The Why, What, and How of Simplified Models

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Why?

Why?

Want to find new physics at colliders:

Scenario 1)

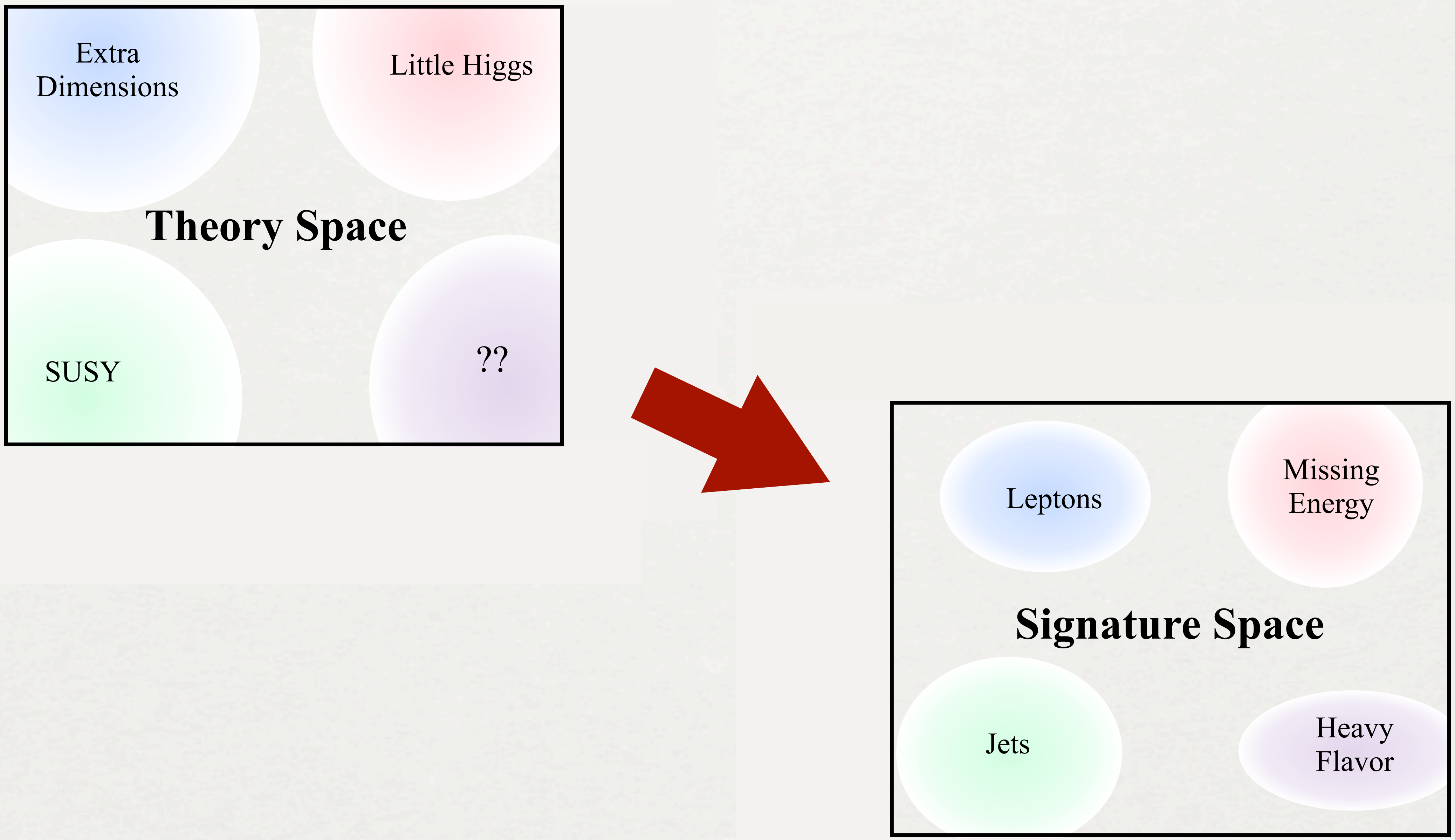
Nothing looks like the SM.
Totally obvious that there is new physics.
(More likely that the machine is broken.)

Scenario 2)

New physics requires doing searches.
How do we decide what searches to do?!?

Scenario 2

How do we go from theory to experimental predictions?



Two approaches

Top down

vs

Bottom up

Top Down

Start with a “complete” model.

Example: the CMSSM.

Specify 4 parameters at the GUT scale (and a sign).

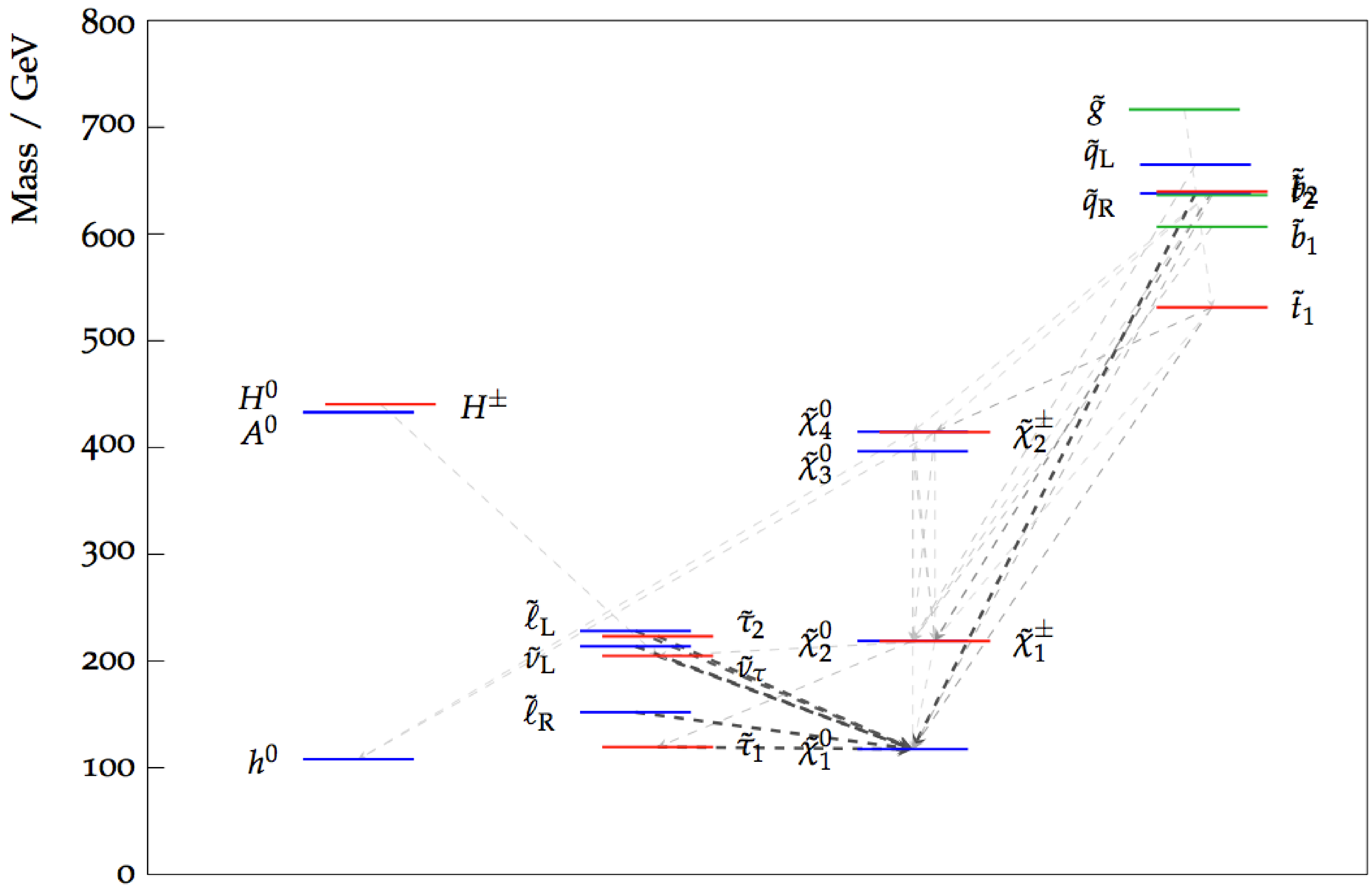
Run them down to the weak scale.

