Collider phenomenology of Gauge-Higgs unification scenarios in warped extra dimensions

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Phys. Rev.D76:095010,2007 and Phys. Rev.D77:076003, 2008.

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Holographic Higgs

• Bulk gauge symm.: $SU(3)_c \times SO(5) \times U(1)_X \longrightarrow SO(5) \supset SU(2)_R \times SU(2)_L$.

UV: $SU(2)_L \times U(1)_Y$ IR: $SO(4) \times U(1)_X$.

Extra gauge bosons have the quantum numbers of the Higgs

$SO(5)/SO(4) \longrightarrow A^{1\ldots4}{}_{\mu}(-,-)$ $A^{1\ldots4}{}_{5}(+,+) \longleftarrow$ Identify with H.

No tree level Higgs potential $\longrightarrow$ Induced at one-loop (calculable).

• Coleman-Weinberg Potential has been computed for the model under consideration [A.M, N. Shah and C. Wagner].

1. EWSB minima in large regions of parameter space consistent with EWPT.
2. Consistent with Z, W, bottom quark, top quark masses and Higgs LEP bound.

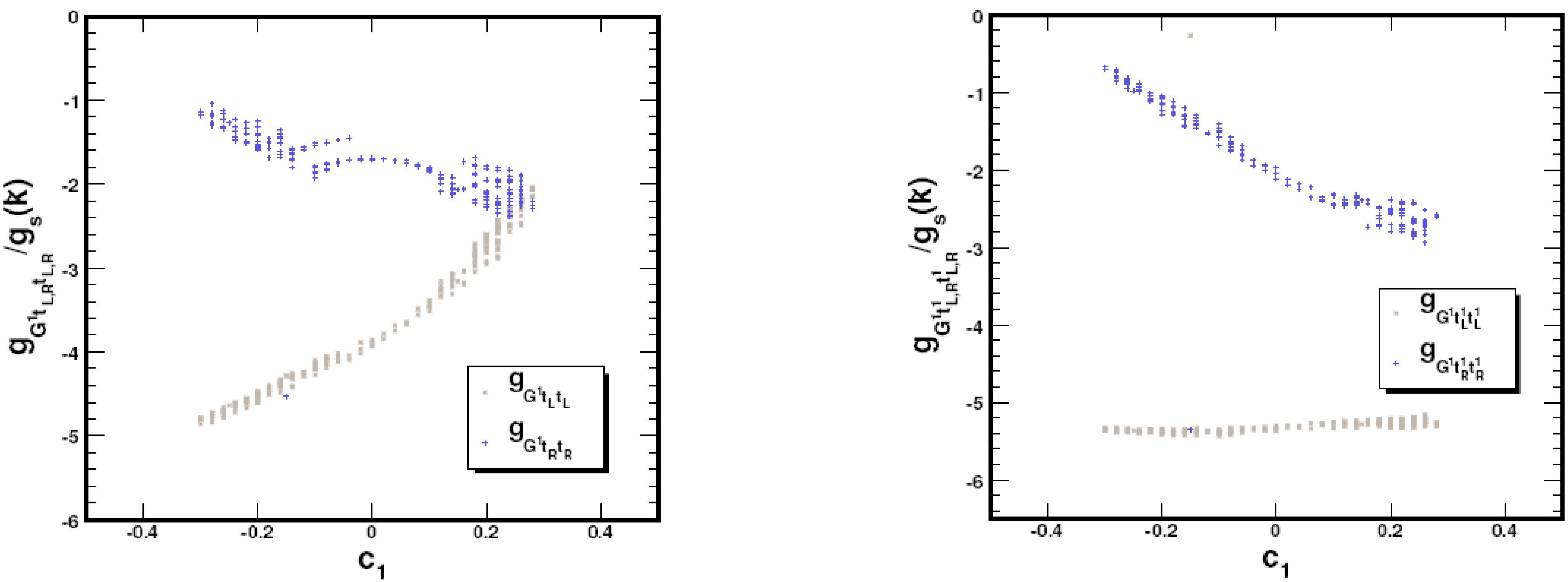
• EW fit easier in regions Higgs couplings are linear (similar to those of the SM).

Gauge-Higgs Unification: Collider Phenomenology

- Decays of excited state of gluons G^1 into pairs of excited tops t^1, mostly singlets under SM gauge group. Improve reach to probe t^1-masses further than direct QCD production. The pairs of t^1 decay into either W^+b, Ht or Zt.

