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MSSM

		SU(3)	SU(2)	U(1)
	Q^i	3	2	$\frac{1}{6}$
	$\bar{u}^{\,i}$	$\bar{3}$	$\diagup$	$-\frac{2}{3}$
3 families	$\bar{d}^{\,i}$	$\bar{3}$	$\diagup$	$\frac{1}{3}$
	L^i	$\diagup$	2	$-\frac{1}{3}$
	$\bar{e}^{\,i}$	$\diagup$	$\diagup$	1
	$H_{(u)}$	$\diagup$	2	$\frac{1}{2}$
	$H_{(d)}$	$\diagup$	2	$-\frac{1}{2}$

$\bar{u}$ does not mean complex conjugation. $\bar{u}$ contains a boson and a fermion. $\bar{u} = \bar{u}$, $\psi_{\bar{u}} = \tilde{\bar{u}}$, $\bar{u}$.

$$\to \psi_{\bar{u}}\psi_{\bar{d}}\bar{d} + \bar{u}\psi_{\bar{d}}\psi_{\bar{d}} \text{ Yukawa}$$

Cubic $Q\ \bar{u}\bar{d}L\bar{e}$ in W: $\lambda_{ijk}\ L^i_\alpha\ L^j_\beta\ \bar{e}^{\,k}\ \varepsilon^{\alpha\beta}$, $\lambda'_{ijk}\ L^i_\alpha\ Q^{ja}_\beta \bar{d}_a^{\,k}\varepsilon^{\alpha\beta}$, $\lambda''_{ijk}\bar{u}_a^{\,i}\ \bar{d}_b^{\,j}\ \bar{d}_c^{\,k}\ \varepsilon^{abc}$. α not spin but $\mathrm{SU}(2)_W$.

$$g_a^{a'}\bar{u}_{a'}g_b^{b'}\bar{d}_{b'}g_c^{c'}\bar{d}_{c'}\varepsilon^{abc} = \det(g)\varepsilon^{a'b'c'}\bar{u}_{a'}\bar{d}_{c'}\bar{d}_{d'}$$

We do not want these terms. Give rise to proton decay within milliseconds.

$$p\!: \quad \begin{matrix}\psi_u\\ \psi_u\\ \psi_d\end{matrix}$$

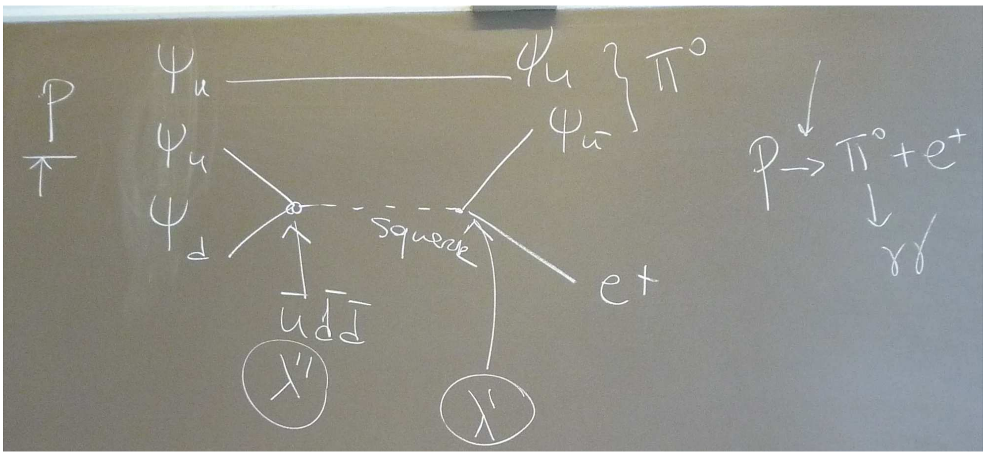

Figure 1.

$\mu^- \nrightarrow e^- + \gamma$.

W with 1 higgs. In Standard Model $\mathcal{L}_{\text{Yukawa}} = \psi_Q H \psi_{\bar{u}}, \psi H^\dagger \psi_{\bar{d}}, \psi_L H^\dagger \psi_{\bar{e}}$.

$$W = Q\, H\, \bar{u}\, , Q\, \cancel{H}^\dagger\, \bar{d}\, , L\, \cancel{H}^\dagger \bar{e}$$

$$Q\, H_u \bar{u}\, , \quad Q\, H_d\, \bar{d}\, , \quad L\, H_d\, \bar{e}$$

$$+ \mu H_u H_d \quad :\mu\text{-term}$$

Good	Bad
$Q\, H_u\, \bar{u}$	$L\, L\, \bar{e}$
$Q\, H_d\, \bar{d}$	$L\, Q\, \bar{d}$
$\mu\, H_u H_d$	$\bar{u}\, \bar{d}\, \bar{d}$
	$L\, H_u$

$\psi \rightarrow \mathrm{e}^{i\alpha}\psi$, $\bar{\psi} \rightarrow e^{-\mathrm{i}\alpha}\bar{\psi} \Rightarrow Q$ conserved, because of symmetry.

