Light Stop Phenomenology

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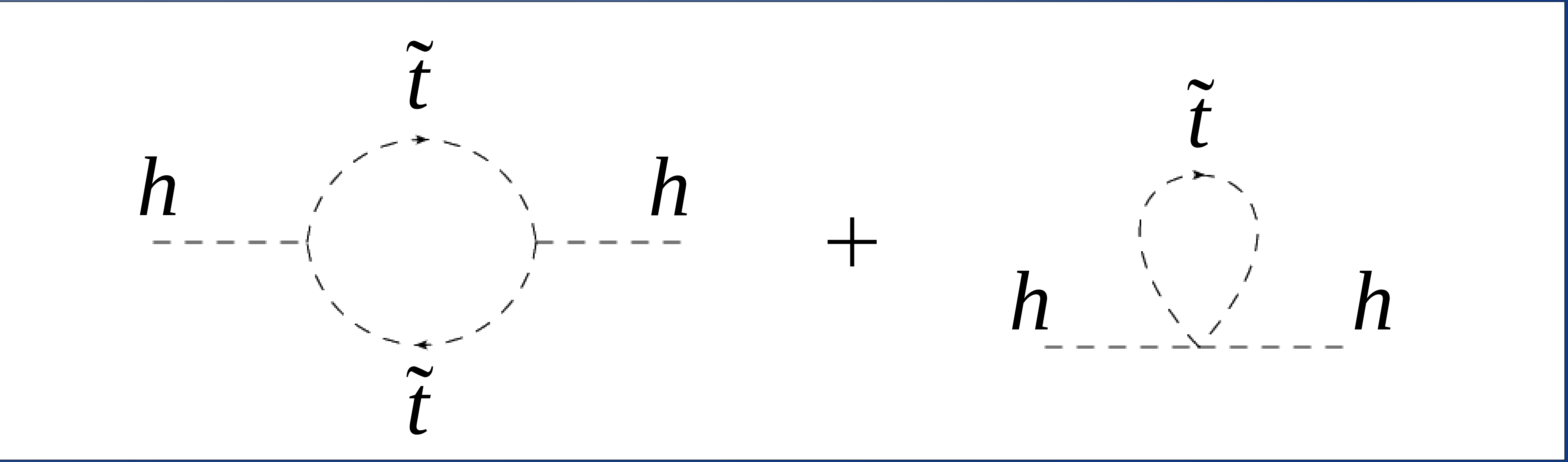
Outline

- Motivation
  - Why look for stops?
  - Current experimental searches
- Simplified Model
  - Simple case
  - Intermediate gauginos
- Branching Ratios and Signals

