Title: Particle Physics Lecture - 230306

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Collection: Particle Physics (2022/2023)

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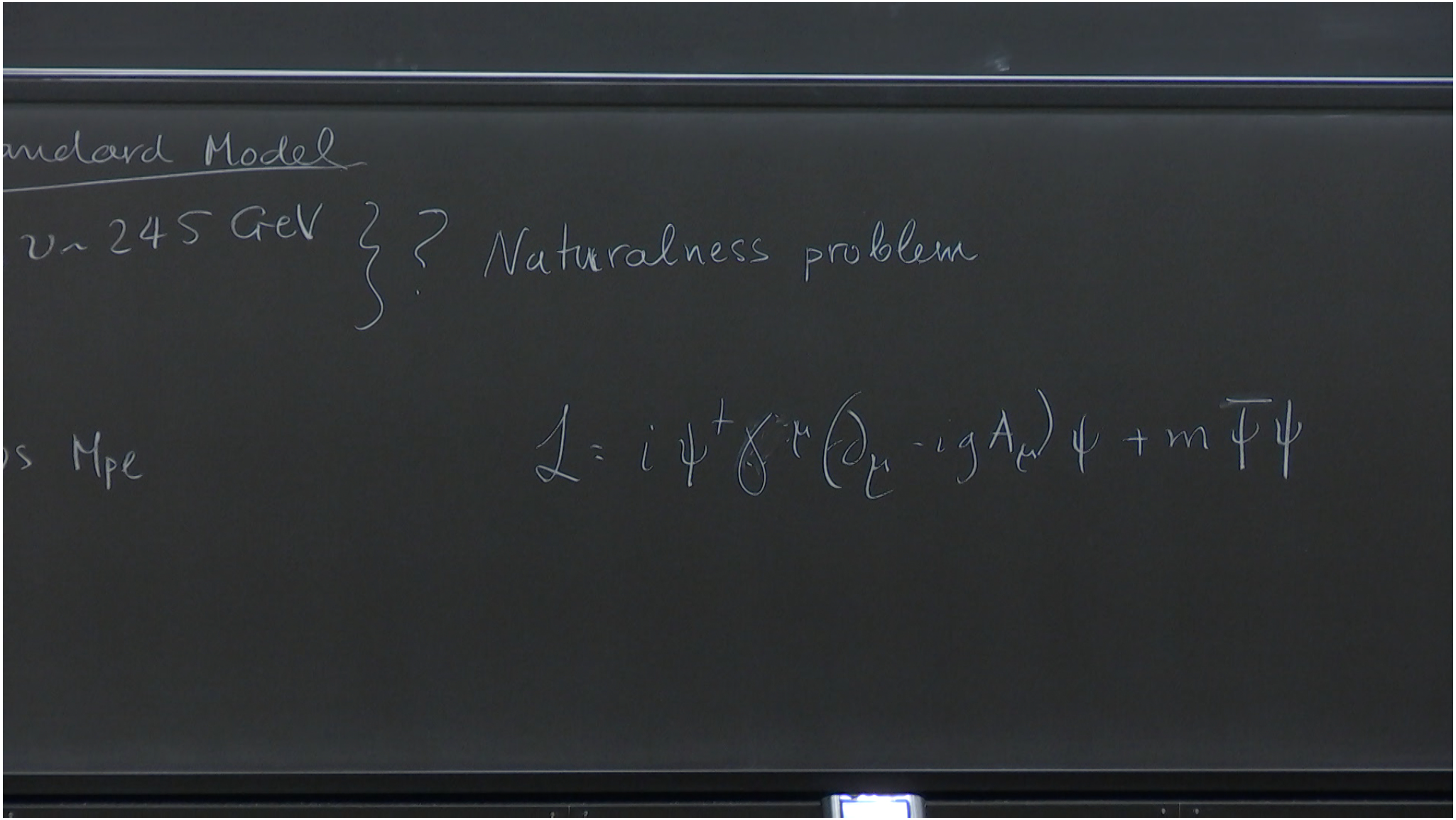
Hierarchies in the Standard Model

