Using top quarks to probe the Randall-Sundrum model

Ben Lillie
Argonne / University of Chicago

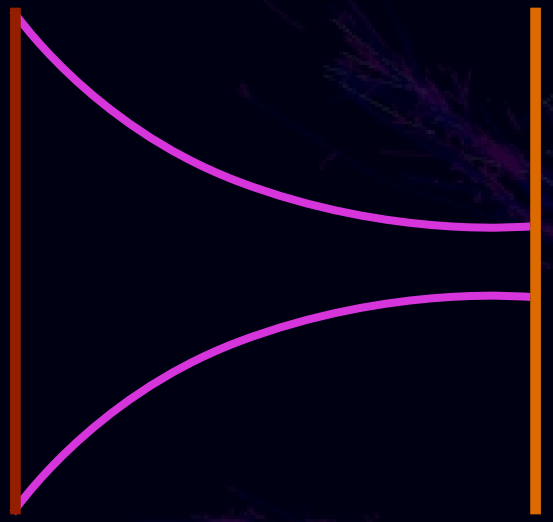
Outline

B. Lillie, L. Randall, L. Wang hep-ph/0701166

- Description of the RS model
- Importance of top quarks
- Top jets
- ILC channels?
- Outlook

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

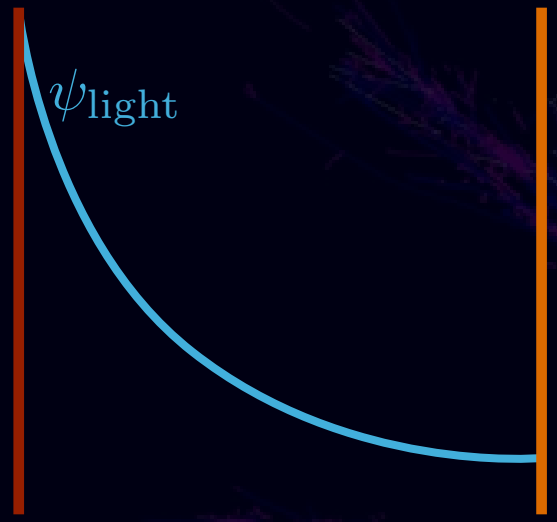
Standard Model fields

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

Standard Model fields

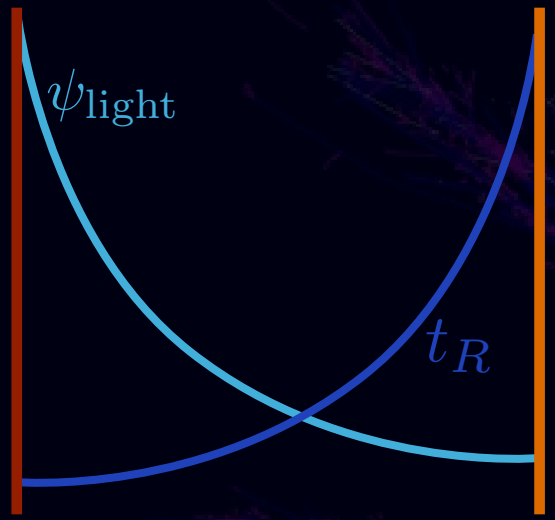
H. Davoudiasl, J. Hewett, T. Rizzo hep-ph/9911262
A. Pomarol hep-ph/9911294



- 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

Standard Model fields

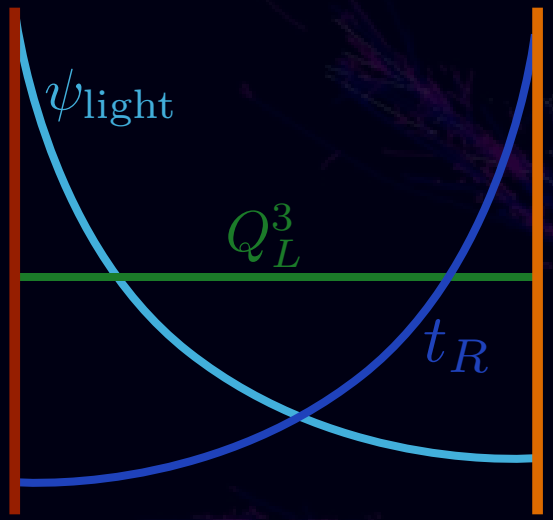
H. Davoudiasl, J. Hewett, T. Rizzo hep-ph/9911262
A. Pomarol hep-ph/9911294



