

Outline I

- 1 Extra Gluon and Quarks
 - Randall - Sundrum

- 2 Top FB Asymmetry
 - Signal
 - The Asymmetry within the SM
 - Stealth Gluon

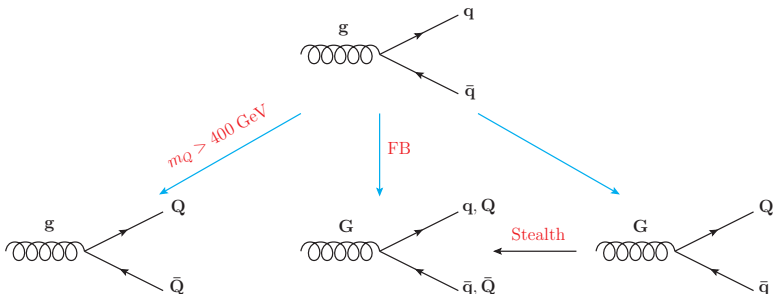
- 3 Implications in Hadron Colliders
 - Experimental Implications

- 4 Conclusions

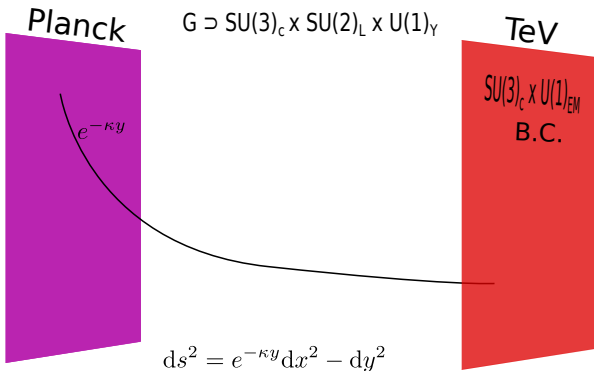
Extra Gluon and Quarks

Extra Gluon and Quarks

- Kaluza-Klein excitations of the SM particles.
- Background model \rightarrow X-dim (Randall-Sundrum).
- Color octet massive boson $m_G \lesssim 1$ TeV.
- Small axial couplings to the light quarks ($g_L = -g_R$).
- Large axial and vector couplings to the top quark.
- New quarks opening new decay modes at $m_Q + m_{\bar{q}} \sim 600$ GeV.



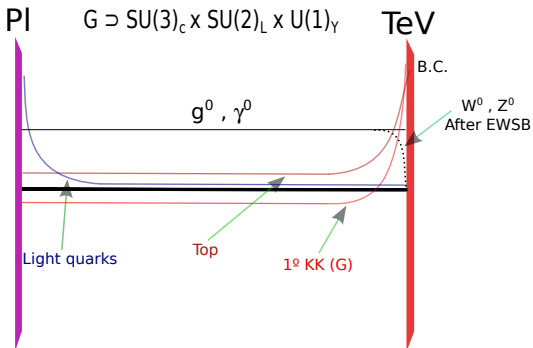
Randall - Sundrum



Randall - Sundrum

- The warped geometry of the 5th dimension is AdS.
- Solves the gauge and fermion mass hierarchy problems.

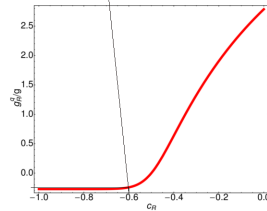
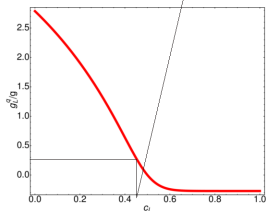
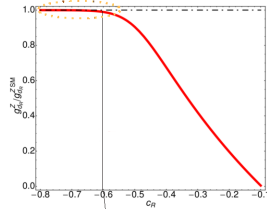
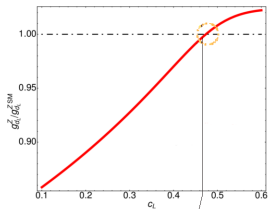
Randall - Sundrum



Randall - Sundrum

- There is a 5-dim field for each chirality.
- Flavor symmetry $\rightarrow c_{u_L, d_L} = c_{c_L, s_L}$ and $c_{u_R, d_R} = c_{c_R, s_R}$.

Randall - Sundrum



$c_L < 0.5$, $c_R > -0.5 \rightarrow$ IR (TeV) Brane.

