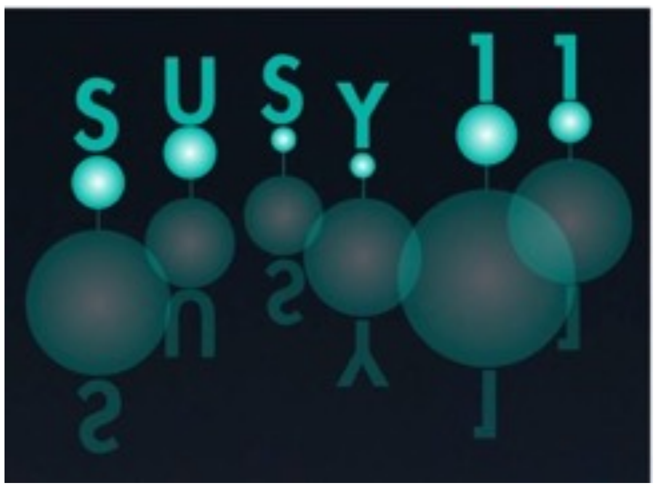
Search for stops and sbottoms at the LHC - status and prospects

Iacopo Vivarelli
University of Sussex
Seminar - RAL - March 2015

University of Sussex

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

$$W \ni \frac{1}{2}\lambda_{ijk}L_iL_jE_k^c + \lambda'_{ijk}L_iQ_jD_k^c + \frac{1}{2}\lambda''_{ijk}U_i^cD_j^cD_k^c + \mu_iL_iH_u$$

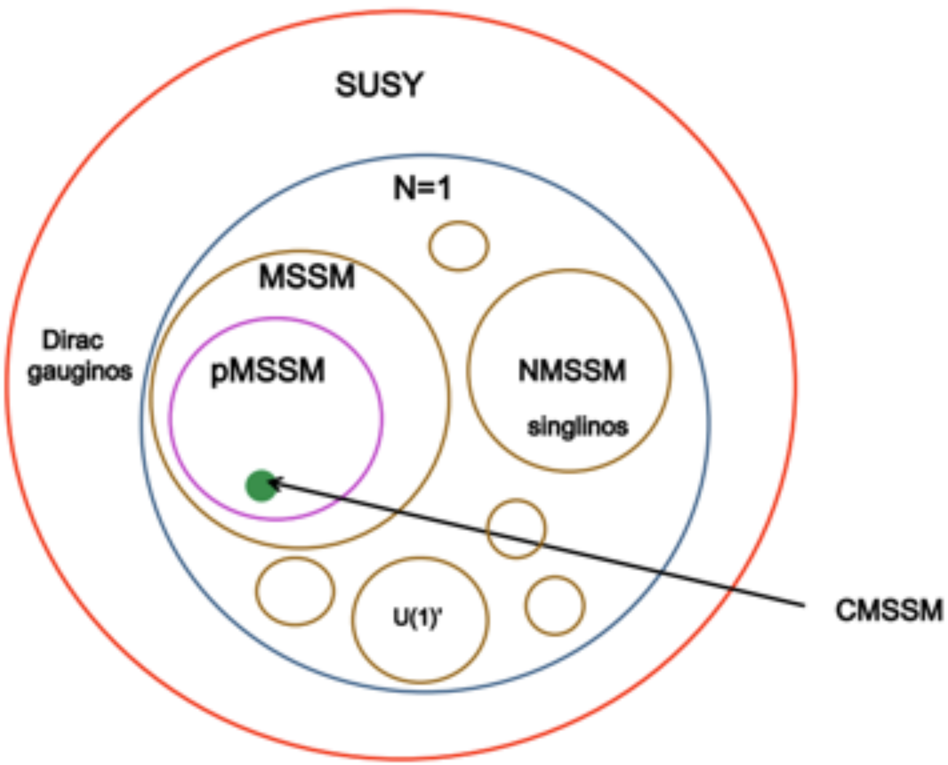
R-parity = $(-1)^{3(B-L) + 2s}$
-1 for sparticles
1 for particles

Lepton and baryon number violation allowed → proton decay

If R-parity conserved, the Lightest Supersymmetric Particle (LSP) is stable

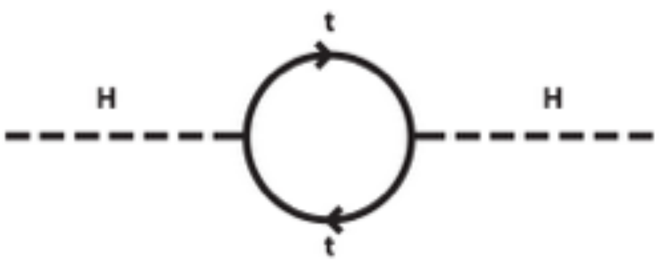
When will we stop searching for SUSY?

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



In general, little to no indication on sparticle masses

Higgs mass stability in a nutshell



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

$$\Delta m_H^2 = 2 \times \frac{|\lambda_f|^2}{16\pi^2}\Lambda_{\mathrm{UV}}^2 + \ldots$$

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

With SUSY, quadratic effects are cancelled exactly

Higgs boson mass

- The Higgs boson mass in MSSM

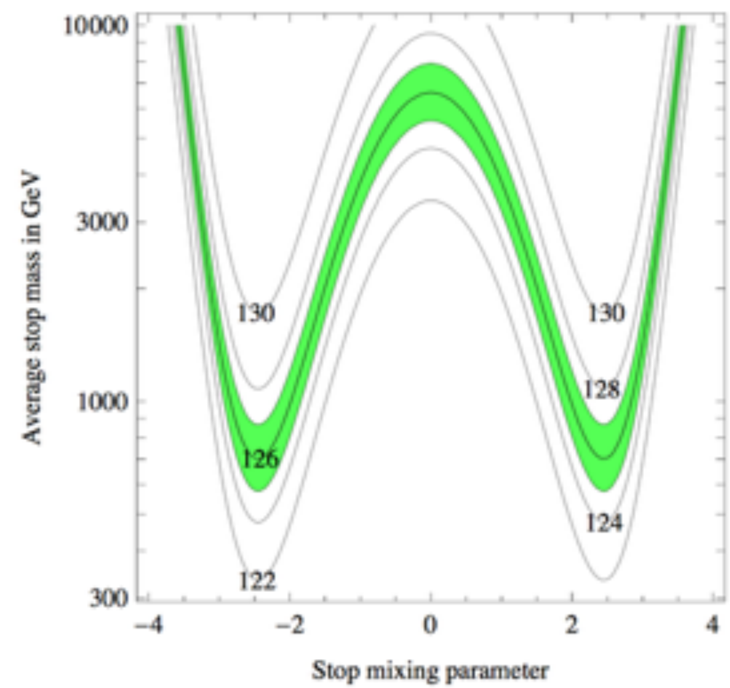
$$m_h^2 = m_Z^2 \cos^2 2\beta + \frac{3y_t^2 m_t^2}{4\pi^2}\left[\log\left(\frac{m_S^2}{m_t^2}\right) + X_t^2\left(1 - \frac{X_t^2}{12}\right)\right] + \cdots$$

m_S is the product of the two stop masses

X_t is the mixing between the two stop states

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

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



From arXiv:1212.6847

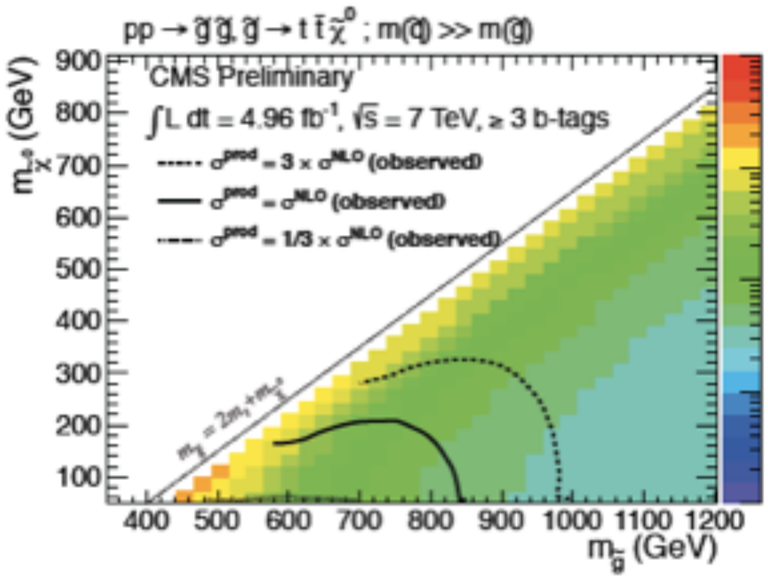
When will we stop searching for EW SUSY?

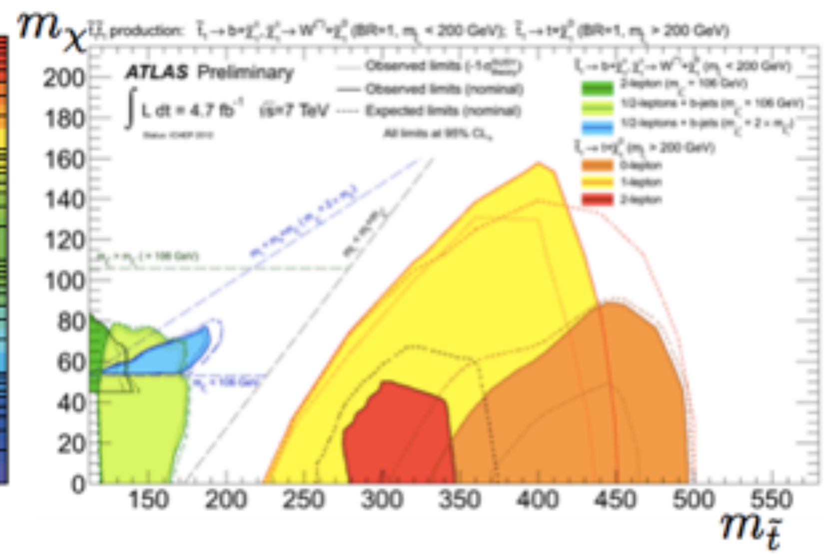
Frequently asked question:

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

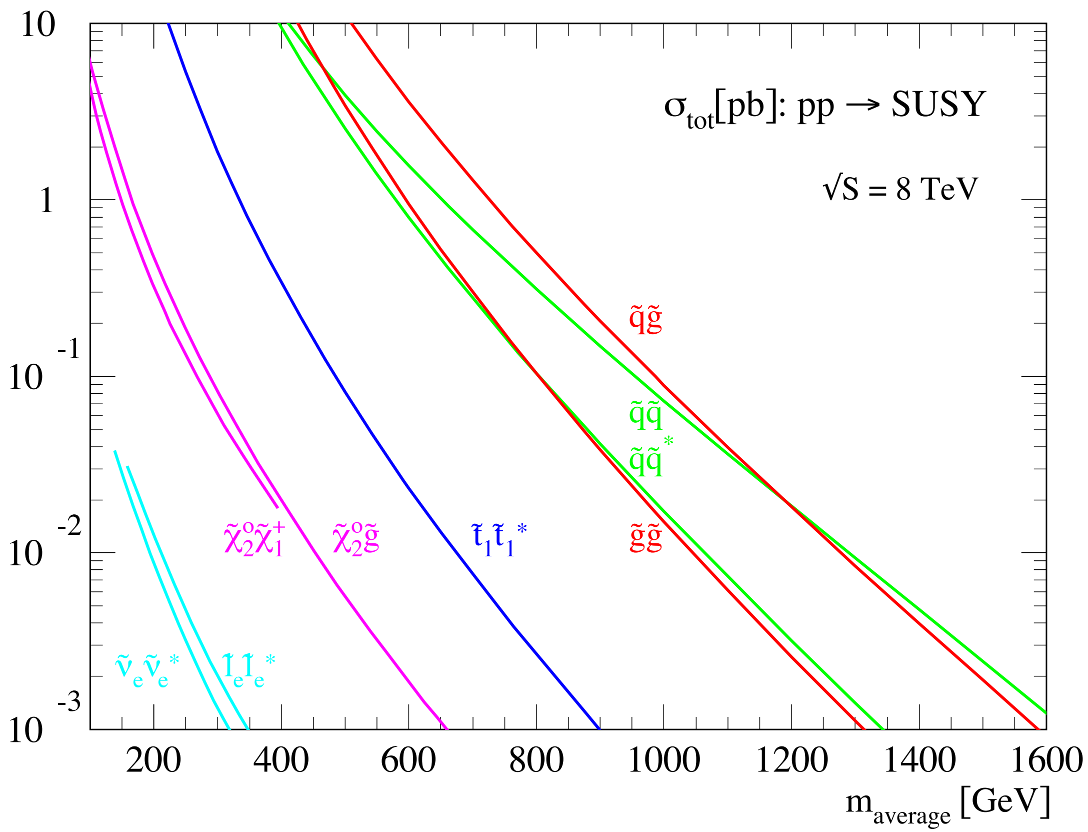


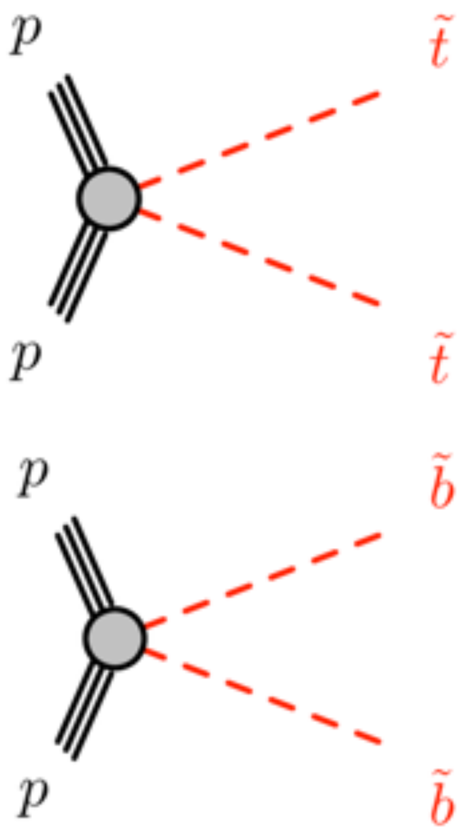


R. Barbieri - ICHEP2012 physics highlights - Melbourne 2012

Production cross sections….

University of Sussex



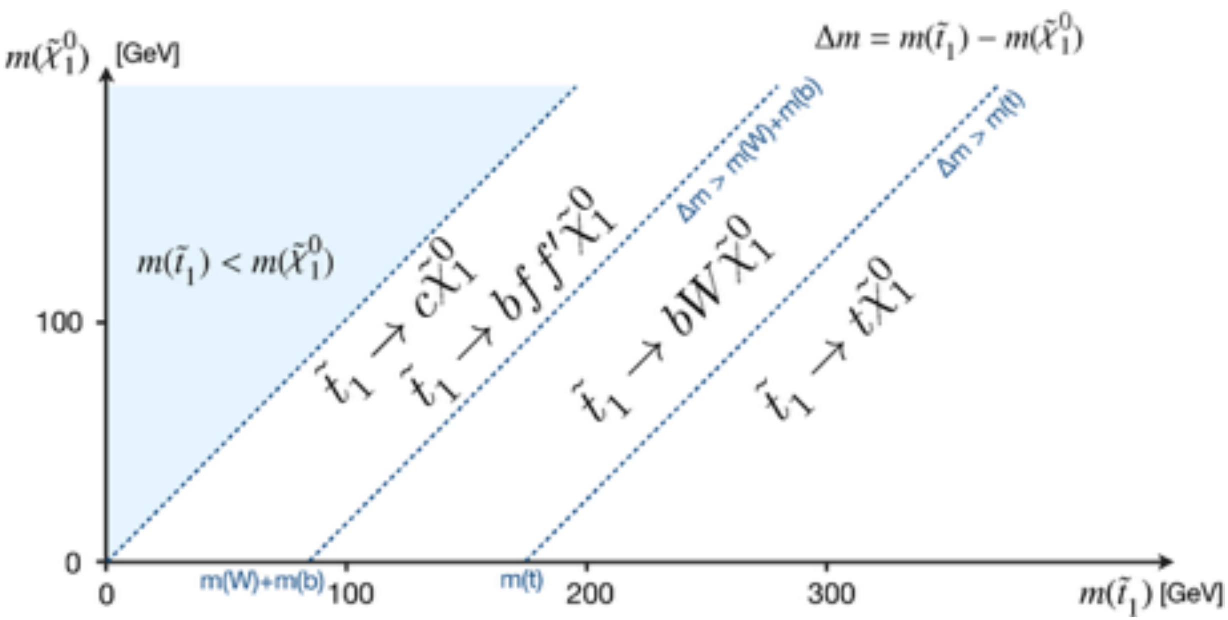


Taken from http://www.thphys.uni-heidelberg.de/~plehn/index.php?show=prospino&visible=tools

…and decays

In the simplest case
(only stop and LSP have small mass)

BUT:
Good reasons to expect lightest chargino **relatively light**: increasingly complex phenomenology

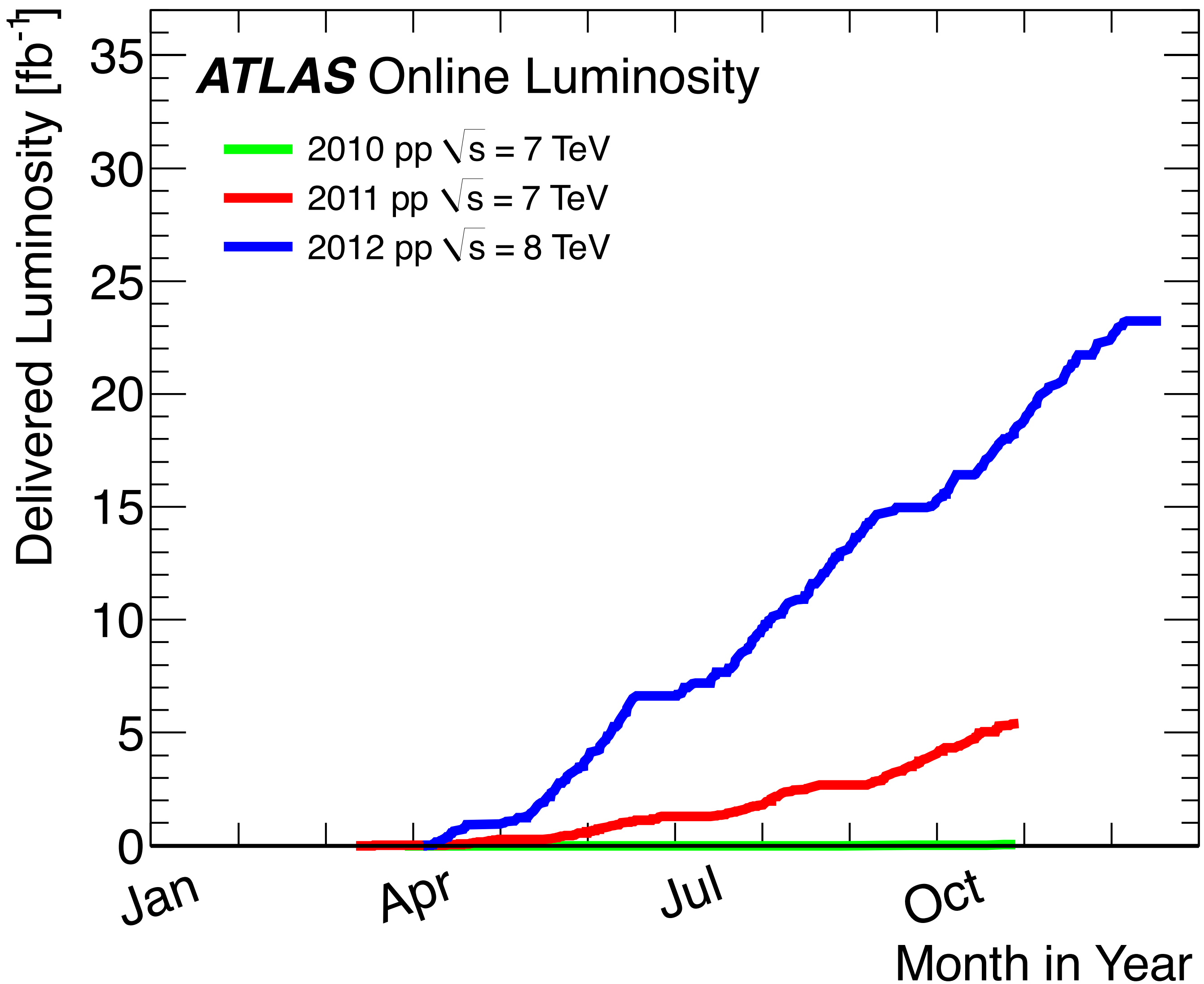


Final state characterised by

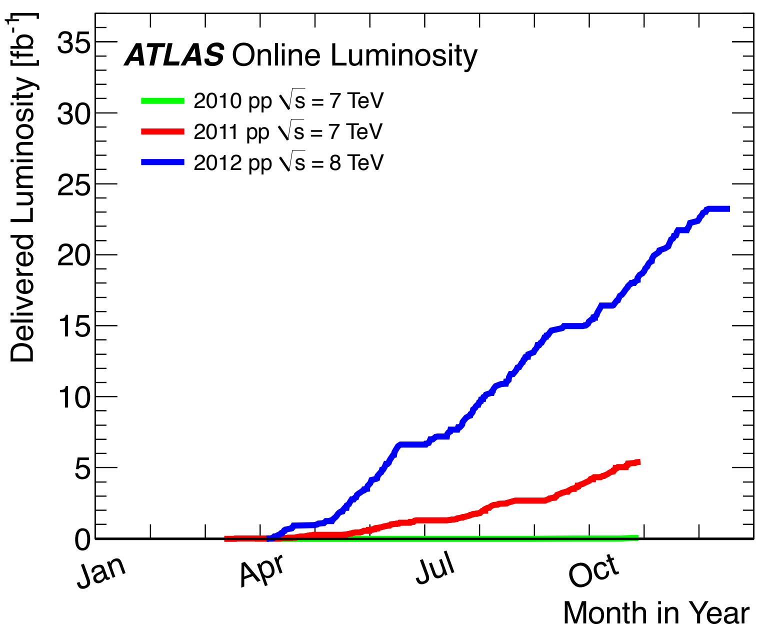
- missing transverse momentum (LSP)
- b-jets
- kinematical constraints (resonances/end points) from top/W decay

