Simplified Models for Snowmass '13

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Snowmass 2013 - Brookhaven Energy Frontier Workshop
w/Jay Wacker (SLAC) and Timothy Cohen (SLAC)

Outline

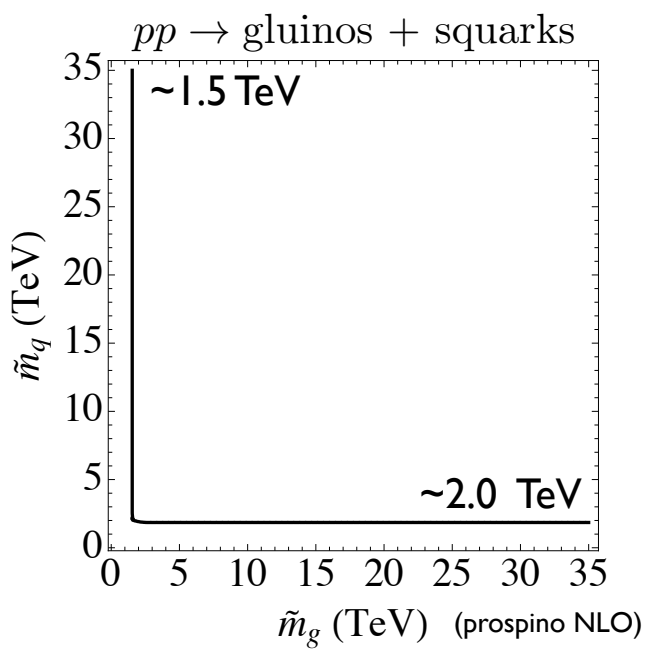
- SUSY production at future colliders and a few questions worth answering
- Simplified models and some simple motivations
- Simplified model scans for Snowmass '13 LHC studies

A *too* simplified model

SUSY discovery in a perfect world...

10 events at the....

LHC8 (20 fb^{-1})



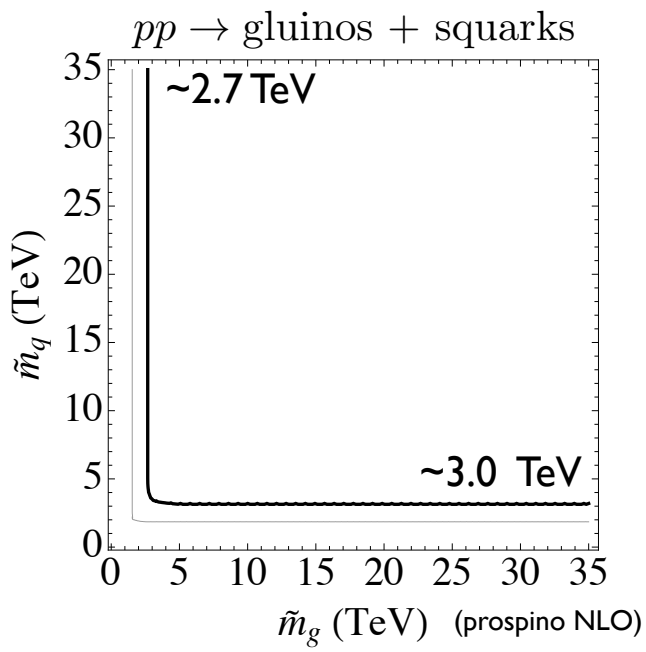
(prospino NLO)

SUSY discovery in a perfect world...

10 events at the....