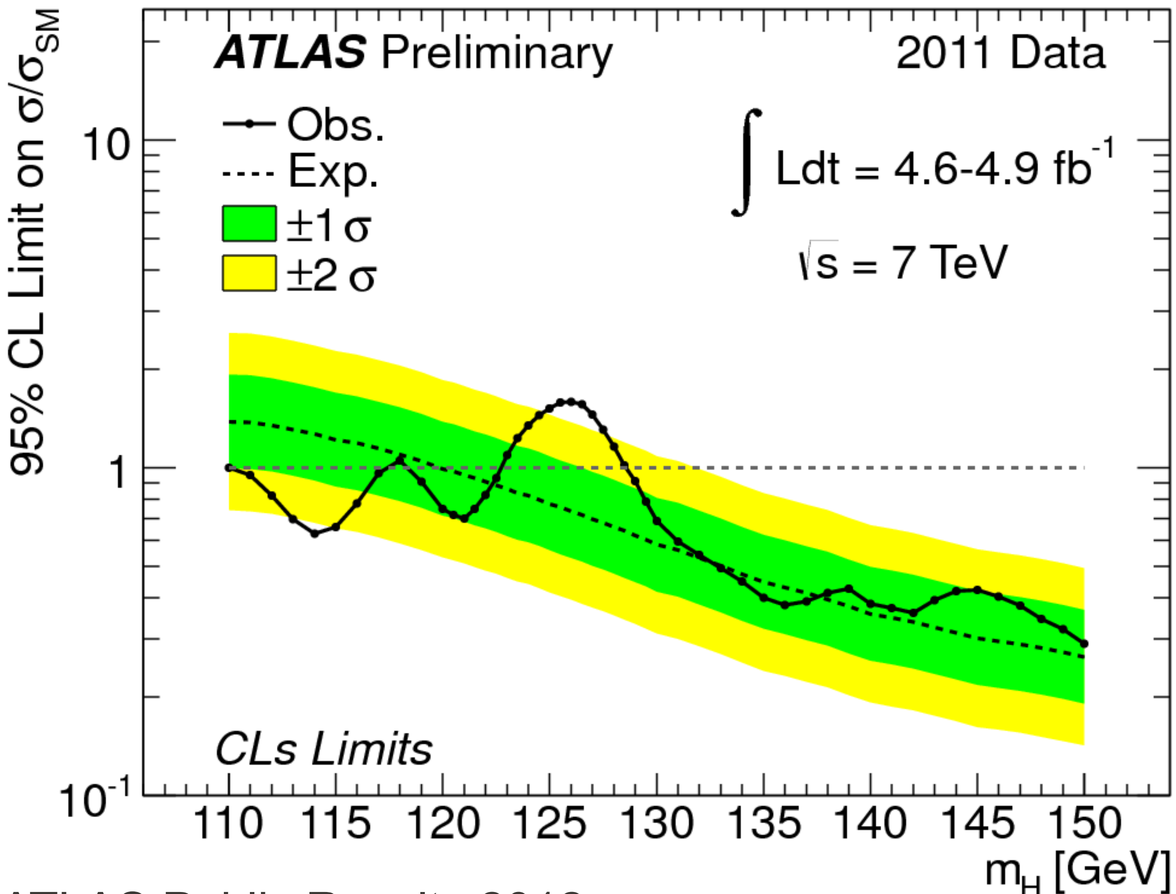
Higgs/Stop Coupling

- Stops expected to be light
  - Naturalness M_{STOP} ~ 1 TeV

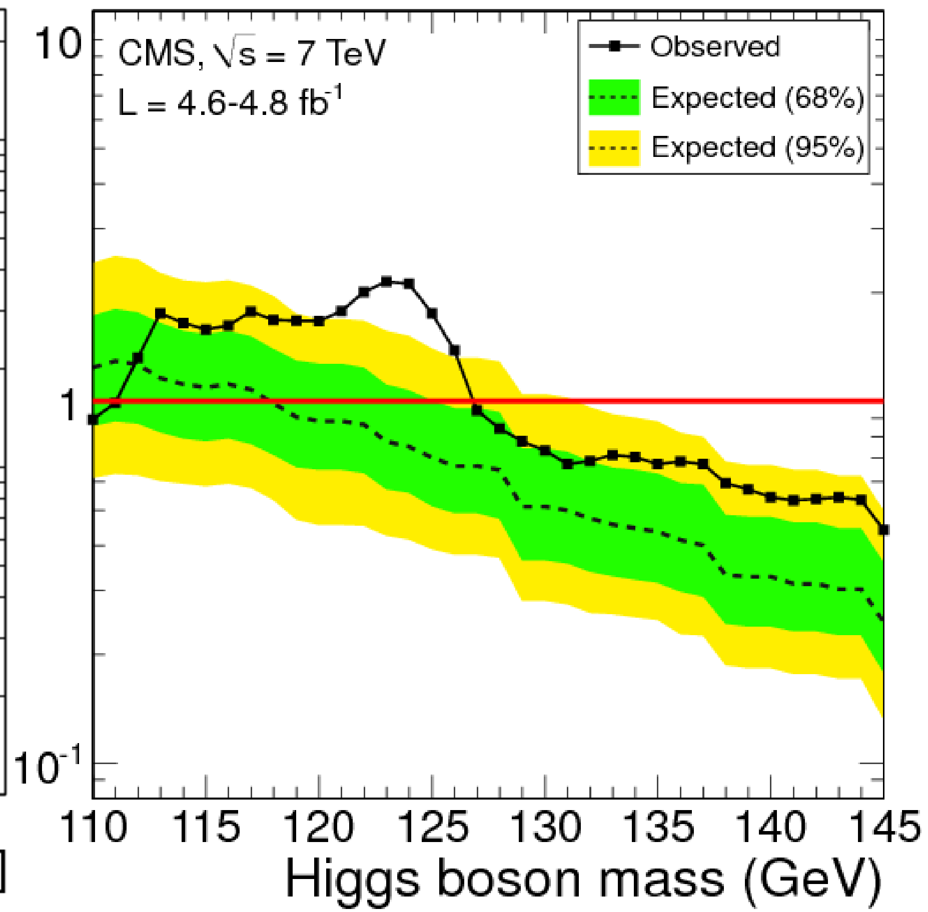
$$\Delta m_h^2 \sim \frac{y_t^2}{(4\pi)^2} m_{SUSY}^2 \ln(\ldots)$$



Hints of a Higgs at 125 GeV?



ATLAS Public Results 2012



CMS Public Results 2012