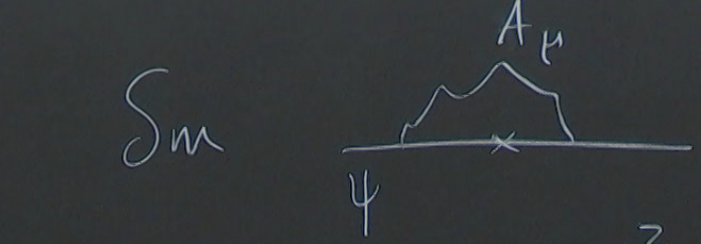
$m_h \sim 125$ GeV, $v \sim 245$ GeV

$M_{Pl} \sim 10^{19}$ GeV

$m_e \sim 0.5$ MeV vs M_{Pl}


andard Model
v ~ 245 GeV
? Naturalness problem
s Mpe
$\mathcal{L} = i\psi^\dagger \gamma^\mu (\partial_\mu - igA_\mu)\psi + m\bar{\psi}\psi$

alness problem

δm 

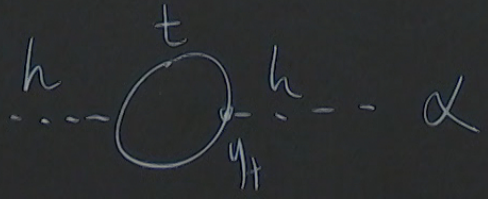
$\propto m \log \Lambda$

