LHC Capability for Dark Matter

Bhaskar Dutta
Texas A&M University

Discovery Time…

We are about to enter into an era of major discovery

Dark Matter: we need new particles to explain the content of the universe

Standard Model: we need new physics

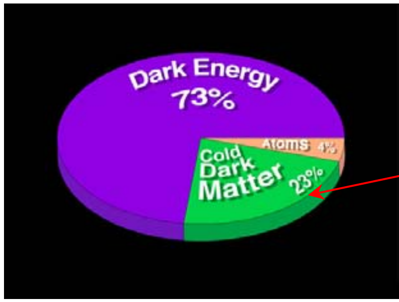
Supersymmetry solves both problems!

The super-partners are distributed around 100 GeV to a few TeV

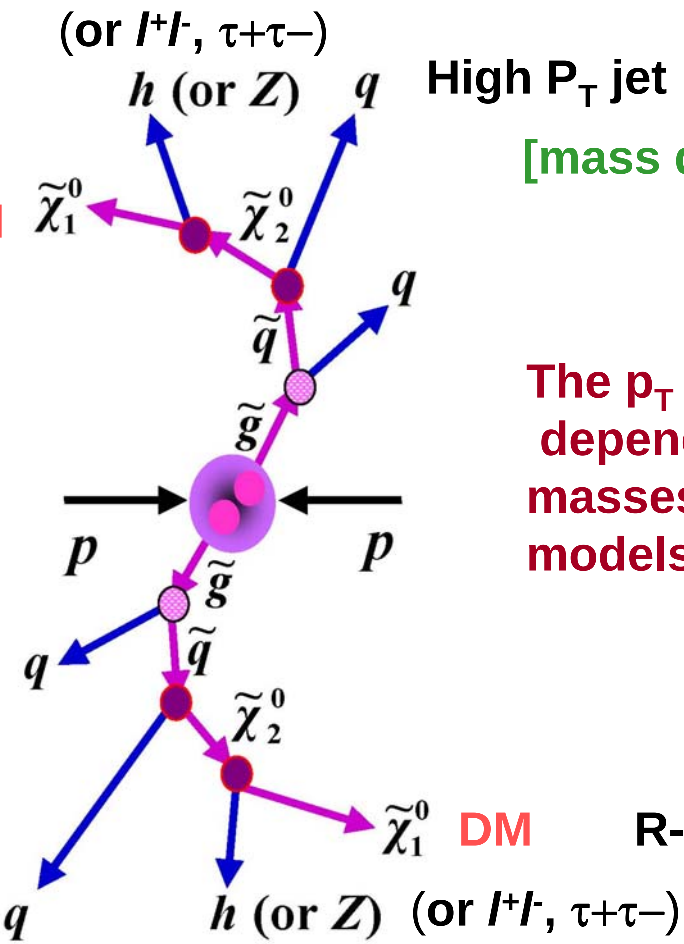
LHC: directly probes TeV scale

Future results from PLANCK, direct and indirect detection experiments in tandem with the LHC will confirm a model

SUSY at the LHC



DM



High P_T jet

[mass difference is large]

The p_T of jets and leptons depend on the sparticle masses which are given by models

Colored particles are produced and they decay finally into the weakly interacting stable particle

DM

R-parity conserving

High P_T jet

The signal : jets + leptons + missing E_T

SUSY at the LHC

Final states → Model Parameters

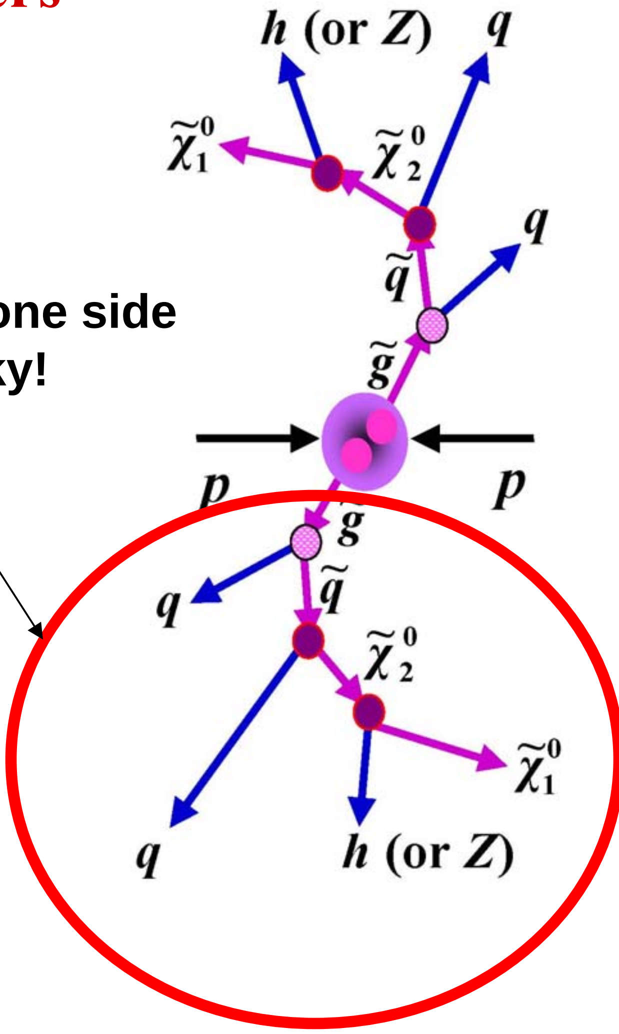
Reconstruct sparticle masses, e.g.,

$$\tilde{Q} \rightarrow q + l + \tilde{\chi}_1^0$$

$$\tilde{L} \rightarrow l + \tilde{\chi}_1^0$$

$$\tilde{\chi}_{2,3,4}^0 \rightarrow Z, h, \bar{l}l + \tilde{\chi}_1^0 \quad \text{etc.}$$

Identifying one side is very tricky!



We may not be able to solve for masses all the sparticles from a model

Solving for the MSSM : Very difficult

SUSY at the LHC

We can use simpler models to understand the cascades and solve for the model parameters

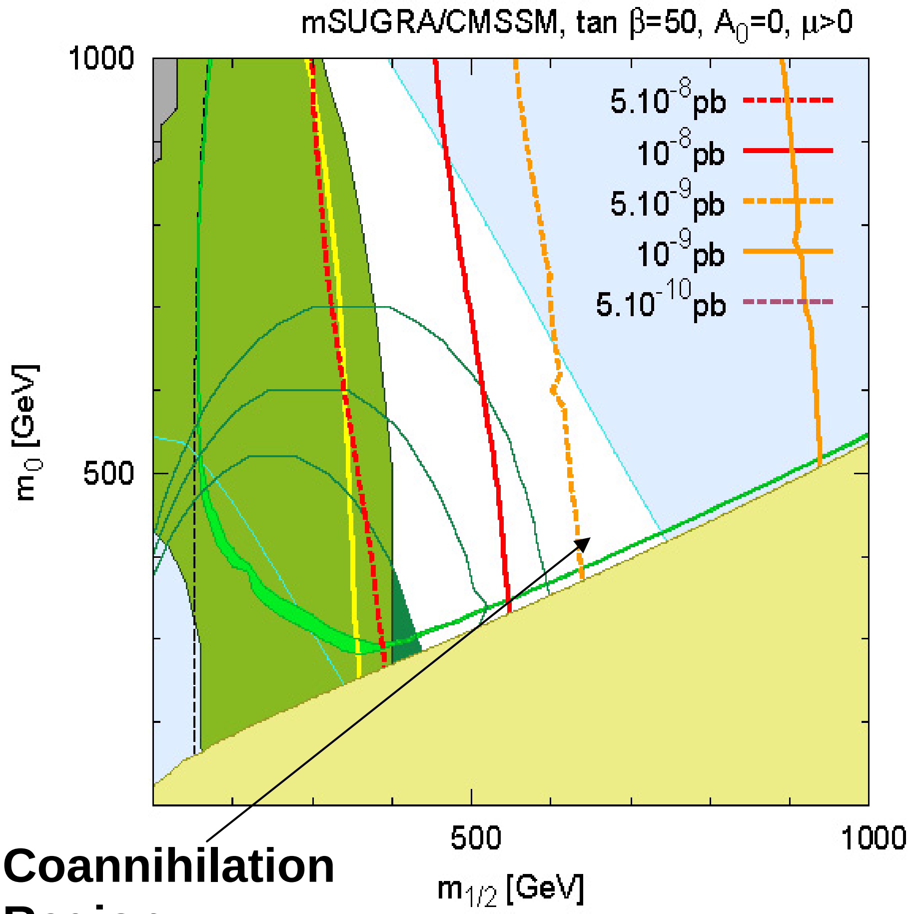
The best strategy:

Solve for the minimal model: mSUGRA →
4 parameters: m_0, $m_{1/2}$, A_0, $\tan\beta$ and Sign(μ)

The cascades can be understood in a simple way [hopefully!]

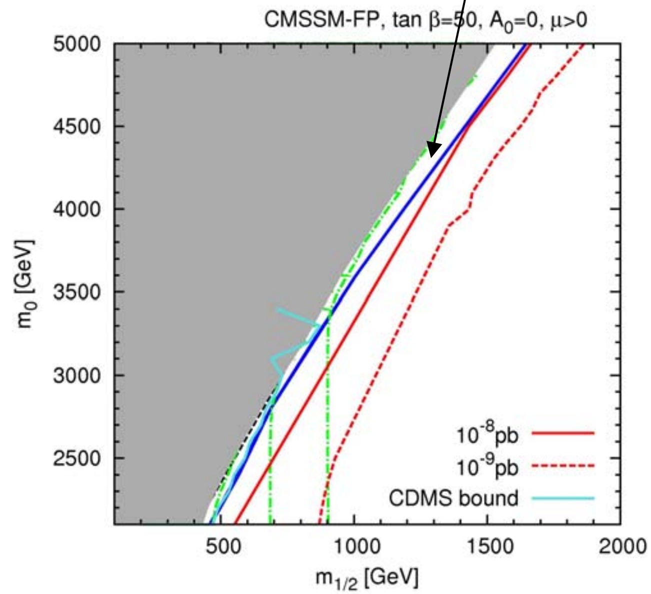
Next step:
Next to minimal model (first round of result…)

mSUGRA Parameter space



Coannihilation Region

Focus point



Allahverdi, Dutta, Santoso

PLB 687:225 ,2010

- **The bounds from CDMS/Xenon 100 have started becoming competitive with b →s γ and Higgs mass constraints.**

1. Coannihilation, GUT Scale

In mSUGRA model the lightest stau seems to be naturally close to the lightest neutralino mass especially for large tanβ

For example, the lightest selectron mass is related to the lightest neutralino mass in terms of GUT scale parameters:

$$m^2_{\tilde{E}^c} = m_0^2 + 0.15 m_{1/2}^2 + (37\,\mathrm{GeV})^2 \qquad m^2_{\tilde{\chi}_1^0} = 0.16 m_{1/2}^2$$

Thus for $m_0 = 0$, $\tilde{E}_c^2$ becomes degenerate with $\tilde{\chi}_1^0$ at $m_{1/2} = 370$ GeV, i.e. the coannihilation region begins at

