Title: Particle Physics Lecture - 230308

Speakers: Asimina Arvanitaki

Collection: Particle Physics (2022/2023)

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URL: https://pirsa.org/23030058

Consider two binary systems (outcomes of observables measurements are ± 1) and a pair
For system A we denote the settings of the measurement as a and
that the outcome of the measurement s could also depend, in princip
the result of a measurement on A (denoted by A) will be $A($
and on B (denoted B) $B($

MSSM particle content

particle	sparticle	charge
q_i	$\tilde{q}_i$	$(3, 2, 1/6)$
u_i	$\tilde{u}_i$	$(\bar{3}, 1, -2/3)$
d_i	$\tilde{d}_i$	$(\bar{3}, 1, 1/3)$
l_i	$\tilde{l}_i$	$(1, 2, -1/2)$
e_i	$\tilde{e}_i$	$(1, 1, 1)$
W	$\tilde{W}$	$(1, 3, 0)$
B	$\tilde{B}$	$(1, 1, 0)$
G	$\tilde{G}$	$(8, 1, 0)$

Higgs:

particle	sparticle	charge
H	$\tilde{H}$	$(1, 2, 1/2)$

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A supersymmetry primer S. Martin '97

SUSY (ϕ_i, ψ_i, F_i)

ϕ_i: complex scalar; ψ_i: Weyl Fermion; F_i: dim-2 scalar

gauge multiplets: $(\lambda^a, A_\mu^a, D^a)$ ← aux field.

SUSY (ϕ_i, ψ_i, F_i)

ϕ_i: complex scalar; ψ_i: Weyl Fermion; F_i: dim. 2 scalar

gauge multiplets: $(\lambda^\alpha, A_\mu^\alpha, D)$ — D: aux. field.

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superpotential: $W = -t^i \phi_i + \frac{1}{2} M^{ij} \phi_i \phi_j + \frac{1}{6} y_{ijk} \phi_i \phi_j \phi_k$ [mass]^3

SUSY (ϕ_i, ψ_i, F_i)

ϕ_i: complex scalar; ψ_i: Weyl Fermion; F_i: dim-2 scalar

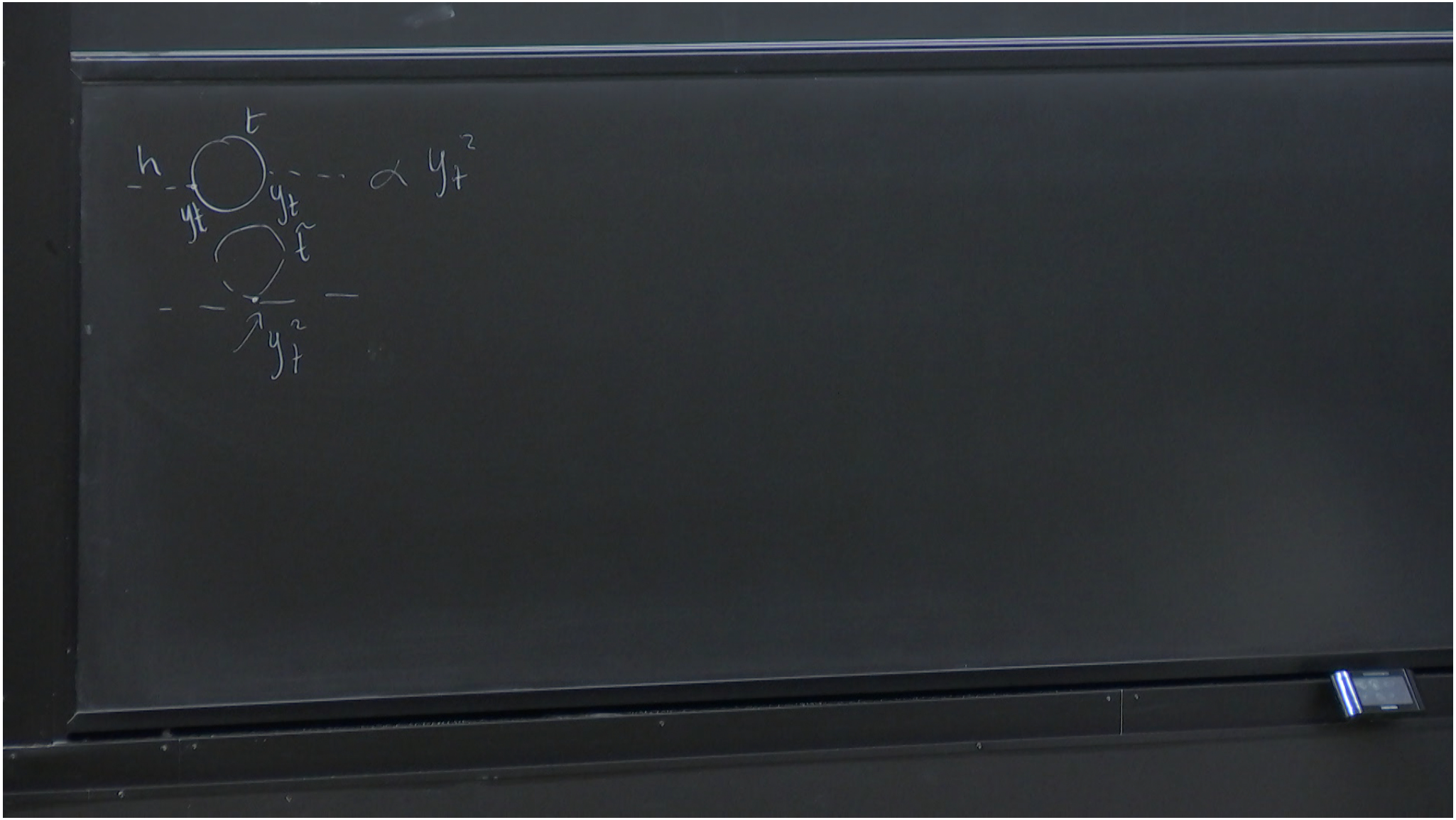
gauge multiplets: $(\lambda^\alpha, A_\mu^\alpha, D)$ — D: aux. field.

