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Supersymmetry searches at ATLAS - status and prospects

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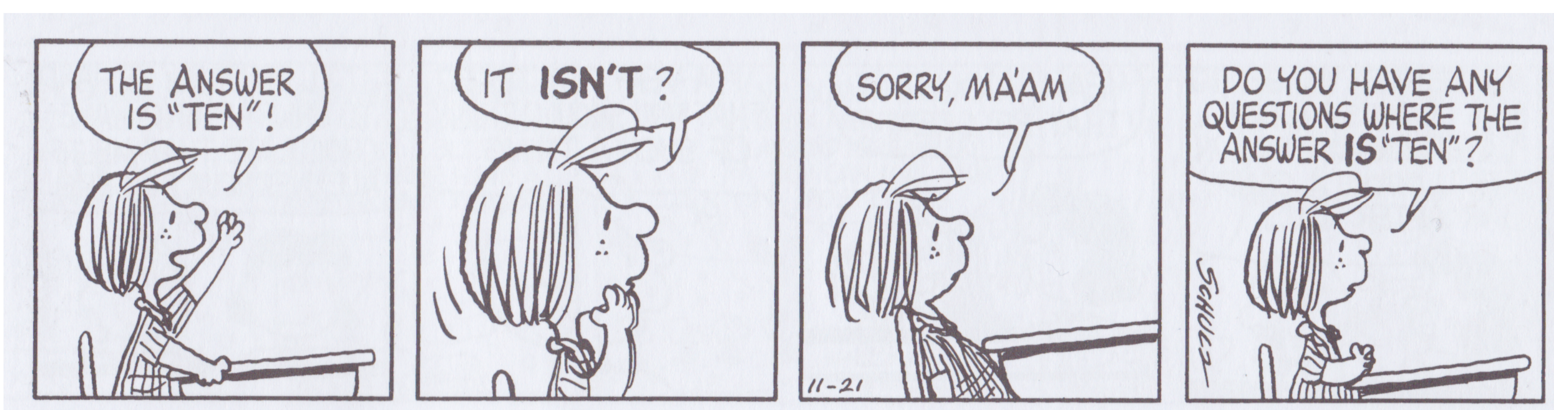
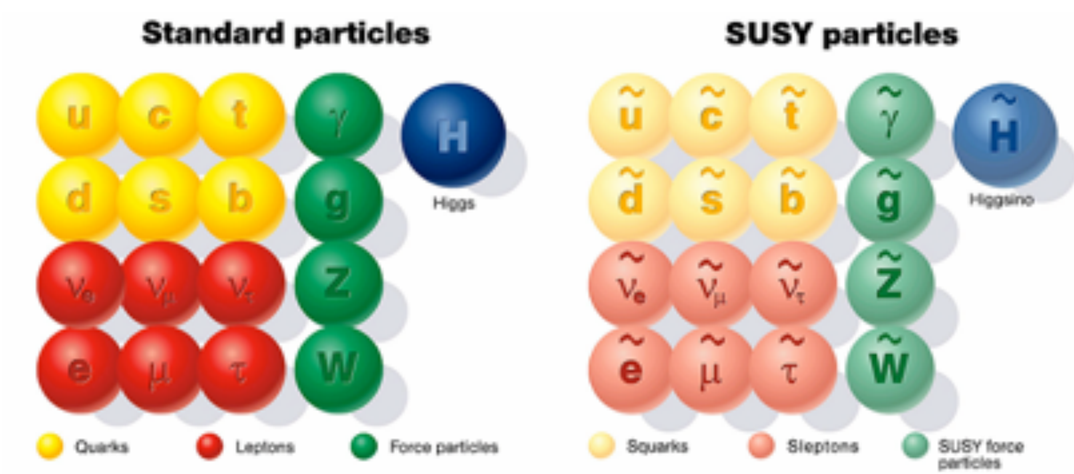


Supersymmetry (SUSY)

- SUSY is **a symmetry that relates bosons and fermions**
  - a new set of fields differing in spin by 1/2 w.r.t. the SM partners



SUSY is not an exact symmetry

Sparticle masses ≠ particle masses

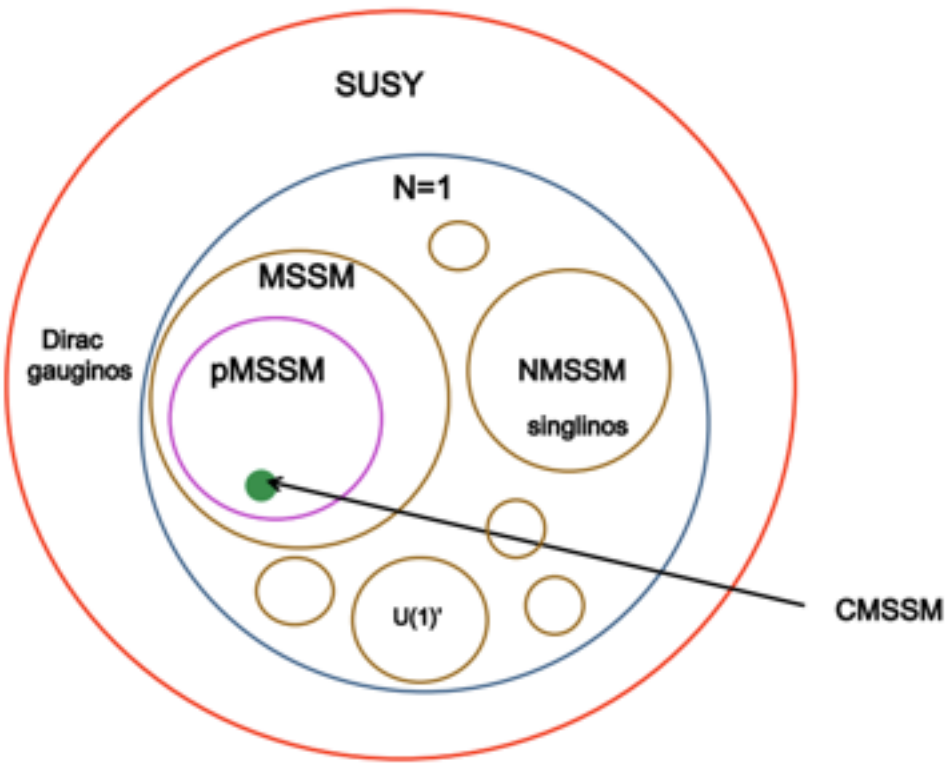
$$W \ni \frac{1}{2}\lambda_{ijk}L_iL_jE^c_k + \lambda'_{ijk}L_iQ_jD^c_k + \frac{1}{2}\lambda''_{ijk}U^c_iD^c_jD^c_k + \mu_iL_iH_u$$

R-parity = $(-1)^{3(B-L) + 2s}$
-1 for sparticles
1 for particles

Lepton and baryon number violation allowed → proton decay
If R-parity conserved, the **Lightest Supersymmetric Particle (LSP)** is stable

When will we stop searching for SUSY?

- Ill-posed question:
  - Supersymmetry **is a symmetry**. We can exclude supersymmetric models, not supersymmetry.



In general, little to no indication on sparticle masses

When will we stop searching for EW-SUSY?

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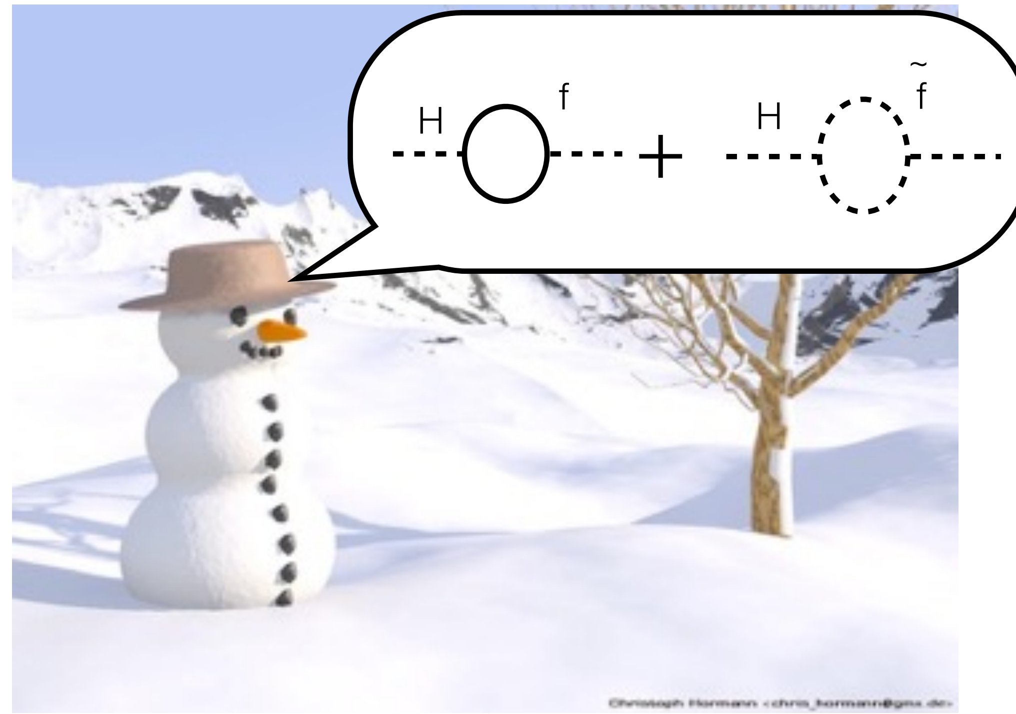
Taken from http://www.quantumdiaries.org/2012/07/01/the-hierarchy-problem-why-the-higgs-has-a-snowballs-chance-in-hell/



$$\Delta m_H^2 = \frac{|\lambda_f|^2}{8\pi^2}\Lambda_{\mathrm{UV}}^2 + \ldots$$

Higgs mass has a quadratic dependency from physics at a higher scale

With SUSY only logarithmic quantum corrections

Fine tuning - a deeper look

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- One needs to **quantify the fine tuning**:
  - One possible choice: **stability of EW scale** w.r.t. **model parameters** [Nucl. Phys. B306 (63-76) (1987)]

$$m_Z^2 = -2\mu^2 + 2\frac{m_{H_d}^2 - \tan^2\beta\, m_{H_u}^2}{\tan^2\beta - 1}$$

model parameters

$$max_{a_i}\left(\left|\frac{a_i}{m_Z^2}\frac{\partial m_Z^2(a_i)}{\partial a_i}\right|\right) < \Delta$$

tolerated fine tuning

- **What are the important a_i?**
  - **μ (higgs mass parameter)** enters at tree level → light higgsinos
  - **A_t, M_{Q3}, M_{u3}** are relevant → light stops
  - **gluinos** introduce large corrections to the stop masses → light gluinos

Parameters and masses

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Neutralinos

$$\psi^0 = (\widetilde{B}, \widetilde{W}^0, \widetilde{H}_d^0, \widetilde{H}_u^0)$$

$$\mathcal{L}_{\text{neutralino mass}} = -\frac{1}{2}(\psi^0)^T \mathbf{M}_{\widetilde{N}} \psi^0 + \text{c.c.},$$

$$\mathbf{M}_{\widetilde{N}} = \begin{pmatrix} M_1 & 0 & -c_\beta\, s_W\, m_Z & s_\beta\, s_W\, m_Z \\ 0 & M_2 & c_\beta\, c_W\, m_Z & -s_\beta\, c_W\, m_Z \\ -c_\beta\, s_W\, m_Z & c_\beta\, c_W\, m_Z & 0 & -\mu \\ s_\beta\, s_W\, m_Z & -s_\beta\, c_W\, m_Z & -\mu & 0 \end{pmatrix}$$

Stops and sbottoms

$$\mathbf{m}^2_{\tilde{\mathbf{t}}} = \begin{pmatrix} m^2_{Q_3} + m_t^2 + \Delta_{\tilde{u}_L} & v(a_t^* \sin\beta - \mu y_t \cos\beta) \\ v(a_t \sin\beta - \mu^* y_t \cos\beta) & m^2_{\overline{u}_3} + m_t^2 + \Delta_{\tilde{u}_R} \end{pmatrix}$$

$$\mathbf{m}^2_{\tilde{\mathbf{b}}} = \begin{pmatrix} m^2_{Q_3} + \Delta_{\tilde{d}_L} & v(a_b^* \cos\beta - \mu y_b \sin\beta) \\ v(a_b \cos\beta - \mu^* y_b \sin\beta) & m^2_{\overline{d}_3} + \Delta_{\tilde{d}_R} \end{pmatrix}$$

When will we stop searching for EW SUSY?

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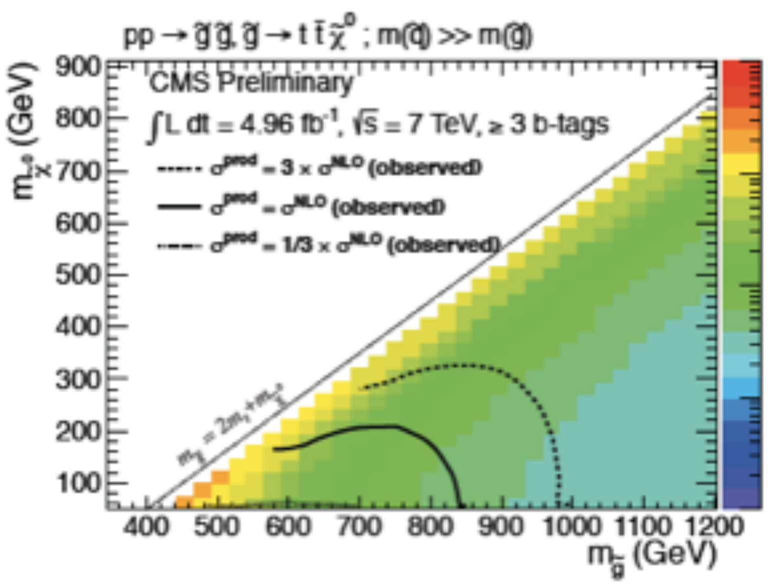
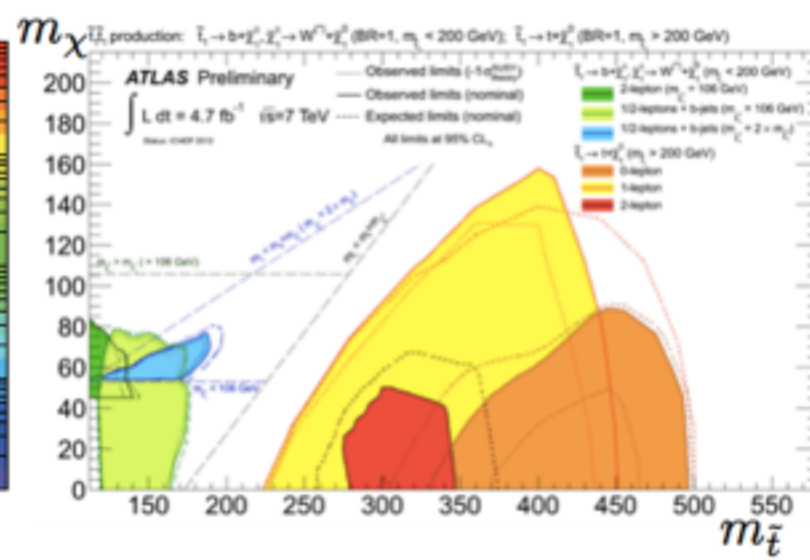
Frequently asked question:

Is supersymmetry at the Fermi scale dead?

Speaking for myself, I would like to see:

left plot extended to $m_{\tilde{g}} = 1.5 \div 1.8\ TeV$ OR right-plot plane fully explored



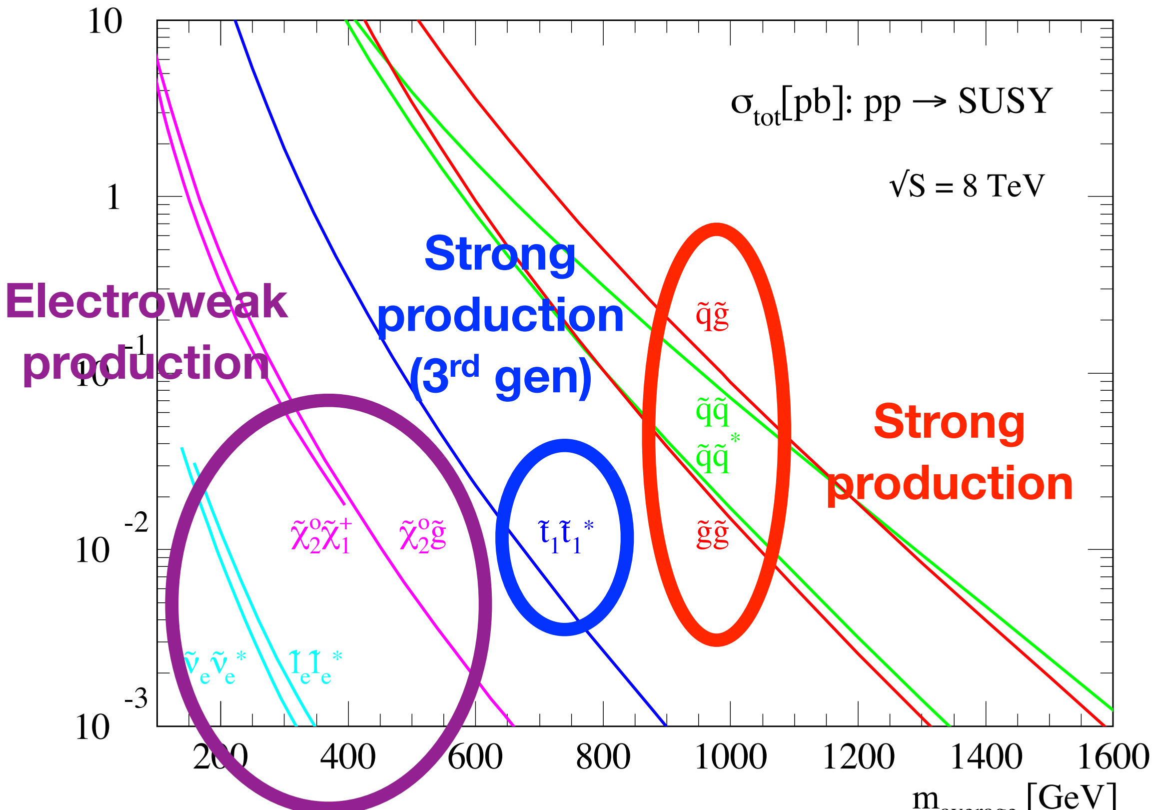


Question: Isn't it easier to study the $(m_{\tilde{b}}, m_{\tilde{\chi}})$ plane via $\tilde{b} \to b + \chi$

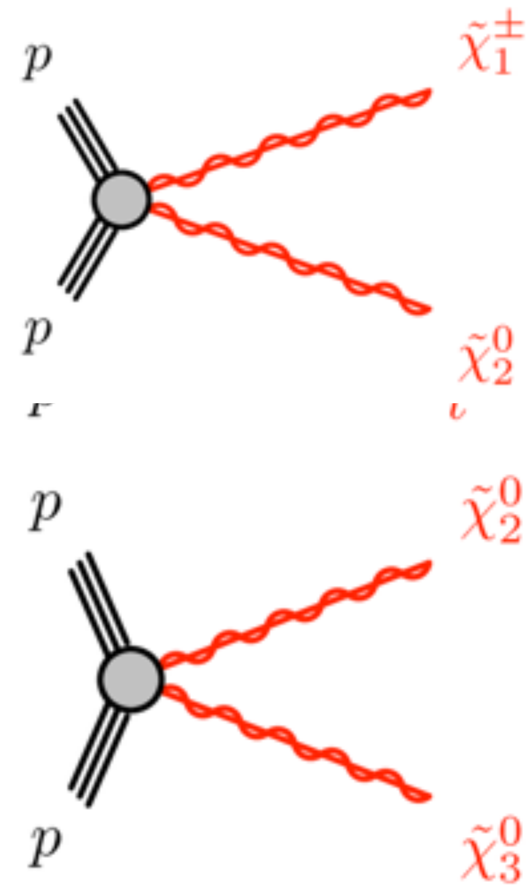
Answer: Yes, but less relevant since $\tilde{b}_L$ wants to go to $t\chi^- \to t\chi(l^-)$

R. Barbieri - ICHEP2012 physics highlights - Melbourne 2012

What processes are we looking for?



