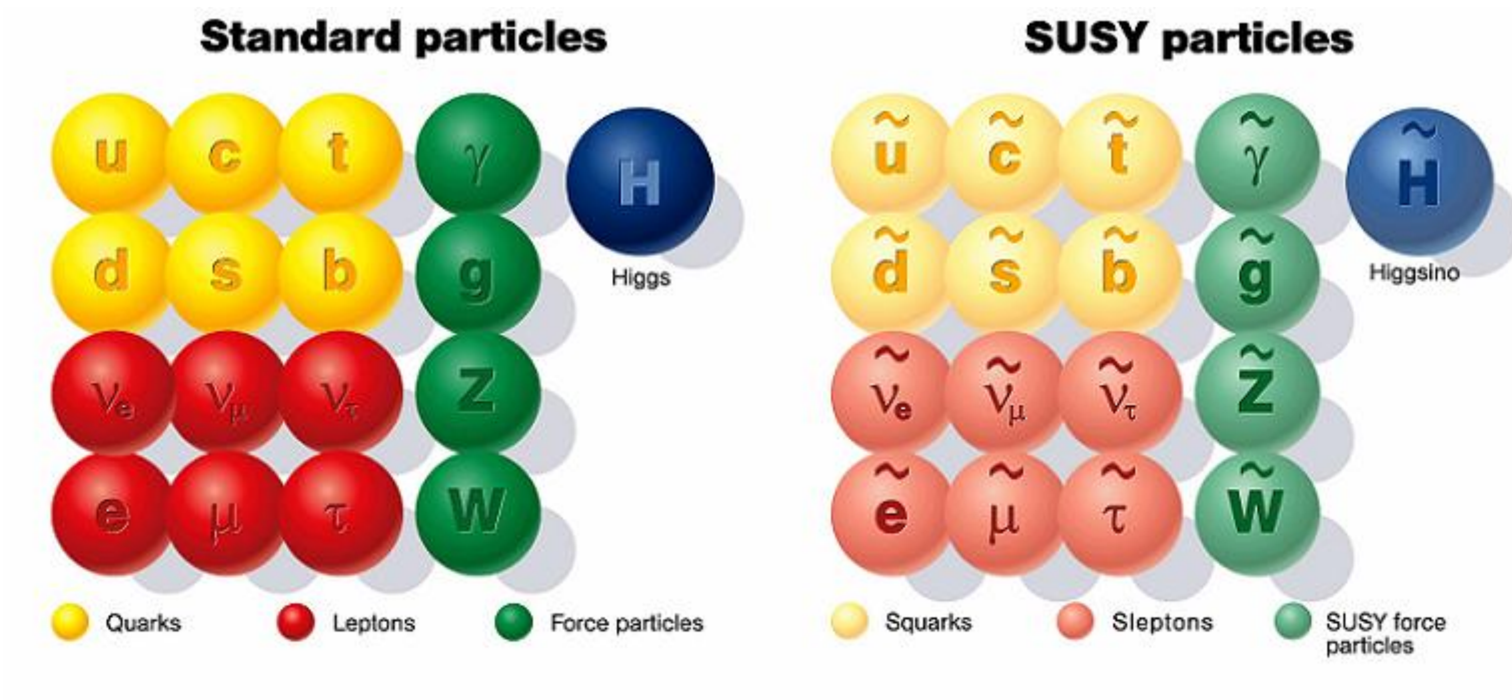
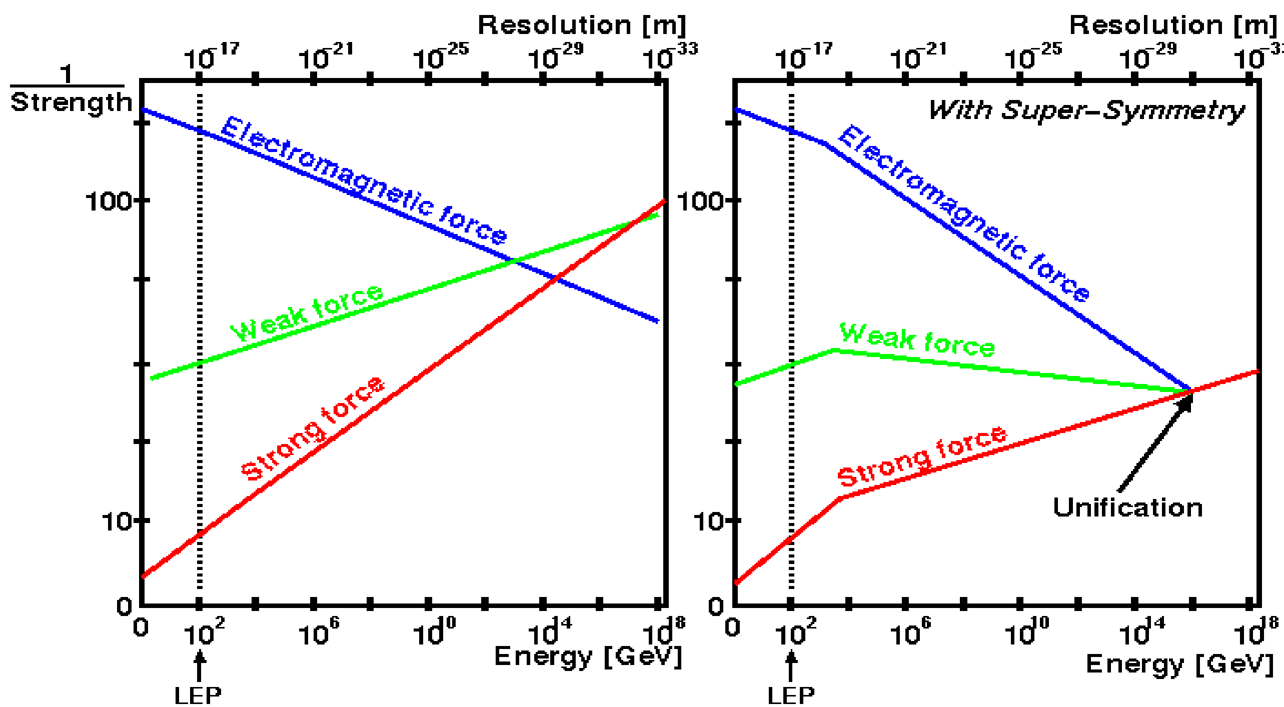
Hunt for supersymmetry using large jet multiplicities and missing transverse momentum at ATLAS



HASCO 2012 - Gizzarelli F. (University of Rome “La Sapienza”) and Graverini E. (University of Pisa)

