Simplified Models

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What limit has the LHC set on the gluino mass?

(No, I don’t mean some bizarre RPV decaying gluino)

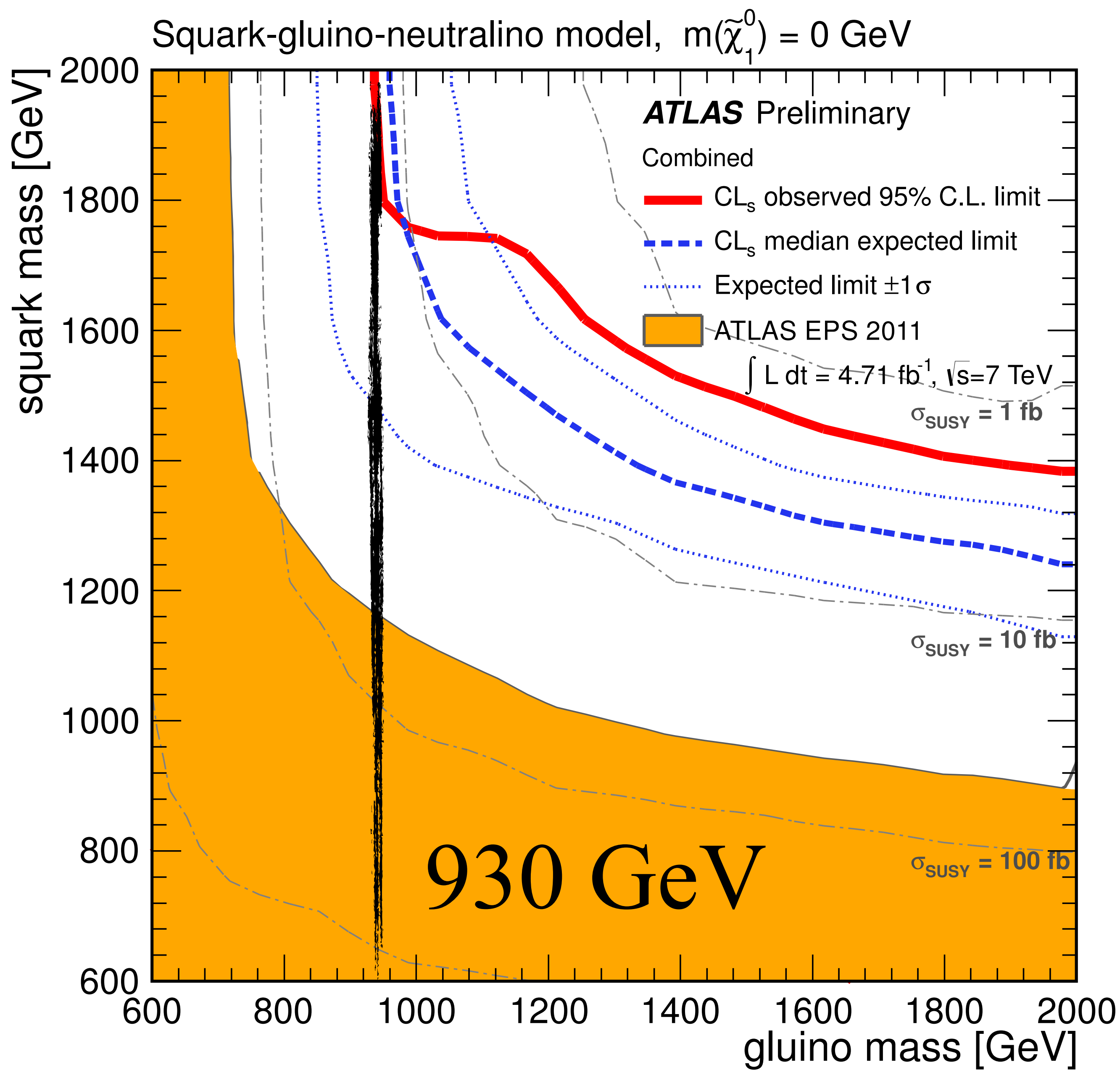
None

None

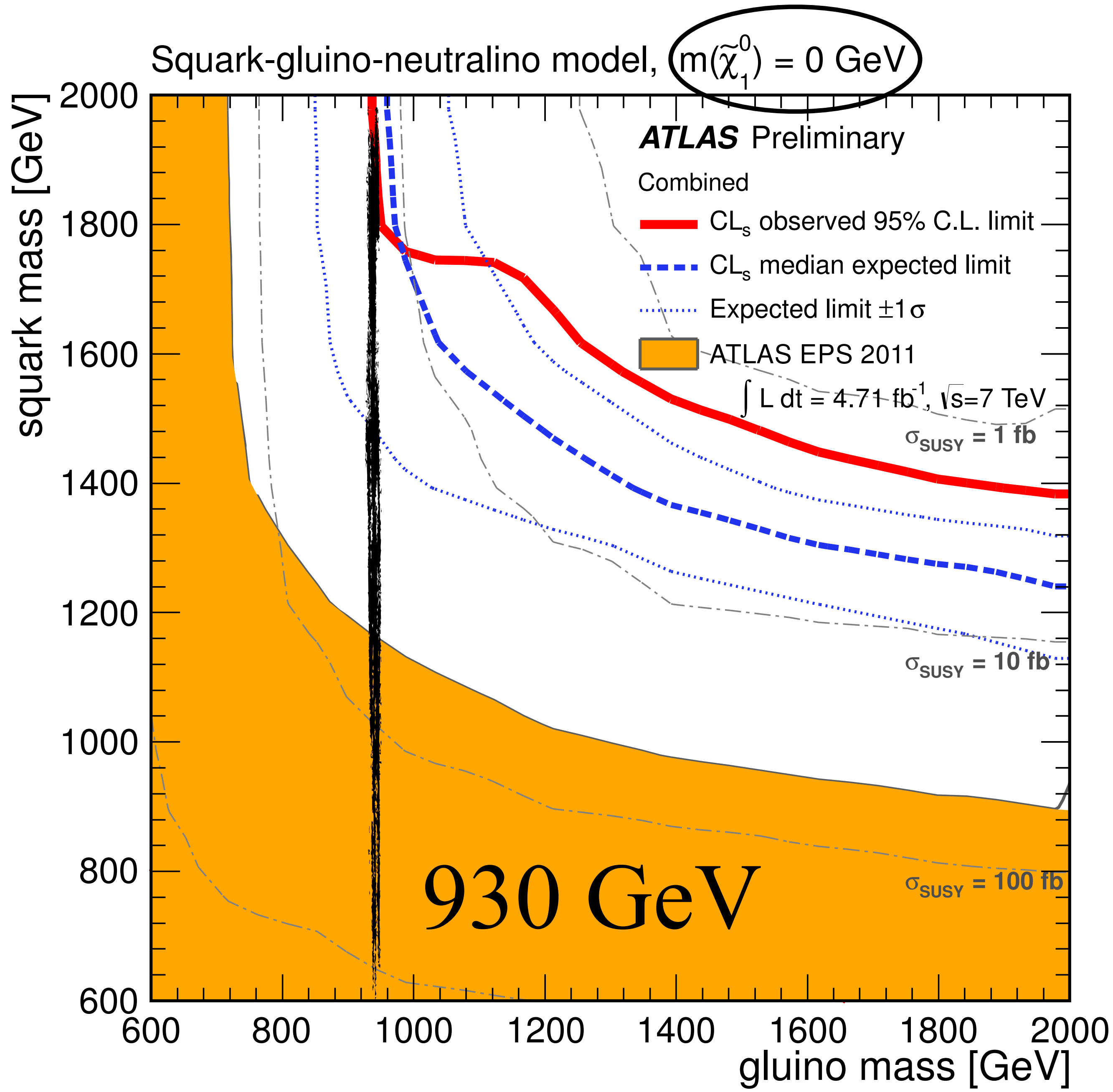
if

$$m_{\tilde{\chi}^0} \gtrsim 250\,\mathrm{GeV}$$

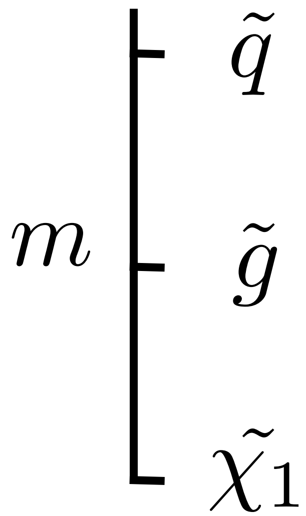
ATLAS 4.7fb^{-1} results



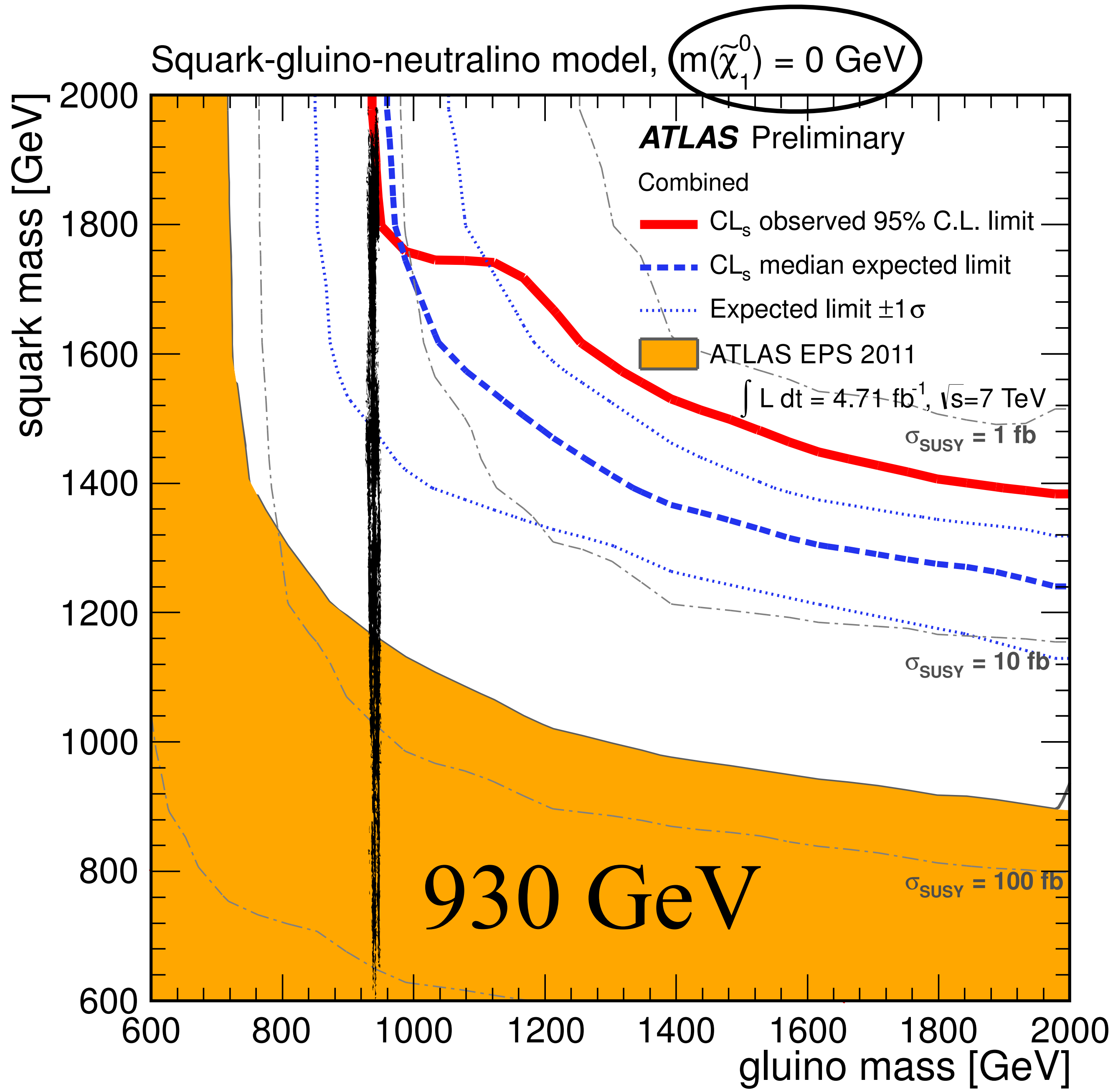
