Title: Standard Model sources of CP violation and EDMs

Speakers: Maxim Pospelov

Series: Particle Physics

Date: April 05, 2022 - 1:00 PM

URL: https://pirsa.org/22040105

Abstract: I review the main mechanisms that convert fundamental CP-violating parameters (theta_QCD and Kobayashi-Maskawa phase) to the observable electric dipole moments (EDMs). Given recent progress, the EDMs connected to electron spin (paramagnetic EDMs) are calculated. The limit on QCD theta angle is 3 * 10^(-8) and somewhat subdominant to neutron EDM, but can be improved. The Kobayashi-Maskawa phase contributes to paramagnetic EDMs at the level of 10^{-35} e cm in units of equivalent electron EDM, which is much larger than what was previously expected.

Zoom Link: https://pitp.zoom.us/j/96502704646?pwd=ZThQWGU2dEZPWjdPQnp2ZEpPVXRIdz09

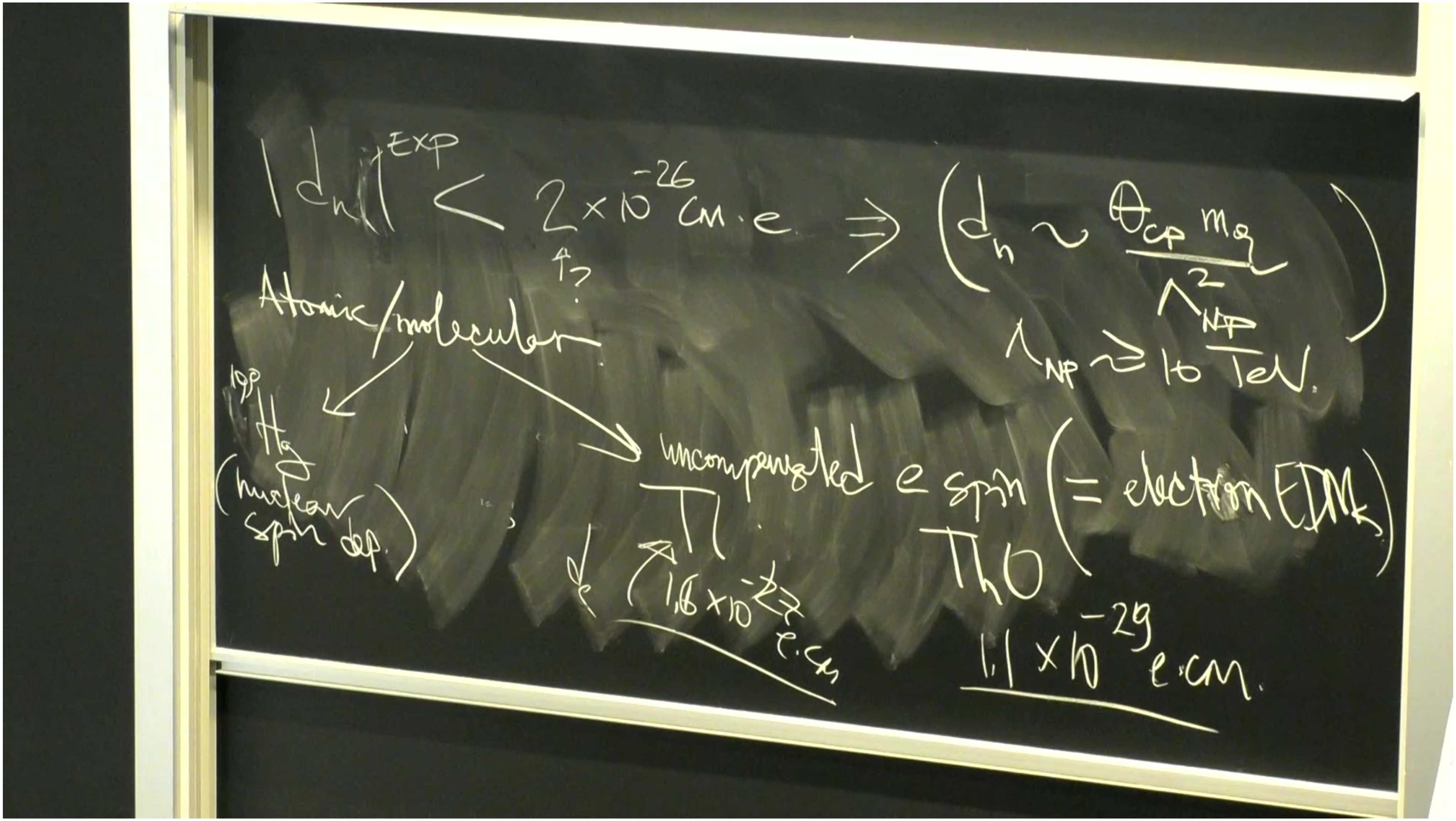
SM predictions for „paramagnetic" EDMs

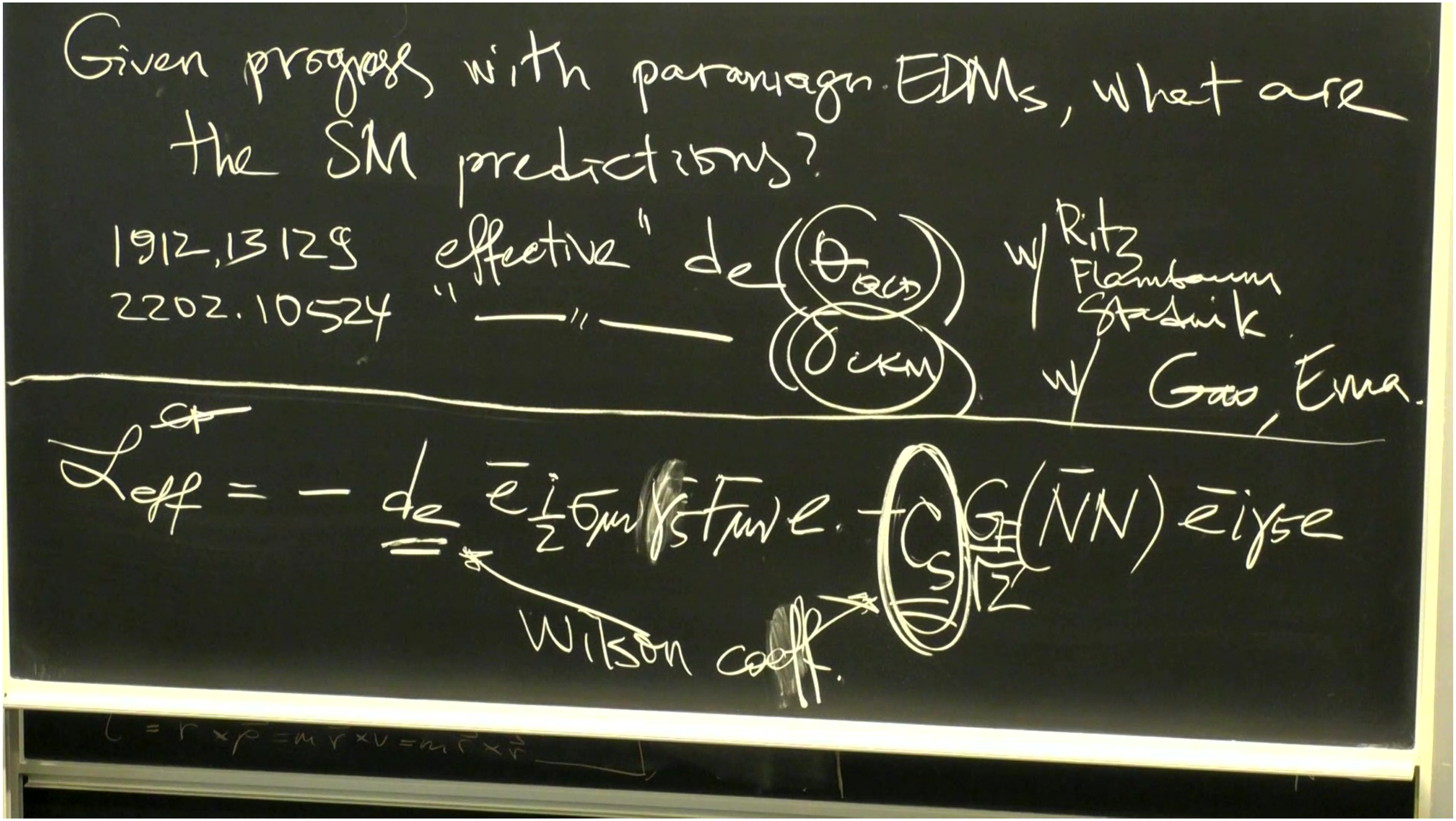
① θ_{QCD} (not seen)

