e-EDM induced by octet-colored scalars

Jae Ho Heo, Wai–Yee Keung
PLB 661 259 (2008)[hep-ph/0801.0231]

Jae Ho HEO
University of Illinois at Chicago

PHENO08

Motivation

- *The octet-colored scalars if exist will be copiously produced by LHC in coming years because of its strong interaction and larger color representation.*

A.V. Manohar, PRD 74 035009 (2006)
M. Gerbush, hep-ph/0710.3122
M.I. Gresham, PRD 76 075003 (2007)
B.A. Dorescue, hep-ph/0709.2378

- *When their masses and couplings are determinded, e-EDM measurement could be the key to disclose its nature of the CP violation.*

Theoretical Description

- Yukawa potential

$$\mathcal{L}_Y = -\overline{Q_L}\mathbf{y}_d\left(\phi_d + \eta_d O_d^a T^a\right)d_R - \overline{Q_L}\mathbf{y}_u\left(\tilde{\phi}_u + \eta_u \tilde{O}_u^a T^a\right)u_R + \text{h.c.}$$

O_u, O_d **: octet-colored scalar**

$\mathbf{y}_u, \mathbf{y}_d$ **: Yukawa coupling matrix**

η_u, η_d **: complex constants (trivial)**

T^a **: QCD generator**

A.V. Manohar, PRD 74 035009 (2006)

Z_2 symmetry : $\phi_d \to -\phi_d, O_d \to -O_d, d_R \to -d_R$ odd, others are even

⇩

Minimum flavor violation (MFV) respected (y : digonal matrix in flavor space)

S.L. Glashow, PRD 15 1958 (1977)

Af_Lf_R coupling

Transformation to Higgs Basis

$$\begin{pmatrix} \phi_u \\ \phi_d \end{pmatrix} = \begin{pmatrix} \cos\beta & \sin\beta \\ -\sin\beta & \cos\beta \end{pmatrix} \begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix}$$

$$\tan\beta = \frac{\langle\phi_u\rangle}{\langle\phi_d\rangle}$$

$$\langle\phi_1\rangle = v/\sqrt{2}$$

$$\langle\phi_2\rangle = 0$$

$$v = (\sqrt{2}G_F)^{-1/2} = 246 \ \mathrm{GeV}$$

Three goldstone boson eaten

$$\phi_1 = \begin{pmatrix} 0 \\ \frac{v+h_1}{\sqrt{2}} \end{pmatrix}, \quad \phi_2 = \begin{pmatrix} H^+ \\ \frac{h_2+iA}{\sqrt{2}} \end{pmatrix}$$

Mass eigenstate in Z_2-symmetry conservation for Higgs potential i.e. there is no mixing between CP-odd and even scalars.

Af_Lf_R coupling :

$$-\left[\tan\beta\left(\frac{m_e}{v}\bar{e}i\gamma_5 e + \frac{m_d}{v}\bar{d}i\gamma_5 d\right) + \cot\beta\frac{mu}{v}\bar{u}i\gamma_5 du\right] A$$

Higgs potential and *AOO* coupling

A lot of CP-violation sources in Higgs potential, but we need AO_lO_lcoupling

$$\mathcal{L} \supset \eta(\phi_u^\dagger \phi_d)(O_d^\dagger O_u) + \eta'(\phi_d^\dagger \phi_u)(O_d^\dagger O_u) + \text{h.c.}$$

Diagonalize the octet scalars

Z_2-symmetry conservative

η, η' **: complex constants**

there are two complex phase, but one phase is abosrbed by the global field rotation. So only one phase survives.

The unitary diagonalizaton transformation

$$\begin{pmatrix} O_u \\ O_d \end{pmatrix} = \begin{pmatrix} \cos\psi & \sin\psi\, e^{i\delta} \\ -\sin\psi\, e^{-i\delta} & \cos\psi \end{pmatrix} \begin{pmatrix} O_\ell \\ O_h \end{pmatrix}$$

δ : phase difference between complex couplings

ψ : rotation angle between two bases

AOO coupling : $\frac{1}{2}\lambda v \sin 2\psi \sin\delta A(O_\ell^\dagger O_\ell - O_h^\dagger O_h)$ where $|\eta' - \eta| \equiv \lambda$

desirable CP-phase

Barr-Zee Mechanism

Barr,Zee PRL 65 21 (1990)
Chang,Keung,Pilaftsis PRL 82 900 (1999)

$$\mathcal{L}_{CP} = -\tan\beta\frac{m_e}{v}\bar{e}i\gamma_5 eA + \frac{1}{2}\lambda v \sin 2\psi \sin\delta(O_\ell^\dagger O_\ell - O_h^\dagger O_h)A$$

$$\mathcal{L}_{\rm eff} \supset -\frac{i}{2}d_f\left(\bar{f}\sigma^{\mu\nu}\gamma_5 f\right)F_{\mu\nu}$$

EDM

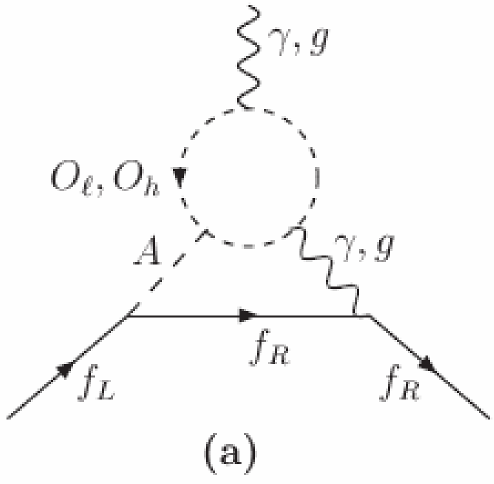

Figure 1: Two-loop contributions to EDM and CDM by octet-colored scalars (mirror graphs are not displayed.)

