The Hypercharged Anomaly-Mediated Supersymmetry Breaking Model

Rencontre de Physique des Particules 2010

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Homer L. Dodge Dept. of Physics and Astronomy

25 January 2010

Introduction

Authors

- Hypercharged Anomaly Mediation

  Radovan Dermisek, Herman Verlinde, Lian-Tao Wang

  Phys.Rev.Lett.100:131804,2008

  arXiv:0711.3211 [hep-ph]

- Prospects for Hypercharged Anomaly-Mediated SUSY Breaking at the LHC

  H. Baer, R. Dermisek, S. Rajagopalan, H. Summy

  JHEP 0910:078,2009

  arXiv:0908.4259 [hep-ph]

Introduction

Overview

- Describe the HCAMSB model.
- Look at the spectrum + p-space.
- Look at signatures.
- Conclude

HCAMSB

Anomaly Mediation

Soft Parameters in SUGRA Models

HCAMSB

Anomaly Mediation

Soft Parameters in SUGRA Models

Visible Sector
(MSSM)

Hidden Sector
(SM Gauge Singlets)

HCAMSB

Anomaly Mediation

Soft Parameters in SUGRA Models

Visible Sector (MSSM) — tree-level - - - - - - - - - - gravitational int. — Hidden Sector (SM Gauge Singlets)

HCAMSB

Anomaly Mediation

Soft Parameters in SUGRA Models

Visible Sector (MSSM)	tree-level - - - - - - - - - - gravitational int. + additional 1-loop contribution (super-Weyl anomaly)	Hidden Sector (SM Gauge Singlets)

HCAMSB

Anomaly Mediation

Soft Parameters in SUGRA Models

Visible Sector (MSSM)	tree-level - - - - - - - - - - gravitational int. + additional 1-loop contribution (super-Weyl anomaly)	Hidden Sector (SM Gauge Singlets)

Tree-level suppression $\Longleftrightarrow$ *Geometry*

HCAMSB

Anomaly Mediation

AMSB is nice because...

HCAMSB

Anomaly Mediation

AMSB is nice because...

- all soft terms depend on single parameter: $m_{3/2}$
- solves SUSY flavor and CP problems

HCAMSB

Anomaly Mediation

AMSB is nice because...

- all soft terms depend on single parameter: $m_{3/2}$
- solves SUSY flavor and CP problems

However AMSB alone is problematic:

- well-known that sleptons are tachyonic: $m^2_{sleptons} < 0$
- adhoc m_0 bumbs up those masses
  $\Rightarrow$ soft terms no longer RGE invariant

HCAMSB

Anomaly Mediation

Soft Contributions in mAMSB Models

Parameter Space:

$$m_0, m_{3/2}, tan\beta, sign(\mu)$$

RGE's:

$$M_a = \frac{b_a g_a^2}{16\pi^2} m_{3/2}, \ \ a = 1, 2, 3$$

$$m_i^2 = -\frac{1}{4}\{\frac{d\gamma}{dg}\beta_g + \frac{d\gamma}{df}\beta_f\} m_{3/2}^2 + m_0^2$$

$$A_i = \frac{\beta_{f_i}}{f_i} m_{3/2}$$

HCAMSB

Hypercharged Mediation

U(1) mediation set up:

HCAMSB

Hypercharged Mediation

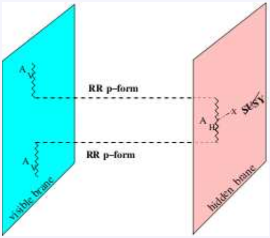
U(1) mediation set up:

- MSSM & hidden sectors *geometrically* sequestered.
- hidden brane in strongly-warped region of manifold
  $\Rightarrow$ filters tree-level gravitational effects.
- visibile (V) & hidden (H) branes carry same U(1) charges
  $\Rightarrow$ gauge bosons: A_V and A_H.
- F-type $< VEV >$ on the hidden brane.

