

# SUSY searches at ATLAS and CMS with LHC Run-2 data

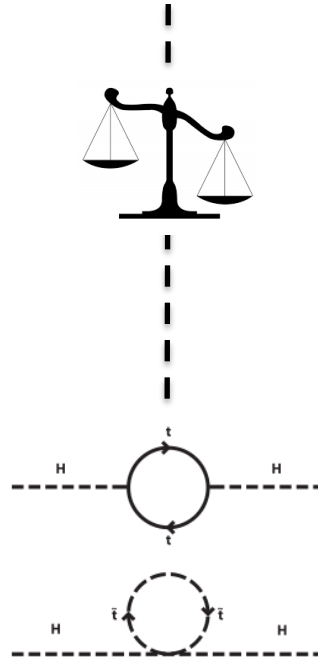
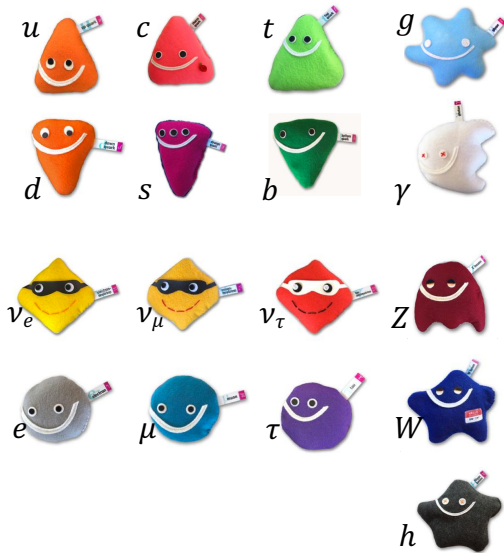
**Bertrand Martin dit Latour**  
**University of Bergen**

on behalf of the ATLAS and CMS collaborations

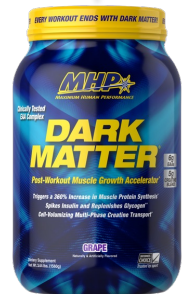
*Moriond QCD 2024*



# Supersymmetry



SUSY partners regulate Higgs  
mass radiative corrections



R-parity  $\equiv (-1)^{3(B-L)+2S}$  SM: R = 1

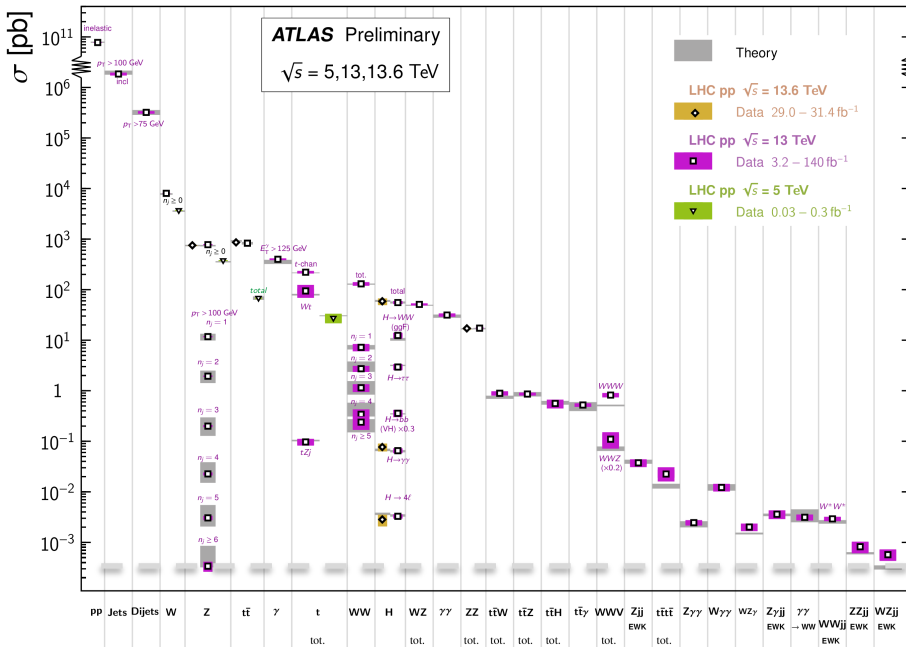
SUSY: R = -1

**SUSY = symmetry associating new boson (fermion) to each SM fermion (boson).**  
**R-parity:** *if conserved*, SUSY particles pair-produced, LSP stable and DM candidate.

# What can we probe with Run2 data?

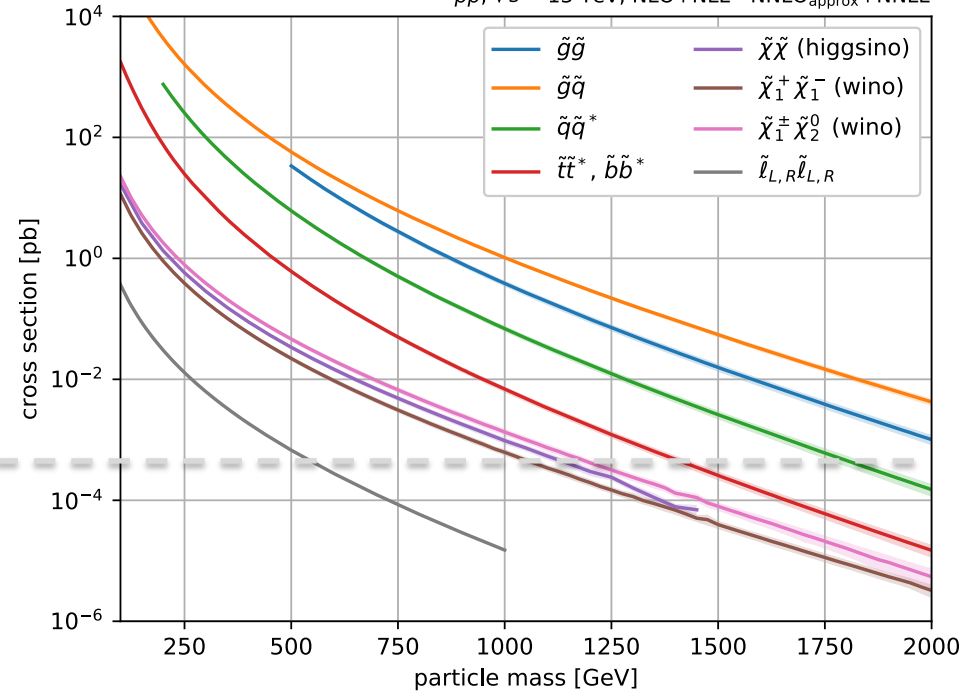
Standard Model Production Cross Section Measurements

Status: October 2023



sparticles kinematically decoupled [ref]

$pp, \sqrt{s} = 13$  TeV, NLO+NLL - NNLO<sub>approx</sub>+NNLL



From cross section consideration, sensitivity with Run2 LHC data up to:

~ 2.4 TeV gluinos

~ 1.3 TeV stop

~ 1 TeV EWKinos

Naturalness favours *light* stop, gluino and Higgsino.

# Search methodology

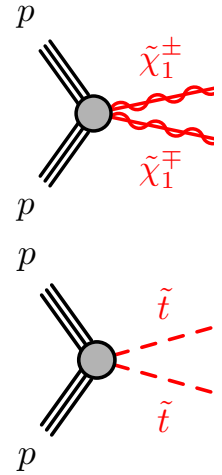
## Simplified models

few production/decay modes  
2-3 free parameters

R-parity conserved

EW production, various  
Bino/Wino/Higgsino scenarios

Strong production



SUSY parameter space looks too constrained?



More realistic model  
pMSSM EW: 5D scan



R-parity violation?



