SINGLE HEAVY-QUARK PRODUCTION AT HADRON COLLIDERS

Manuel Masip

Universidad de Granada

- A *stealth* gluon of mass below 1 TeV can explain the $t\bar{t}$ FB asymmetry
- Does $A^{t\bar{t}}$ come alone? Single heavy-quark production
- Search for $q\bar{q} \to G \to T\bar{t}, B\bar{b}$ at the LHC

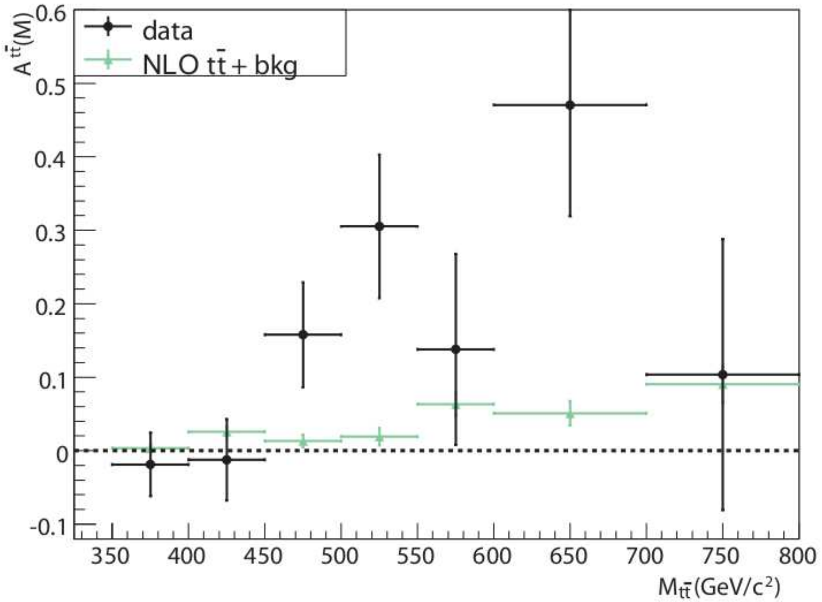
Barceló, **Carmona**, **Masip**, **Santiago**, arXiv:1105.3333, arXiv:1106.4054

CERN, August 2011

- The $t\bar{t}$ forward-backward asymmetry measured at the Tevatron *is* an order 1 (three σ) departure from the SM physics at $\sqrt{\hat{s}} \approx 400$–$800$ GeV

CDF:

$$A^{t\bar{t}} \approx \begin{cases} -0.116 \pm 0.153, & m_{t\bar{t}} < 450 \text{ GeV} \\ 0.475 \pm 0.114 & m_{t\bar{t}} > 450 \text{ GeV} \end{cases}$$

