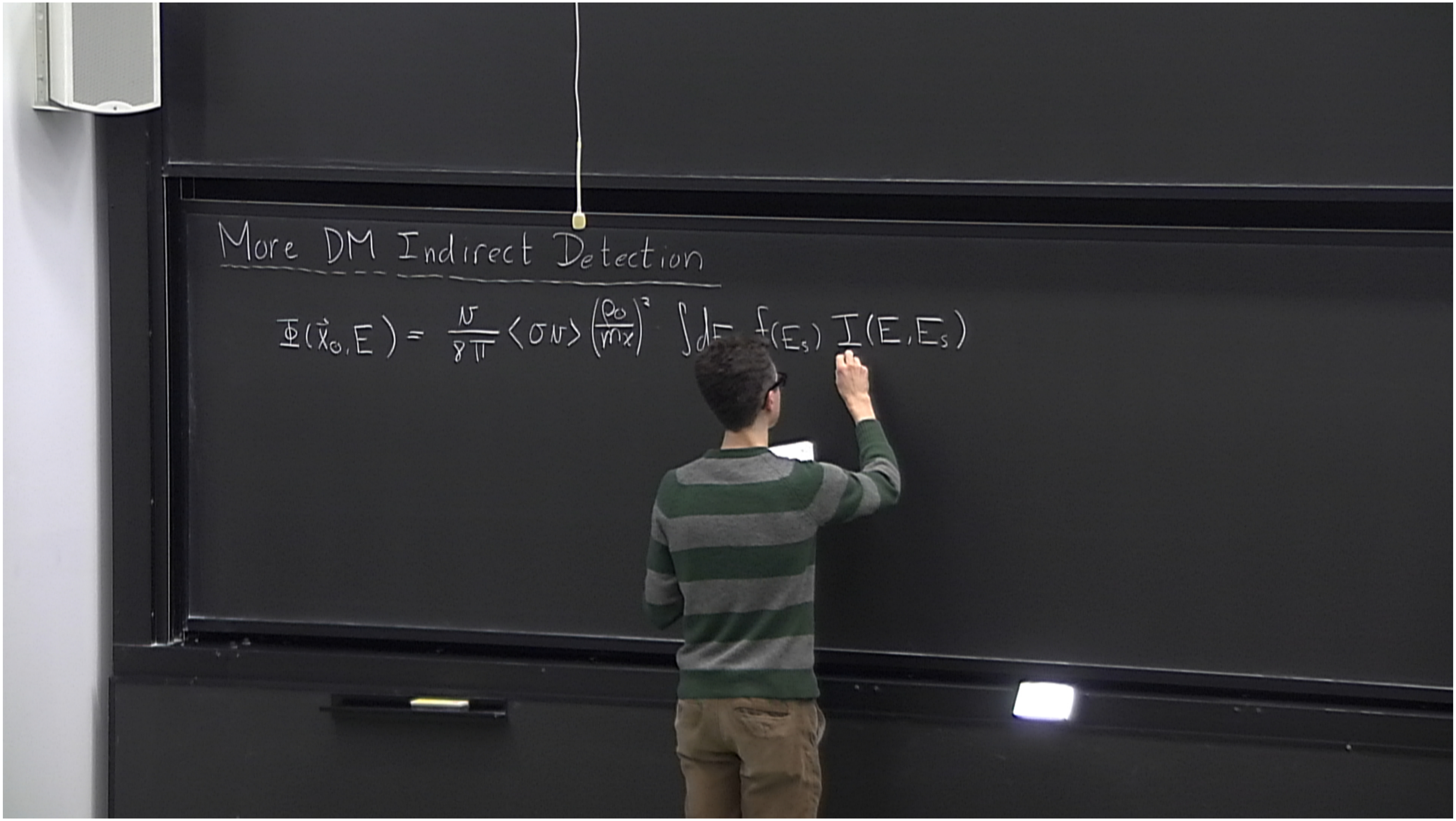
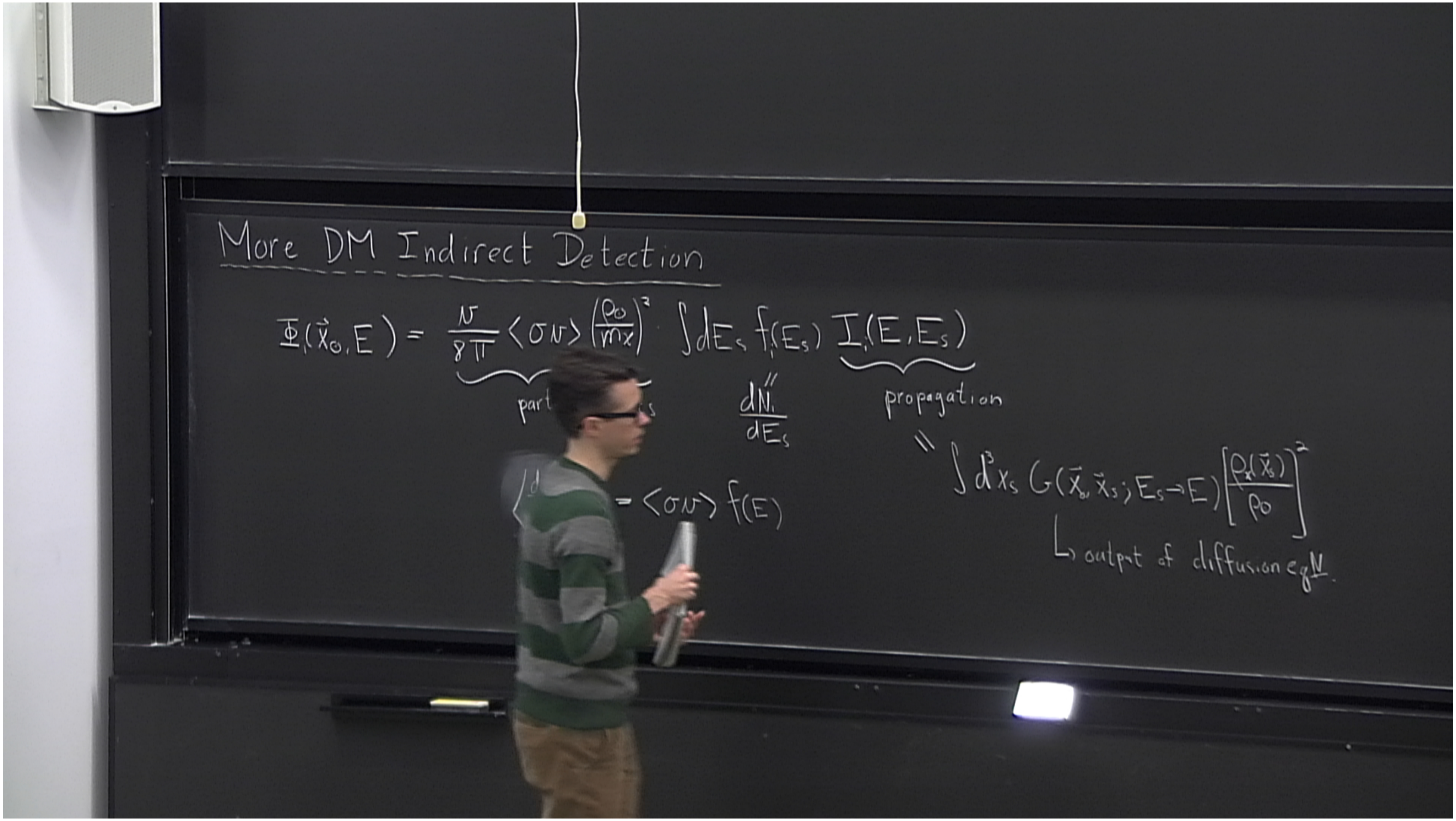
Title: Explorations in Particle Theory - Lecture 11

Date: Apr 17, 2012 09:00 AM

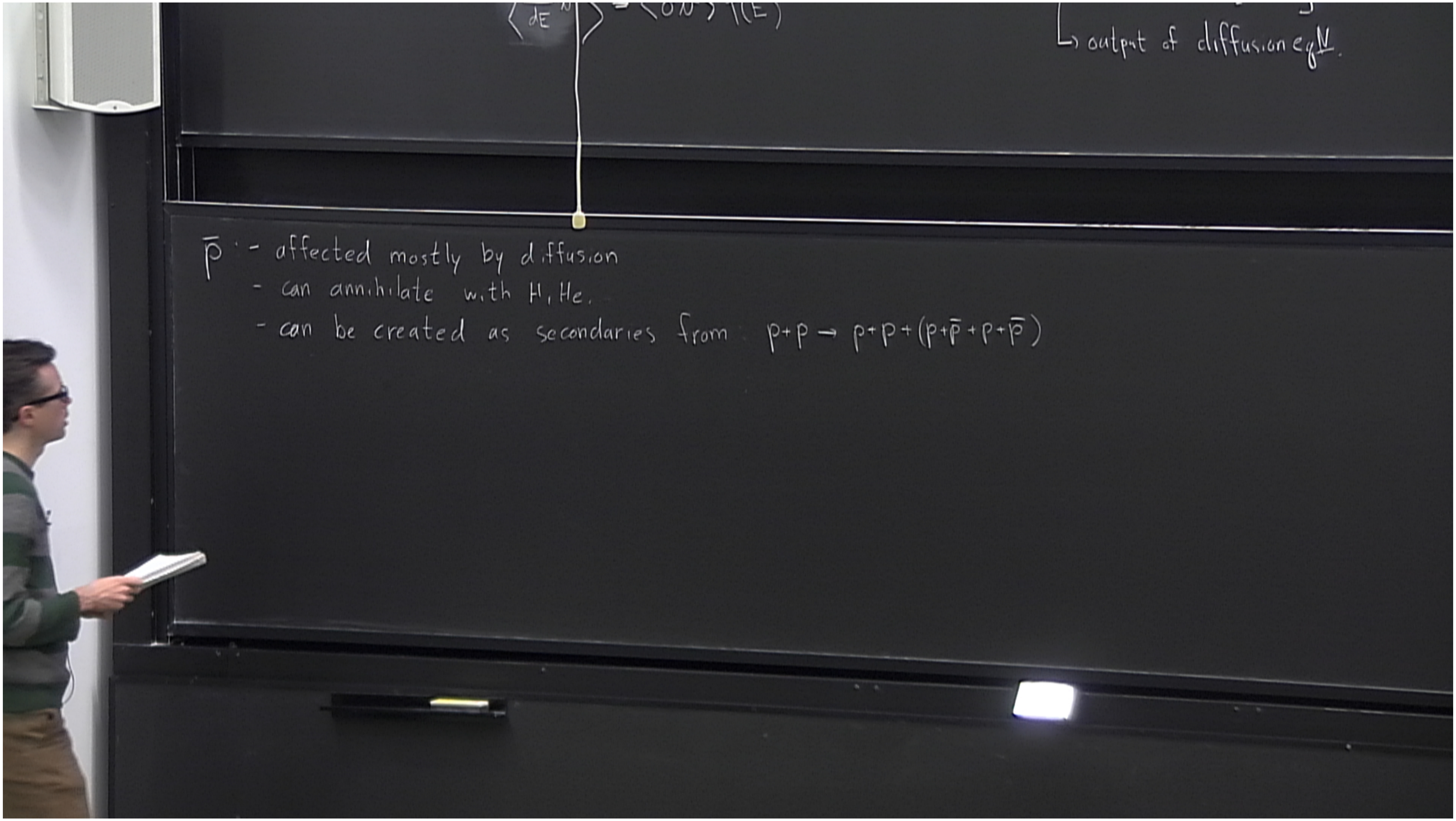
URL: http://pirsa.org/12040015

Abstract:


More DM Indirect Detection
$\Phi(\vec{x}_0, E) = \frac{N}{8\pi} \langle \sigma v \rangle \left(\frac{\rho_0}{m_\chi}\right)^2 \int dE_s \, f(E_s) \, I(E, E_s)$



More DM Indirect Detection
$\Phi_i(\vec{x}_0, E) = \frac{v}{8\pi} \langle \sigma v \rangle \left(\frac{\rho_0}{m_\chi}\right)^2 \int dE_s\, f_i(E_s)\, \underbrace{I_i(E, E_s)}_{\text{propagation}}$
$\frac{dN_i}{dE_s}$
propagation
$= \int d^3x_s\, G(\vec{x}_0, \vec{x}_s; E_s \to E) \left[\frac{\rho_\chi(\vec{x}_s)}{\rho_0}\right]^2$
↳ output of diffusion eqN.
$= \langle \sigma v \rangle f(E)$


↳ output of diffusion eq V.
$\bar{p}$ - affected mostly by diffusion
- can annihilate with H, He.
- can be created as secondaries from $p+p \to p+p+(p+\bar{p}+p+\bar{p})$

$\left\langle \frac{d}{dE} \right\rangle = \langle \sigma v \rangle\, f(E)$

$\hookrightarrow$ output of diffusion eq $\underline{\text{IV}}$.

$\bar{p}$: - affected mostly by diffusion

- can annihilate with H, He.
- can be created as secondaries from : $p + p \to p + p + (p + \bar{p} + p + \bar{p})$

$\to$ they propagate pretty well, travel relatively long distances. $\Rightarrow$ sensitivity to $\rho_\chi(\vec{x}_s)$

↳ output of diffusion eq $\underline{\text{IV}}$.

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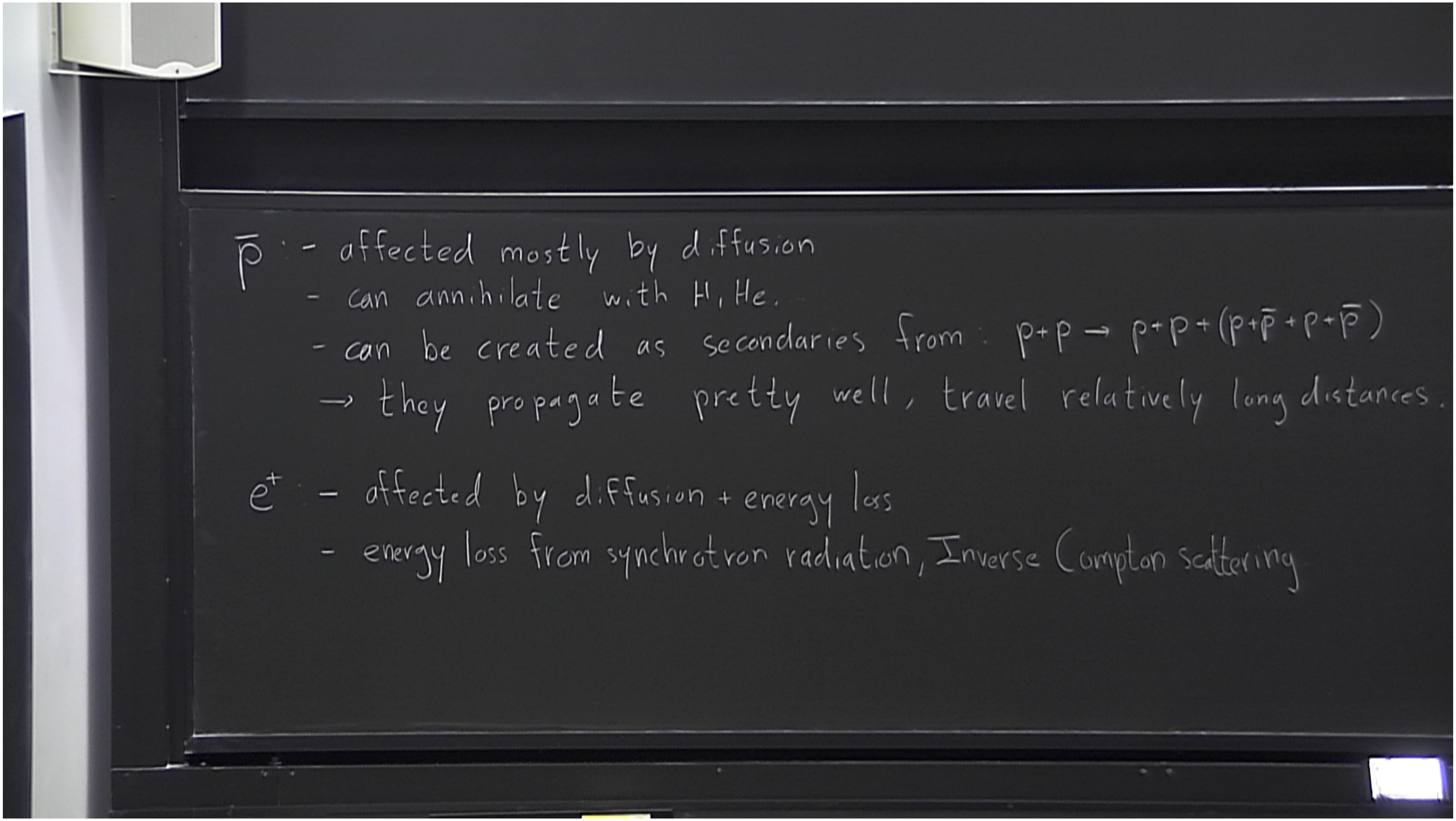
e^+ - affected by diffusion + energy loss
- energy loss from synchrotron radiation, Inverse Compton scattering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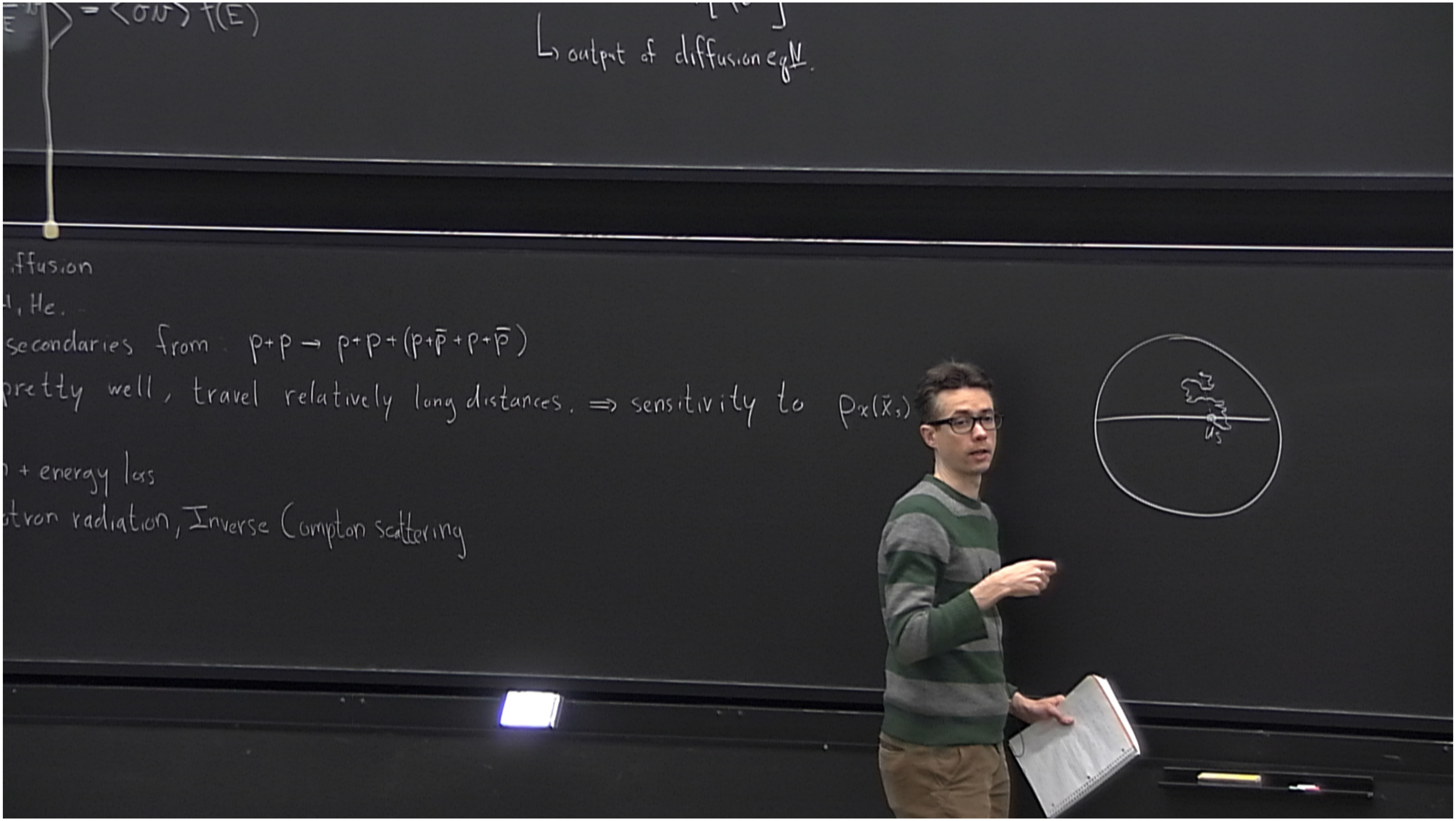
$\rangle = \langle \sigma v \rangle f(E)$
↳ output of diffusion eq^n.
ffusion
, He.
secondaries from : p+p → p+p+(p+p̄+p+p̄)
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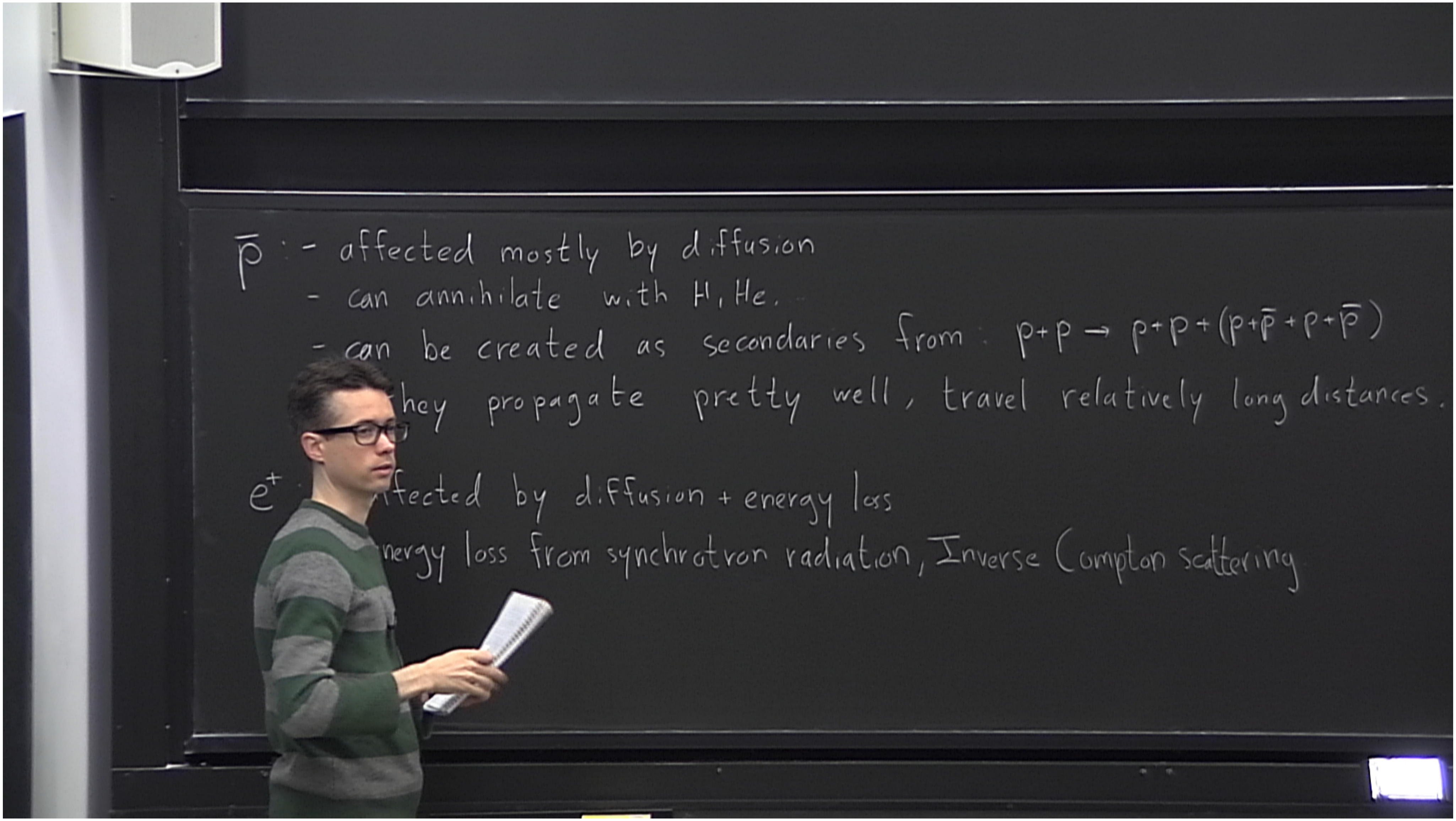
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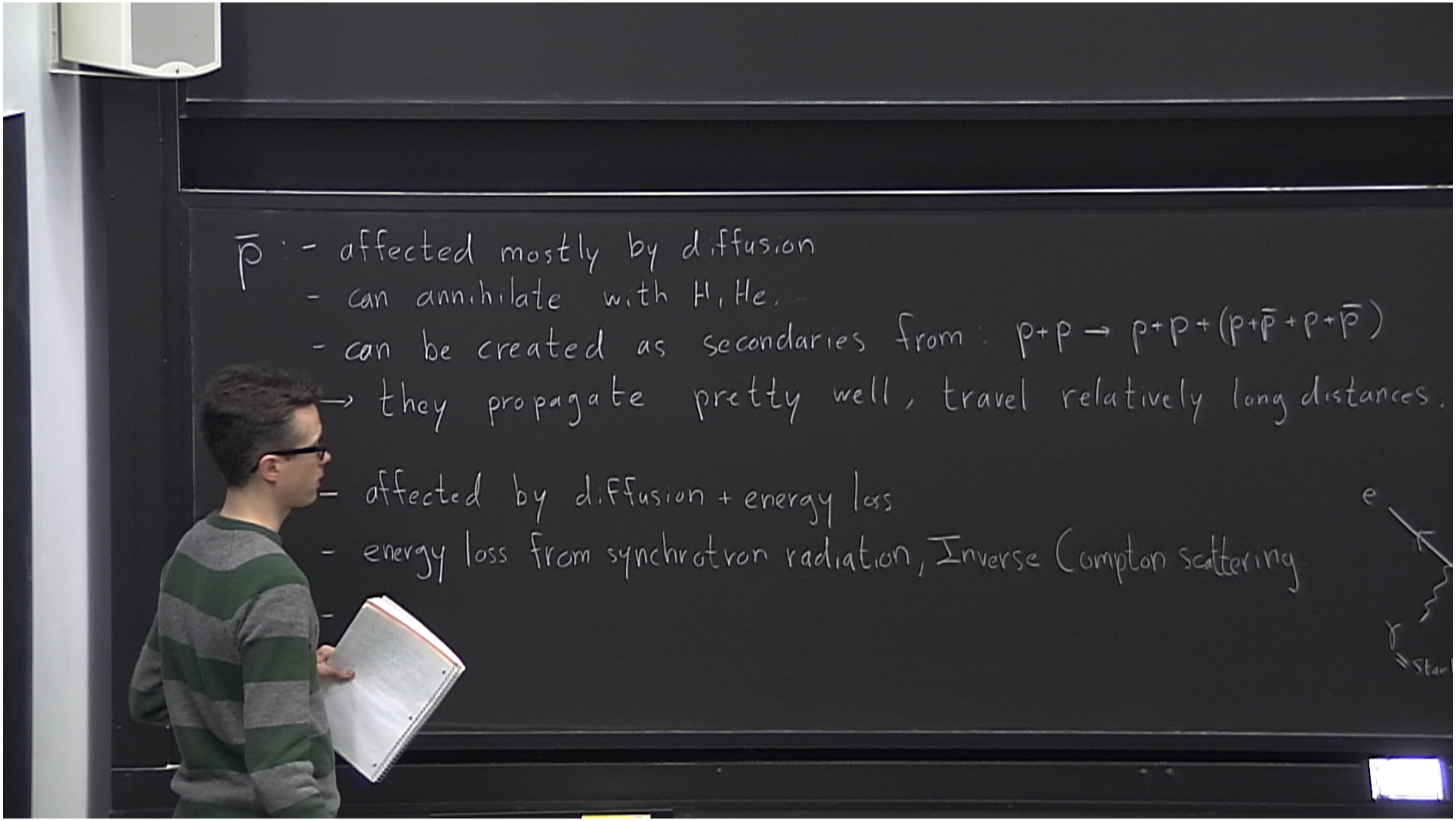
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e
γ

