



# Baryon-Violating RPV

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- Analysis of  $\lambda''_{212}$  RPV decay where LSP decays to three quarks:  
$$\tilde{\chi}_1^0 \rightarrow cds$$
- Using jet and lepton invariant mass combinations to measure SUSY particle masses:  $\tilde{\chi}_1^0, \tilde{l}_R, \tilde{\chi}_2^0, \tilde{q}_L$

- Using decay chain:

$$\tilde{\chi}_2^0 \rightarrow \tilde{l}_R l \rightarrow \tilde{\chi}_1^0 ll$$

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# R-Parity Violation

$$R_p = (-1)^{3B+L+2S}$$

+1 for SM particles

-1 for SUSY particles

- Consequences of RPV
  - Decay of Lightest SUSY Particle (LSP)
  - Large couplings  $\Rightarrow$  single sparticle production.

- $\lambda_{ijk} L^i L^j E^k \Rightarrow \tilde{\chi}_1^0 \rightarrow \text{leptons}$
- $\lambda'_{ijk} L^i Q^j D^k \Rightarrow \tilde{\chi}_1^0 \rightarrow l \text{ or } \nu + \text{jets}$
- $\lambda''_{ijk} U^i D^j D^k \Rightarrow \tilde{\chi}_1^0 \rightarrow qqq$

- Hardest at LHC is  $\lambda''$  - no leptons
- Worst case:  $\lambda''_{212}$  - no heavy-quark jets



# Test Model



- Our test model:

$$m_0 = 100 \text{ GeV}$$

$$m_{1/2} = 300 \text{ GeV}$$

$$A_0 = 300 \text{ GeV}$$

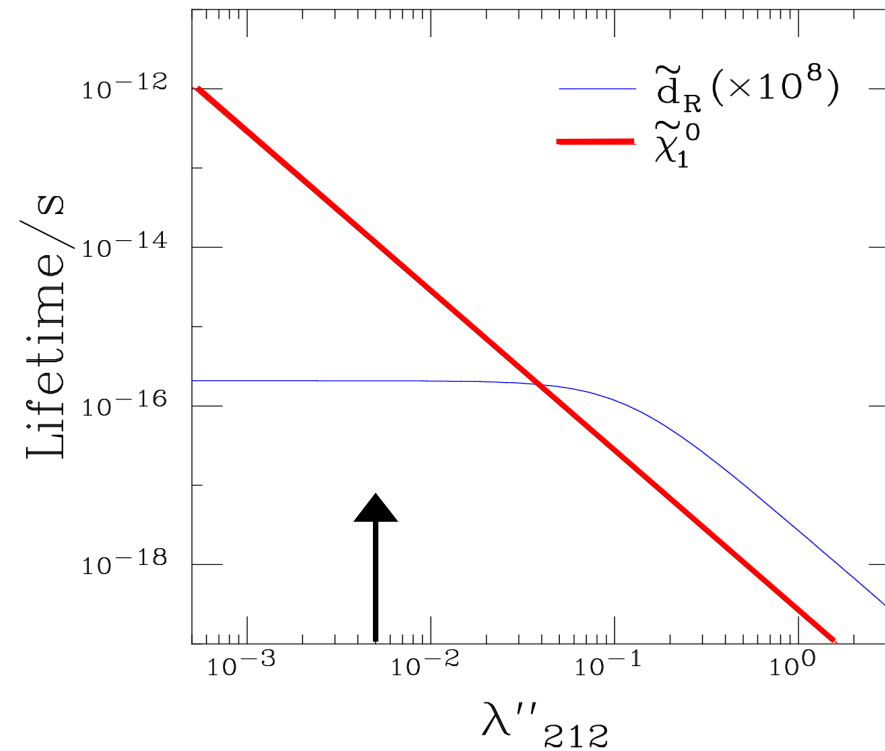
$$\tan\beta = 10$$

$$\mu > 0$$

$$\lambda''_{212} = 0.005$$

LSP decay mode:

$$\tilde{\chi}_1^0 \rightarrow cds$$



$$c\tau(\tilde{\chi}_1^0) = 3 \times 10^{-6} \text{ m}$$



# Cuts summary

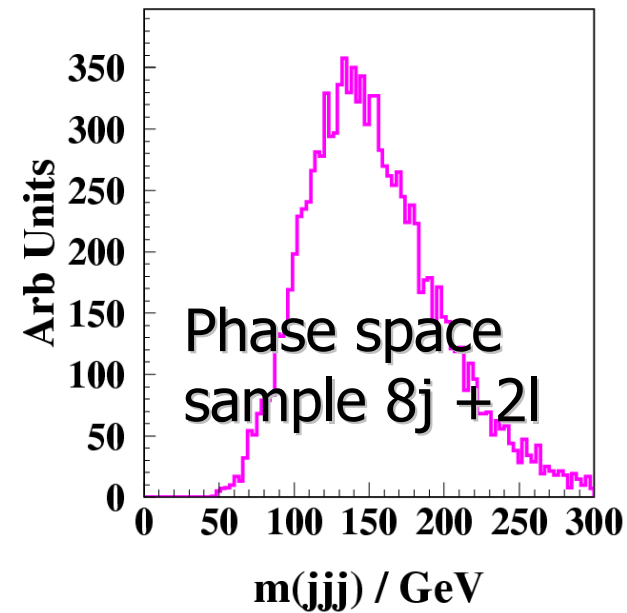
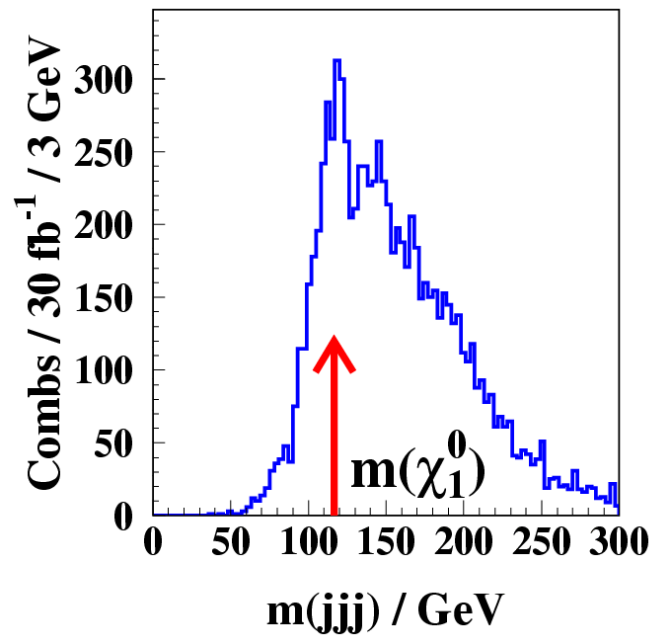
- 8 to 10 jets
- $\Sigma p_T^{\text{jet}} + \Sigma p_T^{\text{lepton}} > 1 \text{ TeV}$   
for  $|\eta| < 2$
- At least 2 leptons ( $e$  or  $\mu$ )  
 $p_T > 15 \text{ GeV}$  and  $|\eta| < 2.5$
- $m_{ll} < \text{kinematic limit}$   
(95.1 GeV)
- transverse sphericity  $> 0.2$
- transverse thrust  $< 0.9$
- 2 hard jets assumed to originate from  $\tilde{q} / \tilde{g}$  decays
  - $E_T^{(h1)} > 200 \text{ GeV}$   
 $E_T^{(h2)} > 100 \text{ GeV}$
- Any combination of 6 other jets with  $p_T$  in range (GeV):
  - $100. < p_T^{(a1)}$   
 $17.5 < p_T^{(a2)} < 300.$   
 $15.0 < p_T^{(a3)} < 150.$
  - $17.5 < p_T^{(b1)} < 300.$   
 $17.5 < p_T^{(b2)} < 150.$   
 $15.0 < p_T^{(b3)} < 75.$
- $\Delta R_{12}^{(a)} < 1.3$  ;  $\Delta R_{12-3}^{(a)} < 1.3$   
 $\Delta R_{12}^{(b)} < 2.0$

