Search for a light stop

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[Kraml, Raklev, hep-ph/0512284]

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  - Baryogenesis
  - Relic density
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Motivation

Scalar tops play a special role in the MSSM because of the large Yukawa coupling $\propto m_t$.

- Mixing of the left and right chiral states, $(\tilde{t}_L, \tilde{t}_R) \to (\tilde{t}_1, \tilde{t}_2)$, can give large mass splitting.
- Influence on RGE running; causing radiative EWSB.
- Influence on m_h through radiative corrections.

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In the MSSM, the $\tilde{t}_1$ is often the lightest squark.

Many scenarios actually prefer a very light stop; $\tilde{t}_1$ can be the next-to-lightest supersymmetric partner (NLSP):

- Electroweak baryogenesis (EWBG).
- Dark matter relic density.

Baryogenesis

Sufficiently strong first order electroweak phase transition is needed to preserve generated baryon asymmetry; requires a light $\tilde{t}_1 \simeq \tilde{t}_R$.

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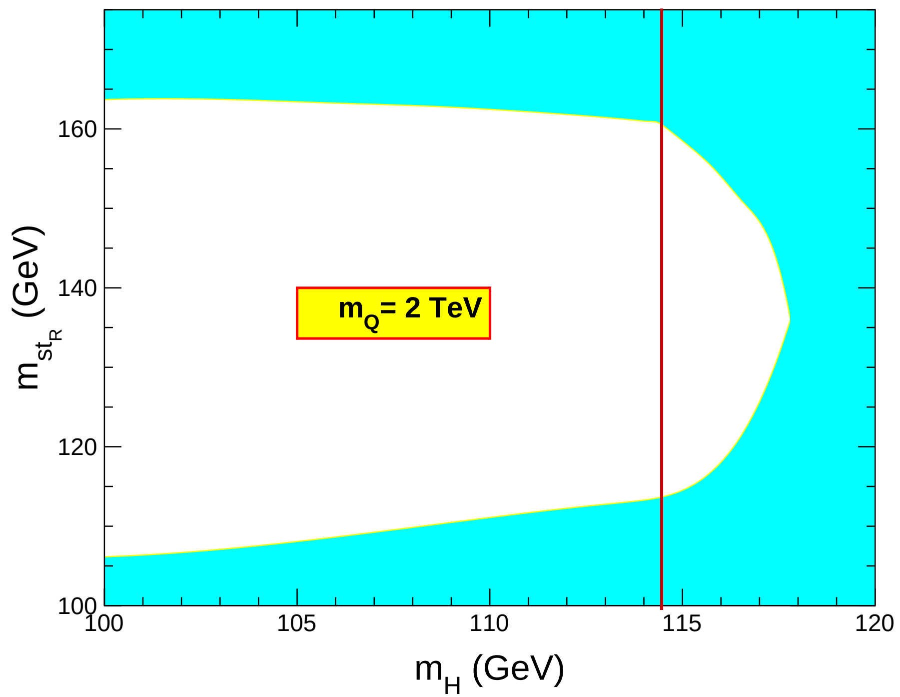

$m_h \lesssim 120$ GeV

$m_{\tilde{t}_1} \lesssim 180$ GeV

$\tan\beta \sim 2\text{–}8$

heavy $\tilde{t}_2 \simeq \tilde{t}_L$

[Carena, Quiros, Wagner, hep-ph/9710401]

[Balazs, Carena, Menon, Morrissey, Wagner, hep-ph/0412264]

Relic density

We fix the gaugino and higgsino spectrum with

$$M_1 = 110 \text{ GeV}, \quad \mu = 300 \text{ GeV}, \quad \tan\beta = 7,$$

and calculate Ωh^2 (micrOMEGAs 1.3.2), varying $m_{\tilde{t}_1}$ and $m_{\tilde{\tau}_1}$.

