Model-Independent Jets and Missing Energy Searches

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Outline

Current status of jets + MET searches

Proposal for model-independent jets + MET searches

Example: Setting bounds on gluino mass

Jets + MET

Signature of new colored particle decaying into dark matter

Promising signature for new physics
(UED, SUSY, Little Higgs)

How do we distinguish between these models?

Can we place bounds on parameter space in a model-independent manner?

Jets + MET at DØ

Inclusive 1 jet - 4+ jet searches

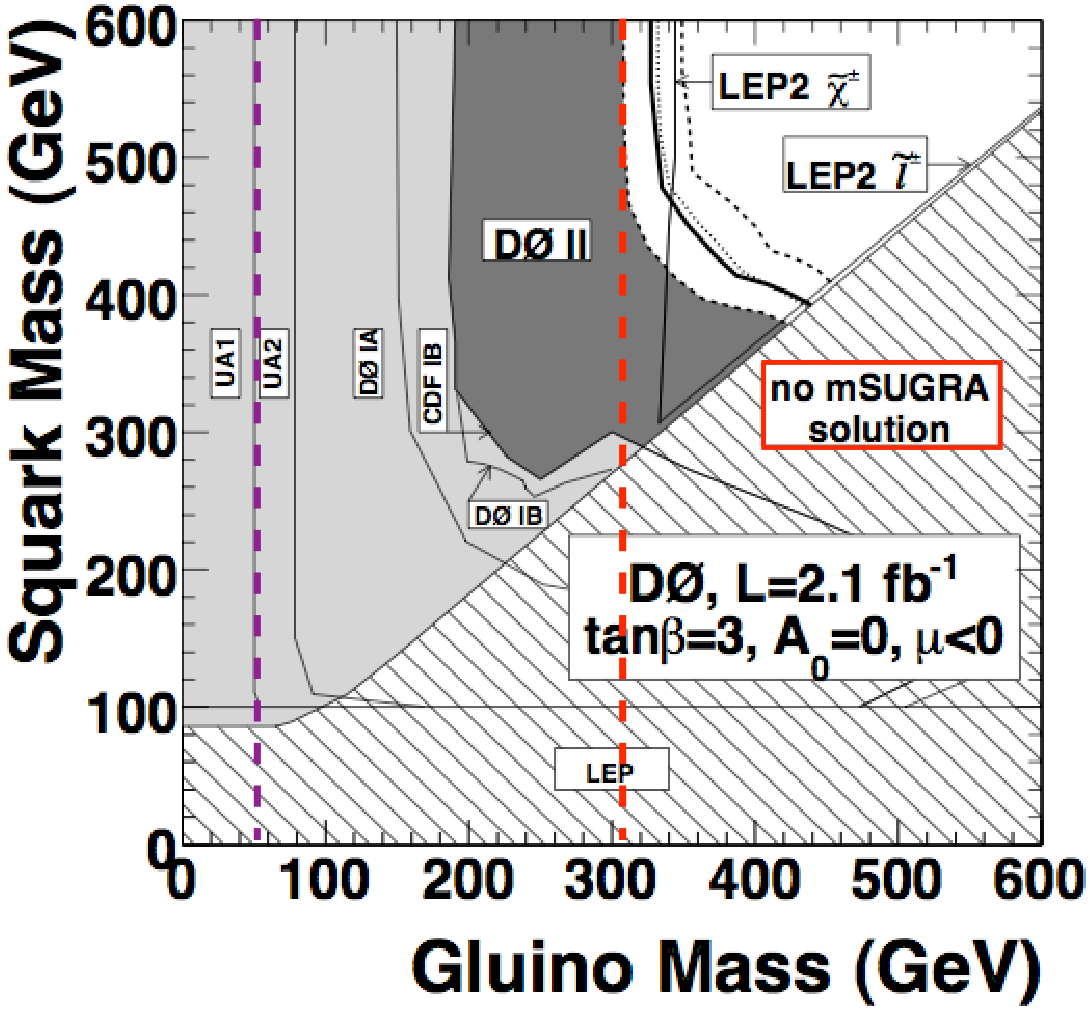
MET and H_T optimized for "characteristic" mSUGRA points

	Gg	$\tilde{q}\tilde{q}$	$\tilde{q}\tilde{g}$	$\tilde{g}\tilde{g}$
	$1j + \not{E}_T$	$2j + \not{E}_T$	$3j + \not{E}_T$	$4j + \not{E}_T$
$E_{T\,j_1}$	≥ 150	≥ 35	≥ 35	≥ 35
$E_{T\,j_2}$	< 35	≥ 35	≥ 35	≥ 35
$E_{T\,j_3}$			≥ 35	≥ 35
$E_{T\,j_4}$				≥ 20
$\not{E}_T$	≥ 150	≥ 225	≥ 150	≥ 100
H_T	≥ 150	≥ 300	≥ 400	≥ 300

(Not exclusive searches)

$$H_T = \sum E_{T\,j}$$

Jets + MET at DØ



- - - : DØ bound

- - - : model-ind. bound

(thrust data ALEPH/OPAL)

Jets + MET

- mSUGRA is not representative of all supersymmetric models
  - ratio of gluino & bino masses is roughly constant

$$m_{\tilde{g}} : m_{\tilde{B}} \simeq 6 : 1$$

- other models of susy breaking have different ratios - i.e.,
  - anomaly mediation $m_{\tilde{g}} : m_{\tilde{B}} \simeq 1 : 1$
  - mirage mediation $m_{\tilde{g}} : m_{\tilde{B}} \simeq 7 : 3$

Jets + MET

There is a large range of kinematically-accessible gluinos with **no** known limits.

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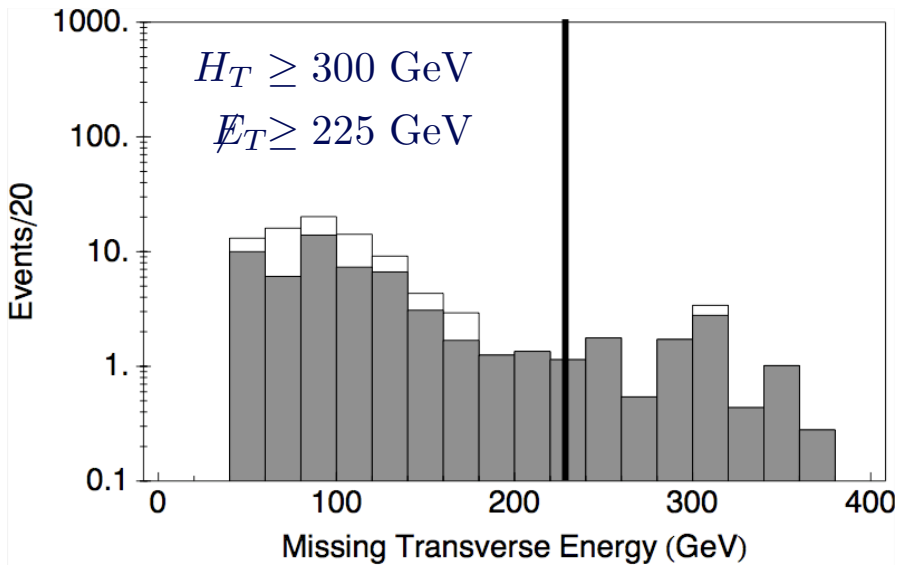
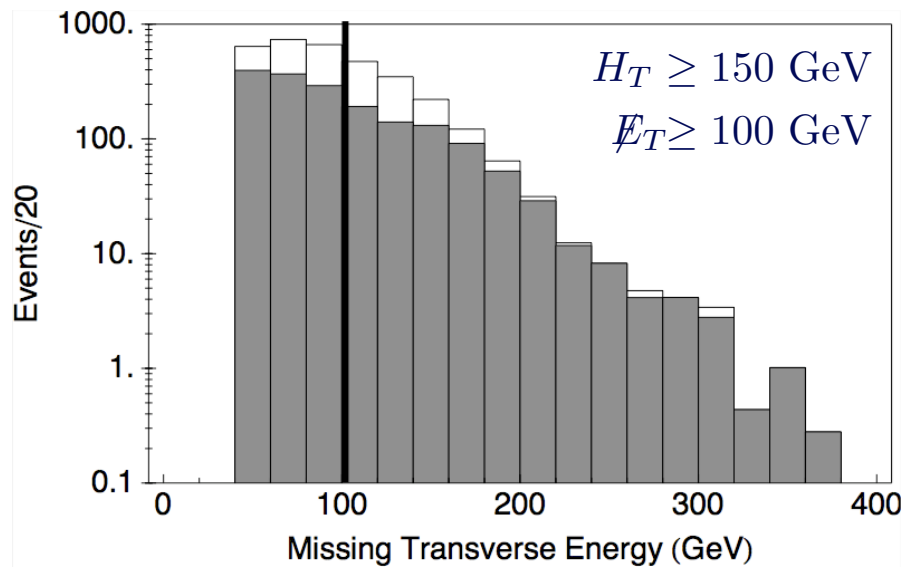
Optimizing Cuts