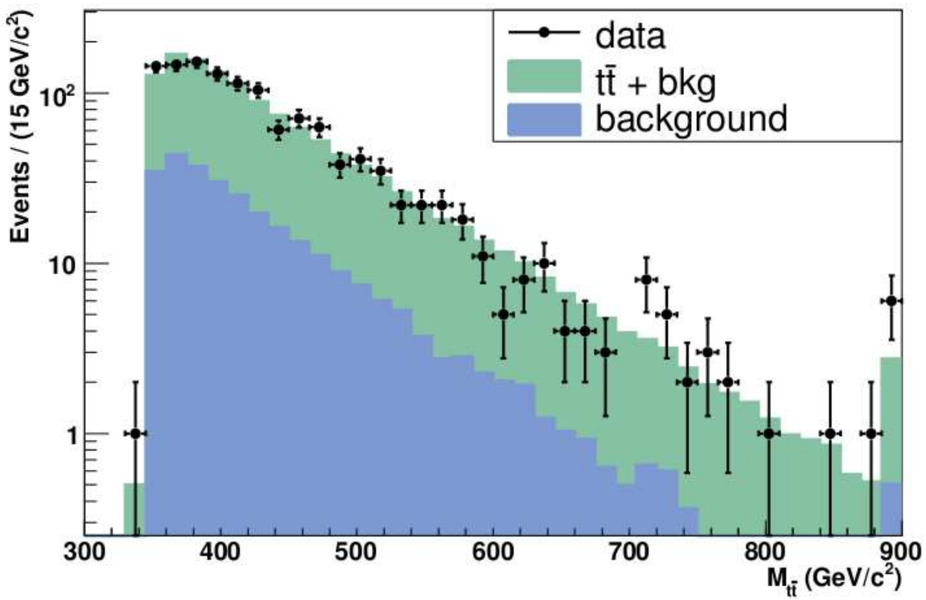


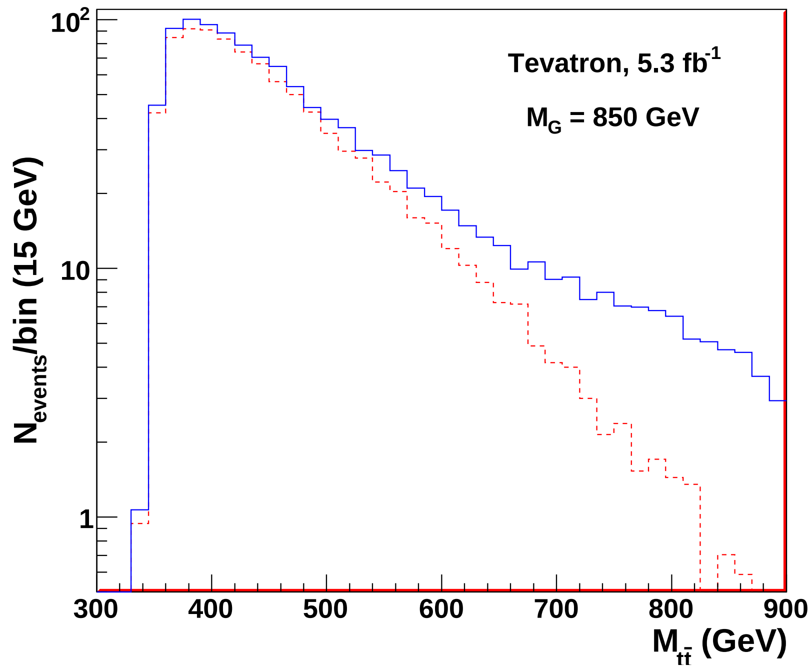
D0 :

$$A^{l}_{FB} \approx \begin{cases} 0.127 \pm 0.055 & (l^+) \\ 0.156 \pm 0.050 & (l^-) \end{cases}$$

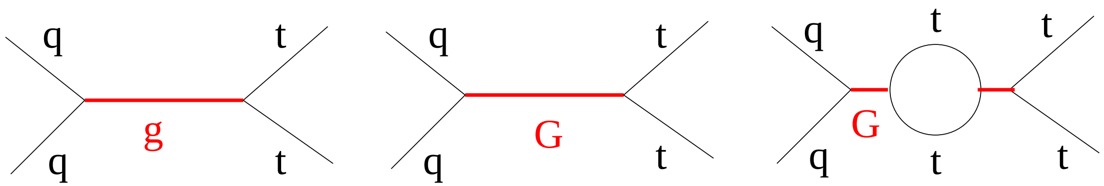
• s-channel resonance (gluon excitation G) strongly coupled to the top quark, with smaller and mostly axial couplings to the light quarks, light enough to compete with QCD at Tevatron energies ($M_G < 1$ TeV). Appears naturally in holographic models.

• Why the Tevatron and the LHC do not see a peak at $m_{t\bar{t}} \approx M_G$?





• The strong coupling of G to the top quark requires a proper treatment of its (energy-dependent) width:



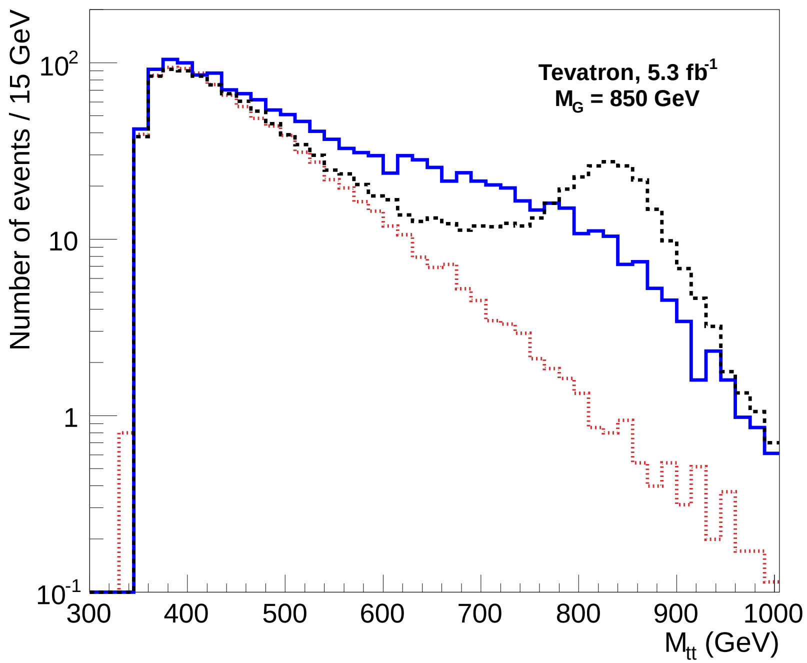
$$A \propto g^2 \left(\frac{1}{\hat{s}} + \frac{g^q g^t}{\hat{s} - M_G^2 + i\sqrt{\hat{s}}\,\Gamma_G(\hat{s})} \right)$$