Electron electric dipole

Summed of eight color channels of O

Evaluating the Barr-Zee diagrams,

$$\left(\frac{d_e}{e}\right) = -\frac{\alpha\lambda m_e}{8\pi^3 m_A^2}\tan\beta\sin(2\psi)\sin\delta\left[F\left(\frac{m_{O_\ell}^2}{m_A^2}\right) - F\left(\frac{m_{O_h}^2}{m_A^2}\right)\right]$$

Chang,Keung,Pilaftsis, PRL 82 900 (1999)

Two-loop function :

$$F(z) = \int_0^1 \frac{x(1-x)}{z - x(1-x)} \log\frac{x(1-x)}{z}$$

The asymptotic behavior :

$$F(z) \longrightarrow \begin{cases} -0.344 & \text{as } z = 1 \\ -\frac{1}{6z}\ln z - \frac{5}{18z} & \text{for } z \gg 1 \\ (2 + \ln z) & \text{for } z \ll 1 \end{cases}$$

About neutron (C)EDM

The rescaled quark EDMs by electric charge and mass w.r.t. electron EDM

$$\left(\frac{d_{d,s}}{d_e}\right) = \left(\frac{-\frac{1}{3}}{-1}\right)\left(\frac{m_{d,s}}{m_e}\right) , \qquad \left(\frac{d_u}{d_e}\right) = \frac{1}{\tan^2\beta}\left(\frac{\frac{2}{3}}{-1}\right)\left(\frac{m_u}{m_e}\right)$$

$$d_n = \frac{1}{3}(4d_d - d_u)\eta^E , \quad d_n^C = \frac{2}{9}(2d_d^C + d_u^C)\eta^C$$

The neutron EDM could be induced by the quark EDMs. But
Due to the sophiscated hadron physics, only a qualitative relation
between the neutron EDM and the CP violating coefficients.
So we neglect the quantitative analysis here.

Electron EDM prediction

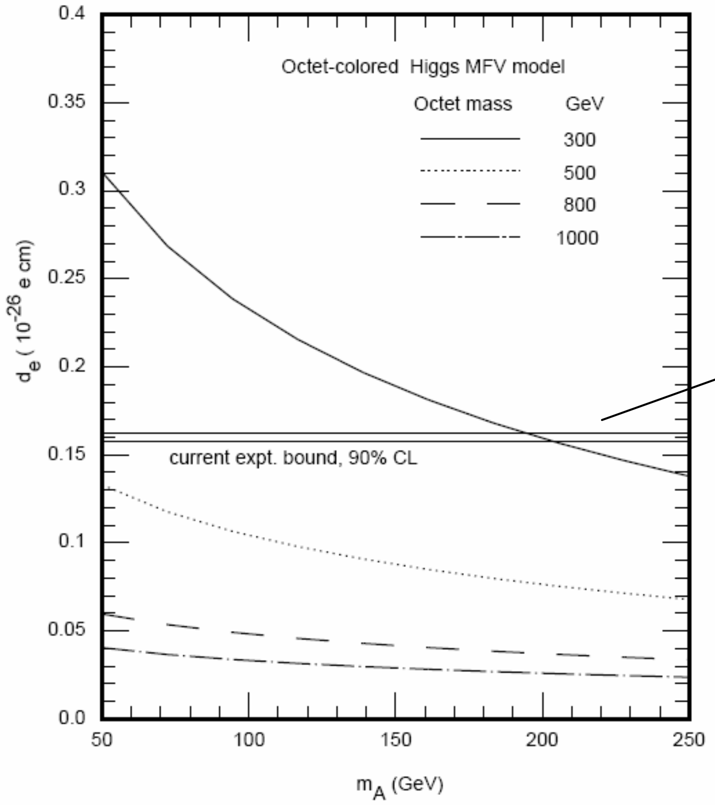

Figure 2: Predicted electron EDM versus m_A for various $m_O = 300$ (solid), 500 (dotted), 800 (dashed), 1000 (dashed-dotted) GeV, with $\lambda \tan\beta \sin(2\psi) \sin\delta = 1$. The horizontal double-line is the present experimental upper bound.

- The neutral pseudoscalar *A* is not constrained from LEP data, so choose light values

B.C. Regan, *et al*, PRL 88 071805 (2002)

- The predicted *e-EDM* is well below experimental sensitivity.

- Expected a sizable *e-EDM* by octet-colored scalars

CONCLUSION

- A simple model with an appended sector of two octet-colored scalars are built under Z_2-symmetry, MFV.
- The octet-colored scalars could generate a sizable *e-EDM* via Barr-Zee mechanism.
- Similary the *q-EDMs* are predicted, which provide *n-EDM*.