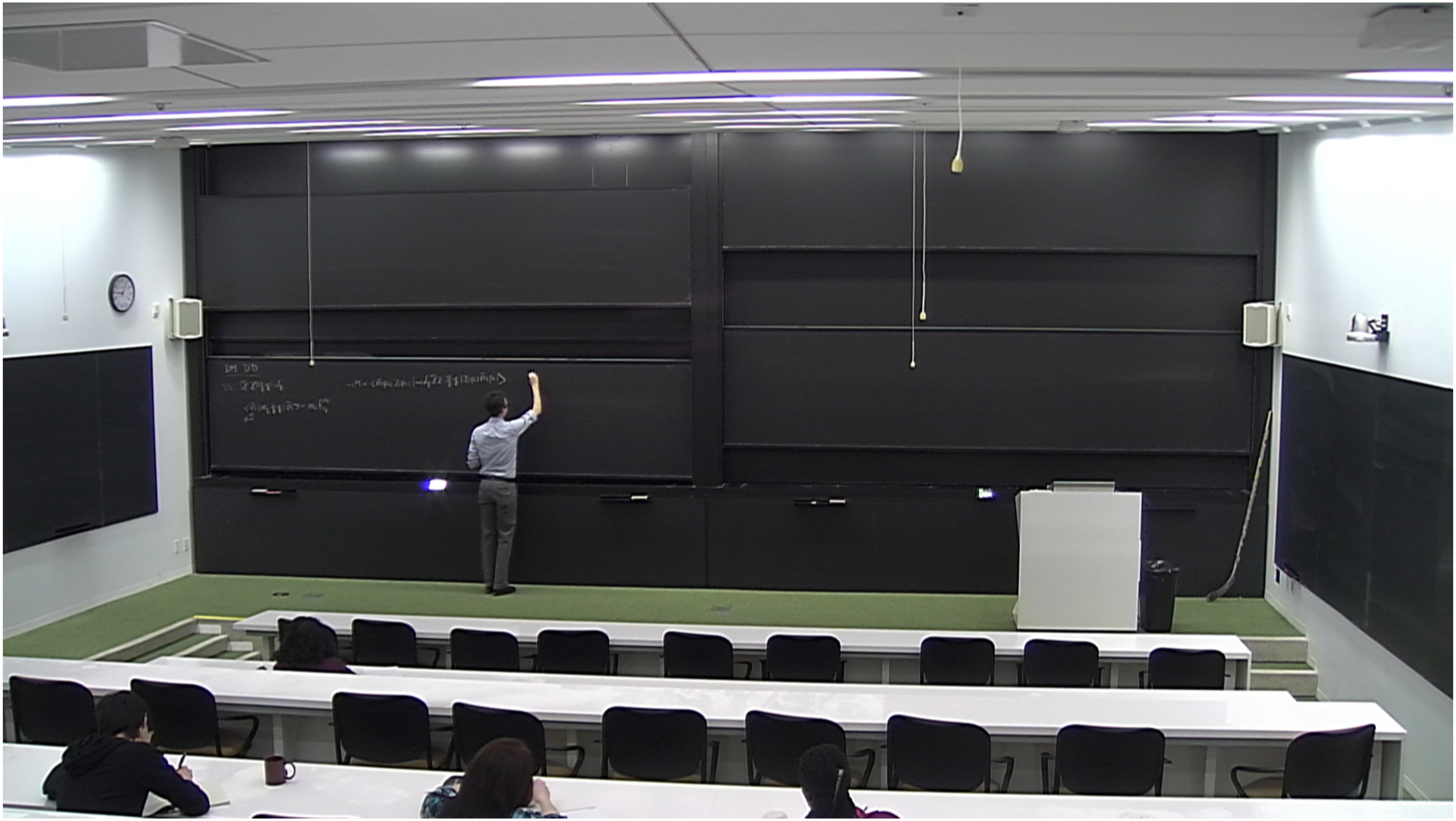
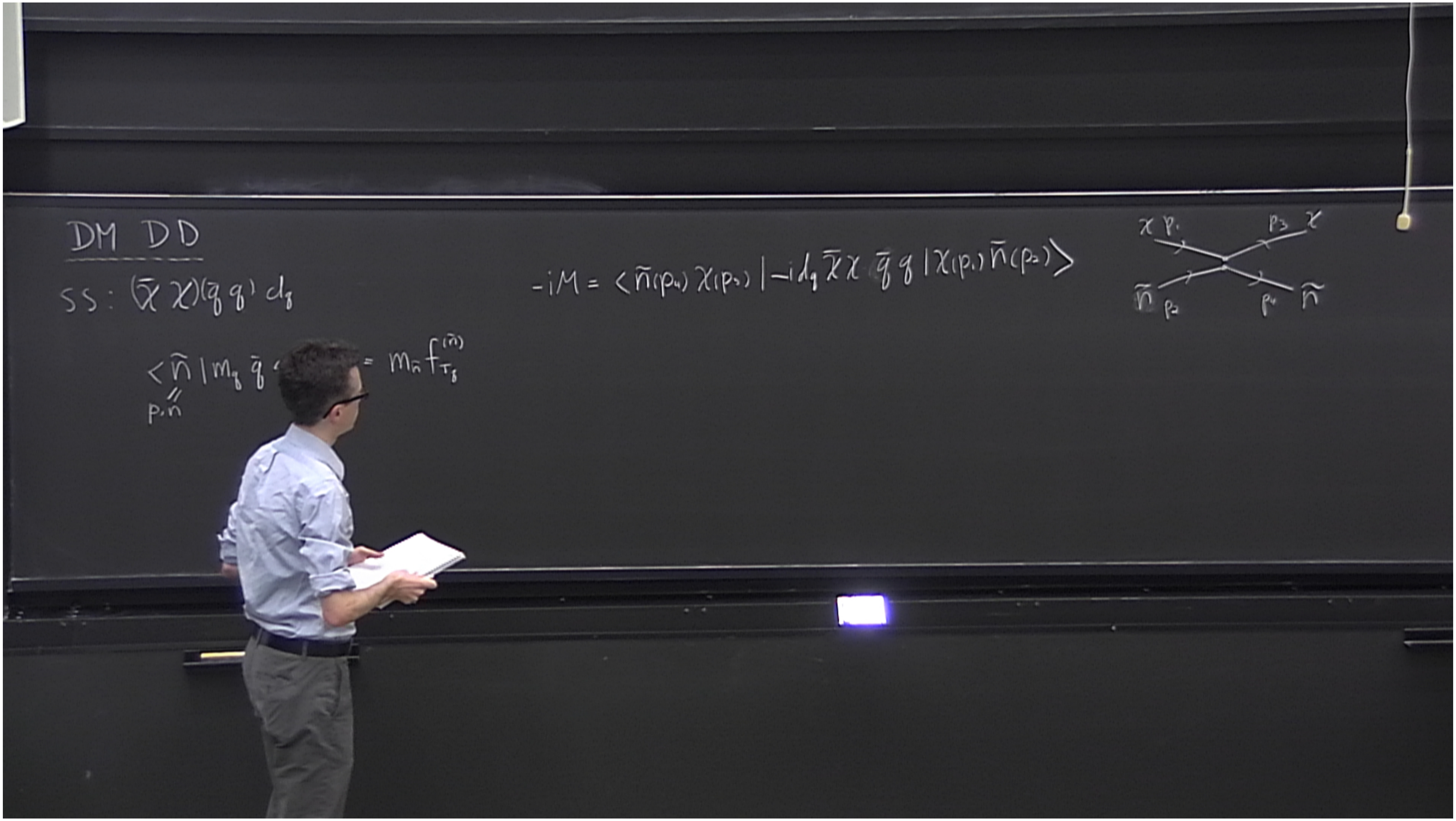
Title: Explorations in Particle Theory - Lecture 8

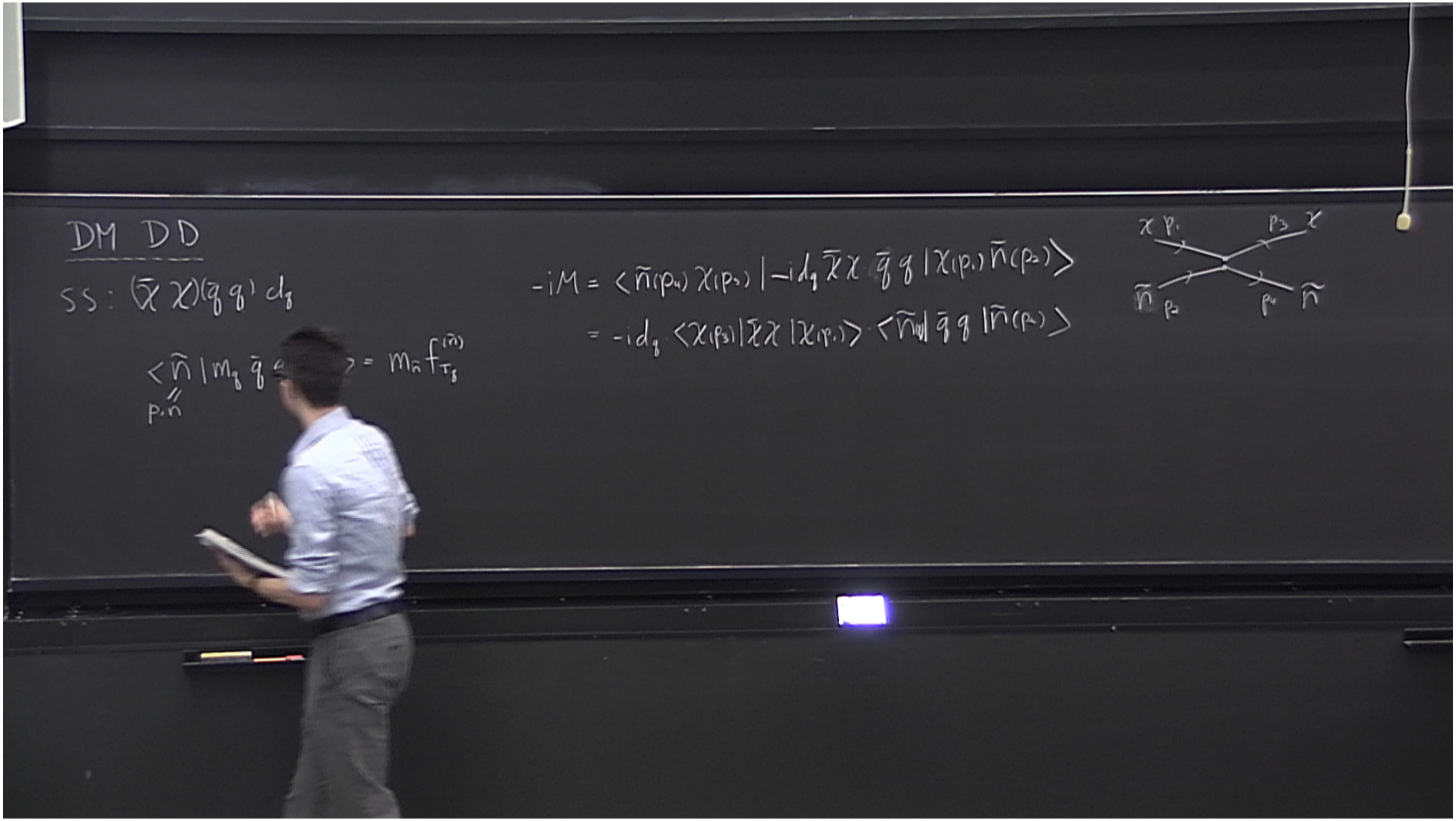
Date: Apr 12, 2012 09:00 AM

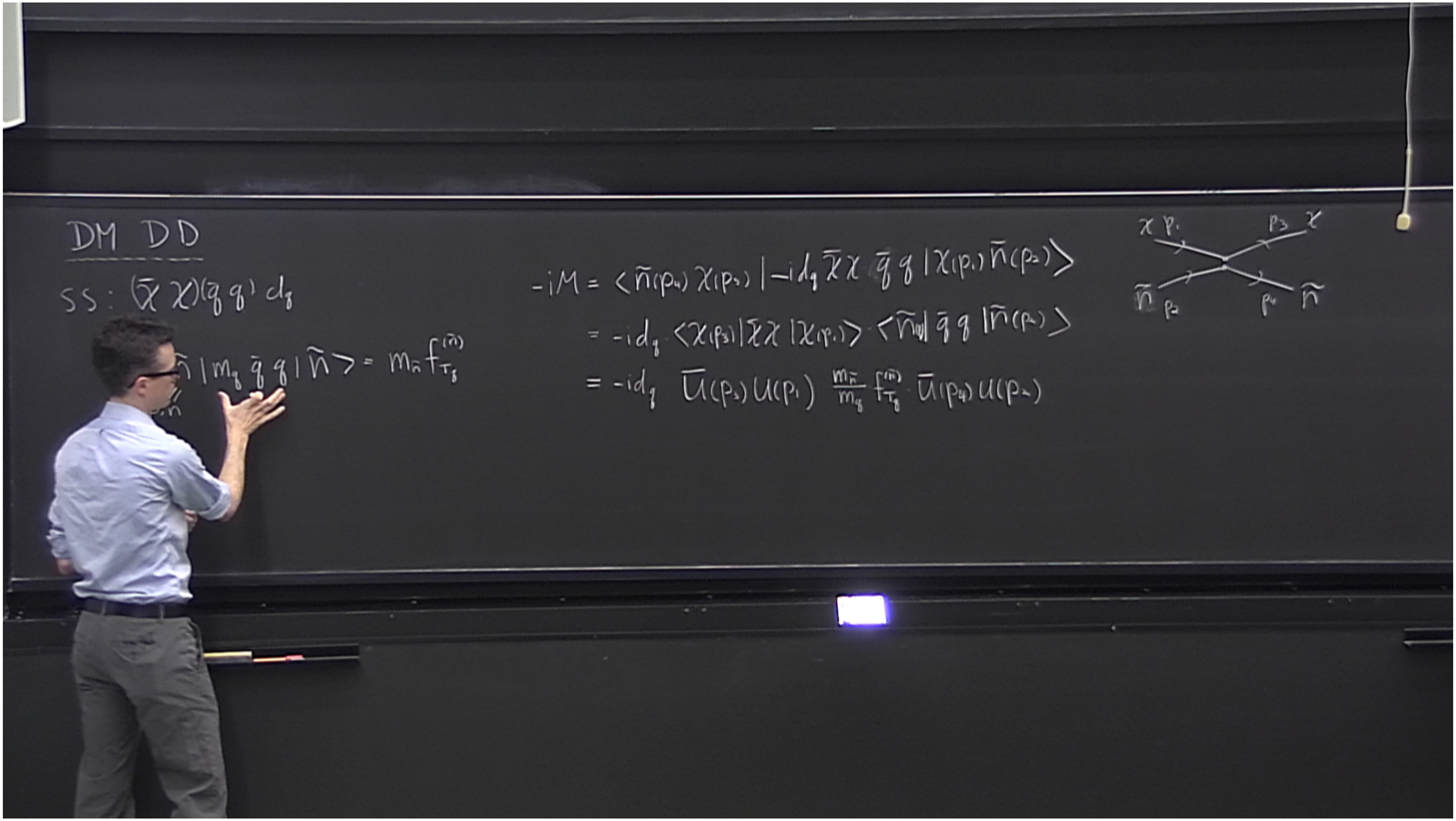
URL: http://pirsa.org/12040010

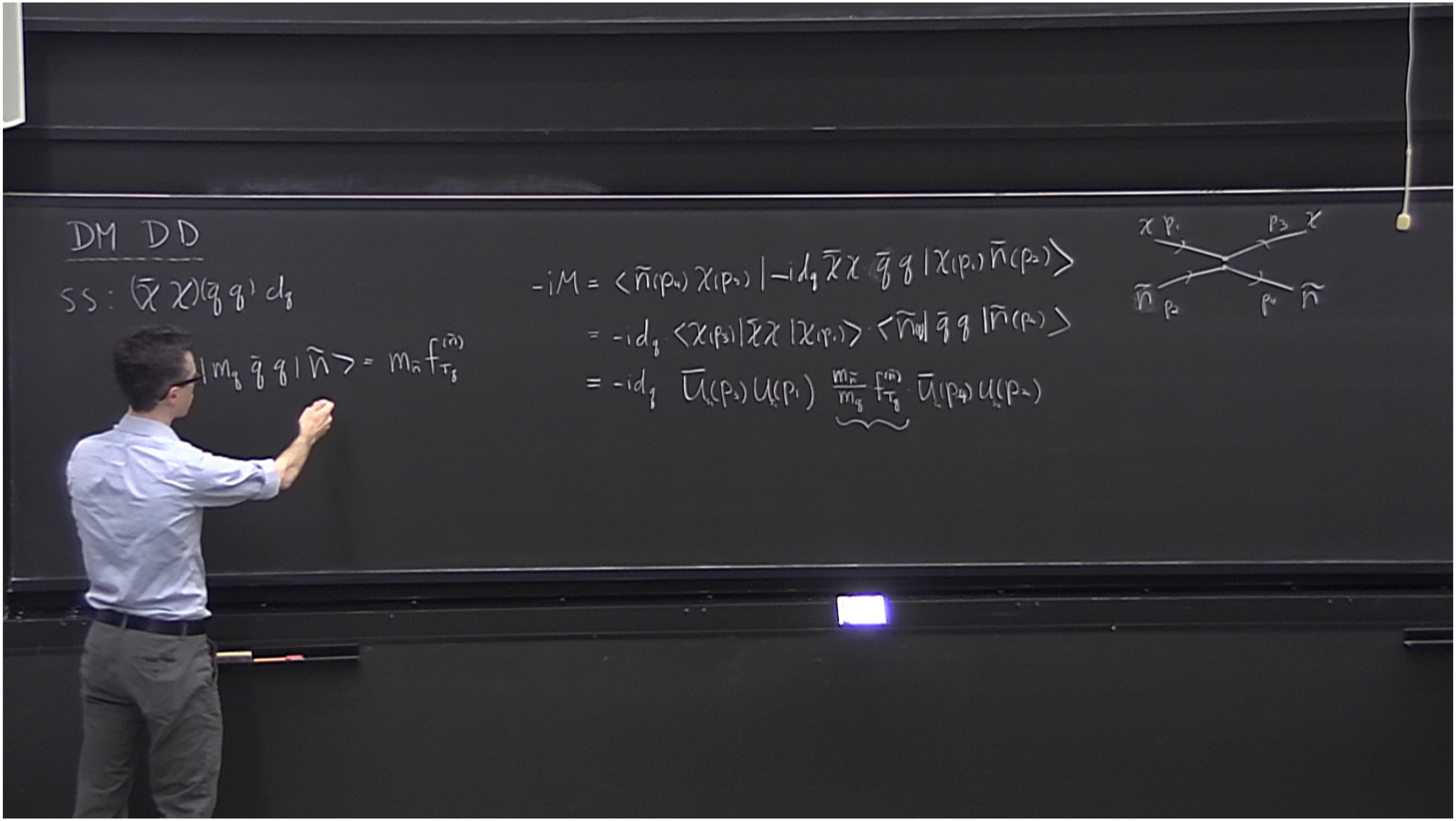
Abstract:

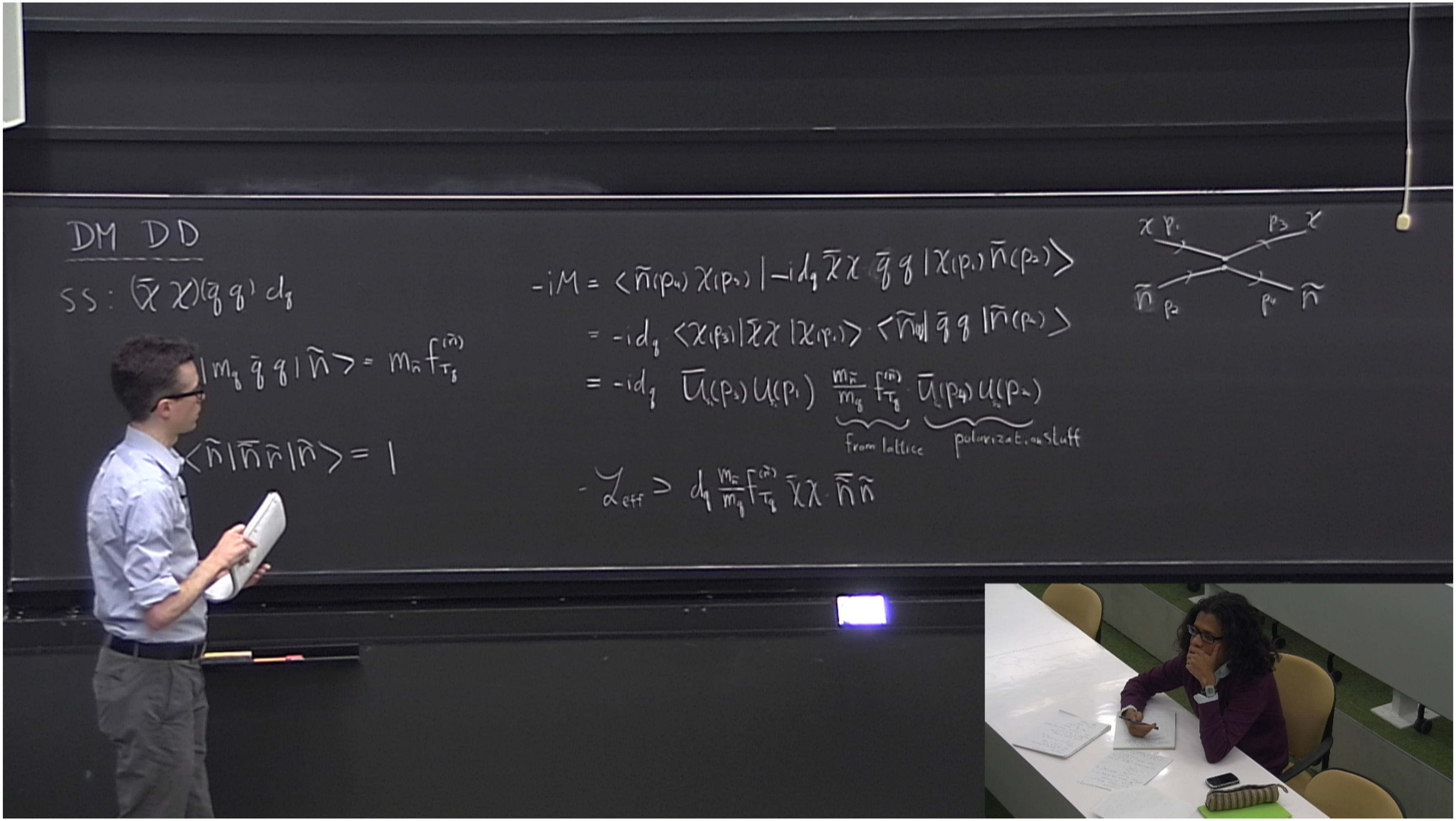


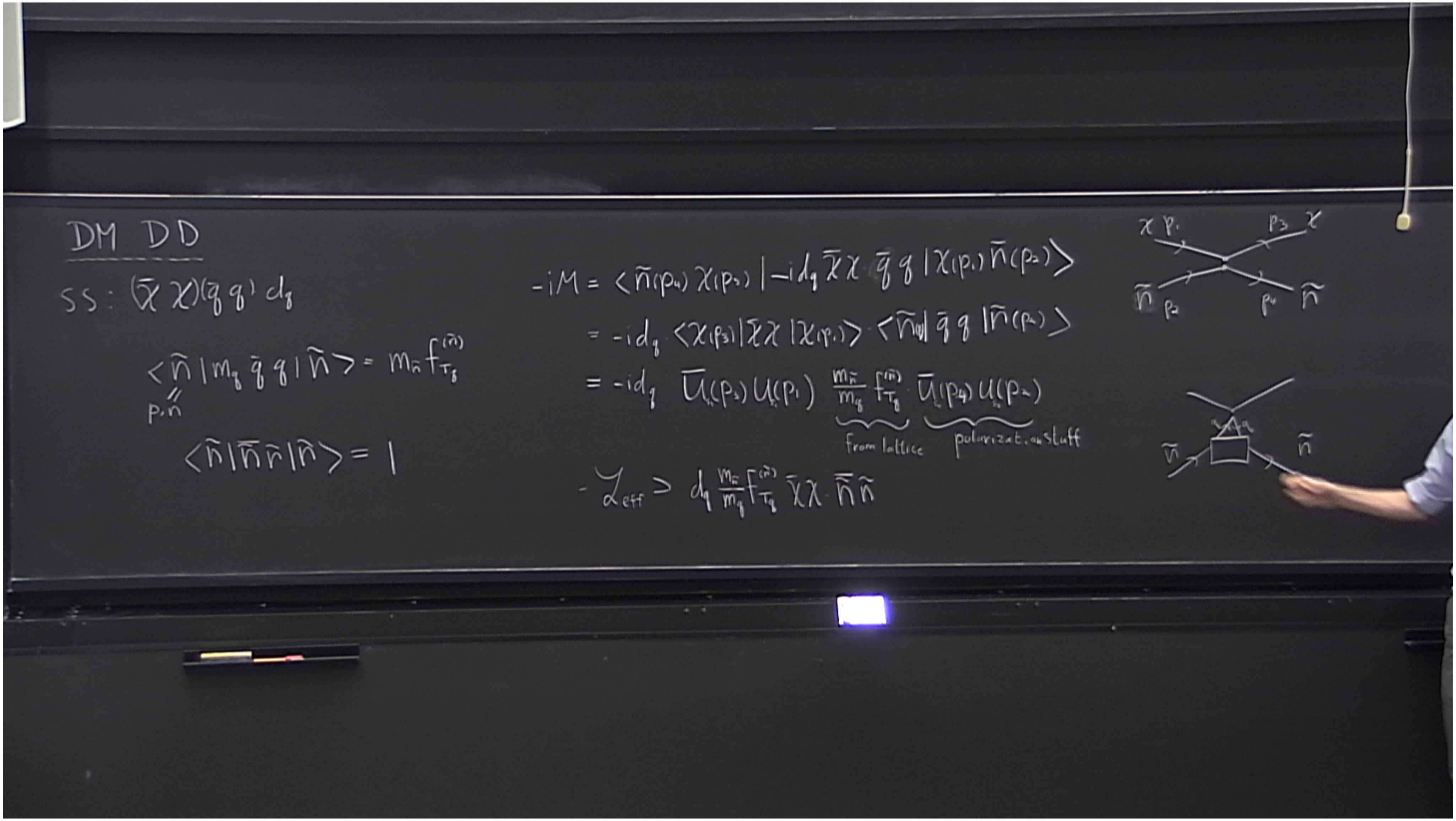

DM DD
SS : (χ̄χ)(q̄q) d_q
-iM = < ñ(p4) χ(p3) | -i d_q χ̄χ q̄q | χ(p1) ñ(p2) >
< ñ | m_q q̄
= m_ñ f_Tq^(ñ)
p, n
χ p1
p3 χ
ñ p2
p4 ñ