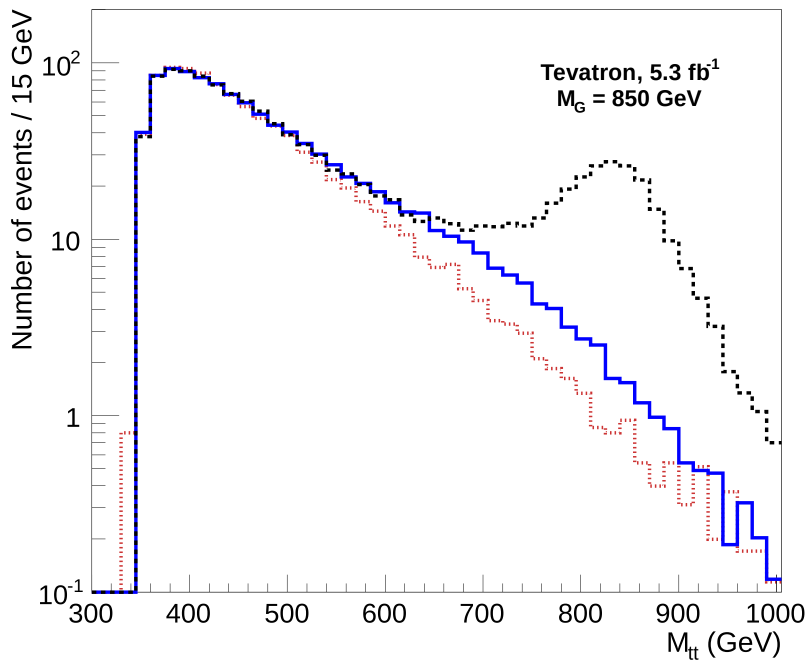
$$\Gamma_G^{t\bar{t}}(\hat{s}) = \theta(\hat{s} - 4m_t^2)\,\frac{g^2}{24\pi}\,\frac{\hat{s}}{M_G}\beta_t \left[\beta_t^2\, g_A^{t\,2} + \left(\beta_t^2 + \frac{6m_t^2}{\hat{s}} \right) g_V^{t\,2} \right]$$

• If Γ_G is large, a *constant* width suppresses the effect of the gluon at $\hat{s} \ll M_G^2$.

● A larger coupling of the top quark to G increases $A^{t\bar{t}}$ and dilutes the peak (left figure)

● Adding a new decay channel for G at $\sqrt{\hat{s}} \approx 600$ GeV that increases its width further reduces top-quark production above that energy (right figure). $A^{t\bar{t}}$ at $m_{t\bar{t}} \leq 600$ GeV is unaffected.





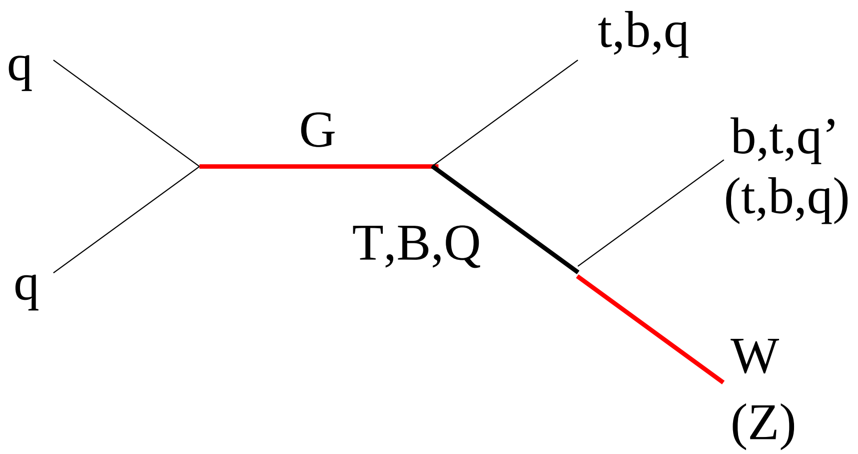
- **STEALTH GLUON:** mass below 1 TeV, large width that makes the *peak* invisible at hadron colliders. Order 1 effect on top-quark physics at $m_{t\bar{t}} \leq 600$ GeV and new decay modes at higher energies:

$$q\bar{q} \;\to\; G \;\to\; T\bar{t}\,,\; B\bar{b}\,,\; Q\bar{q}$$

$$Q\bar{q} \to (Wq')q$$

$$T\bar{t} \to (Wb)W\bar{b}$$

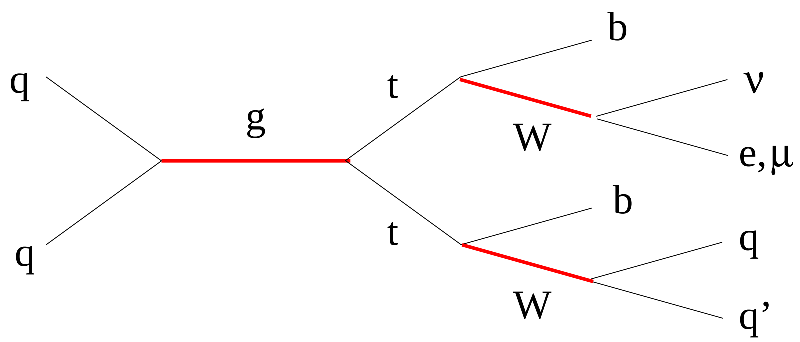
$$B\bar{b} \to (Wt)\bar{b} \to (WWb)\bar{b}$$

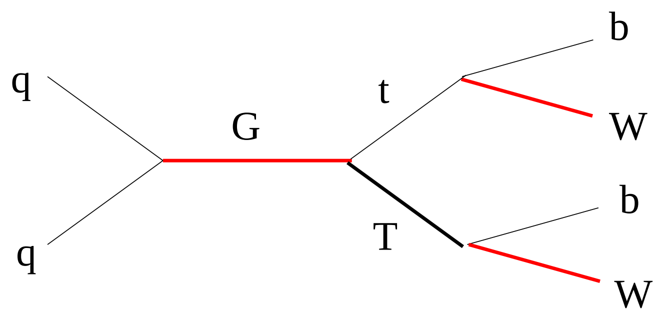


- Single T or B production gives the same final state as

$$q\bar{q} \to g \to t\bar{t} \to W^{+}bW^{-}\bar{b}$$

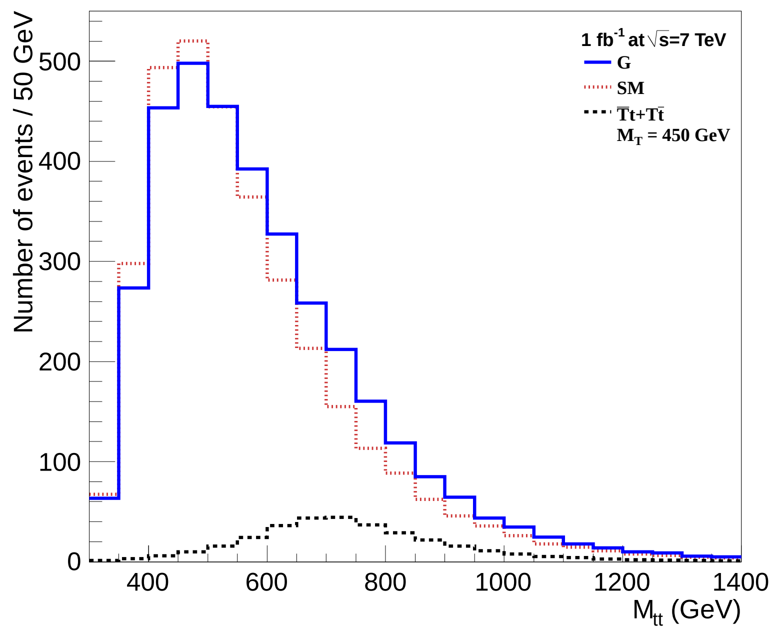
- Would the $T\bar{t}$ channel introduce an observable anomaly in current $t\bar{t}$ searches? How to perform a specific search?