Flavour violation?

# Disappearing tracks

Models with wino/higgsino LSP:

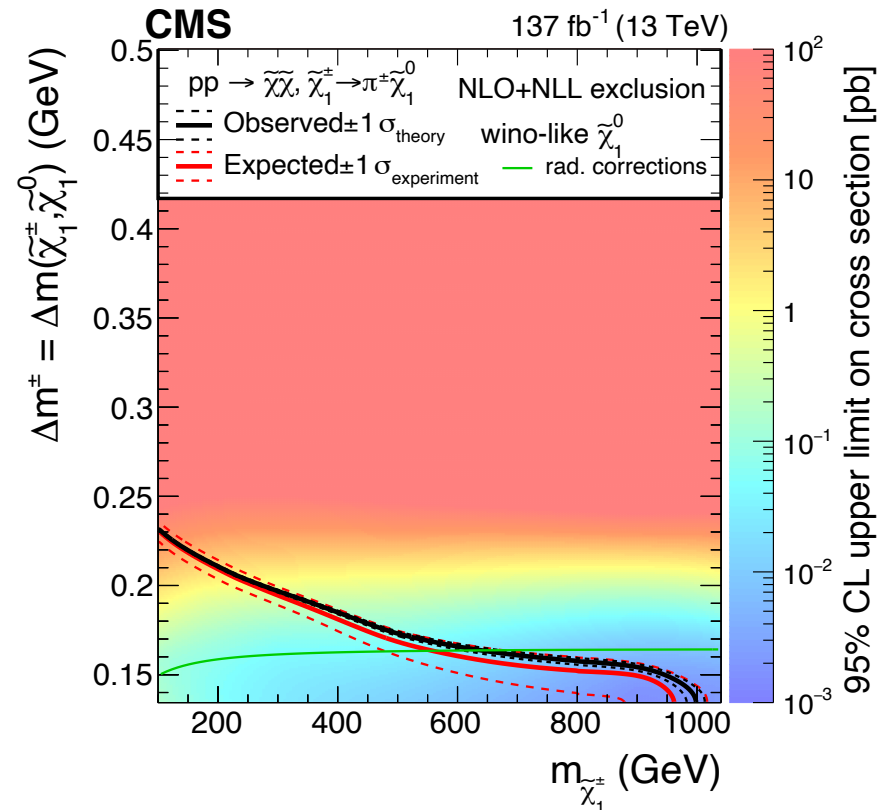
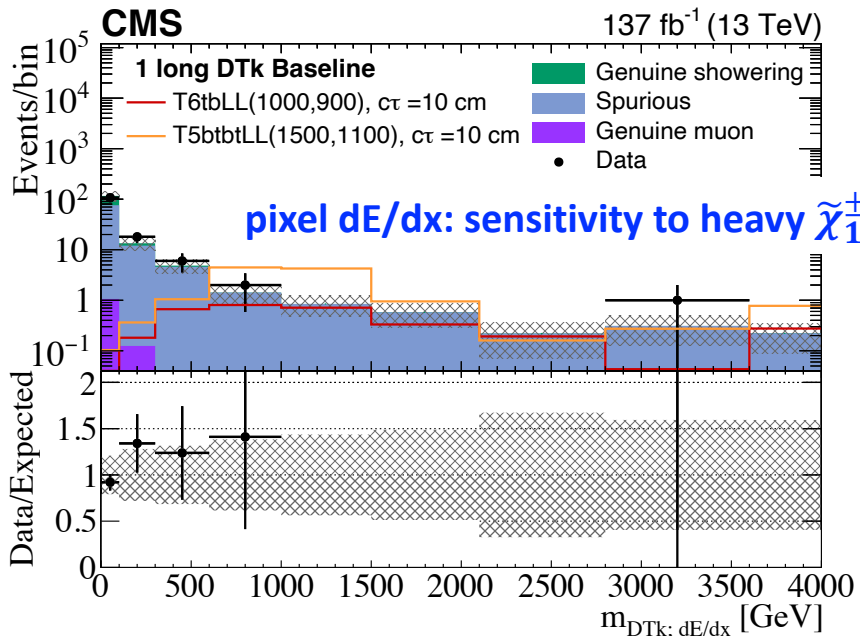
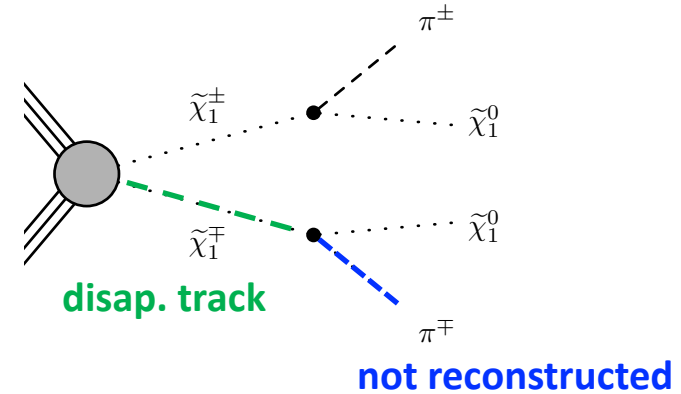
$$\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = \mathcal{O}(200 \text{ MeV}), c\tau \simeq 10 \text{ cm.}$$

$\tilde{\chi}_1^\pm$  long lived and decays inside tracker.

Short (long) track with hits in pixel (+strip),  
 $p_T > 25$  (40) GeV,  $d_0 < 0.1$  cm, no large calo E.

BDT to better reject:

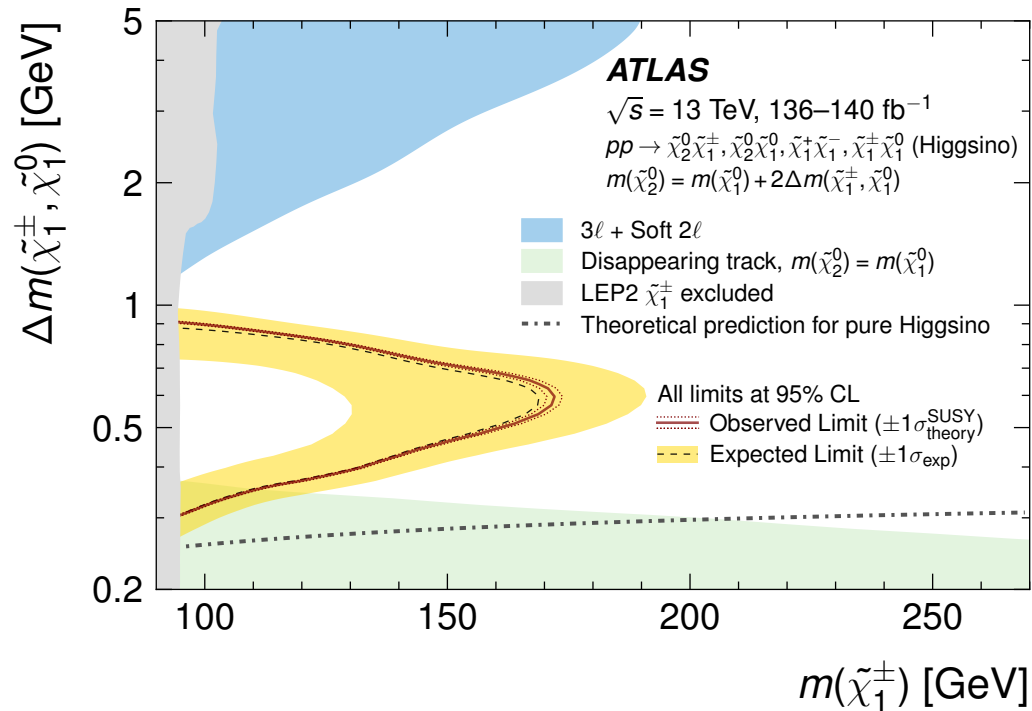
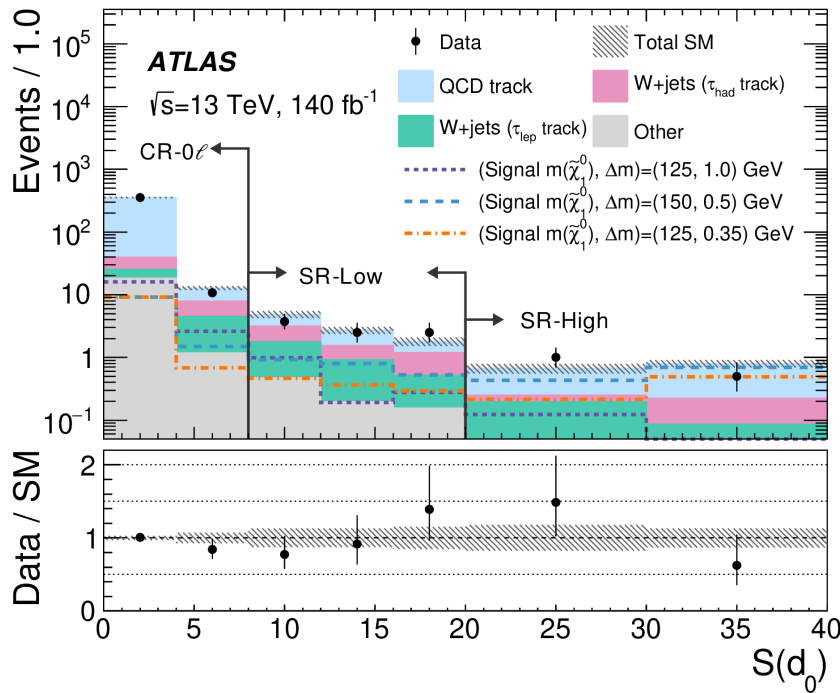
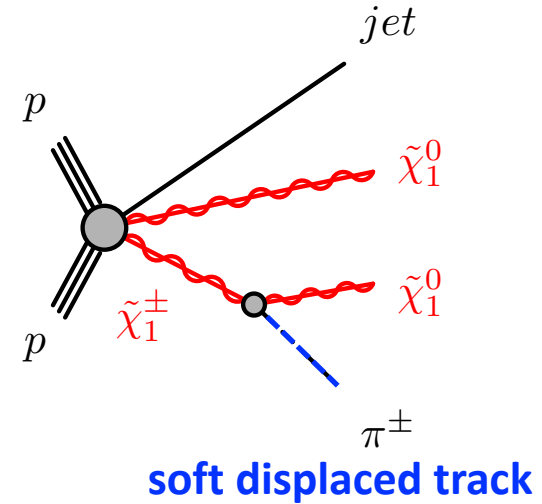
- track with too low calo E
- misaligned muon track
- random hit alignment



# Displaced track

$(\tilde{\chi}_2^0, \tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$  Higgsinos,  $\Delta m \simeq 0.3-1$  GeV,  $c\tau \simeq 0.1-1$ mm

- 1 high- $p_T$  jet
- large MET
- **1 track with  $2 < p_T < 5$  GeV, large  $d_0$  significance**
- **W( $\tau\nu$ ) bkg**: MC scaled to data at higher track  $p_T$
- **QCD bkg**: W( $\mu\nu$ ) data template scaled at low  $S(d_0)$

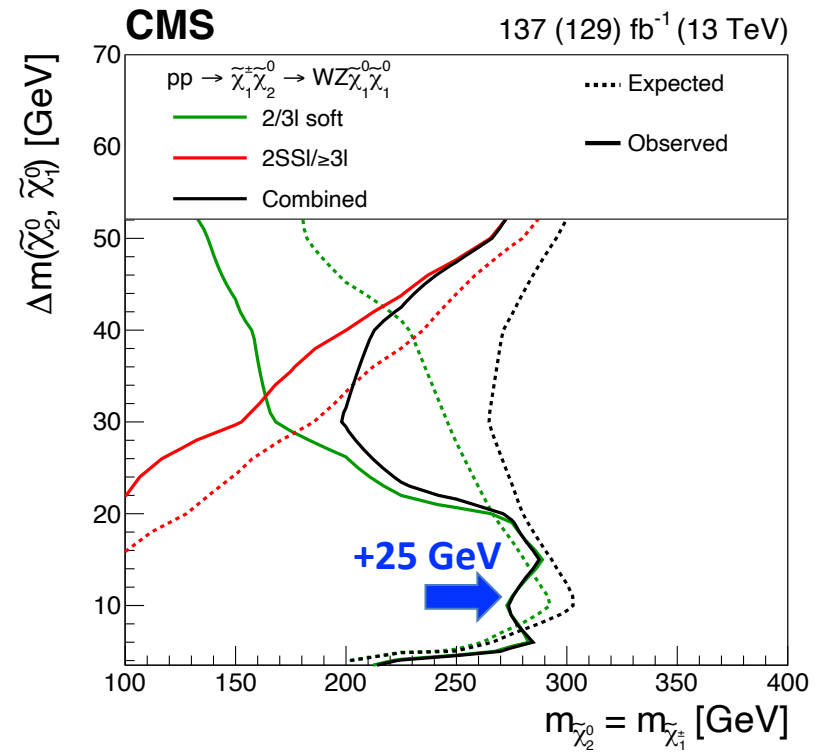
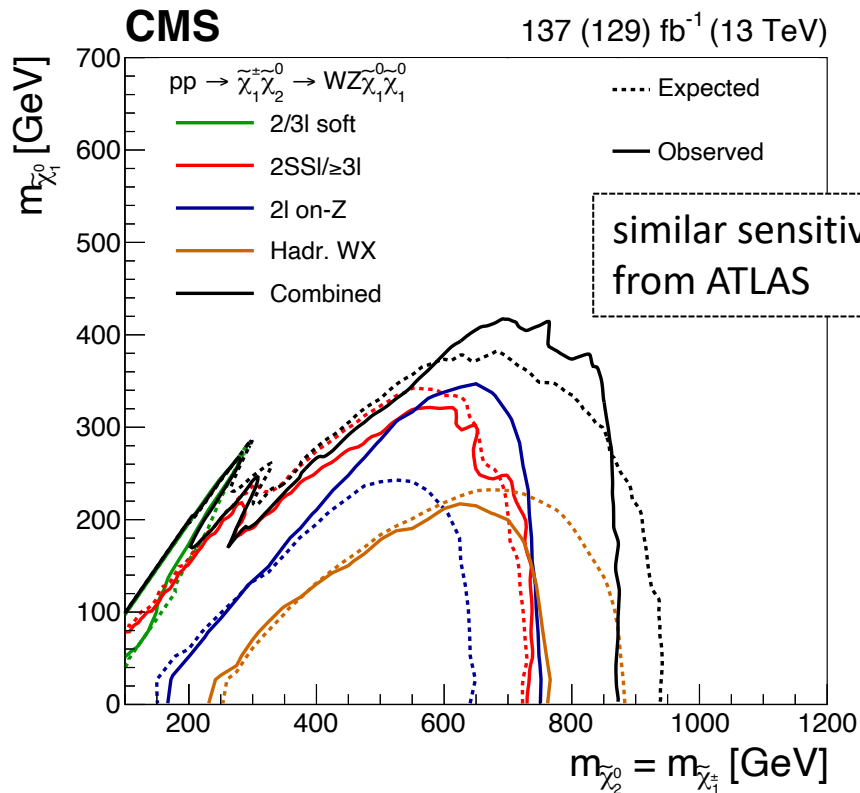
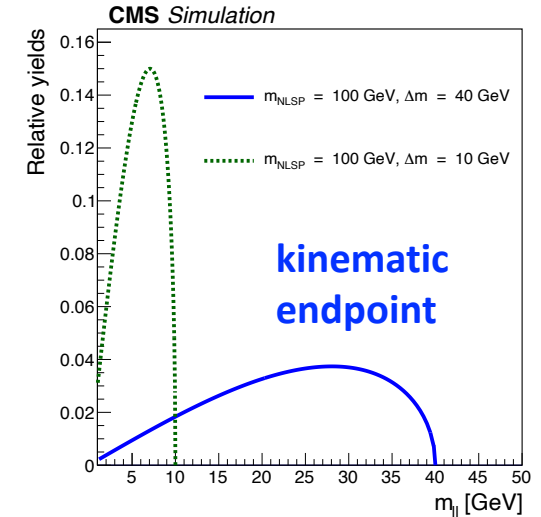
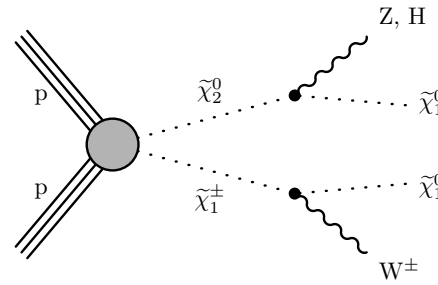


