Title: PSI 2015/2016 More/Beyond Standard Model - Lecture 11

Date: Mar 07, 2016 09:00 AM

URL: http://pirsa.org/16030040

Abstract:

Recall: $\mathcal{L} = \frac{1}{2}|\partial\Phi|^2 - \left(-\mu^2|\Phi|^2 + \frac{\lambda}{2}|\Phi|^4\right)$

$\langle\Phi\rangle = v e^{i\beta}$, $\beta \in [0, 2\pi)$

Expand around $\beta = 0$: $\Phi(x) = \left(v + r(x)/\sqrt{2}\right) e^{i a(x)/\sqrt{2} v}$

$$\mathcal{L} = \frac{1}{2}(\partial r)^2 + \frac{1}{2}\left(1 + \frac{r}{\sqrt{2} v}\right)^2 (\partial a)^2 - V(r)$$

Symmetric under: $r \to r$, $a \to a + \sqrt{2} v \alpha$

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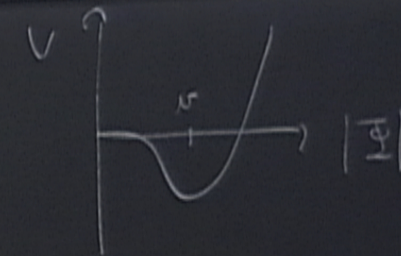

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$$\mathcal{L} = -\frac{1}{4} G^a_{\mu\nu} G^{a\,\mu\nu} + \bar{Q}_L i\gamma^\mu D_\mu Q_L + \bar{Q}_R i\gamma^\mu \partial_\mu Q_R$$

$SU(2)_L \times SU(2)_R \times U(1)_V$ global symmetry.

$$Q_{L,R} = \begin{pmatrix} u_{L,R} \\ d_{L,R} \end{pmatrix}$$

$$\langle \bar{Q}_J Q_I \rangle = \Lambda^3_{QCD}\, \delta_{IJ}$$

$$\mathbb{1} \longrightarrow L\, \mathbb{1}\, R^\dagger$$

$SU(2)_L$: $Q_L \to L\, Q_L$

$SU(2)_R$: $Q_R \to R\, Q_R$

$U(1)_V$: $Q_L \to e^{i\alpha} Q_L$

$Q_R \to e^{i\alpha} Q_R$

$$SU(2)_L \times SU(2)_R \times U(1) \to SU(2)_V \times U(1)_V$$

$\swarrow$

subgroup with $L = R$.

Q_L + $\bar{Q}_R i\gamma^\mu \partial_\mu Q_R$

try $\quad Q_{L,R} = \begin{pmatrix} u_{L,R} \\ d_{L,R} \end{pmatrix}$

$R^\dagger$

$)_R \times U(1) \to SU(2)_V \times U(1)_V$

subgroup with $L=R$

$$\Sigma(x) = \exp\left[2i\,\Pi^a(x)\, t^a/f\right]$$

$$\Sigma(x) \to L\,\Sigma(x)\,R^\dagger$$

$$L = e^{ic_A^a t^a}\, e^{ic_V^b t^b}$$

$$R = e^{-ic_A^a t^a}\, e^{ic_V^b t^b}$$

$C_V^b = 0$

$$\Pi \to \Pi' = \Pi + f\, c_A^a t^a$$

↳ non-linear shift

$$\Pi^a \to \Pi^a(1+\cdots)$$

$C_A^a = 0 \quad \Sigma \to V\Sigma V^\dagger \to \exp\left[2i\,\overbrace{V\,\Pi^a t^a V^\dagger}/f\right]$

$$\partial_\mu \Sigma^\dagger \partial^\mu \Sigma \rightarrow R(\partial_\mu \Sigma^\dagger \partial^\mu \Sigma) R^\dagger$$

$$\mathcal{L}_{p^2} = \frac{f^2}{4} \mathrm{tr}\left(\partial_\mu \Sigma^\dagger \cdot \partial^\mu \Sigma\right)$$

$$= \frac{1}{2}(\partial \pi^a)^2 + \frac{1}{3f^2} \cdot \mathrm{tr}\left[(\partial \pi^a \cdot \pi^a)^2\right] + \cdots$$

$$\sim \frac{p^2}{f^2}$$

$$j^\mu_V = \bar{Q}\gamma^\mu Q \qquad j^{\mu a}_L = \bar{Q}\gamma^\mu P_L t^a Q$$

$$j^\mu_A = \bar{Q}\gamma^\mu\gamma^5 Q \qquad j^{\mu a}_R = \bar{Q}\gamma^\mu P_R t^a Q$$

$$j^\mu_V = i\left(\pi^+\partial^\mu\pi^- - \pi^-\partial^\mu\pi^+\right)$$

$$j^{\mu a}_L = -i\frac{f^2}{2}\,\mathrm{tr}\left(\Sigma^\dagger t^a\partial^\mu\Sigma\right) = f\,\mathrm{tr}\left(t^a\partial^\mu\pi\right) + \ldots$$

$$j^{a\mu}_R = -i\frac{f^2}{2}\,\mathrm{tr}\left(\Sigma t^a\partial^\mu\Sigma^\dagger\right) = \ldots$$

