Study of $\tilde{t}$ and $\tilde{b}$ at LHC

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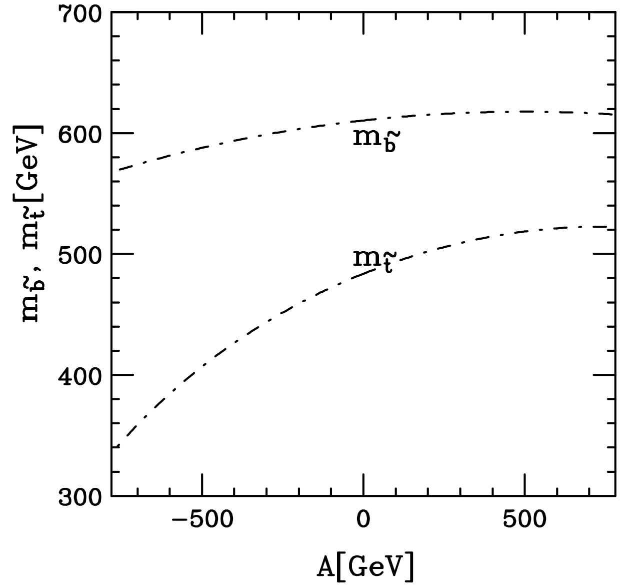
$\tilde{t}$ and $\tilde{b}$ are key particle to understand SUSY Phenomenology

○ Yukawa effect
mass, $\tilde{t}_L - \tilde{t}_R$ mixing effect and Yukawa effect in the decay Br

○ non-universal supersymmetric model

A$_0$ dependence of $m_{\tilde{t}}$



○ Radiative correction to
the higgs mass $\tilde{t}$, A_t

○ **Flavor Physics**
$\mathbf{Br(b \to s\gamma)}$....

Role of LHC? LC?

Major Decay Chains

Reconstruction of $\tilde{g} \to tbX$ including

"Edge Modes" (subsequent two body decay)

$\tilde{g} \to \tilde{t}t$

$\quad \hookrightarrow b\tilde{\chi}^{\pm}$

$\tilde{g} \to \tilde{b}b$

$\quad \hookrightarrow t\tilde{\chi}^{\pm}$

$\tilde{g} \to \tilde{b}b$

$\quad \hookrightarrow \tilde{t}W$

$\quad\quad \hookrightarrow b\tilde{\chi}^{\pm}$

$\mathbf{M_{tb}}$ **the end point of the** m_{tb} **distribution**

(combination of $\mathbf{m_{\tilde{g}}, m_{\tilde{b}}, m_{\tilde{t}}}$....)

Edge heights: $\to \frac{\mathrm{Br}(\tilde{g}\to\text{edge modes})}{\mathrm{Br}(\tilde{g}\to bbX)}$

OUTCOME

MSUGRA parameter

m_0, M, $\tan\beta$, $\mathbf{A_0}$,

Model independent study

$$\begin{pmatrix} m^2_{\tilde{t}_L} & m_t(A_t + \mu \mathrm{ct}\beta) \\ m_t(A_t + \mu \mathrm{ct}\beta) & m^2_{\tilde{t}_R} \end{pmatrix}$$

$\mathbf{t \to bjj}$ **Reconstruction**

- $\mathbf{m_{jj}}$ in **W mass region** (I)

  $n_{bjet} = 2$

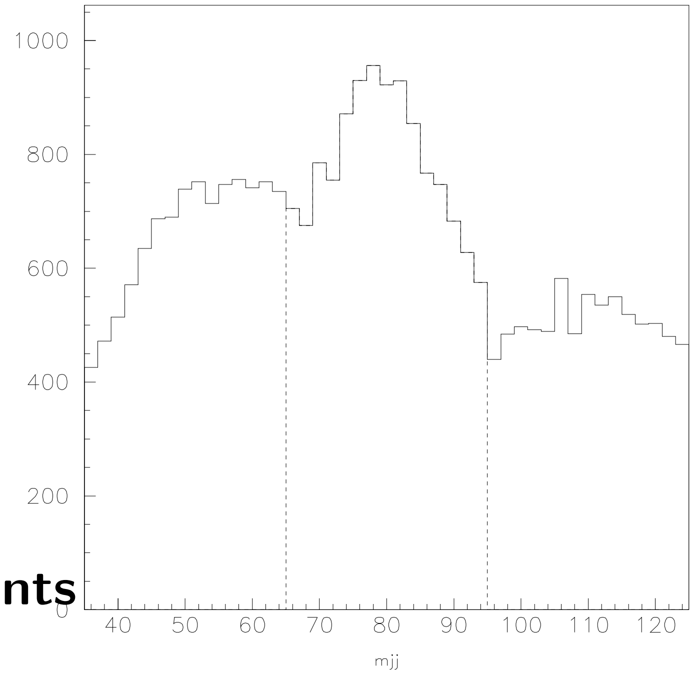
  $|m_{jj} - m_W| < 15$ GeV

  $|m_{bjj} - m_t|$GeV < 30 GeV

  (+ additional cuts like M_{eff}, p_T miss, number of jets...)