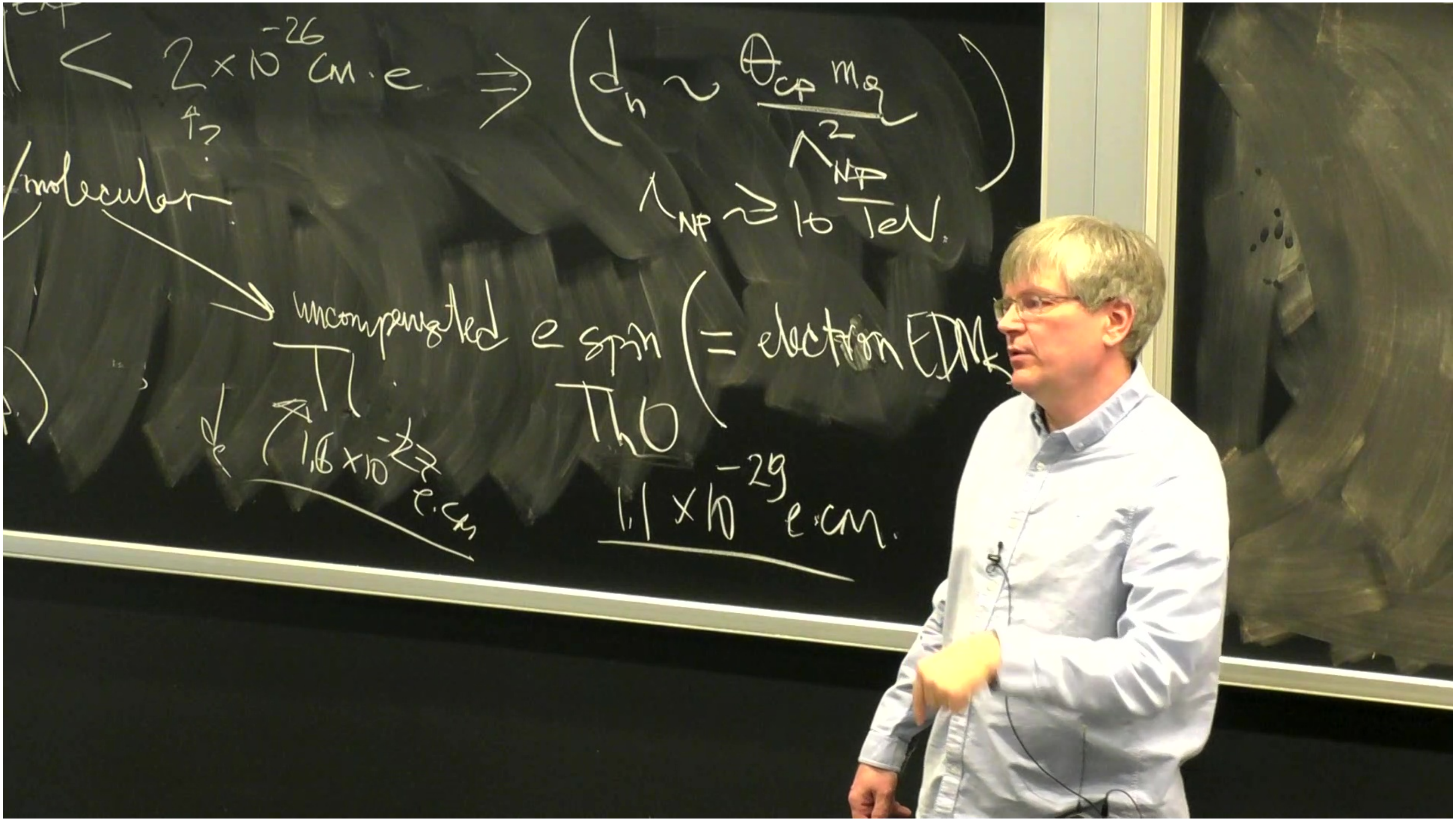
② δ_{CKM} (measured in (K), B, D).

EDMs.