ATLAS 4.7fb^{-1} results



ATLAS 4.7fb^{-1} results



$$\tilde{g} \to q\bar{q}\tilde{\chi}_1$$



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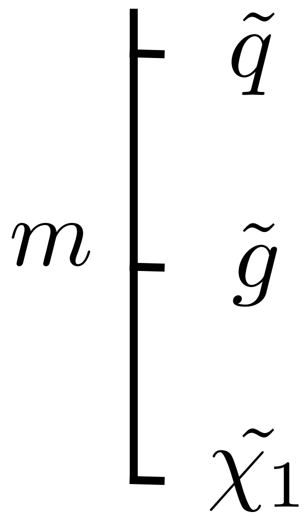

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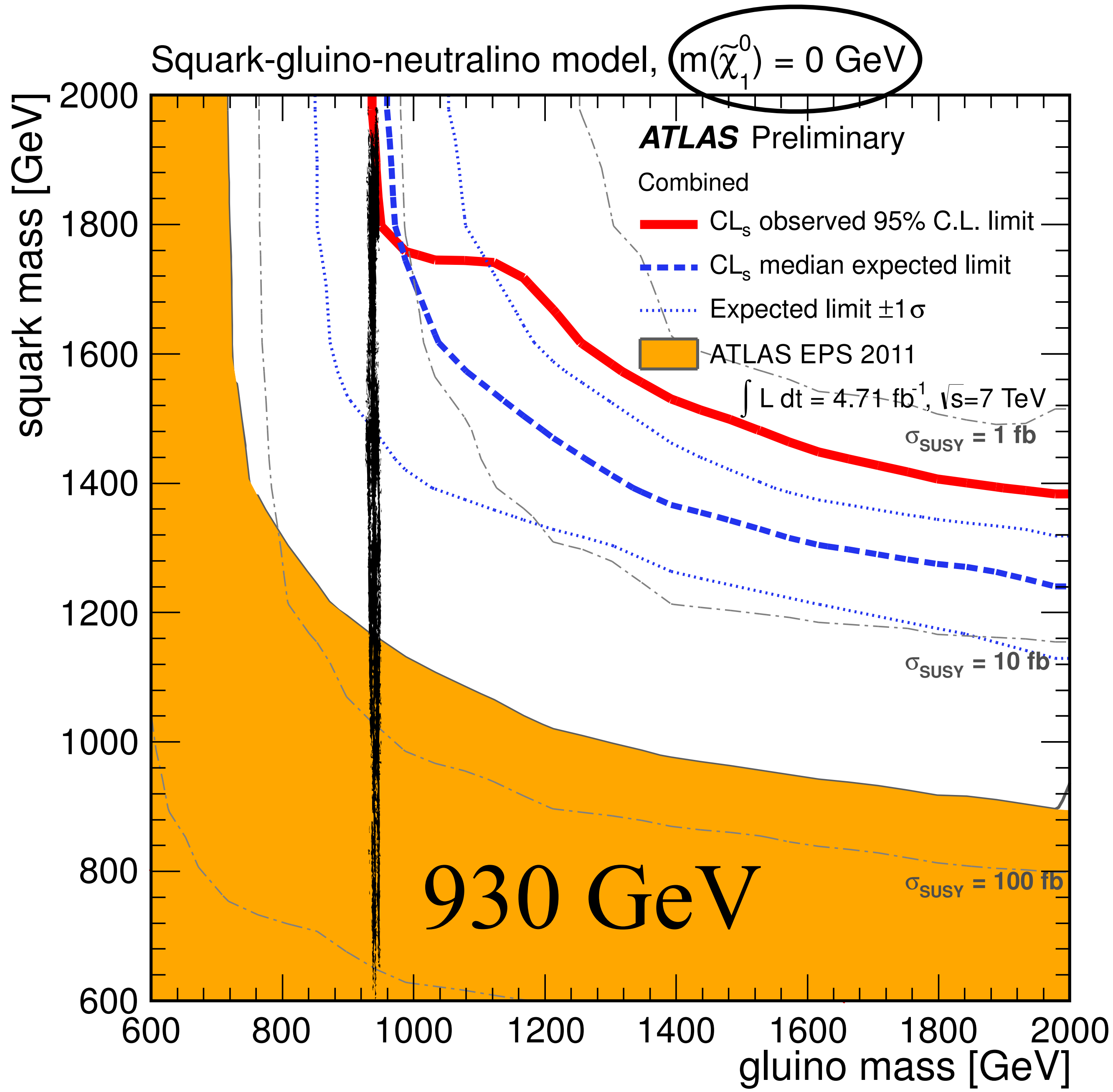
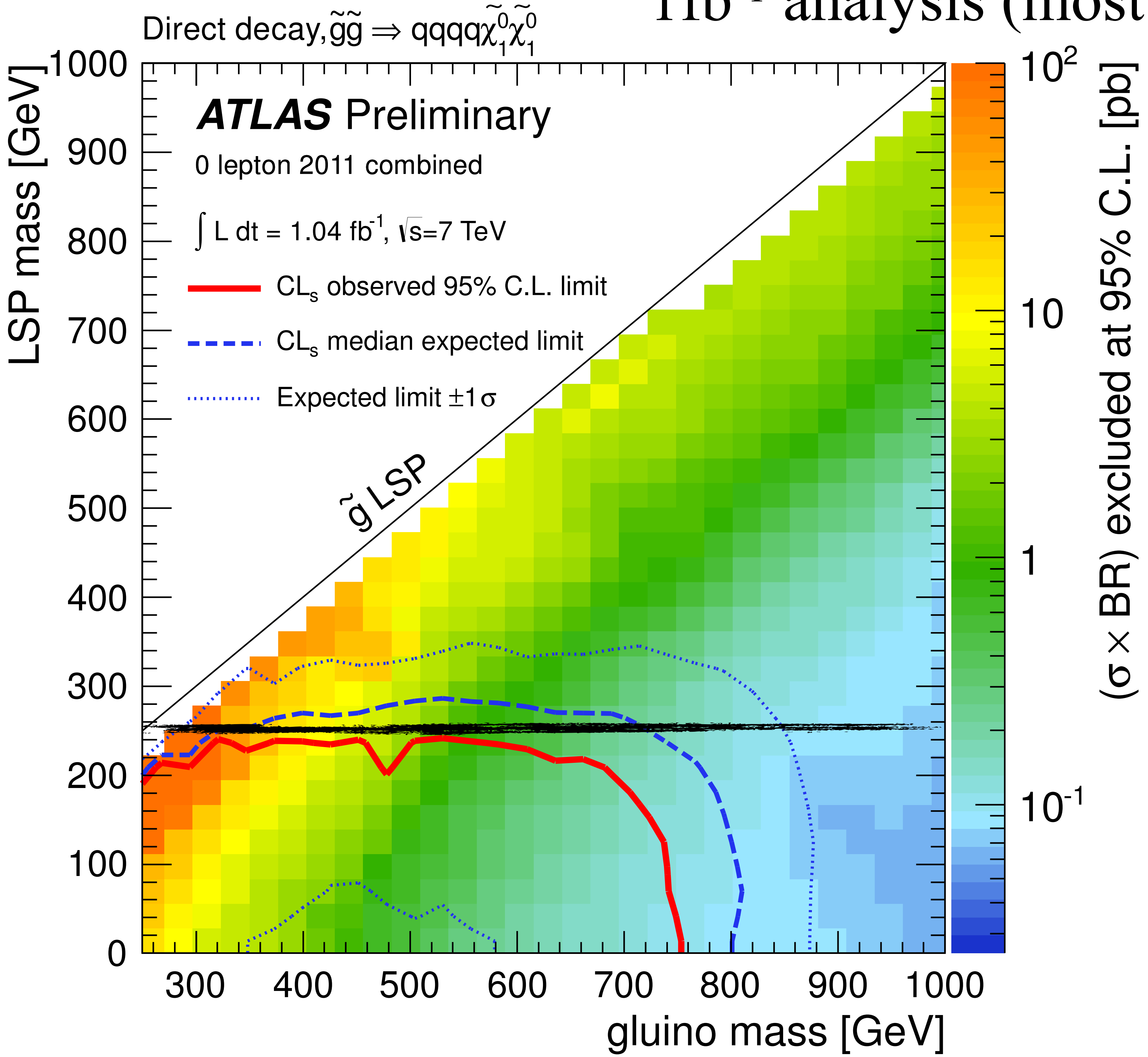


How well do the analyses do for other decay topologies and arbitrary LSP masses?

