

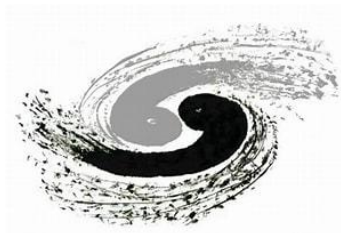
Strong SUSY and RPV SUSY searches summary in ATLAS

Shiyi Liang, on behalf of IHEP SUSY group

Institute of High Energy Physics, Chinese Academy of Sciences

1 November 2025

CLHCP2025

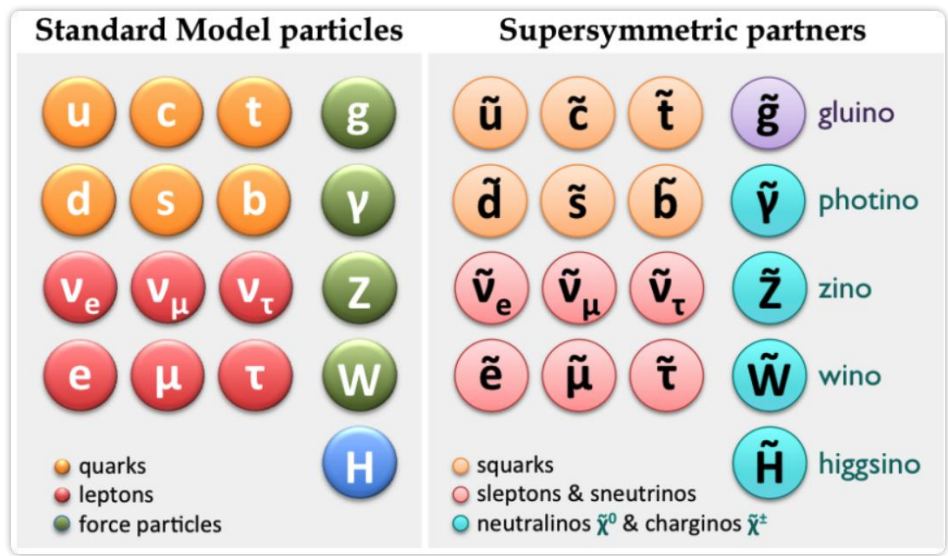


Outline

1. Introduction of SUSY
2. Strong SS/3L analysis
3. Strong SUSY searches summary
 - SUSY particle with RPC decay
 - SUSY particle with RPV decay
4. Long-lived SUSY particles searches summary

Introduction of SUSY

Supersymmetry is a fermion–boson symmetry.



Minimal Supersymmetric
Standard Model

Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	+1	H_u^0 H_d^0 H_u^+ H_d^-	h^0 H^0 A^0 $H^\pm$
squarks	0	-1	$\tilde{u}_L$ $\tilde{u}_R$ $\tilde{d}_L$ $\tilde{d}_R$	(same)
			$\tilde{s}_L$ $\tilde{s}_R$ $\tilde{c}_L$ $\tilde{c}_R$	(same)
			$\tilde{t}_L$ $\tilde{t}_R$ $\tilde{b}_L$ $\tilde{b}_R$	$\tilde{t}_1$ $\tilde{t}_2$ $\tilde{b}_1$ $\tilde{b}_2$
sleptons	0	-1	$\tilde{e}_L$ $\tilde{e}_R$ $\tilde{\nu}_e$	(same)
			$\tilde{\mu}_L$ $\tilde{\mu}_R$ $\tilde{\nu}_\mu$	(same)
			$\tilde{\tau}_L$ $\tilde{\tau}_R$ $\tilde{\nu}_\tau$	$\tilde{\tau}_1$ $\tilde{\tau}_2$ $\tilde{\nu}_\tau$
neutralinos	1/2	-1	$\tilde{B}^0$ $\tilde{W}^0$ $\tilde{H}_u^0$ $\tilde{H}_d^0$	$\tilde{N}_1$ $\tilde{N}_2$ $\tilde{N}_3$ $\tilde{N}_4$
charginos	1/2	-1	$\tilde{W}^\pm$ $\tilde{H}_u^\pm$ $\tilde{H}_d^\pm$	$\tilde{C}_1^\pm$ $\tilde{C}_2^\pm$
gluino	1/2	-1	$\tilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	-1	$\tilde{G}$	(same)

Introduction of SUSY

R-parity: $P_R = (-1)^{3(B-L)+2S}$: SUSY particles $\rightarrow$ odd R-parity; SM-particles $\rightarrow$ even R-parity

R-parity conserved(RPC): SUSY particles produced in pairs, lightest SUSY particle(LSP) stable as a dark matter candidate.

R-parity-violating(RPV): SUSY particles decay to SM particle.

MSSM superpotential

$$\frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k + \frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k + \kappa_iL_iH_2$$

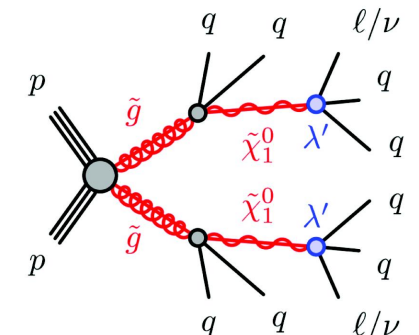
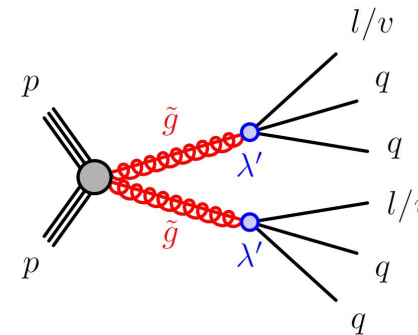
$\tilde{X}_1^0 \rightarrow llv$, violate lepton number conservation

$\tilde{X}_1^0 \rightarrow lqq/vqq$, violate lepton and baryon number conservation

$\tilde{X}_1^0 \rightarrow qqq$, violate baryon number conservation

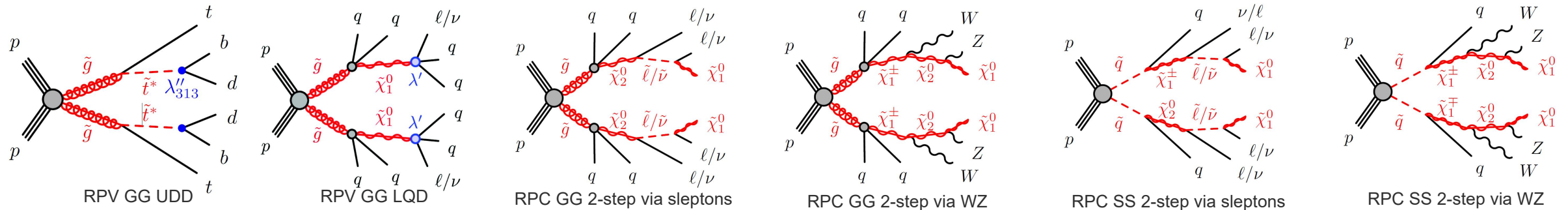
L_i : lepton SU(2)-doublet superfields
 Q_i : quark SU(2)-doublet superfields
 $\bar{E}_i$: charged lepton singlet superfields
 $\bar{U}_i$: up-type quark singlet superfields
 $\bar{D}_i$: down-type quark singlet superfields
 H_2 : Higgs SU(2)-doublet superfield