- 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

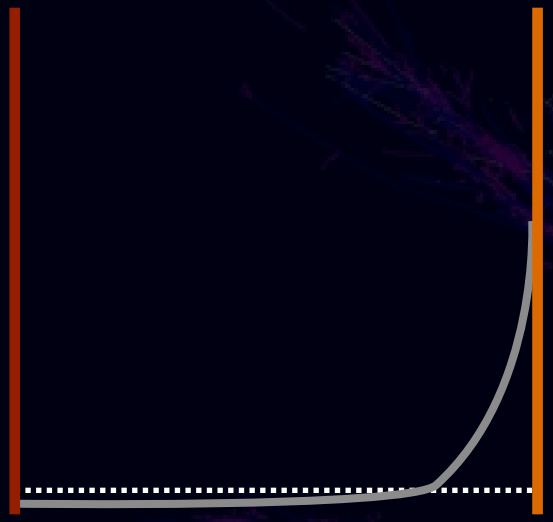
Standard Model fields

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



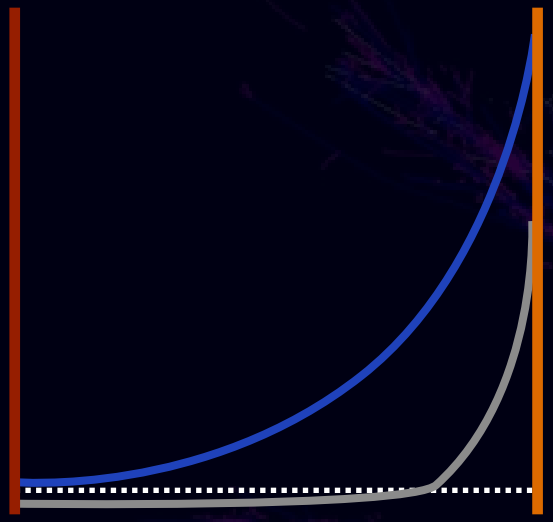
- KK states are IR localized
- Universal couplings to light fermions
- Large coupling to top

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

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

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

Kaluza-Klein states



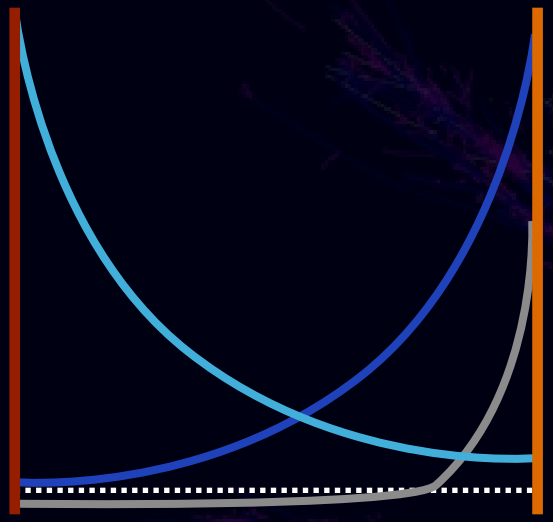
- KK states are IR localized
- Universal couplings to light fermions
- Large coupling to top

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

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

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

Kaluza-Klein states



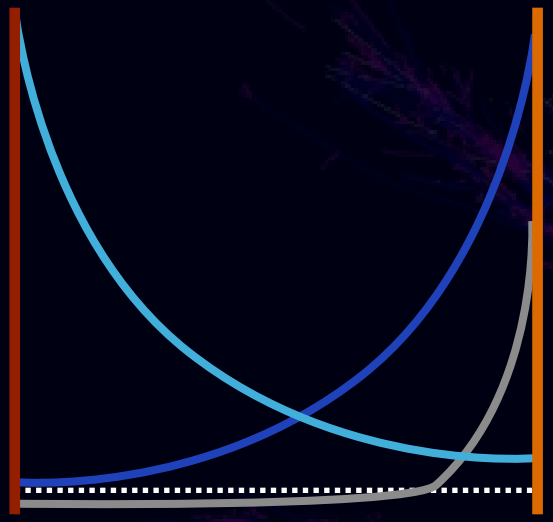
- KK states are IR localized
- Universal couplings to light fermions
- Large coupling to top