DM DD
SS: (χ̄χ)(q̄q) d_q
-iM = ⟨ñ(p4) χ(p3)| -i d_q χ̄χ q̄q |χ(p1) ñ(p2)⟩
= -i d_q ⟨χ(p3)| χ̄χ |χ(p1)⟩ ⟨ñ(p4)| q̄q |ñ(p2)⟩

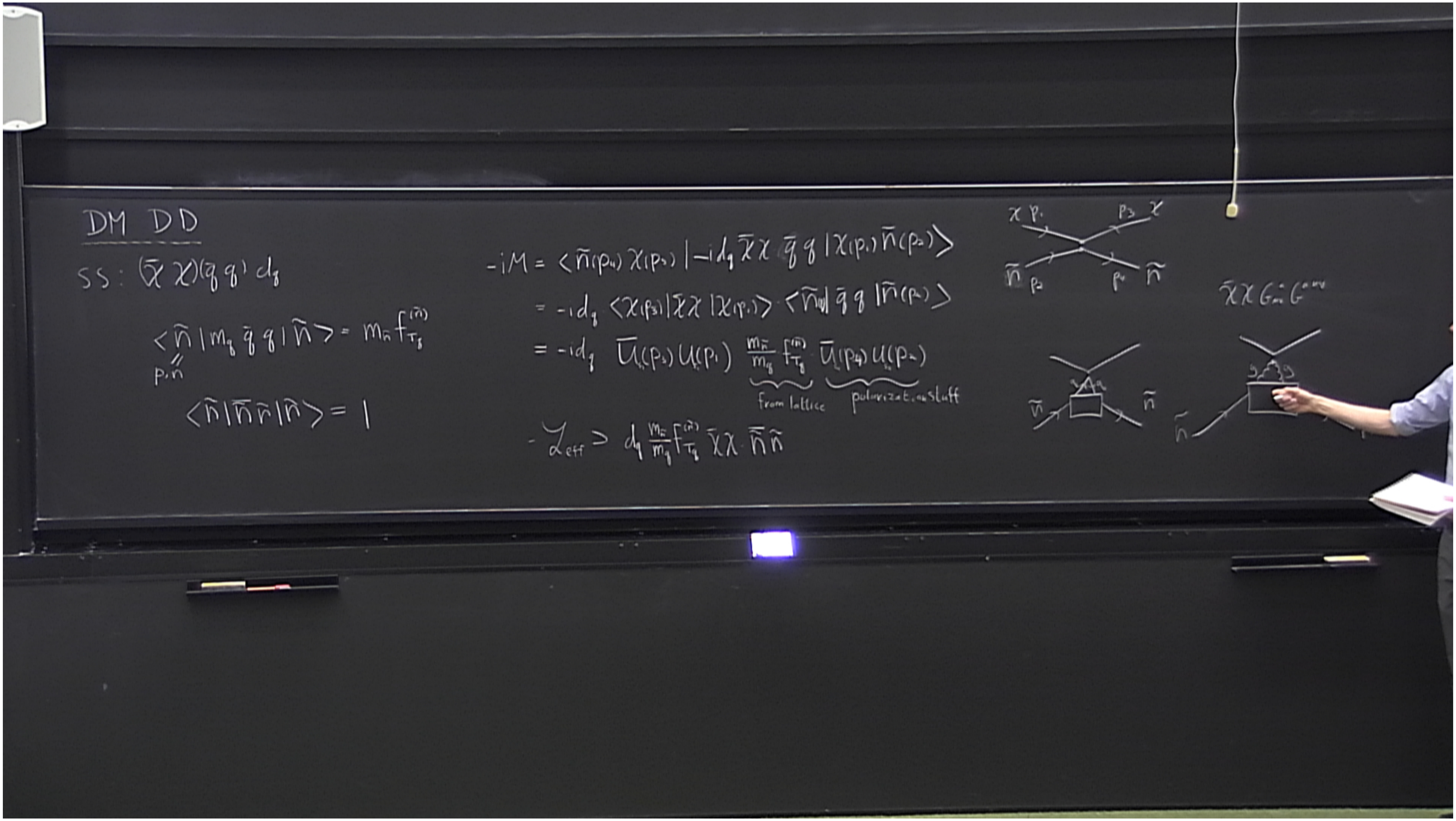

DM DD
SS: $(\bar{\chi}\chi)(\bar{q}q)\, d_q$
$-iM = \langle \tilde{n}(p_4)\chi(p_3) | -i d_q \bar{\chi}\chi \bar{q}q | \chi(p_1)\tilde{n}(p_2) \rangle$
$= -i d_q \langle \chi(p_3)|\bar{\chi}\chi|\chi(p_1)\rangle \langle \tilde{n}(p_4)|\bar{q}q|\tilde{n}(p_2)\rangle$
$= -i d_q\, \bar{u}(p_3)u(p_1) \frac{m_{\tilde{n}}}{m_q} f_{T_q}^{(\tilde{n})} \bar{u}(p_4)u(p_2)$
$m_{\tilde{n}} f_{T_q}^{(\tilde{n})}$
χ p_1 p_3 χ
$\tilde{n}$ p_2 p_4 $\tilde{n}$

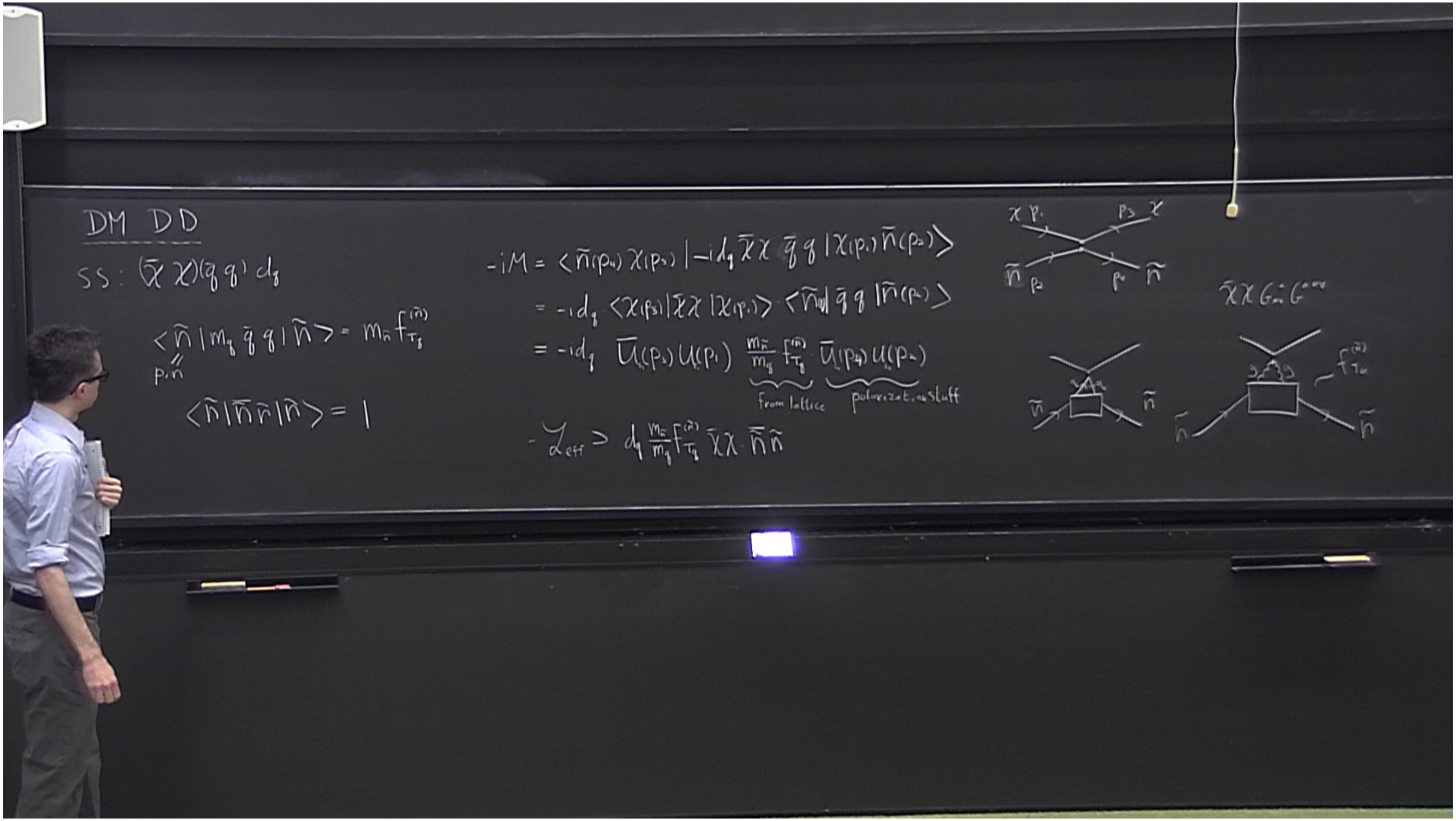

DM DD
SS : (χ̄χ)(q̄q) d_q
|m_q q̄ q | ñ > = m_ñ f_{T_q}^{(ñ)}
-iM = < ñ(p4) χ(p3) | -i d_q χ̄χ q̄ q | χ(p1) ñ(p2) >
= -i d_q < χ(p3) | χ̄χ | χ(p1) > < ñ(p4) | q̄ q | ñ(p2) >
= -i d_q ū(p3) u(p1) m_ñ/m_q f_{T_q}^{(ñ)} ū(p4) u(p2)
χ p1
p3 χ
ñ p2
p4 ñ

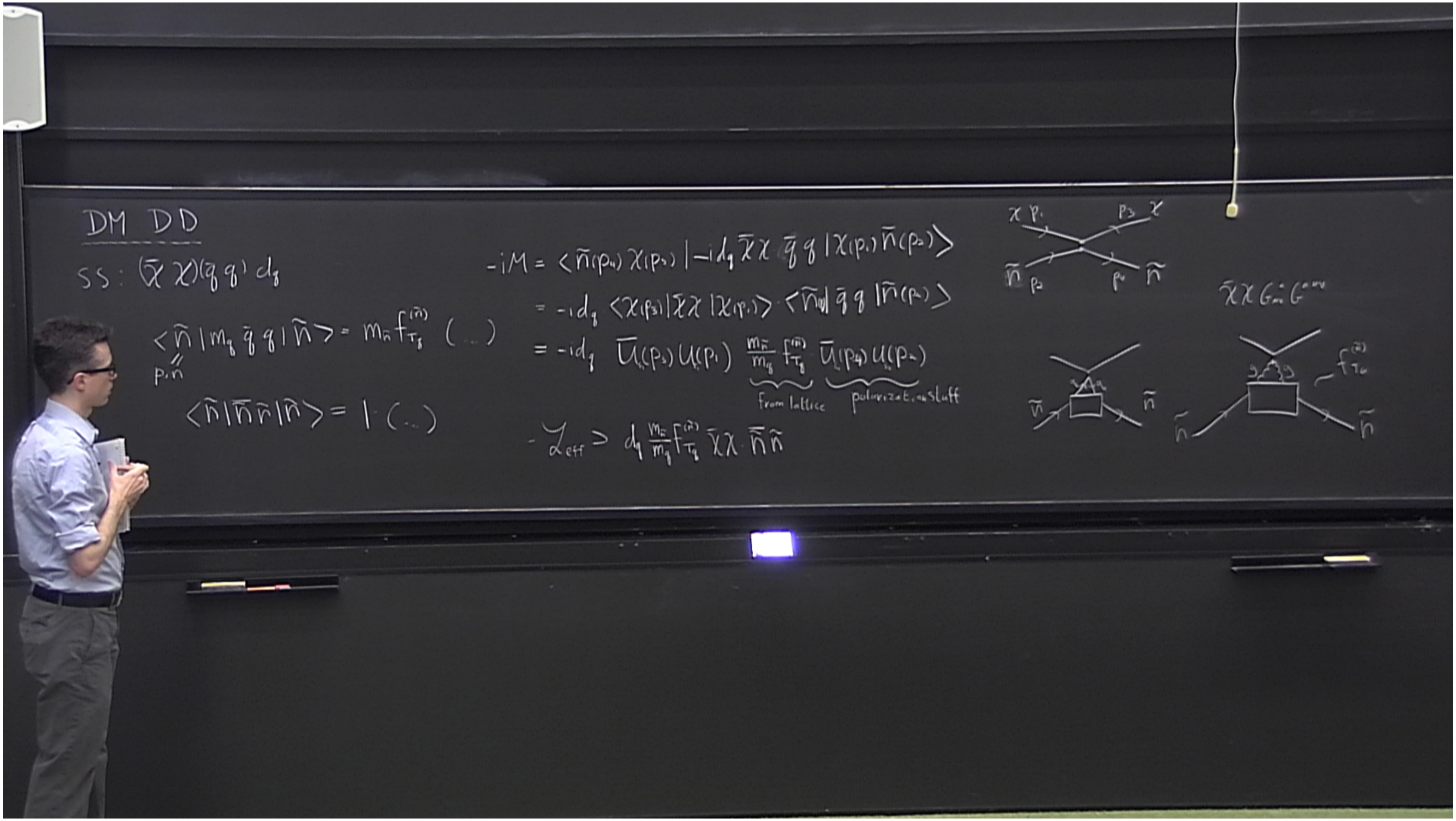

DM DD
SS : (χ̄χ)(q̄q) d_q
|m_q q̄ q | ñ> = m_ñ f_{T_q}^{(ñ)}
<ñ | ñ̄ ñ | ñ> = 1
-iM = <ñ(p_4) χ(p_3) | -i d_q χ̄χ q̄q | χ(p_1) ñ(p_2)>
= -i d_q <χ(p_3) | χ̄χ | χ(p_1)> <ñ(p_4) | q̄q | ñ(p_2)>
= -i d_q ū(p_3) u(p_1) (m_ñ/m_q) f_{T_q}^{(ñ)} ū(p_4) u(p_2)
from lattice
polarization stuff
-L_eff ⊃ d_q (m_ñ/m_q) f_{T_q}^{(ñ)} χ̄χ ñ̄ñ

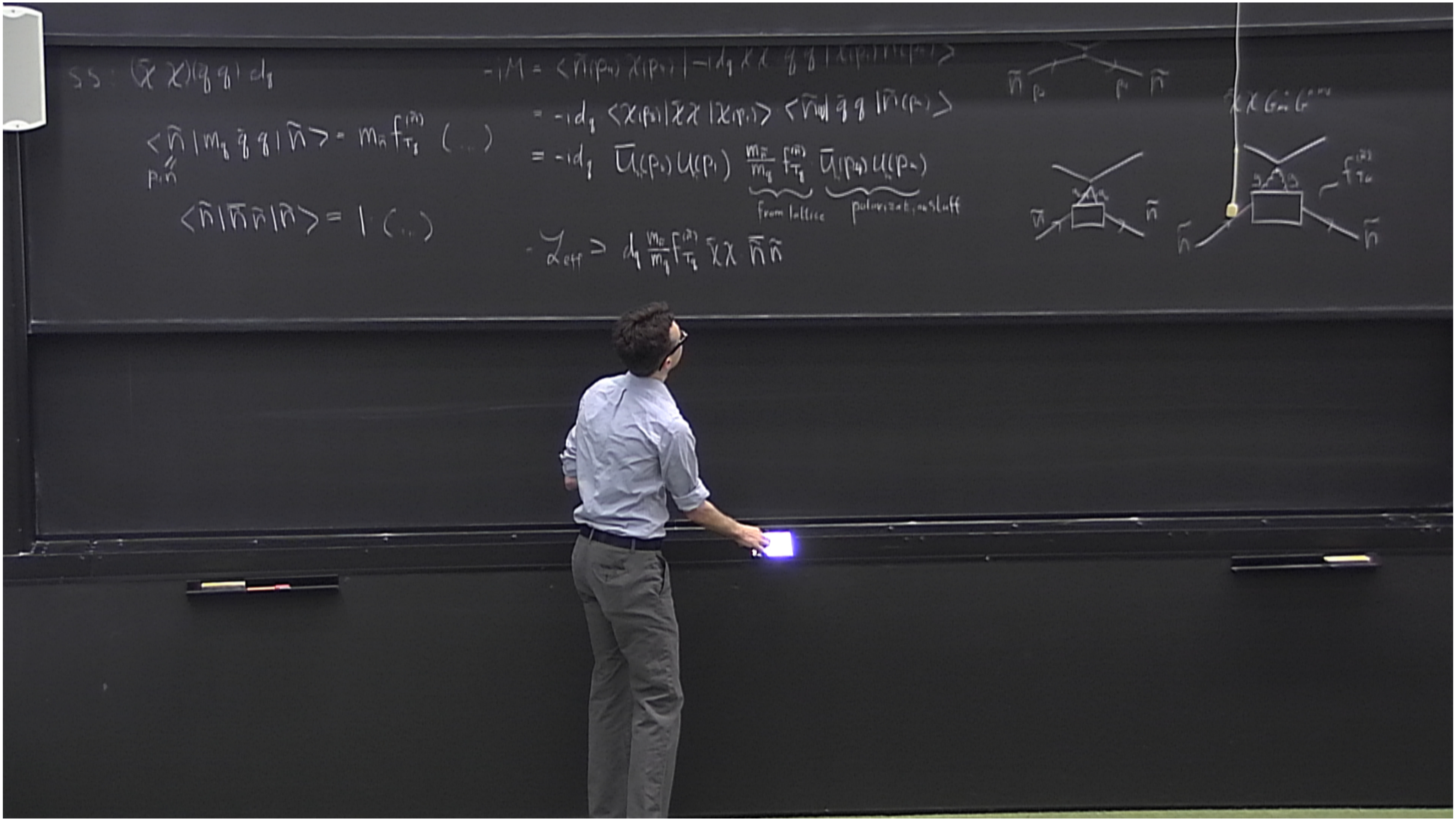


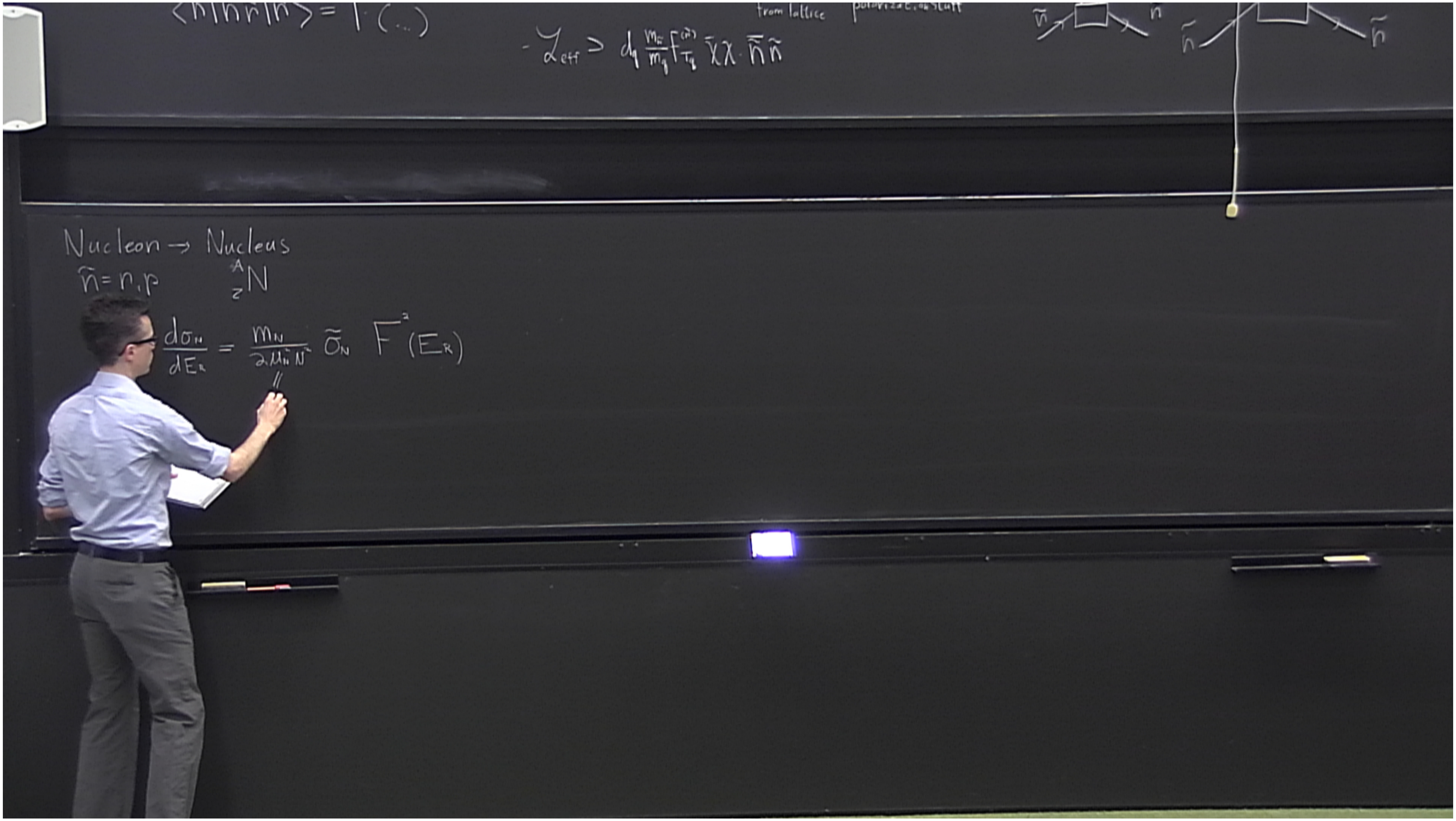
DM DD
SS: $(\bar{\chi}\chi)(\bar{q}q)\,d_q$
$\langle \tilde{n} | m_q \bar{q} q | \tilde{n} \rangle = m_{\tilde{n}} f_{T_q}^{(\tilde{n})}$
p.n
$\langle \tilde{n} | \bar{\tilde{n}} \tilde{n} | \tilde{n} \rangle = 1$
$-iM = \langle \tilde{n}(p_4)\,\chi(p_3) | -i d_q \bar{\chi}\chi\, \bar{q} q | \chi(p_1)\, \tilde{n}(p_2) \rangle$
$= -i d_q \langle \chi(p_3) | \bar{\chi}\chi | \chi(p_1) \rangle \langle \tilde{n}(p_4) | \bar{q} q | \tilde{n}(p_2) \rangle$
$= -i d_q\, \bar{u}(p_3)\, u(p_1)\, \frac{m_{\tilde{n}}}{m_q} f_{T_q}^{(\tilde{n})}\, \bar{u}(p_4)\, u(p_2)$
from lattice
polarization stuff
$-\mathcal{L}_{eff} \supset d_q \frac{m_{\tilde{n}}}{m_q} f_{T_q}^{(\tilde{n})} \bar{\chi}\chi\, \bar{\tilde{n}}\tilde{n}$
χ p1
p3 χ
ñ p2
p4 ñ
ñ
ñ


