Simplified SUSY Model with MadGraph

~For Same-Sign Dilepton & Trilepton Search~

Characterization of New Physics at the LHC II

November 6, 2010

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With contributions from Johan Alwall (National Taiwan U), Arvind Rajaraman (UC Irvine)

Thanks to Konstantin Matchev (U. Florida) for the discussions

Introduction

- The UCI group has been involved in **the Same-Sign Dilepton** and **trilepton analysis** (SUSY, UED, 4th-generation quarks, heavy majorana neutrinos,...),
- Currently developing **model-independent strategies**
  - Simplified SUSY models: *J.Alwall et al., Phys. Rev. D 79, 075020 (2009)*
  - S.Dube et al.,http://arxiv.org/abs/0808.1605
- **Constructed a Simplified SUSY model framework within MadGraph** in collaboration with Johan Alwall, Arvind Rajaraman

Simplified SUSY Model

- Will mention in the context of sparticles, but the strategy can easily be converted to other models (e.g. UED)
- Assumptions: R-parity conservation, spins of sparticles
- Not considering any *specific SUSY models*
- Parameters: **Sparticle masses, cross sections * branching ratios**
- **For same-sign dilepton & multi-lepton search**
  - **charginos/neutralinos**, **sleptons** are the sources of leptons
  - **gluinos**, **squarks** can be initially pair-produced with high rate due to strong interactions
- Consider events with simpler cascade decays as starting points

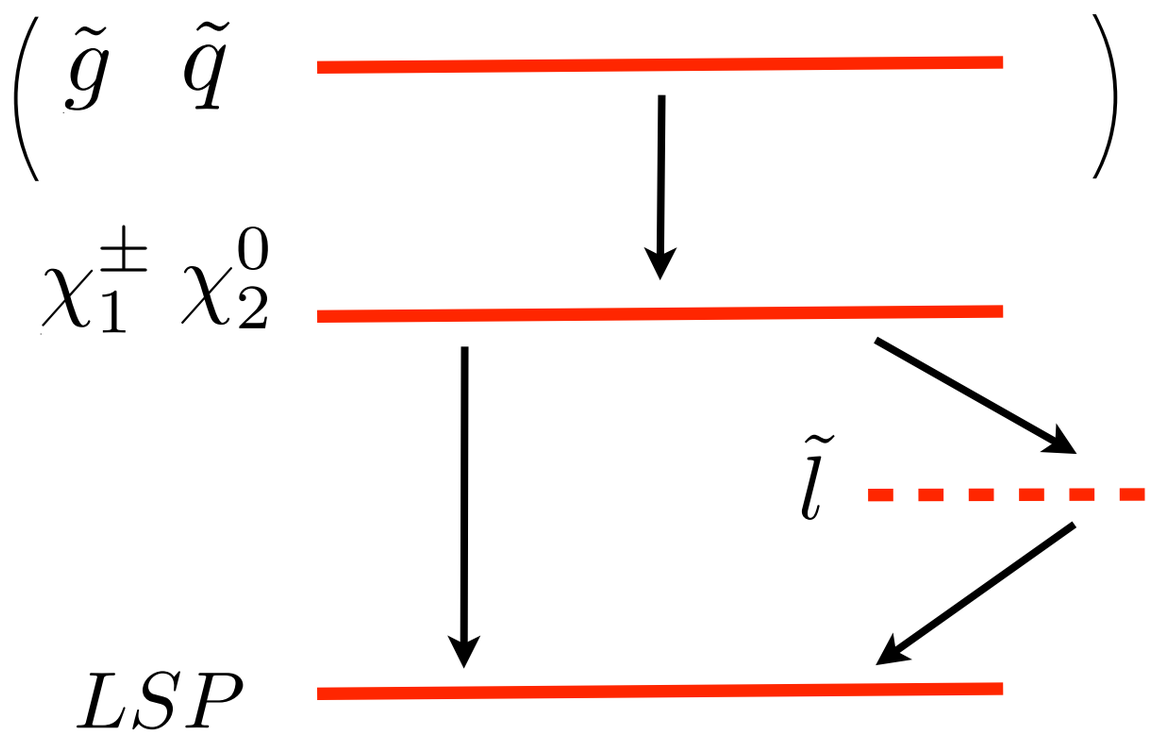
Madgraph & BRIDGE

- Simplified model in Madgraph
  - Less sparticles (one generation of squarks, sleptons)
  - Interactions between sparticles/particles are simplified accordingly
- **Only initial sparticle pair productions** are done with Madgraph
- **The following decay chains are handled with BRIDGE/DECAY**
- This is attractive, since **we can selectively produce MC samples only for the decay chains of our interest**
  → *useful when we do mass-grid productions to gain statistics*

Inclusive/Exclusive SSDilep

- Signals can be grouped into 2 categories
  - **Trilepton including 2 SS leptons:** share the same signals as the trilepton search
  - **Exactly 2 leptons with the same charge**

Overview of Processes



Acceptance will be a function of masses: $\alpha(M_0,M_1,M_2,M_3)$ or $\alpha(M_1,M_2,M_3)$
→ will be extracted from the simulation

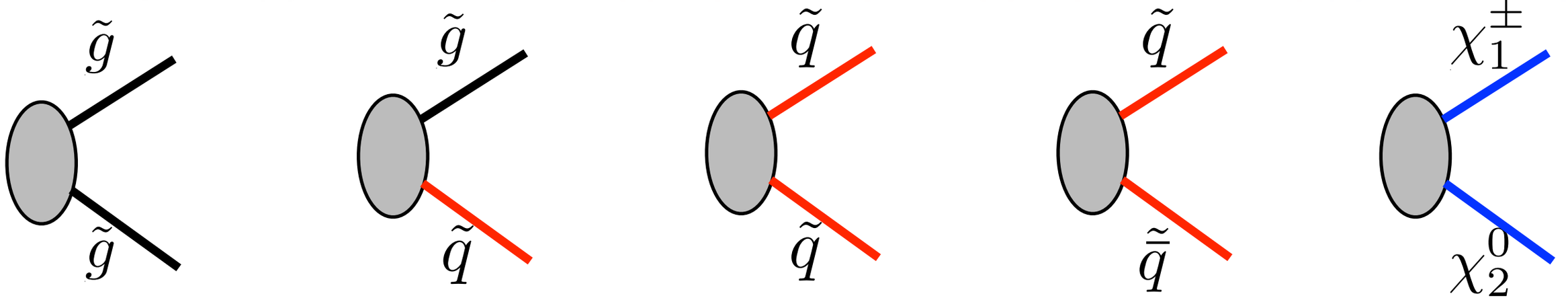
Only modes contributing to the final state of our interest are chosen

- **<u>Decays will go through weakinos for all the channels</u>**
- There can be intermediate state depending on the slepton mass
- Assume $\chi_1^{\pm}$ mass ~ χ_2^0 mass as the first step (corresponds to Mode A of trilepton modules in lhcnewphysics.org)

Initial Pair-Production

Handled in Madgraph

(1) Gluino-pair **(2) Gluino-squark** **(3) Squark-squark** **(4) Squark-antisq** **(5) weakino-pair**



- 5 sets of initial pair-productions we have in mind
- **All (1)-(5) contribute to trilepton**, **(1)-(3) to exclusive SS dilep**
- Concentrate on signatures without *t* & *b*'s (*i.e.* light-flavor squarks)
- Depending on the mass relation of gluino, squark, and weakino, we can narrow down to less sets of productions

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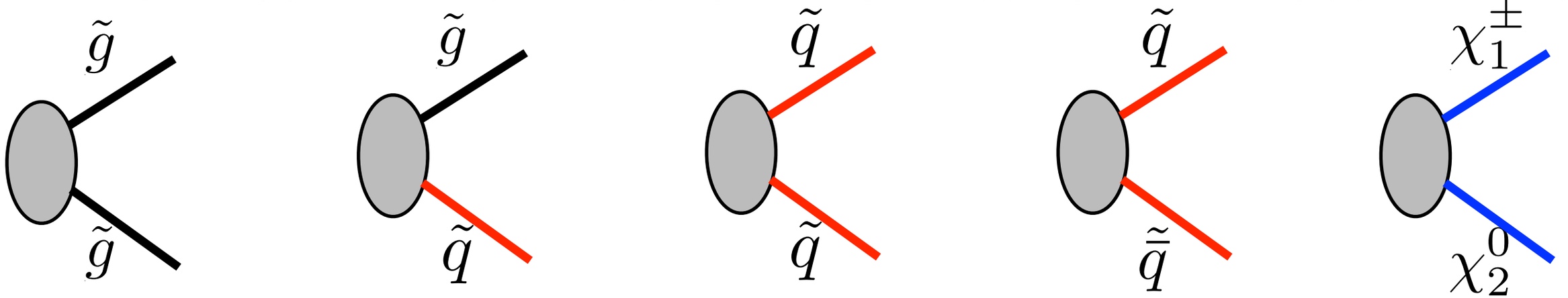