$\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$: Yukawa couplings



SS/3L: Squarks/gluinos search in SS/3L final states

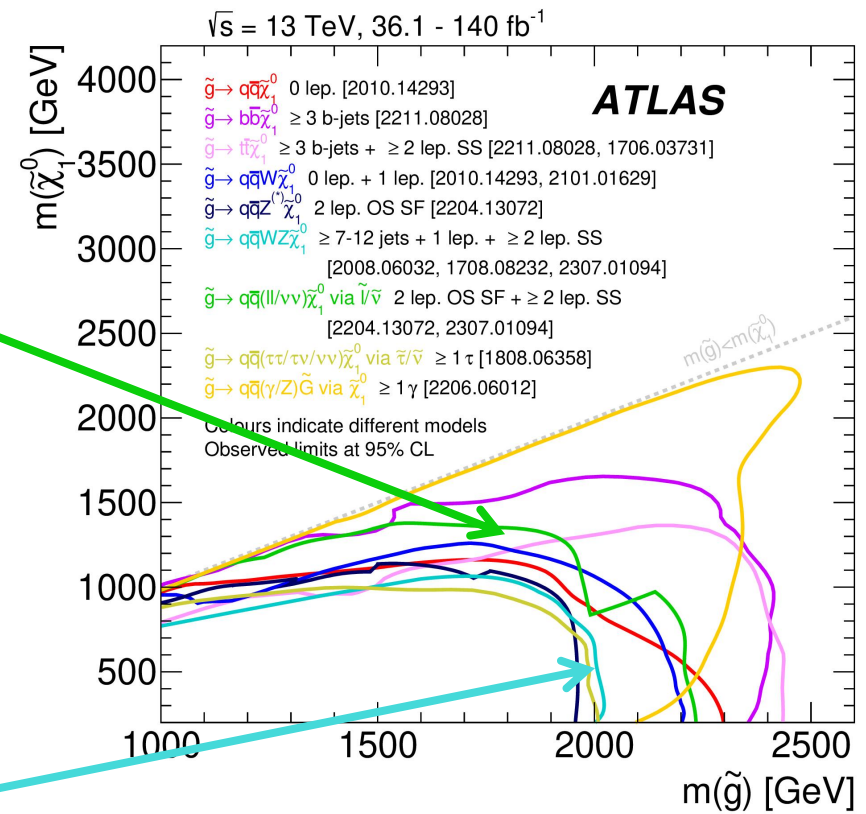
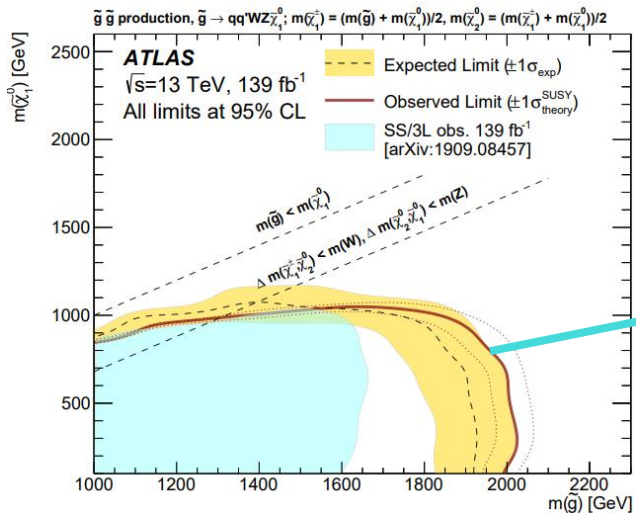
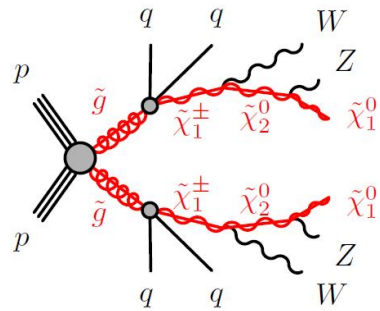
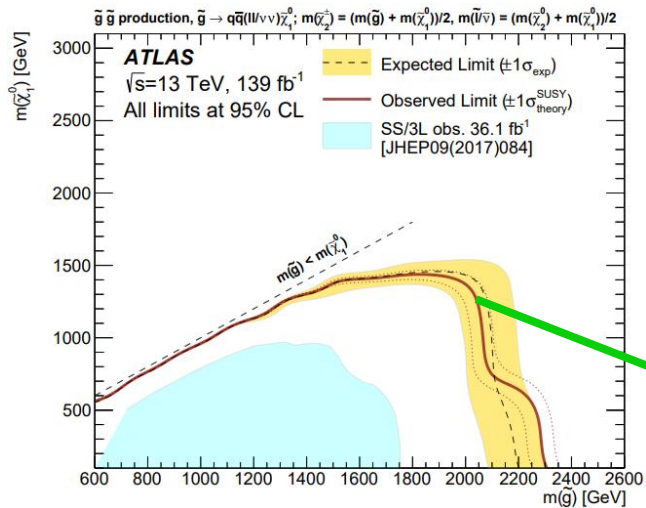
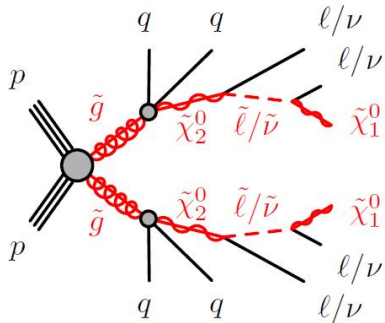
- Target process: pair production of squarks or gluinos decaying via sleptons or WZ bosons or decay into SM particles with RPV coupling.
- Low SM backgrounds in this final state increase sensitivity for Beyond-Standard-Model(BSM) processes with two same-sign or three leptons final states especially in small gluino/squark-LSP mass gap scenario.



