Composite gluino at the LHC

Thomas Grégoire
University of Edinburgh

work in progress with Ami Katz

What will we see at the LHC ?

Natural theory of EWSB?

Supersymmetry?

Higgs as PGSB (LH, RS-like)?

Higgsless?

Technicolor?

Extra-Dimensions?

Twin Higgs?

General Features

- New colored particles
  - Naturaleness
- Third generation of quark special?
- Stable particles?
  - MSSM: R-partiy $(-1)^{3B+L+2S}$
  - Little Higgs : T-parity to avoid electroweak precision constraints.
  - R parity is more general: if conservation of Lepton and Baryon number.

Little Higgs

- Models where the Higgs is a pseudo-Goldstone boson.

- Large spontaneously broken global symmetries. Explicit 'collective breaking': more than one couplings are required to give a mass to the Higgs.

- Extended gauge, Yukawa and Higgs sectors.

- same spin 'partner' cancel quadratic divergences.

- Minimal Little Higgs Spectrum

W'	ϕ	T
cancel quadratic divergence of W	cancel quadratic divergence of Higgs	cancel quadratic divergence of tops

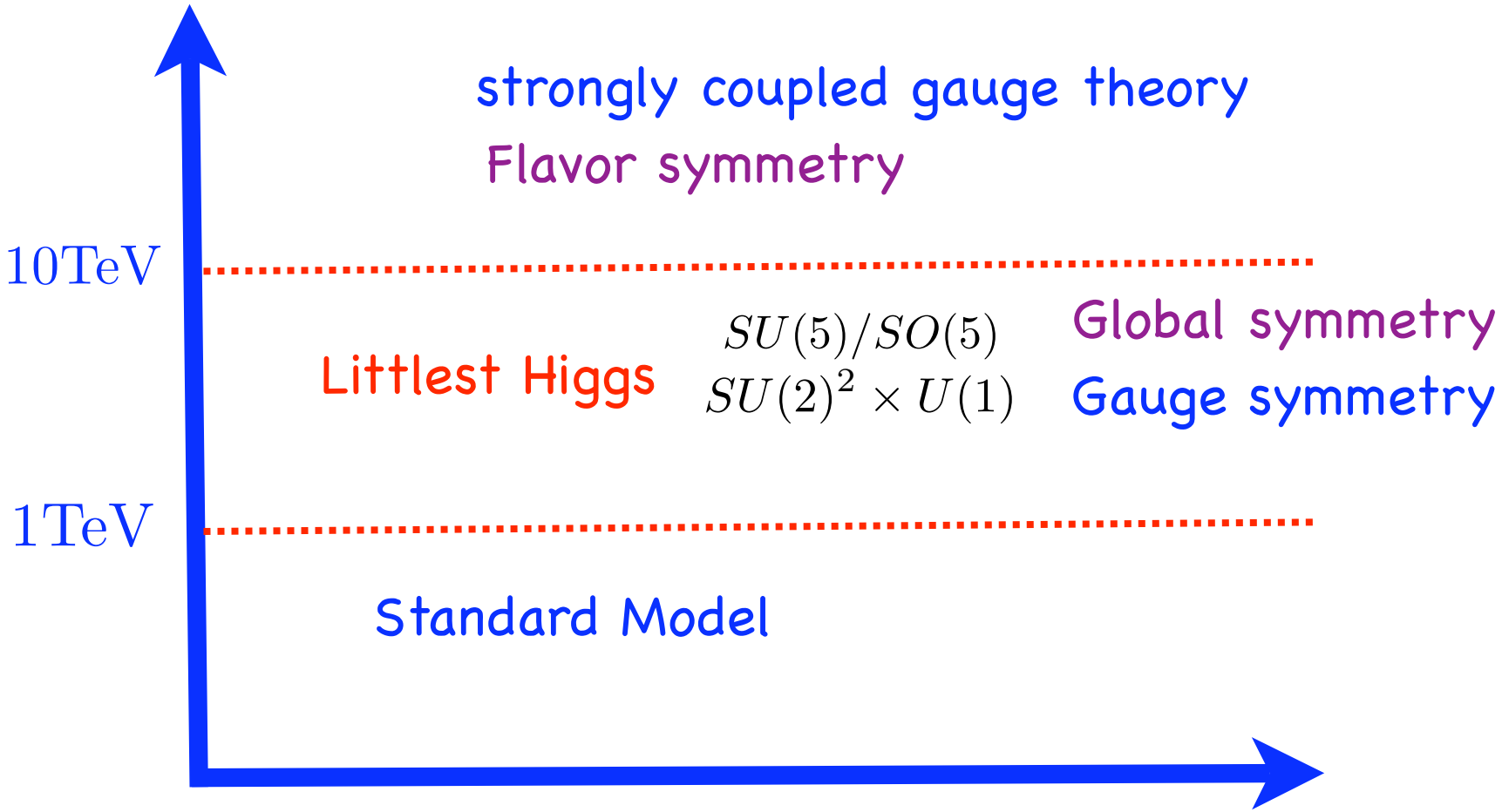
$$\sim 1\mathrm{TeV}$$

- Goldstone bosons become strongly coupled at high energy. Needs a UV completion at $\sim 10\mathrm{TeV}$

might have extra 'light' states

- Model: Strongly coupled UV completion of the littlest Higgs. Katz,Lee,Nelson, Walker '03