~~LHC13 (20 fb^{-1})~~

LHC13 (300 fb^{-1})



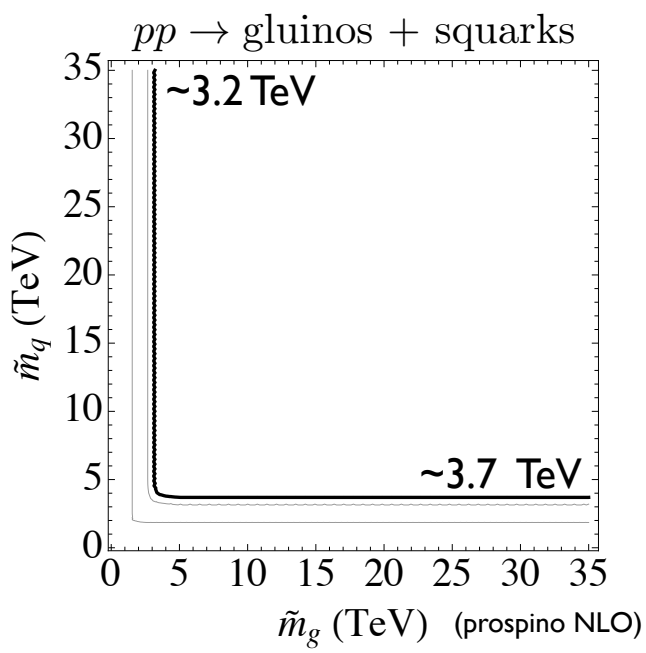
SUSY discovery in a perfect world...

10 events at the....

~~LHC13 (20 fb^{-1})~~

~~LHC13 (300 fb^{-1})~~

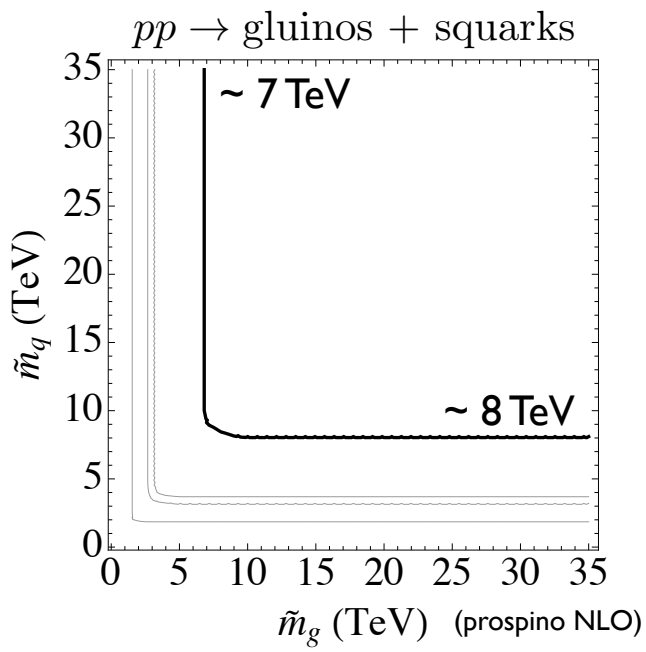
LHC13 (3000 fb^{-1})
(HL-LHC)



SUSY discovery in a perfect world...

10 events at the....

- ~~LHC8 (20 fb^{-1})~~
- ~~LHC13 (300 fb^{-1})~~
- ~~LHC13 (3000 fb^{-1})~~ (HL-LHC)
- LHC33 (3000 fb^{-1}) (HE-LHC)

