New bosons

In SM, we have 3 different gauge groups with 3 coupling constants:

$\Rightarrow$ SU(3)xSU(2)xU(1) subgroup of a unifying group with one g.

Grand Unified Theory (GUT): SU(5), SO(10), E$_6$ etc....

- **Spontaneous breakdown to $\mathrm{G_{SM}}$ at $\mathrm{M_U}$: intermediate scale?.**

$$\mathbf{E_6 \to SO(10) \times U(1)_\psi \to SU(5) \times U(1)_\chi \times U(1)_\psi}$$
$$\mathbf{\to SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_{Y'}}$$

Only one light gauge boson: $\mathbf{Z' = Z'_\chi \cos\beta + Z'_\psi \sin\beta}$

$\beta = 0 \to Z'_\chi$, $\beta = \pi/2 \to Z'_\psi$ **and** $\beta = \arctan(-\sqrt{5/3}) \to Z'_\eta$

- **LR symmetry:** $\mathrm{SO(10) \to SU(2)_R \times SU(2)_L \times U(1)_{B-L}}$

neutral Z'_{LR} **but also new charged gauge bosons** $W^\pm_{LR}$

- **In models of extradimensions: towers of Kaluza–Klein excitations**

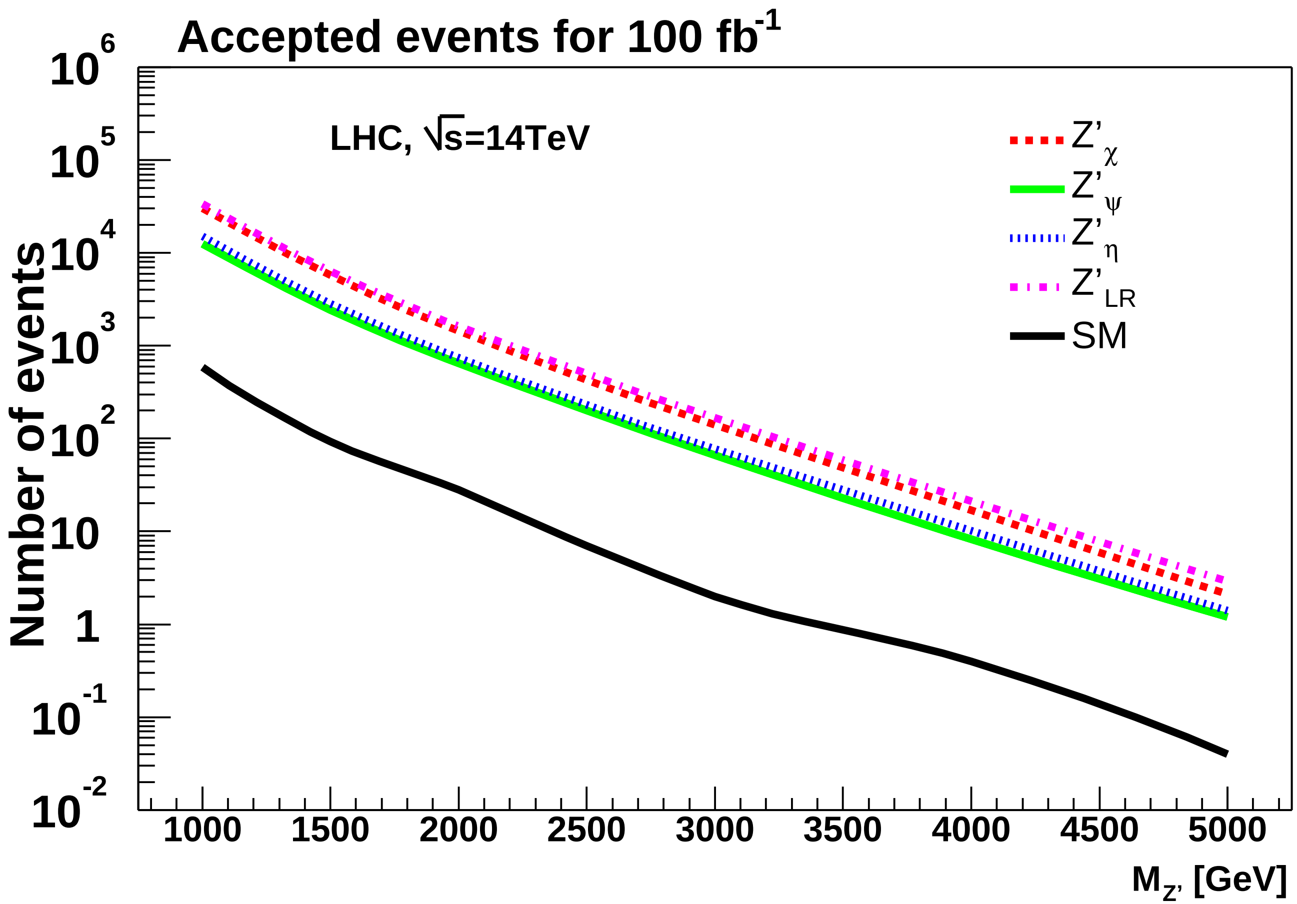
KK excitations of gluon, photon, Z and W bosons but also Z' bosons.