  - Structure



Spectrum above 10 TeV

Ψ_{11} { $SU(5)$ global symmetry { ψ_0, ψ_2, ψ_2' ; Composite top sector { ψ_3^c, ψ_3

	$SU(3)_c$	$SU(2)$
ψ_0	1	1
ψ_2	1	2
ψ_2'	1	2
ψ_3^c	$\bar{3}$	1
ψ_3	3	1

Composites

- Mesons

$$\begin{pmatrix}\psi_2\\ \psi_0\\ \psi_2'\end{pmatrix} \xrightarrow{\Sigma} \langle \Psi_5 \Psi_5 \rangle = \begin{pmatrix}\mathbf{0} & 0 & \mathbf{1}\\ 0 & 1 & 0\\ \mathbf{1} & 0 & \mathbf{0}\end{pmatrix}$$

$SU(5)$ broken to $SO(5)$

- Baryons $\Psi_{11}\Psi_{11}\lambda$

Ψ_{11} {

	ψ_5	ψ_3
ψ_5	'gaugino'	top
ψ_3	top	'gluino'

- composite 'gaugino':

$\psi_5\psi_5\lambda$ → C^+, C^-, N 'higgsino','bino','wino'

$\psi_3\psi_3^c\lambda$ → $\tilde{g}$ 'gluino'

- R - partiy: $(-1)^{3B+L+2S}$

➡ lighest of $\tilde{g}$, $\tilde{C}$, $\tilde{N}$ is stable

dark matter?

Masses are of the same order than the top partner because of flavor symmetry:

$\sim 1\mathrm{TeV}$

Discovery of Little Higgs at LHC

Z' ,W'

many new colored particles:
large cross section

Top partners

couplings predicted by Little Higgs:
Possible to measure but hard

Perelstein, Pierce, Peskin '03

gluinos

large cross section, missing energy signal

We have: missing energy, extra gauge bosons and extra fermions!

can we tell what is going on?

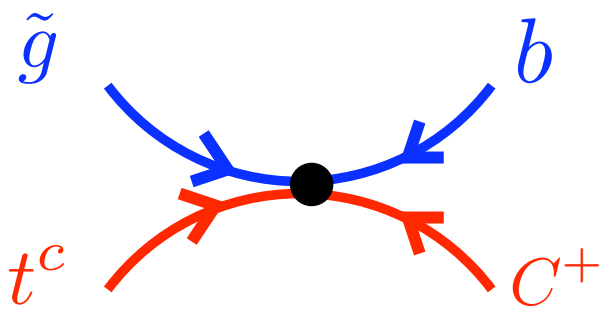
study the gluino

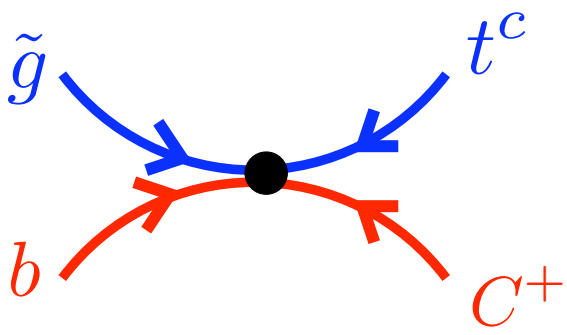
Composite gluino

- Decay of the composite gluino: 4-Fermi operators

  - Many operators. We concentrate on the following:

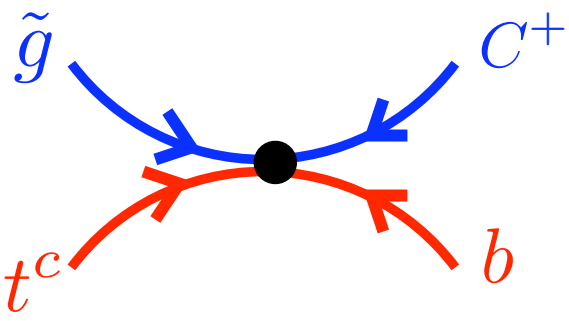
$\frac{\tilde{g}bt^cC^+}{f^2}$

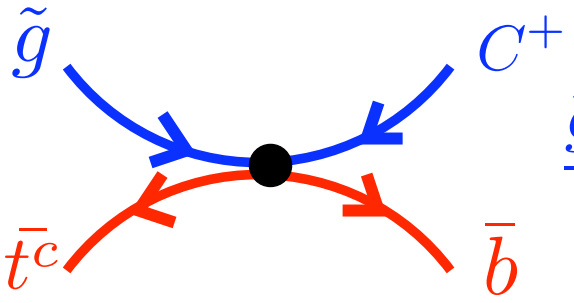




$\frac{\tilde{g}t^cbC^+}{f^2}$

$\frac{\tilde{g}C^+t^cb}{f^2}$



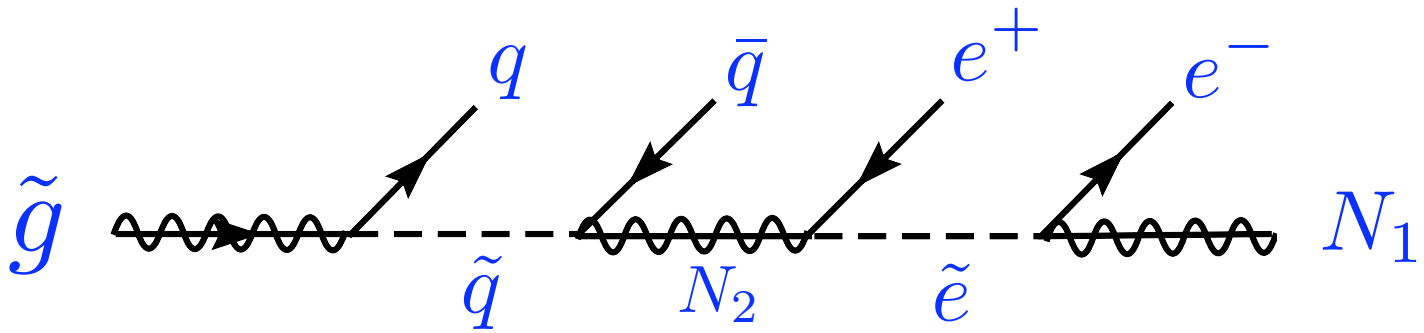


$\frac{\tilde{g}C^-\bar{t}^c\bar{b}}{f^2}$

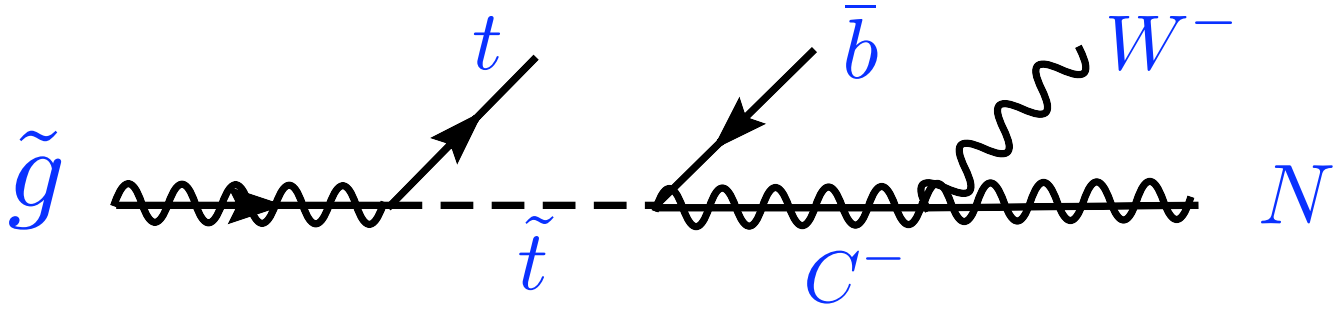
absent in supersymmetry

Supersymmetric gluino

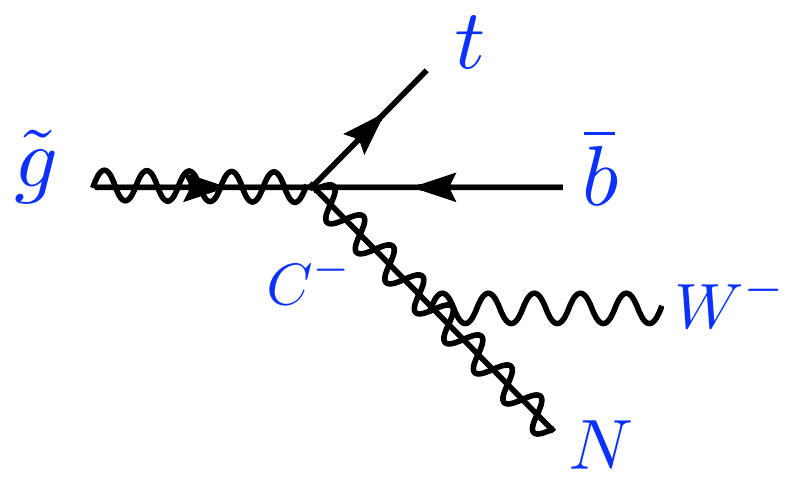
- Decay of a gluino in Supersymmetry



If most slepton and squark except the stop and sbottom are very heavy:



- If the stop and sbottom are off-shell:



$c_b \dfrac{\tilde{g} b t^c C^+}{f^2}$ off shell sbottom

$c_t \dfrac{\tilde{g} t^c b C^+}{f^2}$ off shell stop

There are no operators of the form

$$c_{O_1}\frac{\tilde{g}C^+t^cb}{f^2} \qquad c_{O_2}\frac{\tilde{g}C^+\bar{t}^c\bar{b}}{f^2}$$

- would require the exchange of a charged color octet.

- In supersymmetry we expect

$$c_b \neq c_t$$

- In composite model because of the flavor symmetry:

$$c_b \sim c_t$$

In both susy and non-susy:

Gluino can be seen above background

~ $1fb^{-1}$

De Sanctis, Laris, Montesano,Troncon '07

Gluino mass can be estimated from cross section

at~10% with 100 $1fb^{-1}$

Baer, Barger, Shaughnessy, Summy Wang '07

Susy vs non-susy

- What observables can distinguish a supersymmetric gluino from the composite gluino?

  - with appropriate spectrum, the final states and kinematic of the decay are the same in both cases

  - We look at $m_{tb}^2 = (P_t + P_b)^2$

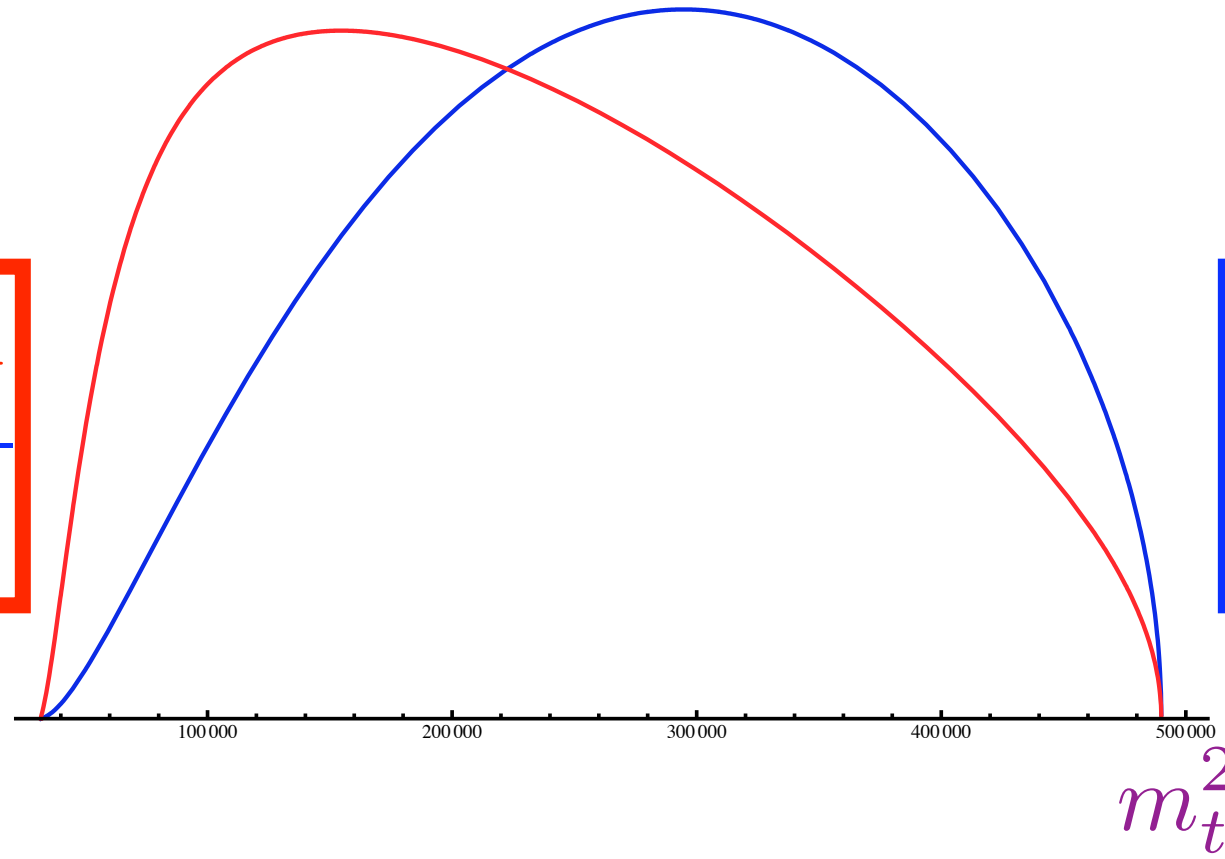
    The distriubtion of m_{tb}^2 is different .