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superpotential: $W = t^i \Phi_i + \frac{1}{2} M^{ij} \Phi_i \Phi_j + \frac{1}{6} y_{ijk} \Phi_i \Phi_j \Phi_k$ [mass]^3

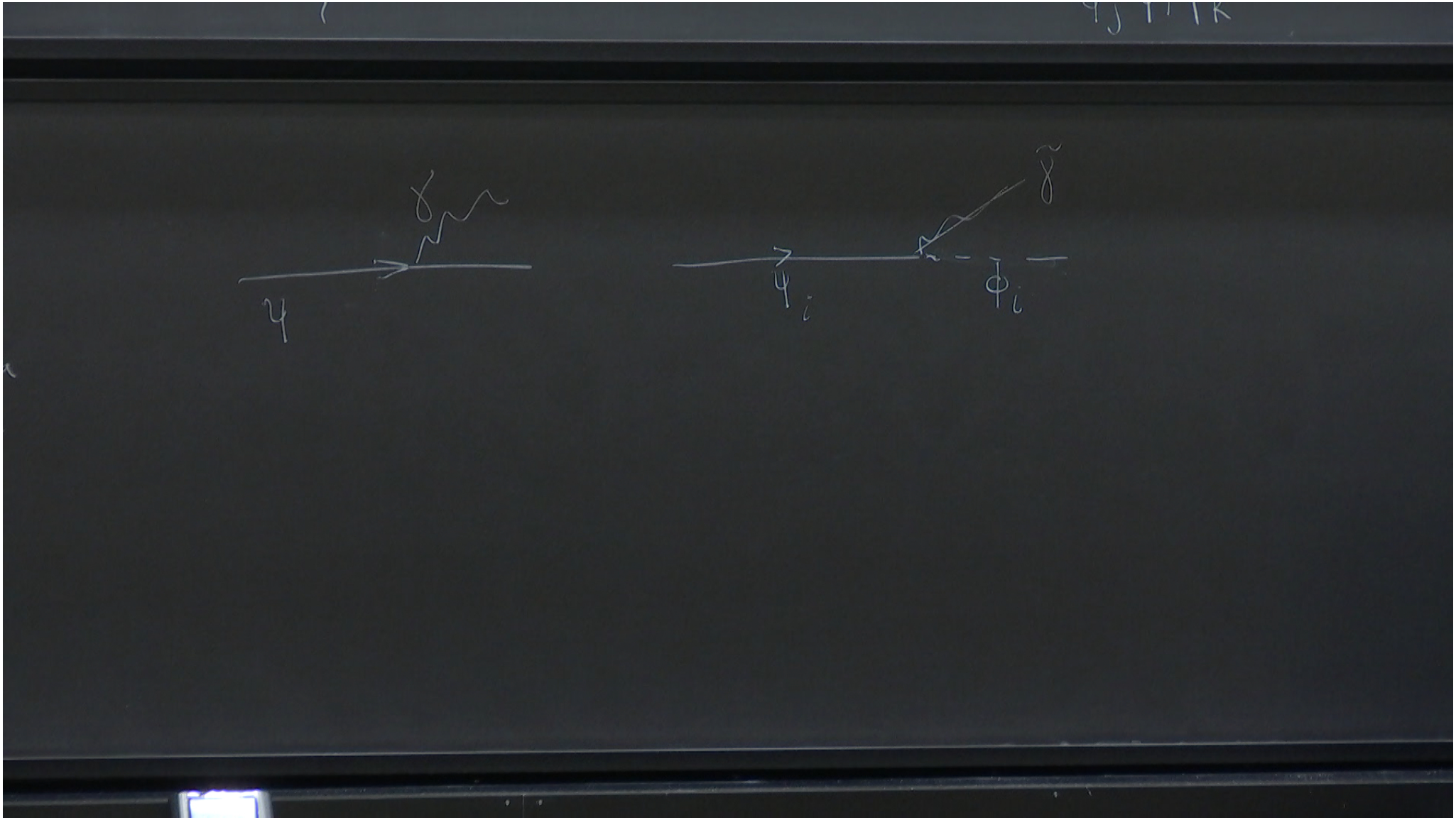
$\mathcal{L} \supset \mathcal{L}_{\text{kinetic}} + \frac{1}{2} \sum_{i,k} \frac{\partial^2 W}{\partial \phi_i \partial \phi_k} \psi_i \psi_k - \sum_i \left| \frac{\partial W}{\partial \phi_i} \right|^2$