Dijet signal for 200 GeV gluino decaying directly to 100 GeV bino

DØ cuts



More optimal cuts



: Background : Signal

Proposal for Analysis

Exclusive 1 jet - 4+ jet searches

Consider effects of **all** possible MET and HT cuts

	$1j + \not{E}_T$	$2j + \not{E}_T$	$3j + \not{E}_T$	$4j + \not{E}_T$
$E_{T\,j_1}$	≥ 150	≥ 35	≥ 35	≥ 35
$E_{T\,j_2}$	< 35	≥ 35	≥ 35	≥ 35
$E_{T\,j_3}$	< 35	< 35	≥ 35	≥ 35
$E_{T\,j_4}$	< 20	< 20	< 20	≥ 20
$\not{E}_T$				
H_T				

Leave unfixed

Proposal for Analysis

Consider differential cross section as a function of MET and H_T

$$\frac{d^2\sigma}{dH_T d\not{E}_T}\Delta H_T \Delta \not{E}_T$$

Signal Limit

From statistical & systematic errors of SM background

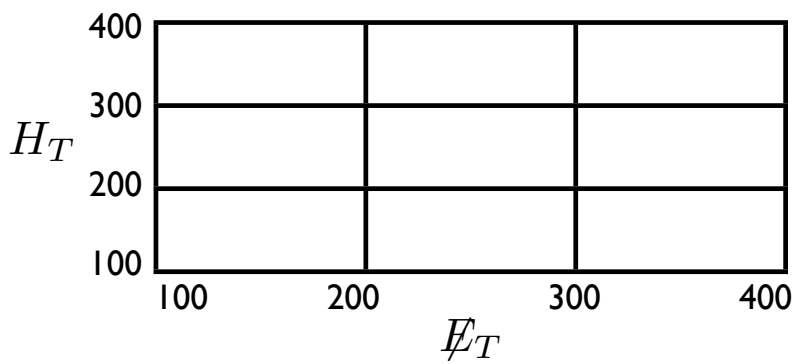
$$(\sigma_{\rm sys} \oplus \sigma_{\rm stat})_j$$

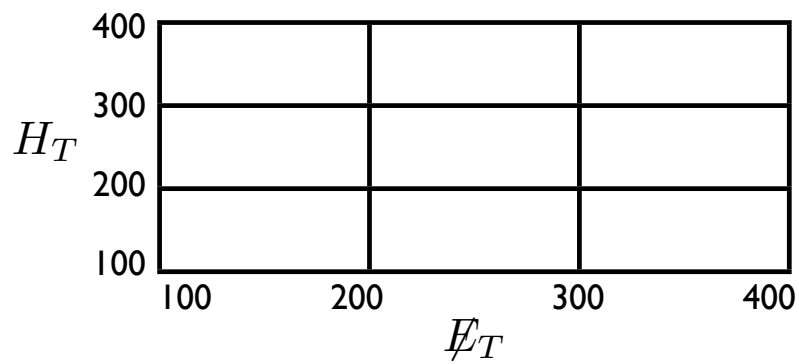
Theoretical Model

Find differential cross section for model-of-choice

$$S_j$$

Model excluded?





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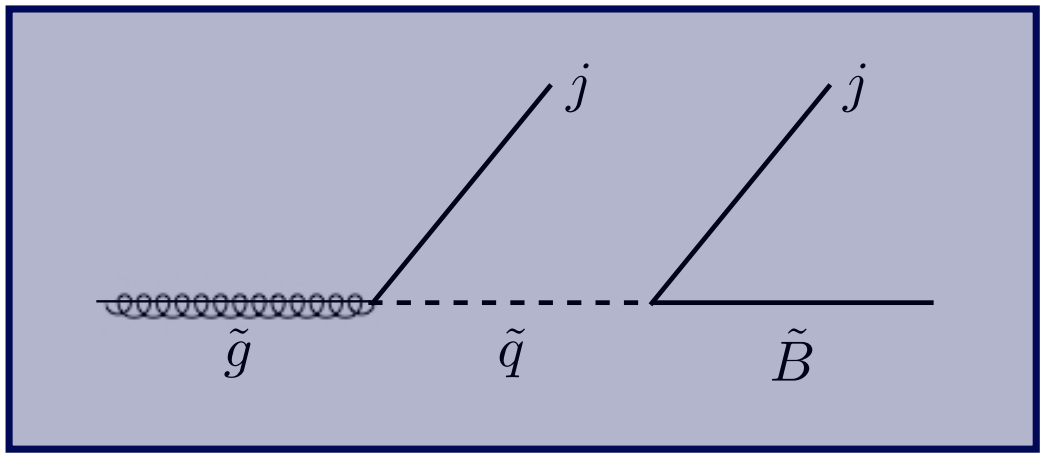
Example: Setting bounds on gluino mass

Kinematics



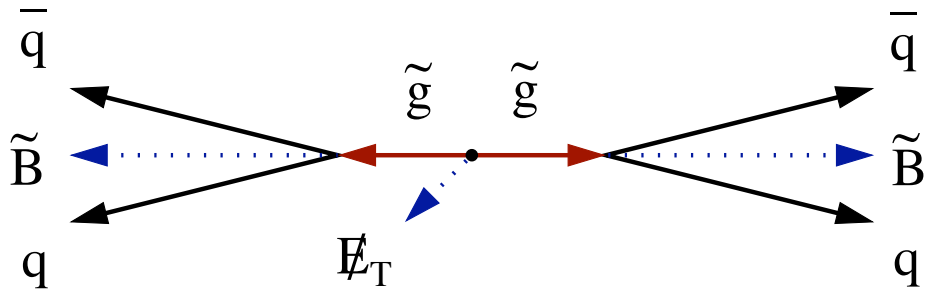
Mass difference between gluino and bino is relevant quantity

$m_{\tilde{g}} \gg m_{\tilde{B}}$ hard, well-separated jets

$m_{\tilde{g}} \sim m_{\tilde{B}}$ jets not as energetic

Let's focus on the degenerate case for a moment...