HCAMSB

Hypercharged Mediation

RR p-forms traverse the bulk

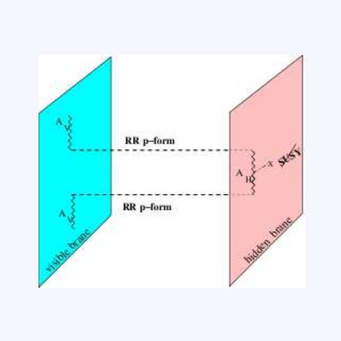


They couple to gauge fields by linear C-S-couplings

HCAMSB

Hypercharged Mediation

RR p-forms traverse the bulk



They couple to gauge fields by linear C-S-couplings

KK reduction

$\Downarrow$

$$\mathcal{L}_{RR} = C \wedge (dA_V + dA_H) + \frac{1}{2\mu^2}|dC|^2$$

equivalent to Stuckelberg mass;

$\mu \sim$ string scale

$\Downarrow$

$$(A_V + A_H)$$

integrates out

$\Downarrow$

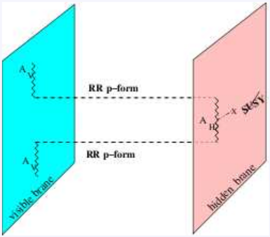
Low-energy combination:

$$A_1 = (A_V - A_H)$$

HCAMSB

Hypercharged Mediation

RR p-forms traverse the bulk



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integrates out

$$\Downarrow$$

Low-energy combination:

$$A_1 = (A_V - A_H)$$

A_1 is the Hypercharge Boson

HCAMSB

Hypercharge + Anomaly Mediation

F-terms give mass to visible sector bino:

- Hypercharged particles: 1-loop bino mass contrib.
- Gauginos: 2-loop contribution.

HCAMSB

Hypercharge + Anomaly Mediation

F-terms give mass to visible sector bino:

- Hypercharged particles: 1-loop bino mass contrib.
- Gauginos: 2-loop contribution.
- Redefine AMSB M_1 RGE

$$\rightarrow M_1 = \tilde{M}_1 + \frac{b_1 g_1^2}{16\pi^2} m_{3/2}$$

Parameterize Hypercharged contrib. relative to AMSB's

$$\alpha = \frac{\tilde{M}_1}{m_{3/2}}.$$

HCAMSB

Hypercharge + Anomaly Mediation

Some problems gone:

HCAMSB

Hypercharge + Anomaly Mediation

Some problems gone:

Pure Anomaly Mediation | Pure HC Mediation

HCAMSB

Hypercharge + Anomaly Mediation

Some problems gone:

Pure Anomaly Mediation

- tachyonic sleptons

Pure HC Mediation

HCAMSB

Hypercharge + Anomaly Mediation

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Pure Anomaly Mediation

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Pure HC Mediation

- bino mass can fix this

HCAMSB

Hypercharge + Anomaly Mediation

Some problems gone:

Pure Anomaly Mediation

- tachyonic sleptons

Pure HC Mediation

- bino mass can fix this
- RGE running to TeV scale $\Rightarrow m_{\tilde{t}_1} < 0$

HCAMSB

Hypercharge + Anomaly Mediation

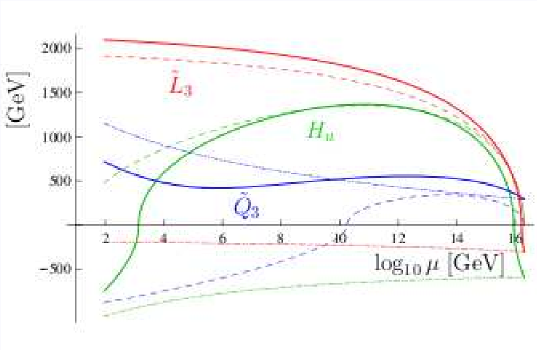
Some problems gone:

Pure Anomaly Mediation

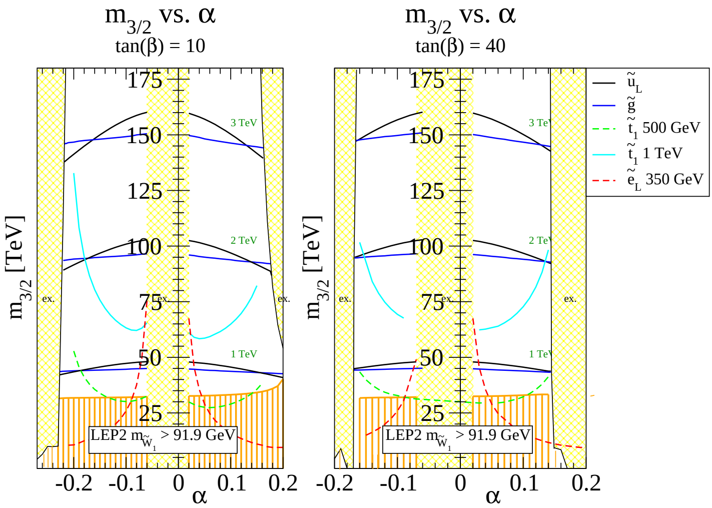
- tachyonic sleptons
- fixed by *anomalous dimension*

Pure HC Mediation

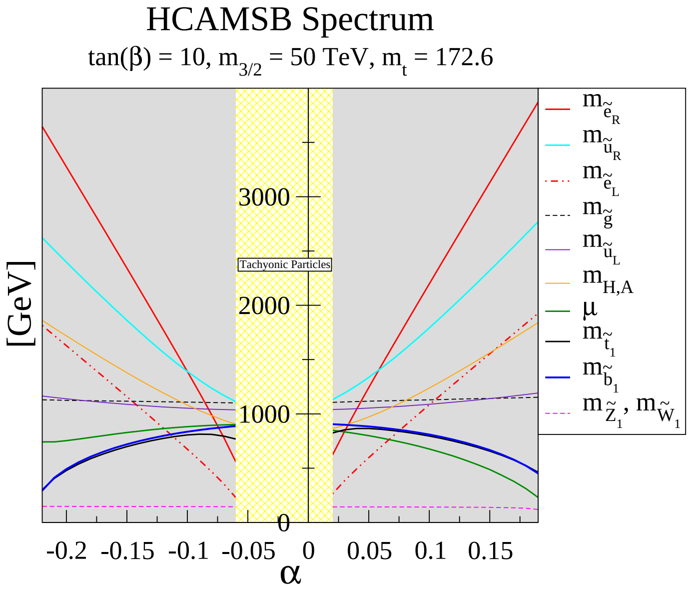
- bino mass can fix this
- RGE running to TeV scale $\Rightarrow m_{\tilde{t}_1} < 0$


[GeV]
2000
1500
1000
500
−500
2
4
6
8
10
12
14
16
$\log_{10}\mu$ [GeV]
$\tilde{L}_3$
H_u
$\tilde{Q}_3$

