

# Searches for RPV SUSY in ATLAS, CMS and LHCb

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on behalf of the ATLAS, CMS and LHCb collaborations  
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# Motivation

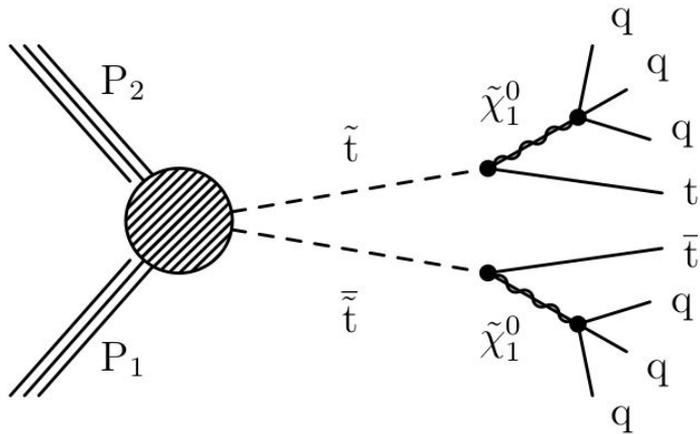
- ❑ Traditional trend of SUSY search: Final state with high  $p_T^{\text{miss}}$
- ❑ In RPV susy models:
  - ➔ LSP can decay to SM particles
  - ➔ Hence provide complementary phase-space for SUSY searches with low  $p_T^{\text{miss}}$  final state

The talk is based on three RPV SUSY searches from CMS, ATLAS and LHCb experiment:

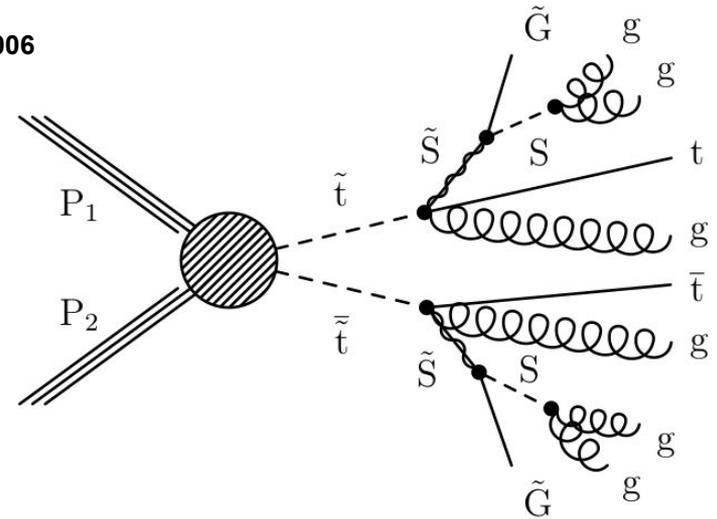
- Search for top squarks in final states with two top quarks and several light-flavor jets in proton-proton collisions at  $\sqrt{s} = 13$  TeV ( **Phys. Rev. D 104, 032006** )
- Search for R-parity-violating supersymmetry in a final state containing leptons and many jets with the ATLAS experiment using  $\sqrt{s} = 13$  TeV proton-proton collision data (<https://doi.org/10.1140/epjc/s10052-021-09761-x> )
- Search for massive long-lived particles decaying semileptonically at  $\sqrt{s} = 13$  TeV (<https://doi.org/10.1140/epjc/s10052-022-10186-3> )

# Top squark search in RPV and Stealth SUSY scenario (CMS)

## Signal Models



Phys. Rev. D 104, 032006



## R-parity violating SUSY

- The LSP is not stable and decays to SM
- Top squark production may end with low  $p_T^{\text{miss}}$  final state

## Stealth (SYY) SUSY

- Consider a hidden sector which simply contains a sfermion and a scalar partner and are very close in mass
- Top squark decays through this hidden sector

## Main Features

- ❑ Final state:  $t\bar{t}$  + jets with very high jet multiplicity
- ❑ Focused on (largely unexplored) low- $p_T^{\text{miss}}$  topologies of  $\tilde{t}$  decays.
- ❑ Require one lepton to reduce QCD
- ❑ To reduce non  $t\bar{t}$  + jets bkg, require one b-jet and  $50 < M_{bl} < 250$  GeV

The signal is distinguished from the dominant and irreducible  $t\bar{t}$  background by means of a neural network (NN).

