Title: Standard Model - Review (PHYS 622) - Lecture 13

Date: Dec 16, 2009 09:00 AM

URL: http://pirsa.org/09120047

Abstract:

$$e^+e^- \longrightarrow Z^0$$

$$q\bar{q} \longrightarrow Z^0$$

$$u\bar{d} \longrightarrow W^+$$

$e^+e^- \to Z^0$

$q\bar{q} \longrightarrow Z^0$

$u\bar{d} \longrightarrow W^+$

$p\bar{p} \to \mu^+\mu^-$

$m(Z)$

91 GeV

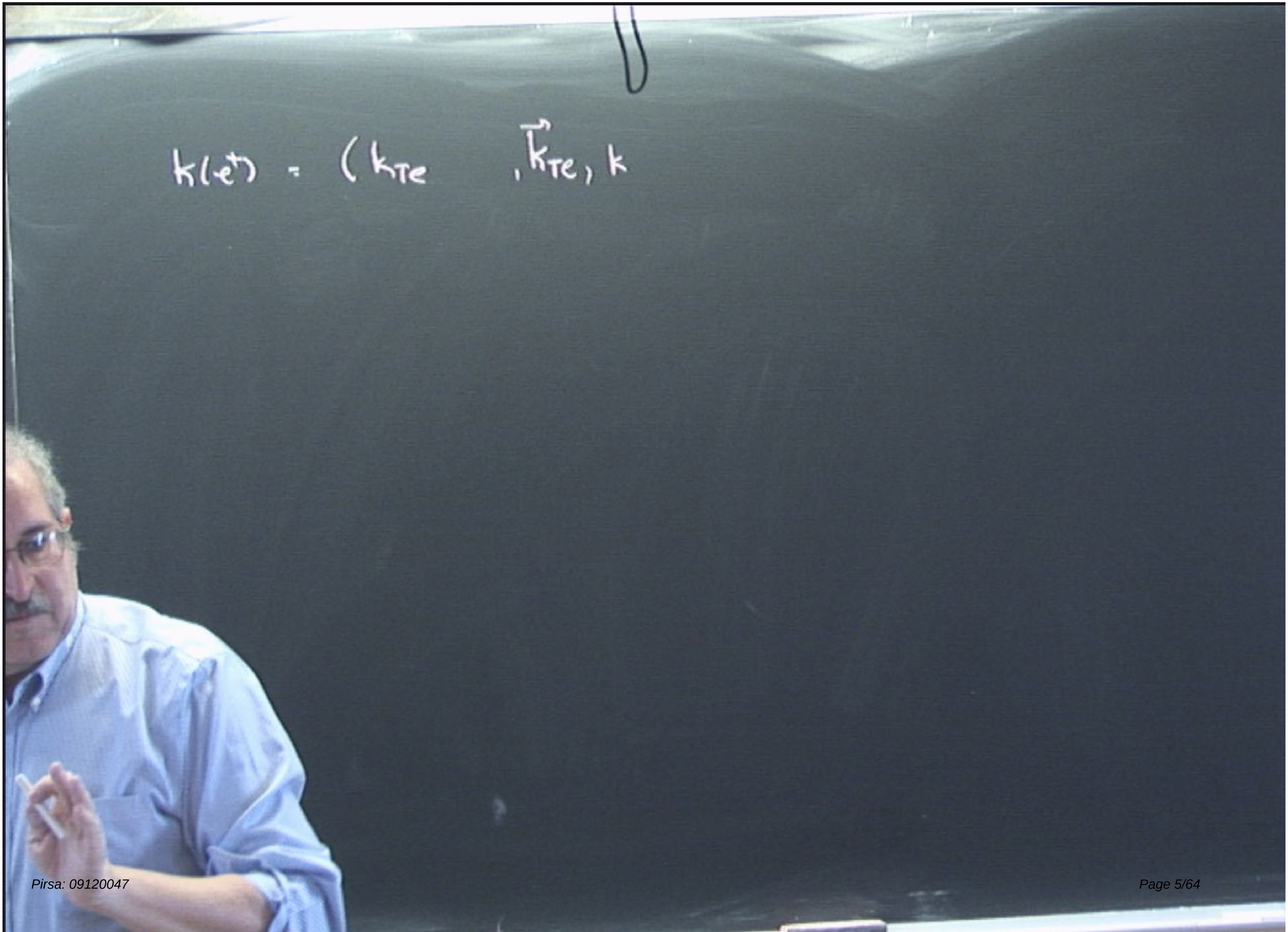
$e^+e^- \to Z^0$

$q\bar{q} \to Z^0$

$u\bar{d} \to W^+ \to e^+\nu$ or $\mu^+\nu$

$p\bar{p} \to \underbrace{\mu^+\mu^-}_{m(Z)}$

91 GeV


$k(e^+) = (k_{Te} \quad , \vec{k}_{Te} , k$

$$k(e^+) = (k_{Te}\cosh\eta_e, \vec{k}_{Te}, k_{Te}\sinh\eta_e)$$

$$k(\nu) = (k_{T\nu}\cosh\eta_\nu, \vec{k}_{T\nu}, k_{T\nu}\sinh\eta_\nu)$$

$$k(e^+) = (k_{Te}\cosh\eta_e, \vec{k}_{Te}, k_{Te}\sinh\eta_e)$$

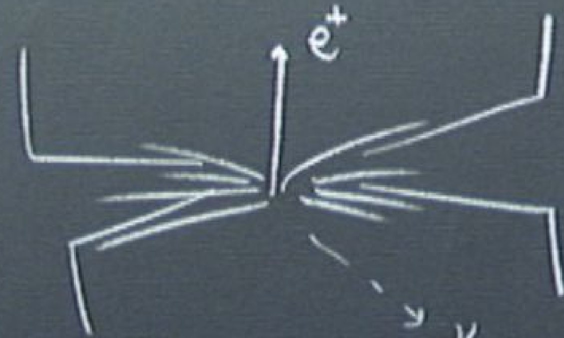
$$k(\nu) = (k_{T\nu}\cosh\eta_\nu, \vec{k}_{T\nu}, k_{T\nu}\sinh\eta_\nu)$$

$$m_W^2 = (k_e + k_\nu)^2 = 2 k_e \cdot k_\nu$$

$$= k_{Te} k_{T\nu} \cosh(\eta_e - \eta_\nu) - \vec{k}_{Te} \cdot \vec{k}_{T\nu}$$

$$k(e^+) = (k_{Te}\cosh\eta_e, \vec{k}_{Te}, k_{Te}\sinh\eta_e)$$

$$k(\nu) = (k_{T\nu}\cosh\eta_\nu, \vec{k}_{T\nu}, k_{T\nu}\sinh\eta_\nu)$$



$$m_W^2 = (k_e + k_\nu)^2 = 2 k_e \cdot k_\nu$$

$$= k_{Te} k_{T\nu} \cosh(\eta_e - \eta_\nu) - \vec{k}_{Te} \cdot \vec{k}_{T\nu}$$

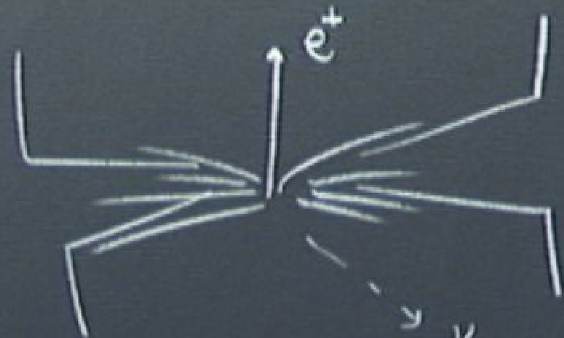
$$\geq k_{Te} k_{T\nu} - \vec{k}_{Te} \cdot \vec{k}_{T\nu}$$

$$k(e^+) = (k_{Te}\cosh\eta_e, \vec{k}_{Te}, k_{Te}\sinh\eta_e)$$

$$k(\nu) = (k_{T\nu}\cosh\eta_\nu, \vec{k}_{T\nu}, k_{T\nu}\sinh\eta_\nu)$$

$$m^2_{tr\,W} = 2(k_{Te}k_{T\nu} - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$\leq \quad m_W^2$$



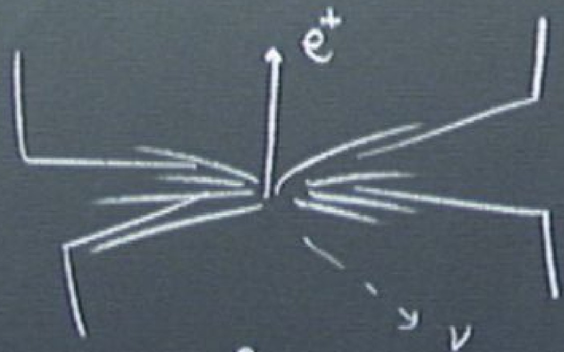
$$m_W^2 = (k_e + k_\nu)^2 = 2k_e\cdot k_\nu$$

$$= 2(k_{Te}k_{T\nu}\cosh(\eta_e - \eta_\nu) - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$\geq 2(k_{Te}k_{T\nu} - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$k(e^+) = (k_{Te} \cosh \eta_e, \vec{k}_{Te}, k_{Te} \sinh \eta_e)$$

$$k(\nu) = (k_{T\nu} \cosh \eta_\nu, \vec{k}_{T\nu}, k_{T\nu} \sinh \eta_\nu)$$



$$m_W^2 = (k_e + k_\nu)^2 = 2 k_e \cdot k_\nu$$

$$= 2(k_{Te} k_{T\nu} \cosh(\eta_e - \eta_\nu) - \vec{k}_{Te} \cdot \vec{k}_{T\nu})$$

