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REVIEW OF RECENT SUSY RESULTS AT THE LHC

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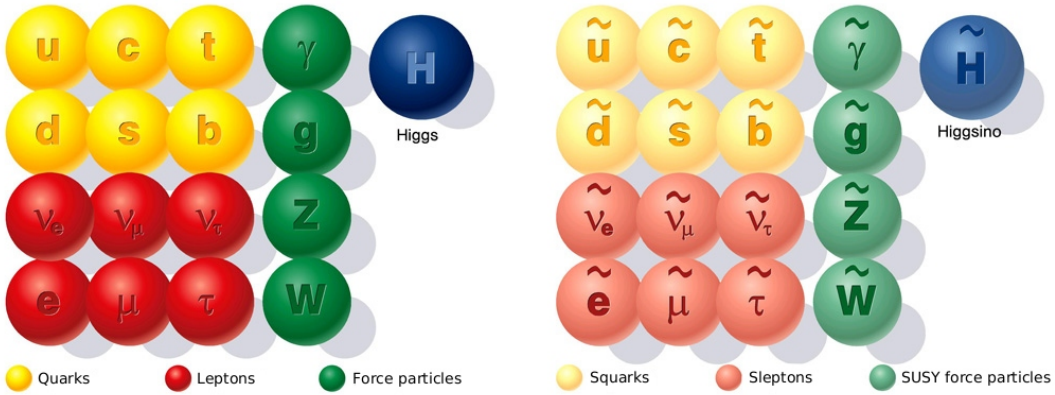
Minimal Extensions to the SM



Standard Model and SUSY particles (MSSM)

Fundamental idea of Supersymmetry (SUSY)

- Introduce an additional symmetry:

$$\text{fermion} \quad \overset{\Delta s = 1/2}{\longleftrightarrow} \quad \text{boson}$$

- Requires (basically) doubling the number of particles (MSSM)

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R-parity

Conservation

- Definition: R-parity $R_p = (-1)^{3B+L+2s}$
  B / L: baryon / lepton number, s: particle spin
- $\Rightarrow$ SM particle fields: $R_p = +1$, superpartner fields: $R_p = -1$
- Phenomenology:
  - superpartners produced in pairs ($\rightarrow$ 2 SUSY decay chains / event)
  - lightest supersymmetric particle (LSP) is stable ($\rightarrow$ DM candidate, $\not{E}_T$)
  - proton is stabilized

Violation

- R_p-violating terms in superpotential:

$$W_{\text{RPV}} = \mu_i H_u L_i + \frac{1}{2}\lambda_{ijk} L_i \cdot L_j \bar{E}_k + \lambda'_{ijk} L_i \cdot Q_j \bar{D}_k + \frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

- i, j, k: generation indices, λ: Yukawa couplings
- L, Q: lepton and quark $SU(2)$ doublet superfields ($L = +1$, $B = +1/3$)
  $\bar{E}$, $\bar{D}$, $\bar{U}$: charged lepton, down-like quark, up-like squark $SU(2)_L$ singlet superfields ($L = -1$, $B = -1/3$)
- λ_{ijk}, λ'_{ijk}: $\Delta L = 1$, λ''_{ijk}: $\Delta B = 1$

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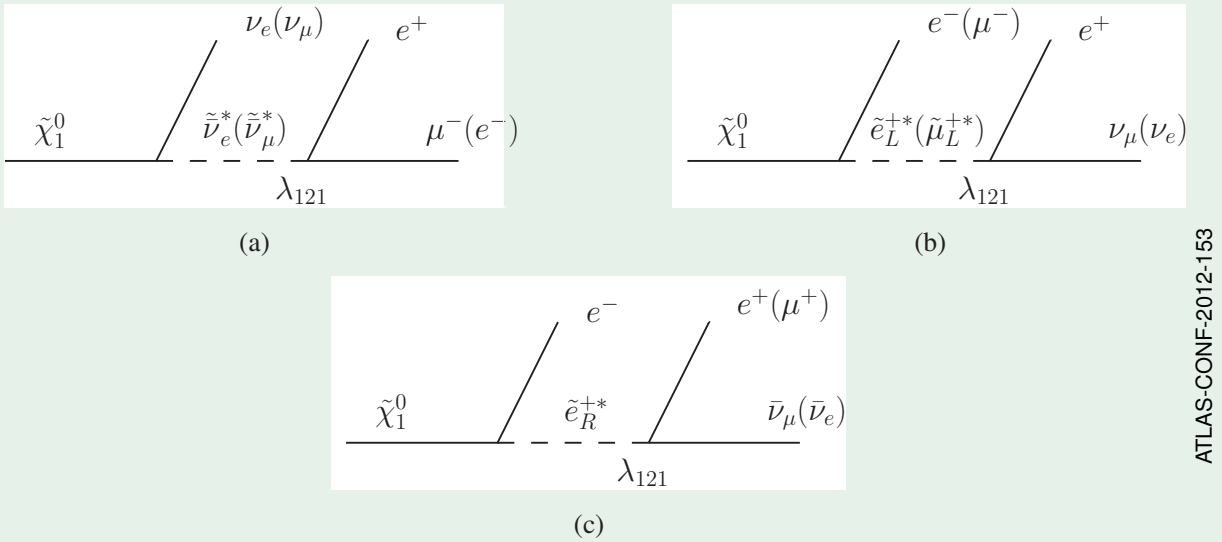
R-parity

Violation: Example with $\lambda_{121} > 0$



ATLAS-CONF-2012-153

Illustration of $\widetilde{\chi}_1^0$ decays via non-zero λ_{121}. In all cases, the charge conjugate decay is implied.

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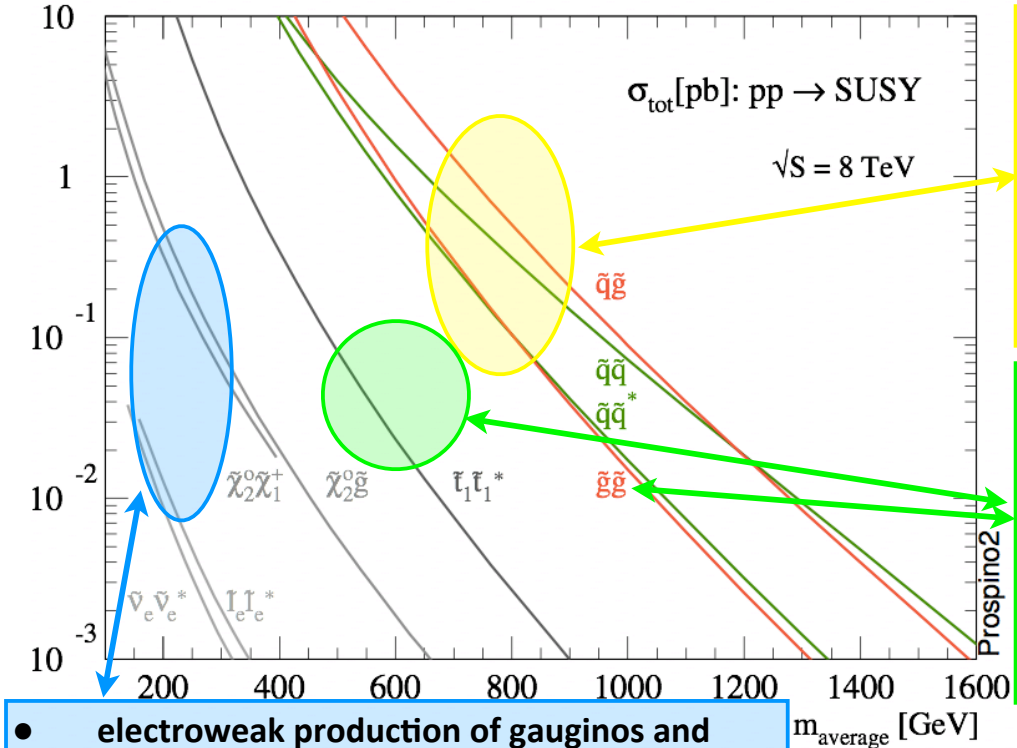
SUSY Searches at the LHC



- **strong production of 1st and 2nd generation scalar quark and gluinos**
  - significant cross section up to more than 1 TeV
  - decay to jets and weakly interacting SUSY particle (LSP): jets and E_T^{miss}
- ***third generation scalar quarks (direct production or gluino-mediated)***
  - significant cross-section for direct production
  - large top background
  - key ingredient in **natural SUSY**
- **electroweak production of gauginos and leptons**
  - small cross section, less than WW, ZZ
  - doable with current integrated luminosity
  - jet veto, leptons, moderate missing E_T
- the SUSY searches at 7 TeV (2010-2011 data) indicate that squark of the first two generations and gluinos might be heavier than ~1 TeV

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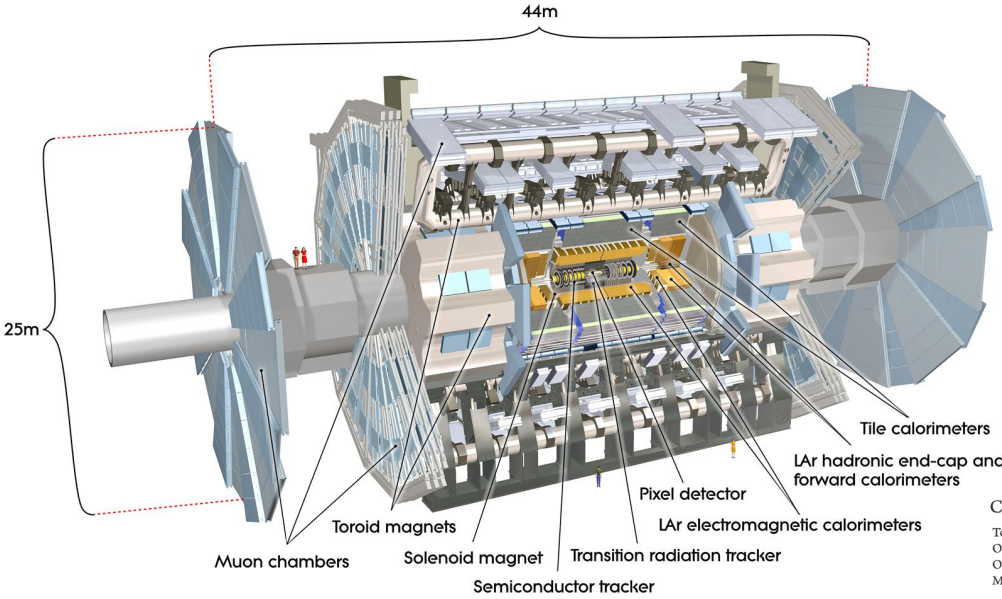
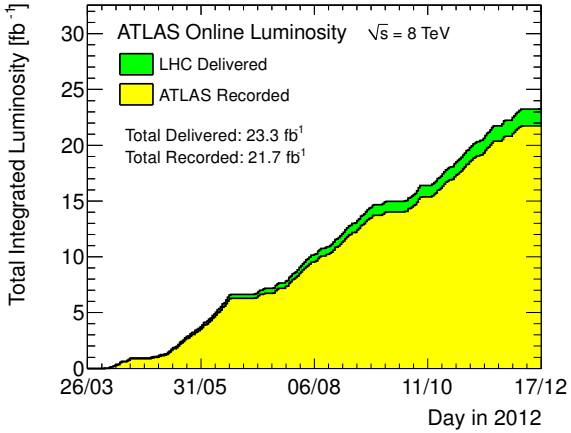
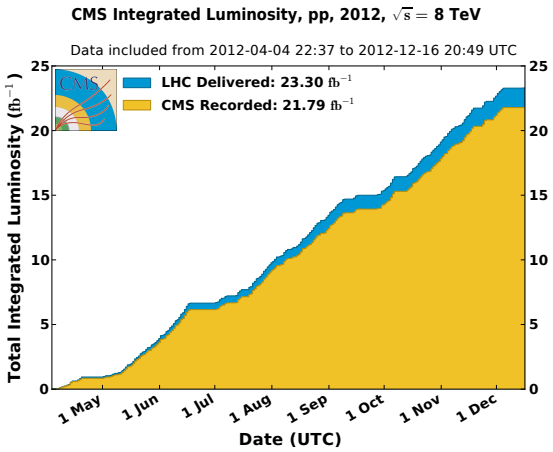
The ATLAS and CMS Detectors

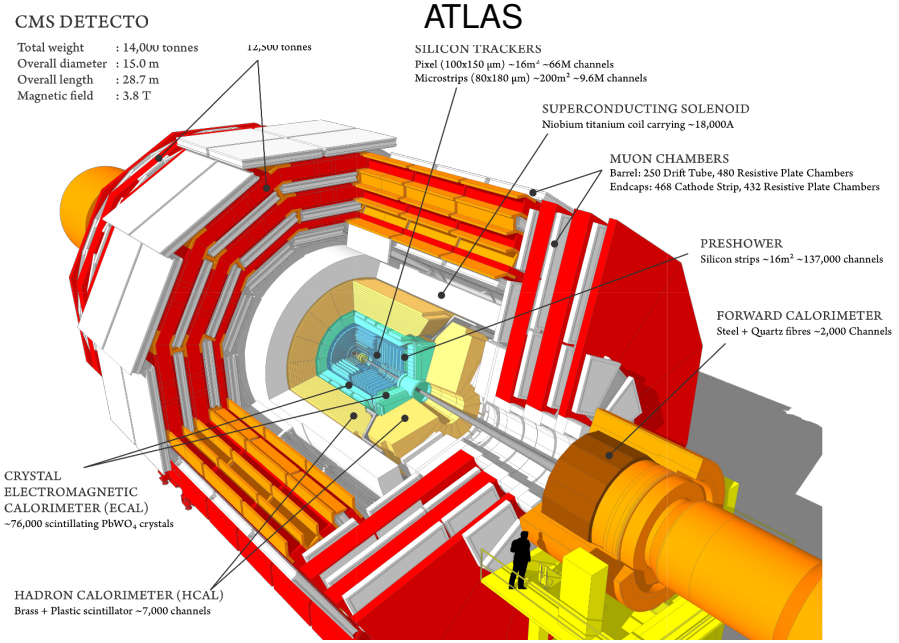






CMS

ATLAS



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Strong Production Searches

NLO cross sections for production of SUSY particles at $\sqrt{s} = 8\,\mathrm{TeV}$

Large cross sections allow to search for signatures with small BRs or long decay chains with heavy initial (SUSY) particles

mSUGRA/CMSSM Parameters

- $\rightarrow$ gravity-mediated SUSY breaking
- m_0: mass of scalar particles
- $m_{1/2}$: gaugino masses
- A_0: trilinear Higgs-sfermion-sfermion coupling parameter
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ

GMSB Parameters

- $\rightarrow$ gauge-mediated SUSY breaking
- Λ: SUSY breaking mass scale felt by the low-energy sector
- M_{mes}: mass scale of the messenger fields
- N_5: number of SU(5) messenger fields
- C_{grav}: scale factor of the gravitino coupling
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ

NGM

- starts from General Gauge Mediation
- GGM: no specific SUSY mass hierarchy is predicted for colored and uncolored states
  $\Rightarrow$ gluinos and squarks can be below the TeV scale = within reach of LHC
- NGM: decouple all sparticles not related to fine-tuning of Higgs sector
  $\Rightarrow$ light stop and light gluino as only light (relevant) coloured sparticle
- some additional mechanism needed (as in GMSB) to produce “correct” Higgs mass

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Kinematic Variables

α_T Variable

- For di-jet events:
  $\alpha_T = \frac{E_T(j_2)}{M_T}$ with $M_T = \sqrt{\left(\sum_{i=1}^{2} E_T(j_i)\right)^2 - \left(\sum_{i=1}^{2} p_x(j_i)\right)^2 - \left(\sum_{i=1}^{2} p_y(j_i)\right)^2}$
  (ratio of the p_T of the second hardest jet and the invariant mass formed from the two hardest jets)
- If $n_{\text{jet}} > 2$: use clustering such that ΔH_T between pseudojets minimized.
- $\alpha_T > 0.5$ indicates genuine $\not{E}_T$, QCD events have $\alpha_T < 0.5$.
- Cf. e. g. PRL 101, 221803 (2008).