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

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

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

Kaluza-Klein states



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

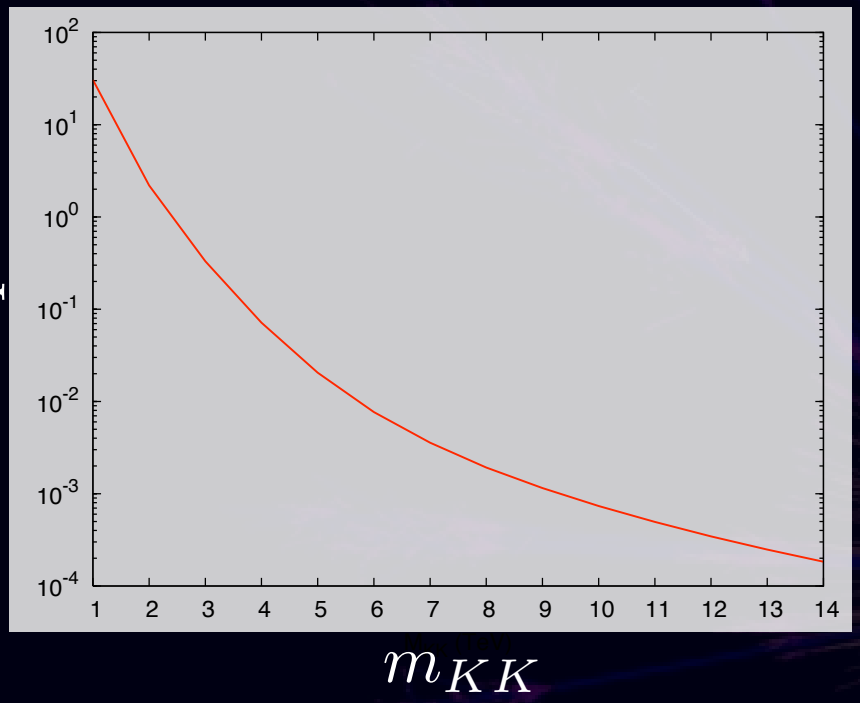
$$g_{f\bar{f}g^{(1)}} \sim 0.2 g_s$$

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

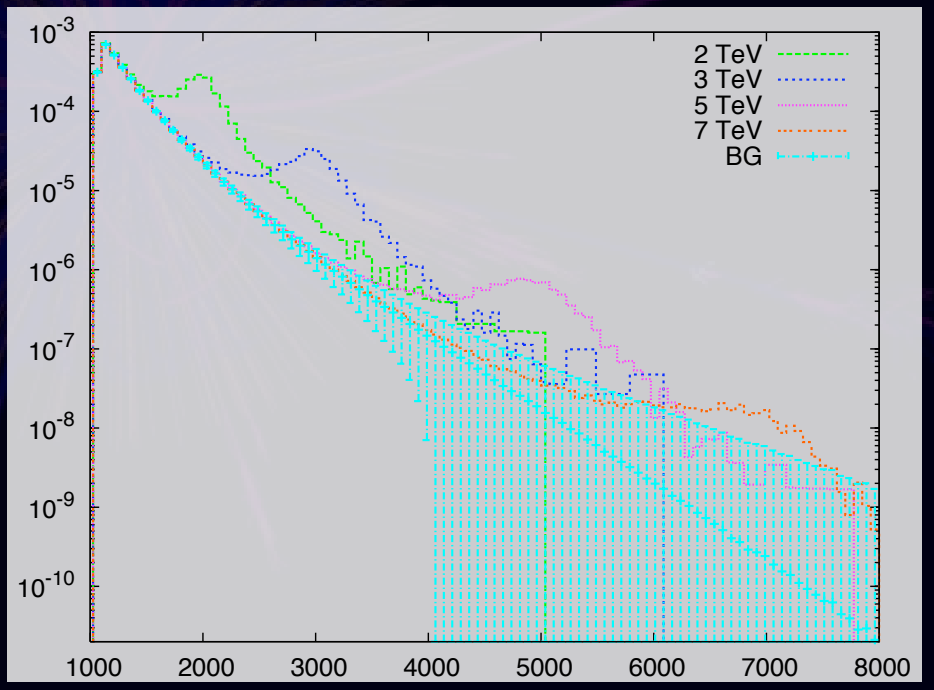
$$g_{t_R\bar{t}_R g^{(1)}} \sim 4 g_s$$

All gauge KK states decay predominantly to top pairs!

