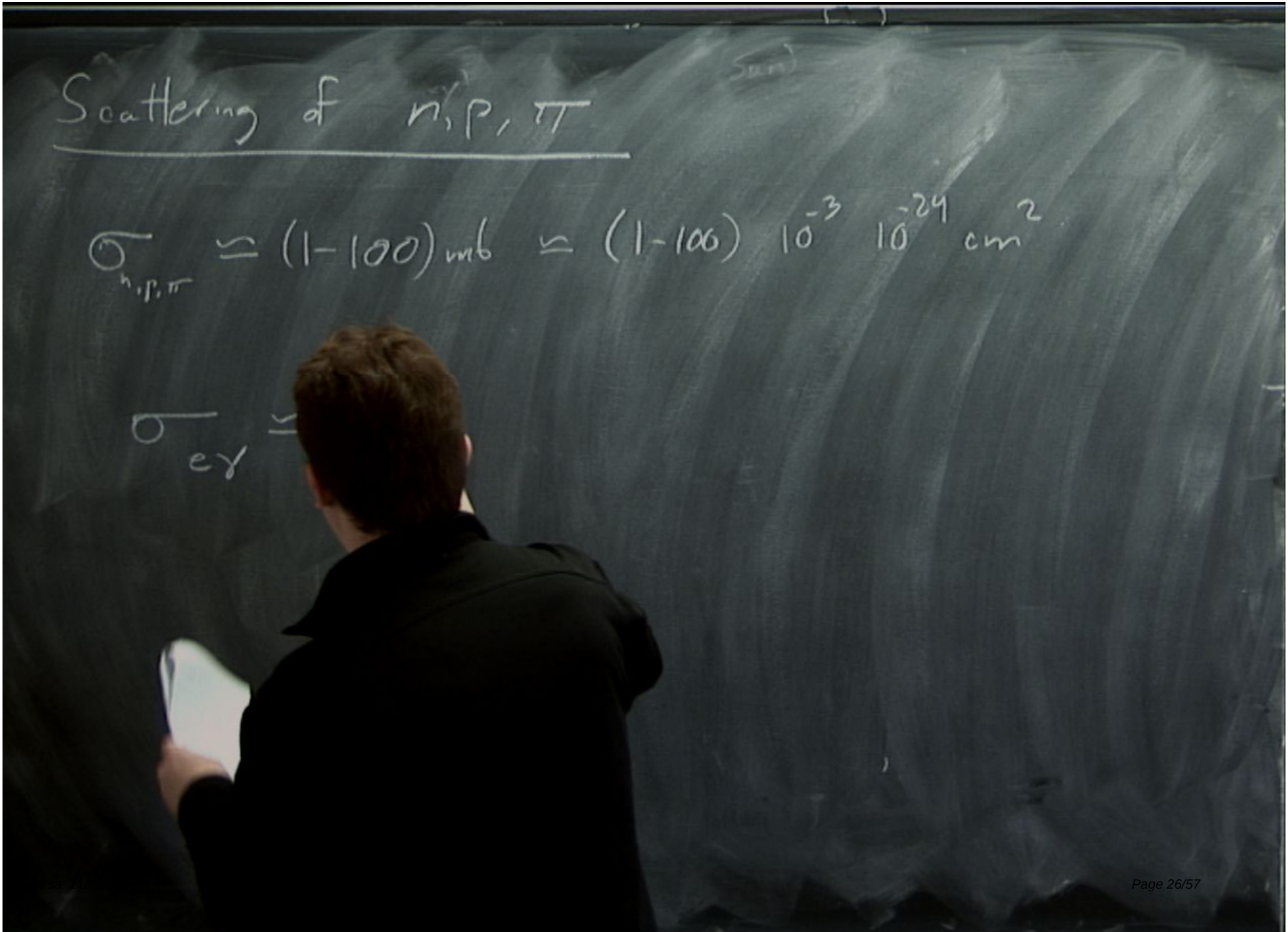

J^P
Mass
lifetime
p
938 MeV
> (2×10^29 yrs or 10^31-33 yrs)
e^±
.511 MeV
> 4.6×10^26 yrs.
γ
1^-
< 1×10^-18 eV
stable
n
939.6 MeV
~ 900s
(n → p e ν̄_e)
⇒ QED
μ^±
105.7 MeV
2.2×10^-6 s
(cτ = 660 m)
μ^± → e ν̄_e ν_μ
π^±
0^-
139.6 MeV
2.6×10^-8 s




J P
Mass
lifetime
p 1/2+ 938 MeV > (2×10^29 yrs or 10^31-33 yrs)
e± 1/2 .511 MeV > 4.6×10^26 yrs.
γ 1− < 1×10^-18 eV stable
n 1/2+ 939.6 MeV ~ 900s (n → p e ν̄e)
⇒ QED
μ± 1/2 105.7 MeV 2.2×10^-6 s (cτ = 660 m) μ± → e ν̄e νμ
π± 0− 139.6 MeV 2.6×10^-8 s (cτ = 7.8 m) π± → μ± ν̄μ ≈ 100%
→ e ν̄e 10^-4


J^P
Mass
lifetime
p
e^±
γ
n
938 MeV
.511 MeV
stable
939.6 MeV
~900s
(n → pe ν̄_e)
⇒ QE
105.7 MeV
(cτ ≃ 660 m)
μ^± → e ν̄_e ν_μ
π^±
139.6 MeV
(cτ ≃ 7.8m)
π^0
135 MeV
(cτ ≃ 25 nm)
π^0 → γγ

Scattering of n, p, π

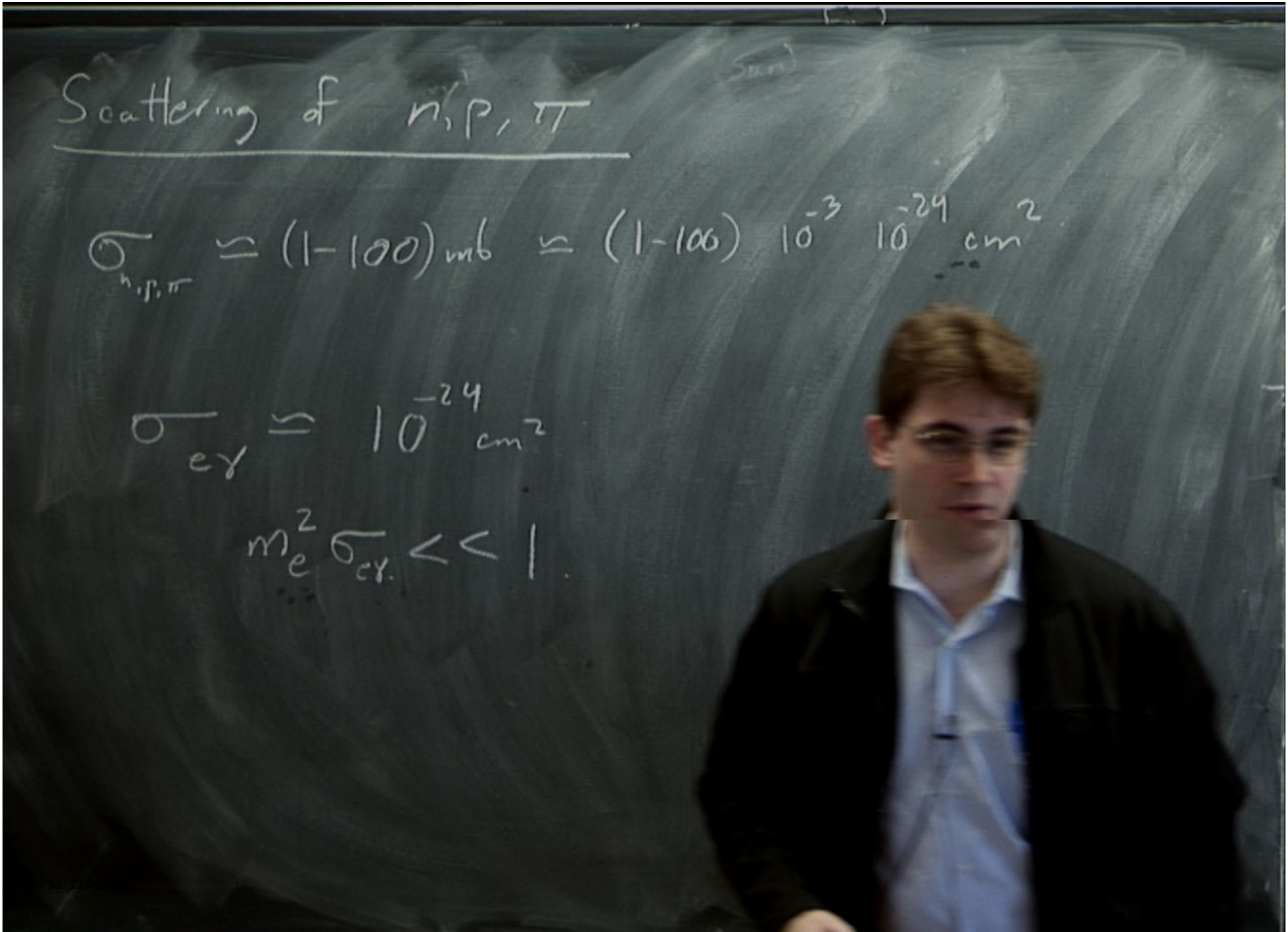

Scattering of n, p, π
$\sigma_{n,p,\pi} \simeq (1\text{-}100)\,\text{mb} \simeq (1\text{-}100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$
$\sigma_{e\gamma} \simeq$

Scattering of n, p, π

$$\sigma_{n,p,\pi} \simeq (1\text{-}100)\,\text{mb} \simeq (1\text{-}100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$$

$$\sigma_{e\gamma} \simeq 10^{-24}\ \text{cm}^2$$

$$m_e^2 \sigma_{e\gamma} << 1$$


Scattering of n, p, π
$\sigma_{n,p,\pi} \simeq (1\text{-}100)\,\text{mb} \simeq (1\text{-}100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$
$\sigma_{e\gamma} \simeq 10^{-24}\ \text{cm}^2$
$m_e^2\,\sigma_{e\gamma} << 1$

