Symmetry in Standard Model

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Review

- Electroweak + Higgs

  SU(2) YM interaction for All left-handed fermion

  Higgs gives fermions & gauge bosons mass

  -> Yukawa interaction

- Strong interaction

  SU(3) YM interaction for only quarks

- Problems and topics in two "sectors"

Role of Symmetry in QM

- Poincaré group

  All particle are a irrep of Poincaré group : m, j

- other symmetry : charge, C, P, T, ...

- Action should be **invariant** under all the symmetrys

  finding All symmetry-preseving possible term

  pick relevant & marginal terms (renormalization)

Why Higgs should come out?

- weak interactions : SU(2) symmetry, **only for left-handed** fermion

- left handed fermion : doublet $\begin{pmatrix} u_L \\ d_L \end{pmatrix}$ $\begin{pmatrix} e_L \\ \nu_e \end{pmatrix}$
- right handed fermion : singlet u_R, d_R, e_R

- mass term : left x right coupling $m\,\bar{f}_R\,f_L + m\,\bar{f}_L\,f_R$

-> can't put SU(2) invariant term without aditional SU(2) doublet

symmetry tells us there is a SU(2)-doublet scalar field $\begin{pmatrix} \phi_+ \\ \phi_0 \end{pmatrix}$

mass term by higgs field

- $\begin{pmatrix} u_L \\ d_L \end{pmatrix}$ 와 $\begin{pmatrix} \phi_+ \\ \phi_0 \end{pmatrix}$ 내적
- $g_d(\overline{u_L} \quad \overline{d_L}) \begin{pmatrix} \phi_+ \\ \phi_0 \end{pmatrix} d_R$
- $g_u(\overline{u_L} \quad \overline{d_L}) \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} \phi_+ \\ \phi_0 \end{pmatrix} u_R$
- $g_d v\, \overline{d_L} d_R$, $g_u v\, \overline{u_L} u_R$

mass term with
SU(2) symmetry!

symmetry in SM

- SU(2)xSU(3)xU(1) : gauge symmetry
- SU(2)xU(1): broken by Higgs , U(1) "electric" charge left
- SU(3) : only scalar (simplest) left by "confinement"
- Baryon number
- Lepton number
- CPT, Poincaré group

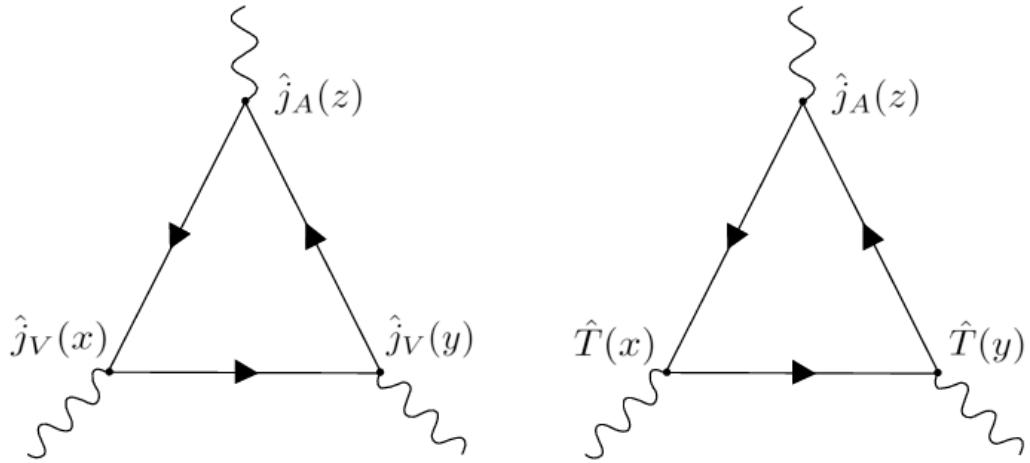
Anomally

- the **failure** of a **symmetry** of a theory's **classical action** to be a symmetry of any regularization of the **full quantum theory**.