$$\geq 2(k_{Te} k_{T\nu} - \vec{k}_{Te} \cdot \vec{k}_{T\nu})$$

$$m_{tr\,W}^2 = 2(k_{Te} k_{T\nu} - \vec{k}$$

$$\leq m_W^2$$

$$m_W = 80.376$$
$$\pm\ 033$$

$$k(e^+) = (k_{Te}\cosh\eta_e, \vec{k}_{Te}, k_{Te}\sinh\eta_e)$$

$$k(\nu) = (k_{T\nu}\cosh\eta_\nu, \vec{k}_{T\nu}, k_{T\nu}\sinh\eta_\nu)$$

$$m^2_{trW} = 2(k_{Te}k_{T\nu} - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$\le m_W^2$$

$$m_W = 80.420 \pm .031 \text{ GeV}$$

$$m_W^2 = (k_e + k_\nu)^2 = 2k_e\cdot k_\nu$$

$$= 2(k_{Te}k_{T\nu}\cosh(\eta_e - \eta_\nu) - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$\ge 2(k_{Te}k_{T\nu} - \vec{k}_{Te}\cdot\vec{k}_{T\nu})$$

$$e^+e^- \longrightarrow W^+W^-$$

$$W^+ \longrightarrow \begin{cases} e^+\nu \\ u\,\bar{d} \\ c\,\bar{s} \end{cases}$$

$$e^+e^- \longrightarrow W^+W^-$$

$$W^+ \longrightarrow \begin{cases} e^+\nu \\ u\,\bar{d} \\ c\,\bar{s} \end{cases}$$

LEP

$$e^+e^- \longrightarrow W^+W^-$$

$$W^+ \longrightarrow \begin{cases} e^+\nu \\ u\,\bar{d} \\ c\,\bar{s} \end{cases}$$

LEP

$$m_W = 80.376 \pm .033$$

$$\mathcal{M}(W^+ \to e^+\nu) = i\frac{g}{\sqrt{2}}\,\bar{u}_L(\nu)\gamma^\mu v_L(e^+)\cdot\varepsilon(W)$$

$$= i\frac{g}{\sqrt{2}}\,\sqrt{2}\,\frac{2E}{m_W}\,\vec{\varepsilon}_L^{\,\mu}\cdot\varepsilon(W)$$

$$\alpha_w = \frac{g^2}{4\pi} = \frac{e^2}{4\pi\sin^2\theta_w} = \frac{1}{29.6}$$

$$|\mathcal{M}|^2 = g^2 m_W^2\,|\vec{\varepsilon}_L\cdot\vec{\varepsilon}(W)|^2$$

$$\Gamma = \frac{1}{2m_W}\,\frac{1}{8\pi}\,\frac{1}{3}\sum_{\varepsilon}|\mathcal{M}|^2 = \frac{g^2}{48\pi}m_W = \frac{\alpha_w}{6}m_W$$

$$\mathcal{M}(W^+ \to e^+\nu) = i\frac{g}{\sqrt{2}}\, \bar{u}_L(\nu)\gamma^\mu v_L(e^+) \cdot \varepsilon(W) \qquad \alpha_W = \frac{g^2}{4\pi}$$

$$= i\frac{g}{\sqrt{2}}\, \sqrt{2}\, \frac{2E}{m_W}\, \varepsilon_L^\mu \cdot \varepsilon(W) \qquad = \frac{e^2}{4\pi \sin^2\theta_W} = \frac{1}{29.6}$$

$$|\mathcal{M}|^2 = g^2 m_W^2 \, |\vec{\varepsilon}_L \cdot \vec{\varepsilon}(W)|^2$$

$$\Gamma = \frac{1}{2m_W}\, \frac{1}{8\pi}\, \frac{1}{3}\sum_\epsilon |\mathcal{M}|^2 = \frac{g^2}{48\pi} m_W = \frac{\alpha_W}{6} m_W$$

quarks $\times\ 3\left(1 + \frac{\alpha_s}{\pi}\right)$

$$\mathcal{M}(W^+ \to e^+\nu) = i\frac{g}{\sqrt{2}}\, \bar{u}_L(\nu)\gamma^\mu v_L(e^+) \cdot \varepsilon(W)$$

$$\alpha_W = \frac{g^2}{4\pi}$$

$$= i\frac{g}{\sqrt{2}}\, \sqrt{2}\, \frac{2E}{m_W}\, \varepsilon_L^\mu \cdot \varepsilon(W)$$

$$= \frac{e^2}{4\pi \sin^2\theta_W} = \frac{1}{29.6}$$

$$|\mathcal{M}|^2 = g^2 m_W^2 \, |\vec{\varepsilon}_L \cdot \vec{\varepsilon}(W)|^2$$

$$\Gamma = \frac{1}{2m_W}\, \frac{1}{8\pi}\, \frac{1}{3}\sum_\varepsilon |\mathcal{M}|^2 = \frac{g^2}{48\pi} m_W = \frac{\alpha_W}{6} m_W$$

quarks $\times\ 3\left(1 + \frac{\alpha_s}{\pi}\right) = 3.1$

$$\Gamma = \frac{\alpha_W m_W}{6}\left[\, 3 \cdot 1 + 2 \cdot 3.1 \,\right] = 2.1 \text{ GeV}$$

$e\ \mu\ \tau$ ud cs

$m($

$e^+e^- \longrightarrow W^+W^-$

$$W^+ \longrightarrow \begin{cases} e^+\nu \quad \mu^+ \quad \tau^+ & BR = 11\% \\ \left.\begin{matrix} u\,\bar{d} \\ c\,\bar{s} \end{matrix}\right) & BR = 34\% \end{cases}$$

$$e^+e^- \to W^+W^-$$

$$W^+ \longrightarrow \begin{cases} e^+\nu \quad \mu^+ \quad \tau^+ & BR = 11\% \\ \left.\begin{matrix} u\bar{d} \\ c\bar{s} \end{matrix}\right) & BR = 34\% \end{cases}$$

$$\sigma(u\bar{d} \to W^+) = \frac{\pi^2 \alpha_w}{3} \delta(\hat{s} - m_w^2)$$

$m($

$$Q_Z = I^3 - \sin^2\theta_W \, Q$$

$$Q_Z = I^3 - \sin^2\theta_W Q$$

$u \quad Q_{ZL} = \frac{1}{2} - \frac{2}{3}\sin^2\theta_W \quad Q_{ZR} = -\frac{2}{3}\sin^2\theta_W$

$$Q_Z = I^3 - \sin^2\theta_W Q$$

$$u \quad Q_{ZL} = \tfrac{1}{2} - \tfrac{2}{3}\sin^2\theta_W \qquad Q_{ZR} = -\tfrac{2}{3}\sin^2\theta_W$$

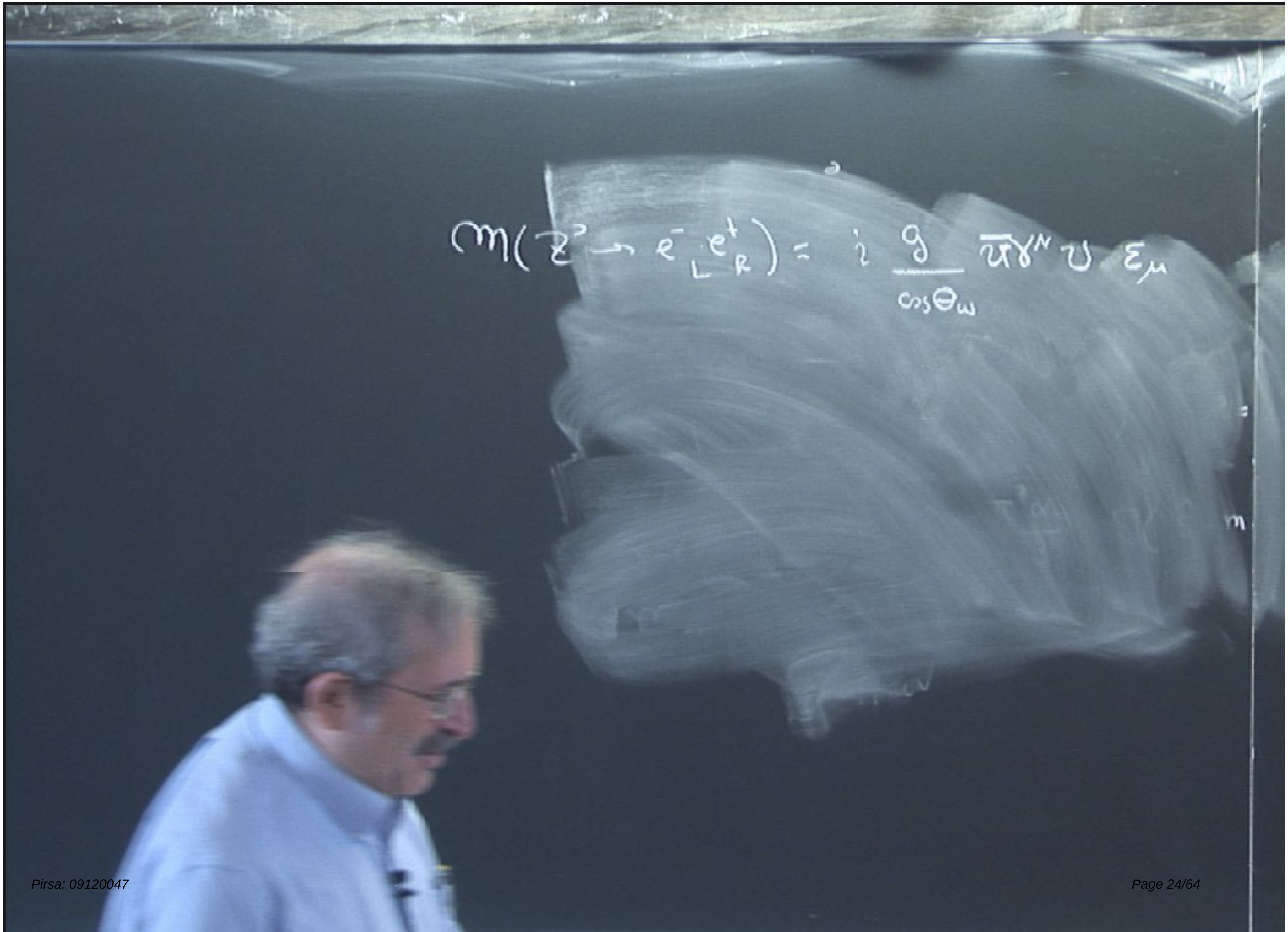
$$S_f = (Q_{ZL}^2 + Q_{ZR}^2) \qquad A_f = \left(\frac{Q_{ZL}^2 - Q_{ZR}^2}{Q_{ZL}^2 + Q_{ZR}^2}\right)$$

