Supersafe Supersymmety @ LHC

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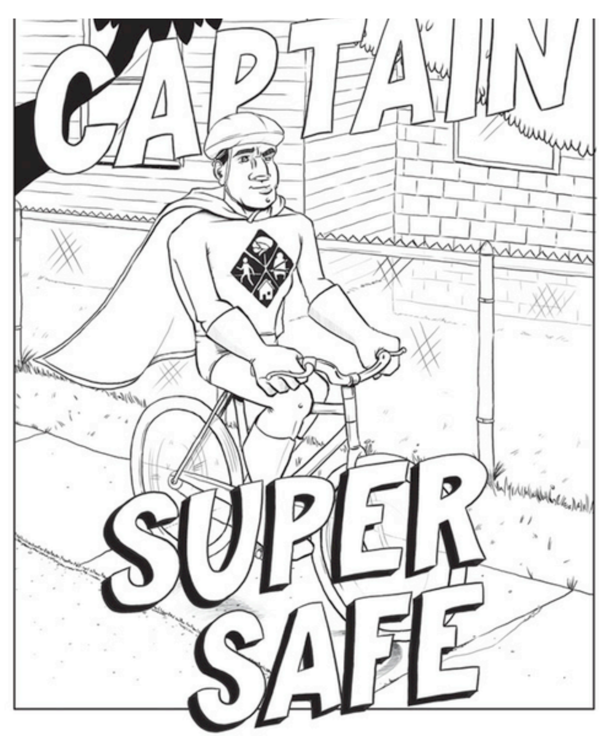
based on 1203.4821 with Adam Martin (CERN/Notre Dame);
and work-in-progress with Nirmal Raj (Oregon)

Supersafe...

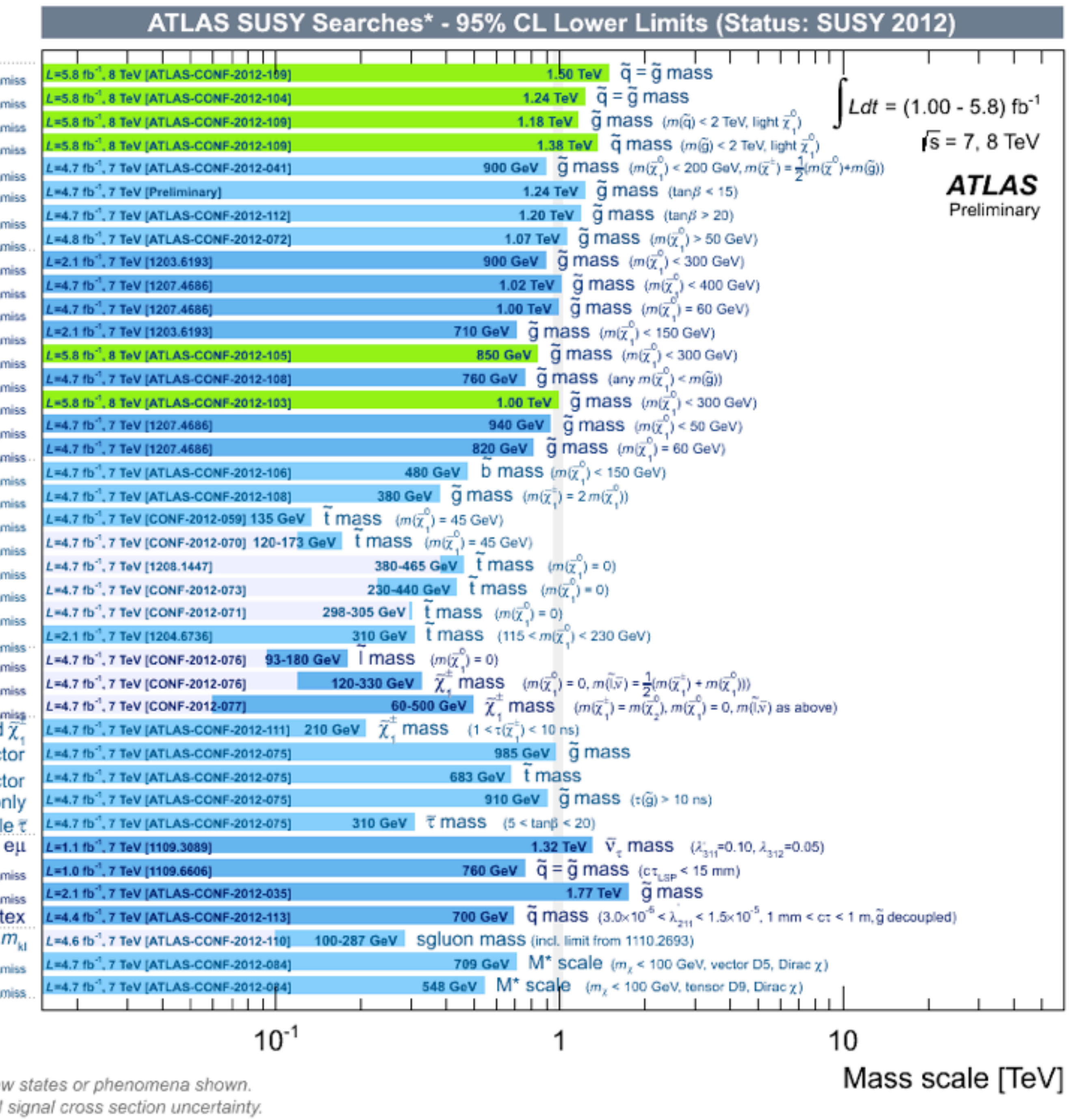


Outline

1. Brief Intro
2. Dirac Gluino and "Supersoft Supersymmetry"
3. Colored Superpartner Production @ LHC
4. Simpified Models
5. Jets + missing searches for supersymmetry @ LHC
   a) ATLAS; CMS α_T; (CMS MHT; CMS "razor")
   b) Comparisons
6. Summary

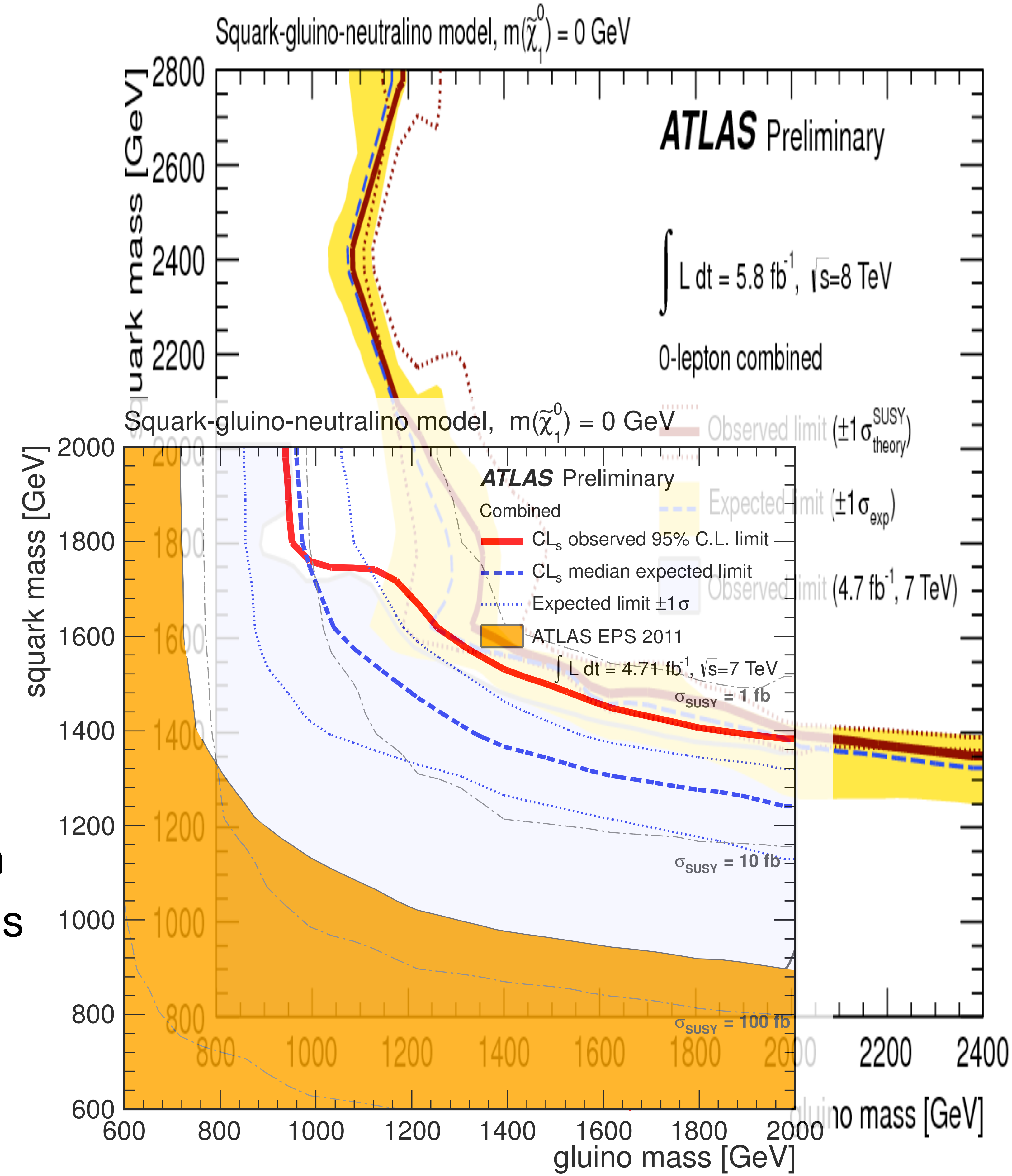
Introduction

Weak Scale Supersymmetry @ LHC



Many Searches!

In this talk, focus on “jets + MET” that arise from squark and gluino production.



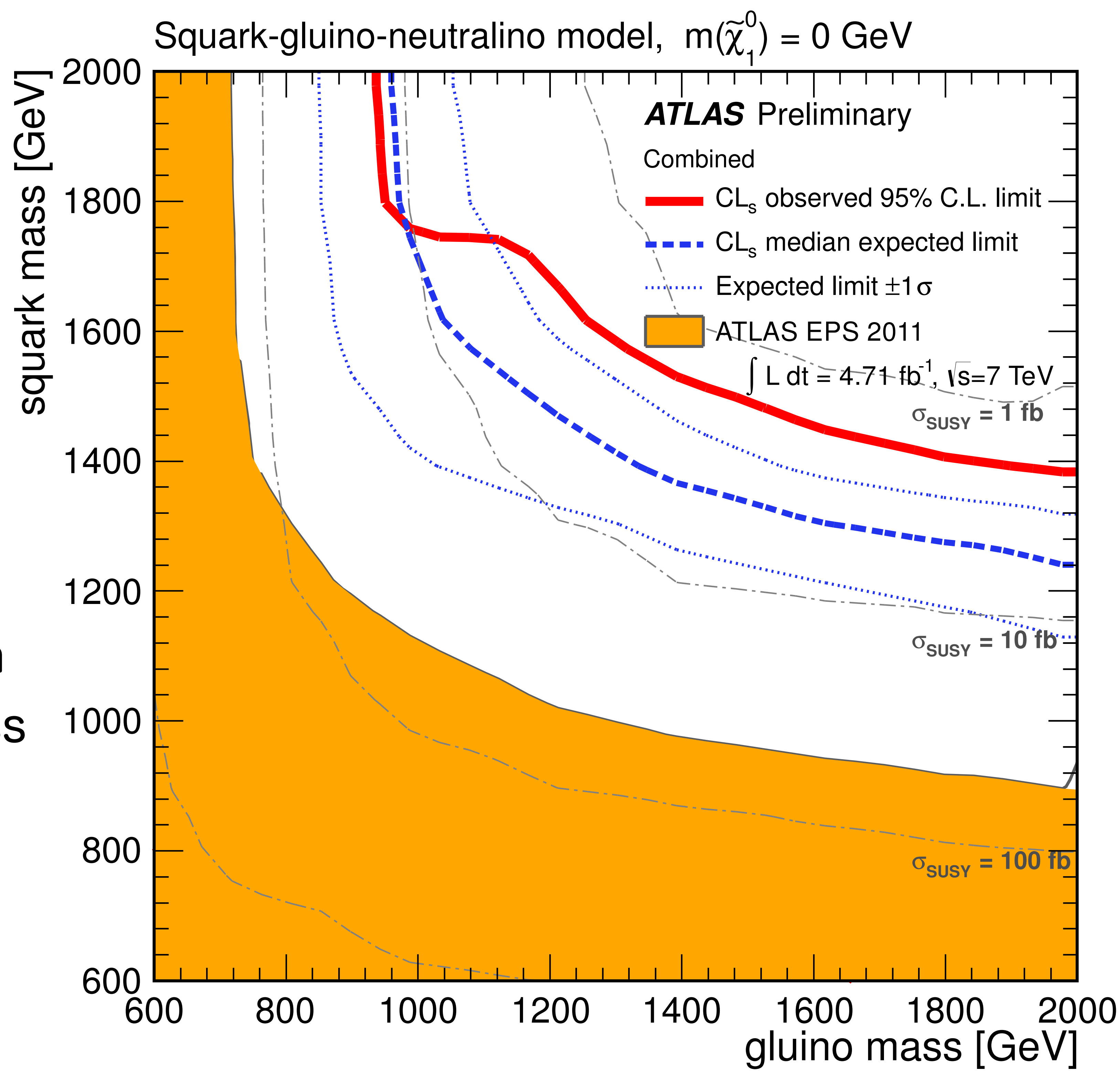
ATLAS
jets + MET
August 2012

ATLAS
jets + MET
March 2011

1st+2nd
generation
squark mass

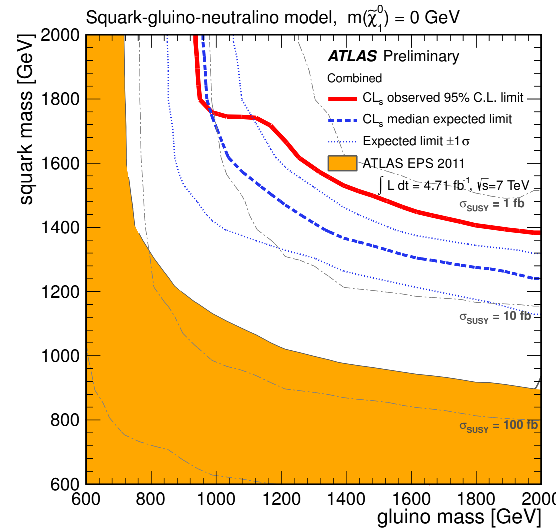
Supersymmetry @ LHC

1st+2nd generation squark mass



ATLAS-CONF-2012-033

If weak scale supersymmetry...



R-parity violation.
LSP decays,
no missing energy.

1st,2nd generation
heavy (> 1.5-2 TeV),
if LSP light
(< 200-300 GeV)

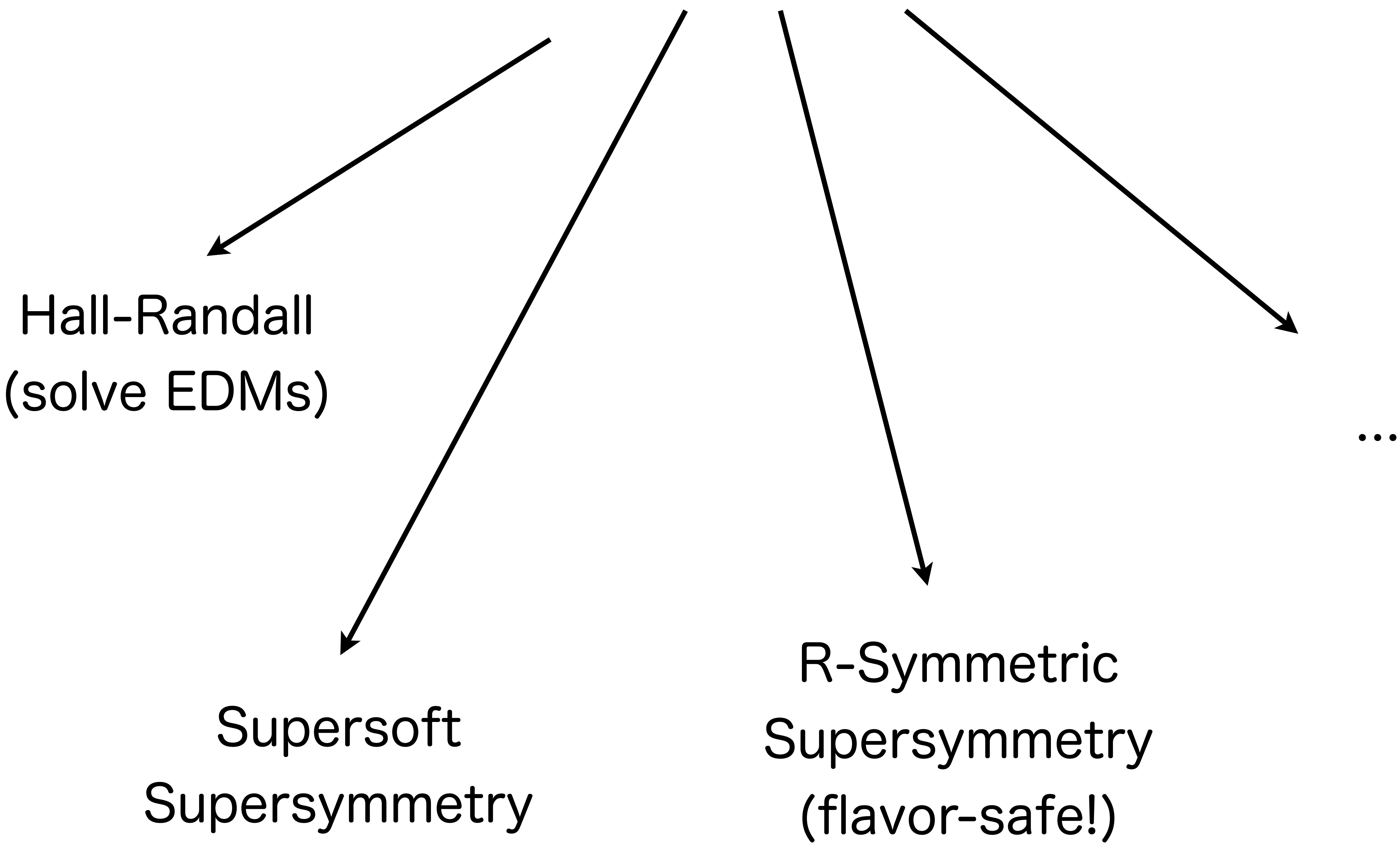
Too simplified
a model
(compressed)

LSP heavier
(at least 300-400 GeV)

Too simplified
a model
(cascades)

Dirac Gluino in Supersymmetry

Dirac Gluino



Dirac Gauginos in Supersymmetry

SUSY breaking to gauginos communicated through D-term spurions:

Polchinski, Susskind (1982)
Hall, Randall (1991)
Fox, Nelson, Weiner (2002)
...

$$W'_\alpha = \theta_\alpha D$$

Dirac gaugino masses arise from:

$$\int d^2\theta \sqrt{2}\frac{W'_\alpha W_j^\alpha A_j}{M}$$

M ← messenger scale

giving

$$\mathcal{L} \supset -m_D \lambda_j \tilde{a}_j$$

$\tilde{a}_j$ ← chiral fermion in adjoint rep

λ_j ← gaugino

m_D ← $m_D = D'/M$

Dirac Gauginos in Supersymmetry II

Dirac gaugino masses require extending the MSSM with chiral adjoint superfields:

$$\left\{ \begin{array}{lll} A_j & j = 1 \ldots 8 & \text{color octet} \\ A_j & j = 1 \ldots 3 & \text{weak triplet} \\ A_j & j = 1 & \text{singlet} \end{array} \right.$$

Gauge coupling unification... (for those who still care)

...still perturbative, but requires unifons.

Dirac Gauginos in Supersymmetry III

Scalar masses could arise from:

$$\int d^4\theta \frac{(W'^{\alpha}W'_{\alpha})^{\dagger}W'^{\beta}W'_{\beta}}{M^6} Q^{\dagger}Q$$

which is finite! This is because the only counterterm

$$\int d^4\theta \frac{\theta^2\overline{\theta}^2 m_D^4}{\Lambda^2} Q^{\dagger}Q$$

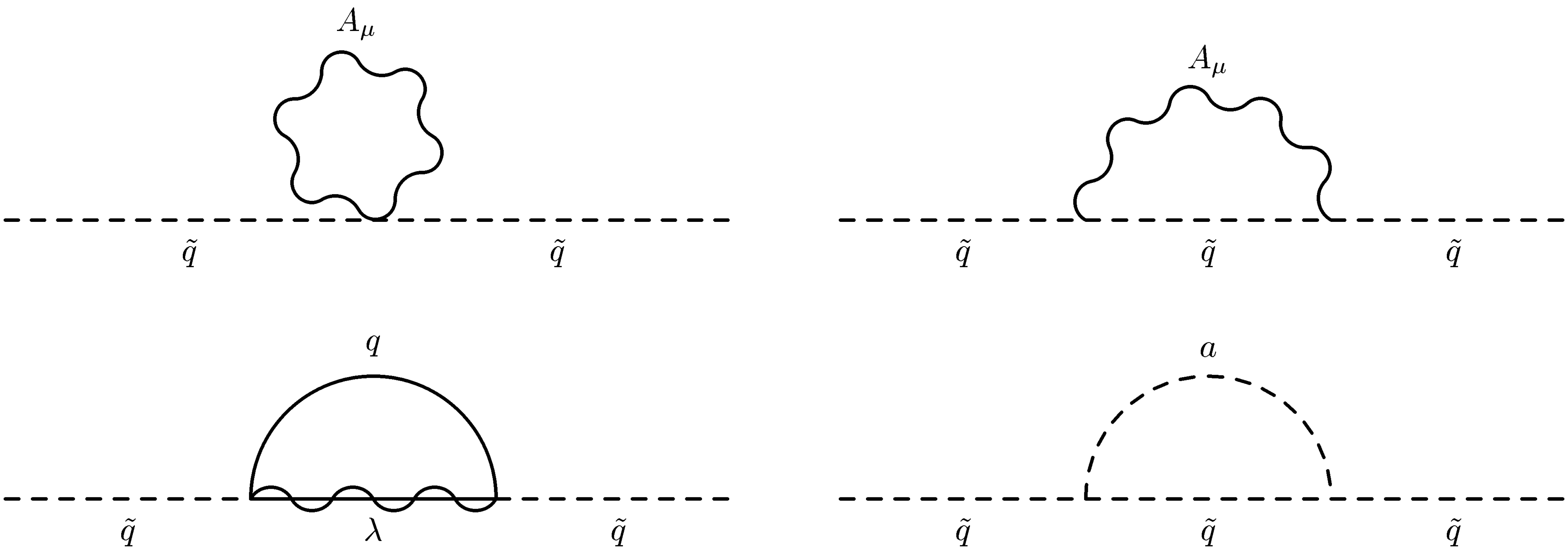
is suppressed by $1/\Lambda^2$.