- why? the path integral measure

$$Z = \int D\varphi \, e^{iS[\varphi]}$$

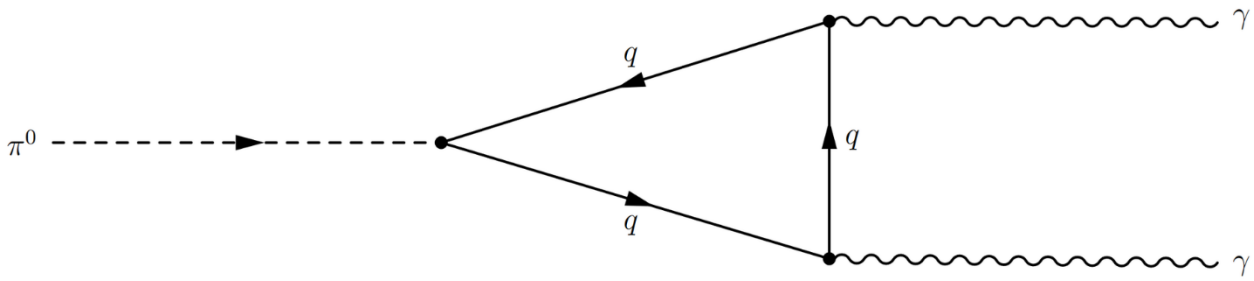
- include Non-perturbative effect!



