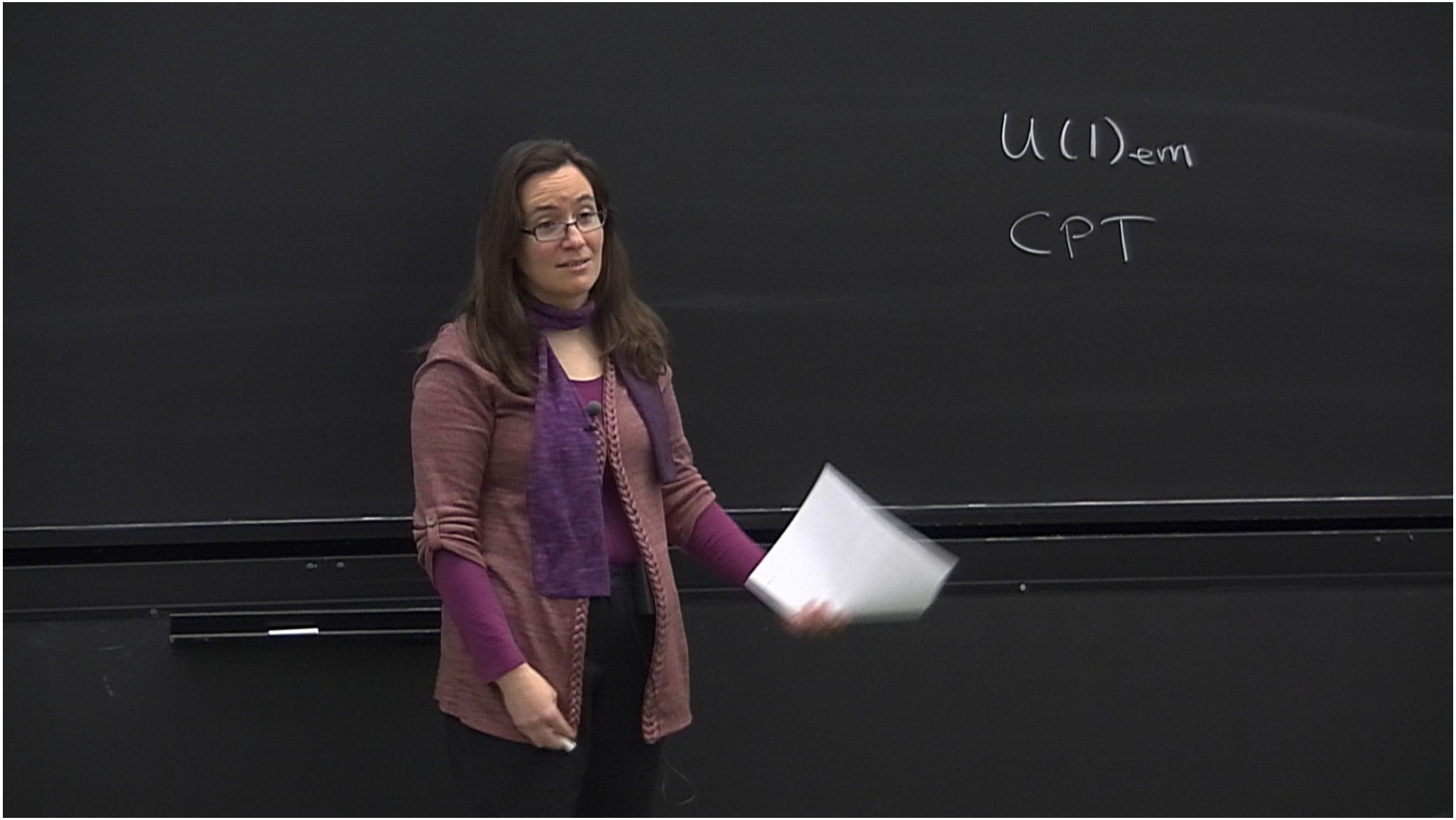
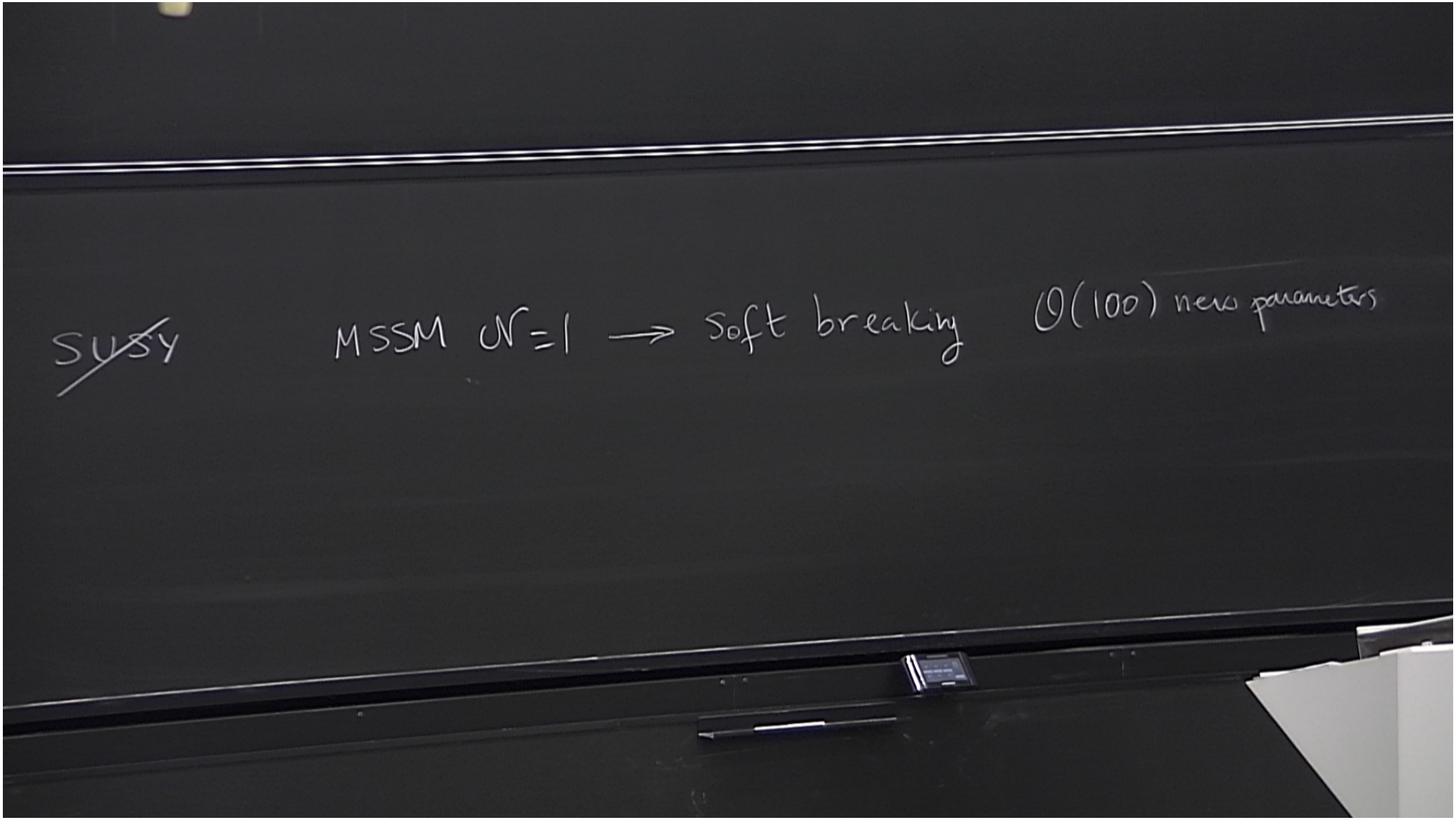
Title: Beyond the Standard Model (Review) - Lecture 8

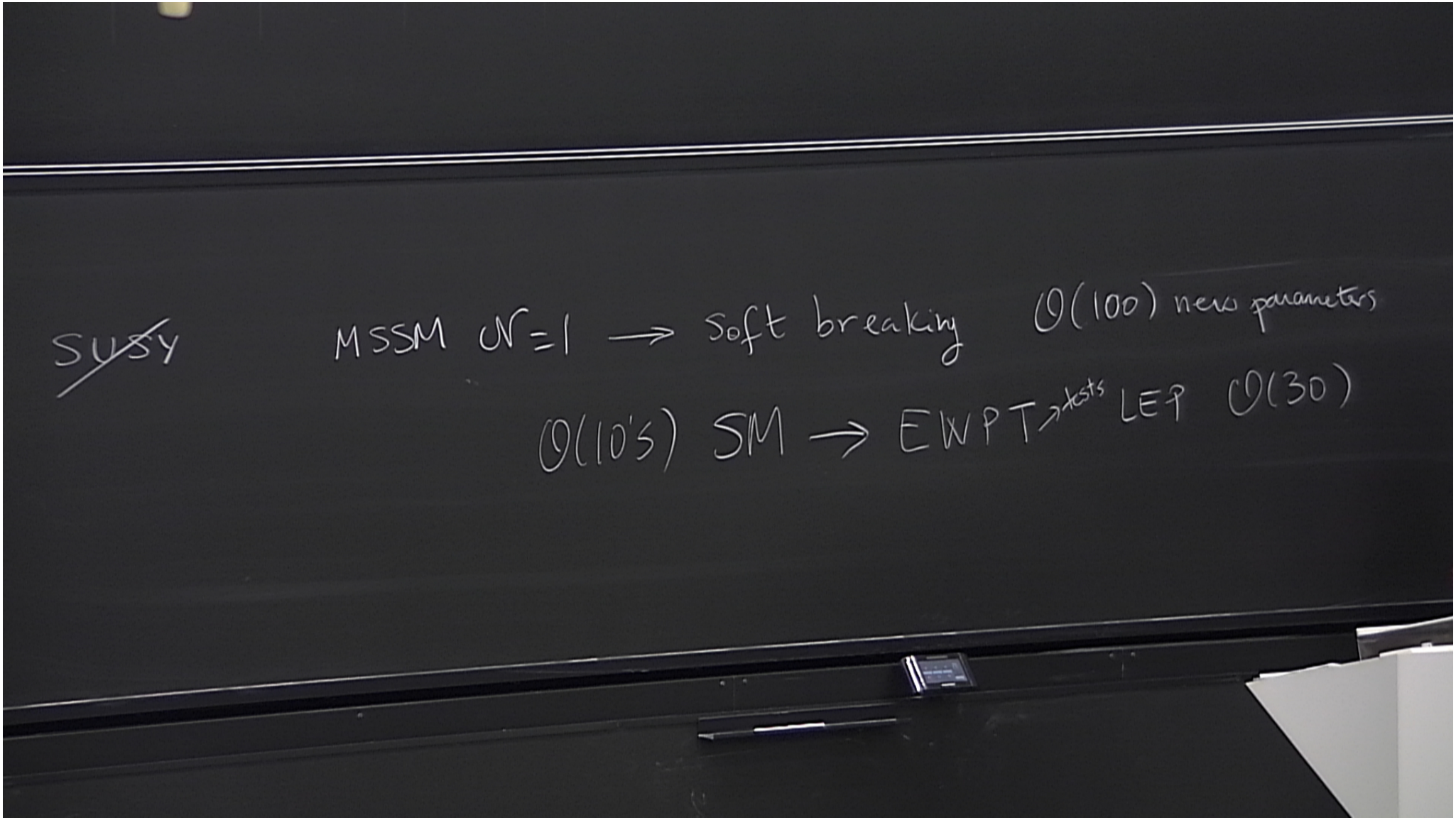
Date: Feb 23, 2012 09:00 AM

URL: http://www.pirsa.org/12020079

Abstract:


U(1)em
CPT


SUSY
MSSM $\mathcal{N}=1$ → Soft breaking
$\mathcal{O}(100)$ new parameters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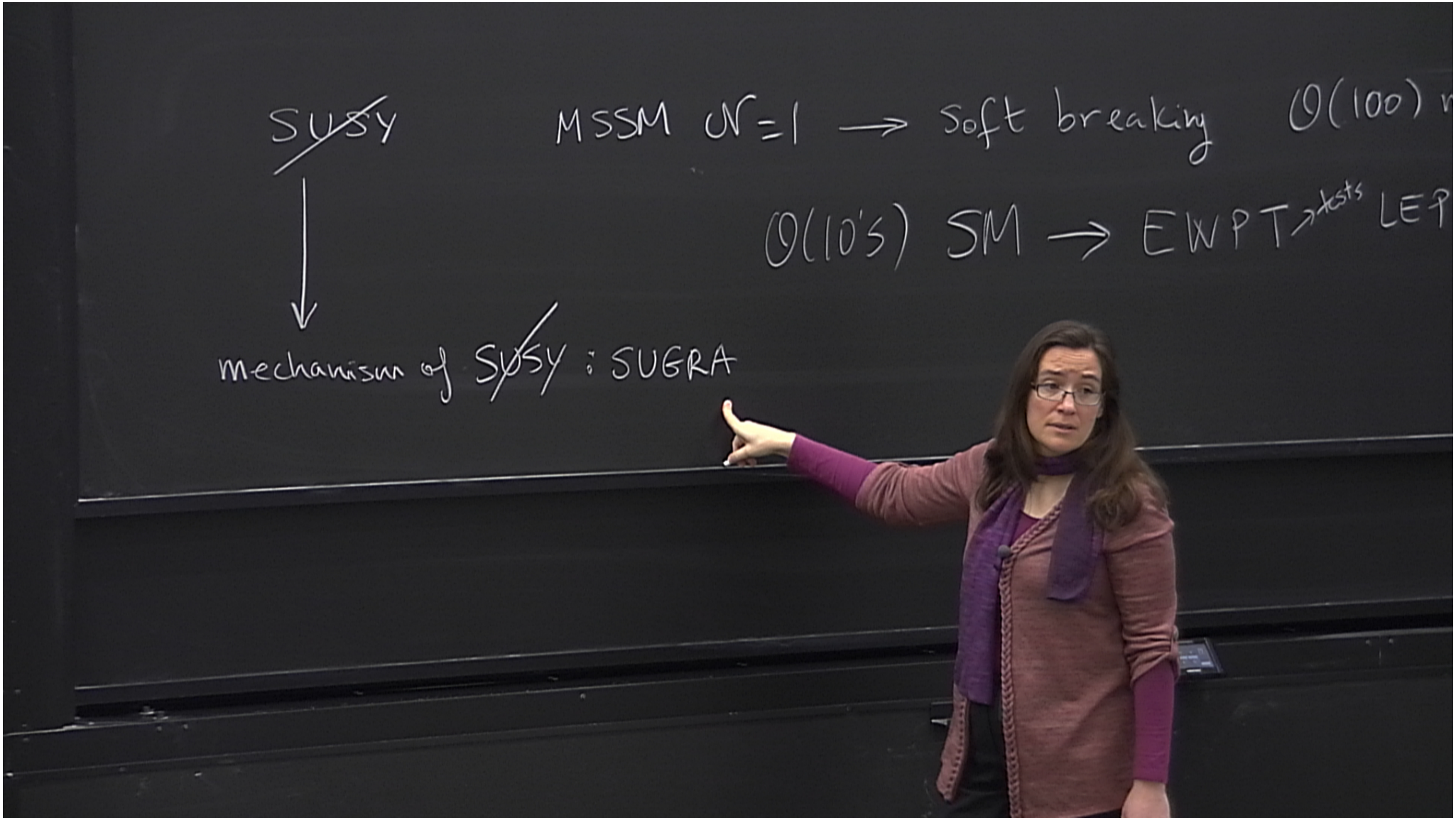
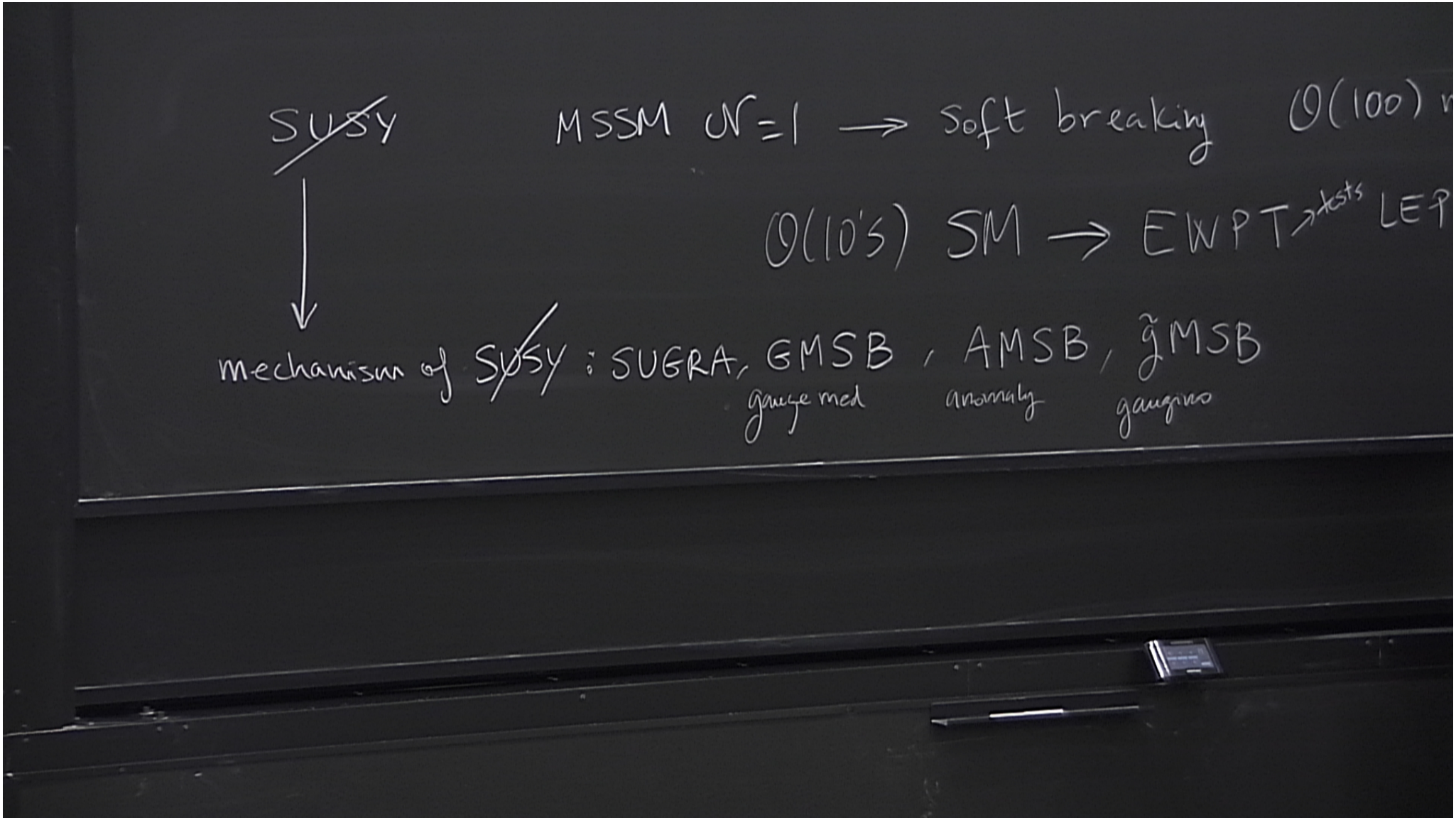
MSSM $\mathcal{N}=1$ → soft breaking $\mathcal{O}(100)$ new parameters
$\mathcal{O}(10's)$ SM → EWPT → tests LEP $\mathcal{O}(30)$