Higgs Mass Corrections

- Decoupling limit $M_A \gg M_Z$

$$\Delta m_h^2 = \frac{3}{4\pi^2}\frac{m_t^4}{v^2}\left[\ln\left(\frac{m_S^2}{m_t^2}\right) + \frac{X_t^2}{m_S^2}\left(1 - \frac{X_t^2}{12 m_S^2}\right)\right]$$

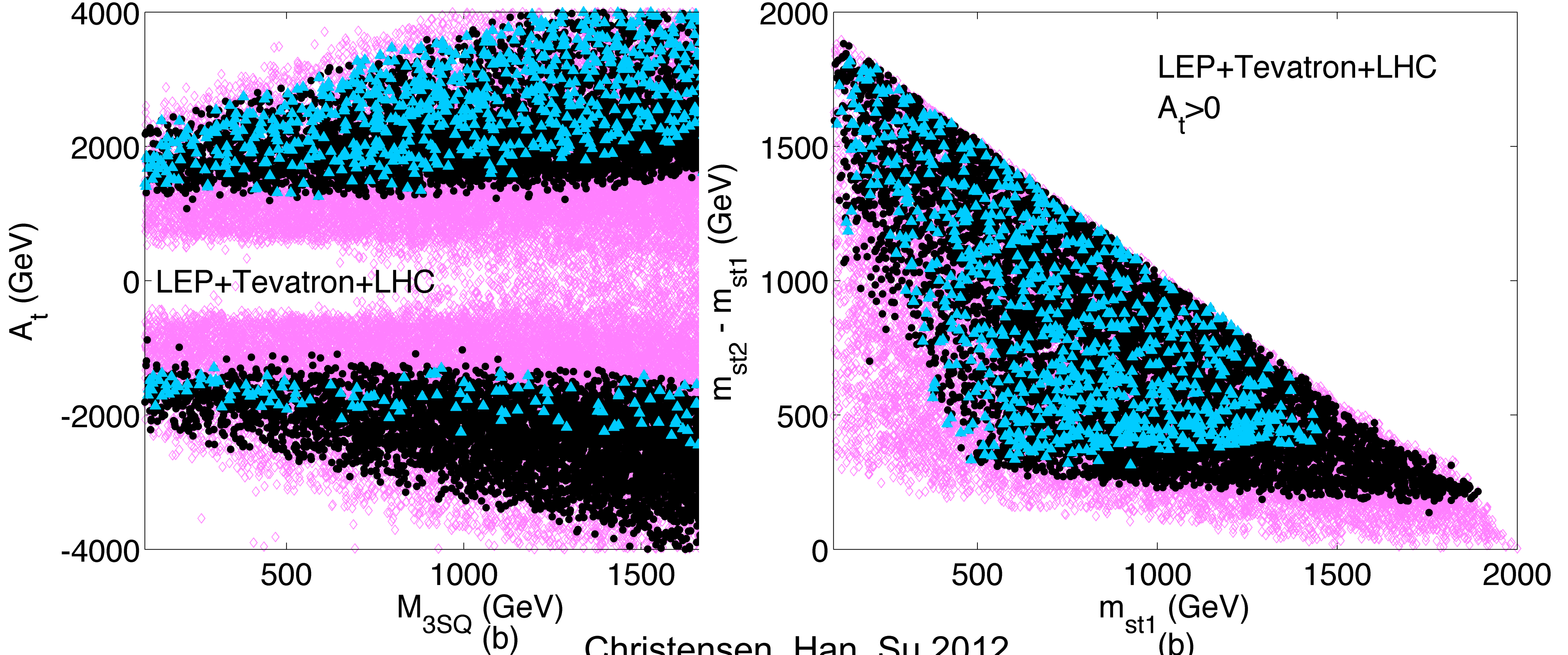
$X_t = 0 \rightarrow m_h^{min} \leq 117$ GeV