Why SUSY

- Mass hierarchy: to avoid unnatural large corrections to the Higgs mass m_H
- SUSY also provides convergence of the couplings at one point – Λ_{SUSY}
- LSP candidate for dark matter



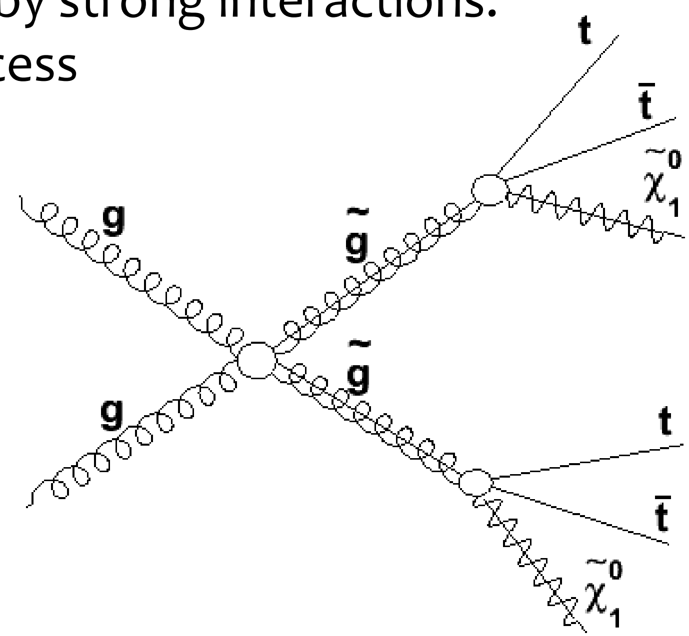
CMSSM and production

Constrained Minimal Supersimmetric Model – one of the simplest models, which depends on 5 parameters. ATLAS' research put a lower boundary on the parameters m_0 (universal scalar mass) and $m_{1/2}$ (universal gaugino mass).

SUSY particles can be produced in pairs by strong interactions. For example, if $m(\tilde{q}) >> m(\tilde{g})$, the process

$$g\,g \rightarrow \tilde{g}\,\tilde{g} \rightarrow \left(t\,\bar{t}\,\tilde{\chi}_1^0\right) + \left(t\,\bar{t}\,\tilde{\chi}_1^0\right)$$

has nearly 100% branching ratio.



Event selection

Signal region	7j55	8j55	9j55	6j80	7j80	8j80
Number of isolated leptons (e, μ)	$= 0$					
Jet p_{T}	> 55 GeV			> 80 GeV		
Jet $\|\eta\|$	< 2.8					
Number of jets	≥ 7	≥ 8	≥ 9	≥ 6	≥ 7	≥ 8
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$	> 4 GeV$^{1/2}$					

- No leptons: independent search in different channels
- High jet P_T to maximise signal over background
- $|\eta| < 2.8$ to exclude forward region and maximise detector response

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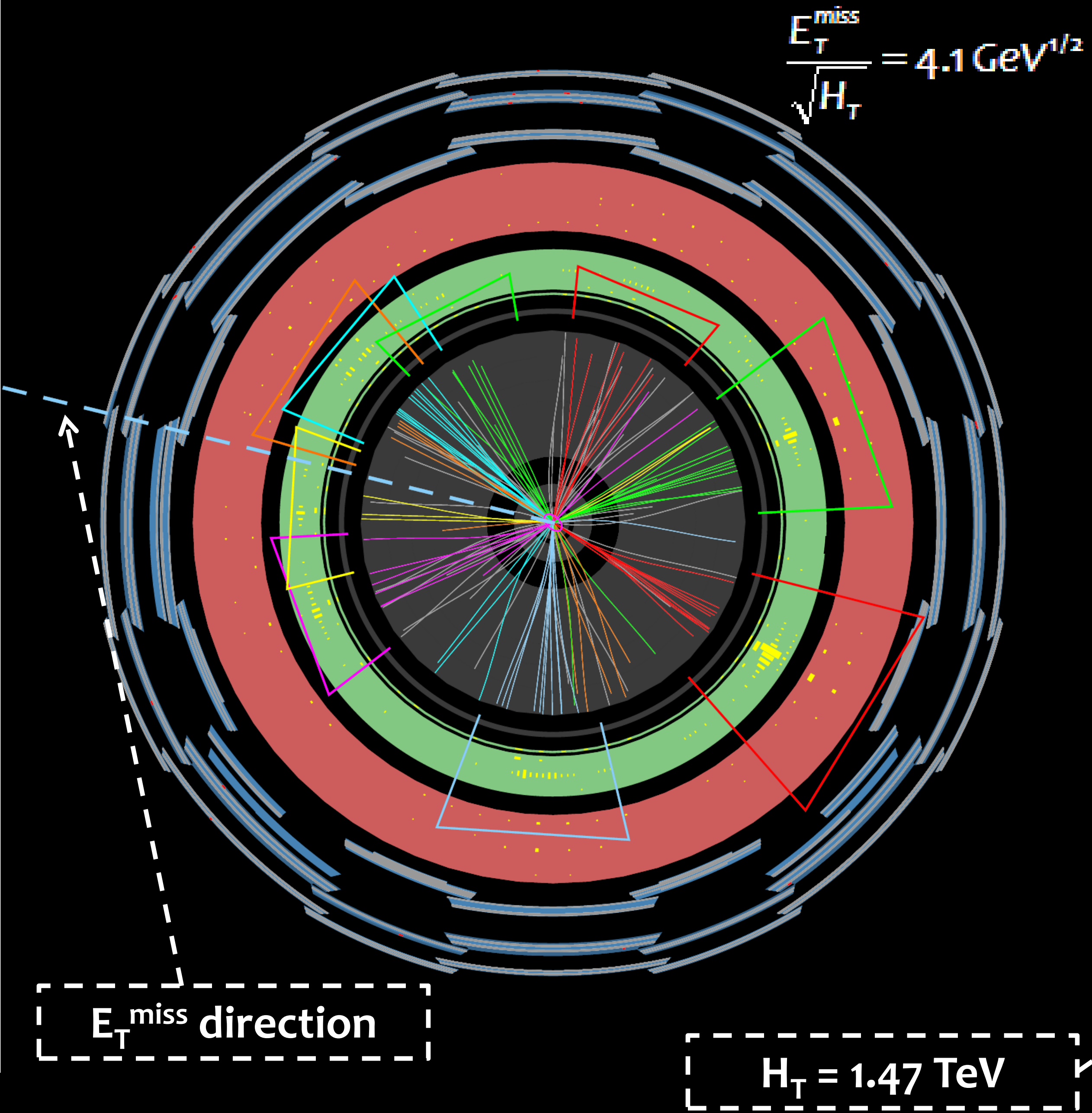
$$\sqrt{H_T} = \sqrt{\sum_{E_T^{jet} > 40GeV} P_T^{jet}}$$