- Transverse mass: $m_T^\ell = \sqrt{2 p_T^\ell \not{E}_T \left(1 - \cos(\Delta\phi(\vec{p}_T^{\,\ell}, \vec{p}_T^{\,\text{miss}}))\right)}$
  (useful in rejecting events with W bosons)
- Total visible energy (scalar sum of transverse momenta):
  $H_T = \sum_\ell p_T(\ell) + \sum_j p_T(j)$ (ℓ: selected leptons, j: selected jets)
- Effective mass: $m_{\text{eff}} = H_T + \not{E}_T$
  (correlates with overall mass scale of hard scatter, independent from details of SUSY cascade)

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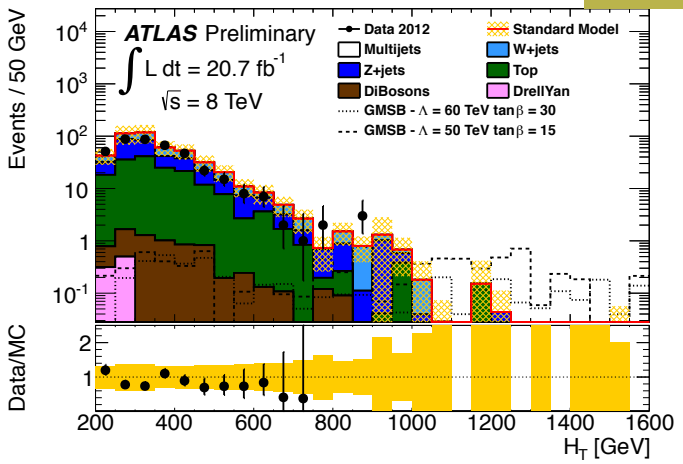
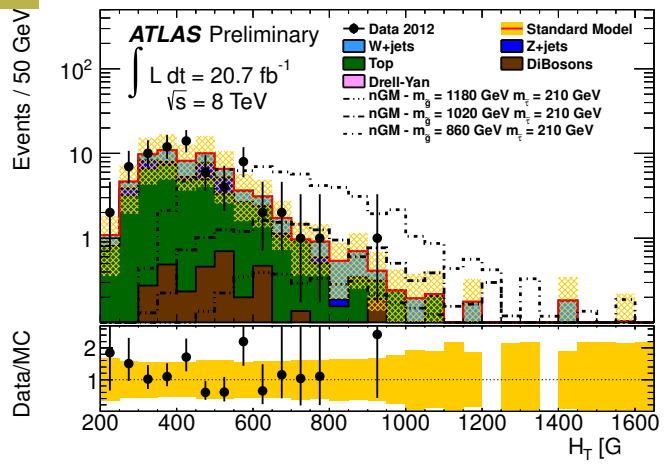
1 or ≥ 2 τ_s + jets + $\not{E}_T$ (ATLAS-CONF-2013-026)

- Motivation: GMSB with $\tilde{\tau}$ as NLSP $\Rightarrow$ final states with many taus
- Event selection:
  - 1 τ_h ($p_T > 30\,\mathrm{GeV}$) or ≥ 2 τ_h ($p_T > 20\,\mathrm{GeV}$), resp., no additional light leptons
  - Plus: $\not{E}_T > 150\,\mathrm{GeV}$, $p_T(j_1) > 130\,\mathrm{GeV}$ (trigger), $p_T(j_2) > 30\,\mathrm{GeV}$
  - QCD rejection: cuts on $\not{E}_T/m_{\mathrm{eff}}$, $\Delta\phi_{\mathrm{min}}(j, \not{E}_T)$
- Three signal regions:
  - 1τ GMSB, 2τ GMSB, 2τ nGM ($n_{\mathrm{jets}} \geq 4$)
  - Different cuts on m_T^{τ}, $H_T > 600\,\mathrm{GeV}$ to $> 900\,\mathrm{GeV}$
- Dominant backgrounds: Z/W + jets, top production

20.7 fb^{-1}@8 TeV





Final distribution of H_T in the 1τ GMSB SR and 2τ nGM SR (w/o N_{jet} cut)

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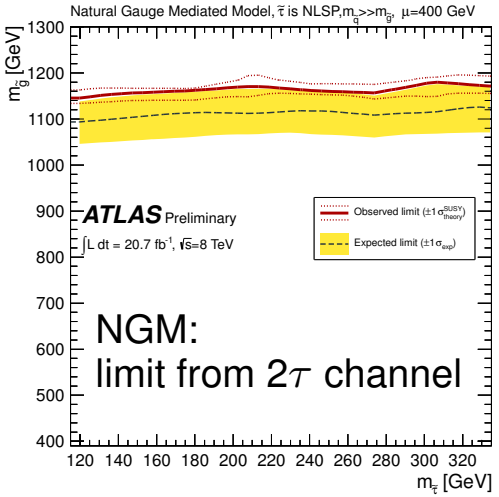
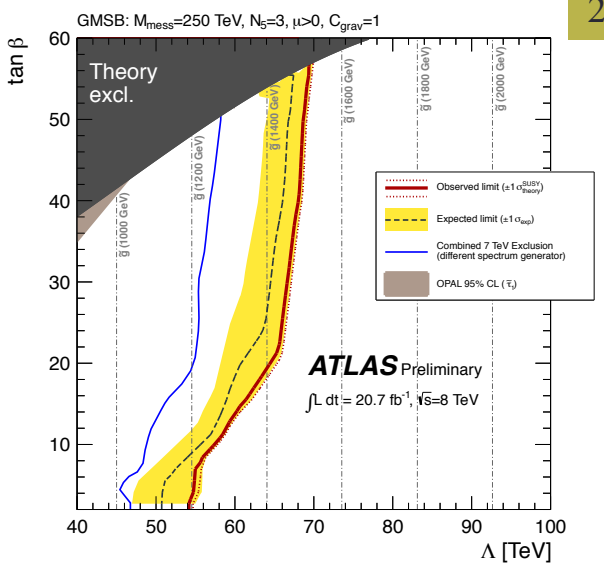
1 or ≥ 2 τ_s + jets + $\not{E}_T$ (ATLAS-CONF-2013-026)

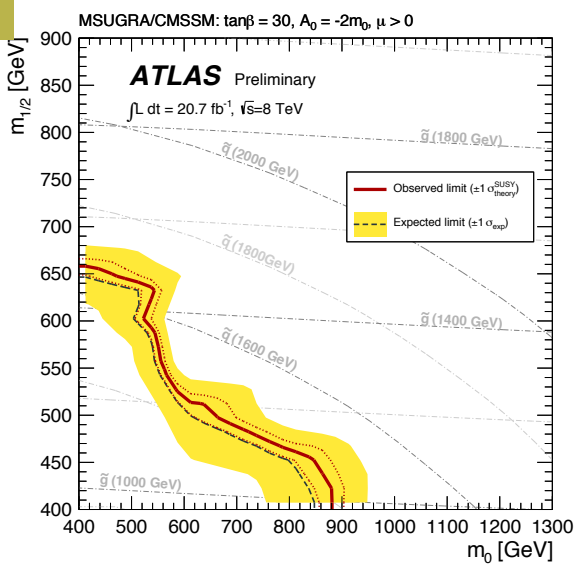
- No excess: ⇒ 95 % C.L. limits, (profile likelihood method, CL_s prescription)
- σ_{vis} down to 0.15 fb (2τ nGM SR)
- Interpreted in:
  - (Λ, tan β) plane (GMSB)
  - (m_0, $m_{1/2}$) plane (mSUGRA/CMSSM)
  - ($m(\tilde{\tau})$, $m(\tilde{g})$) plane (nGM)



20.7 fb^{-1}@8 TeV



GMSB: combined 1τ and 2τ limits



mSUGRA/CMSSM: limit from 1τ channel

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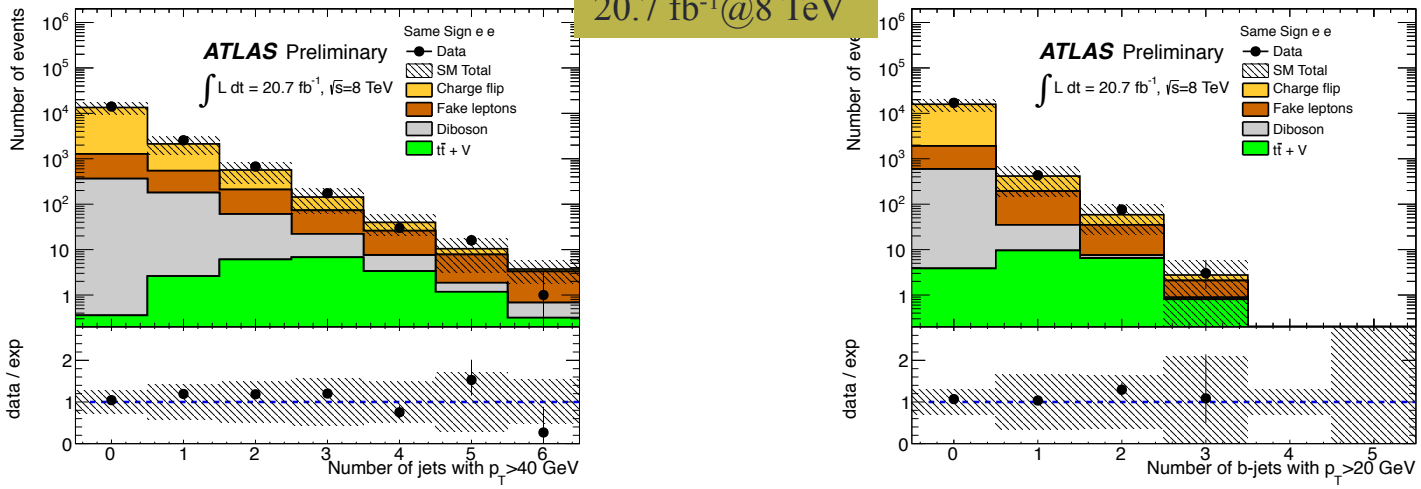
2 SS lep + jets + $\not{E}_T$ (ATLAS-CONF-2013-007)

- Motivation: pair-produced gluinos have same probability to give OS or SS lepton pairs $\rightarrow$ requiring SS lepton pairs suppresses Standard Model background
- Event selection:
  - 2 isolated same-sign leptons (ee, $e\mu$ or $\mu\mu$, $p_T > 20\,\mathrm{GeV}$)
  - 3 SRs (exclusion case): (1) + (2): $\geq$ 3 jets, $\not{E}_T > 150\,\mathrm{GeV}$, $m_T > 100\,\mathrm{GeV}$, 0 or $\geq$ 1 b-jet; (3): $\geq$ 5 jets, $\not{E}_T < 150\,\mathrm{GeV}$ or $m_T < 100\,\mathrm{GeV}$, $\geq$ 3 b-jets
- Main backgrounds:
  - charge misidentification (mainly e, $\rightarrow$ fully data-driven)
  - fake leptons (misidentified jets, heavy-flavor (HF) decays $\rightarrow$ from data)
  - real SS lepton pairs (diboson, $t\bar{t} + V$, VV + jets $\rightarrow$ from MC, checked in VRs)

20.7 fb^{-1}@8 TeV



Jet and b-jet multiplicity in ee channel before SR cuts

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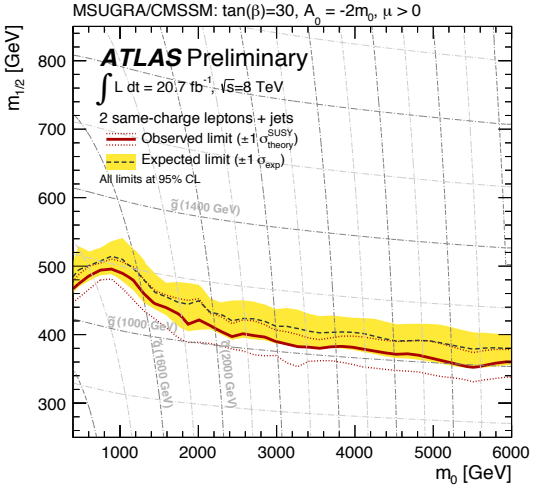
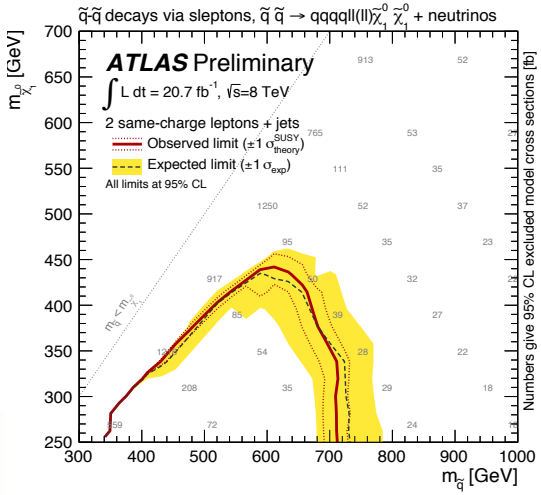
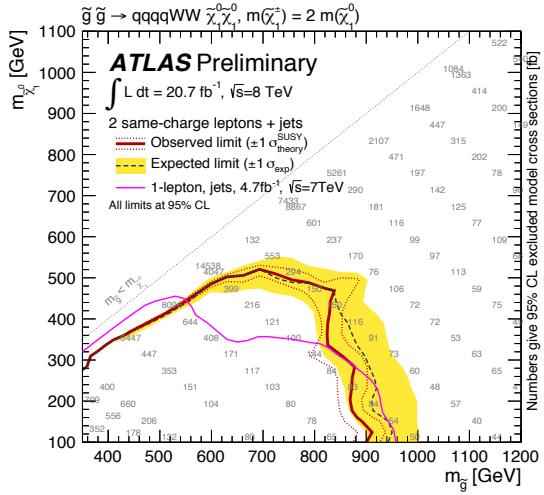
2 SS lep + jets + $\not{E}_T$ (ATLAS-CONF-2013-007)

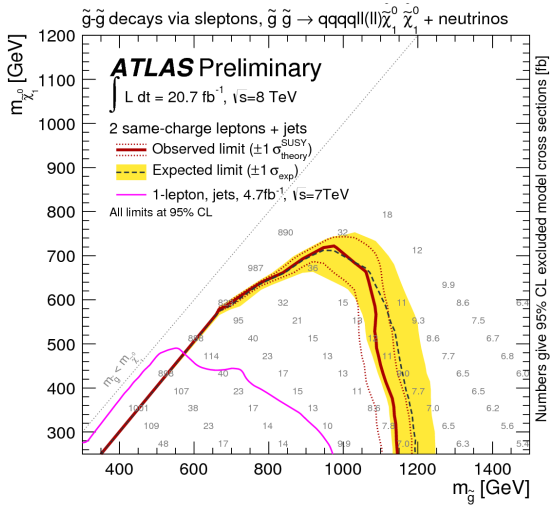
- Limits: simultaneous fit to all 3 SR using binned m_{eff} (profile likelihood method, CL_s prescription)
- Interpretation:
  σ_{vis} down to 0.50 fb (95 % C.L., SR with 0 *b*-jets)
- Model-dependent limits:
  - mSUGRA / CMSSM, “Higgs-compatible”
  - Many simplified models, e. g.:
    $\tilde{g} \to q\tilde{q}, \tilde{q} \to q'\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm} \to W^{\pm}\tilde{\chi}_1^0$ or $\tilde{\ell}\nu, \ell^{\pm}\tilde{\nu}$
    $\tilde{q} \to q'\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm} \to \tilde{\ell}\nu, \ell^{\pm}\tilde{\nu}$



20.7 fb^{-1}@8 TeV







Expected and observed 95 % C.L. limits

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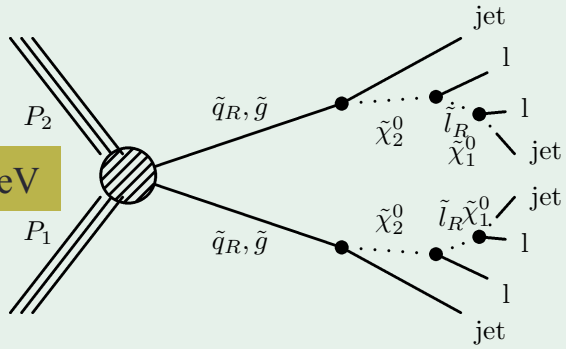
≥ 3 lep (e,μ,τ), w or w/o b-tags, RPV

(CMS-PAS-SUS-12-027)

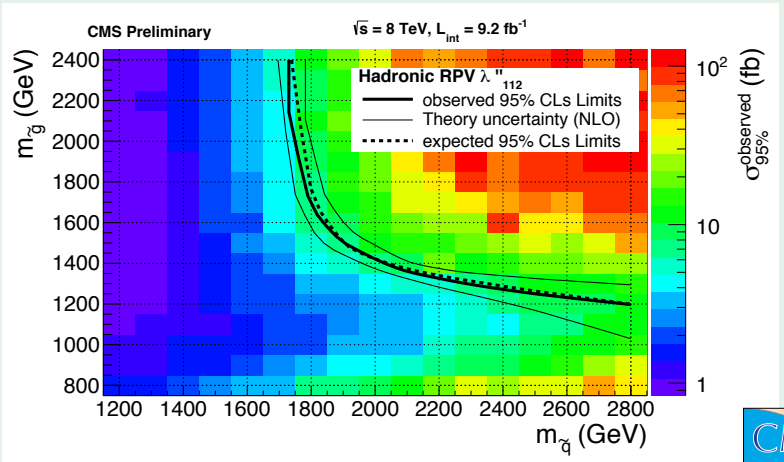
- *R*-parity violation ⇒ LSP unstable ⇒ use S_T instead of $\not{E}_T$:
  $S_T = \not{E}_T + \sum_{\text{jets}} E_T(j) + \sum_{\text{leptons}} p_T(\ell)$
- Event selection:
  - ≥ 3 isolated leptons ($\tau_\ell = e$ or μ, ≤ 1 τ_h)
- Classification: N_{OSSF}? Has an OSSF in Z window (75–105 GeV)? Has b-tags? Has a τ_h?
  - Binning in S_T ⇒ 240 exclusive channels
  - Limit setting: combine channels
- Interpretations in several RPV scenarios (and others) *(full stat's, $\tilde{t}\tilde{t}$: CMS-PAS-SUS-13-003)*

Hadronic RPV (here with $\lambda''_{112} > 0$)

9.2 fb^{-1}@8 TeV



$\tilde{\chi}_1^0 \rightarrow$ 3 jets, ⇒ 4 ℓ + jets, no $\not{E}_T$



$(m(\tilde{\chi}_1^0) = m(\tilde{\chi}_1^\pm) = 150\ \text{GeV}, m(\tilde{\ell}_R^\pm) = 300\ \text{GeV}, m(\tilde{\chi}_2^0) = 500\ \text{GeV}$, wino-like $\tilde{\chi}_1^0$, bino-like $\tilde{\chi}_2^0)$

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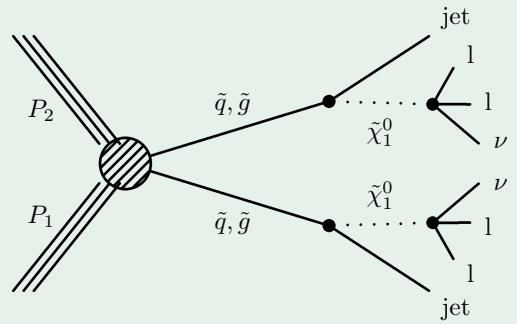
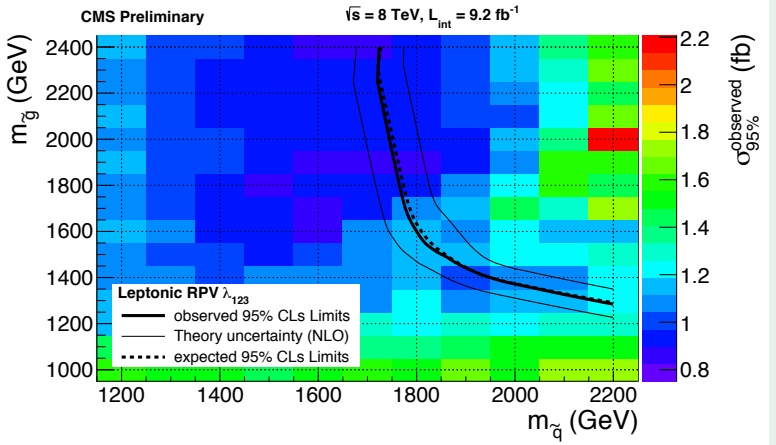
≥ 3 lep (e,μ,τ), w or w/o b-tags, RPV

(CMS-PAS-SUS-12-027)

Leptonic RPV (here with $m(\tilde{\chi}_1^0) = 300\,\mathrm{GeV}$, $\lambda_{123} > 0$, 2 tau + 2 light leptons)

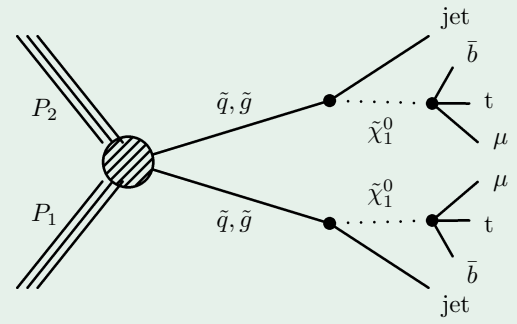


$\tilde{\chi}_1^0 \to \ell_i + \nu_j + \ell_k$ or $\tilde{\chi}_1^0 \to \nu_i + \ell_j + \ell_k$

