

Searches for squarks and gluinos in scenarios with R-parity violating sparticle decays, or long-lived sparticles with ATLAS

Bertrand Martin dit Latour
University of Bergen

on behalf of the ATLAS Collaboration

Lake Louise Winter Institute 2018



Introduction

R-parity is a discrete symmetry in Supersymmetry.

$(-1)^{3(B-L)+2s} = +1$ for SM, -1 for SUSY particles.

R-parity conservation

- **lightest sparticle is a good Dark Matter candidate**
- at LHC, signatures with large E_T^{miss}

R-parity violation

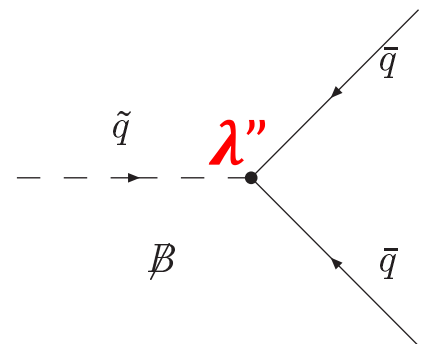
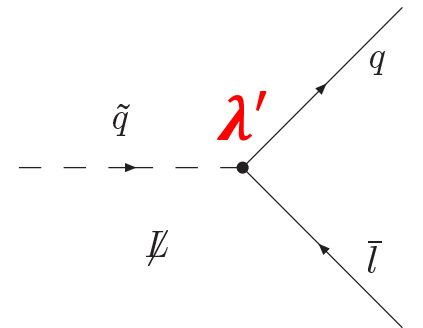
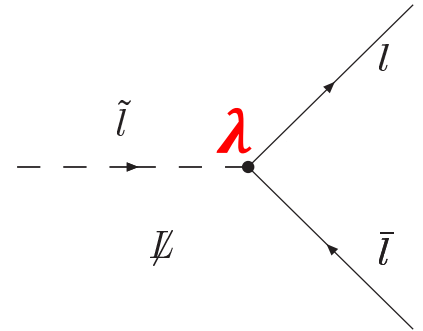
- lepton (λ, λ') and/or baryon (λ'') number violation
- can generate neutrino mass and mixing
- low E_T^{miss} , **unstable LSP** ☹, **LSP can be charged** ☺

Rich phenomenology, but handle with care!

Rapid proton decay, $n - \bar{n}$ oscillations,
large ν masses, neutrinoless double- β decay, ...

Small λ couplings?

Long-lived particles!



Dijet resonance pairs

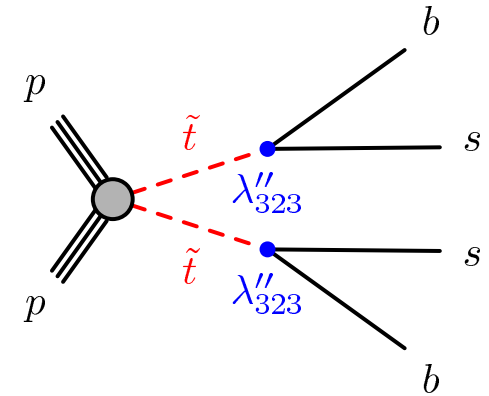
Search for \tilde{t} decaying to dijet via λ'' coupling.

Signature: **2 heavy pairs of close-by jets.**

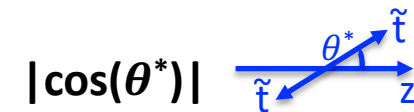
Btag-inclusive search ($\tilde{t} \rightarrow sd$), or **1 b-jet per pair** ($\tilde{t} \rightarrow bs$).

Choose **right jet pairing**:

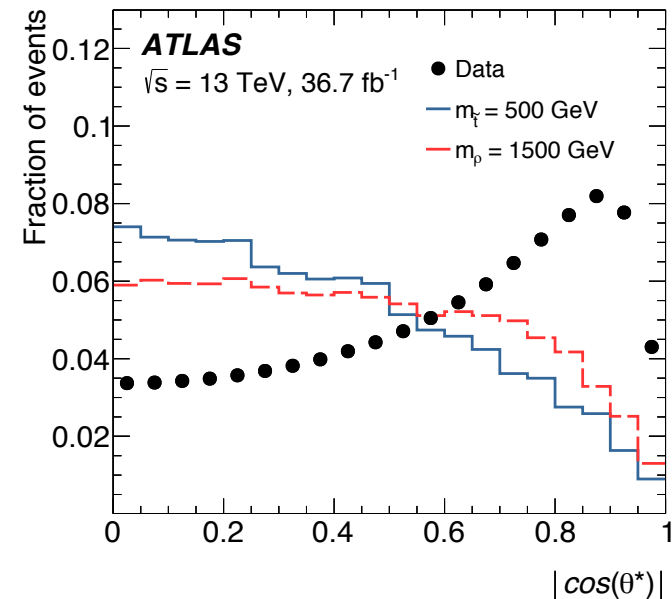
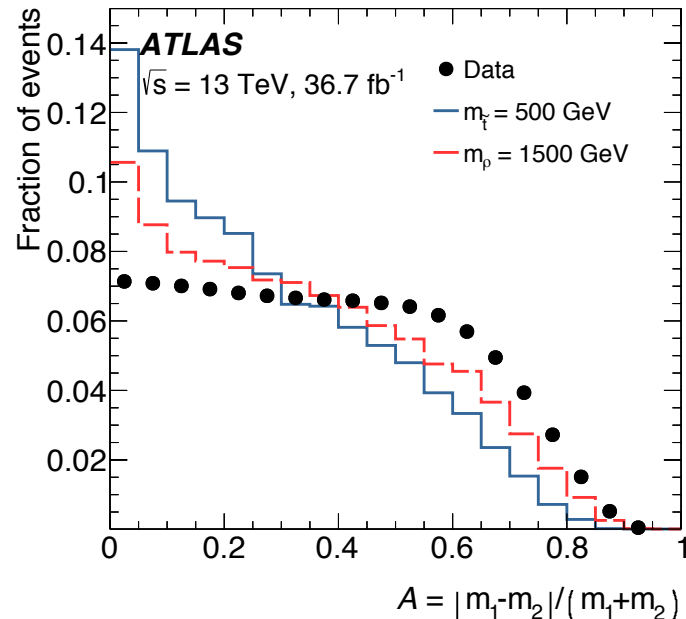
- boosted \tilde{t} has **low $\Delta R(\text{jet}, \text{jet})$**
- **2 resonances have same mass**
- **multijet background mostly in forward region (t-channel)**