Check relic density.

Check consistency with experimental constraints.

Then search for collider signatures.

A CMSSM Spectrum



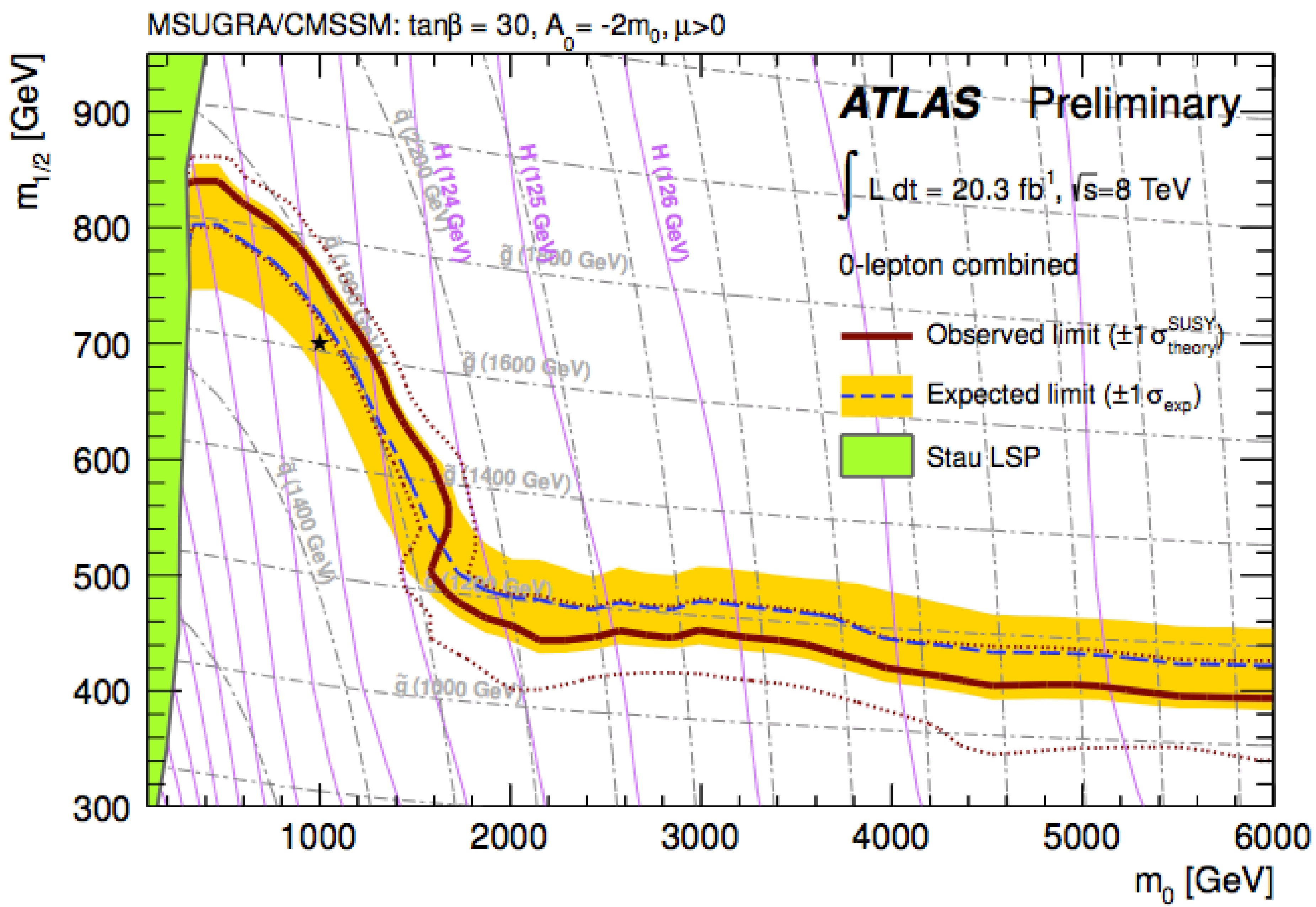
Allanach and Dolan [arXiv:1107.2856]

How do you optimize the search?

How much does strategy change as inputs change?

ATLAS Search

Jets + MET.



ATLAS Collaboration [ATLAS-CONF-2014-047]

Bottom Up

Looking for an approach that focuses on individual classes of signatures.

Want some connection to theoretically compelling models.

Want to be able to optimize for wide range of kinematics.

One approach: Simplified Models.

What

Simplified Models

Identify a signature that has a prayer of being observable over background.

Identify the particles required to minimally produce this signature.

Write down a Lagrangian
(actually a MadGraph model file).

Consistent with Lorentz and gauge symmetry.

Should have a minimal number of parameters, most parameters will be correlated with some property of the signature.

Alwall, Le, Listanti, Wacker [arXiv:0809.3264]
Alwall, Schuster, Toro [arXiv:0810.3921]
LHC New Physics Working Group [arXiv:1105.2838]