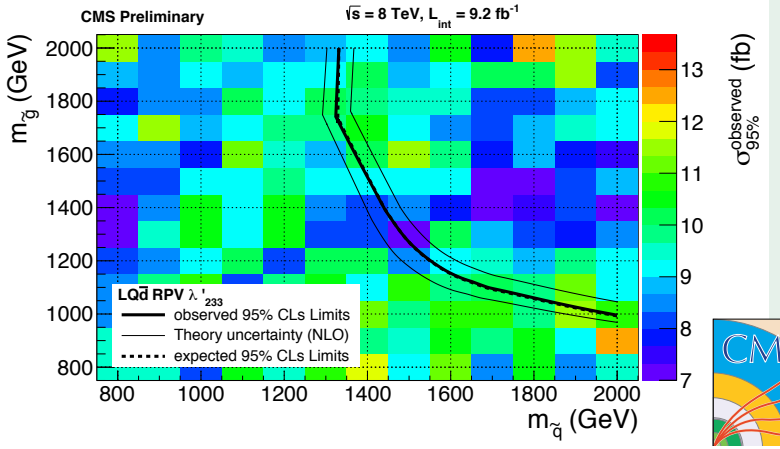


9.2 fb^{-1}@8 TeV

$LQ\bar{D}$ RPV (here with $m(\tilde{\chi}_1^0) = 700\,\mathrm{GeV}$, $\lambda'_{233} > 0$, ≥ 4 b-jets)



$\tilde{\chi}_1^0 \to \mu + t + \bar{b}$ or $\tilde{\chi}_1^0 \to \nu + b + \bar{b}$



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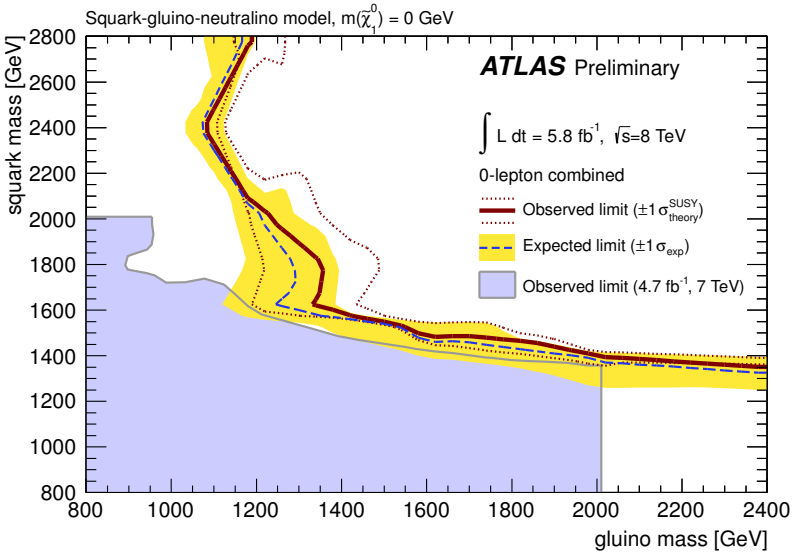
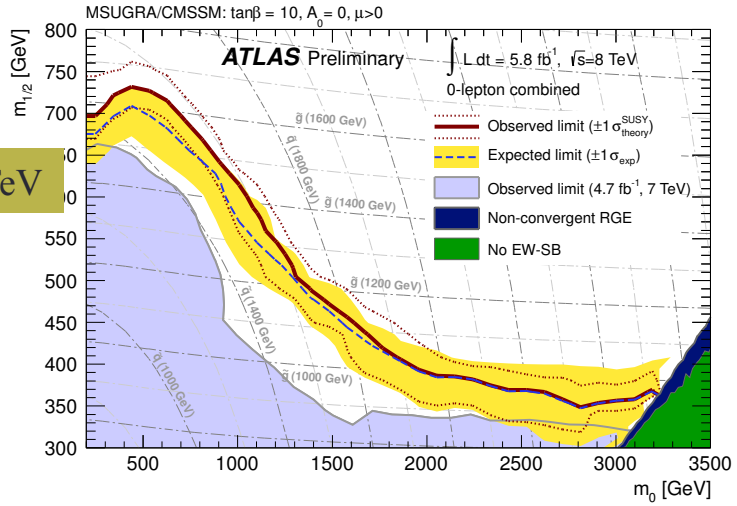
0 lep + jets + $\not{E}_T$

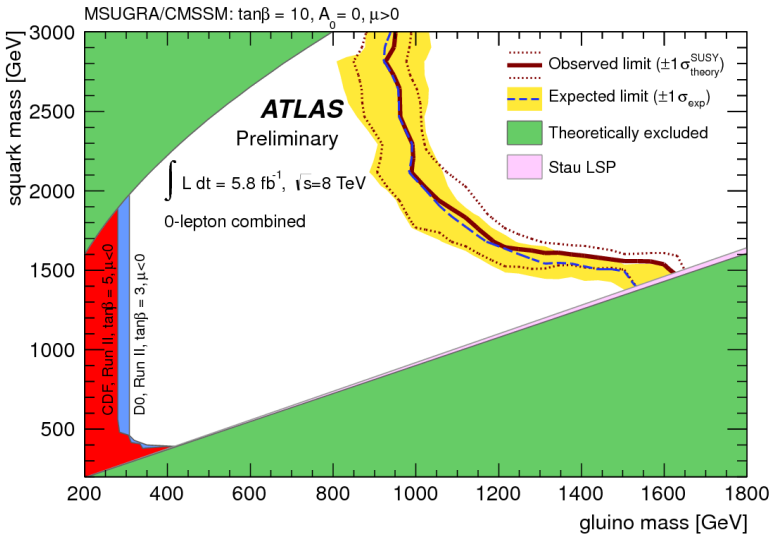
(ATLAS-CONF-2012-109)

- Target: $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, $\tilde{g}\tilde{g} \rightarrow$ jets + $\tilde{\chi}_1^0$
- Event selection:
  - $\not{E}_T > 160\,\mathrm{GeV}$, jets with $p_T > 130, 60\,\mathrm{GeV}$
  - veto e, μ with $p_T > 20, 10\,\mathrm{GeV}$
  - 5 incl. channels ($\geq 2 \ldots 6$ jets) à $1-3$ SRs: cuts on $\not{E}_T/m_{\mathrm{eff}}$, $m_{\mathrm{eff}}^{\mathrm{incl}}$, $\Delta\phi_{\mathrm{min}}(\mathrm{jets}, \not{E}_T)$
- Main backgrounds:
  - $W+$ jets, $Z+$ jets, $t\bar{t}+t$, QCD
  - 4 CRs for each SR, background fit
- Interpretation:
  - Best limit: $\sigma_{\mathrm{vis}} < 0.57\,\mathrm{fb}$ (4 jets, tight SR)
  - mSUGRA/CMSSM, simplified models / MSSM



5.8 fb^{-1}@8 TeV





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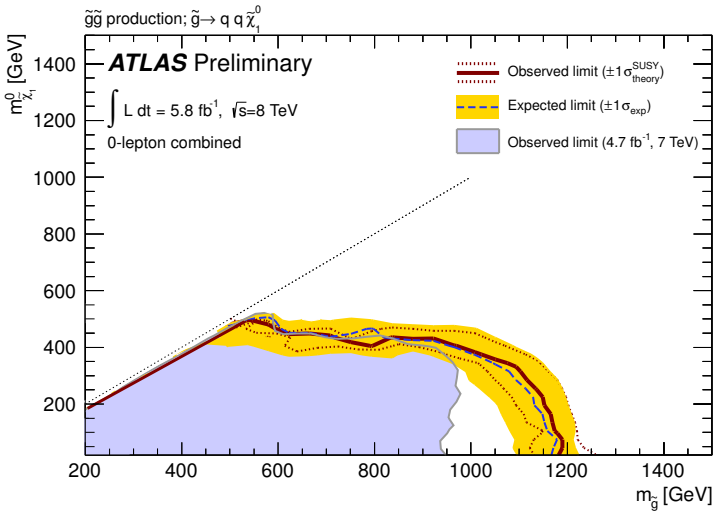
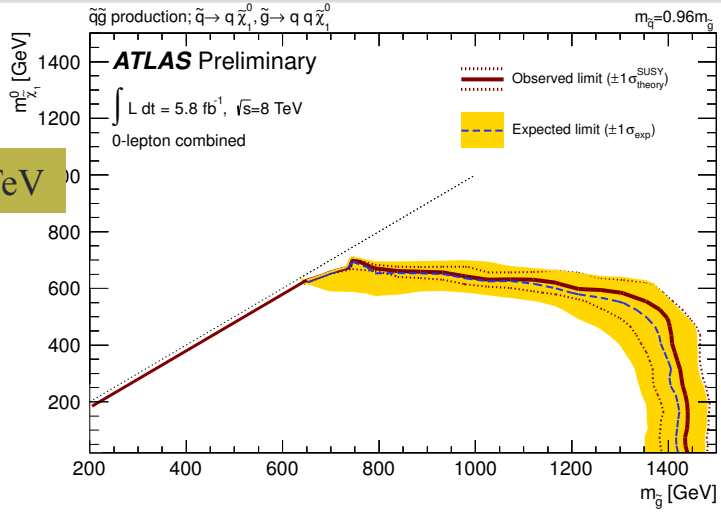
0 lep + jets + $\not{E}_T$

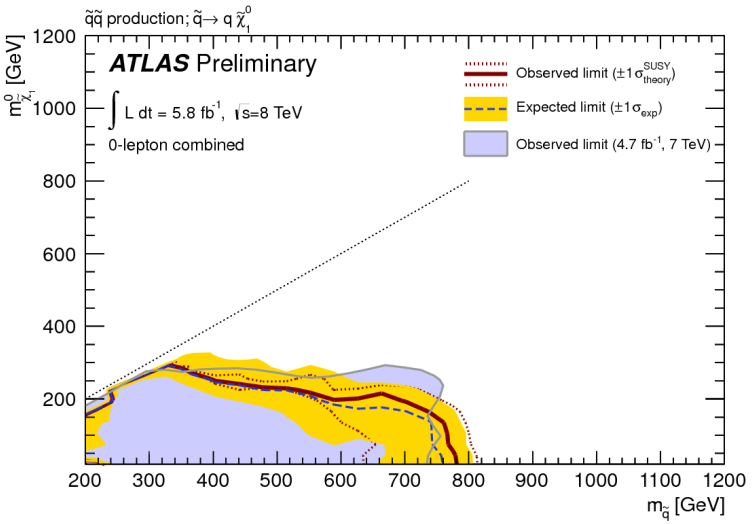
(ATLAS-CONF-2012-109)

- Target: $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, $\tilde{g}\tilde{g} \rightarrow$ jets + $\tilde{\chi}_1^0$
- Event selection:
  - $\not{E}_T > 160\,\mathrm{GeV}$, jets with $p_T > 130, 60\,\mathrm{GeV}$
  - veto e, μ with $p_T > 20, 10\,\mathrm{GeV}$
  - 5 incl. channels ($\geq 2 \ldots 6$ jets) à $1-3$ SRs: cuts on $\not{E}_T/m_{\mathrm{eff}}$, $m_{\mathrm{eff}}^{\mathrm{incl}}$, $\Delta\phi_{\mathrm{min}}(\mathrm{jets}, \not{E}_T)$
- Main backgrounds:
  - $W+$ jets, $Z+$ jets, $t\bar{t}+t$, QCD
  - 4 CRs for each SR, background fit
- Interpretation:
  - Best limit: $\sigma_{\mathrm{vis}} < 0.57\,\mathrm{fb}$ (4 jets, tight SR)
  - mSUGRA/CMSSM, simplified models / MSSM



5.8 fb^{-1}@8 TeV





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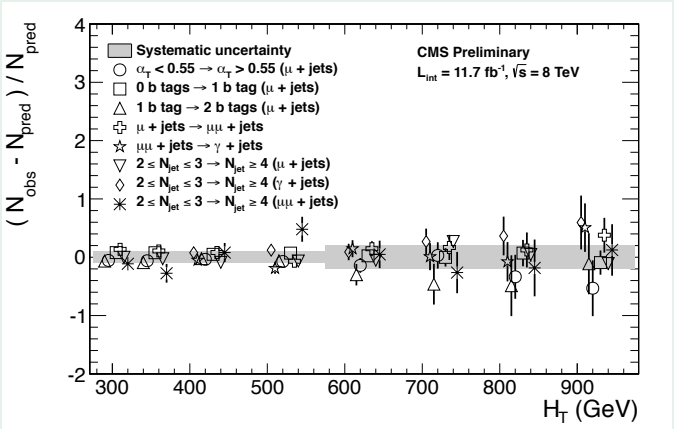
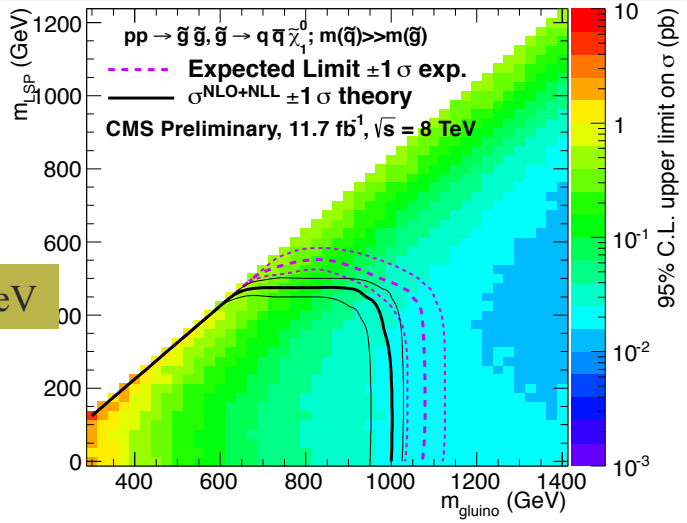
Jets + $\not{E}_T$ w or w/o b-jets (CMS-PAS-SUS-12-028)

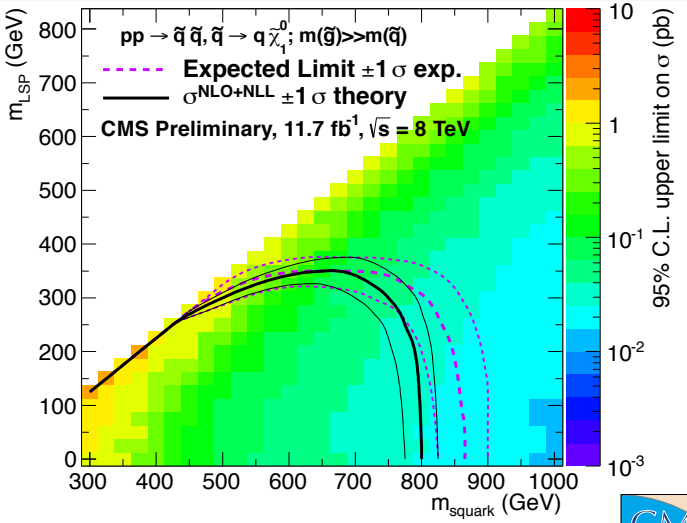
- Targeted final state: $\not{E}_T$ + jets ($p_T > 50\,\mathrm{GeV}$) veto e, μ ($p_T > 10\,\mathrm{GeV}$) and γ ($p_T > 25\,\mathrm{GeV}$)
- $\alpha_T > 0.55$ selects events with genuine $\not{E}_T$
- SR: 8 bins in $H_T = \sum_{\text{jets}} E_T$, event categories:
  - number of reconstructed jets (2 or 3, ≥ 4)
  - number of b-jets (0, 1, 2, 3, ≥ 4)
- Backgrounds: from 3 CRs, transfer factors from MC, closure tests between CRs
- Limits set in several simplified models



11.7 fb^{-1}@8 TeV



pair-produced gluinos, ≥ 4 jets



pair-produced squarks, 2 – 3 jets

(results also interpreted in 3rd generation context)

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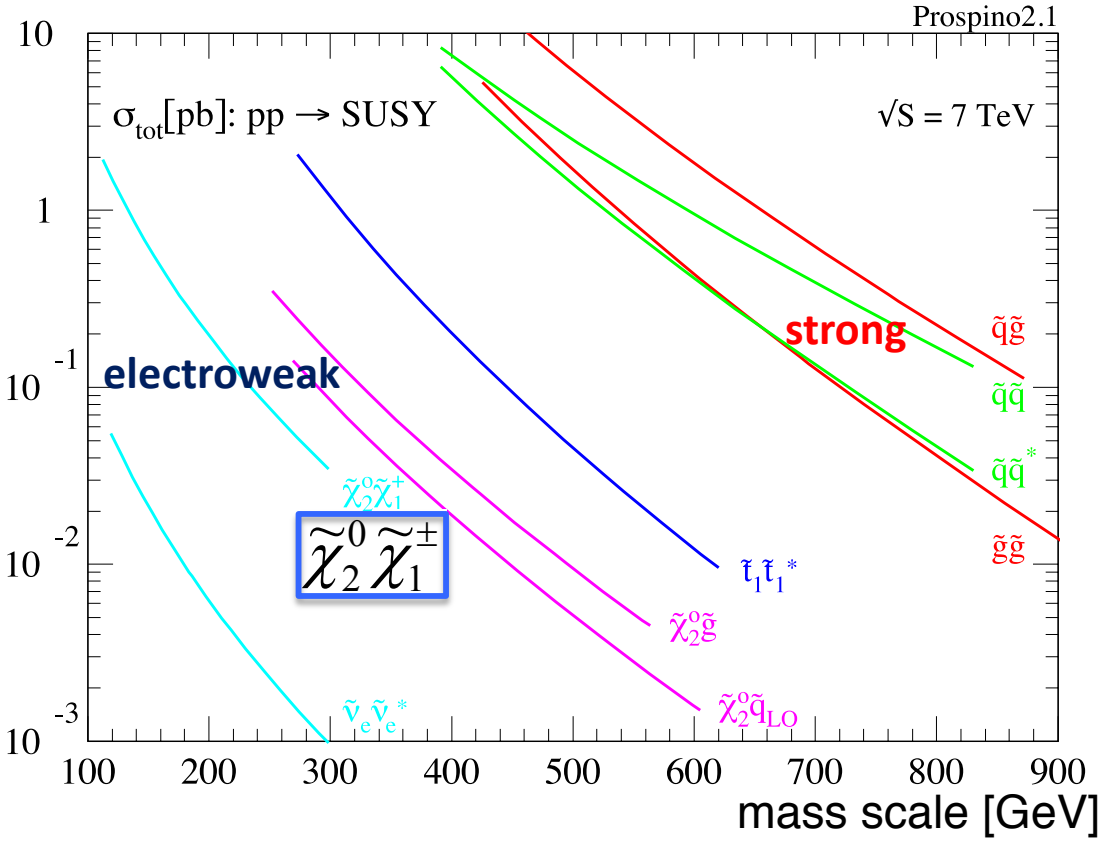
Weak SUSY Production