DM DD
SS: (χ̄χ)(q̄q) d_q
⟨ñ| m_q q̄q |ñ⟩ = m_ñ f_{T_q}^{(n)}
⟨ñ|ñ̄ñ|ñ⟩ = 1
-iM = ⟨ñ(p_4) χ(p_3)| -i d_q χ̄χ q̄q |χ(p_1) ñ(p_2)⟩
= -i d_q ⟨χ(p_3)|χ̄χ|χ(p_1)⟩ ⟨ñ(p_4)| q̄q |ñ(p_2)⟩
= -i d_q ū(p_3) u(p_1) (m_ñ/m_q) f_{T_q}^{(n)} ū(p_4) u(p_2)
from lattice
polarization stuff
-ℒ_eff ⊃ d_q (m_ñ/m_q) f_{T_q}^{(n)} χ̄χ ñ̄ñ
χ̄χ G_{μν} G^{μν}

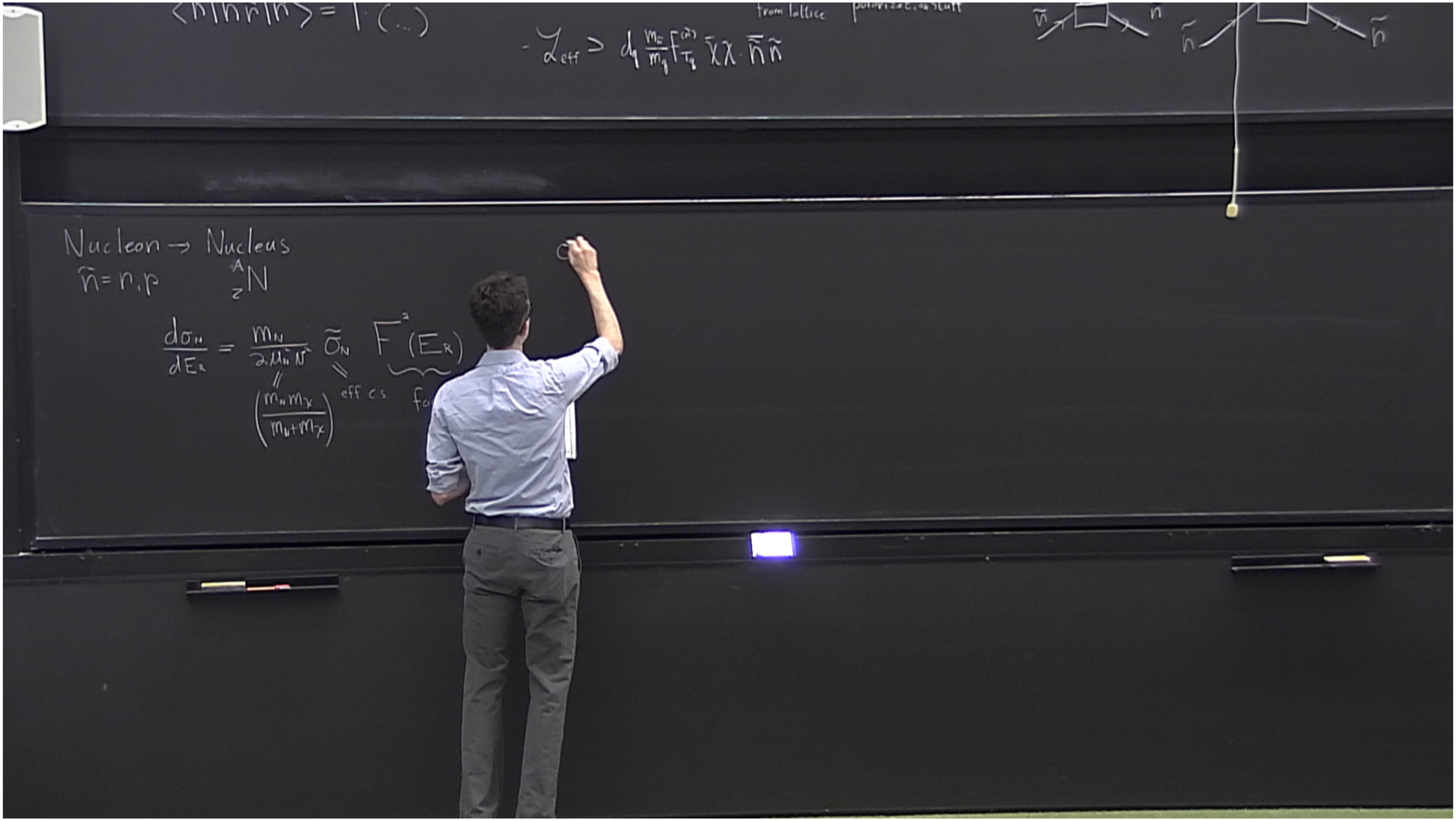

DM DD
from lattice
polarization stuff

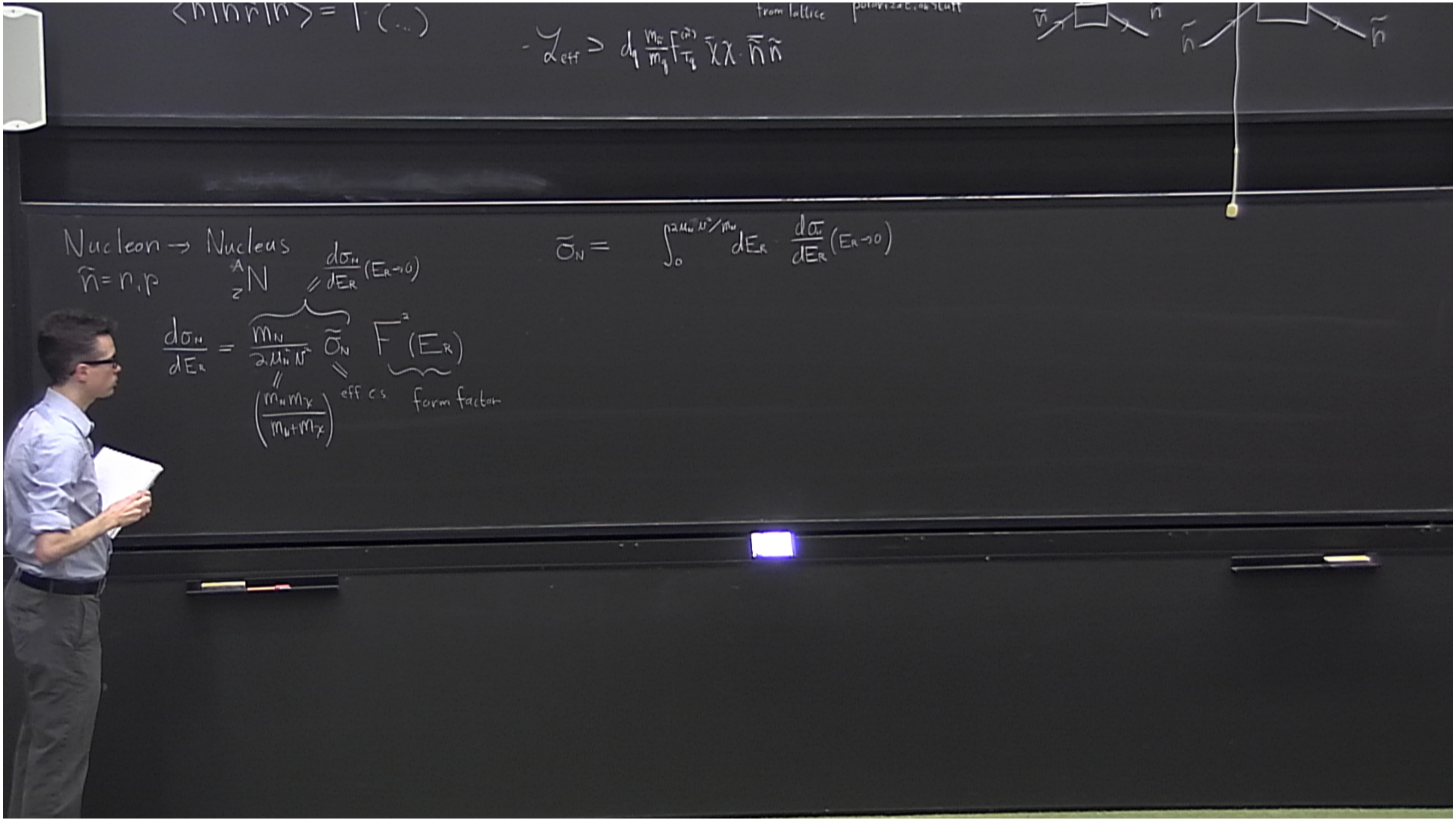

DM DD
SS: (χ̄χ)(q̄q) d_q
⟨ñ | m_q q̄q | ñ⟩ = m_ñ f_{Tq}^{(ñ)} (...)
p, n
⟨ñ | ñ̄ñ | ñ⟩ = 1 · (...)
-iM = ⟨ñ(p4) χ(p3) | -i d_q χ̄χ q̄q | χ(p1) ñ(p2)⟩
= -i d_q ⟨χ(p3) | χ̄χ | χ(p1)⟩ ⟨ñ(p4) | q̄q | ñ(p2)⟩
= -i d_q ū(p3) u(p1) (m_ñ / m_q) f_{Tq}^{(ñ)} ū(p4) u(p2)
from lattice
polarization stuff
-L_eff ⊃ d_q (m_ñ / m_q) f_{Tq}^{(ñ)} χ̄χ ñ̄ñ
χ p1
p3 χ
ñ p2
p4 ñ
χ̄χ G G^{μν}
f_{TG}^{(ñ)}

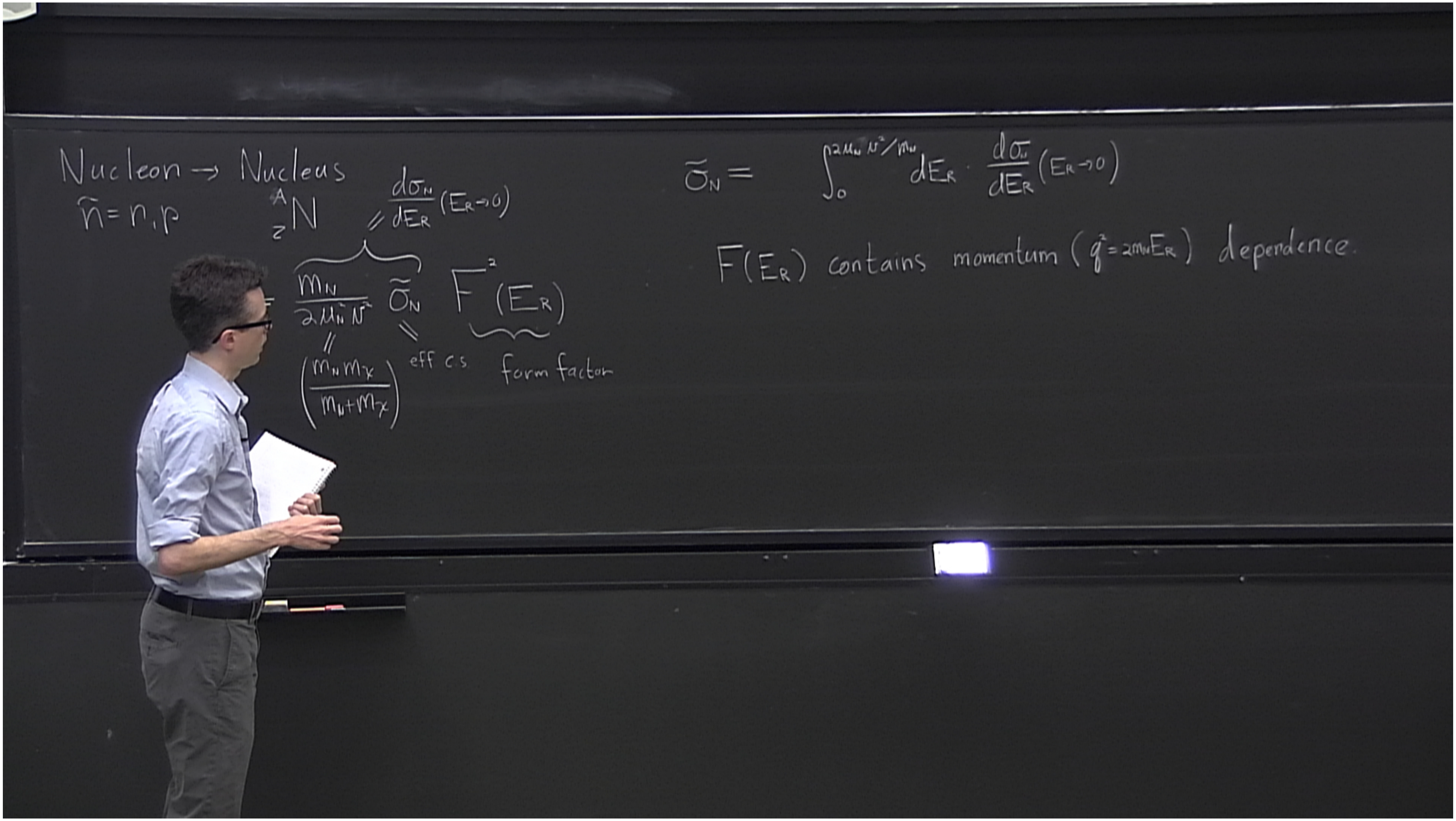

from lattice
polarization stuff

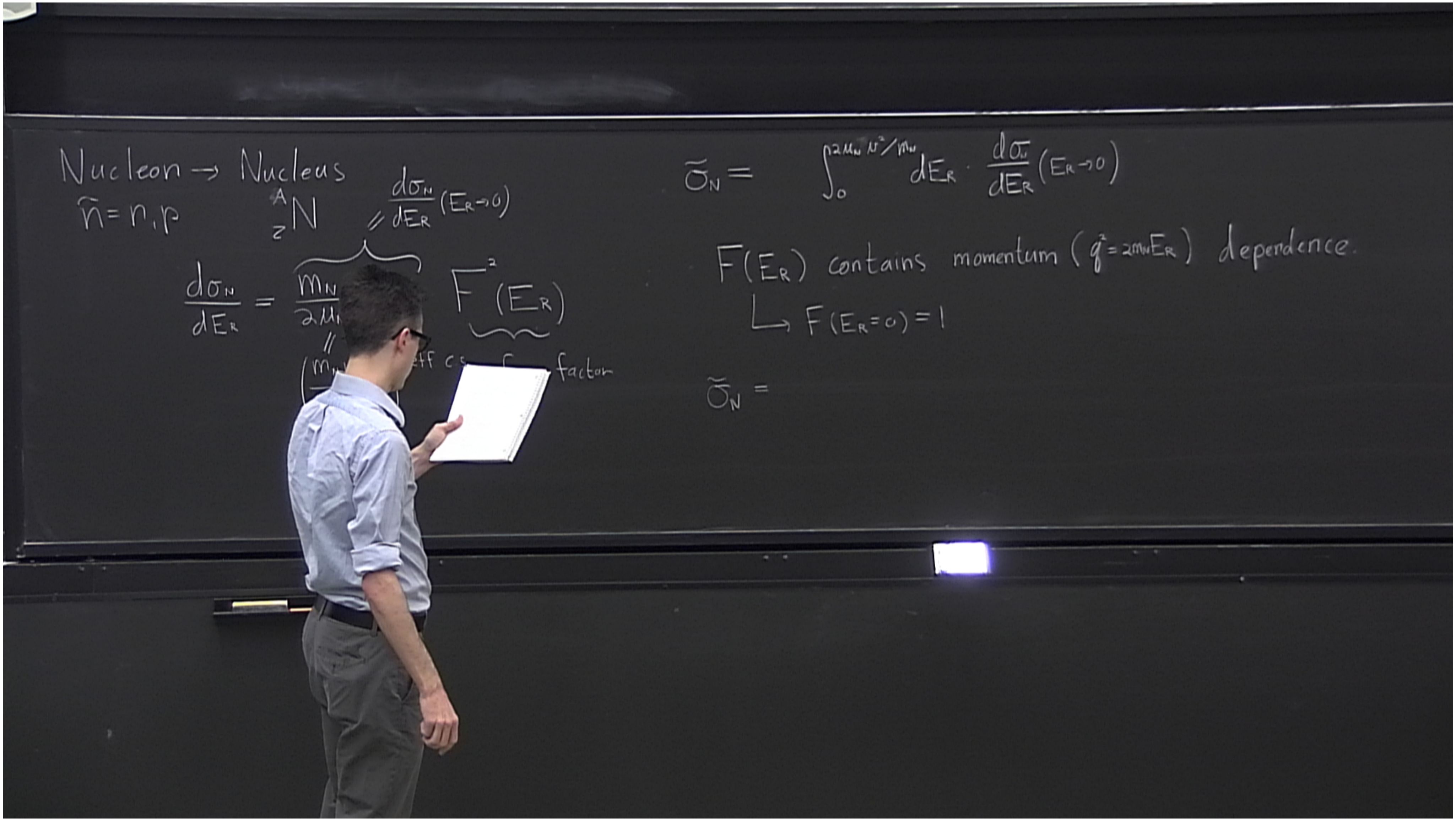


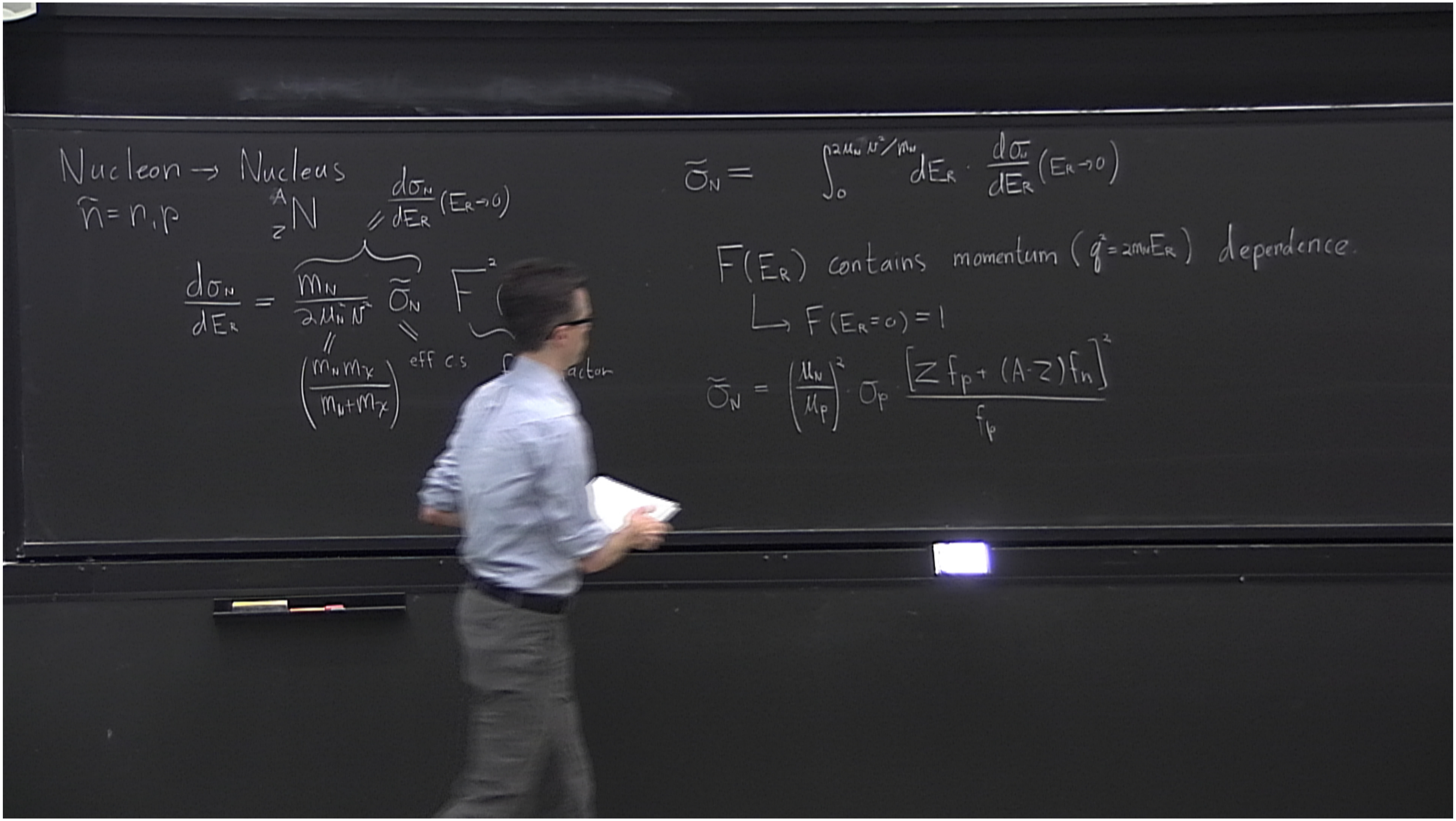
from lattice
Nucleon → Nucleus
ñ = n, p

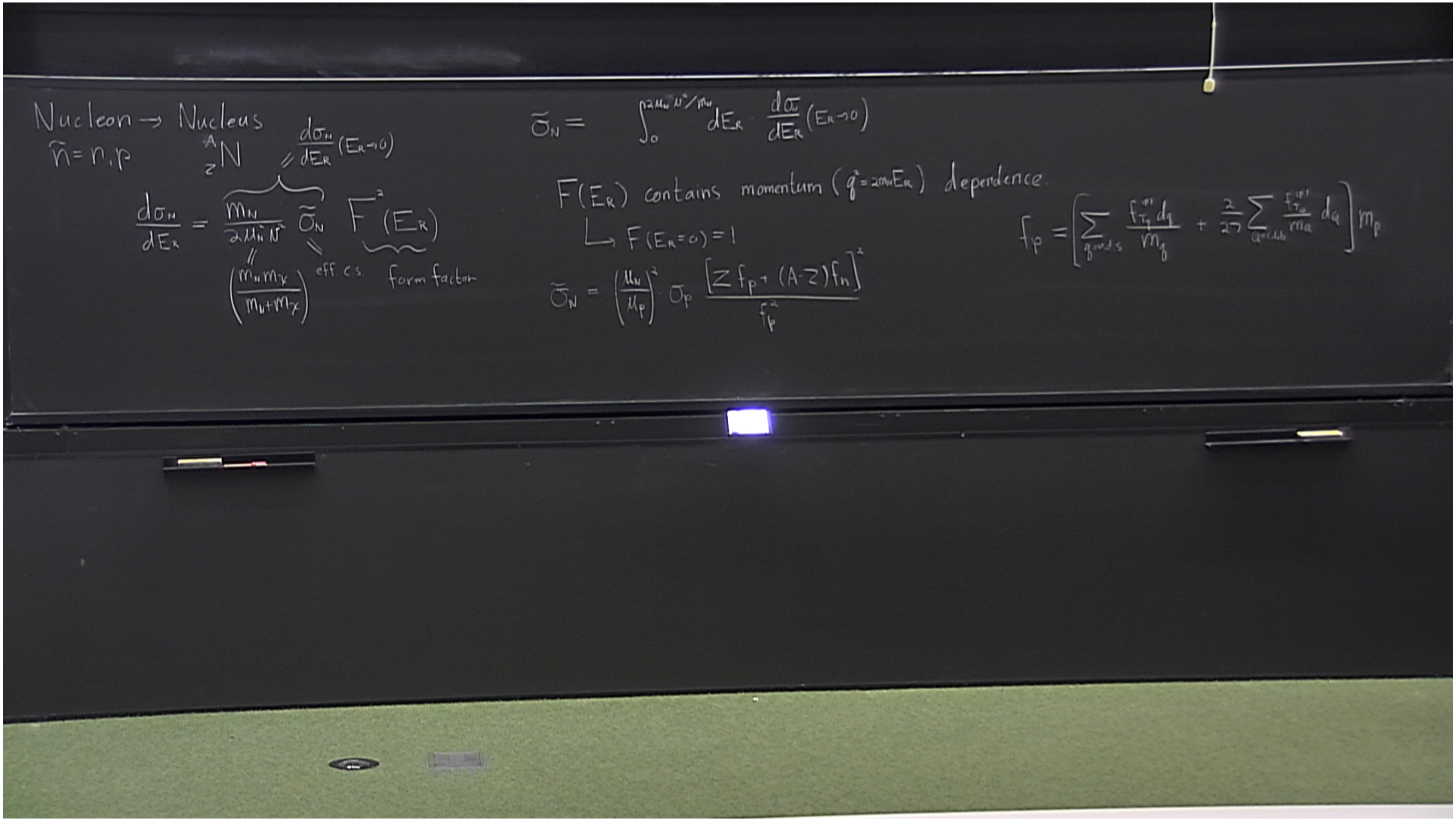

$-\mathcal{L}_{eff} \supset d_q \frac{m_n}{m_q} f^{(n)}_{T_q} \bar{\chi}\chi \cdot \bar{\tilde{n}}\tilde{n}$
Nucleon → Nucleus
$\tilde{n} = n, p$
${}^A_Z N$
$\frac{d\sigma_N}{dE_R} = \frac{m_N}{2\mu_N^2} \tilde{\sigma}_N F^2(E_R)$
$\left(\frac{m_N m_\chi}{m_N + m_\chi}\right)$
eff c.s.