$X_t = \sqrt{6} M_S \rightarrow m_h^{max} \leq 127$ GeV

$$X_t = A_t - \mu \cot(\beta)$$

Parameter Scan

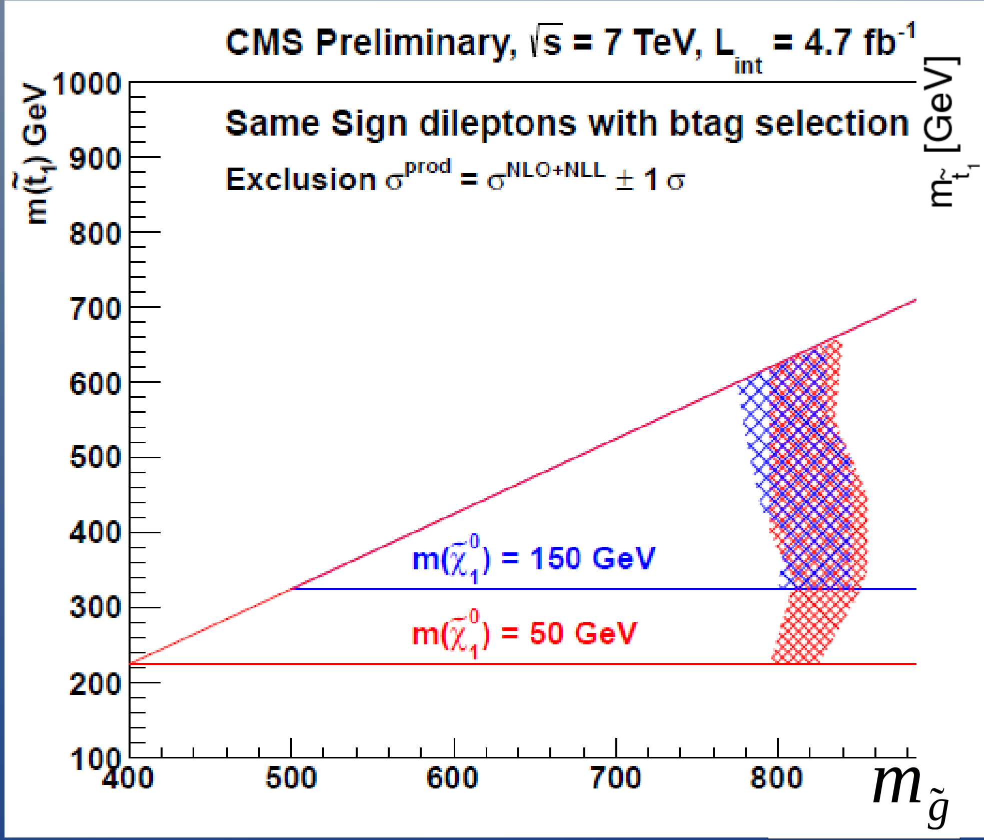
Pink dots pass experimental constraints
Black dots fall in mass range 125 +/- 2 GeV
Blue triangles pass req. $\sigma(gg \rightarrow h \rightarrow \gamma\gamma)/\sigma_{SM} > 0.8$

