Supersymmetry with Trilinear R-Parity Violation at the LHC

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What do we want the LHC to Discover?

- Officially: the Higgs
- ATLAS — “A Tool for Locating Any Supersymmetry”
- E.g. R-Parity Violating SUSY

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$$\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k + \mu_i H L_i$$

L_i, Q_i, H – lepton, quark, Higgs doublets
E_i, D_i, U_i – lepton, down, up quark singlets

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Bilinear Lepton number violating couplings; induces neutrino–neutralino mixing. Not our primary focus

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Trilinear Lepton number violating couplings

Trilinear Baryon number violating couplings

The Studied Scenario

- Neutralino NLSP
- (Gravitino LSP – for Dark Matter)
- Pair production of squarks and gluinos
- Cascade decay down to neutralino
- Three-body decay of neutralino
- Try to determine operator hierarchies

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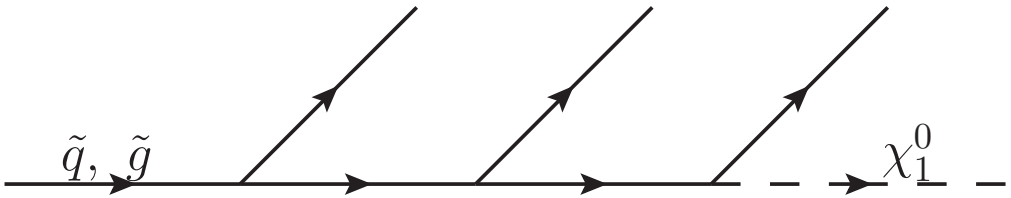

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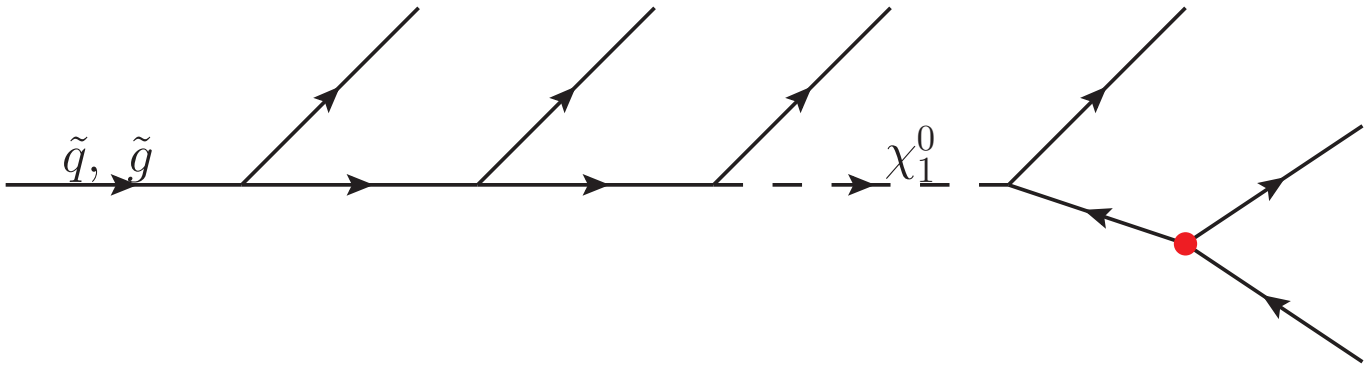

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- Lots of leptons $\Rightarrow$ easy background suppression
- Neutrinos $\Rightarrow$ no peaks or clear edges in Invariant mass distributions
- Need to know the expected distributions!