- Example of important couplings to consider:

$$g_{G^1\bar{t}t} = g_{5s} N_{G^1} \int_0^L \left(\sum_i f^{2/3*}_{F,i,m_t}(x_5,h).f^{2/3}_{F,i,m_t}(x_5,h) \right) C[x_5, m_{G^1}] dx_5$$



- t^1 decay branching ratios,

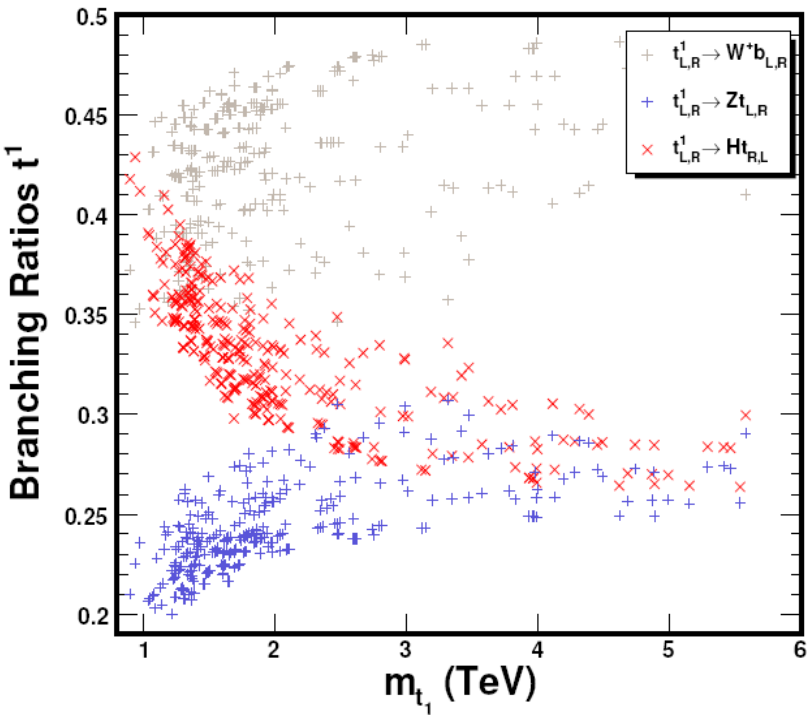


Figure 4: Branching ratios for the decay of t^1 vs m_{t^1} (GeV). Notice that the 2:1:1 relations holds for large m_{t^1}.

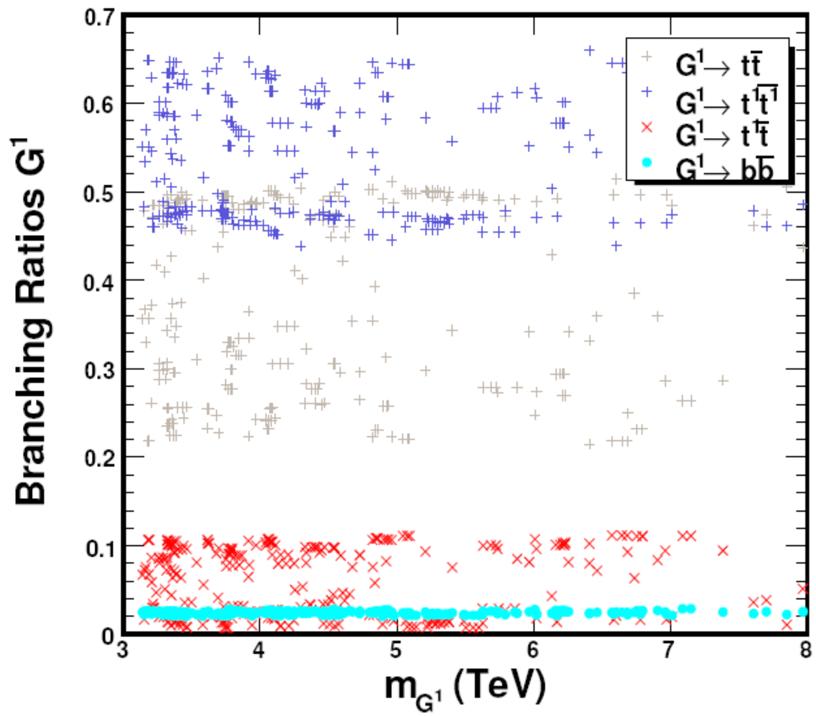


Figure 5: Branching ratios for the decay of G^1 vs m_{G^1} (GeV). Notice that G^1 decays mostly to t^1 pairs.