- ***m(gluino) ~ m(squark)*** **>> m($\chi_1^{\pm}$) : (5)**
- ***m(gluino) ~ m($\chi_1^{\pm}$)*** **<< *m(squark)* : (1),(5)**
- ***m(gluino)*** **>> *m(squark) ~ m($\chi_1^{\pm}$)*** **: (3)-(5)**
- ***m(gluino) ~ m(squark) ~ m($\chi_1^{\pm}$)*** **: (1)-(5)**

"~" can differ by a couple of factor

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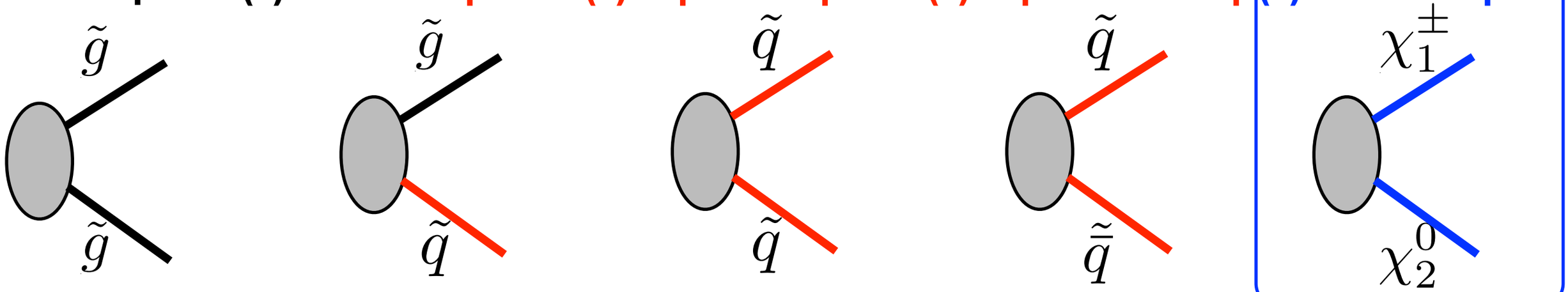

- ***m(gluino) ~ m(squark) >> m($\chi_1^{\pm}$) :*** **(5)**
- ***m(gluino) ~ m($\chi_1^{\pm}$) << m(squark) :*** **(1),(5)**
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Initial Pair-Production

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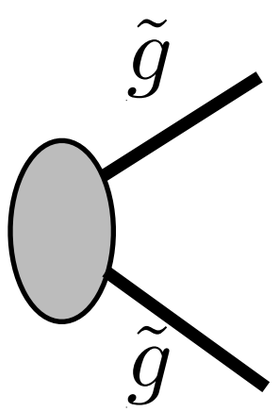
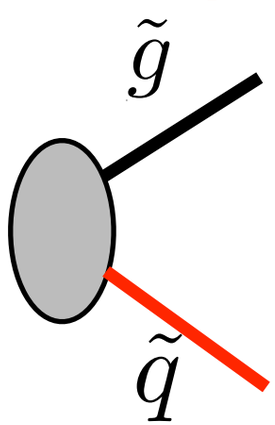
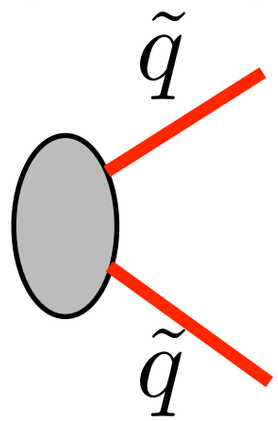


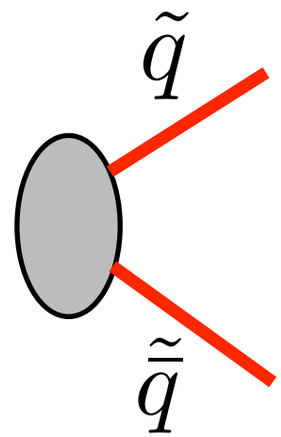
(2) Gluino-squark



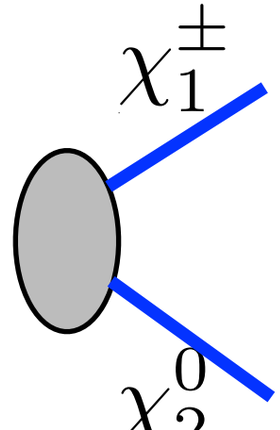
(3) Squark-squark



(4) Squark-antisq



(5) weakino-pair



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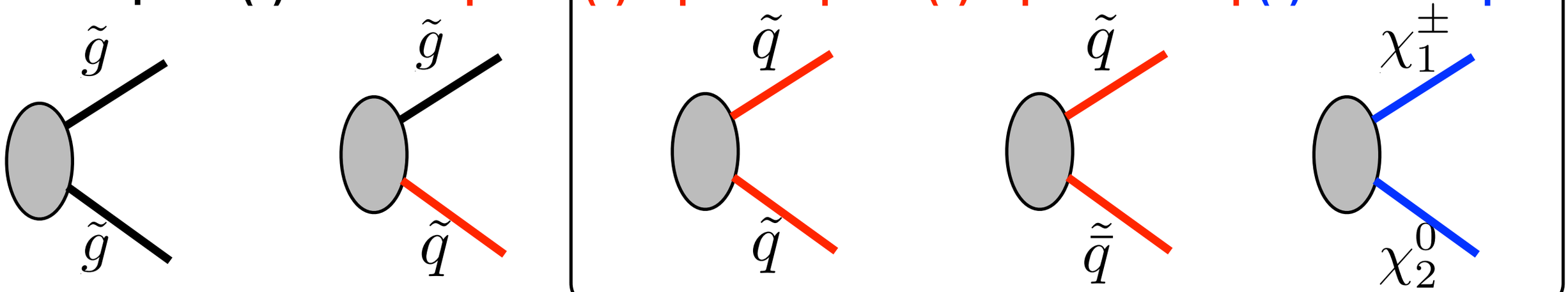

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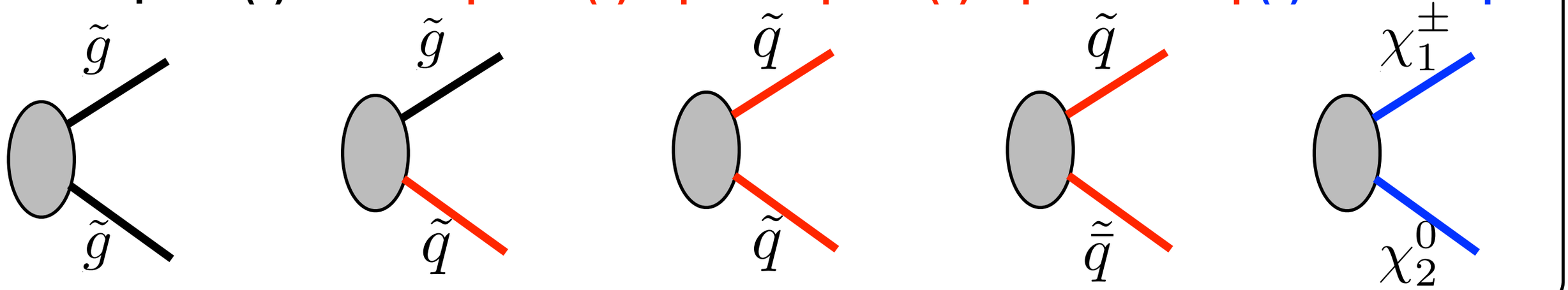