Taken from http://www.thphys.uni-heidelberg.de/~plehn/index.php?show=prospino&visible=tools



Publications

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All results available at https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2012 data (8 TeV)

Short Title of Paper	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
Non-pointing, delayed photons [LLP, GMSB] NEW	09/2014	8	20.3	1409.5542	Link (+ data)	Submitted to PRD
0 leptons + mono-jet/c-jets + Etmiss [Stop in charm+LSP] NEW	07/2014	8	20.3	1407.0608	Link (+ data)	Phys. Rev. D. 90, 052008 (2014)
1 lepton + 4(1 b-)jets + Etmiss [Medium / heavy stop] NEW	07/2014	8	20.3	1407.0583	Link	Submitted to JHEP
1-2 taus + 0-1 leptons + jets + Etmiss [GMSB] NEW	07/2014	8	20.3	1407.0603	Link (+ data)	JHEP 09 (2014) 103
0-1 leptons + >=3 b-jets + Etmiss [3rd gen. squarks] NEW	07/2014	8	20.1	1407.0600	Link (+ data)	JHEP 10 (2014) 024
2 taus + Etmiss [EW production] NEW	07/2014	8	20.3	1407.0350	Link (+ data)	JHEP 10 (2014) 096
Stop constraints from precise ttbar cross-section [Light stop]	06/2014	7, 8	4.6, 20.3	1406.5375	Link (+ data)	Accepted by EPJC
0 lepton + 6 (2 b-)jets + Etmiss [Heavy stop]	06/2014	8	20.3	1406.1122	Link (+data)	JHEP 09 (2014) 015
0 leptons + 2-6 jets + Etmiss [Incl. squarks & gluinos]	05/2014	8	20.3	1405.7875	Link (+ data)	JHEP 09 (2014) 176
4 leptons + Etmiss [EW production, RPV]	05/2014	8	20.3	1405.5086	Link (+ data)	Phys. Rev. D. 90, 052001 (2014)
2 same-sign / 3 -leptons + 0-3 b-jets + Etmiss [Incl. squarks & gluinos]	04/2014	8	20.3	1404.2500	Link (+ data)	JHEP 06 (2014) 035
2 leptons (e,mu) + Etmiss [chargino/neutralino/slepton]	03/2014	8	20.3	1403.5294	Link (+ data)	JHEP 05 (2014) 071
Z + b-jet + jets + Etmiss [Stop in GMSB, stop2]	03/2014	8	20.3	1403.5222	Link (+ data)	Eur. Phys. J. C (2014) 74:2883
2 leptons + (b)jets + Etmiss [stop]	03/2014	8	20.3	1403.4853	Link (+ data)	JHEP 06 (2014) 124
3 leptons (e,mu,tau) + Etmiss [chargino/neutralino]	02/2014	8	20.3	1402.7029	Link (+ data)	JHEP 04 (2014)169
Long-lived stopped gluino or squark R-hadrons [Split-SUSY]	10/2013	7+8	27.9	1310.6584	Link	Phys. Rev. D 88, 112003 (2013)
Disappearing track + jets + Etmiss [Direct long-lived charginos - AMSB]	10/2013	8	20.3	1310.3675	Link (+ data)	Phys. Rev. D 88, 112006 (2013)
0 leptons + 2 b-jets + Etmiss [Sbottom/stop]	08/2013	8	20.1	1308.2631	Link (+ data)	JHEP 10 (2013) 189
0 leptons + >=7-10 jets + Etmiss [Incl. squarks & gluinos]	08/2013	8	20.3	1308.1841	Link (+ data)	JHEP 10 (2013) 130

Experimental setup

LHC - performance of the machine

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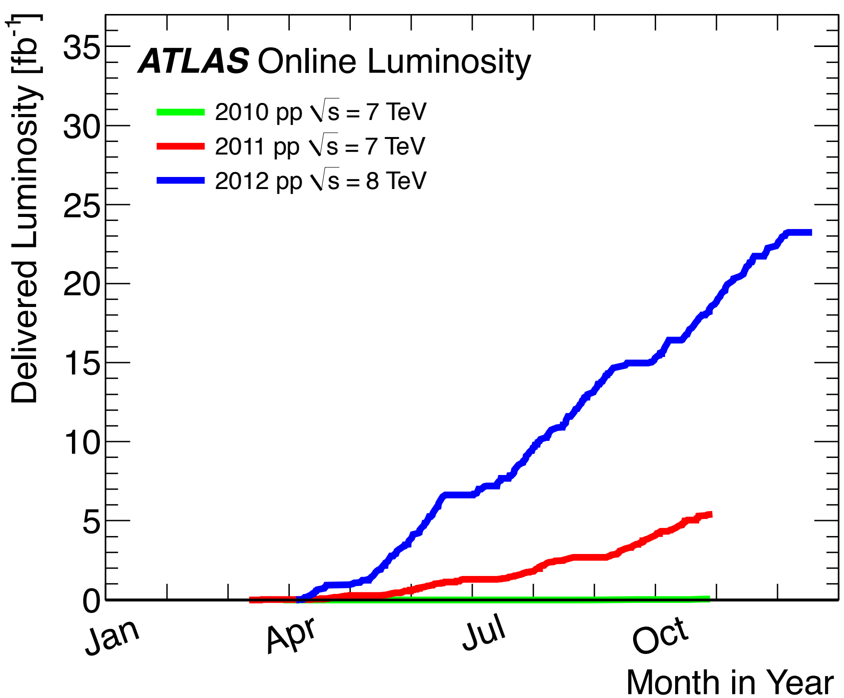
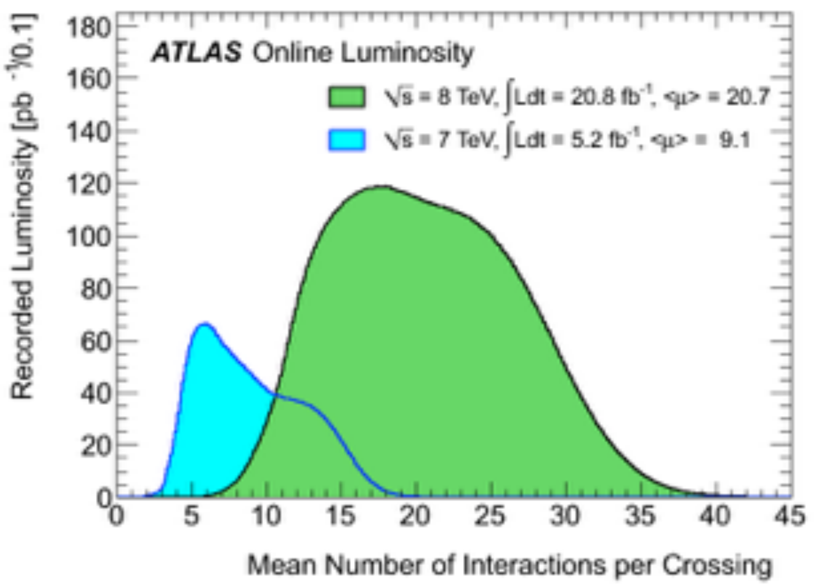
- About 22 fb^{-1} collected at $\sqrt{s}$= 8 TeV and 5 fb^{-1} at $\sqrt{s}$= 7 TeV
  - Most of which with more than 95% of the ATLAS detector operational

- **Only 8 TeV results used for this seminar**



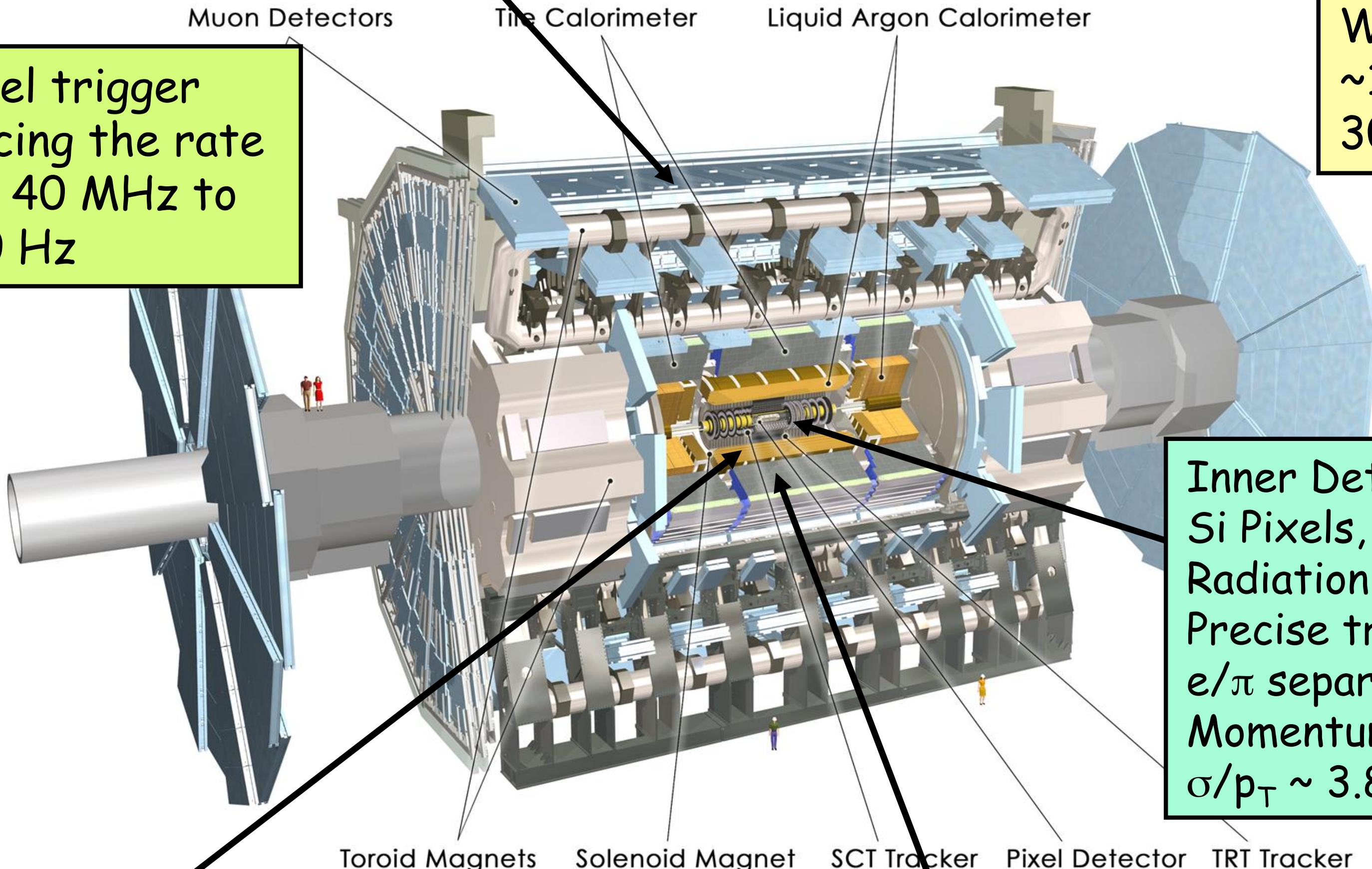
- **Large luminosity** means **large pileup.** Careful pileup suppression strategies developed.



Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz

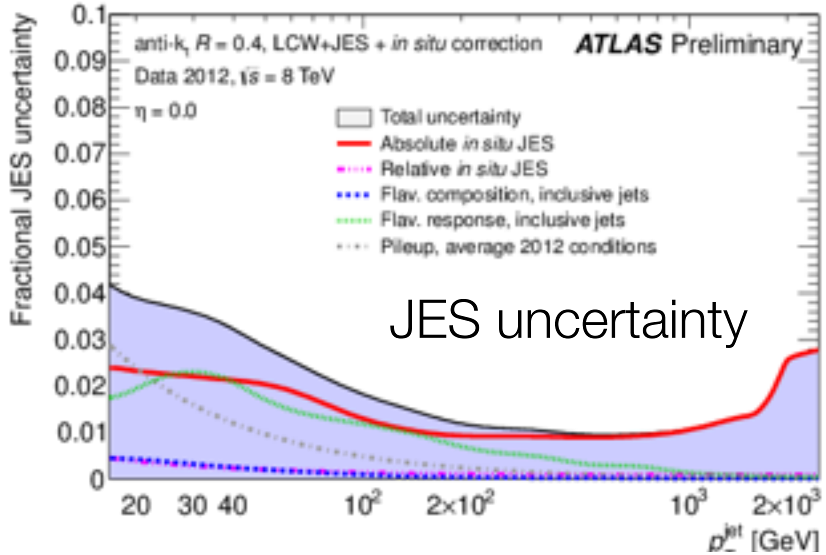


Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing,
e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T(\mathrm{GeV}) \oplus 0.015$

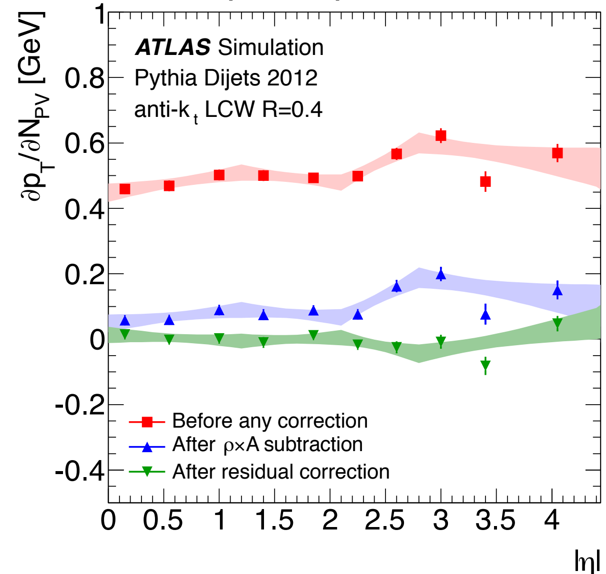
EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

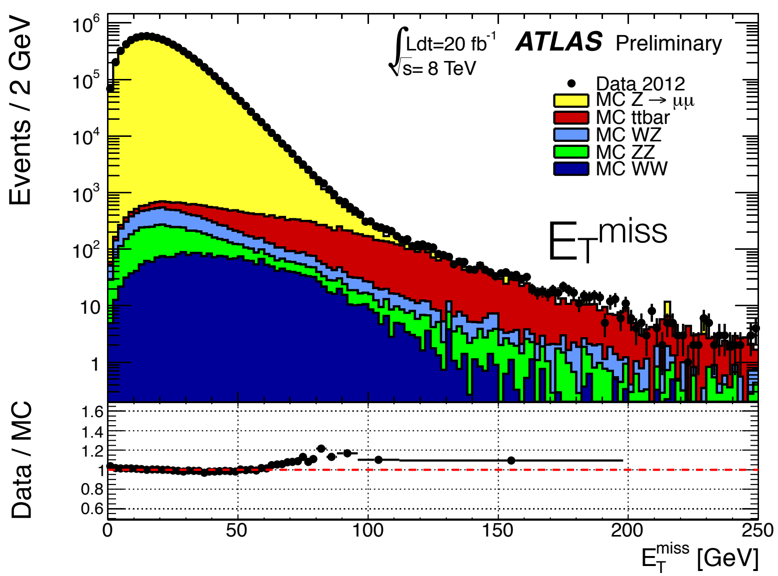
HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

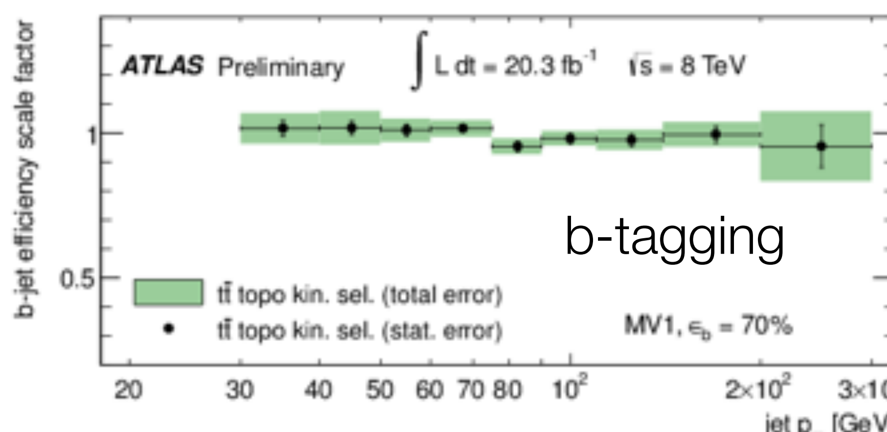
Performance highlights



Effect of pileup corrections







The Standard Model in one slide

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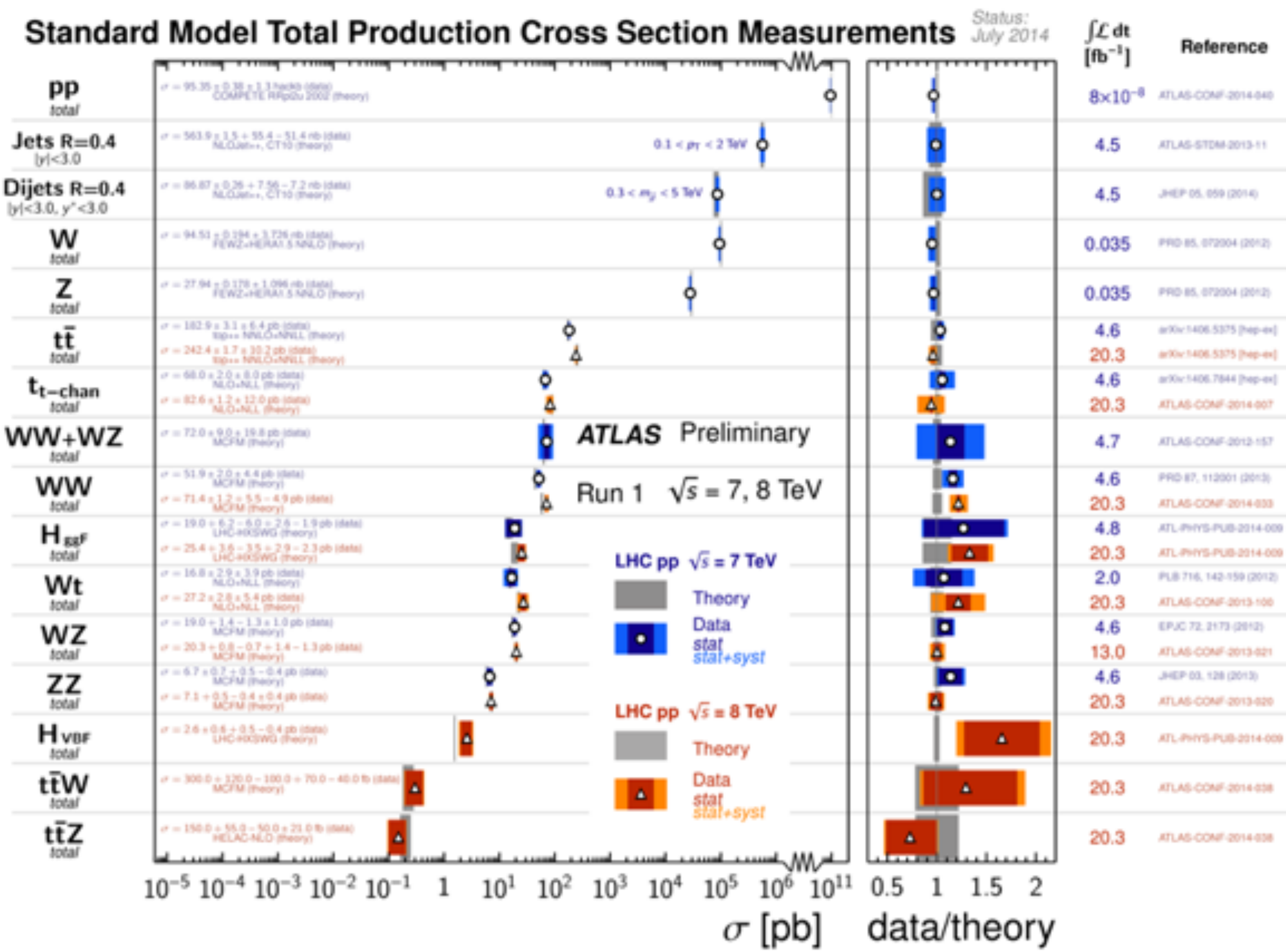
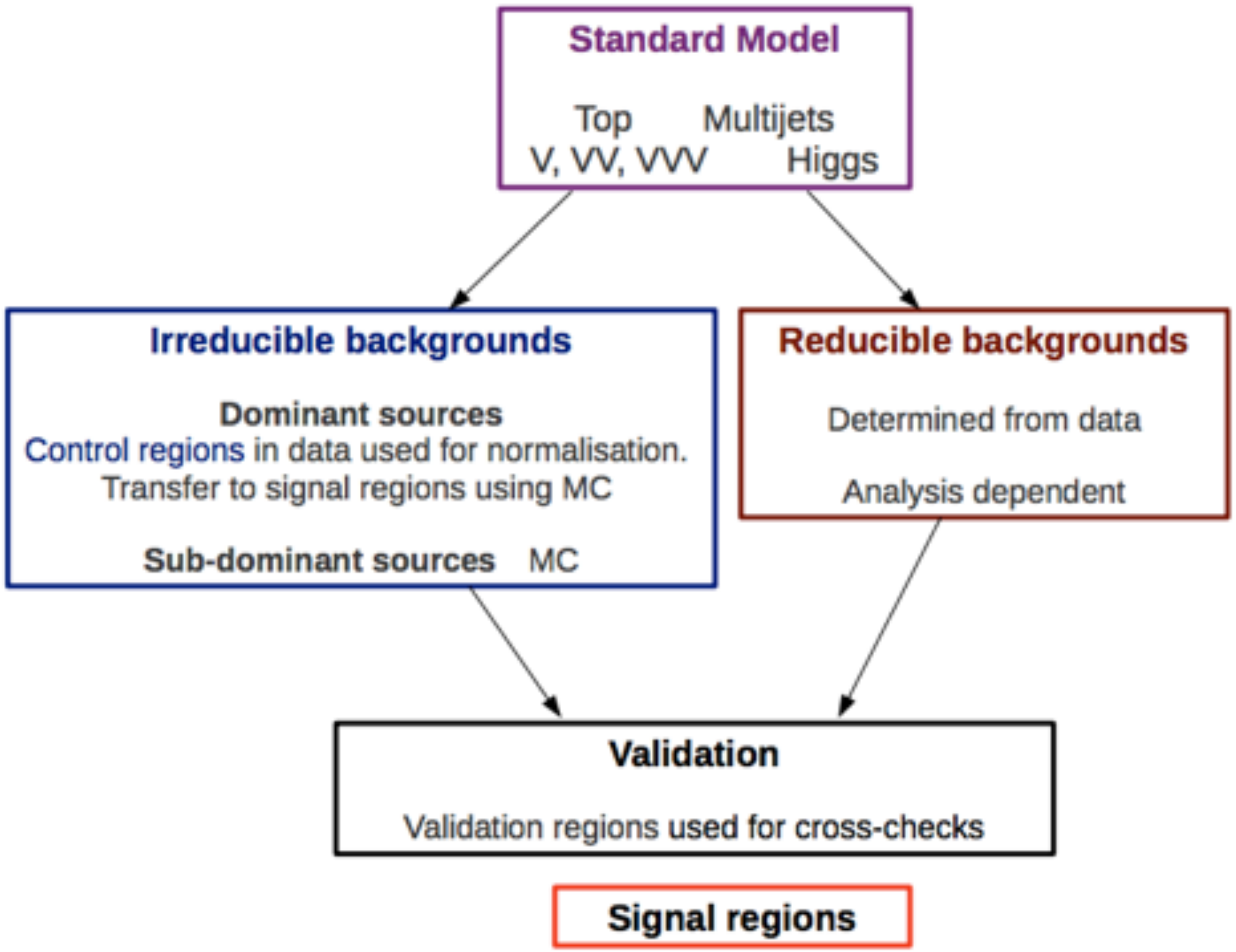


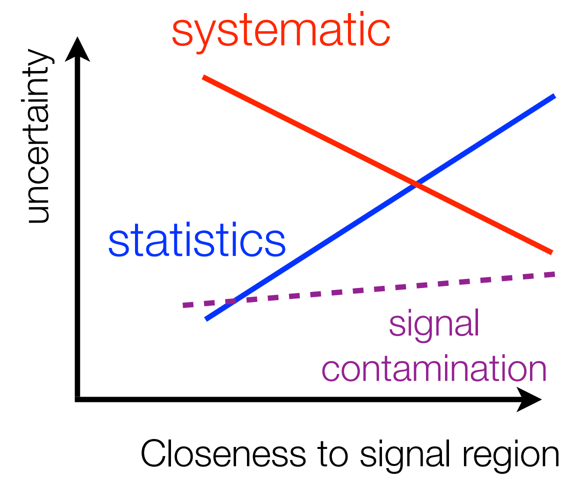
Standard Model background estimation

- Doing **SUSY searches** means primarily **understanding the Standard Model background**.