# Combination of EW searches

**Models:** Bino-Wino/Higgsino,  
GMSB with  $\tilde{G}$  LSP, slepton.  
**6 analyses combined.**

Phase space overlaps resolved.

**Improved sensitivity for 2/3 $\ell$  soft:  
bins in  $m_{\ell\ell}$  to exploit kin endpoint.**

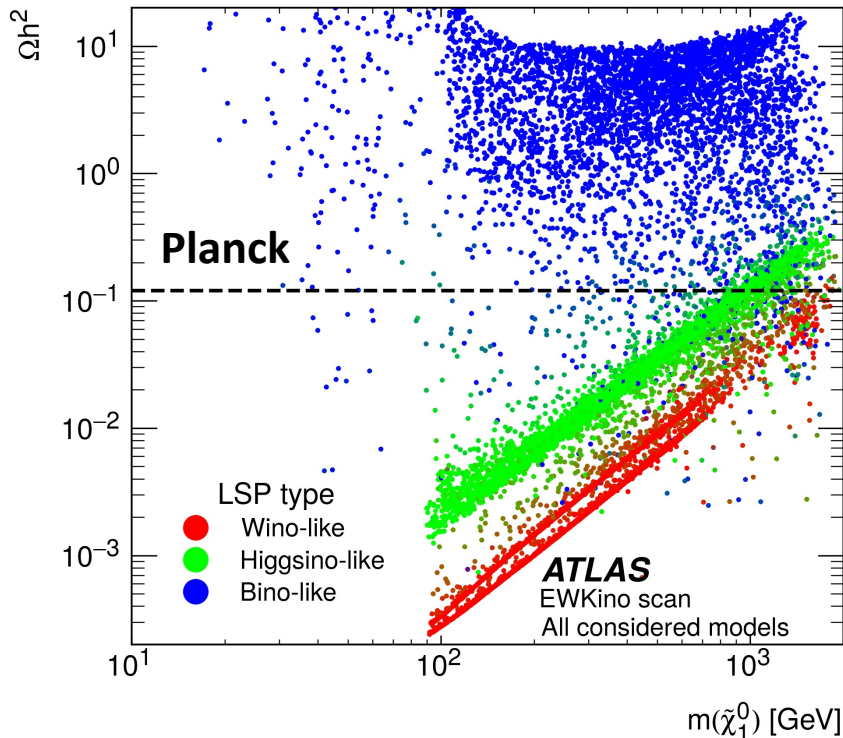


19-parameter pMSSM  
**5 params relevant for EWKino**

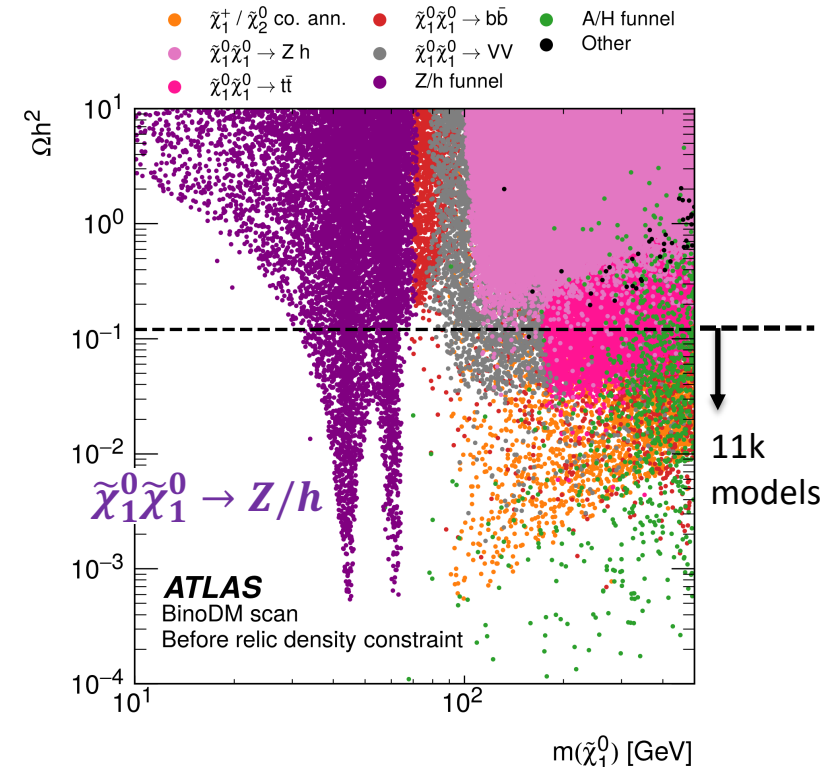
Results from 8 SUSY searches  
 exploited in the scan.

pMSSM Parameter	Meaning
$\tan \beta$	Ratio of the Higgs vacuum expectation values
$M_A$	Pseudoscalar ( $CP$ -odd) Higgs boson mass parameter
$\mu$	Higgsino mass parameter
$M_1, M_2, M_3$	Bino, wino and gluino mass parameters
$A_t, A_b, A_\tau$	Third generation trilinear couplings
$M_{\tilde{q}}, M_{\tilde{u}_R}, M_{\tilde{d}_R}, M_{\tilde{l}}, M_{\tilde{e}_R}$	First/second generation sfermion mass parameters
$M_{\tilde{Q}}, M_{\tilde{t}_R}, M_{\tilde{b}_R}, M_{\tilde{L}}, M_{\tilde{\tau}_R}$	Third generation sfermion mass parameters

