

Title: Particle Physics Lecture

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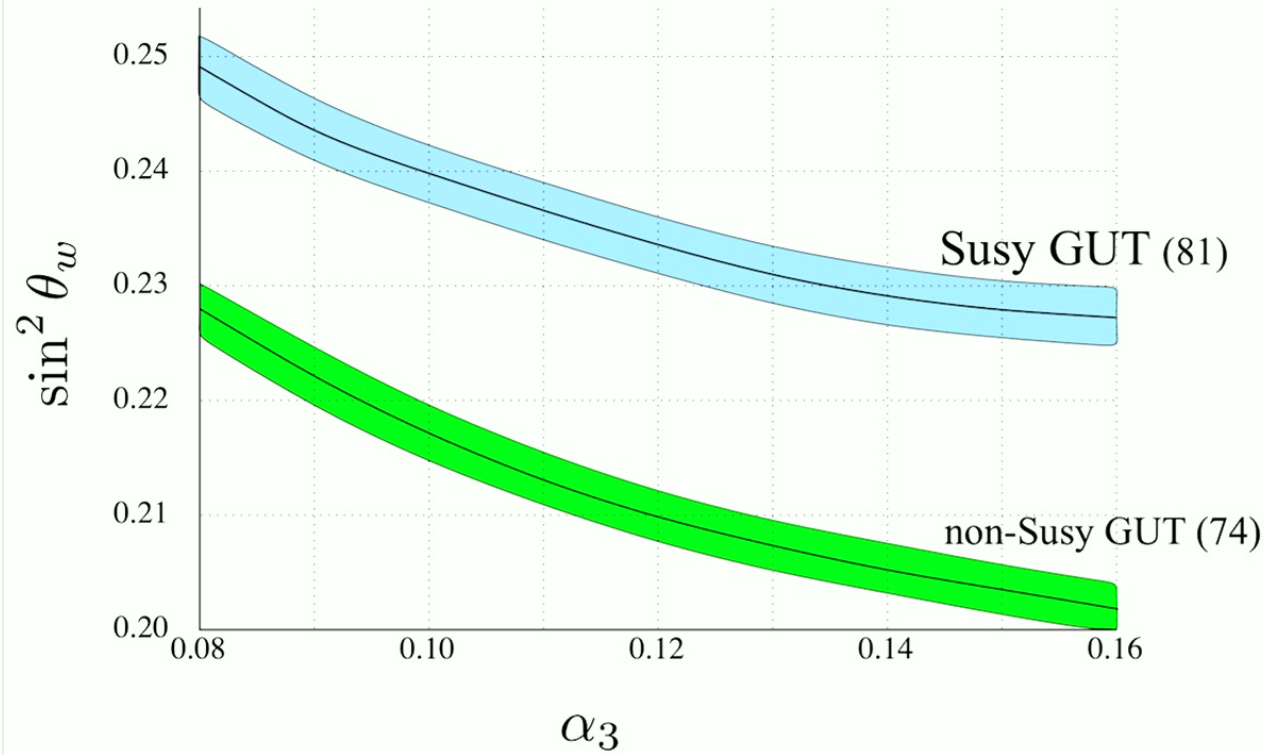
Collection: Particle Physics