Irreducible background estimate

- Normalisation of **irreducible backgrounds** done in **dedicated CR**



$$N^i_{SR} = \frac{N^{i,MC}_{SR}}{N^{i,MC}_{CR}}\left(N^{i,data}_{CR} - \sum_{j=process} N^{j,MC}_{CR}\right) = T\left(N^{i,data}_{CR} - \sum_{j=process} N^{j,MC}_{CR}\right)$$

- If $\sum N_{MC}^{j,MC}$ small, then **all systematic uncertainty associated to T**

- Typical uncertainties considered:

Experimental uncertainties:
-Trigger efficiency
-Jet energy scale and resolution
-Lepton energy scale and efficiency
-E_T^{miss} soft component
-b-tagging
-Luminosity
-pileup modelling

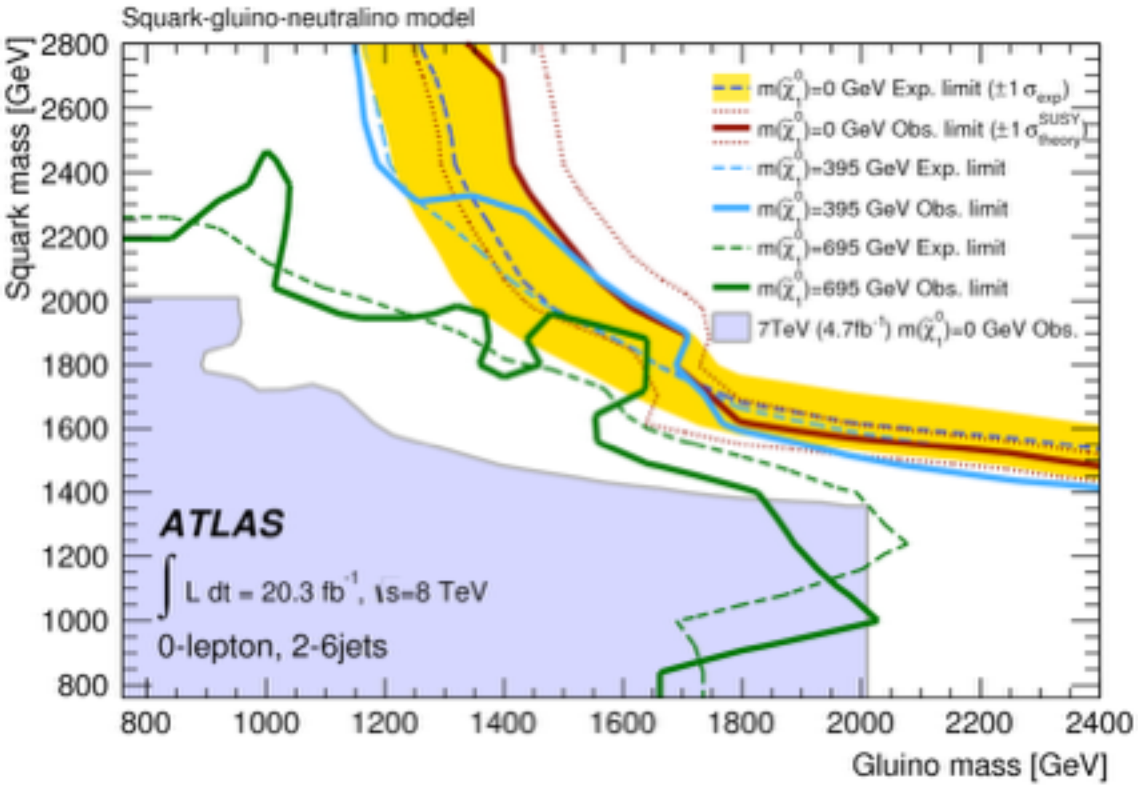
Theory uncertainties:
-Generator modelling (μ_F,μ_R, ME/PS matching, α_s scale choice when possible - otherwise compare generators)
- PS uncertainties (typically compare Pythia and Herwig)
- PDF choice

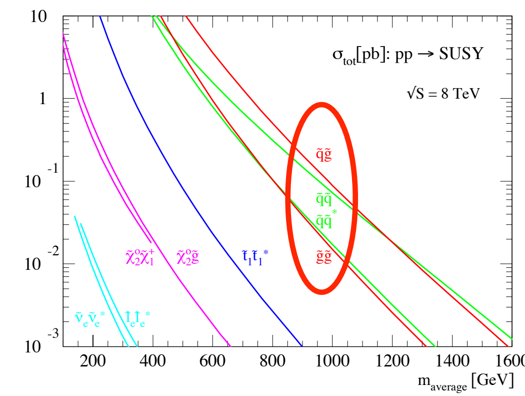
Background (and uncertainty) determination **verified with the use of the validation regions**

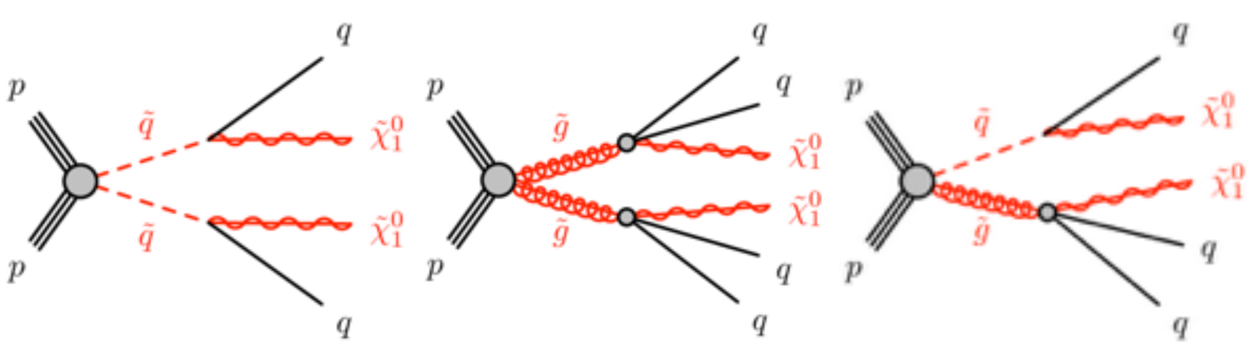
Calculation done **performing a combined fit** to all CR (signal contamination accounted for exclusion)

Results (strong production)

Limits on squark and gluino production





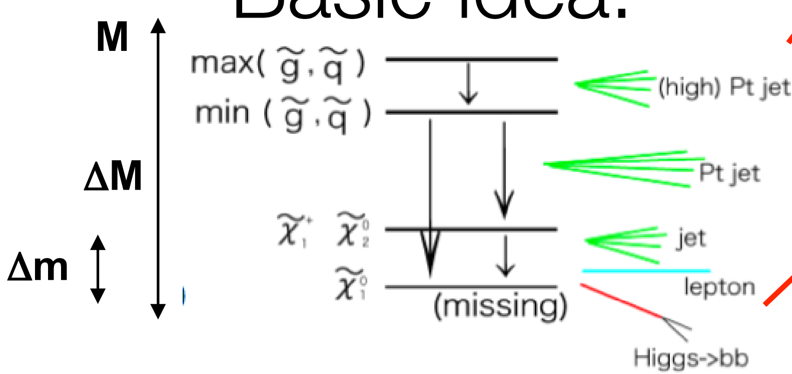


- Hypotheses:
  - All SUSY particles except (1st and 2nd generation) squarks, gluinos and the neutralino LSP are decoupled.
  - All (1st and 2nd generation) squarks assumed to be degenerate

Inclusive searches for gluinos and squark production

Strongest limits set by a 0-lepton analysis using M_{eff} as discriminating quantity

Basic idea:



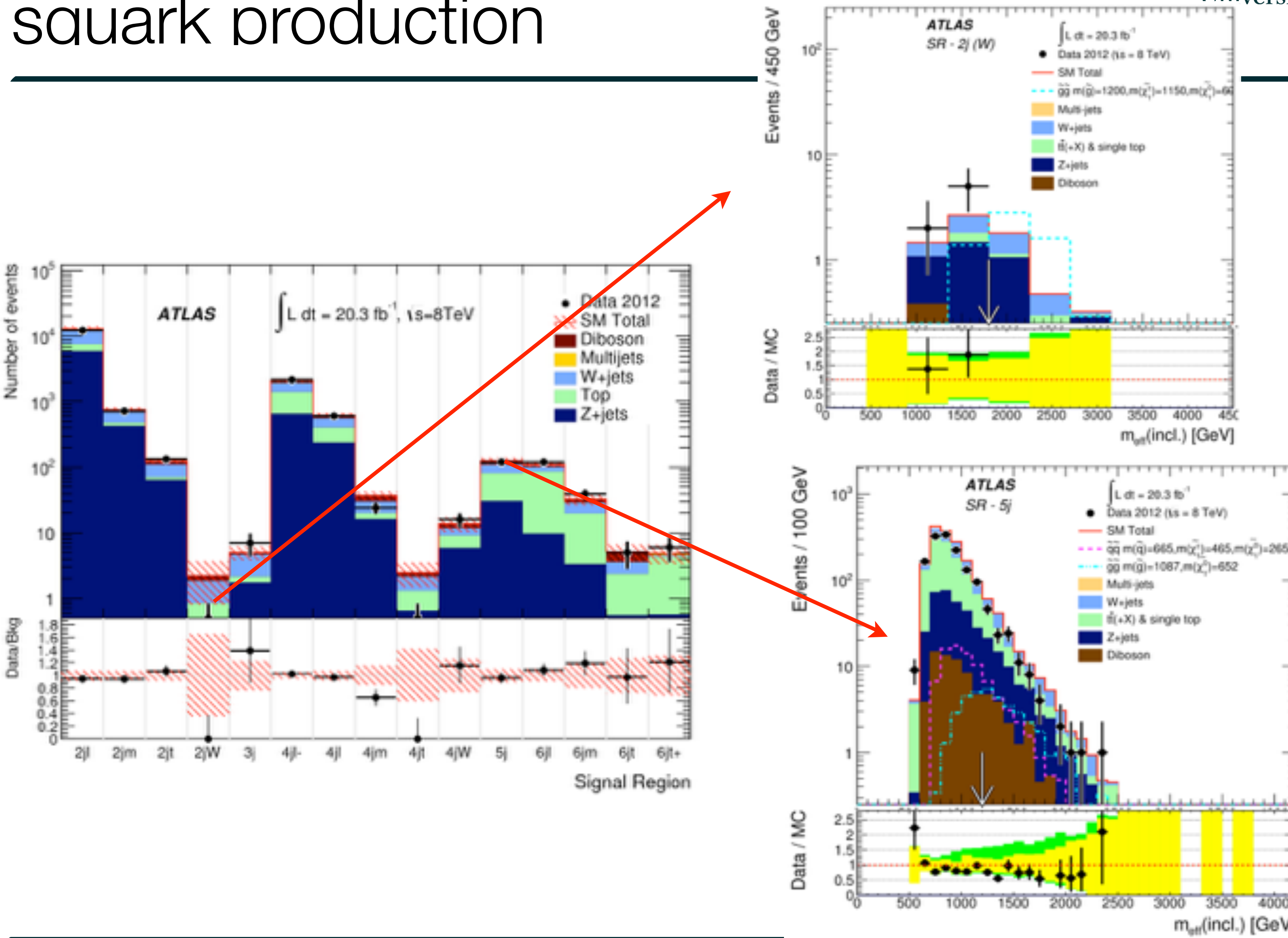
$$H_T = \sum_{jets} p_T^{jets} (+ \sum_{l} p_T^{l} + ...)$$

$$M_{eff} = E_T^{miss} + H_T$$

Requirement	Signal Region					
	2jl	2jm	2jt	[illegible]	[illegible]	4jW
E_T^{miss}[GeV] >	160					
$p_T(j_1)$ [GeV] >	[illegible]					
$p_T(j_2)$ [GeV] >	60					
$p_T(j_3)$ [GeV] >	–				60	40
$p_T(j_4)$ [GeV] >	–					40
$\Delta\phi(\mathrm{jet}_{1,2,(3)}, \mathbf{E}_T^{miss})_{min}$ >	0.4					
$\Delta\phi$([illegible]$)_{min}$ >	–					0.2
W candidates	–			$2(W \to j)$	–	$(W \to j) + (W \to jj)$
$E_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] >	8	15		–		
$E_T^{miss}/m_{eff}(N_j)$ >	–			0.25	0.3	0.35
m_{eff}(incl.) [GeV] >	800	1200	1600	1800	2200	1100

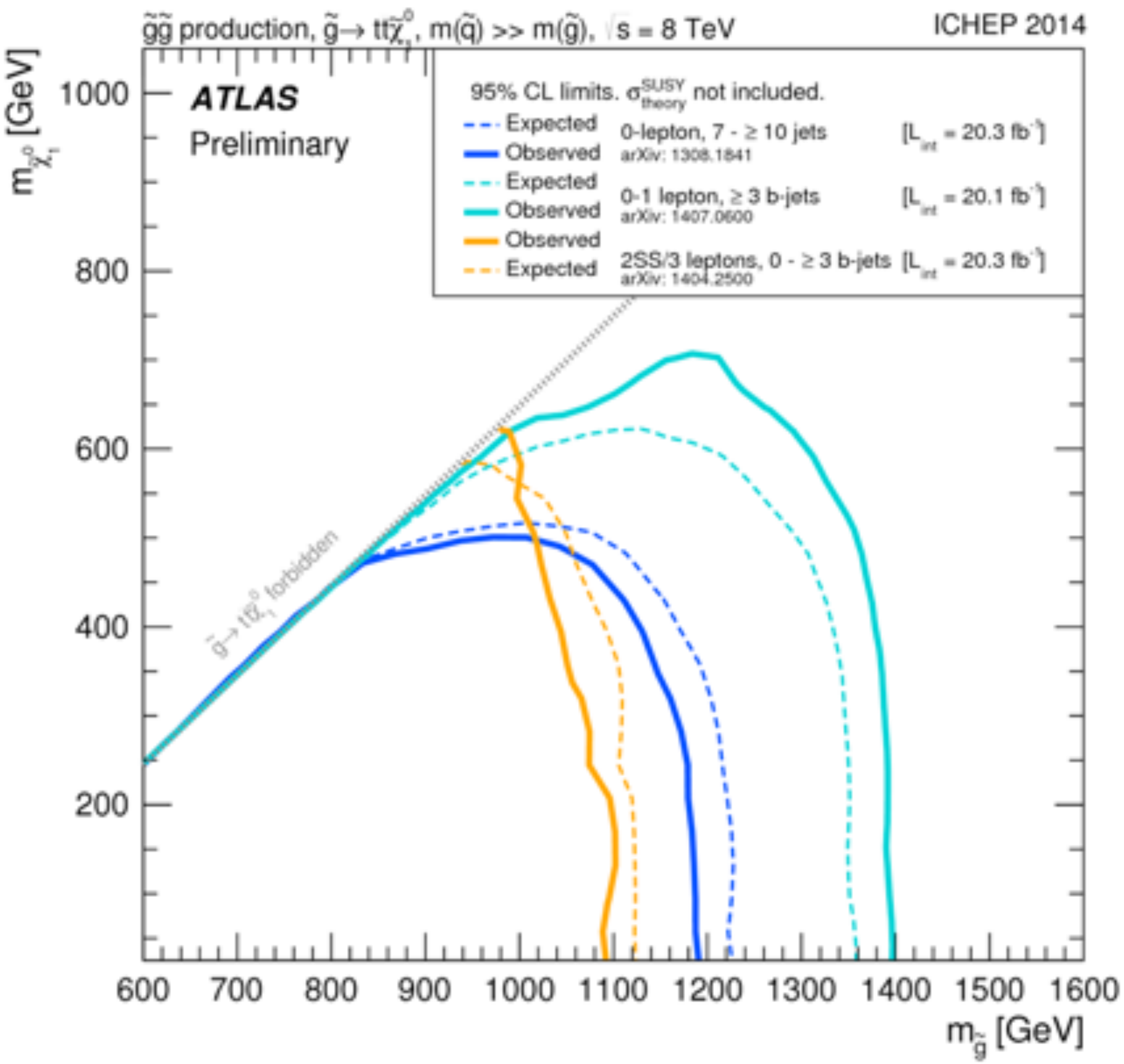
Requirement	Signal Region								
	4jl-	4jl	4jm	4jt	5j	6jl	6jm	6jt	6jt+
E_T^{miss}[GeV] >	160								
$p_T(j_1)$ [GeV] >	130								
$p_T(j_2)$ [GeV] >	60								
$p_T(j_3)$ [GeV] >	60								
$p_T(j_4)$ [GeV] >	60								
$p_T(j_5)$ [GeV] >	–				60				
$p_T(j_6)$ [GeV] >	–					60			
$\Delta\phi(\mathrm{jet}_{1,2,(3)}, \mathbf{E}_T^{miss})_{min}$ >	0.4								
$\Delta\phi(\mathrm{jet}_{i>3}, \mathbf{E}_T^{miss})_{min}$ >	0.2								
$E_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] >	10		–						
$E_T^{miss}/m_{eff}(N_j)$ >	[illegible]		0.4	0.25	0.2			0.25	0.15
m_{eff}(incl.) [GeV] >	700	1000	1300	2200	1200	900	1200	1500	1700

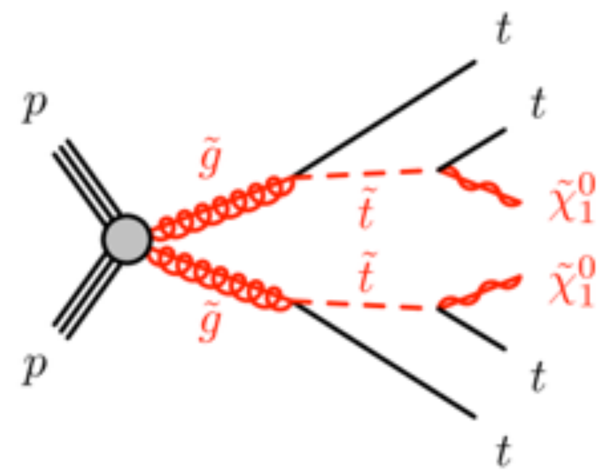
Inclusive searches for gluinos and squark production