Inclusive EWKino scan, 20k models

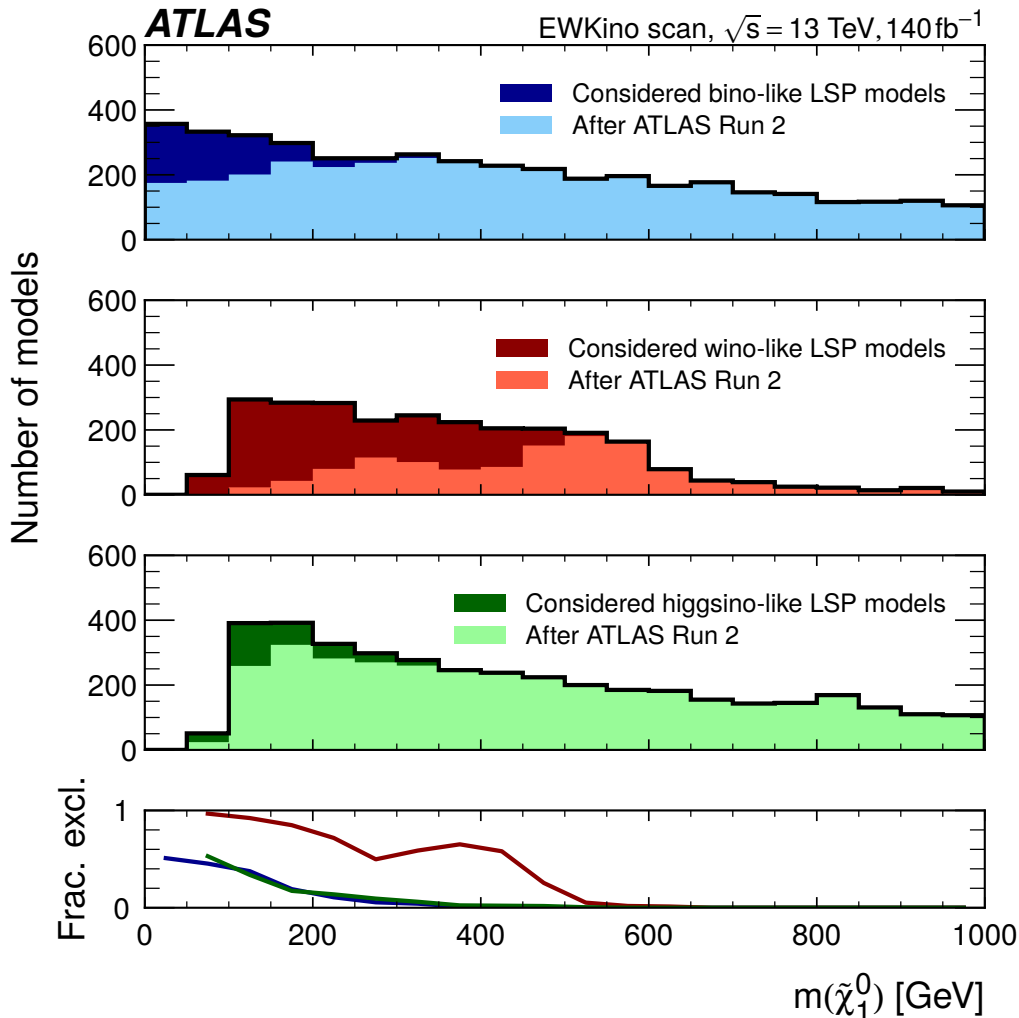


BinoDM scan: low-mass  $\tilde{B}$ , 440k models

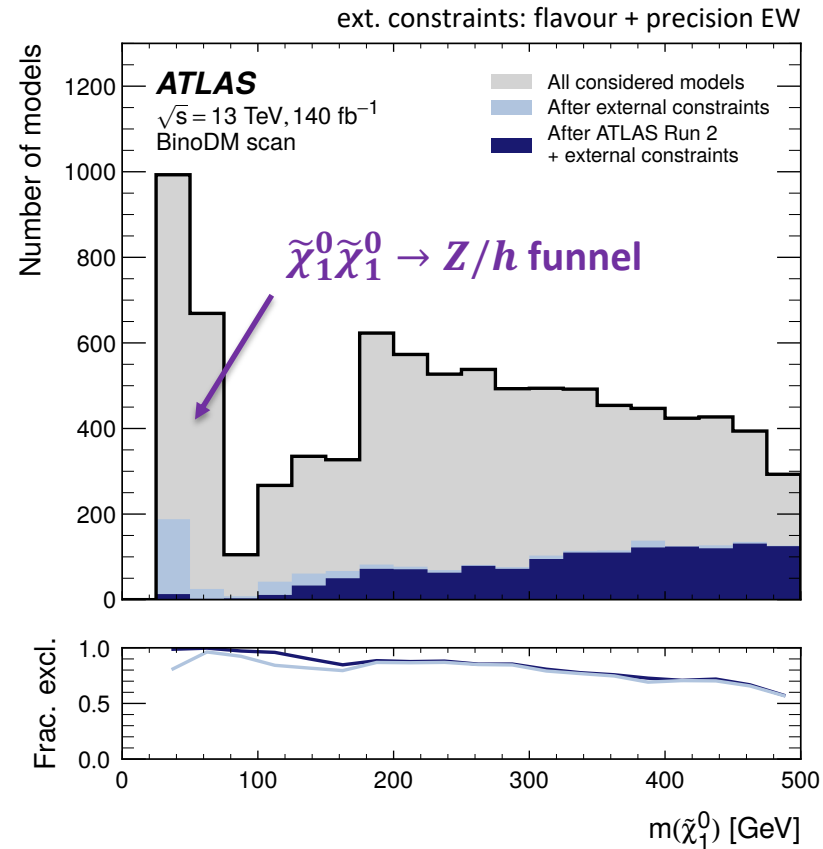




# pMSSM: $m(\tilde{\chi}_1^0)$ constraints

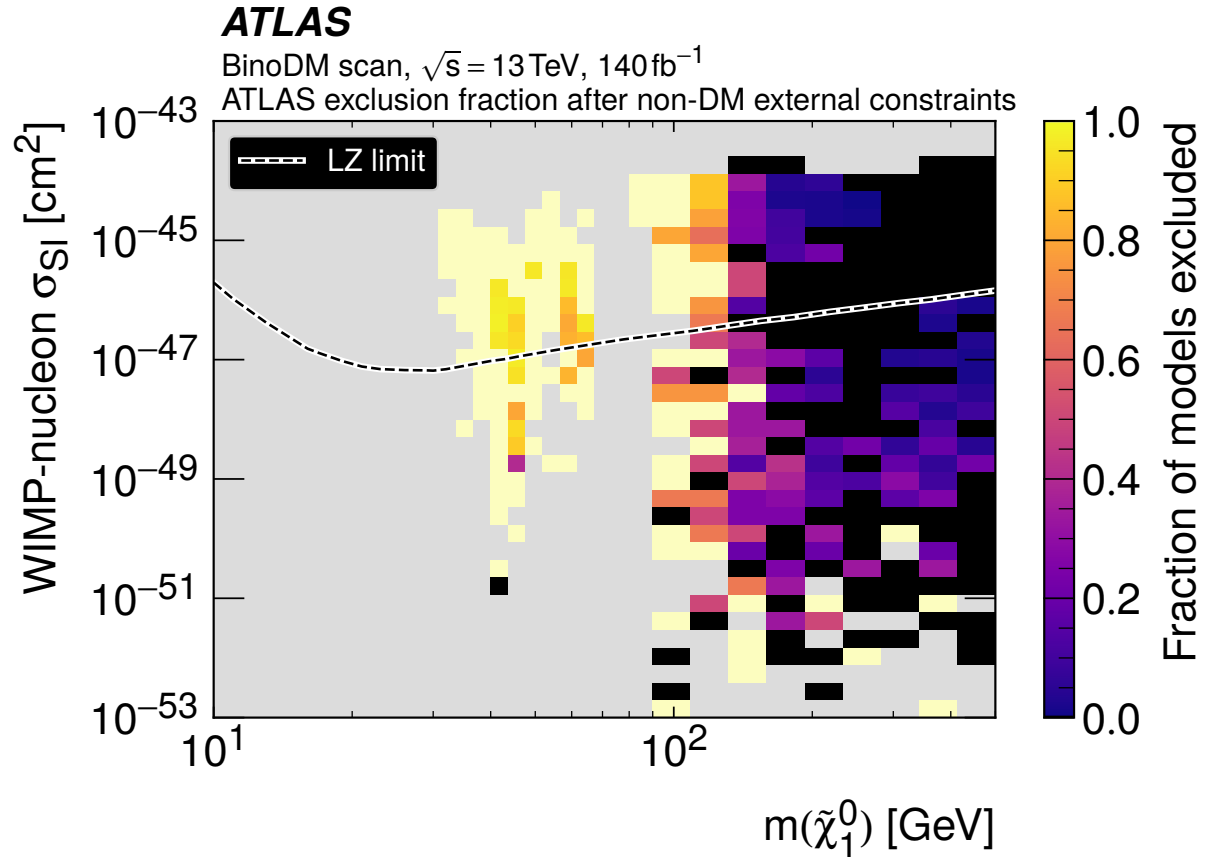
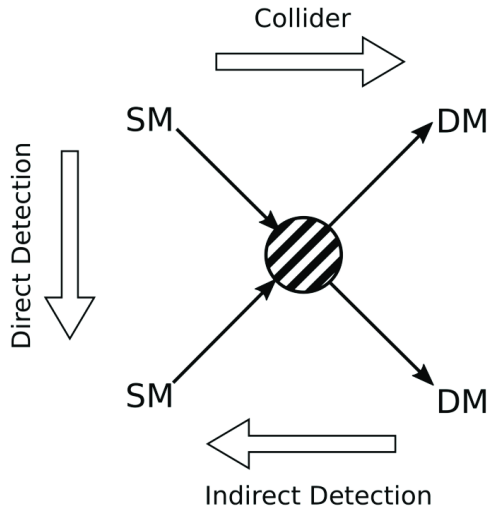