$\partial_\mu \psi_i \psi_k$


t
h
$\alpha\ y_t^2$
y_t
y_t
$\tilde{t}$
y_t^2

$$\mathcal{L}_{gauge} - \frac{1}{8}\sum_a g_a \sum_j \left| \phi_j^* \tau^a \phi_j \right|^2$$

$$- \frac{i}{\sqrt{2}} \sum_{i,\alpha} g_a \left| \phi_i \tau^a \psi_i^+ - \phi_i^+ \tau^a \psi_i \right| \lambda_a$$


γ
ψ
γ
ψ_i
φ_i

MSSM particle content

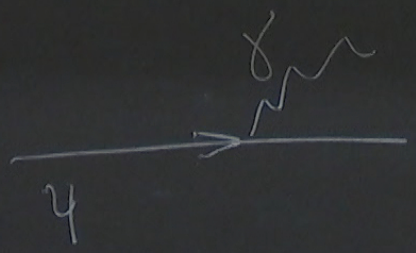
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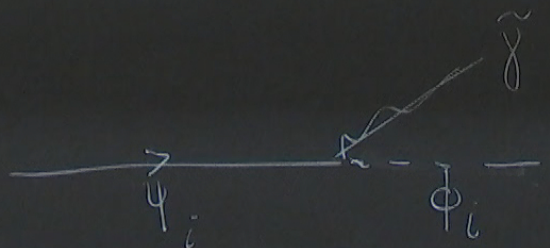
Higgs:

particle	sparticle	charge
H_u	$\tilde{H}_u$	$(1, 2, 1/2)$
H_d	$\tilde{H}_d$	$(1, 3, -1/2)$

A supersymmetry primer S. Martin '97

$q_j \Phi_i \Phi_k$

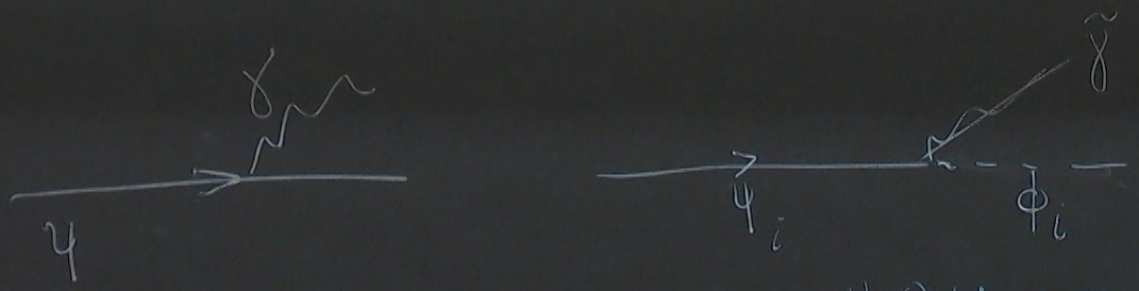




$H^\dagger QD$

$W_{MSSM} = y_u H_u Q U + y_d H_d Q D + y_e H_d L E + \mu H_u H_d$

$q_j \psi_i \psi_k$

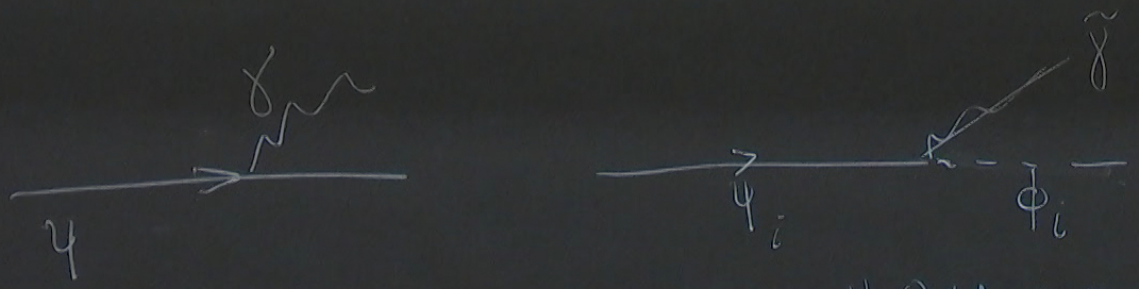


ψ

$\psi^\dagger Q D$ $\quad W_{MSSM} = y_u H_u Q U + y_d H_d Q D + y_e H_d L E + \mu H_u H_d$