Other LSP Masses

1fb^{-1} analysis (most recent)



Outline

- Simplified models
- Quantifying models
- From anomalies to discovery

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Simplified Models

Effective theories for collider physics
Full Lagrangian description

Only keep relevant parameters

Can recast bounds in terms of other theories with similar particle content

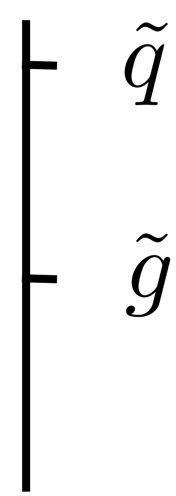
Useful to find holes in search strategy

An Example: Jets + MET

Adopt bottom-up approach

Parameterize new physics in terms of simple reactions
e.g. only one new colored state

Gluino simplified model



$$m_{\tilde{q}} >> m_{\tilde{g}}$$

Gluino Simplified Models

Assume squarks decoupled

Each decay topology = one simplified model

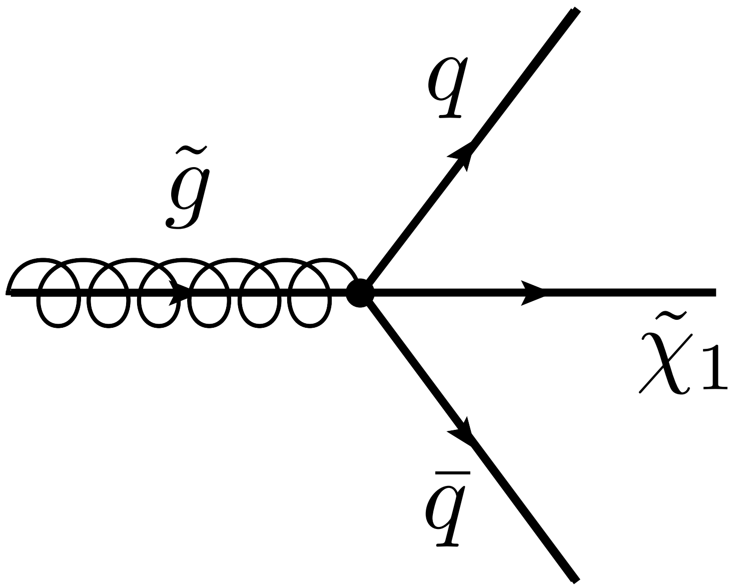
Need a neutral state at the end of decay chain

Add successive levels of complexity
e.g. intermediate states

Gluino Reactions

3-Body direct decay

Parameters



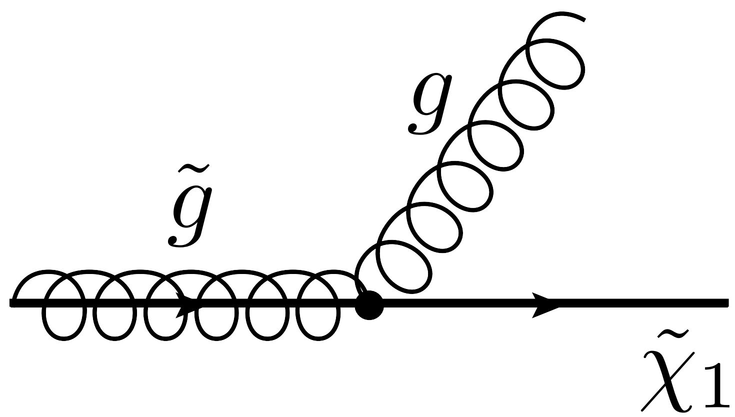
$\sigma_{pp\to\tilde{g}\tilde{g}} \times \mathrm{Br}$

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{g^2}{\Lambda^2}\tilde{g}q_i\bar{q_i}\tilde{\chi}_1 + \mathcal{L}_{\text{kinetic}}$$

Gluino Reactions

2-Body direct decay

Parameters



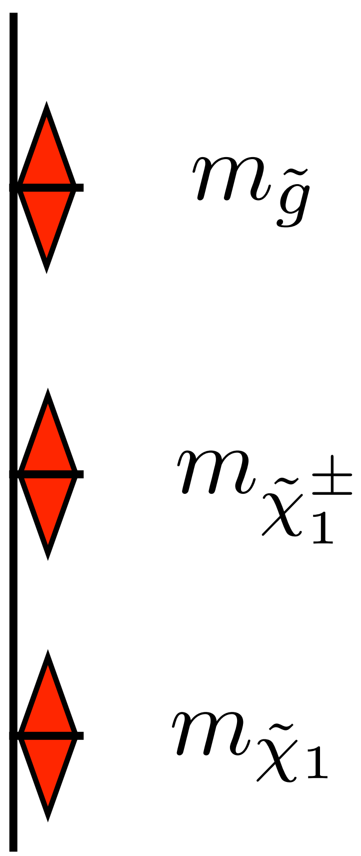
$\sigma_{pp \to \tilde{g}\tilde{g}} \times \mathrm{Br}$

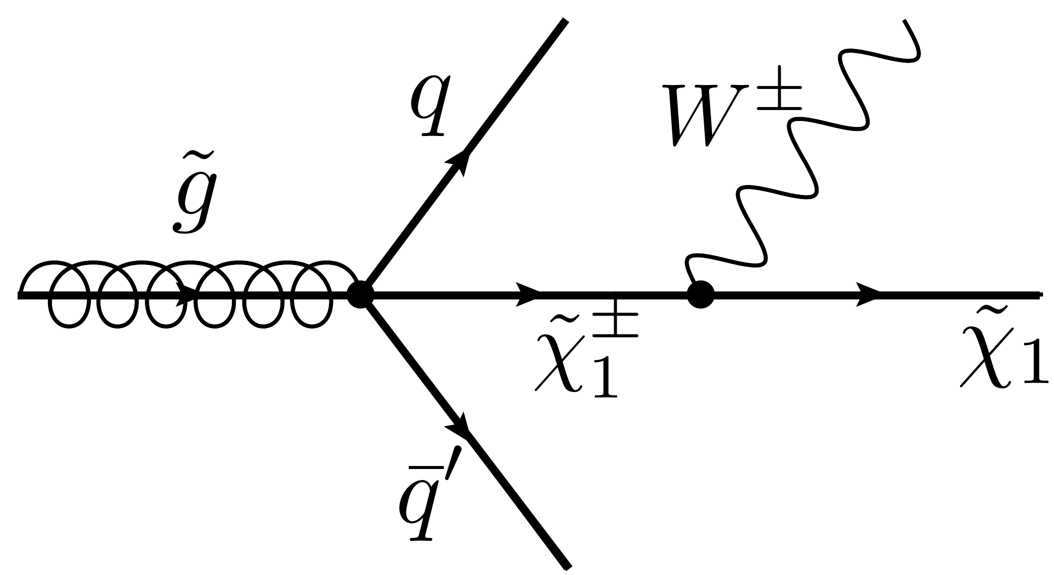
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{g}{\Lambda} \tilde{g} G^{\mu\nu} \sigma_{\mu\nu} \tilde{\chi}_1 + \mathcal{L}_{\text{kinetic}}$$

Gluino Reactions: Next Level of Complexity

1-Step Cascades

Parameters



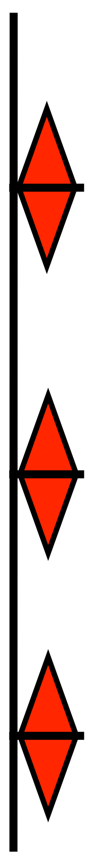


$\sigma_{pp \to \tilde{g}\tilde{g}} \times \mathrm{Br}$

Gluino Reactions: Next Level of Complexity

1-Step Cascades

Parameters



$m_{\tilde{g}}$

$m_{\tilde{\chi}_1^\pm}$

$m_{\tilde{\chi}_1}$

$\sigma_{pp \to \tilde{g}\tilde{g}} \times \mathrm{Br}$

Simplifying assumptions

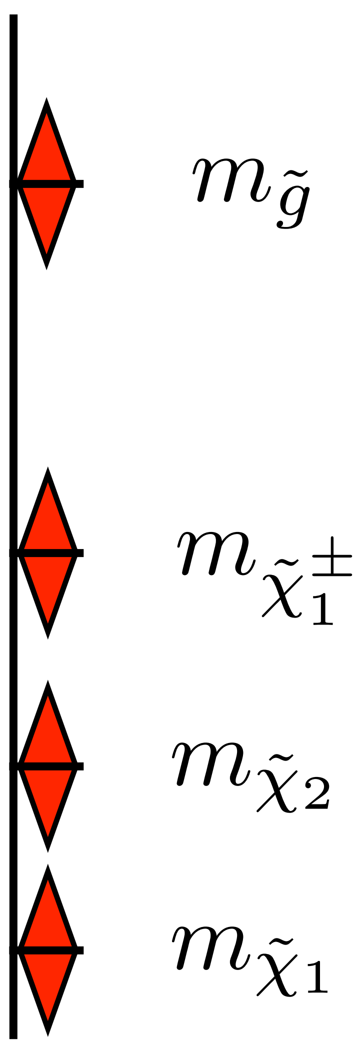
$$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1} + x(m_{\tilde{g}} - m_{\tilde{\chi}_1})$$