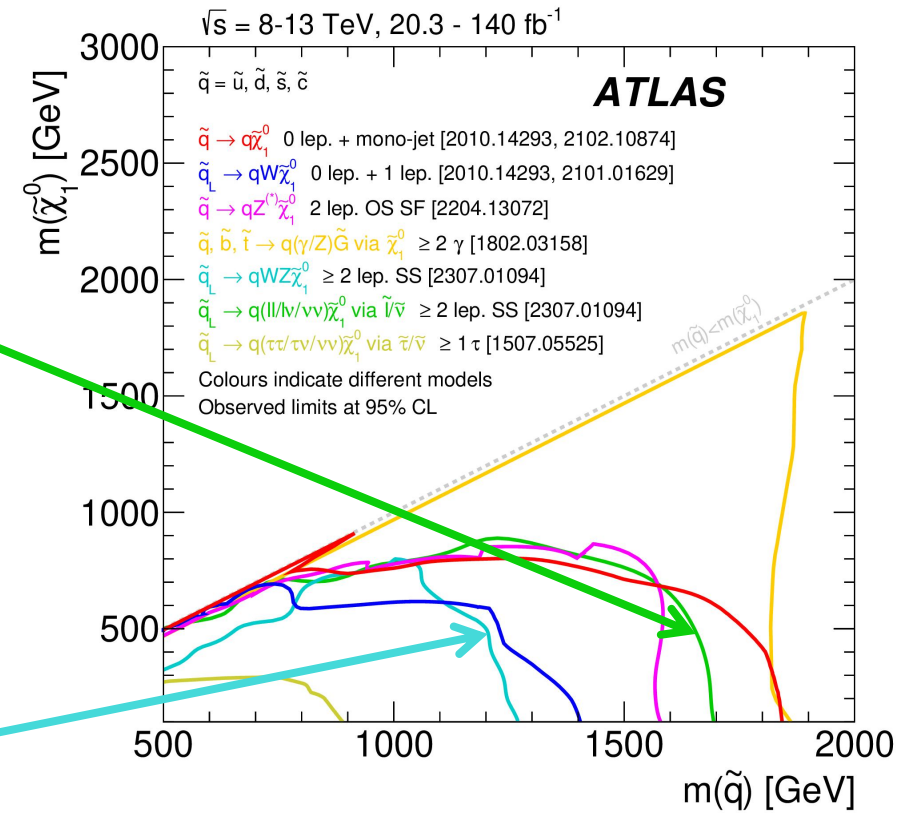
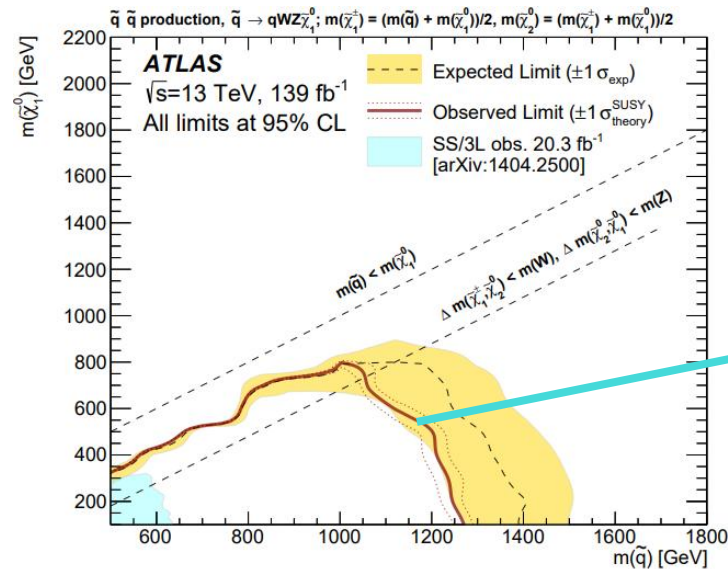
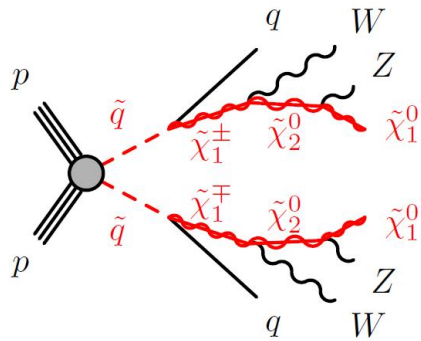
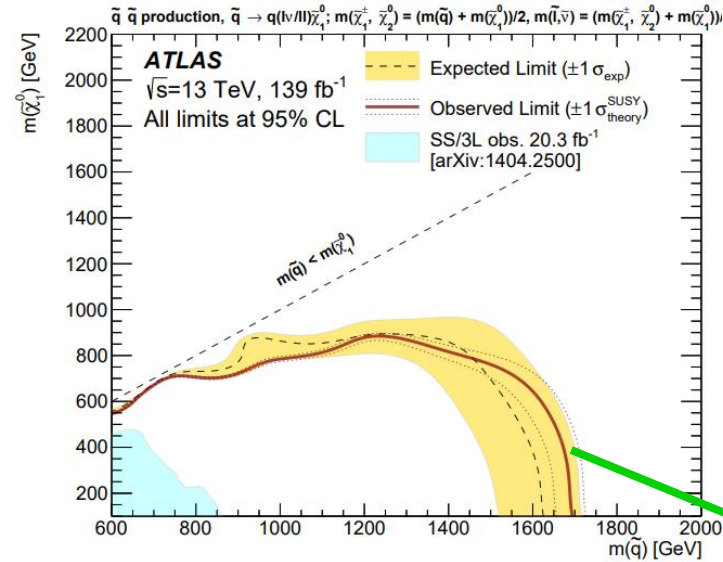
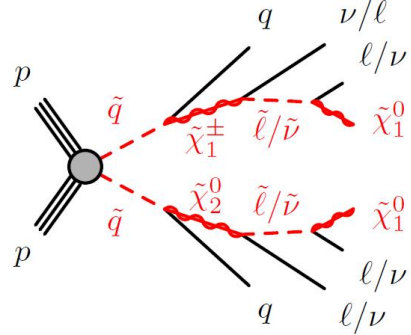
SS/3L: Analysis strategy

- Input: full run2 data of 139 fb^{-1} from ATLAS detector of LHC
- Strategy:
 - For each signal model, design several signal regions targeting benchmark points in different region on gluino/squark-LSP mass plane.
 - For one signal model and for each signal grid, use exclusion fit result from SR providing lowest expected confidence level(CL) to form exclusion limit.
- Background estimation
 - Prompt (irreducible) backgrounds:
 - WZ+jets: Normalisation obtained from a simultaneous fit of the CRWZ2j and the SR.
 - Others: estimated with MC samples
 - Detector (reducible) backgrounds:
 - Charge-flip background, Fake/non-prompt lepton: data-driven method, cross-check with MC samples

