Title: Standard Model - Review (PHYS 622) - Lecture 15

Date: Dec 18, 2009 09:00 AM

URL: http://pirsa.org/09120049

Abstract:

perimeter scholars
international

Higgs boson

$\phi(x)$

Higgs boson

$\phi(x)$

$V(\phi)$

Higgs boson

$$\phi(x) = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v+h(x) \end{pmatrix}$$

$V(\phi)$

Higgs boson

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$V(\phi)$

$$V(\phi) = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

$$v = \left| \frac{\mu^2}{\lambda} \right|^{\frac{1}{2}}$$

$$V(h) = -\frac{\mu^2 v^2}{2} + \mu^2 h^2 +$$

Higgs boson

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$$m_h^2 = 2\mu^2$$

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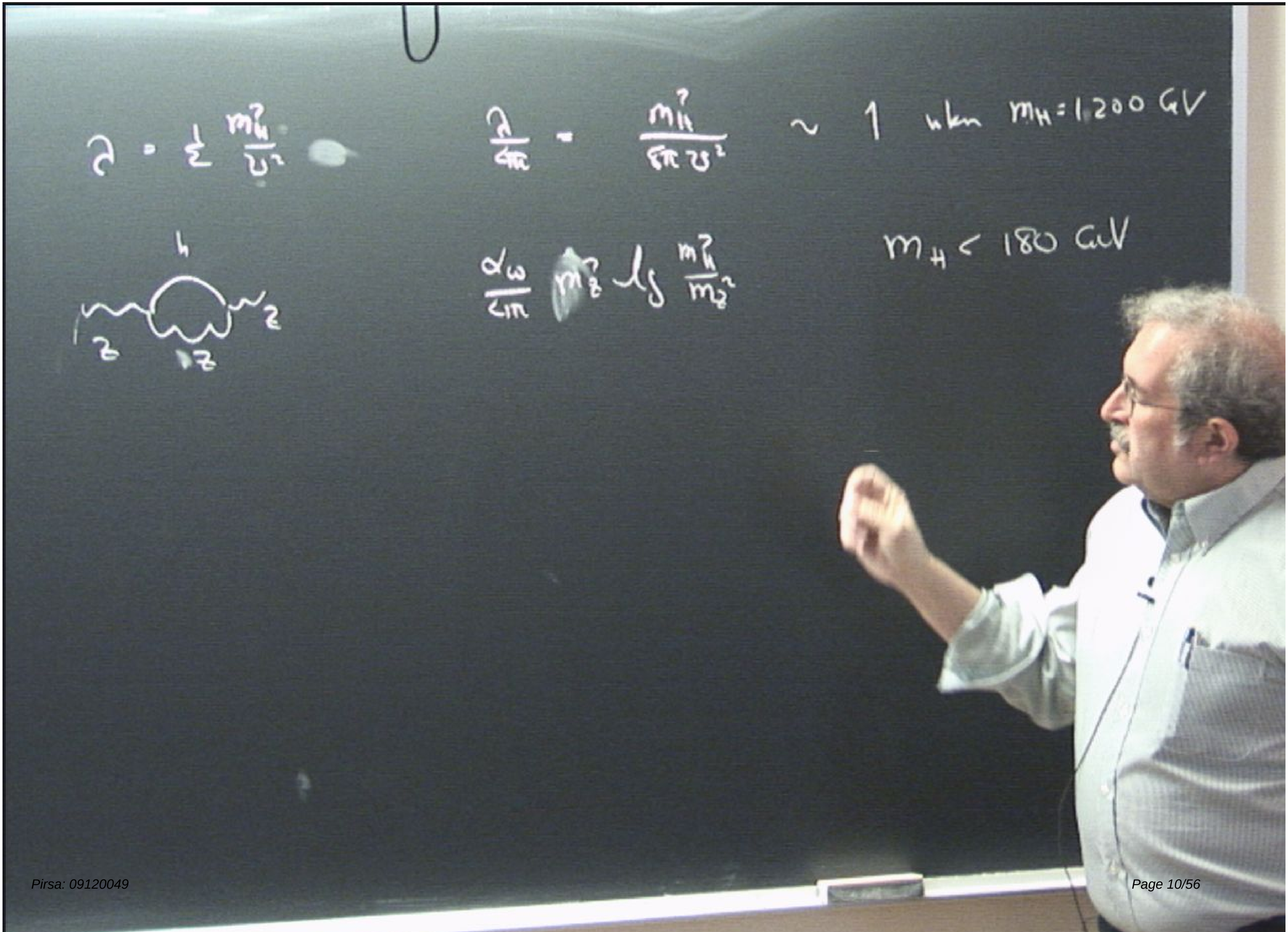
$$m_h^2 = 2\mu^2$$

$$\lambda = \frac{1}{2}\frac{m_H^2}{v^2} \qquad \frac{\lambda}{4\pi} = \frac{m_H^2}{8\pi v^2} \sim 1 \text{ when } m_H = 1{,}200 \text{ GeV}$$


$\lambda = \frac{1}{2}\frac{m_H^2}{v^2}$
$\frac{\lambda}{4\pi} = \frac{m_H^2}{8\pi v^2} \sim 1$ when $m_H = 1,200$ GeV
h
Z
Z
Z
$\frac{\alpha_w}{4\pi} m_Z^2 \lg \frac{m_H^2}{m_Z^2}$
$m_H < 180$ GeV

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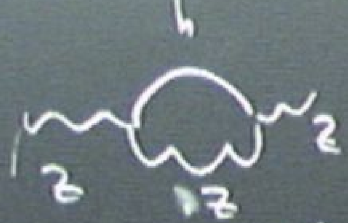
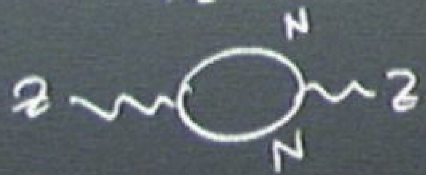
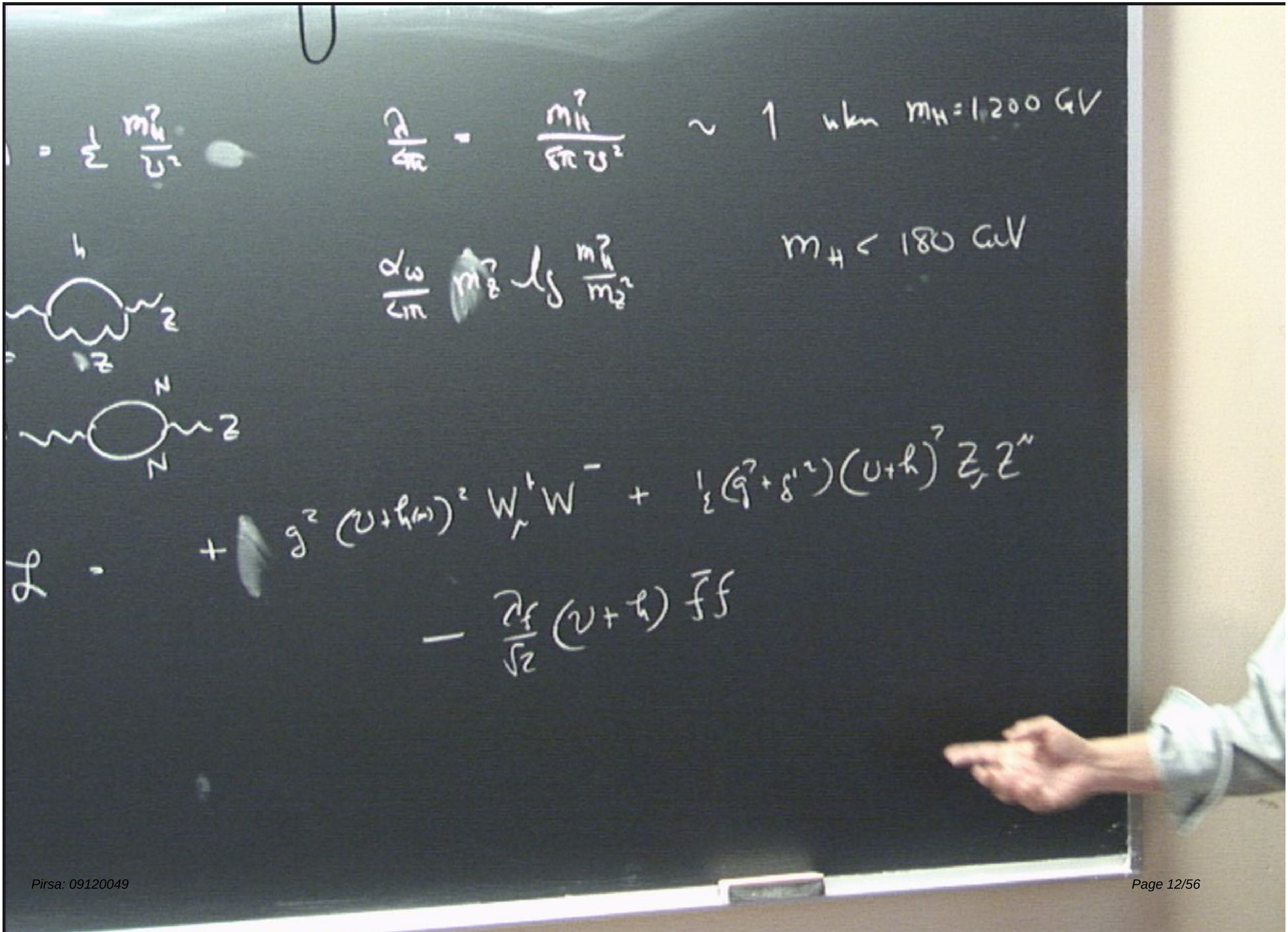
$\frac{\lambda}{4\pi} = \frac{m_H^2}{8\pi v^2} \sim 1$ when $m_H = 1{,}200$ GV

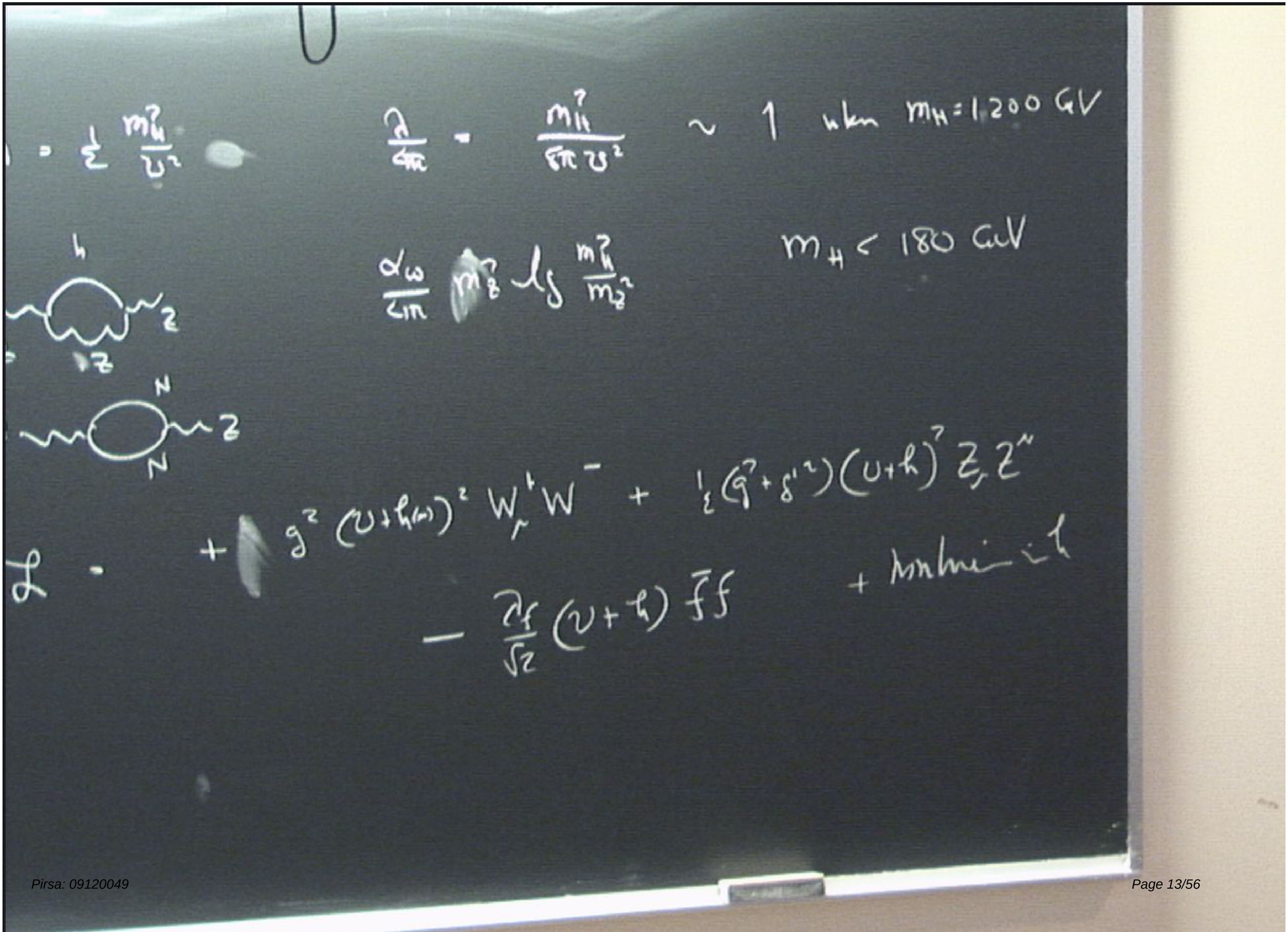


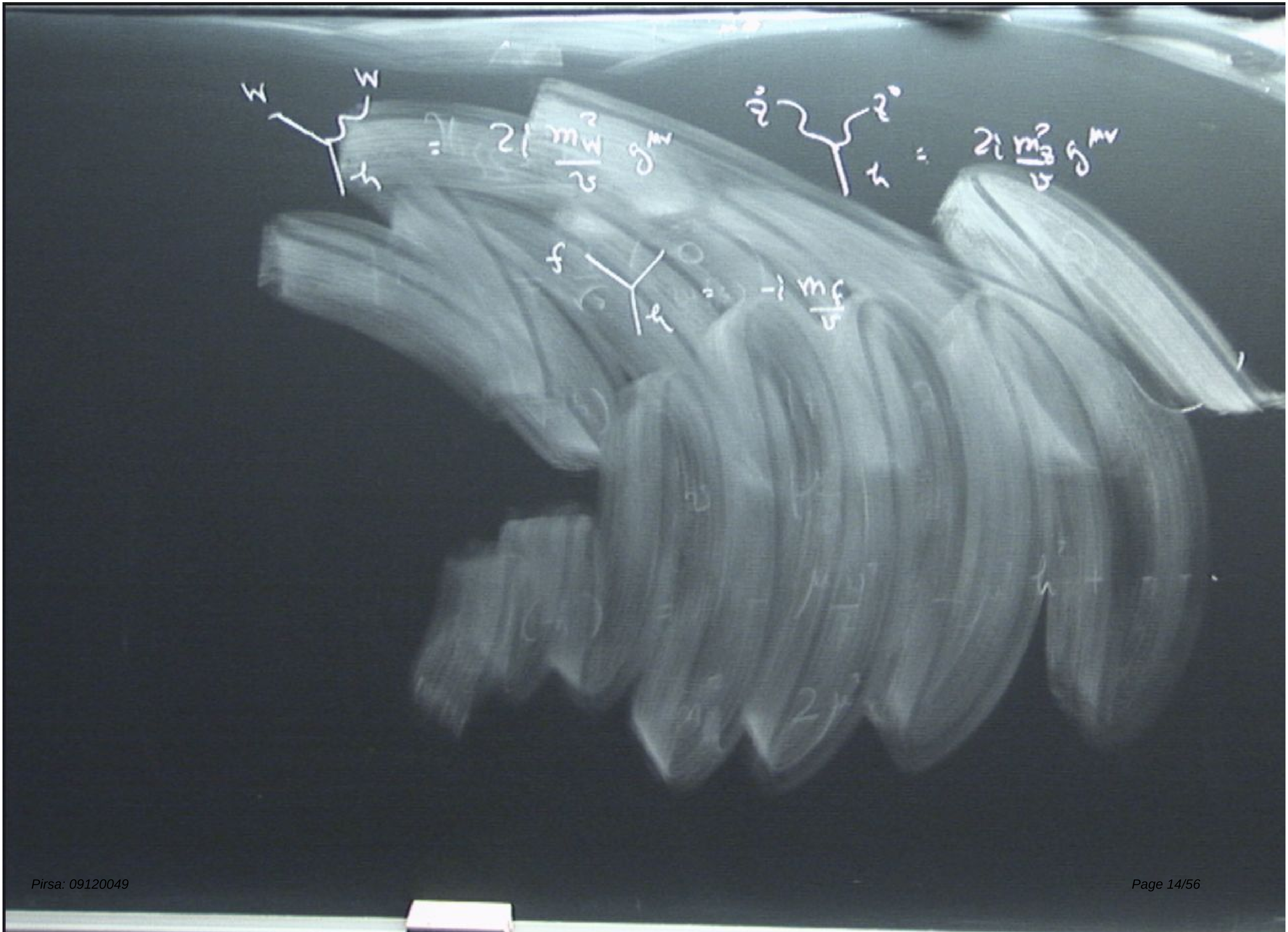
$\frac{\alpha_\omega}{4\pi} m_Z^2 \, \ell g \, \frac{m_H^2}{m_Z^2}$

$m_H < 180$ GeV

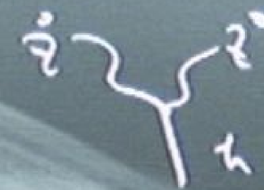



λ/4π = m_H^2/(8π v^2) ~ 1 when m_H = 1,200 GeV
m_H < 180 GeV
α_w/4π m_Z^2 log m_H^2/m_Z^2
h
Z
Z
N
Z
N
L = + g^2 (v + h(x))^2 W_μ^+ W^- + 1/2 (g^2 + g'^2)(v + h)^2 Z_μ Z^μ
− λ_f/√2 (v + h) f̄ f


= ½ m_H²/v²
λ/4π = m_H²/8πv² ~ 1 when m_H = 1,200 GeV
m_H < 180 GeV
α_w/4π m_Z² lg m_H²/m_Z²
h
Z
Z
N
Z
N
g²(v+h(x))² W_μ⁺W⁻ + ½(g²+g'²)(v+h)² Z_μ Z^μ
− λ_f/√2 (v+h) f̄f
+ kinetic