Scalar masses are "supersoft"

Fox, Nelson, Weiner (2002)

Squark/Slepton Masses

One-loop contributions:

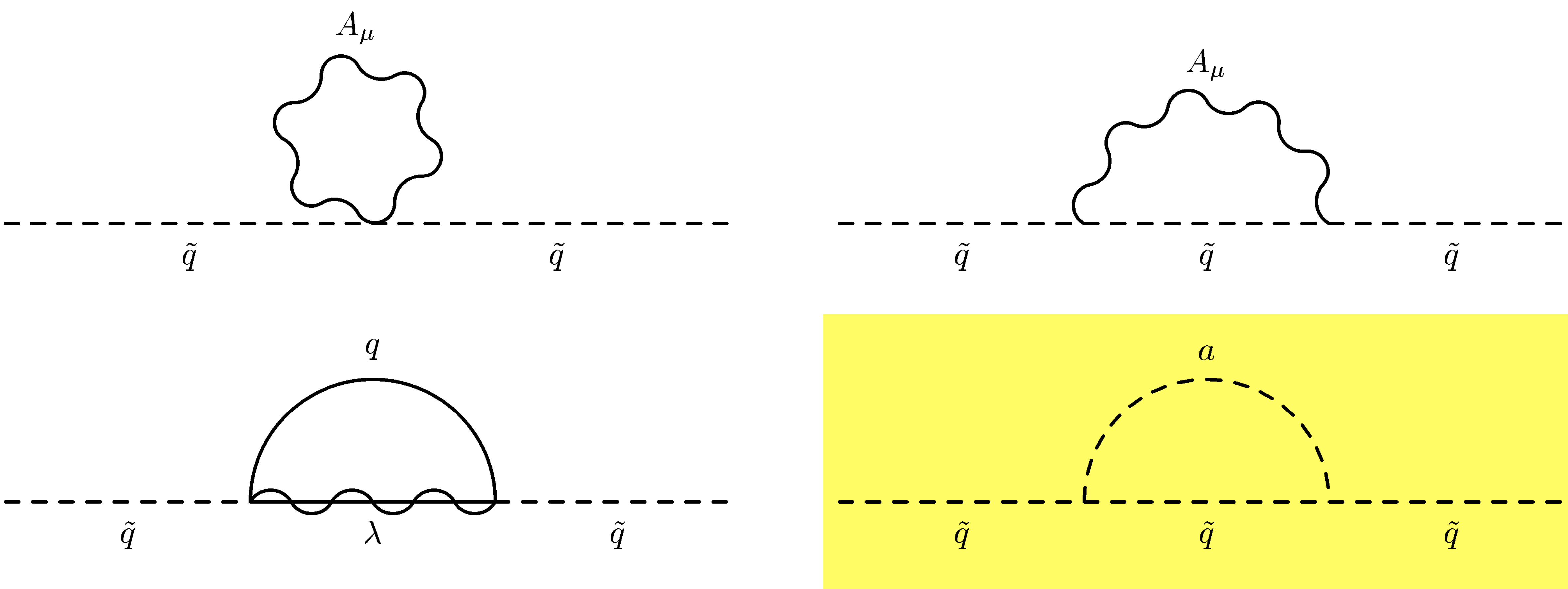


Giving

$$M_{\tilde{f}}^2 = \sum_i \frac{C_i(f)\alpha_i M_i^2}{\pi} \log \frac{\tilde{m}_i^2}{M_i^2}$$

Squark/Slepton Masses

One-loop contributions:



Giving

$$M_{\tilde f}^2 = \sum_i \frac{C_i(f)\alpha_i M_i^2}{\pi} \log \frac{\tilde m_i^2}{M_i^2}$$

Would-be log divergence is cutoff by adjoint scalar contribution.

Adjoint Scalars

Gauginos married off with fermionic components of chiral adjoint superfields:

$$A_j = \begin{pmatrix} \tilde{a}_j \\ a_j \end{pmatrix}$$

Also contain scalars in adjoint representation (e.g. “sgluons”).

$$\int d^2\theta \sqrt{2} \frac{W'_\alpha W_j^\alpha A_j}{M} \xrightarrow{\text{also}} \mathcal{L} \supset \; - m_D^2 (a_j + a_j^*)^2$$

Additional contributions

$$\int d^2\theta \frac{W'_\alpha W'^\alpha}{M^2} A_j^2$$

Masses for Re[a_j] and Im[a_j] (opposite signs)

Finite Squark Masses from Dirac Gauginos

$$M_{\tilde{f}}^2 = \sum_i \frac{C_i(f)\alpha_i M_i^2}{\pi} \log \frac{\tilde{m}_i^2}{M_i^2}$$

Plugging in numbers:

$$M_{\tilde{q}}^2 \simeq (700 \text{ GeV})^2 \left(\frac{M_3}{5 \text{ TeV}}\right)^2 \frac{\log \tilde{r}_3}{\log 1.5}$$

or

$$M_{\tilde{q}}^2 \simeq (760 \text{ GeV})^2 \left(\frac{M_3}{3 \text{ TeV}}\right)^2 \frac{\log \tilde{r}_3}{\log 4}$$

Dirac gluino ≈ (5-7) x squark mass

Naturalness I: Gluino

MSSM

one-loop

$$\delta m_{H_u}^2 = -\frac{3\lambda_t^2}{8\pi^2} M_{\tilde{t}}^2 \log \frac{\Lambda^2}{M_{\tilde{t}}^2}$$

two-loop

$$\delta m_{H_u}^2 = -\frac{\lambda_t^2}{2\pi^2} \frac{\alpha_s}{\pi} |\tilde{M}_3|^2 \left(\log \frac{\Lambda^2}{\tilde{M}_3^2} \right)^2$$

evaluate

$$\delta m_{H_u}^2 |_{\mathrm{MSSM}} \simeq -\left(\frac{\tilde{M}_3}{4} \right)^2 \left(\frac{\log \Lambda / \tilde{M}_3}{3} \right)^2$$

Naturalness I: Gluino

MSSM

one-loop

$$\delta m_{H_u}^2 = -\frac{3\lambda_t^2}{8\pi^2} M_{\tilde{t}}^2 \log \frac{\Lambda^2}{M_{\tilde{t}}^2}$$

two-loop

$$\delta m_{H_u}^2 = -\frac{\lambda_t^2}{2\pi^2}\frac{\alpha_s}{\pi}|\tilde{M}_3|^2 \left(\log \frac{\Lambda^2}{\tilde{M}_3^2}\right)^2$$

evaluate

$$\delta m_{H_u}^2|_{\rm MSSM} \simeq -\left(\frac{\tilde{M}_3}{4}\right)^2 \left(\frac{\log \Lambda/\tilde{M}_3}{3}\right)^2$$

Supersoft

one-loop

$$\delta m_{H_u}^2 = -\frac{3\lambda_t^2}{8\pi^2} M_{\tilde{t}}^2 \log \frac{\tilde{m}_3^2}{M_{\tilde{t}}^2}$$

two-loop

(finite)

evaluate using mstop and:

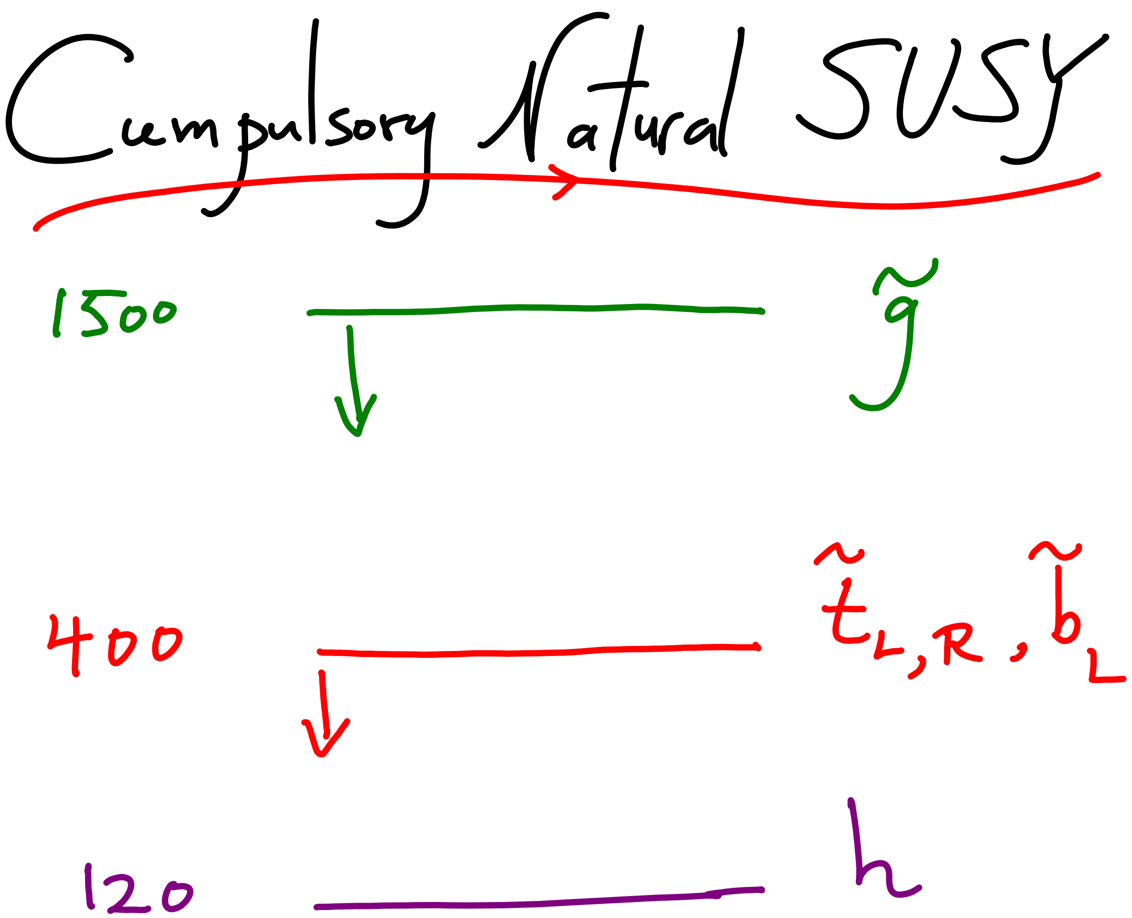
$$M_{\tilde{q}}^2 \simeq (700\ \text{GeV})^2 \left(\frac{M_3}{5\ \text{TeV}}\right)^2 \frac{\log \tilde{r}_3}{\log 1.5} \qquad \log \frac{M_3^2}{M_{\tilde{t}}^2} \simeq \log \frac{3\pi}{4\alpha_s}$$

$$\delta m_{H_u}^2|_{\rm SSSM} \simeq -\left(\frac{M_3}{22}\right)^2 \frac{\log \tilde{r}_3}{\log 1.5}$$

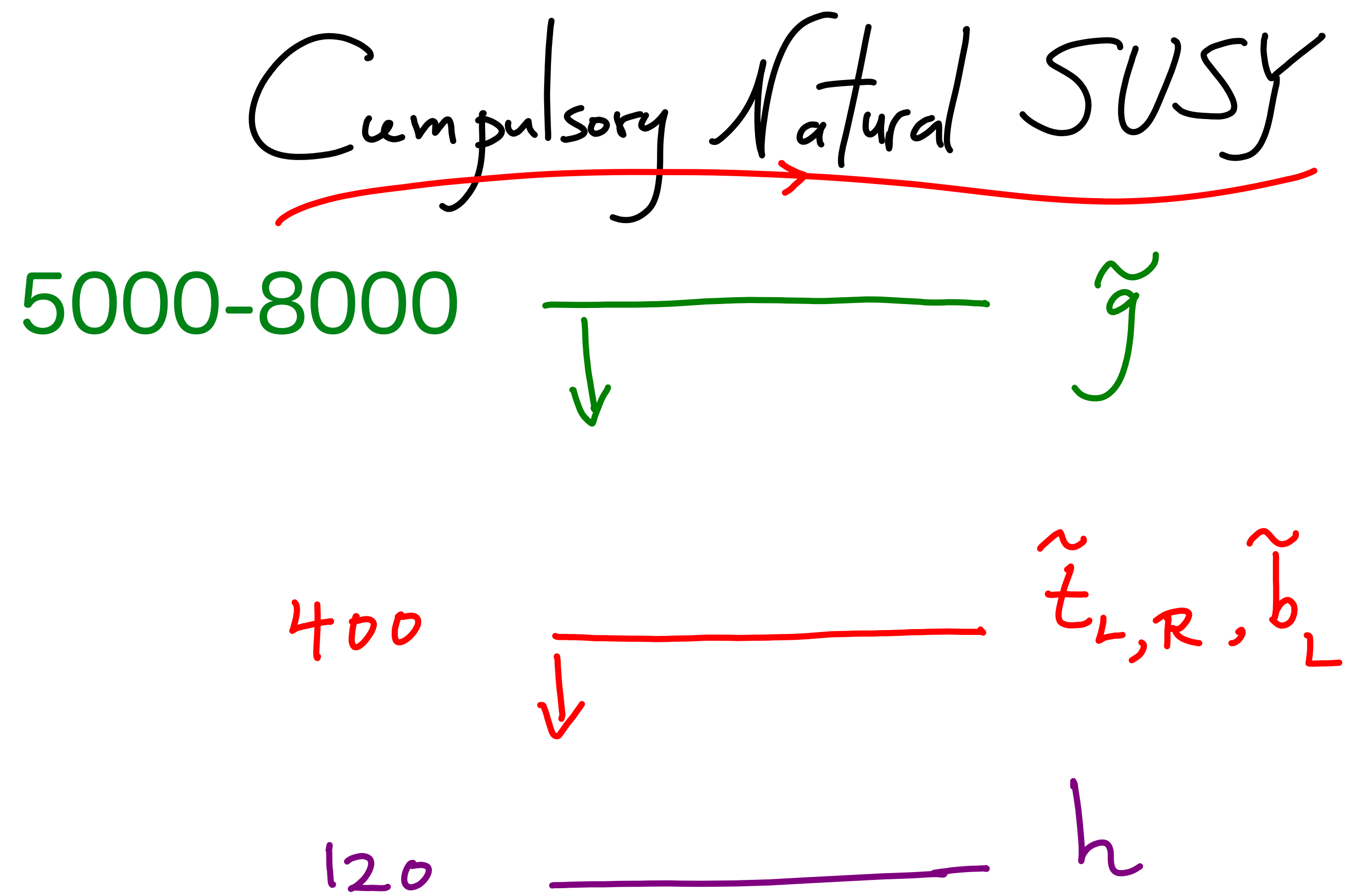
Dirac gluino can be substantially heavier than Majorana gluino while just as natural.

In Nima language...

MSSM



Dirac Gluino



Arkani-Hamed
(Intensity Frontier Workshop)

Naturalness II: Dirac Electroweak Gauginos?

With just D-term spurion

$$\int d^2\theta \sqrt{2} \frac{W'_\alpha W_j^\alpha A_j}{M}$$

in components:

$$\mathcal{L} \supset -m_D \lambda_j \tilde{a}_j - \sqrt{2} m_D (a_j + a_j^*) D_j - D_j (\sum_i g_k q_i^* t_j q_i) - \frac{1}{2} D_j^2$$

Integrate out massive Re[a_j], forces $D_j = 0$, hence tree-level quartic vanishes.

$$m_h^2 = \cancel{m_Z^2 \cos^2 2\beta} + \frac{3}{4\pi^2} \cos^2\alpha \, y_t^2 m_t^2 \ln \frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2}$$

Naively...a DISASTER! Only stop loop contributions to Higgs mass. (Requires >> 10 TeV mass stops.)

Naturalness II: Higgs Mass

"Pure" Supersoft (Dirac gauginos; D-term & no F-terms) dead.

Need either Majorana winos and binos, or other additional contributions to Higgs mass, e.g.

- NMSSMology
- R-symmetric contributions (λ couplings)
- Composite stops (Csaki, Randall, Terning)
- ...

I'm not directly concerned with Higgs mass. Arguably, the MSSM probably needs to be extended anyway...

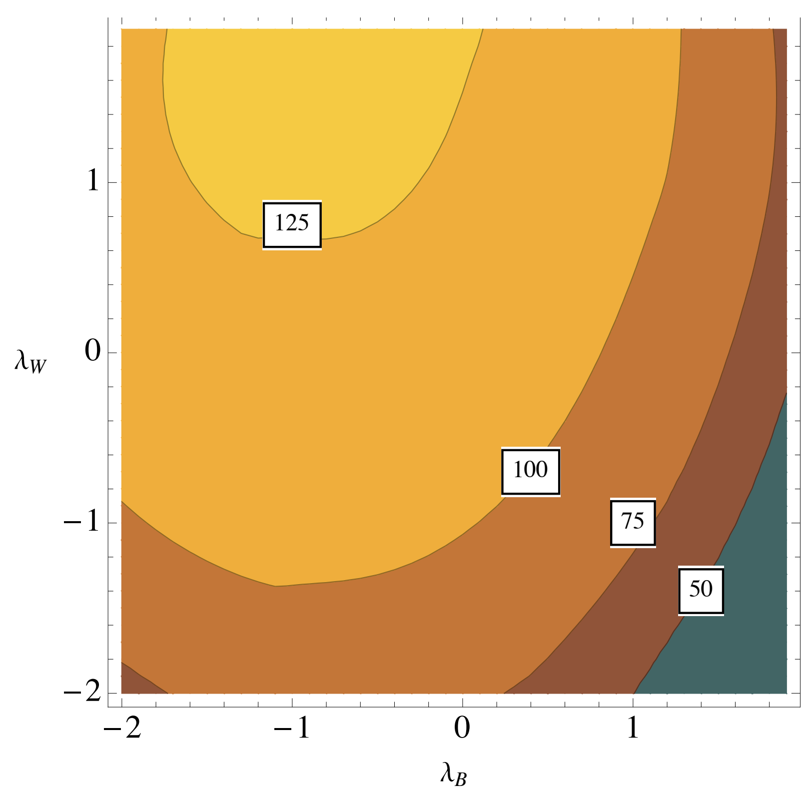
R-Symmetric with λ couplings

In an R-Symmetric model, a tree-level quartic is generated by "mu" terms and "λ" terms:

$$W \supset \mu_u \, H_u \, R_u + \mu_d \, R_d \, H_d$$

$$W \supset \lambda_B^u \, \Phi_B \, H_u \, R_u + \lambda_B^d \, \Phi_B \, R_d \, H_d + \lambda_W^u \, \Phi_W^a \, H_u \, \tau^a \, R_u + \lambda_W^d \, \Phi_W^a \, R_d \, \tau^a \, H_d$$