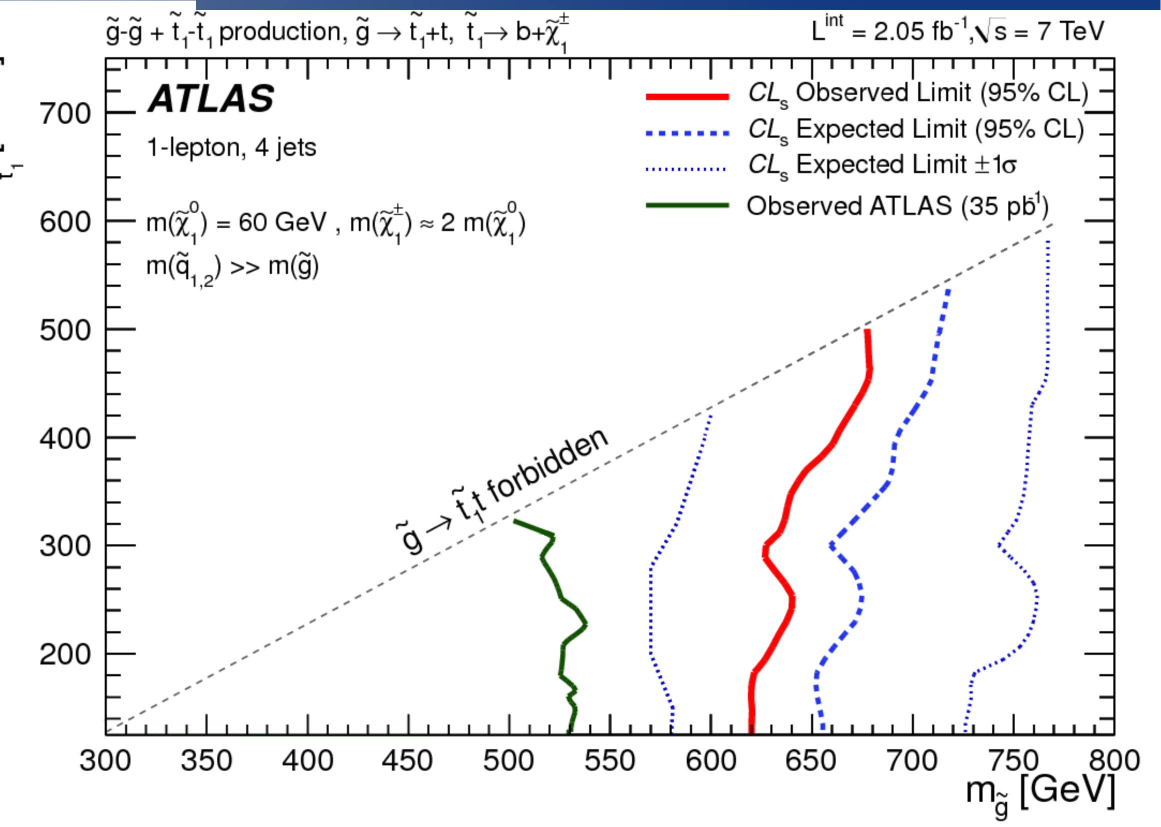


Christensen, Han, Su 2012

Current Stop Searches

Exclusion curves still dependent on gluino mass





Stop Mass Matrix

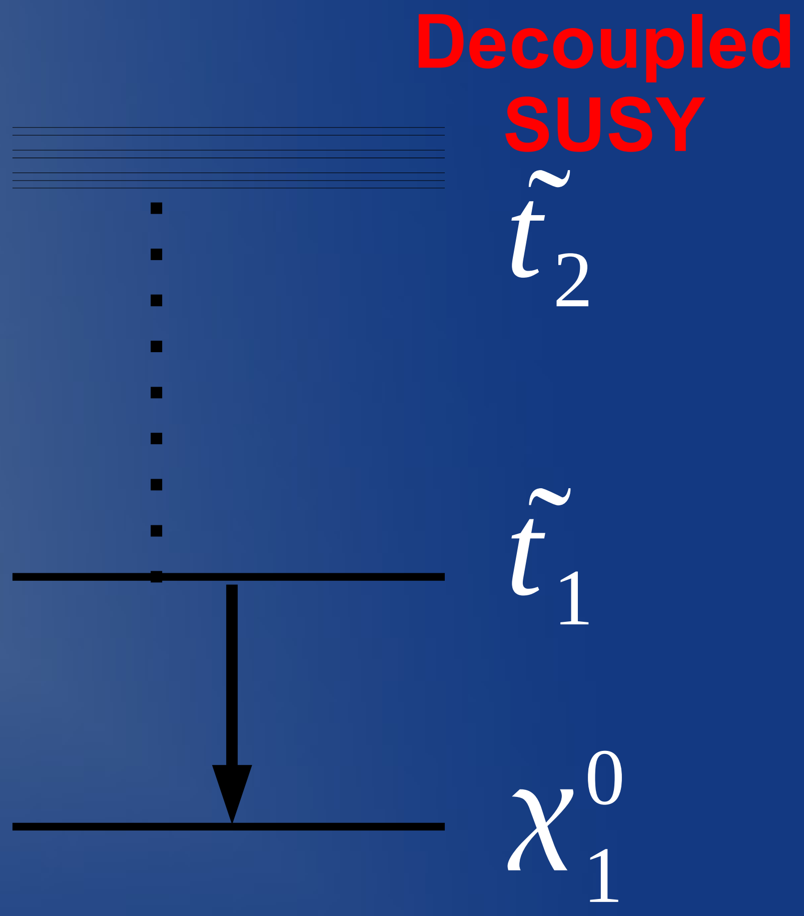
Three Cases:

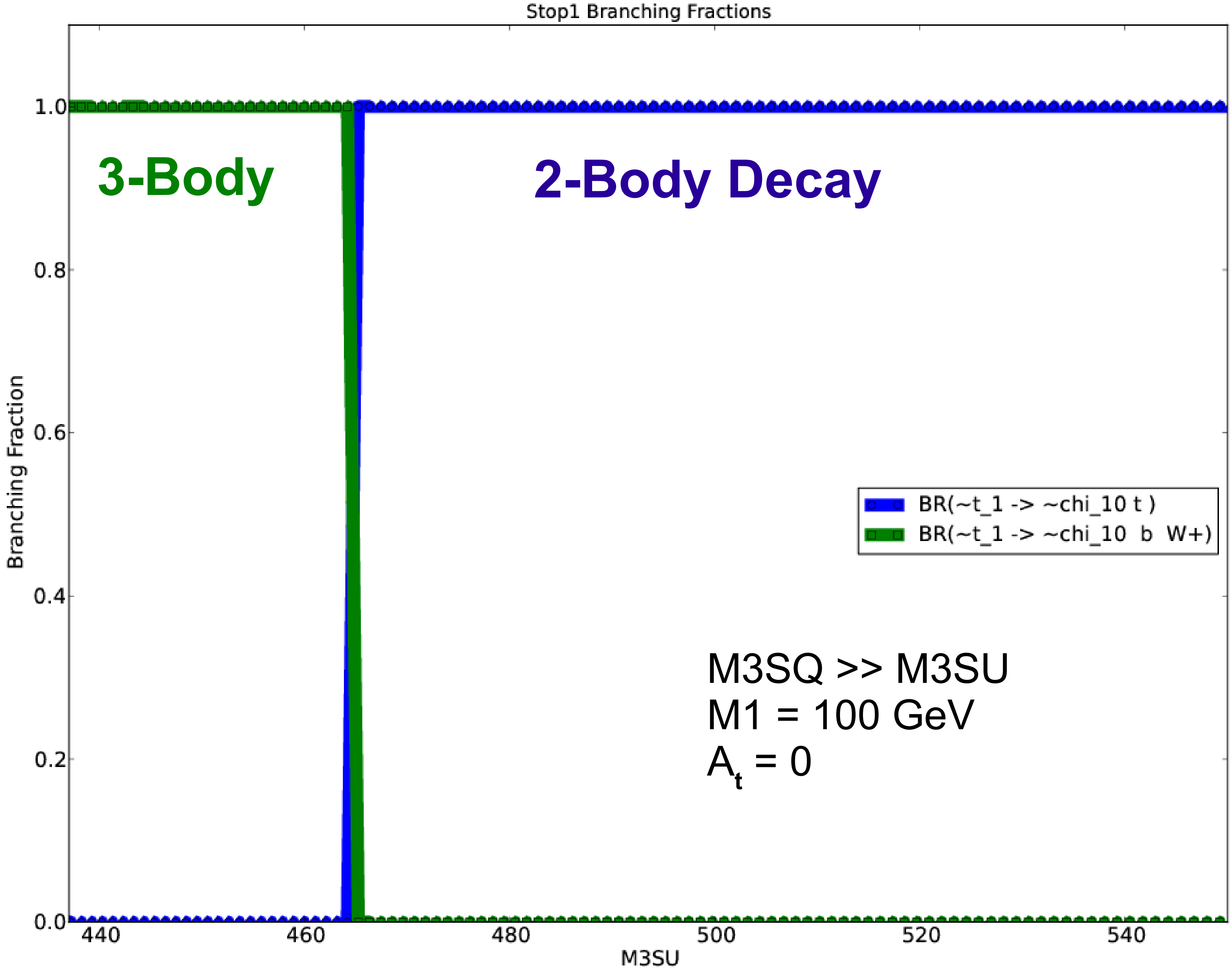
- Light stop mostly left handed $m_{3Q}^2 \ll m_{3U}^2$
- Light stop mostly right handed $m_{3U}^2 \ll m_{3Q}^2$
- LR equal with large mixing $m_{3U}^2 = m_{3Q}^2 \sim v\, X_t$

$$m_{\tilde{t}}^2 \approx \begin{pmatrix} m_{3Q}^2 & v\, X_t \\ v\, X_t & m_{3U}^2 \end{pmatrix}$$

