

Title: Explorations in Particle Theory - Lecture 2

Date: Apr 05, 2011 10:15 AM

URL: <http://pirsa.org/11040022>

Abstract:

$$\mu^{\pm} \rightarrow e^{\pm} \bar{\nu}_e \nu_{\mu} \quad \tau \sim 10^{-6} \text{ s.}$$

$$\mu^+ \rightarrow e^+ \bar{\nu}_e \nu_\mu$$

$$\tau \sim 10^{-6} \text{ s}$$

$$n \rightarrow p e^- \bar{\nu}_e$$

$$\pi \sim 900 \text{ s}$$

$$\mu^{\pm} \rightarrow e^{\pm} \bar{\nu}_e \nu_{\mu} \quad \tau \sim 10^{-6} \text{ s.}$$

$$n \rightarrow p e \bar{\nu}_e \quad \pi \sim 900 \text{ s}$$

$$\mu^+ \rightarrow e^+ \bar{\nu}_e \nu_\mu \quad \tau \sim 10^{-6} \text{ s.}$$

$$n \rightarrow p e^- \bar{\nu}_e \quad \tau \sim 900 \text{ s}$$

$$H_{\text{weak}} \sim G_F J_{\text{had}}^\mu J_{\text{lep} \mu}$$

"baryonic" "lep"

10^{-6} s

900 s

"lep"

17 ~

$$\frac{G_F^2 m_n^5}{192 \pi^3}$$

$\nu_e \nu_e$ $\tau \sim 10^{-6} \text{ s}$

$\bar{\nu}_e$ $\tau \sim 900 \text{ s}$

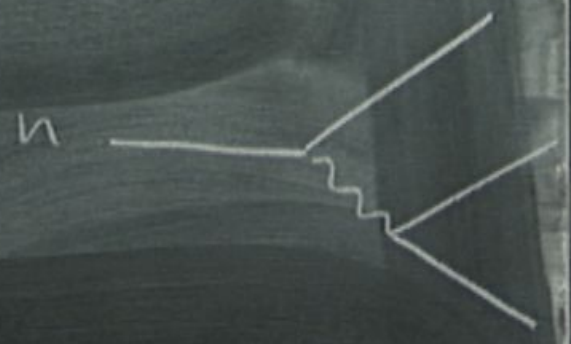
$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

G_F J_{had}^{μ} J_{lep}^{μ}
"hadronic" "lep"

$\nu_e \nu_e$
 $\tau \sim 10^{-6} \text{ s}$
 $\bar{\nu}_e$
 $\tau \sim 900 \text{ s}$

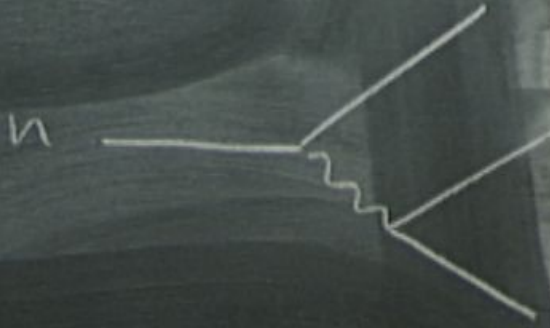
$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

G_F J^{μ} J_{μ}
 "baryonic" "lep"



p
 e
 $\bar{\nu}_e$

$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$



p

e

$\bar{\nu}_e$

$$\Gamma_m \sim$$

$$\left(\frac{d^3 p_e}{2 E_{\text{electron}}} \right)$$

$$\Gamma_m \sim \left(\frac{d^3 p_p}{2E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2E_e} \right) \left(\frac{d^3 p_\nu}{2E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|$$

$$\Gamma_m \sim \left(\frac{d^3 p_e}{2E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2E_e} \right) \left(\frac{d^3 p_\nu}{2E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|^2$$

$$\Gamma_m \sim \left(\frac{d^3 p_p}{2 E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2 E_e} \right) \left(\frac{d^3 p_\nu}{2 E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|^2$$

$$\int \frac{d^3 p_p}{2 m_p}$$

$$\Gamma_m \sim \left(\frac{d^3 p_p}{2 E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2 E_e} \right) \left(\frac{d^3 p_\nu}{2 E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|$$

$$\left(\frac{d^3 p_p}{2 m_p} \right) \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right)$$

$$\Gamma_m \sim \left(\frac{d^3 p_p}{2E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2E_e} \right) \left(\frac{d^3 p_\nu}{2E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|^2$$

$$\left(\frac{d^3 p_p}{2m_p} \right) \left(\frac{d^3 p_e}{2p_e} \right) \left(\frac{d^3 p_\nu}{2p_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \times |M|^2$$

$$\sim \frac{1}{m_p} \left(\frac{d^3 p_e}{2p_e} \frac{d^3 p_\nu}{2p_\nu} \delta(p_e + p_\nu + (m_p - m_n)) \right)$$

$$\begin{aligned}
 \Gamma_m &\sim \left(\frac{d^3 p_e}{2 E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2 E_e} \right) \left(\frac{d^3 p_\nu}{2 E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - p_n) \\
 &\left(\frac{d^3 p_p}{2 m_p} \right) \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right) \delta^{(4)}(\dots) |M|^2 \times |M|^2 \\
 &\sim \frac{1}{m_p} \left(\frac{d^3 p_e}{2 p_e} \frac{d^3 p_\nu}{2 p_\nu} \delta(p_e + p_\nu + (m_p - m_n)) \right) |M|^2
 \end{aligned}$$

$$\mu^+ \rightarrow e^+ \nu_e \nu_\mu \quad \tau \sim 10^{-6} \text{ s}$$

$$n \rightarrow p e \bar{\nu}_e \quad \pi \sim 900 \text{ s}$$

$$H_{\text{weak}} \sim G_F J_{\text{baryonic}}^\mu J_{\text{lep}}^\mu$$

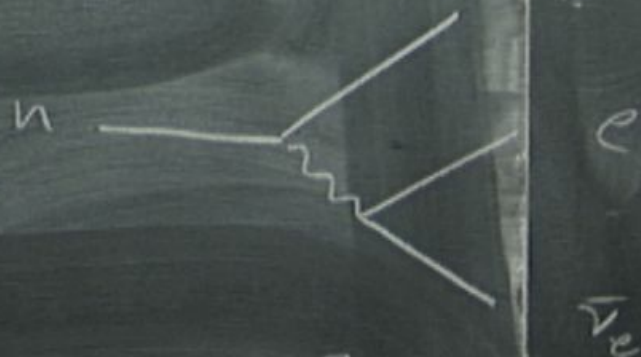
$$\Gamma_m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e$$

$$\mu^+ \rightarrow e^+ \nu_e \nu_\mu \quad \tau \sim 10^{-6} \text{ s}$$

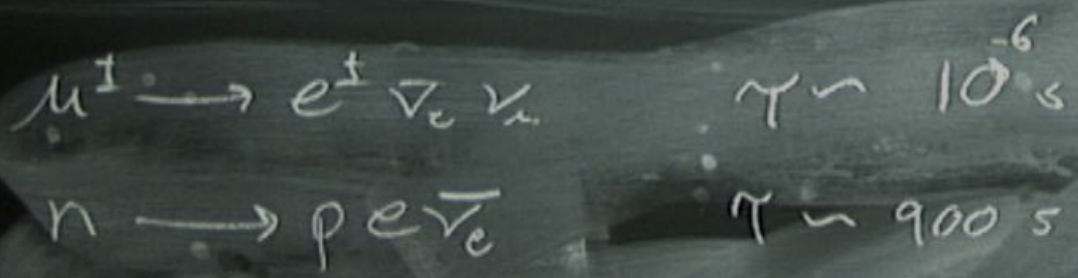
$$n \rightarrow p e \bar{\nu}_e \quad \tau \sim 900 \text{ s}$$

