The Randall-Sundrum model and high pT tops

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Outline

B. Lillie, L. Randall, L. Wang hep-ph/0701166
B. Lillie, J. Shu, T. Tait 0706.3960

- Description of the RS model
- Importance of top quarks
- Model variations
- Probes of model properties
- Outlook

See also: Agashe, Belyaev, Krupovnickas, Perez, Virzi hep-ph/0612015

The Randall-Sundrum model

L. Randall, R. Sundrum hep-ph/9905221

UV
Planck

IR
TeV

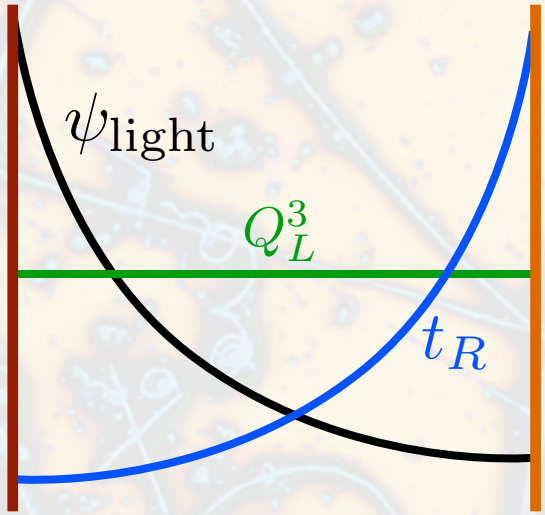
$$M \rightarrow e^{-\pi k r_c}$$

- Five dimensions
- Extra dimention is "warped"
- Warping scales masses, solving the hierarchy problem
- Parameters are natural

W. Goldberger and M. Wise hep-ph/9907447

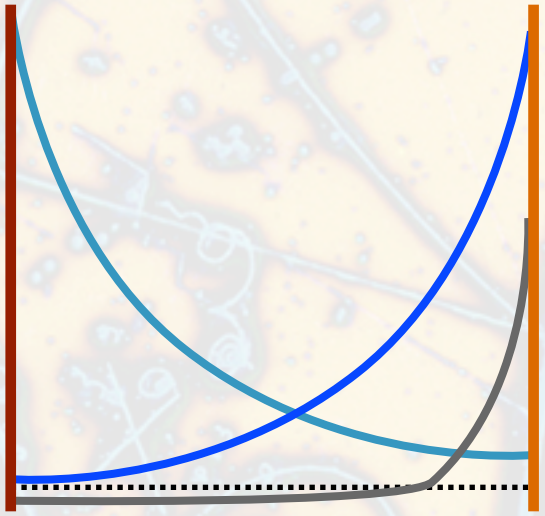
Standard Model fields

H. Davoudiasl, J. Hewett, T. Rizzo hep-ph/9911262
A. Pomarol hep-ph/9911294



- SM fields in bulk to suppress dangerous operators
  - Gauge fields must be in bulk
- Provides explanation of flavor hierarchy
- Structure constrained by SM precision observables
  - $Z \to b\bar{b}$ dominant constraint

Kaluza-Klein states



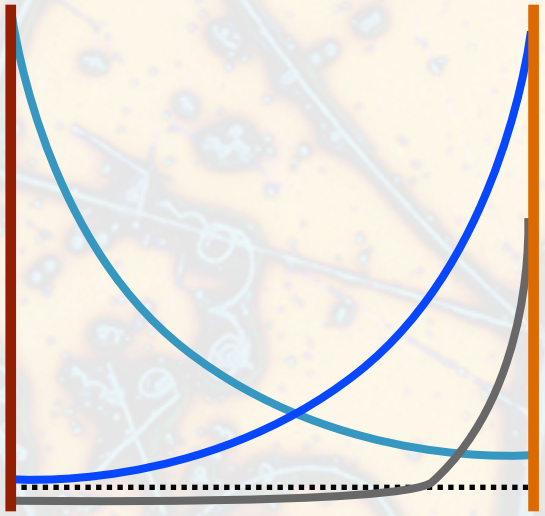
$$g_{f\bar{f}g^{(1)}} \sim 0.2 g_s$$

$$g_{Q^3\bar{Q}^3 g^{(1)}} \sim g_s$$

$$g_{t_R\bar{t}_R g^{(1)}} \sim 4 g_s$$

- KK states are IR localized
- Universal couplings to light fermions
- Large coupling to top

Kaluza-Klein states



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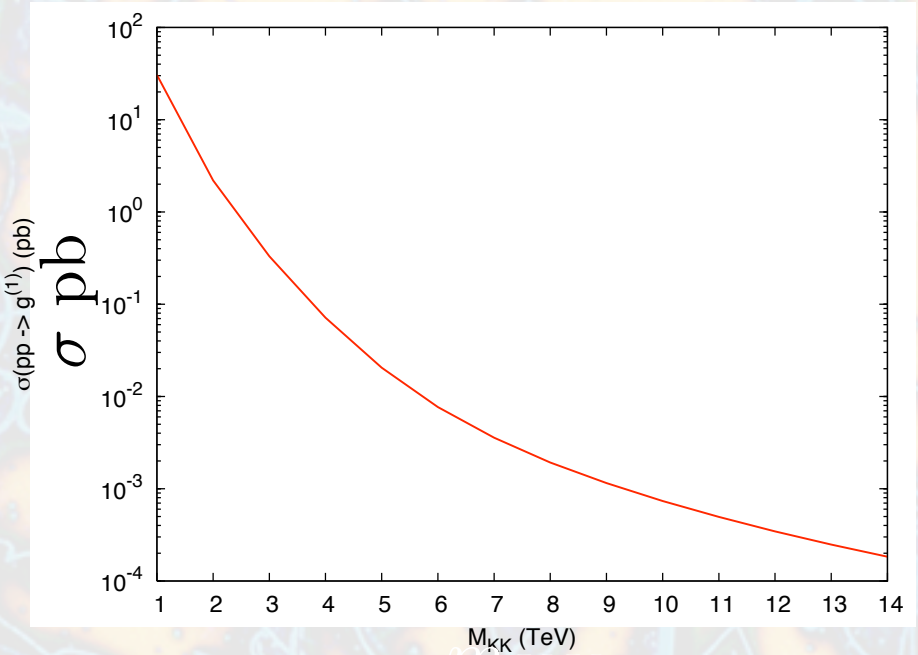
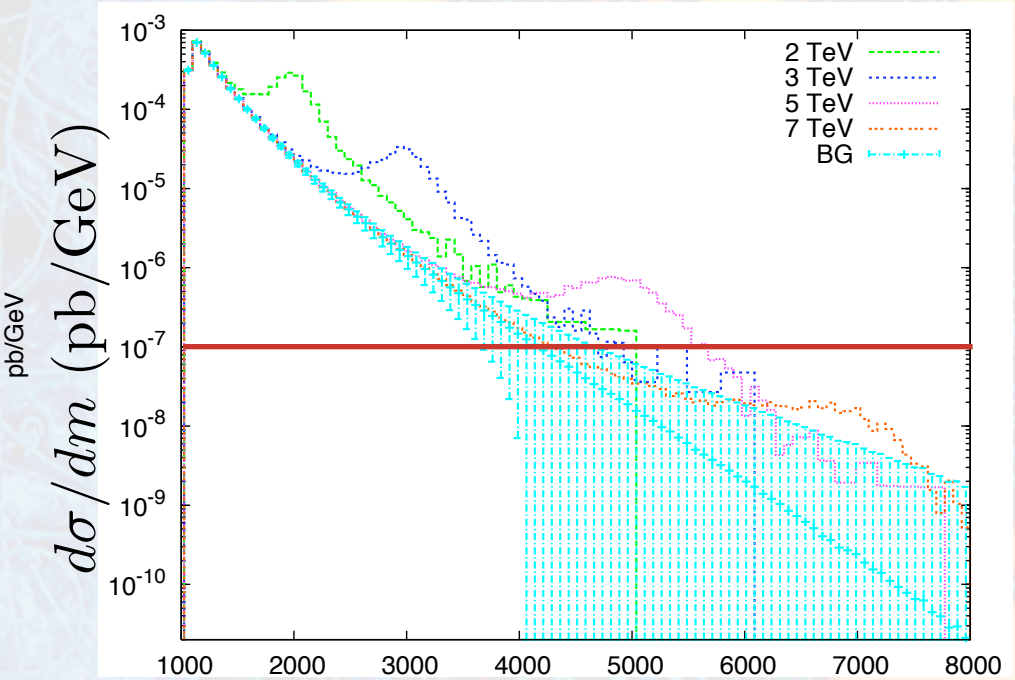
All gauge KK states decay predominantly to top pairs!

