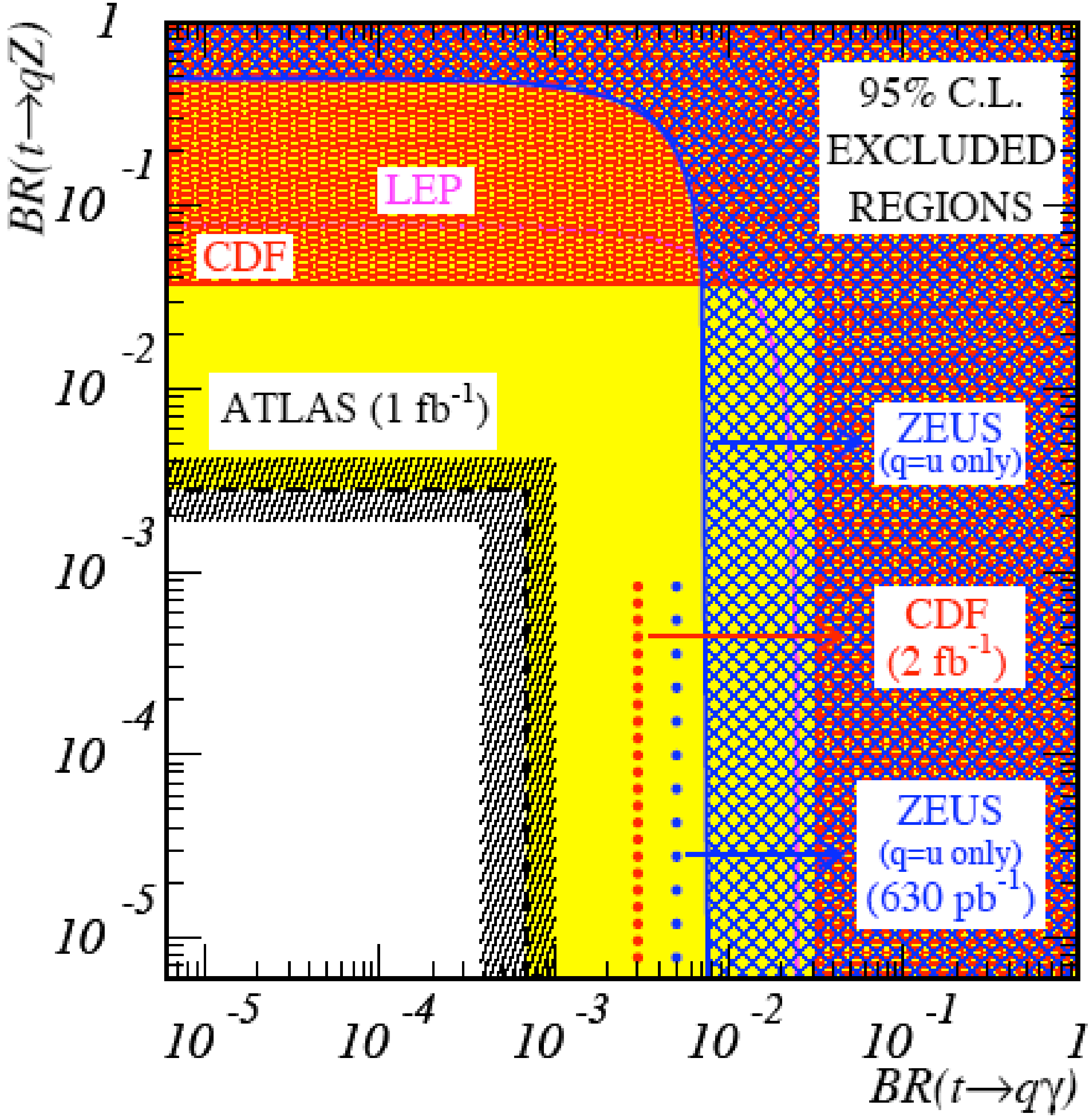


95% C.L.
EXCLUDED
REGIONS
LEP
CDF
ATLAS (1 fb^{-1})
ZEUS
(q=u only)
CDF
(2 fb^{-1})
ZEUS
(q=u only)
(630 pb^{-1})
BR(t→qZ)
BR(t→qγ)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}

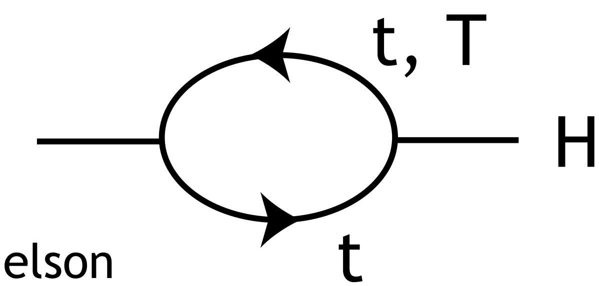
5. search for supersymmetry through $\widetilde{t}\ ,\widetilde{b} \rightarrow t + \not{E}_T$

In models of supersymmetry or extra dimensions, the top quark has partners in the new physics sector. In these models, the top quark is a weakly-coupled, Standard Model particle. However, the new particles with the quantum numbers of the top play a crucial role in the theory.

Even the weakly coupled top is more strongly coupled to the Higgs sector than any other Standard Model particle. The top partners share this coupling. Thus, diagrams with top partners can dominate the radiative corrections to the Higgs potential.

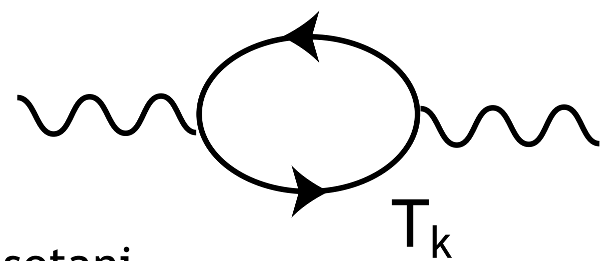
In many cases, these particles have specific effects that generate a negative Higgs mass-squared.

In Little Higgs models, the loop corrections due to the top quark and its partner cancel with a negative residue.



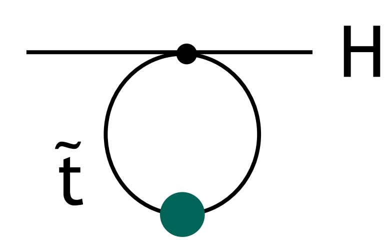
Katz-Nelson

In extra-dimensional models, the Kaluza-Klein excitations of the top quark give a symmetry-breaking potential for A^5



Hosotani

In supersymmetry, the renormalization of masses by the top quark-Higgs coupling gives a negative correction.