$\sim \frac{p}{f^2}$

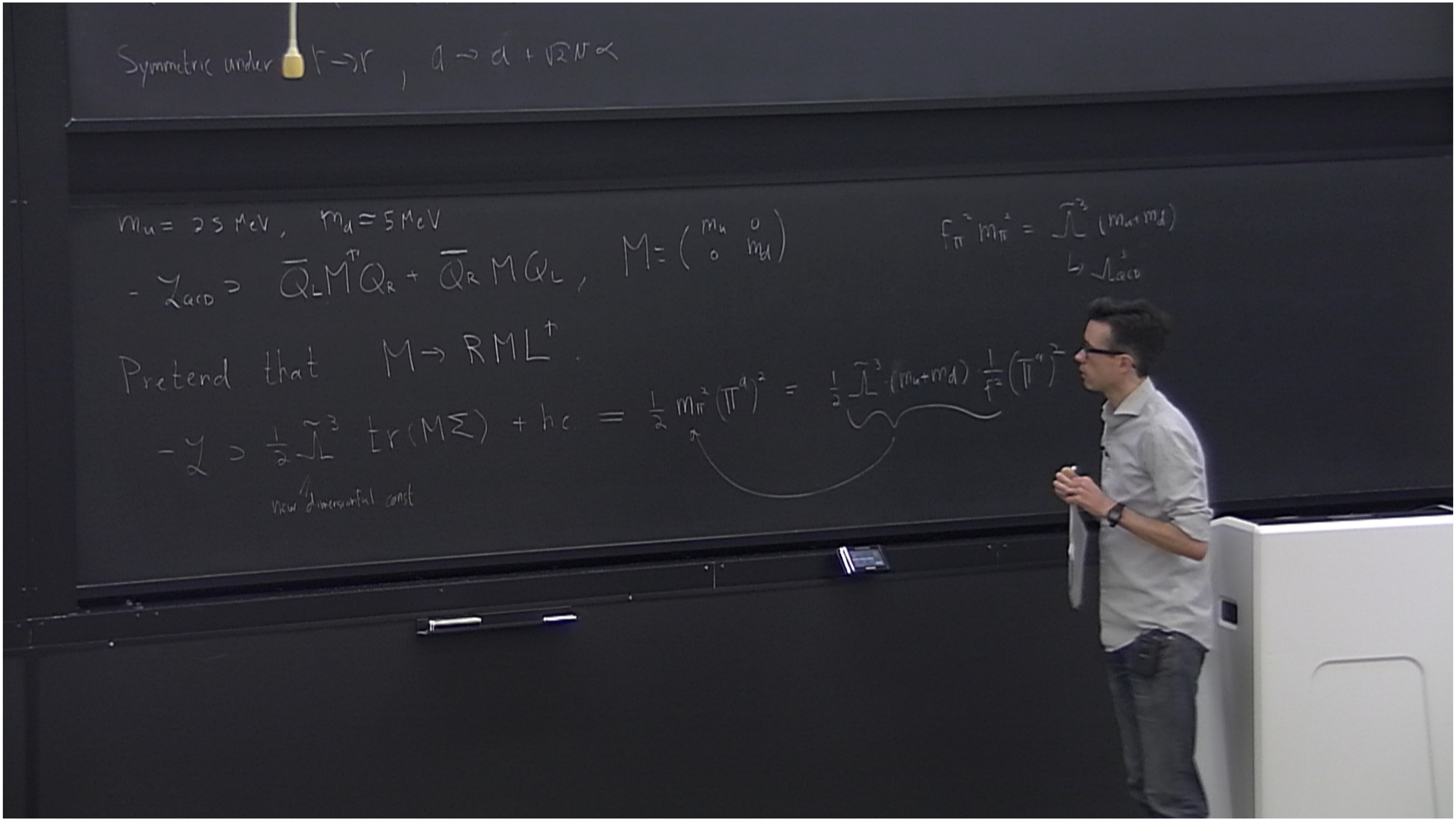
$\bar{Q}\gamma^\mu P_L t^a Q$

$\bar{Q}\gamma^\mu P_R t^a Q$

$\mathrm{tr}(t^a\gamma^\mu \Pi) + \dots$

$$\langle \mu^- \bar{\nu}_\mu | \mathcal{H}_{int} | \pi^-(p)\rangle \sim \Big[\langle \mu^- \bar{\nu}_\mu | \underbrace{\bar{\mu}\gamma_\mu P_L \nu_\mu}_{\text{standard}} |0\rangle\Big]\cdot\Big[\langle 0 | \bar{u}\gamma^\mu P_L d | \pi^-(p)\rangle\Big]$$

$$\mathcal{H}_{int} = \frac{g^2}{m_W^2}(\bar{u}\gamma^\mu P_L d)(\bar{\mu}\gamma_\mu P_L \nu_\mu)$$


Symmetric under r → r , a → a + √2 N α
m_u ≃ 2.5 MeV , m_d ≃ 5 MeV
f_π² m_π² = Λ̃³ (m_u + m_d)
↳ Λ_QCD³
− L_QCD ⊃ Q̄_L M† Q_R + Q̄_R M Q_L , M = (m_u 0 ; 0 m_d)
Pretend that M → R M L† .
− L ⊃ ½ Λ̃³ tr(MΣ) + h.c. = ½ m_π² (π^a)² = ½ Λ̃³ (m_u + m_d) 1/f² (π^a)²
new dimensionful const

$m_s \simeq 110 \text{ MeV}$ $\quad$ ($m_c \simeq 1.2 \text{ GeV}$, $\quad m_b \simeq 4.5 \text{ GeV}$)

$SU(3)_L \times SU(3)_R \times U(1)_V$, mix u, d, s

$$\pi^a t^a = \frac{1}{\sqrt{2}} \begin{pmatrix} \pi^0/\sqrt{2} + \eta/\sqrt{6} & \pi^+ & K^+ \\ \pi^- & -\pi^0/\sqrt{2} + \eta/\sqrt{6} & K^0 \\ K^- & \bar{K}^0 & -2\eta/\sqrt{6} \end{pmatrix}$$