$$Q_Z = I^3 - \sin^2\theta_W \, Q$$

$u \qquad Q_{ZL} = \frac{1}{2} - \frac{2}{3}\sin^2\theta_W \qquad Q = -\frac{2}{3}\sin^2\theta_W$

$$S_f = (Q_{ZL}^2 + Q_{ZR}^2) \qquad A_f = \left(\frac{Q_{ZL}^2 - Q_{ZR}^2}{Q_{ZL}^2 + Q_{ZR}^2}\right)$$

in table $\quad \sin^2\theta_W = 0.231$


$\mathcal{M}(Z^0 \to e^-_L e^+_R) = i \frac{g}{\cos\theta_W} \bar{u}\gamma^\mu v \, \varepsilon_\mu$

$$\mathcal{M}(Z^0 \to e^-_L e^+_R) = i \frac{g}{\cos\theta_w} \bar{u}\gamma^\mu v \, \varepsilon_\mu \quad Q_{Z}$$

$$\Gamma(Z^0 \to e\bar{e}) = \frac{\alpha_w}{6\cos^2\theta_w}\left[\;\; S_f\right]$$

$$\mathcal{M}(Z^0 \to e^-_L e^+_R) = i \frac{g}{\cos\theta_W} \bar{u}\gamma^\mu v \, \varepsilon_\mu \, Q_{ZL}$$

$$\Gamma(Z^0 \to e\bar{e}) = \frac{\alpha_W m_Z}{6\cos^2\theta_W}\left[\; S_f \right]$$

$$\Gamma(Z) = \frac{\alpha_W m_Z}{6\cos^2\theta_W}\Big[3\cdot(0.25) + 3(0.126) + \big[2(0.144) + 2.98(0.185)\big] \, 3.1 \Big]$$

$\mathcal{M}(W$

Γ

Γ

$$\mathcal{M}(Z^0 \to e^-_L e^+_R) = i \frac{g}{\cos\theta_W} \bar{u}\gamma^\mu v \, \varepsilon_\mu \quad Q_{Z L}$$

$$\Gamma(Z^0 \to e\bar{e}) = \frac{\alpha_W m_Z}{6\cos^2\theta_W} [\quad S_f]$$

$$\Gamma(Z) = \frac{\alpha_W m_Z}{6\cos^2\theta_W} \Big[3\cdot(0.25) + 3(0.126) + [2(0.144) + 2.98(0.185)]\, 3.1 \Big]$$

$$= 2.49 \text{ GeV}$$

$\mathcal{M}(W$

Γ

Γ

ν 6.7% e 3.3% u 11.9% d 15.3%

μ c

ν 6.7% e 3.3% u 11.9% d 15.3%

μ τ

$\downarrow$

170 MeV per ν

ν 6.7% e 3.3% u 11.9% d 15.3%

$\mu\,\tau$

$\downarrow$

170 MeV per ν.

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_W (S_{f.i.e})\, \delta(s - m_Z)$$

ν 6.7% e 3.3% u 11.9% d 15.3%

$\mu\ \tau$

$\downarrow$

170 MeV per ν.

$$\frac{1}{q^2 - m_Z^2 + i m_Z \Gamma_Z}$$

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_W (S_{f:e}) \left(\frac{m_Z \Gamma_Z / \pi}{(s - m_Z^2)^2 + (m_Z \Gamma_Z)^2} \right)$$

ν 6.7% e 3.3% u 11.9% d 15.3%

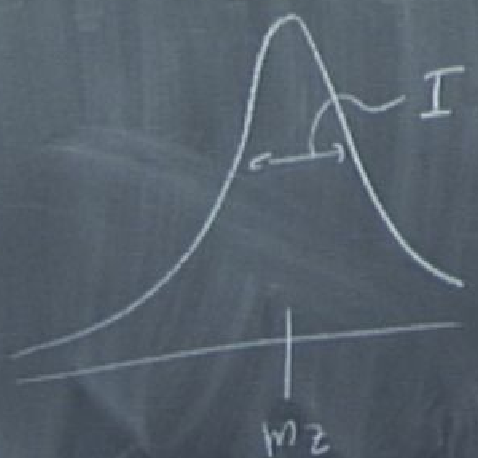
μ τ

$\downarrow$

170 MeV per ν

$$\frac{1}{q^2 - m_Z^2 + i m_Z \Gamma_Z}$$

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_w \left(S_{f:e}\right)\left(\frac{m_Z \Gamma_Z / \pi}{(s - m_Z^2)^2 + (m_Z \Gamma_Z)^2}\right)$$



ν 6.7% e 3.3% u 11.9% d 15.3%

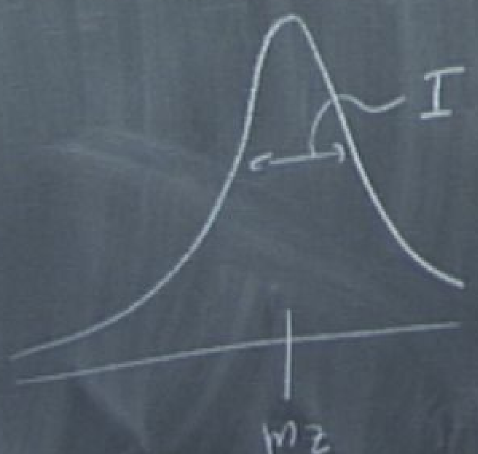
μ τ

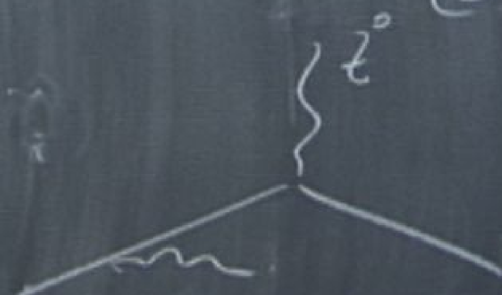
$\downarrow$

170 MeV per ν

$$\frac{1}{q^2 - m_Z^2 + i m_Z \Gamma_Z}$$

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_w (S_{f:e}) \left(\frac{m_Z \Gamma_Z/\pi}{(s - m_Z^2)^2 + (m_Z\Gamma_Z)^2} \right)$$





ν 6.7% e 3.3% u 11.9% d 15.3%

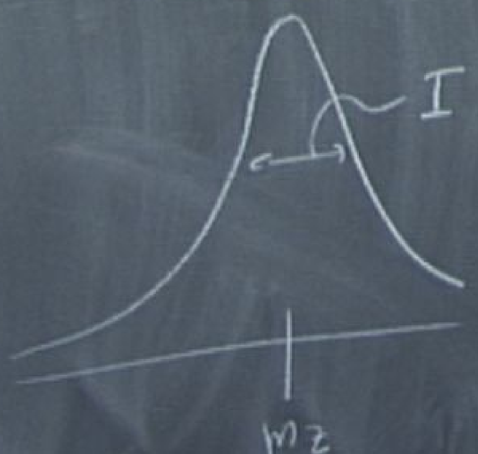
μ τ

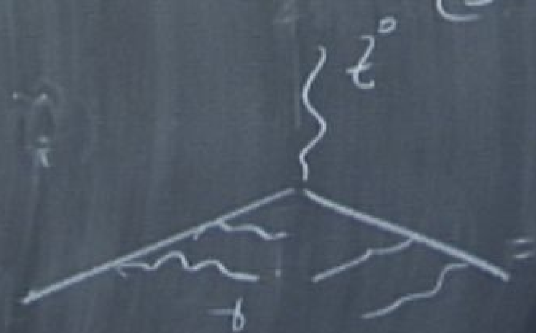
$\downarrow$

170 MeV per ν.

$$\frac{1}{q^2 - m_Z^2 + i m_Z \Gamma_Z}$$

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_W \left(S_{f:e}\right)\left(\frac{m_Z\Gamma_Z/\pi}{(s-m_Z^2)^2 + (m_Z\Gamma_Z)^2}\right)$$





