Status and prospects of MET searches in ATLAS and CMS

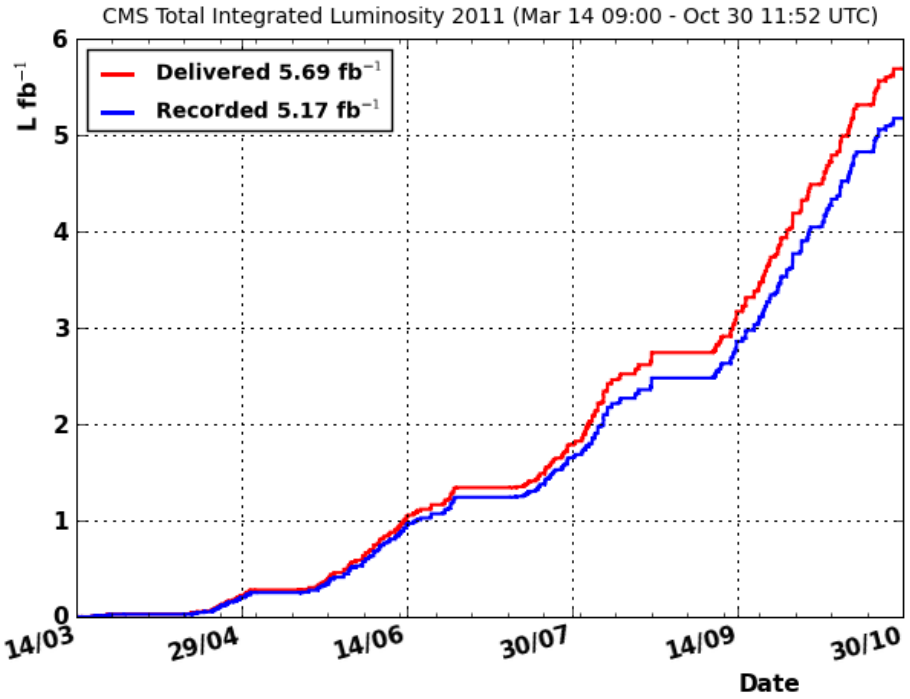
Didar Dobur

University of Florida

On behalf of CMS and ATLAS Collaborations

Workshop on Implications of LHC results for TeV-scale physics
CERN , 31 October – 1 November

2011 recorded LHC data



- As of yesterday LHC stopped proton-proton running for 2011
- Both experiments recorded > 5 fb^{-1} of data
- In this talk results obtained with up to 2.1 fb^{-1} of data are presented

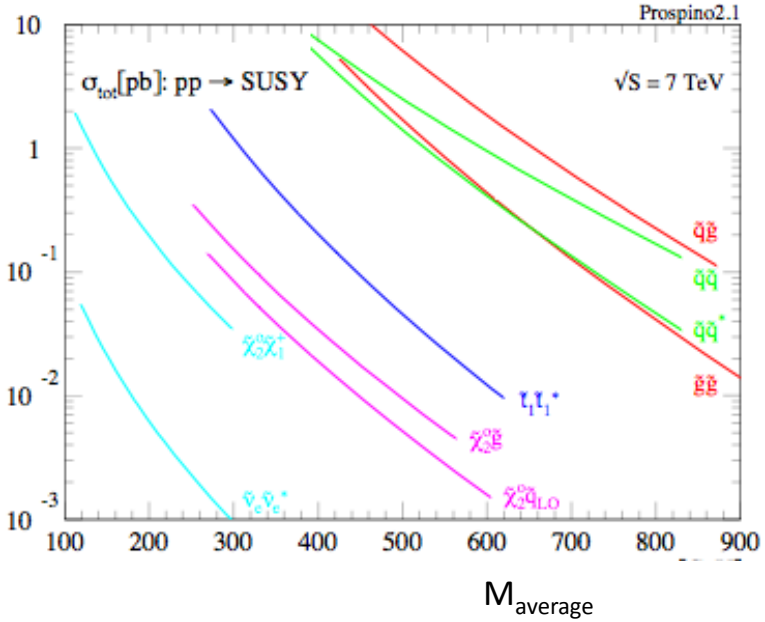
Searches with MET with 2011 data

Signature	ATLAS	CMS
0-Lepton + MET	1.3 fb^{-1} ≥ 6,8 jets ArXiV:1110.2299 1. fb^{-1} ≥ 2,4 jets ArXiV:1109.6572	1.1 fb^{-1} α_T arxiv:1109.2352 1.1 fb^{-1} HT/MHT PAS-SUS-11-004 1.1 fb^{-1} M_{T2} PAS-SUS-11-005
1-lepton +MET	1 fb^{-1} ArXiV:1109.6606	1.1 fb^{-1} PAS-SUS-11-015
0-lepton + MET + b	0.8 fb^{-1} ATLAS-CONF-2011-098	1.1 fb^{-1} PAS-SUS-11-006
1-lepton + MET + b	1 fb^{-1} ATLAS-CONF-2011-130	coming soon
2 SS leptons + MET	1 fb^{-1} paper soon	1 fb^{-1} PAS-SUS-11-010
2 OS(SF) leptons+MET	1 fb^{-1} ArXiV:1109.3089	1 fb^{-1} PAS-SUS-11-011 1 fb^{-1} Z + MET PAS-SUS-11-017 0.2 fb^{-1} JZB PAS-SUS-11-012
Multileptons	coming soon	2.1 fb^{-1} PAS-SUS-11-013
©(©) + MET	1 fb^{-1} arXiv:1107.0561	1.1 fb^{-1} PAS-SUS-11-009
Monojet + MET	1 fb^{-1} ATLAS-CONF-2011-096	1.1 fb^{-1} PAS-EXO-11-059

See R. Bruneliere and S. Padhi 's talks at the previous workshop for a detailed presentation
Some highlights of MET searches in the context of Supersymmetry -> this talk

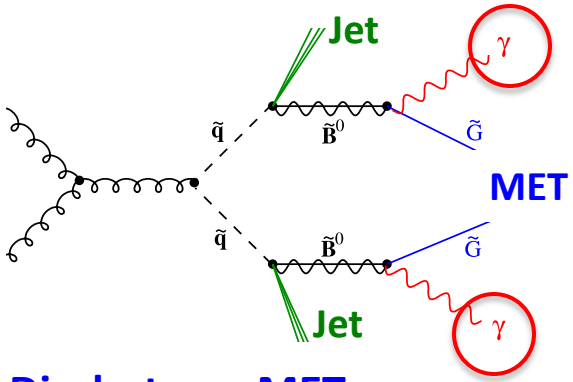
Search strategies so far

Superpartner production x-section versus their mass

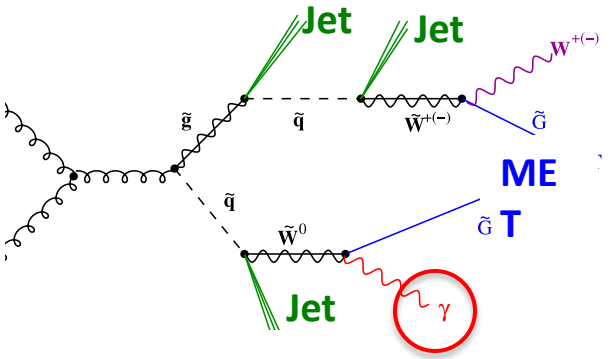


- First target -> gluino-squark production (large x-sections thanks to LHC energies)
- Signature based and rather inclusive
- Multi-object triggers used
- Mostly cut & count (only a few cases explored beyond that)
- Major backgrounds are estimated using fully- or semi- data-driven methods
- No significant deviation from SM expectation observed
- Results are interpreted in various (simplified) models

Photon + MET final states (CMS)



Gauge mediated SUSY
- Gravitino is LSP
- Neutralino is NLSP
- Depending on the nature of the χ^0 (bino/wino-like) and mass hierarchy; 1 or more photons



Di-photon + MET:

≥ 2©, p_T(©) >(45)30 GeV

≥1 jet

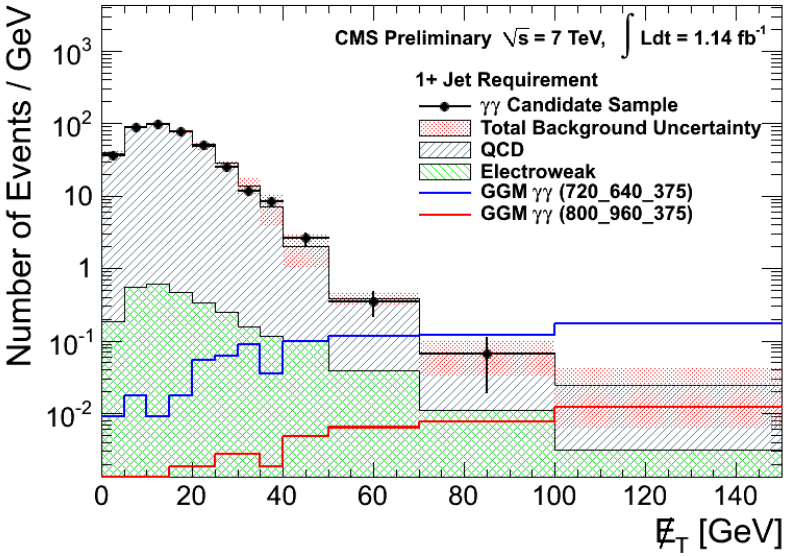
MET > 50 (100) GeV

Single photon +MET:

p_T(©) >75 GeV

H_T > 400 GeV , ≥ 3 jets

MET > 200 GeV

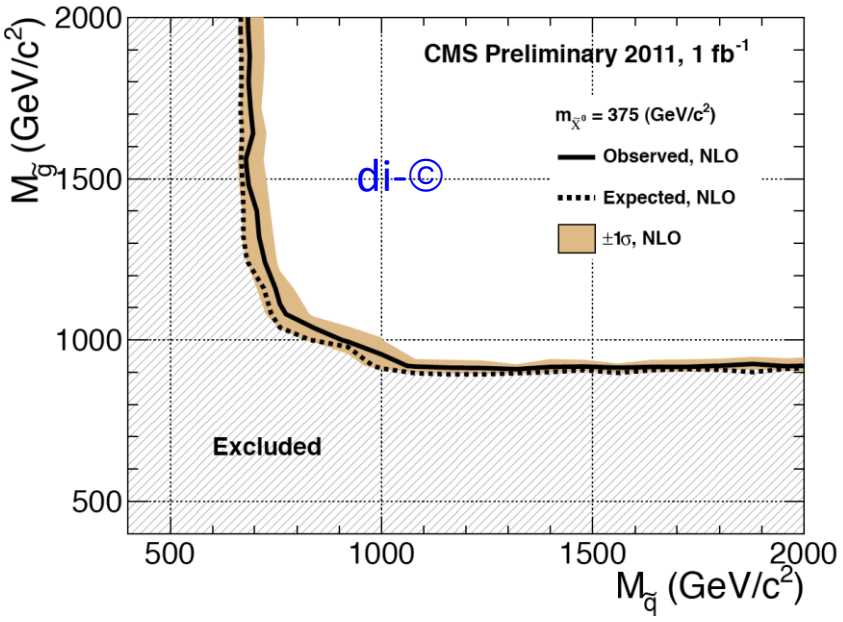


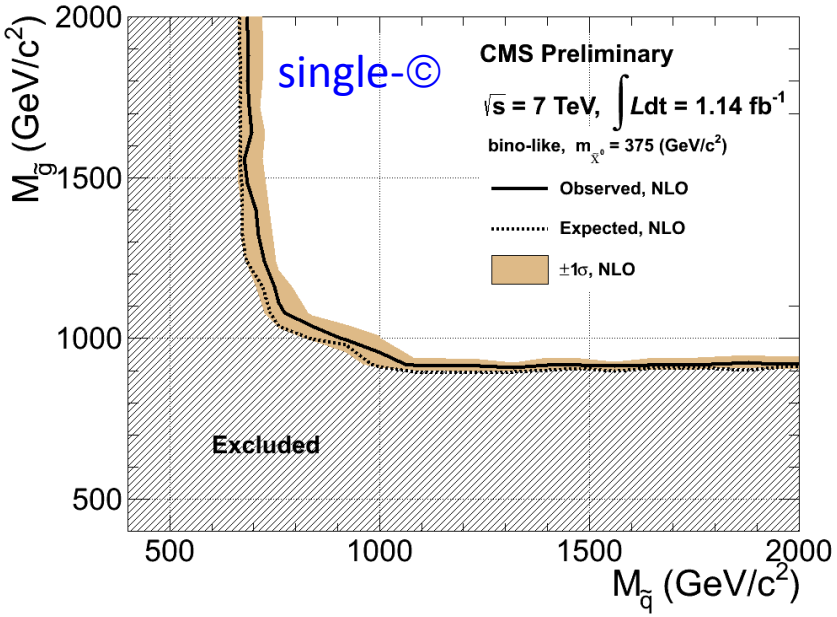
- QCD background (dominant)
  - measure MET shape in control samples, normalization from low-MET region
- W+jets (*e* mis-id as ©) (sub-dominant)
  - *e*→© mis-ID rate determined from *e*©/*ee* events in Z peak
- W/Z/Top where ©from ISR/FSR (very small)
  - taken from simulation

Photon + MET final states (CMS)

	di-© MET > 50 GeV	di-© MET > 100 GeV	single-© MET > 200 GeV
predicted SM	11.3 ± 1.6	1.5 ± 1.0	7.24 ± 3.0
Data	9	0	7

- Interpretation in simplified models in GGMS where m(χ^0)= 375 GeV

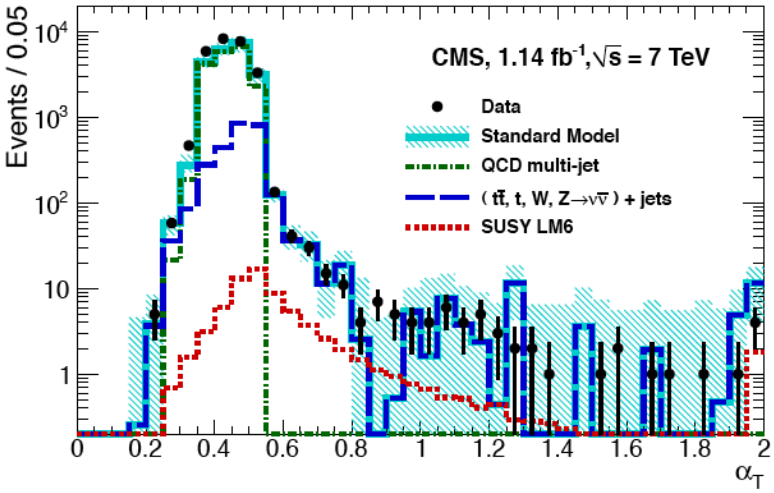




0-lepton + MET search (CMS)

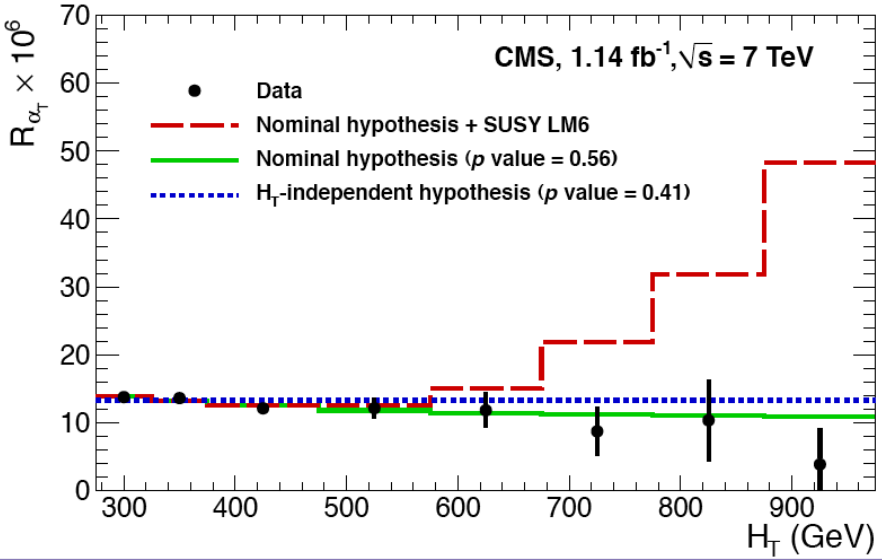
- Search variables: H_T and α_T
  - $\alpha_T > 0.55$; QCD killer; real MET spreads over wide α_T range
  - ≥ 2 jets, leading di-jets E_T>100 GeV
  - HT > 275 GeV
  - lepton, photon and forward jet veto

$$\alpha_T = \frac{\sqrt{E_T^{j2} / E_T^{j1}}}{\sqrt{2(1-\cos\Delta\varphi)}}$$



Significant improvement in sensitivity by performing a shape analysis using exclusive H_T bins

$$R_{\alpha_T} = \frac{\alpha_T > 0.55}{\alpha_T < 0.55}$$



Backgrounds

$Z \to \ell\ell$: irreducible : ©+jets sample with translation factors from MC

W/top : lost leptons and hadronic tau: obtained from muon sample with MC ratio

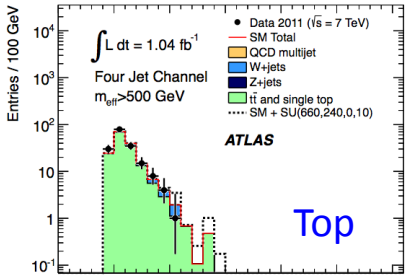
QCD background: shape measured in low-α_T control sample

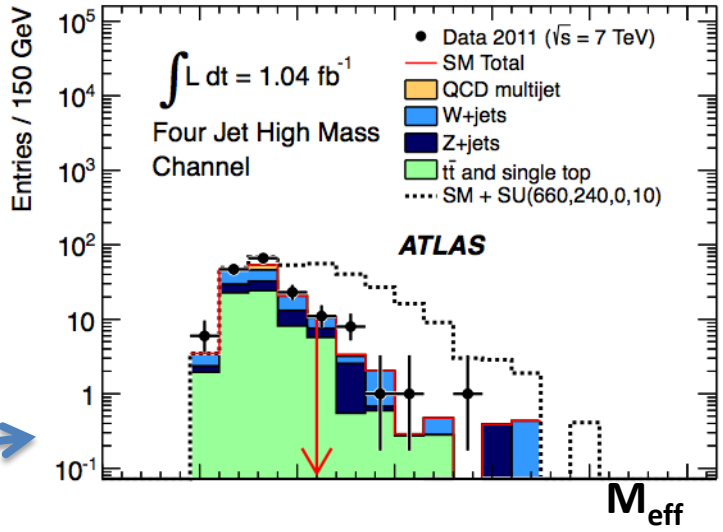
0-lepton + MET search (ATLAS)

