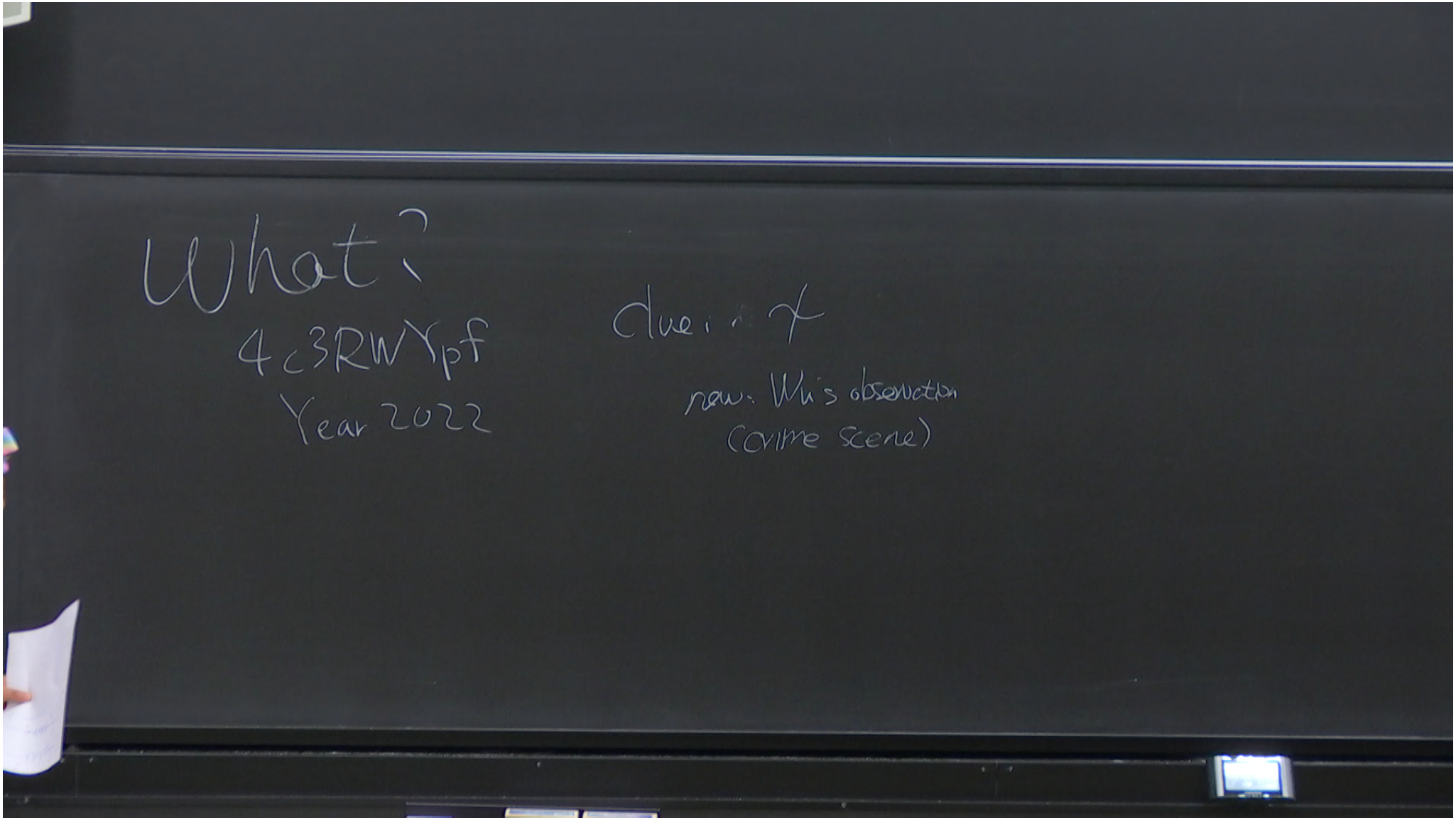
Title: Quantum Field Theory I - Lecture 221031

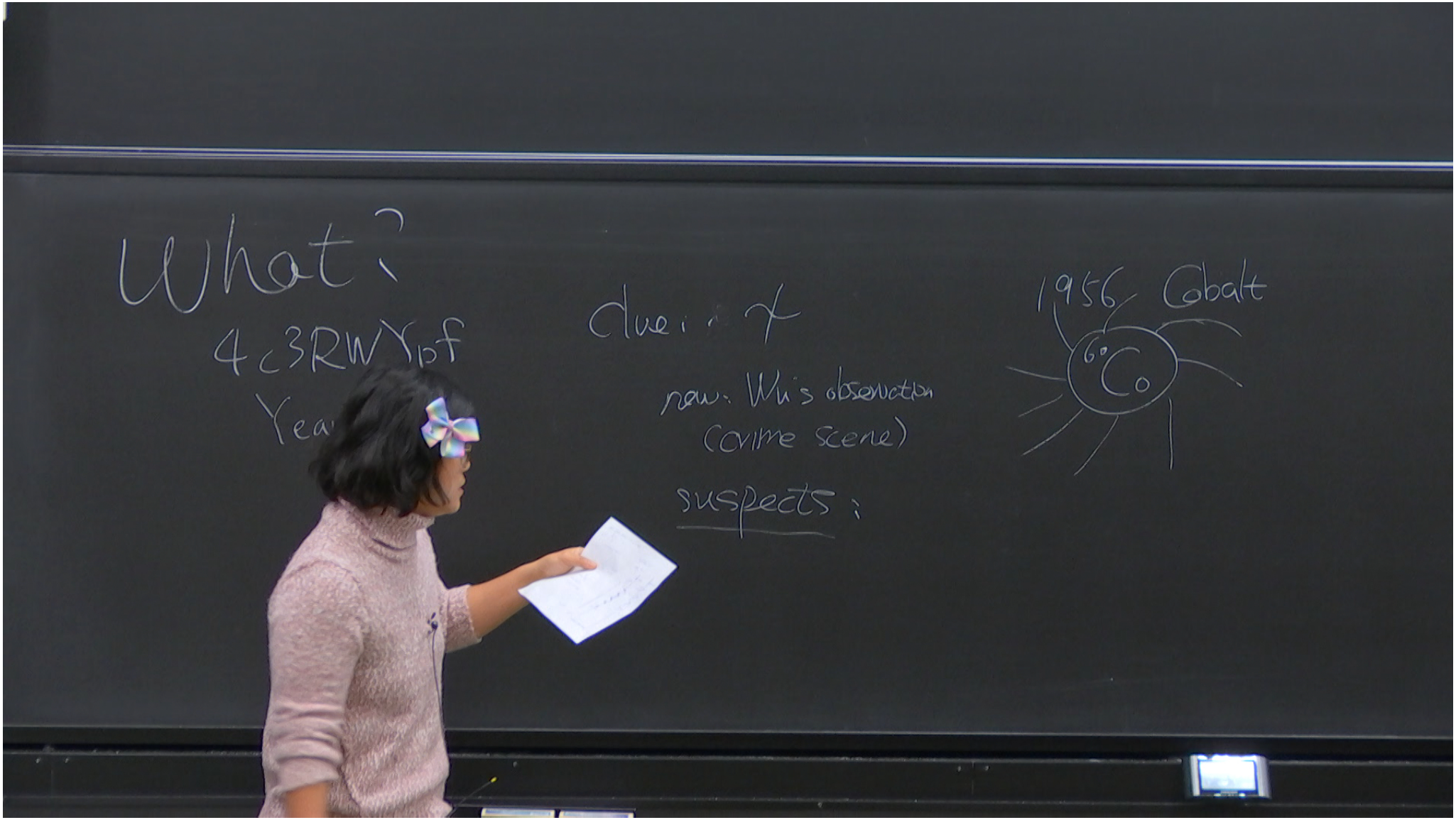
Speakers: Gang Xu

Collection: Quantum Field Theory I (2022/2023)

Date: October 31, 2022 - 10:45 AM

URL: https://pirsa.org/22100057

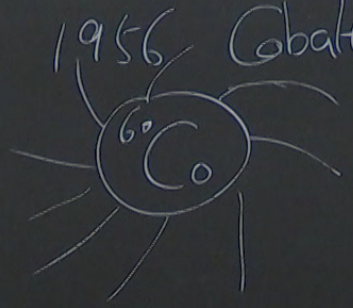

What?
4c3RWYpf
Year 2022
due: x
now: Wu's observation
(crime scene)

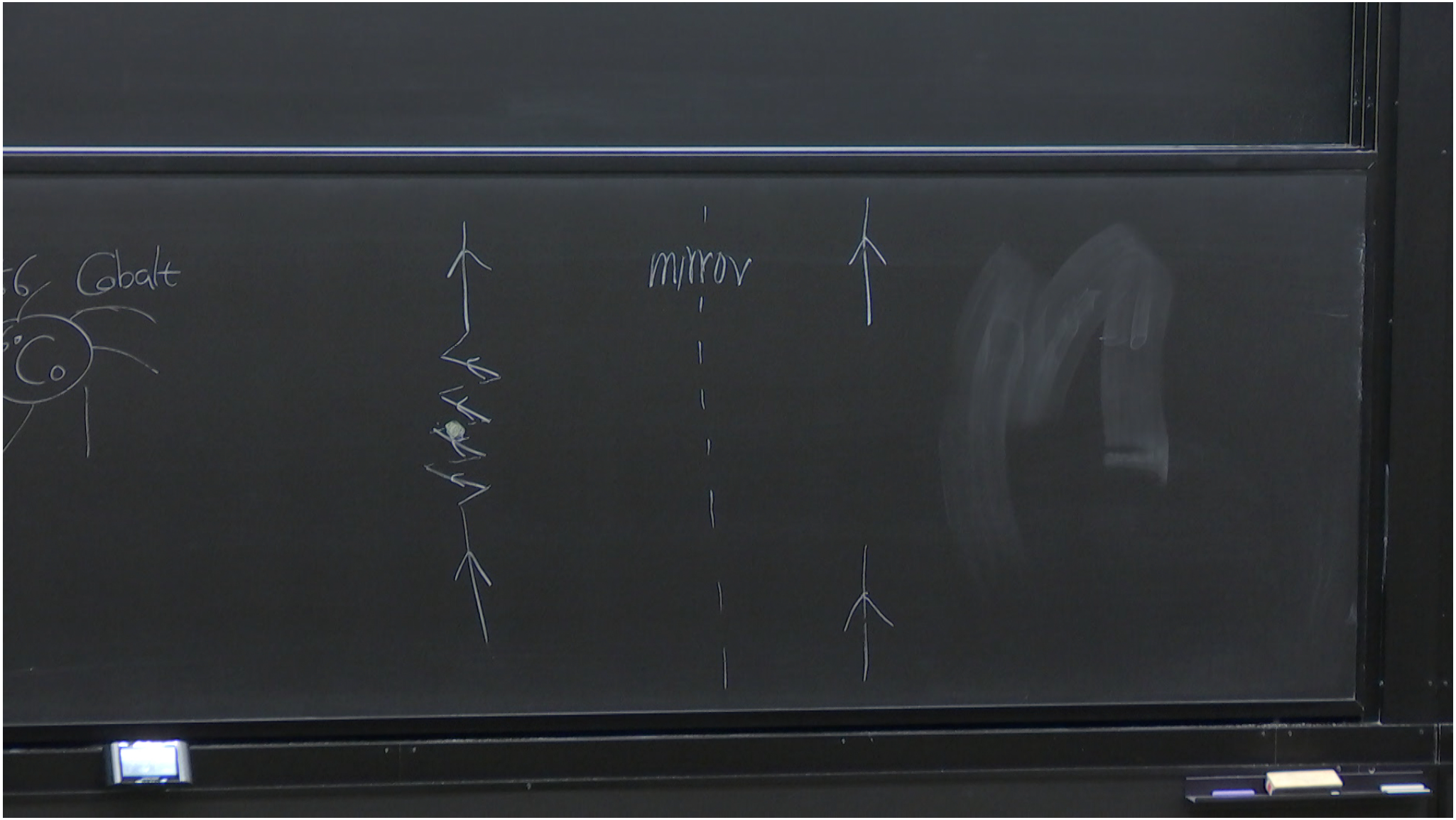

What?
4c3RWYpf
Yea
due: χ
new: Wu's observation
(crime scene)
suspects:
1956 Cobalt
60Co

clue: ?

new: Wu's observation (crime scene)

suspects:

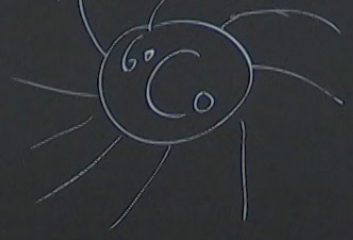



Cobalt
mirror

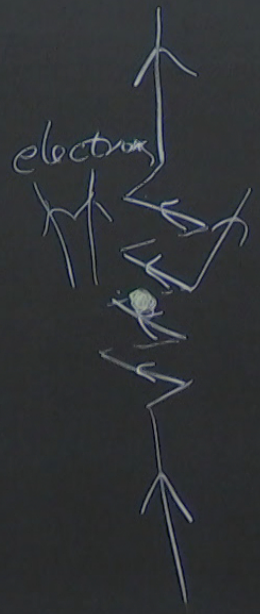
clue: $\not{x}$

new: Wu's observation
(crime scene)

