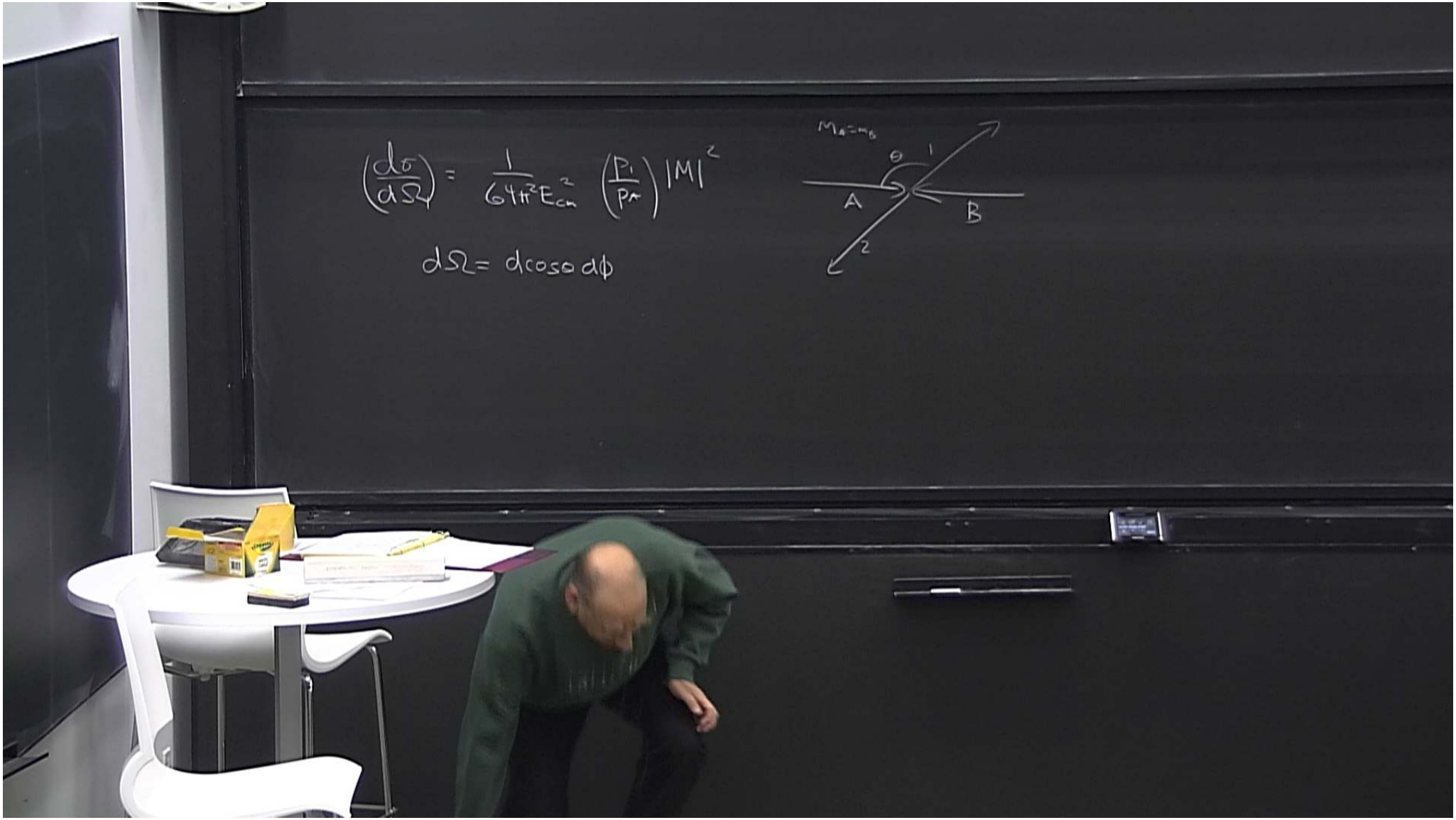
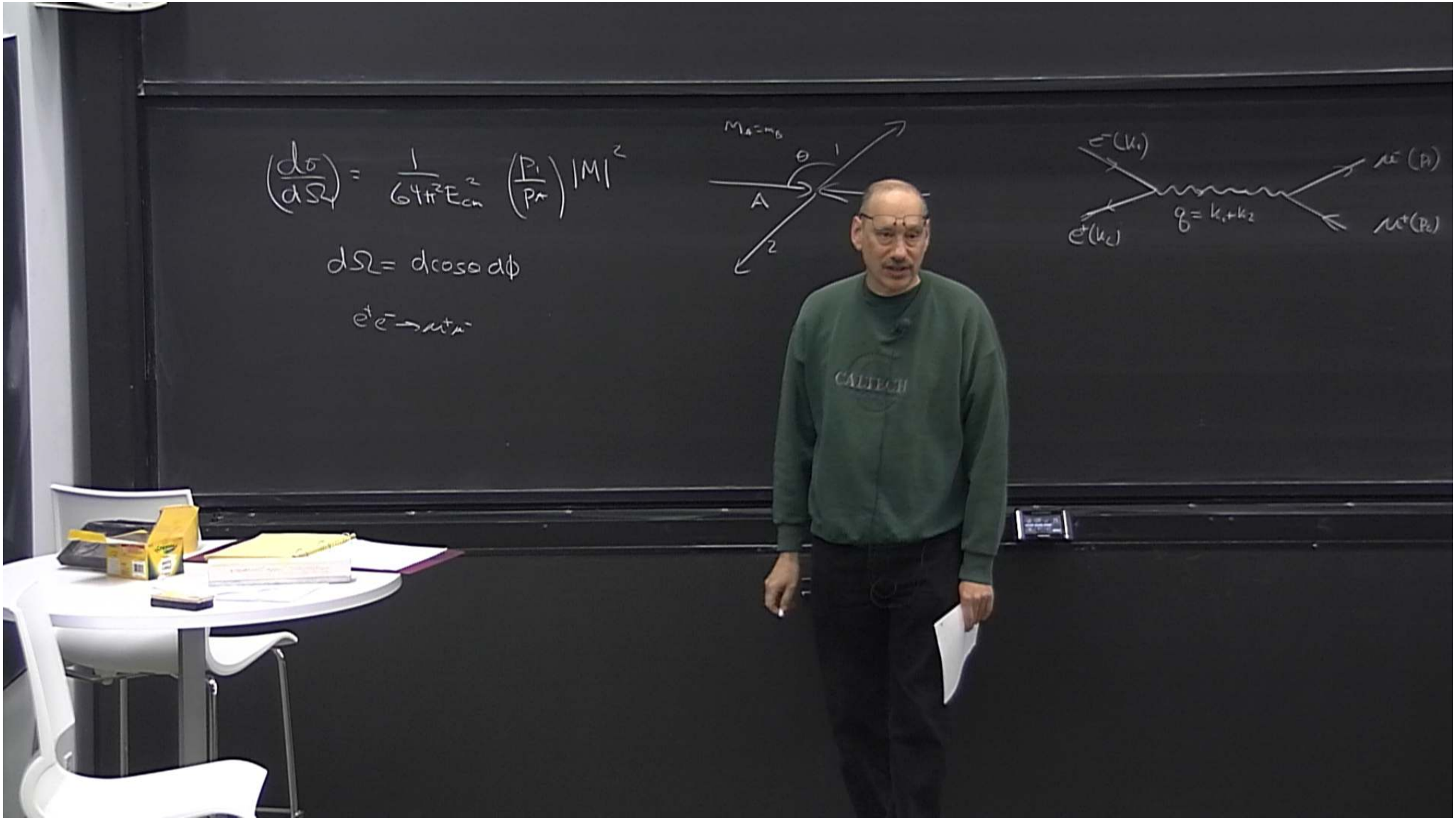
Title: 12/13 PSI - Standard Model Review Lecture 2

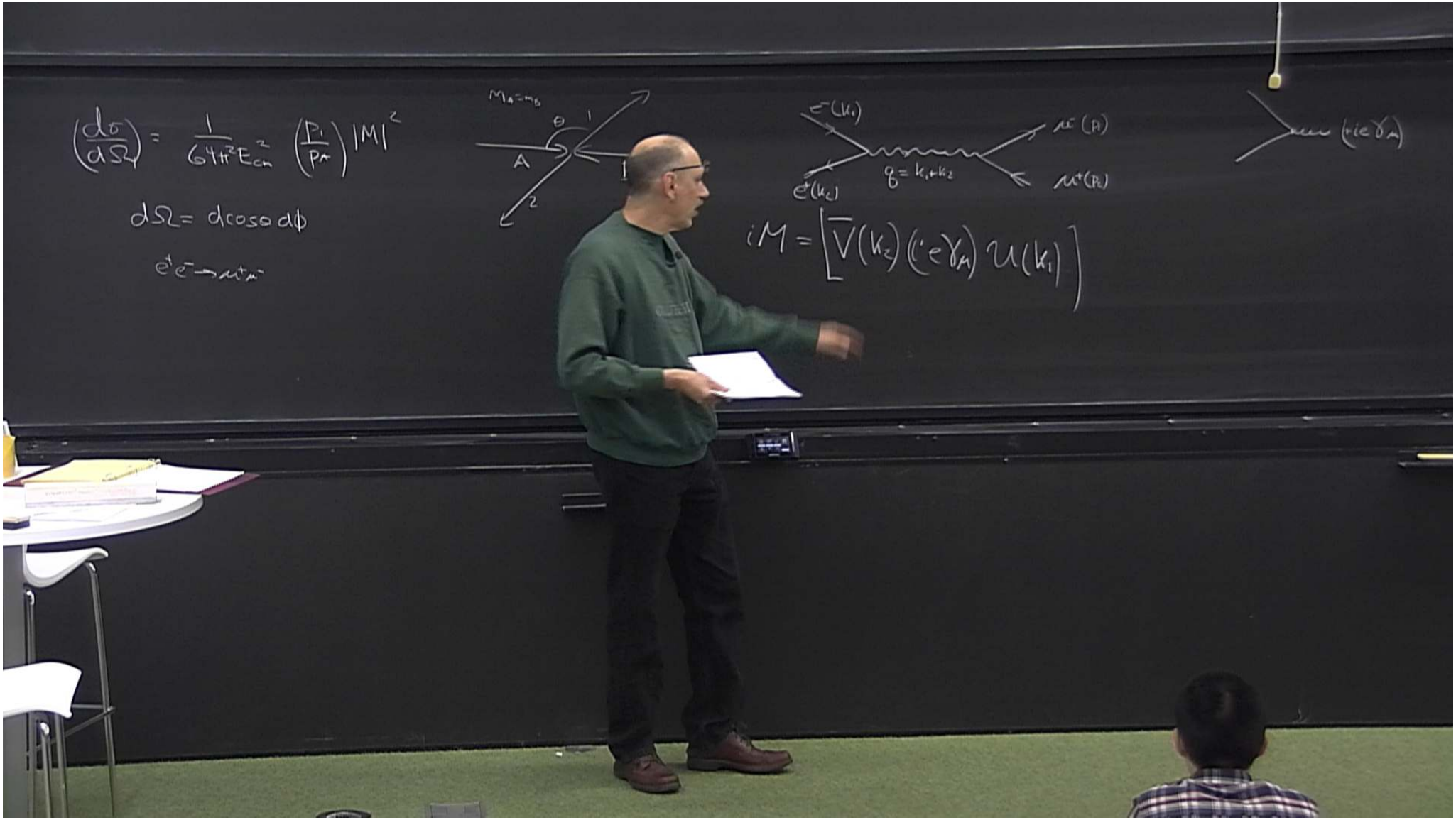
Date: Jan 08, 2013 09:00 AM

URL: http://pirsa.org/13010025

Abstract:


$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{64\pi^2 E_{cm}^2}\left(\frac{P_1}{P_A}\right)|M|^2$
$d\Omega = d\cos\theta\, d\phi$
$M_A = m_B$
θ
1
A
B
2


$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{64\pi^2 E_{cm}^2}\left(\frac{P_f}{P_i}\right)|M|^2$
$d\Omega = d\cos\theta\, d\phi$
$e^+e^- \to \mu^+\mu^-$
$M_A = m_B$
A
1
2
$e^-(k_1)$
$e^+(k_2)$
$q = k_1 + k_2$
$\mu^-(P_3)$
$\mu^+(P_4)$
CALTECH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$d\Omega = d\cos\theta\, d\phi$
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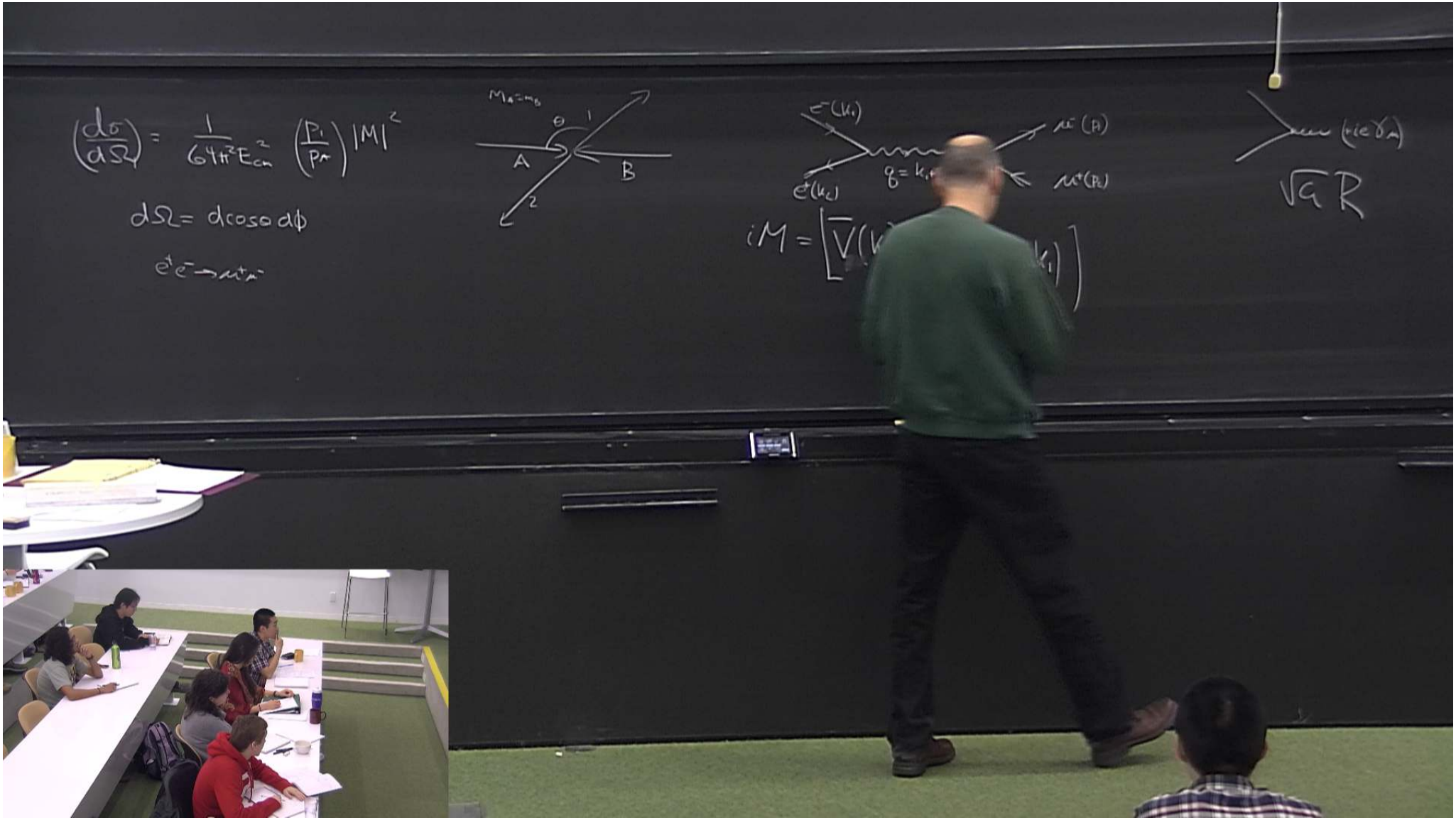
A
B
1
2
θ
$e^-(k_1)$
$\mu^-(P_1)$
$q = k_1 + k_2$
$e^+(k_2)$
$\mu^+(P_2)$
$-ie\gamma_\mu$
$iM = \left[\bar{v}(k_2)(-ie\gamma_\mu)u(k_1)\right]$