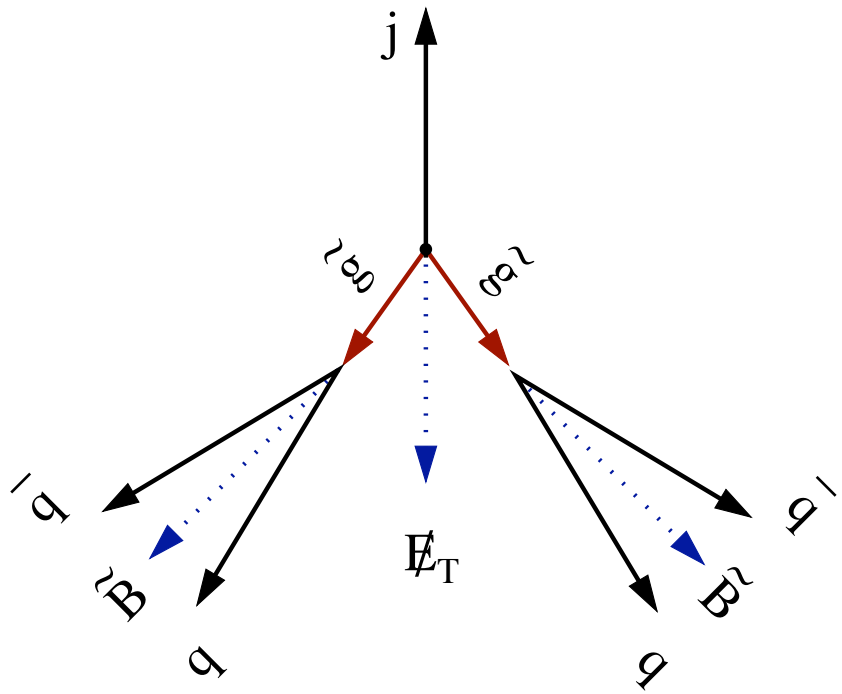
Kinematics



A challenge to see because

- jets are soft
- bino momenta cancel when reconstructing MET

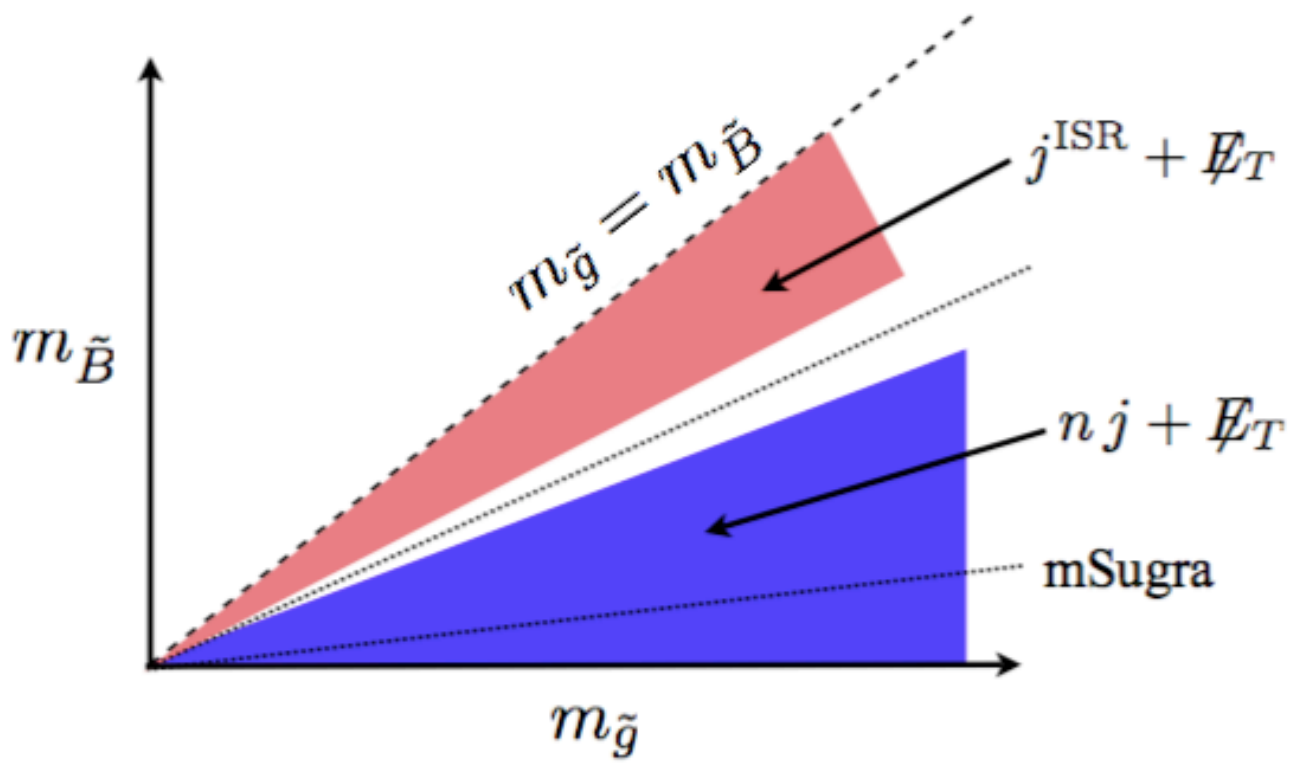
Kinematics



Boost the gluinos with initial-state radiation...

...this increases the MET of the event.

Exclusion Region



Event Generation

Generate signal and background events

MadGraph → Pythia → PGS

Matching procedure necessary to account for ISR

Background events compared with DØ

$Z^0(\to \nu\nu) + nj$	w/in QCD K factors
$W^\pm(\to l^\pm\nu) + nj$	~ 30% scaling
$t\bar{t}$	~ 20% scaling
QCD	not simulated

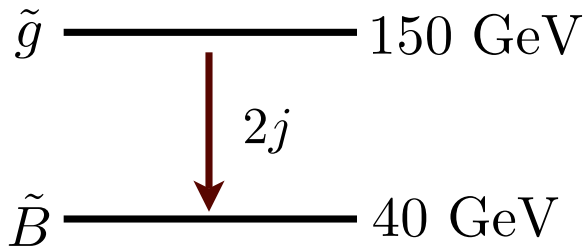
Matching

Parton Showering	Matrix Elements
QCD Bremstrahlung	Necessary for well-separated jets
Soft/Collinear Approximation	Includes quantum interference
Resums large logs	Fixed-order calculation
Computationally Cheap	Computationally expensive
Unlimited number of partons	Limited number of partons