## Bino scan



For  $m(\tilde{\chi}_1^0) \lesssim 100$  GeV, LSP must be Bino-like due to LEP constraint on  $m(\tilde{\chi}_1^\pm)$ .  
**Bino LSP highly excluded below 100 GeV** by ATLAS + other constraints.  
 Wino exclusion driven by disappearing track analysis.

# pMSSM & direct DM searches



**LUX-ZEPLIN limits on WIMPs assume  $\Omega h^2 = 0.12$ .**

**For pMSSM models with  $\Omega h^2 < 0.12$ , to allow comparison, we “set  $\Omega h^2$  to 0.12” by “scaling  $\sigma(\text{WIMP-nucleon})$  by  $\Omega h^2/0.12$ ”, assuming remaining DM is invisible to direct detection.**

**Complementarity between collider and direct searches.**

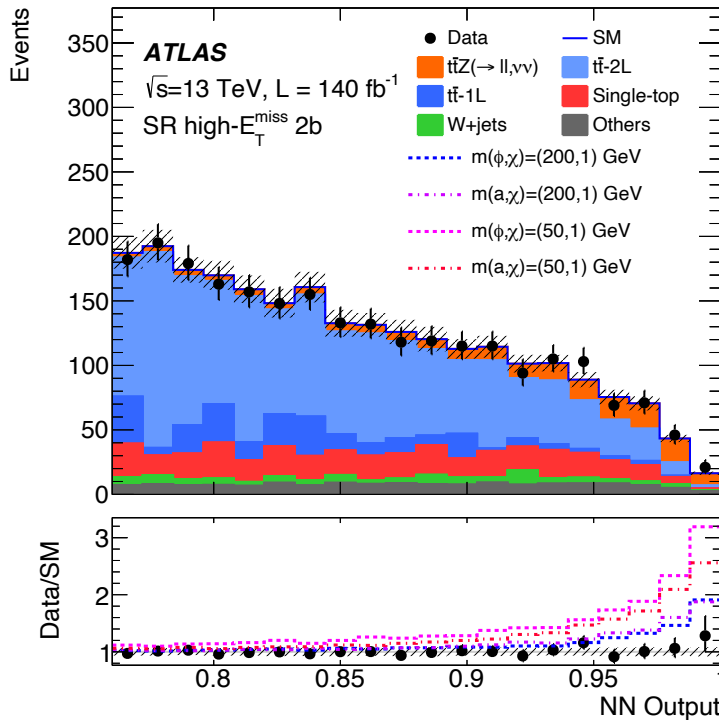
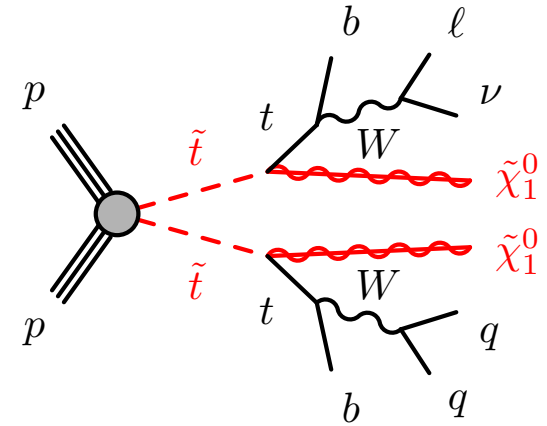
# $\tilde{t}\tilde{t} \rightarrow t\bar{t} + \text{MET} (1L)$

## Hadronic top quark reconstruction:

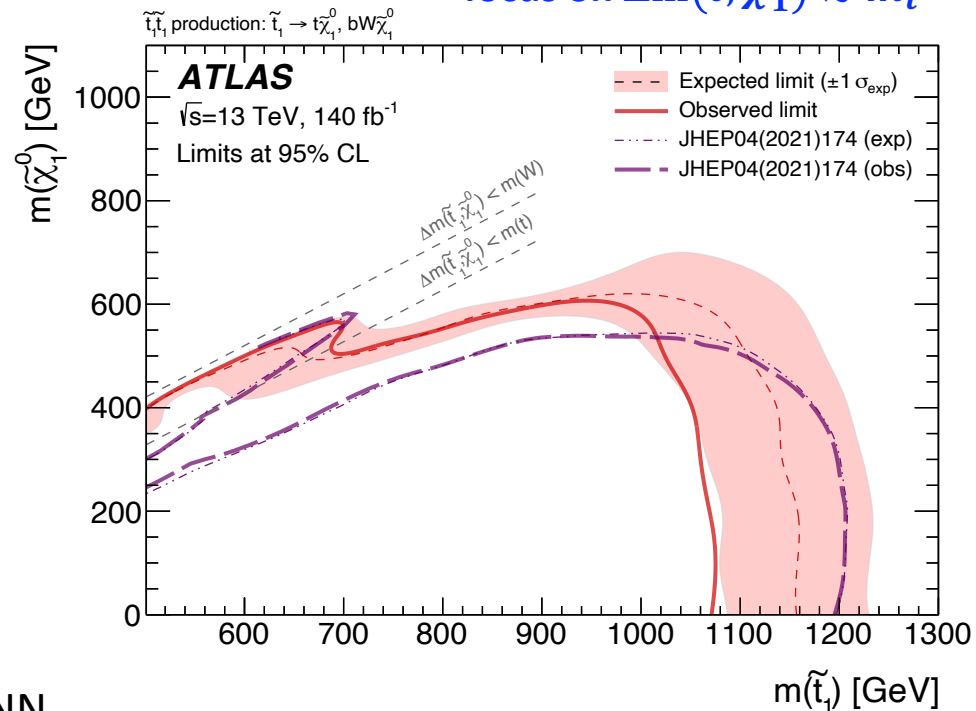
- high  $p_T$ : large-R jet tagging
- low- $p_T$  (high MET): NN combining  $b$ - and light-jets

## Event categories:

- low-/high- $p_T$  top, #  $b$ -jets (in/out large-R jet).
- NN separates sig/bkg in each category.