Scattering of n, p, π

$$\sigma_{n,p,\pi} \simeq (1-100)\,\text{mb} \simeq (1-100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$$

$$\sigma_{e\gamma} \simeq 10^{-24}\ \text{cm}^2$$

$$m_e^2\,\sigma_{e\gamma} << 1$$

$$\sim \alpha^2$$

$$m_{n,p,\pi}\,\sigma_{n,p,\pi} \simeq 1$$

Scattering of n, p, π

$$\sigma_{n,p,\pi} \simeq (1\text{-}100)\ \text{mb} \simeq (1\text{-}100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$$

$$\sigma_{e\gamma} \simeq 10^{-24}\ \text{cm}^2$$

$$m_e^2 \sigma_{e\gamma} << 1$$

$$\sim \alpha^2$$

$$m_{n,p,\pi}\, \sigma_{n,p,\pi} \simeq 1$$

$\hbar c \simeq 200$ MeV fm

$\equiv 1$

$$\sigma_{n,p,\pi} \simeq \frac{\Theta(1)}{(\text{GeV})^2}$$

Scattering of n, p, π

$$\sigma_{n,p,\pi} \simeq (1\text{-}100)\,\text{mb} \simeq (1\text{-}100)\ 10^{-3}\ 10^{-24}\ \text{cm}^2$$

$$\sigma_{e\gamma} \simeq 10^{-24}\ \text{cm}^2$$

$$m_e^2\,\sigma_{e\gamma} << 1$$

$$\sim \alpha^2$$

$$m_{n,p,\pi}\,\sigma_{n,p,\pi} \simeq 1$$

$\hbar c \simeq 200\ \text{MeV fm}$

$\equiv 1$

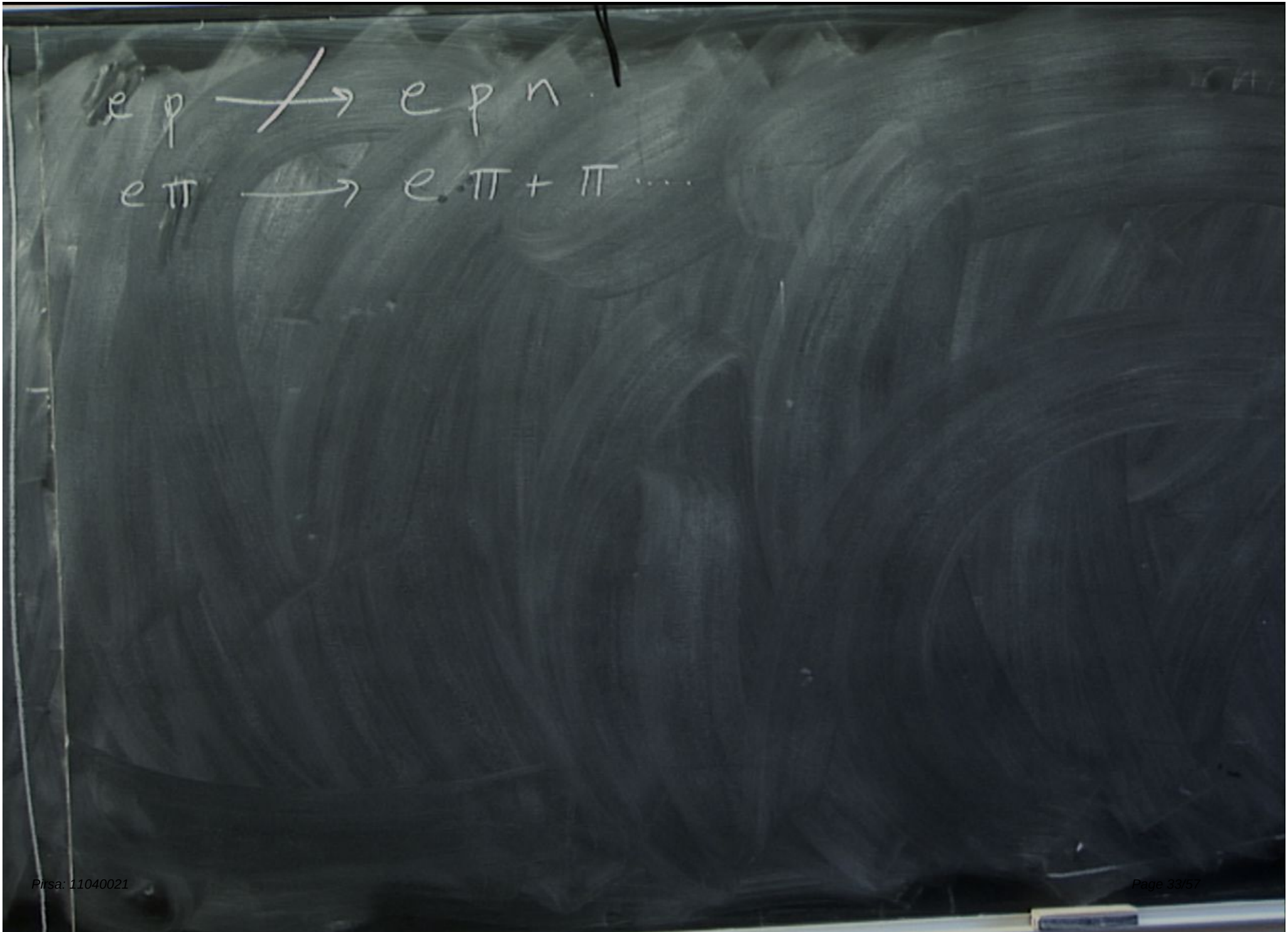
$$\sigma_{n,p,\pi} \simeq \frac{\mathcal{O}(1)}{(\text{GeV})^2}$$