E_T^{miss} = total missing transverse energy

Most background in the region $\frac{E_T^{miss}}{\sqrt{H_T}} < 1.5\, GeV^{1/2}$

This event passed the 9j55 and 7j80 signal region selections, and has



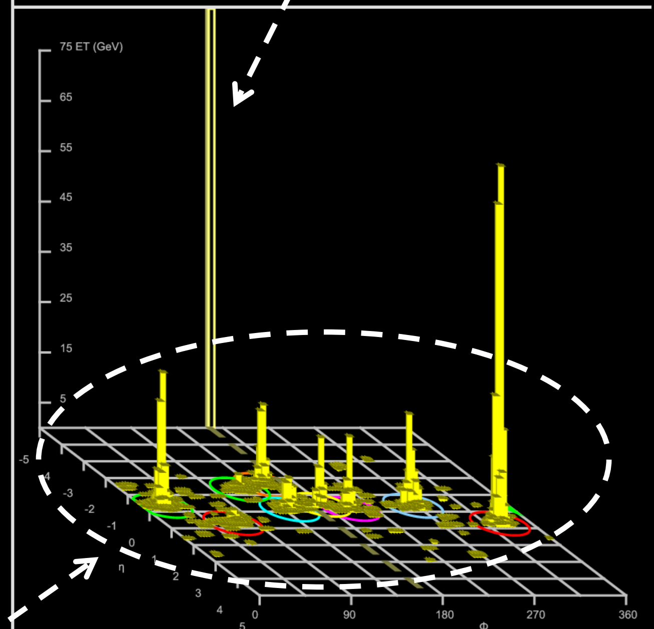
$\sqrt{s} = 7\ TeV$ L = 4.7 fb^{-1}

ATLAS EXPERIMENT

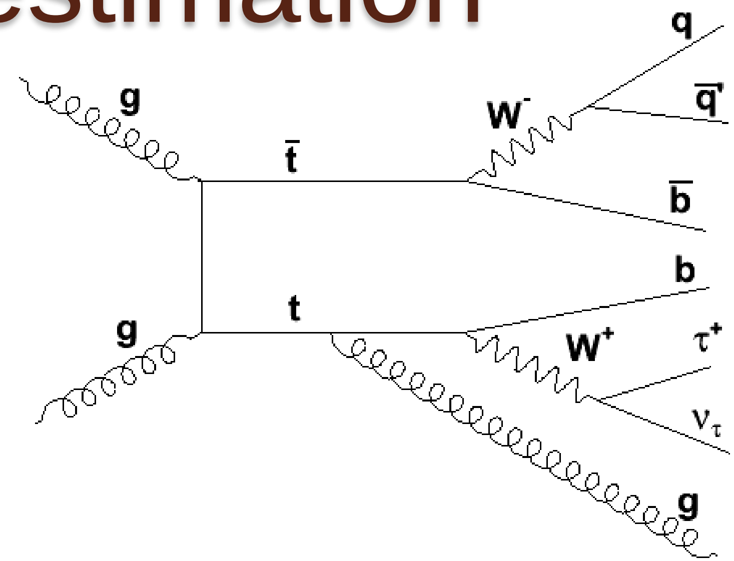
Run Number: 191190, Event Number: 130253155

Date: 2011-10-17 00:22:18 CEST

E_T^{miss} = 157 GeV



Background estimation



1 – Leptonic background

All leptonic and semi-leptonic W, Z and t-t_{bar} decays

	$t\bar{t}$ + jets	W + jets	Z + jets
Muon kinematics	$p_{\mathrm{T}} > 20$ GeV, $\lvert\eta\rvert < 2.4$		
Muon multiplicity	$= 1$		$= 2$
Electron multiplicity	$= 0$		
b-tagged jet multiplicity	≥ 1	$= 0$	—
m_{T} or $m_{\mu\mu}$	50 GeV $< m_{\mathrm{T}} <$ 100 GeV		80 GeV $< m_{\mu\mu} <$ 100 GeV
VR $\rightarrow$ CR transform	$\mu \rightarrow$ jet		$\mu \rightarrow \nu$
Jet p_{T}, $\lvert\eta\rvert$, multiplicity (CR)	As in Table 1.		
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ (CR)			

Background estimation

For example, we know how to compute the process $Z \to \mu\,\mu$ and we use it to validate the MC simulation with data. We then recast the muons as neutrinos in the algorythm to simulate the process $Z \to \nu\,\nu$, which gives the same signal as a SUSY candidate.

Validation region (to check MC accuracy)

Control region (to check the accuracy of the background estimation)