Gluino mediated stop production

Gluino mediated stop production

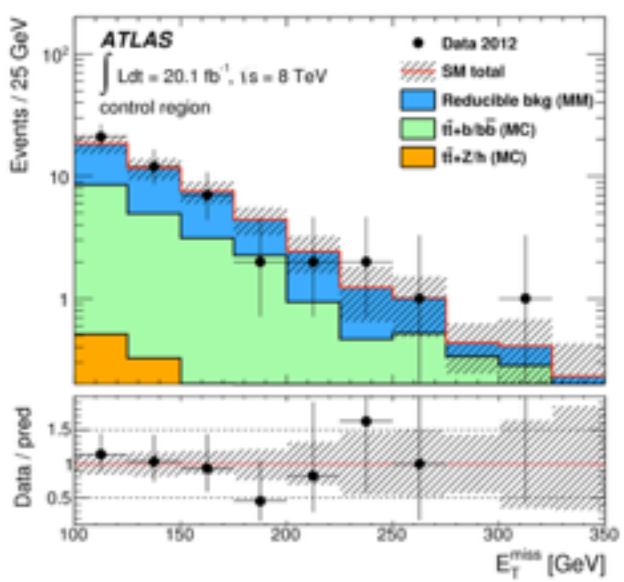




A very rich topology that can be targeted from many points of view

0/1 lepton - 3 b-jets

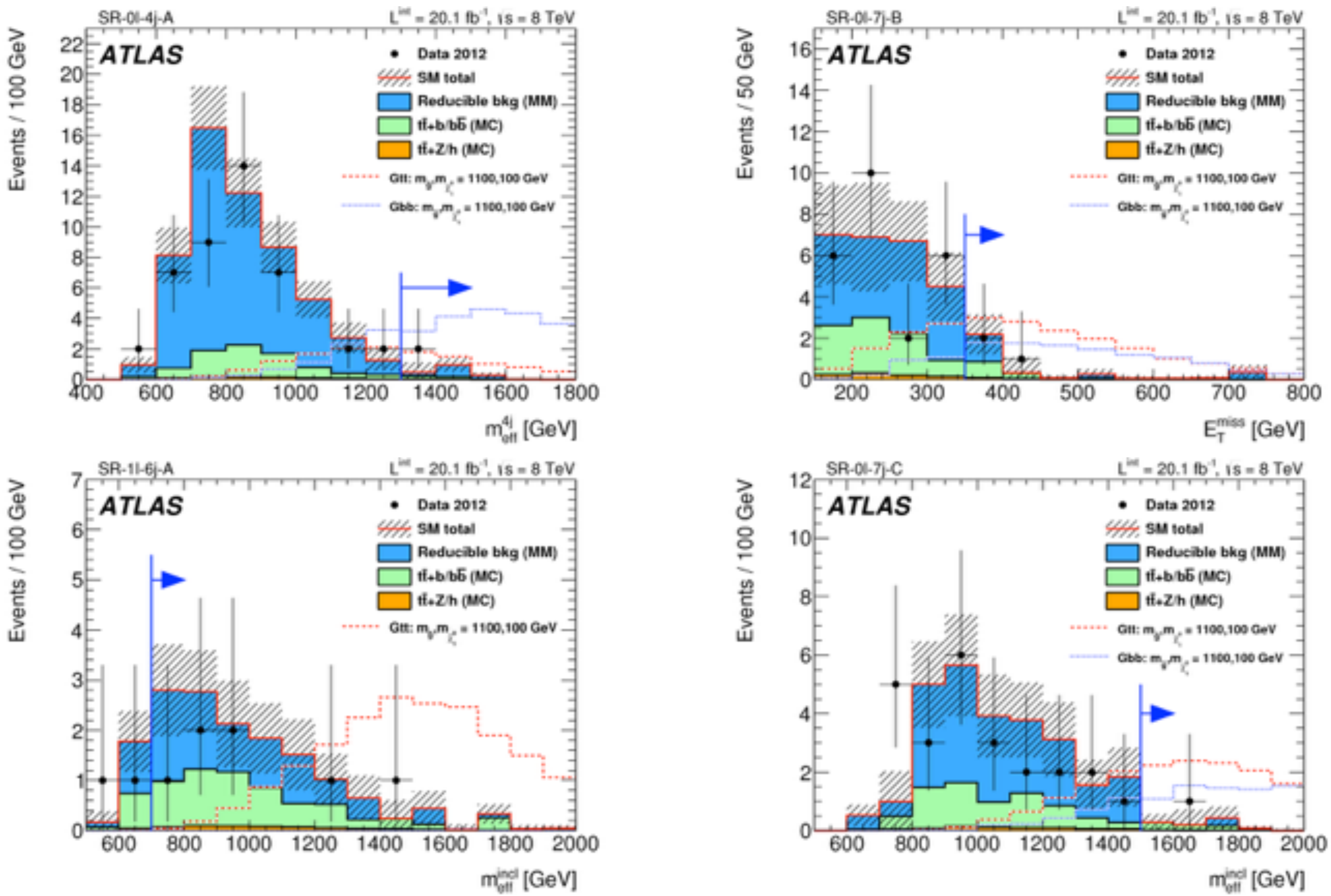
- Background estimation strategy with so-called "matrix method" approach is key
  - Reducible background: mostly ttbar



Baseline 0-lepton selection: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 150$ GeV, ≥ 4 jets with $p_T > 30$ GeV, $\Delta\phi_{min}^{4j} > 0.5$, $E_T^{miss}/m_{eff}^{4j} > 0.2$, ≥ 3 b-jets with $p_T > 30$ GeV				
	N jets (p_T [GeV])	E_T^{miss} [GeV]	m_{eff} [GeV]	$E_T^{miss}/\sqrt{H_T^{4j}}$ [$\sqrt{GeV}$]
SR-0ℓ-4j-A	≥ 4 (50)	> 250	$m_{eff}^{4j} > 1300$	–
SR-0ℓ-4j-B	≥ 4 (50)	> 350	$m_{eff}^{4j} > 1100$	–
SR-0ℓ-4j-C*	≥ 4 (30)	> 400	$m_{eff}^{4j} > 1000$	> 16
SR-0ℓ-7j-A	≥ 7 (30)	> 200	$m_{eff}^{incl} > 1000$	–
SR-0ℓ-7j-B	≥ 7 (30)	> 350	$m_{eff}^{incl} > 1000$	–
SR-0ℓ-7j-C	≥ 7 (30)	> 250	$m_{eff}^{incl} > 1500$	–
Baseline 1-lepton selection: ≥ 1 signal lepton (e,μ), $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 150$ GeV, ≥ 4 jets with $p_T > 30$ GeV, ≥ 3 b-jets with $p_T > 30$ GeV				
	N jets (p_T [GeV])	E_T^{miss} [GeV]	m_T [GeV]	m_{eff}^{incl} [GeV]
SR-1ℓ-6j-A	≥ 6 (30)	> 175	> 140	> 700
SR-1ℓ-6j-B	≥ 6 (30)	> 225	> 140	> 800
SR-1ℓ-6j-C	≥ 6 (30)	> 275	> 160	> 900

Table 2. Definition of the signal regions used in the 0-lepton and 1-lepton selections. The jet p_T threshold requirements are also applied to b-jets. The notation SR-0ℓ-4j-C* means that the leading jet is required to fail the b-tagging requirements to target the region close to the kinematic boundary in the Gbb model.

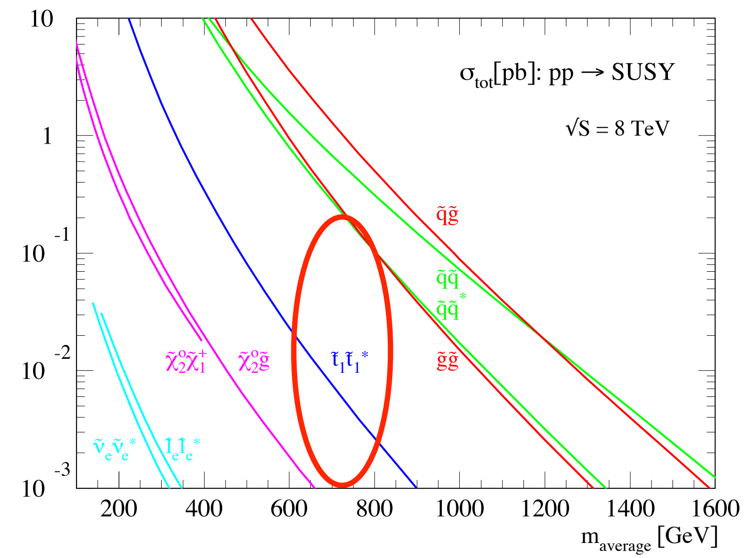
0/1 lepton - 3 b-jets

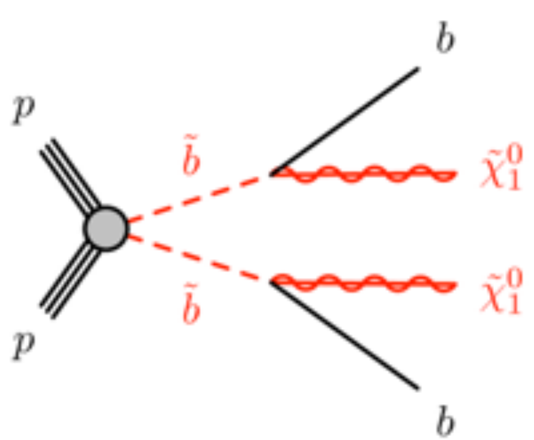


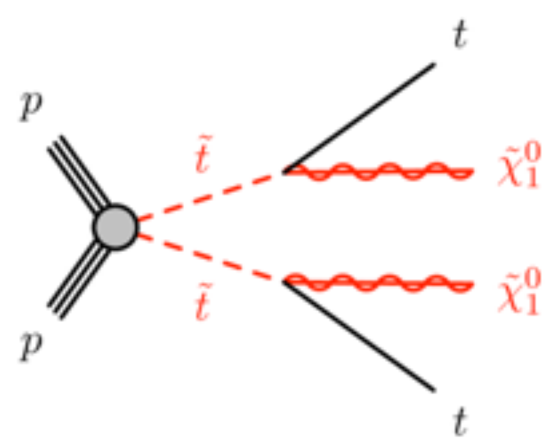
Direct stop/sbottom production

stop/sbottom production and decay

- The **stops (sbottoms)** constrained by naturalness to be **not heavier than ~ 1 TeV**
- Production cross section lower than for other squarks (no incoming b or t in proton)







Direct stop/sbottom production

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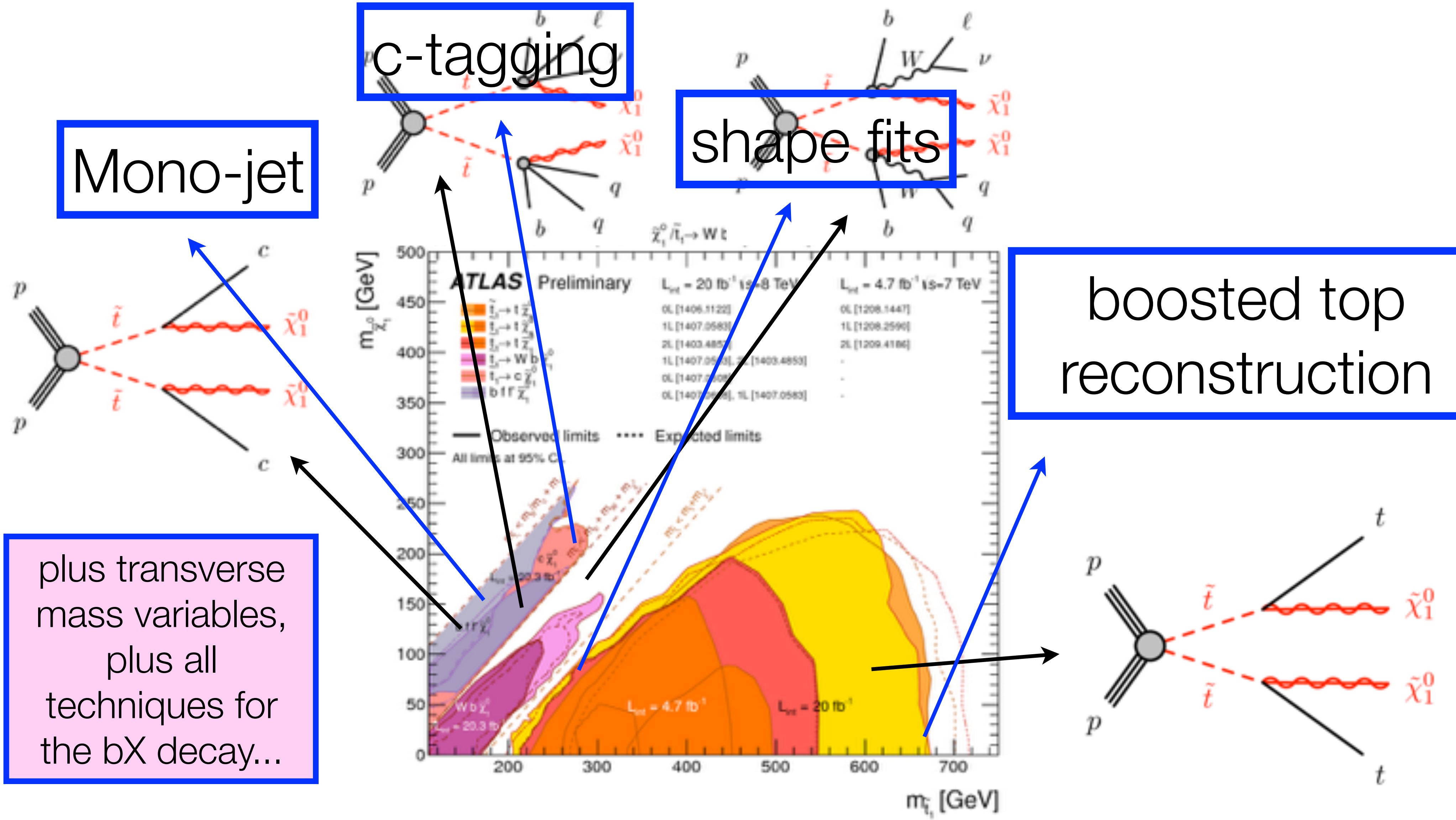

plus transverse mass variables, plus all techniques for the bX decay...

c-tagging

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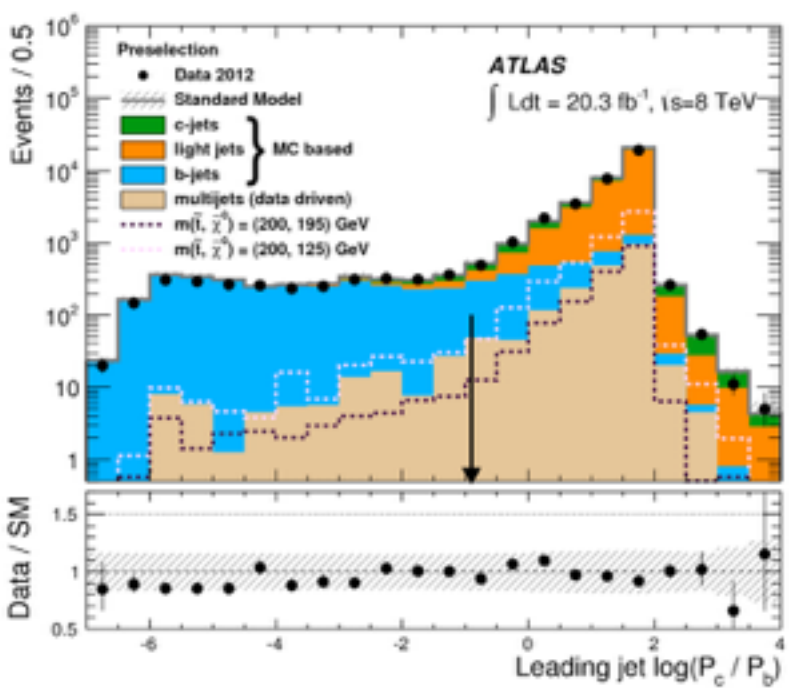
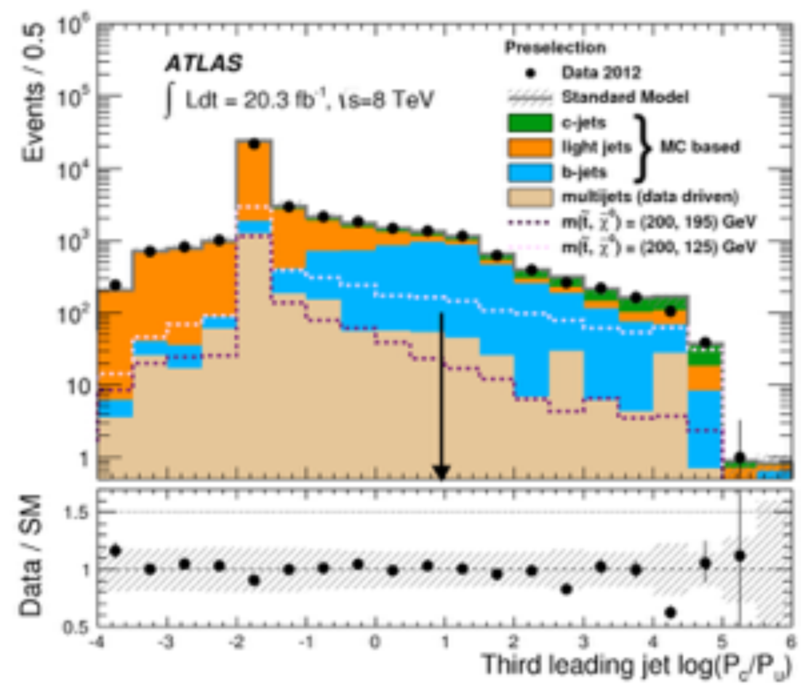
- **Target: stop -> c neut**,
- selection:
  - E_T^{miss} > 150 GeV
  - leading jet p_T > 150 GeV, lepton veto

Background dominated by **Z and W** production

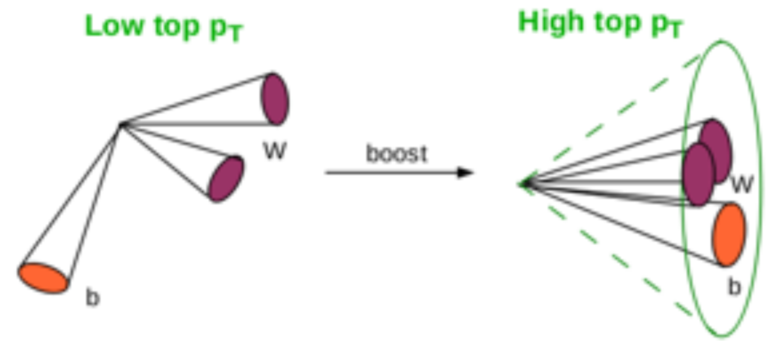
Tag efficiency: 20% for c, 12% for b, 0.5% for light jets



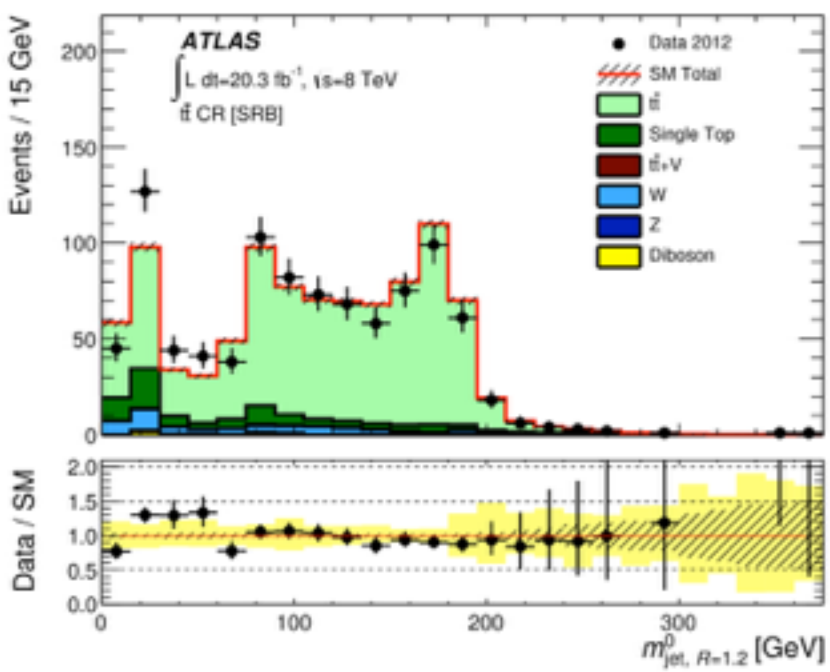


Fat jet reconstruction

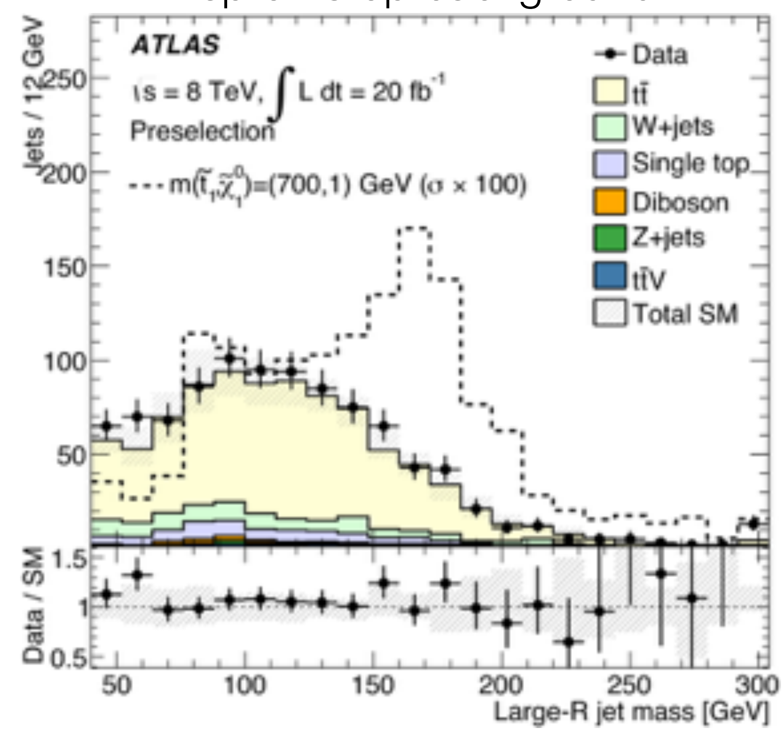
- High stop mass, small LSP mass —> high top boost:
  - Large R jet reconstruction —> all top quark decays into a single big jet