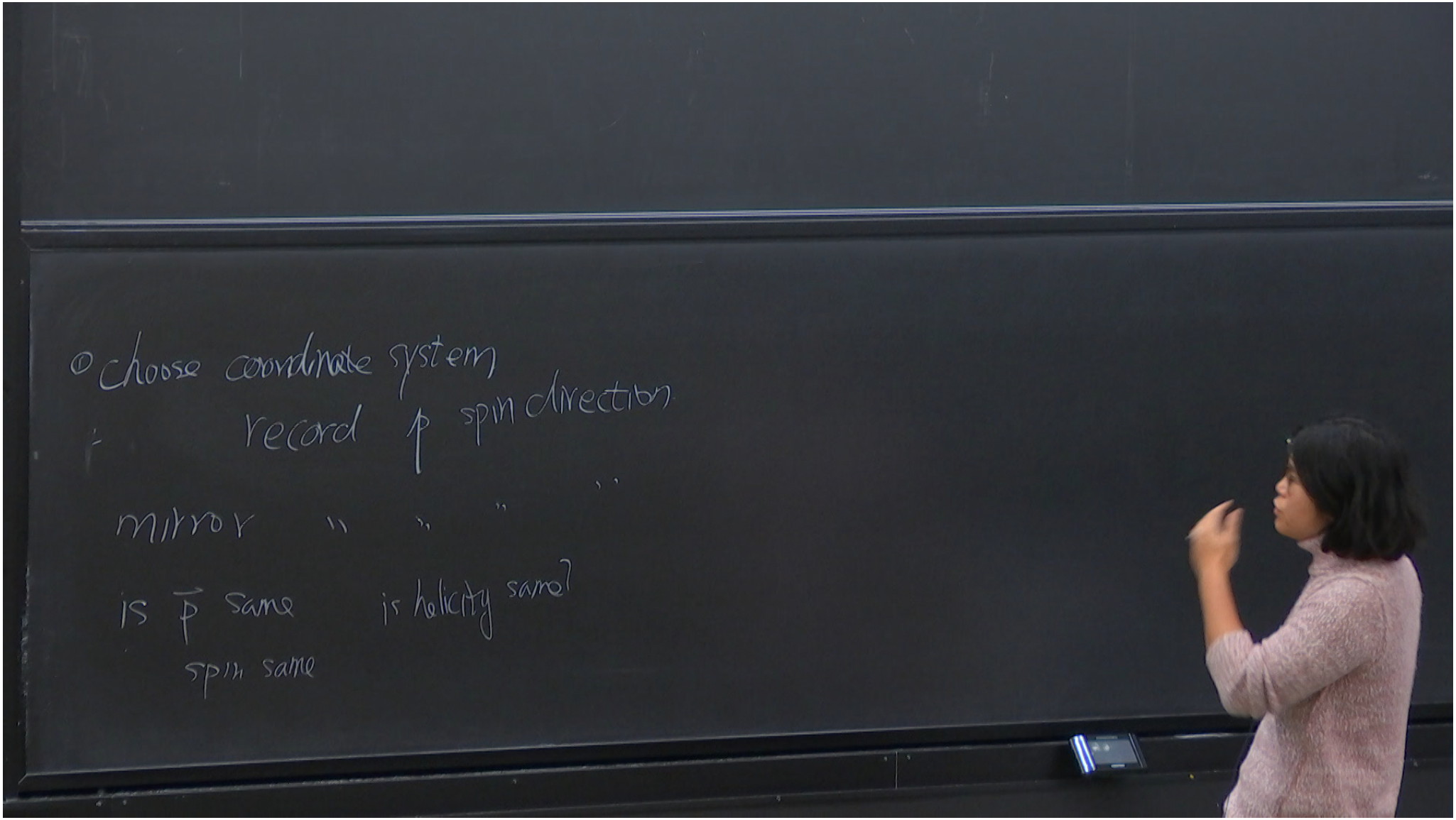
1956 Cobalt

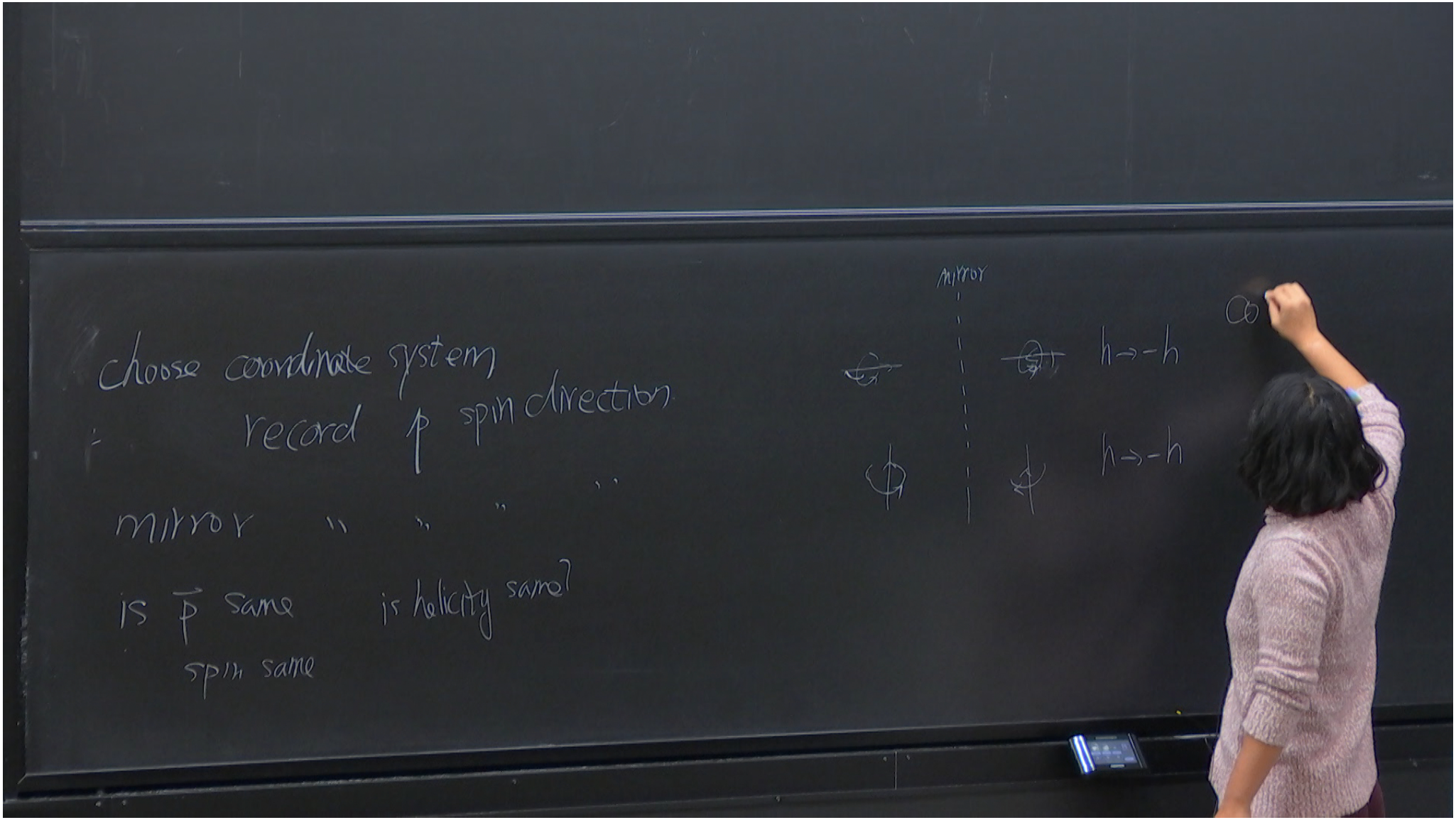


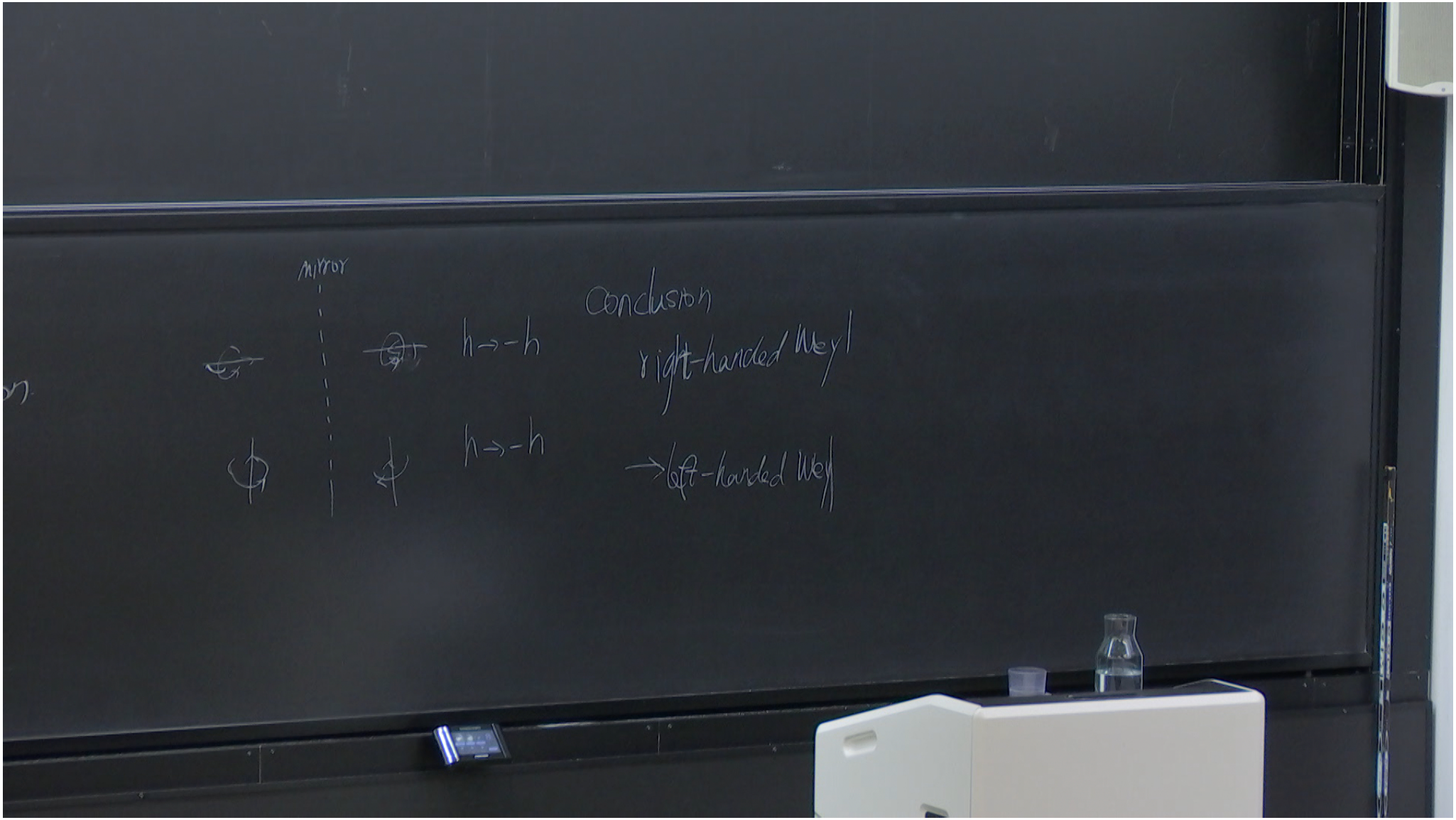
suspects: Dirac Spinor
Weyl Spinor

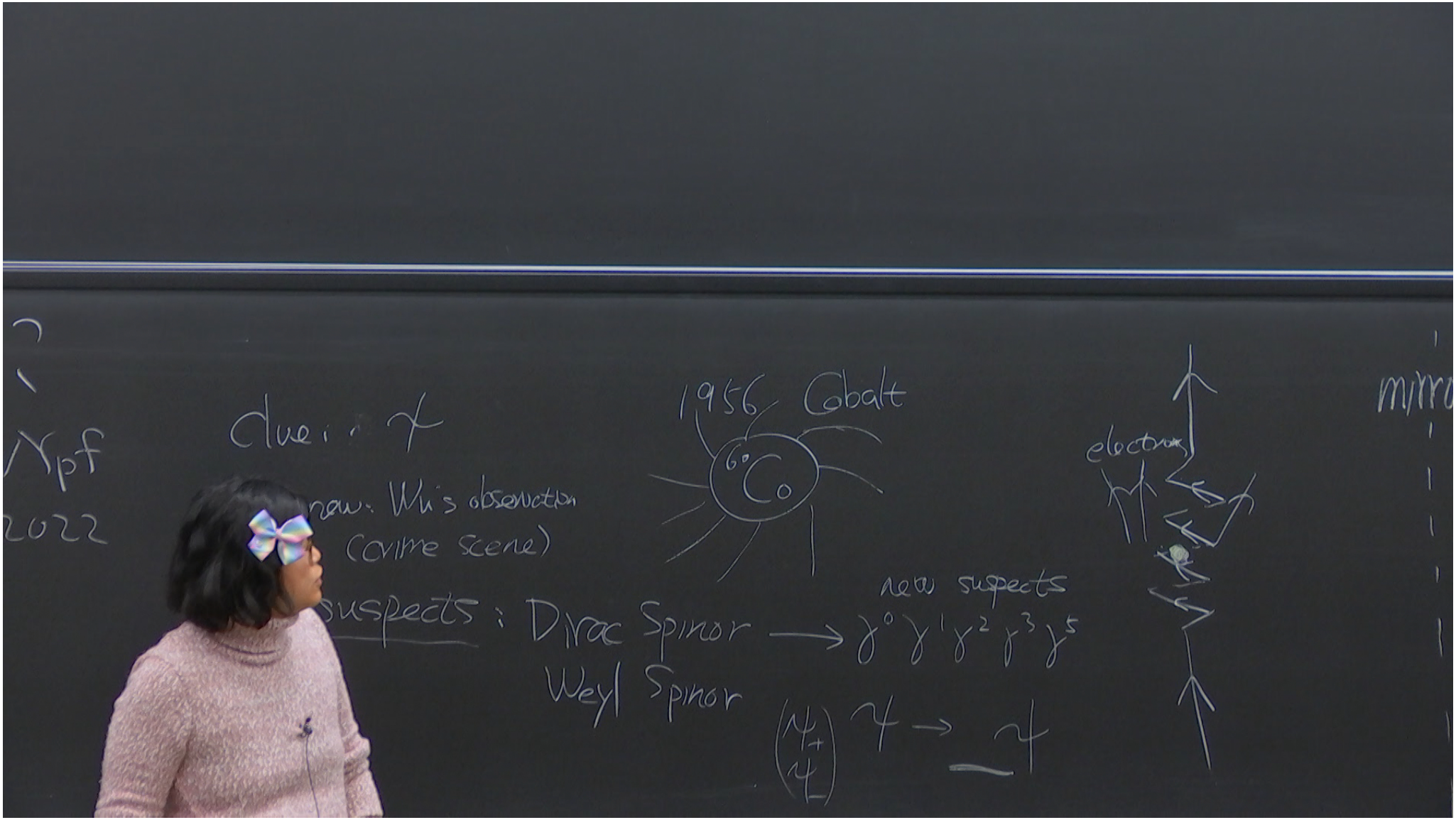


mirror


① choose coordinate system
record ↑ spin direction
mirror " " "
is $\vec{p}$ same
spin same
is helicity same?


choose coordinate system
record ↑ spin direction
mirror " " " "
is $\vec{p}$ same
spin same
is helicity same?
mirror
h→-h
h→-h


mirror
h→-h
h→-h
Conclusion
right-handed Weyl
→left-handed Weyl

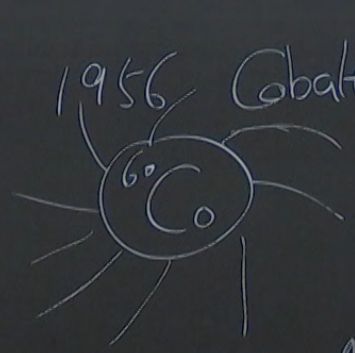


Npf
2022
clue: ψ
new: Wu's observation
(crime scene)
suspects: Dirac Spinor
Weyl Spinor
1956 Cobalt
60Co
new suspects
γ0 γ1 γ2 γ3 γ5
ψ+
ψ−
ψ → ψ
electrons
mirro

Ypf
2022

clue: γ

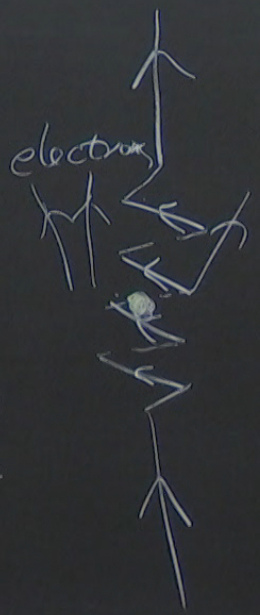
new: Wu's observation
(crime scene)



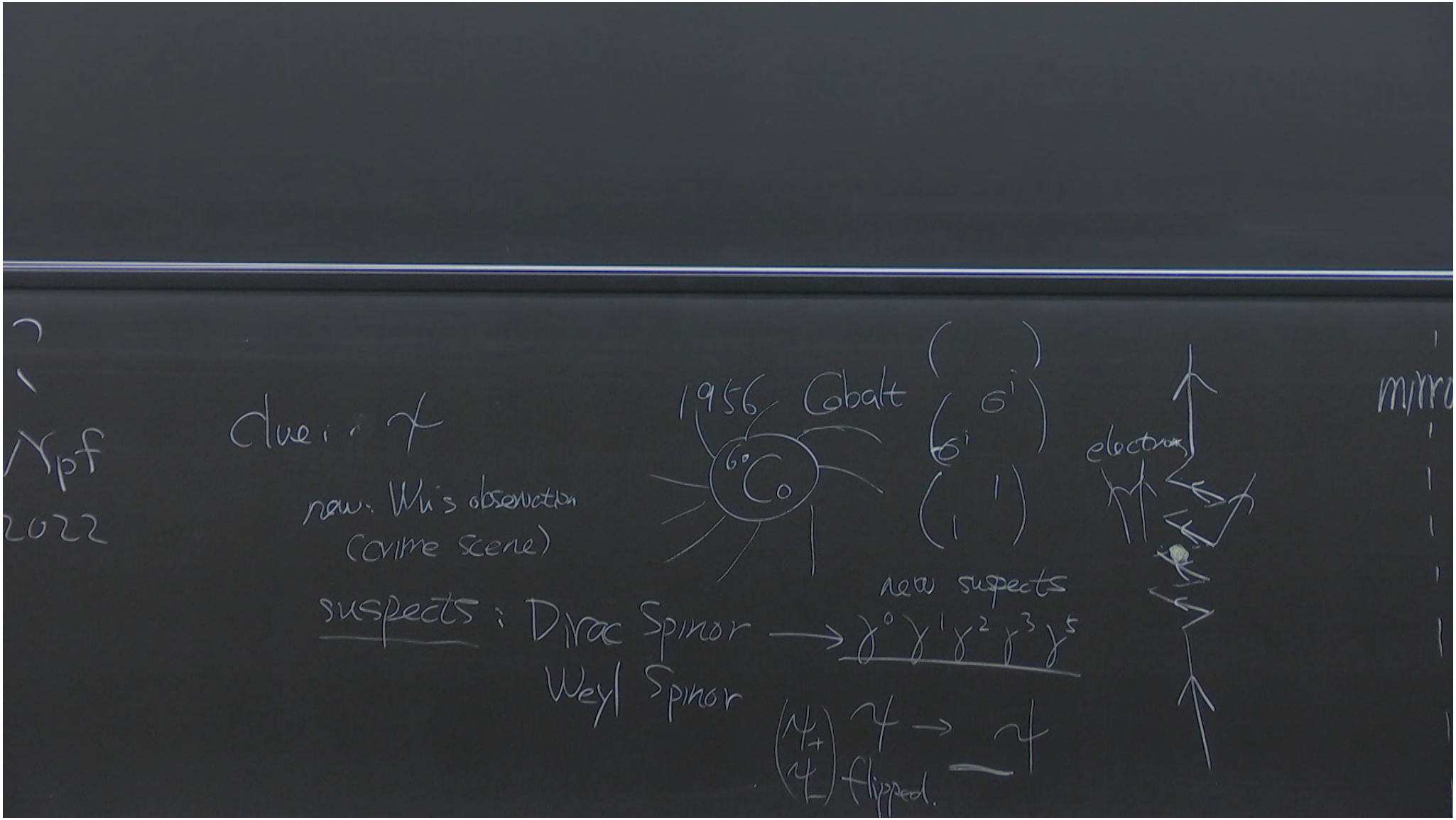
suspects: Dirac Spinor → new suspects $\gamma^0\gamma^1\gamma^2\gamma^3\gamma^5$