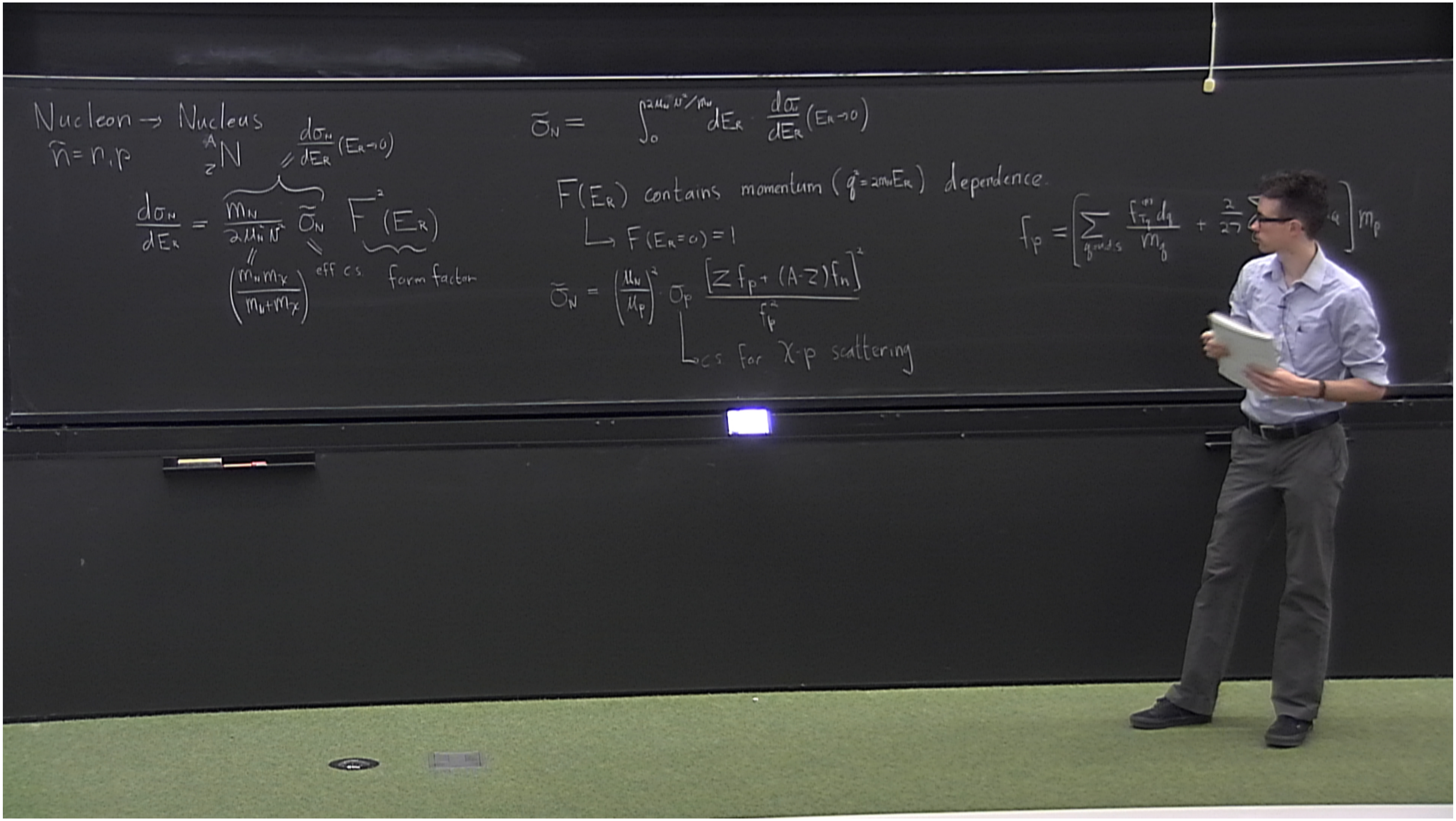

from lattice
Nucleon → Nucleus
ñ = n, p
form factor
eff c.s.

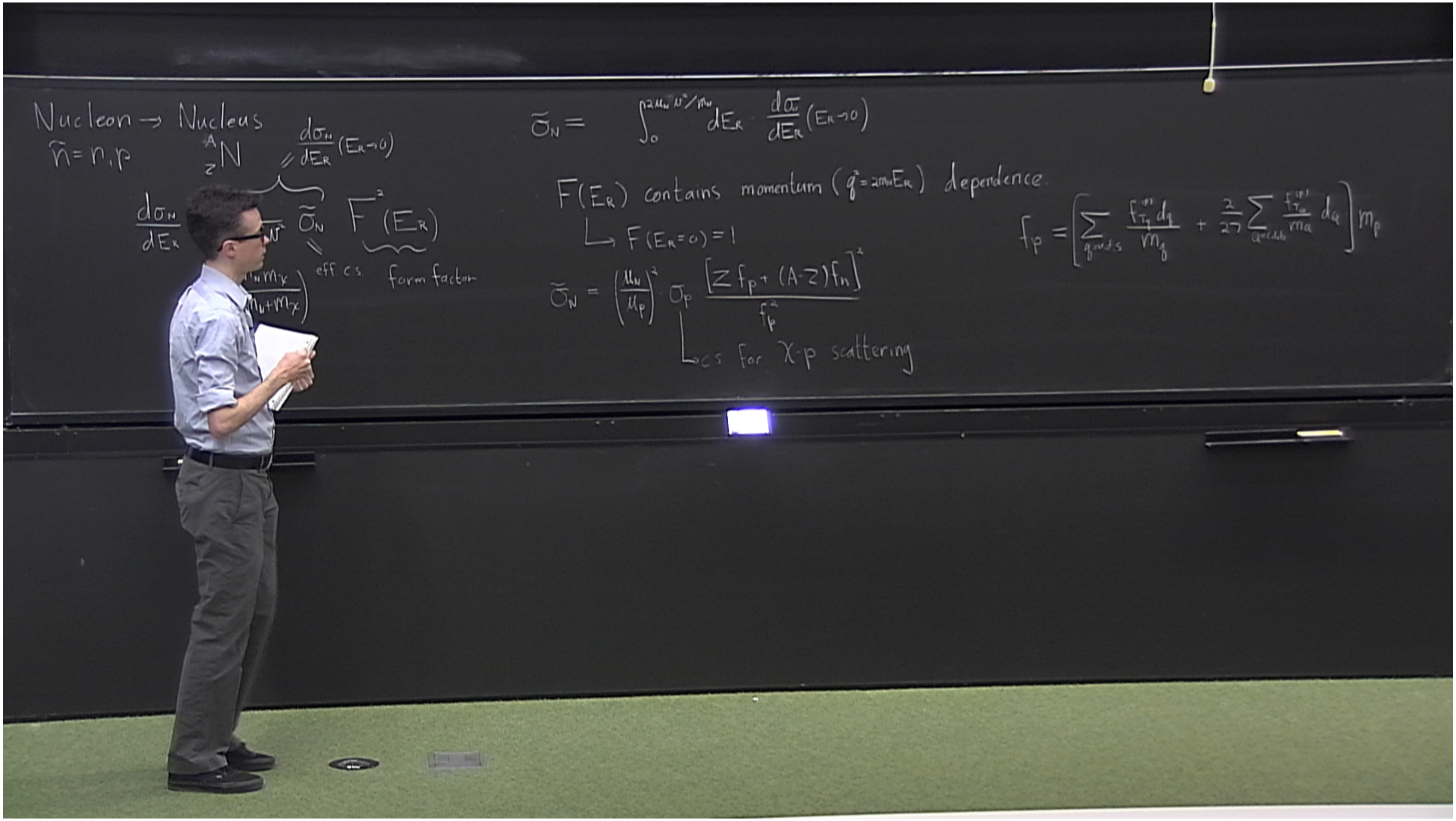

Nucleon → Nucleus
ñ = n, p
A Z N
dσN/dER (ER→0)
mN / 2μN² N² σ̃N F²(ER)
(mN mχ / mN + mχ)
eff c.s.
form factor
σ̃N = ∫0^(2μN N²/mN) dER · dσN/dER (ER→0)
F(ER) contains momentum (q² = 2mN ER) dependence.

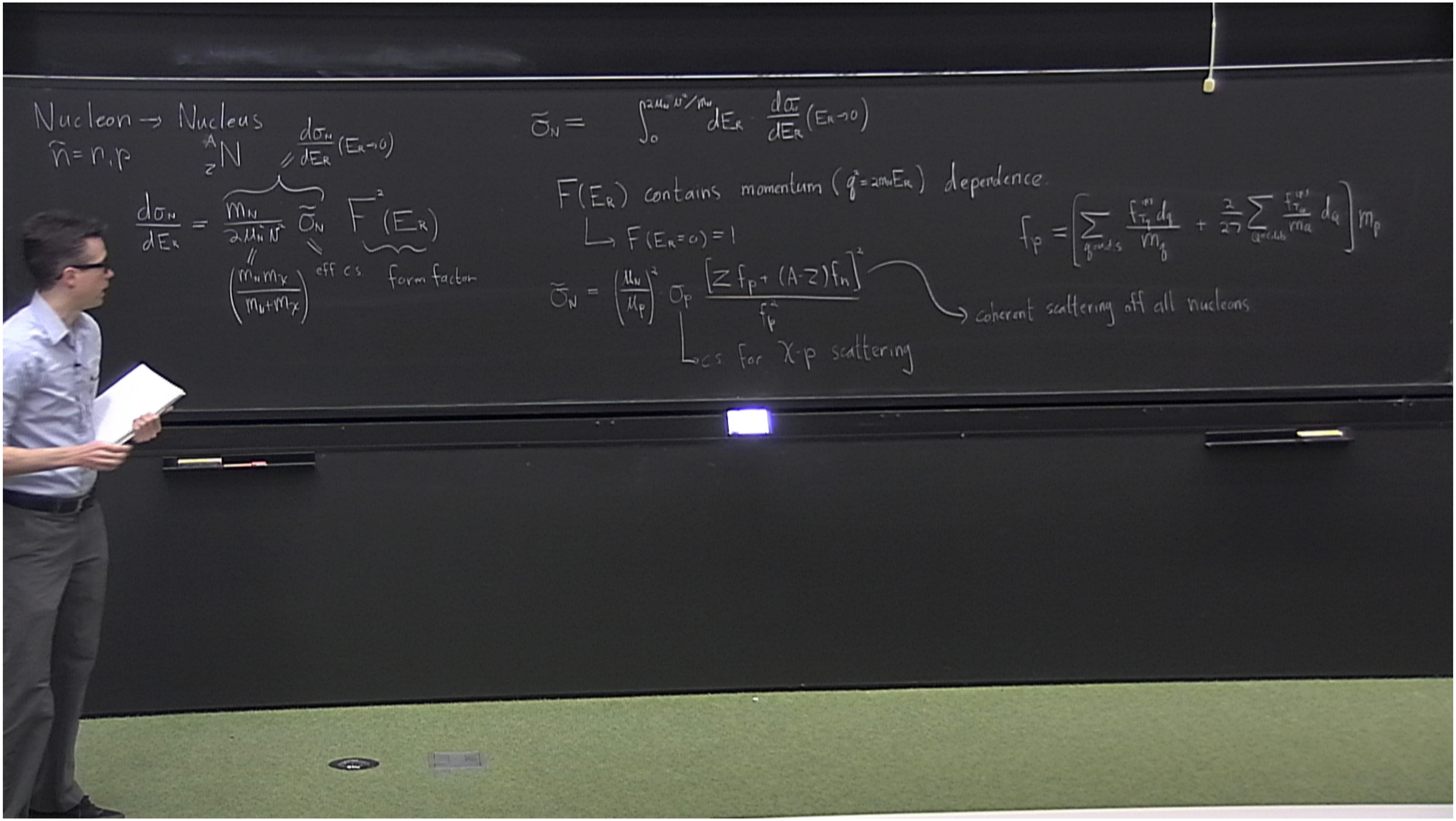

Nucleon → Nucleus
ñ = n, p
dσ_N/dE_R (E_R → 0)
F(E_R) contains momentum (q² = 2m_N E_R) dependence.
↳ F(E_R = 0) = 1
factor
σ̃_N =

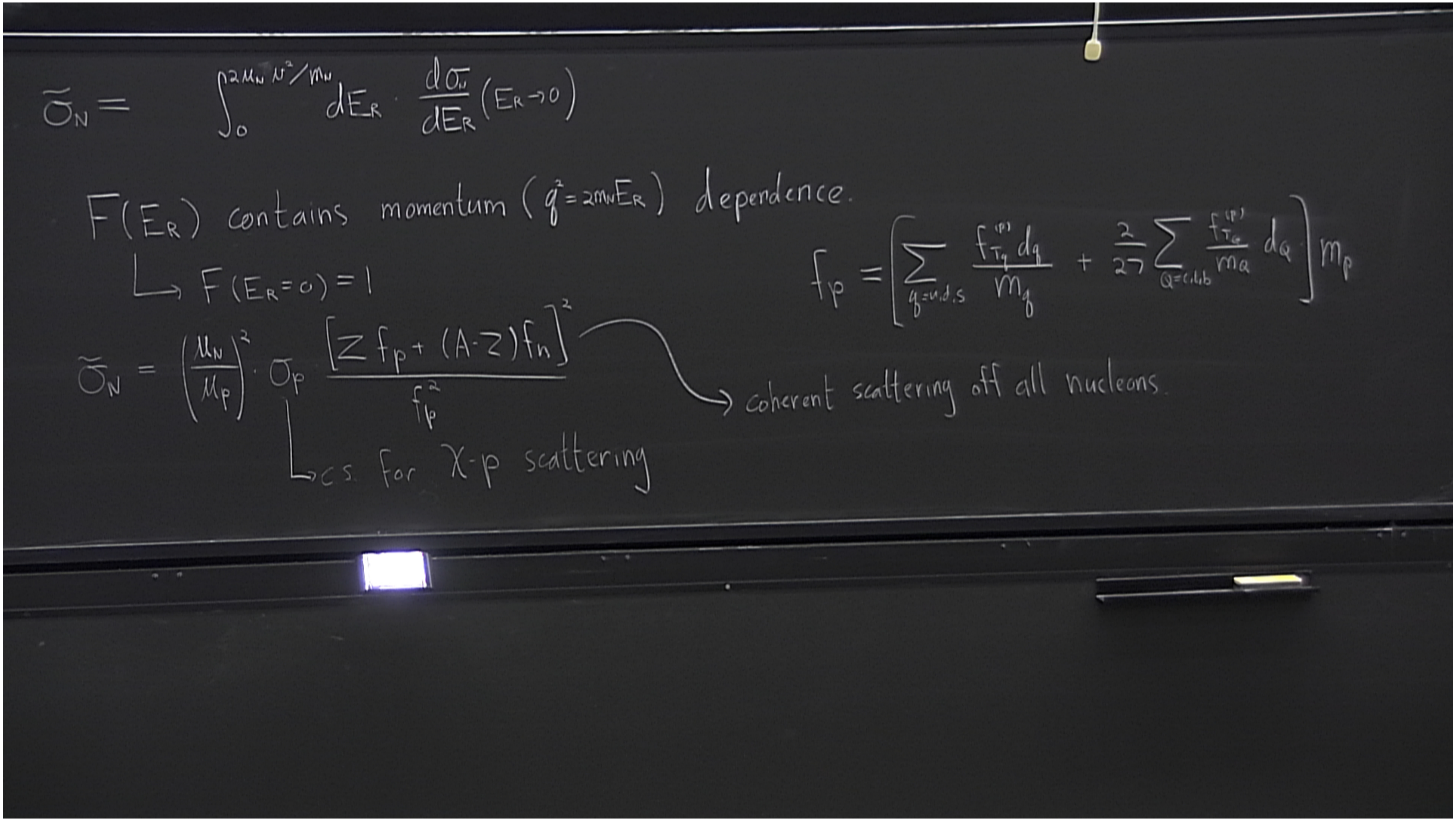

Nucleon → Nucleus
ñ = n, p
$^A_Z N$
$\frac{d\sigma_N}{dE_R}(E_R \to 0)$
$\frac{d\sigma_N}{dE_R} = \frac{m_N}{2\mu_N^2 v^2} \tilde{\sigma}_N F^2$
$\left(\frac{m_N m_\chi}{m_N + m_\chi}\right)$
eff c.s
actor
$\tilde{\sigma}_N = \int_0^{2\mu_N^2 v^2/m_N} dE_R \cdot \frac{d\sigma_N}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \cdot \sigma_p \cdot \frac{[Z f_p + (A-Z) f_n]^2}{f_p}$


Nucleon → Nucleus
$\tilde{n} = n, p$
$^{A}_{Z}N$
$\frac{d\sigma_N}{dE_R}(E_R \to 0)$
$\frac{d\sigma_N}{dE_R} = \frac{m_N}{2\mu_N^2 v^2} \tilde{\sigma}_N F^2(E_R)$
$\left(\frac{m_N m_\chi}{m_N + m_\chi}\right)$
eff c.s.
form factor
$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \frac{d\sigma}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$\hookrightarrow F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \sigma_p \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
$f_p = \left[\sum_{q=u,d,s} \frac{f_{T_q}^{(p)} d_q}{m_q} + \frac{2}{27} \sum_{Q=c,b,t} \frac{f_{T_G}^{(p)}}{m_Q} d_Q\right] m_p$


Nucleon → Nucleus
F(E_R) contains momentum dependence.
F(E_R=0) = 1
eff c.s.
form factor
c.s. for χ-p scattering


Nucleon → Nucleus
F(E_R) contains momentum dependence
F(E_R = 0) = 1
eff cs
form factor
cs for χ-p scattering


Nucleon → Nucleus
$\tilde{n} = n, p$
${}^{A}_{Z}N$
$\frac{d\sigma_N}{dE_R}(E_R \to 0)$
$\frac{d\sigma_N}{dE_R} = \frac{m_N}{2\mu_N^2 v^2}\tilde{\sigma}_N F^2(E_R)$
$\left(\frac{m_N m_\chi}{m_N + m_\chi}\right)$
eff c.s.
form factor
$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \frac{d\sigma}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \sigma_p \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
c.s. for χ-p scattering
coherent scattering off all nucleons
$f_p = \left[\sum_{q=u,d,s} \frac{f_{Tq}^{(p)} d_q}{m_q} + \frac{2}{27}\sum_{Q=c,b,t} \frac{f_{TG}^{(p)}}{m_Q} d_Q\right] m_p$


$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \cdot \frac{d\sigma_N}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$\hookrightarrow F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \cdot \sigma_p \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
$\hookrightarrow$ c.s. for χ-p scattering
coherent scattering off all nucleons
$f_p = \left[\sum_{q=u,d,s} \frac{f_{Tq}^{(p)} d_q}{m_q} + \frac{2}{27} \sum_{Q=c,t,b} \frac{f_{TG}^{(p)}}{m_Q} d_Q\right] m_p$

factor

$$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \cdot \frac{d\sigma_N}{dE_R}(E_R \to 0)$$

$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.