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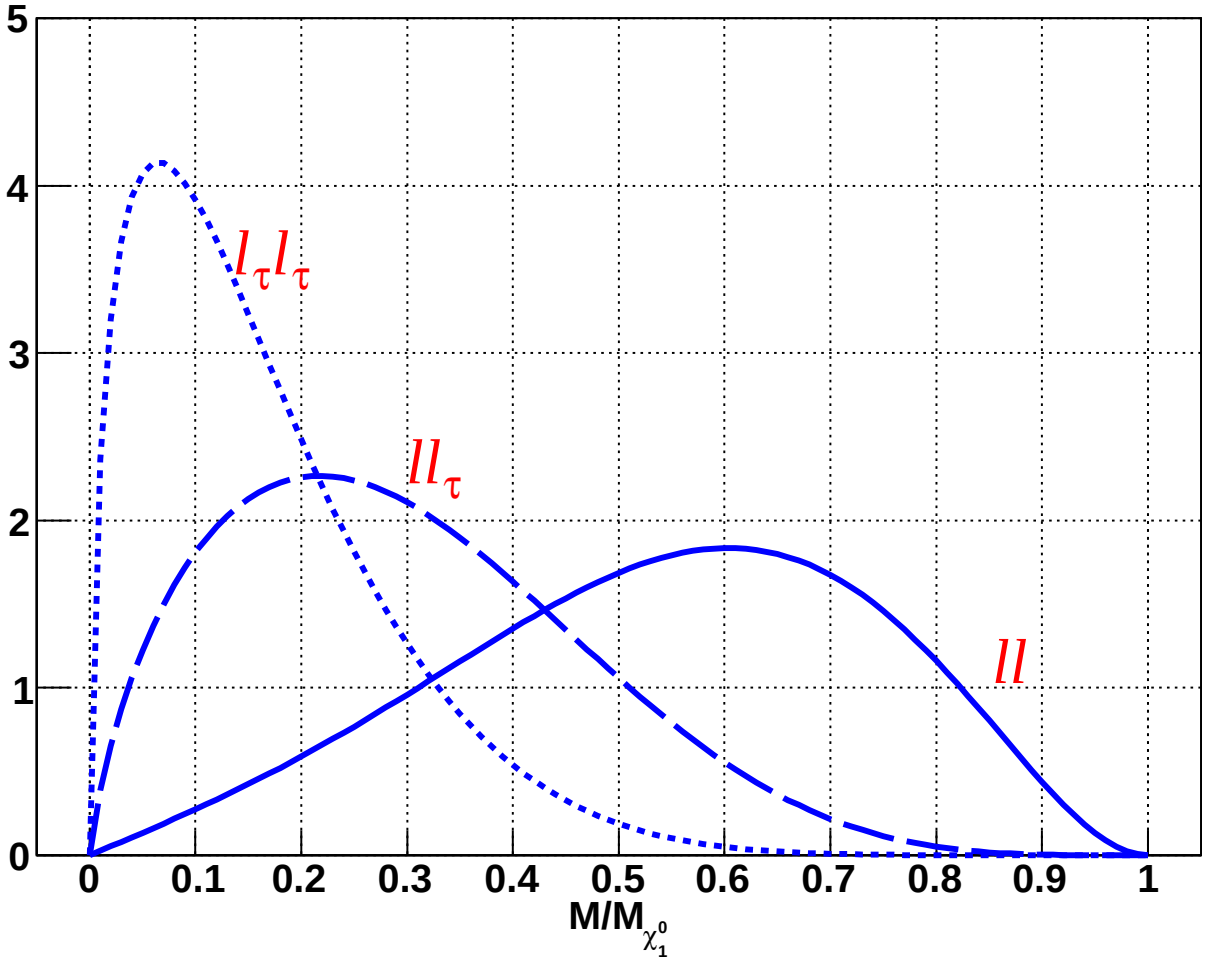
Theoretical Invariant Mass Distributions