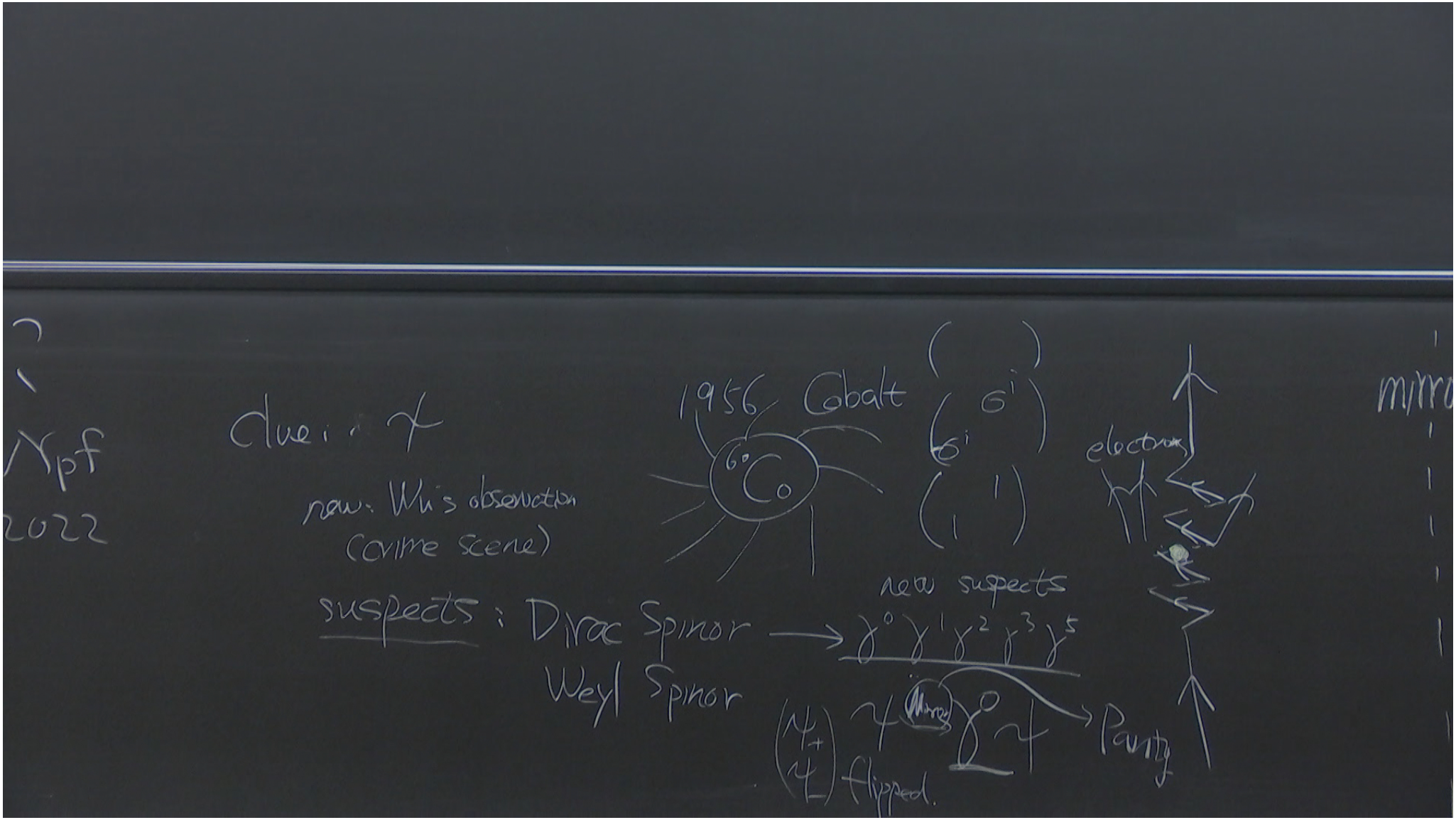
Weyl Spinor

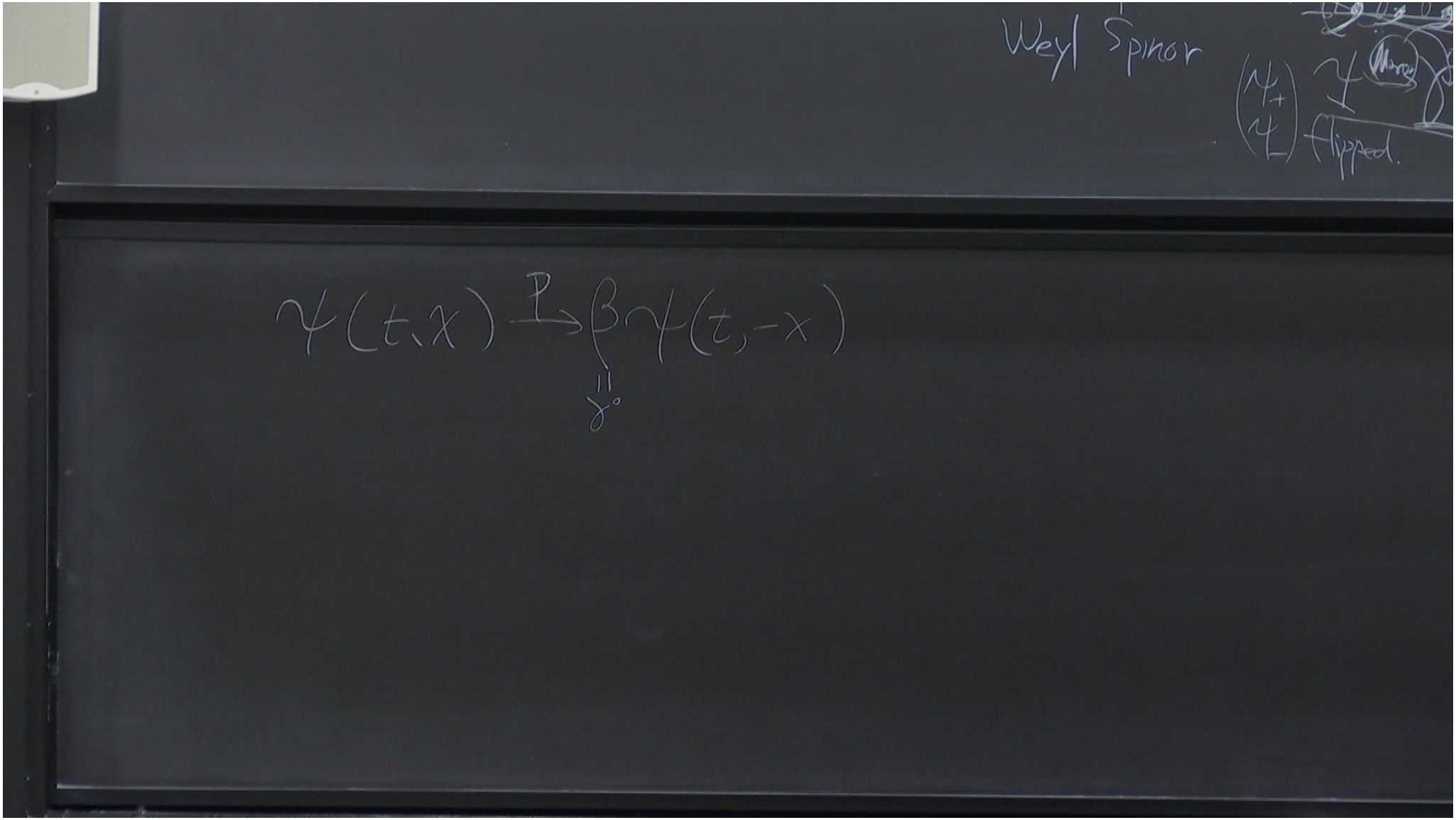
$\begin{pmatrix}\psi_+\\ \psi_-\end{pmatrix}$ $\gamma \to -\gamma$ flipped.



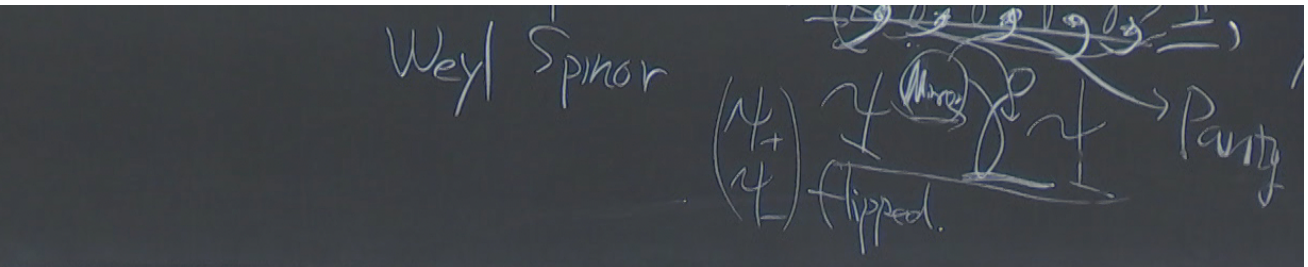
mirro


Npf
2022
clue: ψ
new: Wu's observation
(crime scene)
suspects: Dirac Spinor
Weyl Spinor
1956 Cobalt
60Co
new suspects
γ0 γ1 γ2 γ3 γ5
ψ+ ψ−
ψ → ψ
flipped.
electrons
mirro


Ypf
2022
clue: χ
new: Wu's observation
(crime scene)
1956 Cobalt
60
Co
suspects: Dirac Spinor
Weyl Spinor
new suspects
$\gamma^0\gamma^1\gamma^2\gamma^3\gamma^5$
$\begin{pmatrix}\chi_+\\ \chi_-\end{pmatrix}$ flipped.
Parity
electrons
mirro


Weyl Spinor
flipped.
$\psi(t,x) \xrightarrow{P} \beta\psi(t,-x)$
$\beta = \gamma^0$

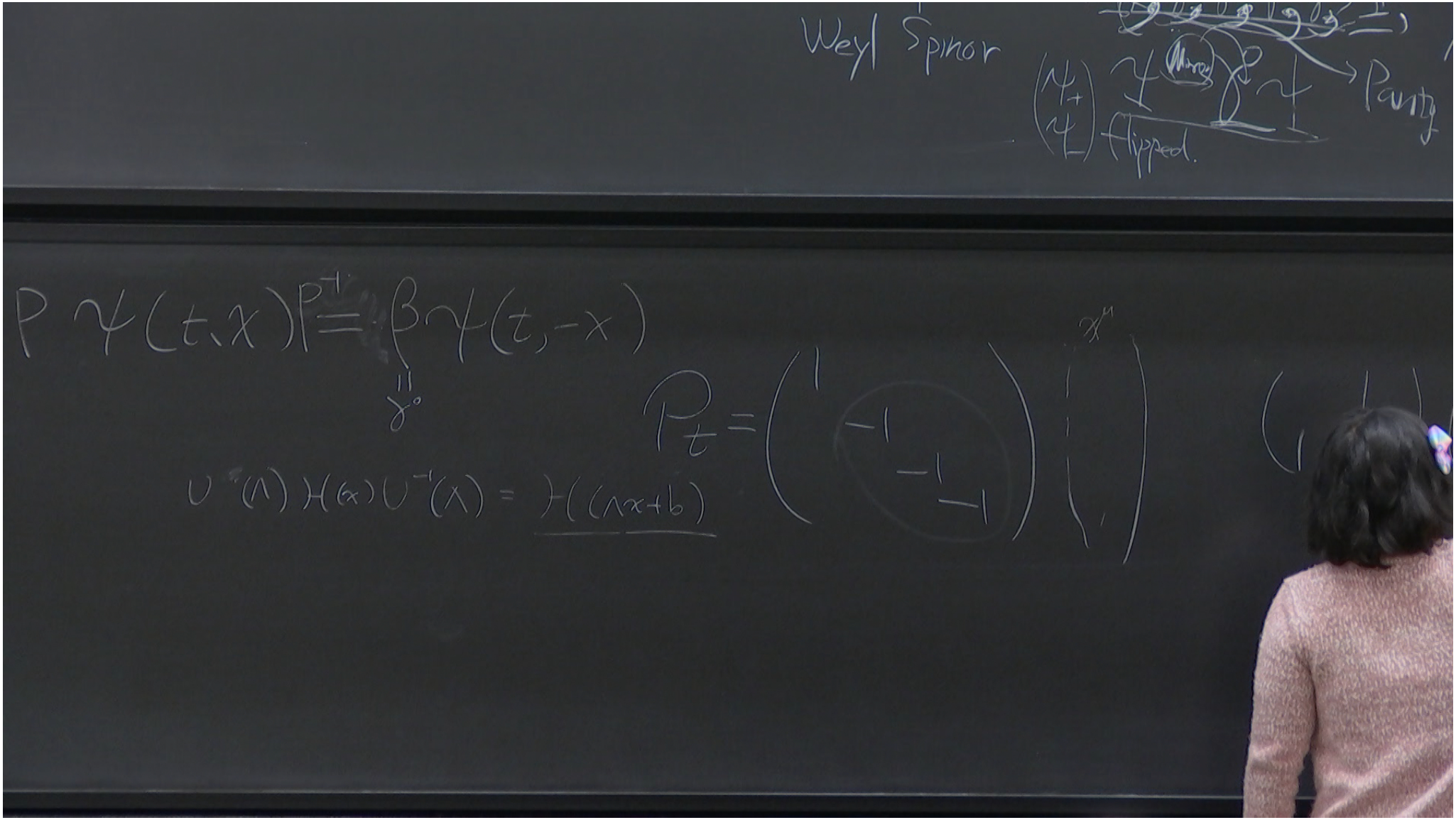
Weyl Spinor

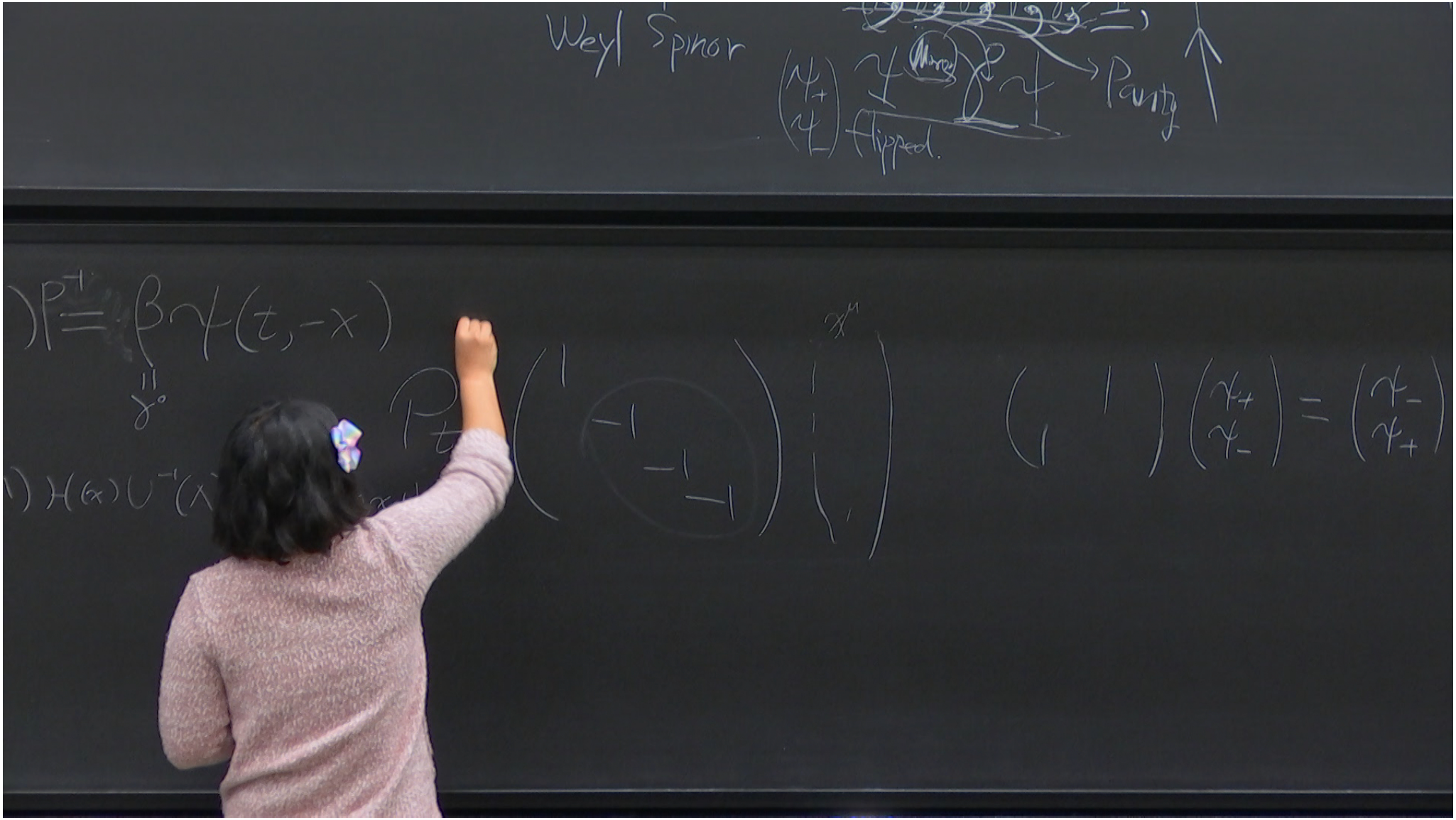


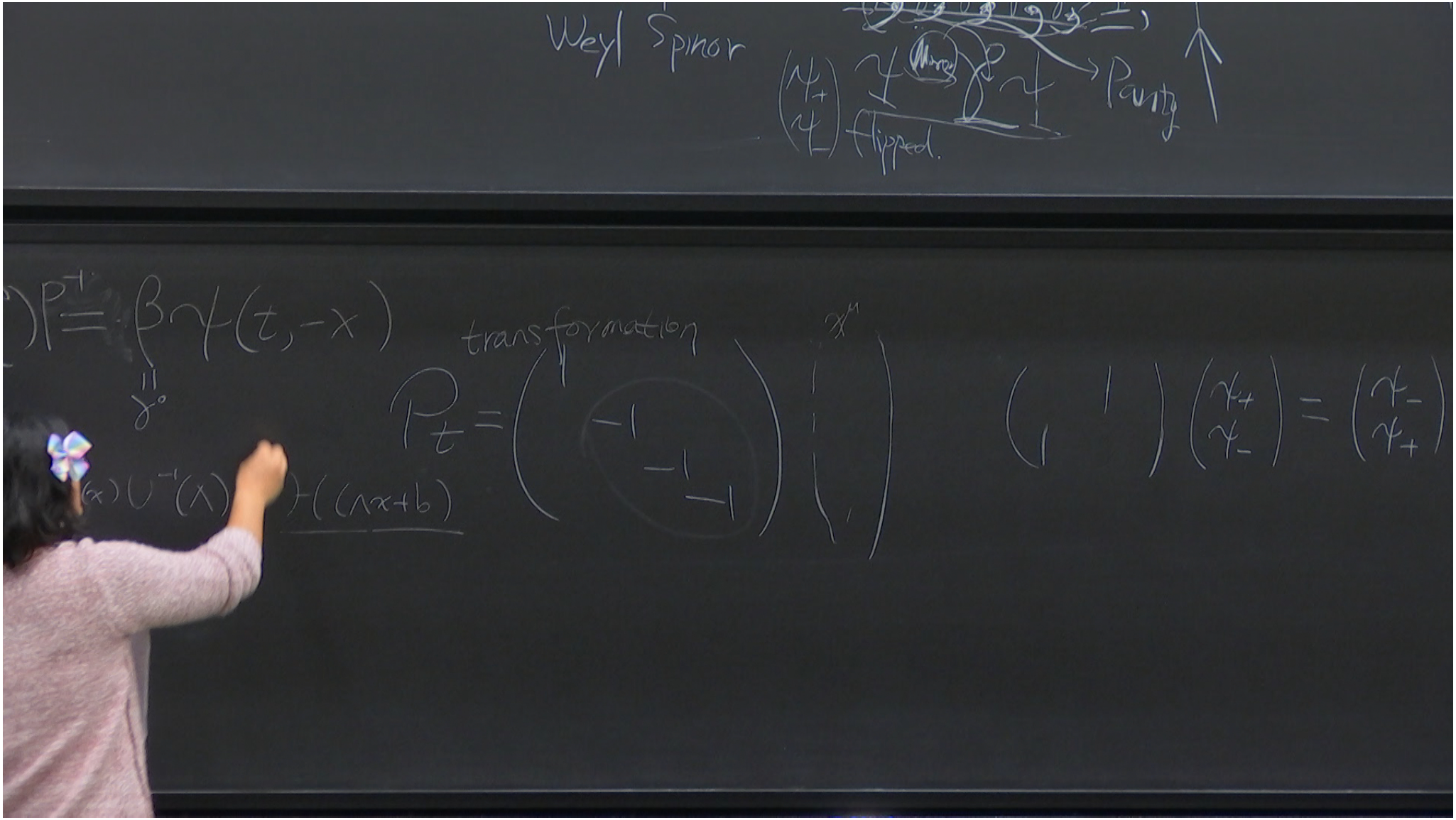
$$P\,\psi(t,x)\,P^{-1} = \beta\,\psi(t,-x)$$

$$\beta = \gamma^0$$

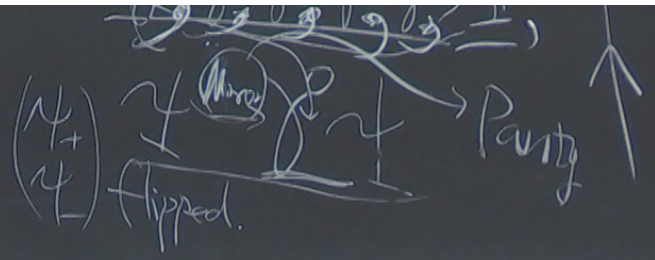
$$P_t = \begin{pmatrix} 1 & & & \\ & -1 & & \\ & & -1 & \\ & & & -1 \end{pmatrix}$$


Weyl Spinor
flipped.
Parity
$P\psi(t,x)P^{-1} = \beta\psi(t,-x)$
$\beta = \gamma^0$
$U(\Lambda)H(x)U^{-1}(\Lambda) = H(\Lambda x+b)$
$P_t =$


Weyl Spinor
Parity
flipped.