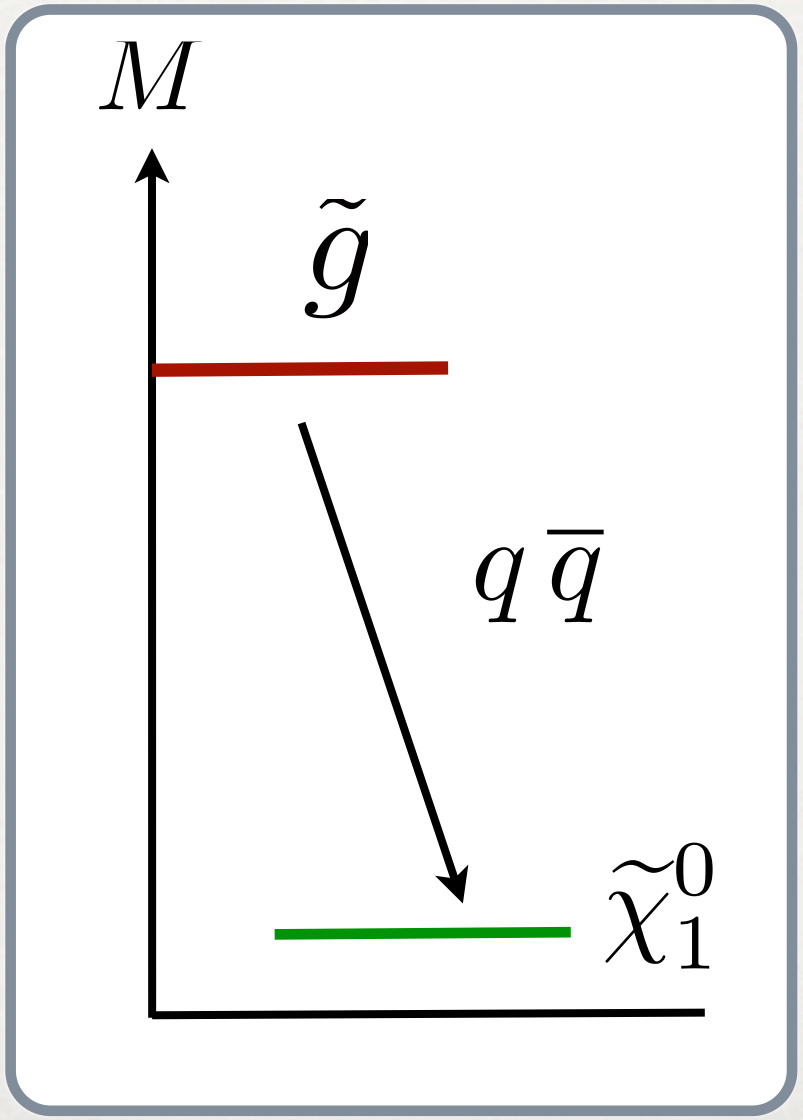
Gluino-Neutralino

A canonical example for jets + MET searches.

Two parameters: $m_{\tilde{g}}$ and $m_{\tilde{\chi}_1^0}$.

Pair production via QCD: rate controlled by $m_{\tilde{g}}$.

Kinematics controlled by $m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$.



How: Jets + MET

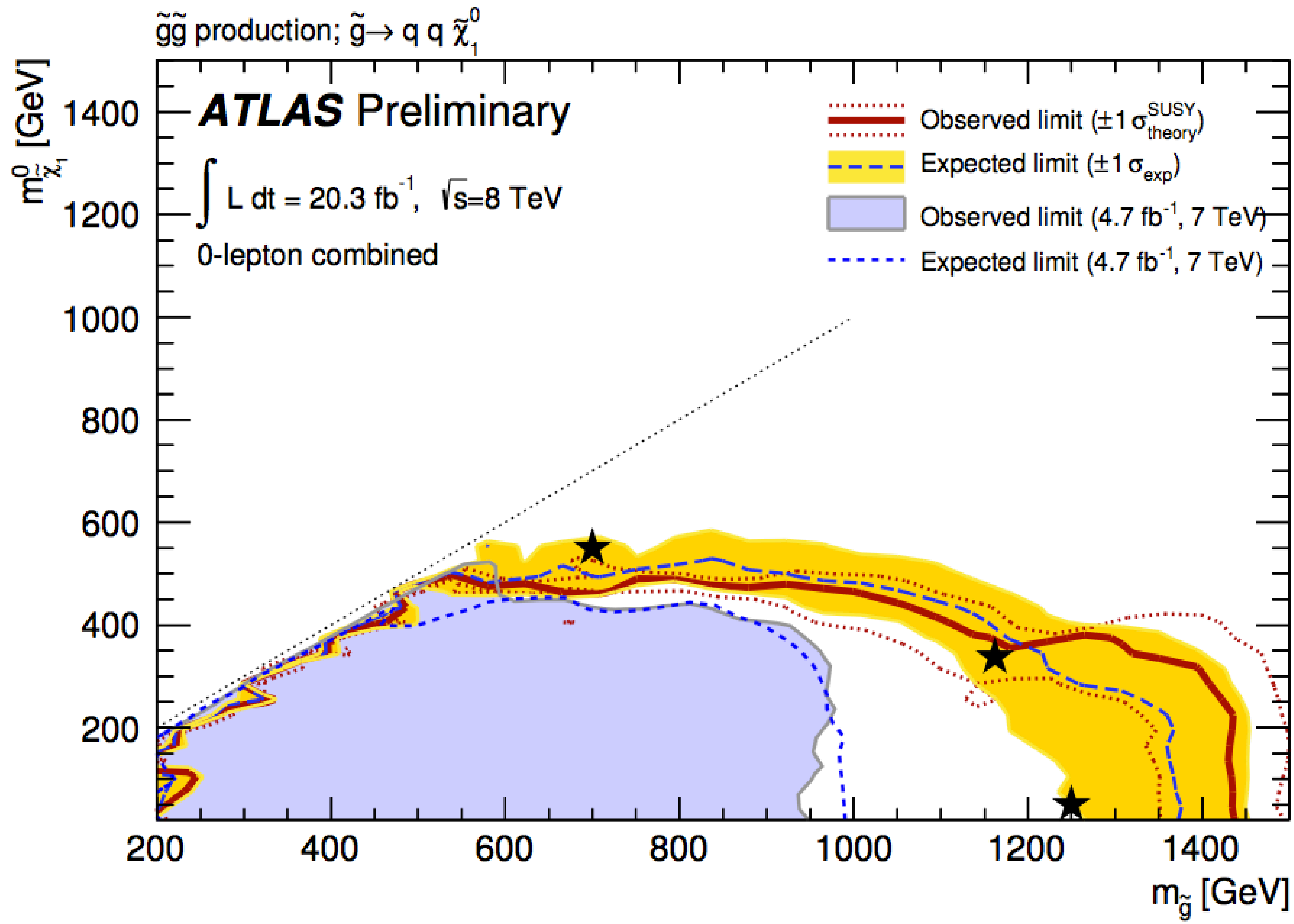
ATLAS SEARCH

Requirement	Channel									
	A (2-jets)		B (3-jets)		C (4-jets)		D (5-jets)	E (6-jets)		
	L	M	M	T	M	T	–	L	M	T
$E_{\mathrm{T}}^{\mathrm{miss}}$[GeV] >	160									
$p_{\mathrm{T}}(j_1)$ [GeV] >	130									
$p_{\mathrm{T}}(j_2)$ [GeV] >	60									
$p_{\mathrm{T}}(j_3)$ [GeV] >	–		60		60		60	60		
$p_{\mathrm{T}}(j_4)$ [GeV] >	–		–		60		60	60		
$p_{\mathrm{T}}(j_5)$ [GeV] >	–		–		–		60	60		
$p_{\mathrm{T}}(j_6)$ [GeV] >	–		–		–		–	60		
$\Delta\phi(\mathrm{jet}_i, \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	0.4 ($i = \{1, 2, (3 \text{ if } p_{\mathrm{T}}(j_3) > 40$ GeV$)\}$)				0.4 ($i = \{1, 2, 3\}$), 0.2 ($p_{\mathrm{T}} > 40$ GeV jets)					
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(Nj)$ >	0.2	–[a]	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
m_{eff}(incl.) [GeV] >	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

(a) For SR A-medium the cut on $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(Nj)$ is replaced by a requirement $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} > 15$ GeV$^{1/2}$.