Need to explain why $\mu \sim$ TeV "μ-problem"

$q_j \psi_i \psi_k$



$\psi^\dagger Q D$ $\quad W_{MSSM} = y_u H_u Q U + y_d H_d Q D + y_e H_d L E + \mu H_u H_d$

Need to explain why $\mu \sim$ TeV "μ-problem"

$+ \lambda L L E + \lambda' Q D L + \lambda'' U D D + K L H_u$

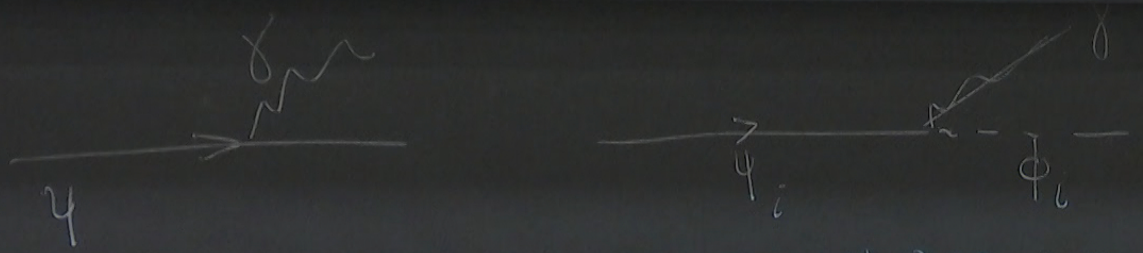


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Need to explain why $\mu \sim$ TeV "μ-problem"

$\not{R} + \lambda LLE + \lambda' QDL + \lambda'' UDD + K L H_u$

proton decay $\begin{cases} u \\ d \\ u \end{cases} \rightarrow \bar{u} \rightarrow e^+ \\ \bar{u} \\ u \end{cases} \pi^0$



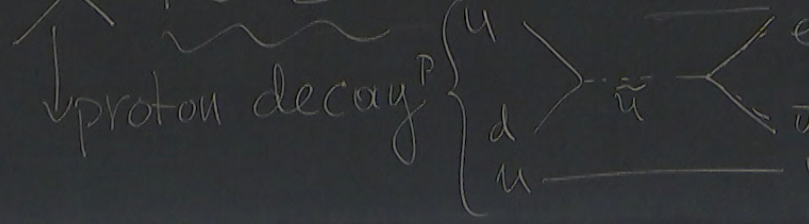
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Need to explain why $\mu \sim$ TeV "μ-problem"

$\not{L} + \not{L} LLE + \lambda' QDL + \lambda'' UDD + K L H_u$

proton decay?



Need R-parity



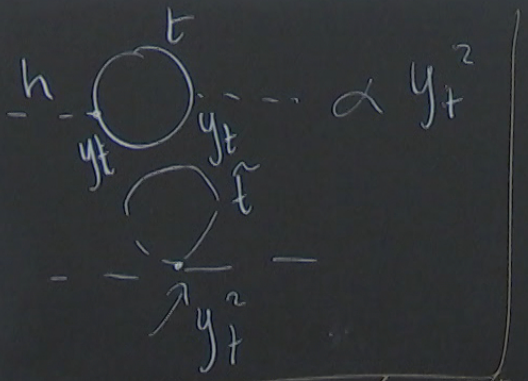
$H^\dagger QD$ $\quad W_{MSSM} = y_u H_u Q U + y_d H_d Q D + y_e H_d L E + \mu H_u H_d$

Need to explain why $\mu \sim$ TeV "μ-problem"