ν 6.7% e 3.3% u 11.9% d 15.3%

μ τ

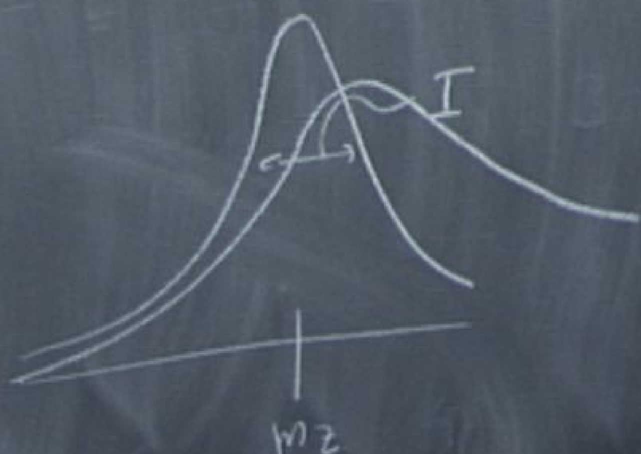
$\downarrow$

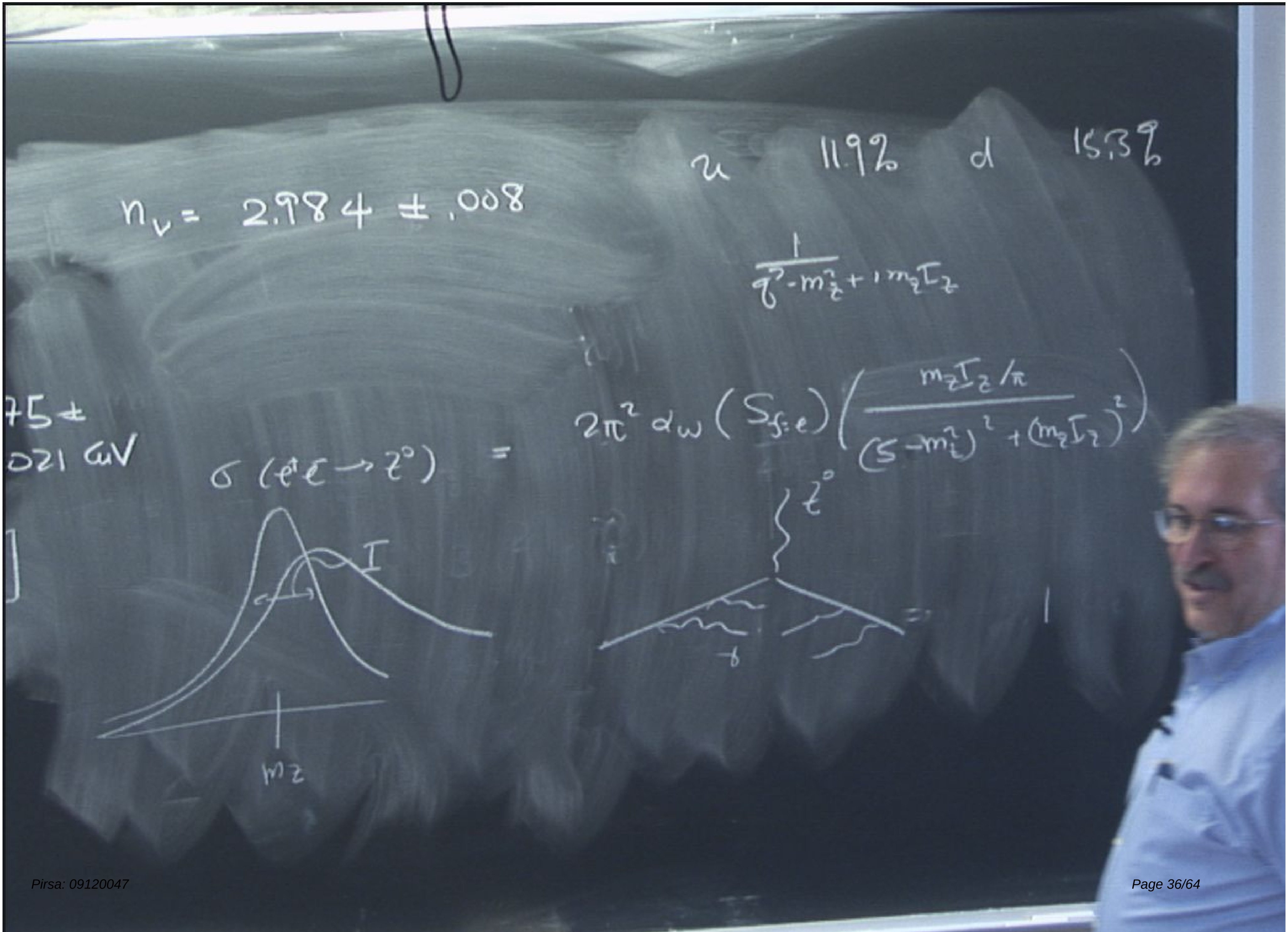
170 MeV per ν

$$\frac{1}{q^2 - m_Z^2 + i m_Z \Gamma_Z}$$

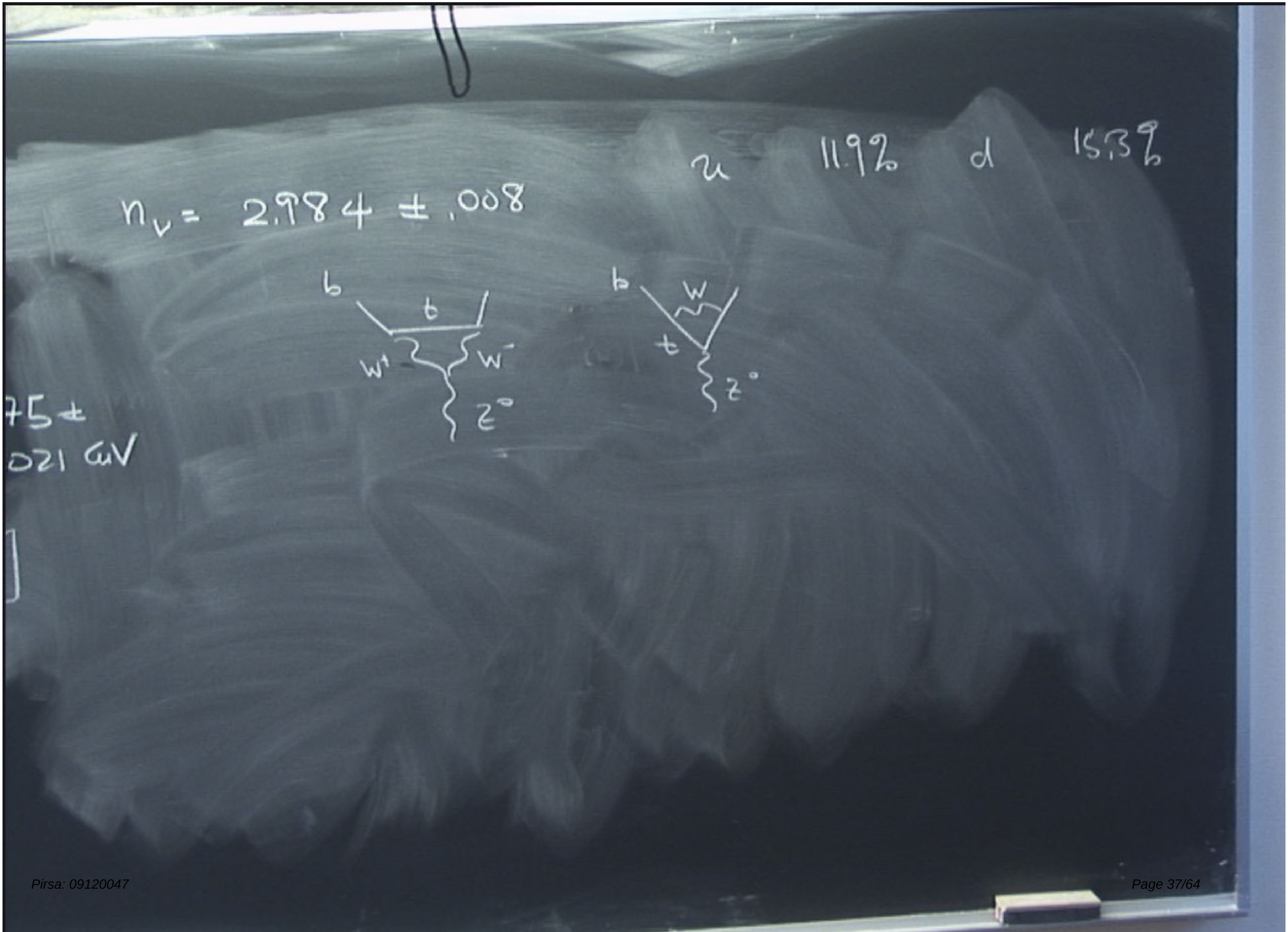
75 ±
.0021 GeV

$$\sigma(e^+e^- \to Z^0) = 2\pi^2 \alpha_w (S_{f:e}) \left(\frac{m_Z \Gamma_Z / \pi}{(s - m_Z^2)^2 + (m_Z \Gamma_Z)^2} \right)$$



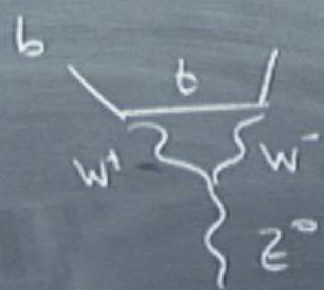


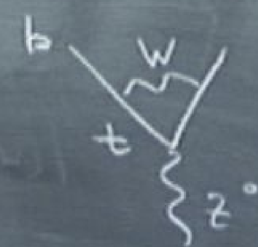
u 11.9%
d 15.3%
n_ν = 2.984 ± .008
1 / (q² - m_Z² + i m_Z Γ_Z)
75 ±
021 GeV
σ (e⁺e⁻ → Z°) =
2π² α_w (S_f:e) ((m_Z Γ_Z / π) / ((s - m_Z²)² + (m_Z Γ_Z)²))
Z°
m_Z


u 11.9%
d 15.3%
n_ν = 2.984 ± .008
75 ±
.021 GeV
b
t
W⁺
W⁻
Z⁰
b
W
t
Z⁰

u 11.9% d 15.3%

$n_\nu = 2.984 \pm .008$



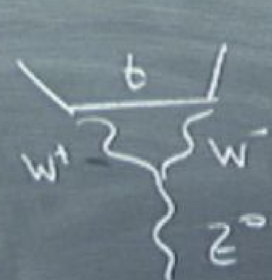


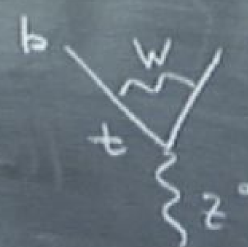
× -2%

75 ±
.021 GeV

u 11.9% d 15.3%

$n_\nu = 2.984 \pm .008$





$\times$ -2%

.1875 ±
.0021 GeV

3.1]

