Search for Compressed SUSY at the LHC

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Implications of LHC results for TeV-scale physics

CERN

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Based on `1109.6572` with Tom LeCompte, updated here to reflect 4.7 fb^{-1} data. (NEW!)

We use published ATLAS results, but this is <u>not</u> an ATLAS talk!

What happens if the superpartner mass spectrum is more compressed than mSUGRA?

Less visible energy: smaller jet p_T's, $m_{\rm eff}$ or H_T, and $E_T^{\rm miss}$.
Signal looks more like QCD, $t\bar{t}$, W+jets, and Z+jets backgrounds.

Radiation of extra jets from the hard SUSY production is important!

We studied models that generalize mSUGRA by including a "compression factor" c. At the TeV scale:

$$M_1 = \left(\frac{1+5c}{6}\right) M_{\tilde{g}}, \qquad M_2 = \left(\frac{1+2c}{3}\right) M_{\tilde{g}},$$

$c = 0$ corresponds to mSUGRA.

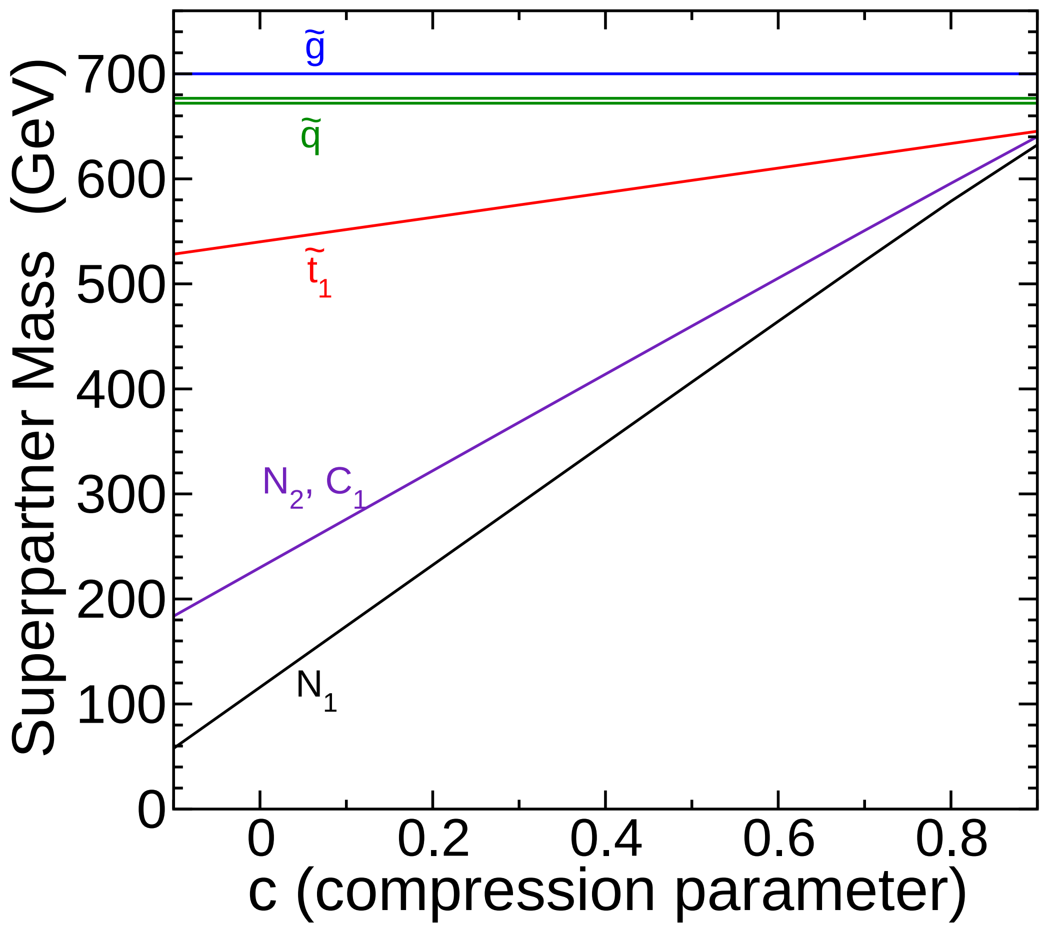
$c = 1$ is total compression (gauginos degenerate).

Also take $\tan\beta = 10$, $\mu > 0$, and squark masses:

- $M_{\tilde{Q}} = 0.96 M_{\tilde{g}}$ Light squark models
- $M_{\tilde{Q}} = M_{\tilde{g}} + 1000\ \mathrm{GeV}$ Heavy squark models

Variable input parameters: $M_{\tilde{g}}$ (overall superpartner mass scale) and c (compression factor).

Masses of important superpartners, as a function of c, for $M_{\tilde{g}} = 700$ GeV:



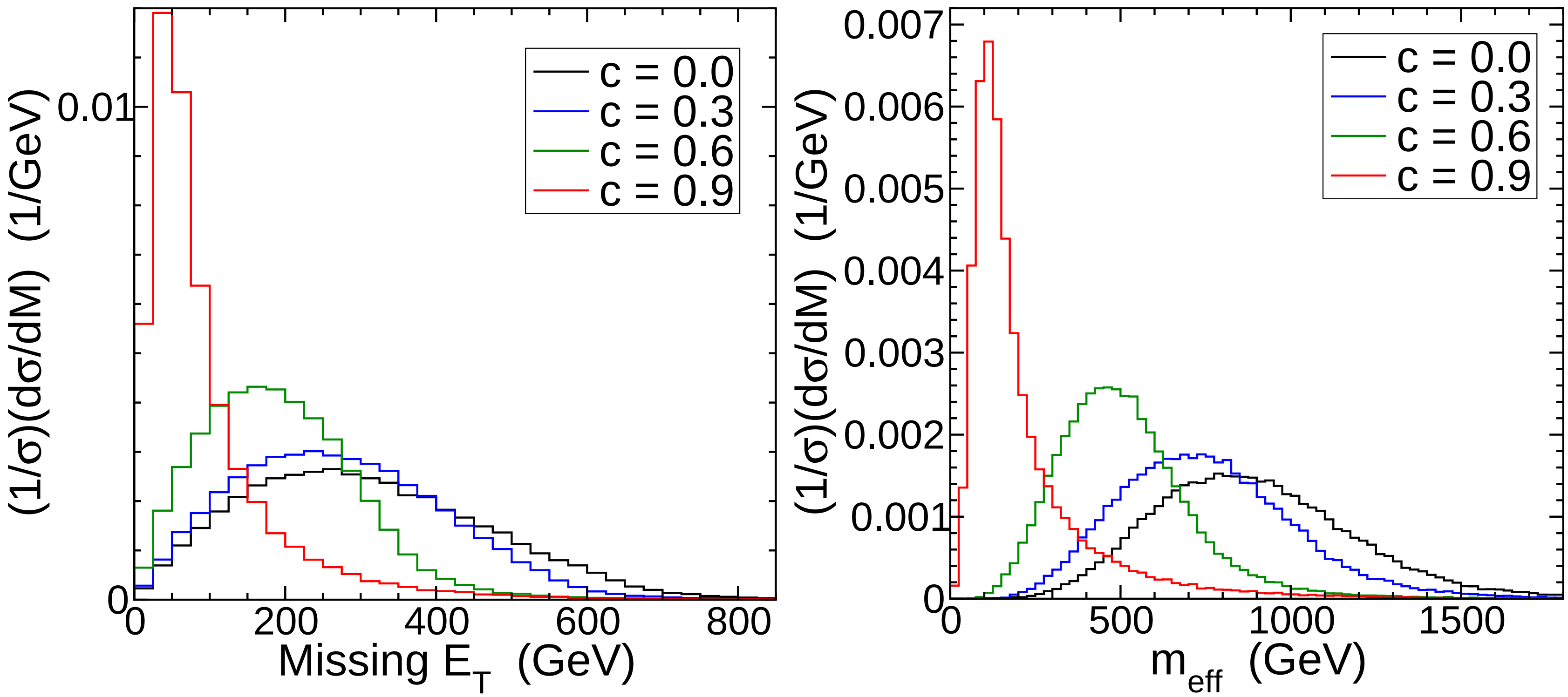
Used MadGraph/MadEvent to generate hard scattering events, Pythia for decays and showering and hadronization, PGS4 for detector simulation.

Matrix element and shower/hadronization jet matching done with MLM method by including 1 extra jet at matrix element level for each signal process.

This is potentially important when the mass spectrum is compressed, but with our setup we found it didn't make a huge difference.

Cross-sections for $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{Q}$, $\tilde{g}\tilde{Q}^*$, $\tilde{Q}\tilde{Q}$, $\tilde{Q}\tilde{Q}^*$, $\tilde{Q}^*\tilde{Q}^*$, $\tilde{t}_i\tilde{t}_i^*$, $\tilde{b}_i\tilde{b}_i^*$, all normalized to Prospino.

$E_T^{\rm miss}$, $m_{\rm eff}$ distributions for $M_{\tilde{g}} = 700$ GeV, and $c = 0.0, 0.3, 0.6, 0.9$.



As c increases, $m_{\rm eff}$ gets soft faster than $E_T^{\rm miss}$ does.

For moderate compression, acceptance can even increase with c;

more events pass $E_T^{\rm miss}/m_{\rm eff} >$ cuts.

Distributions become very soft at high compression c.

ATLAS cuts from Summer 2011 (EPS) data analyses:

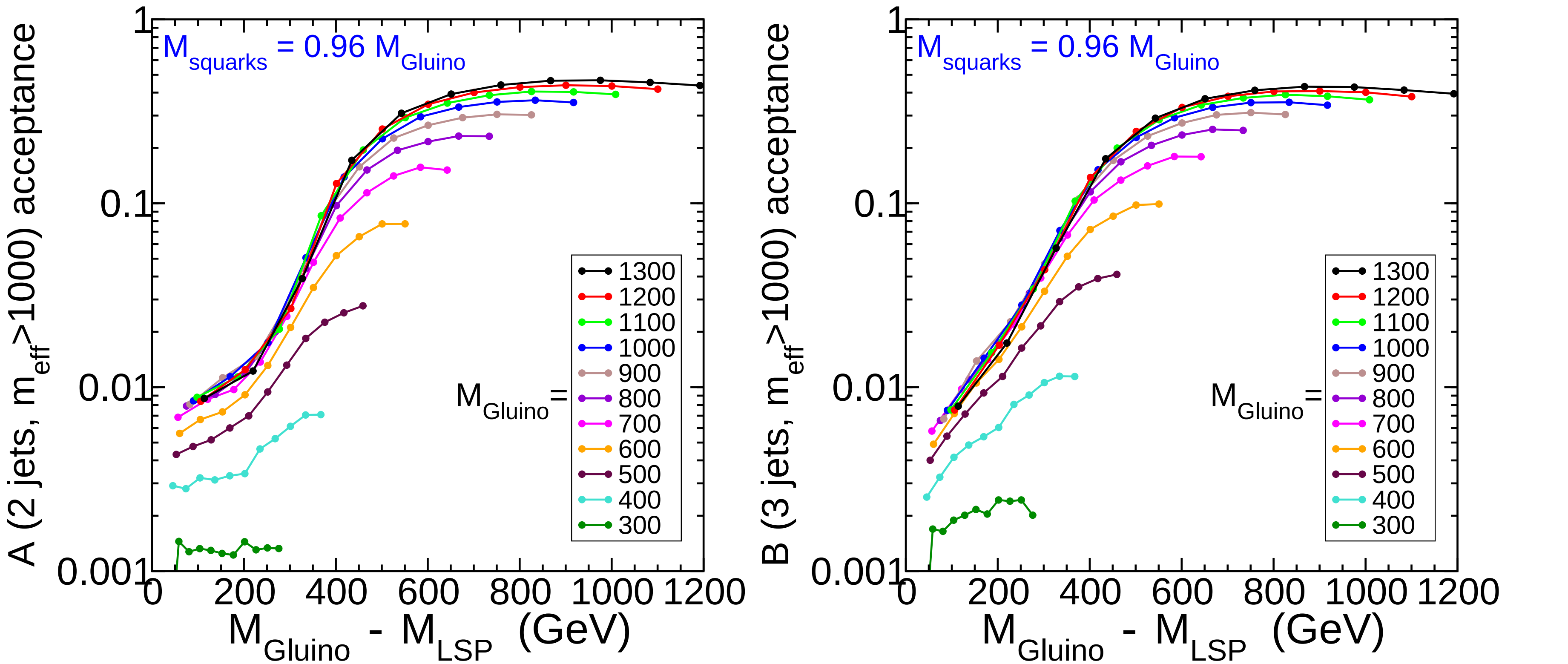
	A	B	C	D	E
number of jets	≥ 2	≥ 3	≥ 4	≥ 4	≥ 4
$p_T(j_1)$ [GeV]	> 130	> 130	> 130	> 130	> 130
$p_T(j_n)$ [GeV]	> 40	> 40	> 40	> 40	> 80
m_{eff} [GeV]	> 1000	> 1000	> 500	> 1000	$> 1100^{\dagger}$
$E_T^{\text{miss}}/m_{\text{eff}}$	> 0.3	> 0.25	> 0.25	> 0.25	> 0.2
1.04 fb^{-1} limit	$<$ 22 fb	$<$ 25 fb	$<$ 429 fb	$<$ 27 fb	$<$ 17 fb