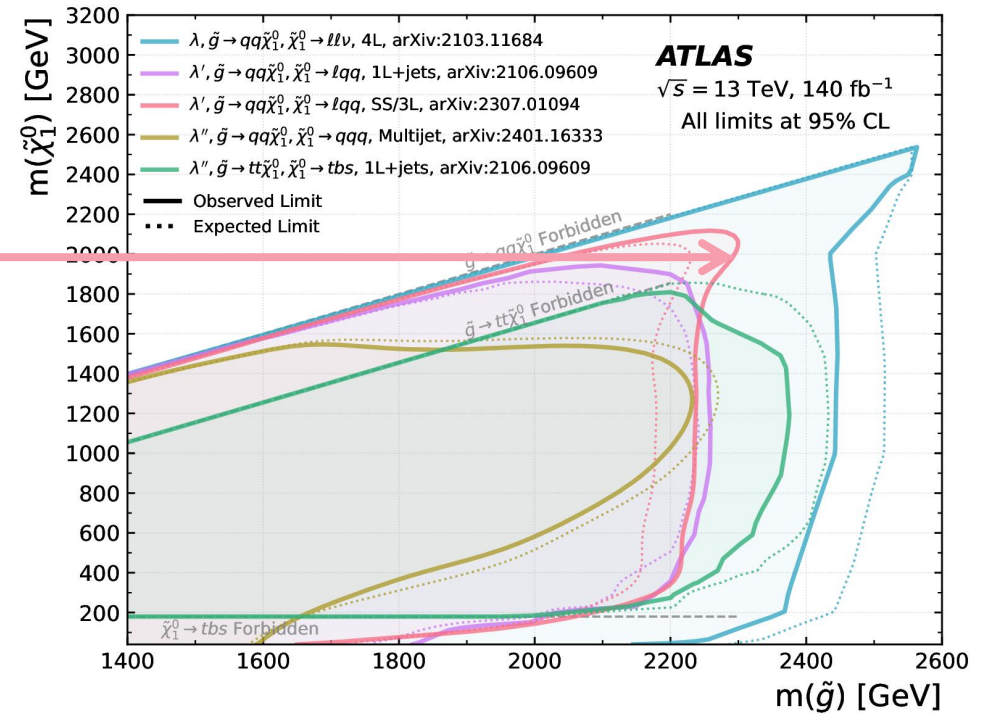
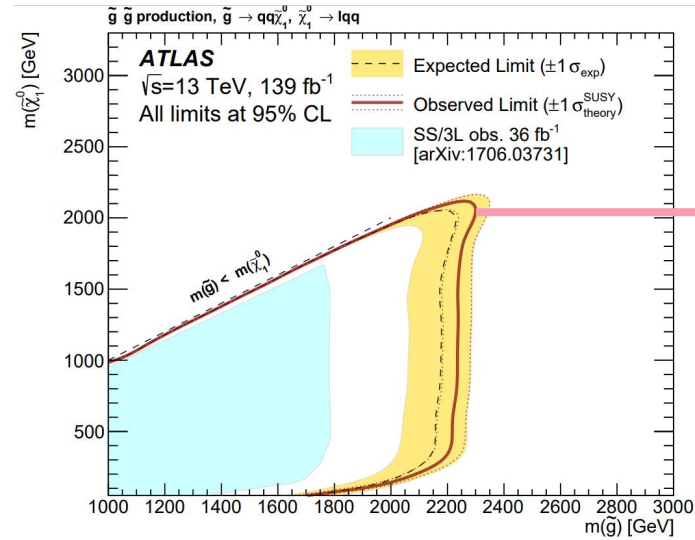
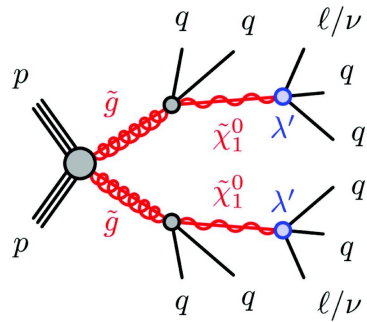
SS/3L: Results



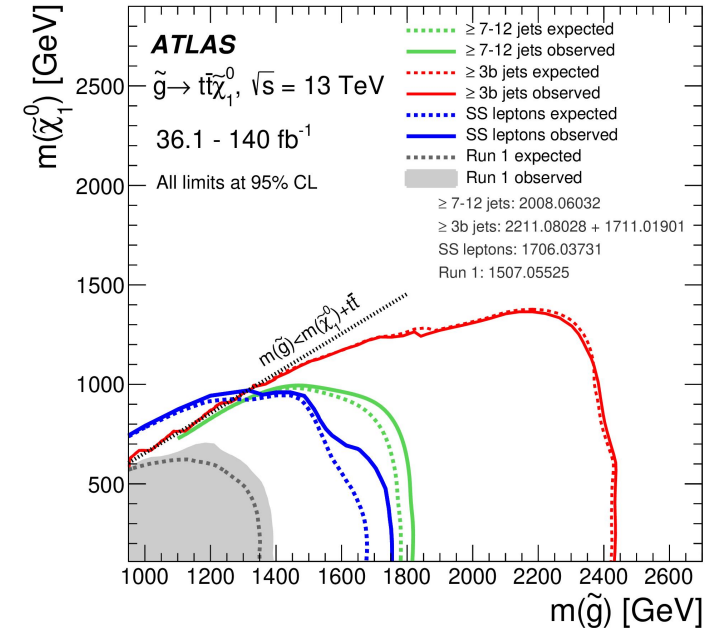
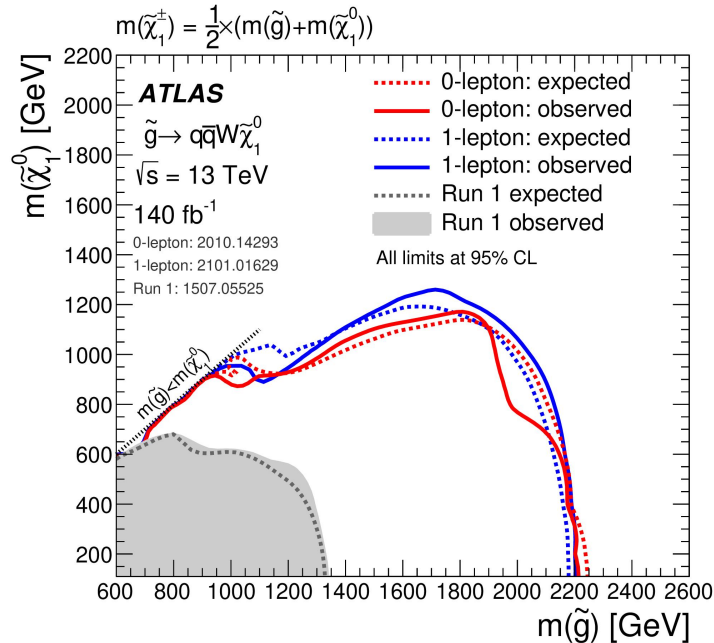
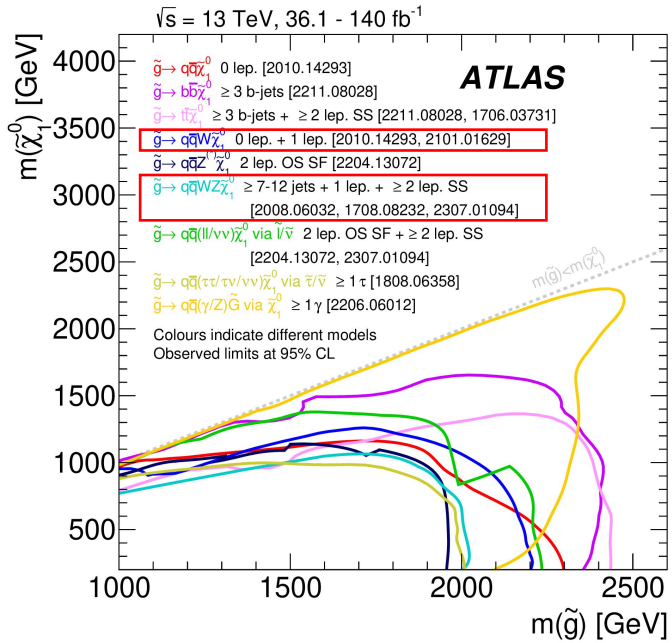
SS/3L: Results