↳ $F(E_R = 0) = 1$

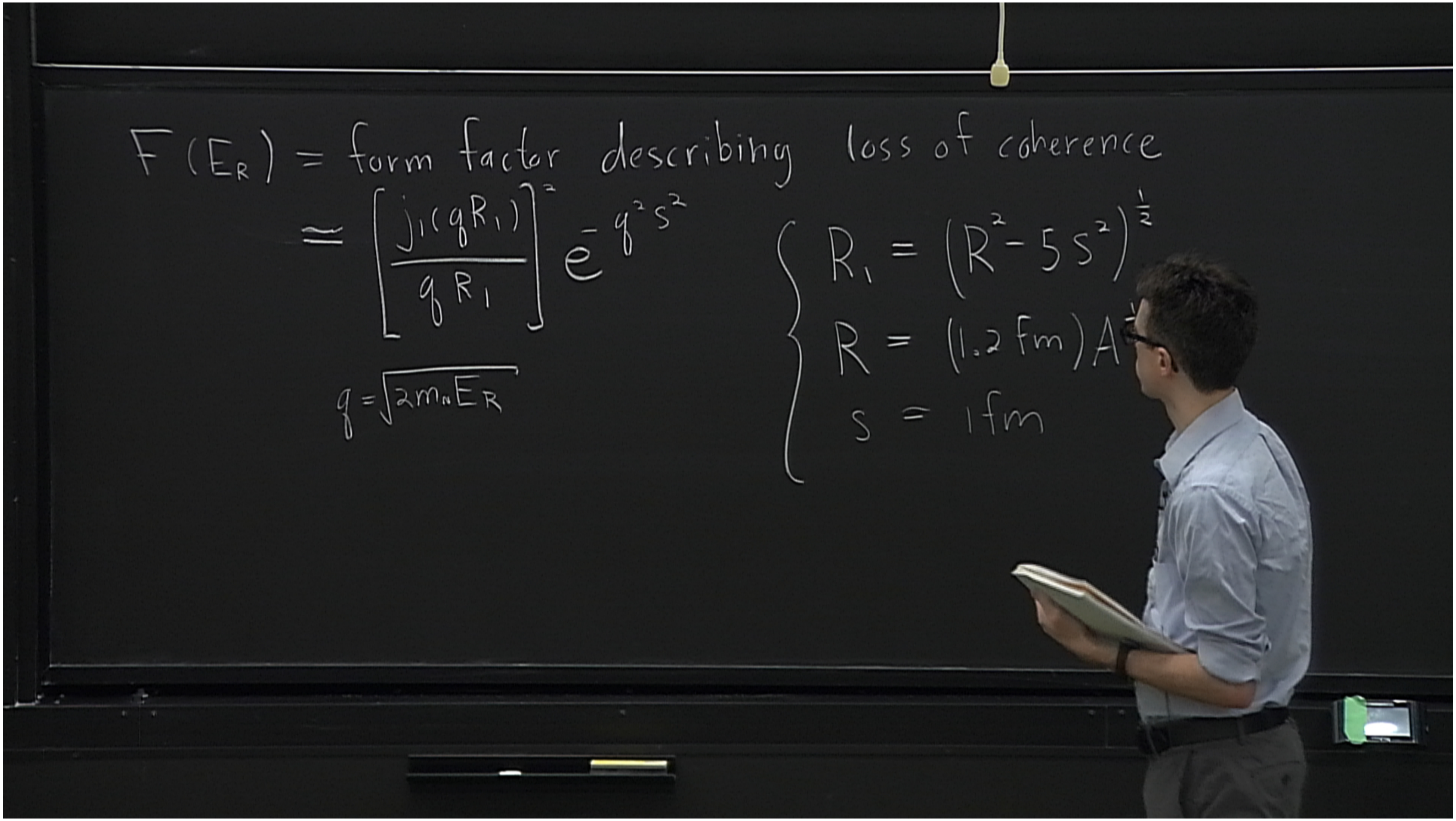
$$f_p = \left[\sum_{q=u,d,s} \frac{f_{Tq}^{(p)} \alpha_q}{m_q} + \frac{2}{27} \sum_{Q=c,b,t} \frac{f_{TG}^{(p)}}{m_Q} \alpha_Q\right] m_p$$

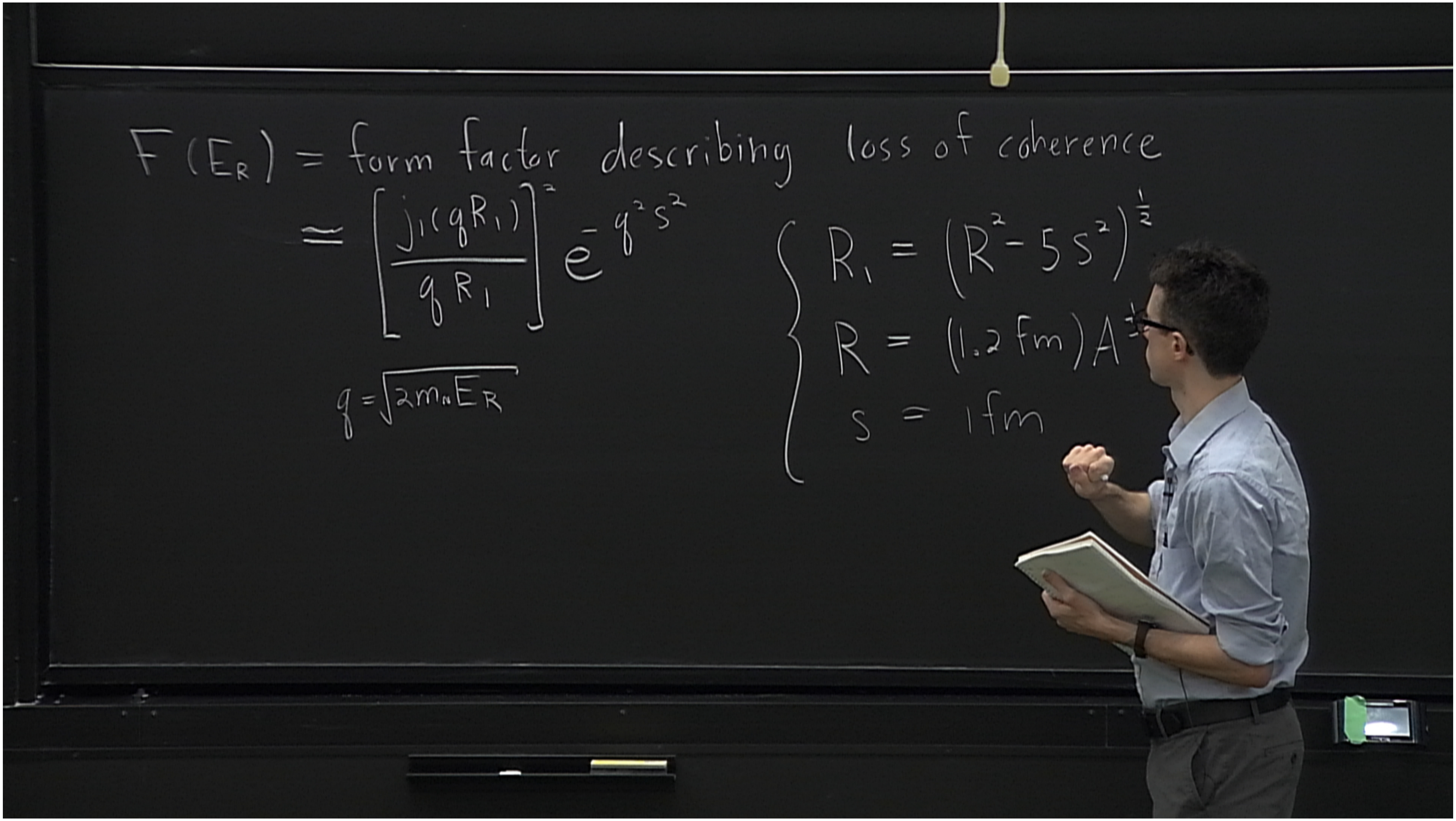
$$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \sigma_p \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$$

→ coherent scattering off all nucleons

↳ spin-independent (SI)

↳ c.s. for χ-p scattering


$F(E_R)$ = form factor describing loss of coherence
$\simeq \left[\frac{j_1(qR_1)}{qR_1}\right]^2 e^{-q^2 s^2}$
$q = \sqrt{2 m_N E_R}$
$R_1 = (R^2 - 5s^2)^{\frac{1}{2}}$
$R = (1.2\,\mathrm{fm})A$
$s = 1\,\mathrm{fm}$

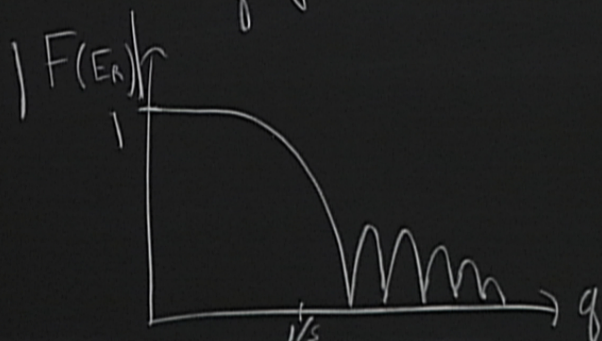

F(E_R) = form factor describing loss of coherence
≃ [j_1(qR_1) / qR_1]^2 e^{-q^2 s^2}
q = √(2m_N E_R)
R_1 = (R^2 - 5s^2)^{1/2}
R = (1.2 fm) A
s = 1 fm

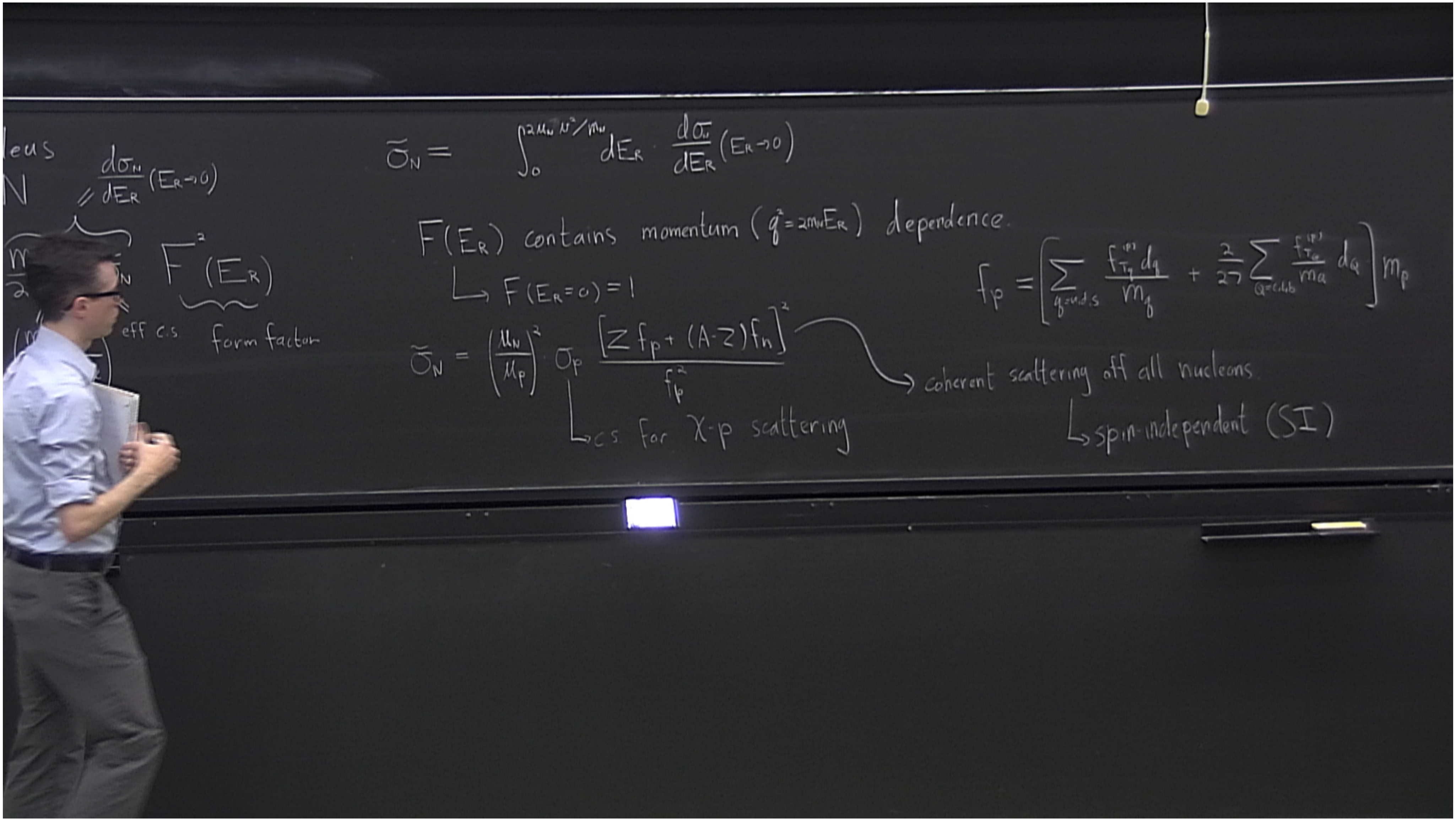
$F(E_R)$ = form factor describing loss of coherence

$$\simeq \left[\frac{j_1(qR_1)}{qR_1}\right]^2 e^{-q^2 s^2}$$

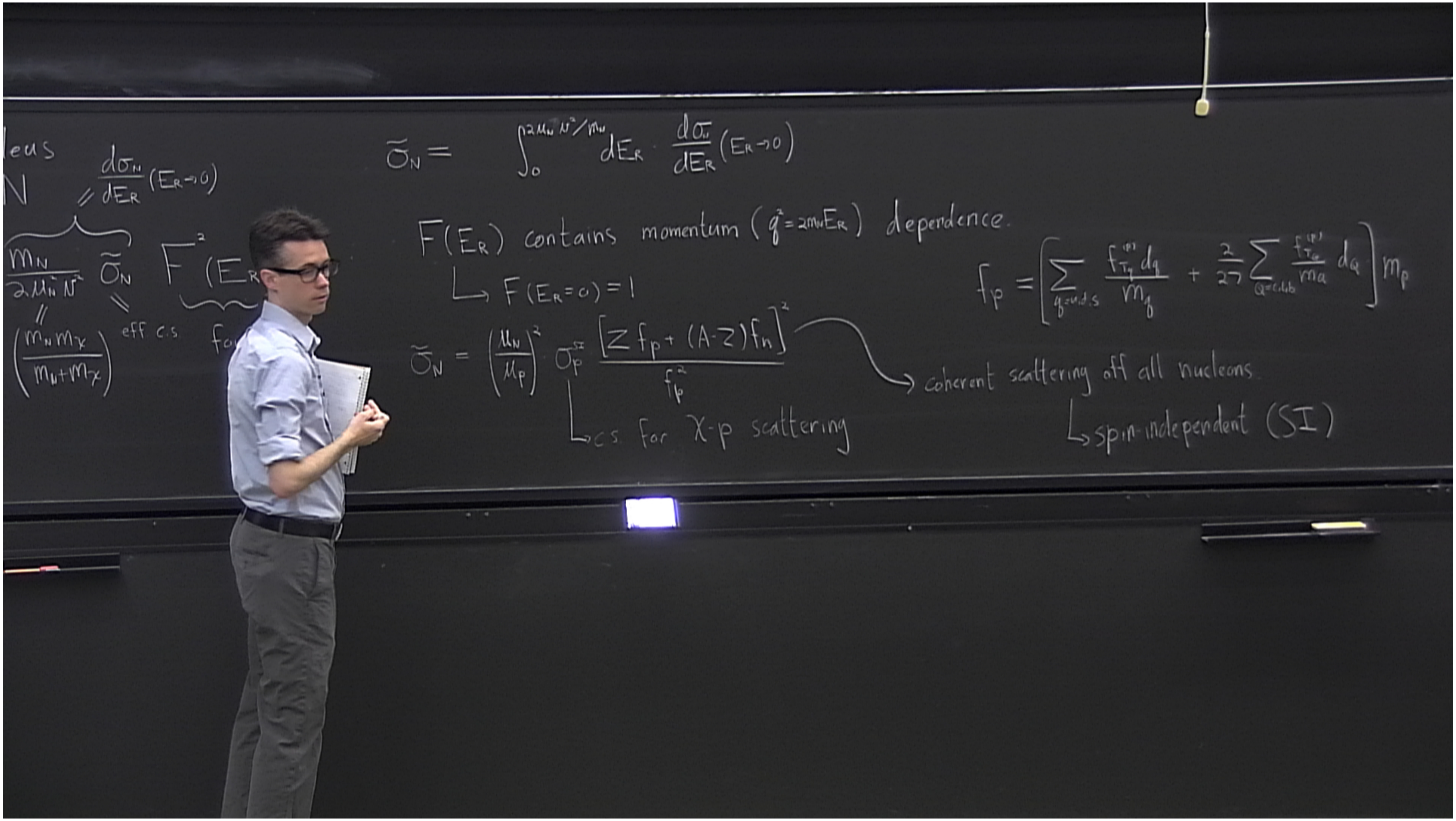
$$\begin{cases} R_1 = (R^2 - 5s^2)^{\frac{1}{2}} \\ R = (1.2\,\mathrm{fm})\,A^{\frac{1}{3}} \\ s = 1\,\mathrm{fm} \end{cases}$$

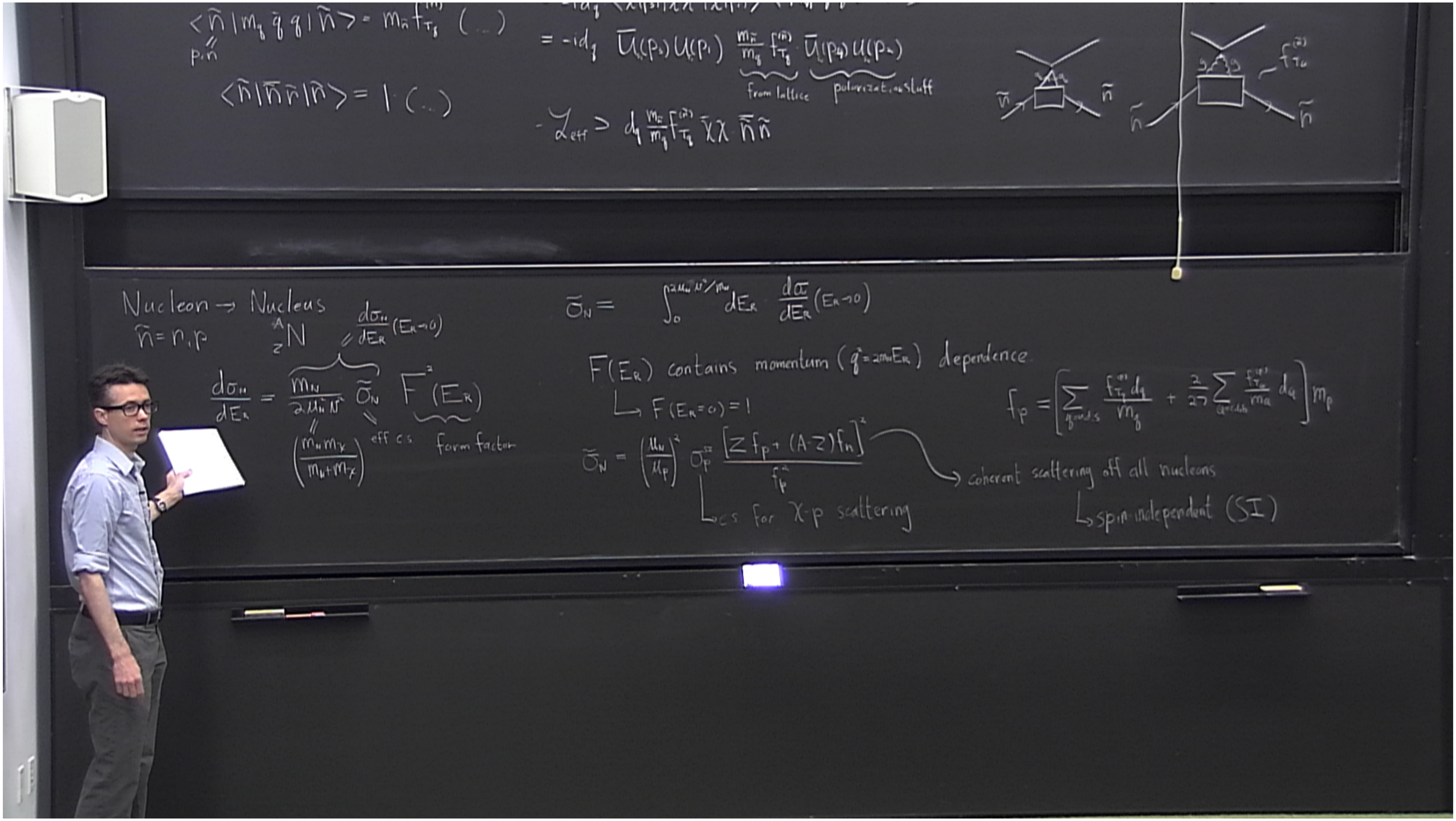
$$q = \sqrt{2 m_N E_R}$$

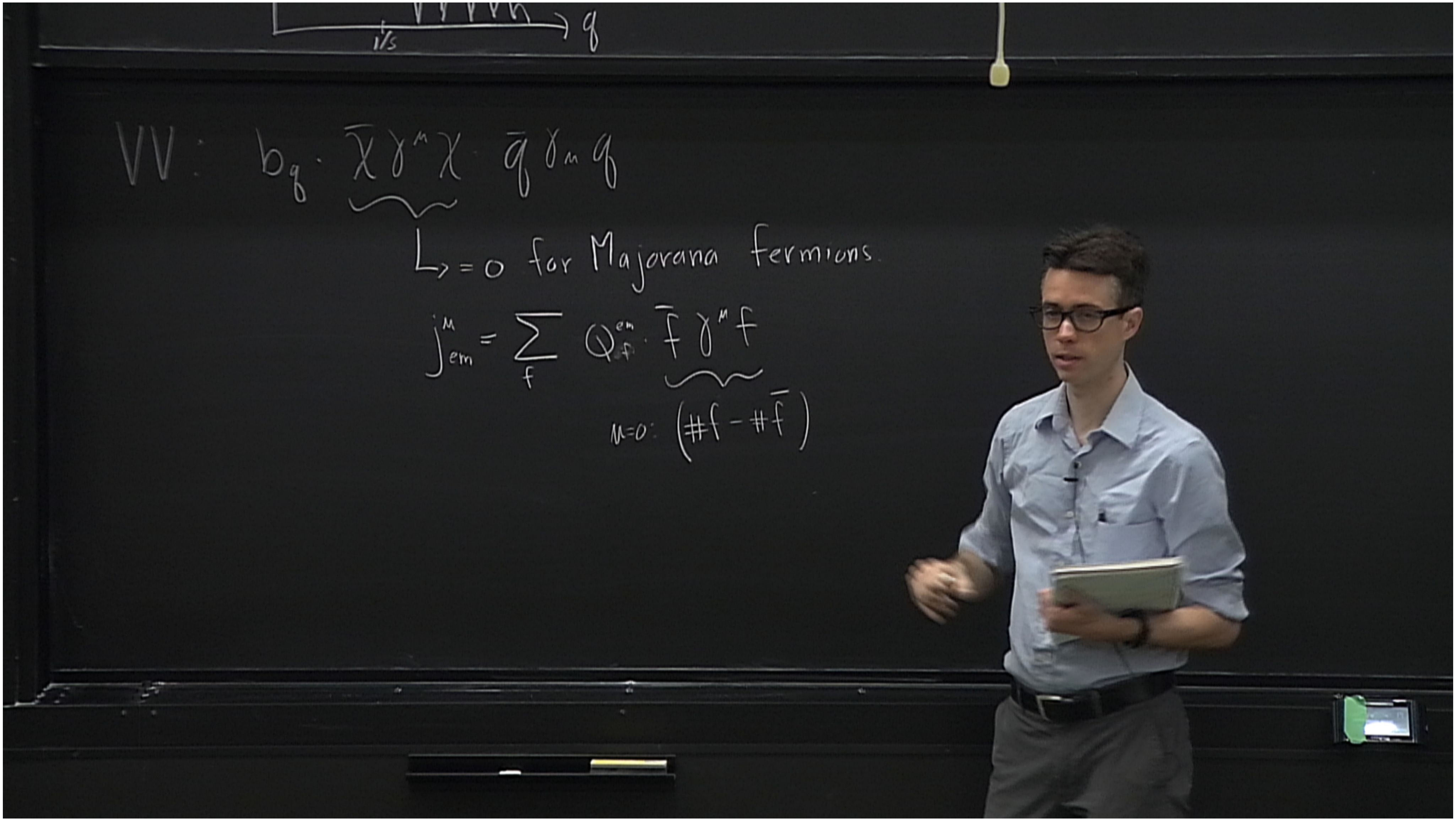




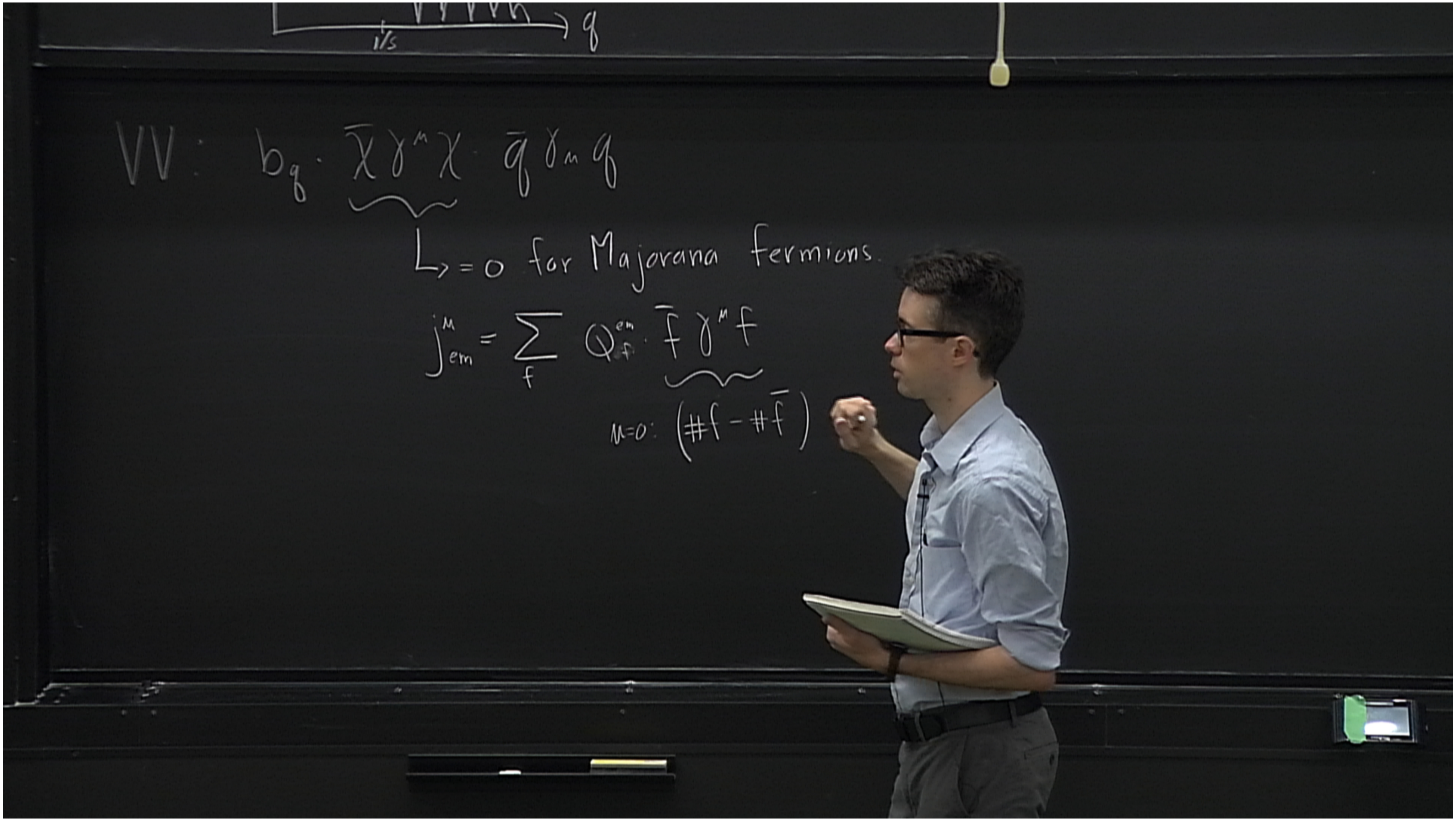
leus
$\frac{d\sigma_N}{dE_R}(E_R \to 0)$
eff c.s
form factor
$F^2(E_R)$
$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \, \frac{d\sigma_N}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$\hookrightarrow F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \sigma_p \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
$\hookrightarrow$ c.s for χ-p scattering
coherent scattering off all nucleons
$\hookrightarrow$ spin-independent (SI)
$f_p = \left[\sum_{q=u,d,s} \frac{f_{T_q}^{(p)} d_q}{m_q} + \frac{2}{27} \sum_{Q=c,b,t} \frac{f_{T_G}^{(p)}}{m_Q} d_Q\right] m_p$


