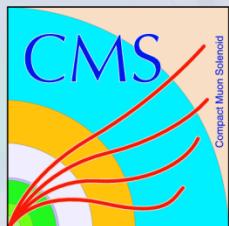


# Supersymmetry experimental scenarios at HL-LHC, following evidence/discovery in $300 \text{ fb}^{-1}$

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*Kenichi Hatakeyama*

*Baylor University*

*for the CMS and ATLAS Collaborations*



**Workshop on Physics at the High-Luminosity LHC**

*May 12, 2015*



# SUSY @ HL-LHC

- CMS and ATLAS have explored **two goals** of the HL-LHC SUSY program:
  - Mass reaches for discovery:
    - Strongly-produced SUSY
    - Weakly-produced SUSY
  - Explore how HL-LHC measurements can illuminate the spectrum of new particles to be discovered in Run 2+3: “Discovery story”

See Dominick's & Sacha's talks

## CMS:

- CMS-PAS-SUS-14-012, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS14012>
- CMS-PAS-FTR-13-014, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsFTR13014>
- CMS-NOTE-13-002, <http://arxiv.org/abs/1307.7135>

## ATLAS:

- ATL-PHYS-PUB-2014-010, <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2014-010>
- ATL-PHYS-PUB-2013-011, <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2013-011>

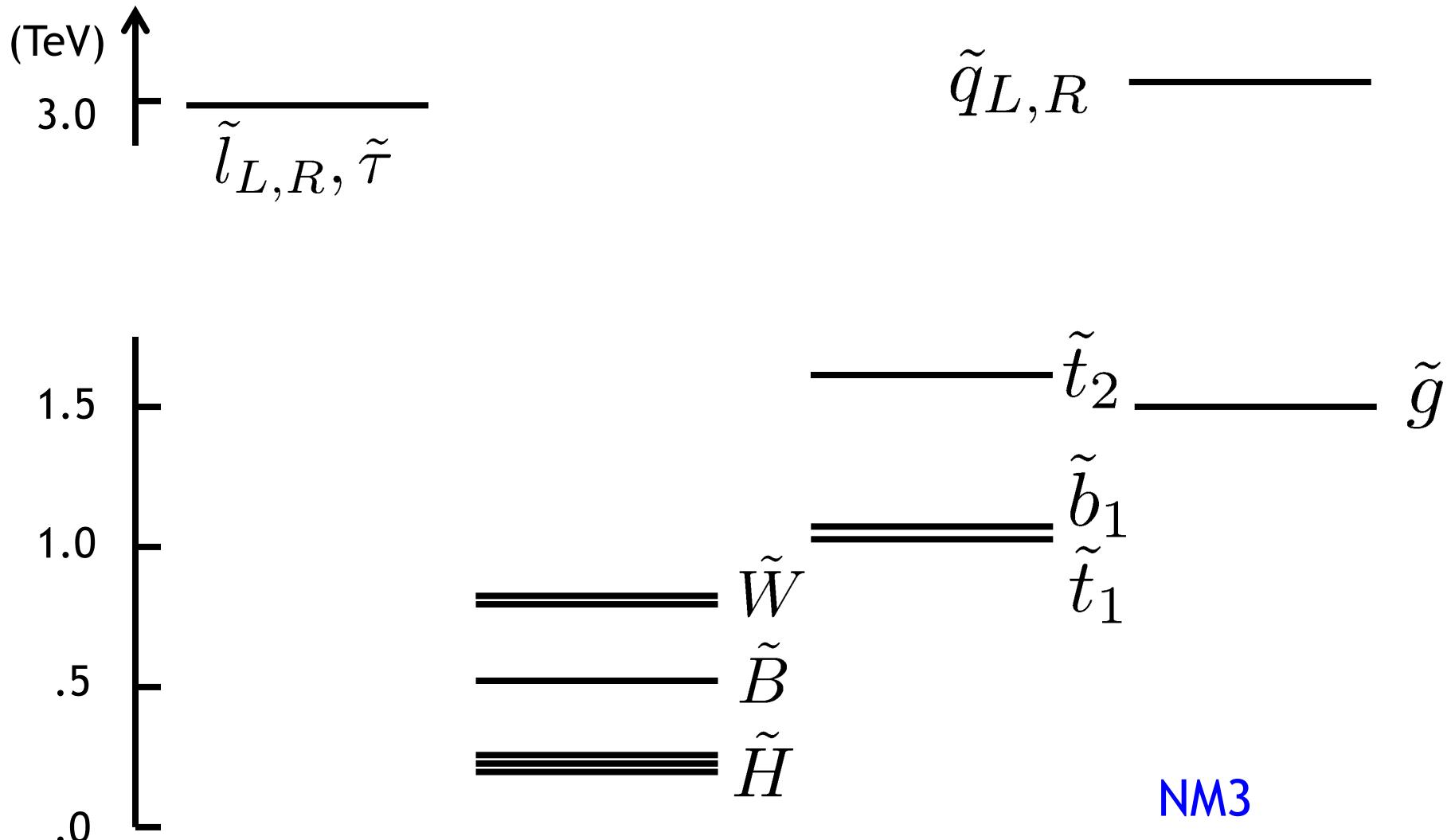


# Benchmark SUSY Models

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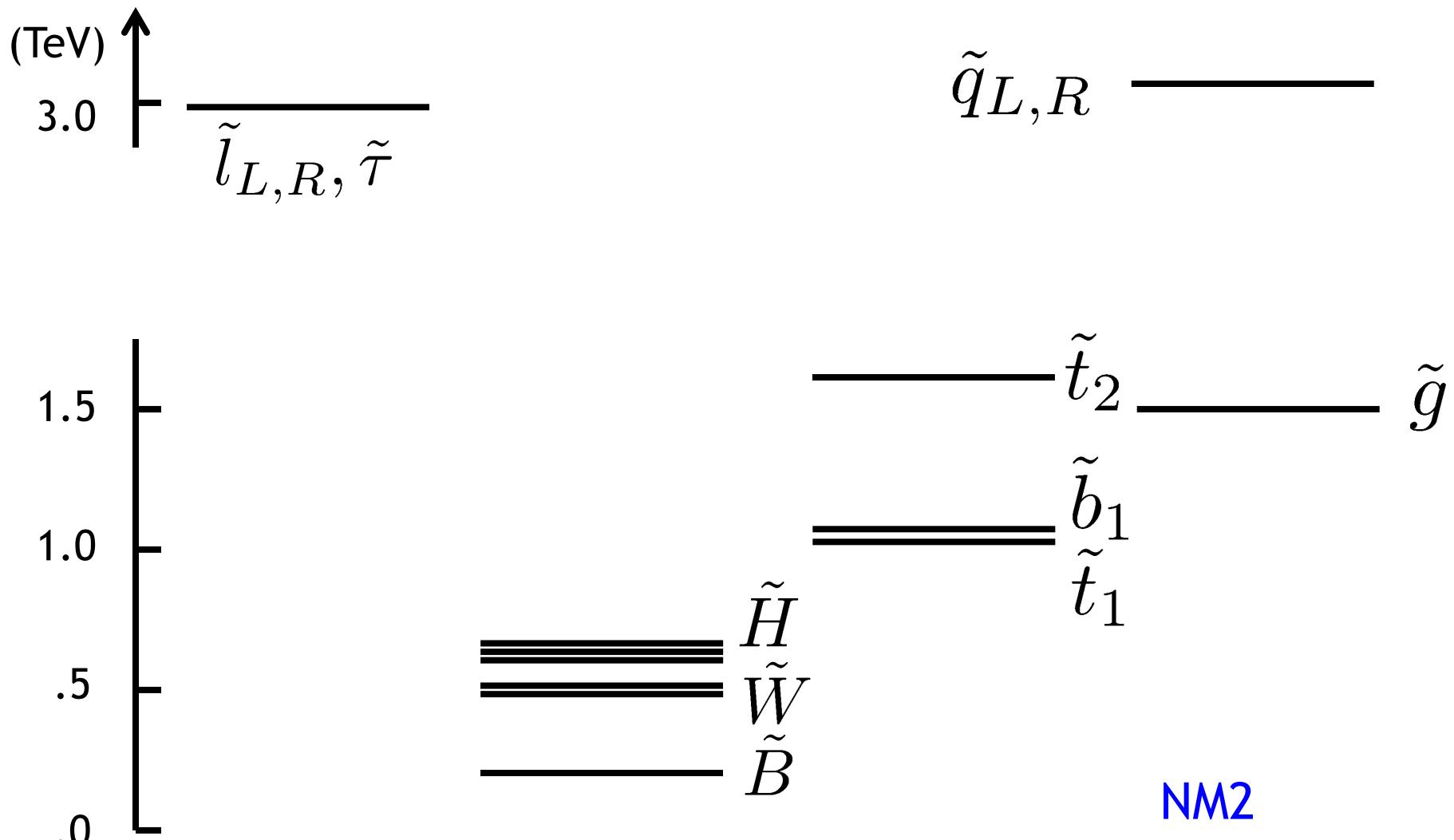
- Five benchmark full-spectrum SUSY models were constructed
  - The model should not be already excluded
    - The model should not be already excluded by existing SUSY & BSM higgs searches, and be consistent with existing measurements of the 125 GeV higgs, relic density, etc.
  - The model should contain production and decay channels that could be discovered with up to  $300 \text{ fb}^{-1}$
  - The model should be well theoretically motivated
    - Natural SUSY inspired models (NM's) and co-annihilation models motivated by dark matter

# Natural SUSY Models (NM's)



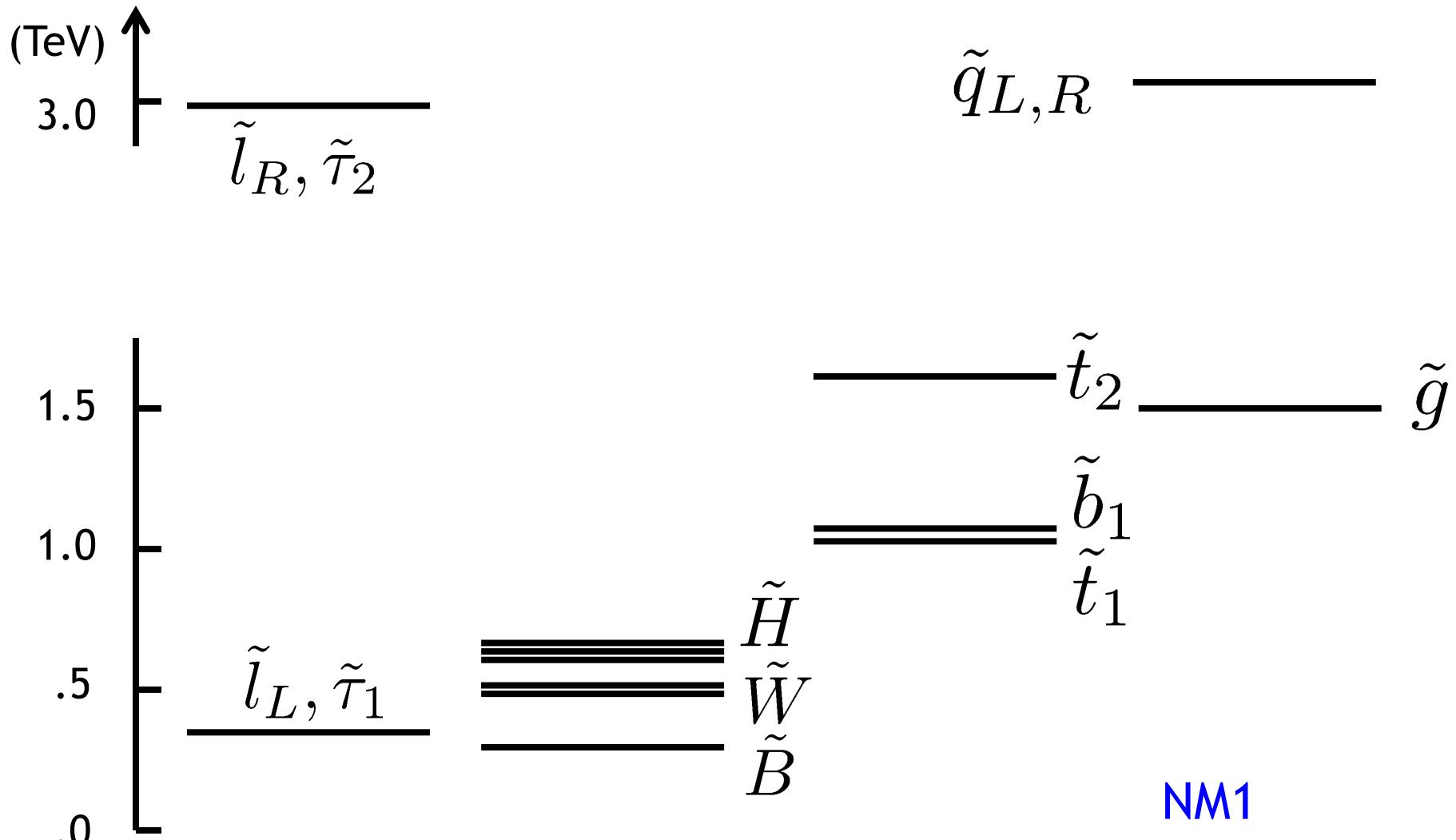
[https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM3\\_slha.txt](https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM3_slha.txt)

# Natural SUSY Models (NM's)



[https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM2\\_slha.txt](https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM2_slha.txt)

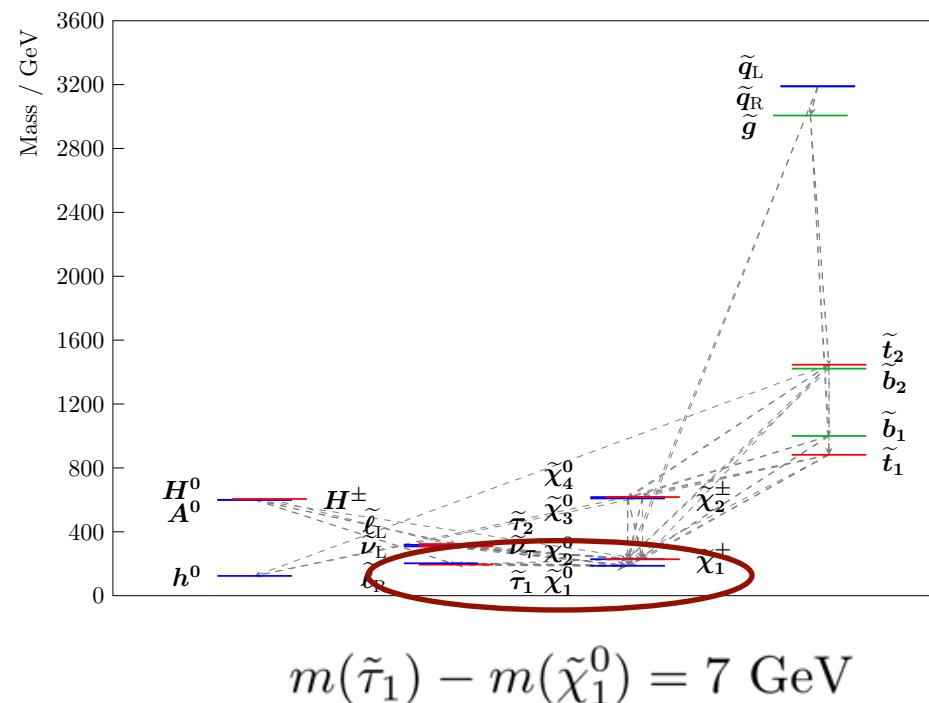
# Natural SUSY Models (NM's)