SS/3L: Results

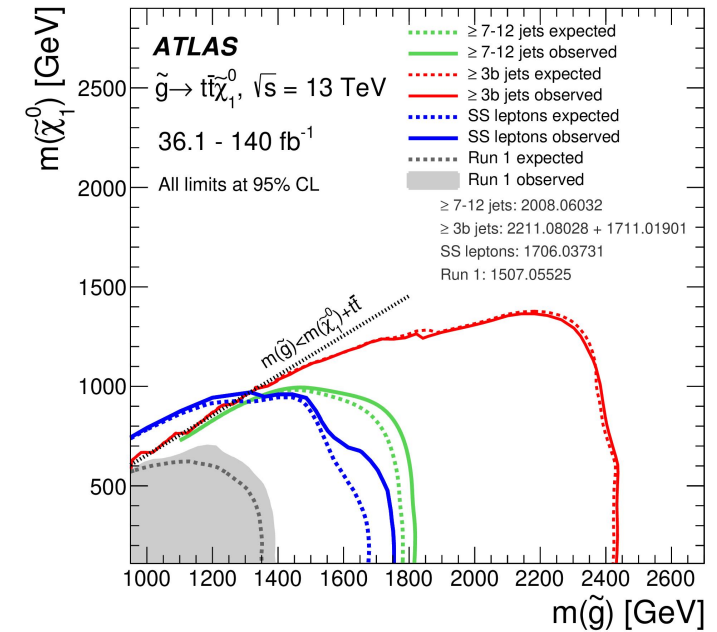
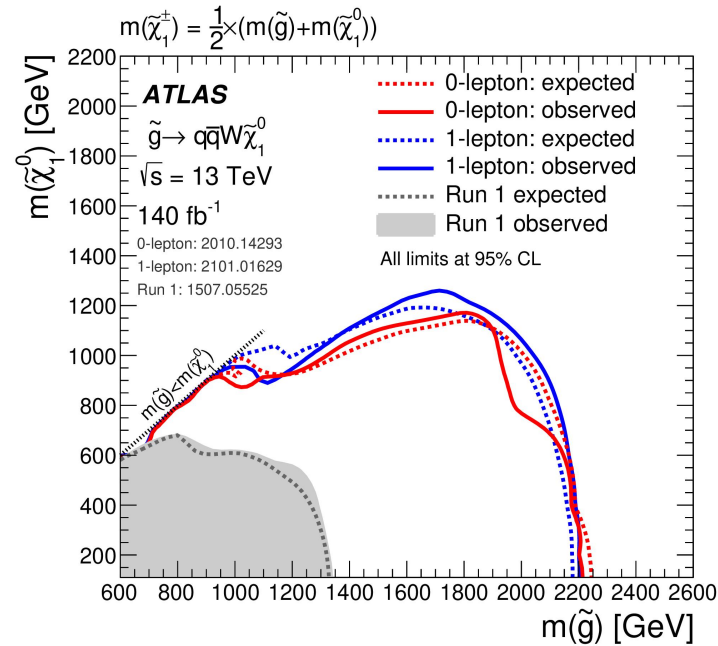
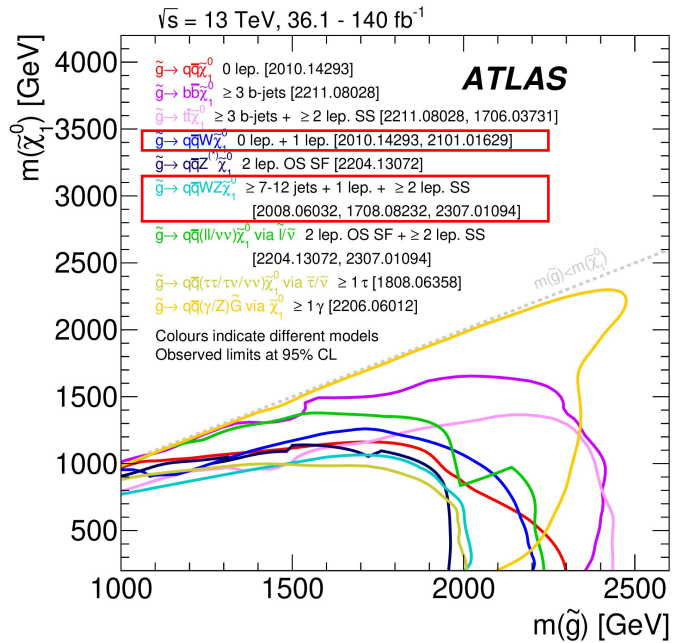