Simplified Model

- Decouple all other SUSY particles
- Consider mostly left/right handed stop
- Bino LSP
- M1 = 100 GeV
- $A_t = 0$




Stop1 Branching Fractions
Branching Fraction
M3SU
1.0
0.8
0.6
0.4
0.2
0.0
440
460
480
500
520
540
3-Body
2-Body Decay
BR(~t_1 -> ~chi_10 t)
BR(~t_1 -> ~chi_10 b W+)
M3SQ >> M3SU
M1 = 100 GeV
A_t = 0

Simplified Model

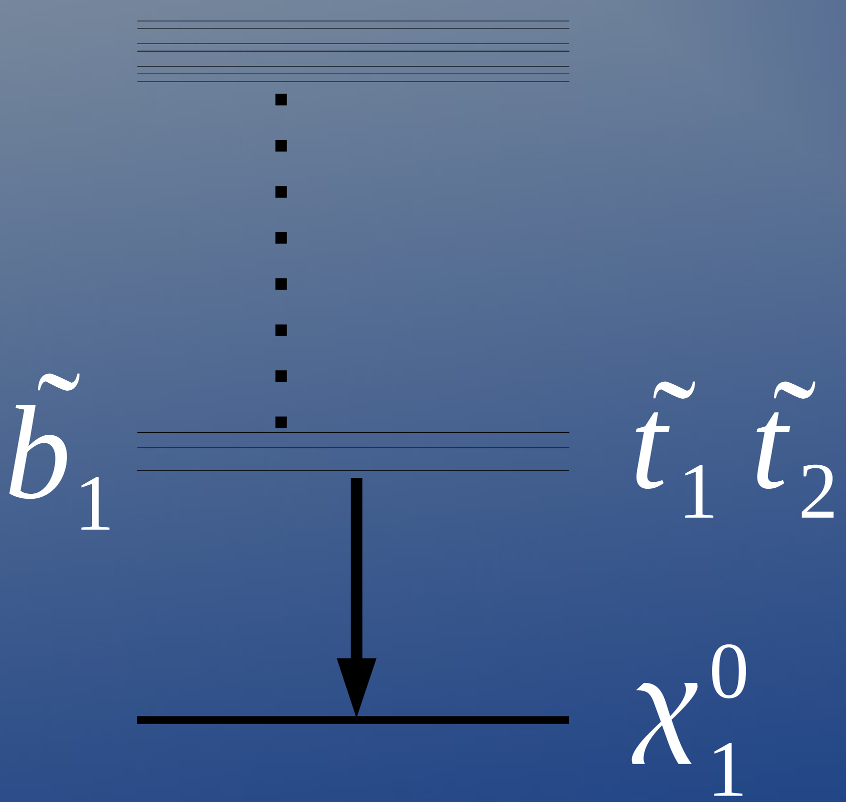
$A_t = 0$

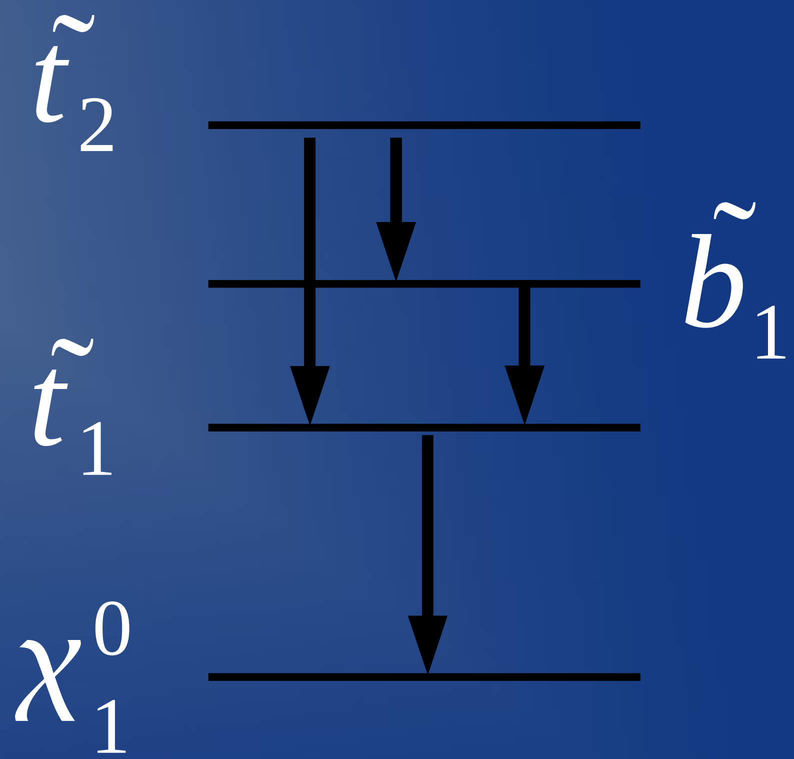
Compressed Spectra

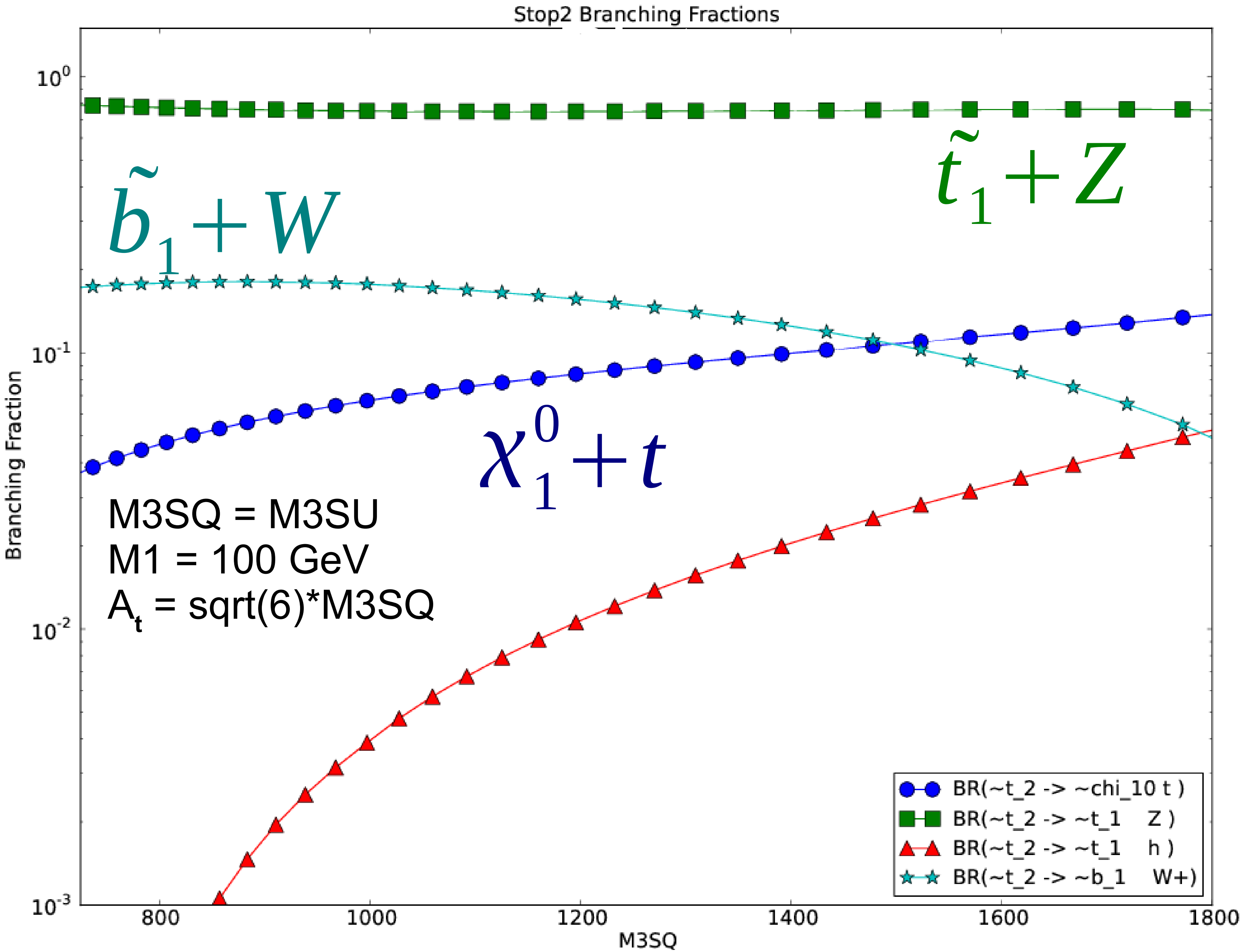
$m^2_{3U} = m^2_{3Q}$

$A_t = \sqrt{6}\, M_S$

High Splitting Spectra





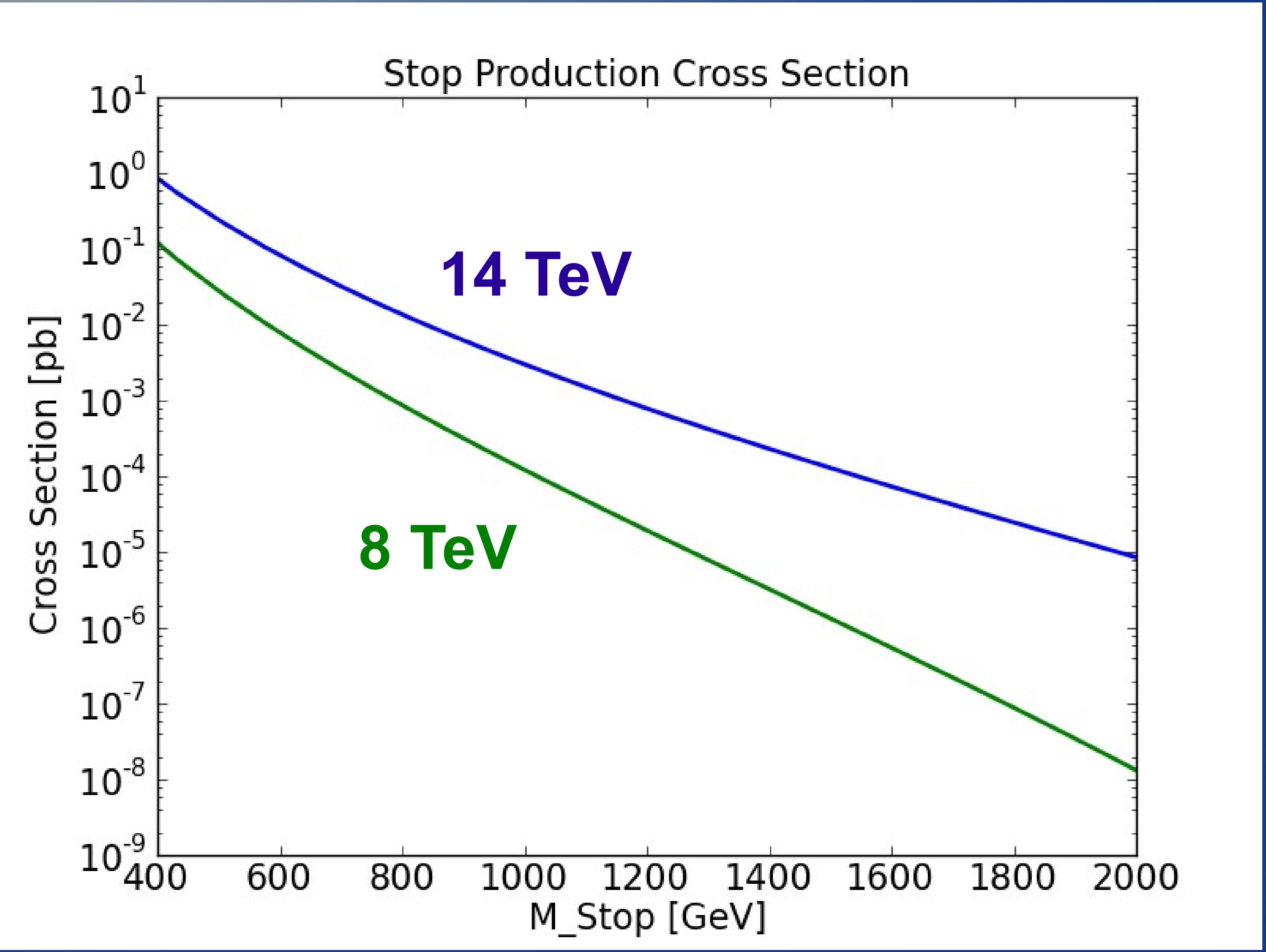

Stop2 Branching Fractions
$\tilde{b}_1 + W$
$\tilde{t}_1 + Z$
$\chi_1^0 + t$
M3SQ = M3SU
M1 = 100 GeV
A_t = sqrt(6)*M3SQ
Branching Fraction
M3SQ
BR(~t_2 -> ~chi_10 t)
BR(~t_2 -> ~t_1 Z)
BR(~t_2 -> ~t_1 h)
BR(~t_2 -> ~b_1 W+)

Relevant Signals

Decay	Signal	Branching Fraction
Light Stop L&R $\tilde{t}_1\tilde{t}_1$	$tt+\not{E}_T$	100%