# Search strategy

- ❑ The crux of the analysis is to estimate the dominant  $t\bar{t}$  background in four bins of  $S_{NN}$  and six  $N_{jets}$
- ❑ Then constrain the  $t\bar{t} N_{jets}$  shape to be the same in all  $S_{NN}$  categories using a simultaneous binned maximum-likelihood fit
- ❑ Jet multiplicity is hard to model at high multiplicity, so it is modelled by fitting the  $N_{jets}$  distribution in data

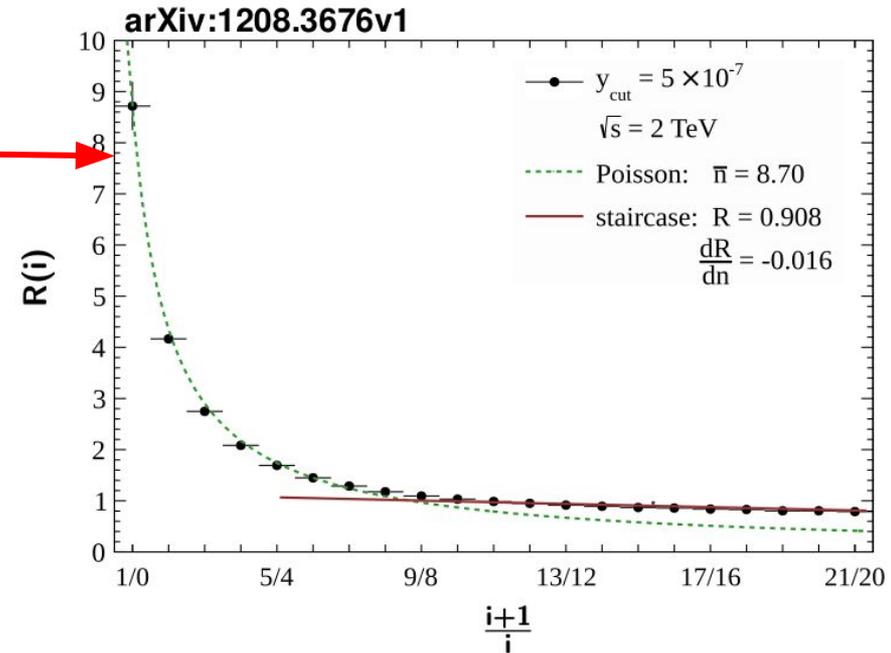
- ❑ Theoretically ratios of  $N_{j+1}/N_j$  can be described by two components
  - a constant at high  $N_{jets}$  (“staircase”)
  - a falling function at lower  $N_{jets}$  (“Poisson”)

- ❑ The fit function that describes the  $N_{jets}$  distribution using the  $R(i)$  parameterization:

$$R(i) = a_2 + \left[ \frac{(a_1 - a_2)^{i-7}}{(a_0 - a_2)^{i-9}} \right]^{1/2}$$

where  $i = N_{jets}$ ,  $a_0 = \frac{M_8}{M_7}$ ,  $a_1 = \frac{M_{10}}{M_9}$ ,  $a_2 = \lim_{x \rightarrow \infty} \frac{M(x+1)}{M(x)}$

$a_2 = a_1 - 1/d$ , if  $d \geq 1$ ,       $a_2 = a_1 - (2 - d)$ , if  $d < 1$



# Search strategy

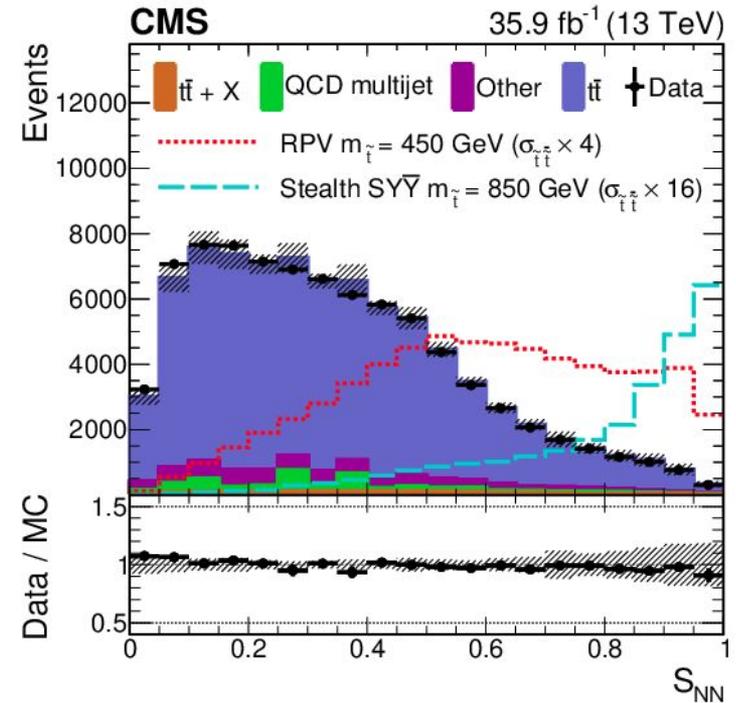
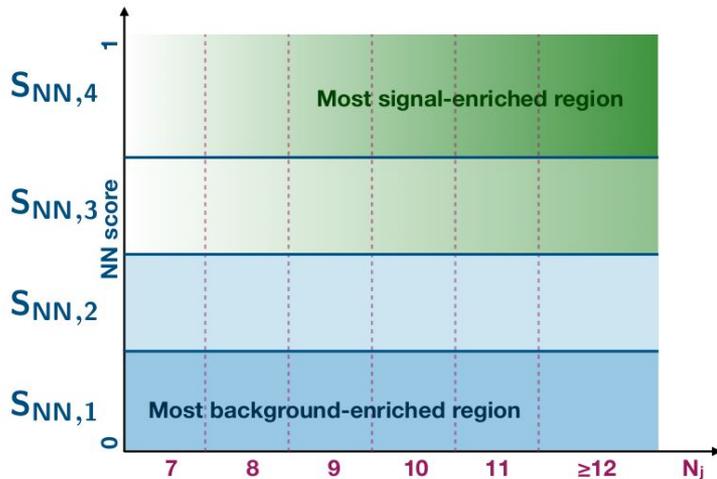
Phys. Rev. D 104, 032006