F(E_R) contains momentum (q^2 = 2m_N E_R) dependence.
F(E_R = 0) = 1
coherent scattering off all nucleons
spin-independent (SI)
c.s. for χ-p scattering
eff c.s

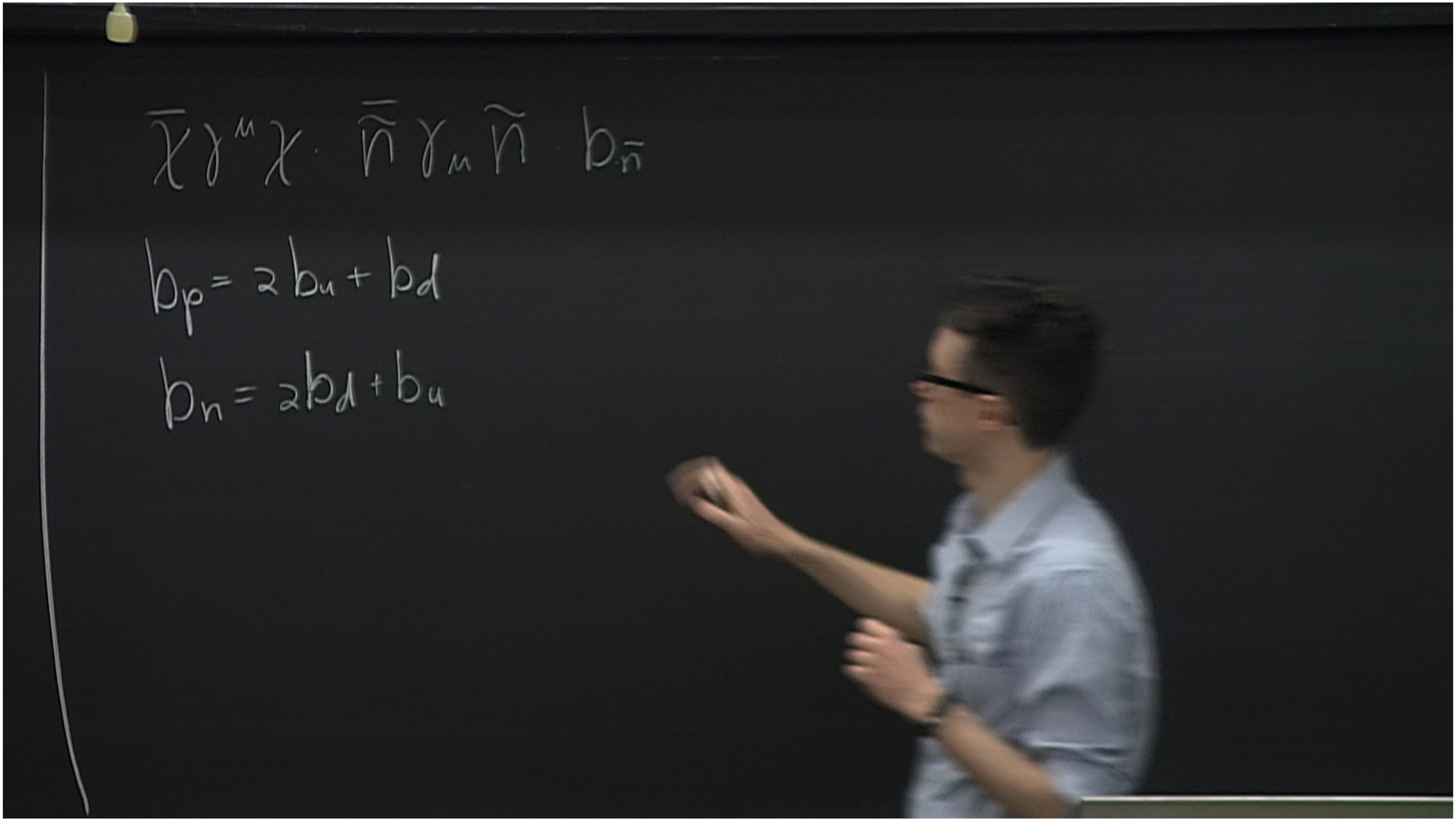

from lattice
polarization stuff
Nucleon → Nucleus
eff c.s
form factor
F(E_R) contains momentum dependence
coherent scattering off all nucleons
spin independent (SI)
c.s for χ-p scattering

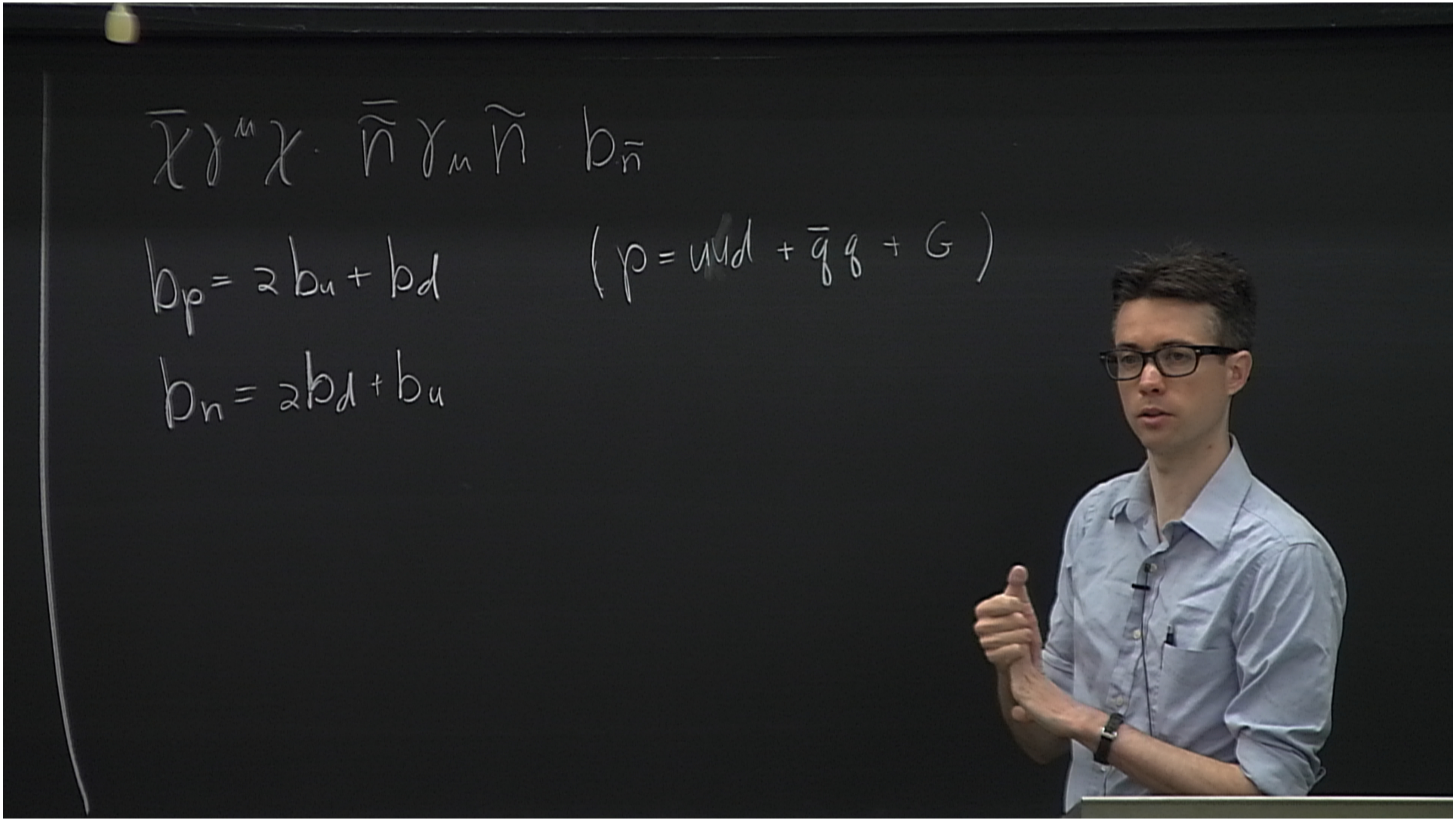


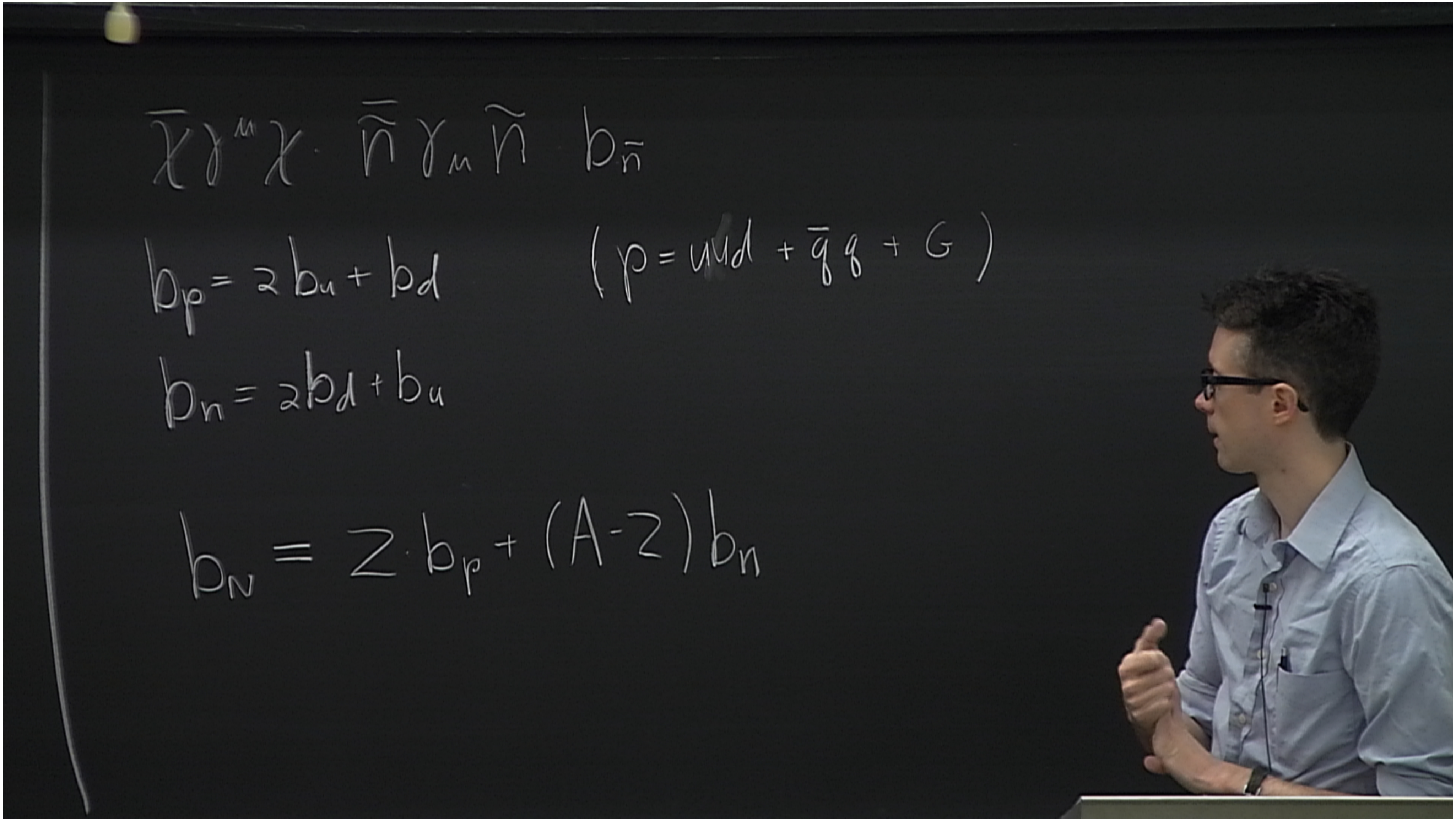
1/s
q
VV: b_q · χ̄ γ^μ χ q̄ γ_μ q
L_γ = 0 for Majorana fermions
j^μ_em = Σ_f Q^em_f · f̄ γ^μ f
μ=0: (#f − #f̄)

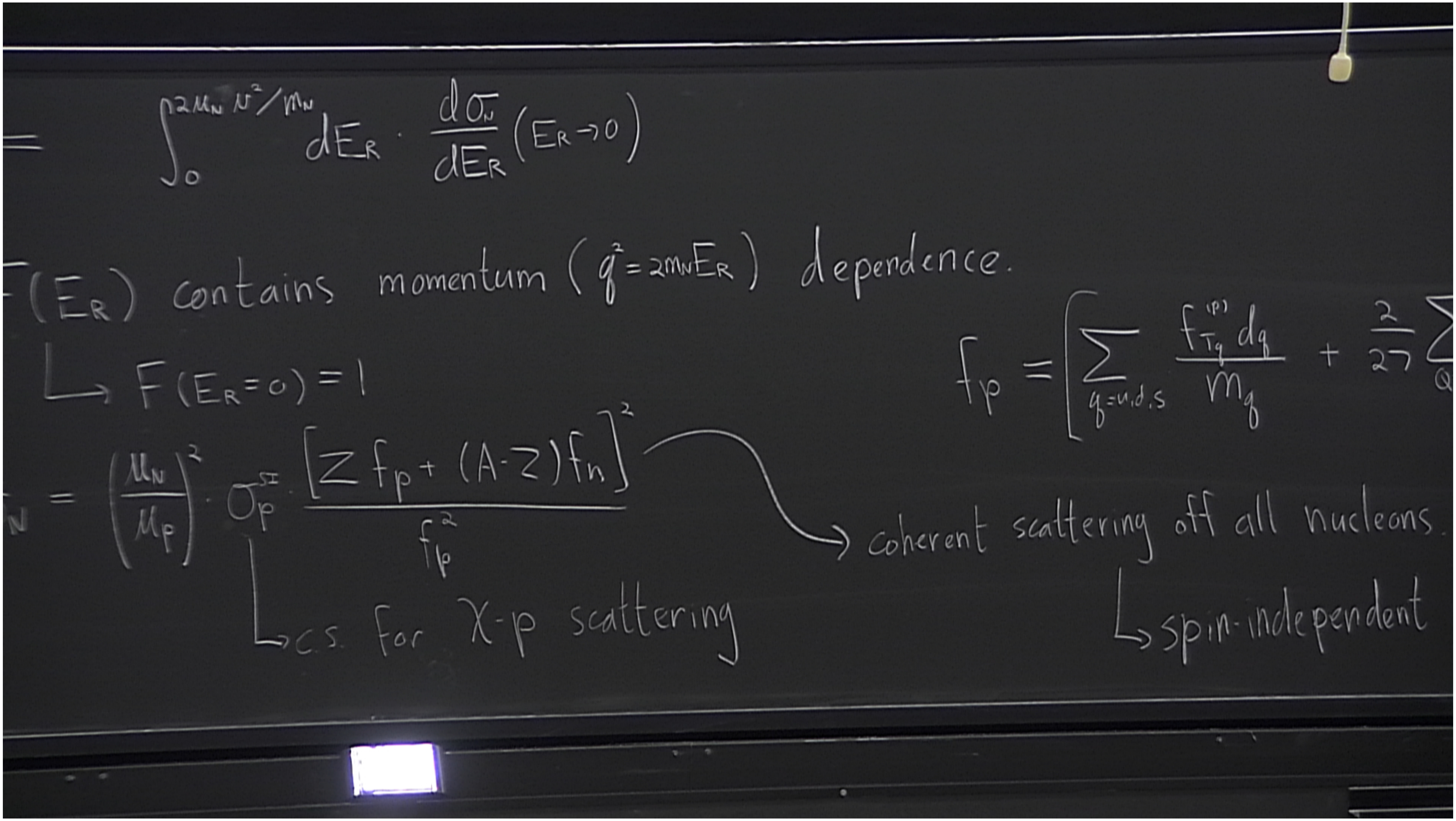


1/s
q
VV: $b_q \cdot \bar{\chi}\gamma^\mu\chi \cdot \bar{q}\gamma_\mu q$
$L_\gamma = 0$ for Majorana fermions.
$j^\mu_{em} = \sum_f Q^{em}_f \cdot \bar{f}\gamma^\mu f$
$\mu = 0$: $(\#f - \#\bar{f})$


$\bar{\chi}\gamma^\mu\chi \cdot \bar{\tilde{n}}\gamma_\mu\tilde{n} \cdot b_{\tilde{n}}$
$b_p = 2b_u + b_d$
$b_n = 2b_d + b_u$


$\bar{\chi}\gamma^{\mu}\chi \cdot \bar{\tilde{n}}\gamma_{\mu}\tilde{n}$ $b_{\tilde{n}}$
$b_p = 2b_u + b_d$
$(p = uud + \bar{q}q + G)$
$b_n = 2b_d + b_u$


$\bar{\chi} \gamma^\mu \chi \cdot \bar{\tilde{n}} \gamma_\mu \tilde{n} \quad b_{\tilde{n}}$
$b_p = 2 b_u + b_d$
$(p = uud + \bar{q} q + G)$
$b_n = 2 b_d + b_u$
$b_N = Z \cdot b_p + (A - Z) b_n$


$= \int_0^{2\mu_N v^2/m_N} dE_R \cdot \frac{d\sigma_N}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
↳ $F(E_R = 0) = 1$
$f_p = \left[\sum_{q=u,d,s} \frac{f_{Tq}^{(p)} \alpha_q}{m_q} + \frac{2}{27} \sum_Q \right.$
$\sigma_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \cdot \sigma_p^{SI} \cdot \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
→ coherent scattering off all nucleons.
↳ spin-independent
↳ c.s. for χ-p scattering

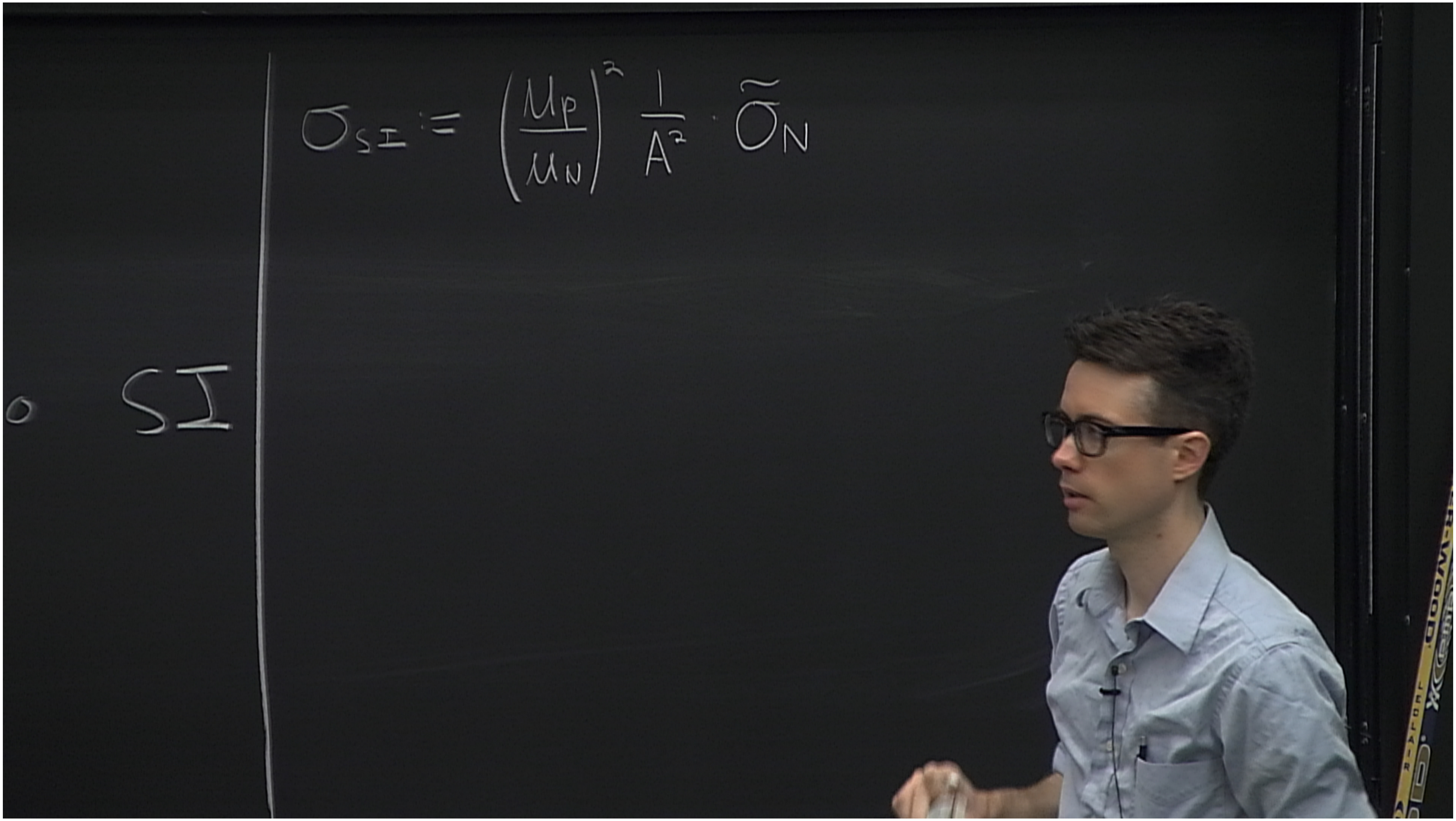
$$\bar{\chi}\gamma^{\mu}\chi \cdot \bar{\tilde{n}}\gamma_{\mu}\tilde{n} \cdot b_{\tilde{n}}$$