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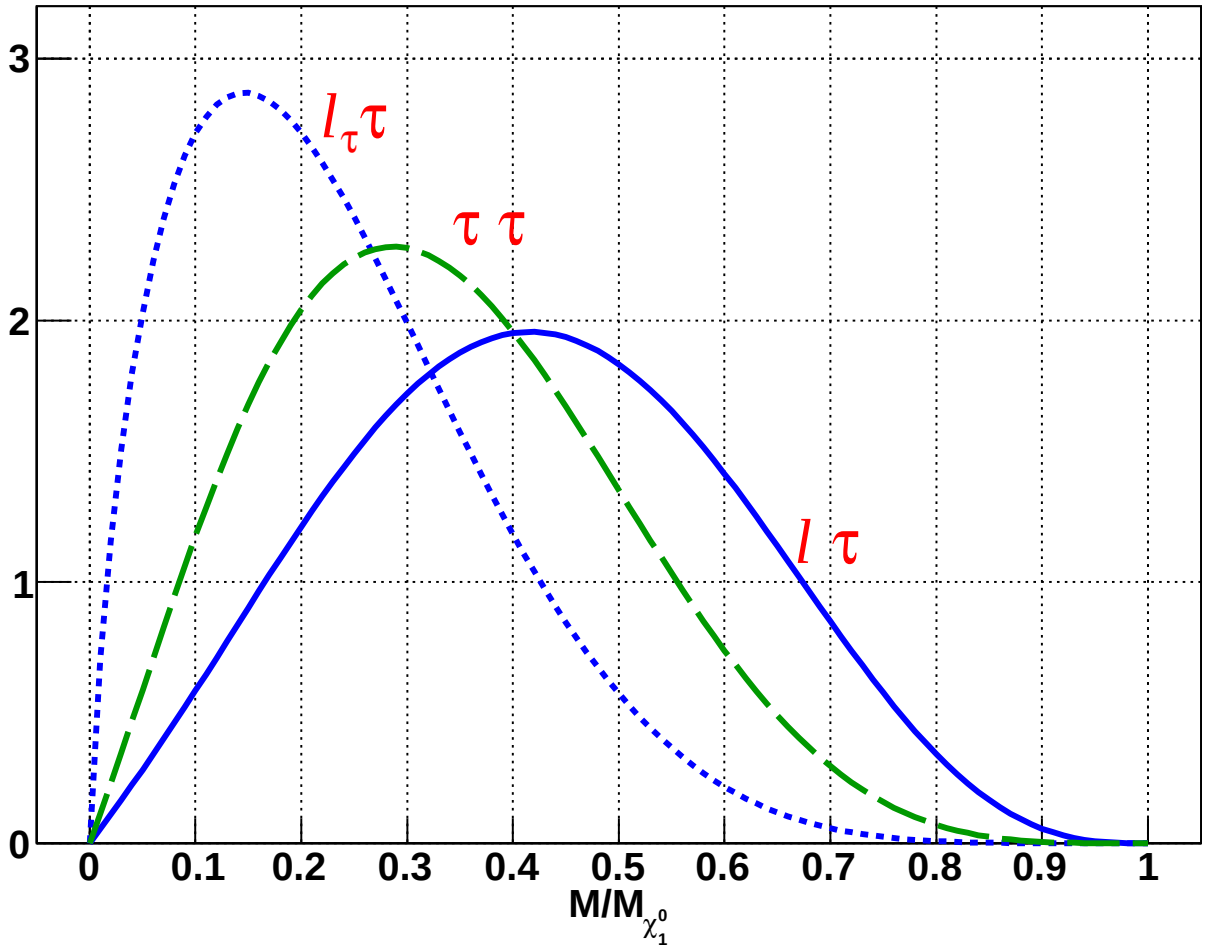
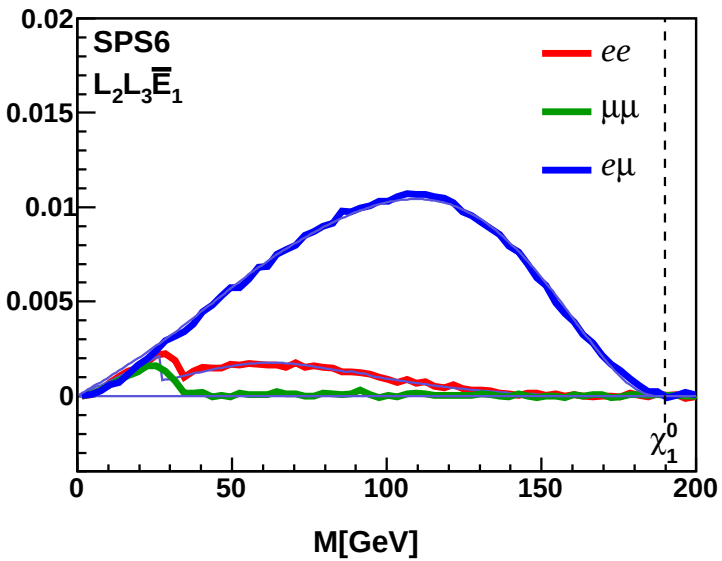
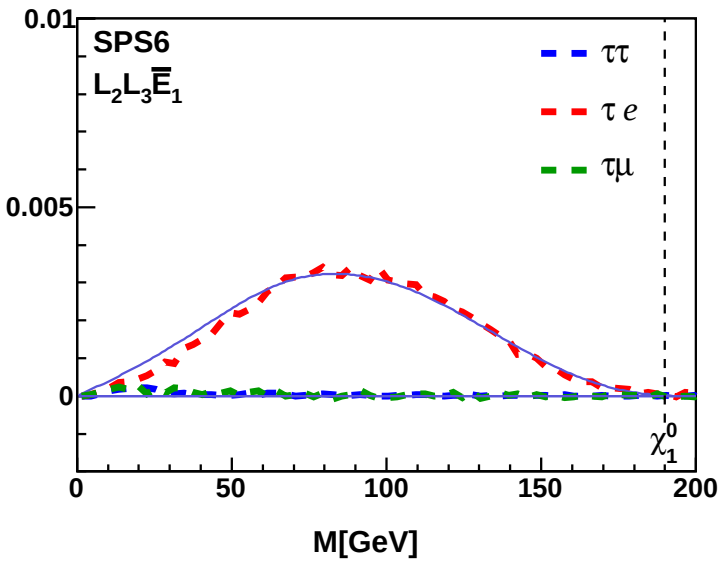