- **Model with strong breaking of EW symmetry (BES), Technicolor:**

additional gauge bosons with masses in the TeV range

New bosons

Production at the LHC: Drell6Yan process $pp \to Z' \to \ell^+\ell^-$



New fermions

- **GUTs have fundamental representation including all SM fermions:**

Ex1: **SO(10) has dim. 16 repr. which incorporates 15 SM fermions.**

- **Space left for RH neutrino N: generation of m_ν via see–saw.**

Ex2: E_6 **has dim. 27 repr. which incorporates 12 new fermions.**

$$\binom{\nu_E}{E}_L ,\ \binom{\nu_E}{E}_R ,\ N ,\ N' ,\ D_L ,\ D_R$$

- **Other possibilities of new fermions:**

– Fourth generation of fermions: $\binom{\nu_E}{E}_L, \binom{U}{D}_L, E_R, N_R, U_R, D_R$

– Mirror Fermions: $\binom{\nu_E}{E}_R, \binom{U}{D}_R, E_L, N_L, U_L, D_L$

– Vector Fermions: $\binom{\nu_E}{E}_L, \binom{\nu_E}{E}_R, \binom{U}{D}_L, \binom{U}{D}_R$

– Singlet fermions: N_R, D_L, D_R**, etc....**

– New fermions in extra dimensions: KK fermions and b' **....**

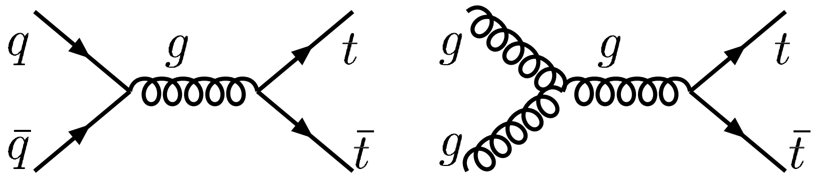
– Excited fermions in composite models: $\binom{\nu_{E^*}}{E^*}_L, \binom{U^*}{D^*}_L, E^*_R, N^*_R, U^*_R,$ I

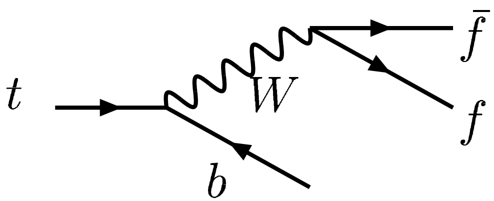
– Other possibilities??

New quarks

Same as top quarks but watch out decay modes!

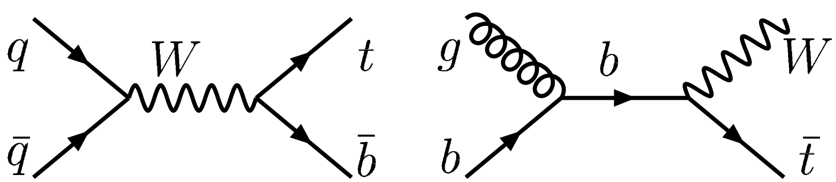
Top quark pair production: $pp \to t\bar{t}$