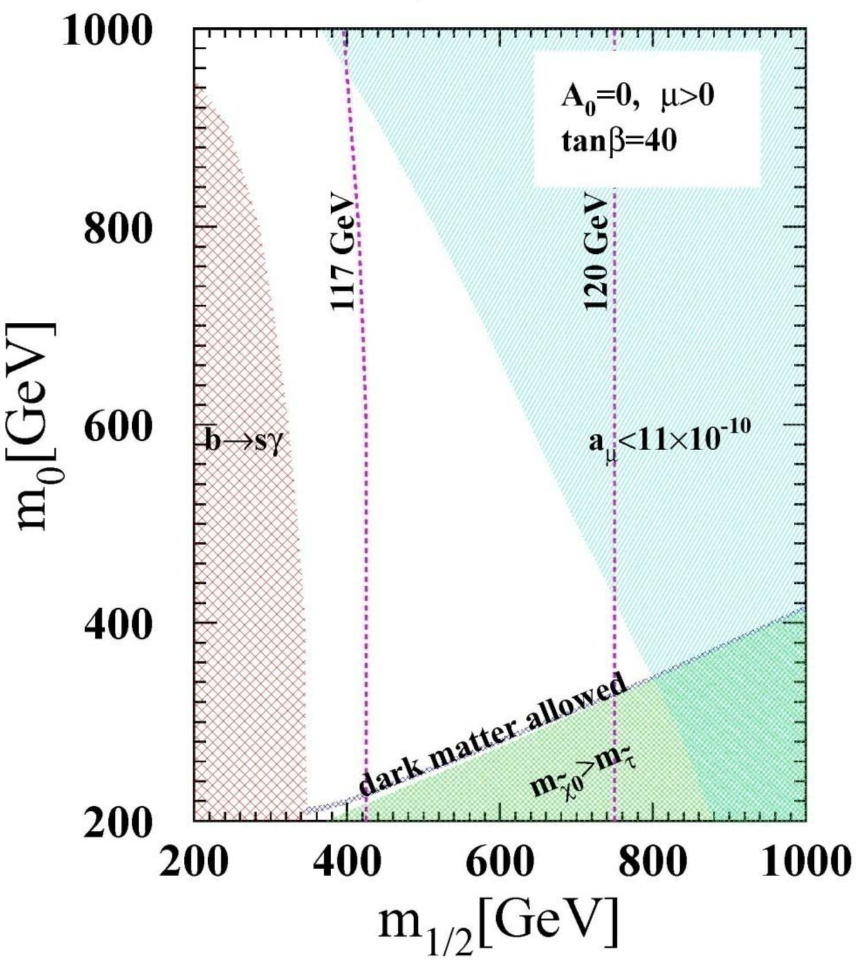
Arnowitt, Dutta, Santoso' 01

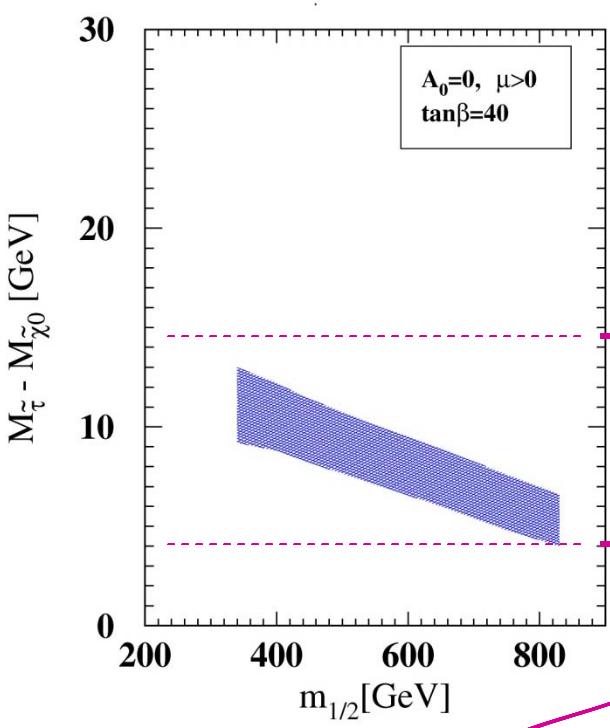
$$m_{1/2} = (370\text{-}400)\ \mathrm{GeV}$$

For larger $m_{1/2}$ the degeneracy is maintained by increasing m_0 and we get a corridor in the m_0 - $m_{1/2}$ plane.

The coannihilation channel occurs in most SUGRA models even with non-universal soft breaking.

CA Region at $\tan\beta = 40$





$$\Delta M \equiv M_{\tilde{\tau}_1} - M_{\tilde{\chi}_1^0} = 5 \sim 15 \ \text{GeV}$$

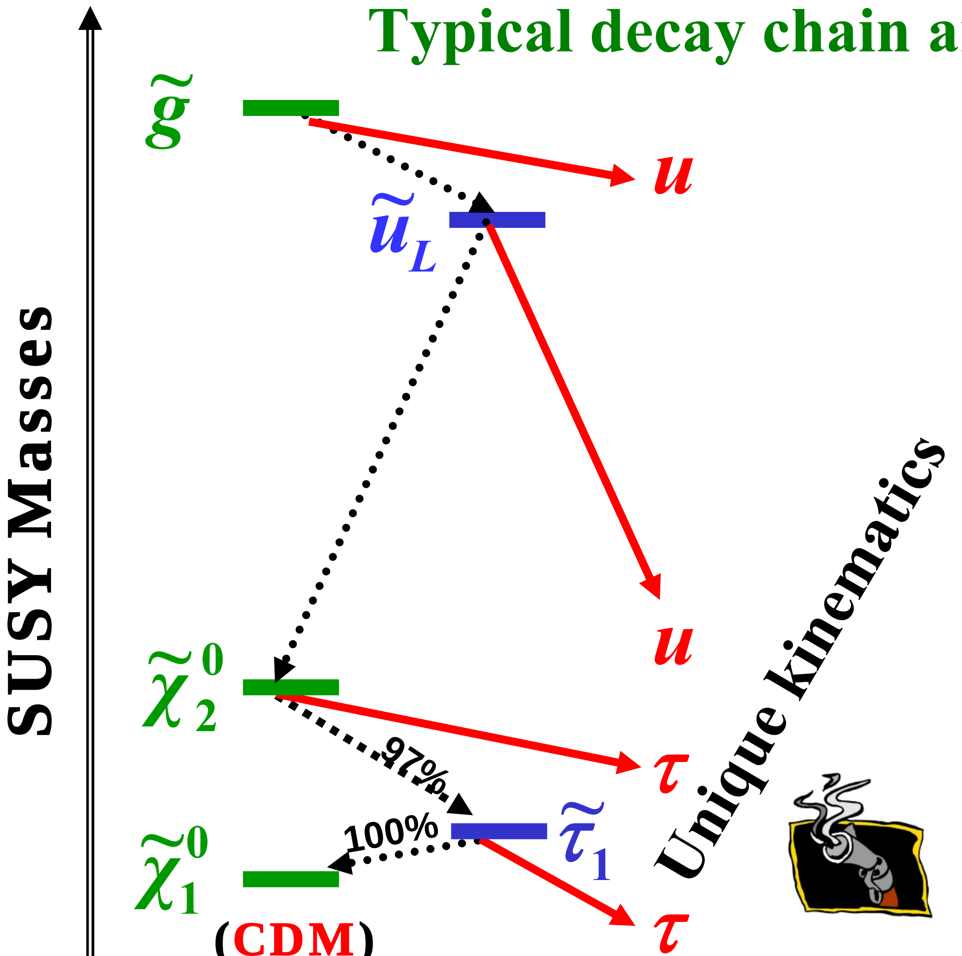
Can we measure ΔM at colliders?

Arnowitt, Dutta, Gurrola, Kamon, Krislock and Toback'PRL, 08

Smoking Gun of CA Region

Typical decay chain and final states at the LHC

Jets + τ's + missing energy



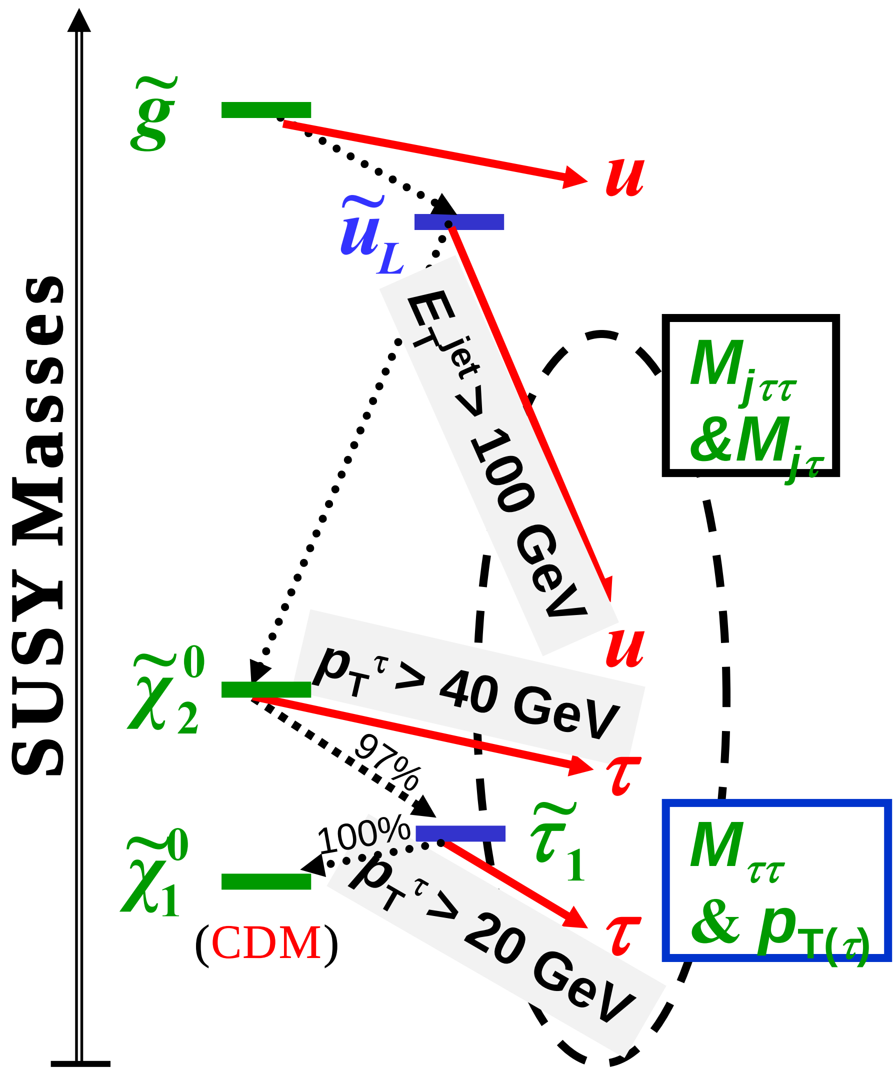
2 quarks + 2 τ's + missing energy

$$\Delta M \equiv M_{\tilde{\tau}_1} - M_{\tilde{\chi}_1^0} = 5 \sim 15\ \text{GeV}$$

Low energy taus characterize the CA region

However, one needs to measure the model parameters to predict the dark matter content in this scenario

CA Region: Final States



$\varepsilon_\tau = 50\%, f_{\text{fake}} = 1\%$ for $p_T^{\text{vis}} > 20$ GeV

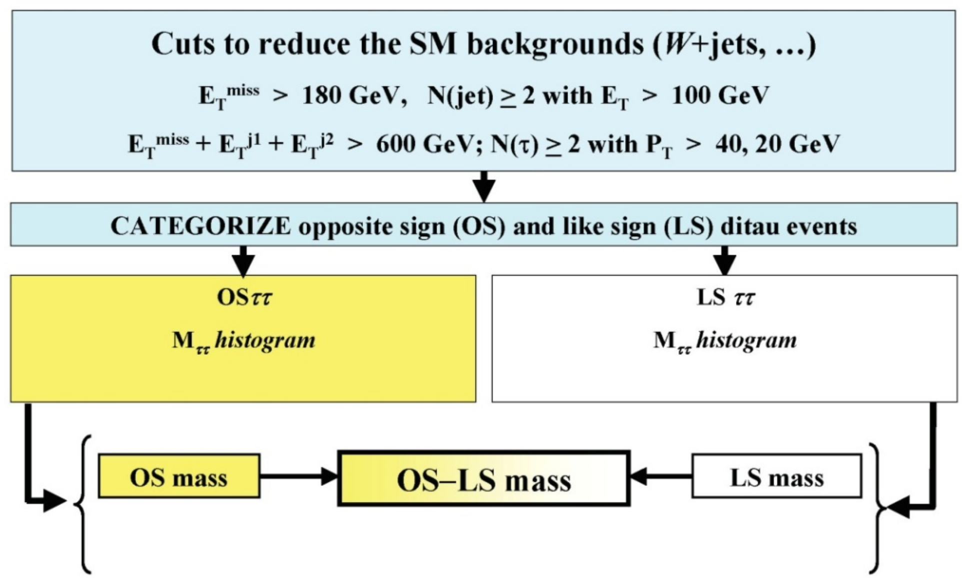
Excesses in 3 Final States:

a) $E_T^{miss} + 4j$
b) $E_T^{miss} + 2j + 2\tau$
c) $E_T^{miss} + b + 3j$

} Kinematical variables

Example of Analysis Chart for b):

