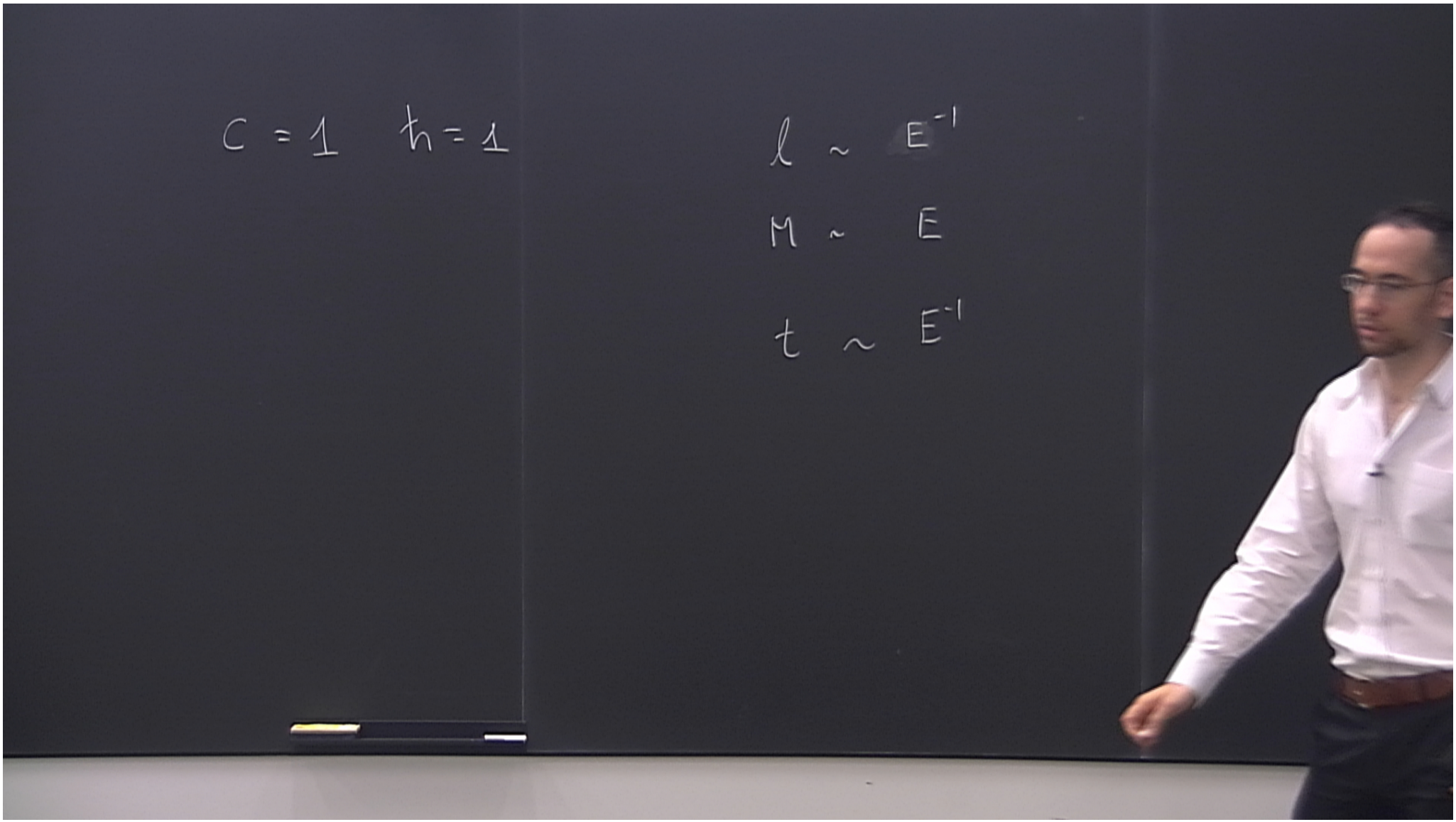
Title: 12/13 PSI - Beyond the Standard Model Lecture 7

Date: Feb 27, 2013 09:00 AM

URL: http://pirsa.org/13020097

Abstract:


c = 1 ħ = 1
ℓ ~ E^-1
M ~ E
t ~ E^-1

$c = 1 \quad \hbar = 1$

$keV = 10^3 eV$

$MeV = 10^6 eV$

$GeV = 10^9 eV$

$TeV = 10^{12} eV$

$l \sim E^{-1}$

$M \sim E$

$t \sim E^{-1}$

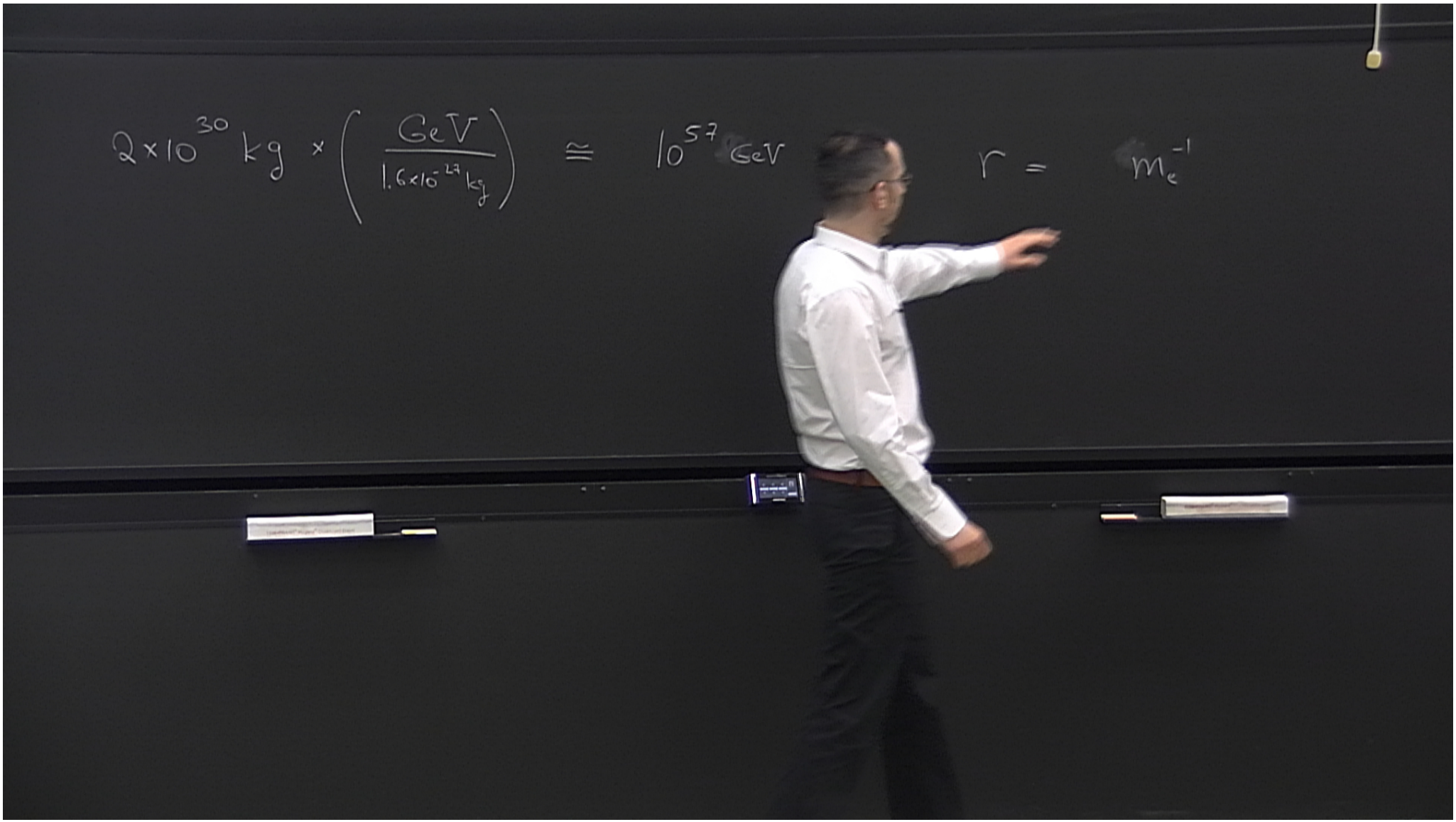
$$\frac{1.6\times10^{-27}\ \mathrm{kg}}{\mathrm{GeV}} = 1$$

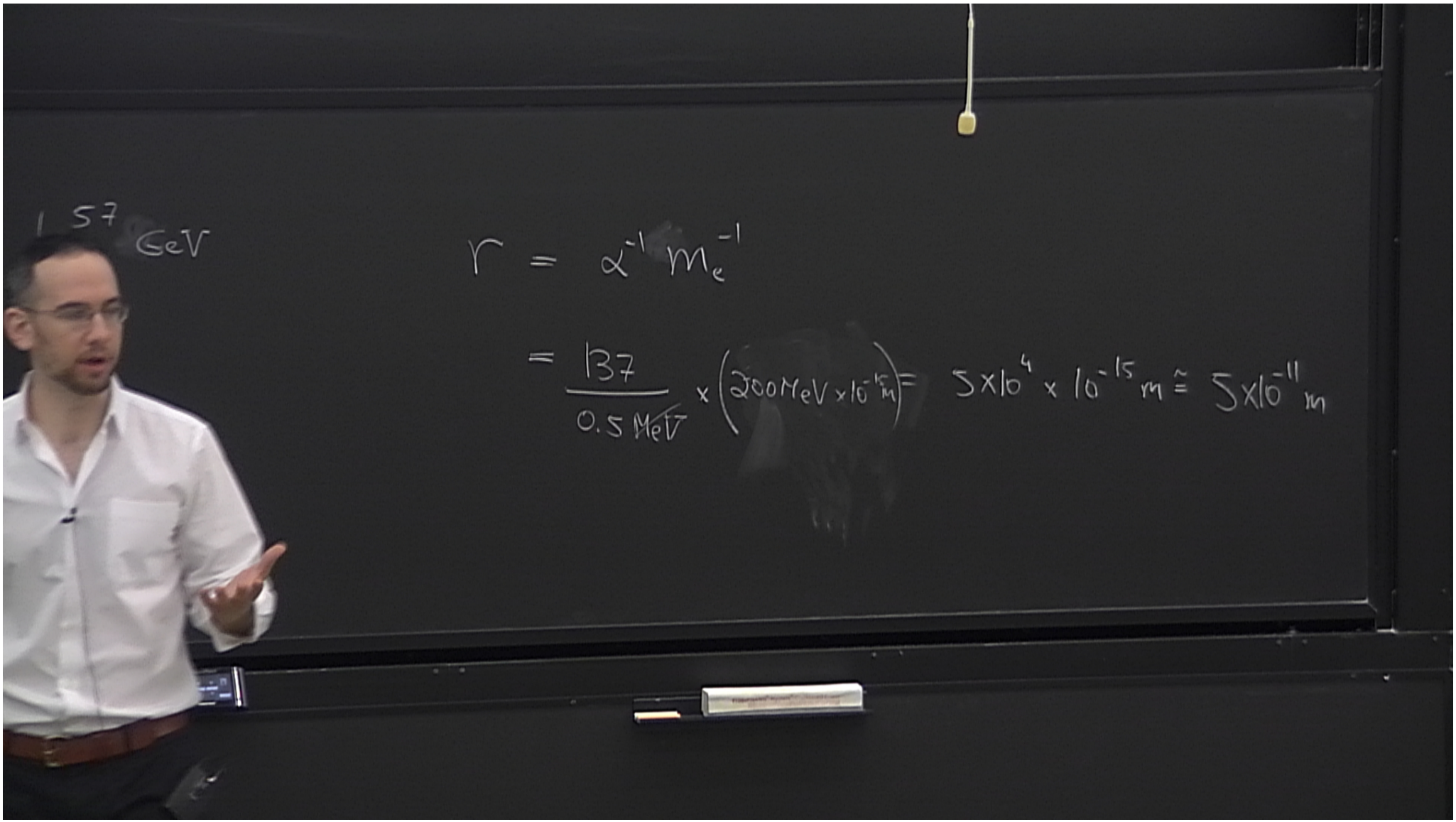
2×10^{30} kg

$$2\times10^{30}\ \mathrm{kg} \times \left(\frac{\mathrm{GeV}}{1.6\times10^{-27}\ \mathrm{kg}}\right) \cong 10^{57}\ \mathrm{GeV}$$

$$\frac{1.6\times10^{-27}\ \mathrm{kg}}{\mathrm{GeV}} = 1$$

$$\left(0.2\ \mathrm{GeV} \times 10^{-15}\ \mathrm{m}\right) = 1$$


$2\times10^{30}\,\mathrm{kg}\times\left(\frac{\mathrm{GeV}}{1.6\times10^{-27}\,\mathrm{kg}}\right)\cong 10^{57}\,\mathrm{GeV}$
$r = m_e^{-1}$