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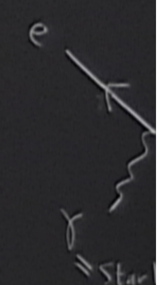
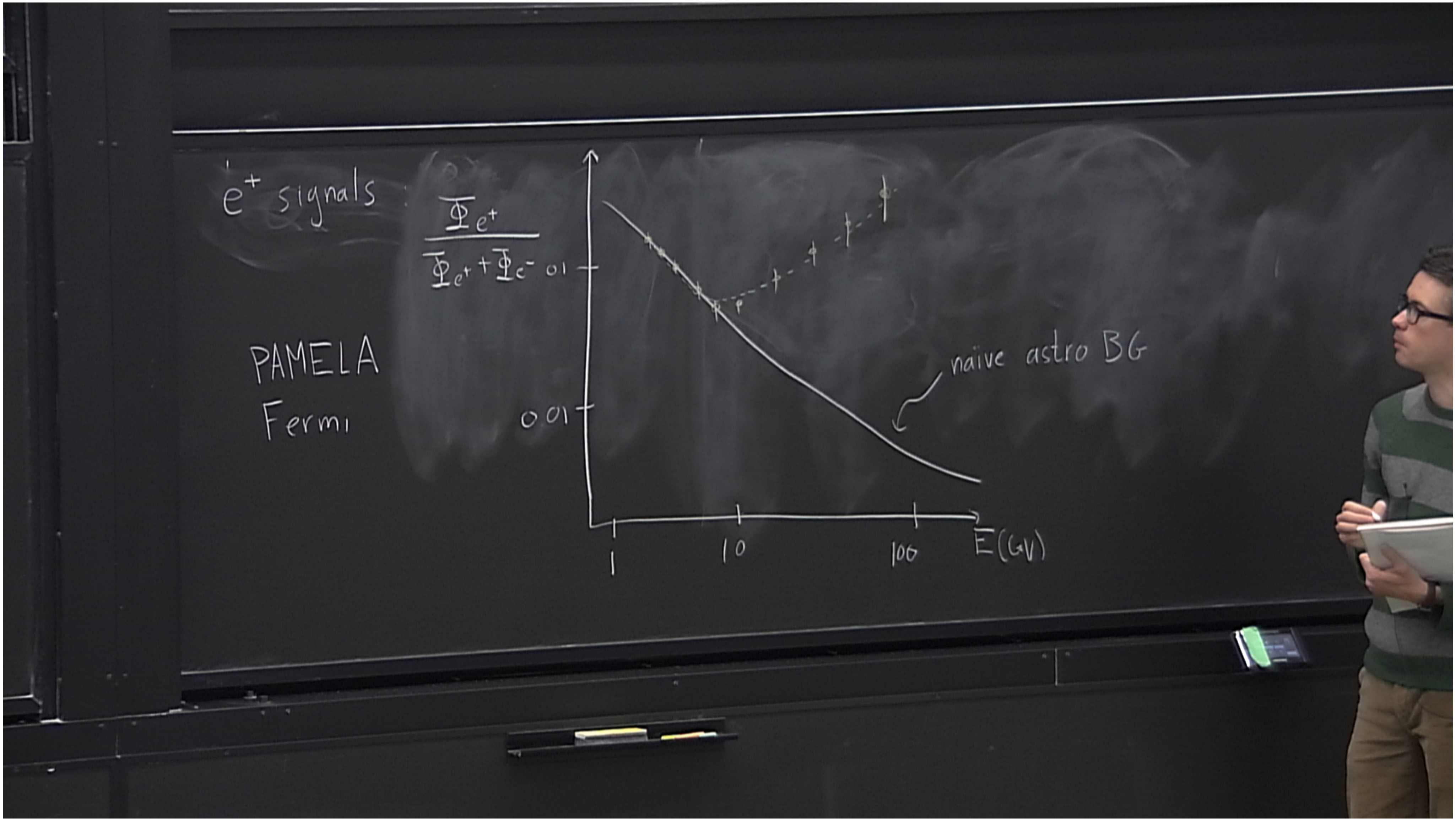
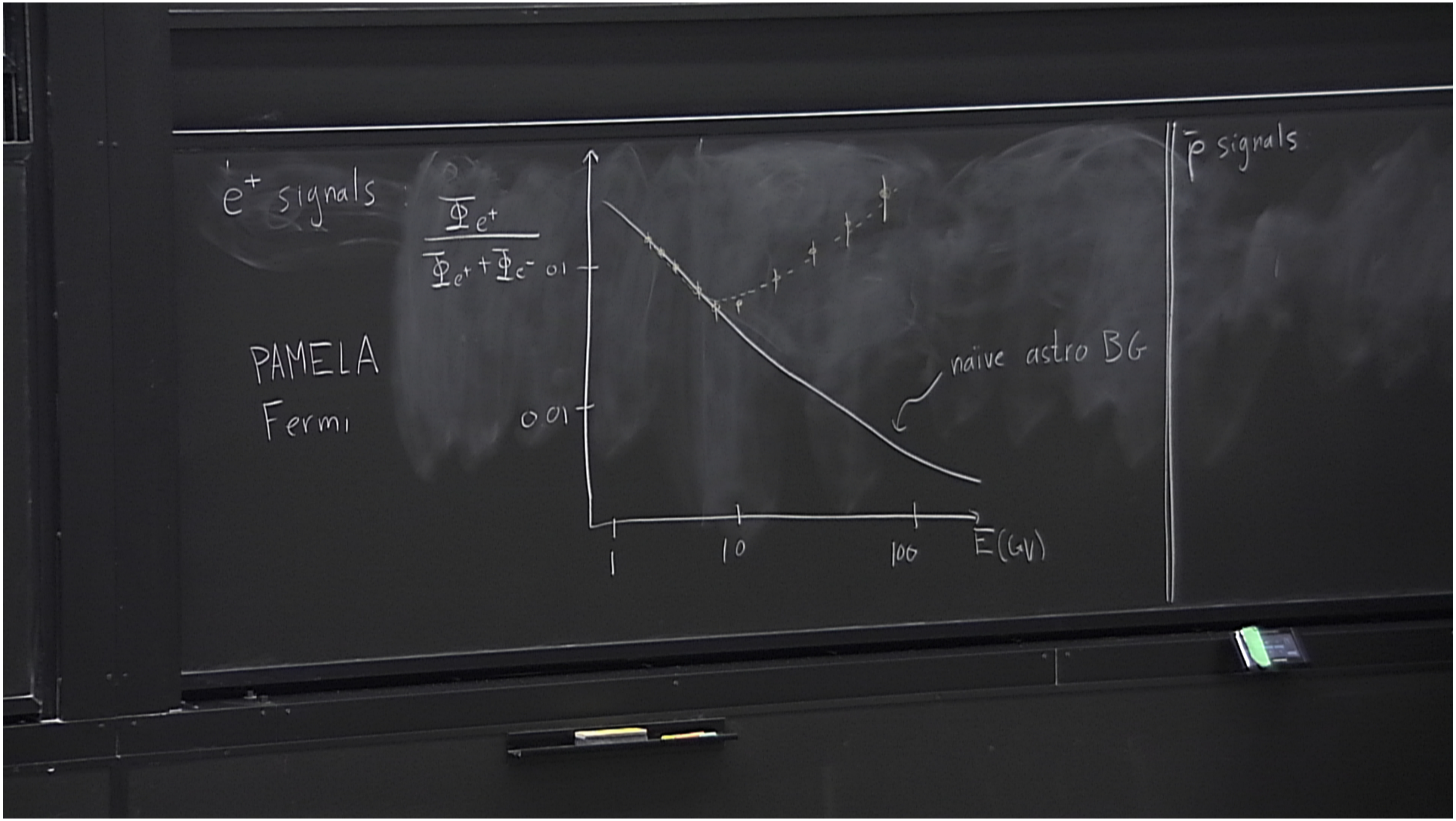
- astro BG: $p + H \rightarrow X + \pi^{\pm} \rightarrow \nu_\mu \mu \rightarrow e\, \nu_\mu \nu_e$