Example (not optimized for maximal Higgs with minimal stops):



$$M_2 = 1 \text{ TeV}$$

$$\mu_u = \mu_d = 200 \text{ GeV}$$

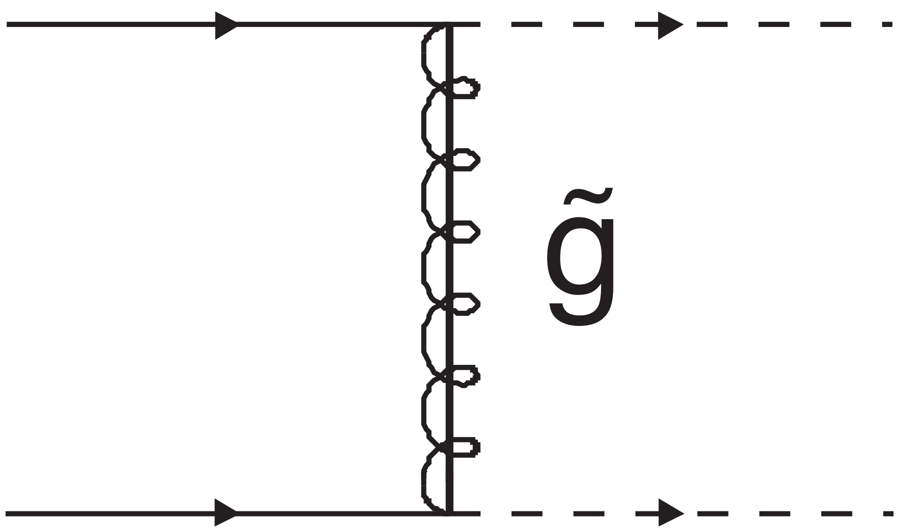
$$m(\tilde{t}_{L,R}) = 3 \text{ TeV}$$

Fok, Martin, Tsai, GK

LHC Squark & Gluino Production

LHC

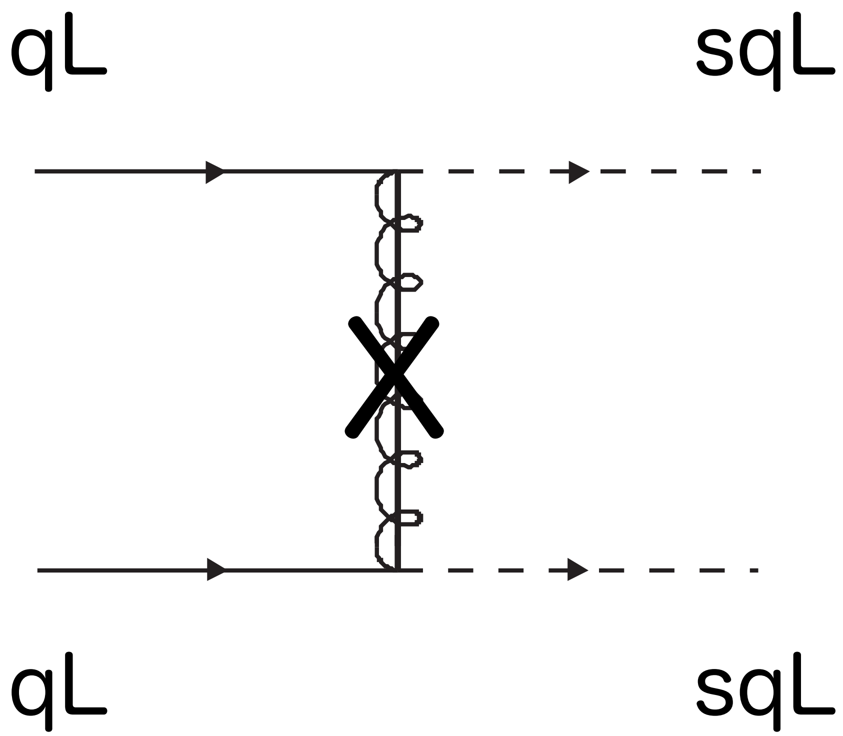
Squark Production

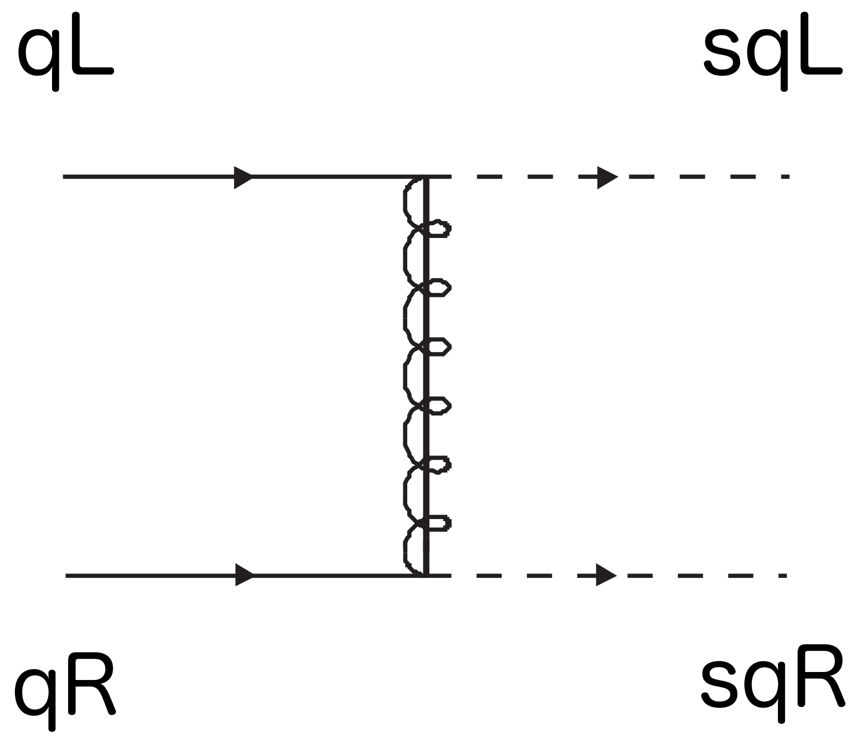


Gluino exchange diagrams
ought to dominate
LHC production of
(1st generation) squarks

But for heavier gluino...

Majorana versus Dirac





Requires Majorana mass insertion. Scales as

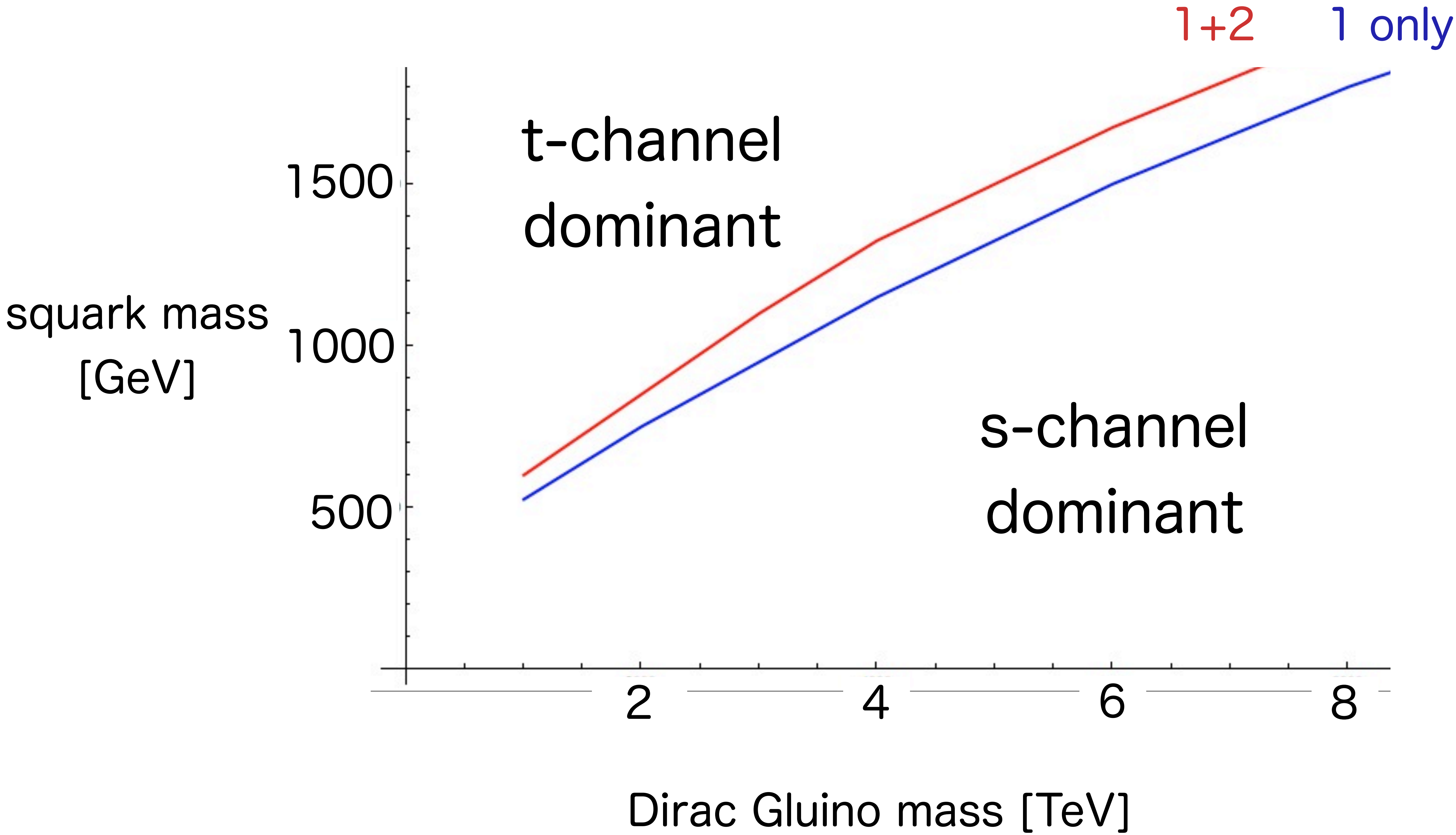
$1/M$

Dirac and Majorana. Scales as

$|p|/M^2$

Suppressed

Suppression of t-channel Dirac Gluino



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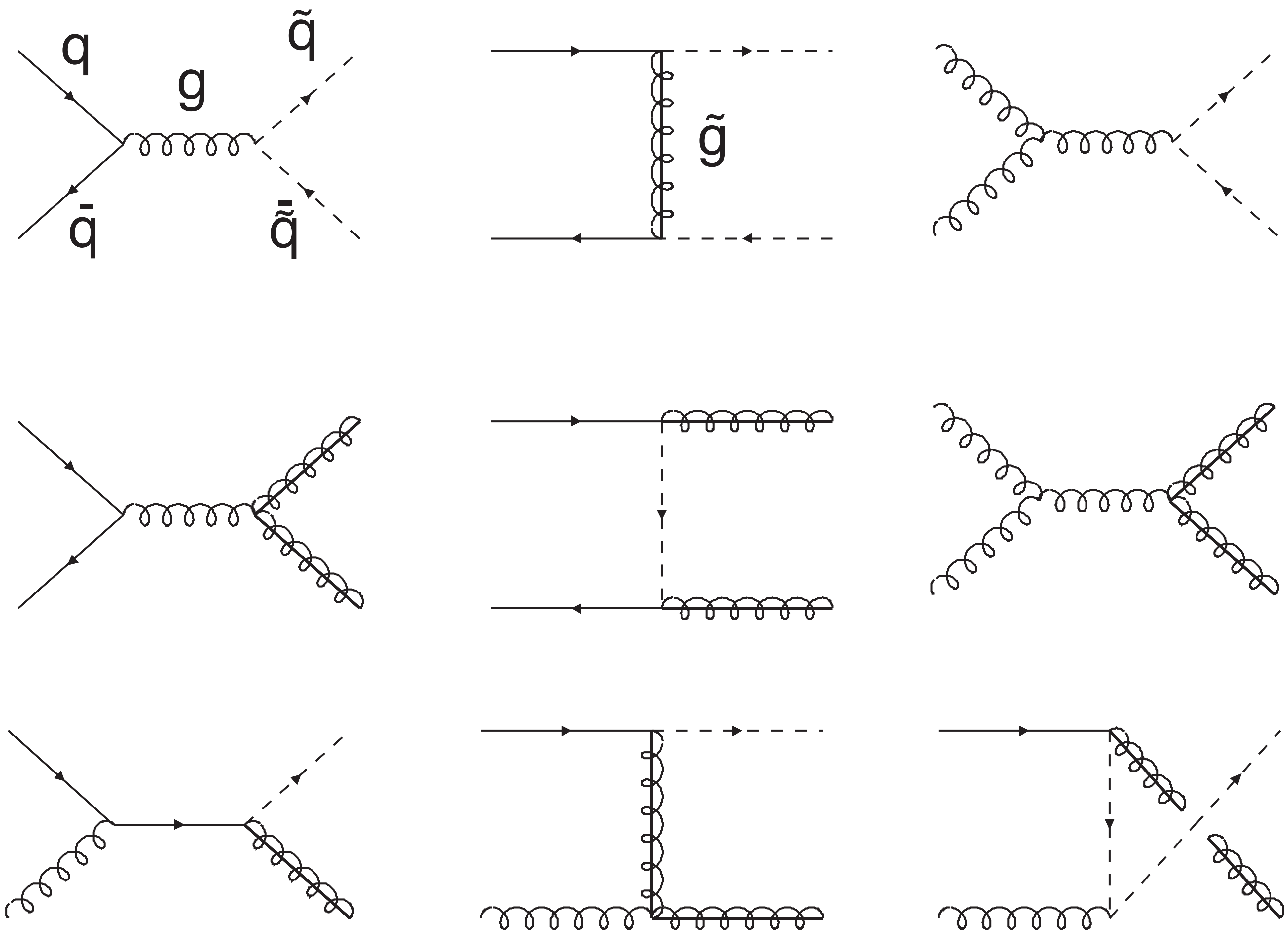
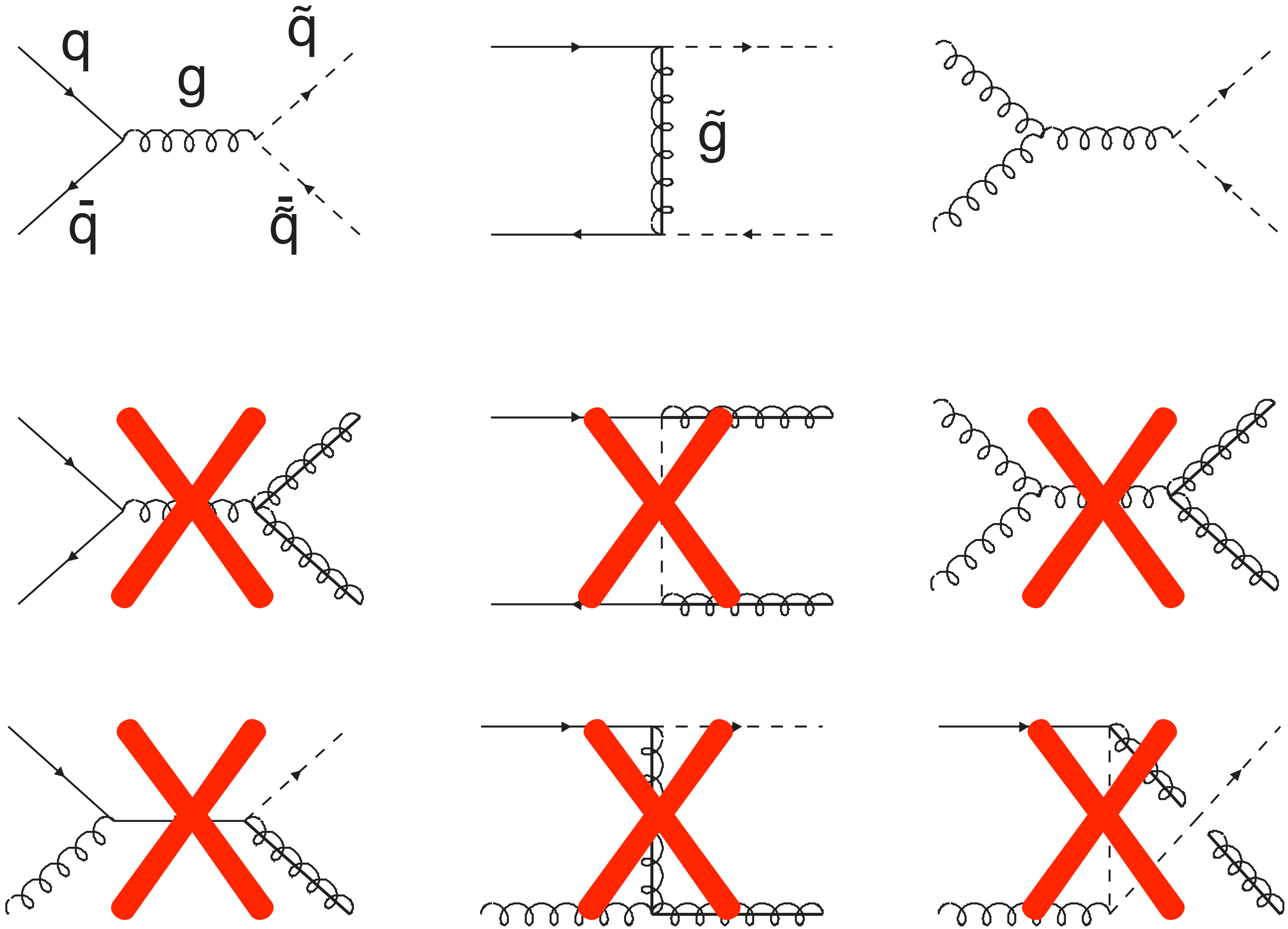
Squark and/or gluino production (LO)

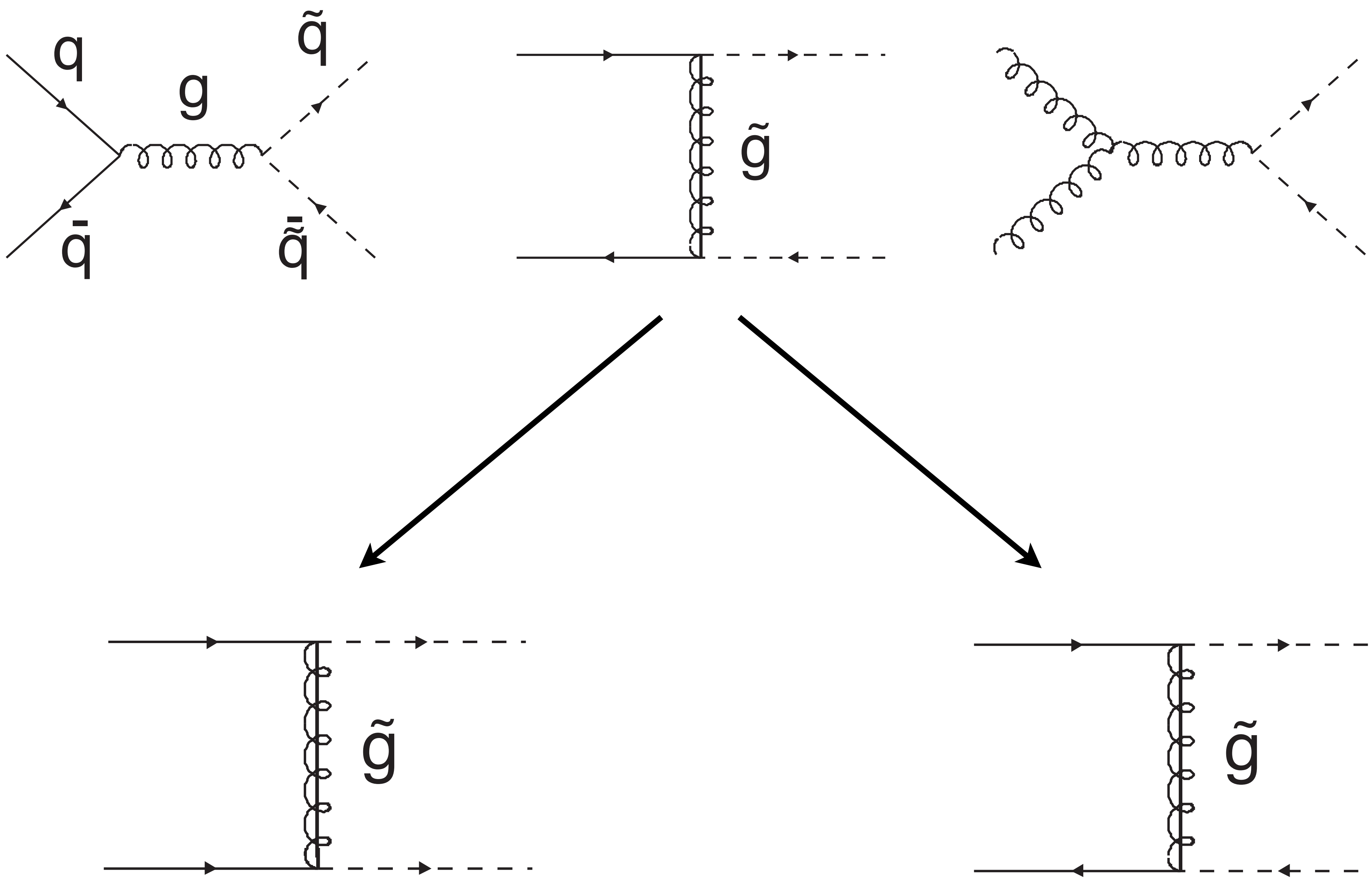


Squark and/or gluino production (LO)

with heavy gluino



Squark production (LO)



LL, RR absent

LR suppressed $1/M^2$

suppressed $1/M^2$ & PDFs

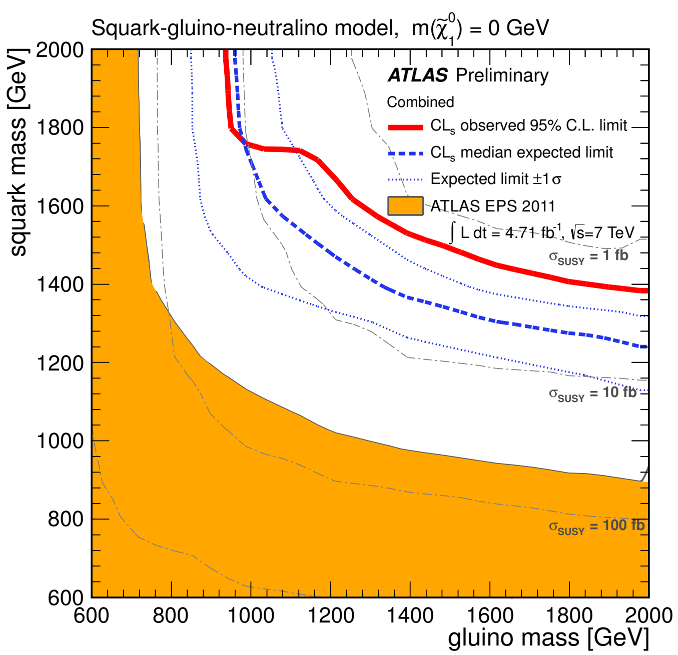
Bottom Line:

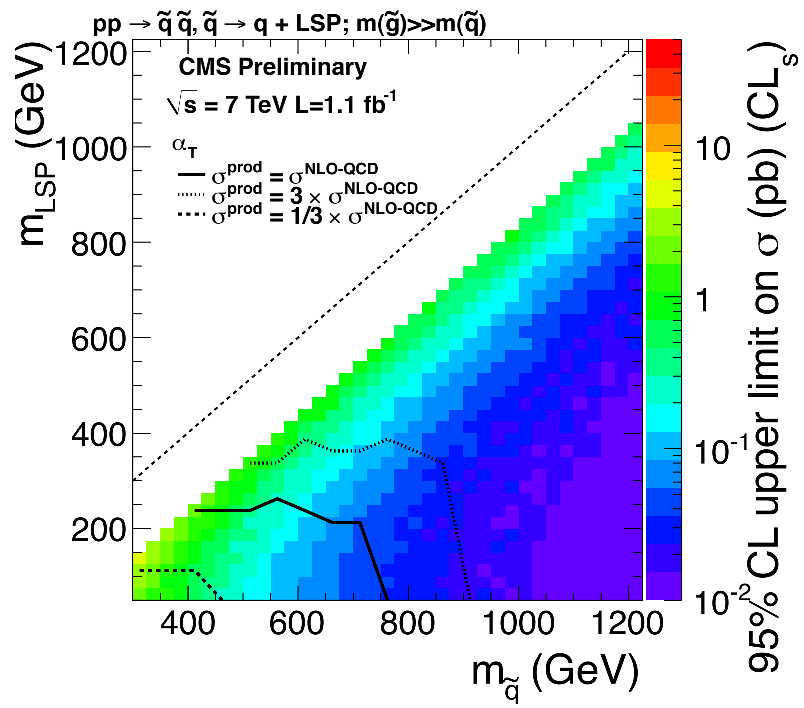
Colored Sparticle Production in
Supersoft Supersymmetric Models
Substantially Suppressed at LHC