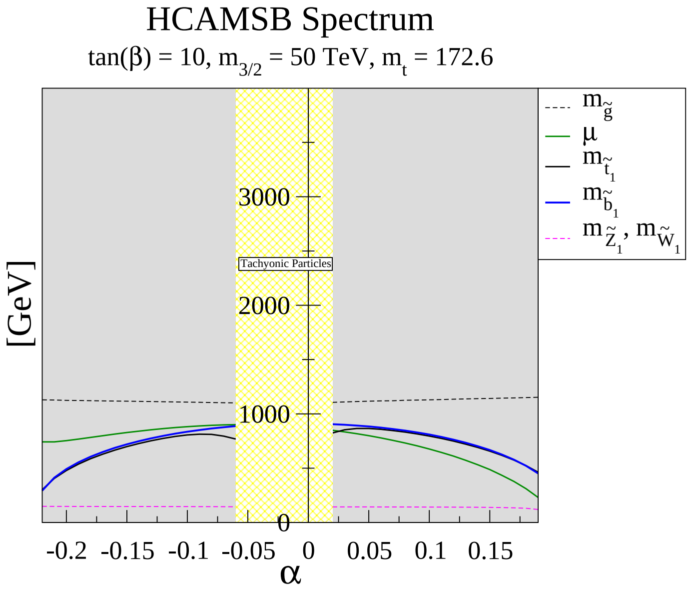
HCAMSB Spectrum



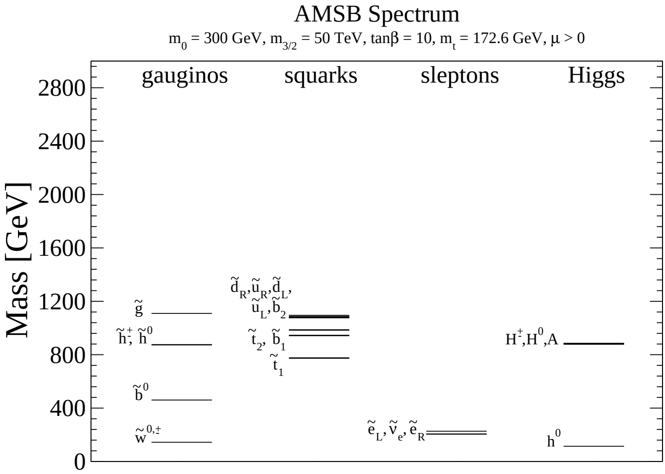
HCAMSB Spectrum



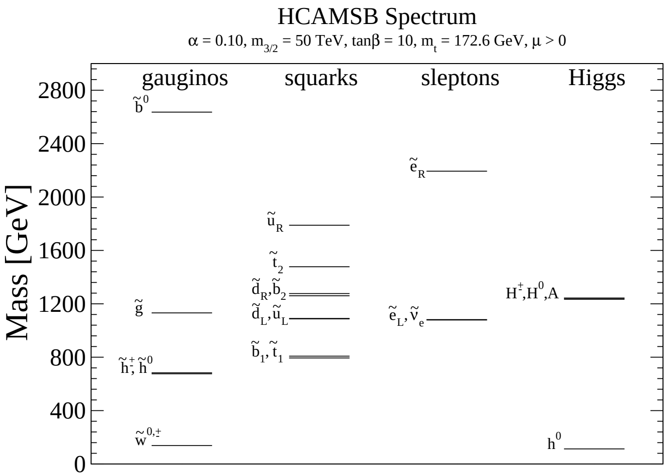
HCAMSB Spectrum



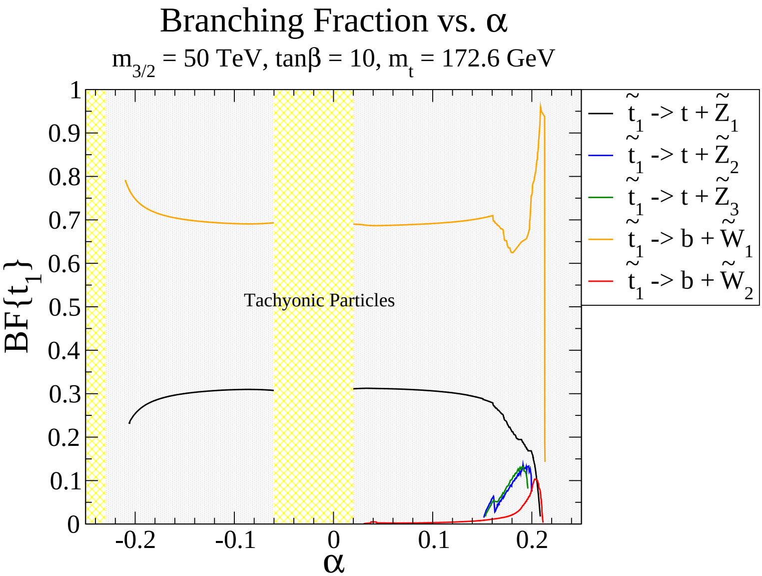
HCAMSB Spectrum



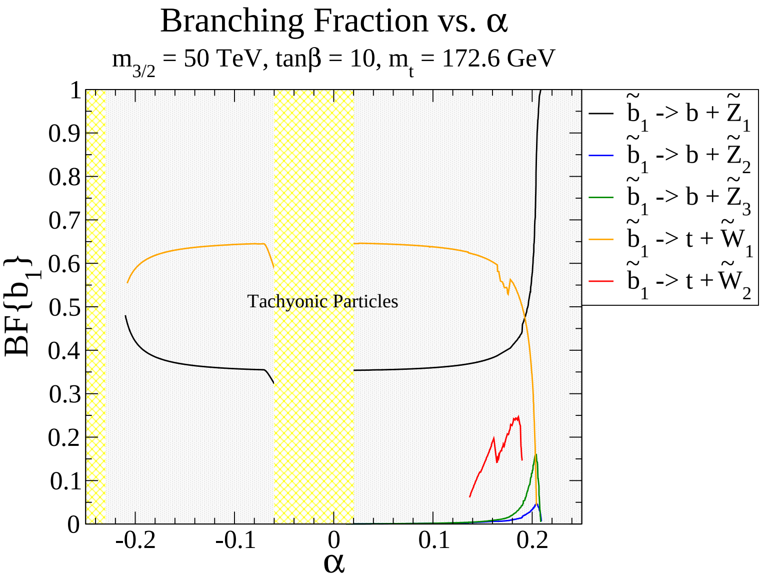
HCAMSB Spectrum



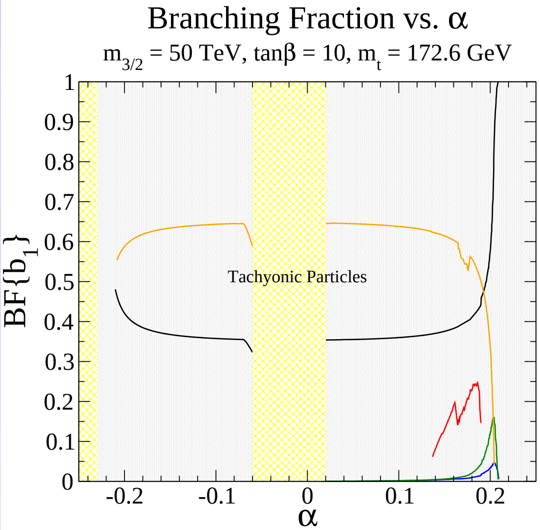
Signatures


Branching Fraction vs. α
m3/2 = 50 TeV, tanβ = 10, mt = 172.6 GeV
BF{t1}
α
Tachyonic Particles
t1 -> t + Z1
t1 -> t + Z2
t1 -> t + Z3
t1 -> b + W1
t1 -> b + W2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-0.2
-0.1
0
0.1
0.2

Signatures


Branching Fraction vs. α
m3/2 = 50 TeV, tanβ = 10, mt = 172.6 GeV