  - m_{tb}^2 is the only invariant distribution that can be measured.

m_{tb}^2 distribution

$m_{\tilde{g}} = 1\text{TeV} \quad m_C = 300\text{GeV} \quad m_N = 200\text{GeV}$

$\frac{\tilde{g} b t^c C^+}{f^2}$



$\frac{\tilde{g} C^+ t^c b}{f^2}$

Susy vs non-susy

Measurement of m_{tb}^2.

Hisano,Kawagoe, Kitano,Nojiri '02

Hisano,Kawagoe, Nojiri '03

De Sanctis, Laris, Montesano,Troncon '07

- Problems:
  - Cuts deform shapes
  - Combinatoric
- Cuts:
  - More than 4 jets with $P_T > 40\mathrm{GeV}$
  - at least one hard jet $P_T > 150\mathrm{GeV}$
  - at least 2 b-tag jets.
  - missing $E_T > 300\mathrm{GeV}$

- We consider the following spectrum:

$$m_{\tilde{g}} = 1\mathrm{TeV}$$
$$m_C = 300\mathrm{GeV}$$
$$m_N = 200\mathrm{GeV}$$

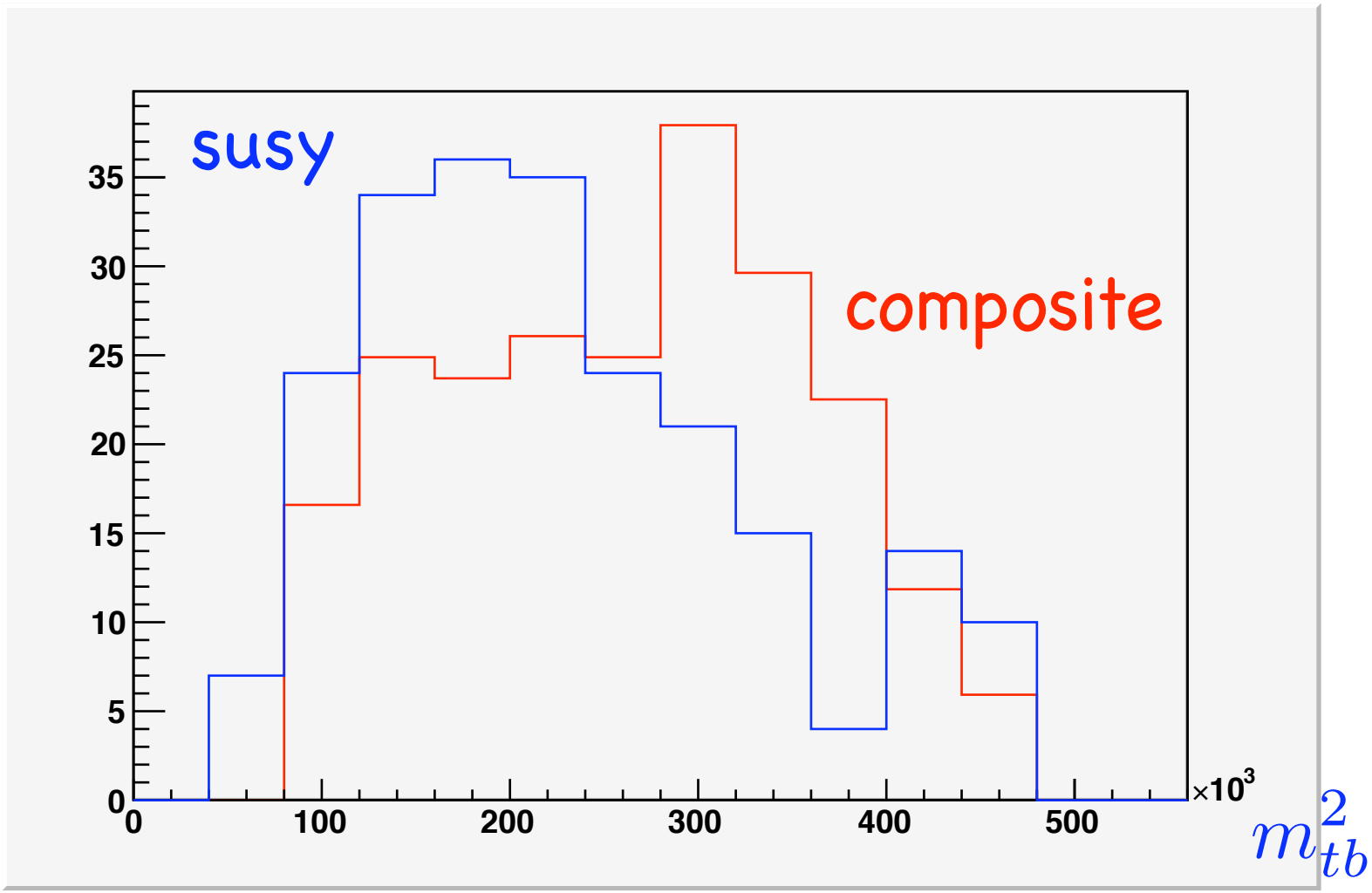
- The signal is isolated by asking
  - 2 non-b jet reconstructing a W
  - W + b jet reconstructing a top
  - another b jet to make m_{tb} (taking the b jet that give the lowest m_{tb} .)