$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{64\pi^2 E_{cm}^2}\left(\frac{p_1}{p_\mu}\right)|M|^2$
$d\Omega = d\cos\theta\, d\phi$
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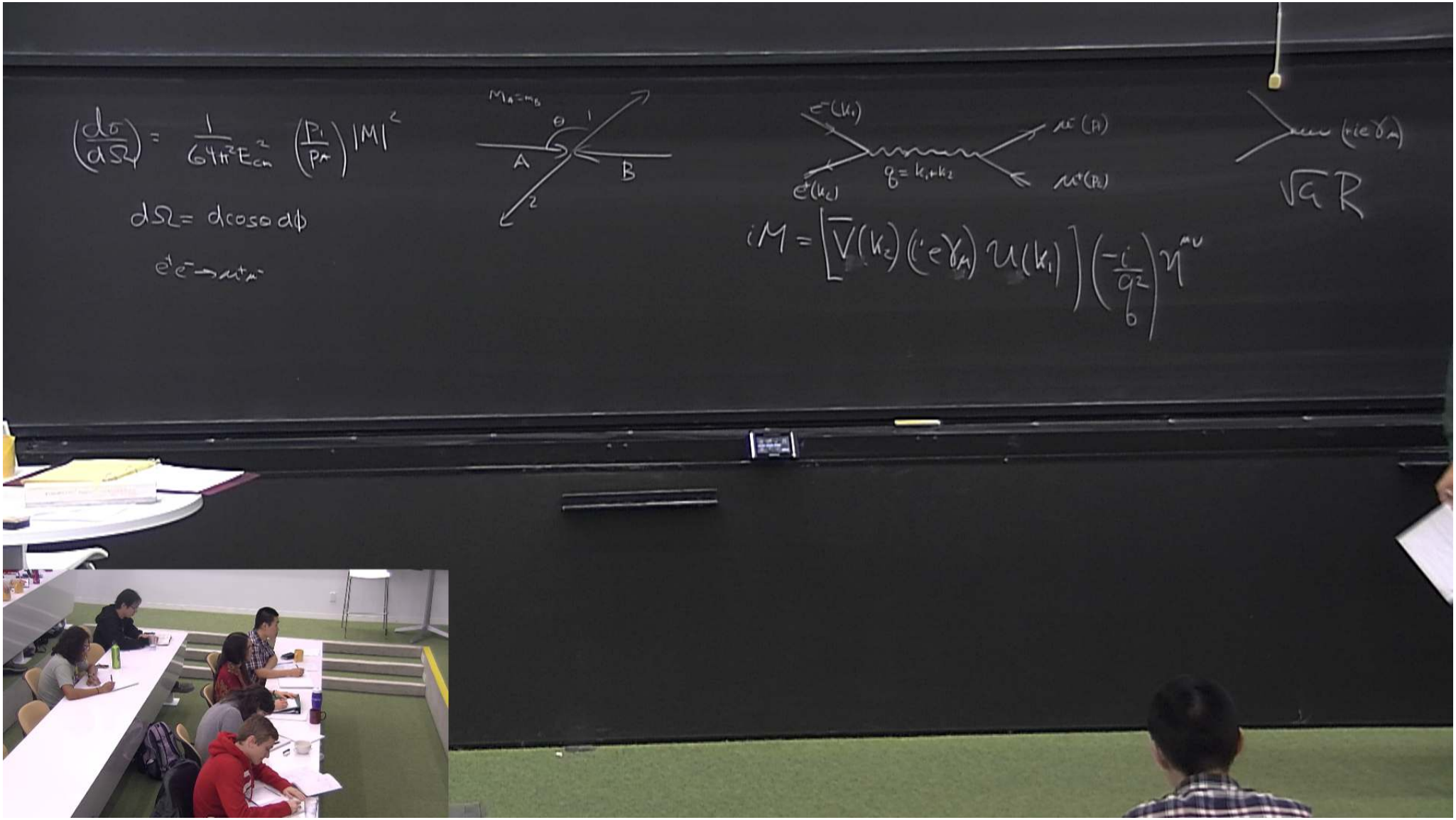
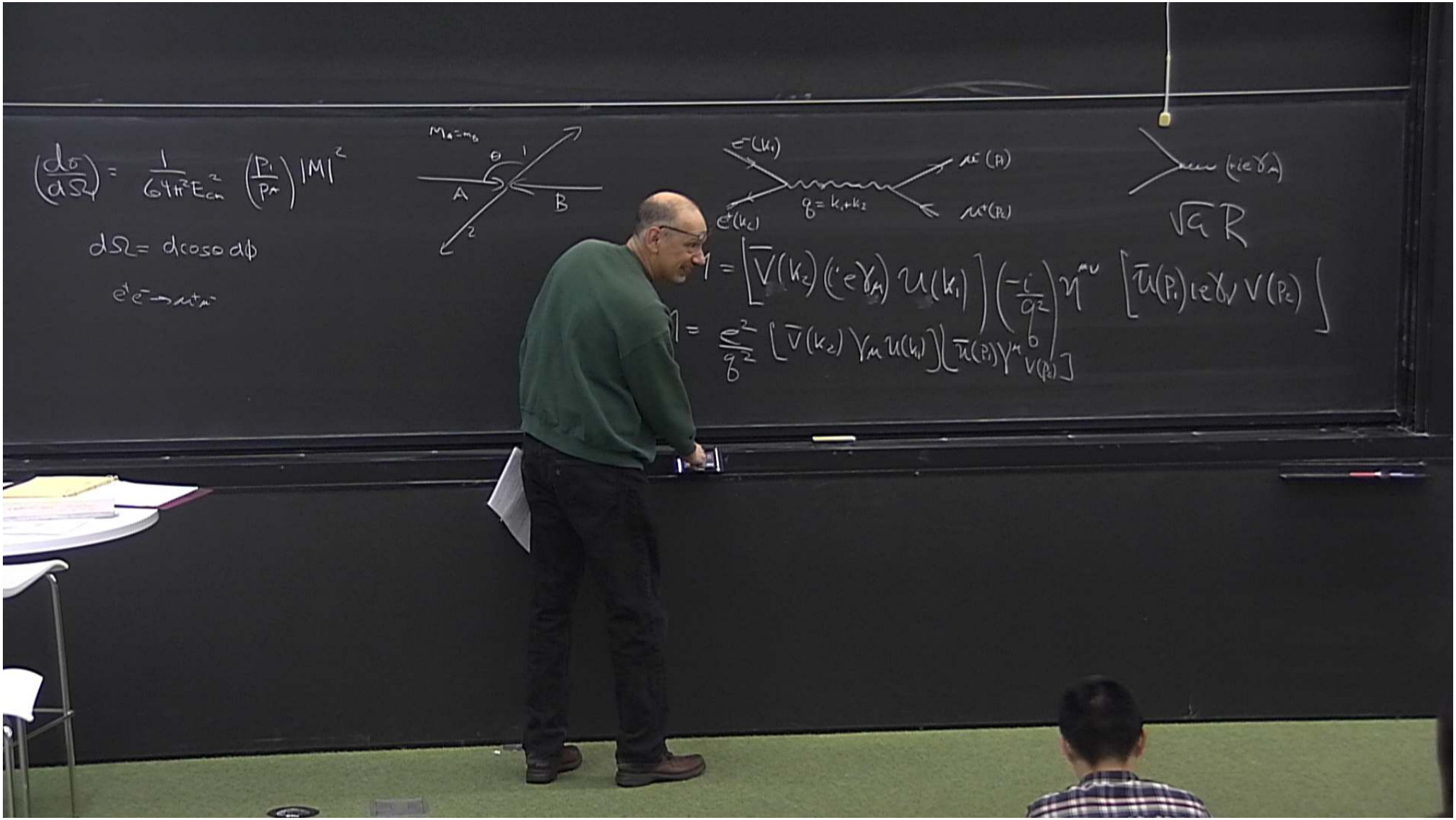
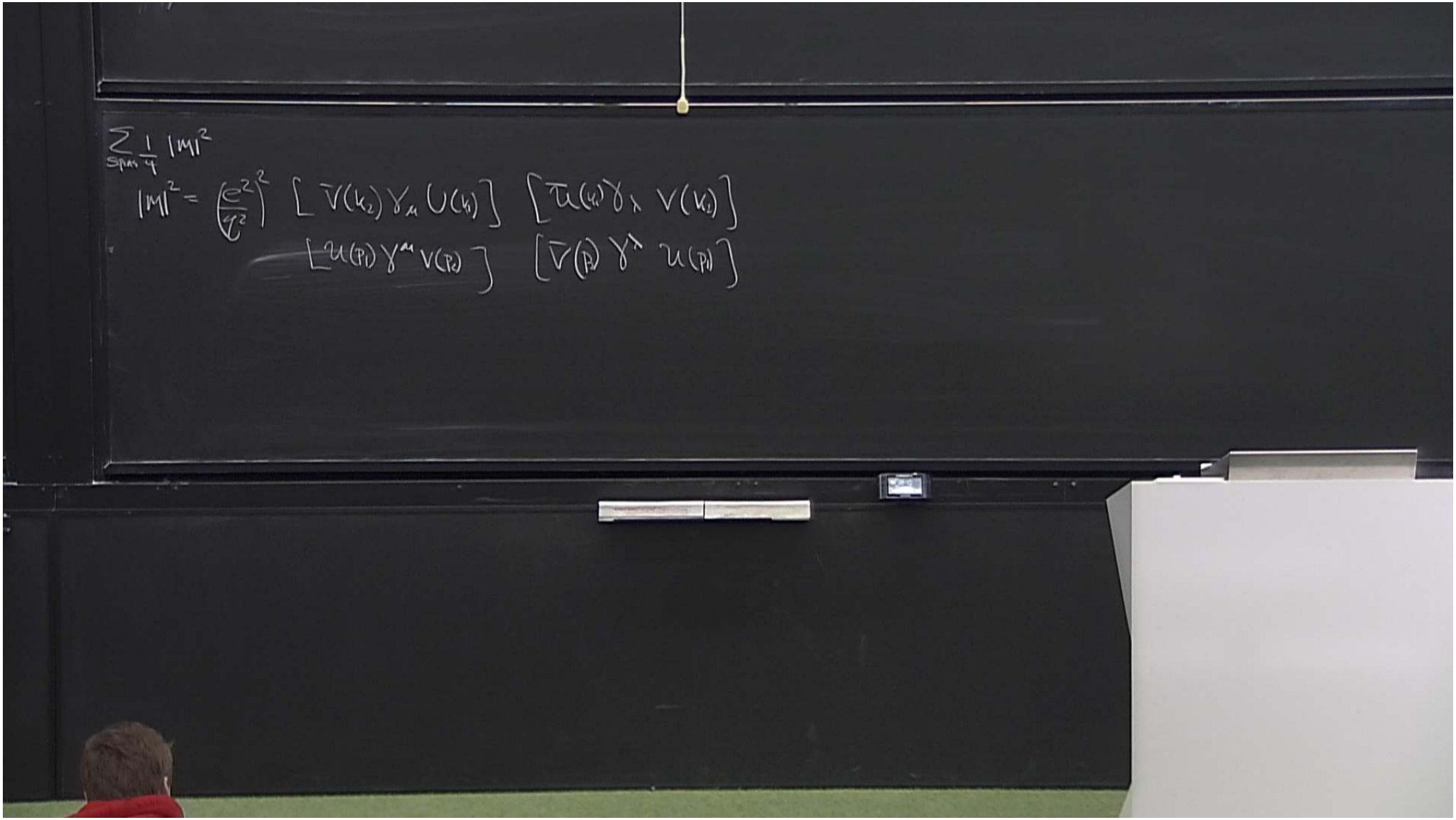
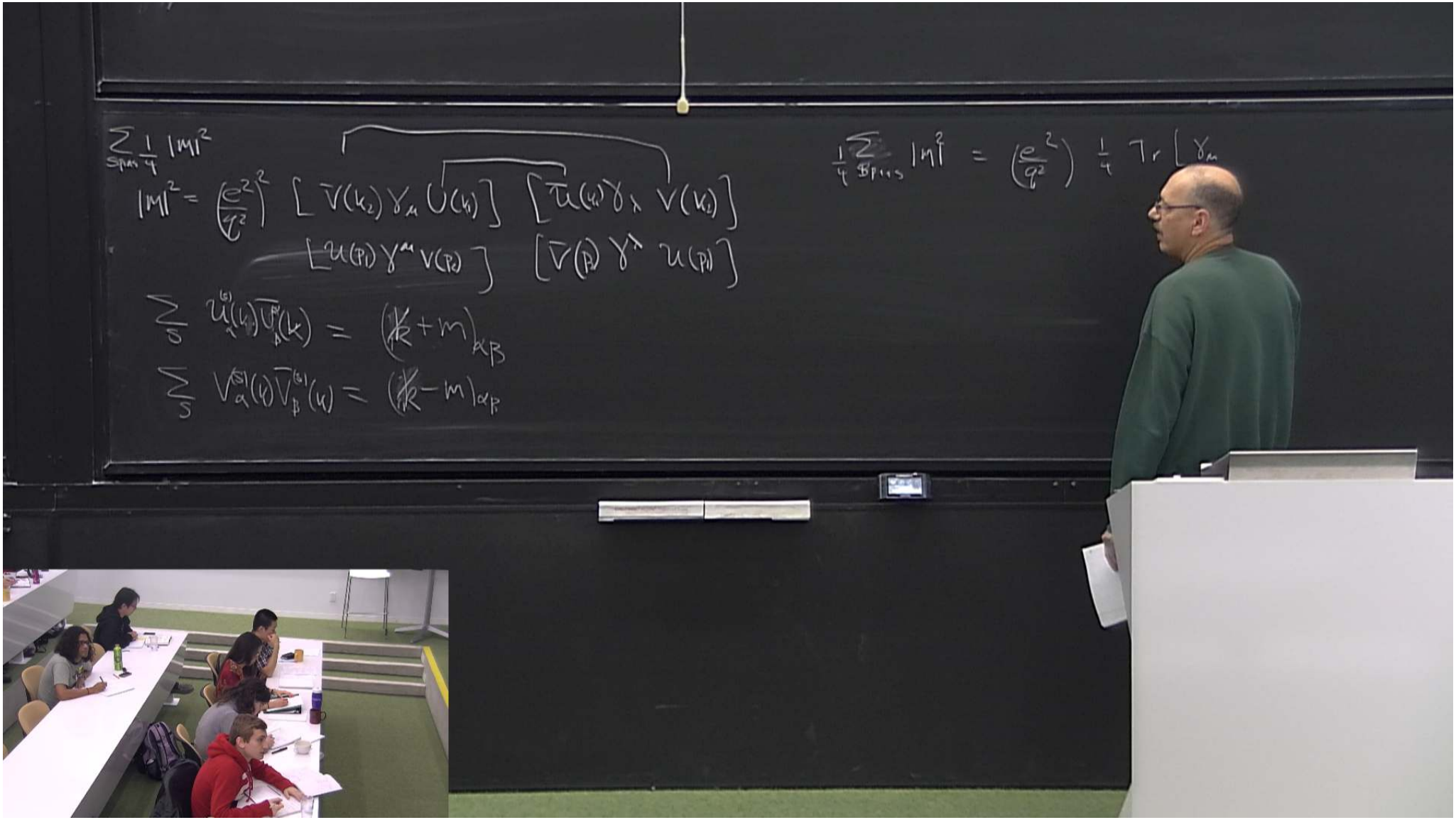
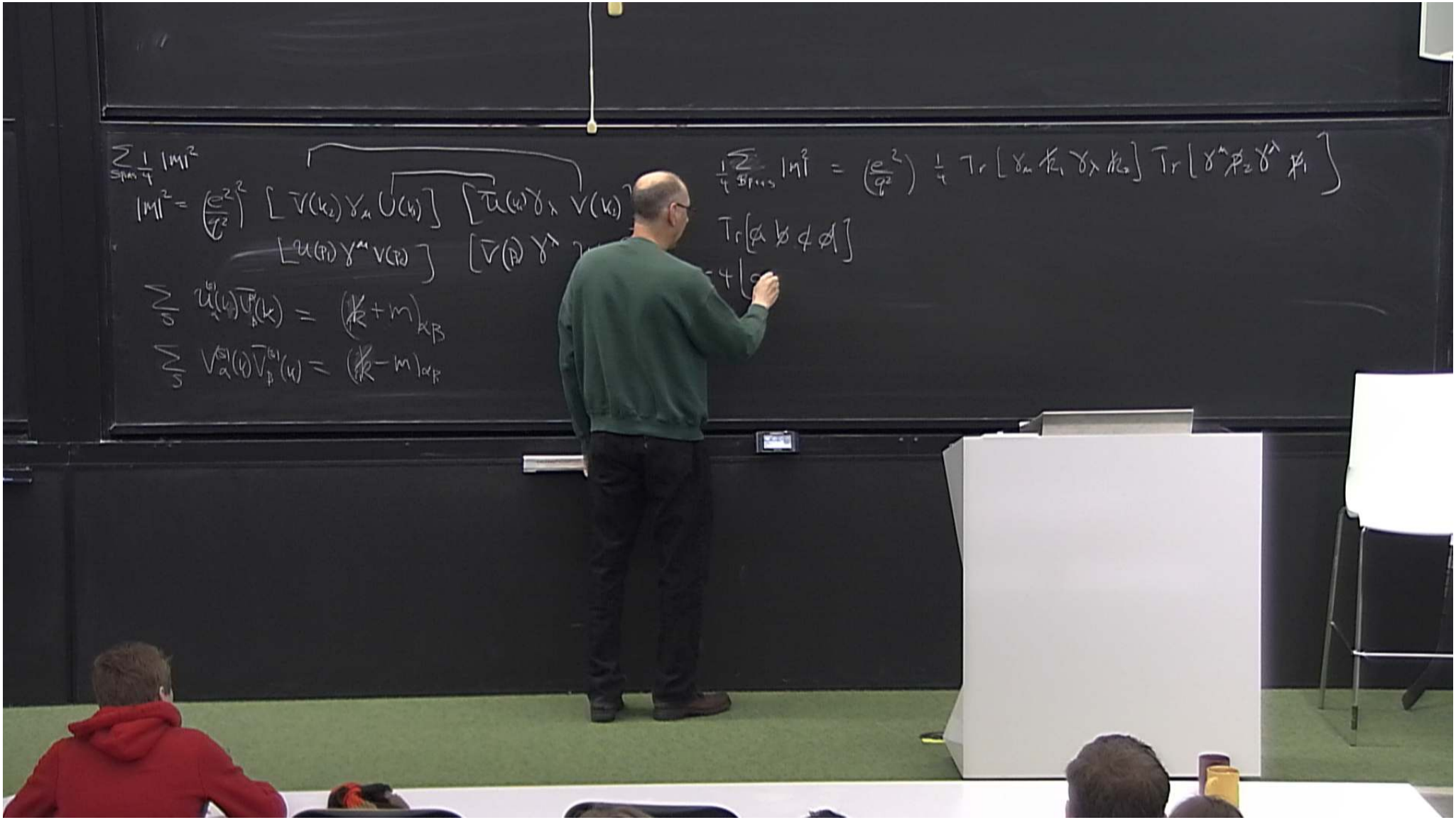
$M_A = m_B$
A
B
$e^-(k_1)$
$e^+(k_2)$
$\mu^-(p_1)$
$\mu^+(p_2)$
$\sqrt{G}\,R$