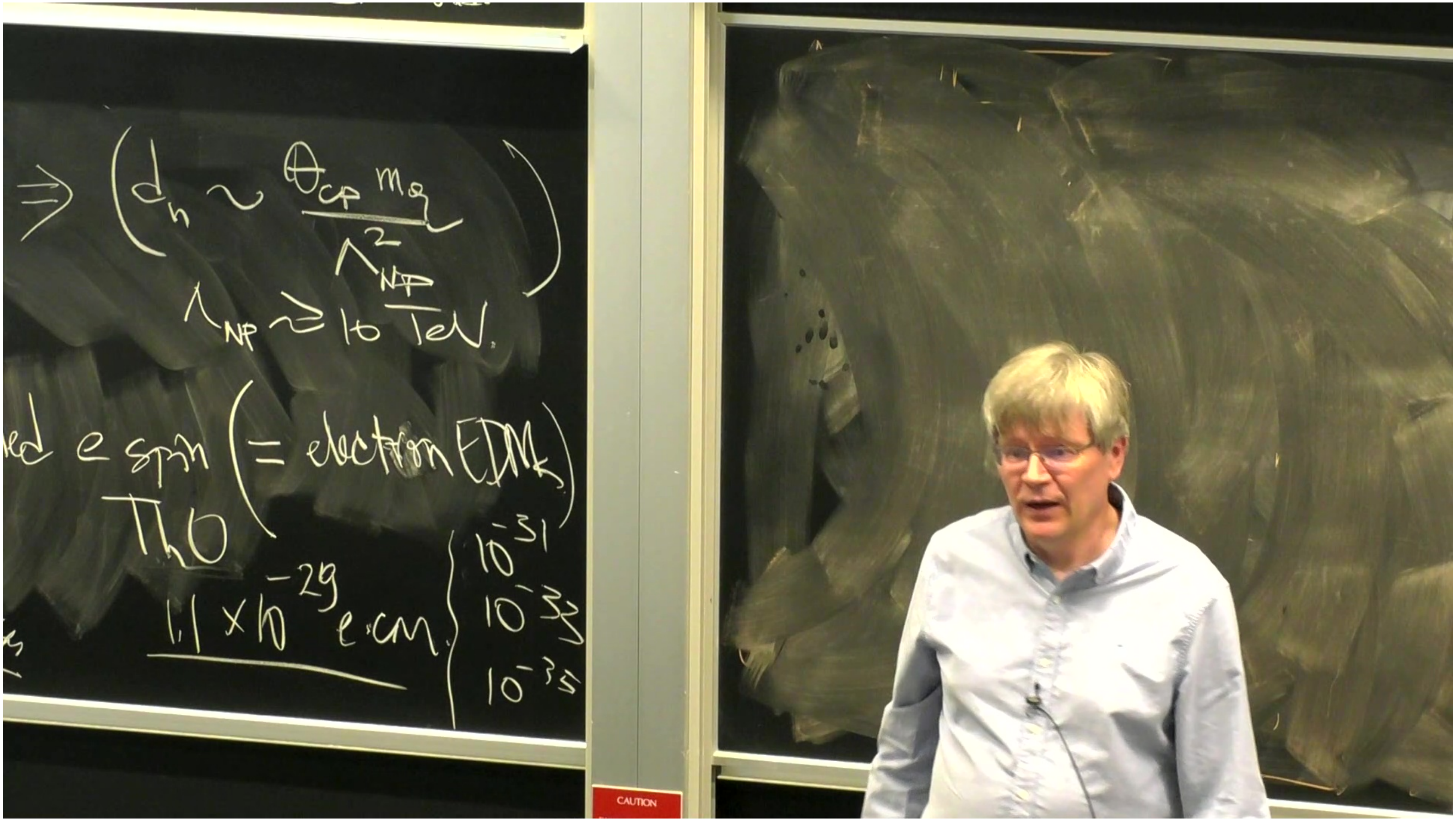
$$H_{eff} = -\mu(\vec{B}\cdot\vec{S}) - d(\vec{E}\cdot\vec{S})$$

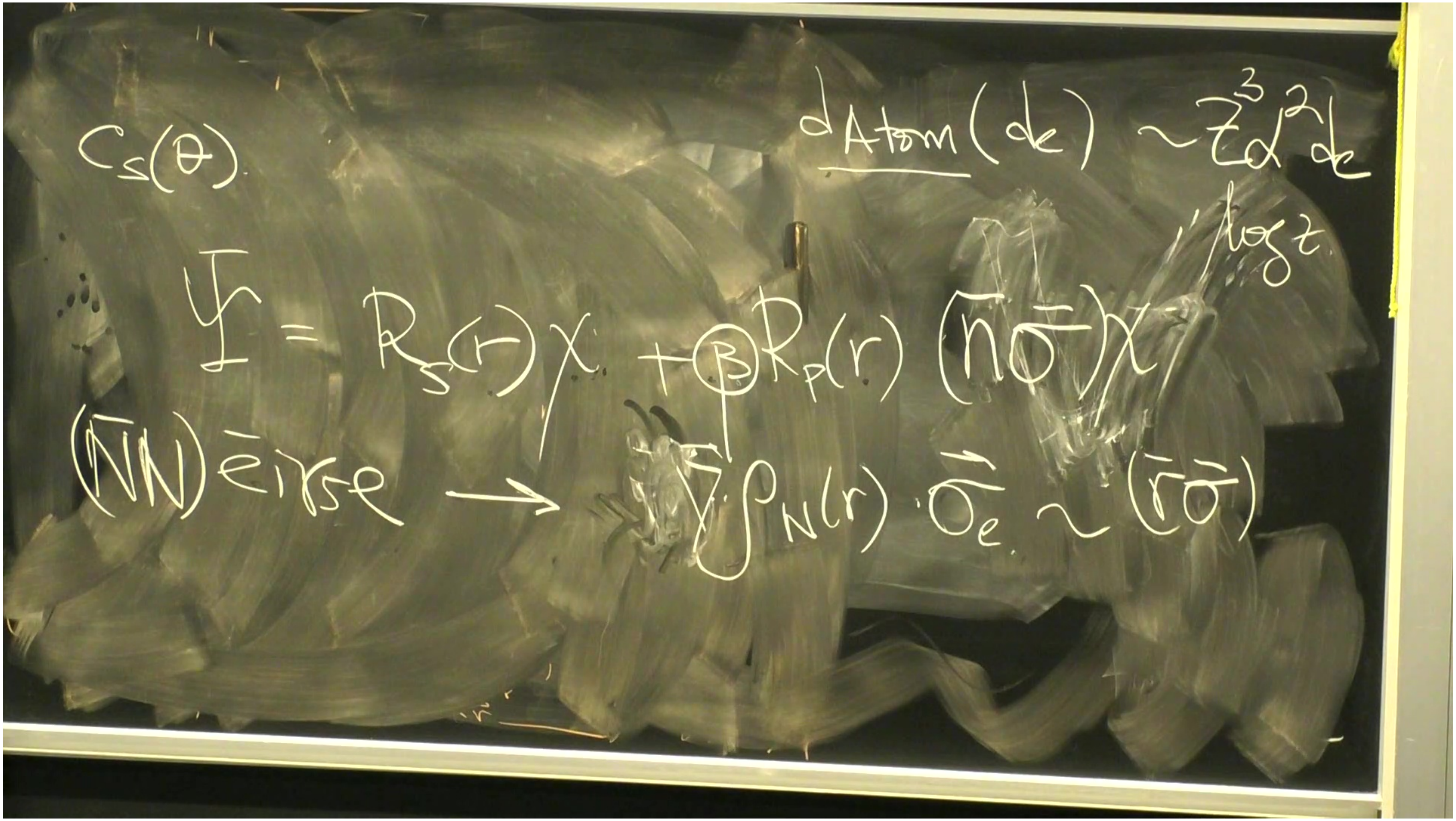

|d_n|^EXP < 2×10^-26 cm·e ⇒ (d_n ~ θ_CP m_q / Λ_NP^2)
Λ_NP ≳ 10 TeV.
Atomic/molecular
199 Hg
(nuclear spin dep.)
uncompensated e spin (= electron EDMs)
Tl
d_e < 1.6×10^-27 e·cm
ThO
1.1×10^-29 e·cm.