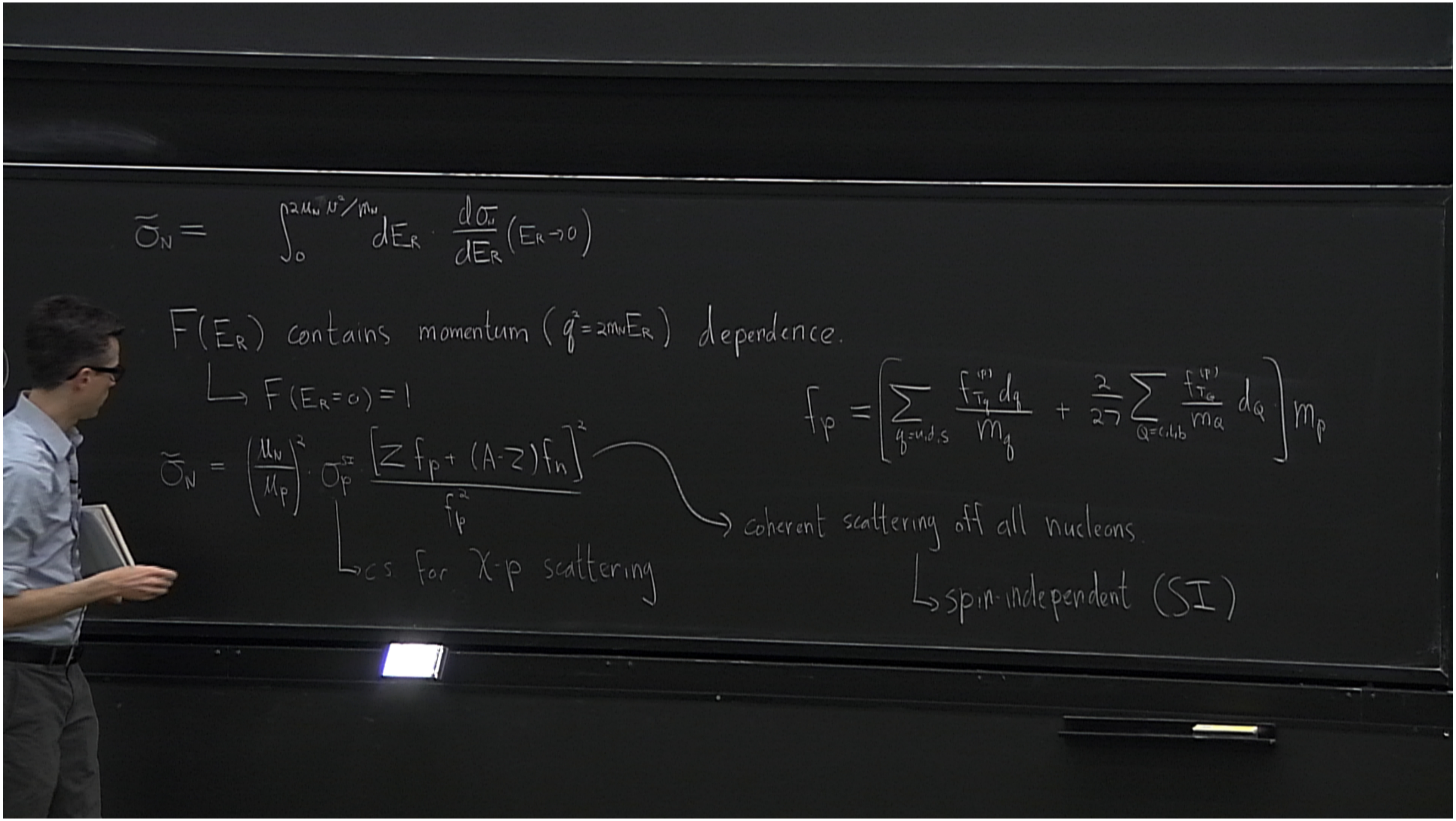
$$b_p = 2b_u + b_d \qquad (p = uud + \bar{q}q + G)$$

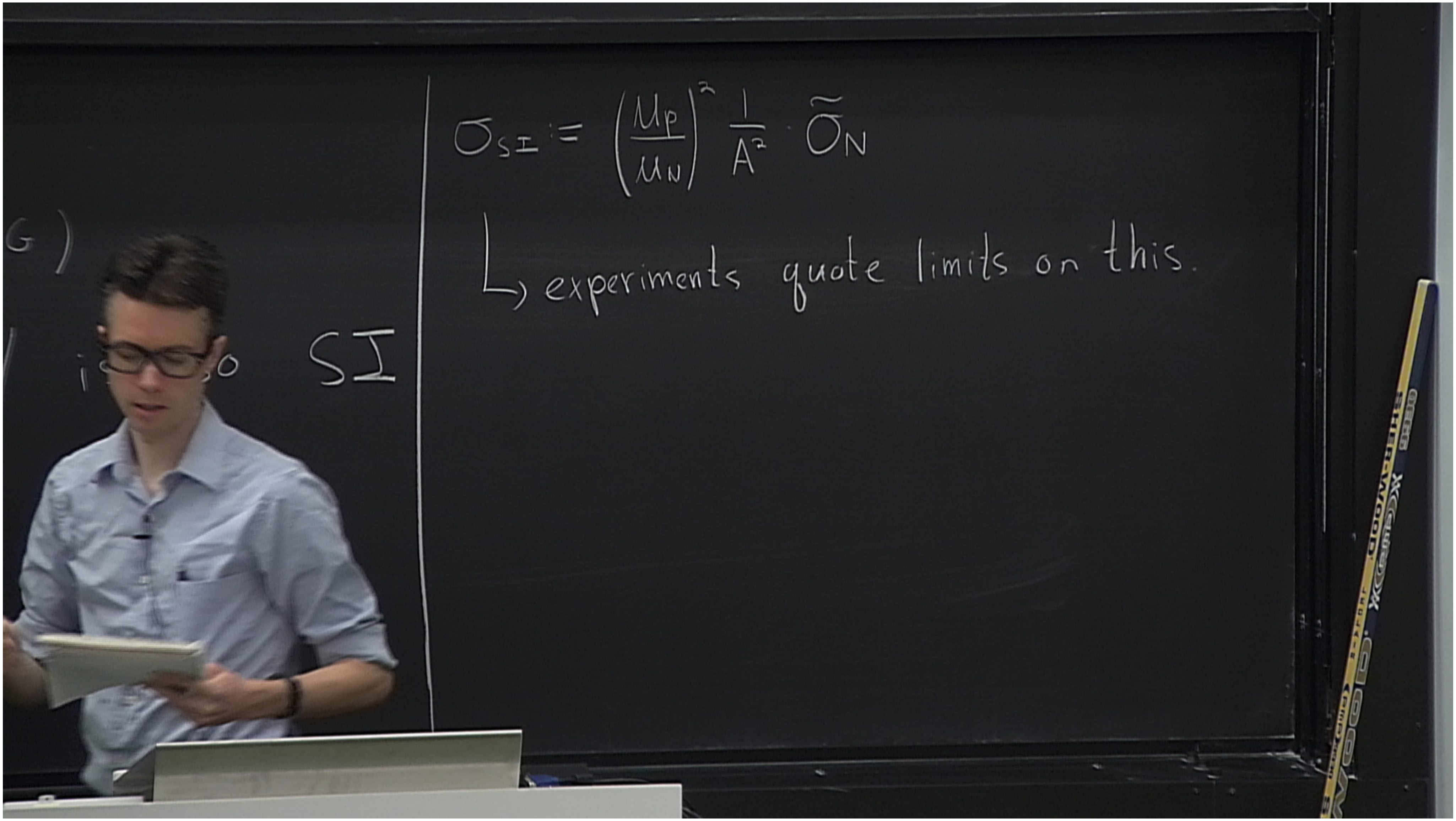
$$b_n = 2b_d + b_u$$

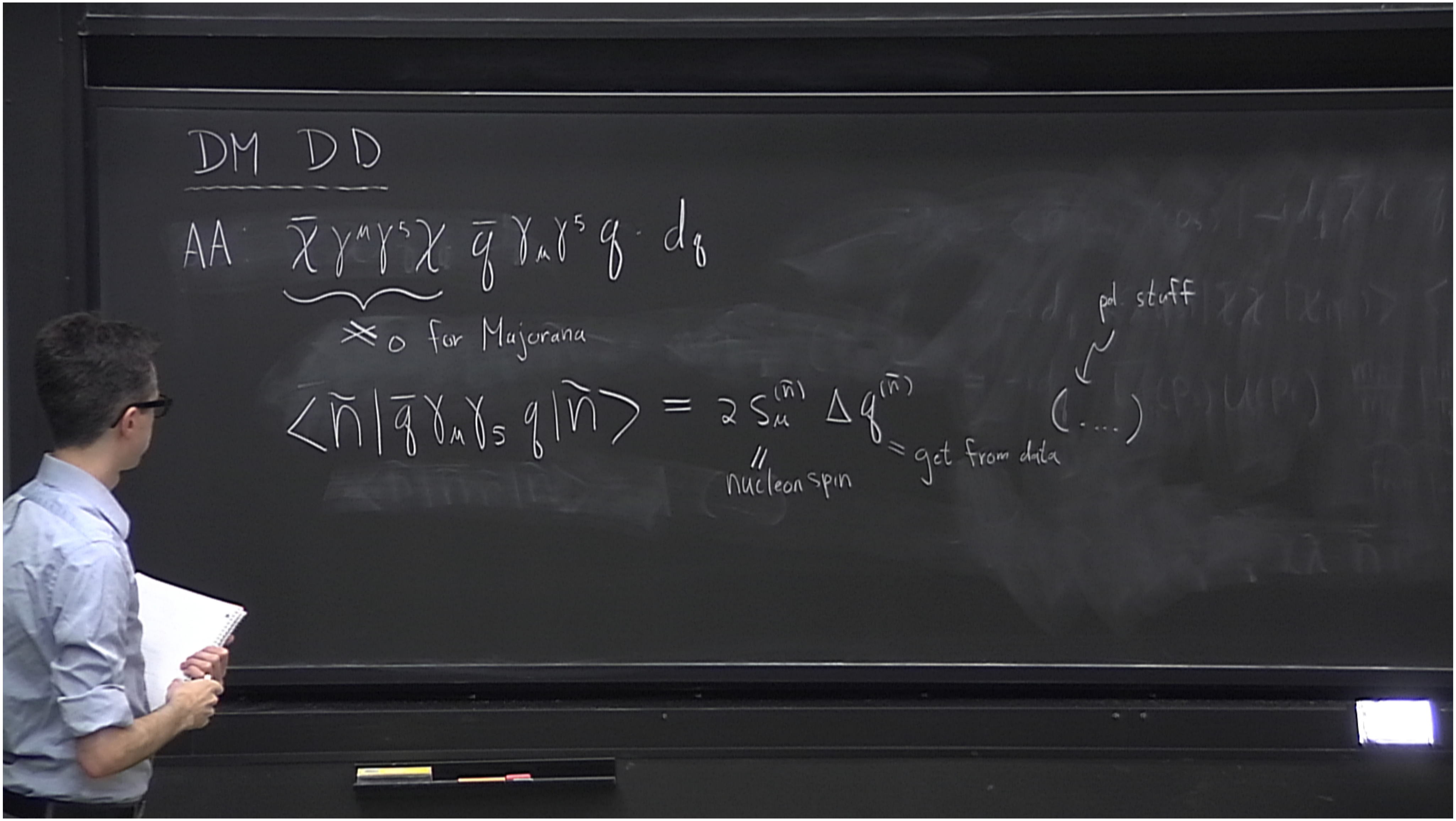
VV is also SI

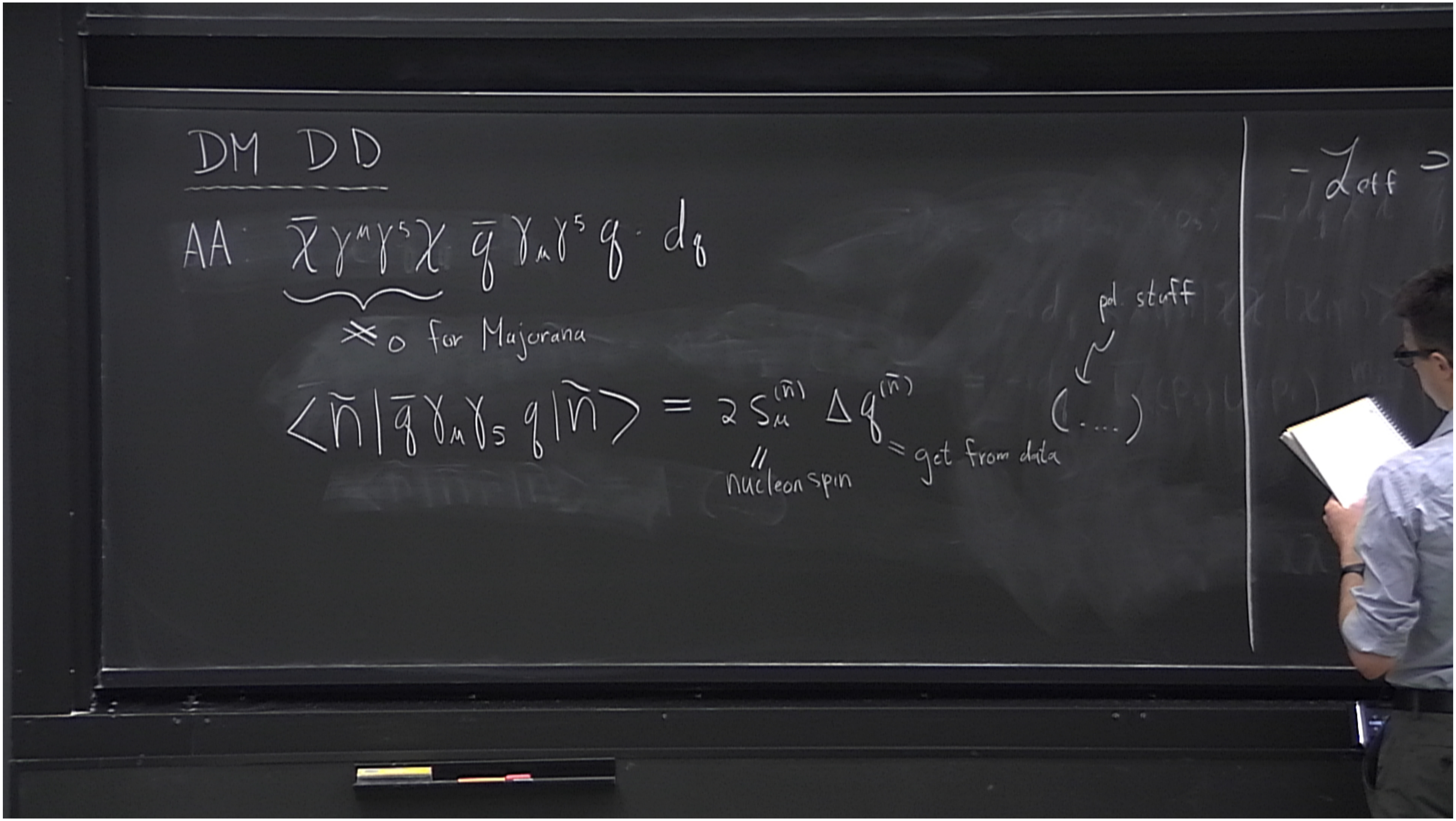
$$b_N = Z \cdot b_p + (A-Z)\, b_n$$

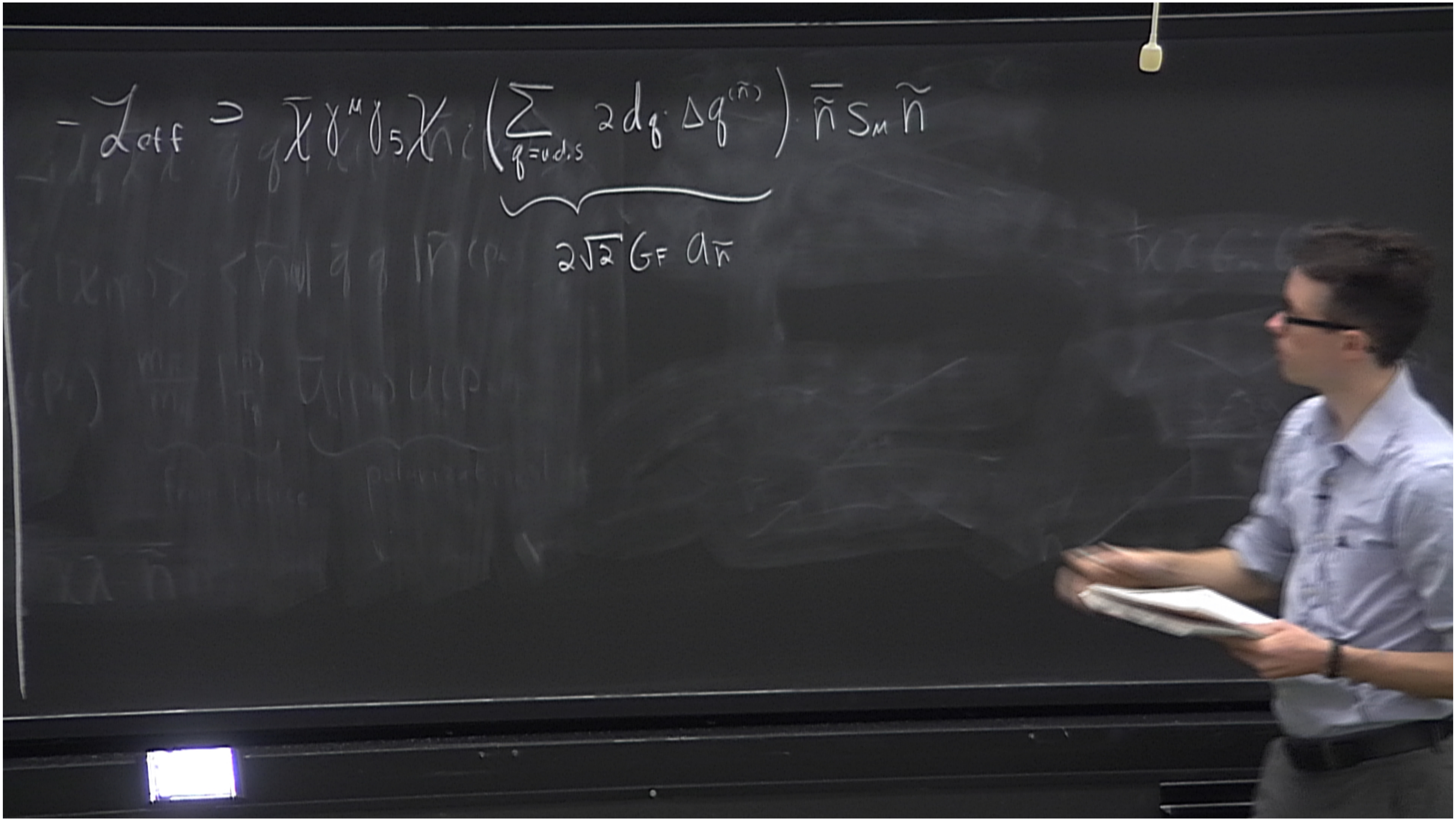

$\sigma_{SI} = \left(\frac{\mu_p}{\mu_N}\right)^2 \frac{1}{A^2} \cdot \tilde{\sigma}_N$
SI

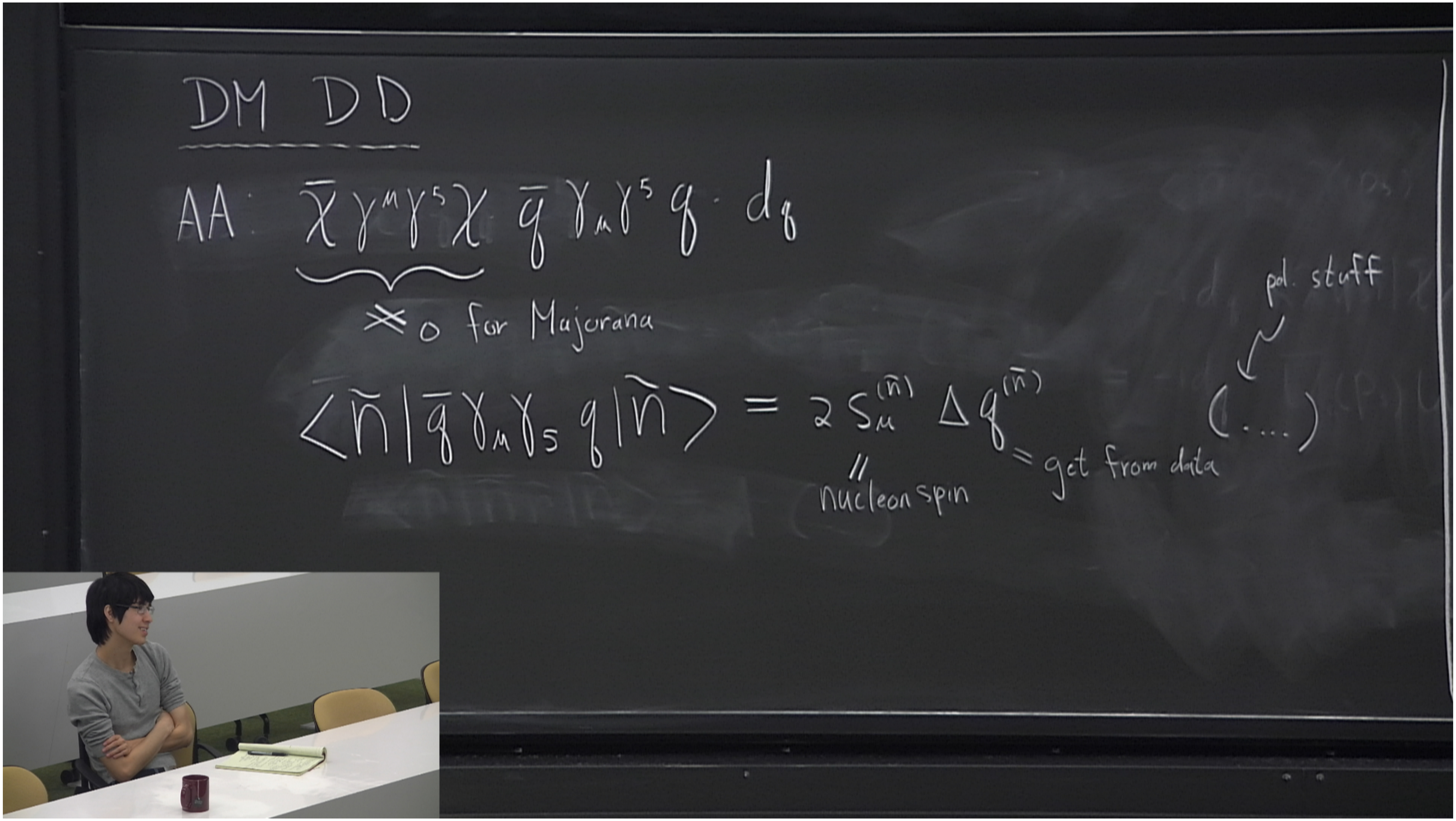

$\tilde{\sigma}_N = \int_0^{2\mu_N v^2/m_N} dE_R \cdot \frac{d\sigma_N}{dE_R}(E_R \to 0)$
$F(E_R)$ contains momentum ($q^2 = 2m_N E_R$) dependence.
$\hookrightarrow F(E_R = 0) = 1$
$\tilde{\sigma}_N = \left(\frac{\mu_N}{\mu_p}\right)^2 \cdot \sigma_p^{SI} \frac{[Z f_p + (A-Z) f_n]^2}{f_p^2}$
$\hookrightarrow$ c.s. for χ-p scattering
$\to$ coherent scattering off all nucleons.
$\hookrightarrow$ spin-independent (SI)
$f_p = \left[\sum_{q=u,d,s} \frac{f_{T_q}^{(p)} d_q}{m_q} + \frac{2}{27} \sum_{Q=c,t,b} \frac{f_{T_Q}^{(p)}}{m_Q} d_Q\right] m_p$