	$t\bar{t}$ + jets	W + jets	Z + jets
Muon kinematics	$p_T > 20$ GeV, $\|\eta\| < 2.4$		
Muon multiplicity	$= 1$		$= 2$
Electron multiplicity	$= 0$		
b-tagged jet multiplicity	≥ 1	$= 0$	—
m_T or $m_{\mu\mu}$	50 GeV $< m_T <$ 100 GeV		80 GeV $< m_{\mu\mu} <$ 100 GeV
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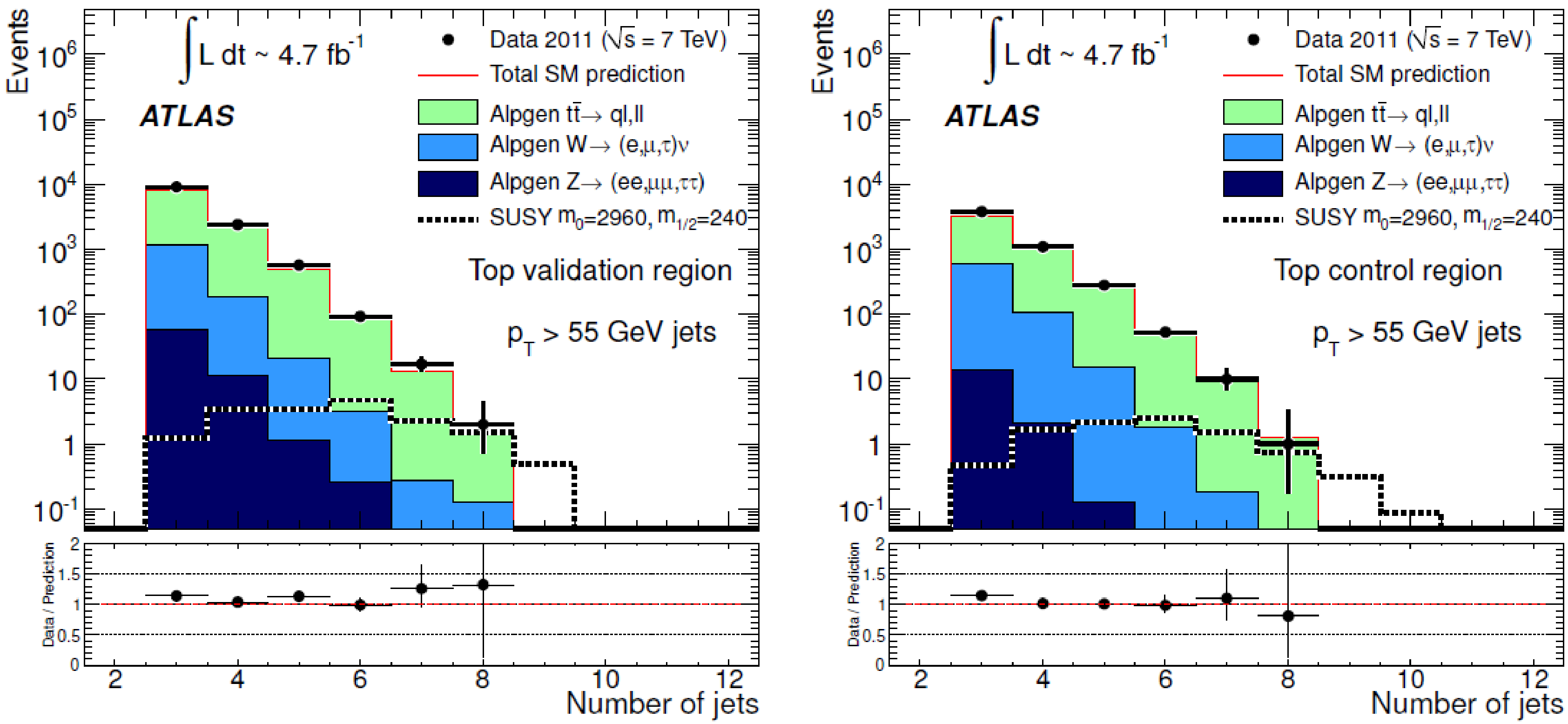
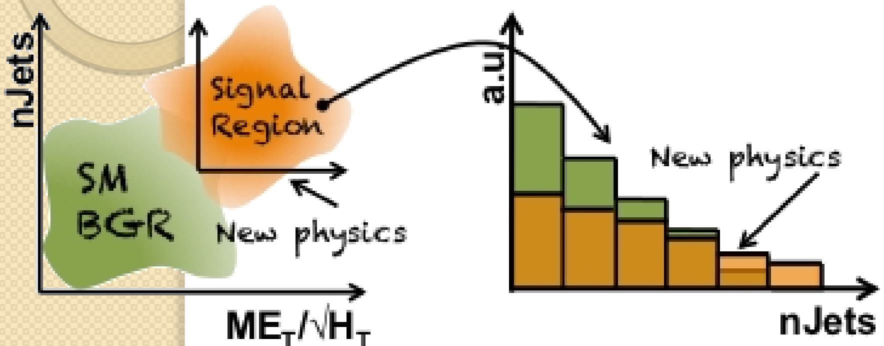
Background estimation

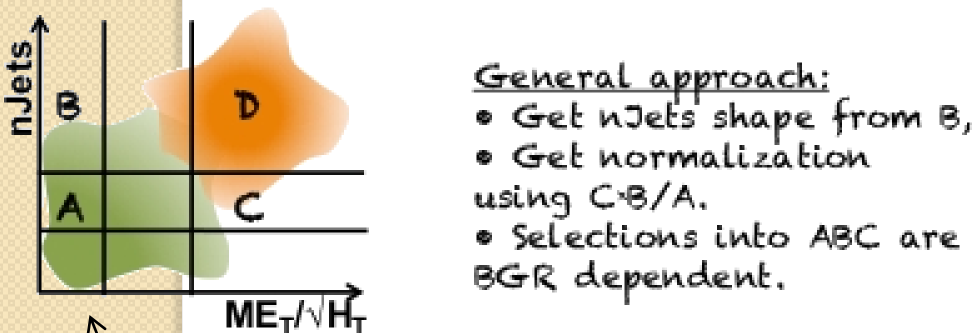


Validation and control regions: background estimates in agreement with experimental data.

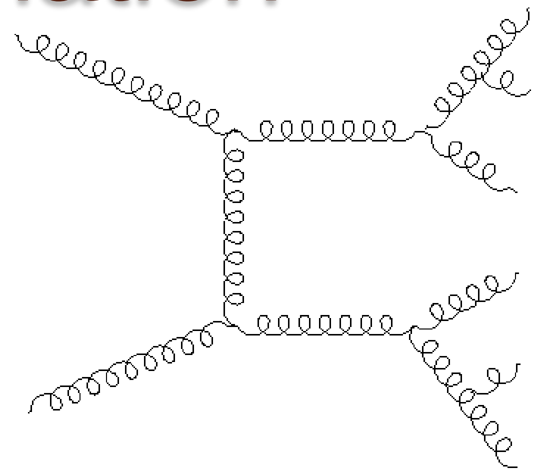
Background estimation

2 – Hadronic background (QCD)





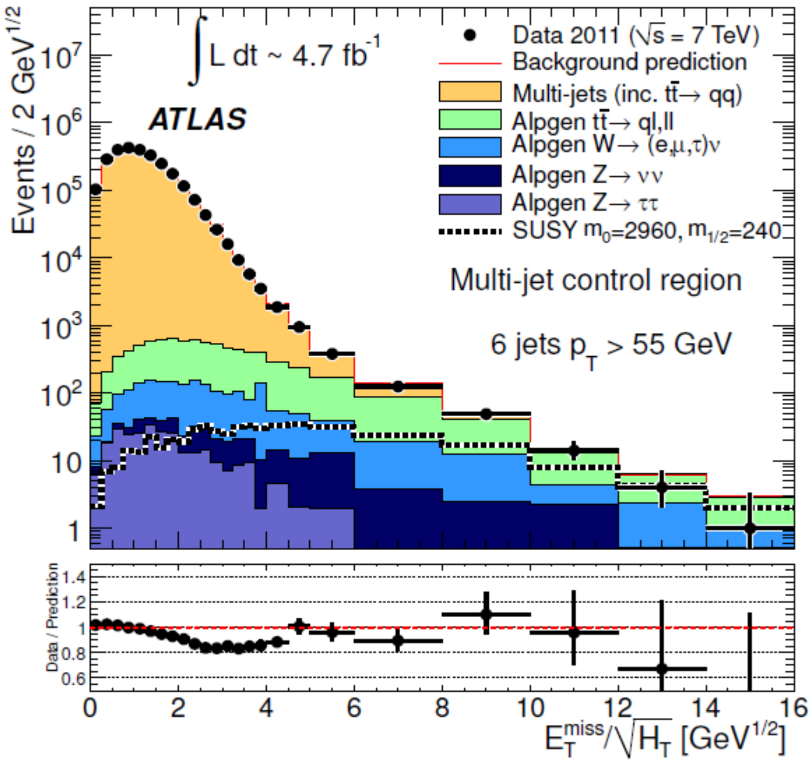
$$0 < \frac{E_T^{miss}}{\sqrt{H_T}} < 1.5\,GeV^{1/2} \qquad 4\,GeV^{1/2} < \frac{E_T^{miss}}{\sqrt{H_T}} < \infty$$

