Diagnosis of Supersymmetry Breaking Mediation Schemes by Mass Reconstruction at the LHC

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Outline

Supersymmetry Flash Review

SUSY

	SM fermions			SUSY bosons			
Quarks	u	c	t	$\widetilde{u}$	$\widetilde{c}$	$\widetilde{t}$	Squarks
	d	s	b	$\widetilde{d}$	$\widetilde{s}$	$\widetilde{b}$	
Leptons	e	μ	τ	$\widetilde{e}$	$\widetilde{\mu}$	$\widetilde{\tau}$	Sleptons
	ν_e	ν_μ	ν_τ	$\widetilde{\nu_e}$	$\widetilde{\nu_\mu}$	$\widetilde{\nu_\tau}$	

SM (gauge) bosons				SUSY gauginos			
g	$W^\pm$	h_1^+	h_2^-	$\widetilde{g}$	$\widetilde{\chi}_1^\pm$	$\widetilde{\chi}_2^\pm$	
γ	Z^0	h_1^0	h_2^0	$\widetilde{\chi}_1^0$	$\widetilde{\chi}_2^0$	$\widetilde{\chi}_3^0$	$\widetilde{\chi}_4^0$

SUSY Breaking

SUSY breaking schemes for gaugino masses

- M_a/g_a does not run at one loop in MSSM.
- Tree-level gauge-kinetic dominant + universal
  $\Rightarrow$ mSUGRA $\rightarrow M_1 : M_2 : M_3 \simeq 1 : 2 : 6$
- One-loop conformal anomaly dominant
  $\Rightarrow$ Anomaly $\rightarrow M_1 : M_2 : M_3 \simeq 3.3 : 1 : 9$
- Mirage mediation: a mix of mSUGRA and anomaly

$$\frac{M_a(\mu)}{g_a^2(\mu)} = \left(1 + \frac{\ln(M_p/m_{3/2})}{16\pi^2} g_{GUT}^2 b_a \alpha\right) \frac{M_0}{g_{GUT}^2}$$

$$\Rightarrow M_1 : M_2 : M_3 \simeq (1 + 0.66\alpha) : (2 + 0.2\alpha) : (6 - 1.8\alpha)$$

All we must do is find the gaugino masses!
We choose some benchmarks and demonstrate using `ISASUGRA`, `PYTHIA`, and `PGS4`.

2 Jets + 2 τ + $\not{E}_T$ Signal

Dominant production at LHC is $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, or $\tilde{q}\tilde{q}$

$$\tilde{q}_L \rightarrow q \quad \text{Hard Jet}$$

$$\searrow$$

$$\tilde{\chi}_2^0 \rightarrow \tau^{\mp}$$

$$\searrow \quad \text{Two } \tau\text{'s}$$

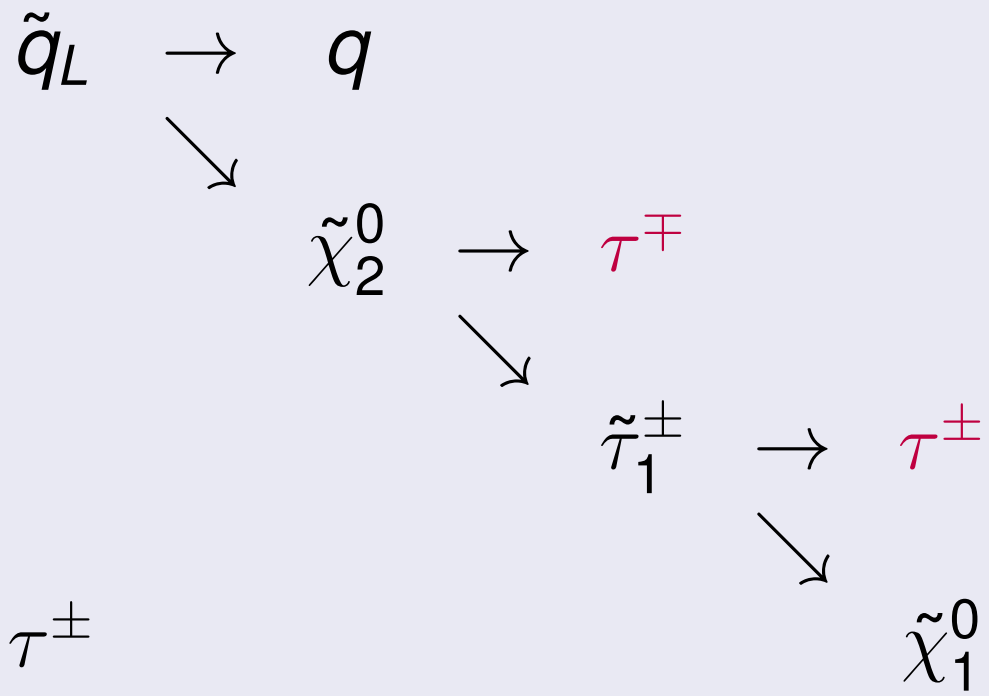
$$\tilde{\tau}_1^{\pm} \rightarrow \tau^{\pm}$$

$$\searrow$$

$$\tilde{\chi}_1^0 \qquad \not{E}_T$$

OS−LS

Making use of Opposite Sign(OS)−Like Sign(LS) subtraction:

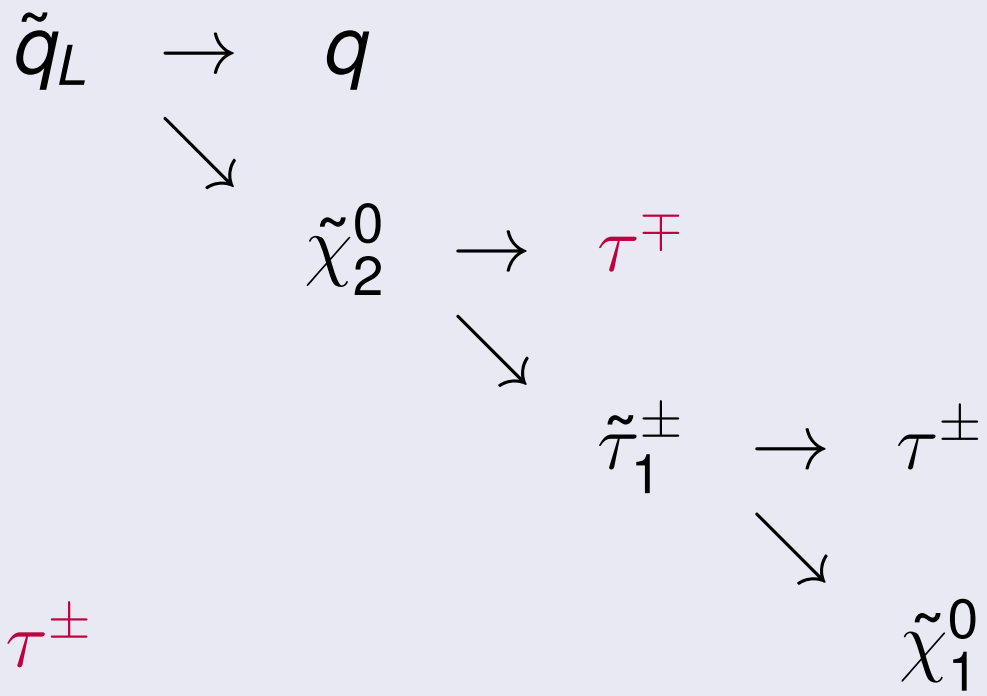


Signal OS

$M_{\tau\tau}^{OS}$

OS−LS

Making use of Opposite Sign(OS)−Like Sign(LS) subtraction:

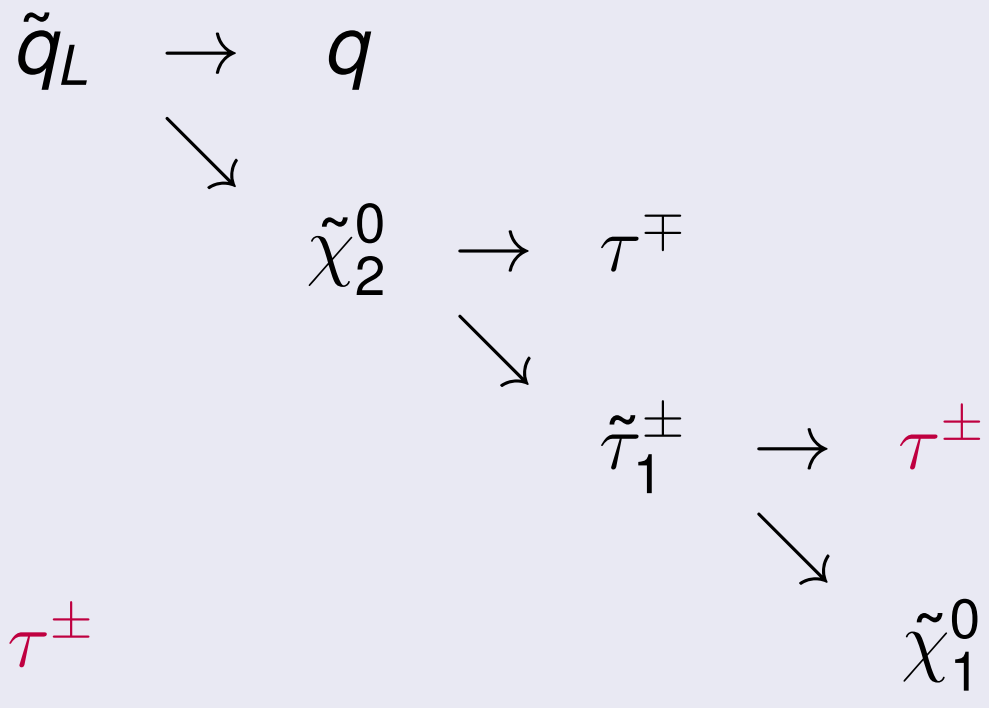


Background OS

$M_{\tau\tau}^{\mathrm{OS}}$

OS−LS

Making use of Opposite Sign(OS)−Like Sign(LS) subtraction:

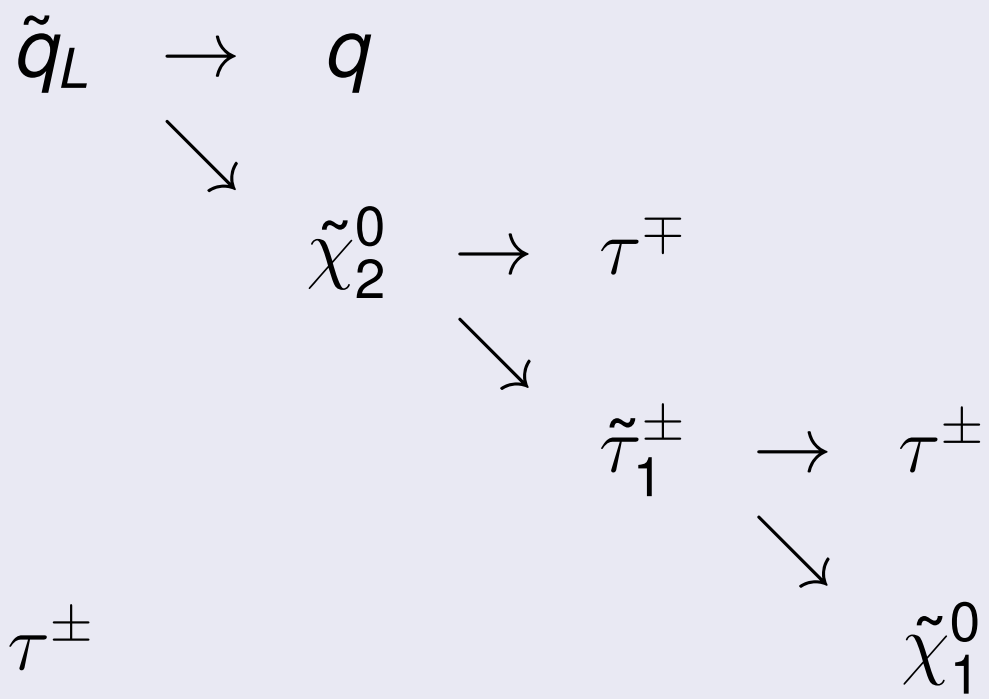


Background LS

$M_{\tau\tau}^{\mathrm{OS}}$ $M_{\tau\tau}^{\mathrm{LS}}$

OS−LS

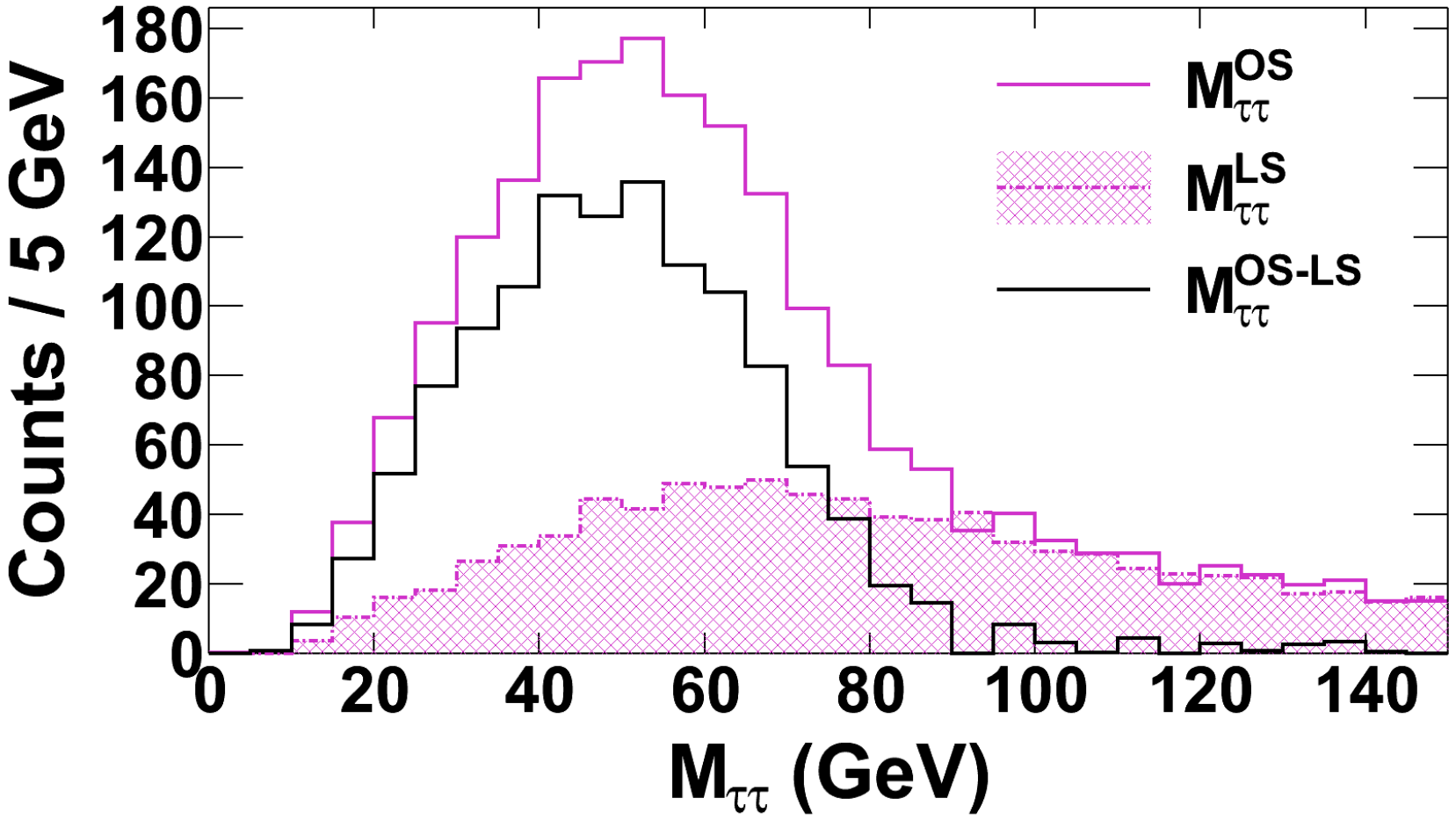
Making use of Opposite Sign(OS)−Like Sign(LS) subtraction:



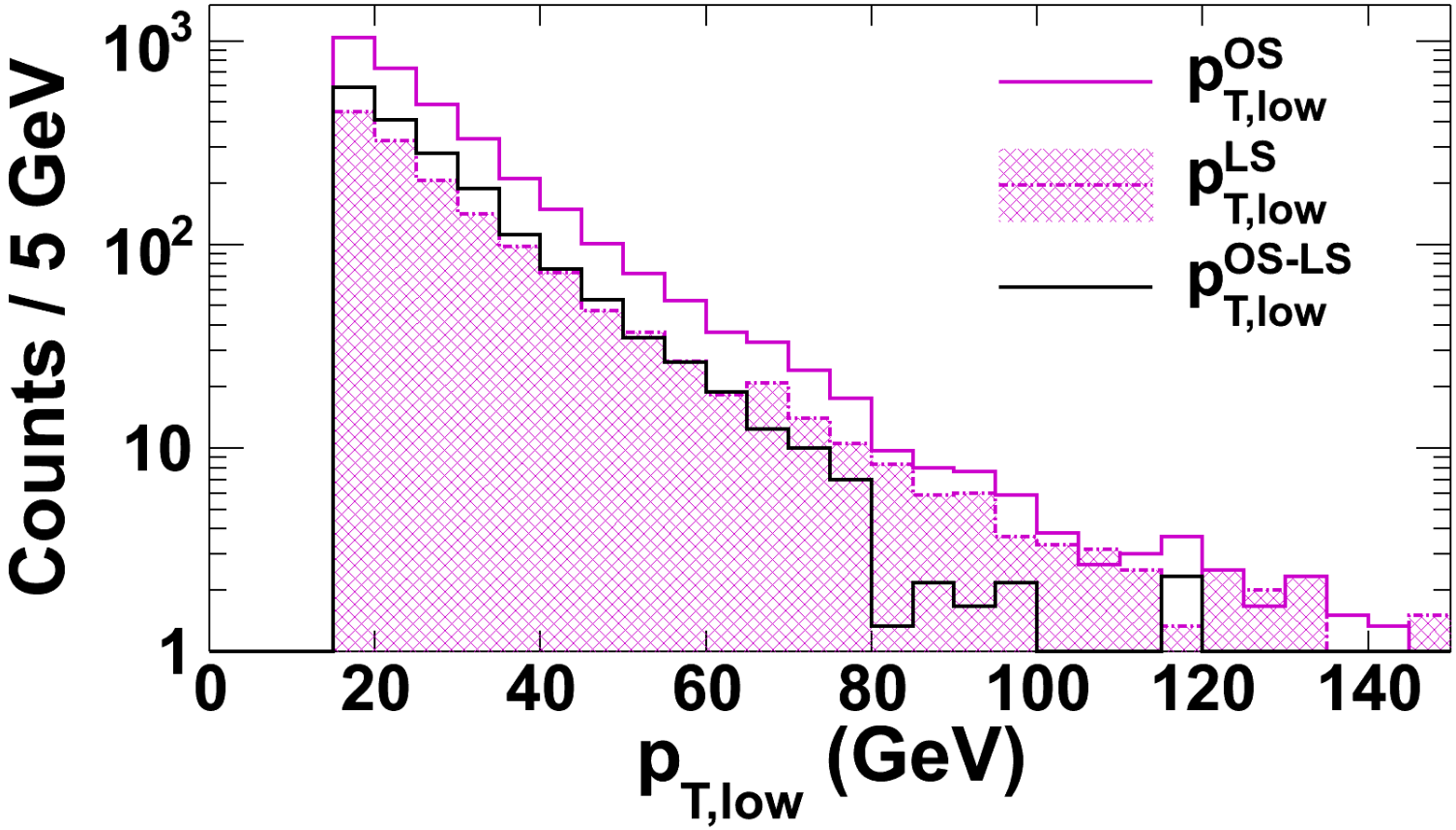
OS−LS
Eats BG

$$M_{\tau\tau}^{\mathrm{OS}} - M_{\tau\tau}^{\mathrm{LS}} = M_{\tau\tau}^{\mathrm{OS-LS}}$$

Ditau Invariant Mass



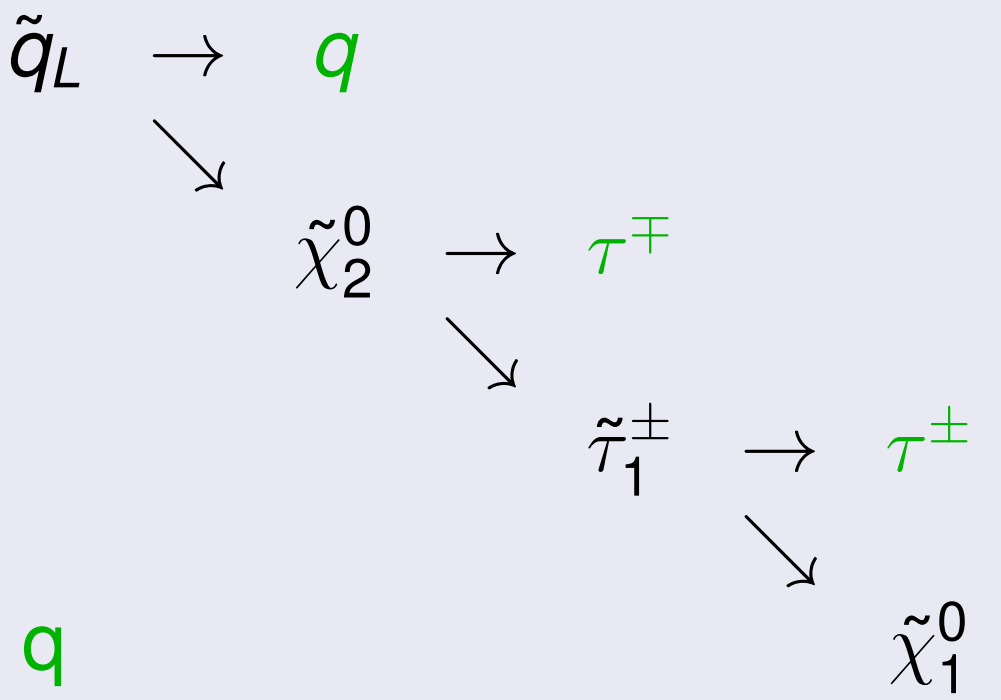
τ p_T variables



$$p_{T,AM} \equiv \frac{1}{2}\left(\text{slope}(p_{T,high}) + \text{slope}(p_{T,low})\right)$$
$$p_{T,diff} \equiv \frac{1}{2}\left(\text{slope}(p_{T,high}) - \text{slope}(p_{T,low})\right)$$

Bi-Event Subtraction Technique (BEST)

Making use of BEST:



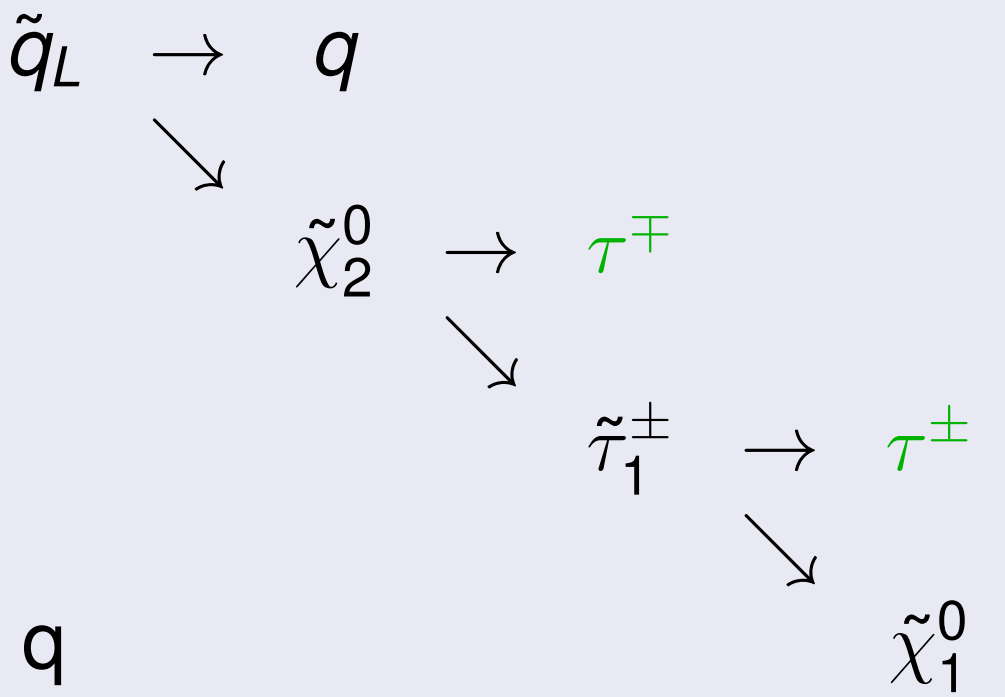
Bi-Event

$q\ q$

$M_{j\tau\tau}^{\text{Same}}$

Bi-Event Subtraction Technique (BEST)