- Most SUSY searches have focused on strong production, which has the largest cross section



- Limits on these models probe masses of strongly-interacting particles up to ~1 TeV
  - Similar cross-sections to EWK gaugino's of 300-400 GeV
- Interesting when squarks and gluino's are heavy, but EWKinos are light

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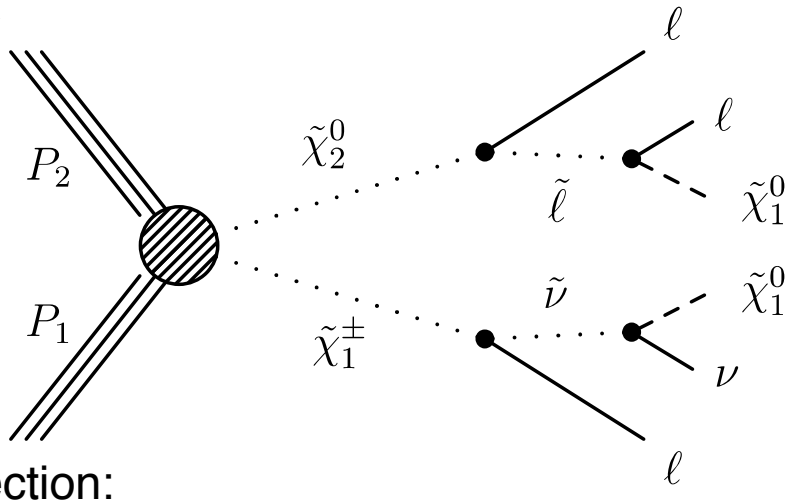
Strategy for the Searches

- Look for direct pair production of gaugino's and sleptons:
  - Very clean multi-lepton signatures
  - Low hadronic activity



- Main backgrounds and rejection:
  - Diboson backgrounds: apply Z mass cut
    - Not for intermediate vectorboson searches
  - ttbar: apply b-jet veto (or jet-veto)
  - Binning in MET or other kinematic variable (m_{T2}, m_{CT})
- Background estimation:
  - Non-prompt backgrounds: data-driven techniques
  - Diboson backgrounds: validated MC, with data-driven corrections
- Main focus on 8 TeV results

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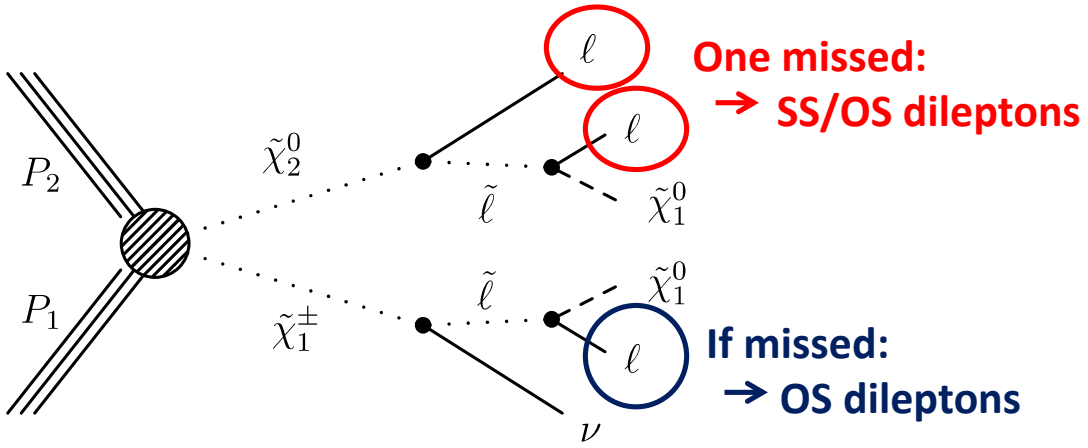
Chargino-neutralino Production

chargino-neutralino production: light sleptons and sneutrinos



- **Model naturally gives 3ℓ (off-Z) signatures, but can give 2ℓ or 3ℓ (on-Z) signatures, depending on mass spectrum**
  - flavor-democratic or tau-enriched

- Dedicated analyses:
  - 3-lepton searches (ATLAS+CMS, 8 TeV)
  - CMS: same-sign di-lepton analysis (Veto third lepton, fully exclusive)
  - ATLAS: same-sign and opposite sign jet-veto analysis (7 TeV)

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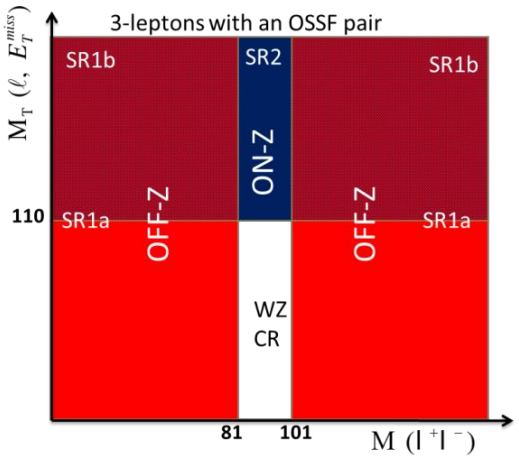
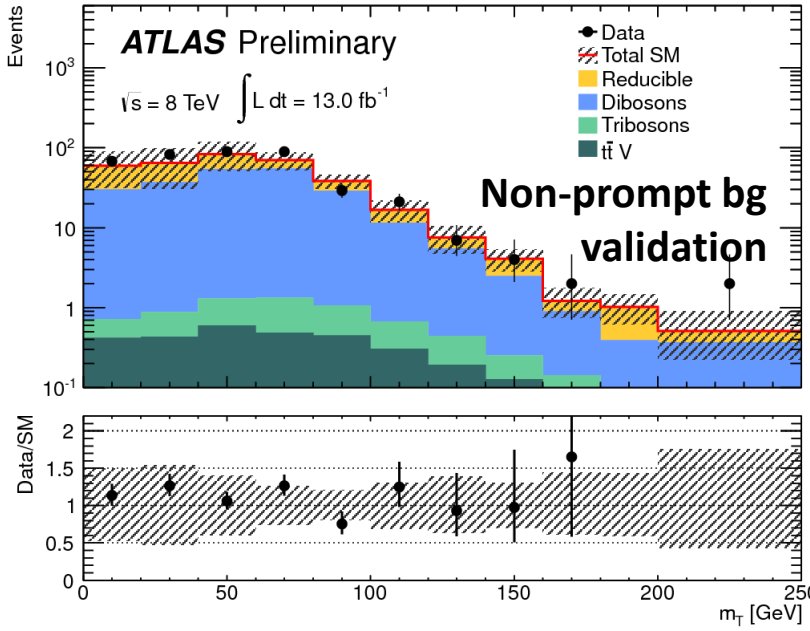
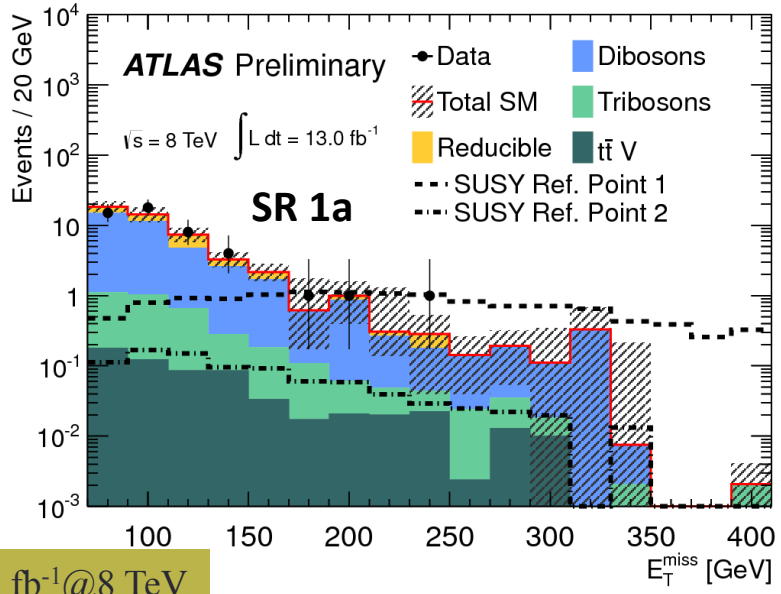
3 lep (e/μ) + $\not{E}_T$ (ATLAS-CONF-2012-154)

- 3 main search regions, targeted for specific models, with :
  - SR 1a: MET>75 GeV, Z-veto and b-jet veto
  - SR 1b: same as SR1a + m_T>110 GeV, lepton p_T>30 GeV
  - SR 2: Z candidate, m_T>110 GeV, MET>120 GeV
- Normalize WZ simulation to WZ control region
- Data-driven non-prompt prediction



8 TeV





13 fb^{-1}@8 TeV

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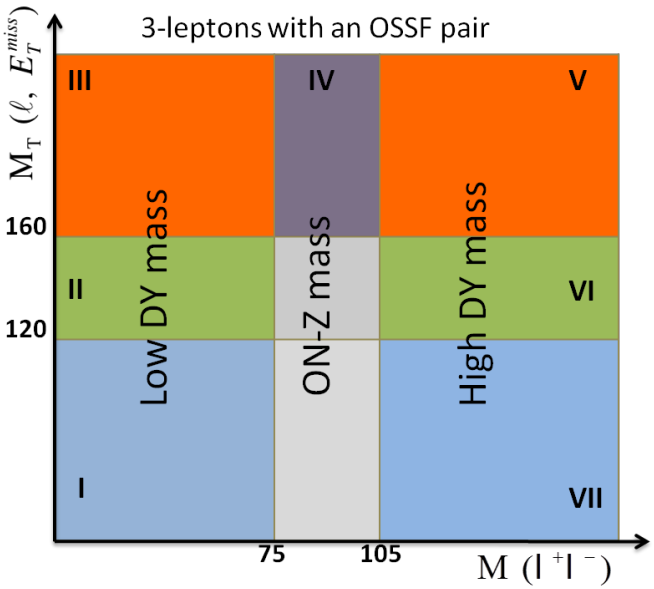
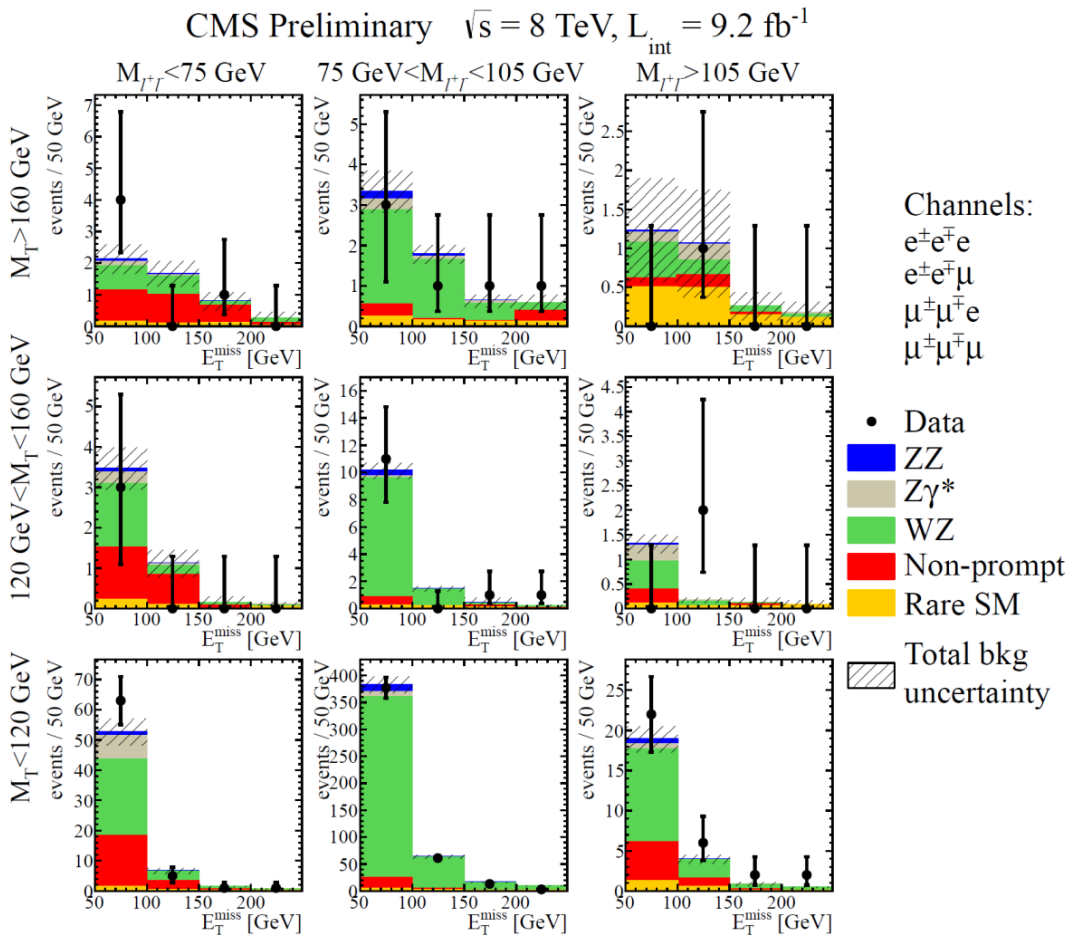
3 lep (e/μ/τ) + $\not{E}_T$ (CMS-PAS-SUS-12-022)

- Use 3D binning : MET, m_T and dilepton mass
  - 50 GeV MET bins
- b-jet veto to suppress ttbar
- Correction to WZ MC MET resolution
- Also hadronic taus and no OS same-flavor pairs
  - Tau-enriched models

8 TeV





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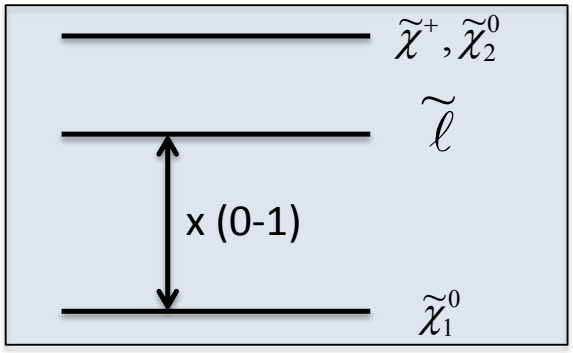
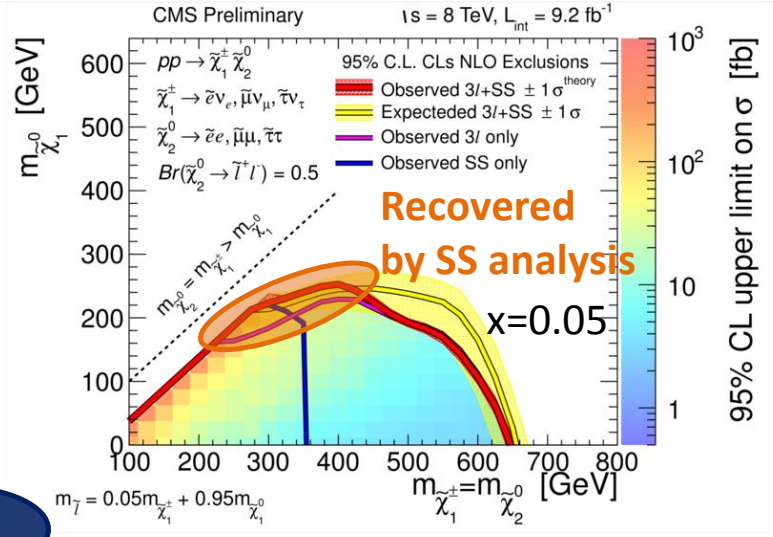
Limits in 3 lep final states

Same branching fraction to e,μ,τ

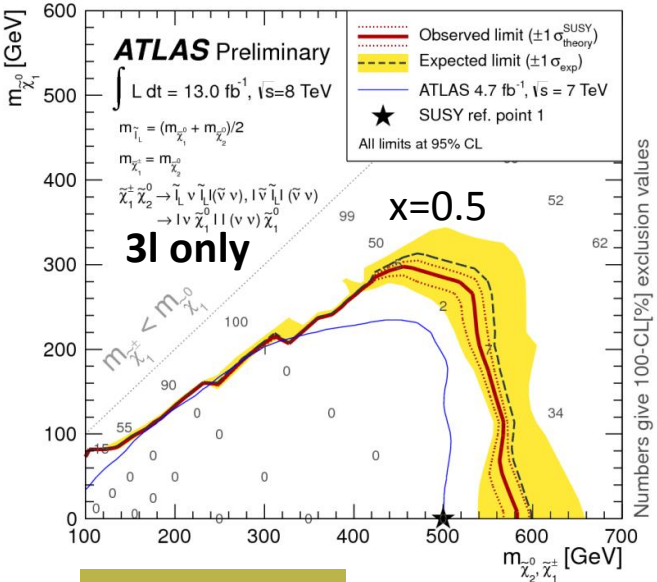


$m_{slep} = x \cdot m_{\chi^+} + (1-x) \cdot m_{LSP}$

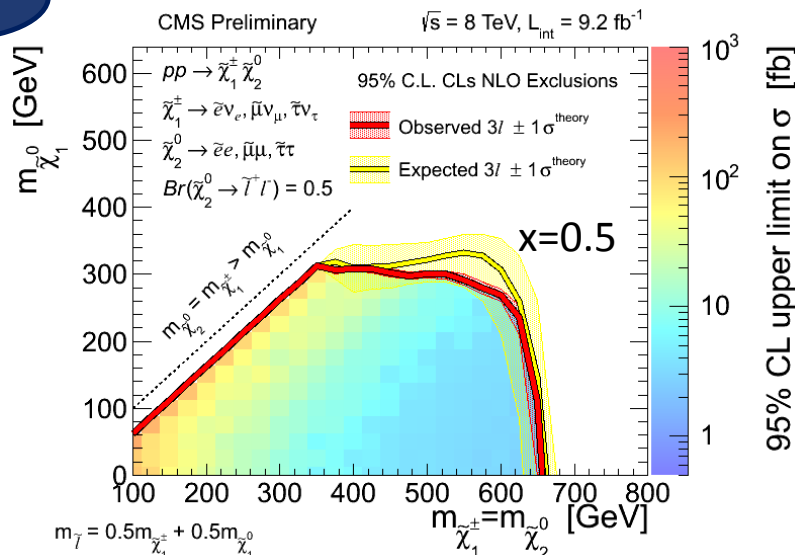
9.2 fb^{-1}@8 TeV



8 TeV



13 fb^{-1}@8 TeV



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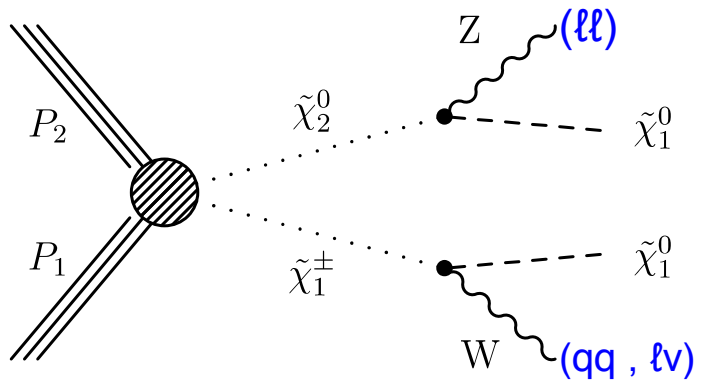
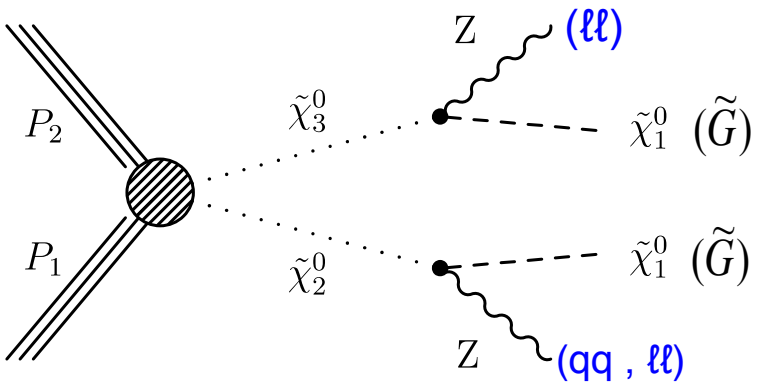
Direct Decays to W/Z Bosons

chargino-neutralino production: direct decays to W/Z bosons (heavy sleptons)