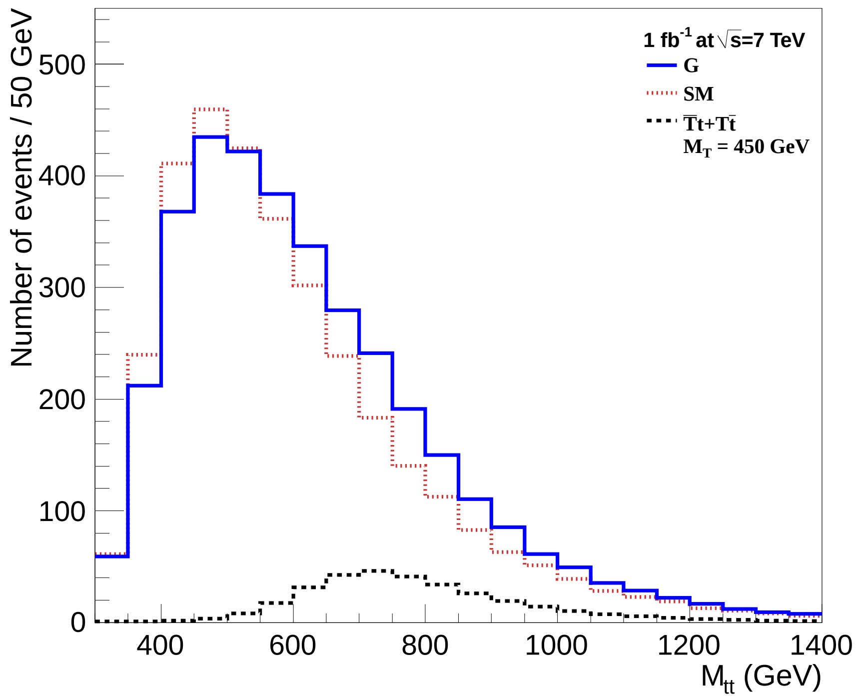


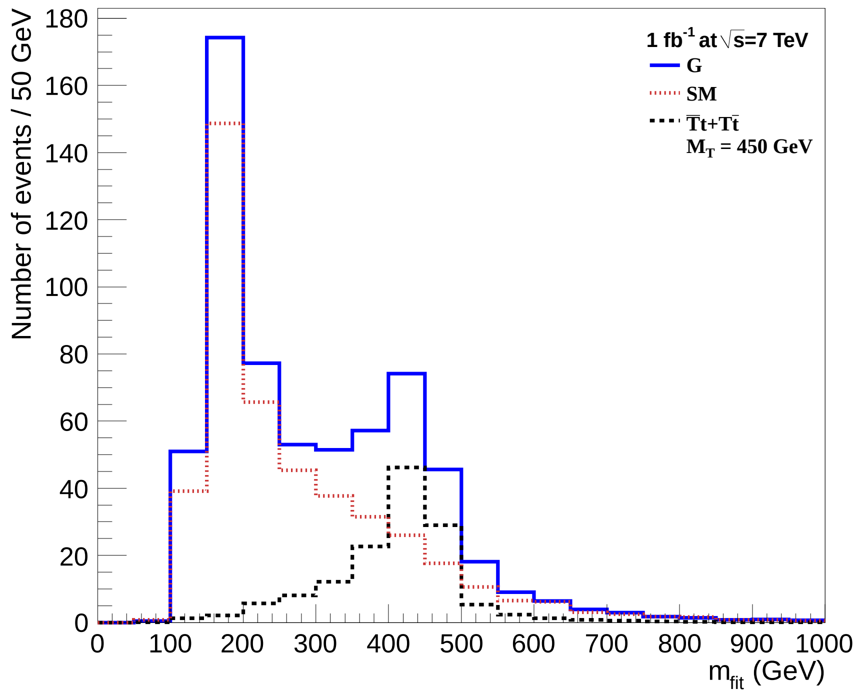
Events with four jets (at least one of them tagged as a bottom), plus lepton, plus missing p_T.

The reconstruction of the t quarks is obtained minimizing a χ^2.