$E_T^{miss} + 2j + 2\tau$ Analysis Path



Kinematical Variables using a) & b)

➢6 equations for 5 SUSY masses

$$M_{\tau\tau}^{\text{peak}} = f_1(\Delta M, \tilde{\chi}_2^0, \tilde{\chi}_1^0) \quad \boxed{1}$$

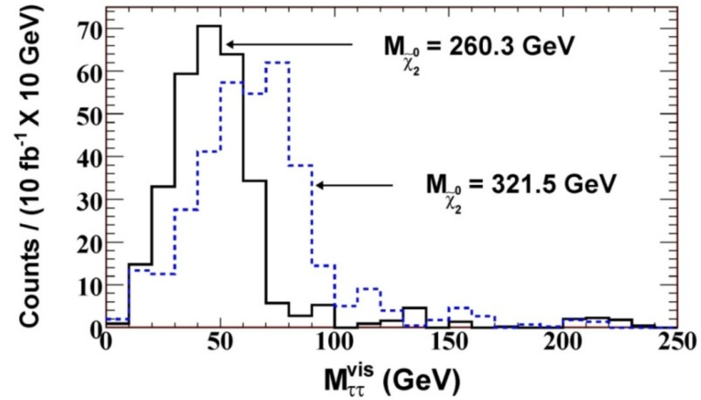
$$Slope = f_2(\Delta M, \tilde{\chi}_1^0) \quad \boxed{1}$$

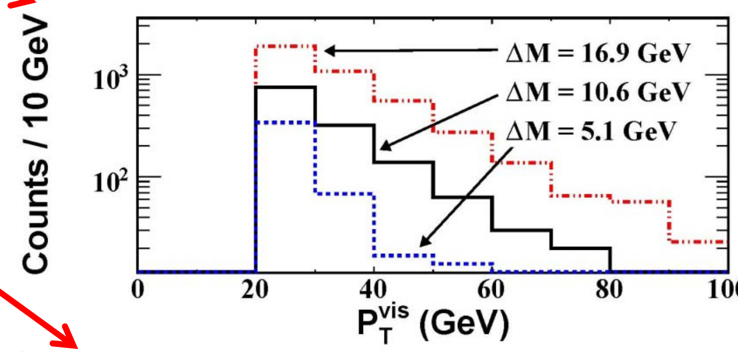
$$M_{j\tau\tau}^{(2)\text{peak}} = f_3(\tilde{q}_L, \tilde{\chi}_2^0, \tilde{\chi}_1^0)$$

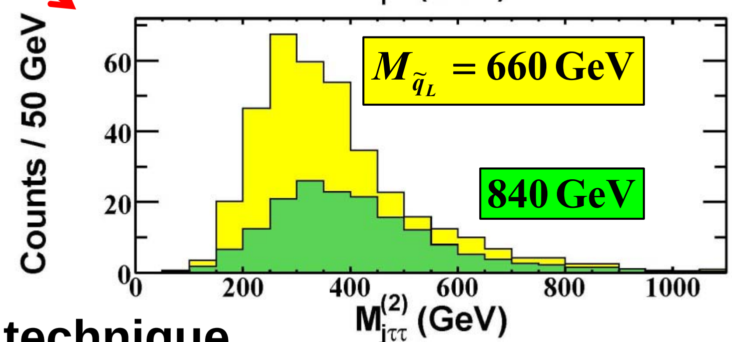
$$M_{j\tau 1}^{(2)\text{peak}} = f_4(\tilde{q}_L, \Delta M, \tilde{\chi}_2^0, \tilde{\chi}_1^0)$$

$$M_{j\tau 2}^{(2)\text{peak}} = f_5(\tilde{q}_L, \Delta M, \tilde{\chi}_2^0, \tilde{\chi}_1^0) \quad \boxed{2}$$

$$M_{\text{eff}}^{\text{peak}} = f_6(\tilde{g}, \tilde{q}_L)$$ [Next page]







➢Invert the equations to determine the masses

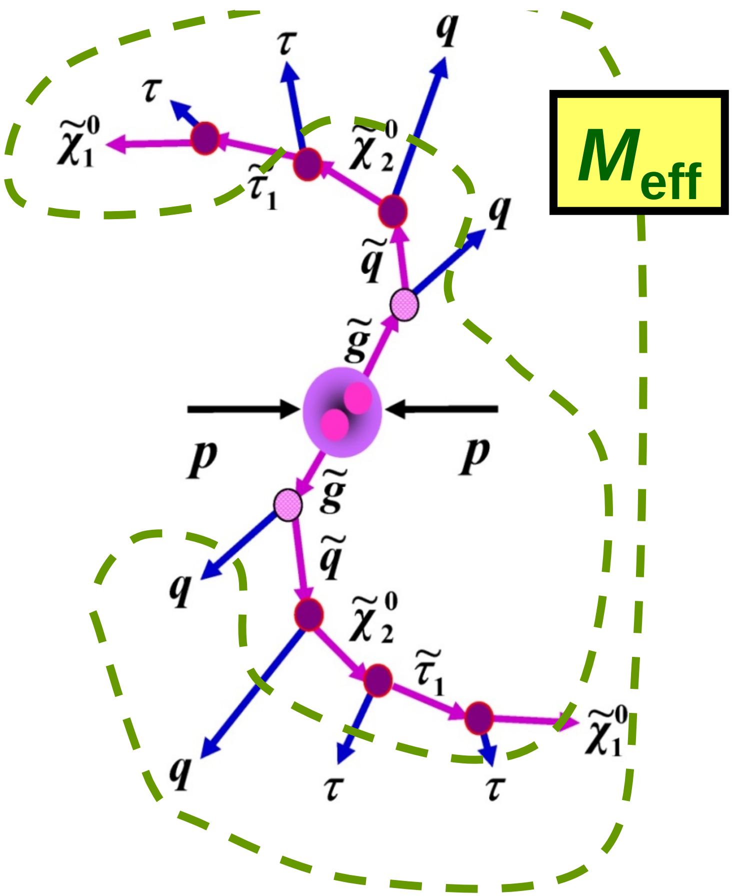
[1] 2 taus with 40 and 20 GeV; $M_{\tau\tau}$ & $p_{T\tau 2}$ in OS–LS technique

[2] $M_{\tau\tau} < M_{\tau\tau}^{\text{endpoint}}$; Jets with E_T > 100 GeV; $M_{j\tau\tau}$ masses for each jet; Choose the 2nd large value → Peak value ~ True Value

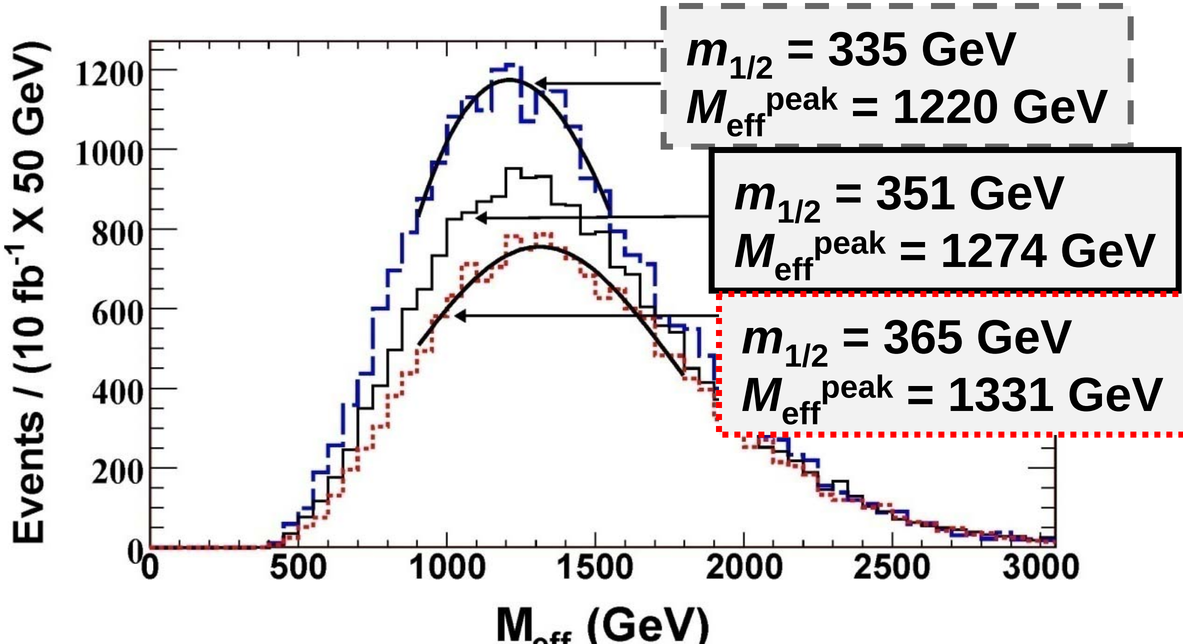
a) E_T^{miss}+4j

$M_{eff} \equiv E_T^{j1}+E_T^{j2}+E_T^{j3}+E_T^{j4}+E_T^{miss}$ [No *b* jets; $\varepsilon_b \sim 50\%$]

e.g., $pp \rightarrow \tilde{g}\tilde{g}$



- $E_T^{j1} > 100$, $E_T^{j2,3,4} > 50$
- No e's, μ's with p_T > 20 GeV
- M_{eff} > 400 GeV;
- E_T^{miss} > max [100, 0.2 M_{eff}]



$$= f_6(\tilde{g}, \tilde{q}_L)$$

DM Relic Density in mSUGRA

$$M_{\tilde{g}} = 831\ \text{GeV}$$
$$M_{\tilde{\chi}_2^0} = 260\ \text{GeV}$$
$$M_{\tilde{\tau}} = 151.3\ \text{GeV}$$
$$M_{\tilde{\chi}_1^0} = 140.7\ \text{GeV}$$

[1] Established the CA region by detecting low energy τ's ($p_T^{vis} > 20$ GeV)

[2] Measured 5 SUSY masses (ΔM, $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{q}$, $\tilde{g}$)

gaugino Universality at ~15% (10 fb^{-1})

$$m_0 =$$
$$m_{1/2} =$$
$$\tan\beta =$$
$$A_0 =$$
$$sgn(\mu) > 0$$

[3] Determine the dark matter relic density by determining m_0, $m_{1/2}$, $\tan\beta$, and A_0

So far using: a) E_T^{miss}+ 4j

b) E_T^{miss}+ 2j+2τ

$$M_{j\tau\tau}^{\text{peak}} = X_1(m_{1/2}, m_0)$$
$$M_{\tau\tau}^{\text{peak}} = X_2(m_{1/2}, m_0, \tan\beta, A_0)$$
$$M_{\text{eff}}^{\text{peak}} = X_3(m_{1/2}, m_0)$$
$$? = X_4(m_{1/2}, m_0, \tan\beta, A_0)$$

$$\Omega_{\tilde{\chi}_1^0} h^2 = Z(m_0, m_{1/2}\tan\beta, A_0)$$

c) E_T^{miss}+b+3j

$$M_{eff}^{(b)} \equiv E_T^{j1=b}+E_T^{j2}+E_T^{j3}+E_T^{j4}+E_T^{miss} \ \text{[j1 = } b \text{ jet]}$$

