NEW SIGNATURES
FOR TOP IN HADRON COLLIDER

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1. Motivation.

2. New Interactions to Top and Bottom

heavy vector resonance $V$

heavy scalar resonance $S$

3. New Signatures at Hadron Collider.

Motivation

In SM, mass generation are from scalar doublet (Higgs).
No explanation on higgs-fermion Yukawa couplings.
No experimental data to find light Higgs.
One possibility: no light Higgs,
at TeV scale, longitudinal vector boson $W, Z$
interactions are strong, need new physics to modify it.
New Interactions to Top and Bottom

New heavy resonances:

- heavy vector resonance $V$
- heavy scalar resonance $S$ (like heavy Higgs).

Top $\Rightarrow$ Main goal of Tevatron and LHC
Strong interactions to top and bottom
Weak couplings to first two generations
Ignore couplings with $W$, $Z$:

(Prof. Han and Valencia)
Heavy vector $V$

Coupling strongly to $t$ and $b$

No mixing with $W$ and $Z$

Framework of effective Lagrangian.

No specific model.
No V-Z mixing, right handed

\[ L = \frac{g}{2} \tan \theta_W \tan \theta_R \left( \frac{1}{3} q_L \gamma^\mu q_L + \frac{4}{3} u_{Ri} \gamma^\mu u_{Ri} - \frac{2}{3} d_{Ri} \gamma^\mu d_{Ri} \right) V_\mu \]

\[ -\frac{g}{2} \tan \theta_W \left( \tan \theta_R + \cot \theta_R \right) \left( \bar{t}_R \gamma^\mu t_R - \bar{b}_R \gamma^\mu b_R \right) V_\mu \]

\[ g_A = g_V = \frac{g}{4} \tan \theta_W \cot \theta_R \]

\[ \Gamma(V \rightarrow f \bar{f}) = \frac{M_V}{2\pi} g_V^2 \left( 1 - 4 \frac{m_f^2}{M_V^2} \right)^{\gamma/2} \left( 1 - \frac{m_f^2}{M_V^2} \right) \]
Theoretical constraint:

\[ g_V < 1.8 \quad \cot \theta_R < 20 \]

\[ g_V = 0.63 \iff \cot \theta_R = 7 \]

*Tevatron*: \( M_V = 400 \ \text{GeV} \)
\( \Gamma_V = 47 \ \text{GeV} \)

*LHC*: \( M_V = 1 \ \text{TeV} \)
\( \Gamma_V = 127 \ \text{GeV} \)
Heavy scalar resonance $S$

$$L = -\frac{m_t}{\nu} S \left( k_b \bar{b}b + k_t \bar{t}t \right)$$

Coupling to $b$ or $t$ or both.

Width mainly from $b$ and $t$.

$W$ and $Z$ ignored

Theoretical constraint: $k_{b, t} \leq 3$

$k_b = 1$, $k_t = 1$
New Signatures at Hadron Collider

A. $b\bar{b}X$ and $t\bar{t}X$ processes
\[ \left| y_{b,t} \right| < 2 \quad p_T(b,t) > 100 \text{ GeV} \]

\[ M_{S,V} - 2 \Gamma_{S,V} < m_{b\ell\tau} < M_{S,V} + 2 \Gamma_{S,V} \]
B. $b\bar{b}tt\bar{t} X$ and $tt\bar{t}t\bar{t} X$ processes
$|y_{b,t}| < 2$

$p_T(b) > 100 \text{ GeV}$

$p_T(t) > 50 \text{ GeV}$

two $b$ tagged: 70%

two top 16%

$M_{S,V} - 4 \Gamma_{S,V} < m_{bbtt} < M_{S,V} + 4 \Gamma_{S,V}$  \hspace{1cm} \text{LHC}$
C. Single Top Processes

\[ Wb \rightarrow tR \rightarrow t, b\bar{b} \text{ and } t, t\bar{t} \]
\[ M_{S,V} - 4 \Gamma_{S,V} < m_{b\ell\ell} < M_{S,V} + 4 \Gamma_{S,V} \]

\[ |y_{b,t}| < 2, \quad p_T(b) > 100 \text{ GeV} \quad p_T(t) > 50 \text{ GeV} \]

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\[ \frac{\sigma_s}{\sqrt{\sigma_B}} \text{ (fb)} \]

- \[ pp \rightarrow bb\, t\, t\, X \]
- \[ Wb \rightarrow t\, bbX \]
- \[ pp \rightarrow tt\, tt\, X \]
- \[ Wb \rightarrow t\, ttX \]

- \[ 5\sigma(300\text{fb}^{-1}) \]

- \[ M_R(\text{GeV}) \]

LHC

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Summary:
Tevatron: almost no reach
LHC can probe new couplings

$LHC: \quad bb\; t\; t\; X \; or \; tt\; tt\; X;$

$Wb \rightarrow t\; bb; t\; tt$

$M_V \sim 2\; TeV, \; M_S \sim 1.2\; TeV$