0-lepton stop background

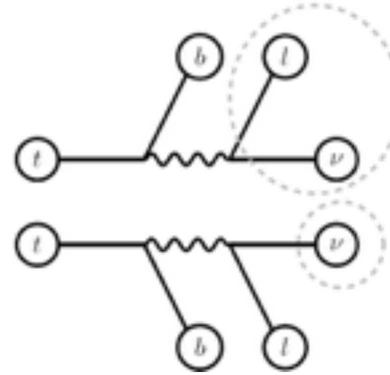


1-lepton stop background



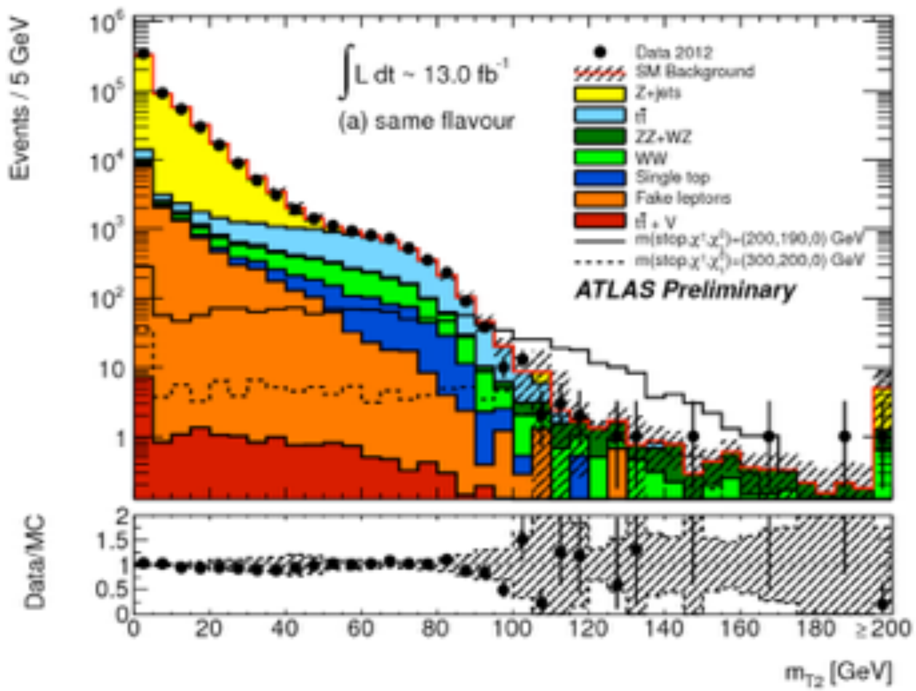
Heavy use of kinematical end-points

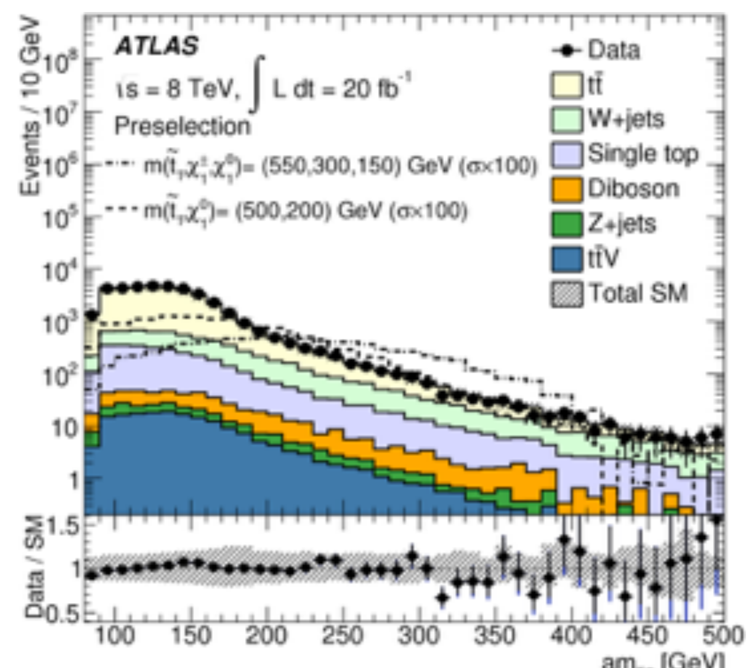
- m_{T2}: an extension of the transverse mass variable



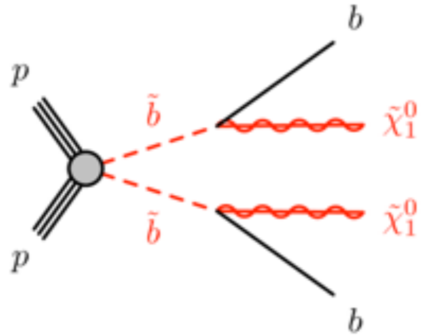
- am_{T2}: a generalisation of the m_{T2} of the transverse mass variable

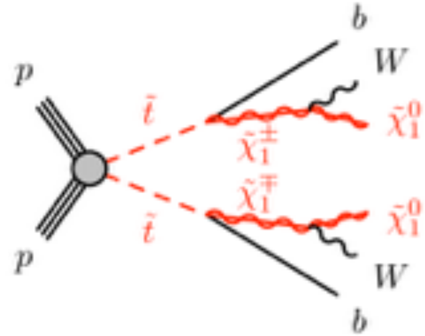
$$m_{T2}(\mathbf{p}_T^{\ell_1},\mathbf{p}_T^{\ell_2},\mathbf{p}_T^{miss}) = \min_{\mathbf{q}_T+\mathbf{r}_T=\mathbf{p}_T^{miss}} \left\{\max[\, m_T(\mathbf{p}_T^{\ell_1},\mathbf{q}_T), m_T(\mathbf{p}_T^{\ell_2},\mathbf{r}_T)\,]\right\}$$





Heavy use of kinematical end-points

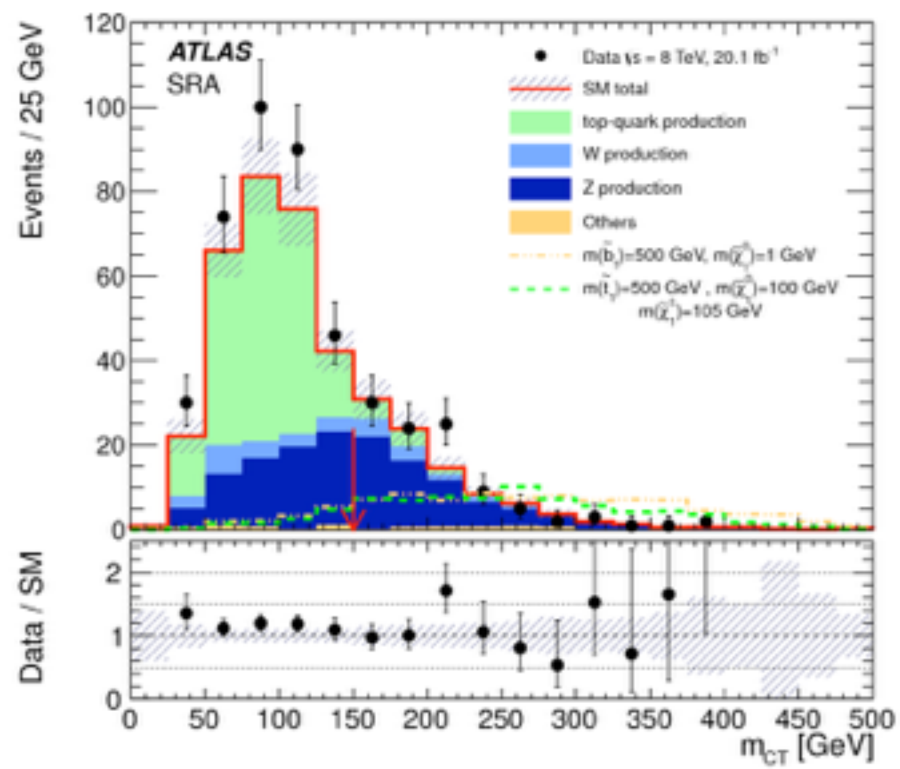




$$\left([E_\mathrm{T}(b_1) + E_\mathrm{T}(b_2)]^2 - [\mathbf{p_T}(b_1) - \mathbf{p_T}(b_2)]^2\right)^{1/2}$$

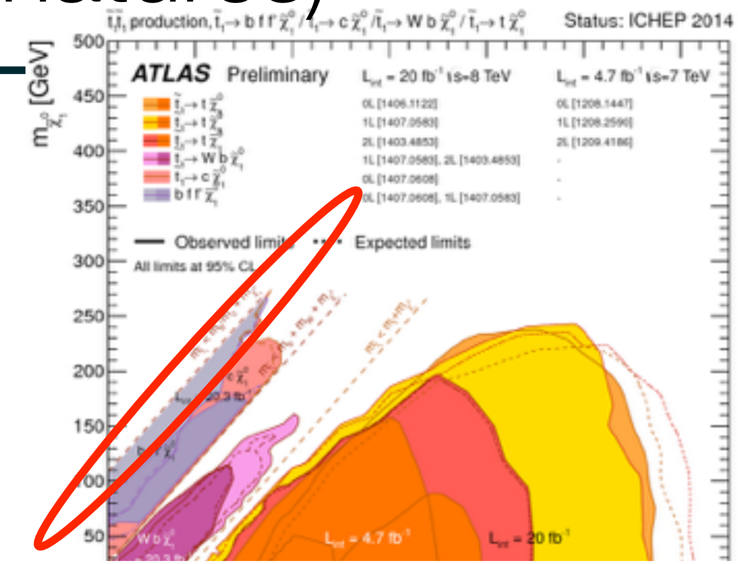
- Same final state topology: bb MET

- $m_{CT}(bb)$: boost-corrected contransverse mass
  - It has an end-point at $(m_{prod}^2 - m_{inv}^2)/m_{prod}$

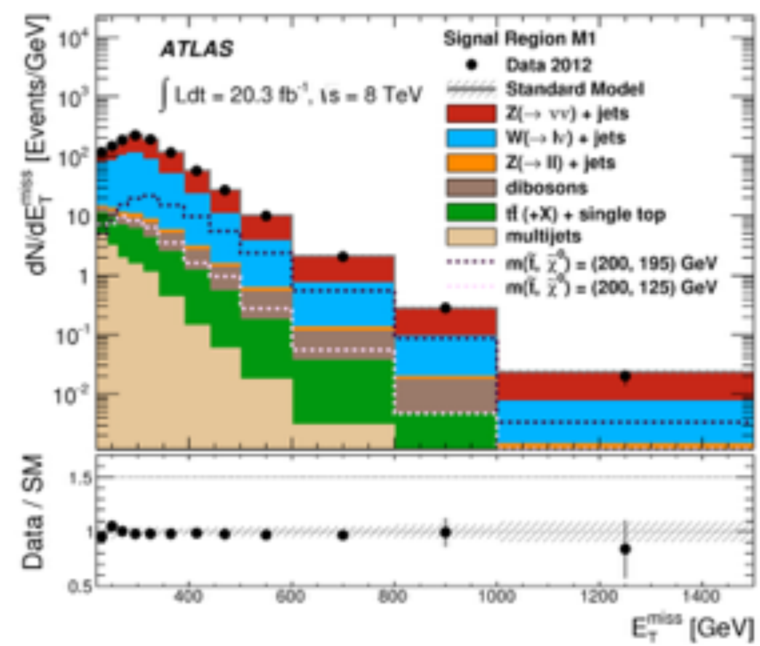


ISR tagging (monojet-like signatures)

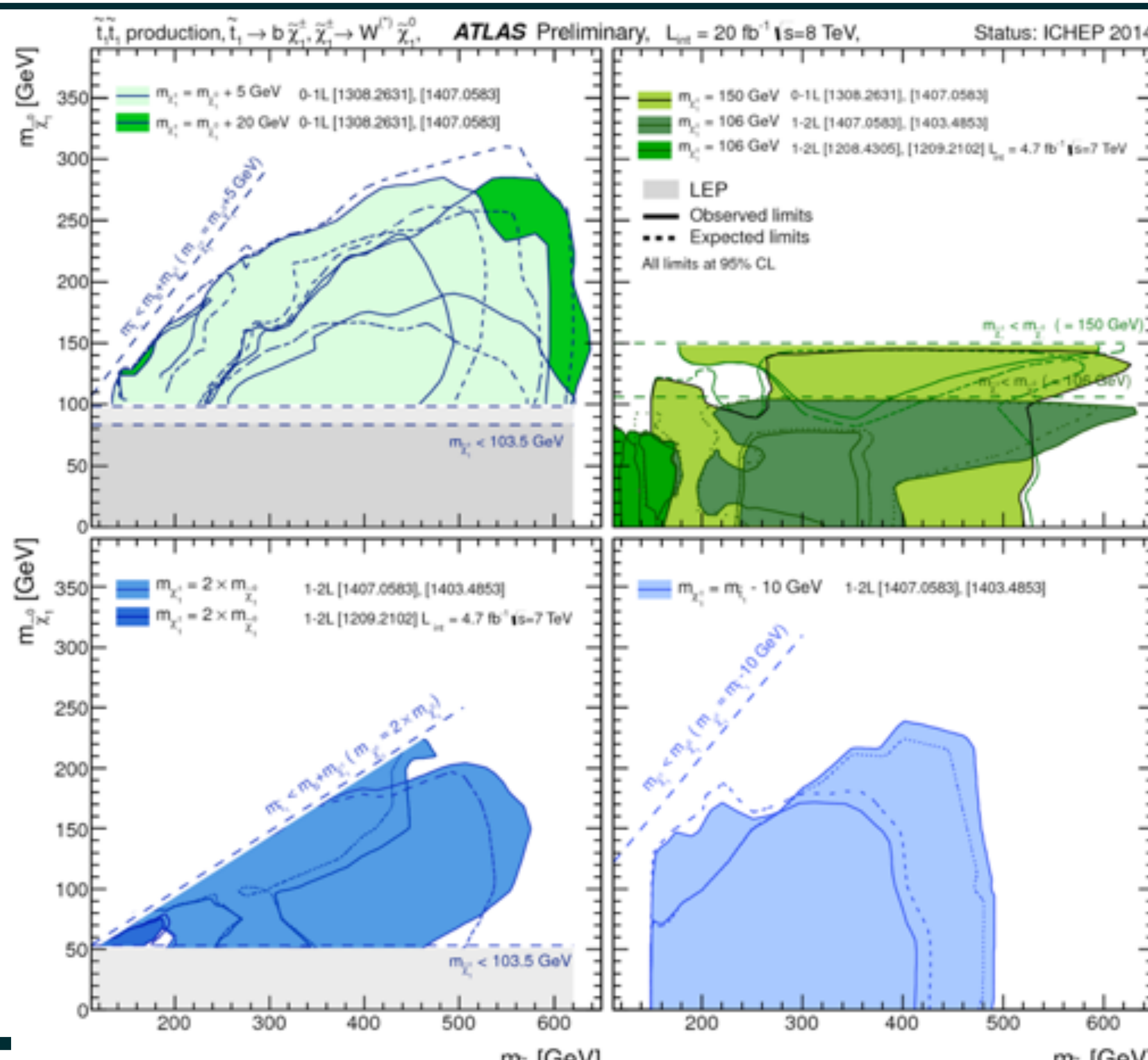
- compressed stop-LSP ⇒ no detectable signal unless boosted stop pair production ⇒ require high p_T ISR jet
  - monojet-like signal (as in DM searches)



Selection criteria			
Preselection			
Primary vertex			
$E_T^{miss} > 150$ GeV			
At least one jet with $p_T > 150$ GeV and $\|\eta\| < 2.8$			
Jet quality requirements			
Lepton vetoes			
Monojet-like selection			
At most three jets with $p_T > 30$ GeV and $\|\eta\| < 2.8$			
$\Delta\phi(\text{jet}, \mathbf{p}_T^{miss}) > 0.4$			
Signal region	M1	M2	M3
Minimum leading jet p_T (GeV)	280	340	450
Minimum E_T^{miss} (GeV)	220	340	450

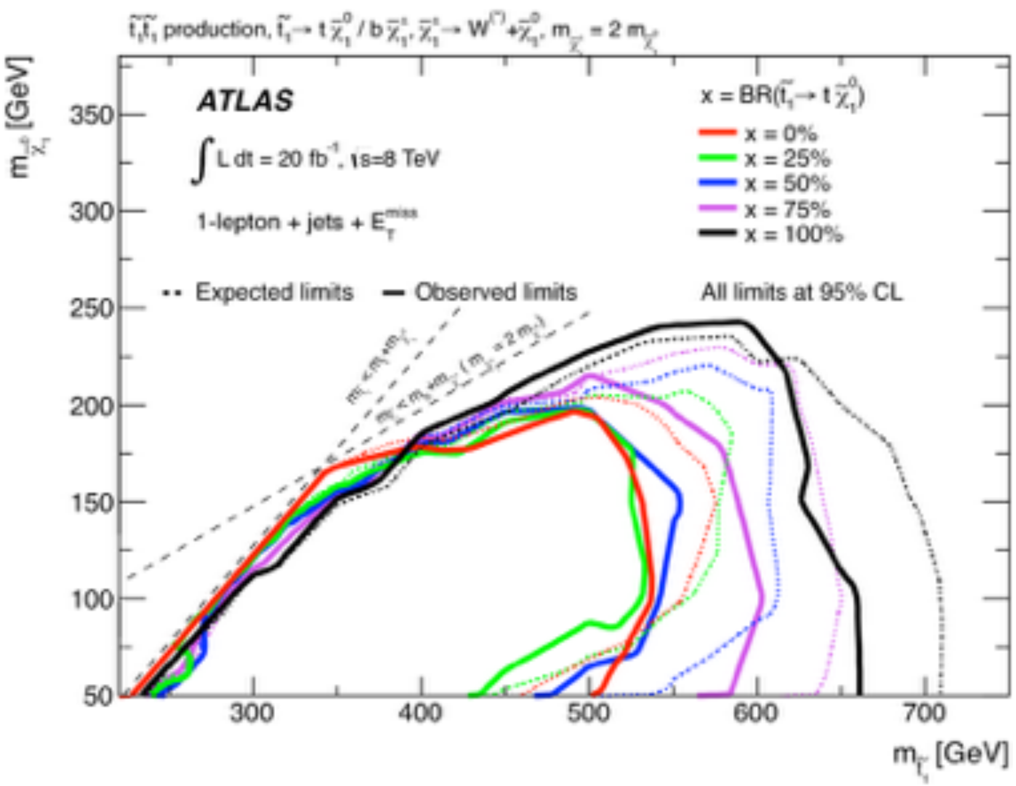


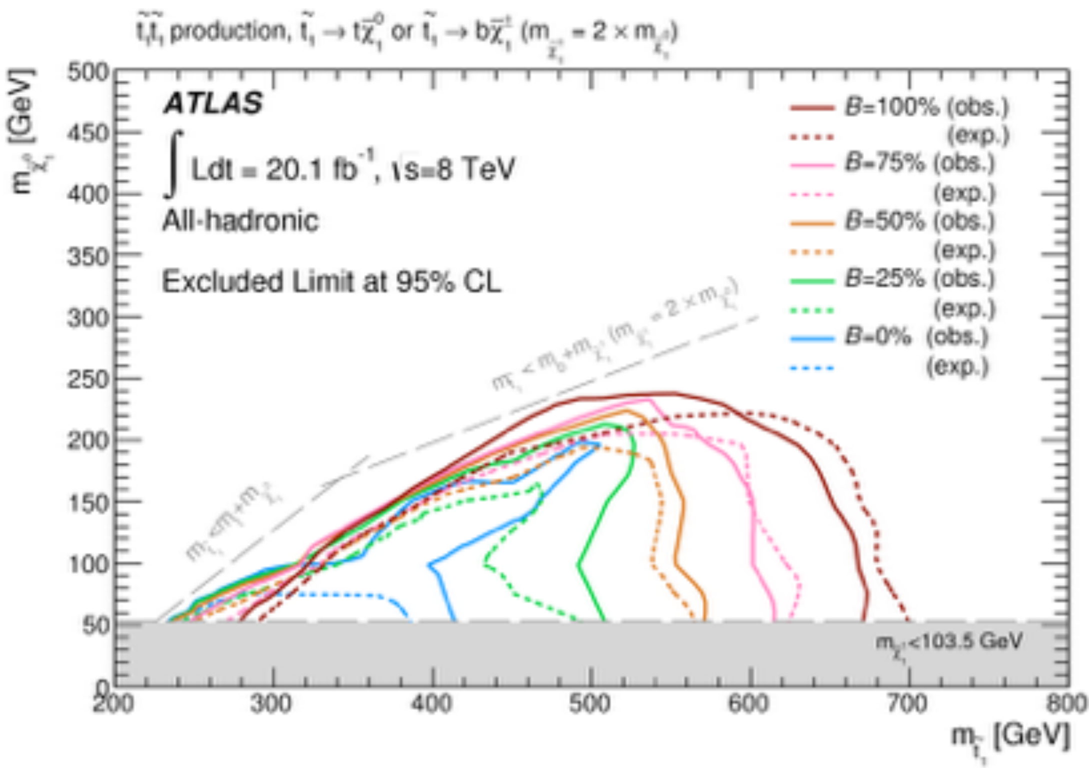
$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$



Limits dependency on BR($t \rightarrow tX_1^0$)

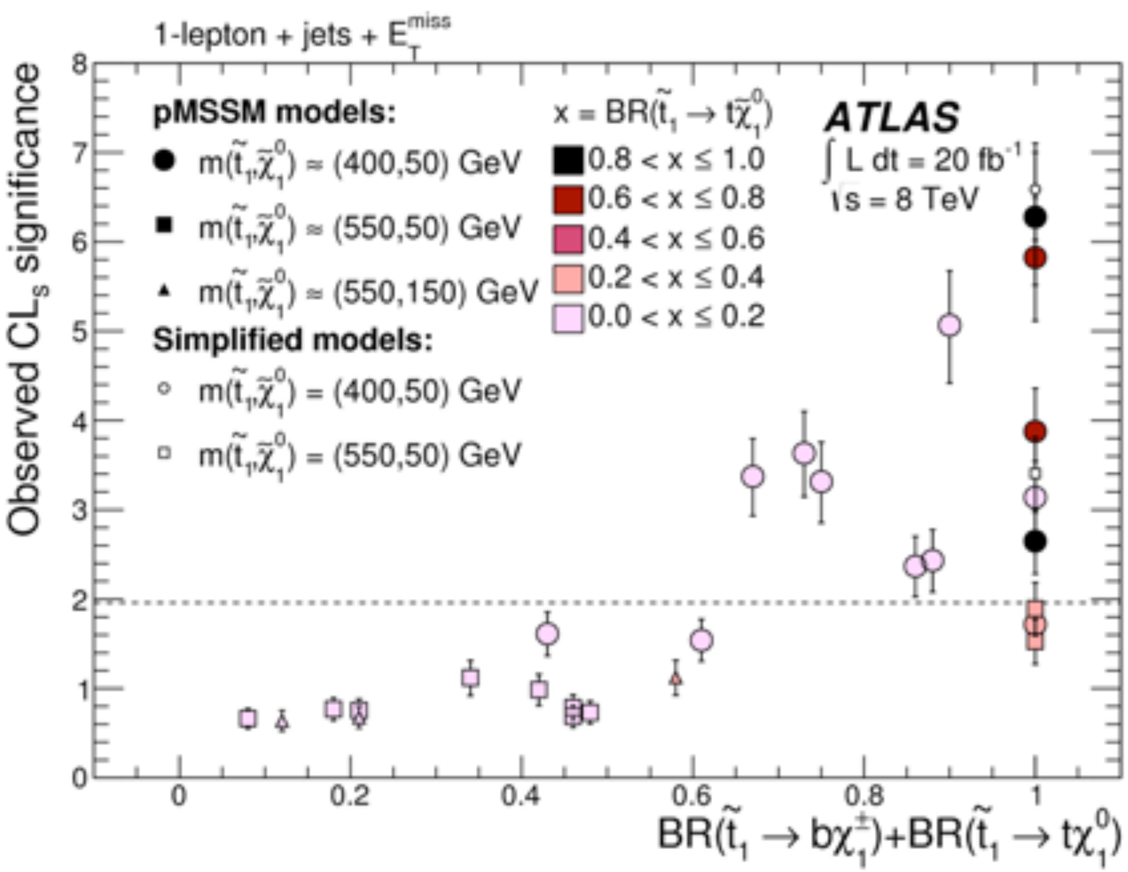
- Signal regions optimised for one specific topology. Combinations of signal regions make results less dependent on the decay details





Limits dependency on BR($t \rightarrow tX_1^0$)

- What if the stop decays into anything else?