Top pairs from KK gluons

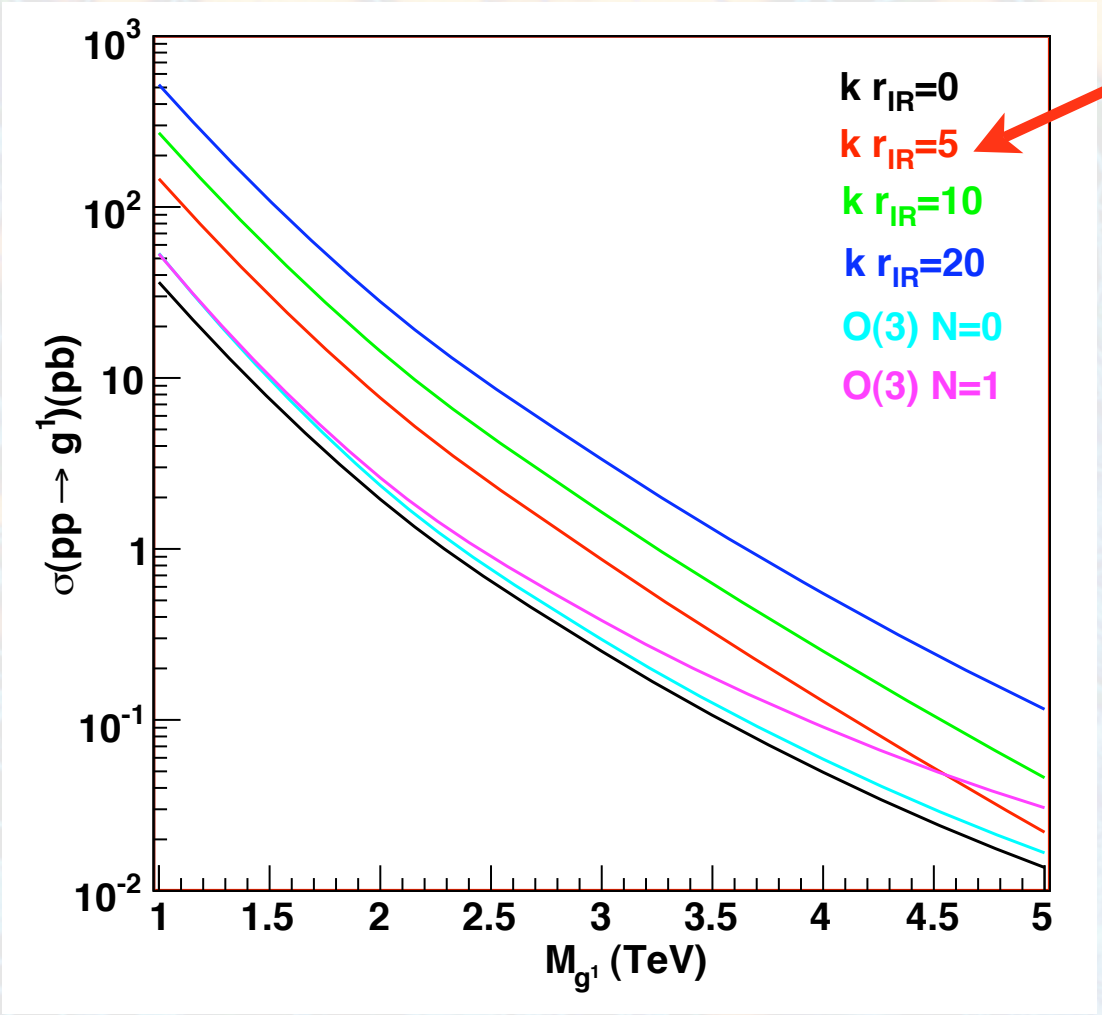


- Nice signal above SM top production
  - PDF and stat. errors shown, assuming 100 fb^{-1}
- Width/Mass ~17%

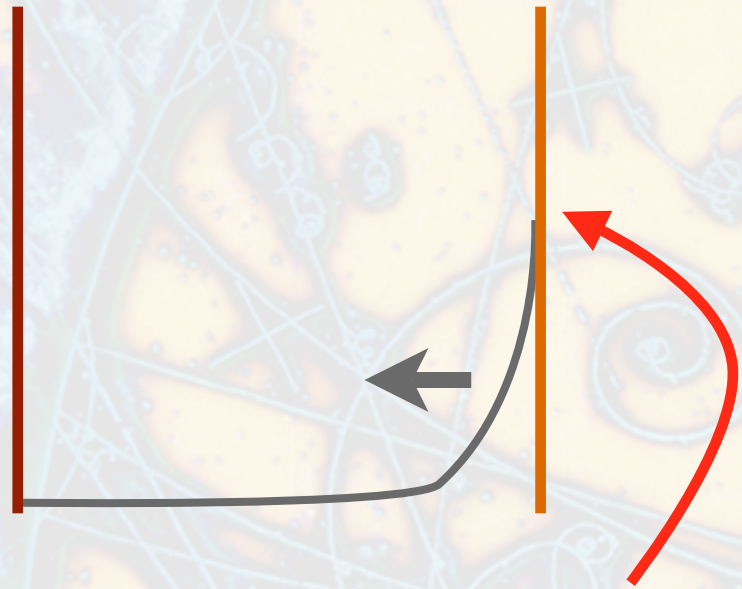
Cross-section at LHC reasonable, limited by small coupling to light fermions, and lack of glue-glue coupling