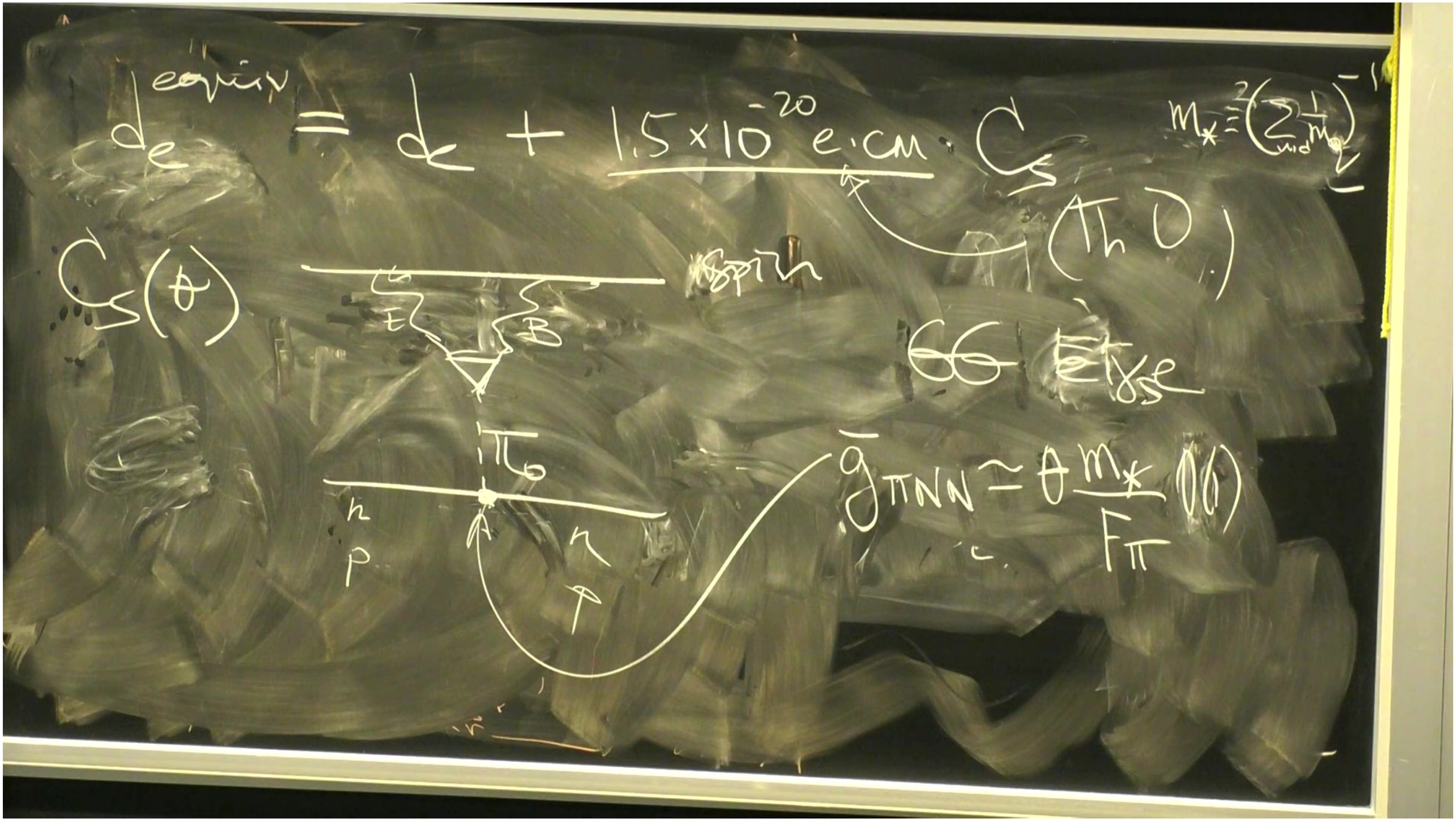

Given progress with paramagn. EDMs, what are the SM predictions?
1912.13129 "effective" de (θQCD) w/ Ritz, Flambaum, Stadnik
2202.10524 " — " — (δCKM) w/ Gao, Ema.
Leff = − de ē i/2 σμν γ5 Fμν e + CS GF/√2 (N̄N) ē iγ5 e
Wilson coeff.