- $\mathbf{m_{jj}}$ in **non-W region**(II) and (III)

for estimation of mis-reconstructed events



$|m_{jj} - (m_W \pm 30\text{GeV})| < 15$ GeV
$\to$ momentum rescale to W mass region
$|m_{bjj}(\text{rescaled}) - 175\text{GeV}| < 30$ GeV

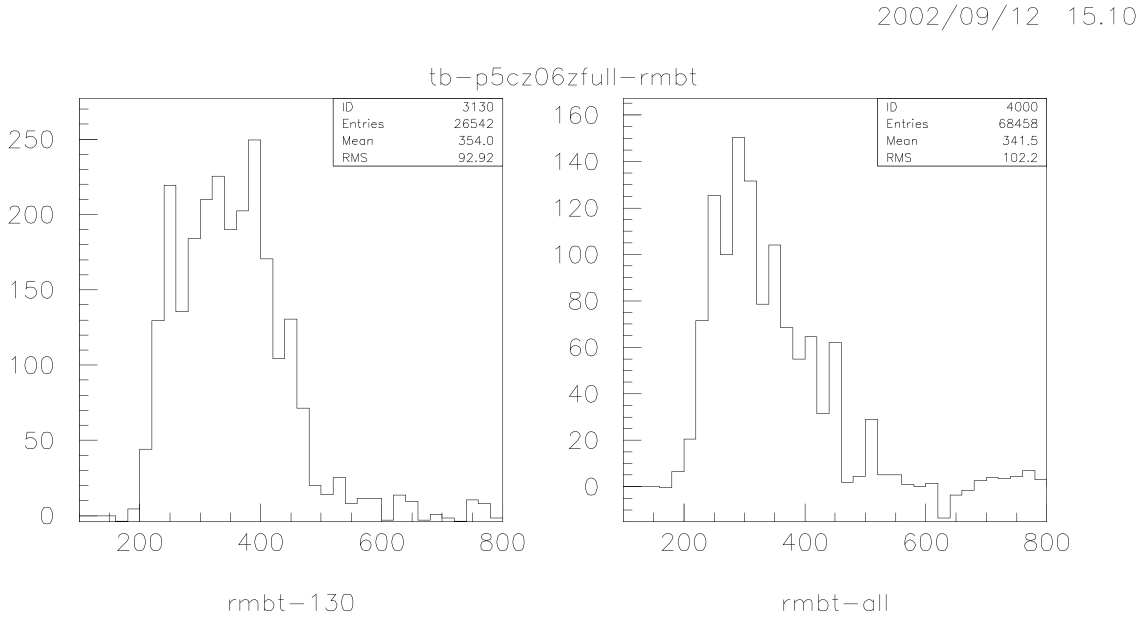
$\to$ SIDE BAND SUBTRACTION

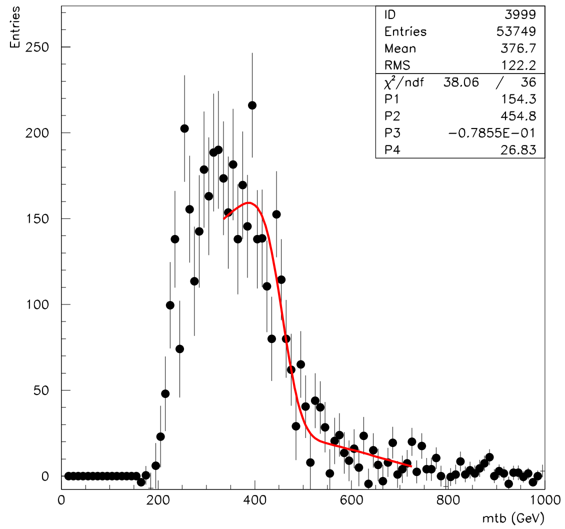
to reconstruct parton level distribution

$$\text{SIGNAL} = (\text{I}) - \frac{[(\text{II}) + (\text{III})]}{2} \tag{1}$$

The $\mathbf{m_{tb}}$ Distributions after Side Band Subtraction

$\boxed{\tilde{g} \to (\tilde{b}, \tilde{t}) \to tb\tilde{\chi}_1^{+}}$ **Other gluino decay** **Fit to all tb events**

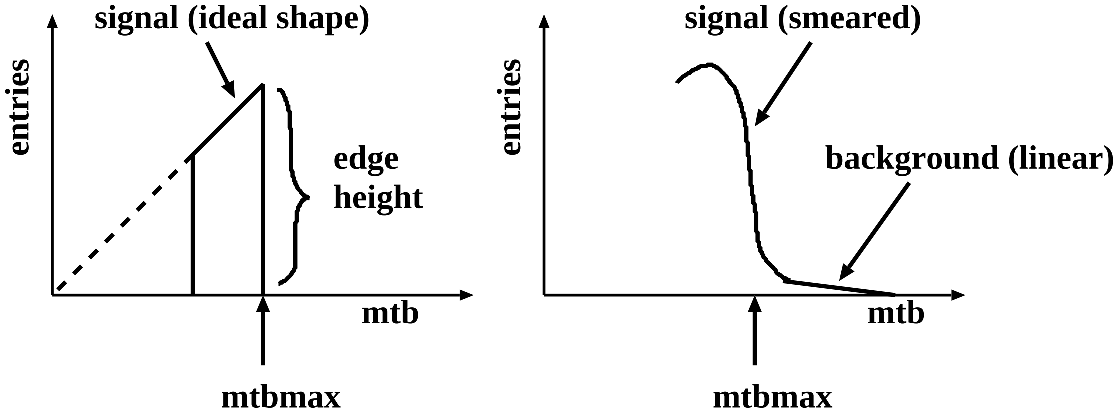




(M_{tb} = 454.8±7.7 GeV, True 459 GeV)

The "edge mode" dominates near the end point

$\boxed{\text{good?}}$



Two end points $\longrightarrow$ Weighted end point

$$M_{tb}(\tilde{t}) = M_{tb}(\tilde{g} \to \tilde{t}t \to tb\tilde{\chi}^{+})$$
$$M_{tb}(\tilde{b}) = M_{tb}(\tilde{g} \to \tilde{b}b \to tb\tilde{\chi}^{+})$$

$$M_{tb}^{w} = \frac{M_{tb}(\tilde{t})Br(\tilde{g} \to \tilde{t} \to \tilde{\chi}^{+}) + M_{tb}(\tilde{b})Br(\tilde{g} \to \tilde{b} \to \tilde{\chi}^{+})}{Br(\tilde{g} \to \tilde{t} \to tb\tilde{\chi}^{+}) + Br(\tilde{g} \to \tilde{b} \to tb\tilde{\chi}^{+})} \quad (2)$$

Height $\rightarrow$ Numberof events

$$N(\mathrm{fit}) \equiv \left(\frac{1}{2}\right)(\mathrm{height})\frac{(M_{tb}^{w})^2 - m_t^2}{(\mathrm{bin\ width})^2} \quad (3)$$

"End Point" fit (14 different point is studied by Pythia and Herwig)

Point studied....