Other model variants



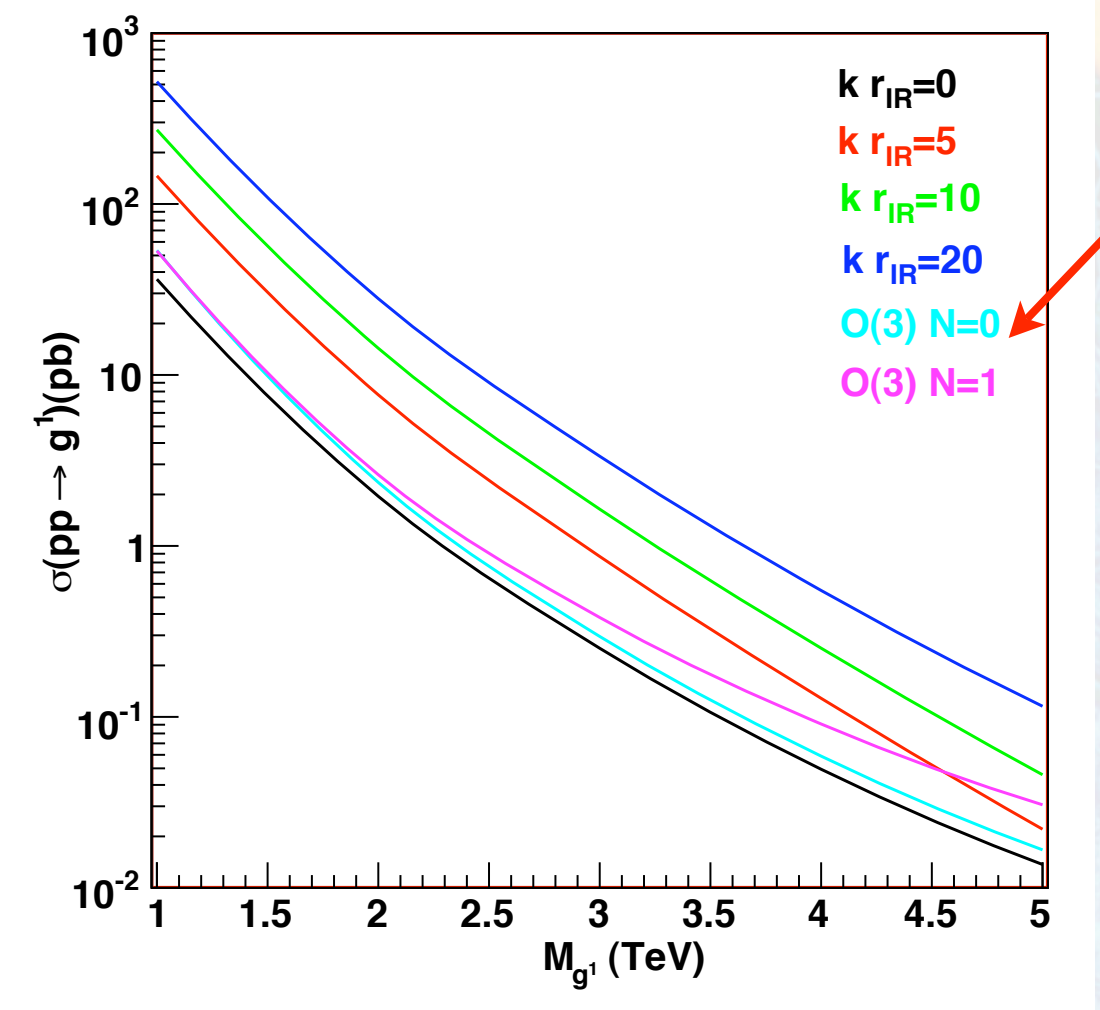
IR brane terms



$$2\delta(y-\pi r_c) r_{\rm IR} F_{\mu\nu} F^{\mu\nu}$$

Davoudiasl, Hewett, Rizzo hep-ph/0212279
Carena, Ponton, Tait, Wagner, hep-ph/0212307