SUSY
MSSM N=1 → soft breaking
O(100)
O(10's) SM → EWPT → tests LEP
mechanism of SUSY : SUGRA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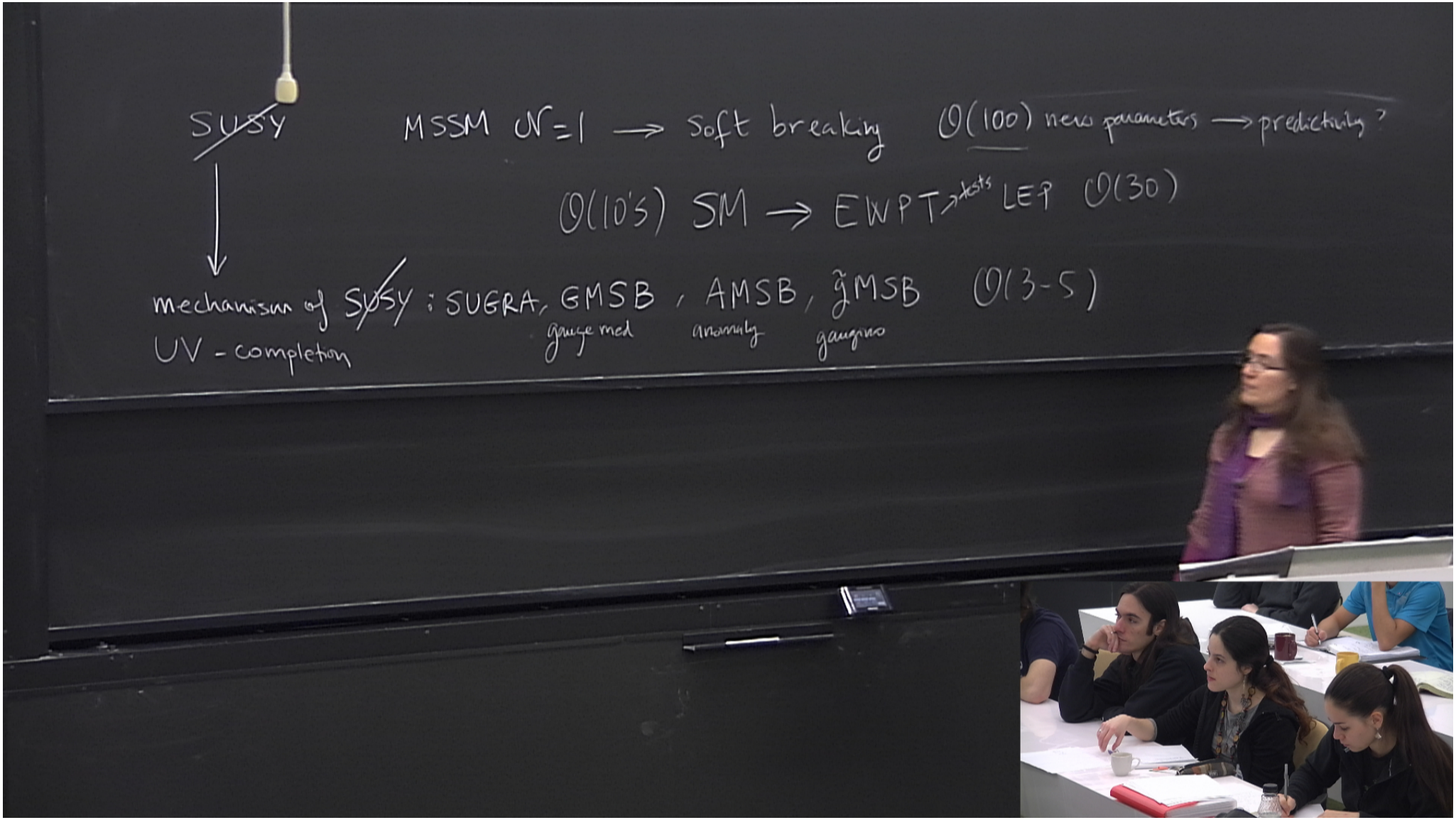
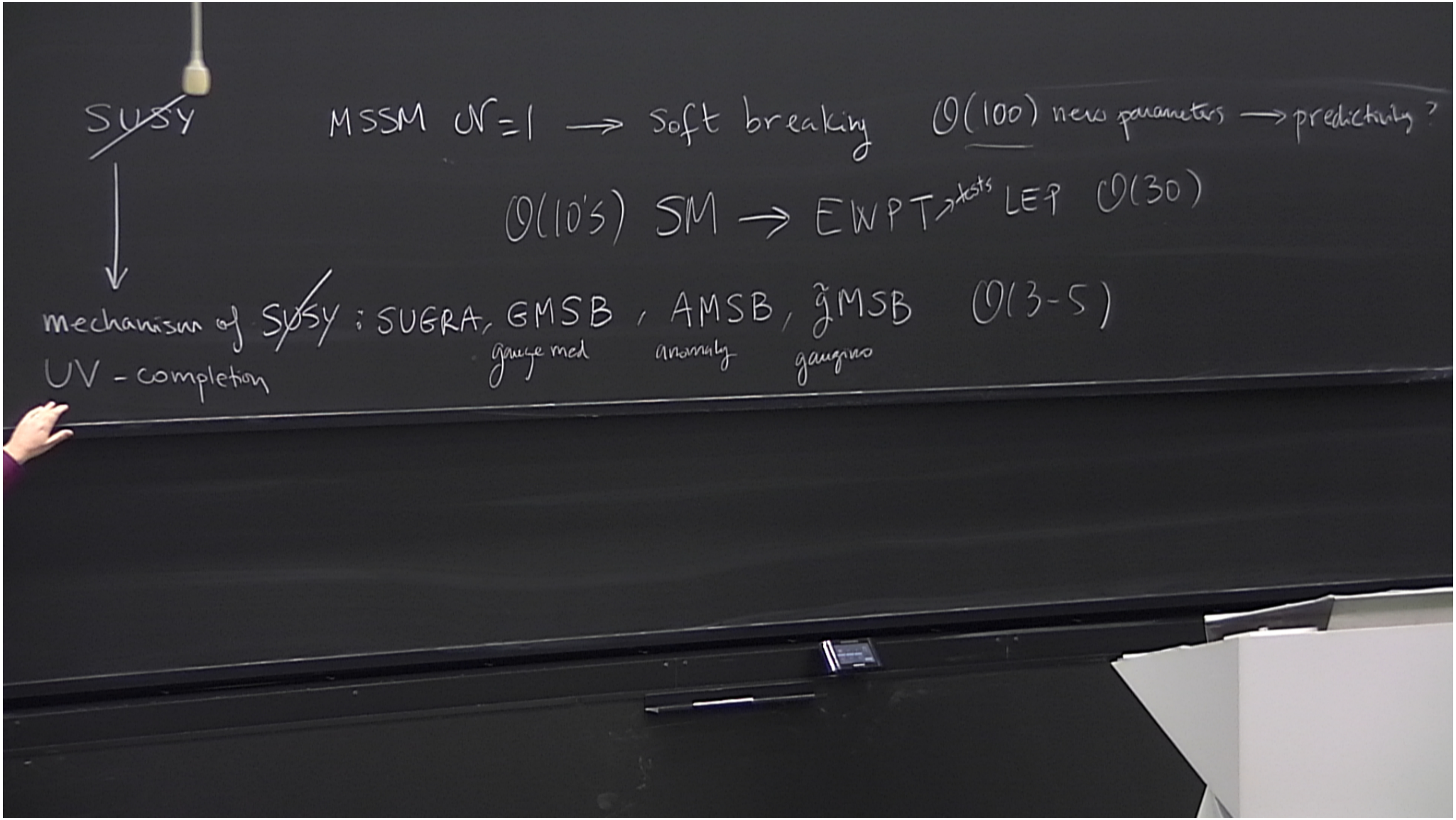
Mechanism of SUSY : SUGRA, GMSB, AMSB, $\tilde{g}$MSB
gauge med
anomaly
gaugino


SUSY
MSSM $\mathcal{N}=1$ → soft breaking $\mathcal{O}(100)$ new parameters → predictivity?
$\mathcal{O}(10's)$ SM → EWPT → tests LEP $\mathcal{O}(30)$
mechanism of SUSY: SUGRA, GMSB (gauge med), AMSB (anomaly), $\tilde{g}$MSB (gaugino) $\mathcal{O}(3-5)$
UV - completion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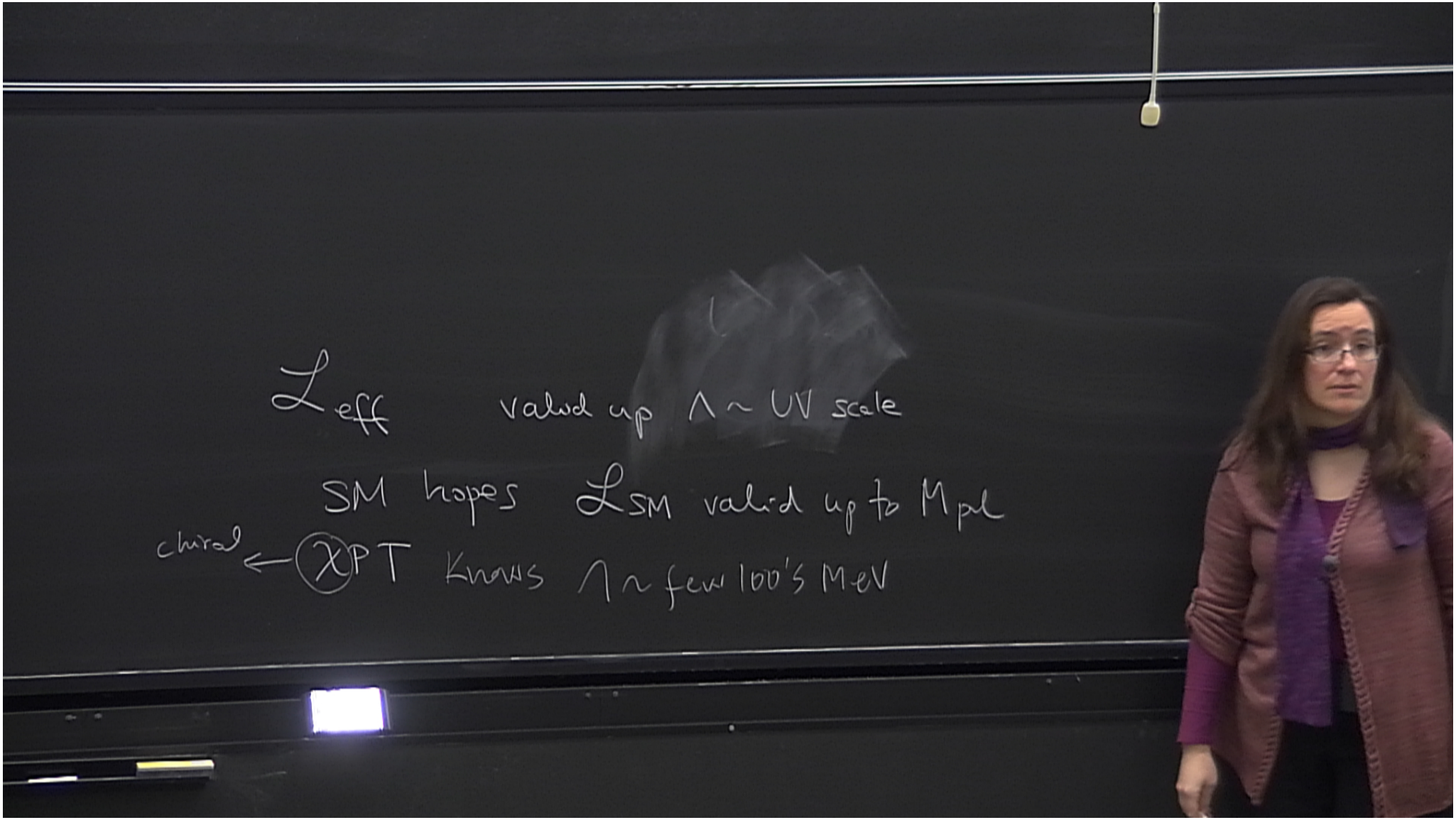
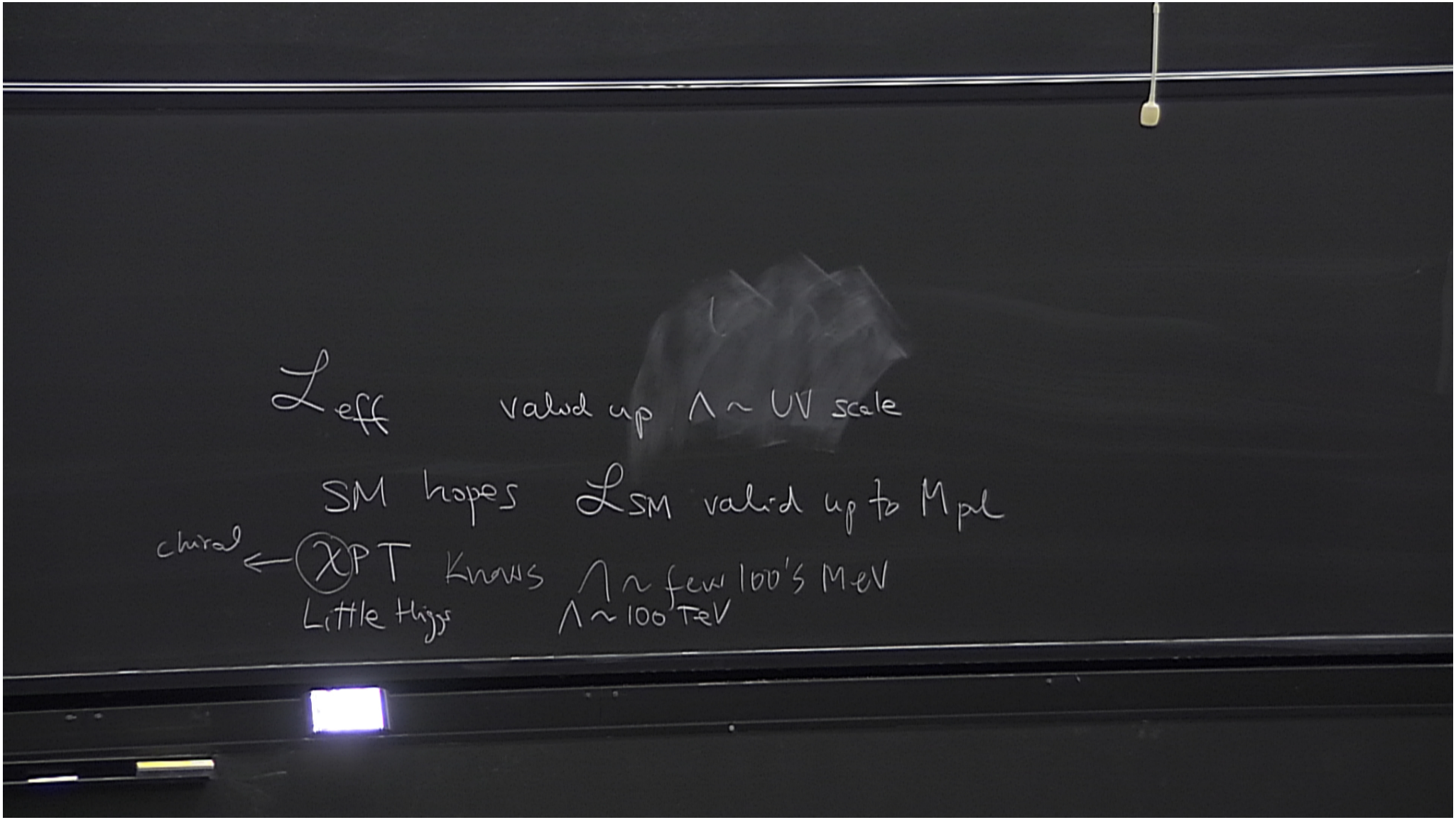