$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

$$H_{\text{weak}} \sim G_F J_{\text{baryonic}}^\mu J_{\text{lep}}^\mu$$

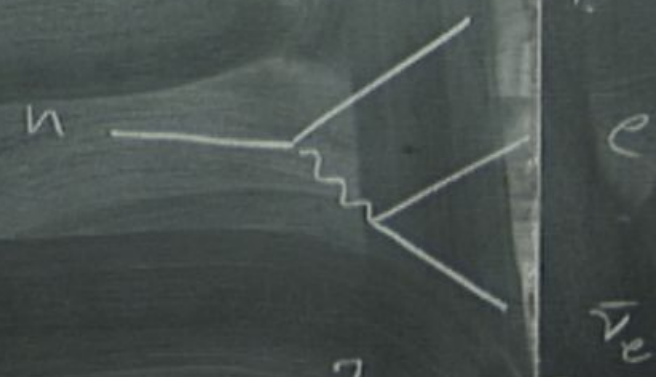


$$\Gamma_m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e \sim \frac{|M|^2 (\Delta m)^3}{m_p}$$



$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

$H_{\text{weak}} \sim G_F J_{\text{baryonic}}^\mu J_{\text{lep}}^\mu$



$$\Gamma_m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e \sim \frac{|M|^2 (\Delta m)^3}{m_p}$$

$|M|^2 \sim G_F^2$

$$\mu^+ \rightarrow e^+ \nu_e \nu_\mu$$

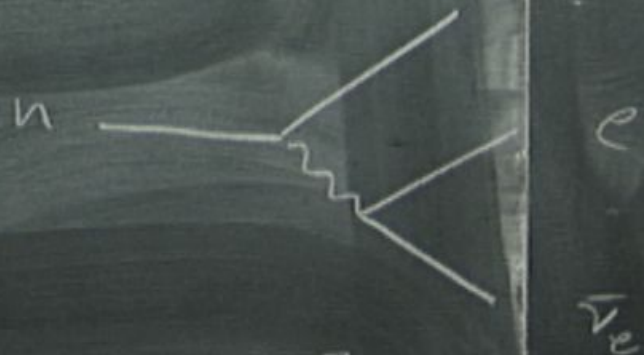
$$\tau \sim 10^{-6} \text{ s}$$

$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

$$n \rightarrow p e \bar{\nu}_e$$

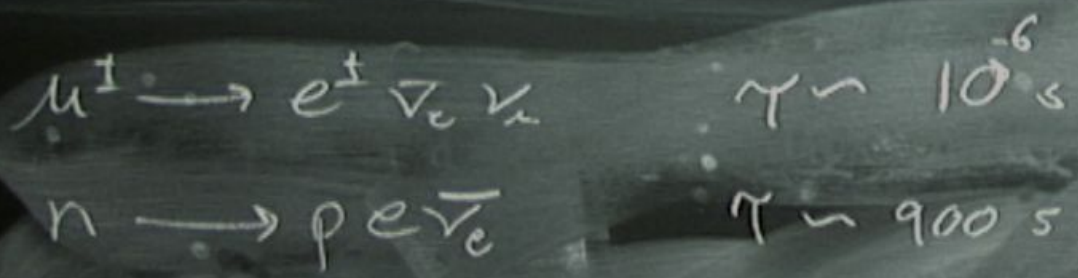
$$\tau \sim 900 \text{ s}$$

$$H_{\text{weak}} \sim G_F J_{\text{baryonic}}^\mu J_{\text{lep}}^\mu$$



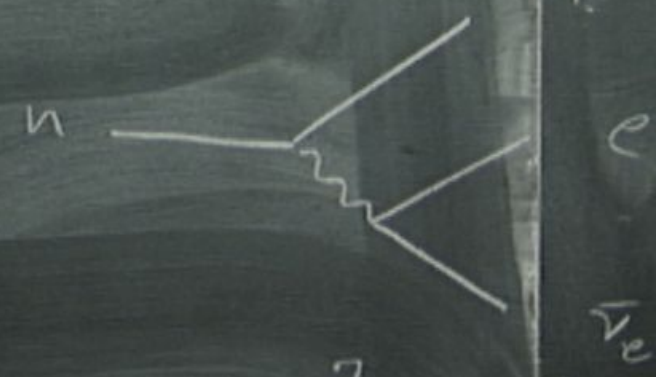
$$m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e \sim \frac{|M|^2 (\Delta m)^3}{m_p}$$

$$|M|^2 \sim G_F^2 L_{\mu\nu}^{(n-p)} L^{(e-\nu)} L_{\mu\nu}^{(p)}$$



$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

$H_{\text{weak}} \sim G_F J_{\text{baryonic}}^\mu J_{\text{lep}}^\mu$



$$m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e \sim \frac{|M|^2 (\Delta m)^3}{m_p}$$

$$|M|^2 \sim G_F^2 L_{\mu\nu}^{(n-p)}(p) L^{(e-\nu)}_{\mu\nu}(p) \sim G_F^2 m_p^2 (\Delta m)^2$$

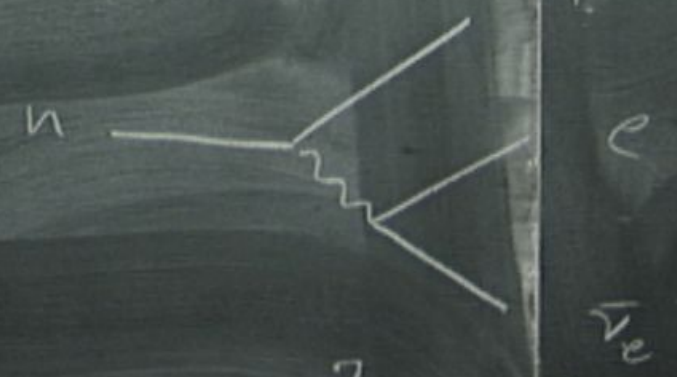
$$\mu^+ \rightarrow e^+ \nu_e \nu_\mu \quad \tau \sim 10^{-6} \text{ s}$$

$$n \rightarrow p e^- \bar{\nu}_e \quad \tau \sim 900 \text{ s}$$

$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

$$H_{\text{weak}} \sim G_F J^{\mu} J_{\mu}$$

"baryonic" "lep"