○ MSUGRA point with

$m = 100$ GeV $M = 300$ GeV

with $A_0 = 300, -300$GeV **A1 A2**

non MSUGRA stop sector **T1 T2**

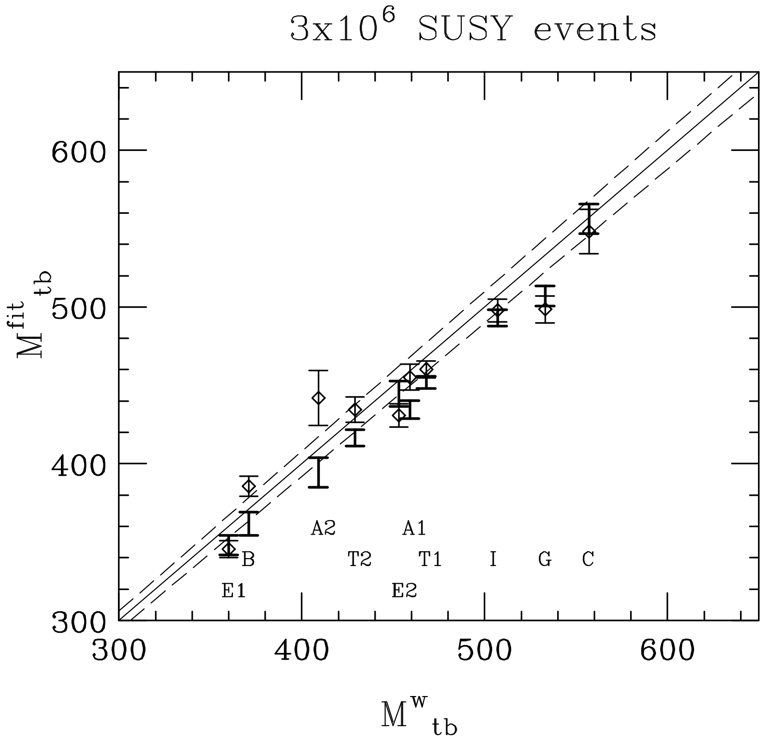
increase gluino mass (OK)

○ MSUGRA point from hep-ph

B,C(sps3),G,I

○ $\tilde{g} \to \tilde{t}_1$ 100 % **E1,E2**

○ "higgsino like LSP" " wino like LSP" (OK)

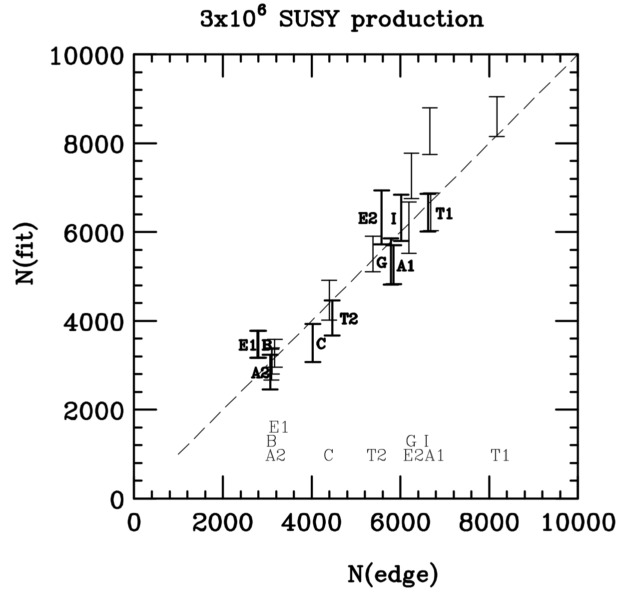


No systematics found. $\pm 5 \sim 8$ GeV

for 3×10^6 SUSY events and $\mathrm{Br}(\tilde{g} \to \tilde{t}, \tilde{b}) > 10\%$

N(events) estimation

No systematics for
N(Reconstructed) vs N(Estimated)



However, N(Reconstructed) depends on **generators** (Herwig vs. Pythia) & **jet definition** (“jet cone” or K_T)

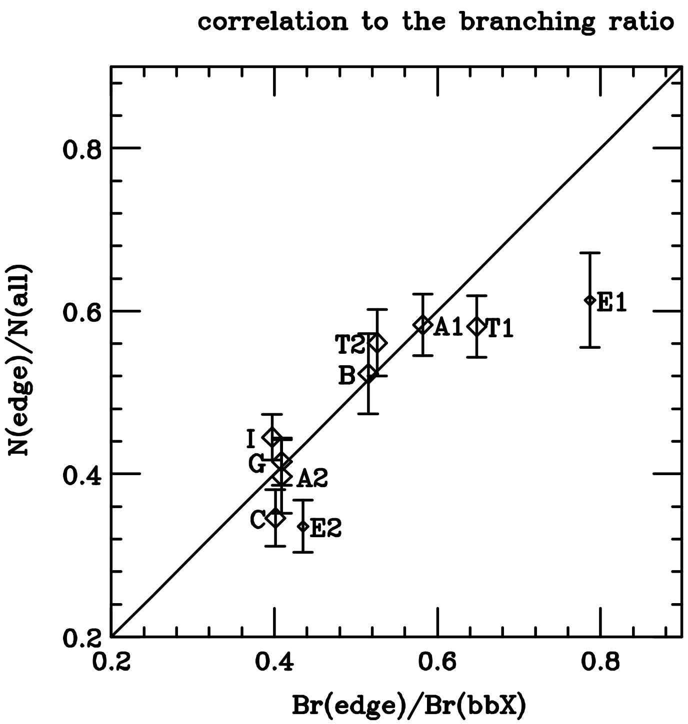
MC	kt/jc	R	signal before subtraction	signal after subtraction
py	jc	0.4	9695	2462
	kt	0.5	8607	2808
hw	jc	0.4	10180	2949
	kt	0.5	9118	3239