Relic density

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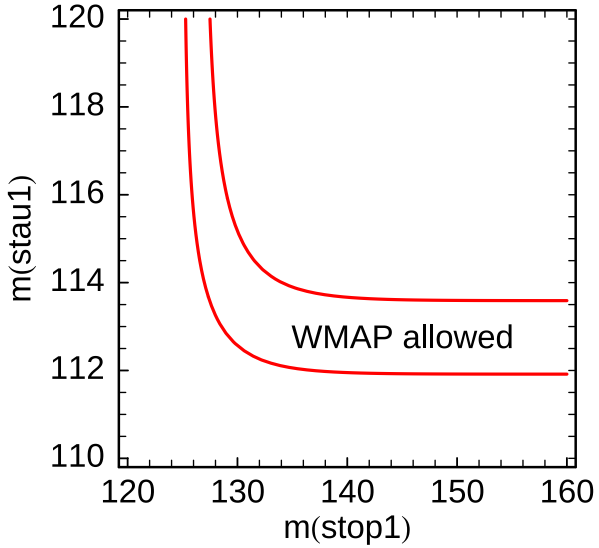

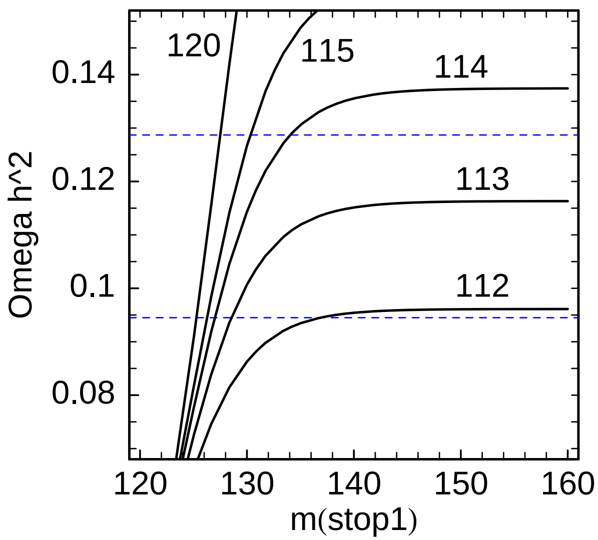

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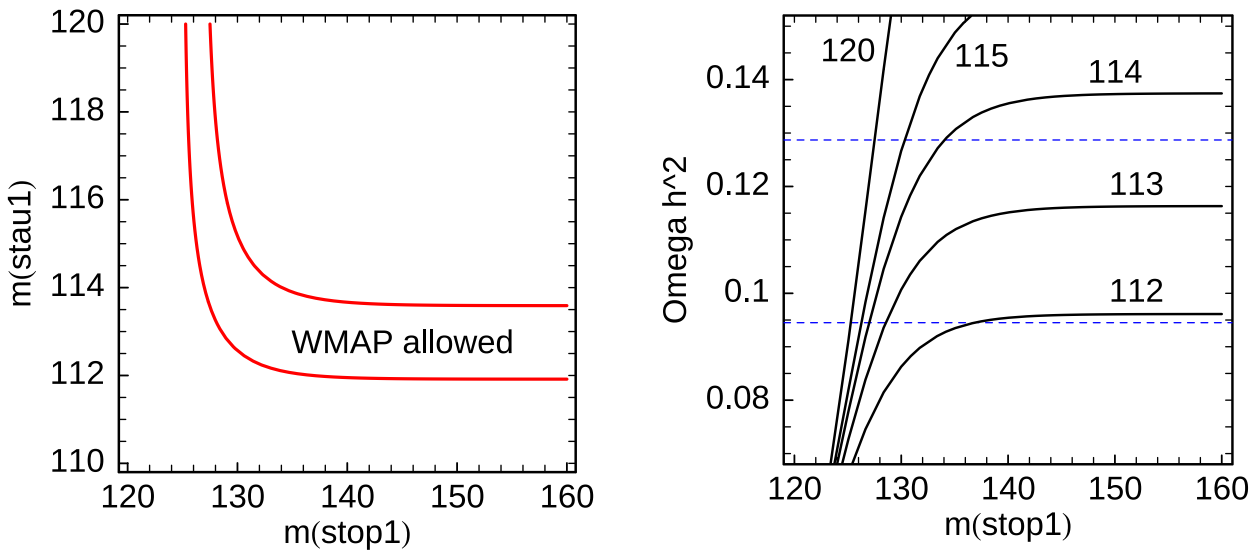

- Neutralino–stop coannihilation for $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \lesssim 25$ GeV.
- Neutralino–stau coannihilation for $m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} \lesssim 10$ GeV.
- Higgs funnel: $\tilde{\chi}_1^0 \tilde{\chi}_1^0 \to A \to b\bar{b}$ for $m_A \sim 250$ GeV.