ATLAS 1109.6572

† inclusive m_{eff}: sum jets with $p_T > 40$

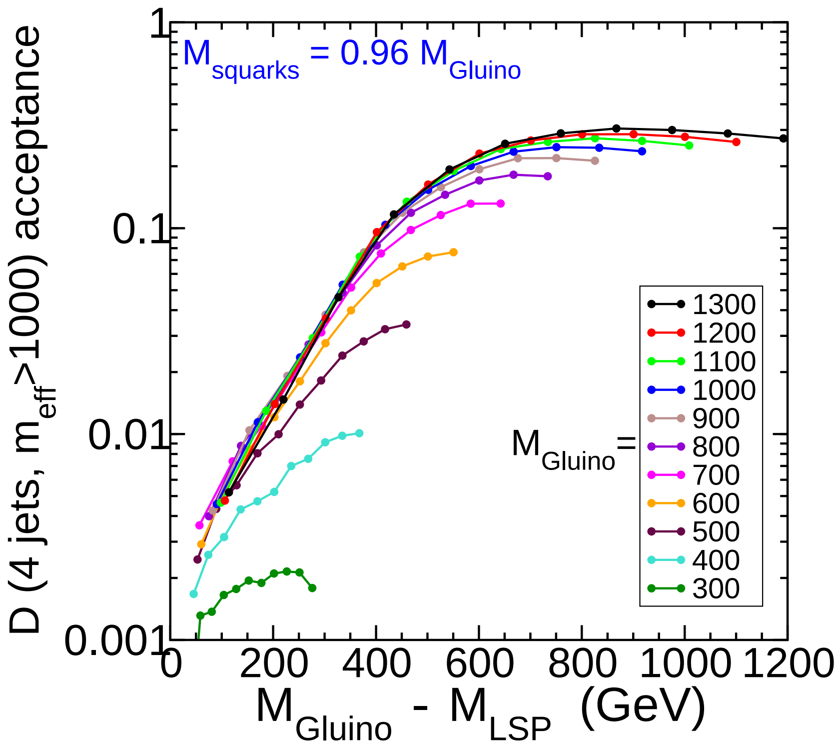
Limits are 95% CL on cross-section times acceptance.

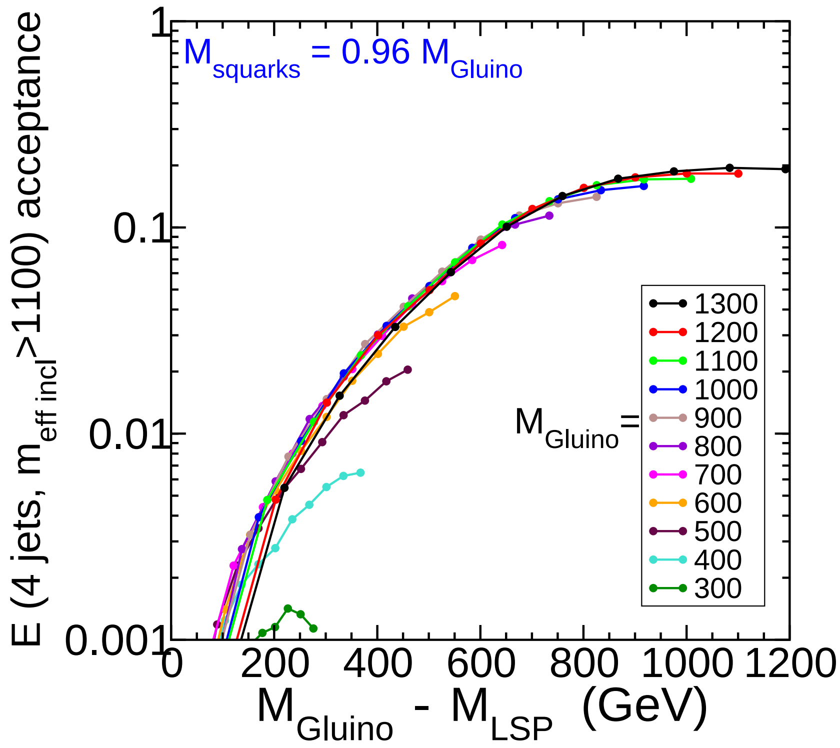
A and B acceptances for $M_{\tilde{g}} = 300, 400, 500, \ldots 1300$ GeV:



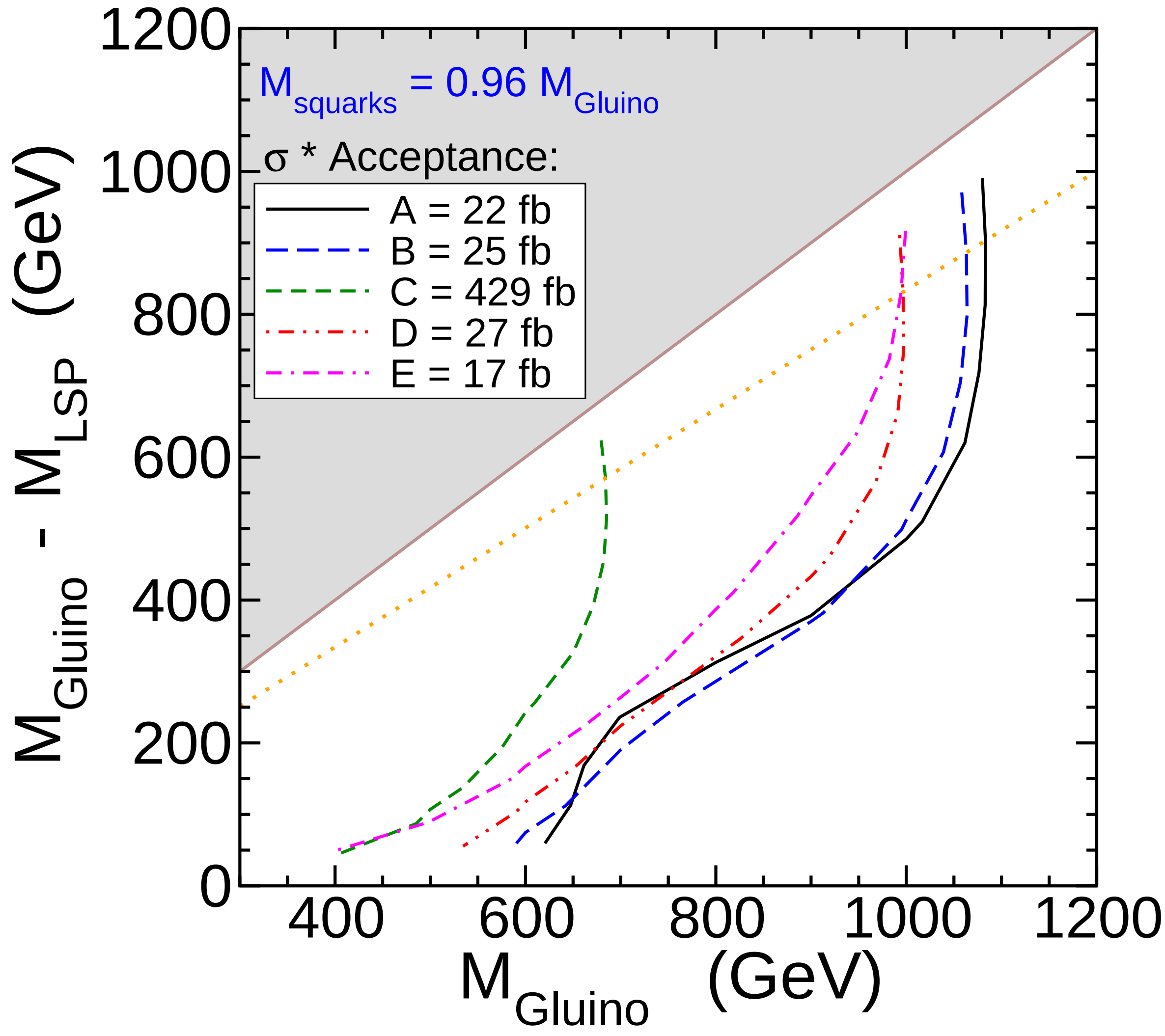
Dots on each line are at $c = -0.1,\ 0,\ 0.1,\ \ldots,\ 0.9$ from right to left.

D and E acceptances are somewhat worse for this class of models, especially at extreme compression:



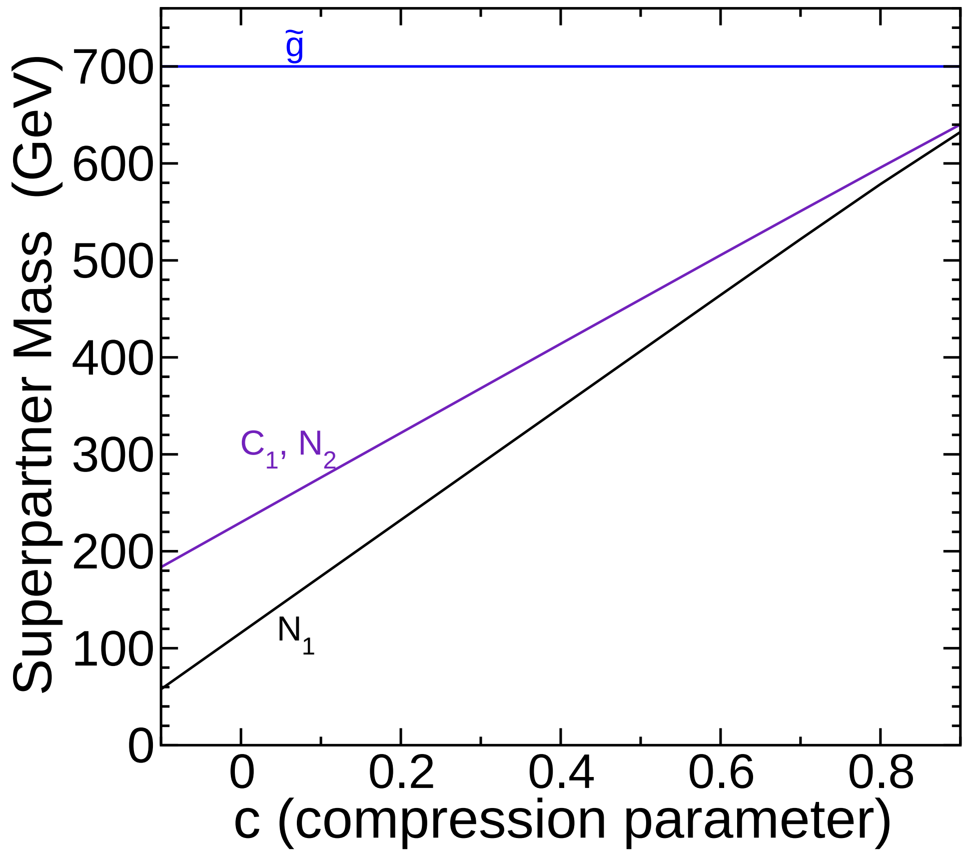


$\sigma \times$ Acceptance contours, corresponding to the ATLAS 1.04 fb^{-1} limits reported in 1109.6572:



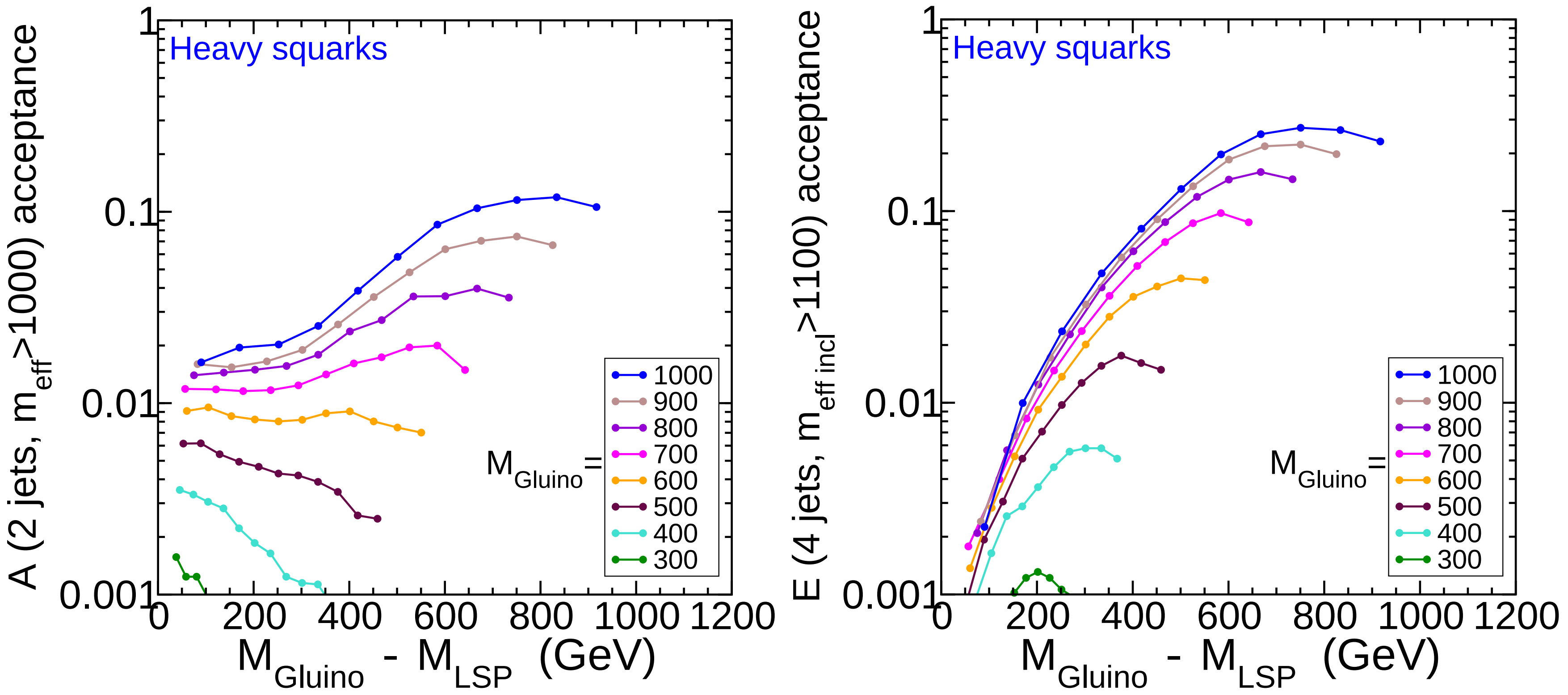
What if squarks are much heavier? (Motivated by $M_h = 125$ GeV!)

Consider variable $M_{\tilde{g}}$ and compression parameter c as before, but now take squarks out of the picture: $M_{\tilde{Q}} = M_{\tilde{g}} + 1000\,\mathrm{GeV}$.

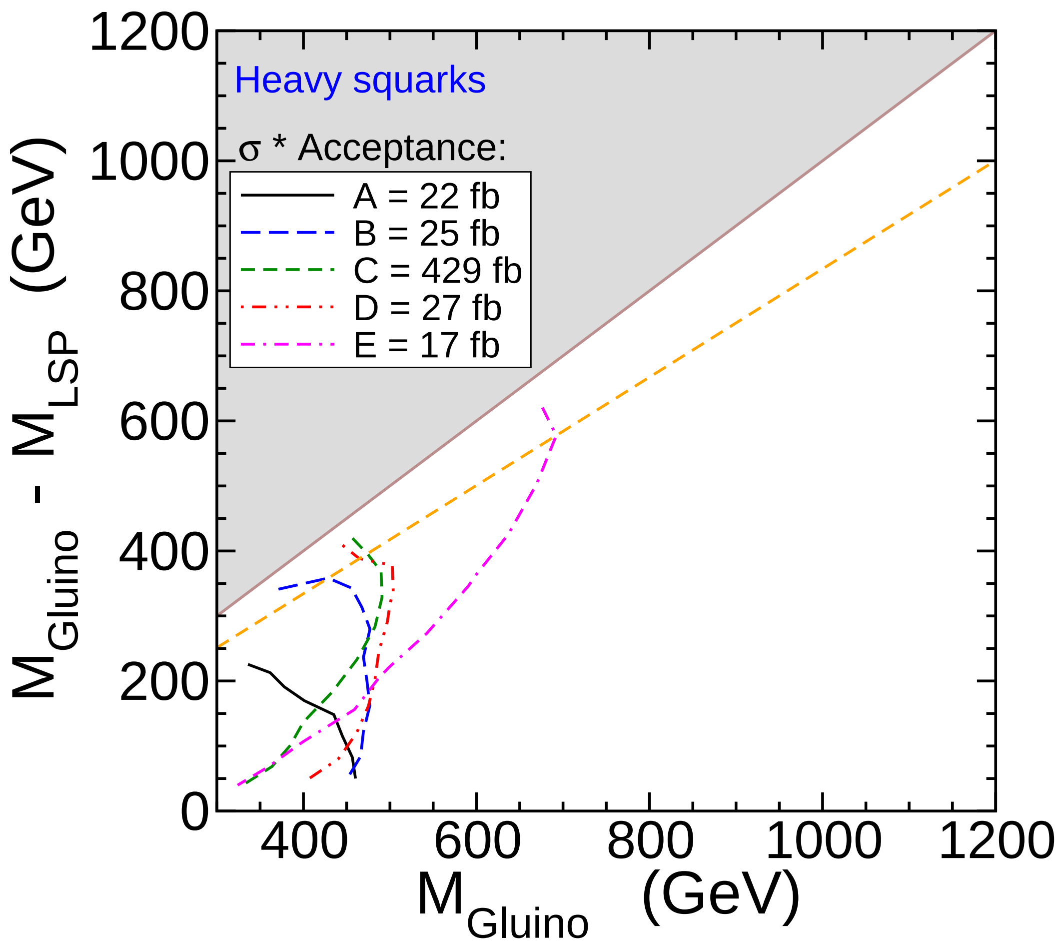


Now $\tilde{g} \to jj\tilde{W} \to jjjj + E_T^{\rm miss}$ dominates.

For low compression, signal E (4 jets, inclusive $m_{\rm eff}$) wins, but as the compression increases, B (3 jets) and then A (2 jets) take over.



$\sigma \times$ Acceptance contours corresponding to the ATLAS 2011 1.04 fb^{-1} limits, for Heavy Squark models:



What to do?

For more compression of masses, $m_{\rm eff}$ gets soft faster than $E_T^{\rm miss}$ does. A high $m_{\rm eff}$ cut is deadly unless one includes many (≥ 4) jets. But, with compressed SUSY, requiring 4 hard jets also kills the signal.

So. . .

Suggestions:

- Require fewer jets (or lower p_T threshold for subleading jets), but sum over more of them in defining $m_{\rm eff}$,

  AND/OR

- Try lower cuts on $m_{\rm eff}$, and higher cuts on $E_T^{\rm miss}/m_{\rm eff}$ to compensate.

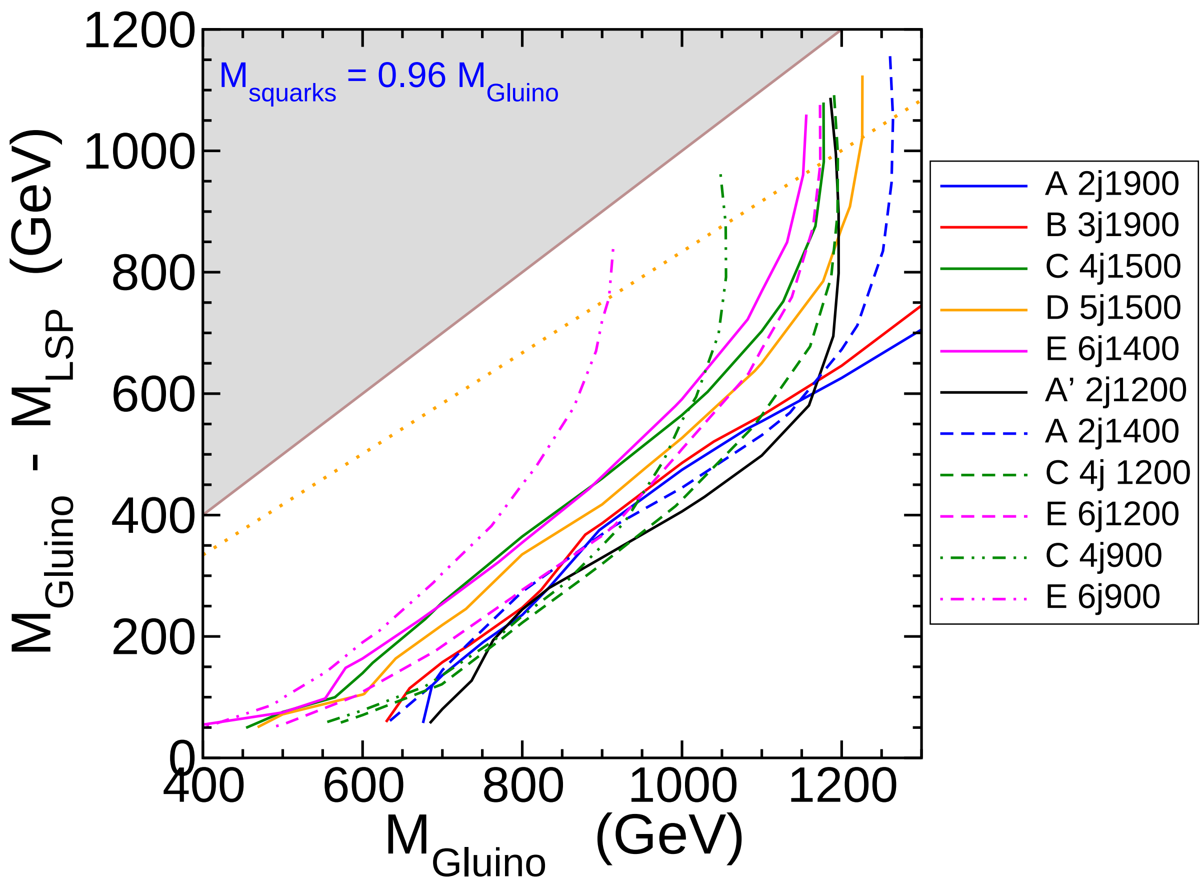
New results: ATLAS-CONF-2012-033 based on 4.7 fb^{-1}

11 distinct Signal Regions. Demand $E_T^{\rm miss} > 160$ GeV, $p_T(j_1) > 130$ GeV, $p_T(j_{2,3,4}) > 60$ GeV, $p_T(j_{5,6}) > 40$ GeV when required.

	A (2j)	A'(2j)	B (3j)	C (4j)	D (5j)	E (6j)
$N_{\rm jets} \geq$	2	2	3	4	5	6
$m_{\rm eff}$(incl) [GeV] $>$	1900, 1400	1200	1900	1500, 1200, 900	1500	1400, 1200, 900
$E_T^{\rm miss}/m_{\rm eff}(N_{\rm jets}) >$	0.3	0.4	0.25	0.25	0.2	0.15
4.7 fb^{-1} limit (fb)	0.62, 5.3	6.2	0.65	3.5, 3.7, 12	2.2	2.6, 2.5, 18

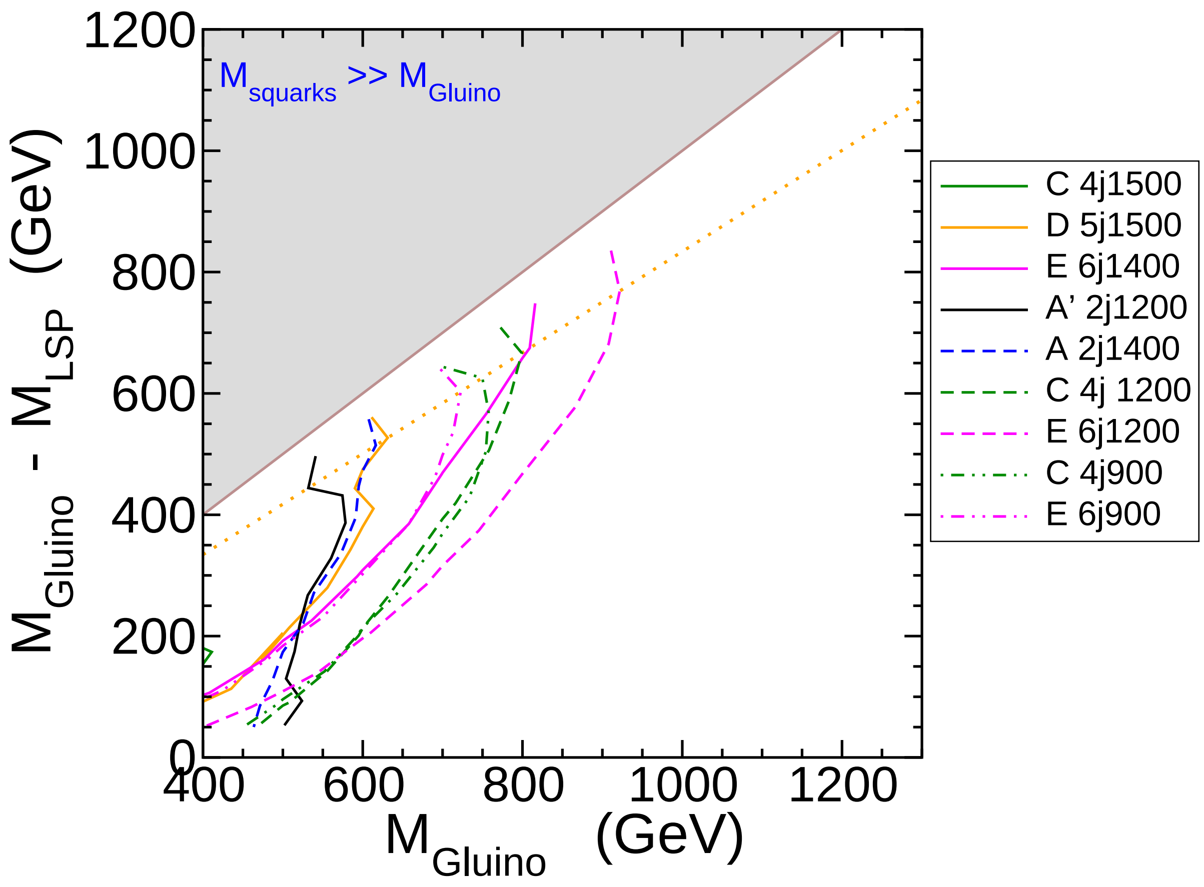
Light squark model $\sigma \times$ Acceptance contours, corresponding to the 4.7 fb^{-1} limits in ATLAS-CONF-2012-033:

[Not an ATLAS plot!]

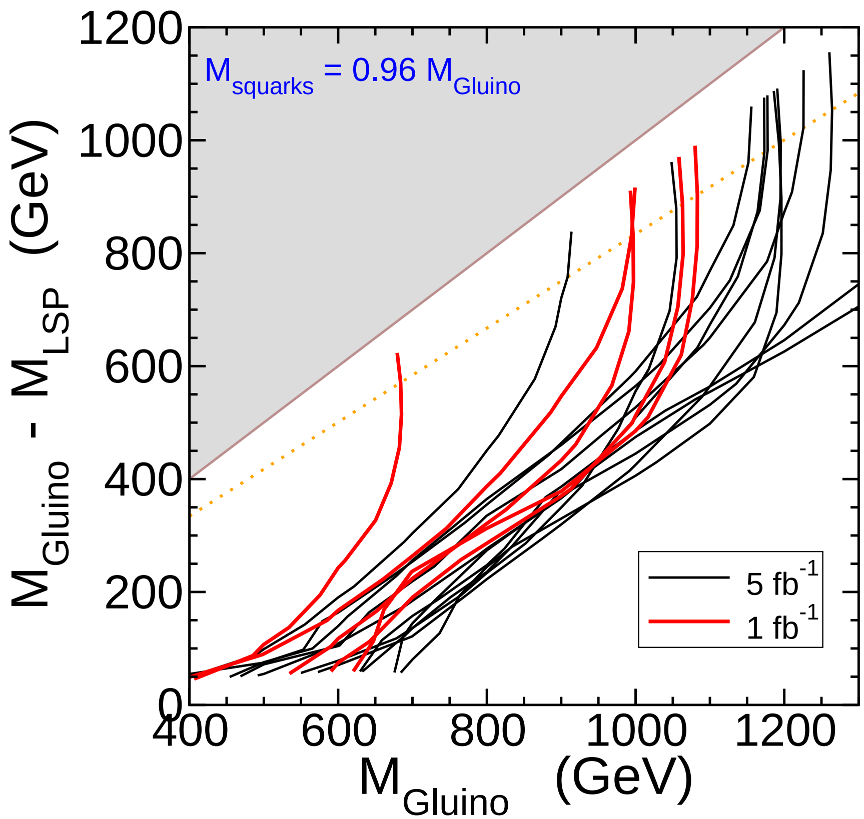


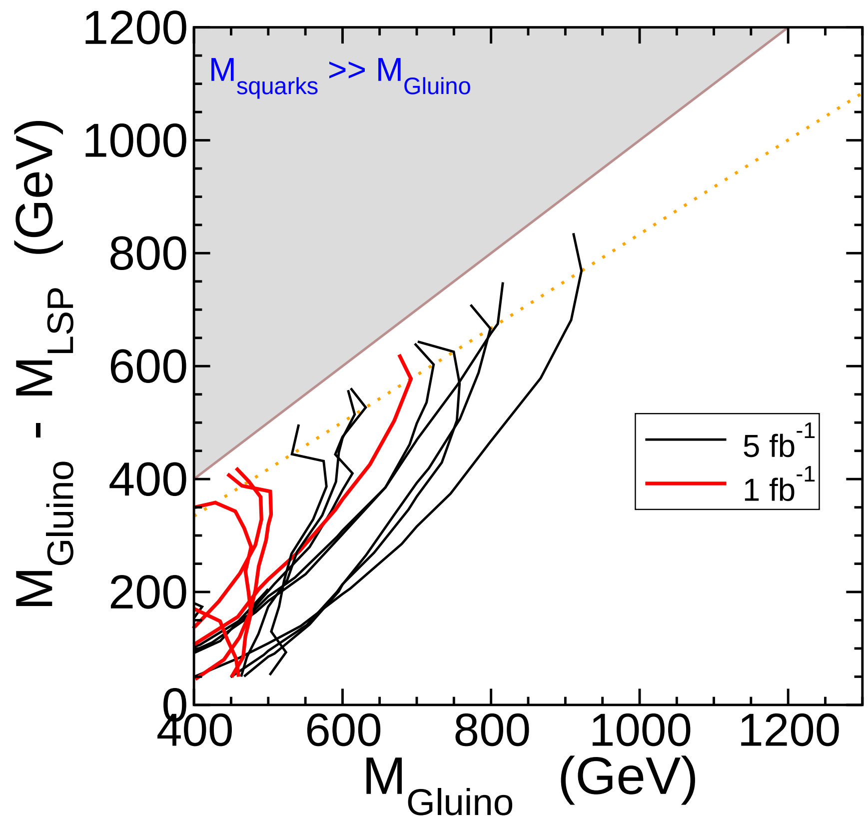
Heavy squark model $\sigma \times$ Acceptance contours, corresponding to the 4.7 fb^{-1} limits in ATLAS-CONF-2012-033:

[Not an ATLAS plot!]



Comparison of 4.7 fb^{-1} signal region exclusions with old 1 fb^{-1} results:





Can we do better?

Outlook

- With mild to moderate compression, acceptances are not bad, and sometimes even better than mSUGRA.
- Acceptances drastically decrease for more severe compression. (Even more dramatic for 1-lepton signal, and $>$6-jet signals, not shown here.)
- Caveat: Compressed SUSY might be contaminating background Control Regions (used to estimate backgrounds from data) in a more significant way than in mSUGRA (?)
- Try lower $m_{\rm eff}$ cuts, include more jets but require fewer, and/or higher $E_T^{\rm miss}/m_{\rm eff}$ cut.