Top paris from KK gluons

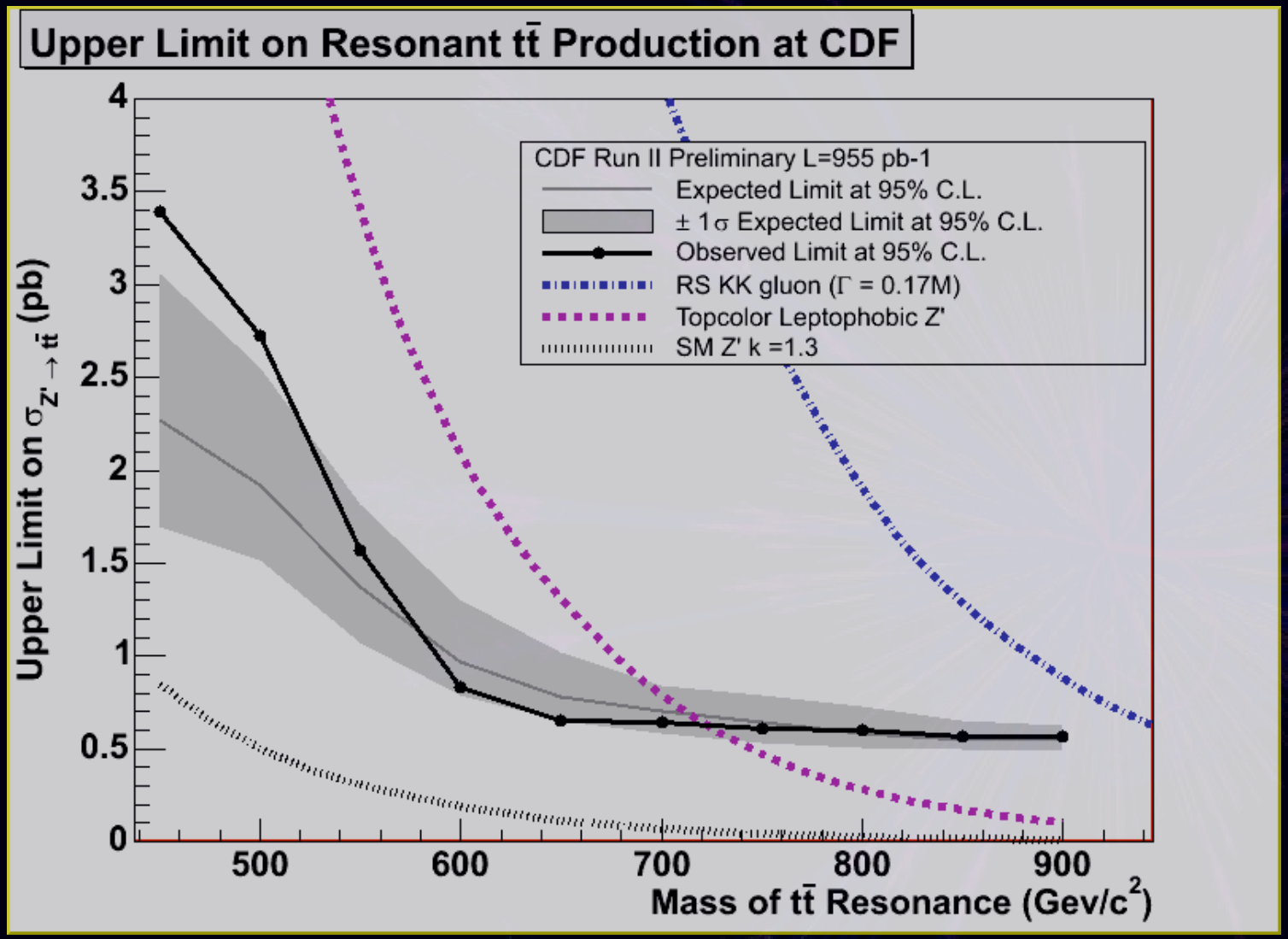


- Nice signal above SM top production
  - PDF and stat. errors shown, assuming 100 fb^{-1}
- Width/Mass ~17%