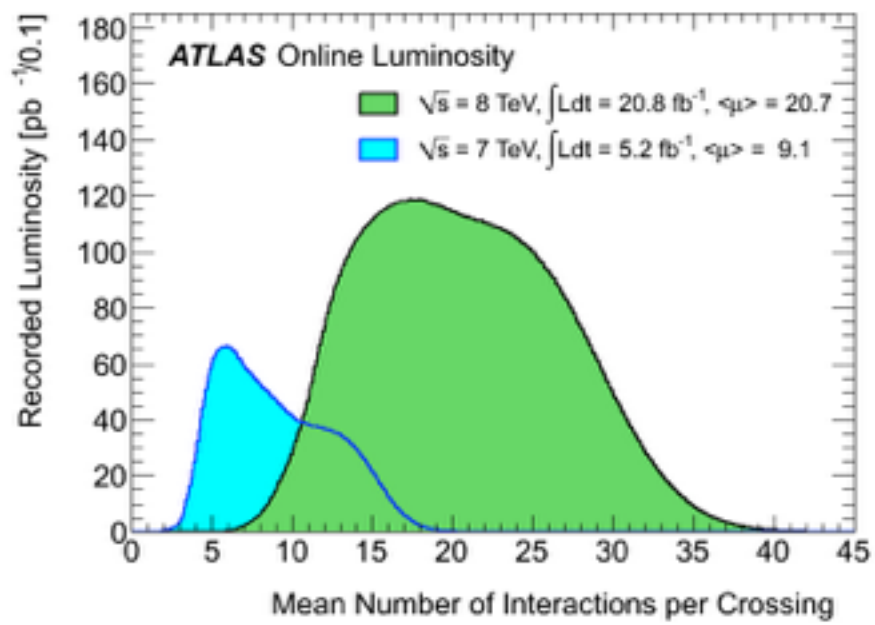
Experimental setup

LHC - performance of the machine

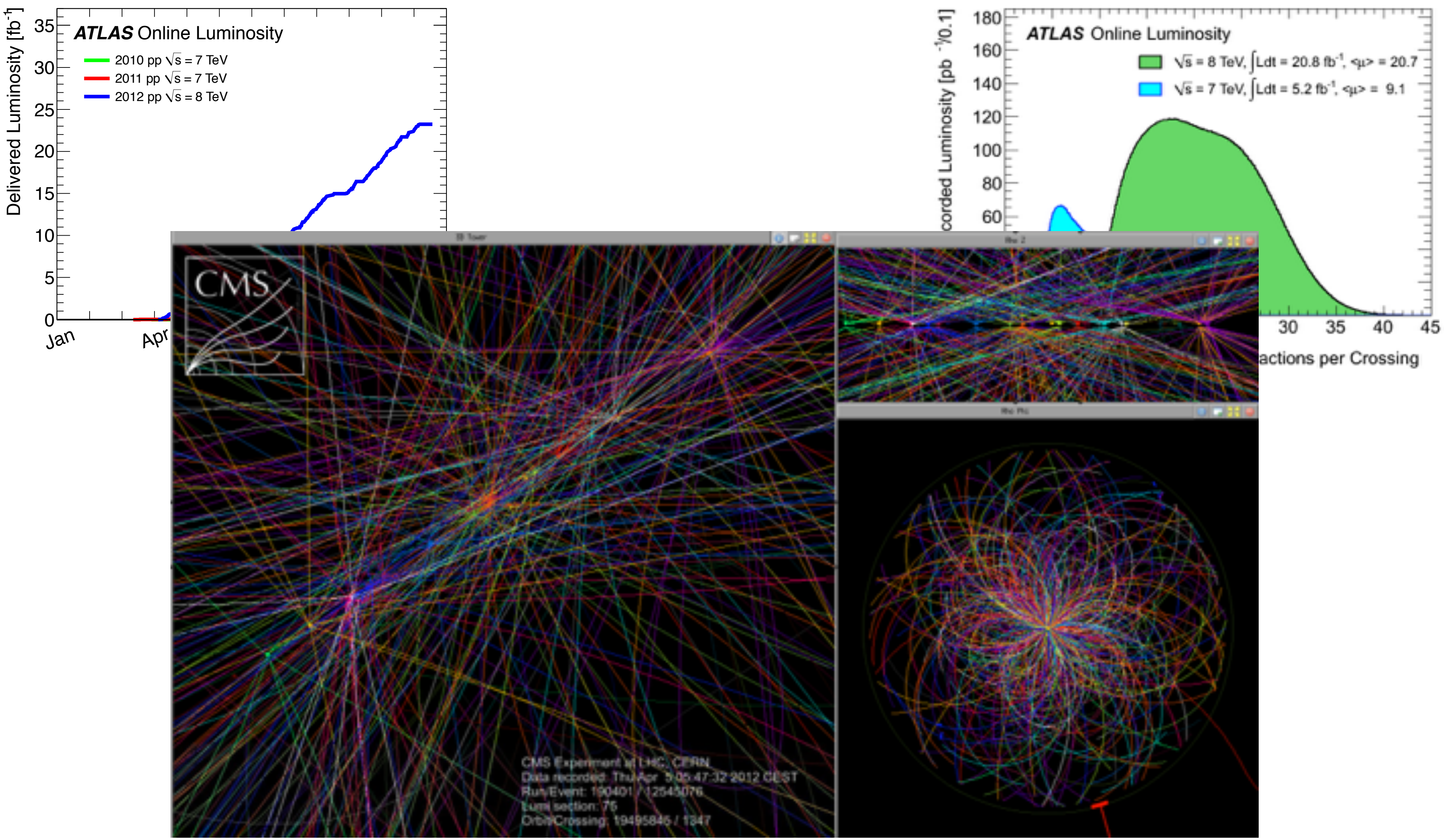


LHC - performance of the machine

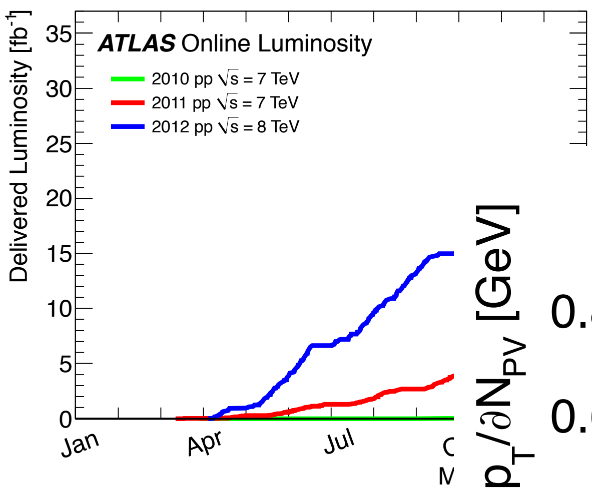


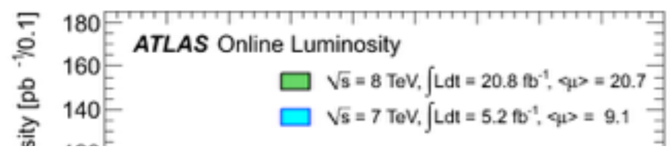


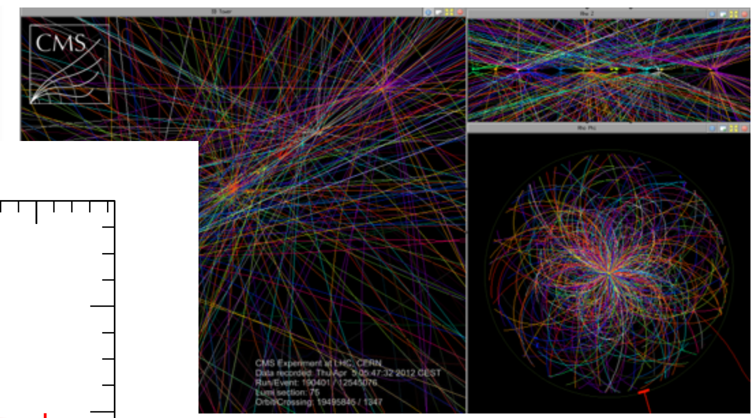
LHC - performance of the machine

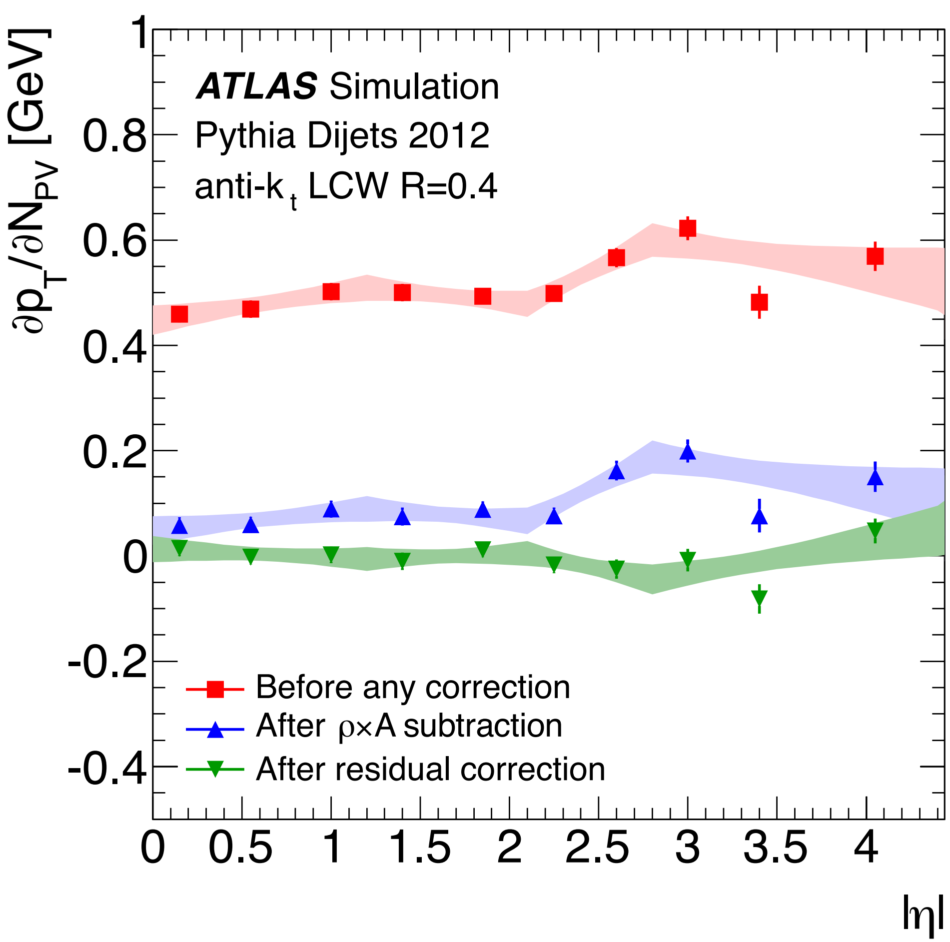


LHC - performance of the machine

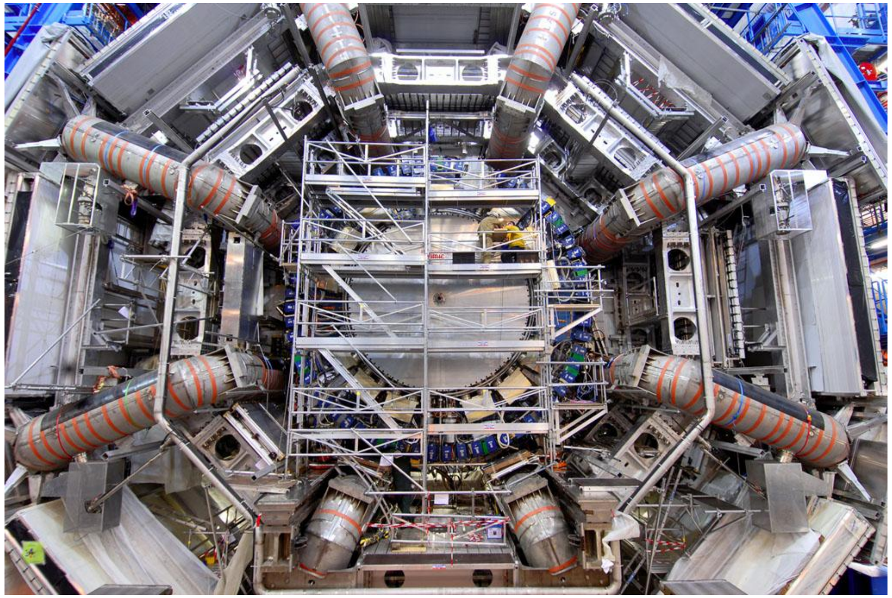






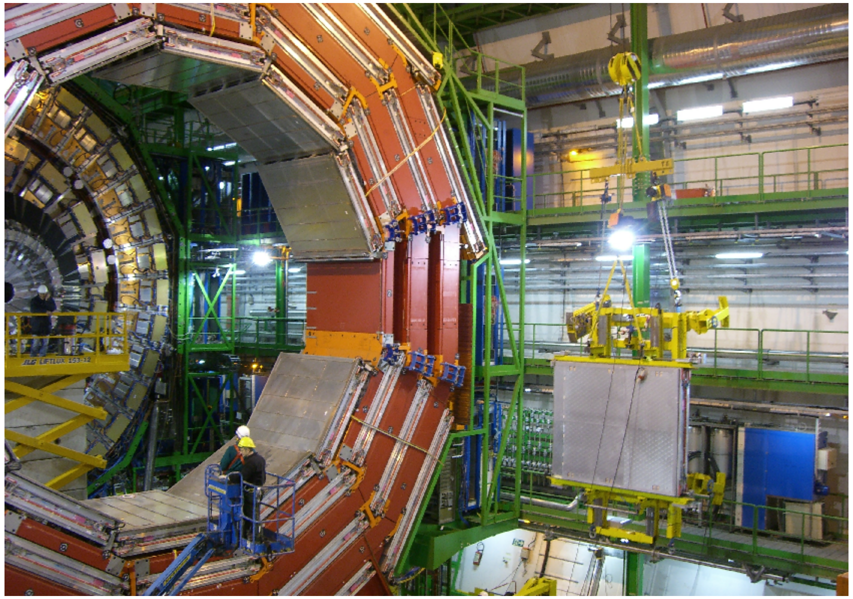


ATLAS and CMS



ATLAS

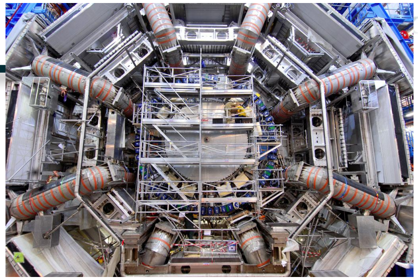
- high-granularity “pointing” EM calorimeter
- good resolution for hadronic calorimetry
- good tracking in ID and muon spectrometer

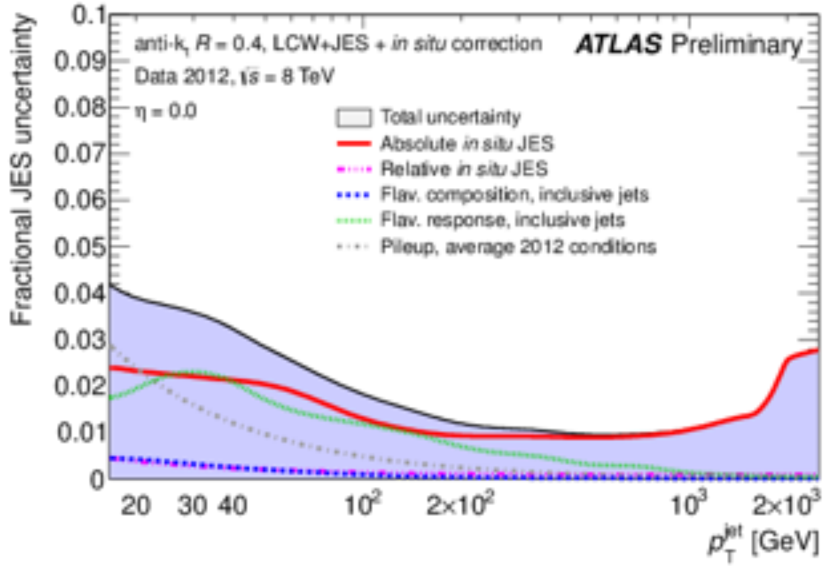


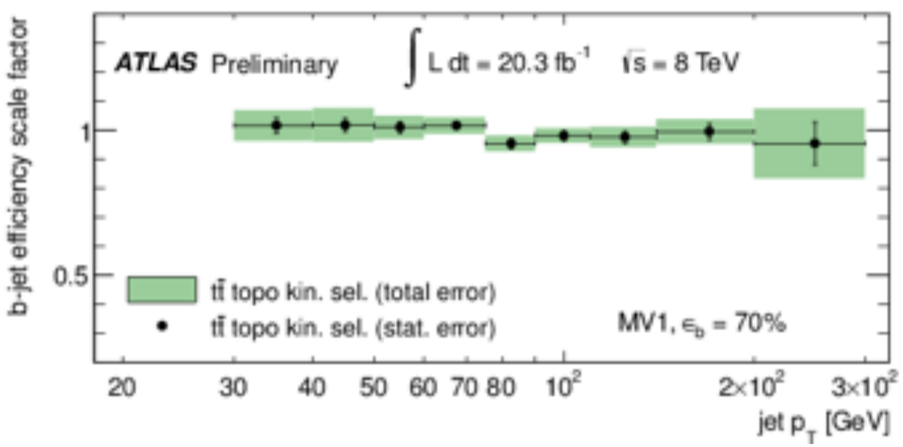
CMS

- high-resolution EM calorimeter
- excellent tracking performance in ID and muon spectrometer, heavily used for jet and MET measurement as well

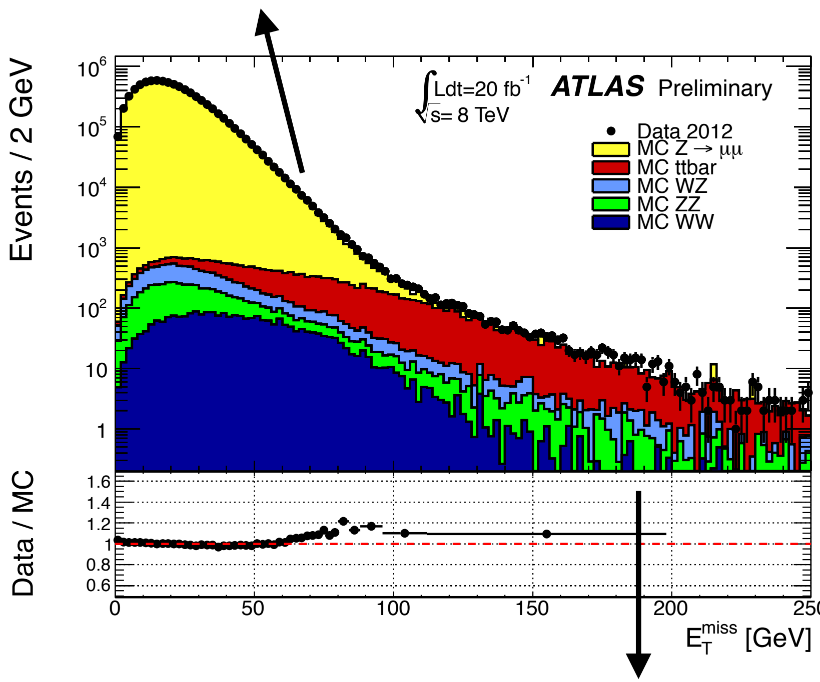
Performance highlights







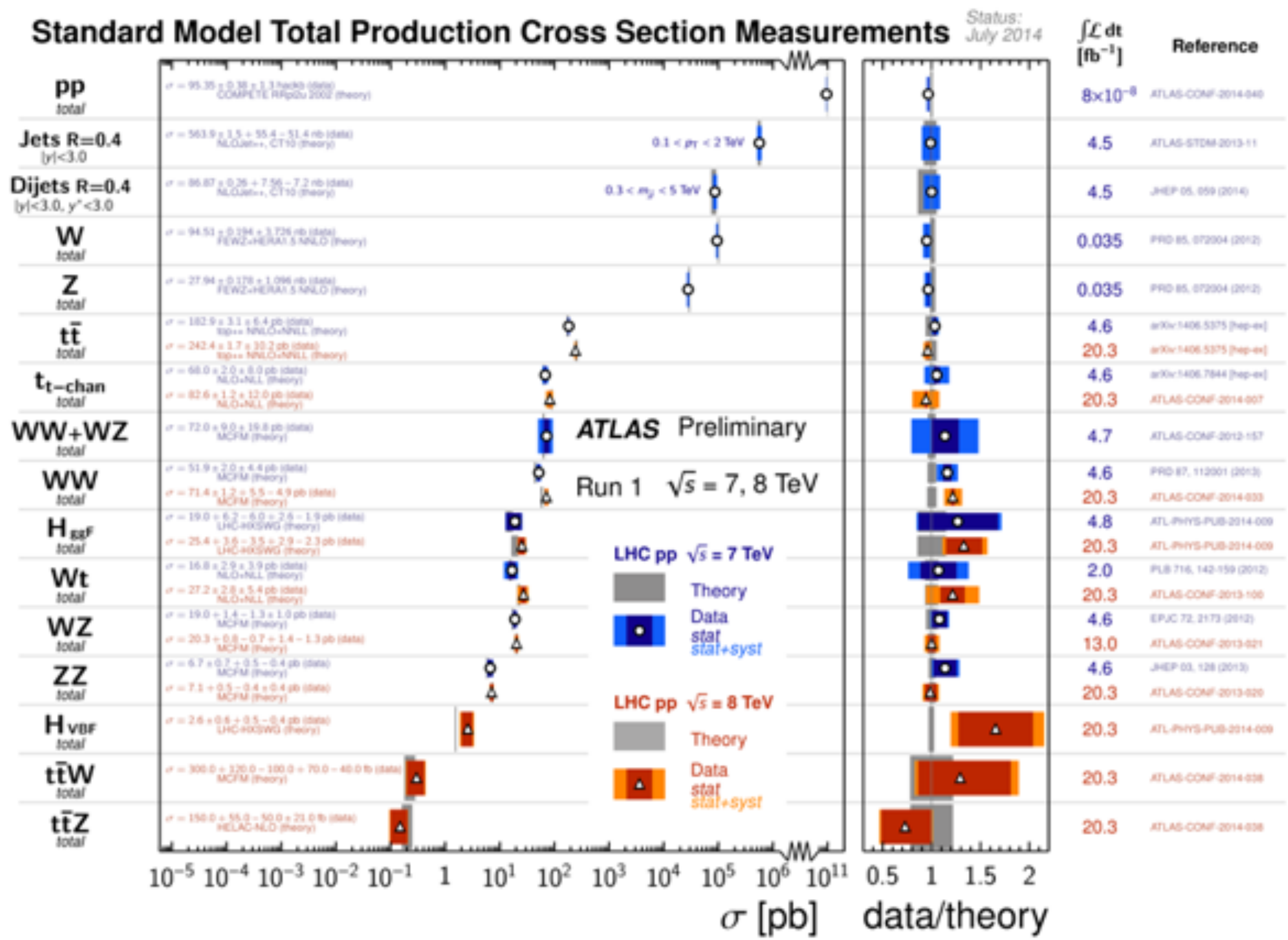
fake



real

The Standard Model in one slide

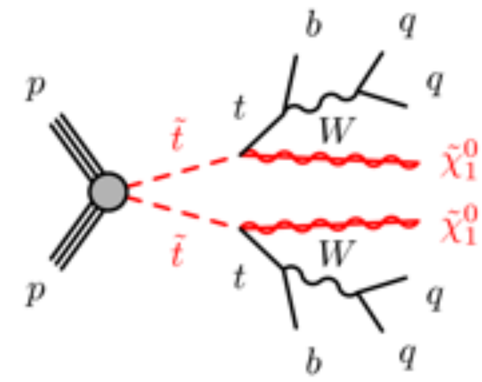
University of Sussex



SUSY searches

Simplified model approach

- Simplified model:
  - only one (or few) **SUSY production mode**
  - only one (or few) **decay mode**
  - only few **SUSY particles** involved in the **decay**