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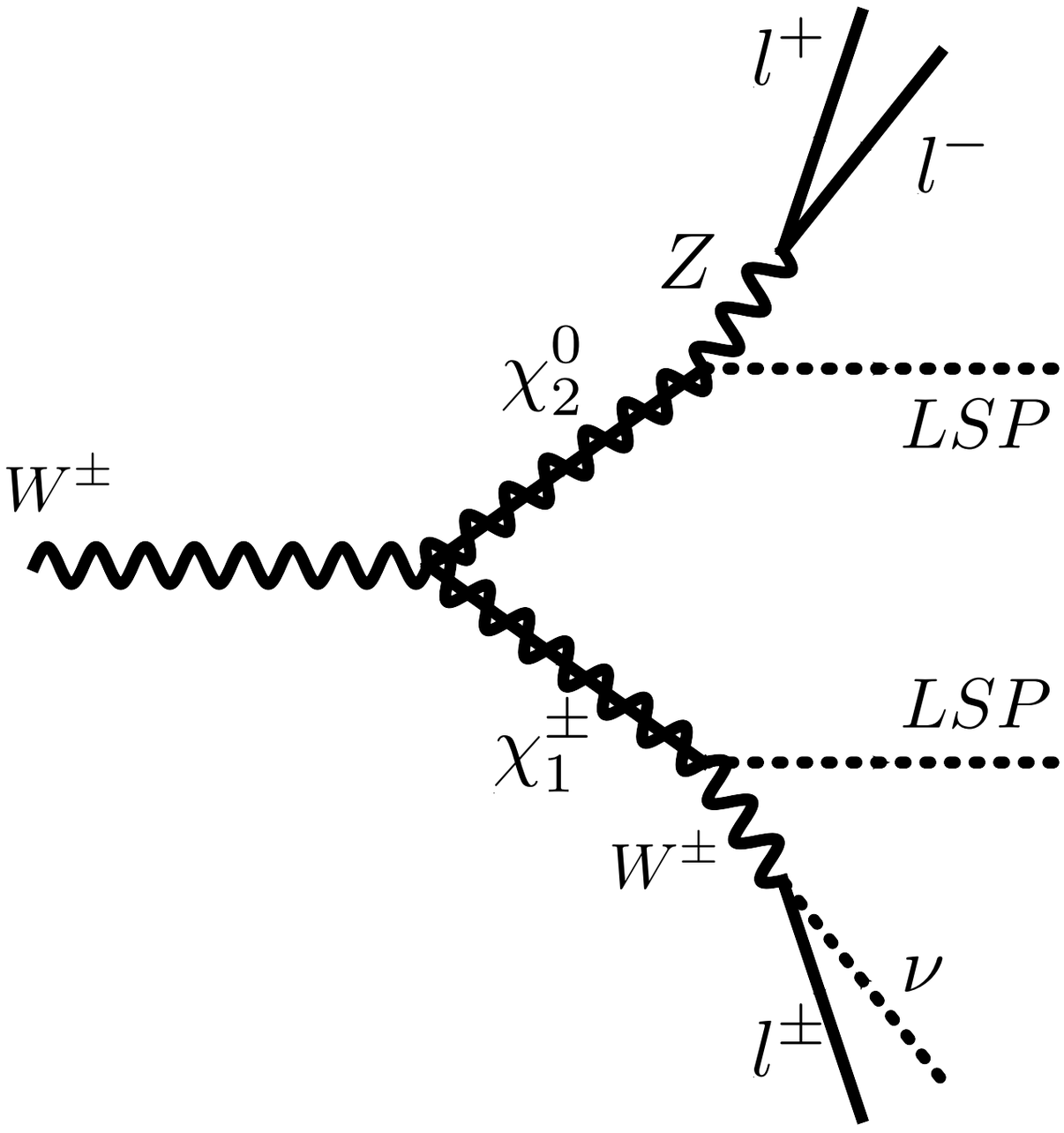
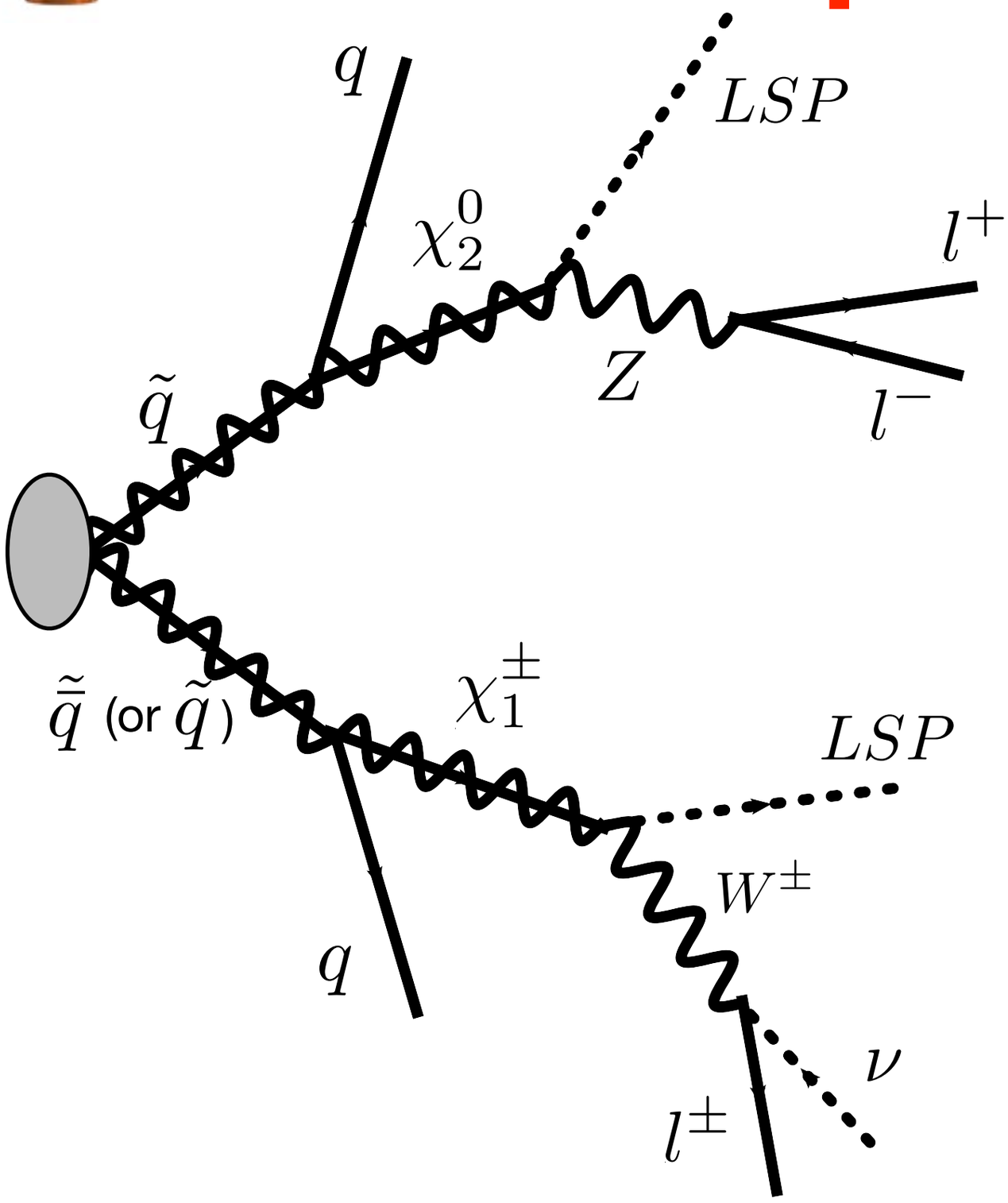
Event Topology (5)