- **Model naturally gives 3ℓ and 4l (on-Z) and 2l (on-Z) + jets signatures**
  - Neutralino pair production suppressed, use GMSB model

- Dedicated analyses:
  - 3-lepton + M(ll) + MT
  - 2-lepton + di-jet + MET

- Dedicated analyses:
  - 4-lepton + MET
  - 2-lepton + di-jet + MET

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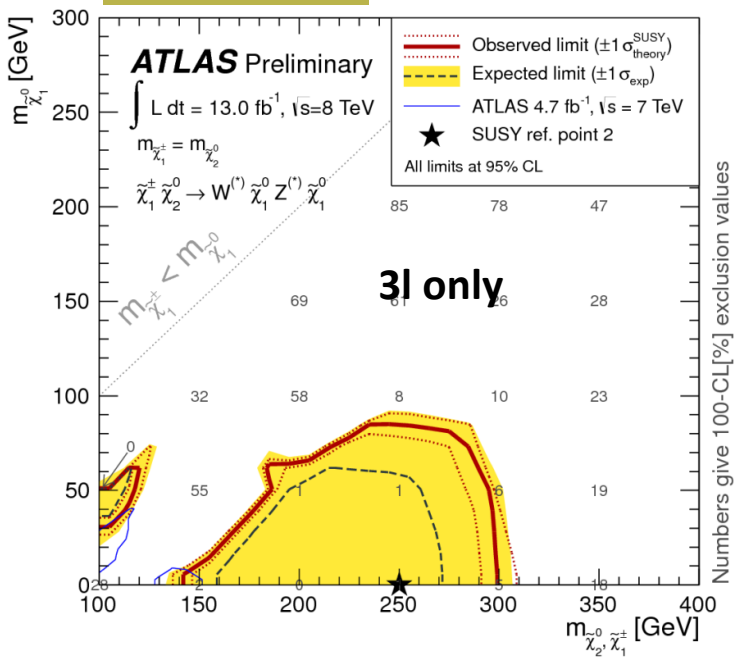
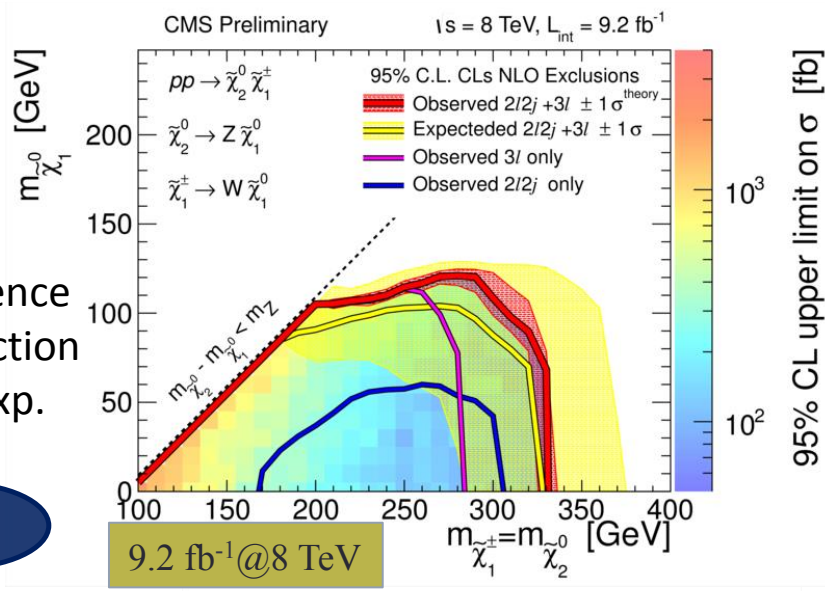
W/Z and GMSB Higgsino (ATLAS-CONF-2012-154) (CMS-PAS-SUS-12-022)

13 fb^{-1}@8 TeV

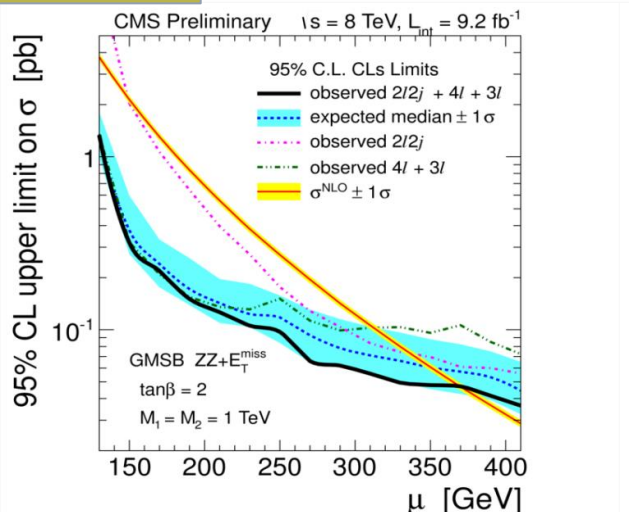


10% difference in cross-section between exp.

8 TeV



9.2 fb^{-1}@8 TeV



- Neutralino pair production in gauge-mediated symmetry breaking (GMSB) higgsino model
  - Exclusion in terms of parameter (μ) that controls the masses for Chargino and LSP

$$m_{\tilde{\chi}_1^\pm} \approx m_{\tilde{\chi}_1^0} \approx \mu$$

ATLAS Z+jets analysis: similar search in cascade decay

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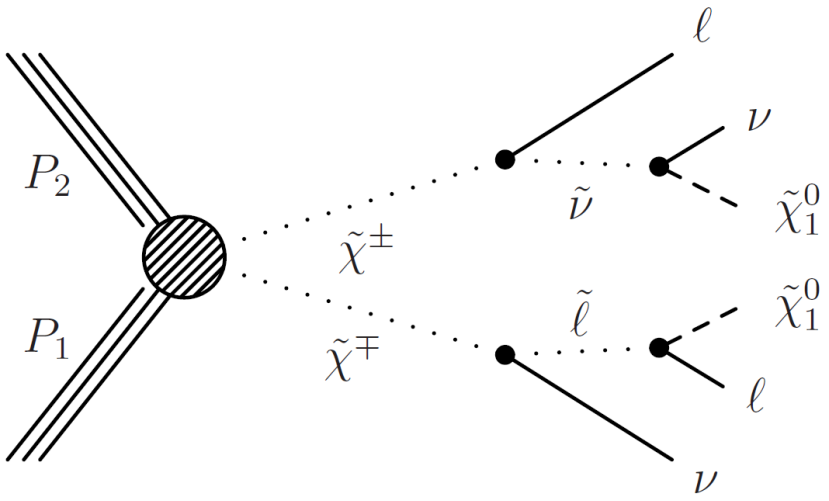
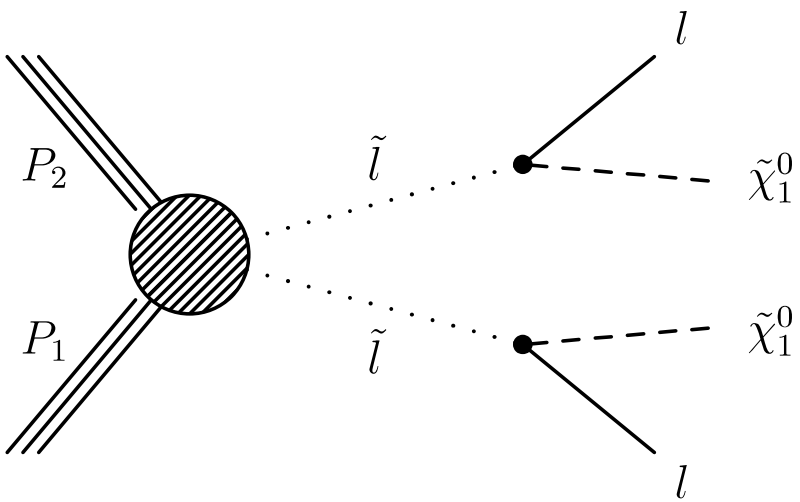
Chargino and Slepton Pair Production





- **Model naturally gives 2ℓ (off-Z) signatures**

- Dedicated analysis:
  - opposite -sign di-lepton analysis

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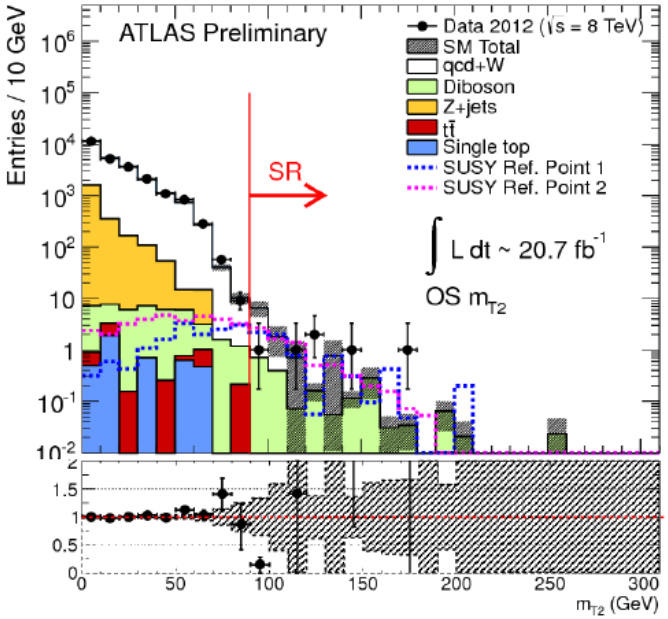
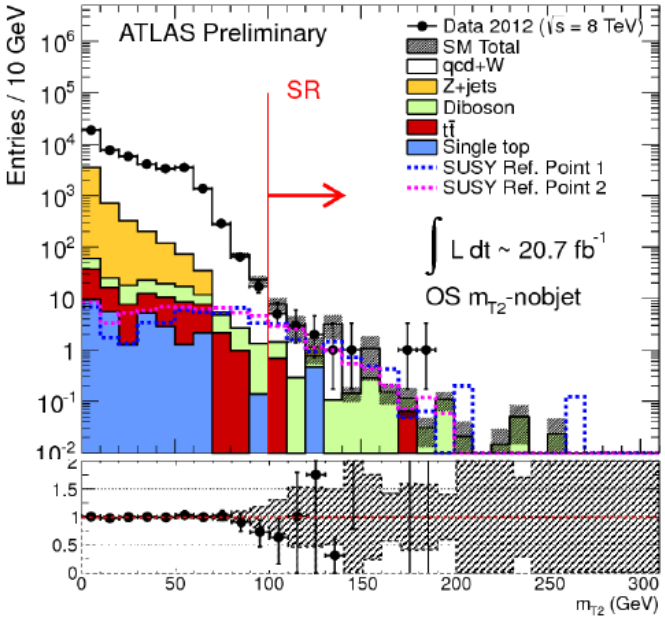
Intermediate Stau Production

(ATLAS-CONF-2013-028)

- Chargino/neutralino pair production or chargino pair production only through intermediate staus
- SR 1: OS hadronic tau, Z-veto, jet-veto, MET>40, m_{T2}>90 GeV
- SR 2: OS hadronic tau, Z-veto, b-jet-veto, MET>40, m_{T2}>100 GeV





8 TeV

- ABCD technique for multi-jet and W+jet backgrounds

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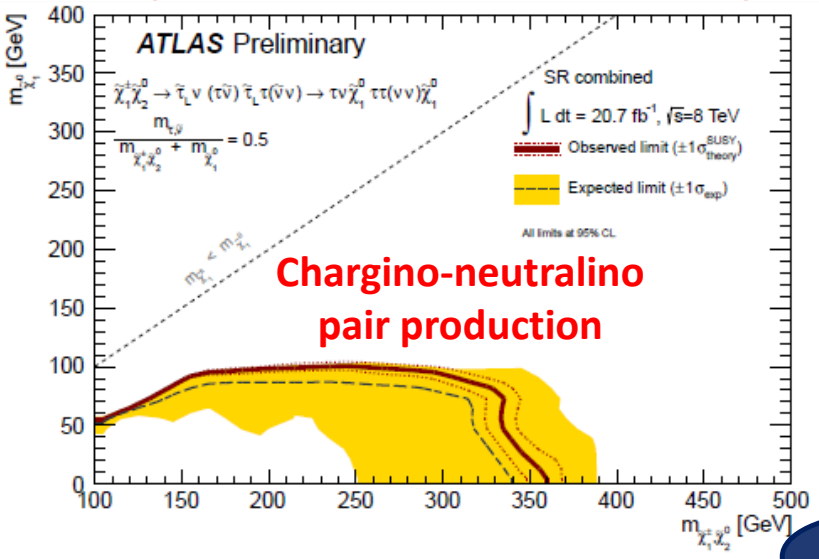
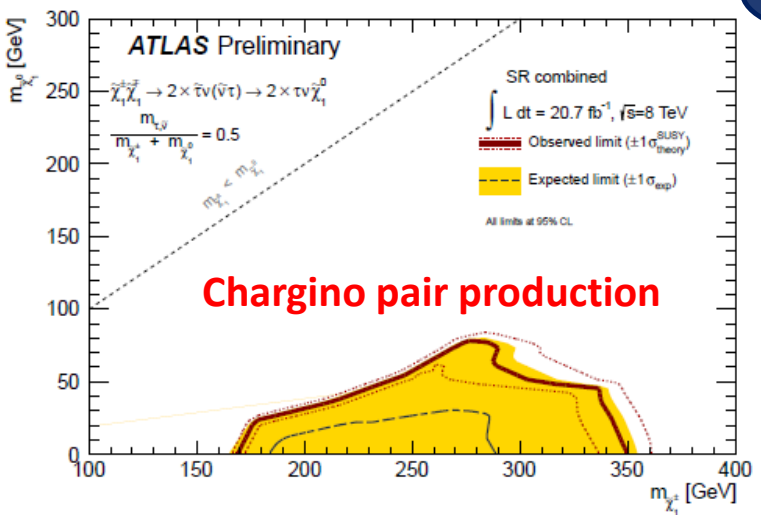
Intermediate Stau Production

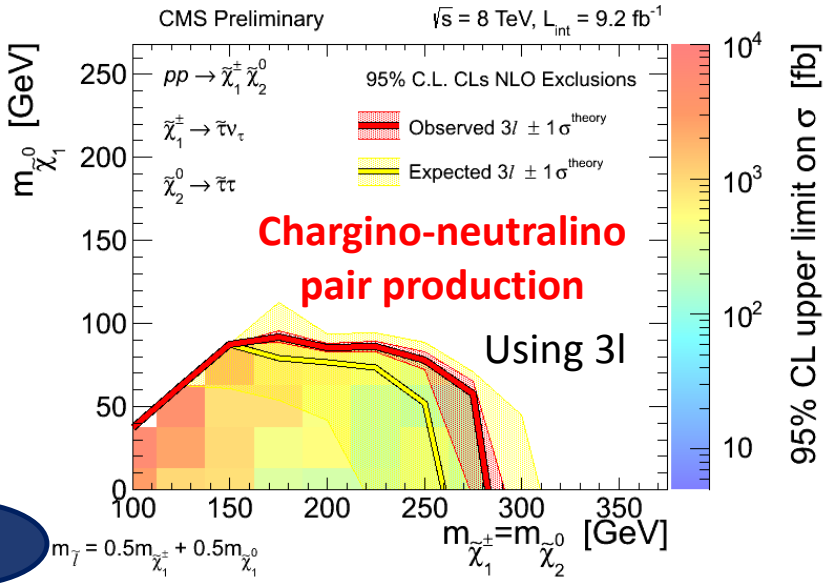
(ATLAS-CONF-2013-028)





8 TeV

(CMS-PAS-SUS-12-022)



20.7 fb^{-1}@8 TeV

- **First result for chargino pair production with decays through intermediate staus**

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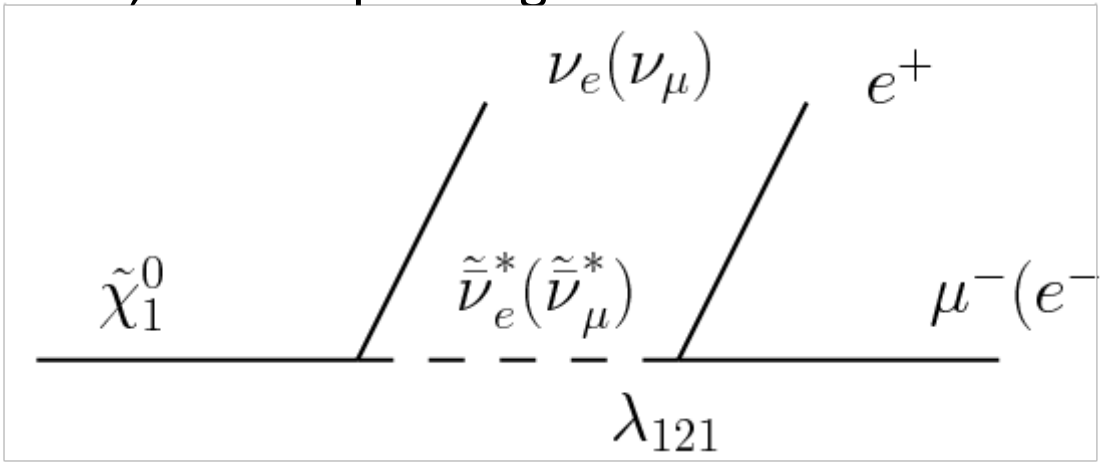
RPV Searches

