Tau studies in the SUSY jets + E_T^{miss} search with the ATLAS detector

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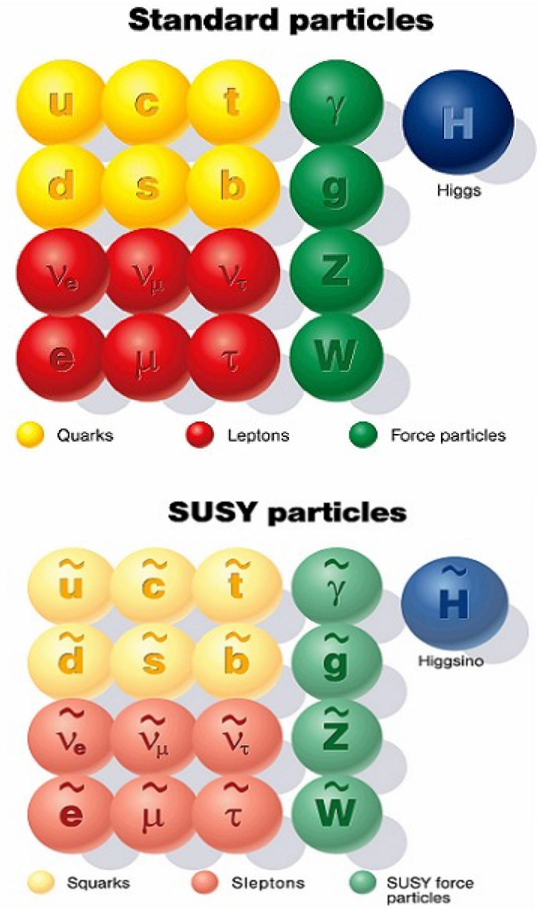
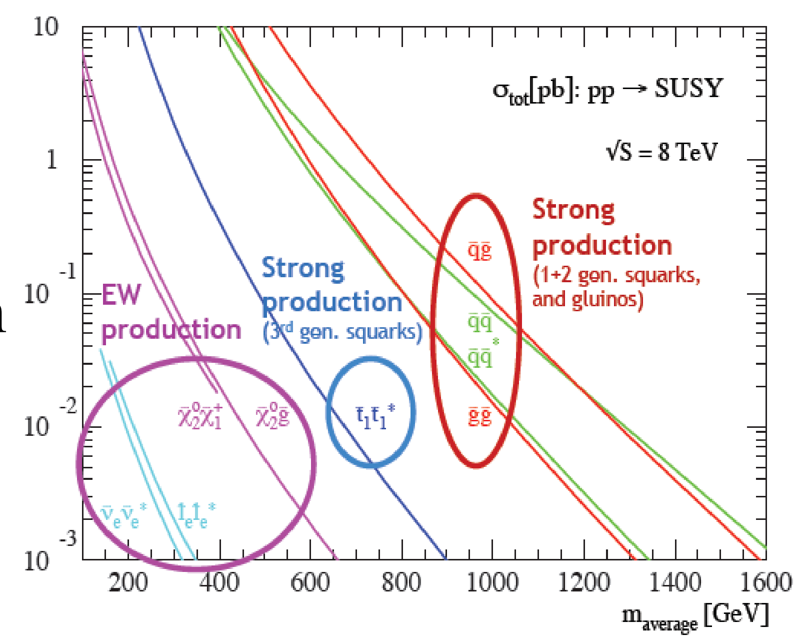
Outline

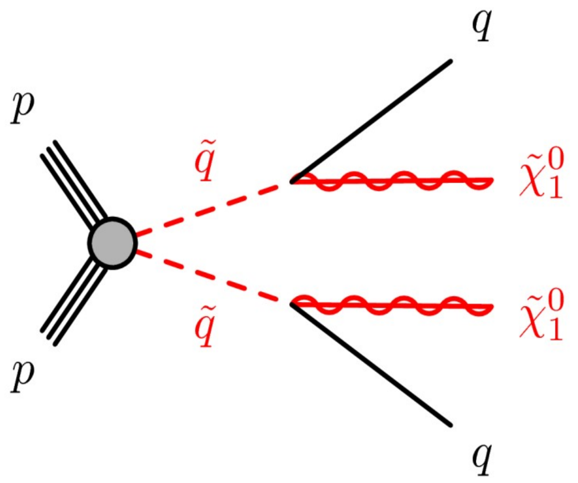
- Introduction
- Signal regions and method
- Taus
- Results and interpretations
- Conclusions and outlook

SUperSYmmetry

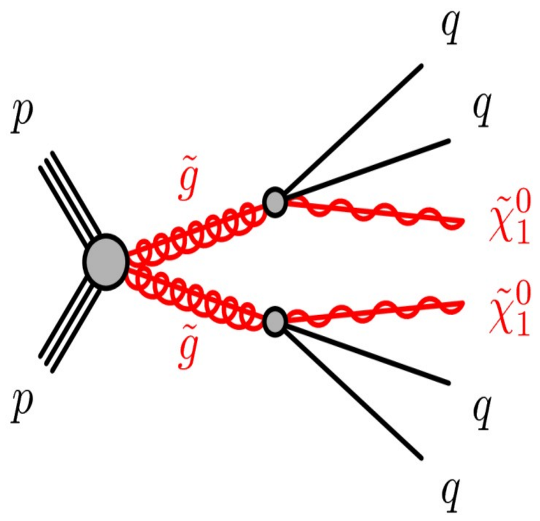
- SUSY adds a symmetry that connects bosons and fermions
- In minimal SUSY, the number of particles is doubled w.r.t the Standard Model
- No SUSY particles observed at the same masses as SM partners
  - SUSY is broken ➡ more then 100 parameters needed to describe SUSY
  - Superpartners are heavier then the SM particles
- Strong production is the dominant mode of producing SUSY particles at the hadron colliders







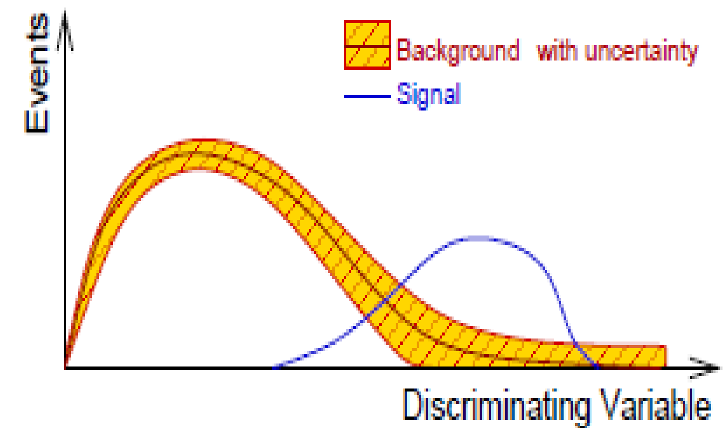
Final states



- R-parity $R=(-1)^{(3B+L+2s)}$
- In SUSY models with R-parity conserved, squarks and gluinos are produced in pairs
- Squarks and gluinos will decay in cascades to final states with jets
- The lightest supersymmetric particle, LSP (it is dark matter candidate), passes the detector without interacting: its signature is E_T^{miss}
- We are looking for SUSY in the final states with jets, E_T^{miss} and 0 lepton (e, mu veto)

Signal regions

- To differentiate between the signal and the background we are using variables that have good discriminating power:
  - missing transverse energy E_T^{miss}
  - dPhi angle between jets and E_T^{miss}
  - E_T^{miss}/m_{eff}
  - effective mass $m_{eff} \equiv \sum_{i=1}^{n} |\mathbf{p}_T^{(i)}| + E_T^{miss}$



- In order to increase sensitivity of our search we define 5 regions depending on number of jets