Gauge-Higgs Unification: Collider Phenomenology

- t^1 production cross section through QCD alone and through QCD+G^1 for M_{G1}=4 TeV.

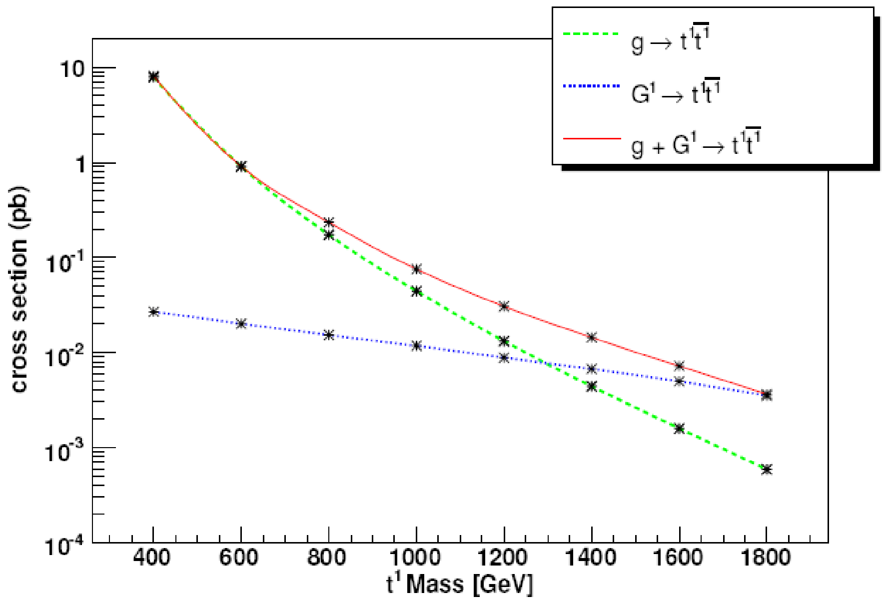


Figure 5: Cross section for $M_{G^1} = 4.0$ TeV with couplings $g_{G^1\bar{t}^1{}_L t^1_L}/g_s(\tilde{k}) = -5.18$ and $g_{G^1\bar{t}^1{}_R t^1_R}/g_s(\tilde{k}) = -2.77$.

Notice that for $M_{t1} \approx$ 1.5 TeV, G^1-induced production contributes in a significant amount to the t^1 production cross section.

Gauge-Higgs Unification: Collider Phenomenology

- From the Goldstone Equivalence Theorem → 50 % of times, t^1 decays in W^+b. We shall therefore concentrate on the channel:

$$pp \to (g + G^1) \to t^1\bar{t}^1 \to W^+bW^-\bar{b} \to l^-\bar{\nu}b\bar{b}jj, \quad (l = e, \mu)$$

- Backgrounds for this signal: top quark pair production induced by G^1 in addition to QCD (main background), W+jets and Z+jets (last two backgrounds are reducible to negligible levels by requiring 2 b-tags and lepton+MET).

- Points chosen to analyze:

c_1	c_2	c_3	M_{B_1}	M_{B_2}	$h/(\sqrt{2}f_h)$	m_{G^1}	m_{t^1}	$g_{G^1\bar{t}t_R}$	$g_{G^1\bar{t}t_L}$	$g_{G^1\bar{t}^1t^1_R}$	$g_{G^1\bar{t}^1t^1_L}$
0.26	-0.41	-0.57	2.2	0.4	0.278	3915.8	1470.2	-2.09	-2.28	-2.73	-5.22
0.24	-0.41	-0.58	2.3	0.5	0.318	3439.6	1250.5	-2.12	-2.50	-2.67	-5.20

Table 1: Points of parameter space chosen for t^1 detection. All masses are given in GeV and the couplings are in units of $g_s(\tilde{k})$.

- We set cone reconstruction algorithm to $\Delta R=(\Delta\eta^2 + \Delta\phi^2)^{1/2}=0.6$ for W invariant mass reconstruction.