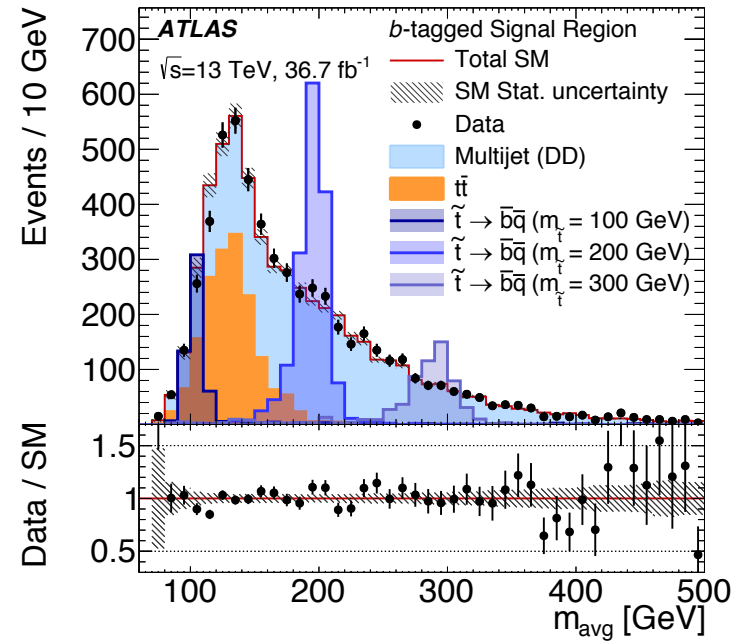
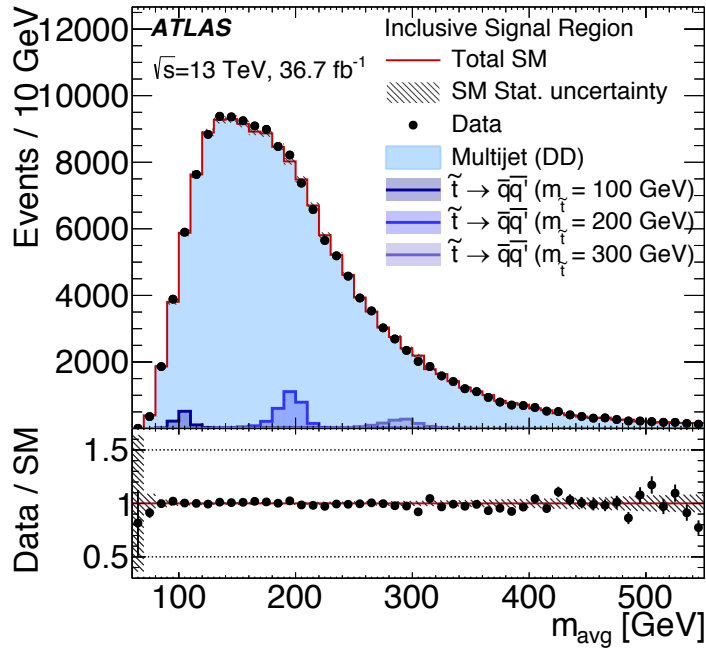
mass asymmetry



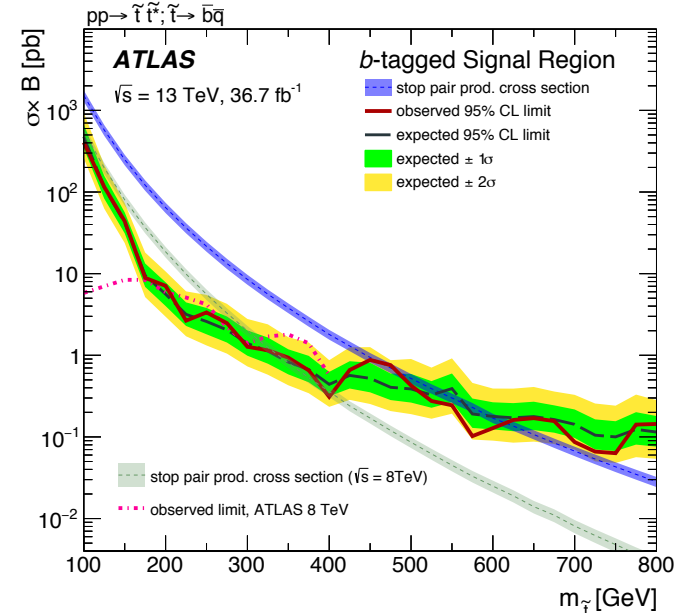
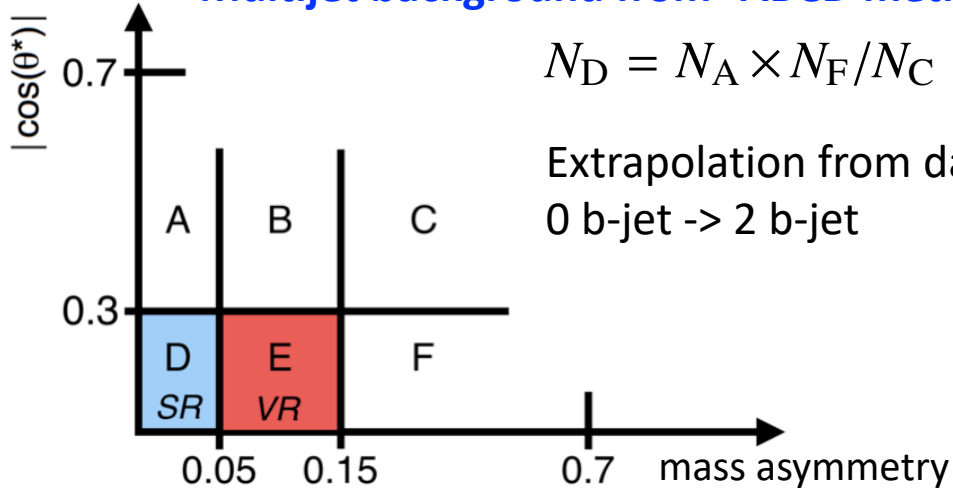
$|\cos(\theta^*)|$



Dijet resonance pairs



Multijet background from “ABCD method”