- Anomally for Global / Gauge symmetry

Global anomally in SM

- newtral pion decay

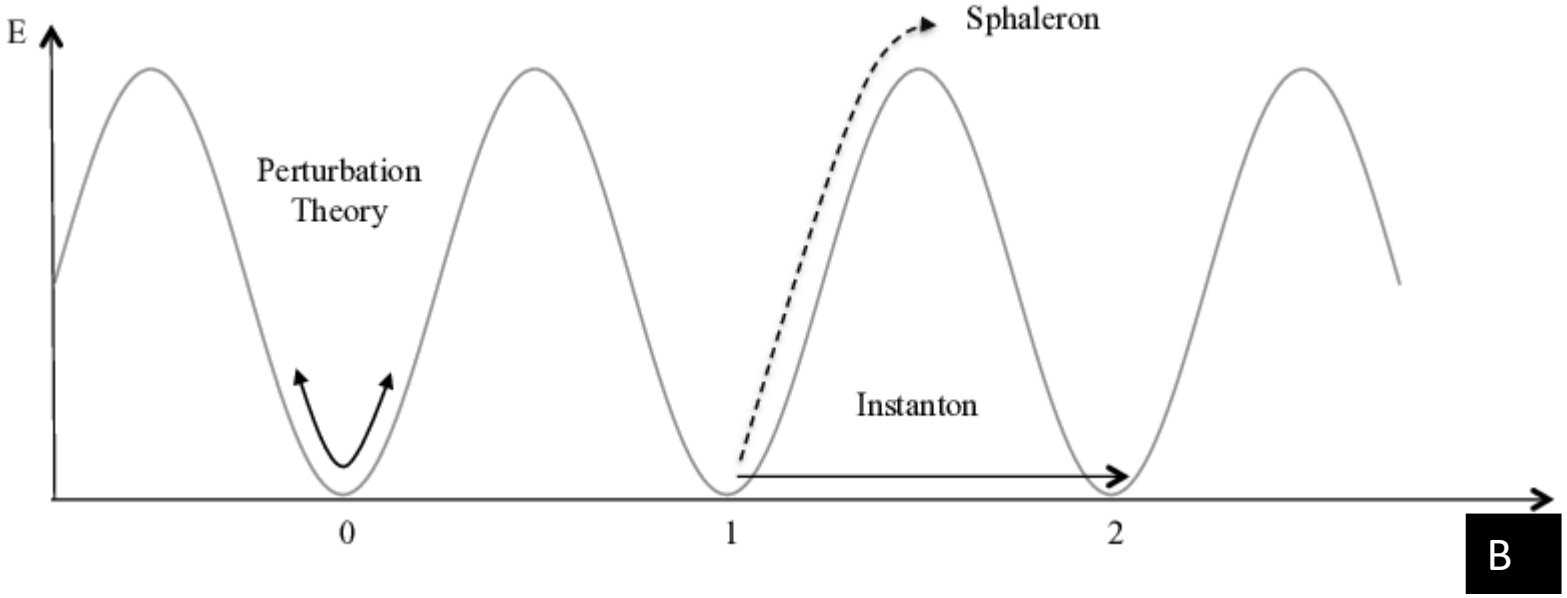


- B,L non-conservation

axial current non-censervation

- B-L is

- Why a



Gauge Anomaly Cancellation

- theory is not consistent with Gauge Anomaly

- Anomaly cancellation condition

$$Tr\ T^a\{T^b, T^c\} = 0$$ for All a,b,c in U(1)xSU(2)xSU(3)

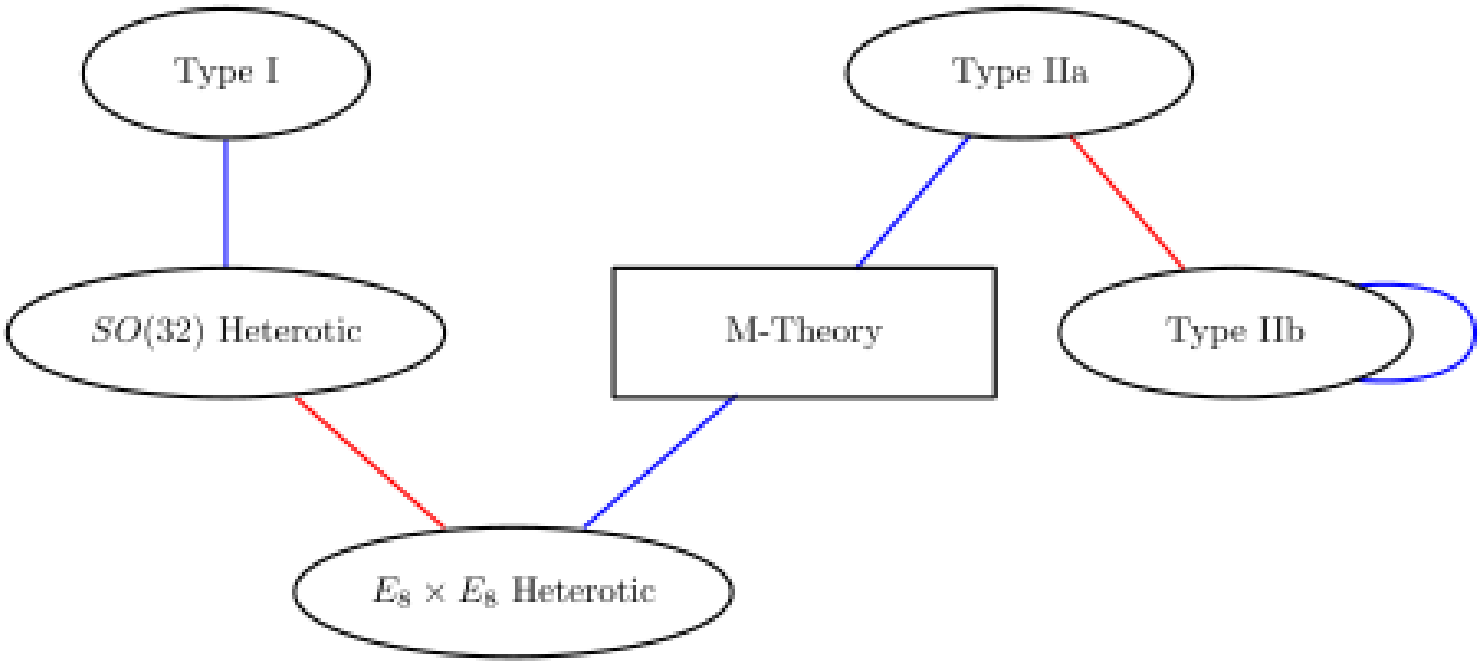
can check for SM

equation for fermion charges, ...

Anomaly cancelation of GUT, String, …

- constrain the gauge group

- one of a "signpost" beyond GUT



10-dim spacetime

SO(32)

E8 x E8