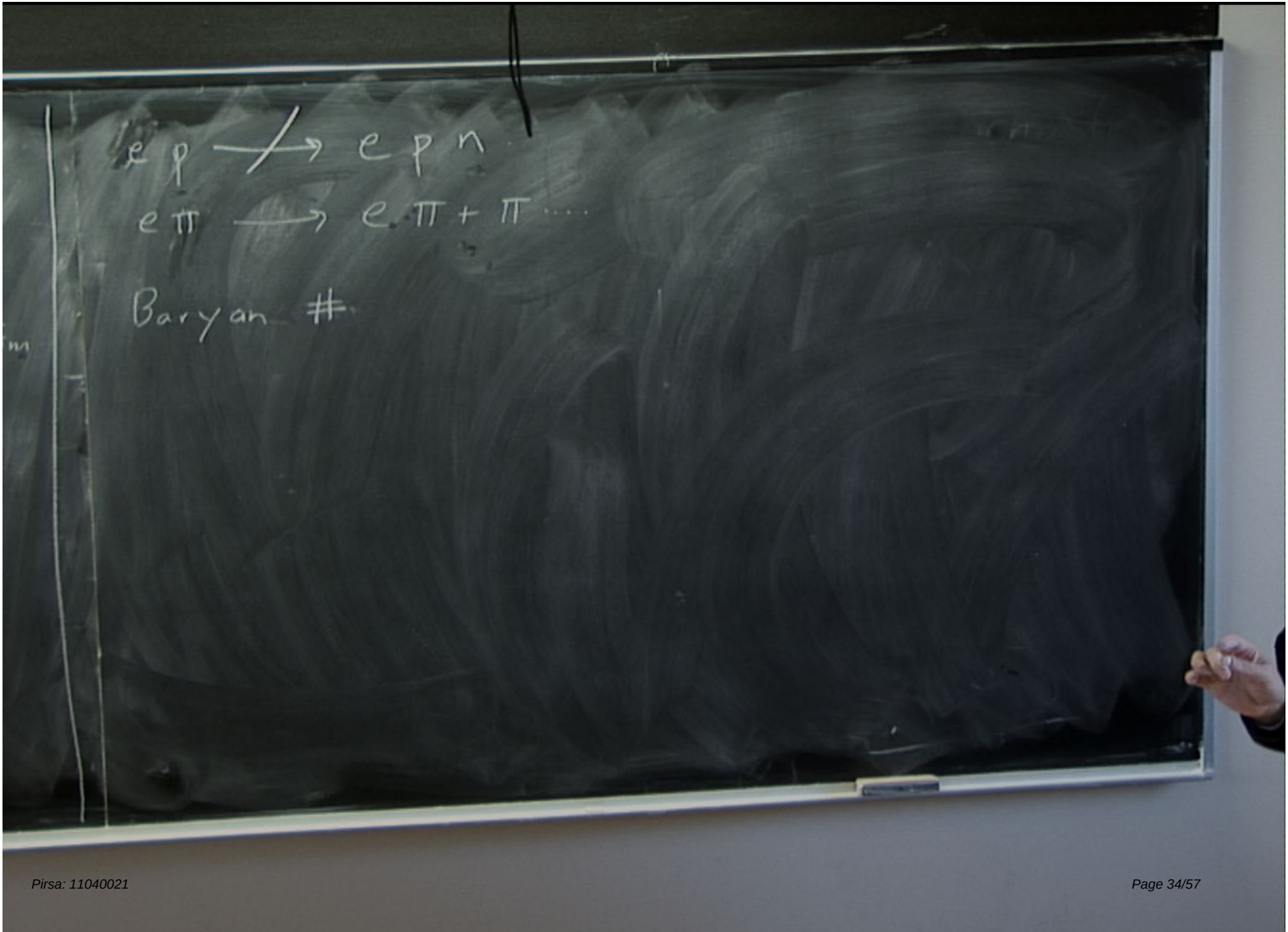
$ep \longrightarrow epn$

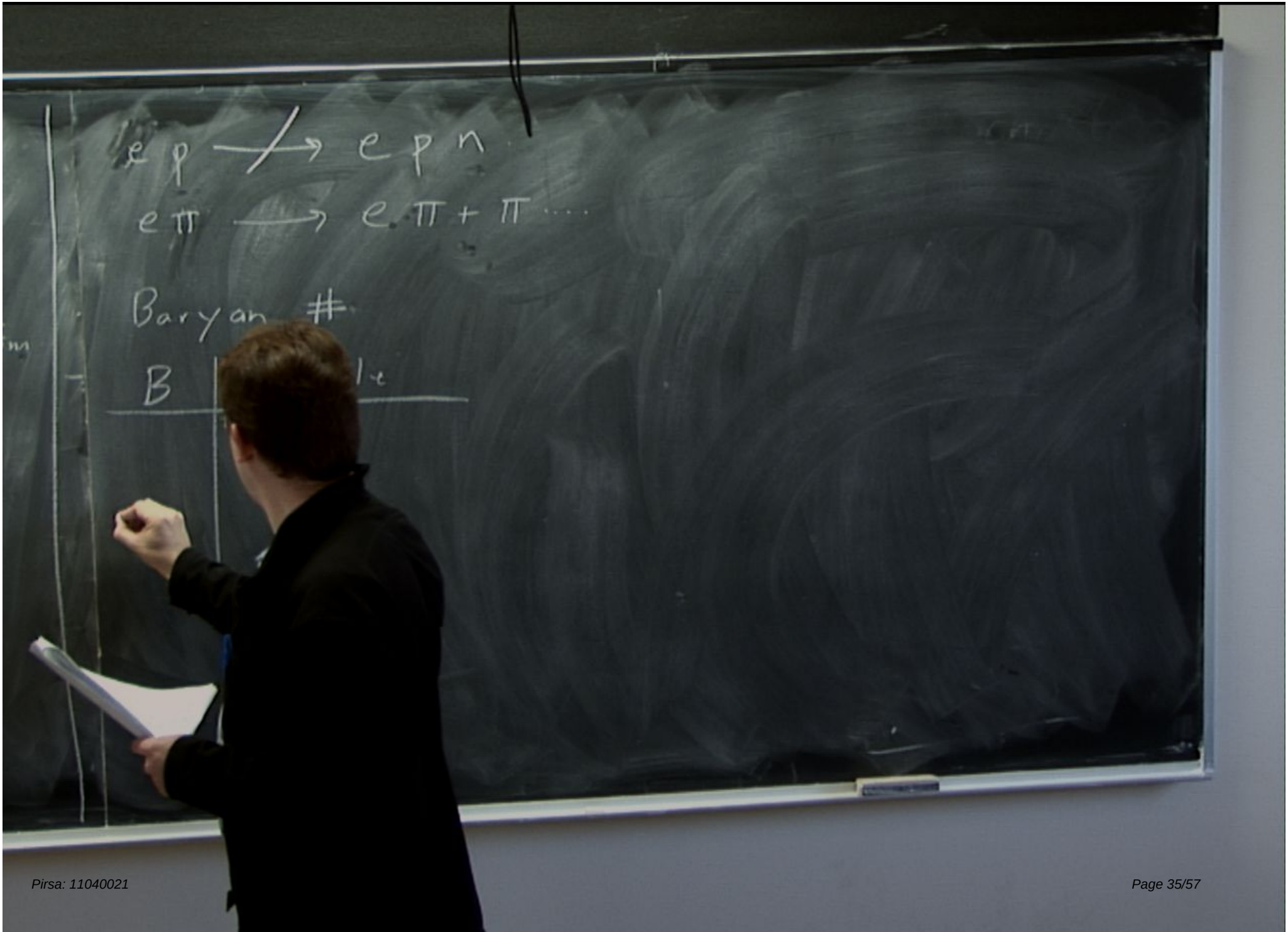
$1 \quad cm^2$

$200 \quad MeV \quad 5_{nn}$

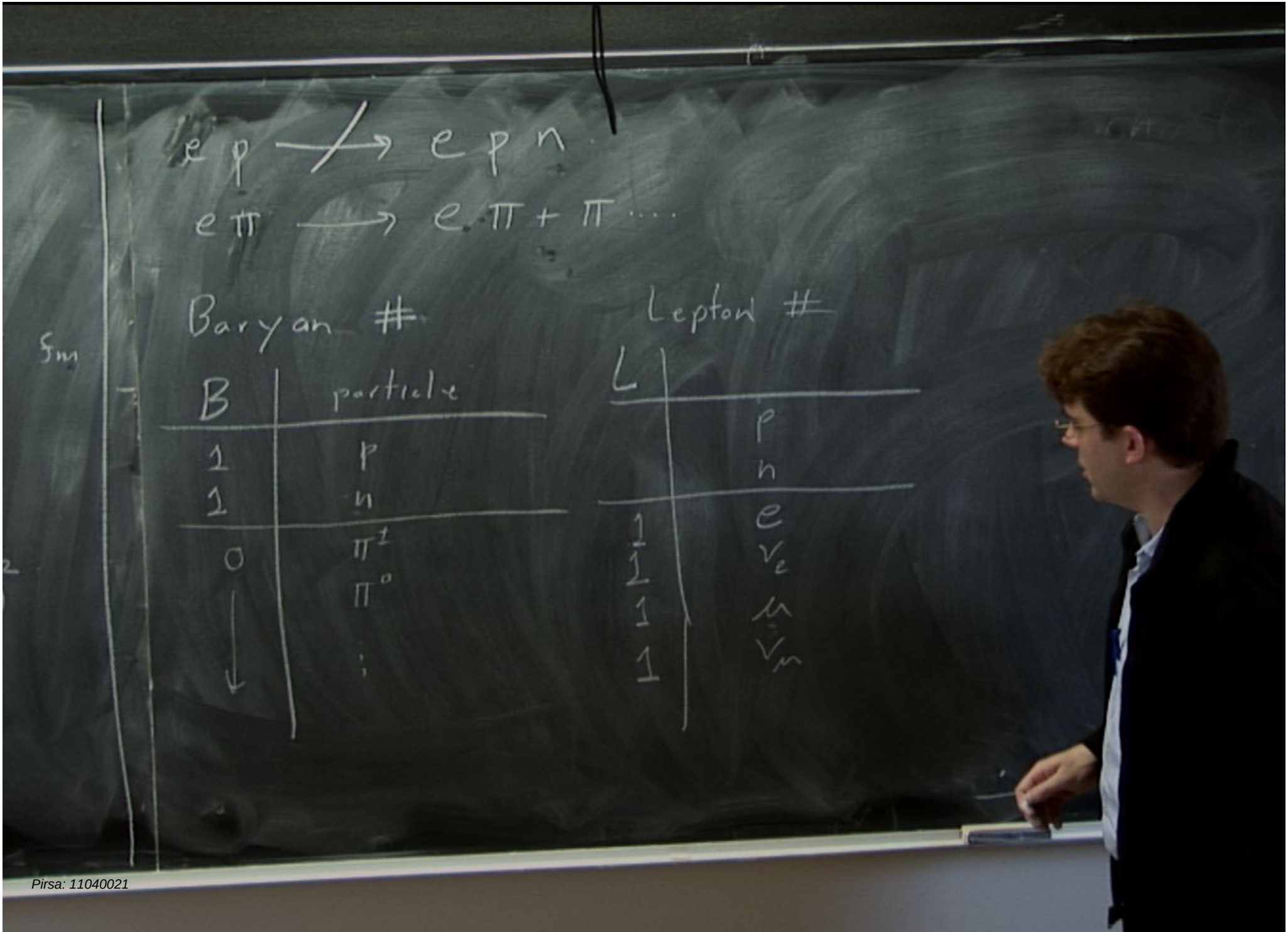
$\sim \frac{O(1)}{(GeV)^2}$

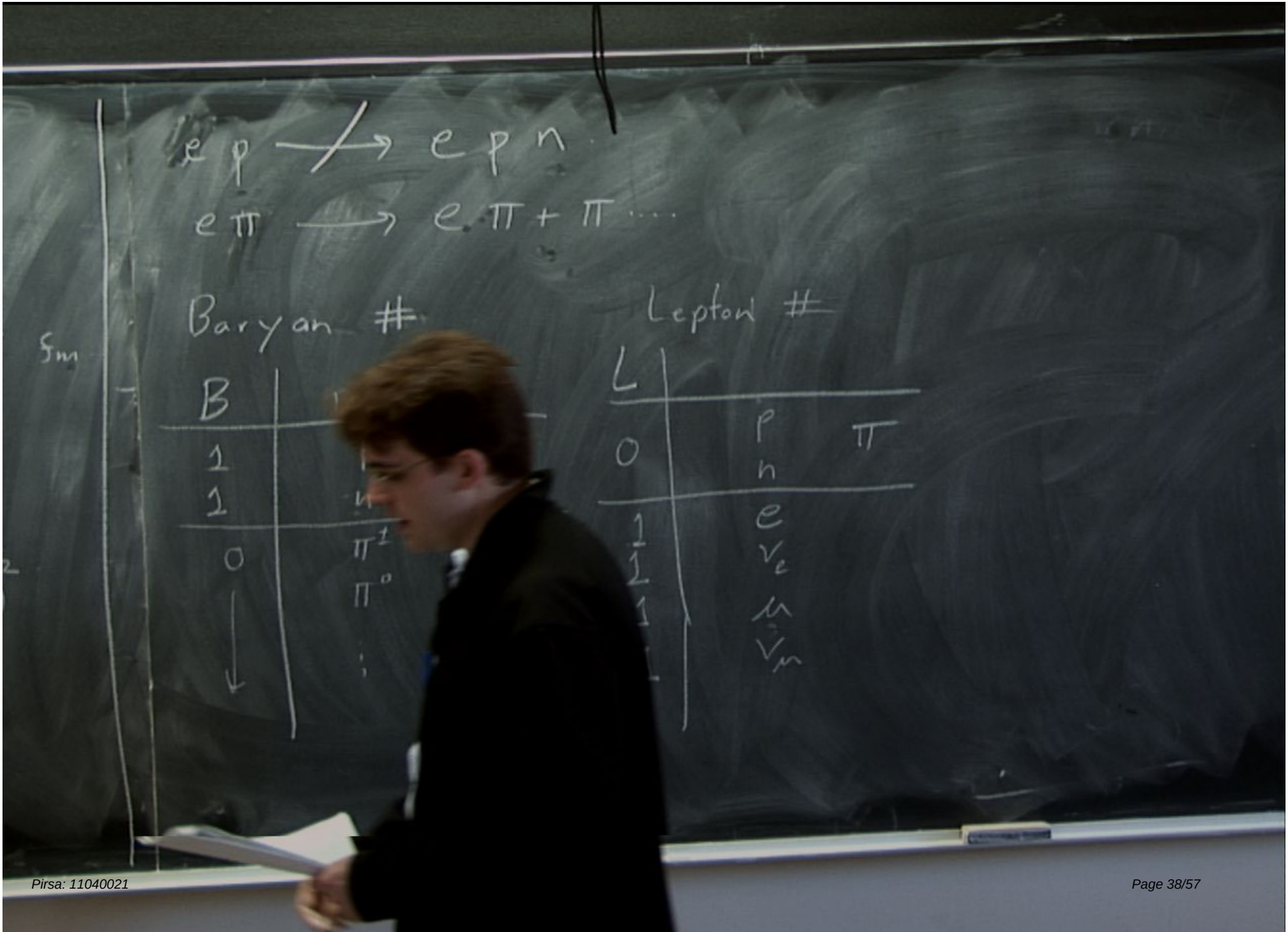

e p ⟶ e p n
e π ⟶ e π + π ....