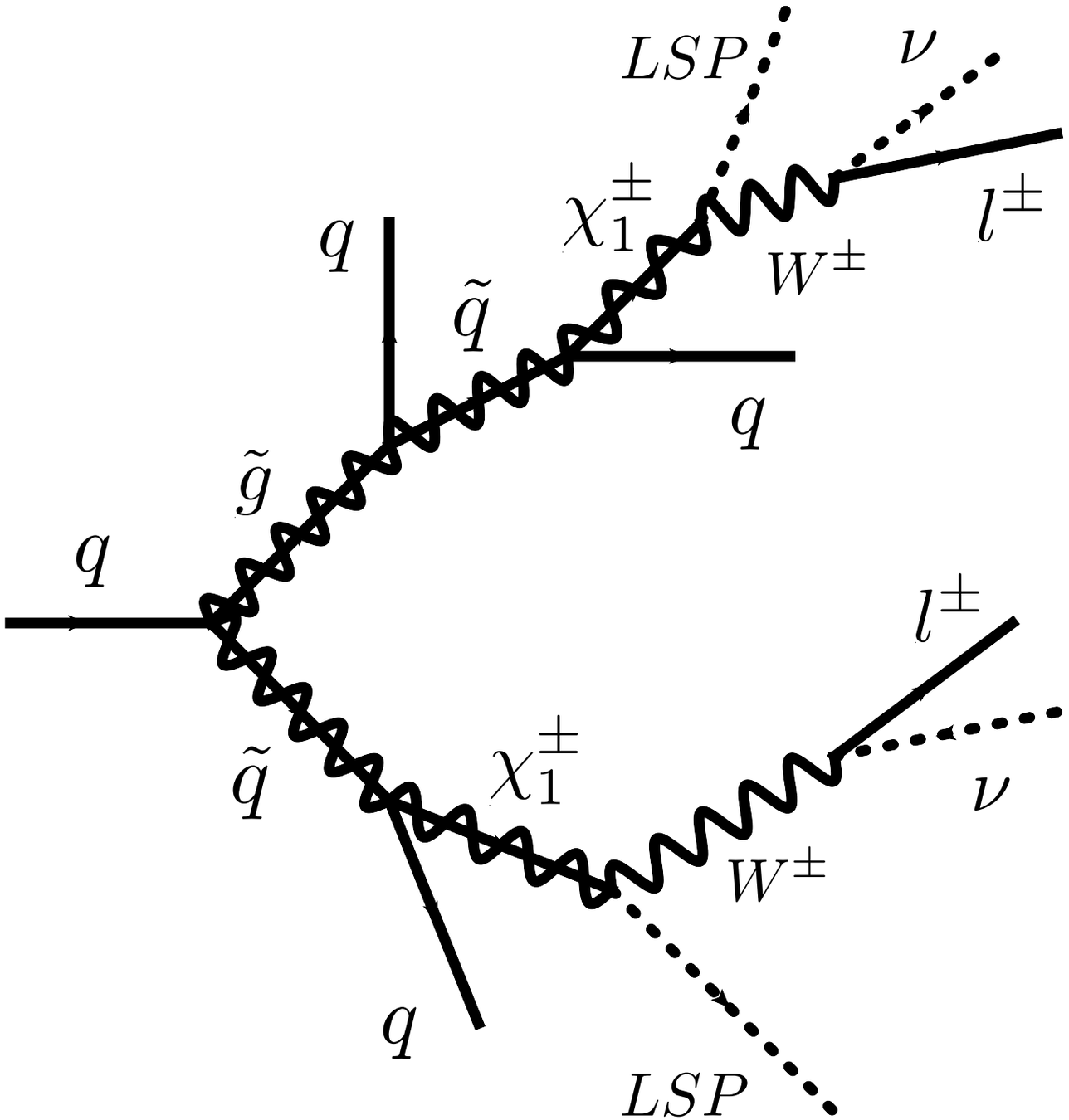
- Here, only showing the diagram with weakinos directly decaying to LSP (slepton can enter as an intermediate state)
- We assume $m(\chi_1^\pm) \approx m(\chi_2^0)$ as a starting point
- In this event topology, only **3 mass parameters** (**wino, slepton** & **LSP**)
- Contributes to trilepton & inclusive SS dilep

Event Topology (3),(4)



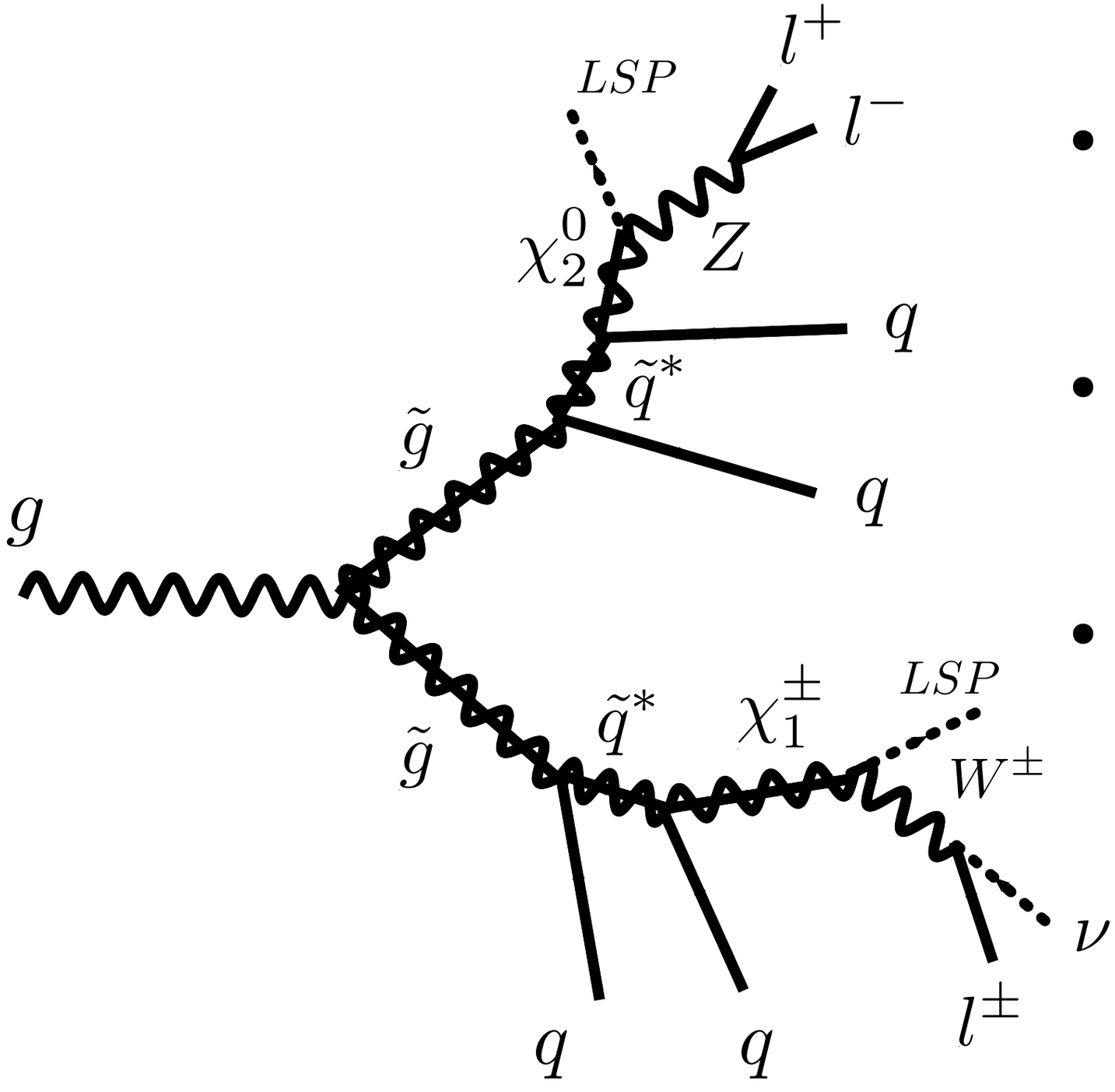
- Here, only showing the diagram with weakinos directly decaying to LSP
- In our simplified model, m(u-squark) ≈ m(d-squark) & $m(\chi_1^\pm) \approx m(\chi_2^0)$
- Stops are treated separately due to significant differences in the event features
- Squark decay-sets can be $(\chi_1^\pm, \chi_2^0)$ or $(\chi_1^\pm, \chi_1^\pm)$
- **4 mass parameters** (**squarks**, **wino**, **slepton** & **LSP**)

Event Topology (2)



- Here, only showing the diagram with weakinos directly decaying to LSP
- We can set m(gluino) ≈ m (squark) as a starting point
- **4 mass parameters** (**gluino**, **wino, slepton** & **LSP**)

Event Topology (1)



- Here, only showing the diagram with weakinos directly decaying to LSP
- **4 or 5 mass parameters : gluino**, (**squark), wino, slepton** & **LSP**
- Effects of squark mass can be included in the branching ratio