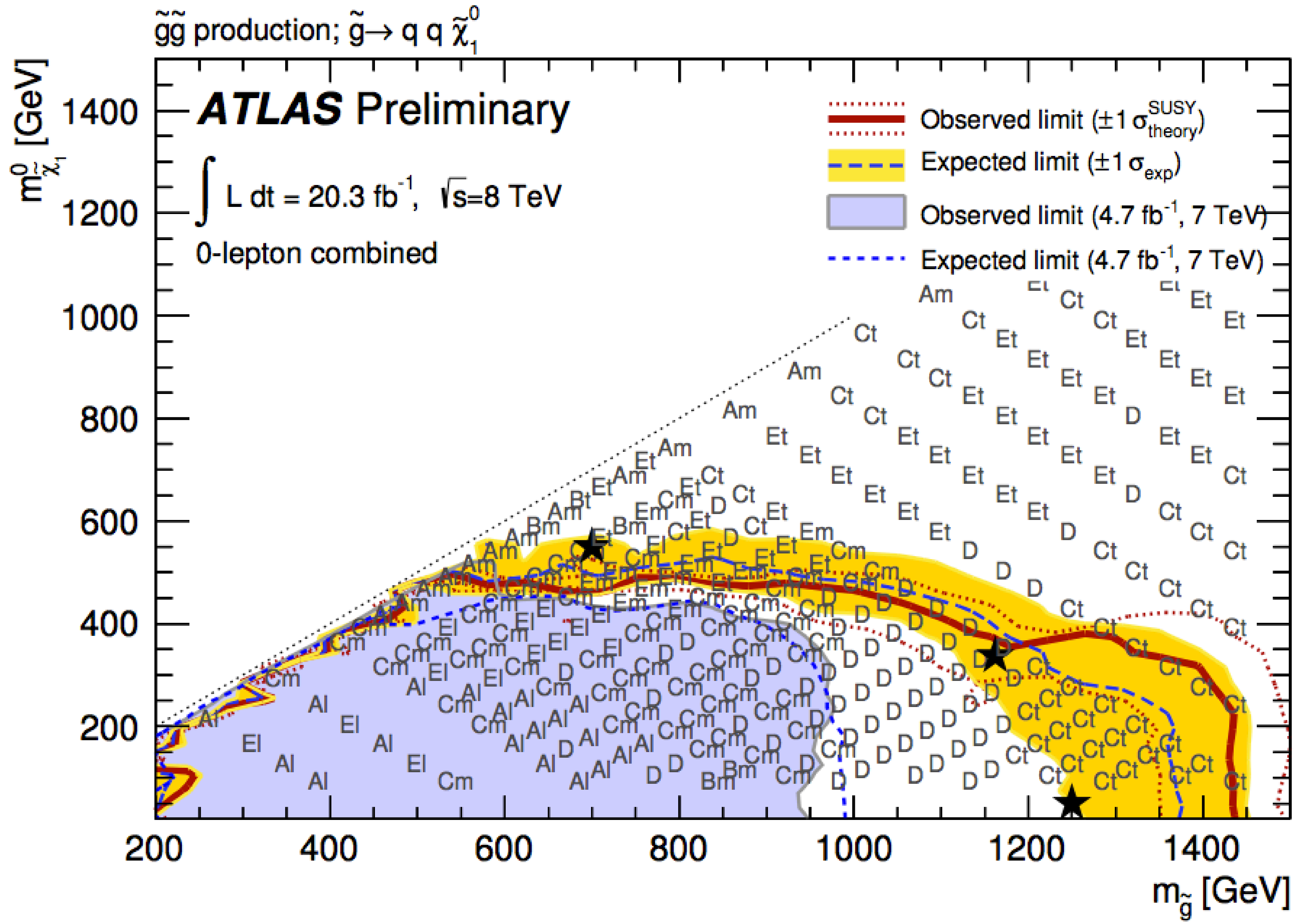
ATLAS Collaboration [ATLAS-CONF-2014-047]

ATLAS Search



ATLAS Collaboration [ATLAS-CONF-2014-047]

ATLAS Search



ATLAS Collaboration [ATLAS-CONF-2014-047]

How: Stops

Stop-Neutralino

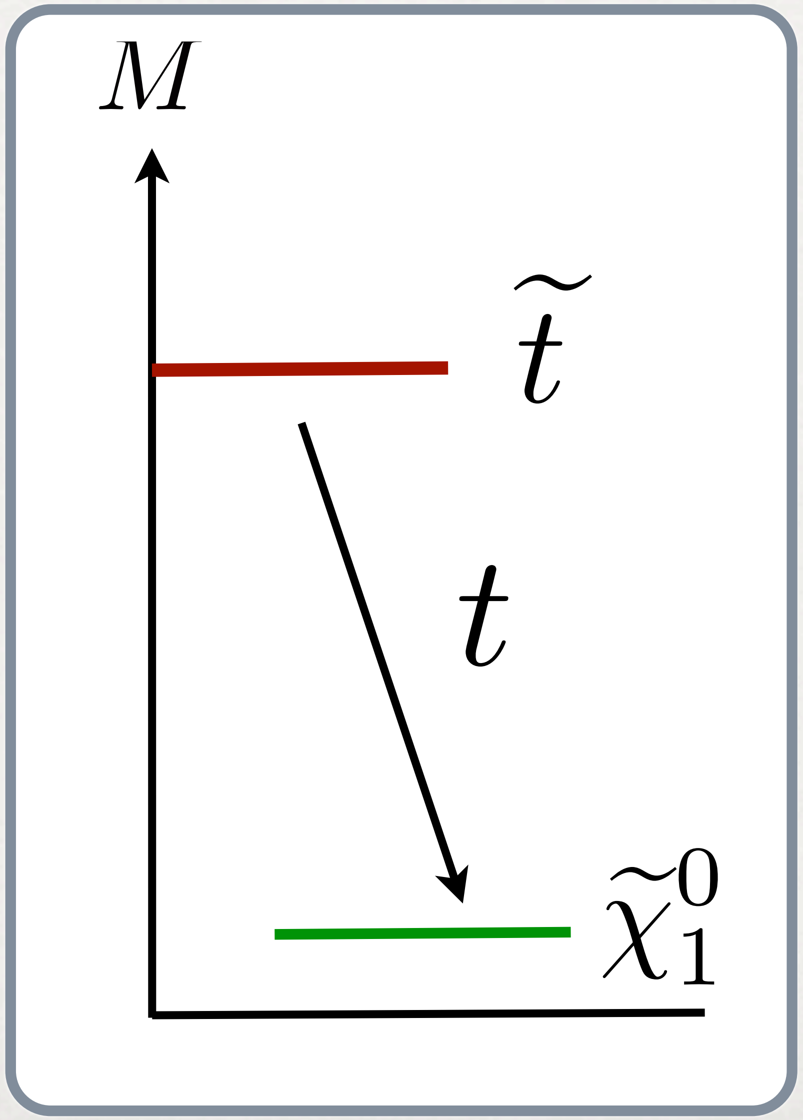
Naturalness: perhaps stops are lightest colored states.

Canonical Simplified Model for stops:

Two parameters: $m_{\tilde{t}}$ and $m_{\tilde{\chi}_1^0}$.

Pair production via QCD: rate controlled by $m_{\tilde{t}}$.

Kinematics controlled by $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$.



Many Signatures

Final state is $t\,\bar{t}$ + MET.

Top decays either hadronically or leptonically.