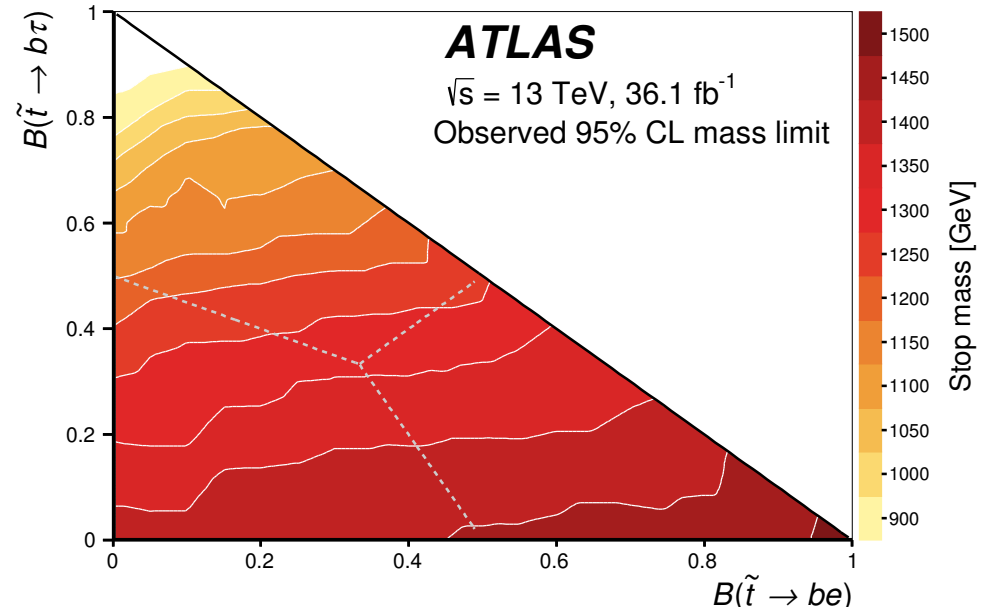
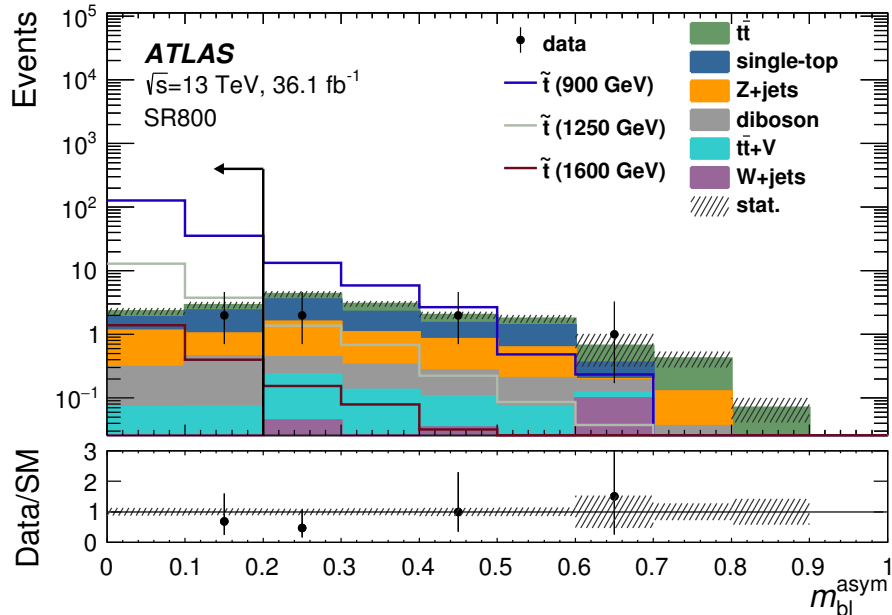
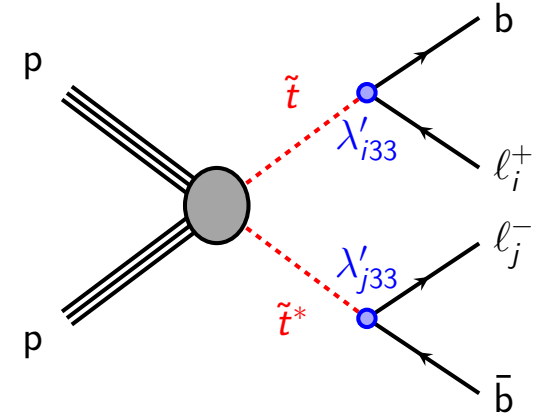


Scalar top LSP in model with $U(1)_{B-L}$ symmetry.
 $\tilde{t} \rightarrow b\mu$ (be) with normal (inverted) ν mass hierarchy.

$ee, \mu\mu, e\mu$ channels with ≥ 2 jets, ≥ 1 b-tag.

Choose ℓj pairing that minimizes mass asymmetry.

$t\bar{t}$, single top and Z+jets scaled to data.



Search based on **jet and b-jet multiplicities** for **high N_{jet}** (5-12). Up to **46 bins**.

Main backgrounds: V+jets, $t\bar{t}$ +jets.

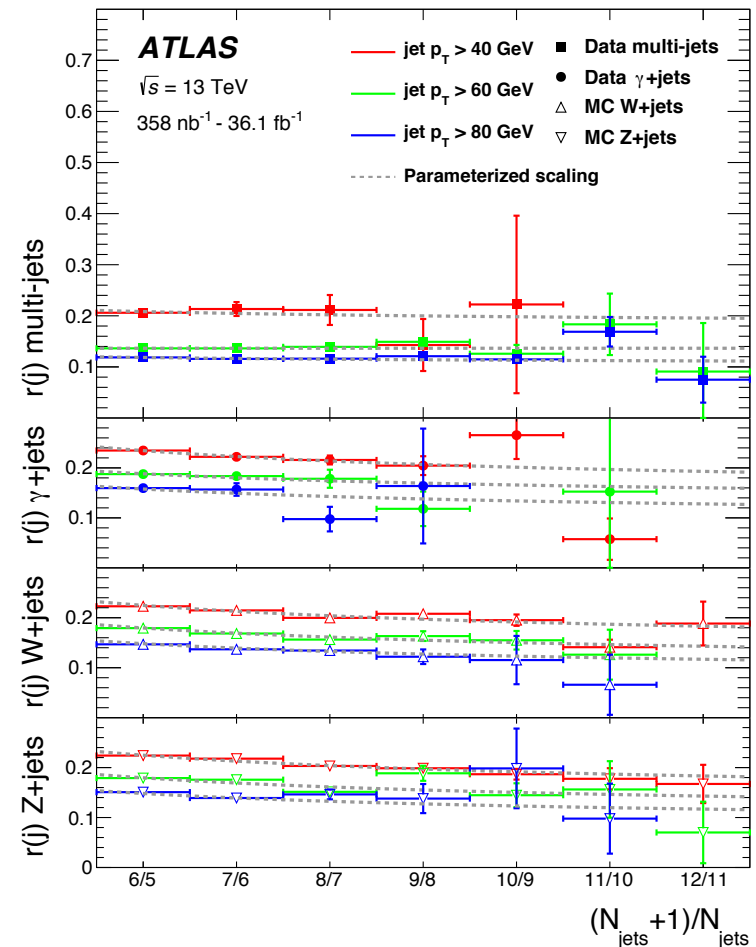
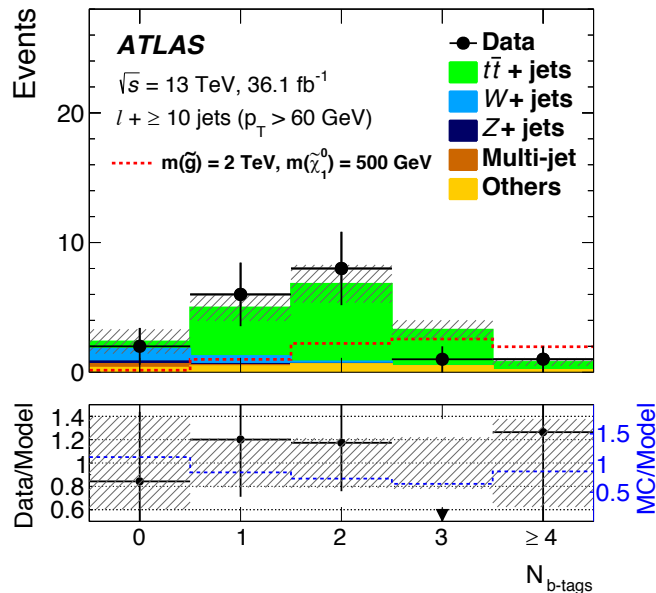
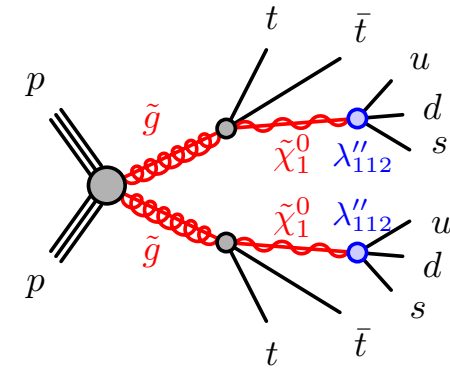
N_{jet} extrapolated from low to high multiplicities