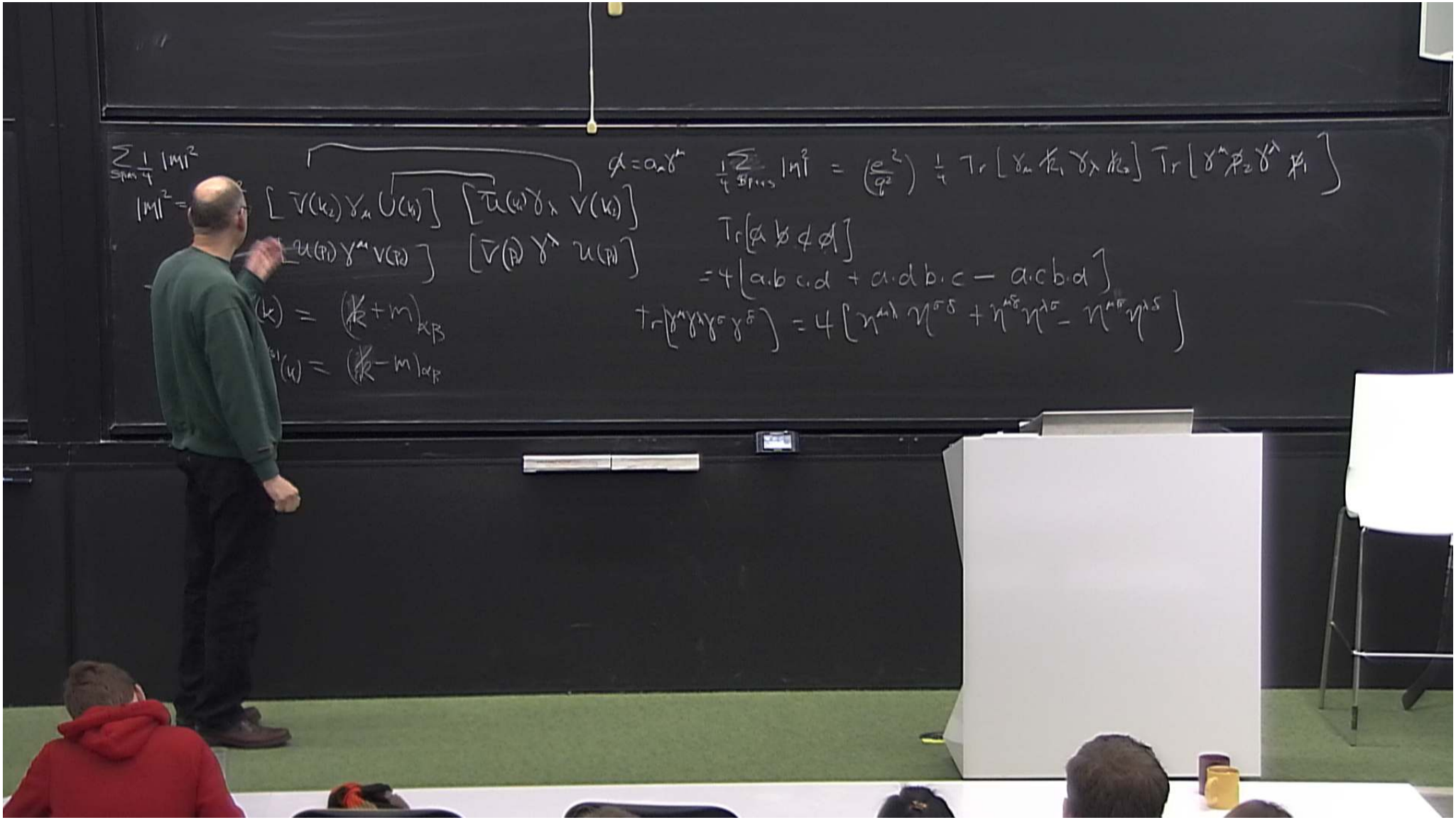

$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{64\pi^2 E_{cm}^2}\left(\frac{p_f}{p_i}\right)|M|^2$
$d\Omega = d\cos\theta\, d\phi$
$e^+e^- \to \mu^+\mu^-$
$m_A = m_B$
A
B
$q = k_1 + k_2$
$i\mathcal{M} = \left[\bar{v}(k_2)(-ie\gamma_\mu)u(k_1)\right]\left(\frac{-i}{q^2}\right)\eta^{\mu\nu}$
$\sqrt{q}\,R$

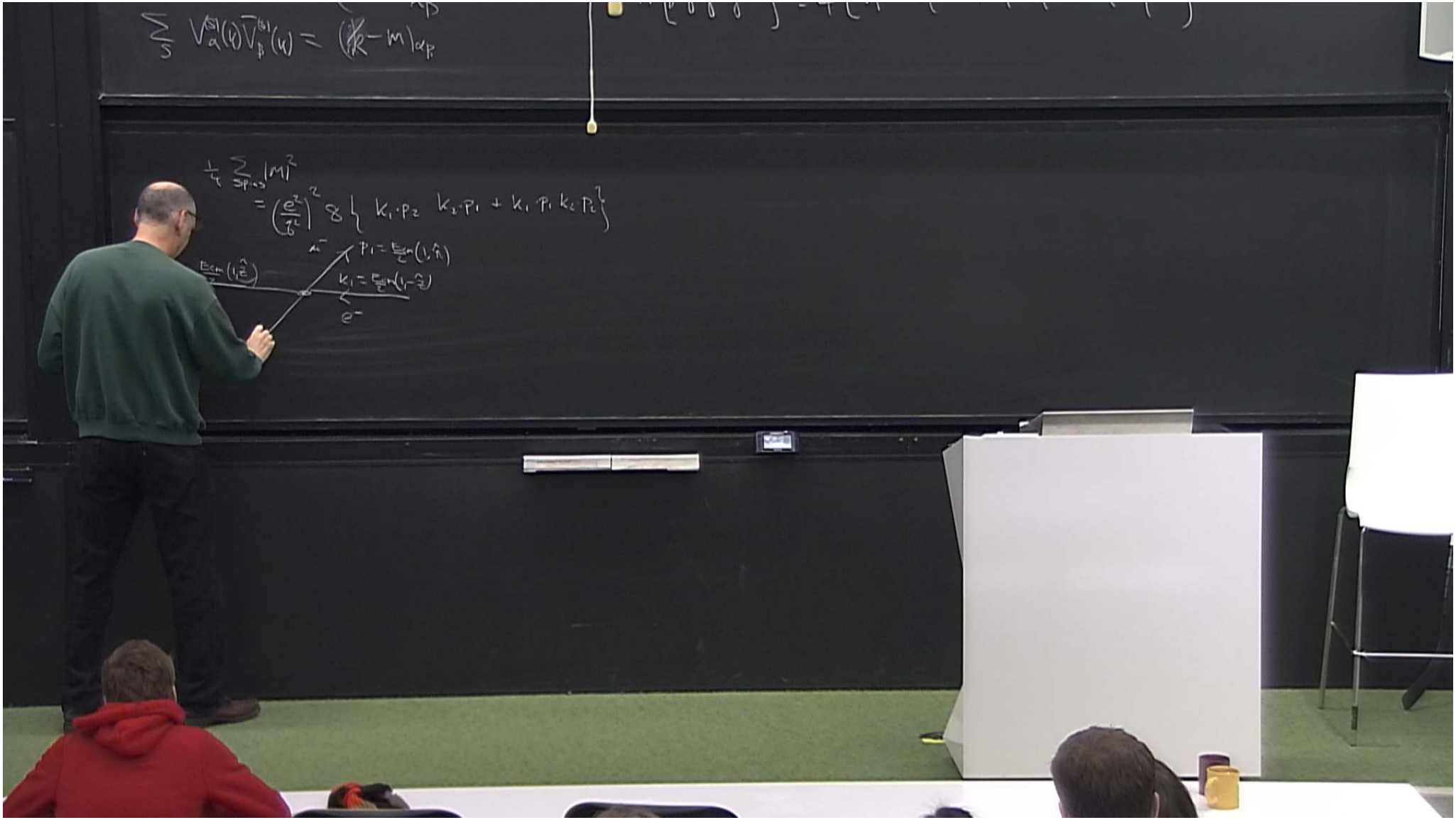

$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{64\pi^2 E_{cm}^2}\left(\frac{P_f}{P_i}\right)|M|^2$
$d\Omega = d\cos\theta\, d\phi$
$e^+e^- \to \mu^+\mu^-$
$M_A = m_B$
A
B
$e^-(k_1)$
$e^+(k_2)$
$\mu^-(P_1)$
$\mu^+(P_2)$
$q = k_1 + k_2$
$-ie\gamma_\mu$
$\sqrt{q}R$
$M = \left[\bar{V}(k_2)(-ie\gamma_\mu)U(k_1)\right]\left(\frac{-i}{q^2}\right)\eta^{\mu\nu}\left[\bar{U}(P_1)ie\gamma_\nu V(P_2)\right]$
$M = \frac{e^2}{q^2}\left[\bar{V}(k_2)\gamma_\mu U(k_1)\right]\left[\bar{U}(P_1)\gamma^\mu V(P_2)\right]$