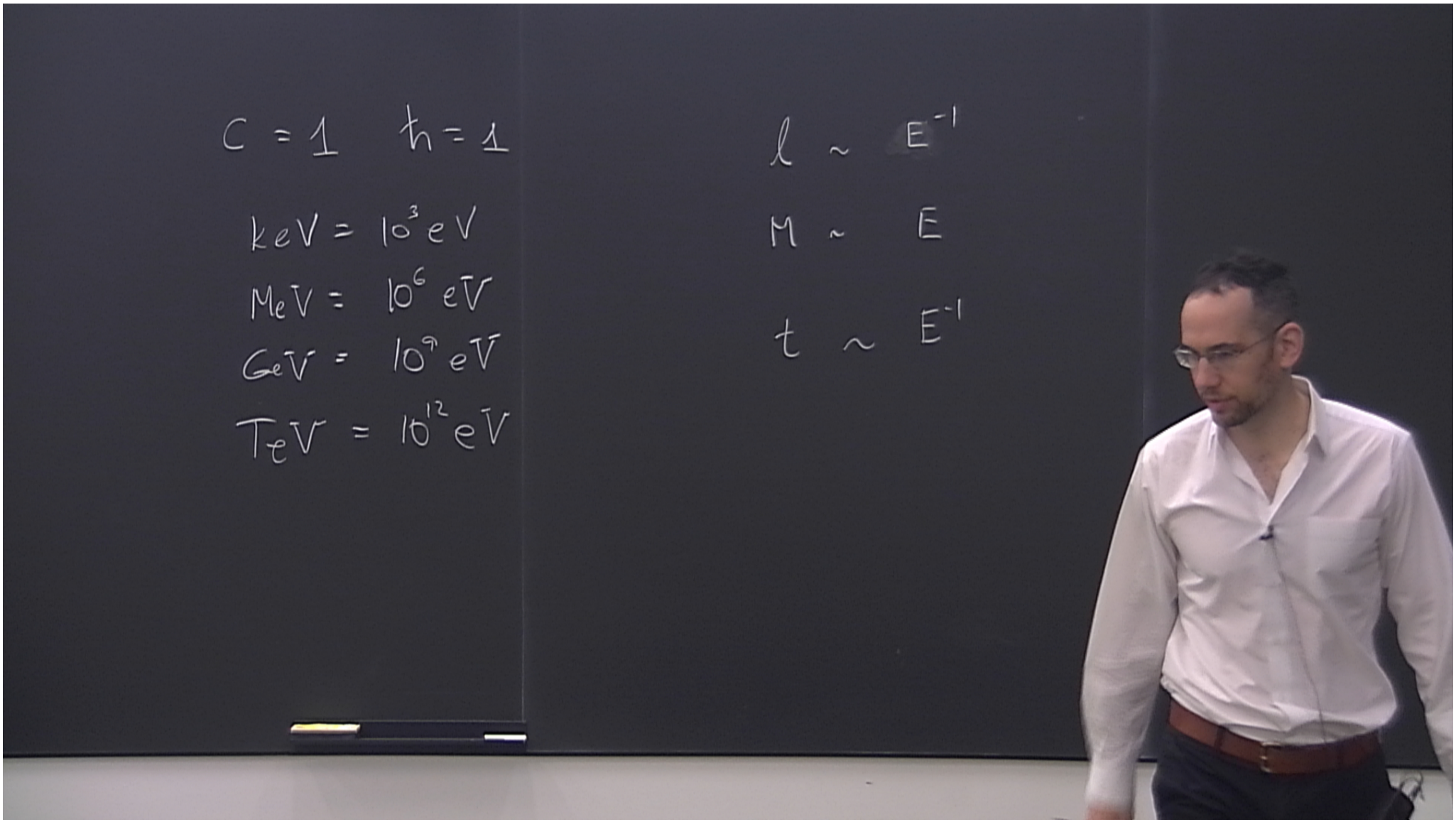

1.57 GeV
r = α^-1 m_e^-1
= 137 / 0.5 MeV × (200 MeV × 10^-15 m) = 5×10^4 × 10^-15 m ≅ 5×10^-11 m

10^{57} GeV

$$r = \alpha^{-1} m_e^{-1}$$

$$= \frac{137}{0.5\,\text{MeV}} \times \left(200\,\text{MeV} \times 10^{-15}\,\text{m}\right) = 5 \times 10^{4} \times 10^{-15}\,\text{m} \cong 5 \times 10^{-11}\,\text{m}$$

$$\cong 1\,\text{Å}$$

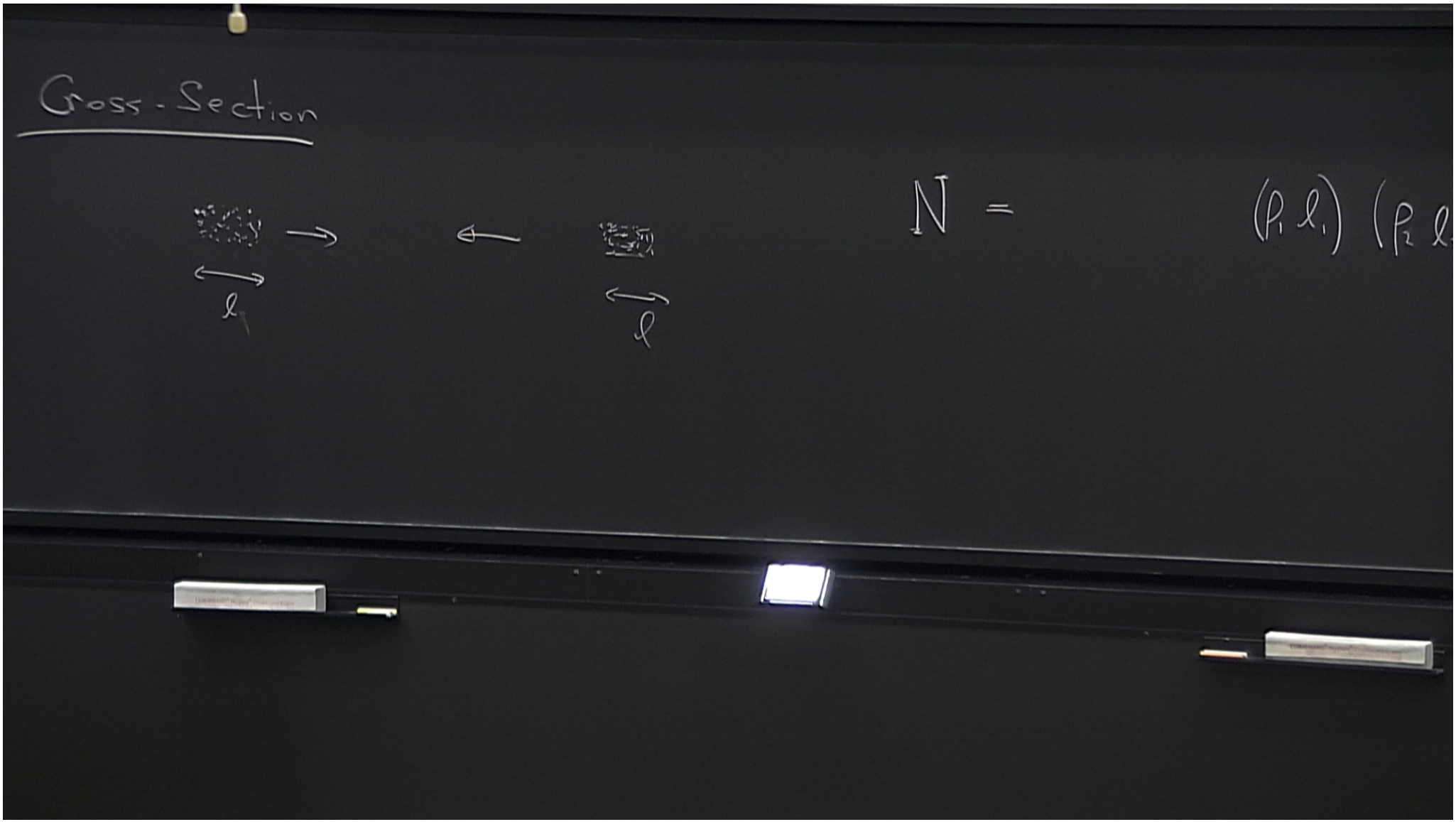

c = 1 ħ = 1
keV = 10^3 eV
MeV = 10^6 eV
GeV = 10^9 eV
TeV = 10^12 eV
ℓ ~ E^-1
M ~ E
t ~ E^-1

$$\frac{1.6\times10^{-27}\ \text{kg}}{\text{GeV}} = 1$$

$$\left(0.2\ \text{GeV} \times 10^{-15}\ \text{m}\right) = 1$$

$$\left(0.2\ \text{GeV} \times 10^{-15}\ \cancel{\text{m}} \times \frac{1}{3\times10^{8}\ \cancel{\text{m}}/\text{s}}\right) = \left(0.6\times10^{-24}\ \text{GeV s}\right) = 1$$

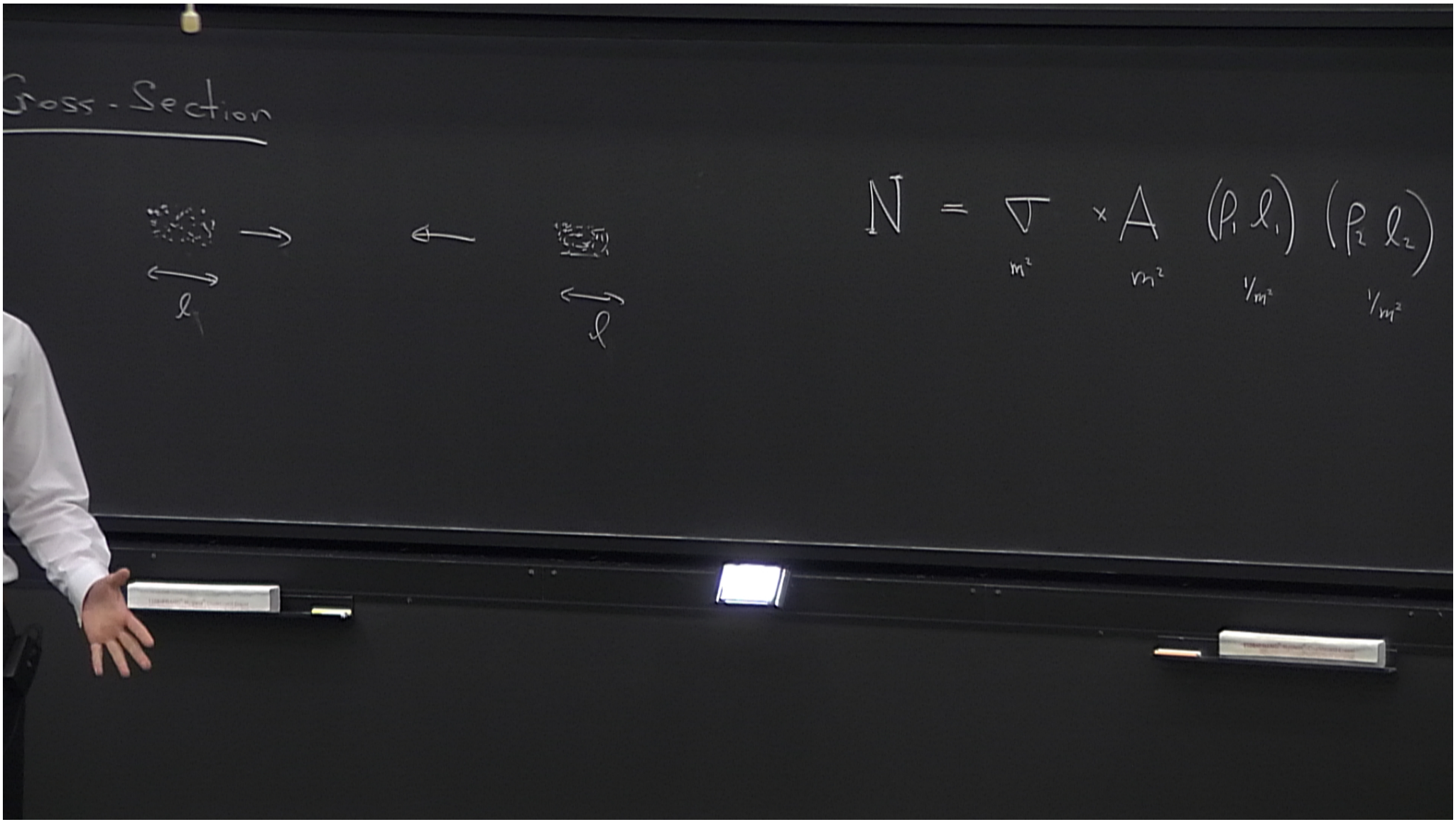
$$\Gamma_Z = 2\ \text{GeV} \Rightarrow \tau = \frac{1}{\Gamma} = \frac{1}{2\,\text{GeV}} \cdot 0.6\times10^{-24}\ \text{s}\ \cancel{\text{GeV}} = 0.3\times10^{-24}\ \text{s}$$