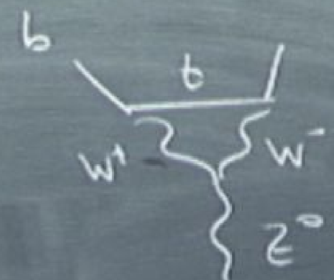
$$R_b = \frac{BR(Z \to b\bar{b})}{BR(Z \to \text{hadrons})} = 0.21629 \pm .00066$$

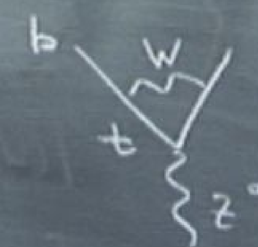
0.220 without t

0.216 with t

u 11.9% d 15.3%

$n_\nu = 2.984 \pm .008$





× −2%

.1875 ±
.0021 GeV

3.1]

$$R_b = \frac{BR(Z \to b\bar{b})}{BR(Z \to \text{hadrons})} = 0.21629 \pm .00066$$

0.220 without t

0.216 with t

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

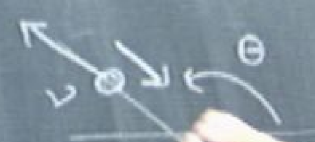
$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

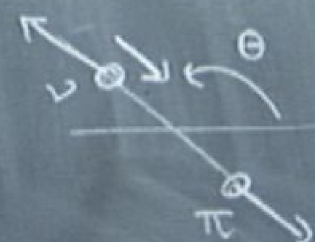


$$\frac{d\Gamma}{d\cos\theta_\nu} \propto (1 - \cos\theta_\nu)$$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

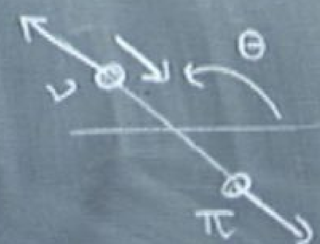


$$\frac{d\Gamma}{d\cos\theta_\nu} \propto (1-\cos\theta_\nu)$$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

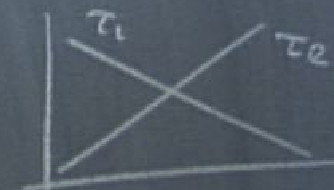


$$\frac{d\Gamma}{d\cos\theta_\nu} \propto (1-\cos\theta_\nu)$$

$$\frac{d\Gamma}{d\cos\theta_\pi} = (1+\cos\theta)$$

$$p_\pi = \left(E_\pi,\ p_\pi \sin\theta_\pi,\ p_\pi \cos\theta_\pi\right) \qquad E_\pi \simeq p_\pi$$

$$E_{\pi\,lab} = \gamma\left(E_\pi + \beta p_\pi \cos\theta\right) \simeq \gamma E_{\pi 0}\left(1+\cos\theta\right)$$



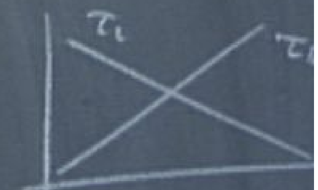
$$\frac{d\Gamma}{dE_{lab,\pi}}(\tau_R^-) \sim E_{lab.}$$

$$\frac{d\Gamma}{dE_{lab\,\pi}}(\tau_L^-) \sim \left(E_{max} - E_{lab}\right)$$

$$p_\pi = (E_\pi,\ p_\pi \sin\theta_\pi,\ p_\pi \cos\theta_\pi) \qquad E_\pi \simeq p_\pi$$

$$A_\tau = 0.1465 \pm .0032$$

$$E_{\pi\,lab} = \gamma(E_\pi + \beta p_\pi \cos\theta) \simeq \gamma E_{\pi 0}(1+\cos\theta$$



$$\frac{d\Gamma}{dE_{lab,\pi}}(\tau_R^-) \sim E_{lab.}$$

$$\frac{d\Gamma}{dE_{lab\,\pi}}(\tau_L^-) \sim (E_{max} - E_{lab})$$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) = 18\%$$

$$BR(\tau \to \pi\nu) = 11\%$$

$$BR(\tau \to \rho\nu) = 26\%$$

$$A_e = \frac{\sigma(e_L^- e^+ \to Z^0) - \sigma(e_R^- e^+ \to Z^0)}{\sigma(e_L^- e^+ \to Z^0) + \sigma(e_R^- e^+ \to Z^0)}$$

$A_\tau = 0.6$

$\pm$

$$BR(\tau \to e\nu\nu) = BR(\tau \to \mu\nu\nu) : 18\%$$

$$BR(\tau \to \pi\nu) : 11\%$$

$$BR(\tau \to \rho\nu) : 26\%$$

$$A_\tau = 0.1\ldots$$

$$\pm \ldots$$

$$A_e = \frac{\sigma(e_L^- e^+ \to Z^0) - \sigma(e_R^- e^+ \to Z^0)}{\sigma(e_L^- e^+ \to Z^0) + \sigma(e_R^- e^+ \to Z^0)}$$

$$0.1513 \pm .0021$$

$$A_\ell = \frac{\left(\frac{1}{2} - \sin^2\theta_w\right)^2 - \left(\sin^2\theta_w\right)^2}{\left(\frac{1}{2} - \sin^2\theta_w\right)^2 + \left(\sin^2\theta_w\right)^2}$$

0.1465

$\pm$ .0032

0.1465

$\pm$ .0032

$$A_\ell = \frac{(\frac{1}{2} - \sin^2\theta_w)^2 - (\sin^2\theta_w)^2}{(\frac{1}{2} - \sin^2\theta_w)^2 + (\sin^2\theta_w)}$$

$$= \frac{(\frac{1}{4} - \sin^2\theta)}{2\sin^4\theta_w + (\frac{1}{4} - \sin^2\theta_w)}$$

$$\cong 8\left(\frac{1}{4} - \sin^2\theta_w\right)$$

$$A_\ell = \frac{\left(\frac{1}{2} - \sin^2\theta_w\right)^2 - \left(\sin^2\theta_w\right)^2}{\left(\frac{1}{2} - \sin^2\theta_w\right)^2 + \left(\sin^2\theta_w\right)^2}$$

$$= \frac{\left(\frac{1}{4} - \sin^2\theta\right)}{2\sin^4\theta_w + \left(\frac{1}{4} - \sin^2\theta_w\right)}$$