Average number of jets:

$$\begin{aligned} \tilde{q}_L, \tilde{q}_L &\Rightarrow 10.7 & \tilde{g}, \tilde{g} &\Rightarrow 12.8 \\ \tilde{q}_R, \tilde{q}_R &\Rightarrow 9.2 & & \end{aligned}$$



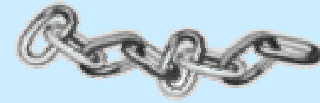
# Lightest neutralino



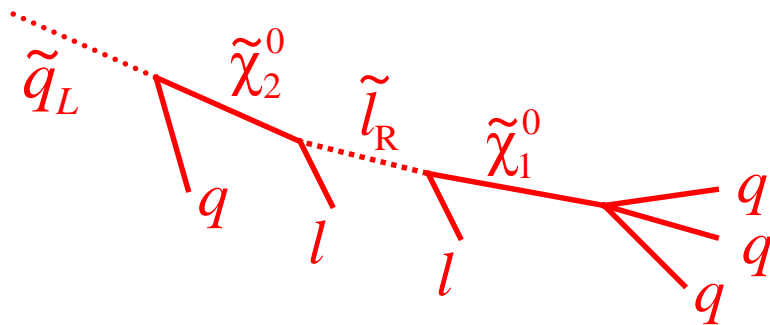
- Neutralino peak visible, but ...
- Large combinatoric background below the peak
- Background shape determined by the cuts



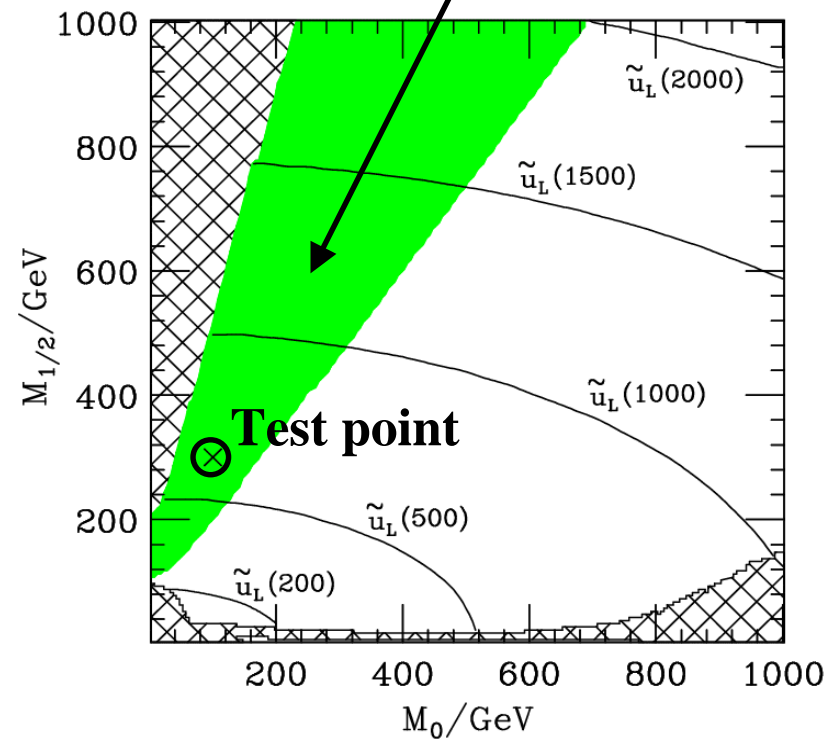
# Using the Chain



- Use extra information from leptons to decrease background.
- Sequential decay of  $\tilde{q}_L$  to  $\tilde{\chi}_1^0$  through  $\tilde{\chi}_2^0$  and  $\tilde{l}_R$  producing Opposite Sign, Same Family (OSSF) leptons