Limits from SM measurements

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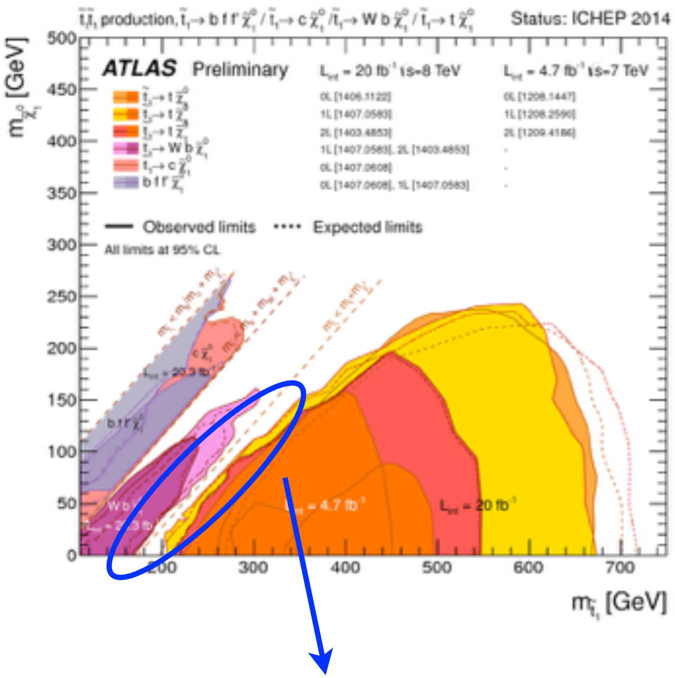
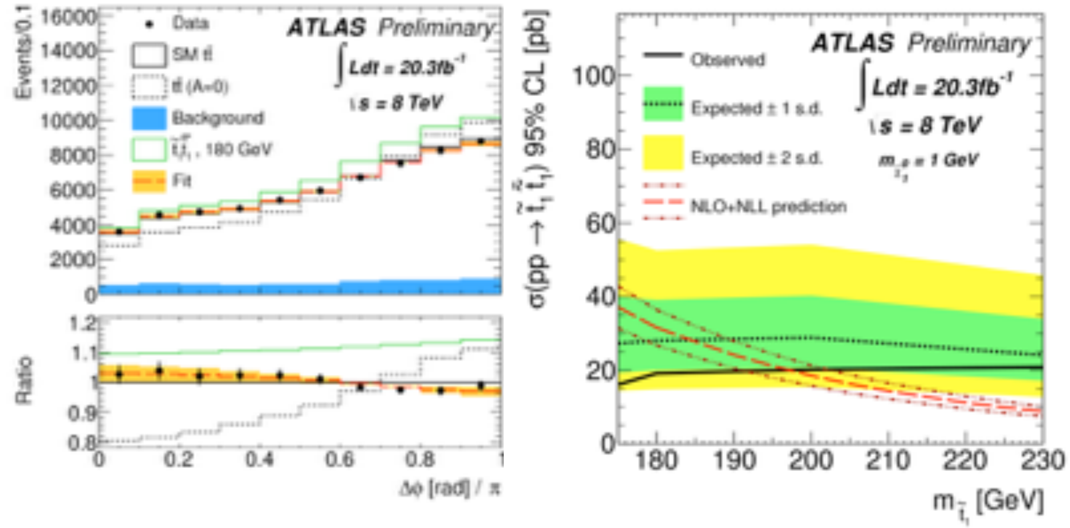
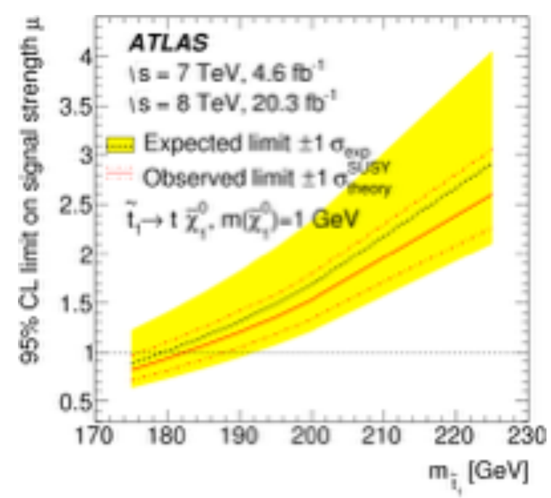


top like kinematics - difficult to approach with searches

Spin correlations

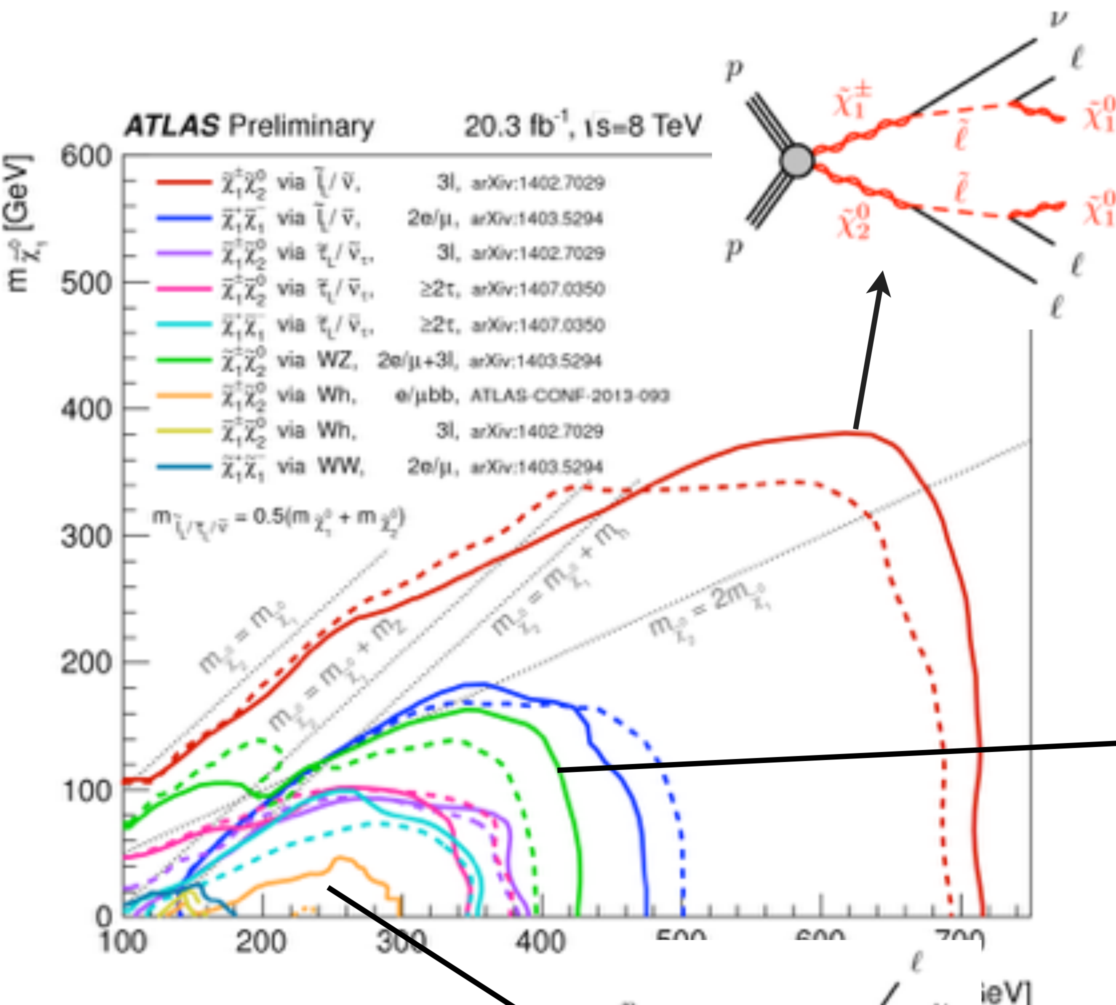


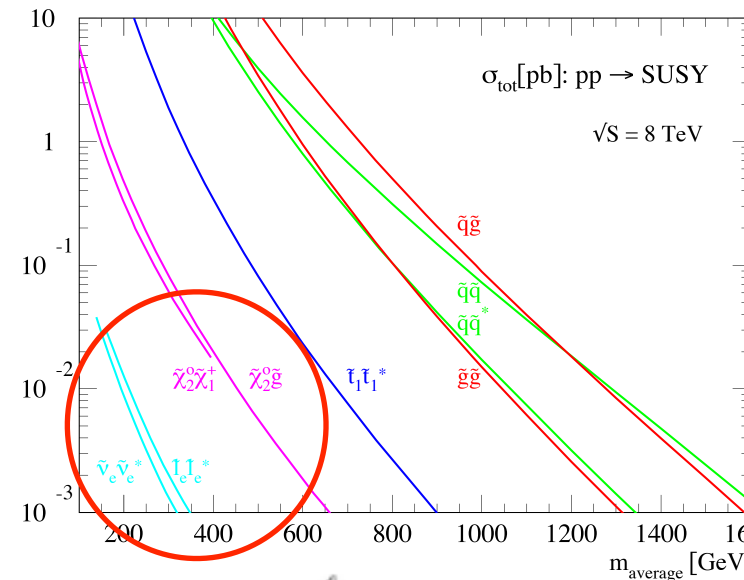
Cross section

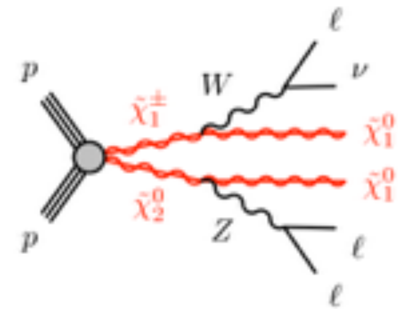


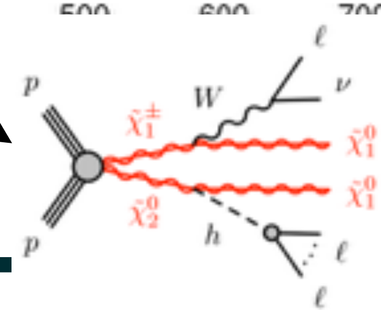
Electroweak production

EW Production







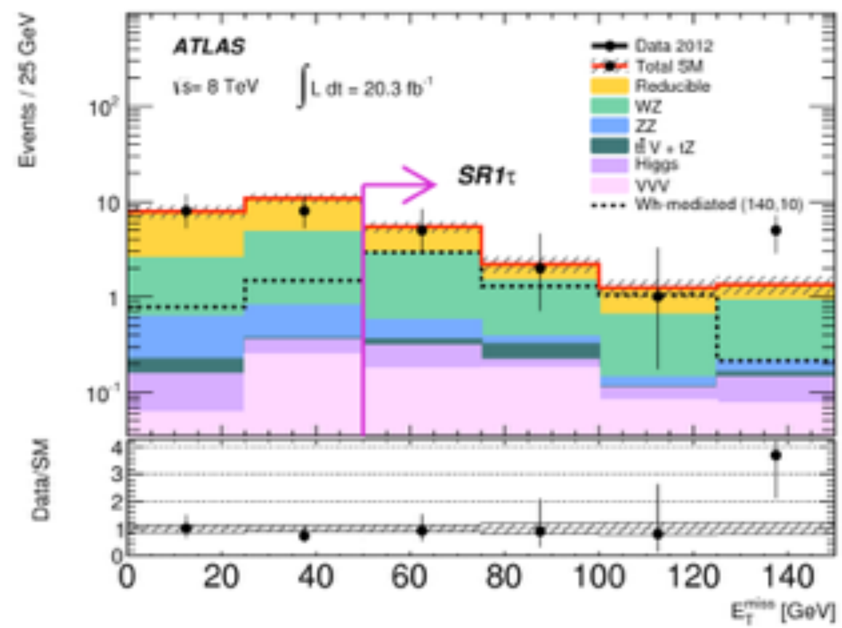


- Unlike strong production, production cross section depends on SUSY parameters.

3-lepton search

Several signal regions defined based on the number of taus

Target several possible scenarios including Higgs production in the final state



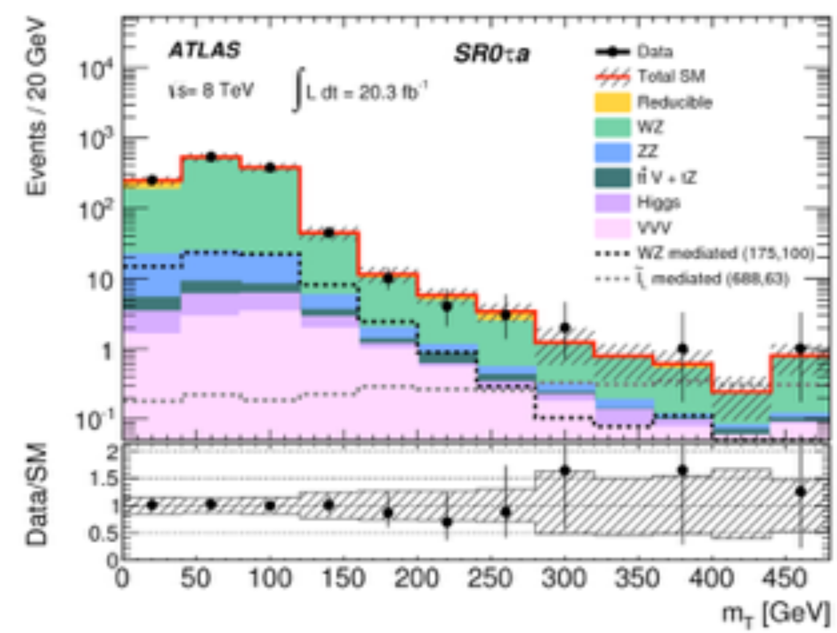
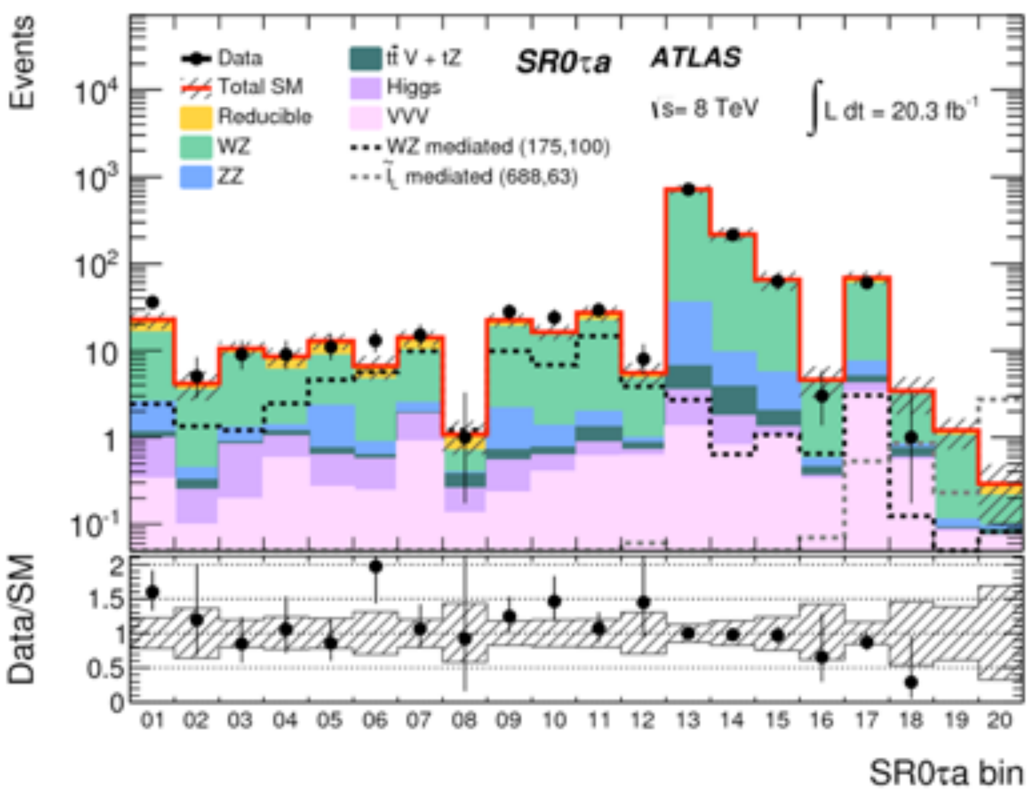


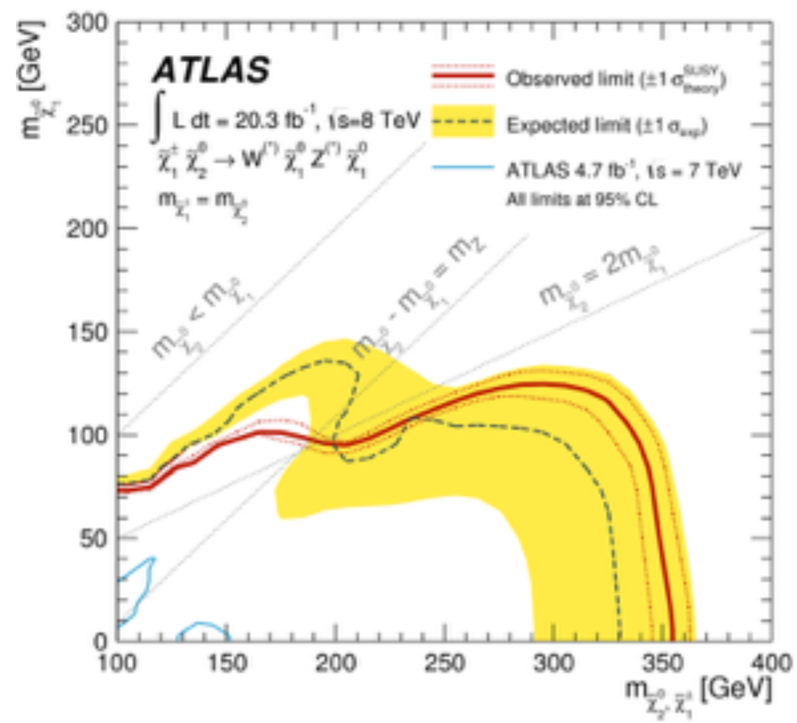
Table 3. Summary of the selection requirements for the signal regions. The index of the signal region corresponds to the number of required τ leptons. The SR0τa bin definitions are shown in table 4. Energies, momenta and masses are given in units of GeV. The signal models targeted by the selection requirements are also shown.