Implies 3 possible signatures:

multi-jet, 0 lepton + MET

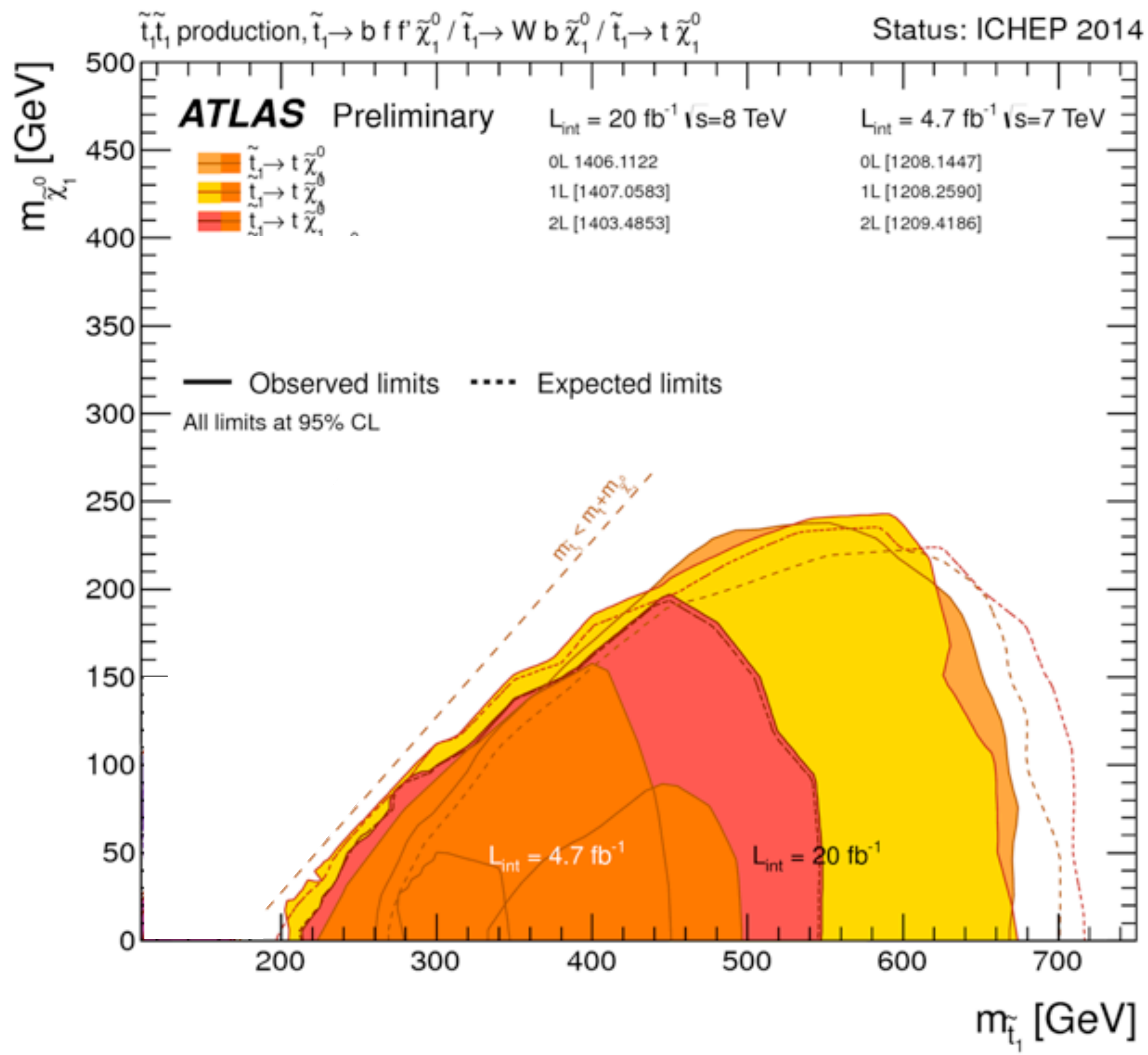
(less) multi-jet, 1 lepton + MET

2 lepton + MET

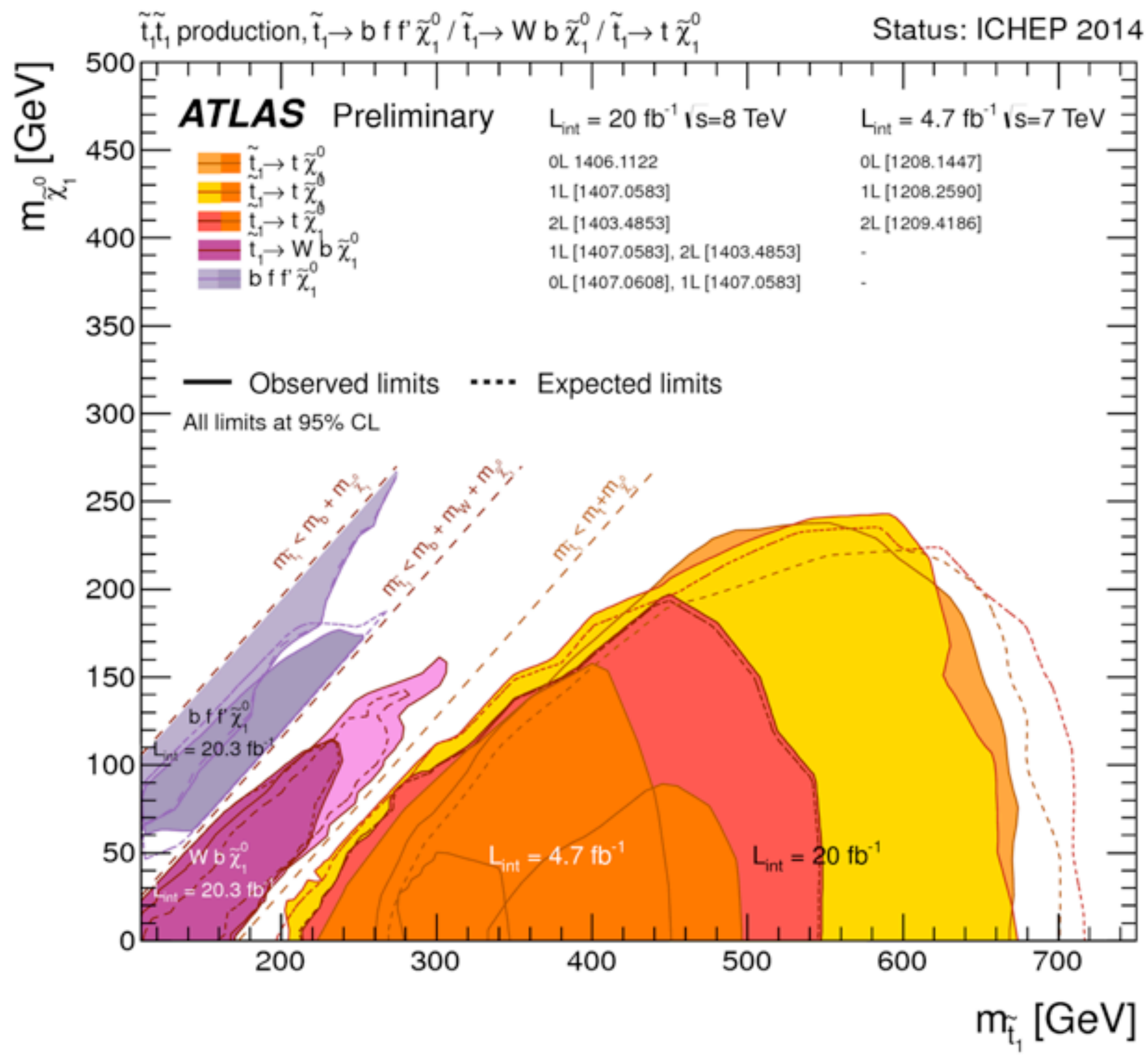
The 0 lepton search has the highest rate (BRs) and correspondingly the best reach.