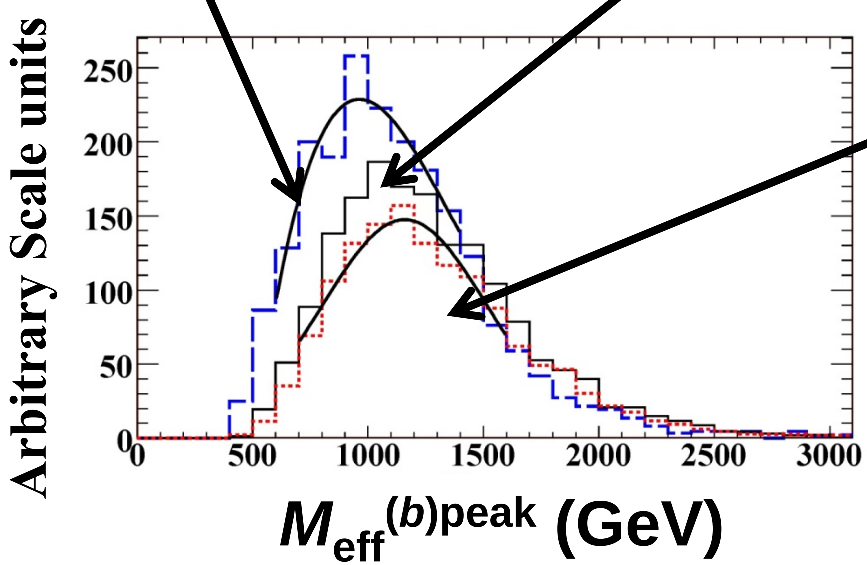
$E_T^{j1} > 100$ GeV, $E_T^{j2,3,4} > 50$ GeV [No e's, μ's with $p_T > 20$ GeV]

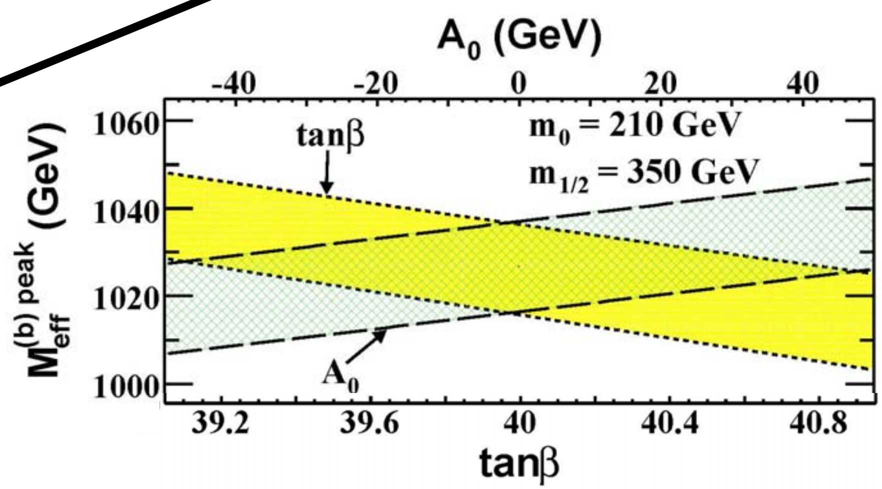
$M_{eff}^{(b)} > 400$ GeV ; $E_T^{miss} > \max\,[100, 0.2\,M_{eff}]$

$\tan\beta = 48$
$M_{eff}^{(b)peak} = 933$ GeV

$\tan\beta = 40$
$M_{eff}^{(b)peak} = 1026$ GeV

$\tan\beta = 32$
$M_{eff}^{(b)peak} = 1122$ GeV





$M_{eff}^{(b)}$ can be used to probe A_0 and $\tan\beta$ without measuring stop and sbottom masses

Determining mSUGRA Parameters

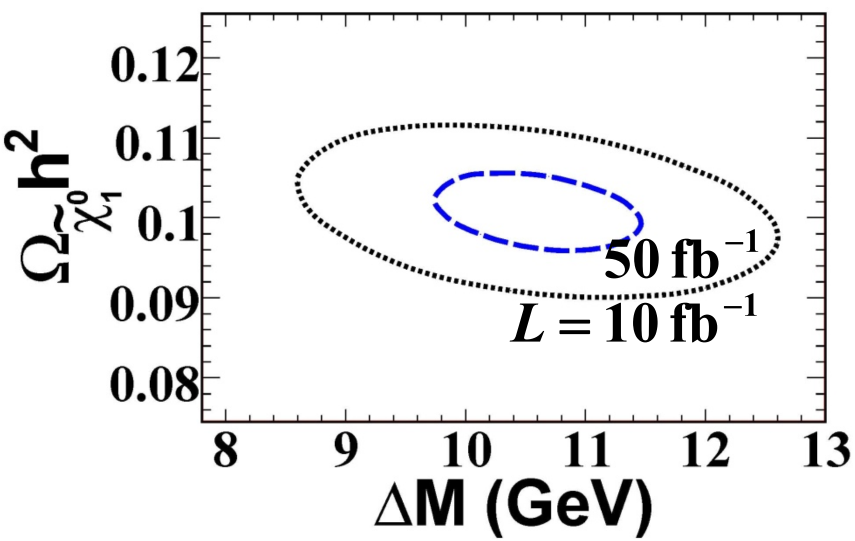
✓Solved by inverting the following functions:

$$M_{j\tau\tau}^{\mathrm{peak}} = X_1(m_{1/2}, m_0)$$
$$M_{\tau\tau}^{\mathrm{peak}} = X_2(m_{1/2}, m_0, \tan\beta, A_0)$$
$$M_{\mathrm{eff}}^{\mathrm{peak}} = X_3(m_{1/2}, m_0)$$
$$M_{\mathrm{eff}}^{(b)\,\mathrm{peak}} = X_4(m_{1/2}, m_0, \tan\beta, A_0)$$

10 fb^{-1}

$$m_0 = 210 \pm 5$$
$$m_{1/2} = 350 \pm 4$$
$$A_0 = 0 \pm 16$$
$$\tan\beta = 40 \pm 1$$

$$\Omega_{\tilde{\chi}_1^0} h^2 = Z(m_0, m_{1/2} \tan\beta, A_0)$$



$$\delta\Omega_{\tilde{\chi}_1^0} h^2 / \Omega_{\tilde{\chi}_1^0} h^2 = 6.2\%\ (30\ \mathrm{fb}^{-1})$$
$$= 4.1\%\ (70\ \mathrm{fb}^{-1})$$

Case 1: Summary

$$M_{\tilde{g}} = 831\,\text{GeV}$$
$$M_{\tilde{\chi}_2^0} = 260\,\text{GeV}$$
$$M_{\tilde{\tau}} = 151.3\,\text{GeV}$$
$$M_{\tilde{\chi}_1^0} = 140.7\,\text{GeV}$$

$$m_0 = 210\,\text{GeV}$$
$$m_{1/2} = 351\,\text{GeV}$$
$$\tan\beta = 40$$
$$A_0 = 0$$
$$sgn(\mu) > 0$$

$$\Omega_{\tilde{\chi}_1^0} h^2 = 0.1$$

[1] The CA region is established by detecting low energy τ's (p_T >20 GeV)

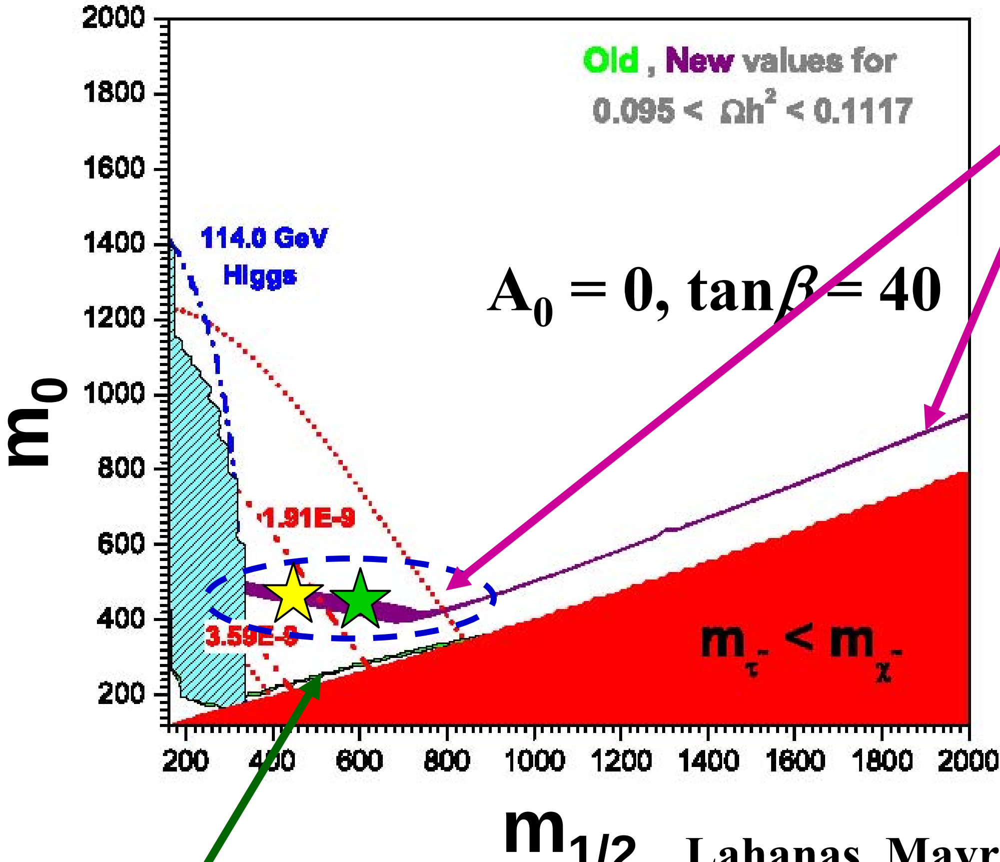
[2] $M_{\tau\tau}$, Slope, $M_{j\tau\tau}$, $M_{j\tau}$, and M_{eff} measure 5 SUSY masses and test gaugino universality at ~15% (10 fb^{-1})

[3] The dark matter relic density is calculated by determining m_0, $m_{1/2}$, $\tan\beta$, and A_0 using $M_{j\tau\tau}$, M_{eff}, $M_{\tau\tau}$, and $M_{\text{eff}}^{(b)}$

$$\boxed{\delta\Omega_{\tilde{\chi}_1^0} h^2 / \Omega_{\tilde{\chi}_1^0} h^2 \approx 6\%\ (30\ \text{fb}^{-1})}$$

$$\boxed{\delta\sigma_{\tilde{\chi}_1^0 - p} / \sigma_{\tilde{\chi}_1^0 - p} \approx 7\%\ (30\ \text{fb}^{-1})}$$

2. Over-dense DM Region



$A_0 = 0, \tan\beta = 40$

$$\underbrace{\Omega_{\tilde{\chi}_1^0} h^2}_{0.23} \sim \int_0^{x_f} \frac{1}{\langle \sigma_{\text{ann}} v \rangle f(x)} dx$$

Dilaton effect creates new parameter space

Lahanas, Mavromatos, Nanopoulos, PLB649:83-90,2007.

$$\underbrace{\Omega_{\tilde{\chi}_1^0} h^2}_{0.23} \sim \int_0^{x_f} \frac{1}{\langle \sigma_{\text{ann}} v \rangle} dx$$

Smoking gun signals in the region?