W W h = 2i m_W^2/v g^{μν}
Z^0 Z^0 h = 2i m_Z^2/v g^{μν}
f h = -i m_f/v

$= 2i\frac{m_W^2}{v} g^{\mu\nu}$

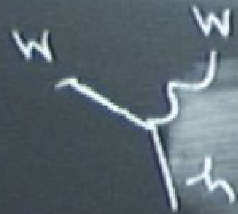


$= 2i\frac{m_Z^2}{v} g^{\mu\nu}$

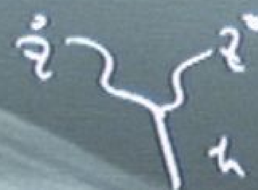
$= -i\frac{m_f}{v}$

$$\Gamma(h^0\to W^+W^-) = \frac{\alpha_w}{16}\frac{m_h^3}{m_W^2}\left(1-4\frac{m_W^2}{m_h^2}+12\frac{m_W^4}{m_h^4}\right)\left(1-\frac{4m_W^2}{m_h^2}\right)$$

$$\Gamma(h^0\to Z^0Z^0) = \frac{\alpha_w}{32}\frac{m_h^3}{m_W}$$



$= 2i \frac{m_W^2}{v} g^{\mu\nu}$



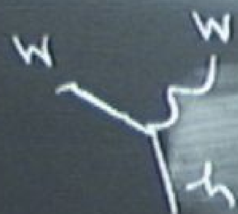
$= 2i \frac{m_Z^2}{v} g^{\mu\nu}$

$= -i \frac{m_f}{v}$

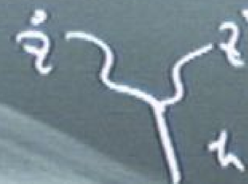
$$\Gamma(h^0 \to W^+W^-) = \frac{\alpha_w}{16} \frac{m_h^3}{m_W^2} \left(1 - 4\frac{m_W^2}{m_h^2} + 12\frac{m_W^4}{m_h^4}\right)\left(1 - \frac{4m_W^2}{m_h^2}\right)^{1/2}$$

$$\Gamma(h^0 \to Z^0 Z^0) = \frac{\alpha_w}{32} \frac{m_h^3}{m_W^2} \left(1 - 4\frac{m_Z^2}{m_h^2} + 12\frac{m_Z^4}{m_h^4}\right)\left(1 - \frac{4m_Z^2}{m_h^2}\right)^{1/2}$$

$$\alpha_w \frac{m_h^2}{m_W^2}$$



$$= 2i \frac{m_W^2}{v} g^{\mu\nu}$$



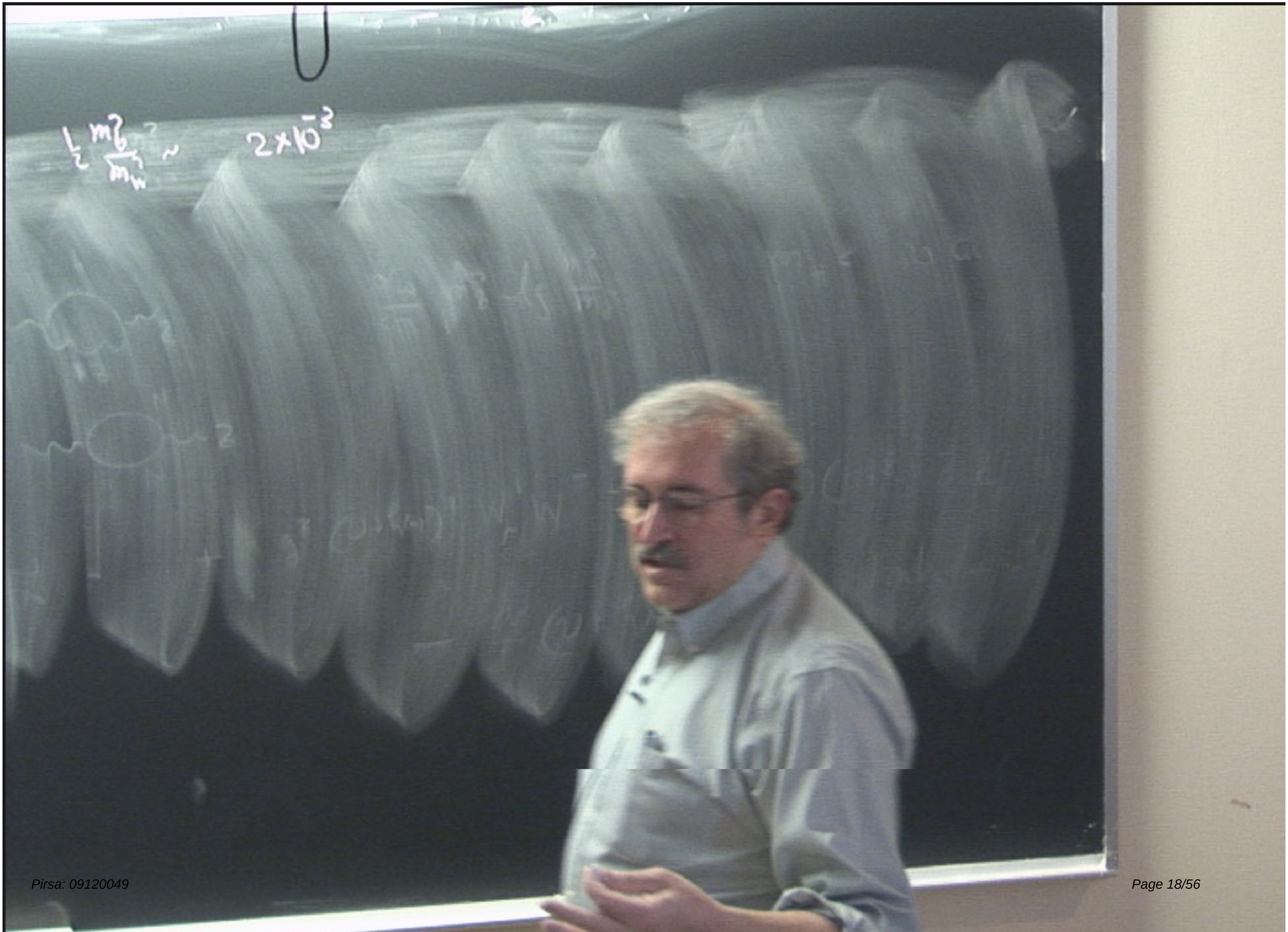
$$= 2i \frac{m_Z^2}{v} g^{\mu\nu}$$

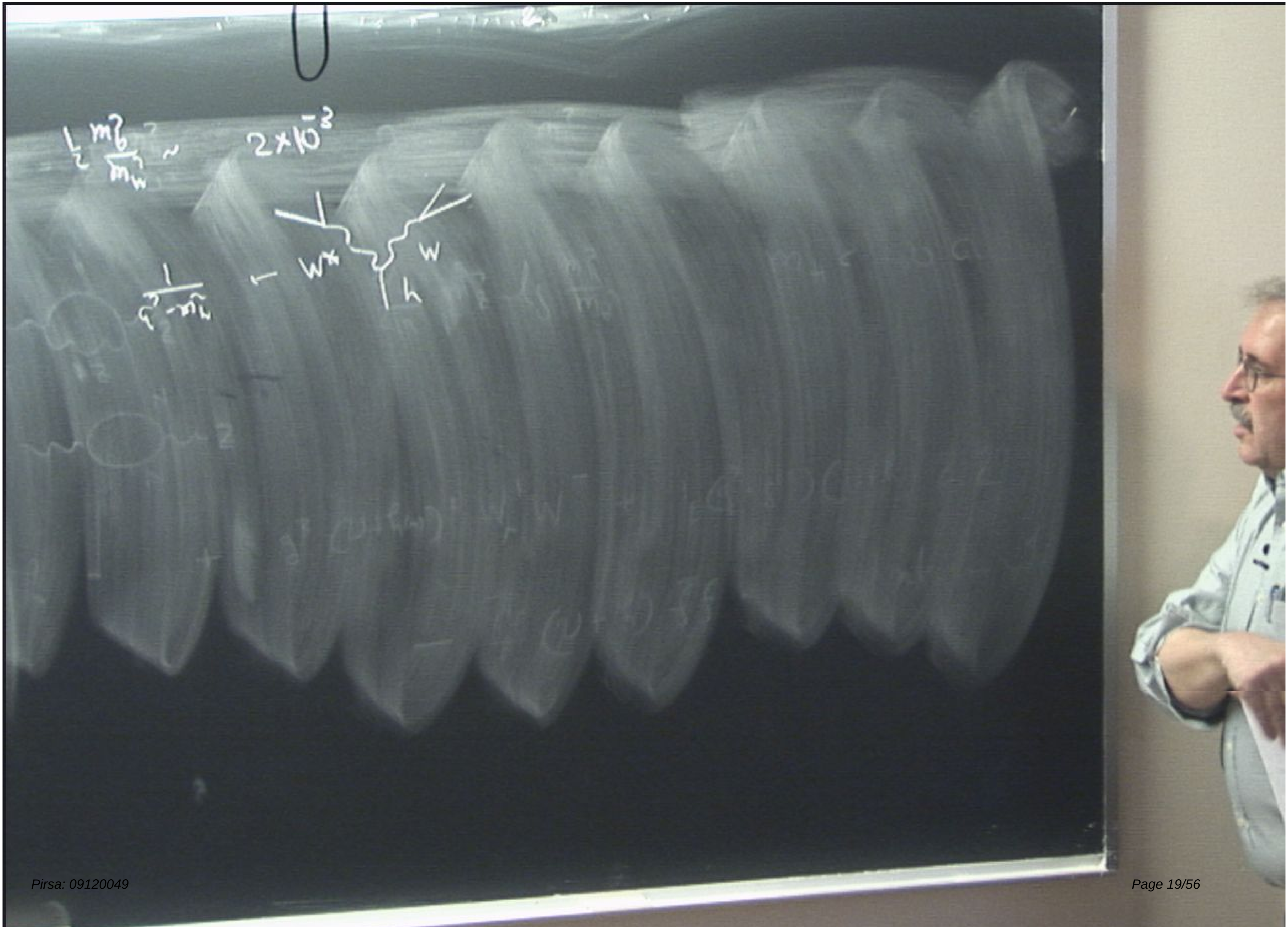
$$= -i \frac{m_f}{v}$$

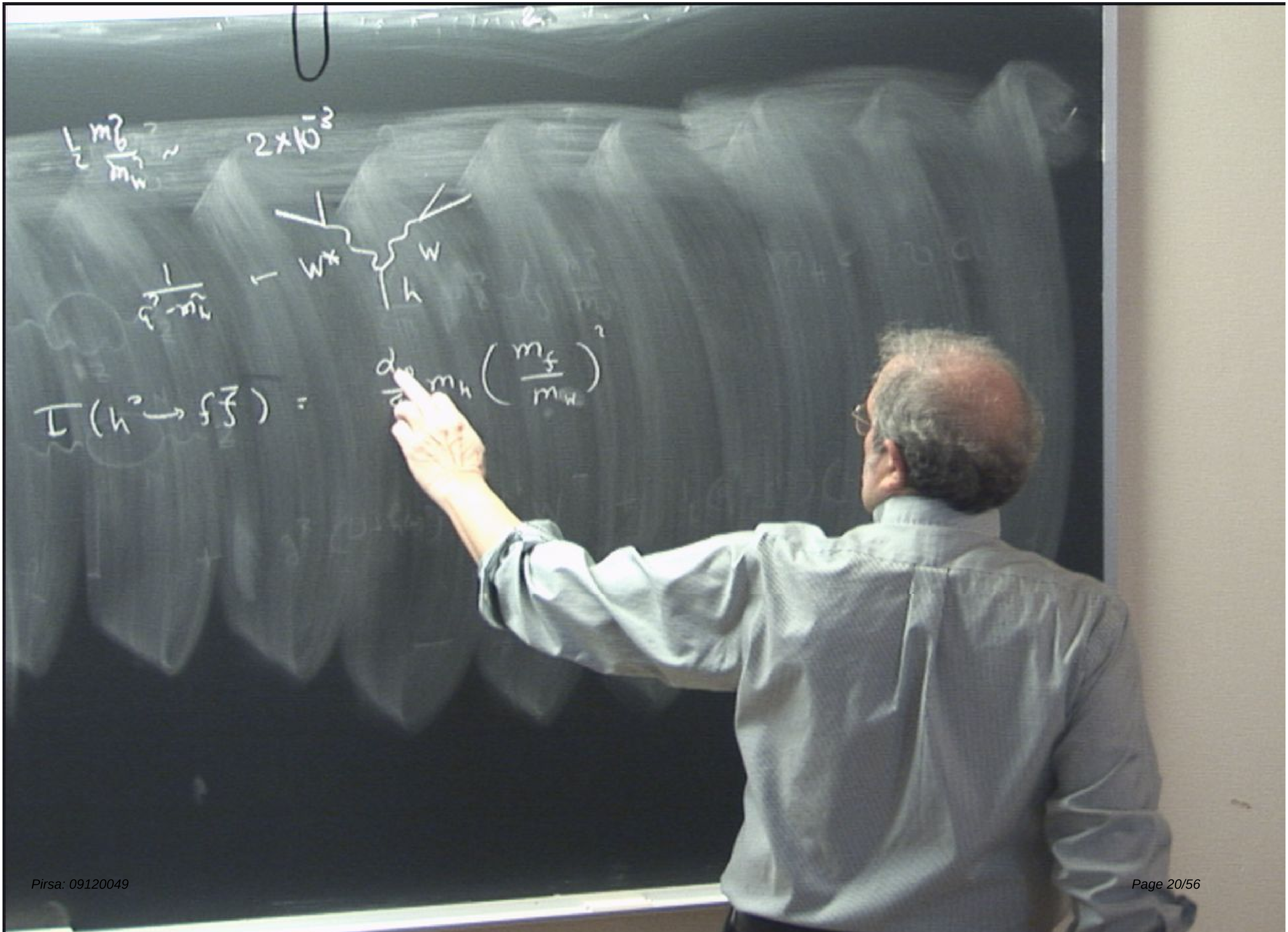
$$\Gamma(h^0 \to W^+W^-) = \frac{\alpha_w}{16} \frac{m_h^3}{m_W^2} \left(1 - 4\frac{m_W^2}{m_h^2} + 12\frac{m_W^4}{m_h^4}\right)\left(1 - \frac{4m_W^2}{m_h^2}\right)^{1/2}$$

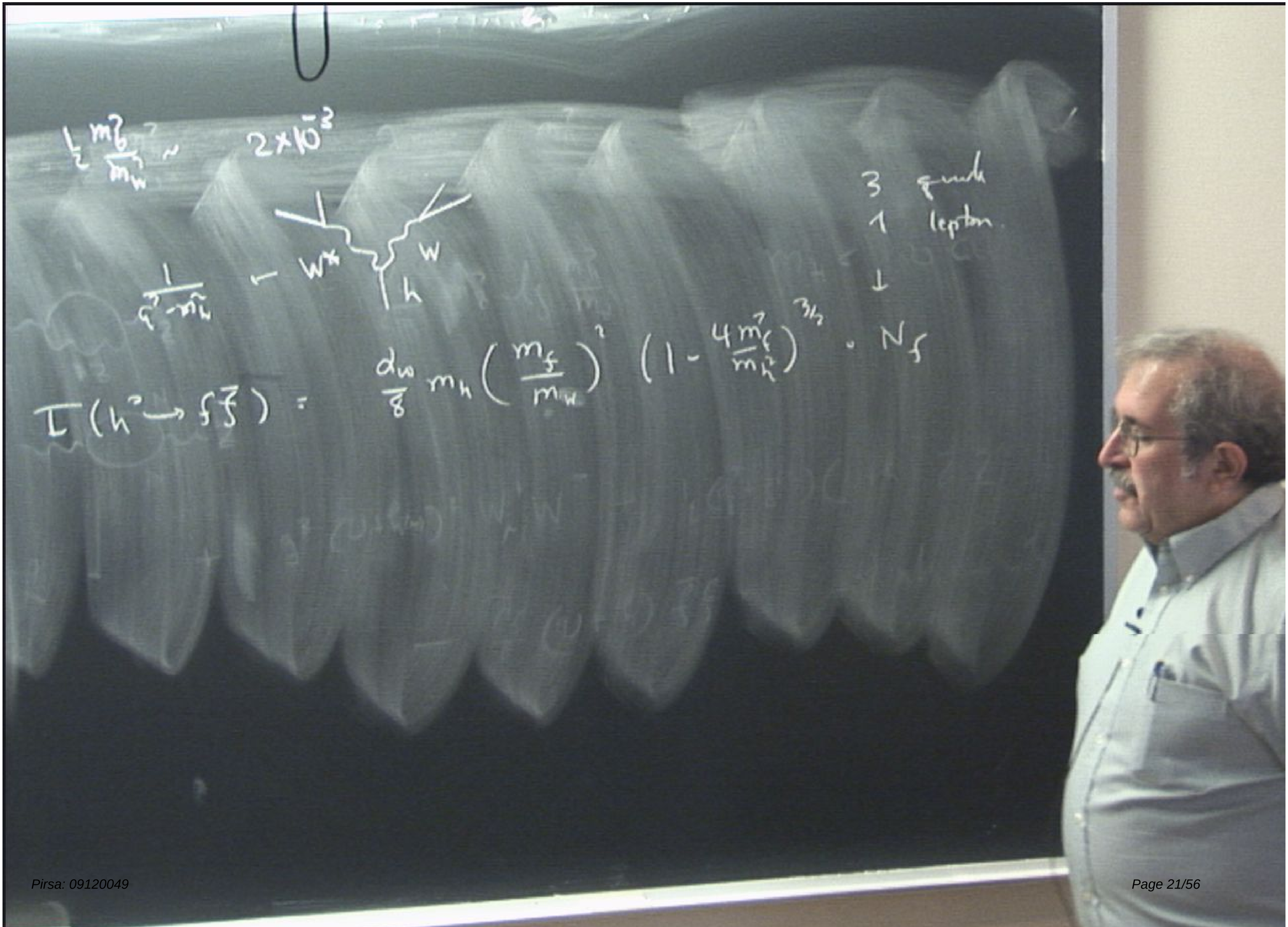
$$\Gamma(h^0 \to Z^0 Z^0) = \frac{\alpha_w}{32} \frac{m_h^3}{m_W^2} \left(1 - 4\frac{m_Z^2}{m_h^2} + 12\frac{m_Z^4}{m_h^4}\right)\left(1 - \frac{4m_Z^2}{m_h^2}\right)^{1/2}$$

$$\alpha_w \frac{m_h^2}{m_W^2} \sim g^2 \frac{\lambda v^2}{g^2 v^2} \sim \lambda$$