- A neural network is trained to enhance the discrimination between signal and the primary background  $t\bar{t}$  + jets.

- **Input of the NN:**

- 4-vectors of 7 highest momentum jets
- 4-vector of lepton
- Jet energy-momentum tensor eigenvalues and Fox-Wolfram moments

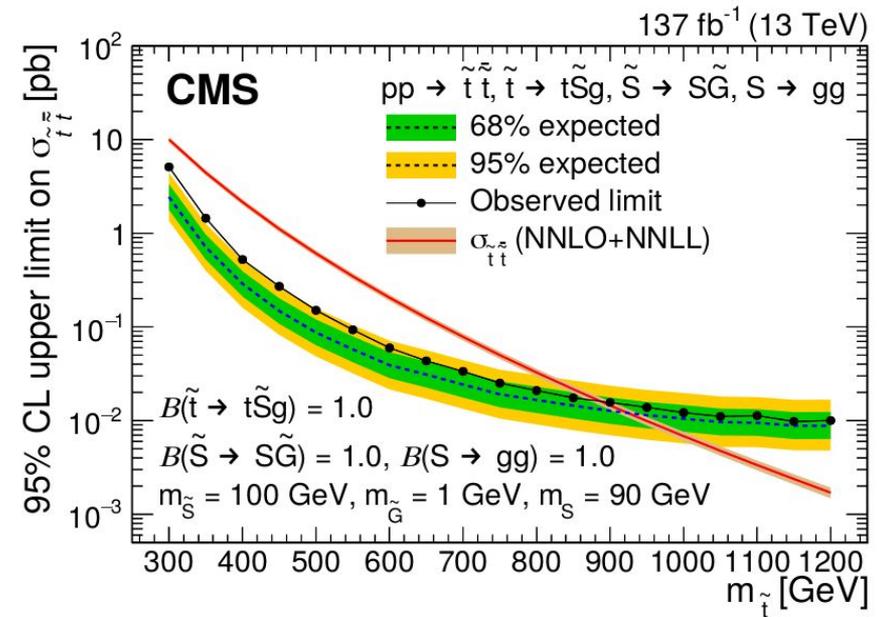
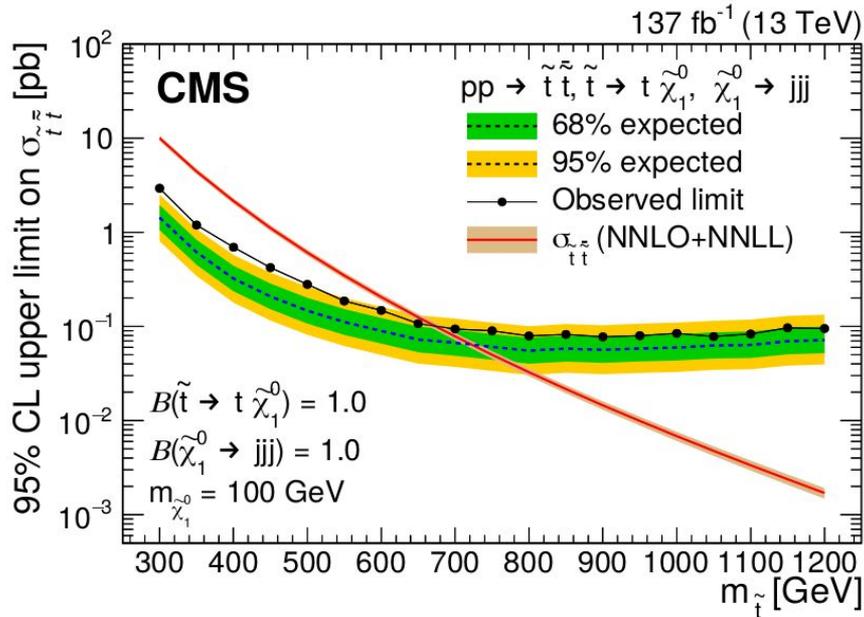
- The neural network uses gradient reversal (GR) to be independent of  $N_{\text{jets}}$ .