Cross-Section
N =
(p1 l1) (p2 l

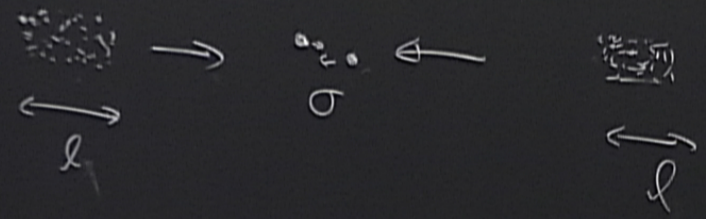
$$N = (\rho_1 \ell_1)(\rho_2 \ell_2)$$

$1/m^2$ $\quad$ $1/m^2$

ℓ

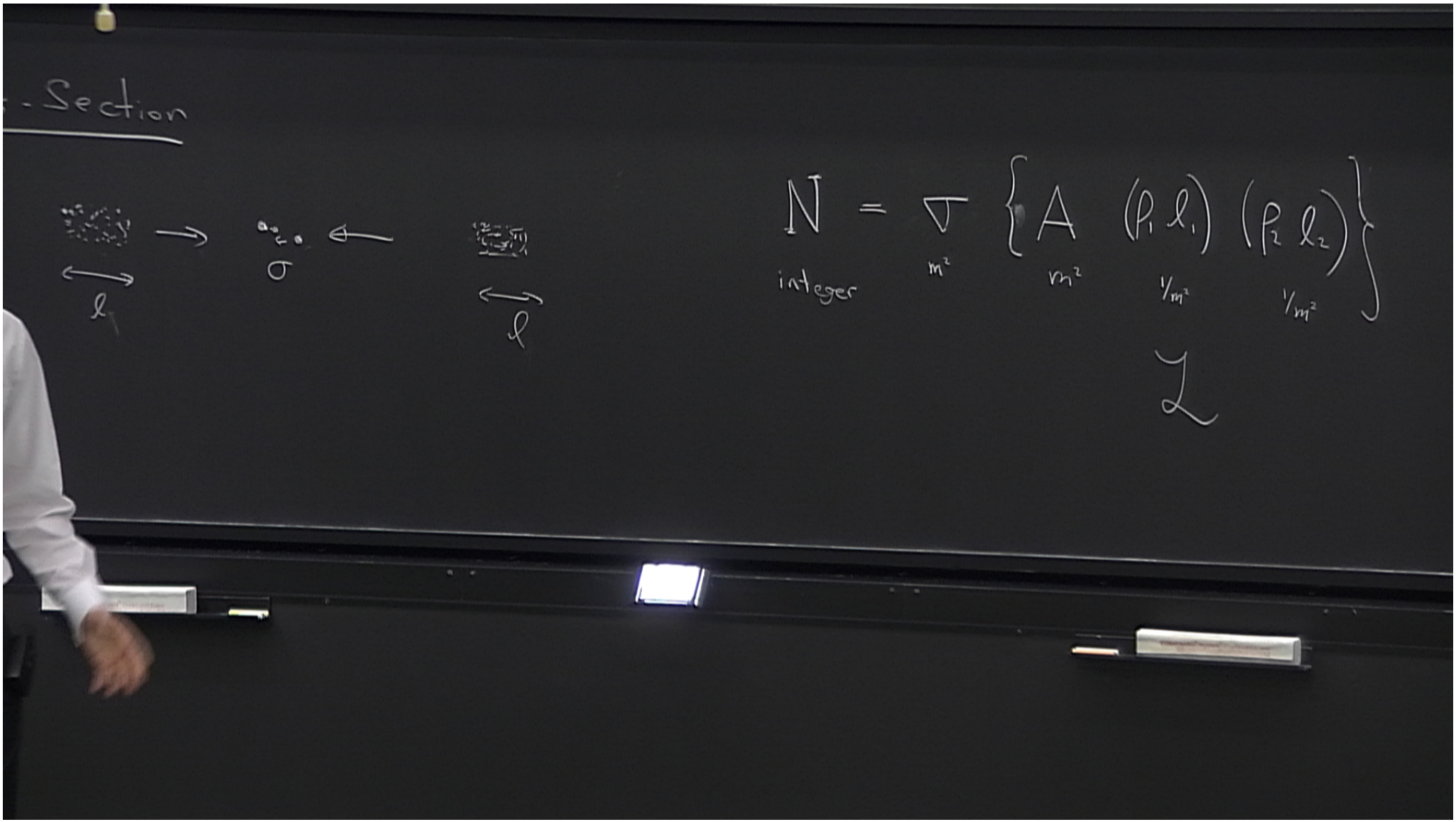

Cross-Section
$N = \sigma \times A \, (\rho_1 \ell_1)(\rho_2 \ell_2)$
m^2 m^2 $1/m^2$ $1/m^2$
ℓ
ℓ

- Section

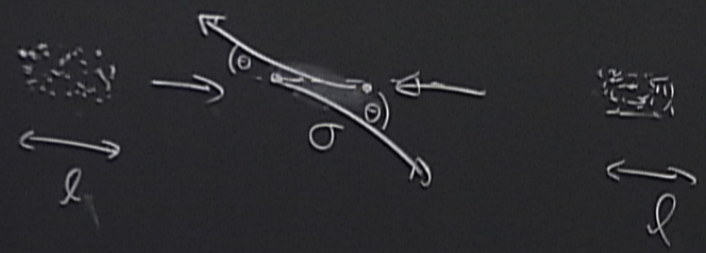


$$N = \underset{m^2}{\sigma} \left\{ \underset{m^2}{A} \; \underset{1/m^2}{(p_1 \ell_1)} \; \underset{1/m^2}{(p_2 \ell_2)} \right\}$$

$$\mathcal{L}$$


-Section
σ
ℓ
ℓ
$N = \sigma \{ A \; (p_1 \ell_1) \; (p_2 \ell_2) \}$
integer
m^2
m^2
$1/m^2$
$1/m^2$
$\mathcal{L}$

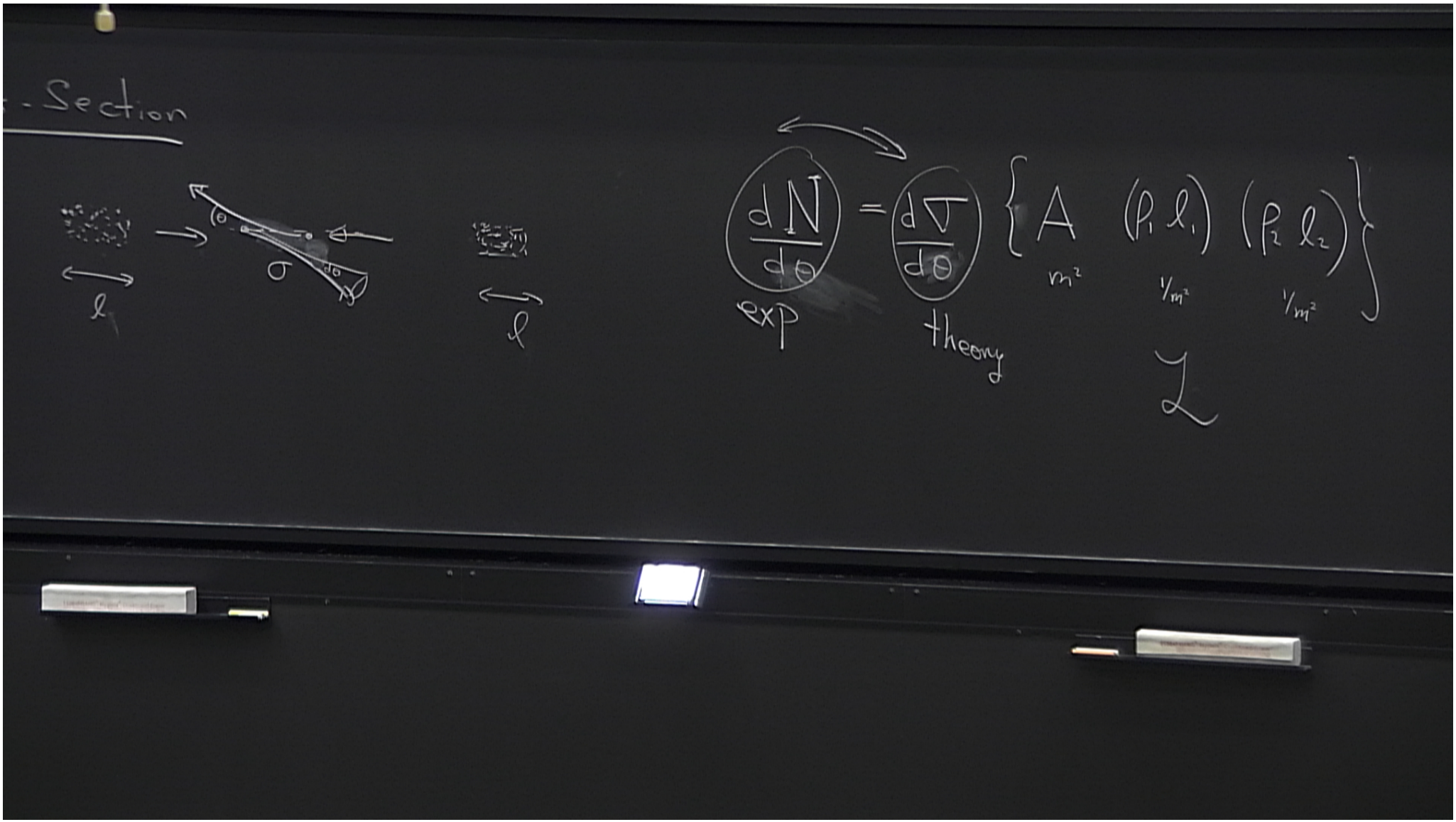
-Section

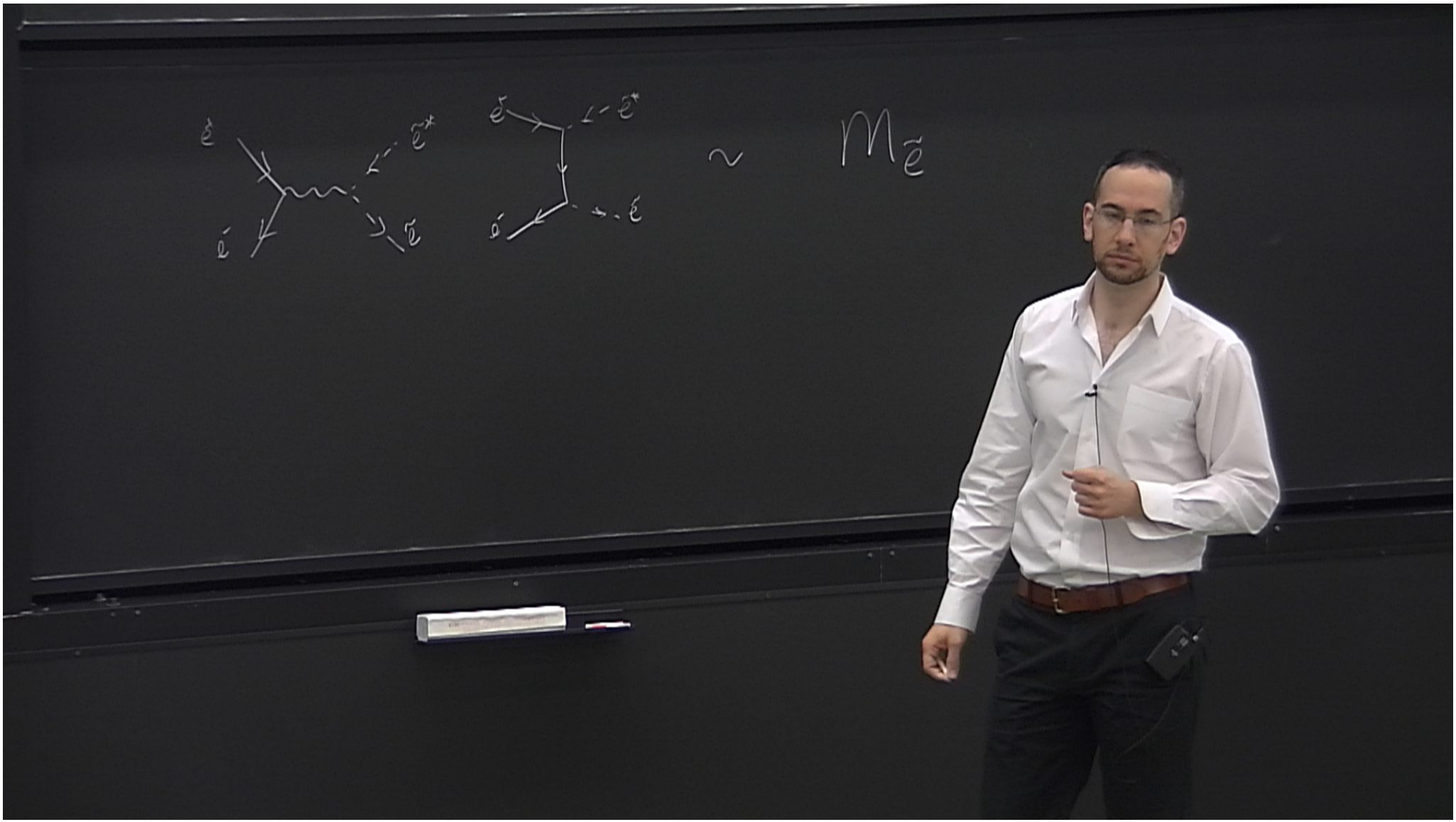


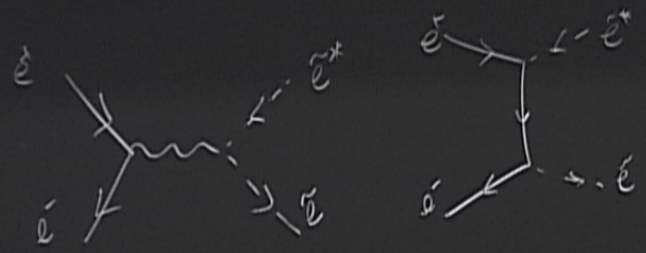
$$\underset{\text{integer}}{N} = \underset{m^2}{\sigma} \left\{ \underset{m^2}{A} \; \underset{1/m^2}{(\rho_1 \ell_1)} \; \underset{1/m^2}{(\rho_2 \ell_2)} \right\}$$

$$\mathcal{L}$$


-Section
dN/dθ = dσ/dθ {A (ρ1 l1) (ρ2 l2)}
exp
theory
m²
1/m²
1/m²
L

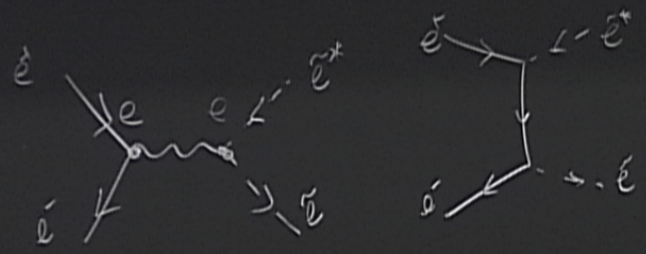

-Section
σ
ℓ
ℓ
$\frac{dN}{d\theta} = \frac{d\sigma}{d\theta} \{ A \; (\rho_1 \ell_1) \; (\rho_2 \ell_2) \}$
exp
theory
m^2
$1/m^2$
$1/m^2$
$\mathcal{L}$