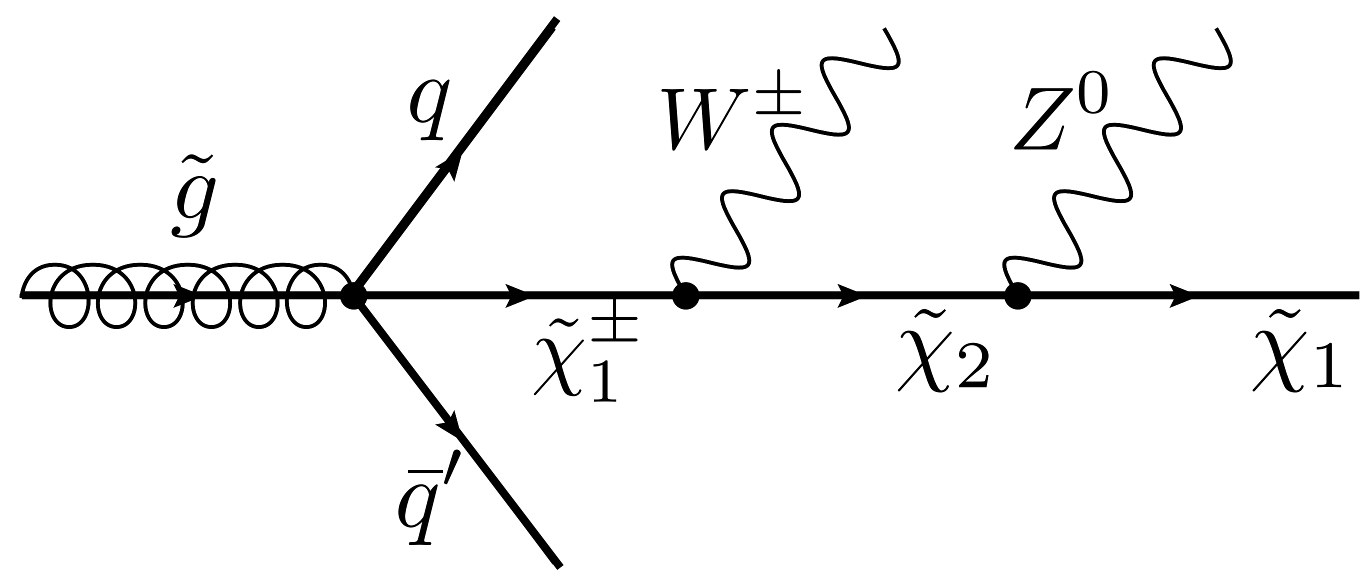
$$x = 0.25, 0.5, 0.75$$

Gluino Reactions: One More Level of Complexity

2-Step Cascades

Parameters



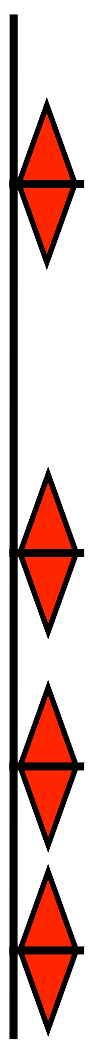


$\sigma_{pp\to\tilde{g}\tilde{g}} \times \mathrm{Br}$

Gluino Reactions: One More Level of Complexity

2-Step Cascades

Parameters



$m_{\tilde{g}}$

$m_{\tilde{\chi}_1^\pm}$

$m_{\tilde{\chi}_2}$

$m_{\tilde{\chi}_1}$

$\sigma_{pp\to\tilde{g}\tilde{g}} \times \mathrm{Br}$

Simplifying assumptions

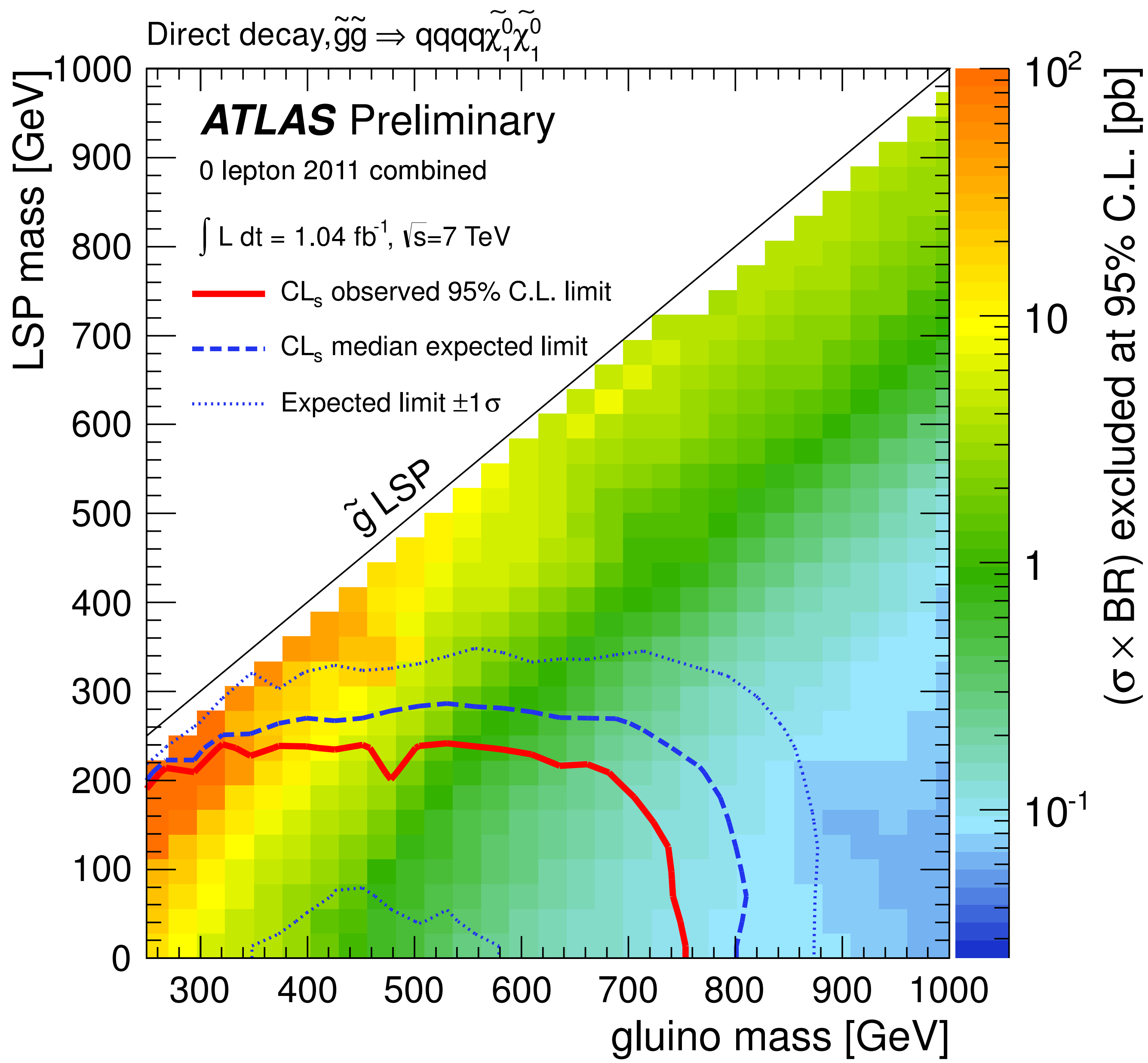
$$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1} + x(m_{\tilde{g}} - m_{\tilde{\chi}_1})$$

$$m_{\tilde{\chi}_2} = m_{\tilde{\chi}_1} + x'(m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1})$$

$$x = x' = 0.5$$

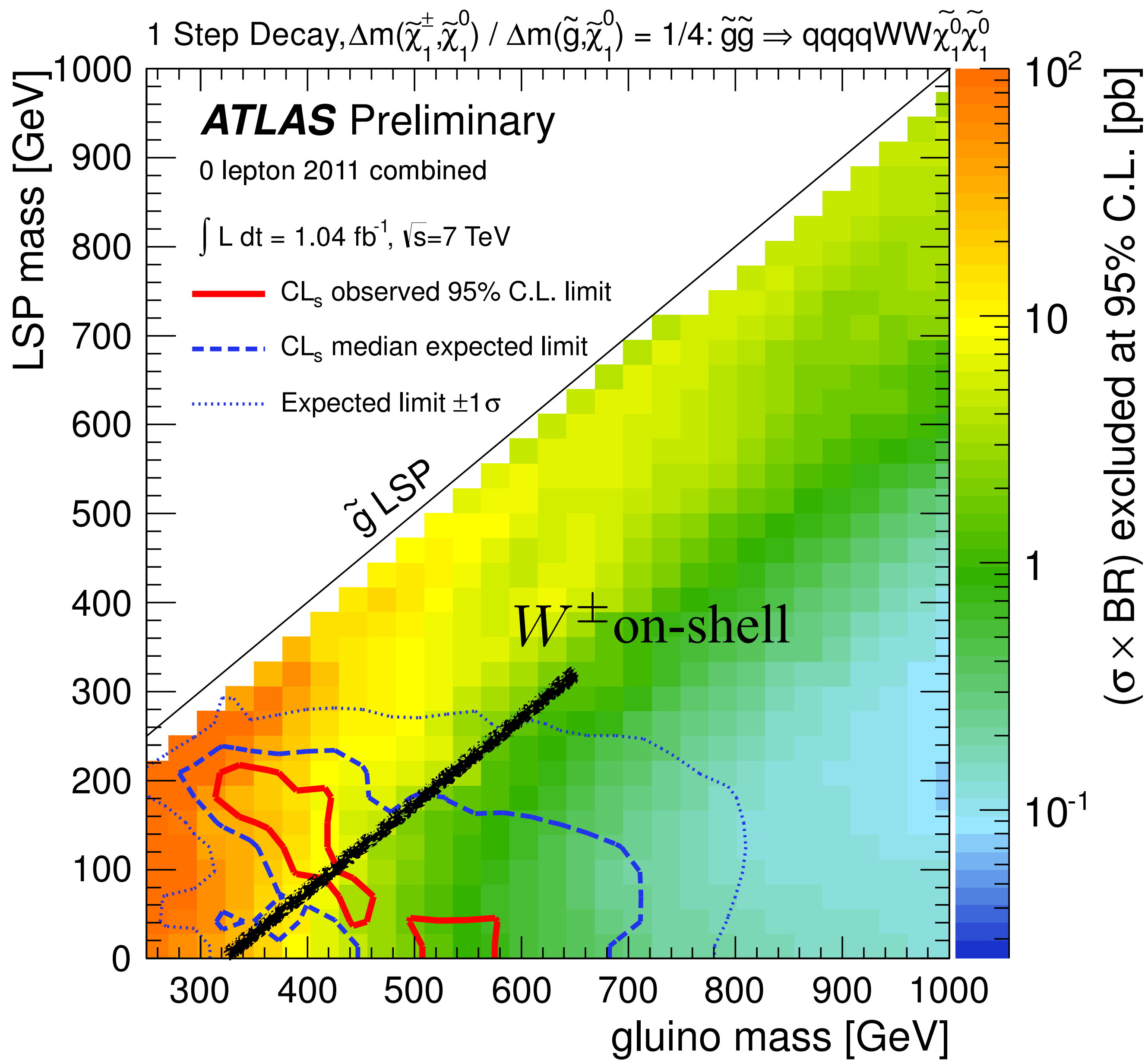
What are the limits set by ATLAS?

3-Body direct decay



What are the limits set by ATLAS?

1-Step Cascade (x=0.25)



So Far

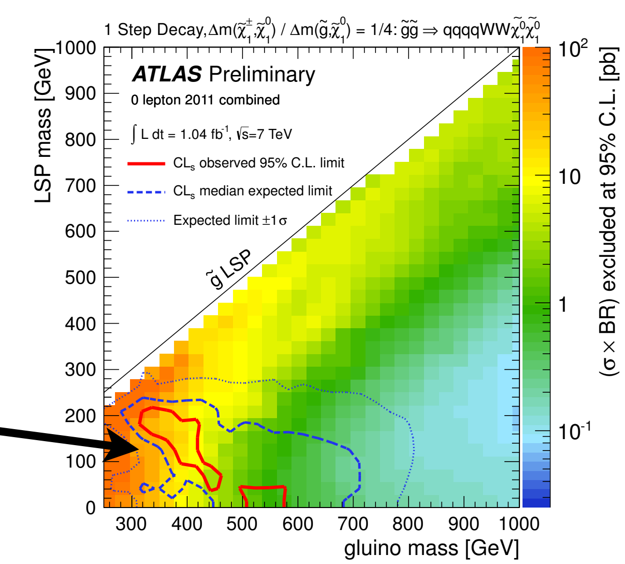
Used simplified models to parameterize
jets and missing energy searches

Sensitivity greatly reduced in non-standard BSM kinematics

e.g. cascades and compressed spectra

The way forward: Use simplified models to make
sure there are no holes in searches

Seems non-optimal!