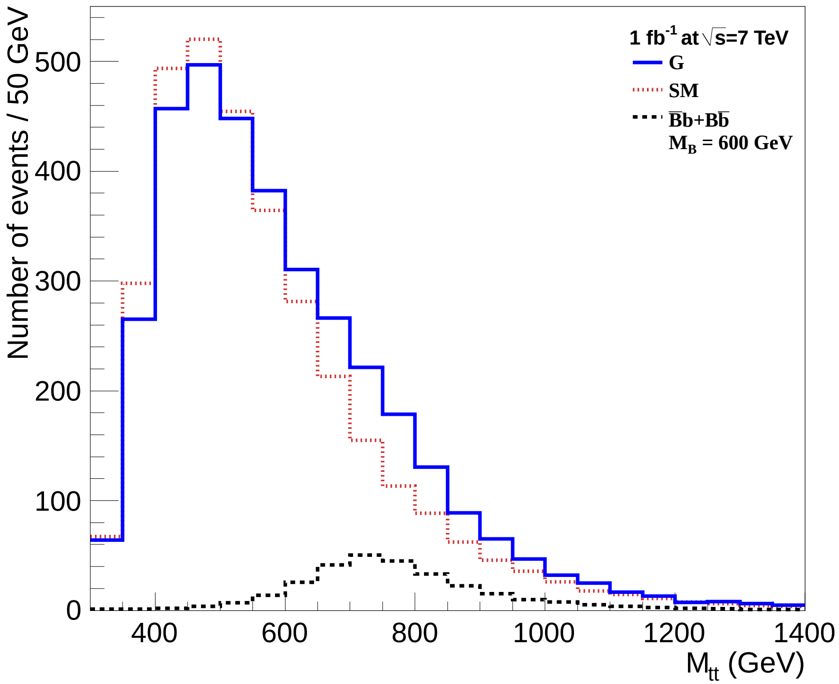


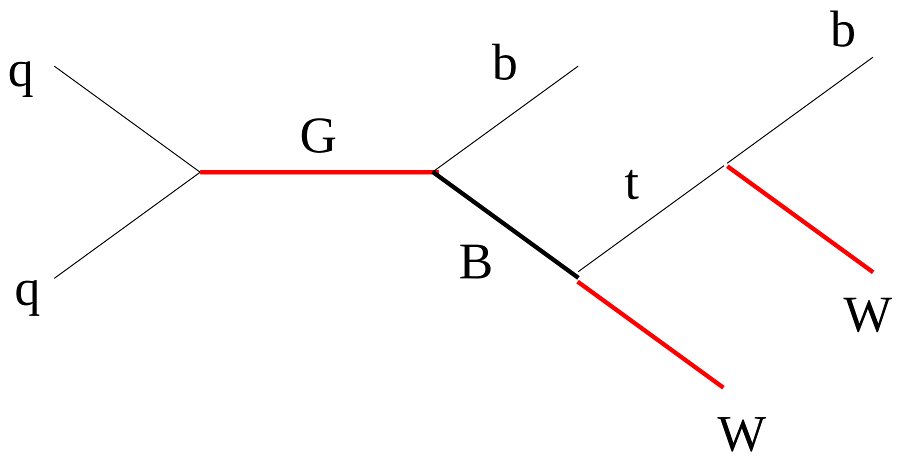
• One could instead reconstruct a t quark plus a T quark of arbitrary mass. Improves the χ^2. We can then plot the reconstructed mass of the T quark, and require *(i)* $\chi^2 \leq 5$; *(ii)* $m_{t\bar{t}} \geq 600$ GeV.