$\sim$
$M_{\tilde{e}}$



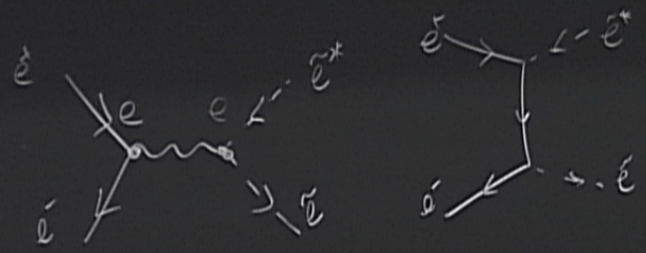
$\sim \quad m_{\tilde{e}}$

$$\sigma \sim \frac{1}{E^2} \sim \frac{1}{m_{\tilde{e}}^2}$$



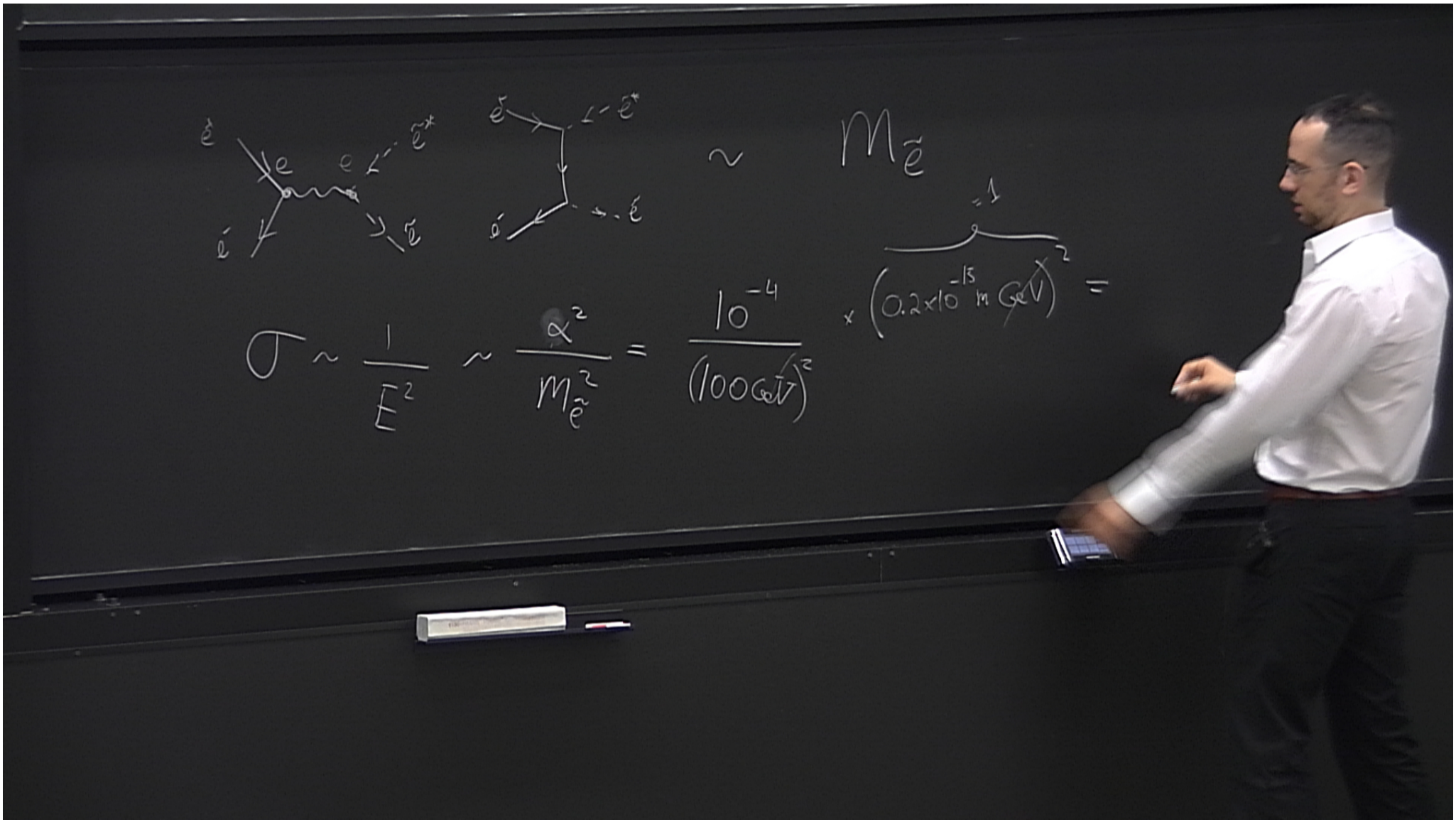
$\sim \quad M_{\tilde{e}}$

$$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2}$$

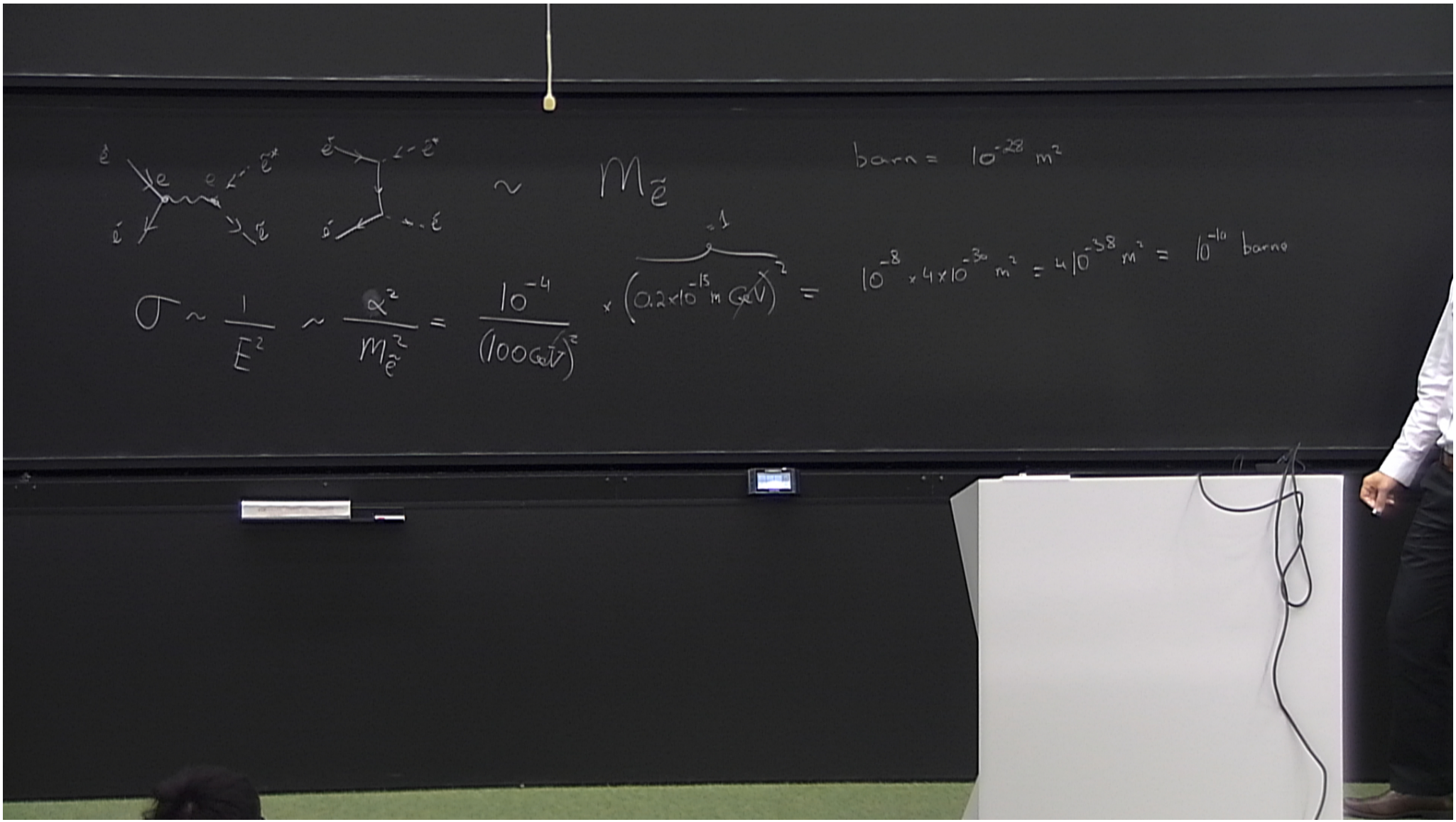


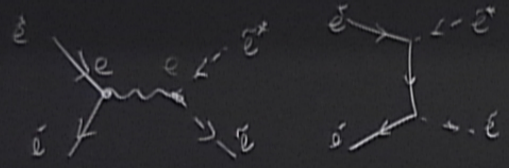
$$\sim \quad M_{\tilde{e}}$$

$$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2} = \underline{10^{-4}}$$


$\sim M_{\tilde{e}}$
$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{m_{\tilde{e}}^2} = \frac{10^{-4}}{(100\,\mathrm{GeV})^2} \times \overbrace{(0.2\times10^{-15}\,\mathrm{m}\,\mathrm{GeV})^2}^{=1} =$


$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{m_{\tilde{e}}^2} =$
$\sim m_{\tilde{e}}$
$10^{-8} \times 4 \times 10^{-30}\ m^2 = 10^{-38}\ m^2$


$\sim M_{\tilde{e}}$
barn = 10^{-28} m^2
$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2} = \frac{10^{-4}}{(100\,\text{GeV})^2} \times \overbrace{(0.2\times10^{-15}\,\text{m}\,\text{GeV})^2}^{=1} = 10^{-8} \times 4\times10^{-30}\,\text{m}^2 = 4\,10^{-38}\,\text{m}^2 = 10^{-10}$ barns



$\sim \quad M_{\tilde{e}}$

$\text{barn} = 10^{-28}\ m^2$

10^{-12} barn

$\shortparallel$

10^{2} pb

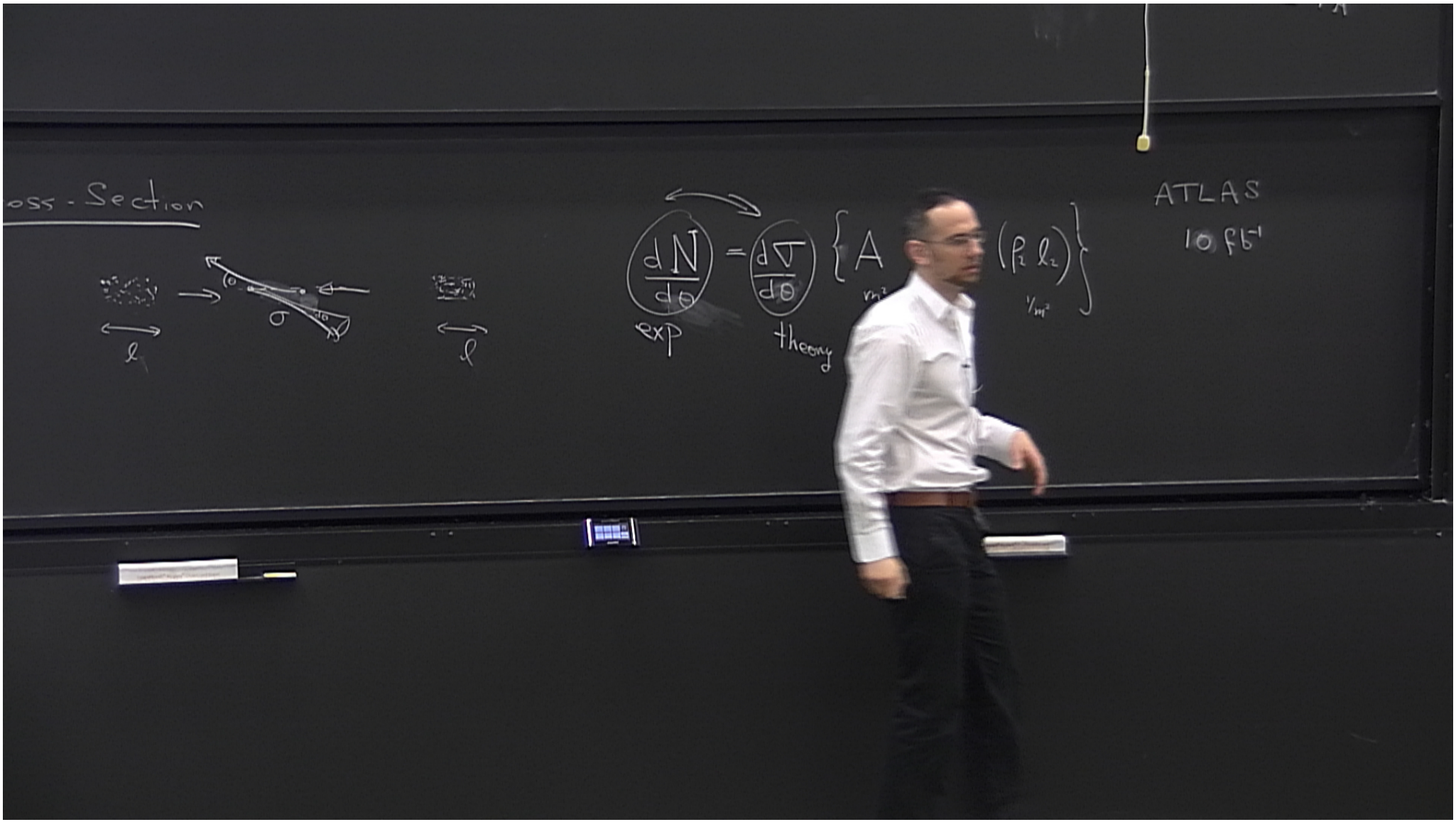
$$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2} = \frac{10^{-4}}{(100\,\text{GeV})^2} \times \overbrace{\left(0.2\times10^{-15}\,\text{m}\,\text{GeV}\right)^2}^{=1} = 10^{-8} \times 4\times10^{-30}\ m^2 = 4\,10^{-38}\ m^2 = 10^{-10}\ \text{barns} = 10^{2}\ \text{pb}$$

