Simplified Models with MET at ~1 fb^{-1}

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based in part on work with
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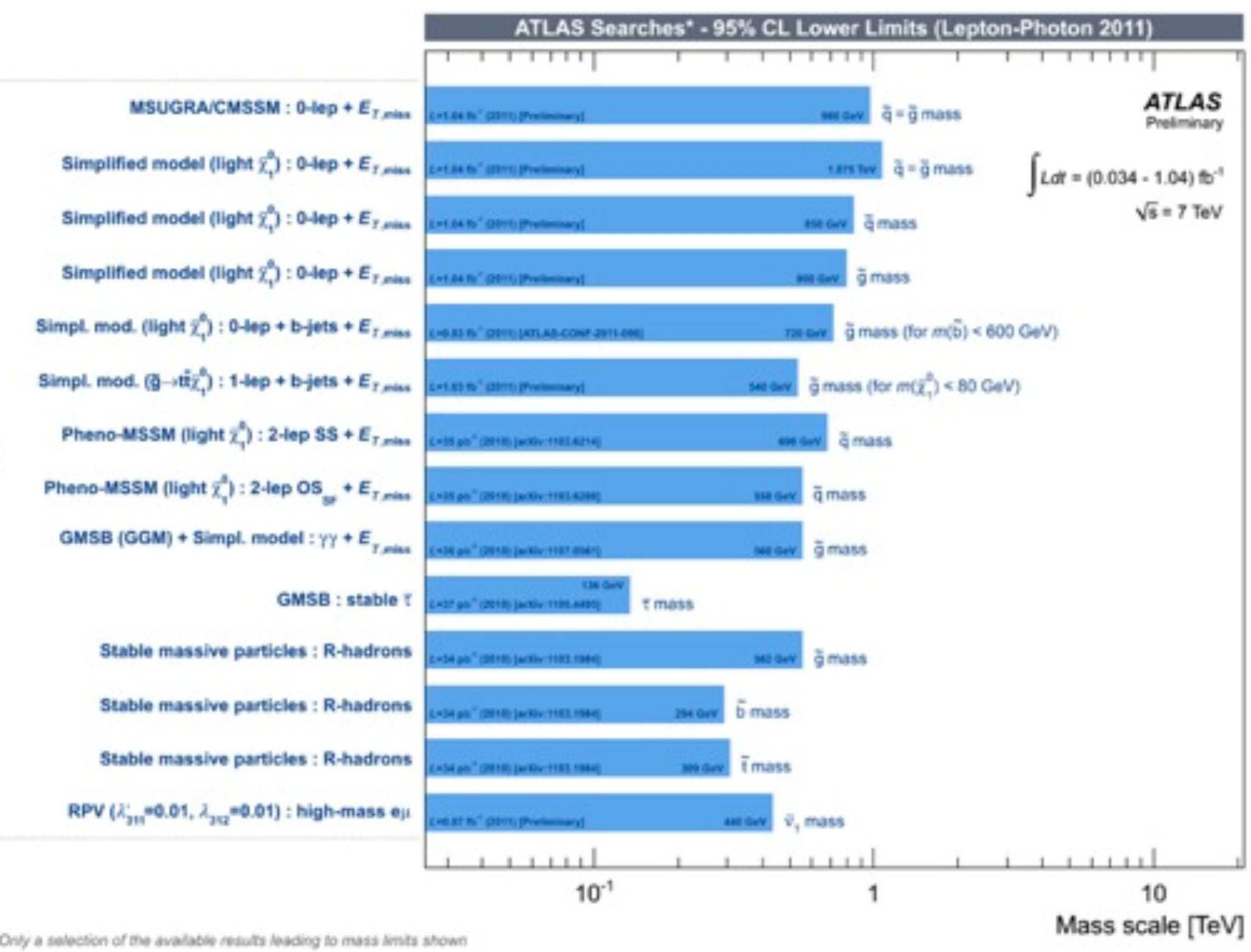
thanks also to M. D'Alfonso, P. Schuster for discussions

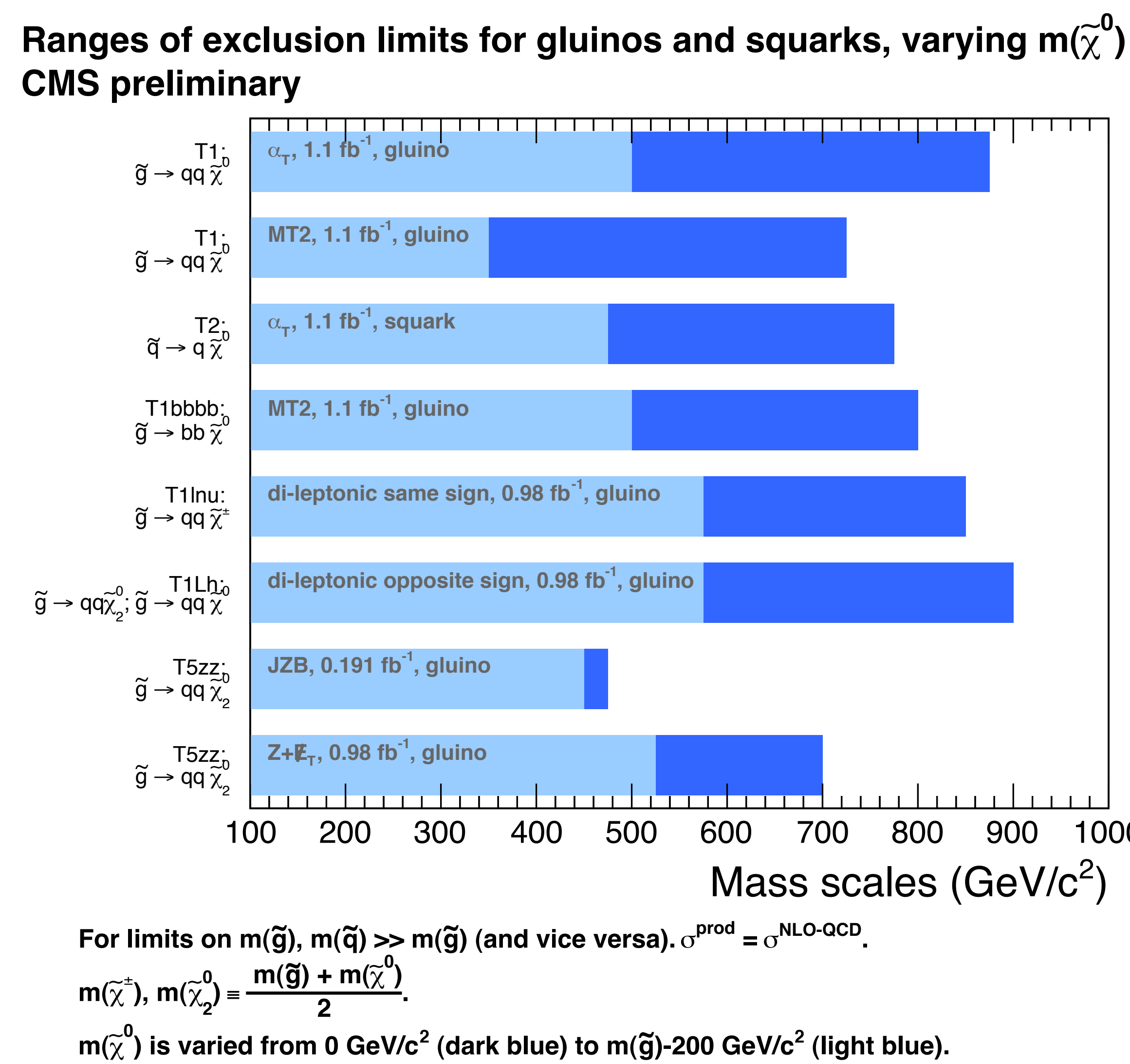
Very broad program of searches

– Jets+MET with ≥0, 1, 2 b-tag and various discriminating variables: α_T, m_{T2}, H_T, $/H_T$
– Jets+MET+1 lepton with ≥0, 1 b-tag
– Di-leptons (OS, SS, Z) and multi-leptons
– $\gamma\gamma$, γ+lepton
– Stable R-hadron or charged LSP
– RPV multi-jet (36 pb^{-1})
– Lepton jets, hidden valleys (36 pb^{-1})

*1 fb^{-1} squark, gluino limits from **500 to 1000 GeV** depending on details of production and decay*
→ a big range



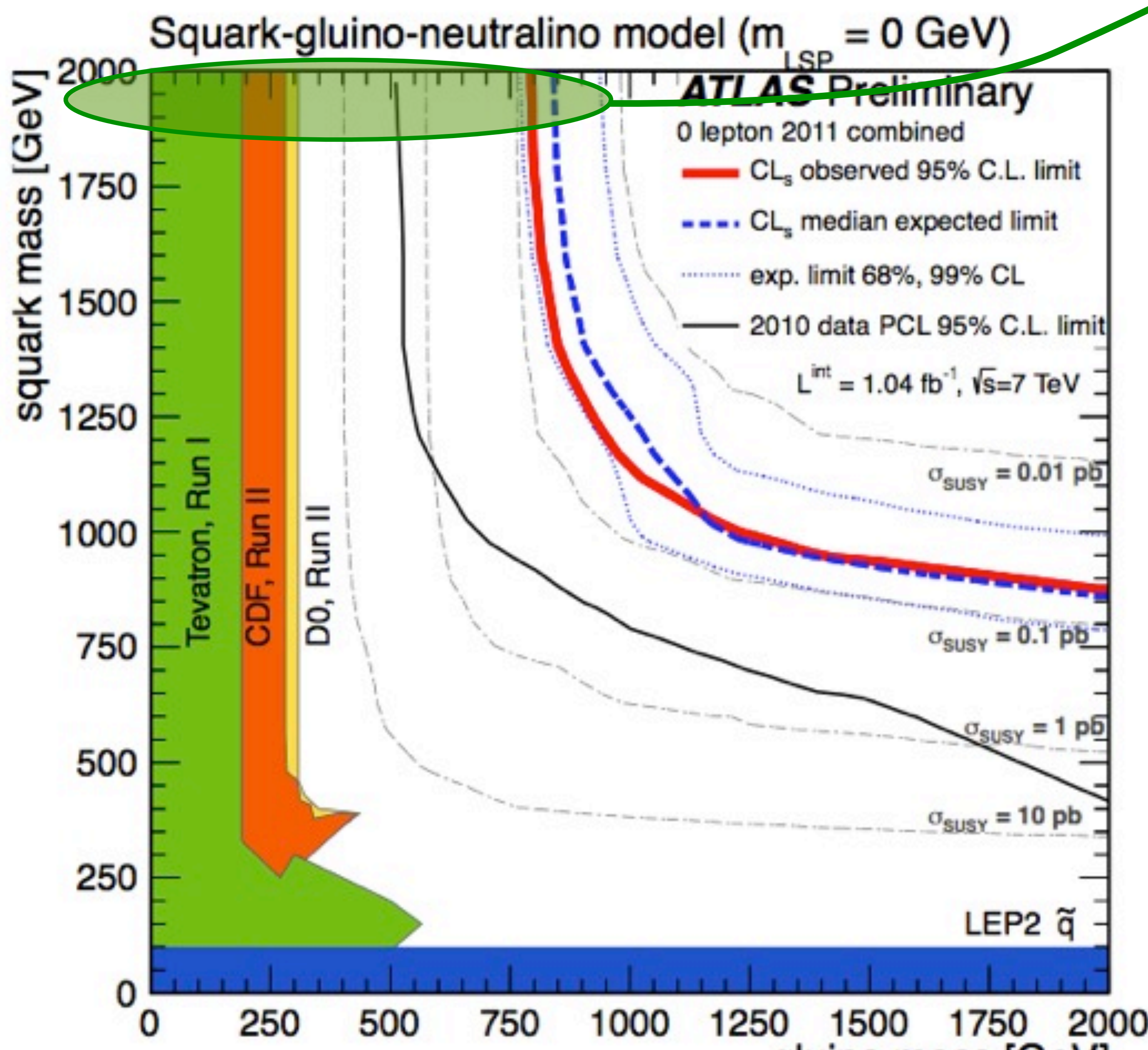
I can't possibly comment on all…



What are we learning?

– Naturalness expectations in conflict with data, *in some scenarios* e.g.:

squark decoupling: only gluino, LSP masses matter



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If gluino and squark decay to light-flavor quarks, and LSP lighter than ~200 GeV:

- heavier of gluino **or** squark ≥ 1.1 TeV
- lighter of gluino **or** squark ≥ 800 GeV
- If only squark **or** gluino is light, lose associated cross-section ⇒ lighter mass still allowed

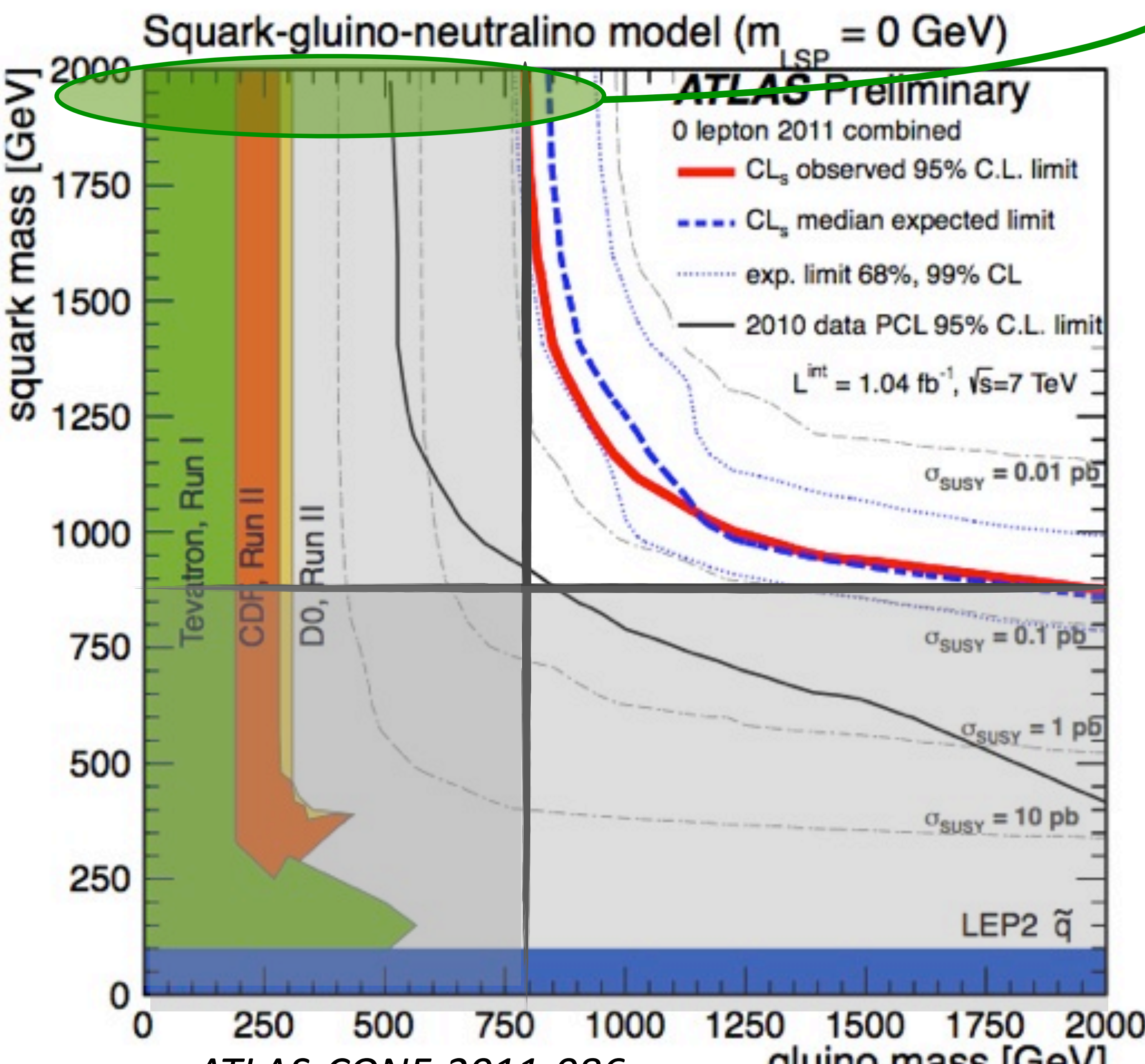
A Simple Case: $\tilde{g}$, $\tilde{q}$, LSP

(no cascades)

- On the other hand, this plot leaves out some crucial information

squark decoupling: only gluino, LSP masses matter

$\Downarrow$



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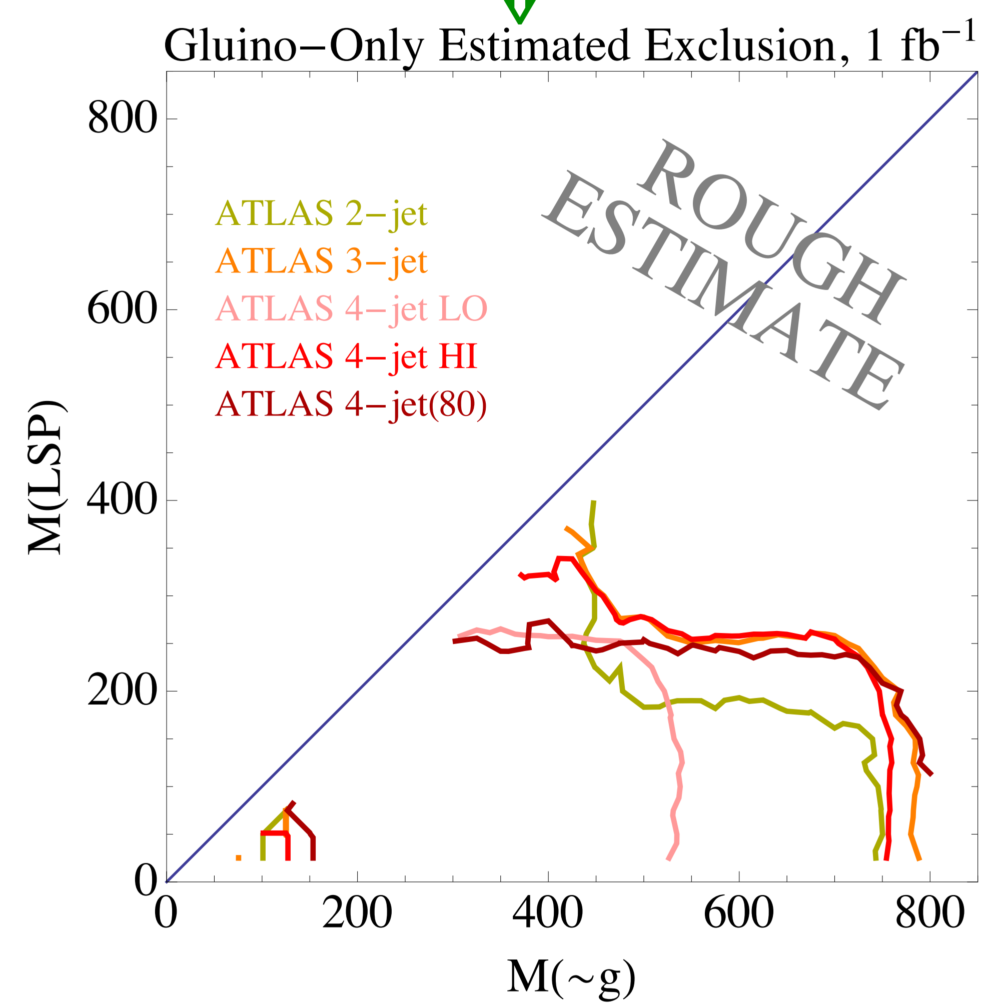
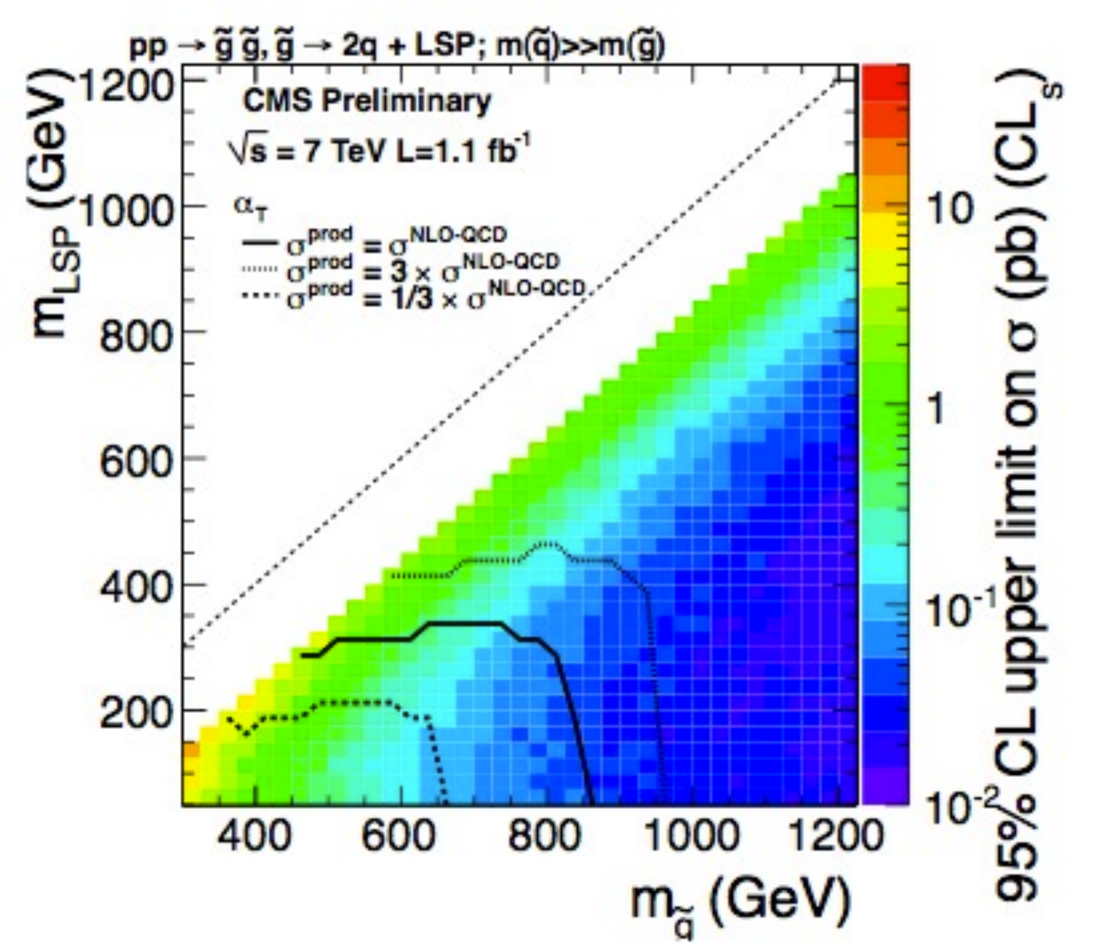


no constraint for M_{LSP}>275?
Important limitation – should be highlighted & studied!

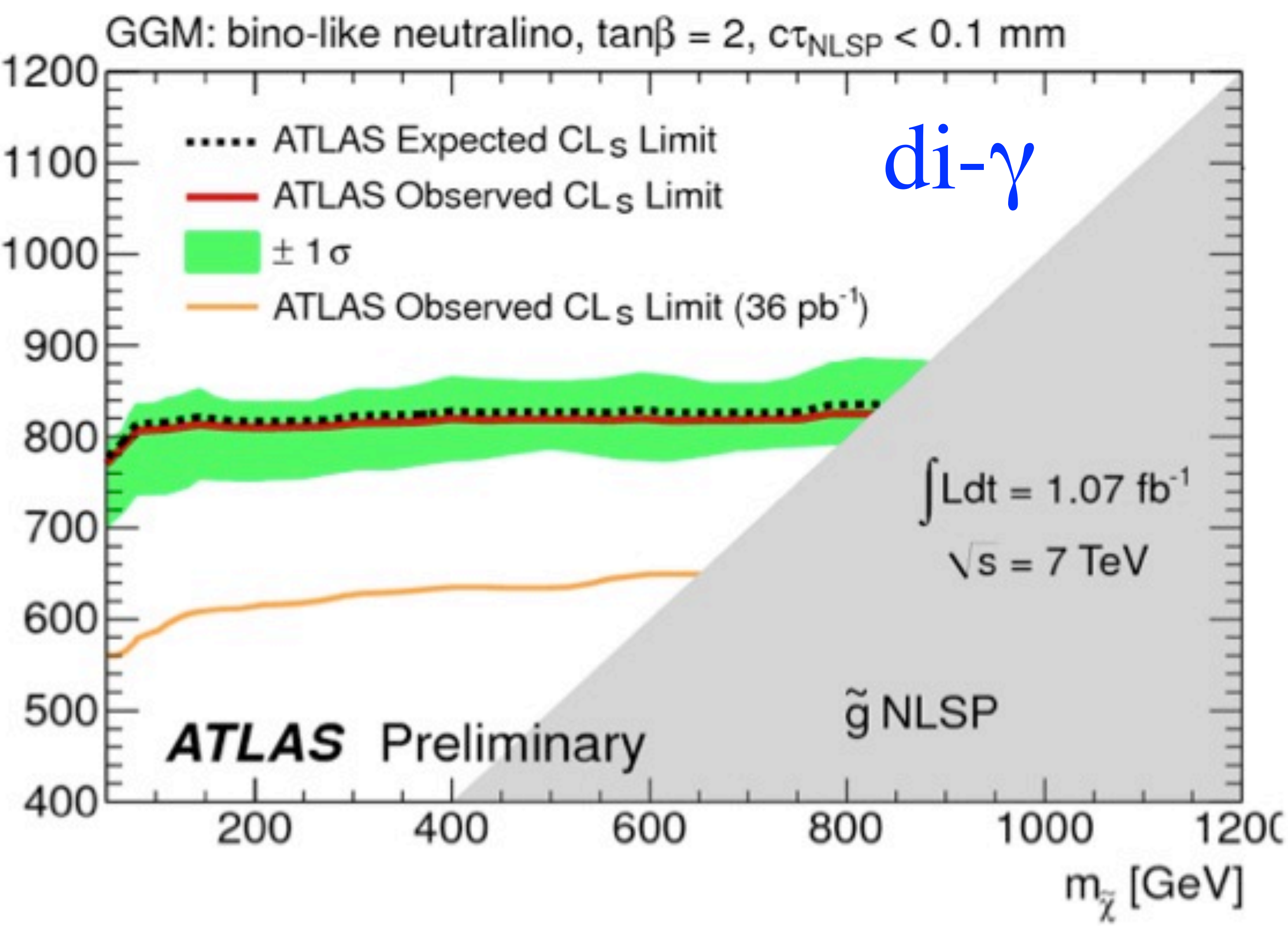
Similar limit shape from CMS α_T

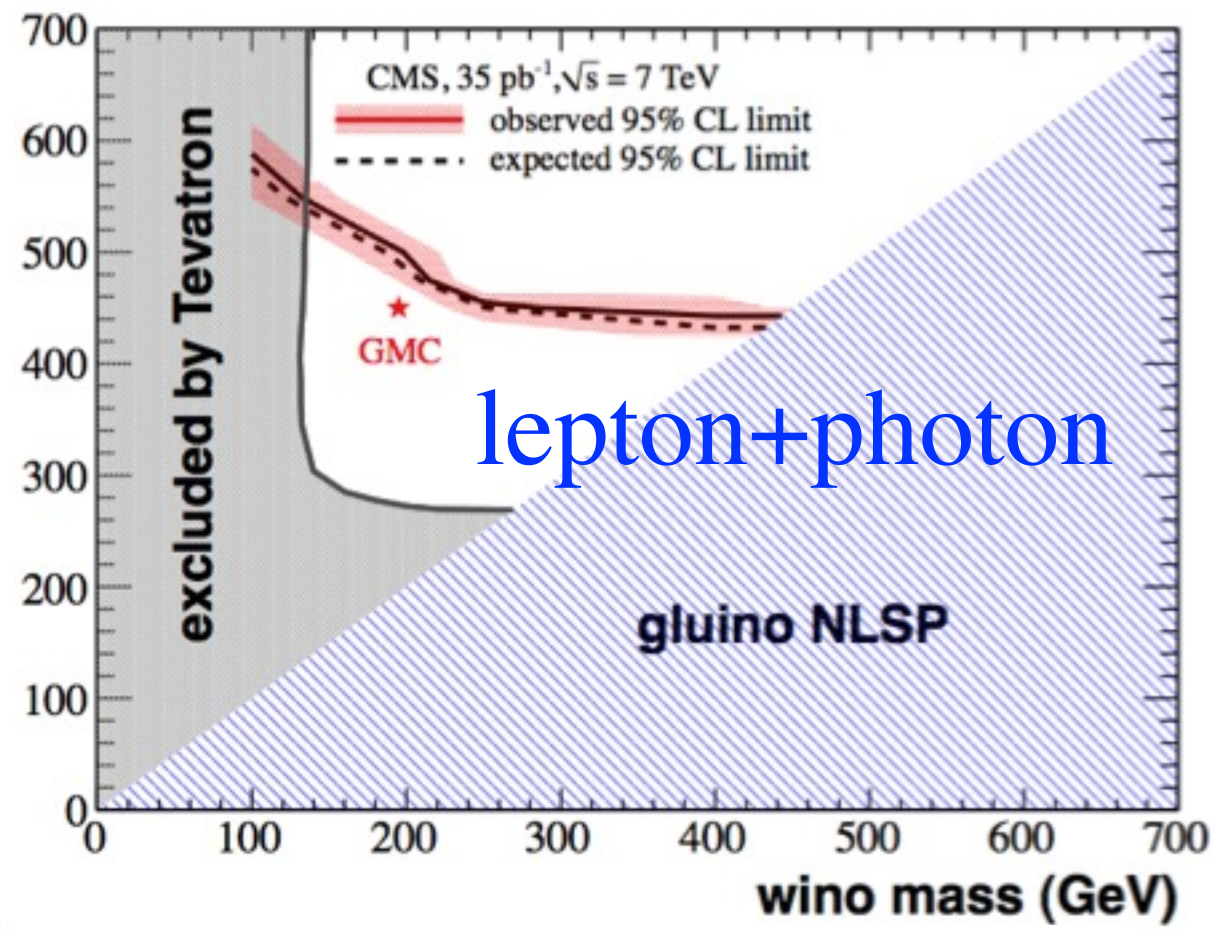


α_T analysis of CMS-PAS-SUS-11-003

see https://indico.fnal.gov/materialDisplay.py?contribId=396&sessionId=11&materialId=slides&confId=3563, as well as https://indico.fnal.gov/materialDisplay.py?contribId=494&sessionId=12&materialId=slides&confId=3563 for additional searches

Some γ simplified models from CMS





800 GeV limits comparable to jets+MET limits on 'direct decay to light bino'

GGM Phenomenology

- If R-parity is conserved, all events have two NLSP's

D. Shih, J. Ruderman

channel	bino	wino	Z-higgsino	bino-higgsino mix
$\gamma\gamma + \not{E}_T$	✓			
$\ell\gamma + \not{E}_T$		✓		
jets $+ \not{E}_T$		✓	✓	✓
$Z(\ell^+\ell^-) +$ jets $+ \not{E}_T$			✓	
$Z(\ell^+\ell^-)Z(\ell'^+\ell'^-) + \not{E}_T$			✓	
$Z(\ell^+\ell^-)h(b\bar{b}) + \not{E}_T$				✓
$h(b\bar{b})h(b\bar{b}) + \not{E}_T$				✓
$\gamma + h(b\bar{b}) + \not{E}_T$				✓
$\gamma +$ jets $+ \not{E}_T$	✓	✓		✓
$\ell +$ jets $+ \not{E}_T$		✓		

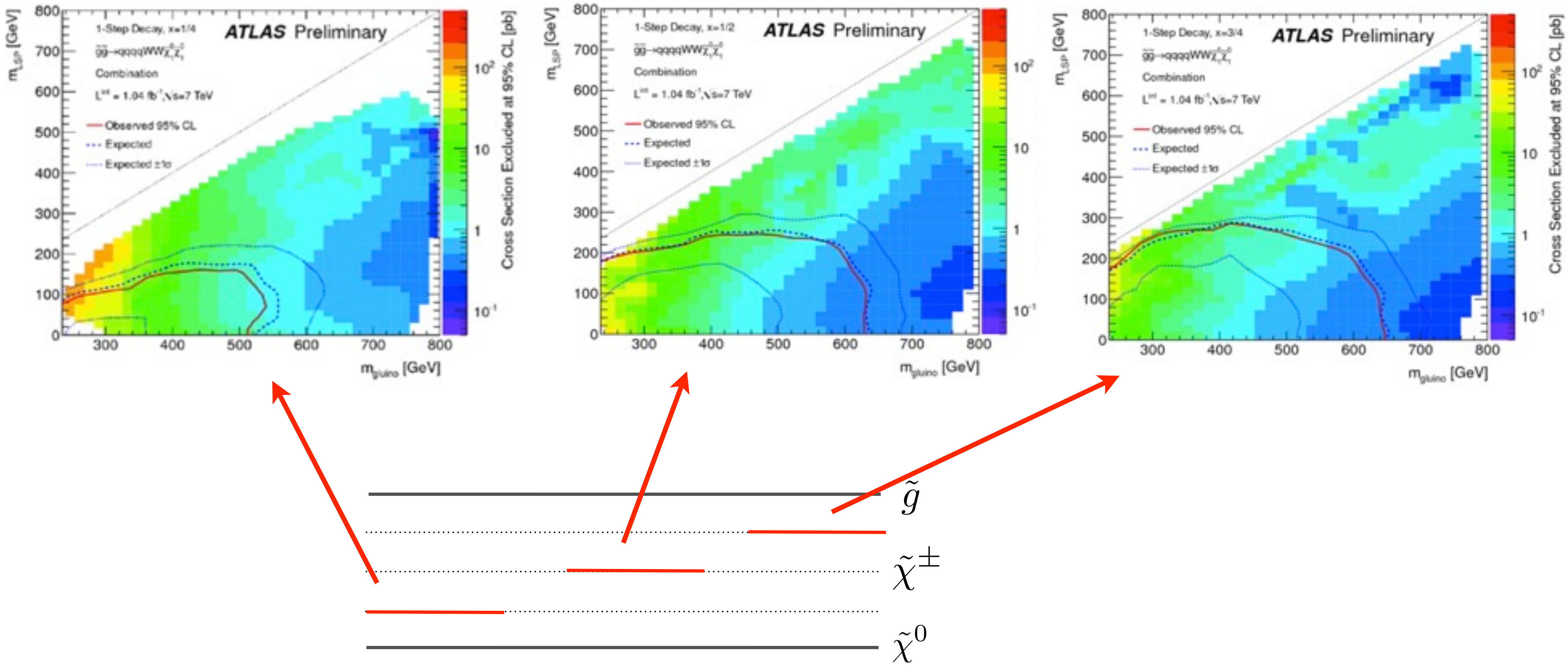
Covered in this talk (only prompt NLSP decays)

CMS/ATLAS search exists

Scenario-dependence

– heavier LSP // cascade decays –

Limits from 1-lepton search (see Renaud Bruneliere’s talk)



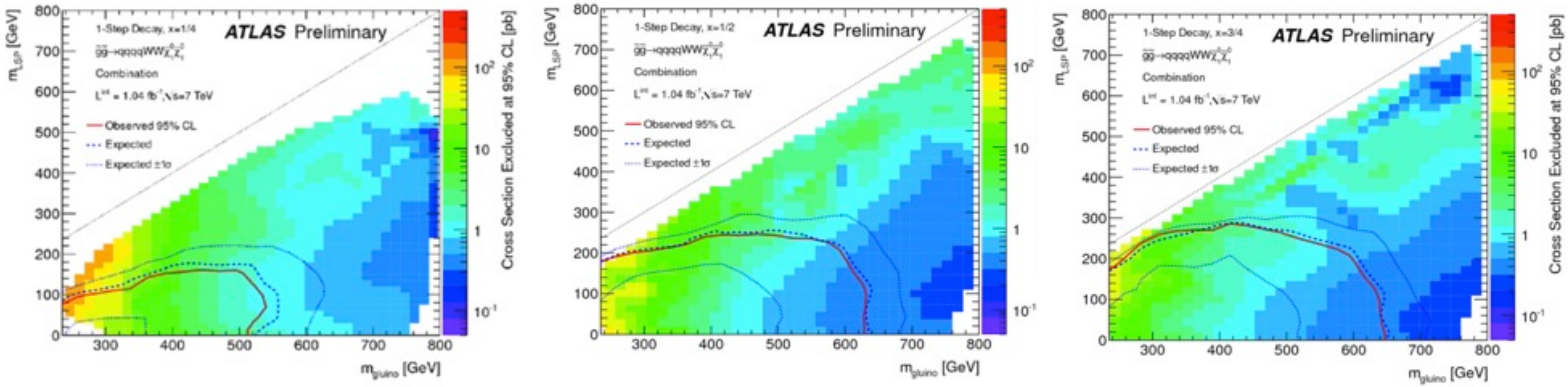
Light (x≈¼) charginos⇒ weakest limit (soft leptons?):

m_{gluino} > 550 GeV, **or** m_{LSP} >175 GeV (contrast 800 GeV and 275 for direct decay)

Scenario-dependence

– heavier LSP // cascade decays –

Limits from 1-lepton search (see Renaud Bruneliere's talk)



Same parameter space probed by hadronic search – here limited by lower MET at low x (nearby χ^0 and $\chi^{\pm}$), and softer jets for intermediate x.

> … in many cases, inaccessible "low" MET need not be buried below trigger thresholds, but **buried below systematics**.
> There is hope to probe this parameter range, but it isn't easy.

Scenario-dependence
– light 3rd-generation squarks –

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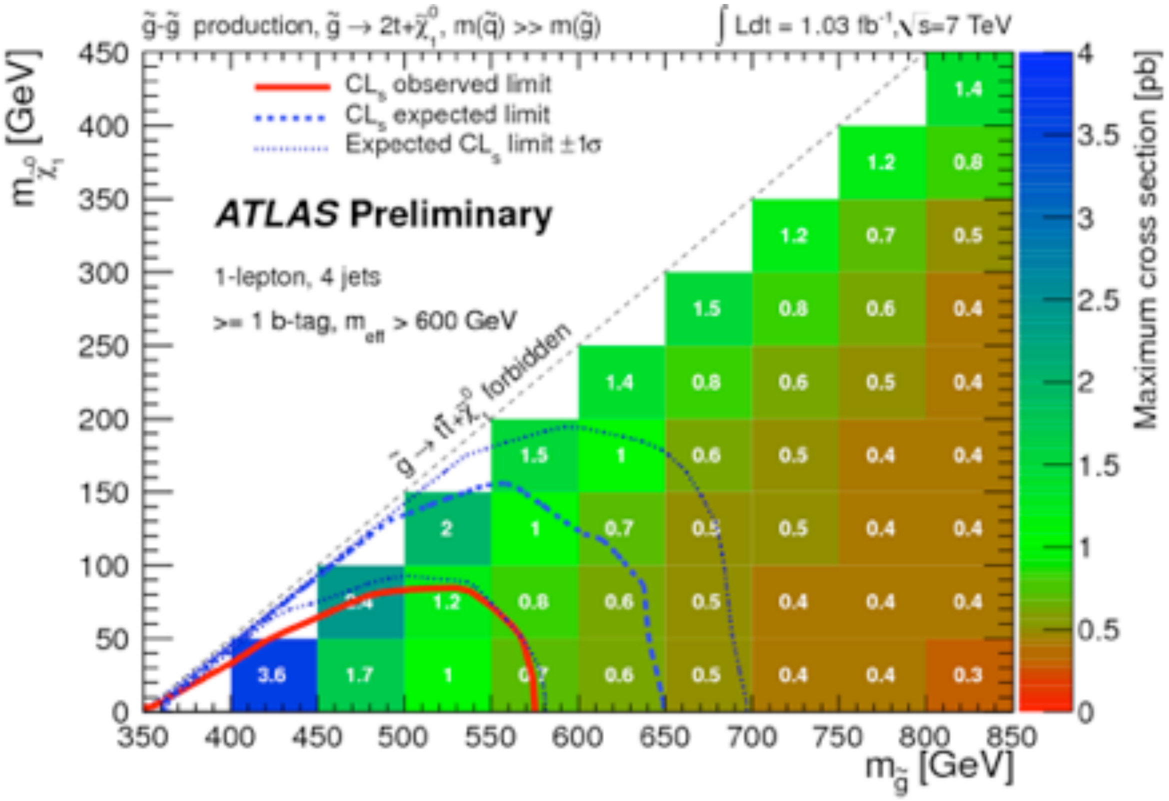

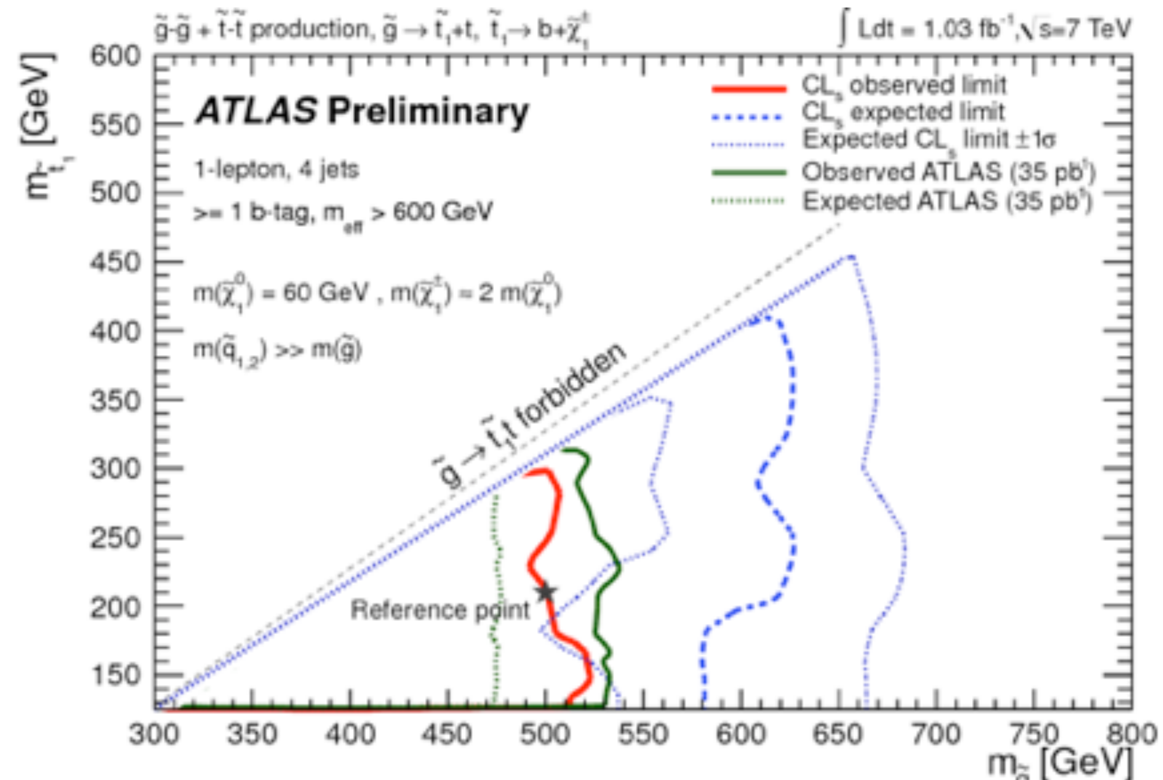

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As an example, the impact of a non-negligible BR in $t\tilde{\chi}_1^0$ is studied for a specific MSSM point with gluino mass of 500 GeV and stop mass of 290 GeV. In case of $b\tilde{\chi}_1^\pm$ decay mode only, the efficiency for gluino-pair production is found to be 3.2%, while in the case of $t\tilde{\chi}_1^0$ decays the efficiency is about 4%. For stop pair production, the increase in efficiency with respect to the $b\tilde{\chi}_1^\pm$ decay mode is found to be about 40% if both stops decay as $t\tilde{\chi}_1^0$. Since this decay mode is not considered in the interpretation of the results, conservative exclusion limits are set.

(at least in this kinematic regime, the difference *bW*+MET* vs. *t+MET* has only minor impact
...but LSP mass evidently significant)

Prejudice?

- Models where each of these topologies is "typical" have been discussed over the last 20+ years
  - proponents advertise each as "generic", while opponents call it "contrived" (a new HSBC ad for GVA?)

    We are learning step by step about what nature **isn't**. Figure of merit for what topologies to spend time on is

    (1) is it **reasonable**?

    (2) is it **non-trivial** (new signature or phase space)?

    i.e. exclud*able* but non-excluded regions

    A ***large*** collection of simplified models can form basis for wide-ranging model exclusion studies …

    but with data doubling frequently, this is far less vital than trying to expand the range of signatures explored

- Focus on areas where limits are weak

Scenarios with Light Stops

— motivation —

- Stop regulates 1-loop $\Rightarrow$ should be light
  - Separating from 1st, 2nd generations motivated by flavor
    Dimopoulos & Giudice 1995; Cohen, Kaplan, Nelson 1996; …
  - Realized in single-sector models w/ composite 1st, 2nd gen
    Arkani-Hamed, Luty, Terning 1997; Luty, Terning 1998; …

- The Price
  - Need to hide or lift higgs mass (more new physics e.g. nMSSM...)
  - Very heavy squarks or flavor symmetry to suppress FCNC
    concerns are surmountable (in multiple ways)
    e.g. Barbieri's talk

- LHC is **only starting** to directly test this scenario **– the limits are weak**

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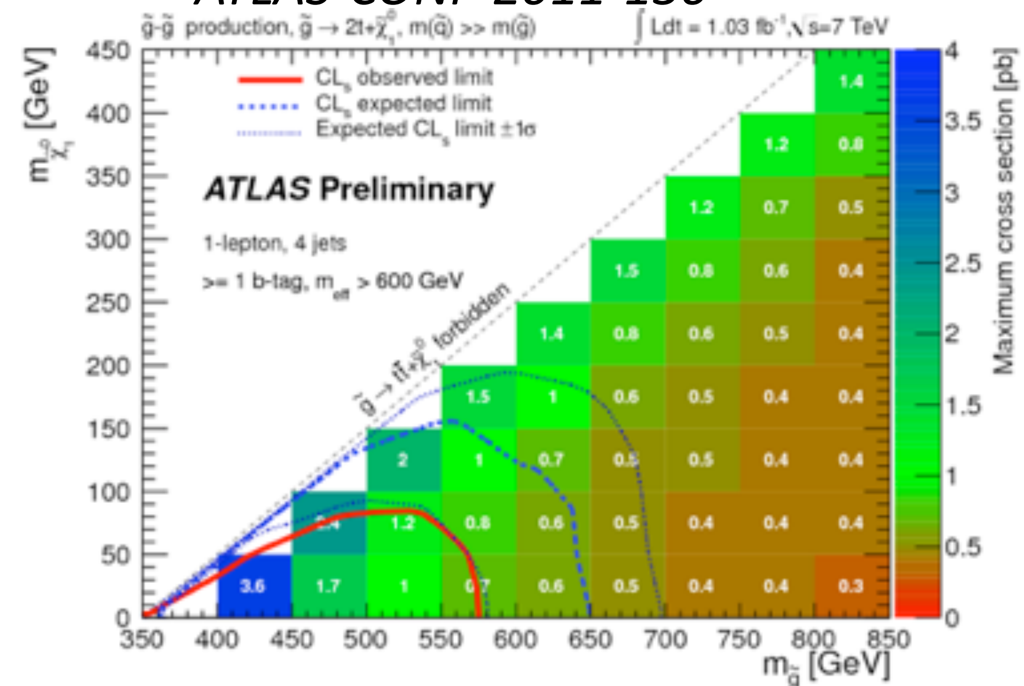


This search was "lucky" – is the expected power of other searches greater?

In general, I hope different searches can share some high-overlap "benchmark topologies" (e.g. gluino pair →4t + MET also shows up in jets+btag+MET, jets+0, 1, 2 lepton+MET)
It's useful to know where strongest limits come from

Probably not:

– $2t$-like decay ⇒ more/softer jets, less MET, moderate M_{eff}
⇒ harder to find in jets+MET

Physics process	σ · BR [nb]	
$W \to \ell\nu$ (+jets)	31.4±1.6	[20–22]
$Z/\gamma^* \to \ell\ell$ (+jets)	3.20±0.16	[20–22]
$Z \to \nu\nu$ (+jets)	5.82±0.29	[20–22]
$t\bar{t}$	$0.165^{+0.011}_{-0.016}$	[23–25]
Single top	0.085±0.003	[26,27]

4jets+MET

Process	≥ 4-jet, m_{eff} > 500 GeV	≥ 4-jet, m_{eff} > 1000 GeV
Z/γ+jets	208 ± 9 ± 37	16.2 ± 2.1 ± 3.6
W+jets	367 ± 30 ± 126	12.7 ± 2.1 ± 4.7
$t\bar{t}$+ single top	375 ± 37 ± 74	3.7 ± 1.2 ± 2.0
QCD jets	34 ± 2 ± 29	0.74 ± 0.14 ± 0.51
Total	984 ± 39 ± 145	33.4 ± 2.9 ± 6.3
Data	1118	40

(see I. Vivarelli EPS and ATLAS-CONF-2011-130 for full tables)

– For this signal, only top is irreducible
– Btag and m_T reduce background, allows looser M_{eff} and MET cuts
(600 GeV) (80 GeV)

4jets+tag+lepton+MET

top	48 ± 27
W+jets	3.1 ± 2.9
Z+jets	0.4 ± 0.3
diboson	0.2 ± 0.2
QCD (d-d)	0.9 ± 1.2
SM (MC)	52 ± 28
SM (d-d)	54.9 ± 13.6
data	74

Scenarios with Light Stops

— what next? —

- m_t isn't small – impact on kinematics needs to be explored (not a simple sector)
  - Combined effects of on-shell squarks and changing LSP mass
  - LSP with chargino partner (Wino or Higgsino) vs. Bino

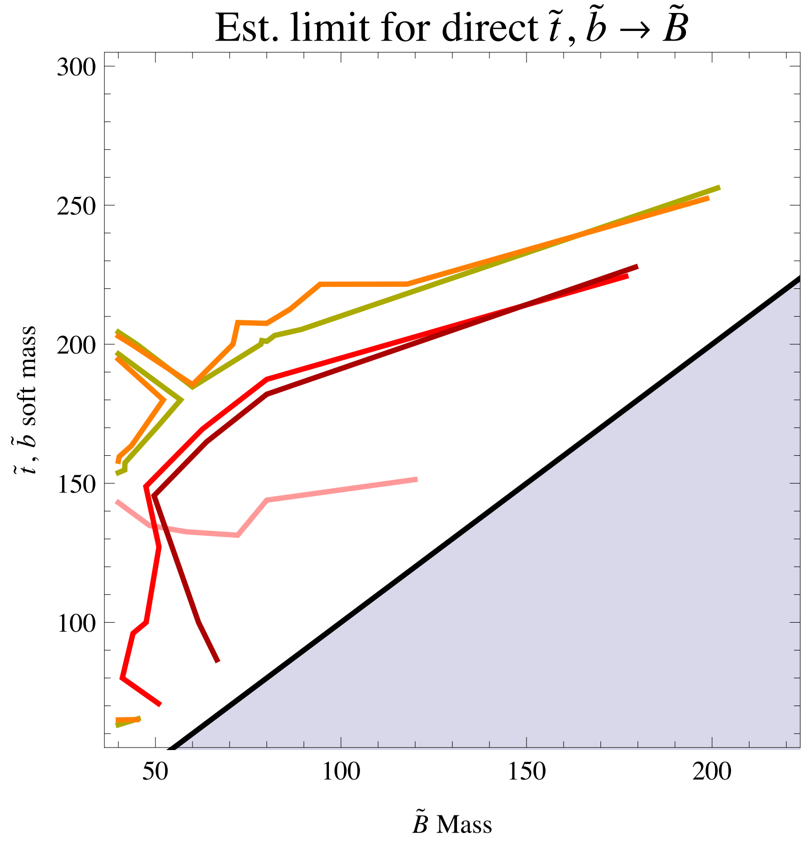
- Optimization on sbottom/stop direct production

  (and even quantifying existing searches' sensitivity)

- Moving towards combining channels for gluino → stop searches?

Direct Stop/Sbottom Constraints?

estimated direct stop/sbottom limits from ATLAS 2-4 jet searches at 1 fb^{-1}



(both stops and the left-handed sbottom are all taken to be light)

Dedicated search could likely improve reach

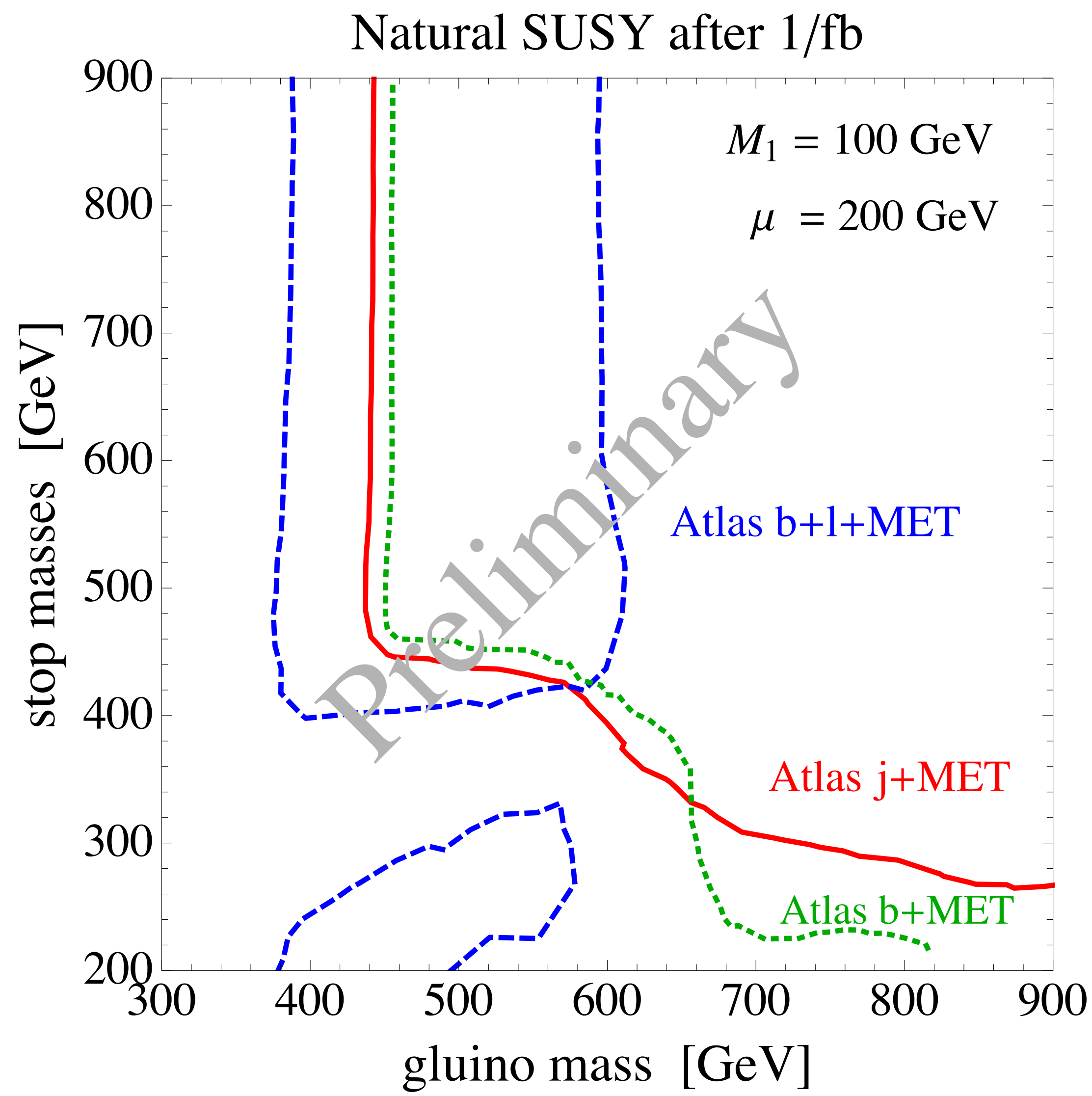
But already many searches and measurements likely constrain light stop/sbottom.

Are Natural-Looking Models OK?

- A look at one parameter space, with various processes and searches
- Preliminary study of one scenario:
  - μ=200 GeV
  - M_1=100 GeV
  - ($M_2 \gg M_3$ GeV)
  - ~q_{3L} and ~t_R light; other squarks ≥1.5 TeV
  - several but not all 1 fb^{-1} searches accounted for

  ATLAS jets+MET, bjets+MET, b+l+MET shown

  CMS jets+MET similar



Making Contact with Nature

- Both ATLAS and CMS have presented broad and aggressive arrays of new-physics searches with MET
- Simplified model interpretations have accentuated when these searches are applicable, and what signature/model regions require further study
- While reaching up in mass, reach out as well!
  - direct stop/sbottom and even weakino production
  - squeezed spectra
  - stop-rich gluino decays

  Low energy supersymmetry is still a possibility (with some heavier partners) – the scenarios that remain unconstrained are important ones to wrestle with!
- (low-MET possibilities, which I've omitted, also deserve some thought)