$$\Gamma_m \sim \frac{|M|^2}{m_p} \int_0^{\Delta m = m_n - m_p} p_e (\Delta m - p_e) dp_e \sim \frac{|M|^2 (\Delta m)^3}{m_p}$$

$$|M|^2 \sim G_F^2 L_{\mu\nu}^{(n-p)} L^{(e-\nu)} \sim G_F^2 m_p^2 (\Delta m)^2$$

$$\tau \sim 10^{-6} \text{ s}$$

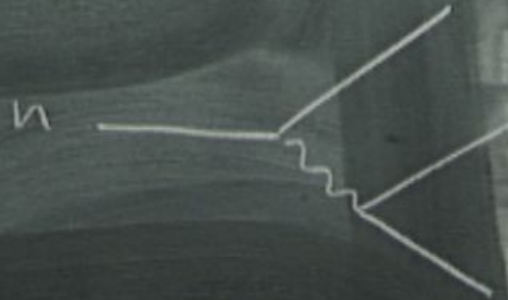
$$\tau \sim 900 \text{ s}$$

$$\Gamma = \frac{G_F^2 m_n^5}{192 \pi^3}$$

J^u J^d

"baryonic"

"lep"



P^u

$$\Gamma_m \sim$$

$$\Delta m = m_n - m_p$$

$$p_e (\Delta m - p_e) dp_e \sim$$

$$\frac{|M|^2 (\Delta m)^3}{m_p}$$

$$\sim G_F^2 (\Delta m)^5 m \int \frac{d^3 p_e}{2 m_p}$$

$(e-\nu) \gamma$
 $(p) \quad (p)$

$$\sim G_F^2 m_p^2 (\Delta m)^2$$

$$\sim \frac{1}{m_p}$$

$$\frac{G_F^2 m_m^5}{192 \pi^3}$$

$$\Gamma_{\text{neutrino}} \propto G_F^2 (\Delta m)^5$$

$$\Gamma_m \sim \left(\frac{d^3 p_e}{2 E_{\text{neutrino}}} \right) \left(\frac{d^3 p_e}{2 E_e} \right) \left(\frac{d^3 p_\nu}{2 E_\nu} \right) \delta^{(4)}(p_e + p_\nu - p_m)$$

$$(\Delta m)^3 \sim G_F^2 (\Delta m)^5 \left(\frac{d^3 p_e}{2 m_p} \right) \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right) \delta^{(4)}(p_e + p_\nu - p_m)$$

$$m_p \sim \frac{1}{m_p} \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right) \delta^{(4)}(p_e + p_\nu - p_m)$$

$$\frac{G_F^2 m_n^5}{192 \pi^3}$$

$$\Gamma_{n \rightarrow p e \nu} \propto G_F^2 (\Delta m)^5$$

$\Gamma_m \sim \left(\frac{d^3 p_e}{2 E_{\text{proton}}} \right) \left(\frac{d^3 p_e}{2 E_e} \right) \left(\frac{d^3 p_\nu}{2 E_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - m)$
 $(\Delta m)^3 \sim G_F^2 (\Delta m)^5 \left(\frac{d^3 p_p}{2 m_p} \right) \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right) \delta^{(4)}(p_p + p_e + p_\nu - m) |M|^2$
 $\frac{m_p}{m_p} \sim \frac{1}{m_p} \left(\frac{d^3 p_e}{2 p_e} \right) \left(\frac{d^3 p_\nu}{2 p_\nu} \right) \delta^{(4)}(p_e + p_\nu + (m_p - m_n)) |M|^2$
 $\frac{1}{m_p^2 (\Delta m)^2}$



$$\pi \pm \rightarrow \mu \pm \sqrt{\mu}$$

□

$$\pi^\pm \rightarrow \mu^\pm \bar{\nu}_\mu$$

✓

G_F^2



□

$$\pi^\pm \rightarrow \mu^\pm \bar{\nu}_\mu$$

$$G_F^2 f_\pi^2 m_\mu^2 m_\pi \left(1 - \frac{m_\mu^2}{m_\pi^2}\right)^2$$



$$\pi^\pm \rightarrow \mu^\pm \bar{\nu}_\mu$$

$$G_F^2 f_\pi^2 m_\mu^2 m_\pi \left(1 - \frac{m_\mu^2}{m_\pi^2}\right)^2$$

$M \leq 500 \text{ MeV}$

K^+, K^-, K^0, \bar{K}^0

$M \leq 500 \text{ MeV}$
 K^+, K^-, K^0, \bar{K}^0

$M \leq 500 \text{ MeV}$

K^+, K^-, K^0, \bar{K}^0

$K^+ \rightarrow \mu^+ \nu \quad (64\%)$
 $\rightarrow \pi^+ \pi^0 \quad (21\%)$

$$M \approx 500 \text{ MeV}$$

$$K^+, K^-, K^0, \bar{K}^0$$

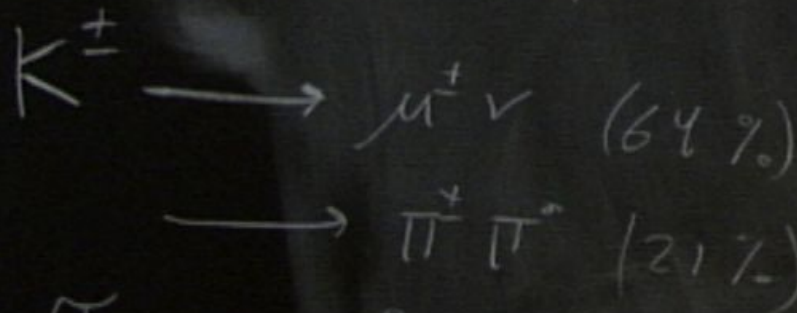
$$K^{\pm} \longrightarrow \mu^{\pm} \nu \quad (64\%)$$

$$\longrightarrow \pi^{\pm} \pi^0 \quad (21\%)$$

$$\tau_{K^{\pm}} \approx 10^{-8} \text{ s}$$

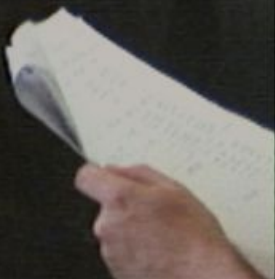
$$M \leq 500 \text{ MeV}$$

K^+, K^-, K^0, \bar{K}^0



K_S^0

$$\tau_{K^{\pm}} \approx 10^{-8} \text{ s}$$



500 MeV

K^- , K^0 , \bar{K}^0

$\rightarrow \mu^+ \nu$ (64%)

$\rightarrow \pi^+ \pi^-$ (21%)

$10^{-8} s$

$\tau \sim 10^{-8} s$

$K_S^0 \longrightarrow \pi^+ \pi^-$

$\longrightarrow \pi^0 \pi^0$

$K_L \longrightarrow \pi^0 \pi^+ \pi^-$
 $\pi^+ \pi^-$

500 MeV

K^-, K^0, \bar{K}^0

$\rightarrow \mu^+ \nu$ (64%)