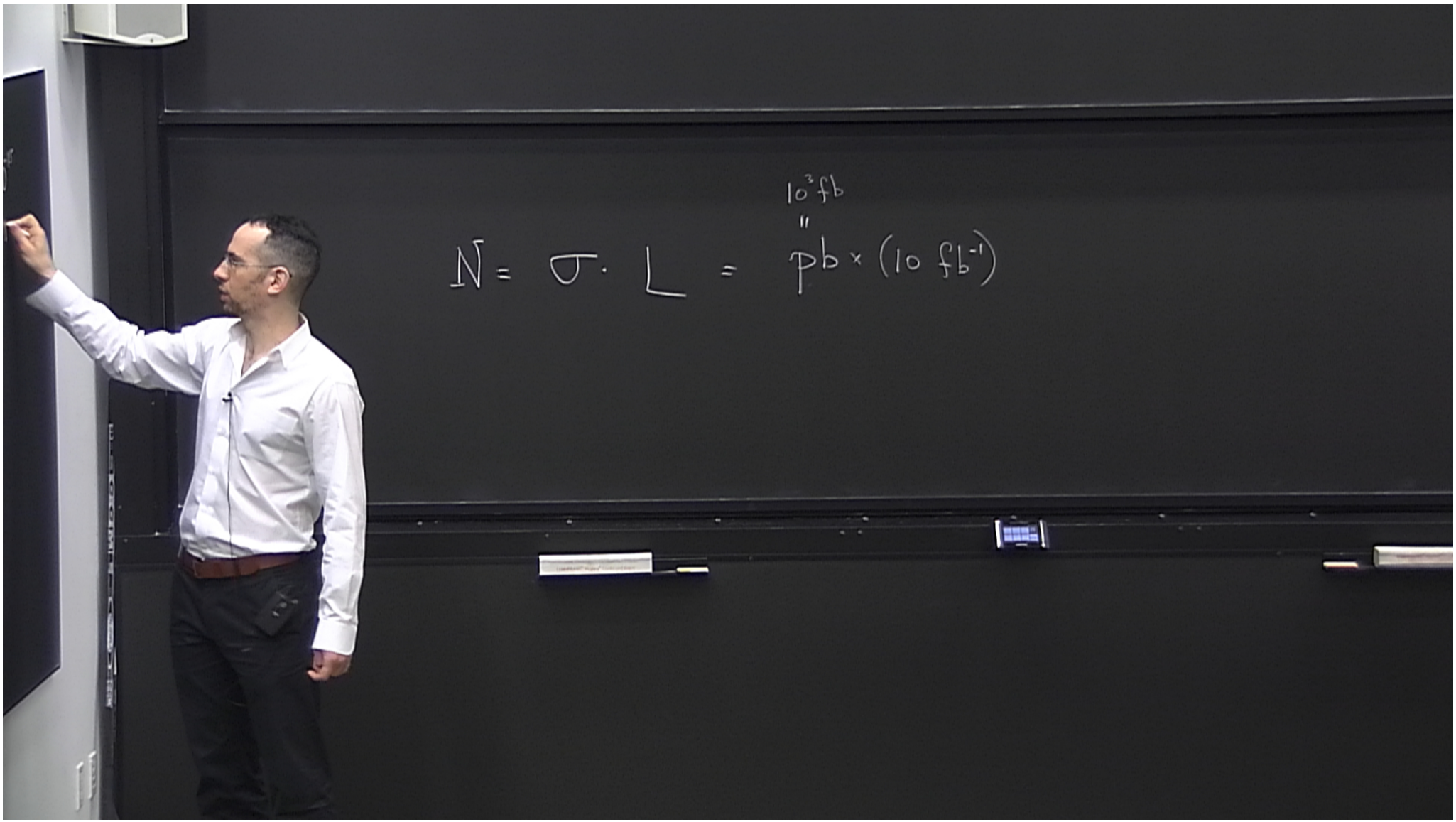
$\sim M_{\tilde{e}}$

$\text{barn} = 10^{-28}\ m^2$

10^{-12} barn

$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2} = \frac{10^{-4}}{(100\,GeV)^2} \times \overbrace{(0.2\times10^{-15}\ m\ GeV)^2}^{=1} = 10^{-8} \times 4\times10^{-32}\ m^2 = 4\,10^{-40}\ m^2 = 10^{-12}\ \text{barns} = pb$