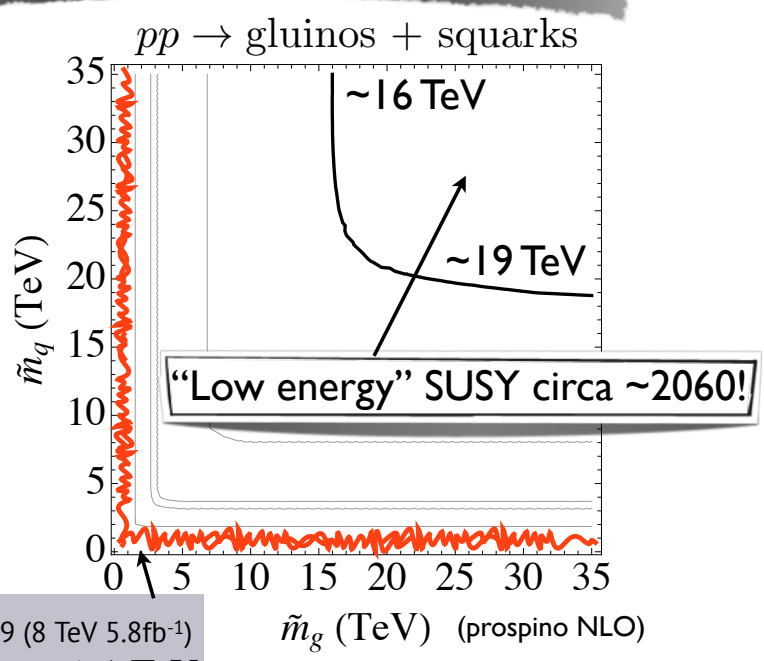


SUSY discovery in a ~~perfect~~ world...

Tuned? Standard Model? Bleak?

10 events at the....

- ~~LHC8 (20 fb^{-1})~~
- ~~LHC13 (300 fb^{-1})~~
- ~~LHC13 (3000 fb^{-1})~~ (HL-LHC)
- ~~LHC33 (3000 fb^{-1})~~ (HE-LHC)
- LHC100 (3000 fb^{-1}) (VHE-LHC)

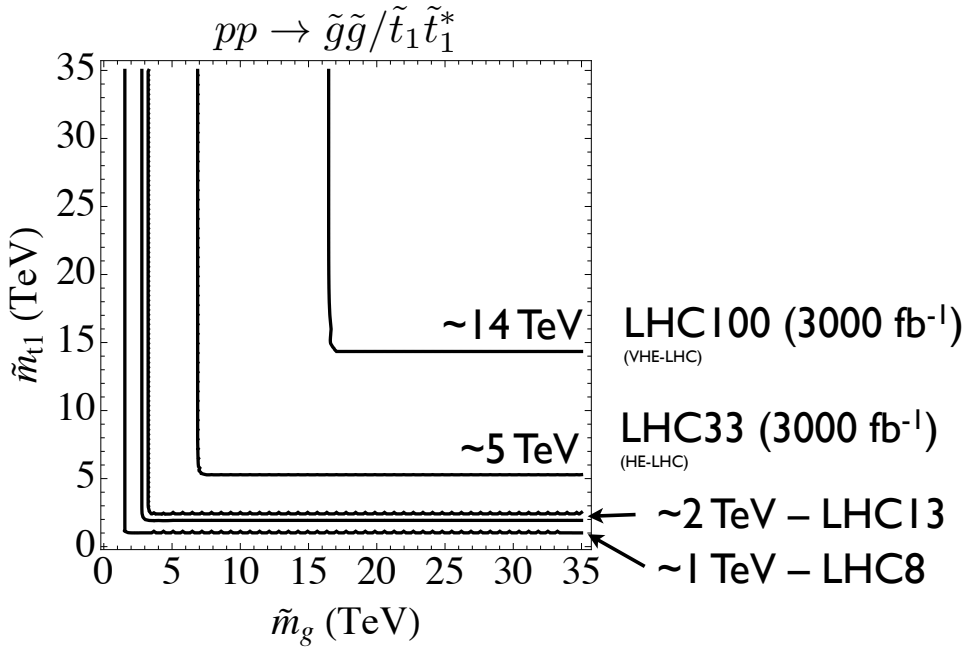


ATLAS-CONF-2012-109 (8 TeV 5.8fb^{-1})

$\tilde{m}_g > 1.2$ TeV $\tilde{m}_q > 1.4$ TeV

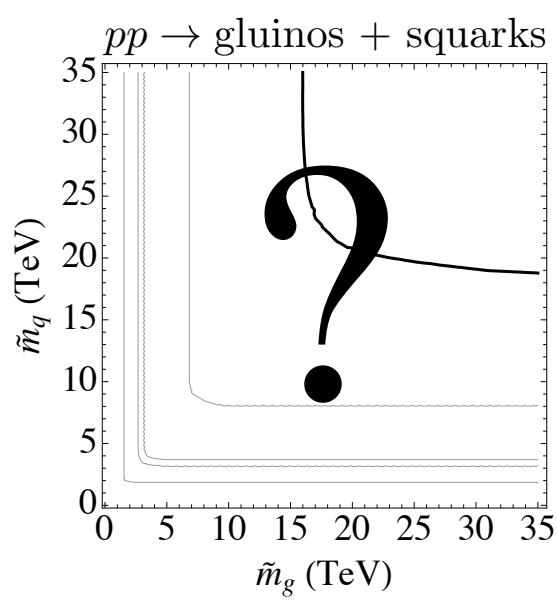
"Natural" SUSY discovery in a perfect world...