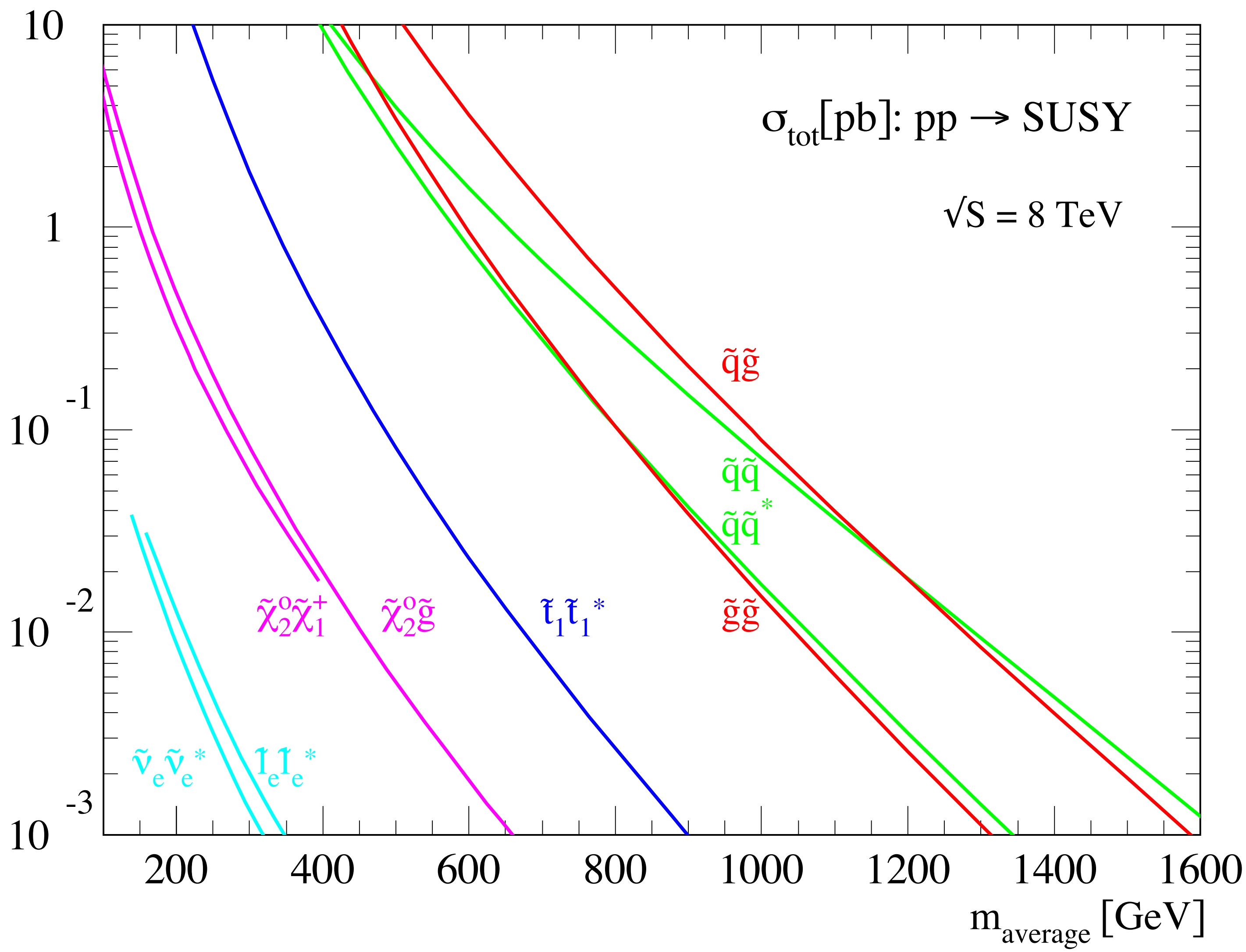


The good:
- Optimise for a well defined topology
- Intuitive understanding of sensitivity
- Exclusion limits easily reproducible by theory colleagues

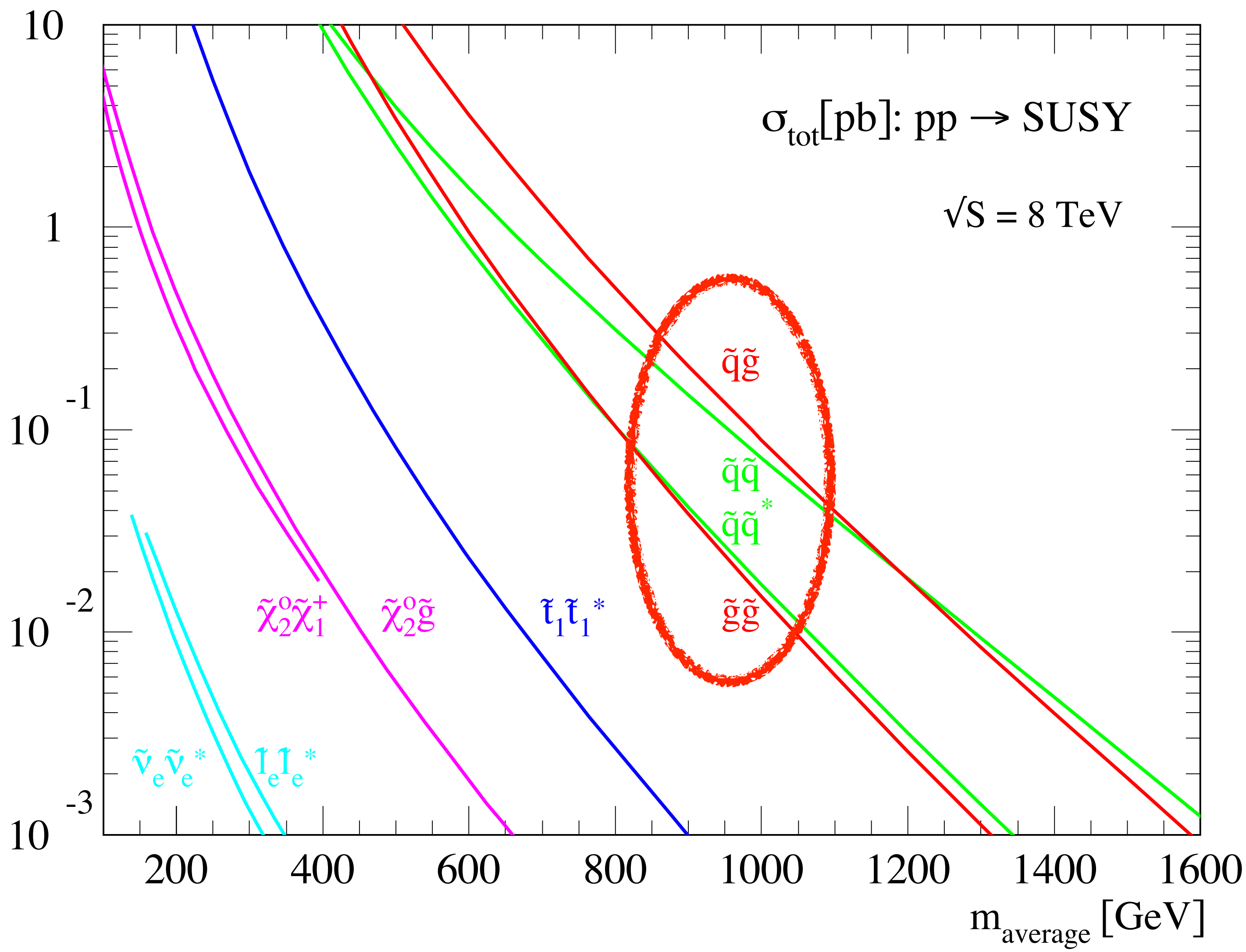
The bad:
- The approach becomes quickly cumbersome at increasing complexity of final state

The ugly:
- Real model complexity hidden: sensitivity claimed on simplified model does not necessarily map to a real model

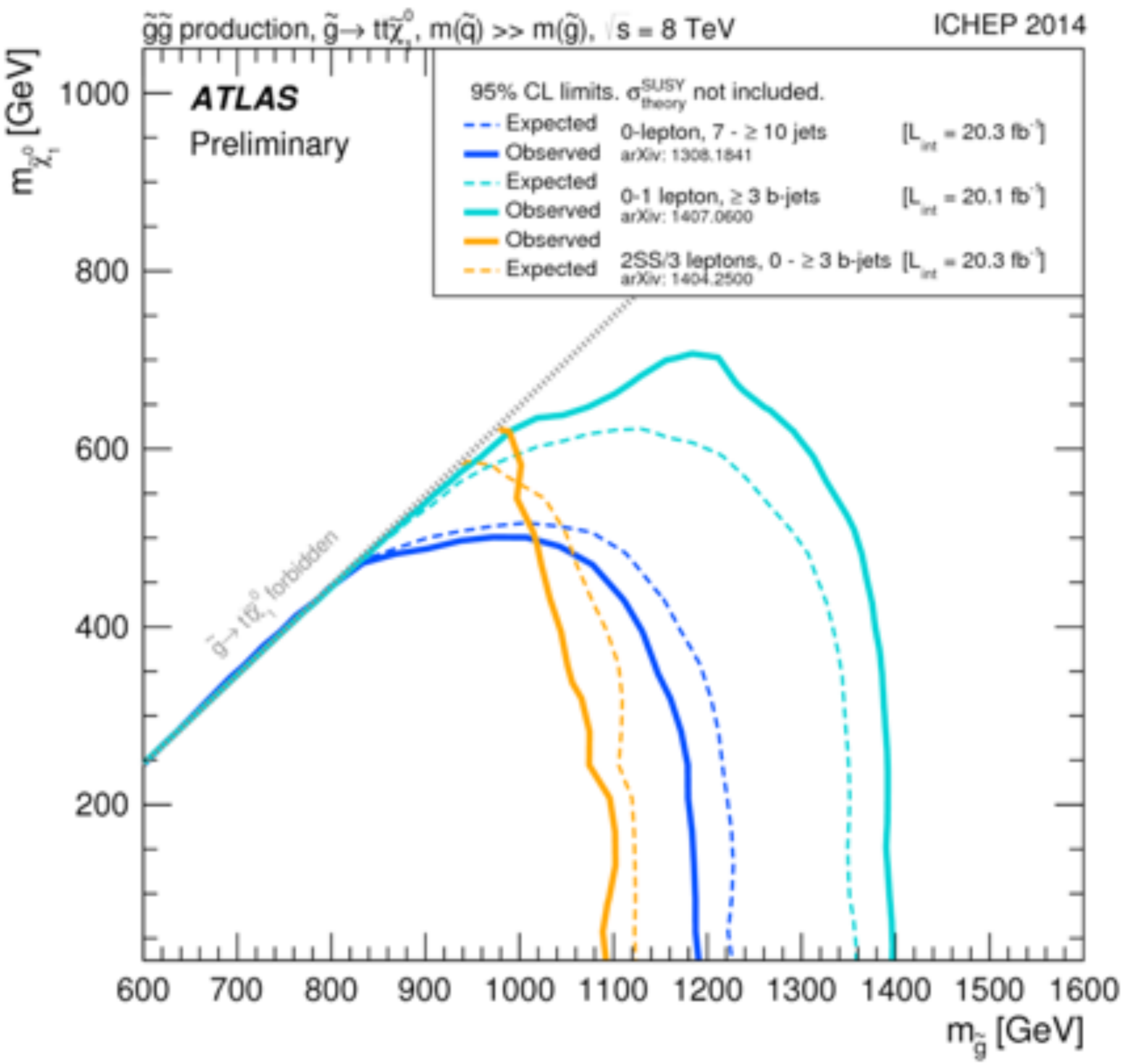
SUSY searches

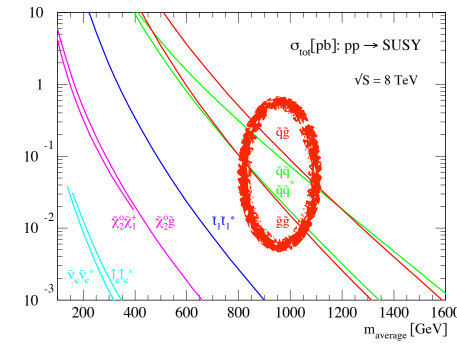


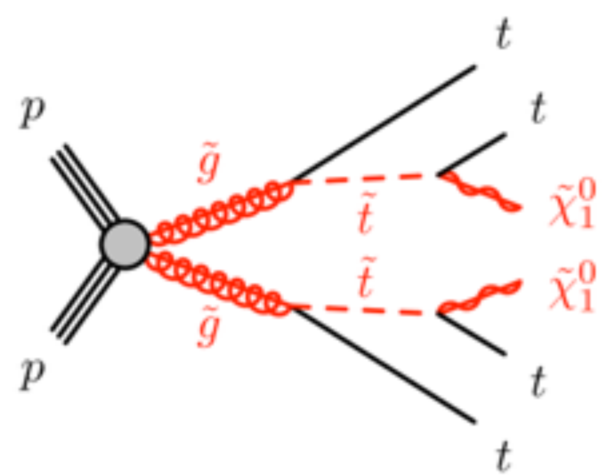
SUSY searches



Gluino mediated stop production





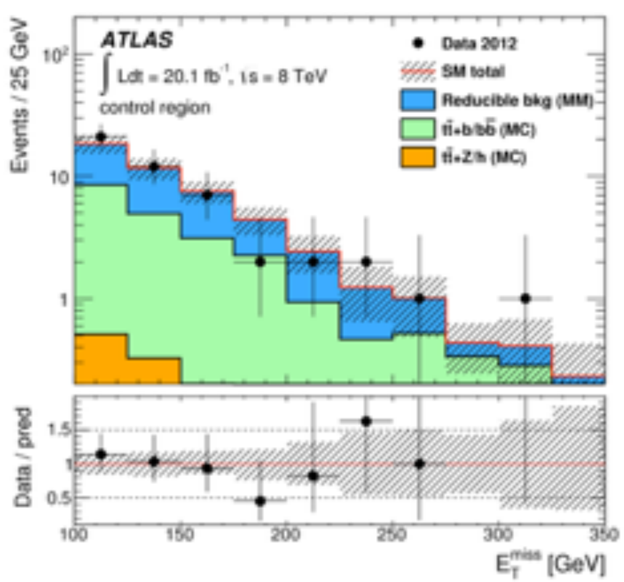


A very rich topology that can be targeted from many points of view

0/1 lepton - 3 b-jets

University of Sussex

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

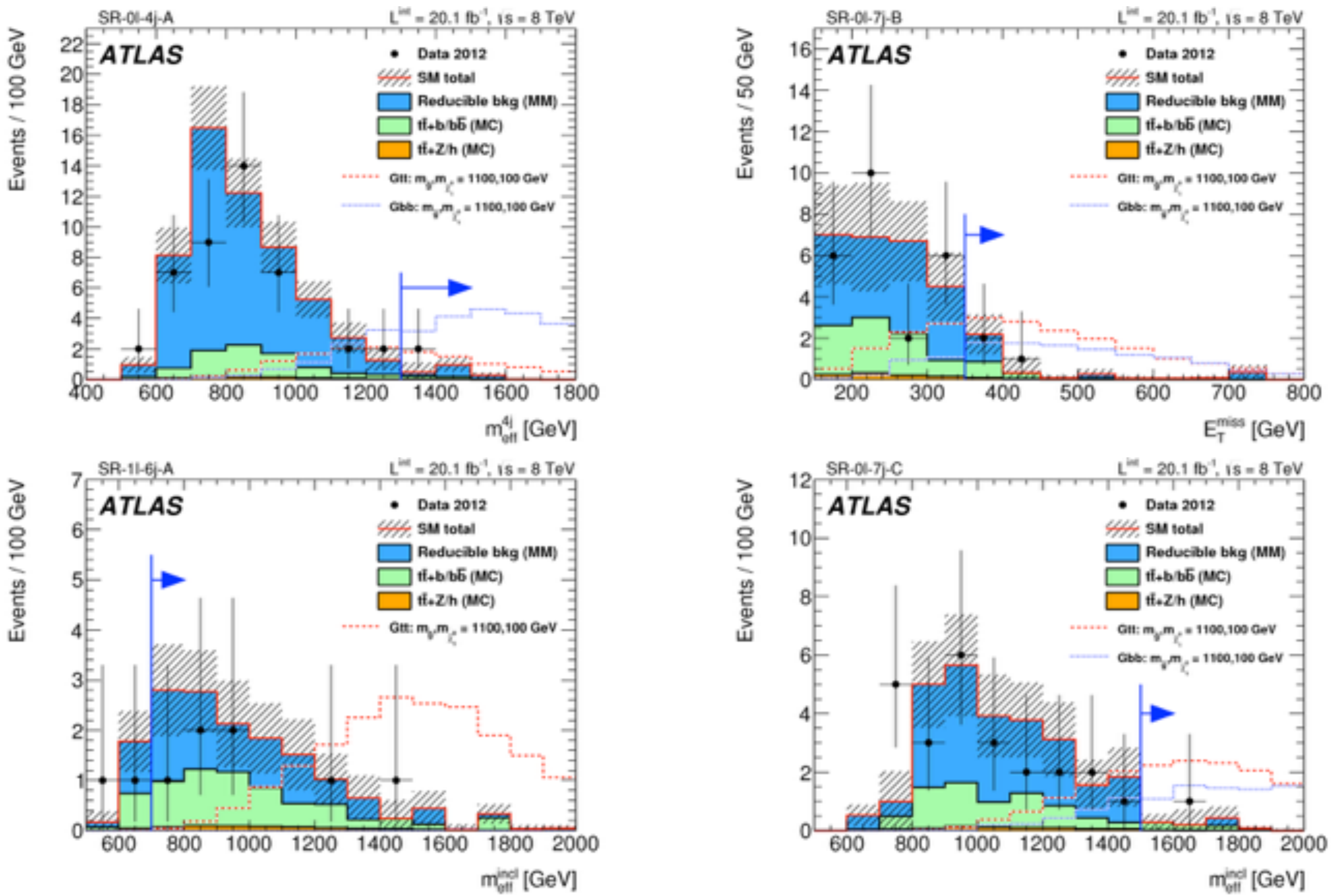


Baseline 0-lepton selection: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{miss} > 150$ GeV, ≥ 4 jets with $p_T > 30$ GeV, $\Delta\phi_{min}^{4j} > 0.5$, $E_T^{miss}/m_{eff}^{4j} > 0.2$, ≥ 3 b-jets with $p_T > 30$ GeV				
	N jets (p_T [GeV])	E_T^{miss} [GeV]	m_{eff} [GeV]	$E_T^{miss}/\sqrt{H_T^{4j}}$ [$\sqrt{\text{GeV}}$]
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

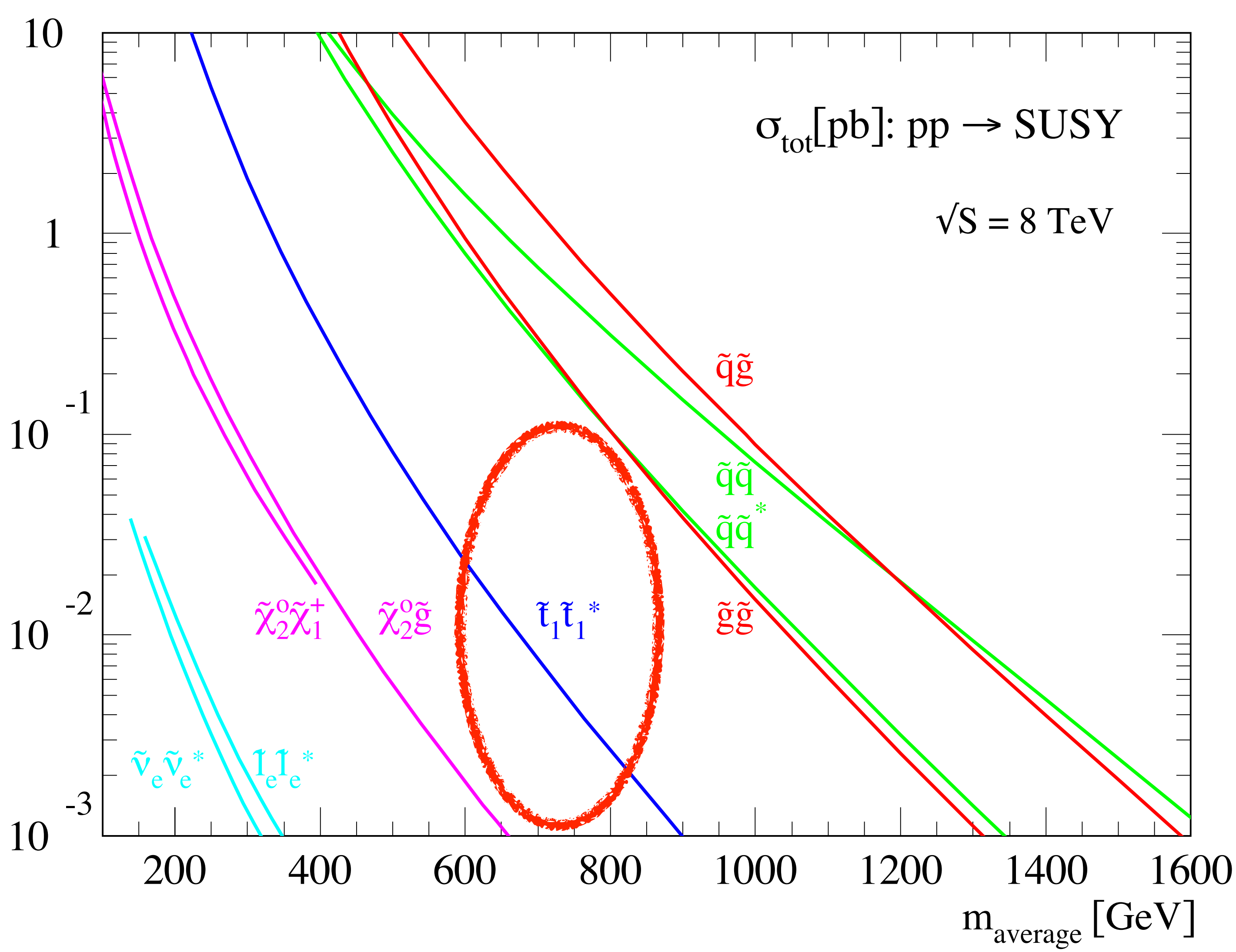
Table 2. Definition of the signal regions used in the 0-lepton and 1-lepton selections. The jet p_T threshold requirements are also applied to b-jets. The notation SR-0ℓ-4j-C* means that the leading jet is required to fail the b-tagging requirements to target the region close to the kinematic boundary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