Gauge-Higgs Unification: Collider Phenomenology

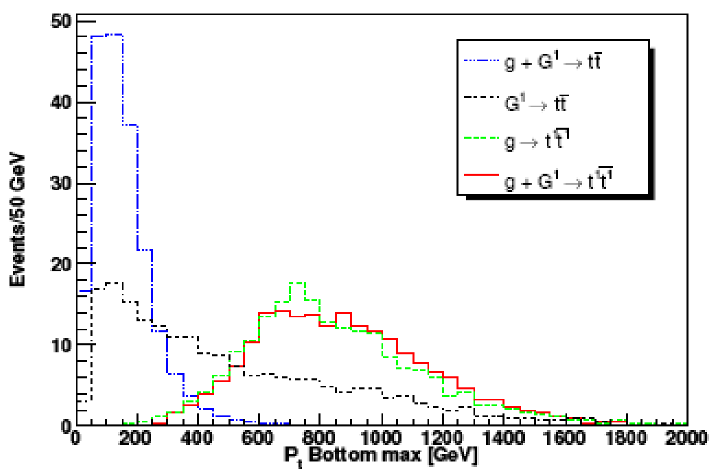
Event Selection: First selection cut on hadronized events:

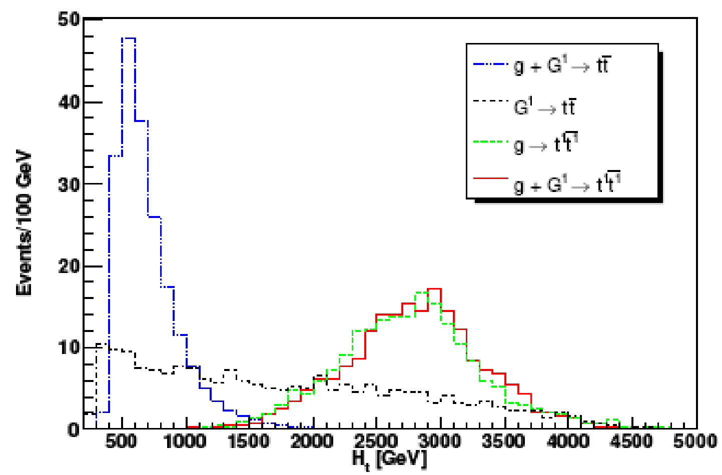
1. Isolated lepton with p_t>20 GeV and $|\eta|$<2.5 plus missing energy with p_t>20 GeV.
2. At least three jets with p_t>20 GeV and $|\eta|$<2.5, with exactly 2 bottom-tags.

Isolated lepton+MET reduces backgrounds from QCD jets.

	Point 1			Point 2		
Process	σ $[fb]$	N^0 Events	N^0 after cuts	σ $[fb]$	N^0 Events	N^0 after cuts
$G^1 \to t\bar{t}$	4.12	1236	1	4.43	443	0
$g \to t^1\bar{t}^1$	0.23	70	6	0.687	69	5
$g + G^1 \to t\bar{t}$	3025	907527	7	3085	308509	6
$g + G^1 \to t^1\bar{t}^1$	0.88	266	24	2.015	201	14

Big top background which must be reduced to manageable levels → Cuts $p_{t,bottom}$ and H_t.





Gauge-Higgs Unification: Collider Phenomenology

W-mass reconstruction through two methods:

1. $W \rightarrow$ 2 jets. Works well for t^1 masses less than 1 TeV. Uses $\Delta R=0.4$.
2. $W \rightarrow 1$ jet. Works well for t^1 masses bigger than 1 TeV. Increases signal and decreases background. Uses $\Delta R=0.6$. Figures in the case of point 1.

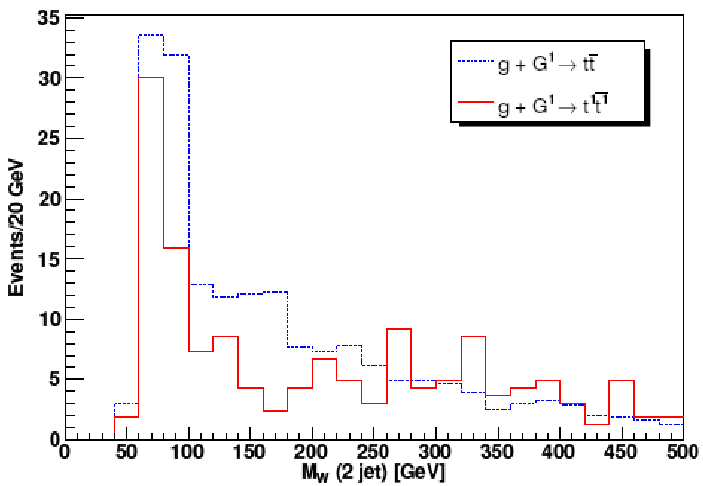


Figure 9: Invariant reconstructed W mass using the method of two jets. Distribution normalized to 200 events.