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

Tevatron constraints

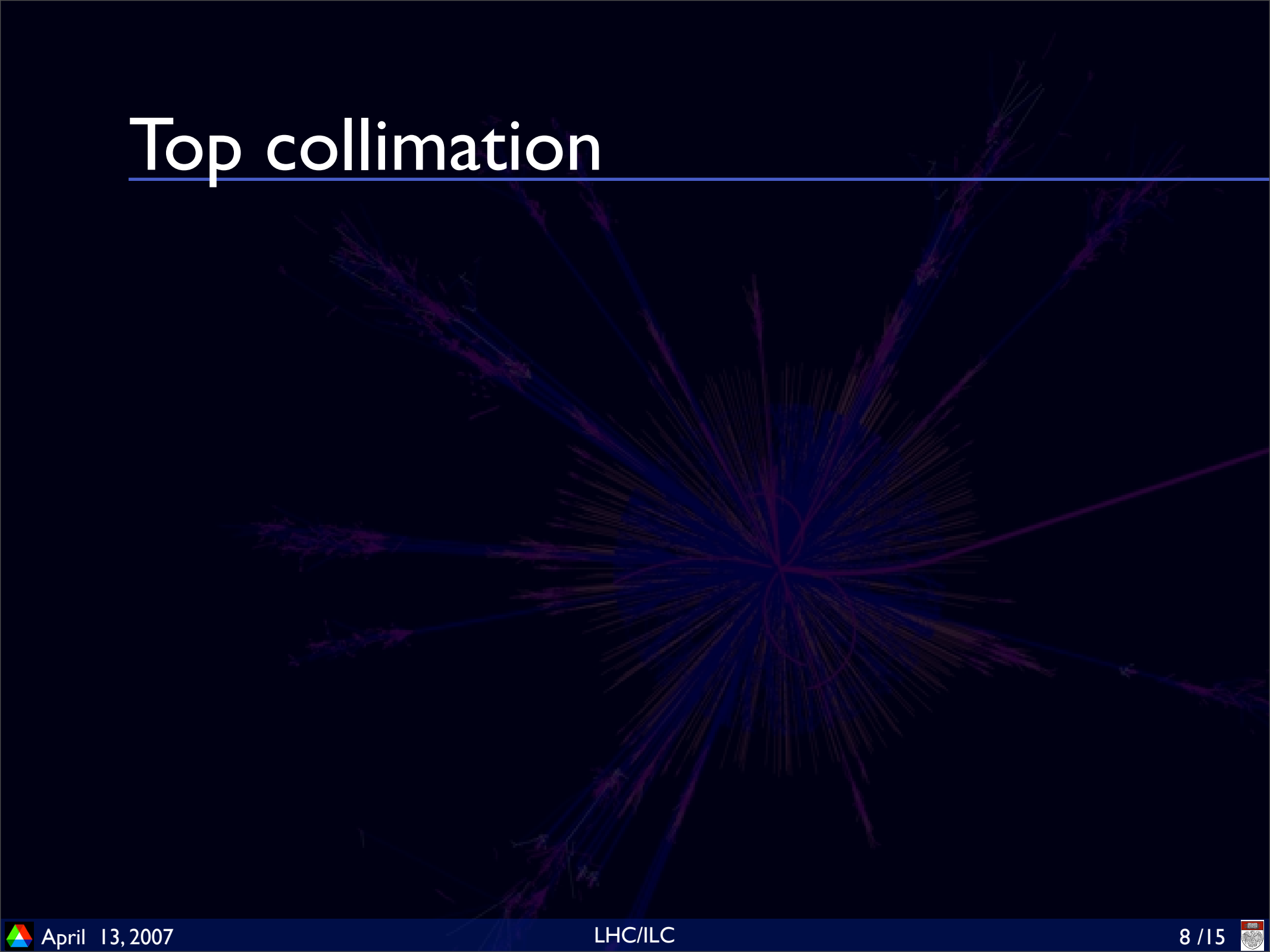


~ 950 GeV

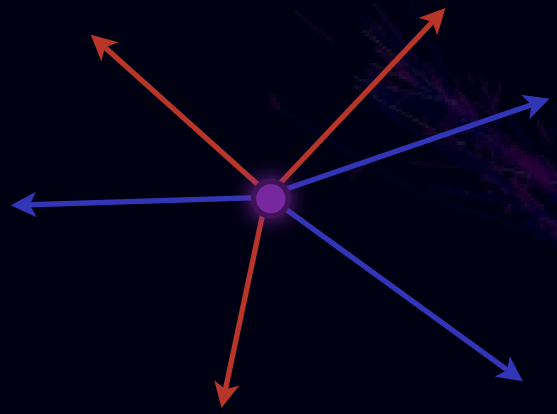
Used narrow-width approximation, so constraint is qualitative, but probably improves with proper treatment