0/1 lepton - 3 b-jets

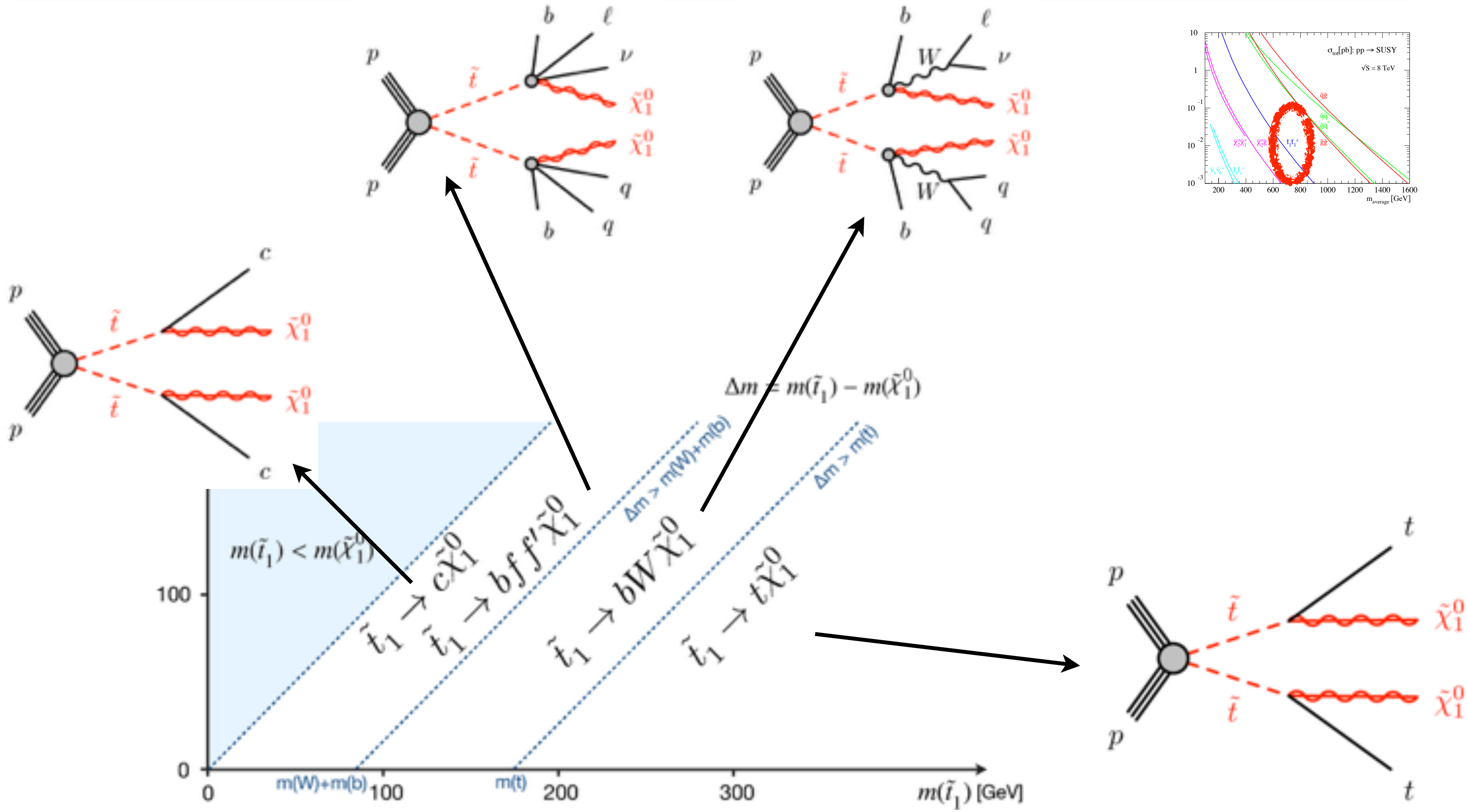
University of Sussex



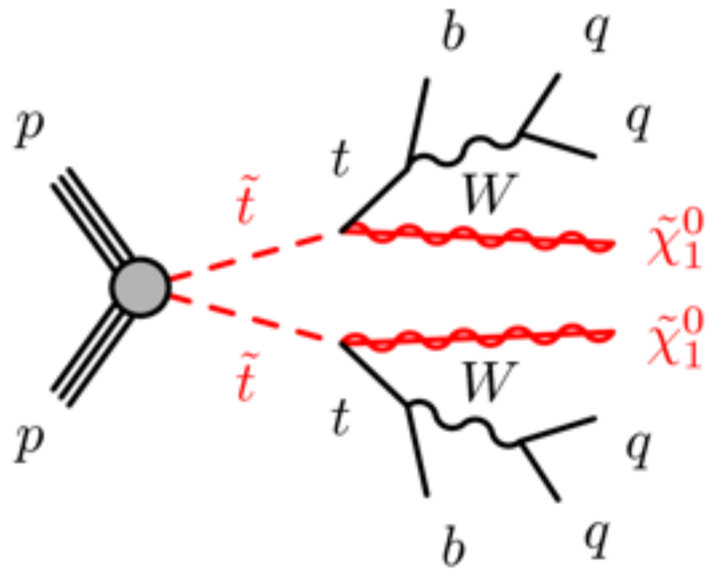
SUSY searches

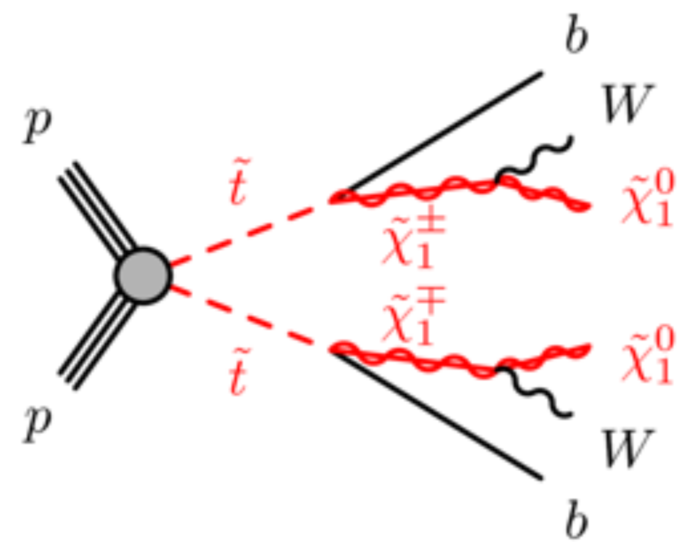


Direct stop/sbottom production



Stop 0-lepton

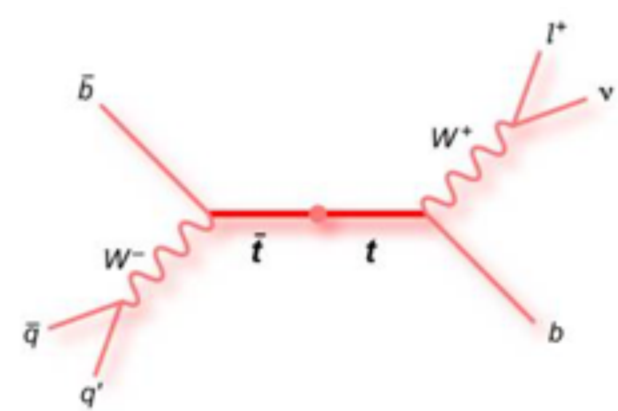




Main SM background: top pair production

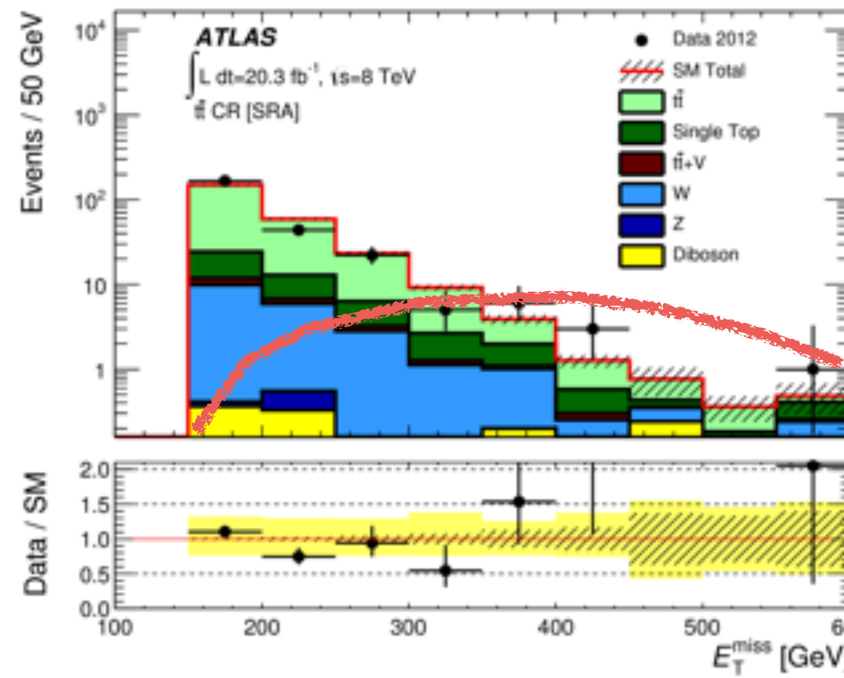
Semileptonic decay of tt

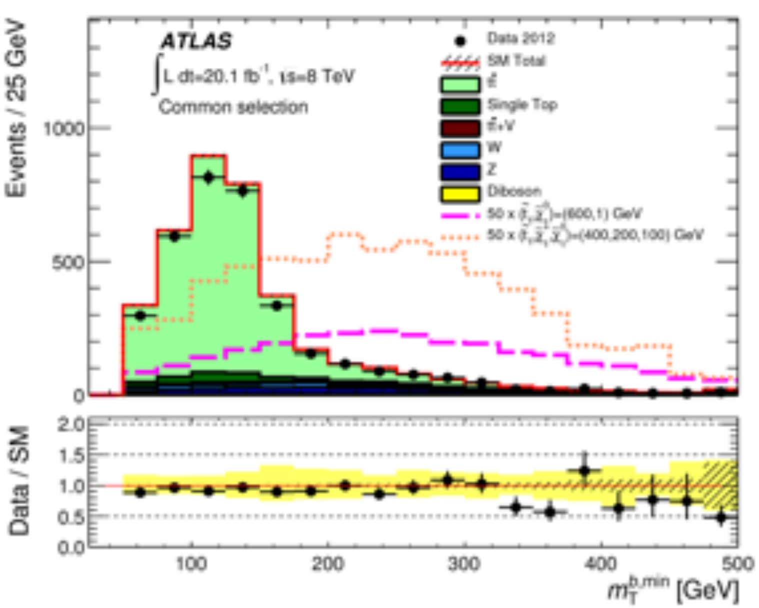
The lepton is either lost or it is a hadronically decaying tau



Fighting the background

The signal has **more MET than the background**

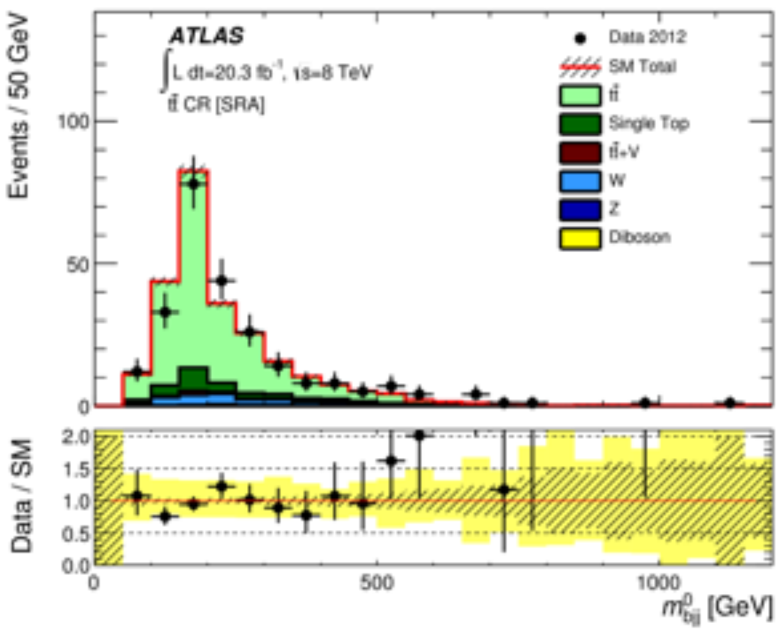




In semileptonic tt, consider the leptonic decay leg. The **transverse mass** between the b and the MET has a **kinematic end-point** (it isn't the case for signal)

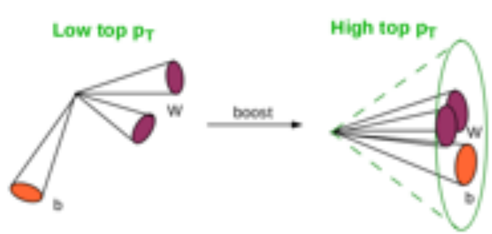
Fighting the background

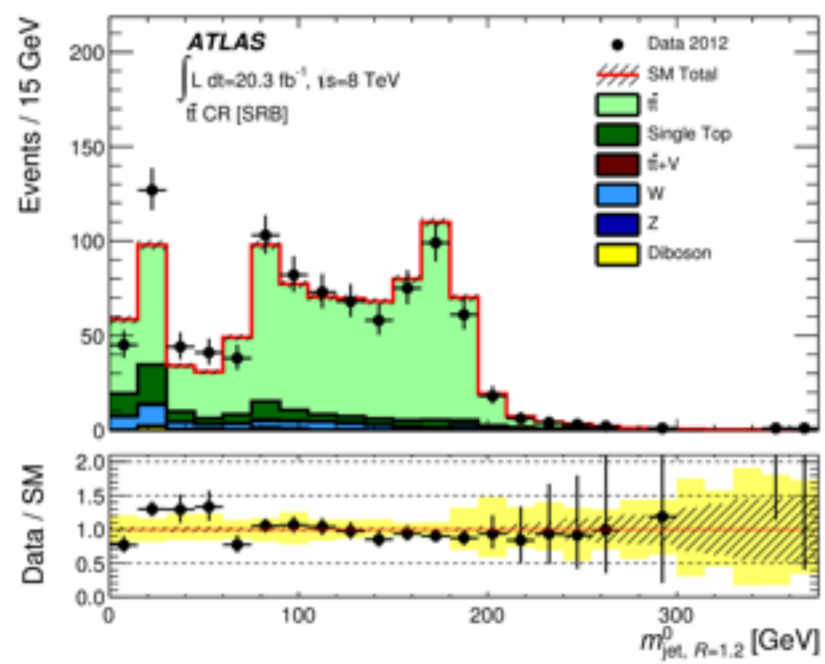
Use of top mass shell conditions



The signal has **two three-jet resonant system**, the background only one

Or boosted top reconstruction





Signal region definition

University of Sussex

Preselection

Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$
N_{lep}	0
b-tagged jets	≥ 2
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150 GeV
$\left\lvert\Delta\phi\left(\mathrm{jet}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}\right)\right\rvert$	$> \pi/5$
$\left\lvert\Delta\phi\left(\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss,track}}\right)\right\rvert$	$< \pi/3$
$m_{\mathrm{T}}^{b,\mathrm{min}}$	> 175 GeV

Resolved signal region for t neut

	SRA1	SRA2	SRA3	SRA4
anti-k_t $R = 0.4$ jets	≥ 6, $p_{\mathrm{T}} > 80, 80, 35, 35, 35, 35$ GeV			
m_{bjj}^{0}	< 225 GeV		[50,250] GeV	
m_{bjj}^{1}	< 250 GeV		[50,400] GeV	
$\min\left[m_{\mathrm{T}}\left(\mathrm{jet}^{i}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}\right)\right]$	–		> 50 GeV	
τ veto	yes			
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150 GeV	> 250 GeV	> 300 GeV	> 350 GeV

Boosted top SR

	SRB1	SRB2
anti-k_t $R = 0.4$ jets	4 or 5, $p_{\mathrm{T}} > 80, 80, 35, 35, (35)$ GeV	5, $p_{\mathrm{T}} > 100, 100, 35, 35, 35$ GeV
$\mathcal{A}_{m_t}$	< 0.5	> 0.5
$p_{\mathrm{T,jet},R=1.2}^{0}$		> 350 GeV
$m_{\mathrm{jet},R=1.2}^{0}$	> 80 GeV	[140, 500] GeV
$m_{\mathrm{jet},R=1.2}^{1}$	[60, 200] GeV	–
$m_{\mathrm{jet},R=0.8}^{0}$	> 50 GeV	[70, 300] GeV
$m_{\mathrm{T}}^{\mathrm{min}}$	> 175 GeV	> 125 GeV
$m_{\mathrm{T}}\left(\mathrm{jet}^{3}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}\right)$	> 280 GeV for 4-jet case	–
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$	–	$> 17\sqrt{\mathrm{GeV}}$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 325 GeV	> 400 GeV

Recover on b-chargino

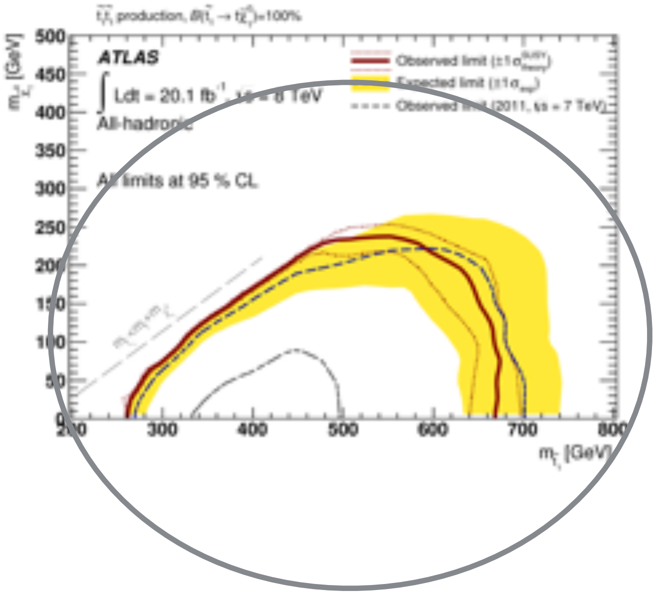
	SRC1	SRC2	SRC3
anti-k_t $R = 0.4$ jets	5, $p_{\mathrm{T}} > 80, 80, 35, 35, 35$ GeV		
$\lvert\Delta\phi(b,b)\rvert$	$> 0.2\pi$		
$m_{\mathrm{T}}^{b,\mathrm{min}}$	> 185 GeV	> 200 GeV	> 200 GeV
$m_{\mathrm{T}}^{b,\mathrm{max}}$	> 205 GeV	> 290 GeV	> 325 GeV
τ veto	yes		
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 160 GeV	> 160 GeV	> 215 GeV