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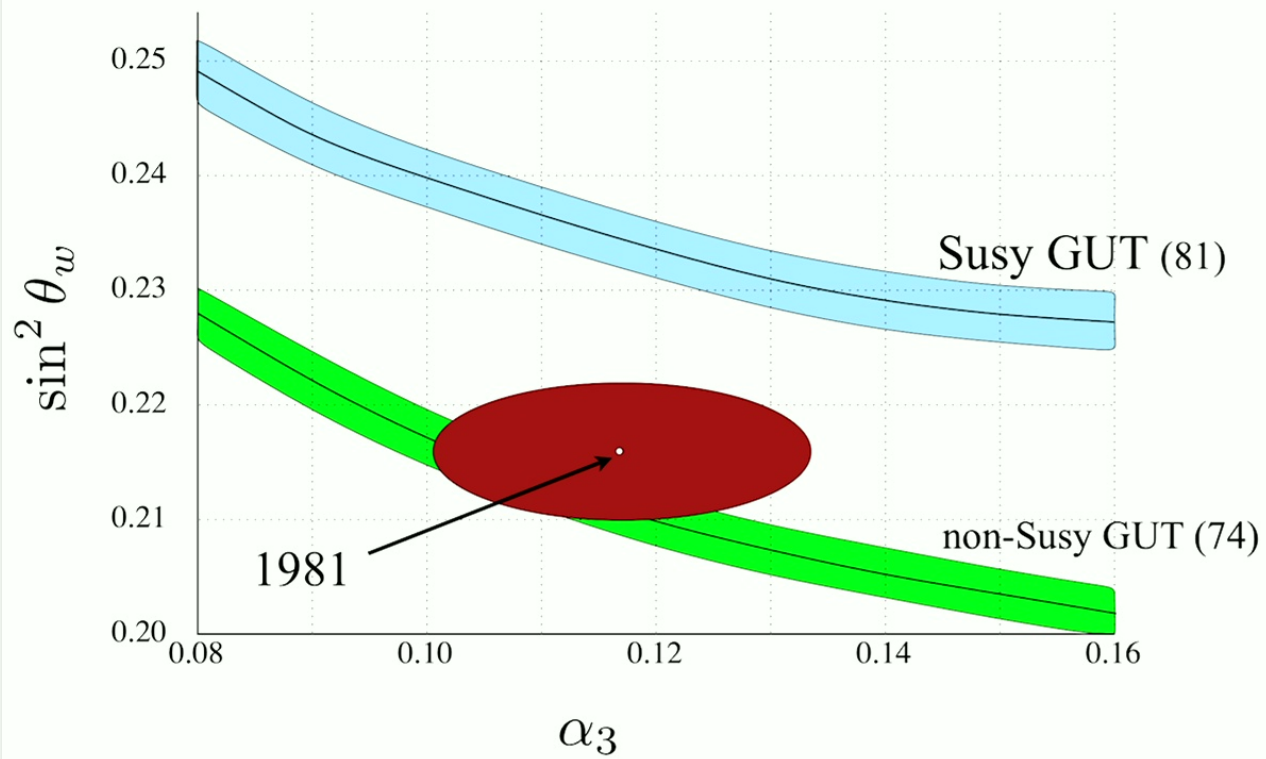