Invariant Mass Distributions





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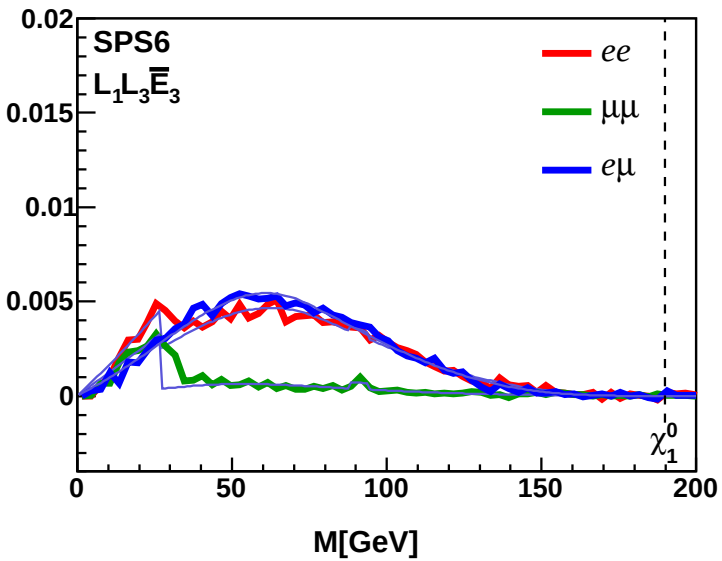

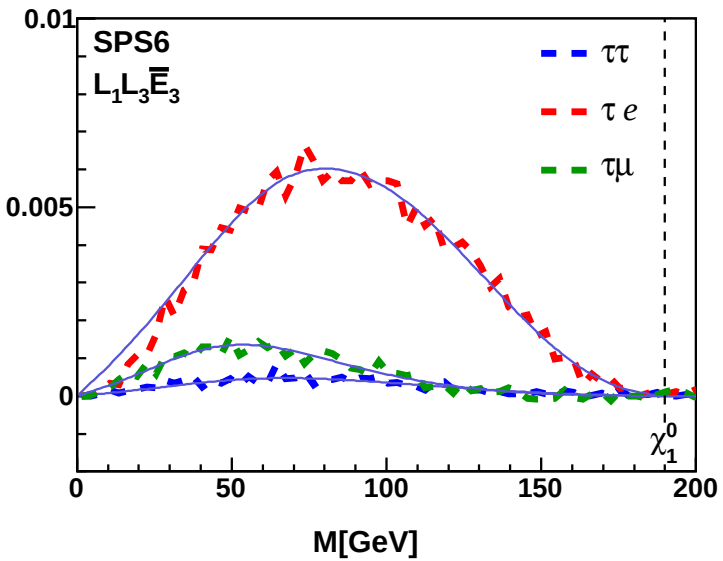

$LQ\bar{D}$

Neutralino $\longrightarrow$ lepton + 2 jets, neutrino + 2 jets

- $L_{1,2}Q_{1,2}\bar{D}_3 \Rightarrow$ lepton + b-jet + light jet
- taus $\Rightarrow$ loss of information (momentum) through neutrinos
- $Q_3 \Rightarrow$ only neutrino + 2 jets (at least one b-jet)