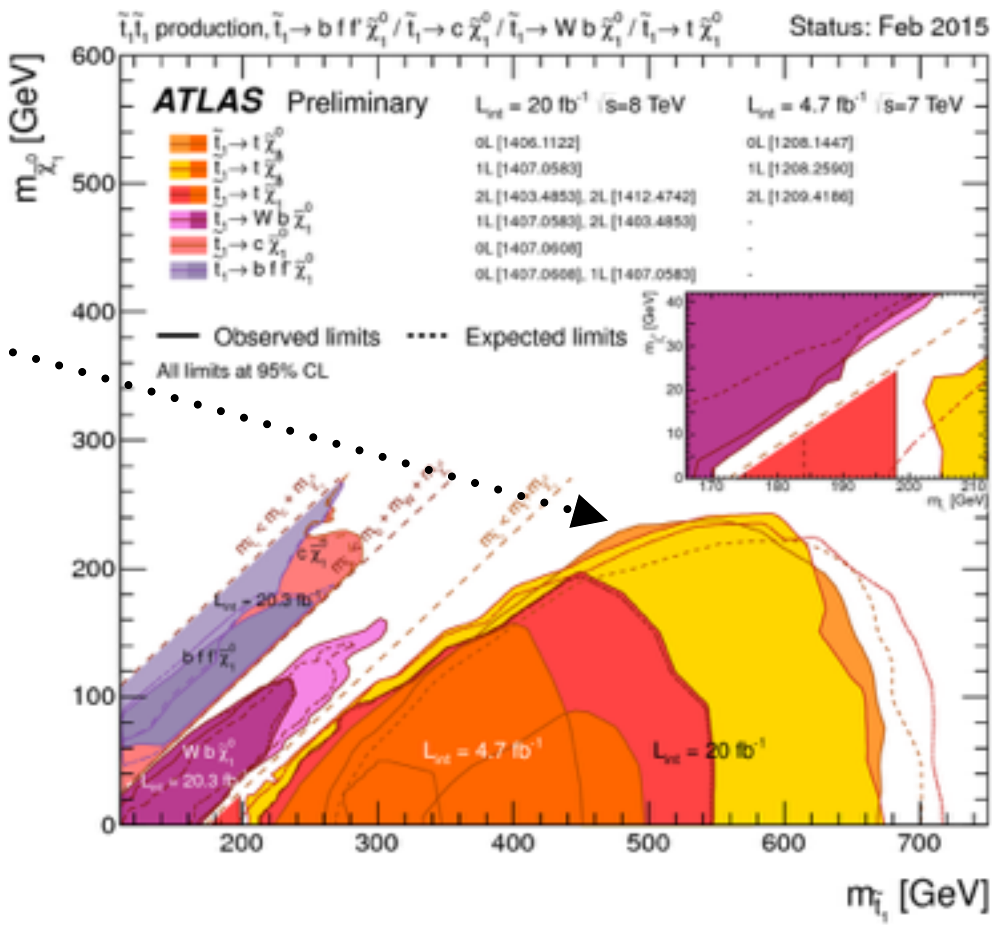
Results

University of Sussex

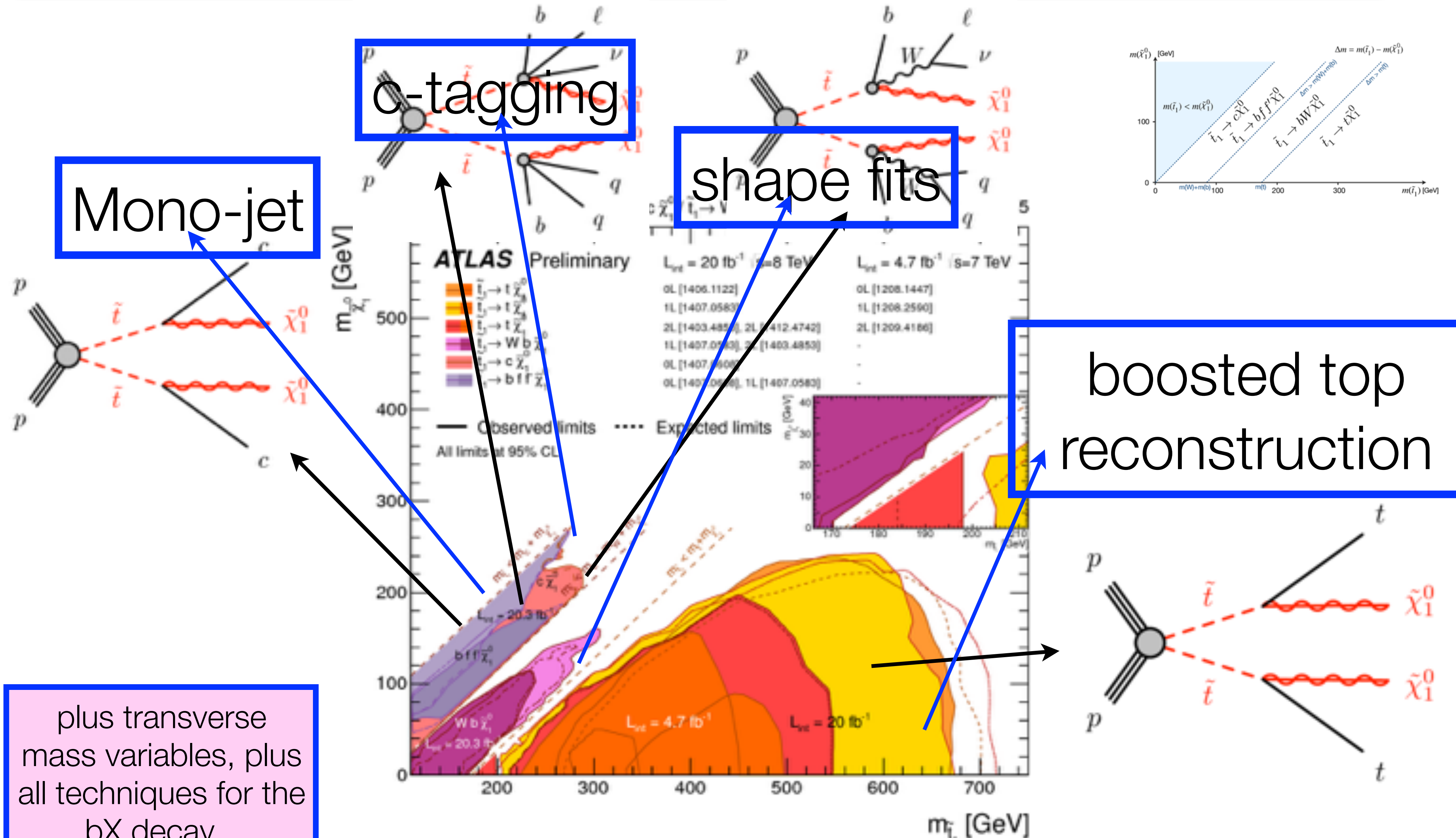
	SRA1	SRA2	SRA3	SRA4	SRB	SRC1	SRC2	SRC3
Observed events	11	4	5	4	2	59	30	15
Total SM	15.8 ± 1.9	4.1 ± 0.8	4.1 ± 0.9	2.4 ± 0.7	2.4 ± 0.7	68 ± 7	34 ± 5	20.3 ± 3.0
$t\bar{t}$	10.6 ± 1.9	1.8 ± 0.5	1.1 ± 0.6	0.49 ± 0.34	$0.10^{+0.14}_{-0.10}$	32 ± 4	12.9 ± 2.0	6.7 ± 1.2
$t\bar{t} + W/Z$	1.8 ± 0.6	0.85 ± 0.29	0.82 ± 0.29	0.50 ± 0.17	0.47 ± 0.17	3.2 ± 0.8	1.9 ± 0.5	1.3 ± 0.4
Z + jets	1.4 ± 0.5	0.63 ± 0.22	1.2 ± 0.4	0.68 ± 0.27	1.23 ± 0.31	15.7 ± 3.5	9.0 ± 1.9	6.1 ± 1.3
W + jets	1.0 ± 0.5	0.46 ± 0.21	0.21 ± 0.19	$0.06^{+0.10}_{-0.06}$	0.49 ± 0.33	8 ± 4	4.8 ± 2.2	2.8 ± 1.2
Single top	1.0 ± 0.4	0.30 ± 0.17	0.44 ± 0.14	0.31 ± 0.16	0.08 ± 0.06	7.2 ± 2.9	4.5 ± 1.8	2.9 ± 1.4
Diboson	< 0.4	< 0.13	0.32 ± 0.17	0.32 ± 0.18	0.02 ± 0.01	1.1 ± 0.8	$0.6^{+0.7}_{-0.6}$	$0.6^{+0.7}_{-0.6}$
Multijets	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.24 ± 0.24	0.06 ± 0.06	0.01 ± 0.01
σ_{vis} (obs) [fb]	0.33	0.29	0.33	0.32	0.21	0.78	0.62	0.40
σ_{vis} (exp) [fb]	$0.48^{+0.21}_{-0.14}$	$0.29^{+0.13}_{-0.09}$	$0.29^{+0.14}_{-0.09}$	$0.25^{+0.13}_{-0.07}$	$0.24^{+0.13}_{-0.06}$	$1.03^{+0.42}_{-0.29}$	$0.73^{+0.31}_{-0.21}$	$0.55^{+0.24}_{-0.15}$
N^{95}_{obs}	6.6	5.7	6.7	6.5	4.2	15.7	12.4	8.0
N^{95}_{exp}	$9.7^{+4.3}_{-3.0}$	$5.8^{+2.6}_{-1.8}$	$5.9^{+2.8}_{-1.9}$	$5.0^{+2.6}_{-1.4}$	$4.7^{+2.6}_{-1.2}$	$20.7^{+8.4}_{-5.8}$	$14.7^{+6.2}_{-4.2}$	$11.0^{+4.9}_{-3.1}$

Limits


ATLAS
All-hadronic
All limits at 95 % CL
Observed limit
Expected limit
m_t̃ [GeV]


Status: Feb 2015
ATLAS Preliminary
Observed limits
Expected limits
All limits at 95% CL
L_int = 4.7 fb^-1
L_int = 20 fb^-1
m_t̃1 [GeV]
m_χ̃1^0 [GeV]

Direct stop/sbottom production



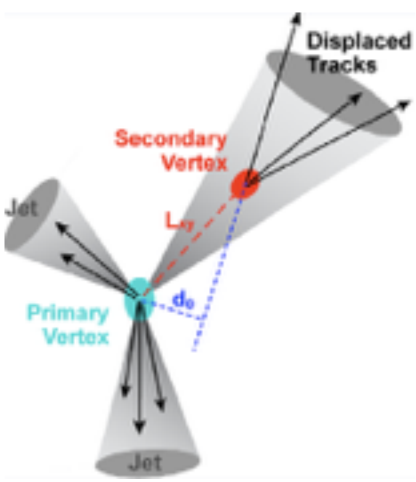
plus transverse mass variables, plus all techniques for the bX decay...

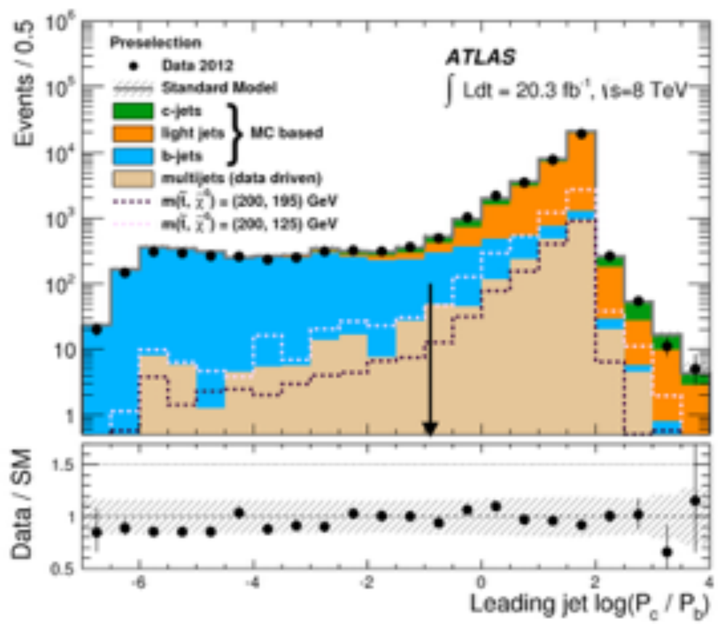
c-tagging

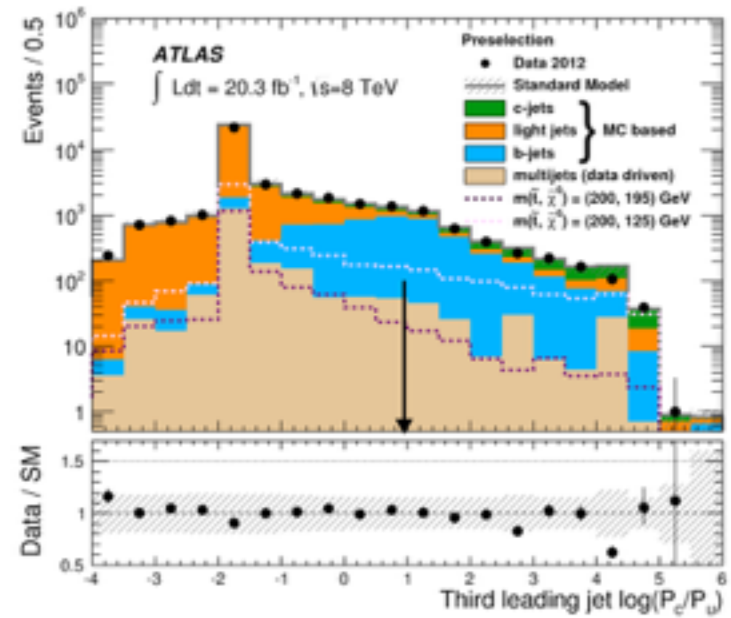
- Target: **stop -> c neutralino**
- Selection:
  - Large missing transverse momentum
  - Leading jet pT > 150 GeV
  - lepton veto

Background dominated by Z and W production

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



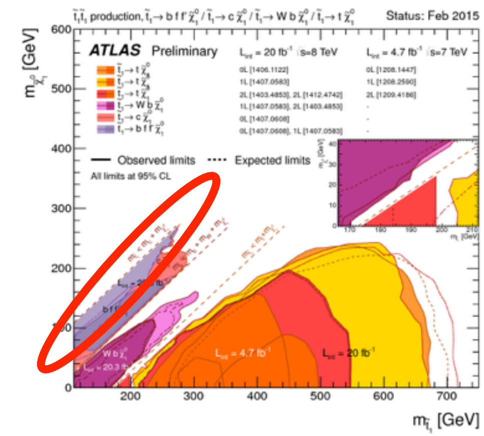


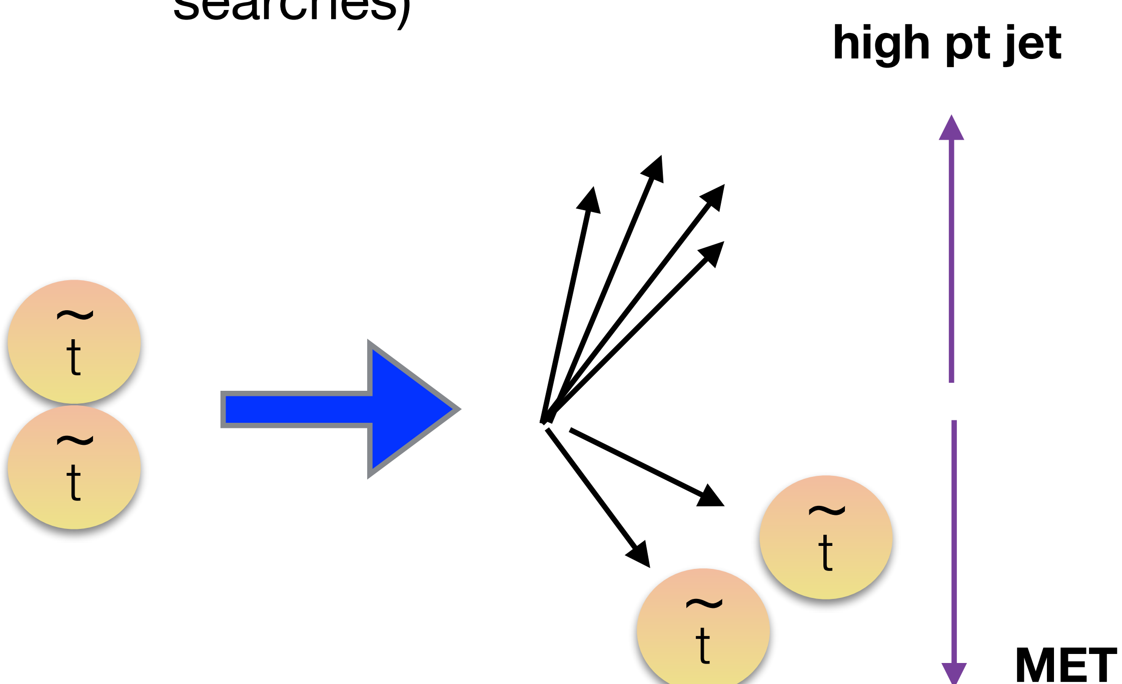


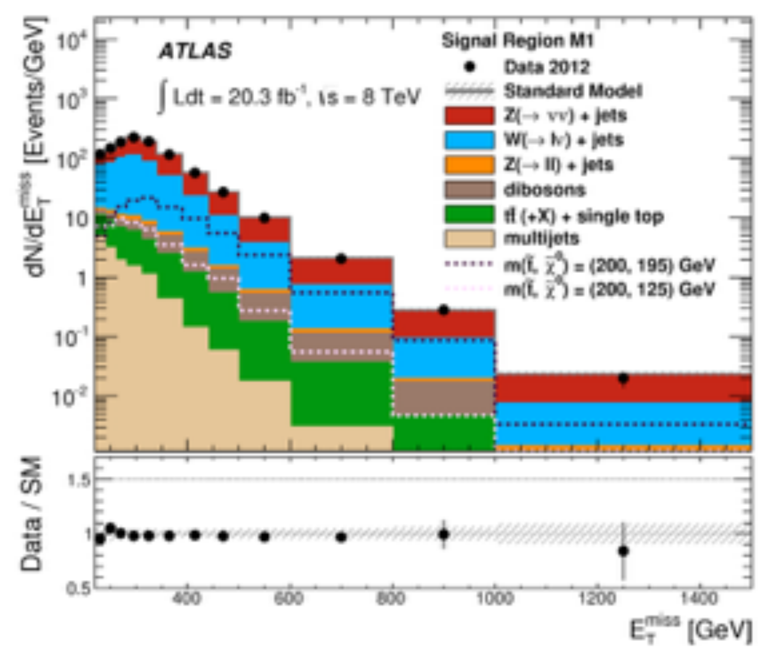
ISR tagging (monojet-like signatures)

University of Sussex

- m(top) ~ m(neutralino):
  - Pair produced stops are **invisible**….
  - … unless **we boost them**
    - monojet-like signal (as in DM searches)



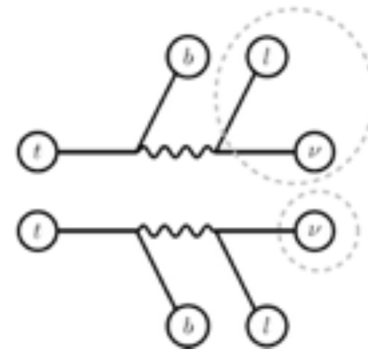




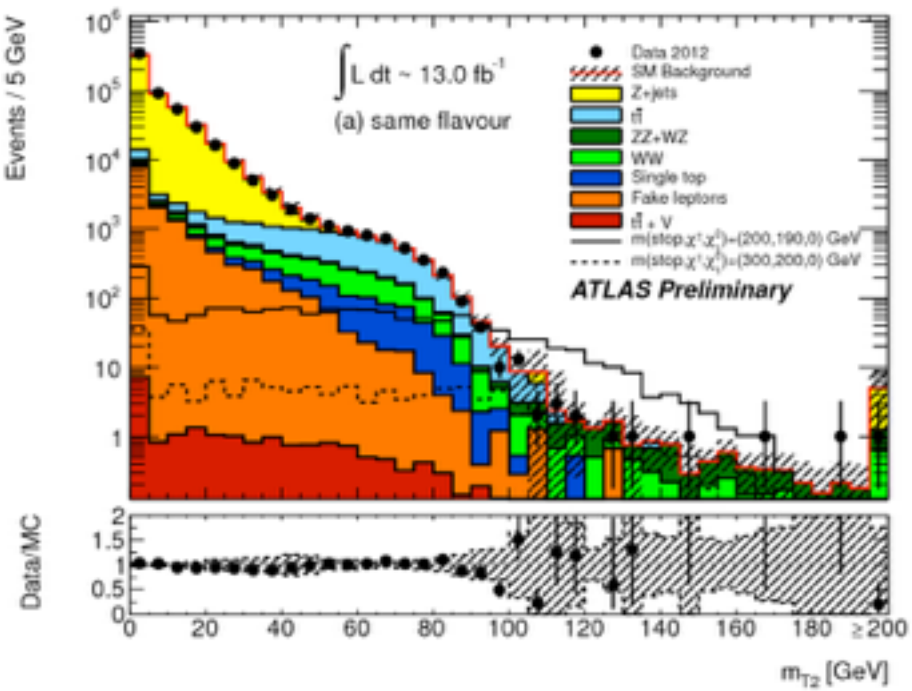
Heavy use of kinematical end-points

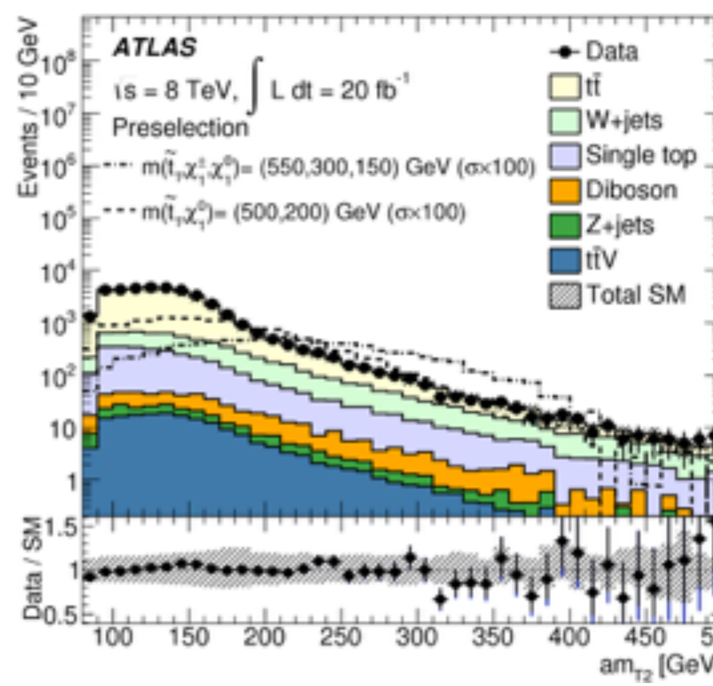
- mT2: an extension of the transverse mass variable

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



- amT2: a generalisation of the mT2

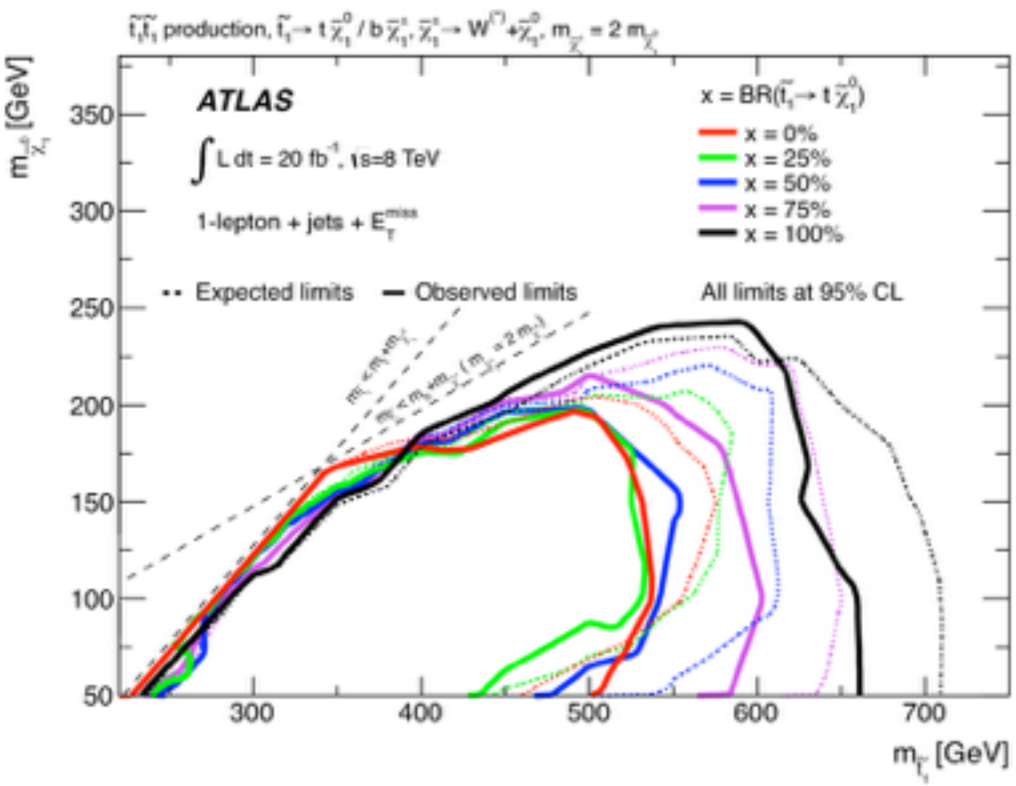


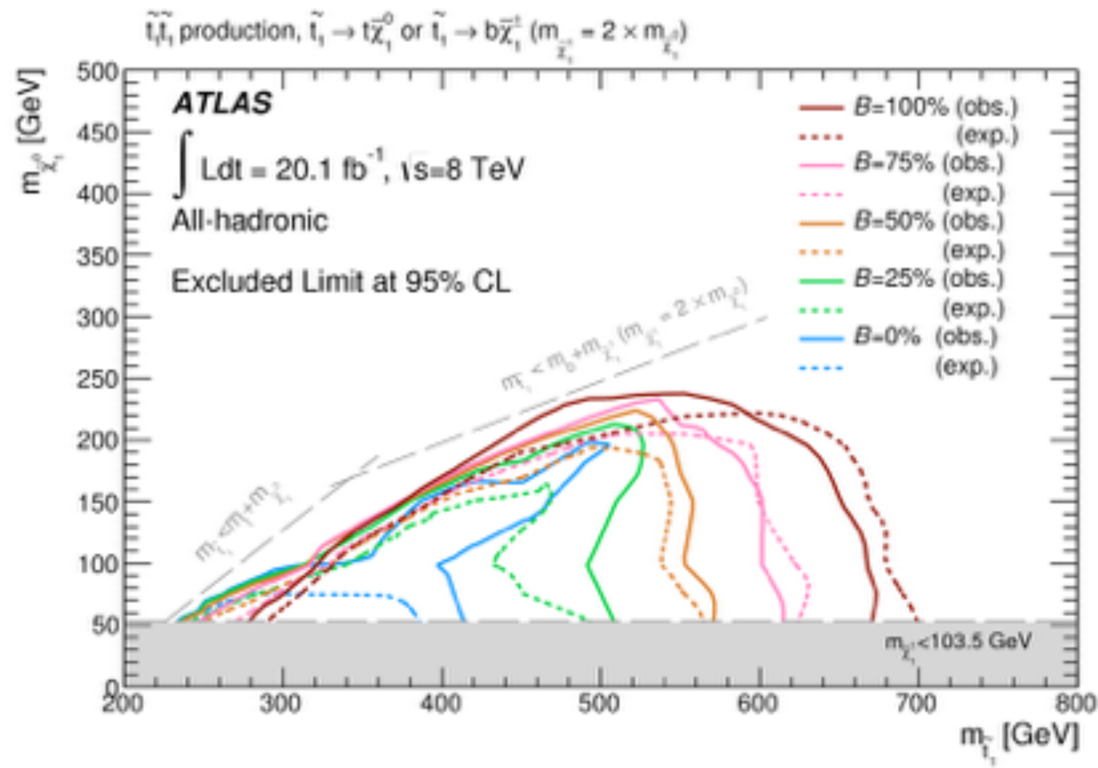


Limits dependency on BR($t \rightarrow t\tilde{\chi}_1^0$)