$\not{R} + \lambda LLE + \lambda' QDL + \lambda'' UDD + K L H_u$

proton decay? $\{ u, d, u \to \tilde{S} \to e^+, \bar{u}, u, \pi^0 \}$

Need R-parity

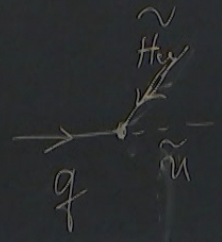


$\propto y_t^2$

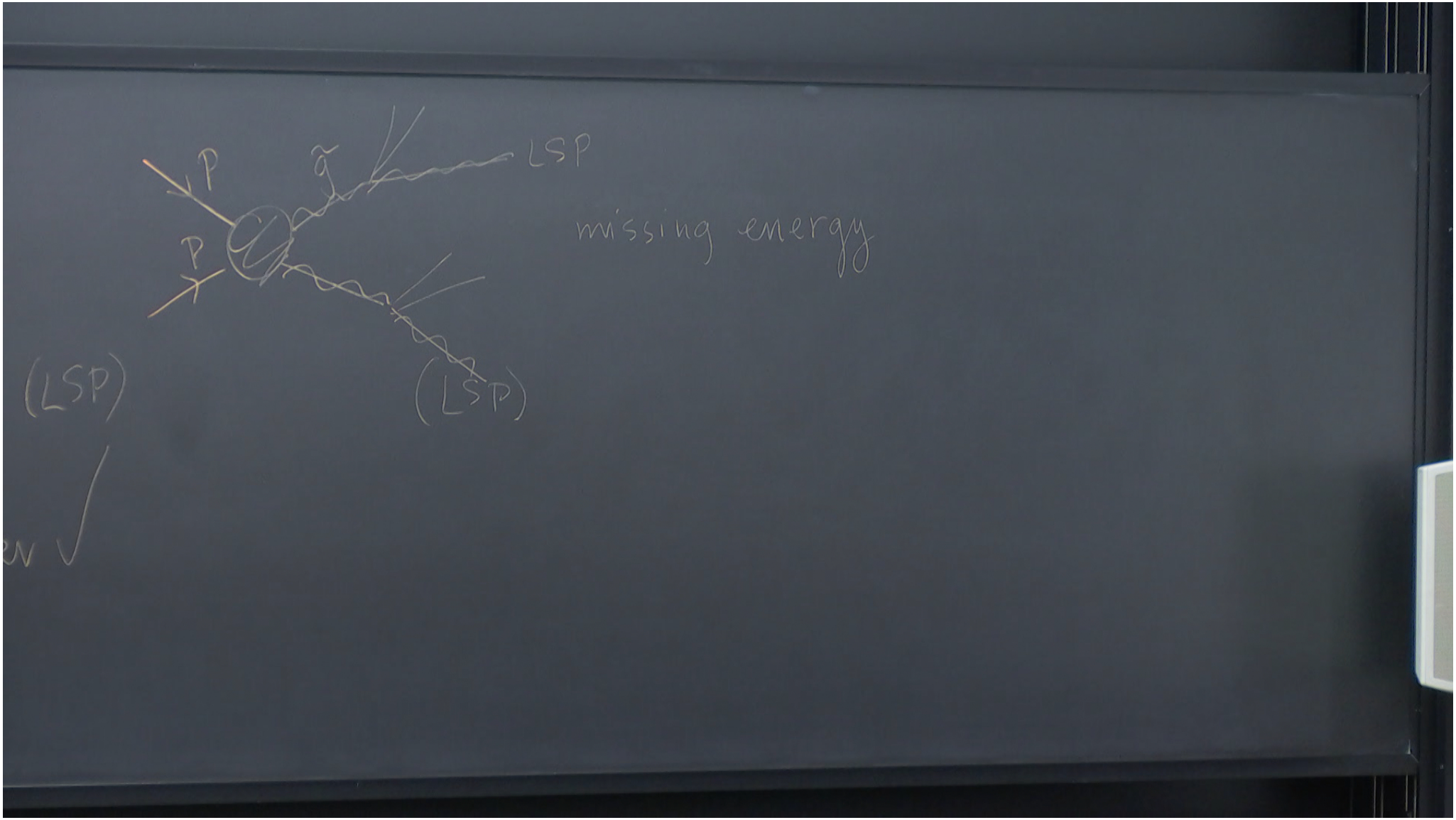
R-parity: $(-1)^{3(B-L)+2s}$

SM particles: $+1$

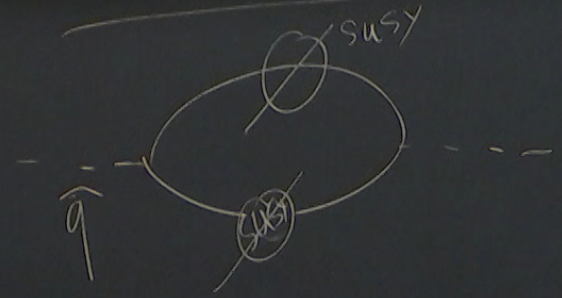
sparticles: -1



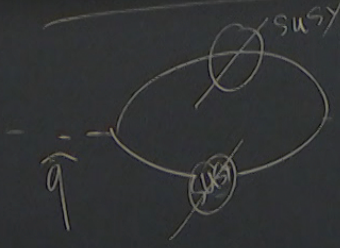
Lightest SUSY particle is stable: WIMP Dark Matter ✓


P
P
$\tilde{q}$
LSP
missing energy
(LSP)
(LSP)