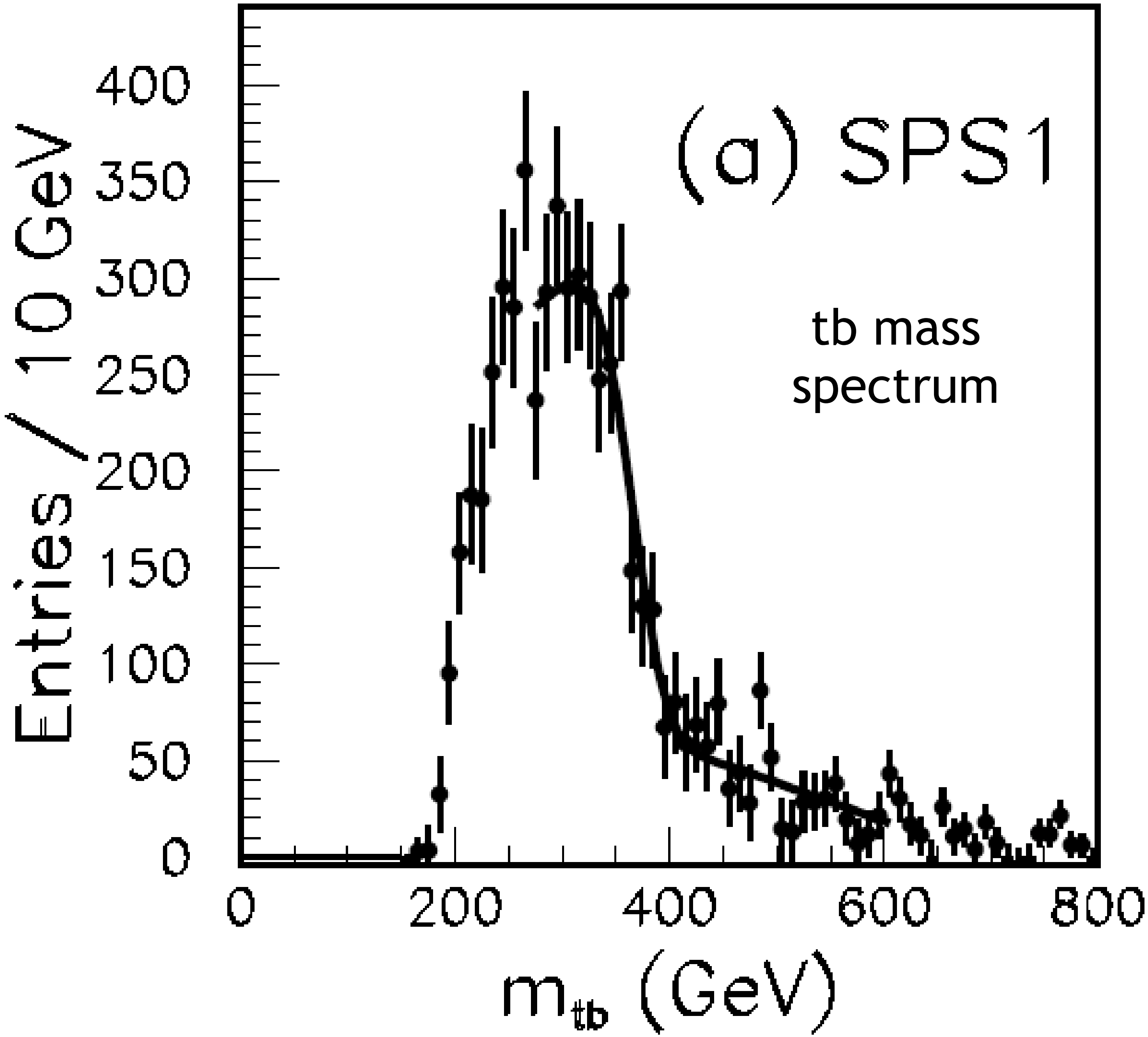
Ibanez-Ross-Alvarez-Gaume-Polchinski-Wise

The top partners decay to top if this is kinematically allowed.

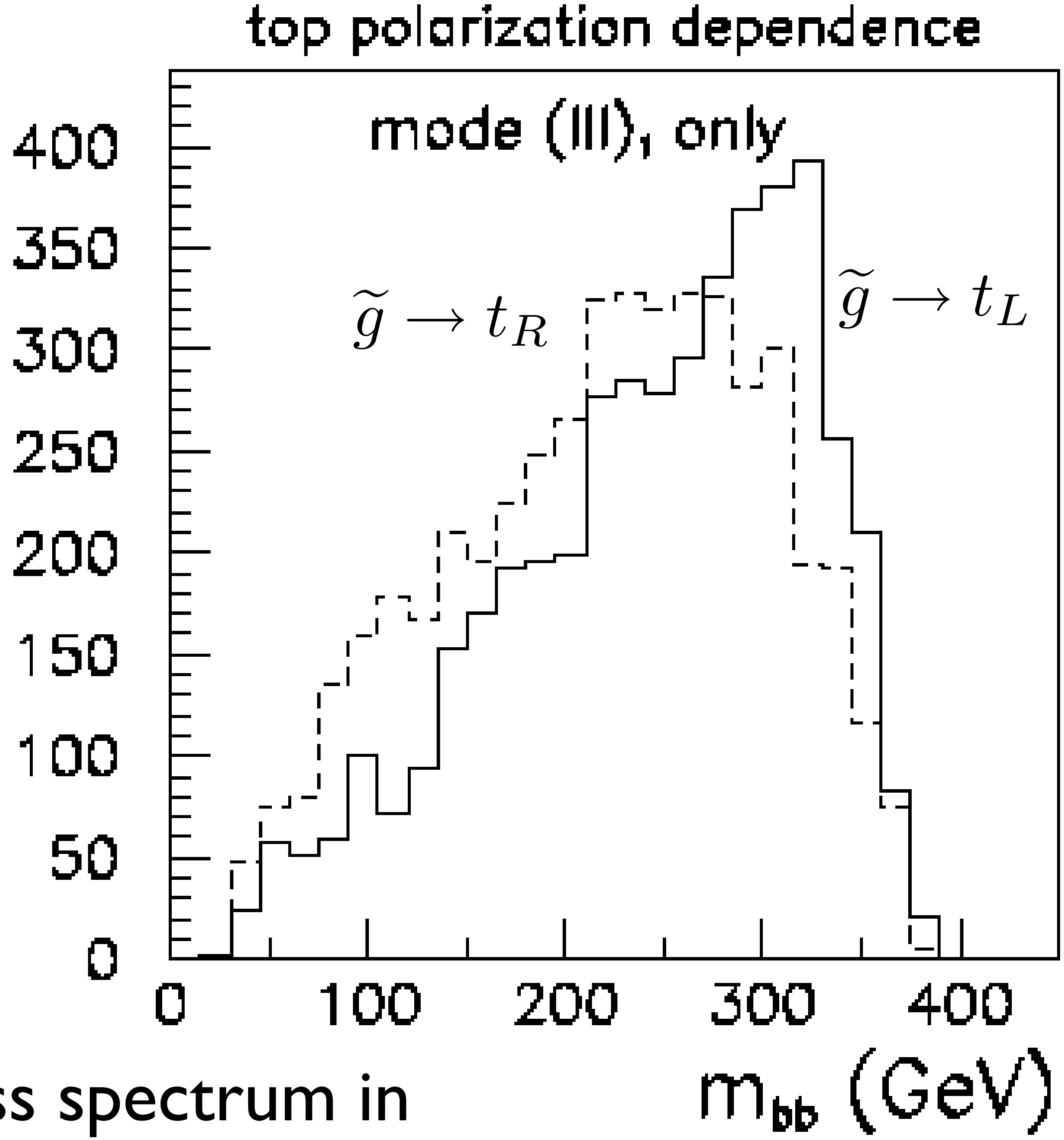
A typical production and decay pattern is