Other model variants

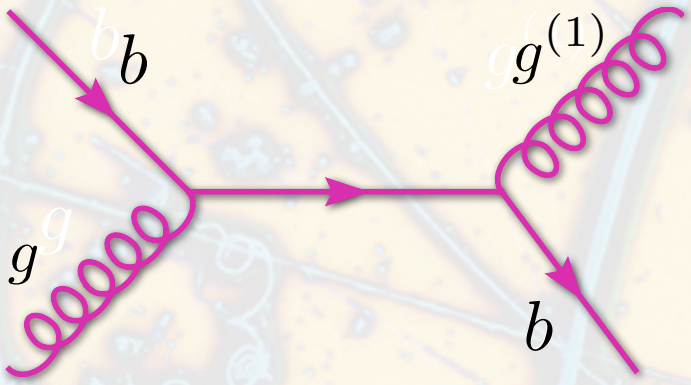


Custodial symmetry for $Z \to b\bar{b}$

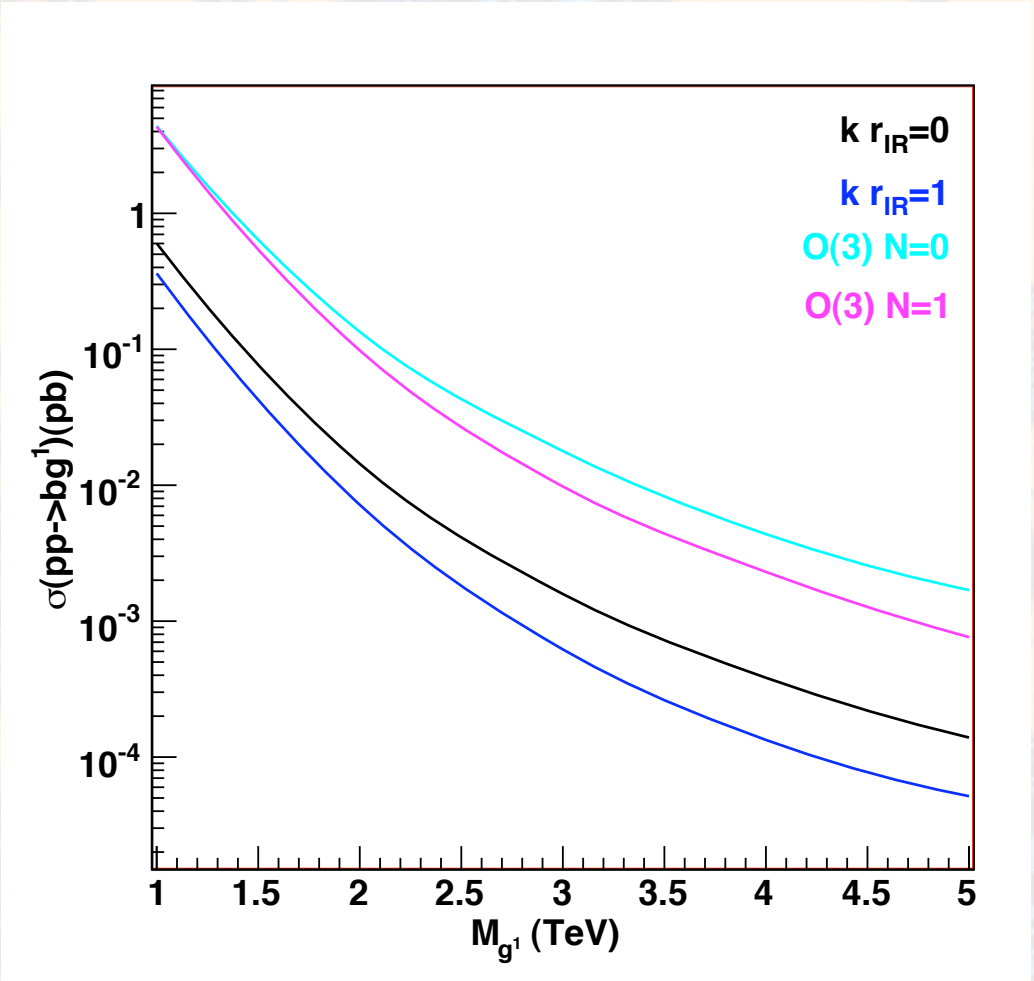
- Produces new light fermions
- KK gluon can decay into N new states

Agashe, Contino, Da Rold, Pomarol, hep-ph/0605341

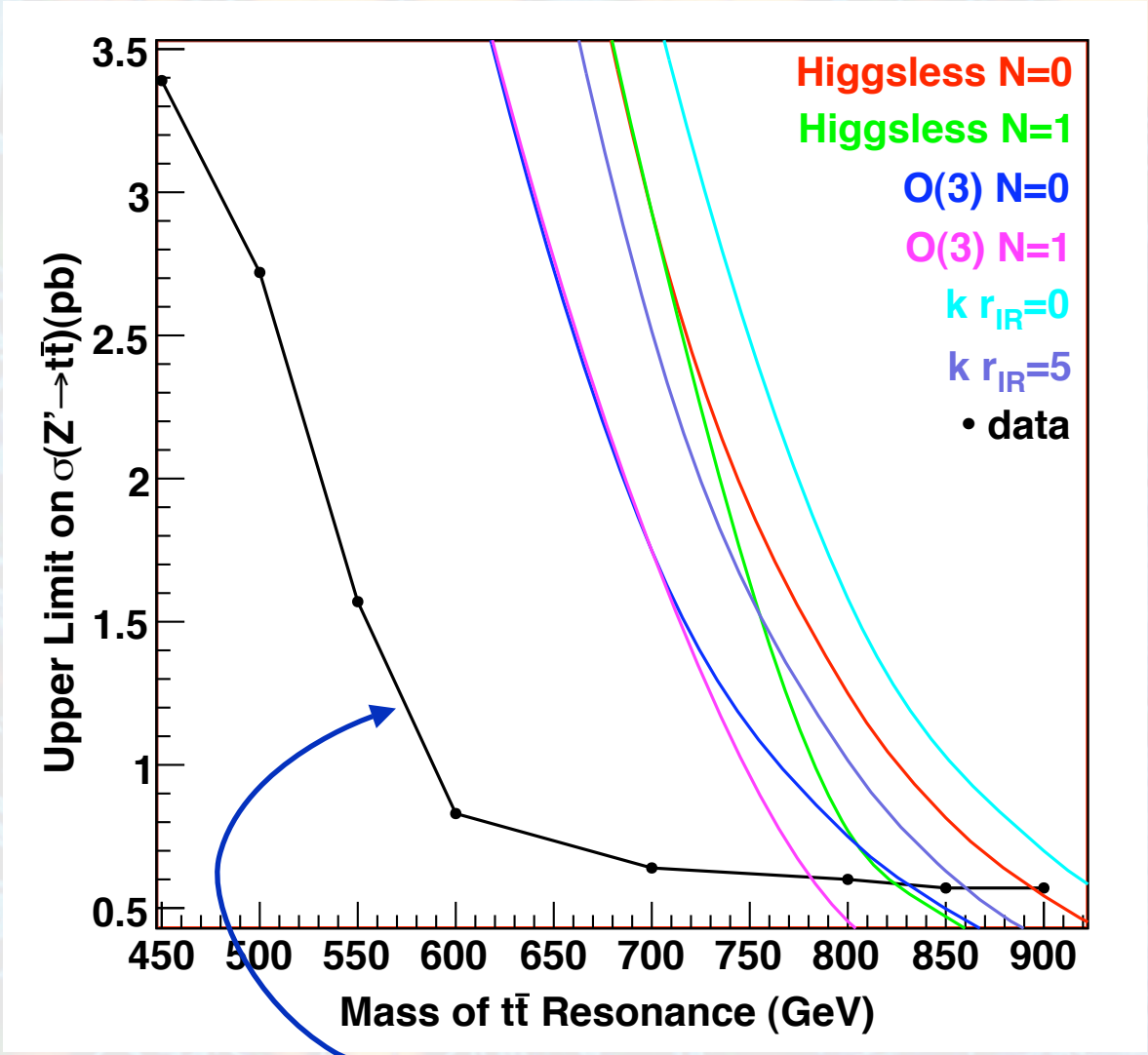
Bottom quark coupling



- Measure b associated production
- Probe of b localization



Tevatron constraints

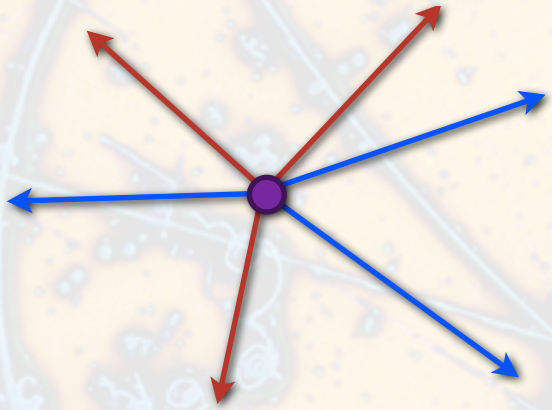


~ 950 GeV

Used narrow-width approximation, so constraint is qualitative, but probably improves with proper treatment