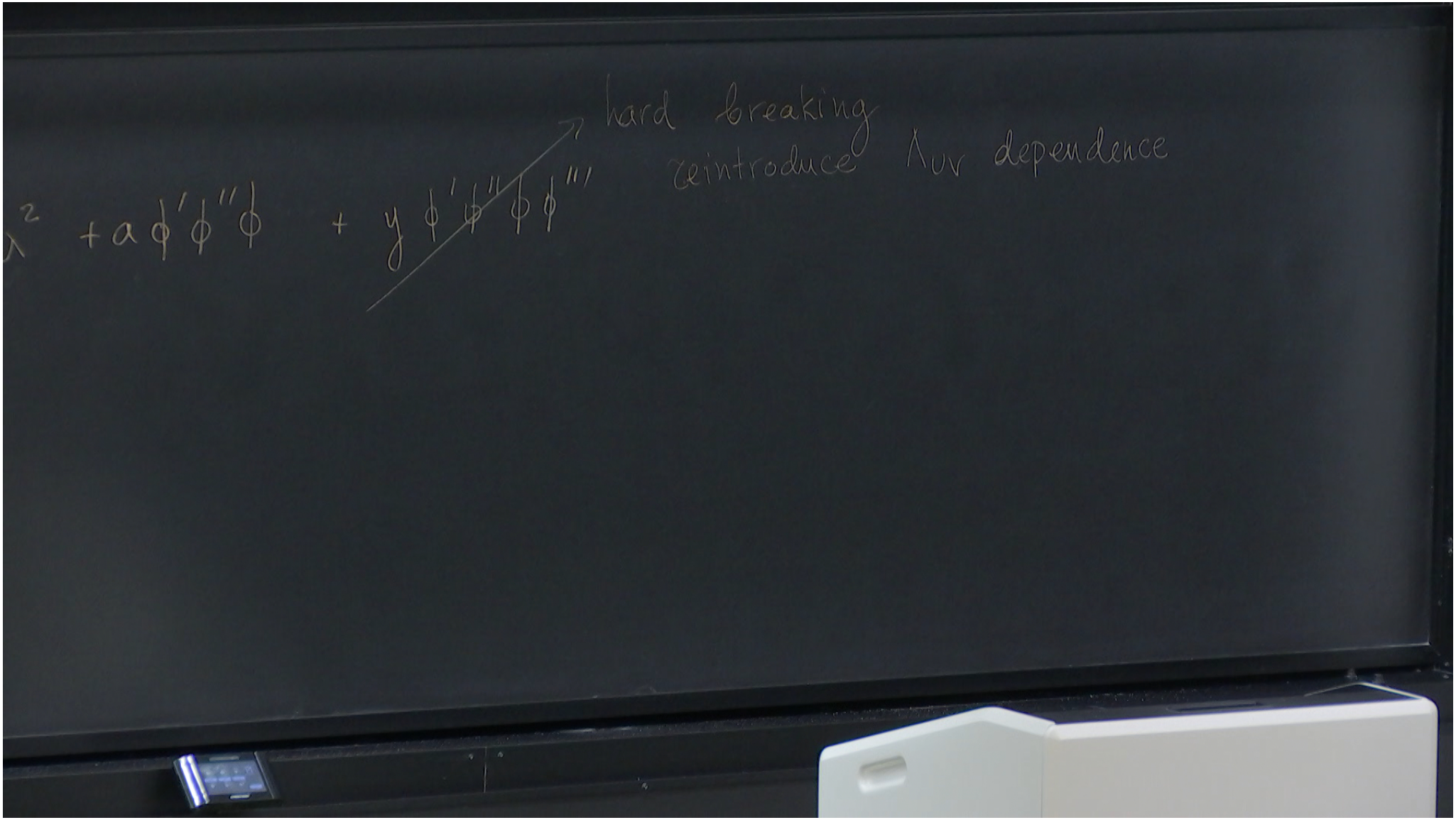
Mediated SUSY breaking



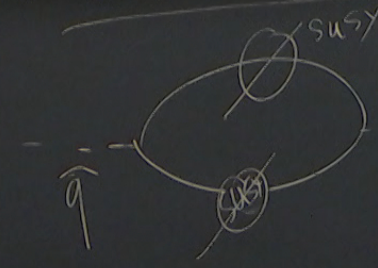
Mediated SUSY breaking



$$\mathcal{L}_{soft} = b\phi'\phi + m^2\phi^\dagger\phi + m\lambda^2 + a\phi'\phi''\phi + y\phi'\phi''\phi\phi'''$$


$\lambda^2 + a\phi'\phi''\phi + y\phi'\phi''\phi\phi'''$
hard breaking
reintroduce
Λ_{UV} dependence