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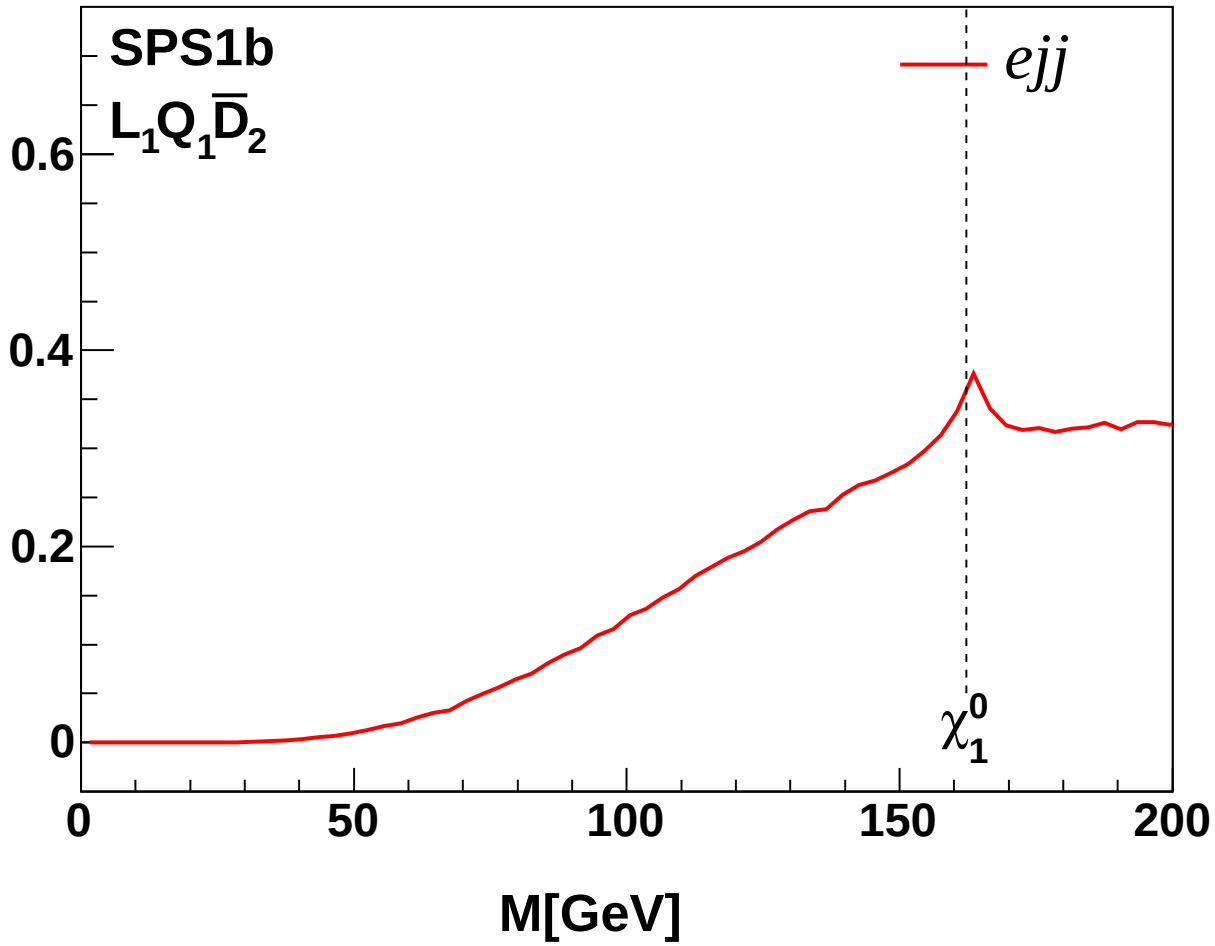
Need to suppress $t\bar{t}$ background; require 2 Same-sign leptons.