Weyl Spinor
Parity
flipped.
transformation

Weyl Spinor



$$\psi(t,\vec{x})P^{-1} = \beta\psi(t,-\vec{x})$$

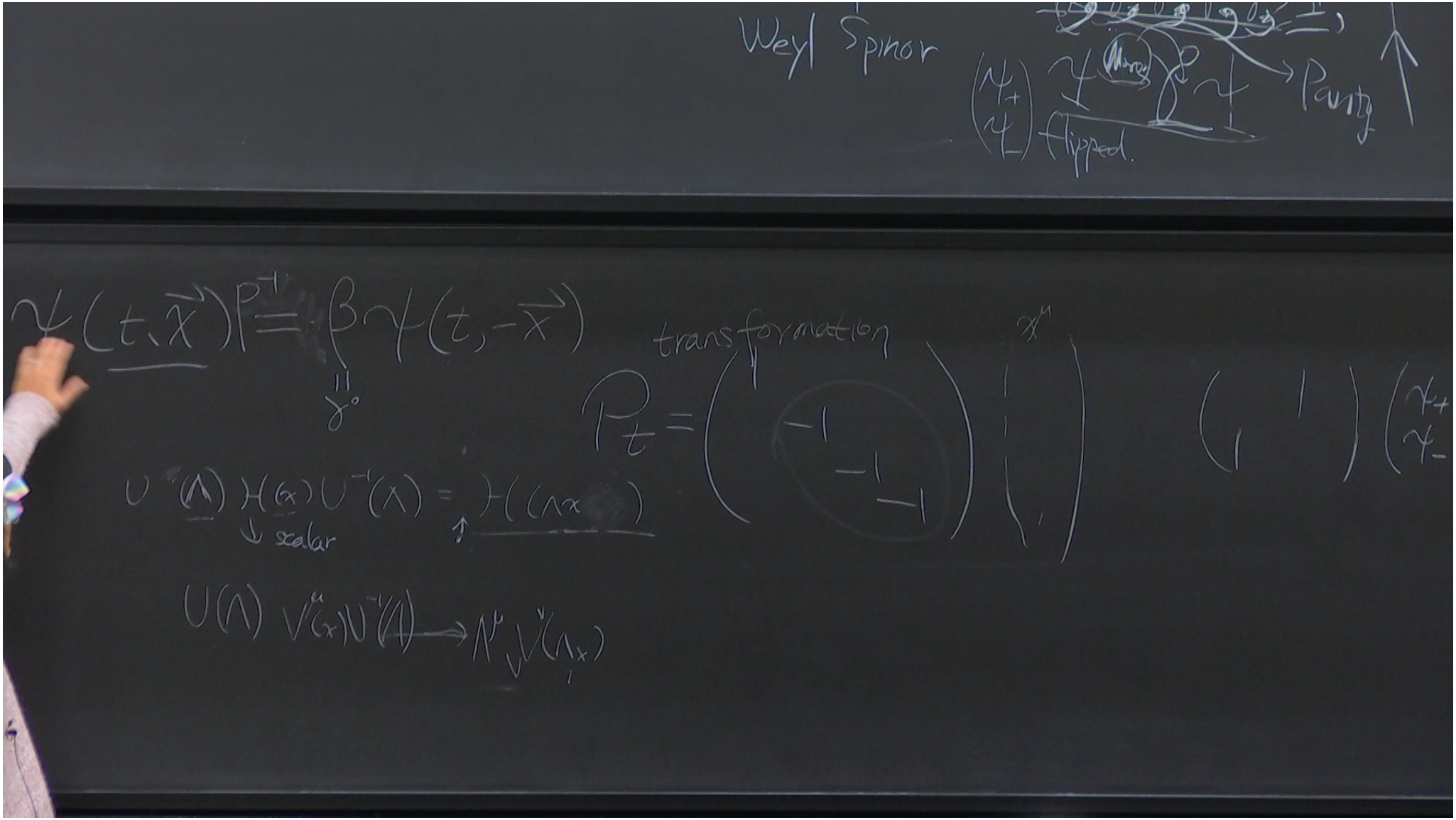
$$\beta = \gamma^0$$

$$U^{-1}(\Lambda)\,\psi(x)\,U(\Lambda) = \psi(\Lambda x)$$

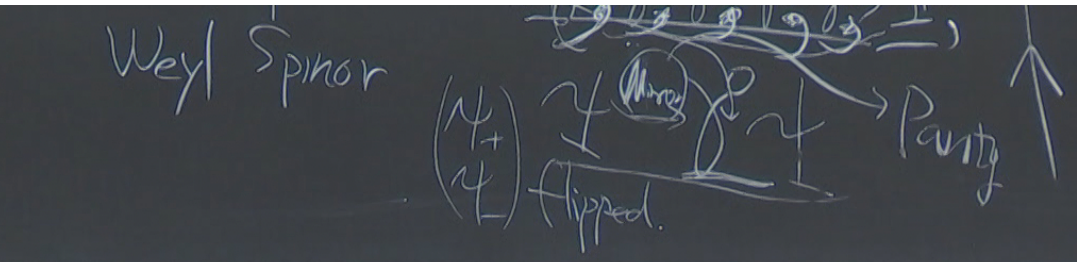
transformation

$$P_t = \begin{pmatrix} -1 & & & \\ & -1 & & \\ & & -1 & \\ & & & 1 \end{pmatrix} \qquad x^\mu$$

$$\begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & 1 \end{pmatrix} \begin{pmatrix} \psi_+ \\ \psi_- \end{pmatrix}$$


Weyl Spinor
Parity
flipped.
transformation

Weyl Spinor



$\psi(t,\vec{x}) \longrightarrow \beta\psi(t,-\vec{x})$

$\beta = \gamma^0 \rightarrow$ activity

P_t = transformation $\begin{pmatrix} -1 & & & \\ & -1 & & \\ & & -1 & \\ & & & -1 \end{pmatrix} \begin{pmatrix} x^\mu \\ t \\ x \\ y \\ z \end{pmatrix} = \begin{pmatrix} t \\ -x \\ -y \\ -z \end{pmatrix}$ $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} \psi_+ \\ \psi_- \end{pmatrix}$

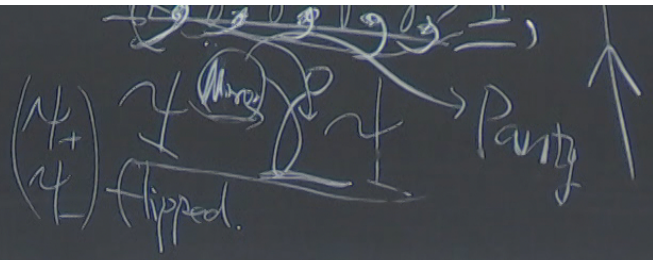
$U(\Lambda)\, H(x)\, U^{-1}(\Lambda) = H(\Lambda x)$

$H(x)$ ↓ scalar

$U(\Lambda)\, V^\mu(x)\, U^{-1}(\Lambda) \longrightarrow \Lambda^\mu{}_\nu V^\nu(\Lambda x)$

$P^2 = 1$

Weyl Spinor



$\psi(t,\vec{x}) \longrightarrow \beta\gamma(t,-\vec{x})$

$\beta = \gamma^0 \rightarrow$ activity

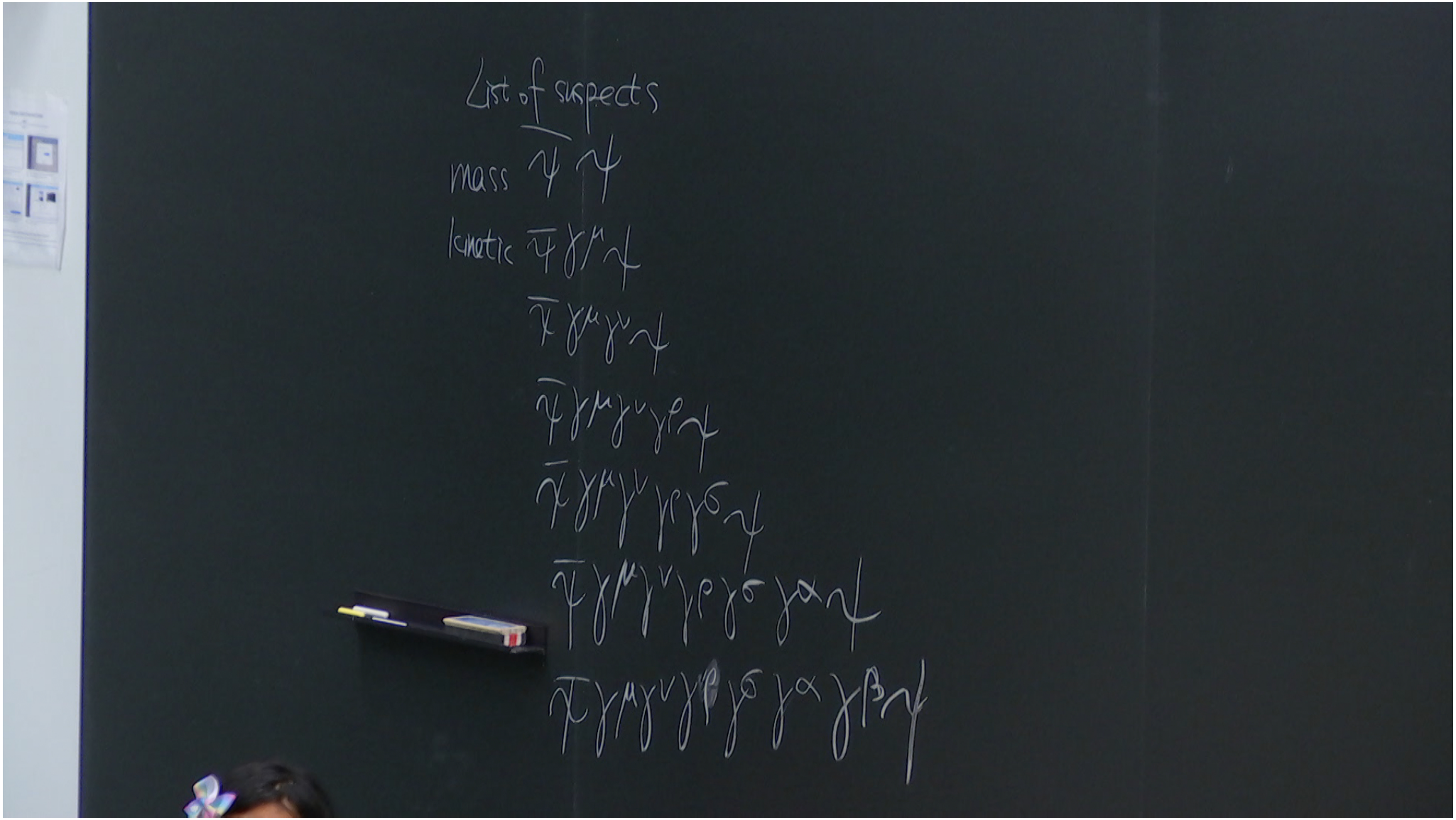
P_t = transformation $\begin{pmatrix} -1 & & & \\ & -1 & & \\ & & -1 & \\ & & & -1 \end{pmatrix}$ $\begin{pmatrix} x^\mu \\ t \\ x \\ y \\ z \end{pmatrix} = \begin{pmatrix} t \\ -x \\ -y \\ -z \end{pmatrix}$ $\begin{pmatrix} 1 & \\ & 1 \end{pmatrix} \begin{pmatrix} \psi_+ \\ \psi_- \end{pmatrix}$

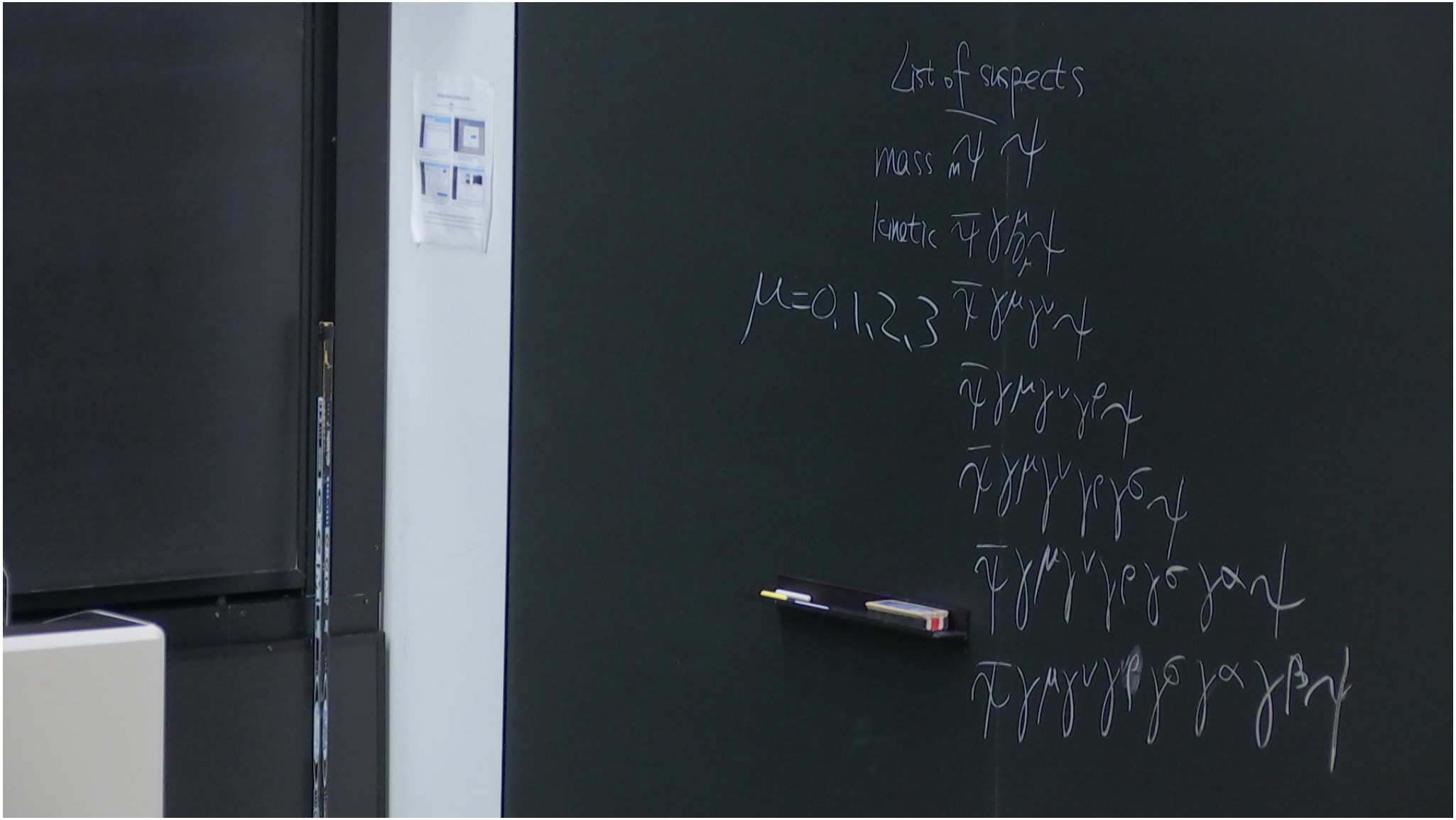
$U(\Lambda)\,\psi(x)\,U^{-1}(\Lambda) = \psi(\Lambda x)$