Unification





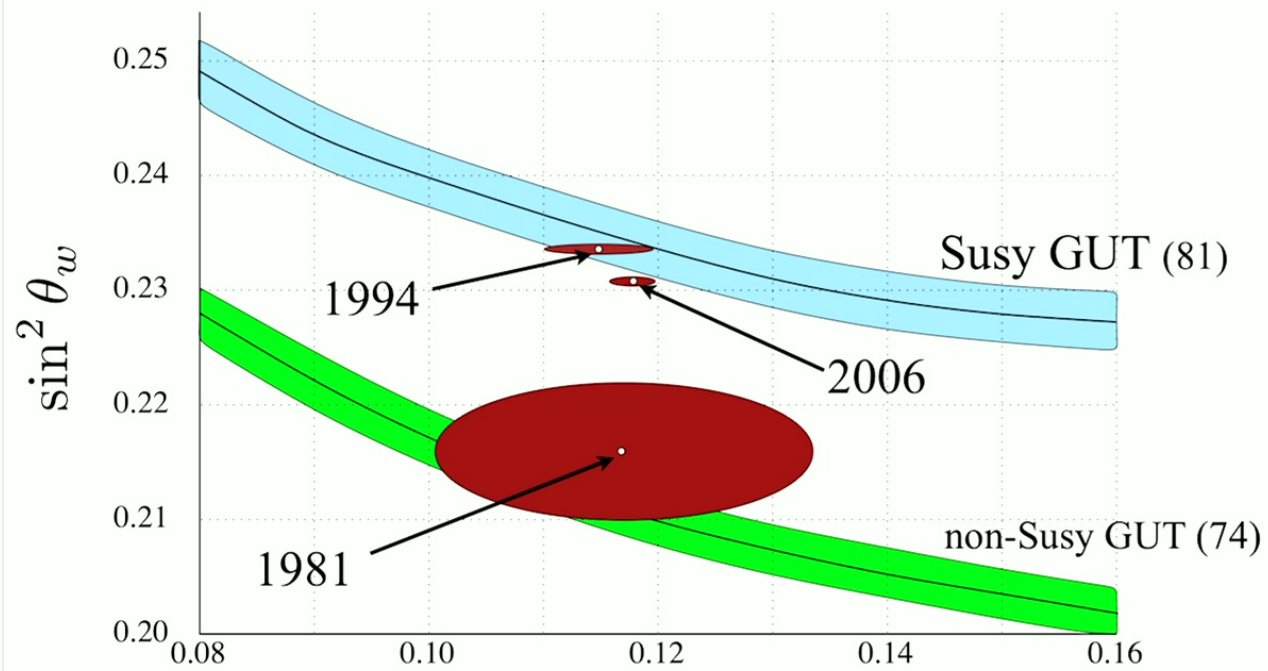
Unification

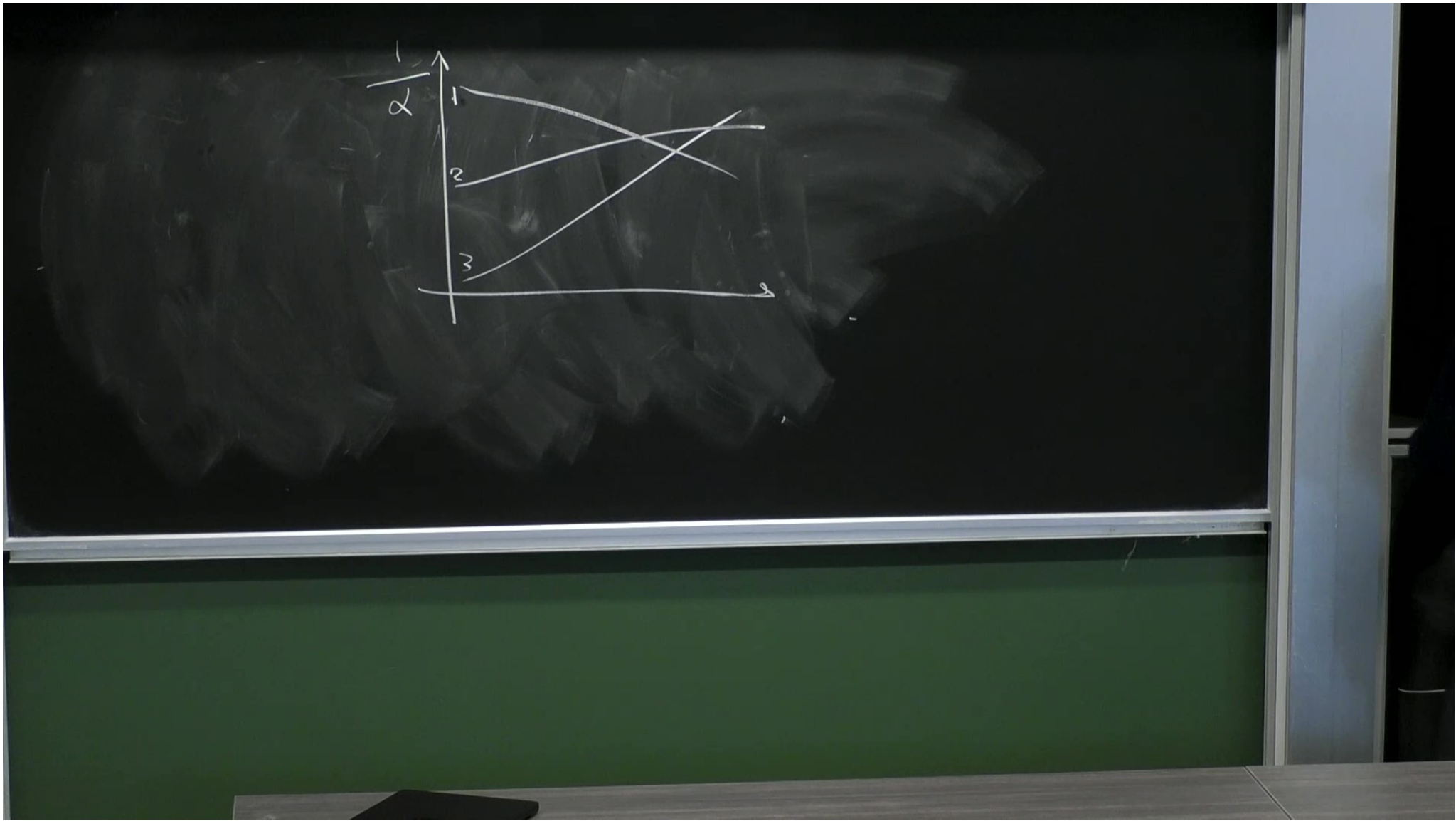




α_3

Unification





Dirac

$$\begin{array}{l}
 3 \times \left\{ \begin{array}{l} Q_L (3, 2, 1/6) \\ U_R (3, 1, 2/3) \\ D_R (3, 1, -1/3) \end{array} \right. \\
 3 \times \left\{ \begin{array}{l} L (1, 2, -1/2) \\ E_R (1, 1, -1) \end{array} \right.
 \end{array}$$

$$h Q_L \bar{U}_R, \lambda_{ij}$$

$$Q_L = \begin{pmatrix} q \\ 0 \\ 0 \end{pmatrix}$$

$$U_R = \begin{pmatrix} 0 \\ \bar{u} \end{pmatrix}$$

$$\bar{u} = i \sigma_2 u^*$$

Weyl

$$u = (\bar{3}, 1, -2/3)$$

$$d = (\bar{3}, 1, 1/3)$$

$$e = (1, 1, 1)$$

$$\lambda_{ij}^u h q u + \lambda_{jd}^+ h q d$$

Georgi & Glashow:

1974

$$SU(3)_c \times SU(2)_L \times U(1)_Y \subset SU(5)$$

$$\left(\begin{array}{c} SU(3) \\ X, Y \\ SU(2) \end{array} \right)$$

$$U(1)_Y \Rightarrow \left(\begin{array}{ccc} 1/3 & 1/3 & 1/3 \\ & -1/2 & -1/2 \end{array} \right) \sqrt{\frac{3}{5}}$$

$$(\mathbf{8}, \mathbf{1}, 0) + (\mathbf{1}, \mathbf{3}, 0) + (\mathbf{1}, \mathbf{1}, 0) + (\mathbf{3}, \mathbf{2}, -5/6) + (\bar{\mathbf{3}}, \mathbf{2}, 5/6)$$

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$$(\mathbf{8}, \mathbf{1}, 0) + (\mathbf{1}, \mathbf{3}, 0) + (\mathbf{1}, \mathbf{1}, 0) + (\mathbf{3}, \mathbf{2}, -5/6) + (\bar{\mathbf{3}}, \mathbf{2}, 5/6)$$

X, Y X^c, Y^c

I Matter fields:

$$\begin{aligned}
 3+ \left\{ \begin{aligned}
 \bar{5} &= (\bar{3}, 1, \frac{1}{3}) + (1, 2, -\frac{1}{2}) \\
 &\quad \text{qd} \qquad \qquad \quad \ell \\
 10 &= (3, 2, \frac{1}{6}) + (\bar{3}, 1, -\frac{2}{3}) + (1, 1, 1) \\
 &\quad \quad \quad \uparrow \qquad \quad \quad \quad \uparrow \\
 &\quad \quad \quad q \qquad \quad \quad \quad u \qquad \quad \quad e
 \end{aligned} \right.
 \end{aligned}$$

$$5 = (\underbrace{3, 1, -\frac{1}{3}}_{\text{colored Higgses } h}) + (\underbrace{1, 2, \frac{1}{2}}_h)$$

$$\mathcal{L} = \bar{5} 10 10$$

I Matter fields:

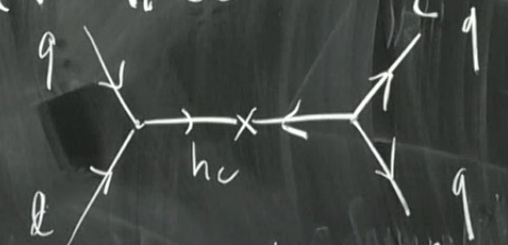
$$\begin{aligned}
 3^+ \left\{ \begin{aligned}
 \bar{5} &= (\bar{3}, 1, \frac{1}{3}) + (1, 2, -\frac{1}{2}) \\
 &\quad \text{quarks } q \quad \text{leptons } l \\
 10 &= (3, 2, \frac{1}{6}) + (\bar{3}, 1, -\frac{2}{3}) + (1, 1, 1) \\
 &\quad \quad \quad \uparrow \quad \quad \quad \uparrow \quad \quad \quad \uparrow \\
 &\quad \quad \quad q \quad \quad \quad u \quad \quad \quad e
 \end{aligned} \right.
 \end{aligned}$$

$$5 = (\underbrace{3, 1, -\frac{1}{3}}_{\text{colored Higgses } h}) + (\underbrace{1, 2, \frac{1}{2}}_{h})$$

$$\mathcal{L} = \underbrace{5 10 10}_{\text{up-type Yukawas}} \lambda_{ij}^u + 5^+ 10 5 \lambda_{ij}^d$$

up-type Yukawas d-type Yukawas

$$5^+_{10} 10^-_5 \rightarrow h^+_{qd} \checkmark + h^+_{le} \checkmark + h^+_{cd} \checkmark + h^+_{ql} ?$$



$$\Gamma \sim \frac{y^2}{16\pi^2} \frac{m_p^5}{M_c^4} \frac{1}{4\pi}$$

$$\Gamma \sim 10^{-1} \frac{(1 \text{ GeV})^5}{(100 \text{ GeV})^4}$$

$$\sim 10^{-9} \text{ GeV} \sim 1 \text{ MeV} \sim 10^{-15} \text{ Hz}$$

$$\langle \Sigma \rangle = v \begin{pmatrix} 1/3 & & & & & \\ & 1/3 & & & & \\ & & 1/3 & & & \\ & & & -1/2 & & \\ & & & & 1/2 & \\ & & & & & 1/2 \end{pmatrix}$$

$$Z 55^+$$

$$T_p > 10^{34} \text{ yrs}$$

$$\frac{dN}{dt} = N T_p$$

so

$$SO(10) \supset SU(5) \times U(1)_{B-L}$$

$$16 : 10 + \bar{5} + 1$$

Pati-Salam: $(SU(4) \times SU(2)_L \times SU(2)_R)$ neutrino

$$(4, 2, 1) \supset q + l$$

$$(4, 1, 2) \supset u + d + e + \nu$$