M. Kagan, D. Amidei, C. Cully, T. Schwarz, M. Soderberg (Michigan)
http://www-cdf.fnal.gov/physics/new/top/2006/mass/mttb/pub_page.html

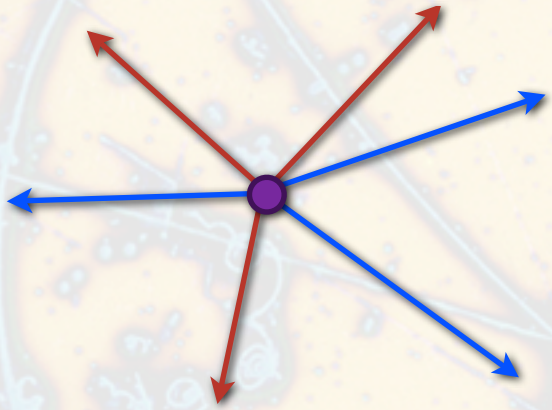
Top collimation



Threshold production

High mass production

Top collimation



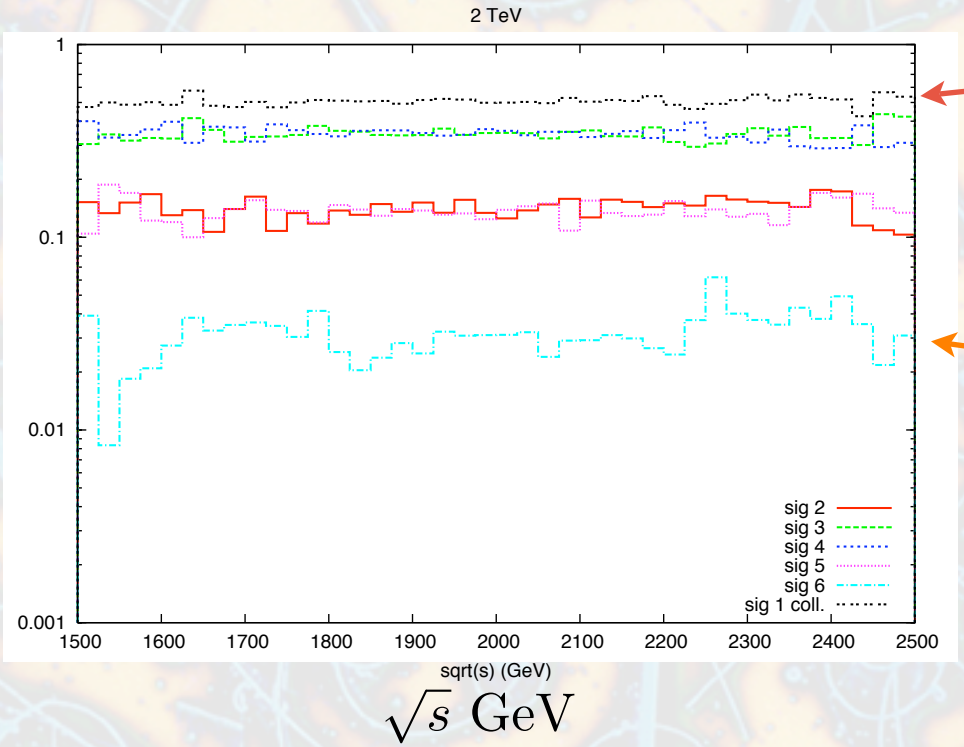
Threshold production

High mass production

- Tops can be highly boosted
- Can they be resolved into separate objects for top ID and reconstruction?

Top collimation (cont.)