$\rightarrow \pi^+ \pi^-$ (21%)

$10^{-8} s$

$K_S^0 \xrightarrow[\tau_S \sim 10^{-10} s]{\pi}$ $\pi^+ \pi^-$ (69%)

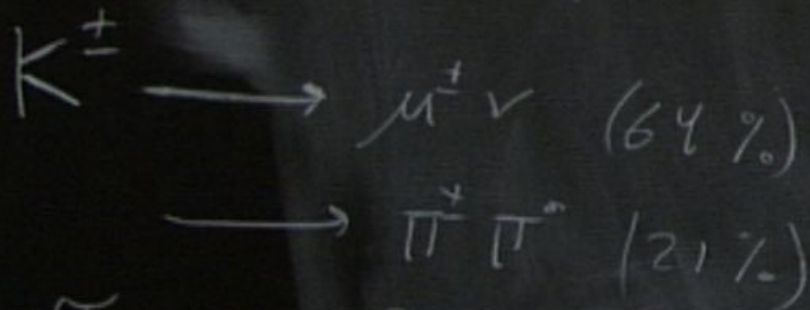
$\xrightarrow{\pi}$ $\pi^0 \pi^0$ (31%)

$K_L \rightarrow \pi^0 \pi^+ \pi^-$
 $\pi^+ \pi^- \pi^0$

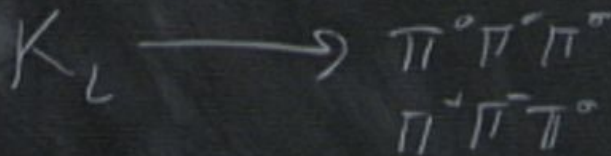
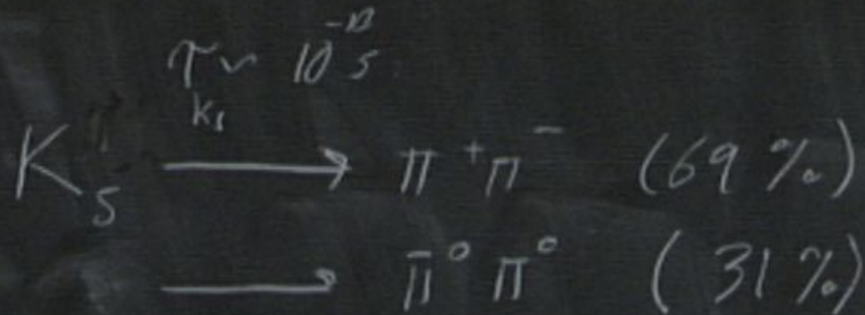
$\tau_L \sim 5 \times 10^{-8} s$

$$M \approx 500 \text{ MeV}$$

$$K^+, K^-, K^0, \bar{K}^0$$



$$\tau_{K^{\pm}} \approx 10^{-8} \text{ s}$$



$$\tau_{K_L} \approx 5 \times 10^{-8} \text{ s}$$

$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$

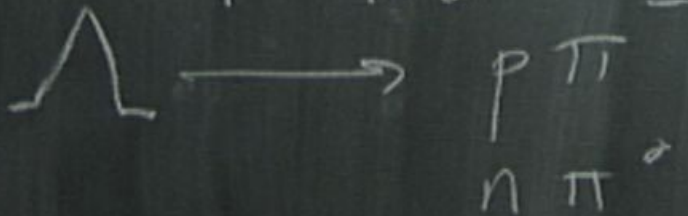
$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$

$$M \approx 1100 \text{ MeV}$$

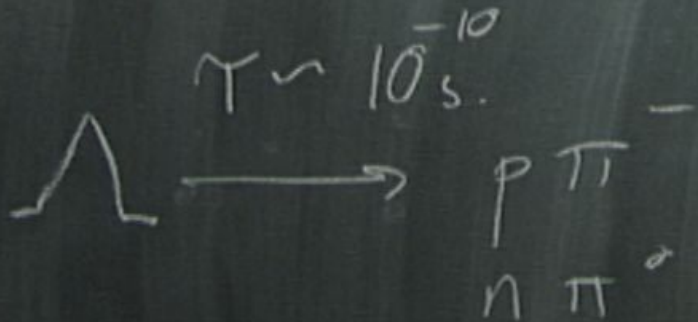
$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$

$$\tau \sim 10^{-10} \text{ s.}$$

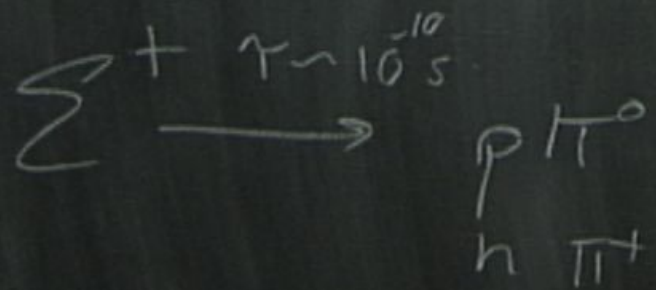


$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$

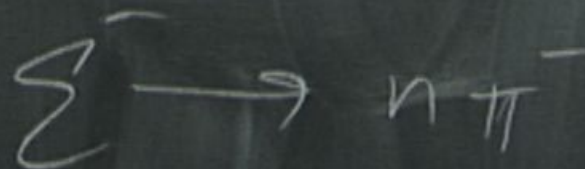
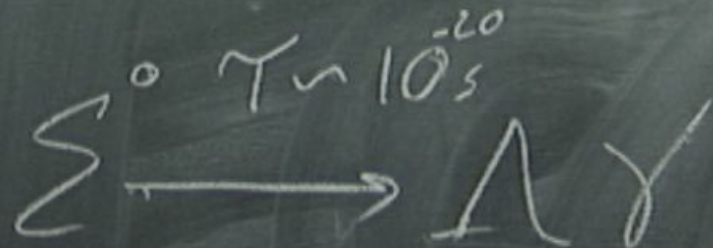
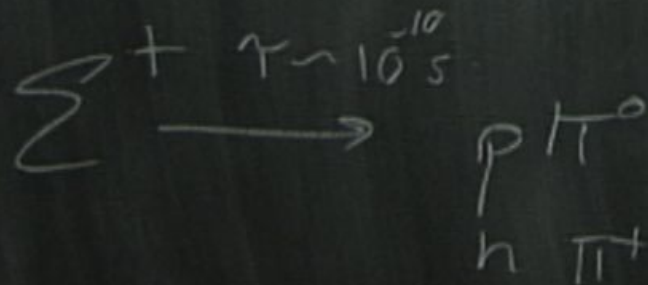
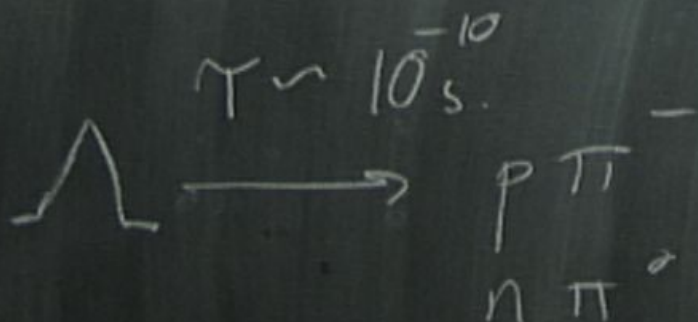