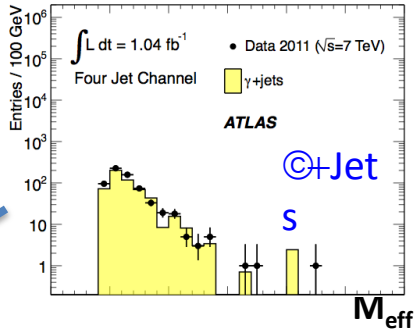
Complementary search regions to maximize the sensitivity

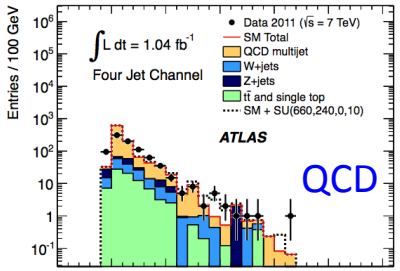
Large MET, lower jet multiplicities ≥ 2,4 Jets M_{eff} = MET + HT	Lower MET higher jet multiplicities ≥ 6,7 Jets MET/$\sqrt{H_T}$
Leading jet p_T > 130 MET > 130 , M_{eff} > (500)1000	Leading jet p_T > 55 (80) GeV MET/$\sqrt{H_T}$ > 3.5 $GeV^{1/2}$

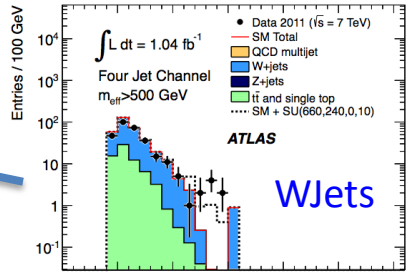
Measured distributions in Control regions are used to estimate the background in signal region





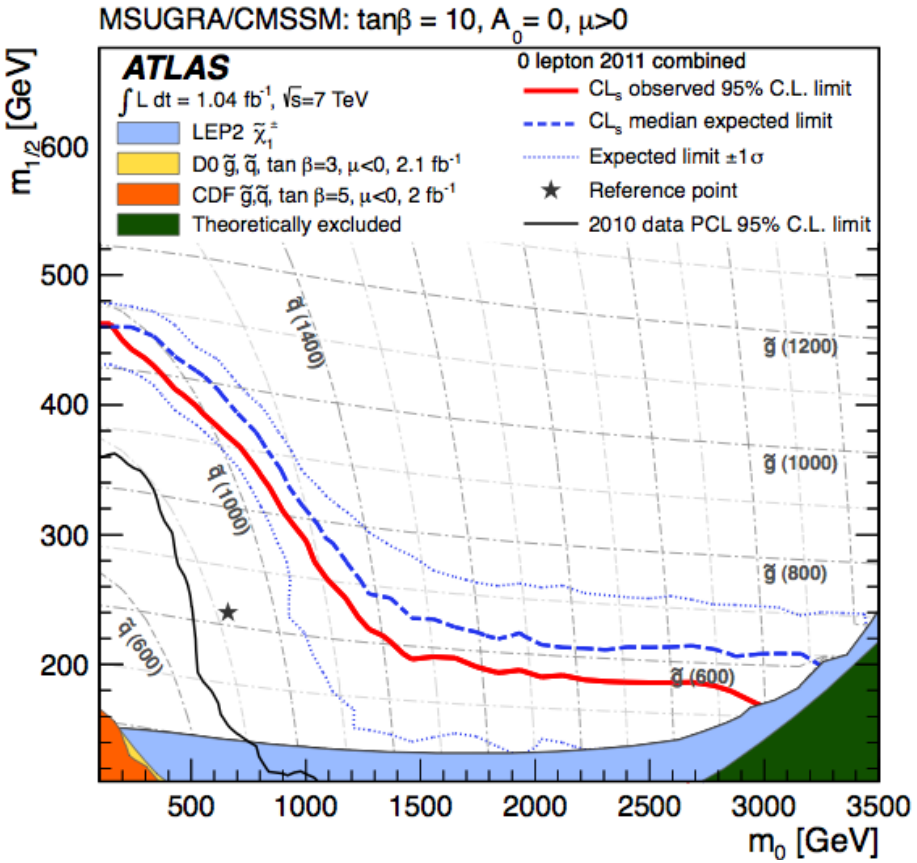






0-lepton + MET search (ATLAS)

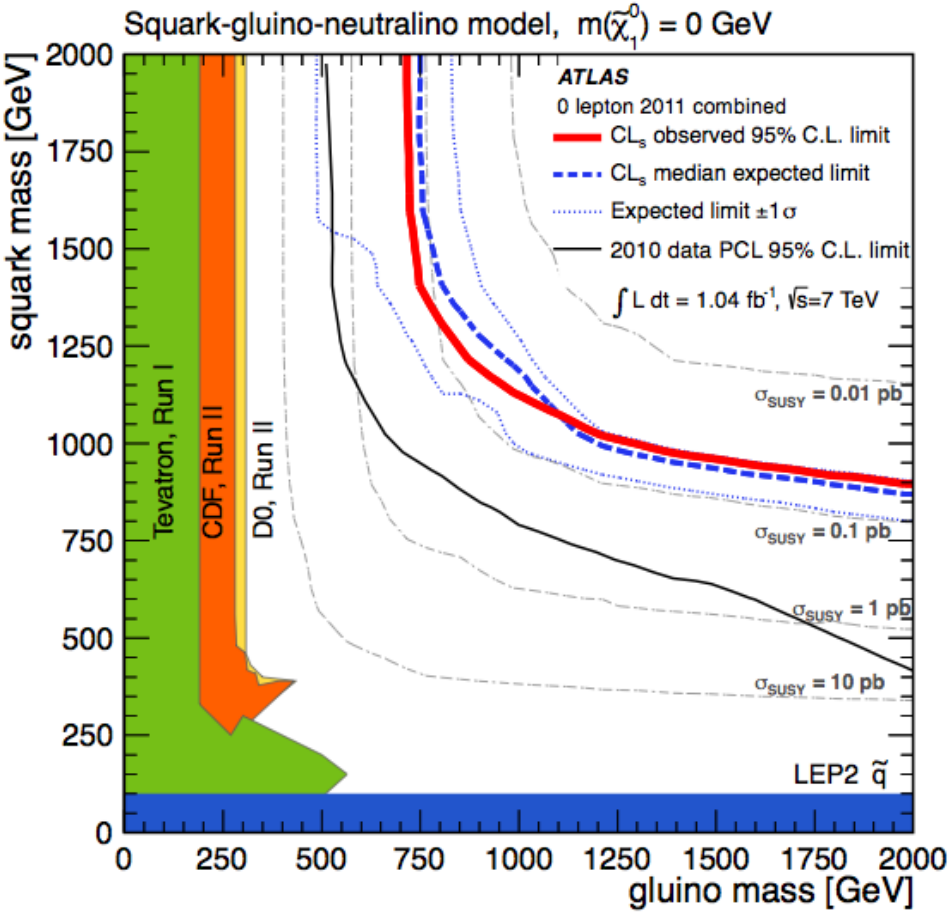
njet ≥ 2,4 + MET : interpretation in CMSSM

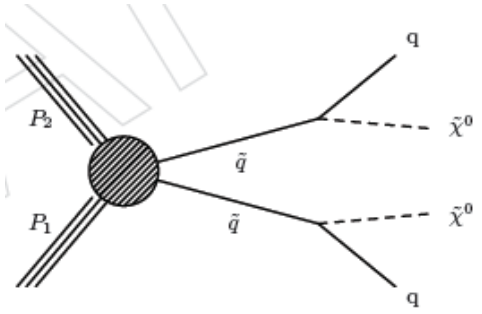


- ≥ 2 and ≥ 4 search results are combined -> best sensitivity in CMSSM
- Equal squark and gluino masses below 950 GeV are excluded

0-lepton + MET search (ATLAS)

njet ≥ 2,4 + MET : Interpretation in Simplified Models (SMS)



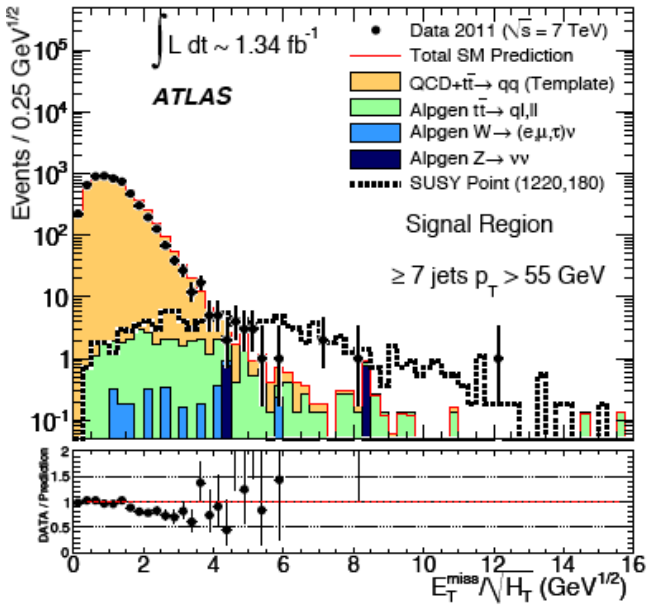


- Neutralino ($\tilde{\chi}^0$) as LSP
- M_{LSP} = 0
- all other superpartner masses set to 5 TeV except gluino and 1st and 2nd generation squarks
- Scan Mgluino and Msquark up to 2TeV