Matching combines both techniques
Necessary to avoid double-counting of events

Effects of Matching

Large mass difference between gluino & bino

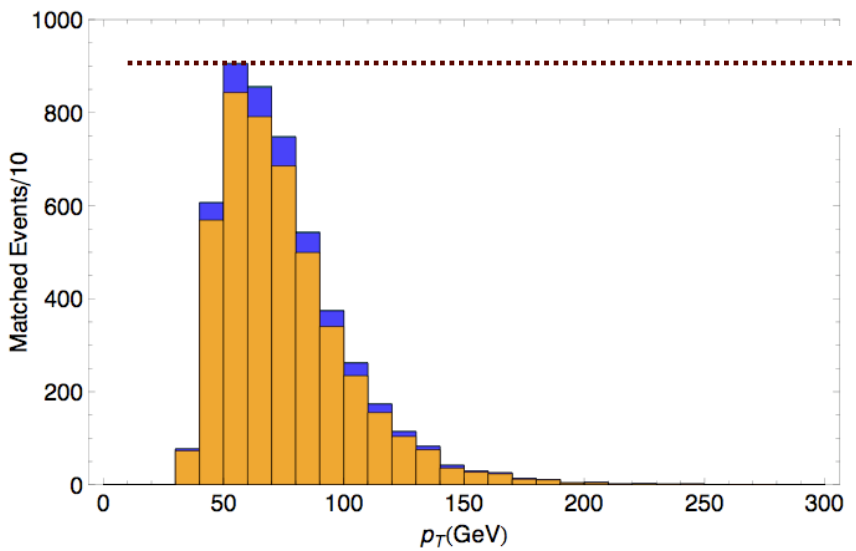


: $\tilde{g}\tilde{g} + 0j$

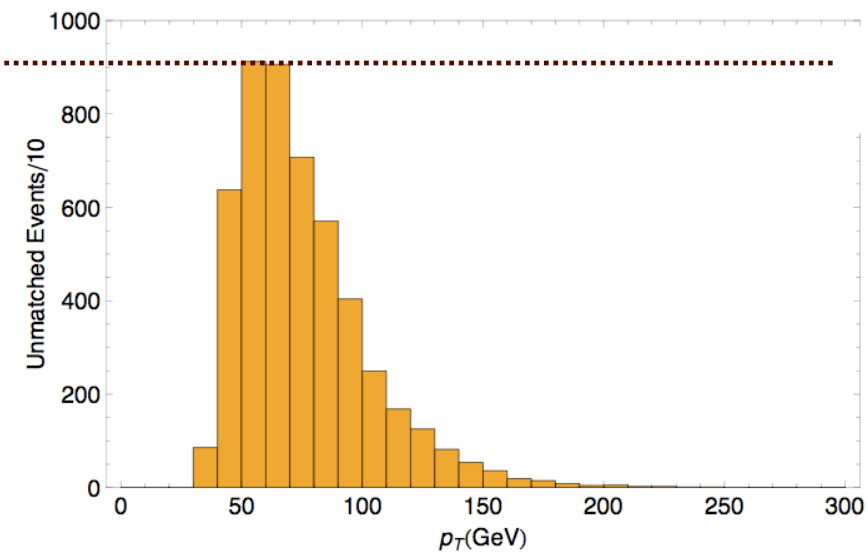
: $\tilde{g}\tilde{g} + 1j$

: $\tilde{g}\tilde{g} + 2j$

Matched

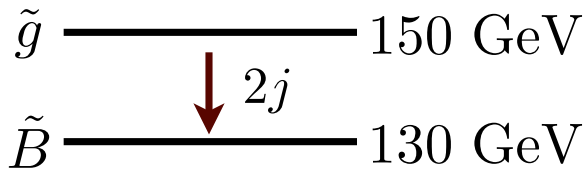


Unmatched



Effects of Matching

Nearly-degenerate gluino and bino

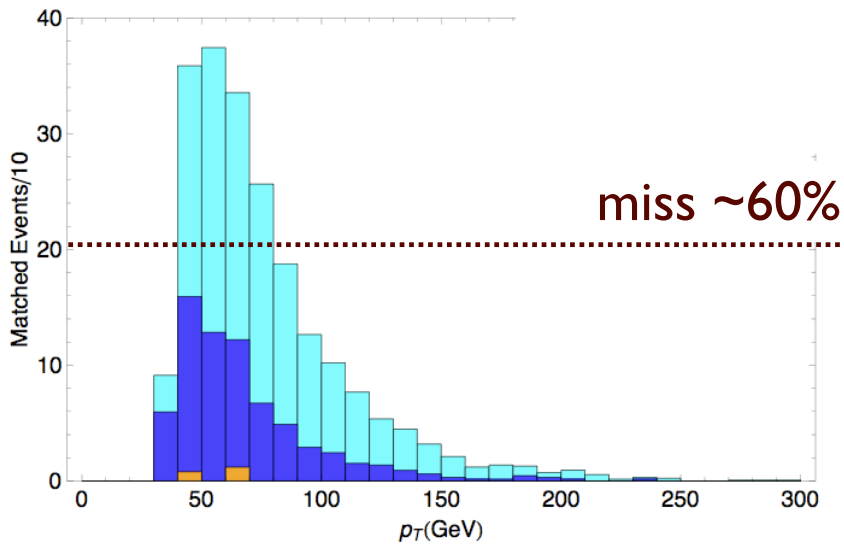


: $\tilde{g}\tilde{g} + 0j$

: $\tilde{g}\tilde{g} + 1j$

: $\tilde{g}\tilde{g} + 2j$

Matched



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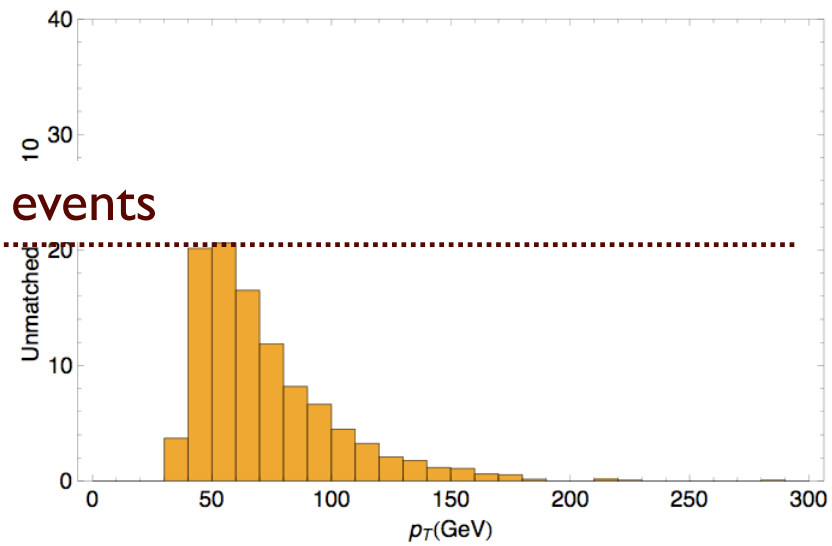


miss ~60% of events

Setting Gluino Limits

Multijet Signal Limit

H_T \ $\not{E}_T$	100–150	150–200	200–250	250–300	300–350
500–600	0.8⊕0.5	0.5⊕0.1	0.5⊕0.1	0.5⊕0.1	0.5⊕0.0
400–500	1.3⊕2.1	1.1⊕1.2	0.8⊕0.6	0.7⊕0.3	0.5⊕0.1
300–400	1.9⊕7.5	1.3⊕3.5	1.0⊕1.1	0.7⊕0.3	0.5⊕0.1
200–300	3.2⊕21	1.6⊕5.0	0.8⊕0.6	0.6⊕0.2	
100–200	1.5⊕4.3	0.8⊕0.5			