Outline

- Simplified models
- Quantifying models
- From anomalies to discovery

Quantifying Visibility of a Model

Want to design analyses that
cover all simplified models

Need some notion of how easy or difficult to see
are different points in model space

Use this to find a robust search strategy
i.e. find search regions that are optimal for
challenging patches of model space

Quantifying Visibility of a Model

Define "Efficacy"

$$\mathcal{E} = \frac{\sigma_i}{\sigma_0}$$

σ_i is the cross section limit given by the *i*th search region in analysis

σ_0 is the best cross section limit one could obtain

Efficacy tells us how effective a signal region is *relative* to how well it is possible to do

We want $\mathcal{E} \gtrsim 1$

Quantifying Visibility of a Model

Suppose a search region is statistically limited
Then

$$\mathcal{E}^2 \sim \frac{\mathcal{L}_{\rm required}}{\mathcal{L}_{\rm min}}$$

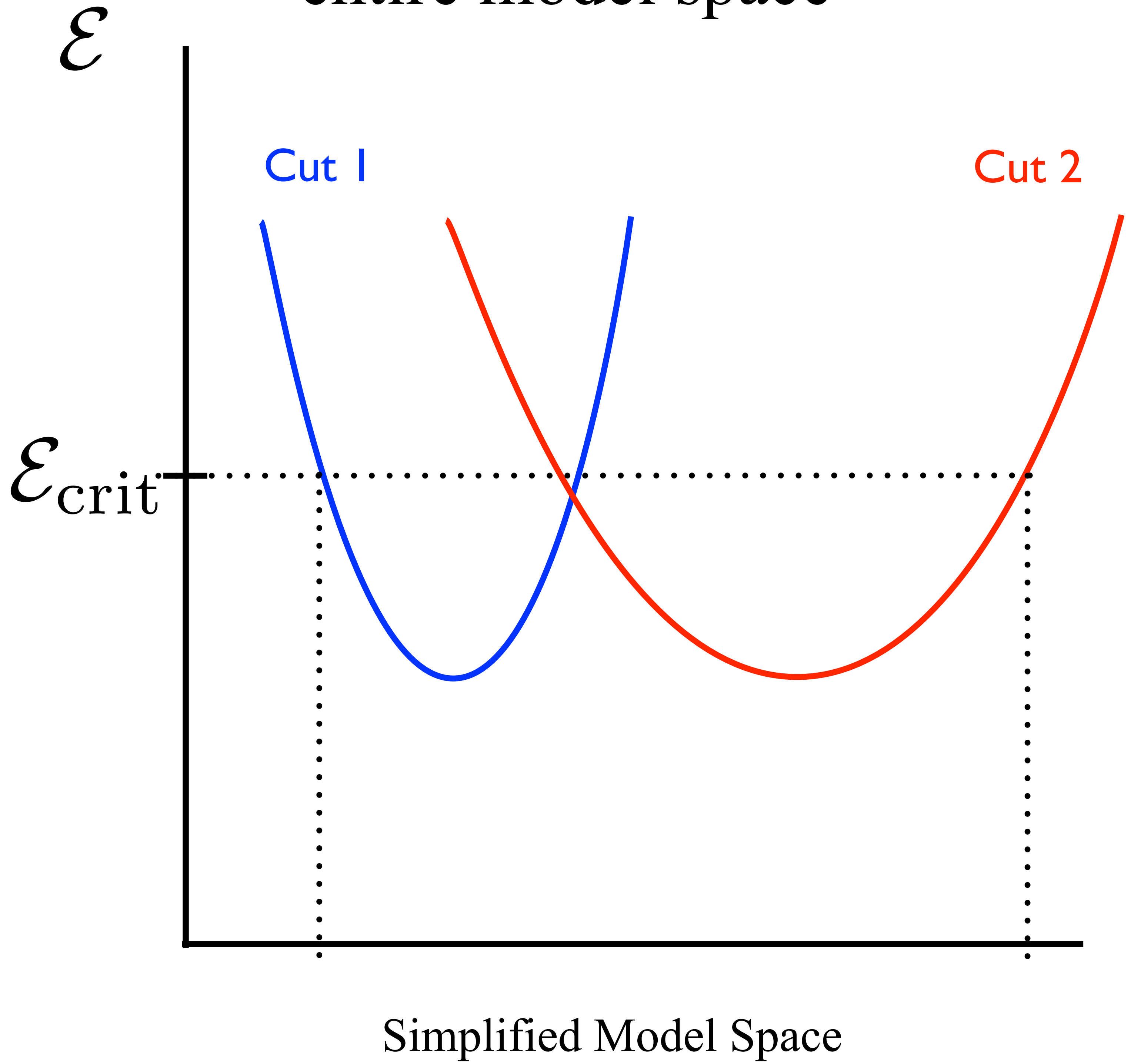
So, say for $\mathcal{E} = 3$

Need to collect 9 times more data
than you'd have to

Also important to keep Efficacy close to unity to
minimize model prejudice

Strategy

Find a set of search regions that cover entire model space



Strategy: An Example

For $\mathcal{E}_{\rm crit} = 1.3$

6 search regions needed to cover space of simplified models, found by optimizing over every point

cut	NAME	ch	MET (GeV)	H_T (GeV)
	Dijet High MET	2^{+}j	> 500	> 750
	Trijet High MET	3^{+}j	> 450	> 500
	Multijet Low MET	4^{+}j	> 100	> 450
	Multijet High H_T	4^{+}j	> 150	> 950
	Multijet Moderate MET	4^{+}j	> 250	> 300
	Multijet High MET	4^{+}j	> 350	> 600

Benchmarks

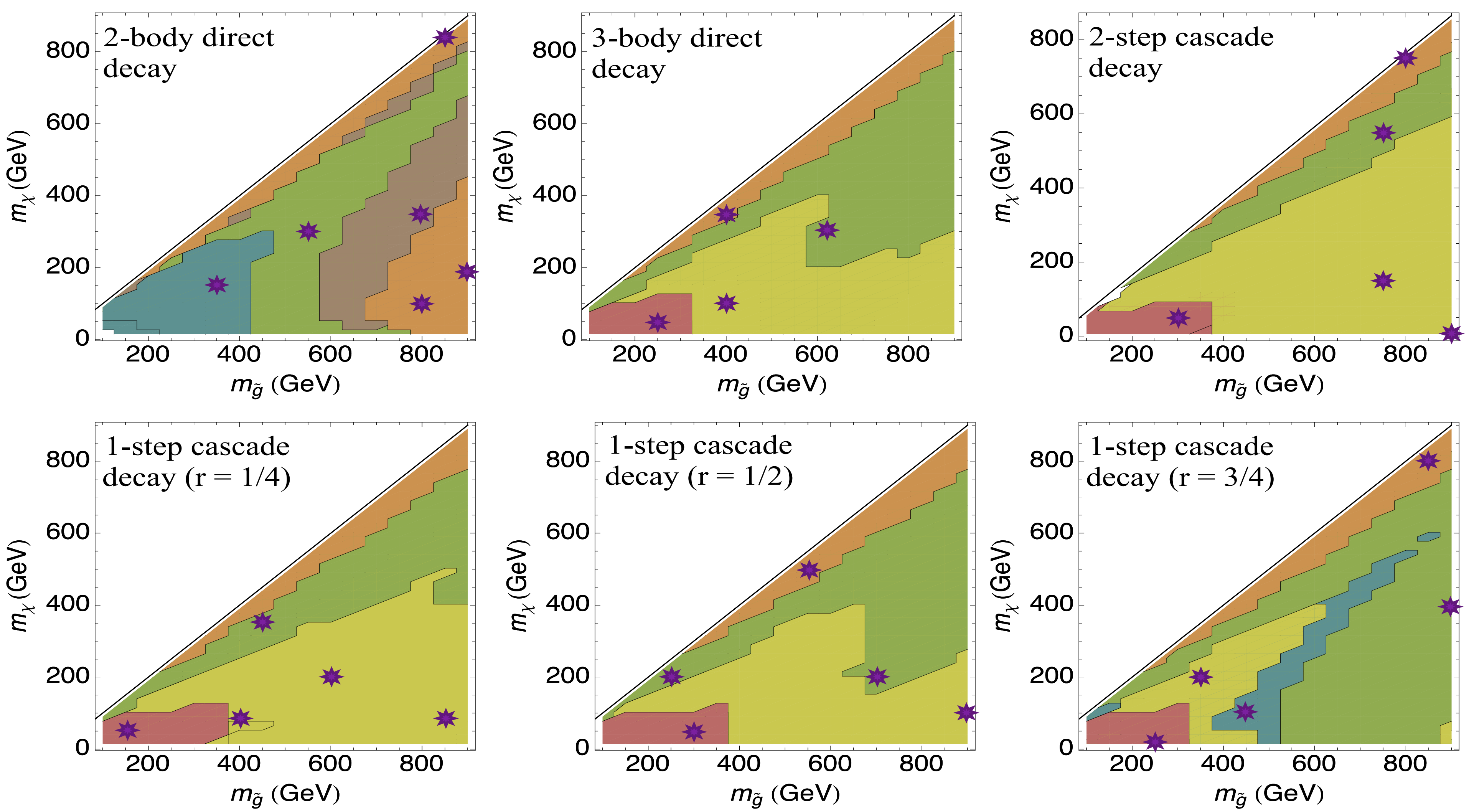
Minimize effort needed to cover space of models
by using Benchmarks

Space of simplified models is dense
Nearby points have similar kinematics

Task:
1. Find a small number of benchmarks, so that when optimizing over these, you find a search that covers benchmarks with some efficacy
2. This search also covers the entire model space with same efficacy