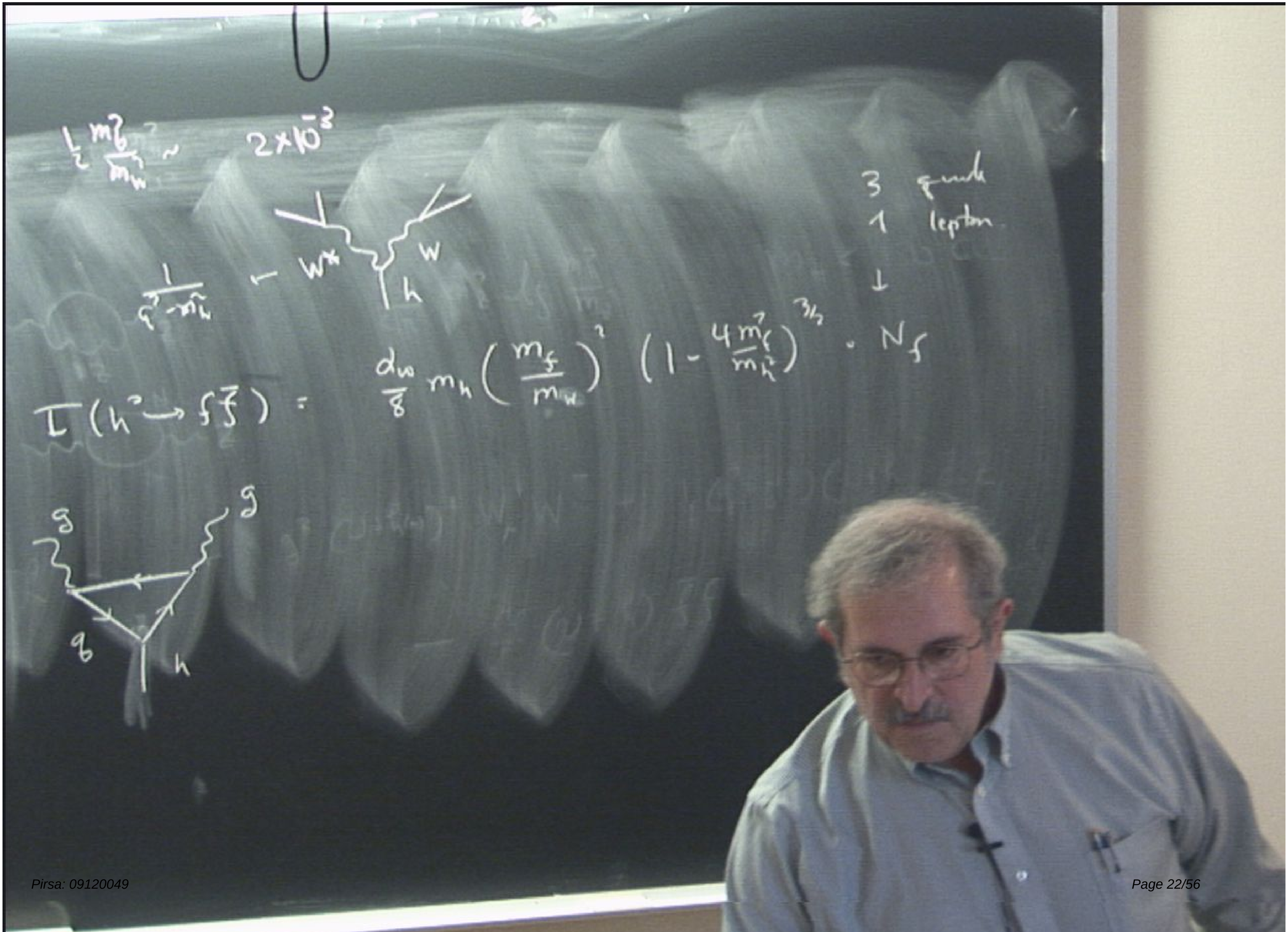

$\frac{1}{2}\frac{m_b^2}{m_W^2} \sim 2\times10^{-3}$

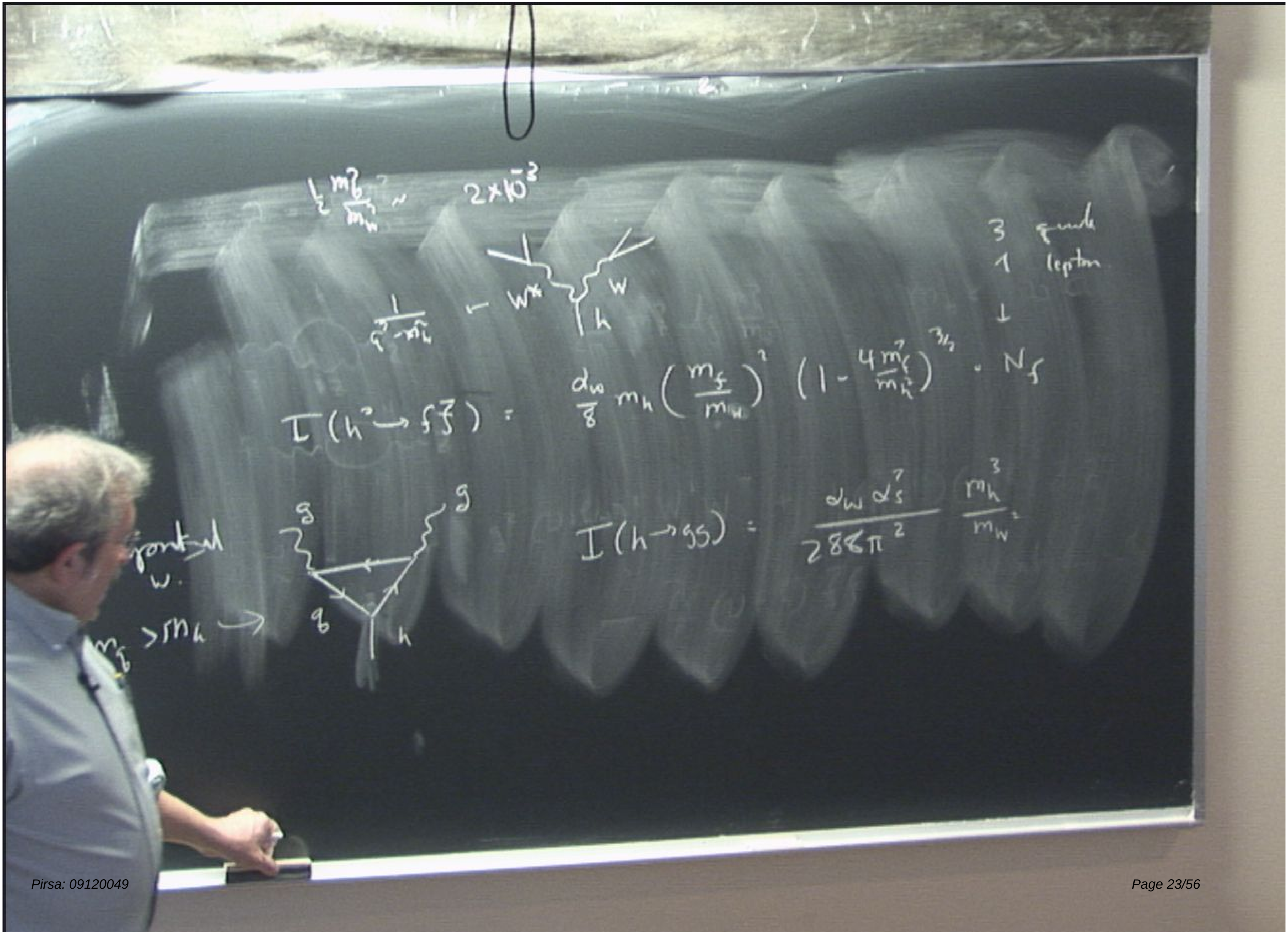

$\frac{1}{2}\frac{m_b^2}{m_W^2} \sim 2\times10^{-3}$
$\frac{1}{q^2 - m_W^2} \leftarrow W^*$
W
h

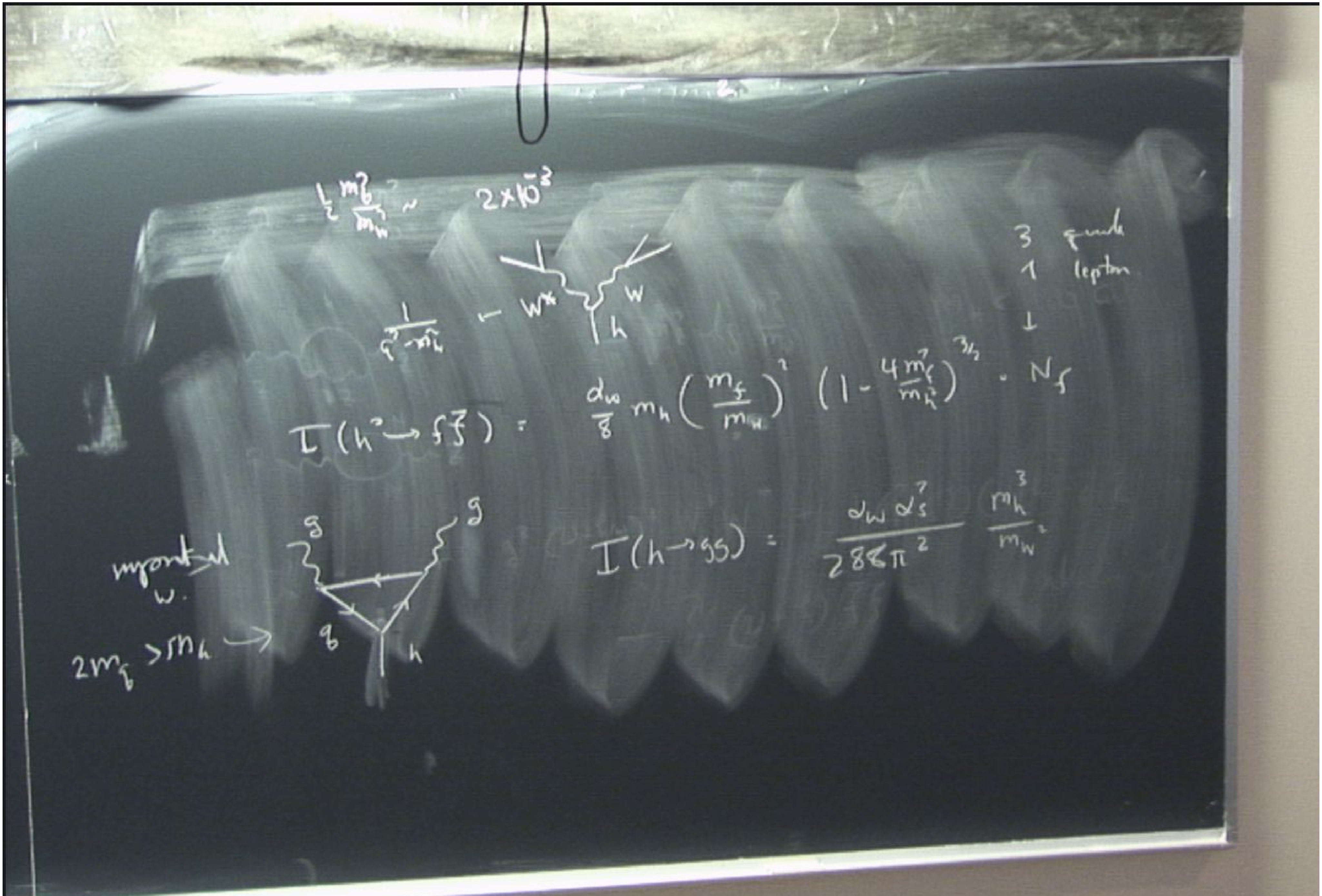

2×10⁻³
W*
W
h
Γ(h⁰ → f f̄) =

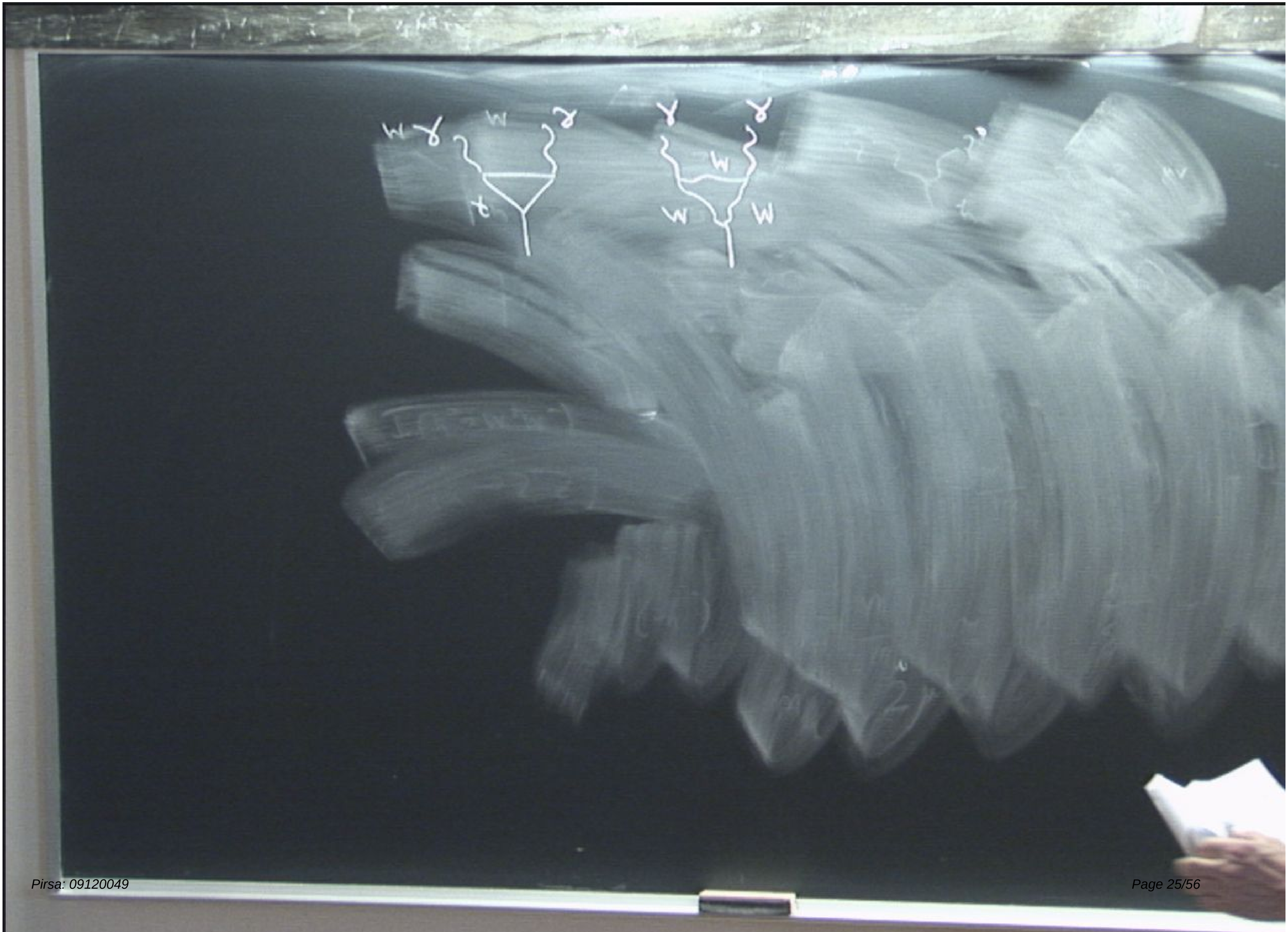


½ m_b² / m_W² ~ 2×10⁻³
W* W h
1 / (q² − m_W²)
3 quark
1 lepton
Γ(h⁰ → f f̄) = (α_W / 8) m_h (m_f / m_W)² (1 − 4 m_f² / m_h²)^{3/2} · N_f


2×10^-3
W*
W
h
3 quark
1 lepton
N_f
g
g
q
h


2×10^-3
3 quarks
1 lepton
W* W h
I (h → f f̄) = α_w/8 m_h (m_f/m_w)^2 (1 - 4 m_f^2/m_h^2)^3/2 · N_f
I (h → gg) = α_w α_s^2 / 288π^2 · m_h^3/m_w^2
g g
q h


1/2 m_b^2/m_W^2 ~ 2×10^-3
3 quarks
1 lepton
W* W h
1/(q^2 - m_W^2)
Γ(h → f f̄) = α_w/8 m_h (m_f/m_W)^2 (1 - 4m_f^2/m_h^2)^3/2 · N_f
g g
Γ(h → gg) = α_w α_s^2/288π^2 m_h^3/m_W^2
important w.
2m_t > m_h →
t h


W γ
W
γ
t
γ
γ
W
W
W

$m_H = 120$ GeV

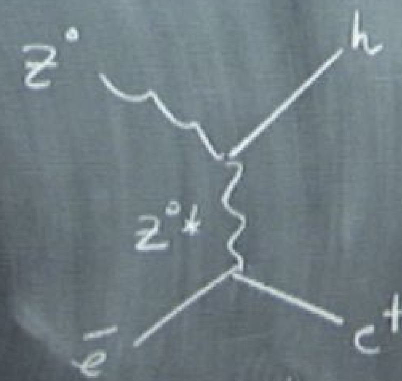
$$\Gamma(h \to \gamma\gamma) = .027 \frac{\alpha_W \alpha^2}{\pi} \frac{m_h^3}{m_W^2}$$