Invariant Masses – $L_1 Q_1 \bar{D}_2$: electron - 2 jets



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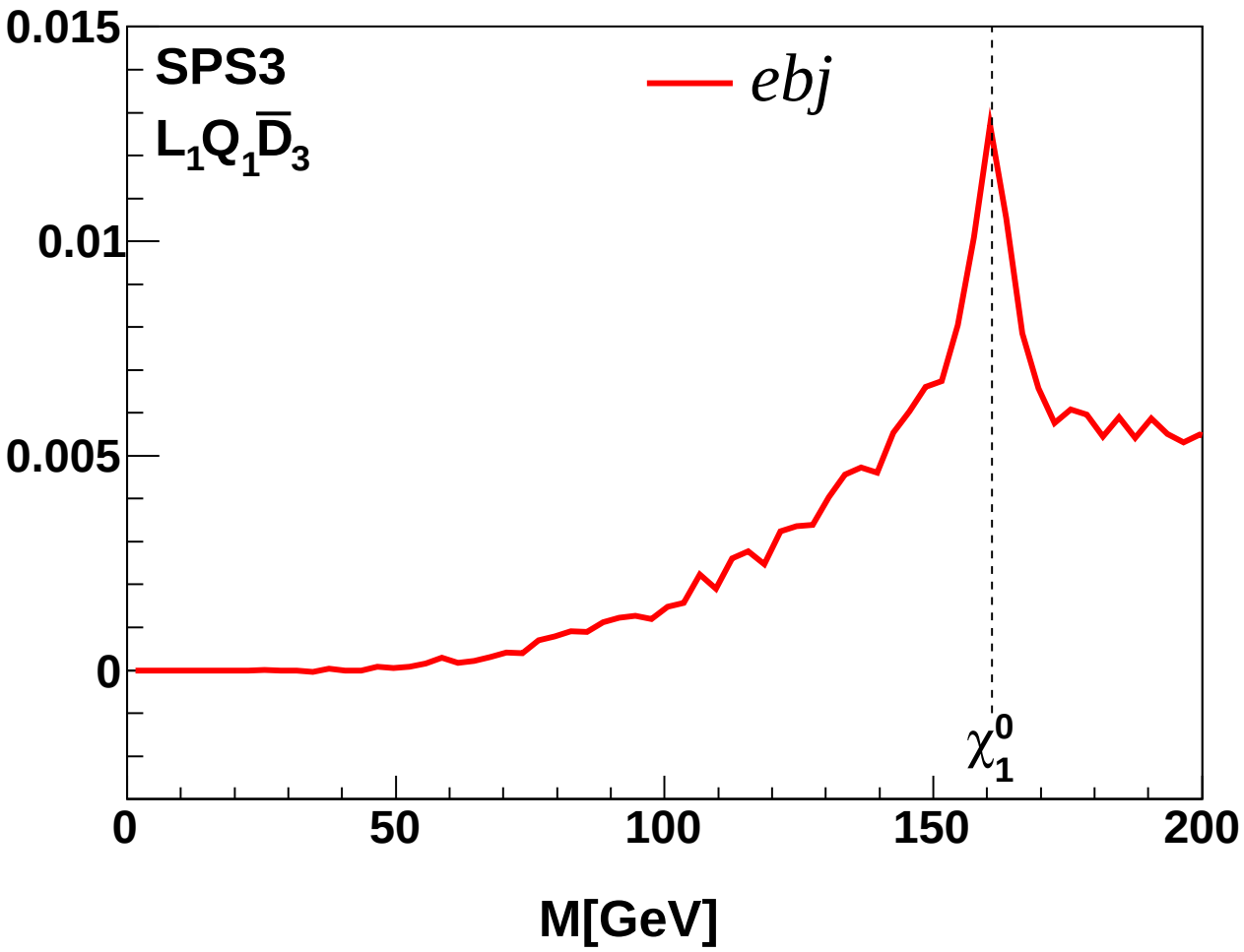
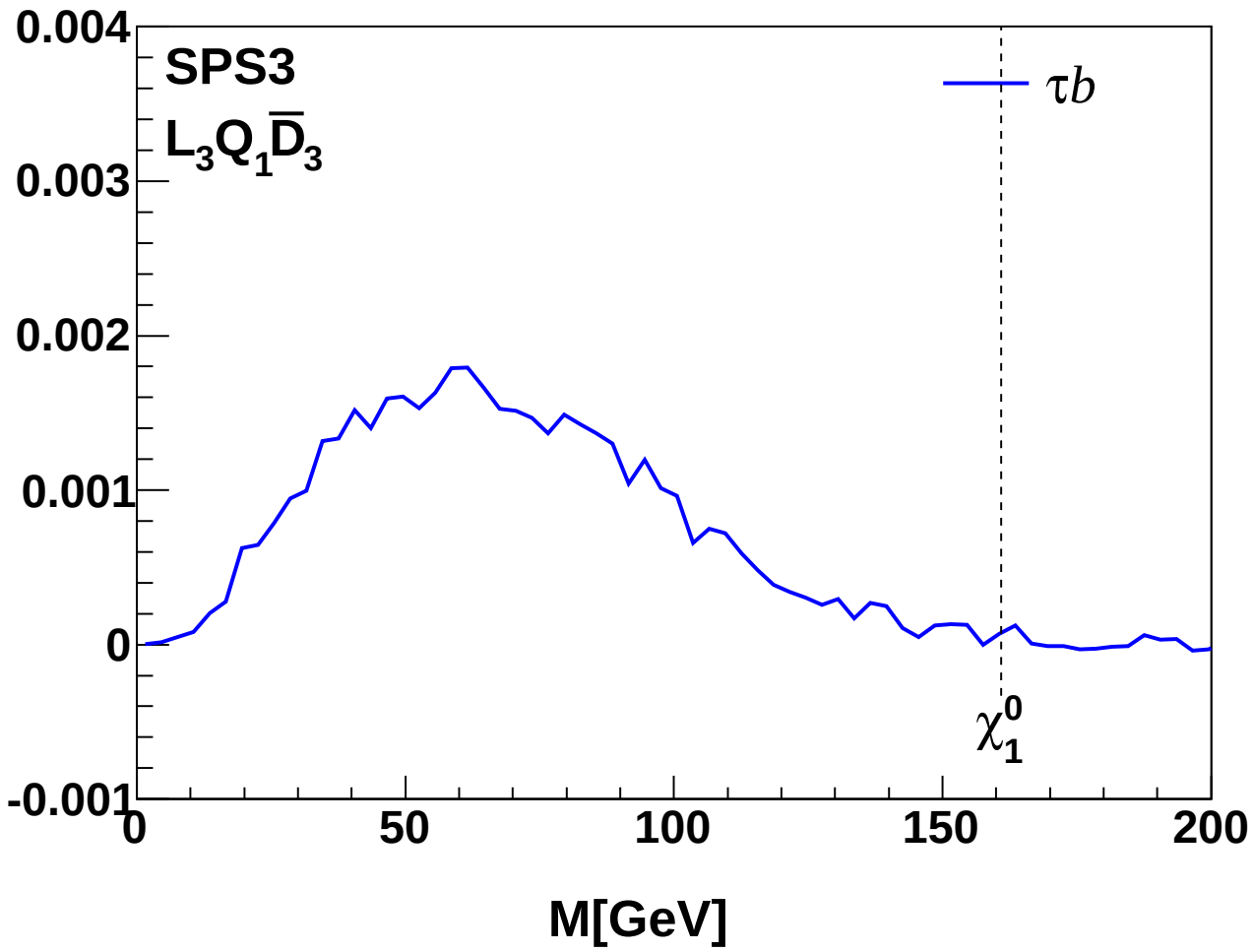


Invariant Masses – $L_3 Q_1 \bar{D}_3$: tau-jet - b-jet



$\bar{U}\bar{D}\bar{D}$

Difficult! : $\chi_1^0 \rightarrow$ 3 jets

Exception: $\bar{U}_3 \Rightarrow \begin{cases} M_{\chi_1^0} < M_{top} & \Rightarrow \quad \chi_1^0 \text{ escapes} \\ M_{\chi_1^0} > M_{top} & \Rightarrow \quad \chi_1^0 \rightarrow t(\bar{t}) + 2 \text{ (soft) jets} \end{cases}$

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What can we identify?

coupling	identifiable	remark
$LL\bar{E}$	✓	For all flavours
$L_{1,2}Q\bar{D}$	✓	Cannot identify light quark flavors
$L_3Q\bar{D}$	?	More difficult with τ
$LQ\bar{D}_3$	✓	Better identification with b-jet
$LQ_3\bar{D}$	?	No charged lepton
$\bar{U}_{1,2}\bar{D}\bar{D}$	✓	But difficult
$\bar{U}_3\bar{D}\bar{D}$	✓(?)	Only if $M_{\chi_1^0} > M_{top}$

Conclusions

- Three-body decays of the neutralino allows us to study all 45 trilinear R-Parity violating operators simultaneously and to measure flavour hierarchies.
- Most operators can be successfully detected and the neutralino mass can be measured.
- Difficult cases include $L_3 Q \bar{D}$, $L Q_3 \bar{D}$ and some cases with $\bar{U}\bar{D}\bar{D}$.
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