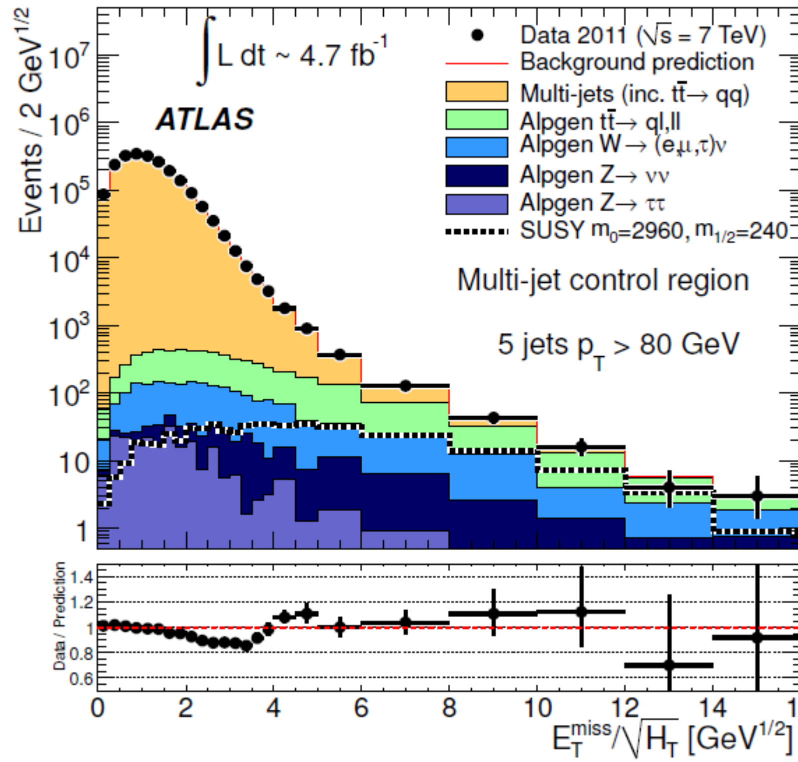


1. Hypotesis (verified with data): **the background shape does not depend on the jet multiplicity → B/A = D/C**
2. Measure **C** background content
3. Adapt it to the **D** region with a transfer factor **D=CB/A**

Background estimation

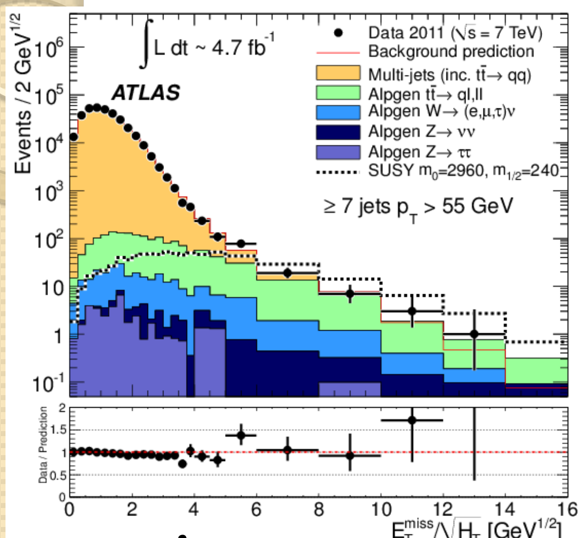
2 – Hadronic background (QCD)



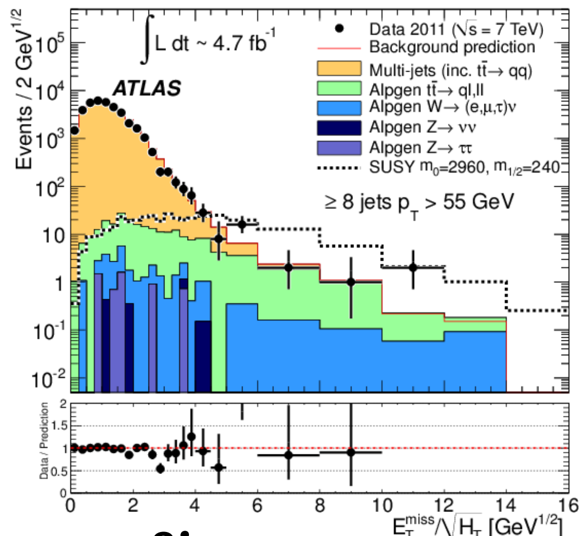


$\frac{E_T^{miss}}{\sqrt{H_T}}$ has the same shape! (after the subtraction of leptonic background)