focus on  $\Delta m(\tilde{t}, \tilde{\chi}_1^0) \gtrsim m_t$



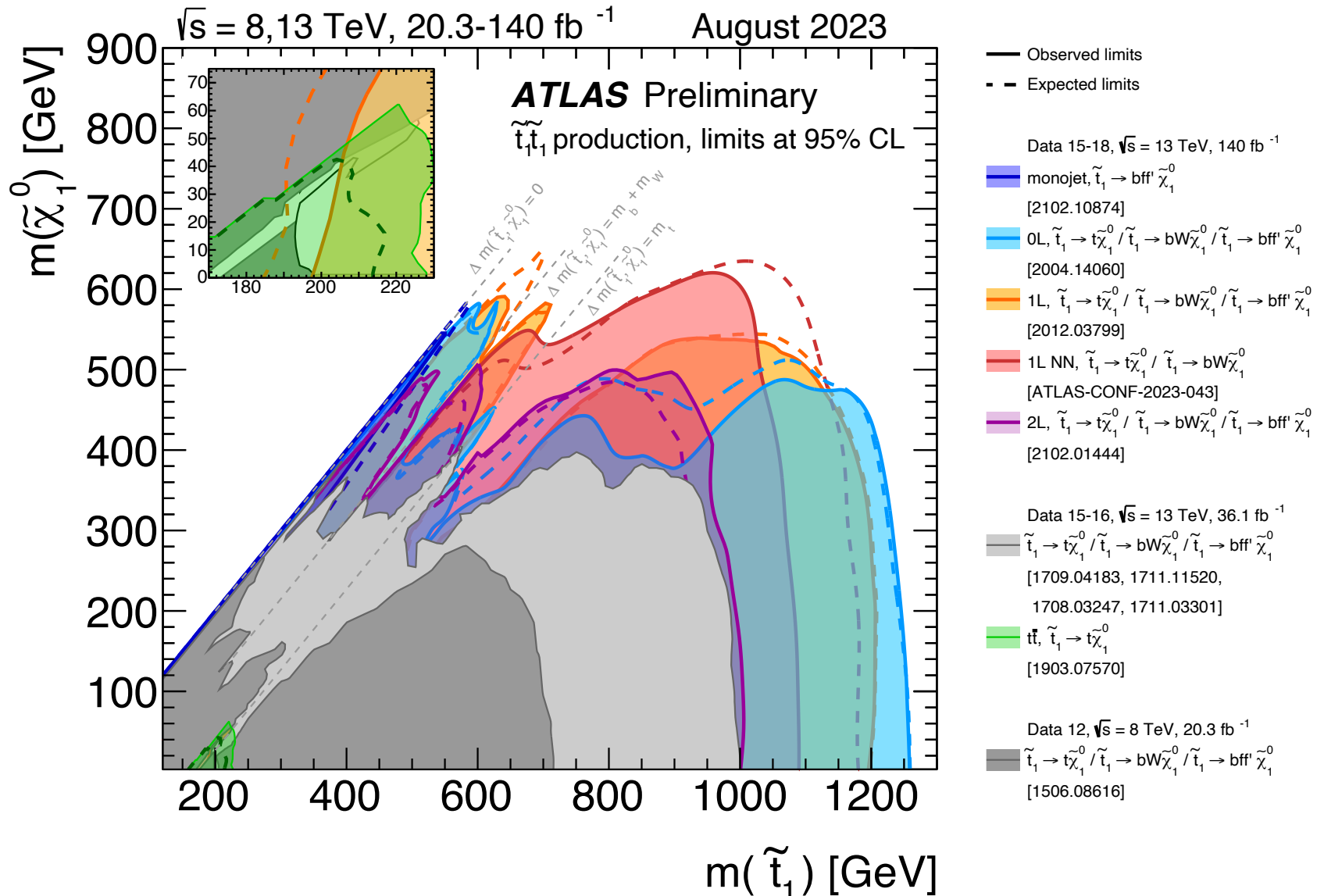
Control

Validation

Signal Region

NN

# $\tilde{t}$ search summary



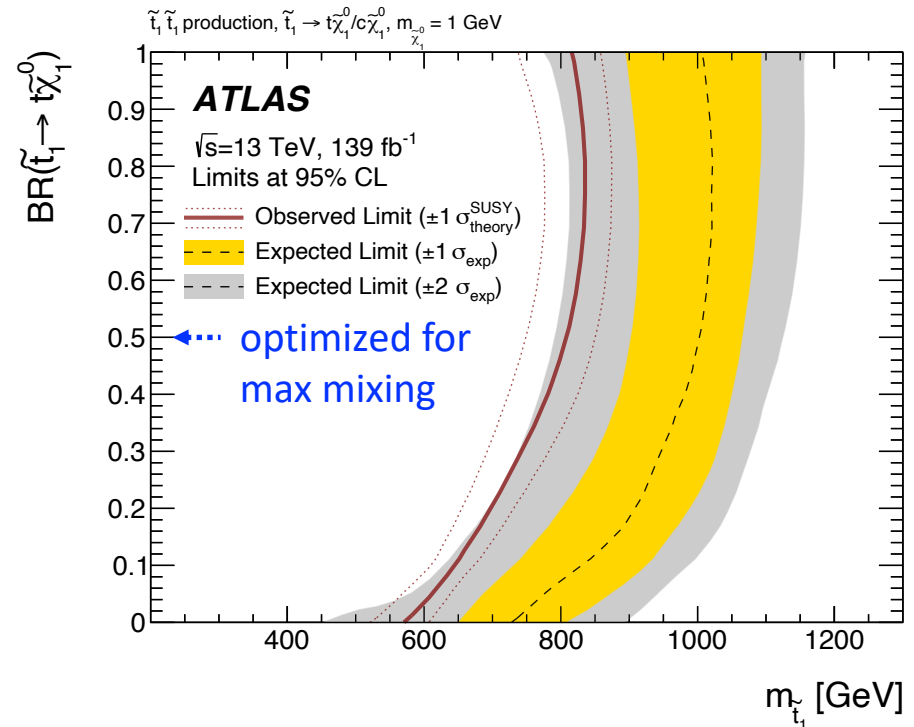
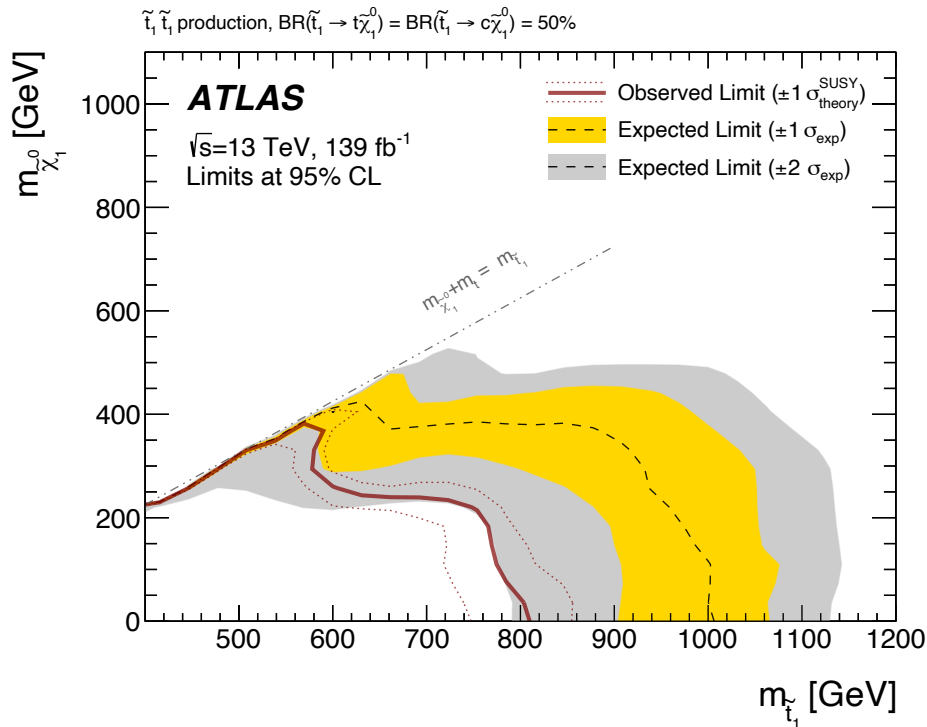
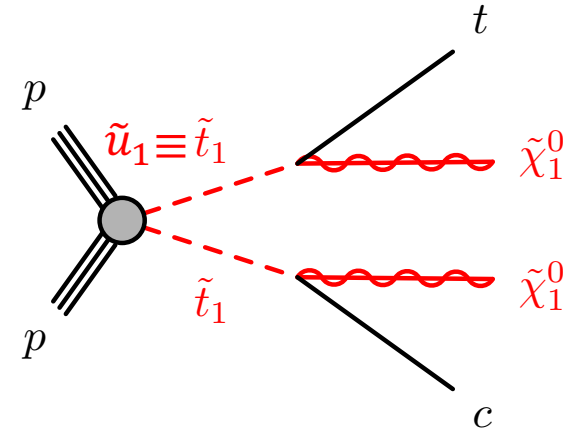
Sensitivity driven by 0L+1L combination, similar exclusion reach for CMS [ref].