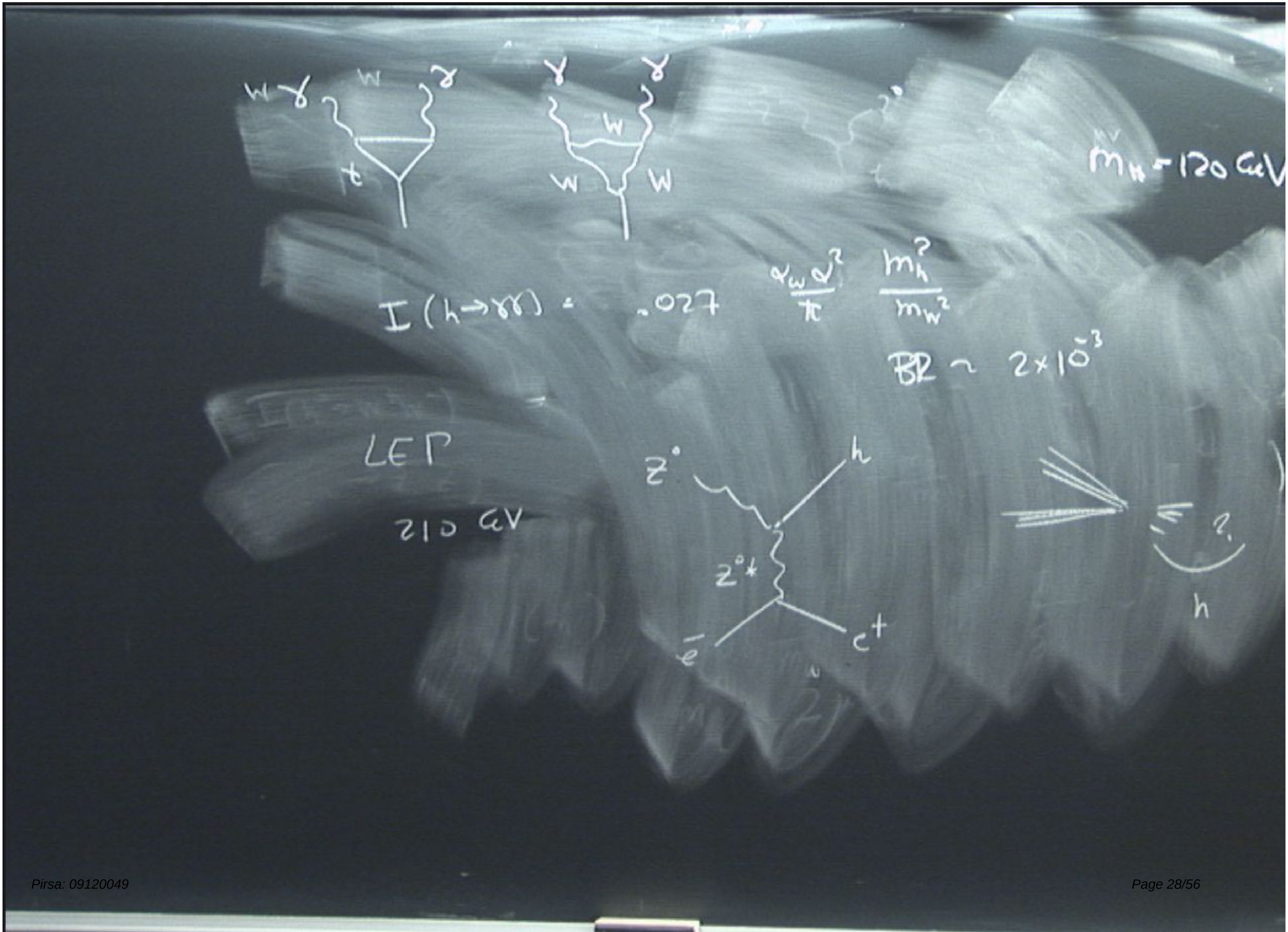
$$BR \sim 2 \times 10^{-3}$$

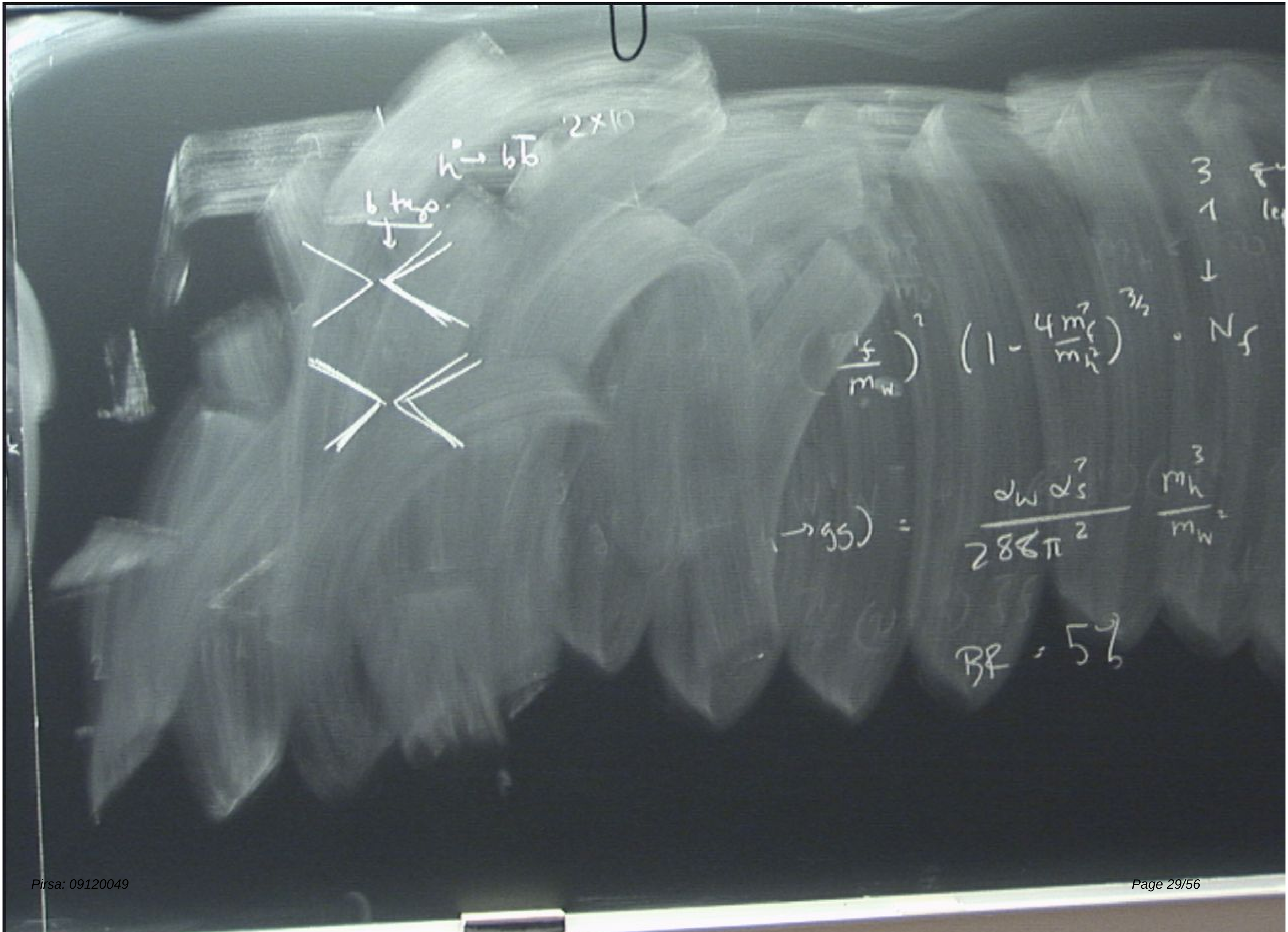
$m_H = 120$ GeV

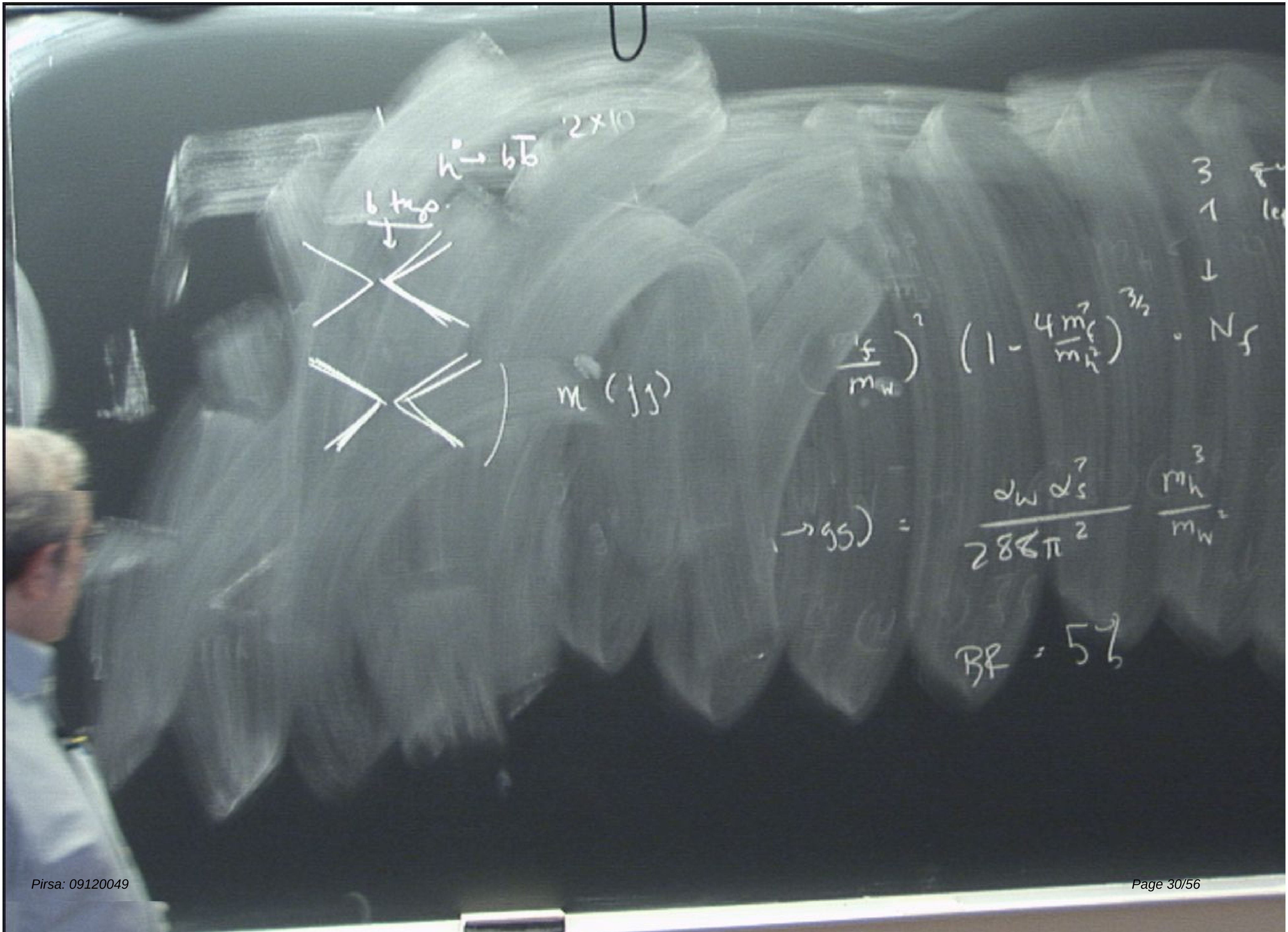
$$\Gamma(h \to \gamma\gamma) = .027 \frac{\alpha_w \alpha^2}{\pi} \frac{m_h^2}{m_W^2}$$

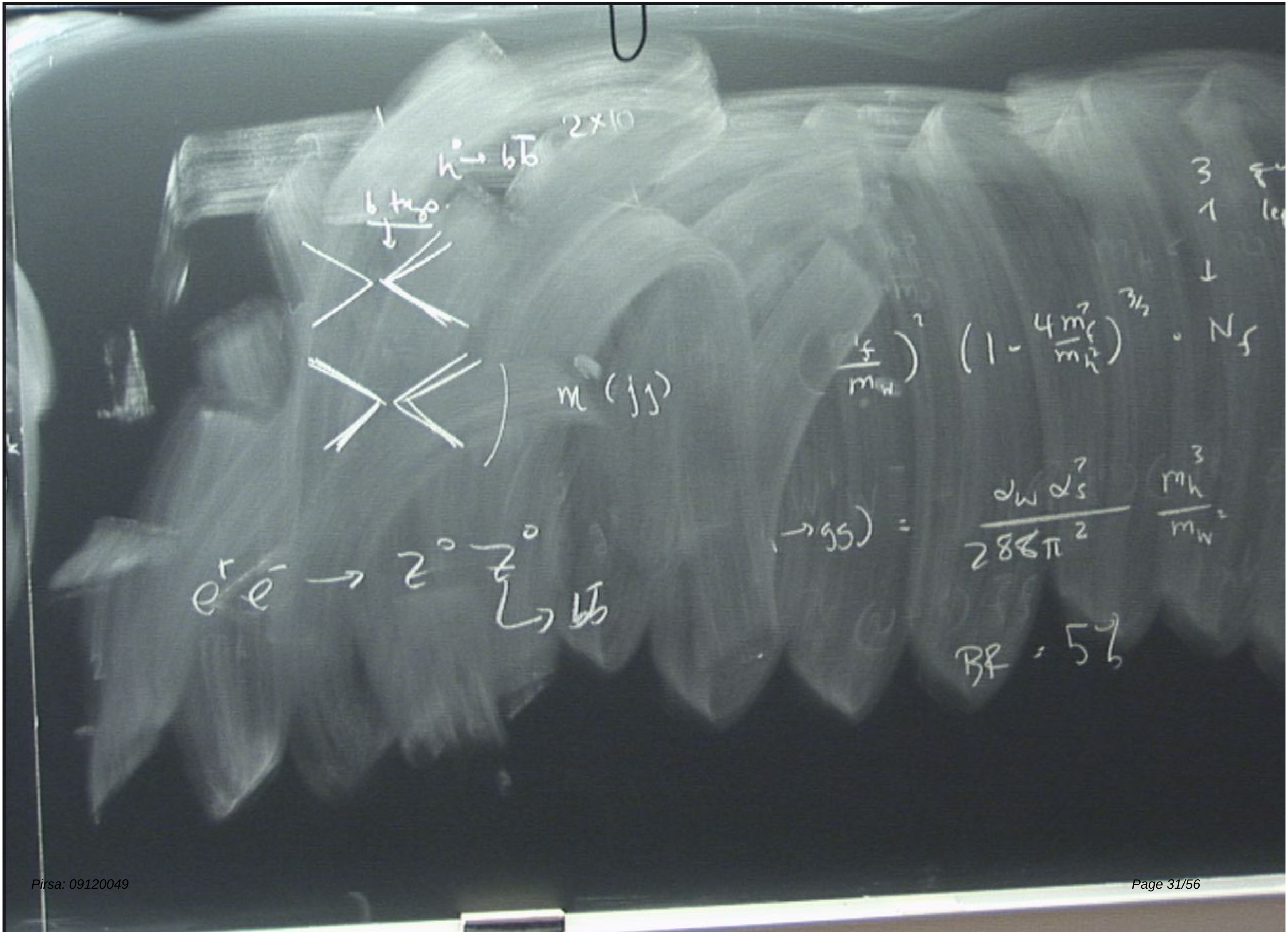
$$BR \sim 2 \times 10^{-3}$$




W γ
W
γ
t
γ γ
W
W W
$m_H = 120$ GeV
$\Gamma(h \to \gamma\gamma) = .027 \frac{\alpha_w \alpha^2}{\pi} \frac{m_h^2}{m_W^2}$
BR ~ 2×10^{-3}
LEP
210 GeV
Z°
h
Z°*
e^-
e^+
?
h


h → bb̄
2×10
b tag.
3
1
(1 - 4m_f²/m_h²)^3/2 · N_f
→ gg) =
α_w α_s² / 288π²
m_h³ / m_w²
BR = 5%


h° → b b̄
2×10
b tag
3
1
m (jj)
$\left(\frac{m_f}{m_W}\right)^2 \left(1 - \frac{4 m_f^2}{m_h^2}\right)^{3/2} \cdot N_f$
→ gg) = $\frac{\alpha_W \alpha_s^2}{288 \pi^2} \frac{m_h^3}{m_W^2}$
BR = 5%


h° → bb̄
2×10
b tags
m (jj)
(1 - 4m_f²/m_h²)^{3/2} · N_f
m_W
→ gg) = α_W α_s² / 288π² · m_h³/m_W²
e+e- → Z° Z°
↳ bb̄
BR ~ 5%

$h^0 \to b\bar{b}$ 2×10

b tag.

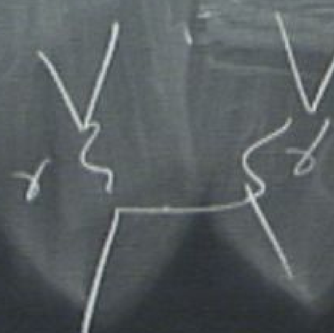
$m(jj)$

$\left(\frac{m_f}{m_W}\right)^2 \left(1-\frac{4m_f^2}{m_h^2}\right)^{3/2} \cdot N_f$