10 events at the....



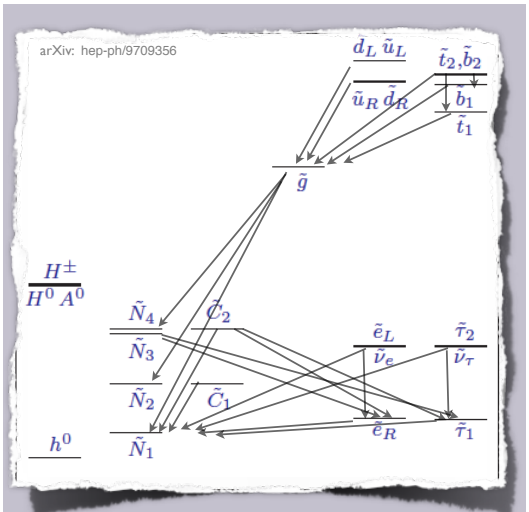
Snowmass studies for the real world...

- How do we make this more realistic?
  - Kinematics
  - Detector simulation
  - Backgrounds
- How close to ideal are the limits for *typical* realistic models?
- When does the cross section dependence break down?

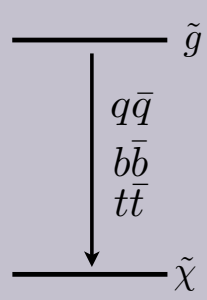


Simplified models

A Simple Simplified Model - Gluino + LSP



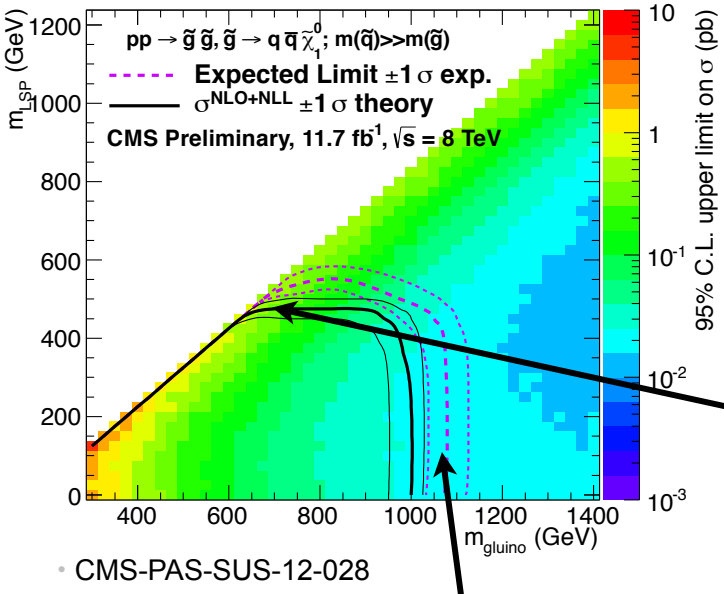
$M_1, M_2, M_3, A_u^i, A_d^i, A_e^i,$
$m_Q^i, m_D^i, m_L^i, m_E^i, \mu, ...$



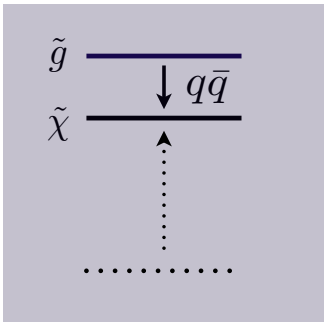
$M_{\tilde{g}}, M_\chi, \mathrm{BR}(\tilde{g} \to \chi t\bar{t}),$
$\mathrm{BR}(\tilde{g} \to \chi q\bar{q}), \mathrm{BR}(\tilde{g} \to \chi b\bar{b})$