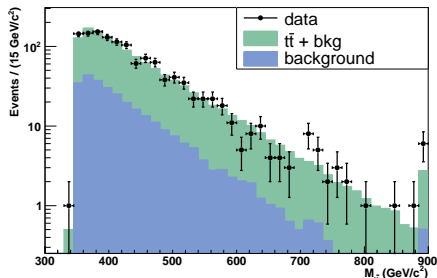
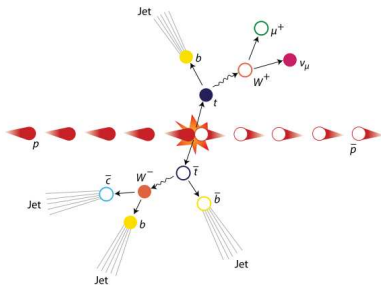
FB Signal at the Tevatron

CDF Mass Dependent FB Asymmetry

$$A_{CDF}^{t\bar{t}} \approx \begin{cases} 0.078 \pm 0.054 & M_{t\bar{t}} < 450 \text{ GeV}, \\ 0.296 \pm 0.067 & M_{t\bar{t}} > 450 \text{ GeV}. \end{cases} \quad A_{SM}^{t\bar{t}} \rightarrow \text{Next slide}.$$

$D\emptyset$ FB Lepton Asymmetry

$$A_{D\emptyset}^l \approx \begin{cases} 0.127 \pm 0.055 & (l^+), \\ 0.156 \pm 0.050 & (l^-). \end{cases} \quad A_{SM}^l \approx 0.035 \pm 0.010.$$



The Asymmetry within the SM

No asymmetry at tree level within the SM

$$A_{SM}^{t\bar{t}}(\text{NLO QCD}) \approx \begin{cases} 0.047 & M_{t\bar{t}} < 450 \text{ GeV}, \\ 0.100 & M_{t\bar{t}} > 450 \text{ GeV}. \end{cases}$$

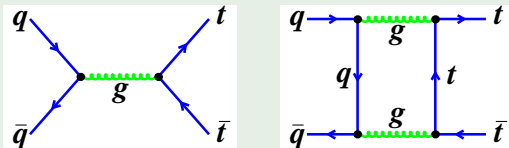


Figure: The interference of these diagrams leads to a positive asymmetry.

- 3σ deviation at $M_{t\bar{t}} > 450 \text{ GeV}$.
- No anomaly in the cross section, invariant-mass distribution, dijets production, same-sign top pair production and charge asymmetry.
- New particles proposed to explain it are pushed above 1-2 TeV.

Stealth Gluon

Stealth Gluon

- Color octet massive boson.
 - Small axial couplings to the light quarks ($g_L = -g_R$).
 - Order one axial and vector couplings to the top quark.
 - Region overlooked in the past: $m_G \lesssim 1$ TeV.
-
- Axial couplings contribute maximally to $A_G^{t\bar{t}} (\propto -g_A^q g_A^t)$.
 - The left(right)-handed quarks gives an excess(defect) in the parton cross section \rightarrow cancel each other to leading order (not enough to suppress the peak near the pole).
 - New decay channels opening at $\sqrt{\hat{s}} \approx m_Q + m_q \sim 600$ GeV:
$$q\bar{q} \rightarrow G \rightarrow Q\bar{q}, q\bar{Q}.$$
 - At $m_{t\bar{t}} \leq 600$ GeV \rightarrow asymmetry unchanged.
 - At $m_{t\bar{t}} > 600$ GeV \rightarrow dilute the peak in $M_{t\bar{t}}$.

Stealth Gluon

Same $W^+W^-b\bar{b}$ final state

$$q\bar{q} \rightarrow G \rightarrow t\bar{t} \rightarrow (W^+b)W^-\bar{b},$$

$$q\bar{q} \rightarrow G \rightarrow T\bar{t} \rightarrow (W^+b)W^-\bar{b},$$

$$q\bar{q} \rightarrow G \rightarrow B\bar{b} \rightarrow (W^-t)\bar{b} \rightarrow (W^-W^+b)\bar{b}.$$

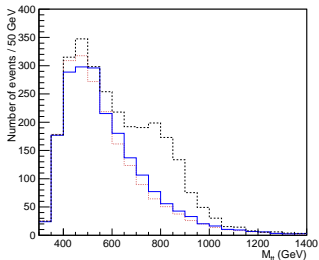
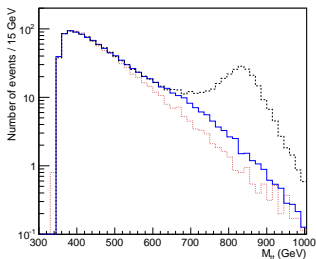


Figure: Left: 5.3 fb^{-1} Tevatron . Right: 1 fb^{-1} LHC. SM (red), our model with (blue) and without (black) the new channels $G \rightarrow Q\bar{q}$. $\Gamma_G \approx 0.7 M_G$.

- **BM**: $A^{t\bar{t}} = 0.33$ for $M_{t\bar{t}} > 450 \text{ GeV}$ (SM contribution included), which is less than 1σ away from the CDF measurement.