Theoretical Model

340 GeV gluino → 100 GeV bino

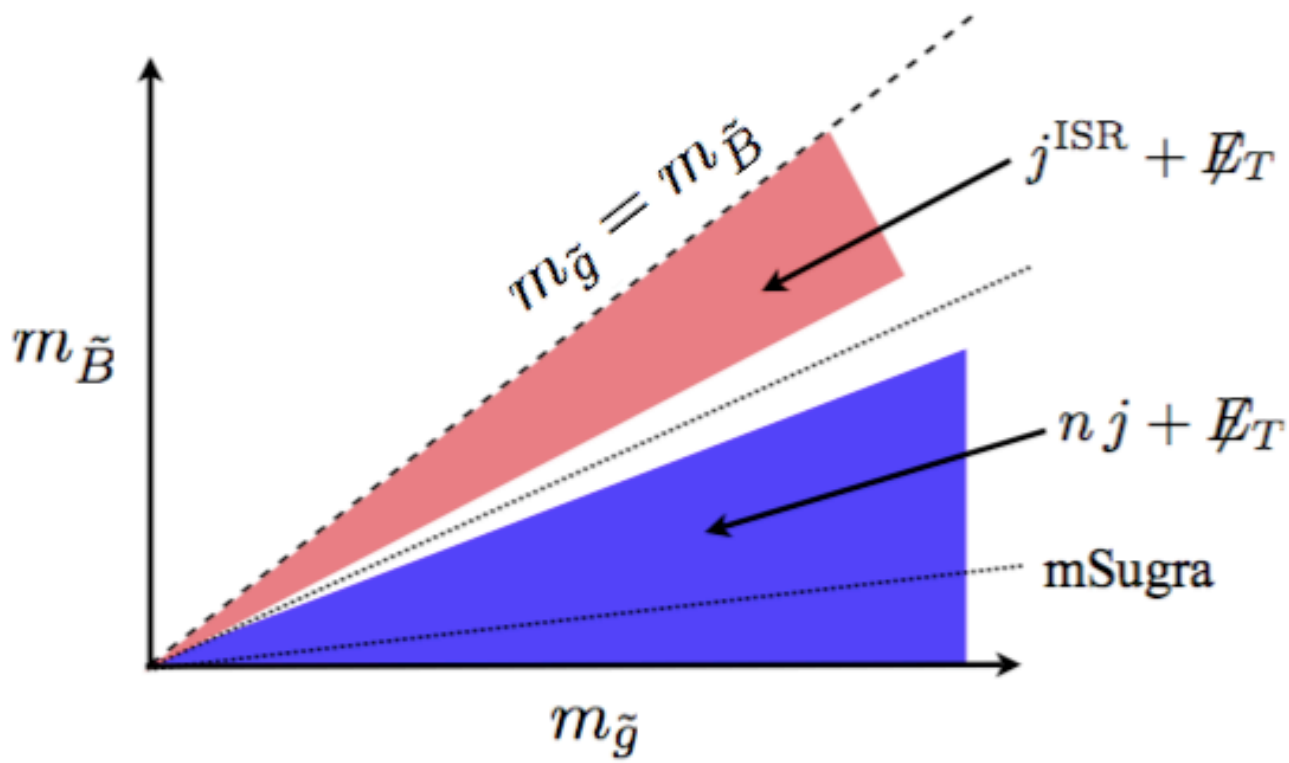
H_T \ $\not{E}_T$	100–150	150–200	200–250	250–300	300–350
500–600	0.8	0.6	0.4	0.1	0
400–500	4.0	3.0	1.3	0.4	0.1
300–400	12	10	4.7	1.0	0.1
200–300	7.9	5.8	1.8	0.2	
100–200	0.2	0.1			

Find chi-squared value for grid to see if model is excluded

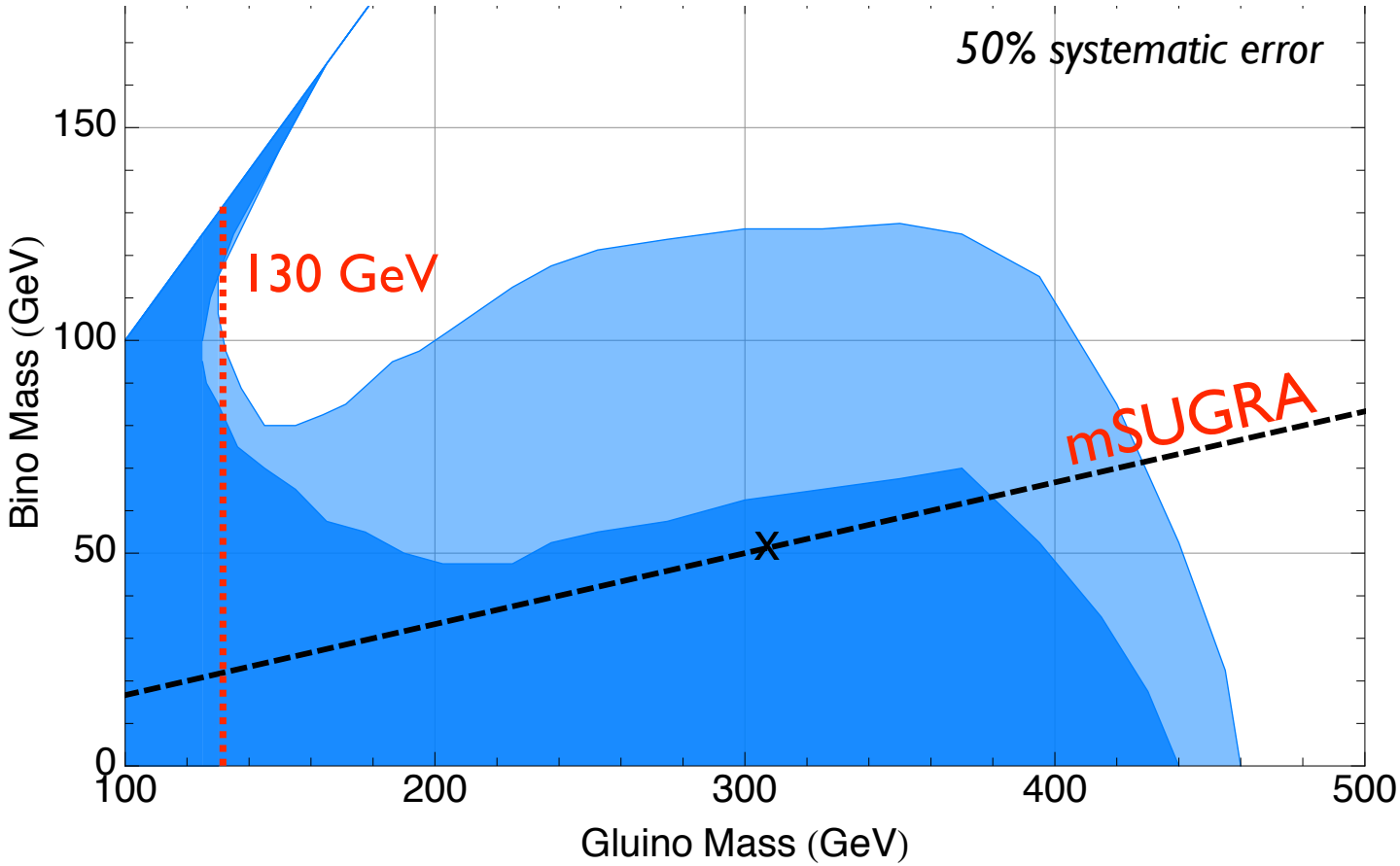
$$\chi^2 = \sum_{i=1}^{n} \chi_i^2 = \sum_{i=1}^{n} \left[\frac{S_i}{(\sigma_{\rm stat} \oplus \sigma_{\rm sys})_i} \right]^2$$