2 Reference Points

$m_{1/2}$= 440 GeV; m_0 = 471 GeV

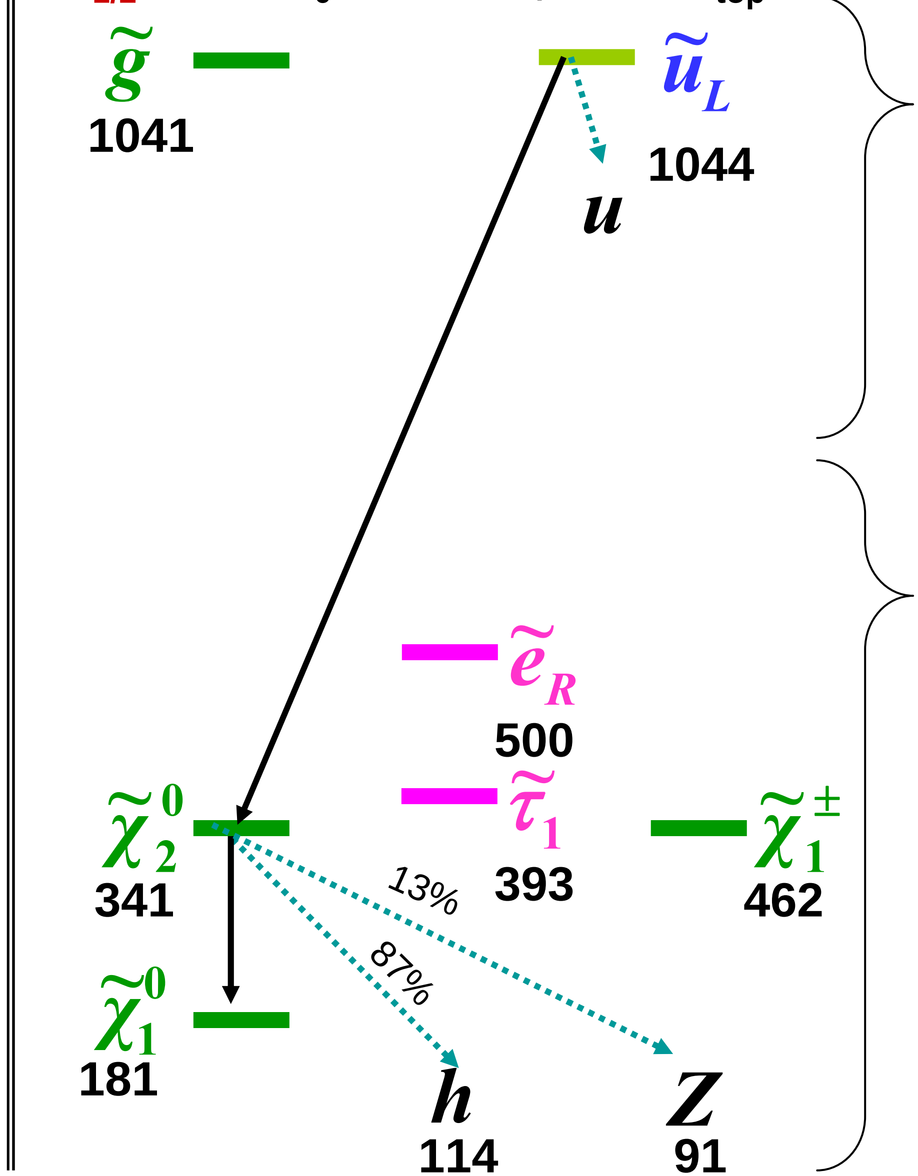
$\tilde{g}$	$\tilde{u}_L$ / $\tilde{u}_R$	$\tilde{t}_2$ / $\tilde{t}_1$	$\tilde{b}_2$ / $\tilde{b}_1$	$\tilde{e}_L$ / $\tilde{e}_R$	$\tilde{\tau}_2$ / $\tilde{\tau}_1$	$\tilde{\chi}_2^0$ / $\tilde{\chi}_1^0$	$\mathcal{B}(\tilde{\chi}_2^0 \to h^0 + \tilde{\chi}_1^0)$ (%) / $\mathcal{B}(\tilde{\chi}_2^0 \to Z^0 + \tilde{\chi}_1^0)$ (%)
1041	1044	954	958	557	532	341	86.8%
	1017	768	899	500	393	181	13.0

$m_{1/2}$= 600 GeV; m_0 = 440 GeV

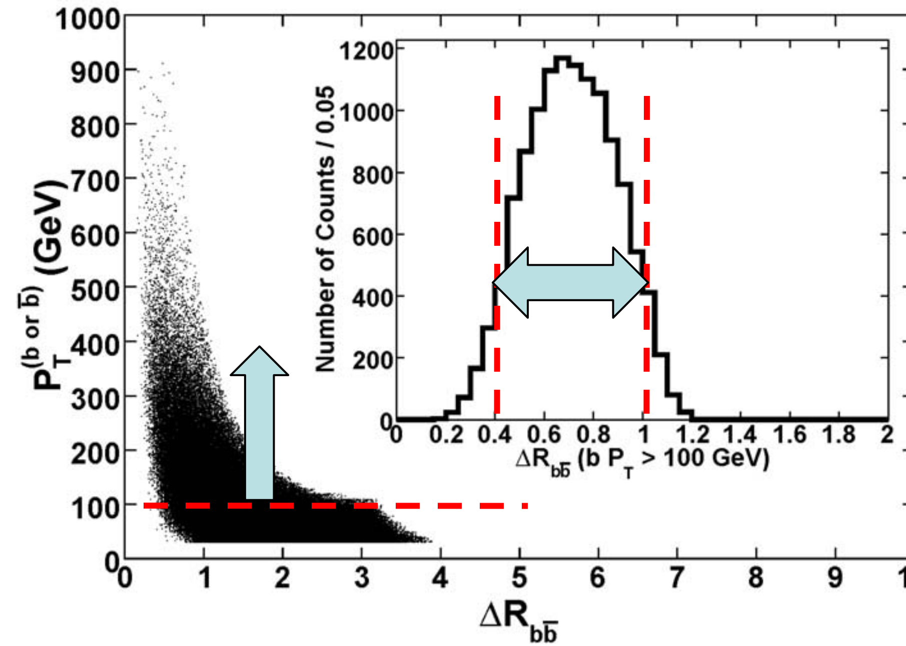
$\tilde{g}$	$\tilde{u}_L$ / $\tilde{u}_R$	$\tilde{t}_2$ / $\tilde{t}_1$	$\tilde{b}_2$ / $\tilde{b}_1$	$\tilde{e}_L$ / $\tilde{e}_R$	$\tilde{\tau}_2$ / $\tilde{\tau}_1$	$\tilde{\chi}_2^0$ / $\tilde{\chi}_1^0$	$\mathcal{B}(\tilde{\chi}_2^0 \to h^0 + \tilde{\chi}_1^0)$ (%) / $\mathcal{B}(\tilde{\chi}_2^0 \to \tau + \tilde{\tau}_1)$ (%)
1366	1252	1153	1153	594	574	462	20.5
	1211	957	1094	494	376	249	77.0%

Case 2(a) : Higgs ☆

$m_{1/2}=440$, $m_0=471$, $\tan\beta=40$, $m_{top}=175$



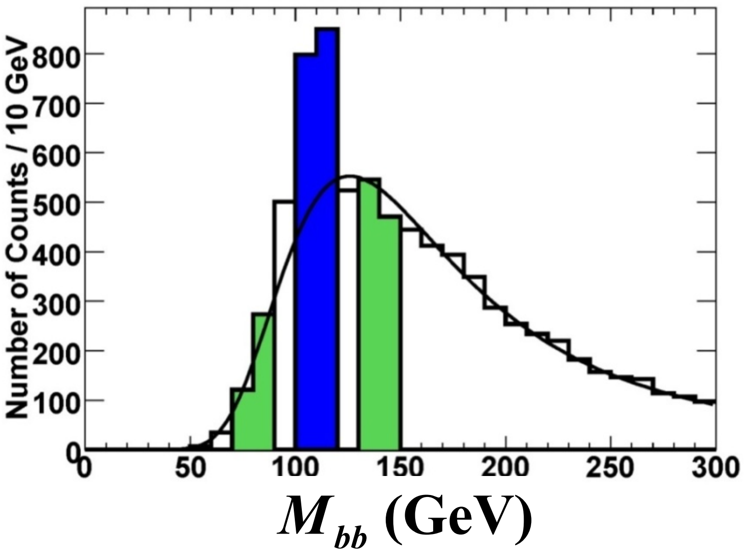
$E_T^{miss} > 180$ GeV;
N(jet) ≥ 2 with $E_T > 200$ GeV;
$E_T^{miss} + E_T^{j1} + E_T^{j2} > 600$ GeV

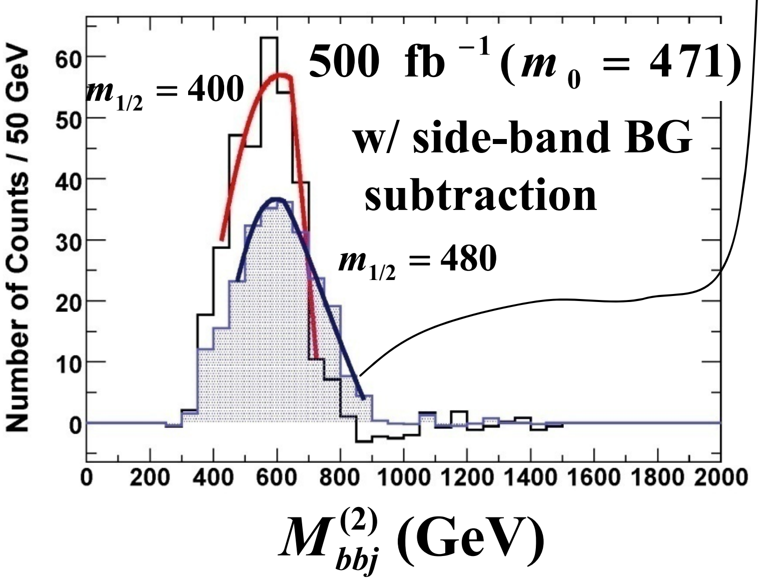


N(b) ≥ 2 with
$P_T > 100$ GeV; $0.4 < \Delta R_{bb} < 1$

4 Kinematical Variables

Side-band BG subtraction





$$M^{\text{end point}}_{jbb} = X_1(m_{1/2}, m_0)$$

$$M^{\text{peak}}_{\text{eff}} = X_2(m_{1/2}, m_0)$$

$$M^{(b)\,\text{peak}}_{\text{eff}} = X_3(m_{1/2}, m_0, \tan\beta, A_0)$$

$$M^{(bb)\,\text{peak}}_{\text{eff}} = X_4(m_{1/2}, m_0, \tan\beta, A_0)$$

where:

$$M_{\text{eff}} \equiv E_T^{j1} + E_T^{j2} + E_T^{j3} + E_T^{j4} + E_T^{\text{miss}}$$

[No *b* jets; ε_b ~ 50%]

$$M_{\text{eff}}^{(b)} \equiv E_T^{j1=b} + E_T^{j2} + E_T^{j3} + E_T^{j4} + E_T^{\text{miss}}$$

$$M_{\text{eff}}^{(bb)} \equiv E_T^{j1=b} + E_T^{j2=b} + E_T^{j3} + E_T^{j4} + E_T^{\text{miss}}$$