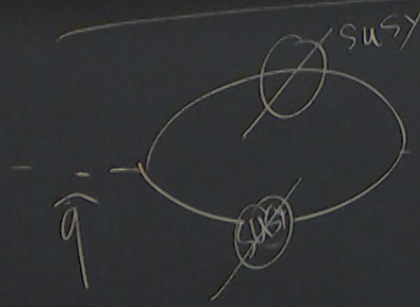
Mediated SUSY breaking



$$\mathcal{L}_{soft} = b\phi'\phi + m^2\phi^\dagger\phi + m\lambda^2 + a\phi'\phi''\phi + y\phi'$$

$$c\phi^*\phi\phi''$$

Mediated SUSY breaking



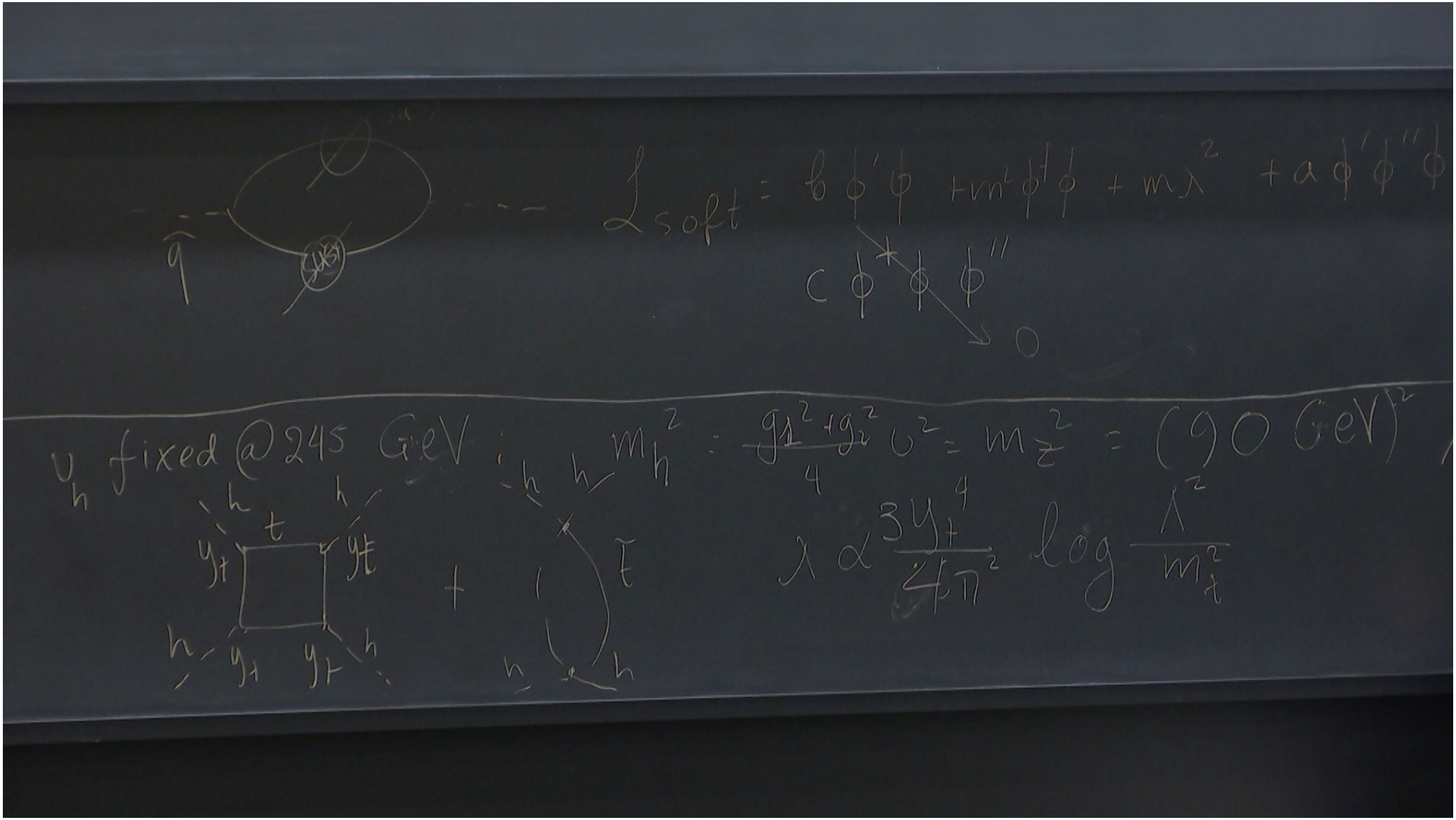
$\mathcal{L}_{soft} = b\phi'\phi + m^2\phi^\dagger\phi + m\lambda^2 + a\phi'\phi''\phi$

$c\phi^\dagger\phi\phi''$

v_h fixed @ 245 GeV: $m_h^2 = \frac{g_1^2+g_2^2}{4}v^2 = m_Z^2 = (90\ \text{GeV})^2$ X

$+ m\lambda^2 + a\phi'\phi''\phi + y\phi'\phi''\phi\phi'''$ introduced Λ_{UV} dependence