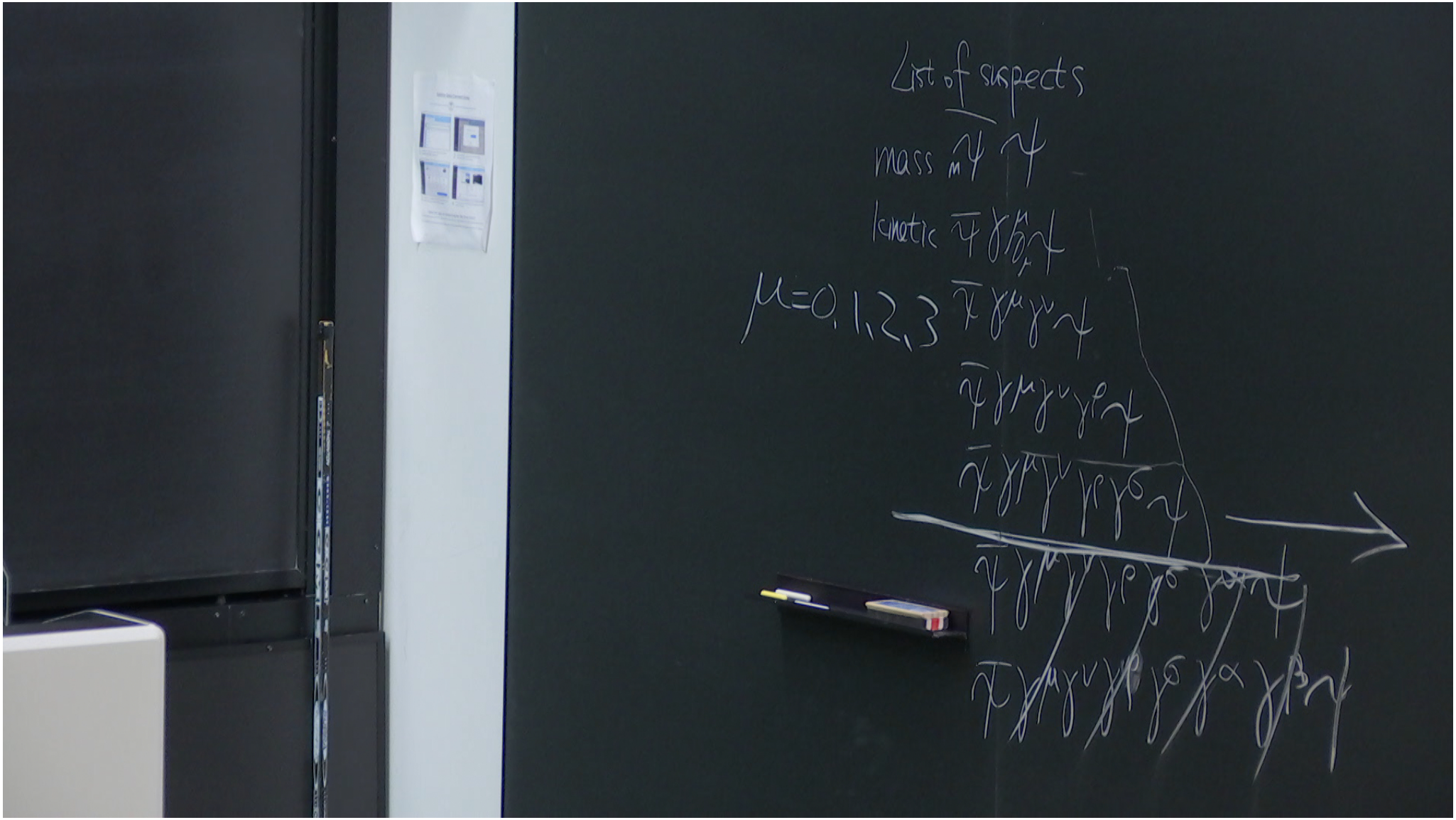
$U(\Lambda)$ scalar

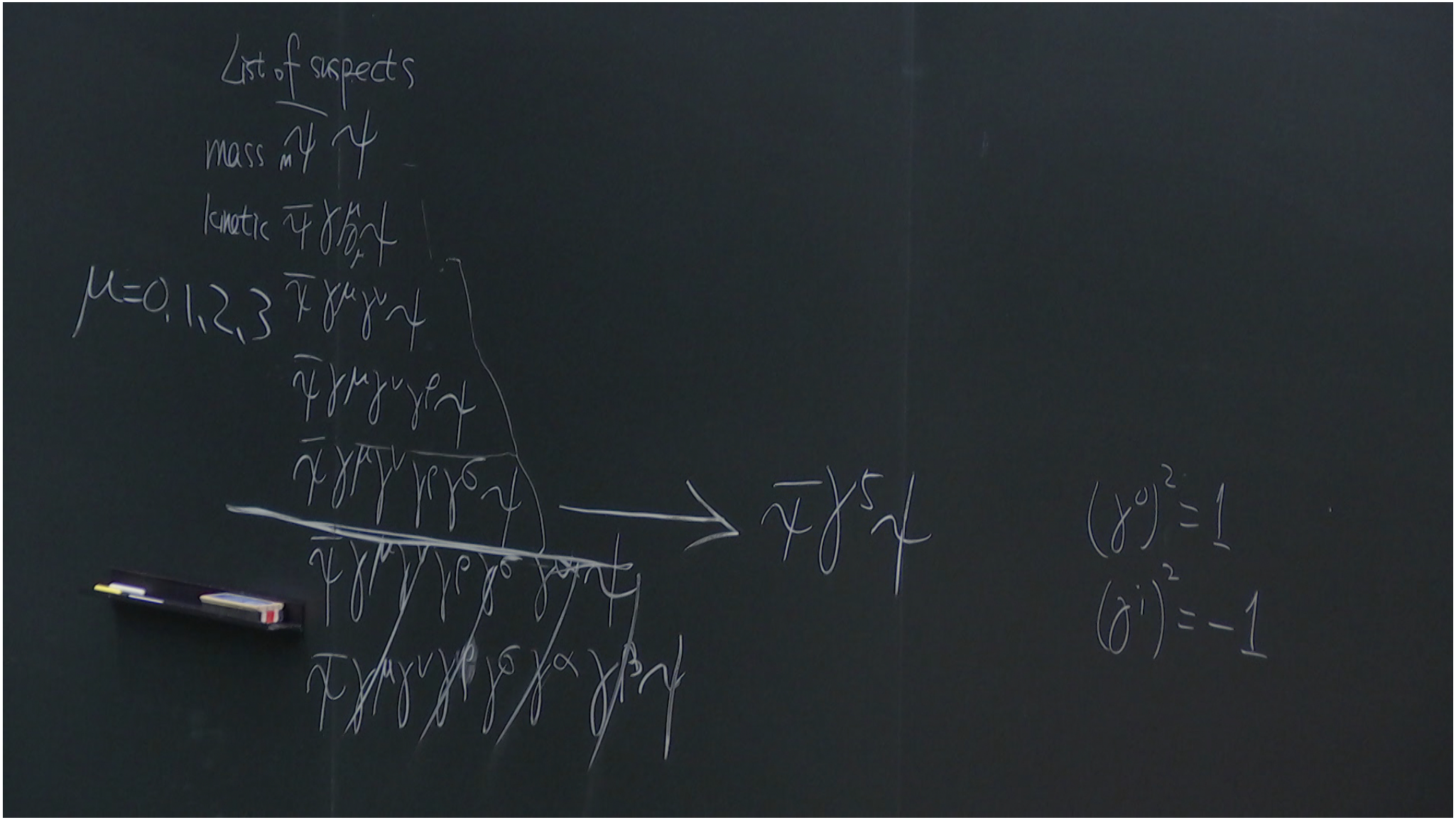
$U(\Lambda)\,V^\mu(x)\,U^{-1}(\Lambda) \longrightarrow \Lambda^\mu{}_\nu V^\nu(\Lambda x)$

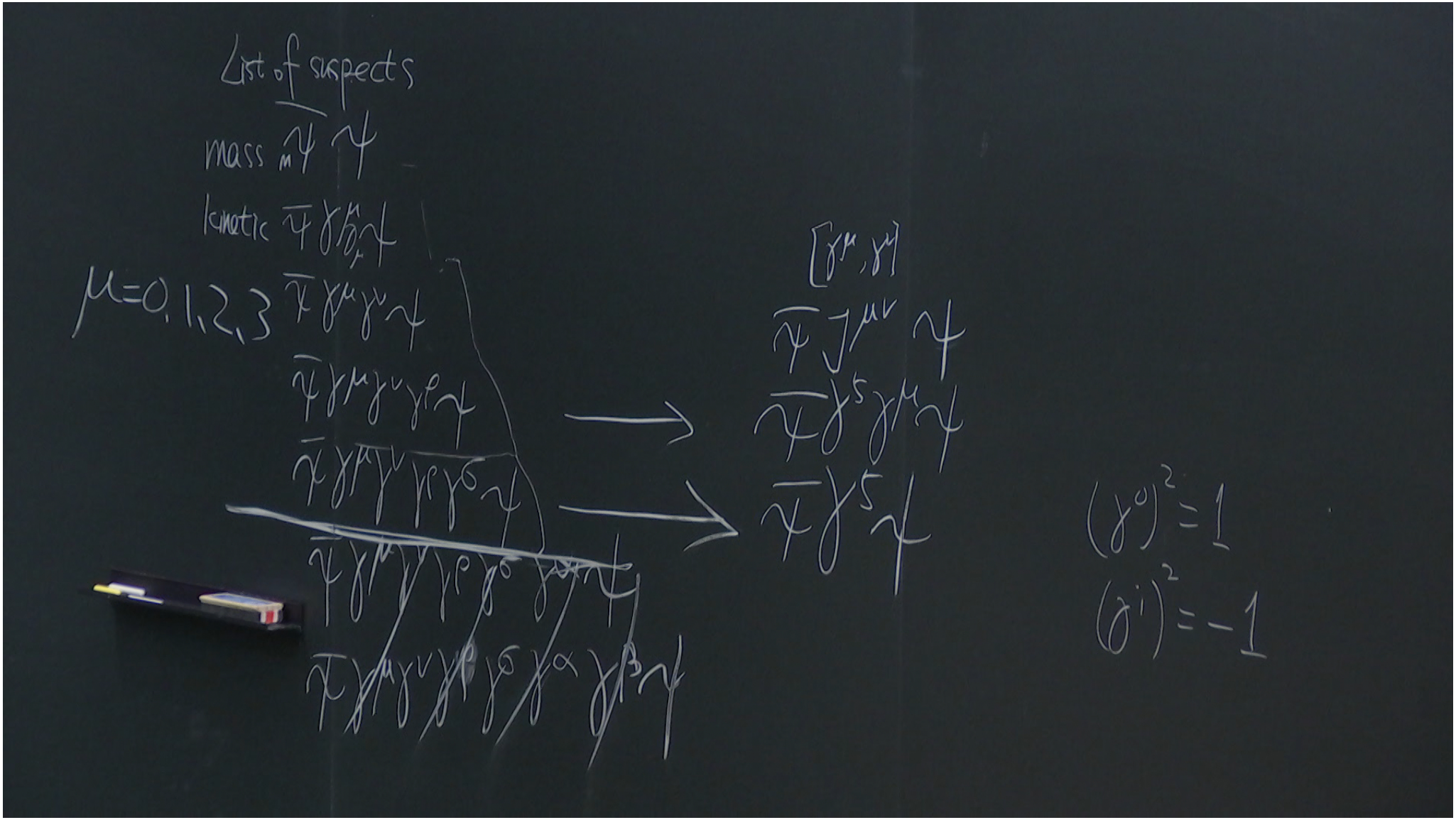
$P^2 = 1 \qquad P = P^{-1}$

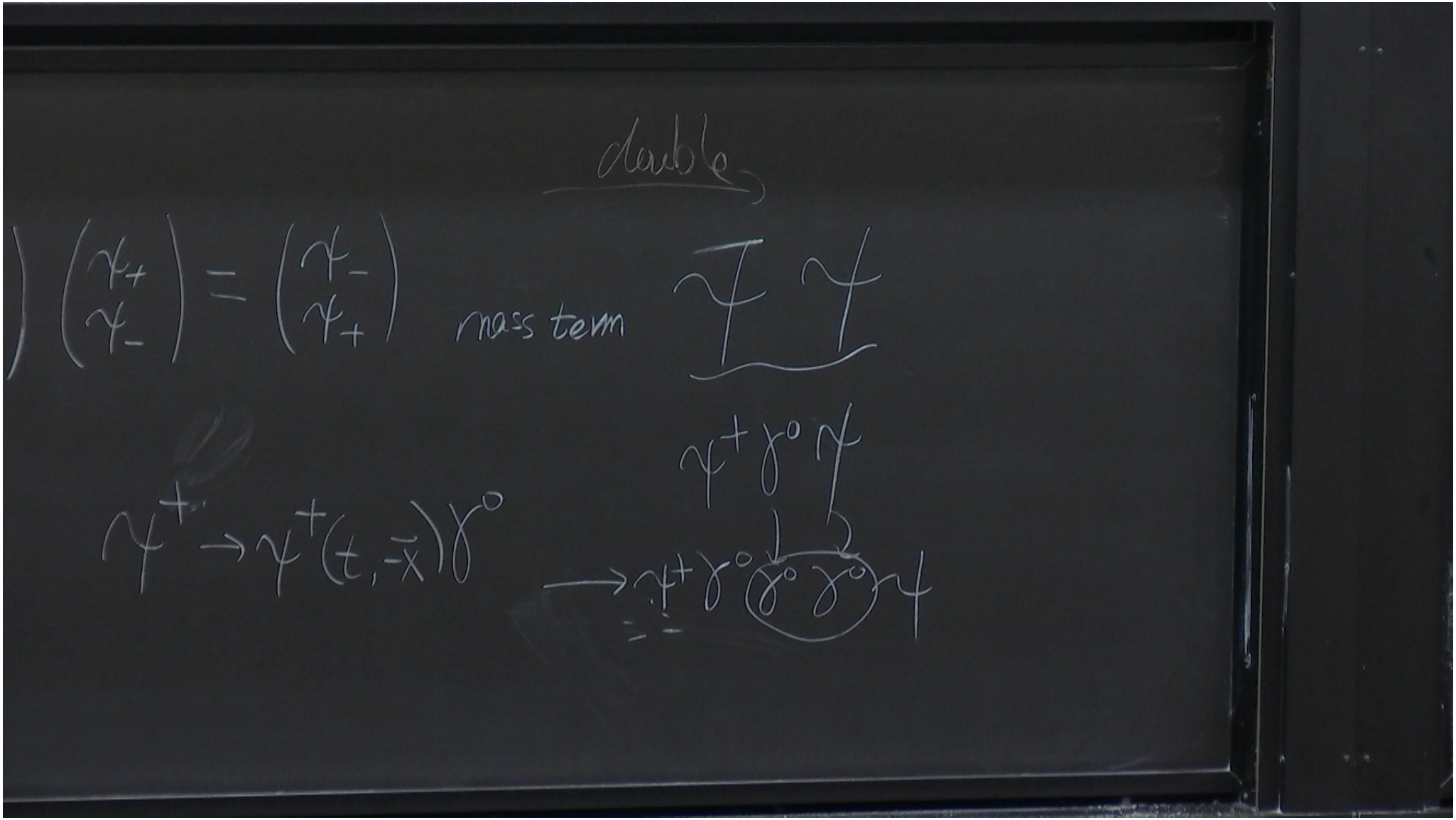

List of suspects
mass
kinetic

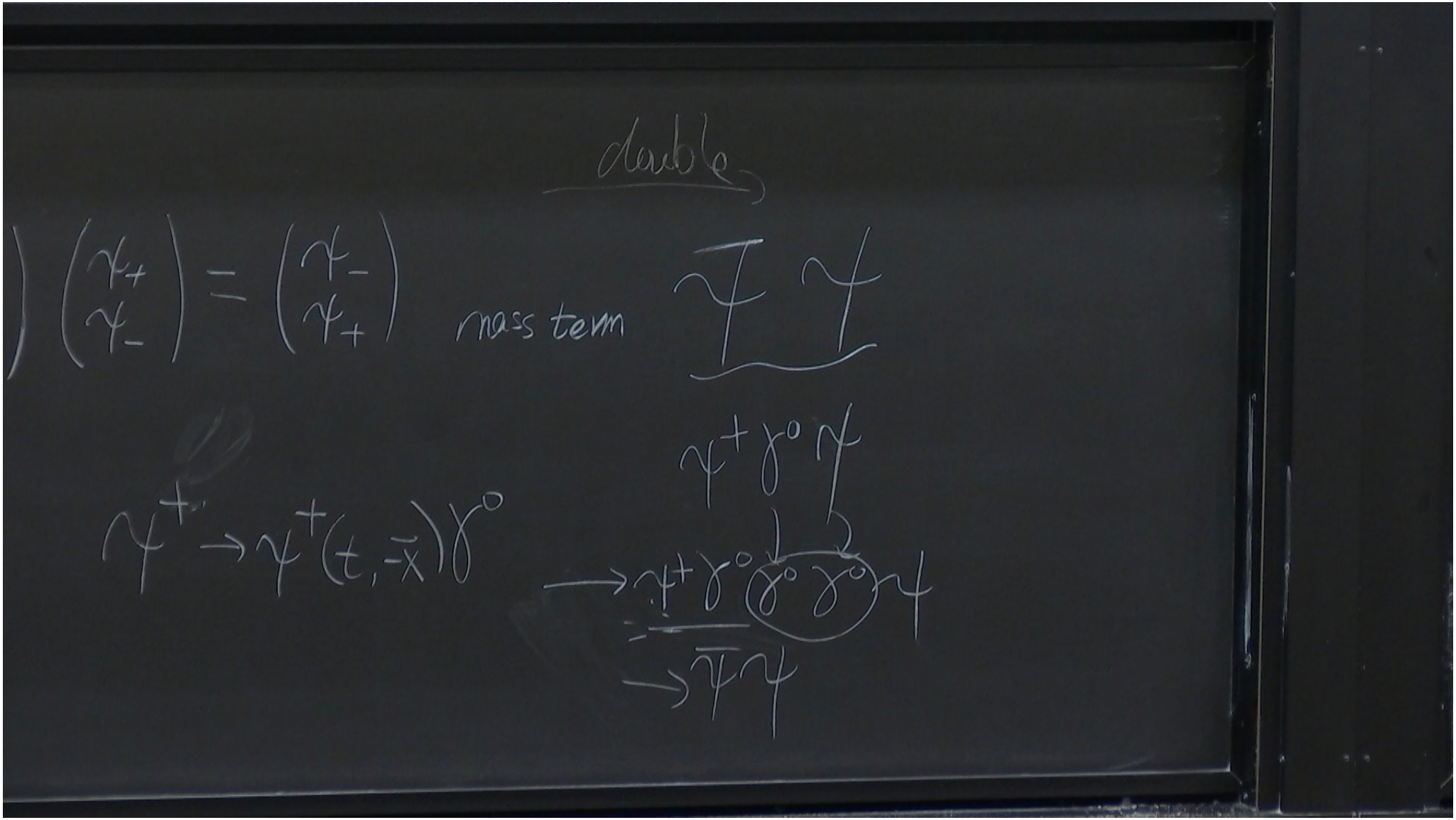

List of suspects
mass
kinetic
μ=0,1,2,3

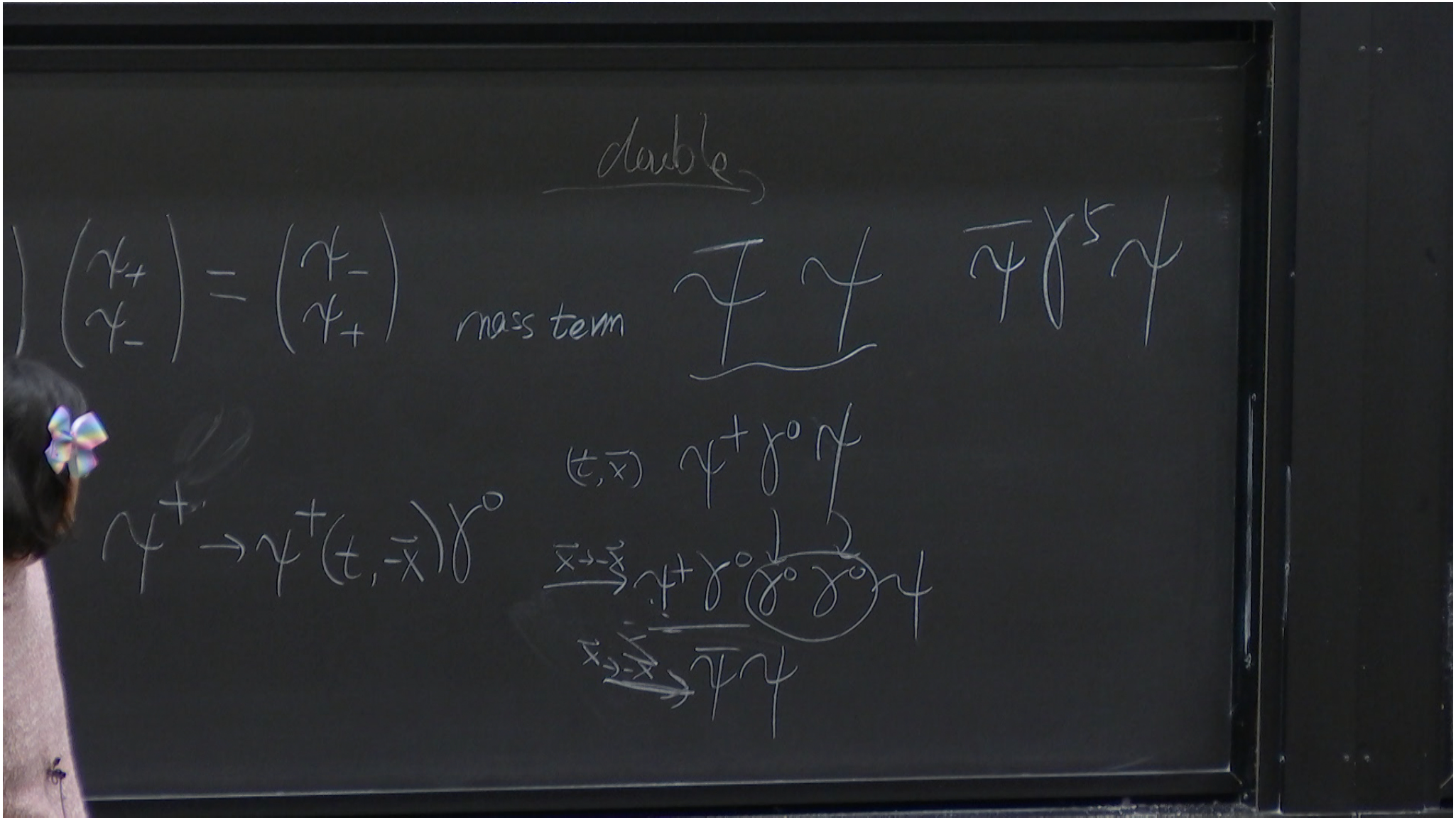

List of suspects
mass
kinetic
μ=0,1,2,3

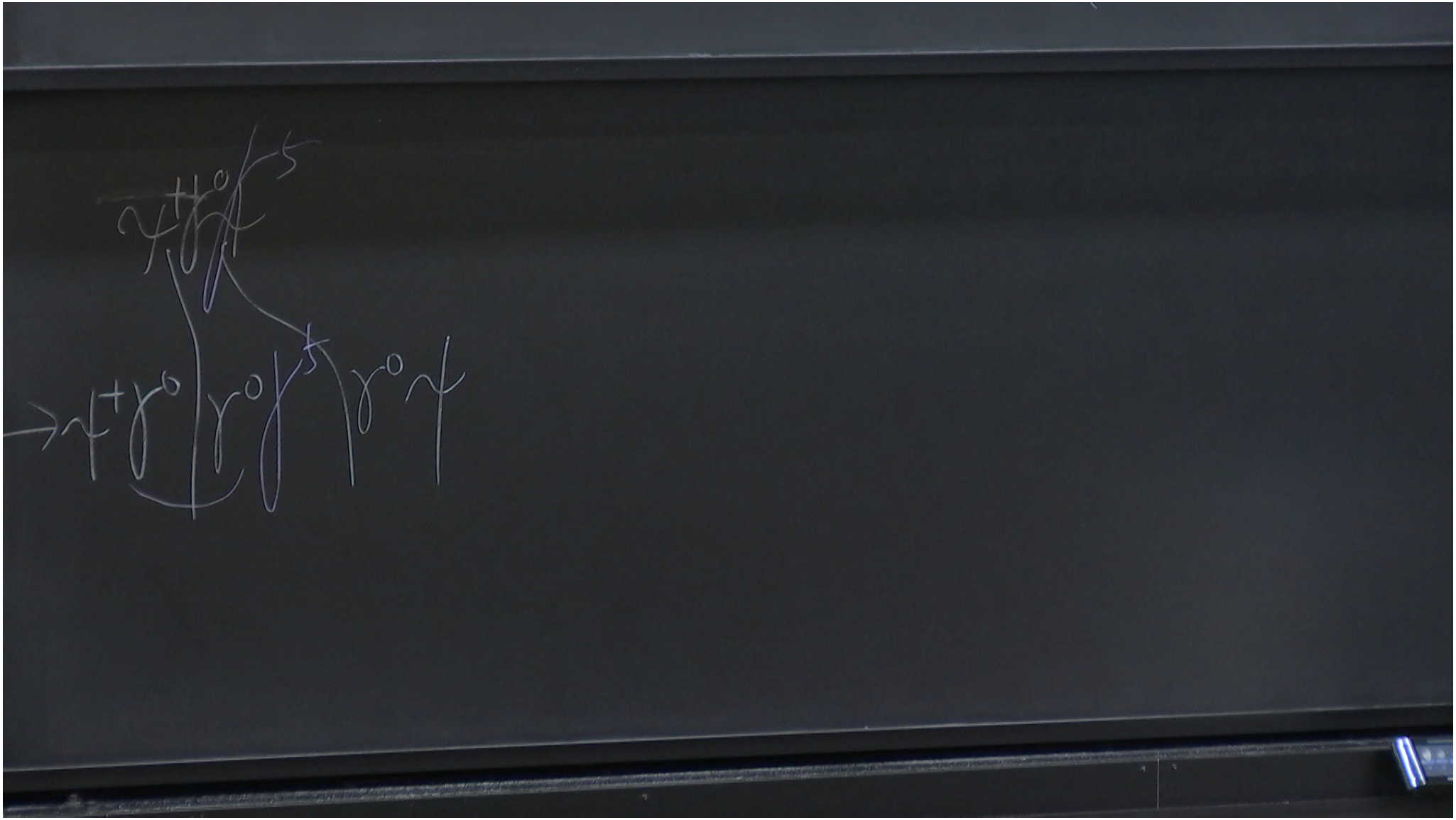

List of suspects
mass
kinetic
$\mu=0,1,2,3$
$\bar{\psi}\psi$
$\bar{\psi}\gamma^\mu\partial_\mu\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\partial_\mu\partial_\nu\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\partial_\mu\partial_\nu\partial_\rho\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\partial_\mu\partial_\nu\partial_\rho\partial_\sigma\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\gamma^\alpha\partial_\mu\partial_\nu\partial_\rho\partial_\sigma\partial_\alpha\psi$
$\bar{\psi}\gamma^5\psi$
$(\gamma^0)^2=1$
$(\gamma^i)^2=-1$

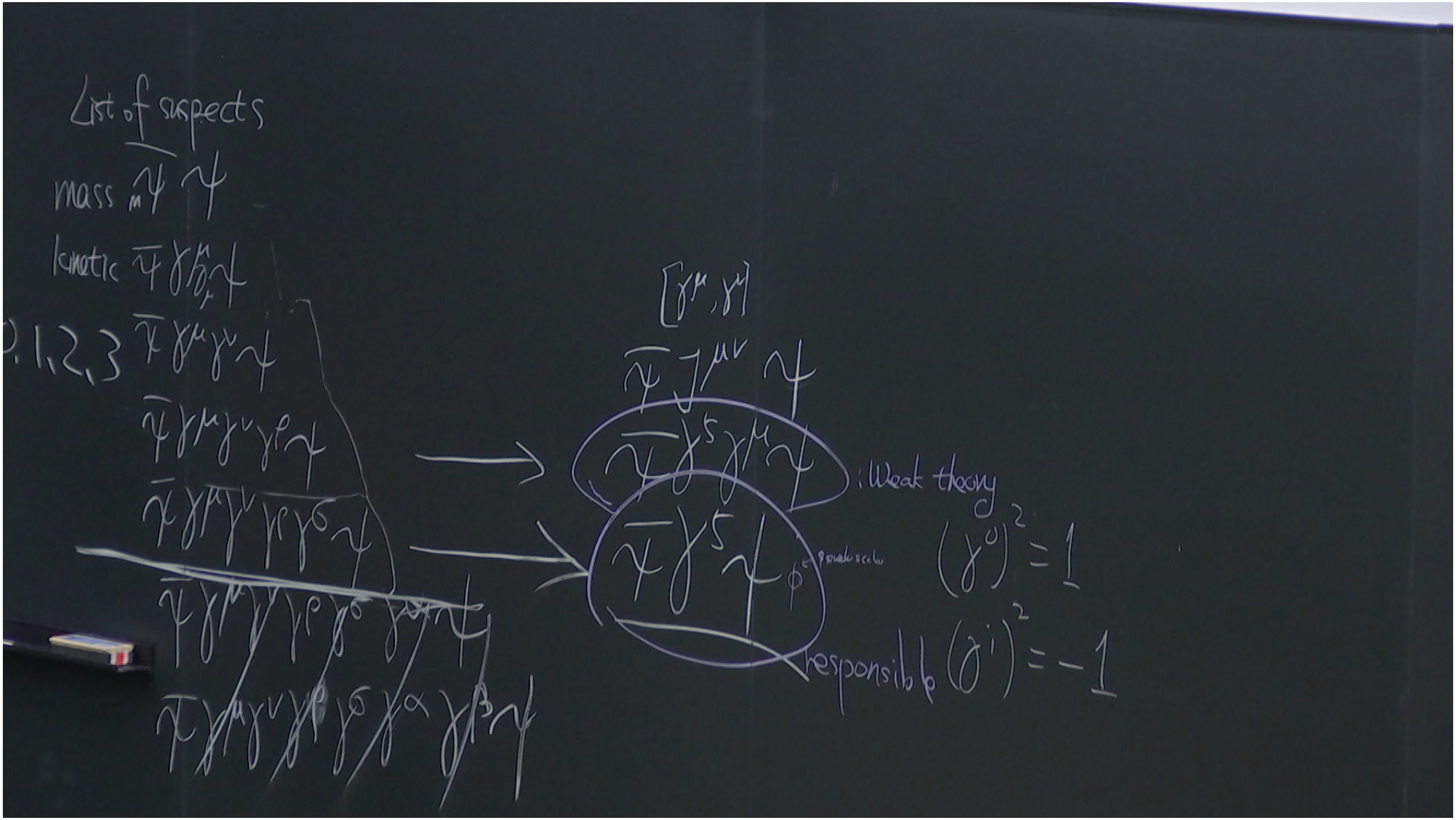

List of suspects
mass $m\bar{\psi}\psi$
kinetic $\bar{\psi}\gamma^\mu\partial_\mu\psi$
$\mu=0,1,2,3$
$\bar{\psi}\gamma^\mu\gamma^\nu\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\gamma^\alpha\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\gamma^\alpha\gamma^\beta\psi$
$[\gamma^\mu,\gamma^\nu]$
$\bar{\psi}J^{\mu\nu}\psi$
$\bar{\psi}\gamma^5\gamma^\mu\psi$
$\bar{\psi}\gamma^5\psi$
$(\gamma^0)^2=1$
$(\gamma^i)^2=-1$

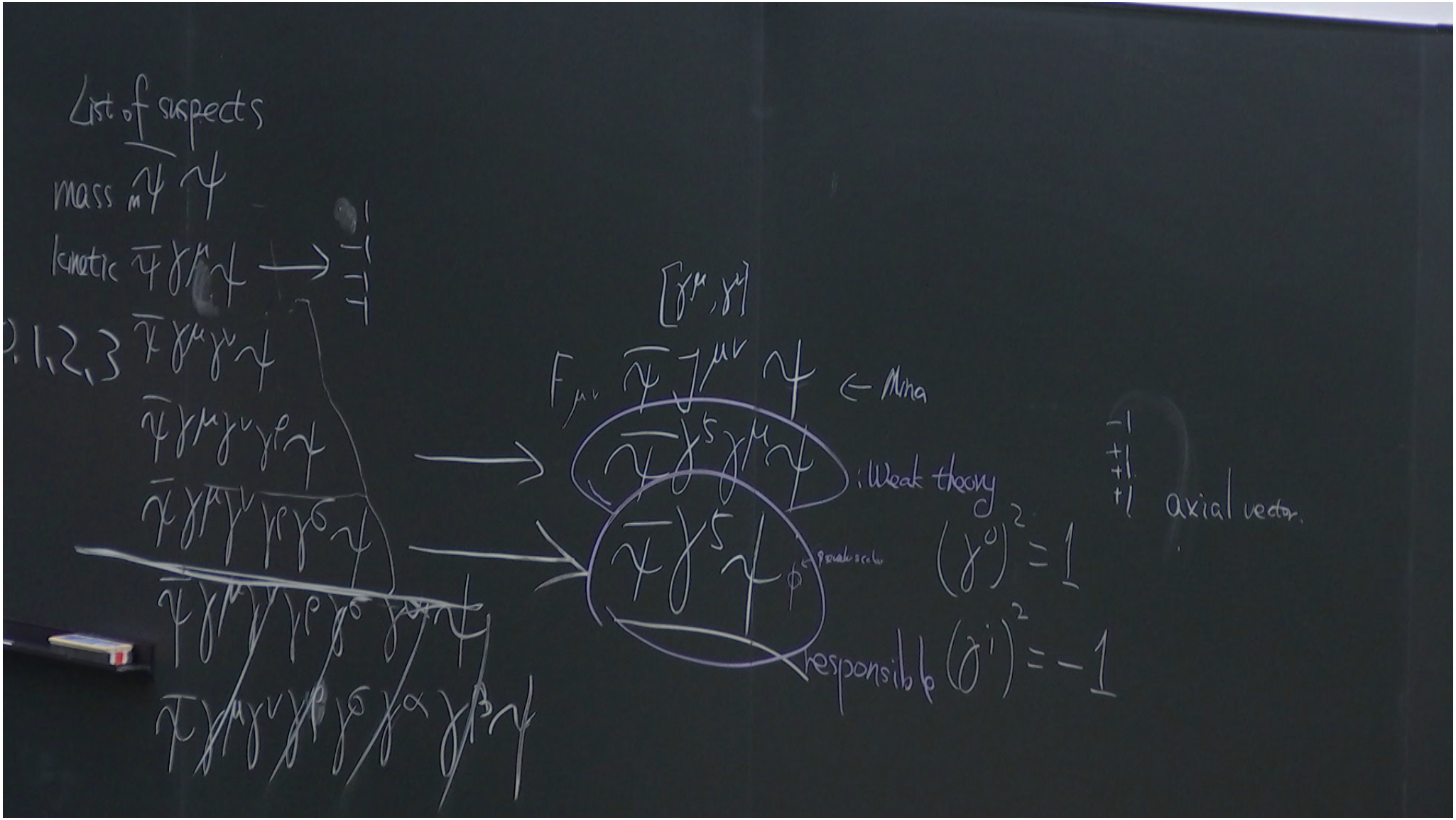

double
mass term
$\psi^+ \to \psi^+(t,-\vec{x})\gamma^0$
$\psi^+\gamma^0\psi$
$\gamma^0\gamma^0$

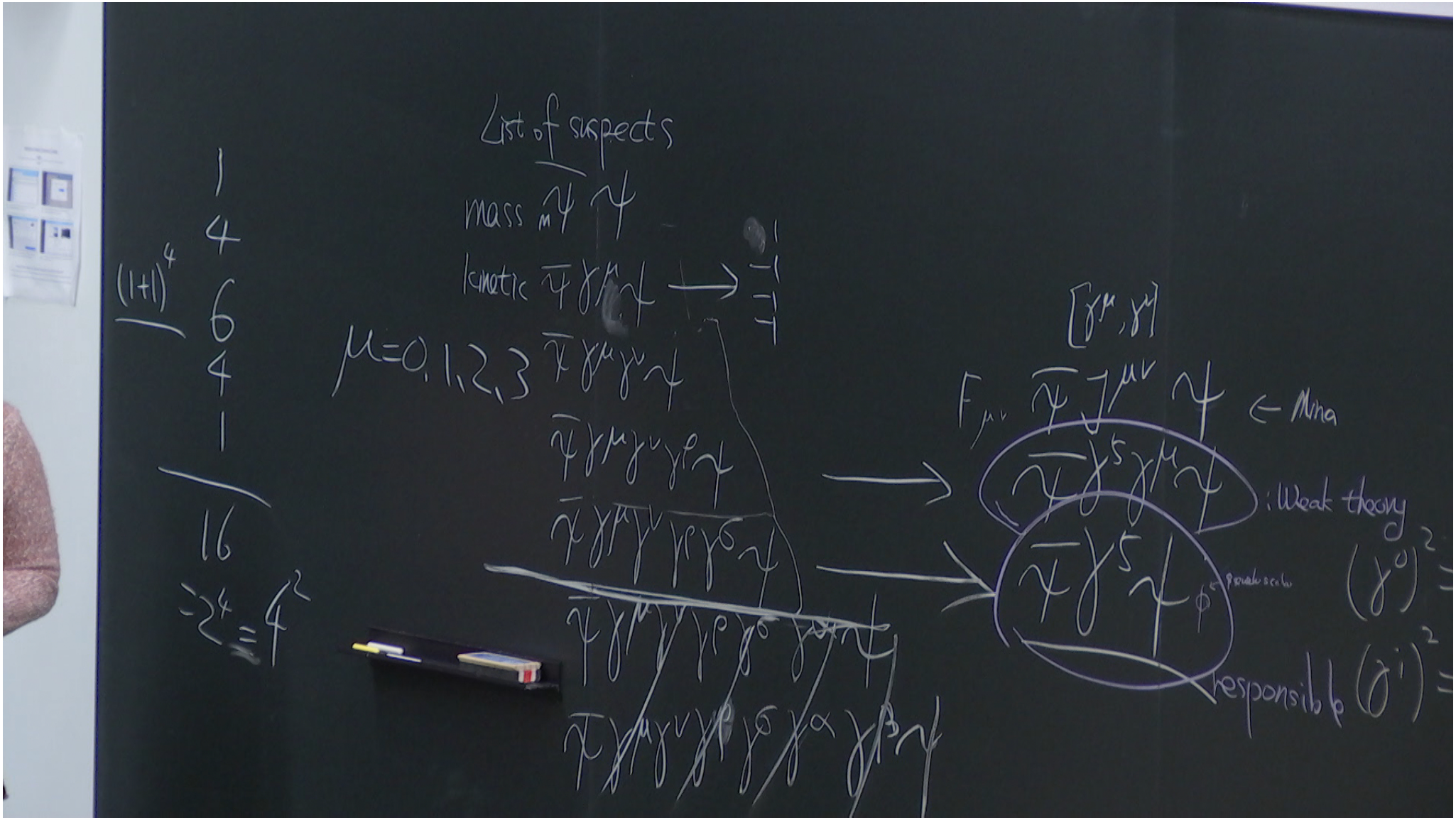

double
$\begin{pmatrix} \psi_+ \\ \psi_- \end{pmatrix} = \begin{pmatrix} \psi_- \\ \psi_+ \end{pmatrix}$
mass term
$\bar{\psi}\psi$
ψ^+
$\psi^+(t,-\vec{x})\gamma^0$
$\psi^+\gamma^0\psi$
$\bar{\psi}\psi$

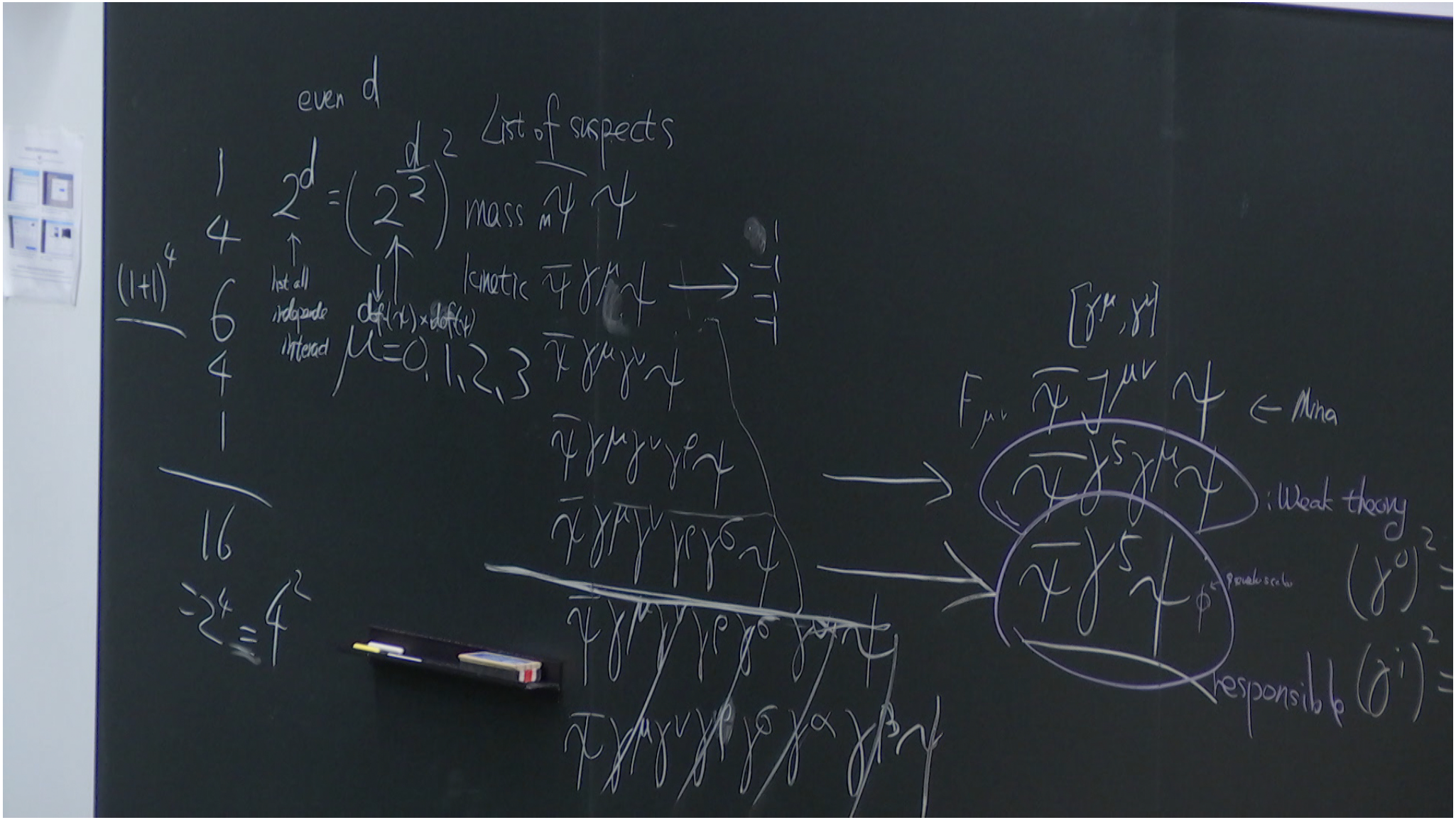

double
mass term
$\bar{\psi}\psi$
$\bar{\psi}\gamma^5\psi$
$\psi^+ \to \psi^+(t,-\vec{x})\gamma^0$
$(t,\vec{x})$ $\psi^+\gamma^0\psi$
$\vec{x}\to-\vec{x}$
$\psi^+\gamma^0\gamma^0\gamma^0\psi$
$\bar{\psi}\psi$