$\mathcal{L}_{eff}$ valid up $\Lambda \sim$ UV scale
SM hopes $\mathcal{L}_{SM}$ valid up to M_{pl}
chiral $\leftarrow$ χPT Knows $\Lambda \sim$ few 100's MeV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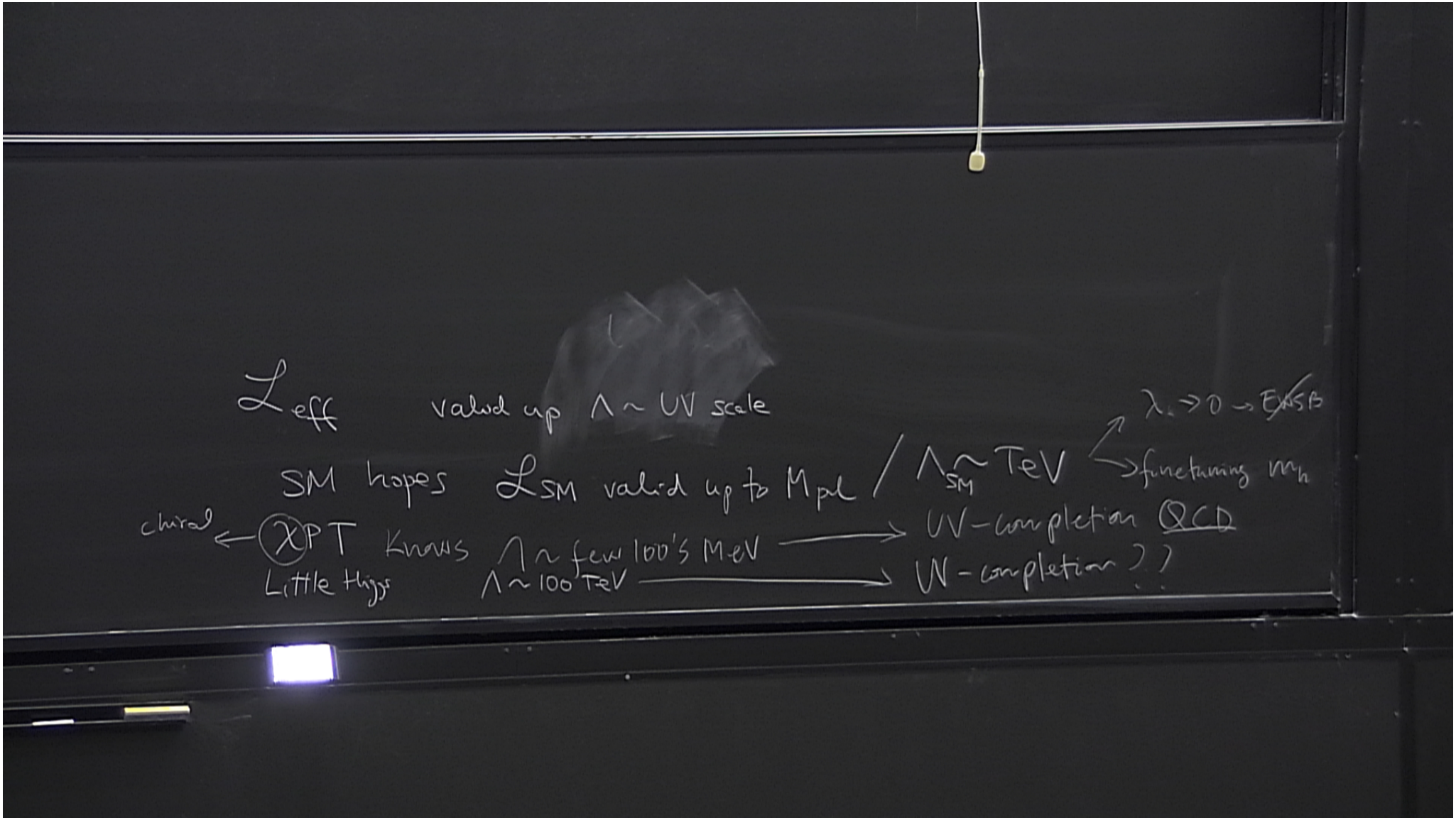
Little Higgs $\Lambda \sim 100$ TeV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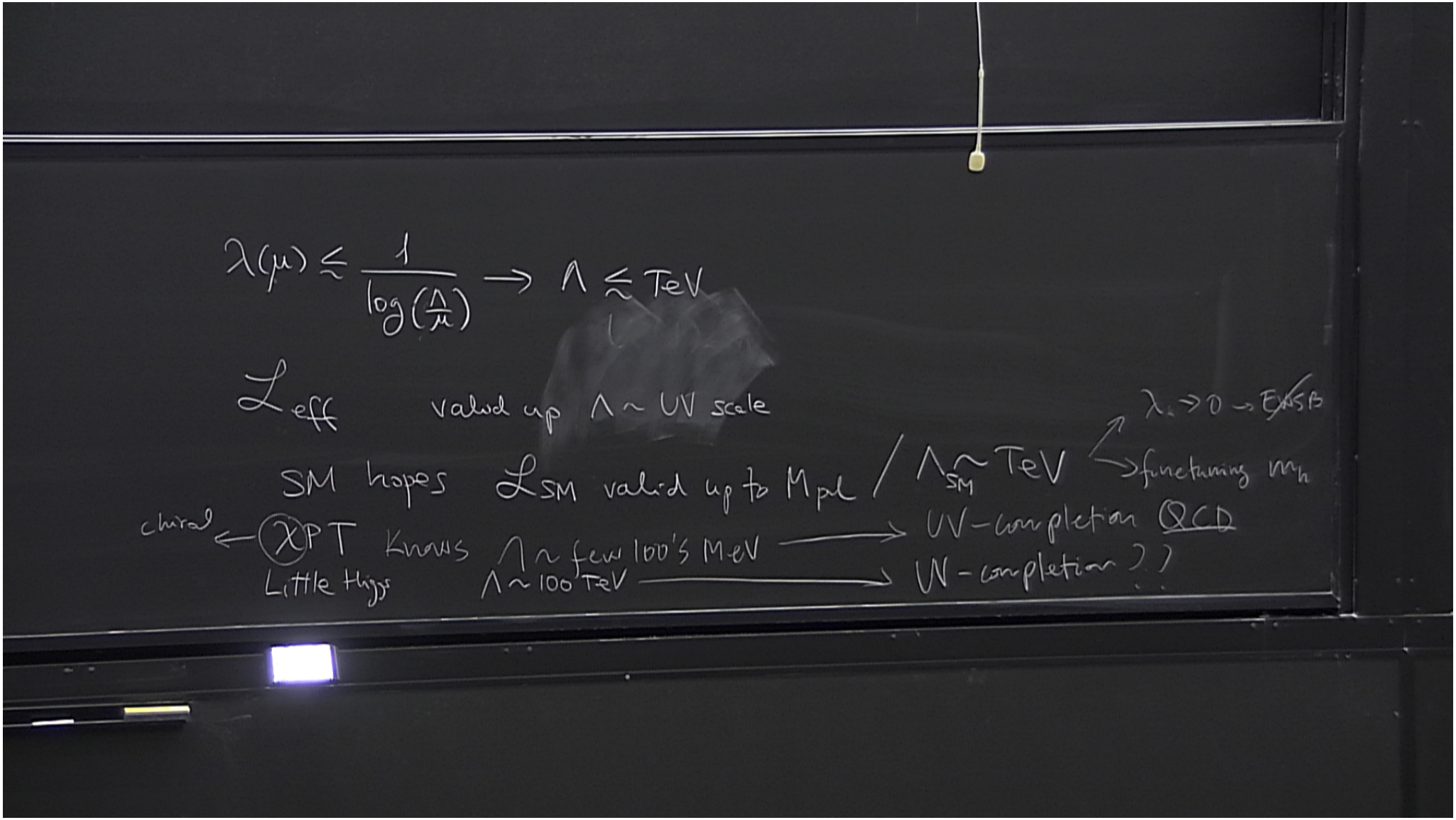
$\lambda_h \to 0 \to$ EWSB
finetuning m_h
chiral
χPT Knows $\Lambda \sim$ few 100's MeV
UV-completion QCD
Little Higgs $\Lambda \sim 100$ TeV
UV-completion ??


$\lambda(\mu) \lesssim \frac{1}{\log(\frac{\Lambda}{\mu})} \rightarrow \Lambda \lesssim$ TeV
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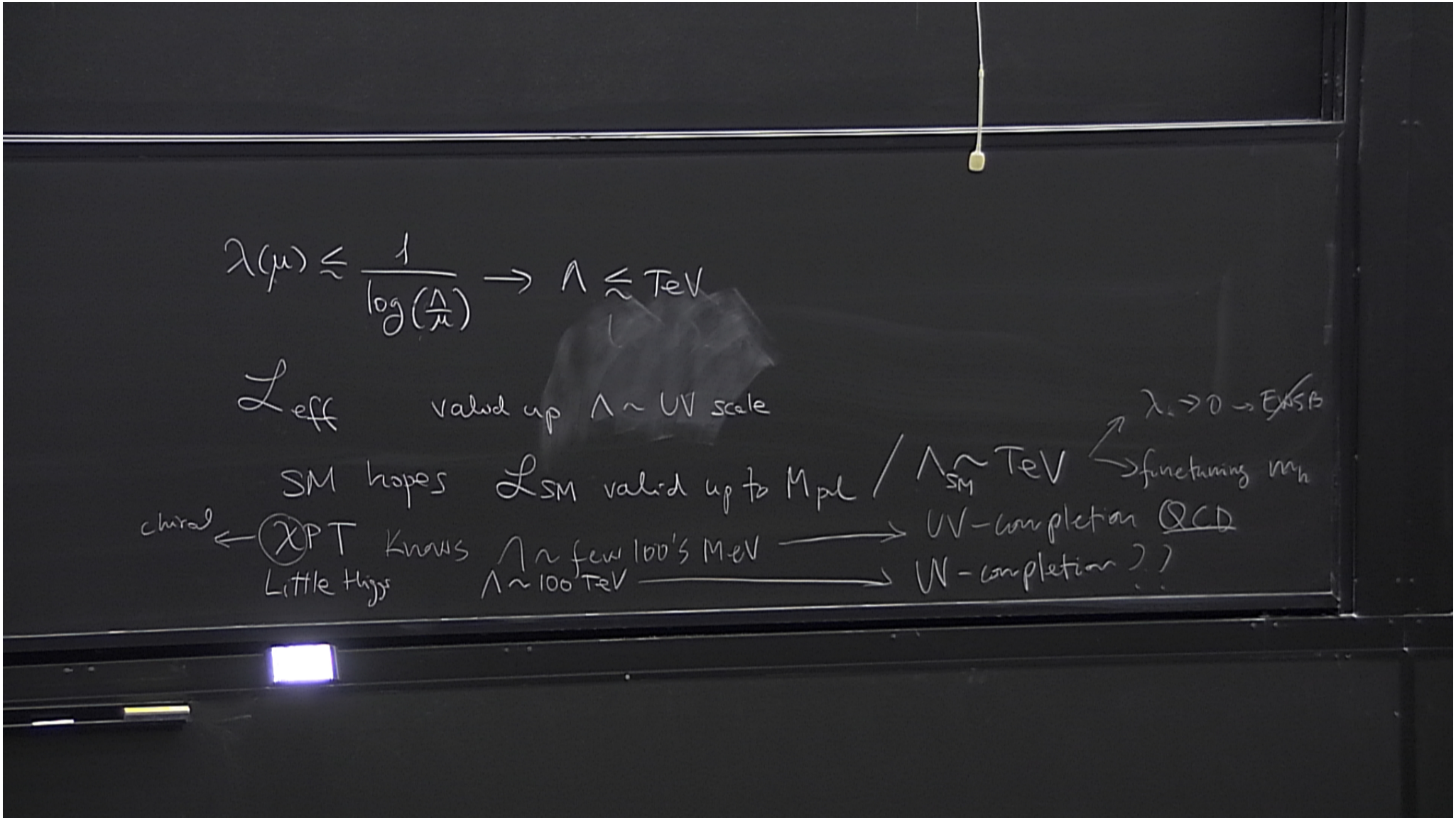
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UV-completion QCD
UV-completion ??

mechanism of ~~SUSY~~ : SUGRA, GMSB, AMSB, gMSB

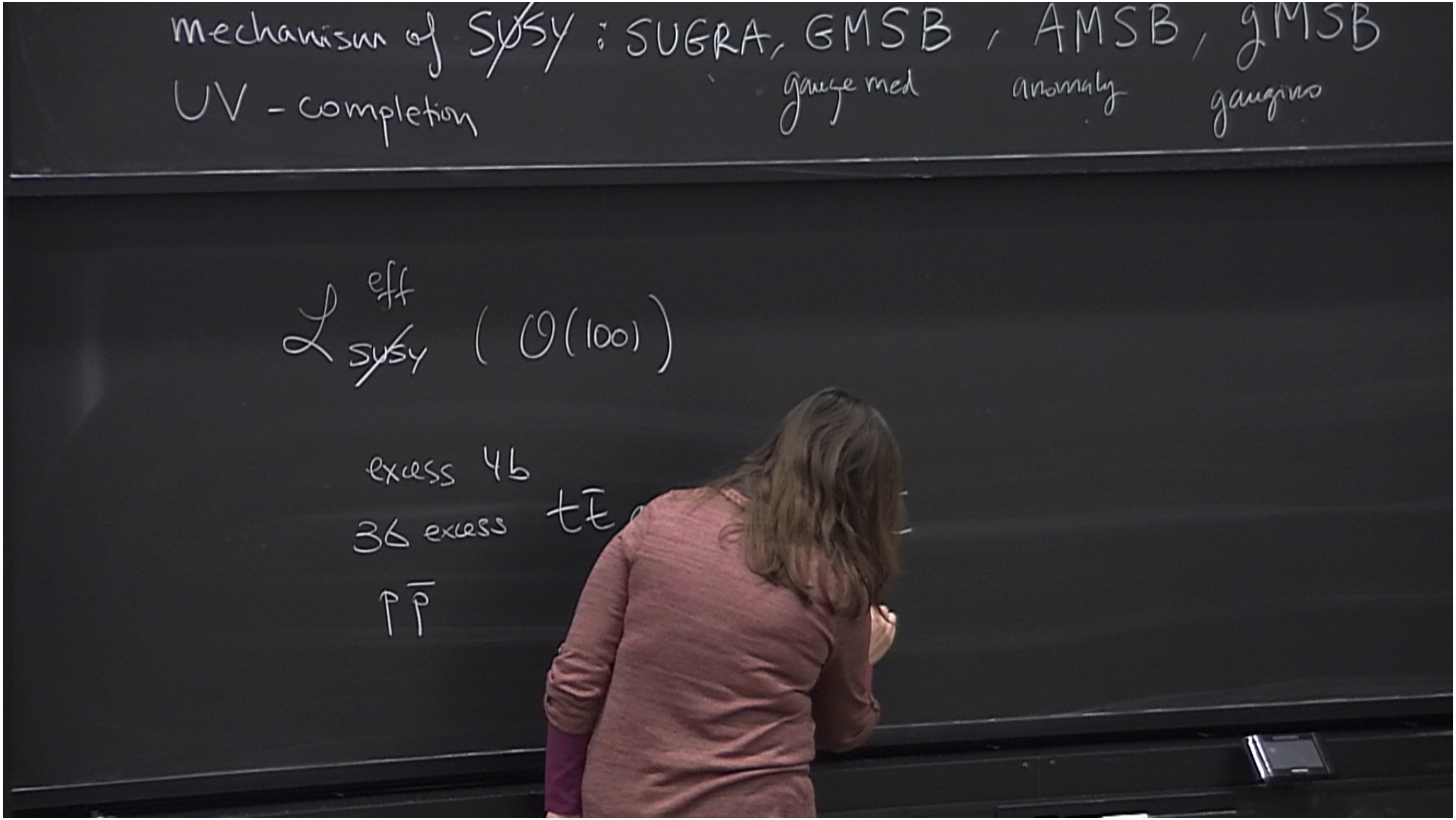
UV - completion

gauge med

anomaly

gaugino

$\mathcal{L}^{\text{eff}}_{\text{~~SUSY~~}}$ ($\mathcal{O}(100)$)


mechanism of SUSY : SUGRA, GMSB, AMSB, gMSB
UV - completion
gauge med
anomaly
gaugino
$\mathcal{L}^{eff}_{susy}$ ($\mathcal{O}(100)$
excess 4b
3b excess $t\bar{t}$
$p\bar{p}$