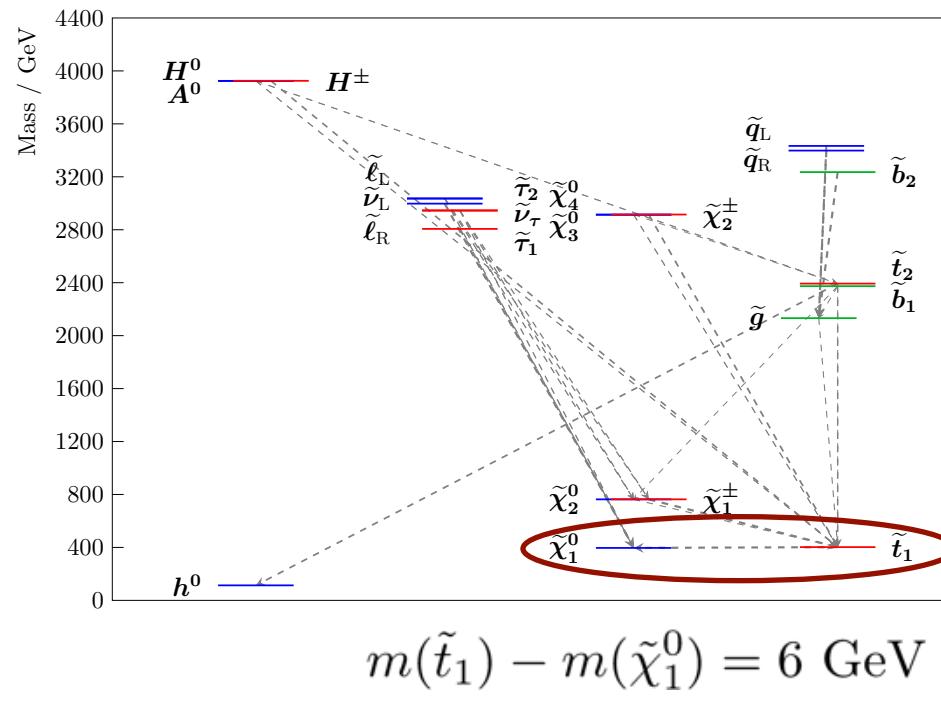
[https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM1\\_slha.txt](https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/NM1_slha.txt)

# Co-annihilation Models

## Stau coannihilation model (STC)



## Stop coannihilation model (STOC)



[https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/STC\\_slha.txt](https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/STC_slha.txt)  
[https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/STOC\\_slha.txt](https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS14012/STOC_slha.txt)



# SUSY Particle Decays

Decay	Branching fraction				
	NM1	NM2	NM3	STC	STOC
$\tilde{g} \rightarrow \tilde{t}_1 \tilde{t}, \tilde{t}_1^* \tilde{t}$	59%	60%	53%	28%	50%
$\tilde{g} \rightarrow \tilde{b}_1 \tilde{b}, \tilde{b}_1^* \tilde{b}$	41%	40%	47%	28%	50%
$\tilde{g} \rightarrow \tilde{t}_2 \tilde{t}, \tilde{t}_2^* \tilde{t}$	-	-	-	22%	-
$\tilde{g} \rightarrow \tilde{b}_2 \tilde{b}, \tilde{b}_2^* \tilde{b}$	-	-	-	21%	-
$\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	0.6%	1.5%	39%	20%	-
$\tilde{t}_1 \rightarrow t \tilde{\chi}_2^0$	13%	13%	41%	5.4%	-
$\tilde{t}_1 \rightarrow t \tilde{\chi}_3^0$	22%	23%	1.5%	20%	-
$\tilde{t}_1 \rightarrow t \tilde{\chi}_4^0$	30%	30%	5.5%	9.2%	-
$\tilde{t}_1 \rightarrow b \tilde{\chi}_1^+$	16%	12%	2.1%	12%	-
$\tilde{t}_1 \rightarrow b \tilde{\chi}_2^+$	18%	21%	11%	34%	-
$\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$	-	-	-	-	99%
$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$	1.5%	1.0%	1.3%	67%	-
$\tilde{b}_1 \rightarrow b \tilde{\chi}_2^0$	11%	10%	1.0%	2.2%	5.7%
$\tilde{b}_1 \rightarrow b \tilde{\chi}_3^0$	0.6%	0.6%	0.4%	8.2%	-
$\tilde{b}_1 \rightarrow b \tilde{\chi}_4^0$	4.5%	5.7%	5.7%	7.6%	-
$\tilde{b}_1 \rightarrow t \tilde{\chi}_1^-$	32%	34%	80%	3.4%	11%
$\tilde{b}_1 \rightarrow t \tilde{\chi}_2^-$	49%	48%	12%	12%	-
$\tilde{b}_1 \rightarrow W^- \tilde{t}_1$	0.4%	0.7%	-	< 0.1%	65%
$\tilde{b}_1 \rightarrow b \tilde{g}$	-	-	-	-	18%

Decay	Branching fraction				
	NM1	NM2	NM3	STC	STOC
$\tilde{\chi}_1^+ \rightarrow \ell^+ \tilde{\nu}$	56%	-	-	-	-
$\tilde{\chi}_1^+ \rightarrow \nu \tilde{\ell}^+$	43%	-	-	100% (only $\nu_\tau \tilde{\tau}_1^+$ )	-
$\tilde{\chi}_1^+ \rightarrow W^+ \tilde{\chi}_1^0$	1.8%	100%	-	-	-
$\tilde{\chi}_1^+ \rightarrow q \bar{q} \tilde{\chi}_1^0$	-	-	70%	-	-
$\tilde{\chi}_1^+ \rightarrow \ell^+ \nu \tilde{\chi}_1^0$	-	-	30%	-	-
$\tilde{\chi}_1^+ \rightarrow \tilde{t}_1 b$	-	-	-	-	100%
$\tilde{\chi}_2^0 \rightarrow \ell^+ \tilde{\ell}^-, \ell^- \tilde{\ell}^+$	59%	-	-	100%	-
$\tilde{\chi}_2^0 \rightarrow \tilde{\nu} \bar{\nu}, \tilde{\nu}^* \nu$	41%	-	-	-	-
$\tilde{\chi}_2^0 \rightarrow Z \tilde{\chi}_1^0$	< 0.1%	12%	-	-	-
$\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$	-	88%	-	-	-
$\tilde{\chi}_2^0 \rightarrow q \bar{q} \tilde{\chi}_1^0$	-	-	56%	-	-
$\tilde{\chi}_2^0 \rightarrow \ell^+ \ell^- \tilde{\chi}_1^0$	-	-	10%	-	-
$\tilde{\chi}_2^0 \rightarrow \nu \bar{\nu} \tilde{\chi}_1^0$	-	-	21%	-	-
$\tilde{\chi}_2^0 \rightarrow q \bar{q}' \tilde{\chi}_1^\pm$	-	-	8.8%	-	-
$\tilde{\chi}_2^0 \rightarrow \ell^+ \nu \tilde{\chi}_1^-, \ell^- \bar{\nu} \tilde{\chi}_1^+$	-	-	4.0%	-	-
$\tilde{\chi}_2^0 \rightarrow \tilde{t}_1 \bar{t}, \tilde{t}_1^* t$	-	-	-	-	100%

Top squark decay modes strongly depend on ewkino spectrum and composition



# SUSY Particle Decays

Decay	Branching fraction				
	NM1	NM2	NM3	STC	STOC
$\tilde{g} \rightarrow \tilde{t}_1 \bar{t}, \tilde{t}_1^* \bar{t}$	59%	60%	53%	28%	50%
$\tilde{g} \rightarrow \tilde{b}_1 \bar{b}, \tilde{b}_1^* \bar{b}$	41%	40%	47%	28%	50%
$\tilde{g} \rightarrow \tilde{t}_2 \bar{t}, \tilde{t}_2^* \bar{t}$	-	-	-	22%	-
$\tilde{g} \rightarrow \tilde{b}_2 \bar{b}, \tilde{b}_2^* \bar{b}$	-	-	-	21%	-
$\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	0.6%	1.5%	39%	20%	-
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$\tilde{t}_1 \rightarrow t \tilde{\chi}_4^0$	30%	30%	5.5%	9.2%	-
$\tilde{t}_1 \rightarrow b \tilde{\chi}_1^+$	16%	12%	2.1%	12%	-
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$\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$	-	-	-	-	99%
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$\tilde{b}_1 \rightarrow t \tilde{\chi}_1^-$	32%	34%	80%	3.4%	11%
$\tilde{b}_1 \rightarrow t \tilde{\chi}_2^-$	49%	48%	12%	12%	-
$\tilde{b}_1 \rightarrow W^- \tilde{t}_1$	0.4%	0.7%	-	< 0.1%	65%
$\tilde{b}_1 \rightarrow b \tilde{g}$	-	-	-	-	18%

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	NM1	NM2	NM3	STC	STOC
$\tilde{\chi}_1^+ \rightarrow \ell^+ \tilde{\nu}$	56%	-	-	-	-
$\tilde{\chi}_1^+ \rightarrow \nu \tilde{\ell}^+$	43%	-	-	100% (only $\nu_\tau \tilde{\tau}_1^+$ )	-
$\tilde{\chi}_1^+ \rightarrow W^+ \tilde{\chi}_1^0$	1.8%	100%	-	-	-
$\tilde{\chi}_1^+ \rightarrow q \bar{q} \tilde{\chi}_1^0$	-	-	70%	-	-
$\tilde{\chi}_1^+ \rightarrow \ell^+ \nu \tilde{\chi}_1^0$	-	-	30%	-	-
$\tilde{\chi}_1^+ \rightarrow \tilde{t}_1 \bar{b}$	-	-	-	-	100%
$\tilde{\chi}_2^0 \rightarrow \ell^+ \tilde{\ell}^-, \ell^- \tilde{\ell}^+$	59%	-	-	100%	-
$\tilde{\chi}_2^0 \rightarrow \tilde{\nu} \bar{\nu}, \tilde{\nu}^* \nu$	41%	-	-	-	-
$\tilde{\chi}_2^0 \rightarrow Z \tilde{\chi}_1^0$	< 0.1%	12%	-	-	-
$\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$	-	88%	-	-	-
$\tilde{\chi}_2^0 \rightarrow q \bar{q} \tilde{\chi}_1^0$	-	-	56%	-	-
$\tilde{\chi}_2^0 \rightarrow \ell^+ \ell^- \tilde{\chi}_1^0$	-	-	10%	-	-
$\tilde{\chi}_2^0 \rightarrow \nu \bar{\nu} \tilde{\chi}_1^0$	-	-	21%	-	-
$\tilde{\chi}_2^0 \rightarrow q \bar{q}' \tilde{\chi}_1^\pm$	-	-	8.8%	-	-
$\tilde{\chi}_2^0 \rightarrow \ell^+ \nu \tilde{\chi}_1^-, \ell^- \bar{\nu} \tilde{\chi}_1^+$	-	-	4.0%	-	-
$\tilde{\chi}_2^0 \rightarrow \tilde{t}_1 \bar{t}, \tilde{t}_1^* \bar{t}$	-	-	-	-	100%

Bottom squarks often decay into a mode including a top quark, making it challenging to distinguish bottom squark from top squark



# SUSY Particle Decays

Decay	Branching fraction				
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$\tilde{g} \rightarrow \tilde{t}_1 \tilde{t}, \tilde{t}_1^* \tilde{t}$	59%	60%	53%	28%	50%
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$\tilde{g} \rightarrow \tilde{t}_2 \tilde{t}, \tilde{t}_2^* \tilde{t}$	-	-	-	22%	-
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$\tilde{t}_1 \rightarrow b \tilde{\chi}_1^+$	16%	12%	2.1%	12%	-
$\tilde{t}_1 \rightarrow b \tilde{\chi}_2^+$	18%	21%	11%	34%	-
$\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$	-	-	-	-	99%
$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$	1.5%	1.0%	1.3%	67%	-
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$\tilde{b}_1 \rightarrow W^- \tilde{t}_1$	0.4%	0.7%	-	< 0.1%	65%
$\tilde{b}_1 \rightarrow b \tilde{g}$	-	-	-	-	18%

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	NM1	NM2	NM3	STC	STOC
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$\tilde{\chi}_1^+ \rightarrow W^+ \tilde{\chi}_1^0$	1.8%	100%	-	-	-
$\tilde{\chi}_1^+ \rightarrow q \bar{q} \tilde{\chi}_1^0$	-	-	70%	-	-
$\tilde{\chi}_1^+ \rightarrow \ell^+ \nu \tilde{\chi}_1^0$	-	-	30%	-	-
$\tilde{\chi}_1^+ \rightarrow \tilde{t}_1 b$	-	-	-	-	100%
$\tilde{\chi}_2^0 \rightarrow \ell^+ \tilde{\ell}^-, \ell^- \tilde{\ell}^+$	59%	-	-	100%	-
$\tilde{\chi}_2^0 \rightarrow \tilde{\nu} \bar{\nu}, \tilde{\nu}^* \nu$	41%	-	-	-	-
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$\tilde{\chi}_2^0 \rightarrow \ell^+ \nu \tilde{\chi}_1^-, \ell^- \bar{\nu} \tilde{\chi}_1^+$	-	-	4.0%	-	-
$\tilde{\chi}_2^0 \rightarrow \tilde{t}_1 \tilde{t}, \tilde{t}_1^* \tilde{t}$	-	-	-	-	100%

Obviously ewkino decays strongly depend on the ewkino spectrum and composition

# Analysis Overview

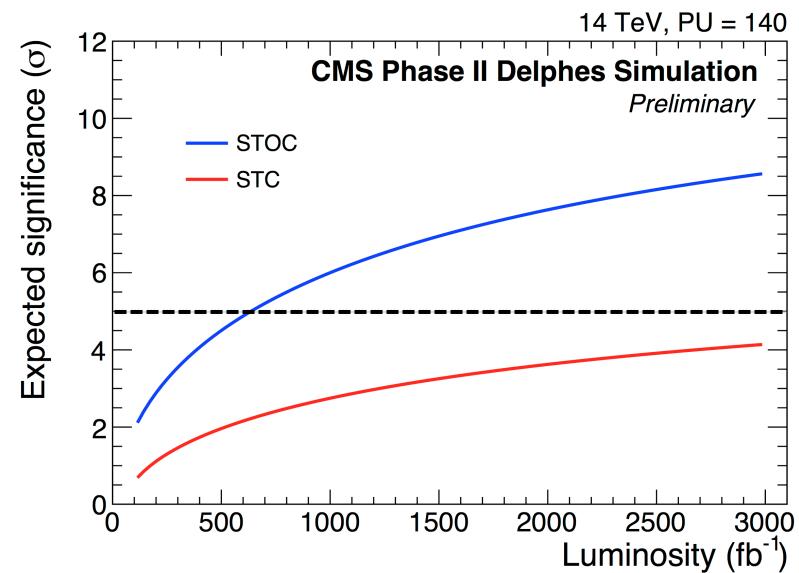
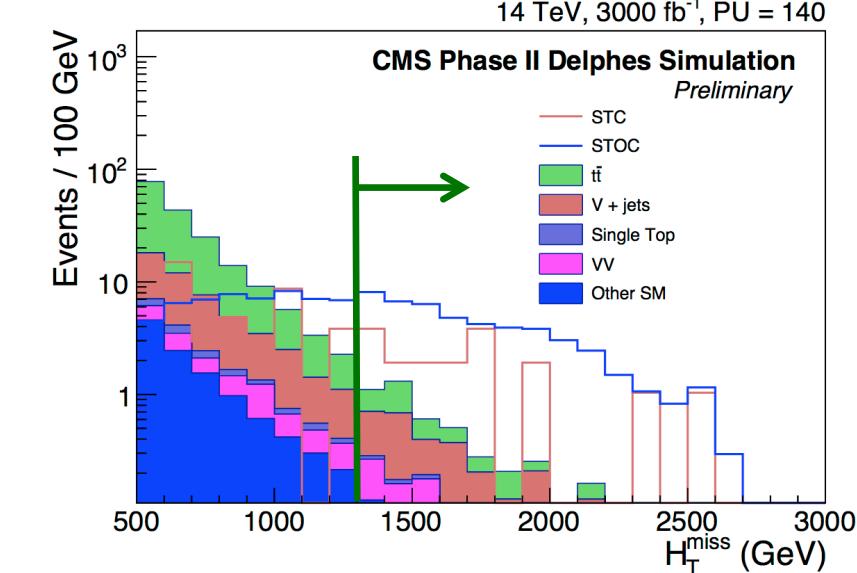
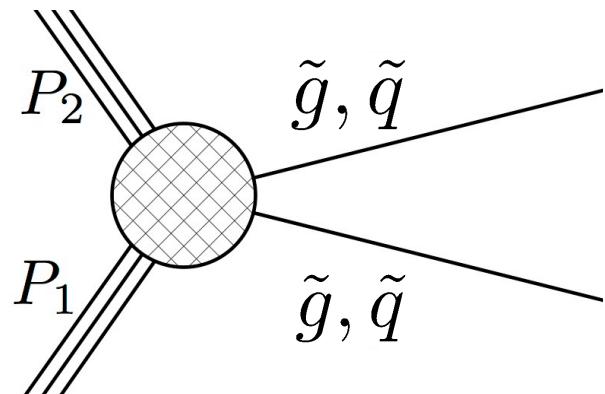
- Explored:
    - Five different models.
    - Nine different experimental signatures.
- Exploring experimental signature space ↓
- | Analysis  | Luminosity<br>( $\text{fb}^{-1}$ ) | Model  |        |        |        |      |
|---|------------------------------------|--------|--------|--------|--------|------|
|   |                                    | NM1    | NM2    | NM3    | STC    | STOC |
| all-hadronic ( $H_T - H_T^{\text{miss}}$ ) search | 300                                |        |        |        |        |      |
|   | 3000                               |        |        |        |        |      |
| all-hadronic ( $M_{T2}$ ) search                  | 300                                | Blue   | Orange | Orange |        |      |
|   | 3000                               | Orange | Orange | Orange |        |      |
| all-hadronic $\tilde{b}_1$ search                 | 300                                |        |        |        | Blue   |      |
|   | 3000                               |        |        |        | Orange |      |
| 1-lepton $\tilde{t}_1$ search                     | 300                                |        | Orange | Orange | Blue   |      |
|   | 3000                               |        | Orange | Orange | Blue   |      |
| monojet $\tilde{t}_1$ search                      | 300                                |        |        |        |        | Blue |
|   | 3000                               |        |        |        |        | Blue |
| $m_{\ell^+ \ell^-}$ kinematic edge                | 300                                |        |        |        |        |      |
|   | 3000                               | Orange |        |        |        |      |
| multilepton + b-tag search                        | 300                                |        | Orange | Orange | Blue   |      |
|   | 3000                               |        | Orange | Orange | Blue   |      |
| multilepton search                                | 300                                |        |        |        |        |      |
|   | 3000                               | Blue   | Blue   | Grey   | Blue   |      |
| ewkino WH search                                  | 300                                |        |        |        |        |      |
|   | 3000                               |        | Blue   | Grey   |        |      |
- Exploring SUSY model space
- Different types of SUSY models lead to different patterns of discoveries in different final states after different amounts of data.
  - HL-LHC measurements can be crucial to illuminate a Run 3 discovery, and thus answer fundamental questions about gauge hierarchy or dark matter.