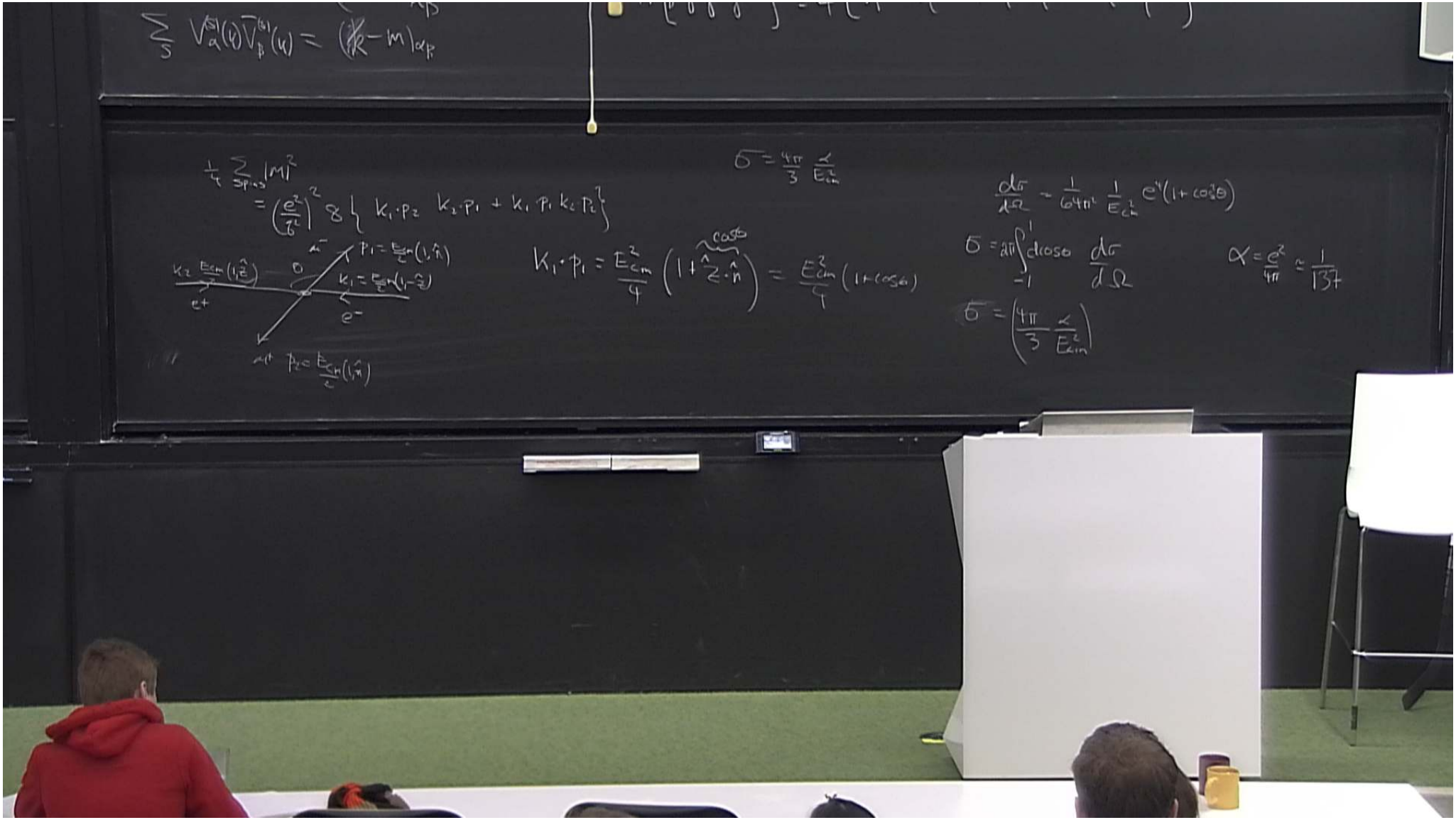

$\sum_{\text{spins}} \frac{1}{4} |M|^2$
$|M|^2 = \left(\frac{e^2}{q^2}\right)^2 [\bar{v}(k_2)\gamma_\mu u(k_1)][\bar{u}(k_1)\gamma_\nu v(k_2)]$
$[\bar{u}(p_1)\gamma^\mu v(p_2)][\bar{v}(p_2)\gamma^\nu u(p_1)]$

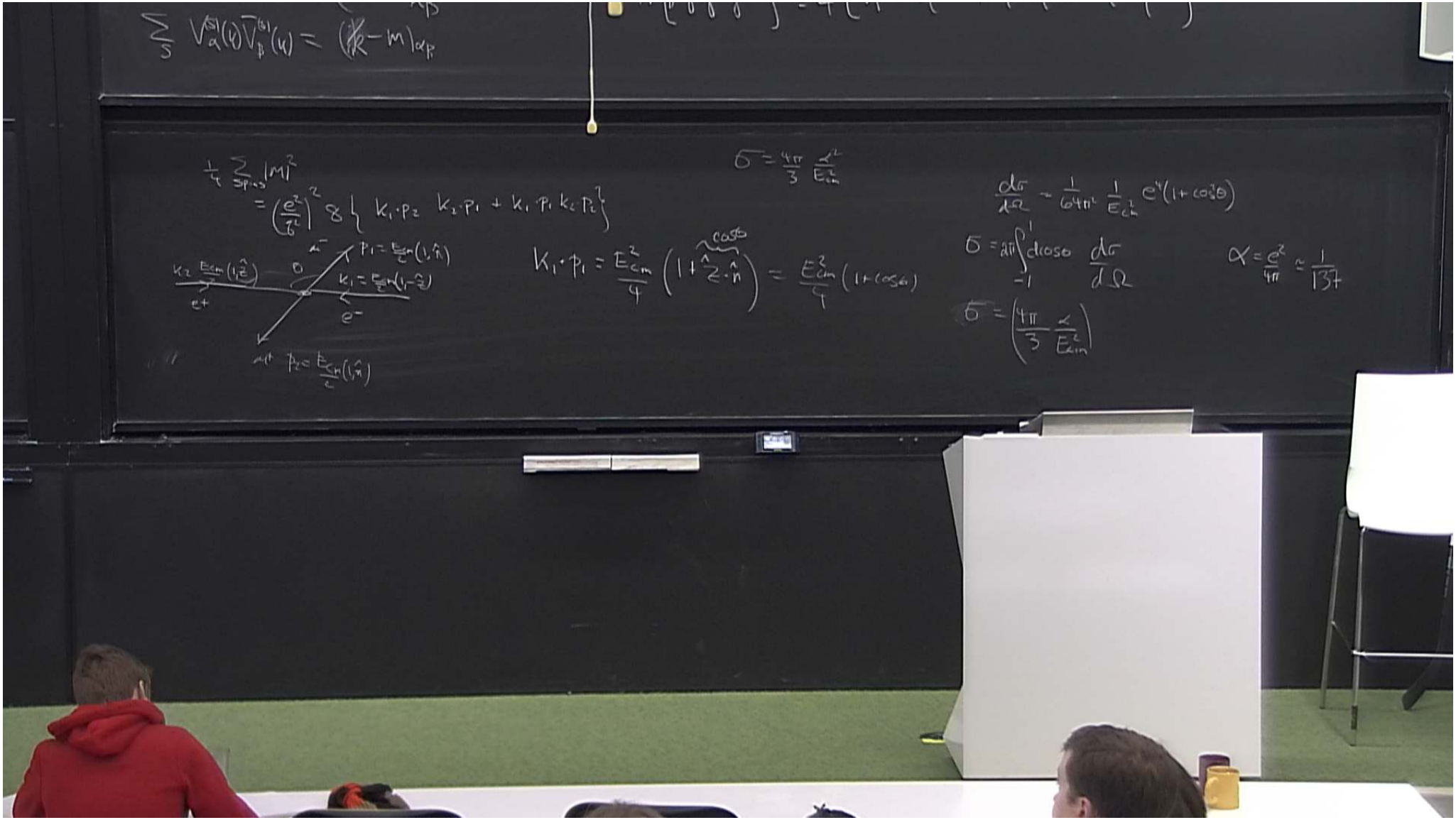

$\sum_{spins} \frac{1}{4} |M|^2$
$|M|^2 = \left(\frac{e^2}{q^2}\right)^2 [\bar{v}(k_2)\gamma_\mu u(k_1)][\bar{u}(k_1)\gamma_\nu v(k_2)]$
$[\bar{u}(p_1)\gamma^\mu v(p_2)][\bar{v}(p_2)\gamma^\nu u(p_1)]$
$\sum_s u^{(s)}_\alpha(k)\bar{u}^{(s)}_\beta(k) = (\not{k} + m)_{\alpha\beta}$
$\sum_s v^{(s)}_\alpha(k)\bar{v}^{(s)}_\beta(k) = (\not{k} - m)_{\alpha\beta}$
$\frac{1}{4}\sum_{Spins} |M|^2 = \left(\frac{e^2}{q^2}\right)\frac{1}{4} Tr[\gamma_\mu$

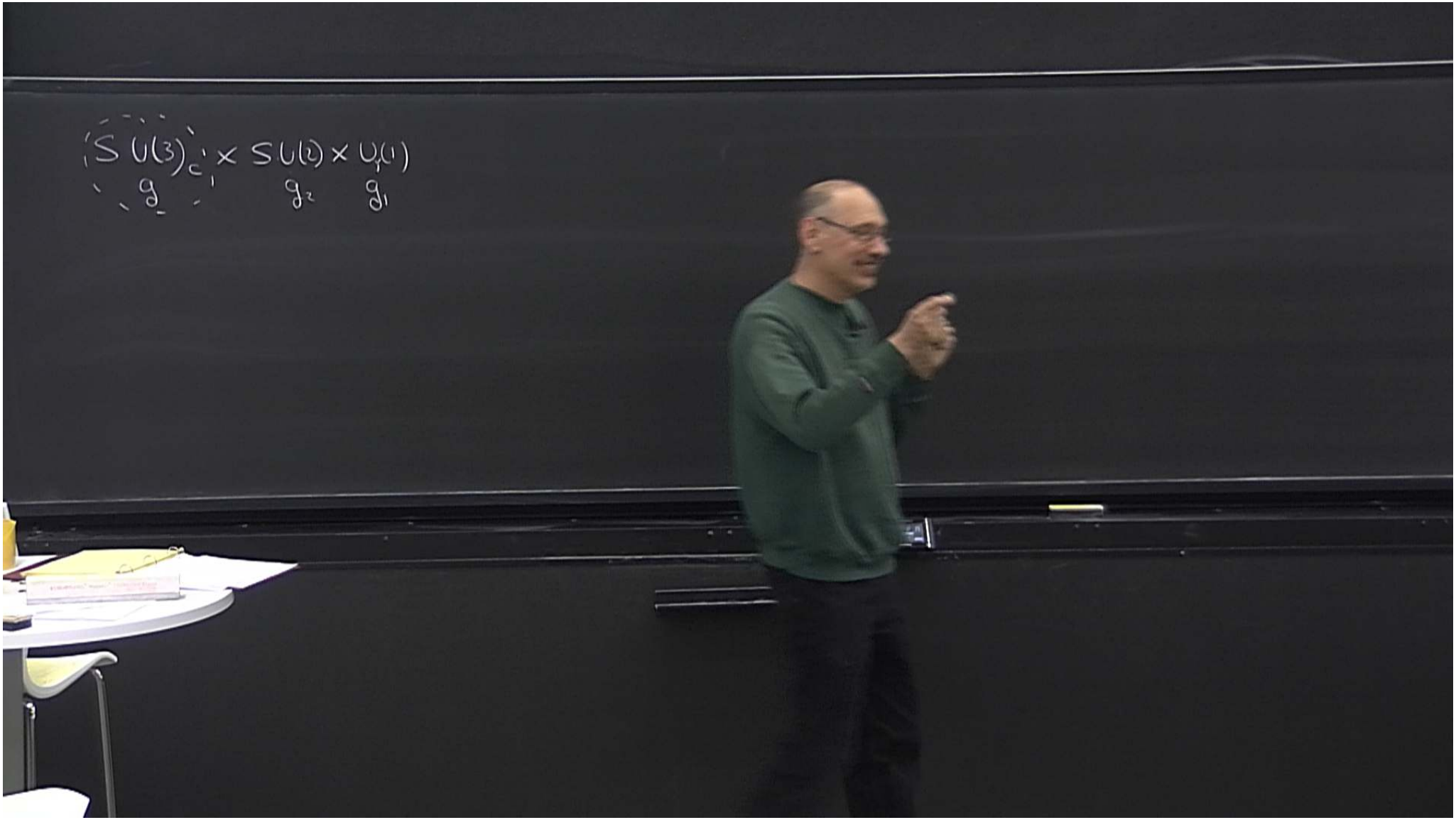

$\sum_{\text{spins}} \frac{1}{4} |\mathcal{M}|^2$
$|\mathcal{M}|^2 = \left(\frac{e^2}{q^2}\right)^2 [\bar{v}(k_2)\gamma_\mu u(k_1)][\bar{u}(k_4)\gamma_\nu v(k_3)]$
$[u(p_3)\gamma^\mu v(p_4)][\bar{v}(p_4)\gamma^\nu$
$\sum_s u^{(s)}_\alpha(k)\bar{u}^{(s)}_\beta(k) = (\not{k} + m)_{\alpha\beta}$
$\sum_s v^{(s)}_\alpha(k)\bar{v}^{(s)}_\beta(k) = (\not{k} - m)_{\alpha\beta}$
$\frac{1}{4}\sum_{\text{spins}} |\mathcal{M}|^2 = \left(\frac{e^2}{q^2}\right)\frac{1}{4} \text{Tr}[\gamma_\mu \not{k}_1 \gamma_\nu \not{k}_2] \text{Tr}[\gamma^\mu \not{p}_2 \gamma^\nu \not{p}_1]$
$\text{Tr}[\not{a}\not{b}\not{c}\not{d}]$
$+ 4[$

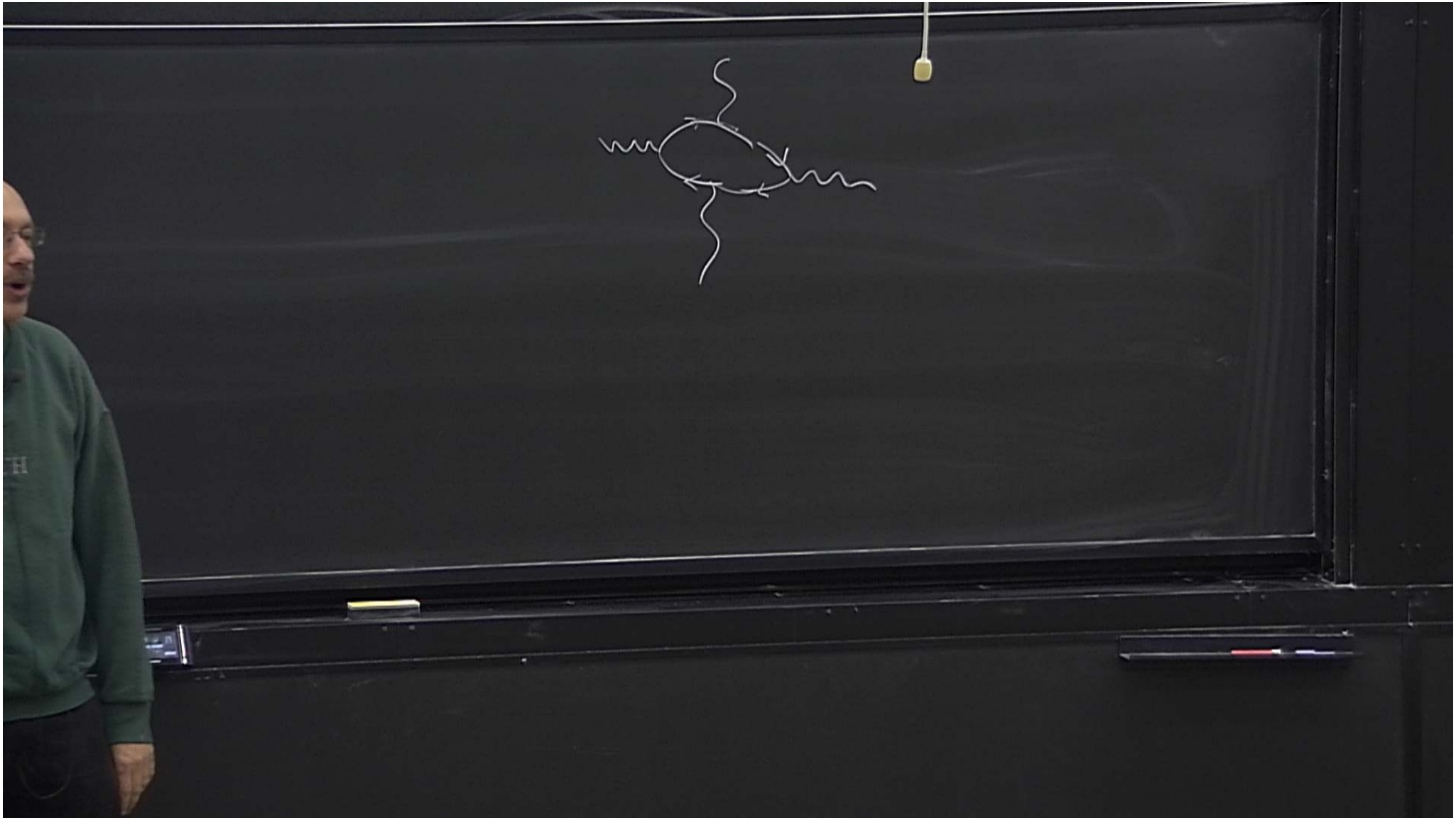

$\not{a} = a_\mu \gamma^\mu$
$\frac{1}{4}\sum_{spins} |\mathcal{M}|^2 = \left(\frac{e^2}{q^2}\right)^2 \frac{1}{4} Tr\left[\gamma_\mu \not{k}_1 \gamma_\lambda \not{k}_2\right] Tr\left[\gamma^\mu \not{p}_2 \gamma^\lambda \not{p}_1\right]$
$Tr[\not{a}\not{b}\not{c}\not{d}]$
$= 4[a\cdot b\, c\cdot d + a\cdot d\, b\cdot c - a\cdot c\, b\cdot d]$
$Tr[\gamma^\mu\gamma^\nu\gamma^\sigma\gamma^\delta] = 4[\eta^{\mu\nu}\eta^{\sigma\delta} + \eta^{\mu\delta}\eta^{\nu\sigma} - \eta^{\mu\sigma}\eta^{\nu\delta}]$