Determining mSUGRA Parameters

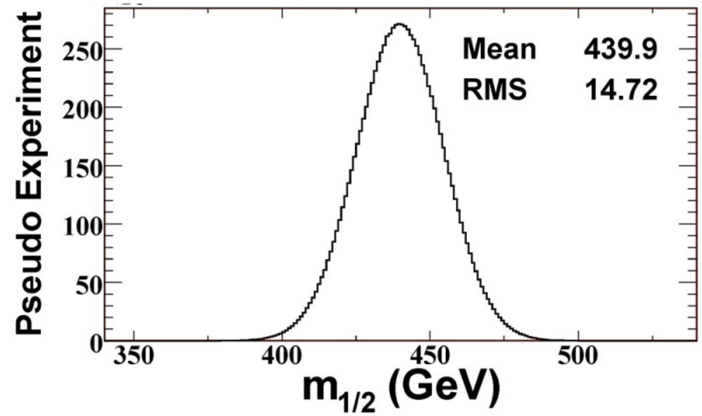
✓**Solved by inverting the following functions:**

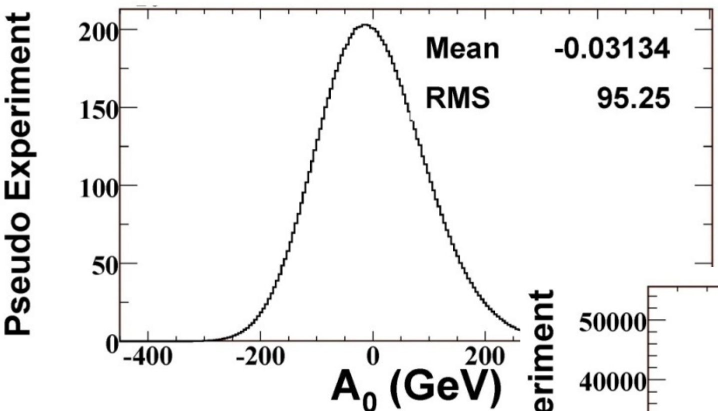
$$M_{jbb}^{\text{end point}} = X_1(m_{1/2}, m_0)$$

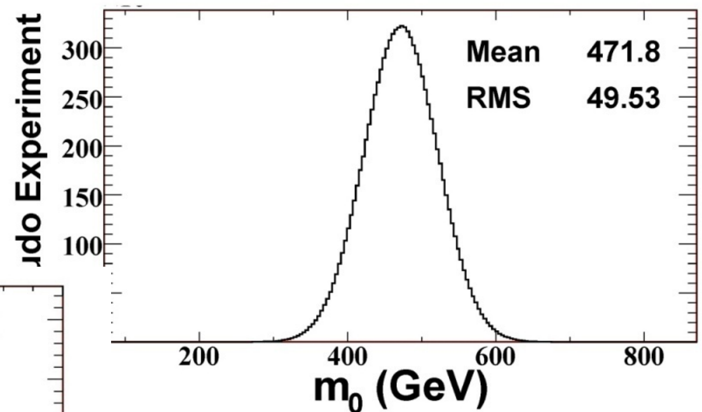
$$M_{\text{eff}}^{\text{peak}} = X_2(m_{1/2}, m_0)$$

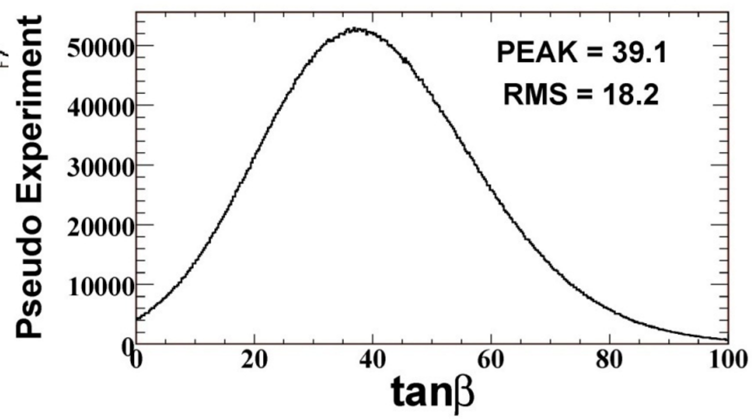
$$M_{\text{eff}}^{(b)\,\text{peak}} = X_3(m_{1/2}, m_0, \tan\beta, A_0)$$

$$M_{\text{eff}}^{(bb)\,\text{peak}} = X_4(m_{1/2}, m_0, \tan\beta, A_0)$$









Determining Ωh^2

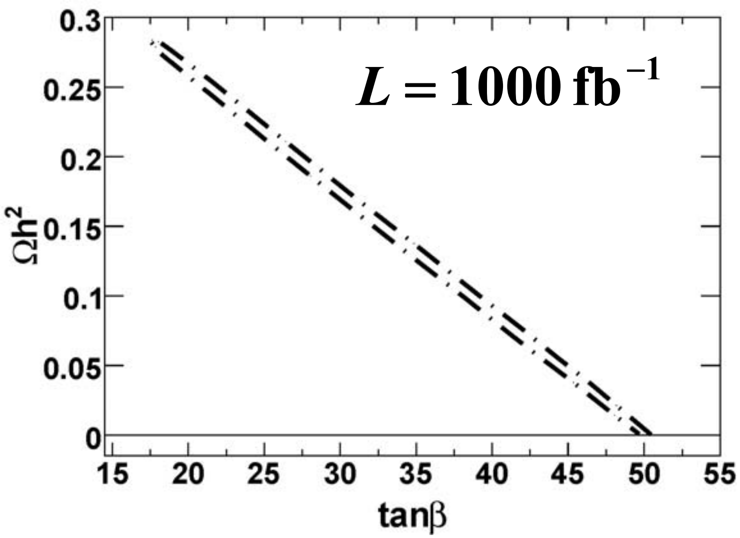
✓Solved by inverting the following functions:

$$
\begin{aligned}
M_{jbb}^{\text{end point}} &= X_1(m_{1/2}, m_0) \\
M_{\text{eff}}^{\text{peak}} &= X_2(m_{1/2}, m_0) \\
M_{\text{eff}}^{(b)\,\text{peak}} &= X_3(m_{1/2}, m_0, \tan\beta, A_0) \\
M_{\text{eff}}^{(bb)\,\text{peak}} &= X_4(m_{1/2}, m_0, \tan\beta, A_0)
\end{aligned}
$$

1000 fb^{-1}

$$
\left\{
\begin{aligned}
m_0 &= 472 \pm 50 \\
m_{1/2} &= 440 \pm 15 \\
A_0 &= 0 \pm 95 \\
\tan\beta &= 39 \pm 18
\end{aligned}
\right.
$$

$$\Omega_{\tilde{\chi}_1^0} h^2 = Z(m_0, m_{1/2} \tan\beta, A_0)$$



$$\delta\Omega_{\tilde{\chi}_1^0} h^2 / \Omega_{\tilde{\chi}_1^0} h^2 \sim 150\%$$

Dutta, Gurrola, Kamon, Krislock , Nanopoulos, Lahanas, Mavromatos, PRD 09

Case 2: Summary

Over-dense Dark Matter Region:

- ✓ $\sigma_{OD\text{-}CDM} \sim \sigma_{CDM}/10$

Implication at the LHC:

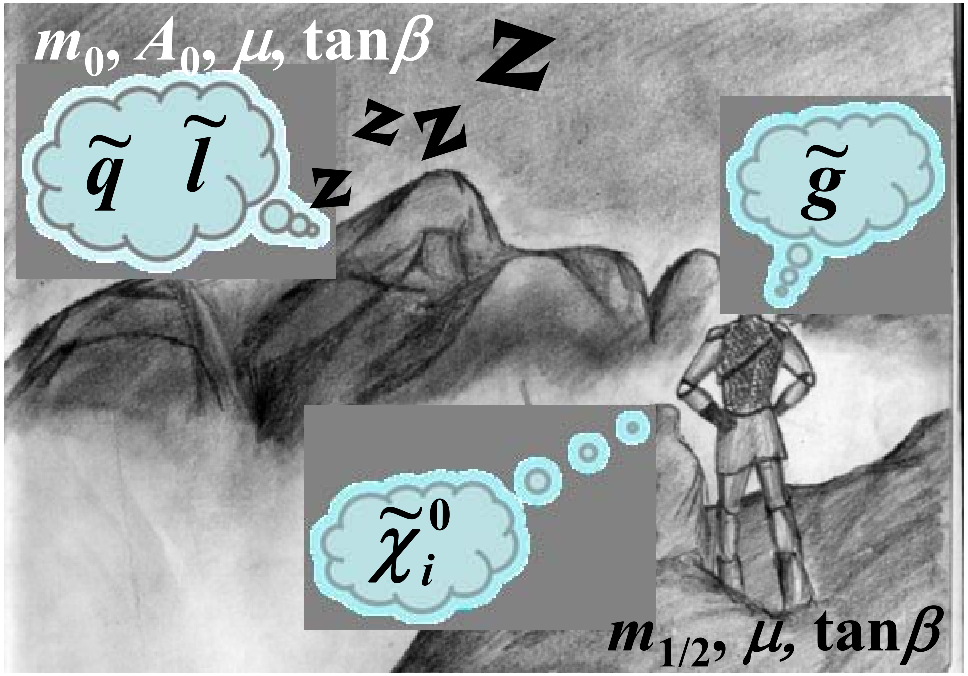
- ✓ Region where χ_2^0 decays to Higgs

  $\delta\Omega_{CDM}/\Omega_{CDM} \sim 150\%$ (1000 fb^{-1})

- ✓ Region where χ_2^0 decays to stau and Higgs

  $\delta\Omega_{CDM}/\Omega_{CDM} \sim 20\%$ (500 fb^{-1})

Case 3 : Focus Point/Hyperbolic Branch



Prospects at the LHC:

A few mass measurements are available: 2nd and 3rd neutralinos, and gluino

Can we determine the dark matter content?

Goals:

1)technique on Ωh^2

2)SUSY mass measurements

Ωh^2

$$M_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -M_Z s_W c_\beta & M_Z s_W s_\beta \\ 0 & M_2 & M_Z c_W c_\beta & -M_Z c_W s_\beta \\ -M_Z s_W c_\beta & M_Z c_W c_\beta & 0 & -\mu \\ M_Z s_W s_\beta & -M_Z c_W s_\beta & -\mu & 0 \end{pmatrix}$$

$s_W = \sin(\theta_W)$ $\quad c_W = \cos(\theta_W)$

$s_\beta = \sin(\beta)$ $\quad c_\beta = \cos(\beta)$

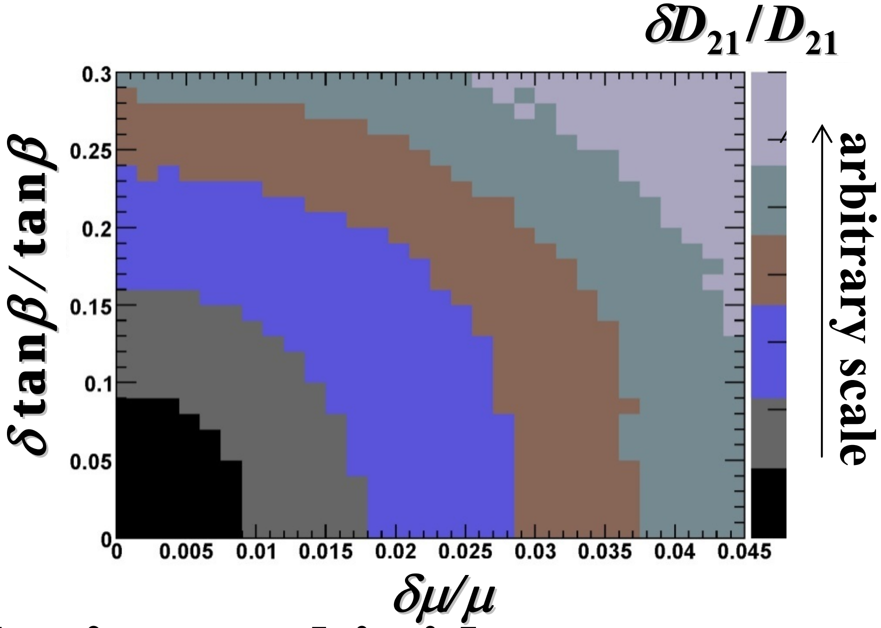
$$M_{\tilde{\chi}^0} = A_{4\mathrm{x}4}\,(m_{1/2}, \underbrace{\mu, \tan\beta}\,)$$