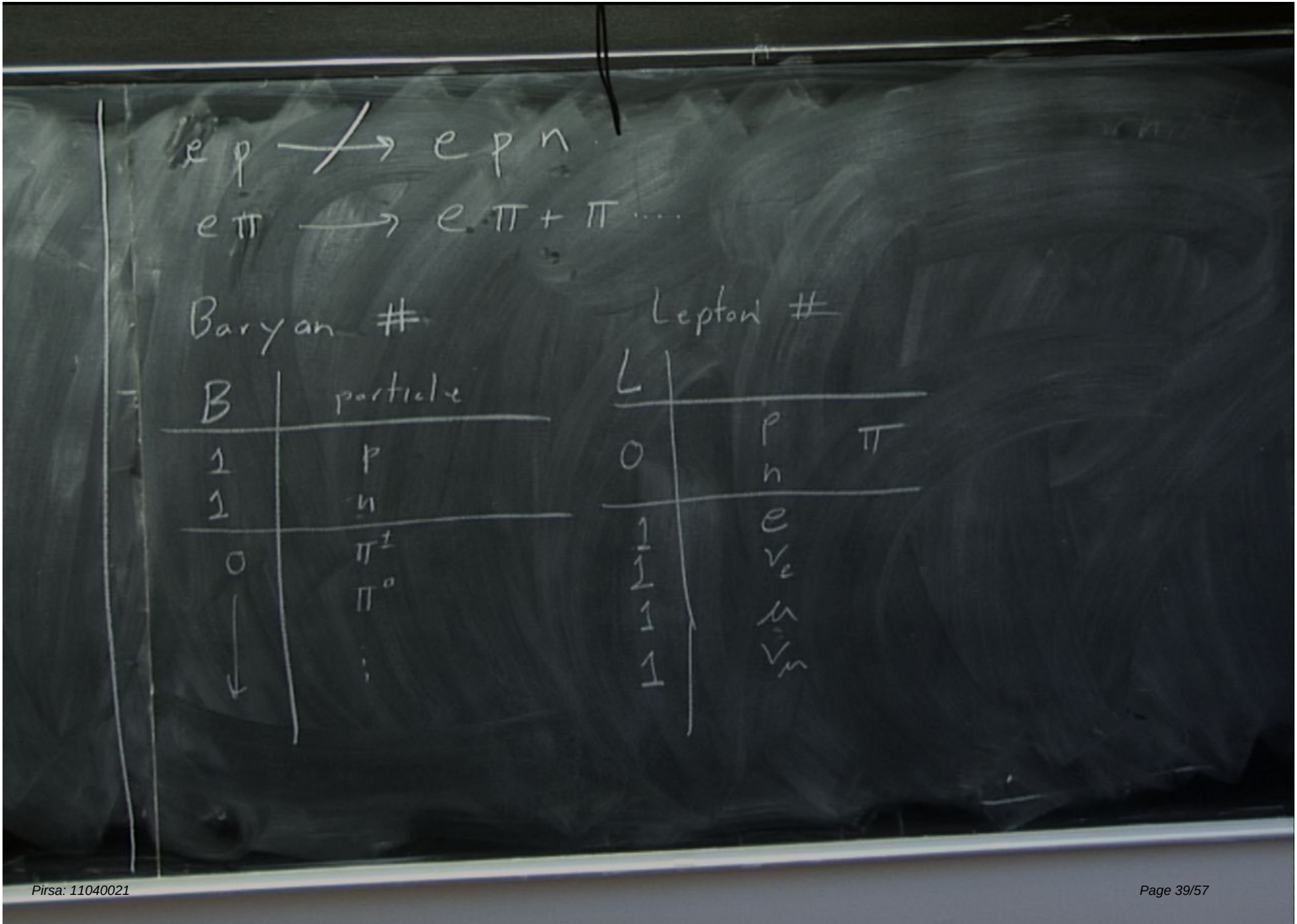

e p → e p n
e π → e π + π ....
Baryan #

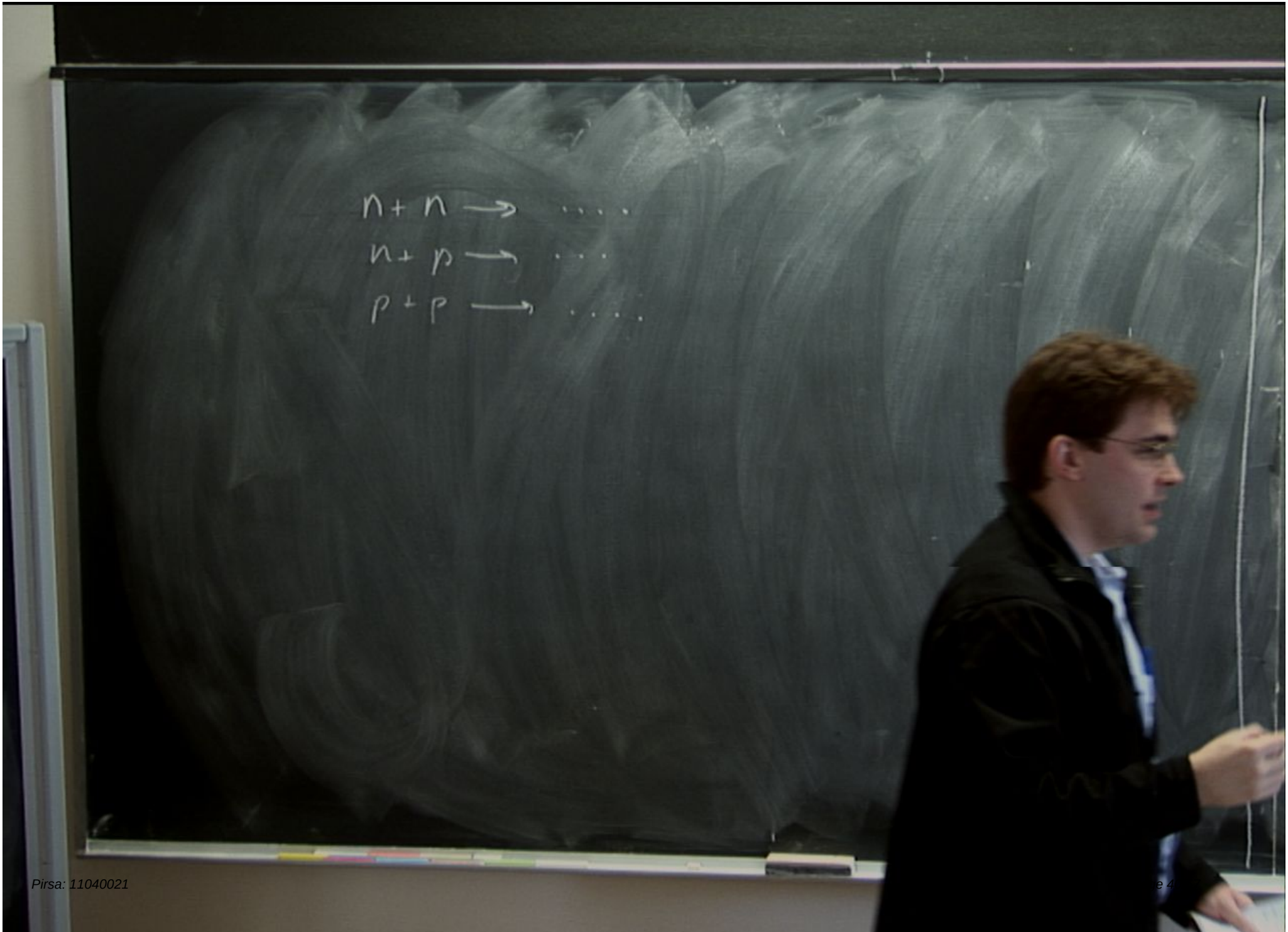

e p → e p n
e π → e π + π ....
Baryan #
B

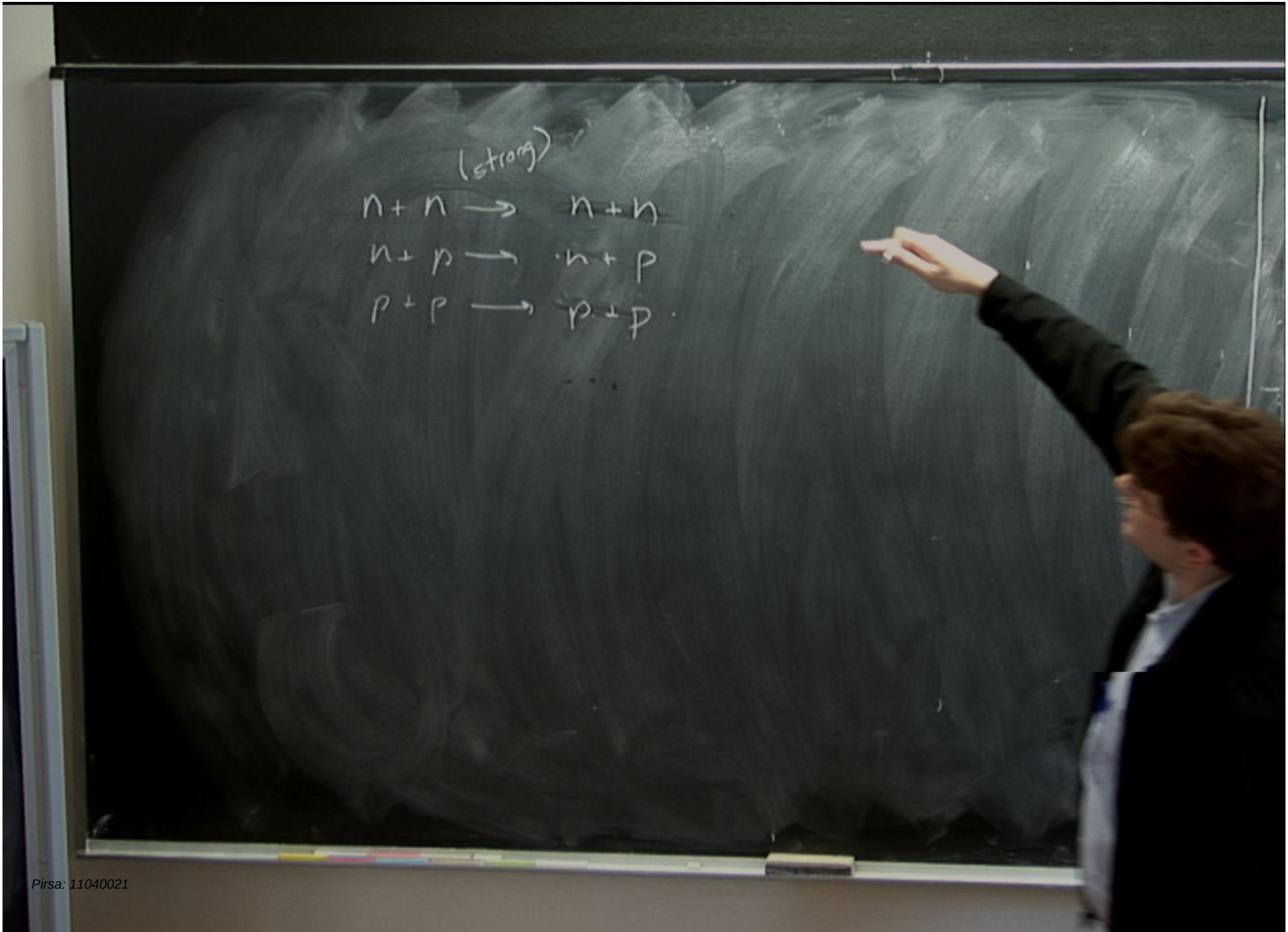

e p → e p n
e π → e π + π ....
Baryan #
B | particle
1 | p
1 | n
0 | π¹
π°
;