- LSP is not stable but will decay to two leptons
  - Low MET, multi-lepton signatures



- nLSP can be wino, L-slepton, sneutrino, gluino

- **Model naturally gives 4ℓ (off-Z) signatures**

- Dedicated analysis:
  - four lepton analysis

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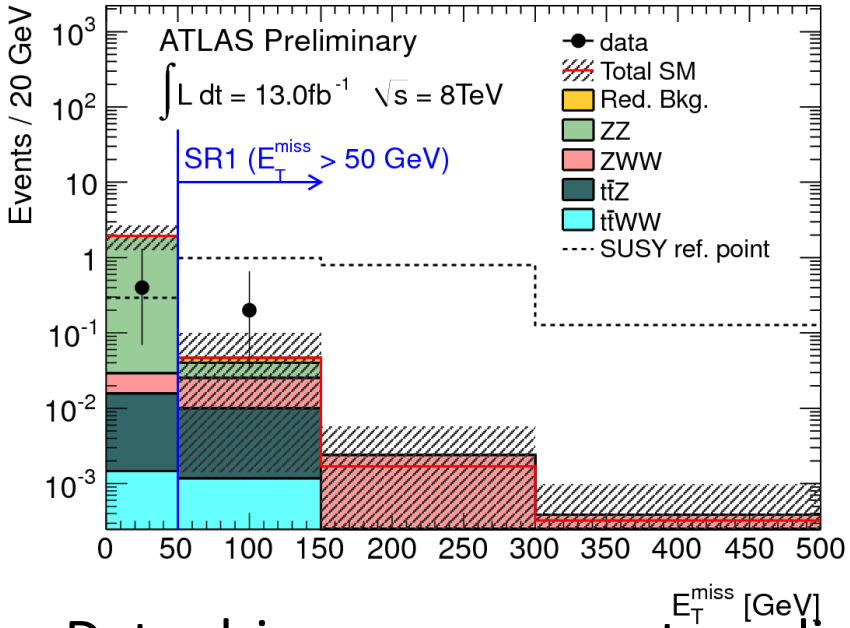
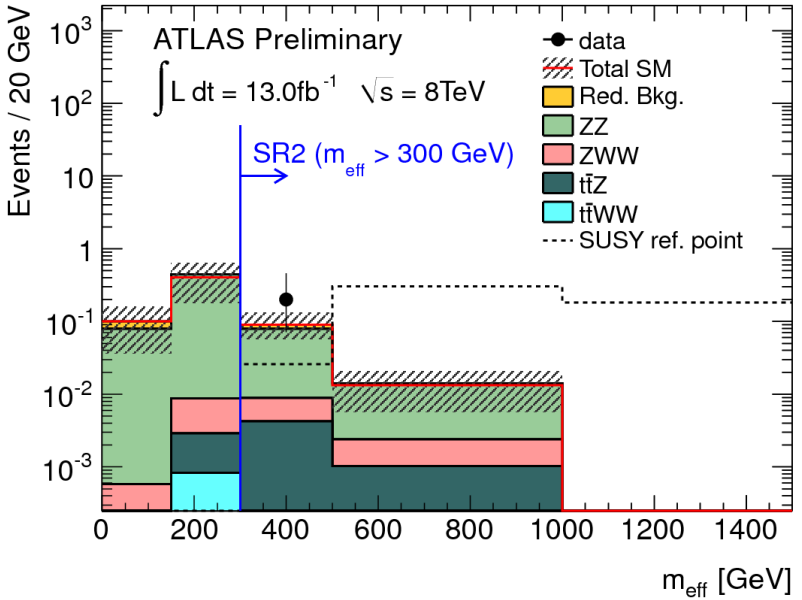
4 lep RPV Search (ATLAS-CONF-2012-153)

- 2 search regions:
  - SR 1: 4 leptons, Z-veto and MET>50 GeV (neutrinos in final state)
  - SR 2: 4 leptons, Z-veto and m_{eff}>300 GeV (sparticle cascade decays)

$$m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + \sum_{\mu} p_{\text{T}}^{\mu} + \sum_{e} E_{\text{T}}^{e} + \sum_{j} E_{\text{T}}^{j}$$

8 TeV





- Data-driven non-prompt prediction
- 3 validation regions (ttbar, ZZ, off-shell Z)

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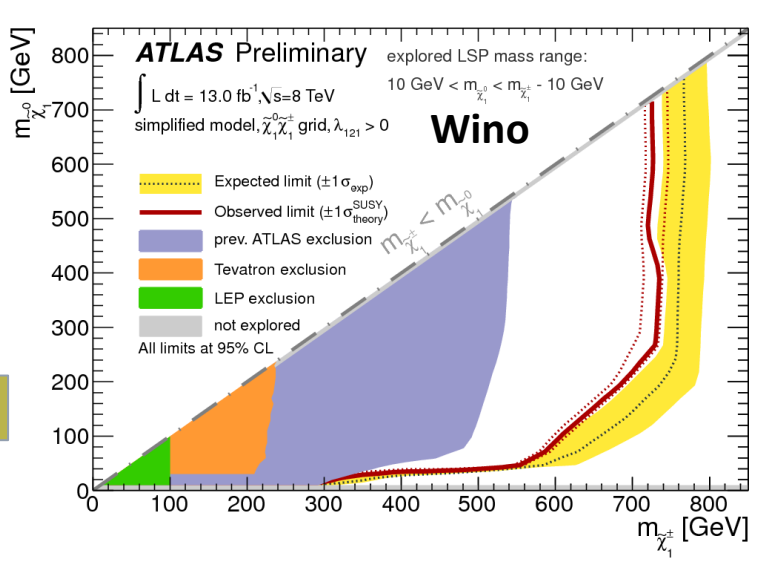
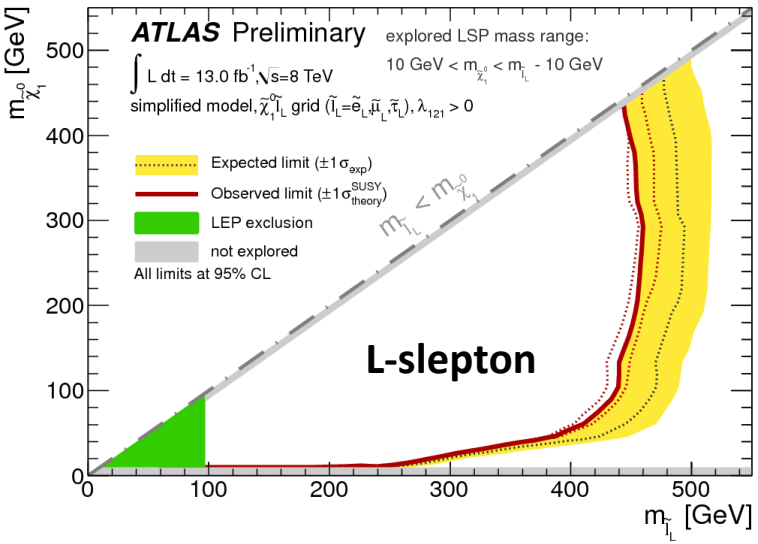
4 lep RPV Search (ATLAS-CONF-2012-153)

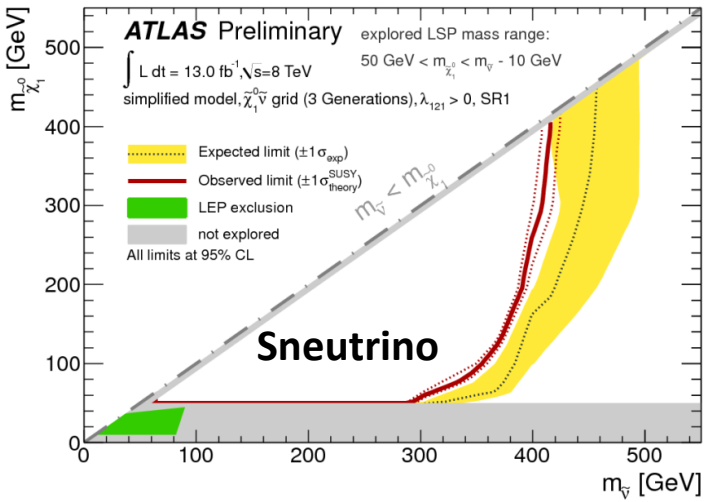
- Four NLSP choices
  - Results shown for Wino, left-slepton and sneutrino models
    - Only results for λ_{121}>0 shown, results for λ_{122} >0 similar

8 TeV

13 fb^{-1}@8 TeV







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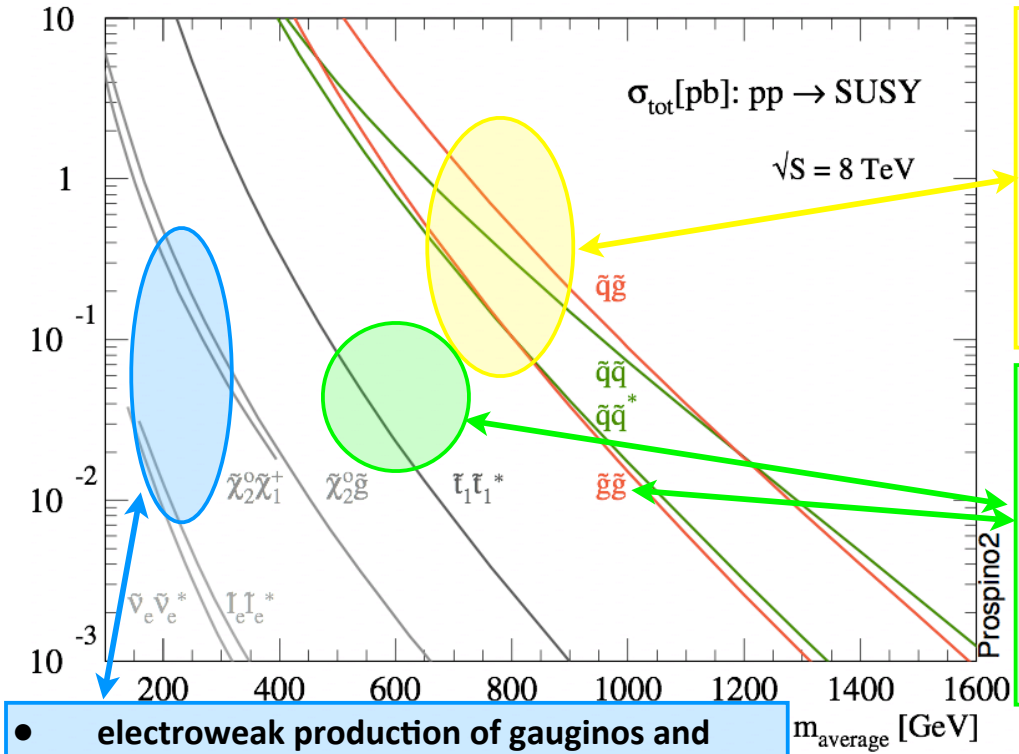
3rd Generation Scalar Quarks



- **strong production of 1st and 2nd generation scalar quark and gluinos**
  - significant cross section up to more than 1 TeV
  - decay to jets and weakly interacting SUSY particle (LSP): jets and E_T^{miss}
- ***third generation scalar quarks (direct production or gluino-mediated)***
  - significant cross-section for direct production
  - large top background
  - key ingredient in **natural SUSY**
- **electroweak production of gauginos and leptons**
  - small cross section, less than WW, ZZ
  - doable with current integrated luminosity
  - jet veto, leptons, moderate missing E_T
- the SUSY searches at 7 TeV (2010-2011 data) indicate that squark of the first two generations and gluinos might be heavier than ~1 TeV

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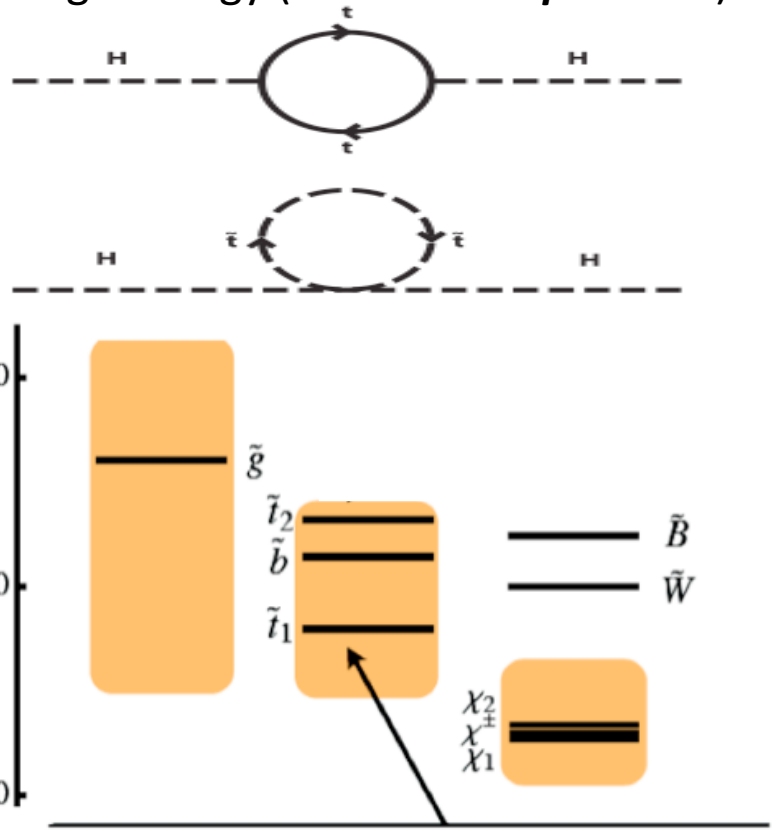
Natural SUSY and 3rd Gen Squarks

- Supersymmetry stabilises the Higgs mass to the electroweak scale without a fine tuning of the theoretical parameters at high energy (***naturalness problem***)

- squark loops cancel quadratically divergent quark loop corrections to the Higgs mass
  - largest contribution comes from top quark loop
  - important to have a light stop

- in several supersymmetric models renormalization group equations push the lightest stop state to low masses
  - in these models stop is favoured to be the lightest squark
  - gluinos mass should be less than ~1.5-2 TeV



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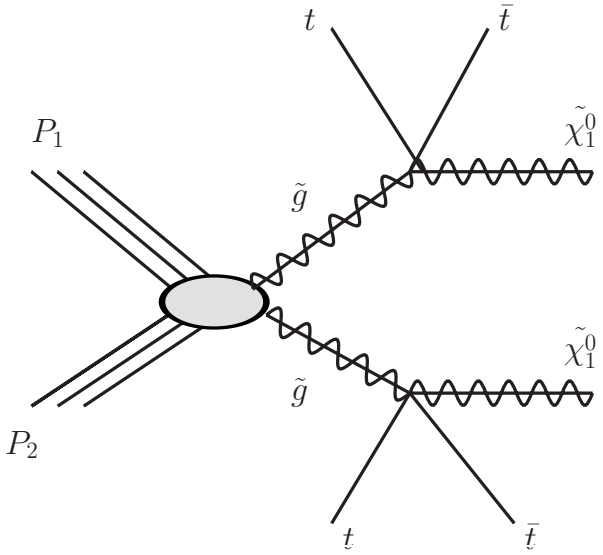
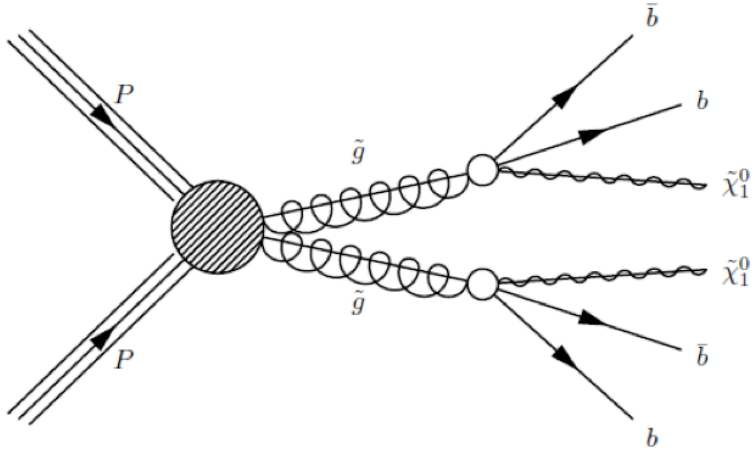
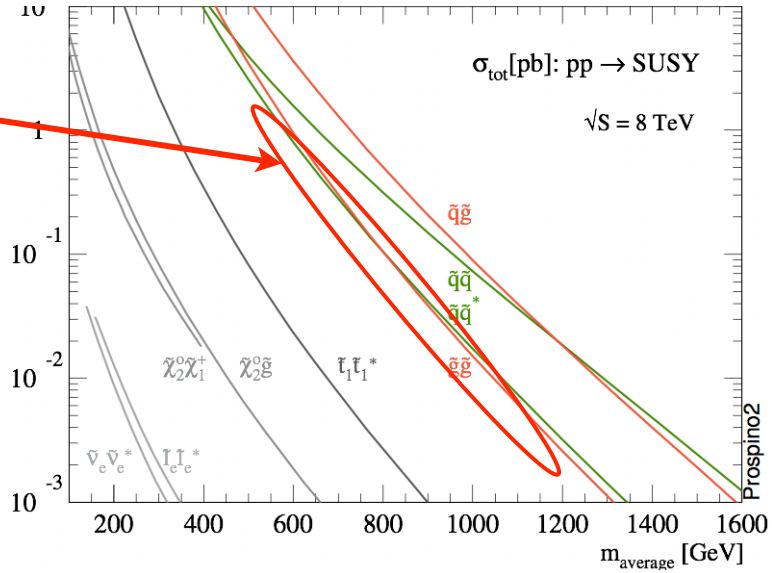
Gluino Mediated Stop and Sbottom





- dominates if gluino light enough
  - final state rich in b-jets and tops



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Gluino Mediated Stop (ATLAS-CONF-2013-007)