Σ^0



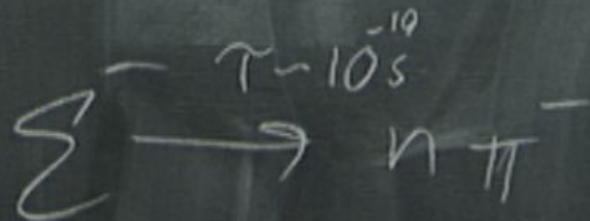
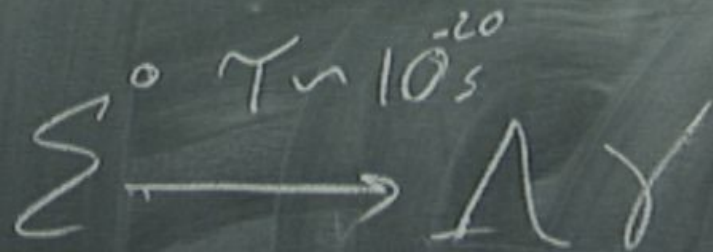
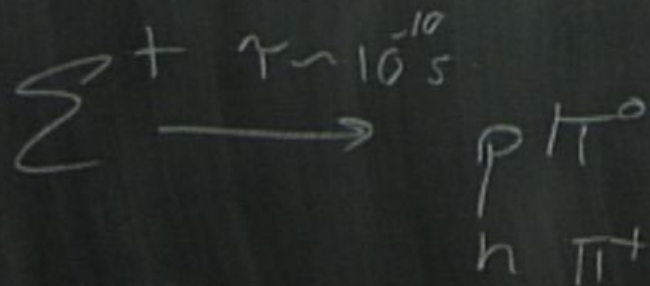
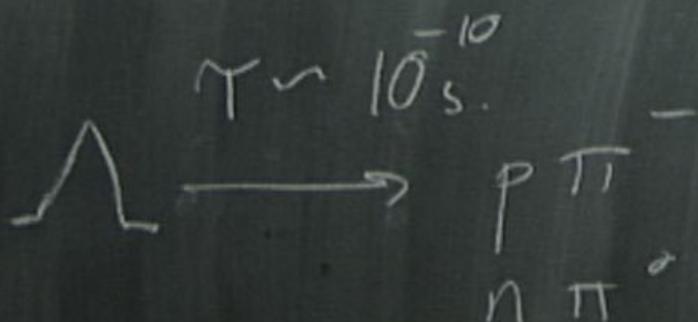
$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$



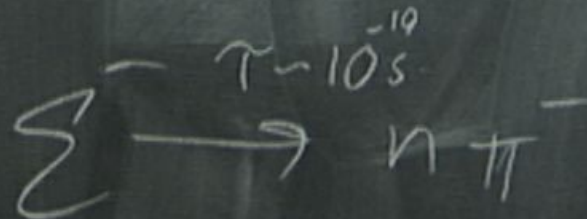
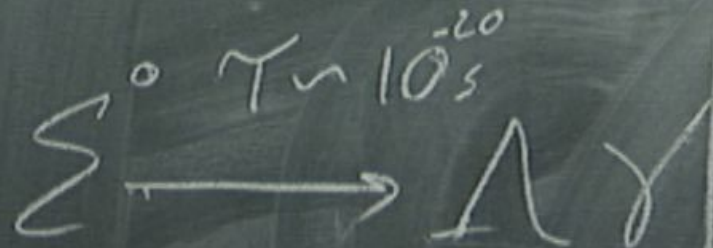
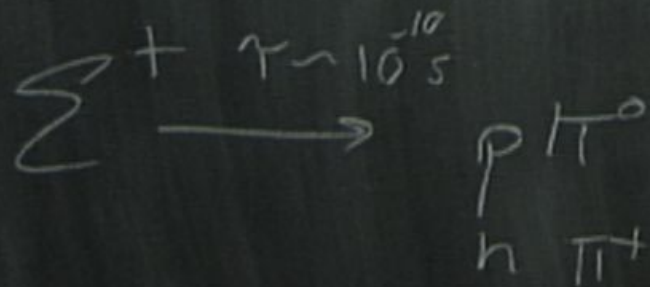
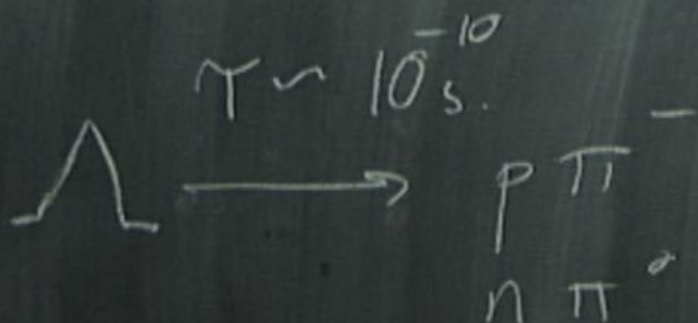
$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$



$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$



Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

→ pair

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\} \longrightarrow \text{pairs}$$

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

→ pairs

$$\{k^+, k^0, k^-\}$$

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

→ pairs

$$\{K^+, K^0, K^-\}$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

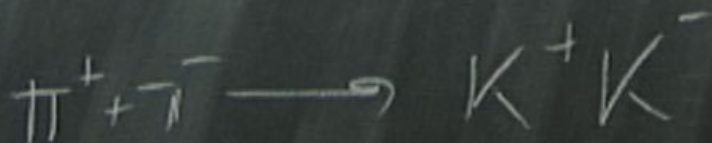
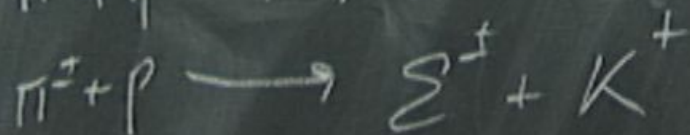
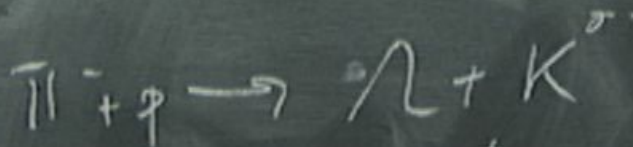
$$\pi^+ + p \rightarrow \Sigma^+ + K^+$$

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

pairs

$$\{K^+, K^0, K^-\}$$



Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

pairs $\{K^+, K^0, K^-\}$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$\pi^+ + p \rightarrow \Sigma^+ + K^+$$

$$\pi^+ + \bar{p} \rightarrow K^+ K^-$$

We see these
\$ \sim \$ mb,
strong!