Consistent: $\mathcal{L} \supset C_1 \overline{q}\tilde{g}\overline{\chi}q + C_2 \overline{b}\tilde{g}\overline{\chi}b + C_3 \overline{q}\tilde{g}\overline{\chi}q$

gluino + squark + LSP simplified model



- CMS-PAS-SUS-12-028



$\tilde{m}_{\rm LSP} \sim 500$ GeV

- where is the "compressed" cut-off at 13/33/100 TeV LHC?

~200 events

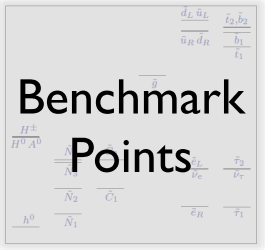
Simplified Models in Context...

Complexity

UV scans (CMSSM, ...)

Phenomenological Scans (PMSSM, ...)

+ topology coverage
+ complementarity (DM, precision, ...)



Simplified Models

+ kinematic coverage
+ generality (recasting)
+ extensibility (beyond the MSSM)
+ search optimization

Coverage

LHC simplified model scans for Snowmass '13

Simplified Models for Snowmass '13

SLAC simplified models group providing signal scans of LHC colored production models:

- gluino + light squarks + LSP

"Generic" R-parity conserving SUSY signature: jets + MET

- gluino + stop + LSP

+ Direct connection to naturalness
+ Signatures: multilepton, b-jets, heavy object tagging

see: http://www.stanford.edu/~timcohen/SimplifiedModelsForSnowmass.pdf

Other SUSY simplified model scans for Snowmass?

- Electroweak production
- GMSB (light gravitino), R-parity violation

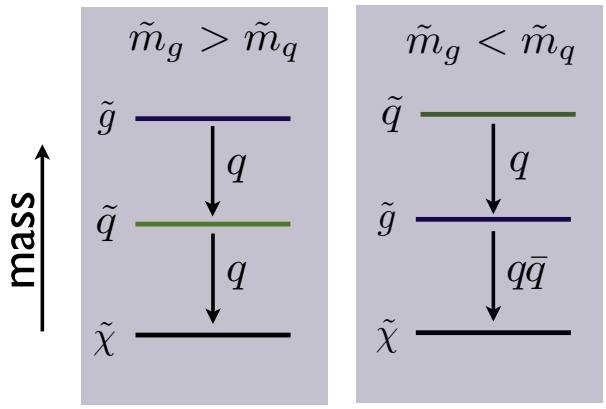
gluino + squark + LSP simplified model

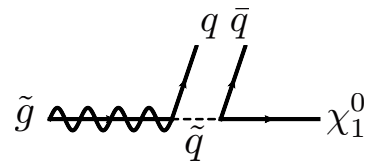
Production:

$$pp \to \tilde{q}\tilde{q},\ \tilde{q}\tilde{q}^*,\ \tilde{g}\tilde{q}^{(*)},\ \tilde{g}\tilde{g}$$

$$\tilde{q} = \tilde{u}_{L/R}, \tilde{d}_{L/R}, \tilde{c}_{L/R}, \tilde{s}_{L/R}$$

Decays:





$$(2-6)j + \mathrm{MET}$$

gluino + squark + LSP simplified model

Parameter Scans:

1) $(\tilde{m}_g, \tilde{m}_q)$ plane :

$\tilde{m}_g$	$\tilde{m}_q$
500 GeV	500 GeV
629 GeV	629 GeV
792 GeV	792 GeV
...	...