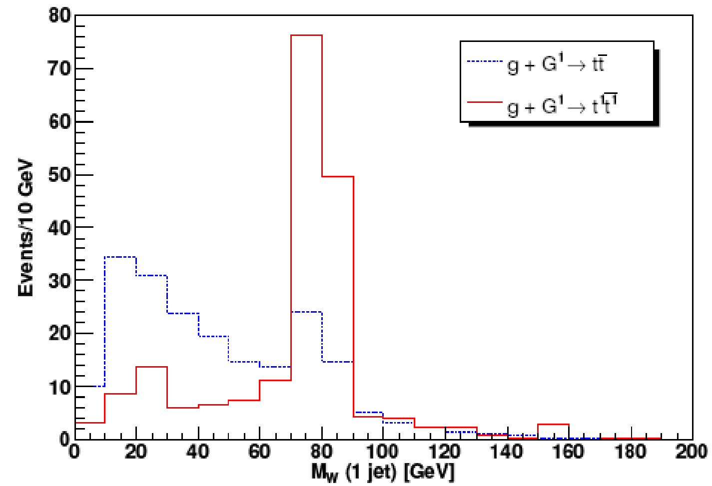


Figure 10: Invariant reconstructed W mass using the method of only one jet. Distribution normalized to 200 events.

Gauge-Higgs Unification: Collider Phenomenology

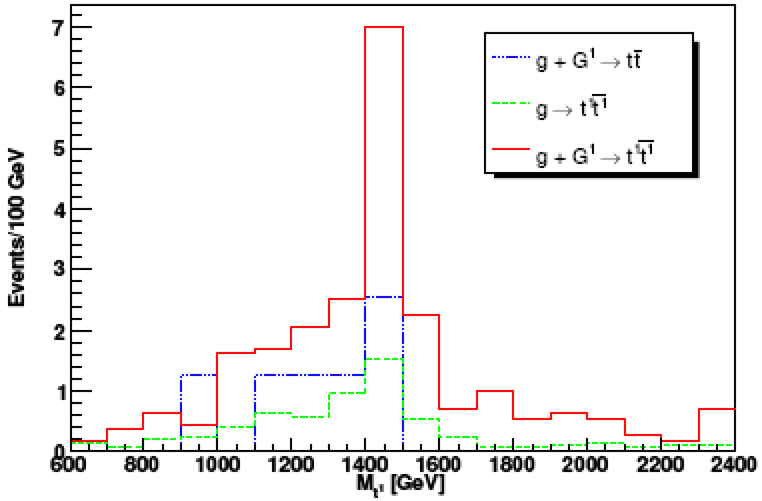
- Final set of cuts for reconstruction of t^1 mass distribution:

$$
\begin{aligned}
p_t^{b,max} &\geqslant 350 \ \text{GeV}, \qquad & p_t^{b,max} &\geqslant 300 \ \text{GeV}, \\
H_t &\geqslant 1900 \ \text{GeV}, \qquad & H_t &\geqslant 1800 \ \text{GeV}, \\
p_t^{lepton} &\geqslant 200 \ \text{GeV}, \qquad & p_t^{lepton} &\geqslant 150 \ \text{GeV}.
\end{aligned}
$$

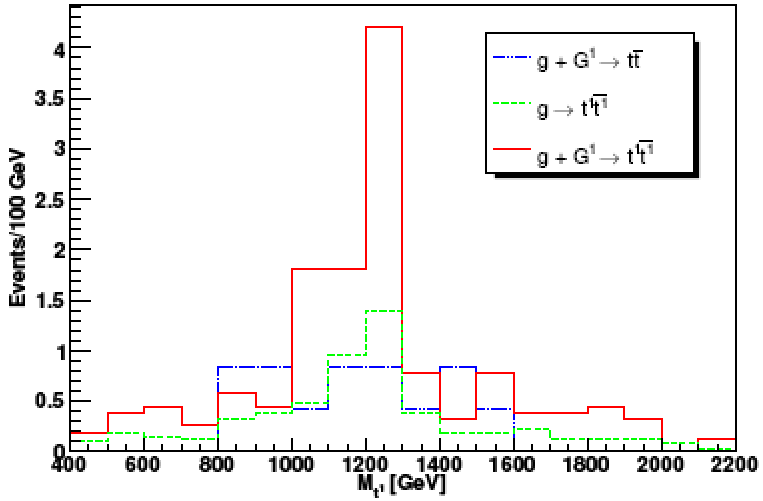
$$
\begin{aligned}
p_t^{j,max} &\geqslant 250 \ \text{GeV}, \\
|M_W - M_W^j| &\leqslant 20 \ \text{GeV}, \\
|m_{Wb_i} - m_t| &\geqslant 50 \ \text{GeV},
\end{aligned}
$$