# All-hadronic Search w/ HT+MHT

## □ Search selection:

- $\geq 3$  jets
- $\Delta\phi(\text{MHT}, \text{jet}_{1,2,3}) > 0.5, 0.5, 0.3$
- Lepton vetos
- $\geq 2$  btags
- $H_T > 2.5 \text{ TeV}$
- $\text{MHT} > 1.3 \text{ TeV}$

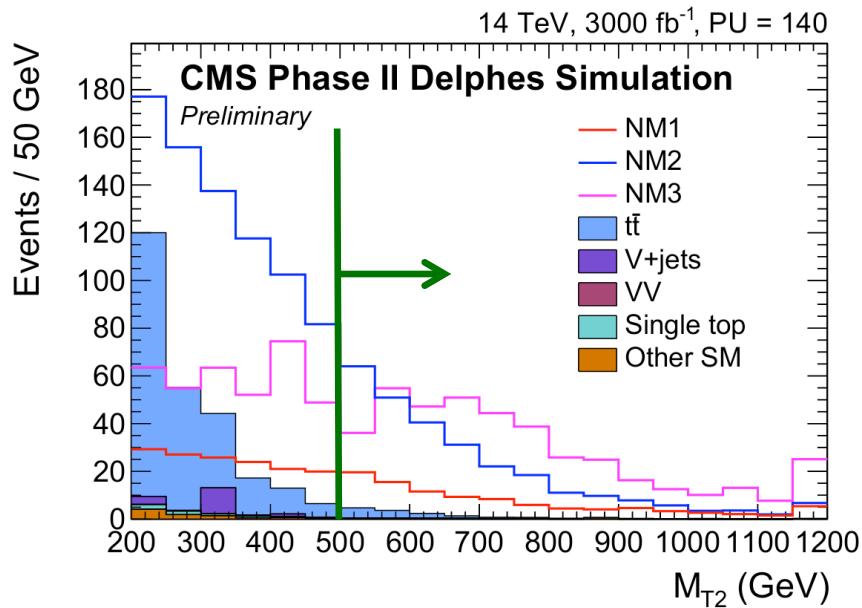
## Target signatures:



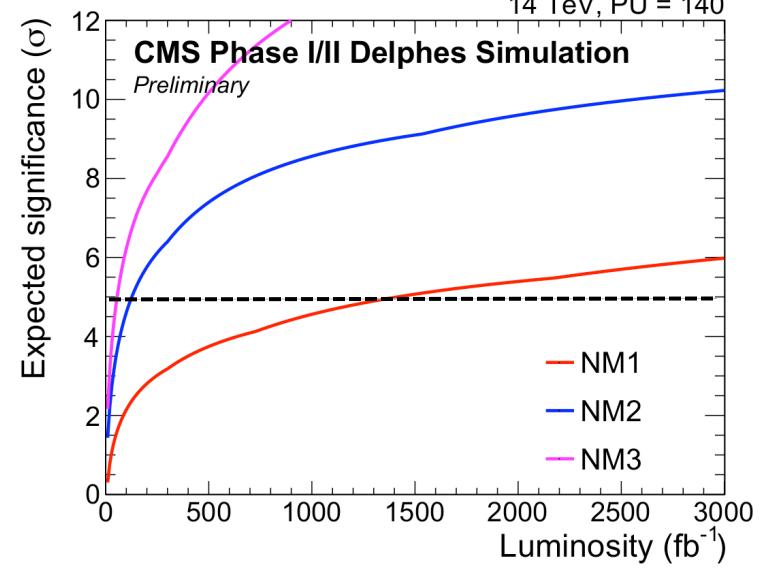
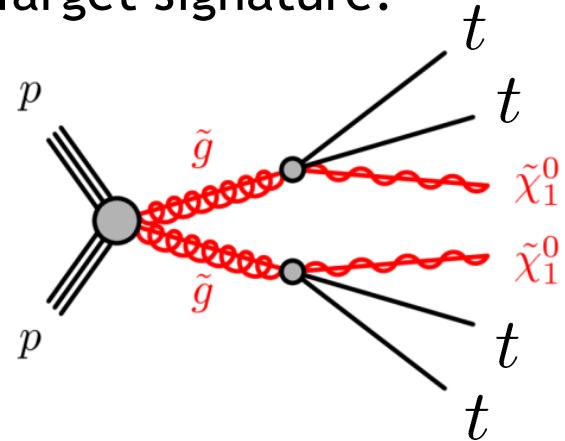
# All-hadronic Search w/ MT2

Search selection:

- $\geq 8$  jets
- $\Delta\phi(\text{MET}, \text{jet}_{1,2,3}) > 0.4$
- $\geq 3$  b-tags
- no leptons
- $H_T > 2 \text{ TeV}$
- $M_{T2} > 500\text{-}800 \text{ GeV}$



Target signature:

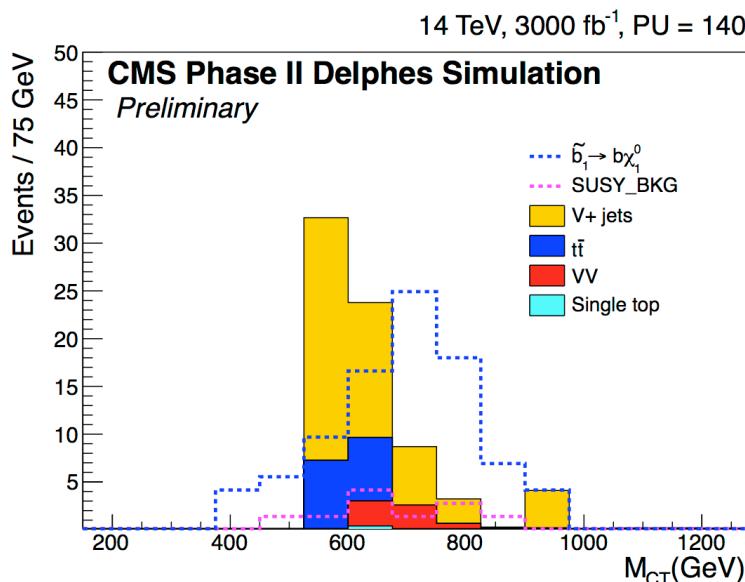


# Search for Sbottom in $bb + \text{MET}$

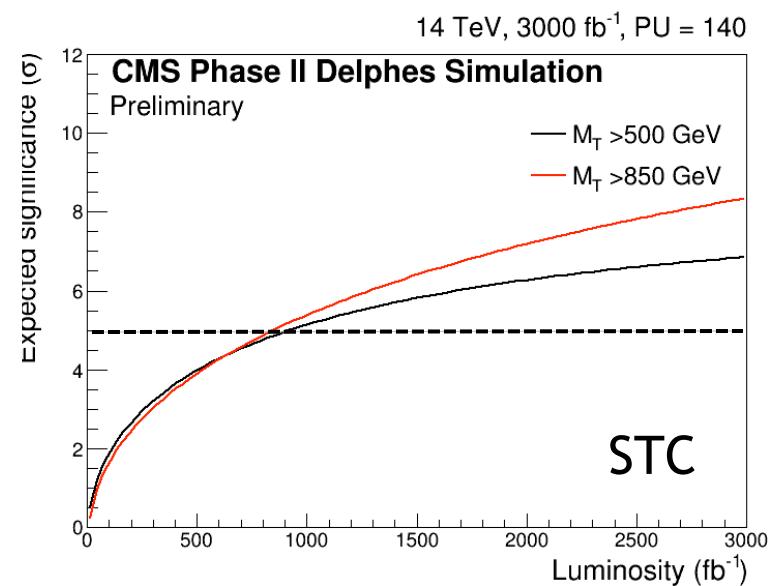
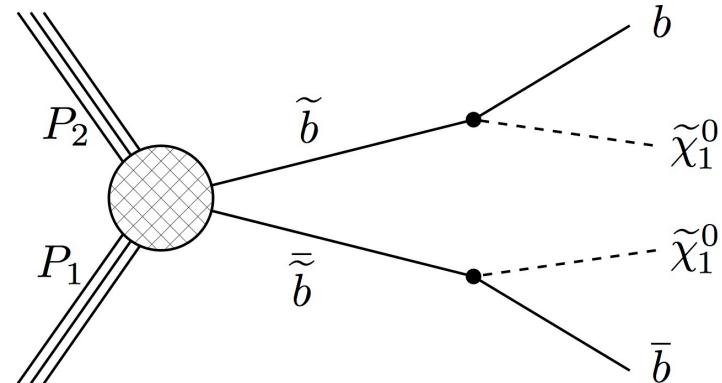
## □ Search selection:

- Lepton veto ( $e/\mu$ )
- =2 b-tags
- Veto third jet
- $\Delta\phi(b_1, b_2) < 2.5$  (QCD rejection)
- $H_T > 750 \text{ GeV}$ ,  $\text{MET} > 450 \text{ GeV}$
- $M_T(b_{1,2}, \text{MET}) > 500 - 900 \text{ GeV}$

STC  
searching for sbottoms



## Target signature:

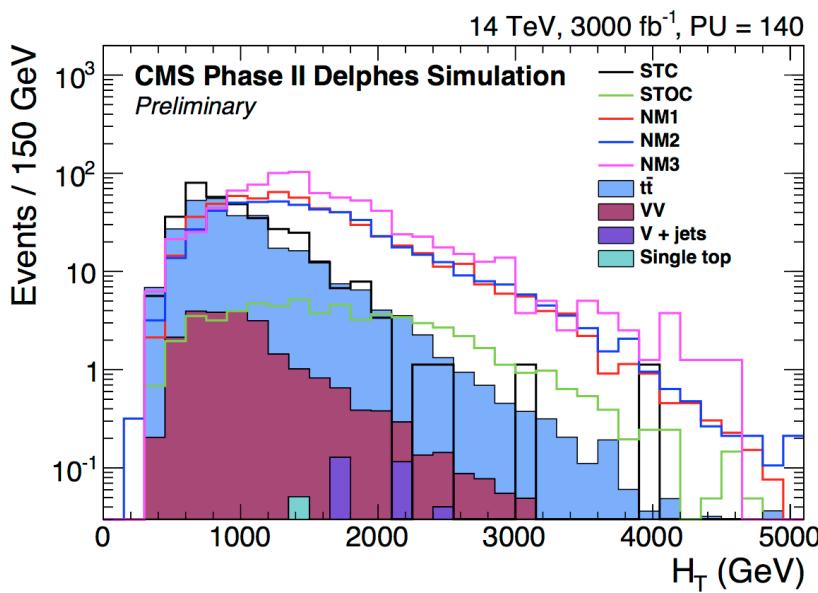


# 1-lepton Stop Search

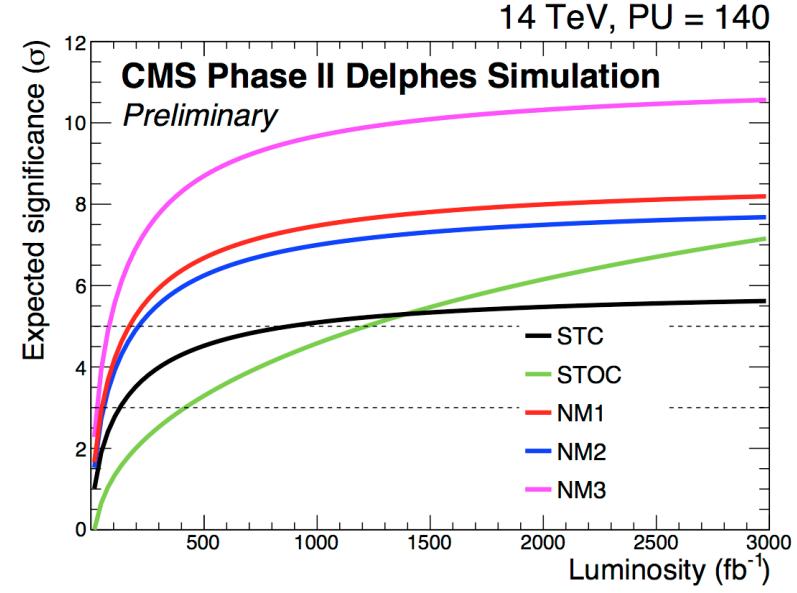
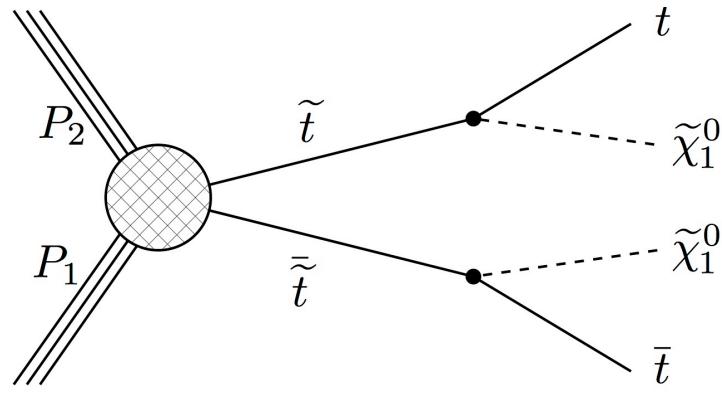
## □ Search selection:

- 1 lepton ( $e/\mu$ )
- $\geq 5$  jets 1 or 2 b-jets
- Centrality  $> 0.6$
- $\Delta\phi(\text{MET}, \text{jet}_{1,2}) > 0.8$
- $\text{MET} > 400$  (800) GeV
- $M_T > 260$  GeV,  $M_{T2}^W > 260$  GeV

STC, NM1, NM2, NM3  
searching for stop pair production



Target signature:

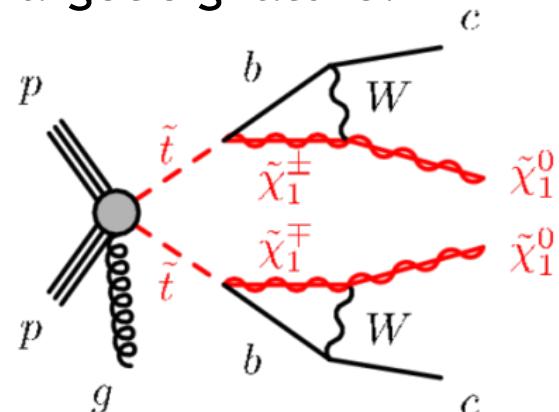


# Monojet Stop Search

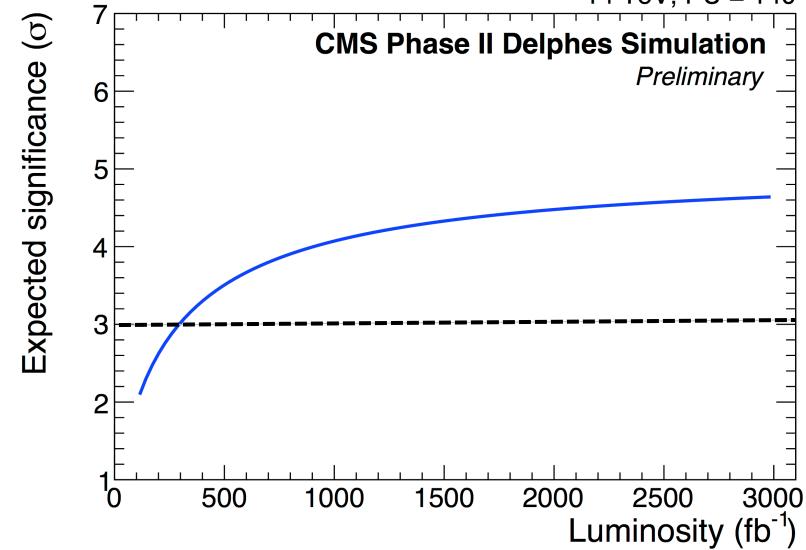
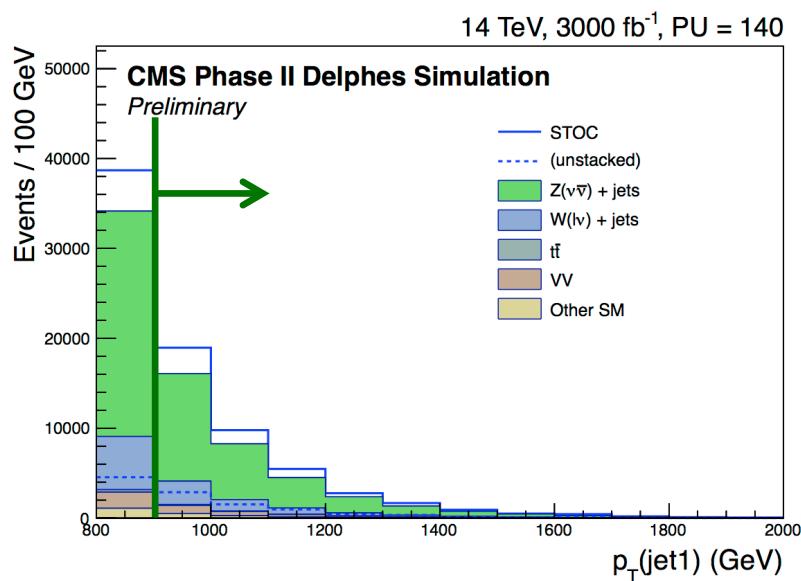
□ Search selection:

- $p_T(j_1) > 110 \text{ GeV}, |\eta| < 2.4$
- $\Delta\phi(j_1, j_2) < 1.8$
- **Veto 3rd jet** ( $p_T > 100 \text{ GeV}, |\eta| < 4.5$ )
- Electron/muon veto
- **MET**  $> 600 \text{ GeV}$
- $p_T(j_1) > 900 \text{ GeV}$

Target signature:



STOC  
search for stop  $\rightarrow$  invisible ( $c \sim \chi_1^0$ )

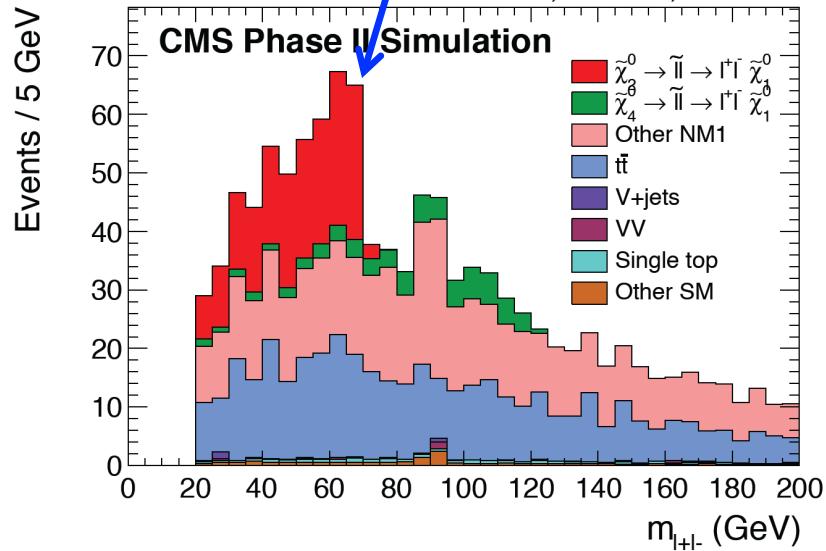


# M( $\ell^+\ell^-$ ) Kinematic Edge Search

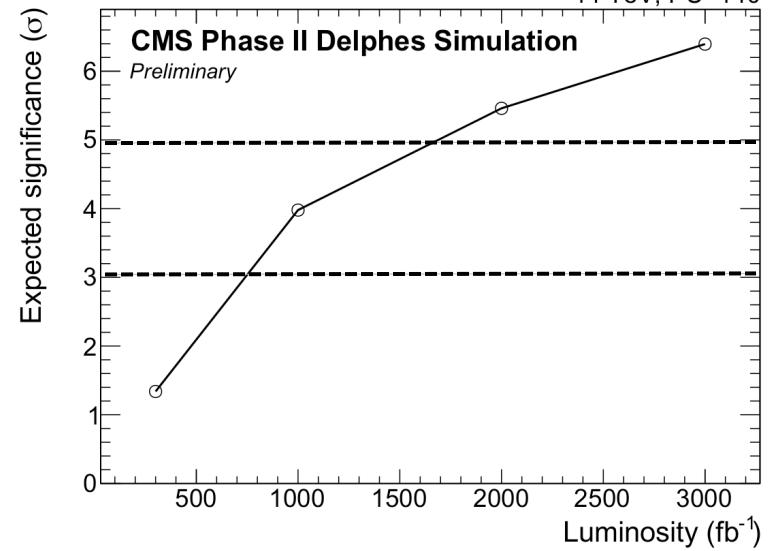
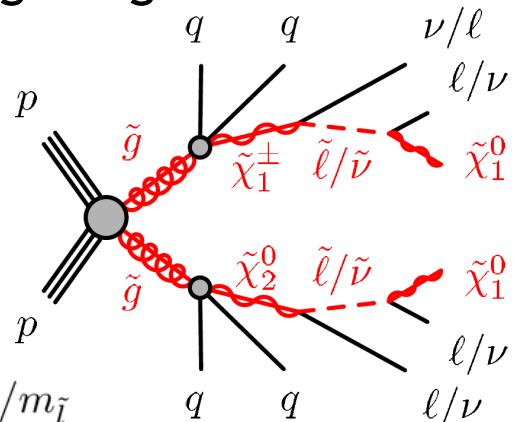
## Search selection:

- An opposite-sign (OS) same-flavor (SF)  $\ell^+\ell^-$  pair ( $e/\mu$ ,  $p_T > 10$  GeV,  $|\eta| < 2.4$ )
- $m(\ell^+\ell^-) > 20$  GeV
- $\geq 6$  jets ( $p_T > 40$  GeV,  $|\eta| < 2.4$ ),  $\geq 1$  btags
- **MET > 450 GeV**
- **H<sub>T</sub> > 1250 GeV**

$$m_{\text{edge}} = \sqrt{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}}^2)(m_{\tilde{l}}^2 - m_{\tilde{\chi}_1^0}^2)/m_{\tilde{l}}}$$



## Target signature:

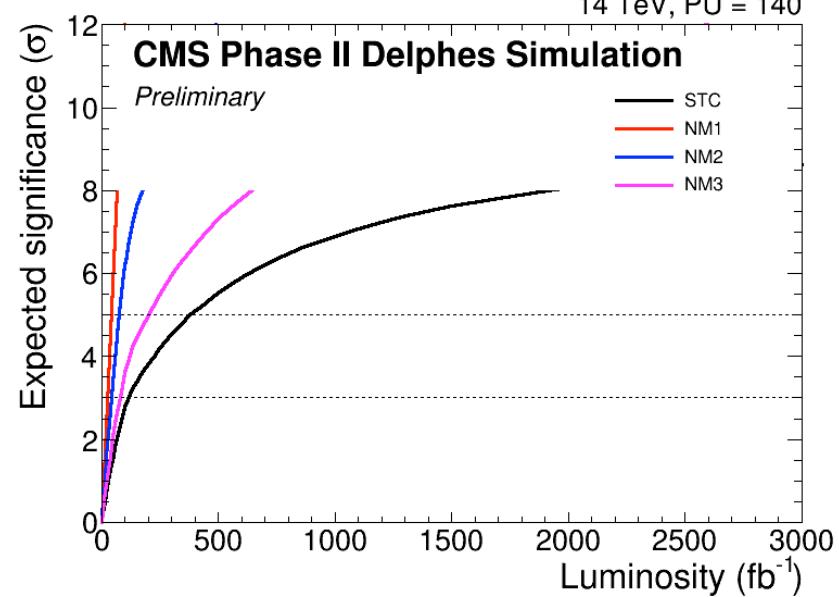
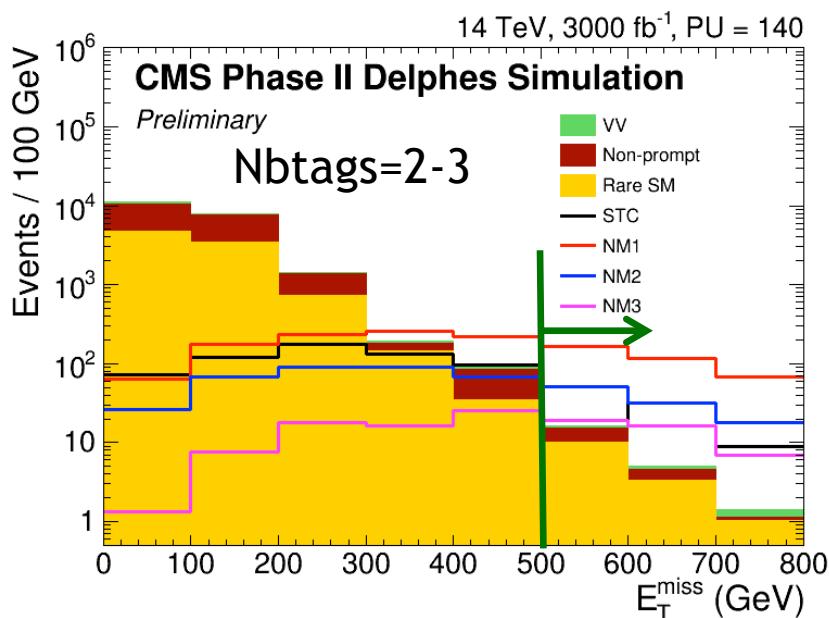
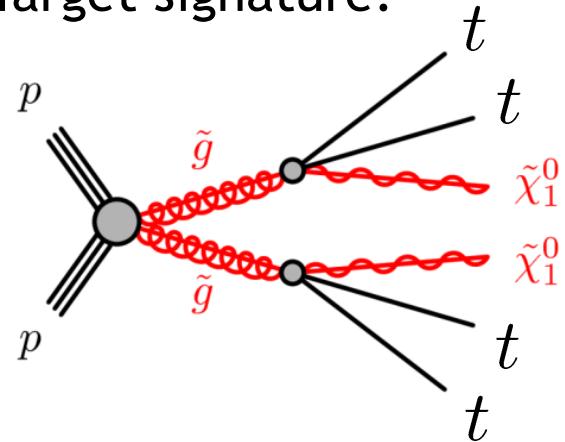


# Searches w/ Trileptons + b-tags

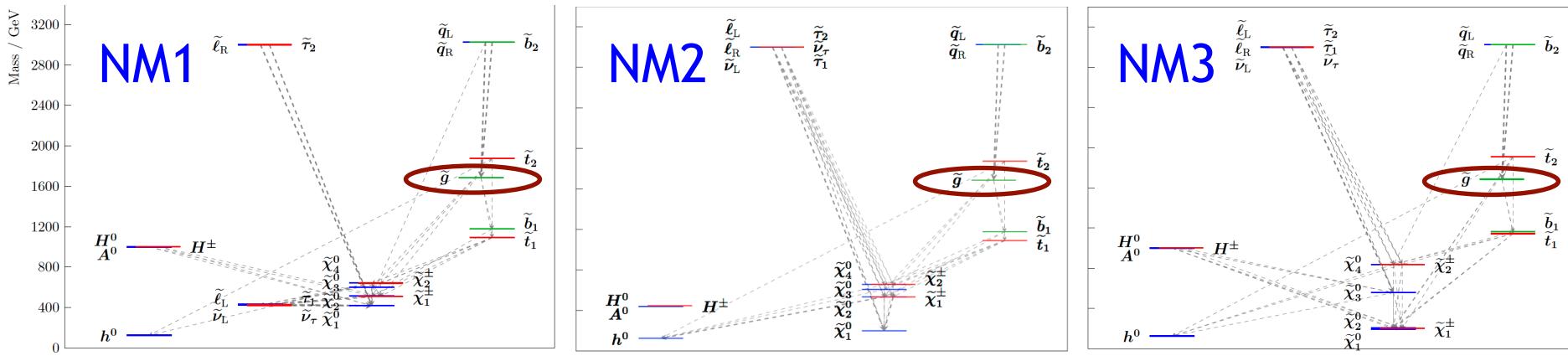
## □ Search selection:

- 3 leptons ( $p_T > 25/15/10$  GeV,  $|\eta| < 4$ )
- b-tags (2-3 or  $\geq 4$ ,  $p_T > 50$  GeV,  $|\eta| < 1.8$ )
- MET  $> 500$  GeV

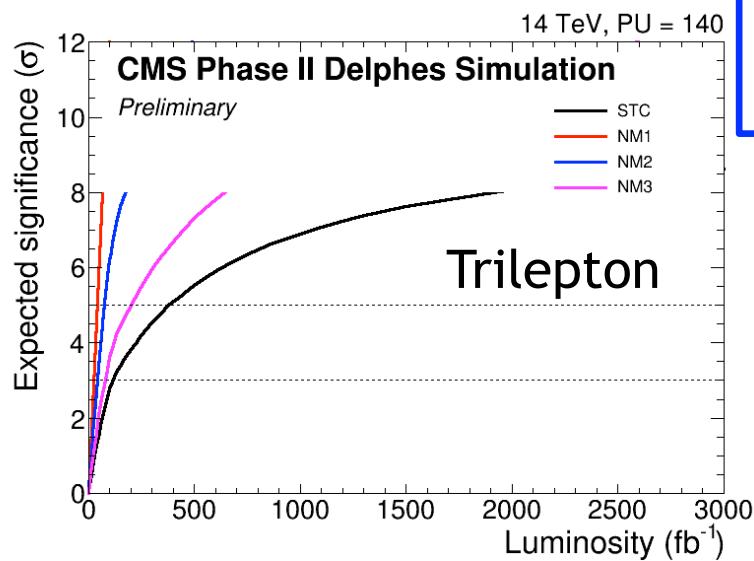
## Target signature:



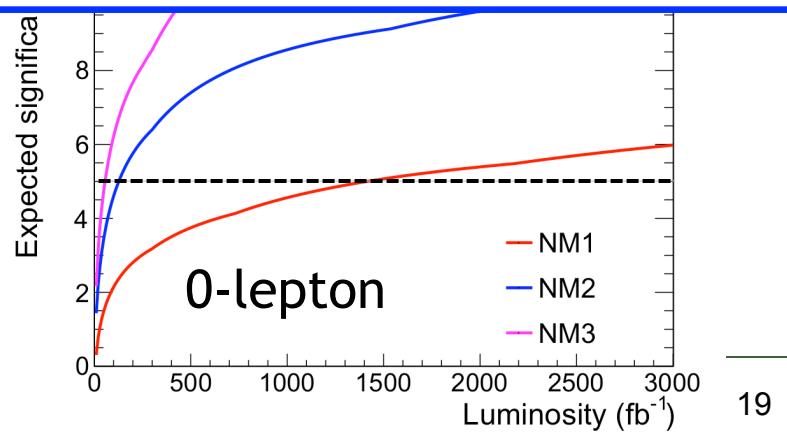
# Discovery Scenarios: Natural Models



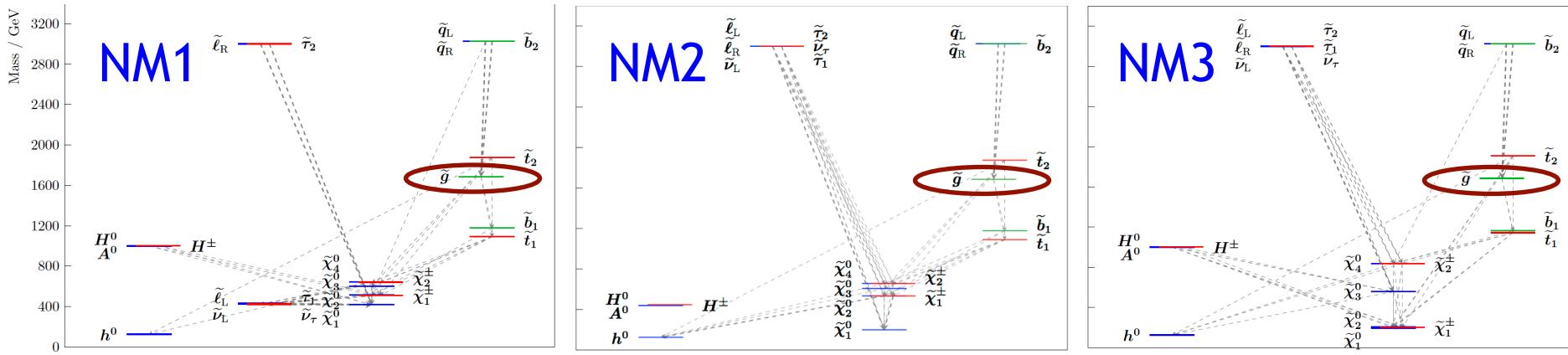
- Discovery of “gluino-like” signature in jets + MET + b-tags (w/ 0-, 1-, and multi-leptons) in Run 2+3.