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

pairs $\{K^+, K^0, K^-\}$

$$\left. \begin{aligned} \pi^- + p &\rightarrow \Lambda + K^0 \\ \pi^+ + p &\rightarrow \Sigma^+ + K^+ \\ \pi^+ + \bar{p} &\rightarrow K^+ K^- \end{aligned} \right\}$$

We see these
\$ \odot \sim mb\$

We don't see:

$$\begin{aligned} \pi + \pi &\not\rightarrow \Lambda + \text{Kans} + \dots \\ &\not\rightarrow \Sigma^\pm + \text{Kans} + \dots \end{aligned}$$

Scatter

$$\{n, p, \pi\} + \{n, p, \pi\}$$

pairs $\{K^+, K^0, K^-\}$

$$\left. \begin{aligned} \pi^- + p &\rightarrow \Lambda + K^0 \\ \pi^+ + p &\rightarrow \Sigma^+ + K^+ \\ \pi^+ + \bar{p} &\rightarrow K^+ K^- \end{aligned} \right\}$$

We see these
\$ \sim \$ mb, strong!

We don't see:

$$\begin{aligned} \pi + \pi &\not\rightarrow \Lambda + \text{Kans} + \dots \\ &\not\rightarrow \Sigma^\pm + \text{Kans} + \dots \end{aligned}$$

$$M \approx 1300 \text{ MeV}$$

$$\Sigma^-, \Sigma^0$$

$$\pi^-$$

$$M \approx 1300 \text{ MeV}$$

$$\bar{\Sigma}^-, \Sigma^0$$

$$\bar{\Sigma}^-, \bar{\Sigma}^0$$

$$\bar{\Sigma}^- + p \rightarrow \bar{\Sigma}^- K^+ K^0 \nu \dots$$

1

$$M \approx 1300 \text{ MeV}$$

$$\Sigma^-, \Sigma^0$$

$$\Sigma^-, \Sigma^0$$

$$\pi^- + p \rightarrow \Sigma^- K^+ K^0, \dots$$

$$\pi^+ + n \rightarrow \Sigma^0 K^+ K^0, \dots$$

$$\pi^+ \pi^- \quad (69\%)$$

$$\pi^0 \pi^0 \quad (31\%)$$

$$\pi^0 \pi^+ \pi^0$$

$$\pi^+ \pi^- \pi^0$$

$$-8$$
$$10^5$$

$$M \approx 1300 \text{ MeV}$$

$$\Sigma^-, \Sigma^0$$

$$\pi^- + p \rightarrow \Sigma^- K^+ K^0 \dots$$

$$\pi^+ + n \rightarrow \Sigma^0 K^+ K^0 \dots$$

$$\pi^+ \pi^- \quad (69\%)$$

$$\pi^0 \pi^0 \quad (31\%)$$

$$\pi^0 \pi^+ \pi^0$$

$$\pi^+ \pi^- \pi^0$$

$$10^{-8} \text{ s}$$

$$M \approx 1300 \text{ MeV}$$

$$\Sigma^-, \Sigma^0$$

$$\Sigma^-, \Sigma^0$$

$$\pi^- + p \rightarrow \Sigma^- K^+ K^0 \dots$$

$$\pi^+ + n \rightarrow \Sigma^0 K^+ K^0 \dots$$

(69%)

31%)

(Strong process)

$$\pi^+ \pi^- \quad (69\%)$$

$$\pi^0 \pi^0 \quad (31\%)$$

$$\pi^0 \pi^+ \pi^0$$

$$\pi^+ \pi^- \pi^0$$

$$10^{-8} : 5$$

$$M \approx 1300 \text{ MeV}$$

$$\bar{\Sigma}^-, \Sigma^0$$

$$\pi^- + p \rightarrow \bar{\Sigma}^- K^+ K^0 \dots$$

$$\pi^+ + n \rightarrow \Sigma^0 K^+ K^0 \dots$$

(Strong process)