- Good Signal to background separation is obtained

# Result

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- ❑ Top squark masses up to **670 GeV** are excluded at 95% confidence level for the **RPV model**.
- ❑ Top squark masses up to **870 GeV** are excluded for the **stealth supersymmetry model**.

# RPV SUSY search in lepton and many jets final state (ATLAS)

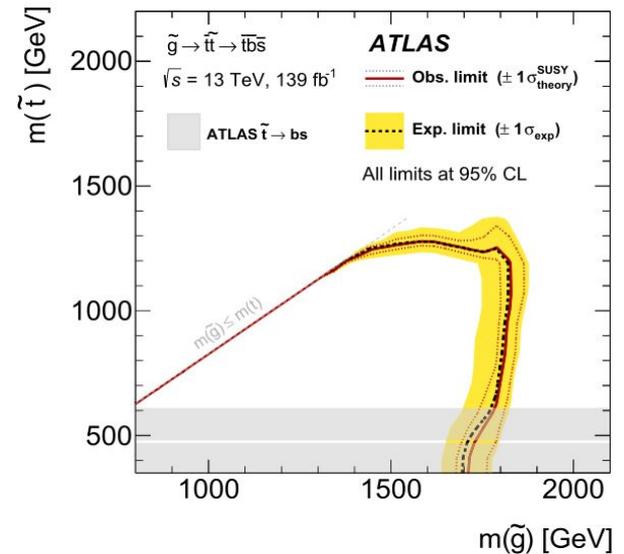
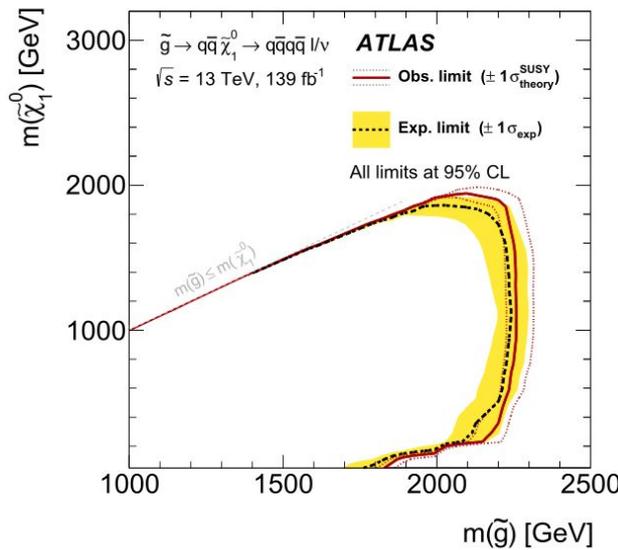
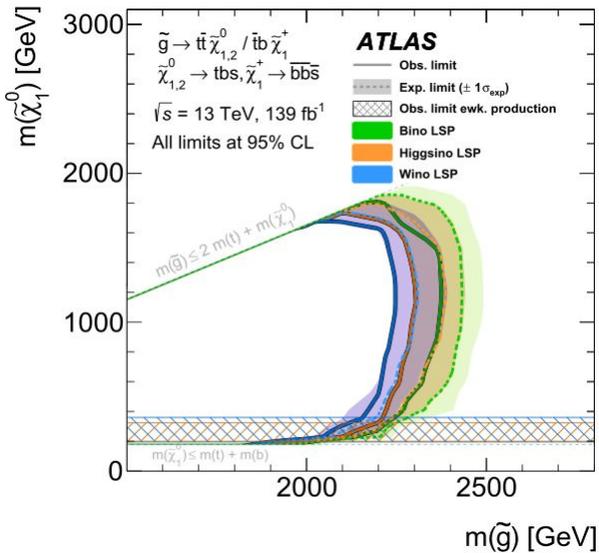
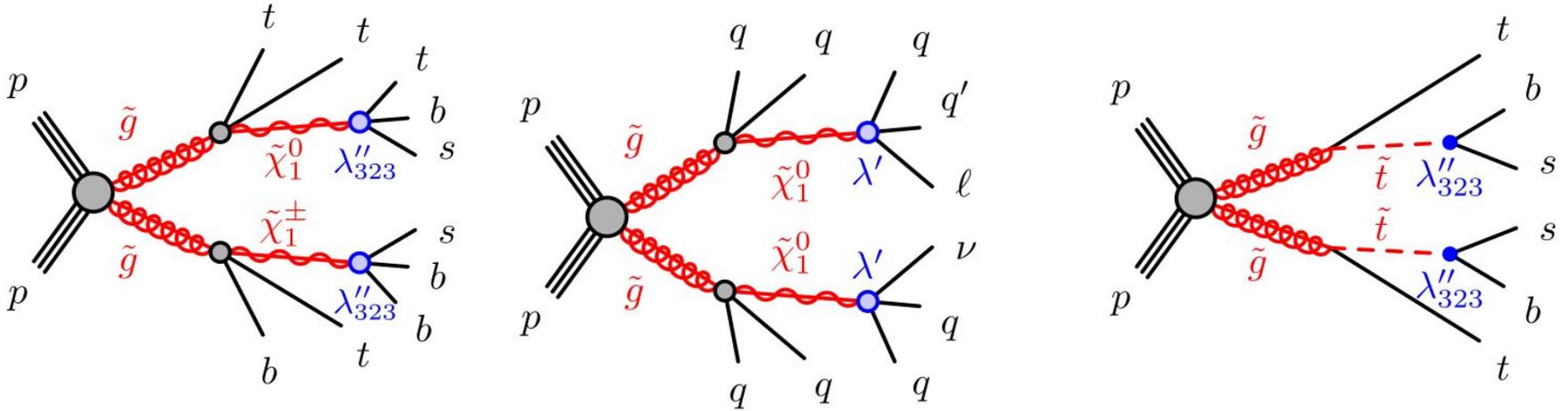
[Eur. Phys. J. C 81 \(2021\) 1023](#)