$$\cong 8\left(\frac{1}{4} - \sin^2\theta_w\right)$$

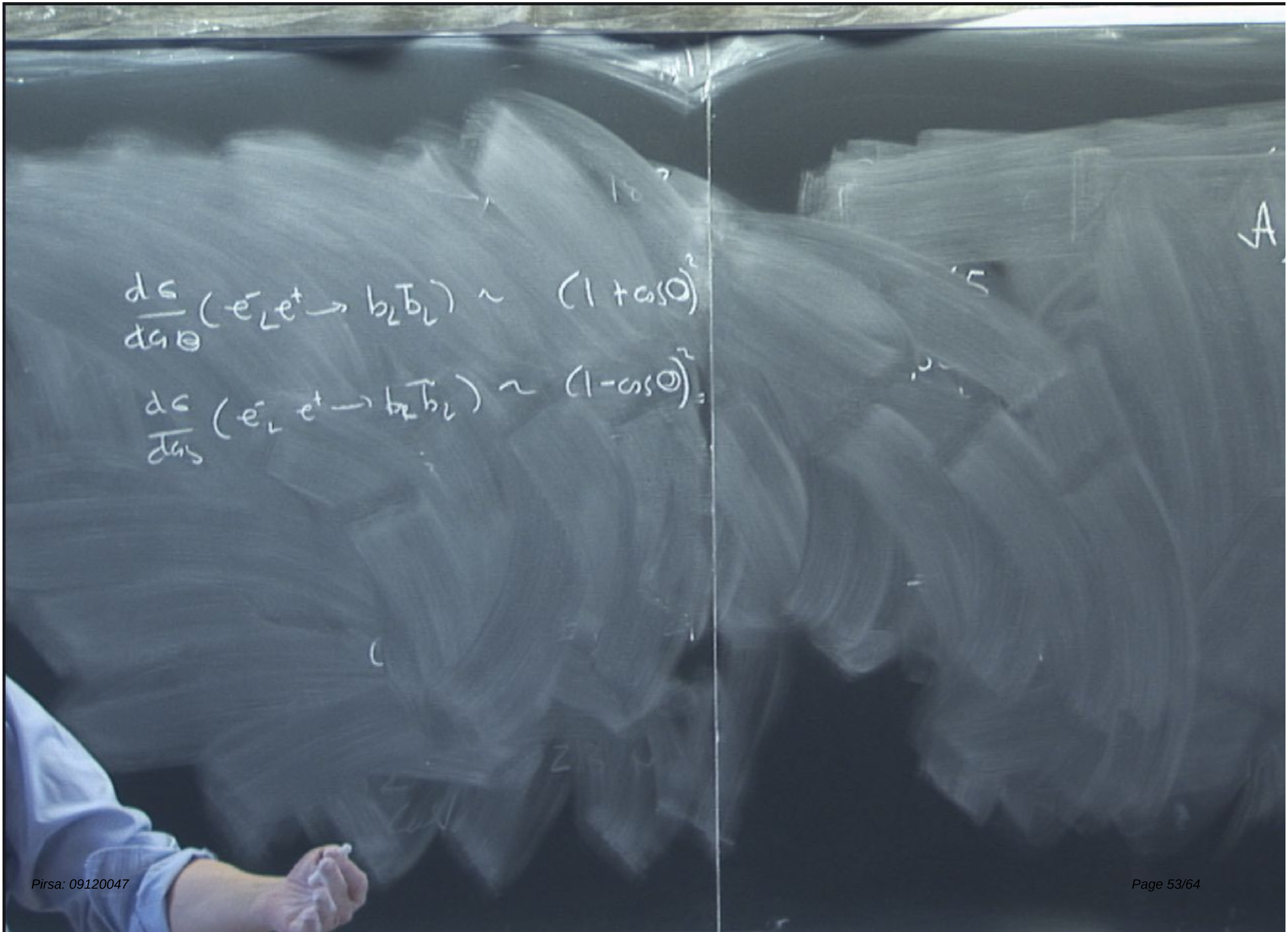
0.1465

$\pm .0032$

$\sin^2\theta_w$

$= 0.23153$

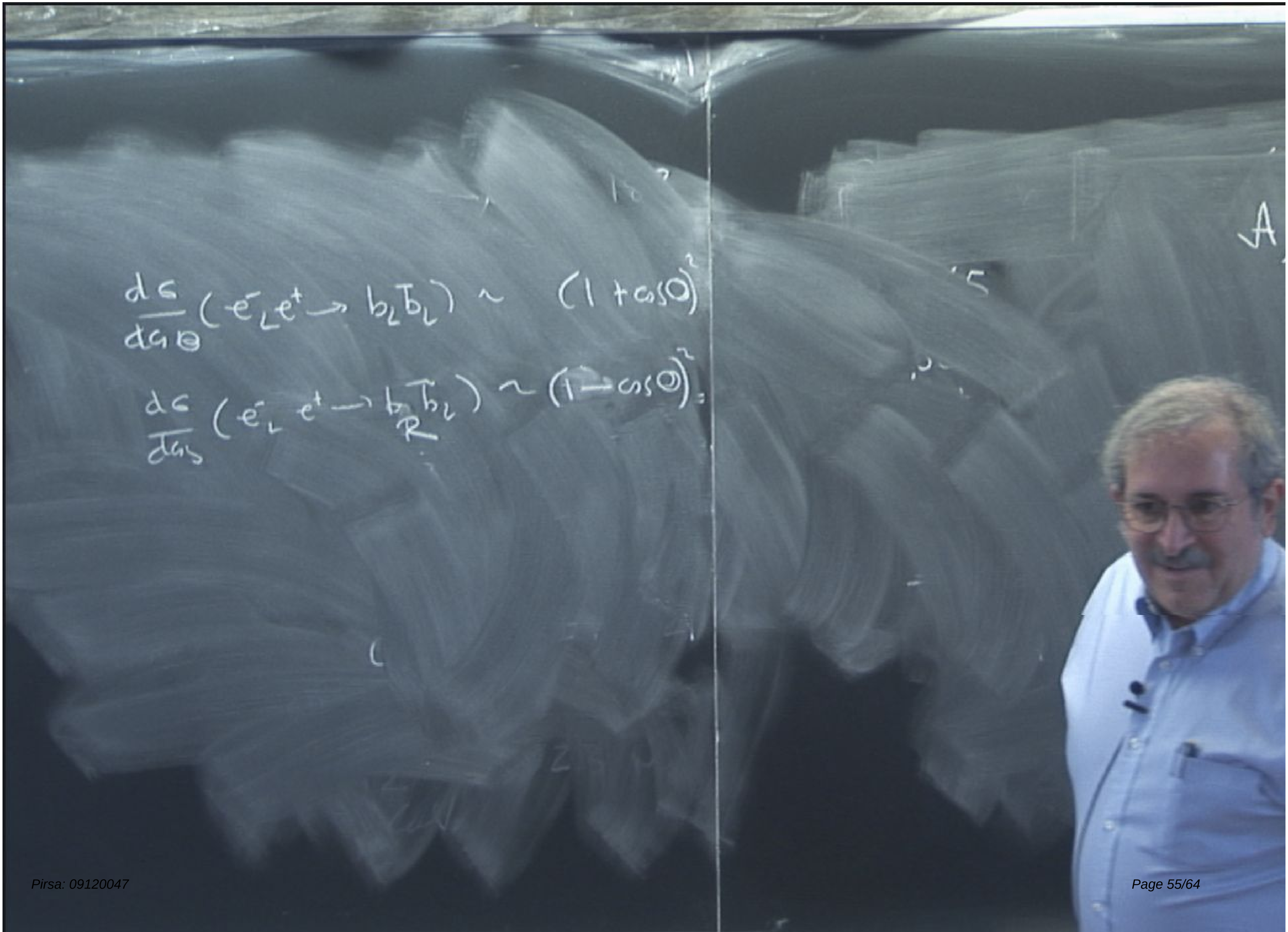
$\pm .00016$

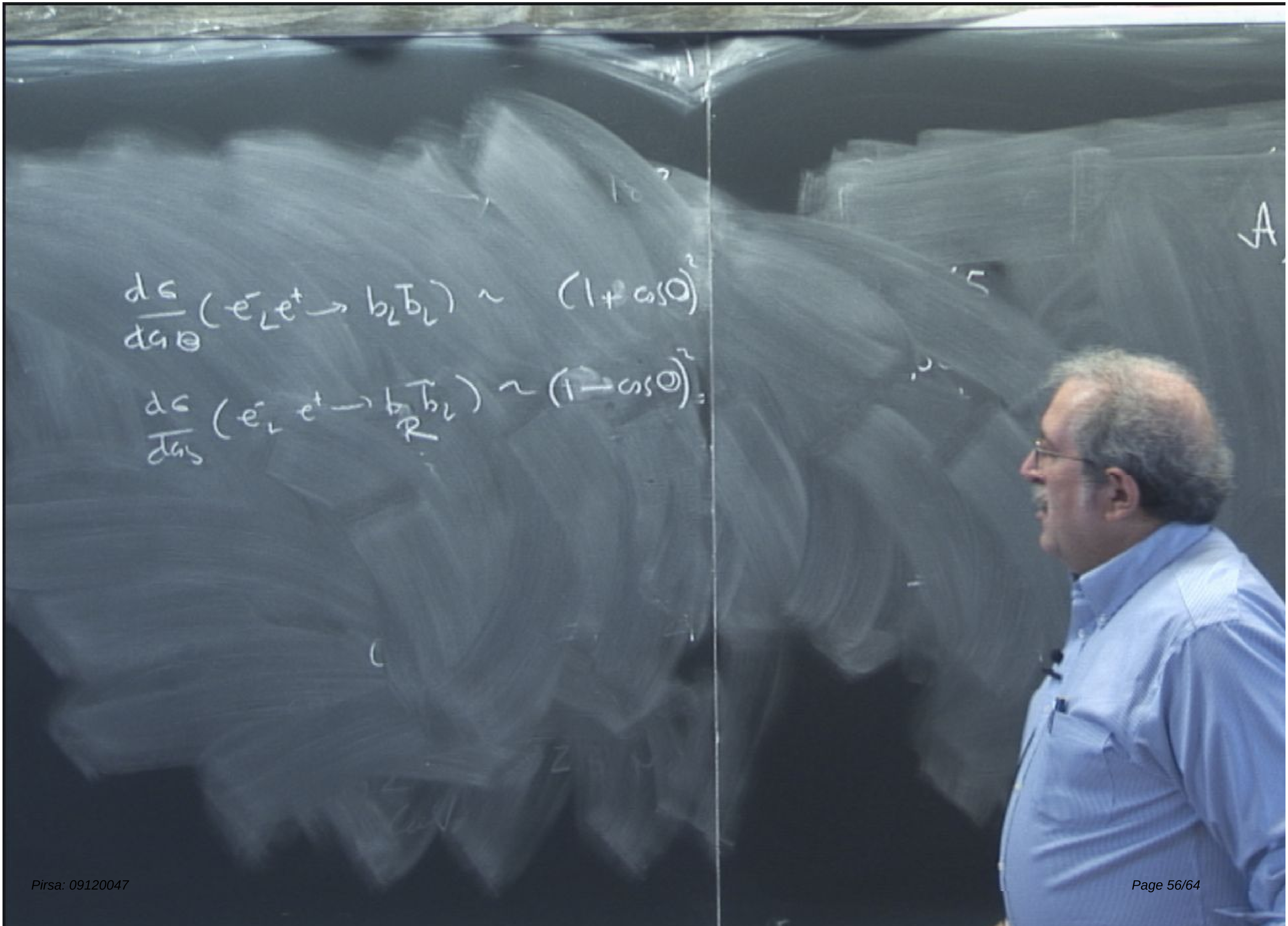


$\frac{d\sigma}{d\cos\theta}(e^-_L e^+ \to b_L \bar{b}_L) \sim (1+\cos\theta)^2$
$\frac{d\sigma}{d\cos\theta}(e^-_L e^+ \to b_R \bar{b}_L) \sim (1-\cos\theta)^2$

$$\frac{d\sigma}{d\cos\theta}(e^-_L e^+ \to b_L \bar{b}_L) \sim (1+\cos\theta)^2$$

$$\frac{d\sigma}{d\cos}(e^-_L e^+ \to b_R \bar{b}_L) \sim (1-\cos\theta)^2$$


$\frac{d\sigma}{d\cos\theta}(e^-_L e^+ \to b_L \bar{b}_L) \sim (1+\cos\theta)^2$
$\frac{d\sigma}{d\cos\theta}(e^-_L e^+ \to b_R \bar{b}_L) \sim (1-\cos\theta)^2$