N(before) 5% difference
N(after) 20% difference
(for mode $\tilde{g} \to \tilde{t} \to \tilde{\chi}^+$)

Br estimation

○ **very good correlation between**
N(edge)/N(all tb) vs
Br(edge mode)/Br($\tilde{g} \to bbX$)
if $\tilde{q}\tilde{g}$ production dominates
$\leftrightarrow$ mostly 2 b

○ **No generator dependence found**



Does not work if

○ $\tilde{q} \to \tilde{g}$
$\to$ 4b signal

○ If $m_{\tilde{t}} \ll m_{\tilde{g}}$:
stop pair production significant.

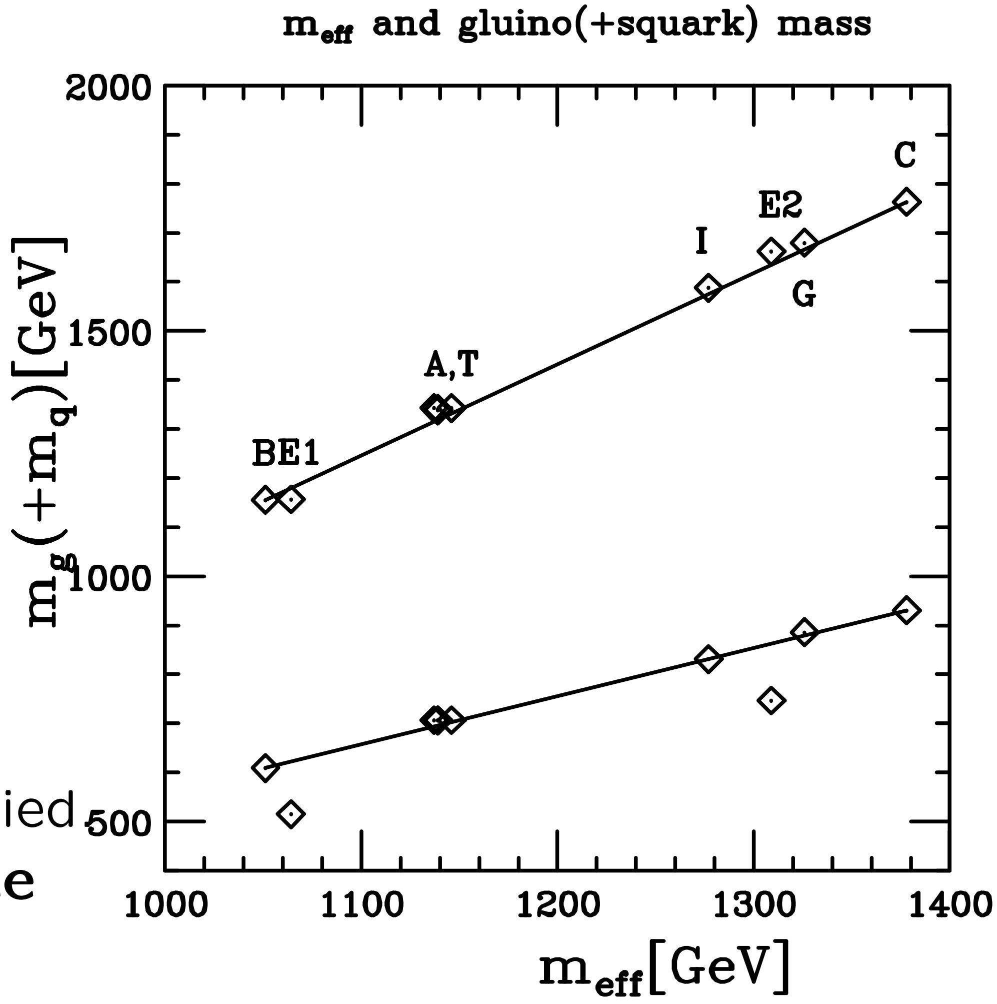
$\boxed{\mathrm{M_{eff}}(\equiv \sum \mathrm{P_{Tj}})\ \text{analysis}}$

upper line:
peak of $\mathbf{M_{eff}} \propto \mathbf{m_{\tilde{q}}} + \mathbf{m_{\tilde{g}}}$
for events with selected tb

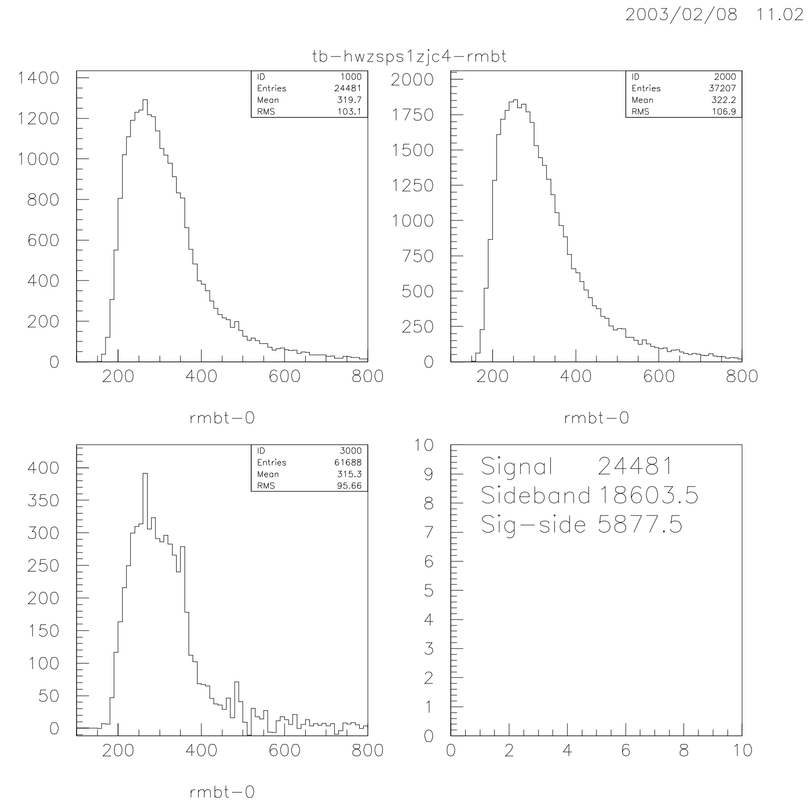
bottom line:
peak of $\mathbf{M_{eff}}$ does not
correlated to $\mathrm{m_{\tilde{g}}}$
if $\mathrm{m_{\tilde{q}}} \gg \mathrm{m_{\tilde{g}}}$