Strong SUSY searches: gluino pair production with RPC decay



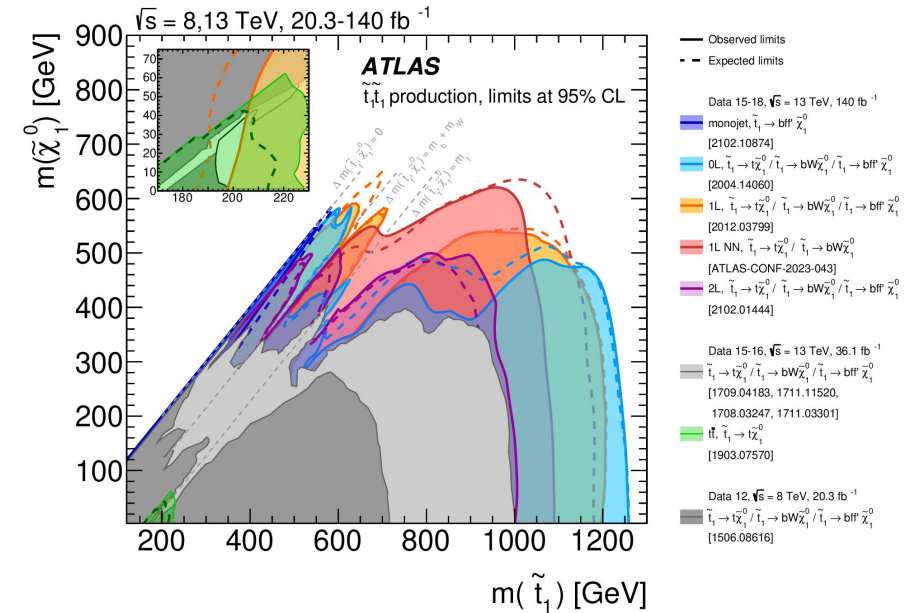
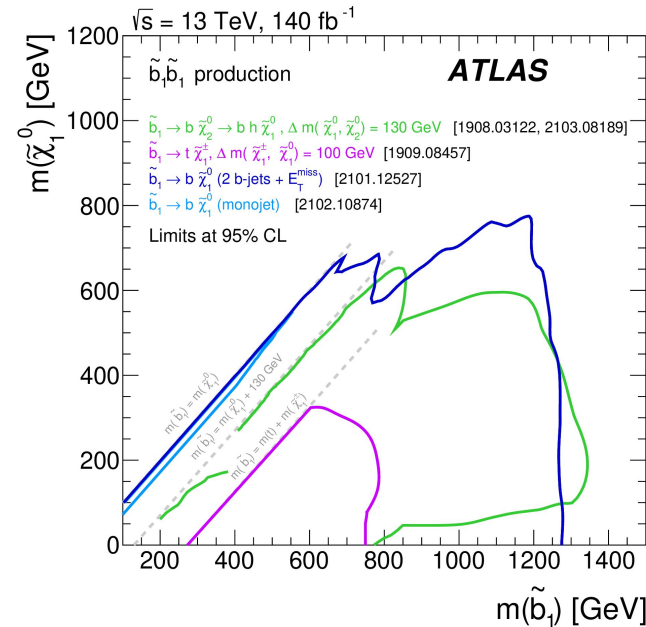
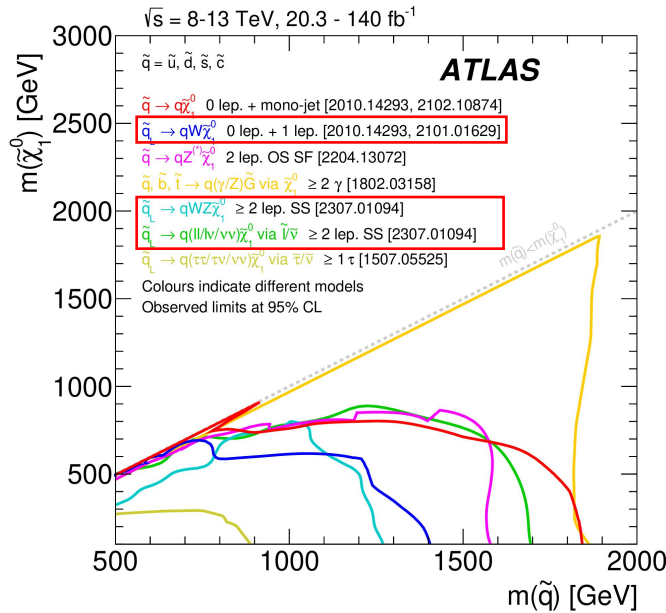
- $\tilde{g} \rightarrow q\bar{q}\tilde{X}_1^0$: gluino masses up to about 2.2 TeV are excluded for massless $\tilde{X}_1^0$. Exclusion on $\tilde{X}_1^0$ mass reach up to 1.3 TeV.
- $\tilde{g} \rightarrow q\bar{q}W\tilde{X}_1^0$: gluino masses up to about 2.2 TeV are excluded for massless $\tilde{X}_1^0$. Exclusion on $\tilde{X}_1^0$ mass reach up to 1 TeV. (IHEP contributions).
- $\tilde{g} \rightarrow q\bar{q}WZ\tilde{X}_1^0$: gluino masses up to about 2 TeV are excluded for massless $\tilde{X}_1^0$. Exclusion on $\tilde{X}_1^0$ mass reach up to 1 TeV. (IHEP contributions).
- $\tilde{g} \rightarrow q\bar{q}(\gamma/Z)\tilde{G}$: gluino masses up to about 2.4 TeV.
- $\tilde{g} \rightarrow t\bar{t}\tilde{X}_1^0$, $\tilde{g} \rightarrow b\bar{b}\tilde{X}_1^0$: gluino masses up to about 2.4 TeV are excluded for massless $\tilde{X}_1^0$.

Strong SUSY searches: gluino pair production with RPC decay



- Exclusion limit with assuming different RPC gluino decays are showed.
- For massless $\tilde{X}_1^0$, gluino masses are excluded above 2 TeV.
- IHEP SUSY group contribute to Strong 1L analysis and SS2L/3L analysis.