e+ signals
Φe+ / (Φe+ + Φe-)
0.1
0.01
PAMELA
Fermi
naïve astro BG
1
10
100
E(GV)



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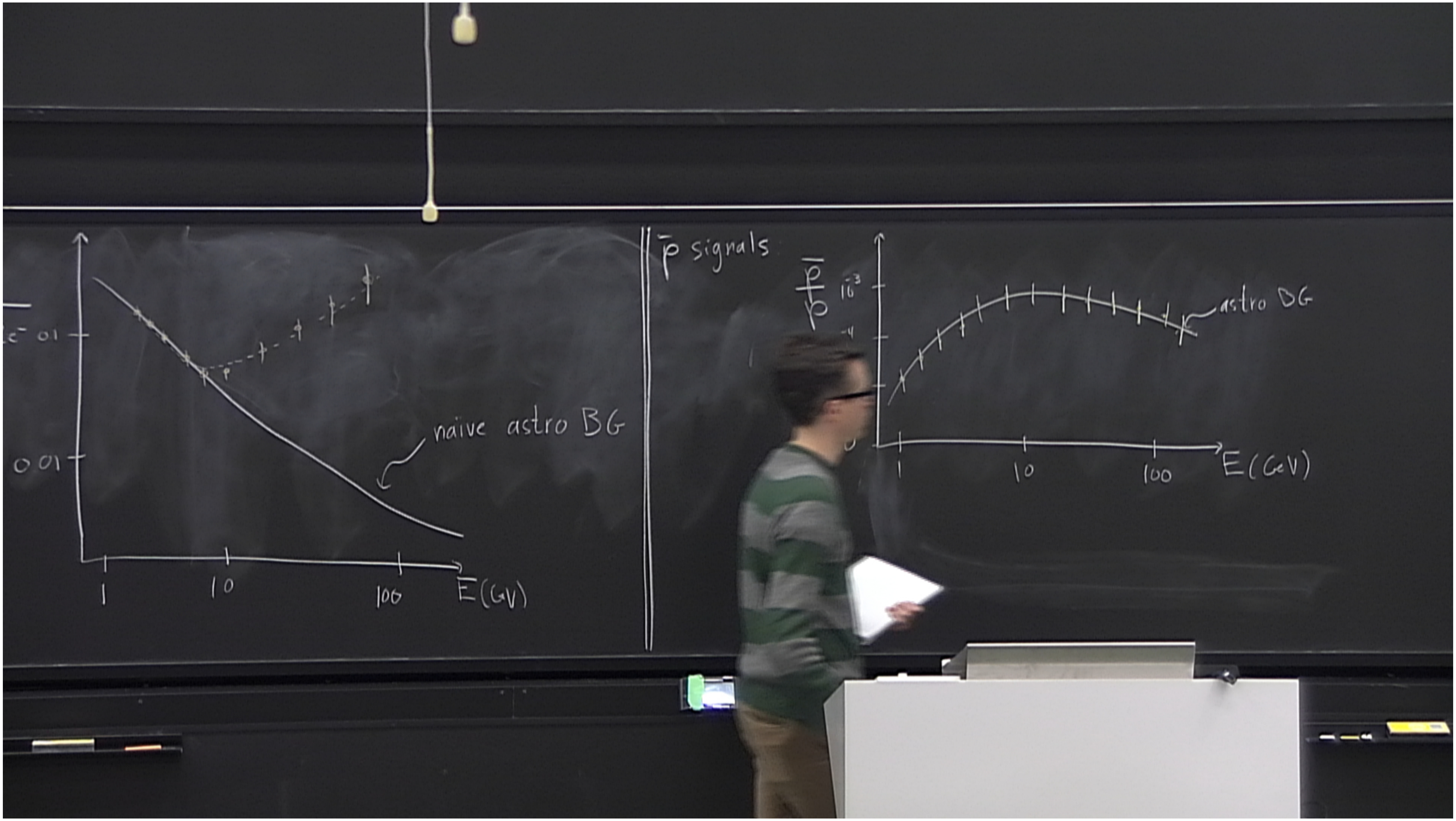
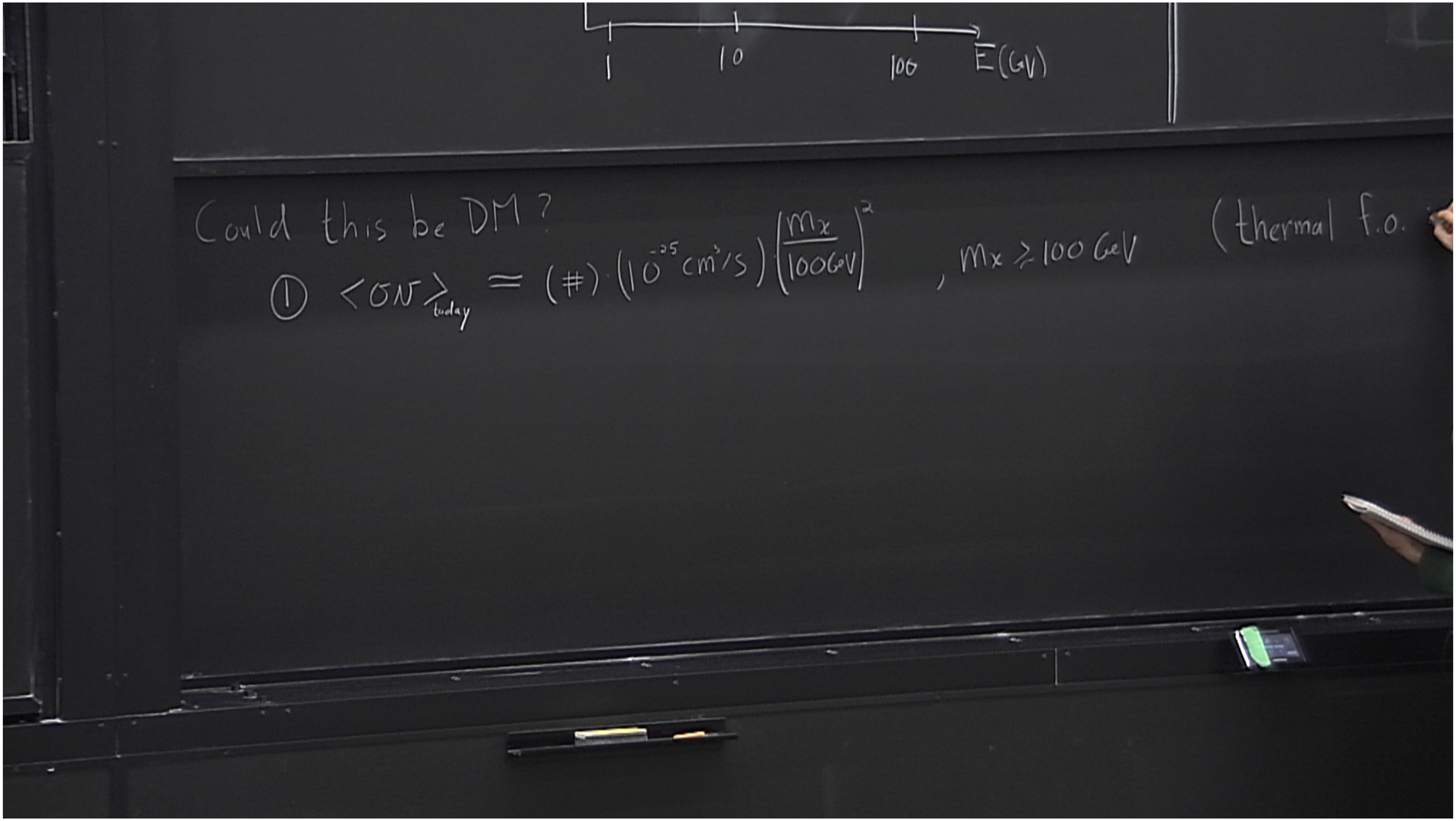
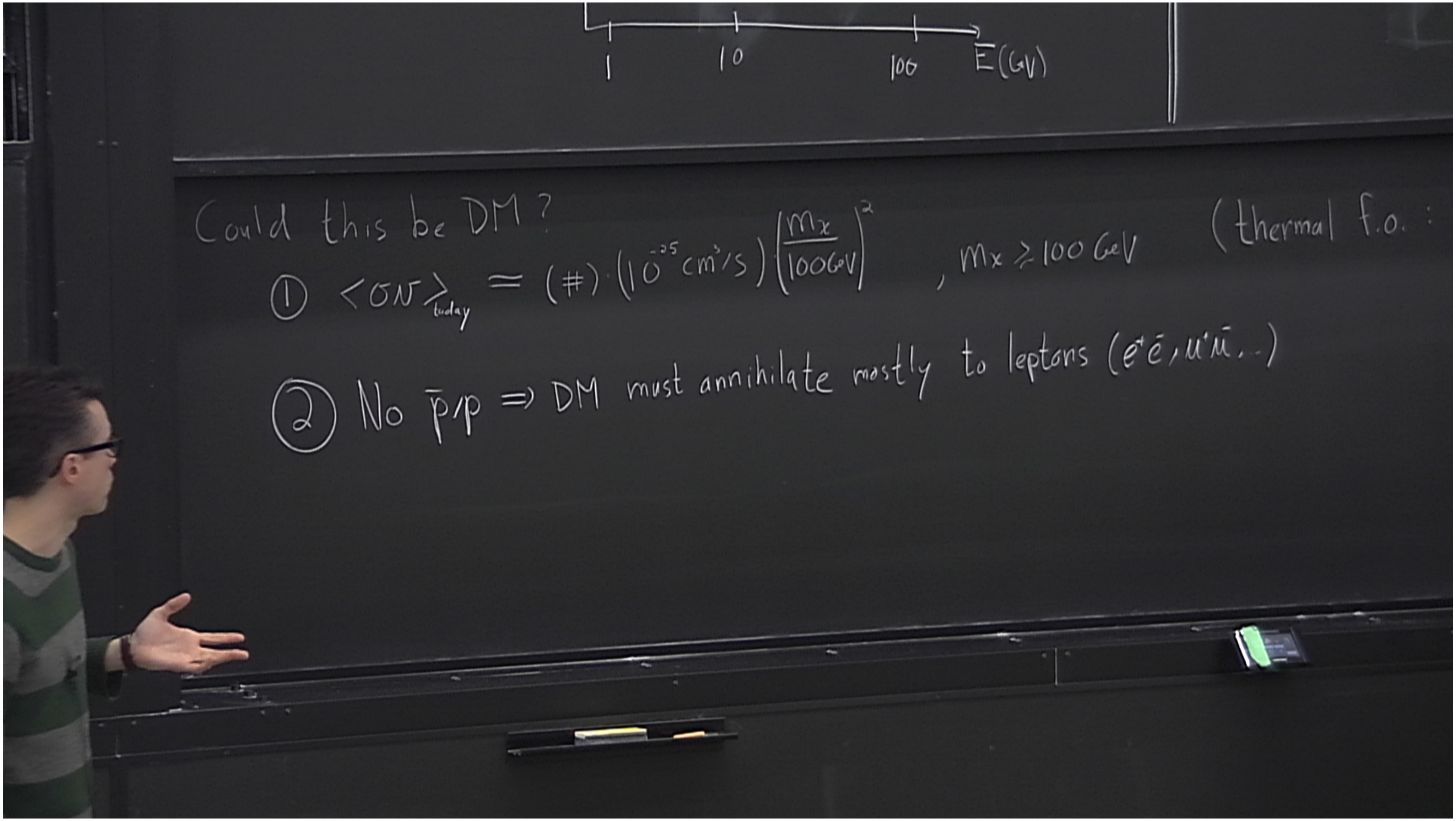


0.01
10
100
E(GV)
naive astro BG
p̄ signals
$\frac{\bar{p}}{p}$
10^{-3}
astro BG
1
10
100
E(GeV)


1
10
100
E(GeV)
Could this be DM?