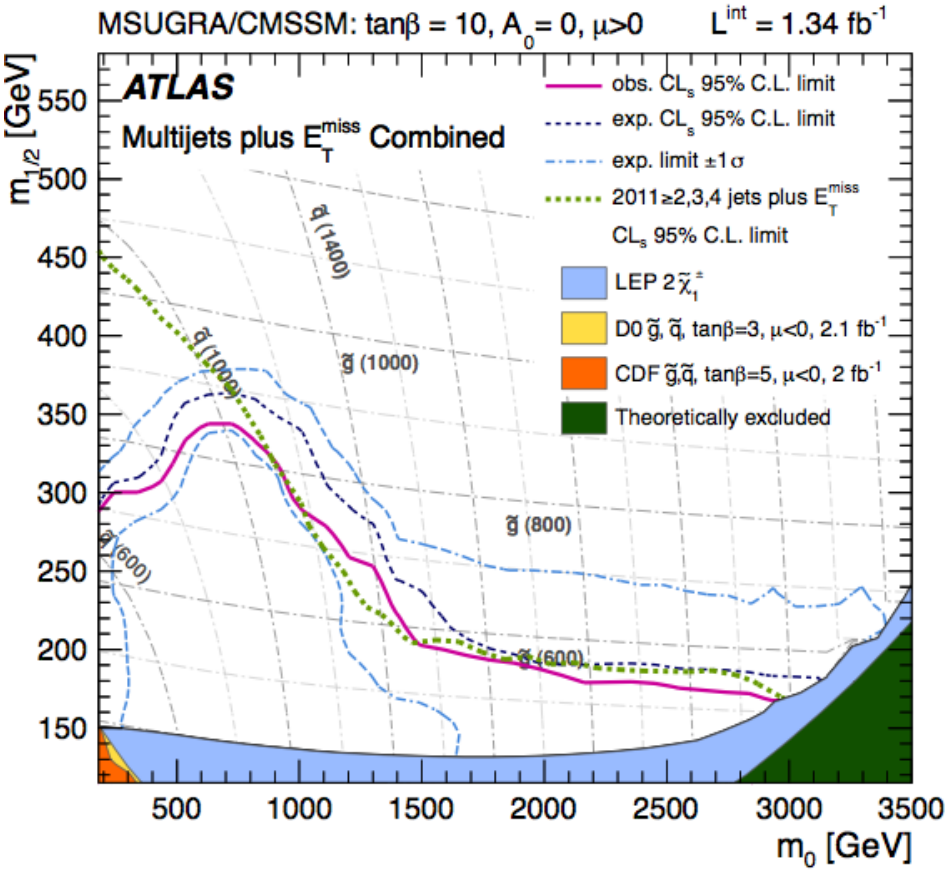
if gluino and squarks are mass degenerate $M_{gluino/squark}$ < 1075 GeV is excluded, these results are roughly unchanged up to M_{LSP} = 200 GeV

0-lepton + MET search (ATLAS)

Multijet (≥ 6,8) + MET search



Expected to increase the sensitivity to long cascade decays of gluinos, including multi-top final states.



- Expected limit curves show better or equal sensitivity at higher m_0 compared to ≥2,4 jet search

1 lepton + MET final state (ATLAS)

1 isolated high p_T (20/25 GeV) lepton

- ≥ 3,4 jets
- m_T > 100 GeV
- m_{eff} > 600 (500) GeV
- MET > 240 (200) GeV

Backgrounds

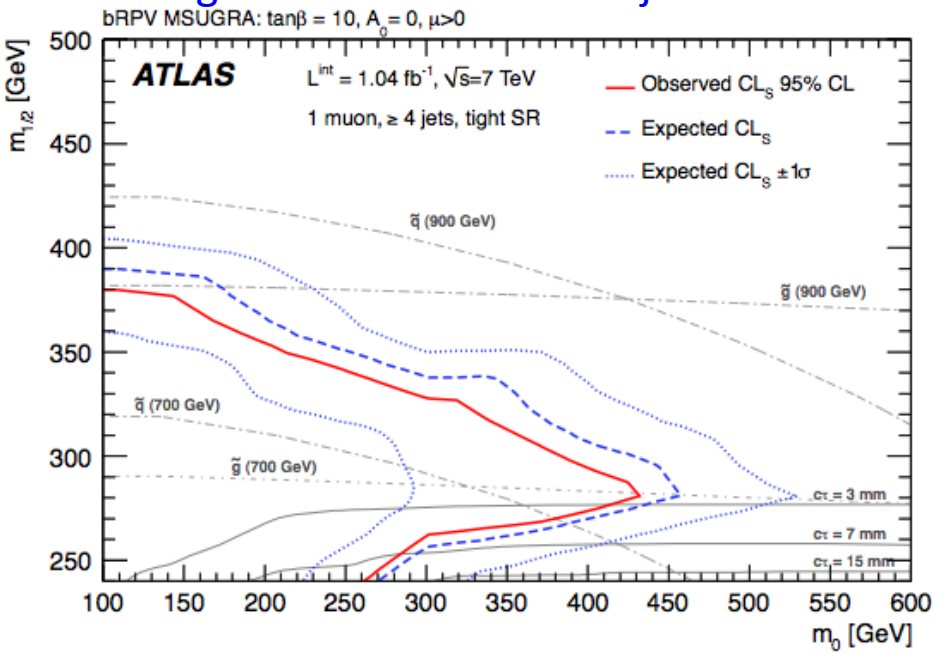
Wjets/top (dominant): Estimated using control regions and transfer factors from simulation

QCD background (small): fully data driven using matrix method

No significant deviation from expected SM predictions is observed

- Interpretation in bilinear R-parity violating models in MSUGRA
- Neutralino(LSP) decays dominantly to neutrinos (some MET is guaranteed). Only prompt decays are considered ($c\tau < 15$ mm), $m_{1/2} > 240$
- $m_{\tilde{q}} = m_{\tilde{g}} < 760$ GeV is excluded
- Targeted analysis with displaced vertices for $c\tau > 15$ mm

Single muon + MET + ≥ 4 jets



1-lepton + MET in SMS (ATLAS)

1 lepton + MET + ≥ 3,4 jets channel interpreted in simplified models

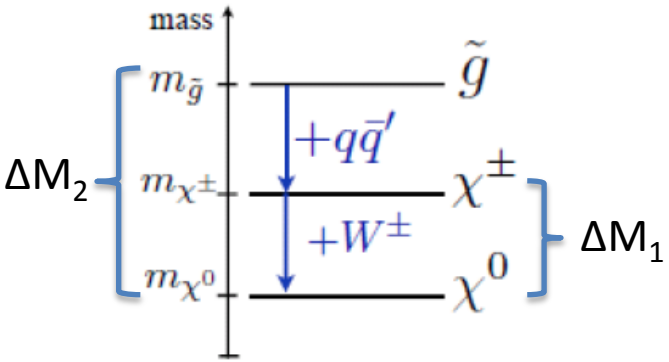
$M_{q\tilde{}}$= 4.5 TeV

$$\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^{\pm} \rightarrow q\bar{q}W\tilde{\chi}_1^0$$

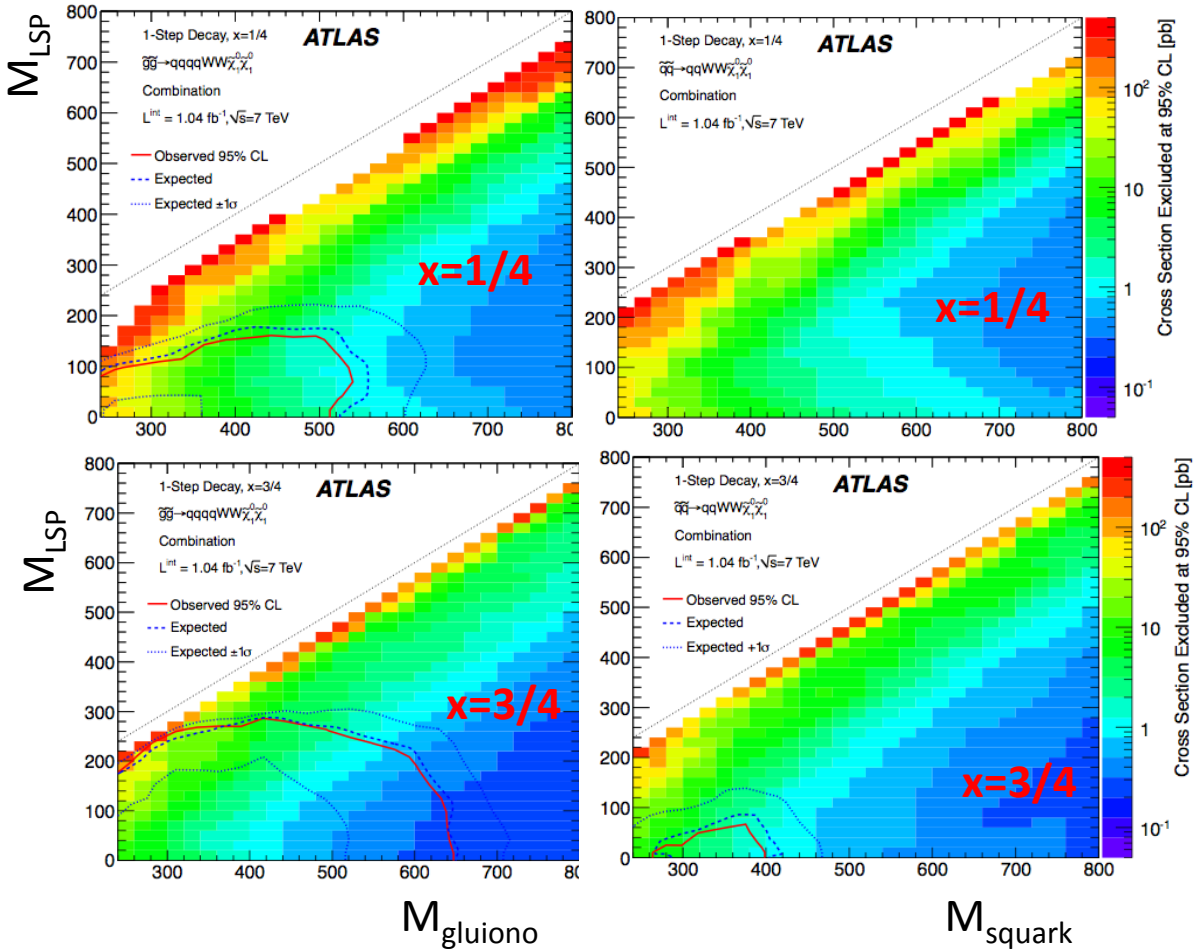
$M_{g\tilde{}}$ / $M_{q\tilde{}\text{-3rd Gen.}}$ = 4.5 TeV