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_T^{miss}[GeV] >	160									
$p_T(j_1)$ [GeV] >	130									
$p_T(j_2)$ [GeV] >	60									
$p_T(j_3)$ [GeV] >	–		60		60		60	60		
$p_T(j_4)$ [GeV] >	–		–		60		60	60		
$p_T(j_5)$ [GeV] >	–		–		–		60	60		
$p_T(j_6)$ [GeV] >	–		–		–		–	60		
$\Delta\phi(\text{jet}_i, E_T^{miss})_{min}$ >	0.4 (i = {1, 2, (3 if $p_T(j_3)$ > 40 GeV)})				0.4 (i = {1, 2, 3}), 0.2 (p_T > 40 GeV jets)					
$E_T^{miss}/m_{eff}(Nj)$ >	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

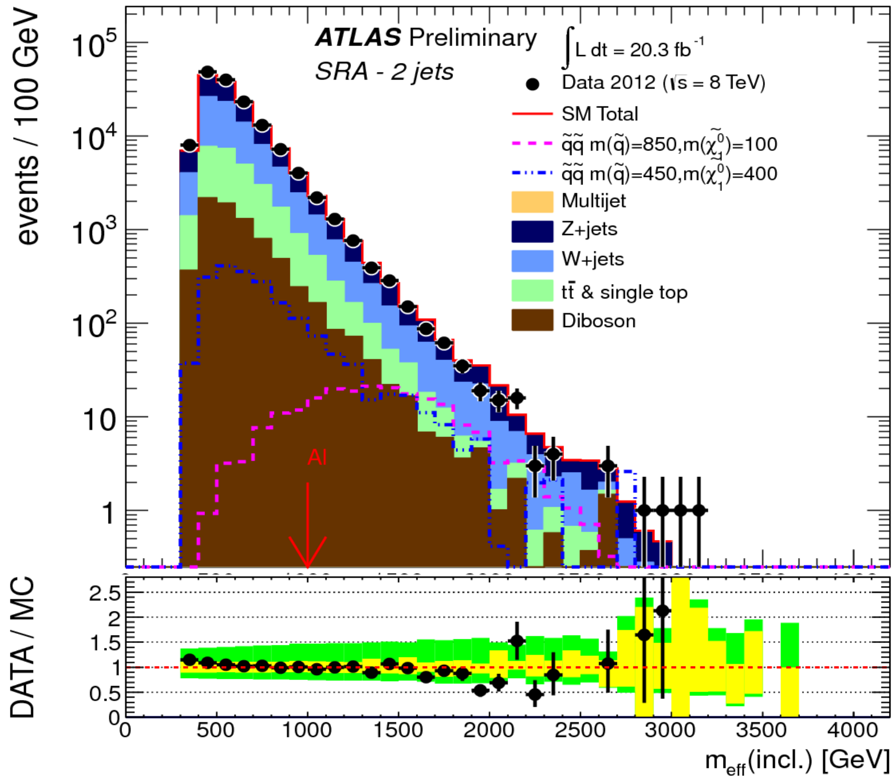
(a) For SR A-medium the cut on $E_T^{miss}/m_{eff}(Nj)$ is replaced by a requirement $E_T^{miss}/\sqrt{H_T} > 15$ GeV$^{1/2}$.

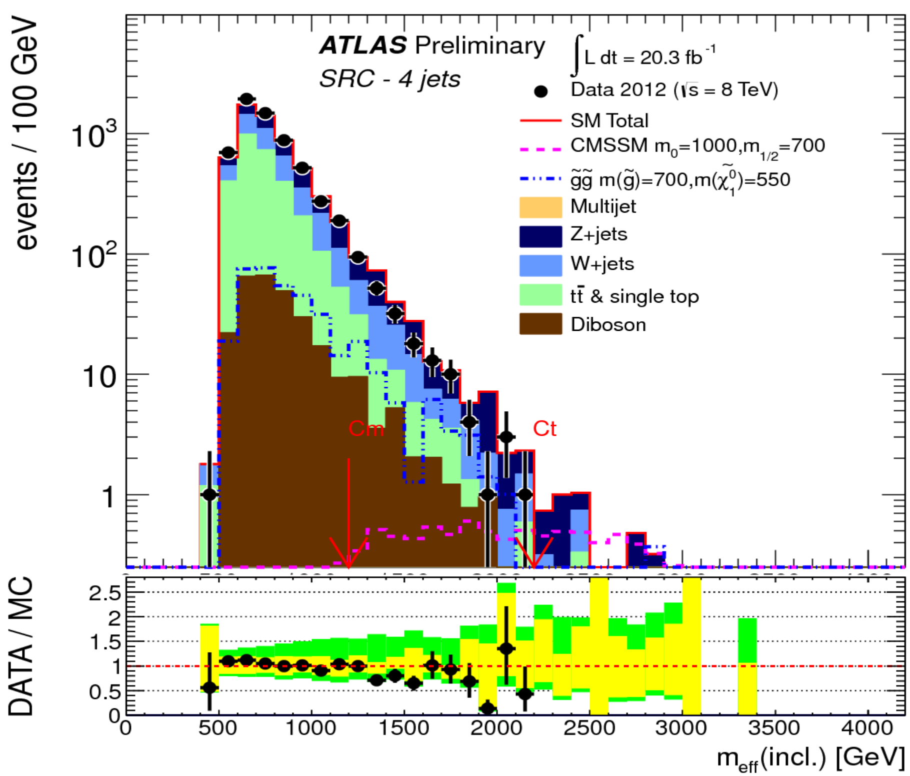
E_T^{miss}

dPhi

E_T^{miss}/m_{eff}

m_{eff}

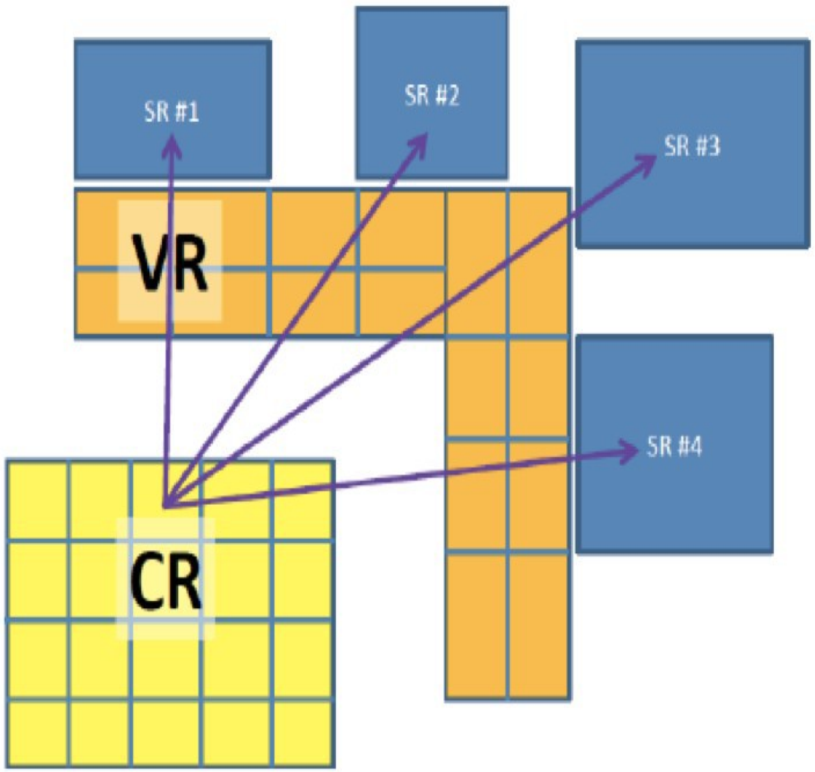




Signal regions

- Distribution of the m_{eff} before final cut
- If the MC prediction was perfect, we could stop here the analysis, but we want to crosscheck background estimation on data
- 70% of the remaining background is coming from taus

Analysis method



$$N_{SR} = N_{SR}^{MC} \frac{N_{CR}^{data}}{N_{CR}^{MC}}$$

- We define 3 types of regions:

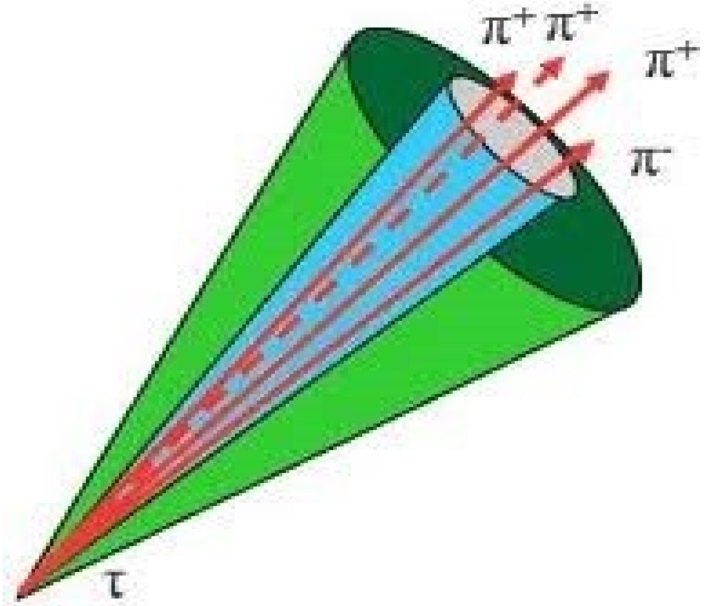
  Signal Regions are optimized for signal

  Control Regions are background enriched (Multijet, Z+jets, W+jets, ttbar) for normalization of the background using data

  Validation Regions are used to validate our method

- We do a global fit using SR and CR, the fit quality is estimated using VR

Tau reconstruction



- tau → e 18%

  tau → mu 18%

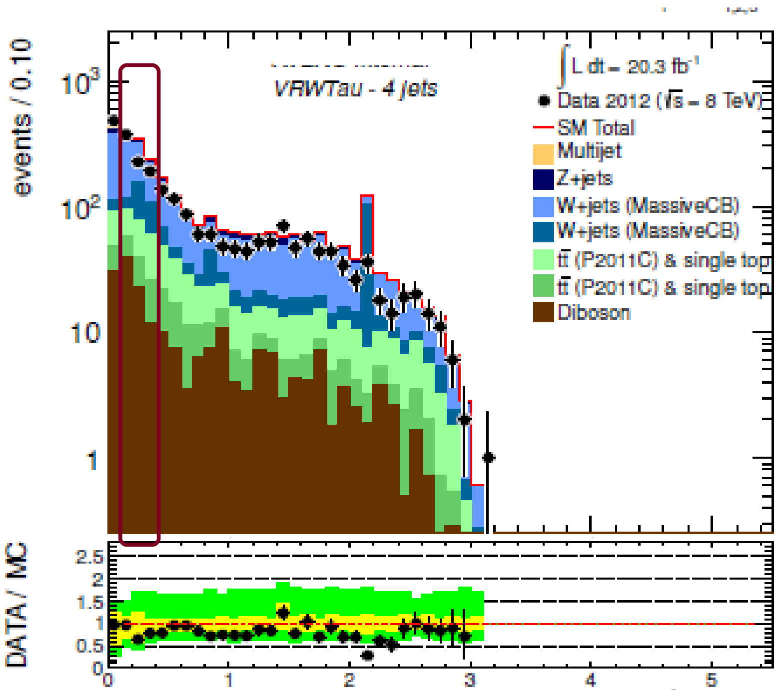
  tau → h+ 49%

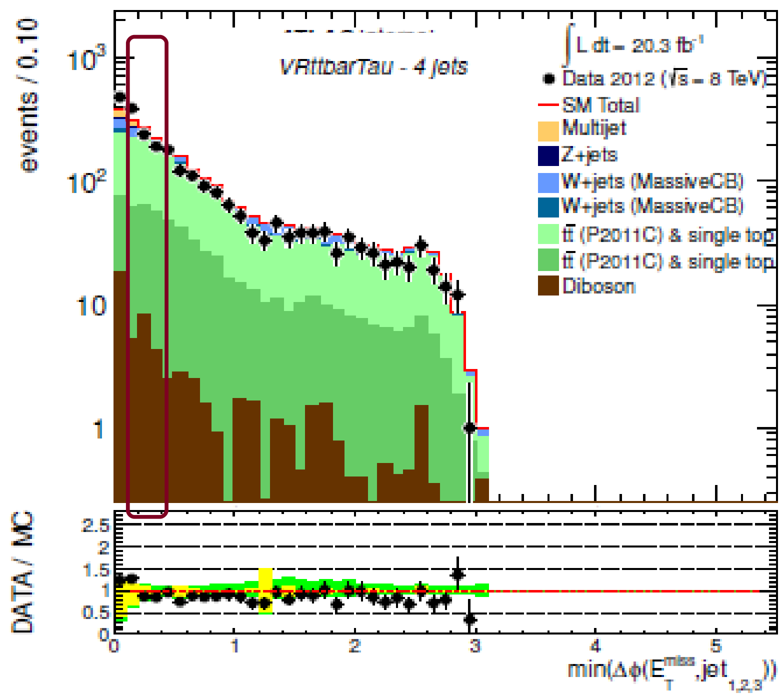
  tau → h+h-h+ 15%

- Hadronic products of tau decay form a narrow jet which has characteristic number of tracks: 1 or 3
- We select only tau candidates with 1 track to reduce the number of fakes
- We are requiring a tau candidate with p_T > 20 GeV
- We are selecting tau candidates which give transverse mass (of tau and $E_{\mathrm{T}}^{\mathrm{miss}}$) less than 100 GeV (to reject fakes)

$$m_T = \sqrt{2 * tauPt * met * (1 - \cos(dPhi))}$$

Tau validation regions



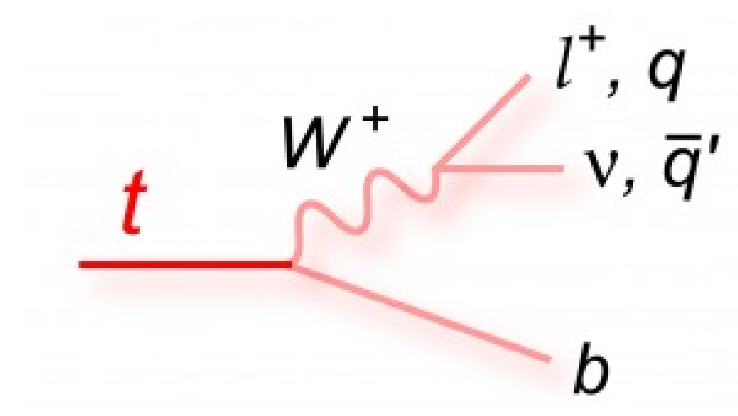


- To be orthogonal to signal and control regions, we select region

  0.2<dPhi(jet, $E_{\mathrm{T}}^{\mathrm{miss}}$)<0.4
- Same m_{eff} cut as in the SR
- 2 validation regions:

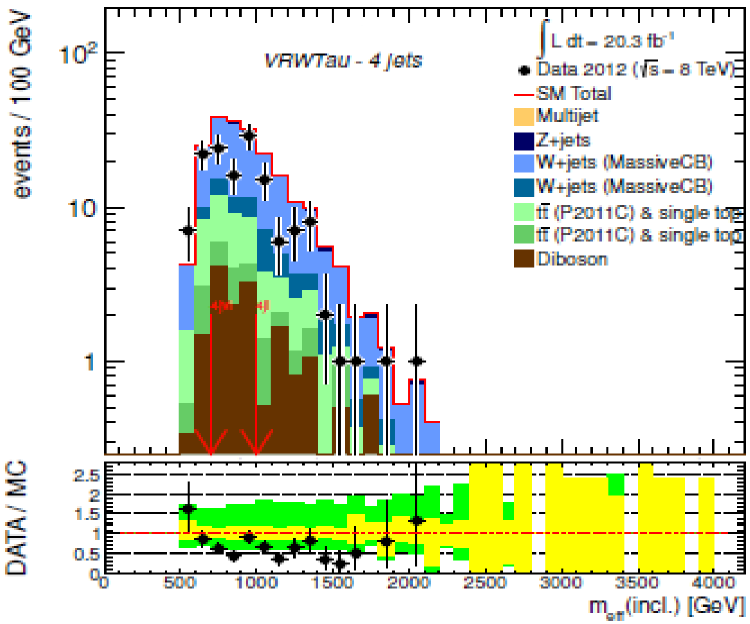
  for W->tau nu: 0 bjets

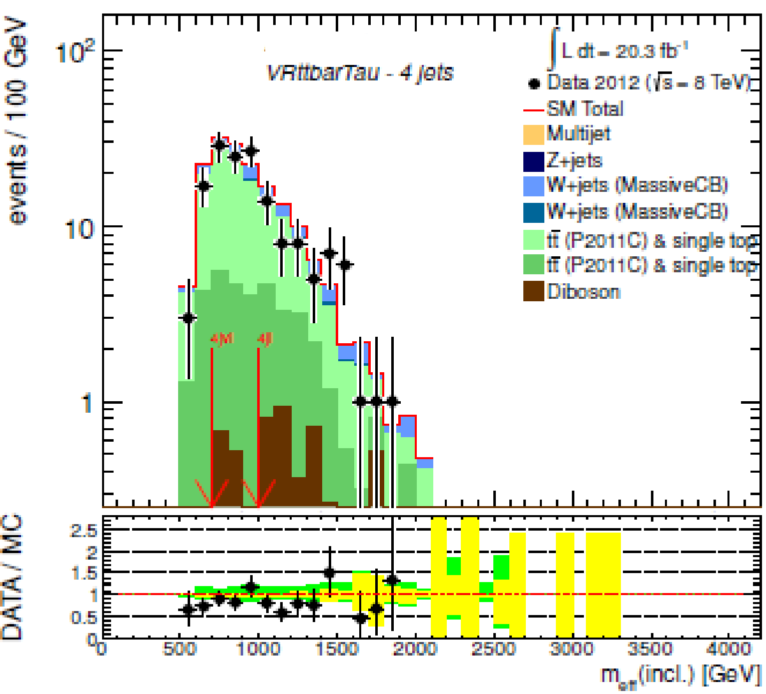
  for top->W b: at least 1 bjet



Taus are in light blue and light green!

Tau validation regions



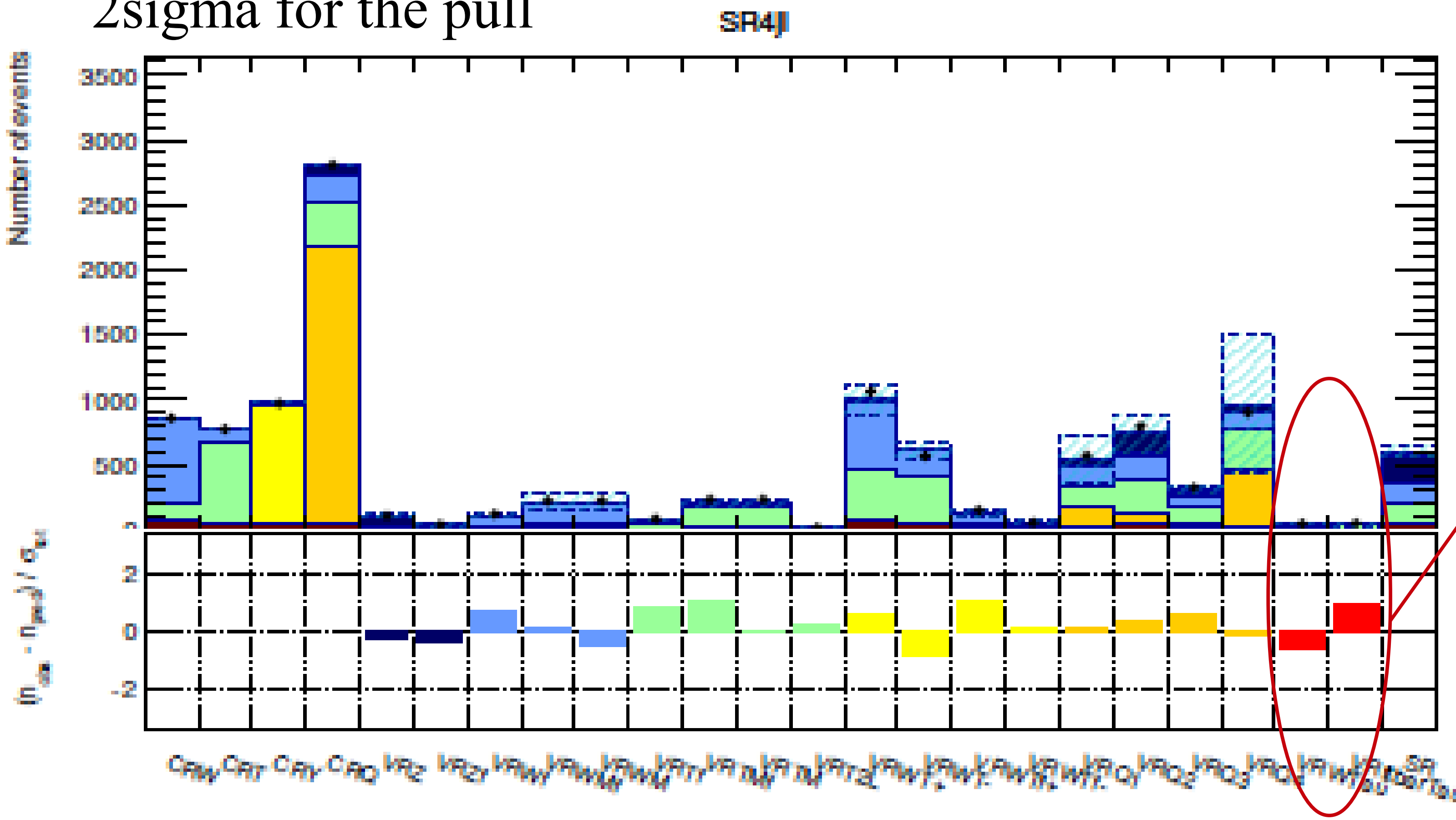


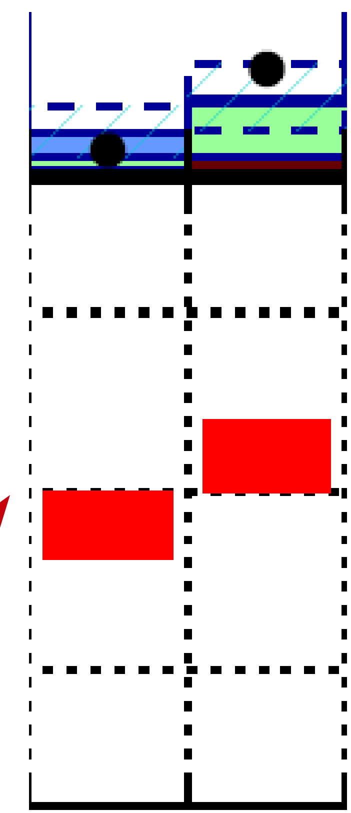
- $m_{\rm eff}$ distributions in tau VR before final cut
- We managed to define a VR enriched in tau!
- Reasonable agreement between data and MC, also true for other jet multiplicities