Without combinatoric background

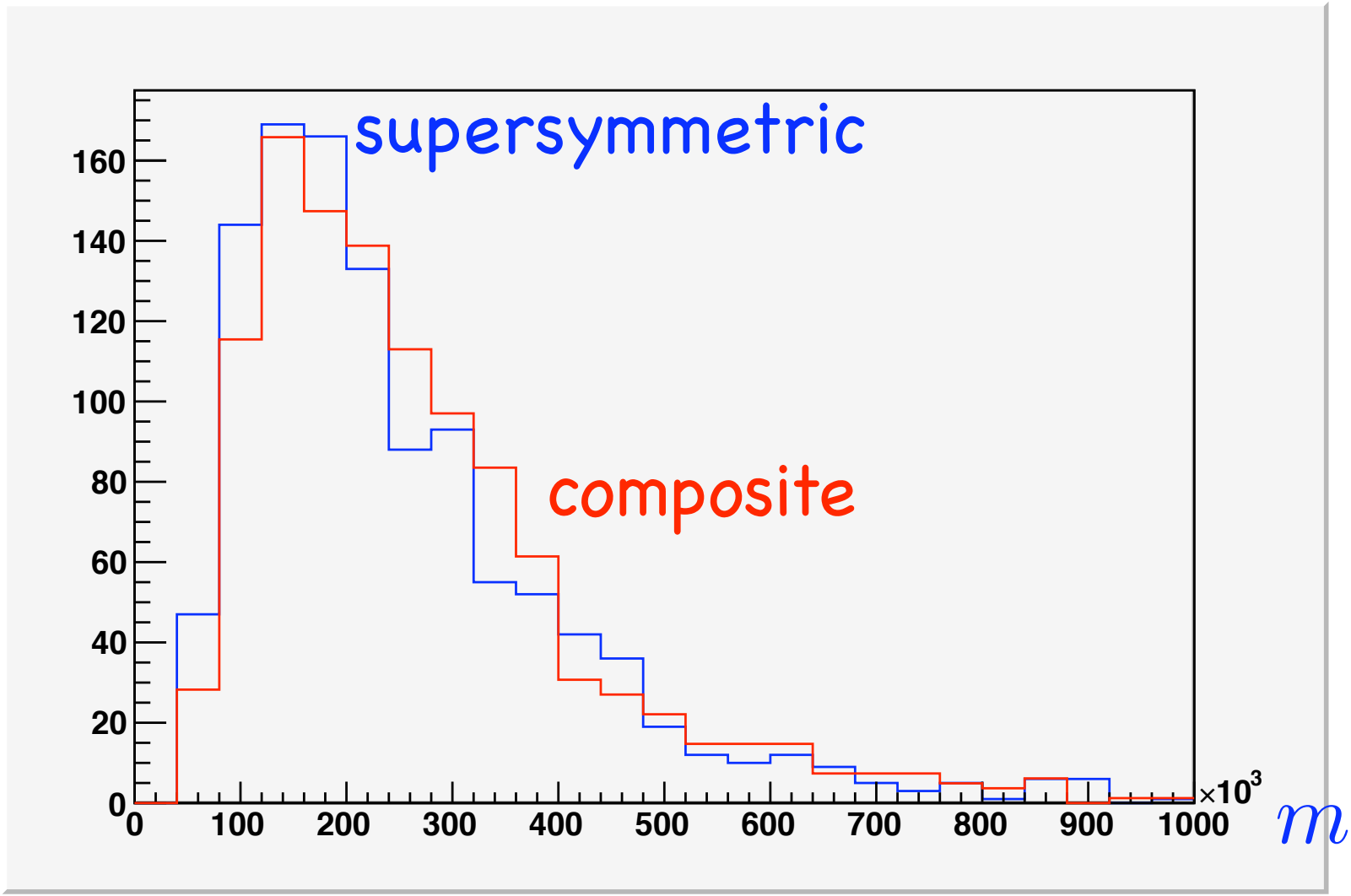
$$pp \to \tilde{g}\tilde{g} \to t\bar{t}b\bar{b}W^-W^-NN$$