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

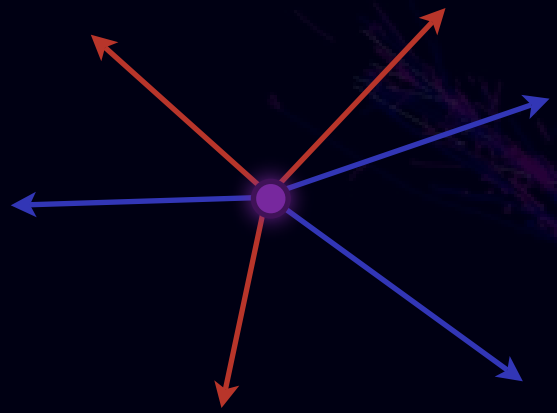


Top collimation

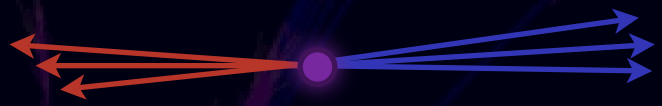


Threshold production

Top collimation

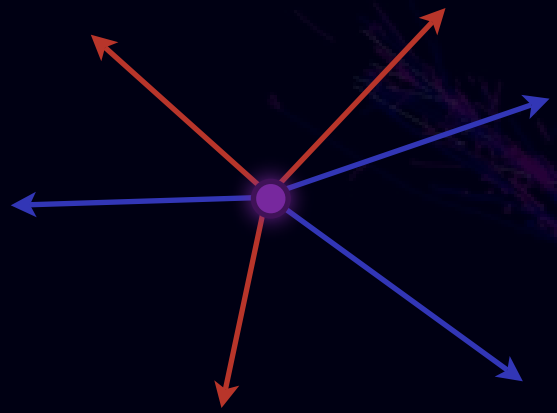


Threshold production

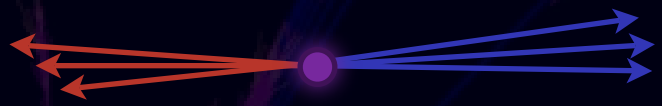


High mass production

Top collimation



Threshold production

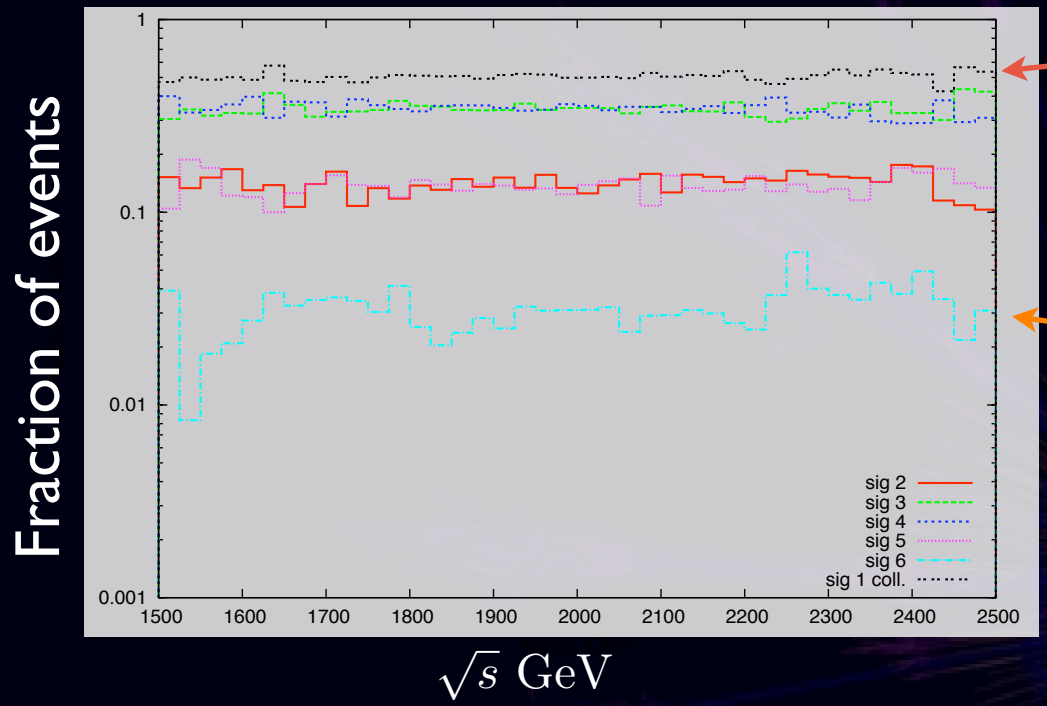


High mass production

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

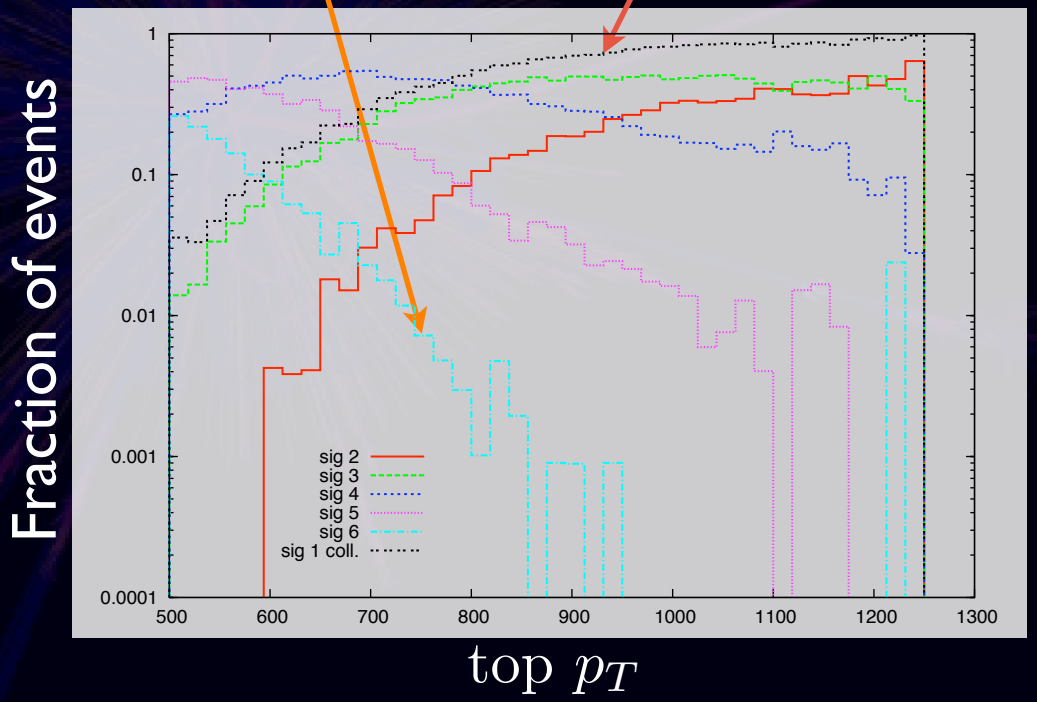
Top collimation (cont.)