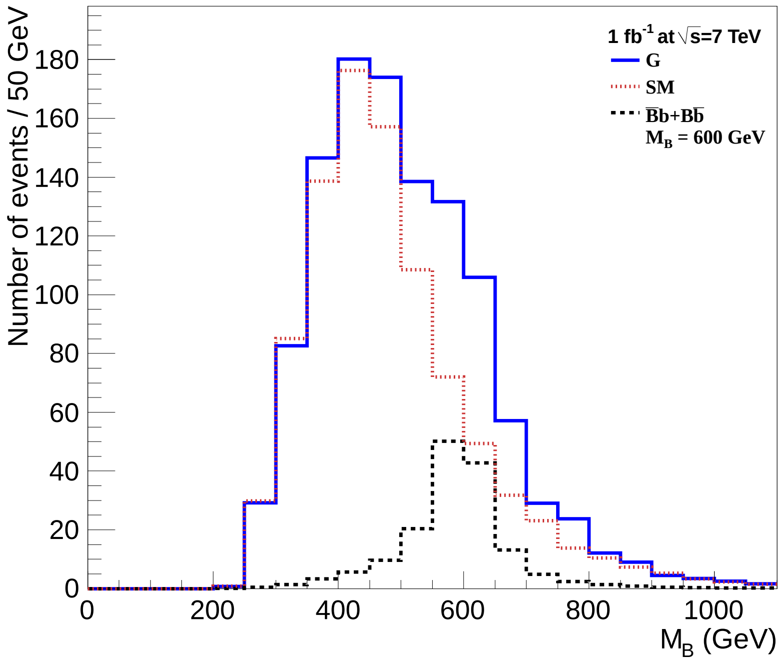


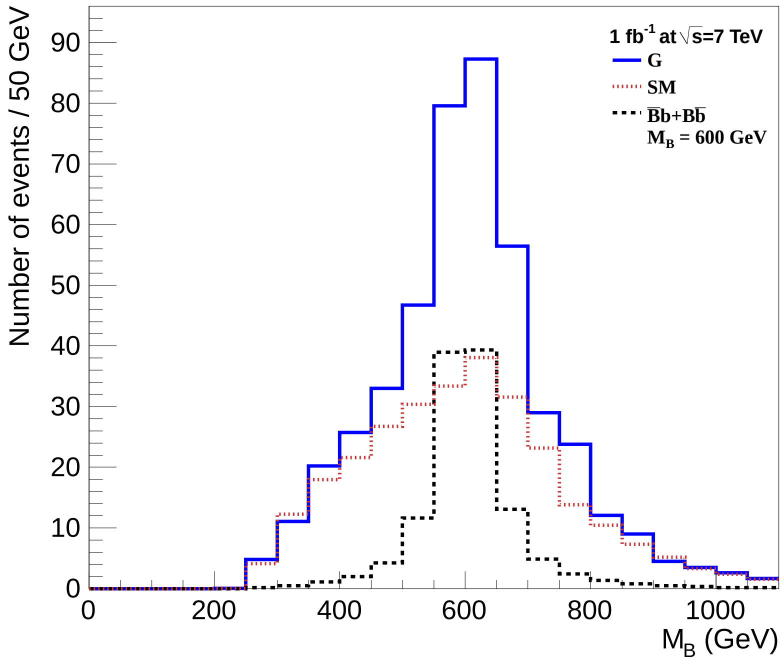
- $B\bar{b}$ production could also introduce anomalies in current $t\bar{t}$ searches.





- One could reconstruct only one top quark plus a W boson in events of $m_{t\bar{t}} > 500, 700$ GeV, and plot the invariant mass.

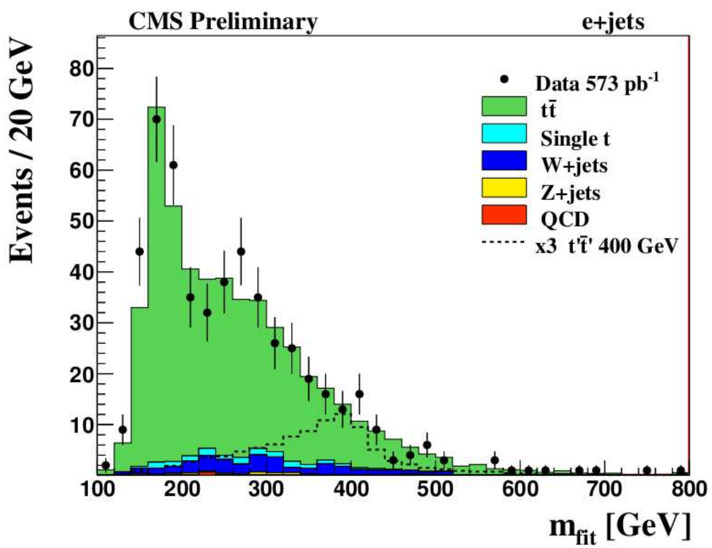


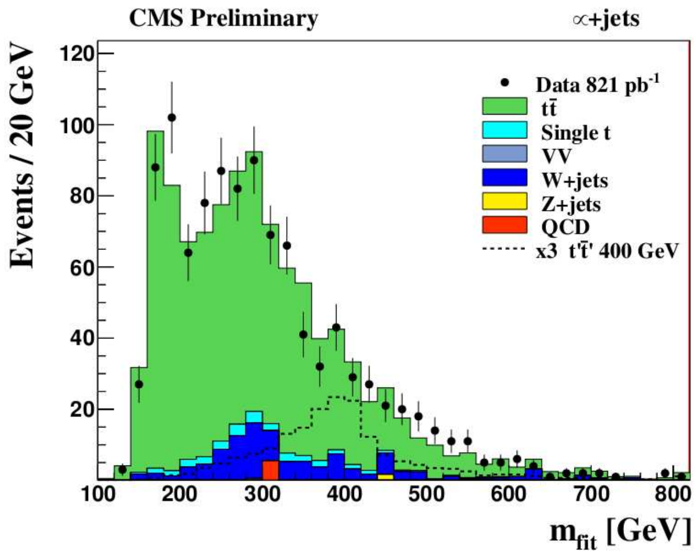


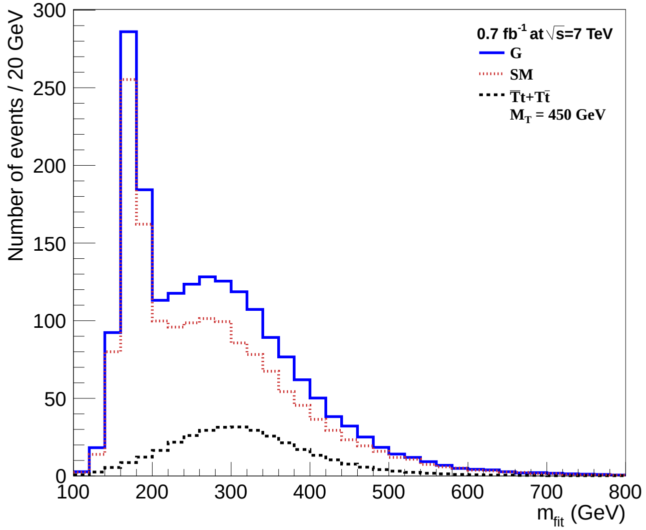
- $2b + 2W$ is also studied in the search for $T\bar{T}$ pairs. Same final state as in $t\bar{t}$ production but different cuts (larger tranverse momenta). Reconstruction of two quarks with the same mass M.