Our ‘toy’ light stop scenario

$$M_1 = 110 \text{ GeV}, \quad \mu = 300 \text{ GeV}, \quad \tan\beta = 7$$

$$\tilde{t}_1 \simeq \tilde{t}_R, \quad m_{\tilde{t}_1} = 150 \text{ GeV}$$

$$m_{\tilde{g}} = 660 \text{ GeV}$$

$$m_{\tilde{l}} \simeq 250 \text{ GeV}, \quad m_{\tilde{q}} \gtrsim 1 \text{ TeV}$$

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To achieve agreement with relic density:

$$m_A \simeq 250 \text{ GeV} \quad \text{or} \quad m_{\tilde{\tau}_1} \simeq 112 - 113 \text{ GeV}$$

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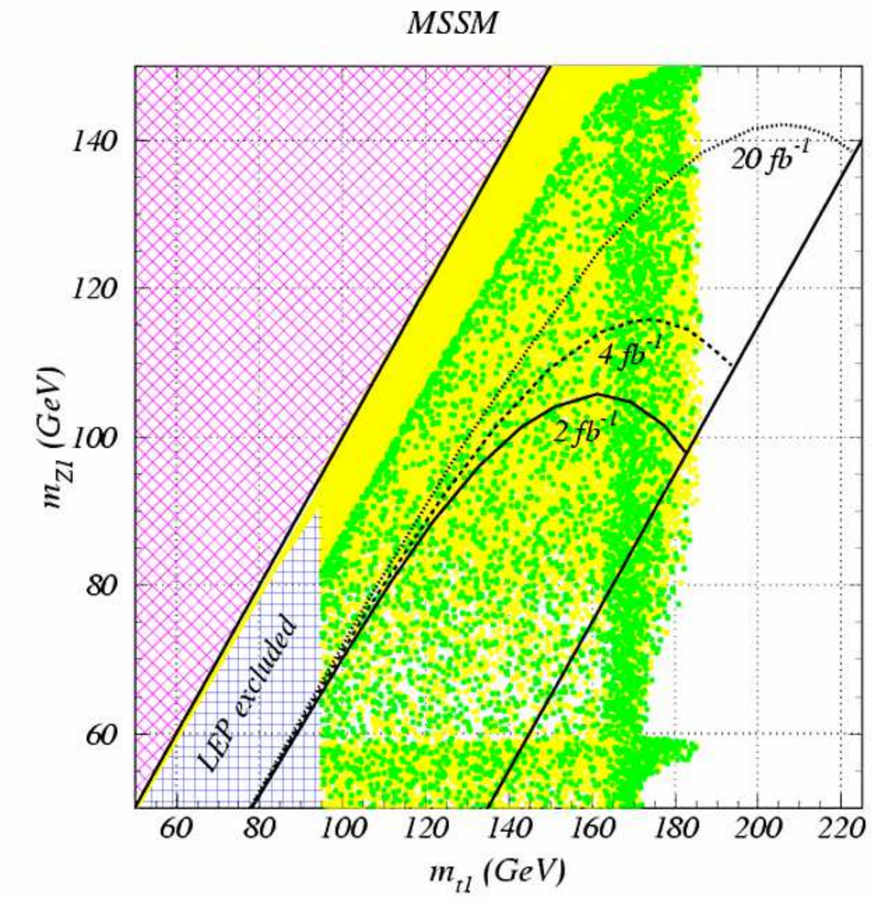
Largest SUSY (NLO) cross sections (PROSPINO 2):

$$\sigma(pp \to \tilde{t}_1\tilde{t}_1^*) = 280 \text{ pb}, \quad \sigma(pp \to \tilde{g}\tilde{g}) = 5.4 \text{ pb}$$