Signal region	SR0τa	SR0τb	SR1τ	SR2τa	SR2τb
Flavour/sign	$\ell^+\ell^-\ell$, $\ell^+\ell^-\ell'$	$\ell^\pm\ell^\pm\ell'^\mp$	$\tau^\pm\ell^\mp\ell^\mp$, $\tau^\pm\ell^\mp\ell'^\mp$	$\tau\tau\ell$	$\tau^+\tau^-\ell$
b-tagged jet	veto	veto	veto	veto	veto
E_T^{miss}	binned	> 50	> 50	> 50	> 60
Other	m_{SFOS} binned m_T binned	$p_T^{3^{rd}\ell} > 20$ $\Delta\phi_{\ell\ell'}^{min} \leq 1.0$	$p_T^{2^{nd}\ell} > 30$ $\sum p_T^\ell > 70$ $m_{\ell\tau} < 120$ m_{ee} Z veto	$m_{T2}^{max} > 100$	$\sum p_T^\tau > 110$ $70 < m_{\tau\tau} < 120$
Target model	$\tilde{\ell}$,WZ-mediated	Wh-mediated	Wh-mediated	$\tilde{\tau}_L$-mediated	Wh-mediated

3-lepton search

- One of the few searches showing some excess
  - To be rechecked with Run 2 data





Prospects for run 2 and beyond

Prospects for run 2 and beyond

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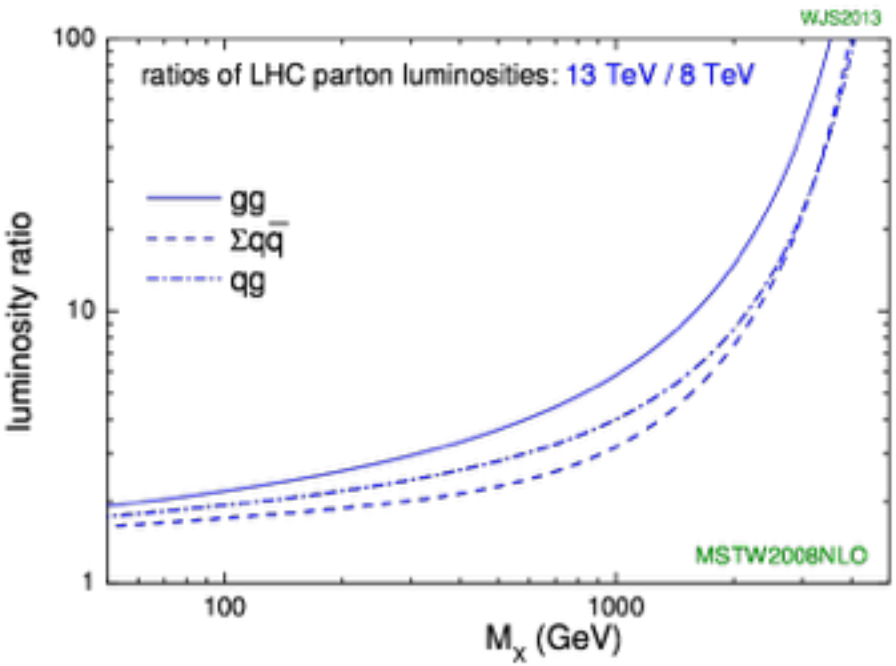
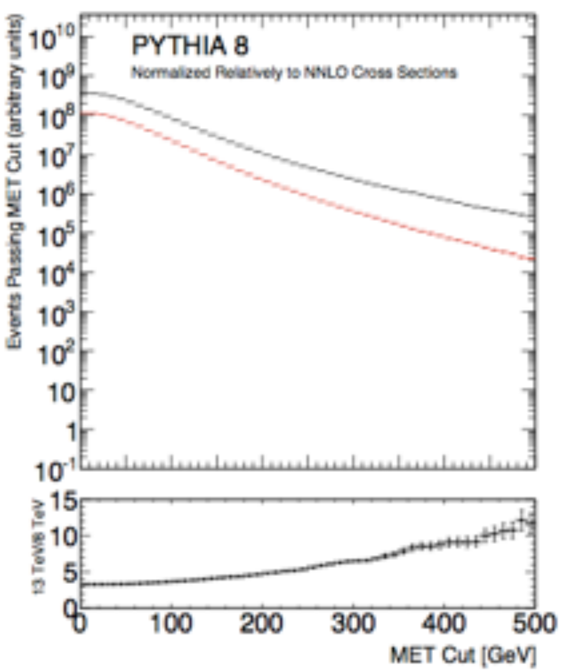
- LHC run 2 due to start next June with $\sqrt{s}$ = 13 TeV.
- **Increase in cms energy** means **increase in cross section**
  - a factor ~8 for mstop = 700 GeV
  - but the **background** increases as well...

Production	fb^{-1} to outperform run 1	expected to be delivered by
strong production	~ 1 fb^{-1}	July/August 2014
Third generation	~ 5 fb^{-1}	End of summer 2014
weak production	~ 20 fb^{-1}	End of run 2014





From http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html

Prospects for run 2 and beyond

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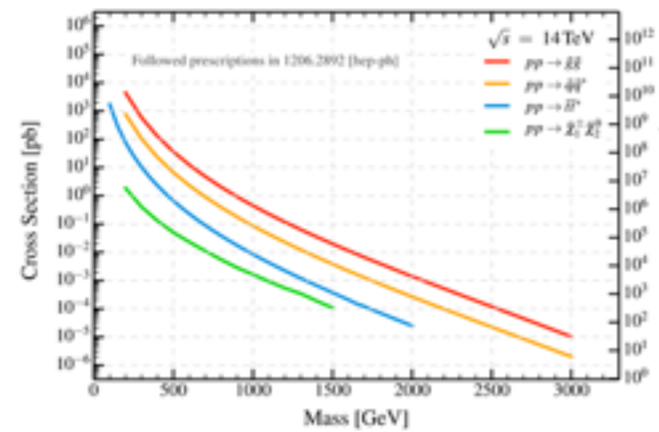
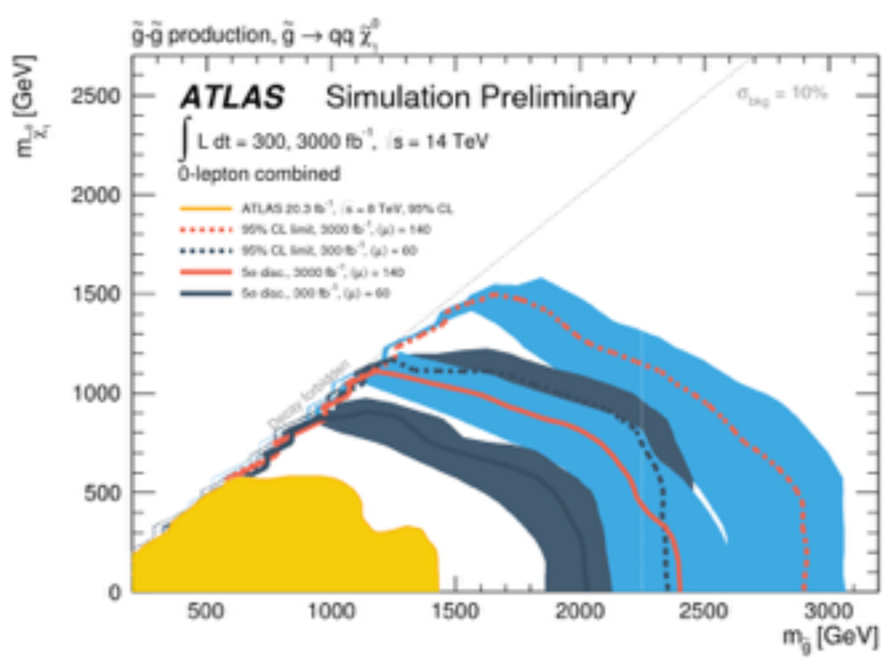
(Highly) simplified detector simulation

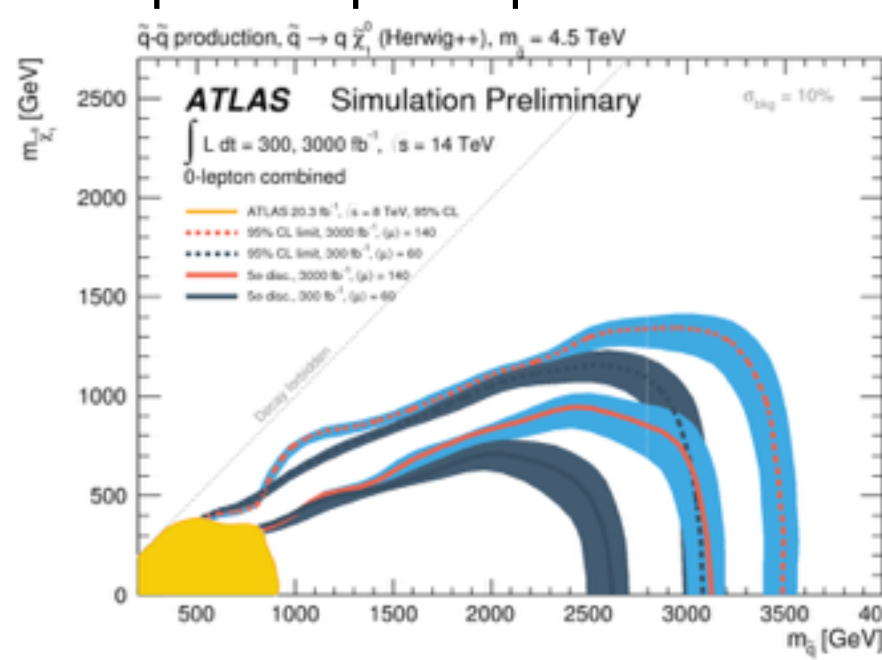
Assuming cms of 14 TeV



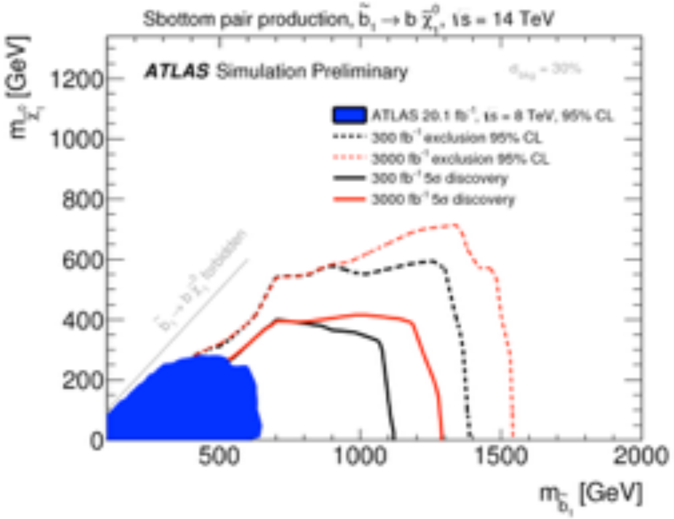
Gluino pair production



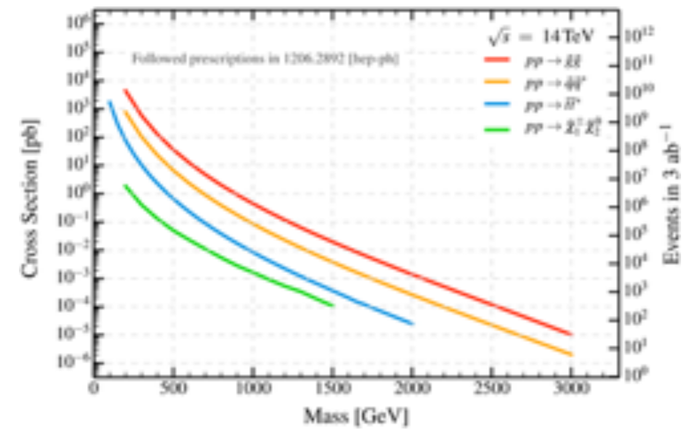
Squark pair production



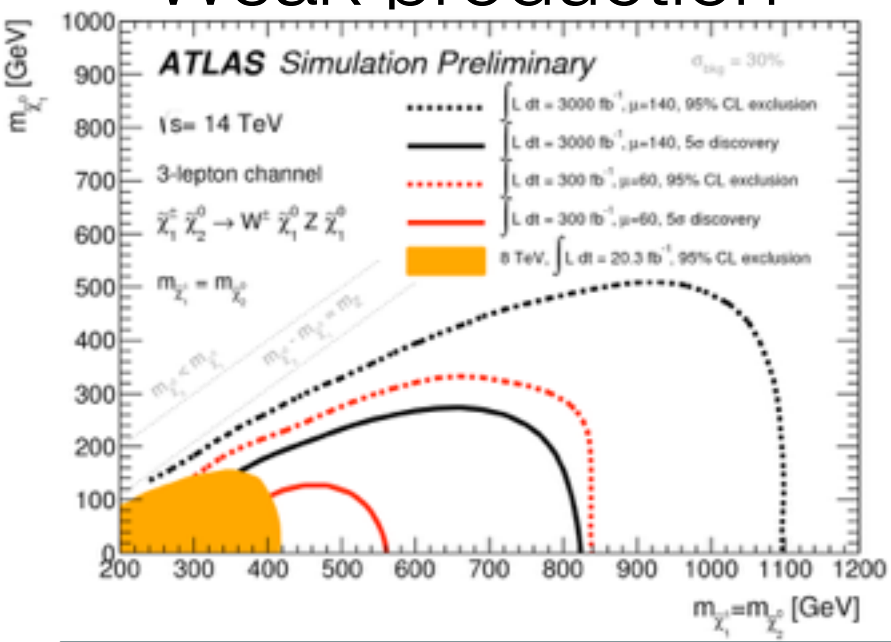
Prospects for run 2 and beyond

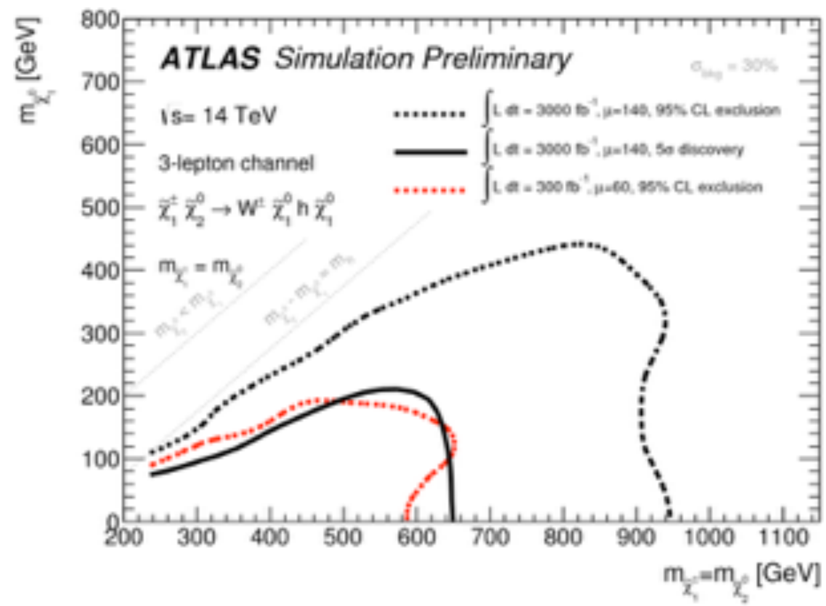


sbottom production



Weak production





Summary

Summary

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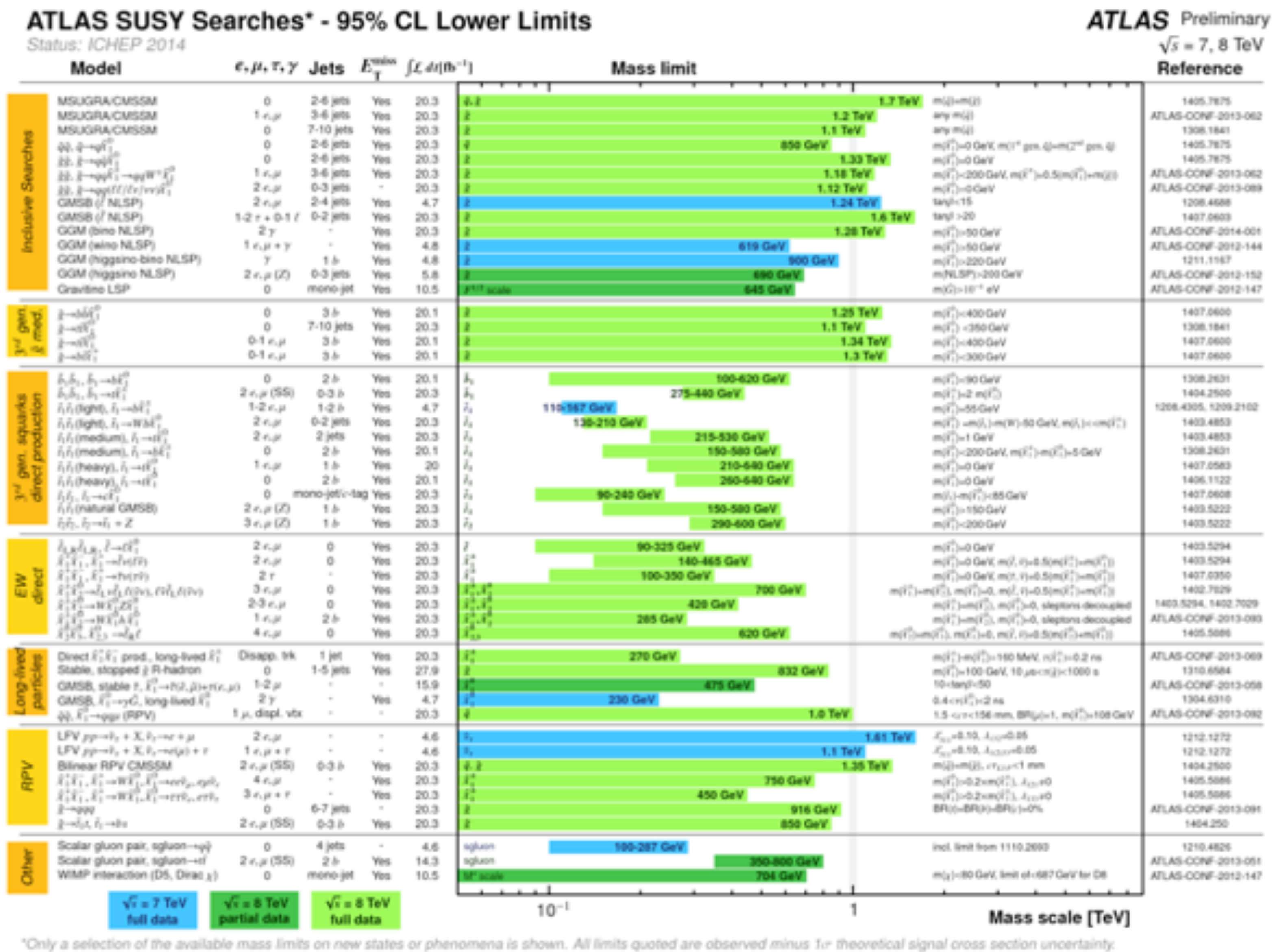

When will we stop looking for SUSY?

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- SUSY yields **an incredible number** of **well motivated possible topologies**
  - While looking for SUSY we effectively constraint **a bunch of BSM models**
- Examples:
  - tt MET and bb MET signatures (stop, sbottom) show up in LQ and DM searches
  - 2j and 3j resonant searches for RPV gluino/squark decay
  - Displaced vertices searches for long-lived charginos sensitive to production of ANY heavy long lived charged particle

BACKUP

Fake lepton background estimate

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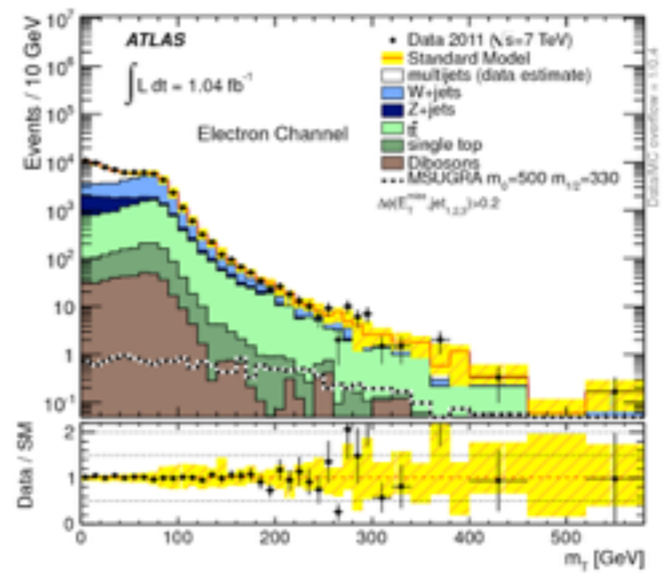
- General approach to **fake lepton background estimation** based on a loose/tight matrix method
- Example with 1 lepton (easily extendable to multi-lepton signatures):

> - A fake lepton lepton can arise from:
>   - Off-axis HF semileptonic decays
>   - Photon conversion

- Strategy: **define a "loose"** (pre-selected) **and a "tight"** (signal) lepton selection.
- Then, solve the following system of equations

$$N^{loose} = N^{loose}_{real} + N^{loose}_{fake}$$

$$N^{tight} = \varepsilon_{real} N^{loose}_{real} + \varepsilon_{fake} N^{loose}_{fake}$$



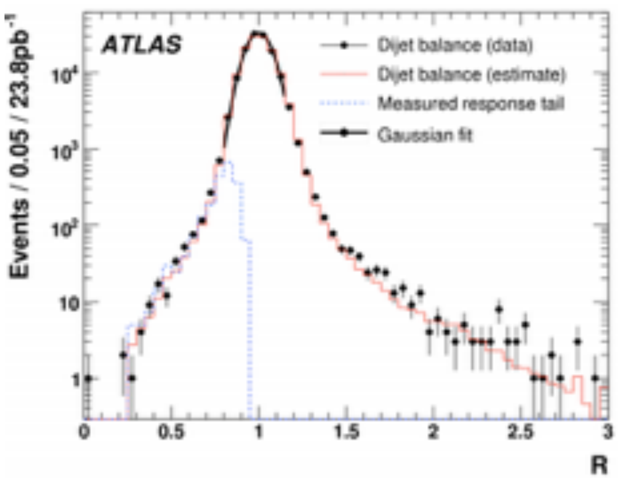
Need to be measured independently from data

Simply count how many of them

$$N^{tight}_{fake} = \frac{\varepsilon_{fake}}{\varepsilon_{real} - \varepsilon_{fake}} \left(N^{loose} \varepsilon_{real} - N^{tight} \right)$$