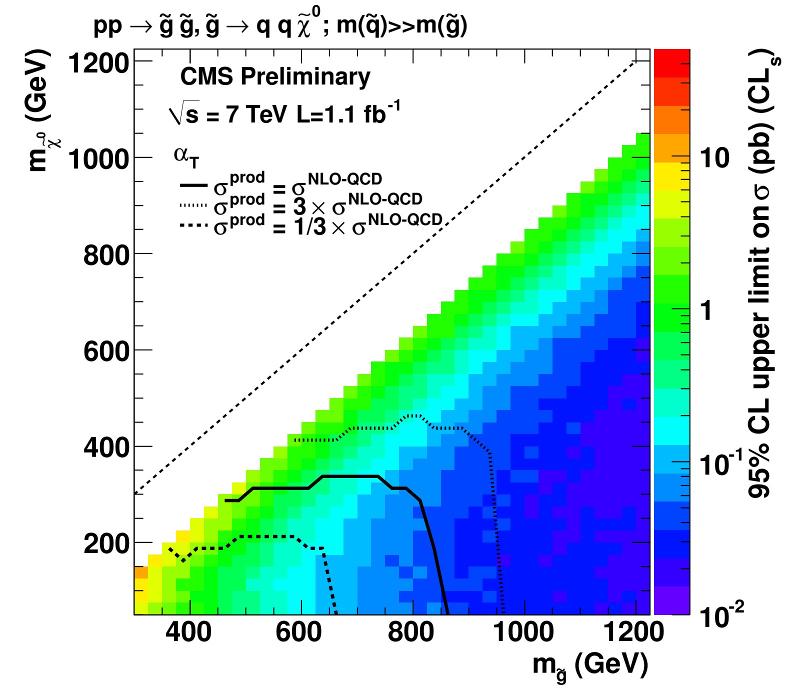
(numbers in 5 slides)

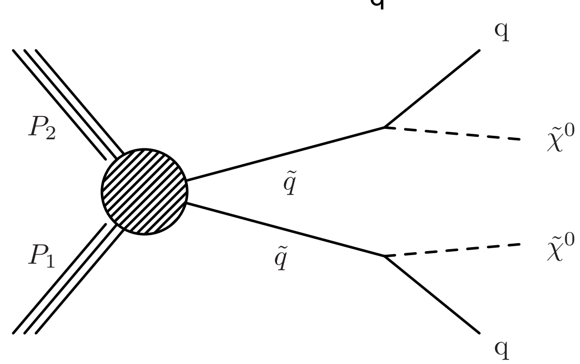
Simplified Models

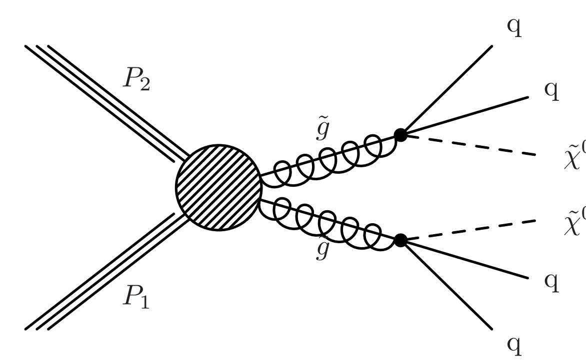
Examples of Simplified Models Bounded @ LHC











- massless LSP

- bounds in (M3, Msq) plane

- gluino >> sq

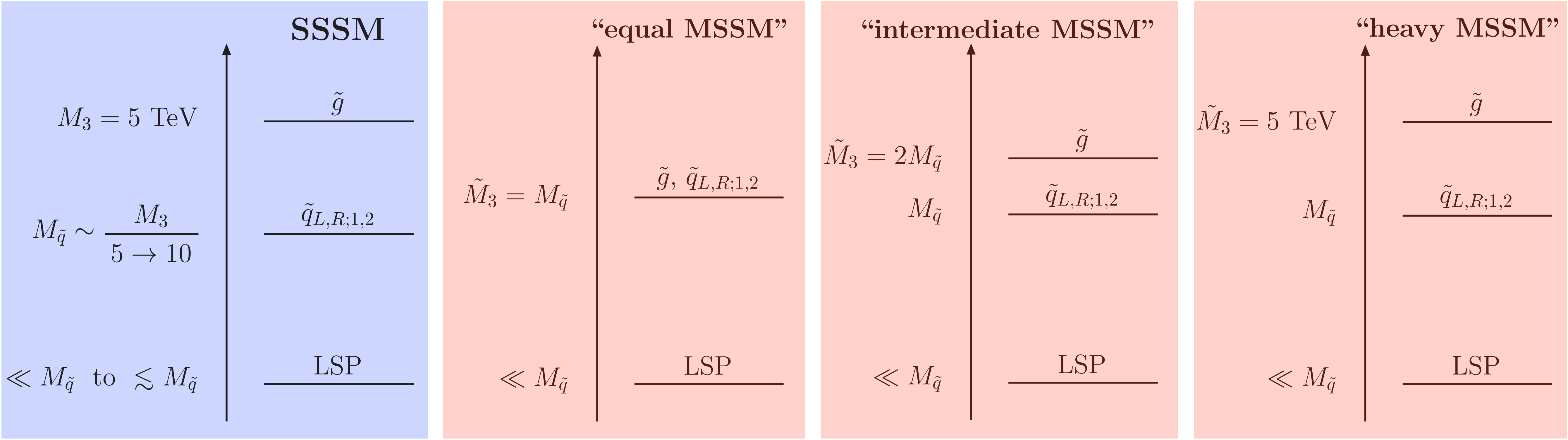
- bounds in (Msq, LSP) plane

- sq >> gluino

- bounds in (M3, LSP) plane

Supersoft versus MSSM Simplified Models

Construct a supersoft supersymmetric simplified model (SSSM) and perform apples-for-apples comparison against MSSM.



Simulations

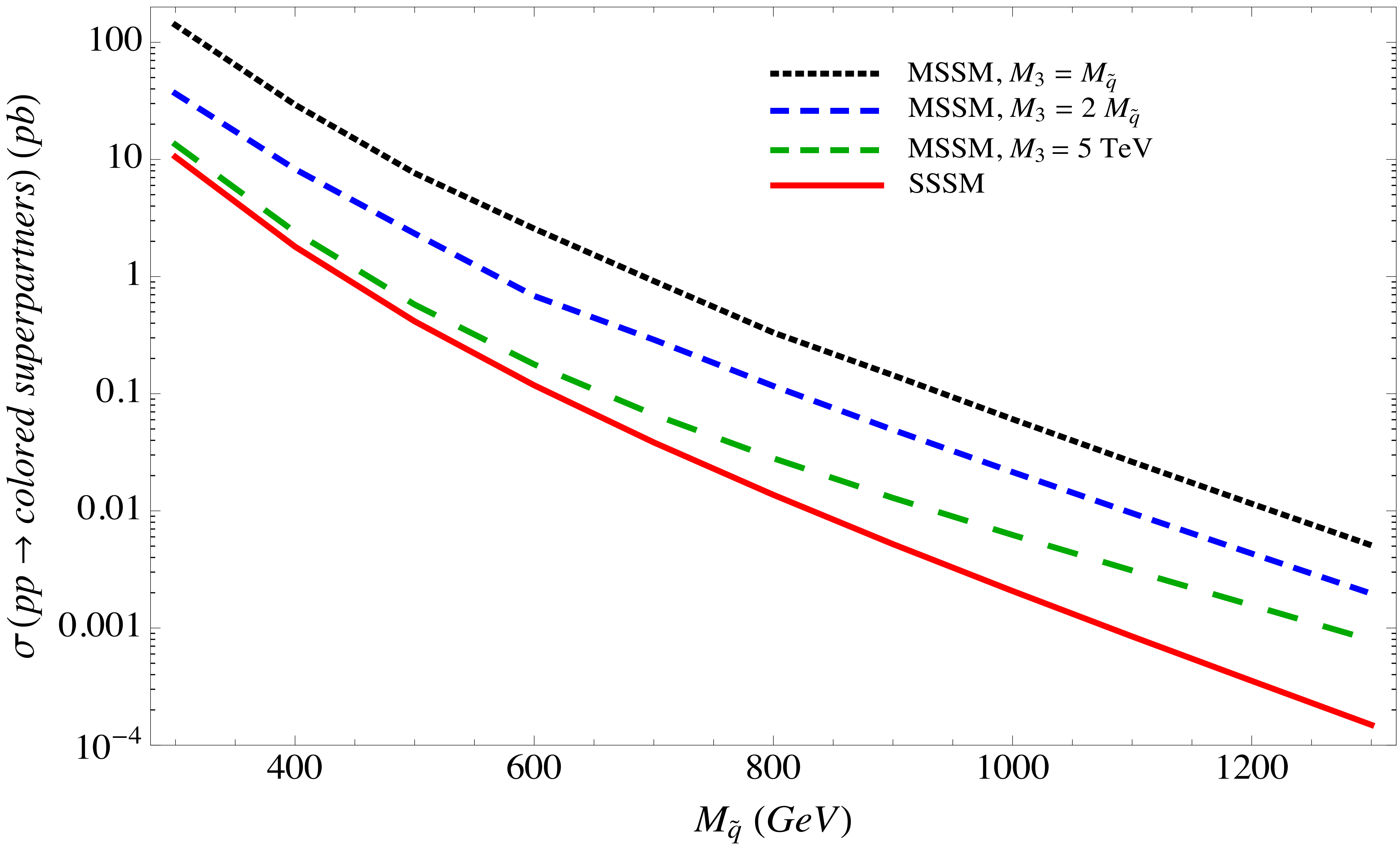
Signal simulation | Depends only on squark mass!

Pythia with NLO K-factors from Prospino
CTEQ6L
DELPHES
jet definitions appropriate to experiments

Backgrounds from ATLAS, CMS analysis notes.

Use simplified models of MSSM as cross checks that we are approximately matching expt analyses limits.

Colored Sparticle Cross Sections



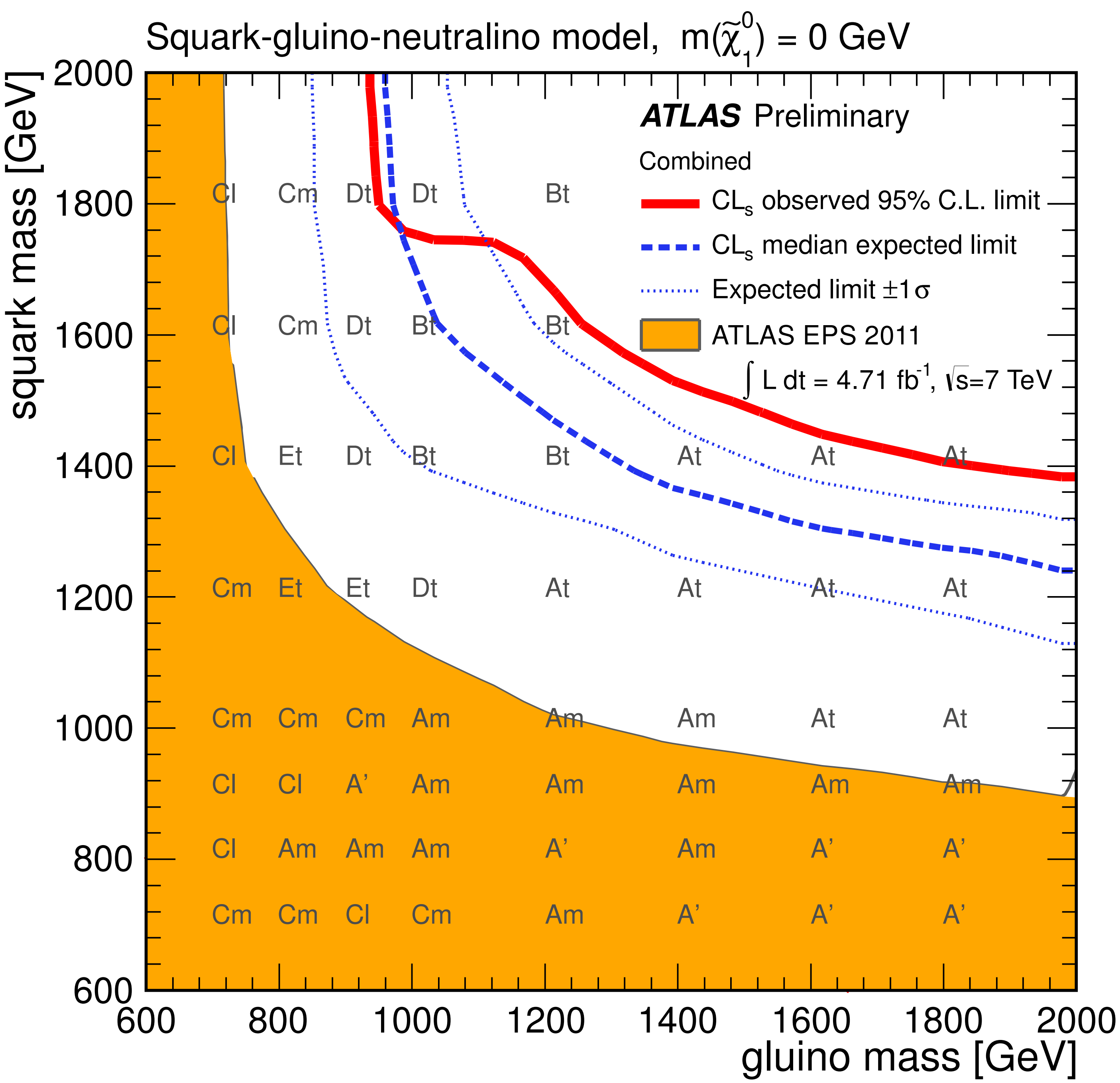
Kribs & Martin

Basic Jets Plus Missing Energy Searches

ATLAS 4.7/fb

CMS 1.1/fb

ATLAS jets + missing search strategy



0 leptons; all jets pT > 40 GeV

Requirement	Channel					
	A	A'	B	C	D	E
E_T^{miss}[GeV] >	160					
$p_T(j_1)$ [GeV] >	130					
$p_T(j_2)$ [GeV] >	60					
$p_T(j_3)$ [GeV] >	–	–	60	60	60	60
$p_T(j_4)$ [GeV] >	–	–	–	60	60	60
$p_T(j_5)$ [GeV] >	–	–	–	–	40	40
$p_T(j_6)$ [GeV] >	–	–	–	–	–	40
$\Delta\phi(\text{jet}, E_T^{miss})_{min}$ >	$0.4\ (i = \{1,2,(3)\})$			$0.4\ (i = \{1,2,3\}),\ 0.2\ (p_T > 40\text{ GeV jets})$		
$E_T^{miss}/m_{eff}(Nj)$ >	0.3 (2j)	0.4 (2j)	0.25 (3j)	0.25 (4j)	0.2 (5j)	0.15 (6j)
m_{eff}(incl.) [GeV] >	1900/1400/–	–/1200/–	1900/–/–	1500/1200/900	1500/–/–	1400/1200/900
	tight mid	mid	tight	tight mid loose	tight	tight mid loose

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Meff

This analysis aims to search for the production of heavy SUSY particles decaying into jets and neutralinos, with the latter creating missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$). Because of the high mass scale expected for the SUSY signal, the 'effective mass', m_{eff}, is a powerful discriminant between the signal and most Standard Model backgrounds. For a channel which selects events with N jets, m_{eff} is defined to be the scalar sum of the transverse momenta of the leading N jets together with $E_{\mathrm{T}}^{\mathrm{miss}}$. The final signal selection uses cuts on m_{eff}(incl.) which sums over all jets with $p_{\mathrm{T}} > 40$ GeV.

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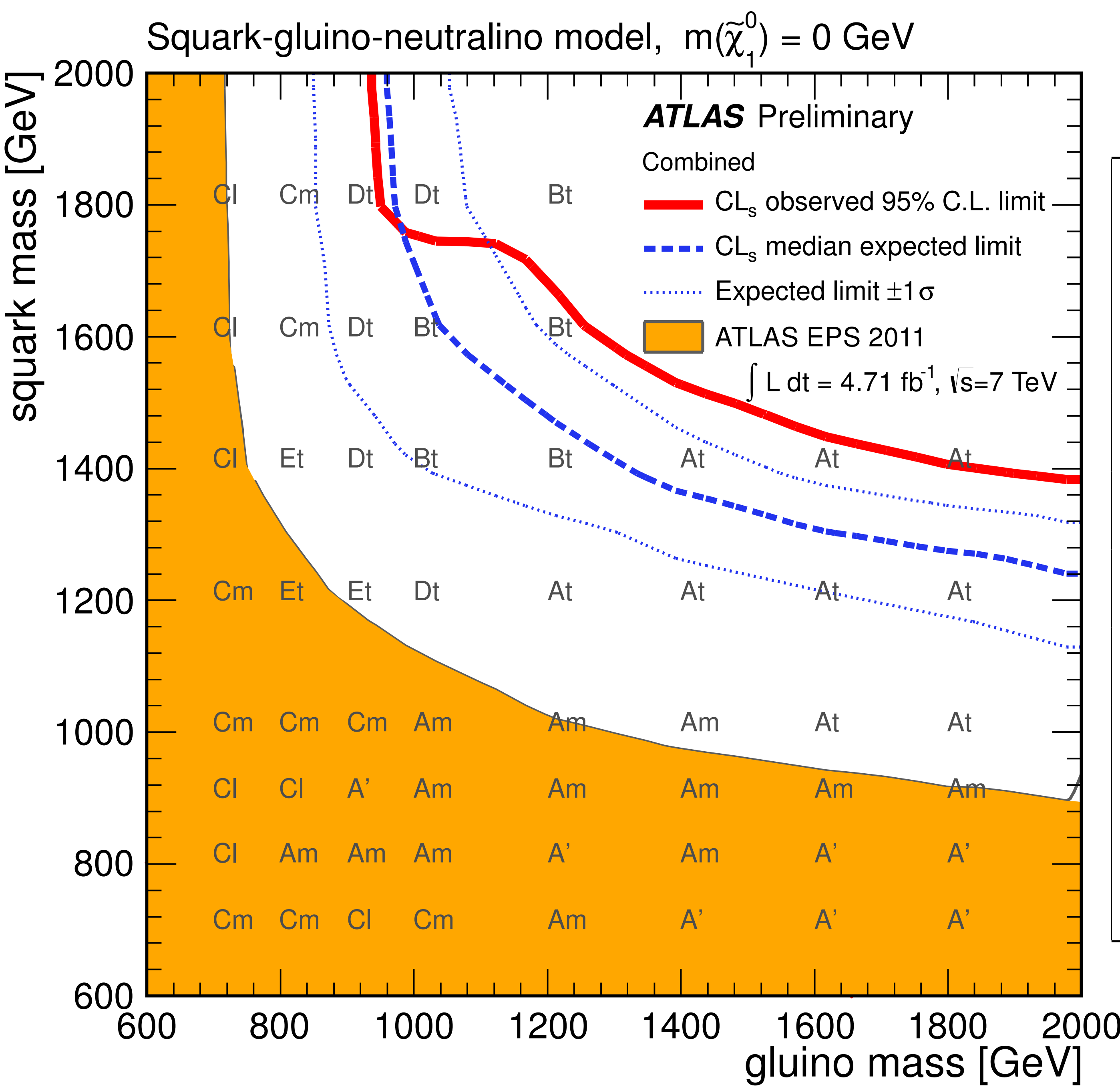
ATLAS jets + missing search strategy



	At	Am	Am'	Bt
$t\bar{t}$+ Single Top	$0.22 \pm 0.35\ (0.046)$	$7 \pm 5\ (5.1)$	$11 \pm 3.4\ (10)$	$0.21 \pm 0.33\ (0.066)$
Z/γ+jets	$2.9 \pm 1.5\ (3.1)$	$31 \pm 9.9\ (34)$	$64 \pm 20\ (69)$	$2.5 \pm 1.4\ (1.6)$
W+jets	$2.1 \pm 0.99\ (1.9)$	$19 \pm 4.5\ (21)$	$26 \pm 4.6\ (30)$	$0.97 \pm 0.6\ (0.84)$
Multi-jets	$0 \pm 0.0024\ (0.002)$	$0.14 \pm 0.24\ (0.13)$	$0 \pm 0.13\ (0.38)$	$0 \pm 0.0034\ (0.0032)$
Di-Bosons	$1.7 \pm 0.95\ (2)$	$7.3 \pm 3.7\ (7.5)$	$15 \pm 7.4\ (16)$	$1.7 \pm 0.95\ (1.9)$
Total	$7 \pm 0.999 \pm 2.26$	$64.8 \pm 10.2 \pm 6.92$	$115 \pm 19 \pm 9.69$	$5.39 \pm 0.951 \pm 2.01$
Data	1	59	85	1
local p-value (Gaus. σ)	0.98(-2.1)	0.65(-0.4)	0.9(-1.3)	0.95(-1.7)
UL on N_{BSM}	$2.9(6.1^{4.2}_{9})$	$25(28^{20}_{39})$	$29(43^{32}_{60})$	$3.1(5.5^{3.8}_{8.3})$
UL on σ_{BSM} /(fb)	$0.62(1.3^{0.89}_{1.9})$	$5.3(6^{4.3}_{8.2})$	$6.2(9.2^{6.7}_{13})$	$0.65(1.2^{0.8}_{1.8})$

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ATLAS Search Bounds

SSSM	MSSM	MSSM	MSSM
M3 = 5 TeV	M3 = Msq	M3 = 2 Msq	M3 = 5 TeV

1st,2nd generation squark mass

Kribs & Martin

CMS MHT Search Strategy

- At least three jets with $p_T > 50\,\text{GeV}$ and $|\eta| < 2.5$.
- $H_T > 350\,\text{GeV}$, with H_T defined as the scalar sum of the p_Ts of all the jets with $p_T > 50\,\text{GeV}$ and $|\eta| < 2.5$.
- $\not{H}_T > 200\,\text{GeV}$, with $\not{H}_T$ defined as the magnitude of the negative vectorial sum of the p_Ts of the jets having, in this case, $p_T > 30\,\text{GeV}$ and $|\eta| < 5$. The majority of QCD events in the MHT tail are removed with this requirement.
- $|\Delta\phi(J_n, \not{H}_T)| > 0.5$ (rad), $n = 1, 2$ and $|\Delta\phi(J_3, \not{H}_T)| > 0.3$ (rad), vetoing events in which $\not{H}_T$ is aligned in the transverse plane along one of the three leading jets. This requirement rejects most of the QCD multijet events in which a single mismeasured jet yields a high $\not{H}_T$.
- Veto on isolated muons and electrons.