- ❑ Five SUSY benchmark simplified models are used
- ❑ Event selection:
  - ➔ At least one isolated lepton
  - ➔ At least eight to fifteen jets, several of which may contain b-jets
  - ➔ No requirement on the missing transverse momentum.
- ❑ Analysis strategy:

Lepton category	Jet multiplicity	Analysis regions
$1\ell$ category	4...7 jets	$0b\ell^-, 0b\ell^+, 0bm_{\ell\ell},$ $1b, 2b, 3b, \geq 4b$
	$8 \dots \geq N_{\text{last}}^{1\ell}$ jets	$0b, 1b, 2b, 3b, \geq 4b$
$2\ell^{\text{sc}}$ category	$4 \dots \geq N_{\text{last}}^{2\ell^{\text{sc}}}$ jets	$0b\ 3\ell, 0b, 1b, 2b, 3b,$ $\geq 4b$

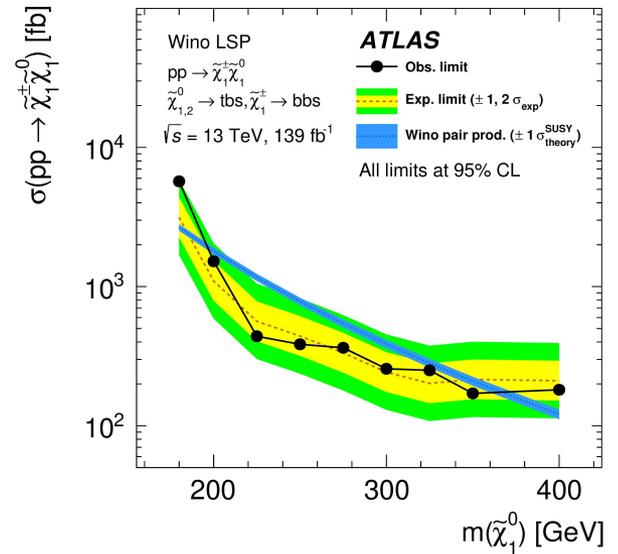
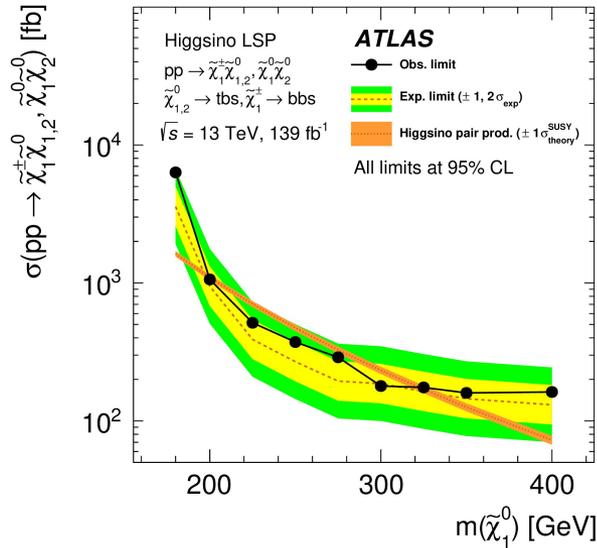
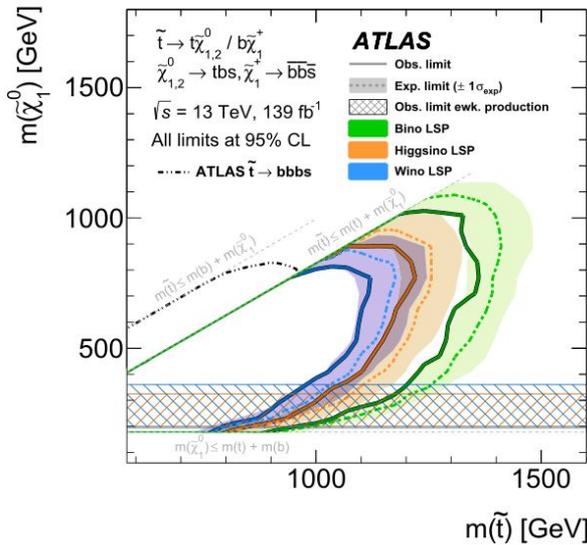
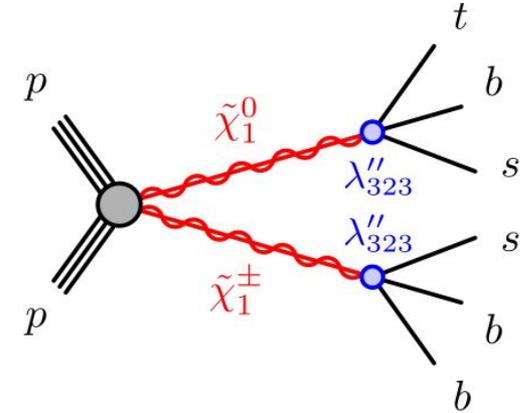
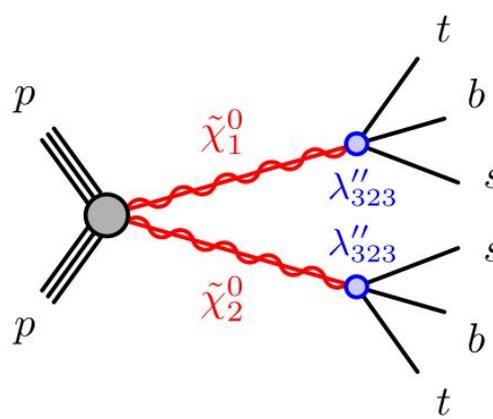
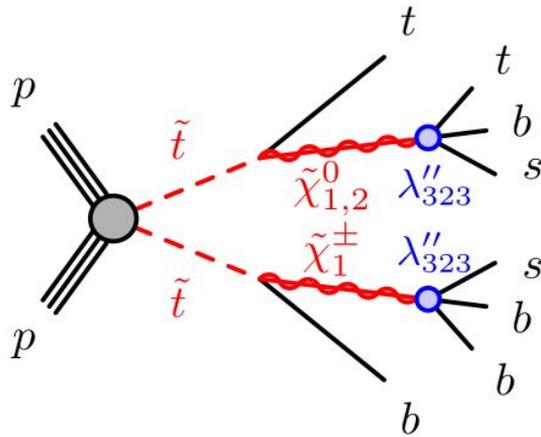
# RPV SUSY search in lepton and many jets final state (ATLAS)

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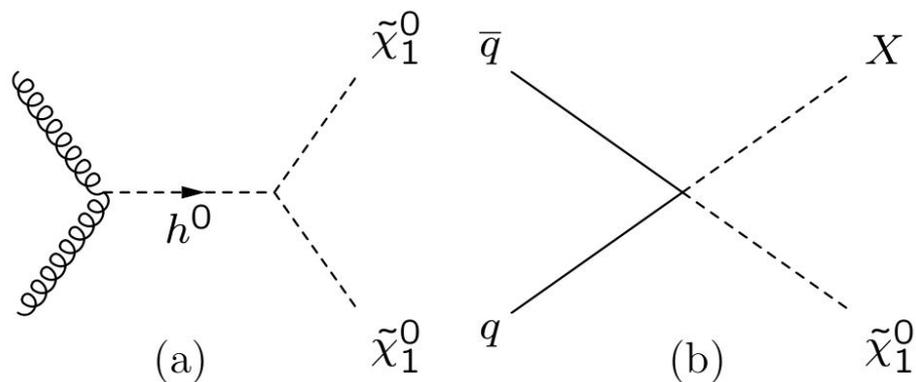
# RPV SUSY search in lepton and many jets final state (ATLAS)