: $1 \leq \chi_i \leq 2$: $2 \leq \chi_i \leq 3$: $3 \leq \chi_i \leq 4$

Exclusion Region



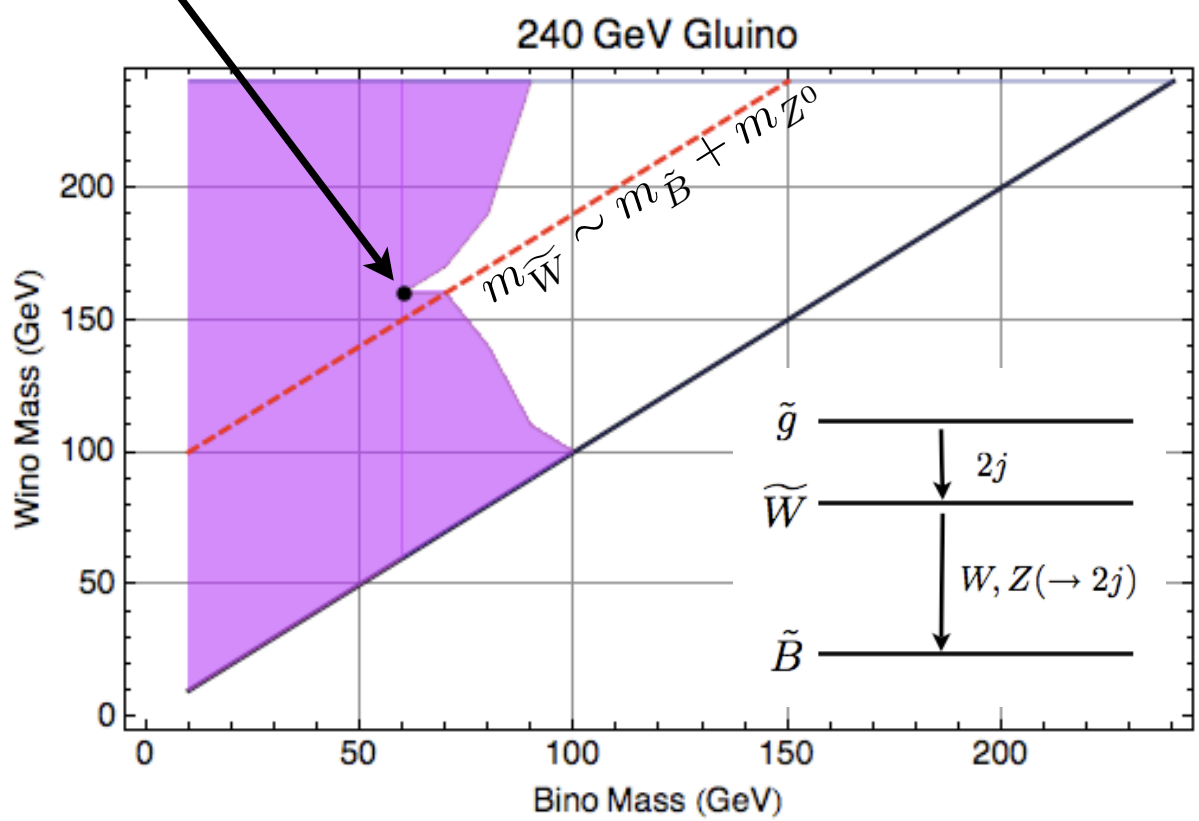
Exclusion Region



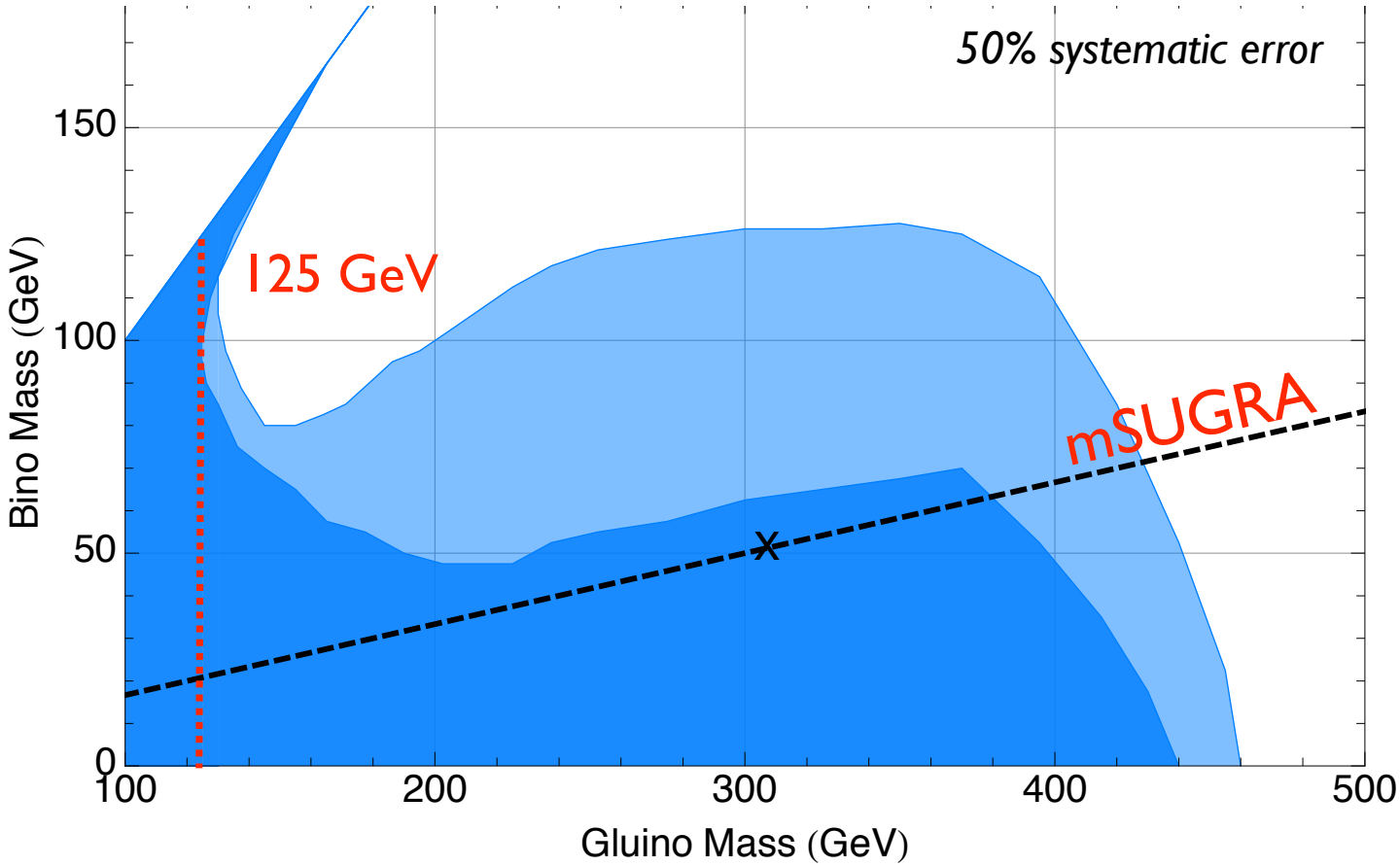
: Cascade : No cascade

Exclusion Region

Most difficult point to see

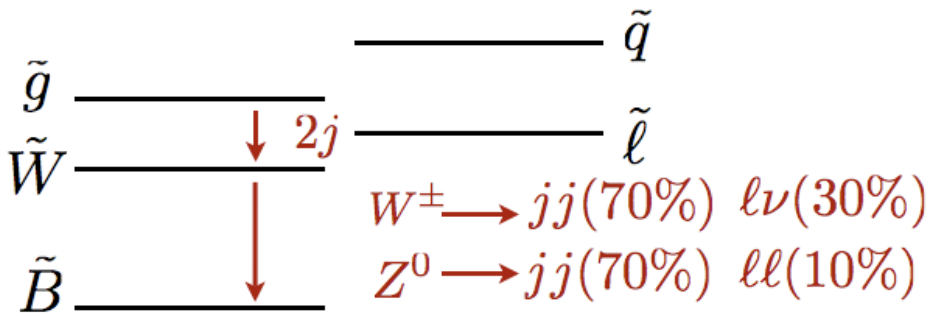


Exclusion Region



: Cascade : No cascade

Leptons



Lepton-poor cascade...but for light gluinos, still possible to get many leptons.