Mechanism of ~~SUSY~~ : SUGRA, GMSB, AMSB, gMSB

UV - completion

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$\mathcal{L}^{\text{eff}}_{\not{S}\text{USY}}$ ($\mathcal{O}(100)$)

excess 4b

3σ excess $t\bar{t}$ asymm LHC

$p\bar{p}$

pp

Mechanism of ~~SUSY~~ : SUGRA, GMSB, AMSB, gMSB

UV - completion

gauge med

anomaly

gaugino

$\mathcal{L}^{eff}_{\not{SUSY}}$ ($\mathcal{O}(100)$)

LEP $e^- e^+$

excess 4b

3σ excess $t\bar{t}$ asymm LHC

$p\bar{p}$

pp

chanism of SUSY : SUGRA, GMSB, AMSB, $\tilde{g}$MSB (O(3-5)

V - completion

gauge med anomaly gaugino

$\mathcal{L}^{eff}_{SUSY}$ (O(100))

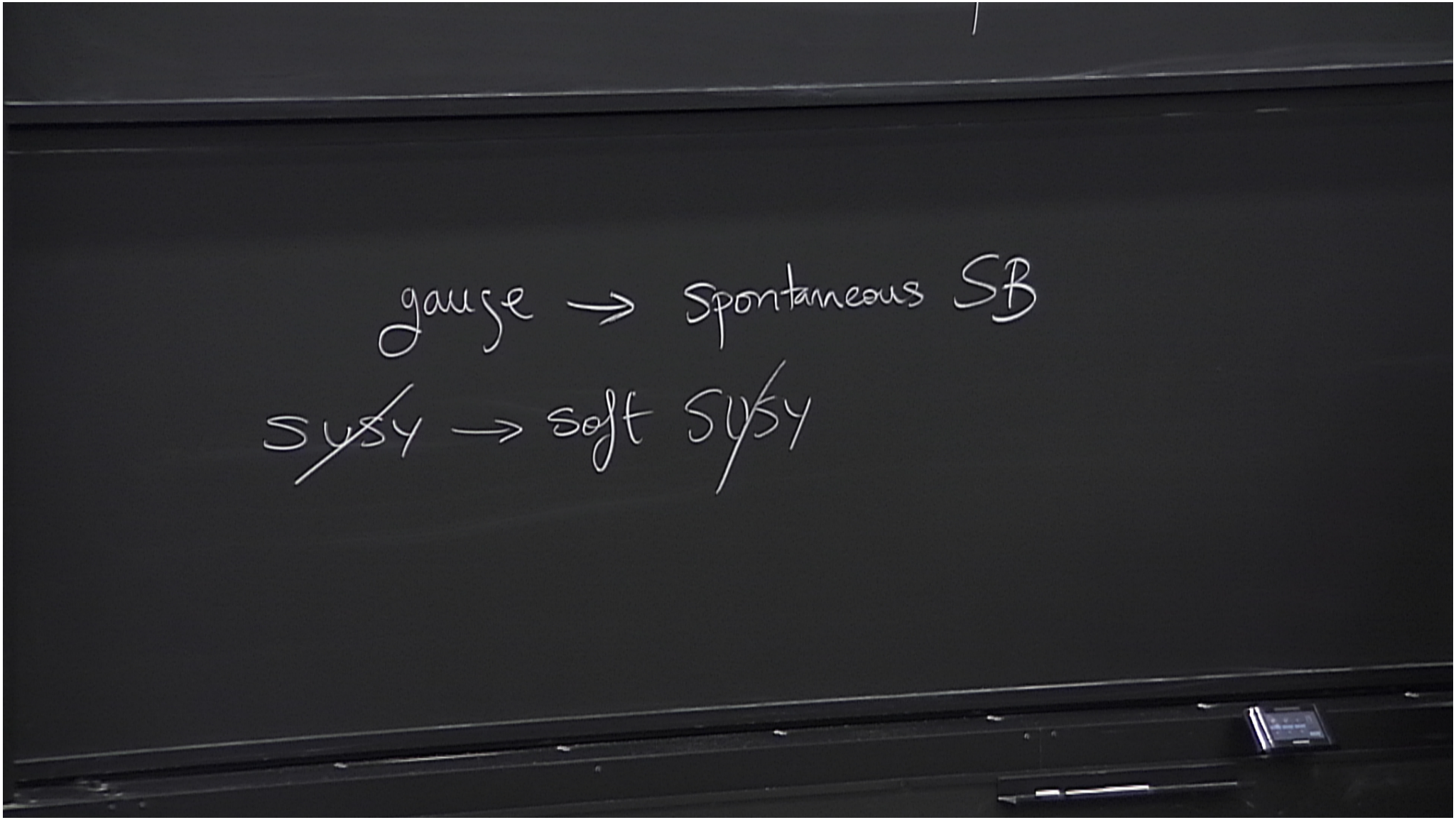
LEP e^- e^+

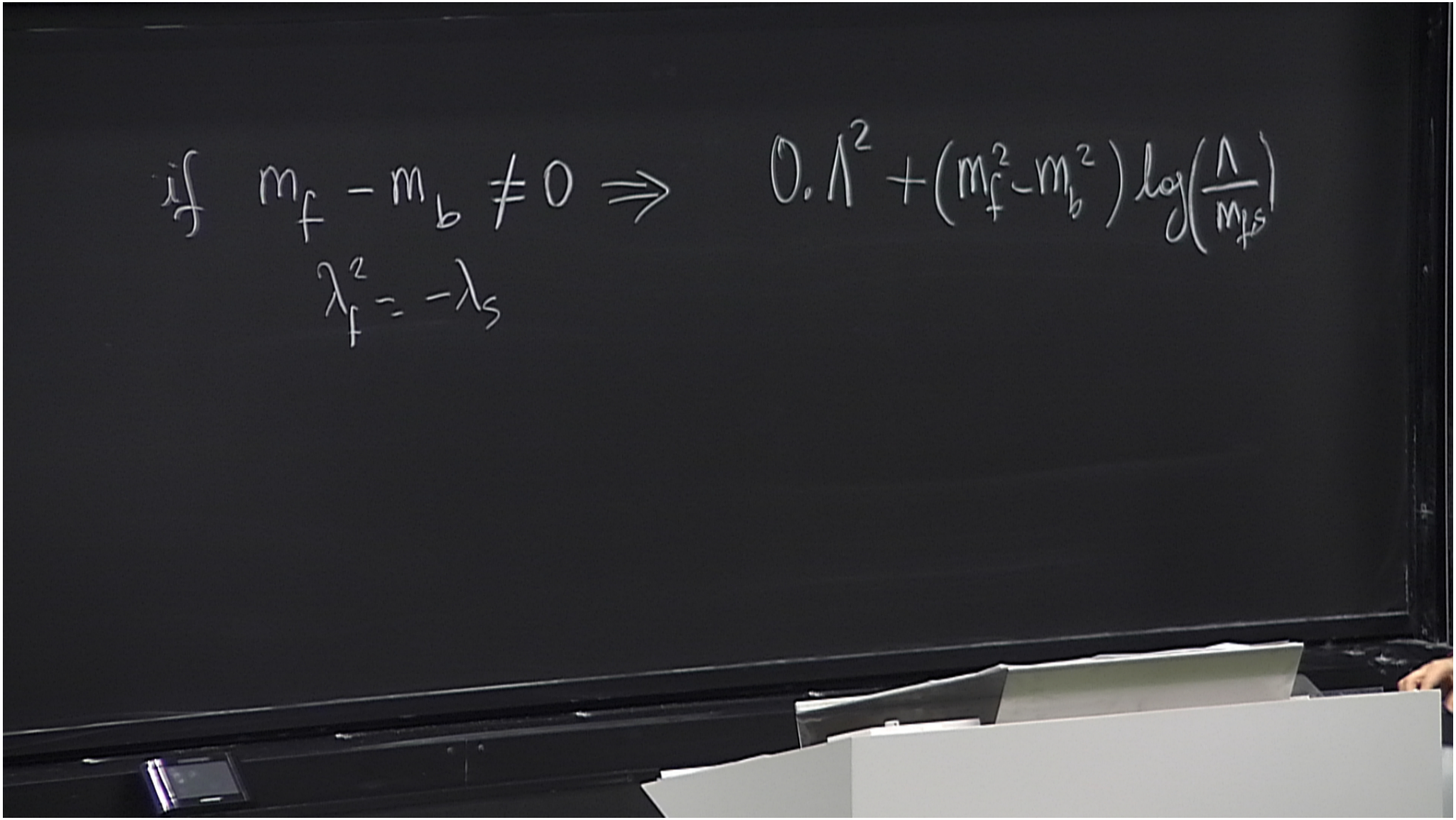
excess 4b

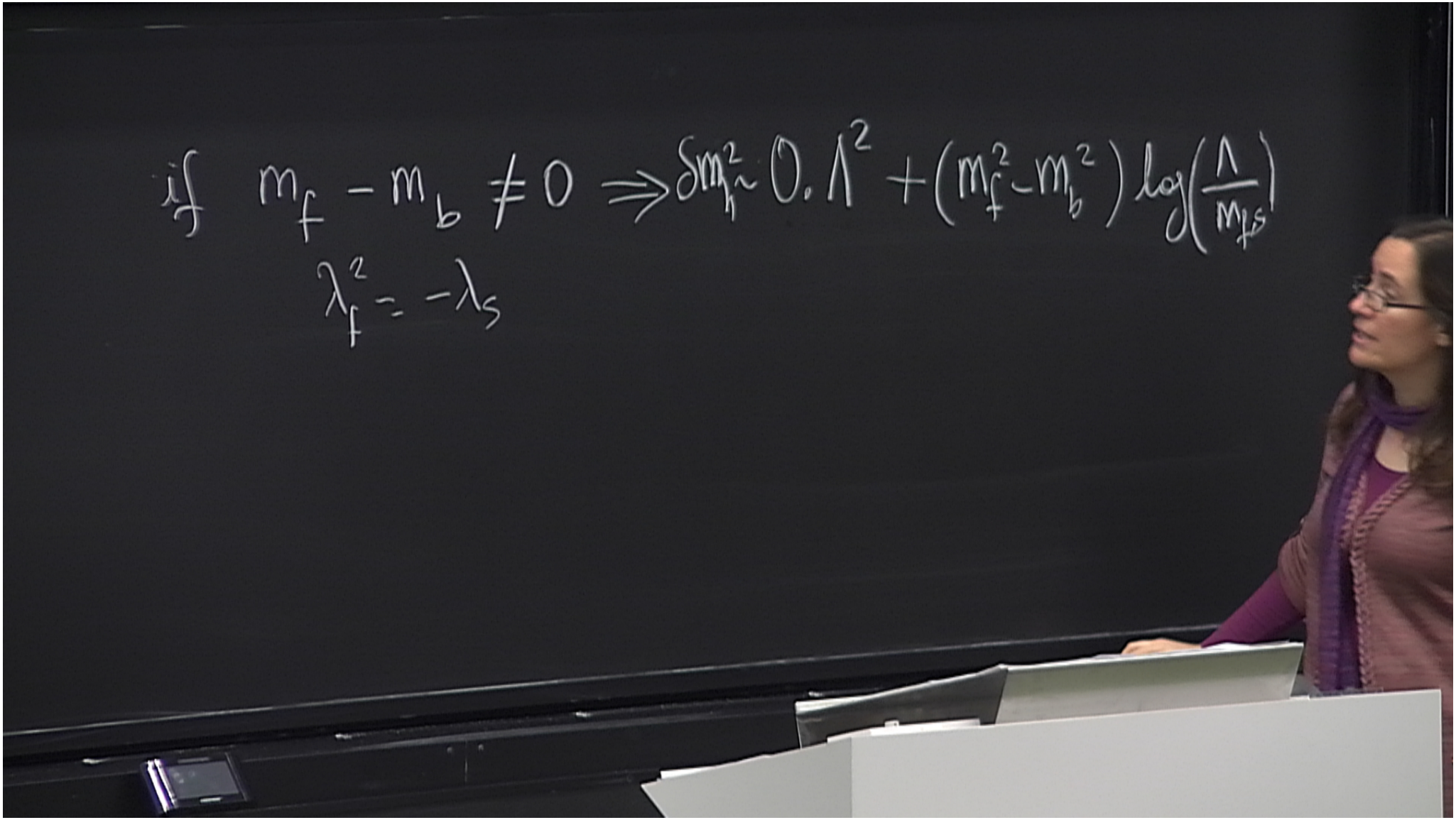
3b excess $t\bar{t}$ asymm LHC

$p\bar{p}$ pp

356 $M_h \sim 125$ GeV


gauge → spontaneous SB
susy → soft susy


if $m_f - m_b \neq 0 \Rightarrow$
$0.\Lambda^2 + (m_f^2 - m_b^2)\log\left(\frac{\Lambda}{m_{fs}}\right)$
$\lambda_f^2 = -\lambda_s$