Strategy

6 search regions needed to cover space of simplified models

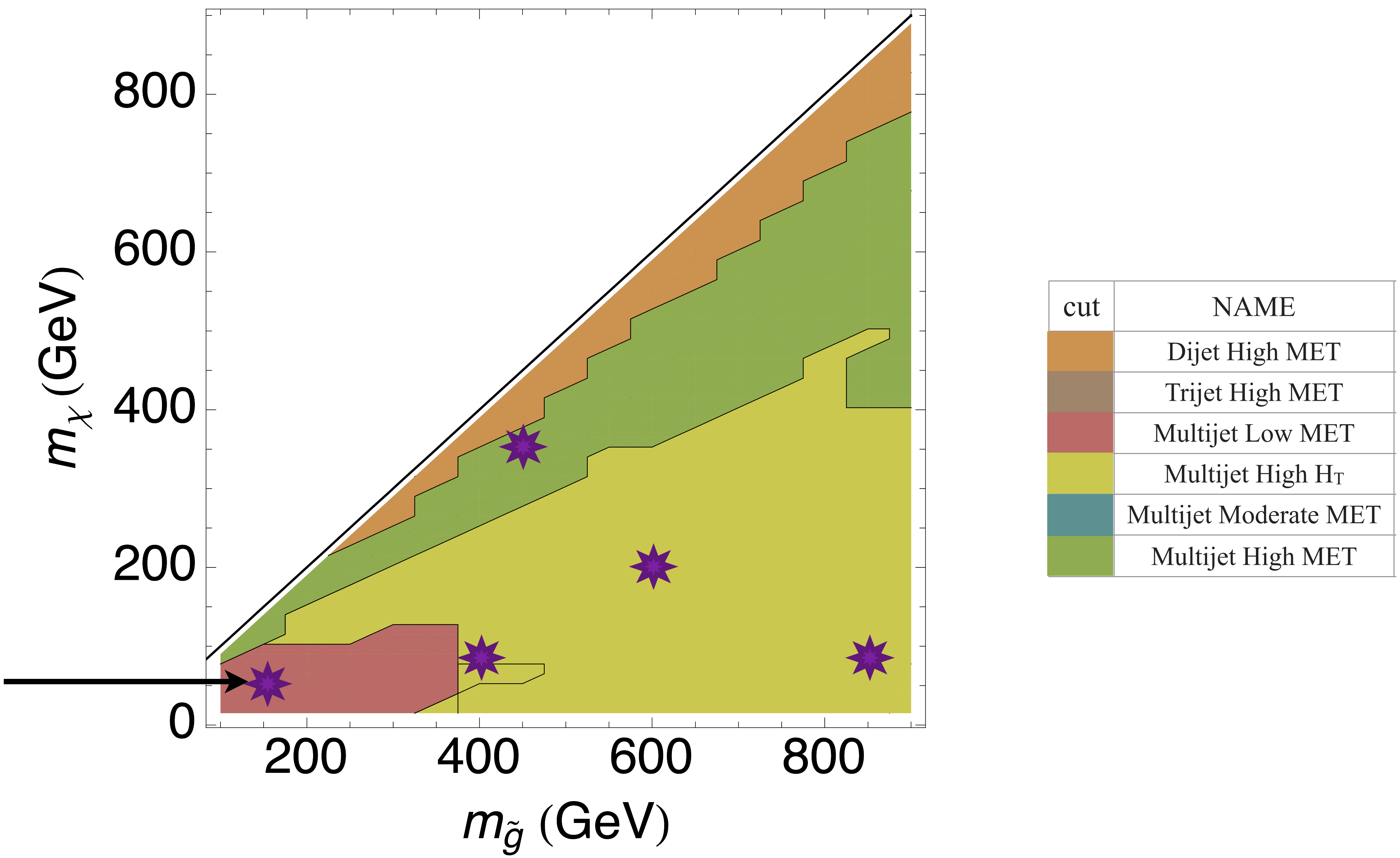


cut	NAME
	Dijet High MET
	Trijet High MET
	Multijet Low MET
	Multijet High H_T
	Multijet Moderate MET
	Multijet High MET

Strategy

1-Step Cascade (x=0.25)

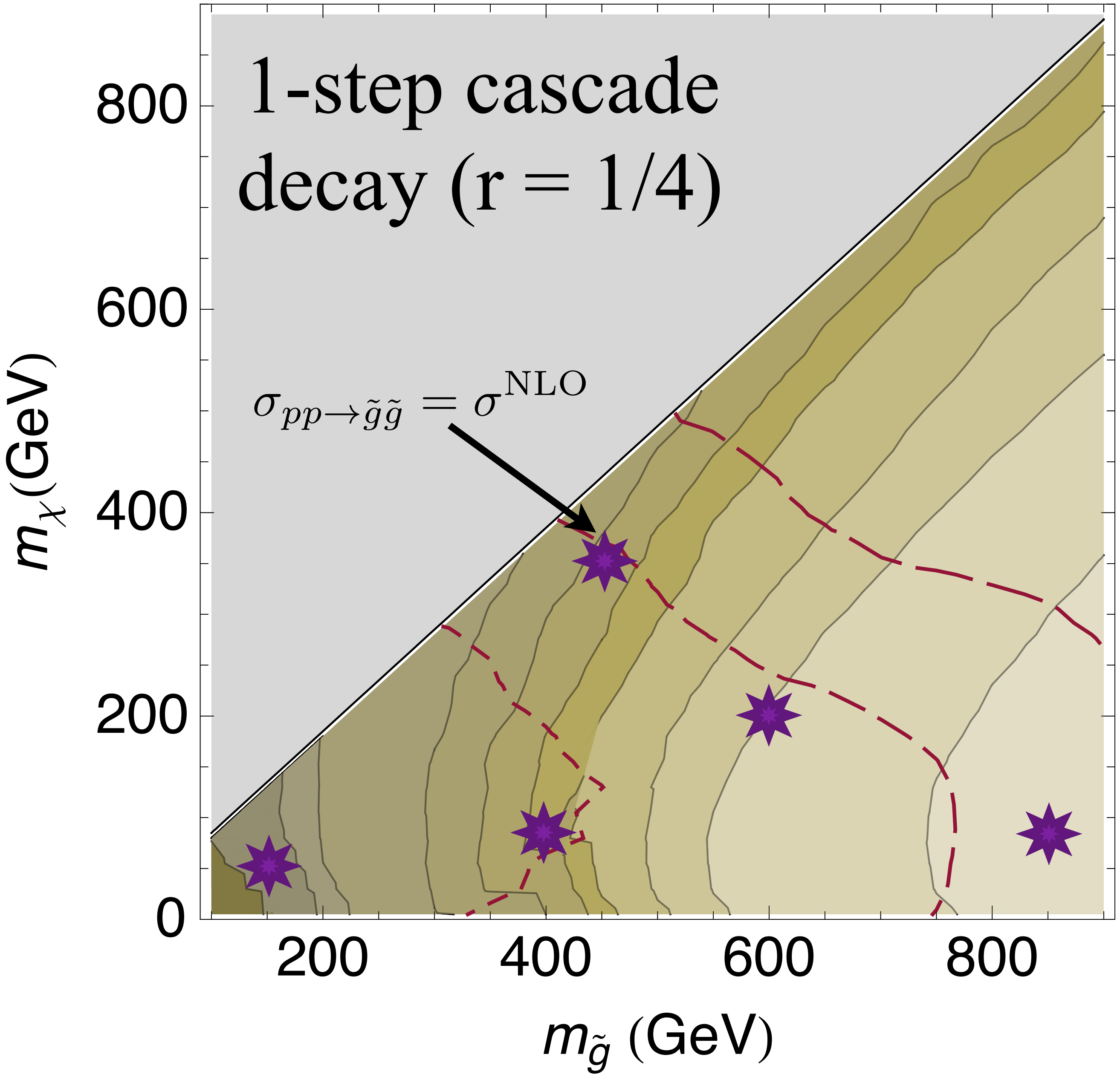
For $\mathcal{E}_{\rm crit} = 1.3$



Benchmark

Estimated Limit with 1 fb^{-1}

1-Step Cascade (x=0.25)



So Far

Used simple notion of efficacy to quantify coverage of models

Showed example of finding a broad search strategy that covers space of simplified models

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Following Your Nose

Suppose you see an anomaly in one channel

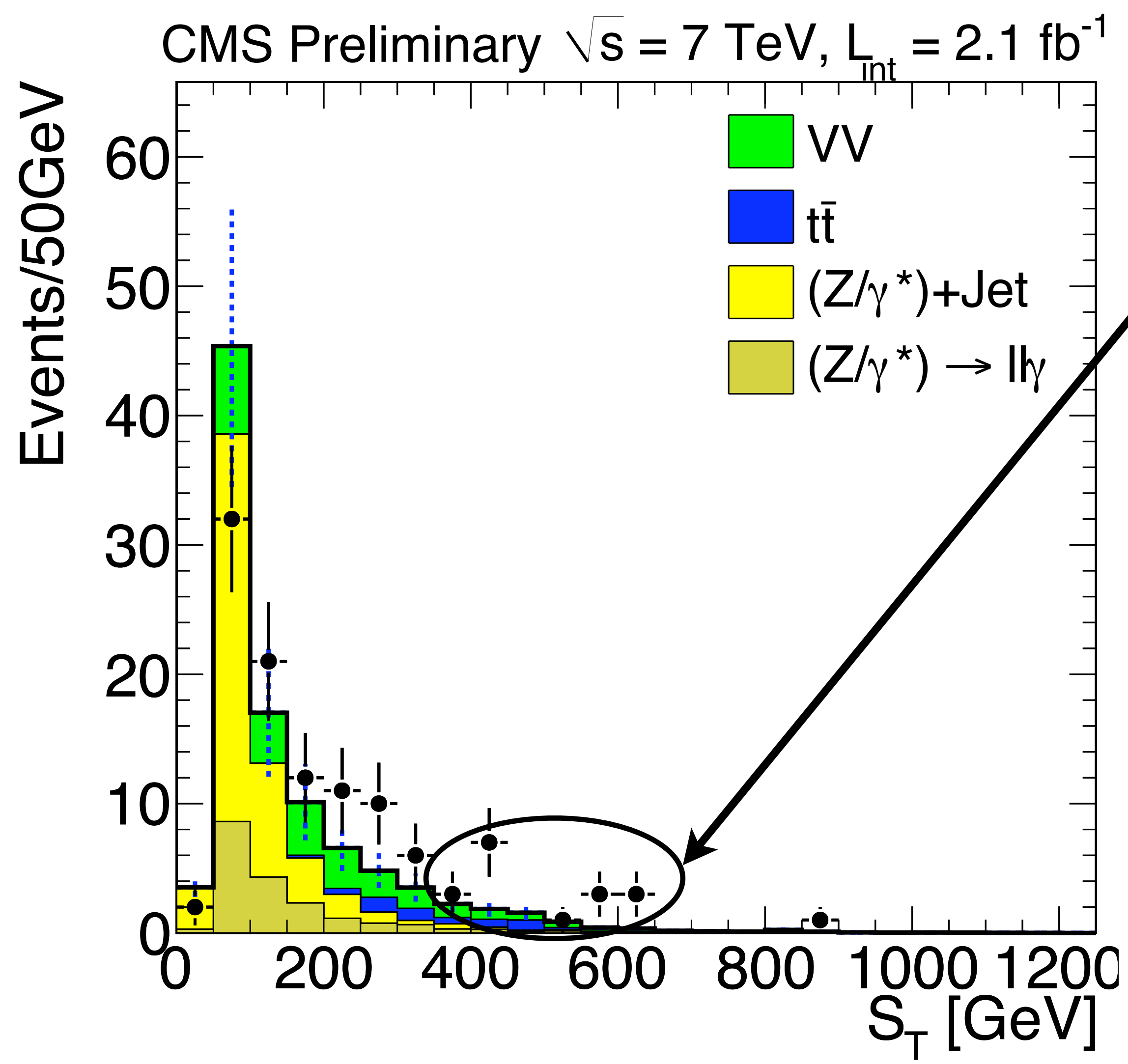
Can ask, what’s the minimal spectrum that explains the anomaly?

Add more layers of complexity as more channels yield more information

Following Your Nose

Let's *assume* that CMS' trilepton analysis was giving us hints of new physics

What does this "anomaly" tell us?



