

LECTURE 2.

THE MSSM

Φ : chiral SF

V : vector SF

↑
superpot

Lagrangian:

$$\int d^2\theta W(\Phi) + \int \phi^\dagger \phi d^4\theta$$

$$= \int \phi^\dagger \phi d^4\theta + i\bar{\Psi} \bar{\sigma}_\mu \partial_\mu \Psi - \sum_i \left| \frac{\partial W}{\partial \varphi_i} \right|^2$$

e.g.
 $W = \phi^3$

$$\underbrace{\frac{\partial^2 W}{\partial \varphi_i \partial \varphi_j}}_{\text{Yukawa couplings}} \psi_i \psi_j - \sum_i \left| \frac{\partial W}{\partial \varphi_i} \right|^2$$

ϕ carries $U(1)$ charge

$$\phi \rightarrow e^{i\Lambda} \phi$$

under $U(1)$ Λ will be
(like a \mathbb{R}^1 SF)

$$\phi^+ \phi \rightarrow e^{\boxed{-i(\Lambda - \Lambda^+)}}$$

$$\phi^+ \phi$$



$$\int \phi^+ e^{\Lambda} \phi d^2\theta$$

Λ is vector SF.

$$\boxed{V \rightarrow V + i(\Lambda - \Lambda^+)}$$

$$A_\mu \rightarrow A_\mu + \partial_\mu \epsilon$$

$$V = -\theta \sigma^\mu \bar{\theta} V_\mu + i\theta^2 \bar{\theta} \bar{\lambda} - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

(Wess-Zumino gauge)

Kinetic term for

V ?

formally make a χ SF

$$W_\alpha = -\frac{1}{4} \bar{D} \bar{D} D_\alpha V$$

↑

usual SF

$$V = V^\dagger$$

$$\bar{D} W_\alpha = 0$$

$$\int W_\alpha W^\alpha d^2\theta$$

=

$$= -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\chi} \bar{\sigma}_m \partial_m \chi$$

MARKUP:

Lagrangian

for SQED?

U(1) gauge theory

→ V

→

photon
photino

V_m
 χ

ϕ_- electron
 ϕ_+ positron

kinetic term for gauge field +
 + gauginos

$$(1) = \int 1/4 (W_\alpha W^\alpha + h.c.) d^2\theta$$

$$(2) = + \int (\phi_+^\dagger e^{eV} \phi_+ + \phi_-^\dagger e^{-eV} \phi_-) d^4\theta$$

$$(3) = + \int m \phi_+ \phi_- d^2\theta + h.c.$$

$W(\phi)$

in component language

(keep F, D)

$$(1) = -1/4 (F_{\mu\nu})^2 + i \bar{\lambda} \bar{\sigma}_m \partial_m \lambda + 1/2 D^2$$

$$(2) = |D_\mu \phi_+|^2 + |D_\mu \phi_-|^2 + i \bar{\psi}_+ D_m \bar{\sigma}_m \psi_+ + i \bar{\psi}_- D_m \bar{\sigma}_m \psi_-$$

$$-i \frac{e}{\sqrt{2}} (\psi_+ \bar{\psi}_+ \bar{\lambda} - \psi_- \bar{\psi}_- \bar{\lambda}) + h.c. + \frac{e}{2} D (|\varphi_+|^2 - |\varphi_-|^2) + F_+^\dagger F_+ + F_-^\dagger F_-$$

$$(3) = m (\psi_+^\dagger \psi_- + \psi_-^\dagger \psi_+ - \psi_+ \psi_-) + \text{h.c.}$$

integrate out D & F

$$\frac{1}{2} D^2 + \frac{e}{2} D (|\psi_+|^2 - |\psi_-|^2)$$

$$V_D = \frac{e^2}{2} (|\psi_+|^2 - |\psi_-|^2)^2$$

Also integrate out F

$$V_F = \sum_i \left| \frac{\partial W}{\partial \varphi_i} \right|^2 =$$

$$m^2 (|\psi_+|^2 + |\psi_-|^2)$$

Same mass for

selection & position

Dirac spinor with mass m

The MSSM matter content

	$SU(3)$	$\times SU(2)_L$	$\times U(1)_Y$
\bar{L}	1	2	$-\frac{1}{2}$
\bar{E}	1	1	+1
\bar{D}	3	2	$\frac{1}{6}$
\bar{U}	3	1	$-\frac{2}{3}$
\bar{D}	3	1	$+\frac{1}{3}$
\bar{H}_u	1	2	$\frac{1}{2}$
\bar{H}_d	1	2	$-\frac{1}{2}$

anomaly free!

$N = ?$

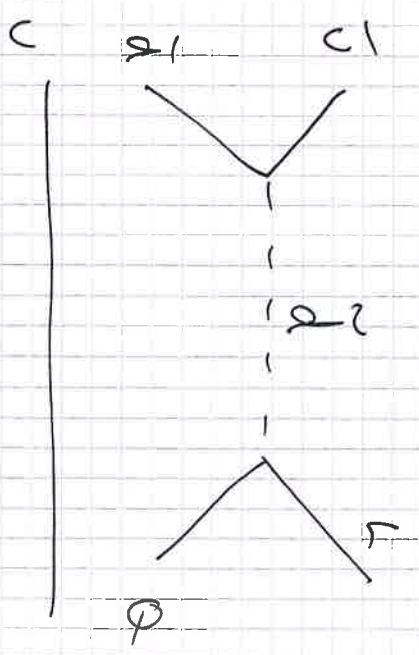
$$N^{(good)} = \chi_0 \bar{Q} H_u \bar{U} + \chi_d \bar{Q} H_d \bar{D} + \chi_e \bar{L} H_d \bar{E} + \mu H_u H_d$$

$$N_{\text{loop}} = \kappa \bar{Q} \bar{L} \bar{D} + \lambda \bar{L} \bar{L} \bar{E} + \kappa' \bar{U} \bar{D} \bar{D} + \mu \bar{L} H_u$$

$\Delta L = 1$

$\Delta B = 1$

give rise to proton decay



$$p^+ \rightarrow e^+ \pi^0$$

impose additional Z_2 symmetry!

$$Q, L, \bar{U}, \bar{D}, E \rightarrow \begin{pmatrix} + \\ - \end{pmatrix} \quad H_{u,d} \rightarrow \begin{pmatrix} + \\ - \end{pmatrix}$$

Matter parity

$$P_M = (-1)^{3(B-L)}$$

$$P_R = (-1)^{3(B-L) + 2S}$$

S Spin of component.

Lorentz sym. every vertex
even # of fermions

R-parity!

(SM fields)

→ +1

(Super partners)

→ -1

- every vertex → even # of superpartners!

- Super partners have to be pair produced!

- LSP must be stable!

- SUSY predicts WIMP candidate!

SUSY breaking

SUSY not exact!

Should be broken

$$\langle 0 | H | 0 \rangle = 0$$

SUSY unbroken

$$\langle 0 | H | 0 \rangle > 0$$

SUSY broken.

$$V = V_F + V_D$$

$$\sum_i \left| \frac{\partial W}{\partial \varphi_i} \right|^2 + \sum_i \left| \frac{\partial \Phi}{\partial \varphi_i} \right|^2 + \tau a \phi_i^2$$

SUSY unbroken

$$\text{STR } M^2 = 0$$

particles & sparticles

bad relation

- renormalizable interactions
- tree-level