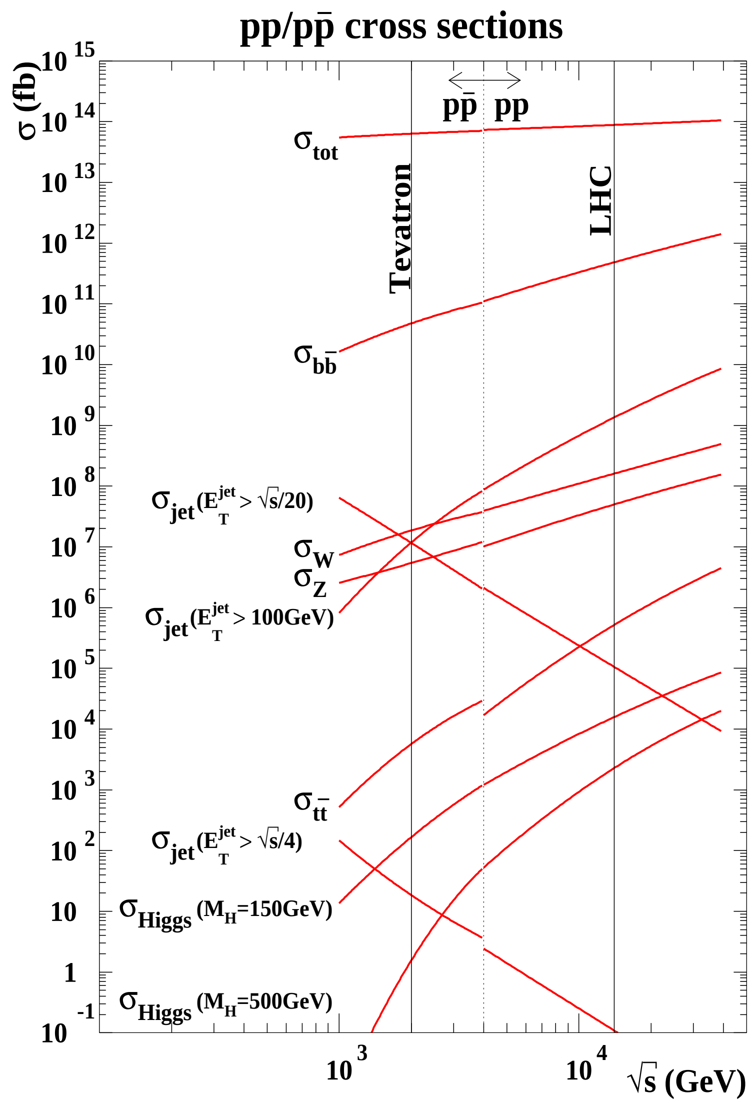


M_t measurement: $\Delta M_t \sim \pm 1$ GeV

Single top production: $pp \to t + X$



Much smaller rates by enough events for precise $V_{bt}^{\rm CKM}$ measurement....



Difermions

Take e.g. the D_L, D_R quarks in E_6 and their SUSY partners $D_0, \bar{D}_0^c$:

the most general Yukawa interaction is discribed by the Largrangian:

$$\mathcal{L} = (\lambda_{\mathbf{Q}} \mathbf{DQQ} + \lambda' \mathbf{D^c u^c d^c}) + (\lambda_{\mathbf{L}} \mathbf{D^c LQ} + \lambda'_{\mathbf{L}} \mathbf{Du^c e^c}) + ((\lambda_\nu \mathbf{d^c N^c})$$

- **Quarks:** $R = +1, B = \frac{1}{3}, L = 0$ **if** $\lambda_Q = \lambda'_Q = \lambda_L = \lambda'_L = \lambda_\nu = 0$.
- **Diquarks:** $R = -1, B = -\frac{2}{3}, L = 0$ **if** $\lambda_L = \lambda'_L = \lambda_\nu = 0$.
- **Leptoquarks:** $R = -1, B = \frac{1}{3}, L = 1$ **if** $\lambda_Q = \lambda'_Q = 0$.

Leptoquarks are similar to squarks and sleptons in $R\!\!\!/_p$ SUSY models.

Leptoquarks also exist in composite models: scalar and vector LQ

with charges from $-5/3$ to $+1/3$

Most general SU(2)xU(1) interactions: 5 scalars and 5 vectors

All these LQ appear in SU(15) and in fact, unify the gauge couplings?