$$pp \to \widetilde{g}\widetilde{g} \ , \ \widetilde{g} \to \widetilde{t}\bar{t} \to b\chi^{+}\bar{t}$$

If there are on-shell tops in the final state, we can use our knowledge of the polarization dynamics of top quark decay to analyze the couplings of the top partners.



Hisano, Kawagoe, Nojiri



bb mass spectrum in
$\widetilde{g} \to t\bar{b}\chi^- \to b\bar{b} + X$

Hisano, Kawagoe, Nojiri

4. search for $T \rightarrow t + Z, h$, $T \rightarrow bW$

Consider next models of top compositeness and strong interactions. From precision electroweak measurements -- in particular, to agreement of $\Gamma(Z^0 \rightarrow b\bar{b})$ with the Standard Model prediction to 0.5% accuracy -- we suspect that the multiplets

$$(t_L, b_L) \ , \ b_R$$

are elementary. We still need to cancel the SU(3)xU(1) anomalies of this multiplet. The simplest way is to have t_R strongly interacting with another vector-like U(1) singlet quark T. Naturally t and T mix.

This structure is found, for example, in the simplest little Higgs models.

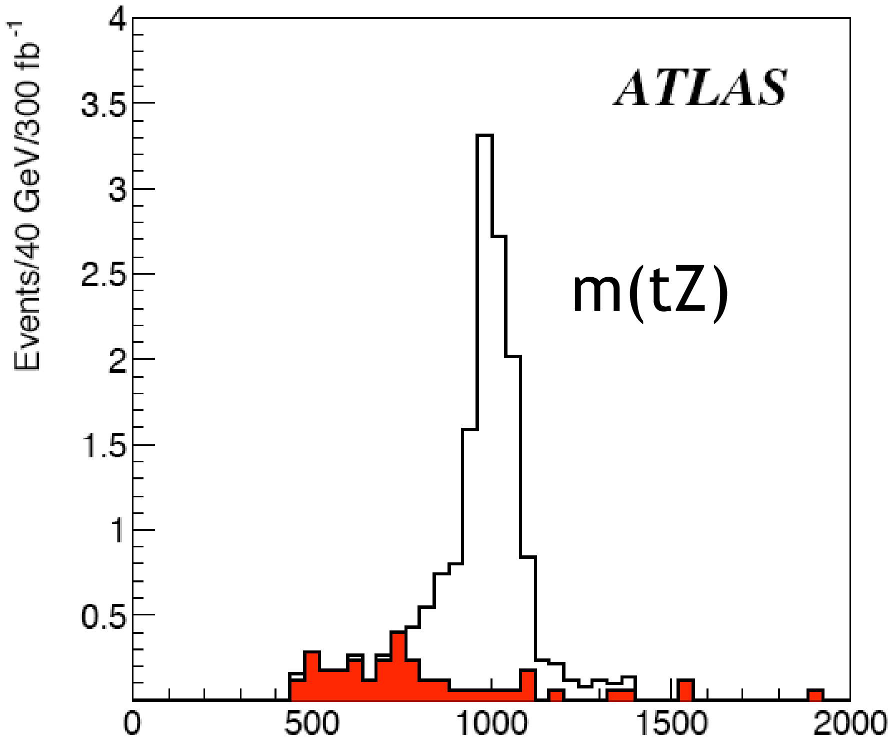
Then the coupling of $(t_R, T_R) \cdot \bar{t}_L$ through the Higgs or electroweak symmetry breaking induces the couplings

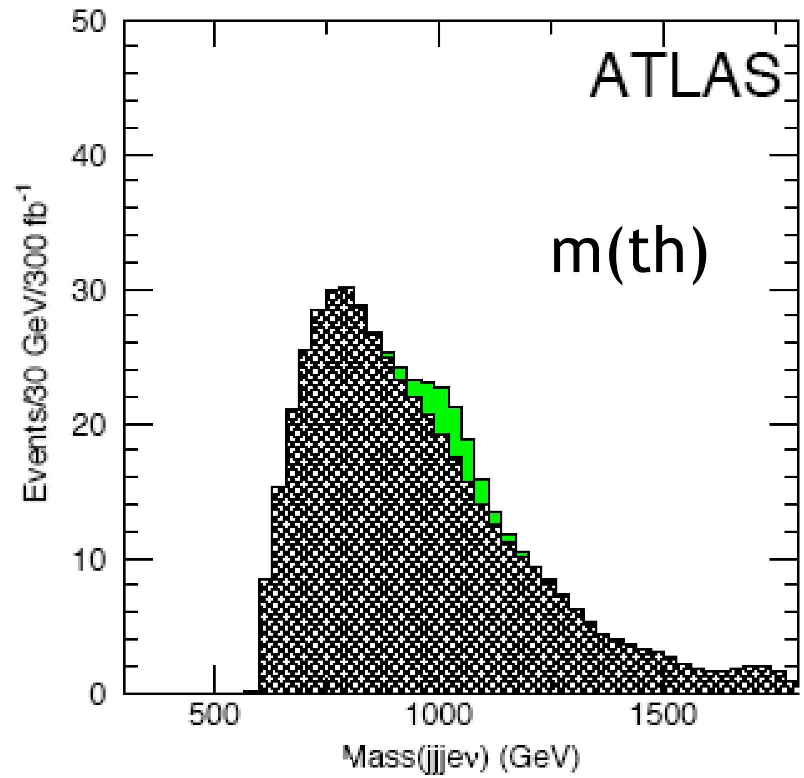
$$T \to t_L h^0 \ , \ T \to t_L \pi^0 \ , \ T \to b_L \pi^+$$