Different analyses weigh in differently depending on SUSY spectrum

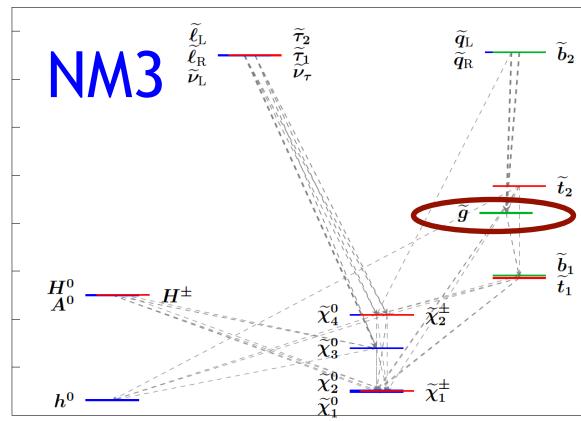
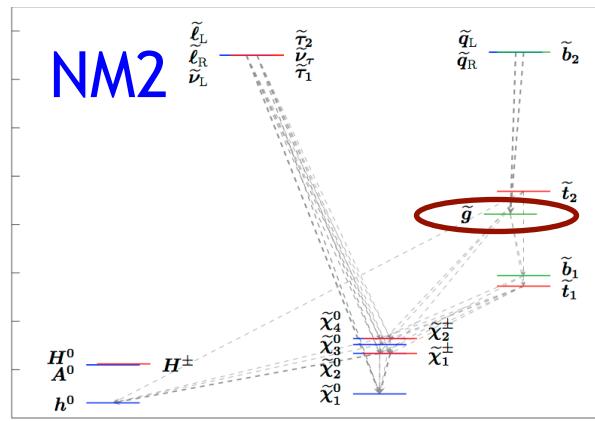
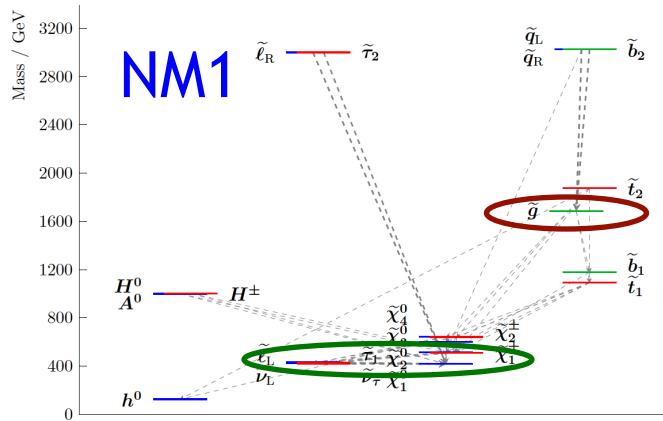


# Discovery Scenarios: Natural Models



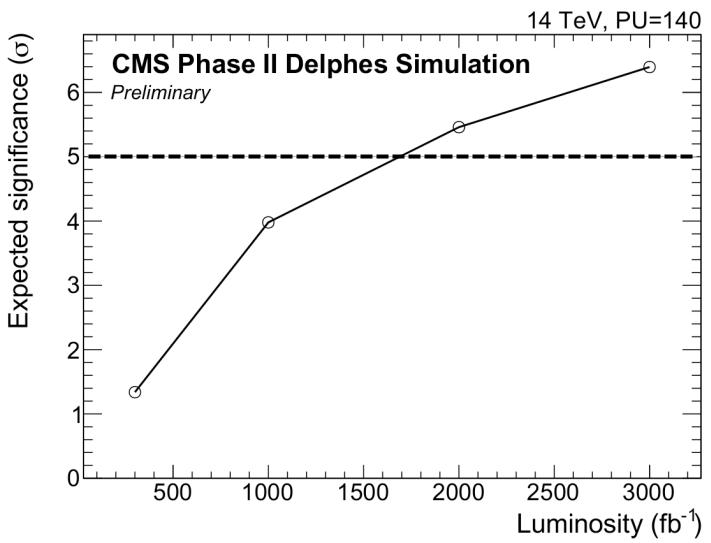
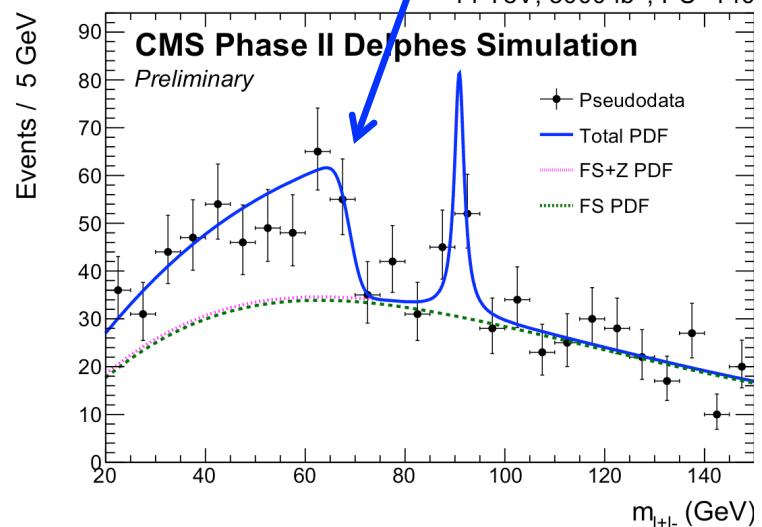
- Discovery of “gluino-like” signature in jets + MET + b-tags (w/ 0-, 1-, and multi-leptons) in Run 2+3.
- HL-LHC adds detailed measurements of:
  - Weakly interacting sector that gluinos cascade down to.
    - **Discover which among several broad classes of SUSY models is implemented in nature.**
  - Distinctive kinematic features indicate the structure of SUSY spectrum.
  - Observations in additional final states not visible yet in Run 3.

# Discovery Scenarios: Natural Models

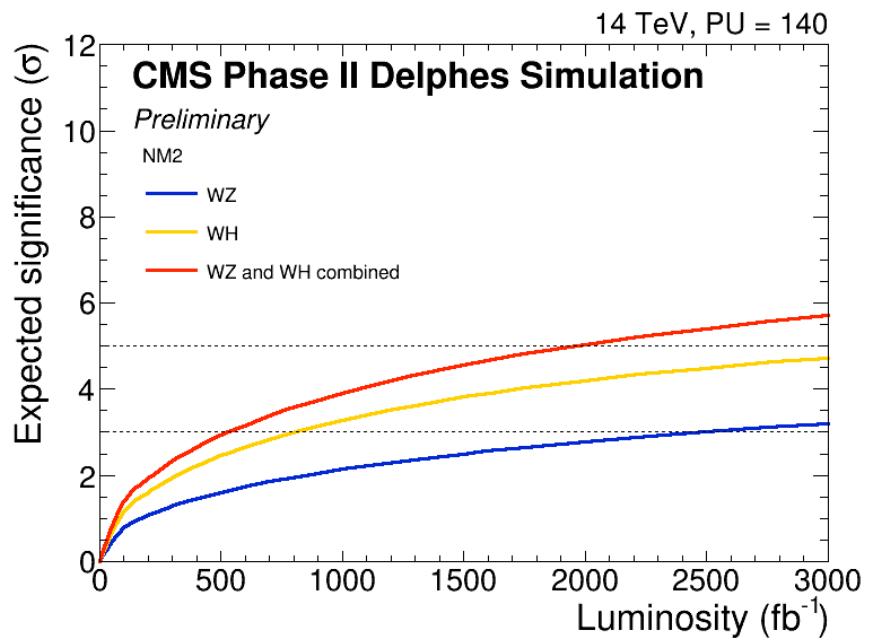
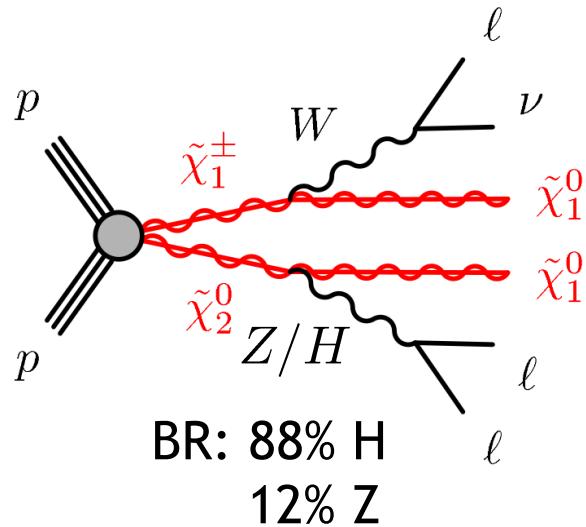
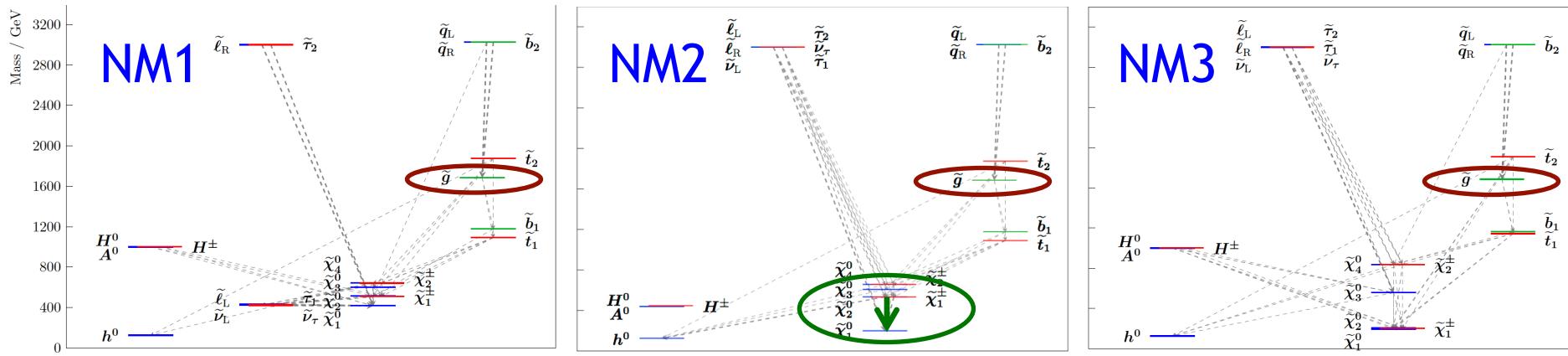


$$\tilde{\chi}_2^0 \rightarrow l\tilde{l} \rightarrow \tilde{\chi}_1^0 l^+ l^-$$

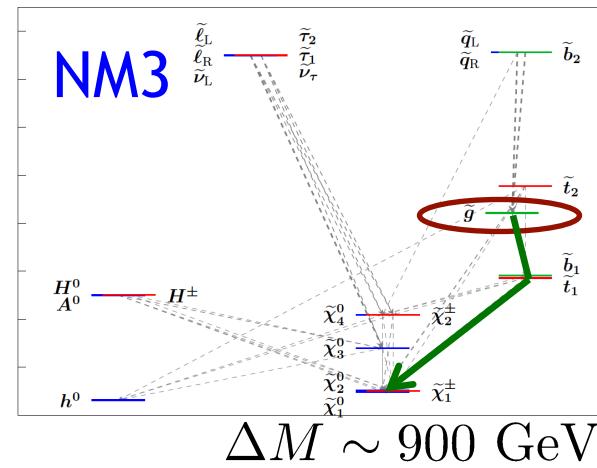
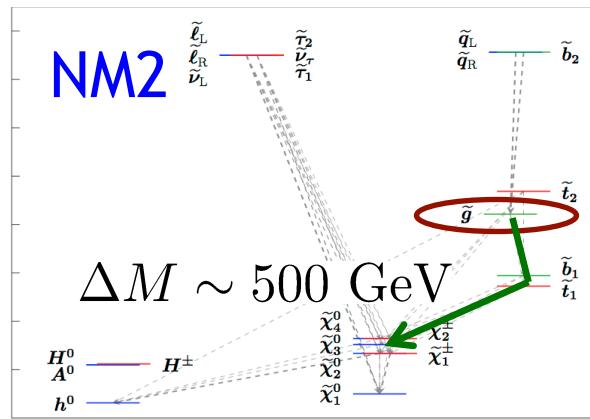
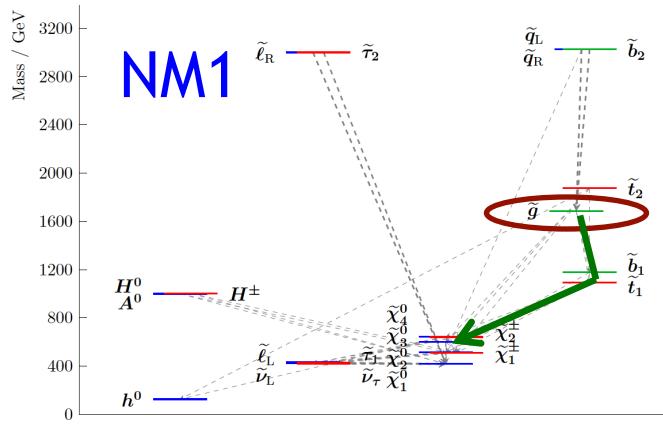
$$m_{\text{edge}} = \sqrt{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}}^2)(m_{\tilde{l}}^2 - m_{\tilde{\chi}_1^0}^2)} / m_{\tilde{l}}$$