Light Stops Mixed, Compressed $\tilde{t}_1\tilde{t}_1$	$tt+\not{E}_T$	100%
$\tilde{b}_1\tilde{b}_1$	$bb+\not{E}_T$	100%
$\tilde{t}_2\tilde{t}_2$	$tt+\not{E}_T$	100%
Light Stops Mixed, Large Splitting $\tilde{t}_2\tilde{t}_2 \to \tilde{t}_1\tilde{t}_1 + ZZ$	$tt + ZZ+\not{E}_T$	58.5%
$\tilde{t}_2\tilde{t}_2 \to \tilde{t}_1\tilde{b}_1 + ZW \to \tilde{t}_1\tilde{t}_1 + ZWW$	$tt + ZWW+\not{E}_T$	26.7%
$\tilde{t}_2\tilde{t}_2 \to \tilde{t}_1\chi_1^0 + t + Z$	$tt + Z+\not{E}_T$	7.0%
$\tilde{t}_2\tilde{t}_2 \to \tilde{b}_1\tilde{b}_1 + WW \to \tilde{t}_1\tilde{t}_1 + WWWW$	$tt + WWWW+\not{E}_T$	3.0%
$\tilde{t}_2\tilde{t}_2 \to \tilde{b}_1\chi_1^0 + t + W \to \tilde{t}_1\chi_1^0 + t + WW$	$tt + WW+\not{E}_T$	1.6%
$\tilde{b}_1\tilde{b}_1 \to \tilde{t}_1\tilde{t}_1 + WW$	$tt + WW+\not{E}_T$	98%
$\tilde{b}_1\tilde{b}_1 \to \tilde{t}_1\chi_1^0 + b + W$	$tb + W+\not{E}_T$	2.0%
$\tilde{t}_1\tilde{t}_1$	$tt+\not{E}_T$	100%