① $\langle \sigma v \rangle_{today} \simeq (\#) \cdot (10^{-25}\,cm^3/s) \left(\frac{m_\chi}{100\,GeV}\right)^2$, $m_\chi \gtrsim 100$ GeV
(thermal f.o.



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Could this be DM?
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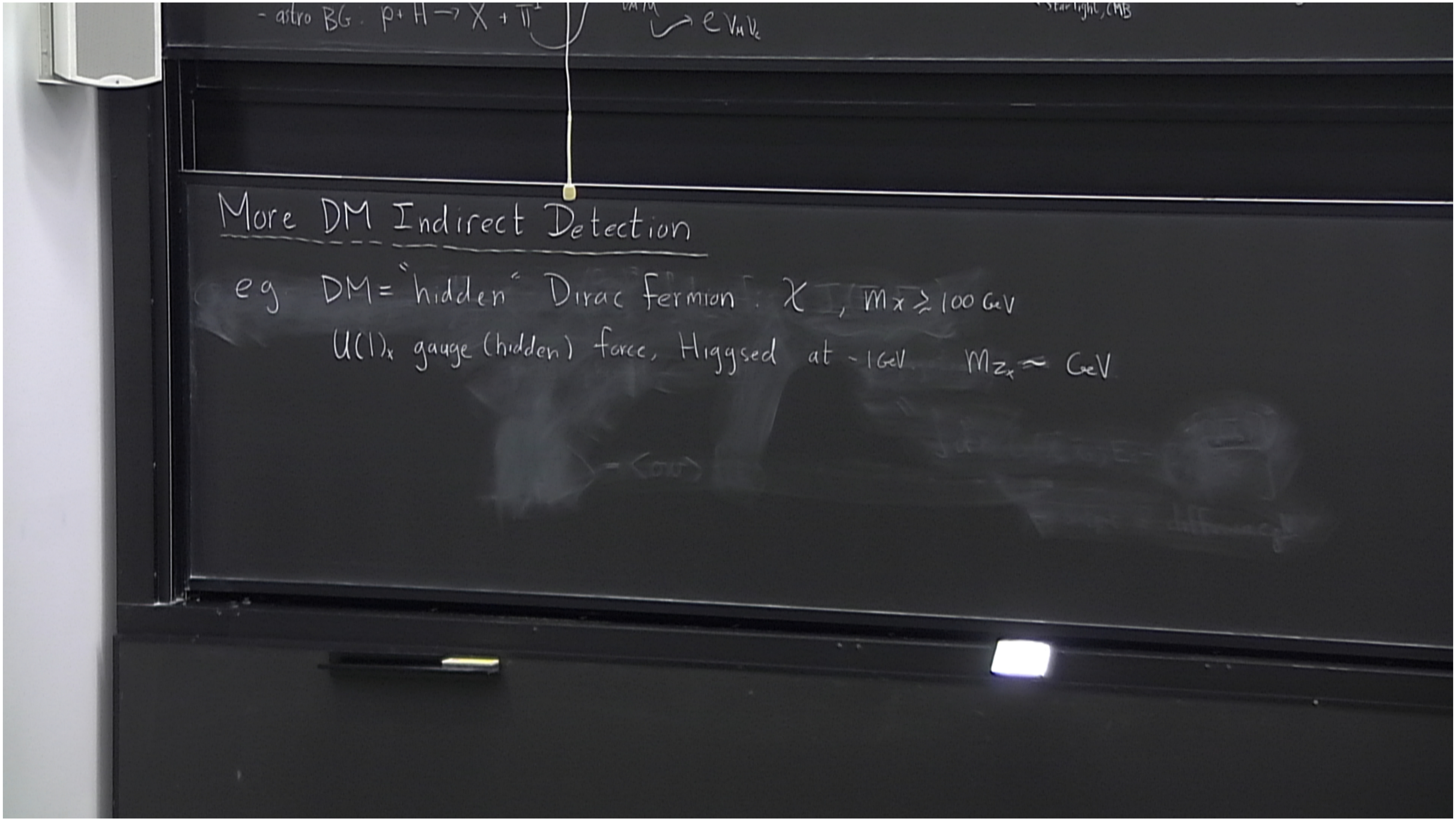
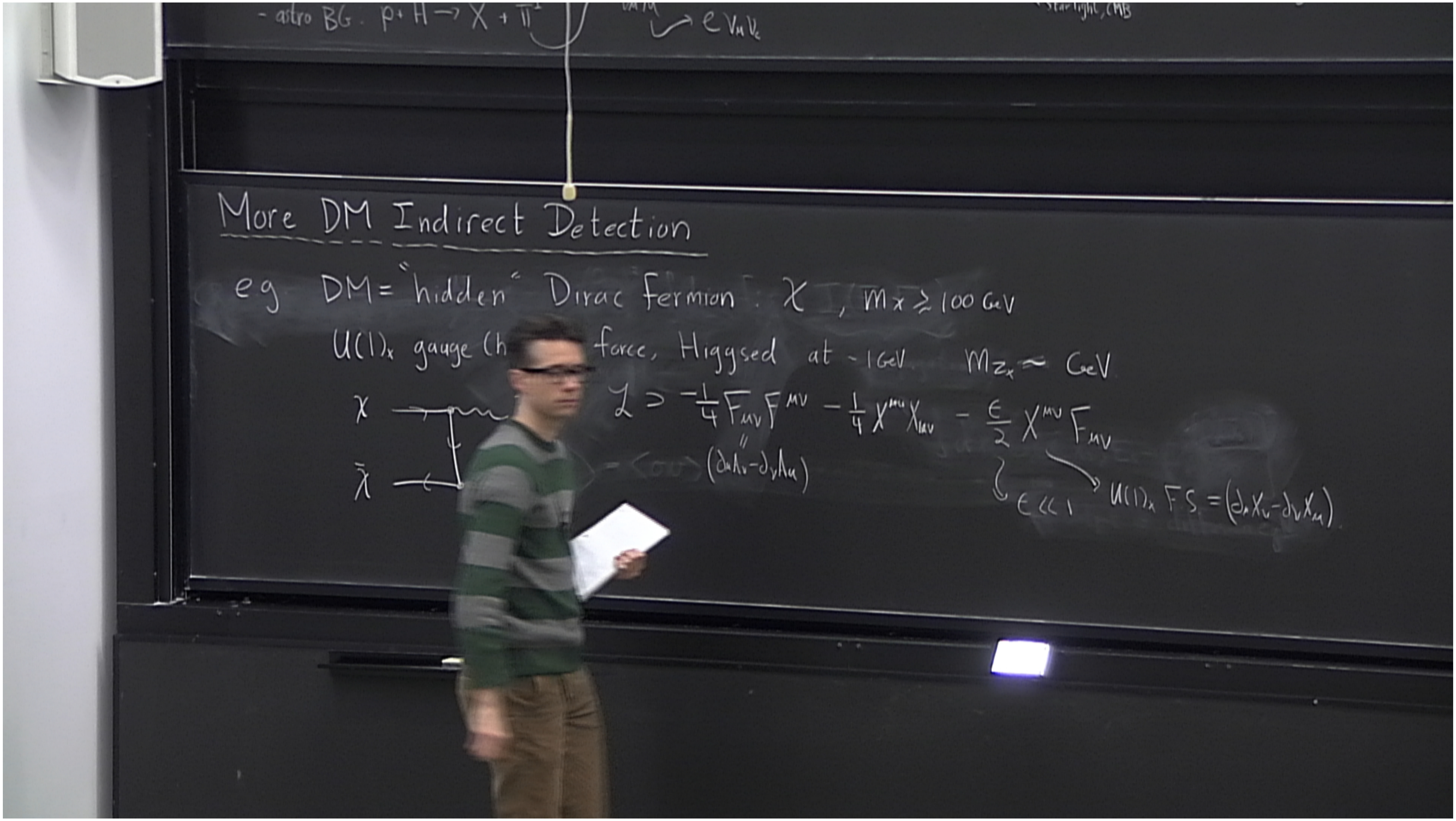
(thermal f.o. :
② No $\bar{p}/p \Rightarrow$ DM must annihilate mostly to leptons ($e^+e^-, \mu^+\mu^-, \ldots$)