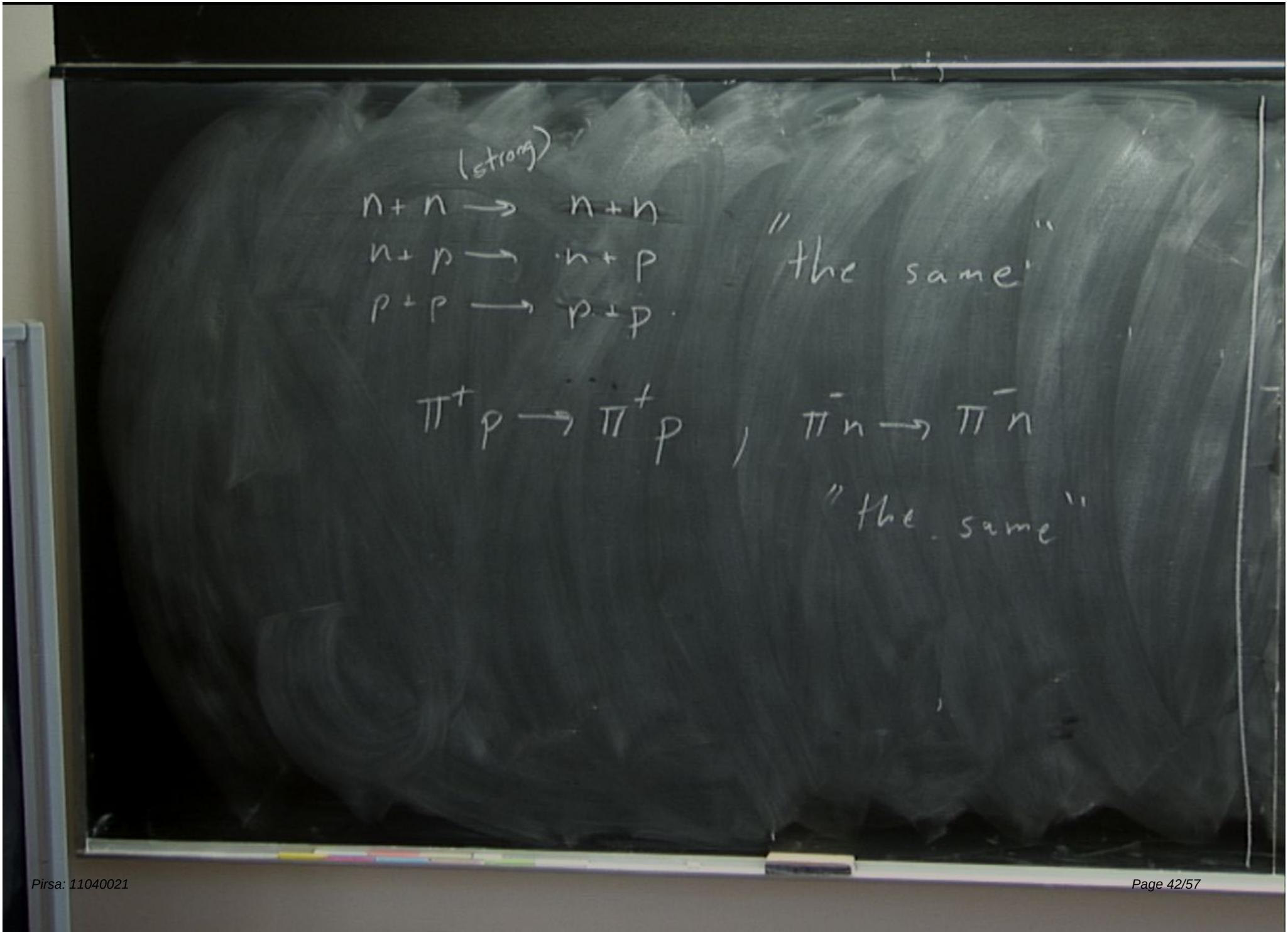


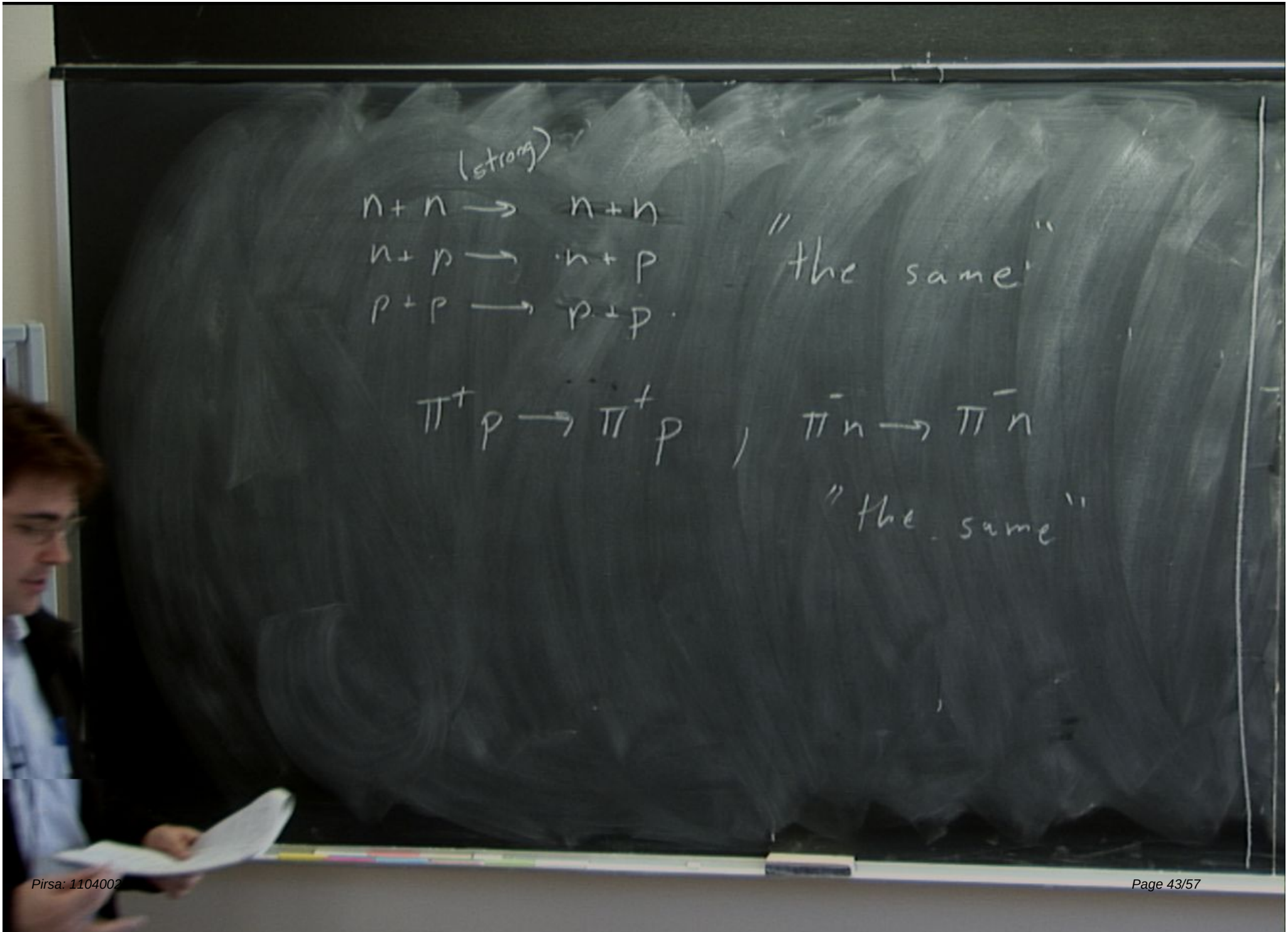

e p → e p n
e π → e π + π ···
Baryan #
Lepton #
B
L
p
n
π
e
ν_e
μ
ν_μ
π^+
π^0


e p → e p n
e π → e π + π ...
Baryan #
B | particle
1 | p
1 | n
0 | π+
π°
Lepton #
L
0 | p π
n
1 | e
1 | νe
1 | μ
1 | νμ


n + n → ....
n + p → ...
p + p → ....




(strong)
n + n → n + n
n + p → n + p
p + p → p + p
"the same"
π⁺ p → π⁺ p , π⁻ n → π⁻ n
"the same"


(strong)
n + n → n + n
n + p → n + p
p + p → p + p
"the same"
π⁺ p → π⁺ p , π⁻ n → π⁻ n
"the same"

(strong)