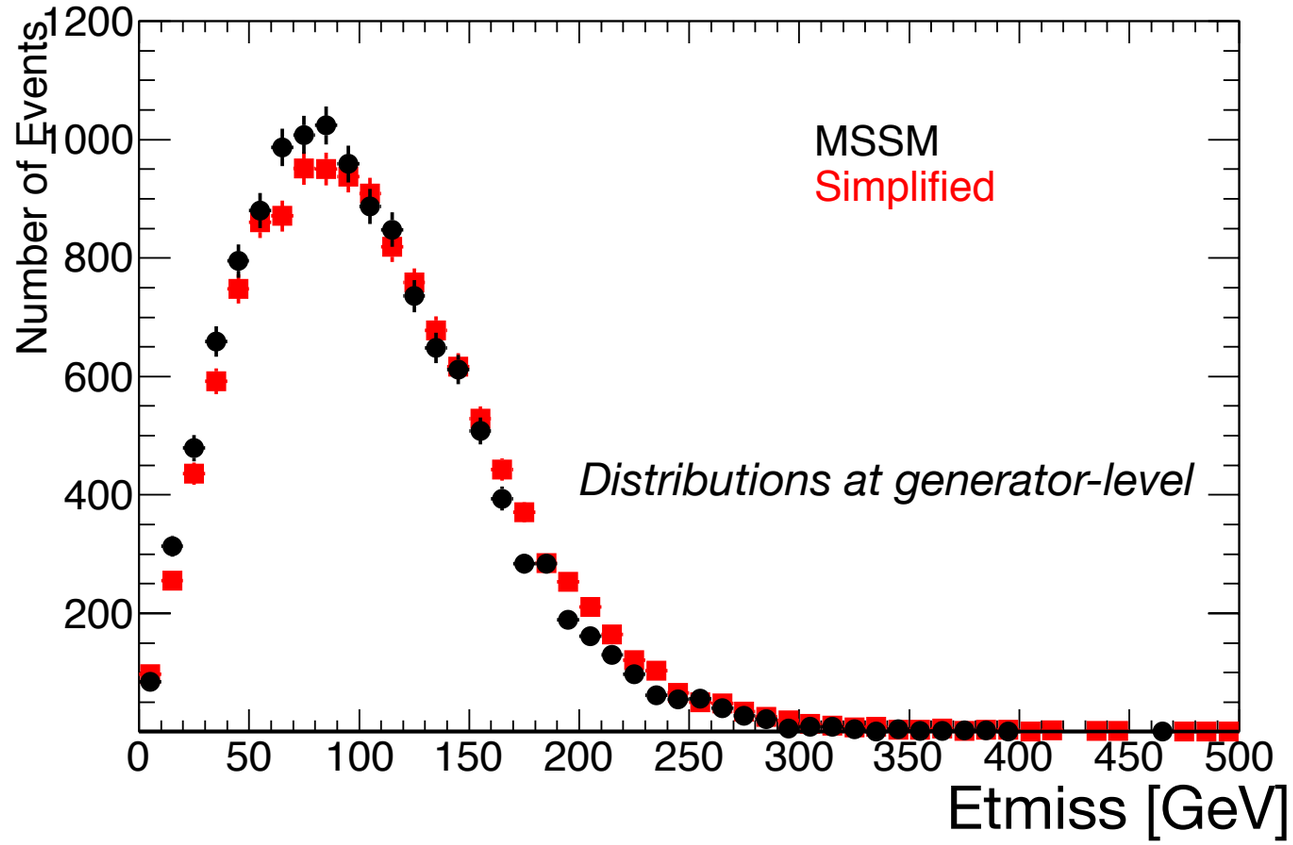
Questions & Strategies

- Is simplified model reliable? Does it describe the kinematics successfully? → see the next slides

- There still are several event topologies contributing to the SS dilepton & trilepton final state. How do we perform searches? → we can coherently search topology-by-topology across the different final states (SS dilep/trilep)

Kinematic Distributions

~ Simplified vs MSSM ~



Checked with gluino pair production processes (decaying to $\chi_1^{\pm}$, χ_2^0)

Event Selection

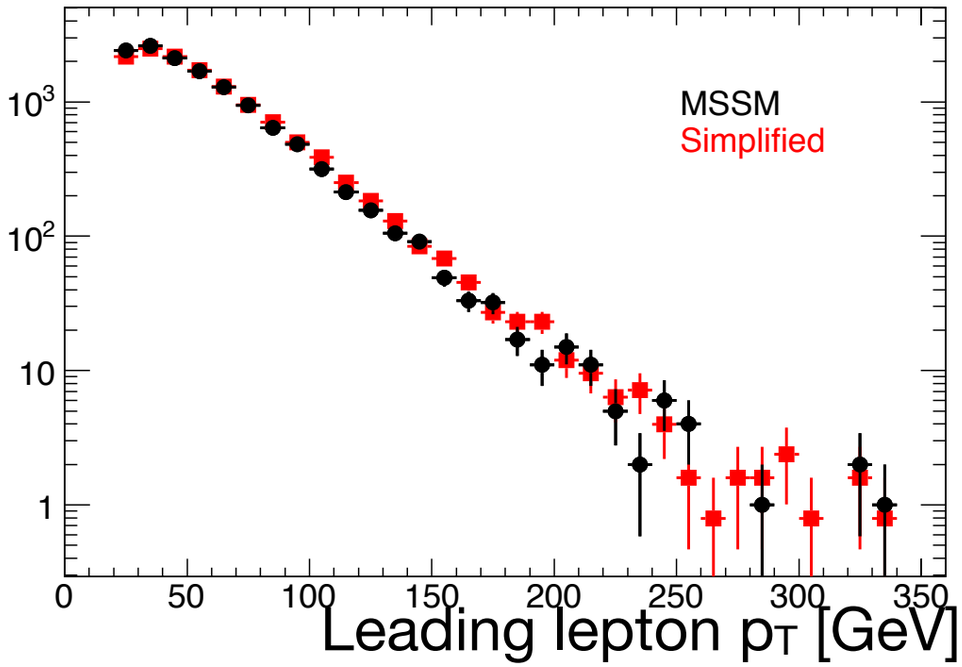
- 2 leptons (e,μ) with the same charge
- Leading lepton p_T>20 GeV, |η|<2.5
- 2nd leading lepton p_T>10 GeV, |η|<2.5
- No 3rd lepton veto (inclusive search)

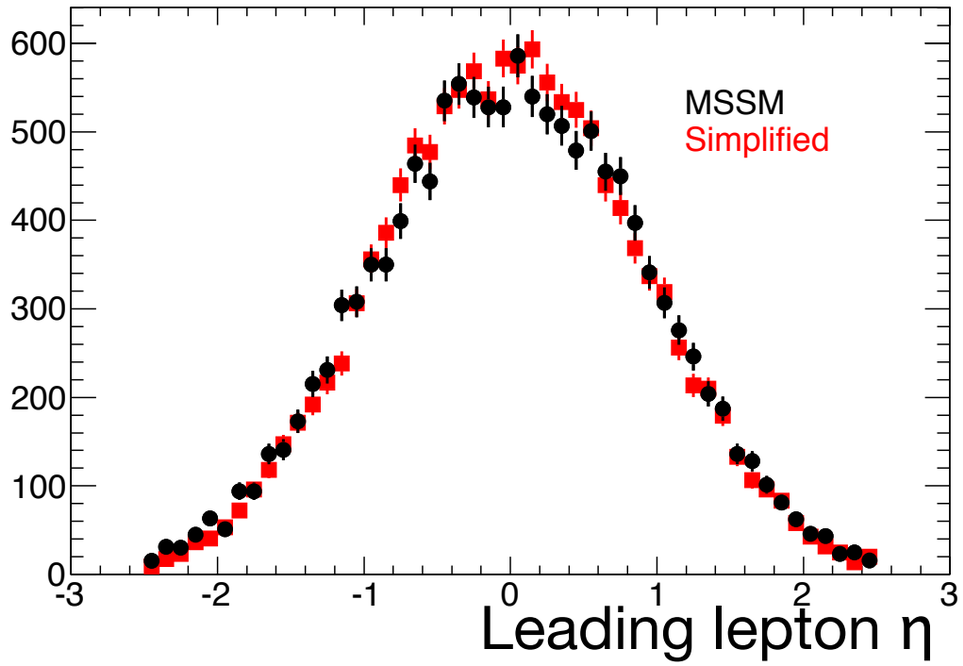
- Same masses for gluino, LSP.
- Simplified wino mass = average of $\chi_1^{\pm}$, χ_2^0 masses in MSSM
- Other heavy sparticle masses are about the same (~ 2 TeV) in Simplified & MSSM (could not put exactly the same)
- Kinematic distributions after this event selection are shown in the following slides