University of Sussex

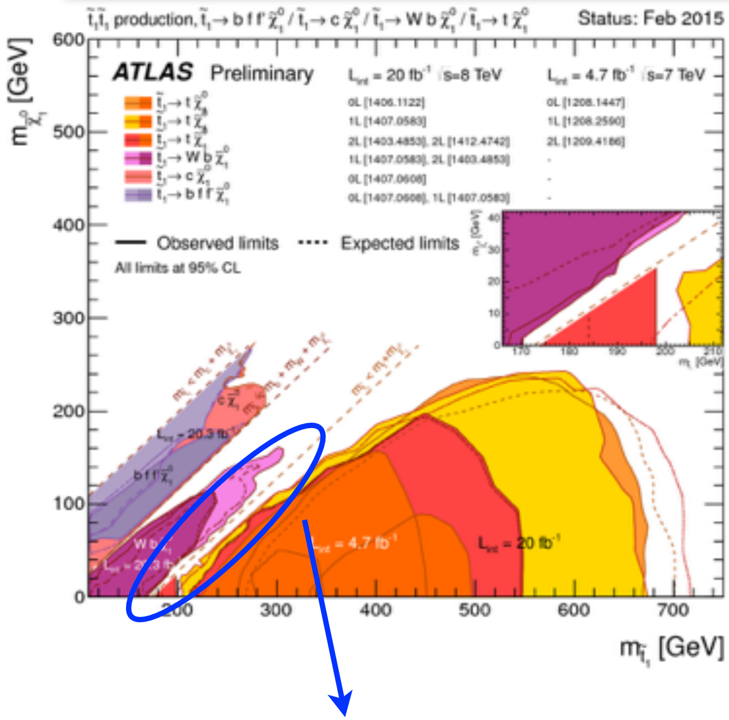
- Signal regions optimised for **one specific topology**. Combinations of signal regions **make results less dependent on the decay details**





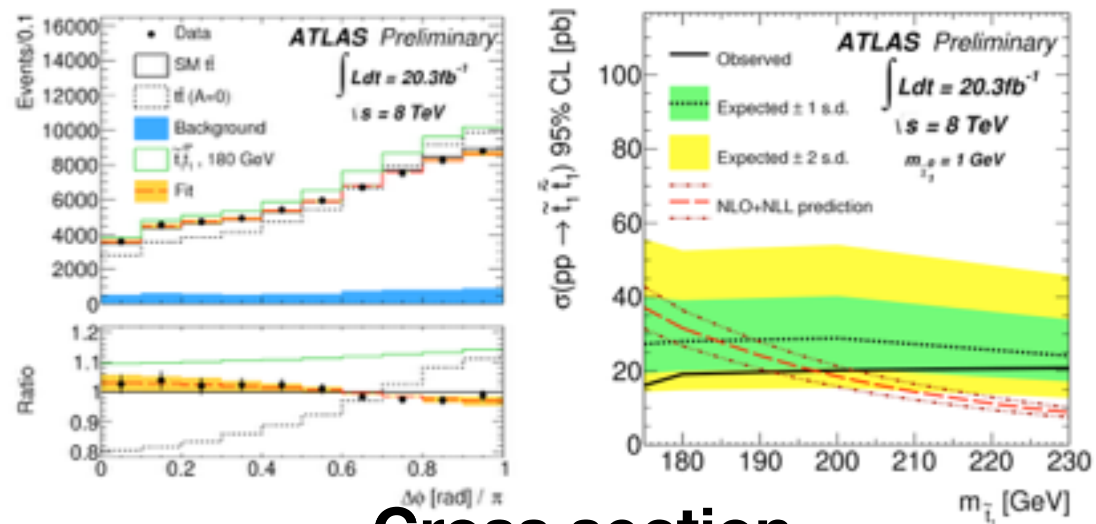
Limits from SM measurements

University of Sussex

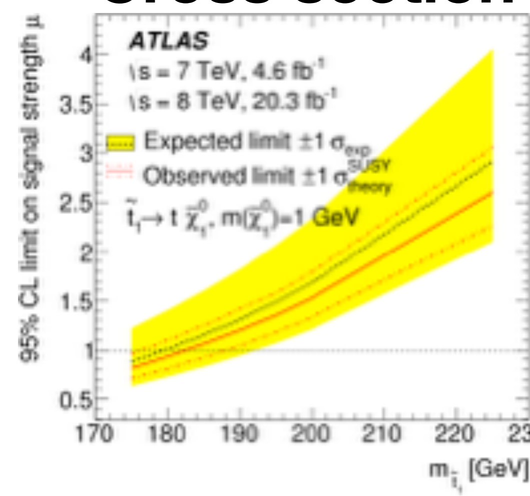


top like kinematics - difficult to approach with searches

Spin correlations

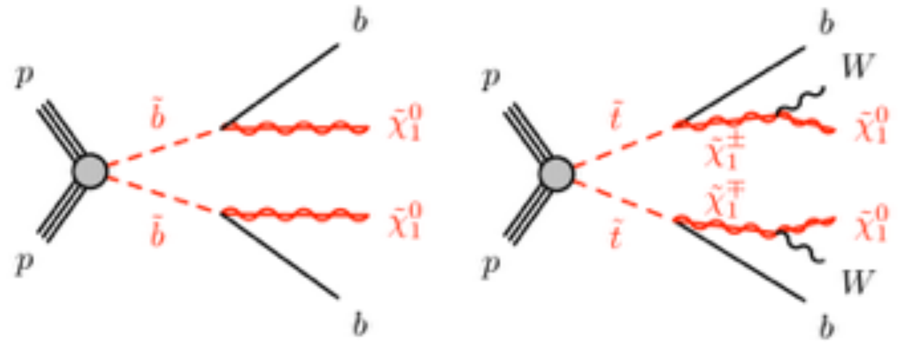


Cross section



Sbottom searches

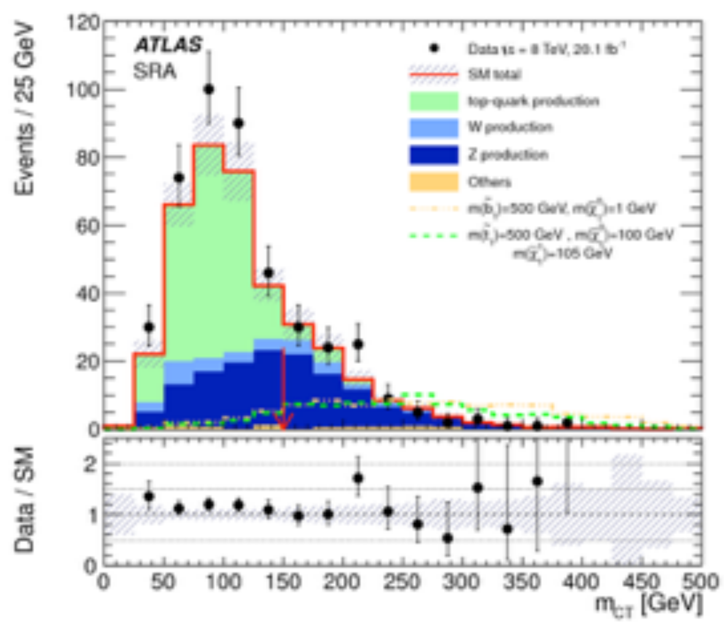
University of Sussex

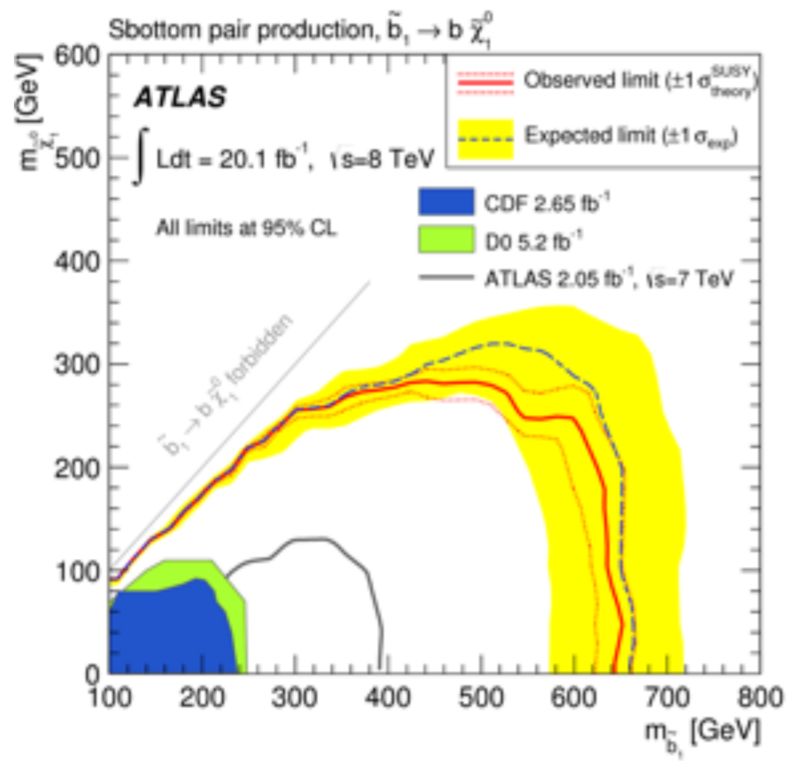


$$m_{CT}(b_1, b_2) = \sqrt{(E_T(b_1) + E_T(b_2))^2 - (\mathbf{p_T}(b_1) - \mathbf{p_T}(b_2))^2}$$

(boost corrected) $m_{CT}(b_1,b_2)$ has an end-point at $(m_{prod}^2 - m_{inv}^2)/m_{prod}$

Same final state topology: bb MET





What happens in a real model?

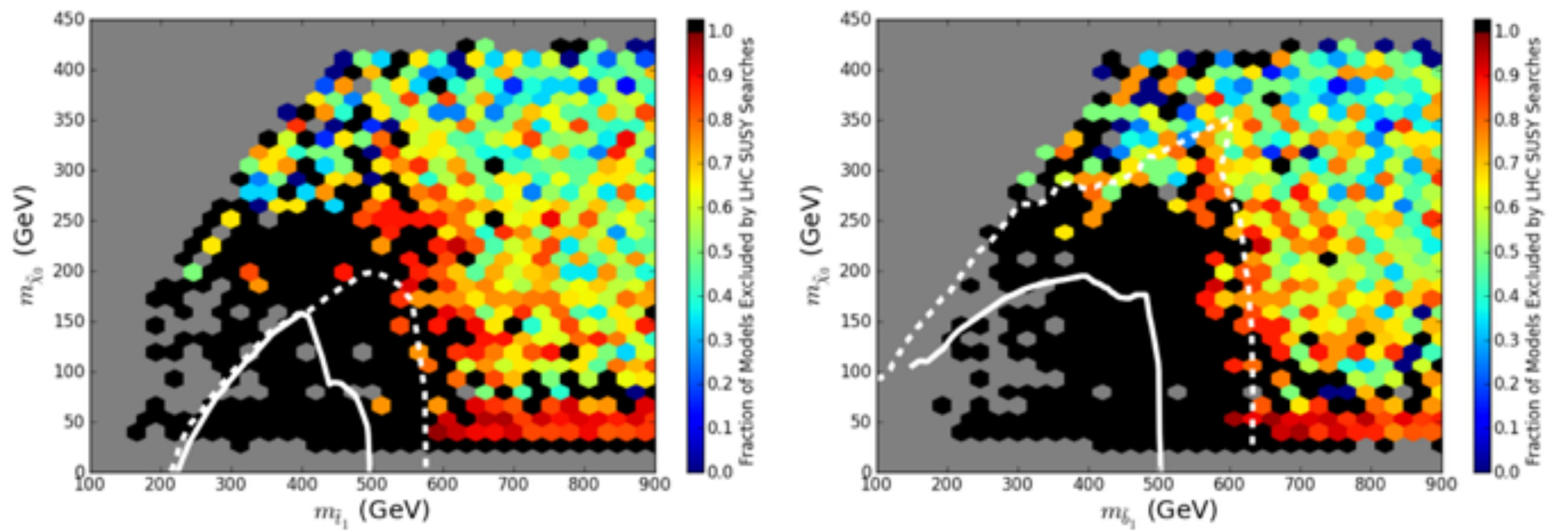
- The MSSM has **124 parameters**…
- … which can be reduced to **19** by requiring:
  - No new source of **CP violation**
  - No **Flavour Changing Neutral Currents**
  - First and second generation **universality**
- This is the phenomenological MSSM (or pMSSM)

Further constraints **can be imposed** (Higgs boson mass, dark matter density, heavy flavour decays)

Parameter	Description
$m_{\tilde{u}R}, m_{\tilde{d}R}, m_{\tilde{q}L1}, m_{\tilde{e}R}, m_{\tilde{\ell}L1}$	First and second generation common mass parameter
$m_{\tilde{b}R}, m_{\tilde{t}R}, m_{\tilde{q}L3}, m_{\tilde{\tau}R}, m_{\tilde{\ell}L3}$	Third generation mass parameter
M_1, M_2, M_3	Gaugino mass parameters
A_b, A_τ, A_t	Trilinear couplings
μ, M_A	Higgs/higgsino mass parameters
$\tan\beta$	Ratio of vacuum expectation values of the two Higgs doublets

What happens in a real model?

- Fraction of **pMSSM models** (with low fine tuning) with a given stop/sbottom mass excluded by ATLAS analyses
- (Stop analyses not completely up to date in the plots below)



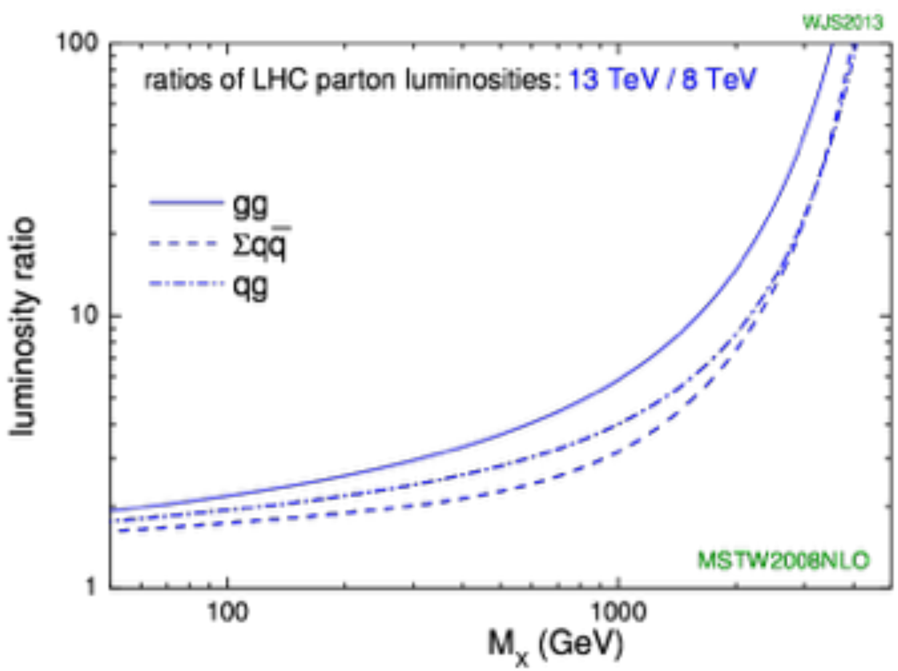
From arXiv:1307.8444

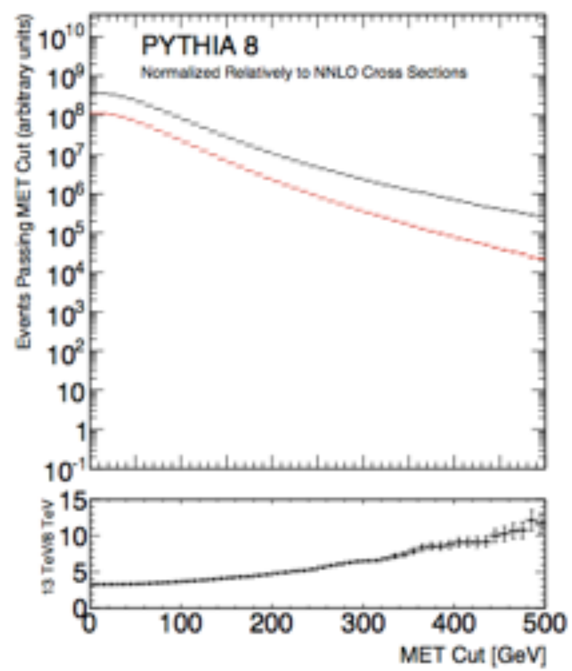
Prospects for run 2 and beyond

Prospects for run 2 and beyond

- LHC run 2 due to start **next June** with **$\sqrt{s}$ = 13 TeV**.
- Increase in **cms energy** means increase in **cross section sensitivity**
  - 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 2015
Third generation	~ 5 fb-1	End of summer 2015
weak production	~ 20 fb-1	End of run 2015