$n + n \longrightarrow n + n$

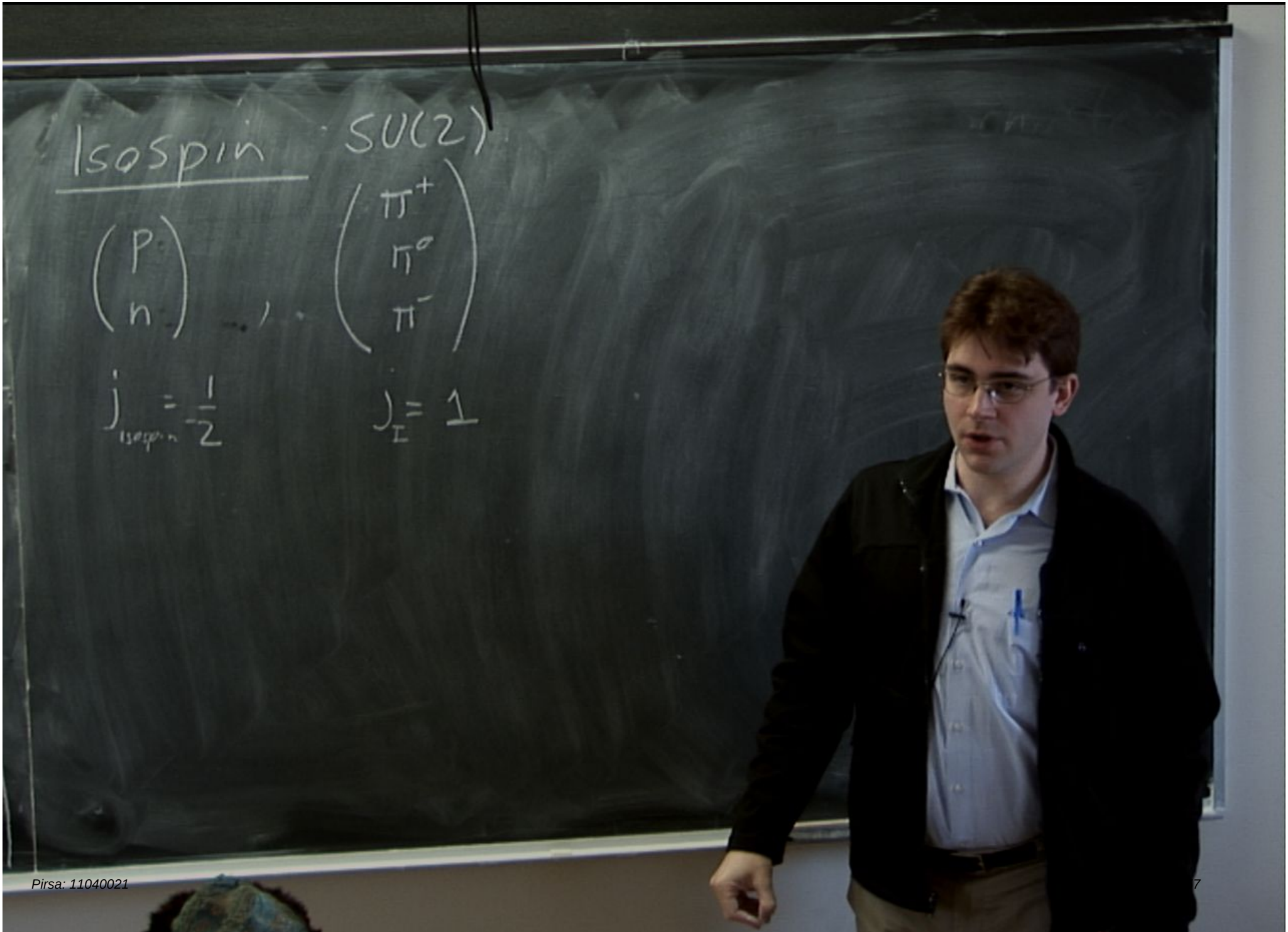
$n + p \longrightarrow n + p$

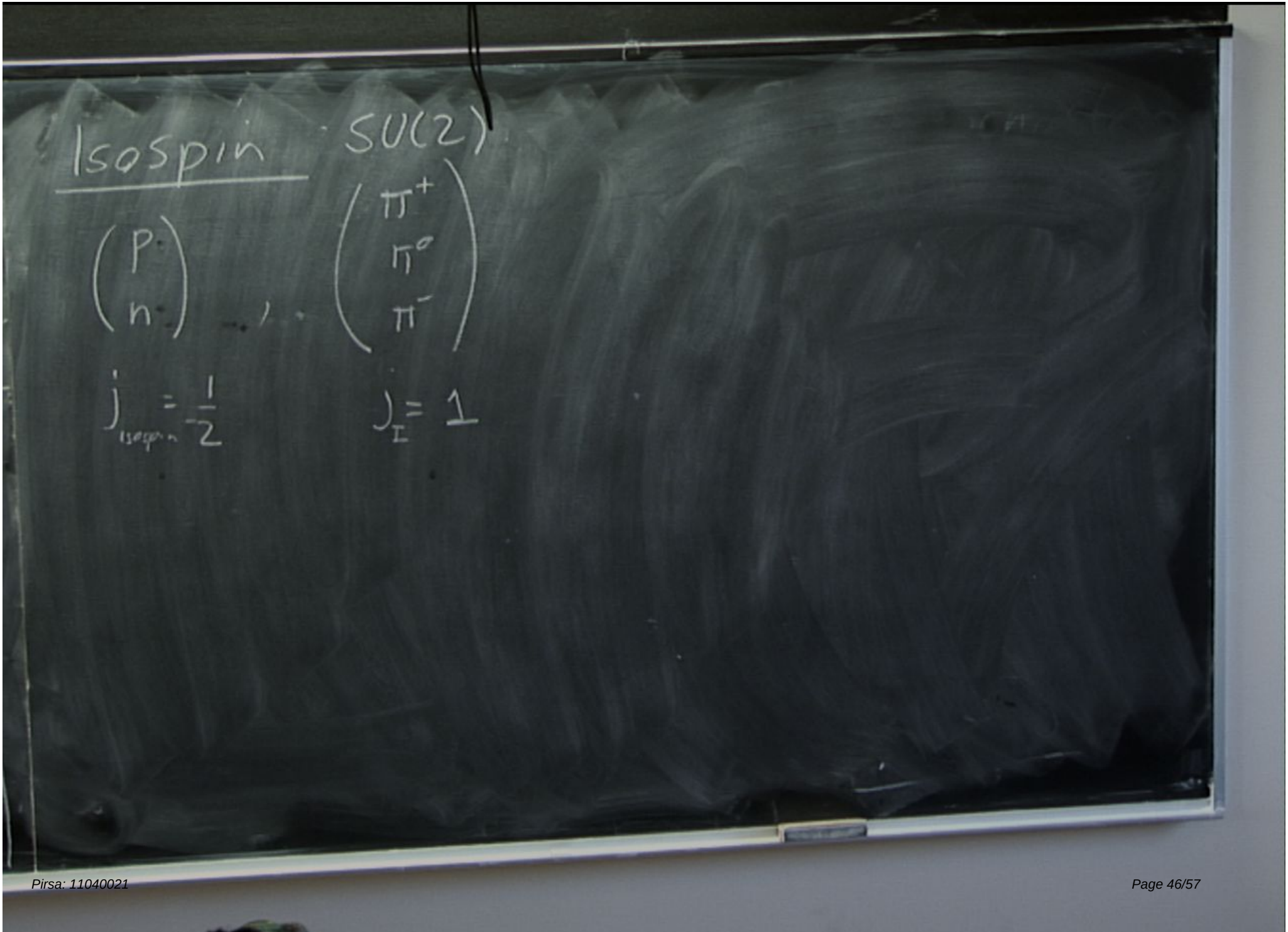
$p + p \longrightarrow p + p$

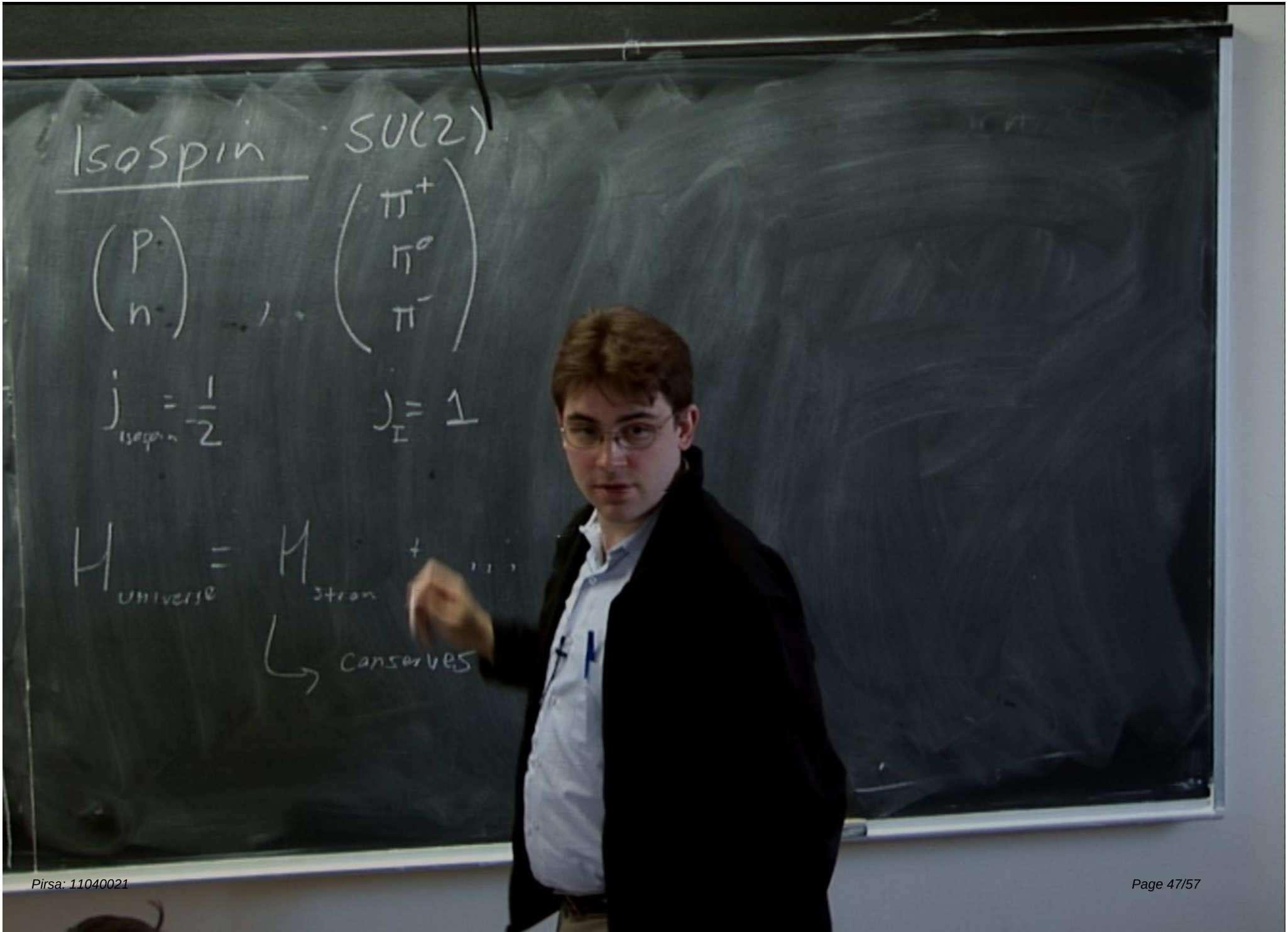
"the same"

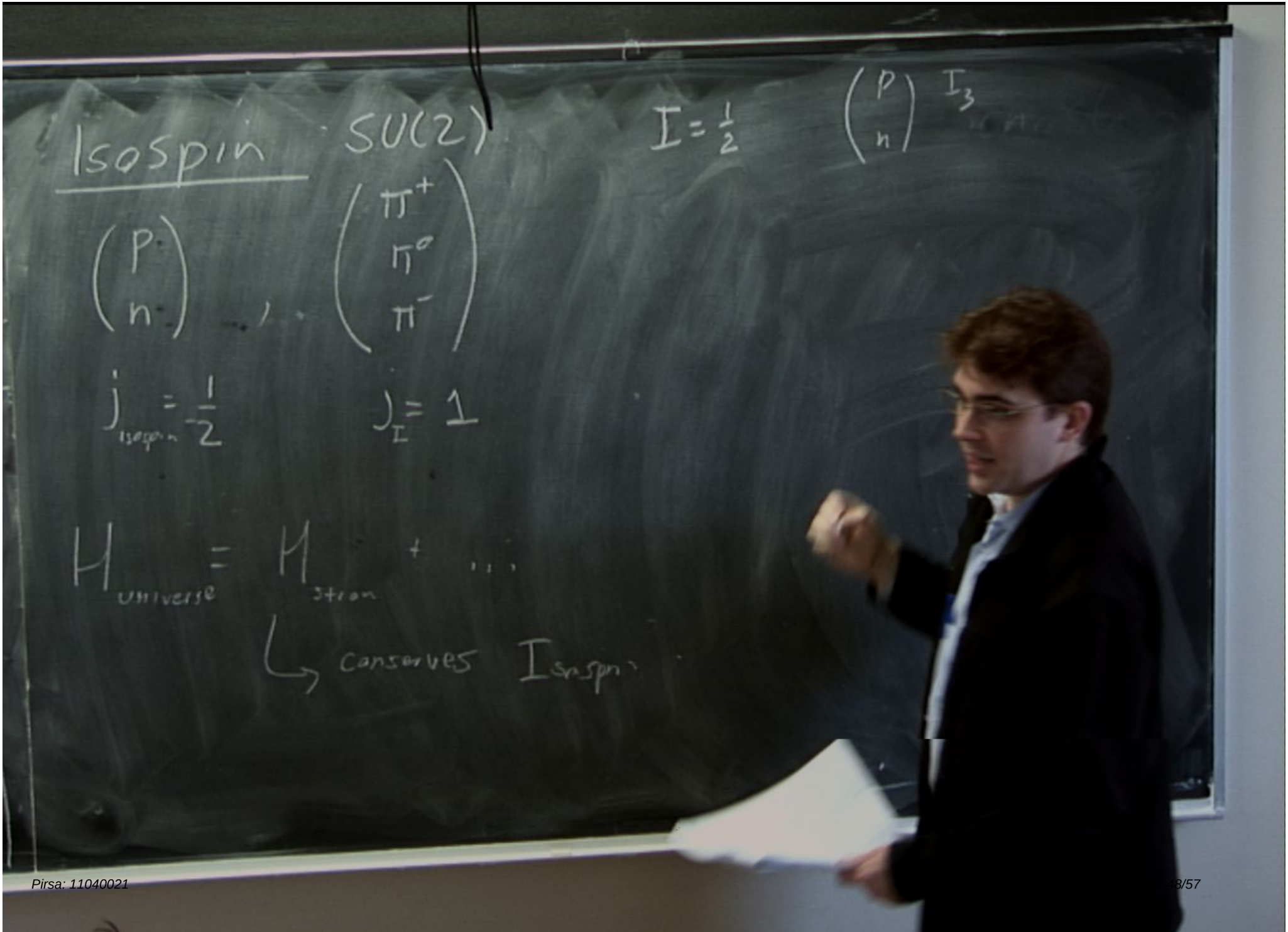
$\pi^+ p \longrightarrow \pi^+ p$, $\pi^- n \longrightarrow \pi^- n$

"the same"


Isospin SU(2)
$\begin{pmatrix} p \\ n \end{pmatrix}$, $\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$
$j_{isospin} = \frac{1}{2}$
$J_I = 1$