The 1 lepton search does slightly better in the compressed region due to lower lepton thresholds.

ATLAS Searches



ATLAS Searches



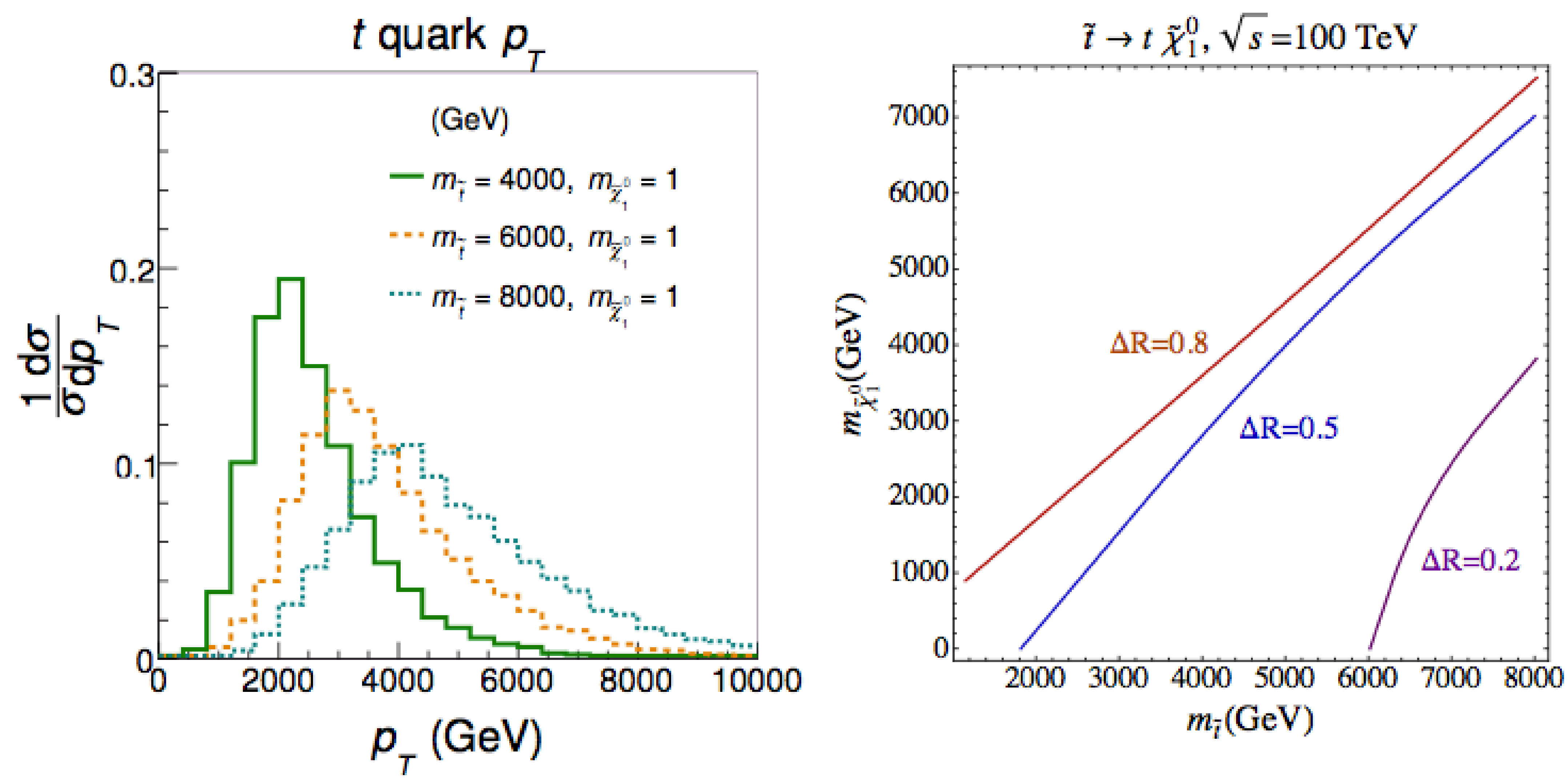
Stops to the future


?????
Nimatron
MONTH
DAY
YEAR
AM
HOUR
MIN
OCT
21
2015
PM
04
29
DESTINATION TIME
MONTH
DAY
YEAR
AM
HOUR
MIN
JUL
10
2014
PM
10
37
PRESENT TIME
MONTH
DAY
YEAR
AM
HOUR
MIN
OCT
26
1985
PM
01
20
LAST TIME DEPARTED

Stops at 100 TeV

At a 100 TeV collider, "tops are the new bottoms."

Do we need a new search strategy for the next generation collider?

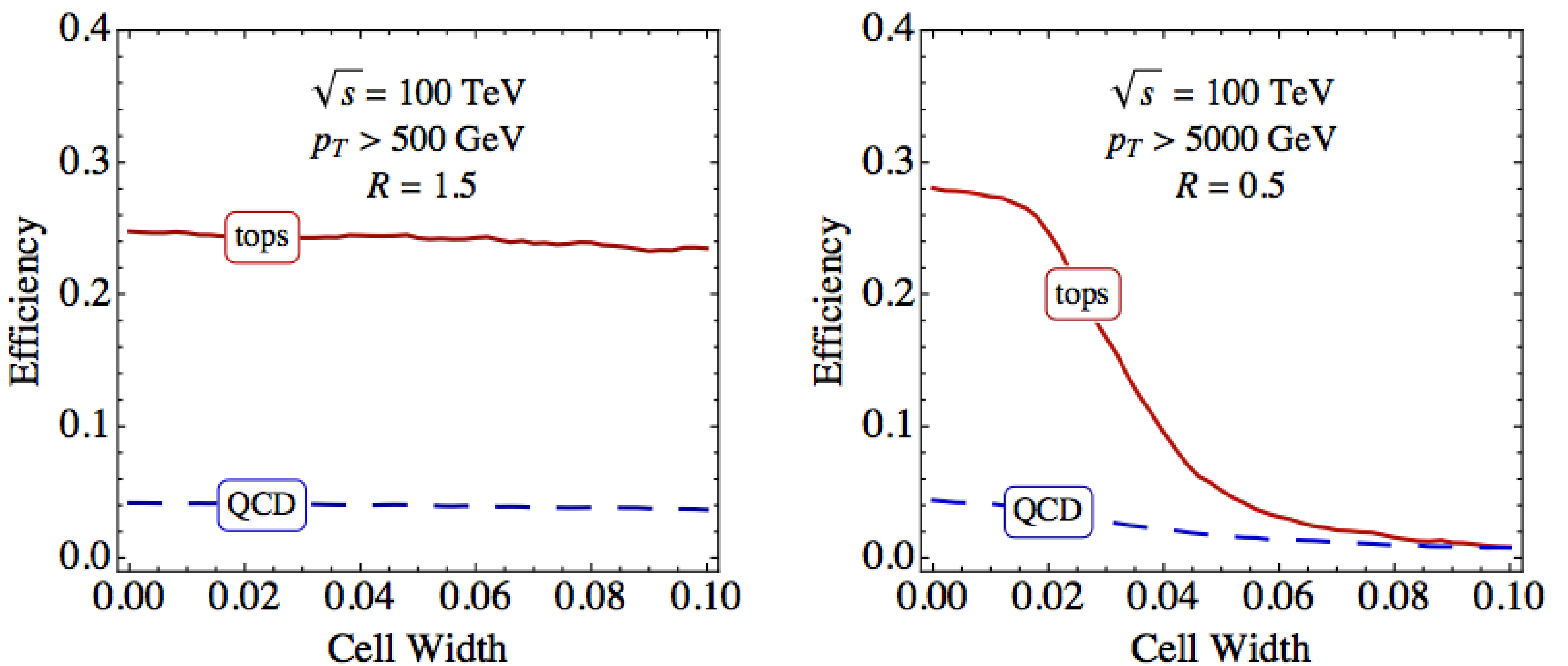


Cohen, D'Agnolo, Hance, Lou, Wacker [arXiv:1406.4512]

How to Tag Tops?