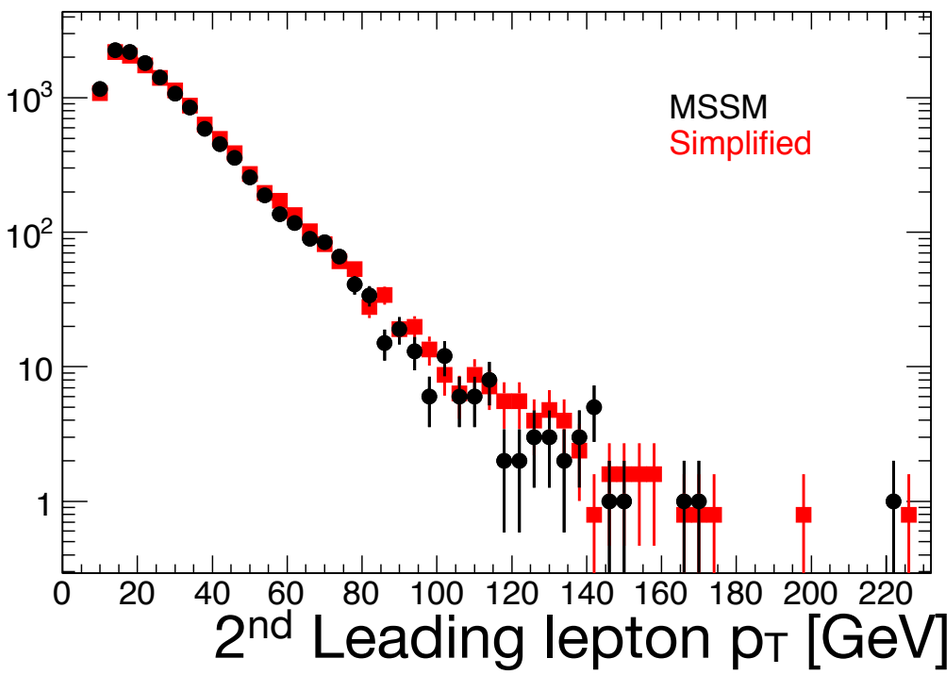
Kinematic Distributions

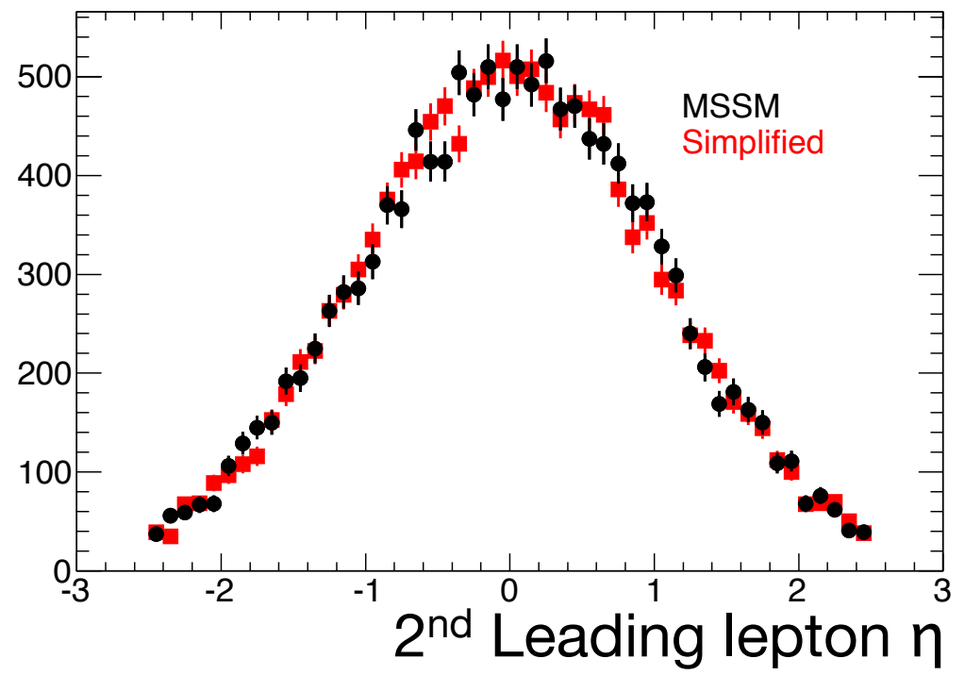
~ Simplified vs MSSM ~

Distributions at generator-level





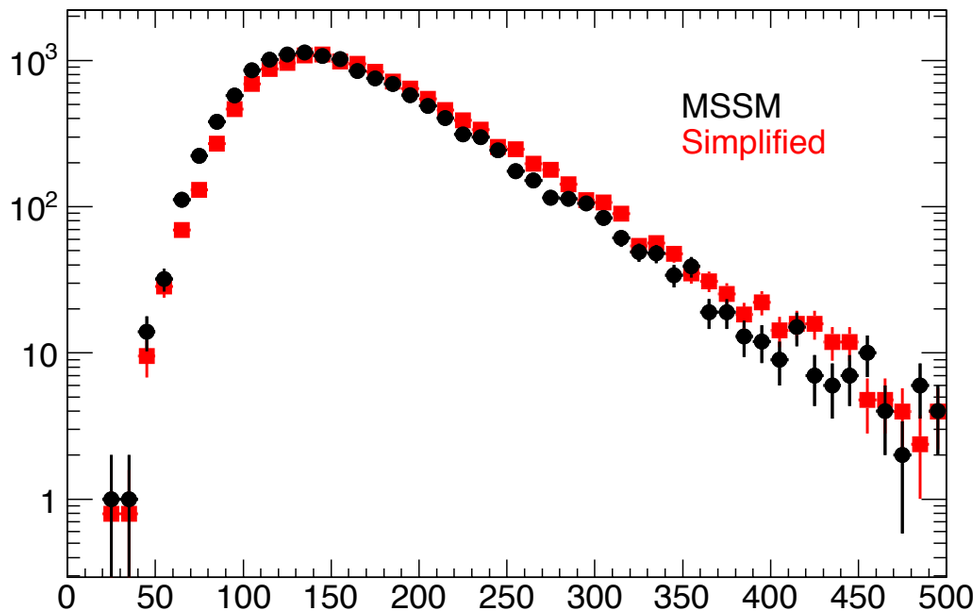


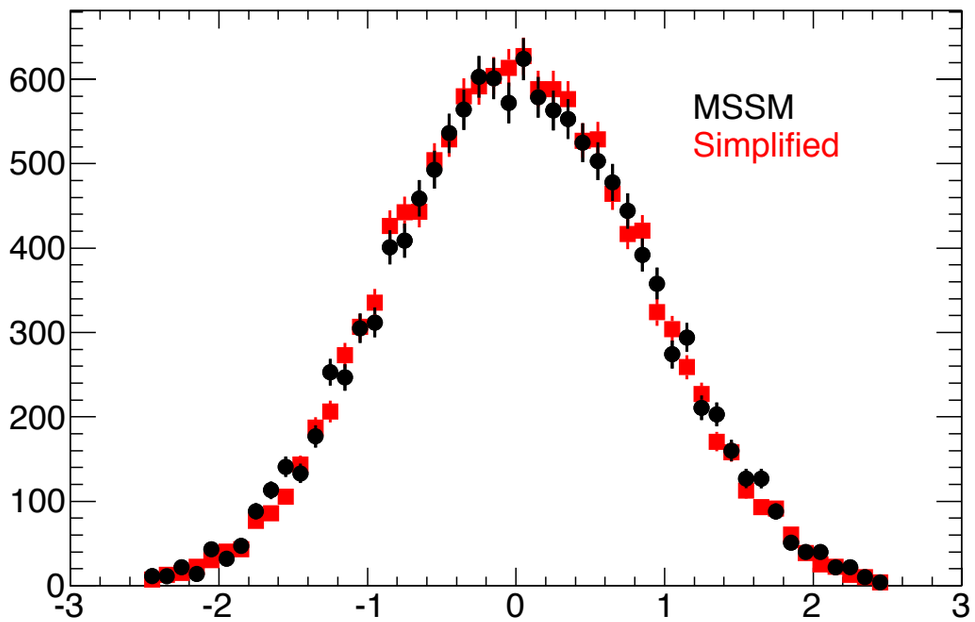


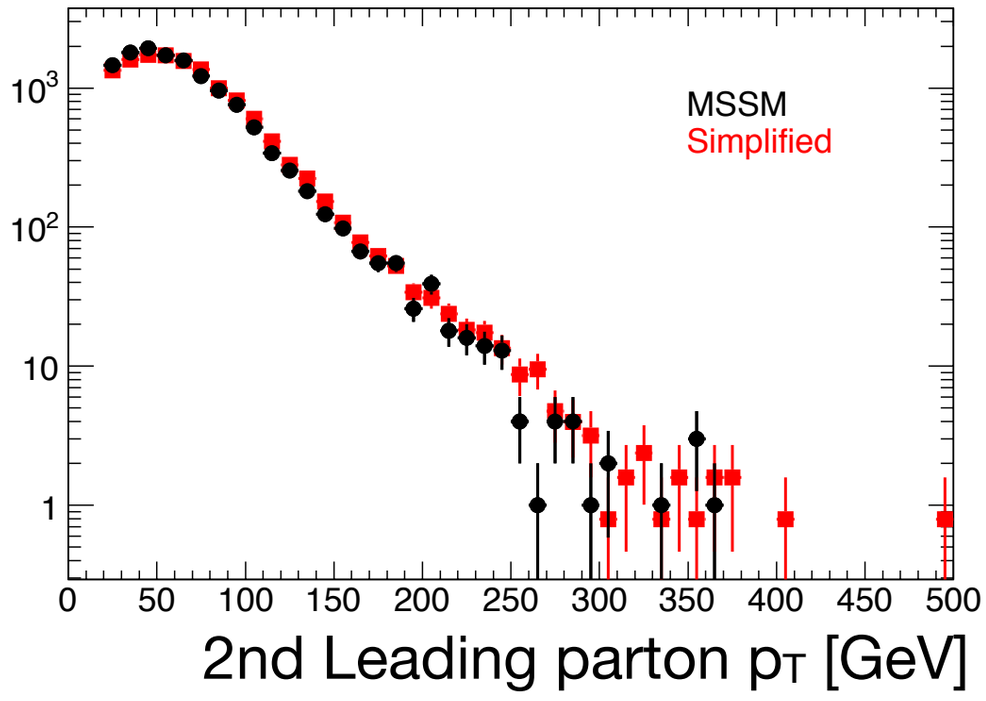
Kinematic Distributions

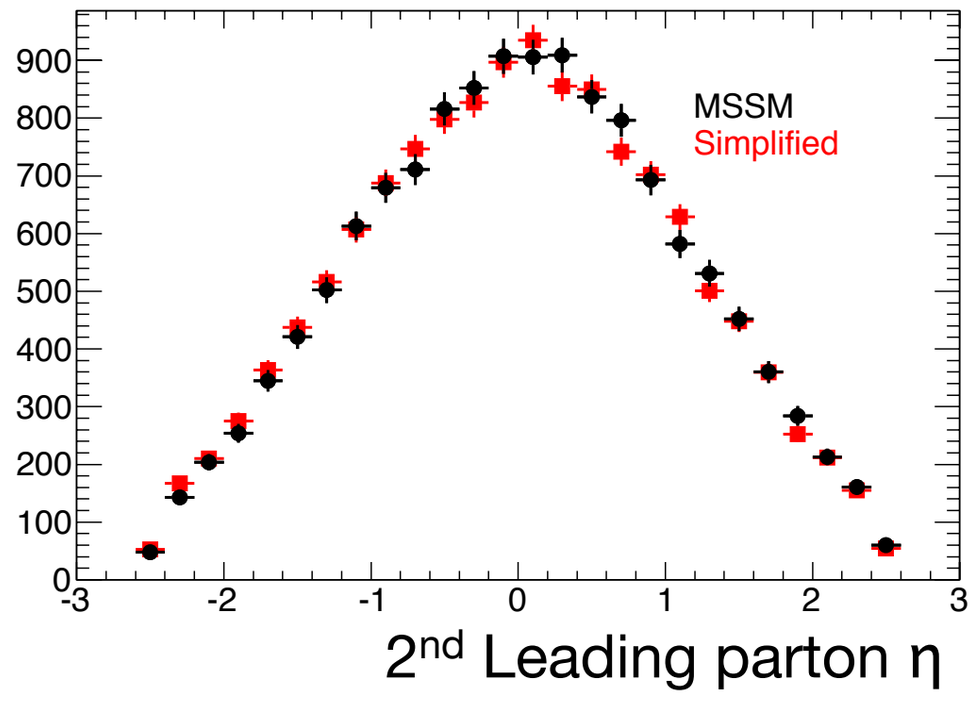
~ Simplified vs MSSM ~

Distributions at generator-level

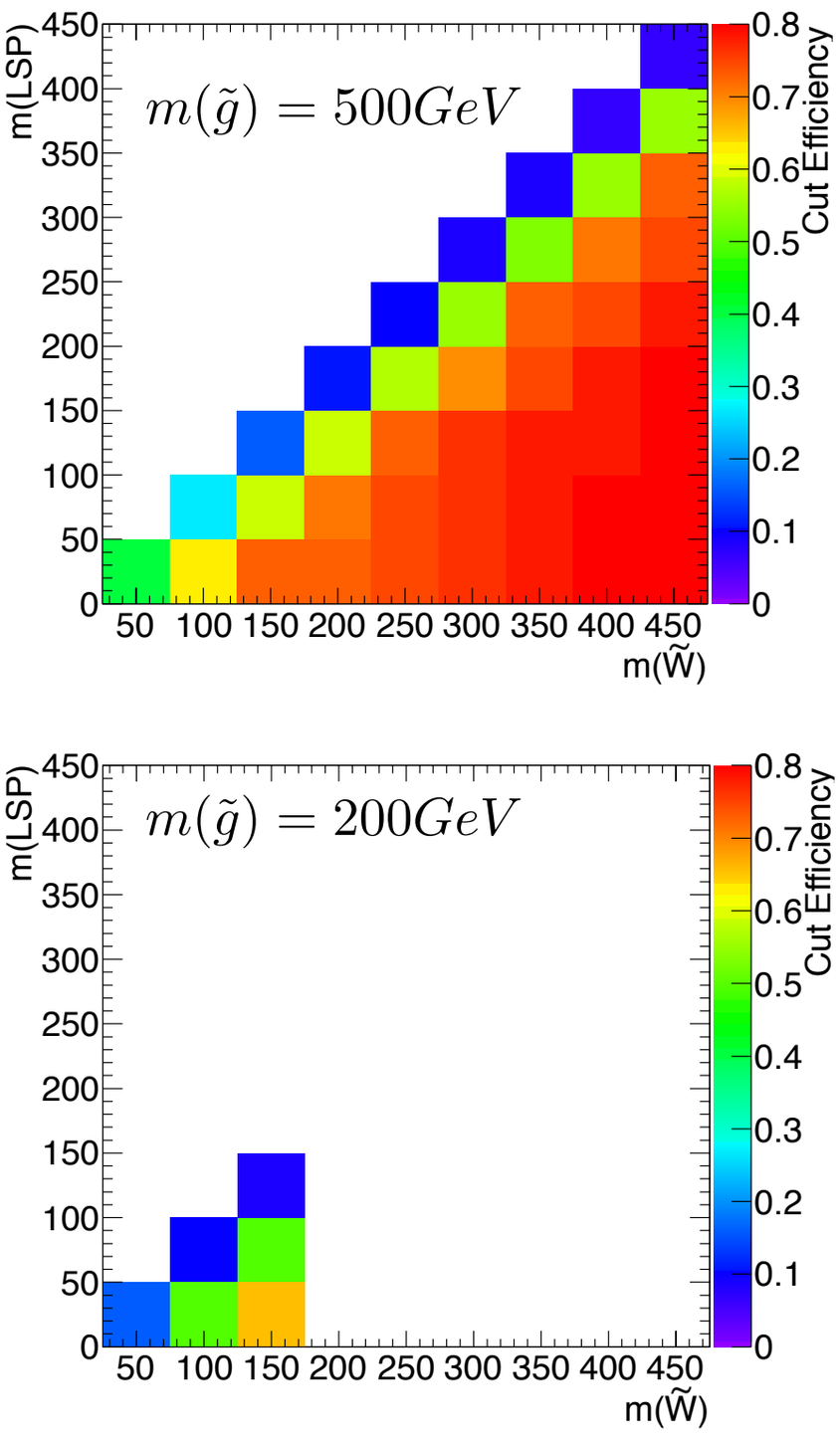


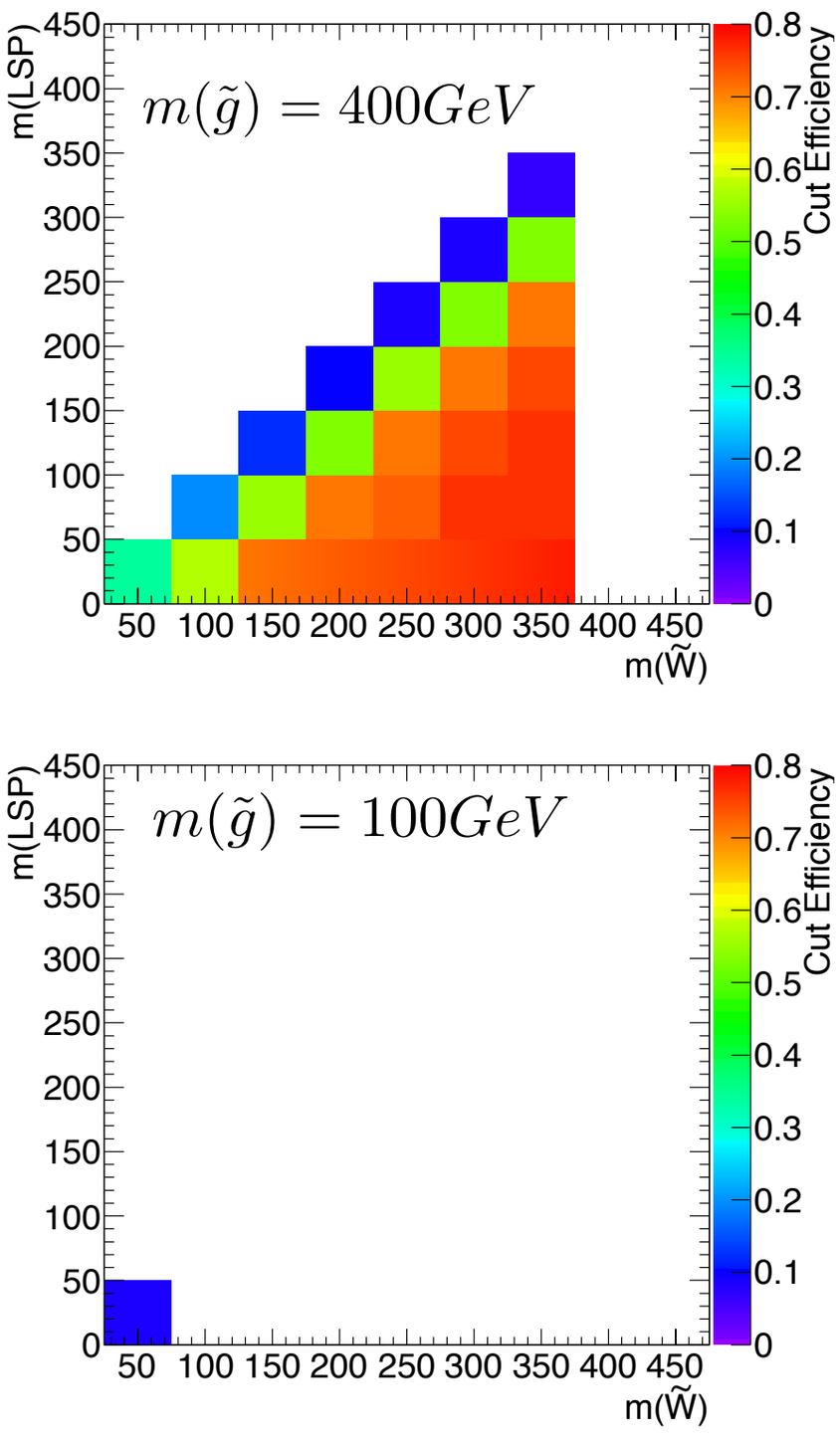


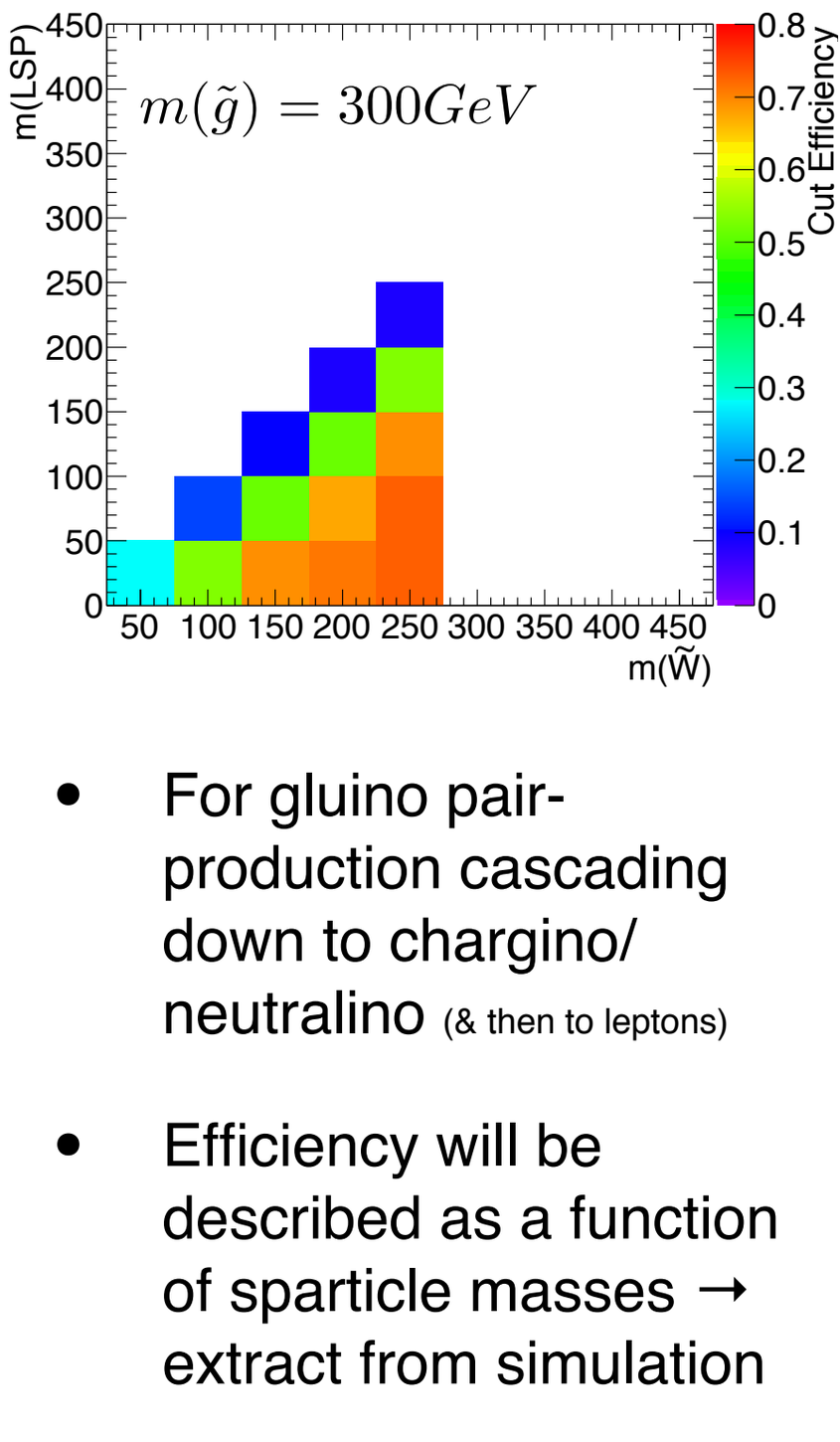




Efficiency of Cuts







- For gluino pair-production cascading down to chargino/ neutralino (& then to leptons)