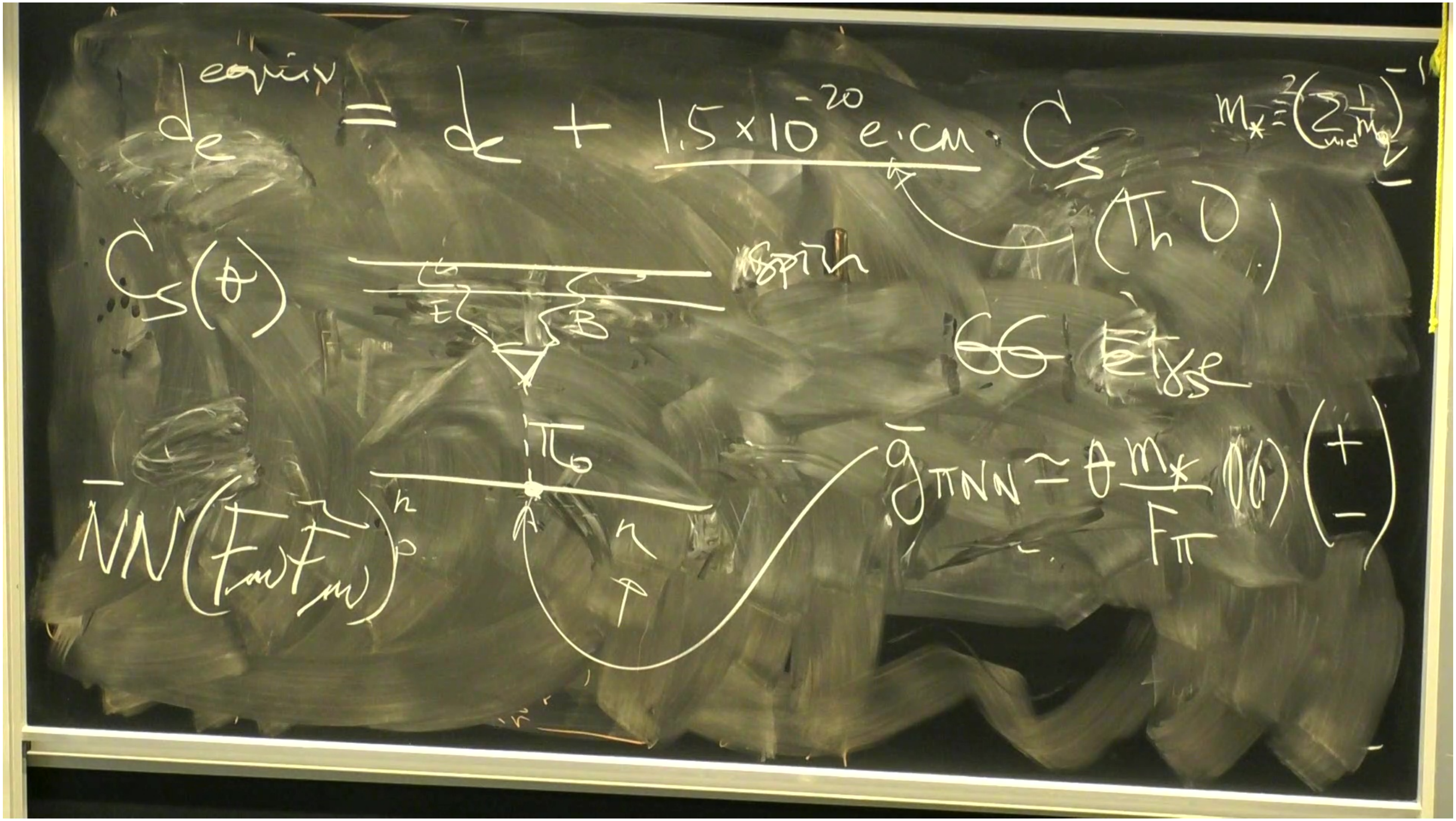


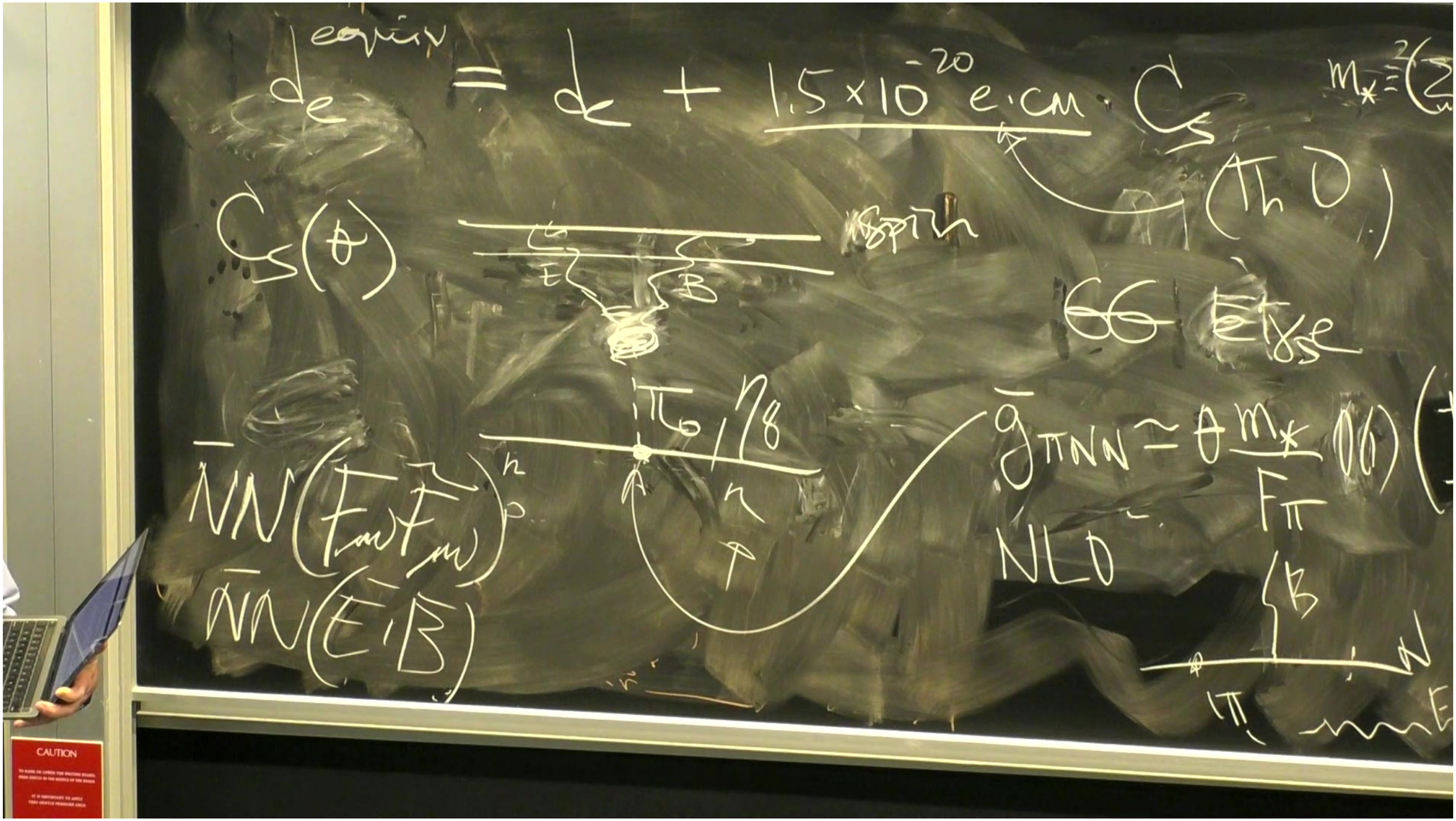
$< 2\times10^{-26}$ cm·e
$\Rightarrow \left(d_n \sim \frac{\theta_{CP}\, m_q}{\Lambda_{NP}^2}\right)$
$\Lambda_{NP} \gtrsim 10$ TeV.
molecular
uncompensated e spin (= electron EDM)
Tl
ThO
1.6×10^{-27} e·cm
1.1×10^{-29} e·cm.

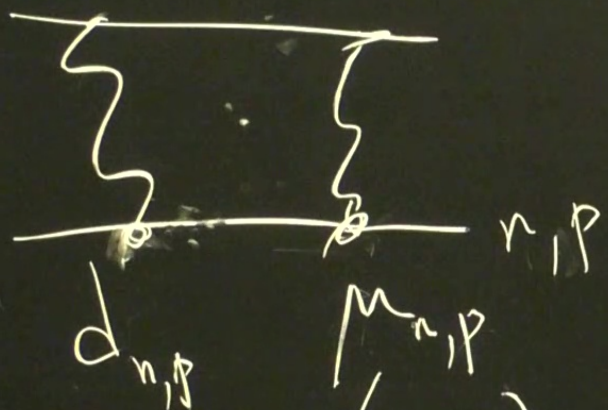

⇒ (d_n ~ θ_CP m_q / Λ²_NP)
Λ_NP ≳ 10 TeV.
e spin (= electron EDM)
ThO
1.1 × 10⁻²⁹ e·cm
10⁻³¹
10⁻³³
10⁻³⁵
CAUTION


$C_s(\theta)$
$d_{Atom}(d_e) \sim Z^3 \alpha^2 d_e$
$/\log Z$
$\Psi = R_s(r)\chi + \beta R_p(r)(\vec{n}\vec{\sigma})\chi$
$(\bar{N}N)\bar{e}i\gamma_5 e \rightarrow \vec{\nabla}\rho_N(r)\cdot\vec{\sigma}_e \sim (\vec{r}\vec{\sigma})$


d_e^equiv = d_e + 1.5×10^-20 e·cm · C_S
m_* = (Σ_{u,d} 1/m_q)^-1
(ThO)
C_S(θ)
spin
E
B
GG̃
Ēiγ5e
π_0
n
p
n
p
ḡ_πNN ≃ θ m_*/F_π O(1)


d_e^equiv = d_e + 1.5 × 10^-20 e·cm · C_S
m_* = (Σ_{u,d} 1/m_q)^-1
(ThO)
C_S(θ)
spin
E
B
π_0
ḡ_πNN ≃ θ m_*/F_π O(1) (+ −)
N̄N (F_μν F̃_μν)
n
p


d_e^equiv = d_e + 1.5 x 10^-20 e·cm · C_S
(ThO)
C_S(θ)
spin
GG̃
ē iγ5 e
ḡ_πNN ≃ θ m_* / F_π O(1)
NLO
N̄N(F_μν F̃_μν)
N̄N(E·B)
CAUTION