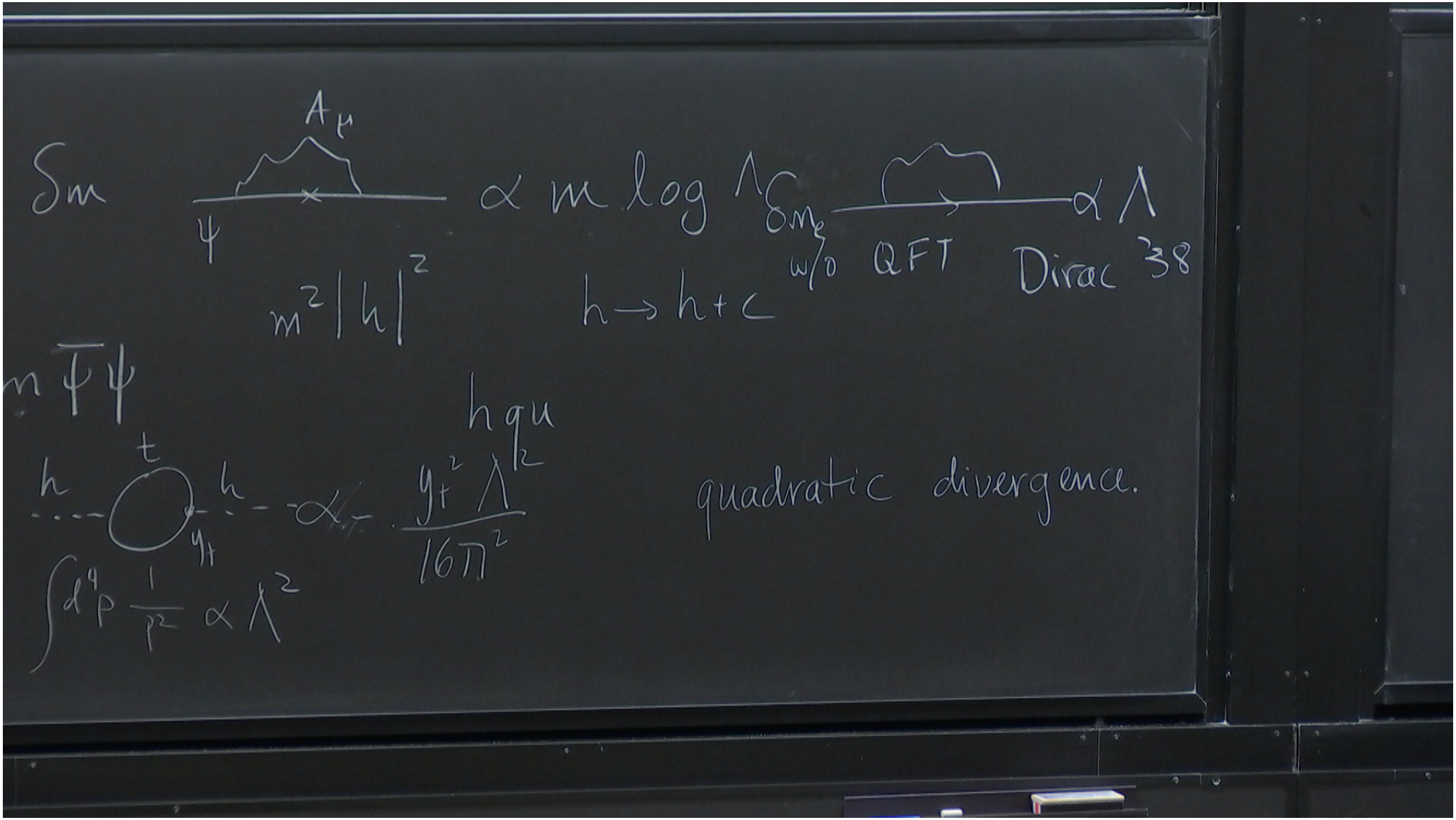
$m^2 |h|^2$ $\quad h \to h + c$

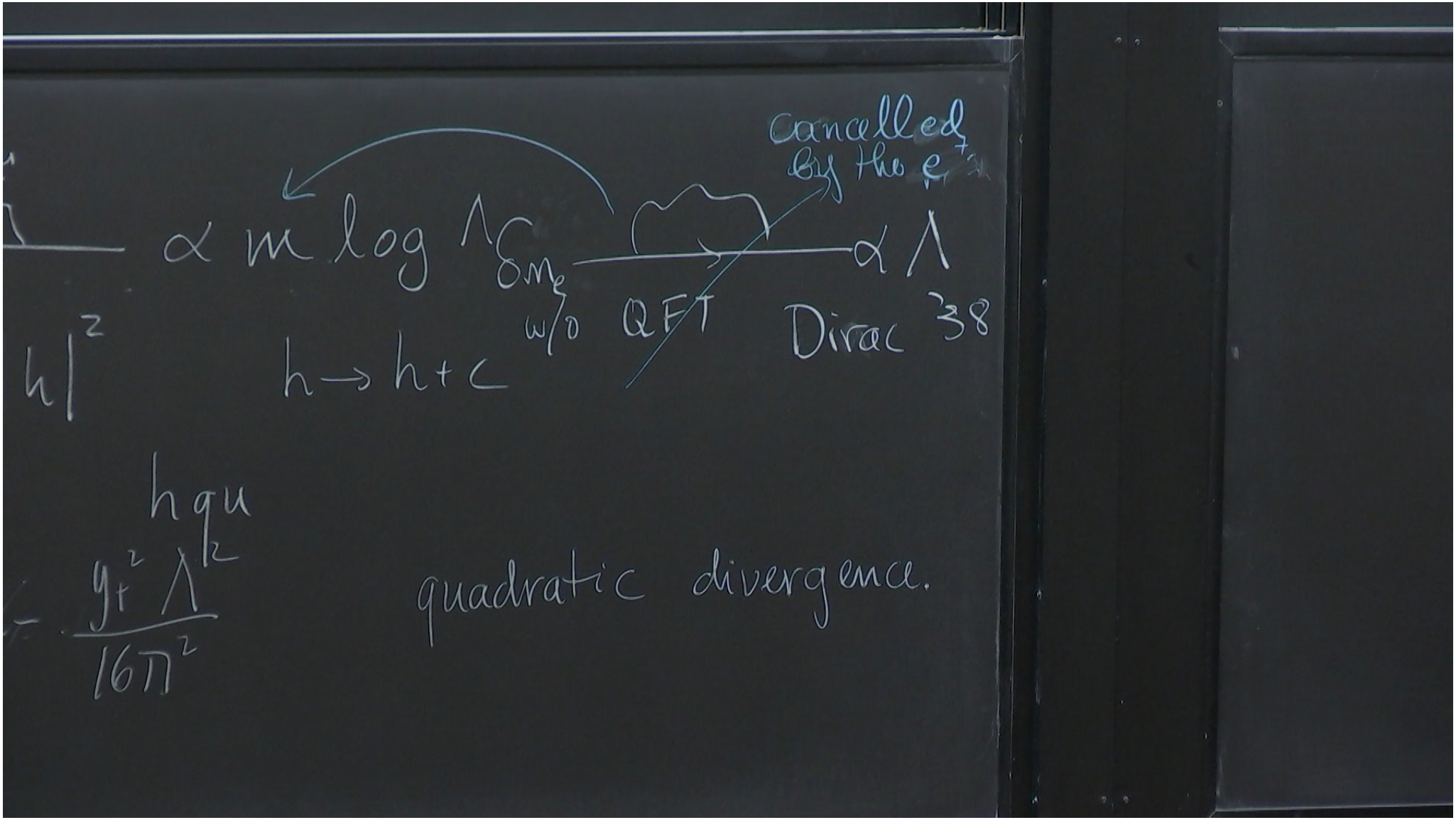
$i \psi^\dagger \gamma^\mu (\partial_\mu - i g A_\mu) \psi + m \bar{\psi} \psi$ $\quad$ hqu