$$\tilde{q} \rightarrow q'\tilde{\chi}_1^{\pm} \rightarrow q'W\tilde{\chi}_1^0$$

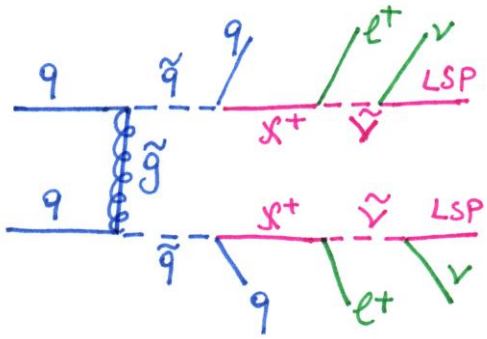
x= $\Delta M_1/\Delta M_2$



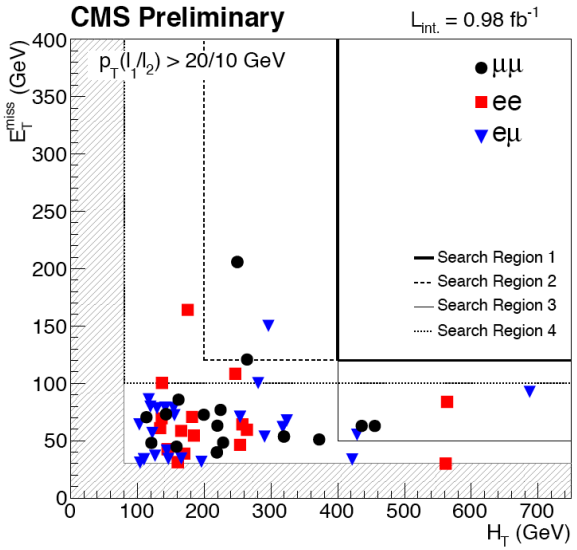
Note: less (no) sensitivity for x=1/4 -> Low pT leptons !



Same-Sign di-leptons + MET (CMS)

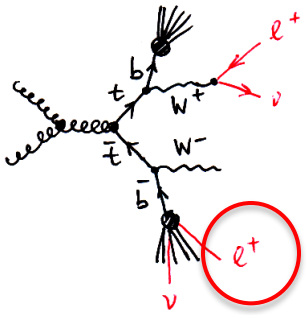


- Low SM background
- p_T (μ/e/ |) down to 5/10/15 GeV
- Multiple search regions
- Hadronic Tau's are included



- ttBar/Wjets/QCD: leptons from b-jets (dominant)

  Isolation templates from bbBar samples with tag-and-probe normalization from sidebands

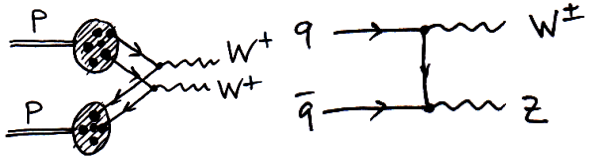


- OS prompt leptons: charge mis-id (small)

  measure charge mis-id rate from cosmic ray data for muons (~10^{-5}) and SS/OS *ee* yields in *Z->ee* events for electrons(~7. 10^{-4})

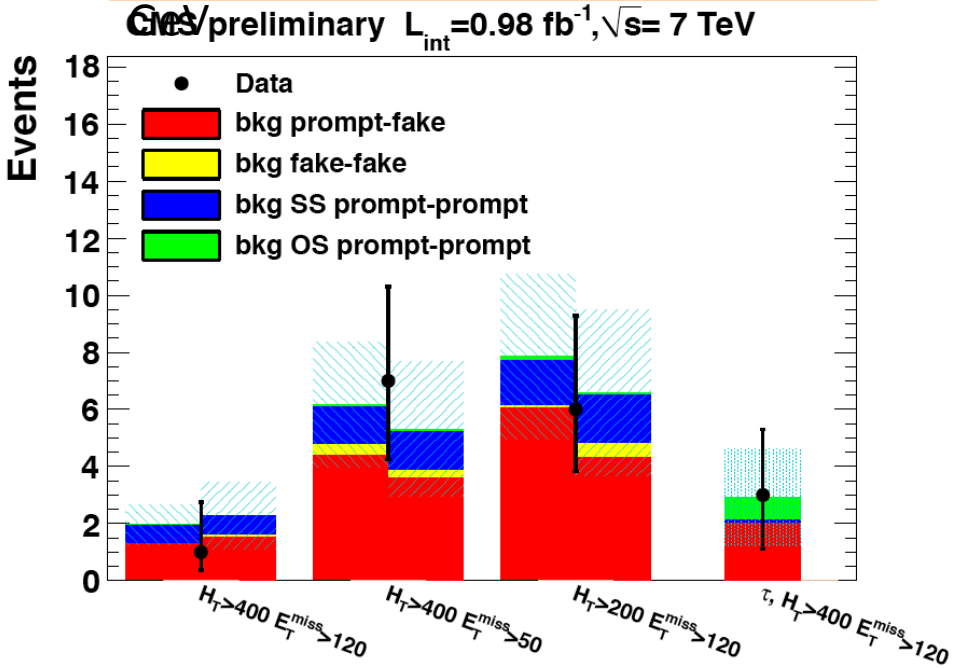
- SS prompt leptons from SSWW, ZZ, WZ, ttZ/W

  take from simulation with large uncertainties

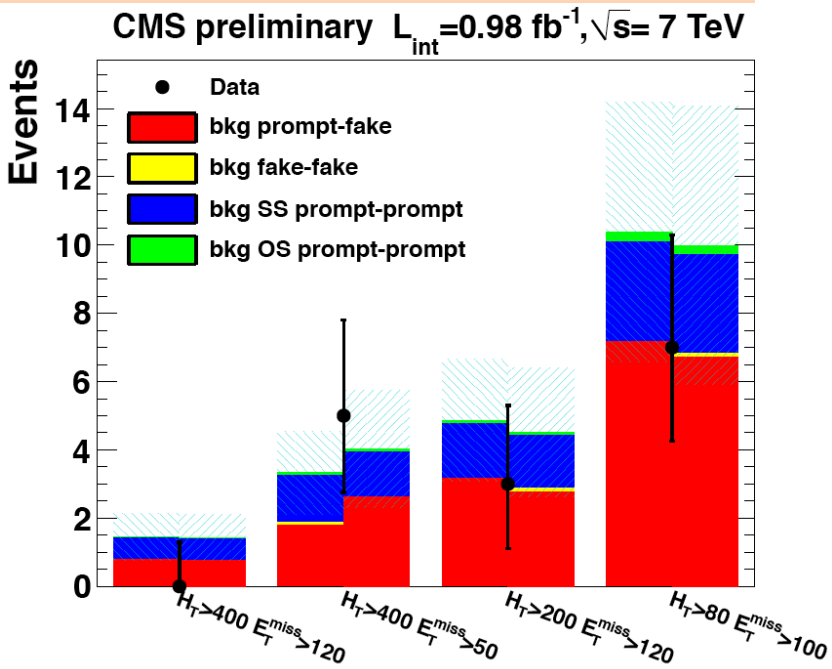


Same-Sign di-leptons + MET (CMS)