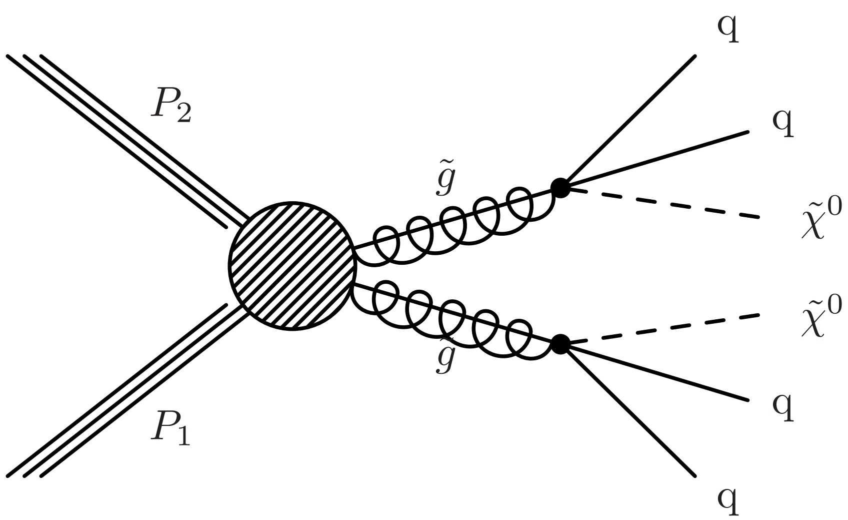
"3"	"1"	"2"
Medium (H_T >500 GeV) ($\not{H}_T$ >350 GeV)	High H_T (H_T >800 GeV) ($\not{H}_T$ >200 GeV)	High $\not{H}_T$ (H_T >800 GeV) ($\not{H}_T$ >500 GeV)

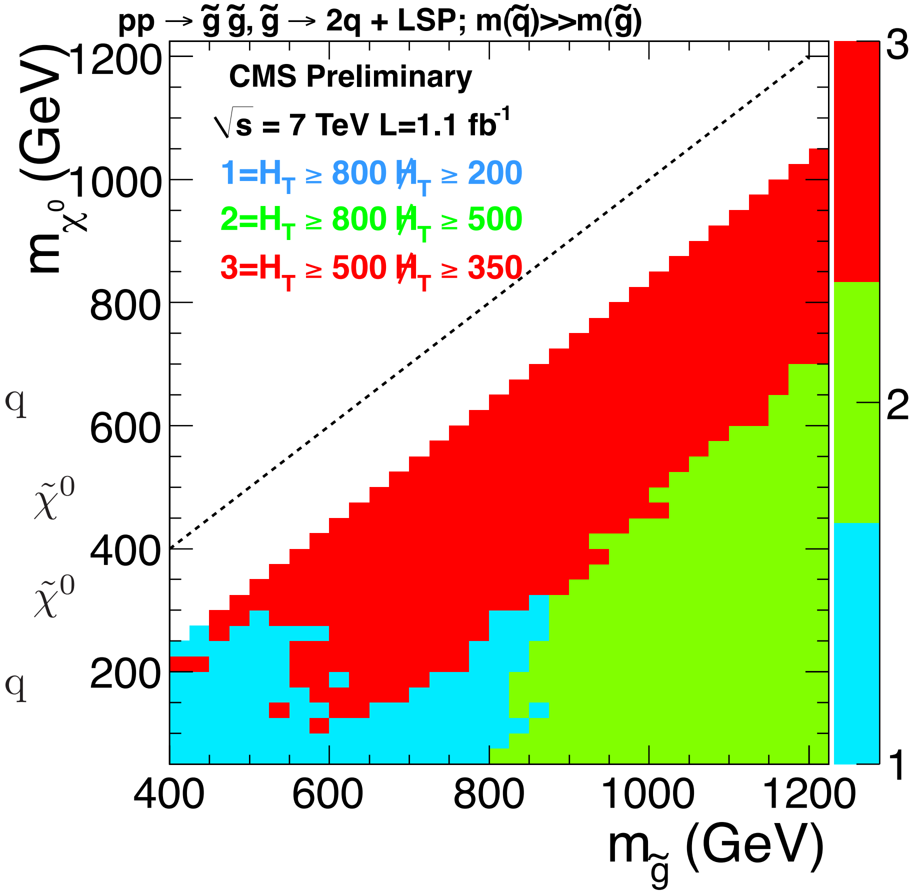
CMS-SUS-11-004

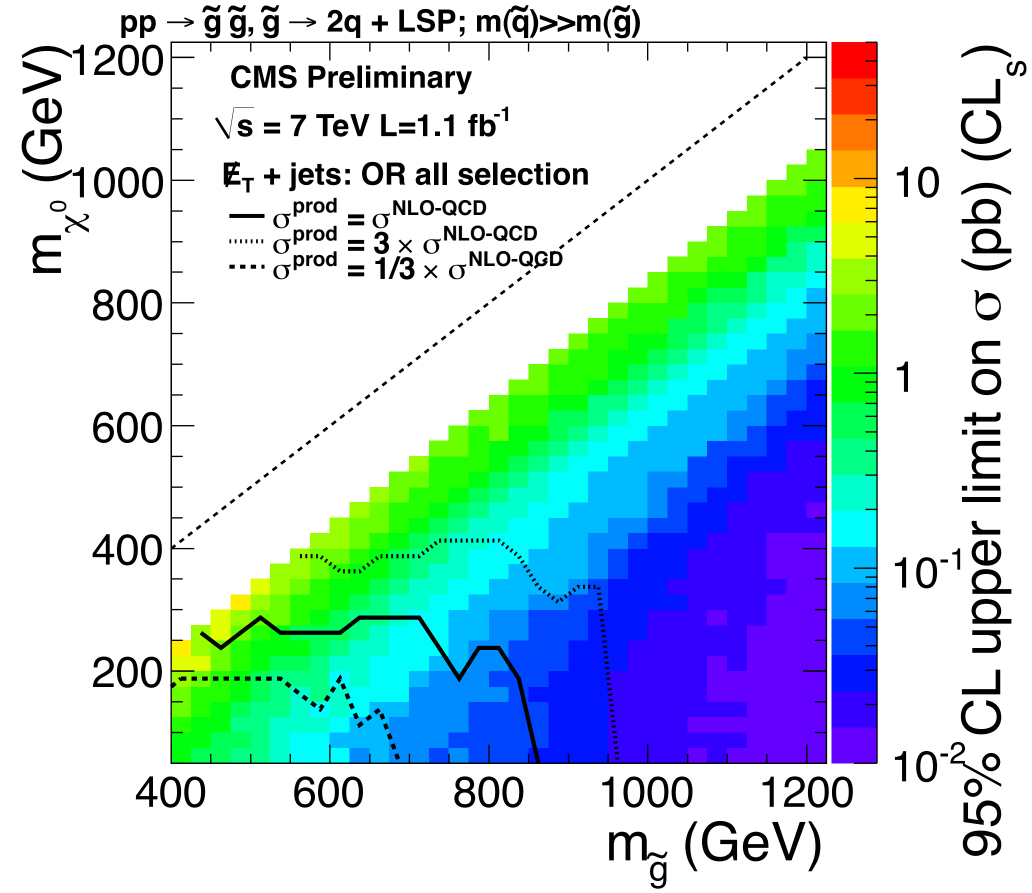
CMS MHT Search Data

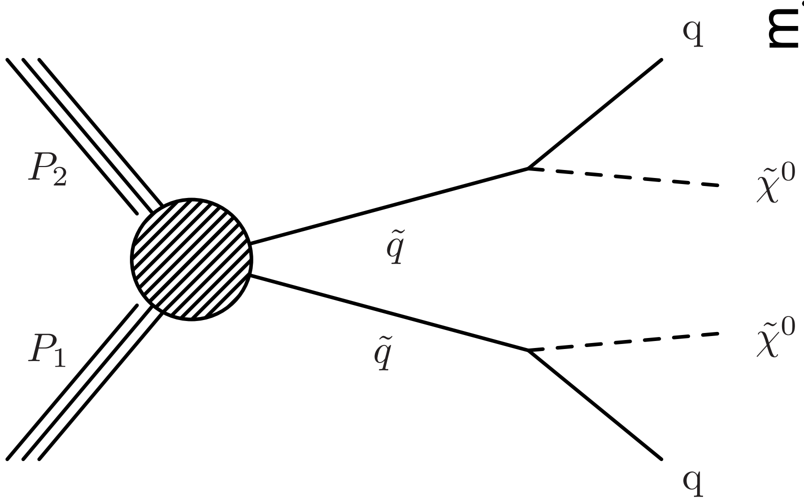
	"3"	"1"	"2"
	Medium (H_T >500 GeV) ($\not{H}_T$ >350 GeV)	High H_T (H_T >800 GeV) ($\not{H}_T$ >200 GeV)	High $\not{H}_T$ (H_T >800 GeV) ($\not{H}_T$ >500 GeV)
$Z \to \nu\bar{\nu}$ from γ+jets	$42.6 \pm 4.4 \pm 8.9$	$24.9 \pm 3.5 \pm 5.2$	$2.4 \pm 1.1 \pm 0.5$
$t\bar{t}/W \to e, \mu$+X	$12.7 \pm 3.3 \pm 1.5$	$22.5 \pm 6.7^{+3.0}_{-3.1}$	$0.8 \pm 0.8 \pm 0.1$
$t\bar{t}/W \to \tau_h$+X	$17 \pm 2 \pm 0.7$	$18 \pm 2 \pm 0.5$	$0.73 \pm 0.73 \pm 0.04$
QCD	$1.3 \pm 1.3^{+0.6}_{-0.4}$	$13.5 \pm 4.1^{+7.3}_{-4.3}$	$0.09 \pm 0.31^{+0.05}_{-0.04}$
Total background	73.9 ± 11.9	79.4 ± 12.2	4.6 ± 1.5
Observed in data	78	70	3

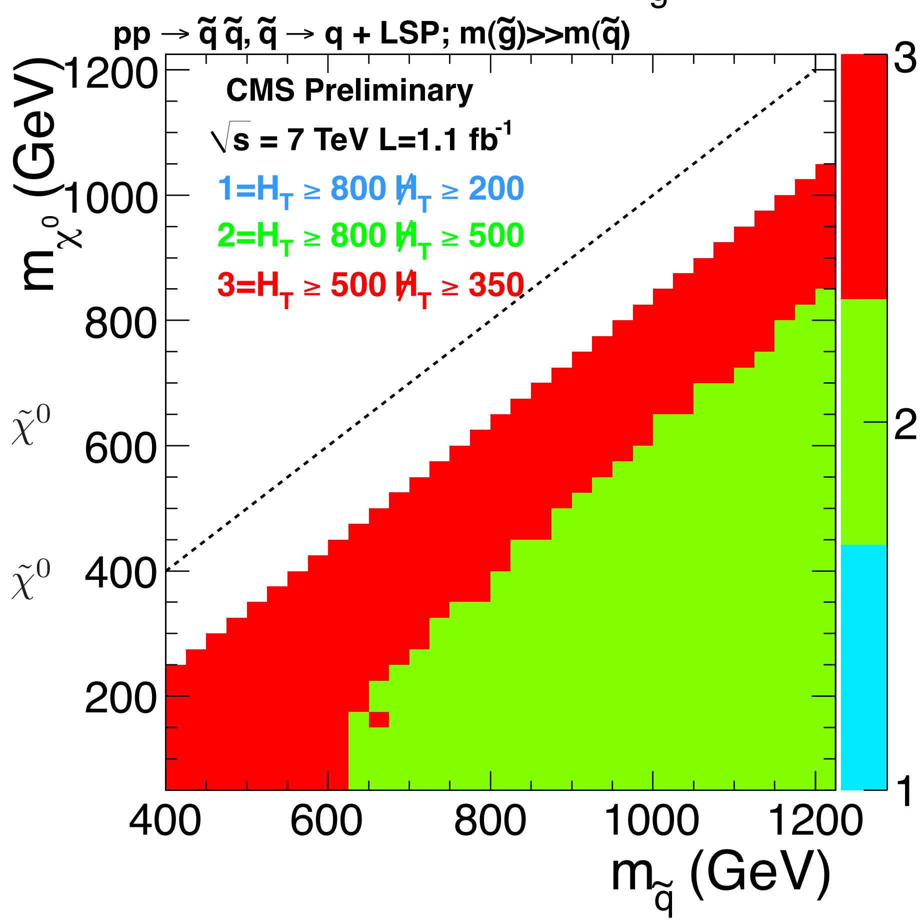
CMS Bounds on Simplified Models

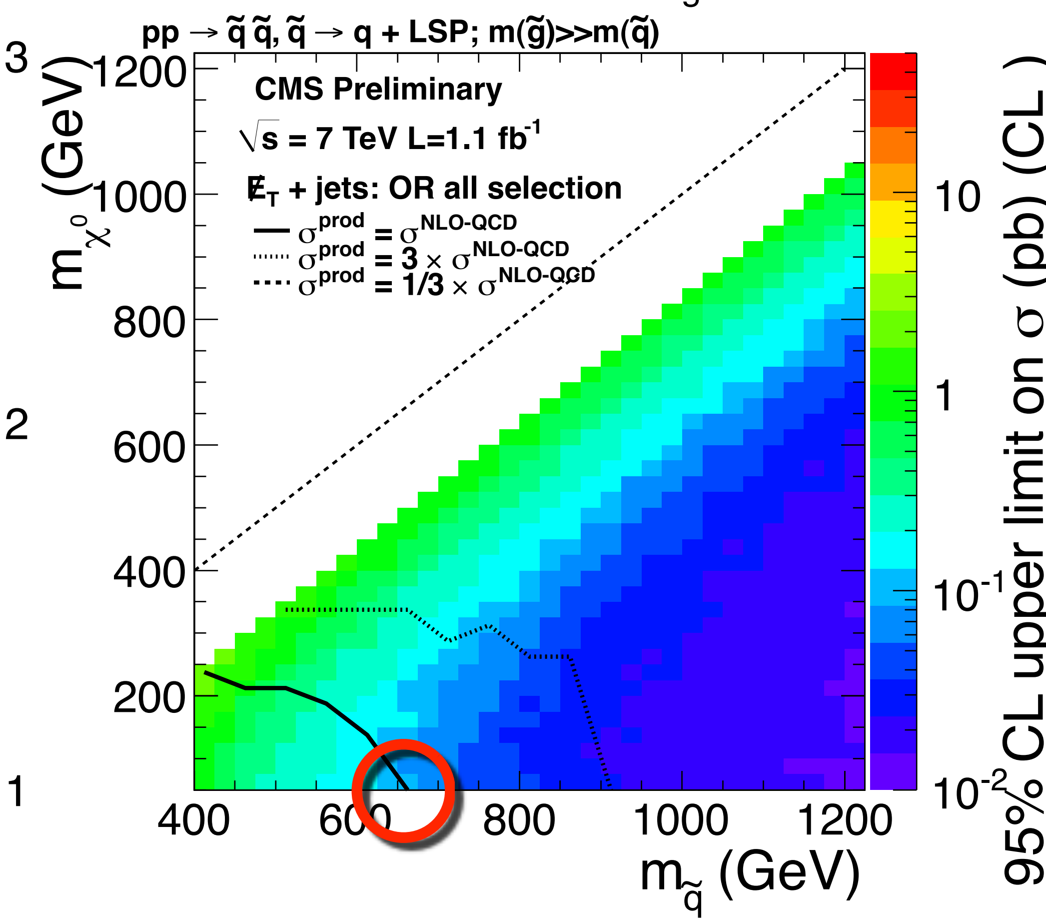












CMS MHT Search Bounds

SSSM	MSSM	MSSM	MSSM
M3 = 5 TeV	M3 = Msq	M3 = 2 Msq	M3 = 5 TeV

1st,2nd generation squark mass

‘3’ ‘1’ ‘2’ ‘3’ ‘1’ ‘2’ ‘3’ ‘1’ ‘2’ ‘3’ ‘1’ ‘2’

Kribs & Martin

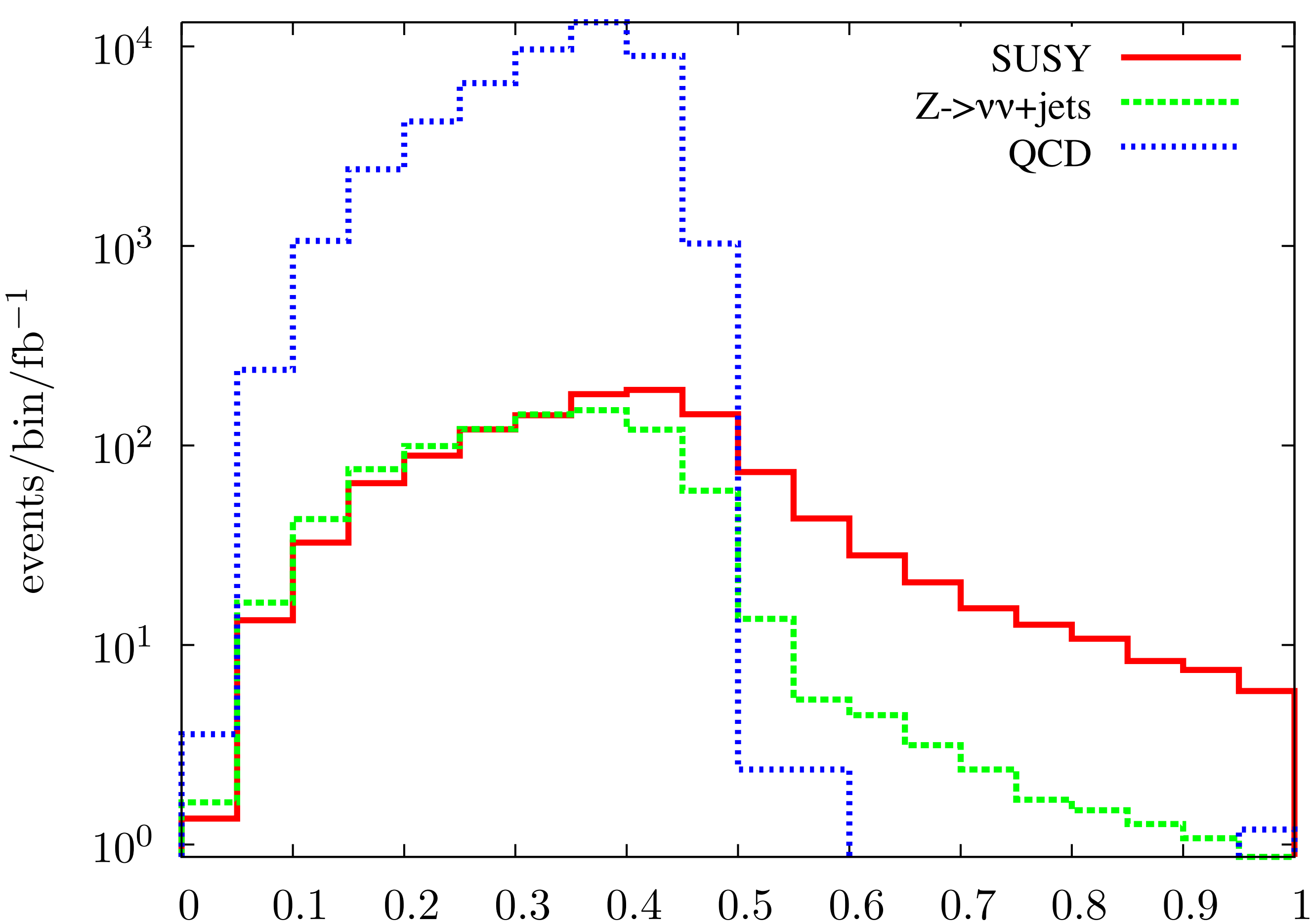
CMS α_T strategy
1.1/fb

α_T strategy

Combine n > 2 jets into 2 “pseudojets”, then calculate:

$$\alpha_T = \frac{E_T{}^{\text{jet}_2}}{M_T} = \frac{E_T{}^{\text{jet}_2}}{\sqrt{\left(\sum_{i=1}^{2} E_T{}^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{\text{jet}_i}\right)^2}}$$

$$= \frac{\text{ET of 2nd hardest jet}}{\text{invariant mass of hardest 2 jets}}$$



Cut on $\alpha_T \approx 0.5$ highly effective at suppressing QCD background.