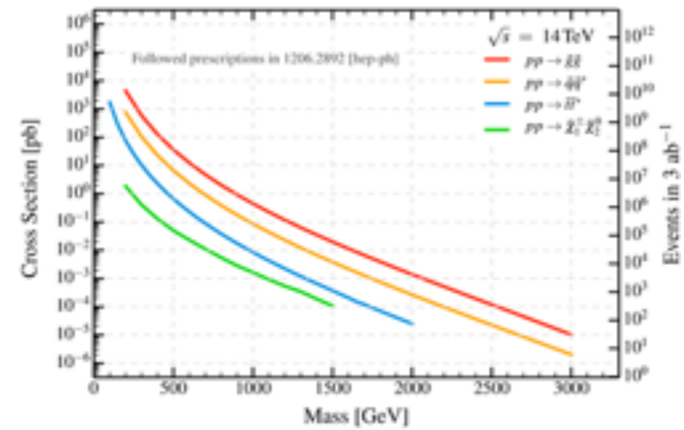


Prospects for run 2 and beyond

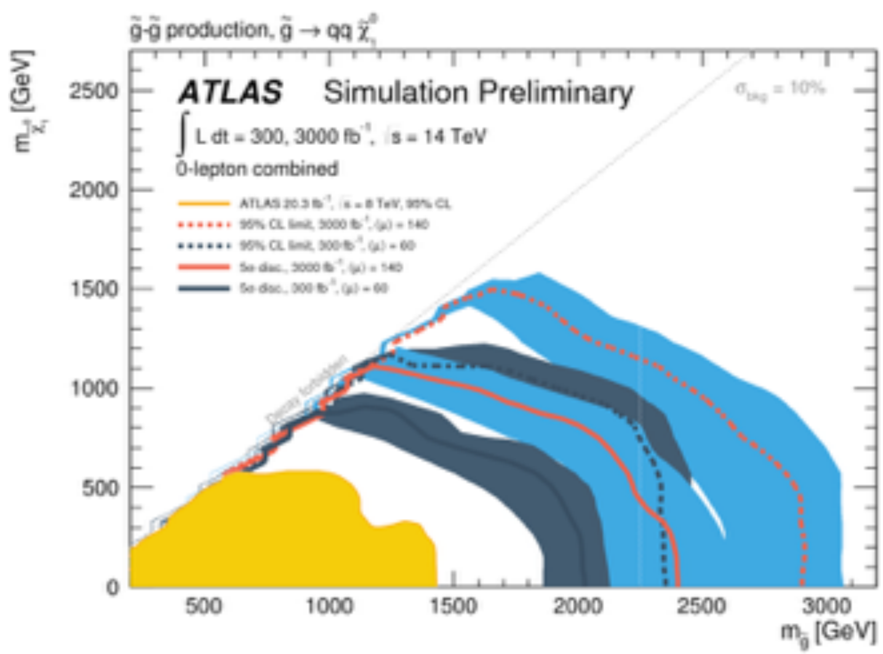
University of Sussex

(Highly) simplified detector simulation

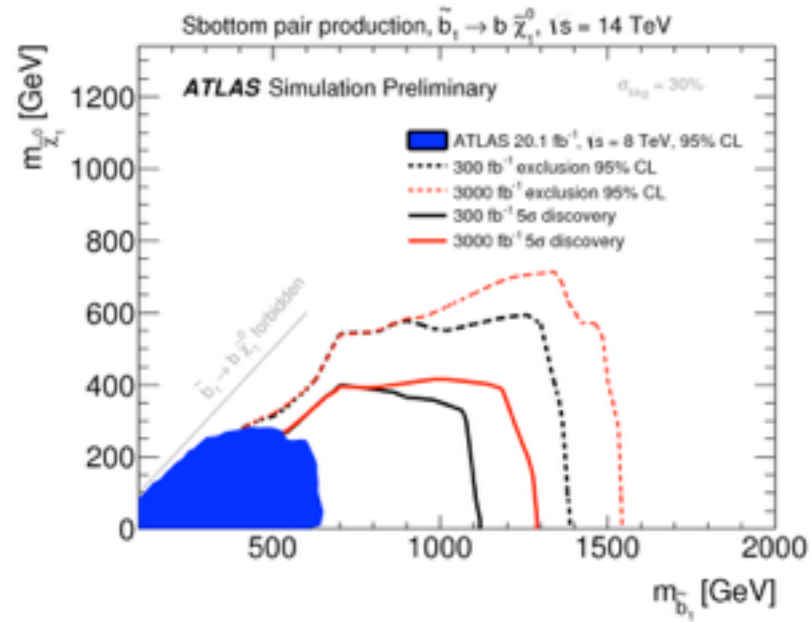
Assuming cms of 14 TeV



Gluino pair production

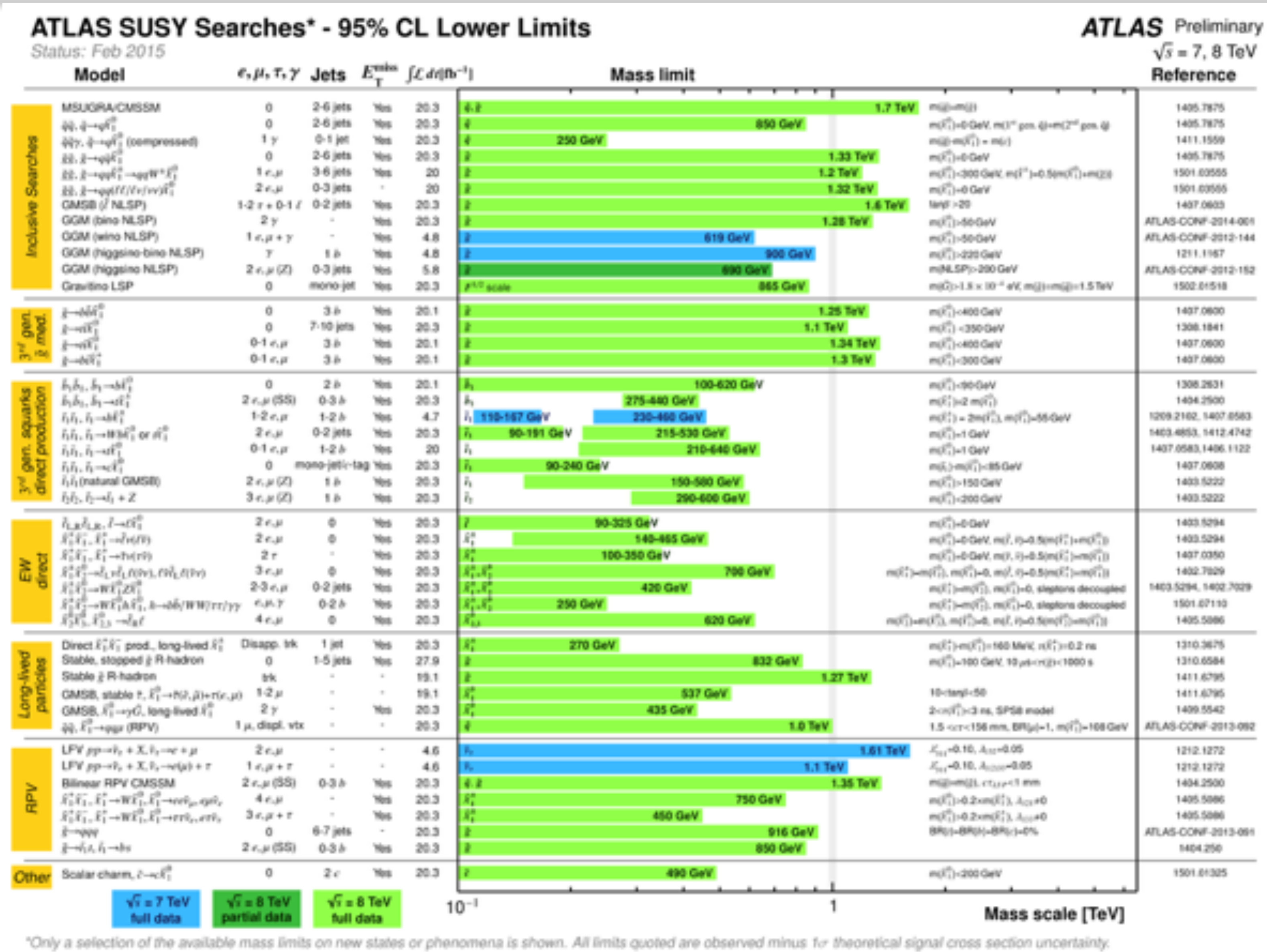


Sbottom pair production



Summary

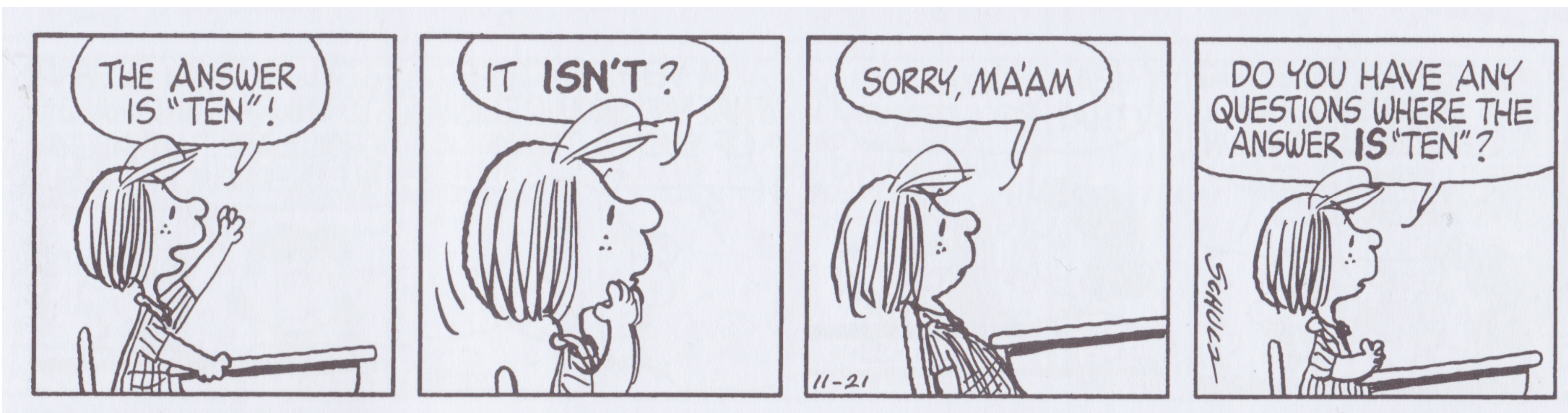
Summary


ATLAS SUSY Searches* - 95% CL Lower Limits
Status: Feb 2015
ATLAS Preliminary
$\sqrt{s}$ = 7, 8 TeV
Model
Jets
Mass limit
Reference
Inclusive Searches
EW direct
Long-lived particles
RPV
Other
$\sqrt{s}$ = 7 TeV full data
$\sqrt{s}$ = 8 TeV partial data
$\sqrt{s}$ = 8 TeV full data
10^{-1}
1
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

When will we stop looking for SUSY?

University of Sussex

- SUSY yields **an incredible number** of **well motivated possible topologies**
  - While looking for SUSY we effectively constraint **many 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


THE ANSWER IS "TEN"!
IT ISN'T ?
SORRY, MA'AM
DO YOU HAVE ANY QUESTIONS WHERE THE ANSWER IS "TEN"?
11-21
SCHULZ

BACKUP

Fake lepton background estimate

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

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

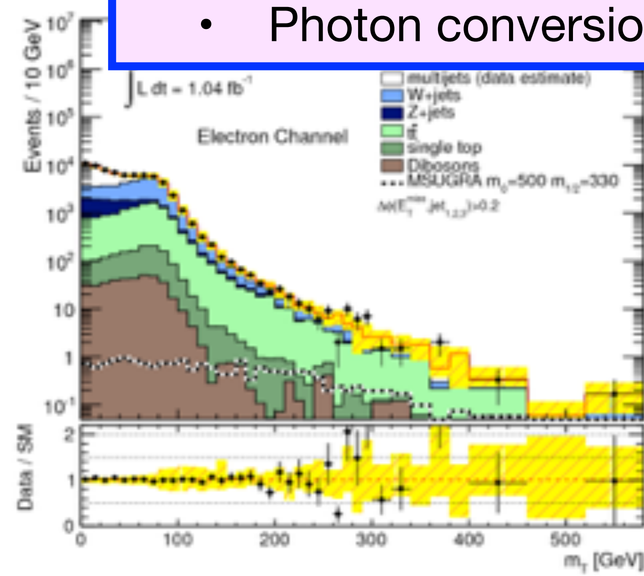
- Strategy: define a "loose" (pre-selected) and a lepton selection.

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

Need to be measured independently from data

Simply count how many of them

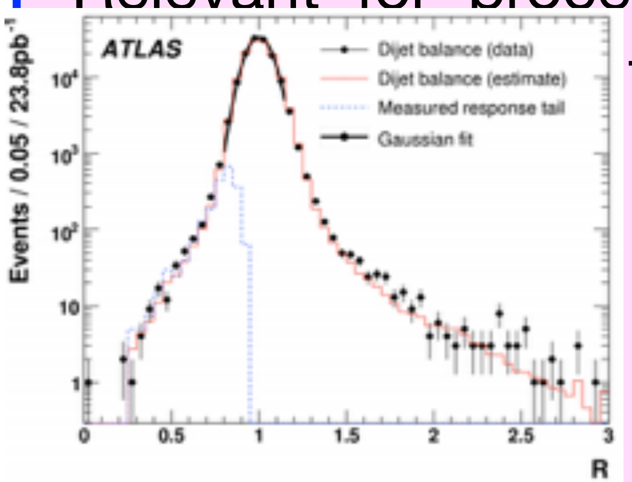
$$N^{tight}_{fake} = \frac{\varepsilon_{fake}}{\varepsilon_{real} - \varepsilon_{fake}} \left(N^{loose} \varepsilon_{real} - N^{tight} \right)$$



Fake ETmiss background estimate

University of Sussex

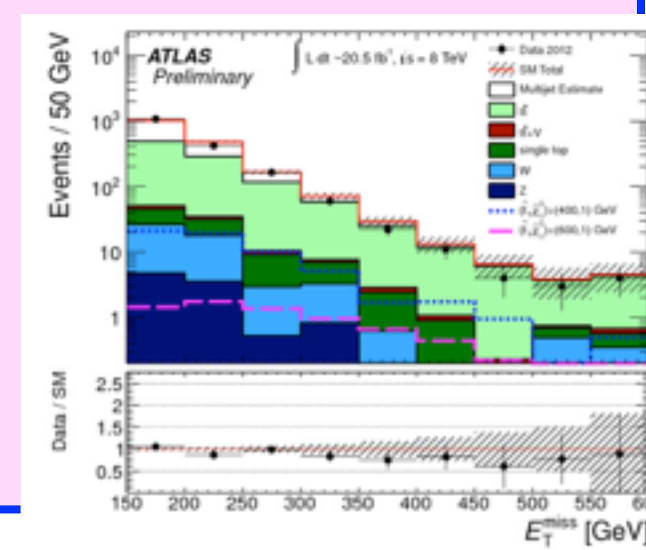
- Large ETmiss can be induced by a jet mis-measurement.
- Relevant for processes with high cross section and no “real” …→ll)



Derive a “jet response function” from MC and adapt it to data:

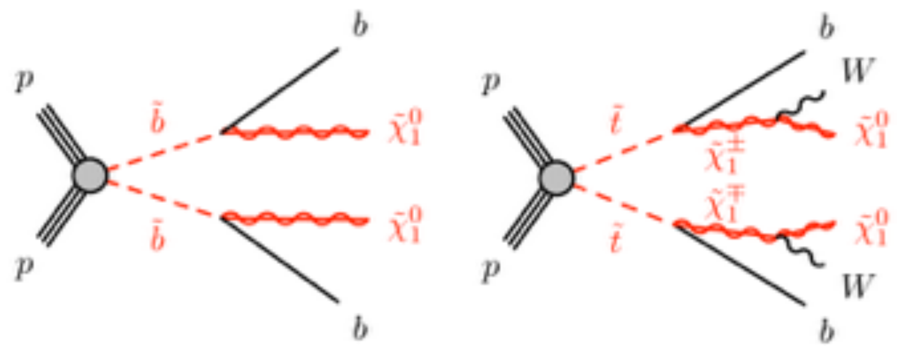
- core: pT balance in di-jet events
- tail: three-jet (Mercedes) events

- Use response function to smear jets in real data events with low MET:
- Obtain events with large “fake” ETmiss



SUSY

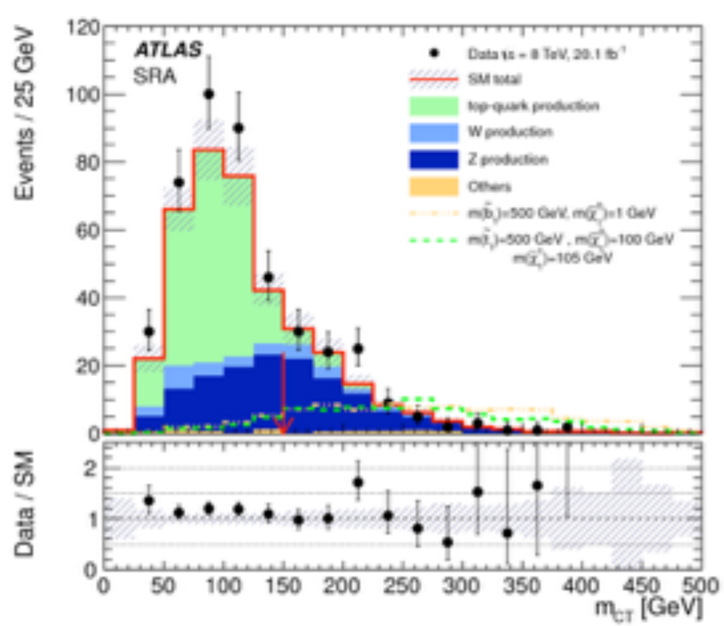
Sbottom searches

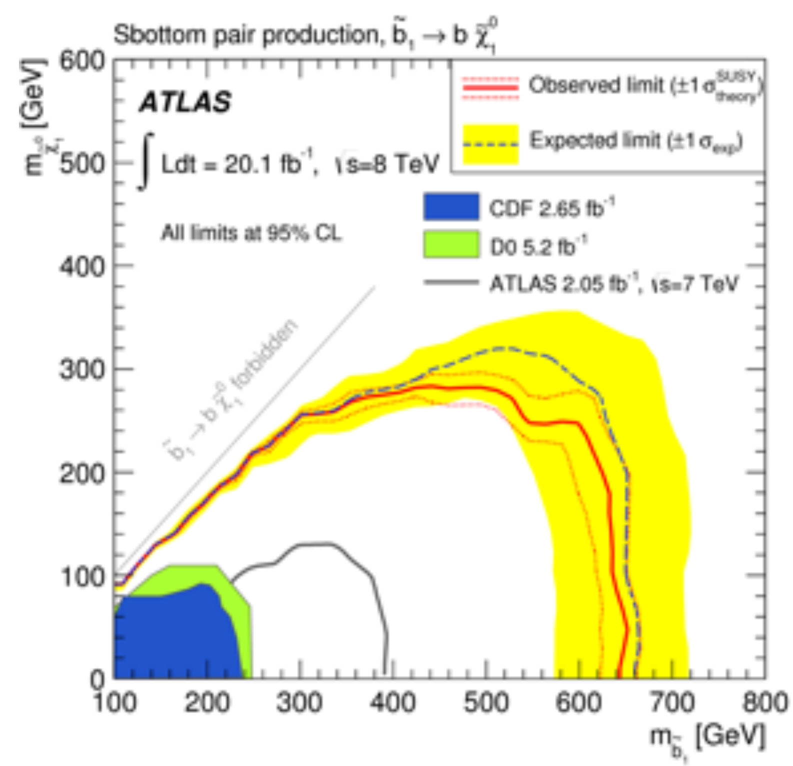


$$m_{\mathrm{CT}}(b_1, b_2) = \sqrt{(E_T(b_1) + E_T(b_2))^2 - (\mathbf{p_T}(b_1) - \mathbf{p_T}(b_2))^2}$$

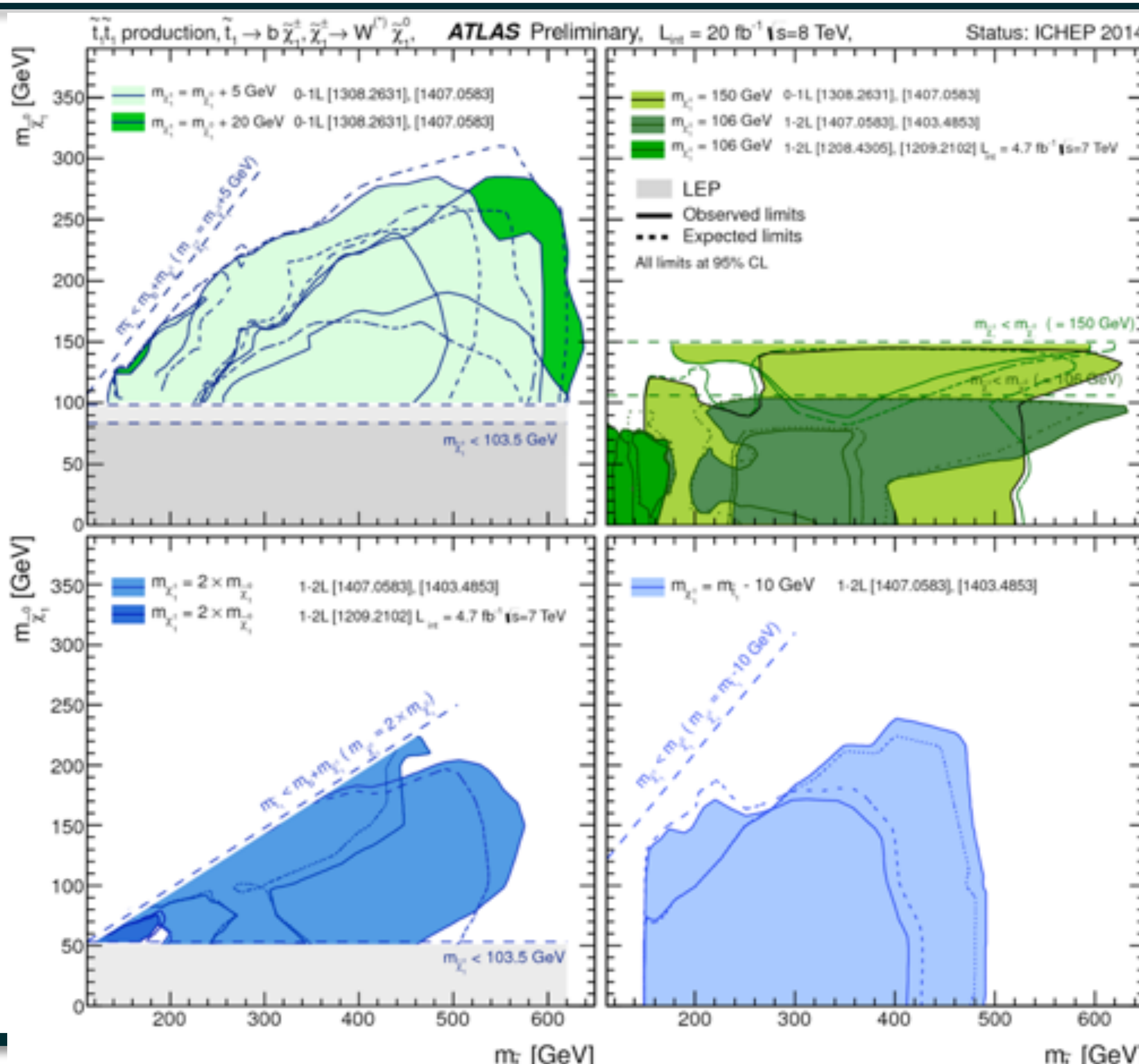
(boost corrected) $m_{CT}(b_1,b_2)$ has an end-point at $(m_{prod}^2 - m_{inv}^2)/m_{prod}$

Same final state topology: bb MET





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



Parameters and masses

University of Sussex

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

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

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

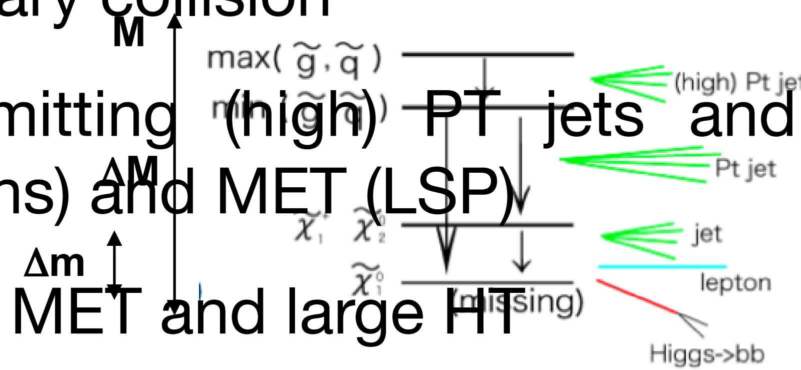
What we are typically doing

University of Sussex

- Heavy sparticles produced in the primary collision

- They decay into lighter objects, emitting (high) PT jets and possibly other objects (leptons, photons) and MET (LSP)

- A "typical" SUSY event will have large MET and large HT

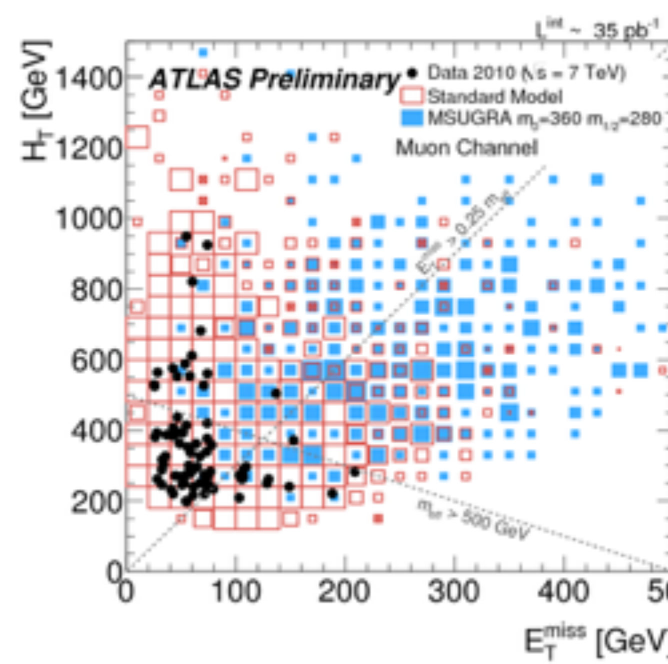


- Useful variables:

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

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

- But also other variables with well defined kinematical end point for the SM background