$$\sigma(pp \to \tilde{g}\tilde{g}) = 300\text{fb}$$

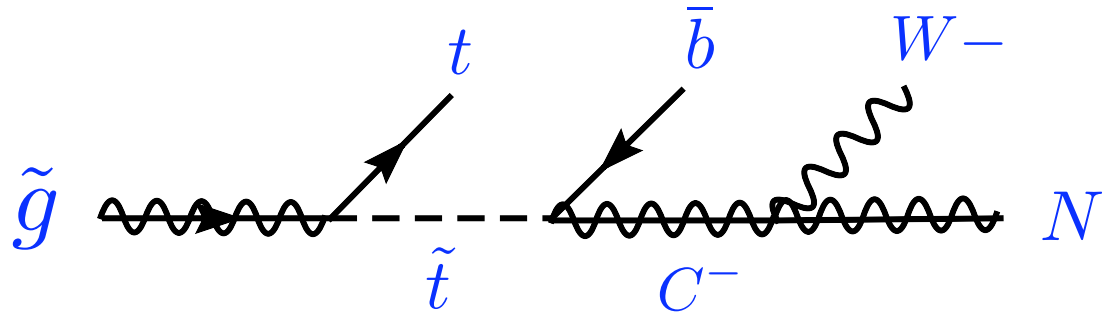
we generated 100 000 events.

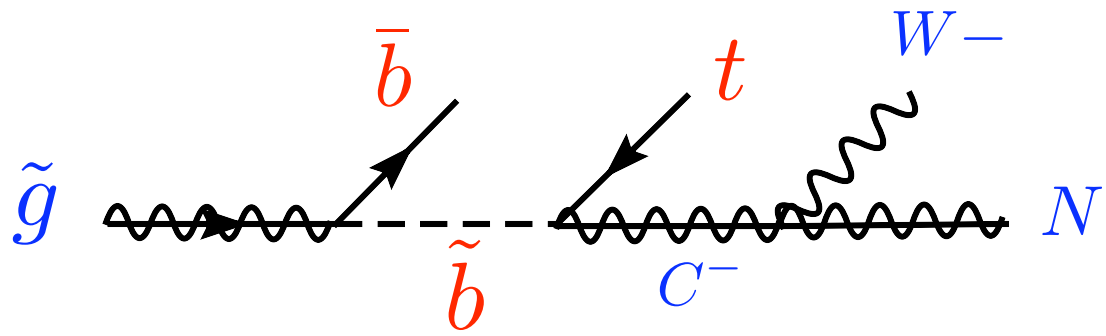


- With combinatoric



Comparison to supersymmetry with on-shell decay.