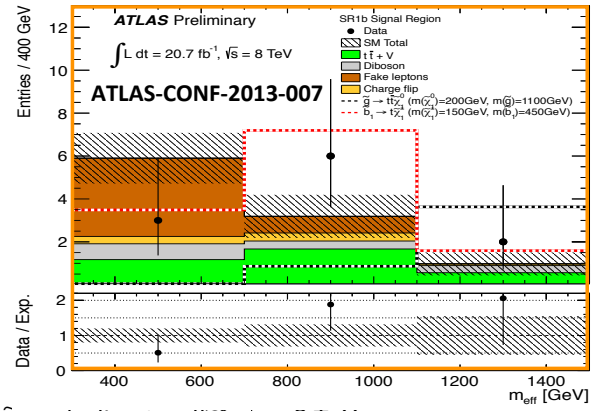
8TeV

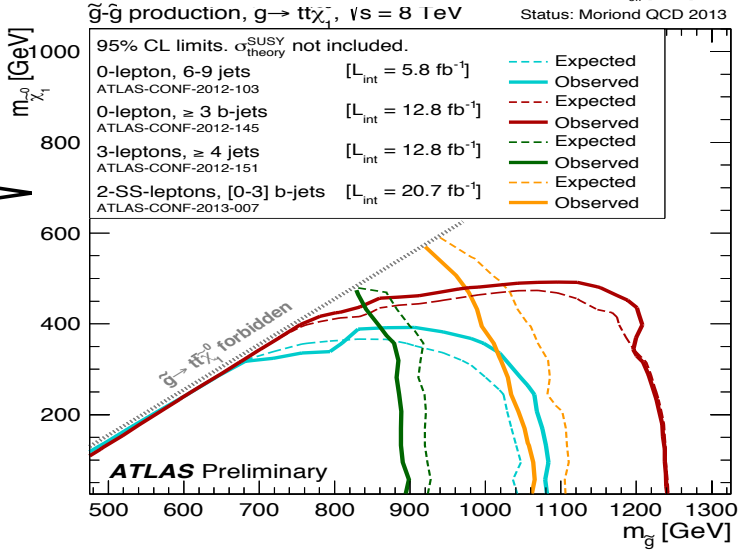
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$

- 4 top quarks in decay. Many searches sensitive

- 0 lep + multi-jet (6-9 jets) + E_T^{miss}. 5.8 fb^{-1}
- 0 lep + ≥3 b-jets (6 jets) + E_T^{miss}. 12.8 fb^{-1}
- 2 SS lep + 0,≥1,≥3 b-jets (≥3,4 jets) + E_T^{miss}. 20.7 fb^{-1}

  NEW!
  - main bkg: ttW/Z, WZ/ZZ+jets (from MC); charge flips, fake leptons (data-driven)
  - discriminant variables: E_T^{miss}, effective mass m_{eff}, lepton-E_T^{miss} transverse mass m_T
- 3 lep + ≥4 jets + E_T^{miss}. 13.0 fb^{-1}





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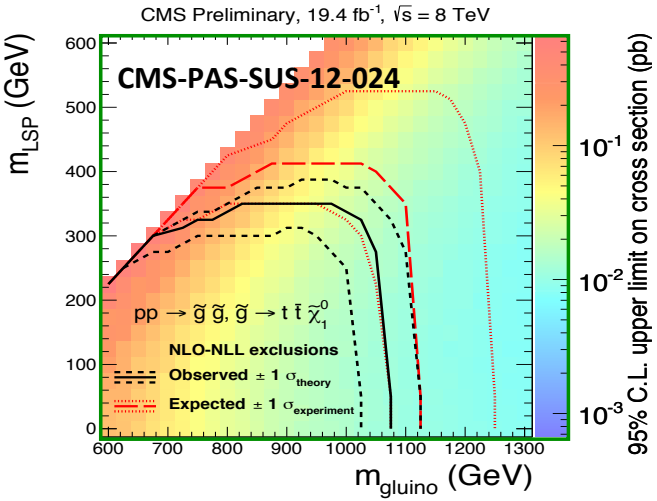
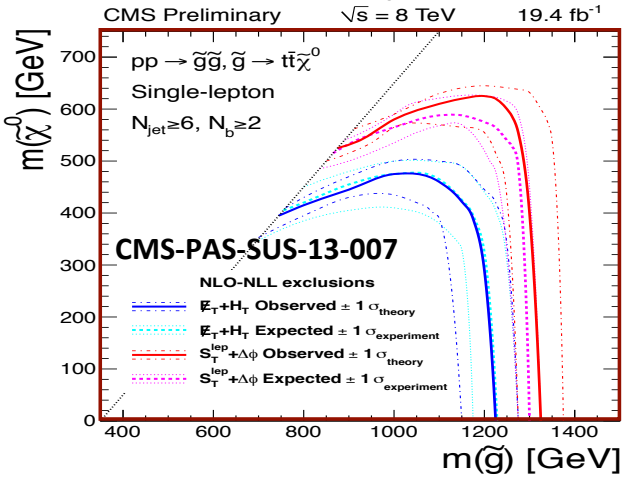
Gluino Mediated Stop

(CMS-PAS-SUS-12-028)
(CMS-PAS-SUS-13-007)

$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ **8TeV**

- 4 top quarks in decay. Many searches sensitive
  - 0 lep + ≥3 jets (≥1 b-jets) + E_T^{miss}. 19.4 fb^{-1} **NEW!**
  - 1 lep + ≥6 jets (≥2,≥3 b-jets) + E_T^{miss}. 19.4 fb^{-1}
    - 2 complementary methods: *Lepton Spectrum* (LS) and *Delta Phi* (DP) **NEW!**
    - main bkg: top pairs, single top, ttbar+W/Z, W+jets, dibosons, Drell-Yan+jets, QCD multijet production
    - discriminant variables: E_T^{miss}, H_T for LS method; $\Delta\phi$(W,l), S_T^{lep} for DP method
  - 2 SS lep + ≥2 b-jets + E_T^{miss}. 10.5 fb^{-1}
    - CMS-PAS-SUS-12-029





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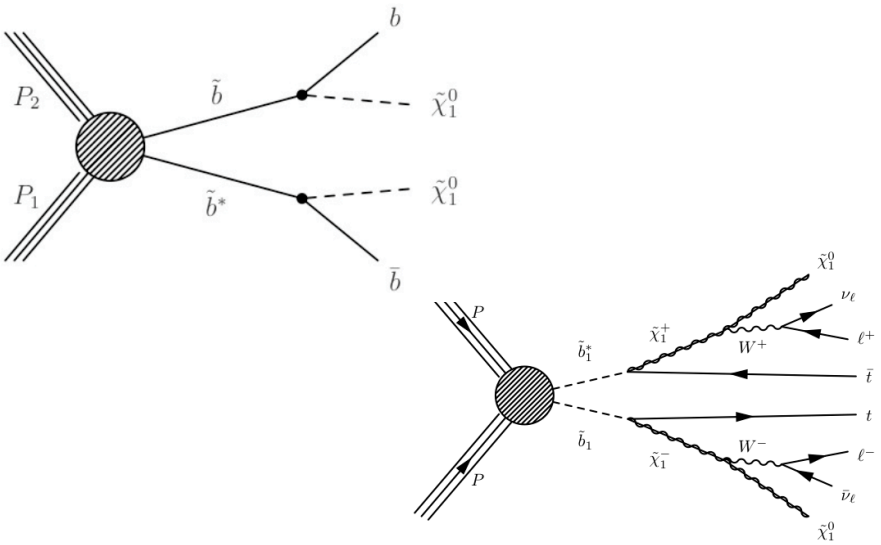
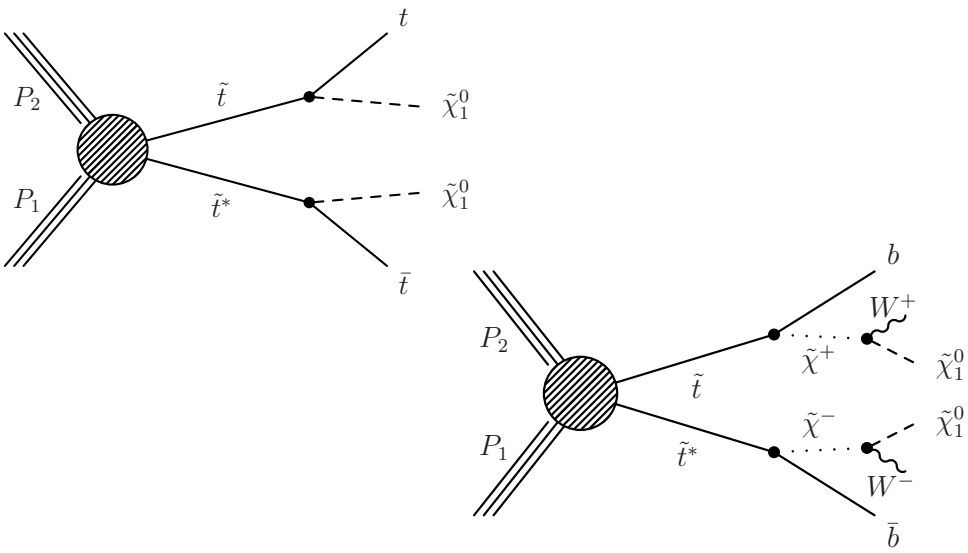
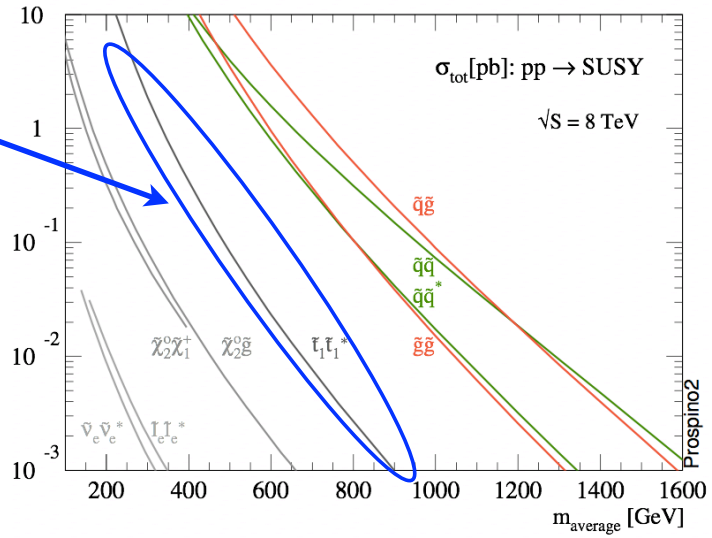
Direct Stop and Sbottom Production





- small cross section for direct production
  - final state is tipically ttbar+E_T^{miss} or bbar +E_T^{miss}



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Direct Stop

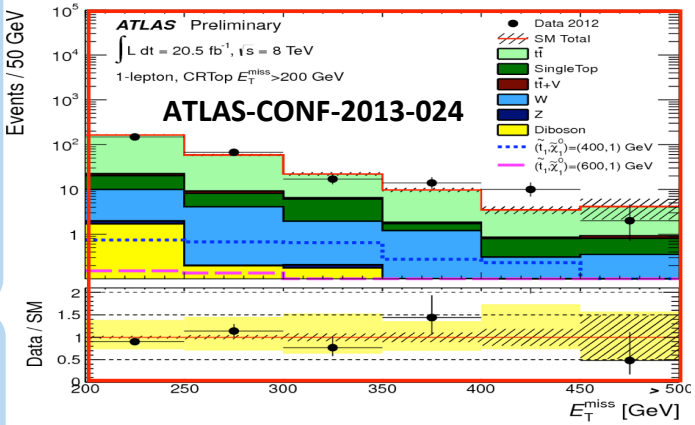
(ATLAS-CONF-2013-024/25)

8TeV: multiple dedicated searches, targeting different stop mass and decay

- 0 lep + ≥6 jets (≥2 b-jets) + E_T^{miss}. 20.5 fb^{-1} $\tilde{t} \to t\tilde{\chi}^0$

NEW!

  - main bkg: *top pairs, Z+jets* (validated and estimated from control region); QCD multijet (data-driven); other bkg (from MC)
  - discriminant variables: E_T^{miss}, several variants of m_T, $\Delta\phi(E_T^{miss}$,closest jet), $\Delta\phi(E_T^{miss}$,*3 higher p_T jets*)



- 2,≥3 lep (SFOS pairs)+ Z + ≥3 jets (≥1 b-jets) + E_T^{miss}. 20.7 fb^{-1}

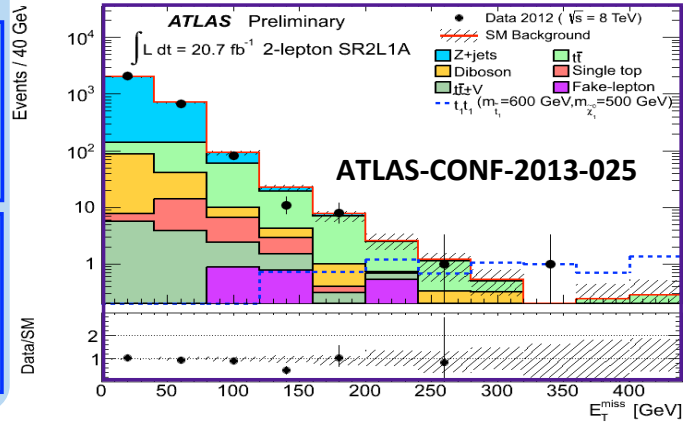
NEW!

  - main bkg: *top pairs* (validated and estimated from control region); QCD multijet, *Z+jets* (data-driven); ttbar+Z/W, dibosons (from MC)
  - discriminant variables: E_T^{miss}, m_{ll}-m_Z, $\Delta\phi^{ll}$, p_T^{ll} (Z boosted)

2 main scenarios

$\tilde{t} \to b\tilde{\chi}^{\pm} \Rightarrow \tilde{\chi}^0 \to Z\tilde{G}$
natural GMSB, m($\chi^{\pm}$)~m(χ^0), χ^0 NLSP

$\tilde{t}_2 \to Z\tilde{t}_1 \Rightarrow \tilde{t}_1 \to t\tilde{\chi}^0$
first of its kind! small $\Delta m(\tilde{t}_1, \chi^0)$=180 GeV



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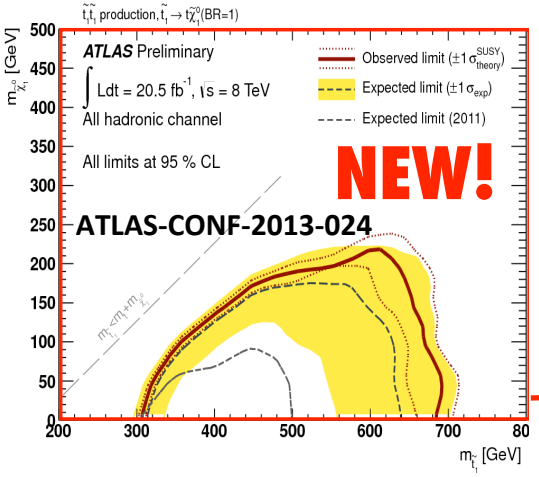
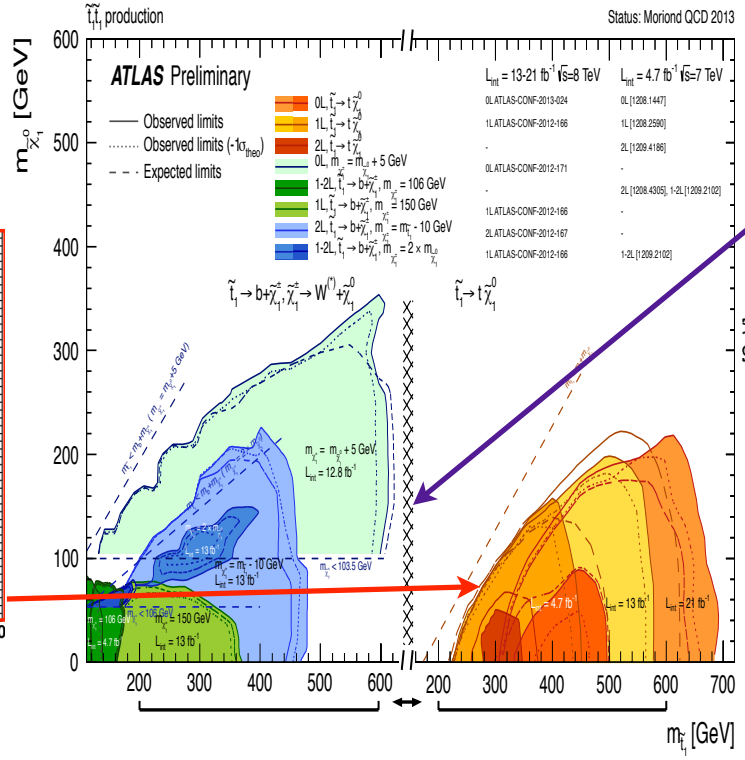
Direct Stop (ATLAS-CONF-2013-025)

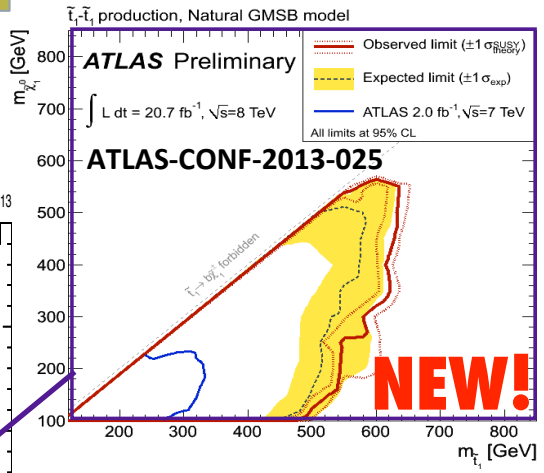
- 2 lep + E_T^{miss}. 13.0 fb^{-1} — $\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$; m($\chi^{\pm}$)-m(χ^0)>m(W)
- 1 lep + ≥4 jets (≥1 b-jets) + E_T^{miss}. 13.0 fb^{-1} — $\tilde{t} \rightarrow t\tilde{\chi}^0$ $\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$
- 0 lep + 2 b-jets + E_T^{miss}. 12.8 fb^{-1} — $\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$; m($\chi^{\pm}$)~m(χ^0)