Low-pT leptons pT(e/μ/ |) > 10/5 GeV

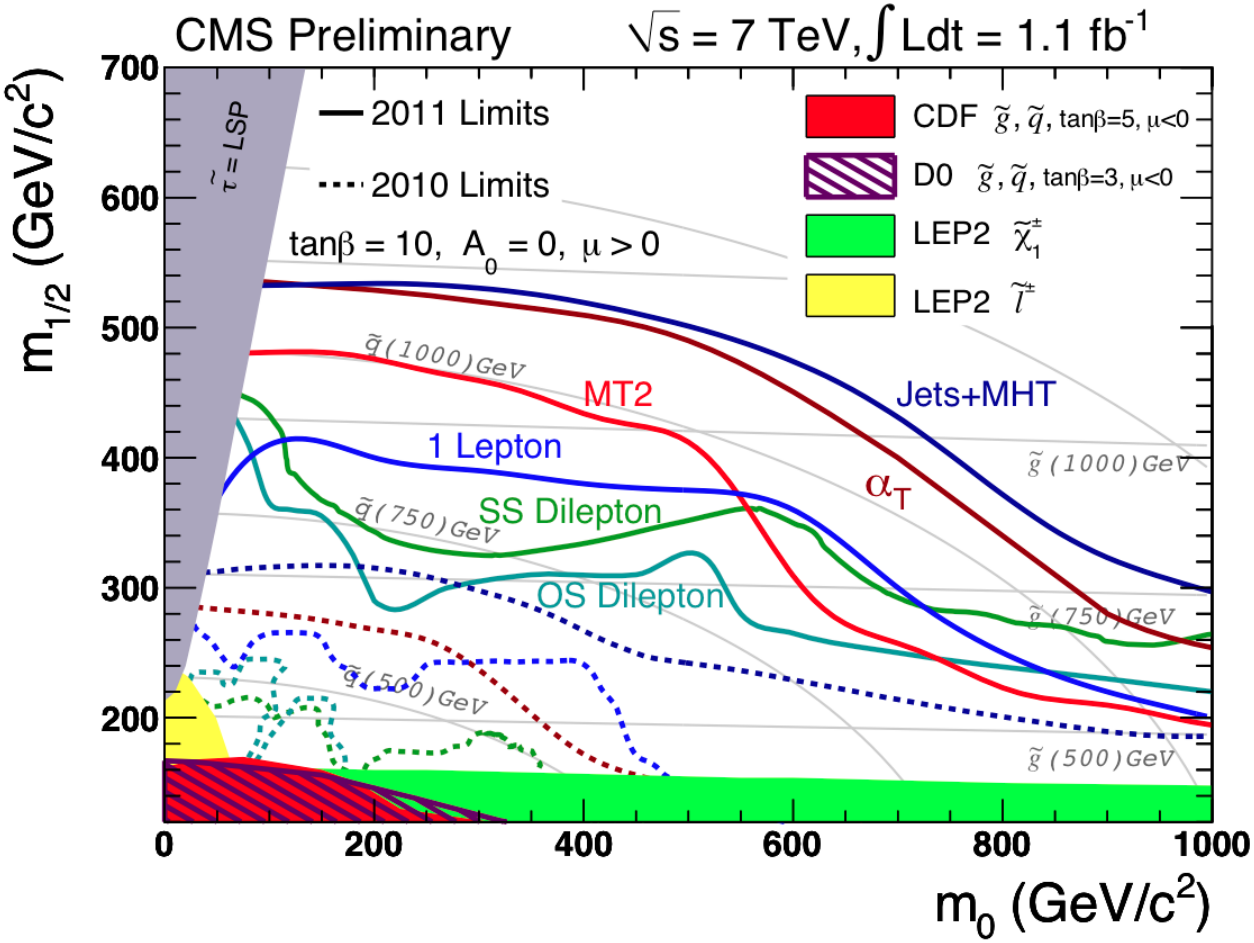


High-pT leptons pT(e/μ) > 10,20 GeV



- Observed event yields consistent with the expected SM yields in all search regions
- Note that the backgrounds from rare processes start to be important at large MET and H_T
- Results are interpreted in CMSSM framework

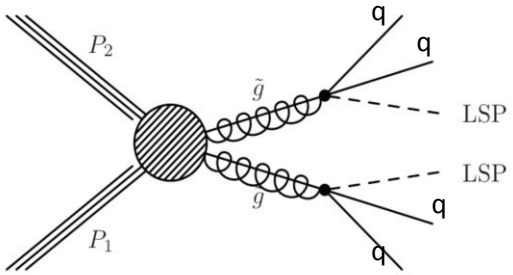
Interpretation of CMS results in CMSSM



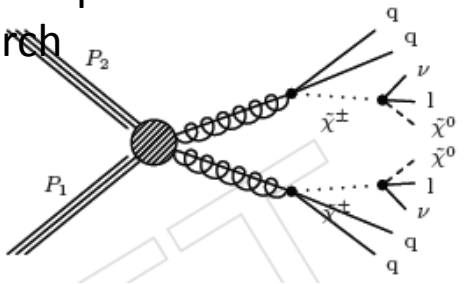
For mass degenerate squark and gluino masses below 1.2 TeV are excluded within the framework of CMSSM and assumed parameter sets

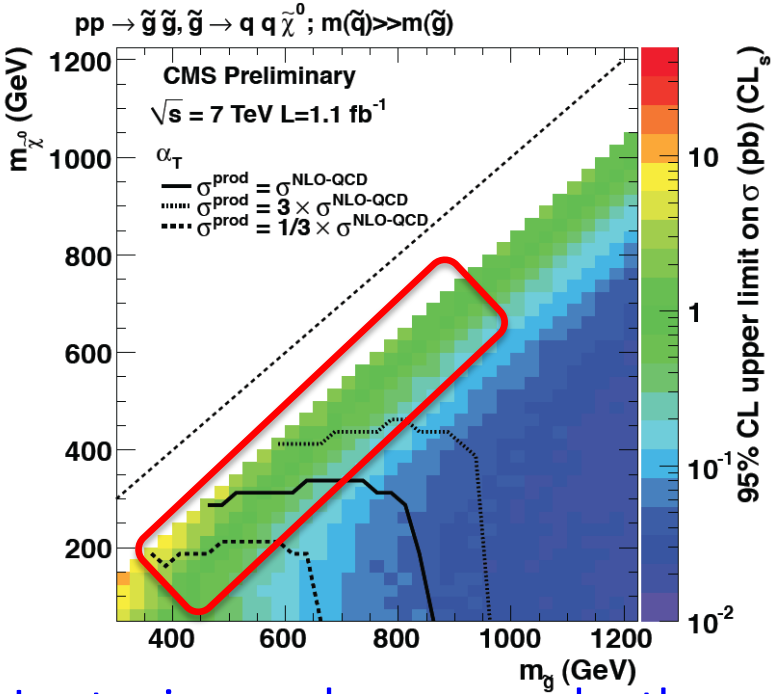
Interpretation in SMS (CMS)