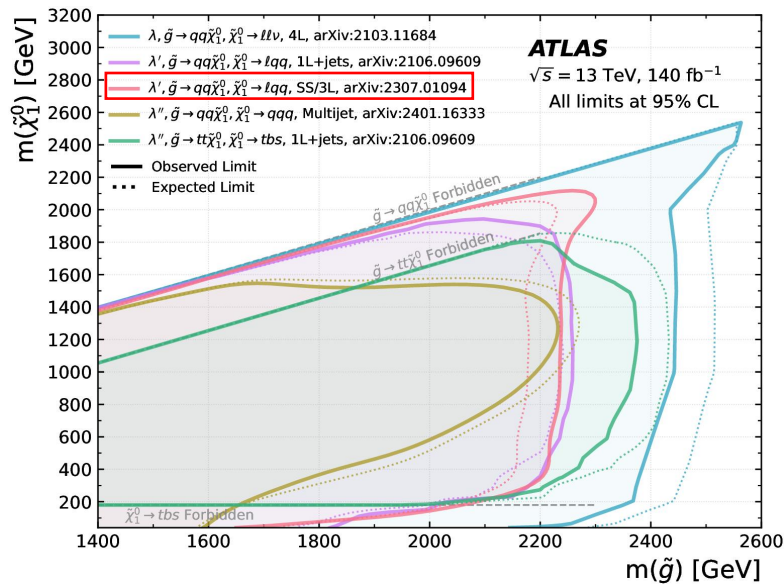
Strong SUSY searches: squark pair production with RPC decay



- Assuming different squark decay modes, exclusion limit on squark masses for first/second generation squarks range from 1.3 to 1.9 TeV for massless $\tilde{X}_1^0$.
- $\tilde{b}_1$ masses up to about 1.25 TeV are excluded for massless $\tilde{X}_1^0$.
- $\tilde{t}_1$ masses up to about 1.25 TeV are excluded for massless $\tilde{X}_1^0$. Exclusion on $\tilde{X}_1^0$ mass reach up to 600 GeV.

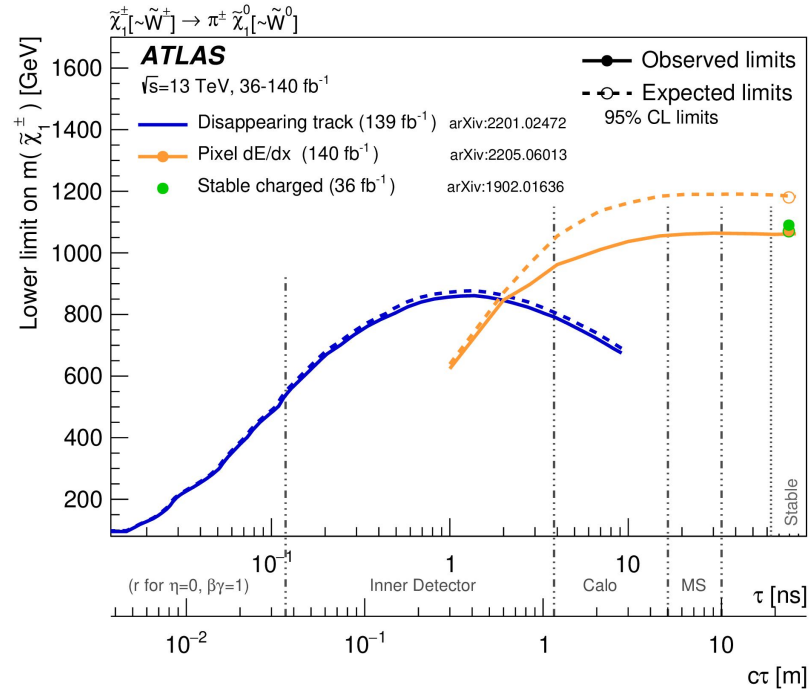
Strong SUSY searches: RPV decay

$$\frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k + \frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k + \kappa_iL_iH_2$$



- $\lambda_{ijk} \neq 0$: $\tilde{g} \rightarrow qq\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow ll\nu$, gluino masses up to 2.5 TeV are excluded.
- $\lambda'_{ijk} \neq 0$: $\tilde{g} \rightarrow qq\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow lqq/\nu qq$, gluino masses up to 2.2 TeV are excluded. (IHEP contribution in SS/3L analysis)
- $\lambda''_{ijk} \neq 0$:
 - $\tilde{g} \rightarrow qq\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow qqq$, gluino masses up to 2.2 TeV are excluded.
 - $\tilde{g} \rightarrow tt\tilde{X}_1^0, \tilde{X}_1^0 \rightarrow tbs$, gluino masses up to 2.35 TeV are excluded.

Long-lived supersymmetric particles

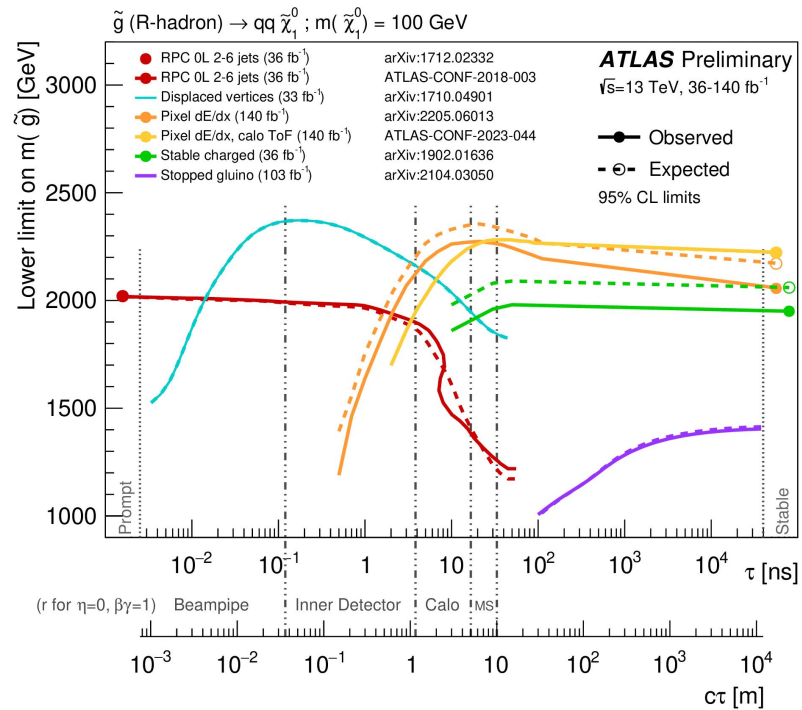


■ Slepton or chargino

- **Disappearing-track analysis:** a track in the inner detector until the point of decay, where that track then disappears. ->0.1–10 ns lifetime
- **Large-dE/dx analysis:** a track with high ionisation energy loss (dE/dx) in the pixel detector. ->above 1 ns lifetime

- The disappearing-track analysis excludes pure-wino charginos with masses up to ~850 GeV for lifetimes of about 1 ns.
- Wino-like charginos with masses up to ~1050 GeV are excluded for lifetimes longer than 10 ns.

