Title: Beyond Standard Model-4

Date: Feb 20, 2015 09:00 AM

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Abstract:

Supersymmetry

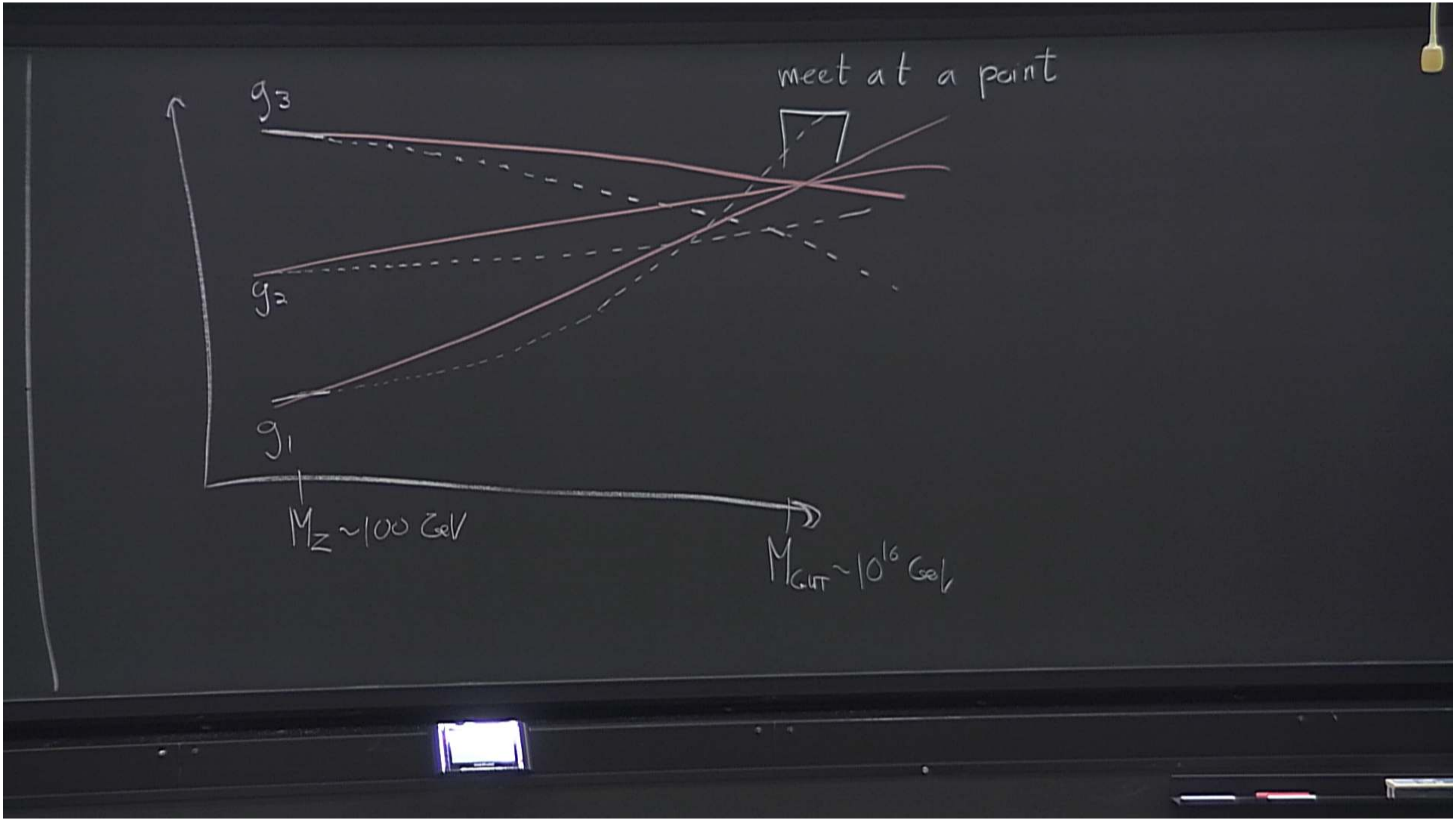
particle $\longrightarrow$ superpartner

$$V = -\mu^2 |H|^2 + \frac{\lambda}{2} |H|^4$$

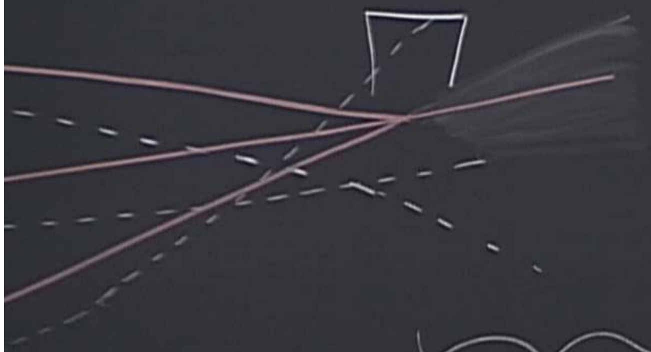
$\Psi, \tilde{\Psi}$:

y_Ψ

$$\Delta\mu^2 \simeq \underbrace{\frac{y_\Psi^2}{(4\pi)^2}\left(M_{\tilde{\Psi}}^2 - M_\Psi^2\right)}_{\lesssim (100\,\mathrm{GV})^2}$$


meet at a point
g3
g2
g1
Mz ~100 GeV
MGUT ~10^16 GeV

meet at a point



$\underbrace{\qquad\qquad}_{SU(5)}$

$$\overset{8}{SU(3)_c} \times \underbrace{\overset{3}{SU(2)_L} \times \overset{1}{U(1)_Y}}_{U(1)_{em}} \subset \overset{24}{SU(5)}$$

$SO(10)$

E_6

$\vdots$

"grand unification"

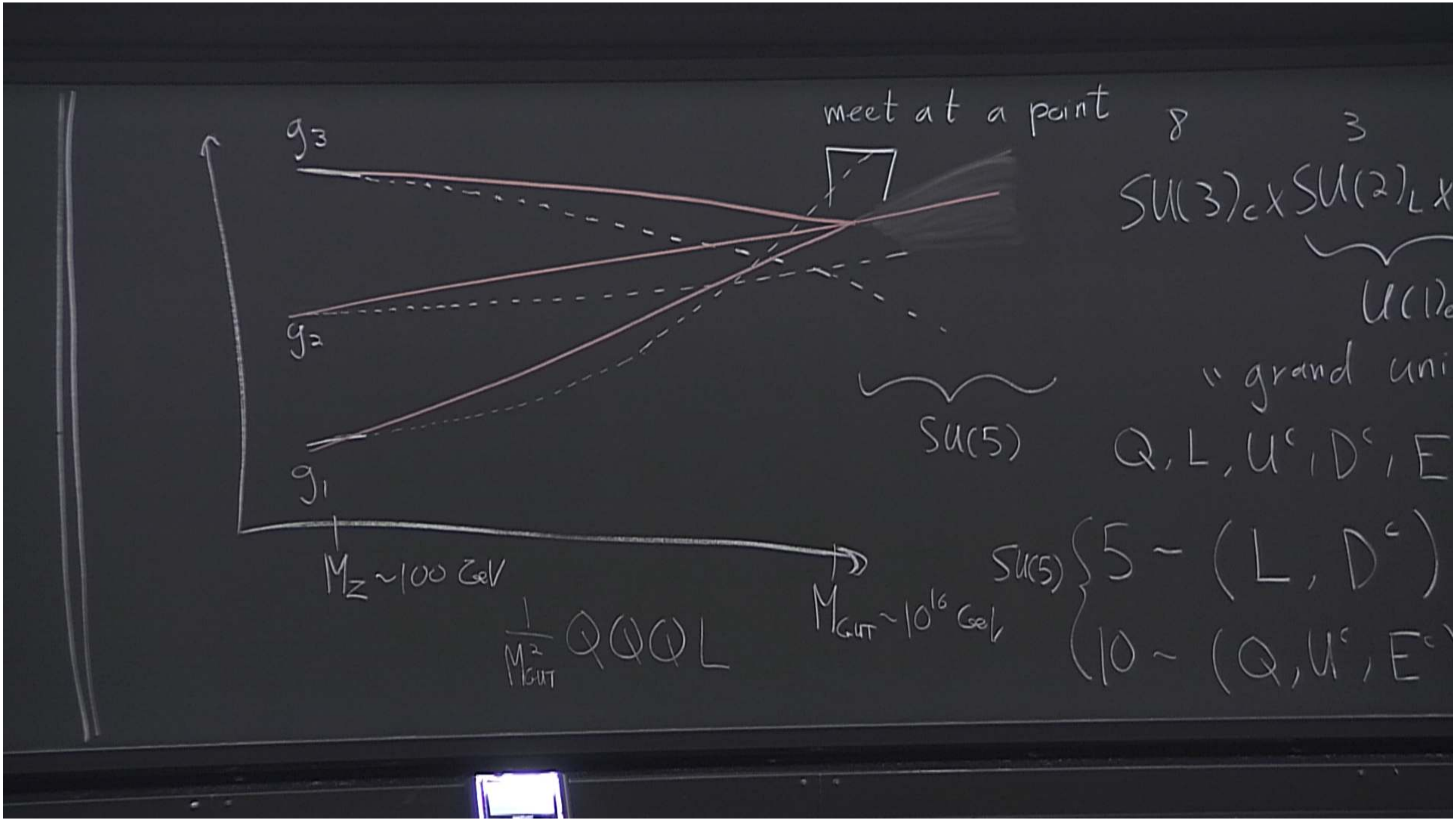
Q, L, U^c, D^c, E^c

$\Rightarrow$ $M_{GUT} \sim 10^{16}$ GeV

$$SU(5) \begin{cases} 5 \sim (L, D^c) \\ 10 \sim (Q, U^c, E^c) \end{cases}$$

$SO(10)$: 16

$\hookrightarrow (Q, U^c, D^c, L, E^c, N)$


meet at a point
8
3
g3
SU(3)c x SU(2)L x
U(1)
g2
"grand uni
SU(5)
g1
Q, L, U^c, D^c, E
Mz ~ 100 GeV
SU(5) 5 ~ (L, D^c)
MGUT ~ 10^16 GeV
1/M^2GUT QQQL
10 ~ (Q, U^c, E^c

Poincaré: translations + Lorentz

P^μ $\qquad$ $J^{\mu\nu} = -J^{\nu\mu}$

$\hookrightarrow$ 6 elements
$\quad = $ 3 rotations + 3 boosts

$$\underbrace{\phi(x),\ \psi_\alpha(x),\ \bar{\psi}^{\dot\alpha}(x)}_{\Psi = \begin{pmatrix} \psi_\alpha \\ \bar{\chi}^{\dot\alpha} \end{pmatrix}},\ A^\mu,\ \ldots$$

Poincaré × (gauge/global)

Combine? $\psi \to e^{i\alpha}\psi$

No (almost). Coleman + Mandula theorem

↳ loophole: fermionic generators

Haag, ...

Supersymmetry!

Q^{A}_{α} , $\bar{Q}^{\dot{\beta}}_{B}$ = SUSY generators. $A, B = 1, 2, \ldots, N$ = # supersym

Lie Group

$$\begin{cases} U(\alpha^a) = e^{-i\alpha^a t^a} = (1 - i\alpha^a t^a + \ldots) \\ U(\alpha^a = 0) = 1 \\ [t^a, t^b] = i f^{abc} t^c \end{cases}$$

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↓

Lie algebra

$$\alpha^a t^a + \xi^\alpha Q_\alpha$$

Lie supergroup

↳ Lie superalgebra

... , $\mathcal{N}$ = # supersymmetries