BF{b1}
α
Tachyonic Particles
b̃1 -> b + Z̃1
b̃1 -> b + Z̃2
b̃1 -> b + Z̃3
b̃1 -> t + W̃1
b̃1 -> t + W̃2

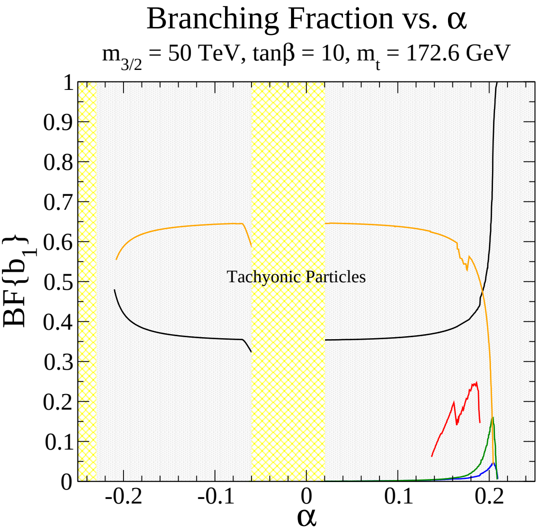
Signatures



$\tilde{b}_1$ decays:

$$\tilde{b}_1 \to b + \tilde{Z}_1$$
$$\tilde{b}_1 \to t + \tilde{W}_1$$

Signatures



$\tilde{b}_1$ decays:

$\tilde{b}_1 \to b + \tilde{Z}_1$
$\tilde{b}_1 \to t + \tilde{W}_1$

high b-jet mult.
E_T^{miss}
isolated leptons
$\tilde{W}_1$ *tracks*

Signatures

Chargino Tracks

$$m_{\tilde{W}_1} \sim m_{\tilde{Z}_1} \ :$$

Both are Wino-like

Nearly degenerate: $\Delta m \sim 200 MeV$

Signatures

Chargino Tracks

$m_{\tilde{W}_1} \sim m_{\tilde{Z}_1}$:

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Nearly degenerate: $\Delta m \sim 200 MeV$

$$\tilde{W}_1^+ \rightarrow \pi^+ + \tilde{Z}_1$$

$\pi^+ \downarrow$ *soft*

$\tilde{Z}_1 \searrow E_T^{miss}$

Signatures

Chargino Tracks

$$m_{\tilde{W}_1} \sim m_{\tilde{Z}_1} :$$

Both are Wino-like

Nearly degenerate: $\Delta m \sim 200 MeV$

$$\tilde{W}_1^+ \rightarrow \pi^+ + \tilde{Z}_1$$

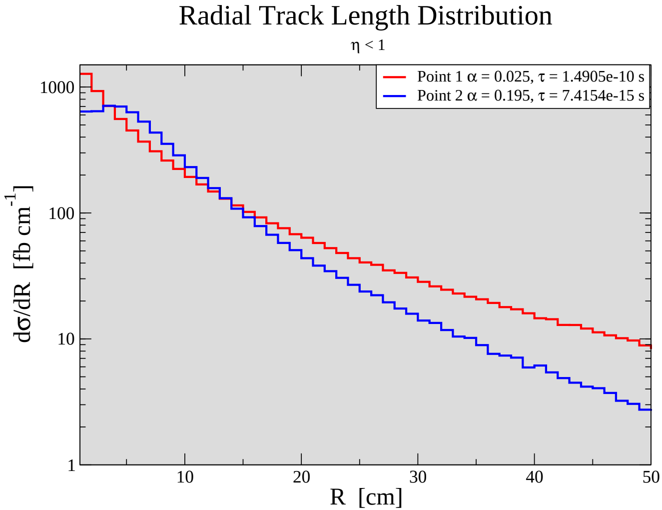
$\pi^+ \downarrow$ *soft*

$\tilde{Z}_1 \searrow E_T^{miss}$

A highly-ionizing track possible with no calorimeter signal.

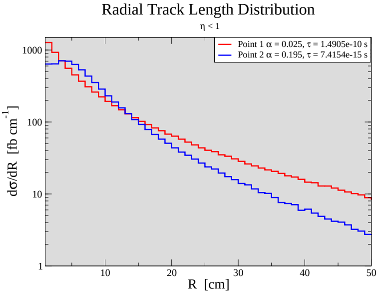
Signatures

Chargino Tracks



Signatures

Chargino Tracks



Atlas Detector

- innermost system
  3 pixel layers
  5,8,12.5 cm
- intermediate system
  4 barrel layers
  30 - 50 cm

Signatures

Smoking Gun?

$\tilde{Z}$ sector: $m(l^+l^-)$ Distribution

AMSB

HCAMSB

Signatures

Smoking Gun?

$\tilde{Z}$ sector: $m(l^+l^-)$ Distribution

AMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{l}^{\pm} l^{\mp}$
  $\rightarrow l^+ l^- \tilde{Z}_1$

HCAMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{W}_1^{\pm} W^{\mp}$
  $\rightarrow \tilde{Z}_1 h$
  $\rightarrow \boldsymbol{\tilde{Z}_1 Z}$

Signatures

Smoking Gun?

$\tilde{Z}$ sector: $m(l^+l^-)$ Distribution

AMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{l}^{\pm} l^{\mp}$
  $\rightarrow l^+ l^- \tilde{Z}_1$

  $\tilde{Z}_2 \rightarrow \tilde{Z}_1 Z$ suppressed

HCAMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{W}_1^{\pm} W^{\mp}$
  $\rightarrow \tilde{Z}_1 h$
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Signatures

Smoking Gun?

$\tilde{Z}$ sector: $m(l^+l^-)$ Distribution

AMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{l}^{\pm} l^{\mp}$
  $\rightarrow l^+ l^- \tilde{Z}_1$
  $\mathbf{\tilde{Z}_2 \rightarrow \tilde{Z}_1 Z}$ **suppressed**
- $\mathbf{M}_2 < \mathbf{M}_1 < \mu$

HCAMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{W}_1^{\pm} W^{\mp}$
  $\rightarrow \tilde{Z}_1 h$
  $\rightarrow \mathbf{\tilde{Z}_1 Z}$
- $\mathbf{M}_2 < \mu < \mathbf{M}_1$

Signatures

Smoking Gun?