A $\tilde{t}_1$ NLSP with $m_{\tilde{t}_1} < m_W + m_{\tilde{\chi}_1^0}$ has $BR(\tilde{t}_1 \to c\tilde{\chi}_1^0) \approx 1$

Tevatron reach for $\tilde{t}_1 \to c\tilde{\chi}_1^0$



[Balazs, Carena, Wagner, hep-ph/0403224]
[Demina, Lykken, Matchev, Nomerotski, hep-ph/9910275]

A peculiar signature

$$\boxed{pp \to \tilde{g}\tilde{g}, \quad \tilde{g} \to t\tilde{t}_1, \quad \tilde{t}_1 \to c\tilde{\chi}_1^0}$$

Since the gluino is a Majorana particle, it can decay either into $t\tilde{t}_1^*$ or into $\bar{t}\,\tilde{t}_1$. Therefore, we get

$$\tilde{g}\tilde{g} \to t\bar{t}\,\tilde{t}_1\tilde{t}_1^*, tt\,\tilde{t}_1^*\tilde{t}_1^*, \, \overline{tt}\,\tilde{t}_1\tilde{t}_1$$

and hence like-sign tops in half of the gluino-to-stop decays!

Together with $t \to bW$ and the W decaying leptonically, we get a peculiar signature: 2b's + 2 SS leptons + jets + $\not{E}_T$

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Together with $t \to bW$ and the W decaying leptonically, we get a peculiar signature:

$$pp \to bb\,l^{\pm}l^{\pm} \;+ \text{jets} + \not{E}_T$$

Isolating the signature

NLO cross sections [pb]:

$\sigma(\tilde{t}_1\tilde{t}_1)$	$\sigma(\tilde{g}\tilde{g})$	$\sigma(\tilde{g}\tilde{q})$	$\sigma(\tilde{q}\tilde{q})$	$\sigma(\tilde{q}\tilde{q}^*)$	$\sigma(t\bar{t})$
280	5.39	4.98	0.666	0.281	737

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We generate events equivalent to 30 fb^{-1} with PYHTIA 6.321 and simulate a generic LHC detector with AcerDET-1.0.

Cuts used:

- Require four jets, $p_T^{\text{jet}} > 50$ GeV, two of which are b-tagged.
- Require two same-sign leptons, with $p_T^{\text{lep}} > 20$ GeV.
- Require $\not{E}_T > 100$ GeV.
- Require two comb. of leptons and b-jets with $m_{bl} < 160$ GeV.

Isolating the signature

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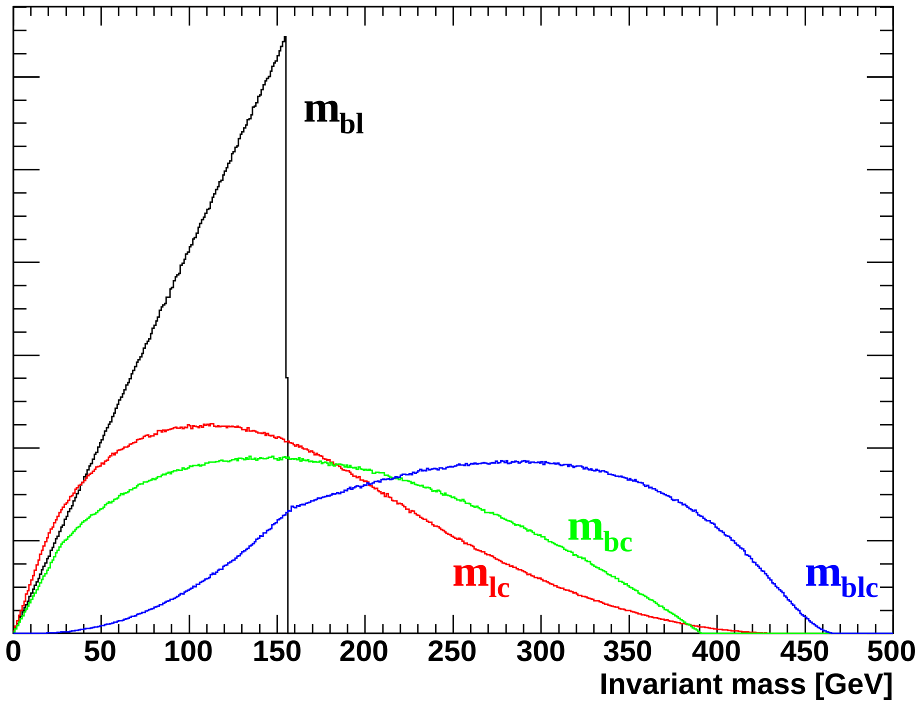
Cut	2lep 4jet	p_T^{lep}	p_T^{jet}	2b	$\not{E}_T$	2t	SS
$\tilde{g}\tilde{g}$	10839	6317	4158	960	806	628	330
Backg.							
SUSY	1406	778	236	40	33	16	5
SM	25.3M	1.3M	35977	4809	1787	1653	12