Does not improve "worst-case" scenario exclusion region for cascade

$\Rightarrow$ gauge bosons are barely on-shell and leptons are very soft

For light gluinos nearly degenerate with the wino,

hard cuts on total lepton p_T may help to exclude additional regions of parameter space

Conclusions

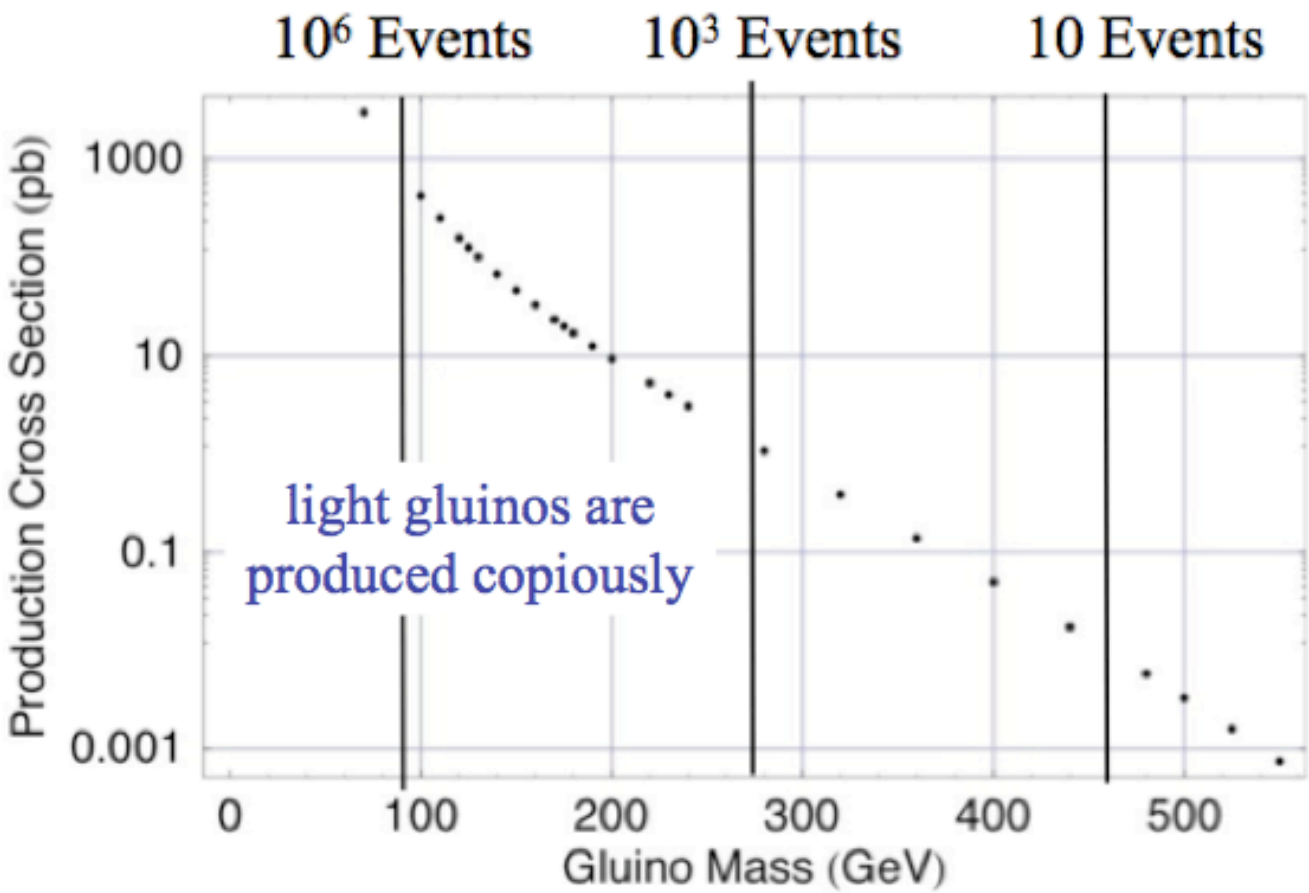
* Proposal for performing model-independent jets + MET searches
    * only requires knowledge of SM background
    * broadens reach of current searches

* Within the MSSM, gluinos can be as light as 125 GeV

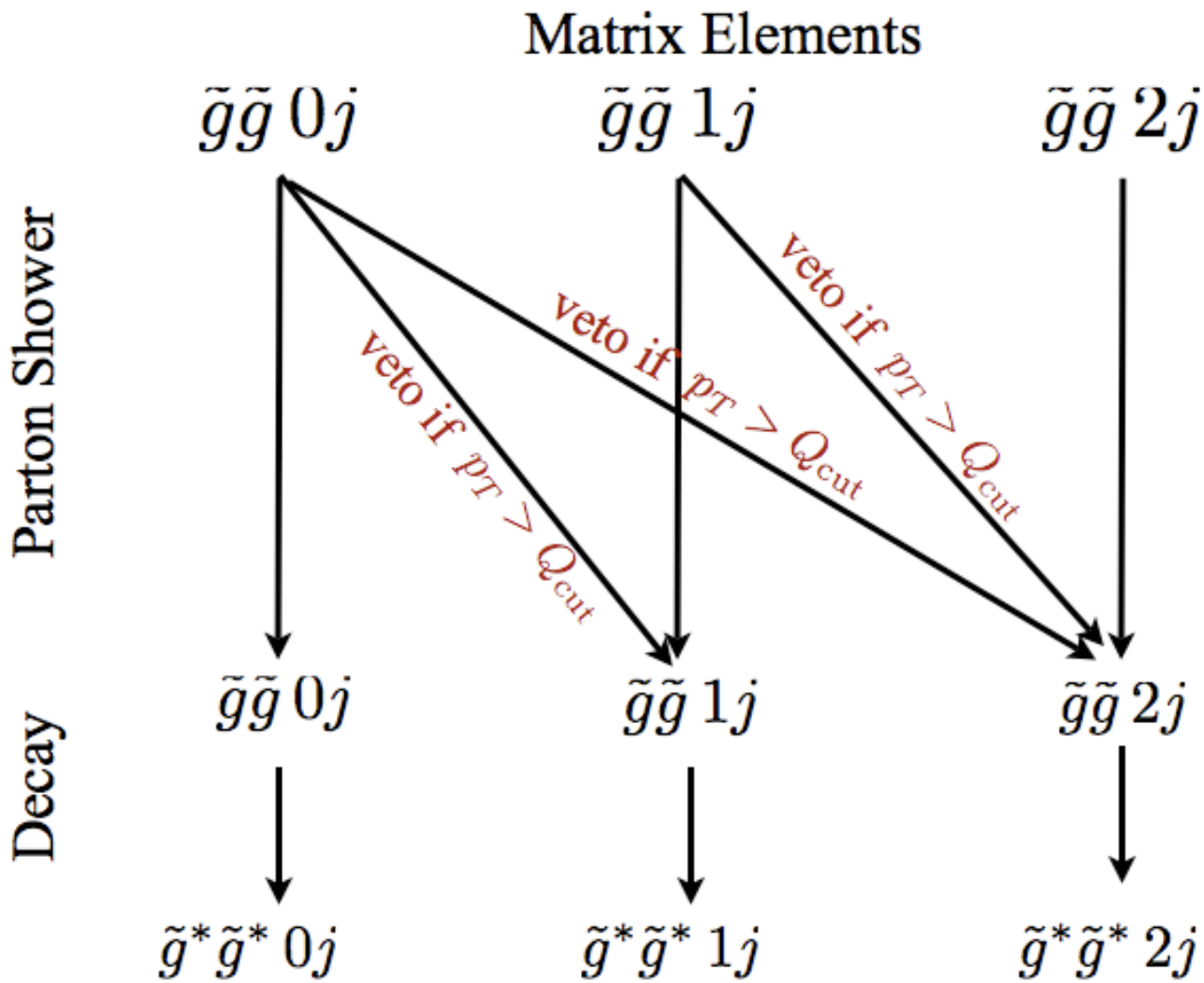
* Straightforward to generalize approach to jets + MET studies at LHC