if $m_f - m_b \neq 0 \Rightarrow \delta m_h^2 \sim 0.\Lambda^2 + (m_f^2 - m_b^2)\log\left(\frac{\Lambda}{m_{fs}}\right)$
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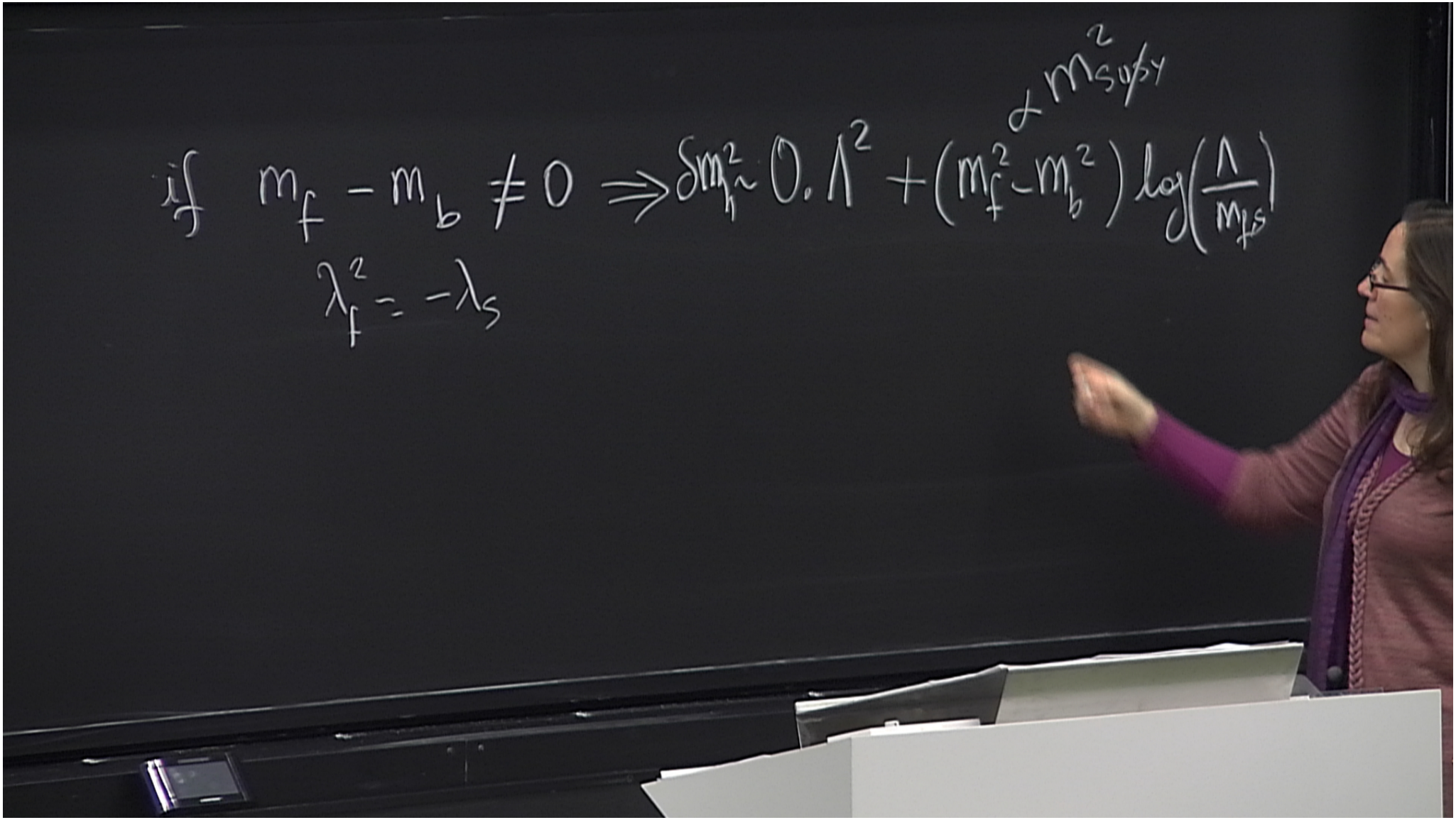
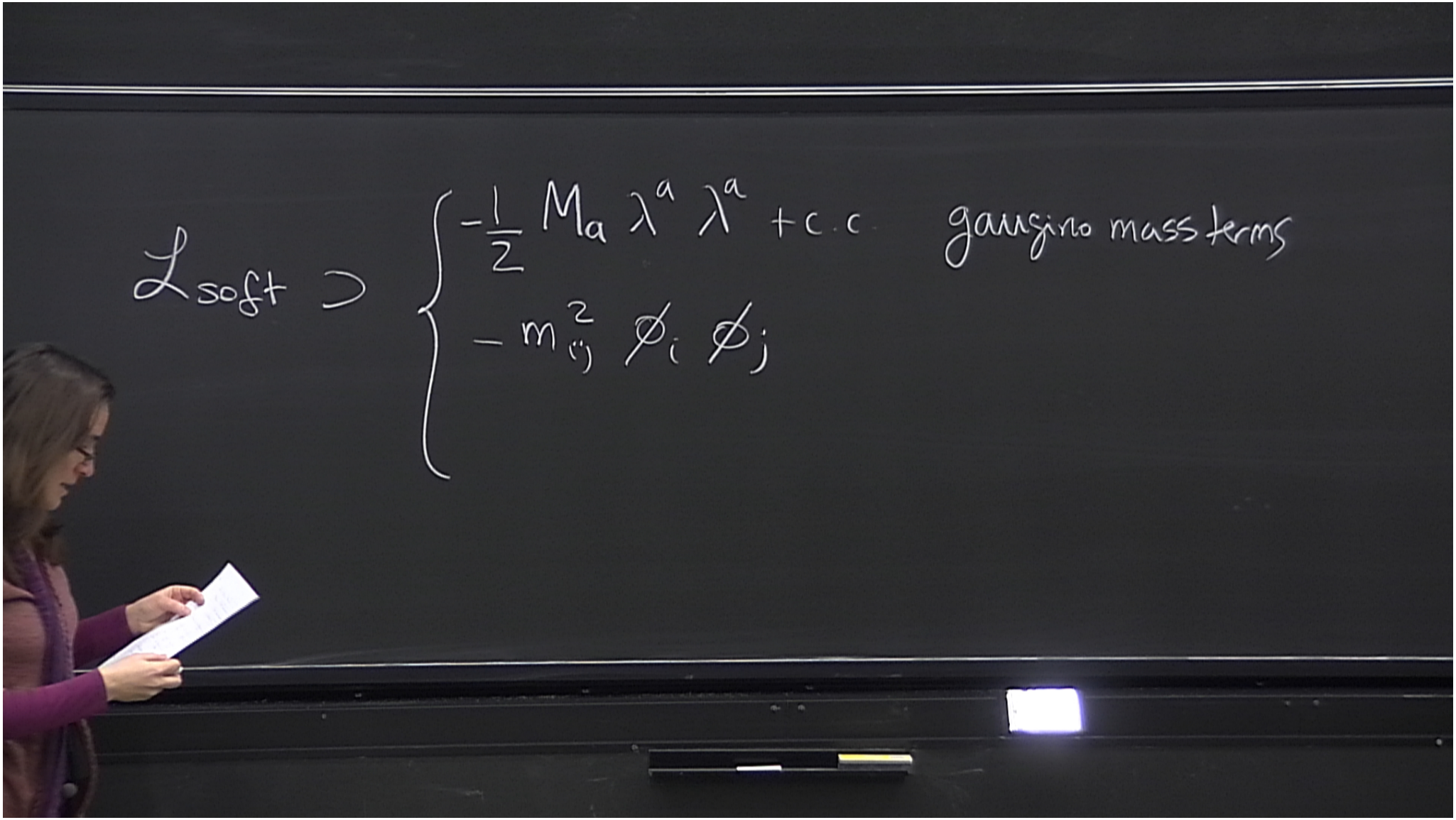
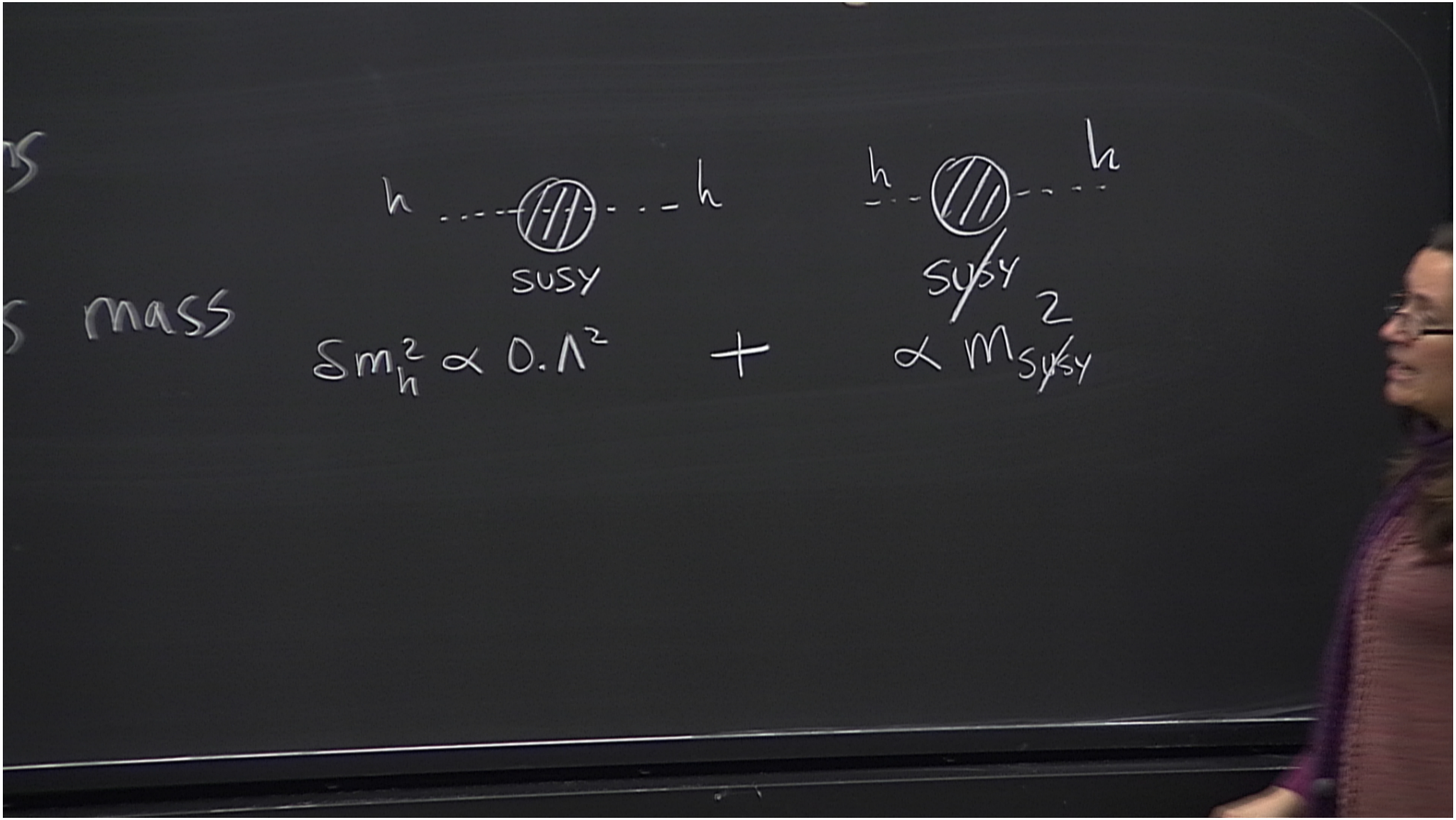
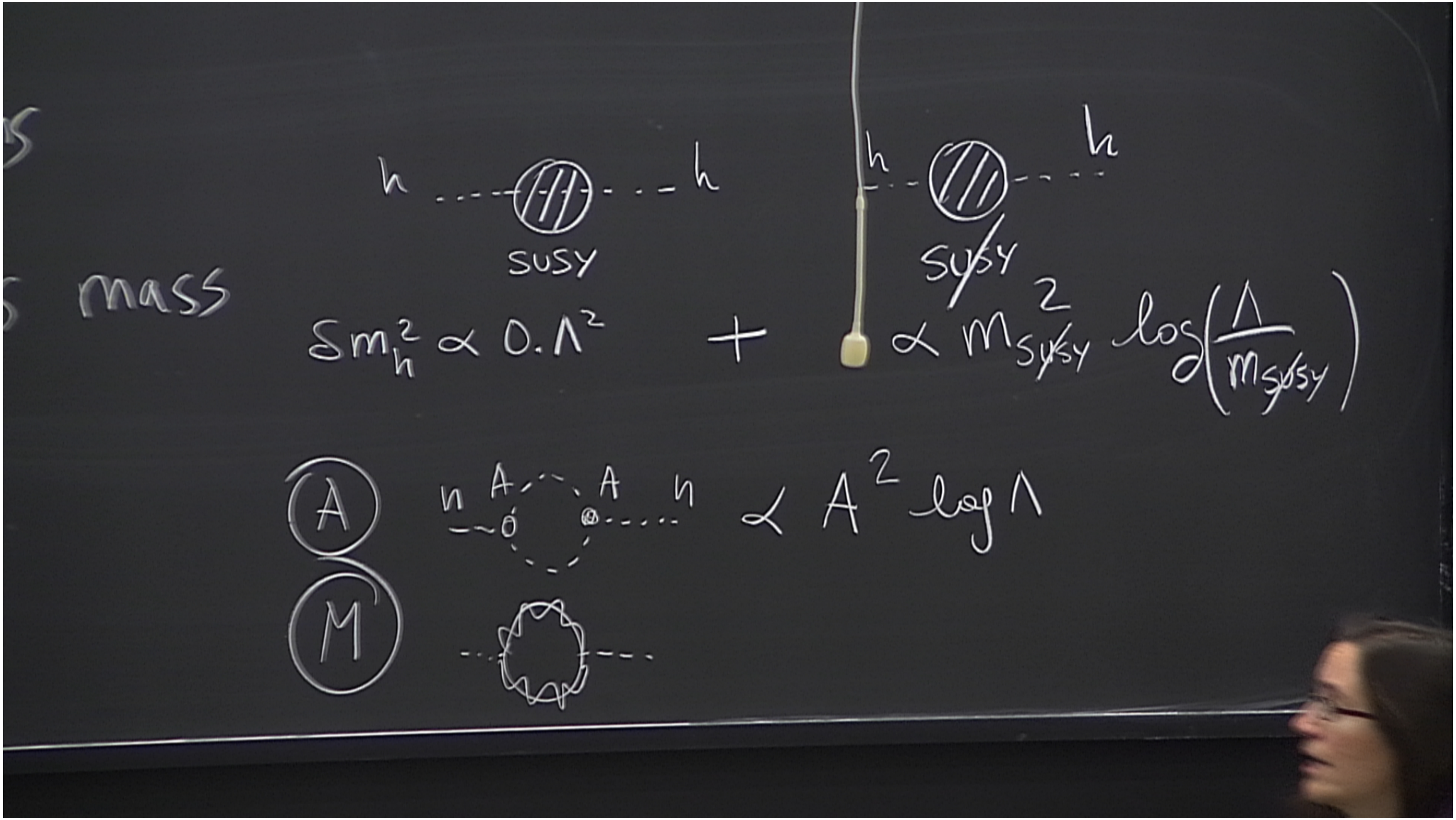
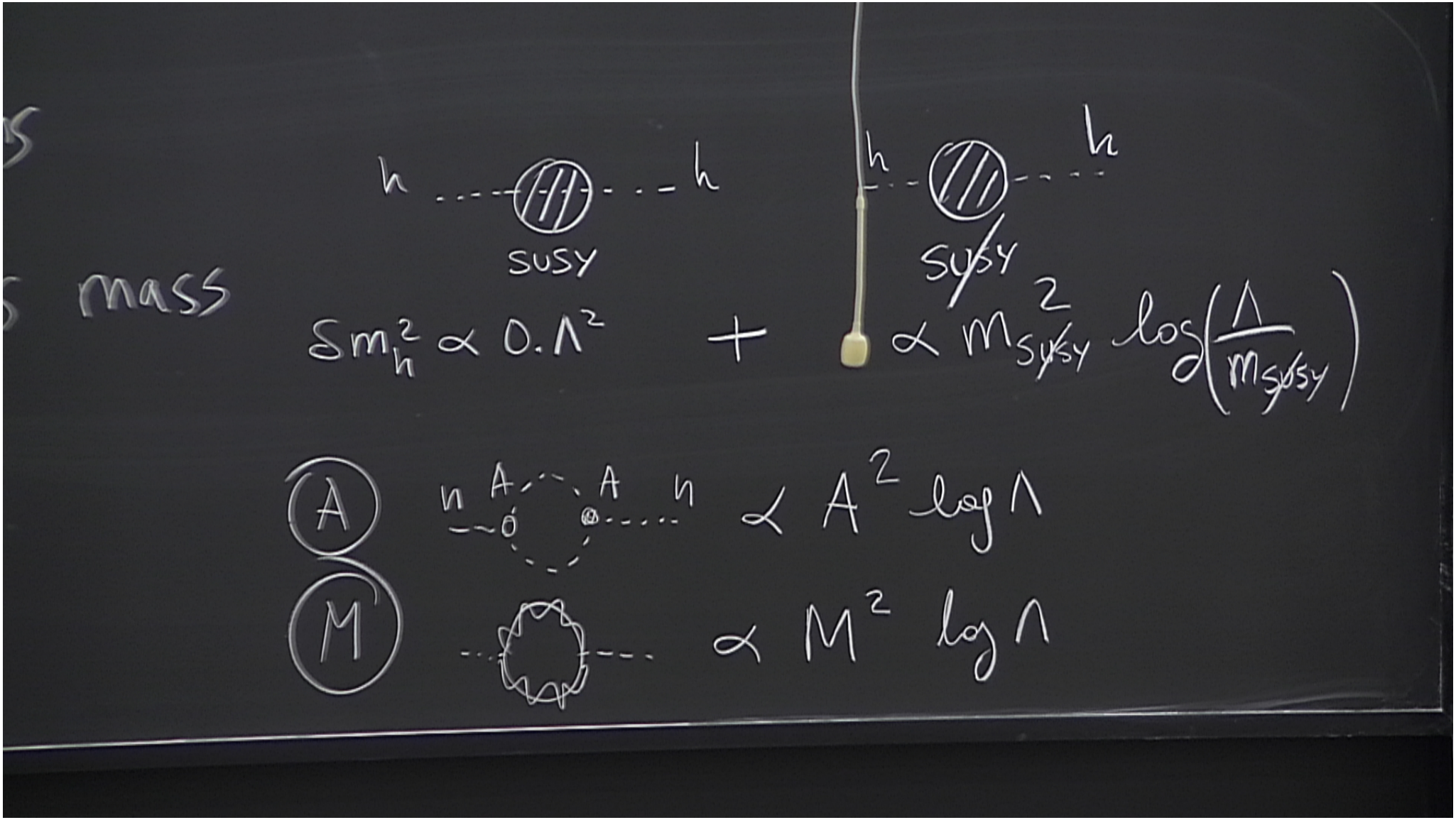

if $m_f - m_b \neq 0 \Rightarrow \delta m_h^2 \sim 0.\Lambda^2 + (m_f^2 - m_b^2)\log\left(\frac{\Lambda}{m_{fs}}\right)$
$\propto m_{susy}^2$
$\lambda_f^2 = -\lambda_s$