Randall & Tucker-Smith 0806.1049

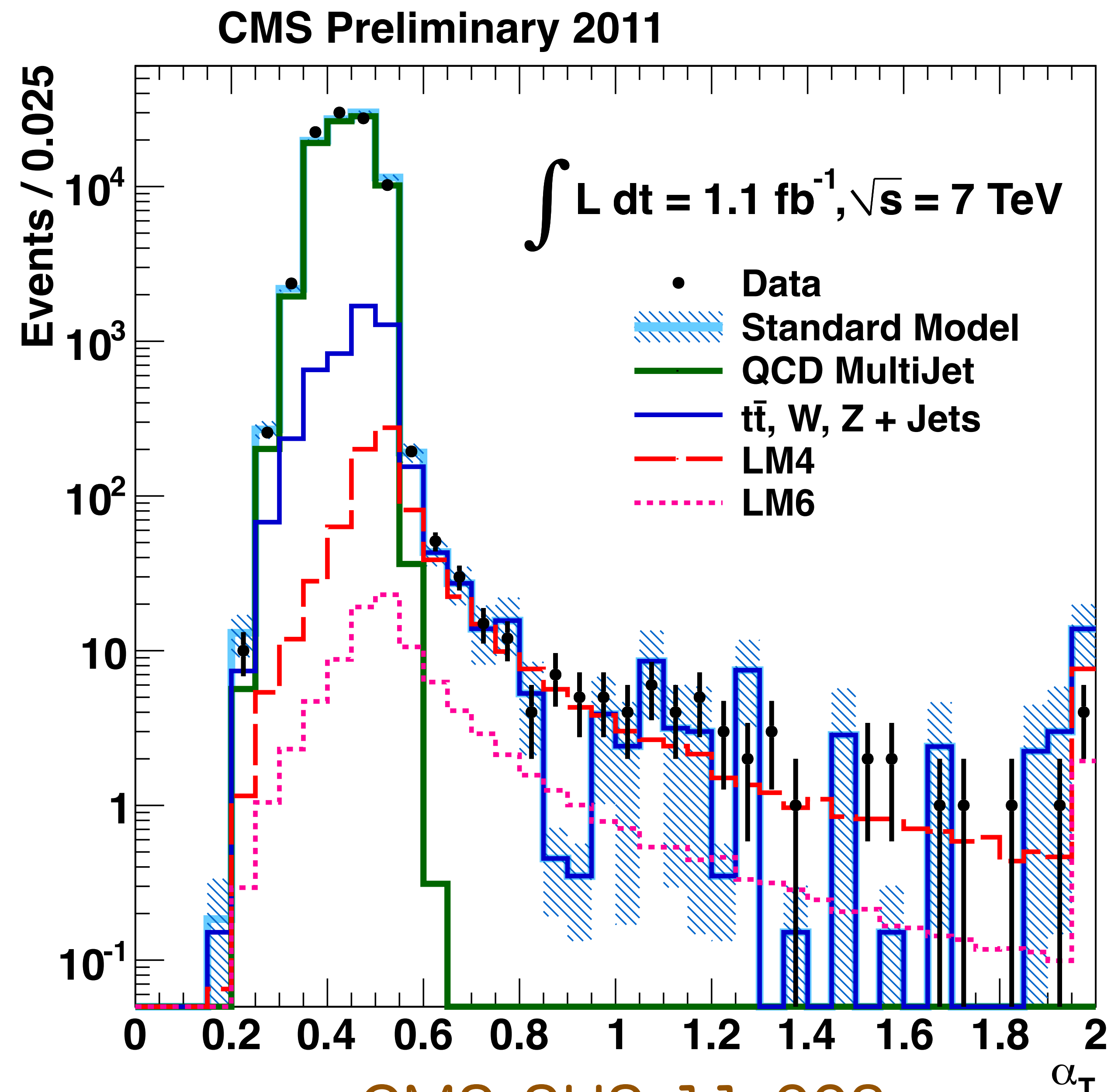
CMS α_T Search Strategy

Triggered >= 2 jets with 0 leptons and 0 photons.

- E_T: all jets > 50 GeV; leading 2 jets > 100 GeV
- Cut and count H_T bins

$$H_T = \sum_{i=1}^{n} E_T^{\text{jet}_i}$$

- missing E_T > 100 GeV
- mild $\Delta\phi$ cut to reduce jet mismeasurement



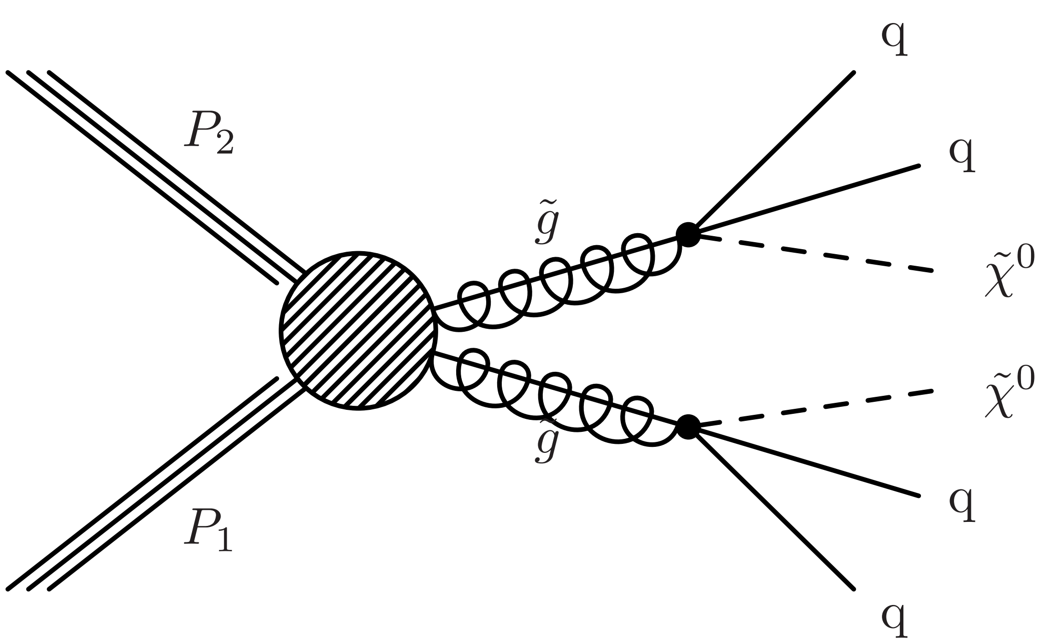
CMS-SUS-11-003

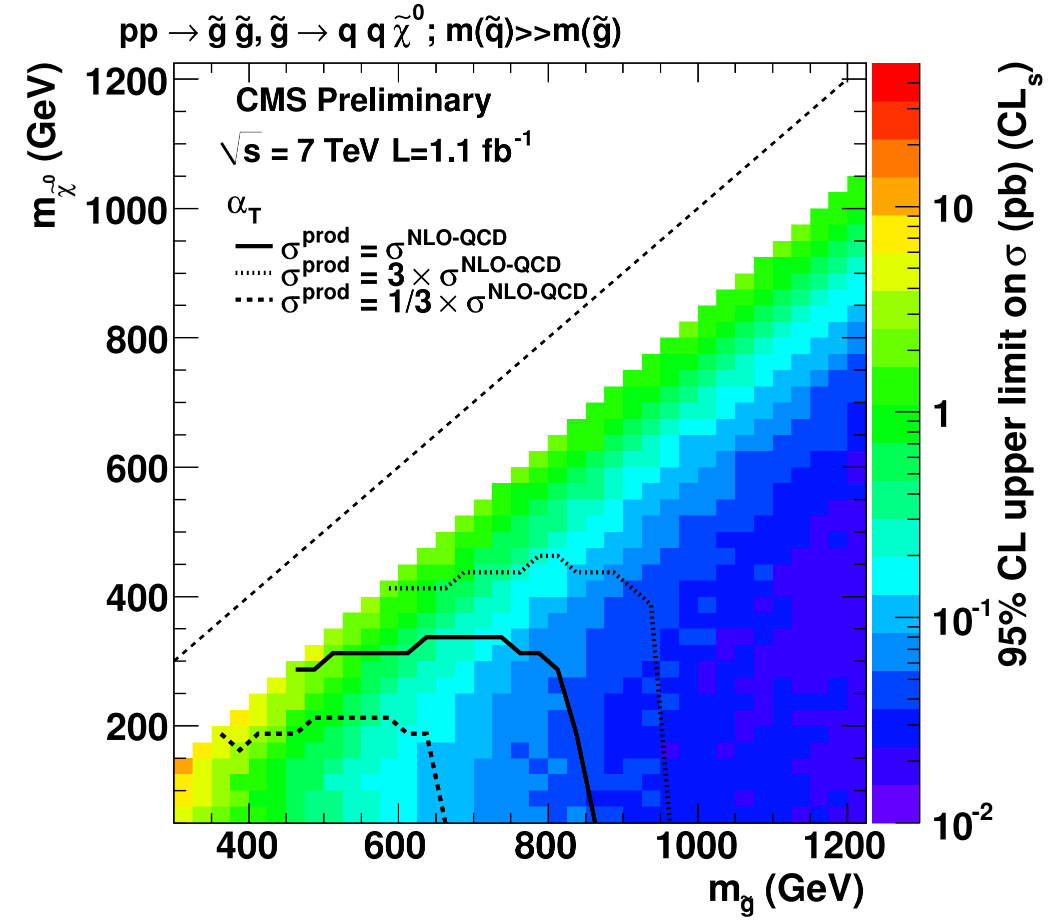
CMS Cuts and Counts

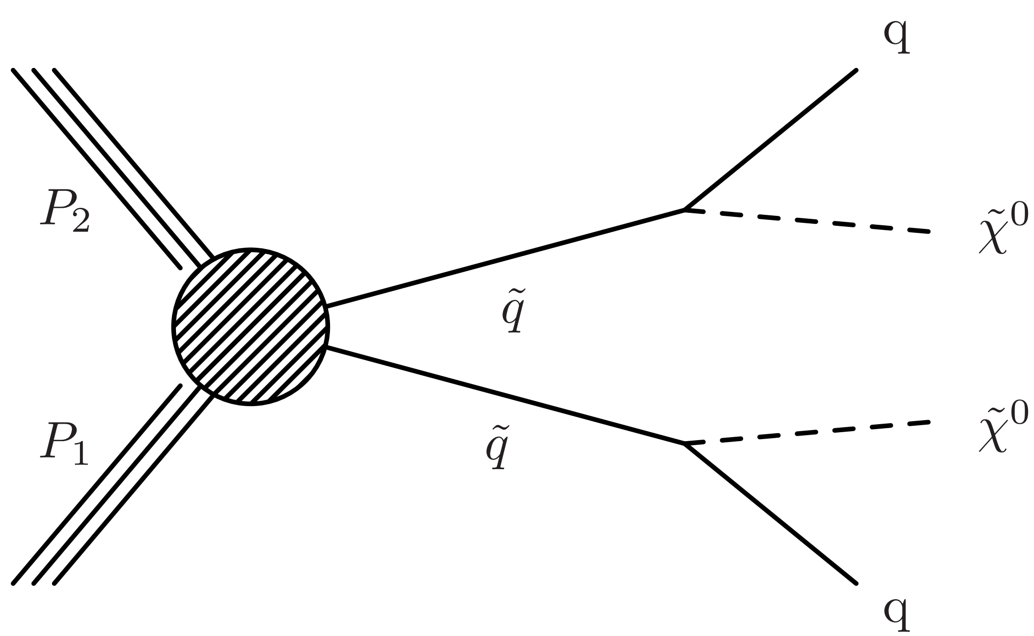
	a	b	c	d	e	f	g	h
H_T Bin (GeV)	275–325	325–375	375–475	475–575	575–675	675–775	775–875	875–∞
$p_T^{leading}$ (GeV)	73	87	100	100	100	100	100	100
p_T^{second} (GeV)	73	87	100	100	100	100	100	100
p_T^{other}(GeV)	37	43	50	50	50	50	50	50
$\alpha_T > 0.55$	782	321	196	62	21	6	3	1
$\alpha_T < 0.55$	$5.73 \cdot 10^7$	$2.36 \cdot 10^7$	$1.62 \cdot 10^7$	$5.12 \cdot 10^6$	$1.78 \cdot 10^6$	$6.89 \cdot 10^5$	$2.90 \cdot 10^5$	$2.60 \cdot 10^5$
$R_{\alpha_T}(10^{-5})$	$1.36 \pm 0.05_{stat}$	$1.36 \pm 0.08_{stat}$	$1.21 \pm 0.09_{stat}$	$1.21 \pm 0.15_{stat}$	$1.18 \pm 0.26_{stat}$	$0.87 \pm 0.36_{stat}$	$1.03 \pm 0.60_{stat}$	$0.39 \pm 0.52_{stat}$

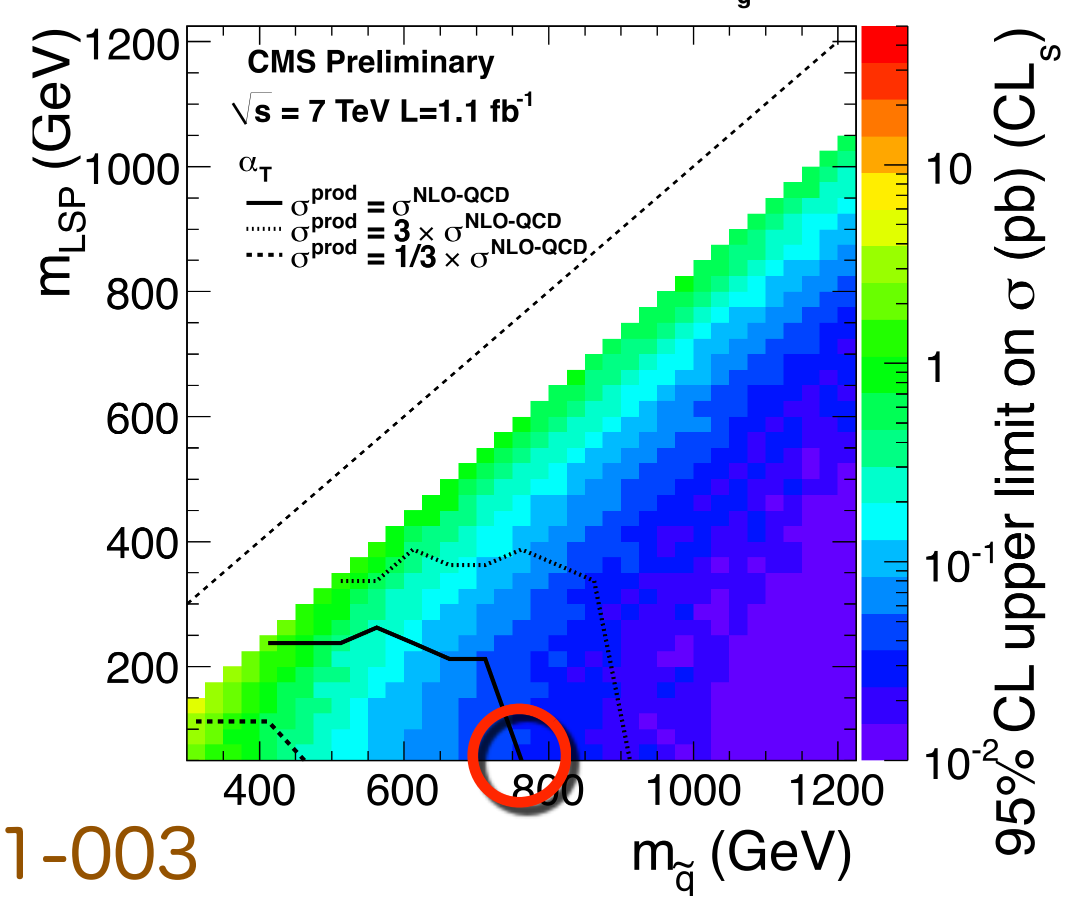
CMS-SUS-11-003

CMS Bounds on Simplified Models









CMS-SUS-11-003

CMS α_T Search Bounds

SSSM	MSSM	MSSM	MSSM
M3 = 5 TeV	M3 = Msq	M3 = 2 Msq	M3 = 5 TeV

1st,2nd generation squark mass

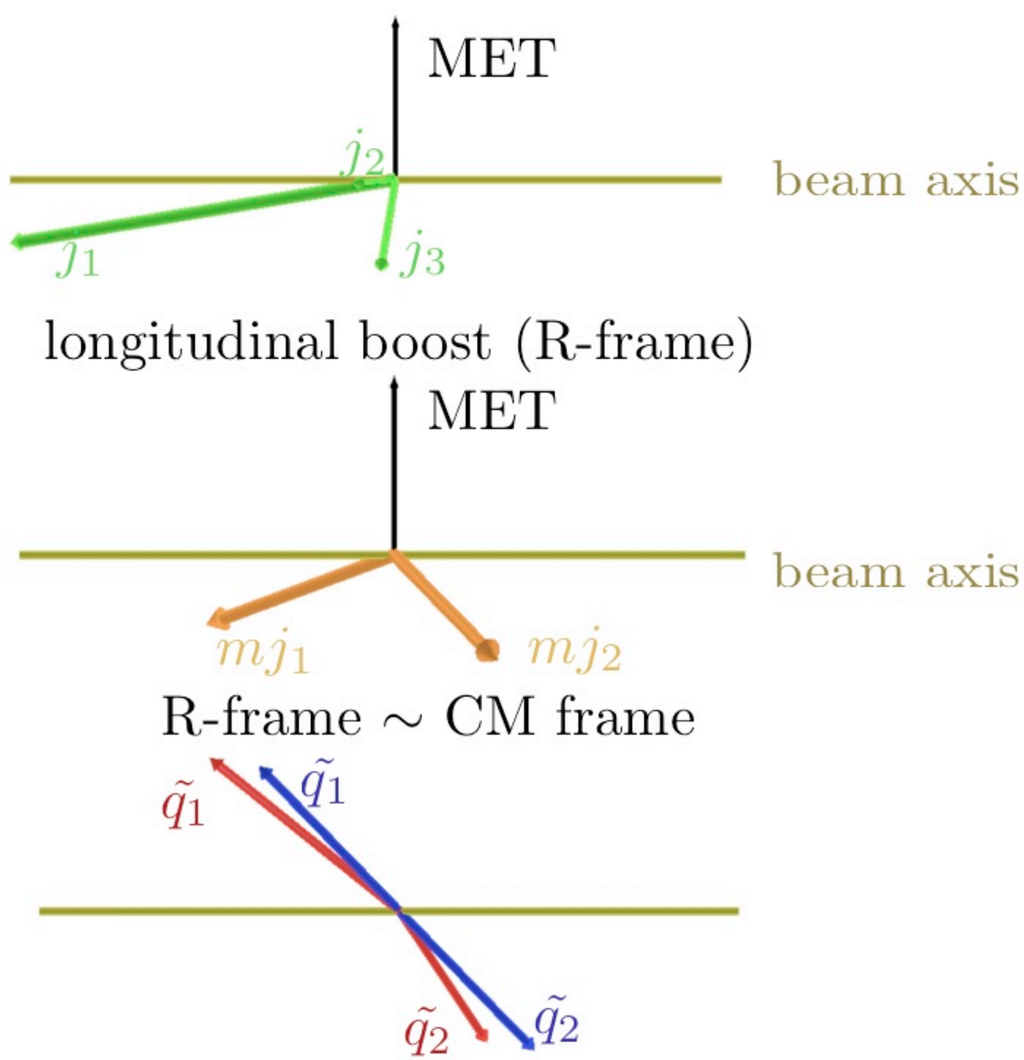
Kribs & Martin

CMS “razor” strategy
4.4/fb

“razor” strategy

Rogan 1006.2727 &
CMS Collaboration Notes

Combine all jets in the event into two “megajets” and boost into the “razor” frame:



$$p_{j_1} = \left(\frac{1}{2}\left(M_R - \frac{(\vec{p}_T^{\,j_1} - \vec{p}_T^{\,j_2}) \cdot \vec{E}_T^{miss}}{M_R}\right), p_T^{j_1}, p_z\right),$$

$$p_{j_2} = \left(\frac{1}{2}\left(M_R + \frac{(\vec{p}_T^{\,j_1} - \vec{p}_T^{\,j_2}) \cdot \vec{E}_T^{miss}}{M_R}\right), p_T^{j_2}, -p_z\right)$$

↑

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

Longitudinal boost invariant.

“razor” strategy II

Key is to construct two kinematic variables that provide an event-by-event estimator of the underlying scale for a massive particle.