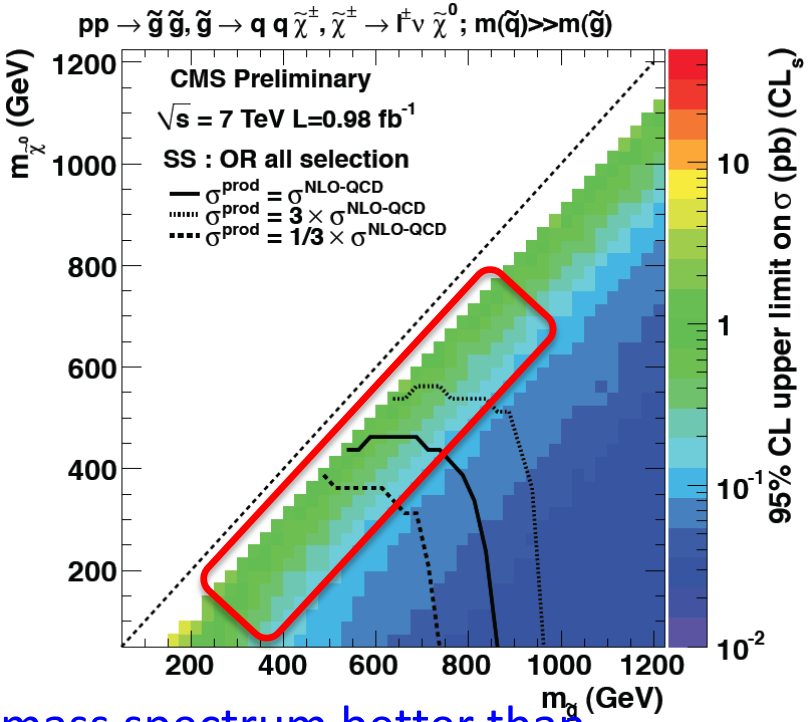
Jets + MET search with α_T



SS di-leptons + MET search



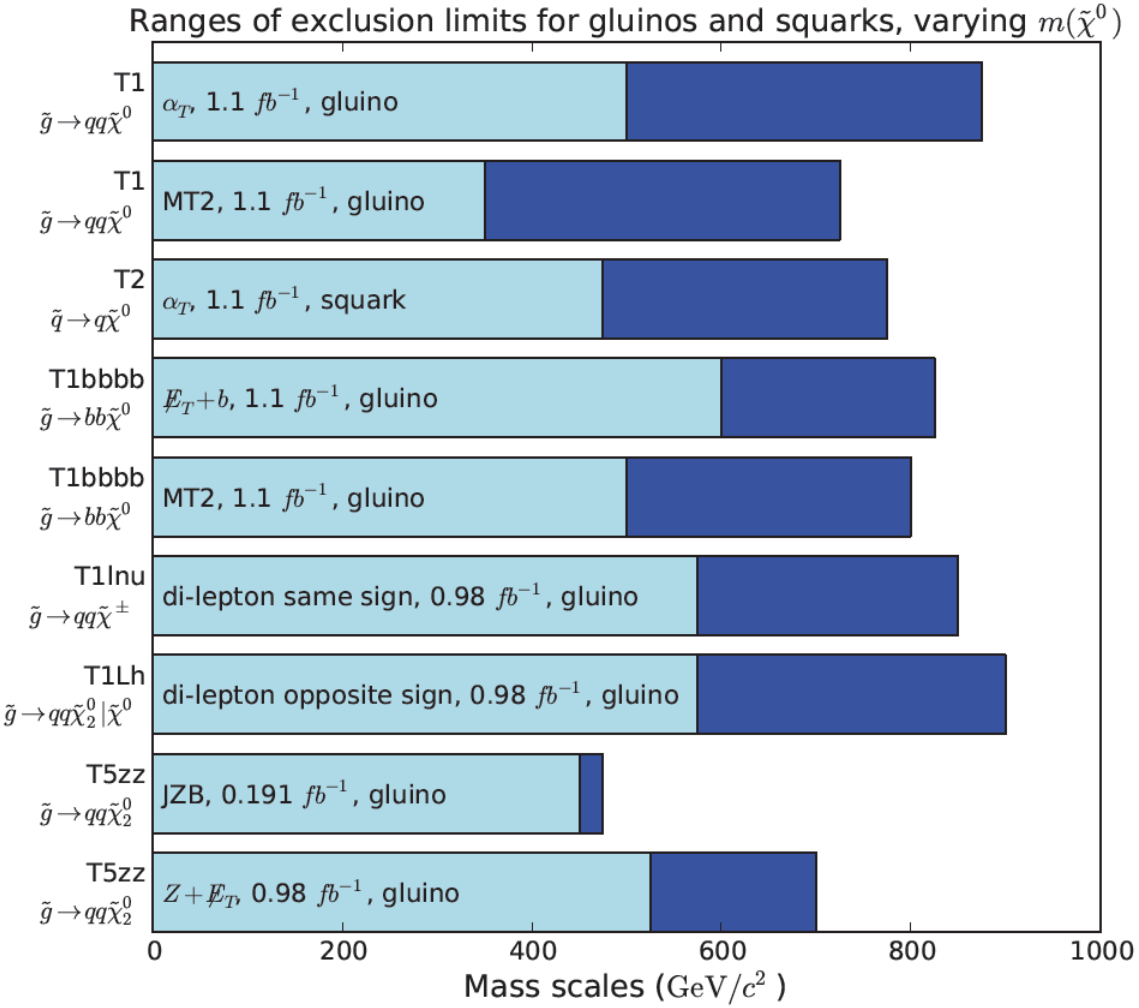




Leptonic searches can probe the compressed mass spectrum better than current hadronic analysis

Overview of CMS results in SMS

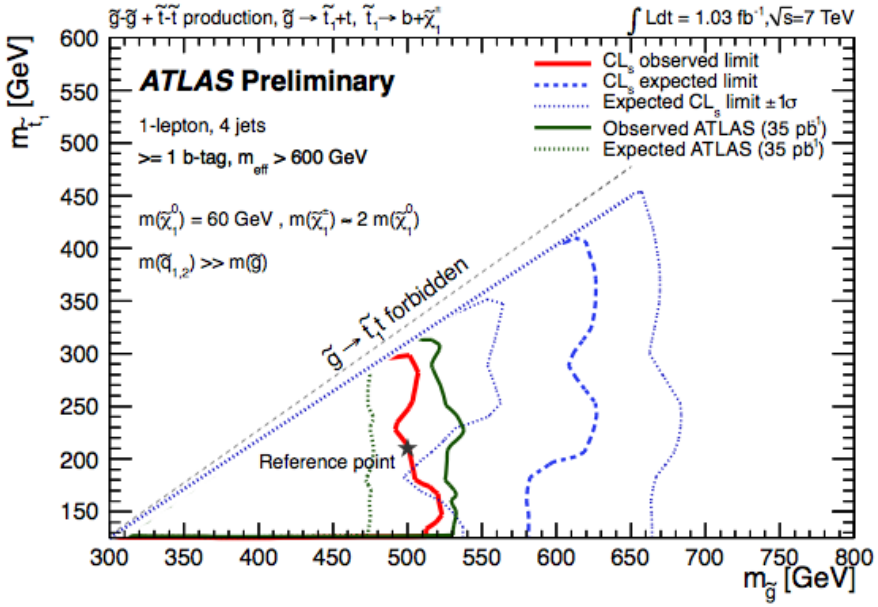
- For limits on $m(\tilde{g}), m(\tilde{q}) >> m(\tilde{g})$ (or vice versa)
- $m(\tilde{\chi}^{\pm}), m(\tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$
- Dark blue band varying LSP mass between zero m(gluino)-200 GeV



- Both ATLAS and CMS searches probe masses from 500 – 1000 GeV

gluino and 3rd generation (ATLAS)

1-lepton + MET + ≥ 1 b-jet + ≥ 3 jets



SMS with:

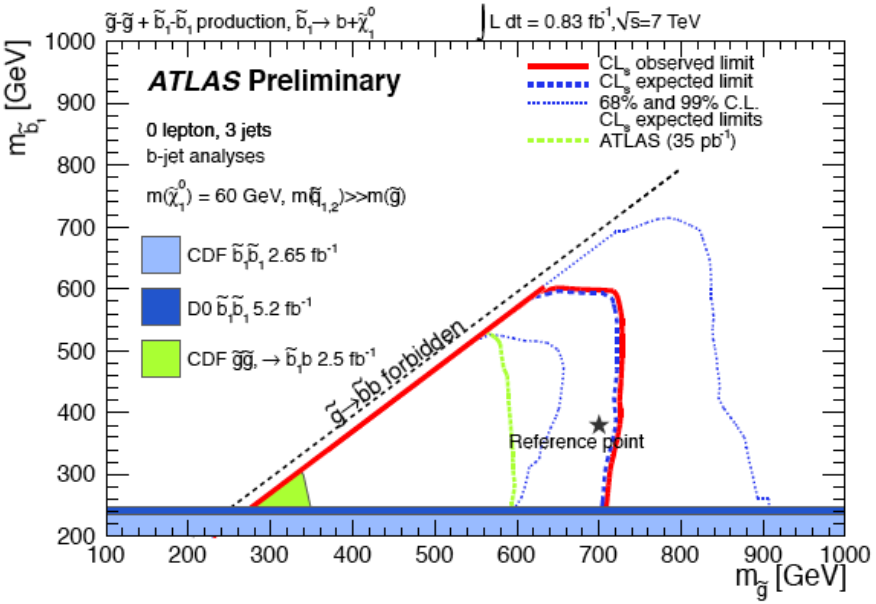
- All masses set to 5 TeV except gluino and 3rd generation squaks

$$Br(\tilde{g} \to \tilde{b}_1 b) = 100\% \text{ or } Br(\tilde{g} \to \tilde{t}_1 t) = 100\%$$

- M_{LSP}= 60 GeV

$$Br(\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}) = 100\%, m(\tilde{\chi}_1^{\pm}) = 2 \cdot m(\tilde{\chi}_1^0)$$

0-lepton + MET + ≥ 1 b-jet + ≥ 3 jets



Exculuded

- $m_{gluino} < 720$ GeV if $m_{sbottom} < 600$ GeV
- $m_{gluino} < 500$ GeV if $m_{stop} < 300$ GeV

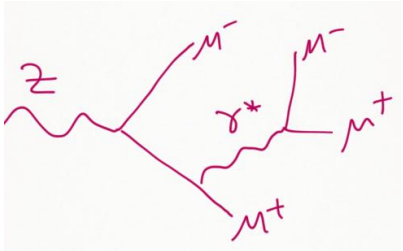
See dedicated talks by S. Lowette (CMS) and T. Sarangi (ATLAS)

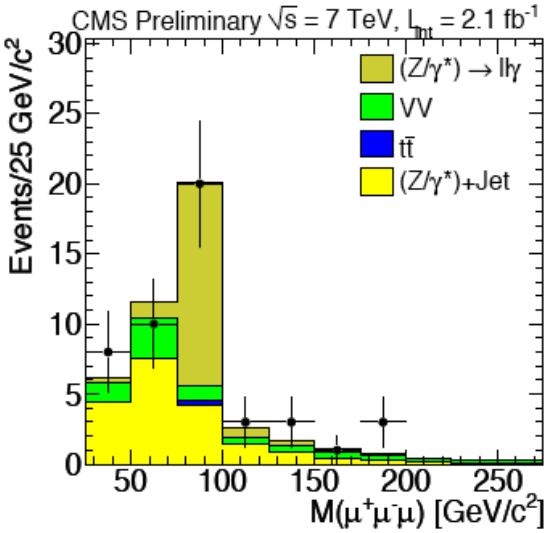
Multi-lepton + MET (CMS)

- ≥ 3 isolated high pT leptons (e, ⌠ and ⌡)
- Multiple search regions:
  - H_T >200 and/or MET > 50 GeV
  - Sensitivity for both EWKino and strong production with multi-leptons

- Depending on the search region the proportion of different backgrounds varies
- ttBar, ZZ, WZ, ttZ/W : take from simulation with large uncertainties