Making use of BEST:



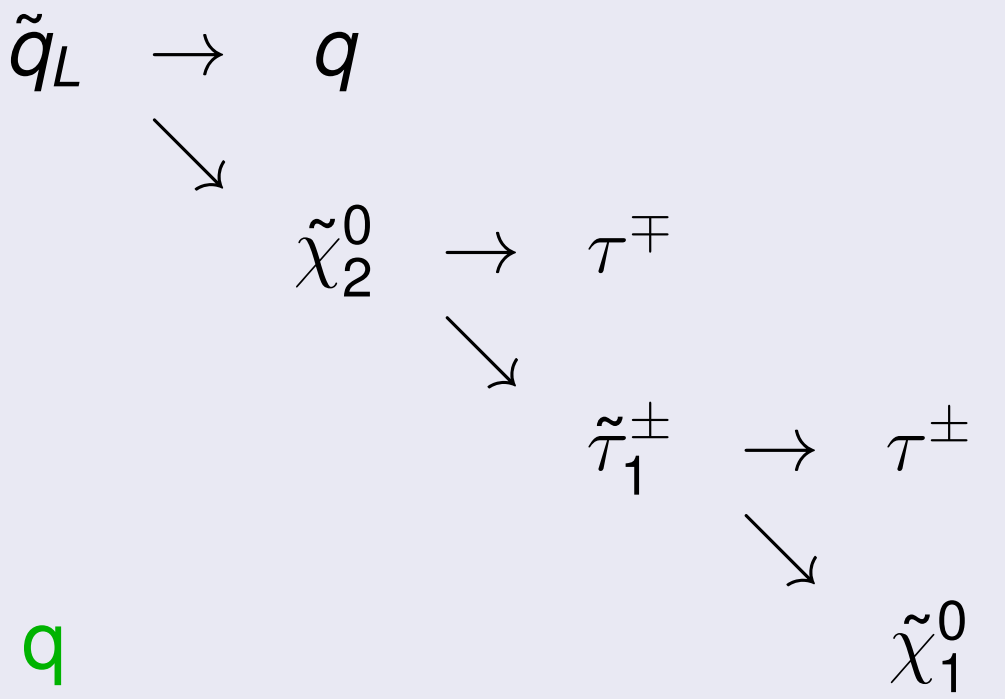
Bi-Event

$q\ q$

$M_{j\tau\tau}^{\text{Same}}$ $M_{j\tau\tau}^{\text{Bi}}$

Bi-Event Subtraction Technique (BEST)

Making use of BEST:



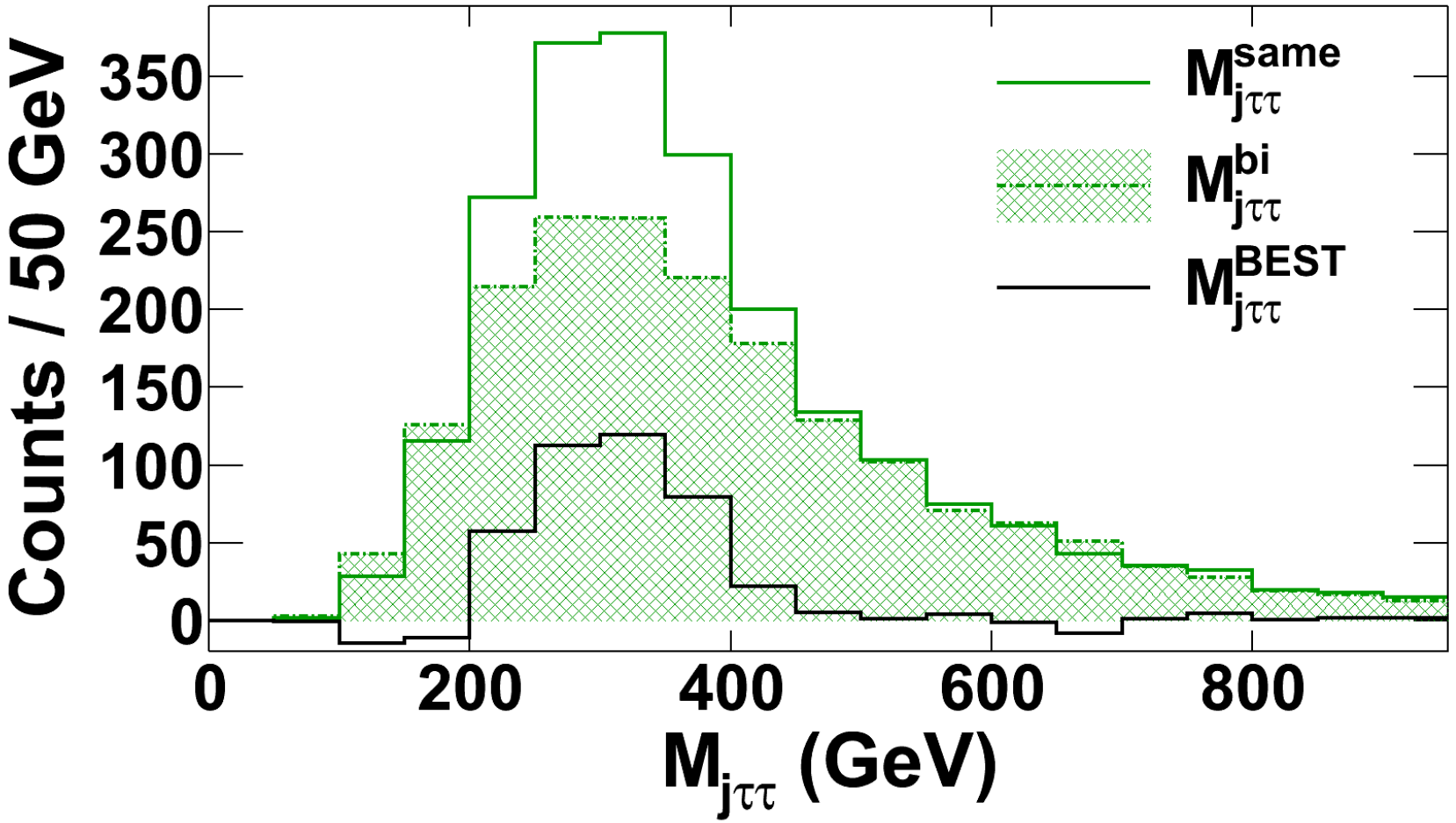
Bi-Event

$q\ q$

BEST
Eats BG

$$M^{\text{Same}}_{j\tau\tau} - N_{\text{BEST}} M^{\text{Bi}}_{j\tau\tau} = M^{\text{BEST}}_{j\tau\tau}$$

Jet + Ditau Invariant Mass



4 Jets + $\not{E}_T$ Signal

Dominant production at LHC is $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, or $\tilde{q}\tilde{q}$

$$\tilde{g} \rightarrow q \quad \text{Soft Jet}$$
$$\searrow$$
$$\tilde{q}_R \rightarrow q \quad \text{Hard Jet}$$
$$\searrow$$
$$\tilde{\chi}_1^0 \quad \not{E}_T$$

$$M_{\text{eff}} \equiv \Sigma_{i=1}^{4} \left(p_{\text{T,jet } i}\right) + \not{E}_T$$

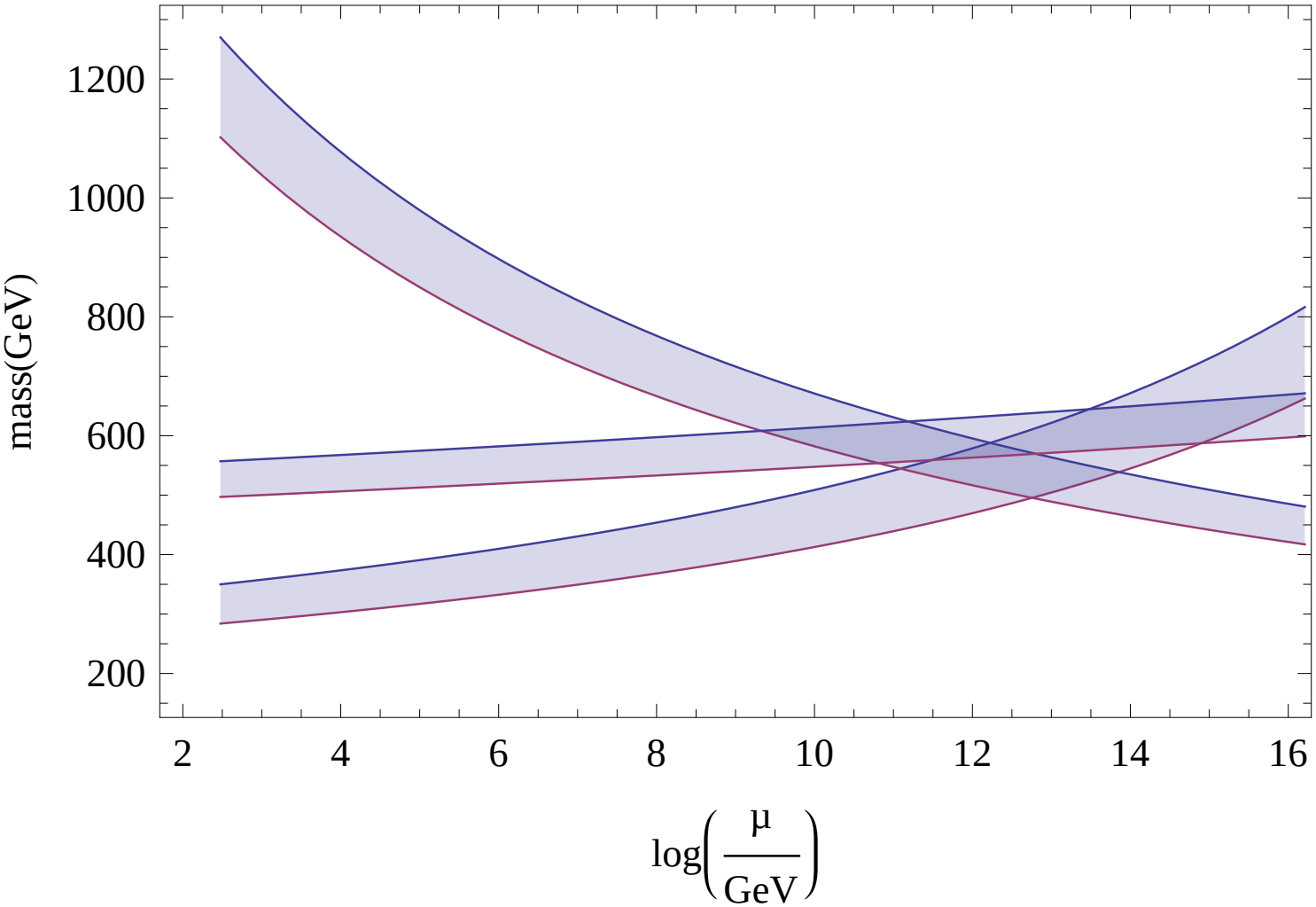
Goal: Gaugino Masses

Equations to solve

$$M_{\tau\tau}^{\text{end}} = f_1(m_{\tilde{\chi}_2^0}, m_{\tilde{\tau}_1}, m_{\tilde{\chi}_1^0})$$
$$p_{\text{T,AM}} = f_2(m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0})$$
$$p_{\text{T,diff}} = f_3(m_{\tilde{\chi}_2^0}, m_{\tilde{\tau}_1}, m_{\tilde{\chi}_1^0})$$
$$M_{j\tau\tau}^{\text{end}} = f_4(m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0})$$
$$M_{\text{eff}}^{\text{peak}} = f_5(m_{\tilde{q}}, m_{\tilde{g}})$$