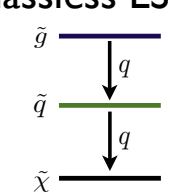
$\frac{m_{n+1}}{m_n} = 10^{\frac{1}{10}}$

until $\sigma < \mathcal{L}^{-1}$ (~ 1 ab)

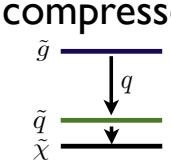
$$\tilde{m}_\chi = x \times \tilde{m}_{\mathrm{LCP}}$$

$$x = 0.0, 0.4, 0.6, 0.7, 0.8, 0.9$$

massless LSP



compressed



2) decoupled squarks ($\tilde{m}_q \gg \tilde{m}_g$)

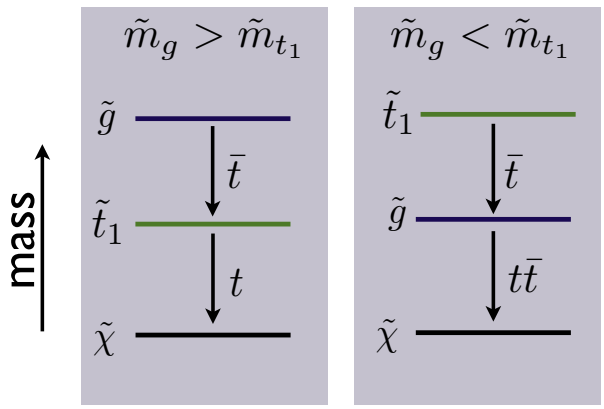
see: http://www.stanford.edu/~timcohen/SimplifiedModelsForSnowmass.pdf

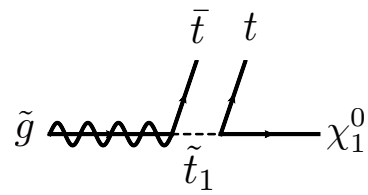
gluino + stop + LSP simplified model

Production:

$$pp \to \tilde{g}\tilde{g},\ \tilde{t}_1\tilde{t}_1^*$$

Decays:





$$(2-6)t + \text{MET}$$

gluino + stop + LSP simplified model

Parameter Scans:

1) decoupled gluinos ($\tilde{m}_g \gg \tilde{m}_{t_1}$)

$\tilde{m}_{t_1}$
500 GeV
629 GeV
792 GeV
...

$\frac{m_{n+1}}{m_n} = 10^{\frac{1}{10}}$ until $\sigma < \mathcal{L}^{-1}$ (~ 1 ab)

$$\tilde{m}_\chi = x(\tilde{m}_{t_1} - m_t + 10\ \text{GeV})$$
$$x = 0.0, 0.25, 0.5, 0.75, 1.0$$

2) decoupled stops ($\tilde{m}_q > \tilde{m}_{t_1} \gg \tilde{m}_g$)

$\tilde{m}_g$
500 GeV
629 GeV
792 GeV
...

$\frac{m_{n+1}}{m_n} = 10^{\frac{1}{10}}$ until $\sigma < \mathcal{L}^{-1}$ (~ 1 ab)

$$\tilde{m}_\chi = x(\tilde{m}_g - 2m_t)$$
$$x = 0.0, 0.25, 0.5, 0.75$$

see: http://www.stanford.edu/~timcohen/SimplifiedModelsForSnowmass.pdf

Simplified model scans

- Simplified model scans at 13, 33, 100 TeV
- Hard process + decays + shower: MadGraph5 + Pythia w/jet matching
- Detector simulation and reconstruction: Delphes3
- Prospino2.1 NLO cross-sections
- Details:

  http://www.stanford.edu/~timcohen/WeightedEventsUsingMadgraph.pdf

Simplified model scans

- Simplified model scans at 13, 33, 100 TeV
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  cross-sections
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Kiel Howe, Stanford, Brookhaven Snowmass High Energy Frontier Workshop '13

Sample 13 TeV gluino + LSP scan
(3 body light quark decay) available:
https://www.dropbox.com/s/bntz81jowvevv06/GO_decoupledSO_13TeV.tar.gz