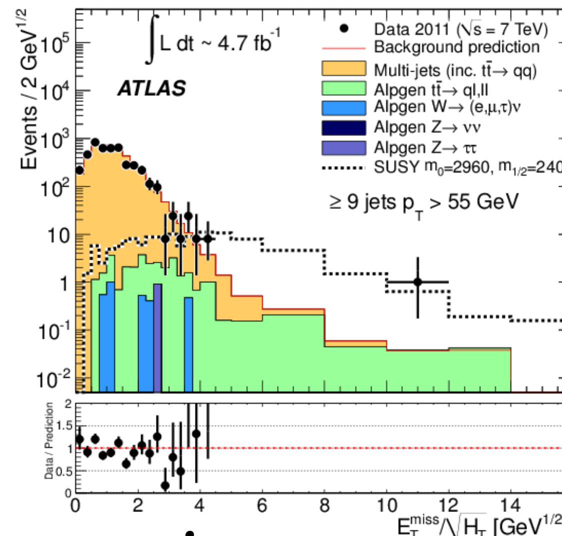
Results



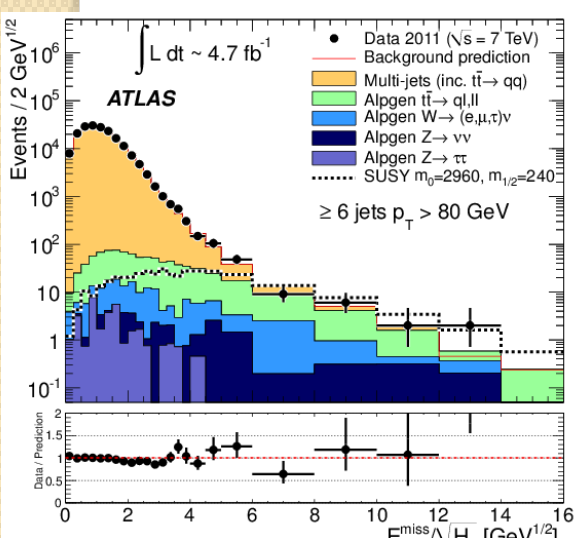
7j55



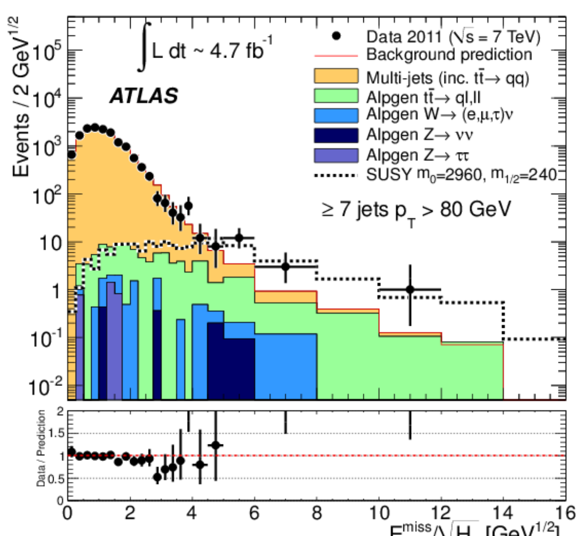
8j55



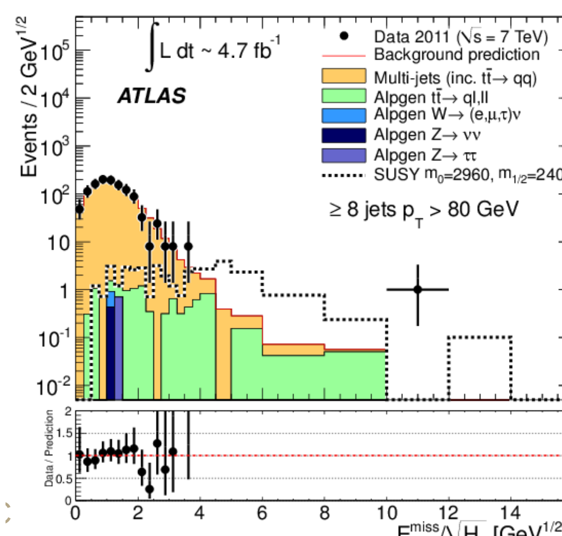
9j55



6j80



7j80



8j80

Results

Signal region	7j55	8j55	9j55	6j80	7j80	8j80
Multi-jets	91±20	10±3	1.2±0.4	67±12	5.4±1.7	0.42±0.16
$t\bar{t} \rightarrow q\ell, \ell\ell$	55±18	5.7±6.0	0.70±0.72	24±13	2.8±1.8	0.38±0.40
W + jets	18±11	0.81±0.72	0+0.13	13±10	0.34±0.21	0+0.06
Z + jets	2.7±1.6	0.05±0.19	0+0.12	2.7±2.9	0.10±0.17	0+0.13
Total Standard Model	**167±34**	**17±7**	**1.9±0.8**	**107±21**	**8.6±2.5**	**0.80±0.45**
Data	**154**	**22**	**3**	**106**	**15**	**1**
$N^{95\%}_{\mathrm{BSM,max}}$ (exp)	72	16	4.5	46	8.4	3.5
$N^{95\%}_{\mathrm{BSM,max}}$ (obs)	64	20	5.7	46	15	3.8
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (exp) [fb]	15	3.4	0.96	9.8	1.8	0.74
$\sigma^{95\%}_{\mathrm{BSM,max}} \cdot A \cdot \epsilon$ (obs) [fb]	14	4.2	1.2	9.8	3.2	0.81
p_{SM}	0.64	0.27	0.28	0.52	0.07	0.43

Expectation

Experimental results

Results

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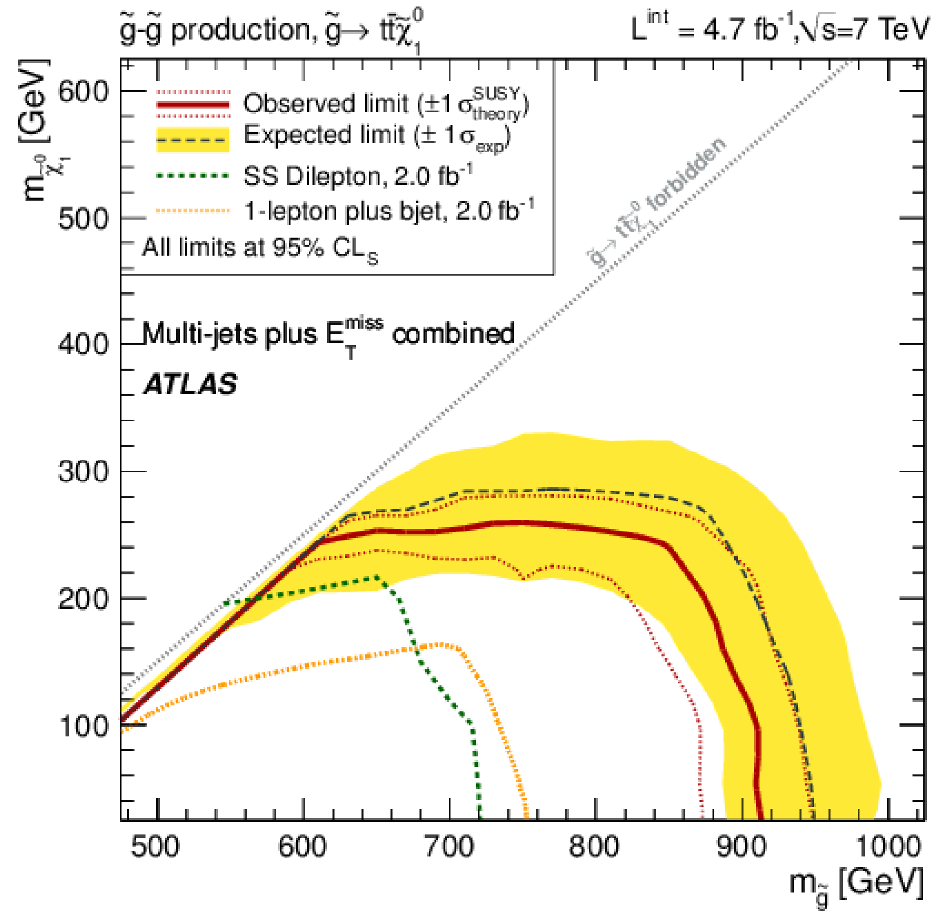
This is still a not significant result! → Limits on σ_{SUSY}