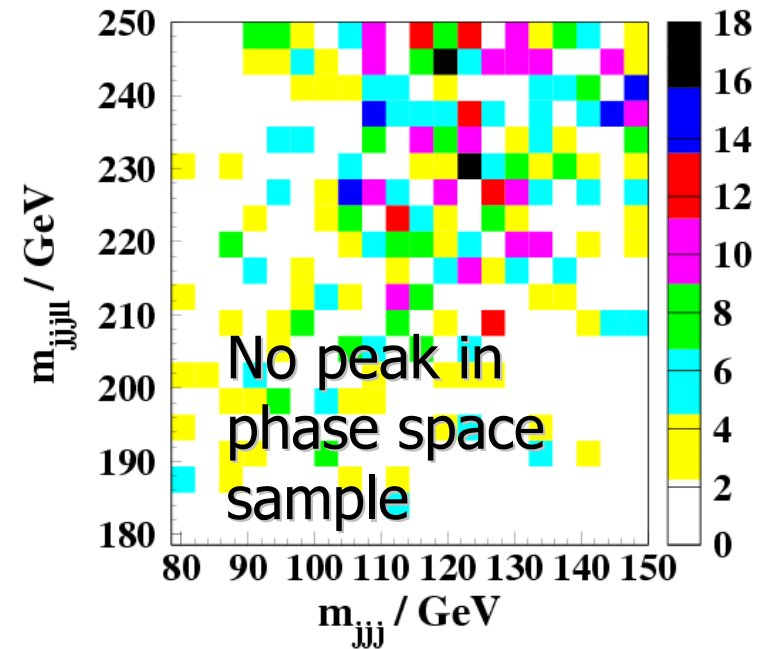
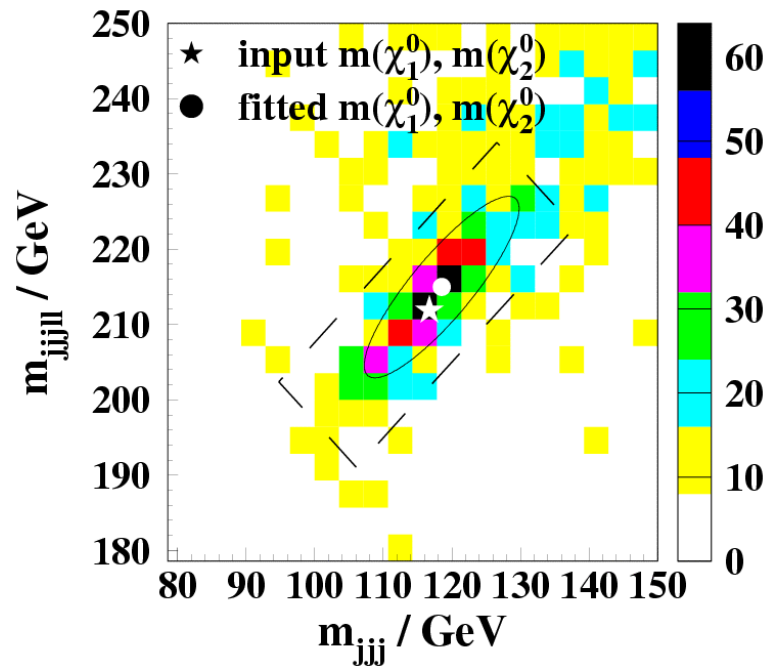


Decay via  $\tilde{l}_R$  allowed where  $m(\tilde{\chi}_2^0) > m(\tilde{l}_R)$





# Neutralino Masses



Gaussian fit:

$$m(\tilde{\chi}_1^0) = 118.9 \pm 3 \text{ GeV},$$

$$m(\tilde{\chi}_2^0) = 218.5 \pm 3 \text{ GeV}$$

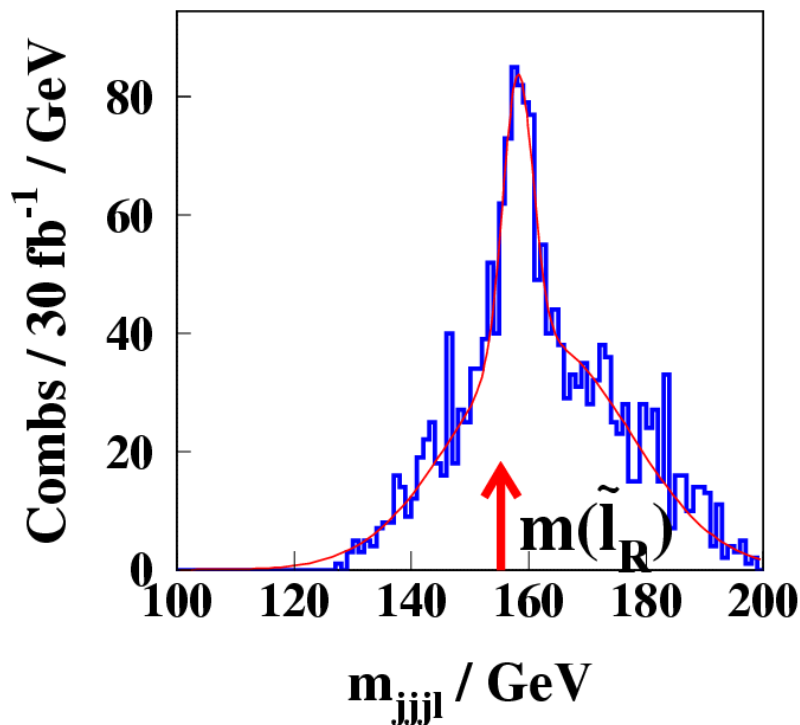
Input masses: 116.7, 211.9 GeV

- Jet energy scale uncertainty  $\approx 3\%$   
 $\Rightarrow 3 \text{ GeV}$  systematic



# Slepton Mass

- Additional  $1 \times \sigma$  cut about the  $\tilde{\chi}_1^0 - \tilde{\chi}_2^0$  peak
- Increase maximum number of jets to 11



- Find  $jjj$  ( $\tilde{\chi}_1^0$  candidate) nearest a lepton in  $\eta$ - $\phi$
- Plot invariant mass combination of that  $jjj + \text{lepton}$