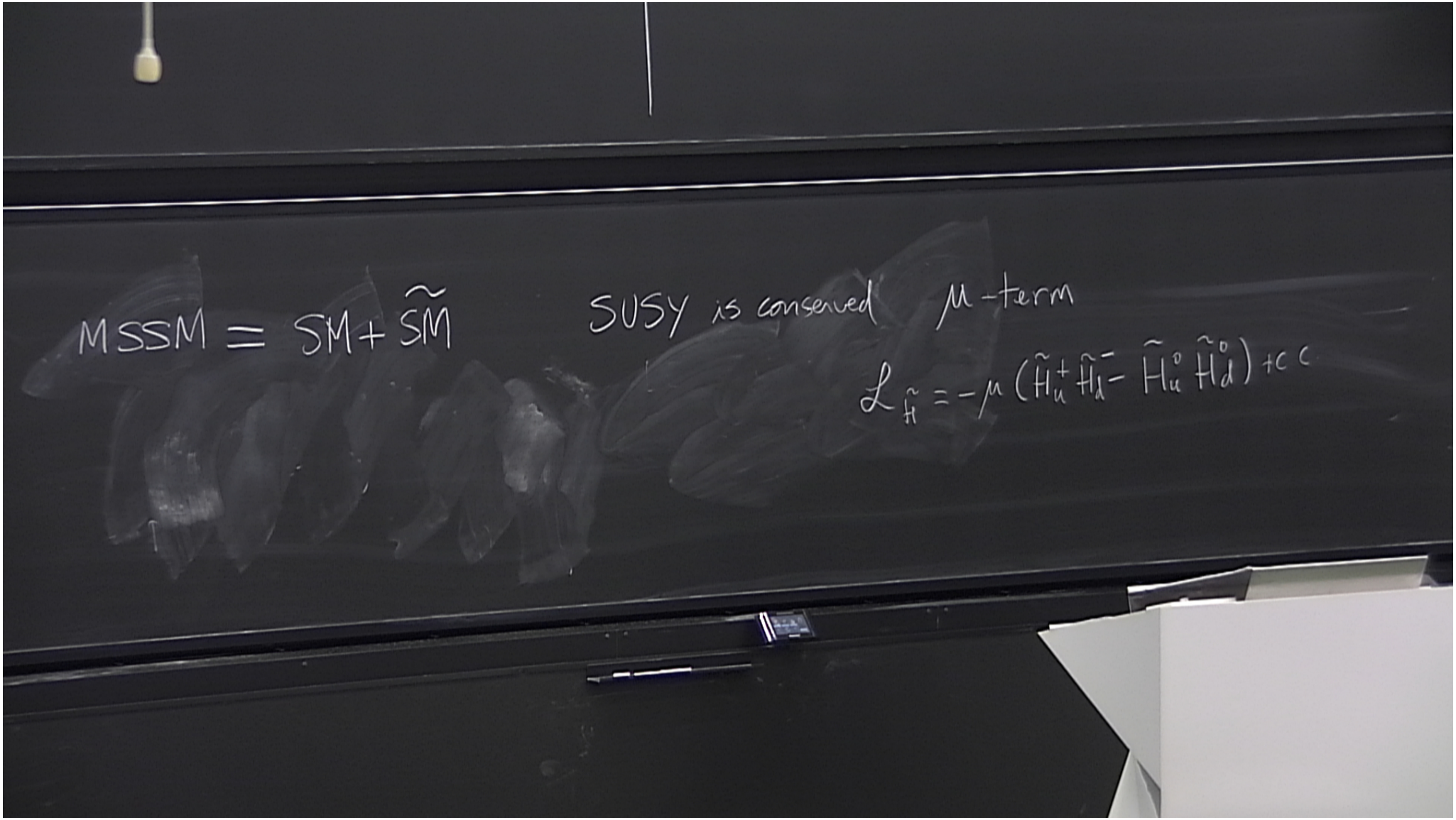

$\mathcal{L}_{soft} \supset$
$-\frac{1}{2} M_a \lambda^a \lambda^a + c.c$
gaugino mass terms
$- m^2_{ij} \phi_i \phi_j$

$$\mathcal{L}_{soft} \supset \begin{cases} -\frac{1}{2} M_a \lambda^a \lambda^a + c.c & \text{gaugino mass terms} \\ -m^2_{ij} \phi_i \phi_j & \text{scalar partners mass} \\ -\frac{1}{6} A_{ijk} \phi_i \phi_j \phi_k & \text{trilinear scalar} \end{cases}$$


h
h
SUSY
h
h
SUSY
mass
$\delta m_h^2 \propto 0.\Lambda^2$
+
$\propto m_{SUSY}^2$

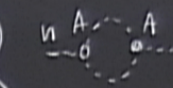

mass
h
h
SUSY
h
h
SUSY
$\delta m_h^2 \propto 0.\Lambda^2$
+
$\propto m_{SUSY}^2 \log\left(\frac{\Lambda}{m_{SUSY}}\right)$
A
M
h
A
A
h
$\propto A^2 \log \Lambda$

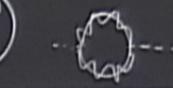

mass
h
h
SUSY
h
h
SUSY
$\delta m_h^2 \propto 0.\Lambda^2$
+
$\propto m_{SUSY}^2 \log\left(\frac{\Lambda}{m_{SUSY}}\right)$
A
h
A
A
h
$\propto A^2 \log\Lambda$
M
$\propto M^2 \log\Lambda$


MSSM = SM + $\widetilde{SM}$
SUSY is conserved
μ-term
$\mathcal{L}_{\tilde{H}} = -\mu(\tilde{H}_u^+ \tilde{H}_d^- - \tilde{H}_u^0 \tilde{H}_d^0) + c.c$

$(-\frac{1}{6} A_{ijk} \phi_i \phi_j \phi_k$ trilinear scalar

$\rightarrow \mathcal{O}(100)$

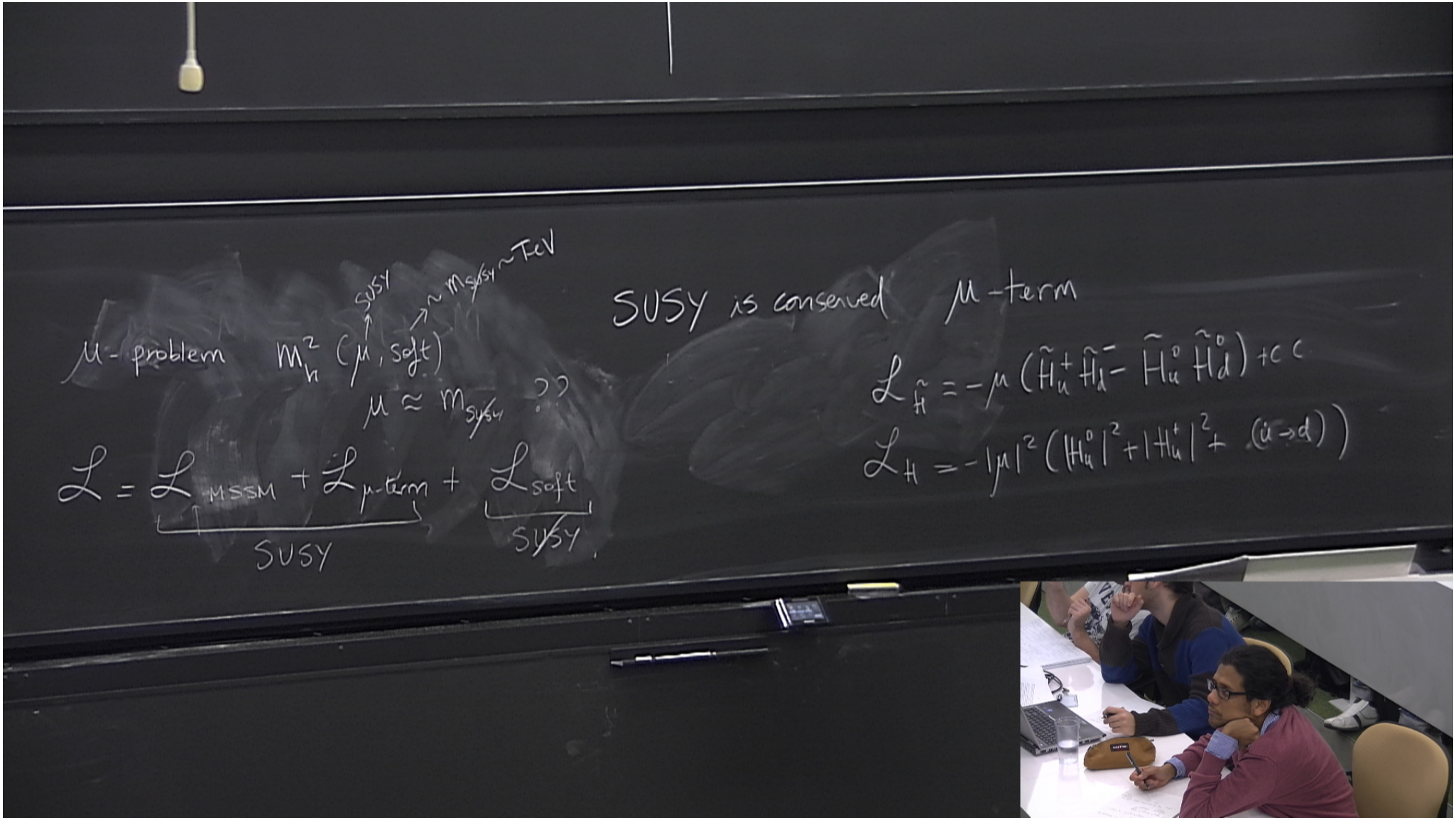
(A)  $\propto A^2 \log \Lambda$

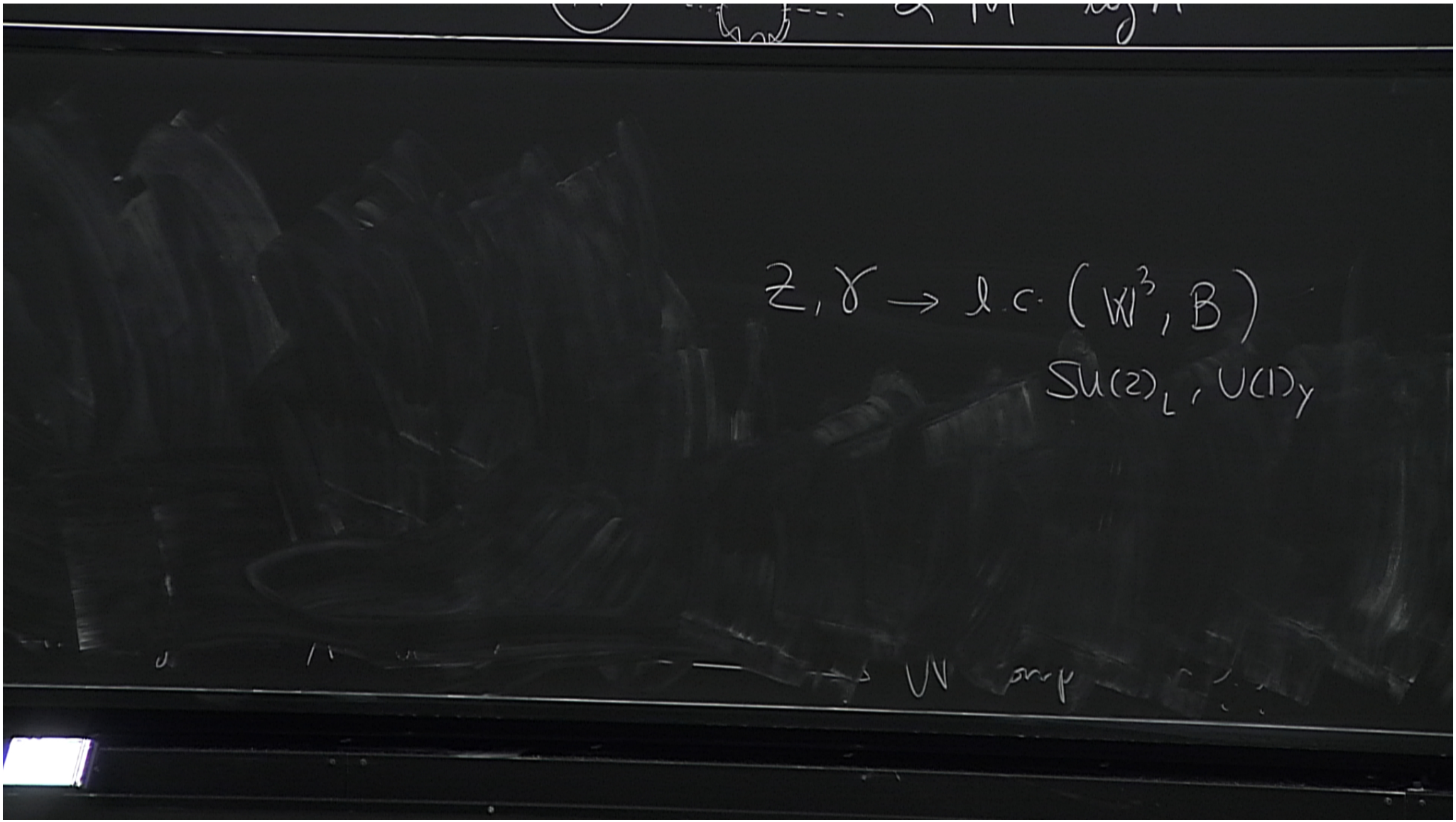
(M)  $\propto M^2 \log \Lambda$

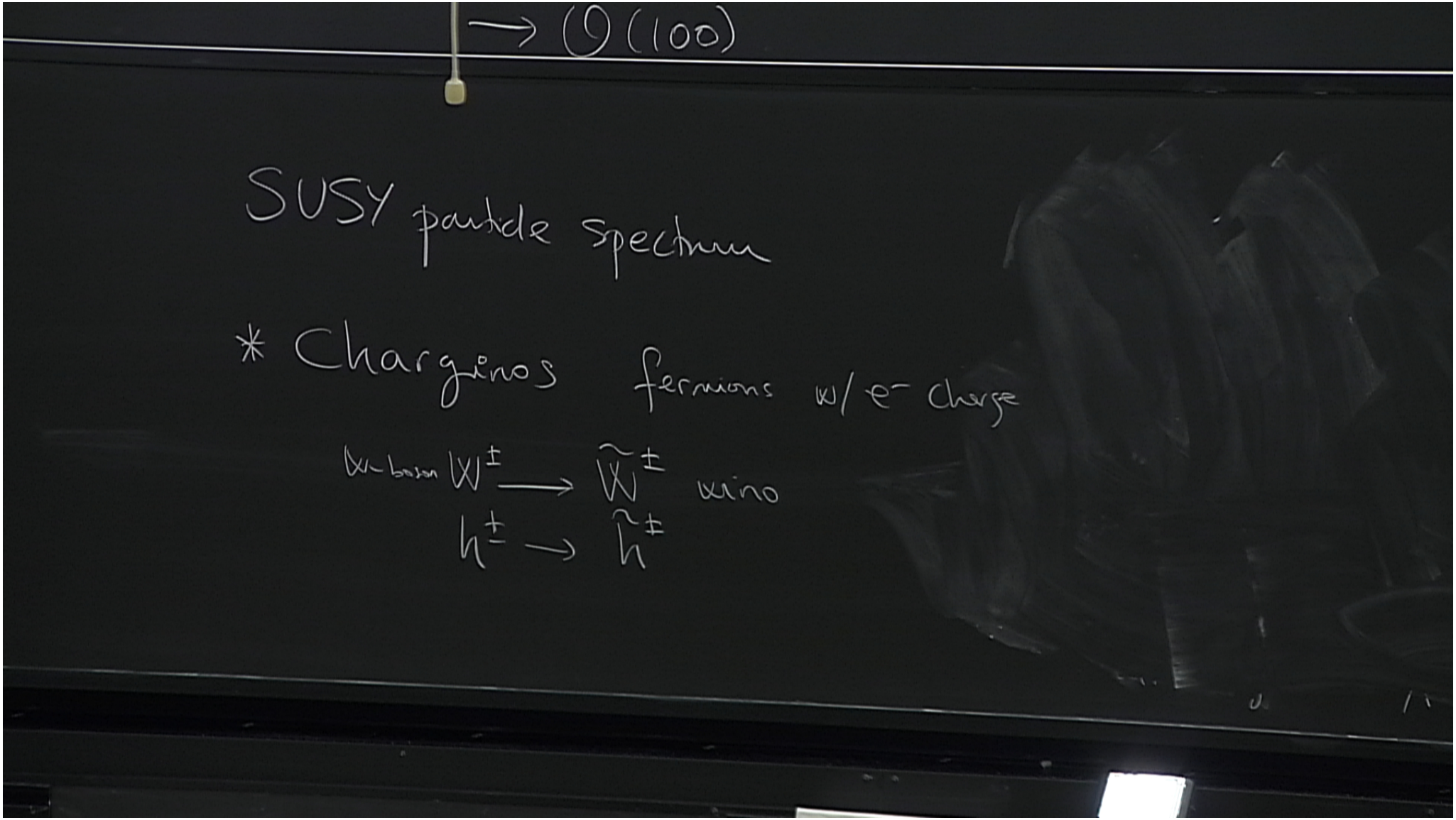
SM one h gives masses to everybody $\bar{Q} h u_R$, $\bar{Q} h^* d_R$ (m_u, m_d)