Conclusions

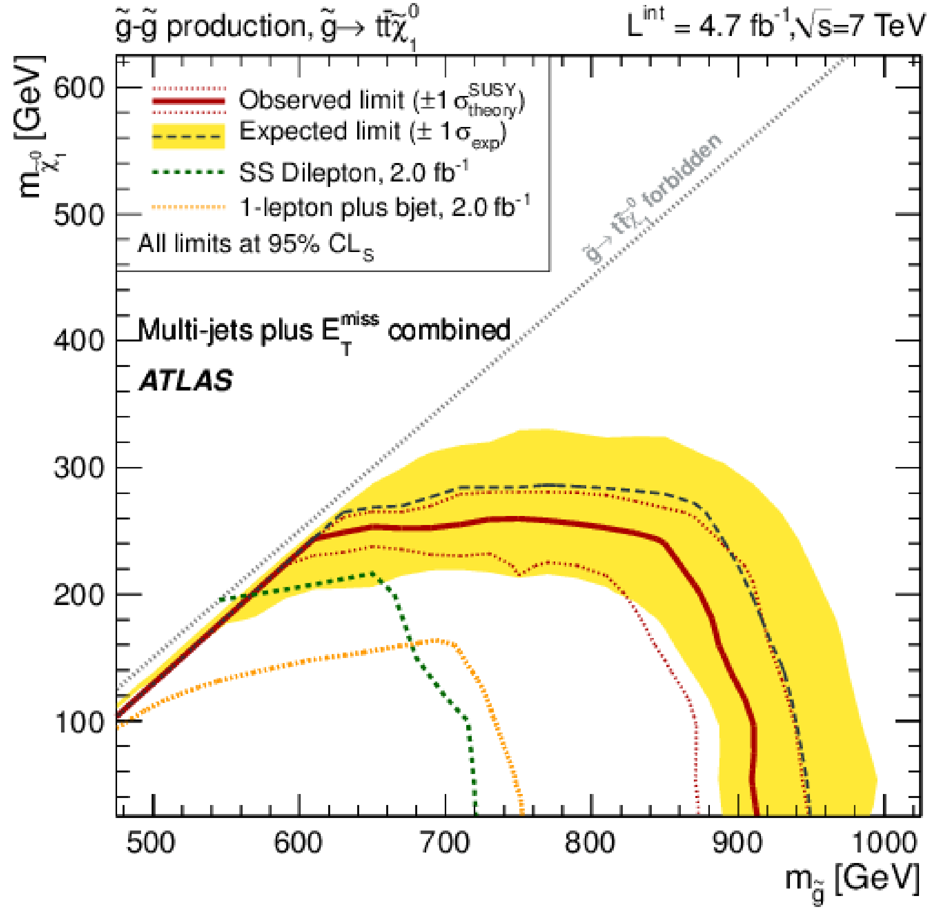
- Each point of this plane represents a couple $m(\tilde{g}), m(\tilde{\chi}_1^0)$ in the simplified model CMSSM
- For each point, a MC simulation is used to estimate the signal for the SUSY process
- Yellow band represents expected limits on SUSY ±1σ with L=4.7 fb^{-1} at $\sqrt{s} = 7\,TeV$
- The observed limit (red line) is slightly lower than the expected one



$$m(\tilde{g}) > 870 GeV \text{ for } m(\tilde{\chi}_1^0) > 100 GeV$$

Conclusions

No evidence for supersymmetry was found.



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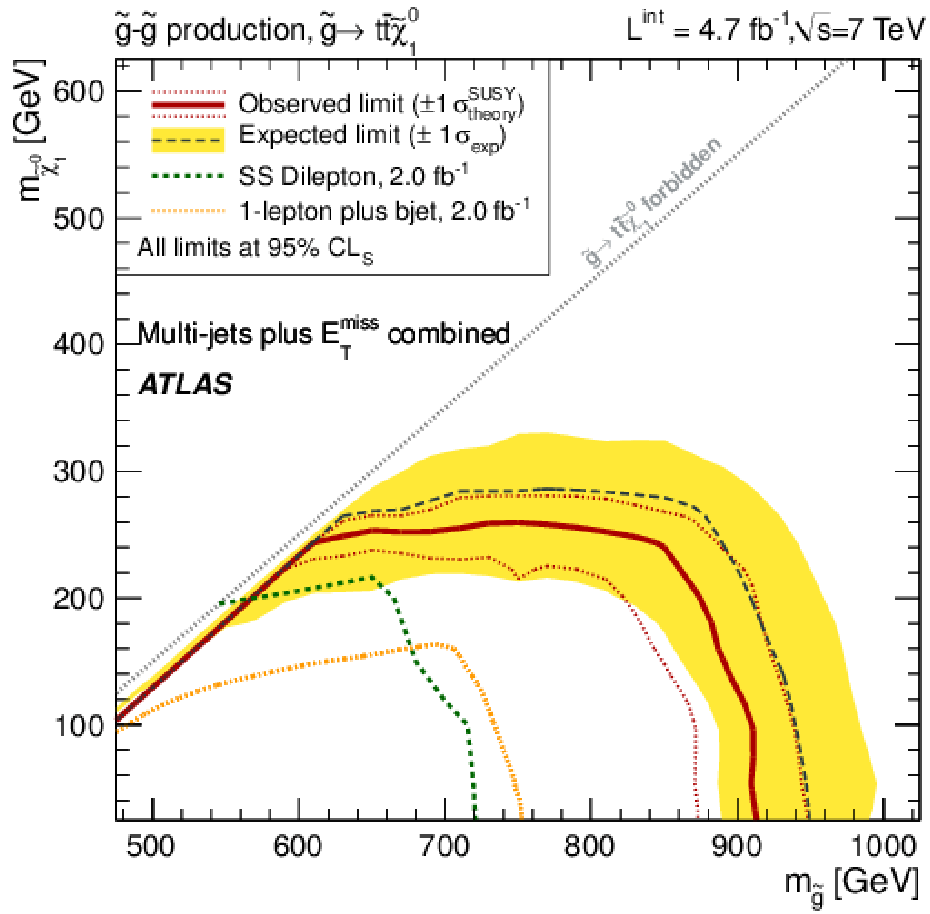
Backup slides