R-parity: $R(\text{SM}) = 1$, $R(\text{superpartners}) = -1$.

b	f
$\tilde{Q}$	Q
-1	$+1$
H	$\tilde{H}$
$+1$	-1

R conserved.

a) superpartners pair produced.

b) an $R = -1$ particle can decay into a host of ordinary particles, but you cannot change R-parity. So at the end of the day one $R = -1$ particle remains. The lightest superparticle is stable. Neutralino.

$$W(\phi...) \rightarrow \psi\psi W'' + |W'|^2$$

$$Q\, H_u\, \bar{u} \xrightarrow[\text{VEV}]{\text{Higgs}} m\, u\, \bar{u} \quad m\psi_{u\bar{u}} \quad m^2(u^* u + \bar{u}^* \bar{u})$$

$$\mathcal{L}_{\text{soft}} = -\frac{1}{2}\Big(M_3 \tilde{g}\tilde{g} + M_2 \tilde{W}\tilde{W} + M_1 \tilde{B}\tilde{B} \Big) - \Big(m_{Q^2}^{ij} \tilde{Q}_i^\dagger \tilde{Q}_j + m_{\bar{e}}^{?ij} \tilde{\bar{e}}_i \tilde{\bar{e}}_j \Big) -$$

$$- \Big(a_4^{ij} \tilde{\bar{u}} \tilde{Q}_j H_u + a_d \tilde{\bar{d}}_i \hat{Q}_j H_d + a_e\, \tilde{\bar{e}} \tilde{L}_j H_d + \text{complex conjugate} \Big)$$

$$- \Big(m_u^2 H_u^\dagger H_u + m_d^2 H_d^\dagger H_d + b\, H_u H_d \Big)$$

$$W = \mu H_u H_d \rightarrow \mu \tilde{H}_u \tilde{H}_d$$

$\mathcal{L}_{\text{soft}}$ is very constrained by LEP measurements. FCNC: Flavour changing neutral currents. EWPT, $\cancel{C}\cancel{P} \Rightarrow$ "all parameters are real".

A process like (1) $\mu^- \rightarrow e^- + \gamma$ has never been observed. We have (2) $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$.

$$\Gamma(2) = \frac{1}{192\pi^3} G_F^2 m_\mu^5 = \frac{1}{\tau} = \frac{1}{10^{-6}\text{ s}}$$

Branching ratio

$$= B(1) = \frac{\Gamma(1)}{\Gamma(\text{tot})} = \frac{\Gamma(1)}{\Gamma(2)} < 1.2 \times 10^{-11}$$

according to experiments.

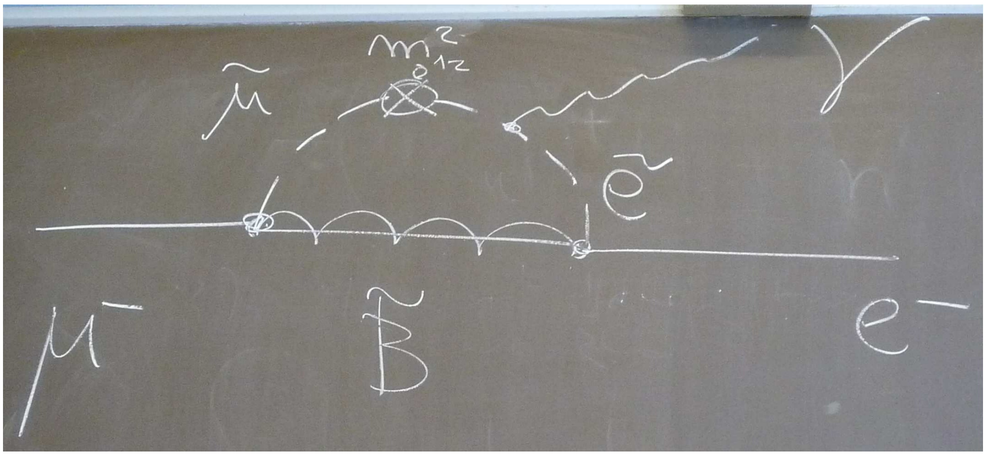

Figure 2.

$$m^2_{Q\,ij} = m^2_Q \mathbf{1}_{3\times 3} + \cdots ?$$

Particle spectrum

gluon $\rightarrow$ gluino

Higgs sector

$$H = \begin{pmatrix} H^0 \\ H^+ \end{pmatrix}$$

(complex). $\langle H^0 \rangle = v$. 3 fields eaten by W^+, W^-, Z^+ via higgs $\rightarrow 1$ neutral h, “the Higgs”.

MSSM

$$H_u = \begin{pmatrix} H_u^0 \\ H_u^+ \end{pmatrix}, \quad H_d = \begin{pmatrix} H_d^- \\ H_d^0 \end{pmatrix}$$

Each one of these is a complex field. Real: 8 fields. 4 charged, 4 neutral. $\rightarrow H^{\pm}$, 2 charged, 3 (h^0, H^0, A^0).