With very little background, can we determine masses?

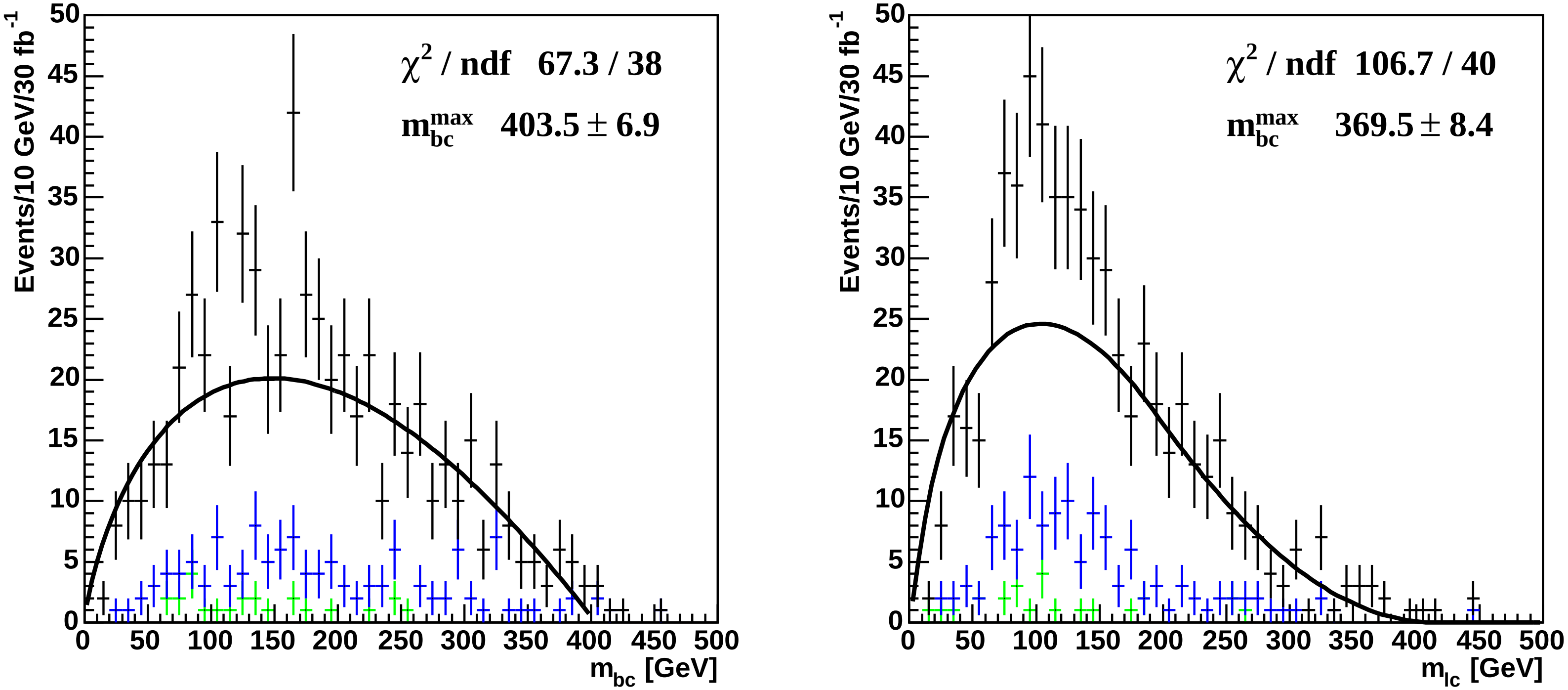
Determining masses

Difficult to find traditional endpoints of SM invariant masses.