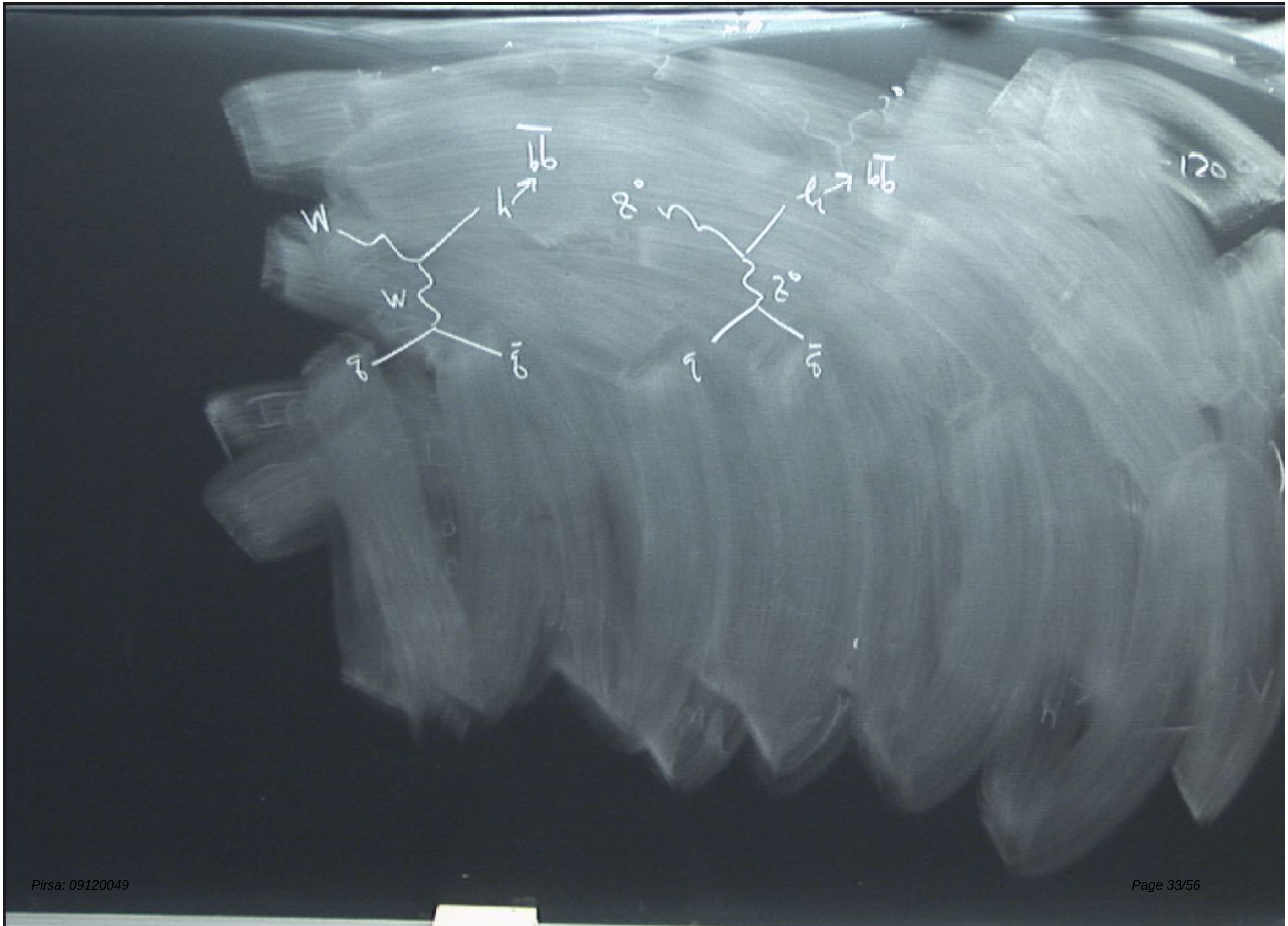
3 q
1 le

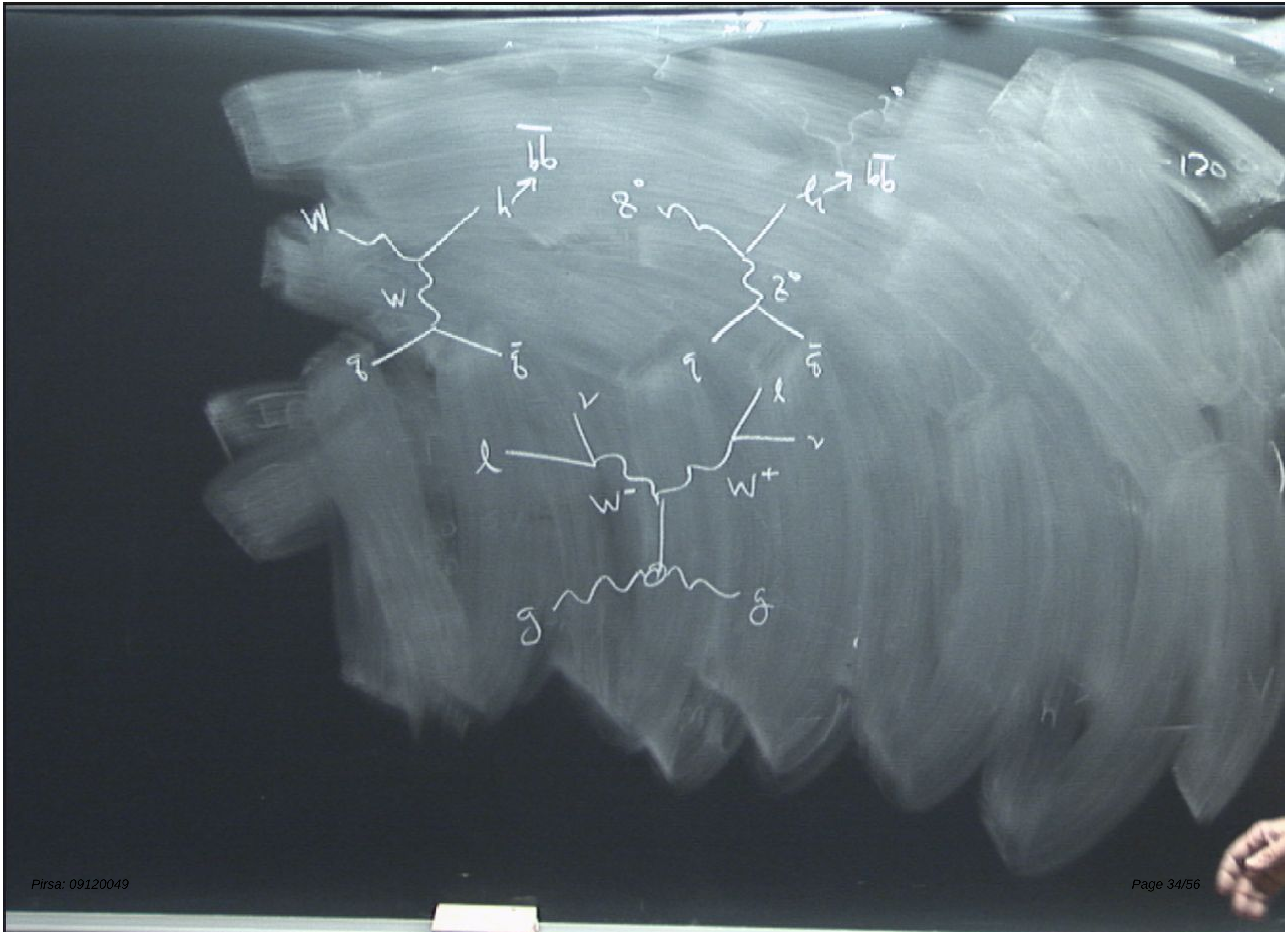
$\frac{\alpha_W \alpha_s^2}{288\pi^2}\,\frac{m_h^3}{m_W^2}$

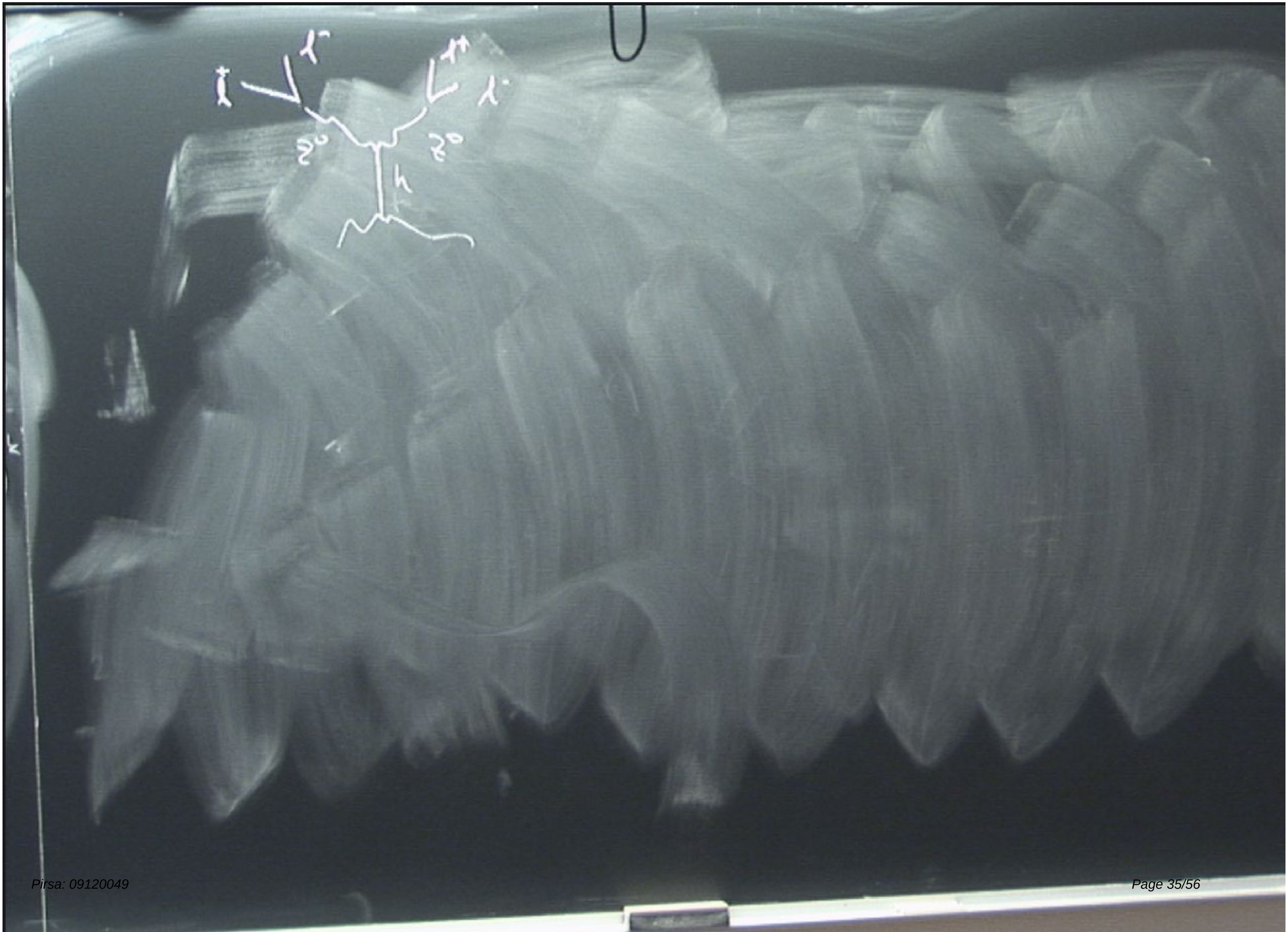
$e^+e^- \to Z^0 Z^0$
$\hookrightarrow b\bar{b}$