Long-lived supersymmetric particles



■ Neutral long-lived SUSY particles

- Reconstruct the long-lived particle's decay products: charged decay products leave tracks that can be traced back to a common **displaced vertex**.
- A long-lived gluino may form an R-hadron with a SM vacuum quark, travel part way through the detector, and then stop in the calorimeter due to energy losses via ionisation and nuclear scattering. ->above 100 ns lifetime

- Prompt-decay SUSY analyses are typically more sensitive to gluino lifetimes below 0.01 ns.
- Gluino masses are excluded up to 2400 GeV for lifetimes of 0.1 ns.
- Long-lived gluinos with masses up to 1400 GeV are excluded for lifetimes of 10^4 – 10^{12} ns.

Summary

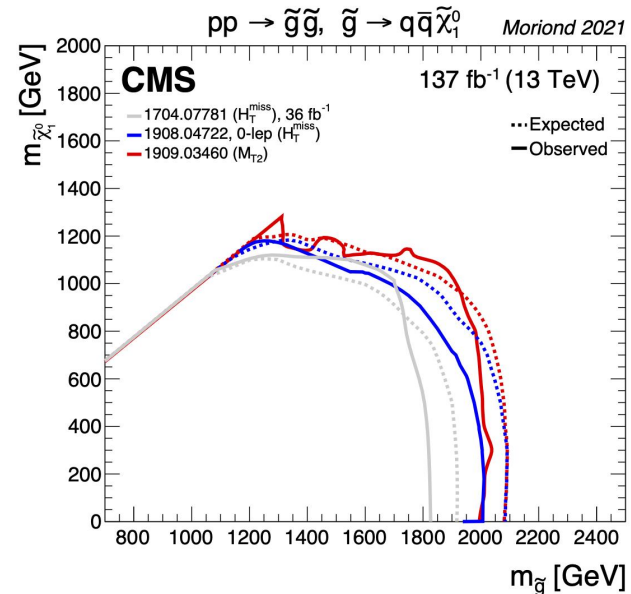
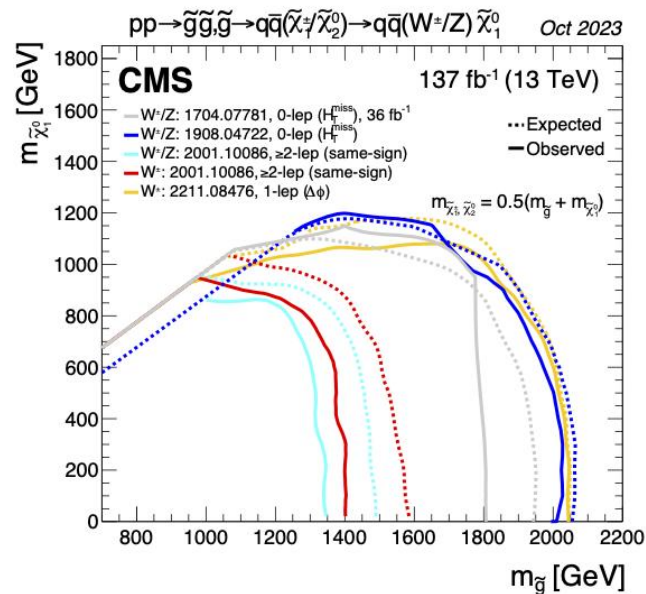
- Strong RPC SUSY searches
 - Gluino masses up to 2 TeV are excluded for massless $\tilde{X}_1^0$.
 - For first/second generation squarks, squark masses up to range from 1.3 to 1.9 TeV are excluded for different squark decay modes for massless $\tilde{X}_1^0$.
 - $\tilde{t}_1, \tilde{b}_1$ masses up to 1.25 TeV are excluded for massless $\tilde{X}_1^0$.
- Strong RPV SUSY searches
 - Gluino masses up to 2.2 TeV are excluded for massless $\tilde{X}_1^0$.
- Long-lived SUSY searches
 - Exclusion limit on $\tilde{X}_1^0$ mass and gluino mass are set.

Reference

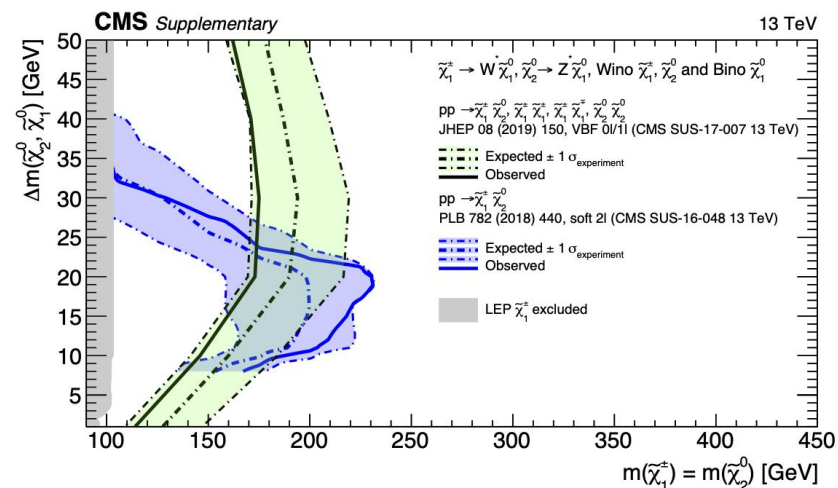
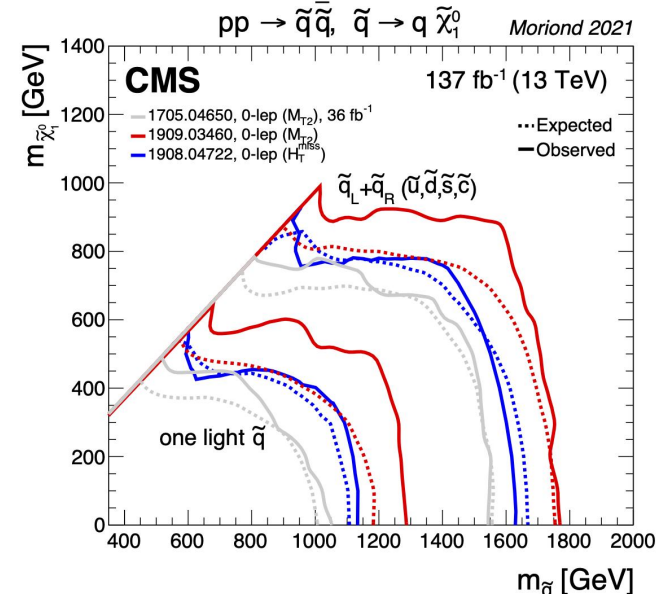
1. The quest to discover supersymmetry at the ATLAS experiment, Physics Reports, Volume 1116, 2025, Pages 261-300, ISSN 0370-1573

Backup

CMS SUSY Summary



Run2 SUSY summary of strong SUSY production



Run2 SUSY summary of EWK SUSY production