Try HEP top tagger:

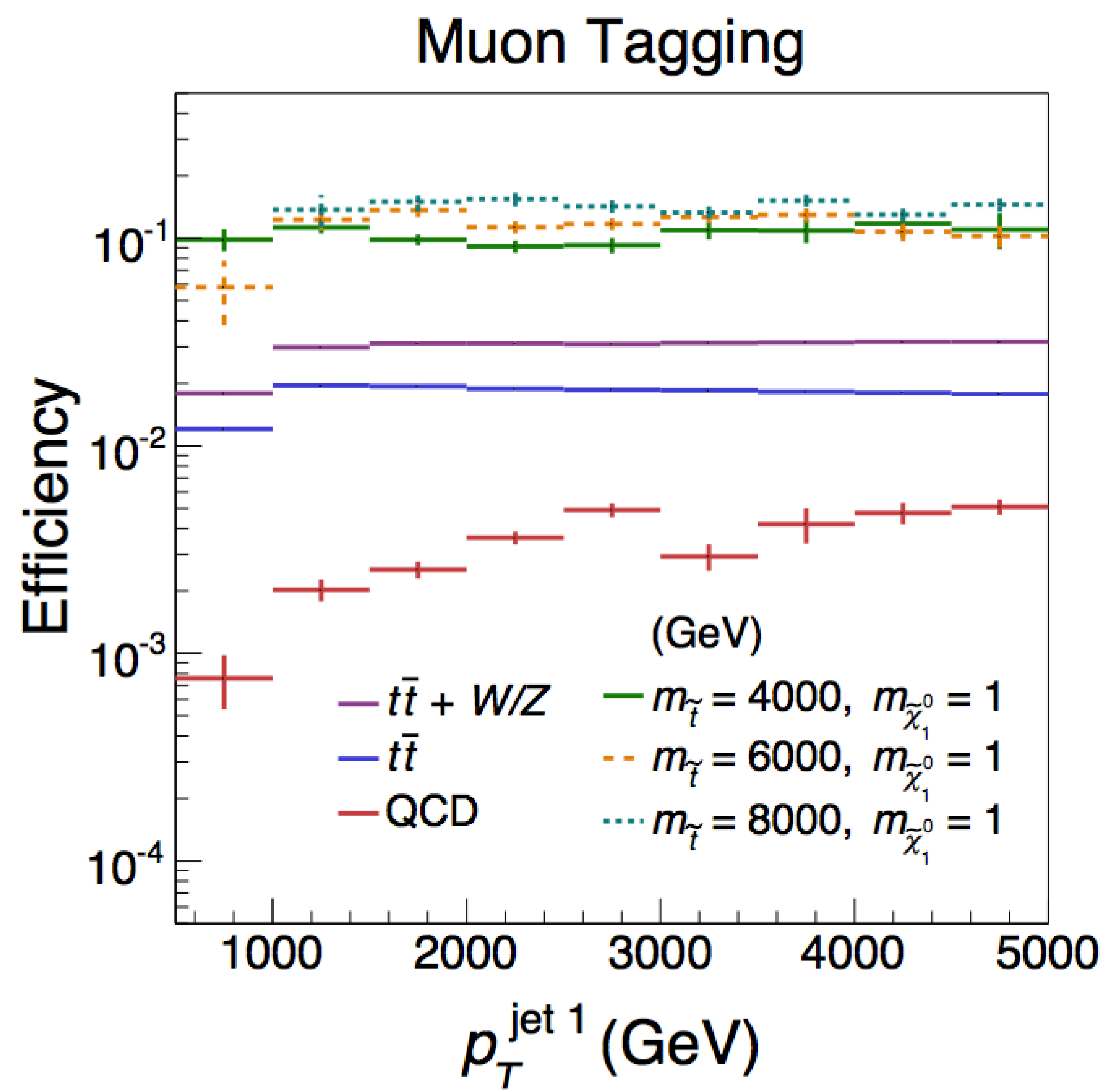
Plehn, Spannowsky, Takeuchi, Zerwas [arXiv:1006.2833]



Sensitive to details of the detectors.
Is there a detector independent approach?

Muon-in-jet

Require a hard muon inside the jet cone.
A "poor man's" top tagger.