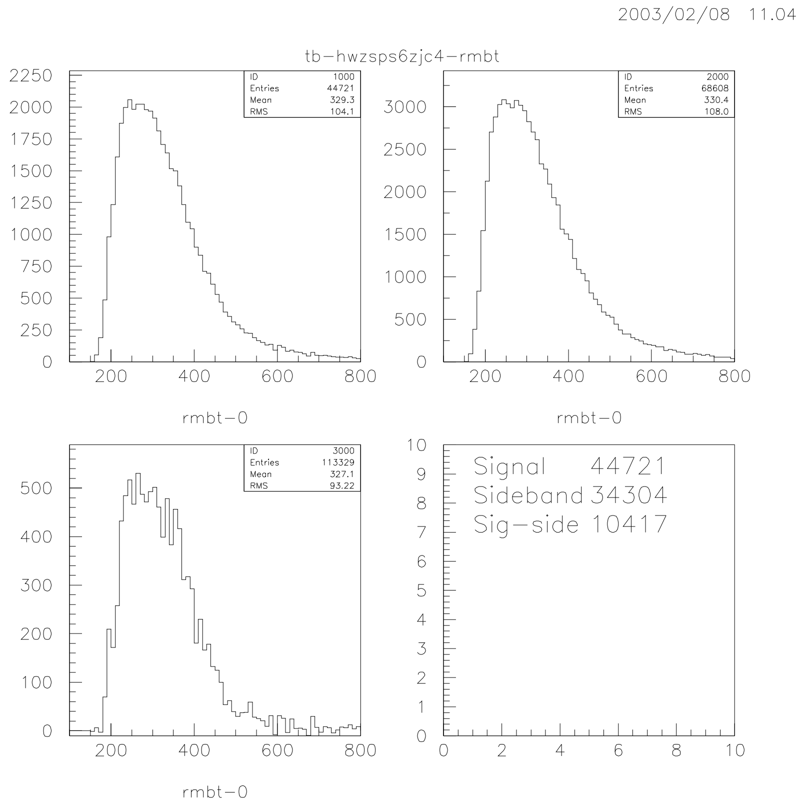
systematical error is within
4%for the parameter we tried

No generator dependence



Snowmass points good case (SPS1 SPS6)





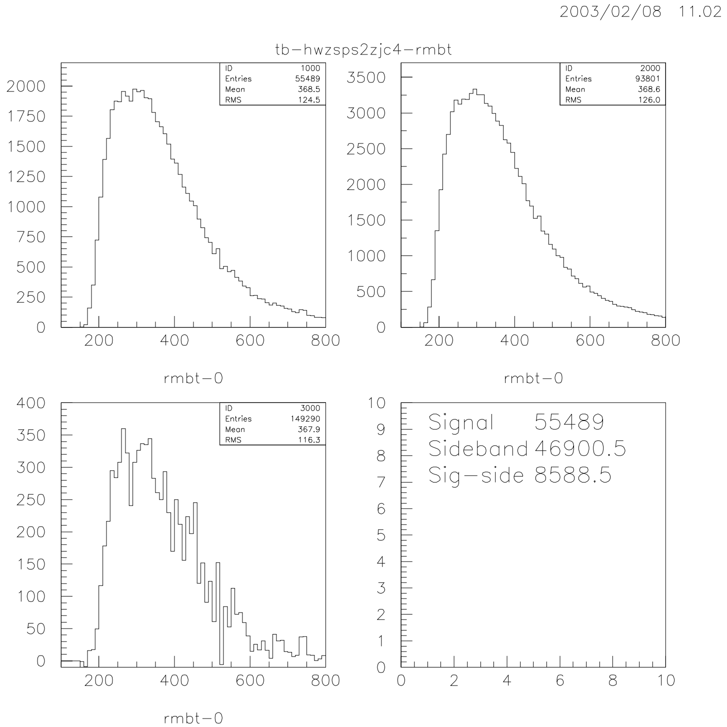
(595.26, 379.3, 490.9, 176.7) (708.6, 473.4, 588.6, 215.8)

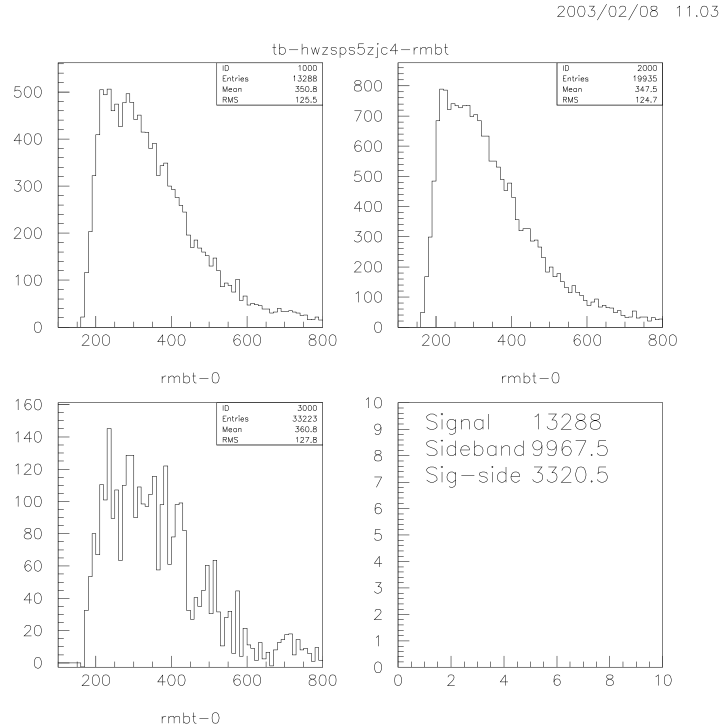
end points (385.42,355.87) 363.9$\pm$ 4.6 (448.79 403.6) 416.2$\pm$ 6.2