$\tilde{Z}$ sector: $m(l^+l^-)$ Distribution

AMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{l}^{\pm} l^{\mp}$
  $\rightarrow l^+ l^- \tilde{Z}_1$
  $\tilde{\mathbf{Z}}_2 \rightarrow \tilde{\mathbf{Z}}_1 \mathbf{Z}$ **suppressed**

- $\mathbf{M}_2 < \mathbf{M}_1 < \mu$
- **AMSB: kinematic mass edge**

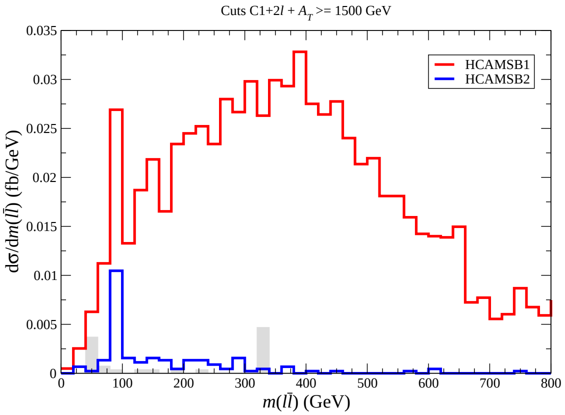
HCAMSB

- $\tilde{Z}_2$
  $\rightarrow \tilde{W}_1^{\pm} W^{\mp}$
  $\rightarrow \tilde{Z}_1 h$
  $\rightarrow \tilde{\mathbf{Z}}_1 \mathbf{Z}$

- $\mathbf{M}_2 < \mu < \mathbf{M}_1$
- **HCAMSB: smooth dist. with Z-peak**

Signatures

Smoking Gun?



Summary

For HCAMSB we should expect to see

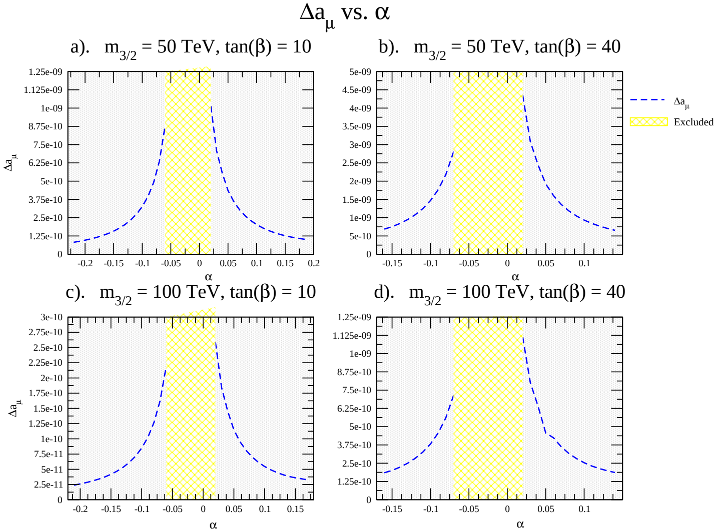
- High b-jet multiplicities.
- Isolated leptons.
- E_T^{miss}

$+$

- Left-right split AMSB
- Occasional HITs from long-lived Charginos
- And possibly a smooth distribution w/ a Z peak that can serve to differentiate from AMSB!