$+ \ \xi^\alpha Q_\alpha$

ralgebra

$$\{Q^A_\alpha, \bar{Q}_{\dot\beta B}\} = 2\sigma^\mu_{\alpha\dot\beta} P_\mu \delta^A{}_B$$

$$\{Q^A_\alpha, Q^B_\beta\} = 0 = \{\bar{Q}^{\dot\alpha}_A, \bar{Q}^{\dot\beta}_B\}$$

$$[P_\mu, Q^A_\alpha] = 0 = [P_\mu, \bar{Q}^{\dot\beta}_B]$$

persymmetries

$\mathcal{N} = 1$ SUSY

$d = 4$

$$\{Q^A_\alpha, \bar{Q}_{\dot\beta B}\} = 2\sigma^\mu_{\alpha\dot\beta} P_\mu \delta^A{}_B$$

$$\{Q^A_\alpha, Q^B_\beta\} = 0 = \{\bar{Q}^{\dot\alpha}_A, \bar{Q}^{\dot\beta}_B\}$$

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$\mathcal{N}=1$ SUSY

$d=4$

$\hookrightarrow Q_\alpha, \bar{Q}_{\dot\beta}$

1. Any gauge/global sym. generators must commute with $P_\mu, J_{\mu\nu}$

$\Rightarrow$ all members of a supermultiplet must have the same globa

2. P^2 commutes with all generators. $\rightarrow$ all elements of a super

$\sim(\text{mass})^2$

3. Number of fermionic and bosonic degrees of freedom in any mu

4. SUSY invariance: $Q_\alpha|0\rangle = 0 \Rightarrow \langle 0|H|0\rangle = 0$

m. generators must commute with $P_\mu, J_{\mu\nu}, Q_\alpha, \bar{Q}_{\dot\beta}$.

a supermultiplet must have the same global/gauge charge. (exception: R-symmetries...)

ll generators. $\Rightarrow$ all elements of a supermultiplet must have the same mass.

and bosonic degrees of freedom in any multiplet are equal.

$_\alpha |0\rangle = 0 \Rightarrow \langle 0|H|0\rangle = 0$

$Q_\alpha \sim$ fermion

$Q\,|\text{boson}\rangle \sim |\text{fermion}\rangle$

$Q\,|\text{fermion}\rangle \sim |\text{boson}\rangle$

$\delta_\xi \phi \sim \xi \psi$

$\delta_\xi \psi \sim \sigma^\mu \bar{\xi}\, \partial_\mu \phi$

Wess + Bagger, Martin (1997)

$\underset{\text{chiral}}{\Phi} = (\phi, \psi, F)$

$\underset{\text{vector}}{V} = (\lambda, A^\mu, D)$