Results

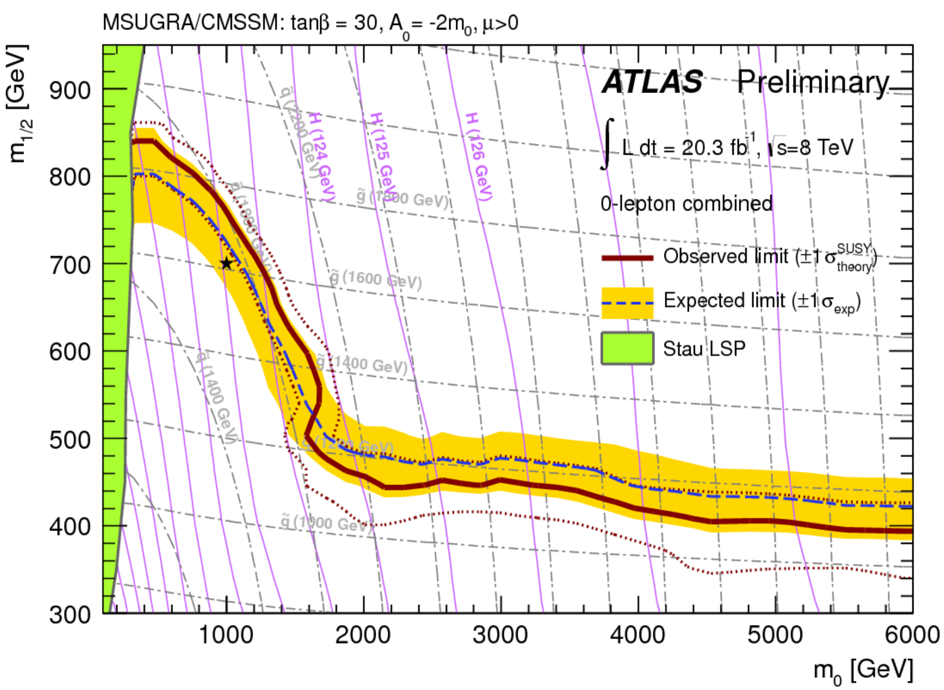
- We do a global fit of the SR and CR, including scale factor on signal and background and systematic uncertainties
- We need the VR to validate the fit
- The lines on the plot correspond to 2sigma for the pull

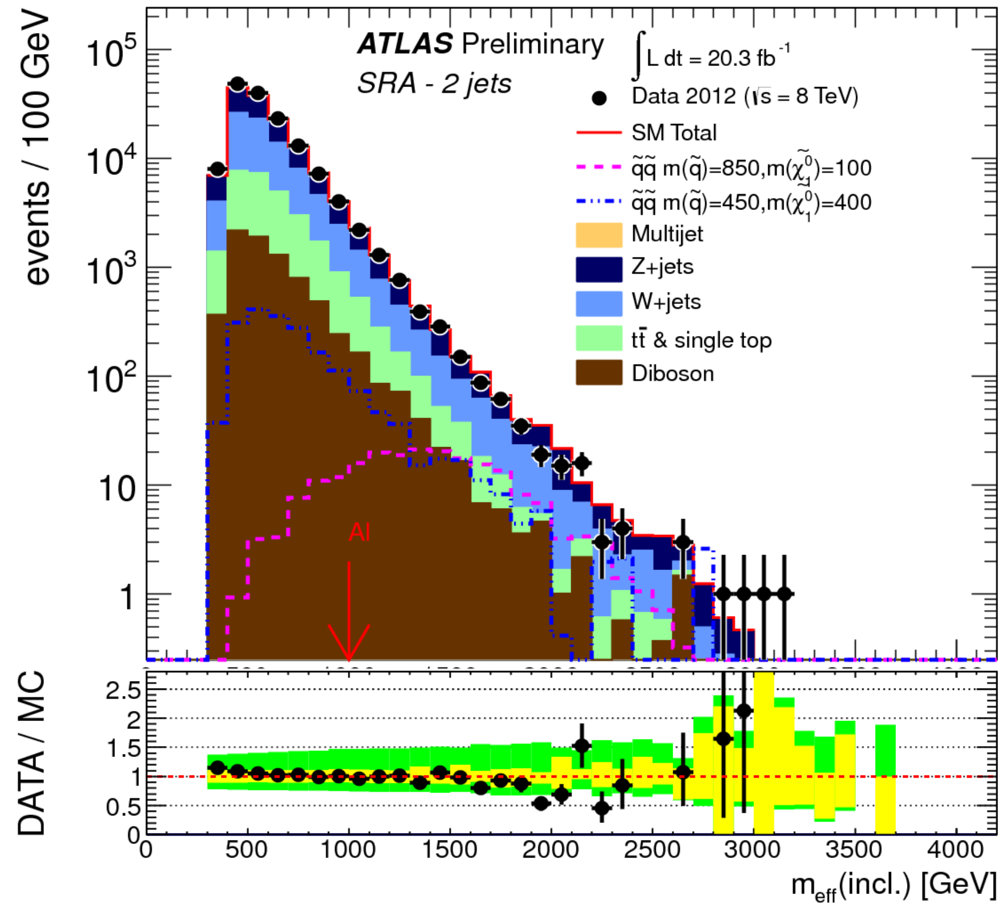
$$\frac{n_{observed} - n_{expected}}{\sigma_{tot}}$$





Results and interpretations

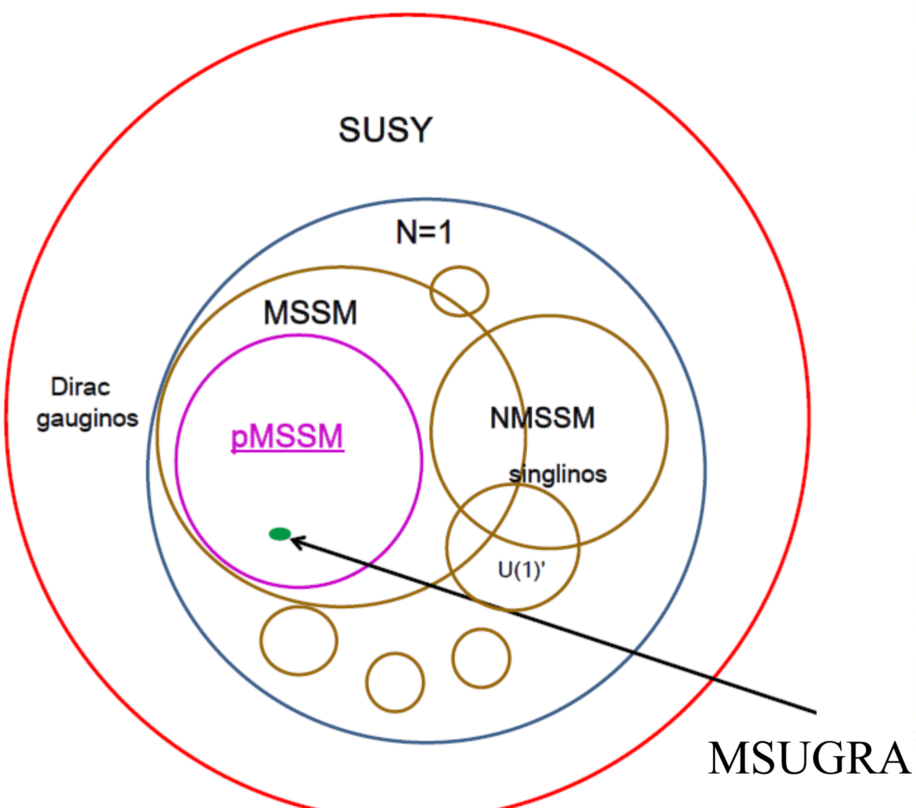




- Good agreement between data and MC
- No significant excess of data over prediction in any of the SR
- Limits derived using SR with the best expected sensitivity for each model point. Limits are set in several SUSY models, eg. MSUGRA (which is described with 5 parameters - 3 are fixed in the above plots)
- Equal mass light-flavour squarks and gluinos are excluded below 1700 GeV