$$\pi^+ \pi^- \quad (69\%)$$

$$\pi^0 \pi^0 \quad (31\%)$$

$$\pi^0 \pi^+ \pi^0$$

$$\pi^+ \pi^- \pi^0$$

$$10^{-8} \text{ s}$$

$$M \approx 1300 \text{ MeV}$$

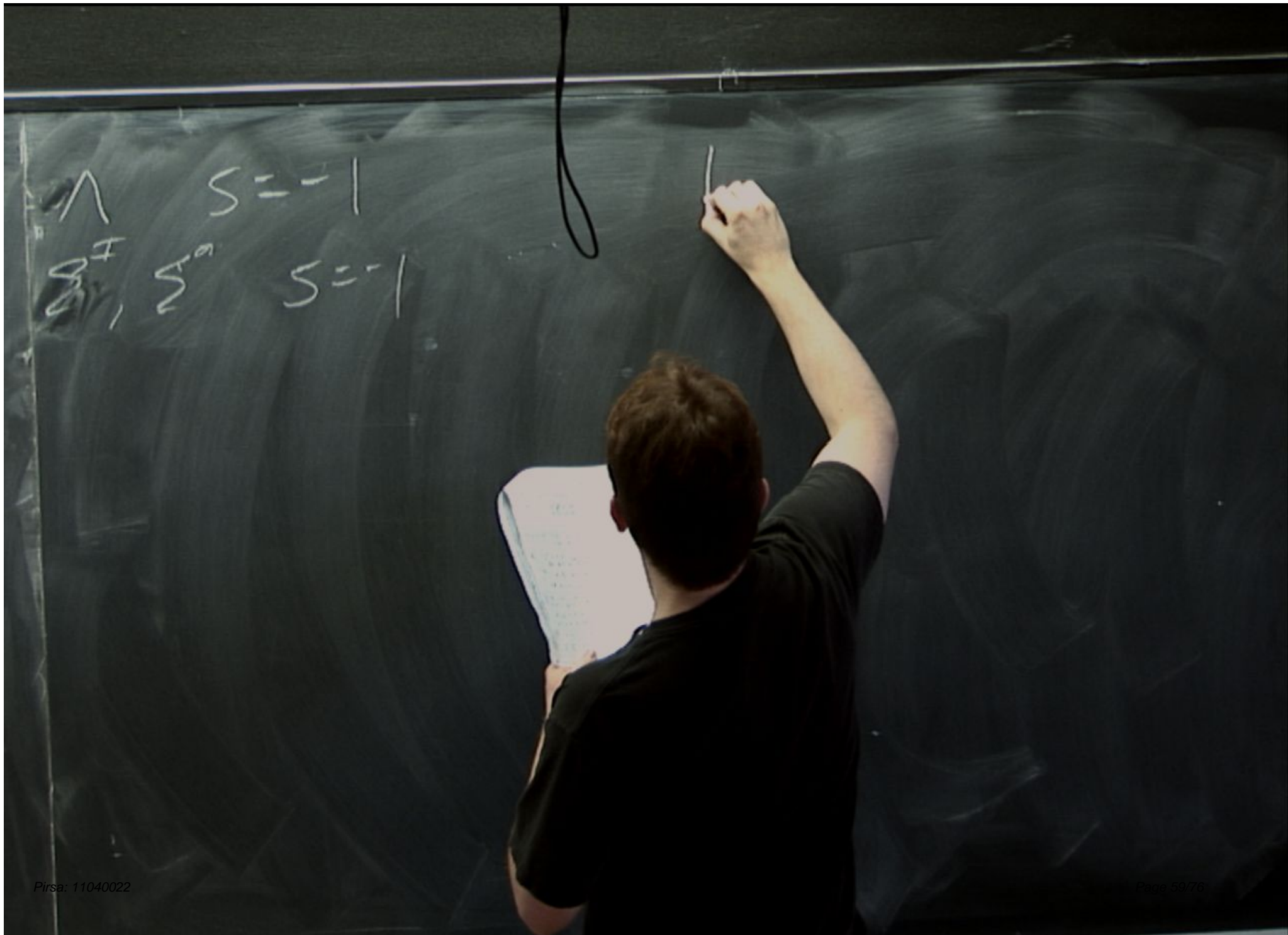
$$\Xi^-, \Xi^0$$

$$\pi^- + p \rightarrow \Xi^- K^+ K^0 \dots$$

$$\pi^+ + n \rightarrow \Xi^0 K^+ K^0 \dots$$

(Strong process)

$$\Xi^- \rightarrow \Lambda + \pi^- \quad (\text{weak decay})$$



$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

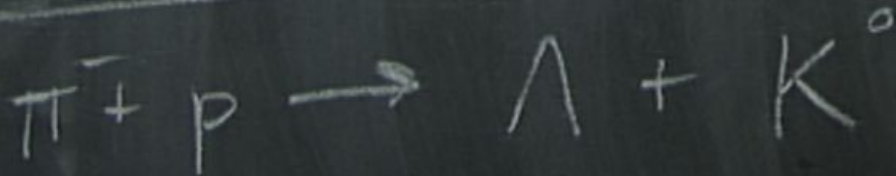
$$\Xi^{\pm}, \Xi^0 \quad S = -2$$

$$\pi^+ p \rightarrow \Lambda + K^0$$

$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

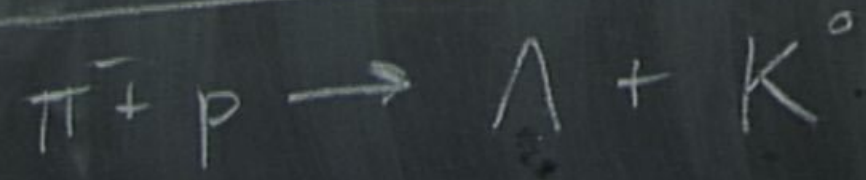
$$\Xi^{\pm}, \Xi^0 \quad S = -2$$



$$\Lambda \quad S = -1$$
$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

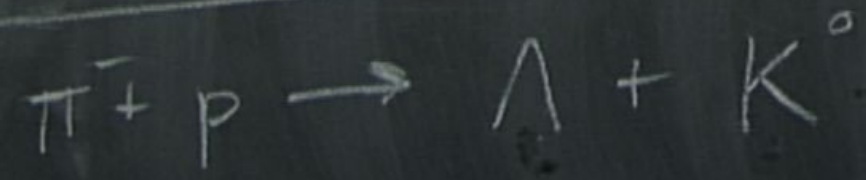


$$Q = I_3 + \frac{B}{2}$$

$$\Lambda \quad S = -1$$
$$\Sigma^{\pm}, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$
$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^{\pm}, \Xi^0 \quad S = -2$$



$$Q = I_3 + \frac{B}{2}$$

Λ has no EM charged partner

$$\Rightarrow I_3 = 0$$

$$\Lambda \quad S = -1$$

$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0$$

$$Q = I_3 + \frac{B}{2}$$

has no EM charged

$$I_3 = 0$$

$$\Lambda \quad S = -1$$

$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0 \quad -\frac{1}{2}$$

$$Q = I_3 + \frac{B}{2}$$

Λ has no EM charged partner

$$\Rightarrow I_3 = 0$$

$$\Lambda \quad S = -1$$

$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0 \quad -\frac{1}{2}$$

$$Q = I_3 + \frac{B}{2}$$

Λ has no EM charged partner

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$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0 \quad -\frac{1}{2}$$