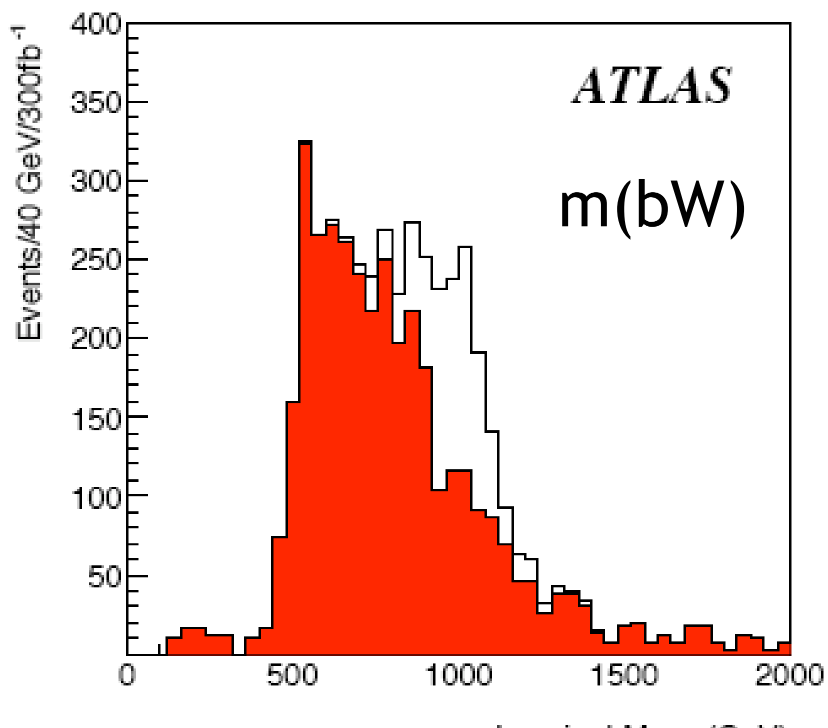
After the Goldstone bosons are eaten in the Higgs mechanism, these decays become

$$T \to t h^0 \ , \ T \to t Z^0 \ , \ T \to b W^+$$

with branching ratios 25%, 25%, 50% up to phase space.







Azuelos et al.

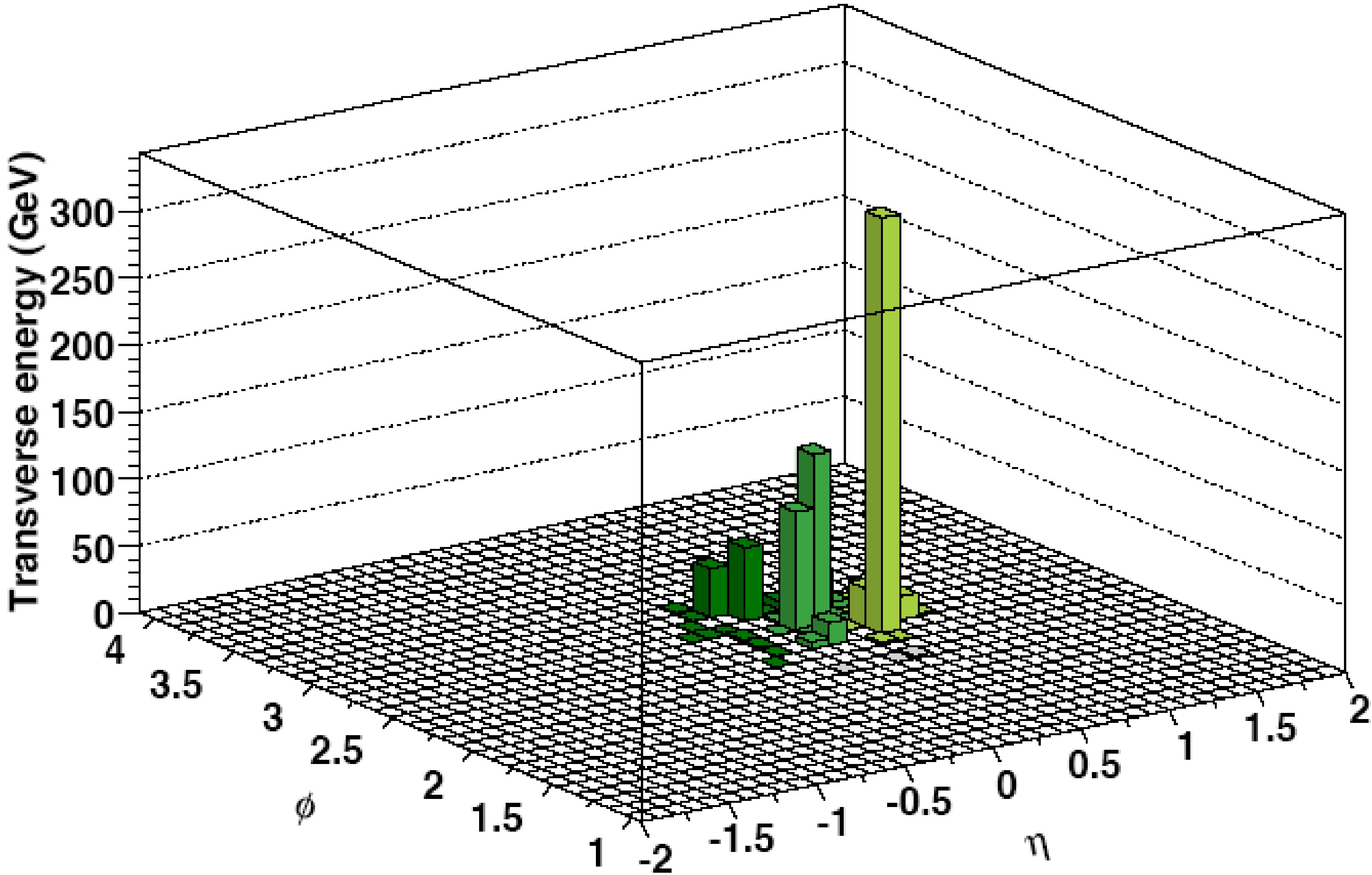
3. study of boosted top jet tagging

In view of these and other ways that top quarks enter new physics, it would be wonderful if we could select a top as a kind of exotic jet.