Prospects

- Within Atlas we are going to evaluate the limits, and combine all the analysis in a more general SUSY framework: the pMSSM (phenomenological Minimum SuperSymmetric Model) which is driven by 19 parameters.
- I am the contact person for the 0 lepton analysis



Search	Reference	Fraction Excluded	
2-6 jets	ATLAS-CONF-2012-109	26.7%	
multijets	ATLAS-CONF-2012-103	3.3%	
1-lepton	ATLAS-CONF-2012-104	3.3%	
SS dileptons	ATLAS-CONF-2012-105	→ 4.9%	
Medium Stop (2l)	ATLAS-CONF-2012-167	0.1%	✓
Medium/Heavy Stop (1l)	ATLAS-CONF-2012-166	1.0%	✓
Direct Sbottom (2b)	ATLAS-CONF-2012-165	→ 5.6%	✓
3rd Generation Squarks (3b)	ATLAS-CONF-2012-145	→ 10.3%	✓
3rd Generation Squarks (3l)	ATLAS-CONF-2012-151	0.4%	✓
3 leptons	ATLAS-CONF-2012-154	0.4%	✓
4 leptons	ATLAS-CONF-2012-153	0.7%	✓
Z + jets + MET	ATLAS-CONF-2012-152	<0.1%	✓

Very (Very) Preliminary

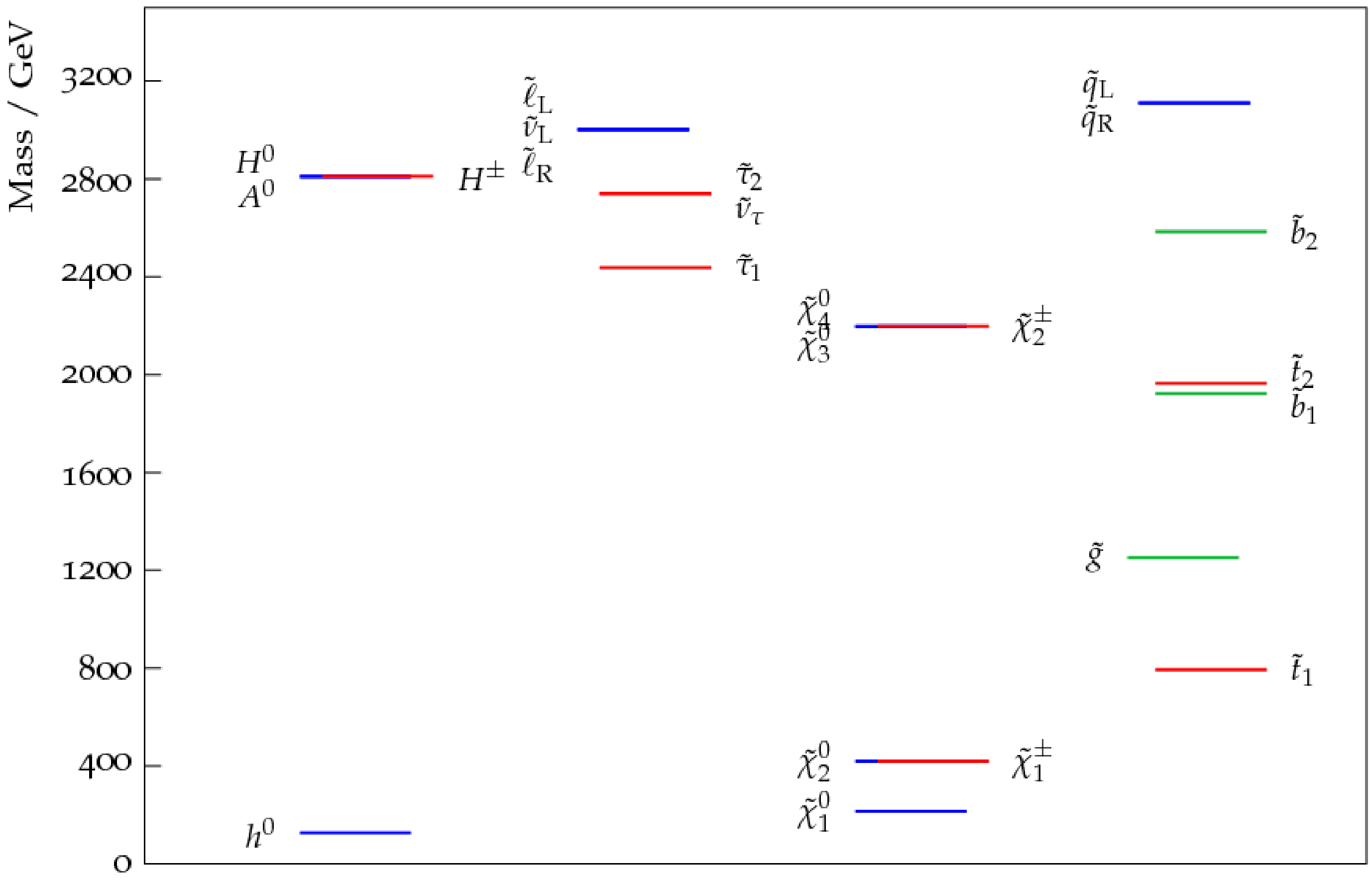
Rizzo et al.