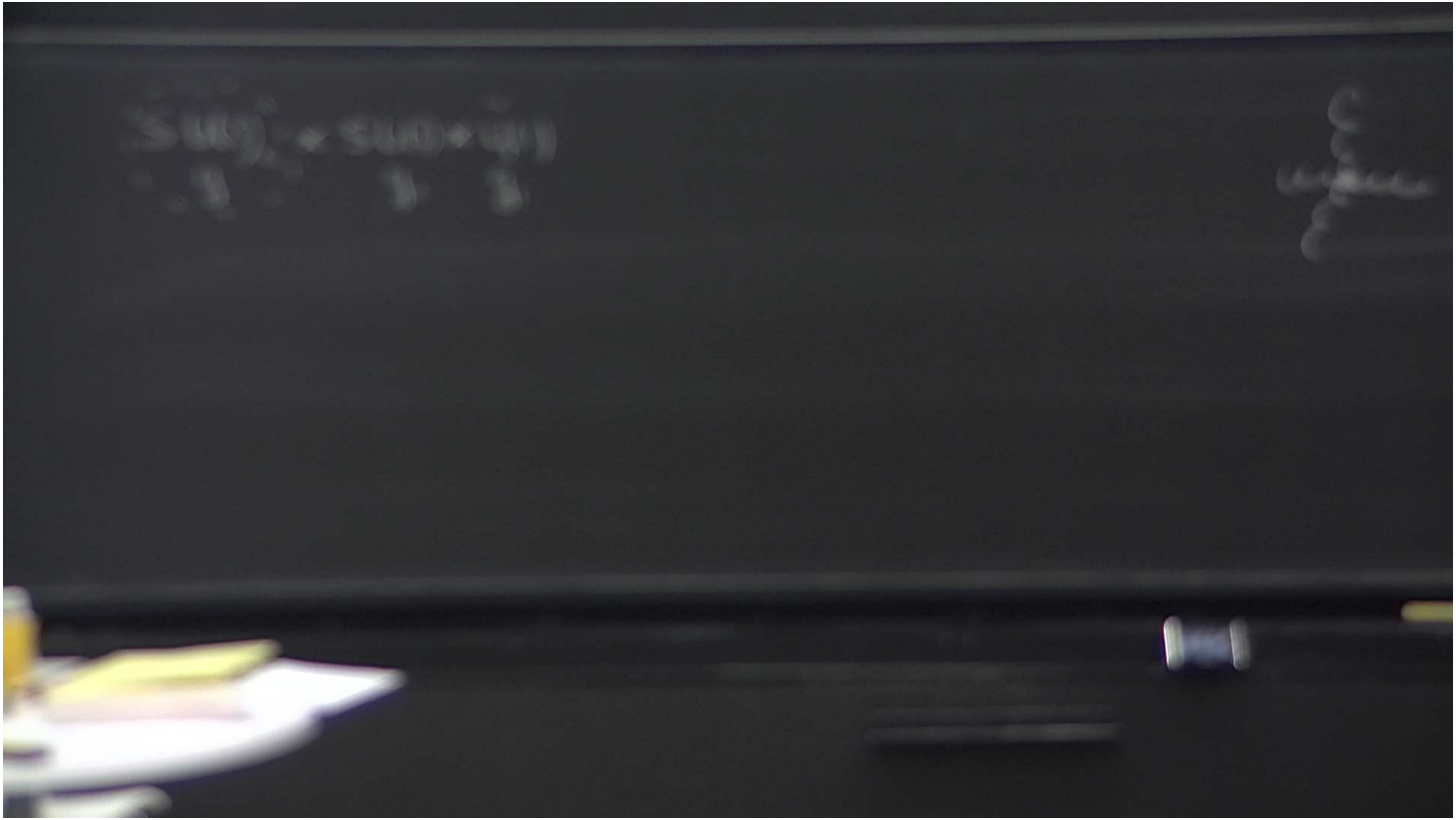

$\sum_s V_\alpha^{(s)}(p)\bar{V}_\beta^{(s)}(w) = (\not{k} - m)_{\alpha\beta}$
$\frac{1}{4}\sum_{spins}|M|^2 = \left(\frac{e^2}{q^2}\right)^2 8\{k_1\cdot p_2\ k_2\cdot p_1 + k_1 p_1 k_2 p_2\}$
μ^-
$p_1 = \frac{E_{cm}}{2}(1,\hat{n})$
$k_1 = \frac{E_{cm}}{2}(1,-\hat{n})$
e^-

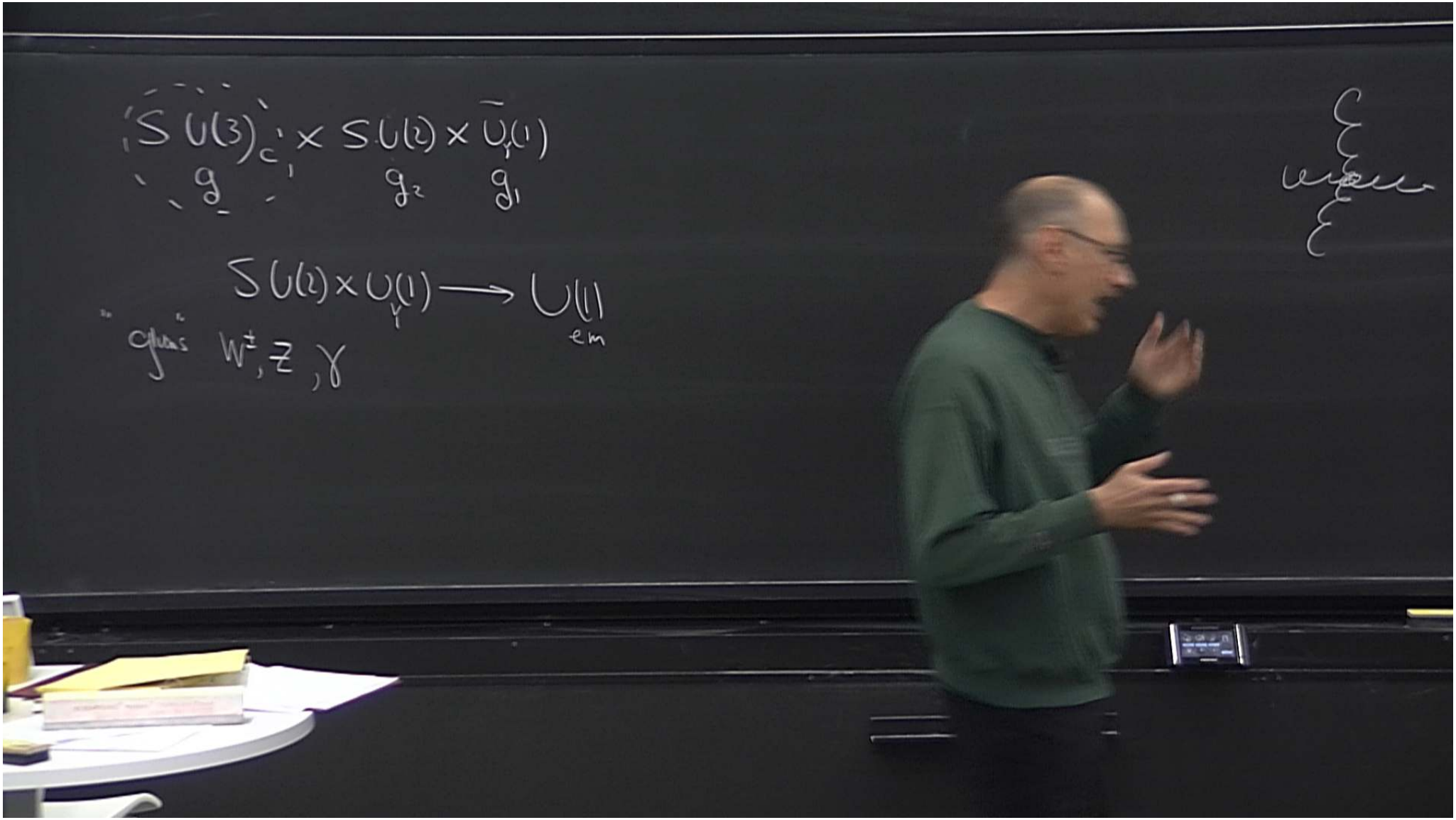

e+
e-
e+
e-

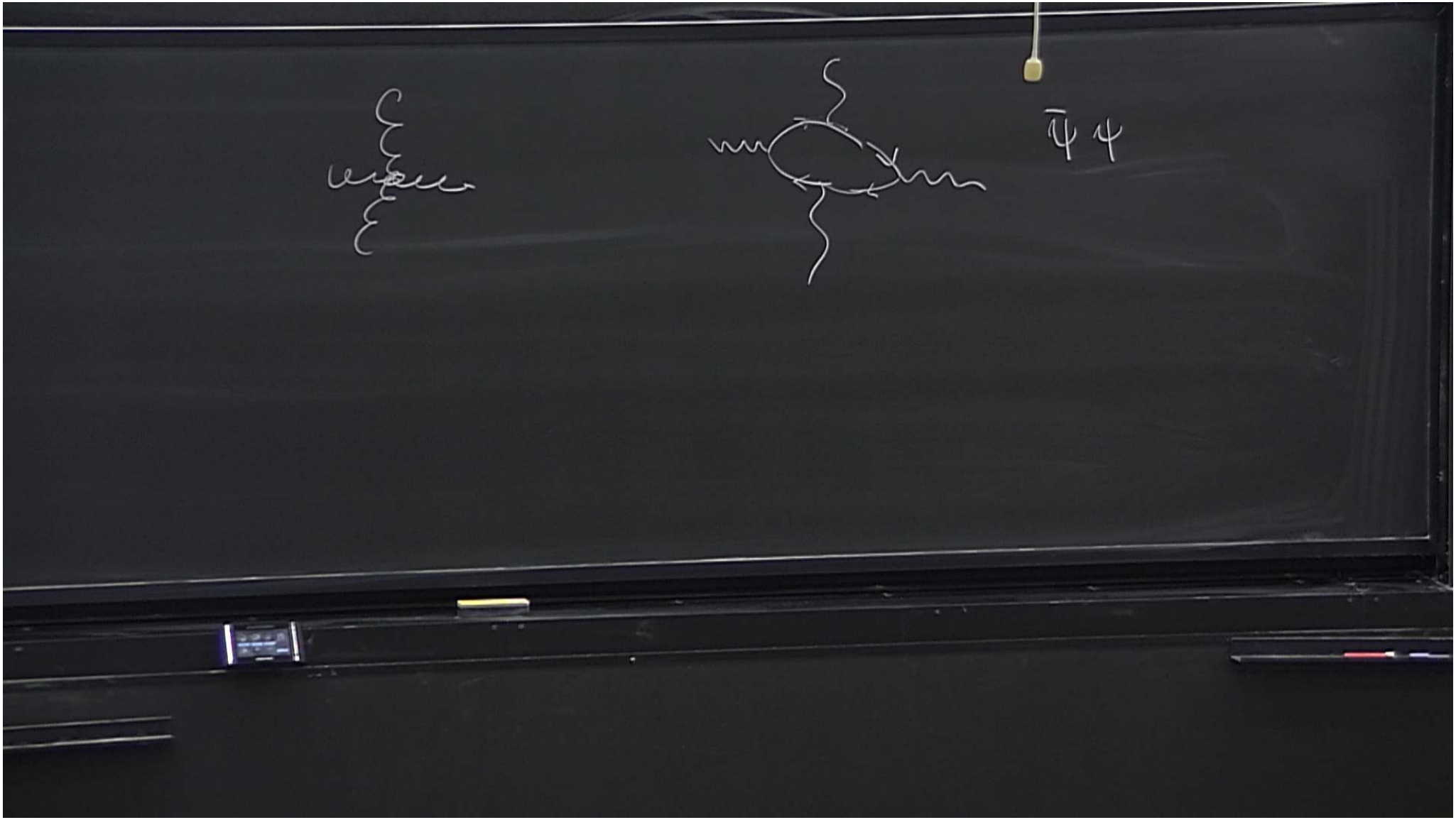

$\sum_s V_\alpha^{(s)}(k)\bar{V}_\beta^{(s)}(k) = (\not{k} - m)_{\alpha\beta}$
$\frac{1}{4}\sum_{spins}|M|^2 = \left(\frac{e^2}{q^2}\right)^2 8\{k_1\cdot p_2\, k_2\cdot p_1 + k_1\cdot p_1\, k_2\cdot p_2\}$
$\sigma = \frac{4\pi}{3}\frac{\alpha^2}{E_{cm}^2}$
$\frac{d\sigma}{d\Omega} = \frac{1}{64\pi^2}\frac{1}{E_{cm}^2}e^4(1+\cos^2\theta)$
$\sigma = 2\pi\int_{-1}^{1} d\cos\theta\, \frac{d\sigma}{d\Omega}$
$\alpha = \frac{e^2}{4\pi} \simeq \frac{1}{137}$
$\sigma = \left(\frac{4\pi}{3}\frac{\alpha}{E_{cm}^2}\right)$
$k_1\cdot p_1 = \frac{E_{cm}^2}{4}\left(1+\overbrace{\hat{z}\cdot\hat{n}}^{\cos\theta}\right) = \frac{E_{cm}^2}{4}(1+\cos\theta)$
$p_1 = \frac{E_{cm}}{2}(1,\hat{n})$
$k_1 = \frac{E_{cm}}{2}(1,-\hat{z})$
$k_2 = \frac{E_{cm}}{2}(1,\hat{z})$
$p_2 = \frac{E_{cm}}{2}(1,\hat{n})$
e^+
e^-
μ^-
μ^+
θ