*Eur. Phys. J. C 81 (2021) 1023*



# Long lived particle search in RPV scenario (LHCb)

*The European Physical Journal C* volume 82, Article number: 373 (2022)



## Signal Model:

Theoretical model inspired by mSUGRA with RPV

1. Higgs-like boson produced by gluon fusion and decays into two LLPs.
2. LLP production mode is directly from quark interactions

The neutralino decays to  $\mu^+ q_i q_j$

## Main motivation:

- ❑ The excellent vertex reconstruction provided by the VELO.
- ❑ Low  $p_T$  threshold of the muon trigger compared to CMS and ATLAS.
- ❑ Probing a rapidity region only partially accessible by other LHC experiments.

LHCb explore regions of the theoretical parameter space where these experiments are limited by their low efficiency to reconstruct highly boosted LLPs.

# Analysis strategy

*The European Physical Journal C* volume 82, Article number: 373 (2022)

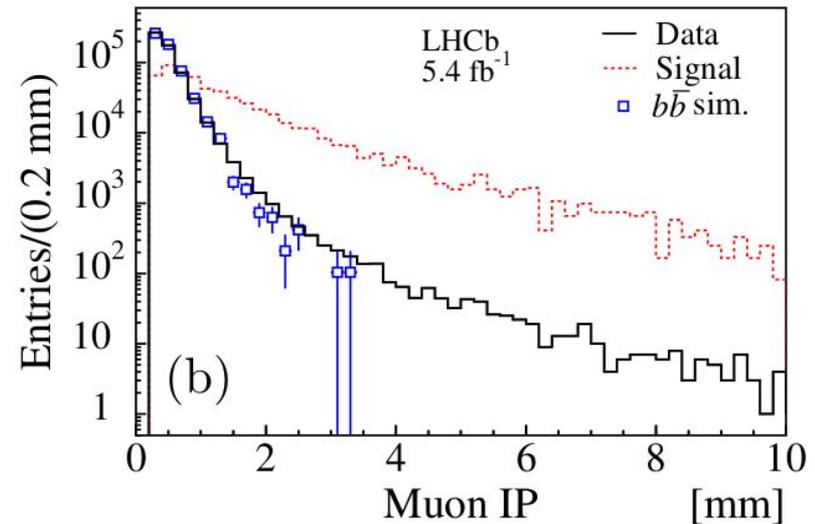
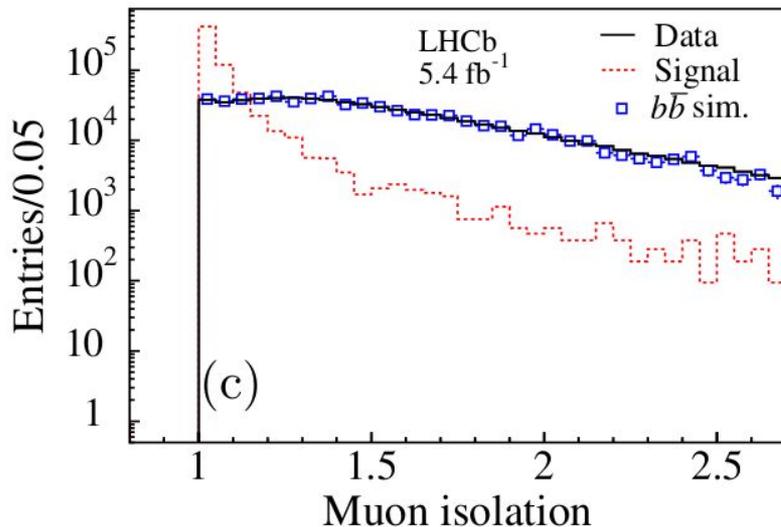
## Signal selection:

- ❑ Require a vertex displaced from any PV
- ❑ An isolated muon with  $p_T > 12$  GeV
- ❑ Muon IP, with respect to any PV  $> 0.25$  mm
- ❑ At least 3 tracks to form an LLP candidate with invariant mass  $> 4.5$  GeV