Can however find analytical description of the shape of the invariant masses and do fits.

Determining masses



We can determine the value of m_{bc}^{max}, which relates the masses of the gluino, light stop and lightest neutralino.

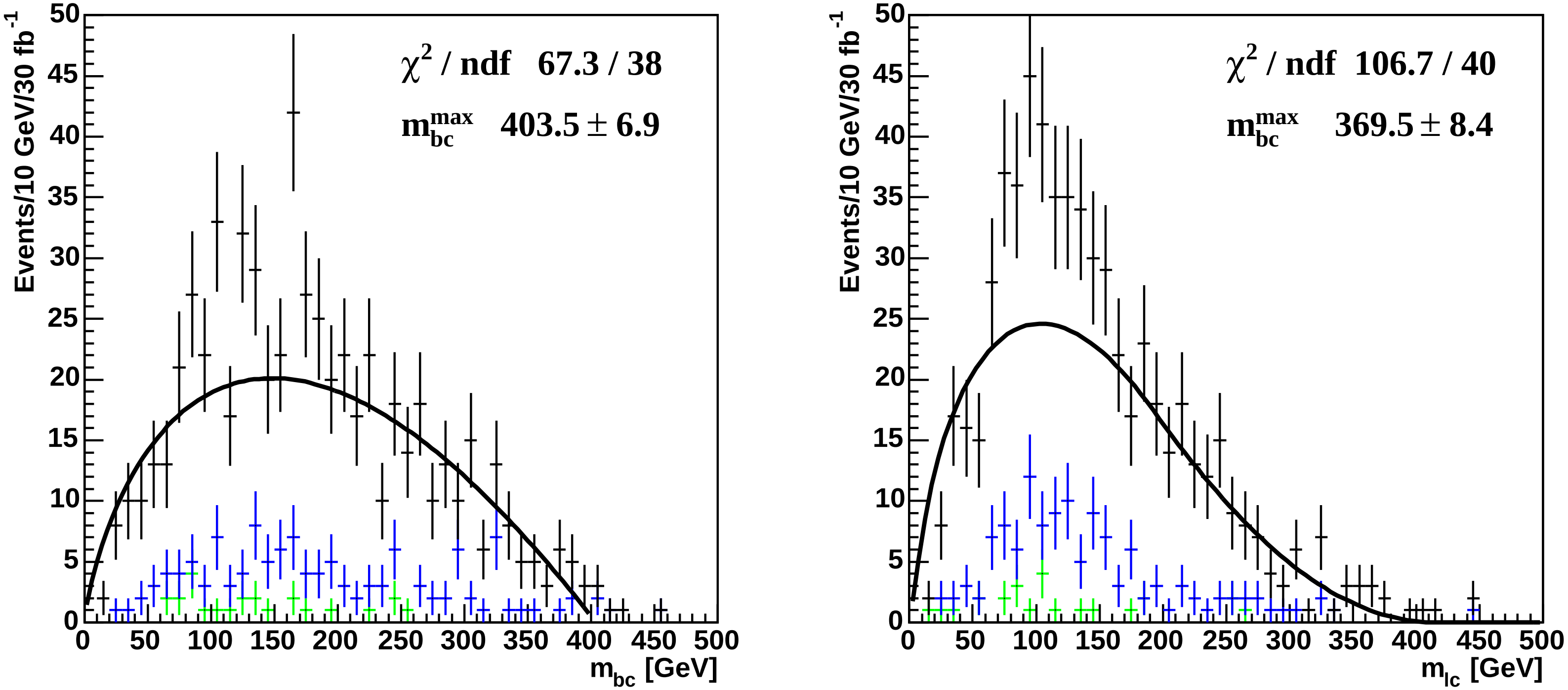
Determining masses

$$(m_{bc}^{\max})^2 = \frac{(m_t^2 - m_W^2)}{m_t^2} \frac{(m_{\tilde{t}_1}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{t}_1}^2} \frac{(m_1^2 + m_2^2)}{2}$$