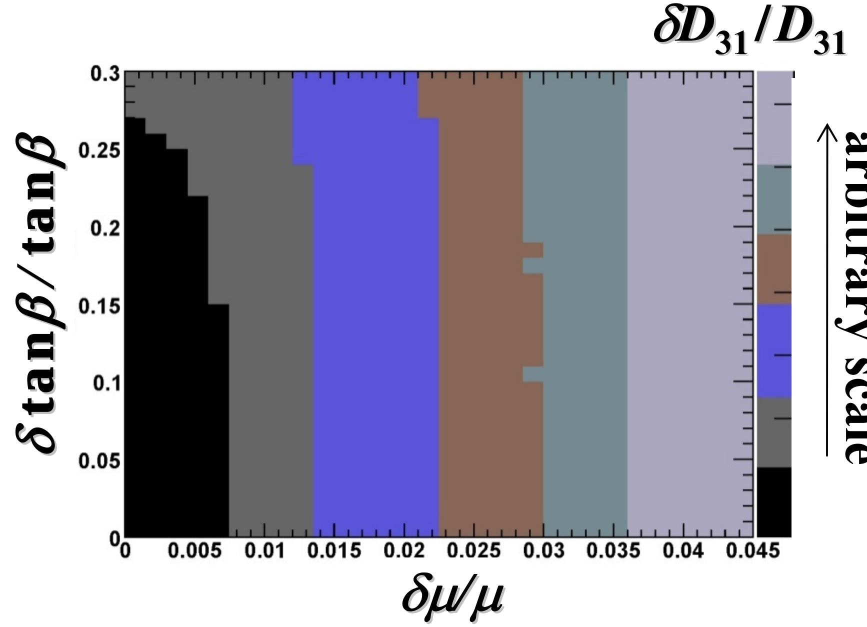
$M_{\tilde{g}}$ $\qquad \overbrace{D_{21} = M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0} \qquad D_{31} = M_{\tilde{\chi}_3^0} - M_{\tilde{\chi}_1^0}}$

$$\boxed{\Omega_{\tilde{\chi}_1^0} h^2 = Z(m_{1/2}, \mu, \tan\beta)}$$

δD_{21} and $\delta D_{32} \leftrightarrow \delta\mu$ and $\delta \tan\beta$

Example ($\mu = 195$, $\tan\beta = 10$): assuming $\delta M_{\tilde{g}} / M_{\tilde{g}} = 0$





Let's test this idea:

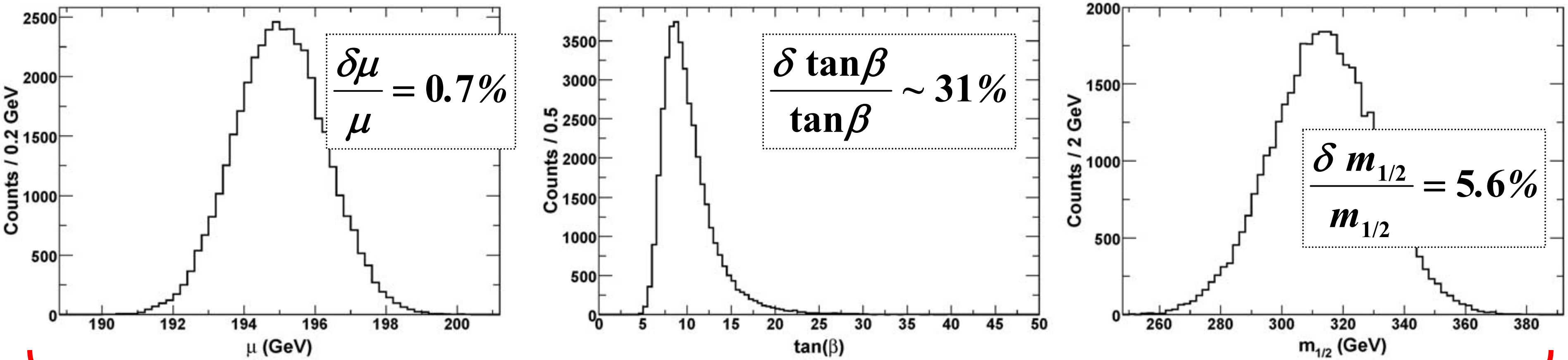
300 fb^{-1}

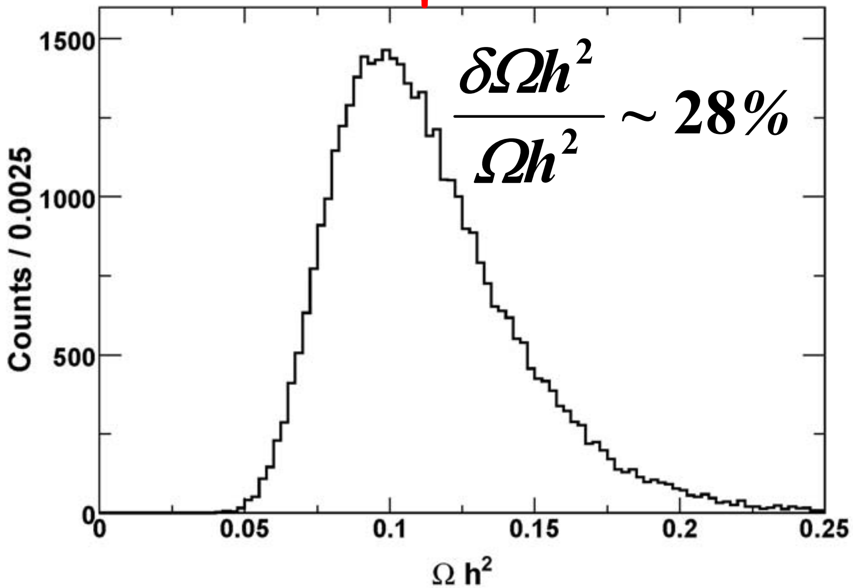
$$\frac{\delta D_{21}}{D_{21}} = 1.7\%^{(1)} \qquad \frac{\delta D_{31}}{D_{31}} = 1.1\%^{(1)} \qquad \frac{\delta M_{\tilde{g}}}{M_{\tilde{g}}} = 4.5\%^{(2)}$$

(1) D. Tovey, "Dark Matter Searches of ATLAS," PPC 2007

(2) H. Baer et al., "Precision Gluino Mass at the LHC in SUSY Models with Decoupled Scalars," Phys. Rev. D75, 095010 (2007), reporting 8% with 100 fb^{-1}

Ωh^2 Determination





Dutta, Flanagan, Kamon, Krislock, to appear

LHC Goal: D_{21} and D_{31} at 1-2% and gluino mass at 5%

Case 4 : Non-U SUGRA

Nature may not be so kind … Our studies have been done based on a minimal scenario (= mSUGRA).

…

Let's consider a non-universal scenario: Higgs non-universality: m_{Hu}, $m_{Hd} \neq m_0$ (most plausible extension)

Steps:

1) Reduce Higgs coupling parameter, μ, by increasing m_{Hu}, … → More annihilation (less abundance) → correct values of Ωh^2

2) Find smoking gun signals → Technique to calculate Ωh^2

Reference Point

Parameters at the GUT scale:

- $m_0 = 360$ GeV, $m_{1/2} = 500$ GeV, $A_0 = 0$ GeV, $\tan\beta = 40$
- Non-universal Higgs: $m_{H_u} = 732$ GeV, $m_{H_d} = 732$ GeV *

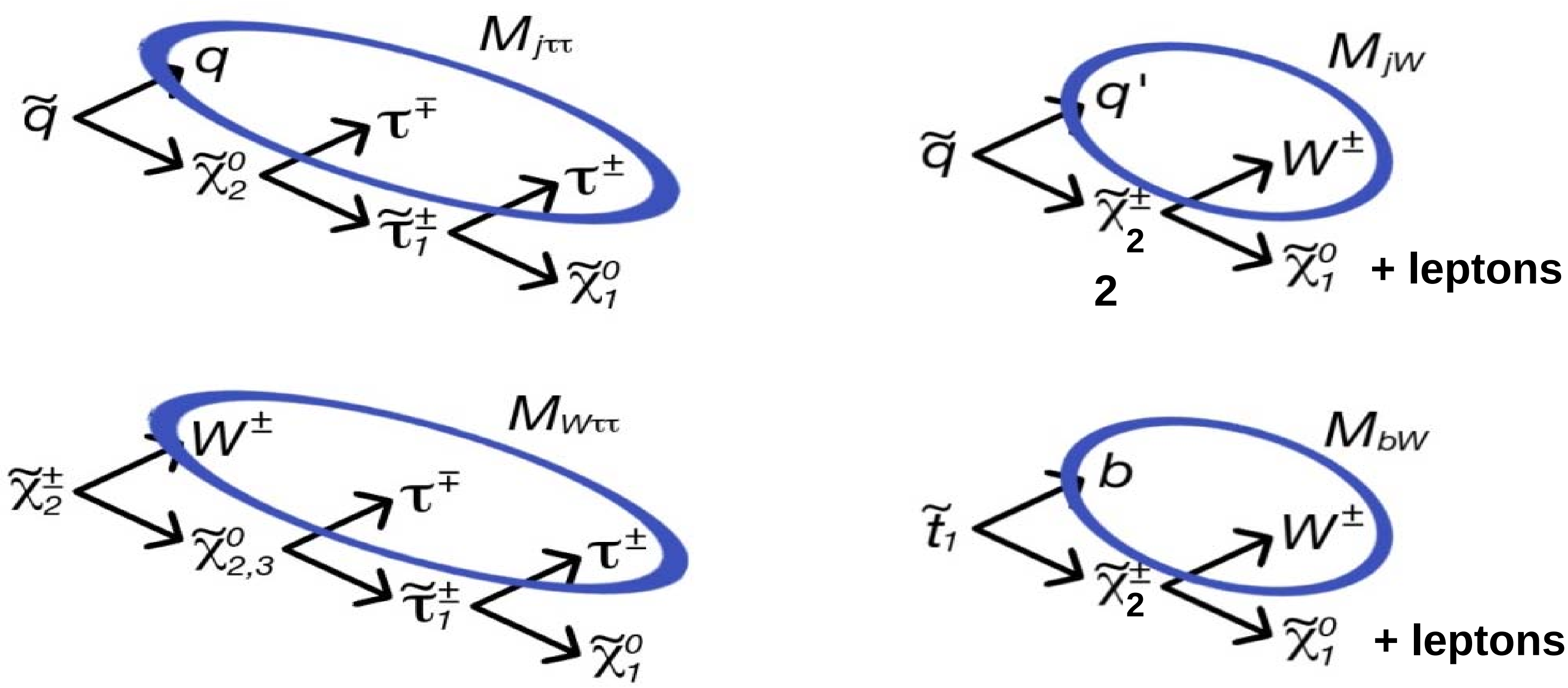
$\Omega h^2 = 0.112$

SUSY masses (in GeV):

$\tilde{g}$	$\tilde{u}_L$ $\tilde{u}_R$	$\tilde{t}_2$ $\tilde{t}_1$	$\tilde{b}_2$ $\tilde{b}_1$	$\tilde{e}_L$ $\tilde{e}_R$	$\tilde{\tau}_2$ $\tilde{\tau}_1$	$\tilde{\chi}^0_4$ $\tilde{\chi}^0_3$ $\tilde{\chi}^0_2$ $\tilde{\chi}^0_1$	$\tilde{\chi}^\pm_2$ $\tilde{\chi}^\pm_1$
1161	1114 1076	992 780	989 946	494 407	446 255	432 317 293 199	428 292