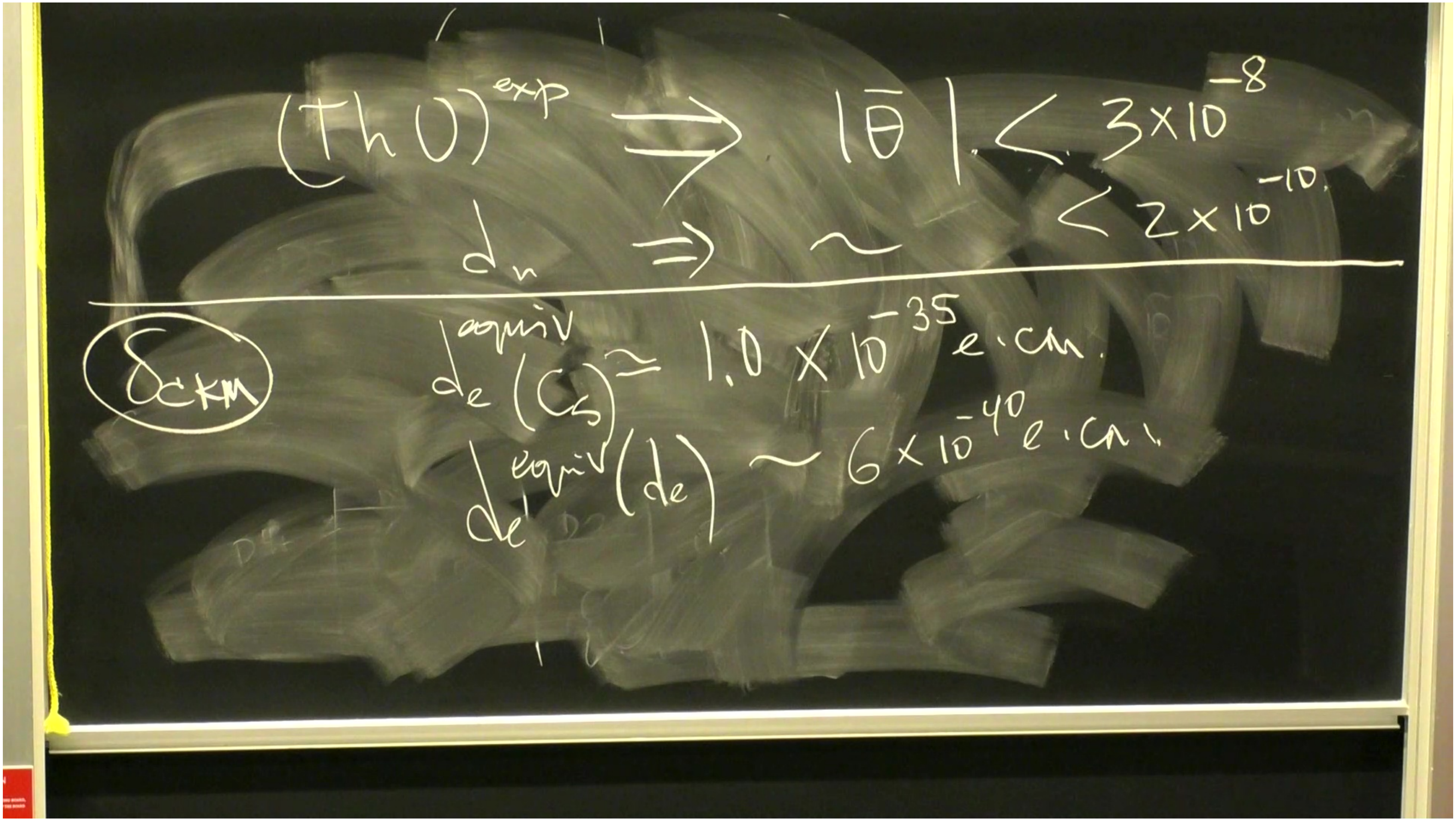


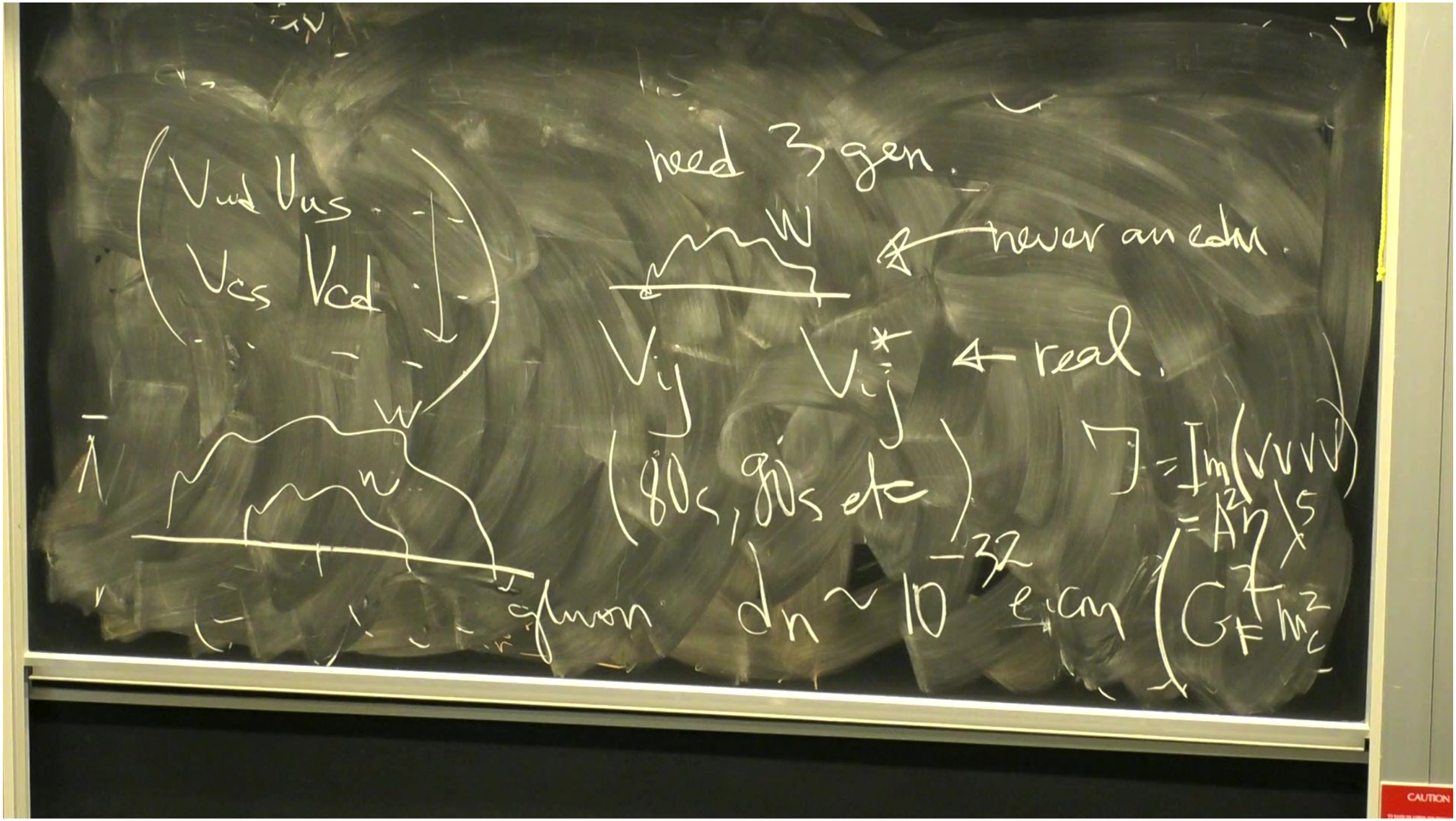
$$\frac{G_F}{\sqrt{2}} C_S = \frac{3\alpha}{2\pi} \log \frac{\Lambda_{W}}{m_e} \times$$