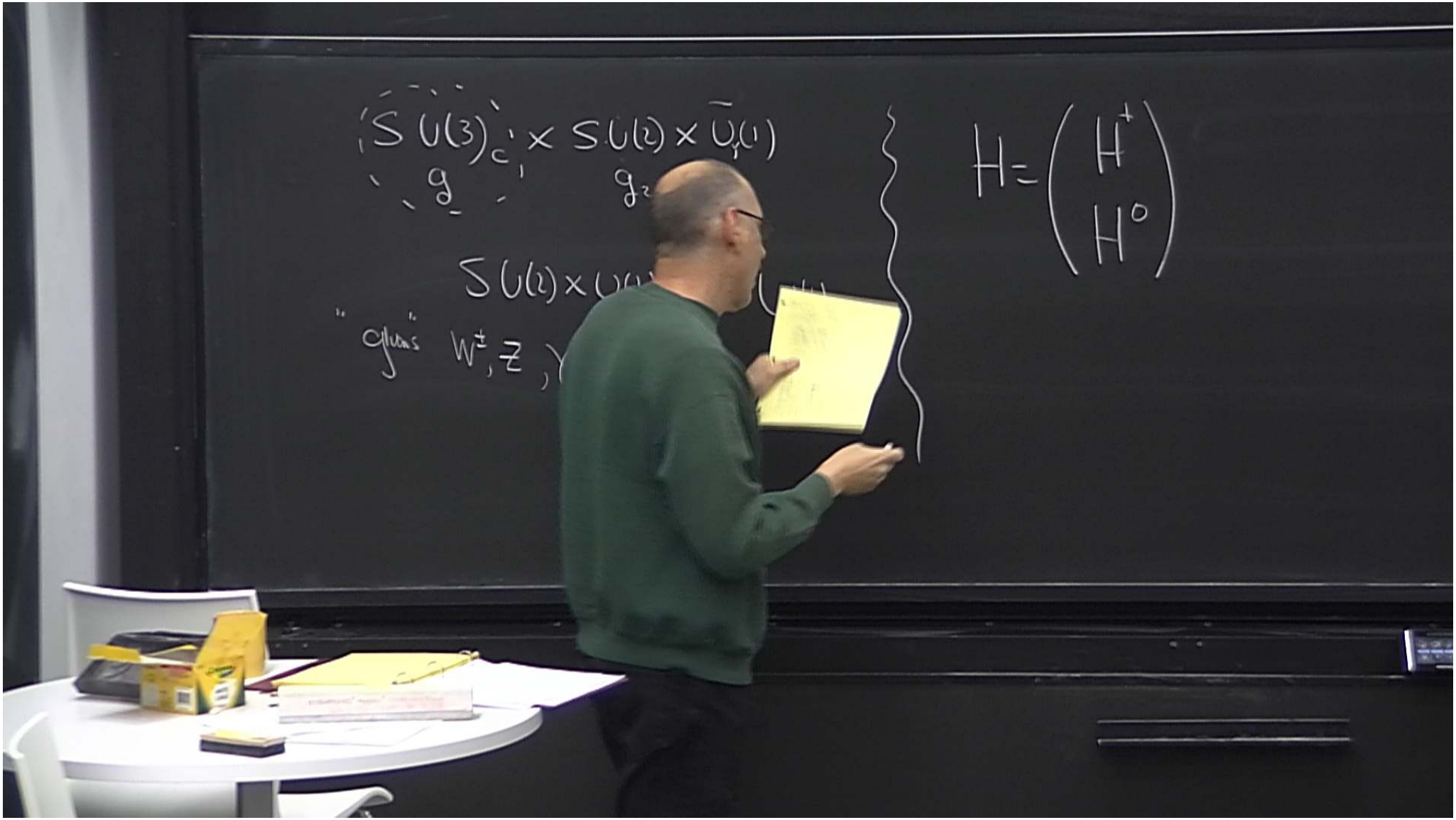

SU(3)c × SU(2) × U(1)
g3 g2 g1

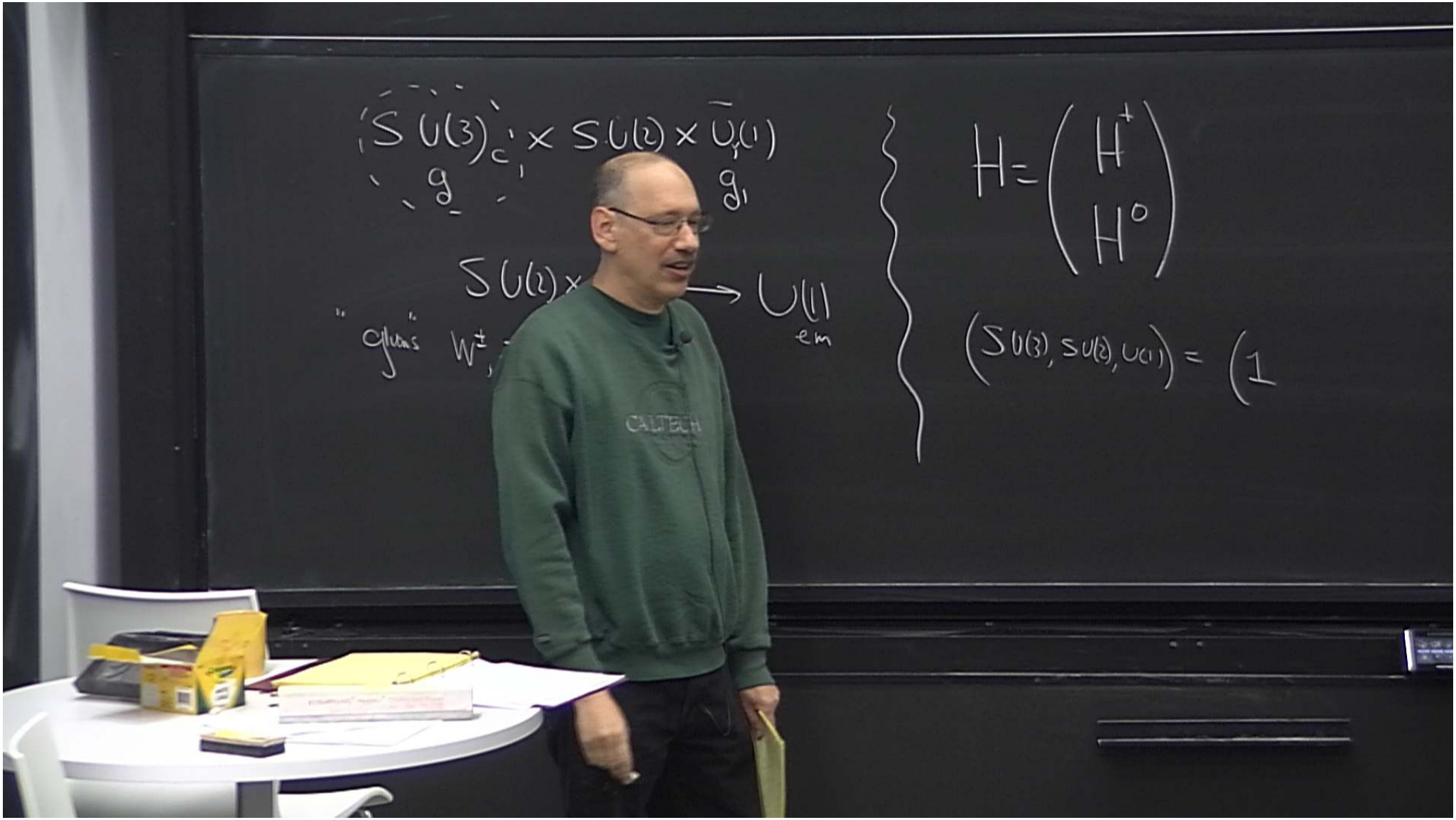


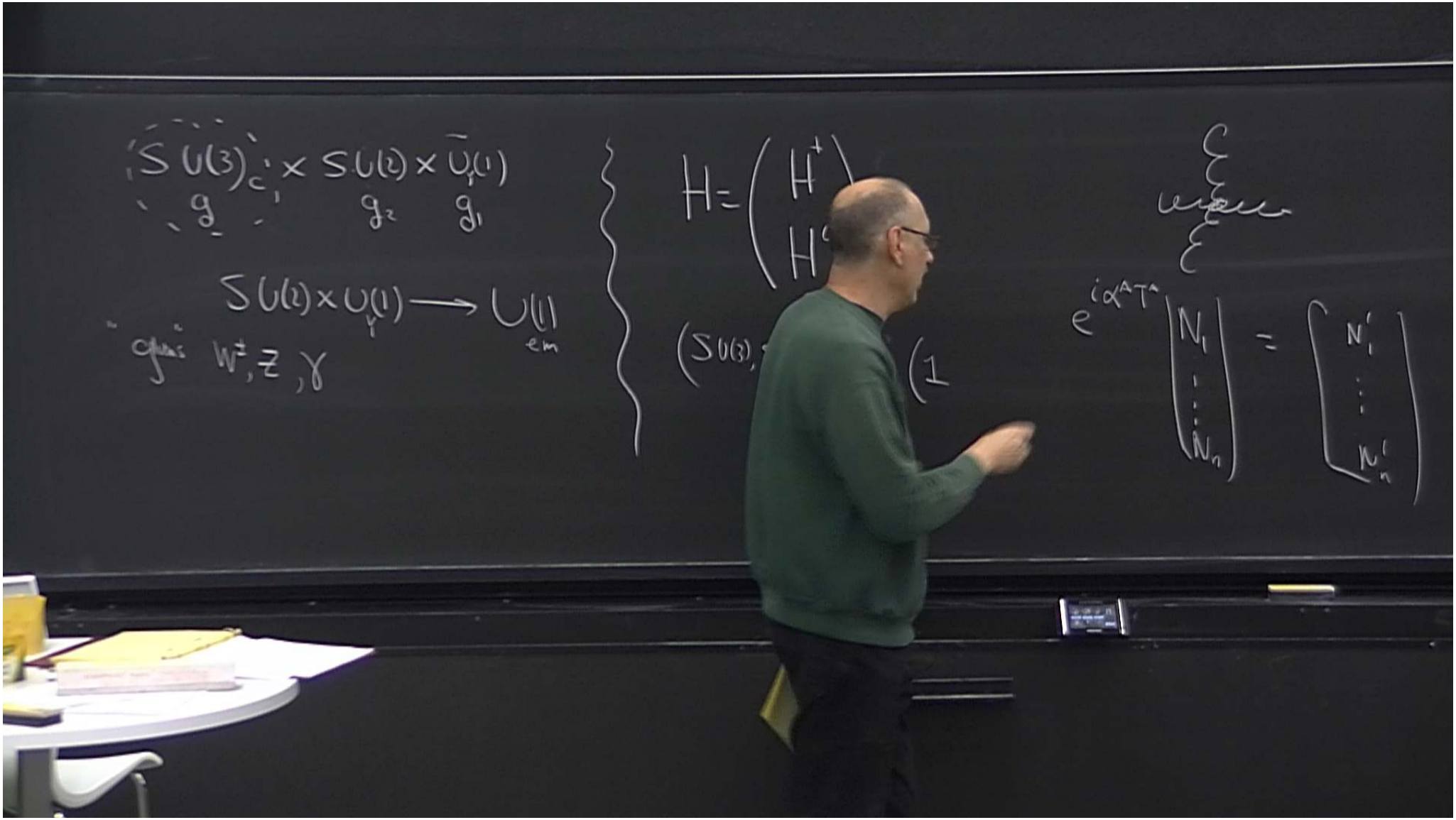


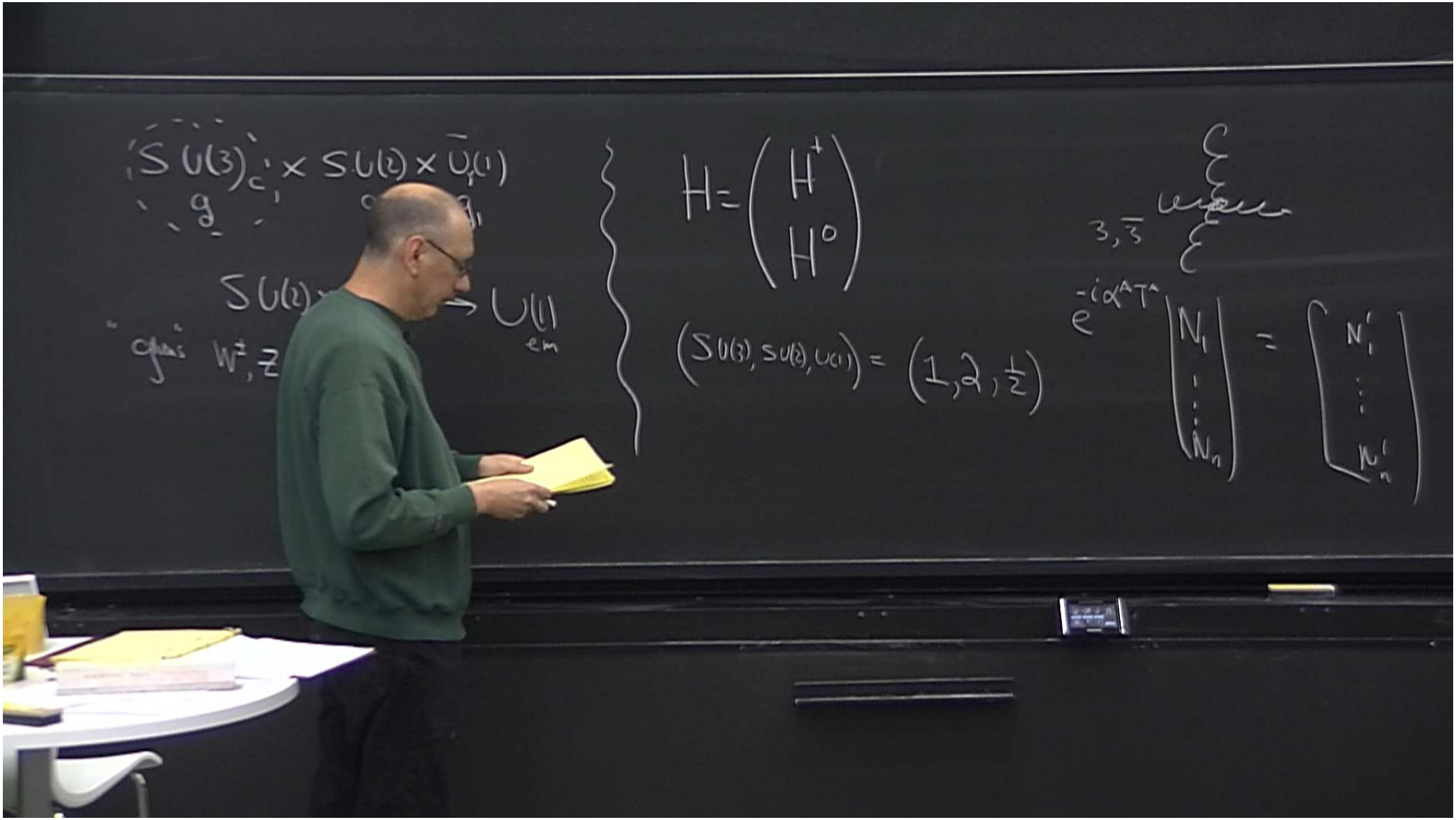

$SU(3)_c \times SU(2) \times U_Y(1)$
g_3 g_2 g_1
$SU(2) \times U_Y(1) \longrightarrow U(1)_{em}$
glue W, Z, γ