$$(N_{\text{jet}} + 1)/N_{\text{jet}} = c_0 + c_1/(N_{\text{jet}} + c_2)$$

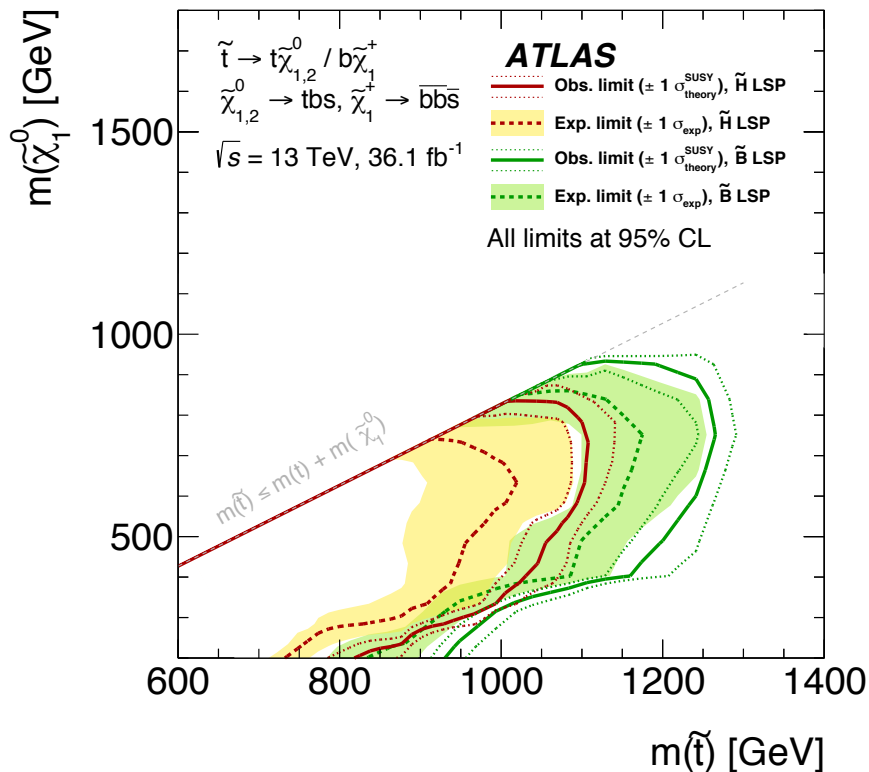
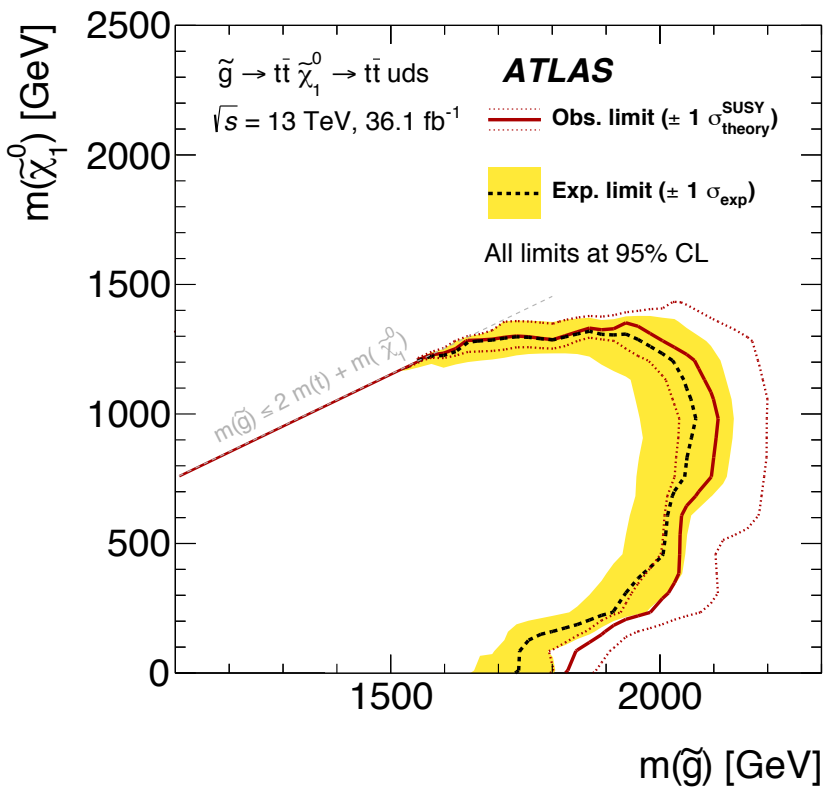
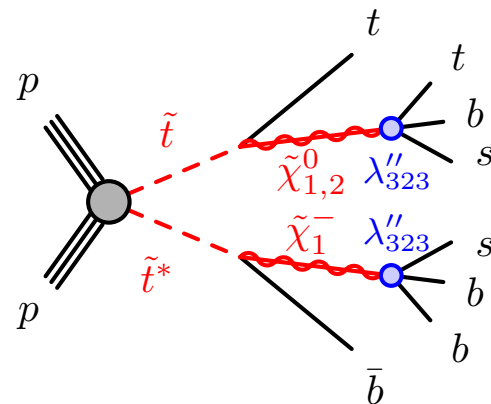
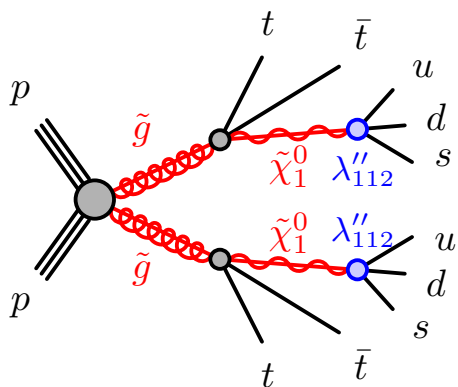
“staircase scaling”
at large N_{jet}

“Poisson scaling”
at lower N_{jet}

$N_{\text{b-jet}}$ from simulation (V+jets) or data ($t\bar{t}$ +jets).



1 ℓ + jets



For \tilde{t} interpretation, **better sensitivity to Bino LSP**, as $\tilde{t} \rightarrow t\tilde{\chi}_1^0$, while for **Higgsino LSP**, $\text{BR}(\tilde{t} \rightarrow b\tilde{\chi}_1^{\pm}) \sim 50\%$, producing fewer leptons and jets.