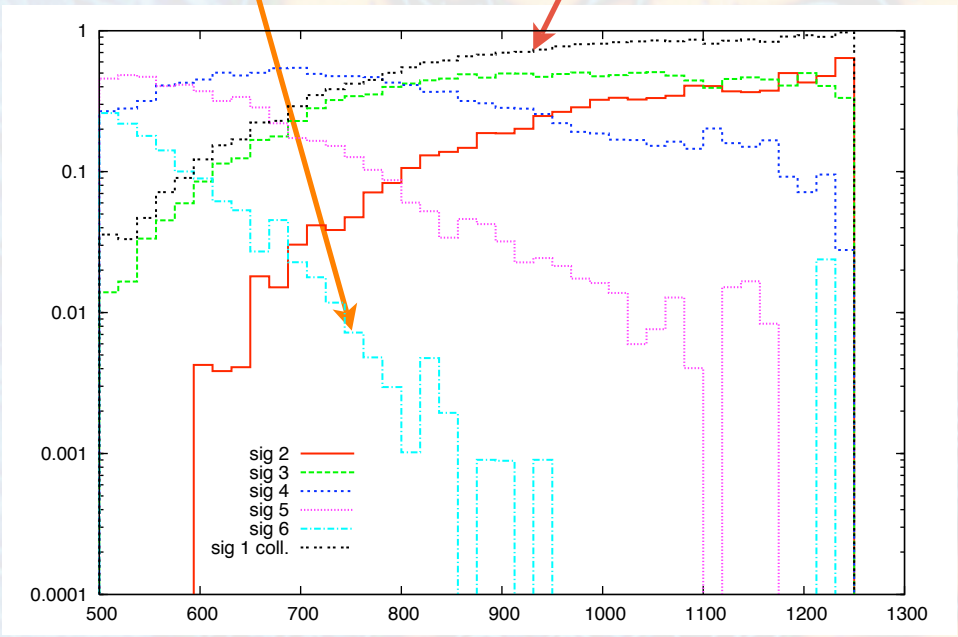
2 TeV resonance



$\sqrt{s}$ GeV

One top completely collimated

6 isolated decay products

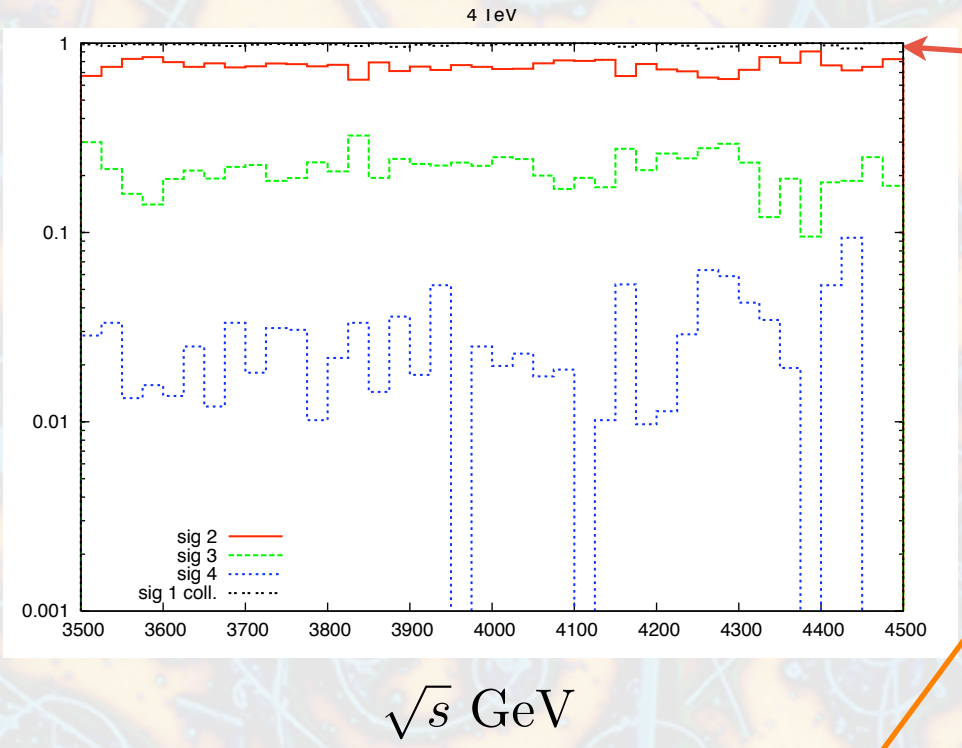


top p_T

Separation: $\Delta R > 0.4$

Top collimation (cont.)

4 TeV resonance



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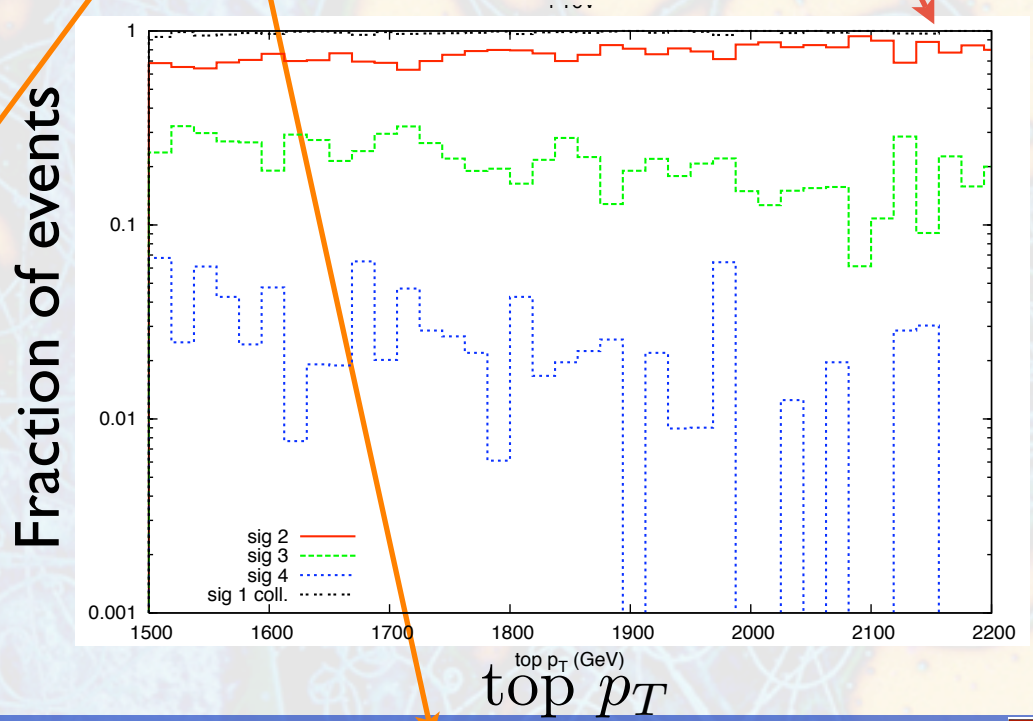
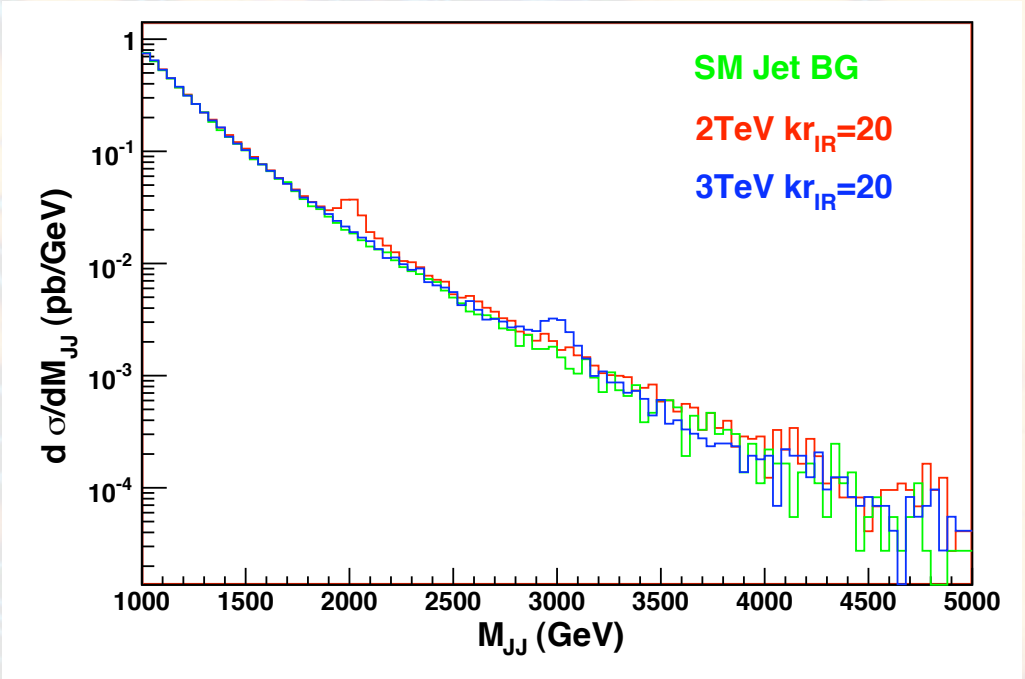


Compare to dijets?