2 TeV resonance



One top completely collimated

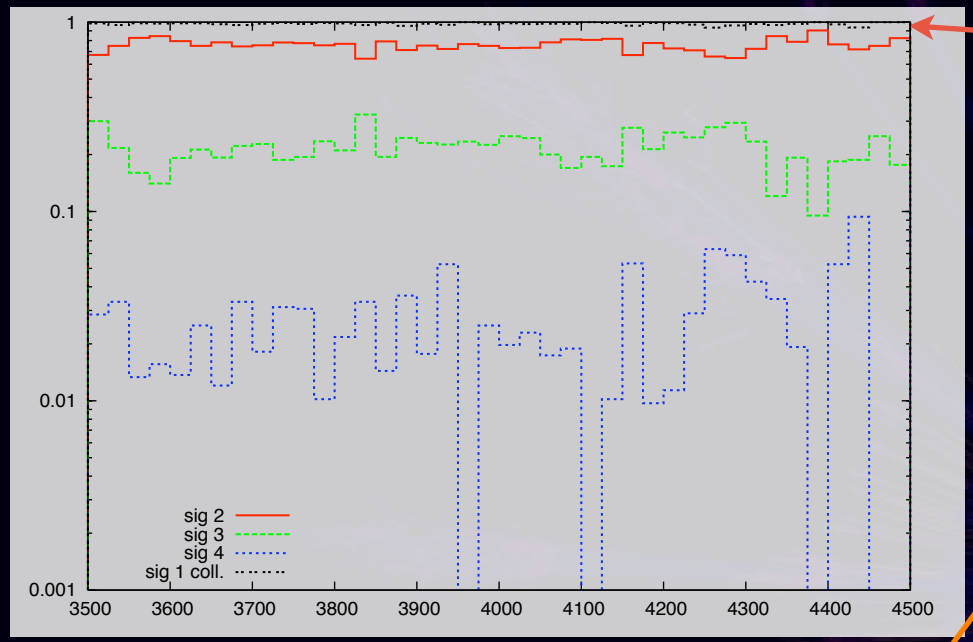
6 isolated decay products



Separation: $\Delta R > 0.4$

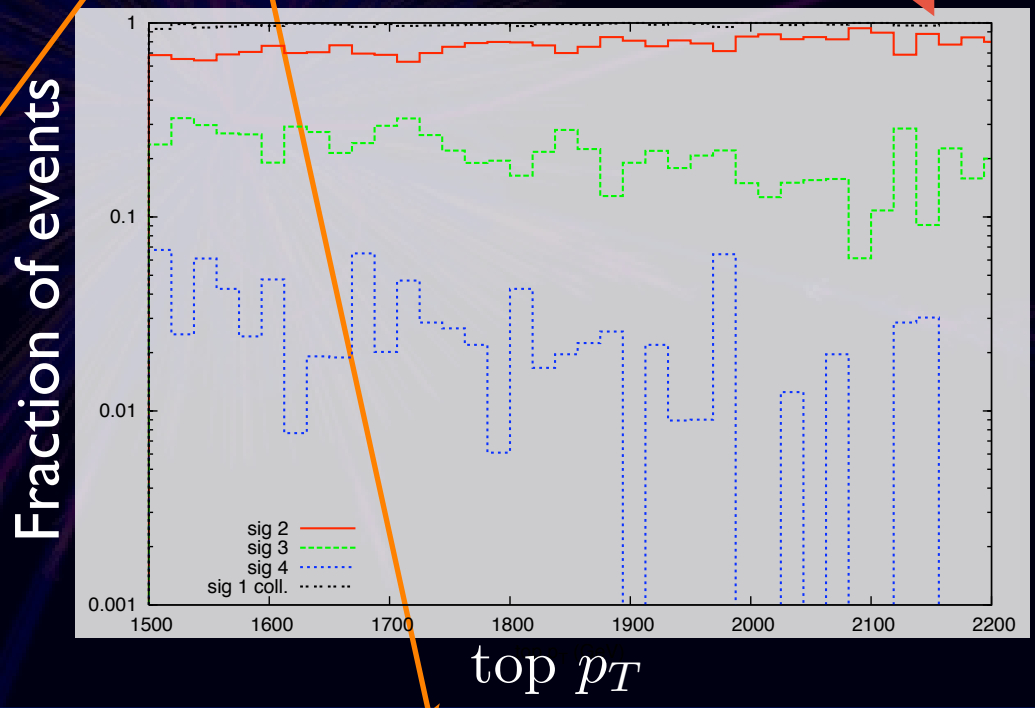
Top collimation (cont.)