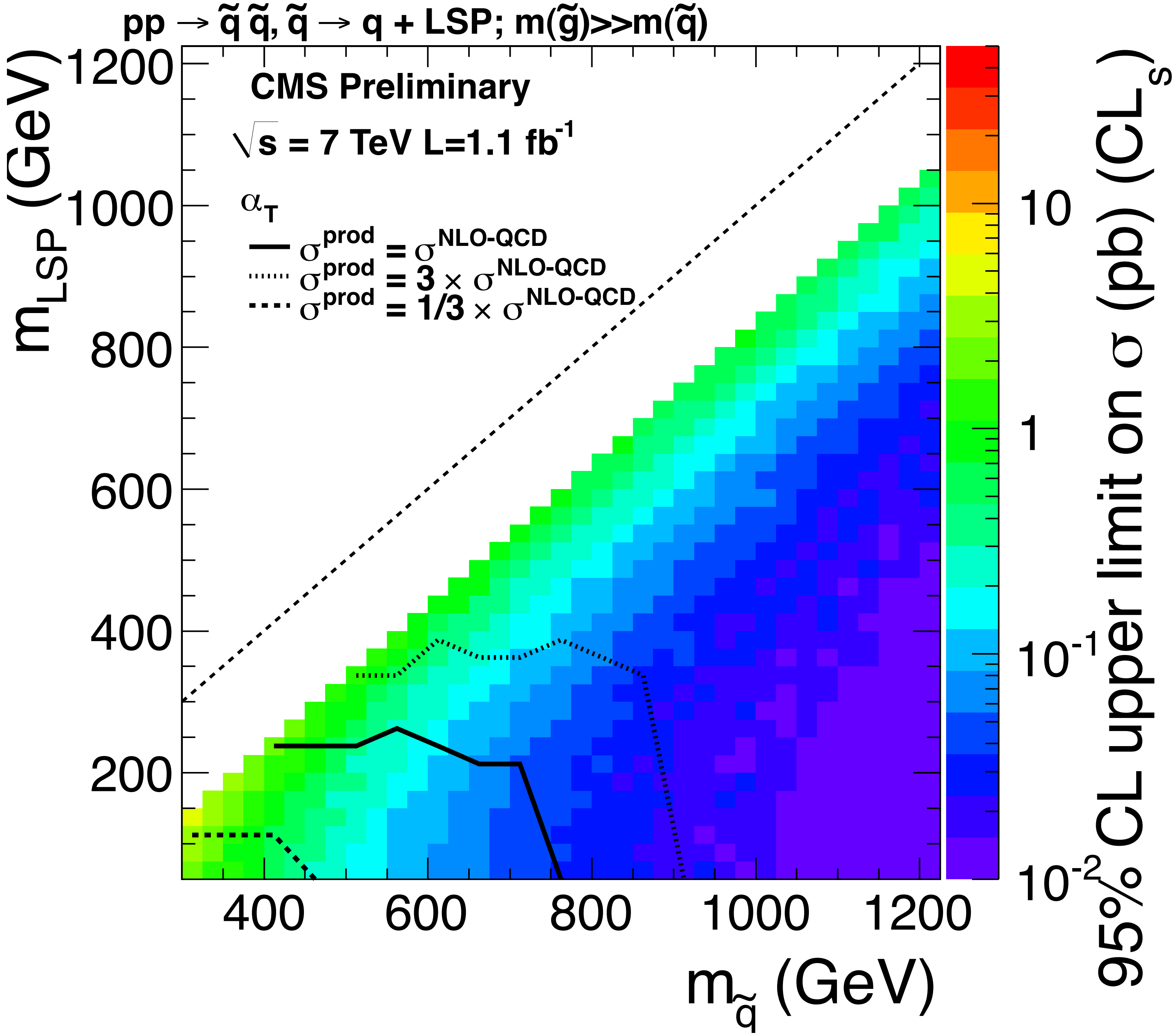
Total mass ~ 600 GeV

Energy scale too high for Electroweakino pair production

Need jets. In SUSY, squarks or gluinos?

Need to be consistent with other null results. Easier to avoid with squark

Following Your Nose

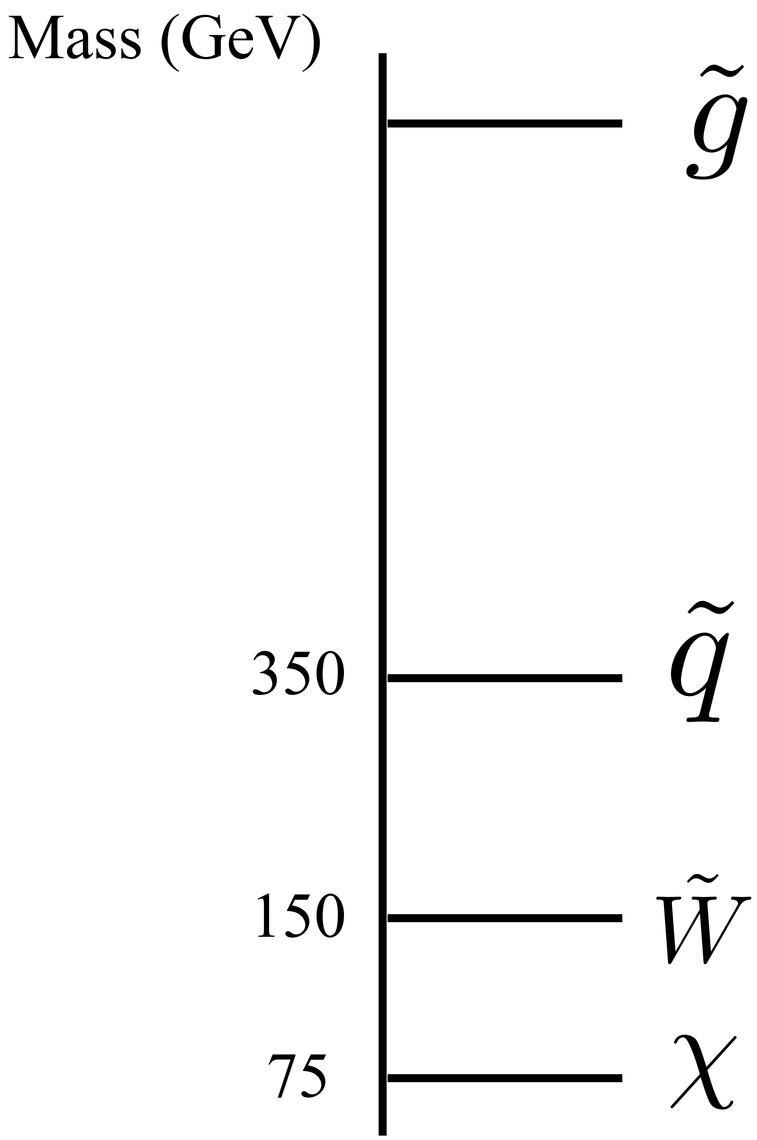


$m_{\tilde{q}} > 800\ \mathrm{GeV}$

Limit driven by α_T analysis looking for $\tilde{q} \to q\ \chi$

Following Your Nose

Need to suppress direct decays
How about an intermediate state?