More DM Indirect Detection

e.g. DM = "hidden" Dirac Fermion : χ , $m_\chi \gtrsim 100$ GeV

$U(1)_\chi$ gauge (hidden) force, Higgsed at ~ 1 GeV. $m_{Z_\chi} =$


- astro BG: p+H → X + π
More DM Indirect Detection
eg DM = "hidden" Dirac fermion: χ, mχ ≳ 100 GeV
U(1)χ gauge (hidden) force, Higgsed at ~1GeV   mZχ ~ GeV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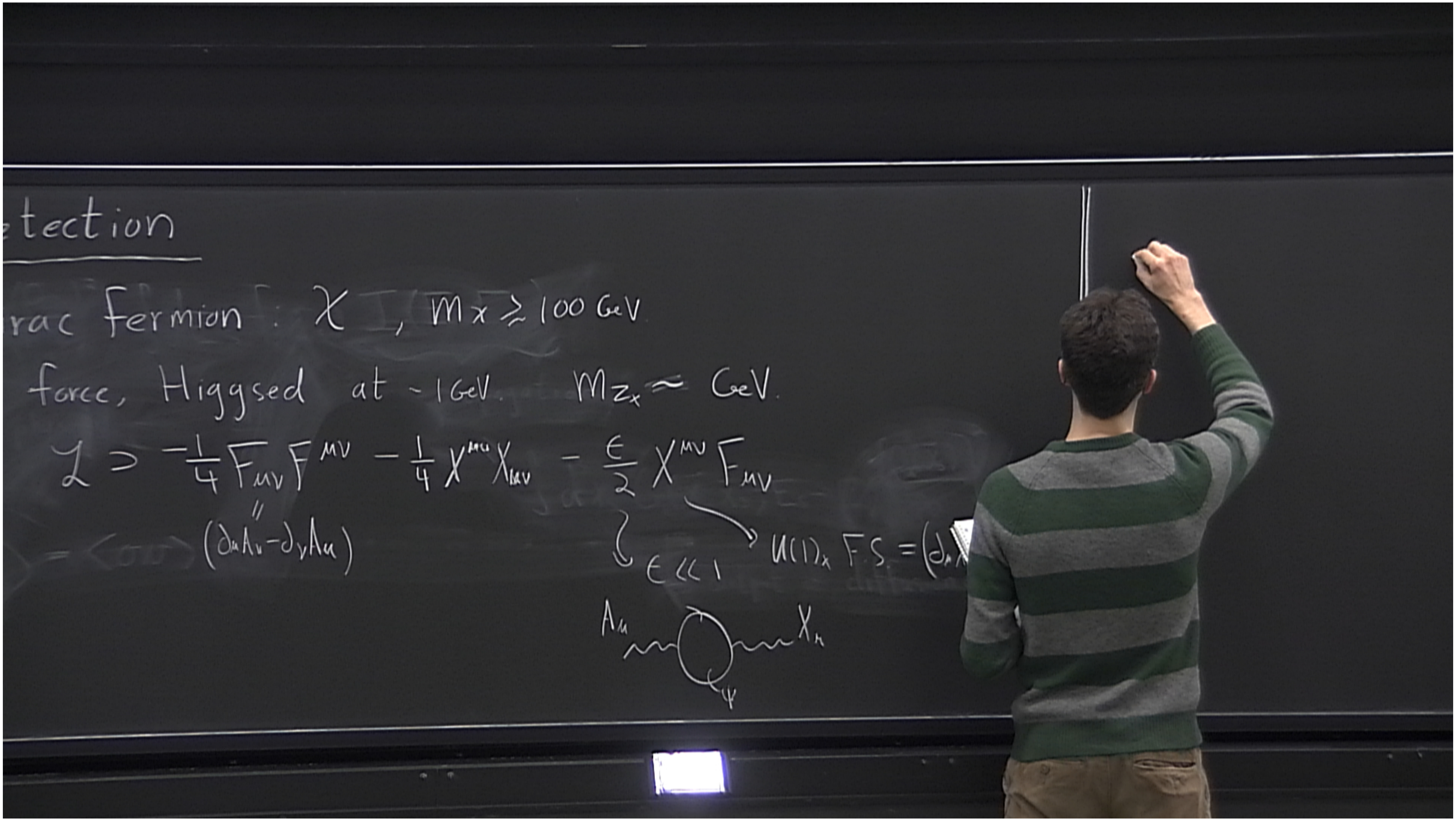
More DM Indirect Detection
eg DM = "hidden" Dirac fermion : χ , $m_\chi \gtrsim 100$ GeV
U(1)$_x$ gauge
force, Higgsed at ~1GeV
$m_{Z_x} \sim$ GeV
$\mathcal{L} \supset -\frac{1}{4} F_{\mu\nu}F^{\mu\nu} - \frac{1}{4} X^{\mu\nu}X_{\mu\nu} - \frac{\epsilon}{2} X^{\mu\nu}F_{\mu\nu}$
$(\partial_\mu A_\nu - \partial_\nu A_\mu)$
$\epsilon \ll 1$
U(1)$_x$ F.S. $= (\partial_\mu X_\nu - \partial_\nu X_\mu)$