Isospin SU(2)
$\begin{pmatrix} p \\ n \end{pmatrix}$
$\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$
$j_{isospin} = \frac{1}{2}$
$J_I = 1$


Isospin SU(2)
$\begin{pmatrix} p \\ n \end{pmatrix}$, $\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$
$j_{isospin} = \frac{1}{2}$
$J_I = 1$
$H_{universe} = H_{strong} + \ldots$
↳ Conserves


Isospin SU(2)
$I = \frac{1}{2}$
$\begin{pmatrix} p \\ n \end{pmatrix}$ I_3
$\begin{pmatrix} p \\ n \end{pmatrix}$
$\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$
$j_{isospin} = \frac{1}{2}$
$J_I = 1$
$H_{universe} = H_{strong} + \ldots$
↳ Conserves Isospin

Isospin

SU(2)

$\begin{pmatrix} p \\ n \end{pmatrix}$, $\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$

$I = \frac{1}{2}$ $\begin{pmatrix} p \\ n \end{pmatrix}$ $I_3 = +\frac{1}{2}$, $I_3 = -\frac{1}{2}$

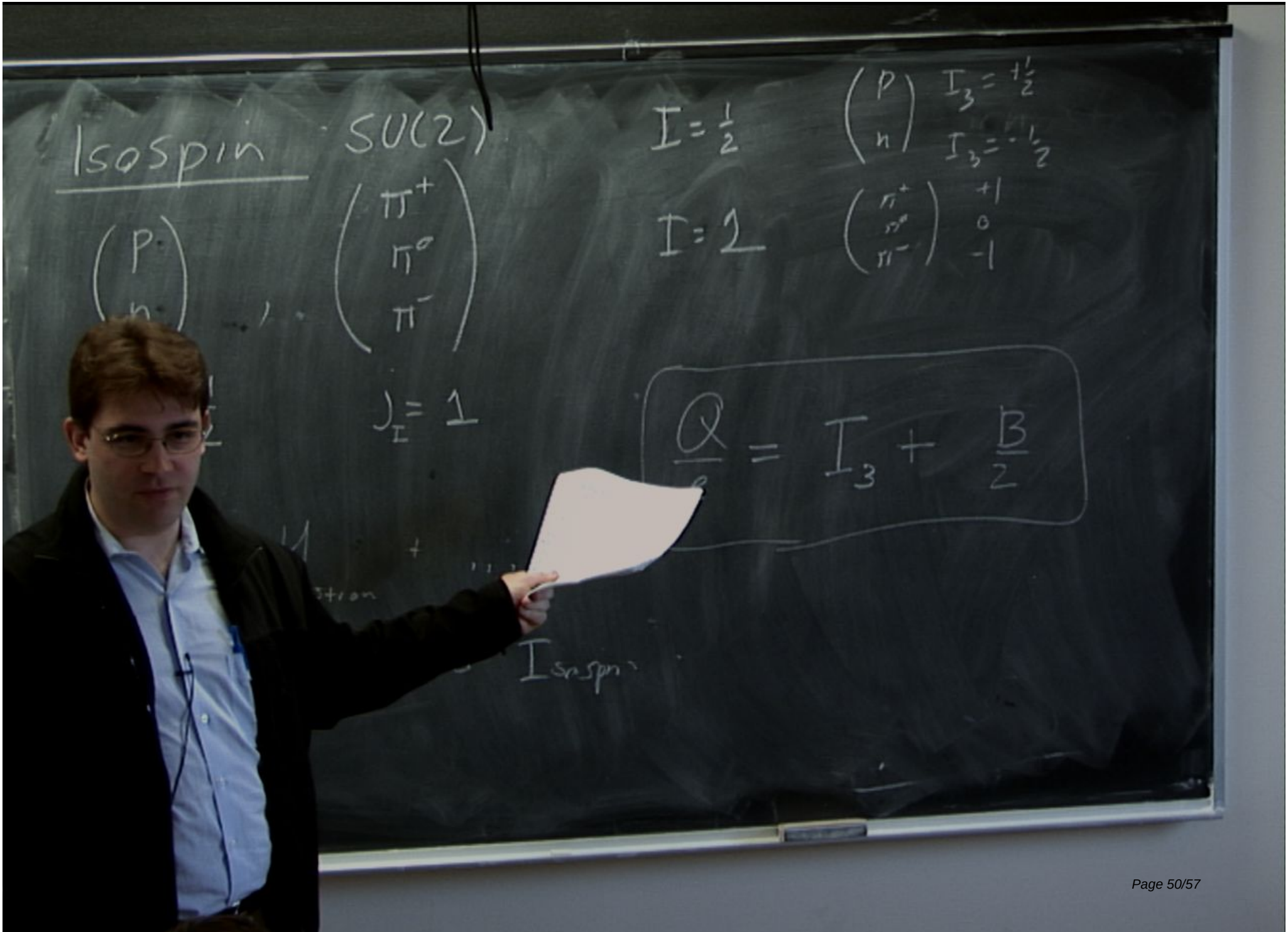
$I = 1$ $\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$ $+1$, 0, -1

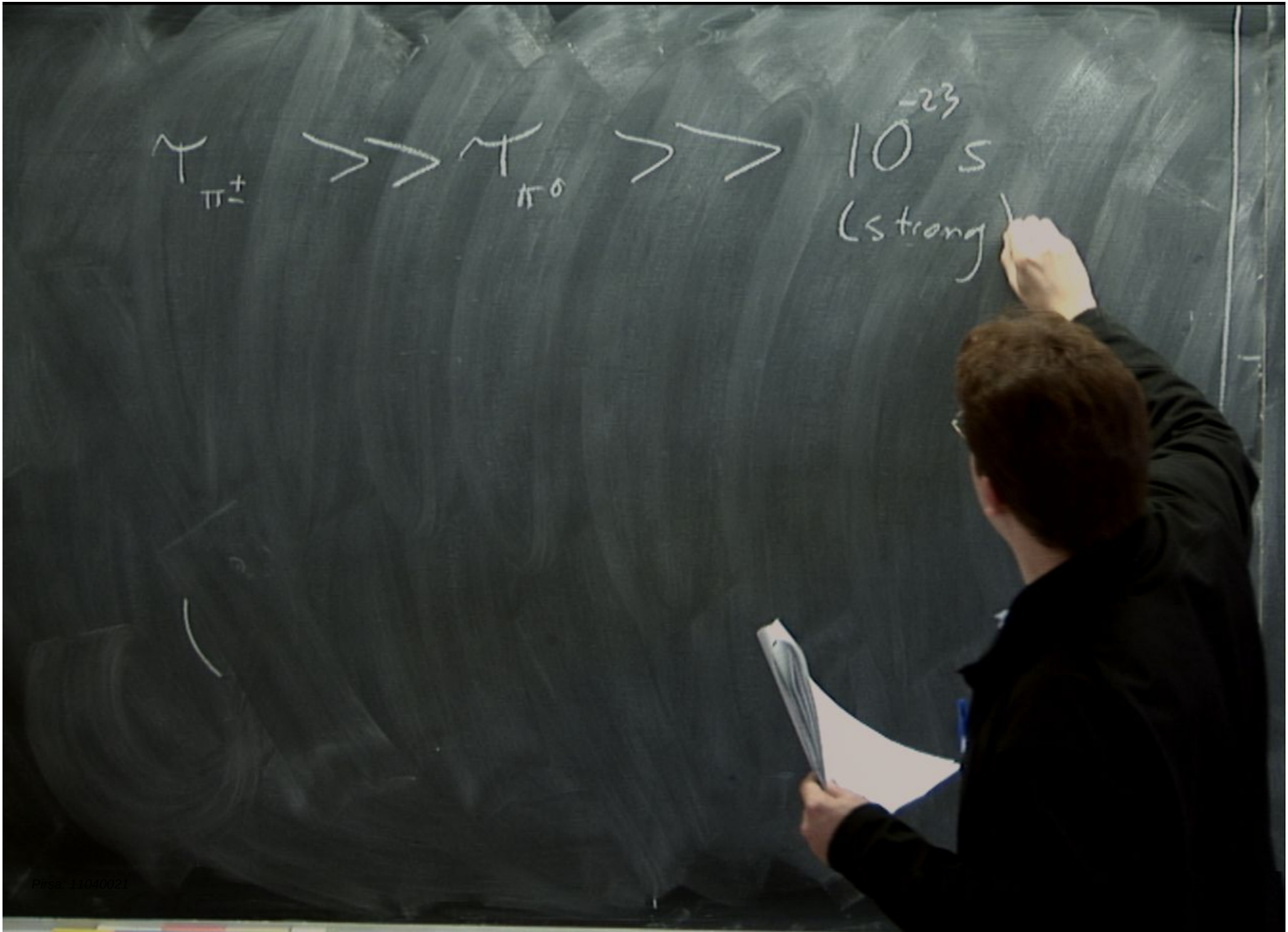
$j_{isospin} = \frac{1}{2}$ $\quad J_I = 1$