This looks very difficult to do near threshold, but it might be possible when the tops are highly boosted in the transverse direction (as they often are in new physics decays).

A hadronically decaying top then makes a jet with three subjets.

The problem is to tell this jet from a gluon splitting to three partons.



ET = 800 GeV top jet and subjets

Kaplan, Reherman, Schwartz, Tweedie

A basic idea: pruning:

Think about the jet as built up from subjets (e.g. using the Cambridge/Aachen jet algorithm).

As each subjet is added, compute the z of the softer jet

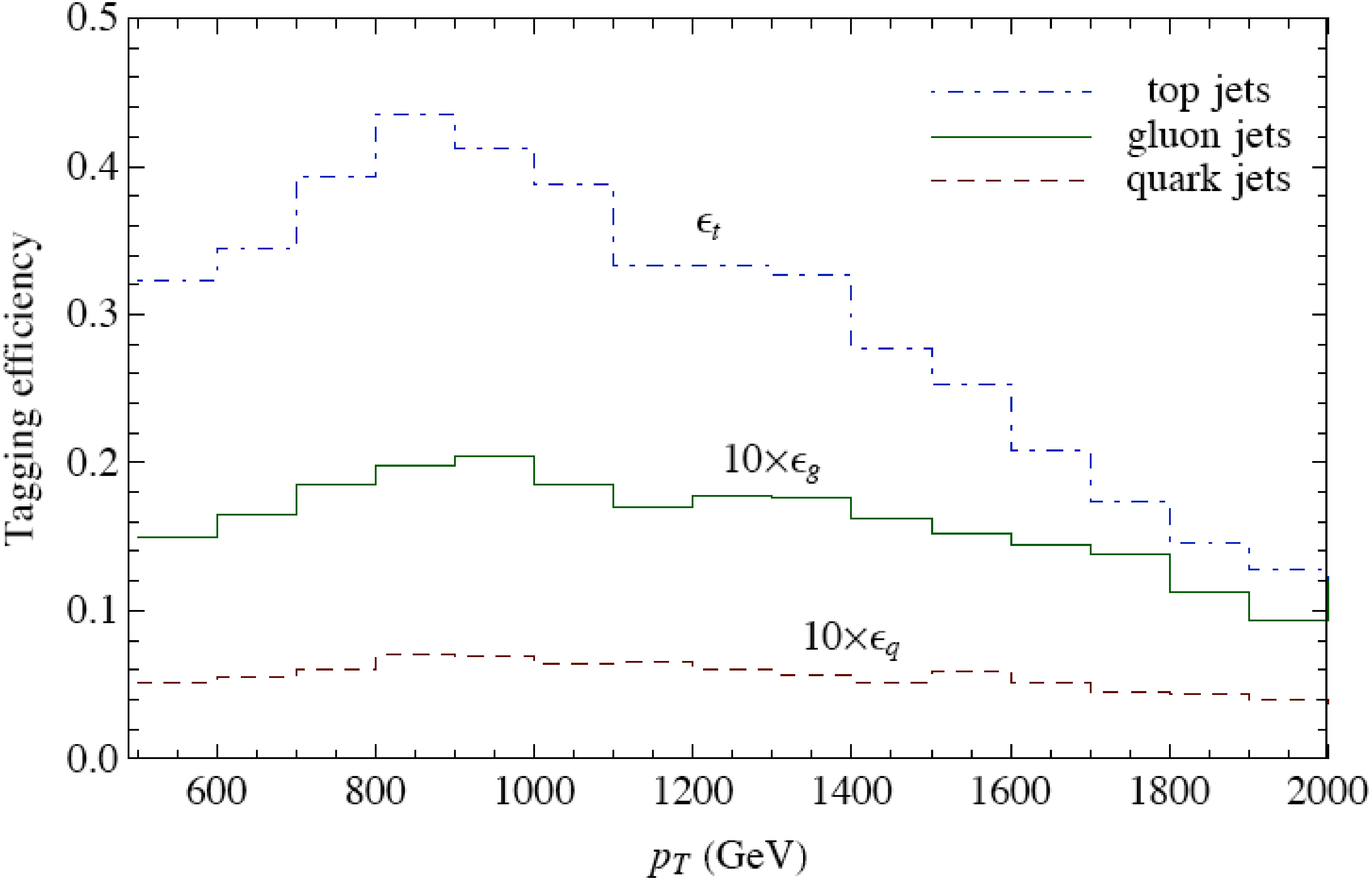
$$z = E_{T2}/(E_{T1} + E_{T2})$$

If z is small, the new subjet is probably a QCD radiation; discard it.

This degrades QCD jets, but leaves jets whose substructure is due to heavy particle decays.

Brooijmans, Kaplan et al., Ellis, Vermilion, Walsh, Butterworth, Davison, Rubin, Salam

have proposed specific realizations of this idea.



Kaplan, Reherman, Schwartz, Tweedie

2. search for $t\bar{t}$ resonances

Many models of new strong interaction physics in the Higgs sector contain resonances that decay to $t\bar{t}$

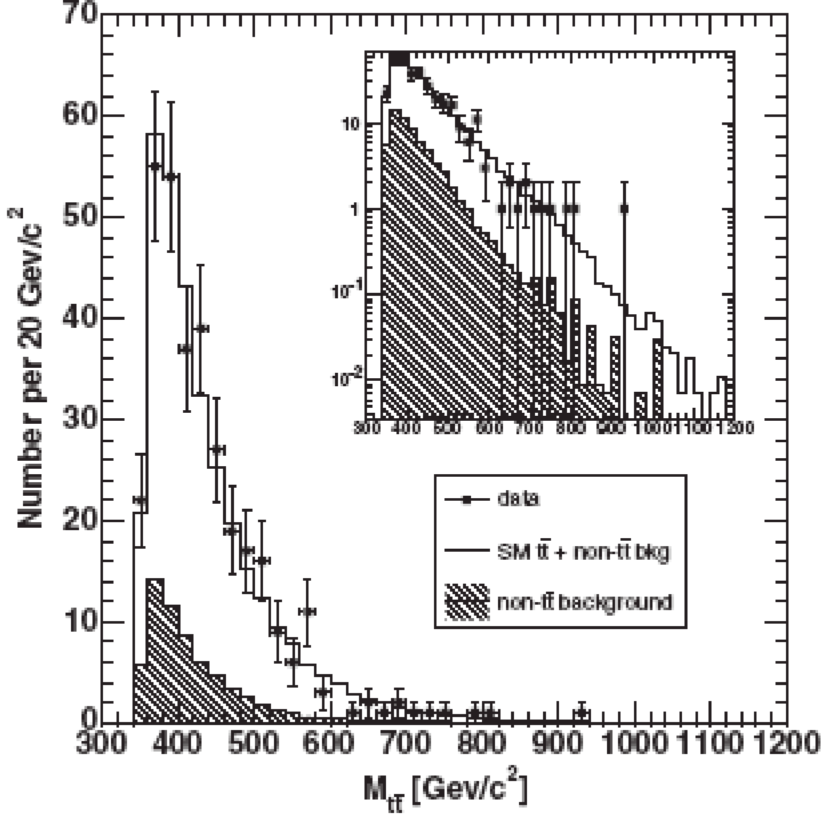
Two prominent examples are:

Topcolor gluons: SU(3) x SU(3) gauge symmetry, broken to SU(3) QCD at 1 TeV, such that (t, b) couple strongly to one of the factors.

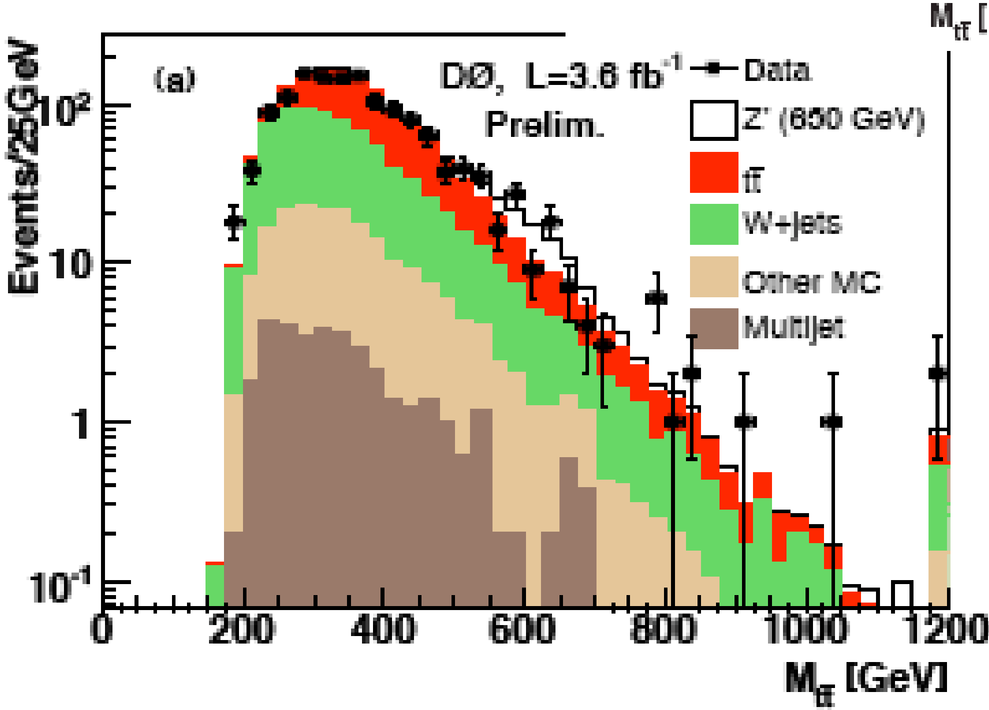
Hill

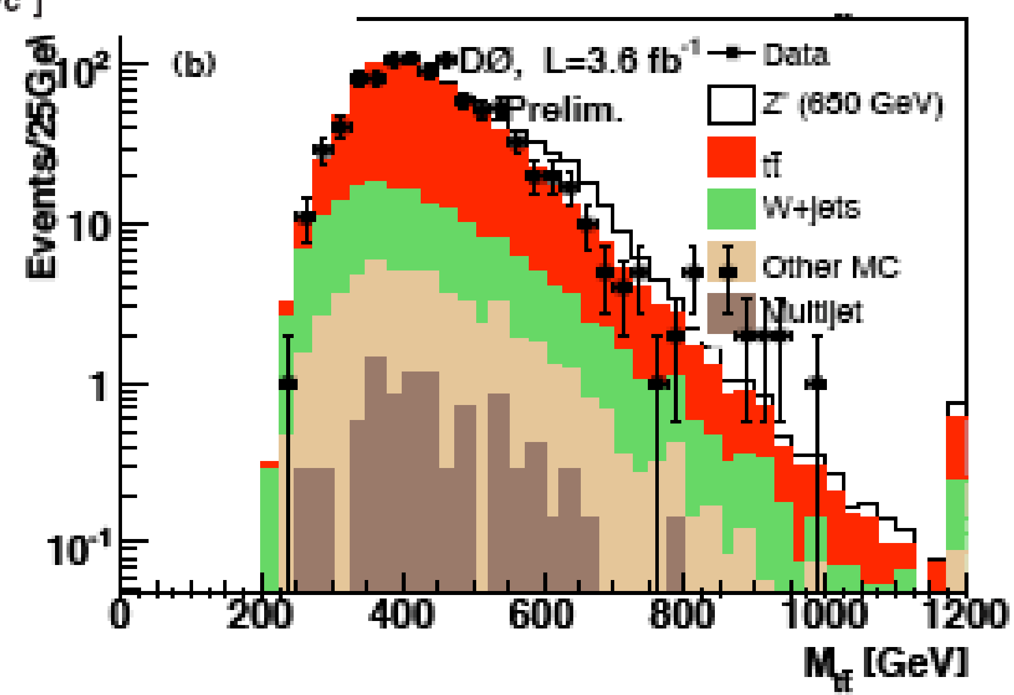
KK gluons: In Randall-Sundrum warped compactifications, the first Kaluza-Klein excitations will decay most strongly to the fermions that are most peaked toward the TeV brane. The strongest coupling will be to t_R .