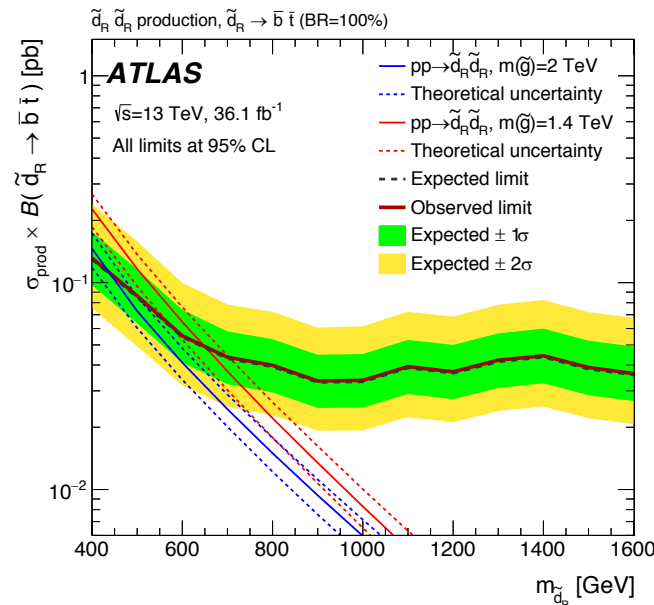
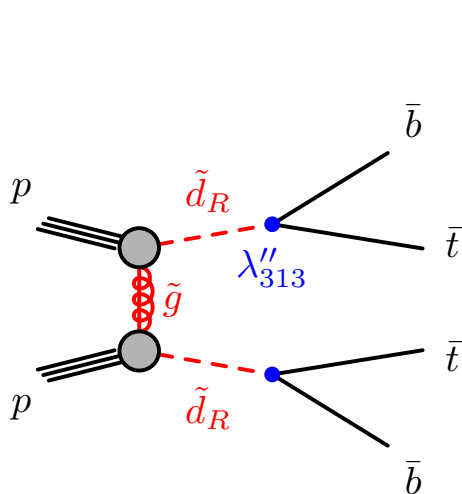
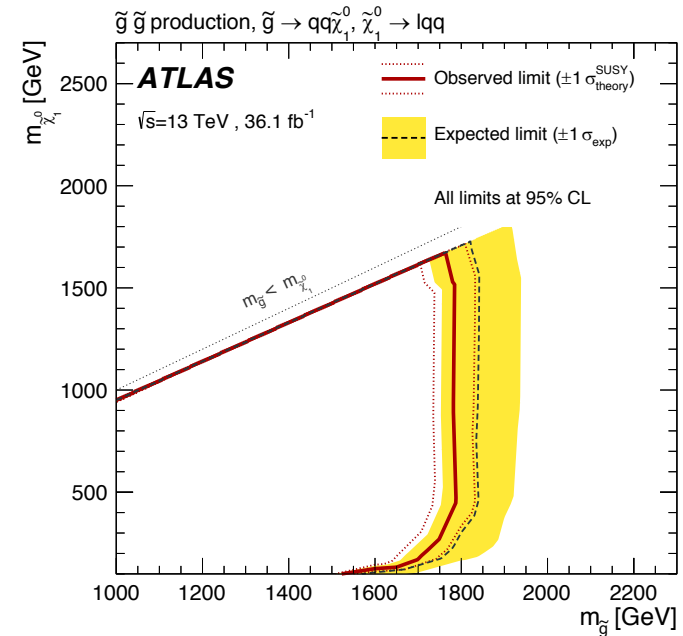
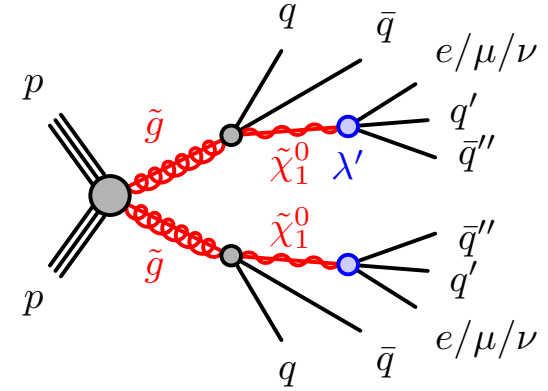
$\ell^\pm \ell^\pm$ or $3\ell + \text{jets}$

Signatures with small SM background.

All (e, μ) combinations considered ($\ell^- \ell^-$ for $\tilde{d}\tilde{d}$).

Backgrounds:

- **Electron charge flip:**
opposite sign events \times flip probability from Z(ee)
- **Fake or non-prompt lepton:**
 - **matrix method** (real/fake vs loose/tight leptons)
 - **template fit** to kinematic distributions
- **VV and $t\bar{t}V$: simulation**

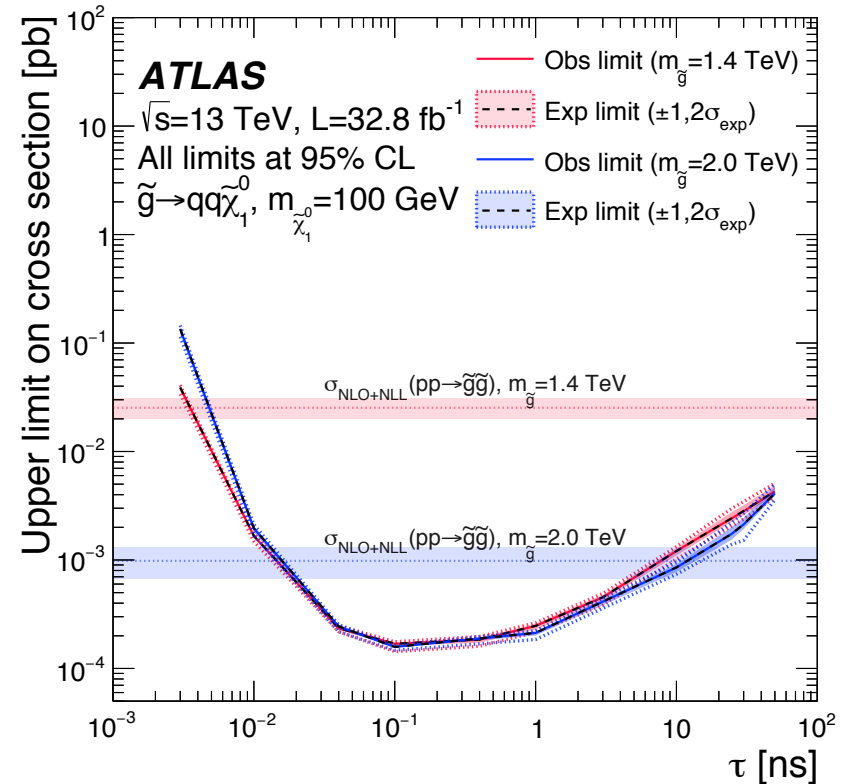
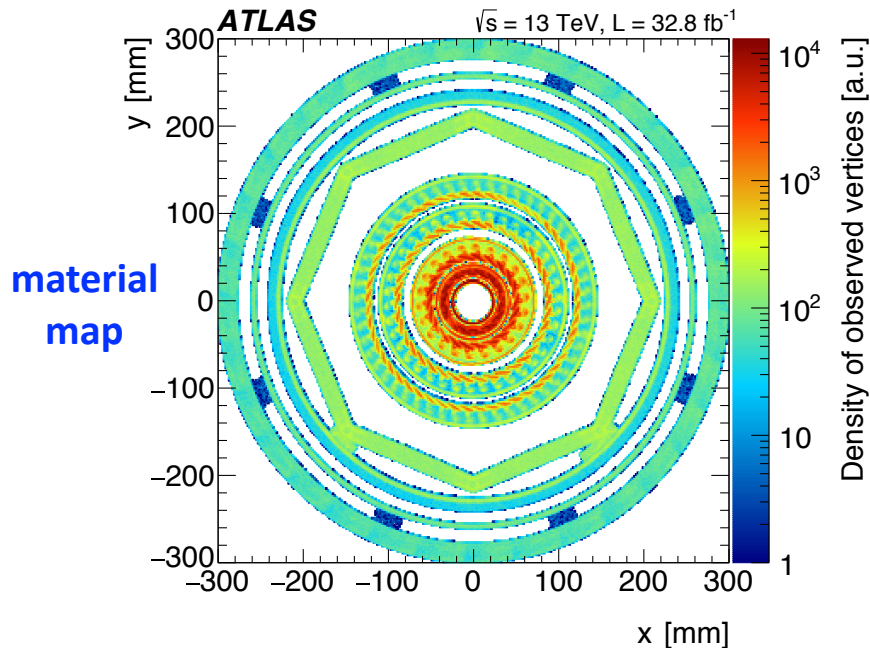
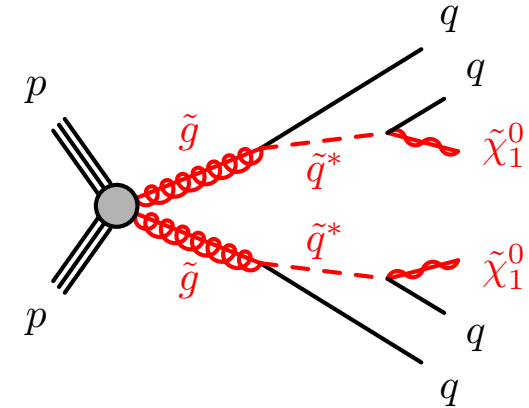