Focus point(SPS2) or too light stop (SPS5)

“We do not see the edge if there should not be”

(SPS2:4σ height and fit is bad. SPS5: hight insignificant)





(778.6,991.2,1289.7,172.0)

$\tilde{g} \to \tilde{\chi}_2^{\pm}$(296GeV) (24%)

$\tilde{g} \to \tilde{\chi}_1^{\pm}$ (20%)

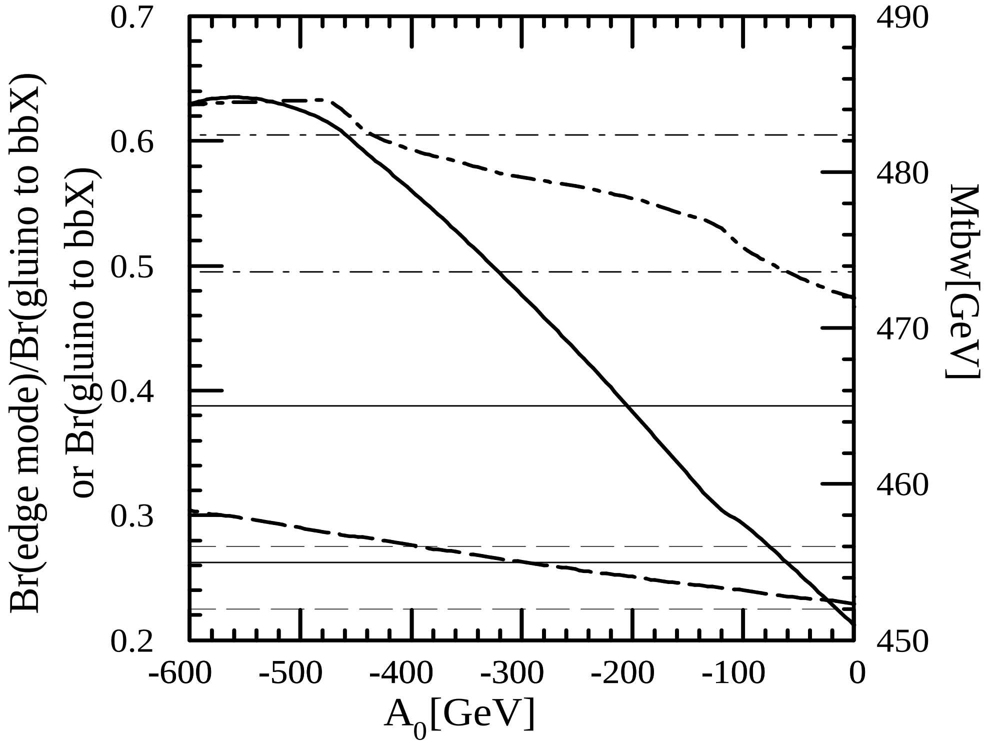
(710.4, 230.7, 536.2, 226,)

endpoints (NA, 450.6)

. $\boxed{A_0 \textbf{ dependence in MSUGRA}}$

$m_0 = 230$ GeV
$M_0 = 300$ GeV
$\tan\beta = 10$(fixed)
$L \sim 100\mathrm{fb}^{-1}$

M^w_{tb} end point
$\rightarrow \delta A_0 \sim 50$ GeV



Br(edge mode)/Br($\tilde{g} \rightarrow$ bbX)
N(all tb)

10 % systematics is shown

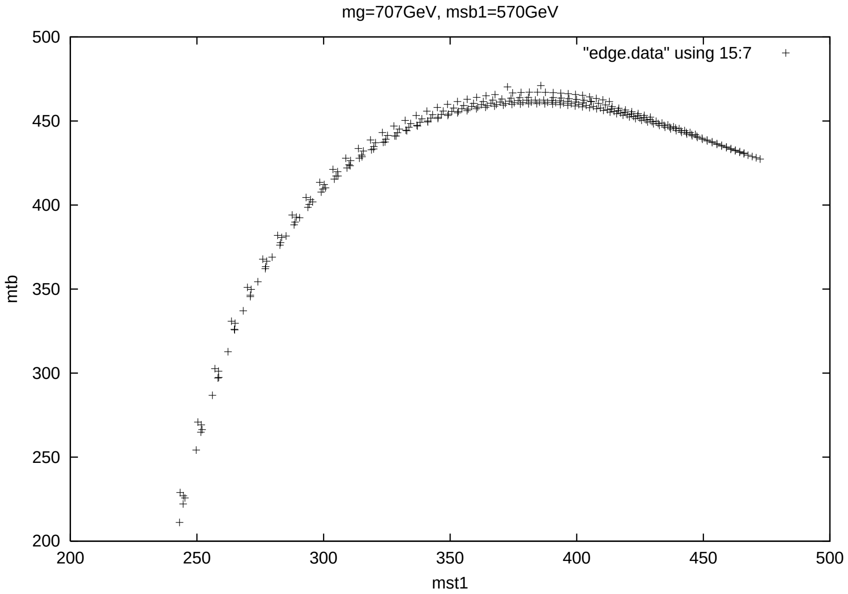
"consistency of observables"
$\rightarrow$ **model independent tag**