$\psi \to e^{i\alpha} \psi$

$\bar{\psi} \to e^{i\alpha} \bar{\psi}$




δm
A_μ
ψ
$\alpha\, m \log \Lambda$
δm_e
$\alpha\, \Lambda$
w/o QFT
Dirac '38
$m^2 |h|^2$
$h \to h + c$
$m \bar{\psi} \psi$
h qu
h
t
h
y_t
$\alpha_{y_t} \cdot \frac{y_t^2 \Lambda^2}{16\pi^2}$
quadratic divergence.
$\int d^4p \frac{1}{p^2} \propto \Lambda^2$


cancelled by the e
$\alpha m \log \Lambda$
δm_e
$\alpha \Lambda$
w/o QFT
Dirac 38
$h|^2$
$h \to h + c$
h qu
$\frac{y_t^2 \Lambda^2}{16\pi^2}$
quadratic divergence.

Hierarchies in the Standard Model

$m_h \sim 125$ GeV, $v \sim 245$ GeV
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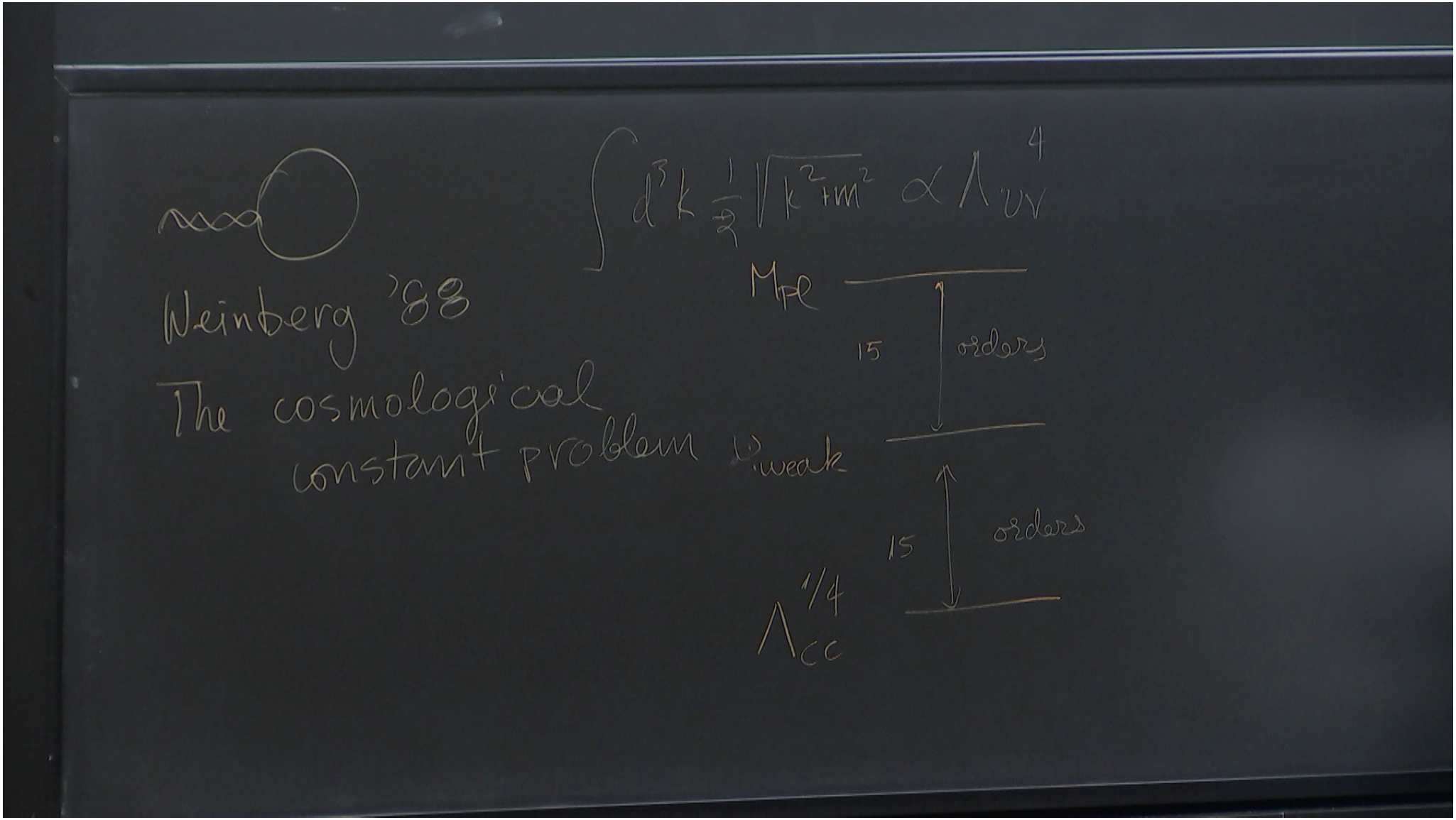
} ? Naturalness pro

$m_e \sim 0.5$ MeV vs M_{Pl}

$\Lambda \sim 10^{-122} M_{Pl}^4$

$\mathcal{L} = i\psi^\dagger \bar{\sigma}^\mu (\partial$

$\psi \rightarrow$
$\bar{\psi} \rightarrow$


$\int d^3k \frac{1}{2}\sqrt{k^2+m^2} \propto \Lambda_{UV}^4$
Weinberg '88
The cosmological constant problem
M_{Pl}
15 orders
weak
15 orders
$\Lambda_{CC}^{1/4}$