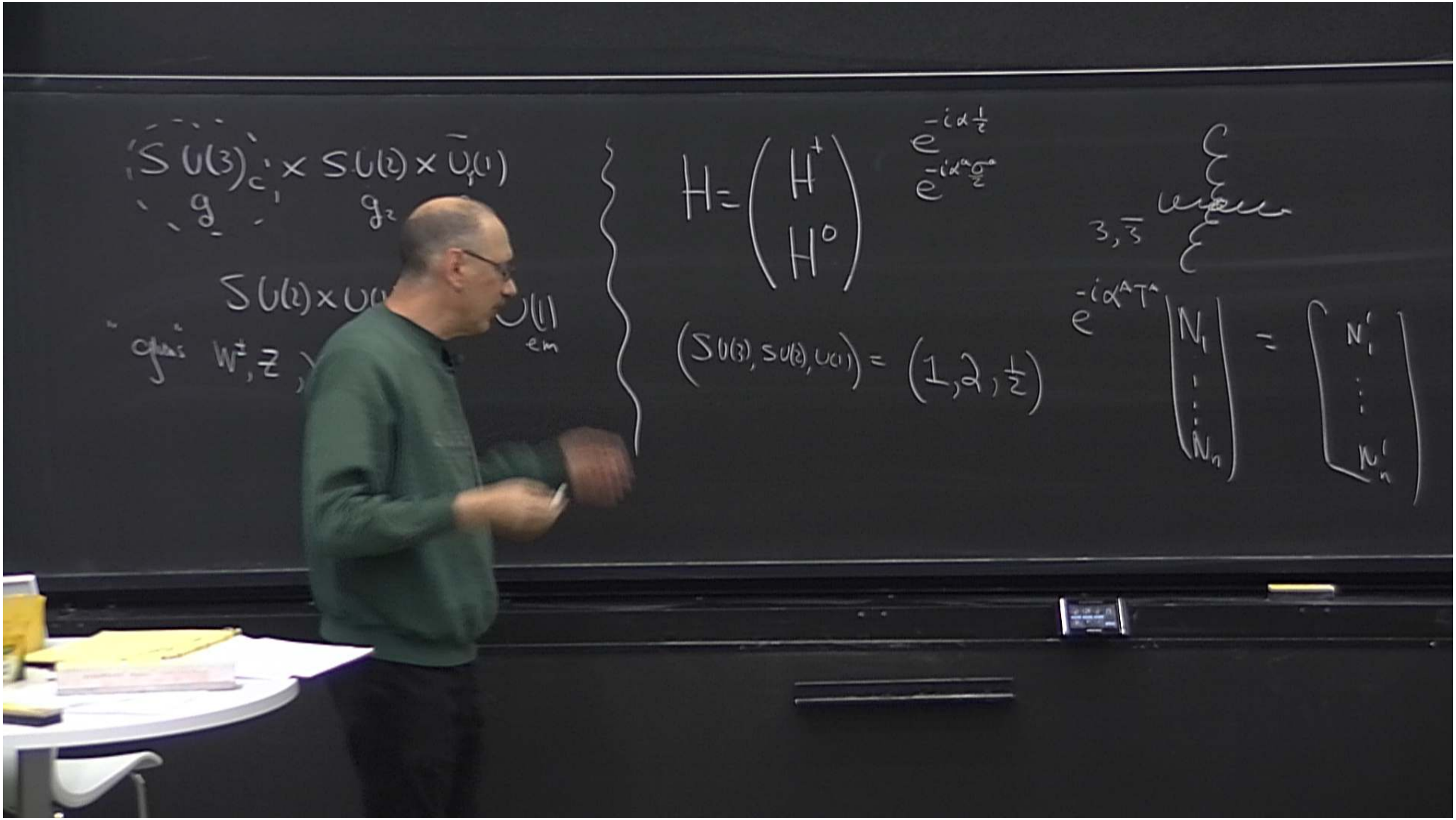

ψ ψ

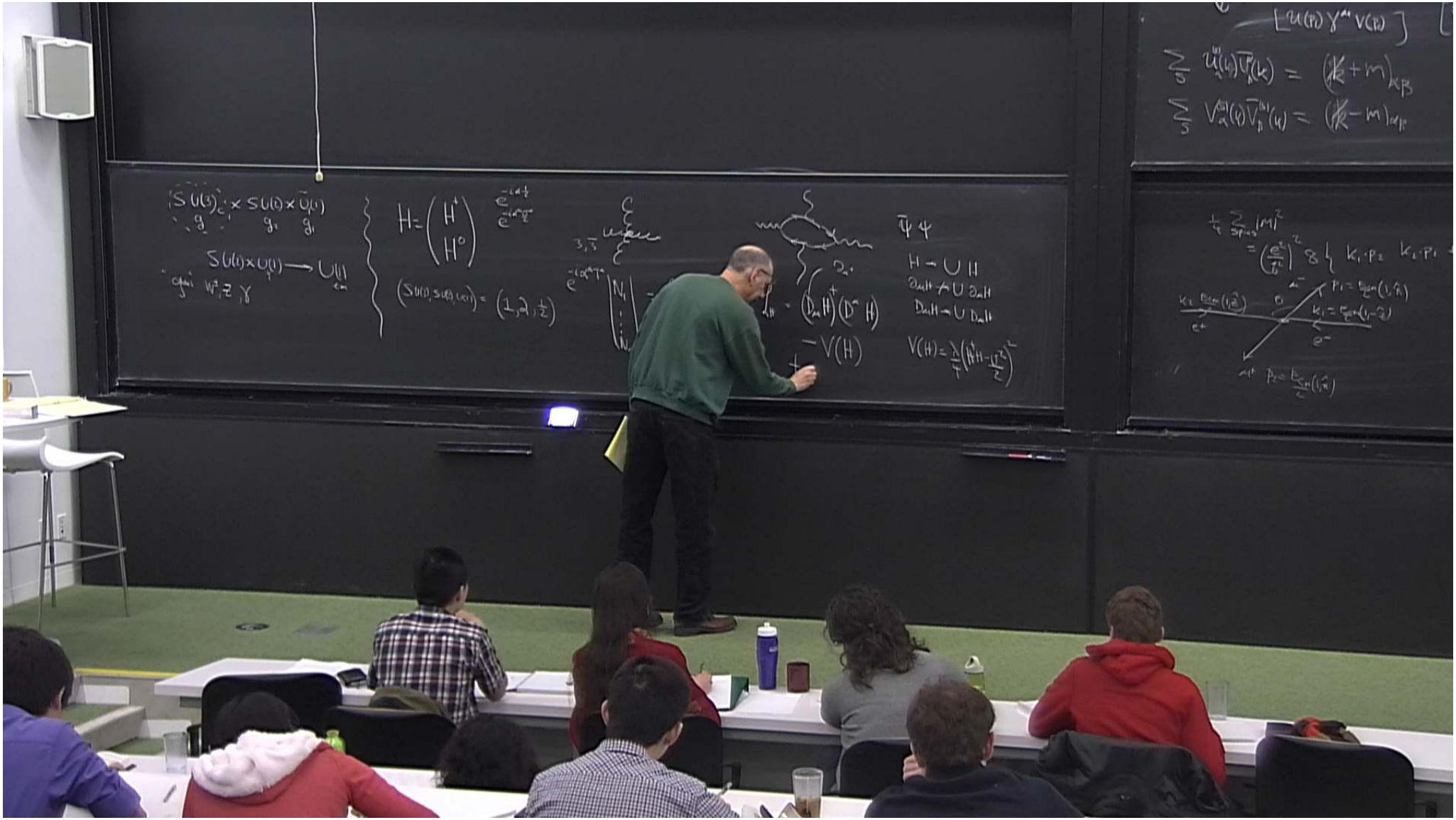

SU(3)c × SU(2) × U(1)
g
g2
SU(2) × U(
"gluons" W±, Z
H = (H+ H0)

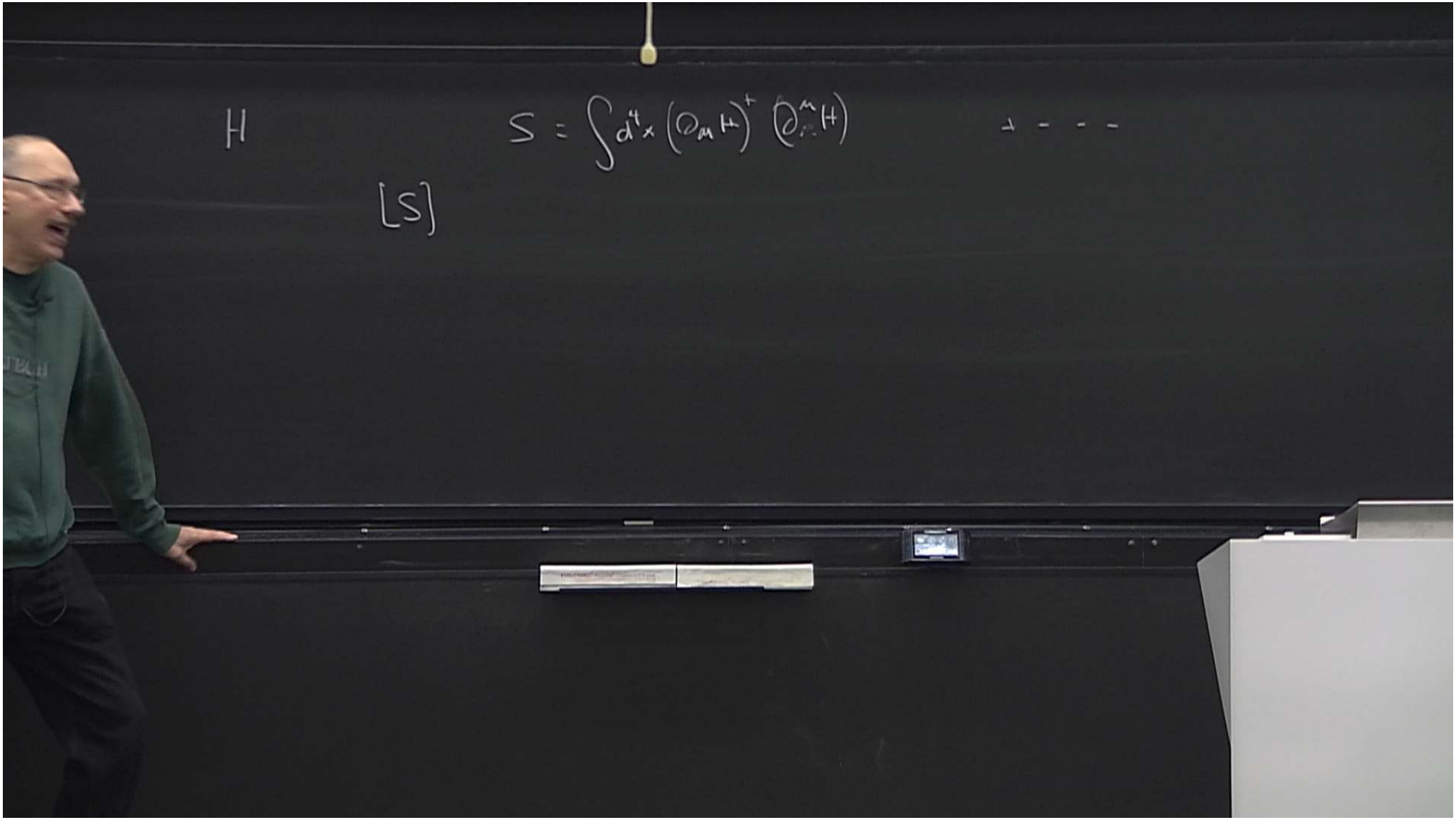

SU(3)c × SU(2) × U(1)
g
g1
SU(2) ×
U(1)
em
"gluons" W±,
H = (H+ H0)
(SU(3), SU(2), U(1)) = (1
CALTECH

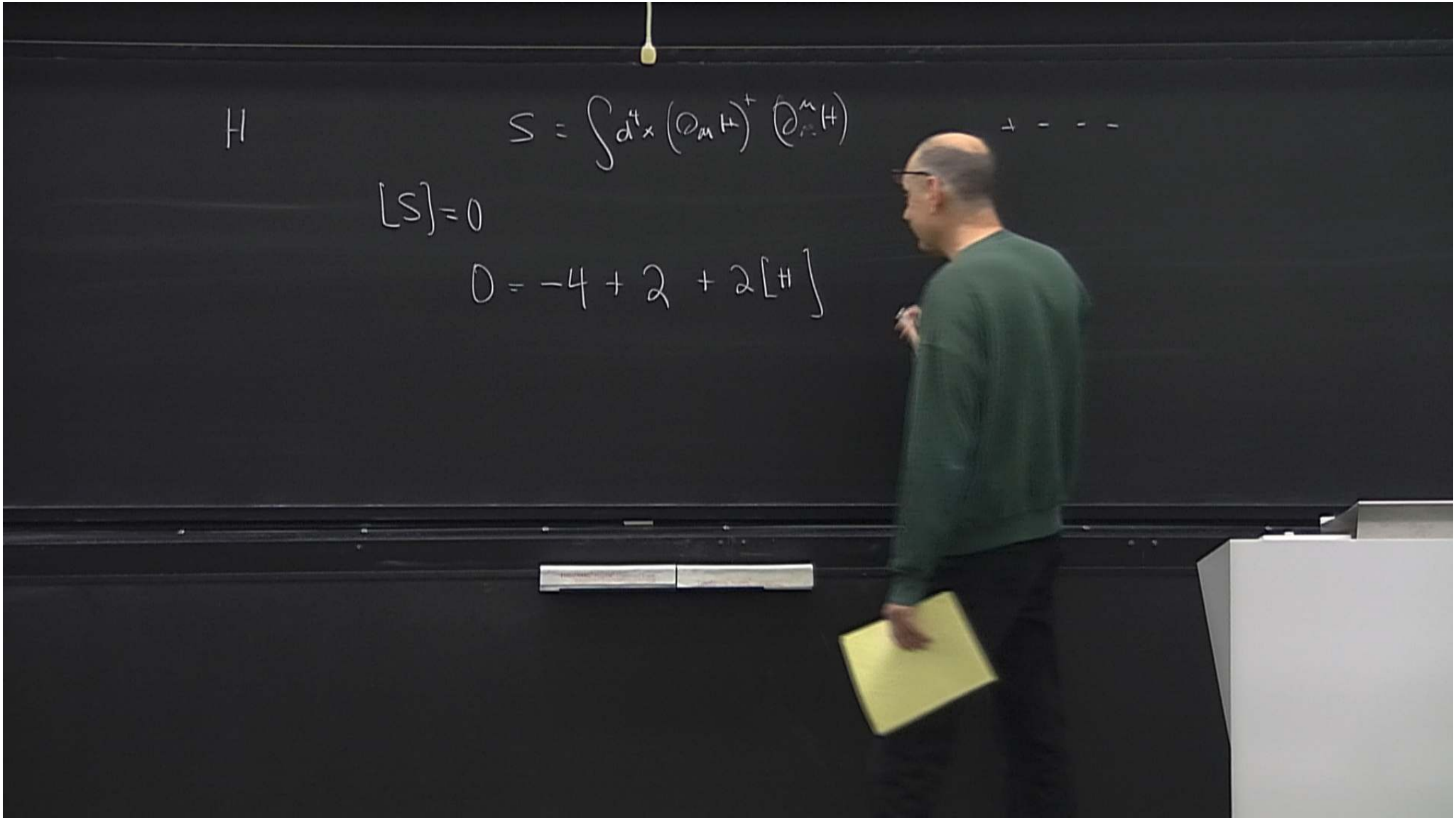

SU(3)c × SU(2) × U(1)
g g2 g1
SU(2) × U(1) → U(1)em
"gluons" W±, Z, γ
H = (H+ H0)
(SU(3), (1
e^{iα^A T^A} (N1 ... Nn) = (N'1 ... N'n)