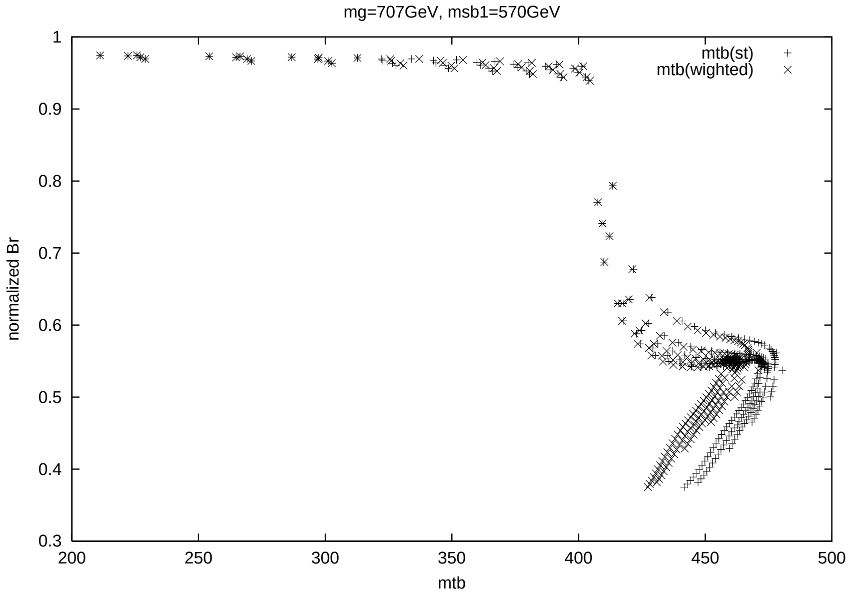
Parameter scan in MSUGRA

fix $m_{\tilde{b}}$, scan A_0 and $\tan\beta$

$m_{\tilde{t}}$ vs m_{tb}

m_{tb} vs normalized branch





Role of LC for LHC

chargino, neutralino decay pattern

- **stop mass, sbottom mass**
  starting point, phase space of the gluino decay
  production cross section

- **N(fit) $\rightarrow$ Br(edge) or Br(edge)/Br(tb)**
  acceptance of each decay modes depends on Br($\rightarrow$ l X) and Br($\rightarrow$ W X)

- **Comparison with** $N(bbll)$ from $\tilde{g} \rightarrow \tilde{b} \rightarrow \tilde{\chi}_2^0 \rightarrow \tilde{l} \rightarrow \tilde{\chi}_1^0$
  Need Br($\tilde{\chi}_2^0 \rightarrow 2l\tilde{\chi}_1^0$)

$\boxed{\text{LHC+LC}}$

- ○ ino mass, slepton mass $\leftarrow LC$
- ○ bbll distribution of $\tilde{g} \to \tilde{b} \to \tilde{\chi}^0_2 \to \tilde{l} \to \tilde{\chi}^0_1 \leftarrow$ LHC

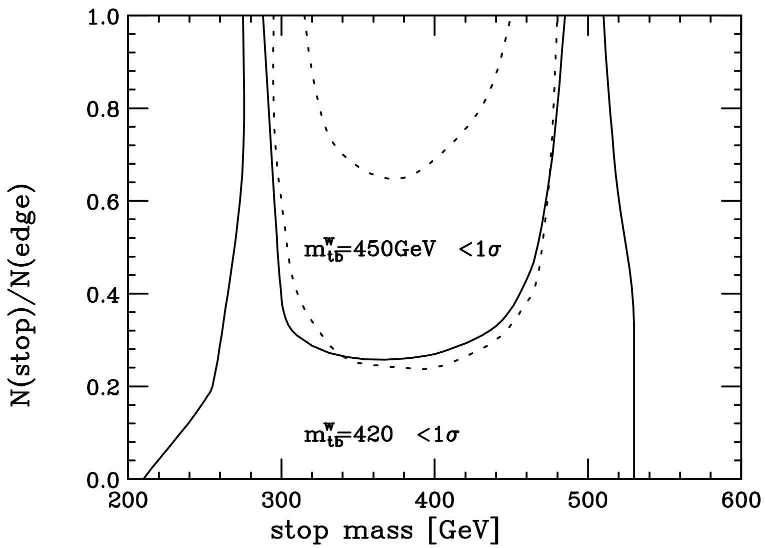
  1% to 2% statistical sensitivity to jet involved edges
- ○ M^w_{tb} **from this study**

If $\beta_t \gg 0$ for $\tilde{g} \to \tilde{t}t$ $O(\delta m_{\tilde{t}}) \sim O(\delta m_{\tilde{q}})$

Require precise theoretical predictions

If $M_{tb}(\tilde{b}) \sim M_{tb}(\tilde{t})$(80 GeV also)
tb edges may not be resolved

Even with LC infomation,
mass sensitivity may not be
good without Br inforamtion



Other applications

1)$\tilde{\mathbf{g}} \to \mathbf{t}\tilde{\mathbf{t}} \to \mathbf{tt}\tilde{\chi}^0_{\mathbf{i}}$