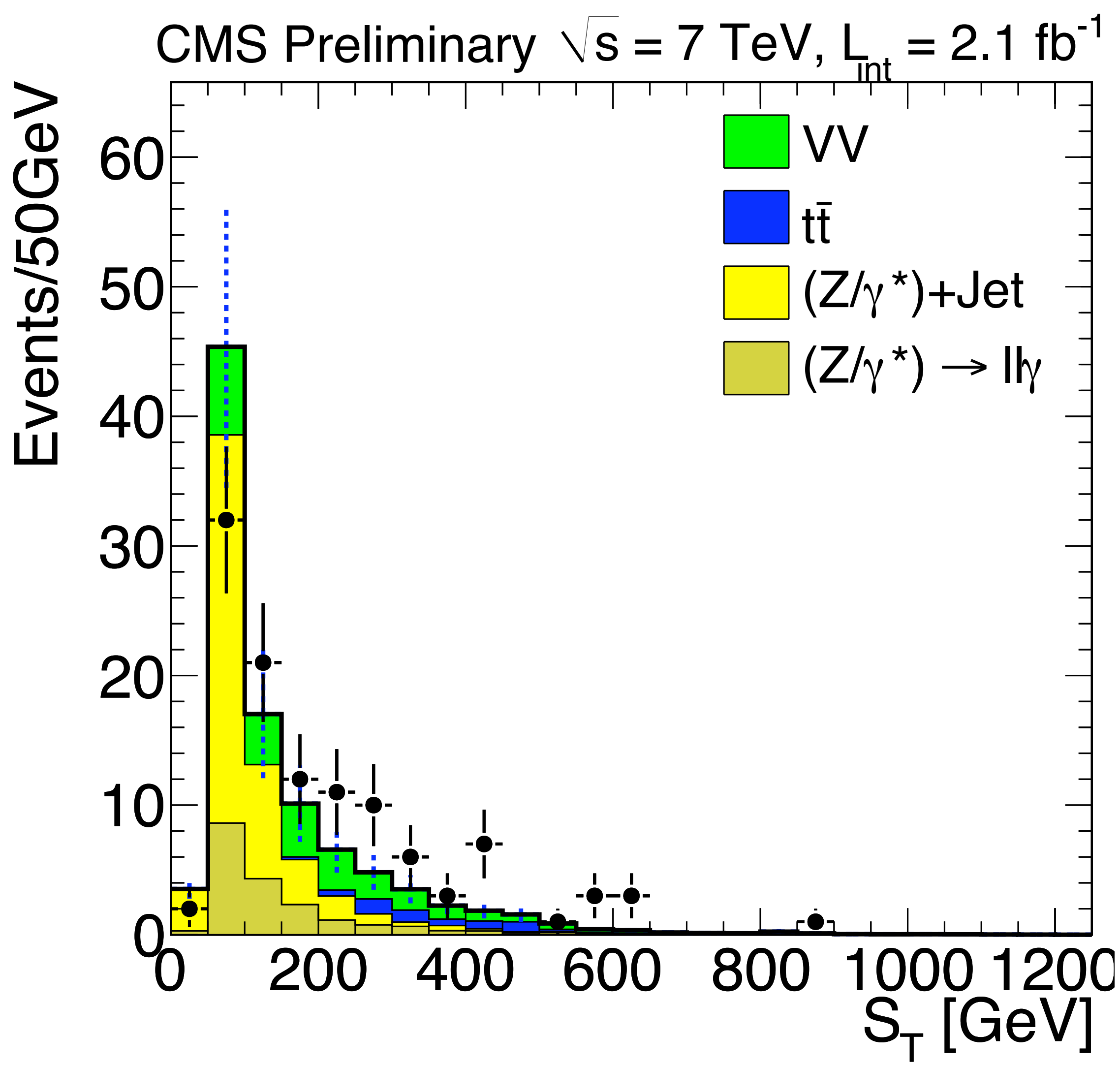


$$\tilde{q} \to q\tilde{W}$$

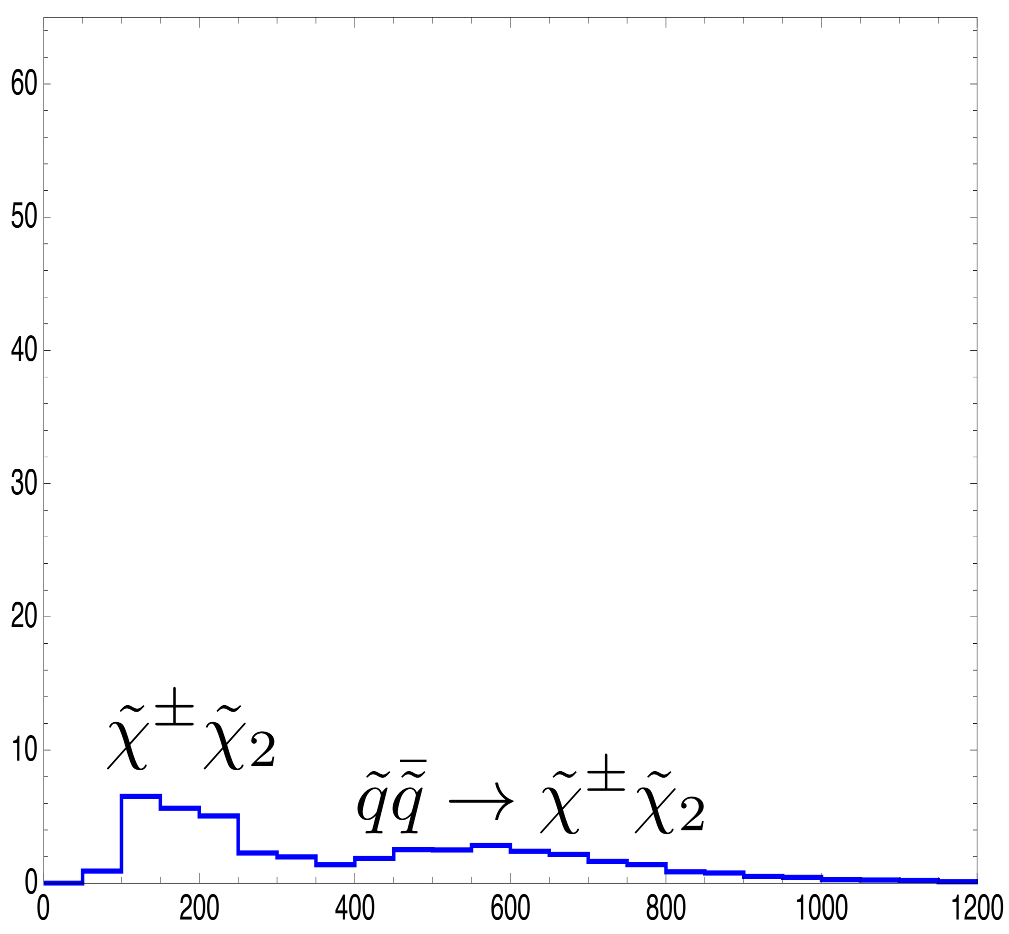
$$\tilde{W} \to V\chi$$

This spectrum is OK with null results from other channels

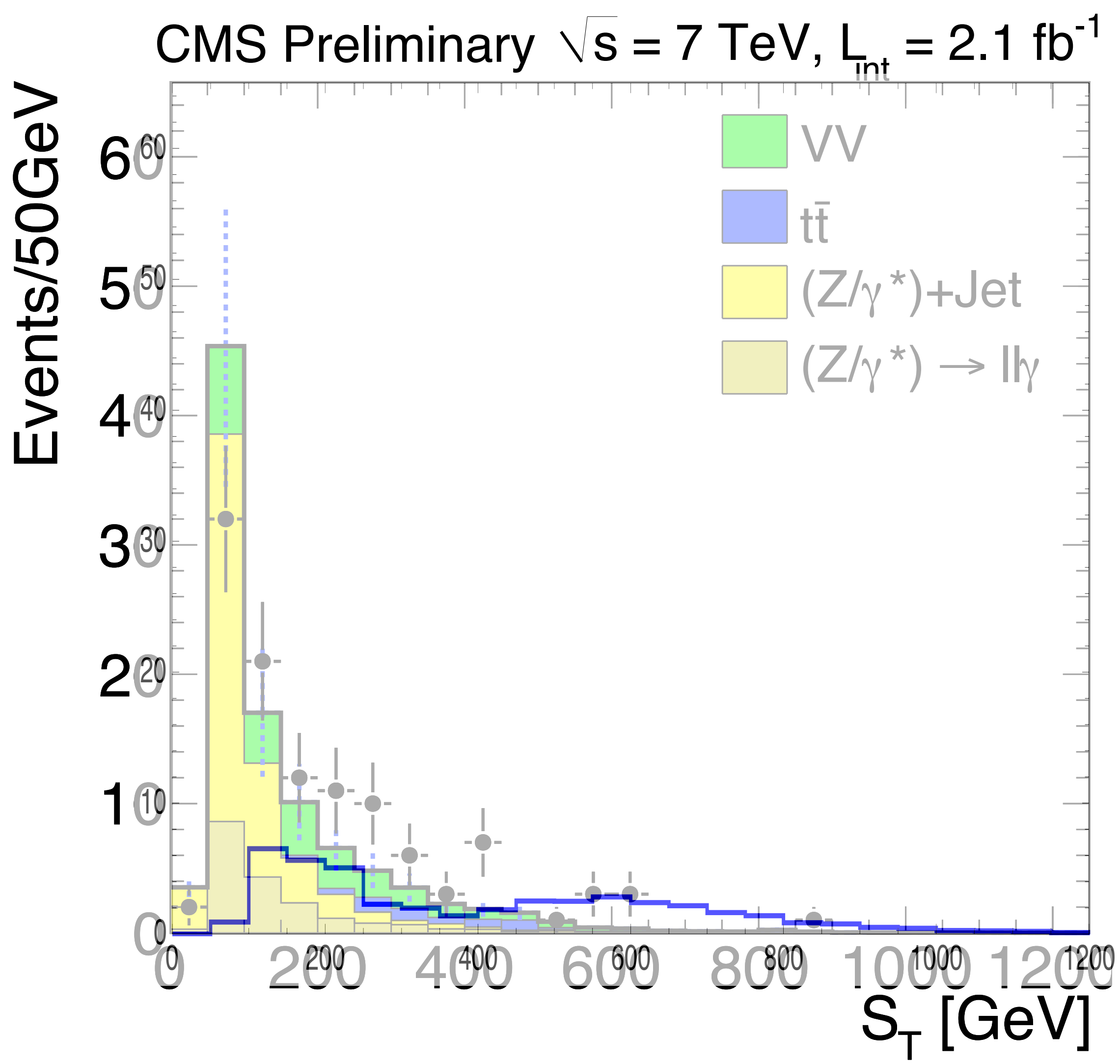
Following Your Nose



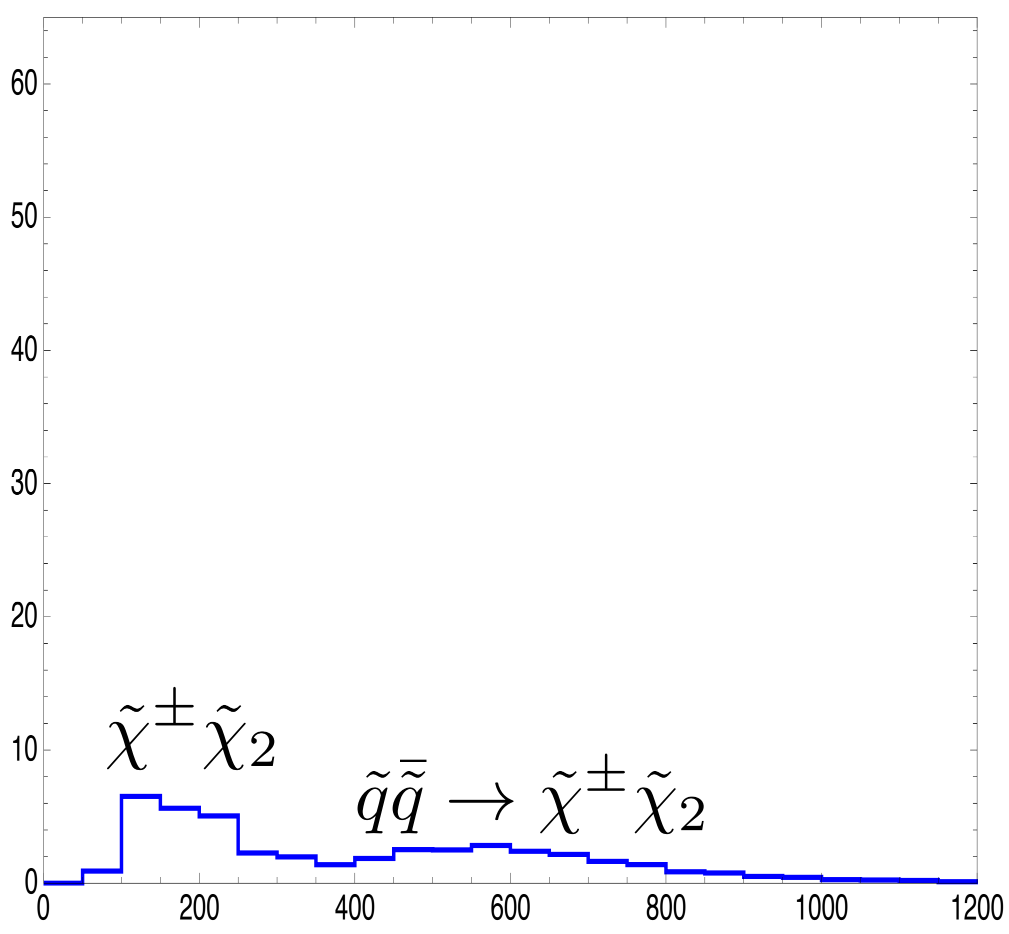
Signal



Following Your Nose



Signal



Following Your Nose

Which channels will show an "anomaly" next?
In this case, OSDL and SSDL

What can we do to improve sensitivity
in all-hadronic channels?

If hypothesis falls short, add more layers of complexity
(or consider different non-minimal spectrum)

Conclusions

Simplified models idea: Parameterize new physics
in terms of minimal spectra

Can be used to make sure there are no obvious holes in searches
Minimizes model prejudice

Important to make all of model space as visible as possible

If anomalies present, can be used to build the
spectrum that fits. Would like to use
this to measure the Lagrangian parameters of model