Recap

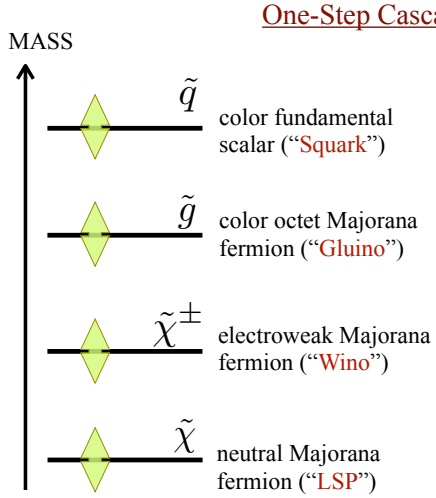
- Nominal reach of LHC100 - 20 TeV squarks and gluinos!
- Simplified models - great tool to explore true sensitivity for variety of collider signals and kinematic regimes
- SLAC simplified model group providing colored production simplified model signal scans for analysis
  (get your dataset here:
  https://www.dropbox.com/s/bntz81jowvevv06/GO_decoupledSQ_13TeV.tar.gz !)

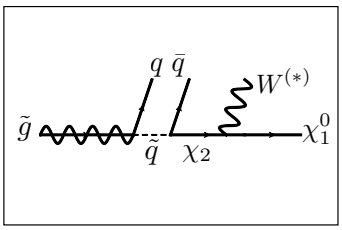
Questions?

Back-ups

Next simplified models? One step cascades

One-Step Cascade Decays





$$m_{\tilde{\chi}^{\pm}} = m_{\tilde{\chi}} + r\,(m_{\tilde{g}} + m_{\tilde{\chi}})$$

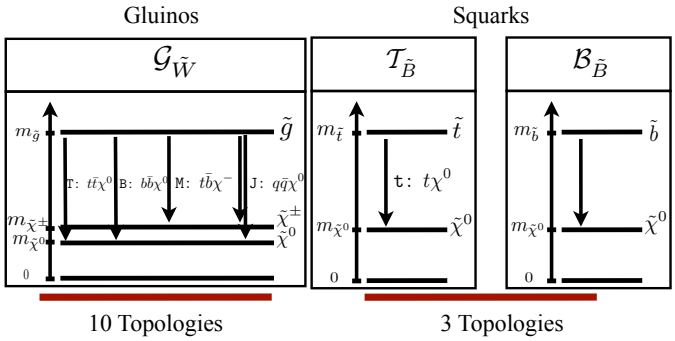
$$r = \frac{1}{4}, \frac{1}{2}, \frac{3}{4}$$

Next simplified models? Heavy Flavor

Heavy Flavor Simplified Models

- Simplified model for "natural SUSY."

Essig, Izaguirre, Kaplan, Wacker [arXiv:1110.6443]



3 Free Parameters in Each Topology

2 Masses & Cross Section x BR

SUSY Simplified Models Motivations

- Collider (LHC) oriented

Alwall, Le, Listanti, Wacker [arXiv:0809.3264]
Alwall, Schuster, Toro [arXiv:0810.3921]
LHC New Physics Working Group [arXiv:1105.2838]

  - Include only particles dominant in *production* and *decay chains*
    - At the LHC:
      production: squarks & gluinos
      decays: neutralinos, charginos, SM particles
    - For comparison to ILC:
      neutralinos, charginos
  - Parameters are physical observables: *gauge representations, masses* and *branching fractions*

More Simplified Models at LHC7/8/13

ATLAS

- ATLAS-CONF-2013-001 (stop - neutralino)
- ATLAS-CONF-2012-165 (sbottom - neutralino)
- ATLAS-CONF-2012-154 (chargino - neutralino - slepton)
- ATLAS-CONF-2012-153 (gluino - slepton - chargino - neutralino with R-Parity Violation)
- ATL-PHYS-PUB-2012-004 (14 TeV High Luminosity Study!
- stop - neutralino, gluino - squark - neutralino, ...)
- ...

CMS

- CMS-PAS-SUS-12-028 (stop - neutralino)
- CMS-PAS-SUS-12-026 (gluino - stop - neutralino and slepton - neutralino)
- CMS-PAS-SUS-12-022 (chargino - neutralino - slepton)
- CMS-PAS-SUS-12-018 (gluino - squark - neutralino - gravitino)
- ...