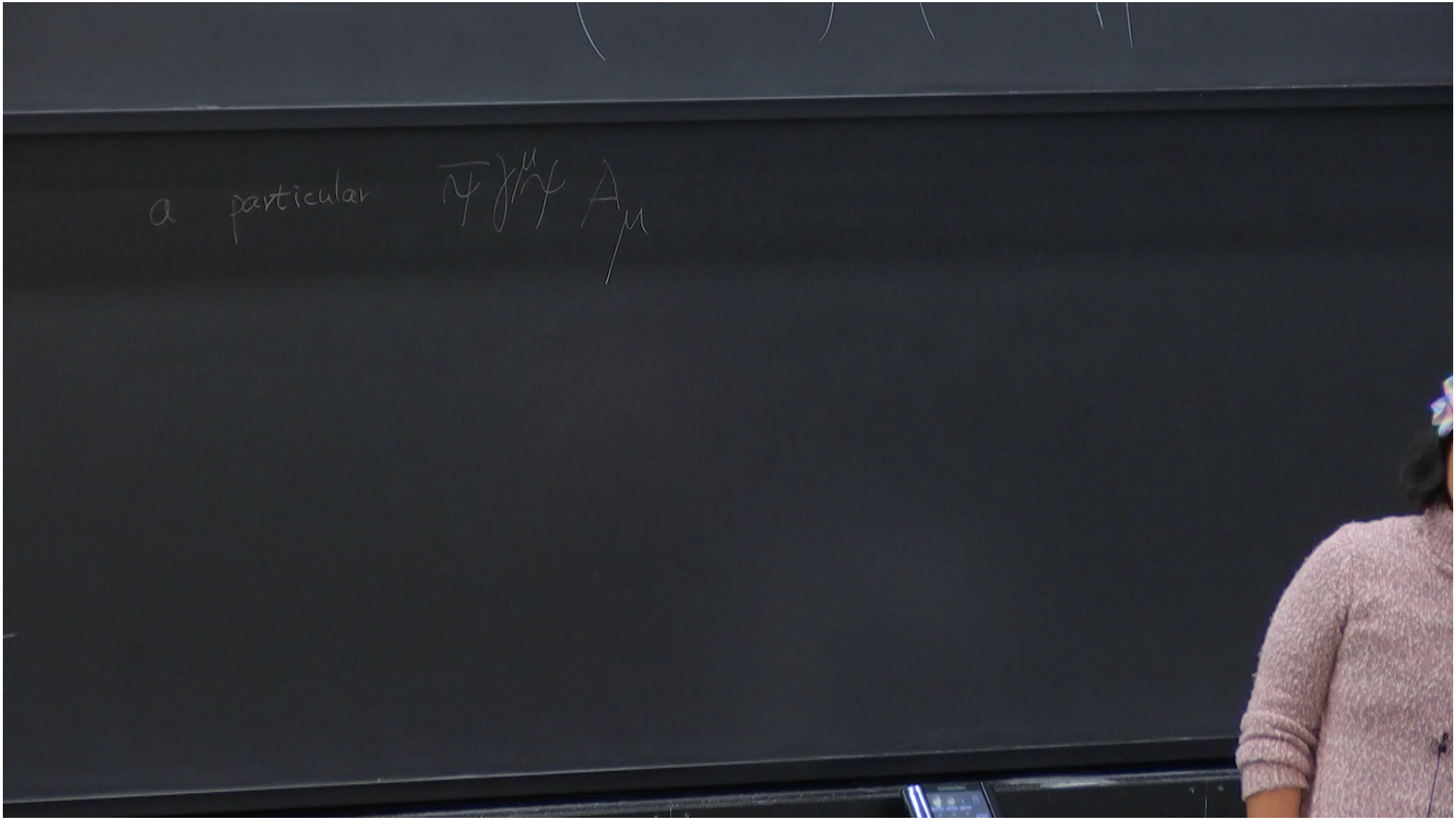


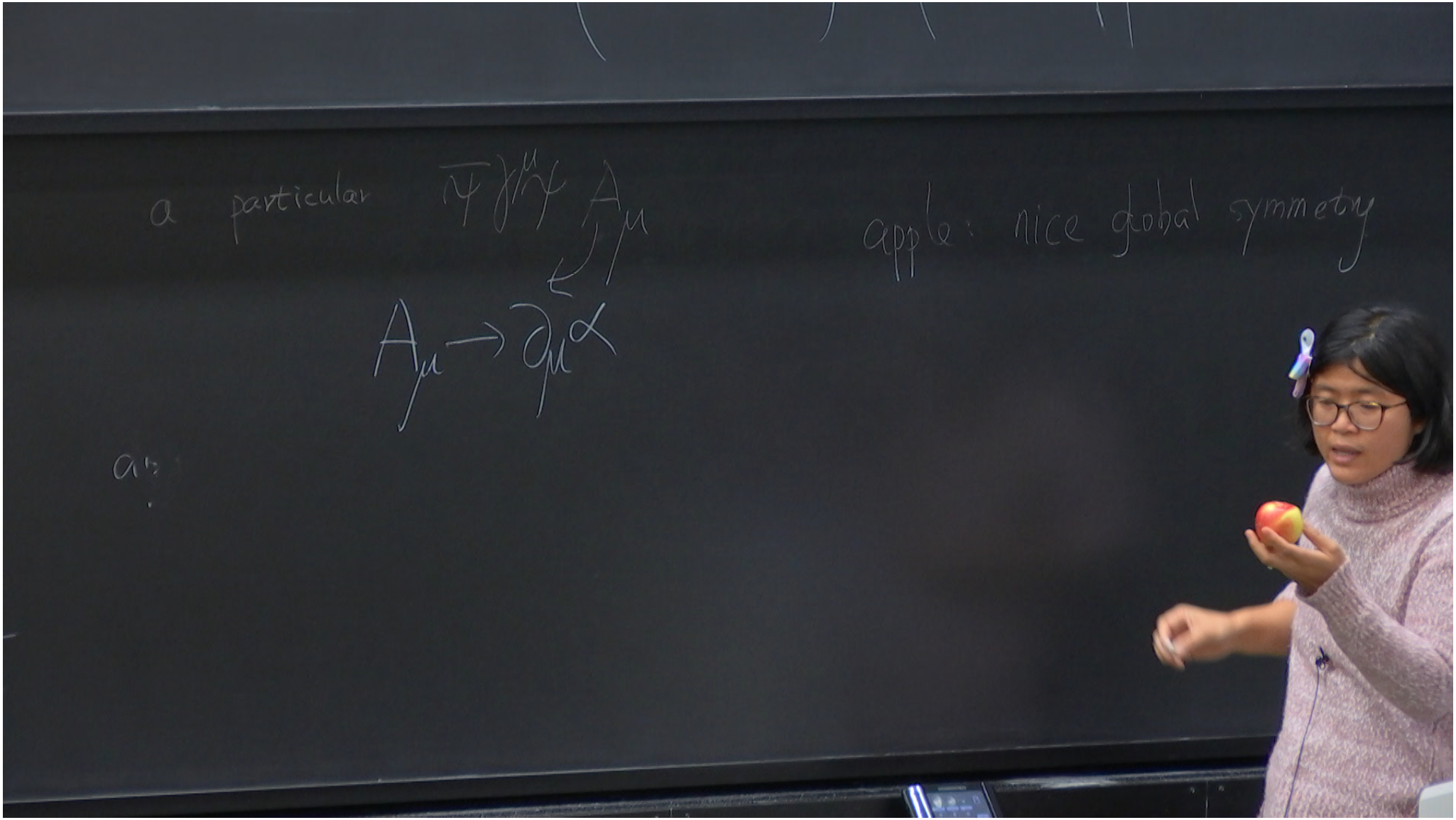

List of suspects
mass
kinetic
: Weak theory
responsible

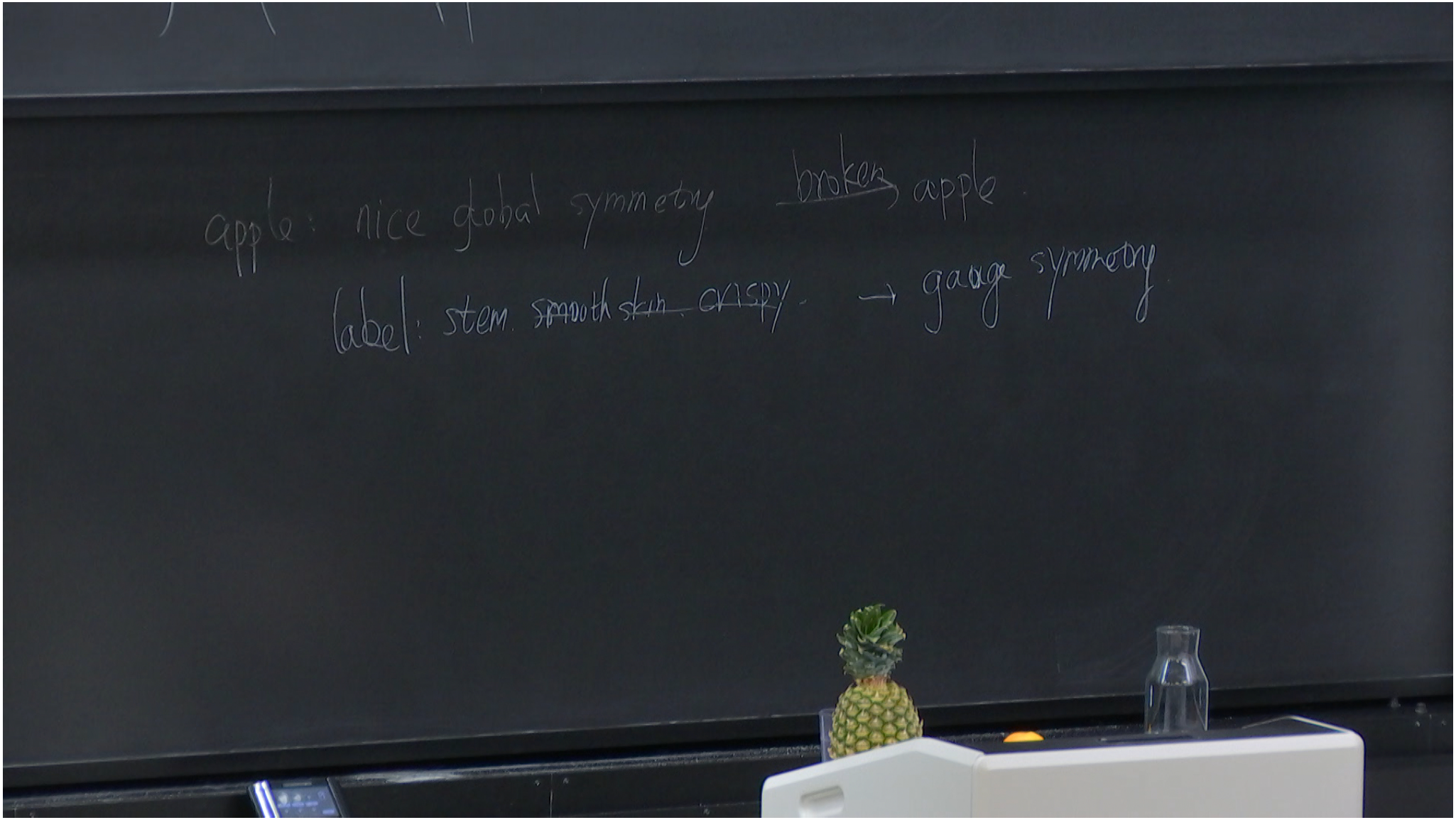

List of suspects
mass
kinetic
: Weak theory
responsible
axial vector.

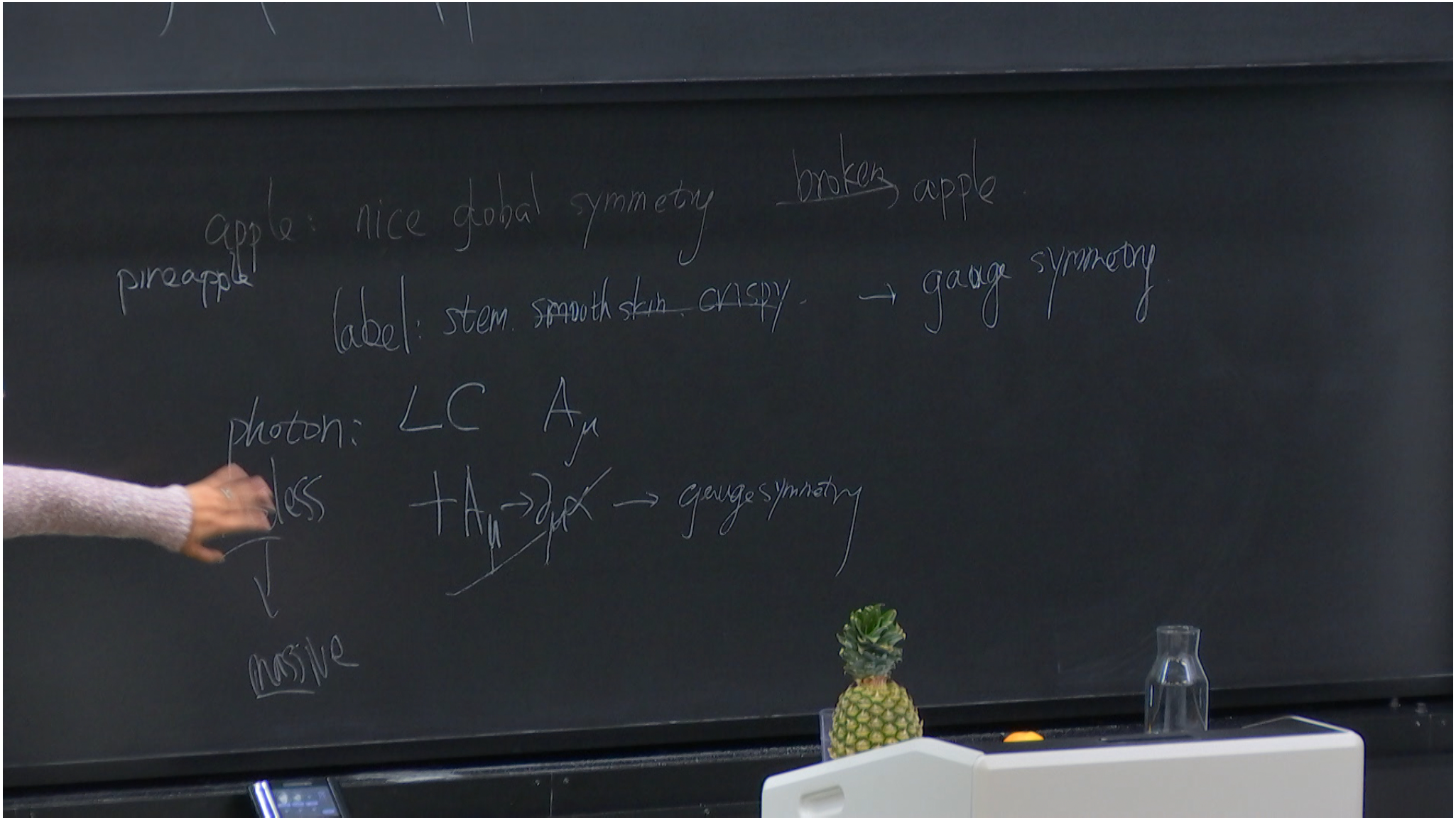

List of suspects
mass
kinetic
$\mu=0,1,2,3$
$[\gamma^\mu,\gamma^\nu]$
$F_{\mu\nu}$
$\in$ Mma
: Weak theory
responsible
$(1+1)^4$
1
4
6
4
1
16
$=2^4=4^2$