Agashe



CDF 1 fb-1

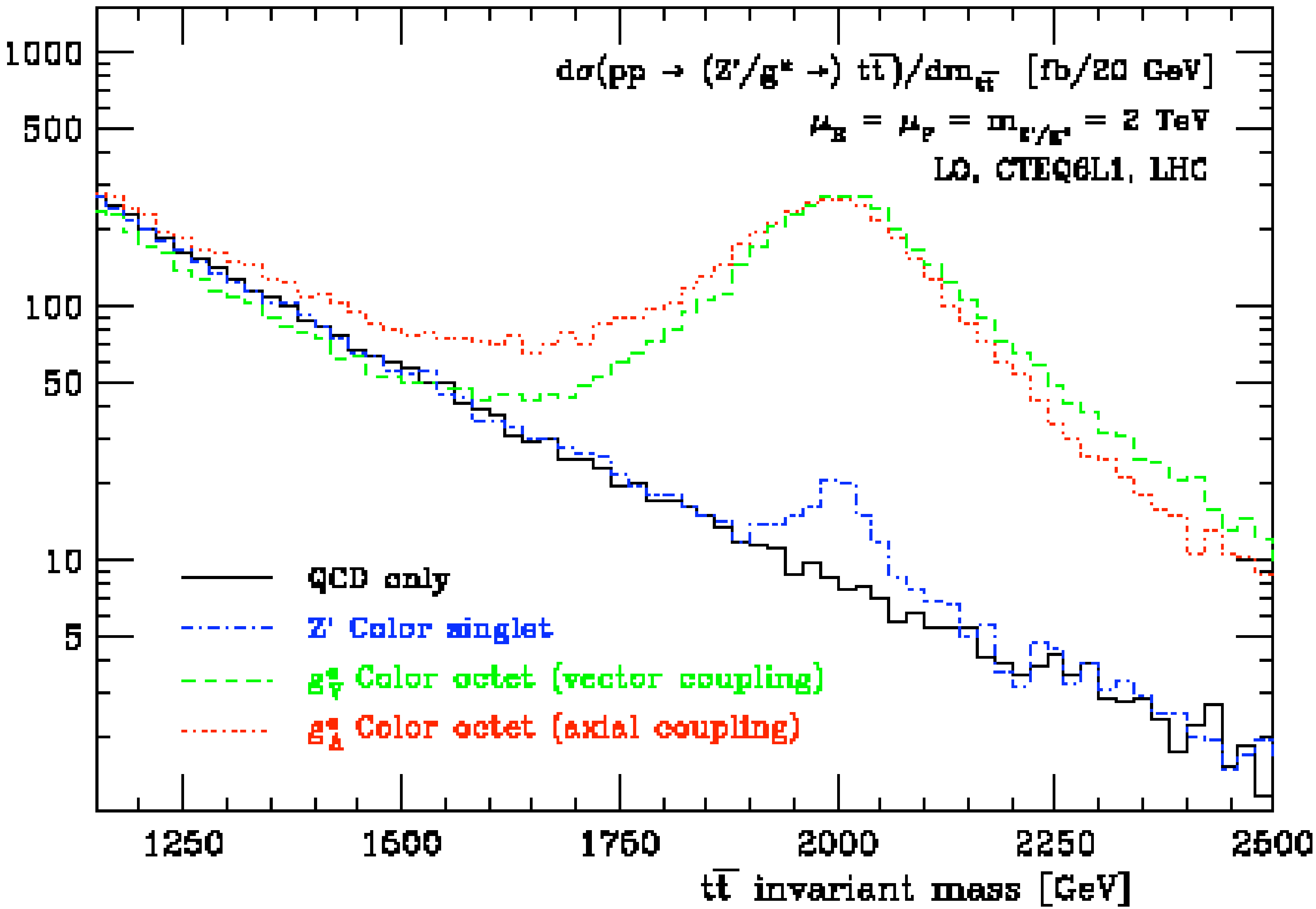




DO W + 3 jet

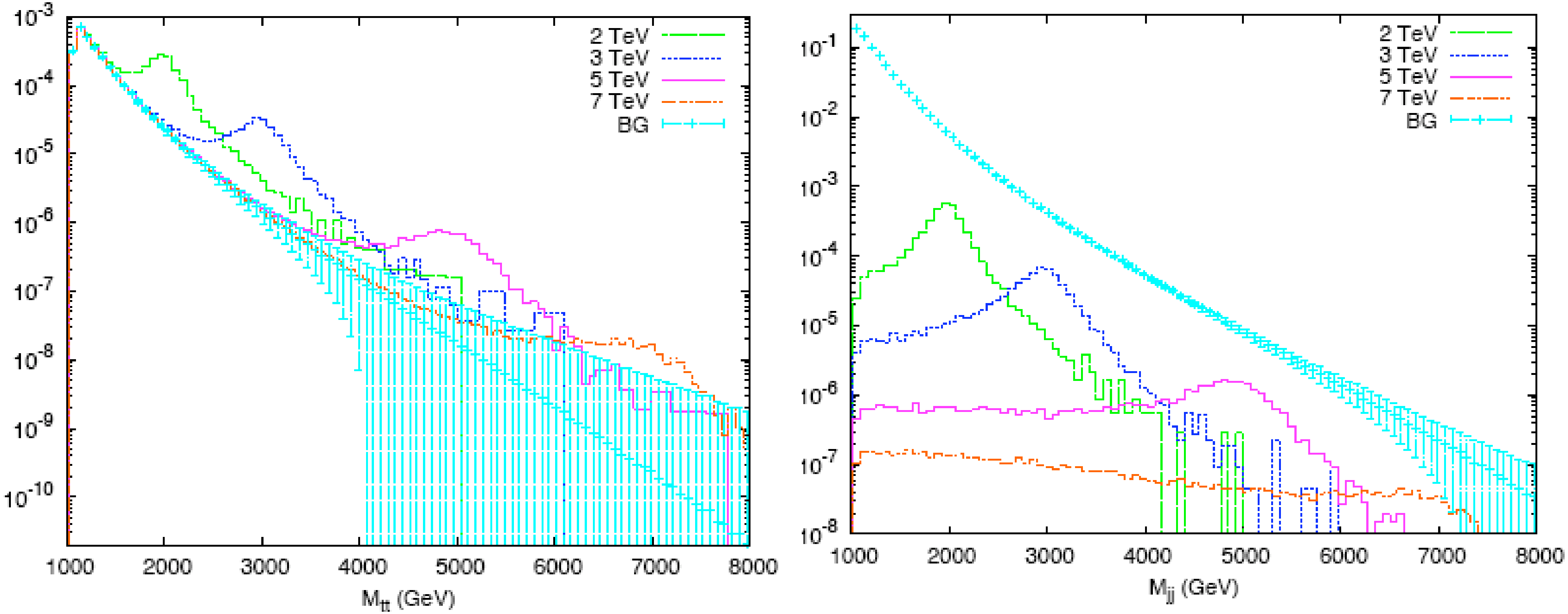
W+ 4 or more jets

topcolor gluons



Maltoni, Frederix

KK gluons



Lillie, Randall, Wang

An effective top-tagging method would be very important for $t\bar{t}$ resonance searches.