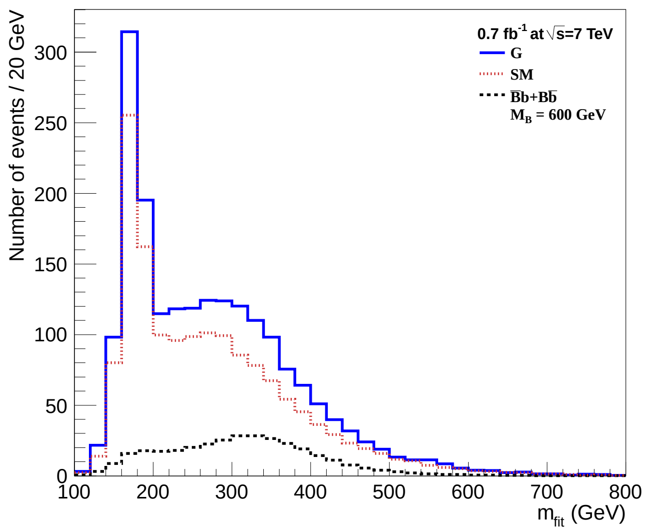
$$q\bar{q} \to g \to T\bar{T} \to W^+ b W^- \bar{b}$$

- The processes $q\bar{q} \to T\bar{t}, B\bar{b}$ would affect these analyses.

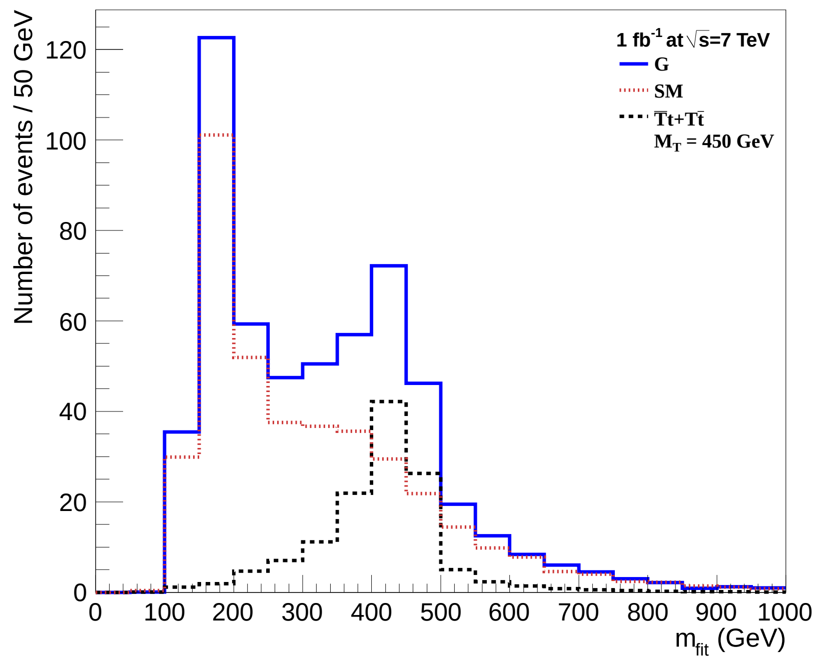








• Again, a plot of the reconstructed mass of the massive T quark in events of $m_{t\bar{t}} > 600$ GeV would reveal a clear peak at M_T.



Summary

If new physics is the explanation of the $t\bar{t}$ FB asymetry, it *should* be relatively light (below 1 TeV) and strongly coupled.

A very wide gluon resonance would work. A stronger coupling to the top quark provides a larger asymmetry and weaker effects near the gluon peak. Stealth gluon: new decay channels $q\bar{q} \to G \to Q\bar{q}$ *open* at 600 GeV, suppressing $q\bar{q} \to G \to t\bar{t}$ at $m_{t\bar{t}} > 600$ GeV. G is a very wide resonance at $m_{t\bar{t}} \approx M_G$ that *becomes* narrow at $m_{t\bar{t}} < 600$ GeV.

Natural scenario in Higgsless models. Csaki, Grojean, Murayama...

$q\bar{q} \to G \to T\bar{t}, B\bar{b}$ have same $2W + 2b$ final state but are easy to miss in current $t\bar{t}$ studies. Taylored analyses could optimize the search at the LHC.