- Possibly significant at lower masses
  - Very challenging!
- Would like a way to identify tops, even if collimated
- In some models may be the discovery mode



Finding collimated $t\bar{t}$

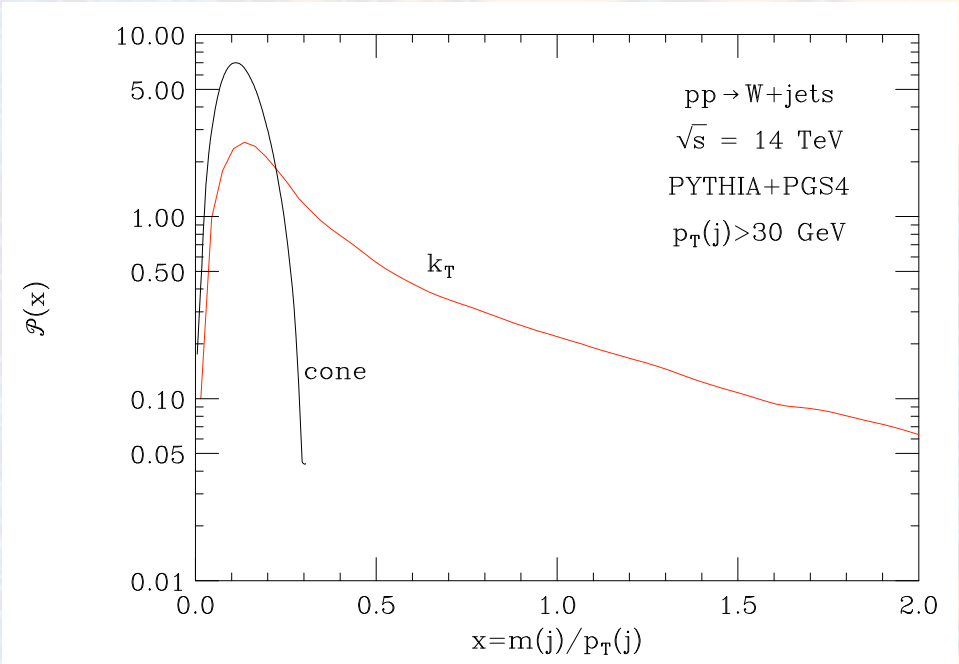
First demonstration

Agashe, Belyaev, Krupovnickas, Perez, Virzi hep-ph/0612015

found leptons inside jets

See also: U. Baur, L. Orr 0707.2006

- Used isolated leptons
- jet mass cut
  - note long tail for k_T algorithm



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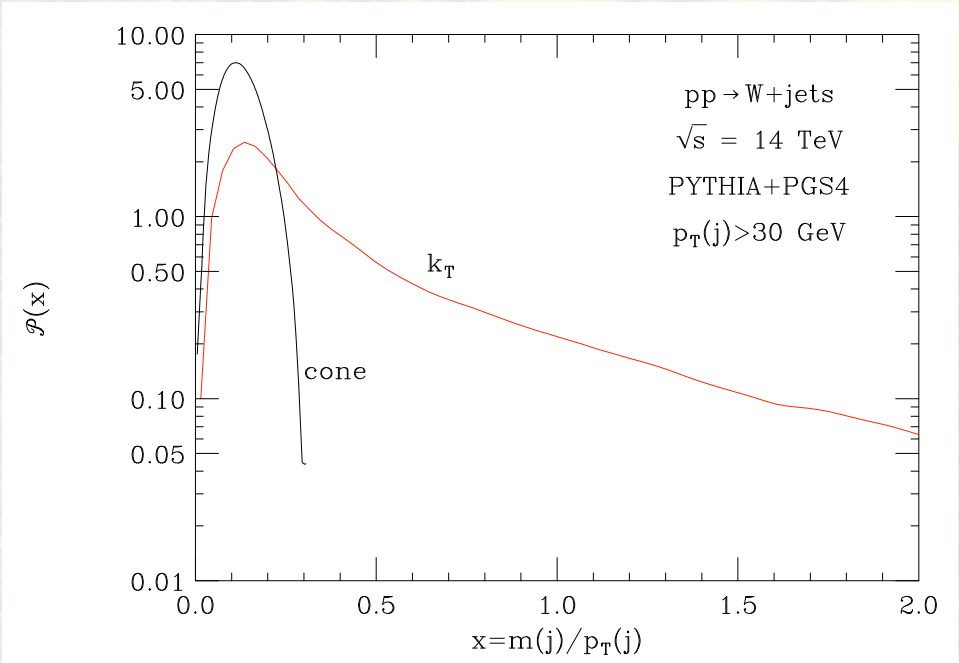
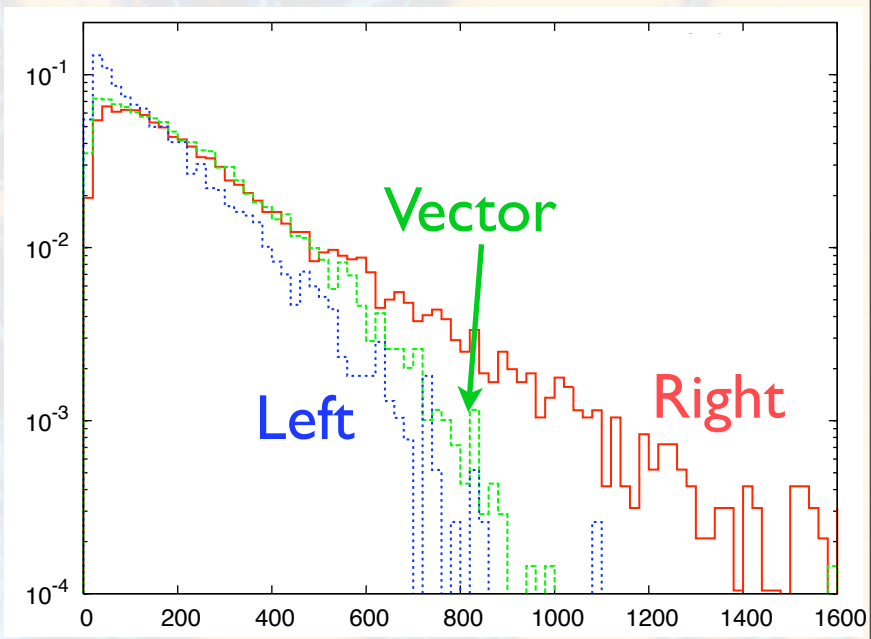
More work ongoing!