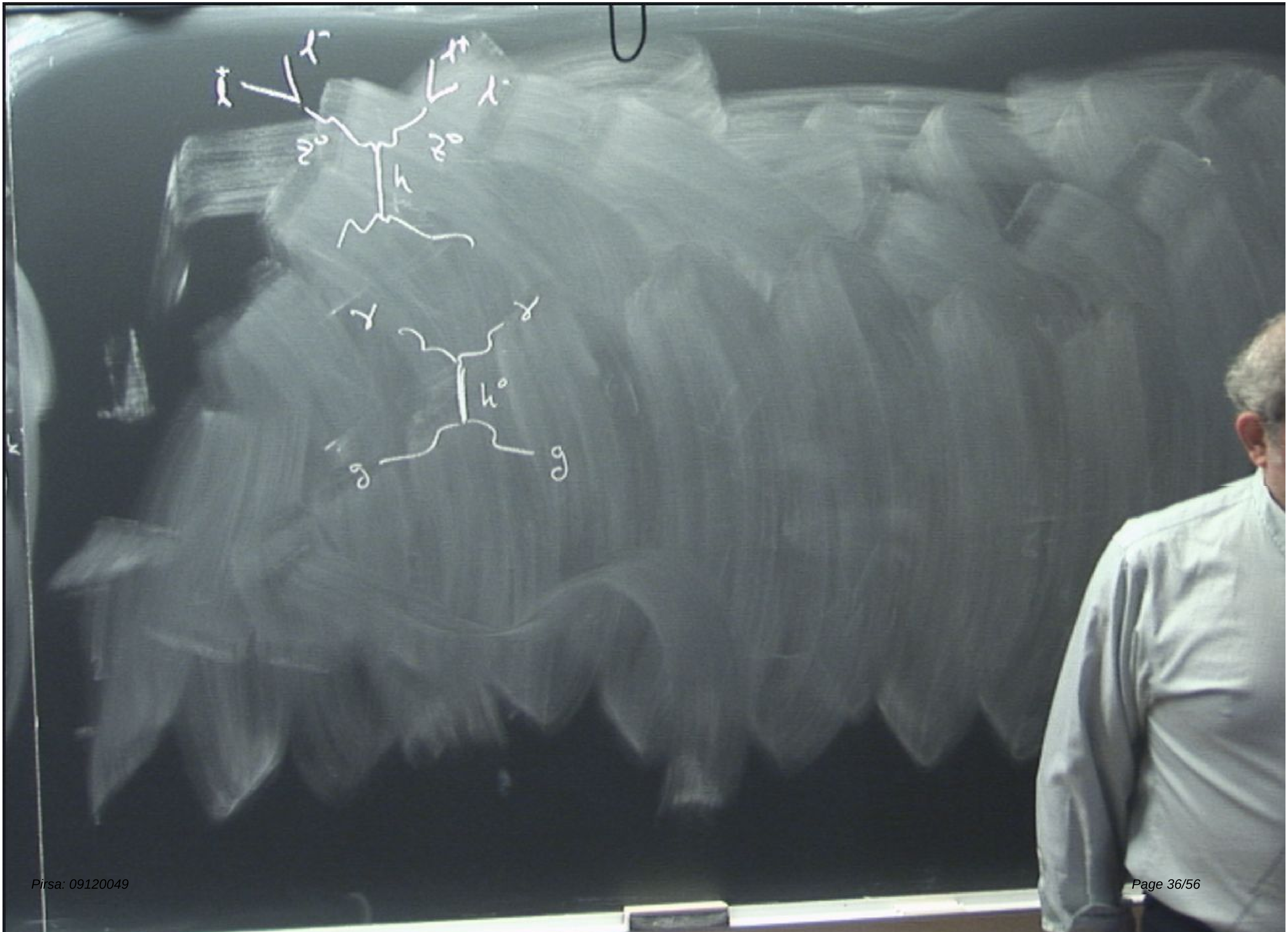


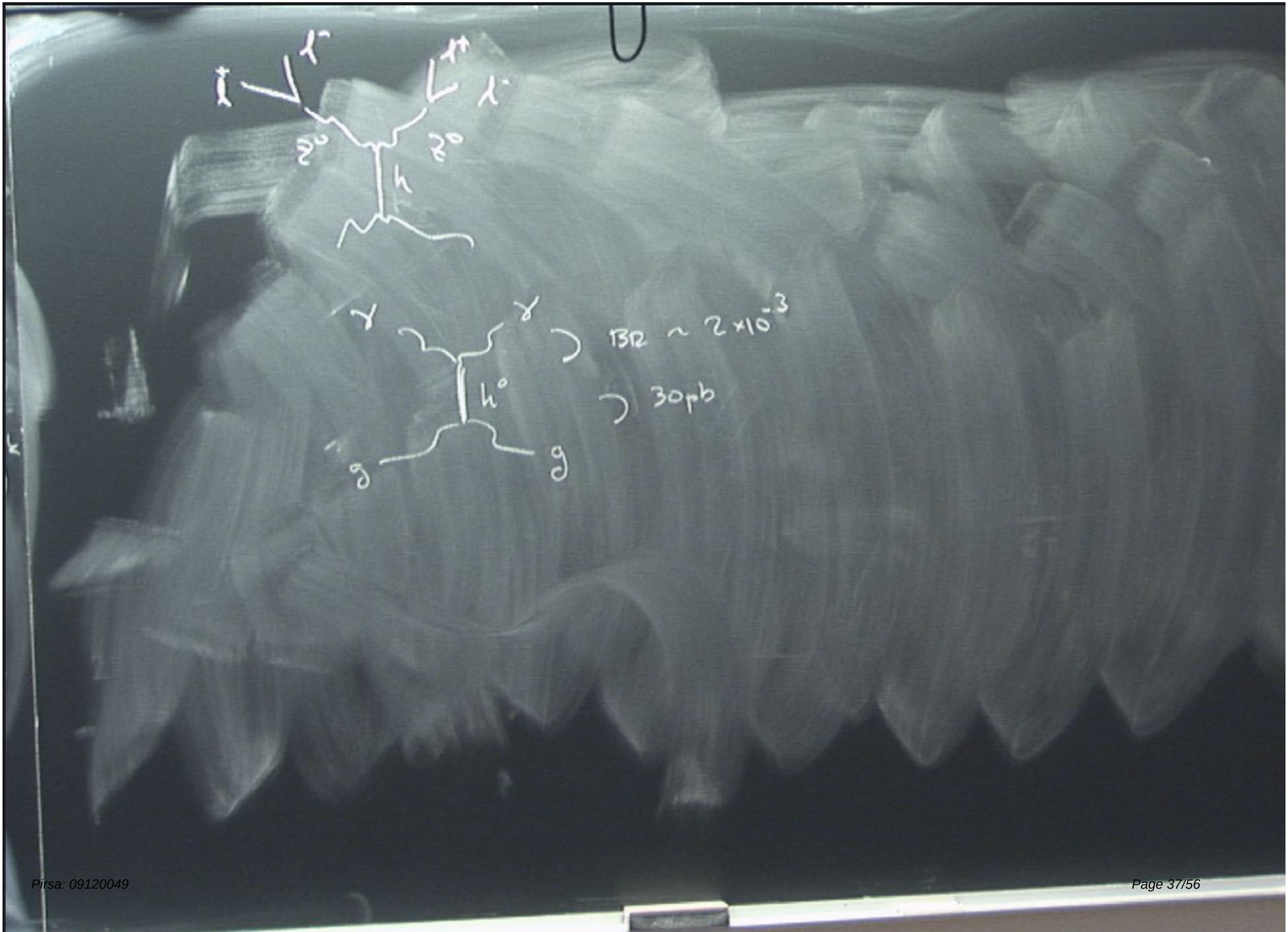
BR = 5%

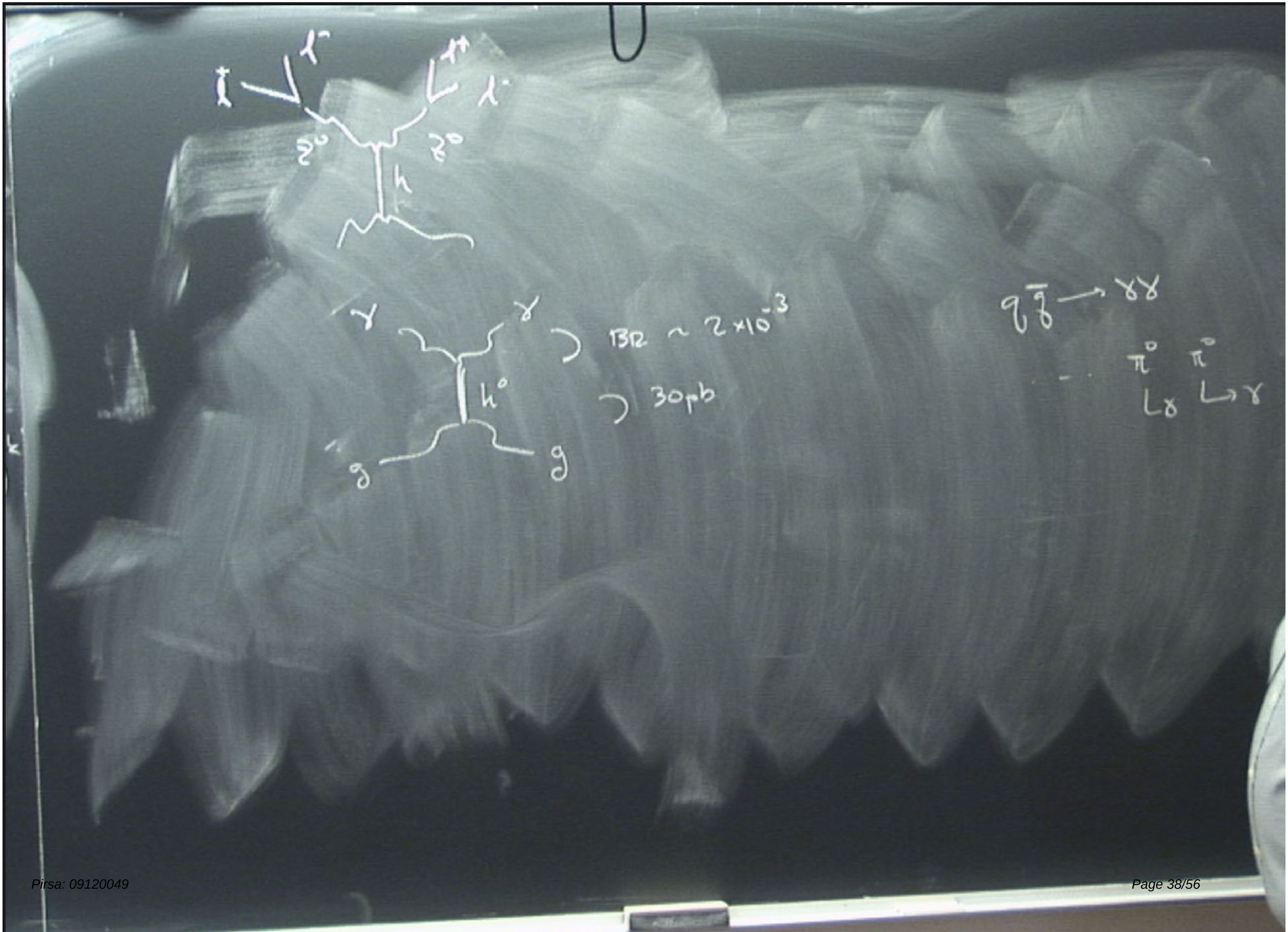

W
h
b̄b
W
q
q̄
Z°
h
b̄b
Z°
q
q̄
120


W
h
b b̄
W
q
q̄
Z°
h
b b̄
Z°
q
q̄
l
ν
l
ν
W⁻
W⁺
g
g
120

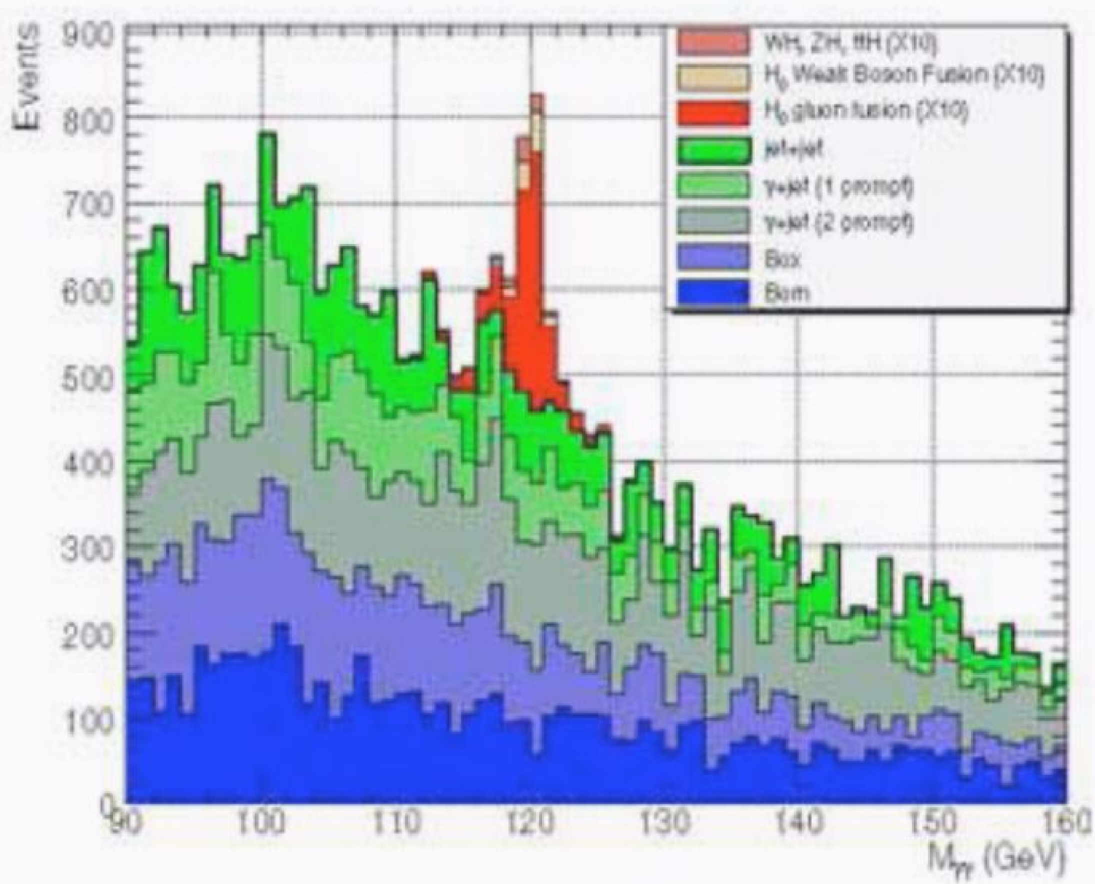

Z°
Z°
h


Z°
Z°
h
γ
γ
h°
g
g

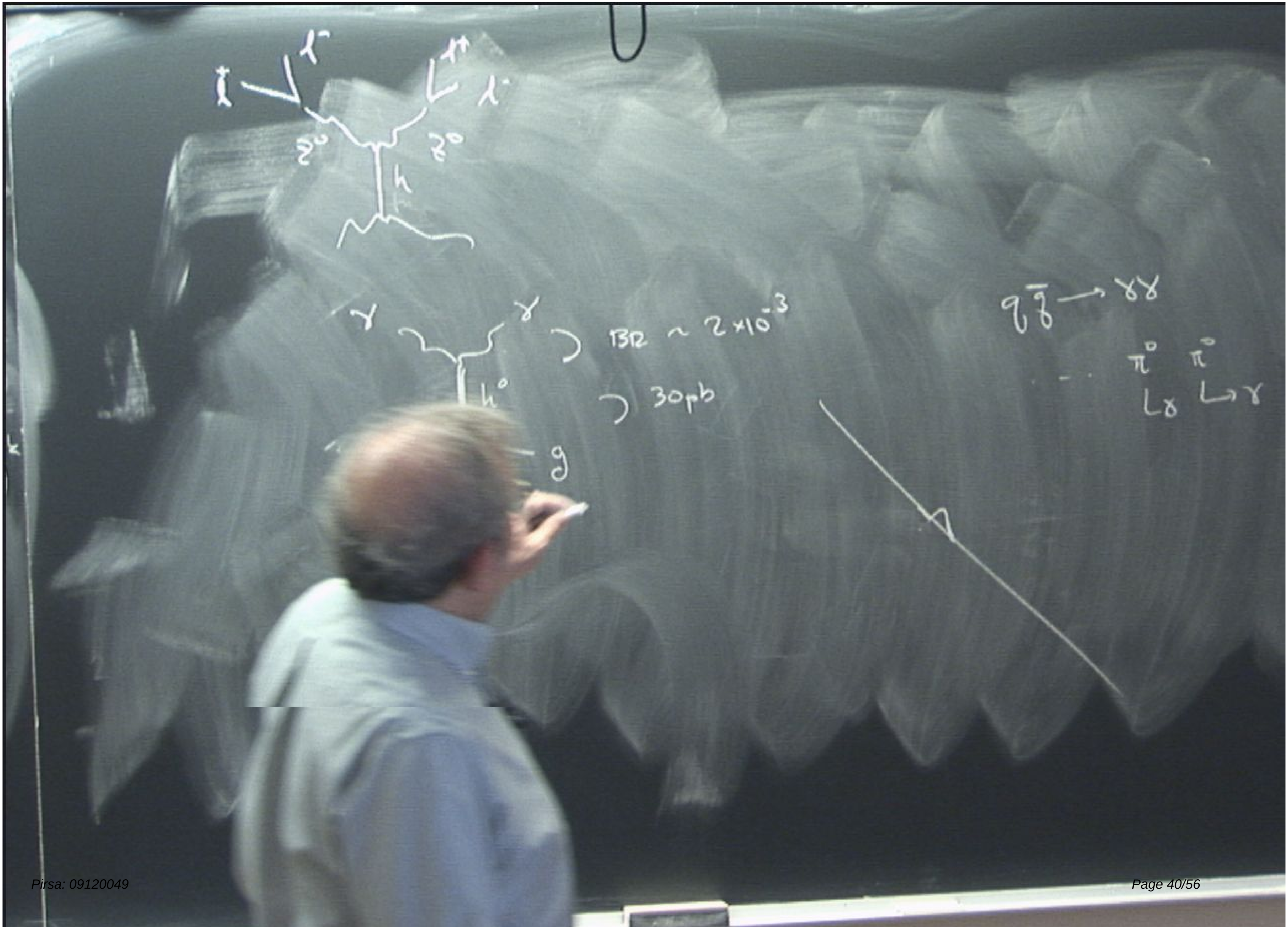

ℓ⁺ ℓ⁻
ℓ⁺ ℓ⁻
Z⁰
Z⁰
h
γ
γ
h⁰
g
g
BR ~ 2×10⁻³
30pb

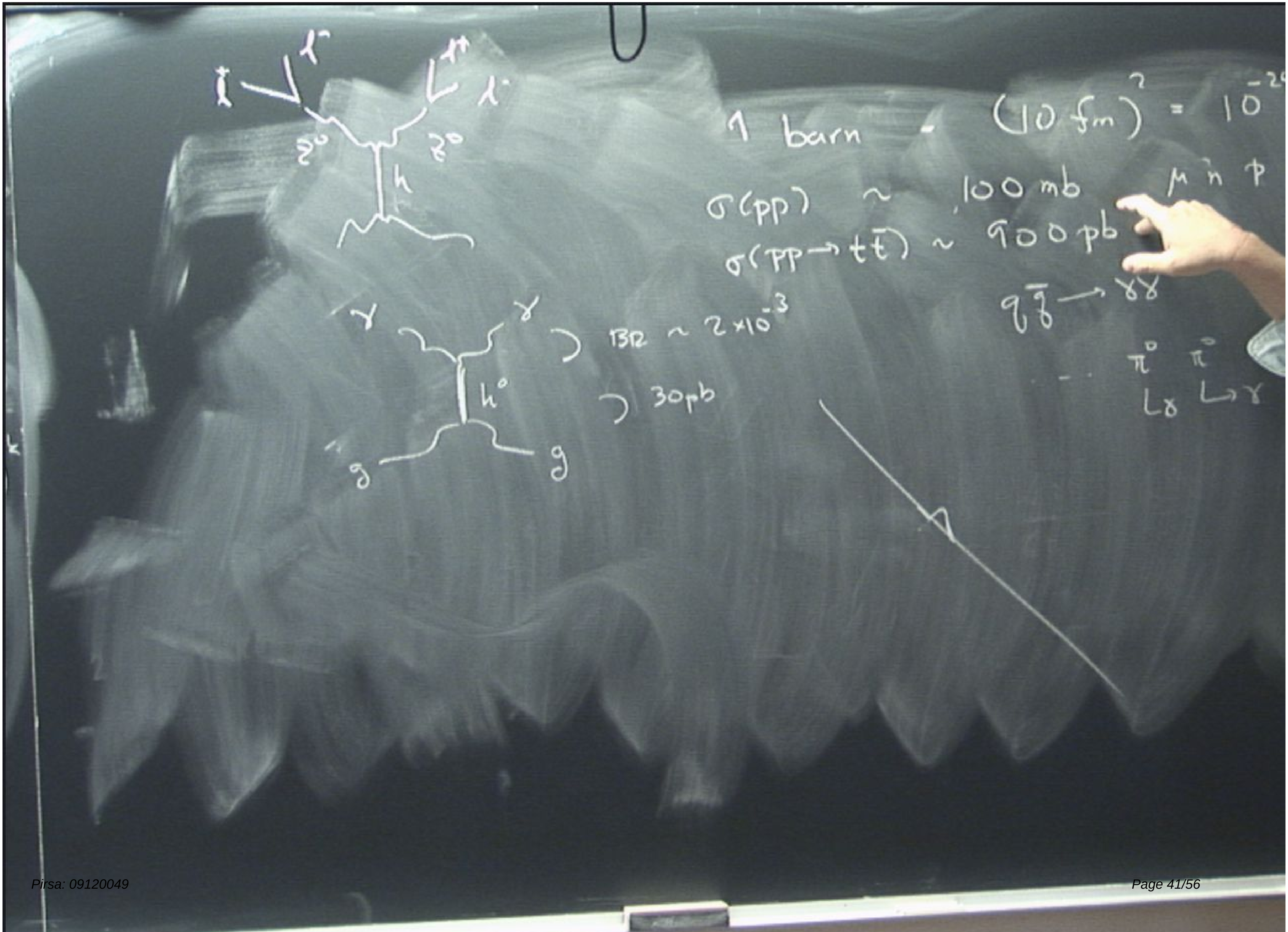

Z0 Z0
h
γ γ
BR ~ 2×10-3
h0
30pb
g g
qq̄ → γγ
π0 π0

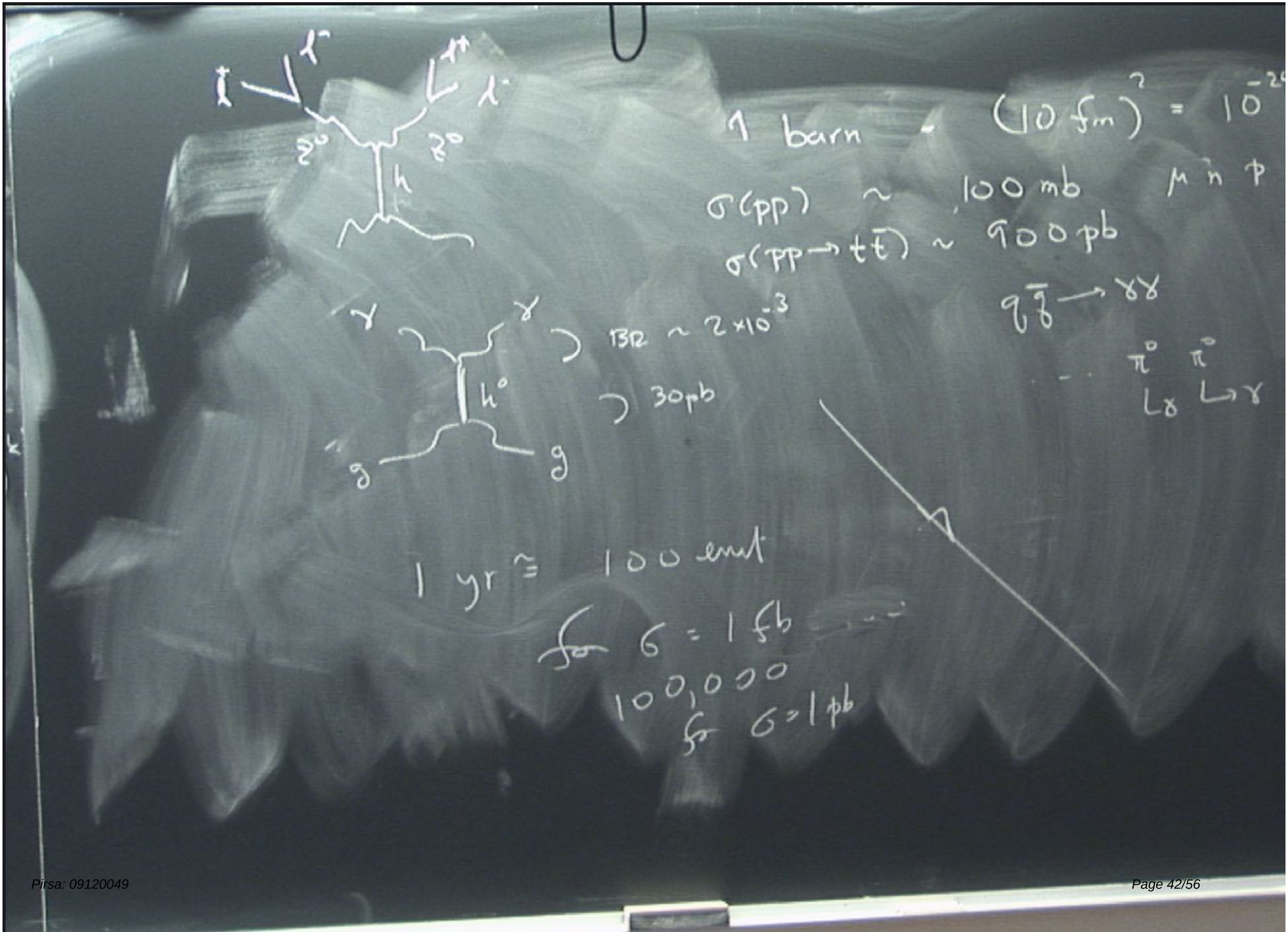
CMS $h^0 \to \gamma\gamma$ $7.7\ \mathrm{fb}^{-1}$