where

$$m_1^2 = m_{\tilde{g}}^2 - m_t^2 - m_{\tilde{t}_1}^2 \quad \text{and} \quad m_2^4 = m_1^4 - 4 m_t^2 m_{\tilde{t}_1}^2$$

Determining masses

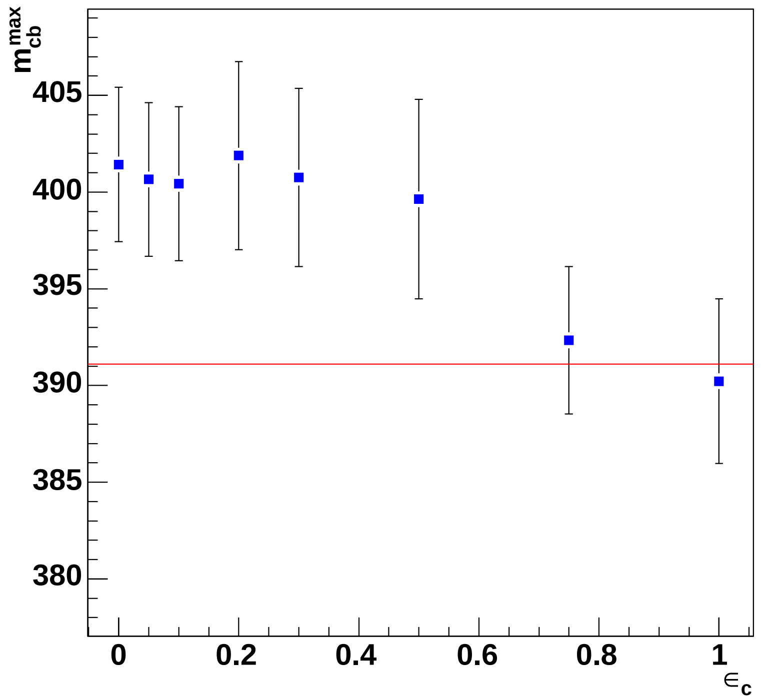


Taken together these two distributions give

$$m_{bc}^{\max} = 388.3 \pm 6.1 \text{ GeV},$$

compared to the nominal value of $m_{bc}^{\max} = 391.1$ GeV.

The importance of flavour



Resulting m_{bc}^{max} vs. assumed c-tagging efficiency.