oss - Section
ATLAS
10 fb⁻¹
exp
theory


$10^3 fb$
$N = \sigma \cdot L = pb \times (10\ fb^{-1})$

$c = 1 \quad \hbar = 1$

$keV = 10^3 eV$

$MeV = 10^6 eV$

$GeV = 10^9 eV$

$TeV = 10^{12} eV$

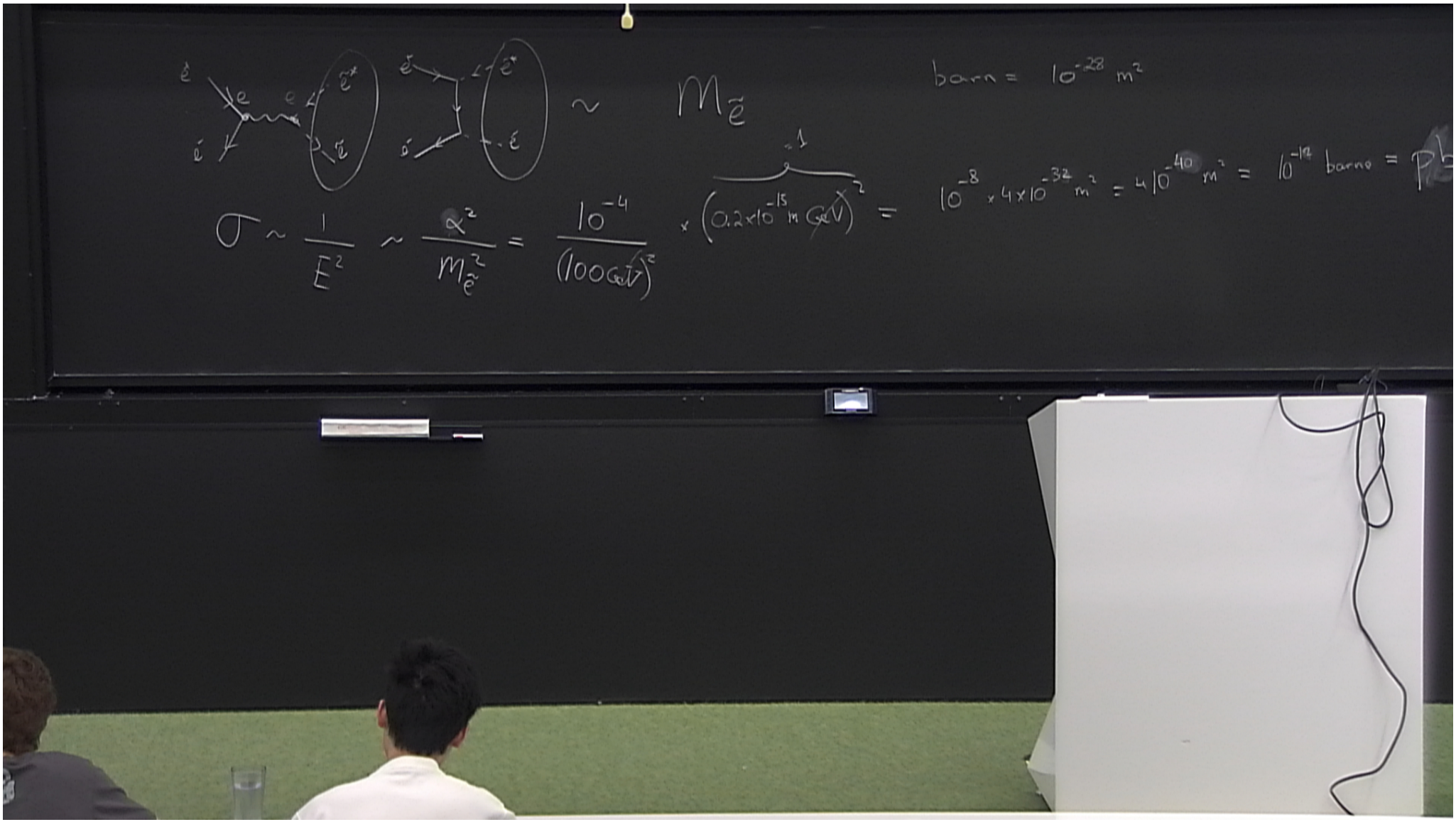
$l \sim E^{-1}$

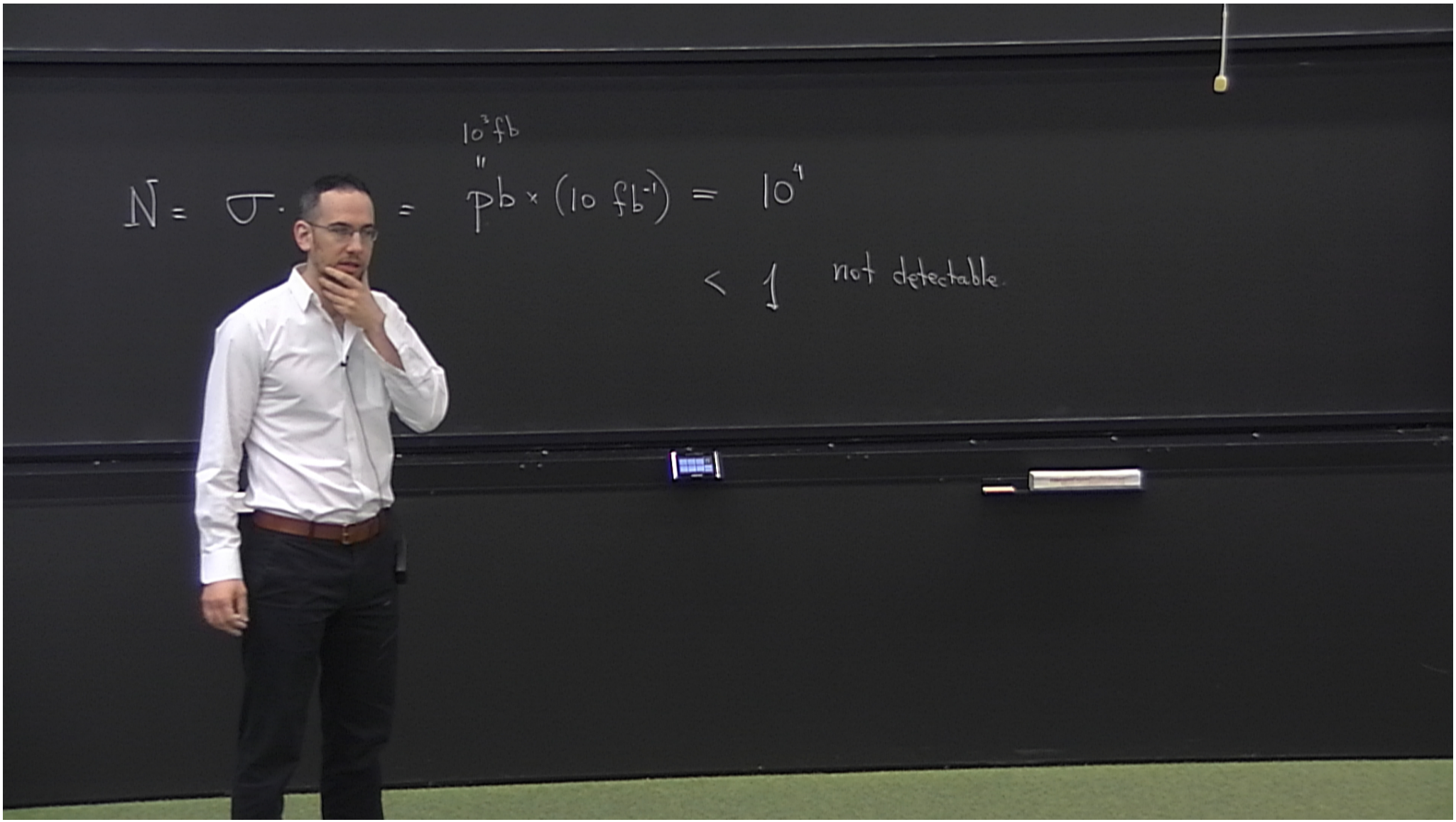
$M \sim E$

$t \sim E^{-1}$

$fento = 10^{-15}$

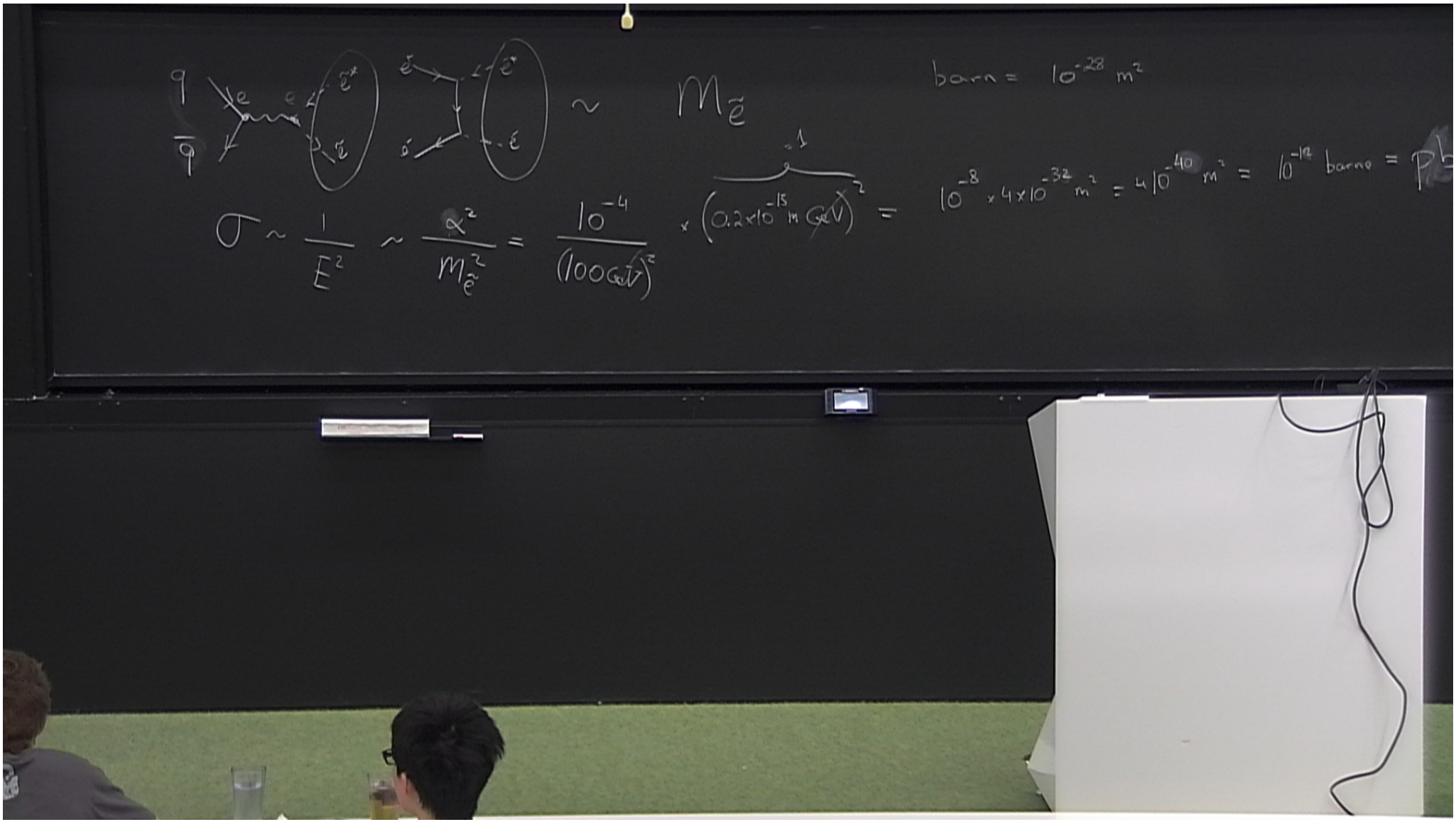
$pico = 10^{-12}$


$\sim M_{\tilde{e}}$
barn = 10^{-28} m^2
$\sigma \sim \frac{1}{E^2} \sim \frac{\alpha^2}{M_{\tilde{e}}^2} = \frac{10^{-4}}{(100\,\mathrm{GeV})^2} \times \overbrace{(0.2\times10^{-15}\,\mathrm{m\,GeV})^2}^{\sim 1} = 10^{-8} \times 4\times10^{-32}\,\mathrm{m}^2 = 4\,10^{-40}\,\mathrm{m}^2 = 10^{-14}$ barns = pb

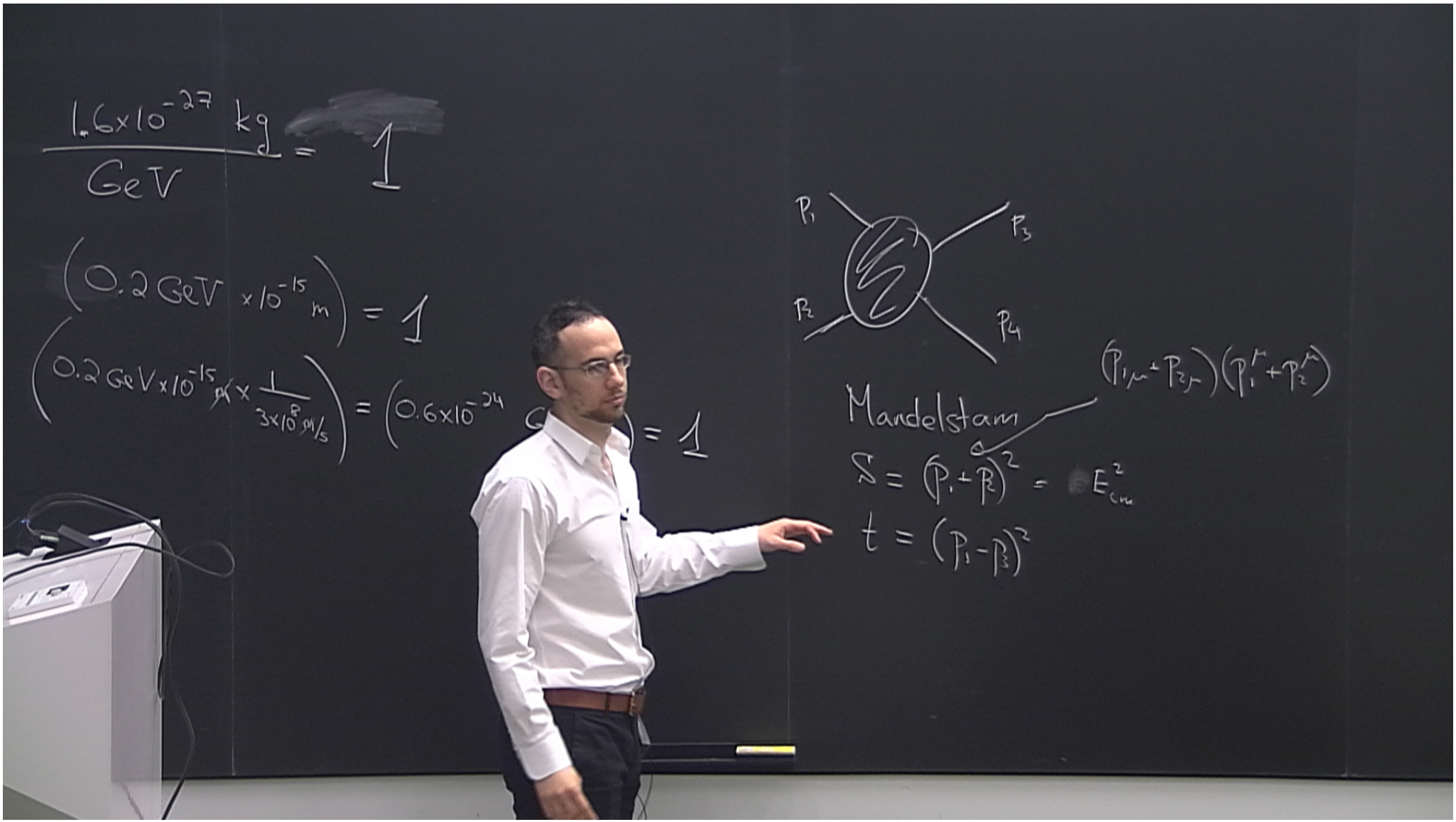

10^3 fb
$N = \sigma \cdot$ = pb × (10 fb^{-1}) = 10^4
< 1 not detectable.

$$N = \sigma \cdot L = \overset{10^3\,fb}{\overset{\shortparallel}{pb}} \times (10\ fb^{-1}) = 10^4$$

$$< 1$$ not detectable.


q
q̄
e
ẽ
ẽ*
ẽ
ẽ*
ẽ
ẽ*
ẽ
~ M_ẽ
barn = 10^-28 m^2
σ ~ 1/E^2 ~ α^2/M_ẽ^2 = 10^-4/(100 GeV)^2 × (0.2×10^-15 m GeV)^2 = 10^-8 × 4×10^-32 m^2 = 4 10^-40 m^2 = 10^-14 barns = pb

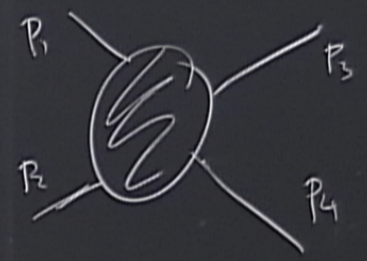

$|\mathcal{M}|^2$


1.6x10^-27 kg / GeV = 1
(0.2 GeV x10^-15 m) = 1
(0.2 GeV x10^-15 m x 1/(3x10^8 m/s)) = (0.6x10^-24 G) = 1
p1
p2
p3
p4
(p1μ + p2μ)(p1^μ + p2^μ)
Mandelstam
s = (p1 + p2)^2 = E_cm^2
t = (p1 - p3)^2

$$\frac{1.6\times10^{-27}\ \text{kg}}{\text{GeV}} = 1$$

$$\left(0.2\ \text{GeV}\times10^{-15}\ \text{m}\right) = 1$$

$$\left(0.2\ \text{GeV}\times10^{-15}\ \cancel{\text{m}}\times\frac{1}{3\times10^{8}\ \cancel{\text{m}}/\text{s}}\right) = \left(0.6\times10^{-24}\ \text{GeV s}\right) = 1$$



$$s + u + t = \sum_i m_i^2$$

$$(p_{1\mu} + p_{2\mu})(p_1^\mu + p_2^\mu)$$

Mandelstam

$$s = (p_1 + p_2)^2 = E_{cm}^2$$

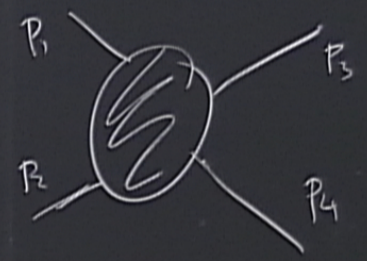
$$t = (p_1 - p_3)^2$$

$$u = (p_1 - p_4)^2$$

$$\frac{1.6\times10^{-27}\ \text{kg}}{\text{GeV}} = 1$$

$$\left(0.2\ \text{GeV}\times10^{-15}\ \text{m}\right) = 1$$

$$\left(0.2\ \text{GeV}\times10^{-15}\ \cancel{\text{m}}\times\frac{1}{3\times10^{8}\ \cancel{\text{m}}/\text{s}}\right) = \left(0.6\times10^{-24}\ \text{GeV s}\right) = 1$$