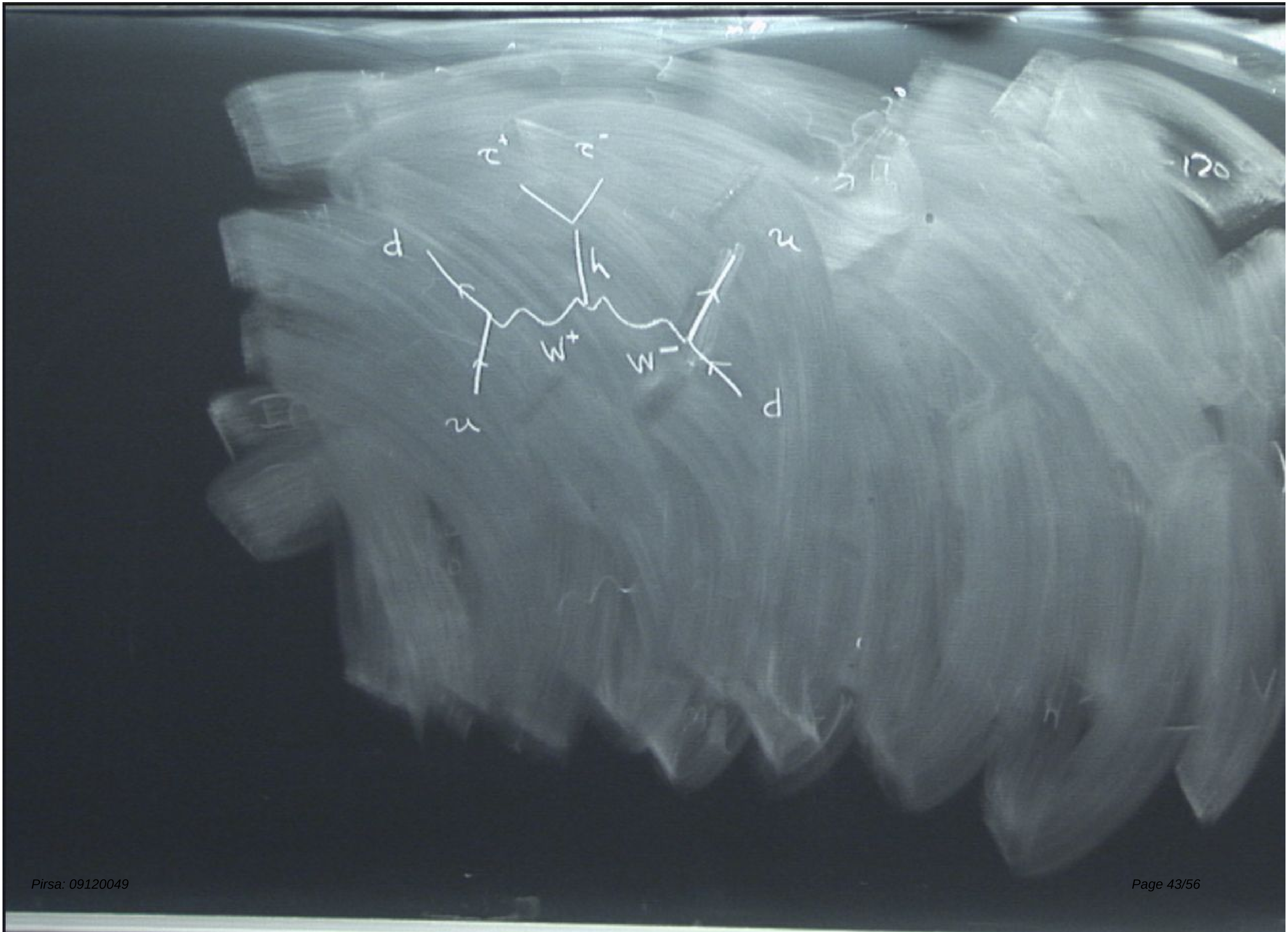


signal x 10 for visibility

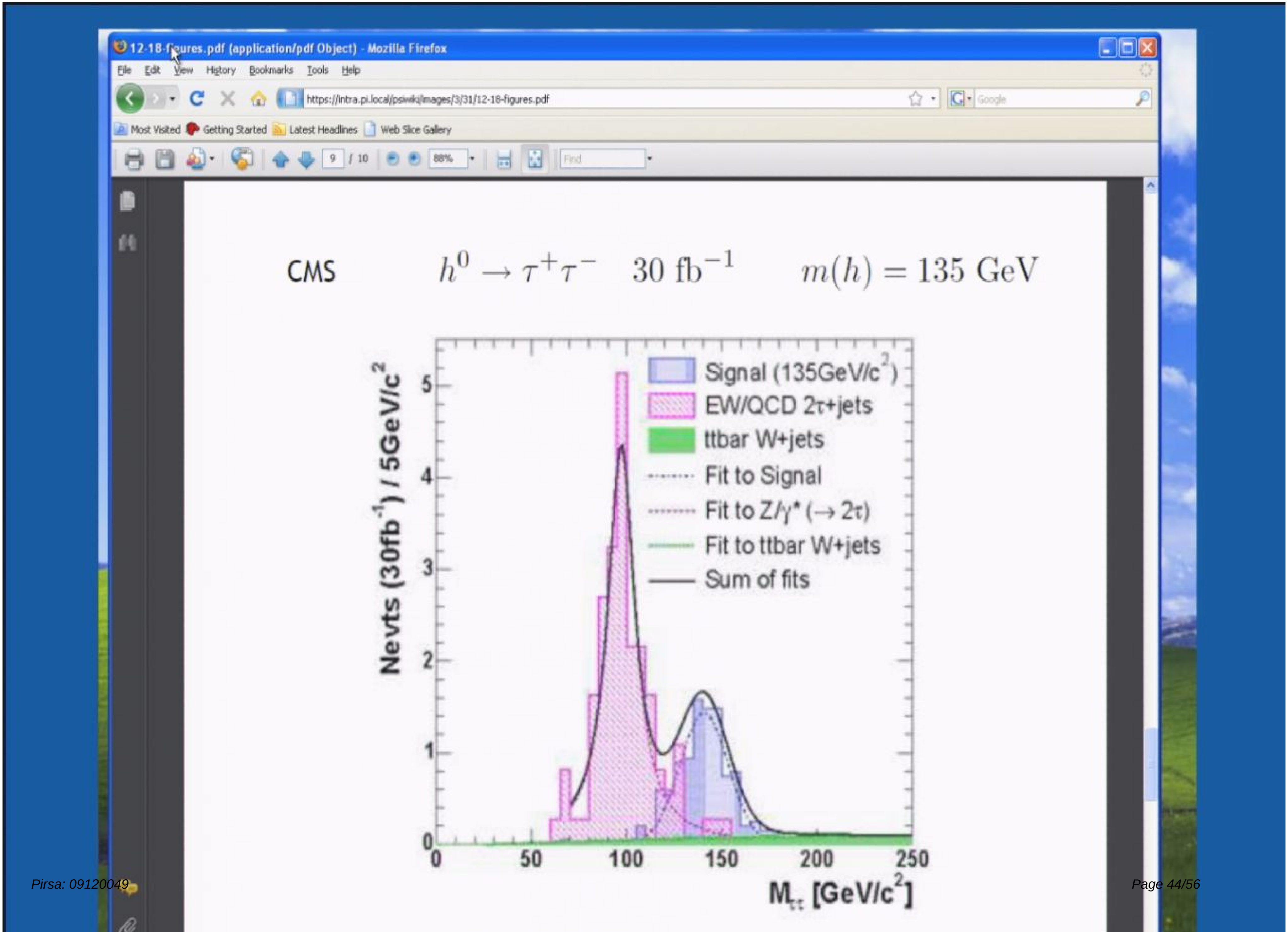

Z°
Z°
h
h°
g
BR ~ 2×10⁻³
30pb
qq̄ → γγ
π° π°

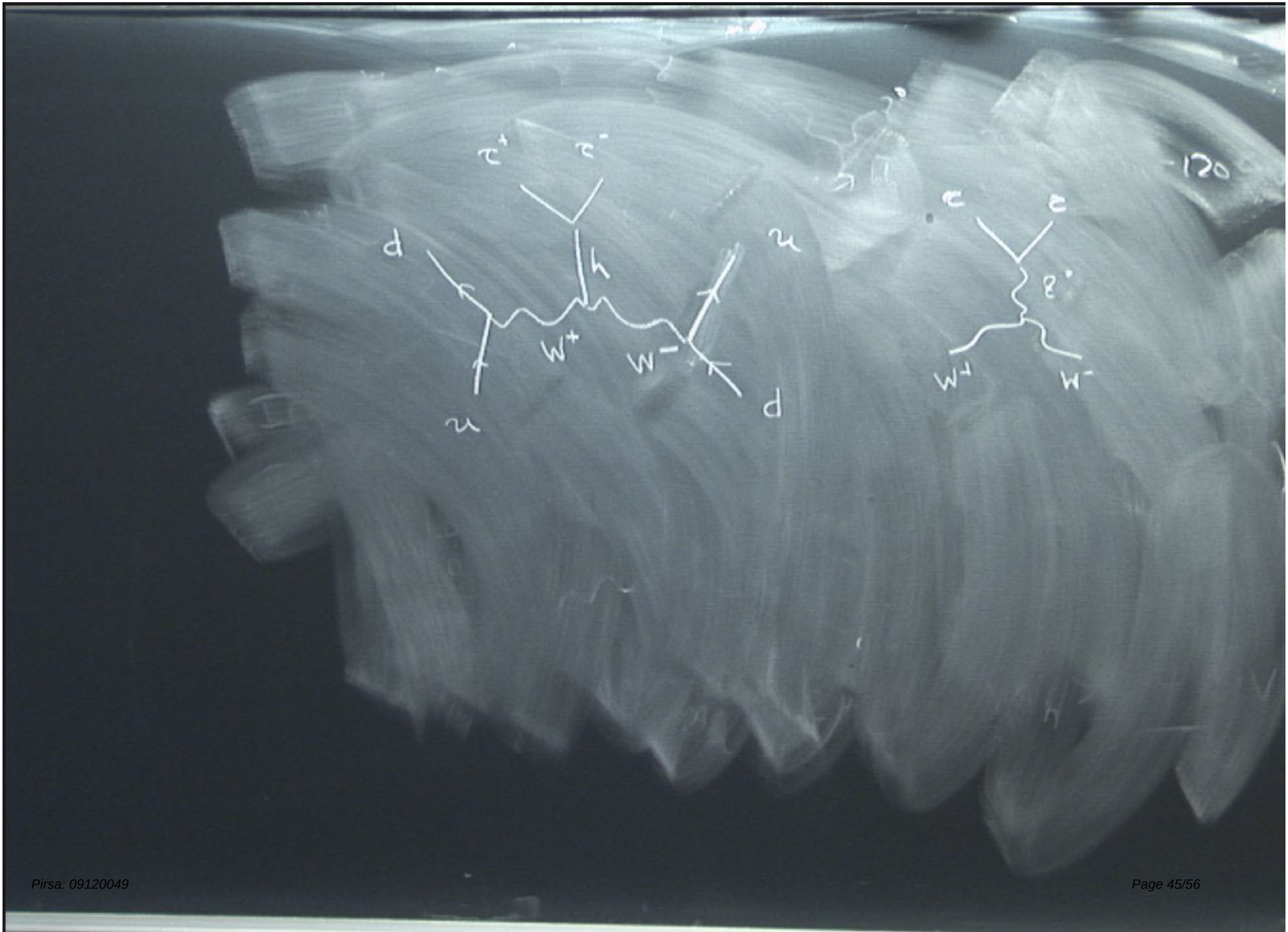

1 barn = (10 fm)²
σ(pp) ~ 100 mb
σ(pp → tt̄) ~ 900 pb
qq̄ → γγ
π° π°
BR ~ 2×10⁻³
30pb
Z° Z°
h
h°
γ γ
g g

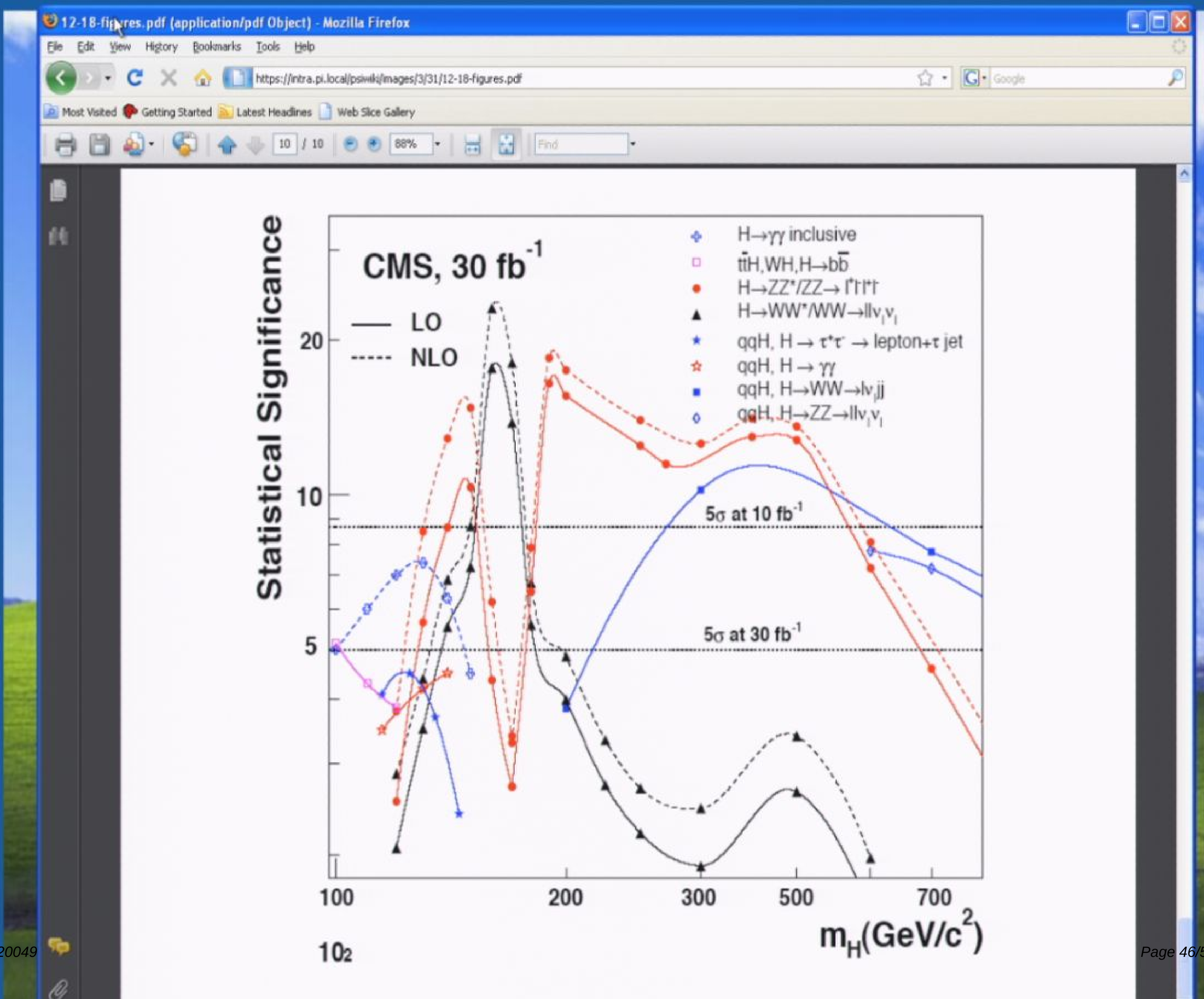

1 barn = (10 fm)^2 = 10^-2
σ(pp) ~ 100 mb
σ(pp → tt̄) ~ 900 pb
qq̄ → γγ
π0 π0
BR ~ 2×10^-3
30pb
1 yr ≅ 100 ...
for σ = 1 fb
100,000
for σ = 1 pb



τ⁺
τ⁻
d
h
u
W⁺
W⁻
u
d
120


12-18-figures.pdf (application/pdf Object) - Mozilla Firefox
https://intra.pi.local/psiwiki/images/3/31/12-18-figures.pdf
CMS
$h^0 \to \tau^+\tau^-$ 30 fb^{-1} $m(h) = 135$ GeV
Signal (135GeV/c^2)
EW/QCD 2τ+jets
ttbar W+jets
Fit to Signal
Fit to Z/γ* (→ 2τ)
Fit to ttbar W+jets
Sum of fits
Nevts (30fb^{-1}) / 5GeV/c^2
M$_{\tau\tau}$ [GeV/c^2]


τ+ τ-
h
d u
W+ W-
u d
-120
e e
γ*
W+ W-


12-18-figures.pdf (application/pdf Object) - Mozilla Firefox
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https://intra.pi.local/psiwiki/images/3/31/12-18-figures.pdf
Most Visited Getting Started Latest Headlines Web Slice Gallery
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Find
CMS, 30 fb^{-1}
LO
NLO
$H\to\gamma\gamma$ inclusive
$t\bar{t}H, WH, H\to b\bar{b}$
$H\to ZZ^*/ZZ\to l^+l^-l^+l^-$
$H\to WW^*/WW\to l\nu_l\nu_l$
$qqH, H\to\tau^+\tau^-\to$ lepton+τ jet
$qqH, H\to\gamma\gamma$
$qqH, H\to WW\to l\nu jj$
$qqH, H\to ZZ\to ll\nu_l\nu_l$
5σ at 10 fb^{-1}
5σ at 30 fb^{-1}
Statistical Significance
20
10
5
100
200
300
500
700
$m_H(\mathrm{GeV}/c^2)$
10_2

120

ϕ

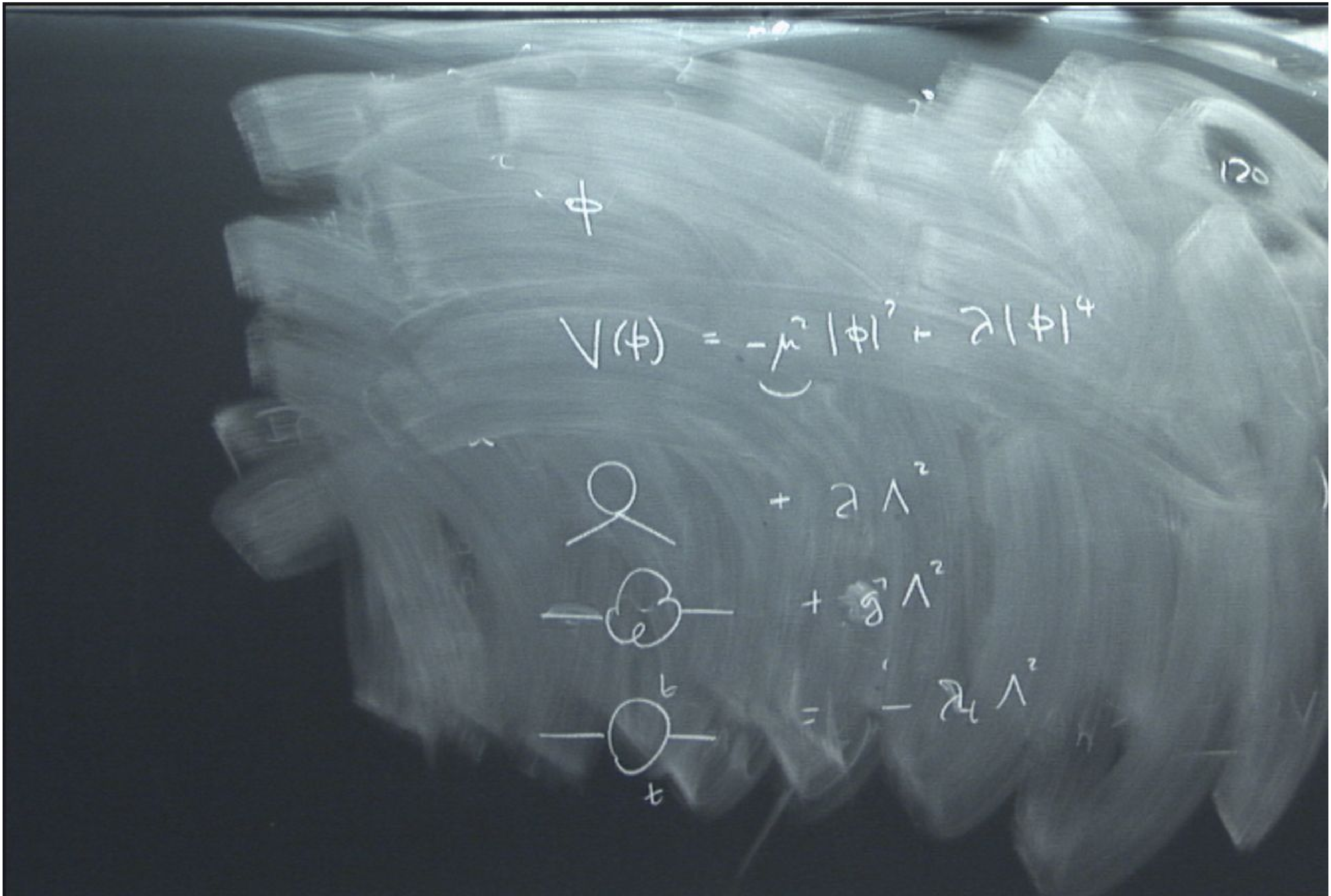
$$V(\phi) = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