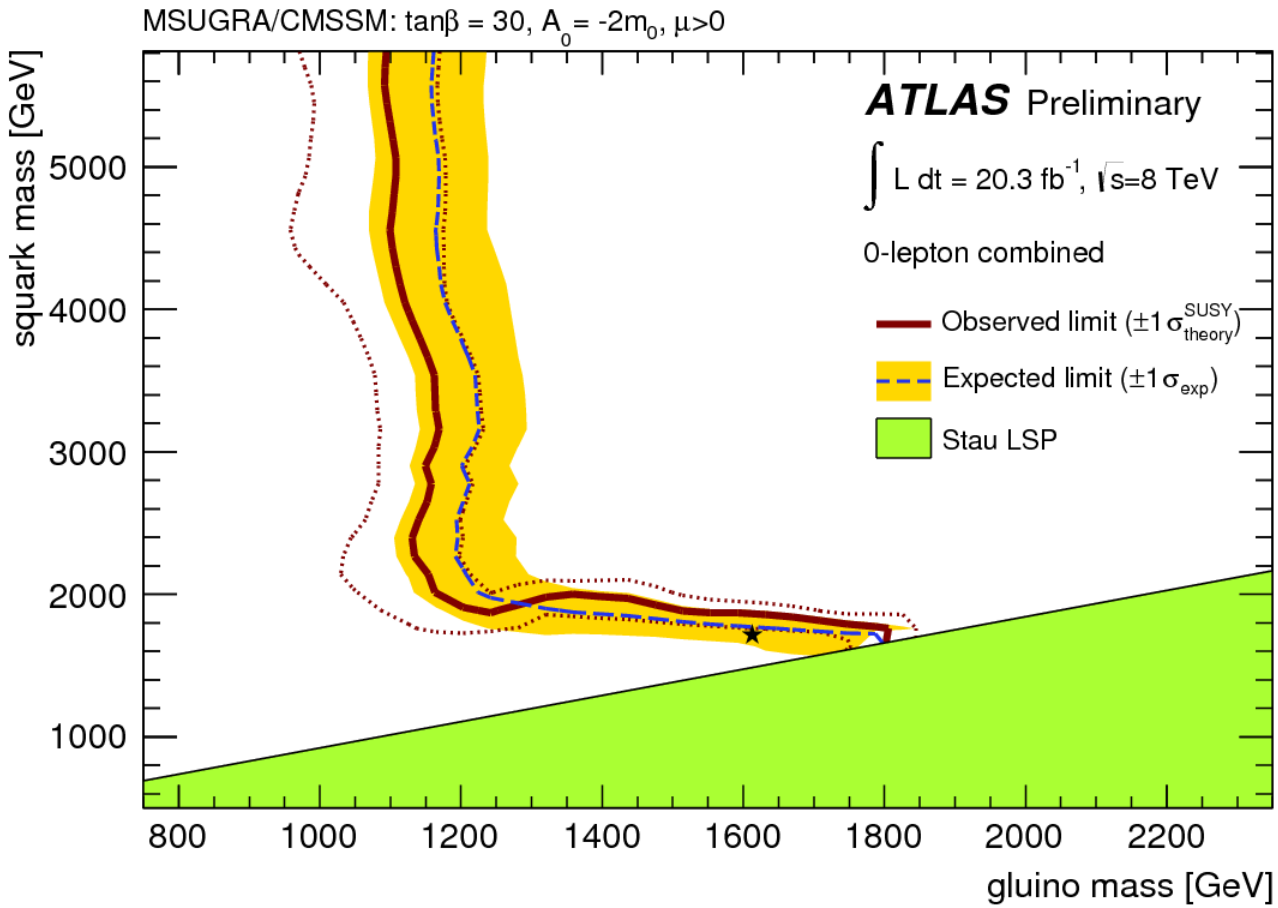
Conclusion

- Jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ one of the most powerful SUSY analysis
- Tau contribution is very large in jet + $E_{\mathrm{T}}^{\mathrm{miss}}$ SUSY search and we have defined VRs to check its modelization
- We have studied the SUSY parameters space and put limits using the observed number of events in mSUGRA
- We will go to a more general SUSY model parameter space in the context of the pMSSM

Back up

MSUGRA spectrum




MSUGRA/CMSSM: tanβ = 30, A_0 = -2m_0, μ>0
ATLAS Preliminary
∫ L dt = 20.3 fb^{-1}, √s=8 TeV
0-lepton combined
Observed limit (±1 σ^{SUSY}_{theory})
Expected limit (±1 σ_{exp})
Stau LSP
squark mass [GeV]
gluino mass [GeV]
1000
2000
3000
4000
5000
800
1000
1200
1400
1600
1800
2000
2200

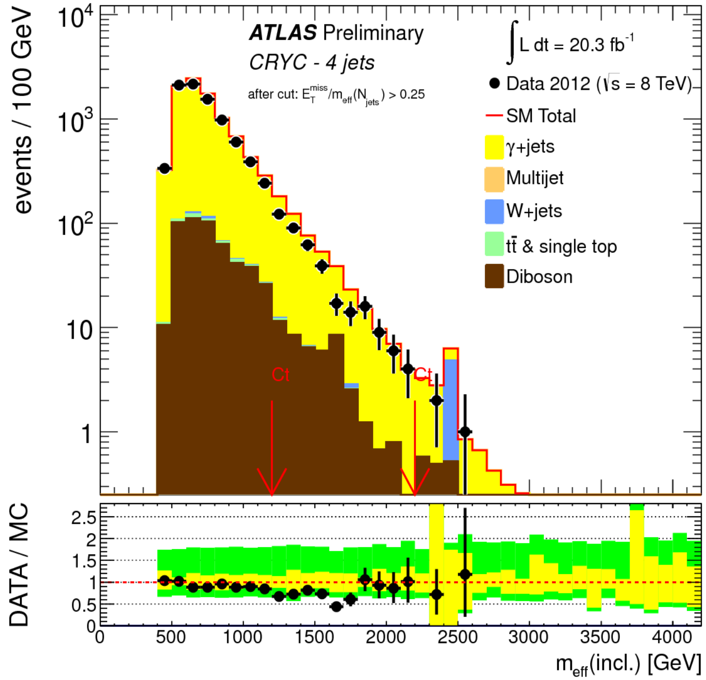
Control regions

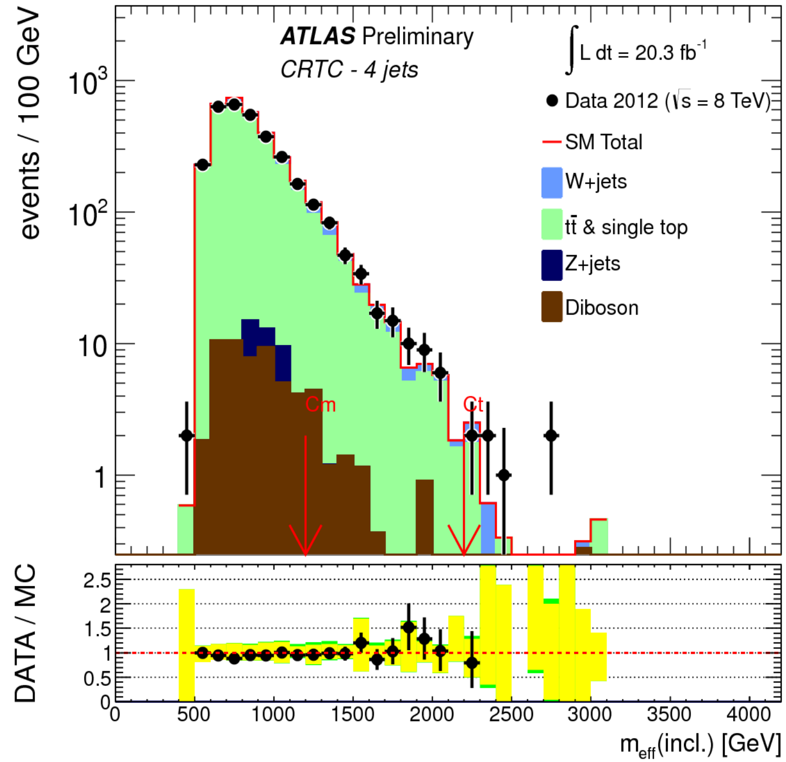
- For each signal region there are 4 control regions, each one optimized to estimate one of the main backgrounds
- Control regions are chosen in such a way to minimize the signal contamination

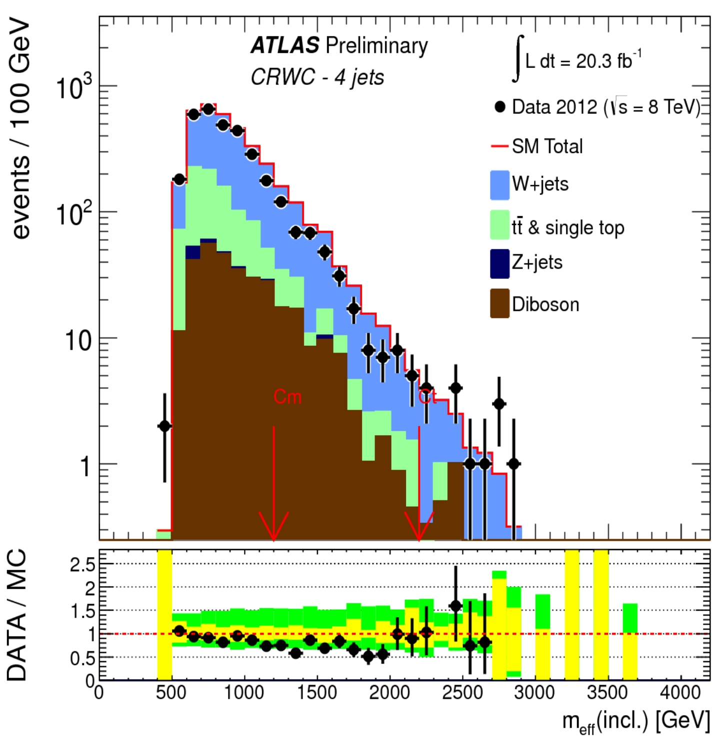
CR	SR background	CR process	CR selection
CRY	$Z(\to \nu\nu)$+jets	γ+jets	Isolated photon
CRQ	multi-jets	multi-jets	Reversed $\Delta\phi(\text{jet}, E_{\mathrm{T}}^{\mathrm{miss}})_{\min}$ and $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(Nj)$ requirements[a]
CRW	$W(\to \ell\nu)$+jets	$W(\to \ell\nu)$+jets	30 GeV $< m_T(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) <$ 100 GeV, b-veto
CRT	$t\bar{t}$ and single-t	$t\bar{t} \to bbqq'\ell\nu$	30 GeV $< m_T(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) <$ 100 GeV, b-tag