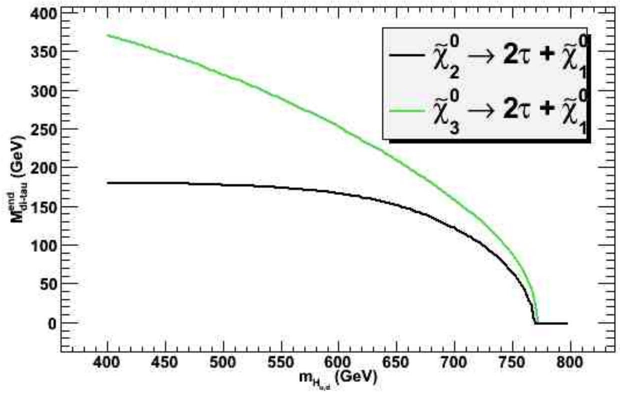
Decays at Reference Point

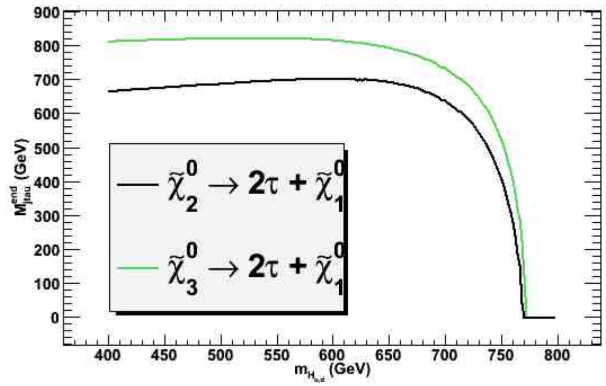
Benchmark Point: Characteristic Decays

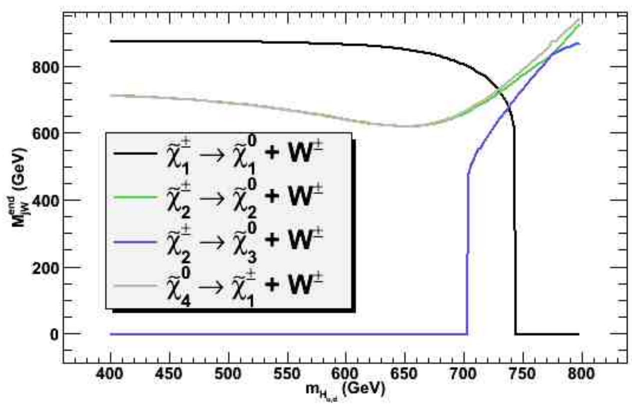


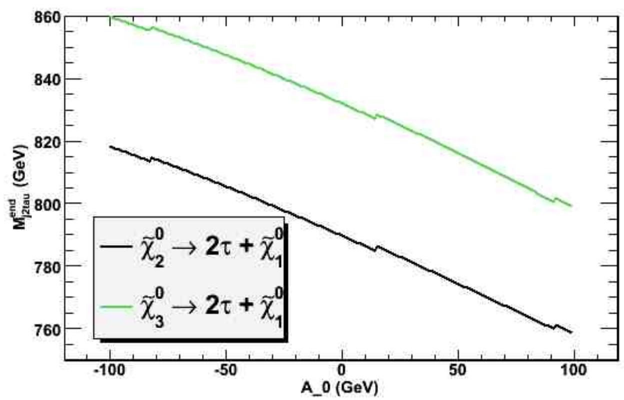
So far we have used observables with:
leptons + jets, taus + jets, Z + jets, Higgs + jets
In the non-universal scenario: We use W + jets etc

Extraction of Model Parameters





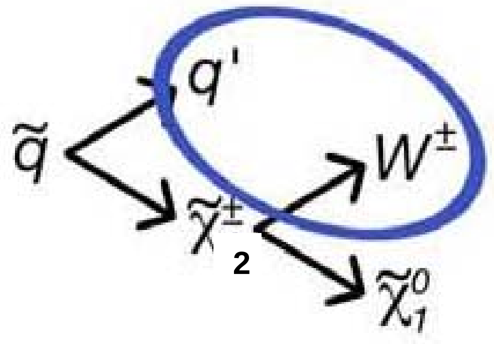




…

Extraction of Observables

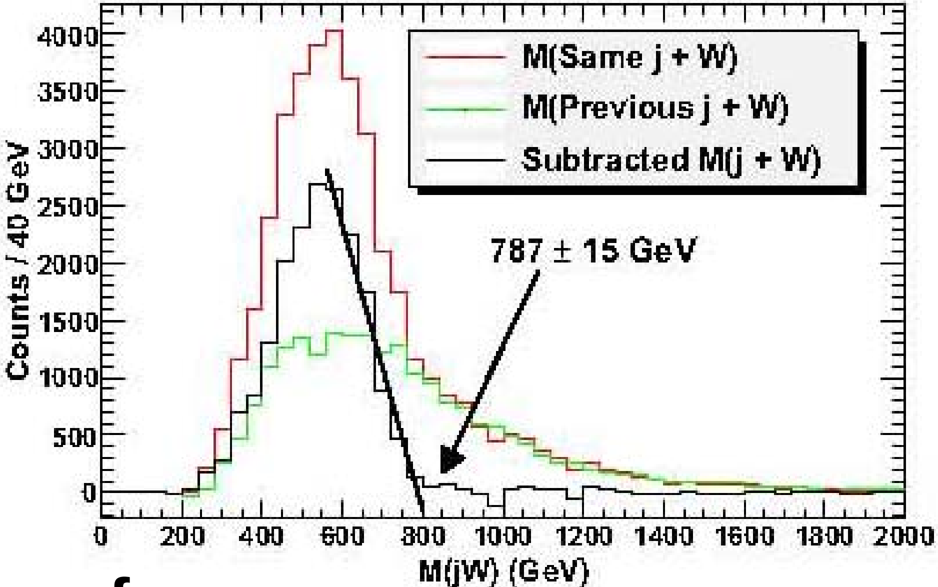
Subtraction Techniques



The *W* momentum is related to the momentum of this Same Event Jet.

We collect W+j pairs:
related pairs plus random pairs
Use jets from the previous events to generate random pairs

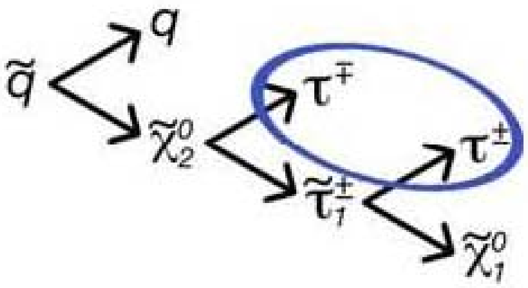
Normalize and perform:
Same jet-previous jet

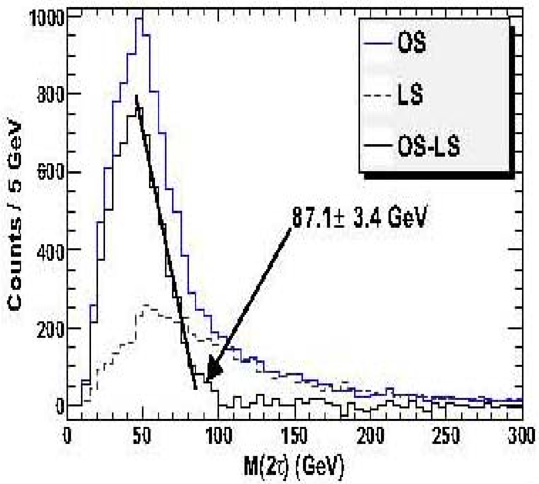


➔ Random pairs will be cancelled
➔ Left with only related pairs

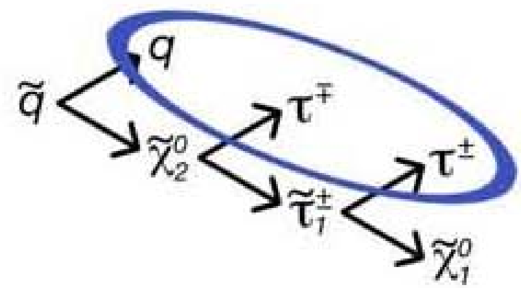
➢**Successful identification of one side of the production process!**

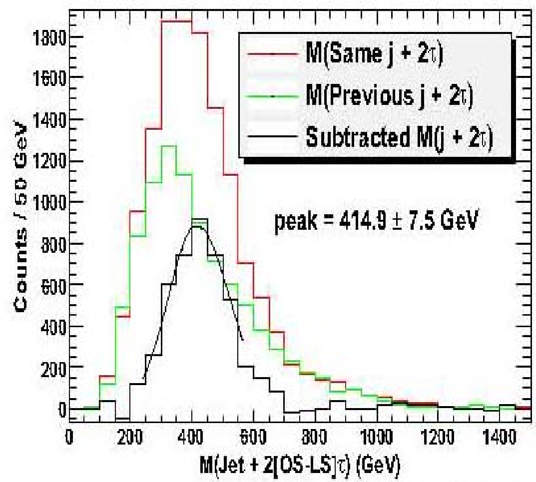
Jet+ 2τ



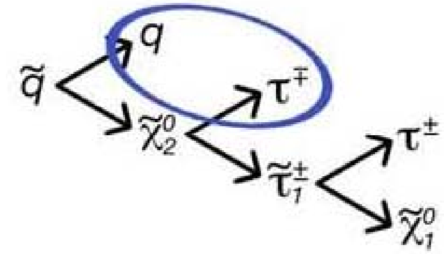


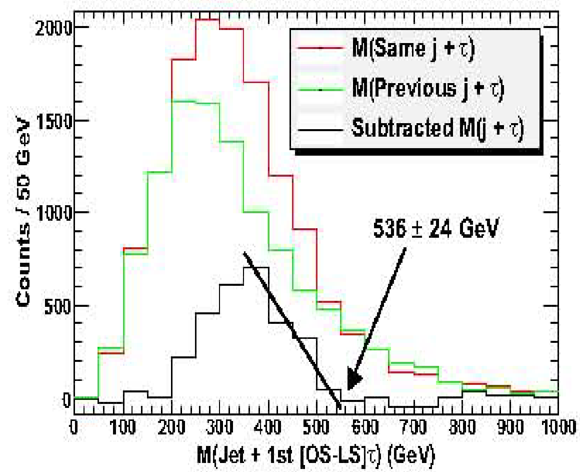
2 τ invariant mass





J+2 τ invariant mass





J+ τ invariant mass

Extraction of Model Parameters

Utilizing the characteristic decays, we can create some observables to determine our model parameters:

$M_{eff}(m_0, m_{1/2})$
$M_{jtt}(m_0, m_{1/2})$
$M_{j\tau}(m_0, m_{1/2}, \mu, \tan\beta)$
$M_{jW}(m_0, m_{1/2}, \mu)$
$M_{\tau\tau}(m_0, m_{1/2}, \mu, \tan\beta)$
P_T(low energy tau) $(m_0, m_{1/2}, \mu, \tan\beta)$

Dutta, Kamon, Kolev, Krislock, to appear

$$m_0 = 359 \pm 10\,\mathrm{GeV}, m_{1/2} = 502.5 \pm 2.9\,\mathrm{GeV},$$
$$m_{H_u} = 725 \pm 25\,\mathrm{GeV}$$

Ωh^2 has 71% uncertainty

Conclusion

Signature contains missing energy (R parity conserving) many jets and leptons : Discovering SUSY should not be a problem!

Once SUSY is discovered, attempts will be made to measure the sparticle masses (highly non trivial!), establish the model and make connection between particle physics and cosmology

Different cosmologically motivated regions of the minimal model have distinct signatures.
It is possible to determine model parameters and the relic density based on the LHC measurements

non-universal model parameters----Can be determined