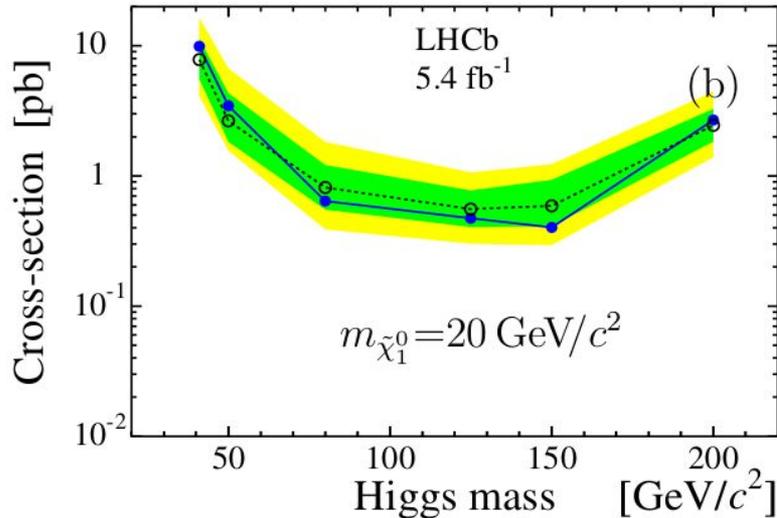
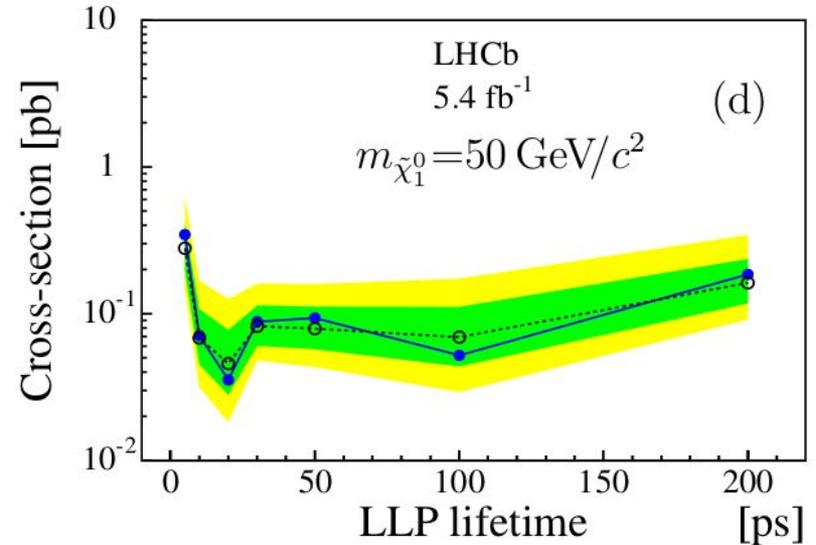
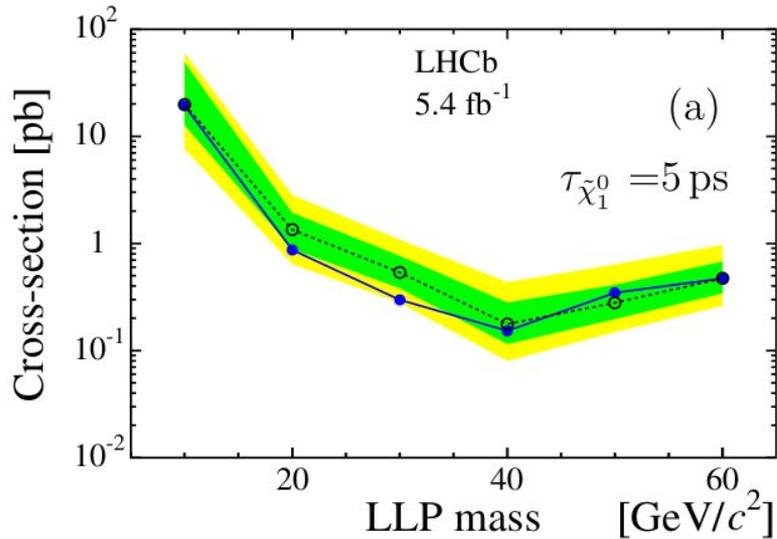
→ A multivariate analysis (MVA) based on a boosted decision tree is used to further purify the data sample.

→ The signal yield is determined by a fit to the LLP reconstructed mass.

- ◆ signal shape inferred from the theoretical models.



# Results



- The results for all theoretical models considered are compatible with the background-only hypothesis.
- At 95% CL, the cross-section times branching fractions are mostly of O(0.1 pb)

# Summary and outlook

- ❑ RPV SUSY search gives alternate phase space with low missing transverse momentum to look for new physics
- ❑ New machine learning based techniques used in object reconstruction and search purposes are helping to probe phase spaces that are not ventured previously
- ❑ LHC Run3 is about to start. With more data more exciting and new results are on the way.

More complete set of RPV SUSY results are available here

[CMS SUSY Results](#)  
[CMS Exo Results](#)

[ATLAS Results](#)

[LHCb Results](#)

*Thank You*

*Back Up*