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rac fermion : χ, $m_\chi \gtrsim 100$ GeV
force, Higgsed at ~ 1 GeV. $M_{Z_x} \sim$ GeV.
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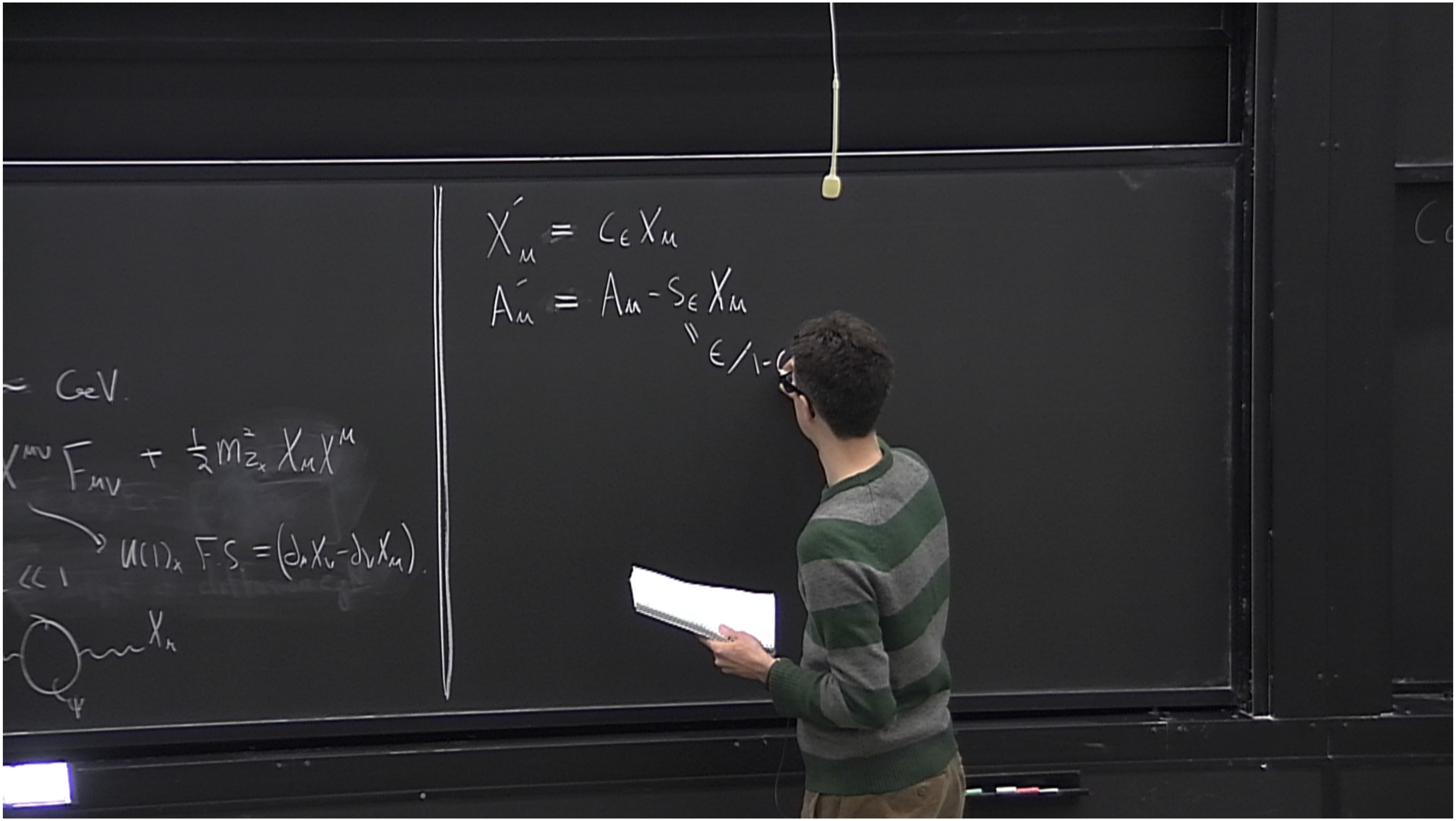
$(\partial_\mu A_\nu - \partial_\nu A_\mu)$
$\epsilon \ll 1$
$U(1)_x$ F.S. = $(\partial_\mu$
A_μ
X_μ
ψ


X'_μ = c_ε X_μ
A'_μ = A_μ - s_ε X_μ
GeV
F_μν + ½ m²_{Z_x} X_μ X^μ
U(1)_x F.S. = (∂_μ X_ν - ∂_ν X_μ)
X_μ
ψ

$\sim$ GeV.