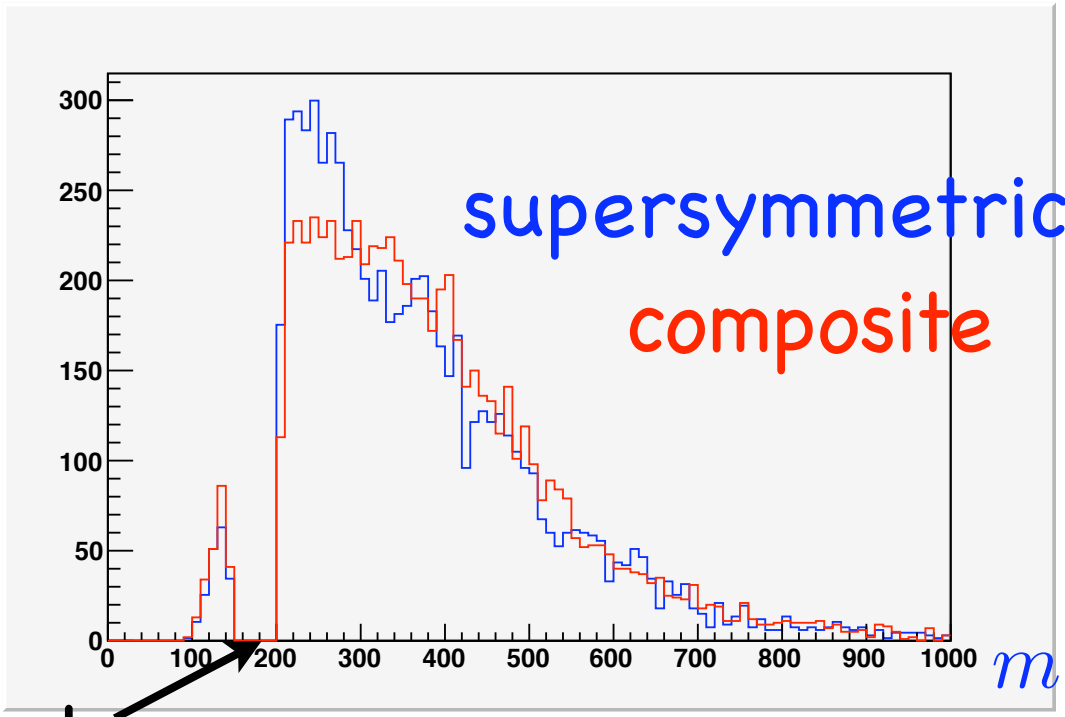


- There is also an endpoint in m_{bW}:

$$m^2_{bW\,\mathrm{endpoint}} \sim (m^2_{\tilde{t}} - m^2_{\tilde{C}})(m^2_{\tilde{C}} - m^2_N)/m^2_{\tilde{t}}$$

$m_{\tilde{t}} = 500\mathrm{GeV}$

$m_{\tilde{b}} = 600\mathrm{GeV}$



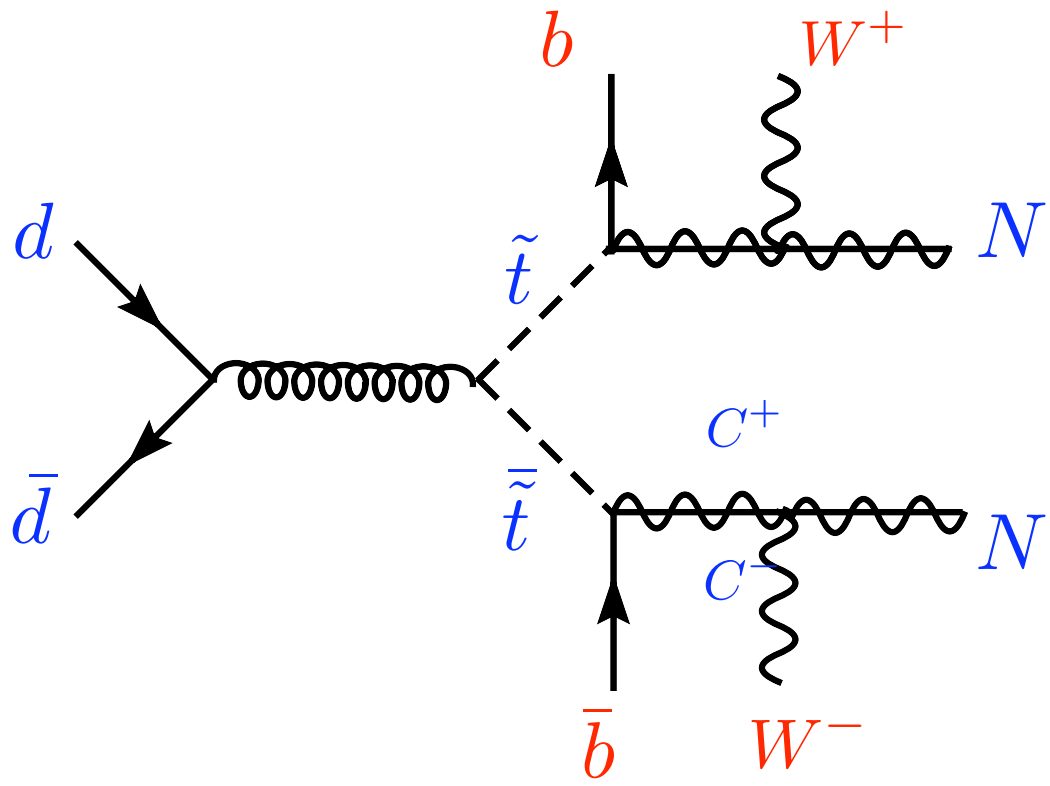
$m_{\tilde{g}} = 1\mathrm{TeV}$

$m_C = 300\mathrm{GeV}$

$m_N = 200\mathrm{GeV}$

top cut

The stop and sbottom can be produce directly



Can it be isolated?

Conclusions

- We presented a model with composite gluinos at the TeV scale. This might be generic in this class of models.
- Could be hard to distinguish from supersymmetry if 3rd generation is lighter than the rest.
- There is information in the shape of invariant mass distribution, not only in endpoints.
- If the stop and sbottom can be produced on-shell, the situation seems better.