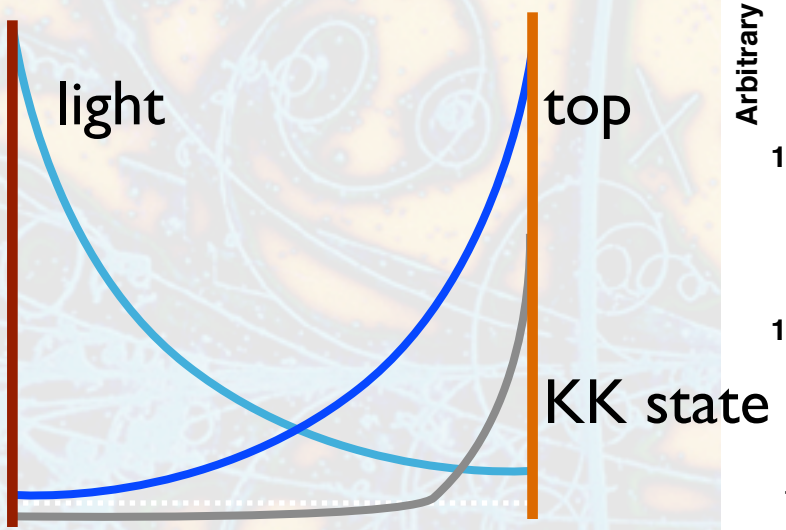
Top helicity

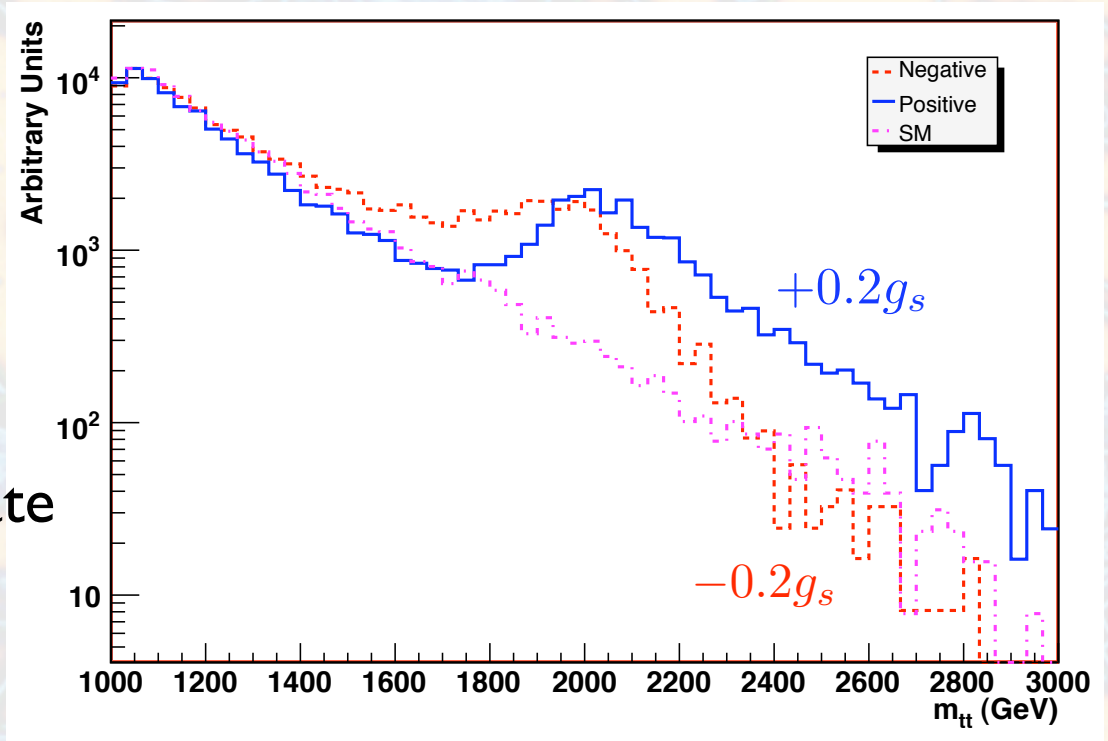
- Tops from KK decays are right-polarized
- Other models where they are left-polarized
  - e.g. Carena *et. al.* hep-ph/0607106 Agashe, Contino, Da Rold, Pomarol, hep-ph/0605341



Lepton p_T

Sign of the couplings



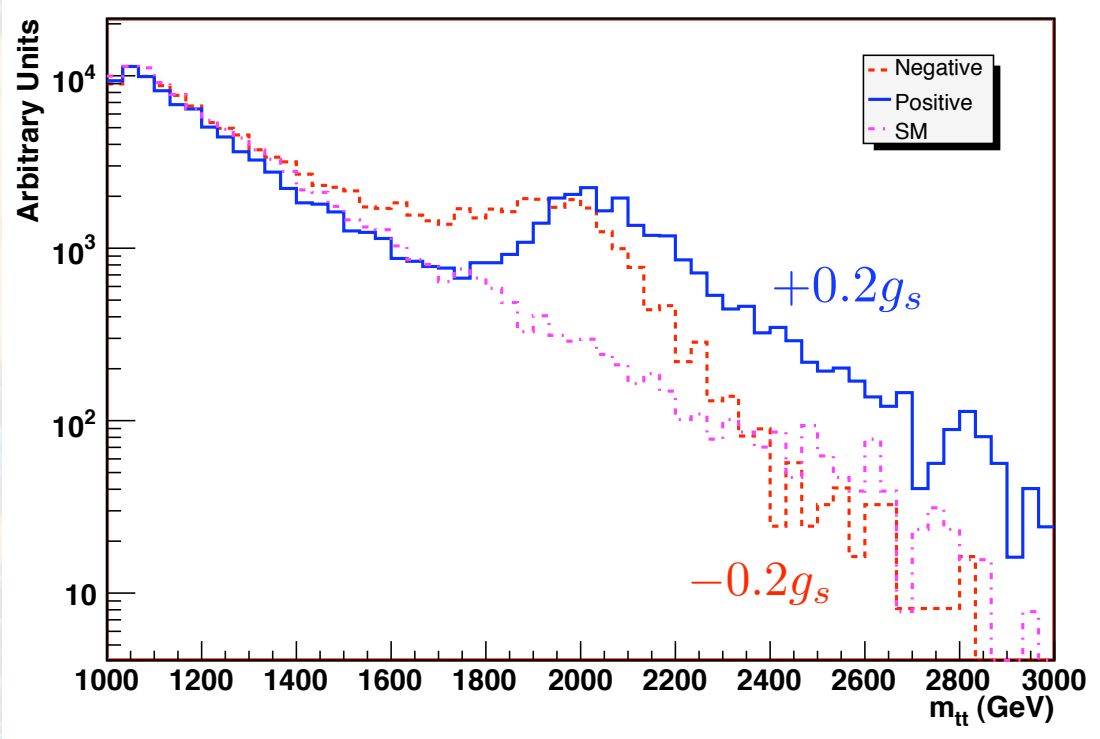


Sign of the couplings

$$A_i = -\frac{\int dm\left(\frac{d\sigma}{dm} - \frac{d\sigma}{dm}_{\mathrm{SM}}\right) * \epsilon(m - M_{g^{(1)}})}{\int dm \left|\frac{d\sigma}{dm} - \frac{d\sigma}{dm}_{\mathrm{SM}}\right|}$$

$g^{(1)}$ Mass	plus	minus
2 TeV	0.57	-0.44
3 TeV	0.54	-0.28
4 TeV	0.52	-0.16

(parton level without efficiencies, just an illustration)



Possibilities at the ILC

- No s-channel gluon production. Gives direct access to EW KK states
  - Disentangle KK gluons from EW bosons
- Unlikely to have on-shell production, but not necessarily problematic
  - See, e.g. TESLA TDR
- Better top helicity measurement?

Outlook

- Another reminder that large resonances can occur in models that solve the hierarchy problem
- Example of a model where almost all new physics appears in hadronic channels
- Possible to extract interesting, qualitative features that probe the model structure.
  - Couplings to top and bottom
  - Light fermion coupling sign