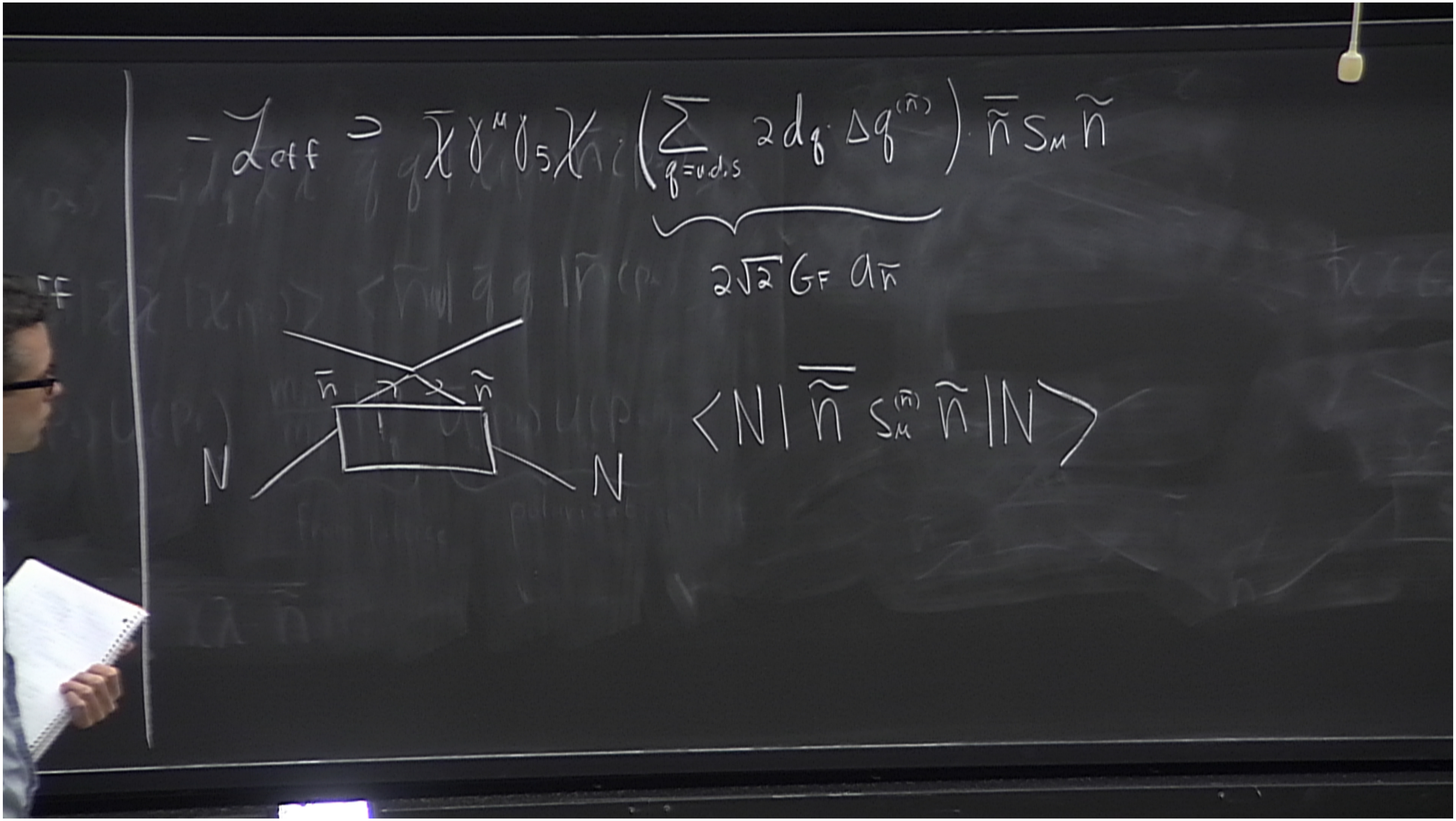

$\sigma_{SI} = \left(\frac{\mu_p}{\mu_N}\right)^2 \frac{1}{A^2} \cdot \tilde{\sigma}_N$
↳ experiments quote limits on this.
SI


DM DD
AA $\bar{\chi}\gamma^\mu\gamma^5\chi\ \bar{q}\gamma_\mu\gamma^5 q \cdot d_q$
$\neq 0$ for Majorana
$\langle \tilde{n} | \bar{q}\gamma_\mu\gamma_5 q | \tilde{n} \rangle = 2 S_\mu^{(\tilde{n})} \Delta q^{(\tilde{n})}$
nucleon spin
get from data
pol. stuff
(. . .)

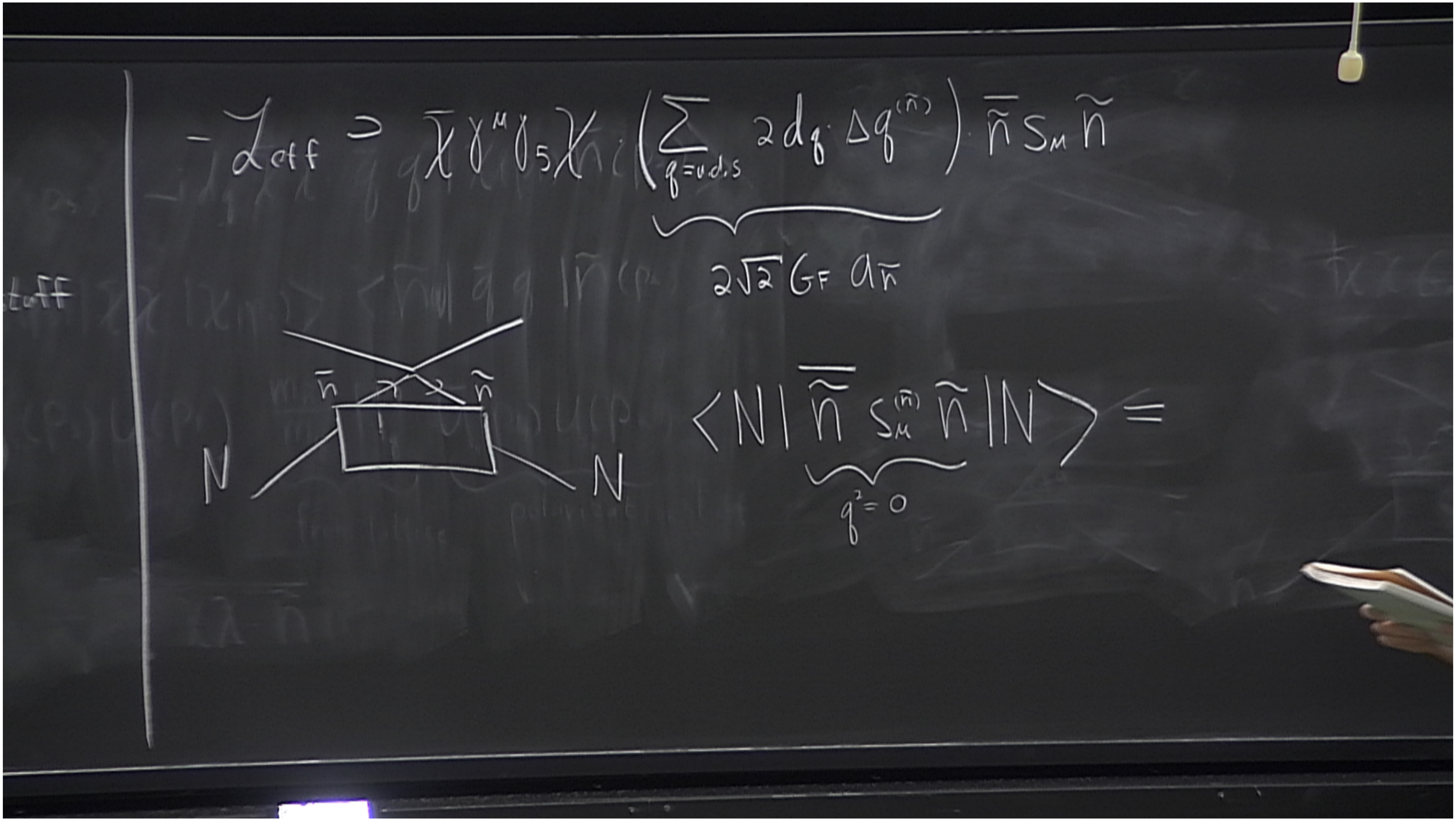

DM DD
AA: $\bar{\chi}\gamma^\mu\gamma^5\chi\ \bar{q}\gamma_\mu\gamma^5 q \cdot d_q$
≠ 0 for Majorana
$\langle \tilde{n}|\bar{q}\gamma_\mu\gamma_5 q|\tilde{n}\rangle = 2 S_\mu^{(\tilde{n})} \Delta q^{(\tilde{n})}$
nucleon spin
= get from data
pol. stuff
(...)
$-\mathcal{L}_{eff}$


$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^\mu\gamma_5\chi \left(\sum_{q=u,d,s} 2 d_q \cdot \Delta q^{(\tilde{n})}\right) \bar{\tilde{n}} S_\mu \tilde{n}$
$2\sqrt{2}\, G_F\, a_{\tilde{n}}$


DM DD
AA: $\bar{\chi}\gamma^{\mu}\gamma^{5}\chi\ \bar{q}\gamma_{\mu}\gamma^{5}q \cdot d_q$
$\neq 0$ for Majorana
$\langle \tilde{n}|\bar{q}\gamma_{\mu}\gamma_{5}q|\tilde{n}\rangle = 2S_{\mu}^{(\tilde{n})}\Delta q^{(\tilde{n})}$
nucleon spin
= get from data
pol. stuff
(....)

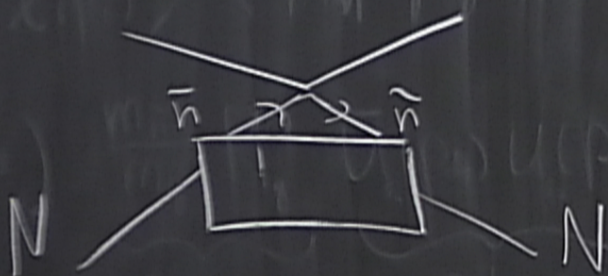


$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^\mu\gamma_5\chi \left(\sum_{q=u,d,s} 2d_q \cdot \Delta q^{(\tilde{n})}\right) \cdot \bar{\tilde{n}} S_\mu \tilde{n}$
$2\sqrt{2}\, G_F\, a_{\tilde{n}}$
$\bar{\tilde{n}}$
$\tilde{n}$
N
N
$\langle N | \bar{\tilde{n}} S_\mu^{(\tilde{n})} \tilde{n} | N \rangle$

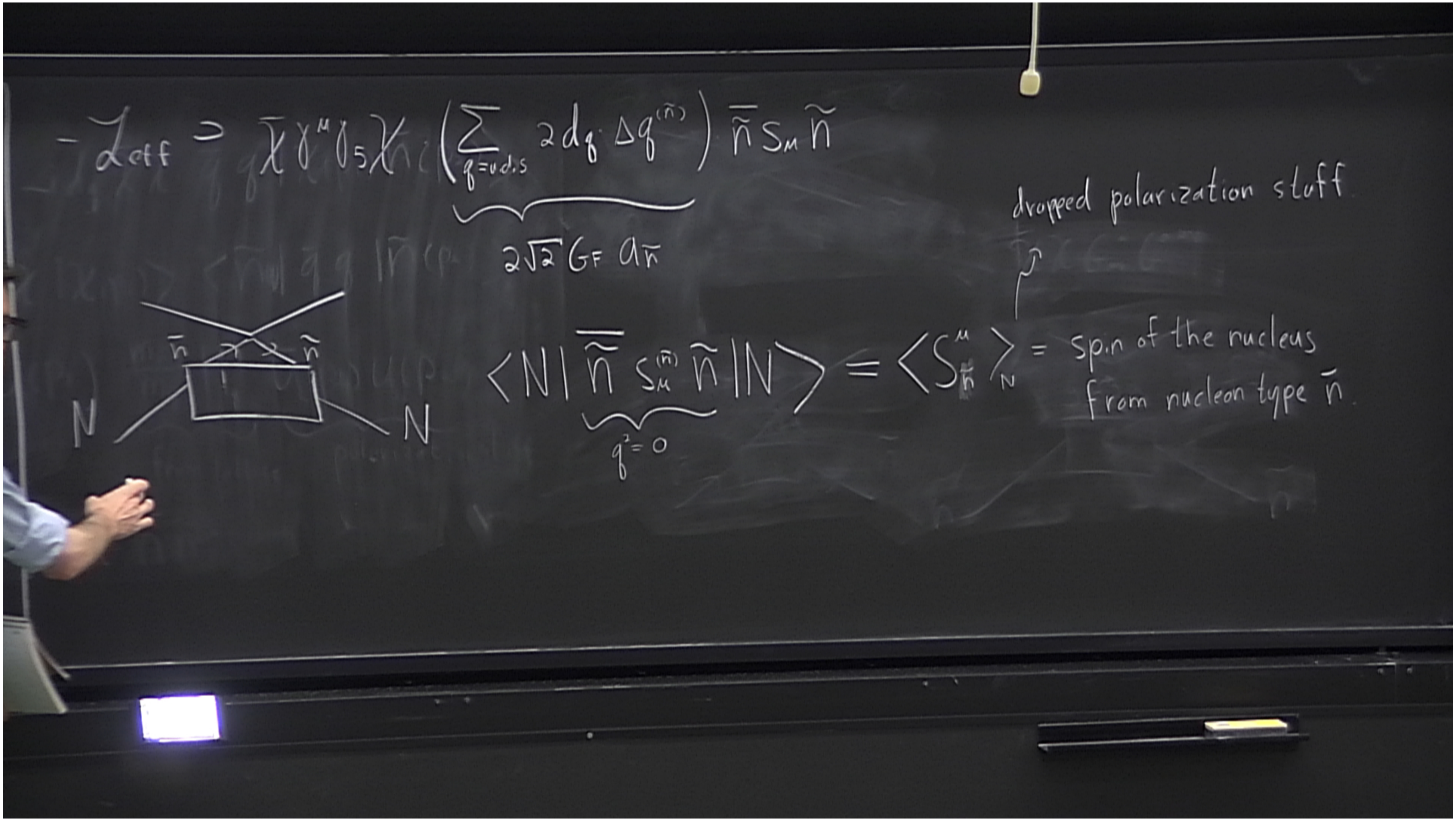


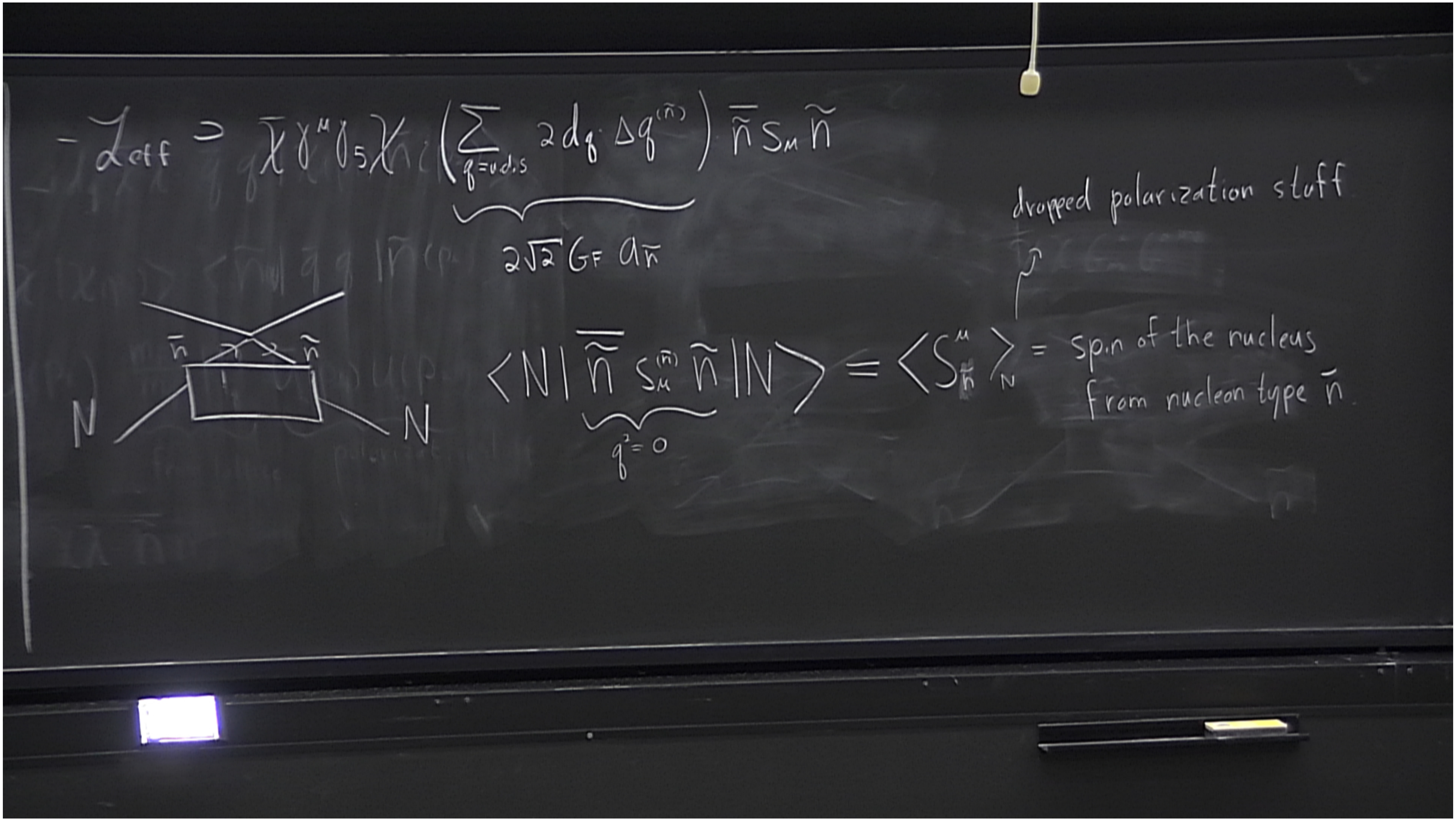
$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^\mu\gamma_5\chi \left(\sum_{q=u,d,s} 2d_q \cdot \Delta q^{(\tilde{n})}\right) \cdot \bar{\tilde{n}} S_\mu \tilde{n}$
$2\sqrt{2}\, G_F\, a_{\tilde{n}}$
$\langle N | \bar{\tilde{n}}\, S_\mu^{(\tilde{n})}\, \tilde{n} | N \rangle =$
$q^2 = 0$
N
N

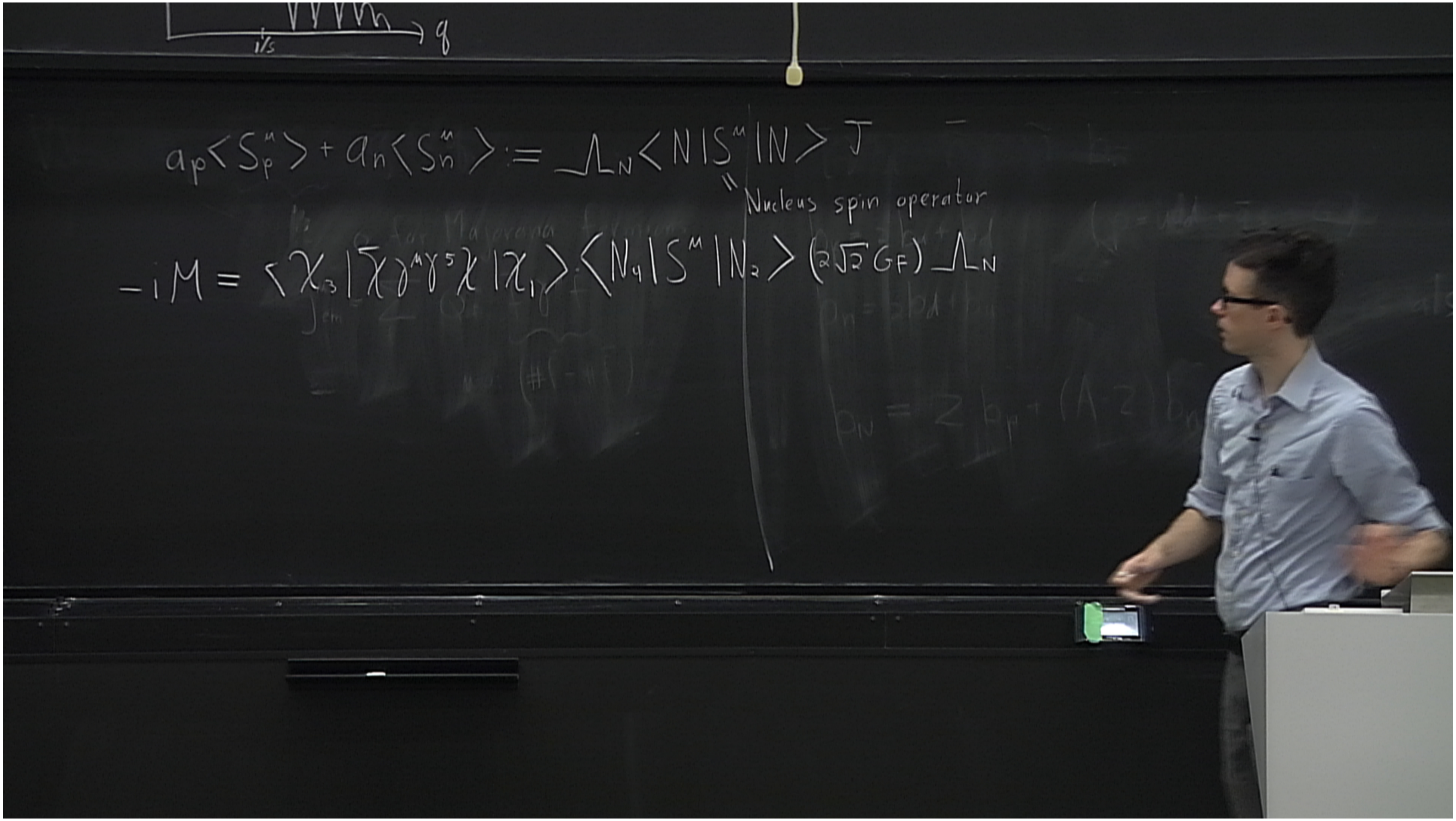
$$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^{\mu}\gamma_5\chi \underbrace{\left(\sum_{q=u,d,s} 2 d_q \cdot \Delta q^{(\tilde{n})}\right)}_{2\sqrt{2}\,G_F\, a_{\tilde{n}}} \bar{\tilde{n}} S_{\mu} \tilde{n}$$



$$\langle N | \underbrace{\bar{\tilde{n}} S_{\mu}^{(\tilde{n})} \tilde{n}}_{q^2=0} | N \rangle \equiv \langle S^{\mu}_{\tilde{n}} \rangle$$


$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^\mu\gamma_5\chi \left(\sum_{q=u,d,s} 2d_q \cdot \Delta q^{(\tilde{n})}\right) \bar{\tilde{n}} S_\mu \tilde{n}$
$2\sqrt{2}\, G_F\, a_{\tilde{n}}$
dropped polarization stuff
$\langle N | \bar{\tilde{n}} S_\mu^{(\tilde{n})} \tilde{n} | N \rangle = \langle S^\mu_{\tilde{n}} \rangle_N$ = spin of the nucleus from nucleon type $\tilde{n}$.
$q^2 = 0$
N
N


$-\mathcal{L}_{eff} \supset \bar{\chi}\gamma^\mu\gamma_5\chi \left(\sum_{q=u,d,s} 2 d_q \cdot \Delta q^{(\tilde{n})}\right) \bar{\tilde{n}} S_\mu \tilde{n}$
$2\sqrt{2}\, G_F\, a_{\tilde{n}}$
dropped polarization stuff
$\langle N | \bar{\tilde{n}} S_\mu^{(\tilde{n})} \tilde{n} | N \rangle = \langle S^\mu_{\tilde{n}} \rangle_N$ = spin of the nucleus from nucleon type $\tilde{n}$
$q^2 = 0$
N
N


q
1/s
a_p < S_p^μ > + a_n < S_n^μ > := Λ_N < N | S^μ | N > J
Nucleus spin operator
-iM = < χ_3 | χ̄ γ^μ γ^5 χ | χ_1 > < N_4 | S^μ | N_2 > (2√2 G_F) Λ_N