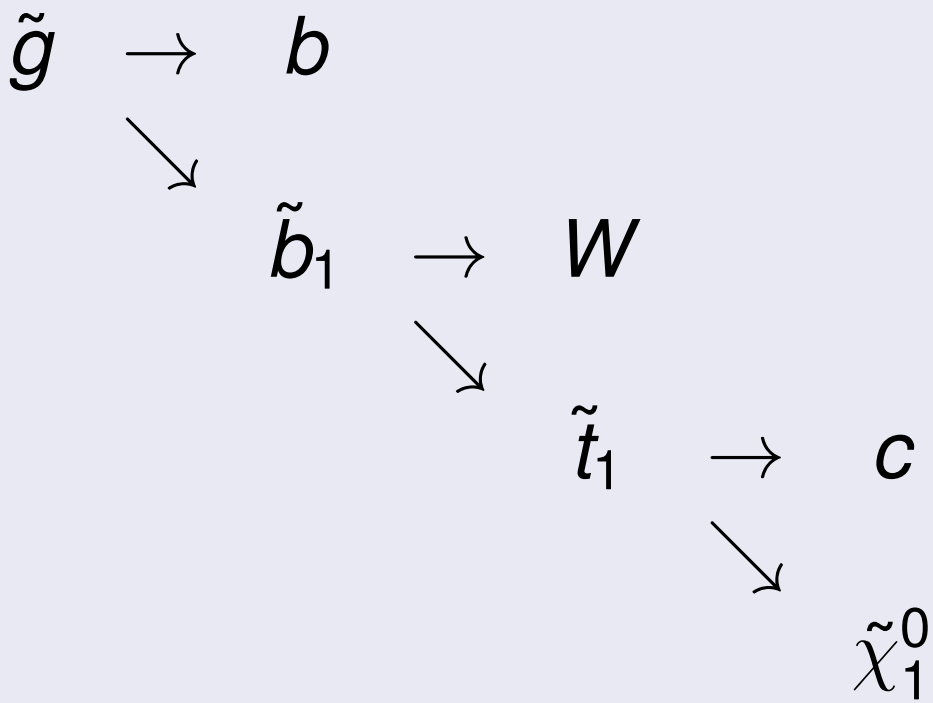
- Find f's using MC simulation.
- Measure observables.
- Invert and solve for masses.

Result: Mirage Scale



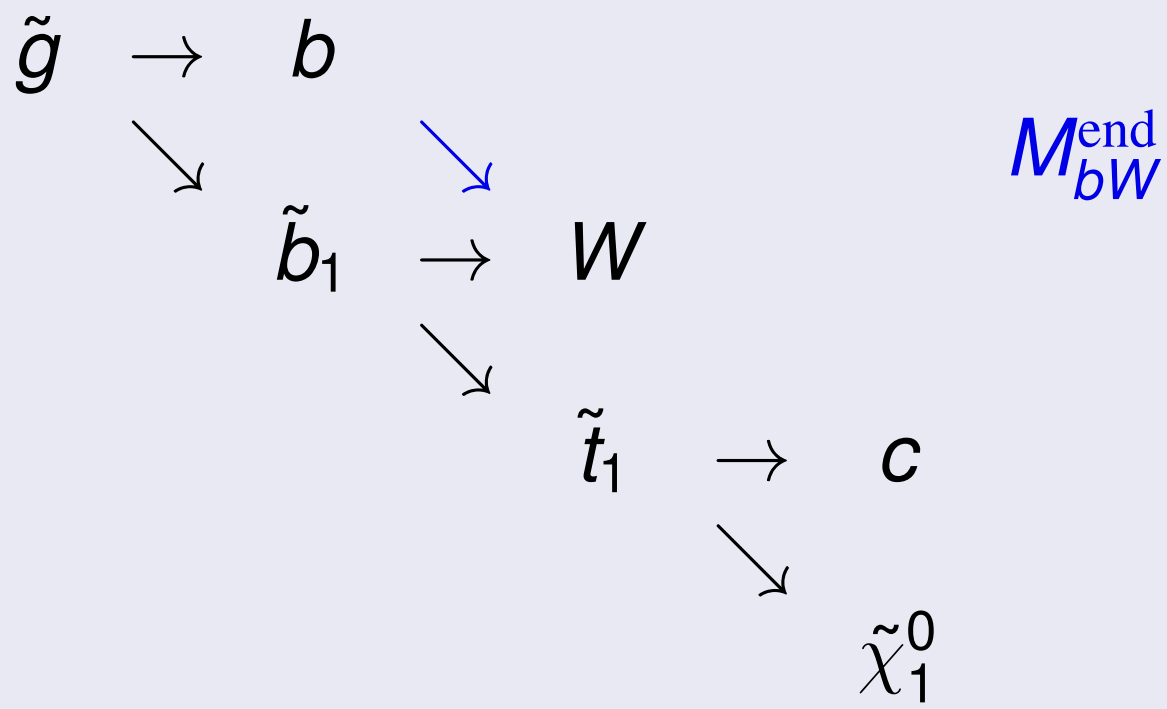
4 Jets (at least one b-Jet) + $\not{E}_T$ Signal

Decay Chain:



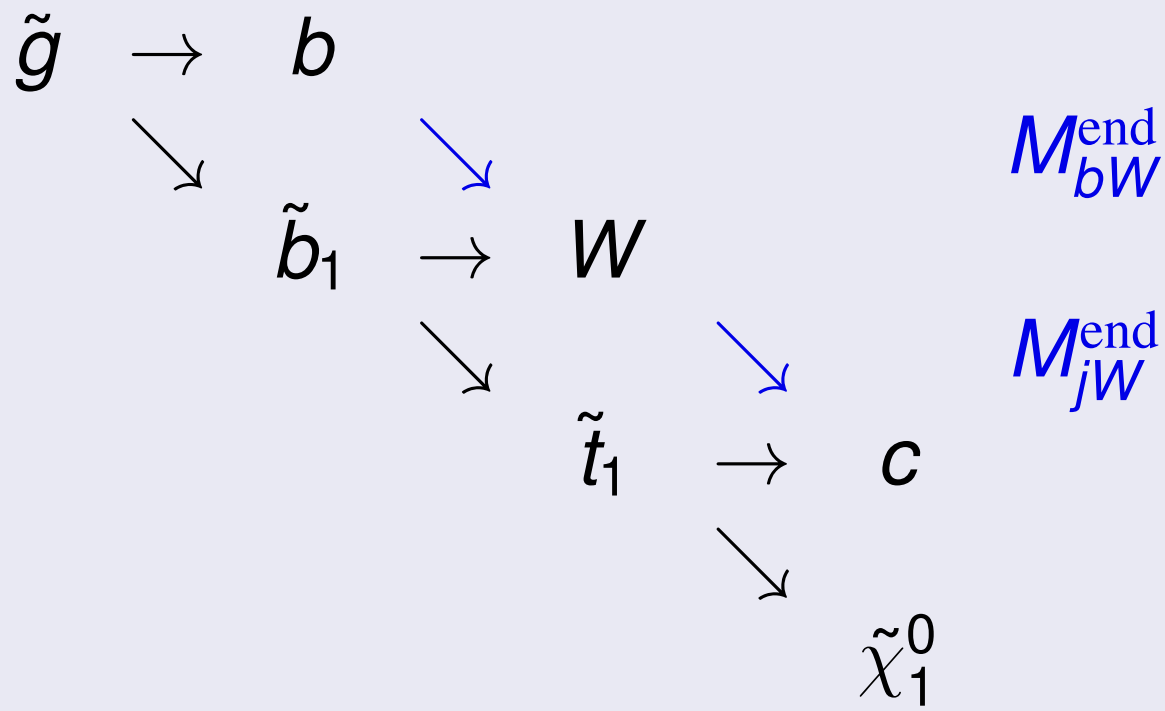
4 Jets (at least one b-Jet) + $\not{E}_T$ Signal

Decay Chain:

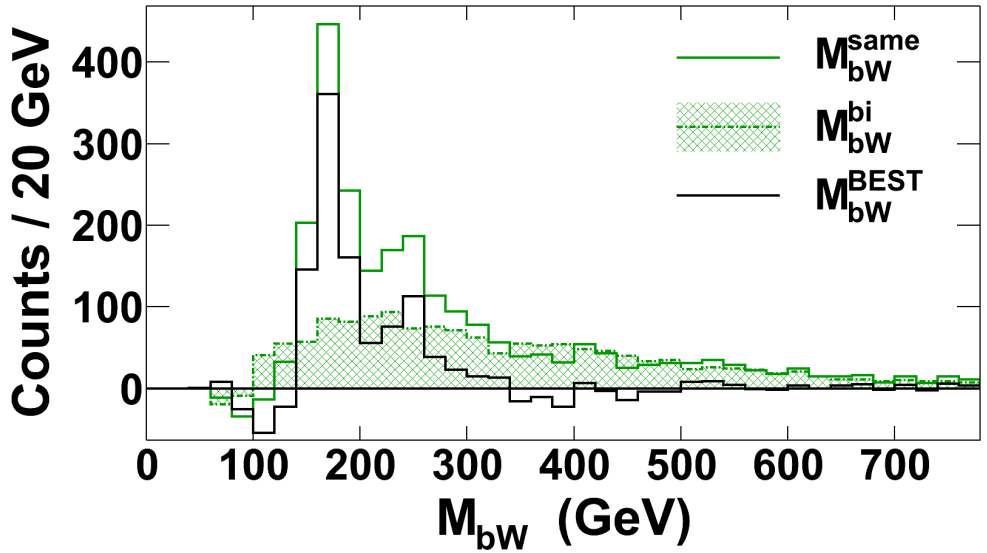


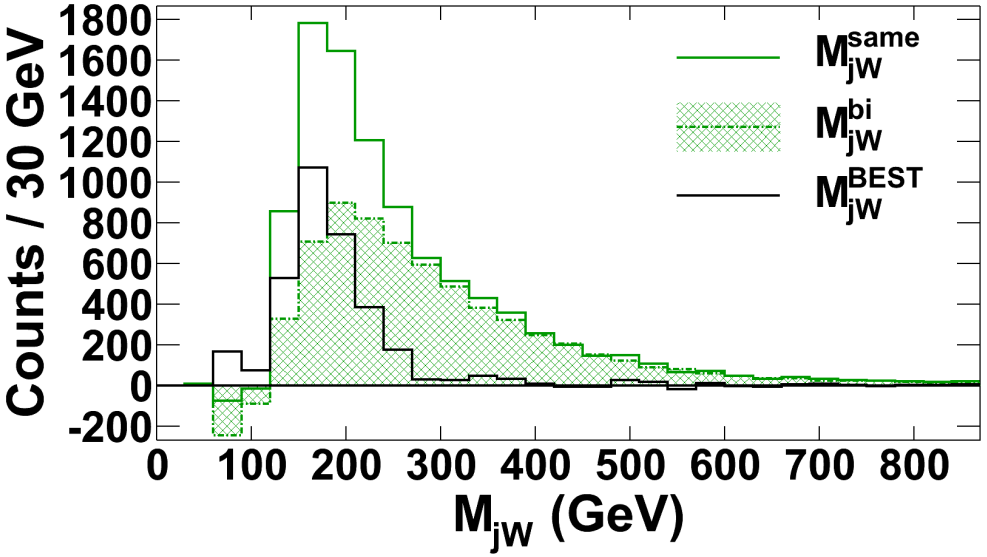
4 Jets (at least one b-Jet) + $\not{E}_T$ Signal

Decay Chain:



M_{bW}^{end} and M_{jW}^{end}





Conclusions

Way too many results for one talk!!

arXiv:1112.3966

- Gaugino masses for multiple benchmark points.
  $\Rightarrow$ SUSY Breaking Mechanism.
- Third generation Squark masses.
- Relic Density of Dark Matter from Model Parameters.
  (`DarkSUSY`)

Thanks for your attention!!