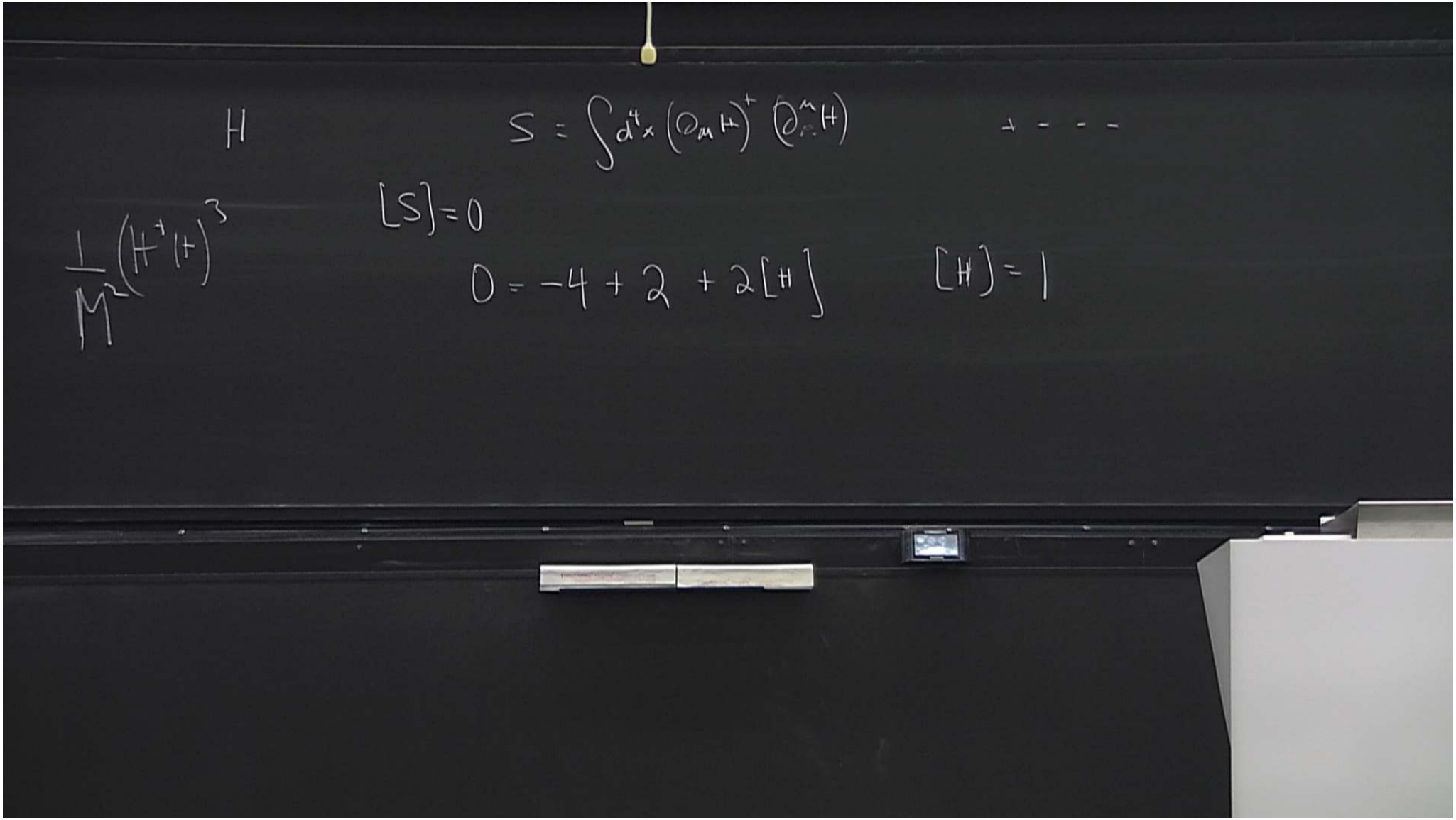

SU(3)c × SU(2) × U(1)
g
SU(2)
U(1)
em
W±, Z
H = (H+ H0)
(SU(3), SU(2), U(1)) = (1, 2, 1/2)
3, 3̄
e^{-iα^A T^A} (N1 ... Nn) = (N'1 ... N'n)

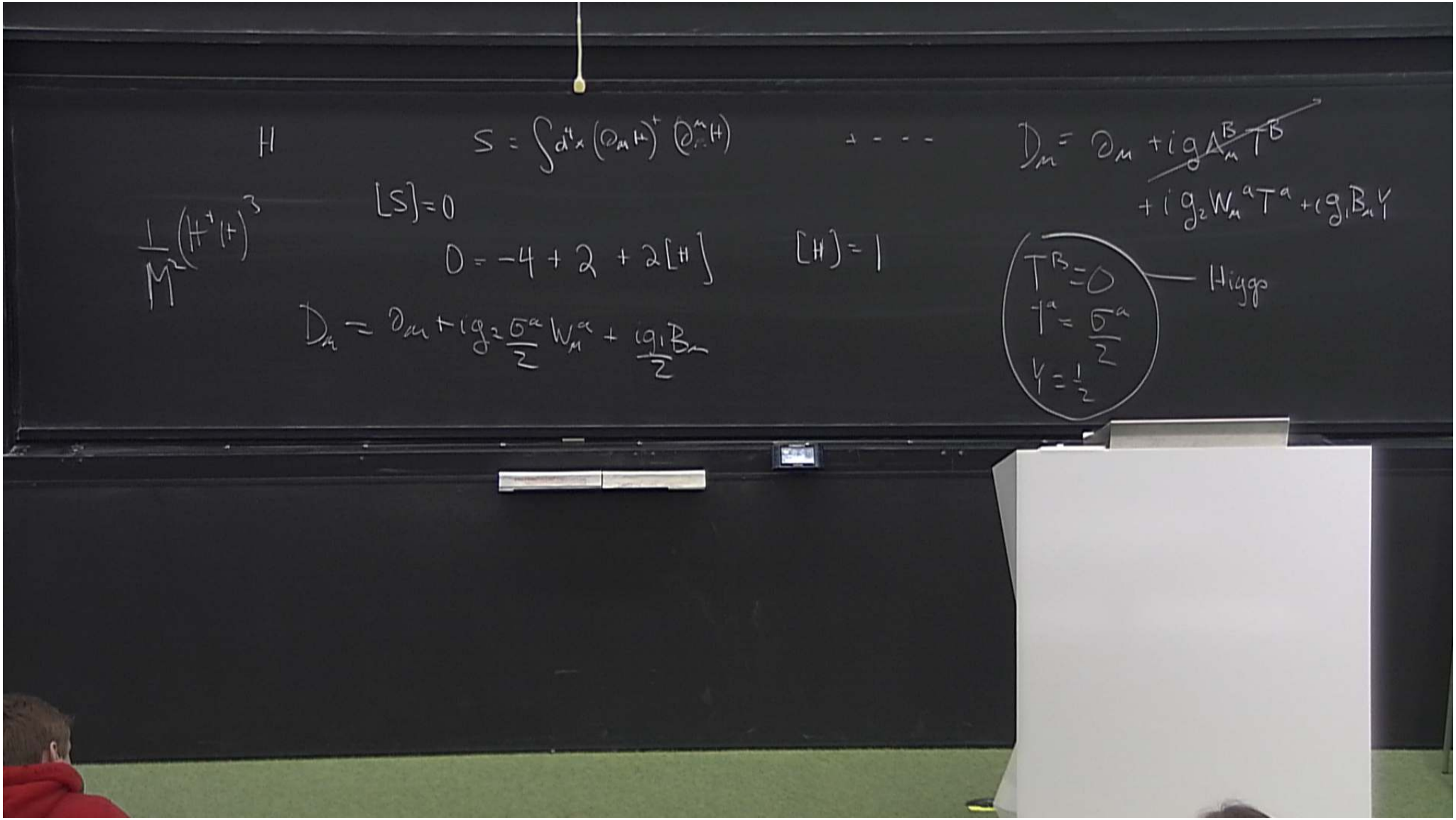

$SU(3)_c \times SU(2) \times U(1)$
g
g_2
$SU(2) \times U($
$U(1)_{em}$
$W^{\pm}, Z$
$H = \begin{pmatrix} H^+ \\ H^0 \end{pmatrix}$
$(SU(3), SU(2), U(1)) = (1, 2, \frac{1}{2})$
$e^{-i\alpha \frac{1}{2}}$
$e^{-i\alpha^a \frac{\sigma^a}{2}}$
$3, \bar{3}$
$e^{-i\alpha^A T^A}$
$\begin{pmatrix} N_1 \\ \vdots \\ N_n \end{pmatrix} = \begin{pmatrix} N_1' \\ \vdots \\ N_n' \end{pmatrix}$

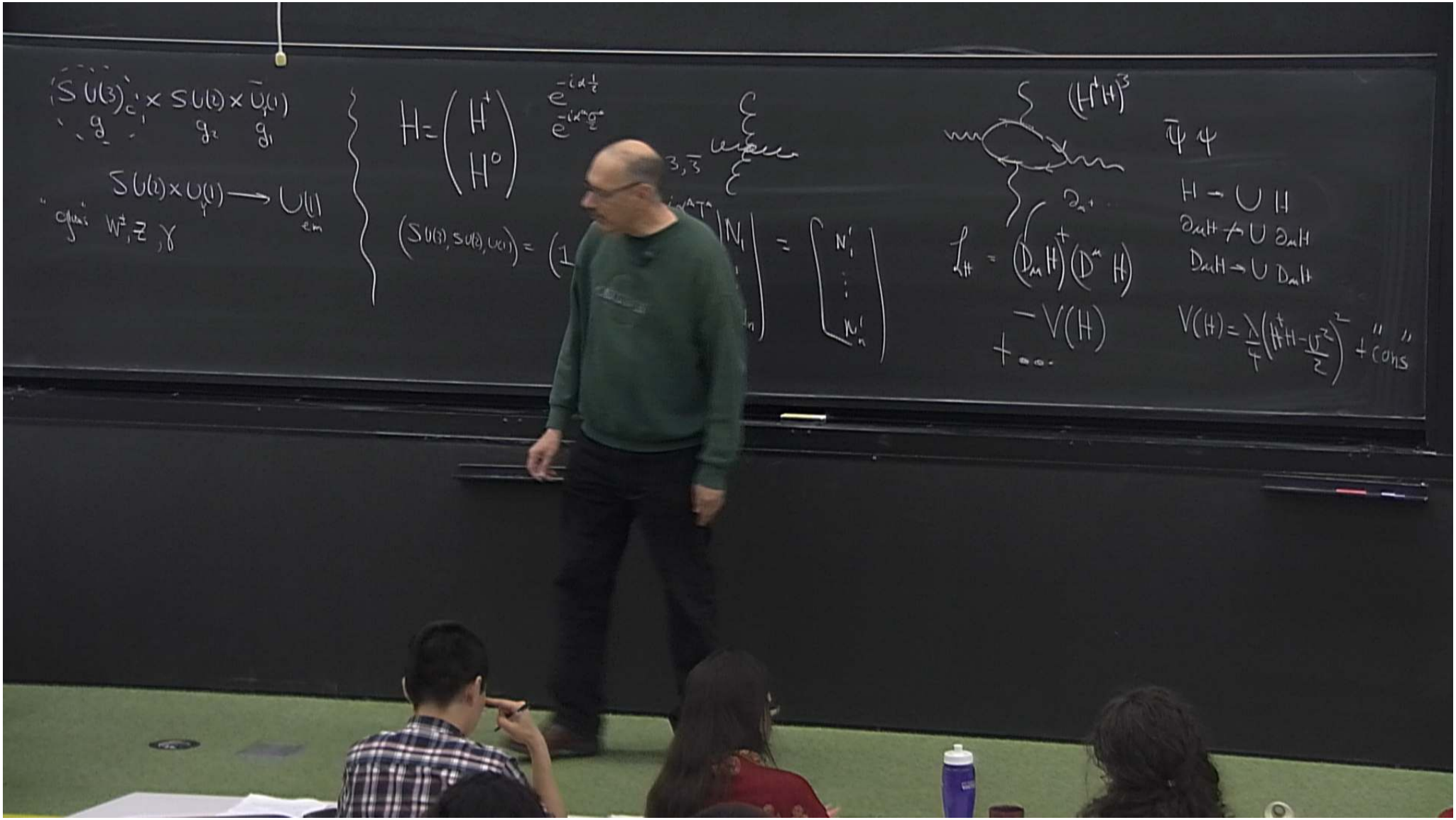



H
$S = \int d^4x \, (\partial_\mu H)^+ (\partial^\mu H)$
[S]


H
$S = \int d^4x \, (\partial_\mu H)^+ (\partial^\mu H)$
+ - - -
$[S] = 0$
$0 = -4 + 2 + 2[H]$


H
$S = \int d^4x \, (\partial_\mu H)^\dagger (\partial^\mu H)$
+ - - -
$\frac{1}{M^2}(H^\dagger H)^3$
$[S] = 0$
$0 = -4 + 2 + 2[H]$
$[H] = 1$


H
$S = \int d^4x \, (\partial_\mu H)^\dagger (\partial^\mu H)$
+ - - -
$D_\mu = \partial_\mu + ig A_\mu^B T^B$
$+ i g_2 W_\mu^a T^a + i g_1 B_\mu Y$
$\frac{1}{M^2}(H^\dagger H)^3$
$[S] = 0$
$0 = -4 + 2 + 2[H]$
$[H] = 1$
$T^B = 0$
$T^a = \frac{\sigma^a}{2}$
$Y = \frac{1}{2}$
Higgs
$D_\mu = \partial_\mu + i g_2 \frac{\sigma^a}{2} W_\mu^a + i g_1 \frac{B_\mu}{2}$


SU(3)c × SU(2) × U(1)
g g2 g1
SU(2) × U(1) → U(1)em
"gauge" W±, Z, γ
H = (H+ H0)
(SU(3), SU(2), U(1)) =
(H+H)3
H → U H
∂μH → U ∂μH
DμH → U DμH
− V(H)
+ ...
V(H) = λ/4 (H+H − v²/2)² + "cons"