$$s + u + t = \sum_i m_i^2$$

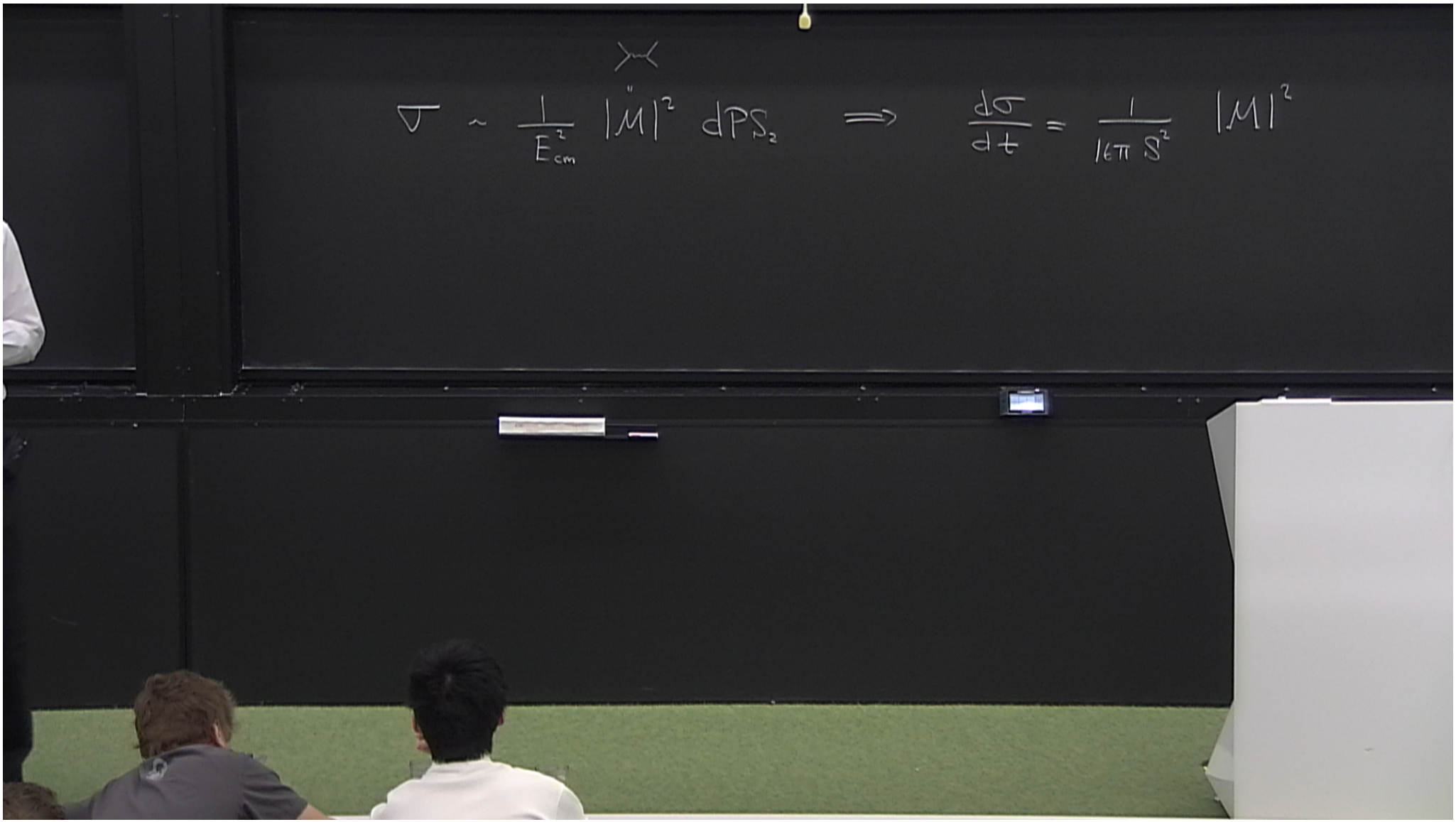
$$(p_{1\mu} + p_{2\mu})(p_1^\mu + p_2^\mu)$$

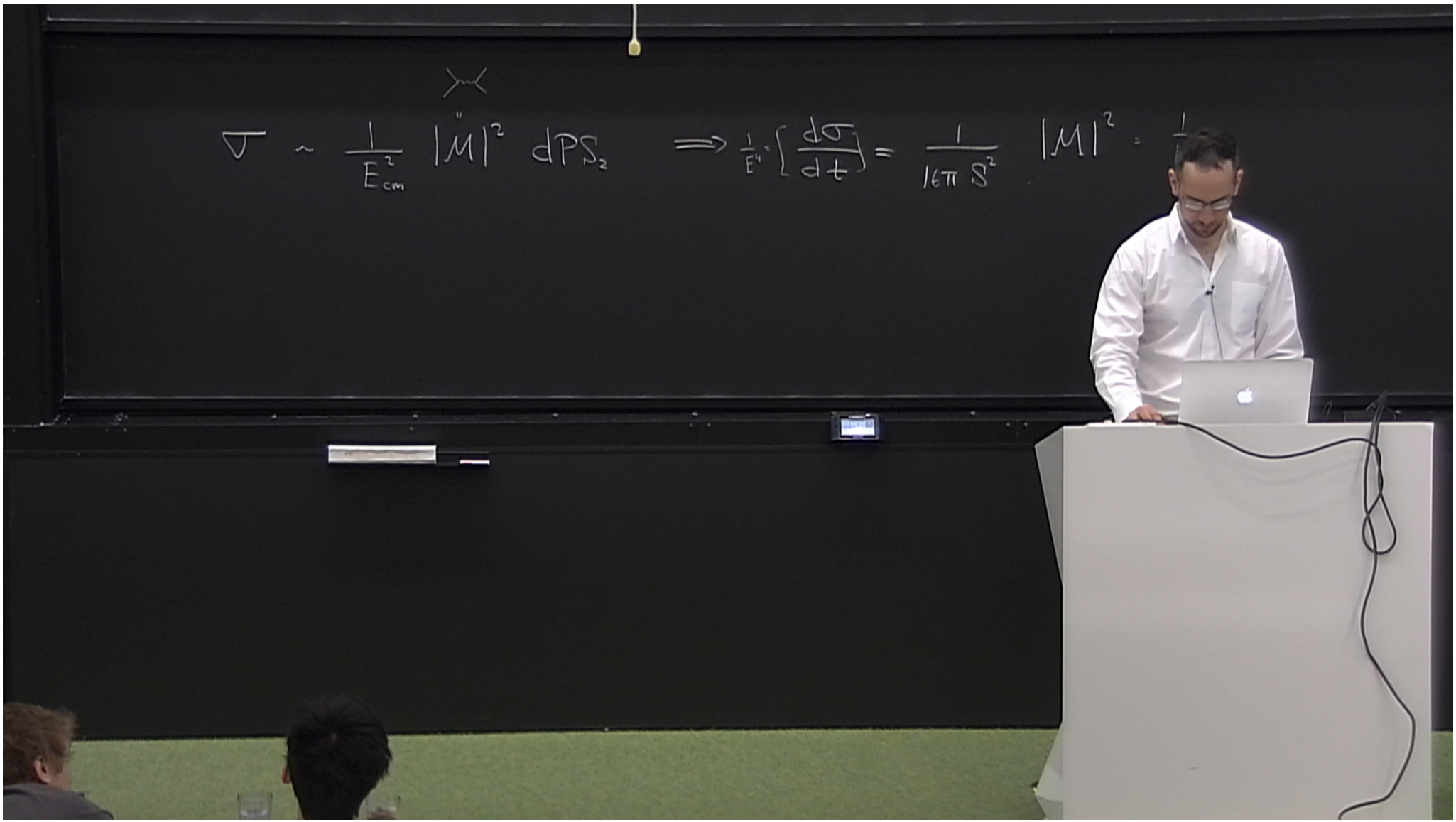
Mandelstam

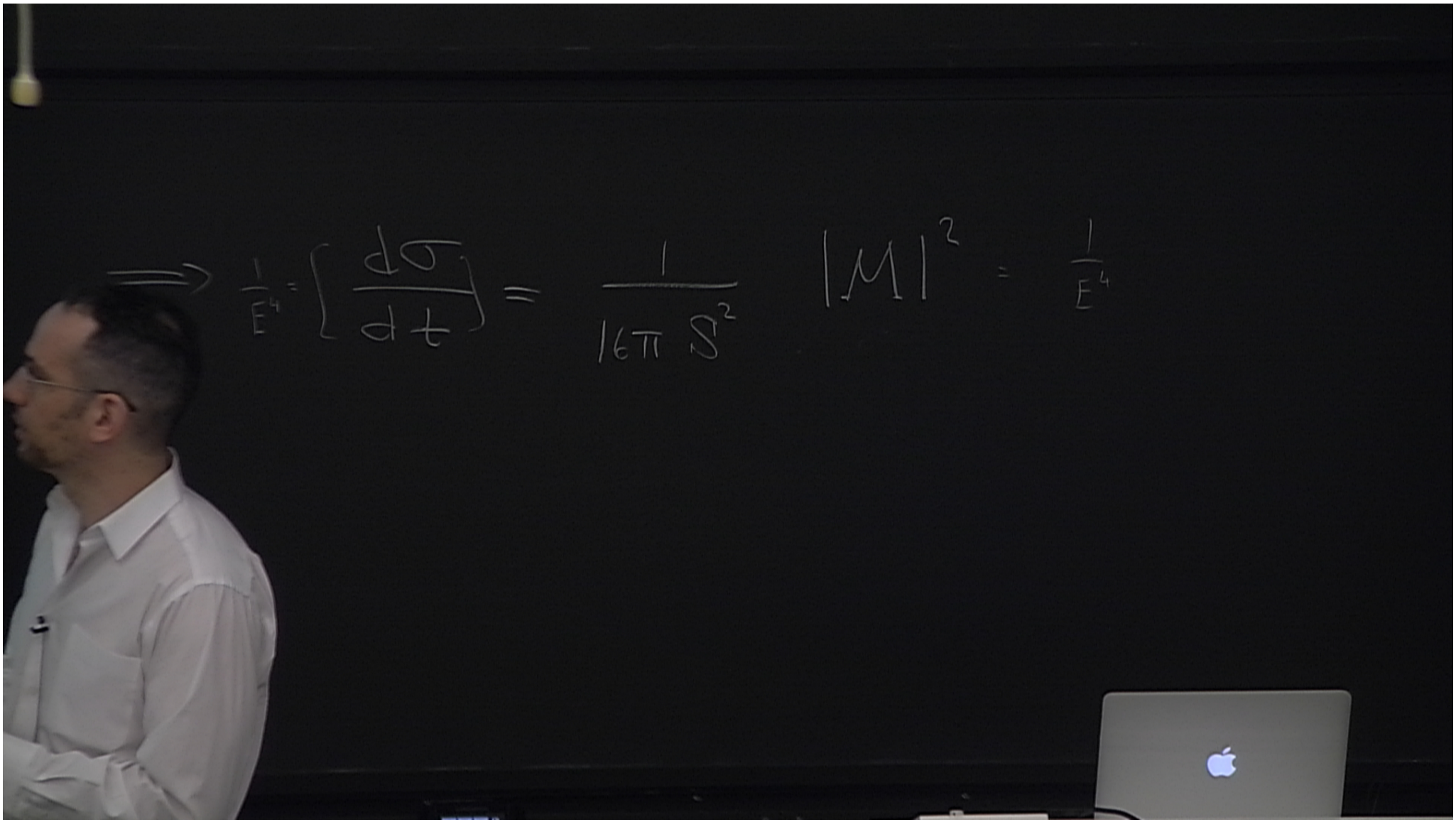
$$s = (p_1 + p_2)^2 = E_{cm}^2$$

$$t = (p_1 - p_3)^2 = E_{cm}^2 \sin^2\theta/2$$

$$u = (p_1 - p_4)^2$$


$\sigma \sim \frac{1}{E_{cm}^2} |\mathcal{M}|^2 \, dPS_2 \implies \frac{d\sigma}{dt} = \frac{1}{16\pi S^2} |\mathcal{M}|^2$


$\sigma \sim \frac{1}{E_{cm}^2} |\mathcal{M}|^2 \, dPS_2 \implies \frac{1}{E^4} \left[\frac{d\sigma}{dt} \right] = \frac{1}{16\pi S^2} |\mathcal{M}|^2 = \frac{1}{}$


$\Longrightarrow \frac{1}{E^4} = \left[\frac{d\sigma}{dt}\right] = \frac{1}{16\pi S^2} |M|^2 = \frac{1}{E^4}$

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Charge_states_production

```
momenta = {p1, p2, p3, p4};

othermomentasub = {};

masses = {0, 0, mX, mX};

mandelstam = {shat, that, uhat};

1/2 1/2 MEsSquared[meList, momenta, othermomentasub, masses, mandelstam]
]
```

The following squared elements were generated: $\{M1.M1^{\dagger}\}$

$$\left\{-\frac{e^4\left(4\,mX^2\,shat-shat^2+(that-uhat)^2\right)}{2\,shat^2}\right\}$$

Differential cross-section

```
dσhatdthat$ScProd =
(1/(16 π shat^2) 1/9 M2$ScProd[[1]]) /. {uhat → 2 mX^2 - shat - that} // FullSimplify
```

$$-\frac{e^4\left(mX^4-2\,mX^2\,that+that\,(shat+that)\right)}{72\,\pi\,shat^4}$$

200%

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Charge_states_production

```
1/2 1/2 MEsSquared[meList, momenta, othermomentasub, masses, mandelstam]
]
```

The following squared elements were generated: $\{M1.M1^{\dagger}\}$

$$\left\{-\frac{e^4\left(4\,mX^2\,shat - shat^2 + (that - uhat)^2\right)}{2\,shat^2}\right\}$$

Differential cross-section

```
dσhatdthat$ScProd =
 (1/(16 π shat^2) 1/9 M2$ScProd[[1]]) /. {uhat → 2 mX^2 - shat - that} // FullSimplify
```

$$-\frac{e^4\left(mX^4 - 2\,mX^2\,that + that\,(shat + that)\right)}{72\,\pi\,shat^4}$$

Total cross-section

```
σhat$ScProd =
 Integrate[dσhatdthat$ScProd,
   {that, -1/4 (2 shat - 4 mX^2 + 2 Sqrt[shat] Sqrt[shat - 4 mX^2]),
```