Long-lived \tilde{g} can hadronise and **decay within tracker** making **displaced high-mass vertex**.

Large-radius track + vertex reconstruction.

Backgrounds:

- Hadronic interaction with detector material
- Merging of low-mass vertices
- Spurious high-angle track crossing vertex

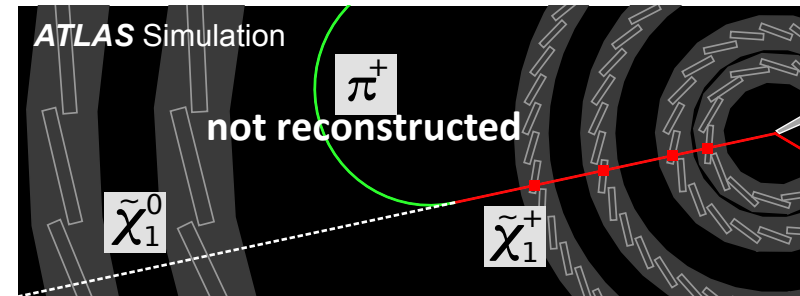
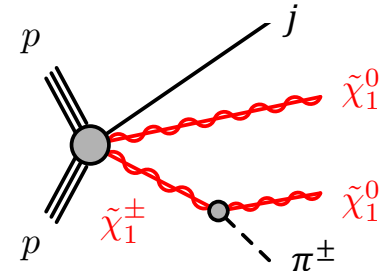


Disappearing tracks

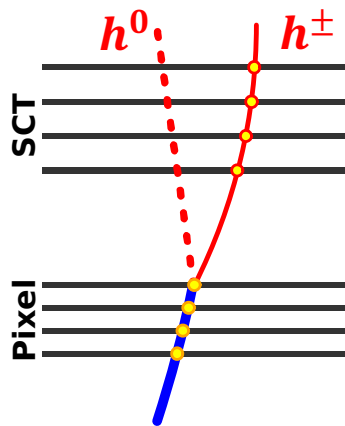
Scenario with $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ are \sim pure wino and almost **mass-degenerate** ($\tilde{\chi}_1^\pm$ long-lived, \sim ns).

Pixel-only tracks, with no additional hits.

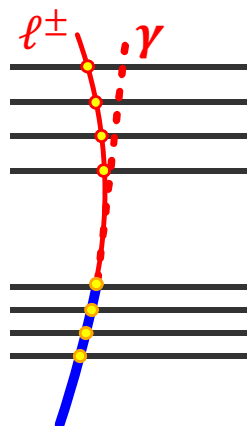
- **Hadron bkg:** long tracks + p_T smearing
- **Lepton bkg:** long tracks + p_T weighting (FSR) + p_T smearing
- **Combinatorial bkg:** tracks with large impact parameter, p_T described by fit function



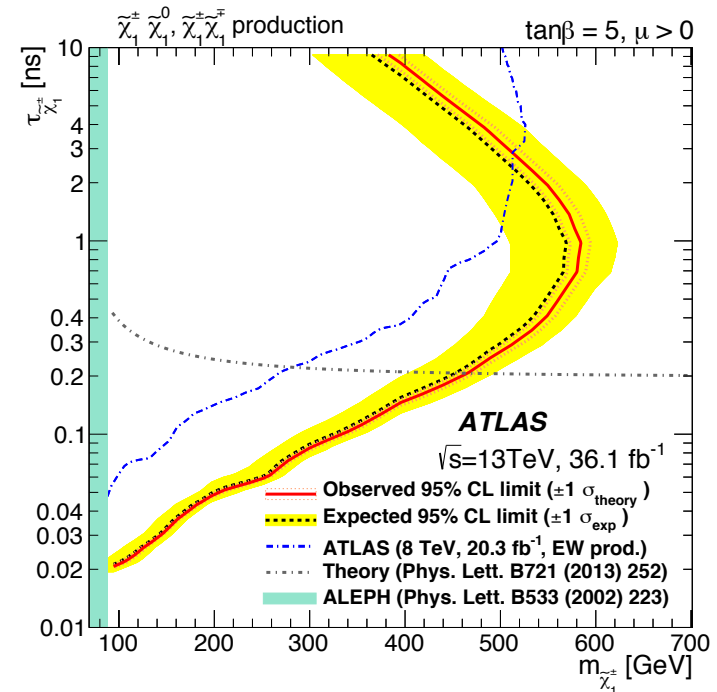
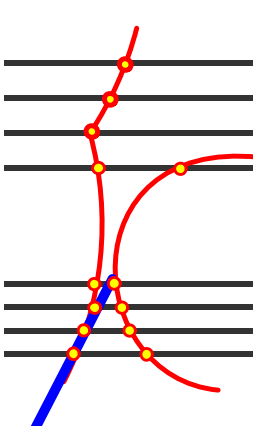
hadron scattering