$= (90\,\text{GeV})^2$ ✗ does not agree with data

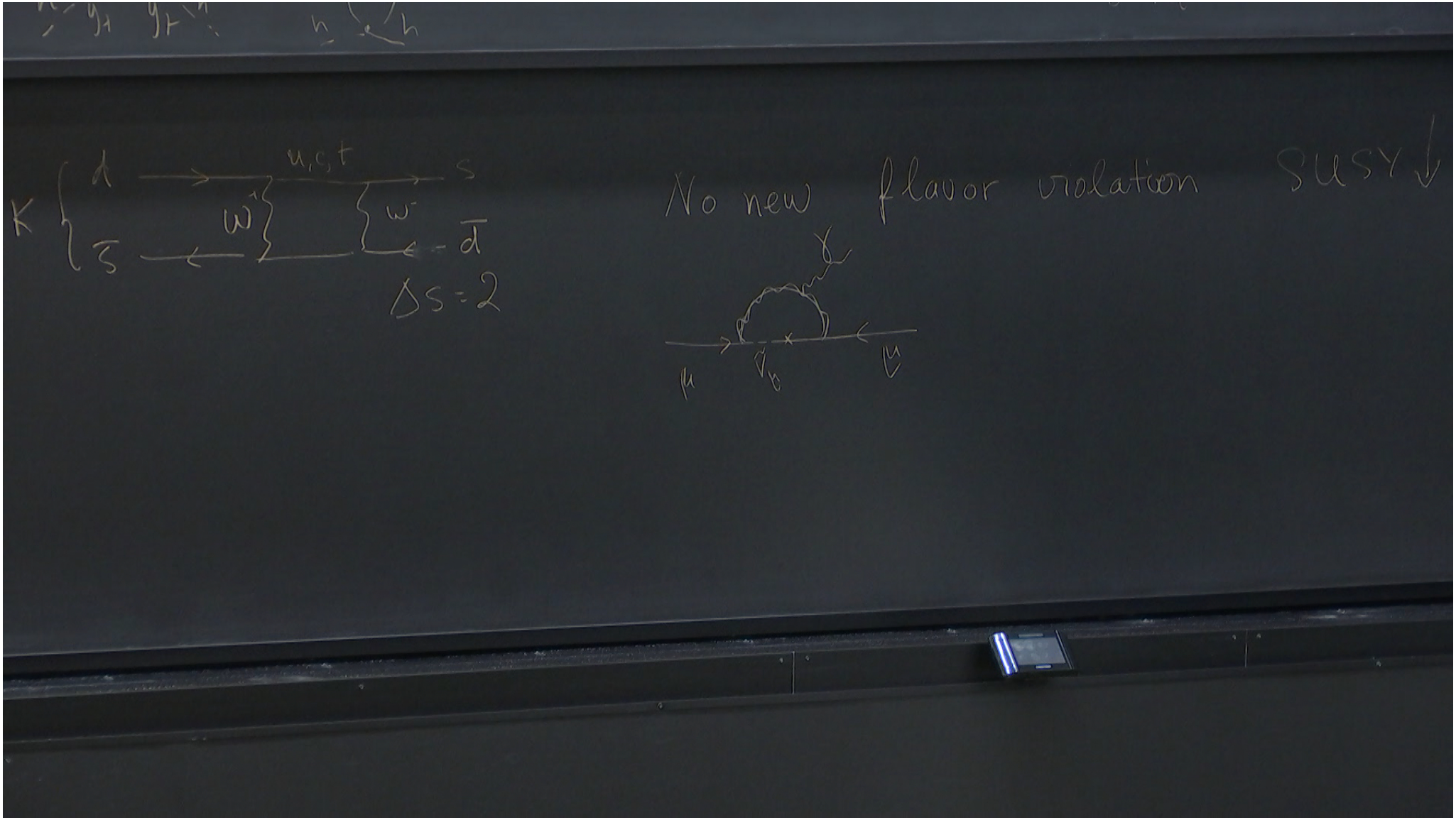

$\mathcal{L}_{soft} = b\phi'\phi + m^2\phi'\phi + m\lambda^2 + a\phi'\phi''\phi$
$c\phi^*\phi\phi''$
0
v_h fixed @ 245 GeV : $m_h^2 = \frac{g_1^2+g_2^2}{4}v^2 = m_Z^2 = (90\,\mathrm{GeV})^2$
$\lambda \propto \frac{3y_t^4}{4\pi^2}\log\frac{\Lambda^2}{m_t^2}$
h
t
y_t
$\bar{t}$

$\mathcal{L}_{soft} = b\,\phi'\phi + m^2\phi'\phi + m\lambda^2 + a\,\phi'\phi''\phi + y\,\phi'\phi''\phi\phi'''$ soft breaking reintroduce

$c\,\phi^*\phi\,\phi''$ → 0

$\frac{g_1^2+g_2^2}{4}v^2 = m_Z^2 = (90\,\mathrm{GeV})^2$ ✗ does not agree with data

$\lambda \alpha \frac{3y_t^4}{4\pi^2}\log\frac{\Lambda^2}{m_t^2}$ in SUSY $\log\frac{\tilde{m}_t^2}{m_t^2}$


K
d
s
u,c,t
W
W
$\bar{s}$
$\bar{d}$
$\Delta S = 2$
No new flavor violation SUSY
γ
μ
ν_μ
$\bar{\nu}_\mu$