# Discovery Scenarios: Natural Models

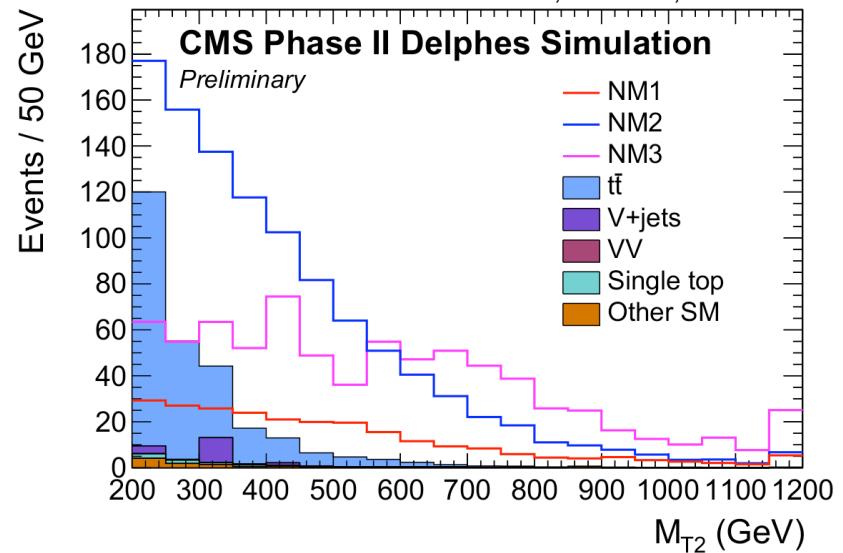


# Discovery Scenarios: Natural Models

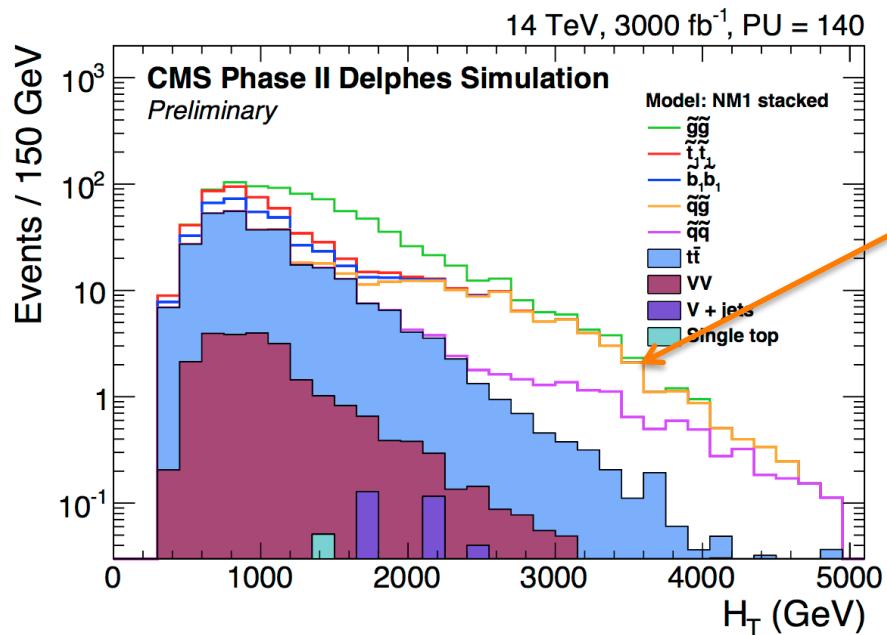
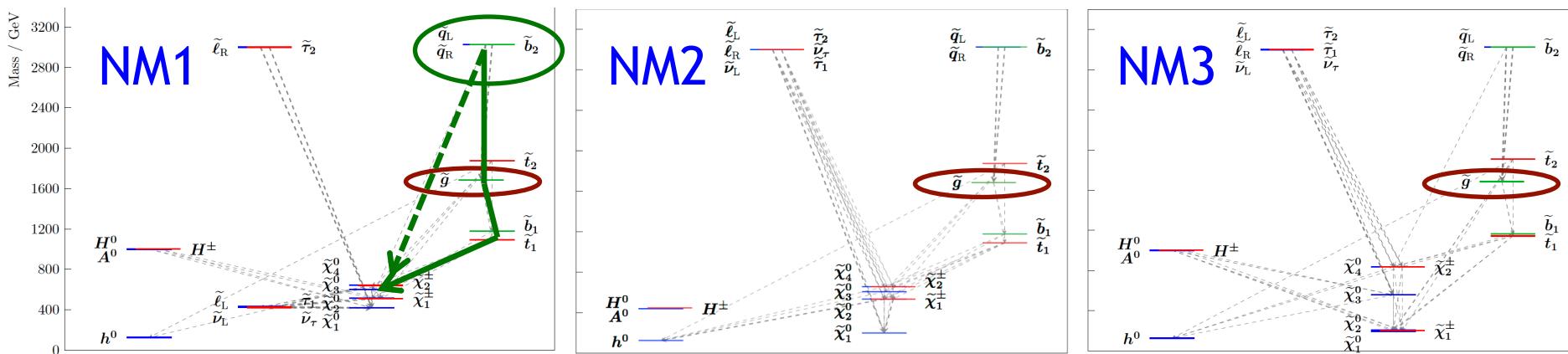


Large mass gaps in NM3  
 $\rightarrow$  massive  $m_{T_2}$  tails

Distinctive kinematic features  
 indicate the structure of SUSY  
 spectrum



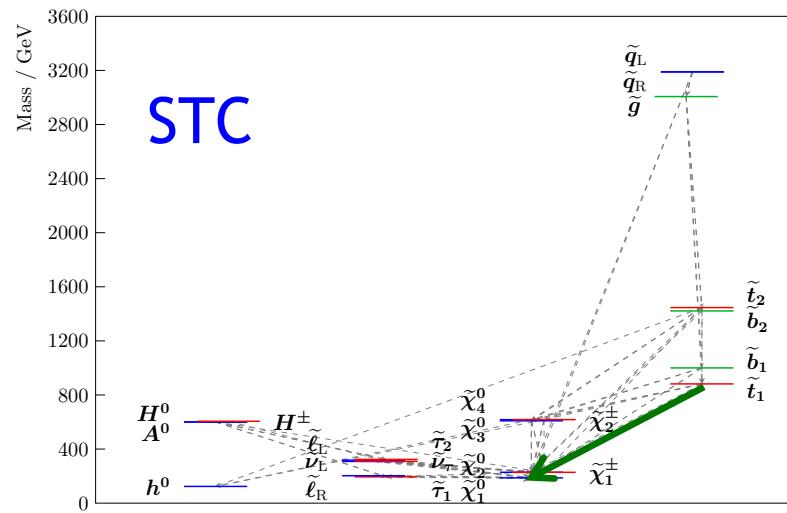
# Discovery Scenarios: Natural Models



Gluino-squark production of  
3TeV u/d/s squarks  
becomes visible

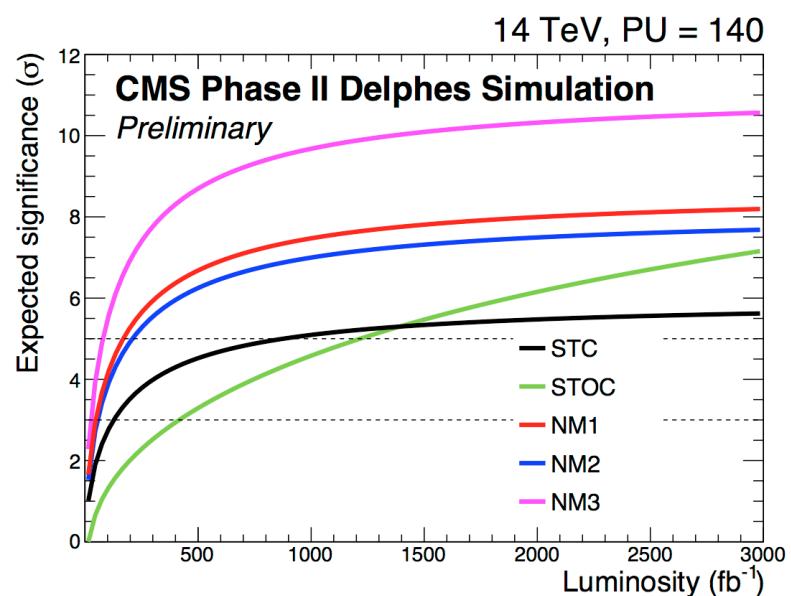
Observations in additional  
final states w/ HL-LHC

# Discovery Scenarios: STC



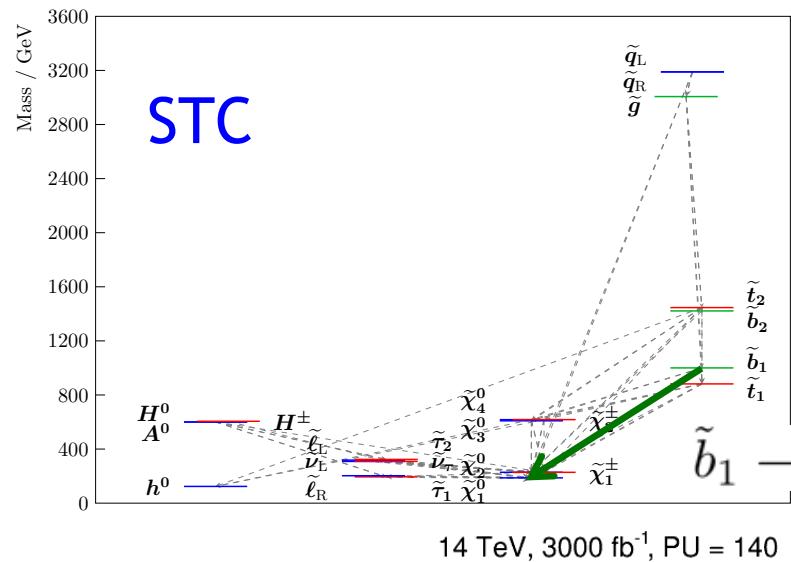
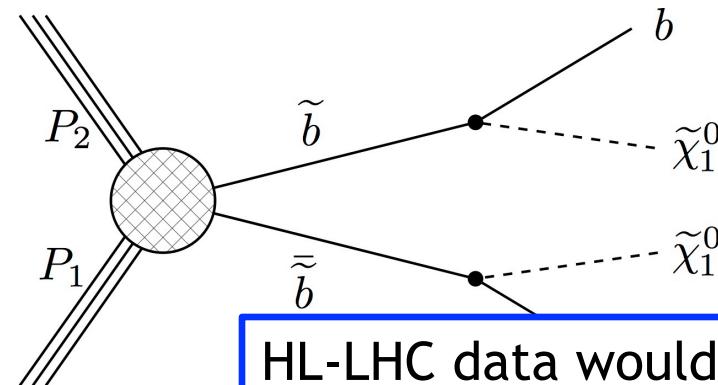
STC

- $\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0$  (20%)
- $\tilde{t}_1 \rightarrow t + \tilde{\chi}_2^0$  (5%)
- $\tilde{t}_1 \rightarrow t + \tilde{\chi}_3^0$  (20%)
- $\tilde{t}_1 \rightarrow t + \tilde{\chi}_4^0$  (9%)
- $\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^+$  (12%)
- $\tilde{t}_1 \rightarrow b + \tilde{\chi}_2^+$  (34%)



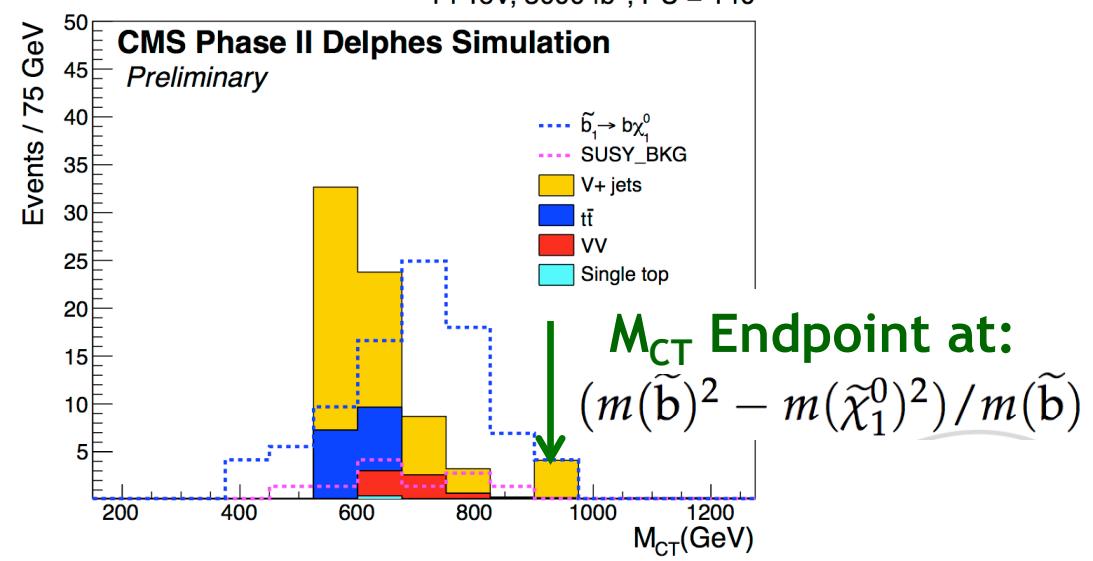
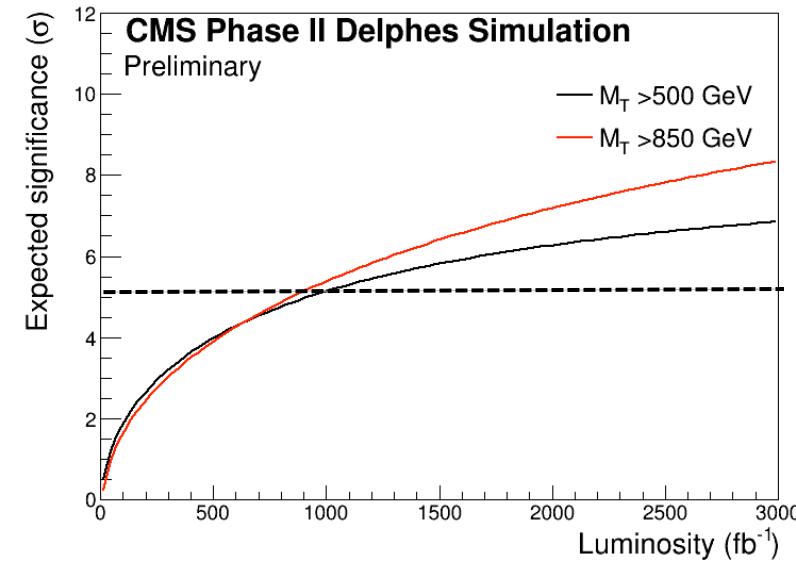
For this stau-coannihilation model, 70% of the signal in the 1-lepton search comes from direct top squark production

# Discovery Scenarios: STC

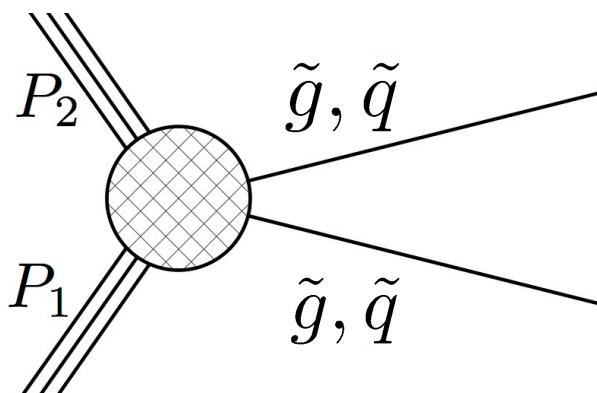
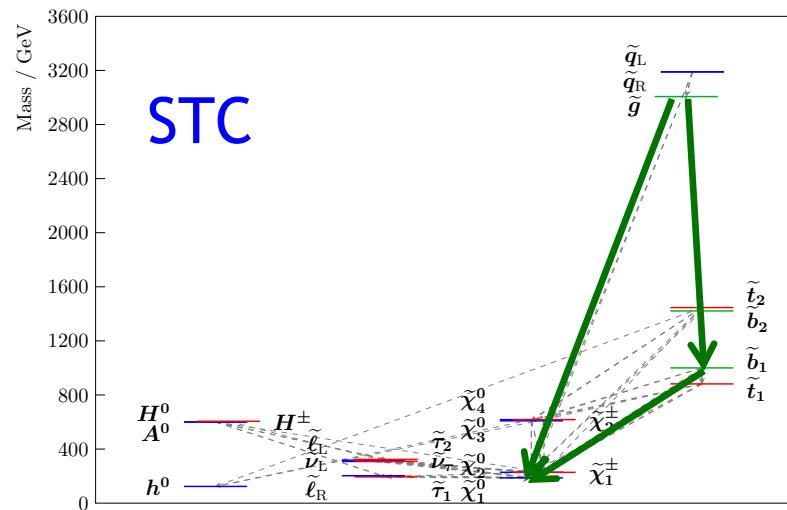