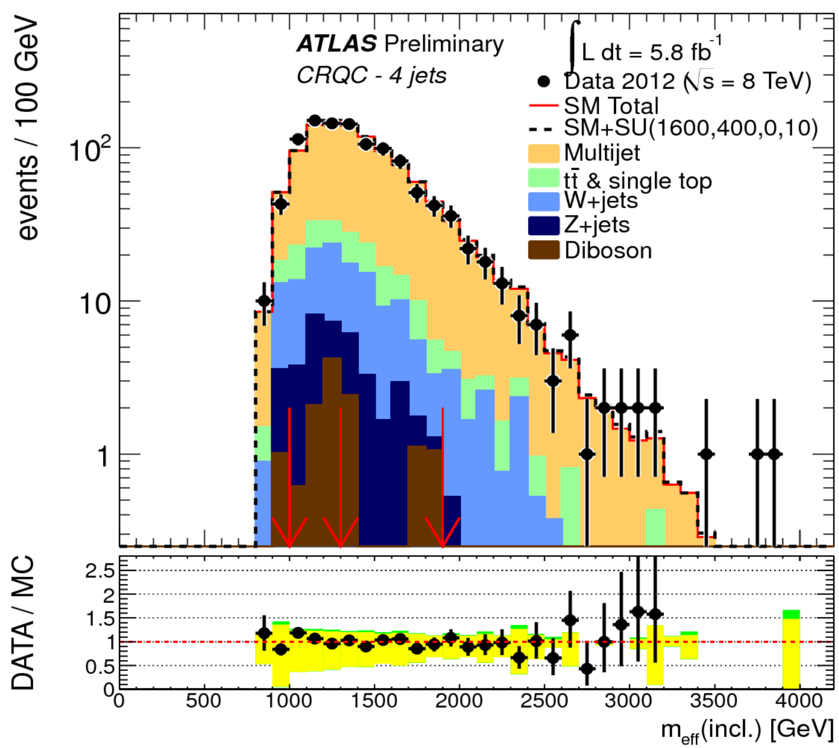
(a) For SR A-medium the selection requirement placed on $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ is reversed.

Control regions





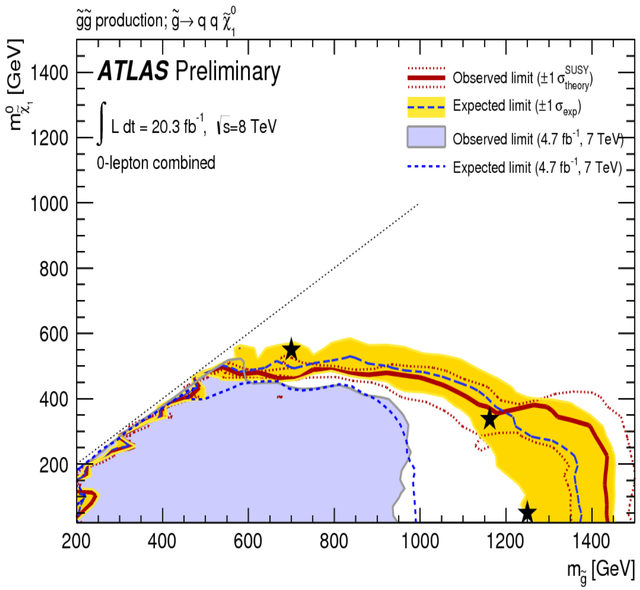


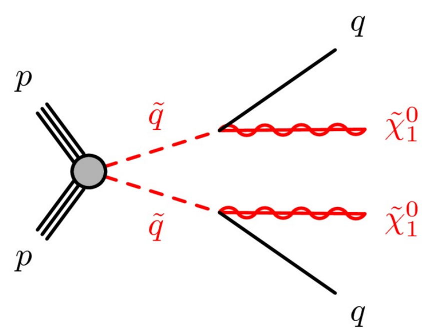


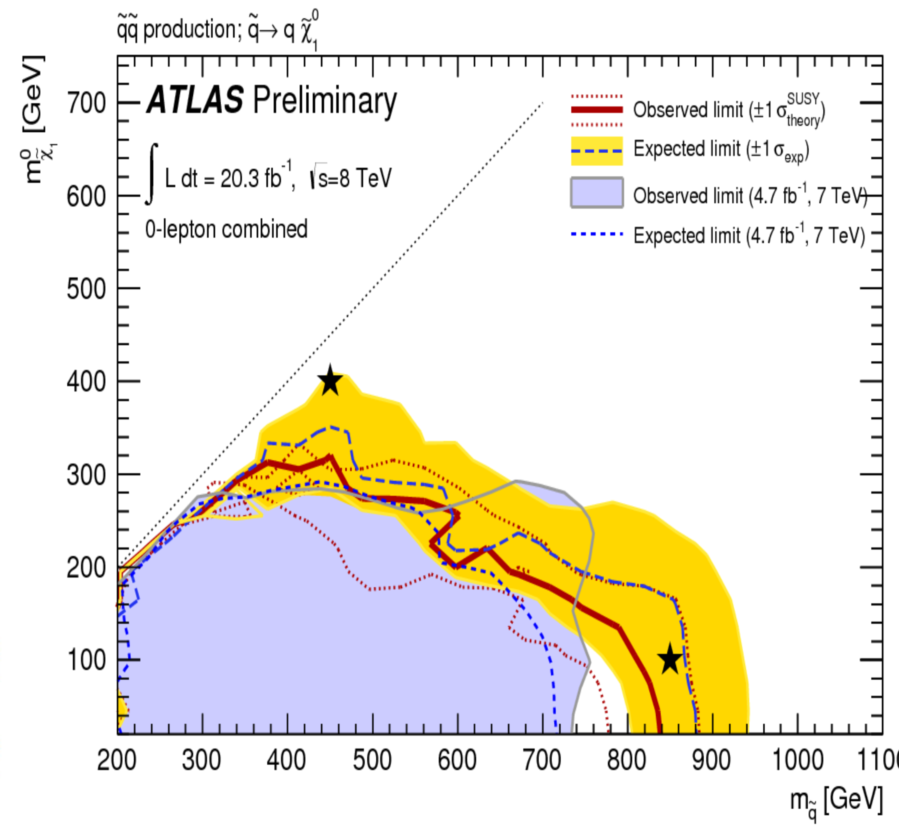
Backgrounds

- Before searching for SUSY, it is necessary to understand the SM processes that give the same final state as the signal we search for (jets $+E_{\mathrm{T}}^{\mathrm{miss}}$)
- Multijet background obtained from data
- Other processes estimated from MC (semi datadriven method):

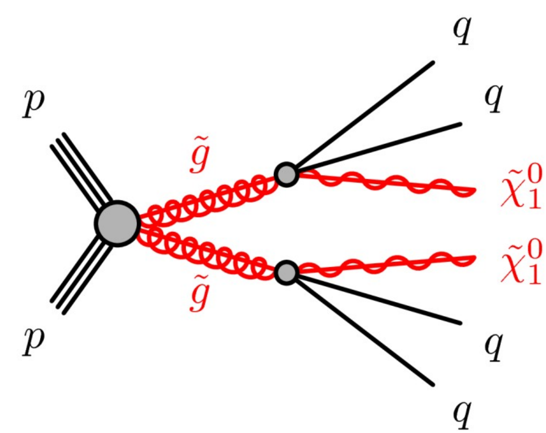
Interpretations







- Limits in the simplified models where the particle we look for is NLSP



Signal regions