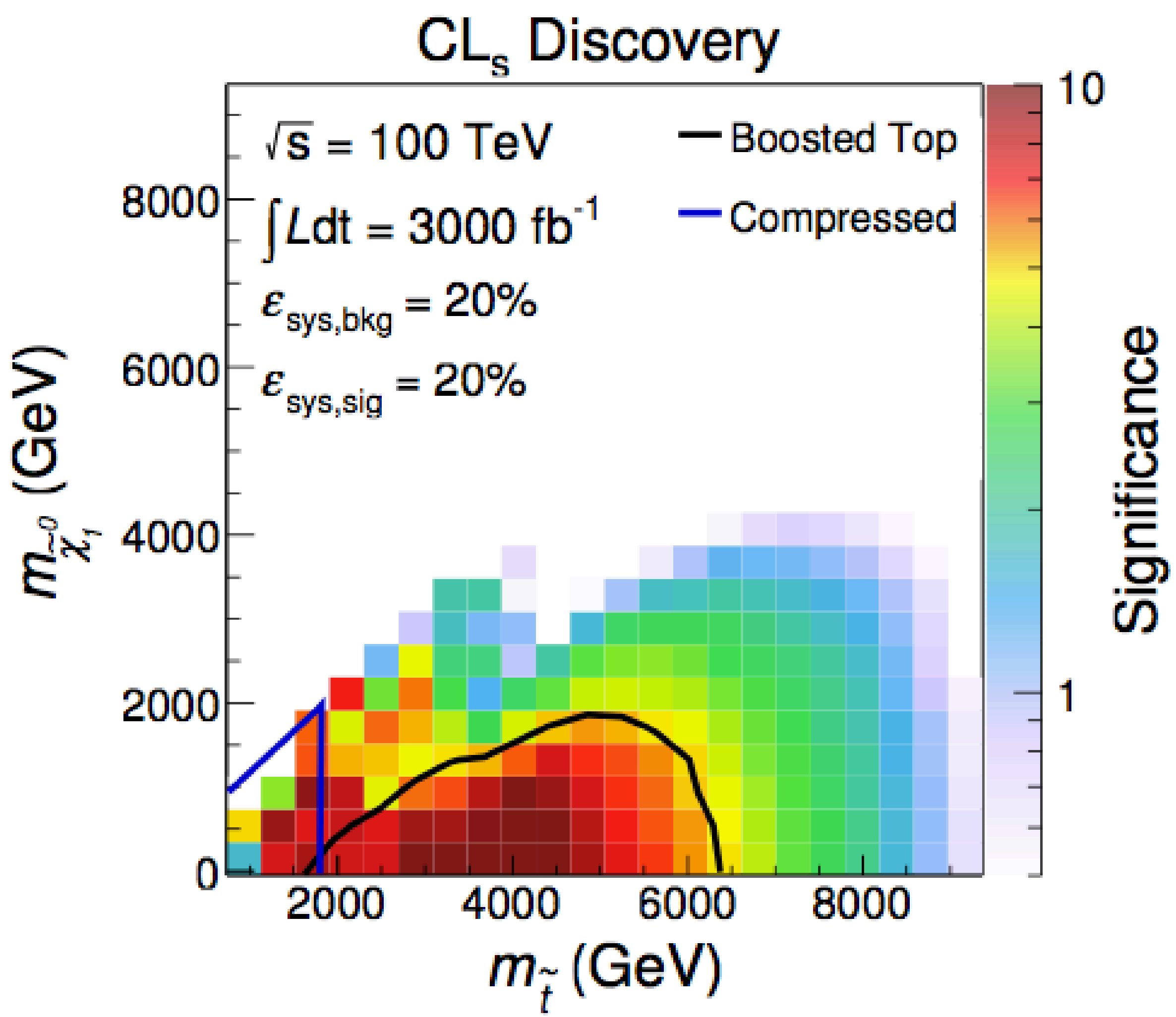


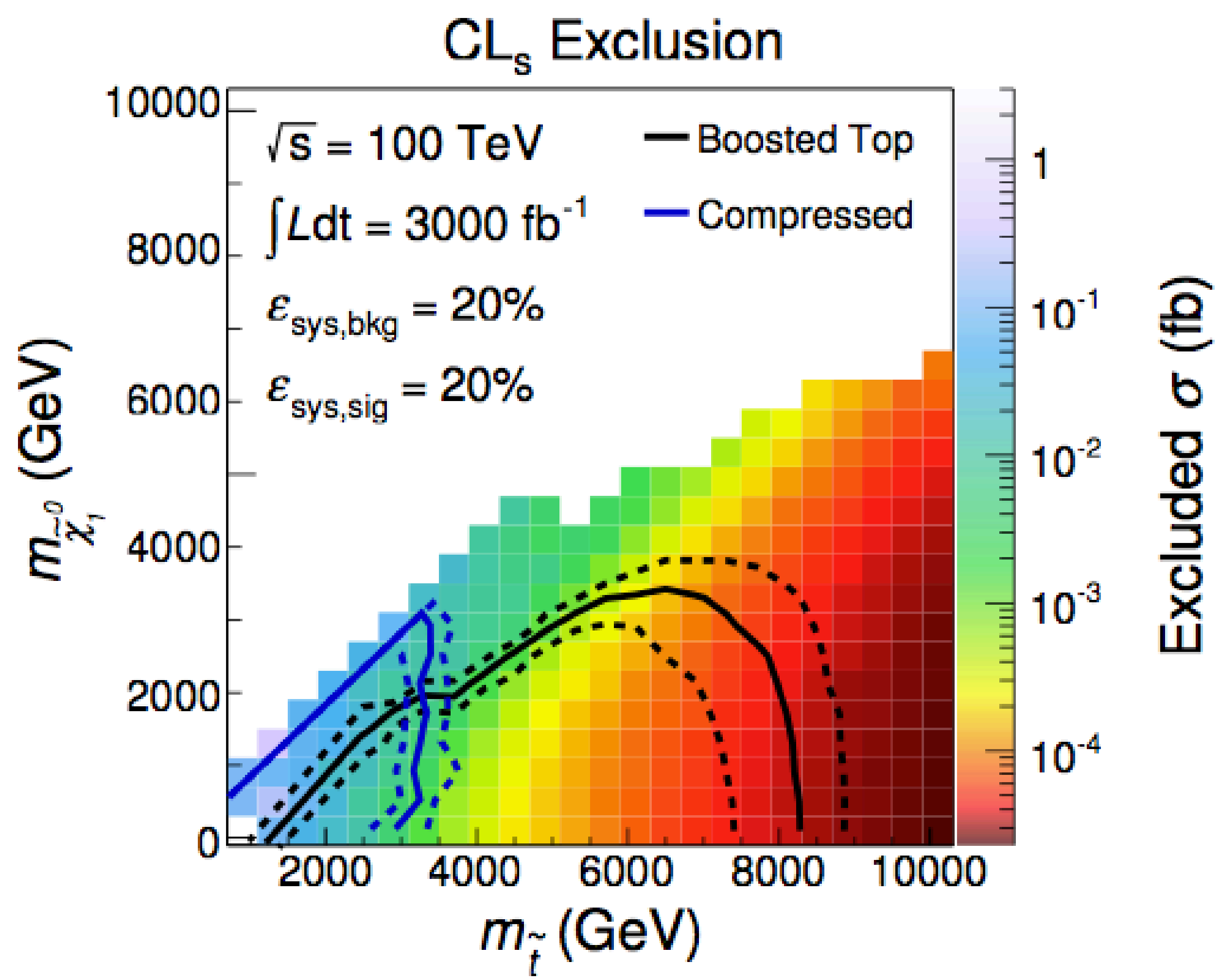
Cut flow

Cuts	Signal $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0})$ (GeV)			$t\bar{t}+W/Z$	$t\bar{t}+j$	single t	$W/Z+j$	QCD
	(4000, 1)	(6000, 1)	(8000, 1)					
$N_{\text{jet}} \geq 2$	6.3×10^3	6.6×10^2	9.4×10^1	1.6×10^6	5.1×10^7	5.4×10^6	6.3×10^7	2.8×10^9
$N_\mu \geq 1$	1.2×10^3	1.5×10^2	2.4×10^1	1.6×10^5	4.3×10^6	3.4×10^5	5.3×10^5	2.3×10^7
isolated $l^\pm$ veto	1.2×10^3	1.5×10^2	2.4×10^1	1.5×10^5	4.1×10^6	3.2×10^5	5.3×10^5	2.3×10^7
$\Delta\phi_{\not{E}_T J} > 1.0$	6.6×10^2	8.1×10^1	1.4×10^1	7.6×10^3	1.6×10^5	1.4×10^4	3.3×10^4	1.1×10^6
$\not{E}_T > 4.0$ TeV	2.0×10^1	2.1×10^1	7.2	3.4	5.0×10^{-1}	6.1×10^{-1}	1.5×10^{-1}	1.2×10^{-3}

Dominant background is $t\,\bar{t} + Z^0$.

Results





Cohen, D'Agnolo, Hance, Lou, Wacker [arXiv:1406.4512]

Exclude stops with mass over 8 TeV!

Conclusions

Conclusions

Simplified Models are a very useful tool.

Focus on signatures rather than theoretical prejudice.

Useful for optimizing searches over wide range of final state kinematics.

Results of searches given in maximally transparent way.

Amenable to recasting!

Useful for benchmarking future colliders.