$$m(\tilde{l}_R) = 157.8 \pm 0.3 \pm 4.2 \text{ GeV}$$

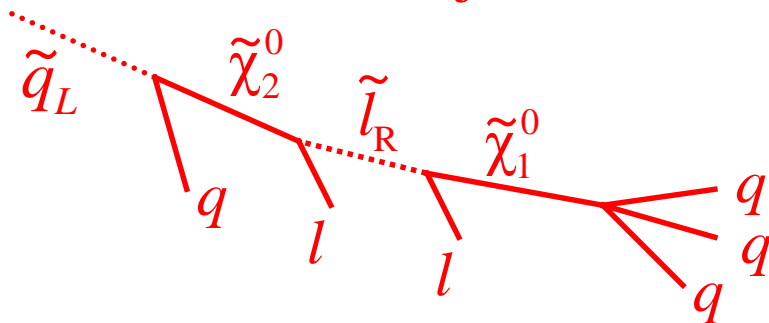
Input: 155.8 GeV



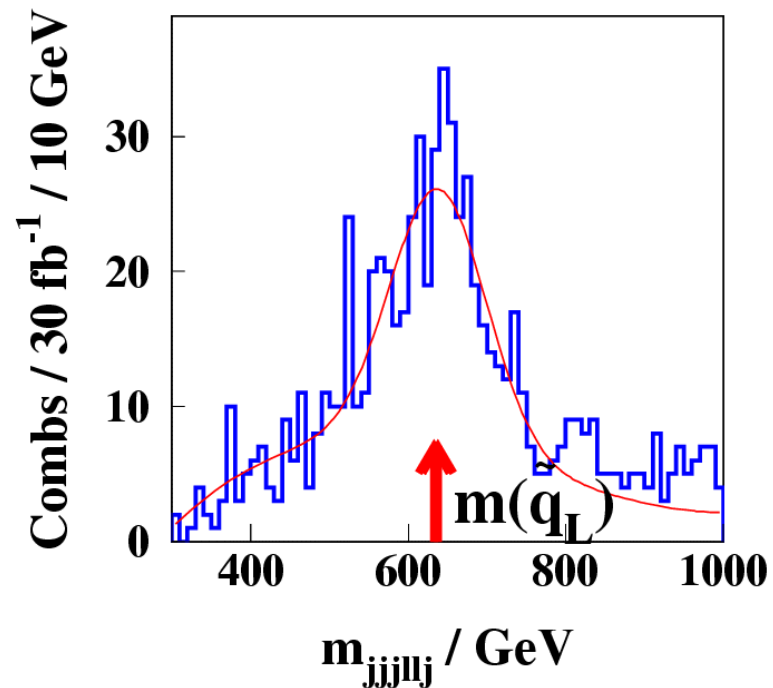


# Squark Mass

- Relax cut about  $\tilde{\chi}_1^0 - \tilde{\chi}_2^0$  peak to  $2 \times \sigma$
- Cut  $2 \times \sigma$  about slepton peak
- Chose same  $jjj$  ( $\tilde{\chi}_1^0$  candidate) as before.
- Plot invariant mass of  $jjj$  + both OSSF leptons + harder jet of the two (previously excluded) hard jets



Systematics from jet energy scale and background shape



$$m(\tilde{q}_L) = 637 \pm 5 \pm 12 \text{ GeV}$$

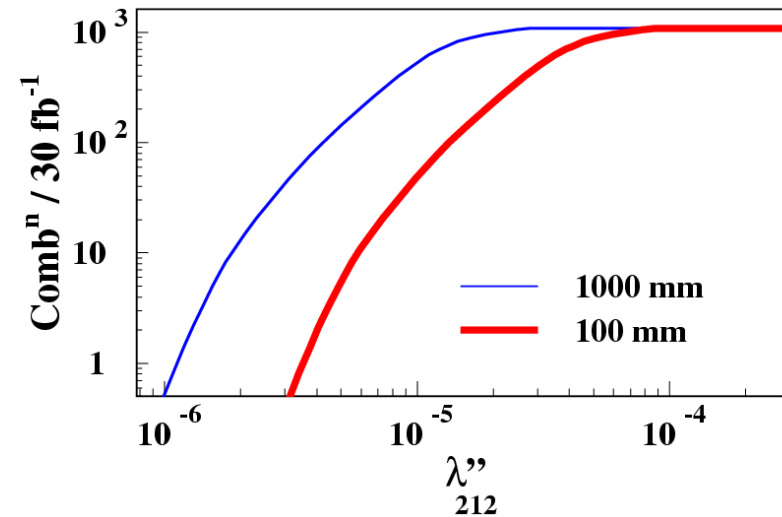
Input:  $u_L = 633$ ,  $d_L = 638$  GeV



# Other Values of $\lambda''_{212}$

**Relatively insensitive to the RPV coupling, but...**

- As  $\lambda''_{212}$  becomes very small the  $\tilde{\chi}_1^0$  decay ‘switches off’
- Long-lived neutral particles go undetected
- RPC-type analysis becomes valid.
- At large couplings  $\sim 1$ , single sparticle production occurs.



- Combinations where neutralino candidates travel less than **100** (**1000**) mm in the transverse direction.



# Conclusions

- In RPV SUSY the LSP can decay within the detector.
- $\cancel{E}_T$  signature disappears.
- Examined hardest case: no leptons or  $b$ -quarks:  
 $\lambda''_{212} \neq 0, \tilde{\chi}_1^0 \rightarrow cds$
- Analysis of chain  $\tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{l}_R l q \rightarrow \tilde{\chi}_1^0 llq$
- Even in the hardest case of RPV with  $\lambda''_{212}$  we can measure:  $m(\tilde{q}_L) m(\tilde{\chi}_2^0) m(\tilde{l}_R) m(\tilde{\chi}_1^0)$
- Valid for coupling  $> 10^{-5}$

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