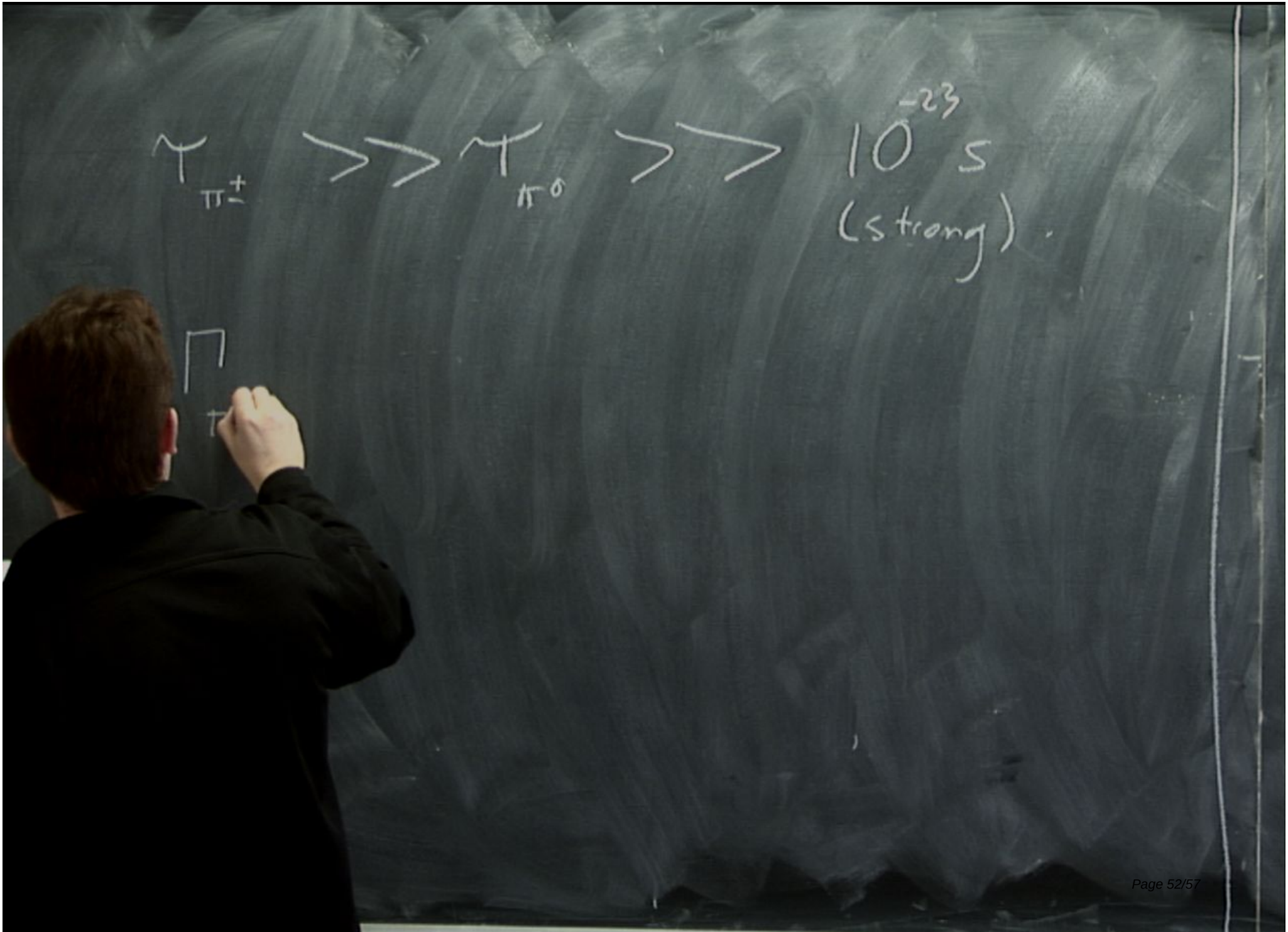
$$\frac{Q}{e} = I_3 + \frac{B}{2}$$

$H_{universe} = H_{strong} + \dots$

↳ conserves Isospin


Isospin
SU(2)
$\begin{pmatrix} p \\ n \end{pmatrix}$
$\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$
$J_I = 1$
$I = \frac{1}{2}$
$\begin{pmatrix} p \\ n \end{pmatrix}$ $I_3 = +\frac{1}{2}$ $I_3 = -\frac{1}{2}$
$I = 1$
$\begin{pmatrix} \pi^+ \\ \pi^0 \\ \pi^- \end{pmatrix}$ $+1$ 0 -1
$\frac{Q}{e} = I_3 + \frac{B}{2}$




$\tau_{\pi^\pm} >> \tau_{\pi^0} >> 10^{-23}$ s
(strong).

$\tau_{\pi^\pm} >> \tau_{\pi^0} >> 10^{-23}\ s$ (strong).

$\Gamma_{\pi^0 \to \gamma\gamma} \simeq \alpha^2 m_{\pi^0}$

(

$\tau_\mu \simeq 100\, \tau_{\pi^\pm}$

$\tau_{\pi^\pm} >> \tau_{\pi^0} >> 10^{-23}\ s$ (strong).

$\Gamma_{\pi^0 \to \gamma\gamma} \simeq \alpha^2 m_{\pi^0}$

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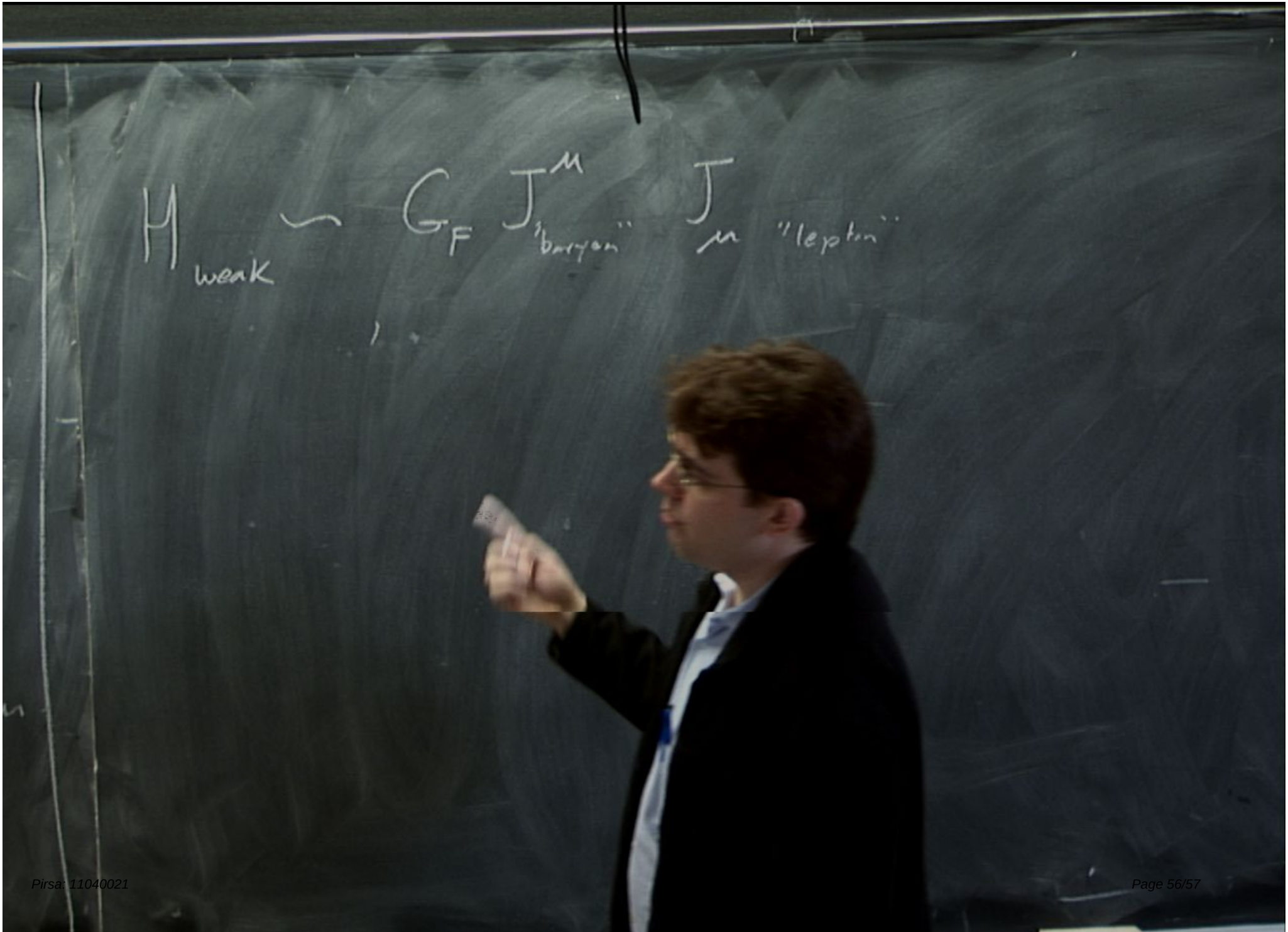
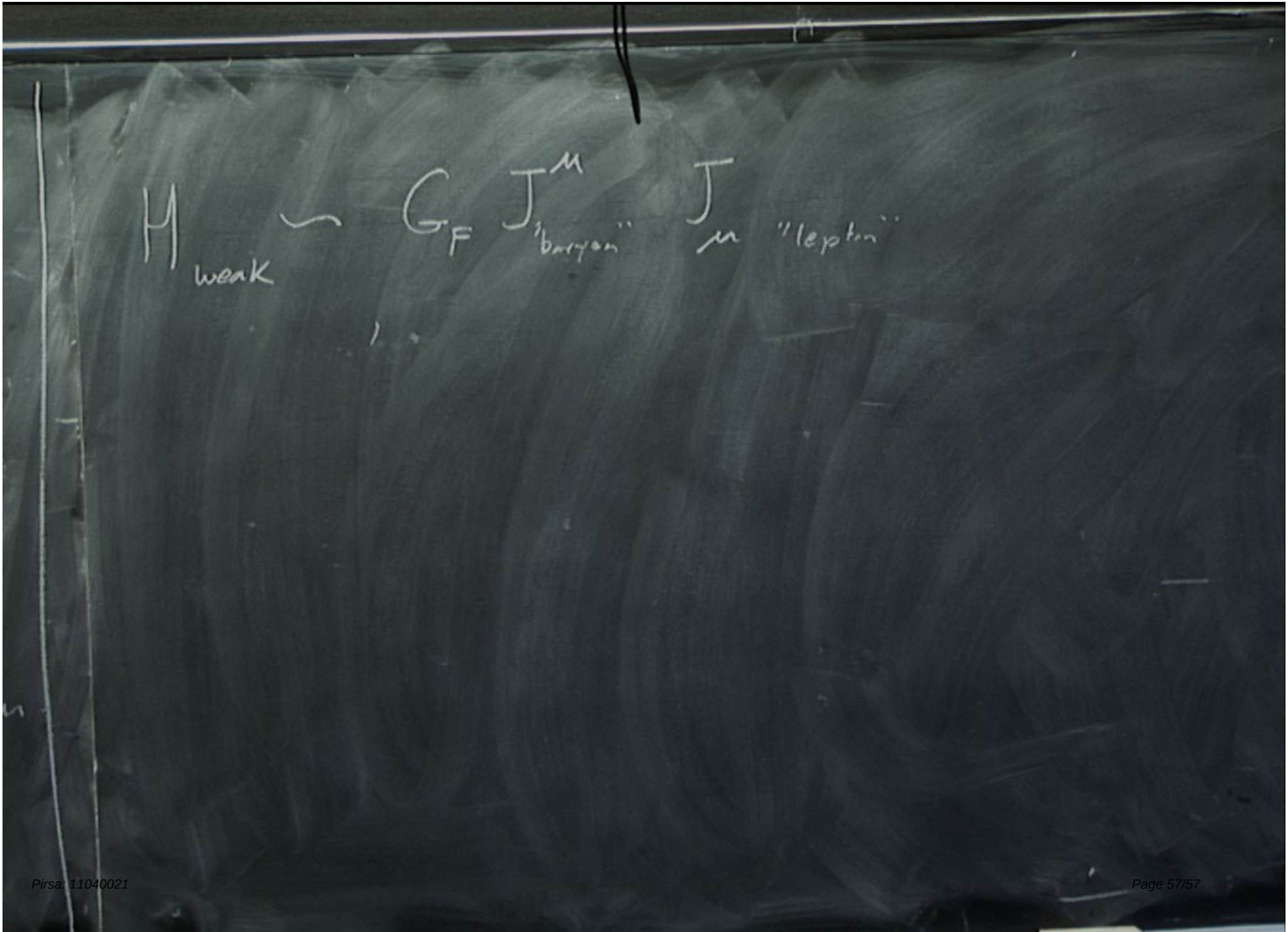
$\tau_{\pi^\pm} >> \tau_{\pi^0} >> 10^{-23}\ s$ (strong).

$\Gamma_{\pi^0 \to \gamma\gamma} \simeq \alpha^2 m_{\pi^0}$

$n \longrightarrow p e \bar{\nu}_e \quad \tau \sim 900\ s >>>> \tau_{\pi,\mu}$

phase space $\simeq 1$ MeV


$H_{weak} \sim G_F J^{\mu}_{\text{"baryon"}} J_{\mu\ \text{"lepton"}}$


$H_{weak} \sim G_F J^{\mu}_{\text{"baryon"}} J_{\mu\ \text{"lepton"}}$