4 TeV resonance



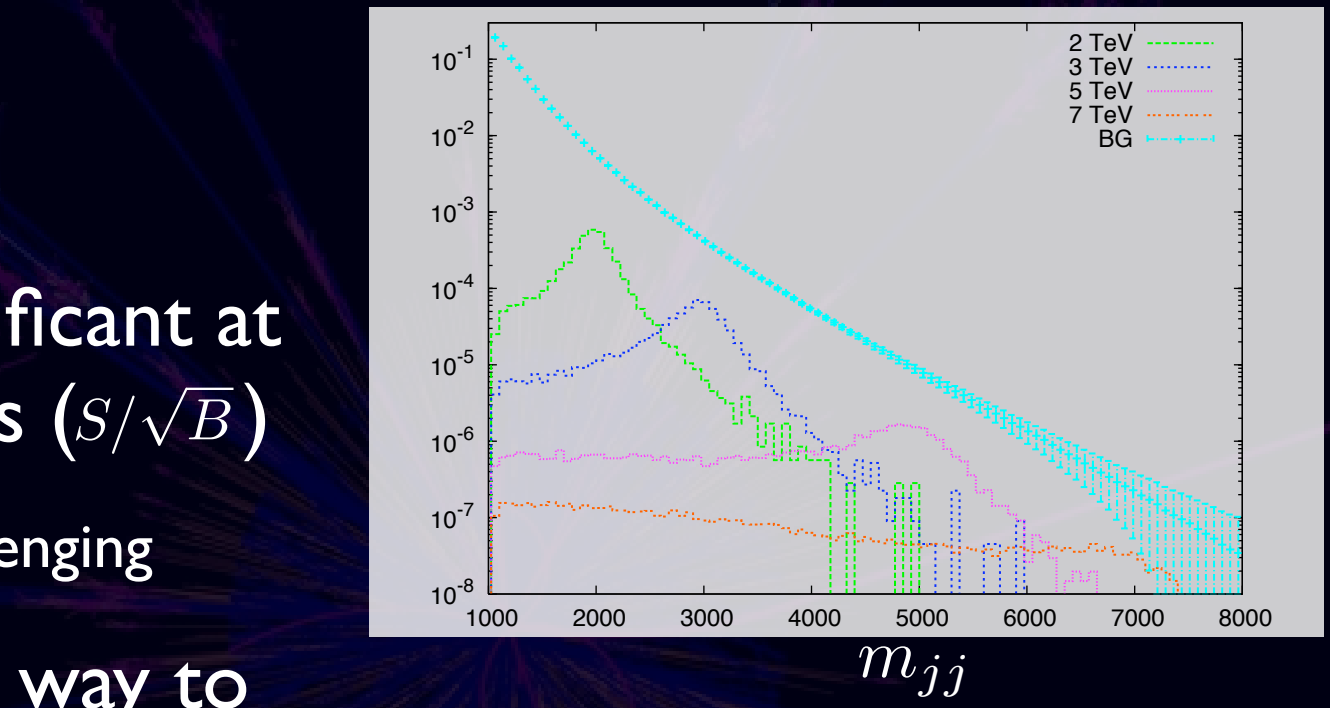
One top completely collimated

6 isolated decay products



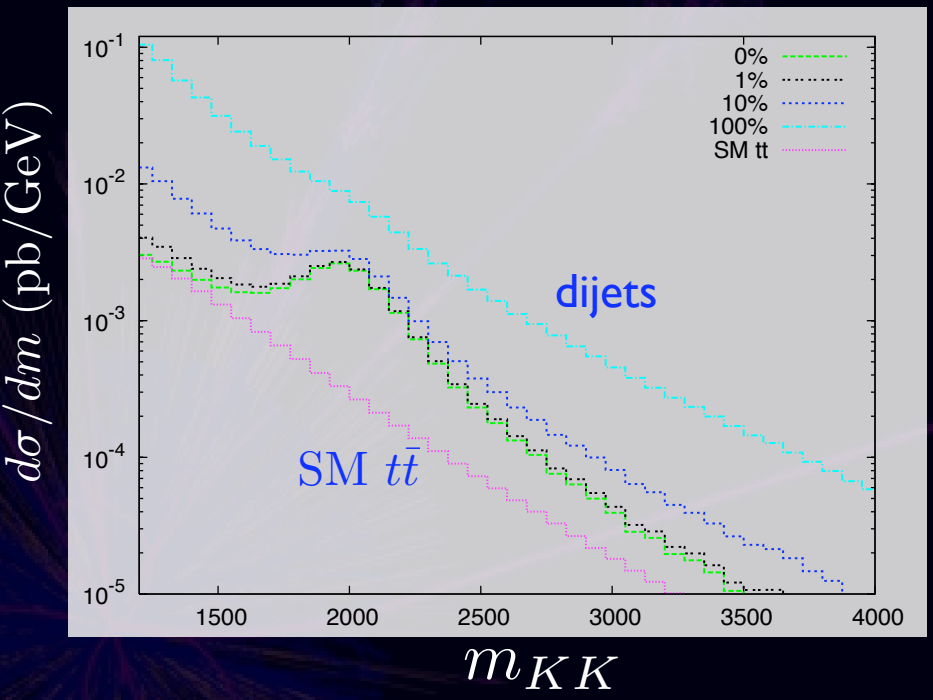
Compare to dijets?

- Possibly significant at lower masses ($S/\sqrt{B}$)
  - Still very challenging
- Would like a way to identify tops, even if collimated



Top-jets

- Challenge: what level of rejection can be obtained?
- Efficiency?



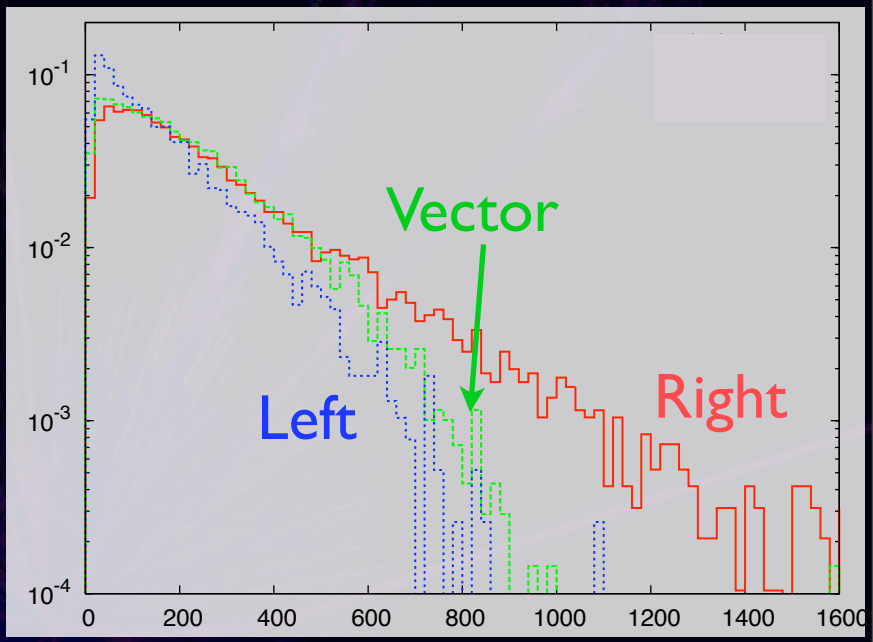
First demonstration

Agashe, Belyaev, Krupovnickas, Perez, Virzi

hep-ph/0612015

Top helicity

- Tops from KK decays are right-polarized
- Other models where they are left-polarized
  - e.g. Carena *et. al.* hep-ph/0607106



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
- How well can KK gluon properties be measured? (mass, width, couplings,...)
- How much can be deduced about the theory by measuring those properties?