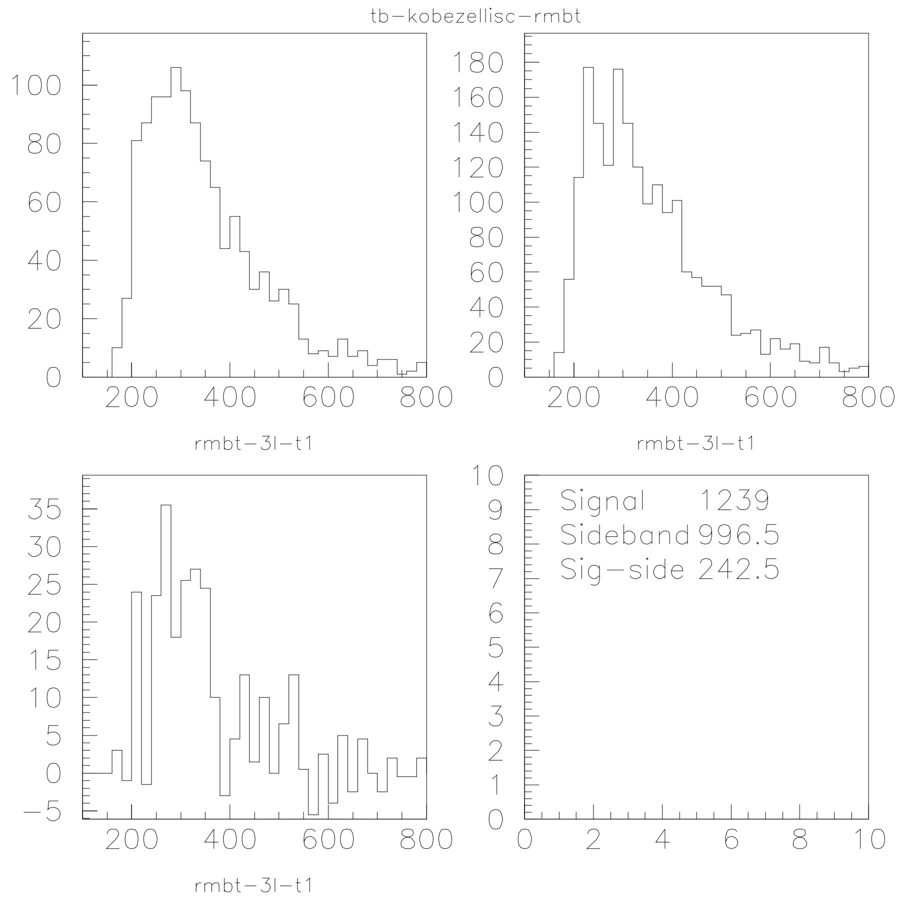
Similar selection.

tb final state contaminates

Require additional leptons

from $\tilde{\chi}^0_2 \to ll\tilde{\chi}^0_1$

$\to$ Pick up $\tilde{g} \to \tilde{t} \to \tilde{\chi}^0_2$



2)**Decay into** $\tilde{\chi}^+_2$

$\tilde{t}$:large coupling both to $\tilde{H}$, $\tilde{W}$

Require 3l or Z to pick up

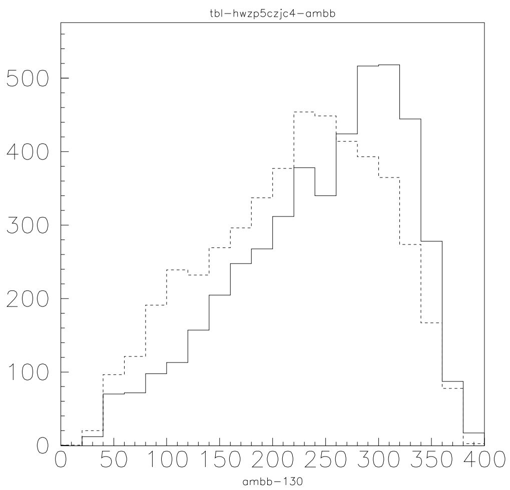
$\tilde{g} \to \tilde{t} \to \tilde{\chi}^+_2$

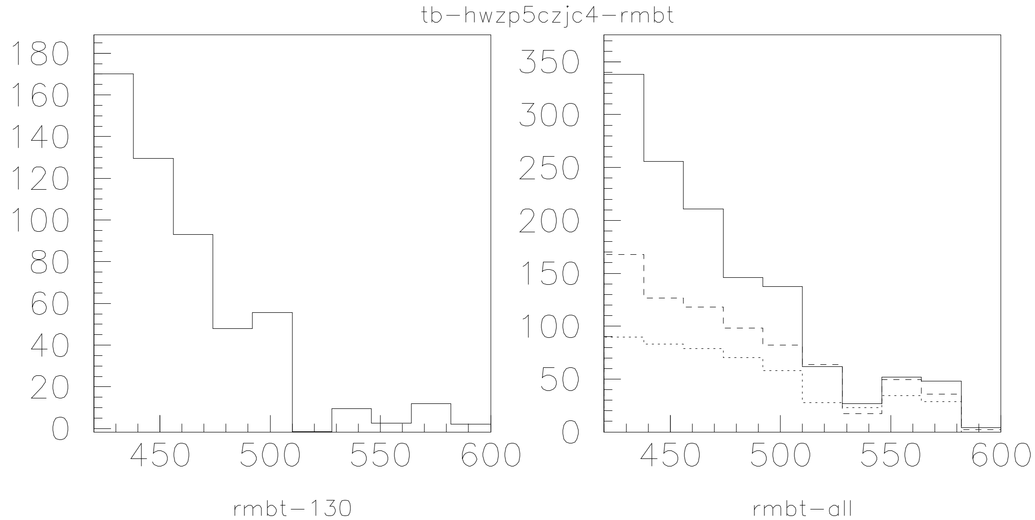
cost of statistics

but SM background is also small.

3) **Top polarization**

$\tilde{g} \to \tilde{t}t$
stop L-R mixing, $\to$ **top polarization** P_t
$\to m_{bb}$ distribution (for the events near the m_{tb} end point)
Herwig takes care the polarization. PY does not.





statistically 3σ difference between t_L and t_R for this case...

Problems and hopes....

- Generator dependence
  M_{tb} end point, M_{eff} OK
  normalization ???

- no perfect generator

	Herwig	Pythia	Isajet
fragmentation	QCD based	String	Independent
Pol.	Yes	No	No
Gluino width	No	Yes	No

- jet definition

- High Luminosity? b tagging? minimum bias?

- LC+LHC $\rightarrow$ better estimate of mass itself.