Conclusions

- Each point of this plane represents a couple $m(\tilde{g}), m(\tilde{\chi}_1^0)$ in the simplified model CMSSM
- For each point, a montecarlo estimates the signal content for SUSY processes
- Yellow band represents expected limits on SUSY ±1σ at L=4.7 fb^{-1} at $\sqrt{s} = 7\ TeV$
- Actual limit is lower because of the excess in the region **7j80** is not significant



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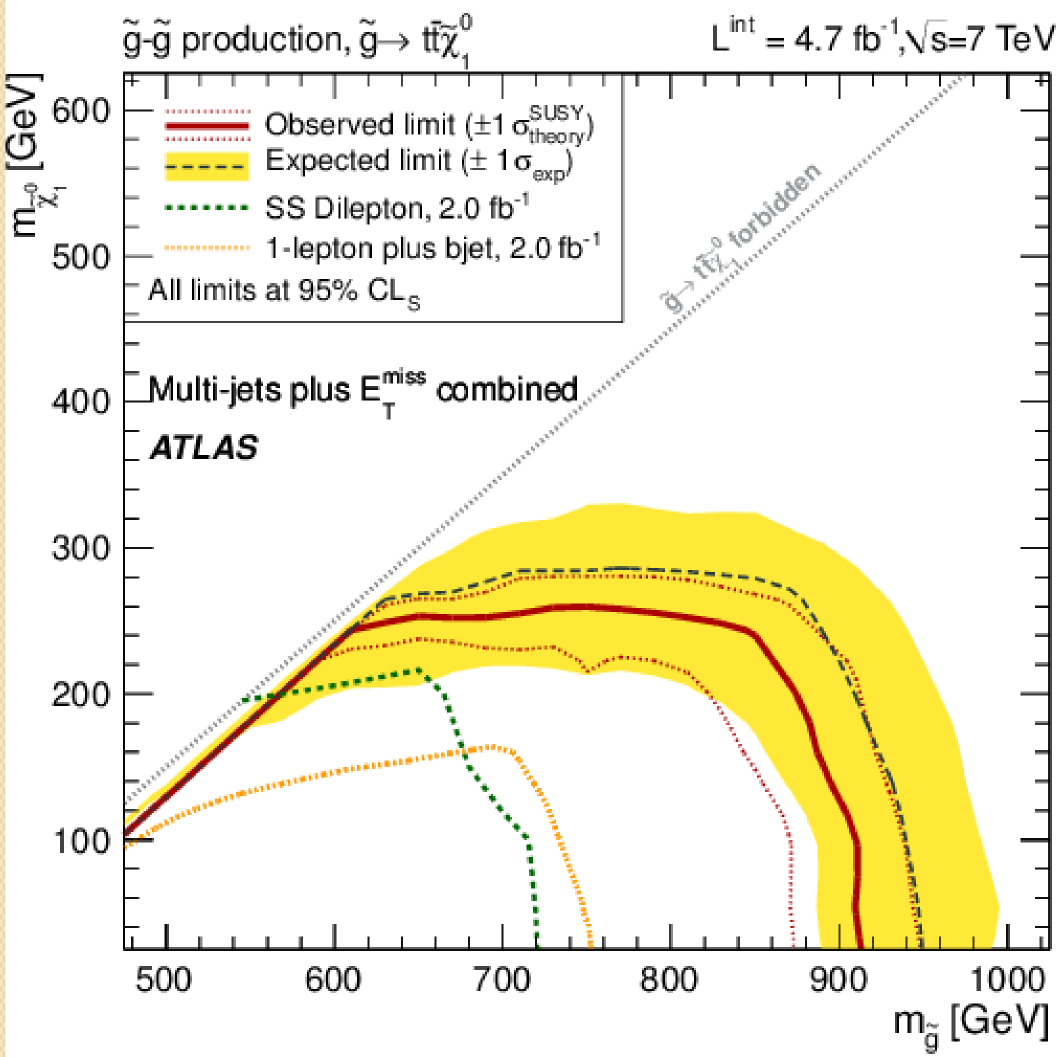

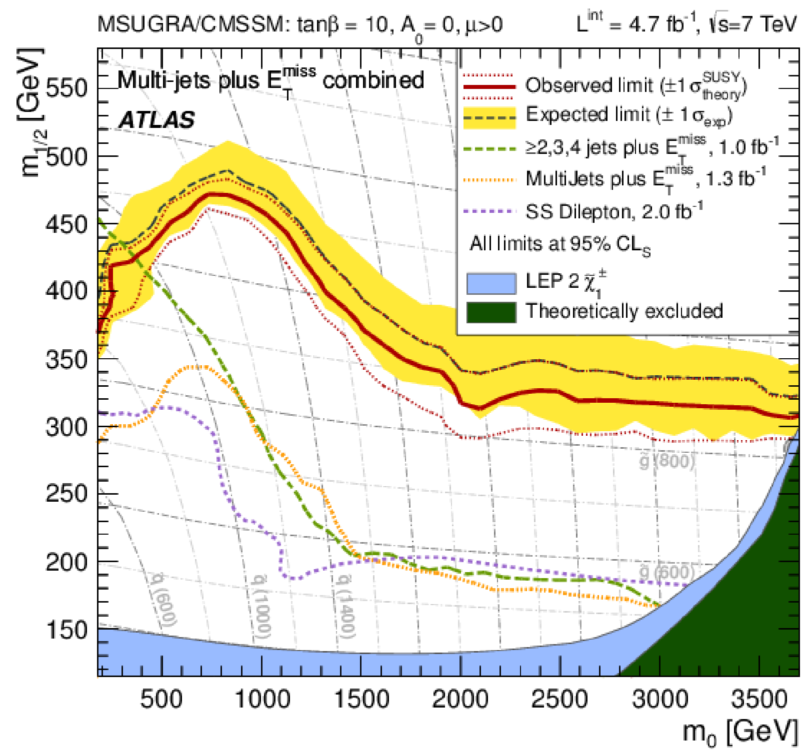

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Conclusions

This plot presents the limits on the gaugino mass $m_{1/2}$ in correlation with those on the universal scalar mass m_0.