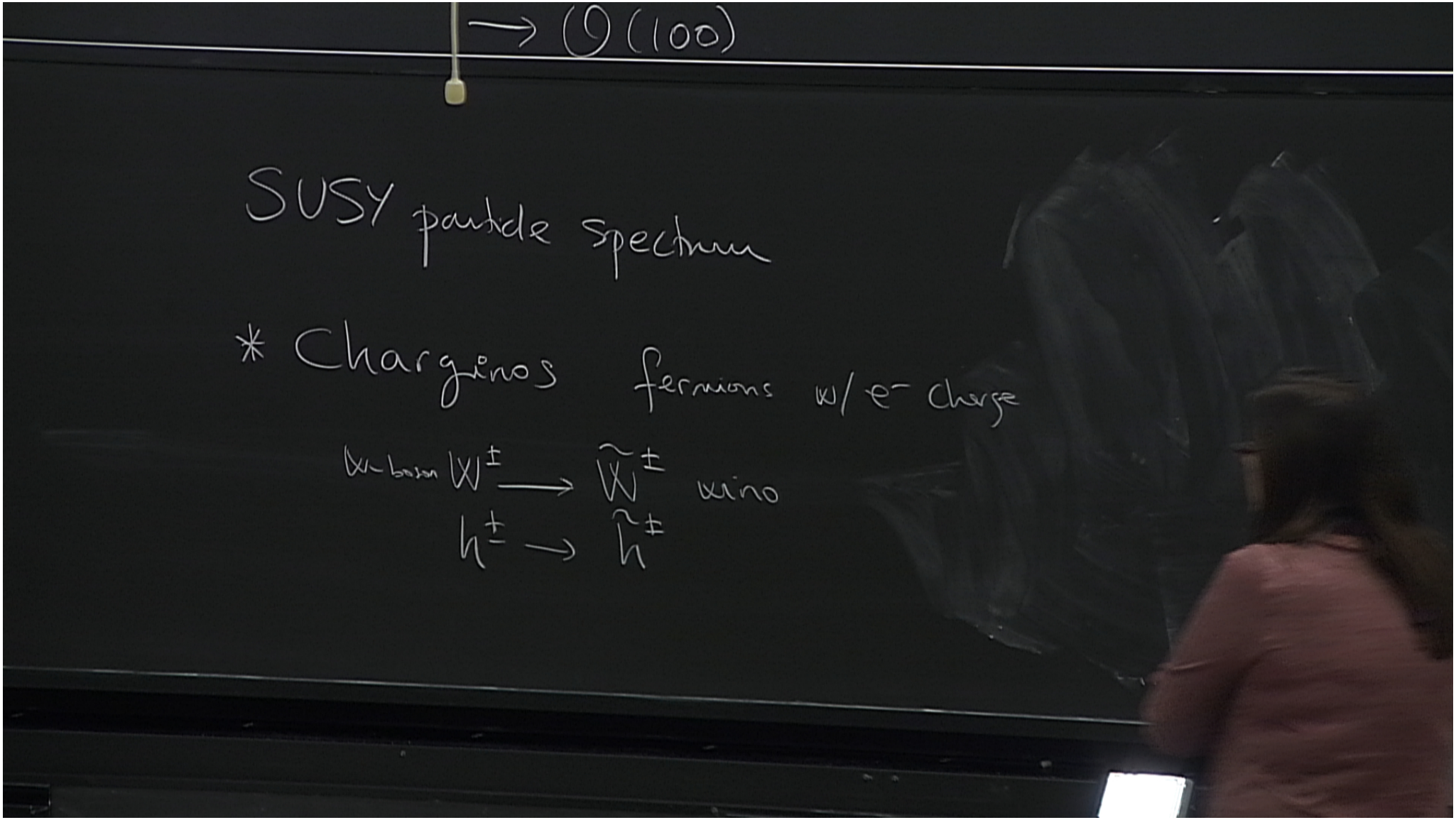
MSSM Higgs sector 2HDM

MSSM $h \leftrightarrow \tilde{h}$ ↳ new fermionic dof → anomalies 2 Higgses H_u, H_d $Y_u = -Y_d$


μ - problem
$m_h^2(\mu, \text{soft})$
SUSY
$\sim m_{SUSY} \sim$ TeV
$\mu \approx m_{SUSY}$??
$\mathcal{L} = \mathcal{L}_{MSSM} + \mathcal{L}_{\mu\text{-term}} + \mathcal{L}_{soft}$
SUSY
SUSY
SUSY is conserved
μ-term
$\mathcal{L}_{\tilde{H}} = -\mu(\tilde{H}_u^+ \tilde{H}_d^- - \tilde{H}_u^0 \tilde{H}_d^0) + c.c$
$\mathcal{L}_H = -|\mu|^2(|H_u^0|^2 + |H_u^+|^2 + (u \to d))$


$Z, \gamma \rightarrow$ l.c. (W^3, B)
$SU(2)_L, U(1)_Y$
UV comp


→ O(100)
SUSY particle spectrum
* Charginos fermions w/ e⁻ charge
W-boson $W^{\pm} \longrightarrow \tilde{W}^{\pm}$ wino
$h^{\pm} \rightarrow \tilde{h}^{\pm}$


→ O(100)
SUSY particle spectrum
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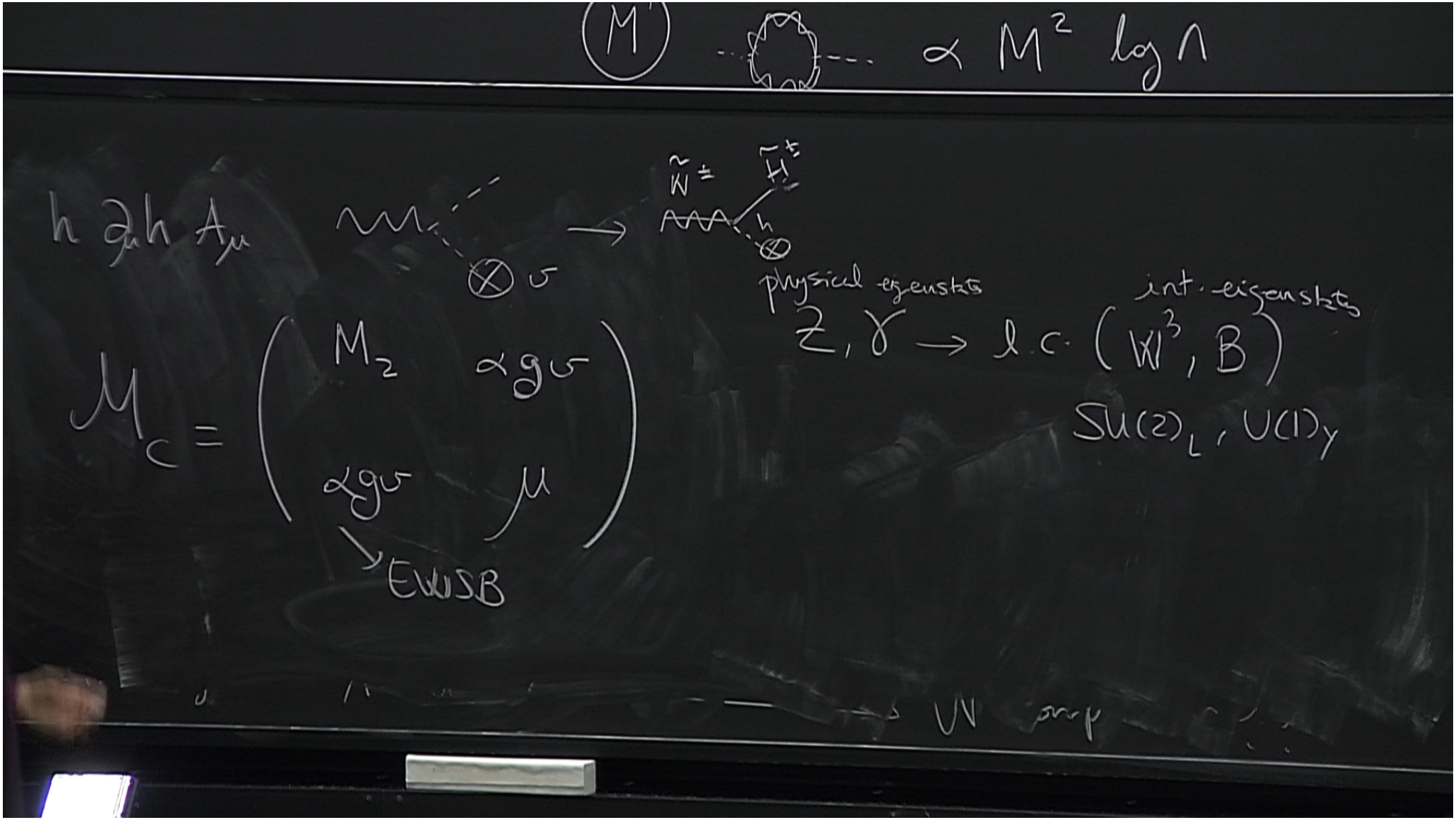
W-boson $W^{\pm} \longrightarrow \tilde{W}^{\pm}$ wino
$h^{\pm} \rightarrow \tilde{h}^{\pm}$

SUSY particle spectrum

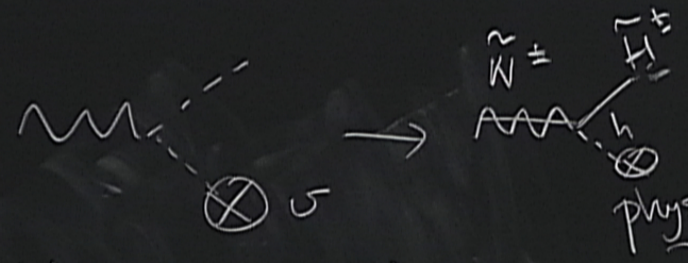
* Charginos fermions w/ e^- charge

W-boson $W^{\pm} \longrightarrow \widetilde{W}^{\pm}$ wino

$h^{\pm} \longrightarrow \widetilde{h}^{\pm}$


M
$\propto M^2 \log \Lambda$
$h\, \partial_\mu h\, A_\mu$
$\tilde{W}^\pm$
$H^\pm$
h
v
physical eigenstates
int. eigenstates
$Z, \gamma \to$ l.c. (W^3, B)
$SU(2)_L, U(1)_Y$
$M_c = \begin{pmatrix} M_2 & \alpha g v \\ \alpha g v & M \end{pmatrix}$
EWSB
UV

M^2 $\propto M^2 \log \Lambda$

$h\, \partial_\mu h\, A_\mu$ 

physical eigenstates Z, γ $\rightarrow$ l.c. int. eigenstates (W^3, B)

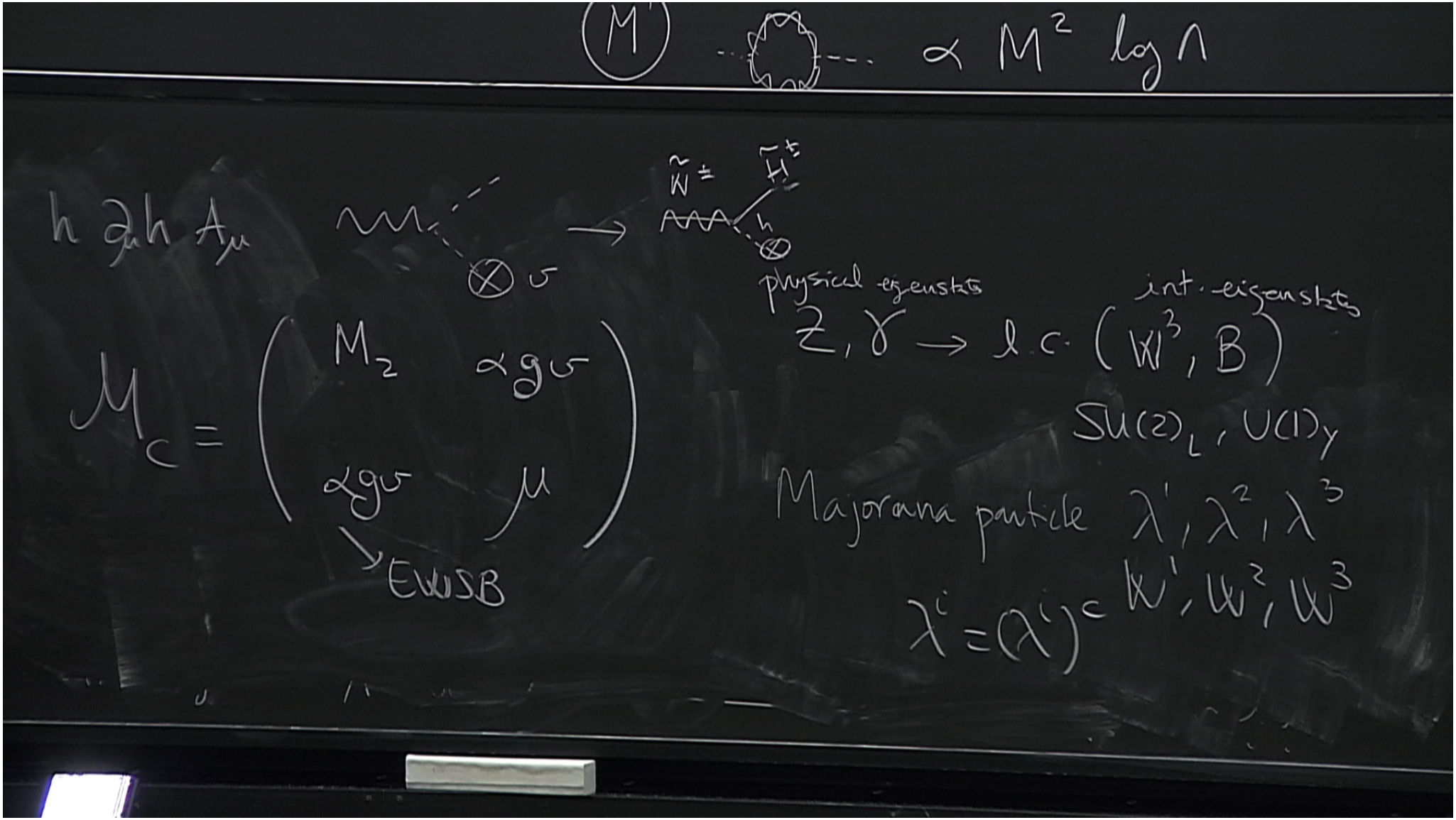
$SU(2)_L$, $U(1)_Y$

$$M_C = \begin{pmatrix} M_2 & \alpha g v \\ \alpha g v & \mu \end{pmatrix}$$

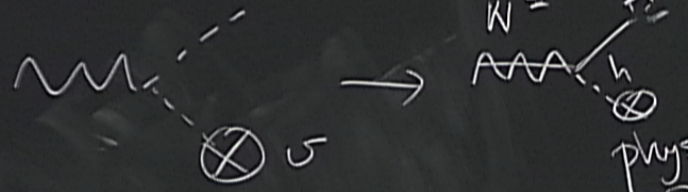
$\searrow$ EWSB

Majorana particle $\lambda^1, \lambda^2, \lambda^3$

UV comp


M
$\propto M^2 \log \Lambda$
$h\,\partial h\,A_\mu$
$\tilde{W}^\pm$
$\tilde{H}^\pm$
h
v
physical eigenstates
int. eigenstates
$Z, \gamma \to$ l.c. (W^3, B)
$SU(2)_L, U(1)_Y$
$M_C = \begin{pmatrix} M_2 & \alpha g v \\ \alpha g v & \mu \end{pmatrix}$
EWSB
Majorana particle $\lambda^1, \lambda^2, \lambda^3$
$\lambda^i = (\lambda^i)^c$ W^1, W^2, W^3