If the estimates of Kaplan et al. for their method are correct, we should be able to discover a $t\bar{t}$ resonance at 1.5 TeV or above in the 2010-11 LHC run.

1. search for CP violation in top production and decay

We still need a source of CP violation not in the CKM model to explain the excess of baryons over antibaryons in the universe.

It would be very attractive for this source to be visible experimentally at the TeV scale. Perhaps it comes from the Higgs or other new physics sector and is visible in top decays.

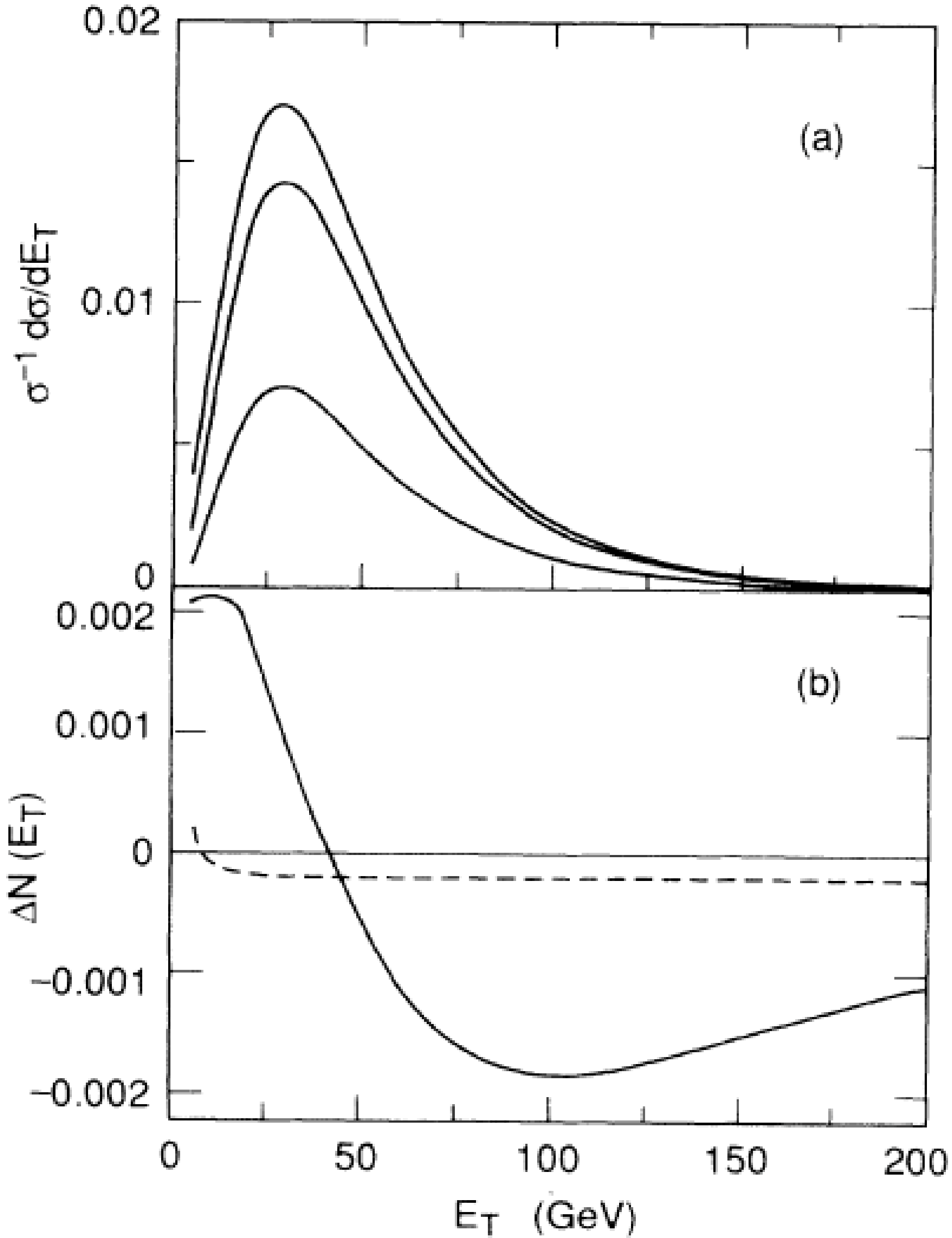
A robust observable is the difference

$$\frac{d\Gamma_t}{dE(e^+)} - \frac{d\Gamma_{\bar{t}}}{dE(e^-)}$$

in top quark pair production events, signalling a difference

$$\sigma(pp \to t_R \bar{t}_R) - \sigma(pp \to t_L \bar{t}_L)$$

Recall that, even though LHC is a pp collider, these events come dominantly from a CP-even initial state.



0.02
0.01
0
(a)
$\sigma^{-1} d\sigma/dE_T$
0.002
0.001
0
−0.001
−0.002
(b)
$\Delta N\ (E_T)$
0
50
100
150
200
E_T (GeV)

MEP-Schmidt

Even if the top quark is a Standard Model object, it offers many new handles for understanding physics at TeV energies.

And, perhaps, the top quark has more importance that simply a probe into TeV physics.   It might be a integral part of new physics, even the key part.

Hopefully, in the next year, we will begin to find out.

summary: top 10 top quark measurements at the LHC

10. measurement of $\sigma(t\bar{t})$
9. measurement of m_t
8. measurement of the single top cross section
7. measurement of the W helicity in top decay
6. search for $t \to c\gamma$, $t \to cZ$
5. search for supersymmetry through $\widetilde{t}$, $\widetilde{b} \to t + \not{E}_T$
4. search for $T \to t + Z, h$, $T \to bW$
3. study of boosted top jet tagging
2. search for $t\bar{t}$ resonances
1. search for CP violation in top production and decay

Extra:

‘Top Ten Reasons not to run the LHC’

a la David Letterman

Top Ten Reasons not to run the LHC

10. Quarks and gluons are so last century.

9. To make room for the data,
   I’ll have to throw away my ABBA CD’s.

8. “When you’re a Jet, you’re a Jet all the way ... ”

7. Exclusion of supersymmetry will put 2,000 theorists
   out of work.

6. The entire population of Switzerland will have squeaky voices.

Top Ten Reasons not to run the LHC

5. Attack of the killer b’s !

4. My pet top quark Alphonse won’t feel special anymore.

3. No # 3; writer’s Root analysis crashed in ATHENA.

2. Black holes in your underwear -- too itchy !

1. Those physicists will just want another 10 billion dollar toy...