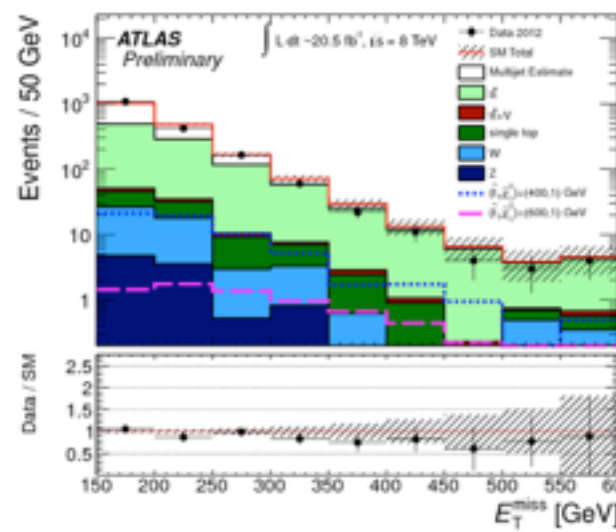
Fake E_T^{miss} background estimate

- Large E_T^{miss} can be induced by a jet mis-measurement.
- Relevant for processes with high cross section and no "real" E_T^{miss} (multi-jet, $Z \rightarrow ll$)



- Derive a **"jet response function"** from MC and **adapt it to data**:
  - **core:** p_T balance in di-jet events
  - **tail:** three-jet (Mercedes) events

- Use response function to smear jets in real data events with low MET:
  - Obtain events with large "fake" E_T^{miss}
- Validate the estimation in a dedicated control region



SUSY

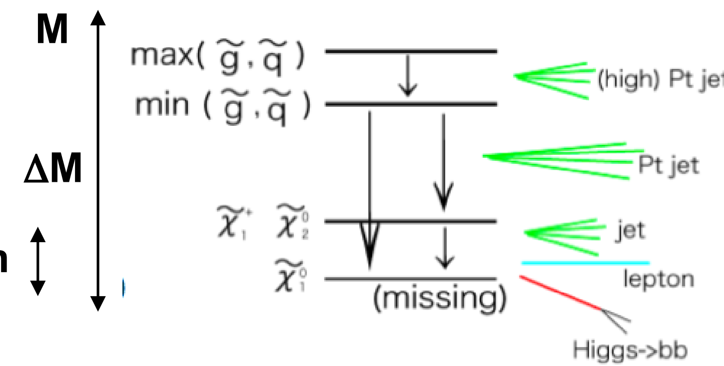
What we are typically doing

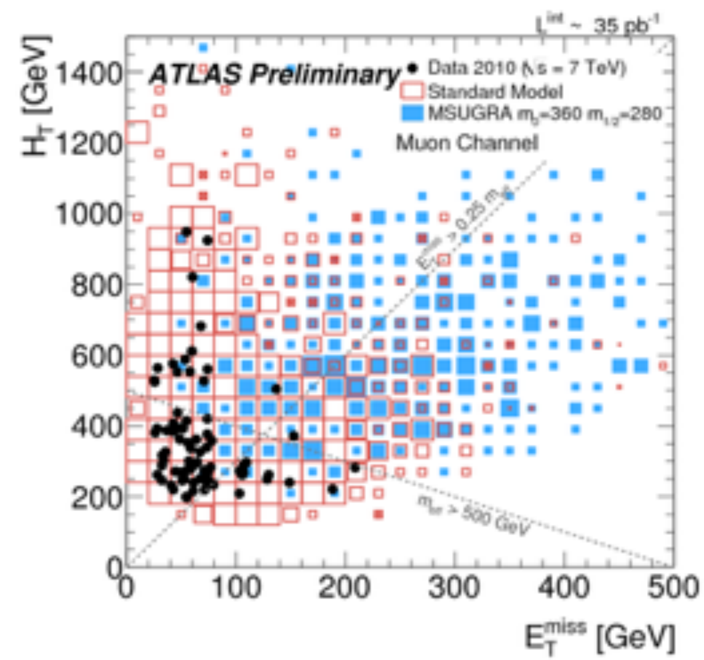
- Heavy sparticles produced in the primary collision
- They decay into lighter objects, emitting (high) P_T jets and possibly other objects (leptons, photons) and MET (LSP)
- A "typical" SUSY event will have large MET and large H_T
- Useful variables:

$$H_T = \sum_{jets} p_T^{jets} (+ \sum_l p_T^l + ...)$$

$$M_{eff} = E_T^{miss} + H_T$$

- But also other variables with well defined kinematical end point for the SM background
  - **M_T (lepton-MET):** end point at M_W if produced in W decay
  - **M_{T2}, M_{CT}:** assume pair produced heavy particles with visible and invisible decays





Higgs and SUSY

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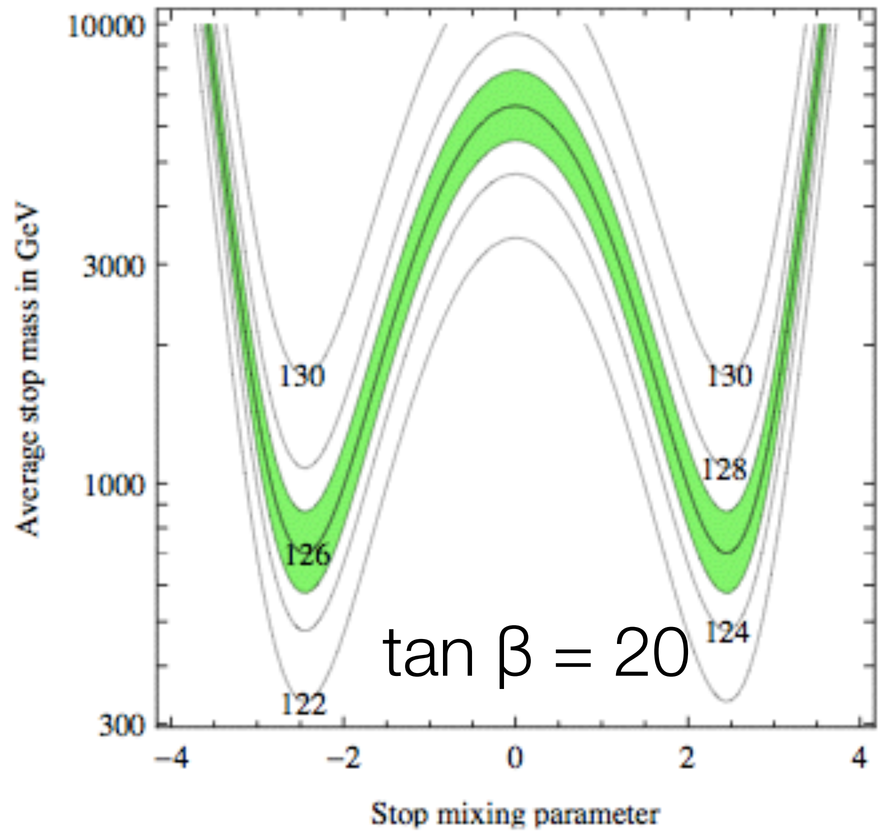
$$X_t = (A_t + \mu \cot\beta)/m_S$$

$$m_h^2 = m_Z^2 \cos^2\beta + \frac{3y_t^2 m_t^2}{(4\pi)^2}\left[\log\left(\frac{m_S^2}{m_t^2}\right) + X_t^2\left(1 - \frac{X_t^2}{12}\right)\right]$$

- The Higgs mass depend on the average stop mass and X_t
- m_h=126 GeV still allows for a light t_1

arXiv:1212.6847



What is missing? (3^{rd} gen)

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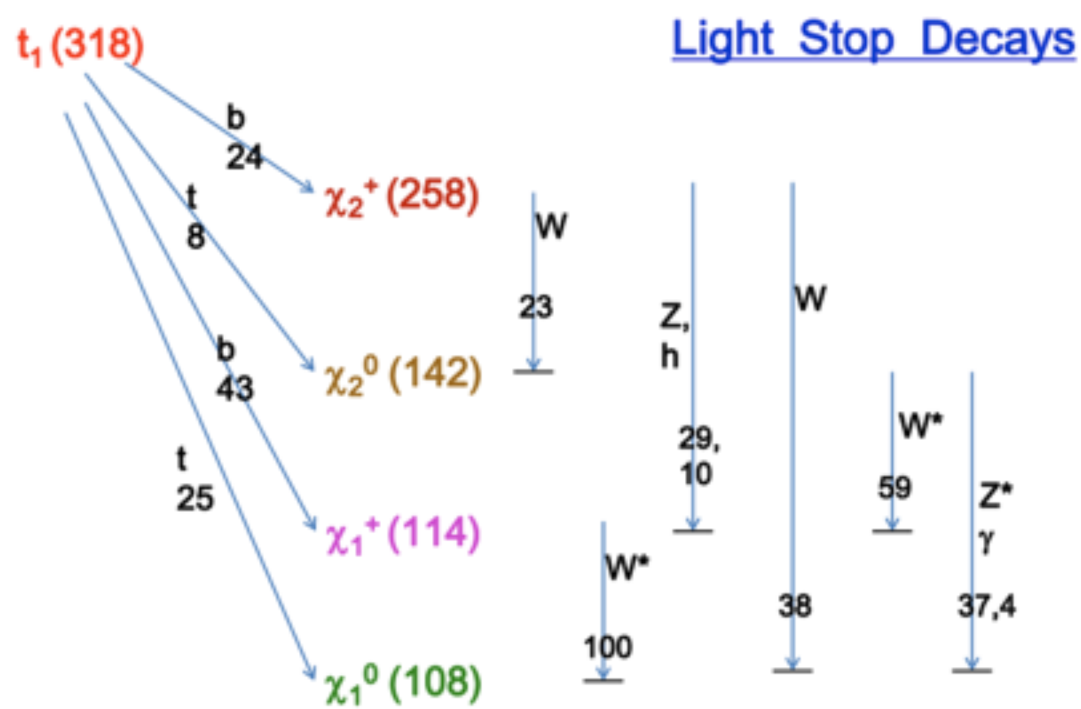
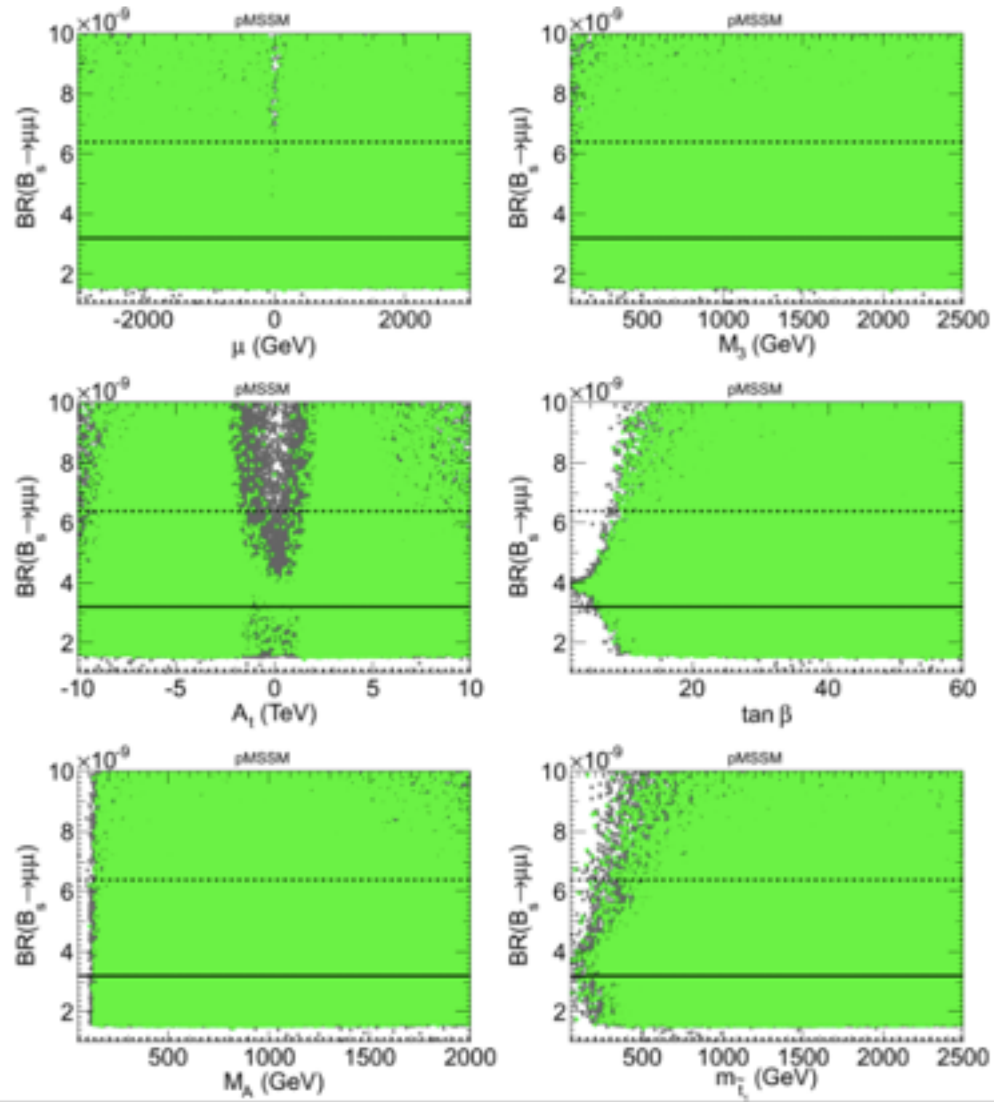
- My own to-do list for the next **few months/years**:
  - Improve limits at **high stop mass**:
    - boosted top reconstruction?
- **Mixed decays (50% $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$, 50% $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$)** still not considered (and somewhat favoured, actually)
- Complete the investigation in **the low mass region** (exclude independently of the stop parameters and mass hierarchy).



Taken from https://indico.cern.ch/contributionDisplay.py?sessionId=75&contribId=58&confId=181298

Bs->mu mu

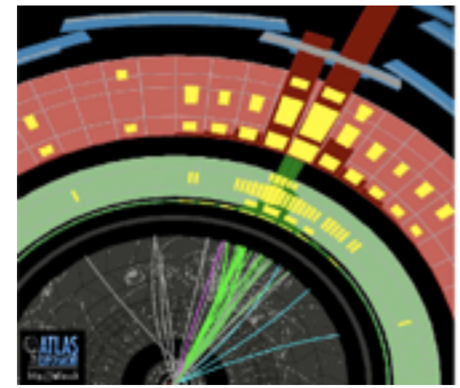
- From http://arxiv.org/pdf/1212.4887v2.pdf

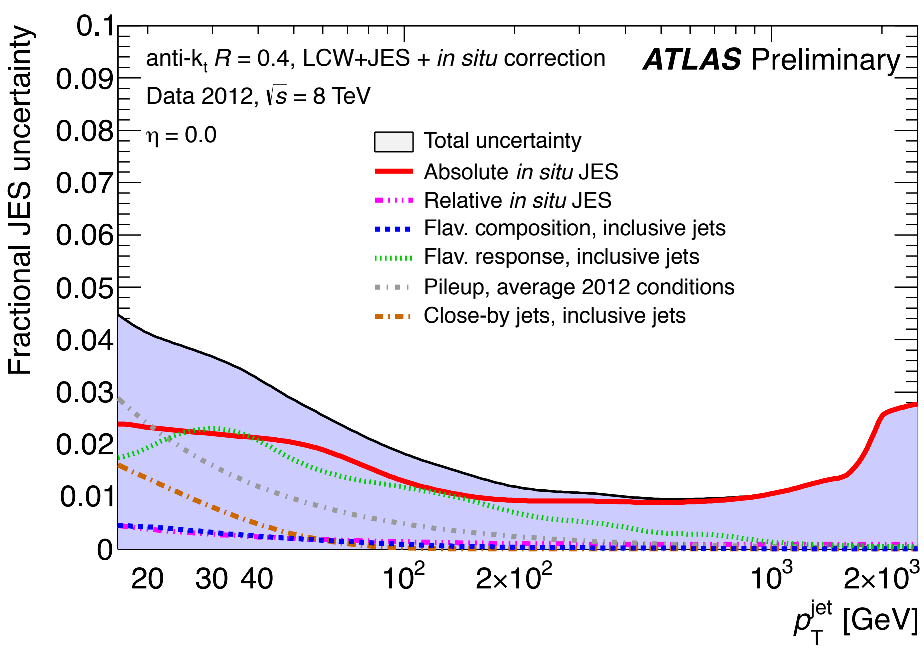


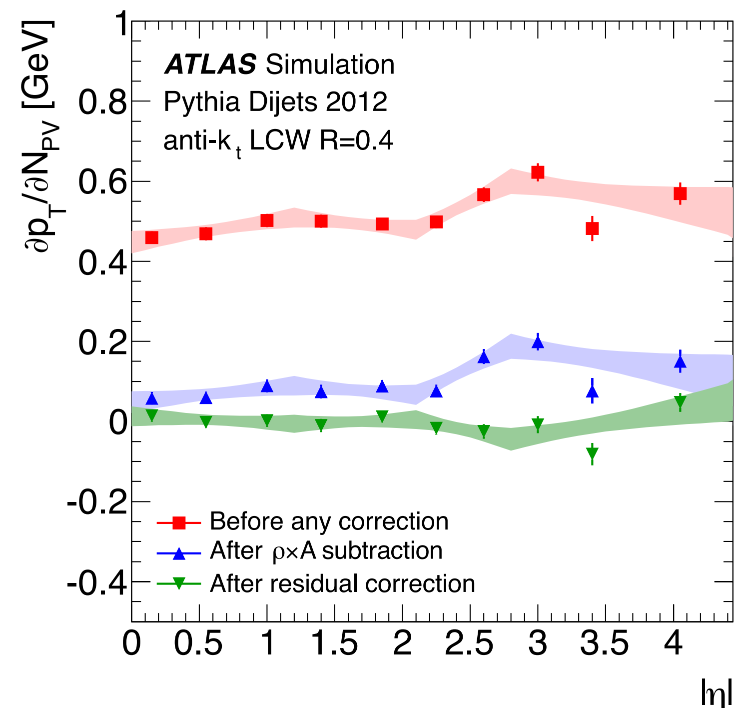
Performance

Jet measurement

- **Constantly improving** on jet measurement and pileup suppression techniques
- **Jet energy scale** known up to the ~1% level
- **Pileup subtraction** based on jet area method

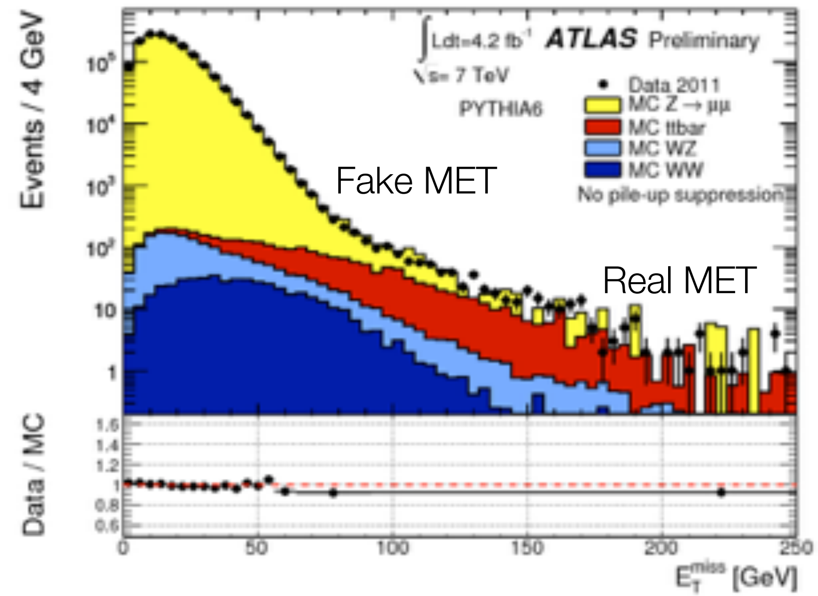


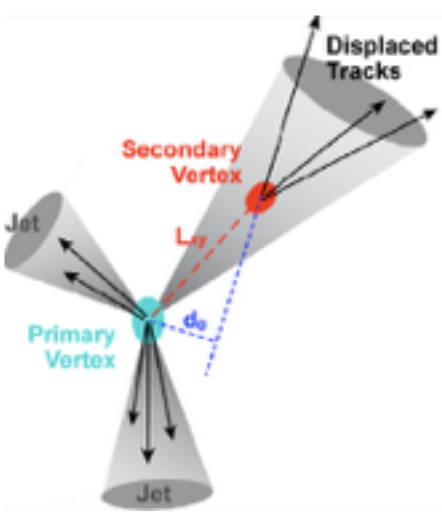


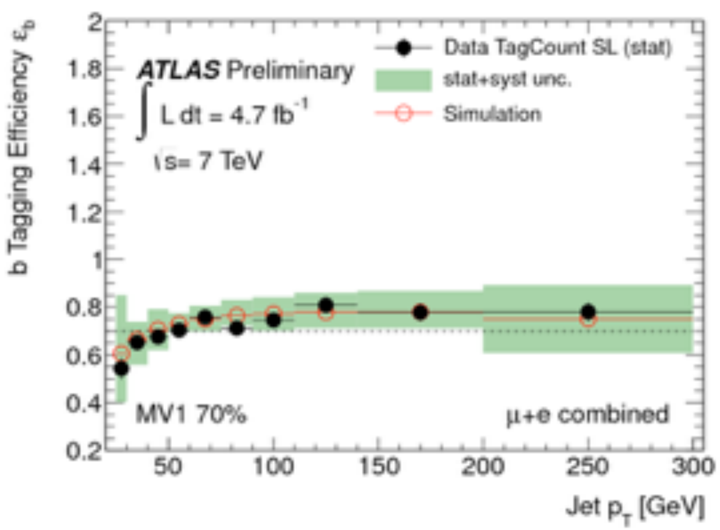


Missing transverse momentum and b-tagging

- Missing E_T (E_T^{miss}) reconstructed from the vectorial sum of **all final state objects:**
- each **with a dedicated calibration.**







- **b-tagging:** neural network algorithm combining informations about **secondary vertex displacement** and **impact parameters of jets**
- efficiencies **generally well reproduced by MC**. Systematic uncertainties **of the order of 10-15%**

strong production

prospects

MSUGRA/CMSSM