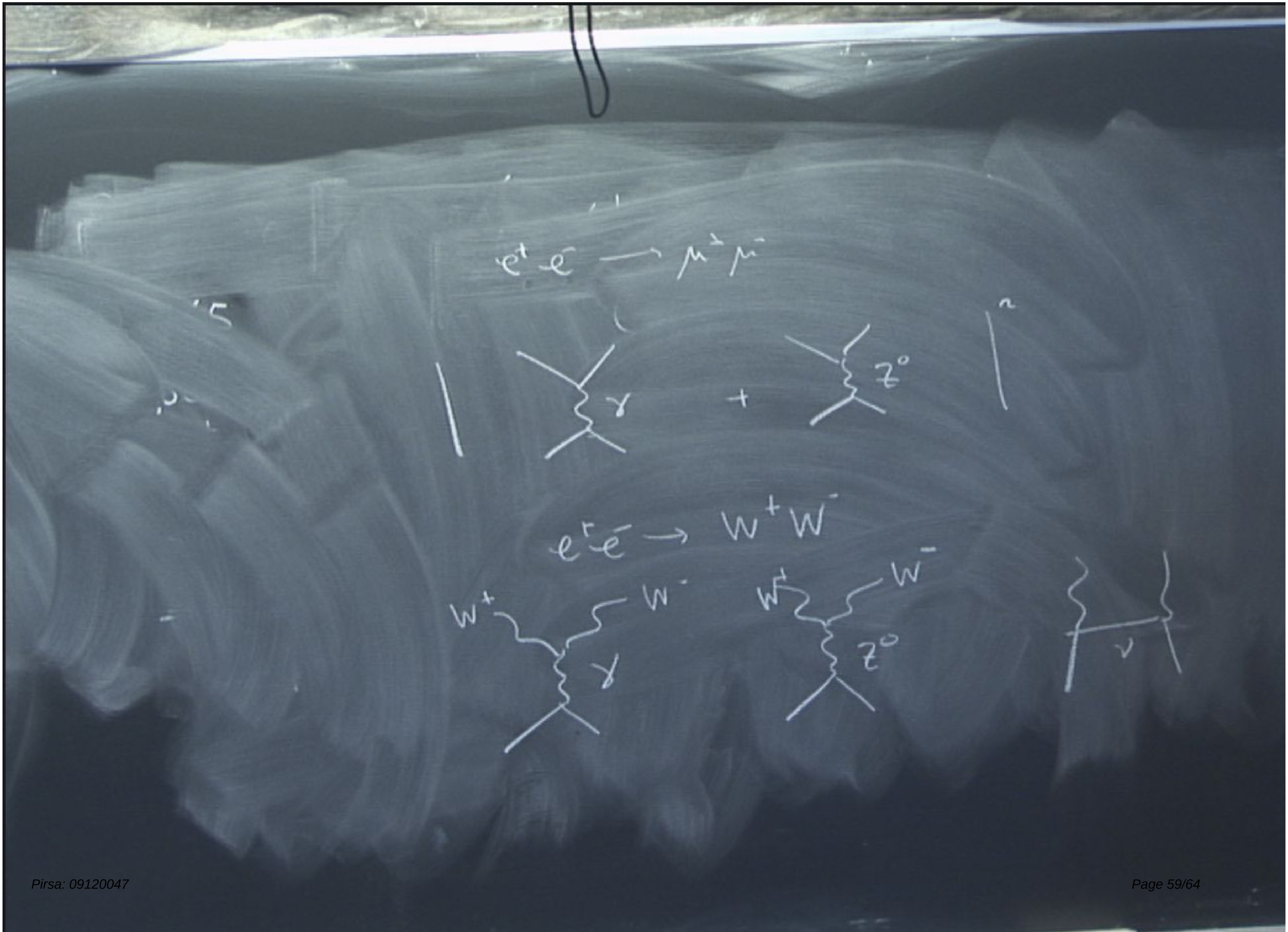
$\frac{d\sigma}{d\Omega}(e^-_L e^+ \to b_L \bar{b}_L) \sim (1+\cos\theta)^2$
$\frac{d\sigma}{d\Omega}(e^-_L e^+ \to b_R \bar{b}_L) \sim (1-\cos\theta)^2$

$$\frac{d\sigma}{d\cos\Theta}(e^-_L e^+ \to b_L \bar{b}_L) \sim (1+\cos\Theta)^2$$