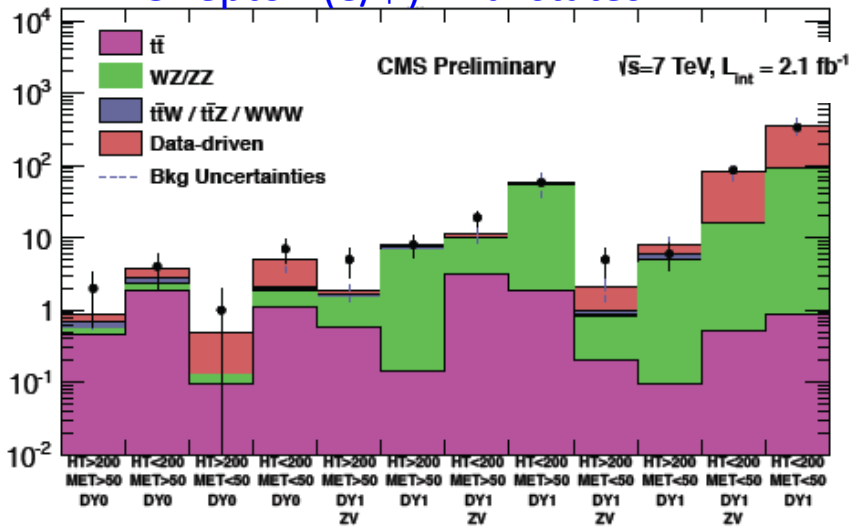
- Z+jets largely reduced @ high MET
  - Leptons arising from jets estimated from data
  - Z->3 leptons: with Internal/external photon conversions : is estimated from data using events with M(ℓ⁺ℓ⁻ℓ)/M(ℓ⁺ℓ⁻ ©) within the Z peak



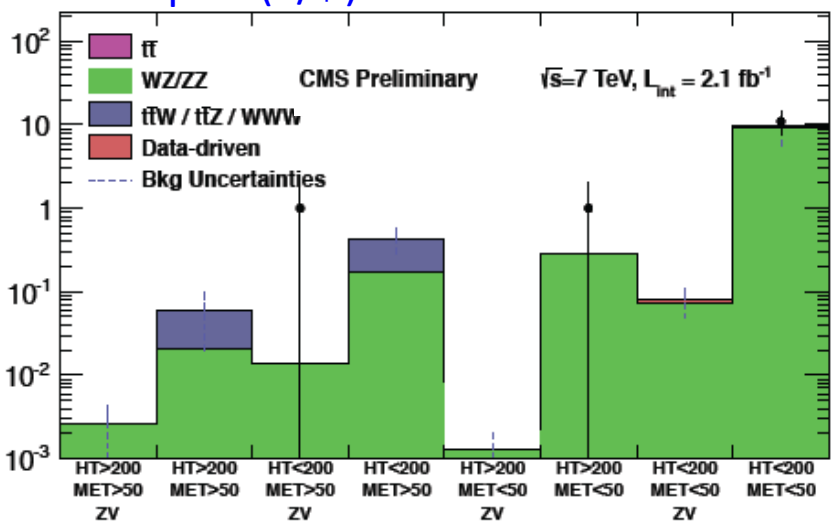


Multi-lepton + MET (CMS)

3-lepton (e/) final states



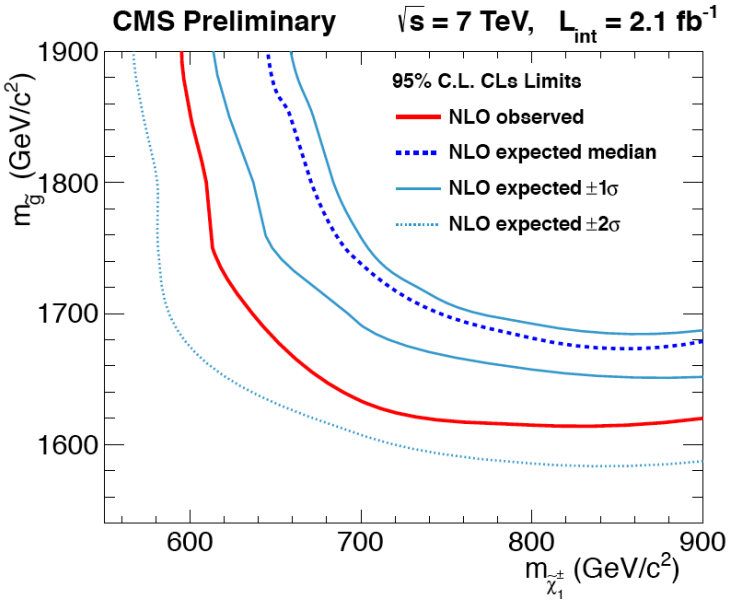
4-lepton(e/) final states



- Interpretation the GMSM framework, LSP= gravitino
  - slepton co-NLSP $\tilde{\ell} \rightarrow \ell + G$ - 100%
  - neutralino is bino like and next in the mass scale

$$B \rightarrow \tilde{\ell}^{\pm}\ell^{\mp} \rightarrow \ell^{\pm}\ell^{\mp} + \tilde{G}$$

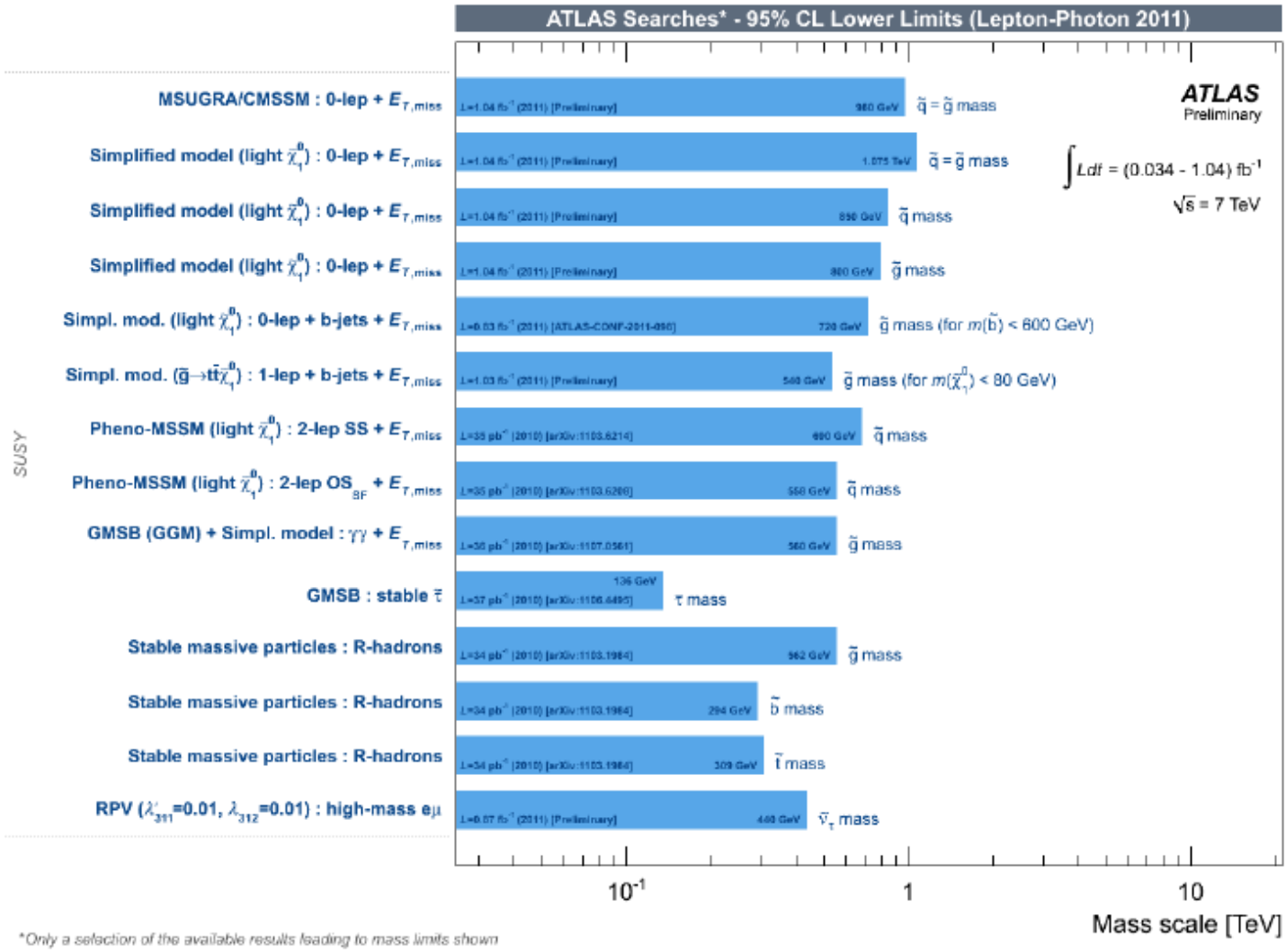
$M(\chi^{\pm}) < 600$ GeV and $M(g\tilde{}) < 1.6$ TeV
is excluded @ 95 CL



Summary & Outlook

- No excess yet
- still ~ 4 fb^{-1} to analyze -> few 100 GeV increase in mass reach
- Room for improving our searches:
  - going from cut & count -> shape analysis using (H_T, M_{eff}, Njets)
  - improve systematic uncertainties on backgrounds (The. & Exp.)
- New signatures
  - Extend existing analysis by requiring b-tagged jets: so far done only for 0/1-lepton+MET signatures -> SS(OS) di-leptons + b-jets
  - dedicated searches for 3rd generation squarks
  - and don't forget about tau
  - get ready to probe direct χ^+/χ^0 production (SS di- and multi-leptons)
- Many updates and new results are on the way

Backup



*Only a selection of the available results leading to mass limits shown

ATLAS SUSY searches typically probe masses ~ 500 – 1000 GeV