200%

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Charge_states_production

$$\left(\frac{}{16\,\pi\,\text{shat}^2}\;\frac{}{9}\;\text{M2\$ScProd}[[1]]\right) /. \{\text{uhat} \to 2\,\text{mX}^2 - \text{shat} - \text{that}\} \;//\; \text{FullSimplify}$$

$$-\frac{e^4\left(\text{mX}^4 - 2\,\text{mX}^2\,\text{that} + \text{that}\,(\text{shat} + \text{that})\right)}{72\,\pi\,\text{shat}^4}$$

Total cross-section

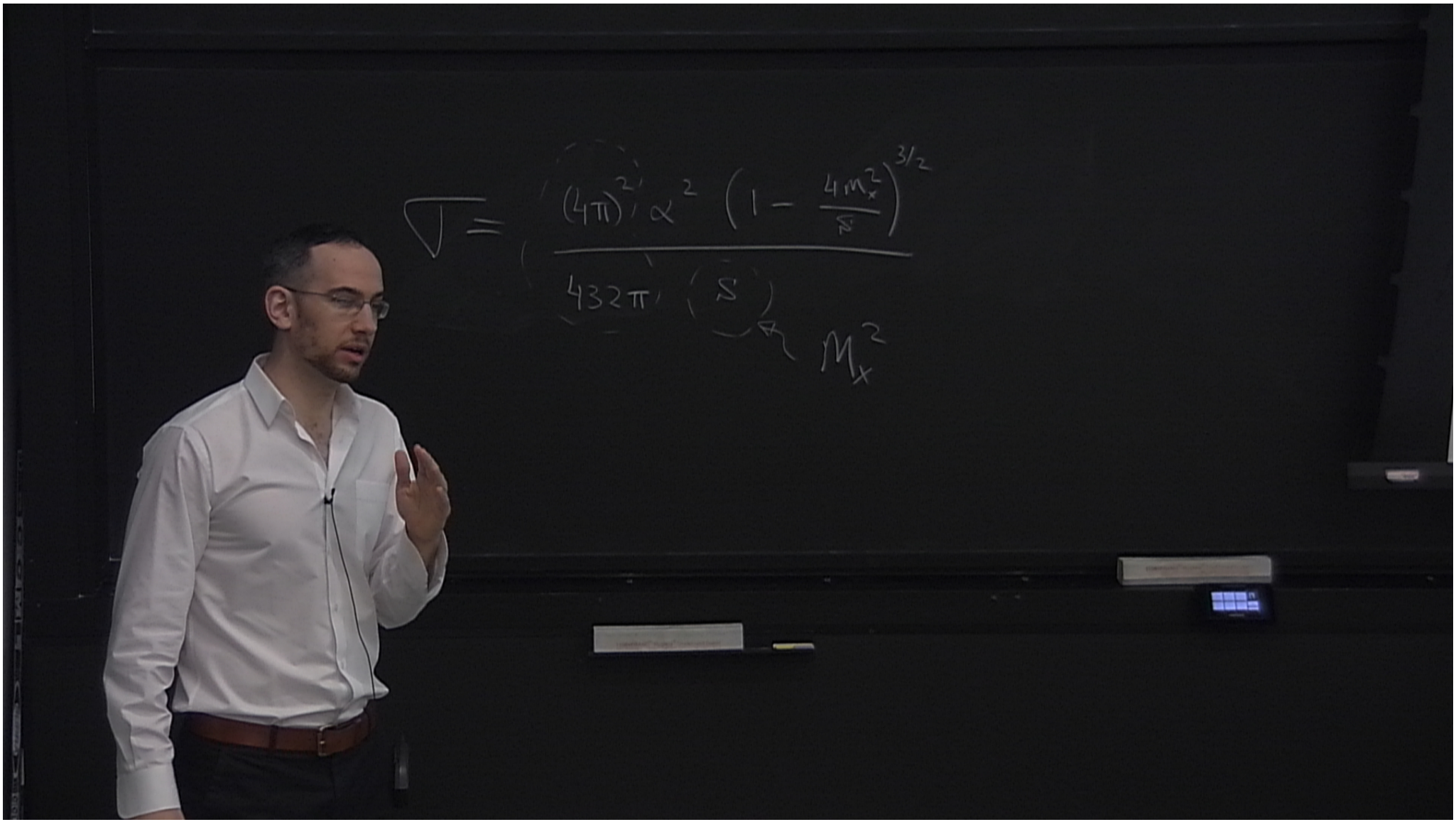
```
σhat$ScProd =
 Integrate[dσhatdthat$ScProd,
   {that, -1/4 (2 shat - 4 mX^2 + 2 Sqrt[shat] Sqrt[shat - 4 mX^2]),
    -1/4 (2 shat - 4 mX^2 - 2 Sqrt[shat] Sqrt[shat - 4 mX^2])}] // Simplify
```

$$\frac{e^4\left(-4\,\text{mX}^2 + \text{shat}\right)^{3/2}}{432\,\pi\,\text{shat}^{5/2}}$$

qqbar → Fe^+ Fe^- through γ

Matrix element squared

```
M2$FeProd =
 Block[{meList, MF1, MF2, momenta, othermomentasub, masses, mandelstam},
```


$\sigma = \frac{(4\pi)^2 \alpha^2}{432\pi s}\left(1 - \frac{4m_x^2}{s}\right)^{3/2}$
m_x^2

$$\sigma = \frac{(4\pi)^2 \alpha^2 \left(1 - \frac{4m_x^2}{s}\right)^{3/2}}{432\pi \, s}$$

$\sim M_X^2$

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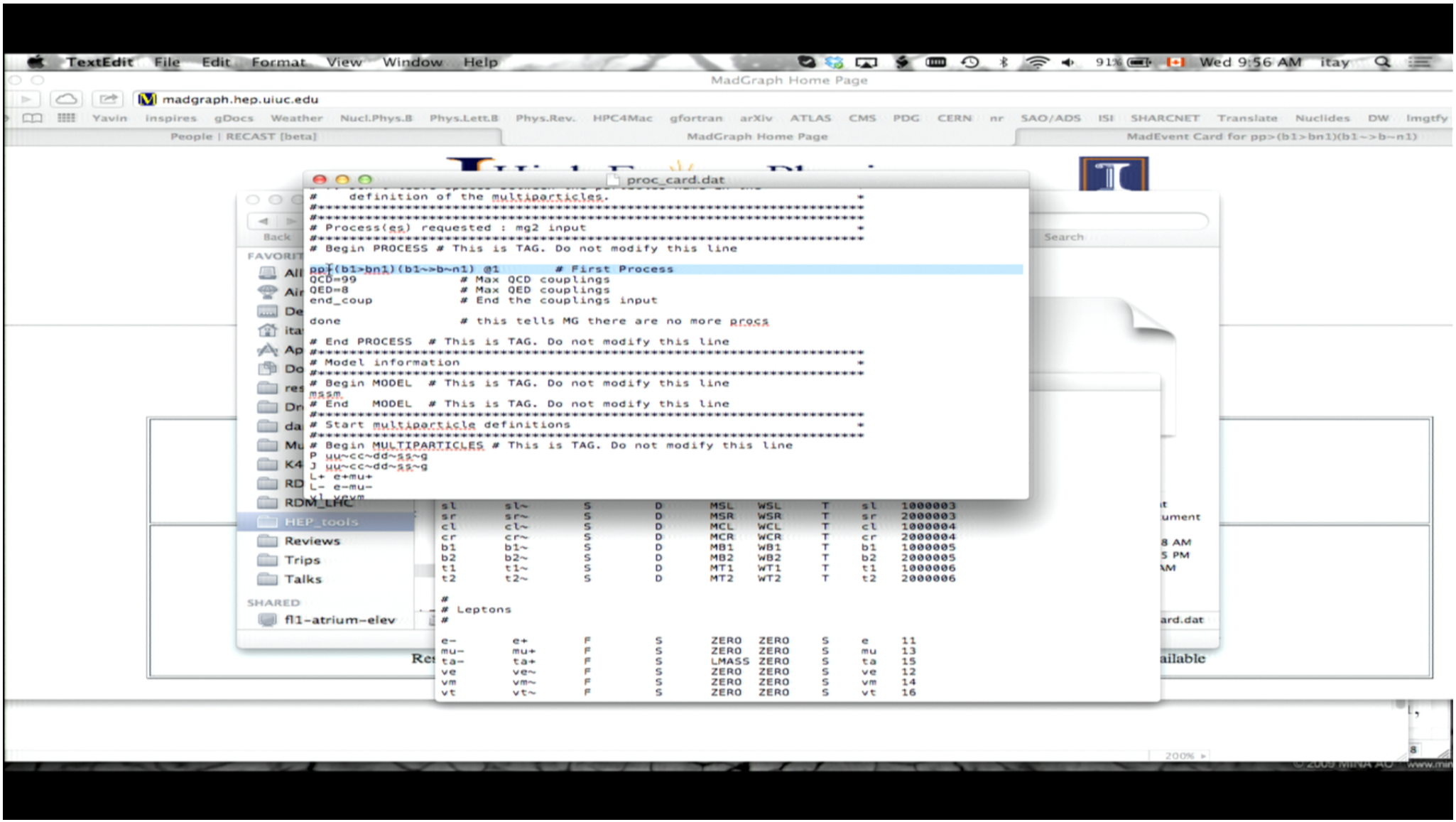
Charge_states_production

Total cross-section

```
σhat$FeProd =
 Integrate[dσhatdthat$FeProd,
   {that, -1/4 (2 shat - 4 mX^2 + 2 Sqrt[shat] Sqrt[shat - 4 mX^2]),
    -1/4 (2 shat - 4 mX^2 - 2 Sqrt[shat] Sqrt[shat - 4 mX^2])}] // Simplify
```

$$\frac{e^4 \sqrt{-4\,mX^2 + shat}\,\left(2\,mX^2 + shat\right)}{108\,\pi\,shat^{5/2}}$$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MadEvent Card for pp>(b1>bn1)(b1~>b~n1)
proc_card.dat
definition of the multiparticles.
Process(es) requested : mg2 input
Begin PROCESS # This is TAG. Do not modify this line
pp>(b1>bn1)(b1~>b~n1) @1 # First Process
QCD=99 # Max QCD couplings
QED=8 # Max QED couplings
end_coup # End the couplings input
done # this tells MG there are no more procs
End PROCESS # This is TAG. Do not modify this line
Model information
Begin MODEL # This is TAG. Do not modify this line
msm
End MODEL # This is TAG. Do not modify this line
Start multiparticle definitions
Begin MULTIPARTICLES # This is TAG. Do not modify this line
P uu~cc~dd~ss~g
J uu~cc~dd~ss~g
L+ e+mu+
L- e-mu-
FAVORITES
HEP_tools
Reviews
Trips
Talks
SHARED
fl1-atrium-elev
Search
Back
sl sl~ S D MSL WSL T sl 1000003
sr sr~ S D MSR WSR T sr 2000003
cl cl~ S D MCL WCL T cl 1000004
cr cr~ S D MCR WCR T cr 2000004
b1 b1~ S D MB1 WB1 T b1 1000005
b2 b2~ S D MB2 WB2 T b2 2000005
t1 t1~ S D MT1 WT1 T t1 1000006
t2 t2~ S D MT2 WT2 T t2 2000006
Leptons
e- e+ F S ZERO ZERO S e 11
mu- mu+ F S ZERO ZERO S mu 13
ta- ta+ F S LMASS ZERO S ta 15
ve ve~ F S ZERO ZERO S ve 12
vm vm~ F S ZERO ZERO S vm 14
vt vt~ F S ZERO ZERO S vt 16

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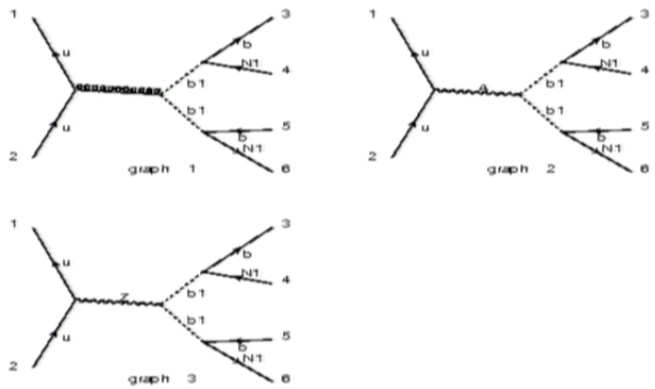
Diagrams by MadGraph u~ u -> b~ n1 b~ n1



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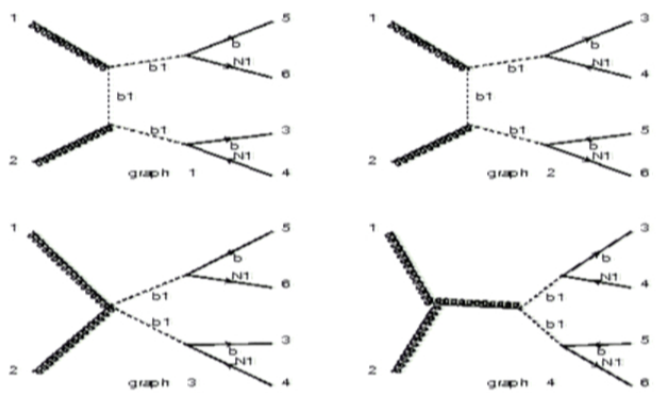

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