# Non-minimal flavour violation

Model with mixing between 2<sup>nd</sup> and 3<sup>rd</sup> gen  $\tilde{q}$ :

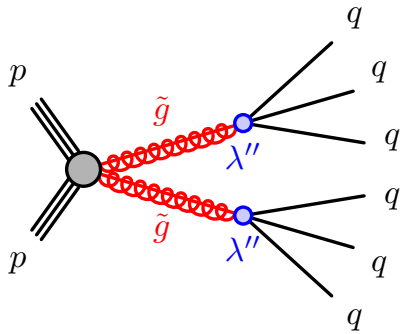
$$\begin{pmatrix} \tilde{u}_1 \\ \tilde{u}_2 \end{pmatrix} = \begin{pmatrix} \cos \theta_{tc} & \sin \theta_{tc} \\ -\sin \theta_{tc} & \cos \theta_{tc} \end{pmatrix} \begin{pmatrix} \tilde{c}_R \\ \tilde{t}_R \end{pmatrix}$$

**Large  $\Delta m(\tilde{t}, \tilde{\chi}_1^0)$ :** large-R jet top-tagged.  
**Small  $\Delta m$ :** ISR jet, NN to separate sig/bkg.  
**ATLAS *b*-tagger repurposed into *c*-tagger,**  
**77% eff for *b*-jets, 20% eff for *c*-jets.**

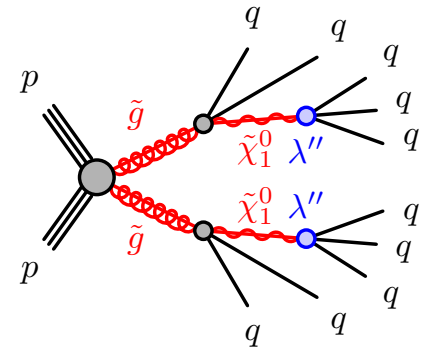


# Gluinos + RPV

[SUSY-2019-24]



UDD couplings  $\lambda''_{112}, \lambda''_{113}$   
violating baryon number

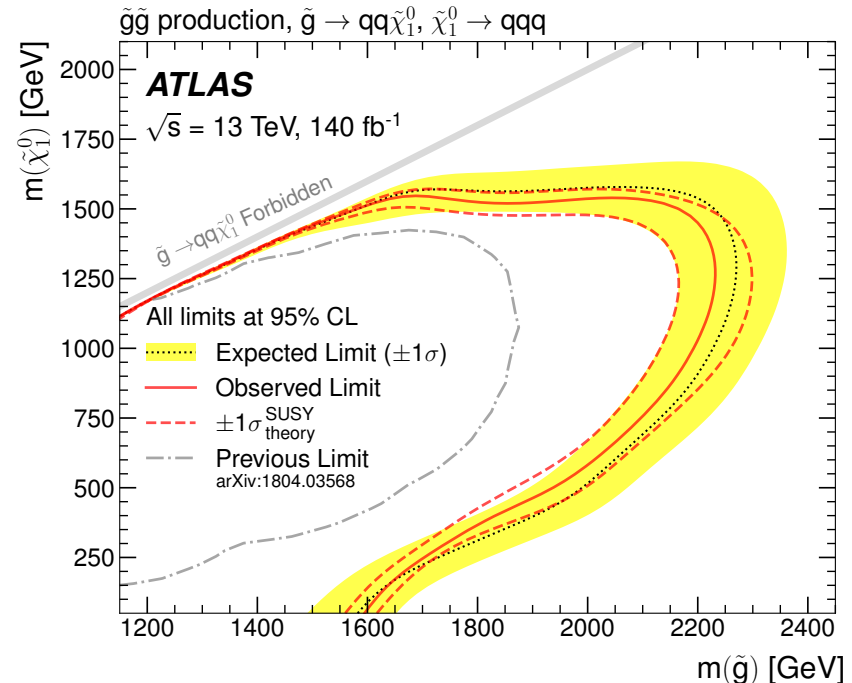
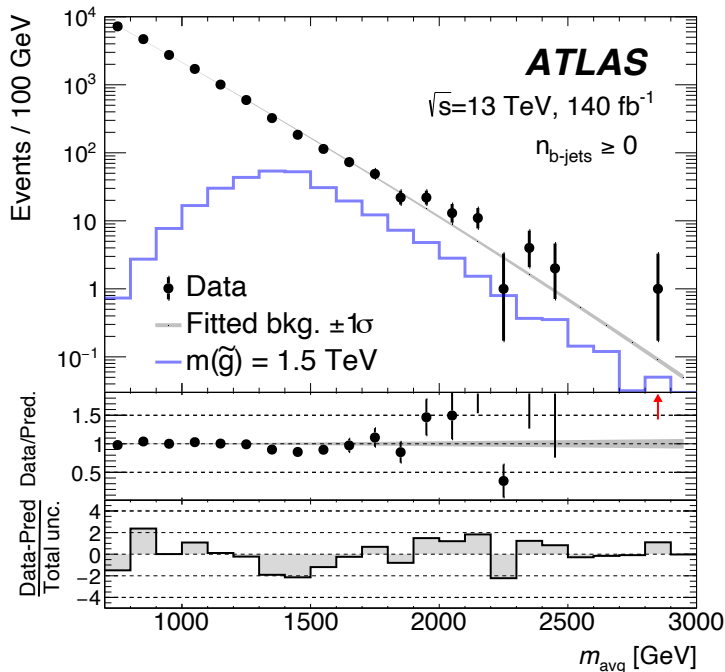


## Mass resonance:

- NN assigns each jet to  $\tilde{g}_1/\tilde{g}_2$ /other
- look for bump in average  $\tilde{g}$  mass, 3-param function describing multijet

## Jet counting:

- SRs with  $\geq 7$  high- $p_T$  jets
- bkg from data with 4 jets, extrap. to high  $N_{\text{jet}}$  and  $p_T$  using MC



CMS analysis still embargoed



Presented latest SUSY searches at ATLAS and CMS, based on LHC Run 2 data.  
Weak-scale SUSY is still hiding, but for how long?  
More focus on less-simplified / non-minimal models.  
Check all our results: [ATLAS](#), [CMS](#).