 $\tilde{b}_1 \rightarrow b + \tilde{\chi}_1^0 \text{ (67\%)}$ 


HL-LHC data would allow the endpoint mass measurements

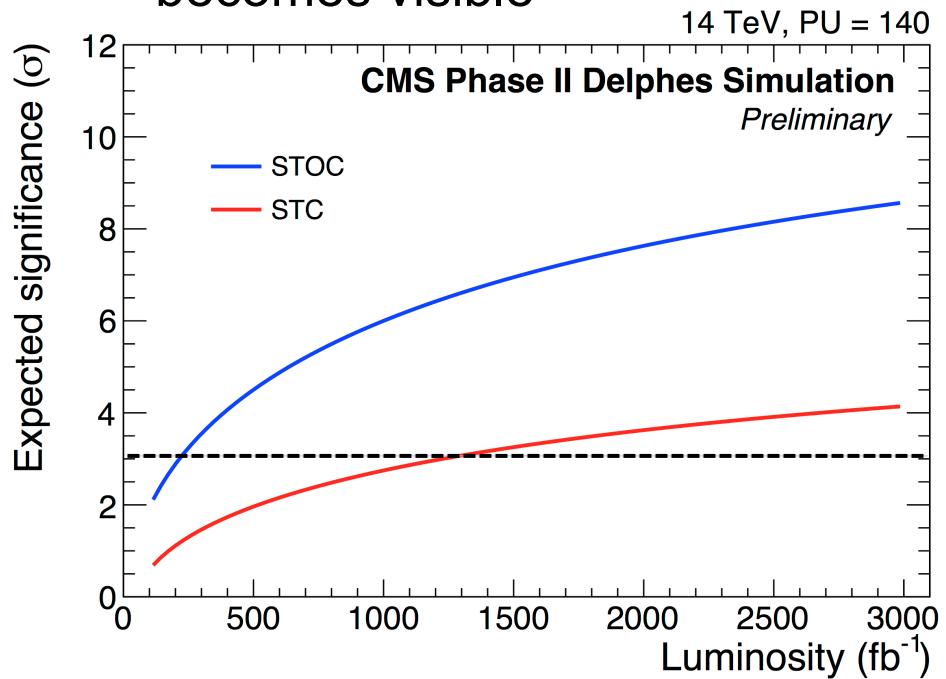
14 TeV, 3000  $\text{fb}^{-1}$ , PU = 140



# Discovery Scenarios: STC

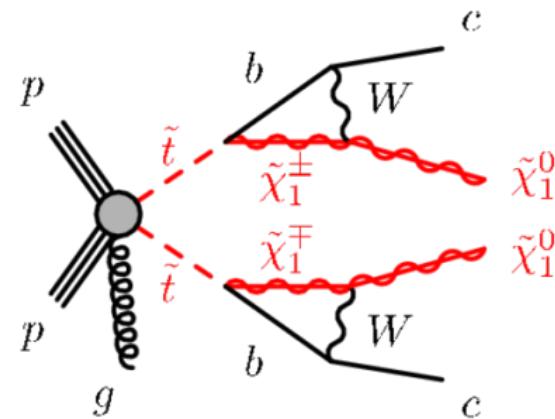
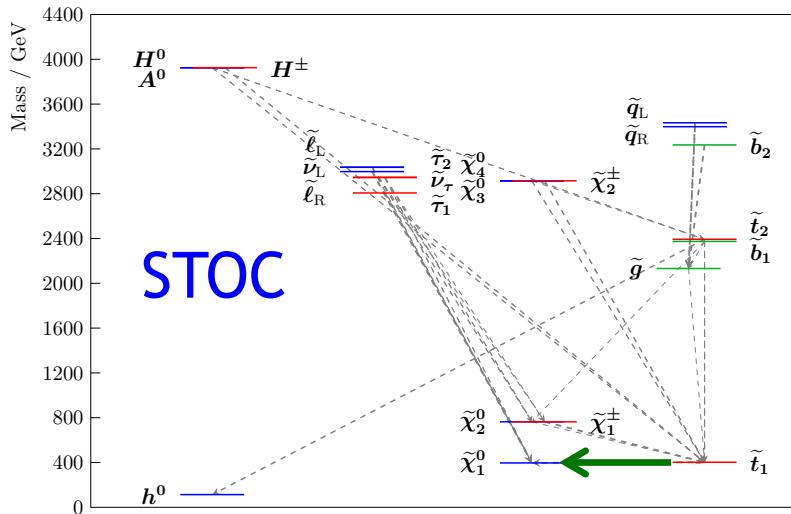


Gluino & squark production of  
3TeV gluinos and u/d/s squarks  
becomes visible

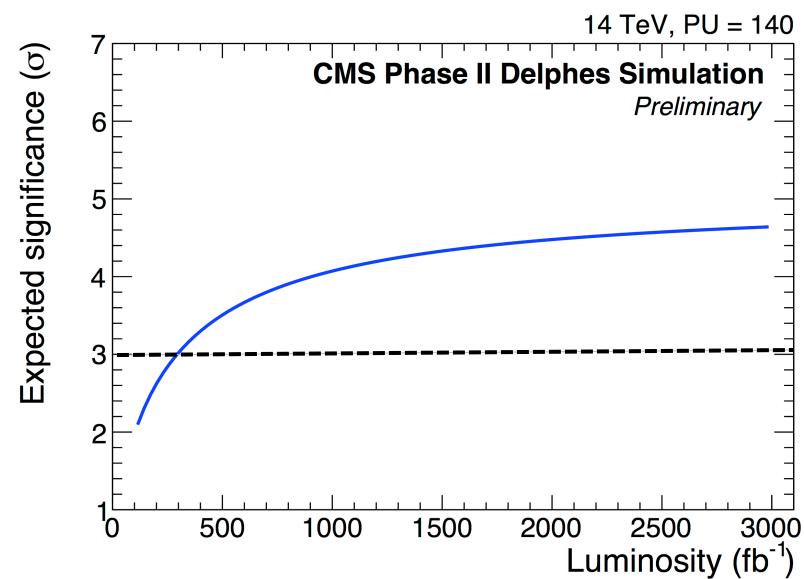


Observations in additional  
final states w/ HL-LHC

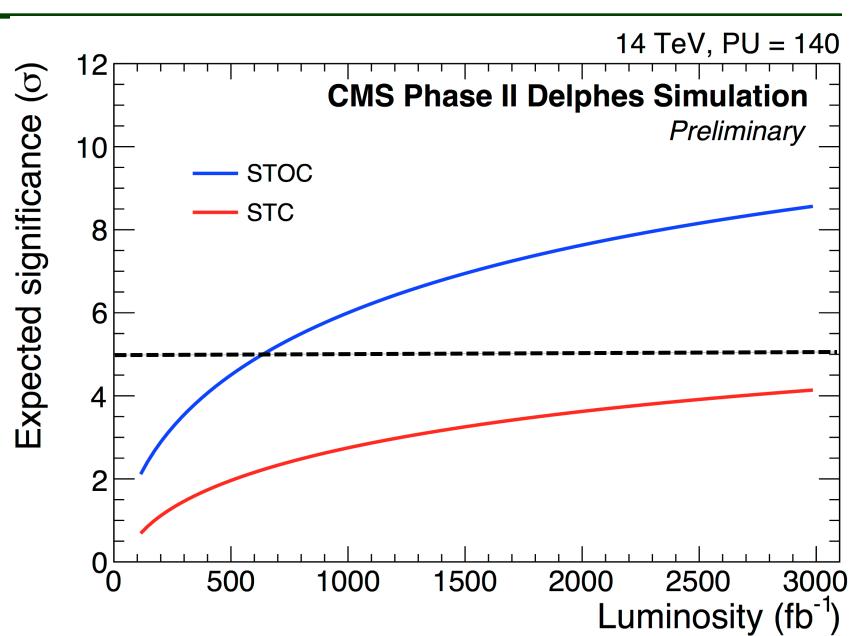
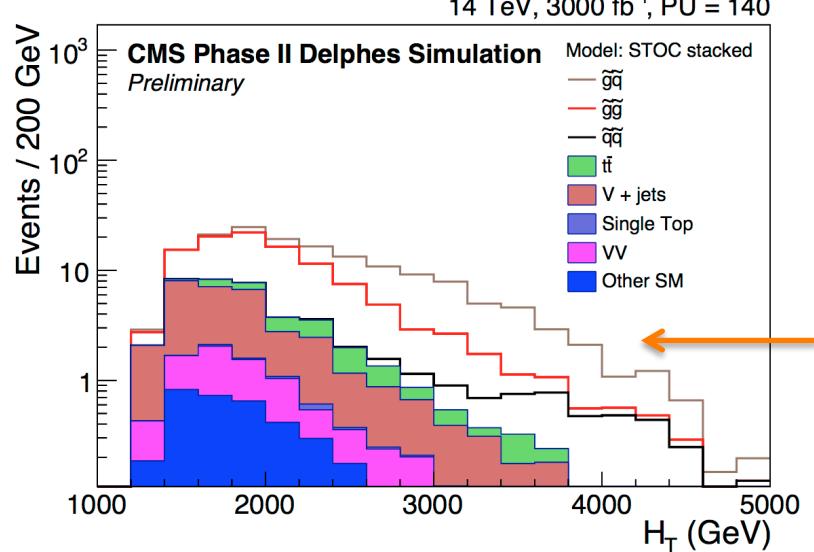
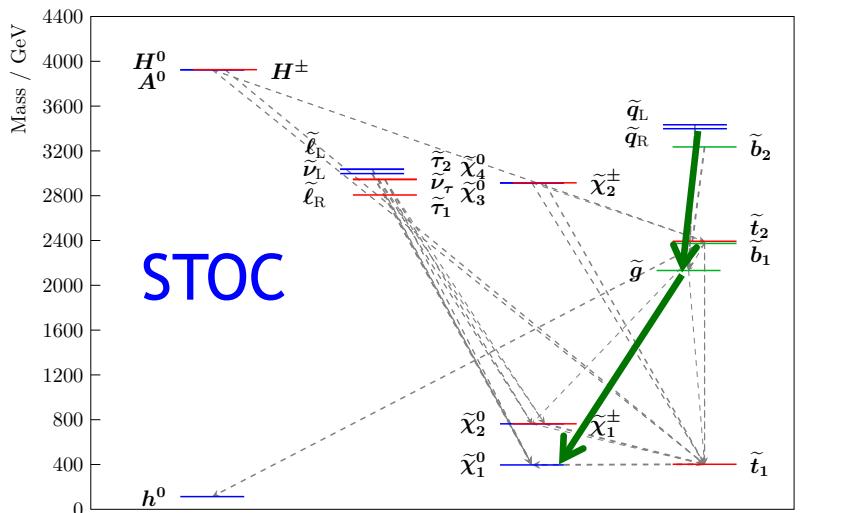
# Discovery Scenarios: STOC



Compressed top squark (~3sigma)  
in Run 2+3



# Discovery Scenarios: STOC



Observations in additional final states w/ HL-LHC

Gluino-squark production of  
3.4TeV u/d/s squarks  
becomes visible



# Conclusions

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- In spite of absence of specific evidence, the motivation for SUSY has never been stronger.
  - Continues to be the most convincing framework to explain dark matter.
  - Discovery of the Higgs has given new urgency to find a “natural” explanation of the gauge hierarchy.
- We have explored how HL-LHC measurements can illuminate the spectrum of the new particles discovered in Run 2+3
- Several major conclusions are:
  - The explored benchmark models would show at least some indication of excess w/  $<300/\text{fb}$ .
  - In order to map out the properties of a particle spectrum, it is essential to have a full pattern of results obtained at the highest integrated luminosities.