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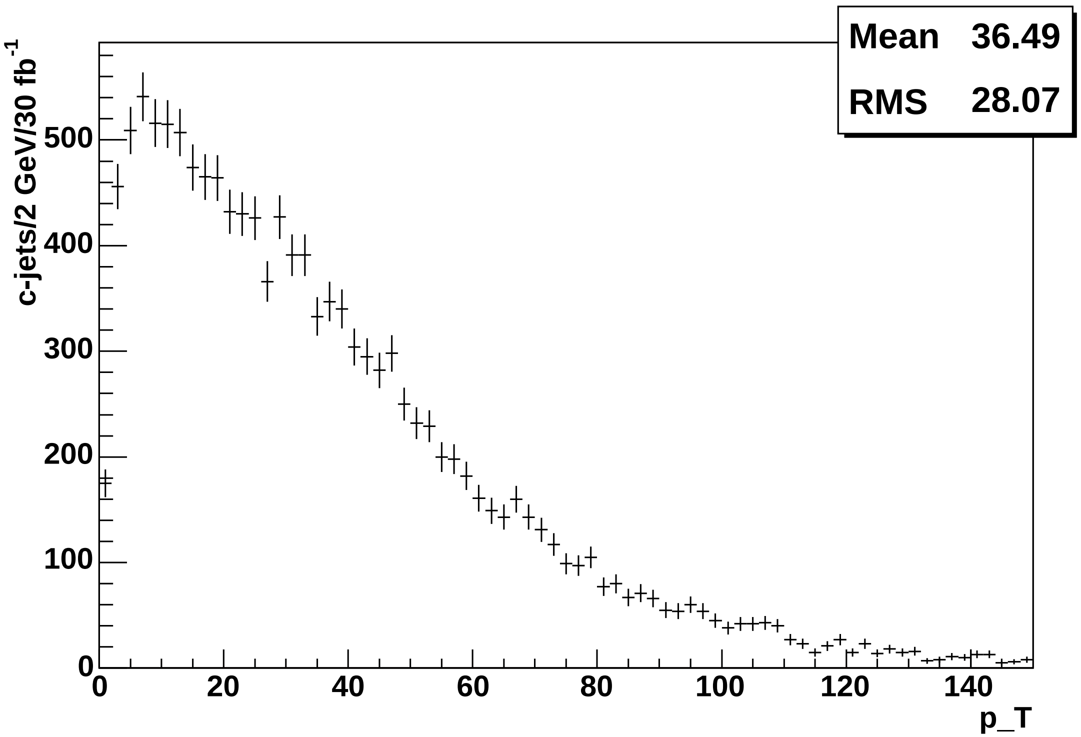
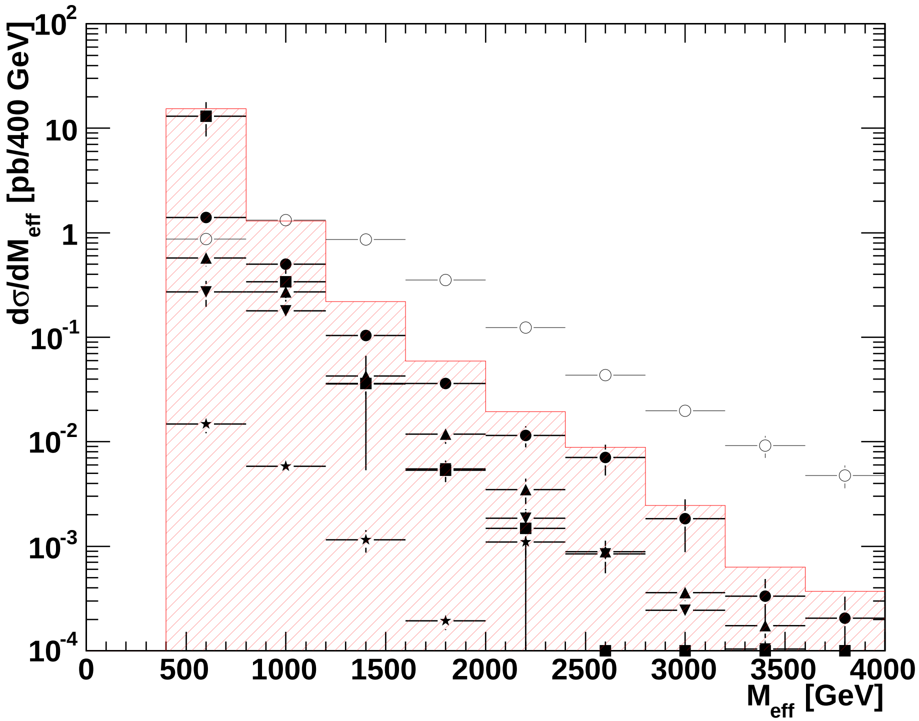
- Robust discovery channel for light stop.
  5σ significance for $m_{\tilde{g}} \lesssim 900$ GeV.
  We have also tested $m_{\tilde{t}_1} = 120$ GeV and $m_{\tilde{b}_1} < m_{\tilde{g}}$,
  finding an only slightly worse signal to background ratio.

Covering the stop-coannihilation region



p_T of c-jets for signal events in model with $m_{\tilde{t}_1} = 120$ GeV.

Effective mass



Distribution of effective mass M_{eff}:

$$M_{\text{eff}} = \not{E}_T + \sum_i p_{T,i}^{\text{jet}}$$