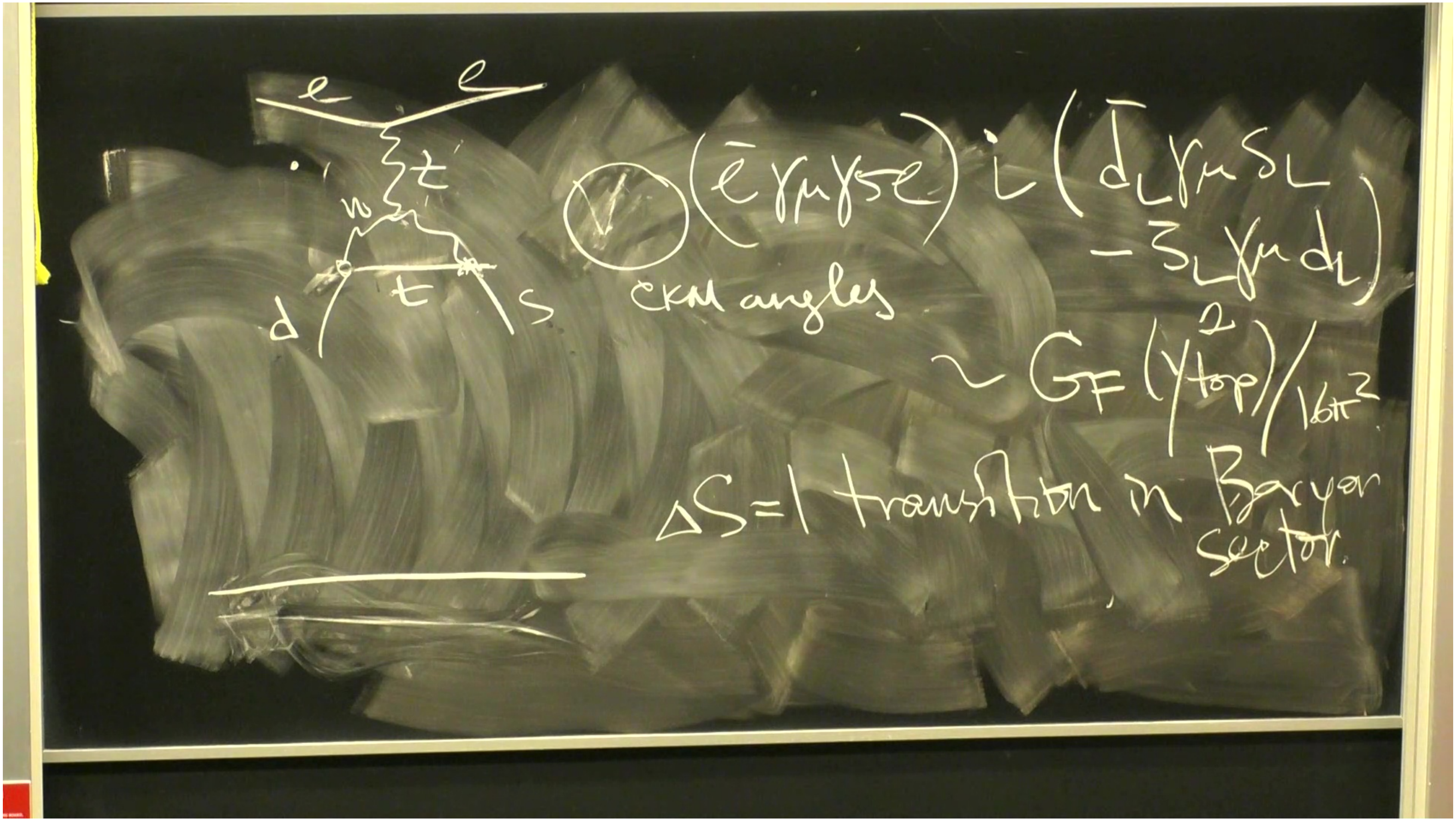
(hadr.)

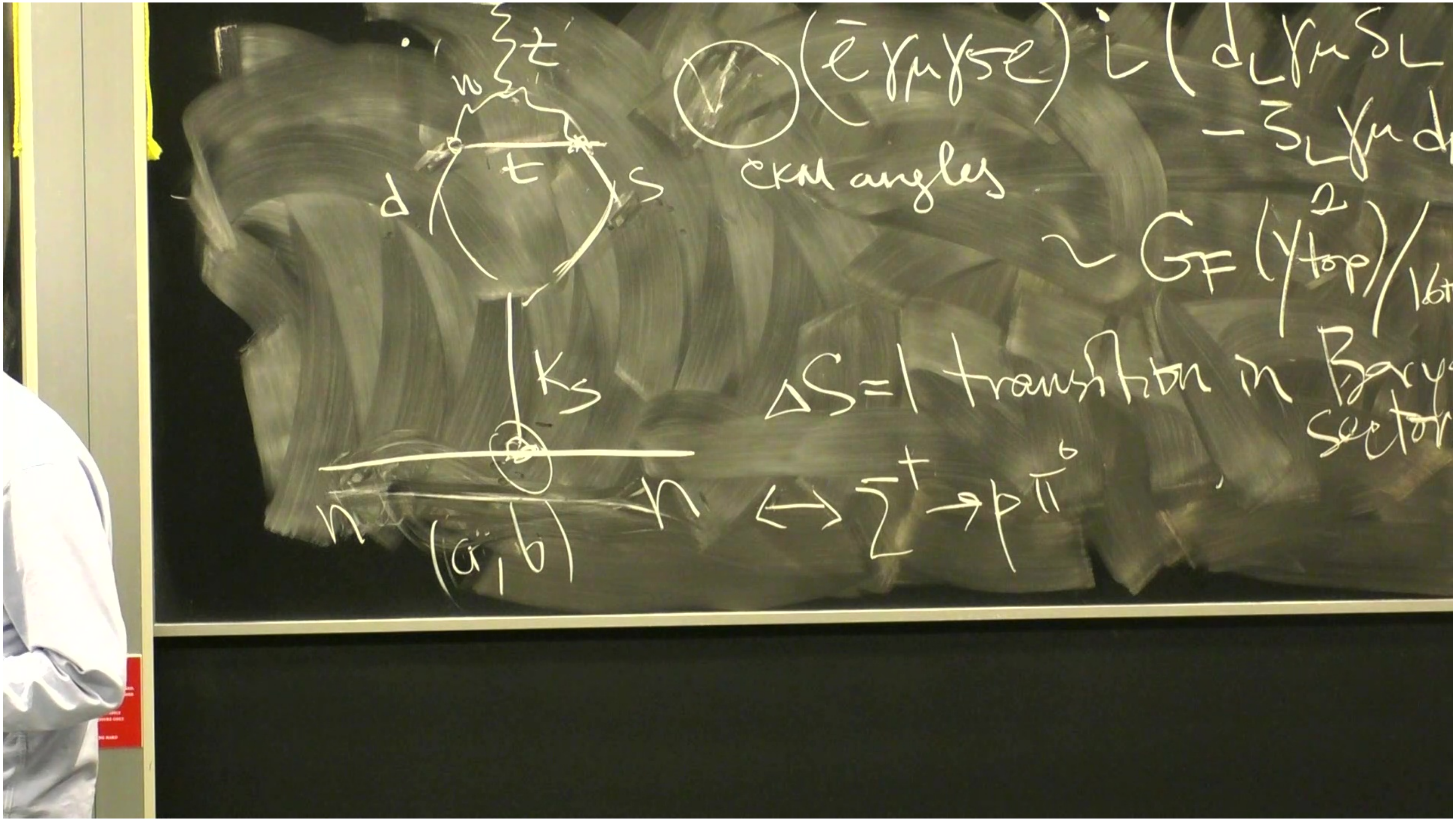
$$\times \left(\frac{\bar{g}_{\pi NN}(\theta)}{F_\pi m_\pi^2} \right)$$