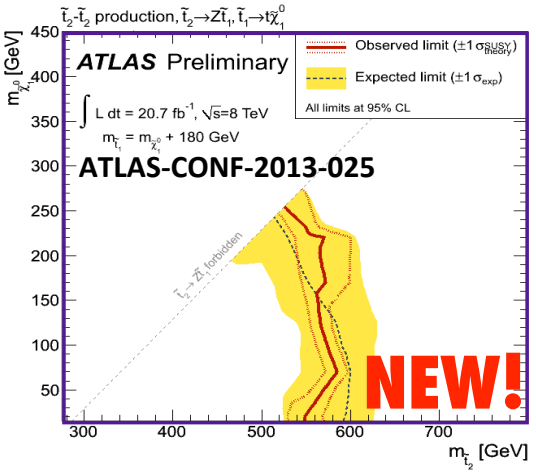
20.7 fb^{-1}@8 TeV

8TeV









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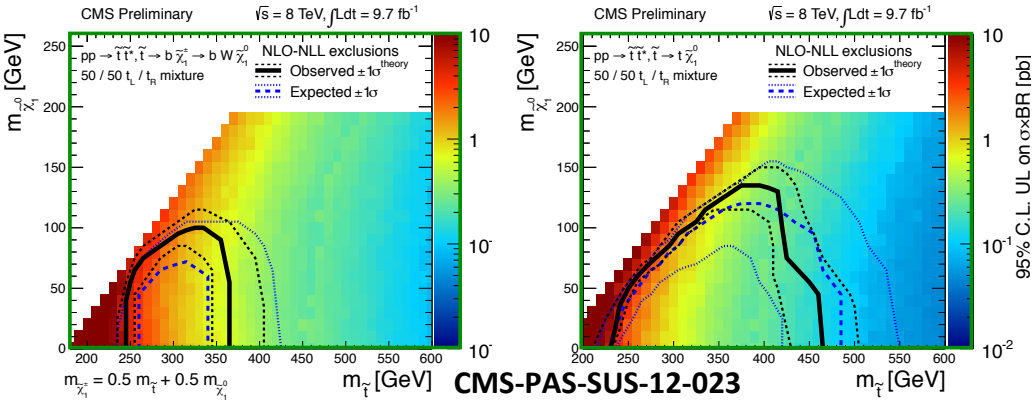
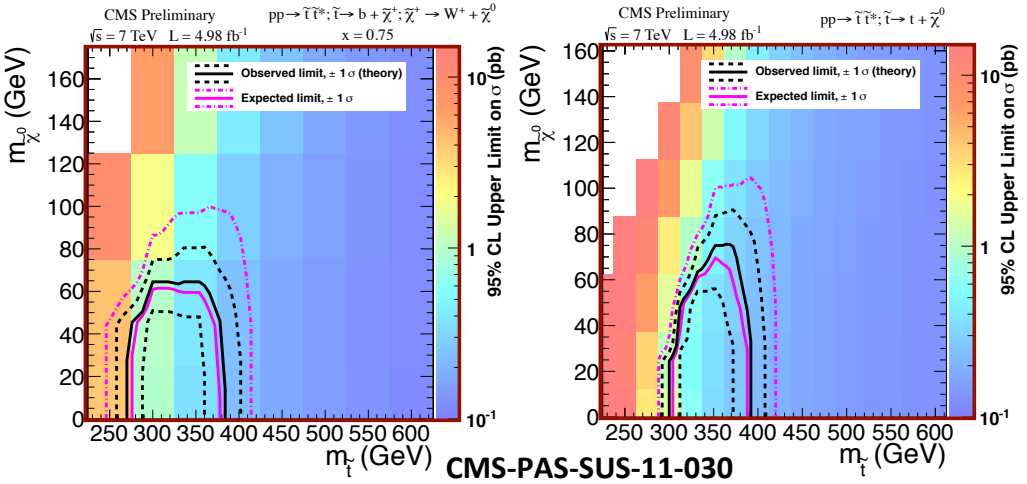
Direct Stop

(CMS-PAS-SUS-12-023)
(CMS-PAS-SUS-11-030)

- 1 lep + ≥4 jets (≥1 b-jets) + E_T^{miss}. 9.7 fb^{-1} **@8TeV**
  - backgrounds: *top pairs, W+jets* (validated and estimated from respective control region); QCD multijet (negligible); dibosons, ttbar+W/Z, single top (from MC)
  - discriminant variables: E_T^{miss}, leptonic transverse mass m_T



- 0 lep + ≥5 jets (≥1 b-jets) + E_T^{miss}. 4.98 fb^{-1} **@7TeV**
  - backgrounds: *top pairs, W+jets* (validated and estimated from respective control region); QCD multijet (negligible); dibosons, ttbar+W/Z, single top (from MC)
  - discriminant variables: E_T^{miss}, $\Delta\phi(E_T^{miss}$,three highest-p_T jets), $\min|\Delta\phi(E_T^{miss},p_T^{b})|$ (enhanced at low angles for top pairs bkg)



$\tilde{t} \to b \tilde{\chi}^{\pm}$

$\tilde{t} \to t \tilde{\chi}^{0}$

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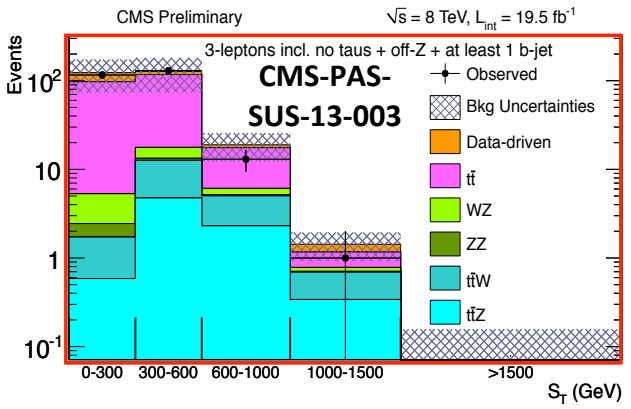
Direct Stop

(CMS-PAS-SUS-13-003)

$$\tilde{t} \to t\tilde{\chi}^0 \Rightarrow \tilde{\chi}^0 \to 2l + \nu \text{ or } \tilde{\chi}^0 \to l/\nu + q\bar{q}$$ **RPV model**

- ≥3 lep + 0,≥1 b-jets + S_T. 19.5 fb^{-1}
  - main bkg: *WZ, ZZ* (validated and estimated from control region); misidentified leptons (data-driven); ttbar+W/Z, top pairs (from MC)
  - discriminant variables: S_T (scalar sum of E_T^{miss}, H_T, L_T), m_{ll} (Z veto if OSSF leptons)
  - LHE files provided by Jared Evans and Yevgeny Kats (arxiv: 1209.0764)

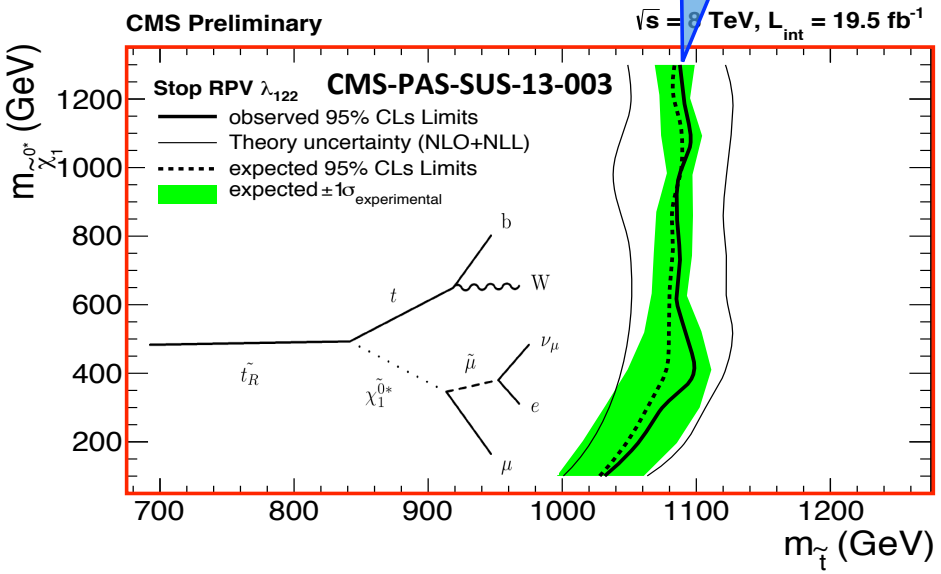
NEW!



8TeV

$\tilde{\chi}^0 \to \mu\nu_\mu e$

other interpretations in backup



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Conclusions

- The performances of the LHC have been outstanding during the 2011-2012 period
  - Many new results by the ATLAS and CMS Collaboration (not just the Higgs!)
- Still no SUSY in sight…
  - No significant excess yet observed in many different channels
  - Very stringent limits already obtained in strong and weak SUSY production
    - Chargino-neutralino masses up to 600 GeV and slepton masses up to 250 GeV
    - In RPV models, wino masses up to 700 GeV and slepton masses up to 430 GeV

Web Pages

- ATLAS public SUSY results:
  https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
- CMS public SUSY results:
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

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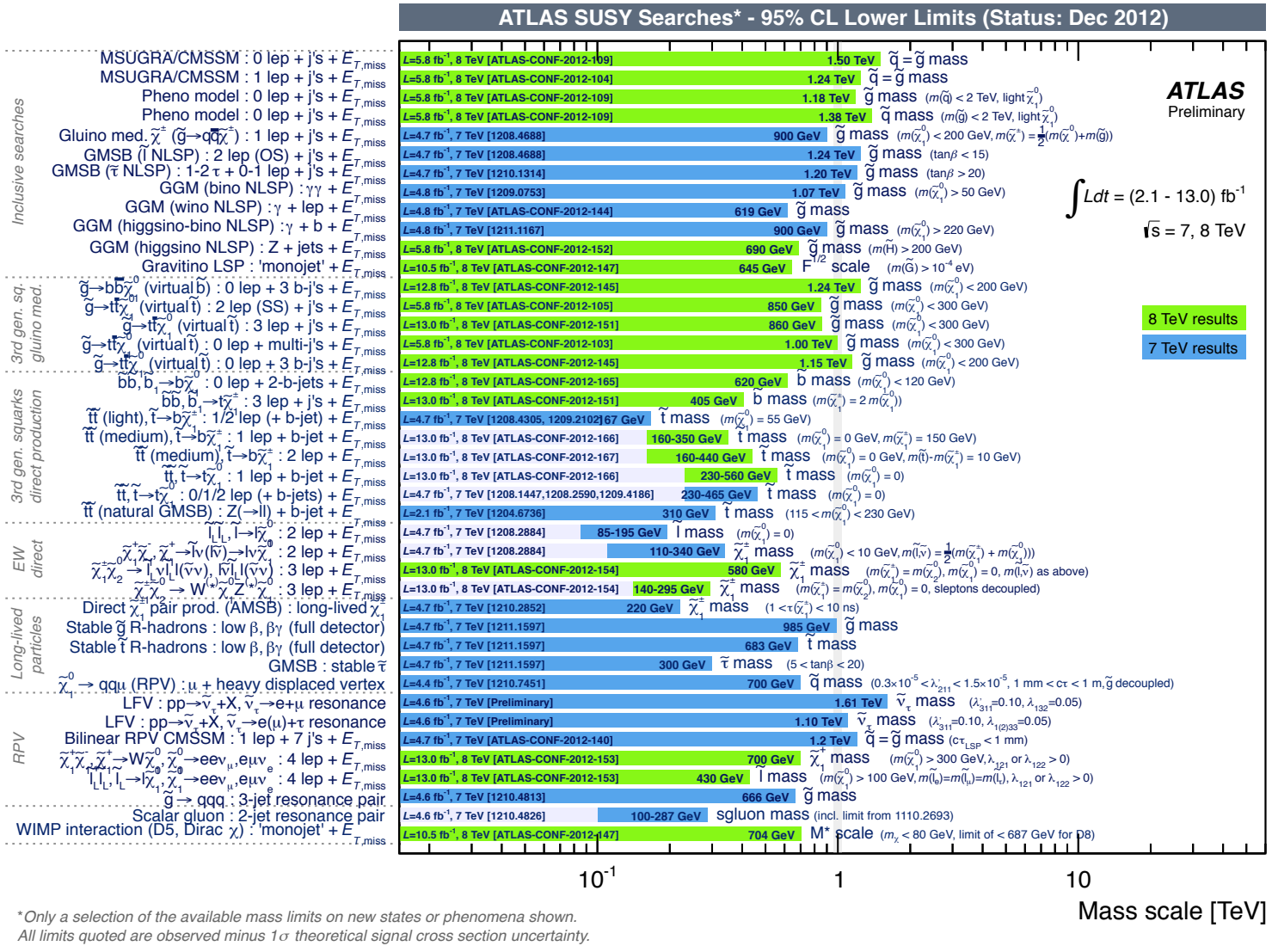
Mass Reach for ATLAS Searches



*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

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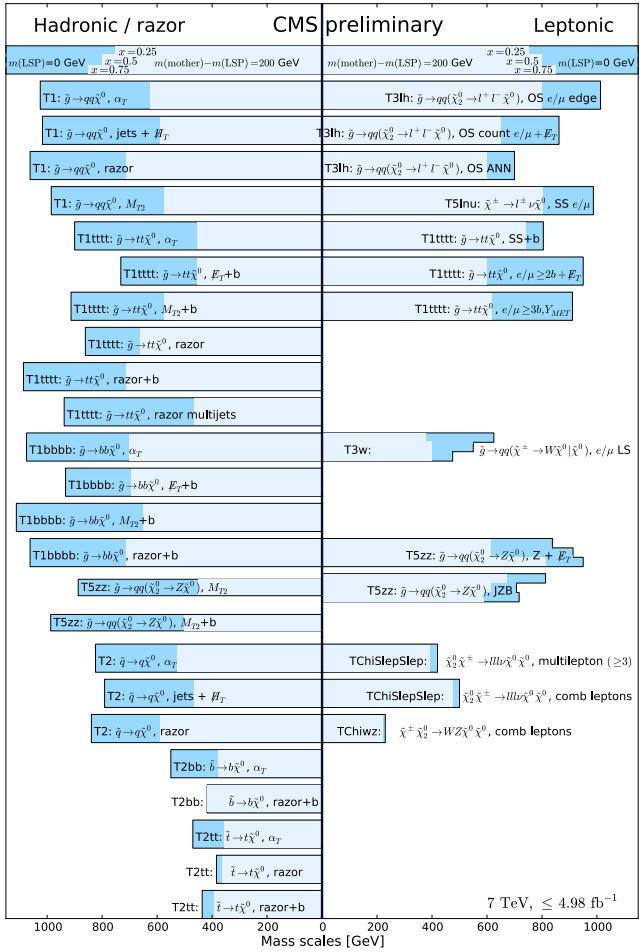
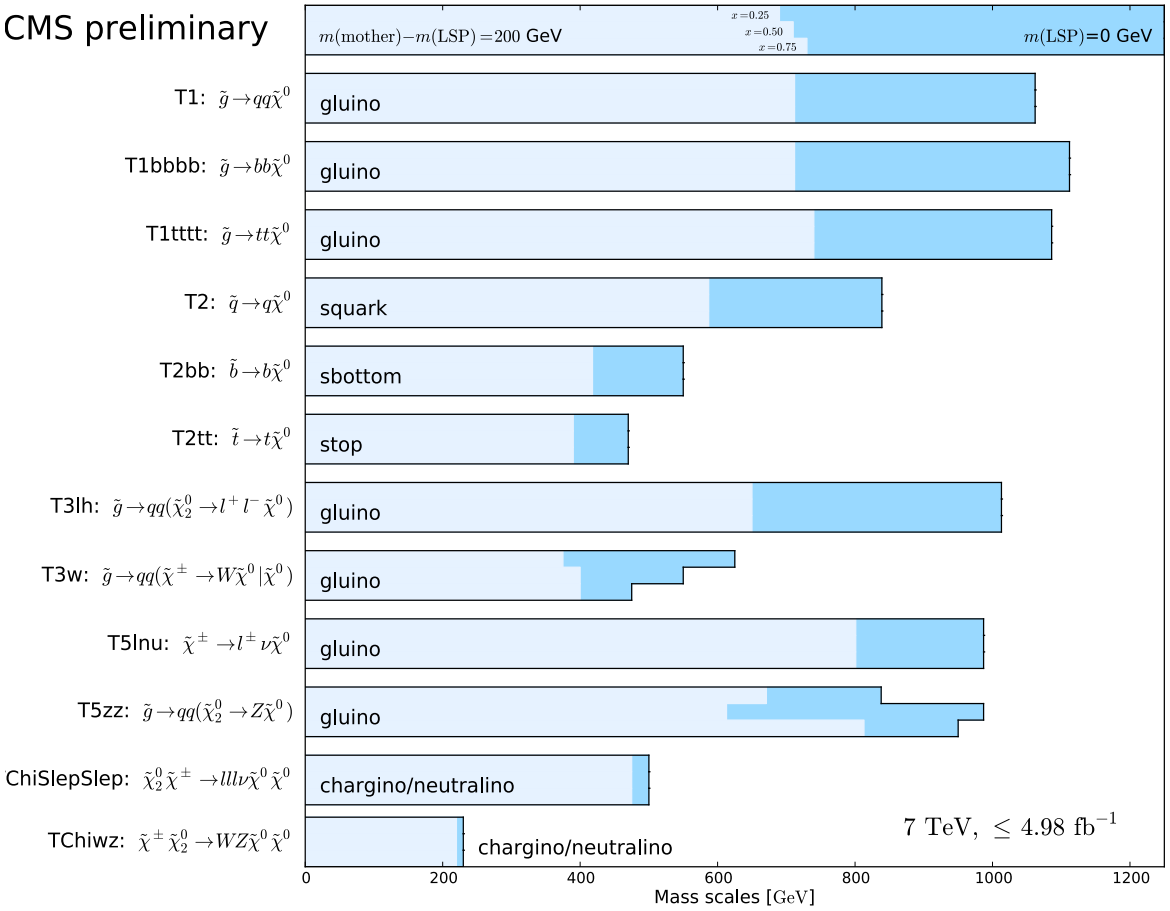
Mass Reach for CMS Searches



CMS preliminary



cf. arXiv:1301.2175
(submitted to Phys. Rev. D)

2011 dataset

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Backup

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Direct Stop

(CMS-PAS-SUS-13-003)

$$\tilde{t} \to t\tilde{\chi}^0 \Rightarrow \tilde{\chi}^0 \to 2l + \nu \text{ or}$$
$$\tilde{\chi}^0 \to l/\nu + q\bar{q} \quad \textbf{RPV model}$$

$\tilde{\chi}^0 \to \tau\nu_\tau\mu$

region label	kinematic region	stop decay mode(s)
A	$m_t < m_{\tilde{t}} < 2m_t, m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\nu b\bar{b}$
B	$2m_t < m_{\tilde{t}} < m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\mu t\bar{b} + t\nu b\bar{b}$
C	$m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_W + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to \ell\nu b\tilde{\chi}_1^0 + jjb\tilde{\chi}_1^0$
D	$m_W + m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_t + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to Wb\tilde{\chi}_1^0$
E	$m_t + m_{\tilde{\chi}_1^0} < m_{\tilde{t}}$	$\tilde{t} \to t\tilde{\chi}_1^0$