$$\frac{d\sigma}{d\cos}(e^-_L e^+ \to b_R \bar{b}_L) \sim (1-\cos\Theta)^2$$

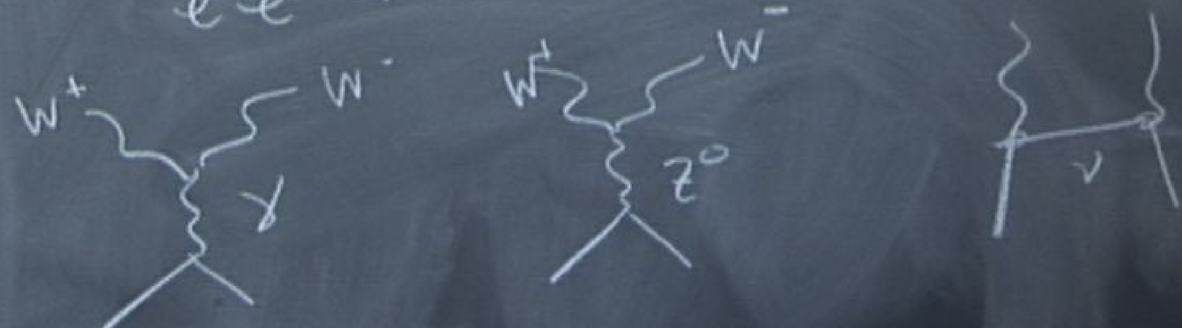
$$A_b = 0.923 \pm .020$$

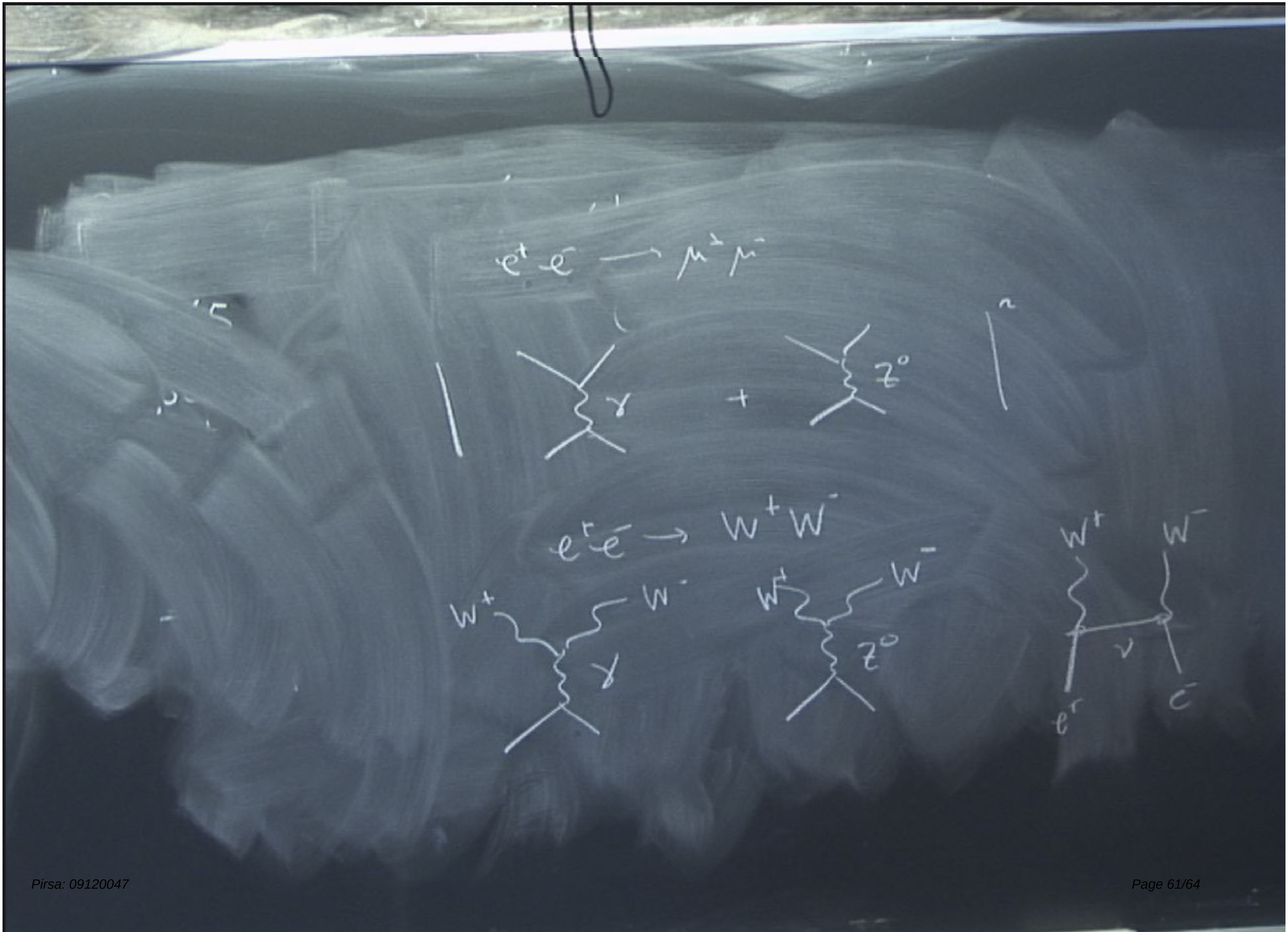
$e^+ e^- \longrightarrow \mu^+ \mu^-$


$e^+e^- \to \mu^+\mu^-$
γ
+
Z^0
$e^+e^- \to W^+W^-$
W^+
W^-
γ
W^+
W^-
Z^0
ν

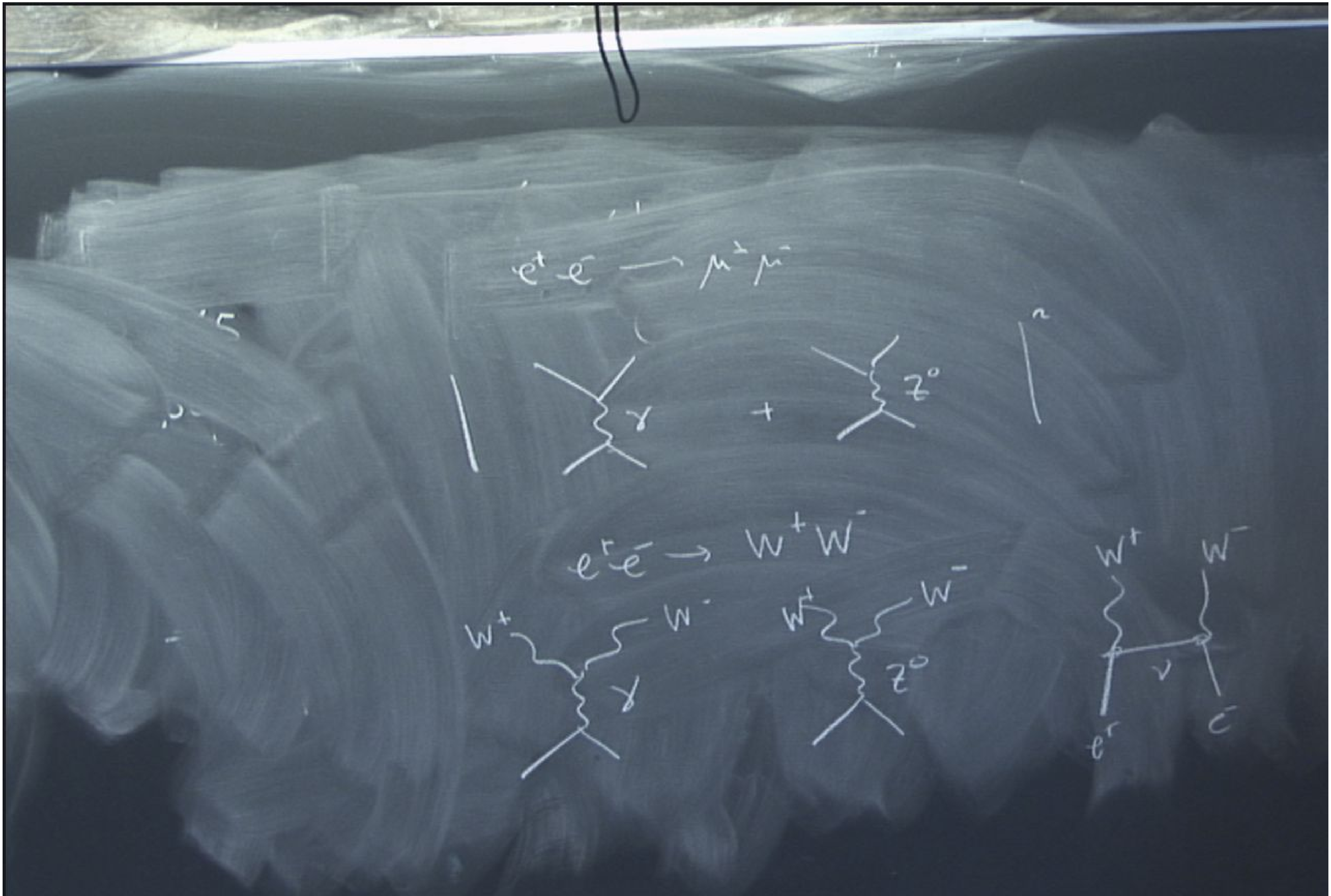
$e^+e^- \to \mu^+\mu^-$

$e^+e^- \to W^+W^-$

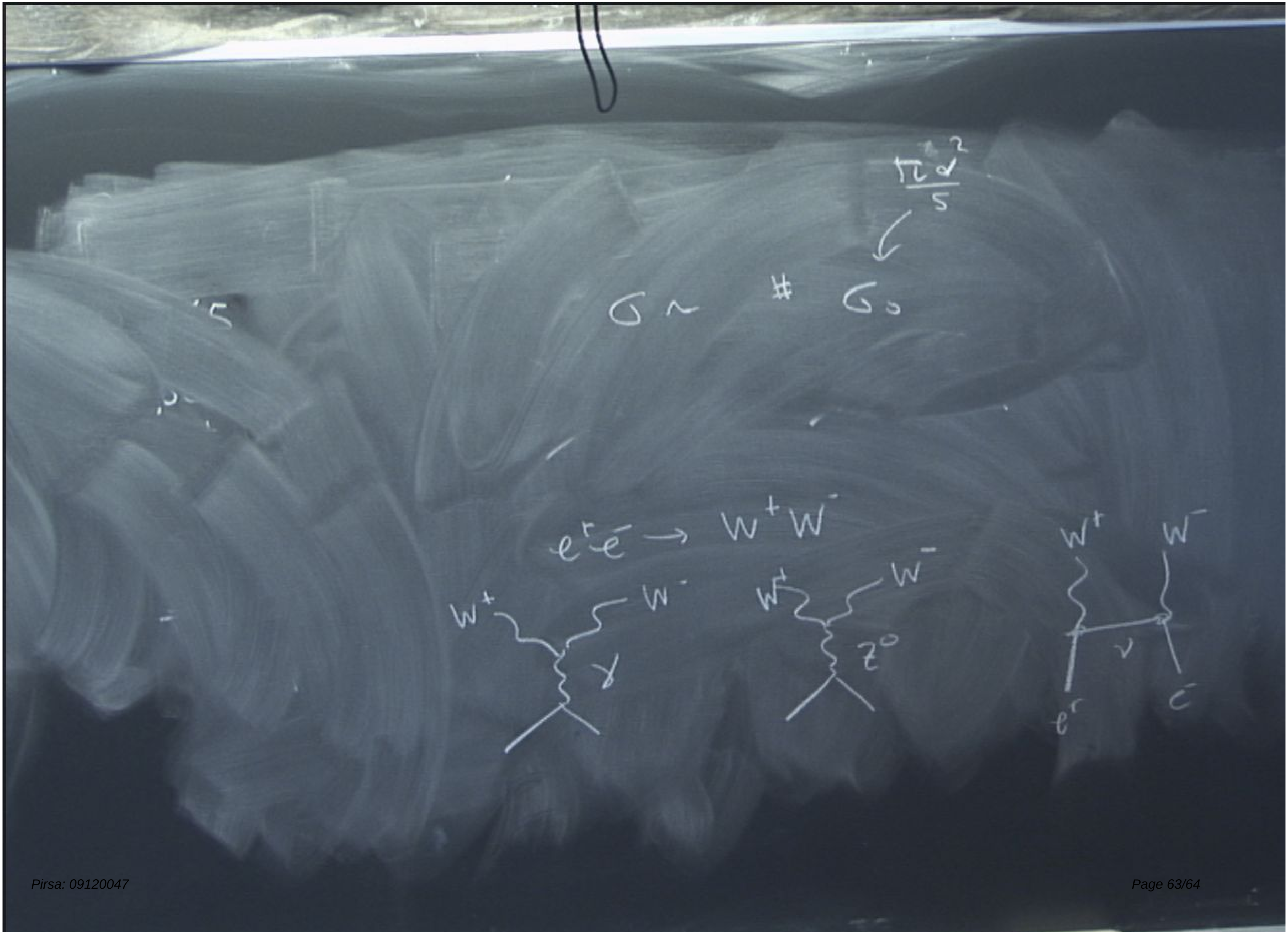




$e^+e^- \longrightarrow \mu^+\mu^-$
γ
$+$
Z^0
$e^+e^- \rightarrow W^+W^-$
W^+
W^-
γ
W^+
W^-
Z^0
W^+
W^-
ν
e^+
e^-



$e^+e^- \longrightarrow \mu^+\mu^-$
γ
+
Z^0
$e^+e^- \longrightarrow W^+W^-$
W^+
W^-
γ
W^+
W^-
Z^0
W^+
W^-
ν
e^+
e^-


πα²/s
σ ~ # σ₀
e⁺e⁻ → W⁺W⁻
W⁺
W⁻
γ
W⁺
W⁻
Z⁰
W⁺
W⁻
ν
e⁺
e⁻

$$\frac{\pi\alpha^2}{s}$$

$$\sigma \sim \# \; \sigma_0 \left(\frac{s}{m_W}\right)^2$$

$$e^+e^- \to W^+W^-$$