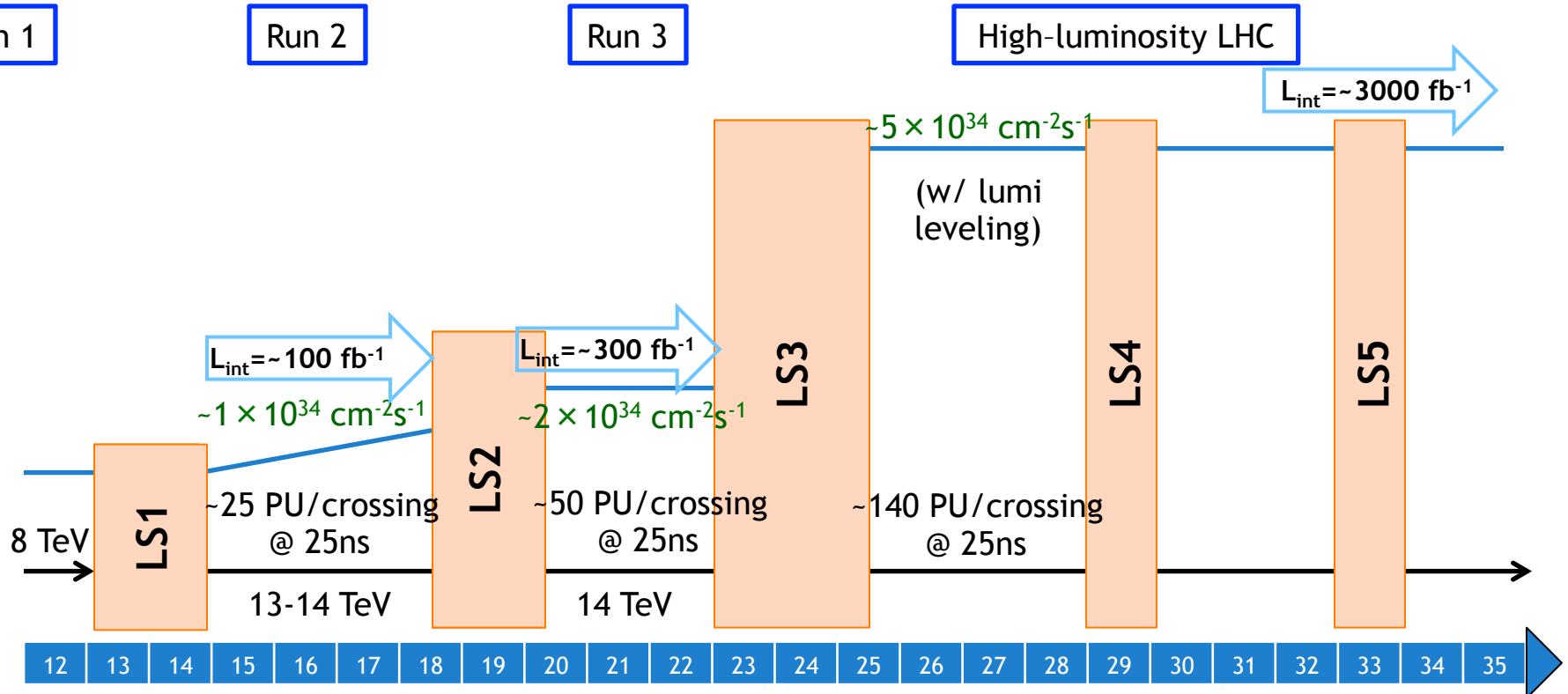
# Backup

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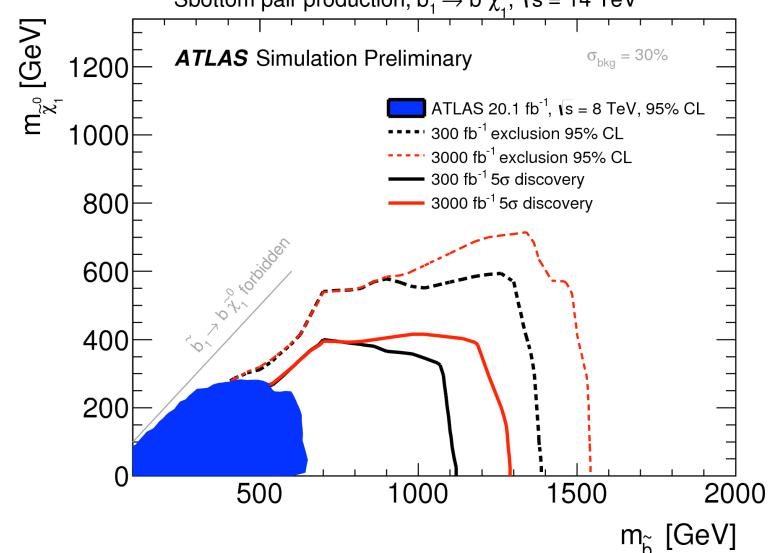
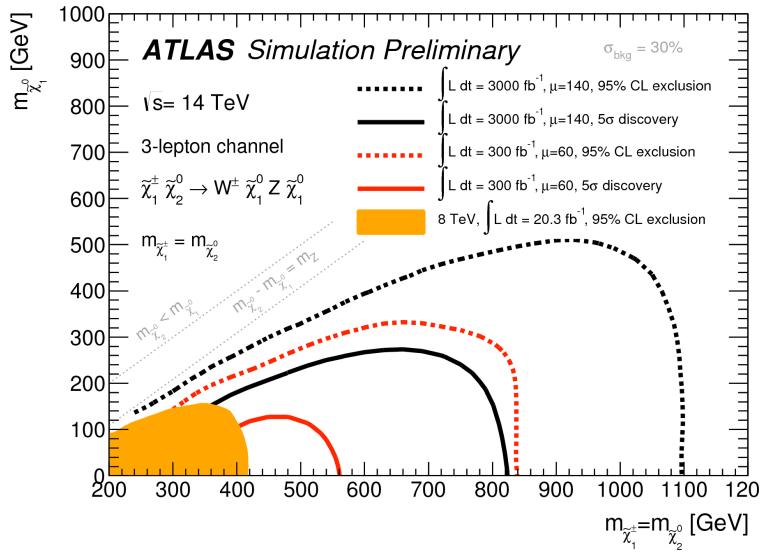
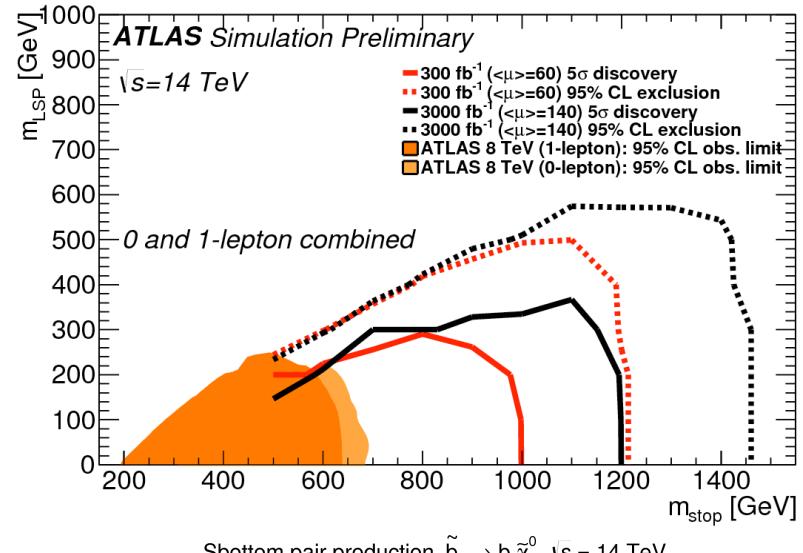
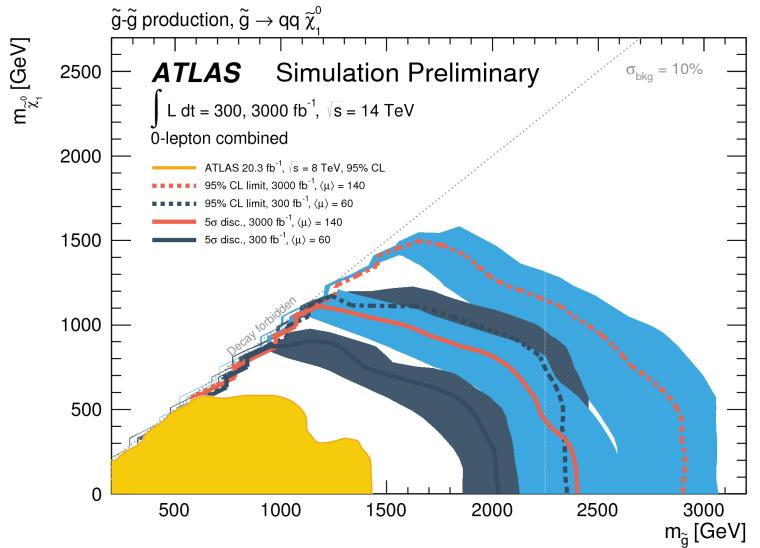
INTERNATIONAL  
YEAR OF LIGHT  
2015

# LHC Evolution

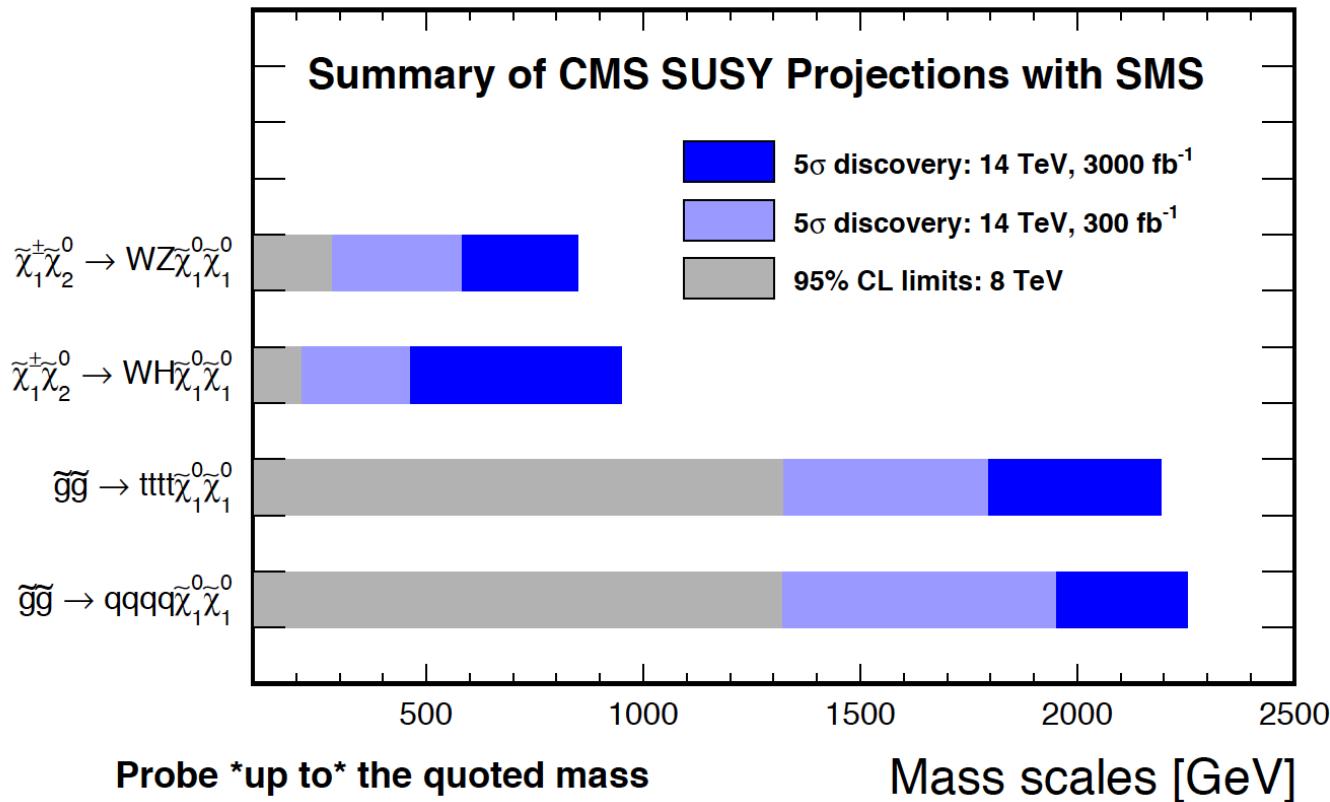


Based on [LHC schedule approved by CERN management, LHC experiment spokespersons and technical coordinators on Dec 2, 2013](#). Also, Bordry at ECFA HL-LHC workshop & Gregor.

# SUSY Discovery Potentials w/ SMS



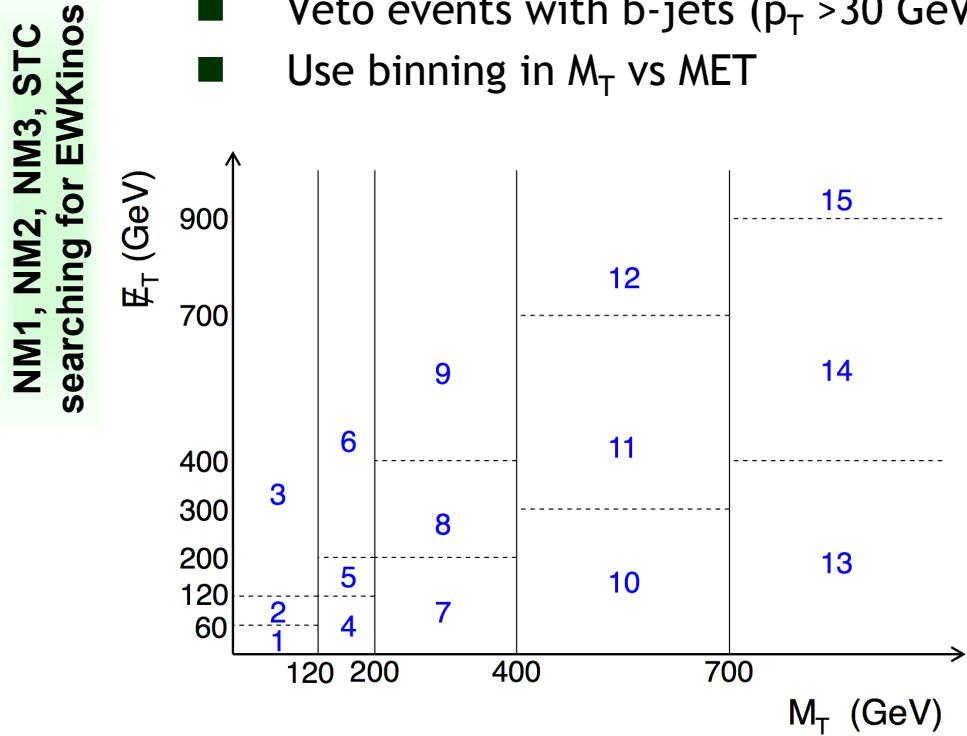
# SUSY Discovery Potentials w/ SMS



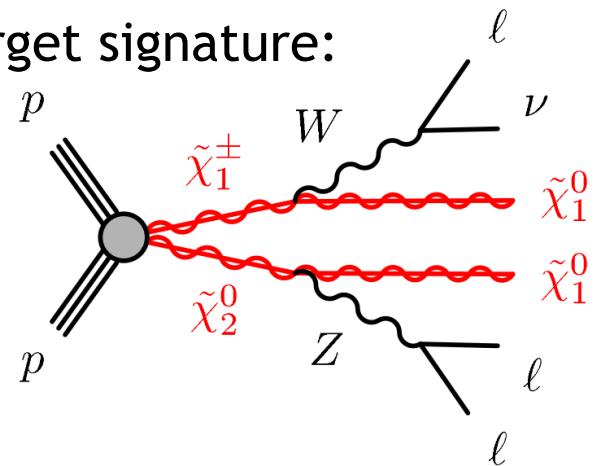
- HL-LHC increases mass reach for pair produced SUSY particles by up to 500 GeV.
- Largest relative gains in weak production processes.

# Search w/ Trileptons + MET

- Search selection:
  - $3\ell$  ( $p_T > 25/15/10$  GeV)  $|\eta| < 4$
  - OSSF ( $m_{\ell\ell}$ ) pair closest to Z(91 GeV):
    - On-Z:  $75 \text{ GeV} < m_{\ell\ell} < 105 \text{ GeV}$
    - Off-Z:  $105 \text{ GeV} < m_{\ell\ell}$
  - Veto events with b-jets ( $p_T > 30$  GeV)
  - Use binning in  $M_T$  vs MET

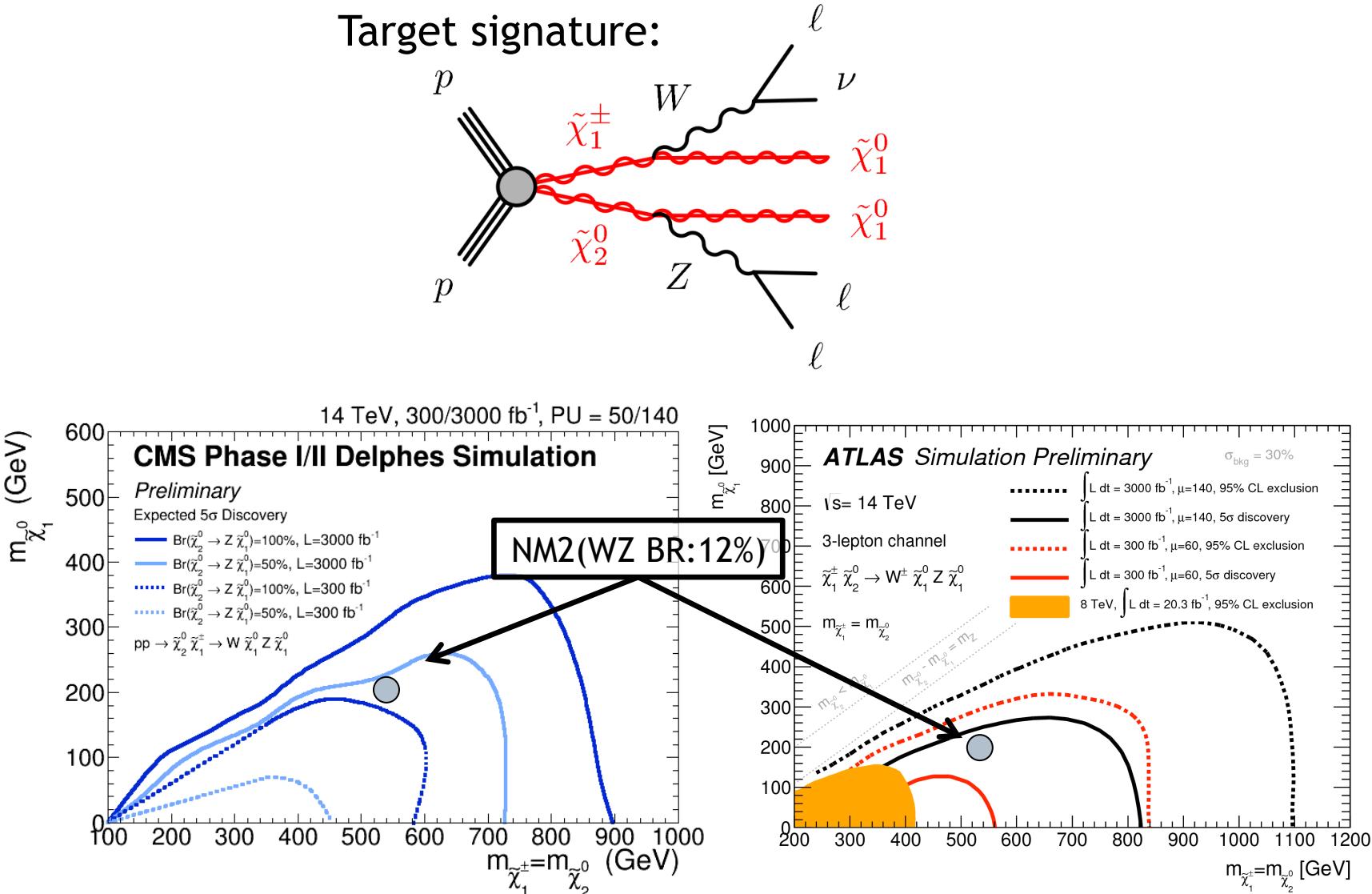


Target signature:



- Additional tighter search selection for heavy C1/N2:
  - $3\ell$  ( $p_T > 120/90/140$  GeV)
  - Veto events with a jet ( $p_T > 100$  GeV)

# Search w/ Trileptons + MET



# Search for WH + MET

## □ Search selection:

- =1 e/ $\mu$
- = 2 jets, b-tagged
- $90 < m_{bb} < 150$  GeV
- $M_{CT} > 160$  GeV,  $M_T > 100$  GeV
- MET > 200, 300, 400, 500 GeV

## Target signature:

