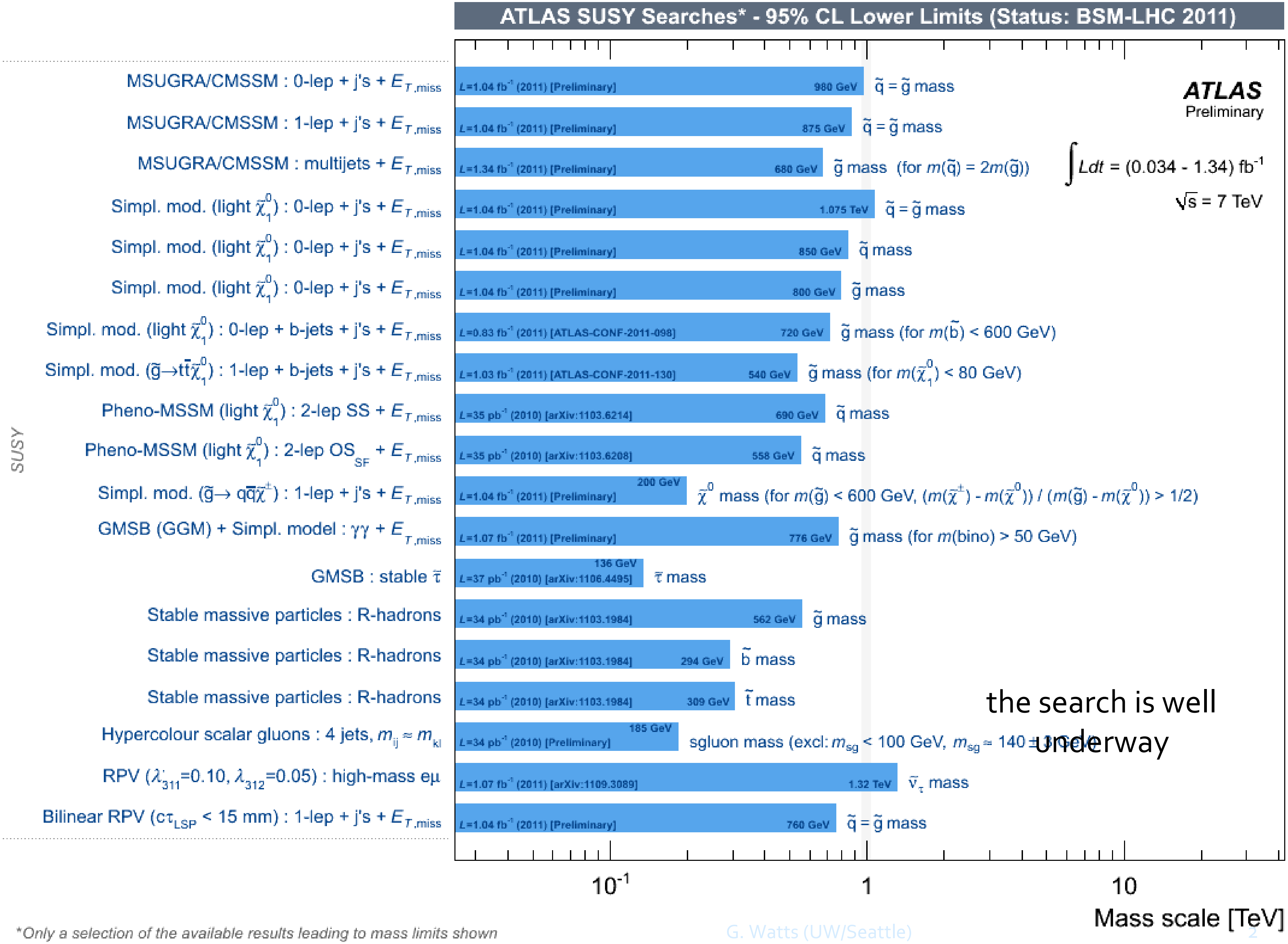
ATLAS – HIDDEN SUSY



the search is well underway

we've seen nothing

where is it?

hiding at a higher scale	→	wait for $\sqrt{s}$ increase (2014/2015)
normal, but low σ	→	wait for more data (HCP, winter for 5 fb^{-1})
already there	→	better search strategies

concentrate on "hidden" searches for this talk

better catalogs of models
better triggers
better offline searches

SUSY with out prejudice

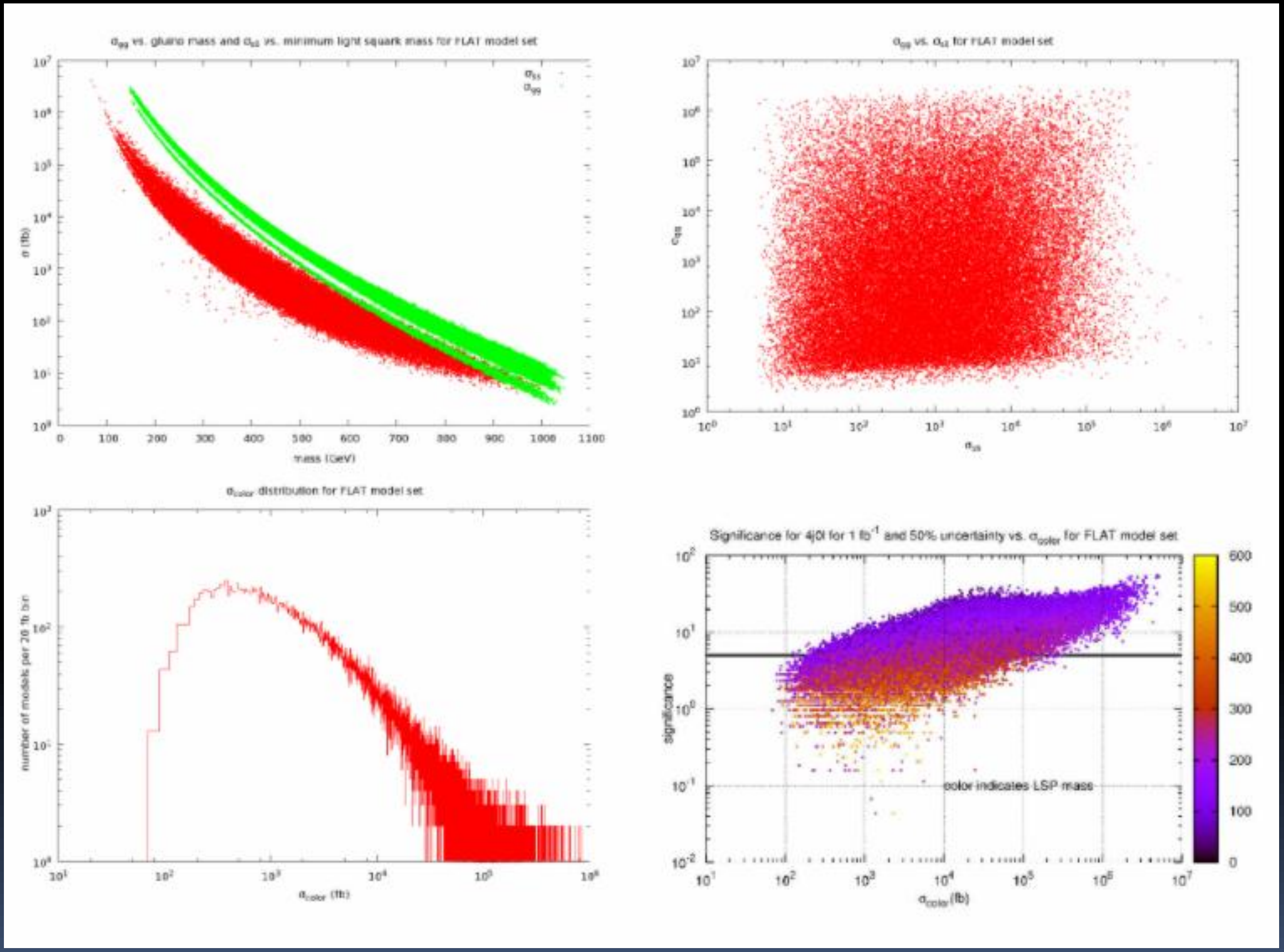
large range of models examined

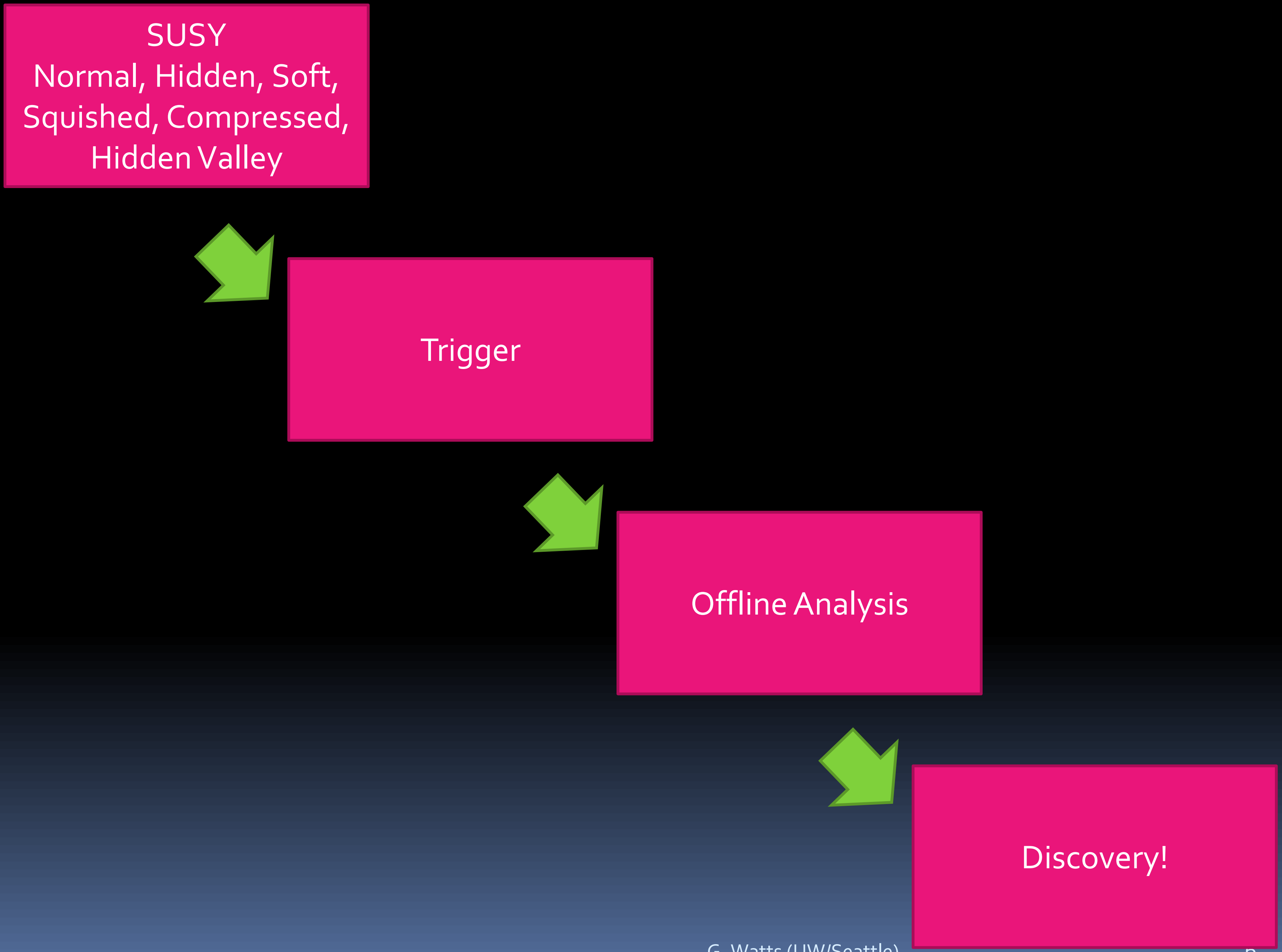
gaps!

or…

simplified models

for hidden senarios




SUSY
Normal, Hidden, Soft, Squished, Compressed, Hidden Valley
Trigger
Offline Analysis
Discovery!

triggering is grim…

… and getting grimmer

bunch spacing, protons in bunch, beam tunes and focus

your favorite trigger squeezed here

rate limit driven by $$ disk, cpu, etc.

unprescaled @ end of 2011

em: 1e@22, 2e@12, 1e@12+2e@6, 1γ@80, 2γ@20, 1e@20+$E_T^{miss} > 40$

muon: 1μ@18, 1μ@40sl, 1μ@15+1μ@10, 1μ@15+$E_T^{miss} > 30$

tau: 1τ@125, 1τ@29+1τ@20, 1τ@29+$E_T^{miss} > 35$

jets: 1j@250, 3j@100, 4j@45, 5j@30, 1j@75+$E_T^{miss} > 55$, 1j@100+$H_T > 400$, 4j@40+$H_T > 350$

combo: 1μ@18+1j@10, 1e@5+1μ@6, 1τ@20+1e@15, 1τ@20+1μ@15

long lived particle triggers

b-tagging triggers

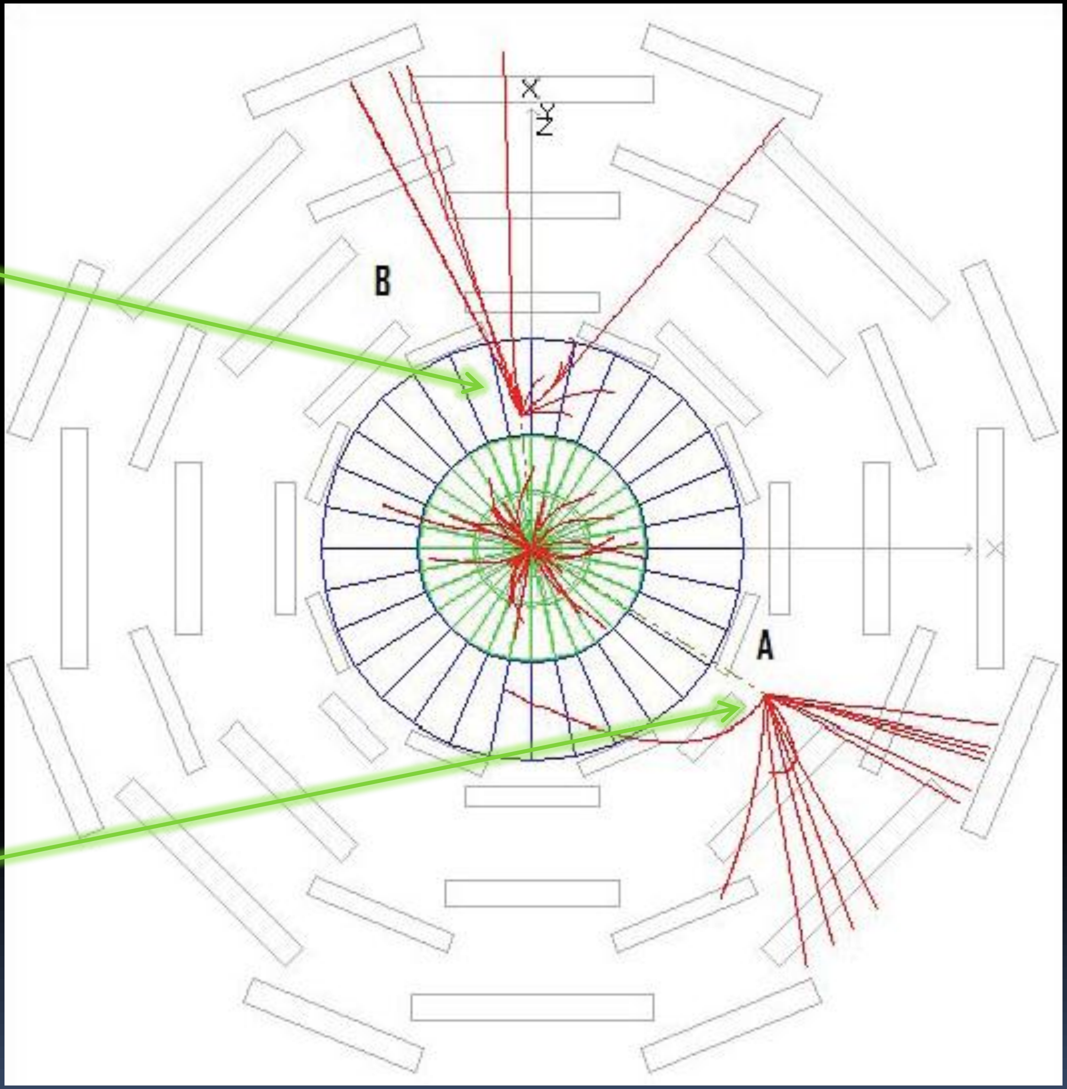
- good for a decay a few millimeters from primary vertex
- commissioned
- not used in any analysis currently

Long Lived Neutral Particle Triggers

- neutral particle decays mid-detector
- appearance trigger
- run for full 2011 dataset (5 fb^{-1})

calorimeter

muon spectrometer



3 triggers

trackless jet trigger

- jet $E_T > 35$ GeV
- no tracks with $p_T > 1$ GeV near jet
- muon spectrometer activity
- low efficiency

decays in inner detector

$\log(E_{had}/E_{EM})$

- jet $E_T > 35\ GeV$
- no tracks with $p_T > 1$ GeV near jet
- $\log(E_{had}/E_{EM}) > 1.0$
- very good efficiency

decays beyond the EM calorimeter

muon spectrometer cluster trigger

- three RoI clusters all close by
- no jets
- no tracks
- really very good efficiency

decays beyond the hadronic calorimeter

offline analysis

standard SUSY analyses

jets $p_T > 50$ GeV
electrons $p_T > 10 - 20$ GeV
muons $p_T > 10 - 20$ GeV
$E_T^{miss} > 50$ GeV

non-standard SUSY searches

highly ionizing particles
displaced vertices
kinked tracks
stopped particles

stable massive particles

color charge, subluminal → time-of-flight, ionization

use calorimeter for electrically neutral R-hadrons

SUSY
UED

pixels: dE/dx
tile calorimeter: time of flight $(0.3 < \beta < 1.0)$

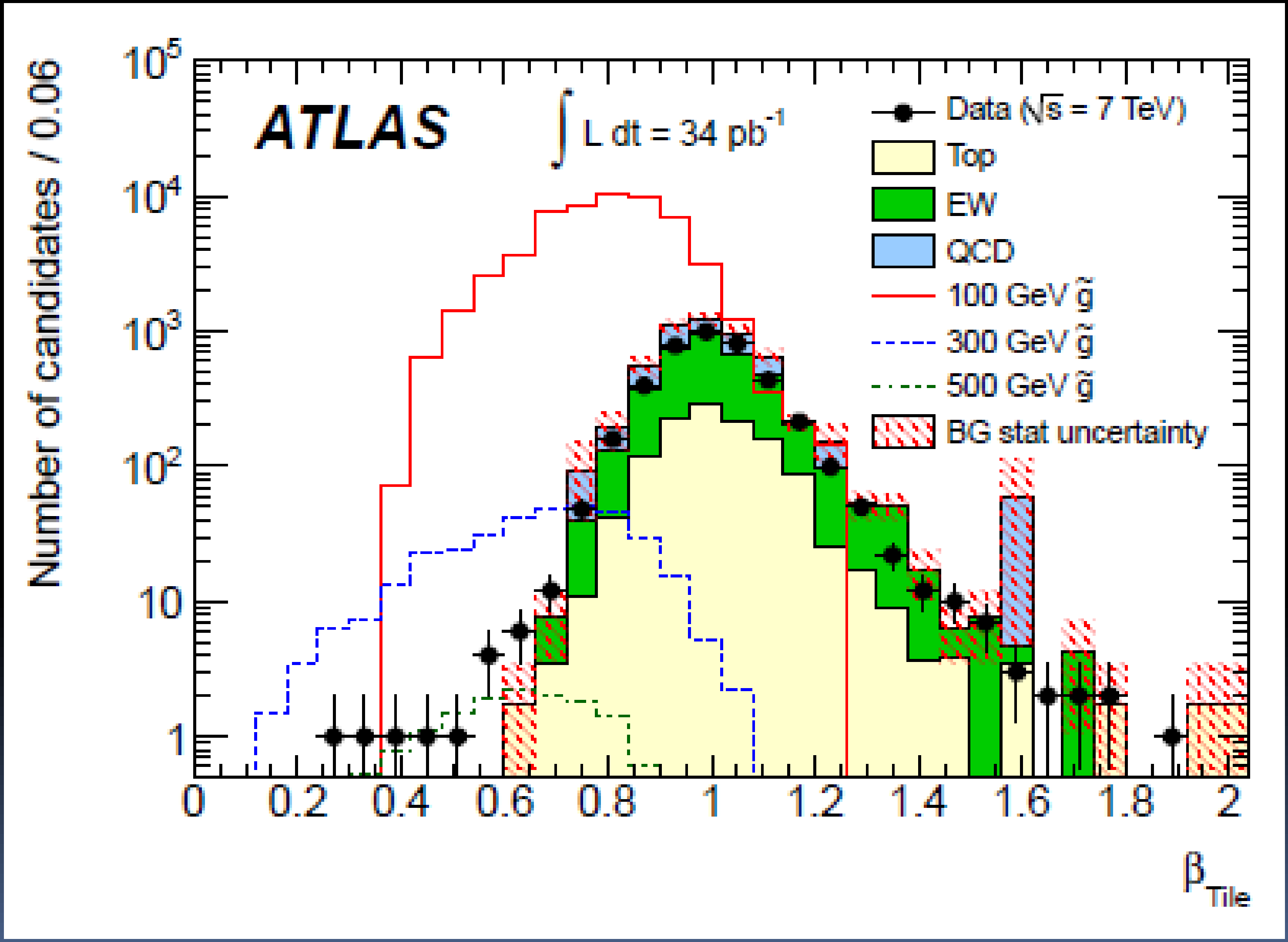
L=$34pb^{-1}$

trigger on calorimeter $E_T^{miss} > 40$ GeV

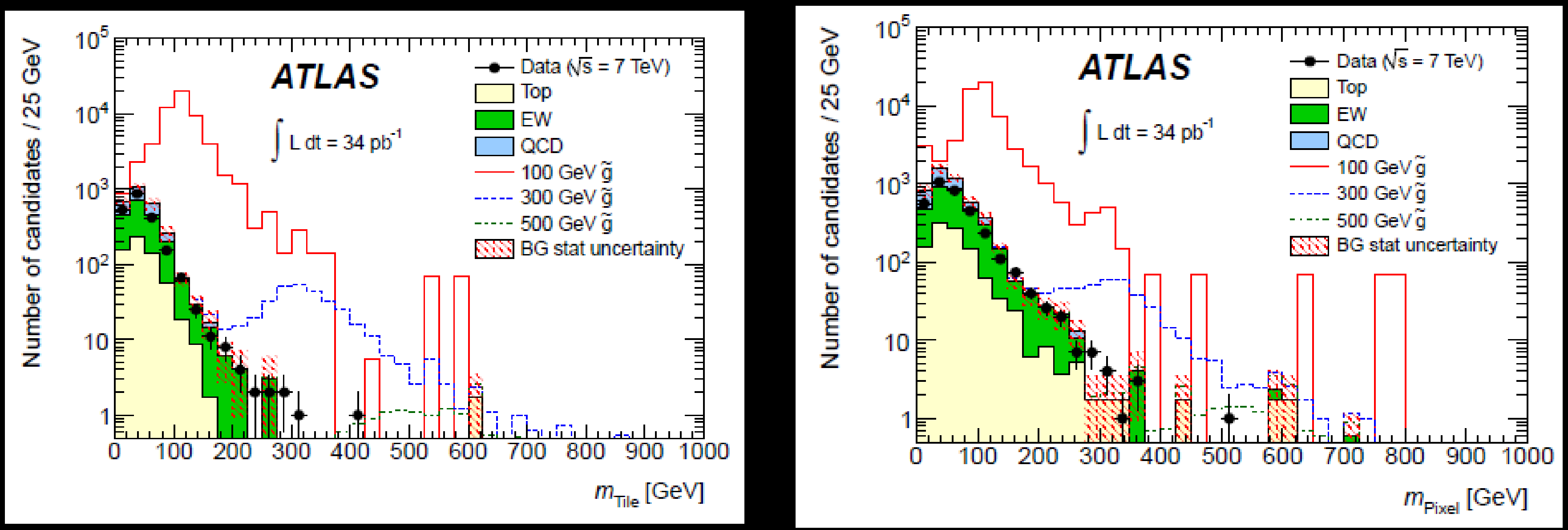
Cut level	Data	Background	300 GeV $\tilde{g}$	500 GeV $\tilde{g}$	600 GeV $\tilde{g}$	200 GeV $\tilde{t}$	200 GeV $\tilde{b}$
No cuts	-	-	2.13×10^3	80.4	21.8	405	405
Trigger	-	-	616	25.6	6.96	109	108
Candidate	75466	68.0×10^3	416	17.6	4.80	87.4	67.9
Vertex	75461	68.0×10^3	416	17.6	4.80	87.4	67.9
$\|\eta\| < 1.7$	64618	60.5×10^3	364	15.7	4.32	75.2	56.8
Track quality	59872	58.1×10^3	355	15.3	4.20	73.3	54.9
$\Delta R > 0.5$	49205	49.4×10^3	349	15.1	4.13	72.7	54.5
$p_T > 50$ GeV	5116	6.56×10^3	330	14.5	3.95	68.9	50.0
Mass preselection	36	56.0	184	9.70	2.75	32.6	18.9
Final selection	-	-	173	9.17	2.62	30.6	17.5

mass from ionization or from time of flight

stable massive particles



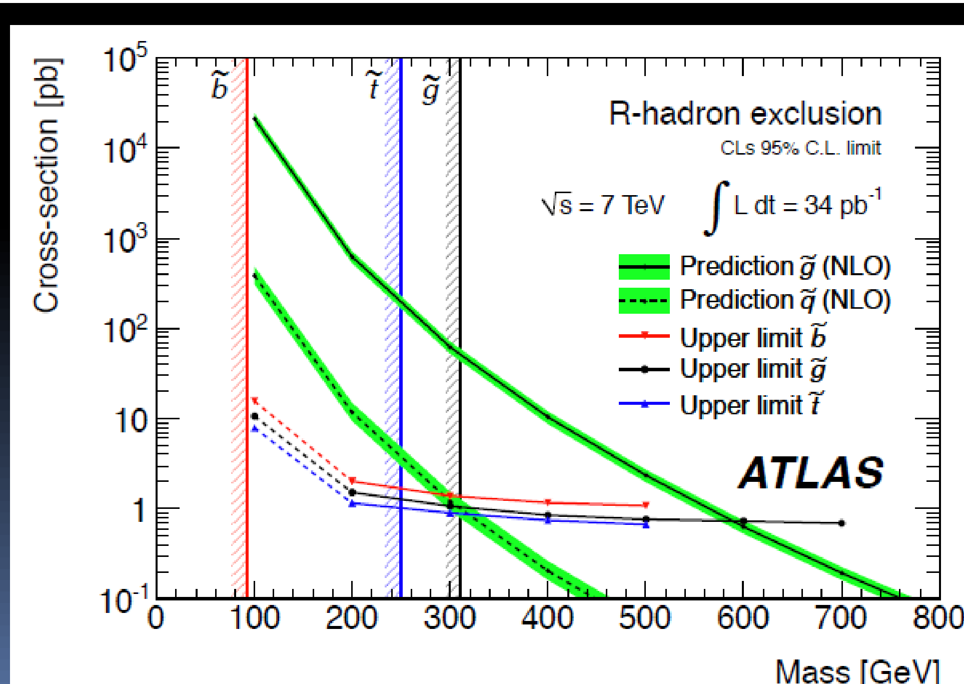
stable massive particles



mass estimates must be compatible

stable massive particles

Nominal mass (GeV)	μ_{Pixel} (GeV)	σ_{Pixel} (GeV)	μ_{Tile} (GeV)	σ_{Tile} (GeV)	No. of signal cand. ($\tilde{g}$) Pixel	Tile	Comb.	Est. no. of bkg. cand. Pixel	Tile	Comb.	N_{Data} Comb.
100	107	10	109	19	15898	49300	13912	61	330	5.4	5
200	214	24	211	36	1417	2471	1235	19	61	0.87	0
300	324	40	315	56	202	304	173	6.5	17	0.22	0
400	425	67	415	75	43	57	37	3.4	7.2	0.082	0
500	533	94	513	106	11	13	9.2	1.82	4.4	0.044	0
600	641	125	624	145	3.1	3.5	2.6	1.08	3.2	0.028	0
700	727	149	714	168	0.99	1.07	0.84	0.74	2.1	0.018	0



Stable, charged (μ-based)

electrically charged by the time they leave the calorimeter

GMSB SUSY

- charged, long lived particles
- colored, but interact in calorimeter leading to a spray of charged particles in the muon spectrometer

L=37 pb^{-1}

trigger is the muon drift tube

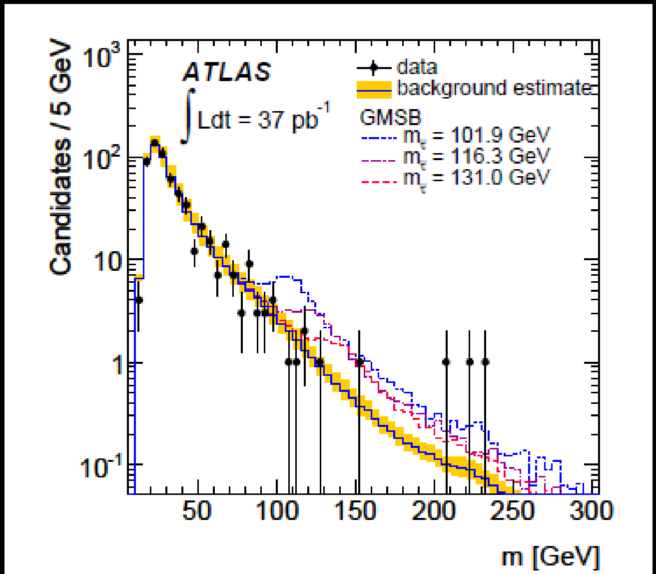
reconstruction method 1:

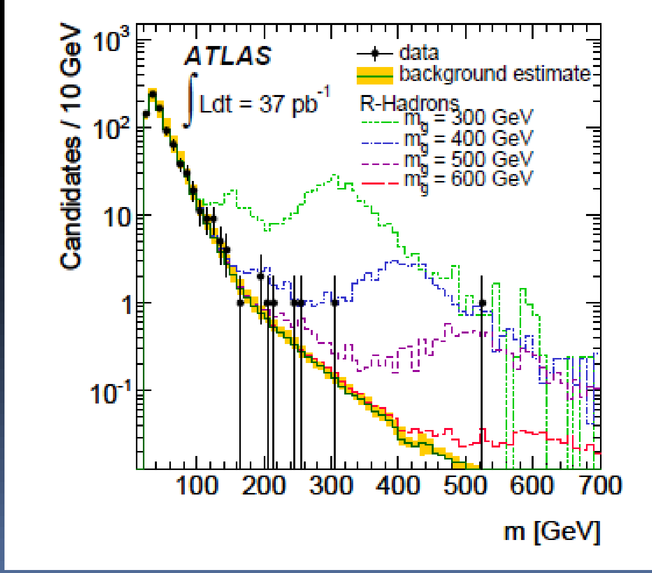
- fit inner detector track to imperfect muon spectrometer segments
- take into account β which alters drift time
- sub-par muon spectrometer segments also used

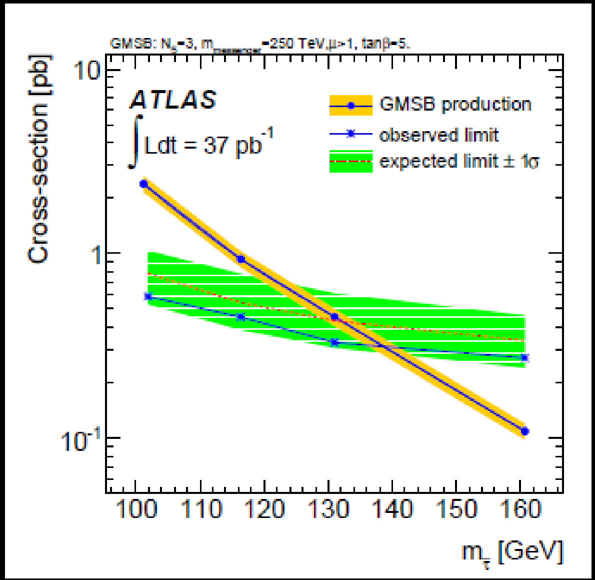
reconstruction method 2:

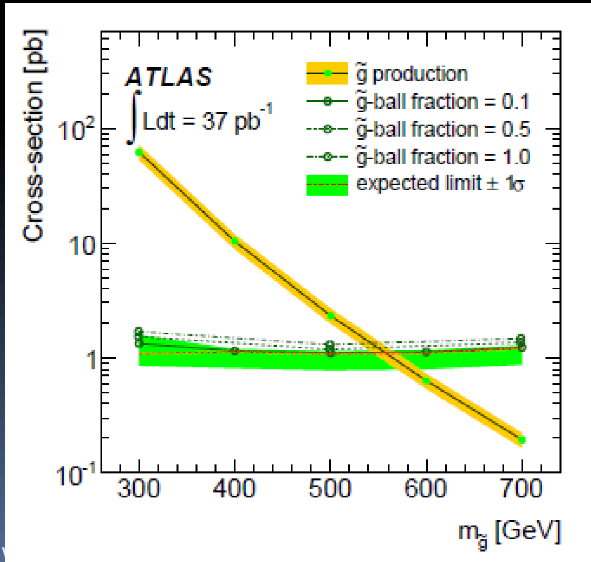
- muon spectrometer based only
- segment reconstruction starts from trigger information
- efficiency is not great for low β.

Stable, charged (μ-based)





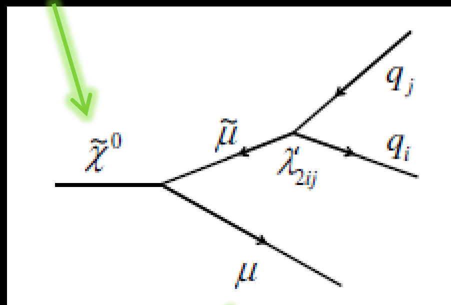




scale [2]. Additional scenarios allowing for such a signature include split-supersymmetry [3], hidden-valley [4], dark-sector gauge bosons [5], stealth supersymmetry [6], or a meta-stable supersymmetry-breaking sector [7].

displaced vertices

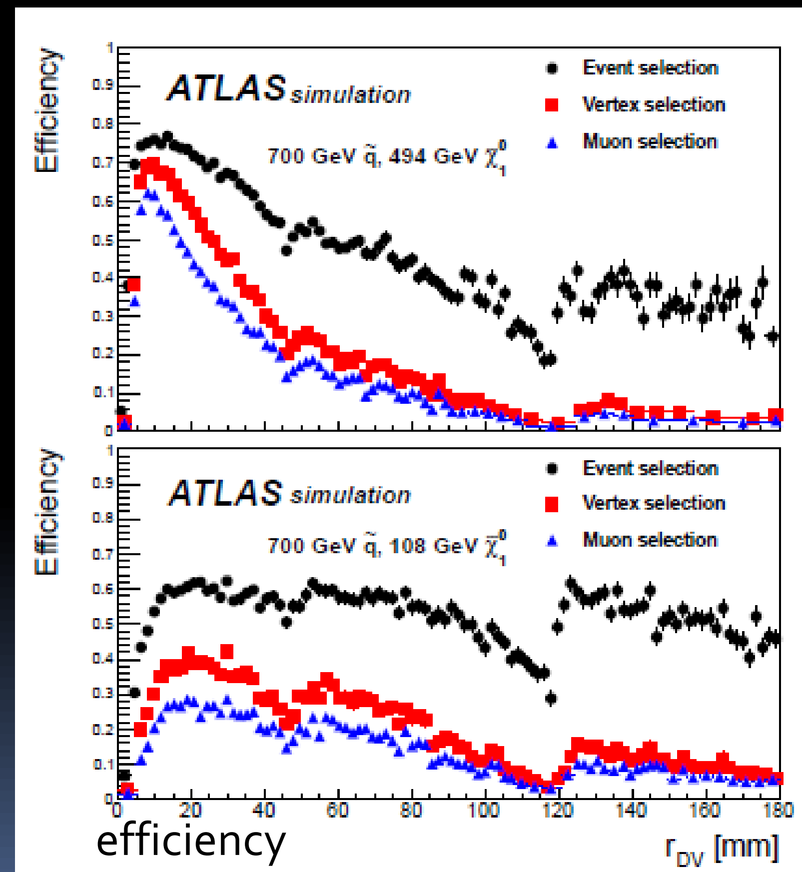
displaced vertex



trigger

SUSY++

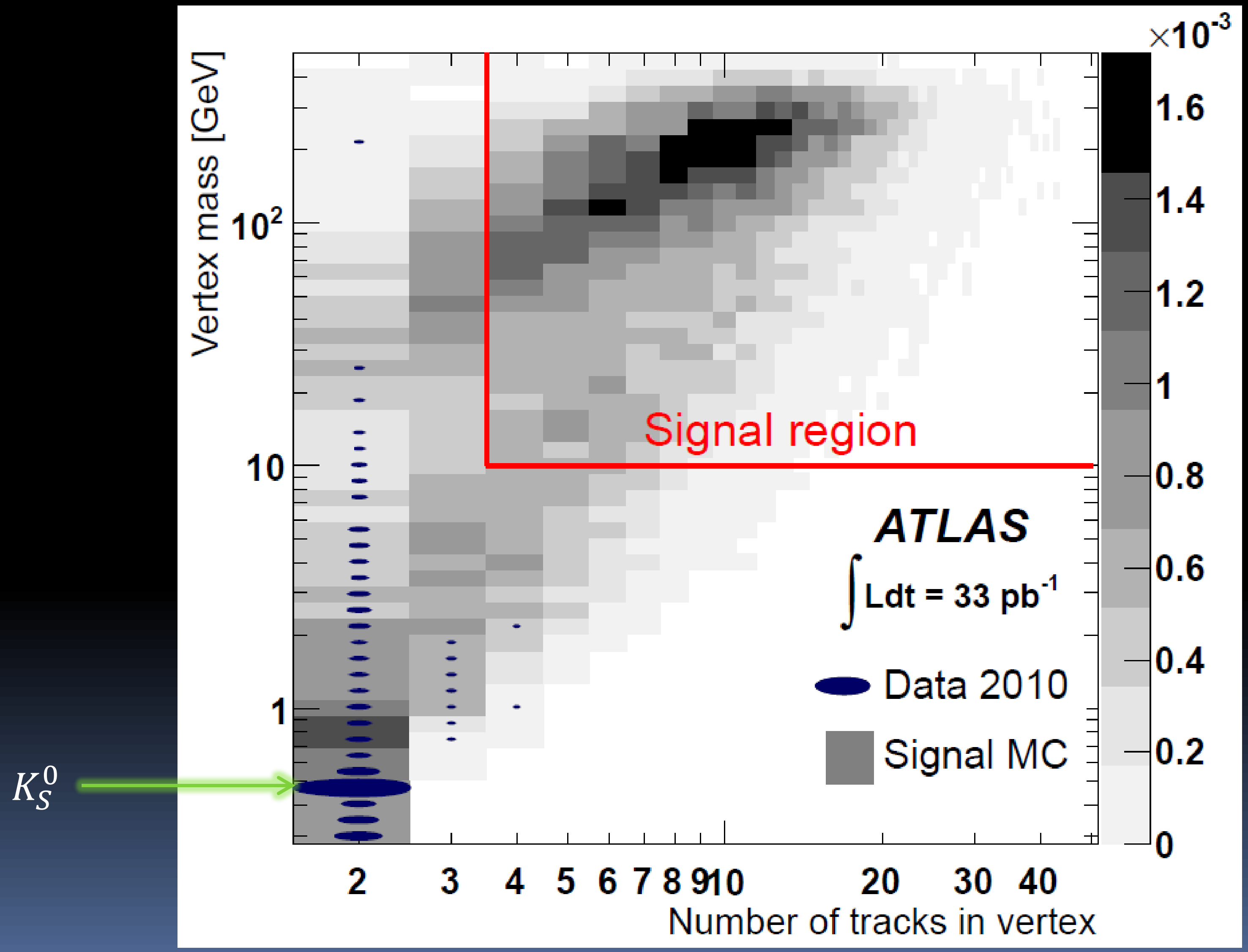
L=33 pb^{-1}



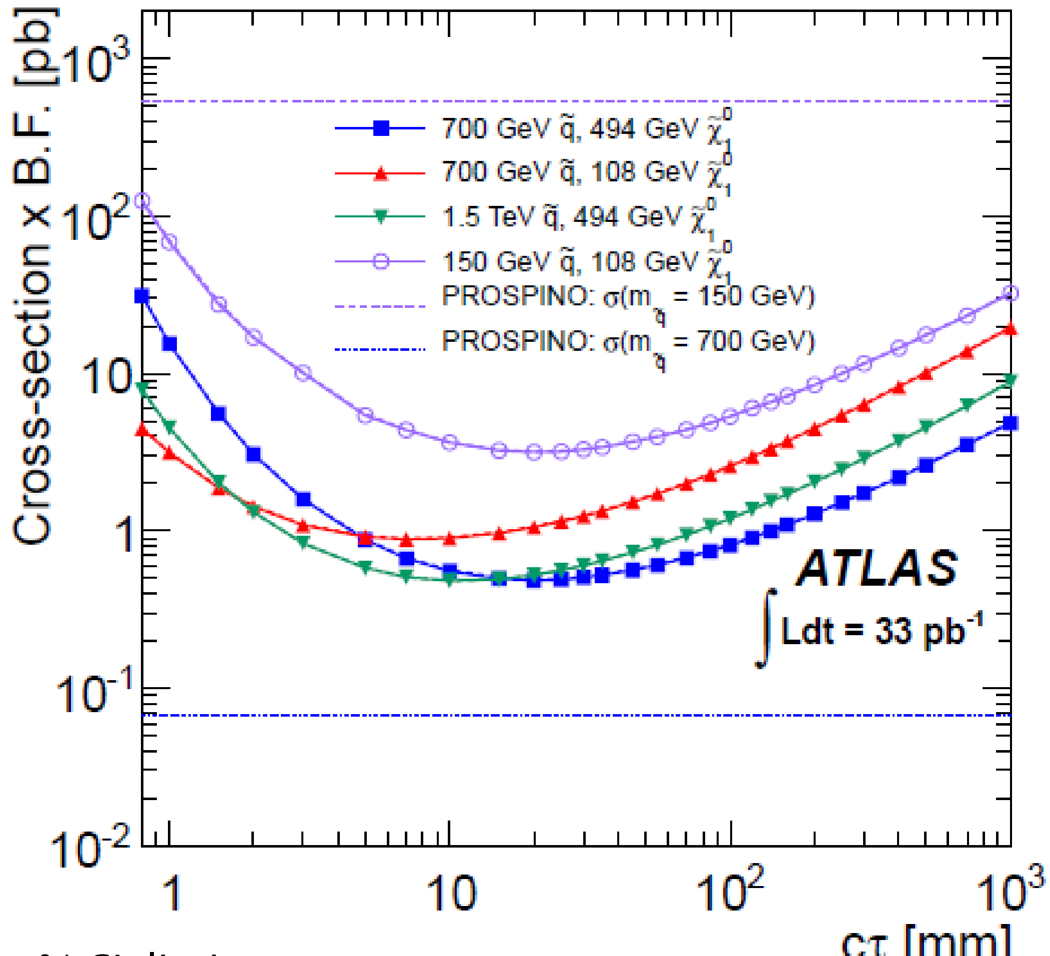
vertex reconstruction

- standard
- use tracks that have no pixel hits
- reject vertices near material

displaced vertices



displaced vertices

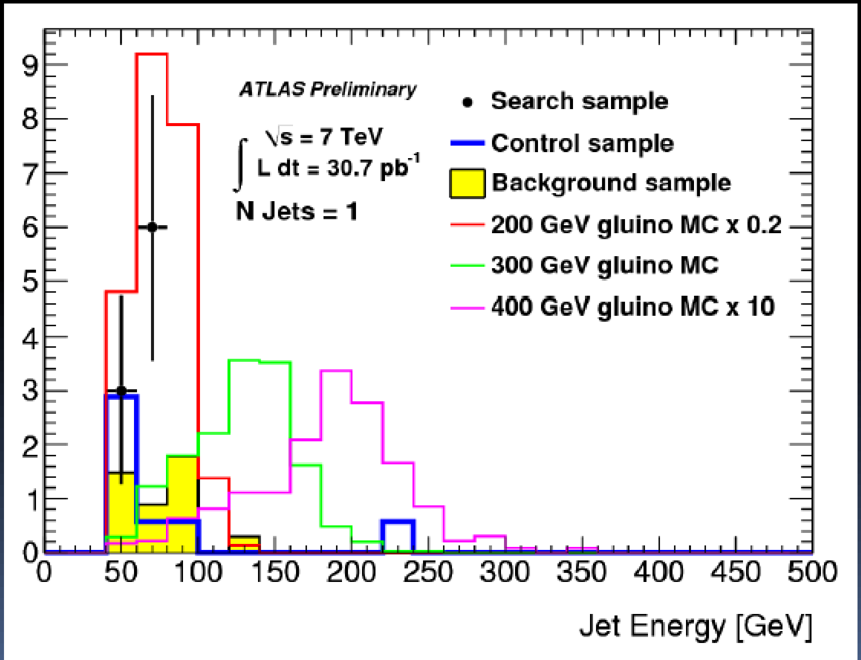


95% CL limit

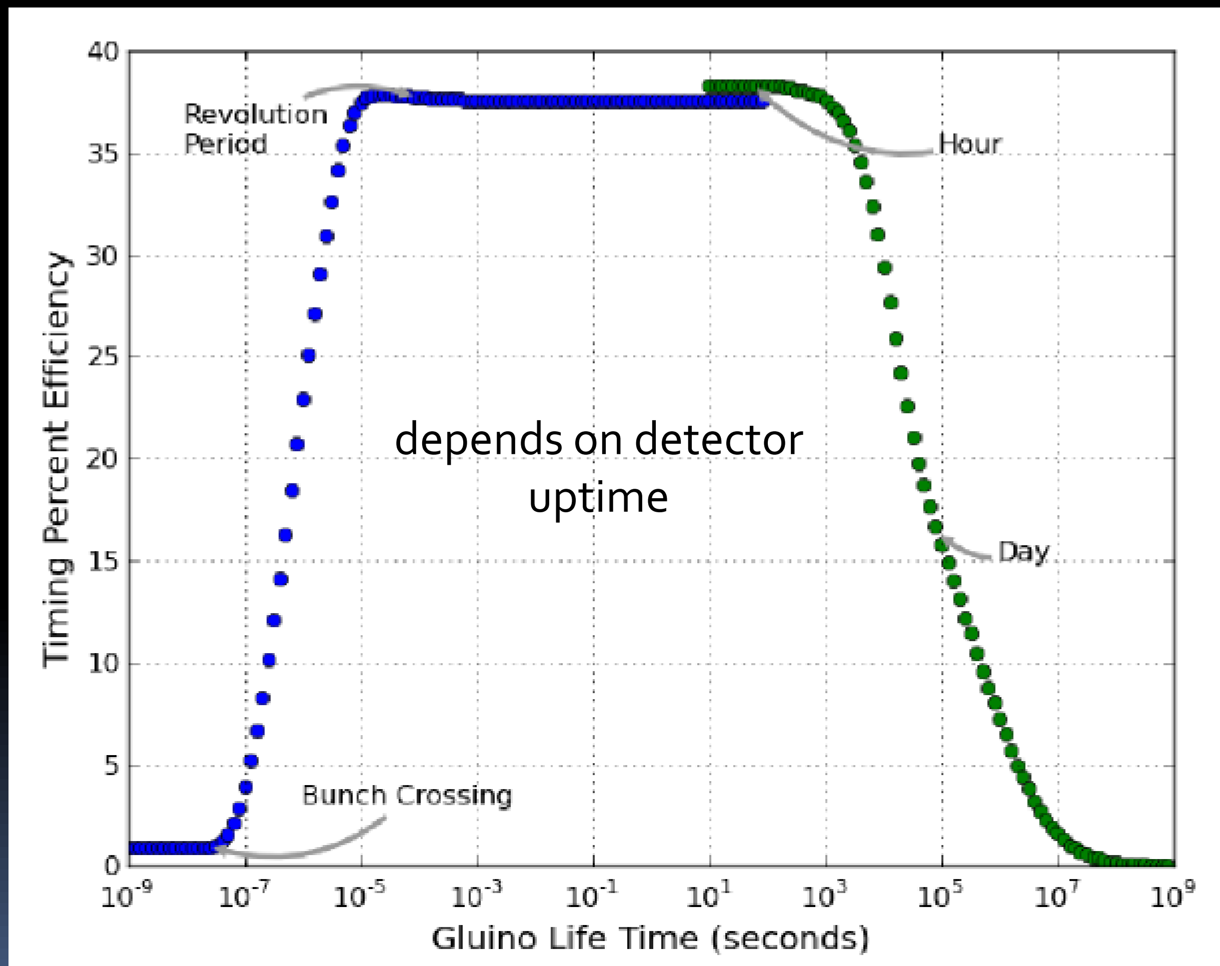
stopped particles

- Long-lived particles produced with low β can stop in detector material and decay much later.
- Most likely to stop in densest part of ATLAS $\Rightarrow$ calorimeters.
- Look for events with large energy deposits in calorimeter in "empty" bunches.

backgrounds: calorimeter noise, cosmics, beam-halo



stopped particles



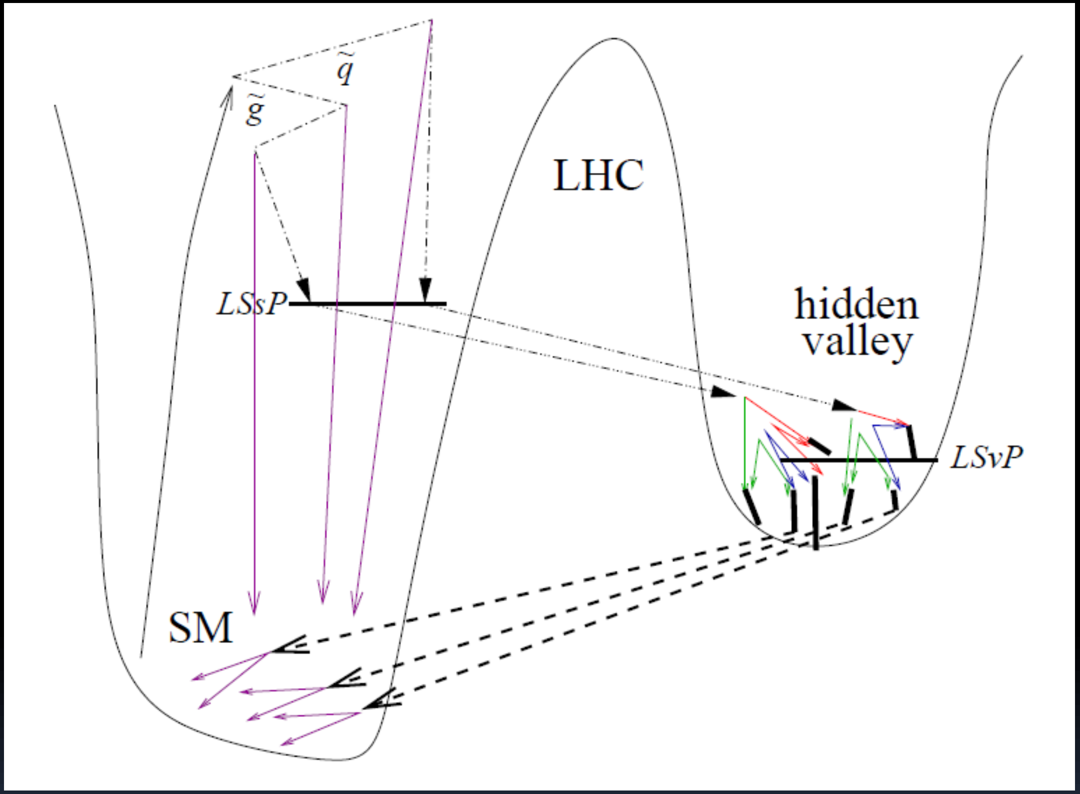
limits soon…

hidden valley SUSY

LSP is in the HV sector

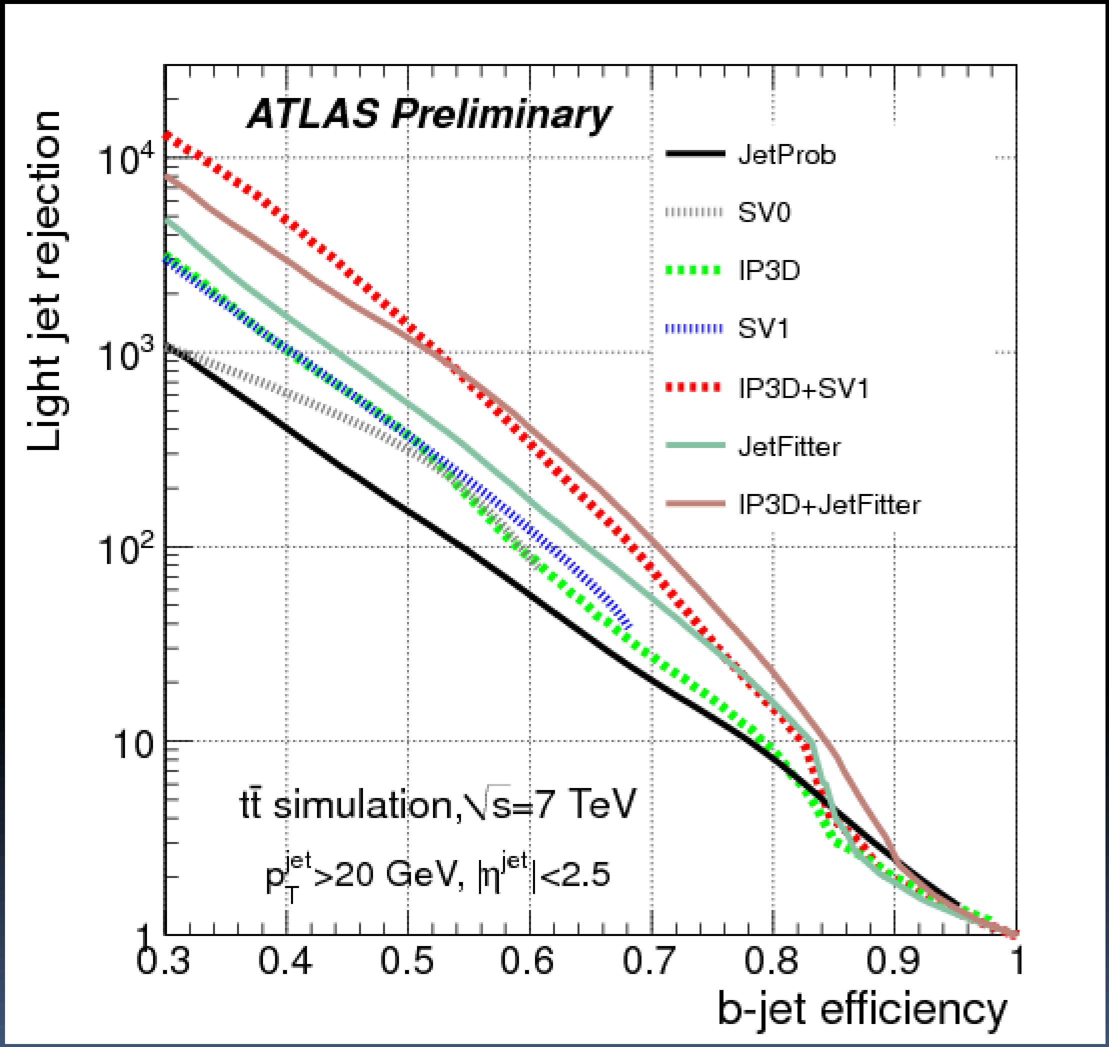
result are long lived decays in the detector

analysis technique is a riff on the long lived triggers



b-tagging

big improvements coming

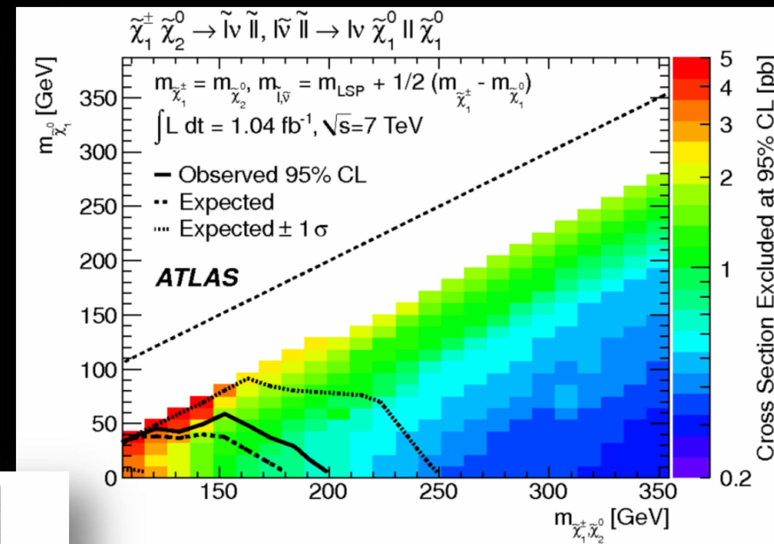


conclusions

- lots of information from the ATLAS detector
- can be used in new ways to help with some corners of SUSY parameter space
  - if we can figure out how to control backgrounds!
- new results at HCP with $2 - 3fb^{-1}$ and $5fb^{-1}$ for winter conferences
- improving algorithms all the time
- other results out there
  - e.g. squashed SUSY reinterpretation

2 leptons, E_T^{miss}

leptons: =2 e, μ (both ss/os)
jets: Bin in # of jets (up to 8)
$p_T > 55{,}80$ GeV
$\frac{E_T^{miss}}{\sqrt{H_T}} > 3.5$ GeV
luminosity: 1.34 fb^{-1}
r parity conserving



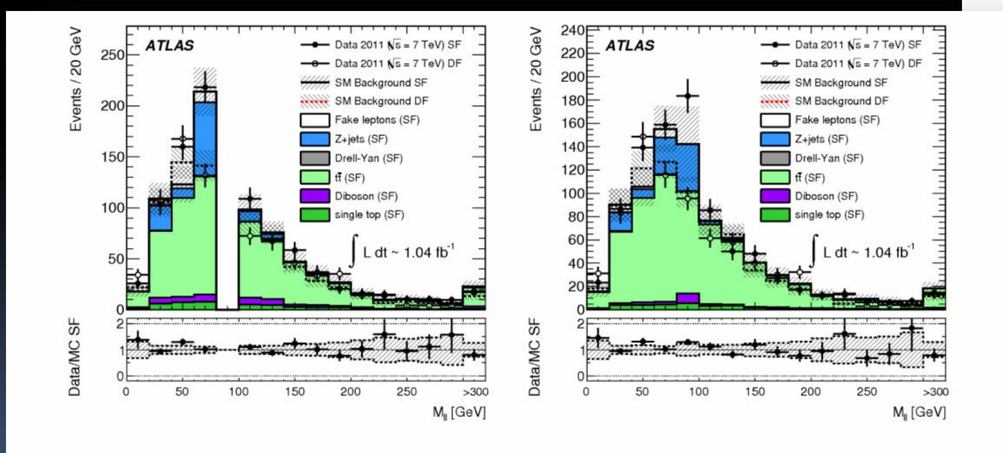
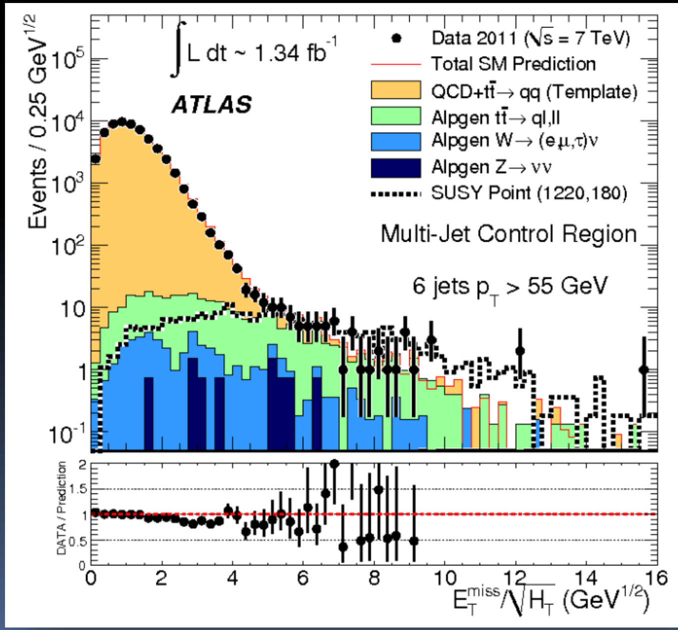
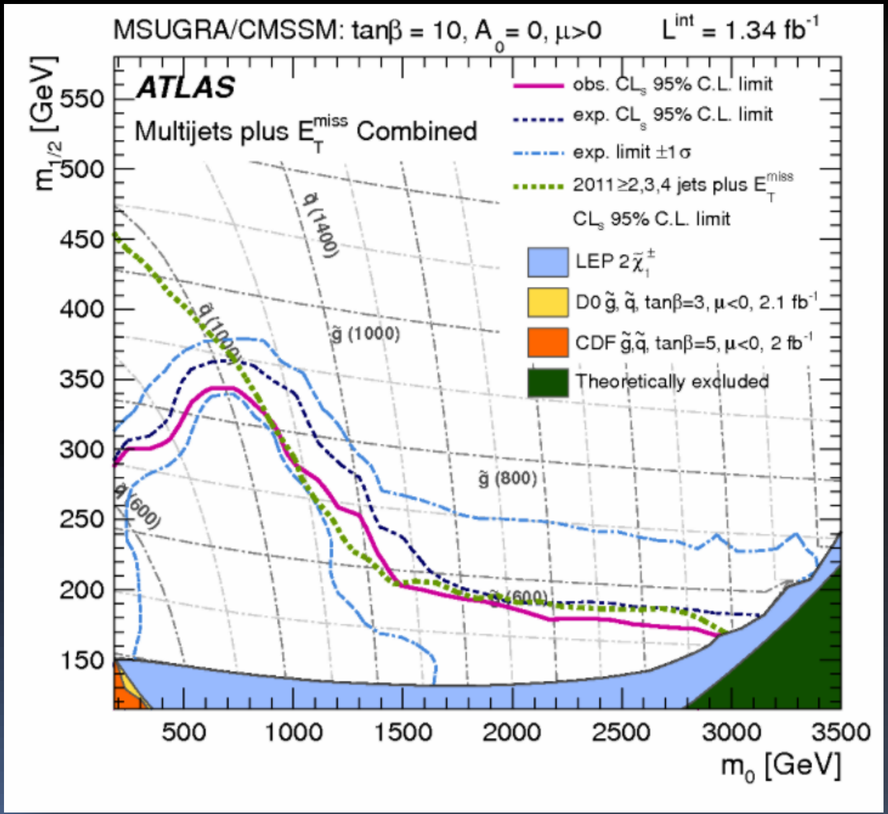


Figure 3: Distributions of the invariant mass in data together with the SM expectation for same-flavour (SF) dilepton events with $E_T^{miss} >$ 80 GeV after a Z-veto requirement (FS-SR1) (a) and 2-jet requirement (FS-SR2) (b). Also shown are the different-flavour (DF) distributiosn. Errors on data points are statistical, while the error bands on the SM predictions represent the total uncertainties.

Large # Jets, E_T^{miss}

leptons: =0 e, μ with $p_T^e > 20$ GeV, $p_T^\mu > 10$ GeV
jets: 0-4, $p_T > 40 - 100$ GeV
E_T^{miss} used as the limit setting variable
luminosity: 1 fb^{-1}
r parity conserving





1 lepton, jets, E_T^{miss}

leptons: =1 e, μ

$p_T^e > 20$ GeV, $p_T^\mu > 10$ GeV

jets: 3, $p_T > 60$ GeV, $E_T^{miss} > 125$

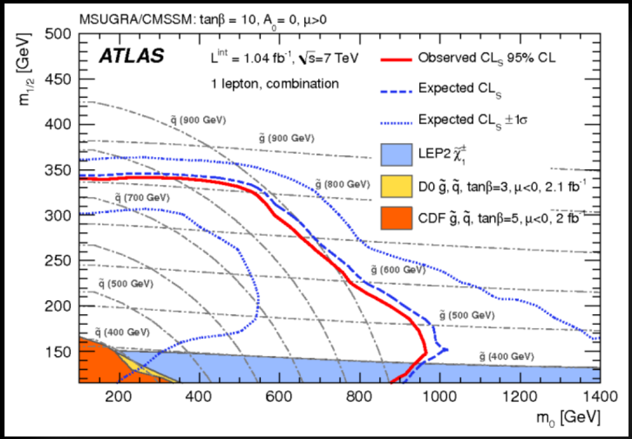
3, $p_T > 80$ GeV, $E_T^{miss} > 240$

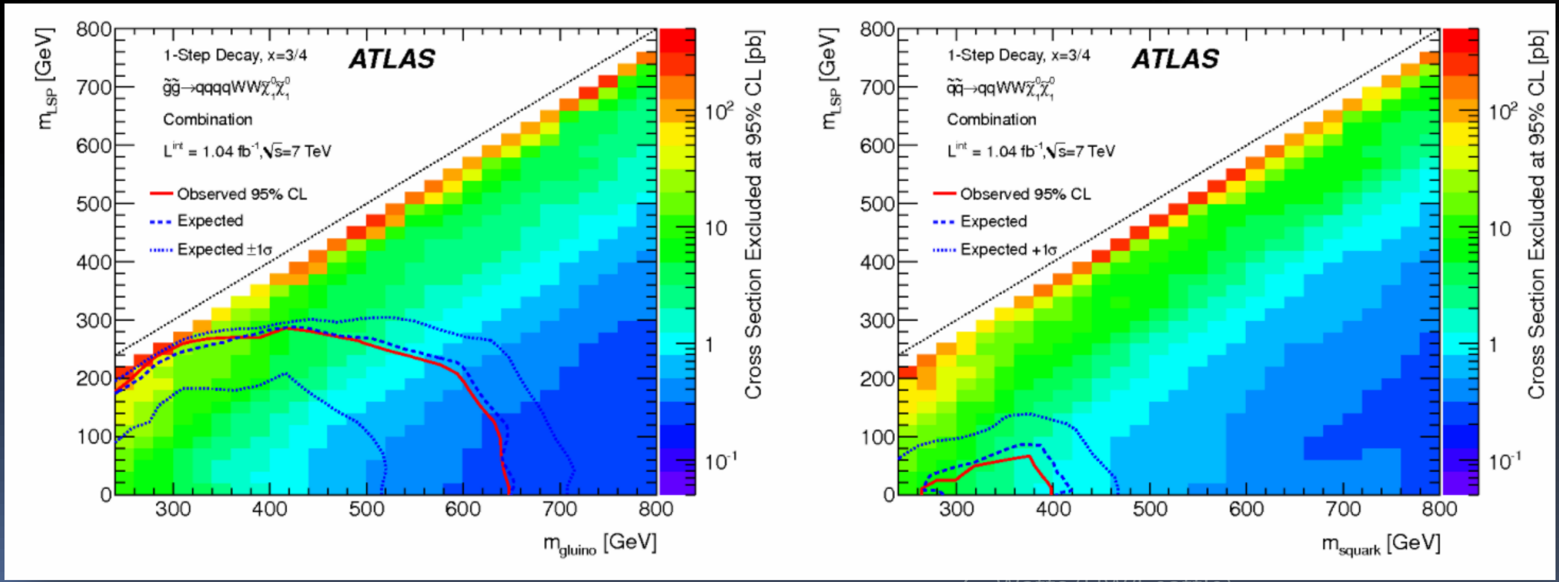
4, $p_T > 60(1), 25(3)$ GeV, $E_T^{miss} > 140$

4, $p_T > 60(1), 40(3)$ GeV, $E_T^{miss} > 200$

luminosity: 1.04 fb^{-1}

r parity conserving





simplified models

jets, E_T^{miss}

leptons: =0 e, μ with $p_T^{e,\mu} > 20$ GeV
jets: leading $p_T > 130$, 2-4 $p_T > 40$, or 4 $p_T > 80$
$E_T^{miss} > 130$ GeV
luminosity: 1.04 fb^{-1}
r parity conserving

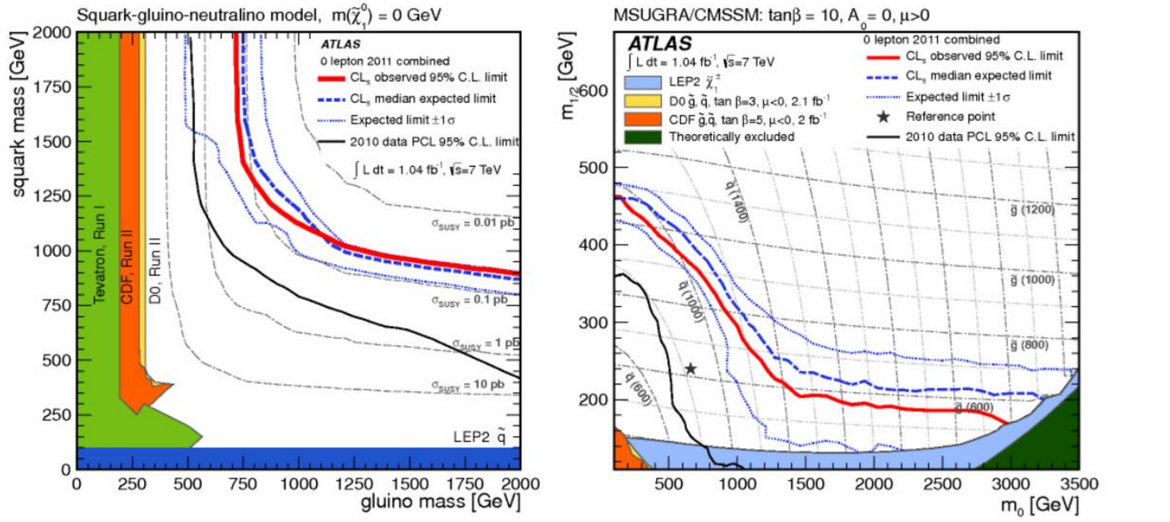


Figure 2: Combined exclusion limits for simplified SUSY models with $m(\tilde{\chi}_1^0) = 0$ (left) and MSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$ (right). The combined limits are obtained by using the signal region which generates the best expected limit at each point in the parameter plane. The dashed-blue line corresponds to the median expected 95% C.L. limit and the red line corresponds to the observed limit at 95% C.L. The dotted blue lines correspond to the $\pm 1\sigma$ variation in the expected limits. Also shown for comparison purposes in the figures are limits from the Tevatron [35, 36, 37, 38] and LEP [39, 40] , although it should be noted that some of these limits were generated with different models or parameter choices (see legends). The previous published ATLAS limits from this analysis [5] are also shown. The MSUGRA/CMSSM reference point used in Figure 1 is indicated by the star in the right-hand figure.

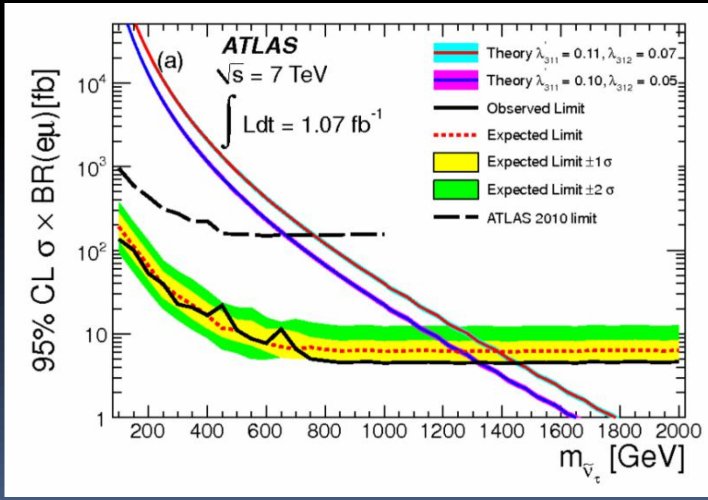
2 lepton (high mass)

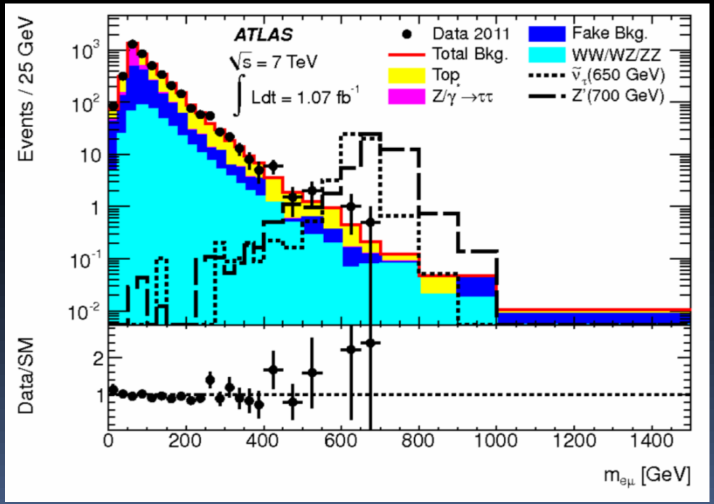
leptons: =1 e, 1 μ

$p_T^{e,\mu} > 25$ GeV

luminosity: 1.07 fb^{-1}

r parity violating





1 lepton, b-jets, E_T^{miss}

leptons: =1 e, μ

$p_T^e > 20$ GeV, $p_T^\mu > 10$ GeV

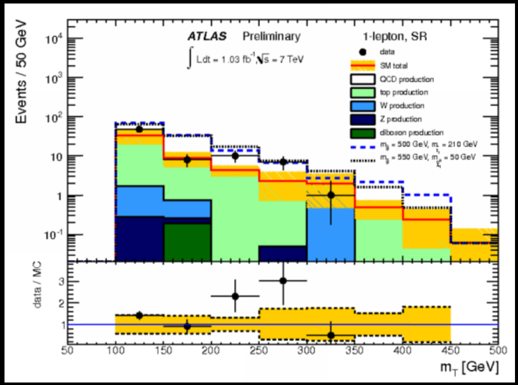
jets: 4, $p_T > 50$ GeV (≥ 1 b-tag)

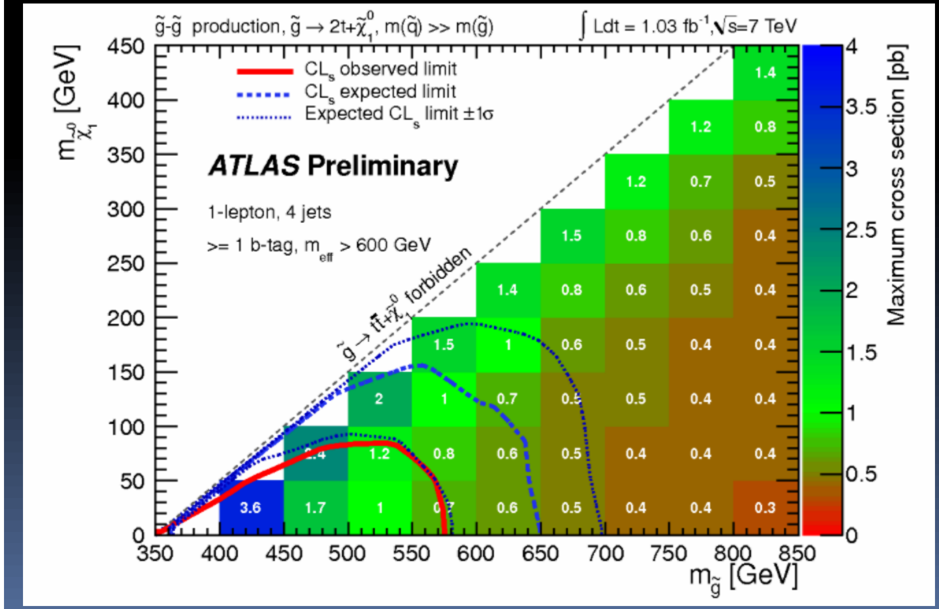
$E_T^{miss} > 80$ GeV

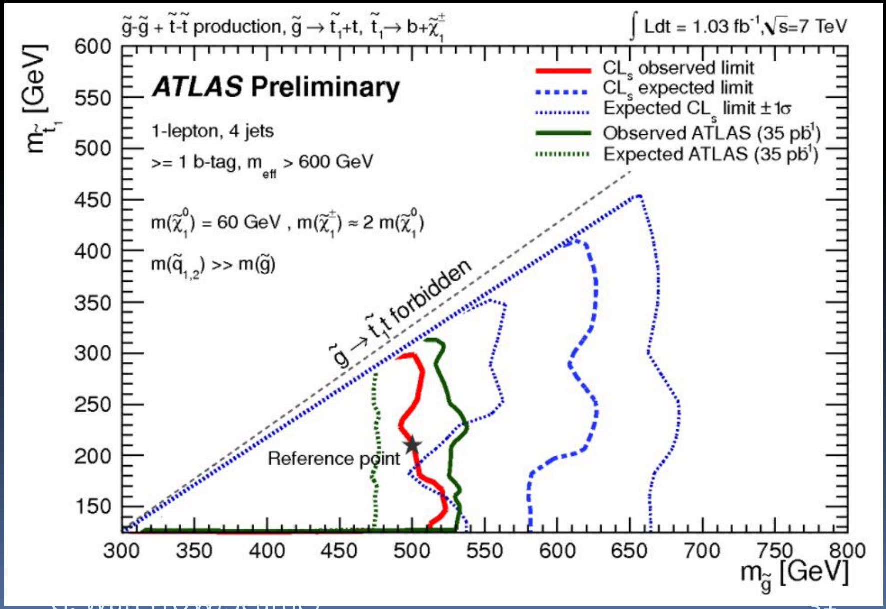
$m_T\left(l, E_T^{miss}\right) > 100$ GeV

luminosity: 1.03 fb^{-1}

r parity conserving







0 leptons, b-jets, E_T^{miss}

leptons: =0 e, μ

$p_T^e > 20$ GeV, $p_T^\mu > 10$ GeV

jets: $\geq 3, p_T > 130{,}50{,}50$ GeV (≥ 1 b-tag w/$p_T > 50$ GeV)

Split signal regions by # of b-jets, m_{eff}

$E_T^{miss} > 130$ GeV

$m_T(l, E_T^{miss}) > 100$ GeV

luminosity: 0.83 fb^{-1}

r parity conserving