$T\bar{T} \rightarrow (W^+b)W^-\bar{b}$ Search at the LHC

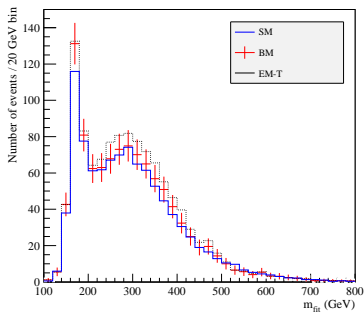
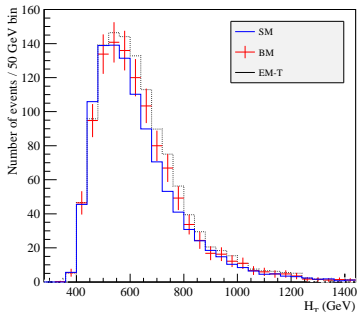


Figure: $T\bar{T}$ search at the LHC for 0.821 fb^{-1} .

- (Left) H_T distribution: scalar sum of the p_T of the jets, the charged lepton and the \cancel{E}_T .
- (Right) T -quark mass reconstructed.
- T -quark pair production negligible in our model.
- $T\bar{t}$ or $B\bar{b}$ events are reconstructed as two particles of the same mass.

$T\bar{T}$ Modified Search at the LHC

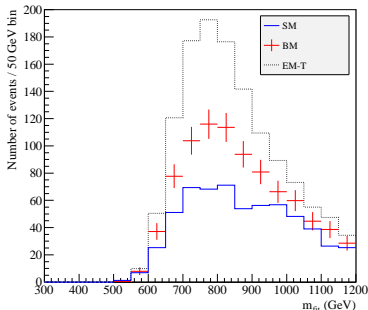
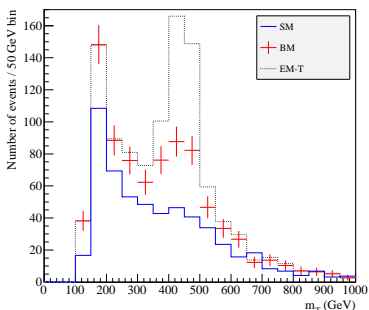


Figure: Slightly modified $T\bar{T}$ search at the LHC for 4 fb^{-1} .

- (Left) T -quark mass reconstructed (t quark plus a T quark of arbitrary mass).
- (Right) Gluon mass reconstructed (total invariant mass $m_{T\bar{t}}$ for events with a reconstructed T mass above 350 GeV).
- The extreme T would imply a clear deviation.

Neutral Decay of the Heavy B

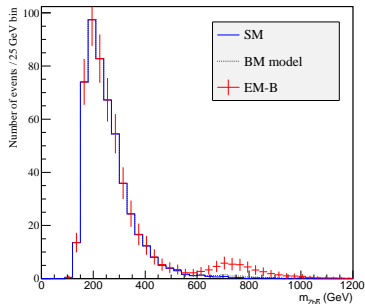
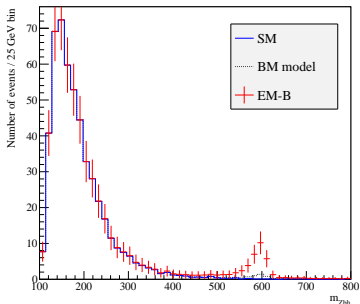


Figure: Search at the LHC for 4 fb^{-1} .

$q\bar{q} \rightarrow G \rightarrow B\bar{b} \rightarrow (Zb)\bar{b}$ channel

- (Left) Reconstruction of m_{Zb_h} .
- (Right) Gluon mass reconstructed (total invariant mass $m_{Zb\bar{b}}$).
- The SM irreducible background is small.

Neutral Decay of the Heavy T

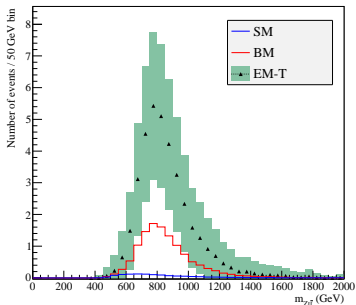


Figure: Total invariant mass reconstruction for the $Zt\bar{t}$ channel. Search at the LHC for 4 fb^{-1} .

$q\bar{q} \rightarrow G \rightarrow T\bar{t} \rightarrow (Zt)\bar{t} \rightarrow (ZW^+b)W^-\bar{b}$ channel

- Harder to reconstruct due to its large multiplicity.
- No expected background events.

Conclusions

Top FB asymmetry

- A light extra gluon with axial couplings to the SM quarks could explain the $A_{FB}^{t\bar{t}}$.
- No anomalies in other observables \rightarrow new quarks (stealth).
- The features of the model naturally arises from Randall-Sundrum.
- Current extra quark searches unable to probe the model.
- Changing slightly the cut criteria and the event reconstruction could discriminate it.