FSR radiation



random hits



Summary

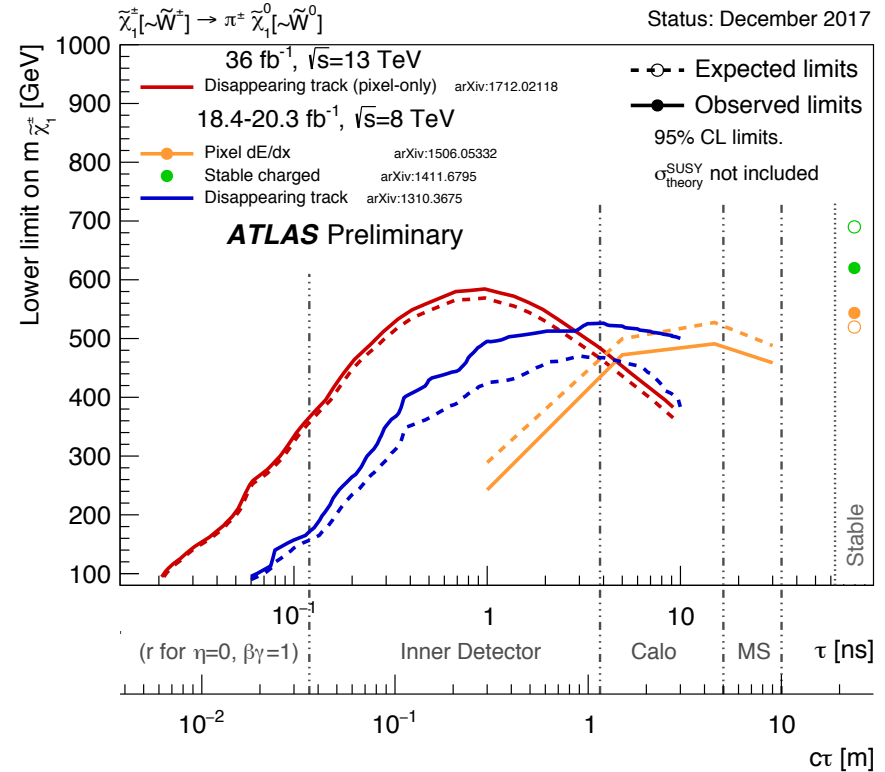
ATLAS SUSY searches with R-parity violation and long-lived particles were presented.

Non-conventional signatures: low E_T^{miss} , disappearing tracks, displaced vertices.

No excess in 2015+2016 data.

Exciting prospects from LHC for 2018!

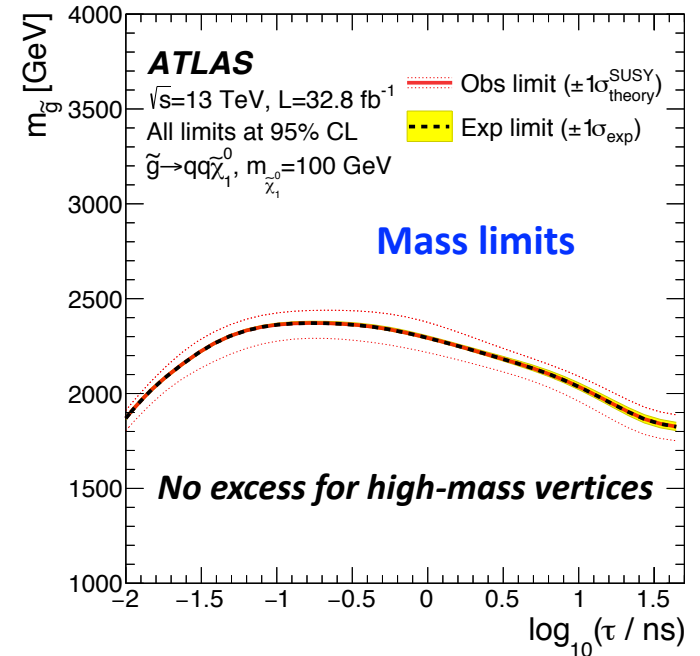
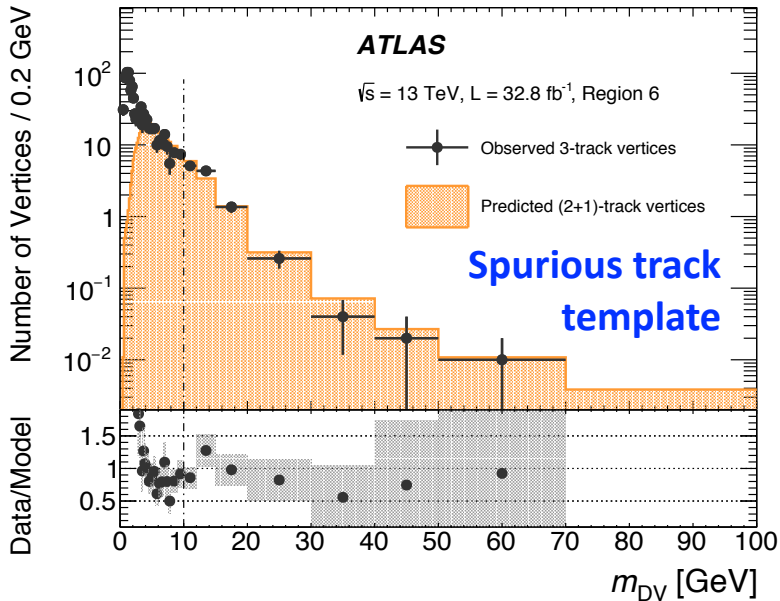
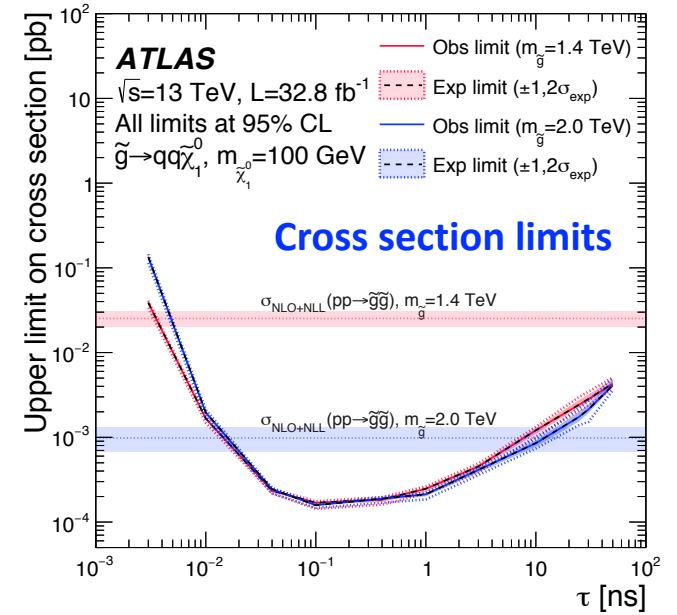
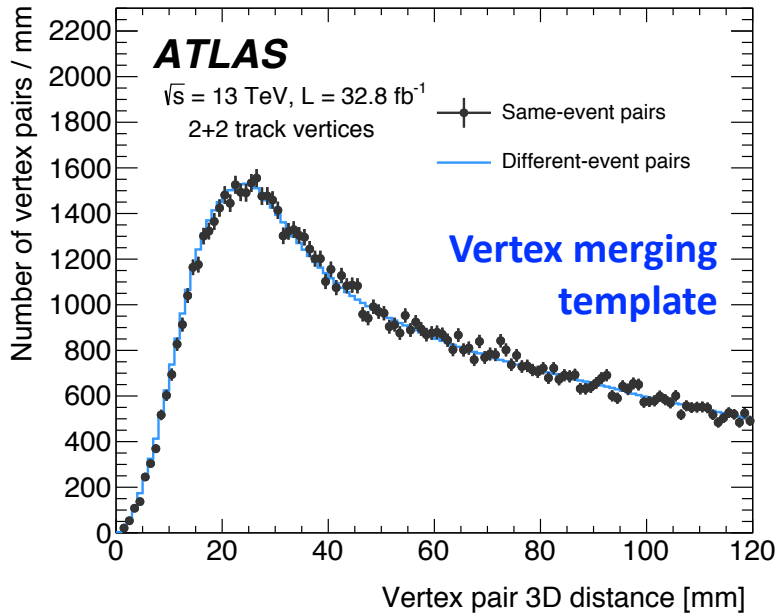
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L} dt [\text{fb}^{-1}]$
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	36.1
	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	dE/dx trk	-	Yes	18.4
	Stable, stopped \tilde{g} R-hadron	0	1-5 jets	Yes	27.9
	Stable \tilde{g} R-hadron	trk	-	-	3.2
	Metastable \tilde{g} R-hadron	dE/dx trk	-	-	3.2
	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq\tilde{\chi}_1^0$	displ. vtx	-	Yes	32.8
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \mu)$	1-2 μ	-	-	19.1
	GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^\pm$	2 γ	-	Yes	20.3
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3
	RPV	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e\mu/e\tau/\mu\tau$	$e\mu, e\tau, \mu\tau$	-	-
Bilinear RPV CMSSM		2 e, μ (SS)	0-3 b	Yes	20.3
$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow ee\nu, e\mu\nu, \mu\mu\nu$		4 e, μ	-	Yes	13.3
$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \tau\tau\nu_e, e\tau\nu_\tau$		3 $e, \mu + \tau$	-	Yes	20.3
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qq\bar{q}$		0	4-5 large- R jets	-	36.1
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qq\bar{q}$		1 e, μ	8-10 jets/0-4 b	-	36.1
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{t}_1 t, \tilde{t}_1 \rightarrow bs$		1 e, μ	8-10 jets/0-4 b	-	36.1
$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow bs$		0	2 jets + 2 b	-	36.7
$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow b\ell$		2 e, μ	2 b	-	36.1