$$X^{\mu\nu} F_{\mu\nu} + \frac{1}{2} m^2_{Z_x} X_\mu X^\mu$$

$$\to U(1)_x \text{ F.S} = (\partial_\mu X_\nu - \partial_\nu X_\mu).$$

$\ll 1$

X_μ

ψ

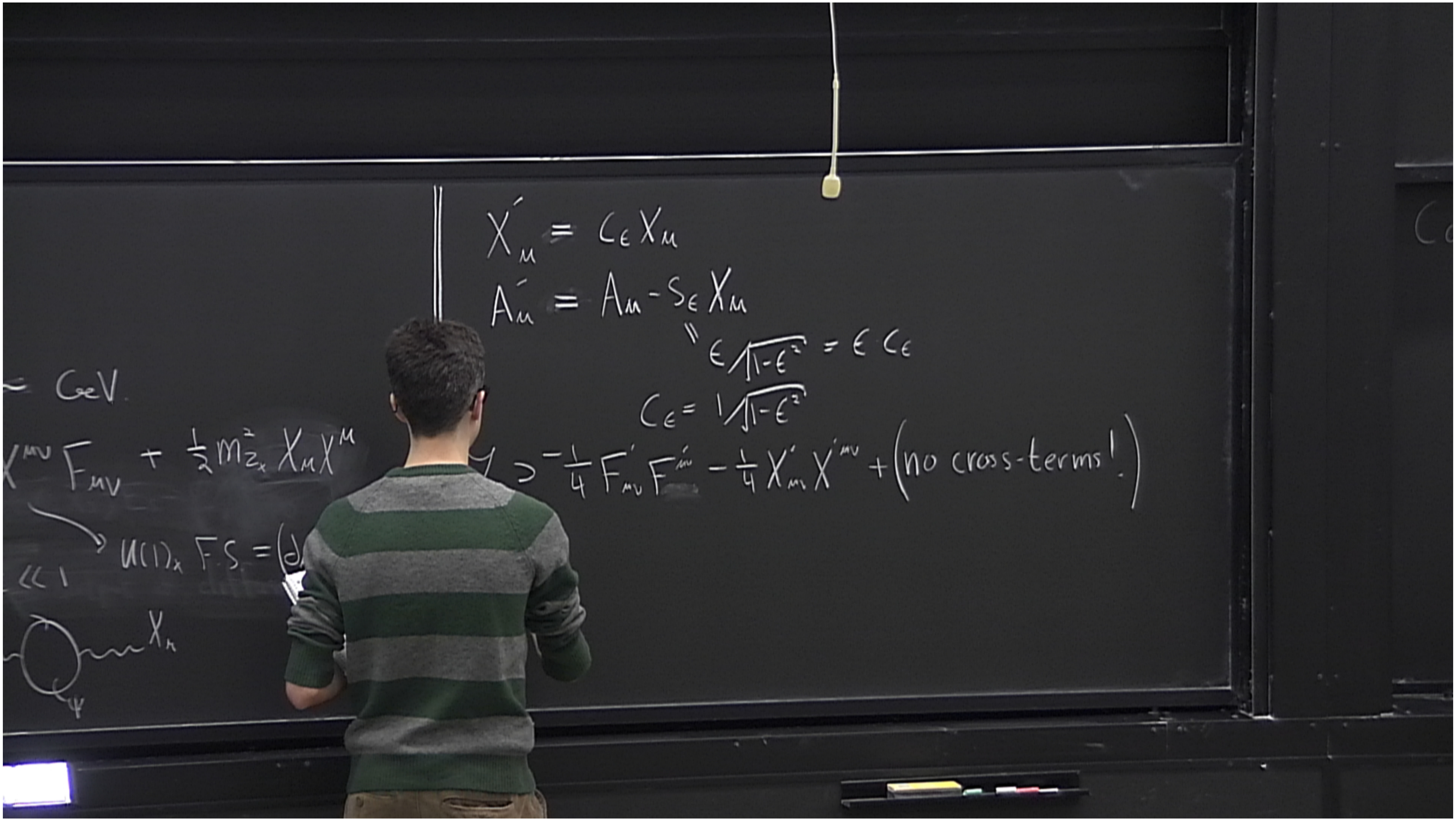
$$X'_\mu = c_\epsilon X_\mu$$

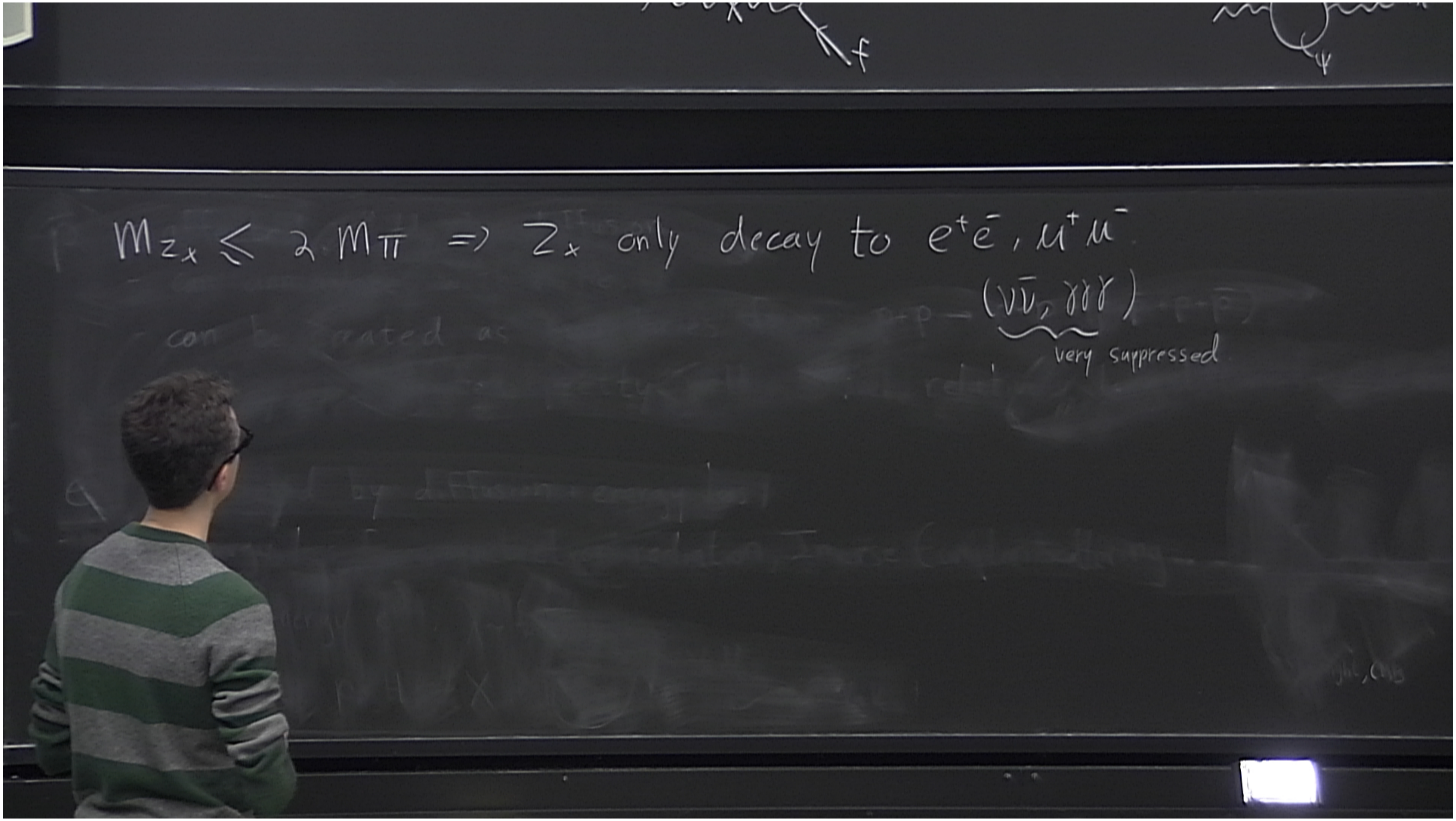
$$A'_\mu = A_\mu - s_\epsilon X_\mu$$

$$s_\epsilon = \epsilon/\sqrt{1-\epsilon^2} = \epsilon\, c_\epsilon$$

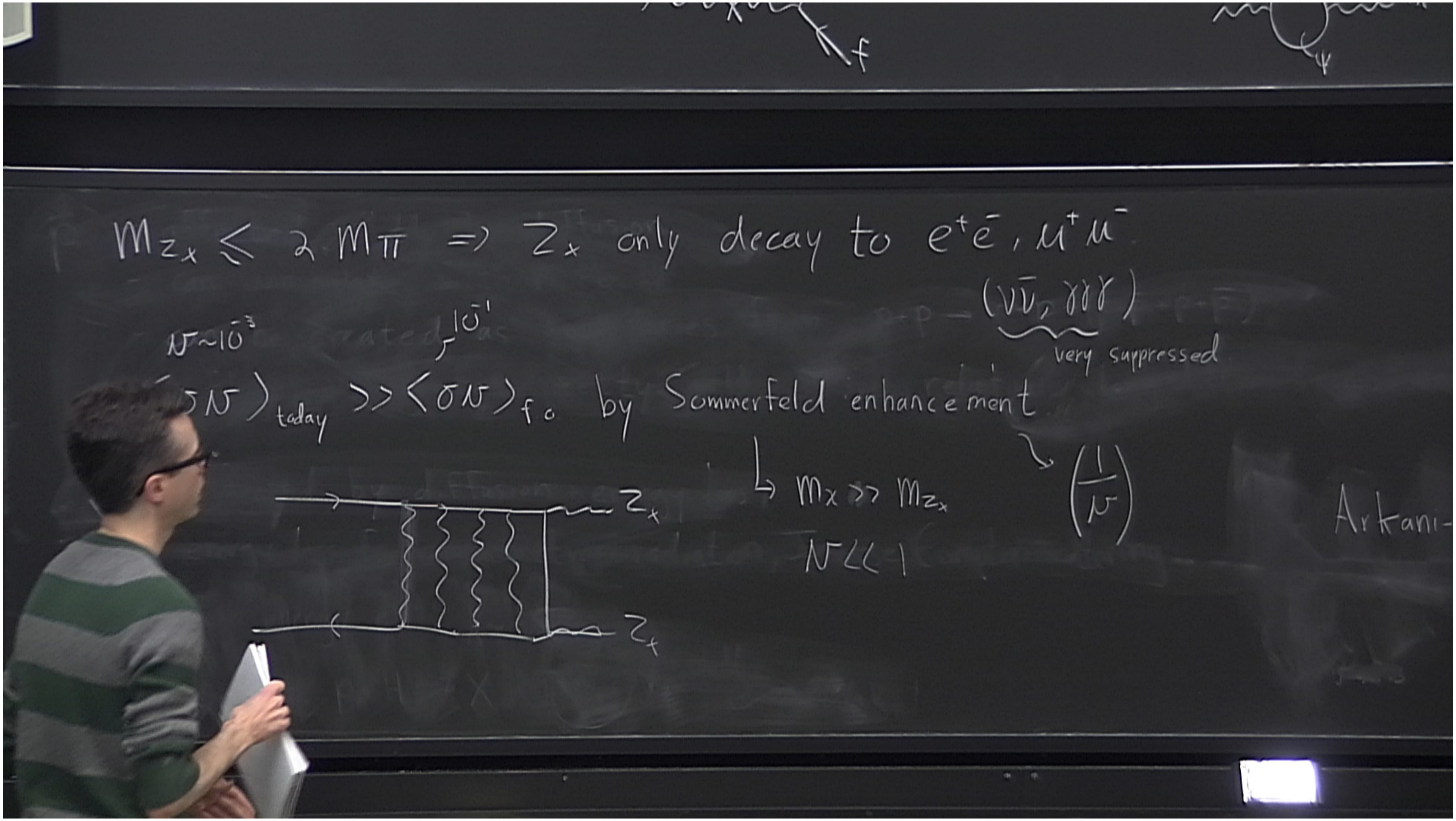
$$c_\epsilon = 1/\sqrt{1-\epsilon^2}$$

$$\mathcal{L} \supset -\frac{1}{4} F'_{\mu\nu} F'^{\mu\nu} - \frac{1}{4} X'_{\mu\nu} X'^{\mu\nu} + (\text{no cross-terms!})$$


$X'_\mu = c_\epsilon X_\mu$
$A'_\mu = A_\mu - s_\epsilon X_\mu$
$\epsilon/\sqrt{1-\epsilon^2} = \epsilon c_\epsilon$
$c_\epsilon = 1/\sqrt{1-\epsilon^2}$
$\mathcal{L} \supset -\frac{1}{4} F'_{\mu\nu} F'^{\mu\nu} - \frac{1}{4} X'_{\mu\nu} X'^{\mu\nu} +$ (no cross-terms!)
GeV
$X^{\mu\nu} F_{\mu\nu} + \frac{1}{2} m^2_{Z_X} X_\mu X^\mu$
$U(1)_X$ F.S. =
$\ll 1$
X_μ
ψ



M_Zx ≲ 2 M_π => Z_x only decay to e⁺e⁻, μ⁺μ⁻
(νν̄, γγγ)
very suppressed

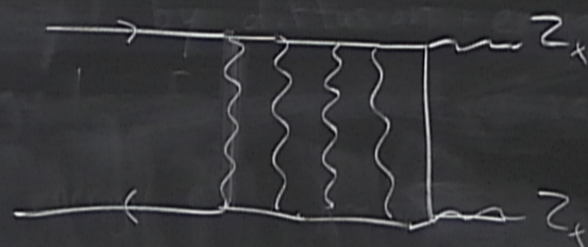

m Zx ≤ 2 mπ => Zx only decay to e+e-, μ+μ-
(νν̄, γγγ)
very suppressed
v~10-3
10-1
<σv>today >> <σv>f.o. by Sommerfeld enhancement
mx >> mZx
v << 1
(1/v)
Zx
Zx
Arkani-
f
ψ

$m_{Z_x} \lesssim 2\, m_\pi \Rightarrow Z_x$ only decay to $e^+ e^-, \mu^+ \mu^-$

$\underbrace{(\nu\bar{\nu}, \gamma\gamma\gamma)}_{\text{very suppressed}}$

$v \sim 10^{-3}$, 10^{-1}

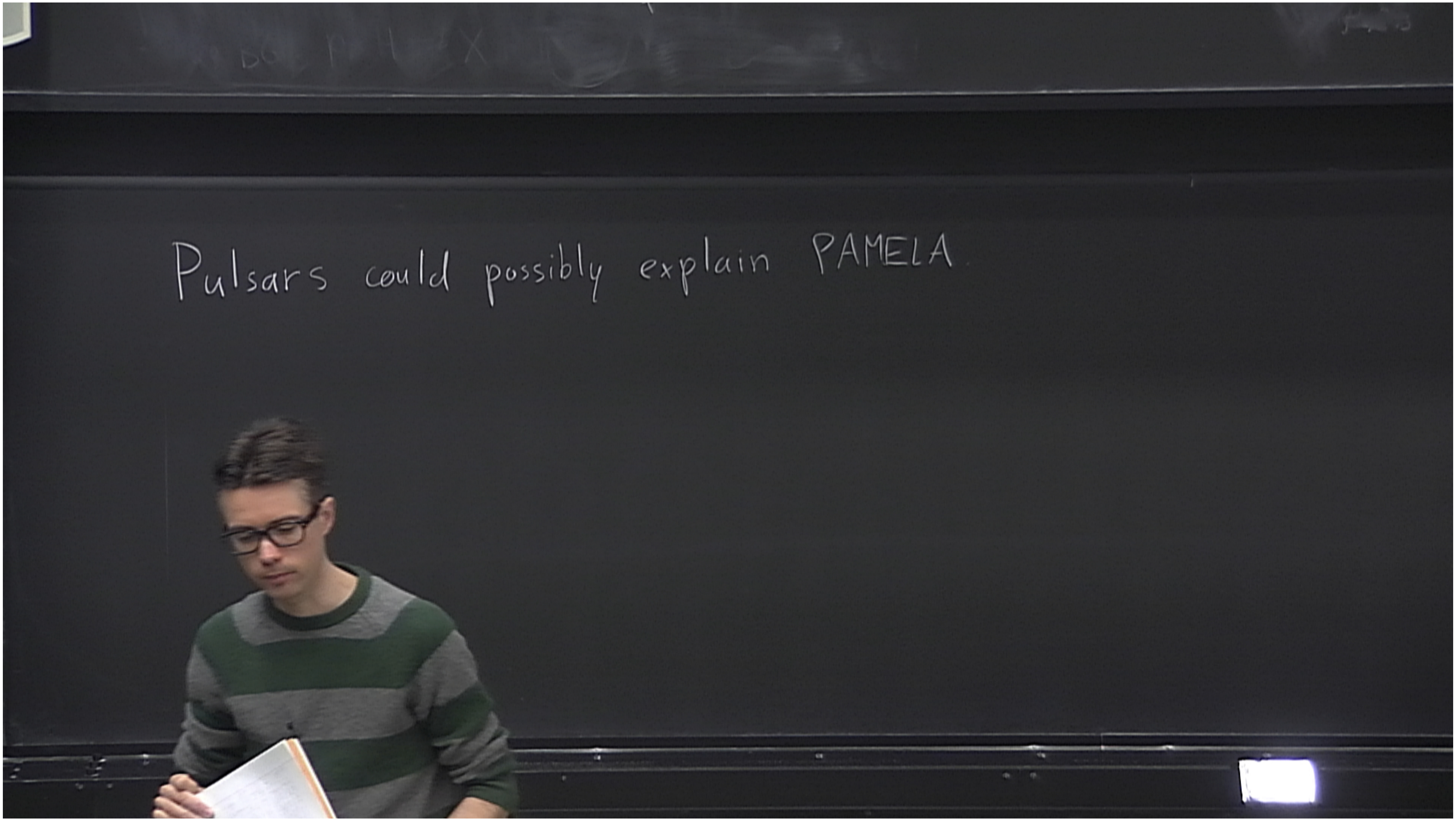
$\langle \sigma v \rangle_{\text{today}} \gg \langle \sigma v \rangle_{\text{f.o.}}$ by Sommerfeld enhancement $\rightarrow \left(\frac{1}{v}\right)$



$\hookrightarrow m_\chi \gg m_{Z_x}$

$v \ll 1$

Arkani-


Pulsars could possibly explain PAMELA.

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↳ anisotropy in the direction of e^+.