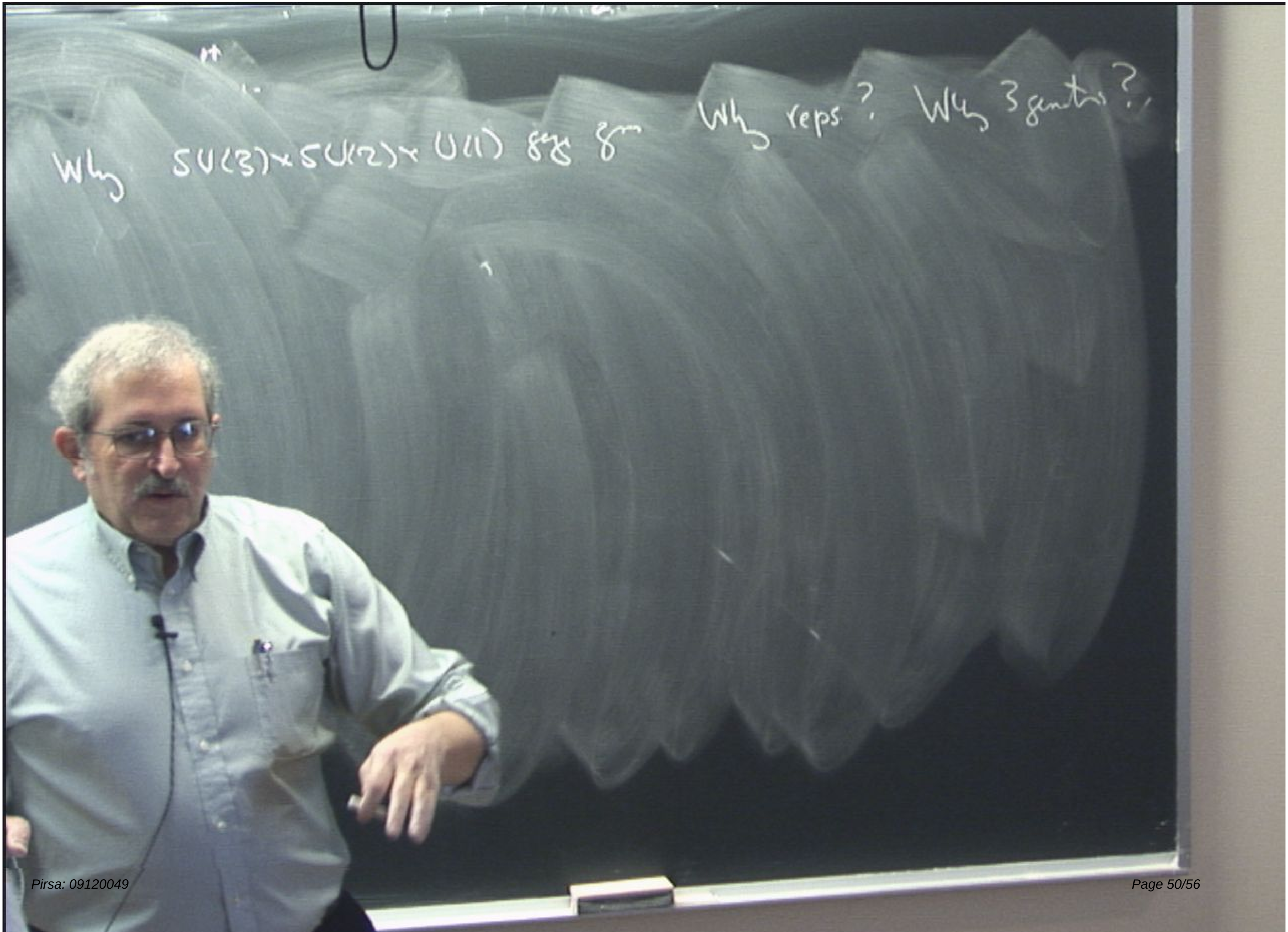
120

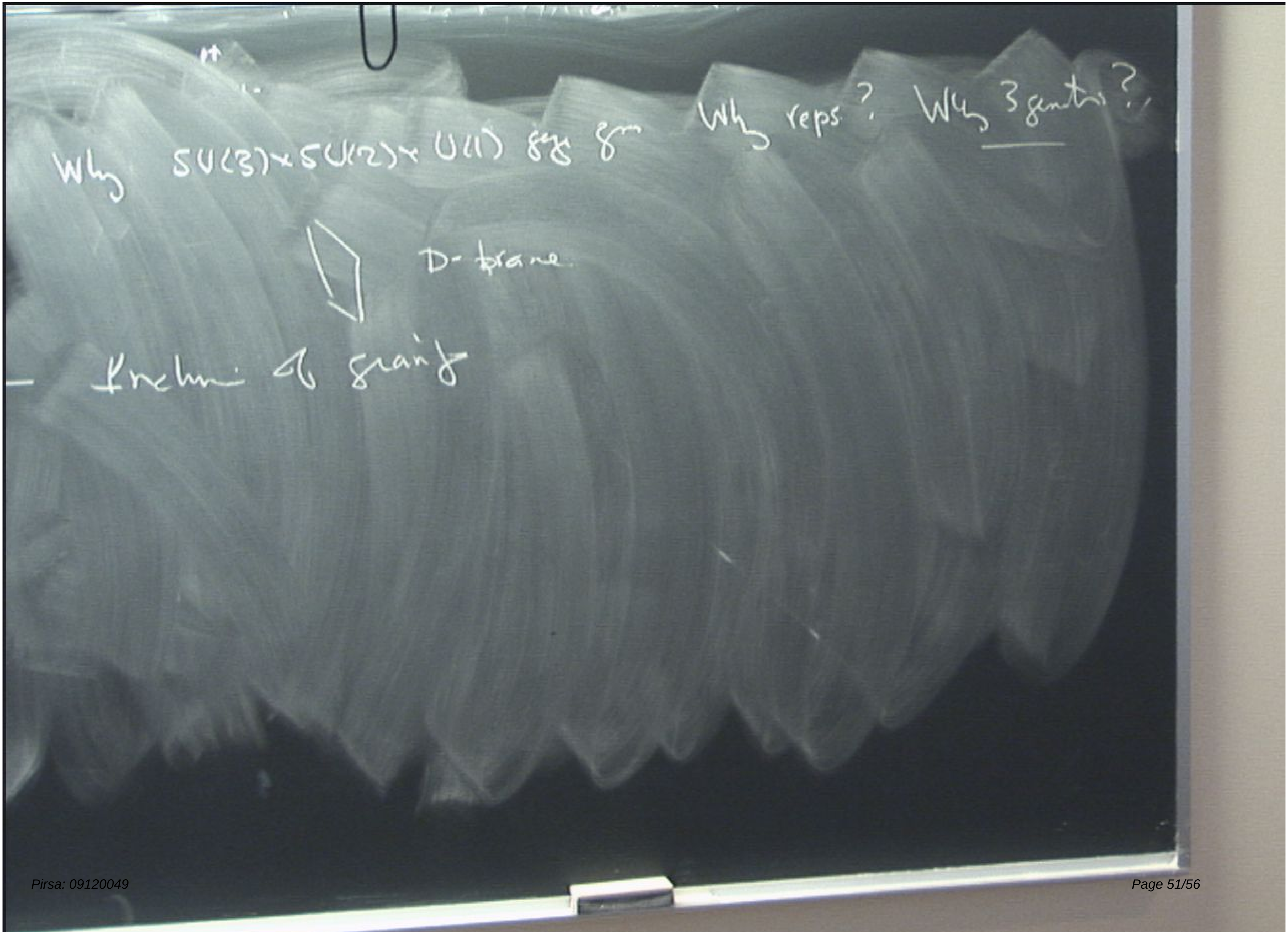
ϕ

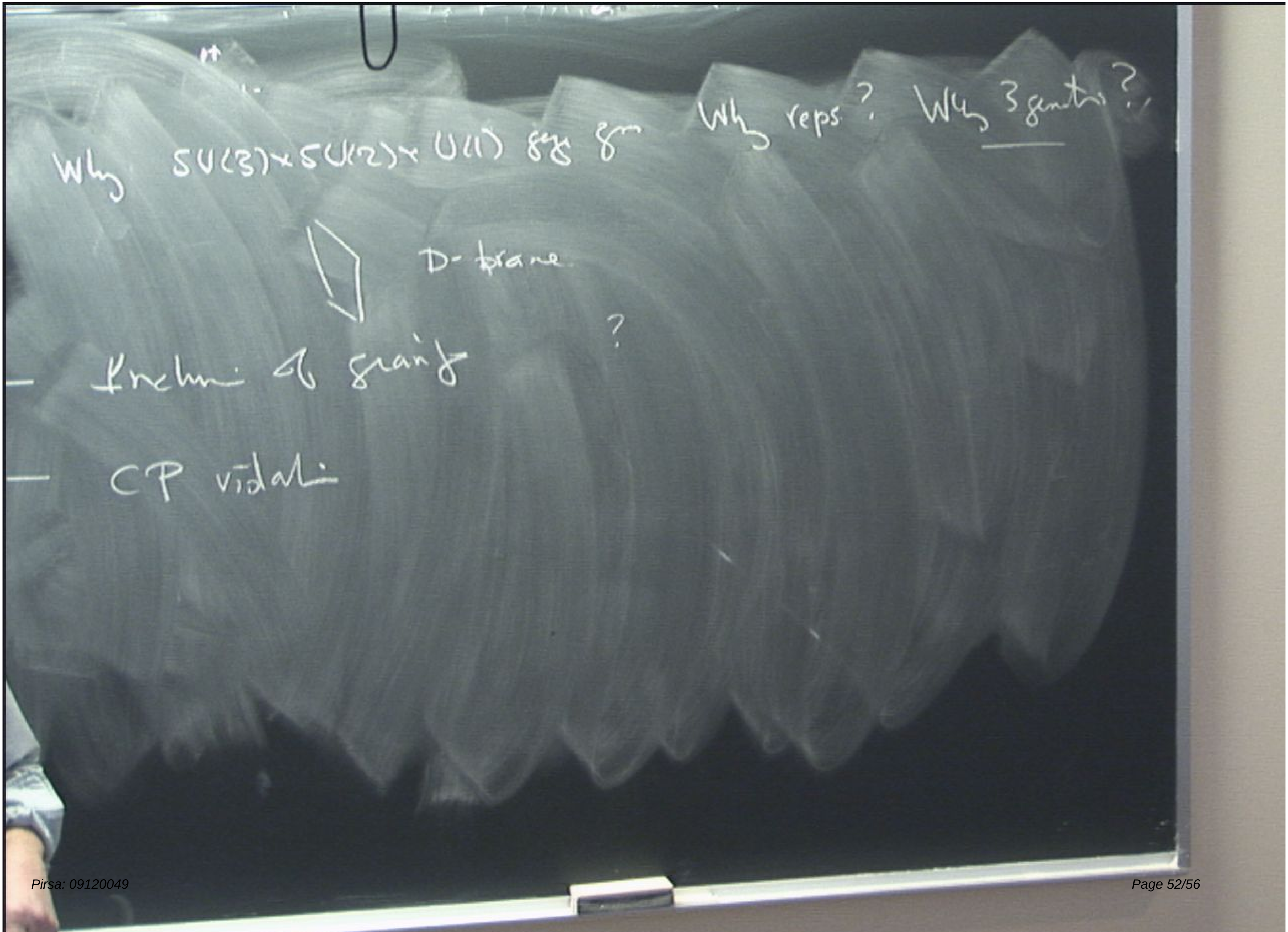
$$V(\phi) = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

 $+ \lambda \Lambda^2$


120
ϕ
$V(\phi) = -\mu^2 |\phi|^2 + \lambda |\phi|^4$
$+ \lambda \Lambda^2$
$+ g^2 \Lambda^2$
t
$= - \lambda_t \Lambda^2$
t


Why SU(3)×SU(2)×U(1)
Why reps?


Why SU(3)×SU(2)×U(1)
Why reps?
D-brane


Why SU(3)×SU(2)×U(1)
Why reps?
D-brane
?
CP violation

— Why $SU(3) \times SU(2) \times U(1)$ gge gr   Why reps ? Why 3

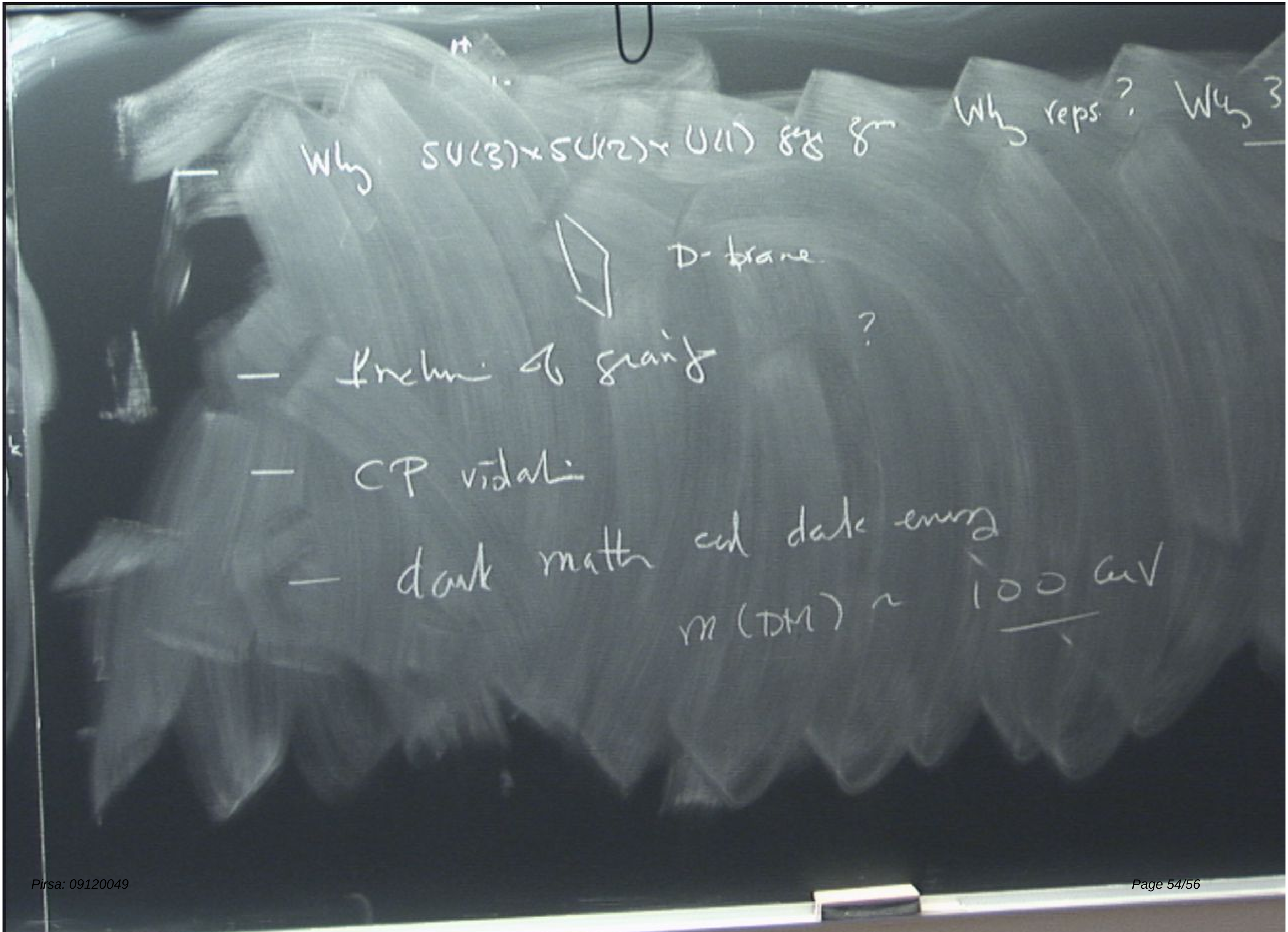
D-brane

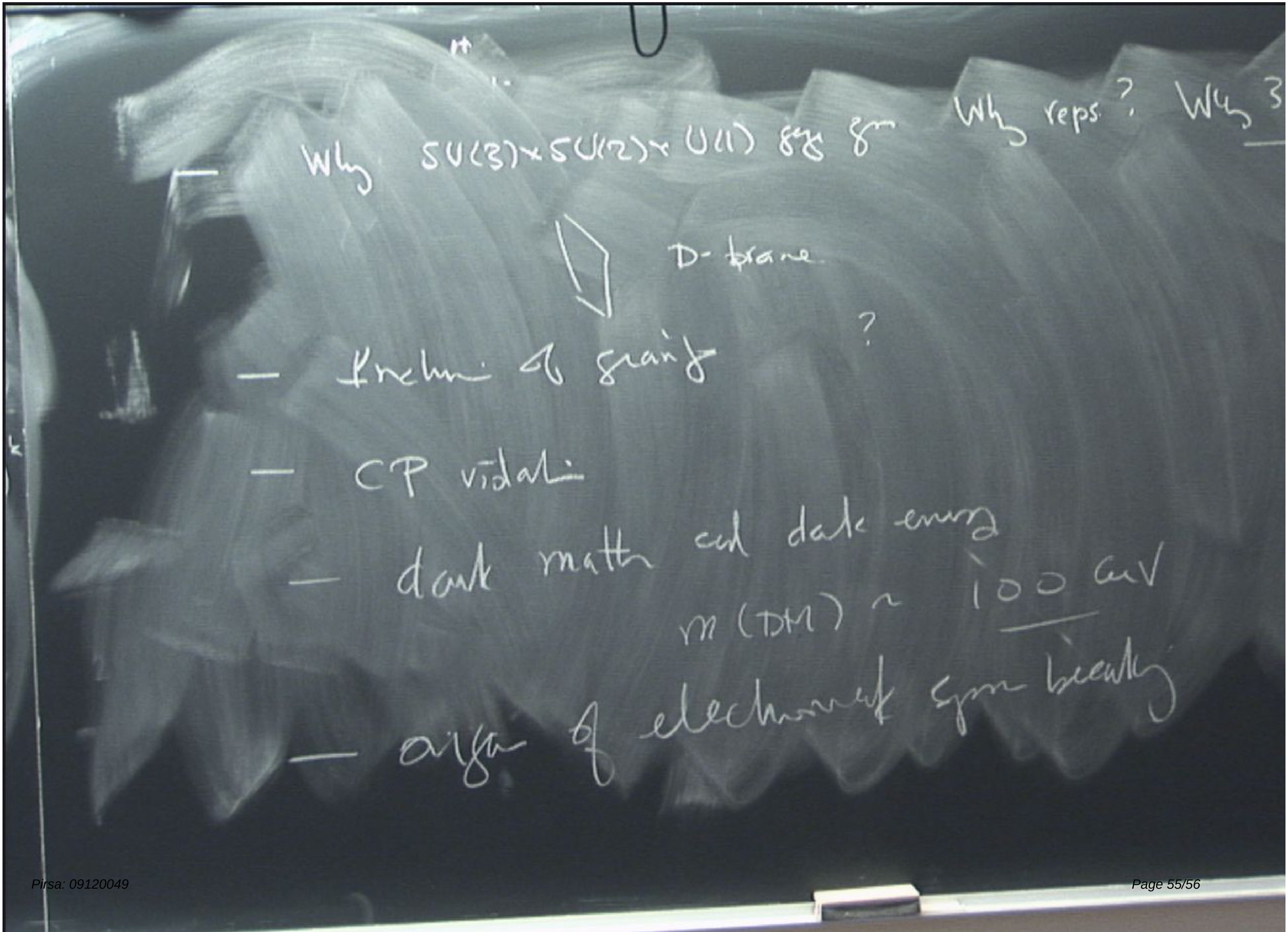
?

— Problem of gravity

— CP violation

— dark matter and dark energy


Why SU(3)×SU(2)×U(1)
Why reps?
D-brane
?
— CP violation
— dark matter and dark energy
m (DM) ~ 100 GeV


Why SU(3)×SU(2)×U(1)
Why reps? Why 3
D-brane
?
CP violation
dark matter and dark energy
m (DM) ~ 100 GeV
origin of electroweak sym breaking

perimeter scholars international