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$

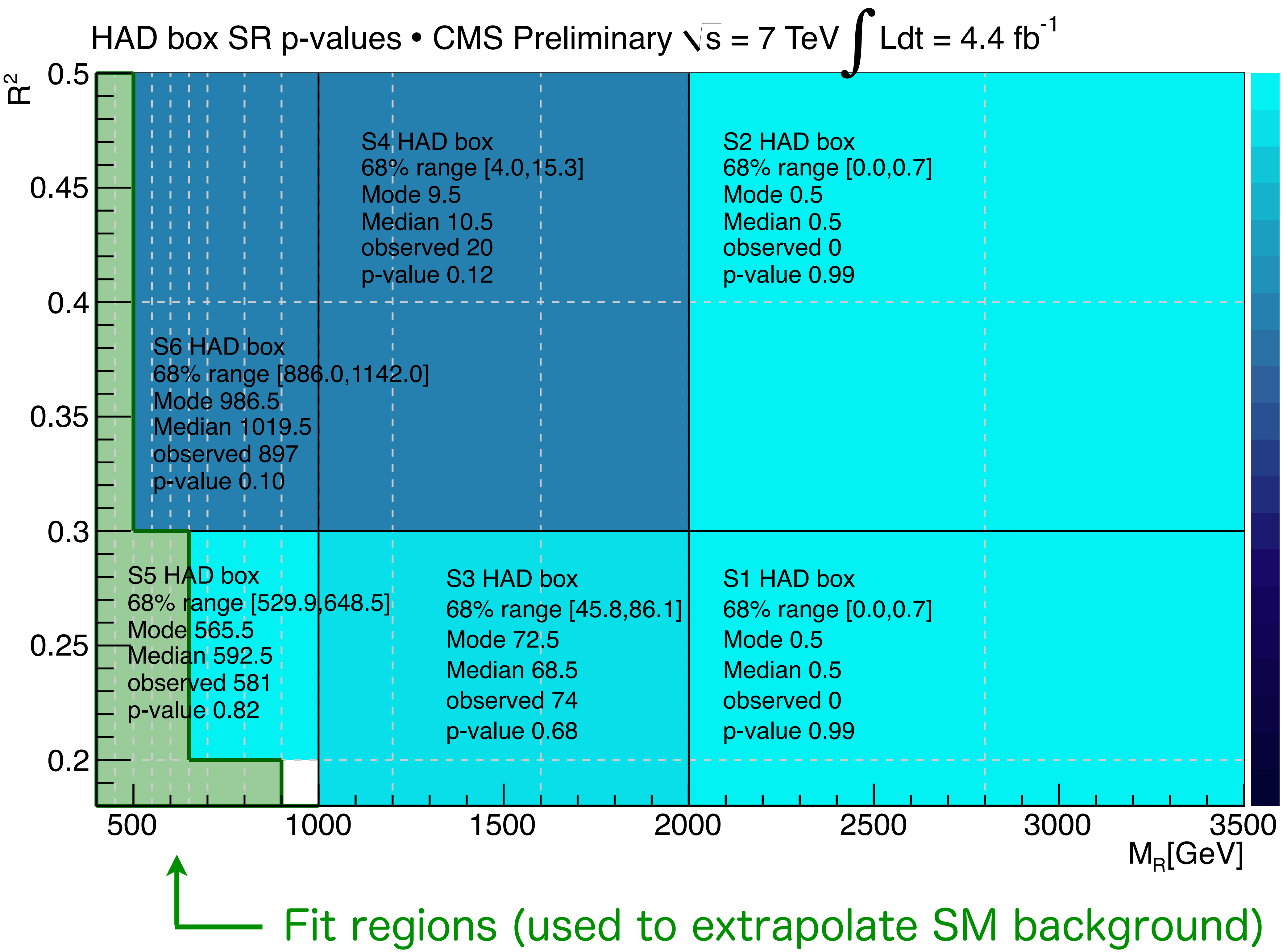
average transverse mass

Cut on the combinations:

$$R \equiv \frac{M_T^R}{M_R} \qquad \text{and} \qquad M_R$$

SM backgrounds have simple exponential (falling) dependence on M_R, R (for $R^2 < 0.5$), while signal peaks $R \approx 0.5$

“razor” signal regions



CMS “razor” Search Bounds

SSSM	MSSM	MSSM	MSSM
M3 = 5 TeV	M3 = Msq	M3 = 2 Msq	M3 = 5 TeV

1st,2nd generation squark mass

Kribs & Martin

Comparisons

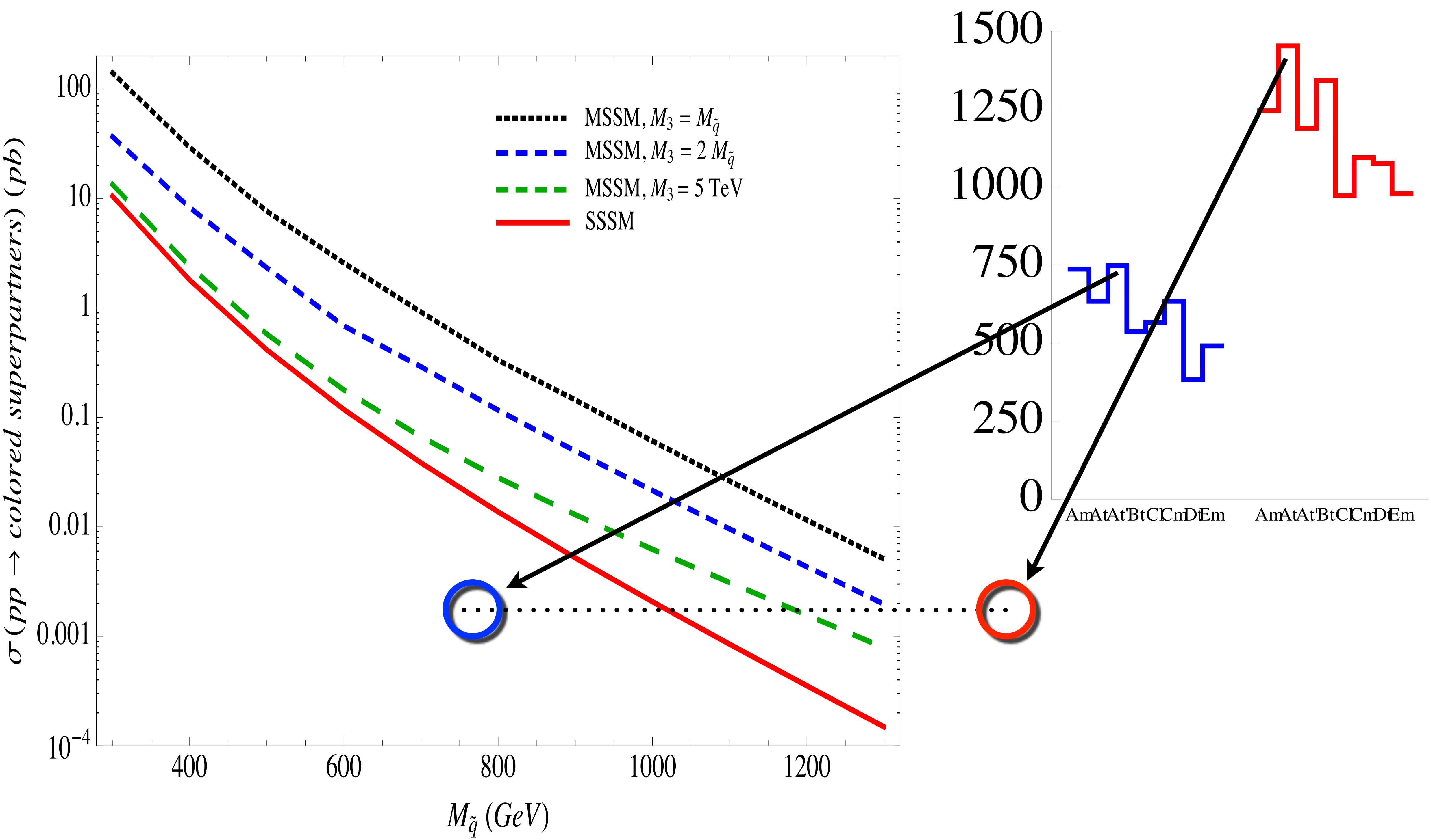
Comparsion of Existing Bounds on SSSM

ATLAS	CMS	CMS	CMS
	α_T	MHT	"razor"
4.7/fb	1.1/fb	1.1/fb	4.4/fb

1st,2nd generation squark mass

Kribs & Martin

Effectiveness of ATLAS strategy



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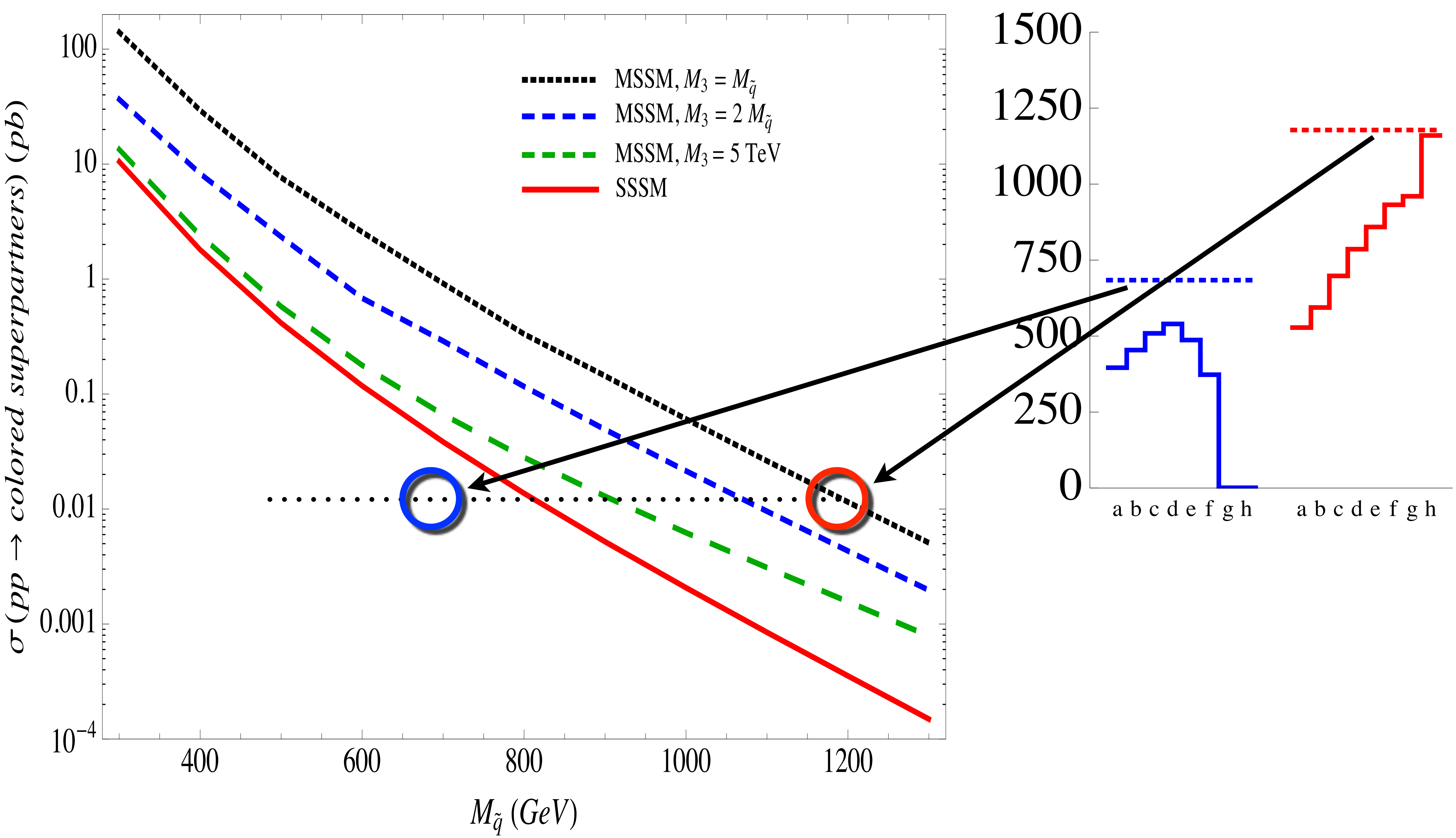
Effectiveness of CMS α_T strategy



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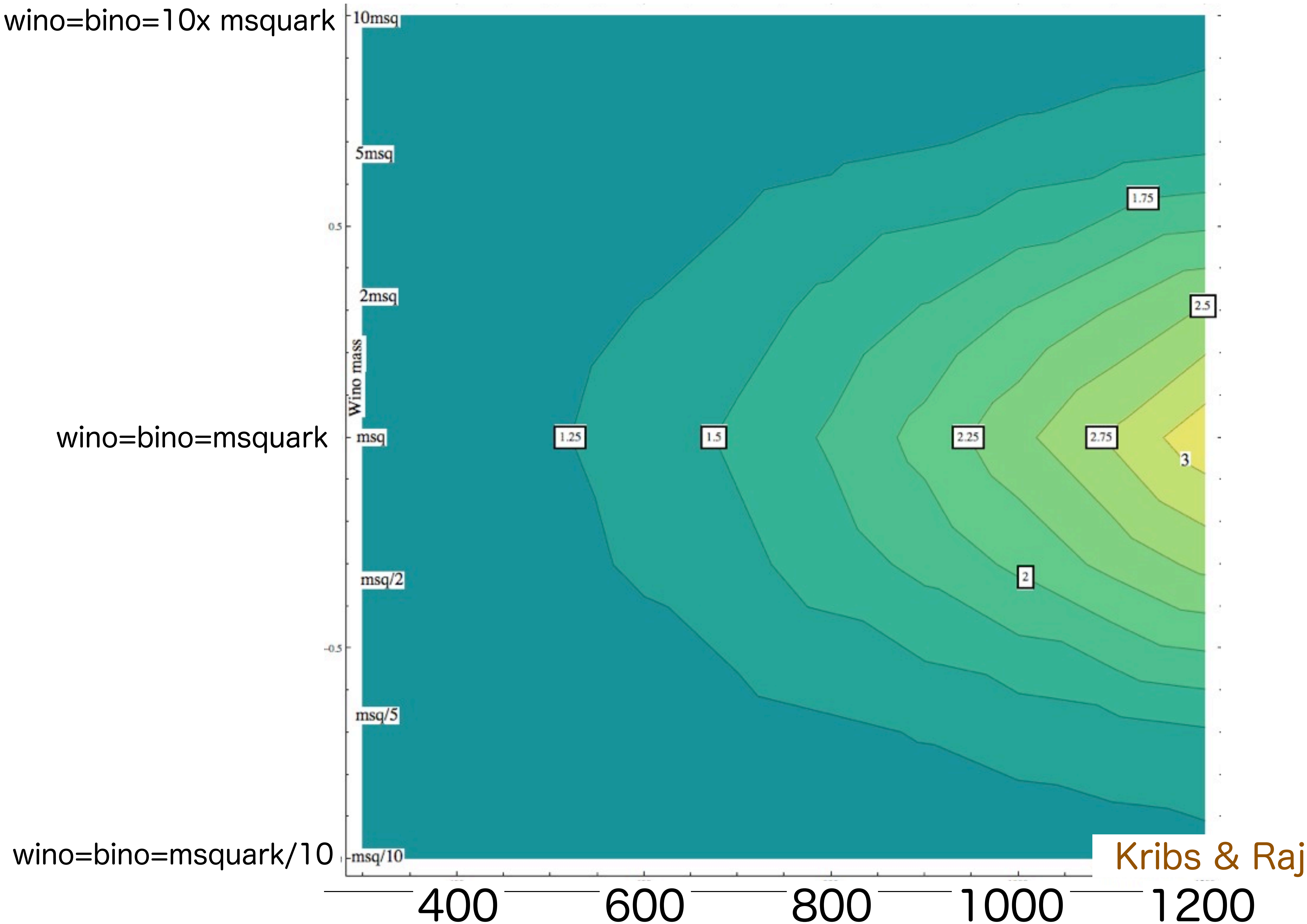
Dirac gluino and Majorana wino & bino

Fractional Increase in Squark Cross Section



Summary

* Heavy Dirac Gluino in “supersoft”, “R-symmetric”
  natural and suppresses colored sparticle production substantially

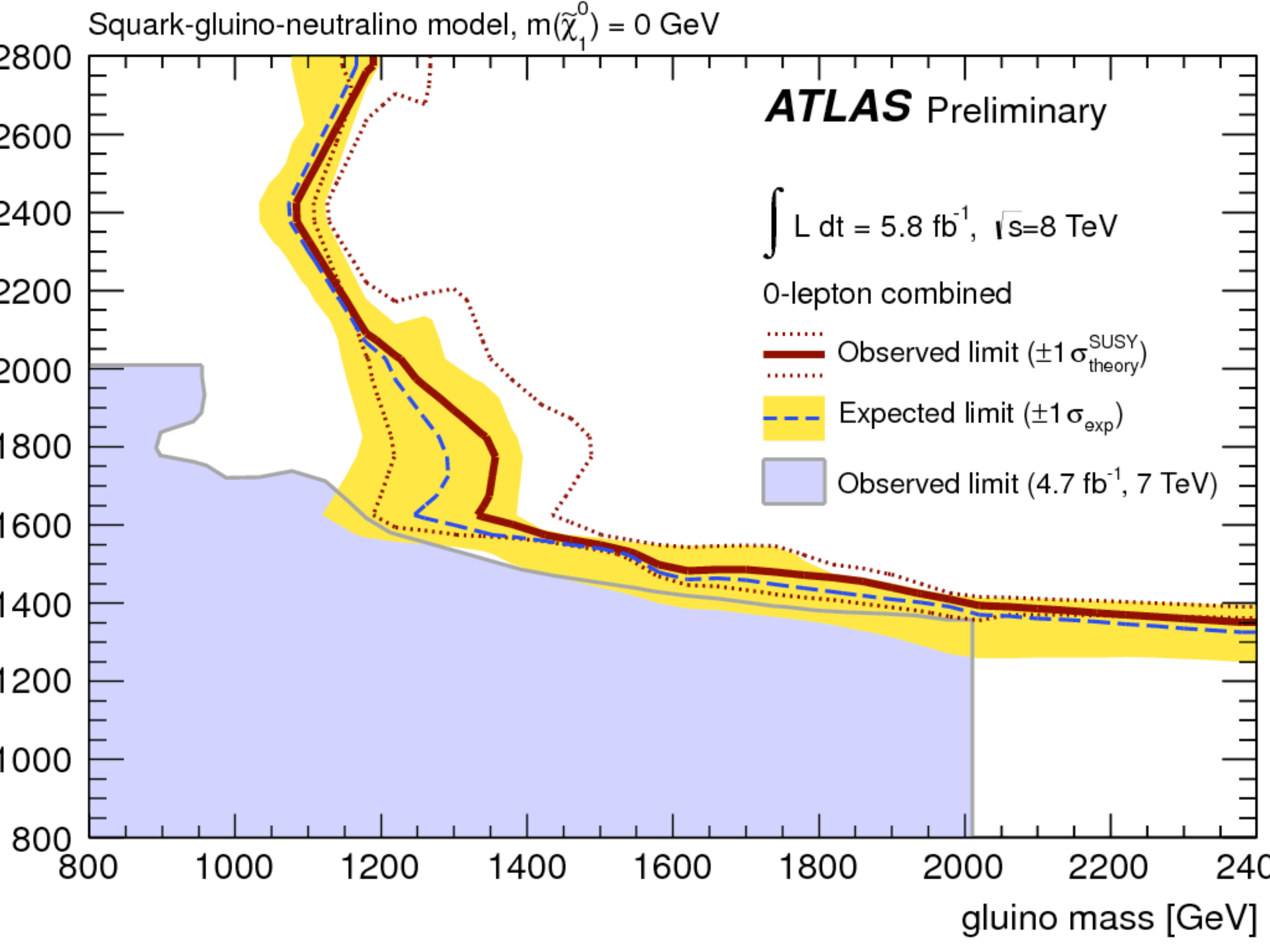
* Bounds on 1st,2nd generation squarks 680-750 GeV

* Best search is α_T (Mar 2012); optimize over range of H_T crucial

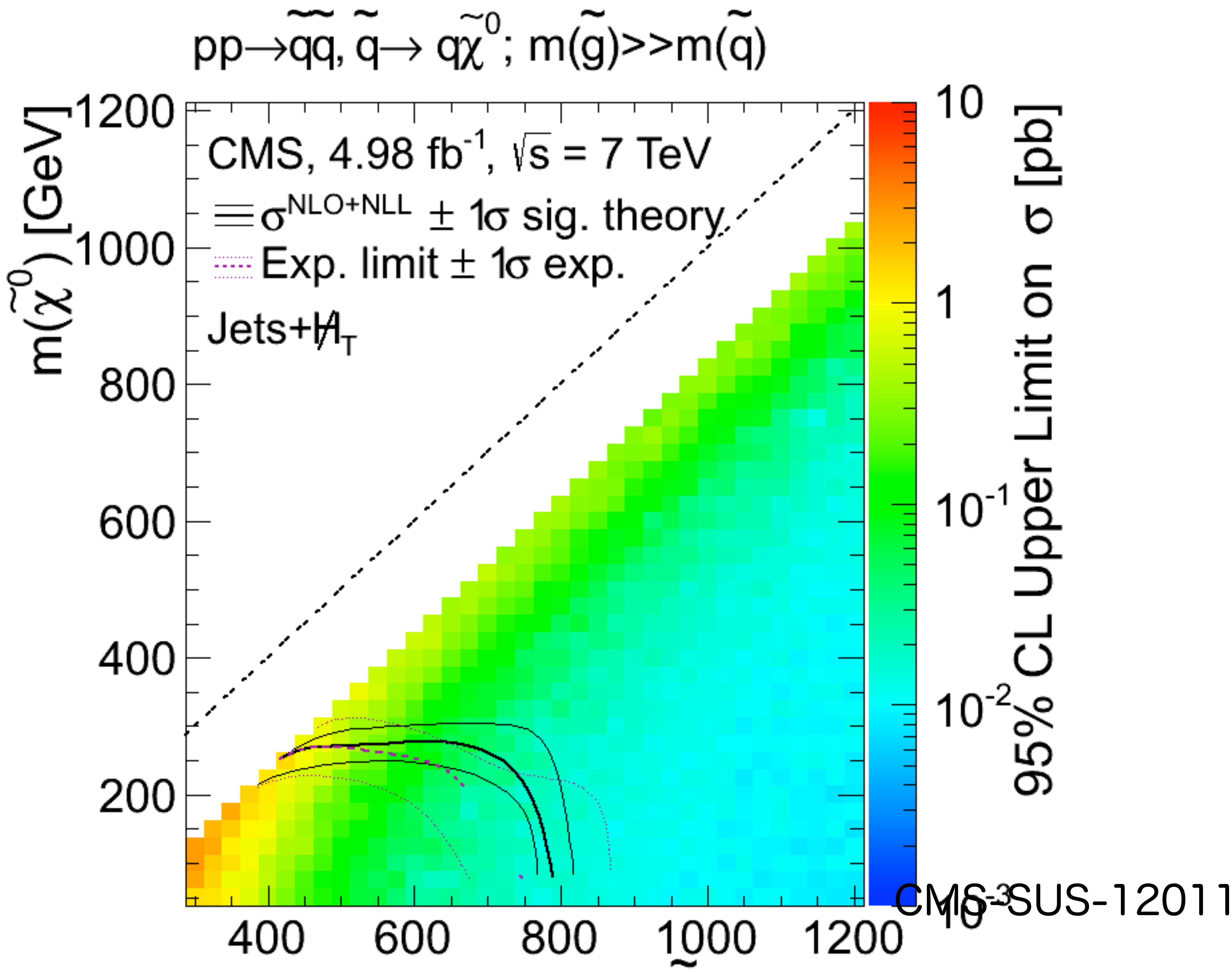
* Very high mass searches
  (e.g. ATLAS Meff > 1900 GeV;
  CMS “razor” MR > 2000 GeV)
  not effective at constraining lighter squarks

* SUSY ain’t ruled out yet…even models not tuned to avoid bounds!