Hierarchies in the Standard Model

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} ? Naturalness prob

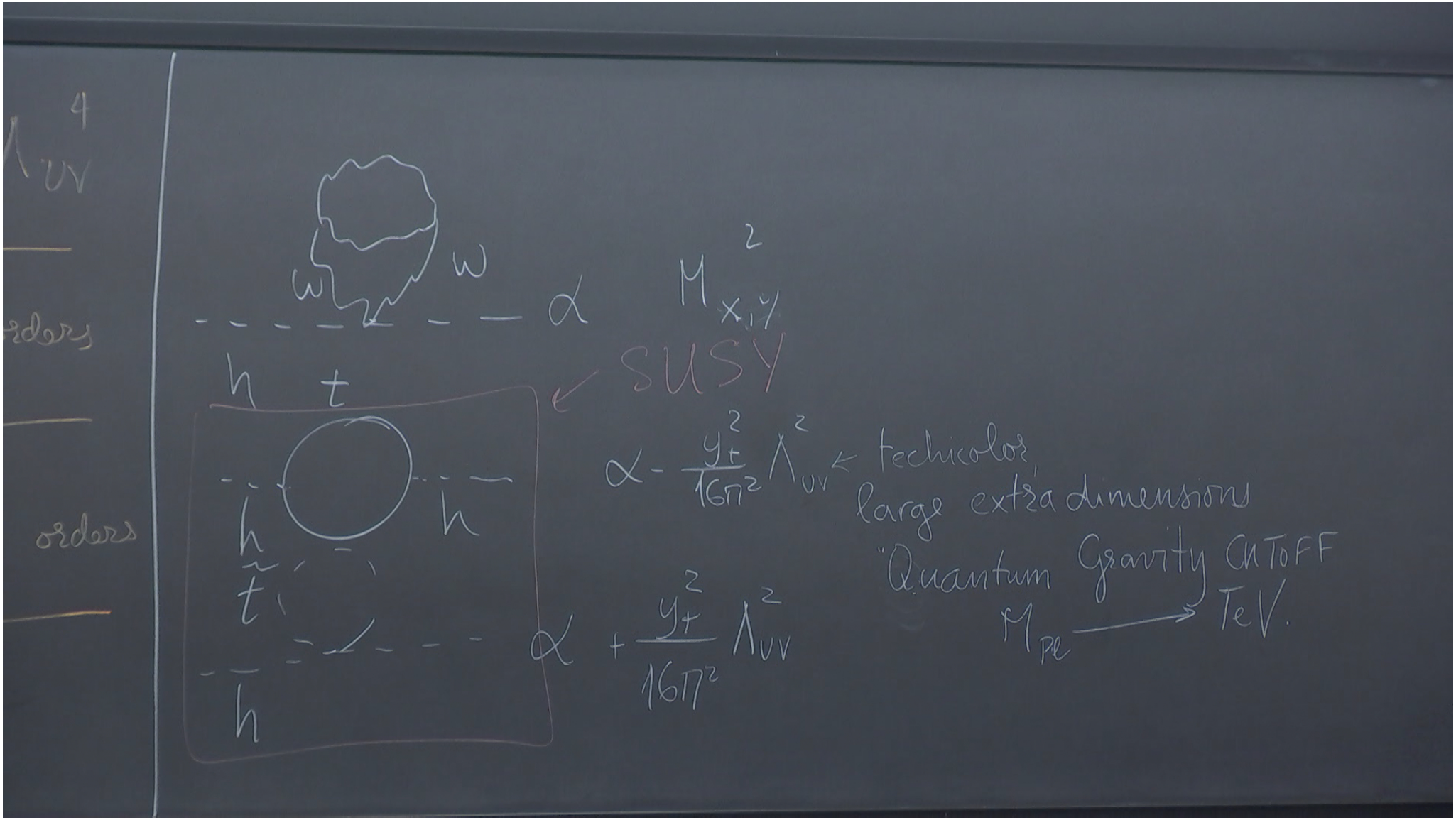
$m_e \sim 0.5$ MeV vs M_{Pl}

$\mathcal{L} = i \psi^\dagger \bar{\sigma}^\mu (\partial_\mu$

$\Lambda \sim 10^{-122} M_{Pl}^4$

$\psi \rightarrow$
$\bar{\psi} \rightarrow$

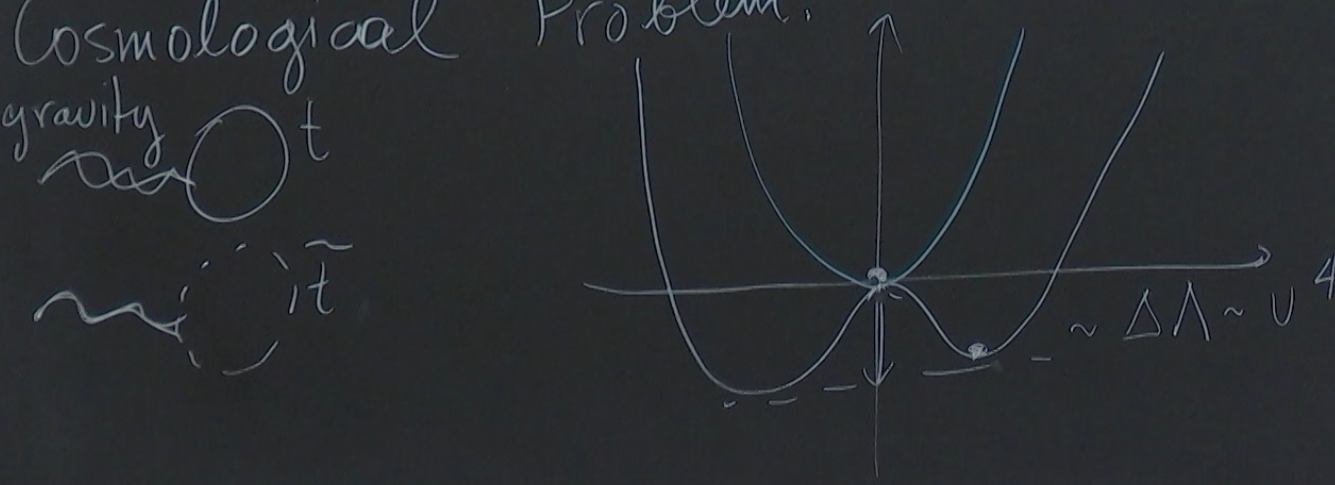
$\rightarrow \theta_{QCD} \frac{g_3^2}{32\pi^2} G^a_{\mu\nu} G_{\alpha\rho\sigma} \varepsilon^{\mu\nu\rho\sigma}$ ← θ-term → EDM neutron
$\theta_{QCD} < 10^{-10}$


W
W
α $M^2_{x,y}$
SUSY
h t
h
h
t
h
$\alpha - \frac{y_t^2}{16\pi^2}\Lambda^2_{UV}$ ← technicolor, large extra dimensions
"Quantum Gravity CUTOFF
M_{Pl} → TeV.
$\alpha + \frac{y_t^2}{16\pi^2}\Lambda^2_{UV}$

$$\delta m_h^2 \sim -\frac{y_t^2}{16\pi^2}\Lambda_{UV}^2 + \frac{y_t^2}{16\pi^2}\Lambda_{UV}^2 + \left(m_{\tilde{t}}^2 - m_t^2\right)\frac{y_t^2}{16\pi^2}$$

Need to add $\tilde{t}$ @ TeV

Cosmological Problem:



$m_{\tilde{t}}^2 - m_t^2) \frac{y_t^2}{16\pi^2}$

$\Delta\Lambda \sim v^4$

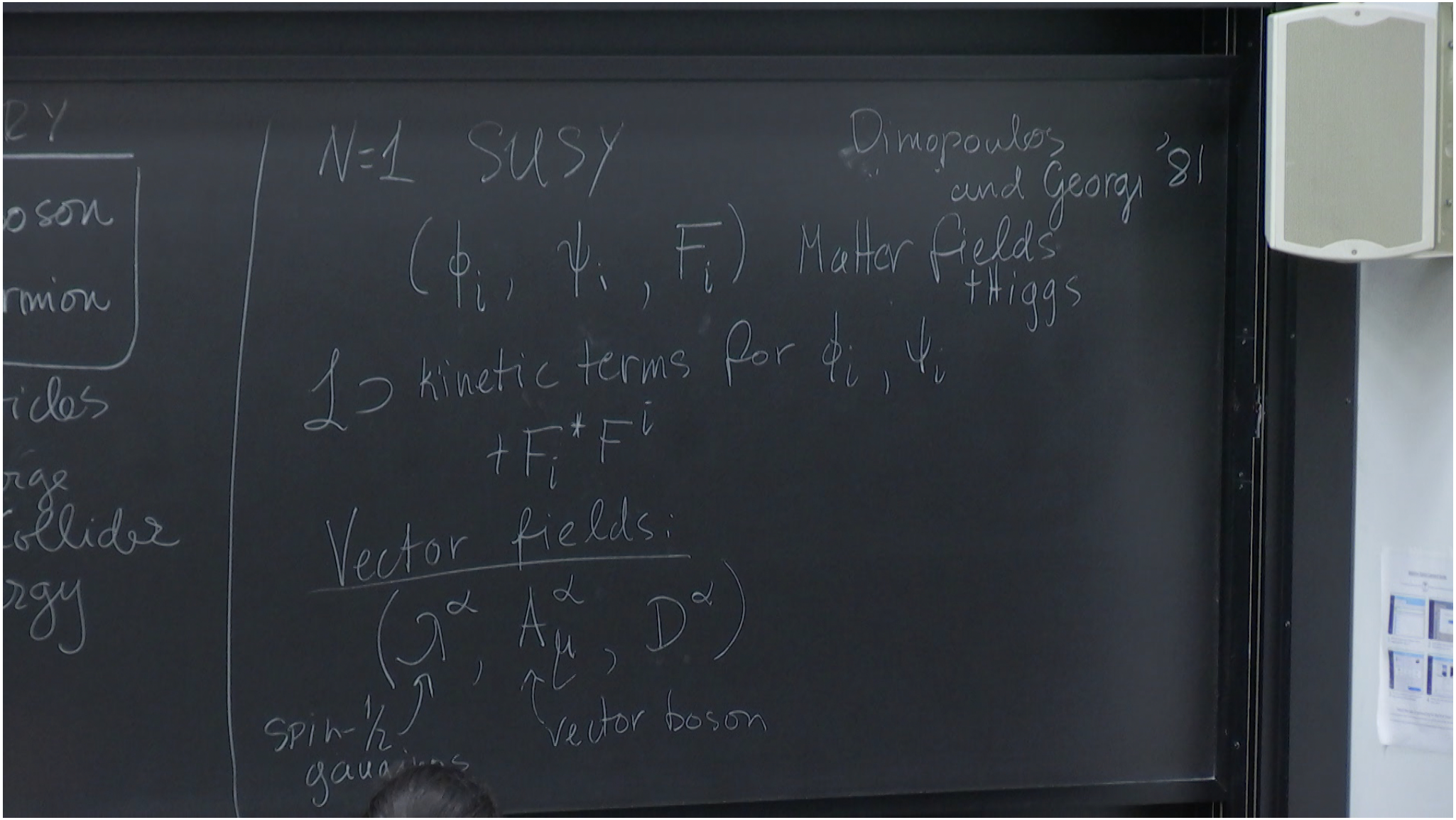
SUPERSYMMETRY

SM fermion → boson

SM boson → fermion

Add SUSY particles

@ TeV ← Large Hadron Collider Energy


N=1 SUSY
Dimopoulos and Georgi '81
(ϕ_i, ψ_i, F_i) Matter fields +Higgs
$\mathcal{L}$ ⊃ kinetic terms for ϕ_i, ψ_i
$+F_i^* F^i$
Vector fields:
$(\lambda^\alpha, A_\mu^\alpha, D^\alpha)$
spin-½ gauginos
vector boson