$$K^0, K^+$$

$$Q = I_3 + \frac{1}{2}$$

Λ has no EM charged partner

$$\Rightarrow I_3 = 0$$

$$\Lambda \quad S = -1$$

$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0 \quad -\frac{1}{2}$$

$$Q = I_3 + \frac{B}{2}$$

Λ has no EM charged partner

$$\{K^0, K^+\}, \{\bar{K}^0, K^-\} \quad I = \frac{1}{2}$$

$$\Rightarrow I_a$$

$$\Lambda \quad S = -1$$

$$\Sigma^+, \Sigma^0 \quad S = -1$$

$$K^0, K^+ \quad S = +1$$

$$\bar{K}^0, K^- \quad S = -1$$

$$\Xi^-, \Xi^0 \quad S = -2$$

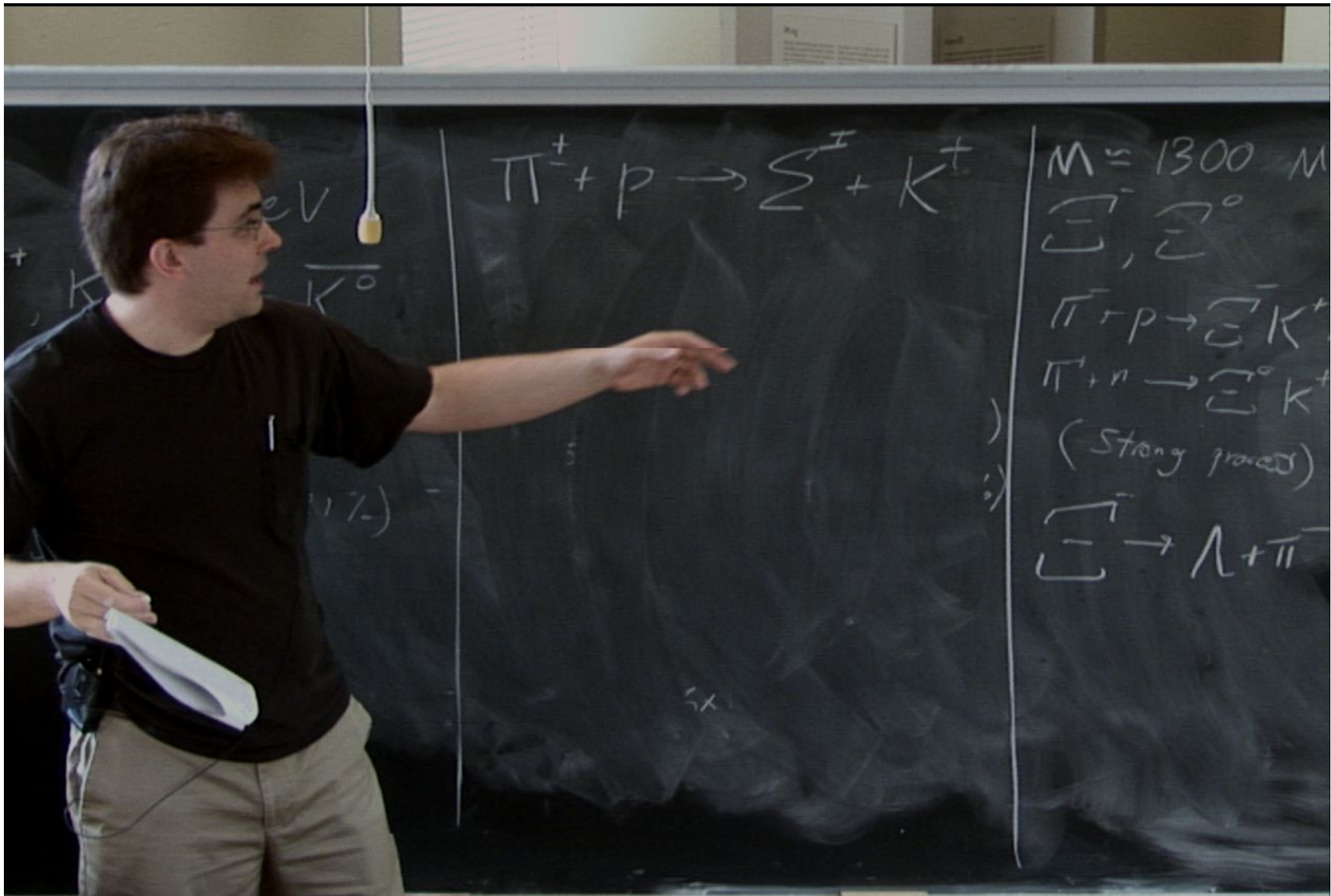
$$\pi^- + p \rightarrow \Lambda + K^0$$

$$I_3 \quad -1 \quad \frac{1}{2} \rightarrow 0 \quad -\frac{1}{2}$$

$$Q = I_3 + \frac{B}{2}$$

Λ has no EM charged partner

$$\{K^0, K^+\}, \{\bar{K}^0, K^-\} \quad I = \frac{1}{2} \quad \Rightarrow I_\Lambda = 0$$



$$\pi^+ + p \rightarrow \Sigma^+ + K^+$$

$$M = 1300 \text{ MeV}$$

$$\Sigma^-, \Sigma^0$$

$$\pi^- + p \rightarrow \Sigma^- K^+$$

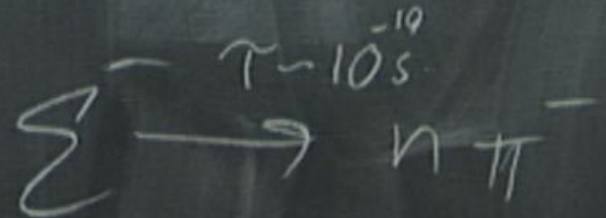
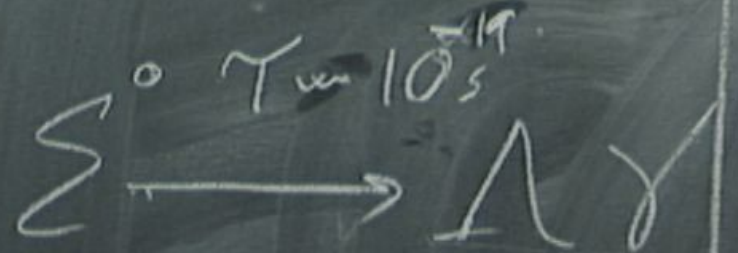
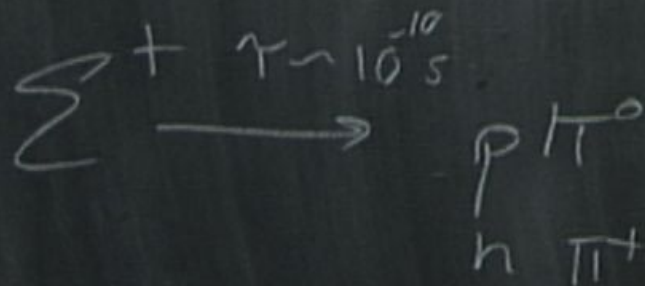
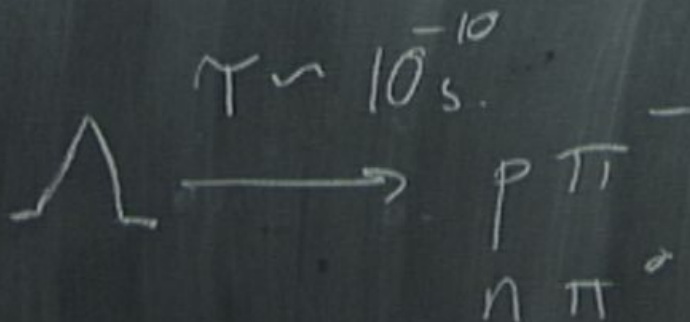
$$\pi^+ + n \rightarrow \Sigma^0 K^+$$

(Strong process)

$$\Sigma^- \rightarrow \Lambda + \pi^-$$

$$M \approx 1100 \text{ MeV}$$

$\Lambda, \Sigma^+, \Sigma^-, \Sigma^0$



500 MeV

K^- , K^0 , \bar{K}^0

$\rightarrow \mu^+ \nu$ (64%)

$\rightarrow \pi^+ \pi^-$ (21%)

$\approx 10^{-8} \text{ s}$

$$\frac{\Delta M}{m} \approx O\left(\frac{\alpha}{\pi}\right)$$

$M \approx 1300 \text{ MeV}$

$\bar{\Sigma}^-$, Σ^0
 $\bar{\Sigma}^-$, $\bar{\Sigma}^0$

$\pi^- + p \rightarrow \bar{\Sigma}^- K^+ K^-$

$\pi^+ + n \rightarrow \bar{\Sigma}^0 K^+ K^-$

(Strong process)

$\bar{\Sigma}^- \rightarrow \Lambda + \pi^-$

500 MeV
 K^-, K^0, \bar{K}^0
 $\rightarrow \mu^+ \nu$ (64%)
 $\rightarrow \pi^+ \pi^-$ (21%)
 $\approx 10^{-8} s$

$$\frac{\Delta M}{m} \approx O\left(\frac{\alpha}{\pi}\right)$$

$$\frac{Q}{e} = \frac{B}{2} + \frac{S}{2} + I_3$$

$M \approx 1300 M$
 Σ^-, Σ^0
 Σ^-, Σ^0
 $\pi^- + p \rightarrow \Sigma^- K^+$
 $\pi^+ + n \rightarrow \Sigma^0 K^+$
 (Strong process)
 $\Sigma^- \rightarrow \Lambda + \pi^-$