* What is “minimally” necessary? (Majorana EW versus Dirac gluino⋯)



Squark-gluino-neutralino model, m($\tilde{\chi}_1^0$) = 0 GeV
ATLAS Preliminary
$\int L\,dt$ = 5.8 fb^{-1}, $\sqrt{s}$=8 TeV
0-lepton combined
Observed limit ($\pm 1\,\sigma^{SUSY}_{theory}$)
Expected limit ($\pm 1\,\sigma_{exp}$)
Observed limit (4.7 fb^{-1}, 7 TeV)
gluino mass [GeV]
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
800
1000
1200
1400
1600
1800
2000
2200
240



pp→q̃q̃, q̃→ qχ̃⁰; m(g̃)>>m(q̃)
CMS, 4.98 fb⁻¹, √s = 7 TeV
σ^NLO+NLL ± 1σ sig. theory
Exp. limit ± 1σ exp.
Jets+H̸T
m(χ̃⁰) [GeV]
95% CL Upper Limit on σ [pb]
CMS-SUS-12011

Selection H_T (GeV)	$\not{H}_T$ (GeV)	$Z \to \nu\bar{\nu}$	$t\bar{t}$/W $\to$ e, μ+X	$t\bar{t}$/W $\to \tau_h$+X	QCD multijet	Total background	Data
500–800	200–350	359 ± 81	327 ± 47	349 ± 40	119 ± 77	1154 ± 128	1269
500–800	350–500	112 ± 26	48 ± 9	62.5 ± 8.7	2.2 ± 2.2	225 ± 29	236
500–800	500–600	17.6 ± 4.9	5.0 ± 2.2	8.7 ± 2.5	0.0 ± 0.1	31.3 ± 5.9	22
500–800	>600	5.5 ± 2.6	0.8 ± 0.8	2.0 ± 1.8	0.0 ± 0.0	8.3 ± 3.2	6
800–1000	200–350	48 ± 19	58 ± 15	56.3 ± 8.3	35 ± 24	197 ± 35	177
800–1000	350–500	16.0 ± 6.7	5.4 ± 2.3	7.2 ± 2.0	$1.2^{+1.3}_{-1.2}$	29.8 ± 7.5	24
800–1000	500–600	7.1 ± 3.7	2.4 ± 1.5	1.3 ± 0.6	$0.0^{+0.2}_{0.0}$	10.8 ± 4.0	6
800–1000	>600	3.3 ± 1.7	0.7 ± 0.7	1.0 ± 0.3	$0.0^{+0.1}_{0.0}$	5.0 ± 1.9	5
1000–1200	200–350	10.9 ± 5.1	13.7 ± 3.8	21.9 ± 4.6	19.7 ± 13.3	66 ± 15	71
1000–1200	350–500	5.5 ± 3.0	5.0 ± 4.4	2.9 ± 1.3	$0.4^{+0.7}_{-0.4}$	13.8 ± 5.5	12
1000–1200	>500	2.2 ± 1.7	1.6 ± 1.2	2.3 ± 1.0	$0.0^{+0.2}_{0.0}$	6.1 ± 2.3	4
1200–1400	200–350	3.1 ± 1.8	4.2 ± 2.1	6.2 ± 1.8	11.7 ± 8.3	25.2 ± 8.9	29
1200–1400	>350	2.3 ± 1.5	2.3 ± 1.4	$0.6^{+0.8}_{-0.6}$	$0.2^{+0.6}_{-0.2}$	5.4 ± 2.3	8
>1400	>200	3.2 ± 1.8	2.7 ± 1.6	1.1 ± 0.5	12.0 ± 9.1	19.0 ± 9.4	16

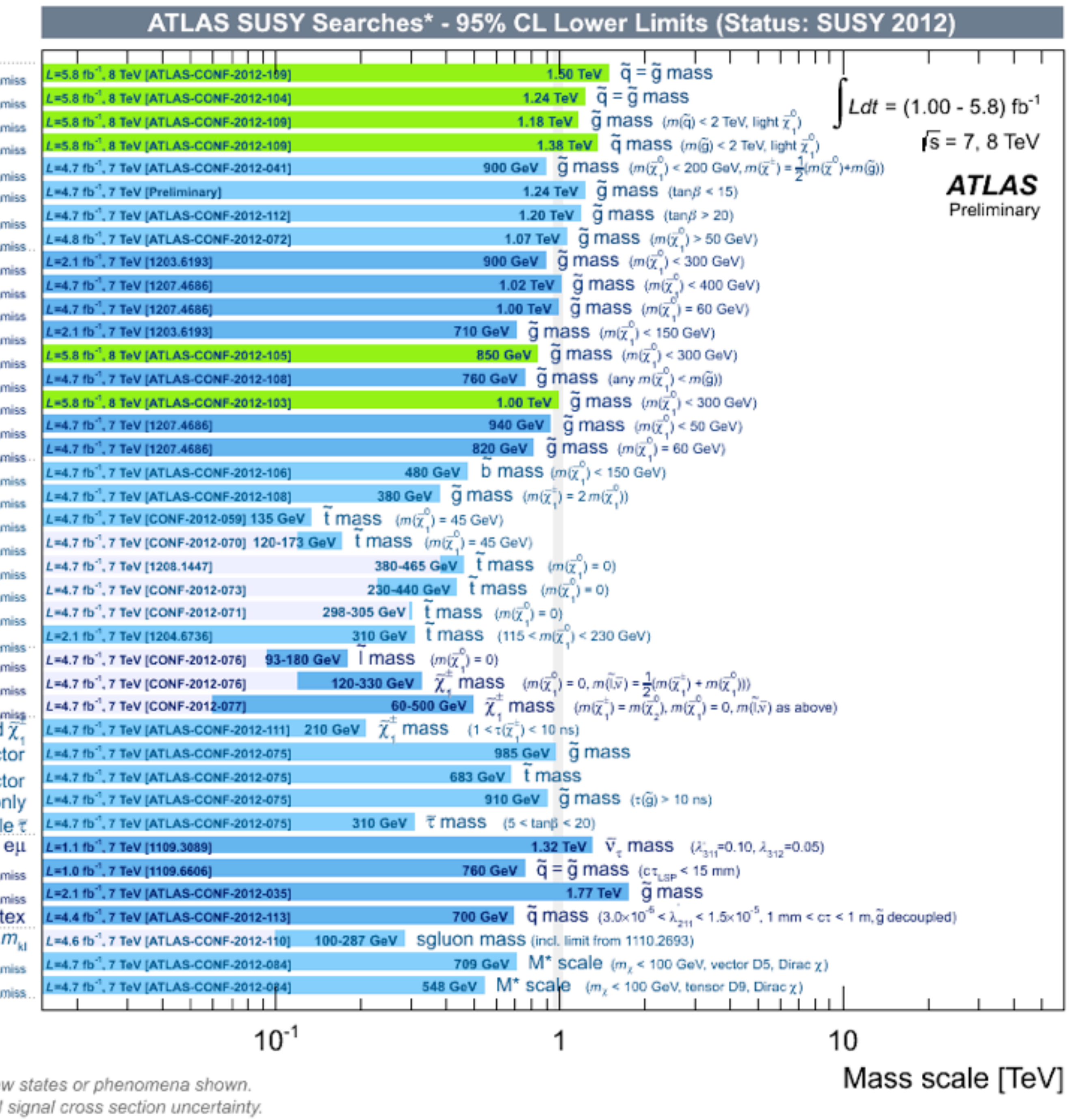
CMS-SUS-12011

On the eve of the first debate...

Are you better off now than 4 years ago?

Supersymmetry

President



One of them is not looking too good...

Naturalness I: Gluino

Supersoft

$$\delta m^2_{H_u}|_{\rm SSSM} \simeq -\left(\frac{M_3}{22}\right)^2 \frac{\log \tilde{r}_3}{\log 1.5}$$

(log cutoff by Dirac gluino mass)

MSSM

$$\delta m^2_{H_u}|_{\rm MSSM} \simeq -\left(\frac{\tilde{M}_3}{4}\right)^2 \left(\frac{\log \Lambda/\tilde{M}_3}{3}\right)^2$$

(log cutoff by messenger scale)

Dirac gluino can be substantially heavier than Majorana gluino while just as natural.

1105.2838

Simplified Models for LHC New Physics Searches

Daniele Alves, Nima Arkani-Hamed, Sanjay Arora, Yang Bai, Matthew Baumgart, Joshua Berger, Matthew Buckley, Bart Butler, Spencer Chang, Hsin-Chia Cheng, Clifford Cheung, R. Sekhar Chivukula, Won Sang Cho, Randy Cotta, Mariarosaria D'Alfonso, Sonia El Hedri, Rouven Essig (Editor), Jared A. Evans, Liam Fitzpatrick, Patrick Fox, Roberto Franceschini, Ayres Freitas, James S. Gainer, Yuri Gershtein, Richard Gray, Thomas Gregoire, Ben Gripaios, Jack Gunion, Tao Han, Andy Haas, Per Hansson, JoAnne Hewett, Dmitry Hits, Jay Hubisz, Eder Izaguirre, Jared Kaplan, Emanuel Katz, Can Kilic, Hyung-Do Kim, Ryuichiro Kitano, Sue Ann Koay, Pyungwon Ko, David Krohn, Eric Kuflik, Ian Lewis, Mariangela Lisanti (Editor), Tao Liu, Zhen Liu, Ran Lu, Markus Luty, Patrick Meade, David Morrissey, Stephen Mrenna, et al. (42 additional authors not shown)

(Submitted on 13 May 2011)

This document proposes a collection of simplified models relevant to the design of new-physics searches at the LHC and the characterization of their results. Both ATLAS and CMS have already presented some results in terms of simplified models, and we encourage them to continue and expand this effort, which supplements both signature-based results and benchmark model interpretations. A simplified model is defined by an effective Lagrangian describing the interactions of a small number of new particles. Simplified models can equally well be described by a small number of masses and cross-sections. These parameters are directly related to collider physics observables, making simplified models a particularly effective framework for evaluating searches and a useful starting point for characterizing positive signals of new physics. This document serves as an official summary of the results from the "Topologies for Early LHC Searches" workshop, held at SLAC in September of 2010, the purpose of which was to develop a set of representative models that can be used to cover all relevant phase space in experimental searches. Particular emphasis is placed on searches relevant for the first ~50-500 pb-1 of data and those motivated by supersymmetric models. This note largely summarizes material posted at this http URL, which includes simplified model definitions, Monte Carlo material, and supporting contacts within the theory community. We also comment on future developments that may be useful as more data is gathered and analyzed by the experiments.

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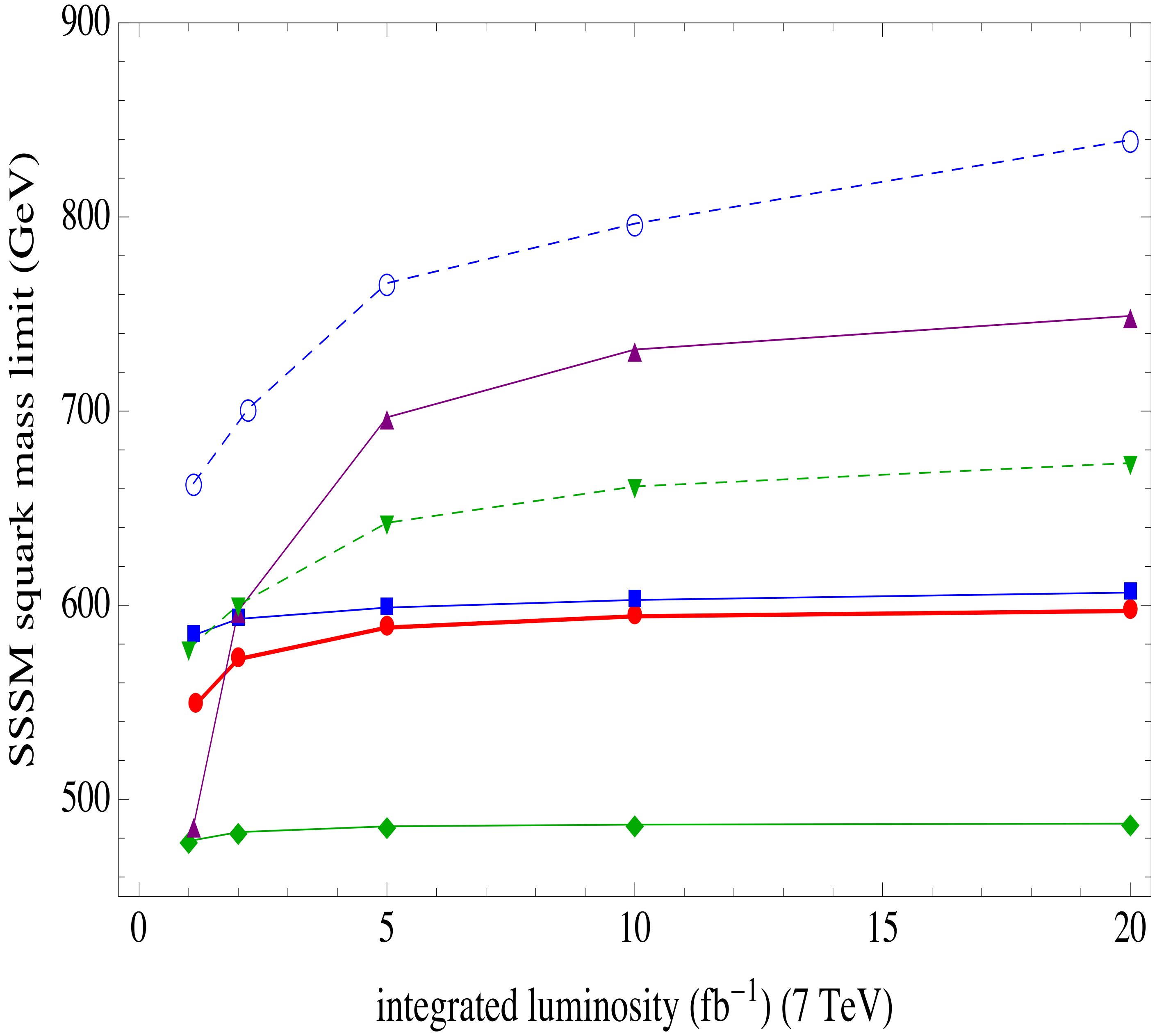
Extrapolation

FIG. 4. Projection of the expected limits to larger integrated luminosity holding the analysis strategy fixed as well as $\sqrt{s} = 7$ TeV. For each detector analysis strategy, the strongest individual channel is shown, while for the α_T and *razor* analyses we show the projection of the combined channel limit as well. The red line corresponds to CMS jets plus $\not{E}_T$, the blue corresponds to CMS α_T (solid is the single channel limit, dashed is the combined limit), green (solid and dashed) shows CMS *razor*, and purple is ATLAS jets + $\not{E}_T$. We emphasize that we have plotted only the *expected* limits, to be distinguished from the *observed* limits that we show in Table I. The small differences between the expected and observed limits are at roughly the 10% level, characteristic of background fluctuations.

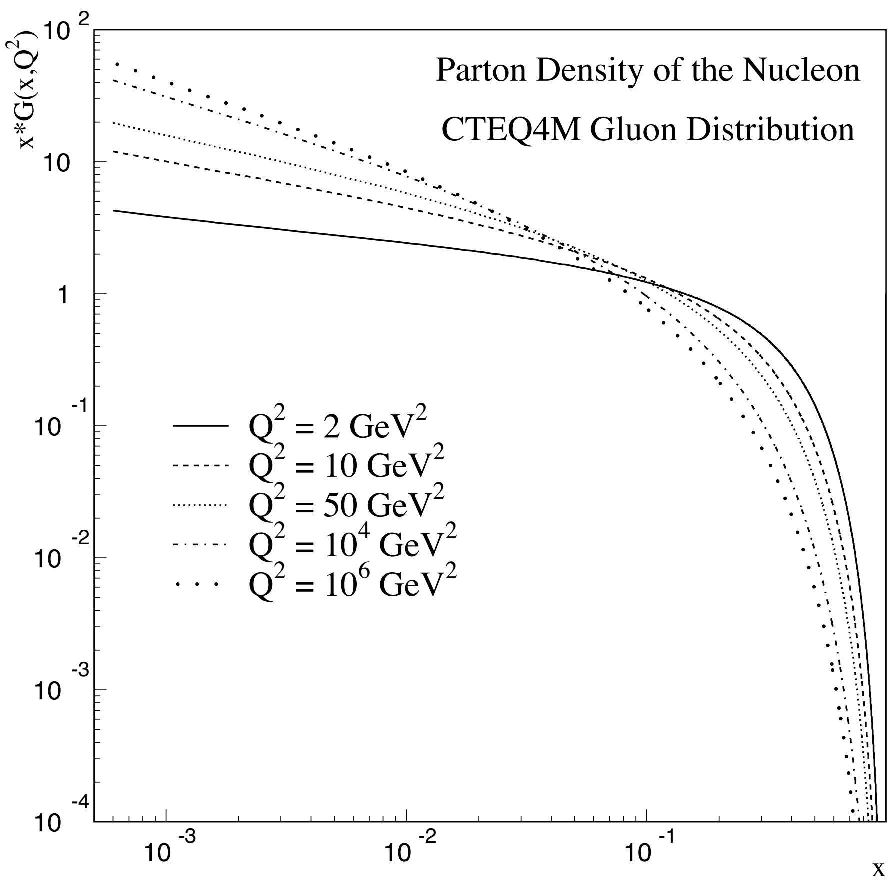


Kribs & Martin

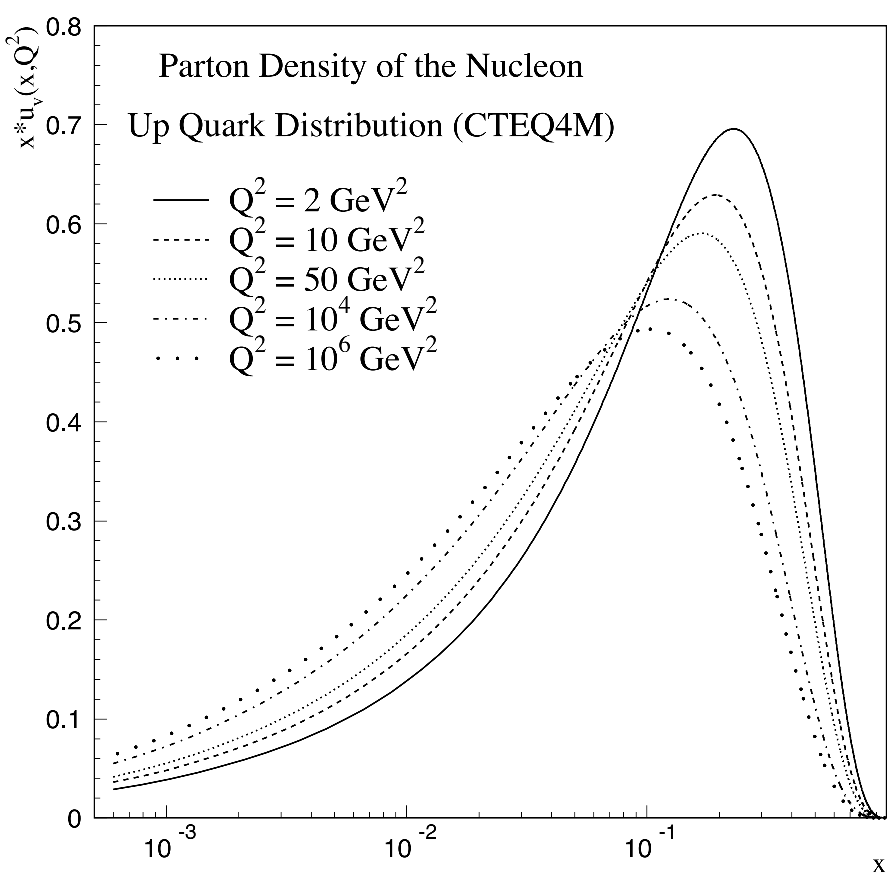
Proton-on-Proton Collisions

PDFs favor valence quark interactions
at high energies.

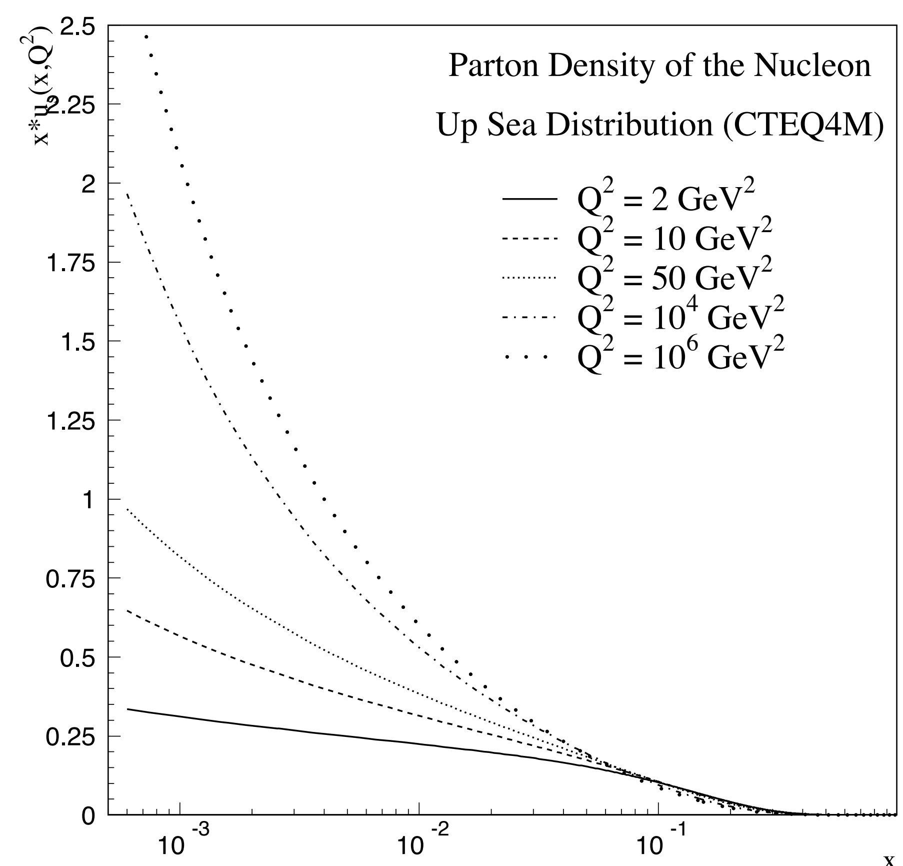
gluon



valance



sea



CTEQ slides