- Efficiency will be described as a function of sparticle masses → extract from simulation

Summary

- Briefly described a strategy for model-independent searches with the simplified SUSY model for the same-sign dilepton & trilepton channel
- Similar approaches can be used for non-SUSY models
- Showed the event topologies of our interest and the lists of free parameters
- Checked the kinematics of the simplified model & MSSM with the same mass spectrum
- **The simplified model well reproduced various kinematics distributions** → **very promising** that the simplified model is robust against the event selections
- Acceptance was checked at the generator-level
- Searches can be coherently performed topology-by-topology across different final states

backups

Weakino Modes

- **Mode A: pp → $X_1^{\pm}X_2^0$**
- Mode B: pp → $X_1^{\pm}X_{LSP}$
- Mode C: pp → $X_1^{+/-}X_1^{-/+}$
- **Mode D: pp → $X_2^0X_2^0$**
- Mode E: pp → $X_{LSP}X_2^0$

- Spectrum 1: $M_{LSP} < M_{X2} < M_{X1\pm}$
- Spectrum 2: $M_{LSP} < M_{X1\pm} < M_{X2}$

T.Tait et al., "Trileptons in Electroweak-ino modules," lhcnewphysics.org

- Currently, 5 modes & 2 mass spectra proposed in lhcnewphysics.org
- B,C,D will only lead to SS dilep or trilepton signatures only when there is a sizable mass splitting between $X_1^{\pm}$ and X_2^0
- We will concentrate on Mode A in this talk, as we concentrate on nearly degenerate $X_1^{\pm}$ and X_2^0