- Reconstructed t^1 invariant mass distribution choosing bottom with biggest ΔR w.r.t W,

Point 1



Point 2



Results

We estimate statistical significance as $S/(S+B)^{1/2}$.

With the inclusion of K factors, K~1.5, presence of these particles may be found already at 100 fb^{-1} for Point 1 (60 fb^{-1} point 2) and discovery at 300 fb^{-1} for point 1 (200 $fb^{-1}$for point 2).

Gauge-Higgs Unification: Collider Phenomenology

- Constant cross-section curves in (m_{G1},m_{t1}) plane to estimate LHC reach at 300 fb^{-1}.

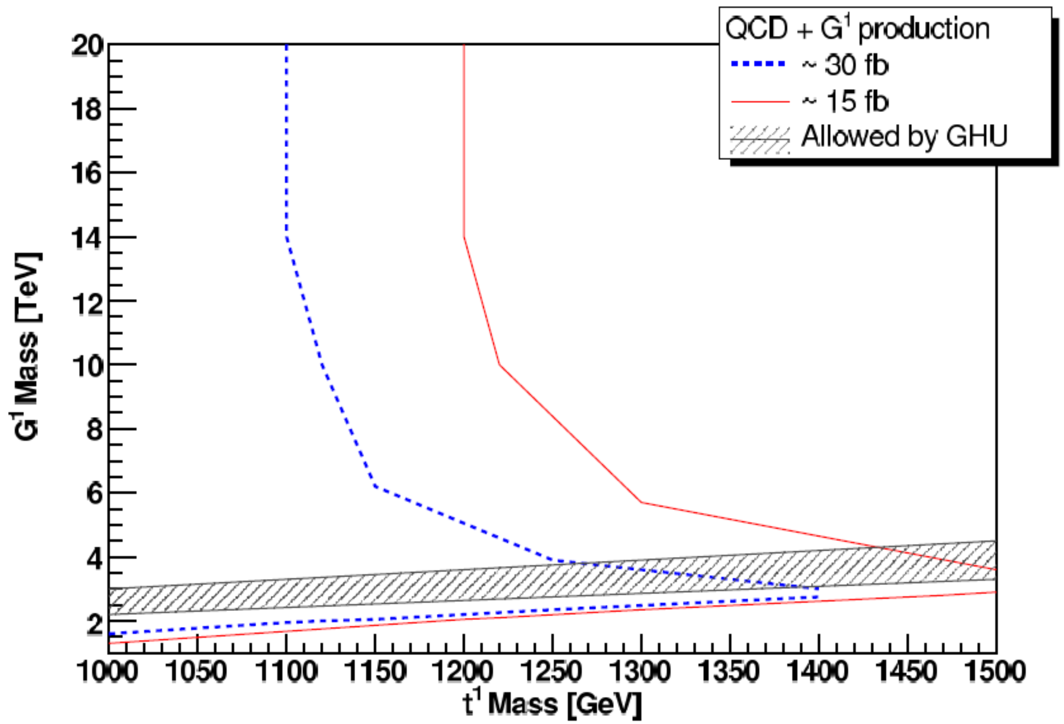


Figure 20: Curves of constant cross section for QCD in addition of G^1 decay, in (m_{G^1}, m_{t^1}) plane.

Conclusions

• First KK excitation of the top quark t^1 light enough to be produced from decays of first excited KK state of the gluon.

• Rich collider phenomenology: G^1 decays into t^1 expand the reach of t^1 detection to masses around 1.5 TeV.

• Consistent phenomenological model which will be tested at the LHC.

References:

[1] "Gauge-Higgs unification and radiative electroweak symmetry breaking in warped extra dimensions", A. Medina, N. Shah, C. Wagner. **arXiv:0706.1281**. Phys. Rev.D76:095010,2007.

[2] "Collider phenomenology of Gauge-Higgs unification scenarios in warped extra dimensions",

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