$h\,\partial_\mu h\,A_\mu$



physical eigenstates — int. eigenstates

$Z, \gamma \rightarrow$ l.c. (W^3, B)

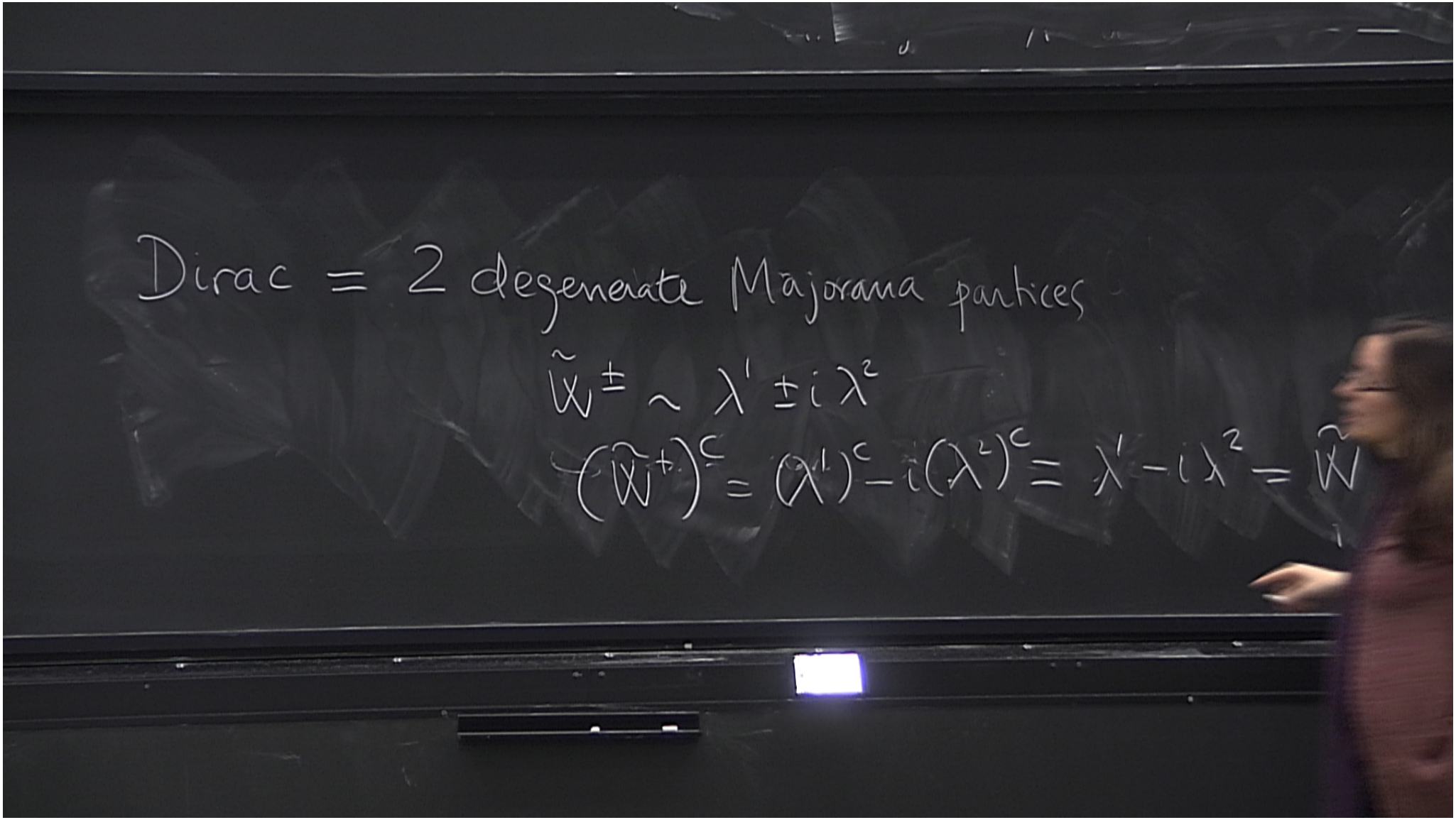
$SU(2)_L, U(1)_Y$

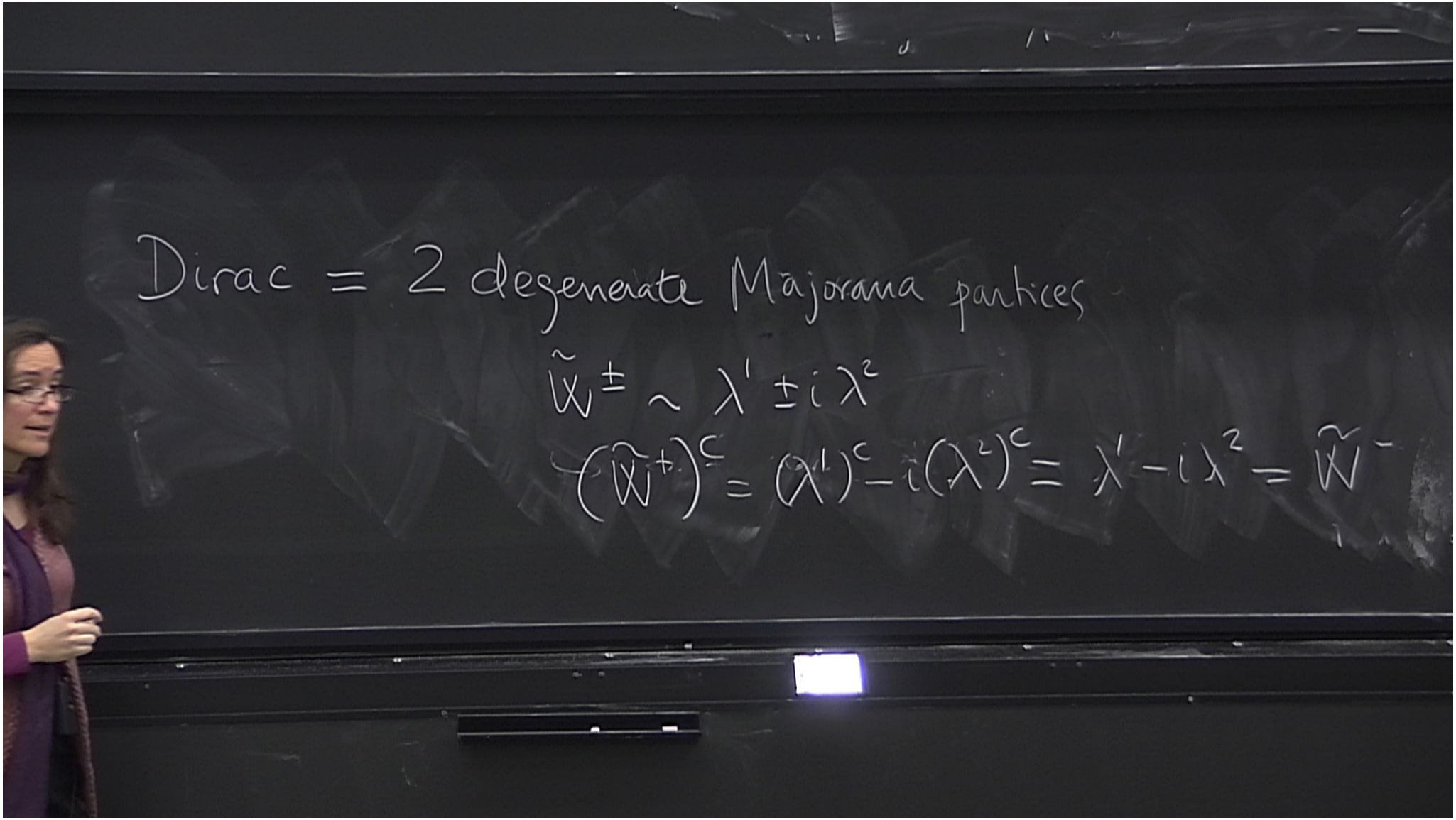
$$M_c = \begin{pmatrix} M_2 & \alpha g v \\ \alpha g v & \mu \end{pmatrix}$$

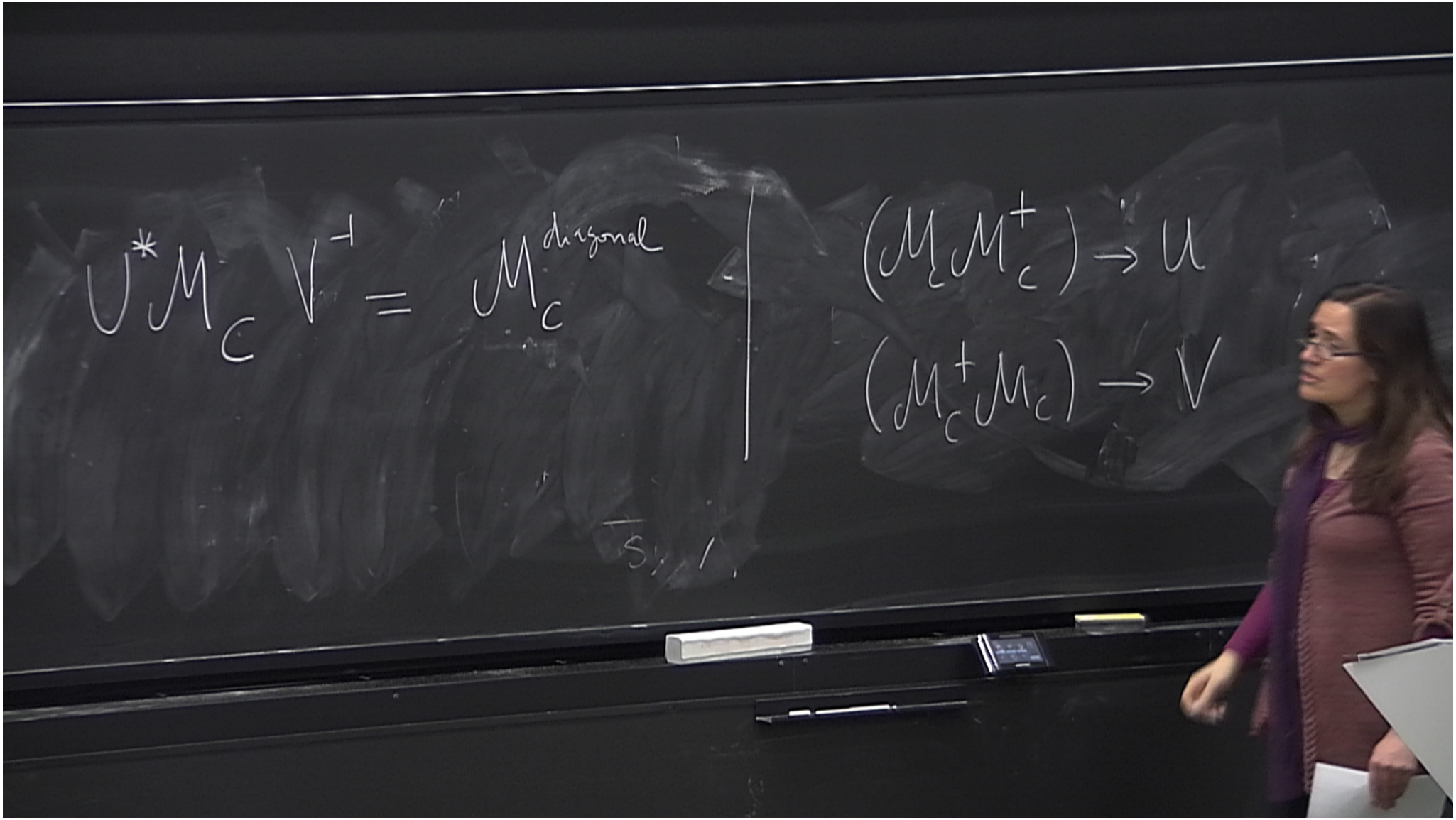
↘ EWSB

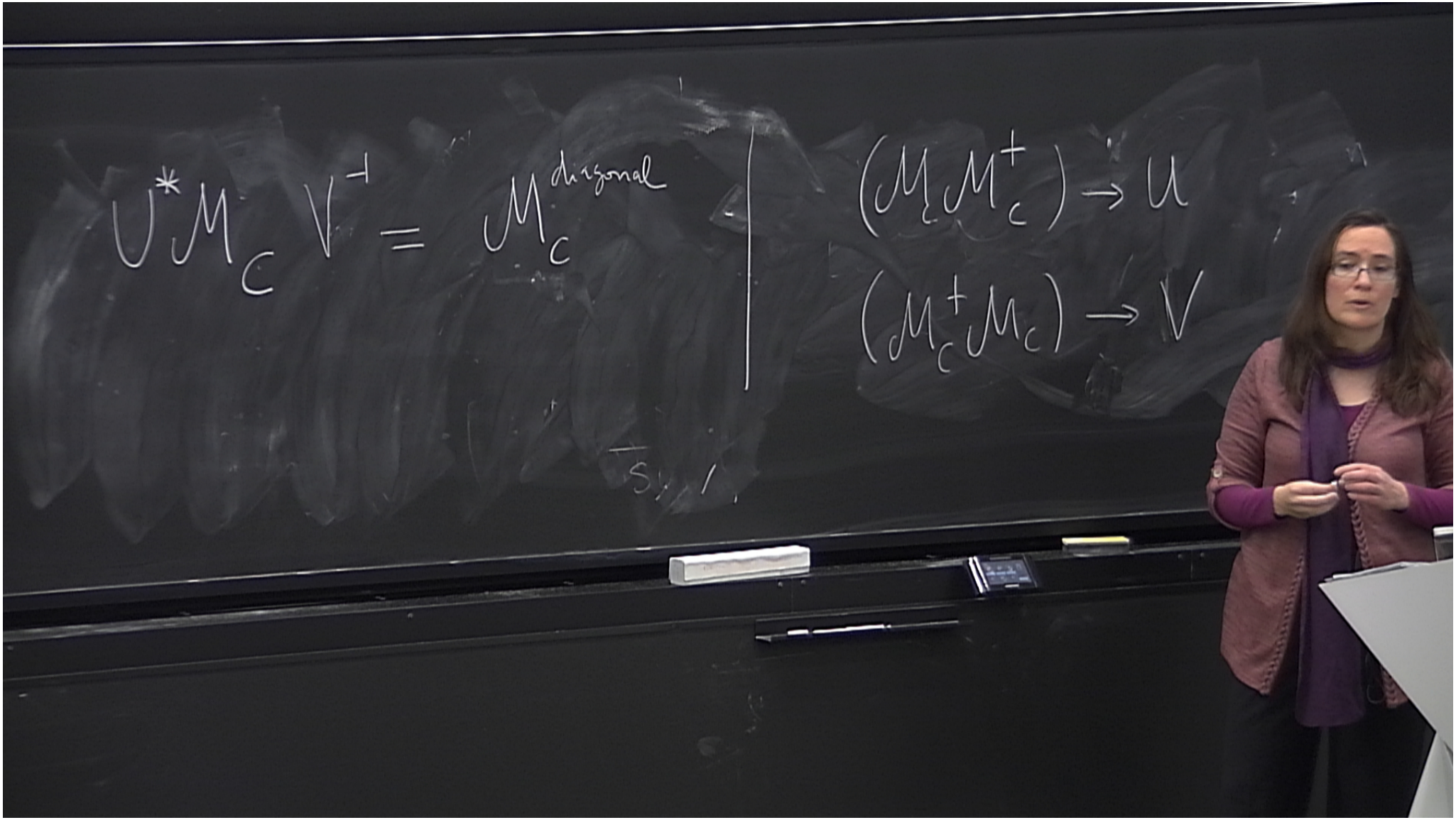
Majorana particle $\lambda^1, \lambda^2, \lambda^3$

$\lambda^i = (\lambda^i)^c$ W^1, W^2, W^3


Dirac = 2 degenerate Majorana particles
$\tilde{W}^{\pm} \sim \lambda^1 \pm i\lambda^2$
$(\tilde{W}^+)^c = (\lambda^1)^c - i(\lambda^2)^c = \lambda^1 - i\lambda^2 = \tilde{W}^-$


Dirac = 2 degenerate Majorana particles
$\tilde{W}^{\pm} \sim \lambda^1 \pm i\lambda^2$
$(\tilde{W}^+)^c = (\lambda^1)^c - i(\lambda^2)^c = \lambda^1 - i\lambda^2 = \tilde{W}^-$


$U^* M_c V^{-1} = M_c^{diagonal}$
$(M_L M_c^+) \rightarrow U$
$(M_c^+ M_c) \rightarrow V$


$U^* M_c V^{-1} = M_c^{diagonal}$
$(M_c M_c^\dagger) \to U$
$(M_c^\dagger M_c) \to V$