Table 1: Simple Case at M3SQ = M3SU = 800 GeV

Stop Pair Production Cross Section

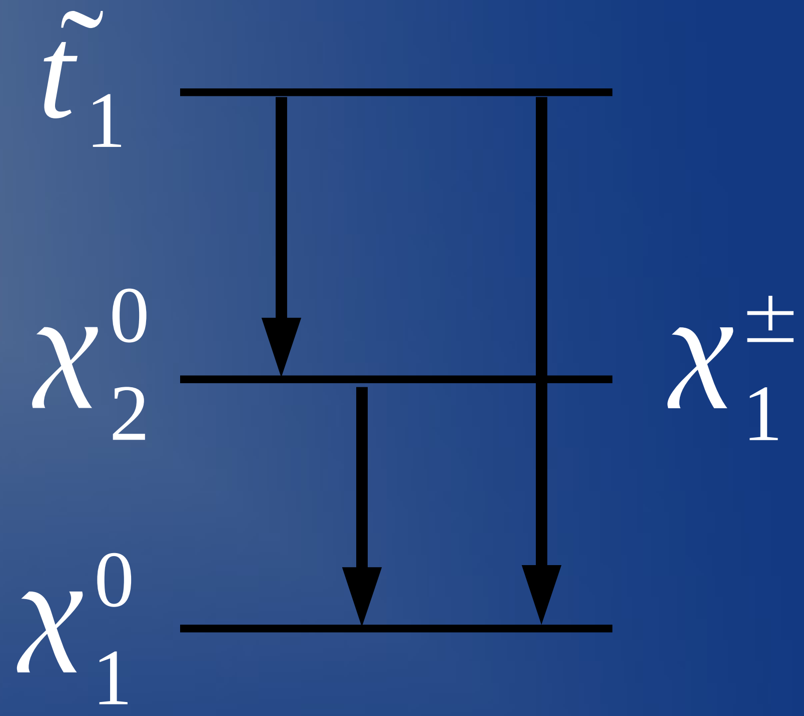


Intermediate Gauginos

- Set M2 = 200 GeV
- Allows for intermediate decays
- Wino-like

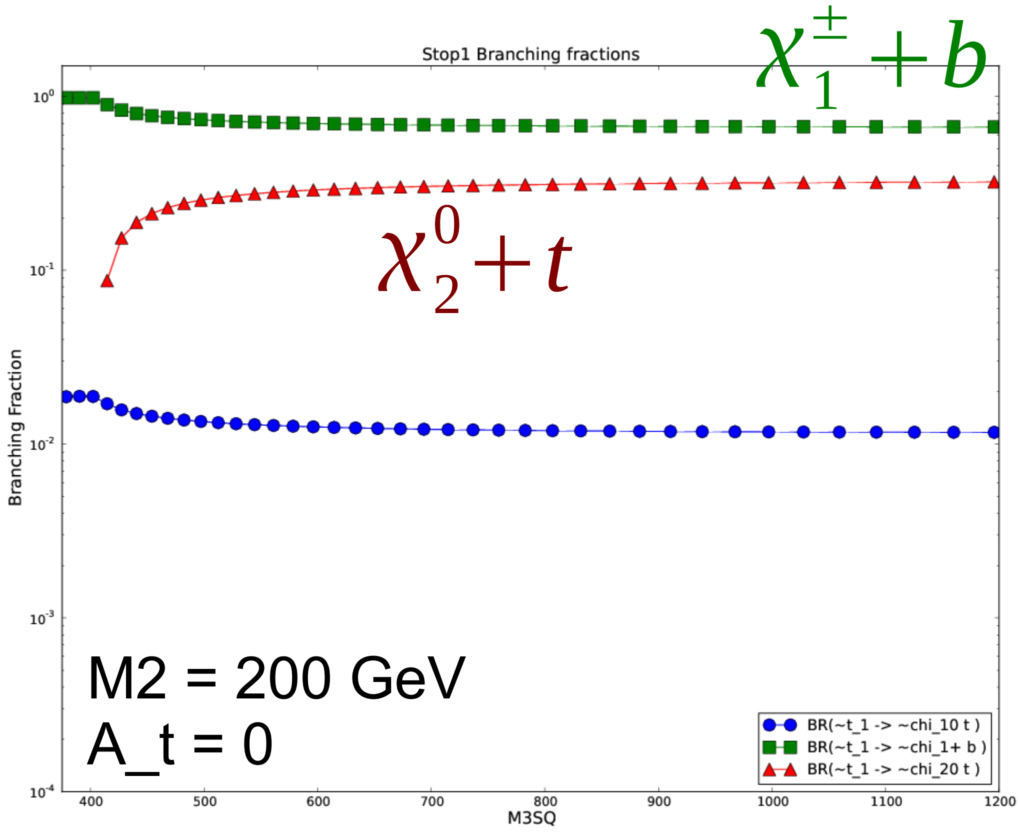
$$\chi_1^{\pm} \rightarrow W^{\pm} \chi_1^0$$

$$\chi_2^0 \rightarrow Z/h\ \chi_1^0$$

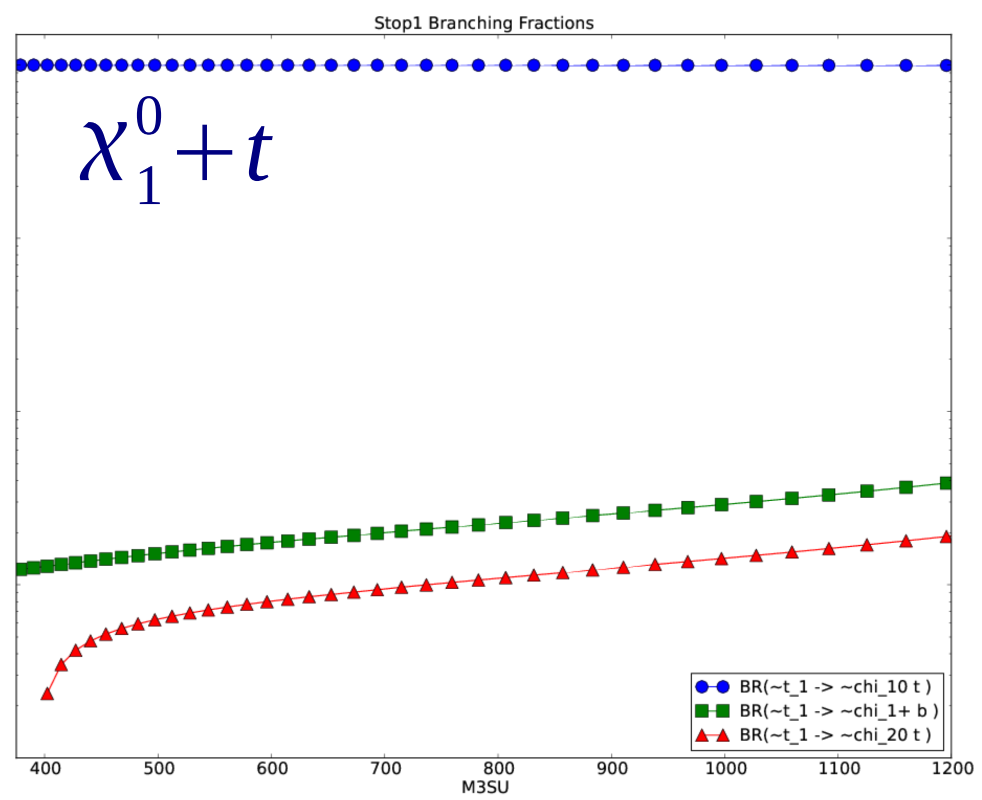


Light Stop Decay

Mostly Left Handed



Mostly Right Handed



Decay Table

Decay	Signal	Branching Fraction
Light Stop Lefthanded $\tilde{t}_1\tilde{t}_1 \to \chi_1^+\chi_1^+ + bb$	$bb + WW + \not{E}_T$	43.6%
$\tilde{t}_1\tilde{t}_1 \to \chi_1^+\chi_2^0 + tb$	$tb + Wh + \not{E}_T$	39.2%
$\tilde{t}_1\tilde{t}_1 \to \chi_1^+\chi_2^0 + tb$	$tb + WZ + \not{E}_T$	4.4%
$\tilde{t}_1\tilde{t}_1 \to \chi_2^0\chi_2^0 + tt$	$tt + hh + \not{E}_T$	8.8%
$\tilde{t}_1\tilde{t}_1 \to \chi_2^0\chi_2^0 + tt$	$tt + hZ + \not{E}_T$	2.0%
$\tilde{t}_1\tilde{t}_1 \to \chi_1^+\chi_1^0 + tb$	$tb + W + \not{E}_T$	1.3%
Light Stop Righthanded $\tilde{t}_1\tilde{t}_1 \to \chi_1^0\chi_1^0 + tt$	$tt + \not{E}_T$	99.9%

A_t = 0, M3SQ (M3SU) = 800, M1 = 100, M2 = 200 GeV

- When both stops light, the highly split spectra scenario gives even more complicated decays
  - tt or bb + 4 VB

Conclusions

- Stops expected to be light (< ~1TeV)
- Stop and Higgs sector coupled
  - Large mass corrections
- Rich signals in stop decays
  - More than just tt + MET
  - tt + ZZ, + WWZ, + ...