Extras

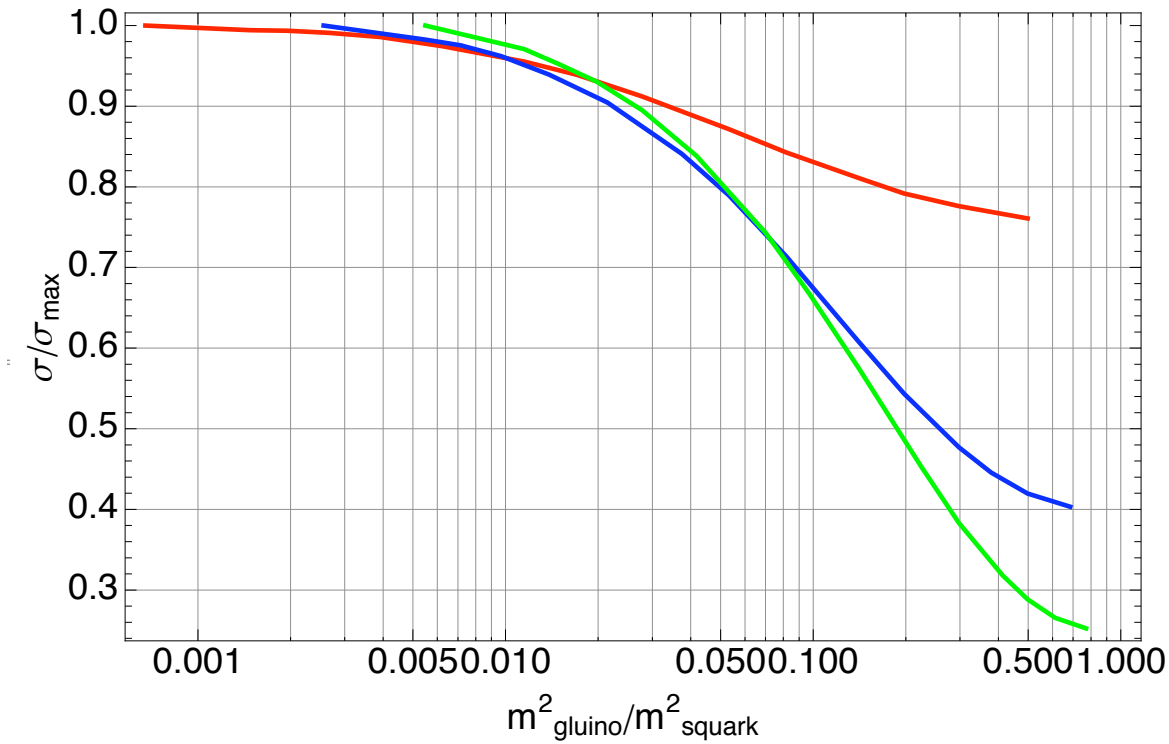
Kinematics


10^6 Events
10^3 Events
10 Events
Production Cross Section (pb)
1000
10
0.1
0.001
0
100
200
300
400
500
Gluino Mass (GeV)
light gluinos are
produced copiously

Matching Procedure

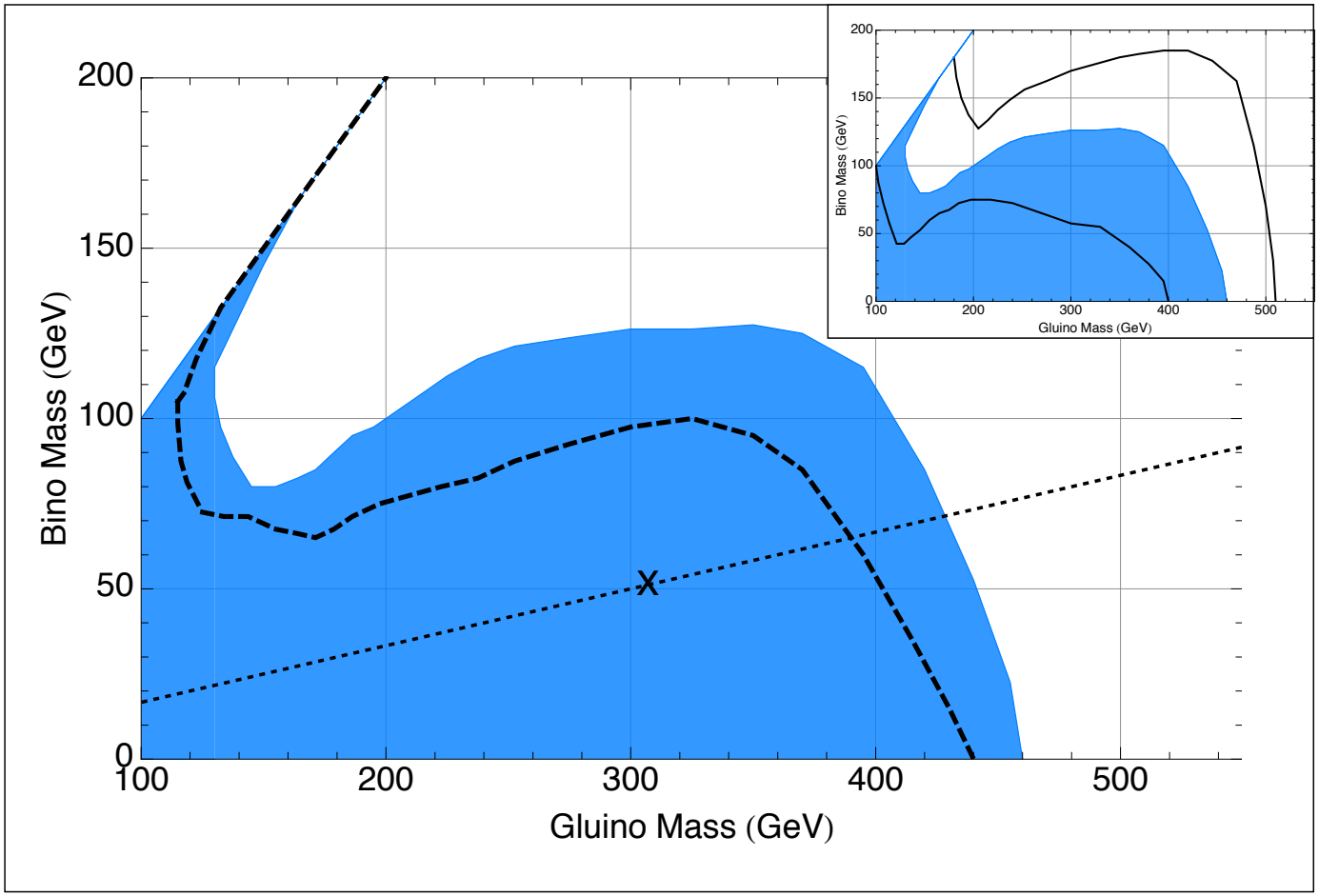


T-channel Squarks



: 120 GeV : 240 GeV : 360 GeV

Scaling Effect



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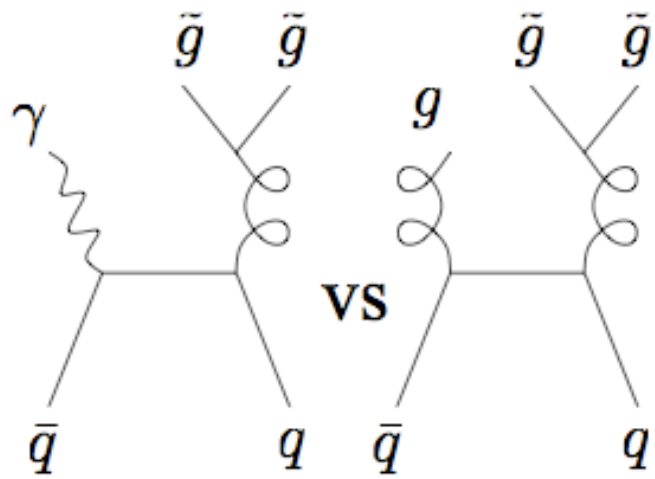

photon ISR more difficult to detect than gluon ISR

$$\alpha_{\rm s} \gg \alpha_{\rm EM}$$

Monojet rate is much larger for gluinos

Monojet discovery potential is significantly better