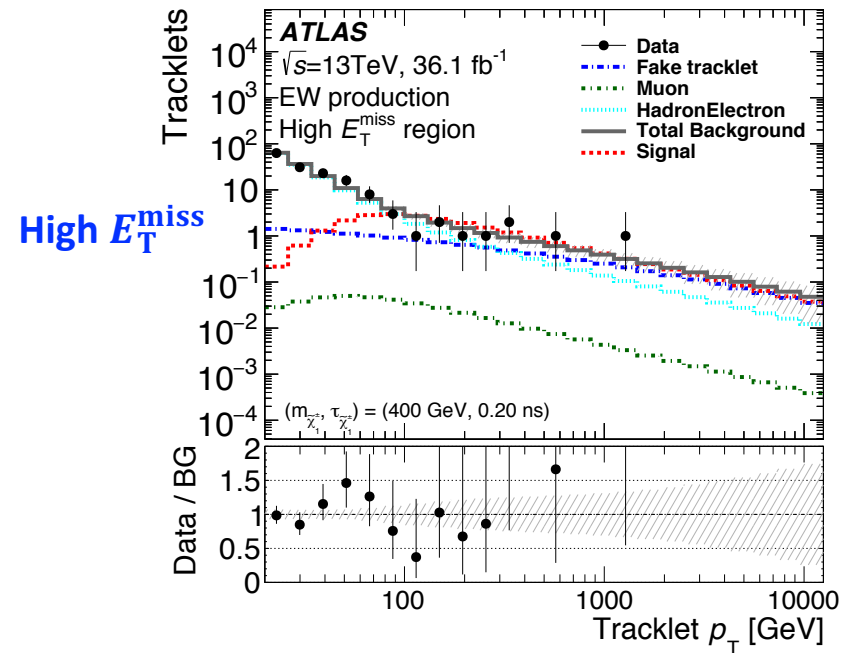
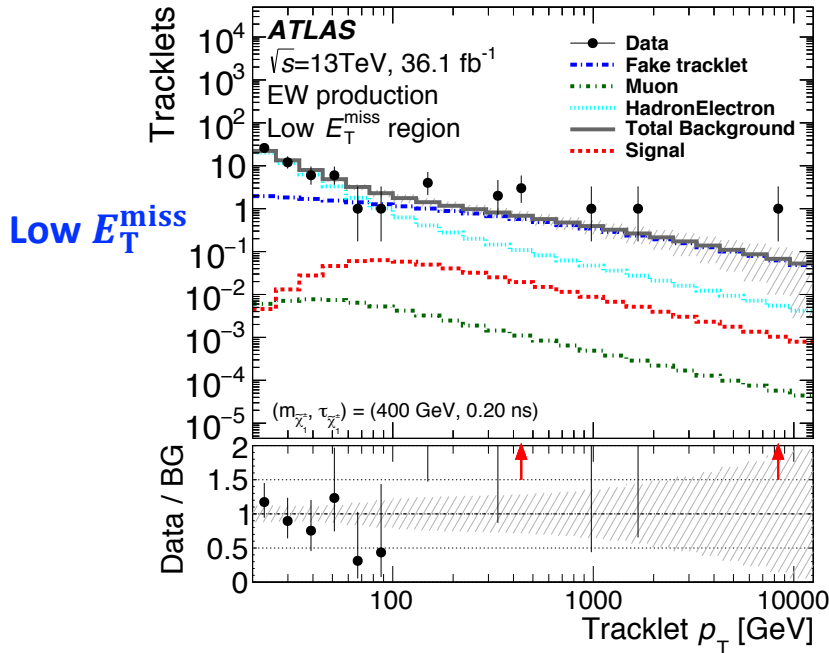
Still many other signatures to explore!

Backup

Displaced vertex + MET



Disappearing tracks

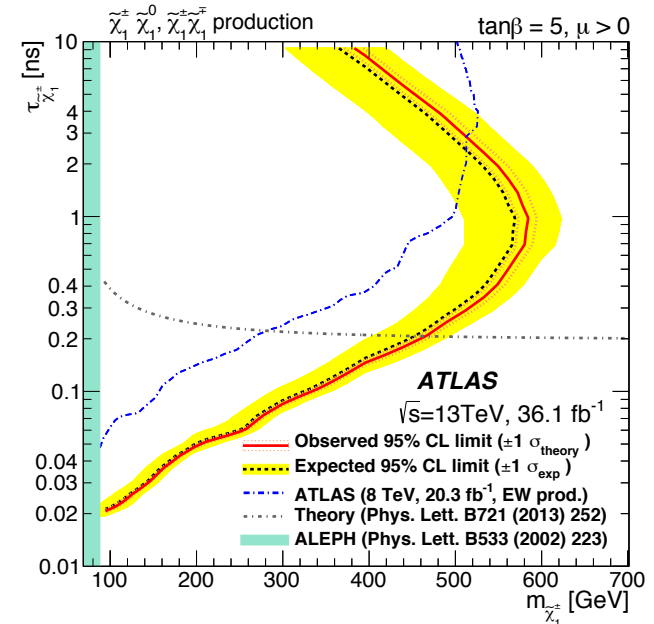


Fit of short-track p_T distribution:

- **low- E_T^{miss}** region constrains:
 - shape and normalisation of **fake-track bkg**
 - normalisation of **other bkg**
- **high- E_T^{miss}** region to extract **signal** strength

No excess in high- E_T^{miss} data.

Best sensitivity for $\tilde{\chi}_1^\pm$ lifetime $\sim 1\text{ ns}$.



$\tilde{t} \rightarrow bs$

Main background = multi-jets.

Estimated from data with **ABCD method**:

- shape and normalization from 0 b-jet
- extrapolation vs N b-jet