Constraining α and $m_{3/2}$

indirect limits



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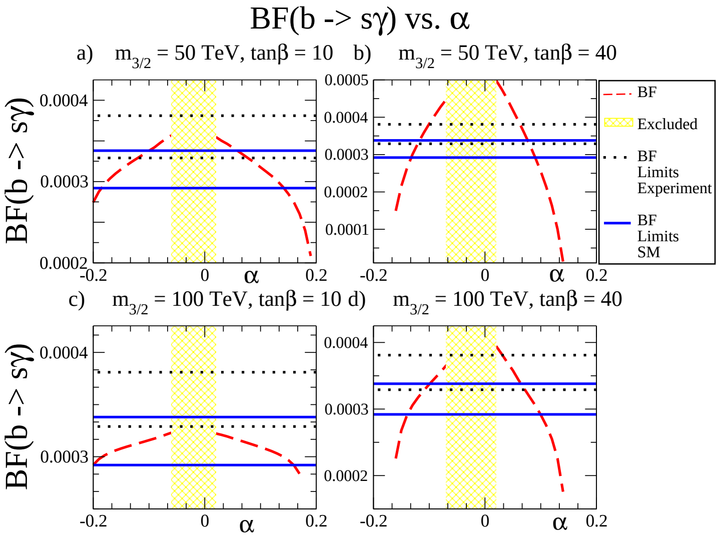
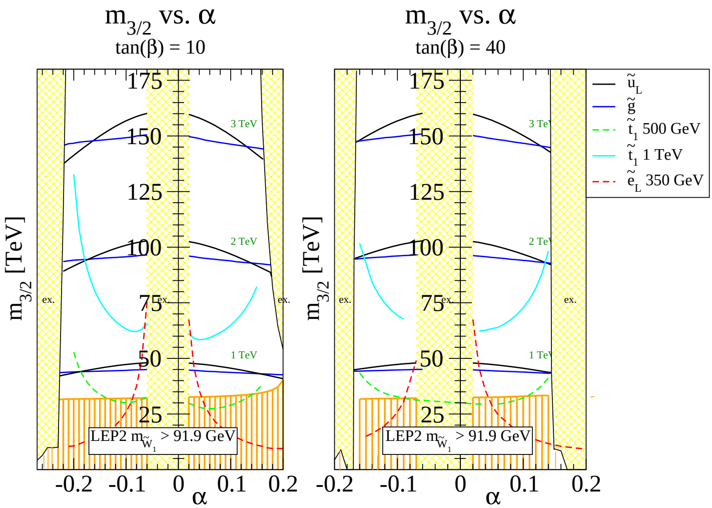
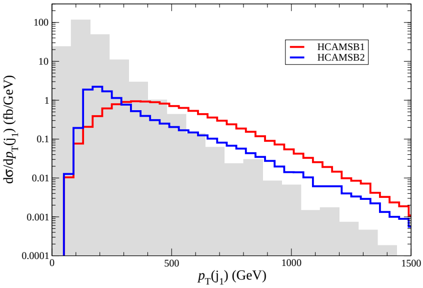
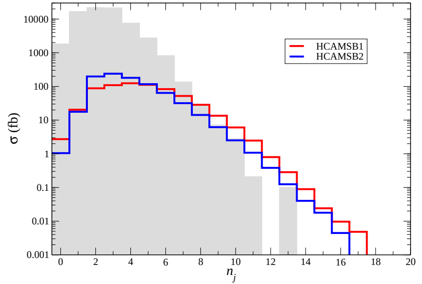


Constraining α and $m_{3/2}$

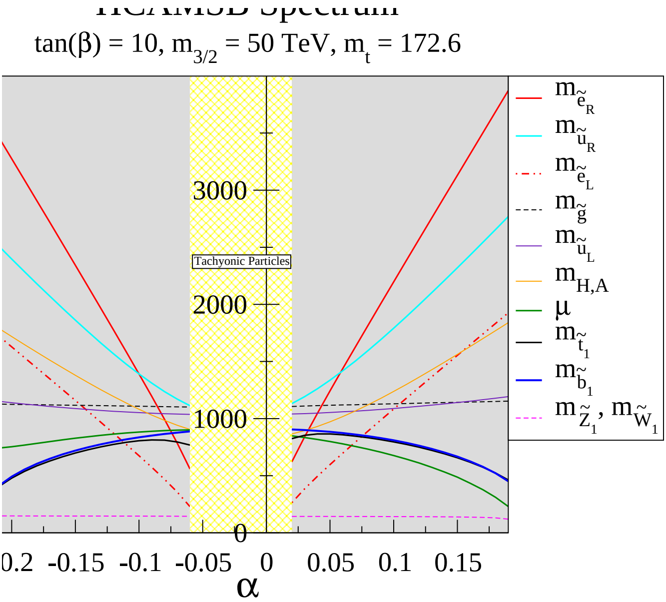


HCAMSB at the LHC





HCAMSB Spectrum



HCAMSB Spectrum