Higgs and SUSY

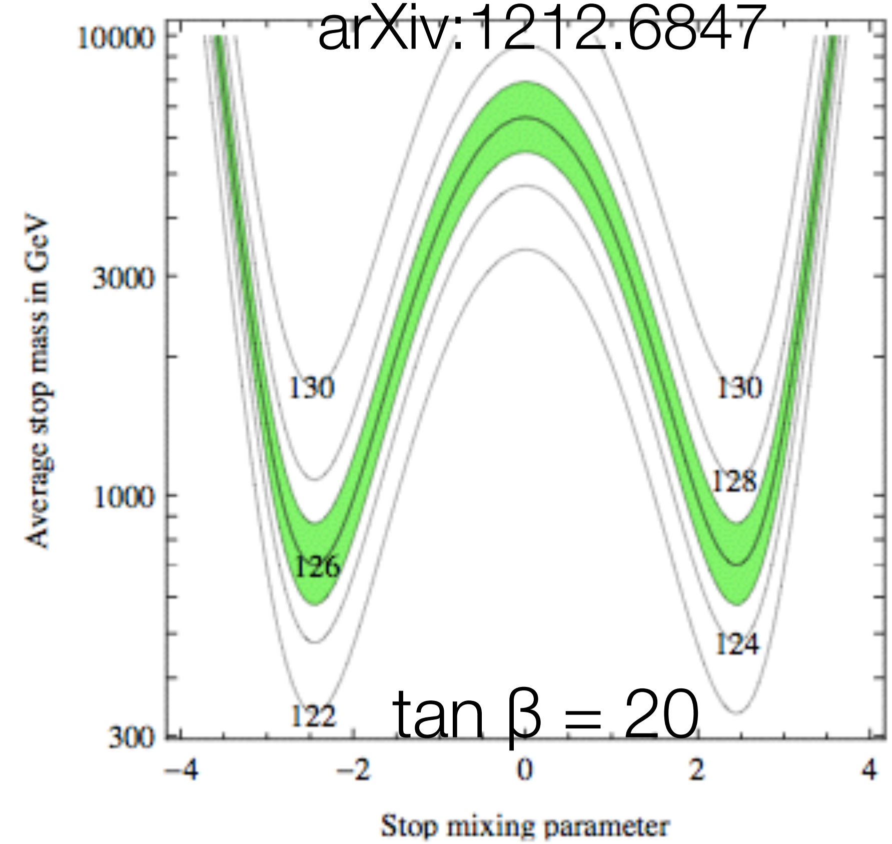
University of Sussex

- The Higgs mass depend o

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

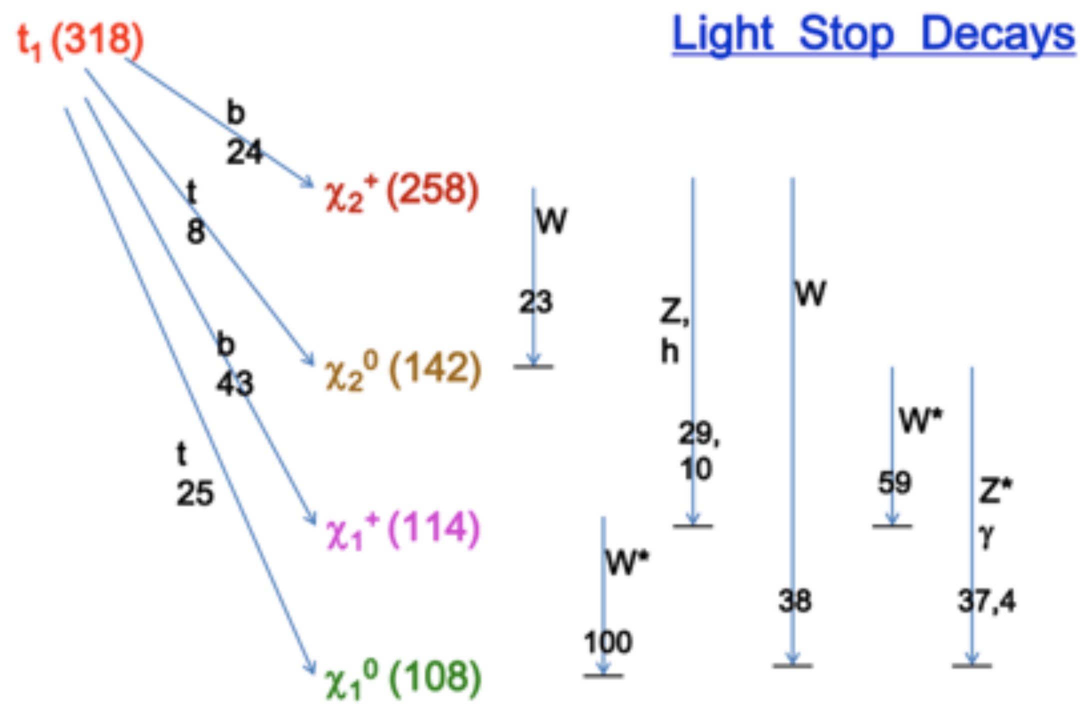
$$m_h^2 = m_Z^2 \cos^2\beta + \frac{3 y_t^2 m_t^2}{(4\pi)^2}\left[\log\left(\frac{m_S^2}{m_t^2}\right) + X_t^2\left(1 - \frac{X_t^2}{12}\right)\right]$$

- mh=126 GeV still allows for a light t



What is missing? (3rd gen)

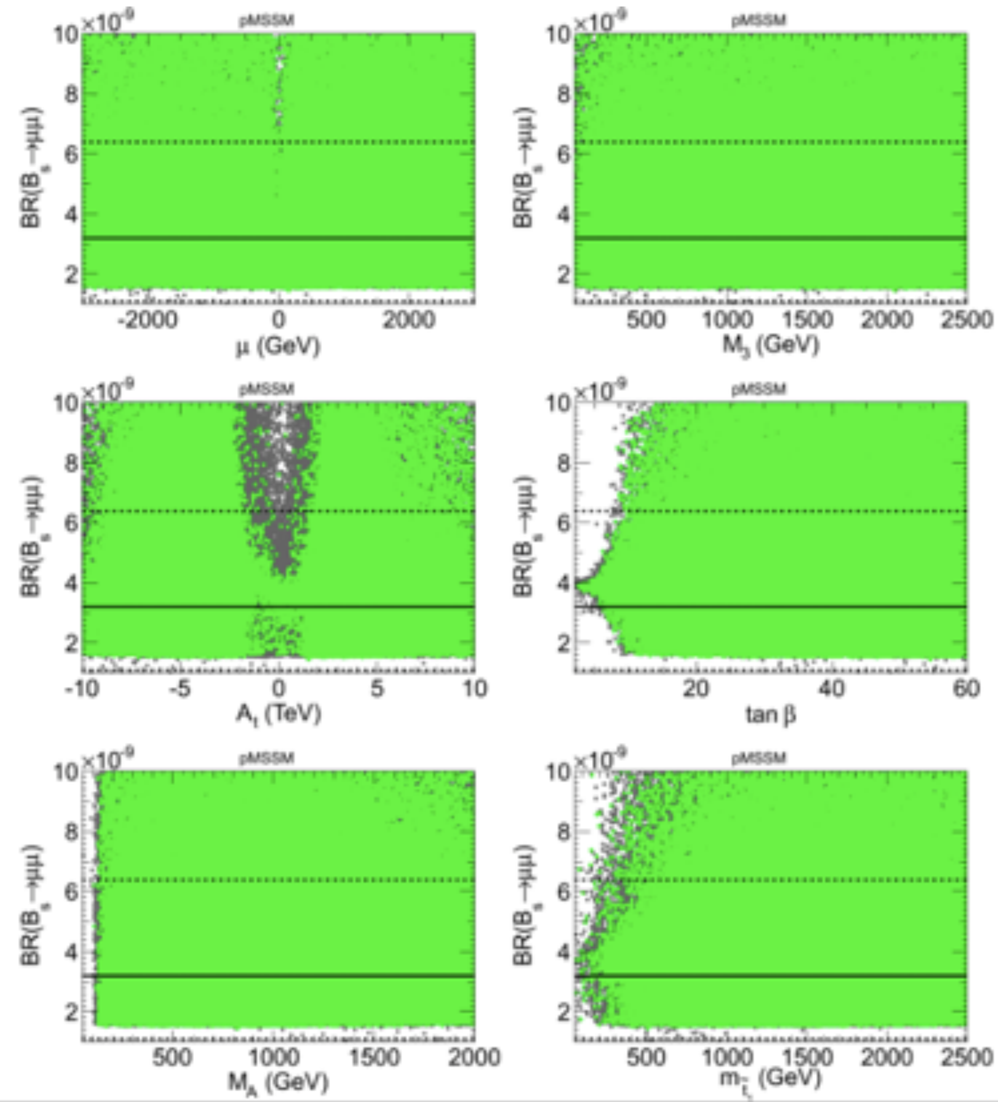
- My own to-do list for the next few months/years:
  - Improve limits at high stop mass:
    - boosted top reconstruction?
- Mixed decays (5̃0% ~ t1→tX̃10, 5̃0% t1→bX1±) still not considered (and somewhat favoured, actually)
- Complete the investigation in the low



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

Bs->mu mu

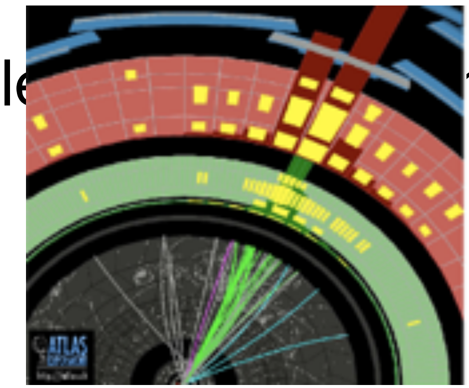
- From http://arxiv.org/pdf/1212.4



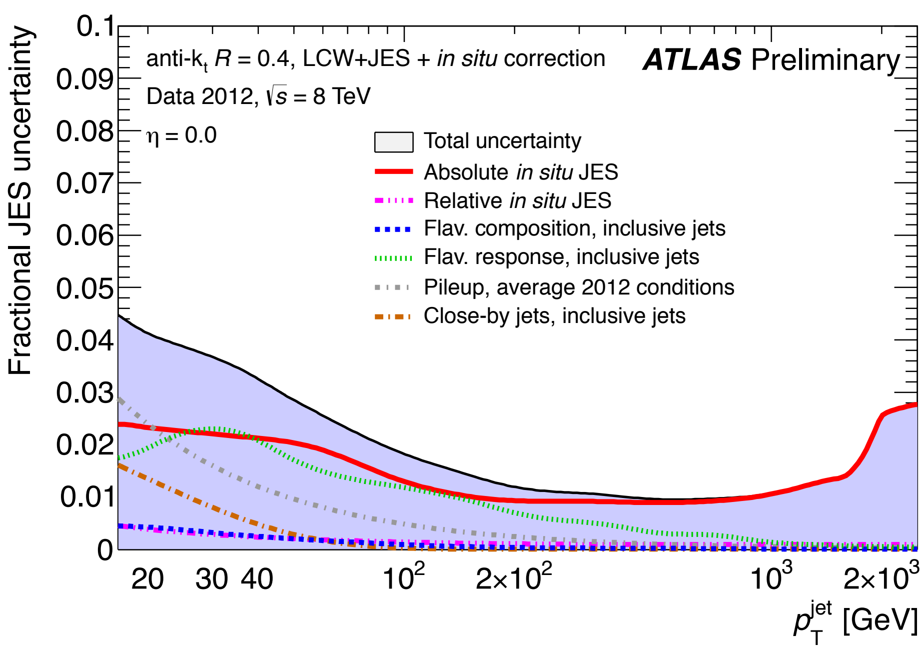
Performance

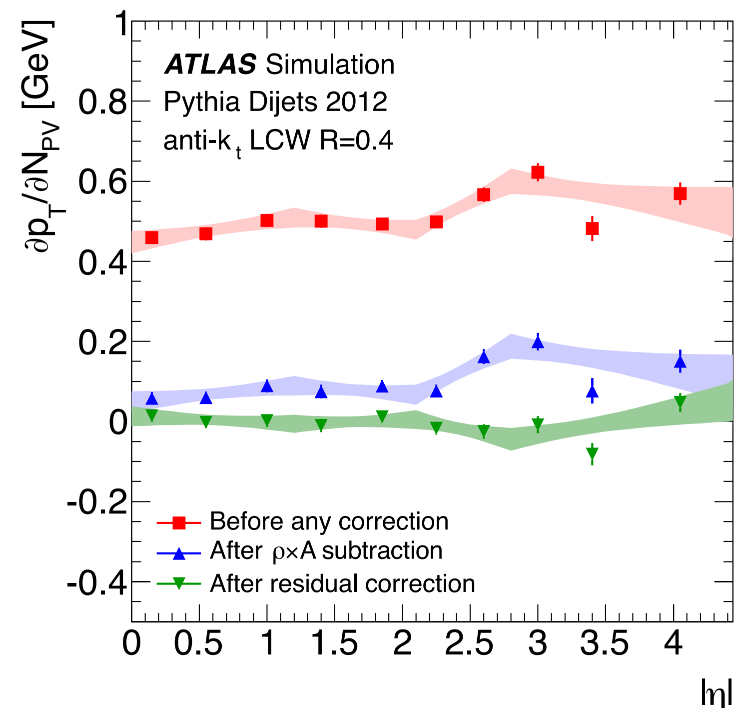
Jet measurement

- Constantly improving on jet measurement and pile n techniques



- Jet energy scale known up to the ~1% level
- Pileup subtraction based on jet area method

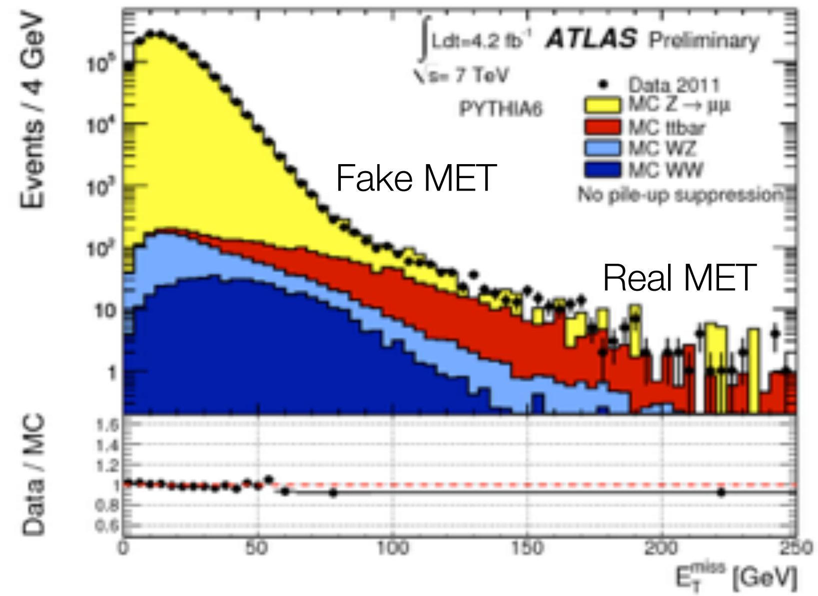


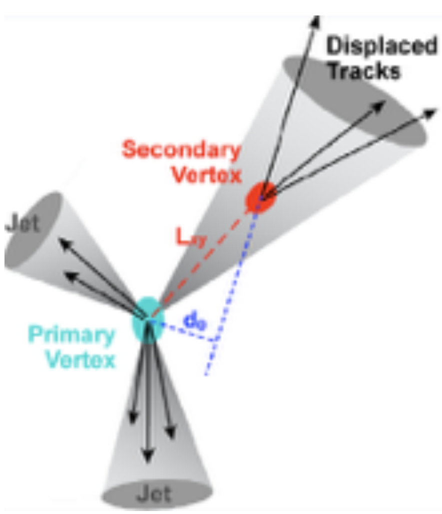


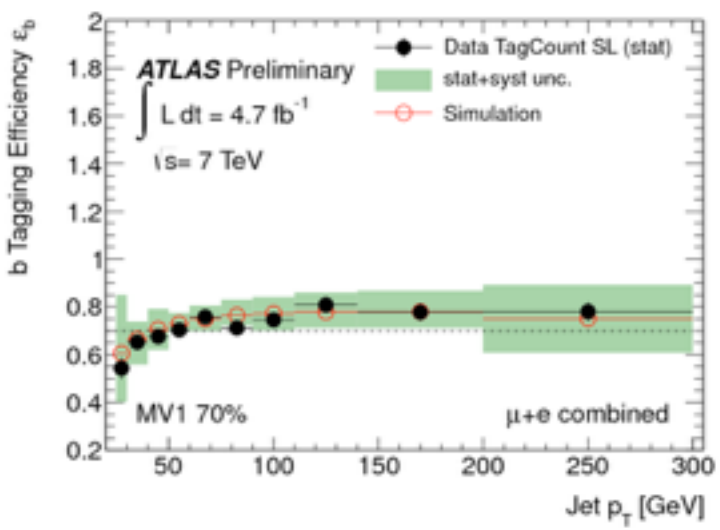
Missing transverse momentum and b-tagging

University of Sussex

- Missing ET (ETmiss) reconstructed fron final state objects:
- each with a dedicated calibration.



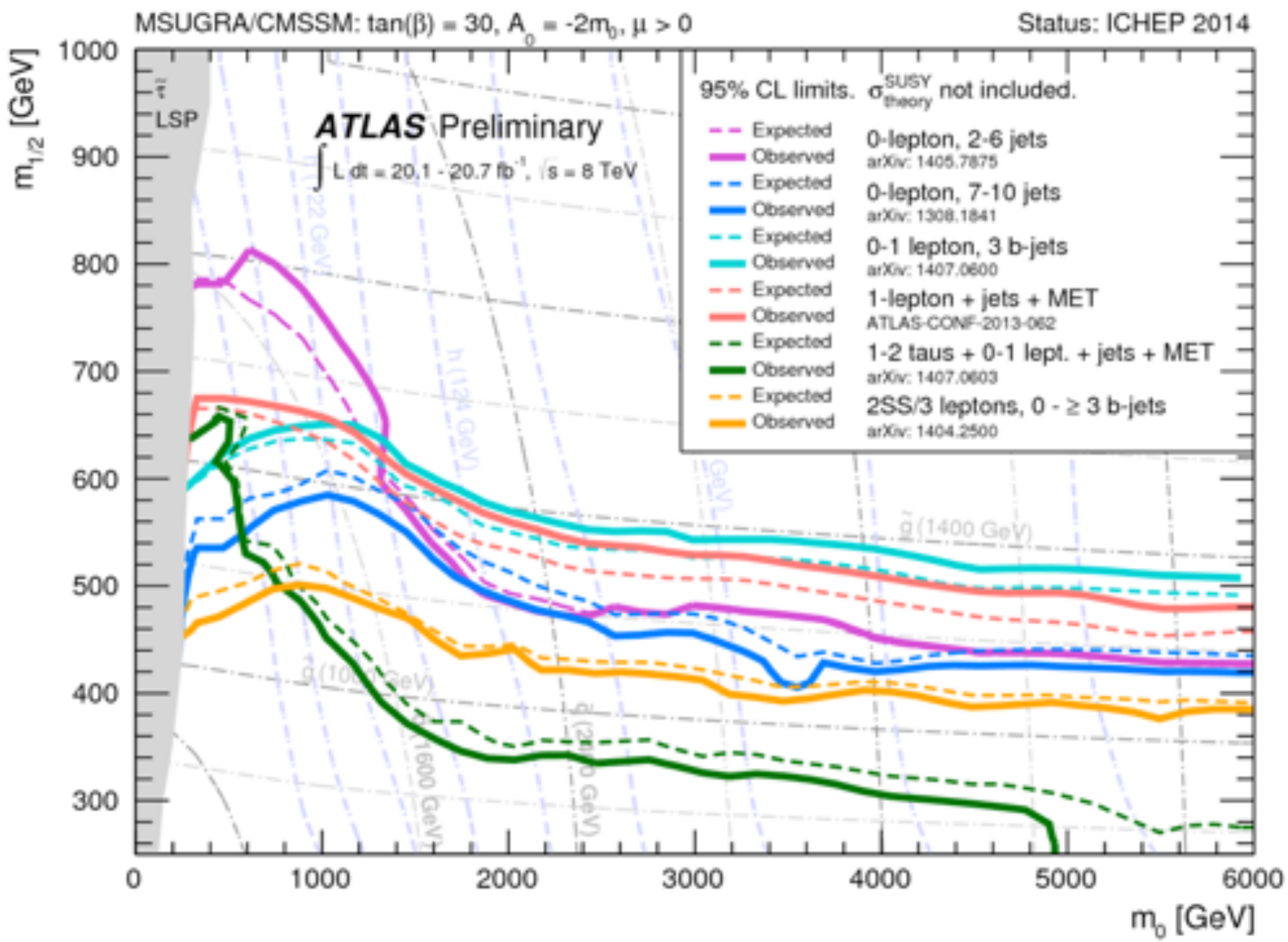




- b-tagging: neural network algorithm combining informations about secondary vertex displacement and impact strong production

prospects

MSUGRA/CMSSM



Publications

University of Sussex

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

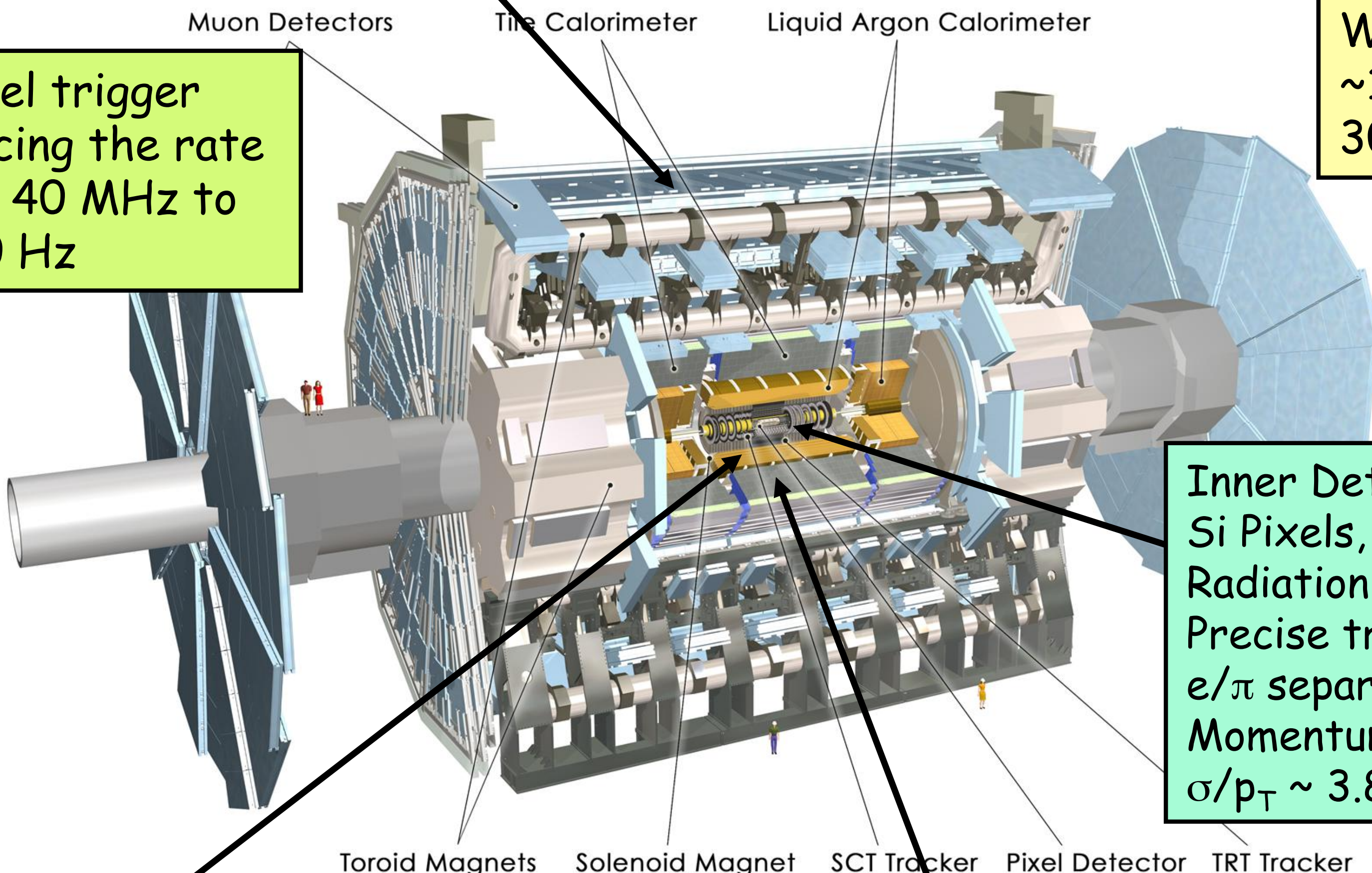
2012 data (8 TeV)

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

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: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$