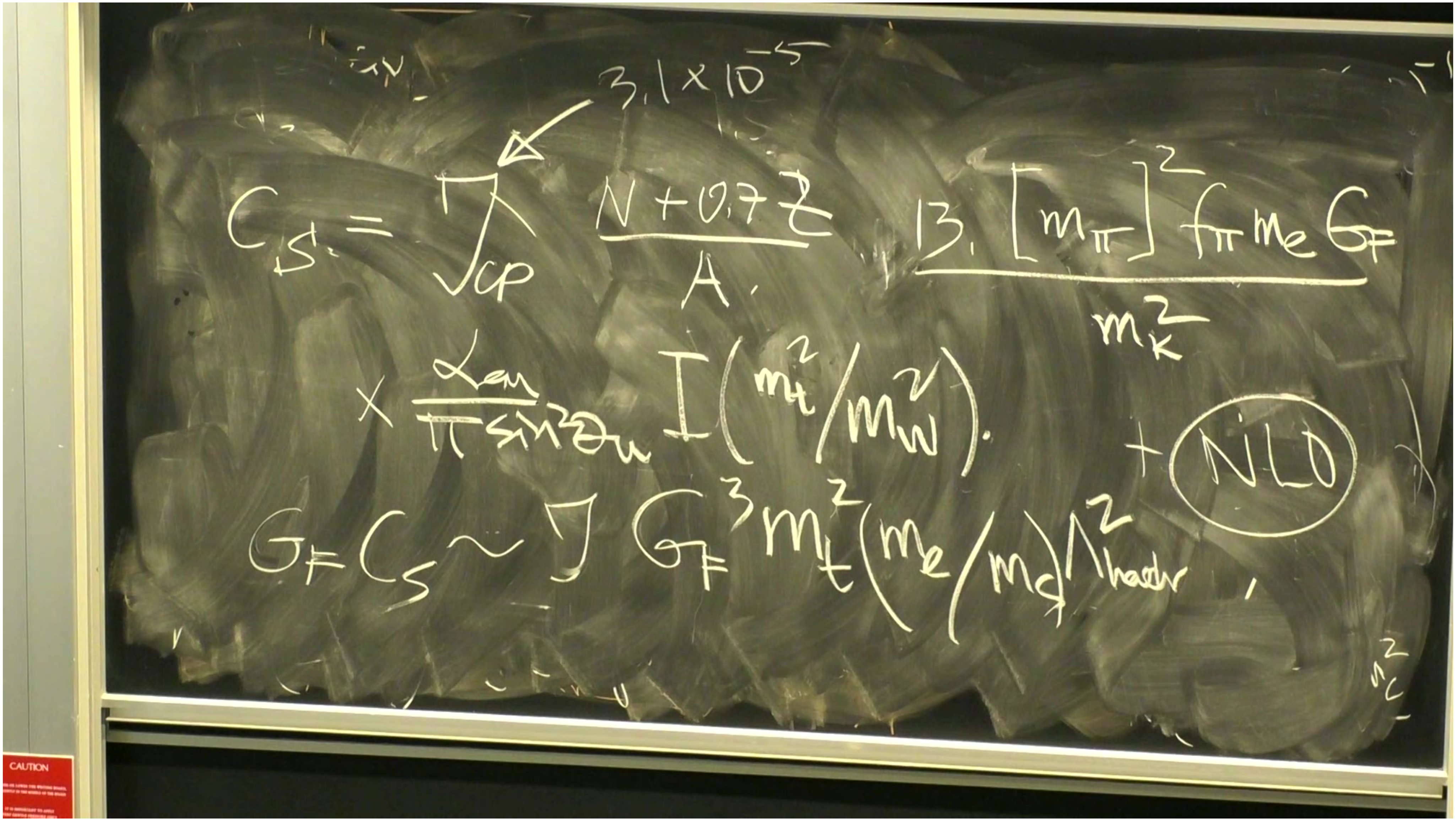
$$C_S \simeq \left((0.1)_{LO} + (1.0)_{NLO} + (1.7)_{(\mu d)} \right) 10^{-2} \bar{\theta} \simeq 0.03 \bar{\theta}$$


$(\mathrm{ThO})^{exp} \Rightarrow |\bar{\theta}| < 3\times 10^{-8}$
$< 2\times 10^{-10}$
$d_n \Rightarrow \sim$
δ_{CKM}
$d_e^{equiv}(Cs) \simeq 1.0 \times 10^{-35}\, e\cdot cm$
$d_e^{equiv}(d_e) \sim 6\times 10^{-40}\, e\cdot cm$


need 3 gen.
never an edm.
real.
(80s, 90s etc)
= Im(VVVV)
gluon


e e
t
t
d s
V
$(\bar{e}\gamma_\mu\gamma_5 e)\, i(\bar{d}_L\gamma^\mu s_L - \bar{s}_L\gamma^\mu d_L)$
CKM angles
$\sim G_F (y_{top}^2)/16\pi^2$
ΔS=1 transition in Baryon sector.


CKM angles
ΔS=1 transition in Baryon sector


3.1 × 10^-5
C_S = J_CP (N + 0.7 Z)/A · 13 [m_π]^2 f_π m_e G_F / m_K^2
× α_em/(π sin^2 θ_W) I(m_t^2/m_W^2) + NLO
G_F C_S ~ J G_F^3 m_t^2 (m_e/m_d) Λ_hadr^2