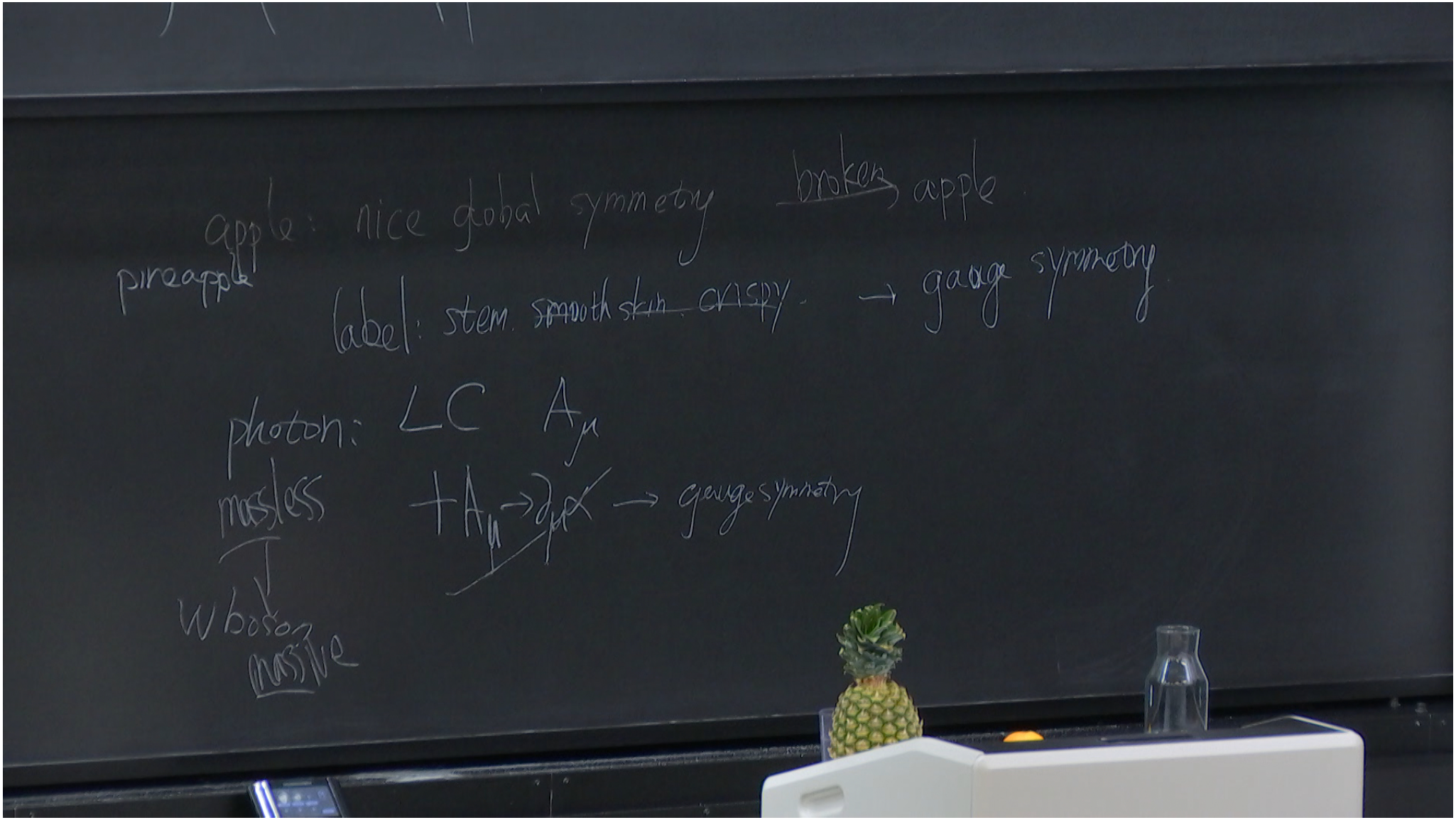

even d
List of suspects
$2^d = \left(2^{\frac{d}{2}}\right)^2$
mass $\bar{\psi}\psi$
kinetic $\bar{\psi}\gamma^\mu\partial_\mu\psi$
$\mu = 0,1,2,3$
$(1+1)^4$
1
4
6
4
1
16
$=2^4=4^2$
$\bar{\psi}\gamma^\mu\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\psi$
$\bar{\psi}\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\gamma^\alpha\gamma^\beta\psi$
$[\gamma^\mu,\gamma^\nu]$
$F_{\mu\nu}\,\bar{\psi}\gamma^\mu\gamma^\nu\psi$ ← Maxwell
$\bar{\psi}\gamma^5\gamma^\mu\psi$
: Weak theory
$\bar{\psi}\gamma^5\psi\,\phi$
$(\gamma^0)^2 =$
$(\gamma^i)^2 =$
responsible for

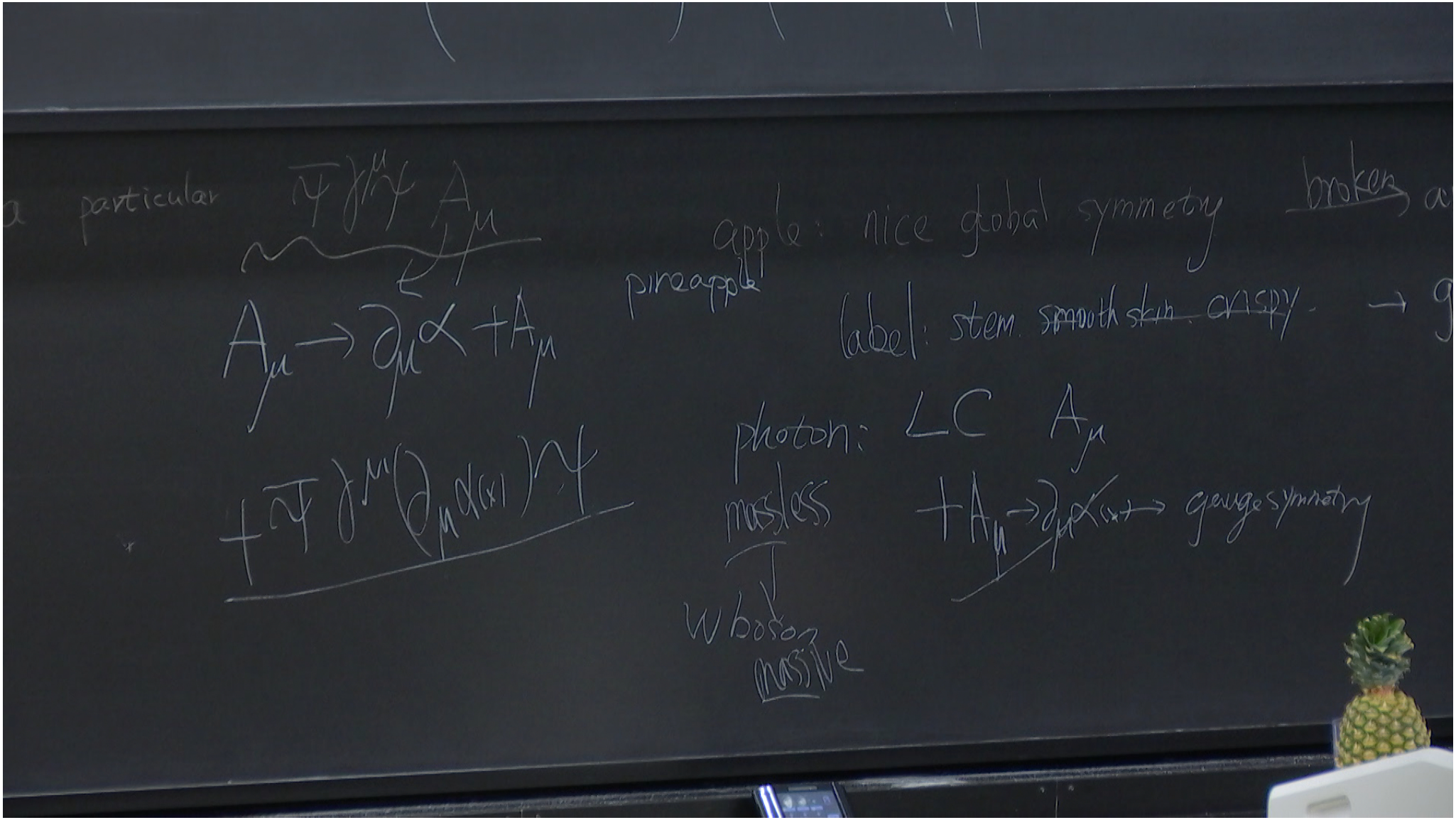

a particular

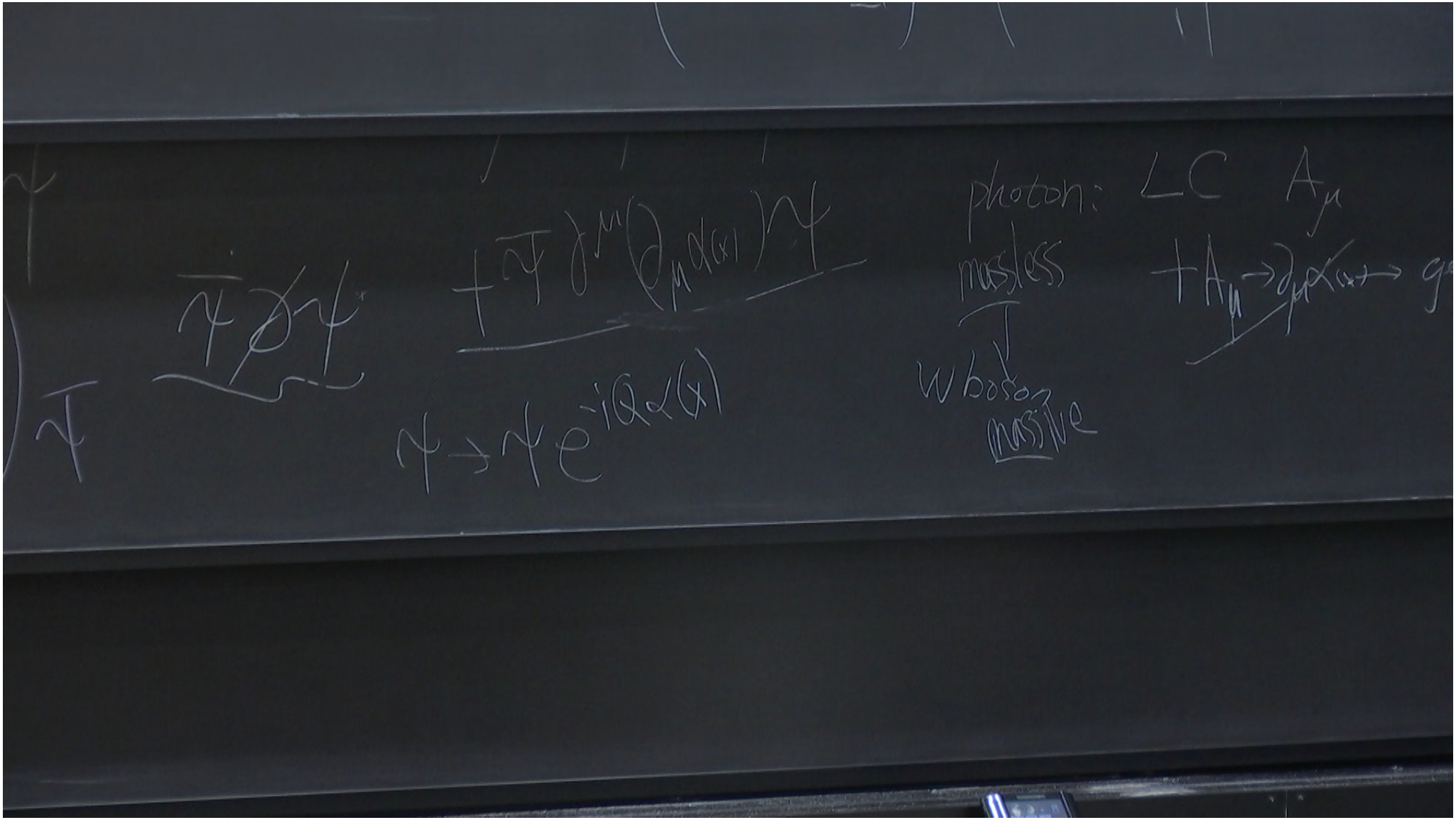

a particular
$\bar{\psi}\gamma^\mu\psi A_\mu$
$A_\mu \to \partial_\mu \alpha$
apple: nice global symmetry

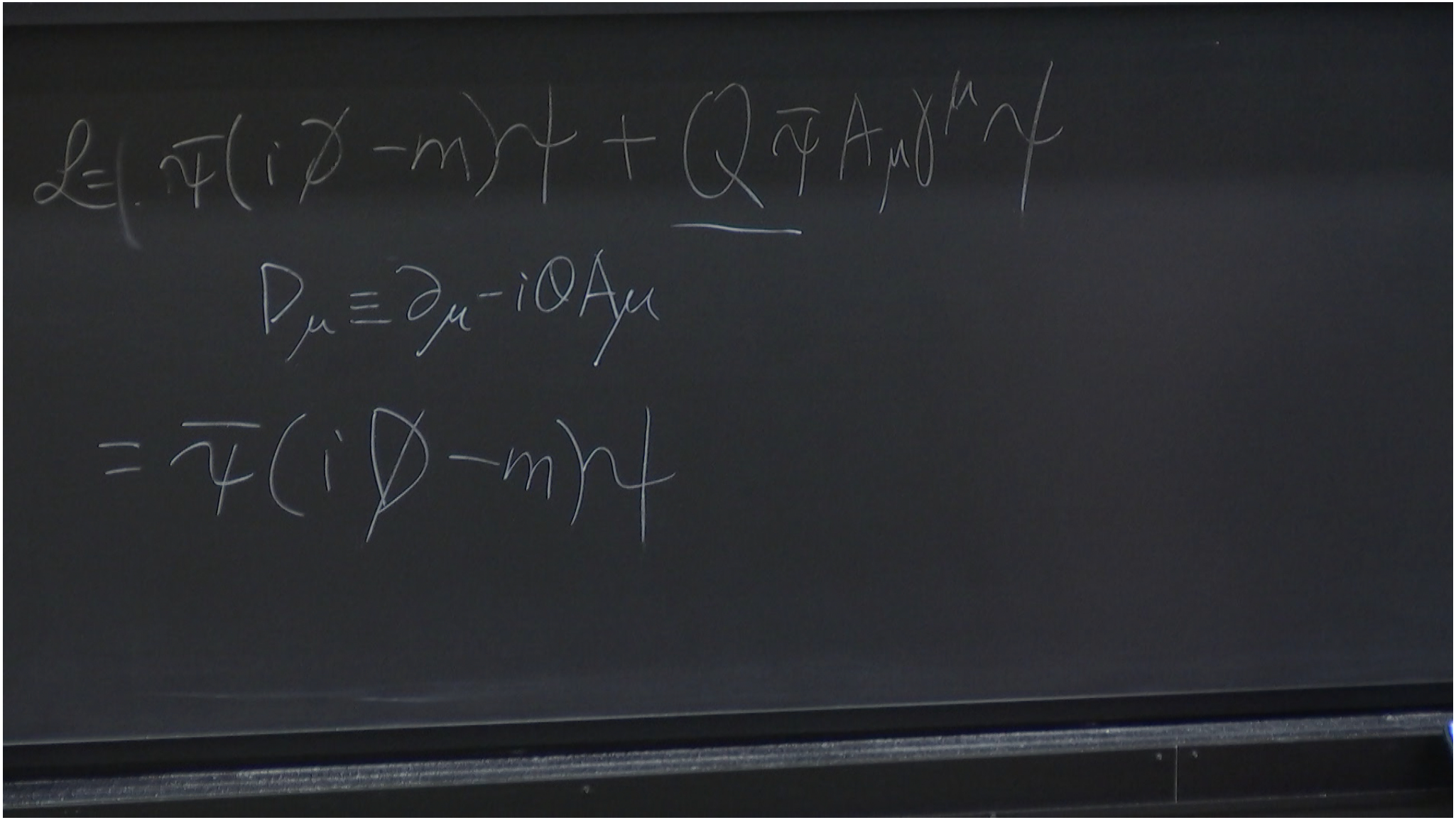

apple: nice global symmetry
broken
apple
label: stem. smooth skin. crispy.
→ gauge symmetry

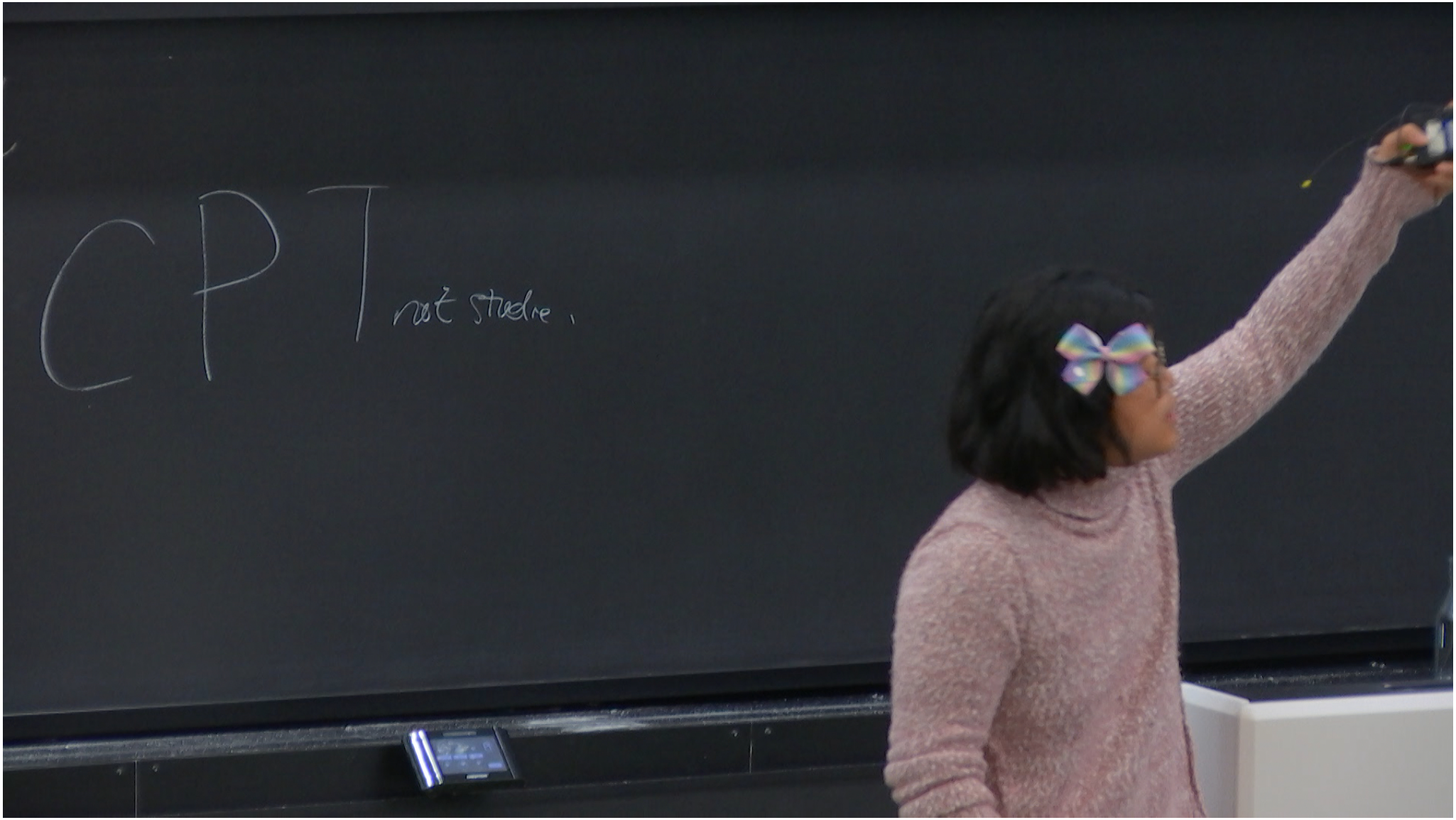

apple: nice global symmetry
broken apple
pineapple
label: stem. smooth skin. crispy.
→ gauge symmetry
photon: LC A_μ
massless
$+A_\mu \to$
→ gauge symmetry
massive


apple: nice global symmetry
broken apple
pineapple
label: stem. smooth skin. crispy.
→ gauge symmetry
photon: LC A_μ
massless
$+A_\mu \to$
→ gauge symmetry
W boson
massive


particular
$\bar{\psi}\gamma^\mu\psi A_\mu$
$A_\mu \to \partial_\mu\alpha + A_\mu$
$+\bar{\psi}\gamma^\mu(\partial_\mu\alpha(x))\psi$
pineapple
apple: nice global symmetry
broken
label: stem smooth skin crispy
photon: LC A_μ
massless
$+A_\mu \to \partial_\mu\alpha(x) \to$ gauge symmetry
W boson
massive


photon: massless
LC
W boson
massive


$\mathcal{L} = \bar{\psi}(i\not{\partial} - m)\psi + Q\bar{\psi}A_\mu\gamma^\mu\psi$
$D_\mu \equiv \partial_\mu - iQA_\mu$
$= \bar{\psi}(i\not{D} - m)\psi$


CPT
not studie.